

Supporting Information

Catalytic Asymmetric Synthesis of 2,5-Dihydrofurans Using Synergistic Bifunctional Ag Catalysis

Taoda Shi,^{a,b} Shenghan Teng,^a Alavala Gopi Krishna Reddy,^d Xin Guo,^c Yueteng Zhang,^b Kohlson T. Moore,^b Thomas Buckley,^b Damian J. Mason,^b Wei Wang,^b Eli Chapman,^{b*} and Wenhao Hu^{d*}

- a. Shanghai Engineering Research Center of Molecular Therapeutics and New Drug Development, School of Chemistry and Chemical Engineering, East China Normal University, Shanghai, China, 200062.
- b. College of Pharmacy, Department of Pharmacology and Toxicology, the University of Arizona, Tucson, Arizona 85721.
- c. School of Pharmaceutical Sciences, Wenzhou Medical University, Wenzhou, Zhejiang Province, China, 325035.
- d. School of Pharmaceutical Sciences, Sun Yat-sen University, Guangzhou, China, 510006.

Table of contents

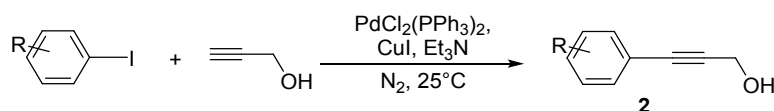
A. General information	3
B. Preparation of substrates	3
C. Primarily screening with [Pd(allyl)Cl]₂ as catalyst	3-4
D. Synthesis and characterization of 2,5-dihydrofurans	5-19
E. Mechanistic experiments	21-26
F. Derivatization of enantiopure 2,5-dihydrofuran 3k	27
G. References	28
H. NMR spectra	29-77
I. HPLC	78-136
J. Structural determination of 7k by X-ray	137

A. General information

All reactions were carried out under nitrogen atmosphere with magnetic stirring. Anhydrous DCM was purified by distillation over calcium hydride after elimination of alcohol stabilizer. Powdered 4Å molecular sieves were dried in a Muffle furnace at 400°C for 5 h prior to use. All other commercially obtained reagents were used as received unless specifically indicated. Flash column chromatography was performed over H silica gel purchased from Qindao Haiyang Chemical Co., China or Agela Technologies USA.

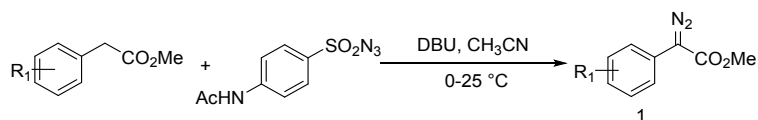
All ^1H NMR and ^{13}C NMR spectra were recorded using a Bruker-400 MHz and Bruker-500 MHz spectrometer in CDCl_3 unless otherwise noted. Residue solvent peaks were chosen as an internal standard (^1H NMR: CDCl_3 at 7.26 ppm, ^{13}C NMR: CDCl_3 at 77.0 ppm). Data of ^1H NMR spectra were reported as follows: chemical shift, integration, multiplicity. (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad). HRMS (ESI) were recorded on IonSpec FT-ICR mass spectrometer. HPLC analyses was performed on Dalian Elite (UV230+ UV/Vis Detector and P230P High Pressure Pump) and Agilent 1100. Chiralpak IA column was purchased from Daicel Chemical Industries, LTD. Single crystal X-ray diffraction data (**7k**) were recorded on Bruker-AXS SMART APEX II single crystal X-ray diffractometer.

B. Preparation of substrates



Scheme S1. preparation of aryl propargyl alcohol

General procedure for the synthesis of aryl propargyl alcohols: All aryl propargyl alcohols were prepared using reported procedures.¹ $\text{Pd}(\text{PPh}_3)_2\text{Cl}_2$ (0.05 mmol, 0.01 equiv) and CuI (0.5 mmol, 0.1 equiv) were added to the flask. To this mixture were added iodoarene (5 mmol, 1 equiv) and Et_3N (10 mL) under nitrogen atmosphere. After 10 minutes, the propargyl alcohol (5.5 mmol, 1.1 equiv) was injected into the mixture. After stirring at 25°C for 10 hours, the solution was then quenched by aqueous NH_4Cl , and extracted with Et_2O 3 times. The combined organic phase was washed with 1M HCl and brine and dried with anhydrous Na_2SO_4 . After filtration, the solvent was removed to give the crude product, which was then purified by flash chromatography on silica gel (PE/EA = 10:1~5:1) to give the pure product.



Scheme S2. preparation of methyl aryldiazoacetates

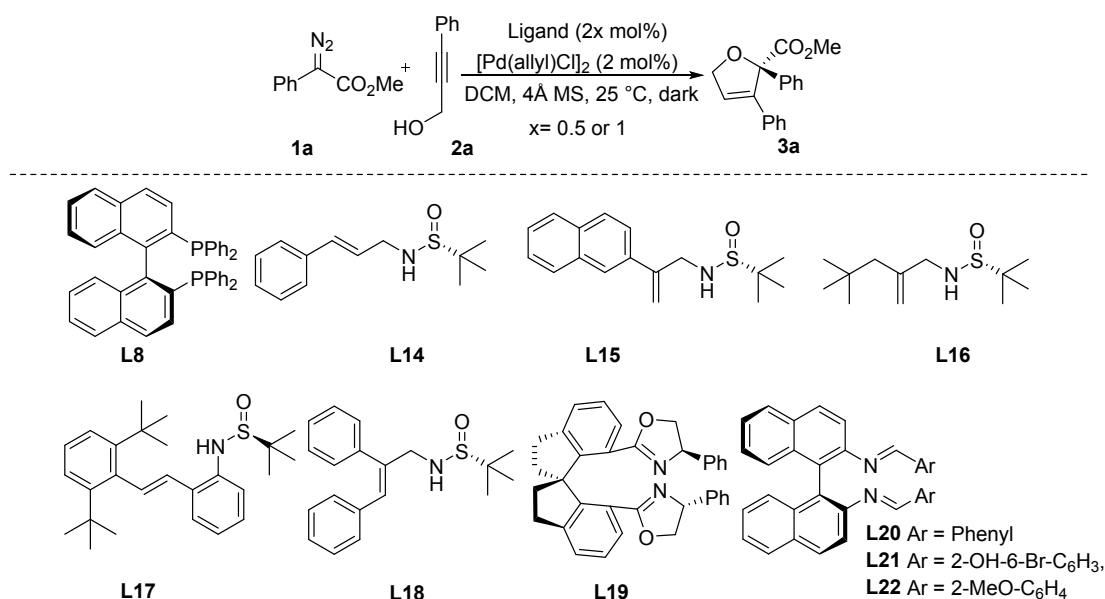
General procedure for the synthesis of diazoacetates: All the diazoacetates were prepared by reported procedures.² Methyl arylacetates (10 mmol, 1.0 equiv) and *p*-ABSA (11 mmol, 1.1equiv) was dissolved in a 100 mL flask with 40 mL CH_3CN . After stirring for 10 min in an ice bath, DBU (1.1 mmol, 1.1 equiv) in 20 mL of CH_3CN was added dropwise. After stirring for 12 hours at 25°C, the reaction mixture was quenched with saturated aqueous NH_4Cl at 0°C. The mixture was then extracted with diethyl ether 3 times. The combined organic phase was washed with 60 mL brine and dried with anhydrous Na_2SO_4 . After

filtration, the solvent was removed to give the crude product. It was then purified by flash chromatography on silica gel with petroleum ether to give the pure product.

C. Preliminary screening with $[Pd(allyl)Cl]_2$ as catalyst

General procedure for evaluation of ligands of $[Pd(allyl)Cl]_2$ in formal [4+1] cycloaddition of diazoacetates and propargyl alcohol: The mixture of 100 mg 4Å MS, $[Pd(allyl)Cl]_2$ (0.01 mmol, 0.1 equiv) and ligand (0.02 mmol, 0.1 equiv) was dissolved in 0.5 mL of anhydrous dichloromethane at 25°C. The reaction mixture was stirred for 2 h. Then aryl propargyl alcohol **2** (0.1 mmol) dissolved in 1 mL of anhydrous dichloromethane was added. After stirring for five minutes, diazoacetate **1** (0.15 mmol, 1.5 equiv) dissolved in 4 mL anhydrous dichloromethane was added via a syringe pump over 1 h. After stirring for 24 h, the 4Å MS were filtered and the solvent was removed to give the crude product. The crude product was then purified by microgram scale preparative TLC (PE/EA = 40:1-20:1) to give the pure product for chiral HPLC analysis. All the ligands presented in Table S1 showed minimal enantioselectivity.

Table S1. Evaluation of ligands of $[Pd(allyl)Cl]_2$ in formal [4+1] cycloaddition of diazoacetates and propargyl alcohol.^a

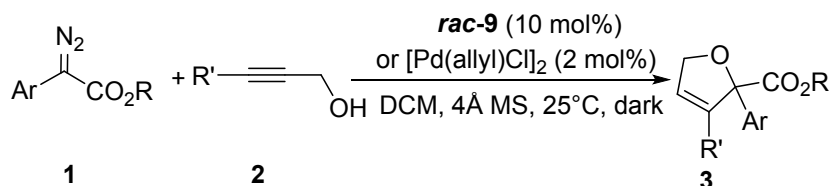


Entry	L	M:L	con. ^b (%)	ee ^c of 3a (%)
1	L8	2:1	>90	54
2	L14	1:1	>90	0
3	L15	1:1	>90	0
4	L16	1:1	>90	0
5	L17	1:1	>90	0
6	L18	1:1	>90	0
7	L19	1:1	>90	0
8	L20	1:1	>90	0

9	L21	1:1	>90	0
10	L22	1:1	>90	0

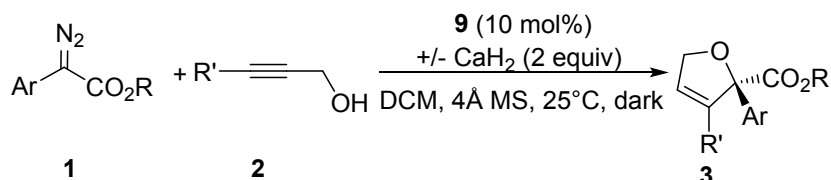
^aReaction conditions: **1a** (0.1 mmol) in DCM (1.0 mL) was added to a solution of **2a** (0.15 mmol, 1.0 equiv), [Pd(allyl)Cl]₂ (0.002 mmol, 0.02 equiv), 100 mg 4Å MS and **L** (0.002 or 0.001 mmol, 0.002 or 0.001 equiv) in 1.0 mL of DCM, 25°C. ^bDetermined by ¹H NMR of the reaction mixture. ^cDetermined by chiral HPLC analysis.

D. Synthesis and characterization of 2,5-dihydrofurans



Scheme S3 preparation of *rac*-3

General procedure for the synthesis of racemic 2,5-dihydrofuran: A mixture of 200 mg 4Å MS, AgSbF₆ (0.04 mmol, 0.2 equiv) and *rac*-BINAP (0.02 mmol, 0.1 equiv) or [Pd(allyl)Cl]₂ (0.002 mmol, 0.02 equiv) was dissolved in 1 mL of anhydrous dichloromethane at 25°C. The reaction mixture was stirred for 2 h. Then aryl propargyl alcohol **2** (0.2 mmol) dissolved in 1 mL of anhydrous dichloromethane was added. After stirring for five minutes, diazoacetate **1** (0.3 mmol, 1.5 equiv) dissolved in 4 mL anhydrous dichloromethane was added via a syringe pump over 1 h. After stirring for 24 h, 4Å MS were filtered and the solvent was removed to give the crude product. The crude product was then purified by flash chromatography on silica gel (PE/EA = 40:1~20:1) to give the pure product.

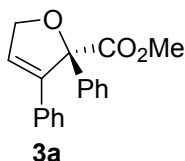


Scheme S4. preparation of (S)-3

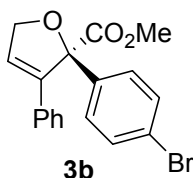
General procedure for the synthesis of (S)-3 with optimal conditions from first-round screening: The glassware was wrapped with aluminum foil to protect silver catalyst from light. The mixture of 200 mg 4Å MS, AgSbF₆ (0.04 mmol, 0.2 equiv) and (*R*)-3,5-DM-BINAP (0.02 mmol, 0.1 equiv) was dissolved in 1 mL of anhydrous dichloromethane at 25°C. The reaction mixture was stirred for 2 h. Then aryl propargyl alcohol **2** (0.2 mmol) dissolved in 1 mL of anhydrous dichloromethane was added. After stirring for 1 h, diazoacetate **1** (0.3 mmol, 1.5 equiv) dissolved in 4 mL anhydrous dichloromethane was added via a syringe pump over 1 h. After stirring for 48 h, 4Å MS were filtered and the solvent was removed to give the crude product. The crude product was then purified by flash chromatography on silica gel (PE/EA = 40:1~20:1) to give the pure product.

General procedure for the synthesis of (S)-3 with optimal conditions from second-round screening: The glassware was dried with heat gun under vacuum and cooled down in an Argon atmosphere. Then it was wrapped with aluminum foil to protect silver catalyst from light. **1** (0.2 mmol, 1 equiv) in DCM (2 mL) was added to the mixture of **2** (0.4 mmol, 2

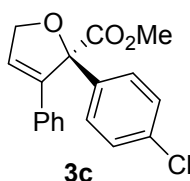
equiv), CaH_2 (0.4 mmol, 2 equiv), 200 mg Å MS, AgSbF_6 (0.04 mmol, 0.2 equiv), (*R*)-3,5-DM-BINAP (0.02 mmol, 0.1 equiv) and 2 mL DCM, via a syringe pump over 1 h. After stirring for 48 h, 4Å MS and catalyst were filtered off and the solvent was removed to give the crude product. The crude product was then purified by flash chromatography on silica gel (PE/EA = 40:1~20:1) to give the pure product.



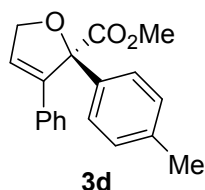
3a: colorless liquid, yield 54%, 78% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 50:1; 254 nm; retention time: $t_{\text{major}} = 11.28$ min, $t_{\text{minor}} = 20.70$ min); ^1H NMR(400 MHz, CDCl_3): δ 7.35 – 7.20 (m, 10H), 6.47 (t, $J = 2.0$ Hz, 1H), 4.99 (dd, $J_1 = 5.2$ Hz, $J_2 = 2.0$ Hz, 1H), 4.93 (dd, $J_1 = 5.2$ Hz, $J_2 = 2.0$ Hz, 1H), 3.78 (s, 3H). ^{13}C NMR(100 MHz, CDCl_3): 172.0, 141.2, 139.4, 132.6, 128.3, 128.2, 128.0, 127.9, 127.4, 126.8, 94.8, 74.8, 52.5. HRMS: calcd 303.0997 for $\text{C}_{18}\text{H}_{16}\text{O}_3\text{Na}$ $[\text{M}+\text{Na}]^+$, found 303.1002.



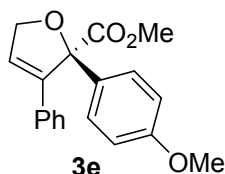
3b: colorless liquid, yield 46%, 87% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 50:1; 254 nm; retention time: $t_{\text{major}} = 14.60$ min, $t_{\text{minor}} = 20.55$ min); ^1H NMR (400 MHz, CDCl_3): δ 7.44 (d, $J = 8.8$ Hz, 2H), 7.26 – 7.24 (m, 7H), 6.47 (t, $J = 2.0$ Hz, 1H), 4.96 (dd, $J_1 = 5.2$ Hz, $J_2 = 2.0$ Hz, 1H), 4.92 (dd, $J_1 = 5.2$ Hz, $J_2 = 2.0$ Hz, 1H), 3.78 (s, 3H). ^{13}C NMR(100 MHz, CDCl_3): 171.7, 141.0, 138.4, 132.3, 131.3, 129.2, 128.2, 128.1, 127.8, 127.1, 122.5, 94.1, 75.0, 52.7. HRMS: calcd 381.0102 for $\text{C}_{18}\text{H}_{15}\text{O}_3\text{BrNa}$ $[\text{M}+\text{Na}]^+$, found 381.0083.



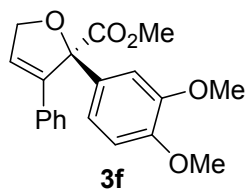
3c: colorless liquid, yield 42%, 88% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 60:1; 254 nm; retention time: $t_{\text{major}} = 14.57$ min, $t_{\text{minor}} = 21.40$ min); ^1H NMR(400 MHz, CDCl_3): δ 7.29 (d, $J = 3.6$ Hz, 4H), 7.23 (s, 5H), 6.47 (t, $J = 1.8$ Hz, 1H), 4.99 (dd, $J_1 = 5.2$ Hz, $J_2 = 2.0$ Hz, 1H), 4.92 (dd, $J_1 = 5.2$ Hz, $J_2 = 2.0$ Hz, 1H), 3.78 (s, 3H). ^{13}C NMR(100 MHz, CDCl_3): 171.74, 140.98, 137.85, 134.25, 132.29, 128.89, 128.38, 128.17, 128.11, 127.82, 127.04, 94.09, 75.00, 52.72. HRMS: calcd 337.0607 for $\text{C}_{18}\text{H}_{15}\text{O}_3\text{ClNa}$ $[\text{M}+\text{Na}]^+$, found 337.0608.



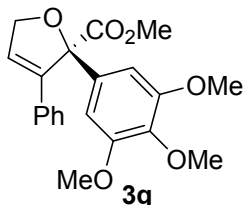
3d: colorless liquid, yield 36%, 76% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 50:1; 254 nm; retention time: $t_{\text{major}} = 15.09$ min, $t_{\text{minor}} = 32.97$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.28 (dd, $J = 6.8, 3.0$ Hz, 2H), 7.25 (s, 1H), 7.22 (dd, $J_1 = 6.6$ Hz, $J_2 = 4.2$ Hz, 4H), 7.13 (d, $J = 8.1$ Hz, 2H), 6.49 (t, $J = 1.8$ Hz, 1H), 4.95 (dd, $J_1 = 8.6$ Hz, $J_2 = 1.8$ Hz, 1H), 4.93 (dd, $J_1 = 8.6$ Hz, $J_2 = 1.8$ Hz, 1H), 3.77 (s, 3H), 2.33 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 172.18, 141.07, 138.16, 136.42, 132.64, 129.56, 128.98, 127.99, 127.85, 127.32, 126.79, 94.64, 74.66, 52.52, 21.16. HRMS: calcd 317.1154 for $\text{C}_{19}\text{H}_{18}\text{O}_3\text{Na}$ $[\text{M}+\text{Na}]^+$, found 317.1163.



3e: colorless liquid, yield 42%, 71% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 25:1; 254 nm; retention time: $t_{\text{major}} = 18.97$ min, $t_{\text{minor}} = 42.16$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.20 – 7.14 (m, 6H), 6.85-6.38 (m, 3H), 6.38 (t, $J = 2.0$ Hz, 1H), 4.91 (dd, $J_1 = 14.0$ Hz, $J_2 = 2.0$ Hz, 1H), 4.86 (dd, $J_1 = 14.0$ Hz, $J_2 = 2.0$ Hz, 1H), 3.70 (s, 3H), 3.66 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 171.9, 159.4, 141.3, 140.8, 132.7, 128.0, 127.9, 126.9, 119.7, 113.8, 113.2, 94.7, 74.8, 55.2, 52.6. HRMS: calcd 333.1103 for $\text{C}_{19}\text{H}_{18}\text{O}_4\text{Na}$ $[\text{M}+\text{Na}]^+$, found 333.1114.

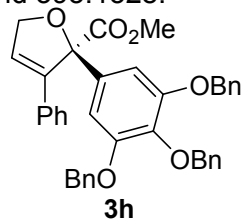


3f: colorless liquid, yield 36%, 69% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 25:1; 254 nm; retention time: $t_{\text{major}} = 35.53$ min, $t_{\text{minor}} = 40.26$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.24 – 6.79 (m, 8H), 6.46 (t, $J = 2.0$ Hz, 1H), 4.98 (dd, $J_1 = 14.0$ Hz, $J_2 = 2.0$ Hz, 1H), 4.92 (dd, $J_1 = 14.0$ Hz, $J_2 = 2.0$ Hz, 1H), 3.86 (s, 3H), 3.78 (s, 3H), 3.74 (s, 3H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 172.2, 149.0, 148.6, 141.3, 132.8, 131.8, 128.0, 127.9, 127.8, 126.8, 119.9, 110.9, 110.6, 94.5, 74.6, 55.8, 55.7, 52.5. HRMS: calcd 363.1208 for $\text{C}_{20}\text{H}_{20}\text{O}_5\text{Na}$ $[\text{M}+\text{Na}]^+$, found 363.1217.

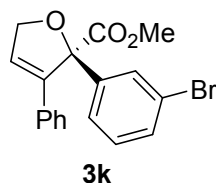


3g: colorless liquid, yield 50%, 79% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 15:1; 254 nm; retention time: $t_{\text{major}} = 36.31$ min, $t_{\text{minor}} = 24.36$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.28 – 7.25 (m, 5H), 6.57 (s, 2H), 6.41 (t, $J = 1.6$ Hz, 1H), 5.00 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.6$ Hz, 1H), 4.92 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.6$ Hz, 1H), 3.83 (s, 3H), 3.79 (s, 3H), 3.70 (s, 6H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 172.0, 152.8, 141.4, 137.9, 134.5,

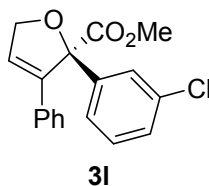
132.9, 128.2, 128.0, 127.9, 127.1, 104.7, 94.5, 74.9, 60.8, 56.0, 52.6. HRMS: calcd 393.1314 for $C_{21}H_{22}O_6Na$ $[M+Na]^+$, found 393.1328.



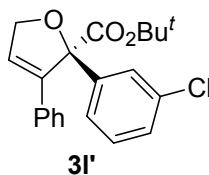
3h: colorless liquid, yield 24%, 68% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 6:1; 254 nm; retention time: t_{major} = 75.17 min, t_{minor} = 44.61 min); 1H NMR(400 MHz, $CDCl_3$): δ 7.43 – 7.27 (m, 16H), 7.19 (dd, J = 10.9, 8.0 Hz, 4H), 6.64 (s, 2H), 6.34 (s, 1H), 5.04 (s, 2H), 4.93 (d, J = 4.4 Hz, 4H), 4.87 (d, J = 1.4 Hz, 2H), 3.69 (s, 3H). ^{13}C NMR(100 MHz, $CDCl_3$): 171.78, 152.44, 141.57, 138.36, 137.85, 137.06, 134.60, 132.90, 128.53, 128.41, 128.17, 128.11, 127.99, 127.95, 127.79, 127.76, 127.46, 126.76, 107.32, 94.51, 75.10, 74.78, 71.21, 58.42, 52.55. HRMS: calcd 621.2253 for $C_{39}H_{34}O_6Na$ $[M+Na]^+$, found 621.2240.



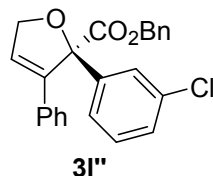
3k: colorless liquid, yield 56%, 88% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 50:1; 254 nm; retention time: t_{major} = 10.87 min, t_{minor} = 14.84 min); 1H NMR(400 MHz, $CDCl_3$): δ 7.55 (s, 1H), 7.44 (d, J = 7.9 Hz, 1H), 7.29 – 7.20 (m, 6H), 7.17 (t, J = 7.9 Hz, 1H), 6.47 (d, J = 1.6 Hz, 1H), 5.00 (dd, J_1 = 13.9 Hz, J_2 = 1.7 Hz, 1H), 4.95 (dd, J_1 = 13.9 Hz, J_2 = 1.7 Hz, 1H), 3.79 (s, 3H). ^{13}C NMR(100 MHz, $CDCl_3$): 171.49, 141.56, 140.94, 132.23, 131.43, 130.46, 129.68, 128.16, 127.89, 127.16, 126.05, 122.38, 94.08, 75.10, 52.78. HRMS: calcd 381.0102 for $C_{18}H_{15}O_3BrNa$ $[M+Na]^+$, found 381.0102.



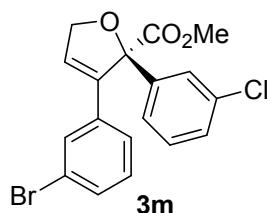
3l: colorless liquid, yield 47%, 88% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 50:1; 254 nm; retention time: t_{major} = 10.84 min, t_{minor} = 14.89 min); 1H NMR(400 MHz, $CDCl_3$): δ 7.39 (s, 1H), 7.29 – 7.22 (m, 8H), 6.45 (t, J = 2 Hz, 1H), 4.99 (dd, J_1 = 13.6 Hz, J_2 = 1.6 Hz, 1H), 4.93 (dd, J_1 = 13.6 Hz, J_2 = 1.6 Hz, 1H), 3.78 (s, 3H). ^{13}C NMR(100 MHz, $CDCl_3$): 171.5, 141.3, 141.0, 134.2, 132.3, 129.3, 128.4, 128.1, 128.0, 127.9, 127.6, 127.1, 125.6, 94.1, 75.0, 52.7. HRMS: calcd 337.0607 for $C_{18}H_{15}ClO_3Na$ $[M+Na]^+$, found 337.0616.



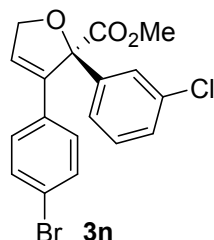
3l': colorless liquid, yield 31%, 55% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 18:1; 254 nm; retention time: $t_{\text{major}} = 5.28$ min, $t_{\text{minor}} = 6.16$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.42 (s, 1H), 7.32 – 7.17 (m, 8H), 6.46 (s, 1H), 4.96 (d, $J = 13.8$ Hz, 1H), 4.90 (d, $J = 13.8$ Hz, 1H), 1.35 (s, 9H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 169.7, 141.8, 141.1, 134.1, 132.8, 129.3, 128.3, 128.0, 127.9, 127.2, 125.8, 94.4, 82.6, 74.9, 27.8.



3l'': pale yellow liquid, yield 28%, 81% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 18:1; 254 nm; retention time: $t_{\text{major}} = 9.61$ min, $t_{\text{minor}} = 14.78$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.38 (s, 1H), 7.35 – 7.24 (m, 4H), 7.24 – 7.12 (m, 9H), 6.46 (s, 1H), 5.23 (d, $J = 13.2$ Hz, 1H), 5.20 (d, $J = 13.2$ Hz, 1H), 4.98 (d, $J = 13.5$ Hz, 1H), 4.93 (d, $J = 13.5$ Hz, 1H). $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 170.7, 141.3, 140.8, 135.2, 134.1, 132.2, 129.3, 128.4, 128.2, 128.1, 128.0, 127.8, 127.7, 127.3, 125.6, 94.1, 75.1, 67.3.

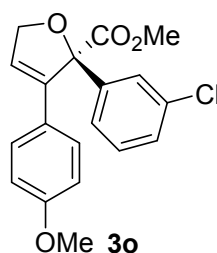


3m: colorless liquid, yield 44%; 81% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 11.22$ min, $t_{\text{minor}} = 15.34$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.43 (t, $J = 4.2$ Hz, 1H), 7.38 (s, 2H), 7.36 – 7.27 (m, 2H), 7.22 – 7.17 (m, 1H), 7.08 (s, 2H), 6.48 (t, $J = 1.9$ Hz, 1H), $^1\text{H NMR}$ (500 MHz, Chloroform-d) δ 7.48 – 7.43 (m, 1H), 7.40 (dq, $J = 5.7, 2.0$ Hz, 2H), 7.36 – 7.25 (m, 3H), 7.22 (ddd, $J = 7.7, 1.8, 1.2$ Hz, 1H), 7.15 – 7.06 (m, 2H), 6.50 (t, $J = 1.9$ Hz, 1H), 5.02 (dd, $J_1 = 14.2$ Hz, $J_2 = 2.0$ Hz, 1H), 4.98 (dd, $J_1 = 14.2$ Hz, $J_2 = 2.0$ Hz, 1H), 3.83 (s, 3H), 3.81 (s, 3H); $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 171.25, 140.95, 139.90, 134.39, 131.11, 130.91, 129.61, 129.53, 128.73, 128.42, 127.42, 126.57, 125.36, 109.76, 109.29, 94.08, 75.00, 52.85. HRMS: calcd $\text{C}_{20}\text{H}_{19}\text{O}_3\text{NaCl}[\text{M}+\text{Na}]^+$ for 365.0920, found 365.0907.

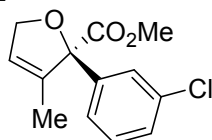


3n: colorless liquid, yield 49%; 80% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 13.29$ min, $t_{\text{minor}} = 16.83$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.40 – 7.33 (m, 3H), 7.32 – 7.28 (m, 1H), 7.24 – 7.14 (m, 2H), 7.10 (d, $J = 8.6$ Hz, 2H), 6.49 (t, $J = 1.8$ Hz, 1H), 5.00 (dd, $J_1 = 14.1$ Hz, $J_2 = 1.9$ Hz, 1H), 4.96 (dd, $J_1 = 14.1$ Hz, $J_2 = 2.0$ Hz, 1H), 3.79 (s, 3H); $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 171.35, 141.02, 139.98, 135.59, 134.40, 131.31, 129.56, 129.50, 128.73, 127.78,

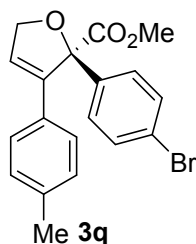
127.49, 125.45, 122.36, 94.08, 75.03, 52.82. HRMS: calcd $C_{18}H_{14}O_3NaClBr[M+Na]^+$ for 414.9713, found 414.9724.



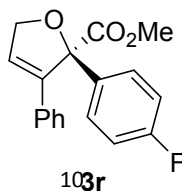
3o: colorless liquid, yield 62%; 82% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 10 : 1; 254 nm; Retention time: t_{major} = 8.42 min, t_{minor} = 11.95 min); 1H NMR(400 MHz, $CDCl_3$): δ 7.39 (d, J = 1.1 Hz, 1H), 7.29 (ddd, J = 4.5, 3.5, 1.8 Hz, 1H), 7.25 – 7.21 (m, 2H), 7.19 (d, J = 8.9 Hz, 2H), 6.76 (d, J = 8.9 Hz, 2H), 6.39 (s, 1H), 4.95 (dd, J_1 = 13.7 Hz, J_2 = 1.9 Hz, 1H), 4.93 (dd, J_1 = 13.7 Hz, J_2 = 1.9 Hz, 1H), 3.79 (s, 3H), 3.77 (s, 3H); ^{13}C NMR(100 MHz, $CDCl_3$):171.64, 159.34, 141.45, 140.20, 134.20, 129.42, 129.13, 128.49, 127.70, 125.69, 125.31, 124.58, 113.56, 94.10, 75.05, 55.20, 52.75. HRMS: calcd 367.0713 for $C_{19}H_{17}O_4NaCl[M+Na]^+$, found 367.0706.



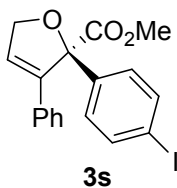
3p: colorless liquid, yield 53%, 49% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/isopropanol = 18:1; 254 nm; retention time: t_{major} = 6.05 min, t_{minor} = 6.80 min); 1H NMR(400 MHz, $CDCl_3$): δ 7.42 (s, 1H), 7.35–7.26 (m, 3H), 5.77 (d, J = 1.4 Hz, 1H), 4.83 (dd, J_1 = 13.7 Hz, J_2 = 1.9 Hz, 1H), 4.81 (dd, J_1 = 13.7 Hz, J_2 = 1.9 Hz, 1H), 3.82 (s, 3H), 1.82 (d, J = 1.4 Hz, 3H). ^{13}C NMR(100 MHz, $CDCl_3$): 171.4, 141.4, 137.4, 134.4, 129.5, 128.3, 126.3, 124.2, 124.1, 94.3, 74.8, 52.6, 13.0. HRMS: calcd 276.0553 for $C_{13}H_{13}ClO_3Na[M+Na]^+$, found 276.0542.



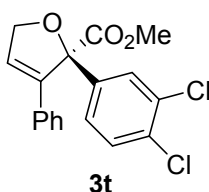
3q: colorless liquid, yield 64%; 92% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: t_{major} = 11.80 min, t_{minor} = 14.97min); 1H NMR(400 MHz, $CDCl_3$): δ 7.46 (d, J = 7.8 Hz, 2H), 7.28 (s, 2H), 7.16 (d, J = 7.6 Hz, 2H), 7.06 (d, J = 7.9 Hz, 2H), 6.46 (t, J = 1.9 Hz, 1H), 4.97 (dd, J_1 = 8.9 Hz, J_2 = 1.9 Hz, 1H), 4.95 (dd, J_1 = 8.9 Hz, J_2 = 1.9 Hz, 1H), 3.80 (s, 3H), 2.33 (s, 3H).; ^{13}C NMR(100 MHz, $CDCl_3$): 171.77, 140.68, 138.45, 138.05, 131.85, 131.31, 129.26, 128.90, 127.67, 126.18, 122.48, 94.23, 75.00, 52.72, 21.16. HRMS: calcd 395.0259 for $C_{19}H_{17}O_3NaBr[M+Na]^+$, found 395.0248.



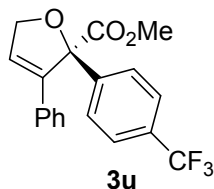
3r: colorless liquid, yield 71%; 71% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 11.53$ min, $t_{\text{minor}} = 16.43$ min); ^1H NMR (500 MHz, CDCl_3) δ 7.44 – 7.34 (m, 2H), 7.28 – 7.24 (m, 4H), 7.03 (t, $J = 8.7$ Hz, 1H), 6.52 (t, $J = 1.9$ Hz, 1H), 5.01 (dd, $J_1 = 13.9$ Hz, $J_2 = 1.9$ Hz, 1H), 4.95 (dd, $J_1 = 13.9$ Hz, $J_2 = 1.9$ Hz, 1H), 3.81 (s, 3H). ^{13}C NMR (125 MHz, CDCl_3) δ 172.01, 141.11, 135.20, 132.38, 129.40, 129.34, 128.15, 128.08, 127.81, 126.93, 115.21, 115.04, 94.07, 74.80, 52.60. HRMS: calcd 299.1005 for $\text{C}_{18}\text{H}_{16}\text{FO}_3[\text{M}+\text{H}]^+$, found 299.1045.



3s: colorless liquid, yield 70%; 92% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane/isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 17.13$ min, $t_{\text{minor}} = 23.83$ min); ^1H NMR (500 MHz, CDCl_3) δ 7.78 – 7.49 (m, 2H), 7.27 (m, 4H), 7.16 – 7.11 (m, 2H), 6.50 (t, $J = 1.9$ Hz, 1H), 5.02 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 4.95 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 3.81 (s, 3H). ^{13}C NMR (125 MHz, CDCl_3) δ 171.76, 140.88, 139.08, 137.34, 132.27, 129.39, 128.20, 128.15, 127.84, 127.13, 94.38, 94.20, 74.97, 52.64. HRMS: calcd 407.0066 for $\text{C}_{18}\text{H}_{16}\text{IO}_3[\text{M}+\text{H}]^+$, found 407.0036.

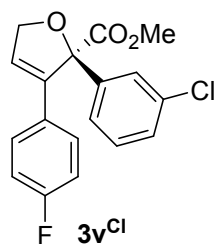


3t: colorless liquid, yield 78%; 88% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 12.97$ min, $t_{\text{minor}} = 17.01$ min); ^1H NMR (500 MHz, CDCl_3) δ 7.54 (d, $J = 2.2$ Hz, 1H), 7.39 (d, $J = 8.4$ Hz, 1H), 7.29 (d, $J = 2.3$ Hz, 1H), 7.29 – 7.27 (m, 2H), 7.27 – 7.23 (m, 2H), 7.21 (dd, $J = 8.4, 2.2$ Hz, 1H), 6.49 (t, $J = 1.9$ Hz, 1H), 5.04 (dd, $J_1 = 13.9$ Hz, $J_2 = 1.9$ Hz, 1H), 4.97 (dd, $J_1 = 13.9$ Hz, $J_2 = 1.9$ Hz, 1H), 3.82 (s, 3H). ^{13}C NMR (125 MHz, CDCl_3) δ 171.41, 140.83, 139.55, 132.46, 132.40, 132.04, 130.06, 129.55, 128.73, 128.32, 127.83, 127.31, 126.89, 93.54, 75.19, 52.80. HRMS: calcd 349.0320 for $\text{C}_{18}\text{H}_{15}\text{Cl}_2\text{O}_3[\text{M}+\text{H}]^+$, found 349.0360.

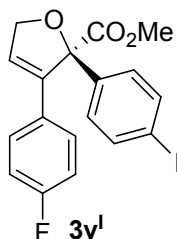


3u: colorless liquid, yield 40%; 76% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 7.80$ min, $t_{\text{minor}} = 8.75$ min); ^1H NMR (400 MHz, CDCl_3): 7.69 (dq, $J_1 = 1.8$ Hz, $J_2 = 0.9$ Hz, 1H), 7.63 – 7.53 (m, 2H), 7.45 (dt, $J_1 = 7.8$ Hz, $J_2 = 0.7$ Hz, 1H), 7.32 – 7.19 (m, 5H), 6.50 (s, 1H), 5.06 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 4.99 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 3.84 (s, 3H).; ^{13}C NMR

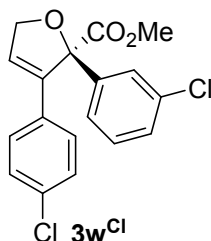
(125 MHz, CDCl₃) δ 171.64, 141.03, 140.32, 132.23, 130.80, 128.55, 128.25, 127.89, 127.33, 125.12, 125.09, 124.33, 124.30, 109.79, 94.04, 75.19, 52.75. HRMS: calcd 349.0973 for C₁₉H₁₆F₃O₃[M+H]⁺, found 349.0943.



3v^{Cl}: colorless liquid, yield 64%; 80% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: t_{major} = 11.41 min, t_{minor} = 15.73 min) ; ¹H NMR (500 MHz, CDCl₃) δ 7.41 – 7.38 (m, 1H), 7.34 – 7.31 (m, 1H), 7.29 (d, J = 2.0 Hz, 1H), 7.25 – 7.20 (m, 3H), 7.00 – 6.87 (m, 2H), 6.44 (t, J = 1.9 Hz, 1H), 5.01 (dd, J_1 = 13.9 Hz, J_2 = 1.9 Hz, 1H), 4.97 (dd, J_1 = 13.9 Hz, J_2 = 1.9 Hz, 1H), 3.82 (s, 3H). ¹³C NMR (125 MHz, CDCl₃) δ 171.51, 141.18, 140.07, 134.37, 129.81, 129.75, 129.53, 128.66, 128.36, 127.51, 127.10, 127.08, 125.47, 115.22, 115.05, 94.12, 74.96, 52.69. HRMS: calcd 333.0616 for C₁₈H₁₅ClFO₃[M+H]⁺, found 333.0666.

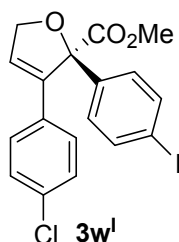


3v^I: colorless liquid, yield 68%; 88% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: t_{major} = 16.51 min, t_{minor} = 22.77 min) ; ¹H NMR (500 MHz, CDCl₃) δ 7.71 – 7.65 (m, 2H), 7.27 – 7.20 (m, 2H), 7.14 – 7.08 (m, 2H), 6.98 – 6.91 (m, 2H), 6.44 (t, J = 1.9 Hz, 1H), 5.00 (dd, J_1 = 13.8 Hz, J_2 = 2.0 Hz, 1H), 4.94 (dd, J_1 = 13.8 Hz, J_2 = 2.0 Hz, 1H), 3.81 (s, 3H). ¹³C NMR (125 MHz, CDCl₃) δ 171.67, 139.97, 138.90, 137.45, 129.77, 129.70, 129.25, 127.05, 115.24, 115.06, 94.51, 94.23, 74.91, 52.67. HRMS: calcd 424.9972 for C₁₈H₁₅FO₃[M+H]⁺, found 424.9932.

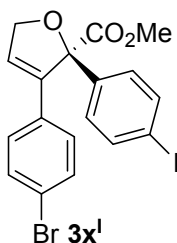


3w^{Cl}: colorless liquid, yield 59%; 80% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: t_{major} = 11.41 min, t_{minor} = 15.53 min) ; ¹H NMR (500 MHz, CDCl₃) δ 7.42 – 7.37 (m, 1H), 7.33 (ddd, J = 7.9, 2.1, 1.2 Hz, 1H), 7.31 – 7.21 (m, 5H), 7.21 – 7.16 (m, 2H), 6.50 (t, J = 1.9 Hz, 1H), 5.01 (dd, J_1 = 14.1 Hz, J_2 = 2.0 Hz, 1H), 4.97 (dd, J_1 = 14.1 Hz, J_2 = 2.0 Hz, 1H), 3.82 (s, 3H). ¹³C NMR (126 MHz, CDCl₃) δ 171.46, 141.09, 139.96, 134.42, 134.13, 130.69, 129.58, 129.24, 128.74, 128.38, 127.72, 127.52, 125.48, 94.08, 74.96, 52.72. HRMS: calcd 349.0320 for C₁₈H₁₅Cl₂O₃[M+H]⁺,

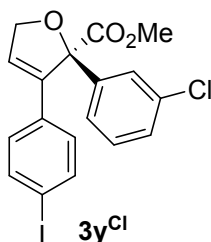
found 349.0350.



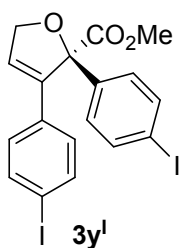
3w^I: colorless liquid, yield 67%; 88% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 15.80$ min, $t_{\text{minor}} = 22.06$ min) ; ¹H NMR(400 MHz, CDCl₃): δ 7.46 (d, $J = 7.8$ Hz, 2H), 7.28 (s, 2H), 7.16 (d, $J = 7.6$ Hz, 2H), 7.06 (d, $J = 7.9$ Hz, 2H), 6.46 (s, 1H), 5.00 (dd, $J_1 = 14.1$ Hz, $J_2 = 1.9$ Hz, 1H), 4.94 (dd, $J_1 = 14.1$ Hz, $J_2 = 1.9$ Hz, 1H), 3.80 (s, 3H), 2.33 (s, 3H).; ¹³C NMR(100 MHz, CDCl₃): 171.77, 140.68, 138.45, 138.05, 131.85, 131.31, 129.26, 128.90, 127.67, 126.18, 122.48, 94.23, 75.00, 52.72, 21.16. HRMS: calcd 440.9676 for C₁₈H₁₄ClIO₃[M+H]⁺, found 440.9696.



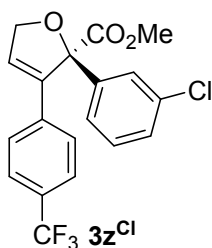
3x^I: colorless liquid, yield 72%; 91% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 16.38$ min, $t_{\text{minor}} = 23.11$ min) ; ¹H NMR(500 MHz, CDCl₃): δ 7.72 – 7.65 (m, 2H), 7.41 – 7.35 (m, 2H), 7.17 – 7.07 (m, 4H), 6.51 (t, $J = 1.9$ Hz, 1H), 4.99 (dd, $J_1 = 14.1$ Hz, $J_2 = 1.9$ Hz, 1H), 4.93 (dd, $J_1 = 14.1$ Hz, $J_2 = 1.9$ Hz, 1H), 3.81 (s, 3H).¹³C NMR (125 MHz, CDCl₃) δ 171.60, 139.92, 138.78, 137.51, 131.36, 131.18, 129.50, 129.26, 127.81, 122.37, 94.61, 94.16, 74.94, 52.71. HRMS: calcd 484.9171 for C₁₈H₁₅BrIO₃[M+H]⁺, found 484.9201.



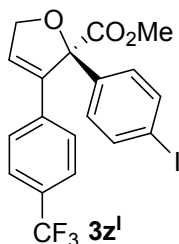
3y^{Cl}: colorless liquid, yield 56%; 78% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 12.32$ min, $t_{\text{minor}} = 16.50$ min) ; ¹H NMR (500 MHz, CDCl₃) δ 7.61 – 7.56 (m, 2H), 7.39 (t, $J = 1.9$ Hz, 1H), 7.36 – 7.24 (m, 3H), 7.22 (dd, $J = 1.9, 1.2$ Hz, 1H), 7.02 – 6.96 (m, 2H), 6.53 (t, $J = 1.9$ Hz, 1H), δ 4.99 (dd, $J_1 = 14.2$ Hz, $J_2 = 1.9$ Hz, 1H), 4.95 (dd, $J_1 = 14.2$ Hz, $J_2 = 1.9$ Hz, 1H), 3.82 (s, 3H).; ¹³C NMR (125 MHz, CDCl₃) δ 171.44, 141.08, 140.07, 137.32, 134.43, 131.72, 129.66, 129.60, 128.76, 127.88, 127.53, 125.50, 94.10, 94.02, 74.98, 52.74. HRMS: calcd 440.9676 for C₁₈H₁₅ClIO₃[M+H]⁺, found 440.9696.



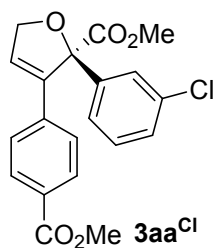
3y^I: colorless liquid, yield 61%; 87% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 17.43$ min, $t_{\text{minor}} = 24.84$ min) ; $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.71 – 7.65 (m, 2H), 7.61 – 7.55 (m, 2H), 7.13 – 7.07 (m, 2H), 7.00 (d, $J = 8.7$ Hz, 2H), 6.53 (t, $J = 1.9$ Hz, 1H), δ 4.98 (dd, $J_1 = 14.1$ Hz, $J_2 = 1.9$ Hz, 1H), 4.93 (dd, $J_1 = 14.1$ Hz, $J_2 = 1.9$ Hz, 1H), 3.81 (s, 3H). $^{13}\text{C NMR}$ (126 MHz, CDCl_3) δ 171.60, 140.00, 138.77, 137.51, 137.33, 131.73, 129.62, 129.26, 127.84, 94.61, 94.13, 94.07, 74.93, 52.71. HRMS: calcd 532.9032 for $\text{C}_{18}\text{H}_{14}\text{I}_2\text{O}_3$ [M+H]⁺, found 532.9052.



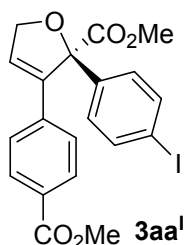
3z^{Cl}: colorless liquid, yield 53%; 78% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 10.28$ min, $t_{\text{minor}} = 12.71$ min) ; $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.54 – 7.48 (m, 2H), 7.39 – 7.26 (m, 5H), 7.22 (ddd, $J = 7.8, 1.8, 1.2$ Hz, 1H), 6.60 (t, $J = 1.9$ Hz, 1H), 5.08 – 4.97 (m, 2H), 3.83 (s, 3H).; $^{13}\text{C NMR}$ (125 MHz, CDCl_3) δ 171.33, 140.95, 140.04, 135.84, 134.53, 129.67, 129.25, 128.87, 128.22, 127.46, 125.39, 125.13, 125.10, 125.08, 125.04, 94.14, 74.99, 52.76. HRMS: calcd 383.0584 for $\text{C}_{19}\text{H}_{14}\text{ClF}_3\text{O}_3$ [M+H]⁺, found 383.0574.



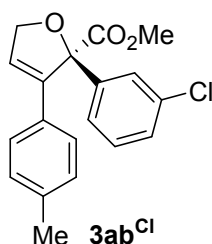
3z^I: colorless liquid, yield 58%; 90% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 13.63$ min, $t_{\text{minor}} = 17.73$ min) ; $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.72 – 7.67 (m, 2H), 7.51 (dt, $J = 8.2, 0.7$ Hz, 2H), 7.37 (dd, $J = 8.5, 1.2$ Hz, 2H), 7.29 (s, 1H), 7.13 – 7.08 (m, 2H), 6.60 (d, $J = 1.9$ Hz, 1H), 5.03 (dd, $J_1 = 14.4$ Hz, $J_2 = 1.9$ Hz, 1H), 4.98 (dd, $J_1 = 14.4$ Hz, $J_2 = 2.0$ Hz, 1H)., 3.82 (s, 3H). $^{13}\text{C NMR}$ (125 MHz, CDCl_3) δ 171.49, 139.94, 138.65, 138.08, 137.89, 137.65, 137.59, 131.33, 129.25, 129.16, 128.18, 125.12, 125.09, 125.06, 94.70, 94.25, 74.98, 52.74. HRMS: calcd 474.9940 for $\text{C}_{19}\text{H}_{15}\text{F}_3\text{IO}_3$ [M+H]⁺, found 474.9945.



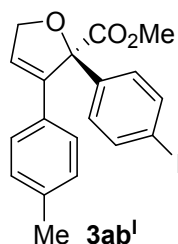
3aa^{Cl}: colorless liquid, yield 43%; 76% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 17.27$ min, $t_{\text{minor}} = 21.58$ min) ; ¹H NMR (500 MHz, CDCl₃): δ 7.92 (d, $J = 8.8$ Hz, 2H), 7.40 (t, $J = 1.9$ Hz, 1H), 7.36 – 7.24 (m, 5H), 7.24 – 7.19 (m, 1H), 6.62 (t, $J = 1.9$ Hz, 1H), 5.03 (dd, $J_1 = 14.3$ Hz, $J_2 = 1.9$ Hz, 1H), 4.99 (dd, $J_1 = 14.3$ Hz, $J_2 = 2.0$ Hz, 1H), 3.91 (s, 3H), 3.81 (s, 3H); ¹³C NMR (125 MHz, CDCl₃) δ 171.39, 166.73, 141.02, 140.32, 136.73, 134.42, 129.59, 129.41, 129.24, 128.77, 127.85, 127.53, 125.48, 94.11, 75.03, 52.73, 52.05. HRMS: calcd 373.0765 for C₂₀H₁₈ClO₅[M+H]⁺, found 373.0756.



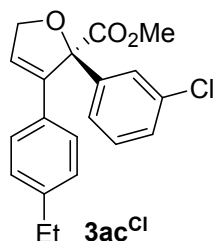
3aa^I: colorless liquid, yield 50%; 90% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 27.76$ min, $t_{\text{minor}} = 34.29$ min) ; ¹H NMR (500 MHz, CDCl₃): δ 7.95 – 7.89 (m, 2H), 7.68 (d, $J = 8.8$ Hz, 2H), 7.36 – 7.27 (m, 3H), 7.13 – 7.08 (m, 2H), 6.62 (t, $J = 1.9$ Hz, 1H), 5.03 (dd, $J_1 = 14.3$ Hz, $J_2 = 1.9$ Hz, 1H), 4.97 (dd, $J_1 = 14.3$ Hz, $J_2 = 2.0$ Hz, 1H), 3.92 (s, 3H), 3.81 (s, 3H); ¹³C NMR (125 MHz, CDCl₃) δ 171.54, 166.71, 140.26, 138.72, 137.51, 136.74, 129.58, 129.43, 129.25, 129.21, 127.82, 94.62, 94.22, 77.22, 76.97, 76.71, 74.98, 52.71, 52.06. HRMS: calcd 465.0121 for C₂₀H₁₈IO₅[M+H]⁺, found 465.0128.



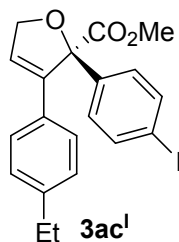
3ab^{Cl}: colorless liquid, yield 76%; 80% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 10.18$ min, $t_{\text{minor}} = 16.55$ min) ; ¹H NMR (500 MHz, CDCl₃): δ 7.43 (dt, $J = 2.1, 0.9$ Hz, 1H), 7.35 – 7.23 (m, 4H), 7.19 – 7.13 (m, 2H), 7.11 – 7.04 (m, 2H), 6.47 (t, $J = 1.9$ Hz, 1H), δ 5.01 (dd, $J_1 = 13.7$ Hz, $J_2 = 1.9$ Hz, 1H), 4.96 (dd, $J_1 = 13.7$ Hz, $J_2 = 2.0$ Hz, 1H), 3.82 (s, 3H); ¹³C NMR (126 MHz, CDCl₃) δ 171.67, 141.49, 140.74, 138.09, 134.21, 129.41, 129.28, 128.91, 128.49, 127.73, 127.71, 126.28, 125.70, 94.07, 75.00, 52.65, 21.03. HRMS: calcd 329.0866 for C₁₉H₁₈ClO₃[M+H]⁺, found 329.0855.



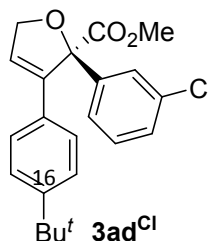
3ab^I: colorless liquid, yield 72%; 86% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 15.10$ min, $t_{\text{minor}} = 19.84$ min) ; ^1H NMR (500 MHz, CDCl_3): δ 7.70 – 7.63 (m, 2H), 7.20 – 7.11 (m, 4H), 7.10 – 7.04 (m, 2H), 6.47 (t, $J = 1.9$ Hz, 1H), 5.00 (dd, $J = 13.8, 1.9$ Hz, 1H), 5.00 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 4.93 (dd, $J_1 = 13.8$ Hz, $J_2 = 2.0$ Hz, 1H), 3.80 (s, 3H), 2.33 (s, 3H).; ^{13}C NMR (125 MHz, CDCl_3) δ 171.84, 140.64, 139.19, 138.09, 137.32, 129.48, 129.30, 128.93, 127.69, 126.24, 94.35, 94.15, 74.96, 52.63, 21.03. HRMS: calcd 421.0222 for $\text{C}_{19}\text{H}_{18}\text{I}\text{O}_3[\text{M}+\text{H}]^+$, found 421.0235.



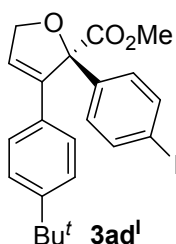
3ac^{Cl}: colorless liquid, yield 78%; 87% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 9.10$ min, $t_{\text{minor}} = 14.21$ min) ; ^1H NMR(400 MHz, CDCl_3): δ 7.40 (s, 1H), 7.28 (d, $J = 4.7$ Hz, 1H), 7.24 (d, $J = 4.5$ Hz, 2H), 7.16 (d, $J = 7.9$ Hz, 2H), 7.07 (d, $J = 7.9$ Hz, 2H), 6.45 (s, 1H), 4.97 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 4.93 (dd, $J_1 = 13.8$ Hz, $J_2 = 2.0$ Hz, 1H), 3.79 (s, 3H), 2.60 (d, $J = 7.6$ Hz, 2H), 1.20 (t, $J = 7.6$ Hz, 3H) ; ^{13}C NMR(100 MHz, CDCl_3): 171.58, 144.30, 141.45, 140.72, 134.17, 129.45, 129.39, 128.47, 127.76, 127.70, 127.66, 126.27, 125.68, 94.10, 75.05, 52.74, 29.70, 15.22 HRMS: calcd 343.1023 for $\text{C}_{20}\text{H}_{20}\text{Cl}\text{O}_3[\text{M}+\text{H}]^+$, found 343.1056.



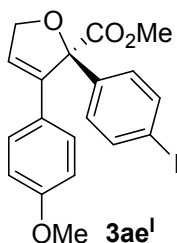
3ac^I: colorless liquid, yield 76%; 82% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 9.22$ min, $t_{\text{minor}} = 11.27$ min) ; ^1H NMR(500 MHz, CDCl_3): δ 7.70 – 7.64 (m, 2H), 7.29 (s, 1H), 7.23 – 7.06 (m, 6H), 6.48 (t, $J = 1.9$ Hz, 1H), 5.00 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 4.93 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 3.80 (s, 3H), 2.63 (q, $J = 7.6$ Hz, 2H), 1.23 (t, $J = 7.6$ Hz, 3H).; ^{13}C NMR (126 MHz, CDCl_3) δ 171.85, 144.35, 140.63, 139.20, 137.32, 129.50, 129.48, 127.72, 127.71, 126.26, 94.34, 94.15, 74.96, 52.63, 28.36, 15.07. HRMS: calcd 435.0379 for $\text{C}_{20}\text{H}_{20}\text{I}\text{O}_3$ [M+H]⁺, found 435.0367.



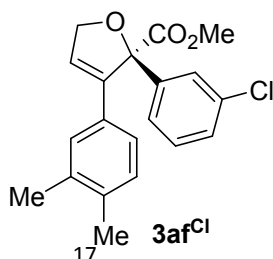
3ad^{Cl}: colorless liquid, yield 78%; 67% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 7.64$ min, $t_{\text{minor}} = 10.68$ min) ; $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.40 (s, 1H), 7.31 – 7.27 (m, 1H), 7.26 – 7.23 (m, 4H), 7.18 (d, $J = 8.3$ Hz, 2H), 6.47 (s, 1H), 5.00 (dd, $J_1 = 13.8$, $J_2 = 2.0$ Hz, 1H), 4.93 (dd, $J_1 = 13.8$, $J_2 = 2.0$ Hz, 1H), 3.79 (s, 3H), 1.28 (s, 9H); $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 171.58, 151.14, 141.51, 140.60, 134.17, 129.41, 129.13, 128.47, 127.73, 127.44, 126.30, 125.70, 125.11, 94.09, 75.05, 52.75, 41.99, 31.18. HRMS: calcd 393.1233 for $\text{C}_{22}\text{H}_{23}\text{O}_3\text{NaCl}[\text{M}+\text{Na}]^+$, found 393.1220.



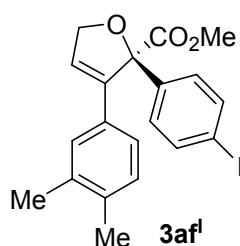
3ad^I: colorless liquid, yield 70%; 71% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 12.65$ min, $t_{\text{minor}} = 15.98$ min) ; $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.71 – 7.65 (m, 2H), 7.31 – 7.25 (m, 2H), 7.25 – 7.20 (m, 2H), 7.19 – 7.13 (m, 2H), 6.51 (t, $J = 1.9$ Hz, 1H), 5.00 (dd, $J_1 = 13.8$, $J_2 = 1.9$ Hz, 1H), 4.93 (dd, $J_1 = 13.8$, $J_2 = 2.0$ Hz, 1H), 3.81 (s, 3H), 1.31 (s, 9H). $^{13}\text{C NMR}$ (126 MHz, CDCl_3) δ 171.87, 151.20, 140.47, 139.26, 137.34, 129.57, 129.15, 127.40, 126.33, 125.16, 94.37, 94.14, 74.96, 52.65, 34.45, 31.07. HRMS: calcd 463.0692 for $\text{C}_{22}\text{H}_{24}\text{IO}_3[\text{M}+\text{H}]^+$, found 463.0703.



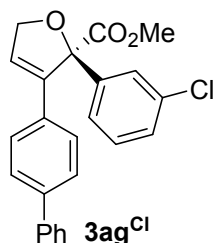
3ae^I: colorless liquid, yield 81%; 82% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 25.29$ min, $t_{\text{minor}} = 45.43$ min) ; $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.70 – 7.64 (m, 2H), 7.25 – 7.19 (m, 2H), 7.17 – 7.11 (m, 2H), 6.82 – 6.76 (m, 2H), 6.41 (t, $J = 1.9$ Hz, 1H), 4.99 (dd, $J_1 = 13.7$ Hz, $J_2 = 1.9$ Hz, 1H), 4.92 (dd, $J_1 = 13.6$ Hz, $J_2 = 2.0$ Hz, 1H), 3.81 (s, 3H), 3.80 (s, 3H).; $^{13}\text{C NMR}$ (126 MHz, CDCl_3) δ 171.90, 159.46, 140.14, 139.20, 137.35, 129.50, 129.12, 125.27, 124.61, 113.57, 94.37, 94.16, 74.95, 55.11, 52.63. HRMS: calcd 437.0172 for $\text{C}_{19}\text{H}_{18}\text{IO}_4[\text{M}+\text{H}]^+$, found 437.0186.



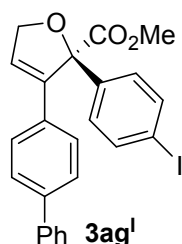
3af^{Cl}: colorless liquid, yield 61%; 80% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 60 : 1; 254 nm; Retention time: $t_{\text{major}} = 8.46$ min, $t_{\text{minor}} = 11.25$ min); ¹H NMR(400 MHz, CDCl₃): δ 7.41 (d, $J = 1.1$ Hz, 1H), 7.30 – 7.26 (m, 1H), 7.25 – 7.21 (m, 2H), 7.05 (s, 1H), 6.98 (d, $J = 7.9$ Hz, 1H), 6.91 (d, $J = 7.9$ Hz, 1H), 6.42 (s, 1H), 4.99 (dd, $J_1 = 13.7$ Hz, $J_2 = 1.9$ Hz, 1H), 4.92 (dd, $J_1 = 13.8$ Hz, $J_2 = 2.0$ Hz, 1H), 3.79 (s, 3H), 2.20 (d, $J = 11.6$ Hz, 6H); ¹³C NMR (100 MHz, CDCl₃): 171.60, 141.53, 140.84, 136.77, 136.30, 134.11, 129.72, 129.39, 129.32, 128.96, 128.41, 127.70, 126.07, 125.68, 125.30, 94.05, 75.04, 52.73, 19.82, 19.49. HRMS: calcd 365.0920 for C₂₀H₁₉O₃NaCl[M+Na]⁺, found 365.0907.



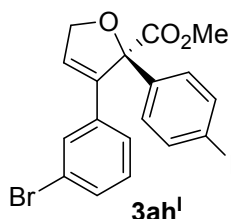
3af^I: colorless liquid, yield 74%; 85% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 12.64$ min, $t_{\text{minor}} = 16.43$ min); ¹H NMR(500 MHz, CDCl₃): δ 7.69 – 7.63 (m, 2H), 7.29 (s, 1H), 7.17 – 7.08 (m, 3H), 7.01 (d, $J = 8.0$ Hz, 1H), 6.96 (d, $J = 2.0$ Hz, 1H), 6.45 (t, $J = 1.9$ Hz, 1H), 4.99 (dd, $J_1 = 13.7$ Hz, $J_2 = 1.9$ Hz, 1H), 4.92 (dd, $J_1 = 13.8$ Hz, $J_2 = 2.0$ Hz, 1H), 3.81 (s, 3H), 2.24 (s, 3H), 2.21 (s, 3H); ¹³C NMR (125 MHz, CDCl₃): δ 171.88, 140.75, 139.27, 137.26, 136.84, 136.39, 129.75, 129.50, 129.44, 128.90, 126.06, 125.25, 94.27, 94.09, 74.94, 52.62, 19.70, 19.34. HRMS: calcd 435.0379 for C₂₀H₂₀IO₃[M+H]⁺, found 435.0398.



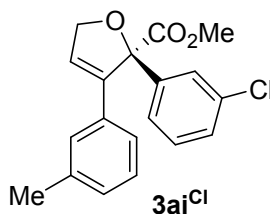
3ag^{Cl}: colorless liquid, yield 71%; 86% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 15.03$ min, $t_{\text{minor}} = 24.37$ min); ¹H NMR(500 MHz, CDCl₃): δ 7.62 – 7.56 (m, 2H), 7.54 – 7.41 (m, 5H), 7.40 – 7.27 (m, 6H), 6.58 (t, $J = 1.9$ Hz, 1H), 5.05 (dd, $J_1 = 14.0$ Hz, $J_2 = 1.9$ Hz, 1H), 4.99 (dd, $J_1 = 14.0$ Hz, $J_2 = 2.0$ Hz, 1H), 3.85 (s, 3H); ¹³C NMR (126 MHz, CDCl₃): δ 171.66, 141.39, 140.82, 140.48, 140.37, 134.33, 131.07, 129.53, 128.83, 128.63, 128.25, 127.73, 127.53, 127.14, 126.96, 126.82, 125.70, 94.12, 75.04, 52.72. HRMS: calcd 391.1023 for C₂₄H₂₀ClO₃[M+H]⁺, found 391.1049.



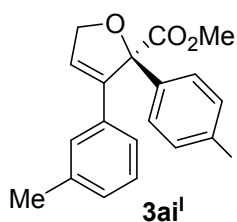
3ag^I: colorless liquid, yield 73%; 92% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 24.07$ min, $t_{\text{minor}} = 48.52$ min) ; $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.46 (d, $J = 7.8$ Hz, 2H), 7.28 (s, 2H), 7.16 (d, $J = 7.6$ Hz, 2H), 7.06 (d, $J = 7.9$ Hz, 2H), 6.46 (s, 1H), 5.03 (dd, $J_1 = 14.0$ Hz, $J_2 = 1.9$ Hz, 1H), 4.97 (dd, $J_1 = 13.9$ Hz, $J_2 = 2.0$ Hz, 1H), 3.80 (s, 3H), 2.33 (s, 3H).; $^{13}\text{C NMR}$ (100 MHz, CDCl_3): 171.77, 140.68, 138.45, 138.05, 131.85, 131.31, 129.26, 128.90, 127.67, 126.18, 122.48, 94.23, 75.00, 52.72, 21.16. HRMS: calcd 483.0379 for $\text{C}_{24}\text{H}_{19}\text{IO}_3[\text{M}+\text{H}]^+$, found 483.0386.



3ah^I: colorless liquid, yield 80%; 93% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 15.77$ min, $t_{\text{minor}} = 24.45$ min) ; $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.72 – 7.66 (m, 2H), 7.48 (dt, $J = 2.1, 0.9$ Hz, 1H), 7.40 (ddd, $J = 6.2, 3.0, 2.0$ Hz, 1H), 7.29 (s, 1H), 7.14 – 7.07 (m, 4H), 6.51 (t, $J = 1.9$ Hz, 1H), 5.01 (dd, $J = 14.2, 1.9$ Hz, 1H), 5.01 (dd, $J_1 = 14.2$ Hz, $J_2 = 1.9$ Hz, 1H), 4.95 (dd, $J_1 = 14.1$ Hz, $J_2 = 2.0$ Hz, 1H), 3.82 (s, 3H).; $^{13}\text{C NMR}$ (125 MHz, CDCl_3) δ 171.51, 139.82, 138.72, 137.48, 134.46, 131.13, 130.85, 129.67, 129.16, 128.46, 126.52, 122.25, 94.58, 94.15, 74.88, 52.73. HRMS: calcd 483.9171 for $\text{C}_{18}\text{H}_{15}\text{BrIO}_3[\text{M}+\text{H}]^+$, found 483.9179.

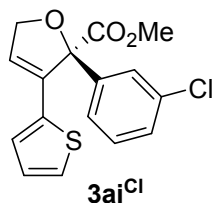


3ai^{Cl}: colorless liquid, yield 73%; 85% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 9.48$ min, $t_{\text{minor}} = 14.60$ min) ; $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.43 (dt, $J = 2.1, 0.9$ Hz, 1H), 7.34 – 7.23 (m, 4H), 7.18 – 7.11 (m, 1H), 7.11 – 7.07 (m, 2H), 7.04 – 6.98 (m, 1H), 6.47 (t, $J = 1.9$ Hz, 1H), 5.02 (dd, $J = 13.8, 1.9$ Hz, 1H), 5.02 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 4.96 (dd, $J_1 = 13.8$ Hz, $J_2 = 2.0$ Hz, 1H), 3.82 (s, 3H), 2.31 (s, 3H).; $^{13}\text{C NMR}$ (125 MHz, CDCl_3): δ 171.63, 141.45, 141.14, 137.74, 134.16, 132.24, 129.35, 128.96, 128.56, 128.46, 128.05, 127.65, 126.93, 125.61, 125.03, 94.06, 75.01, 52.66, 21.29. HRMS: calcd 329.0866 for $\text{C}_{19}\text{H}_{18}\text{ClO}_3[\text{M}+\text{H}]^+$, found 329.0878.

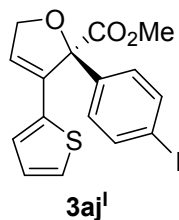


3ai^I: colorless liquid, yield 75%; 85% ee, determined by HPLC (Daicel Chirapak IA, flow rate:

1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 13.07$ min, $t_{\text{minor}} = 18.14$ min); $^1\text{H NMR}$ (400 MHz, CDCl_3): δ 7.70 – 7.64 (m, 2H), 7.18 – 7.06 (m, 5H), 7.01 (d, $J = 7.5$ Hz, 1H), 6.48 (t, $J = 1.9$ Hz, 1H), 5.01 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 4.93 (dd, $J_1 = 13.8$ Hz, $J_2 = 1.9$ Hz, 1H), 3.81 (s, 3H), 2.31 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3): δ 171.81, 141.00, 139.18, 137.79, 137.27, 132.25, 129.43, 128.97, 128.47, 128.08, 126.94, 124.94, 94.31, 94.14, 74.96, 52.64, 21.32. HRMS: calcd 421.0222 for $\text{C}_{19}\text{H}_{18}\text{IO}_3[\text{M}+\text{H}]^+$, found 421.0249.



3aj^{Cl}: colorless liquid, yield 40%; 72% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 11.39$ min, $t_{\text{minor}} = 19.98$ min); $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.46 – 7.41 (m, 1H), 7.36 – 7.27 (m, 4H), 7.21 (dd, $J = 5.1, 1.2$ Hz, 1H), 6.92 – 6.82 (m, 2H), 6.46 (t, $J = 2.0$ Hz, 1H), 5.00 ($J_1 = 14.1$ Hz, $J_2 = 2.0$ Hz, 1H), 4.95 (dd, $J_1 = 14.1$ Hz, $J_2 = 2.1$ Hz, 1H), 3.85 (s, 3H); $^{13}\text{C NMR}$ (125 MHz, CDCl_3) δ 171.31, 140.92, 134.92, 134.76, 134.27, 129.51, 128.79, 127.90, 127.46, 127.35, 126.33, 125.81, 125.52, 94.09, 75.01, 52.72. HRMS: calcd 321.0274 for $\text{C}_{16}\text{H}_{14}\text{ClO}_3\text{S}[\text{M}+\text{H}]^+$, found 321.0292.



3aj^I: colorless liquid, yield 48%; 77% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 50 : 1; 254 nm; Retention time: $t_{\text{major}} = 19.19$ min, $t_{\text{minor}} = 29.04$ min); $^1\text{H NMR}$ (500 MHz, CDCl_3): δ 7.72 – 7.66 (m, 2H), 7.23 – 7.14 (m, 3H), 6.91 – 6.81 (m, 2H), 6.45 (t, $J = 2.0$ Hz, 1H), 4.99 (dd, $J_1 = 14.1$ Hz, $J_2 = 2.0$ Hz, 1H), 4.93 (dd, $J_1 = 14.1$ Hz, $J_2 = 2.1$ Hz, 1H), 3.84 (s, 3H); $^{13}\text{C NMR}$ (126 MHz, CDCl_3) δ 171.49, 138.63, 137.43, 134.83, 134.81, 129.59, 127.47, 127.37, 126.31, 125.50, 94.69, 94.23, 74.97, 52.70.; HRMS: calcd 411.9630 for $\text{C}_{16}\text{H}_{14}\text{IO}_3\text{S}[\text{M}+\text{H}]^+$, found 411.9656.

E. Mechanistic experiments

1. Titration of (*R*)-3,5-DM-BINAP into AgSbF₆ in ¹H NMR analysis

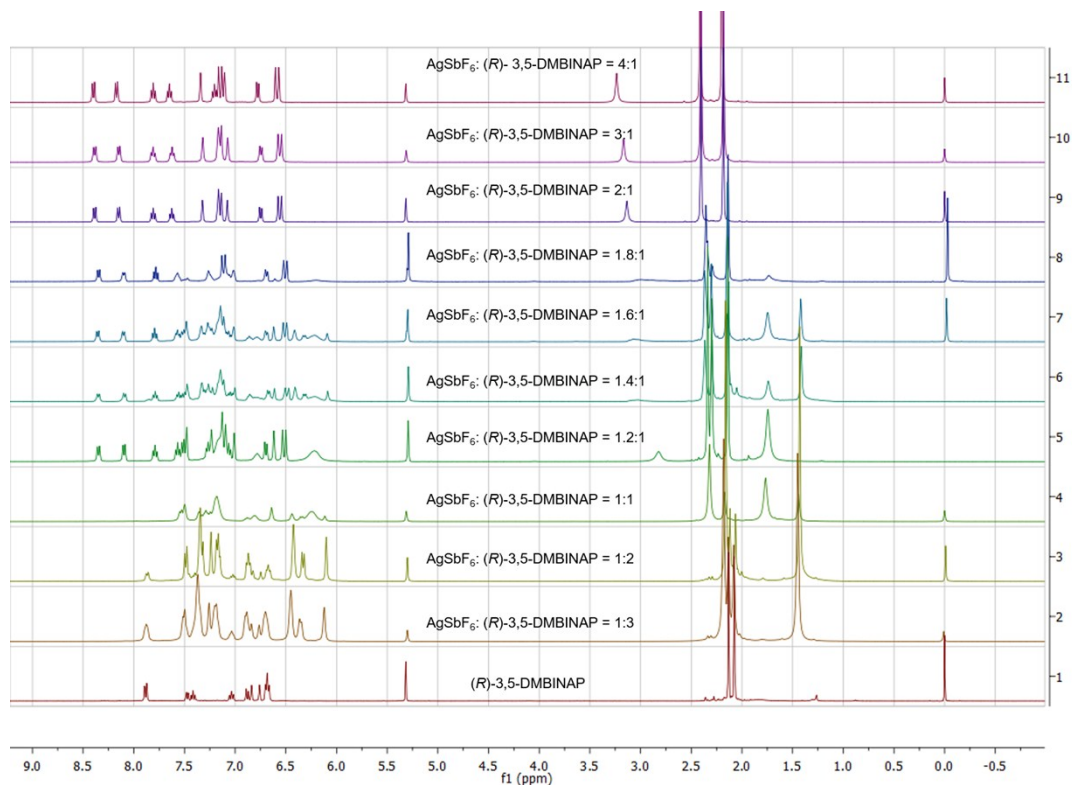


Figure S1: Stacked spectra of ¹H NMR of AgSbF₆ and (*R*)-3,5-DM-BINAP with ratio of 0:1, 1:1, 2:1, 3:1, and 4:1. We observed a stable complex signal when the ratio was increased to 1:2 (Supporting information, Figure S1), suggesting that the complex of (*R*)-3,5-DM-BINAP and AgSbF₆ adopted a 1:2 coordination in the reaction.

2. Titration of (*R*)-3,5-DM-BINAP into AgSbF₆ in ³¹P NMR analysis

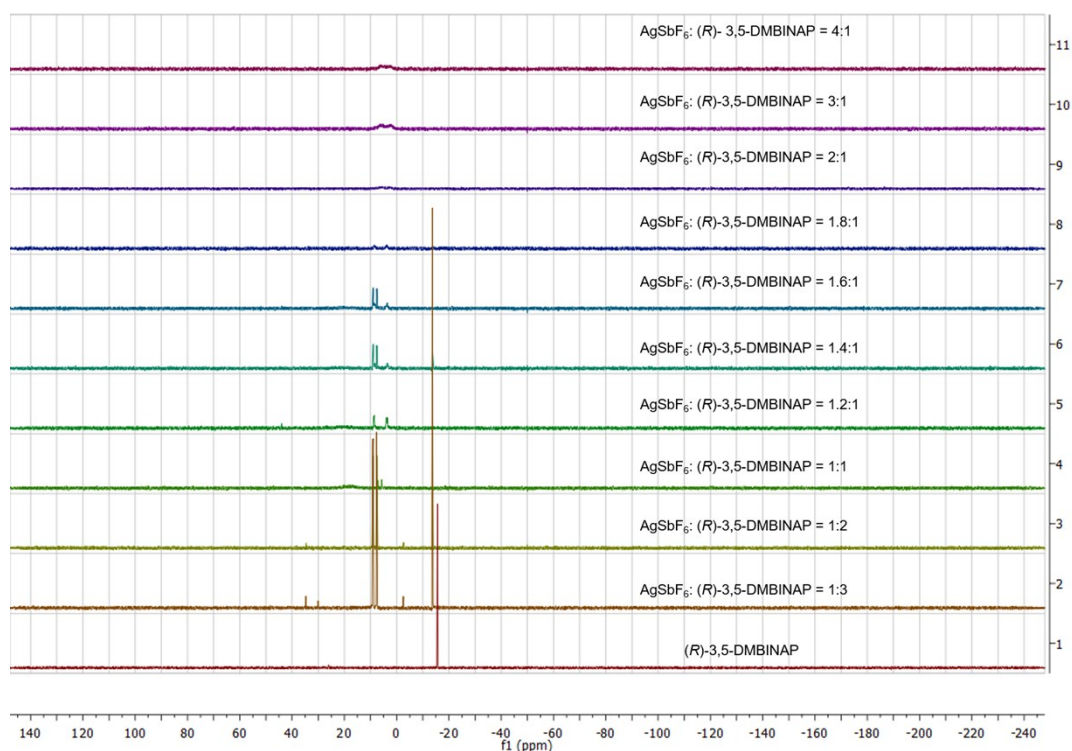


Figure S2: Stacked spectra of ³¹P NMR of AgSbF₆ and (*R*)-3,5-DM-BINAP with ratio of 0:1, 1:1, 2:1, 3:1, and 4:1. ³¹P NMR for 1:1 shows the presence of fine free phosphine peaks along with broad peaks due to complex formation, whereas, the absence of free phosphine peaks and presence of only broad pattern for remaining ratios (1:2, 1:3, 1:4) also suggest a 1:2 ratio is needed for complete conversion of (*R*)-3,5-DM-BINAP to the active chiral catalytic complex.

3. HMRS analysis of the [(R)-3,5-DM-BINAP](AgSbF₆)₂

Elemental Composition Report

Single Mass Analysis

Tolerance = 1000.0 PPM / DBE: min = -1.5, max = 50.0

Element prediction: Off

Monoisotopic Mass, Odd and Even Electron Ions

2 formula(e) evaluated with 1 results within limits (up to 50 closest results for each mass)

Elements Used:

C: 26-26 H: 24-24 P: 1-1 Ag: 0-1

HWH-GK-5-C.32 (0.639)

1: TOF MS ES+

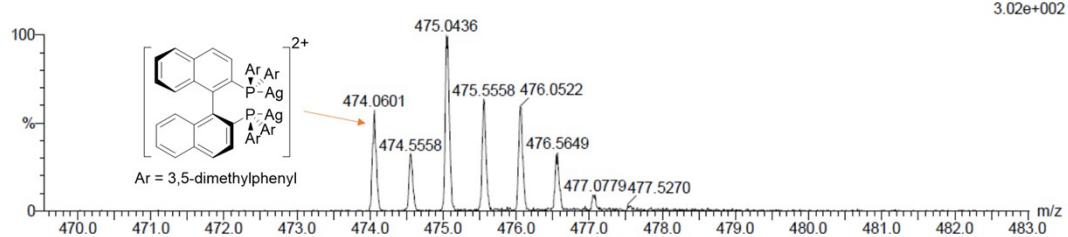
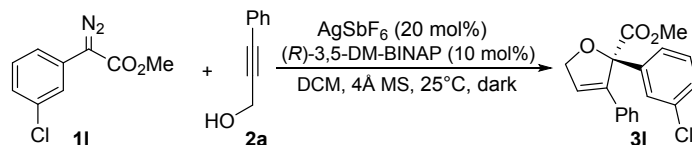


Figure S3: High resolution mass spectrometry (HRMS) of [(R)-3,5-DM-BINAP](AgSbF₆)₂

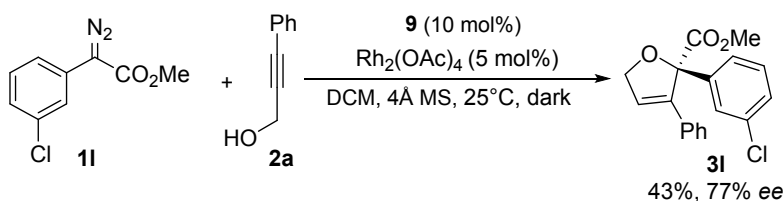
5. Nonlinear effect of silver catalyst



Scheme S5. Nonlinear effect of [(*R*)-3,5-DM-BINAP](AgSbF₆)₂

An oven-dried vial was charged with 50 mg 4 Å MS, (*R*)-3,5-DM-BINAP (0.01 mmol; 20% ee, 40% ee, 60% ee, 80% ee and 100% ee; Daicel Chirapak OD-H, flow rate: 1.0 mL/min, hexane: isopropanol = 800:1), AgSbF₆ (0.02 mmol) and anhydrous dichloromethane (0.5 mL) at 25°C. The mixture was stirred for 2 h, and a solution of phenyl propargyl alcohol (0.05 mmol) in anhydrous dichloromethane (0.5 mL) was added. After stirring for 1 h, a solution of diazoacetate (0.075 mmol) in anhydrous dichloromethane (1 mL) was added slowly. An aliquot of the mixture was taken out after stirring for 12 h. For each reaction using different ee value of the catalyst, the ee value of the target product was determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min, hexane/ isopropanol = 50:1; 254 nm; retention time: $t_{\text{major}} = 10.87$ min, $t_{\text{minor}} = 14.84$ min). The template reaction of **11** and **2a** leading to **31** had a positive nonlinear effect (Figure S1). This finding suggests that there is possibly more than one equivalent of chiral silver catalyst binding to the substrate in the key transition state.

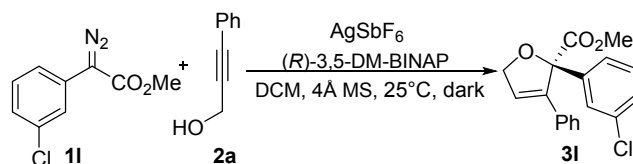
6. Control experiment of using Rh₂(OAc)₄ as a cocatalyst



Scheme S6. Control experiment of using Rh₂(OAc)₄ as a cocatalyst leads to the decrease in chemoselectivity and enantioselectivity.

An oven-dried vial was charged with 100 mg 4 Å MS, (*R*)-3,5-DM-BINAP (10 mol%), AgSbF₆ (20 mol%), Rh₂(OAc)₄ (5% mol%) and anhydrous dichloromethane (0.5 mL) at 25°C in dark. The mixture was stirred for 2 h, and a solution of phenyl propargyl alcohol (0.1 mmol) in anhydrous dichloromethane (0.5 mL) was added. After stirring for 1 h, a solution of diazoacetate (0.15 mmol) in anhydrous dichloromethane (2 mL) was added slowly. After stirring for 48 h, 4 Å MS were filtered and the solvent was removed to give the crude product. The crude product was then purified by flash chromatography on silica gel (PE/EA = 40:1~20:1) to give the pure product. Then the pure product **31** was applied to NMR and chiral HPLC analysis.

7. Kinetic Study: determination of the catalyst order



Scheme S7. Kinetic study of [(*R*)-3,5-DM-BINAP](AgSbF₆)₂-catalyzed formal [4+1] cycloaddition

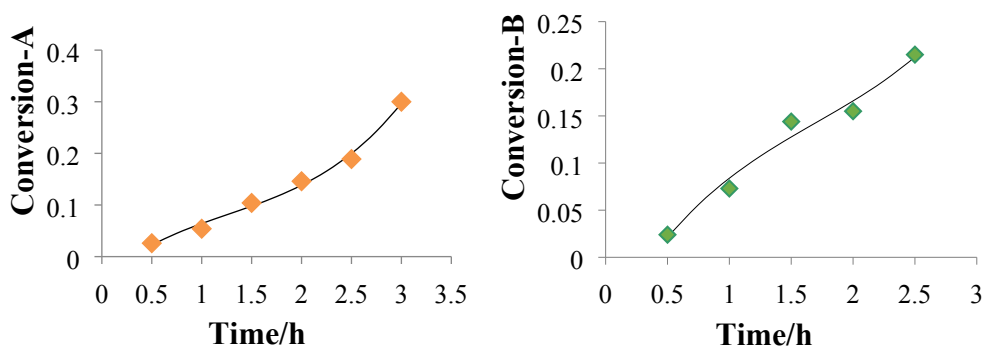
An oven-dried vial was charged with 100 mg 4Å MS, (*R*)-3,5-DM-BINAP (0.005 mmol, 5 mol%; 0.010 mmol, 10 mol%; 0.015 mmol, 15 mol%; 0.020 mmol, 20 mol%), AgSbF₆ (2 equiv of BINAP ligand) and anhydrous dichloromethane (0.5 mL) at 25°C. The mixture was stirred for 2 h, and a solution of phenyl propargyl alcohol (0.1 mmol) in anhydrous dichloromethane (0.5 mL) was added. After stirring for 1 h, a solution of diazoacetate **11** (0.15 mmol) in anhydrous dichloromethane (2 mL) was added slowly. An aliquot of the reaction mixture (0.2 mL) was taken out in every 30 min. After simple work-up to remove 4Å MS, the conversion of the sample (Figure S5) was measured by HPLC (Waters e2695, Kromasil 100-5C18, flow rate: 1.0 mL / min; water / aceto- nitrile = 1:1).

The initial reaction rate V_0 was obtained for each catalyst loading. Then we found a linear correlation between V_0 and the square of catalyst loading, which indicates second order kinetics of the chiral silver catalyst (Table S2 and Figure S6).

The calculation of initial reaction rate. $F(t)$: correlation of HPLC product yield and time, $G(t)$: correlation of product concentration and time; n : the reaction scale; V : the total volume of the reaction mixture. The initial rate = $G'(0) = nF'(0)/V$.

Possible reason to explain why the reaction kinetics contains the induction period.

Since the reaction requires the bifunctionality of **9** which coordinates with carbene and alkyne separately. We assume it needs a short time to get to the equilibrium with the bi-catalysts coordination model as the major coordination model. This is probably why the reaction rate increases after 10-20% conversion.



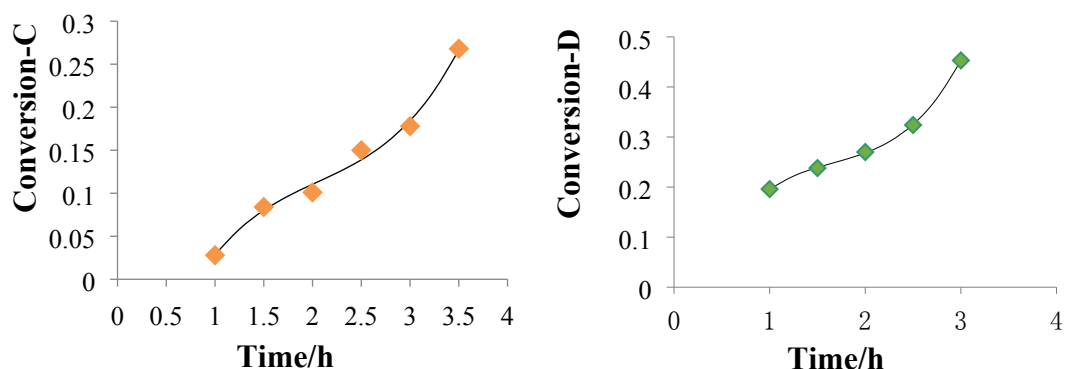
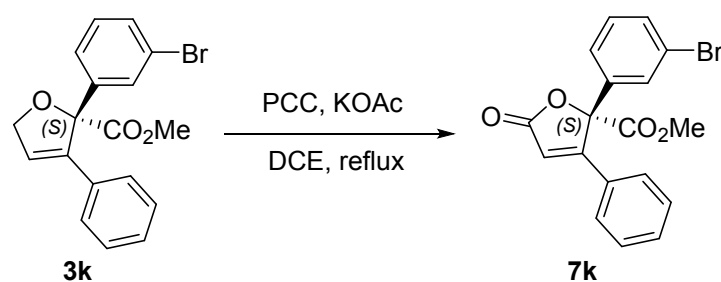


Figure S4: Real-time monitoring of conversion of reactions. A) 5 mol% catalyst loading; B) 10 mol% catalyst loading; C) 15 mol% catalyst loading; D) 20 mol% catalyst loading. The initial reaction rate V_0 was obtained for each catalyst loading. Then we found a linear correlation between V_0 and the square of catalyst loading, which indicates second order kinetics of the chiral silver catalyst.

Table S2: the relationship of initial rate and square of catalyst concentration

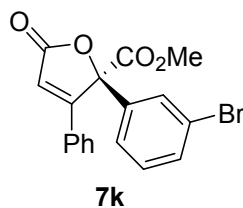
Entry	catalyst loading (mol %)	C^*C (mol ² /L ²)	V_0 (mol·L ⁻¹ ·h ⁻¹)
A	5	0.00008	0.00526
B	10	0.00033	0.00771
C	15	0.00075	0.01251
D	20	0.00133	0.01758

F. Derivatization of enantiopure 2,5-dihydrofuran **3k**



Scheme S8 preparation of lactone **7k**

Procedure for PCC oxidation of 2,5-dihydrofuran (S)-3k**:**³ To a 20 mL flask, (S)-**3k** (0.2 mmol) was added. Then PCC (0.4 mmol, 2.0 equiv) dissolved in DCE and KOAc (0.4 mmol, 2.0 equiv) were added. After refluxing for 2 h, the reaction was cooled to 25°C and quenched with saturated NH₄Cl. The aqueous phase was extracted with ethyl acetate 3 times. The combined organic phase was dried with anhydrous Na₂SO₄. The solvent was removed with vacuum rotator, affording the crude product. Then the crude product was purified by flash chromatography on silica gel (PE/EA = 10:1~5:1) to give the pure product **7k**.

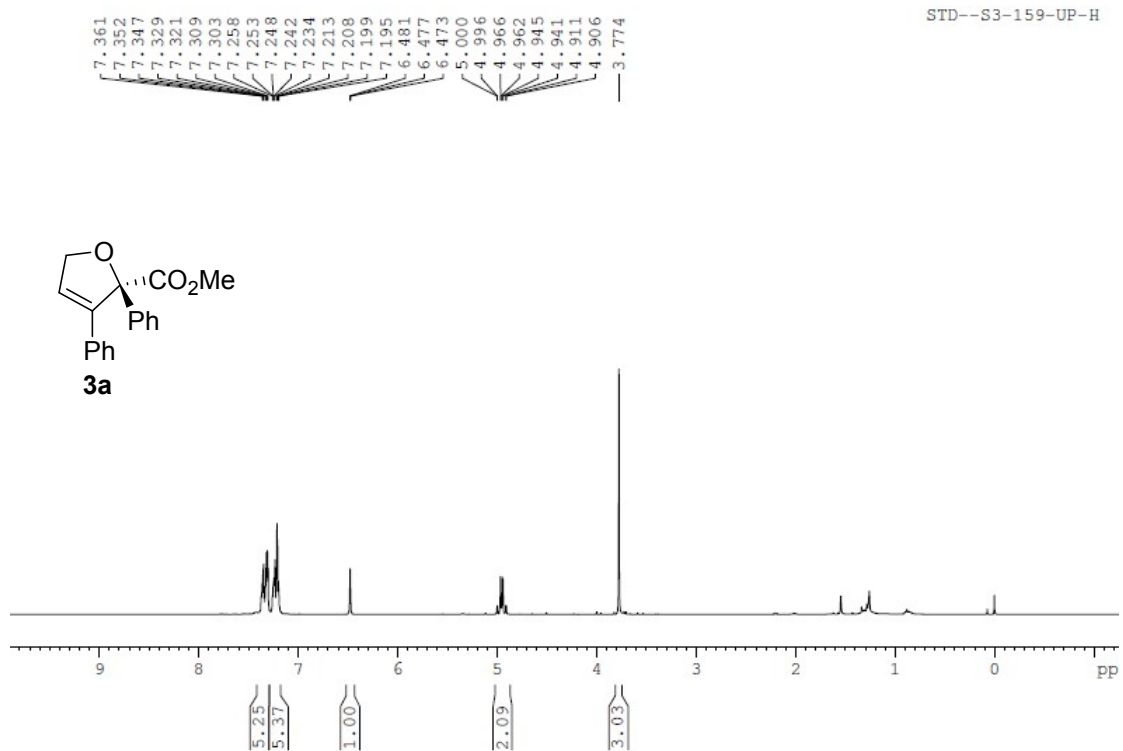


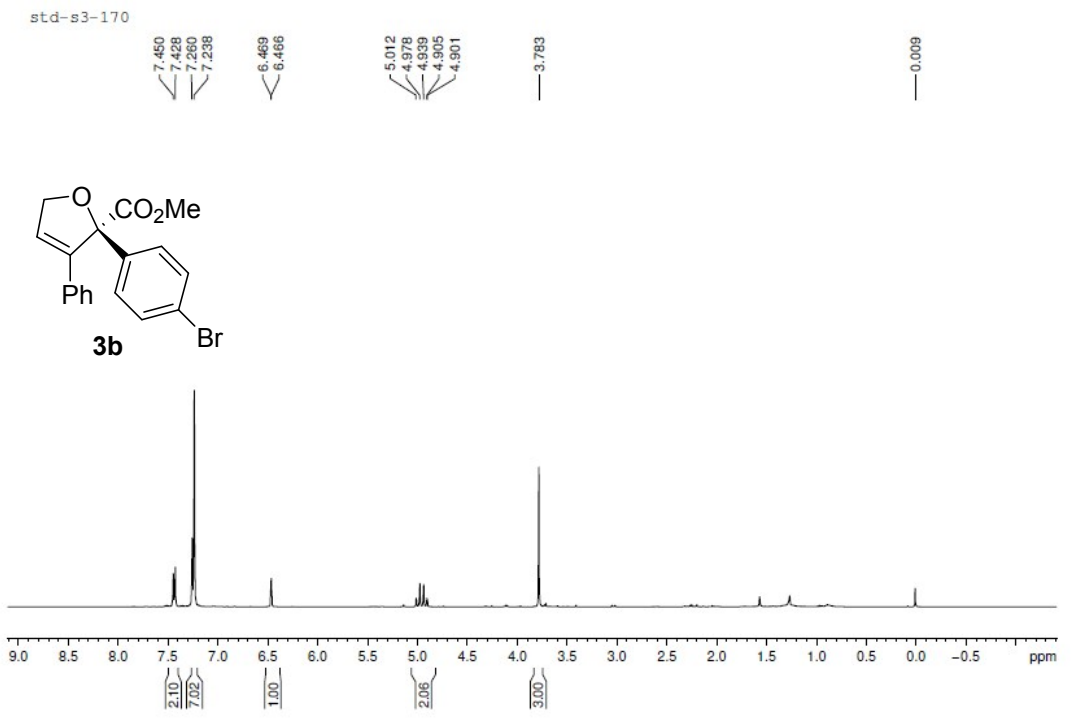
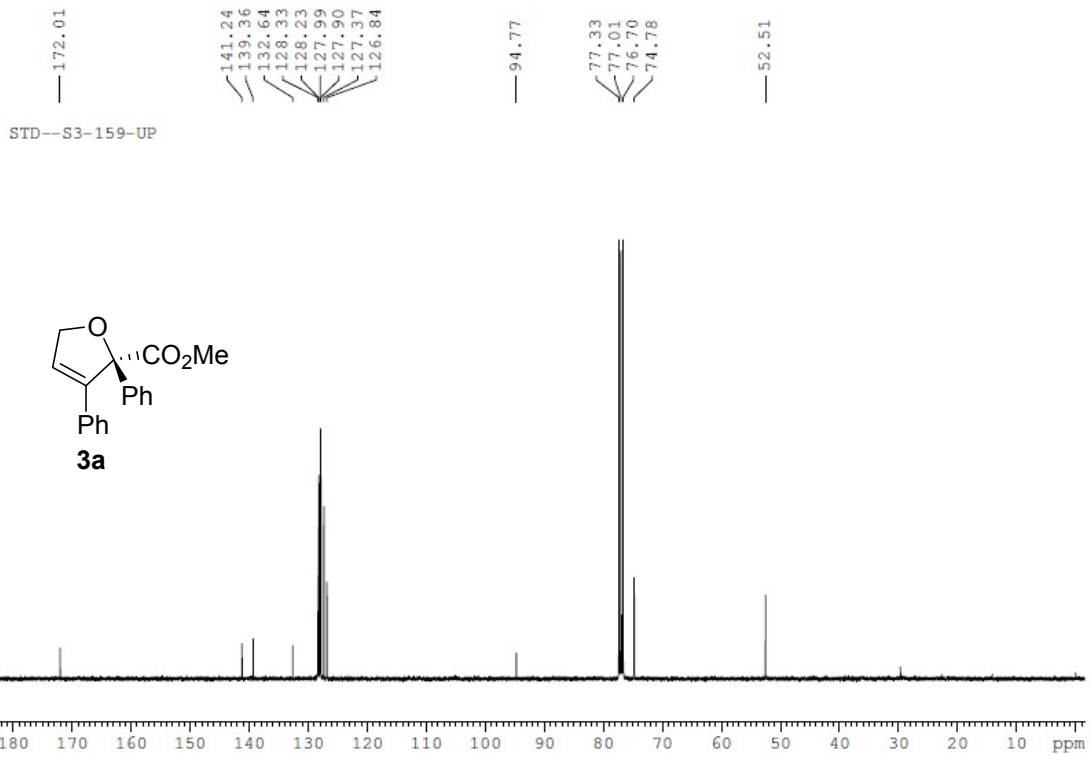
7k: white solid, yield 65%; 91% ee, determined by HPLC (Daicel Chirapak IA, flow rate: 1.0 mL/min; hexane / isopropanol = 80 : 1; 254 nm; Retention time: $t_{\text{major}} = 41.04$ min, $t_{\text{minor}} = 38.26$ min); ^1H NMR(400 MHz, CDCl_3): δ 7.53 (d, $J = 1.8$ Hz, 2H), 7.46 (t, $J = 7.4$ Hz, 3H), 7.41 – 7.33 (m, 2H), 7.28 (d, $J = 7.8$ Hz, 1H), 7.23 (t, $J = 8.1$ Hz, 1H), 6.62 (s, 1H), 3.83 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3): δ 170.60, 167.58, 164.64, 136.69, 132.87, 131.66, 131.11, 130.14, 128.94, 128.64, 126.64, 122.69, 122.26, 116.67, 89.98, 53.90. HRMS: calcd 394.9895 for $\text{C}_{18}\text{H}_{13}\text{BrO}_4\text{Na}[\text{M}+\text{Na}]^+$, found 394.9881.

G. Reference

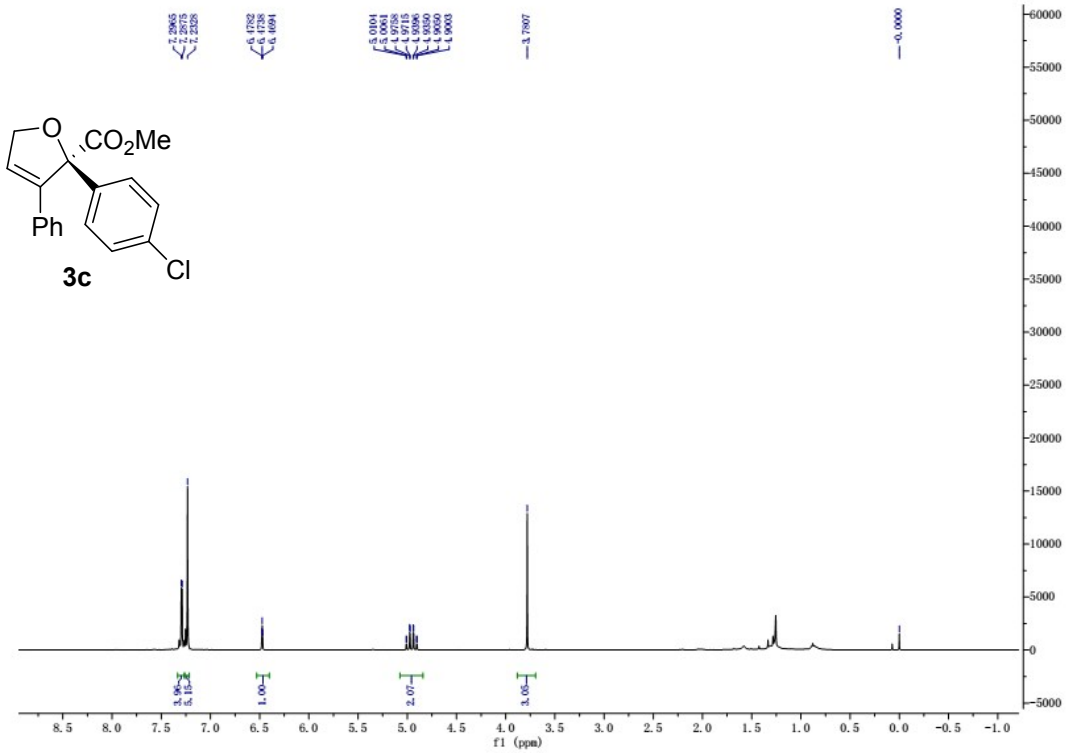
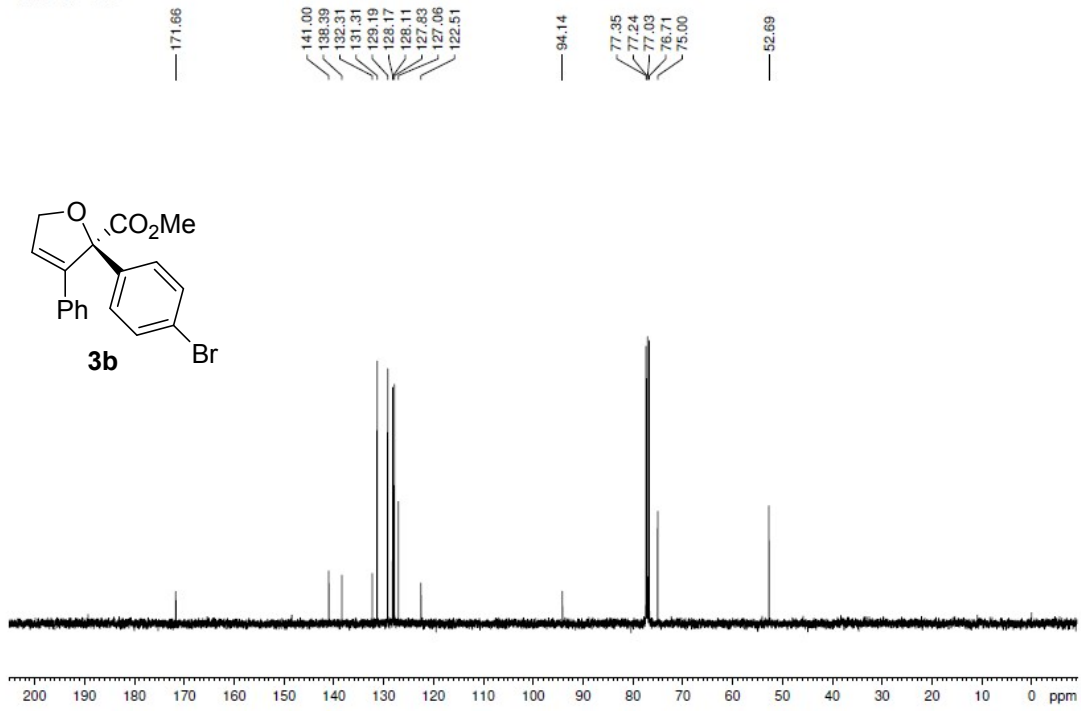
- (a) Liang, Y.; Xie, Y.; Li, J. Modified palladium-catalyzed Sonogashira cross-coupling reactions under copper-, amine-, and solvent-free conditions. *Adv. Synth. Catal.* **2006**, *348*, 545 – 550. (b) Kleinbeck, F.; Toste, F. D. Gold (I)-catalyzed enantioselective ring expansion of allenylcyclopropanols. *J. Am. Chem. Soc.*, **2009**, *131*, 9178–917.
- (a) Starmans, W. A. J.; Thijs, L.; Zwanenburg, B. Novel chiral dirhodium catalysts derived from aziridine and azetidine carboxylic acid for intermolecular cyclopropanation reactions with methyl phenyldiazoacetate. *Tetrahedron*, **1998**, *54*, 629-636. (b) Yu, W. Y.; Tsoi, Y. T.; Zhou, Z.; Chan, A. S. C. Palladium-catalyzed cross coupling reaction of benzyl bromides with diazoesters for stereoselective synthesis of (*E*) - α , β -diarylacrylates. *Org. Lett.* **2009**, *11*, 469-472.
- Bonadies, F.; Bonini, C. Oxidation of active methylene compounds by pyridinium chlorochromate. *Syn. Comm*, **1988**, *18*, 1573-1580.

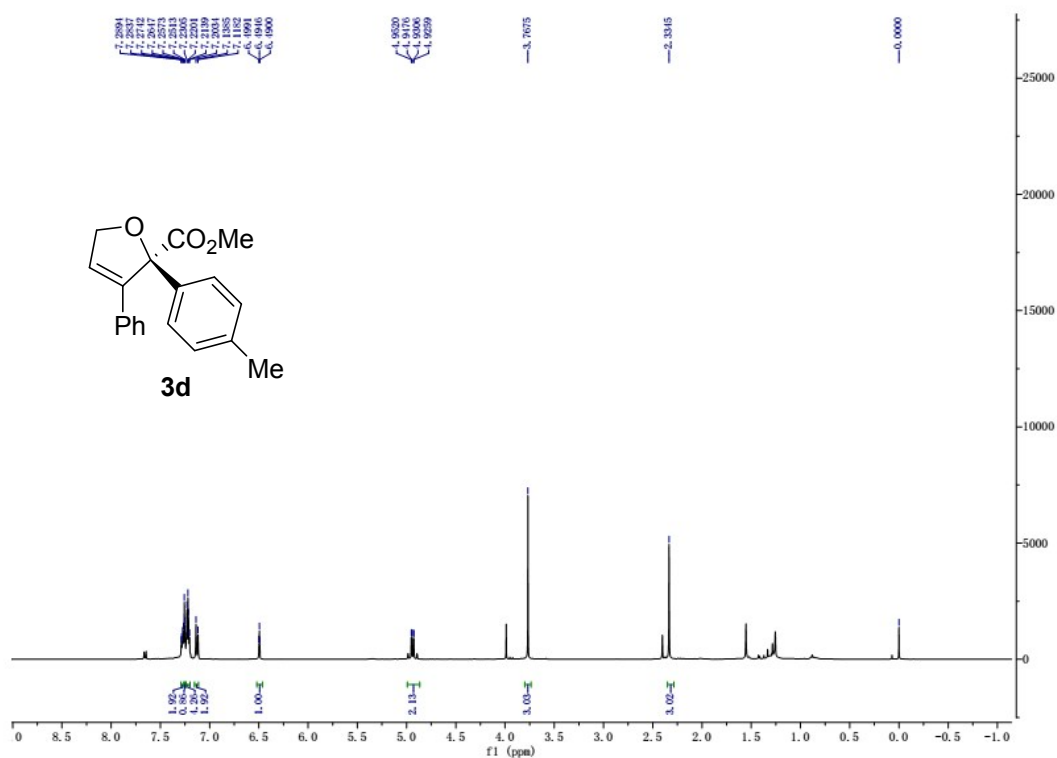
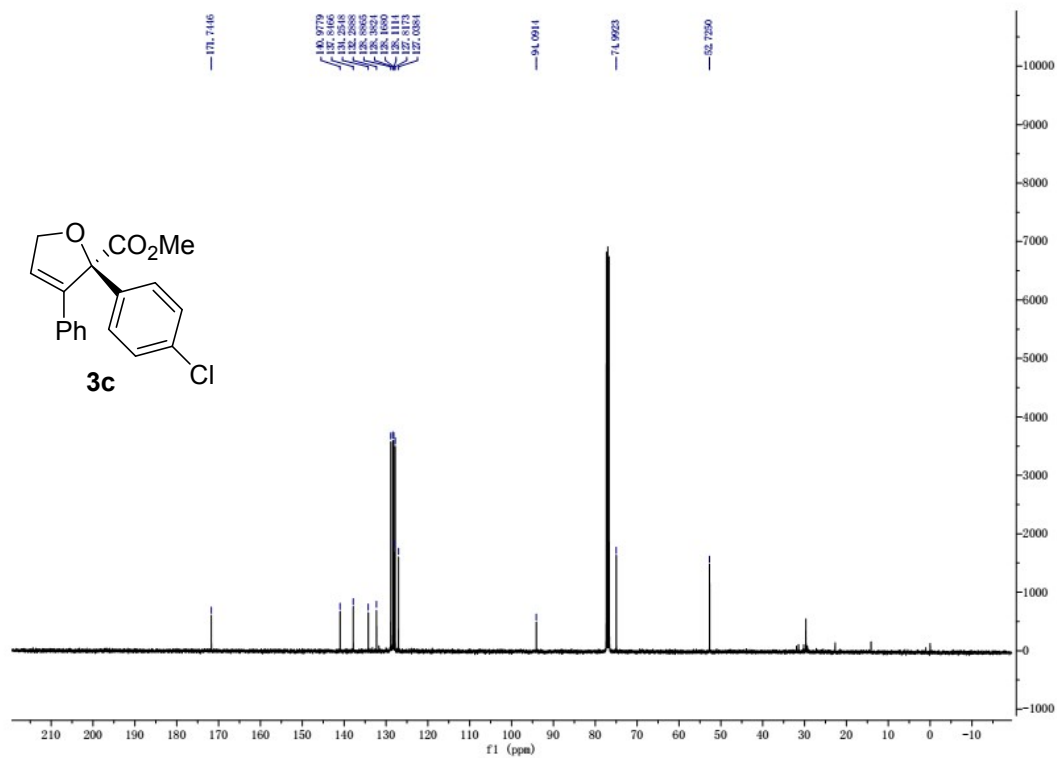
H. ¹H NMR spectra

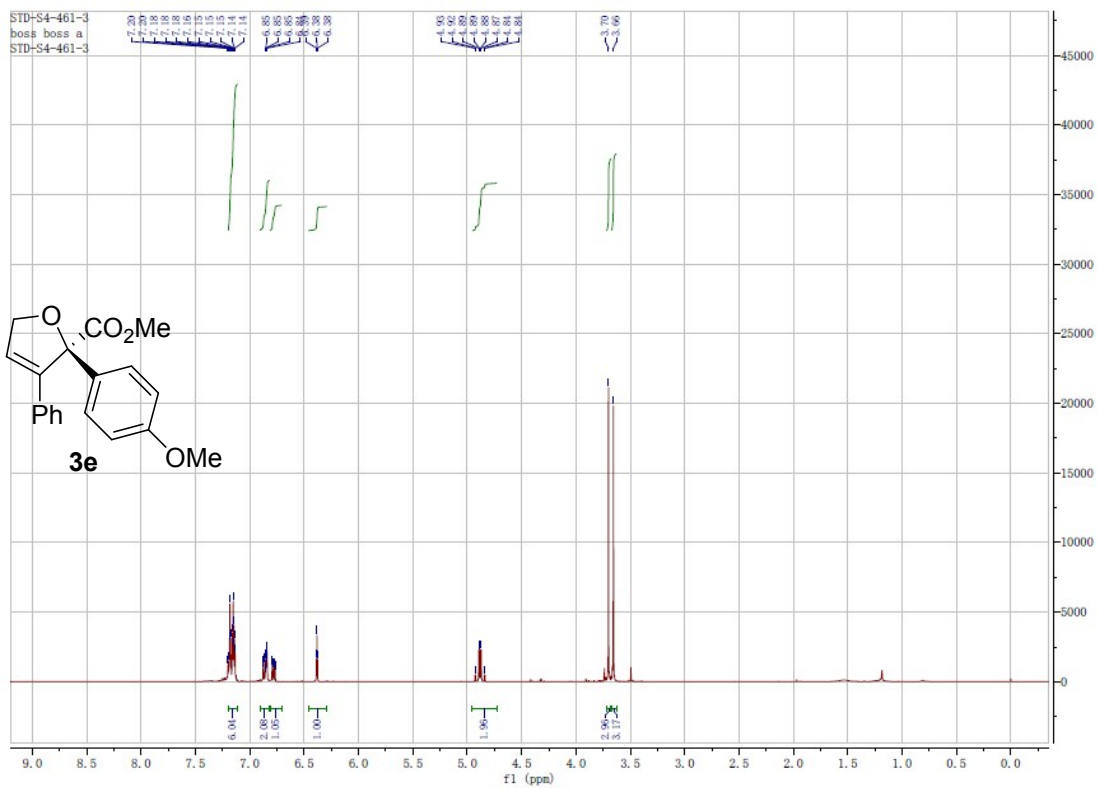
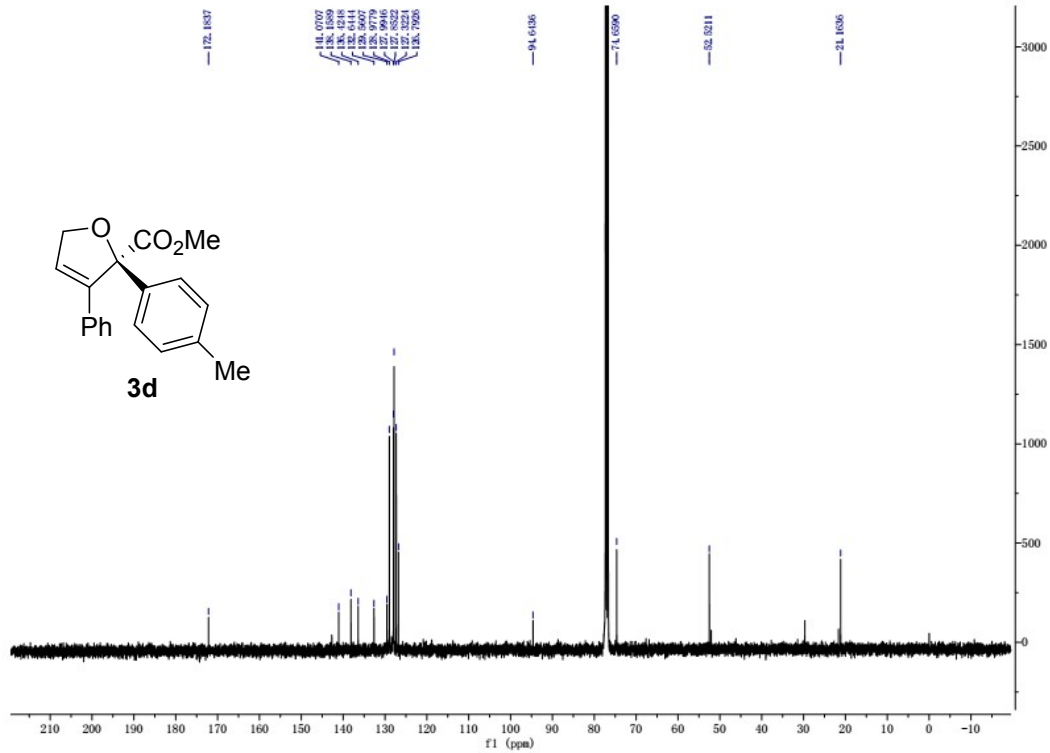


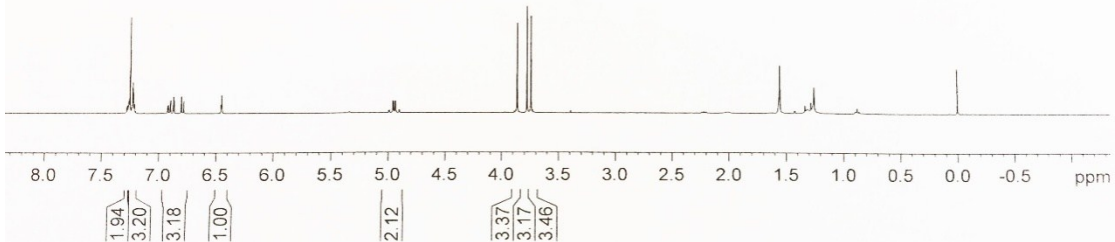
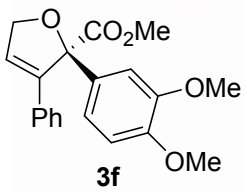
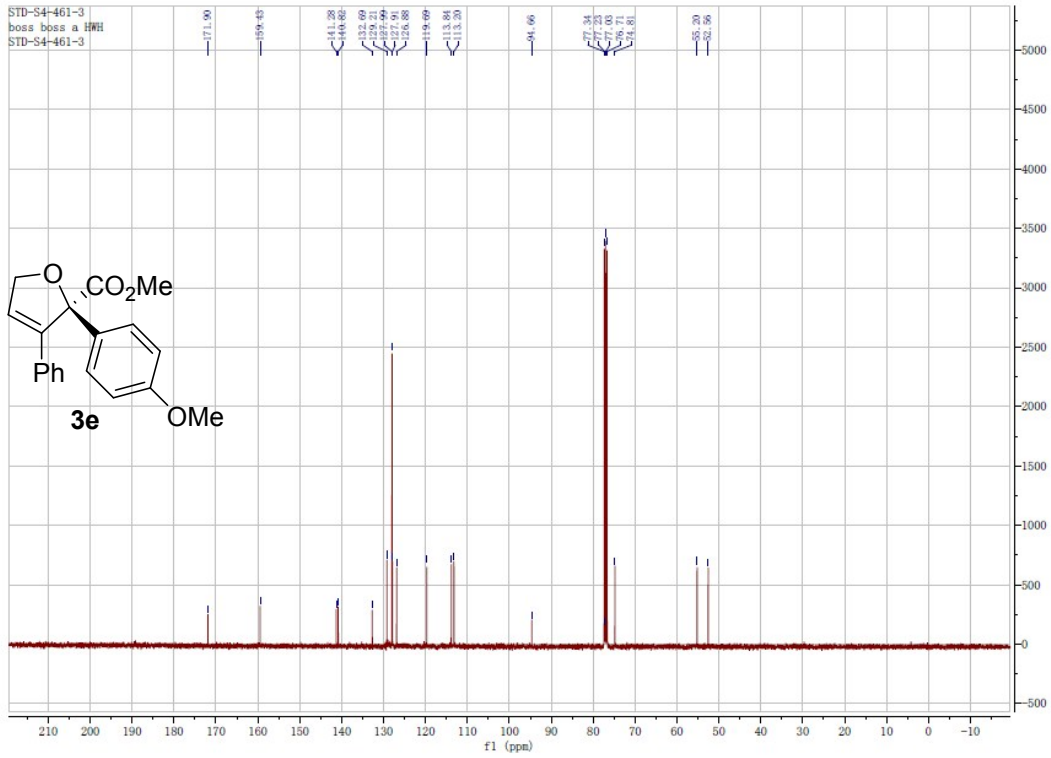


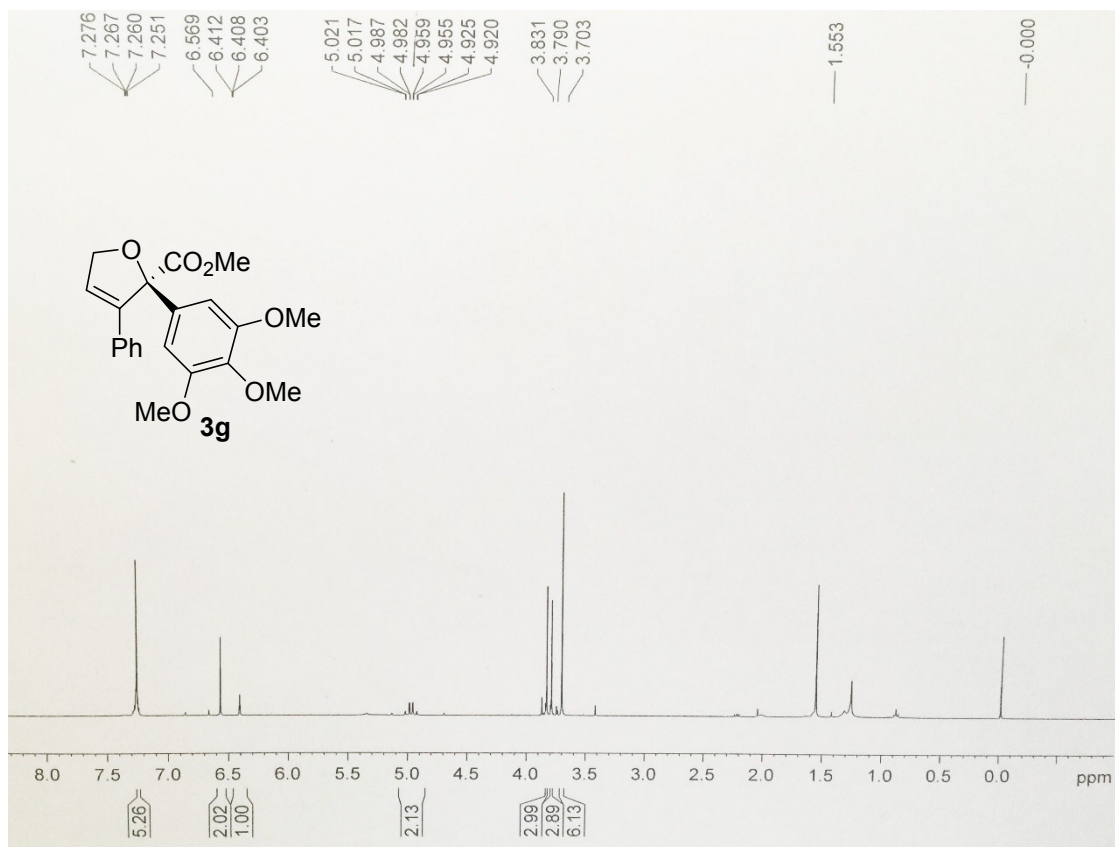
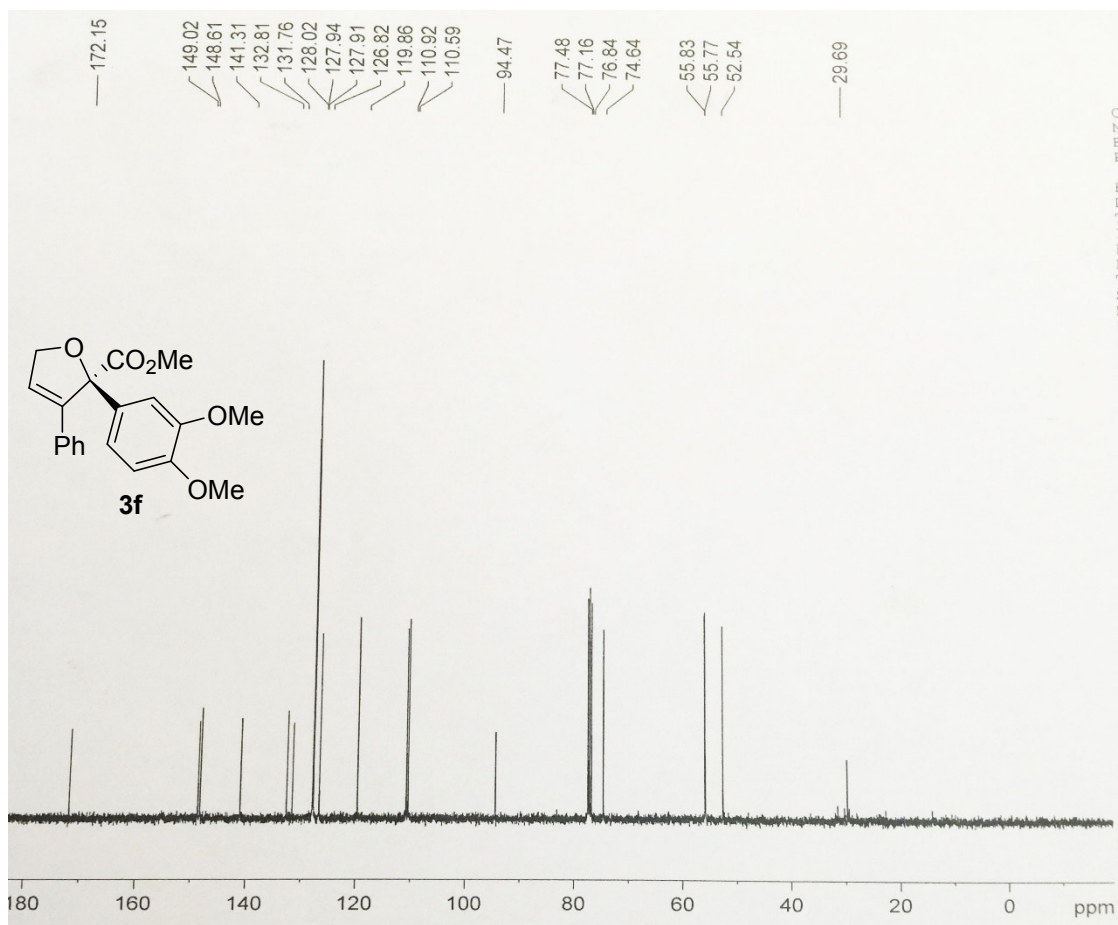
std-s3-170

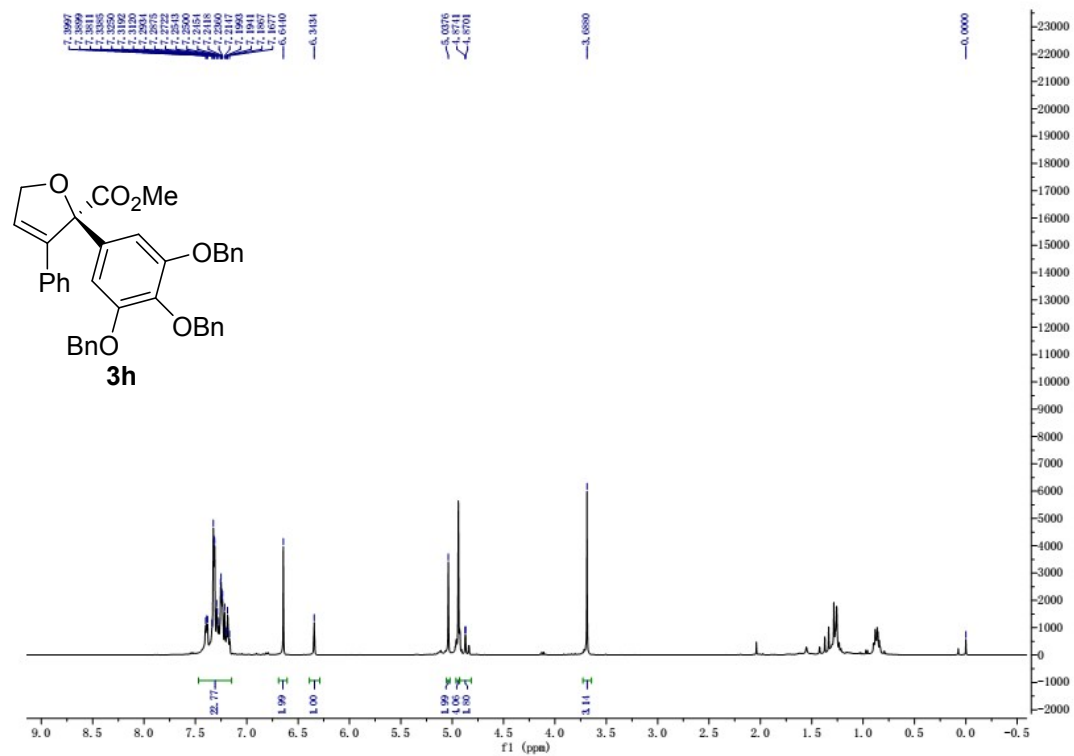
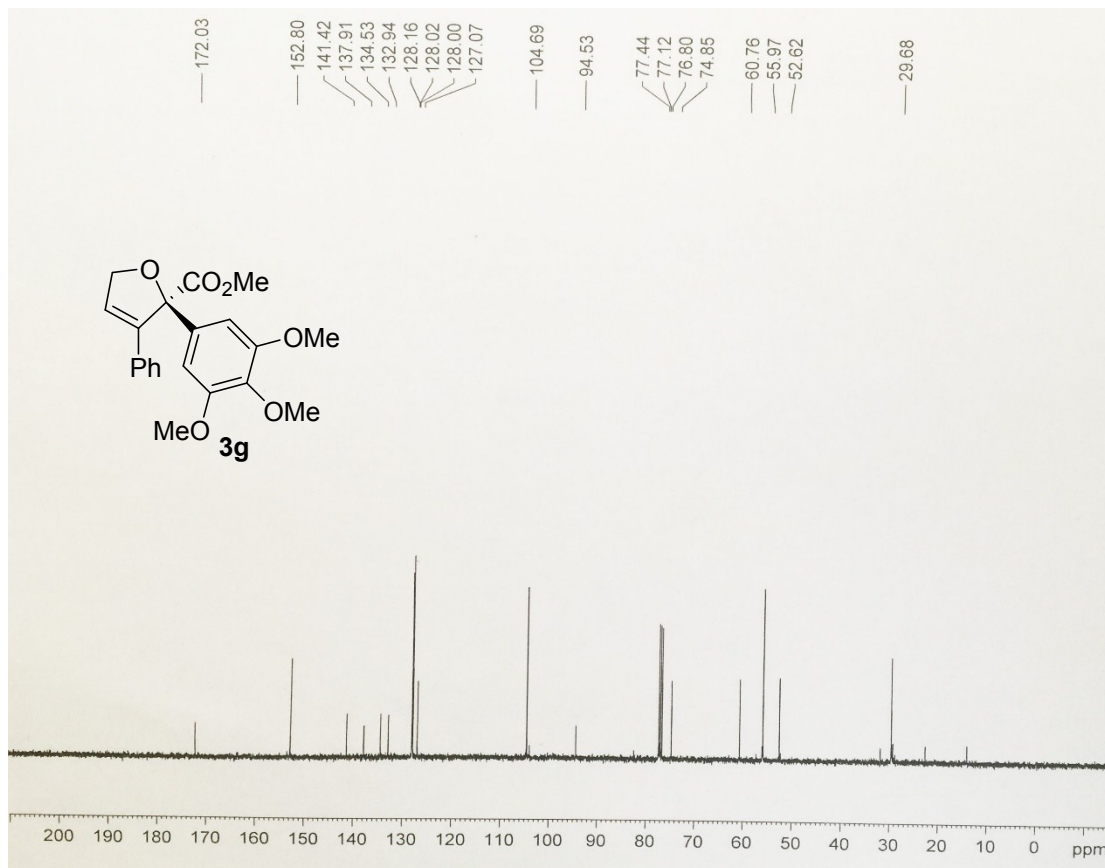


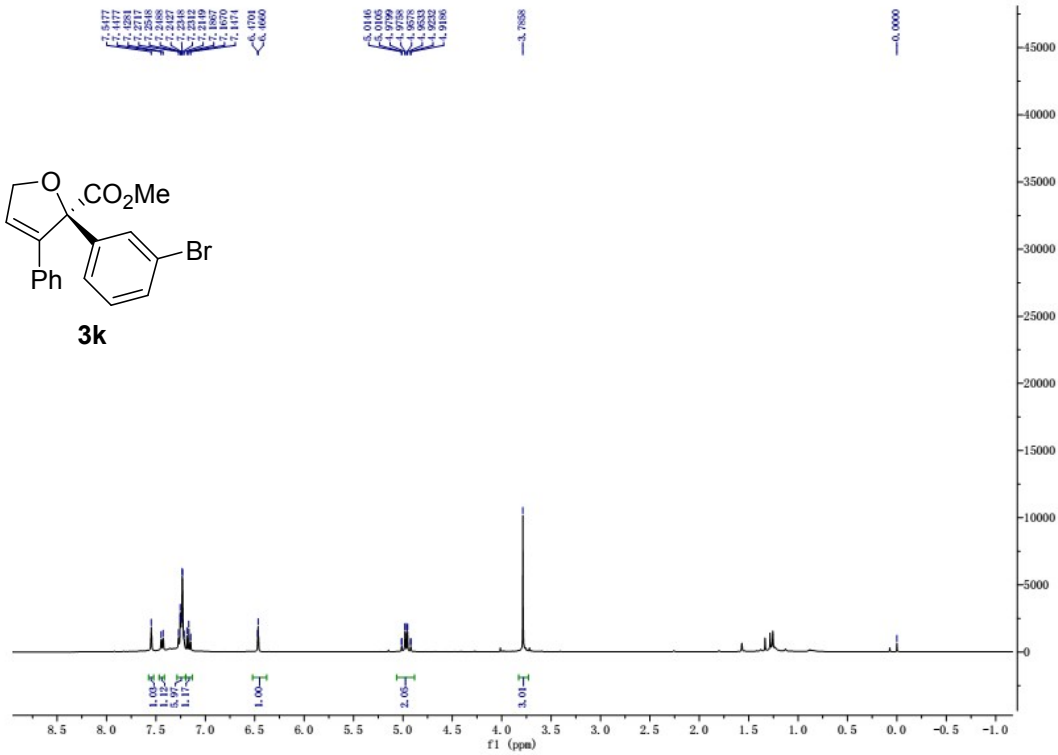
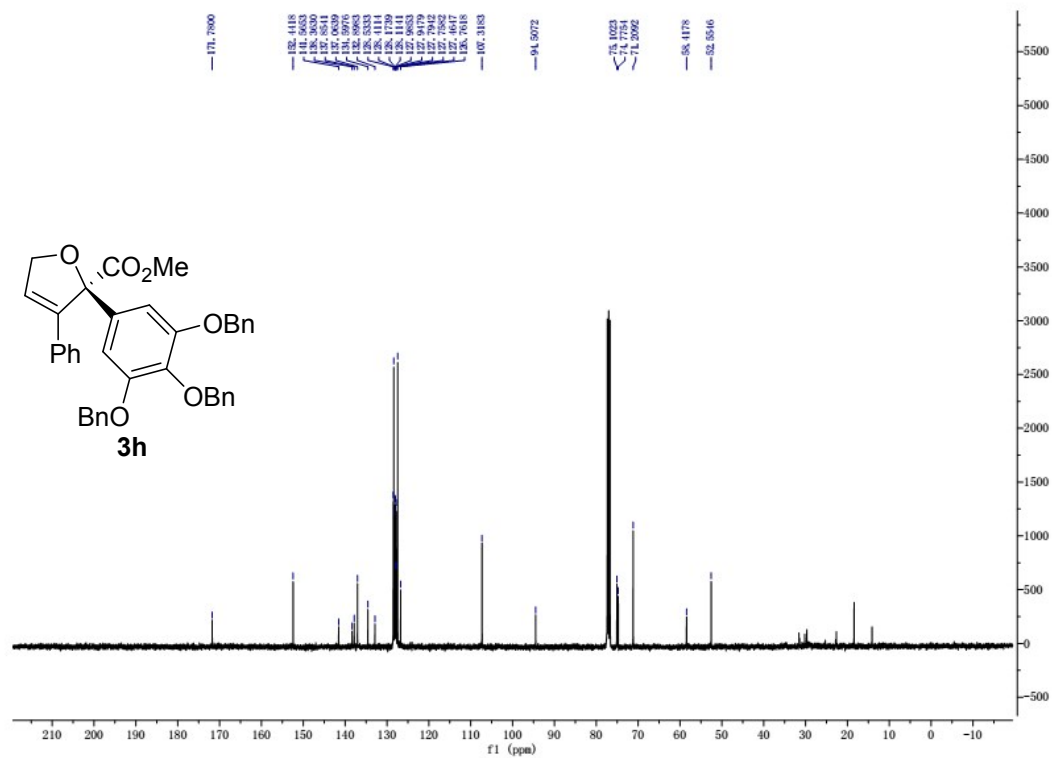


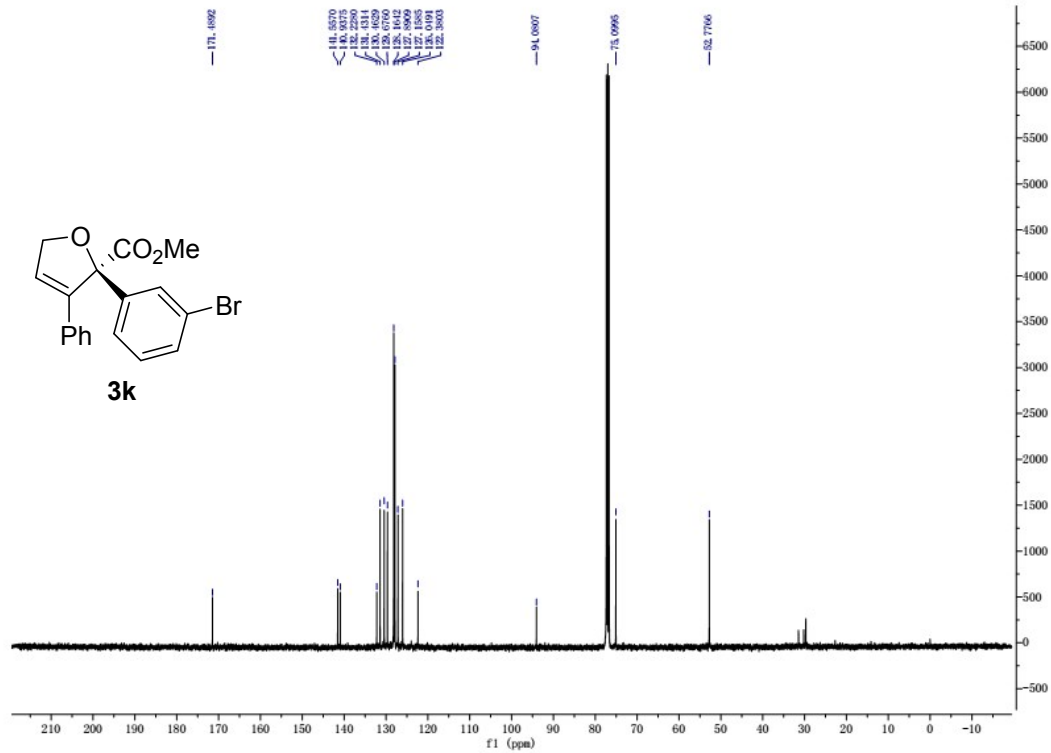




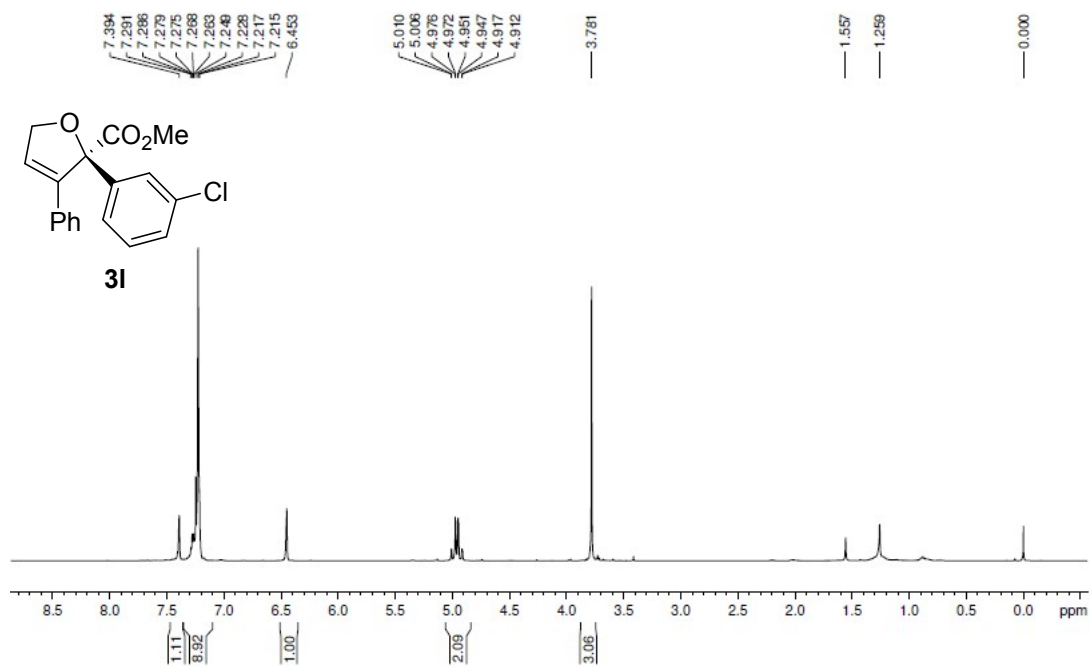




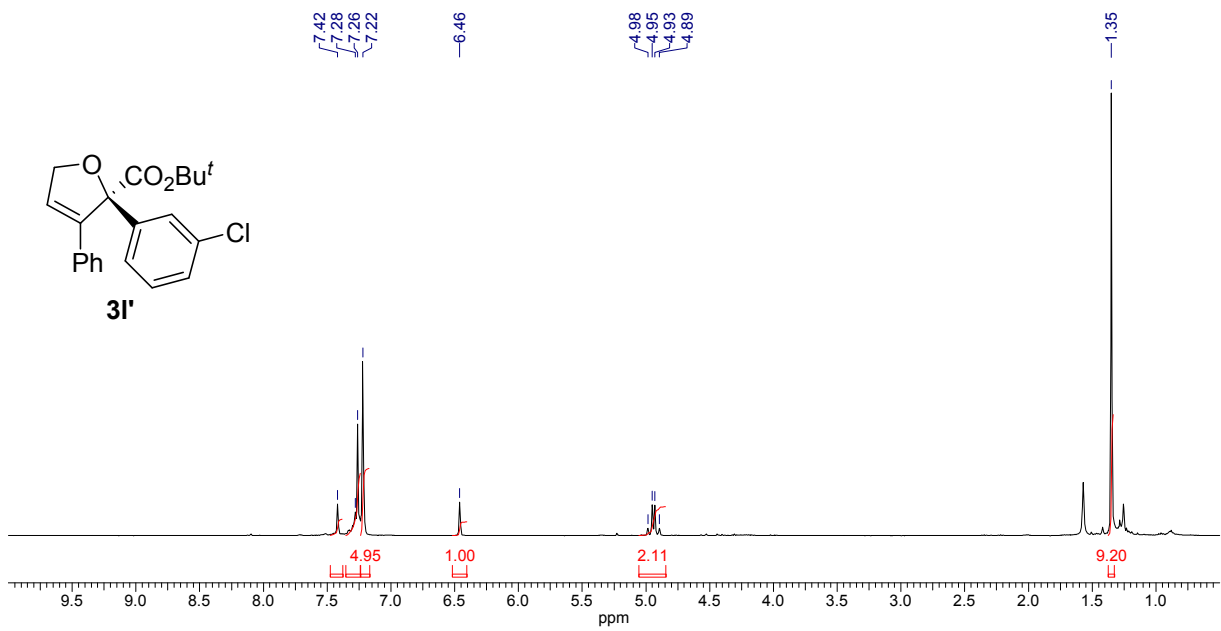
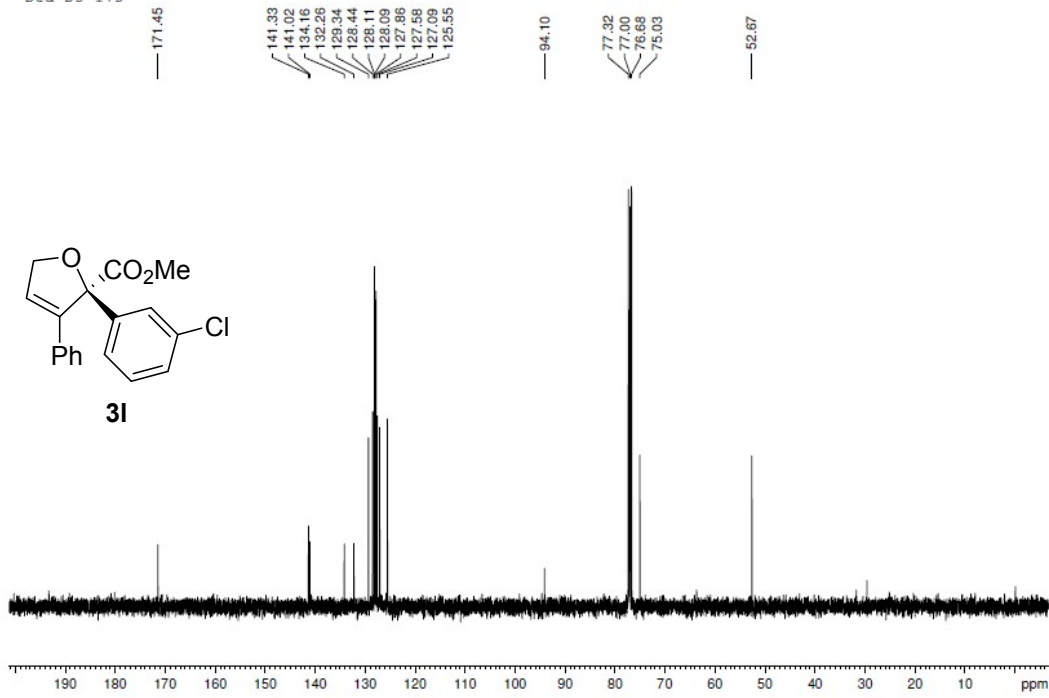


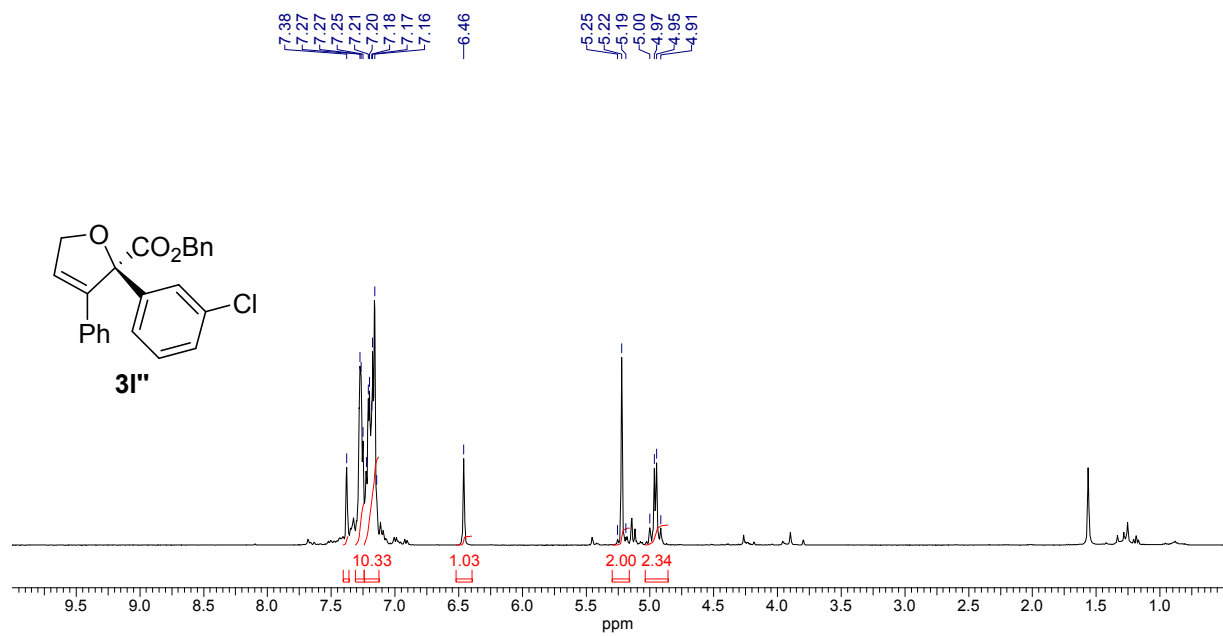
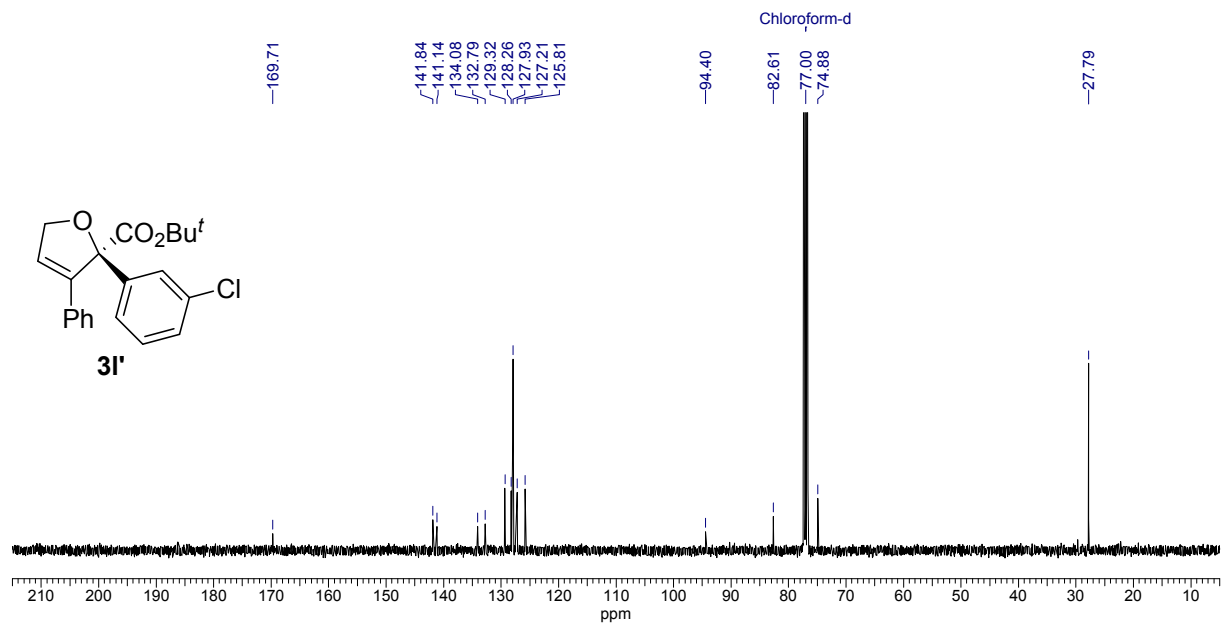


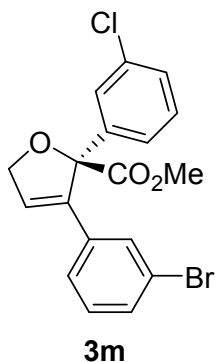
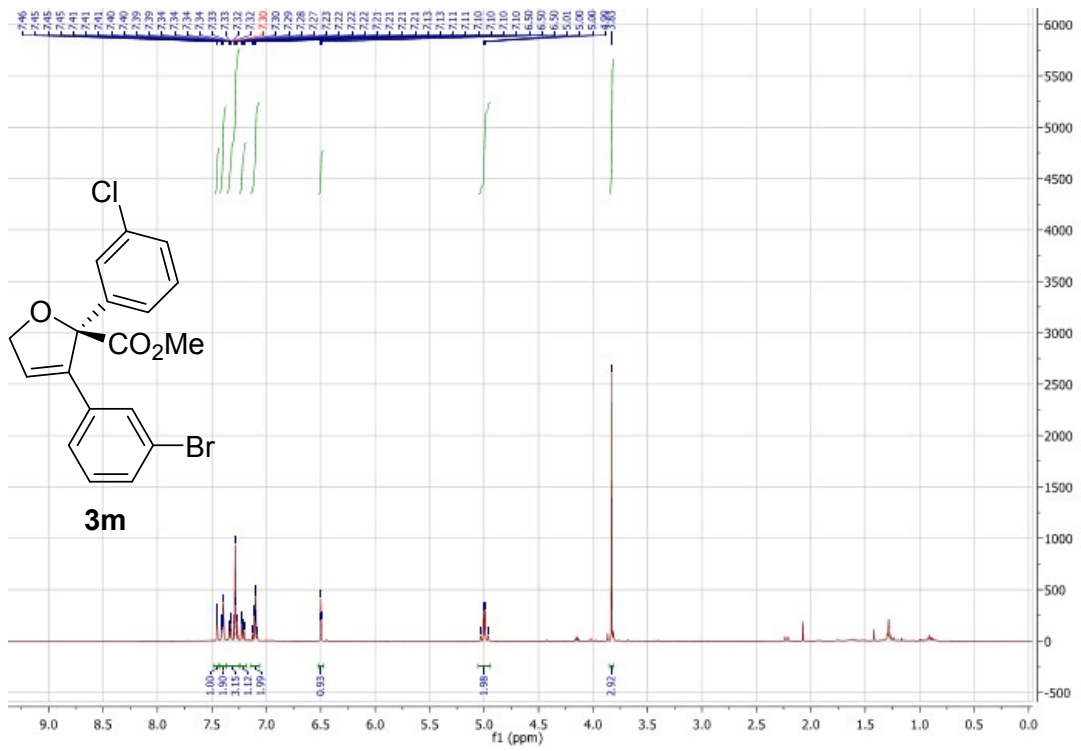
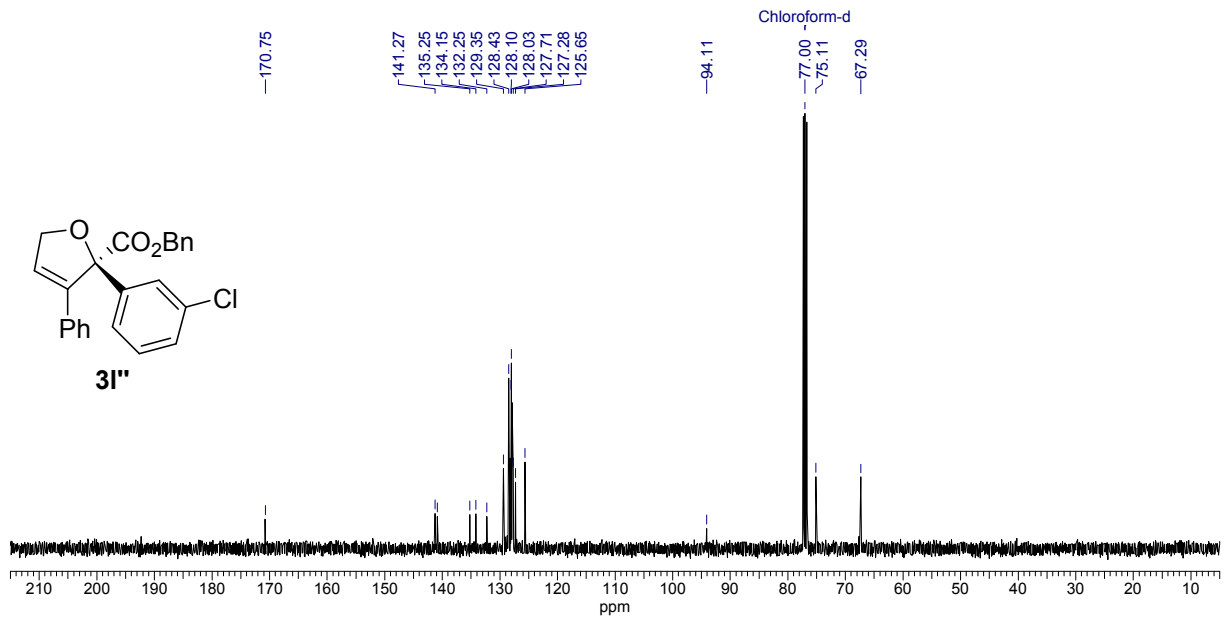
std-s3-173

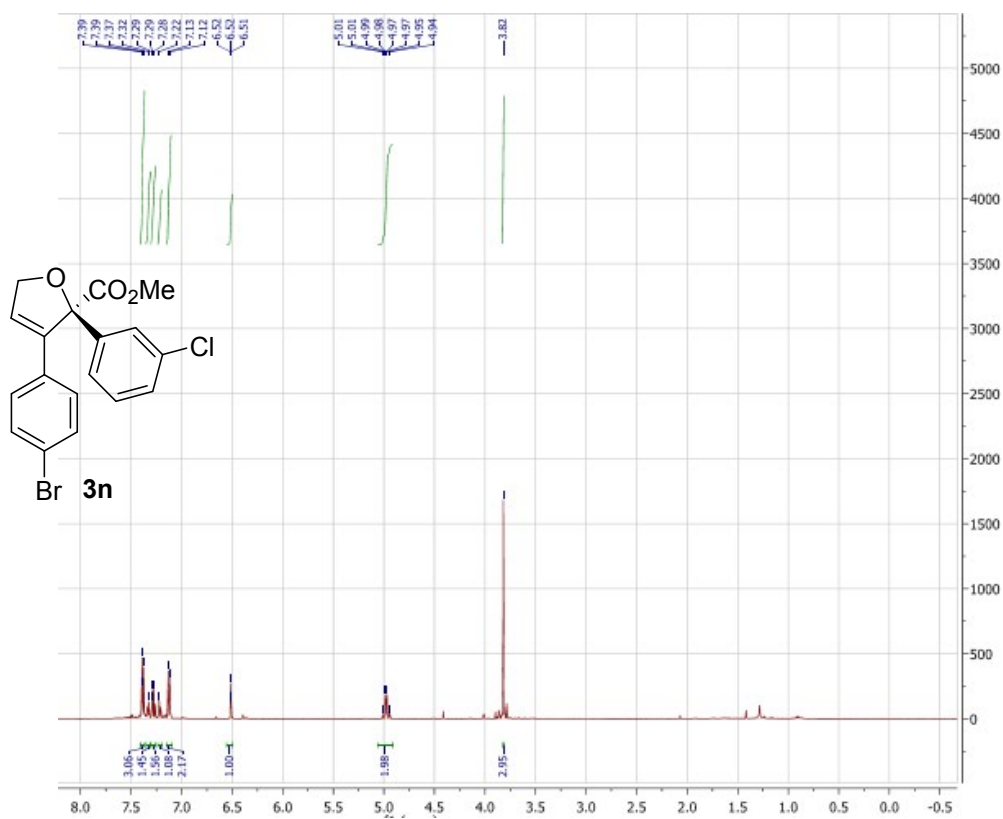
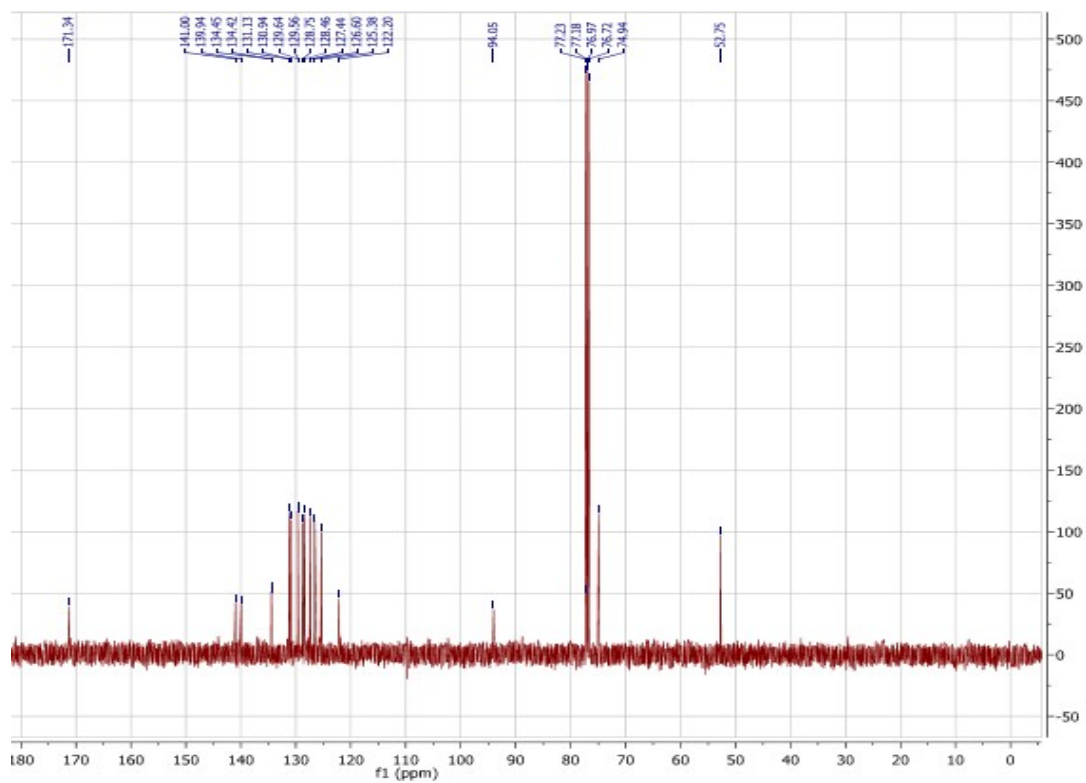


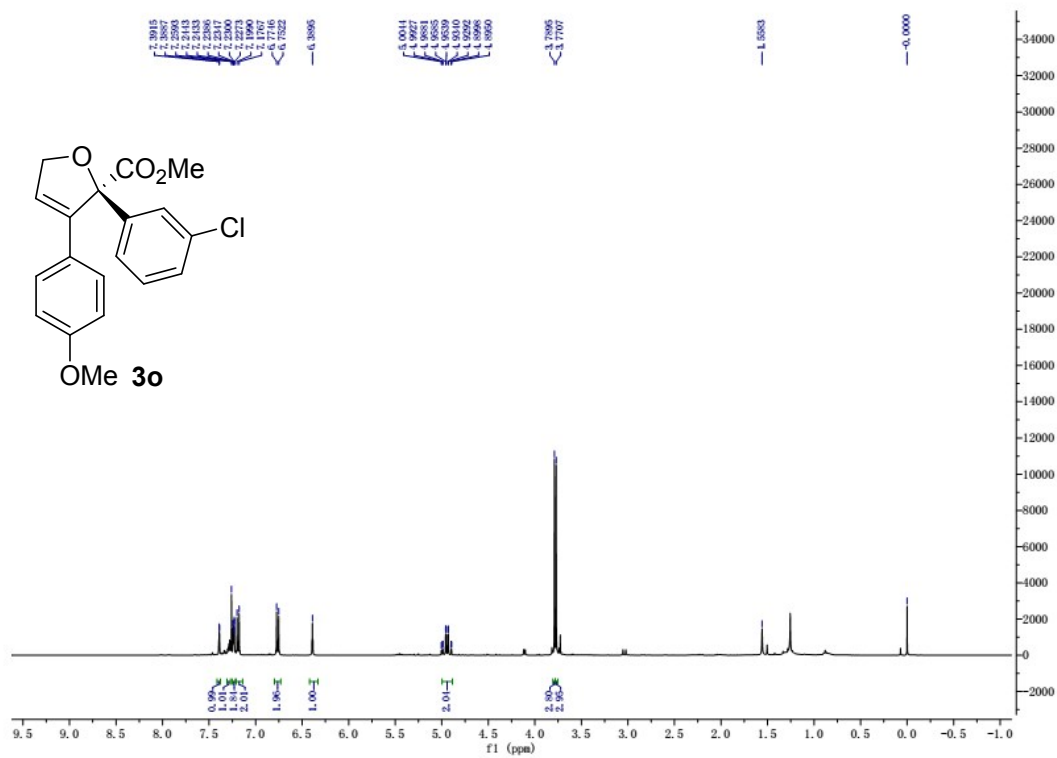
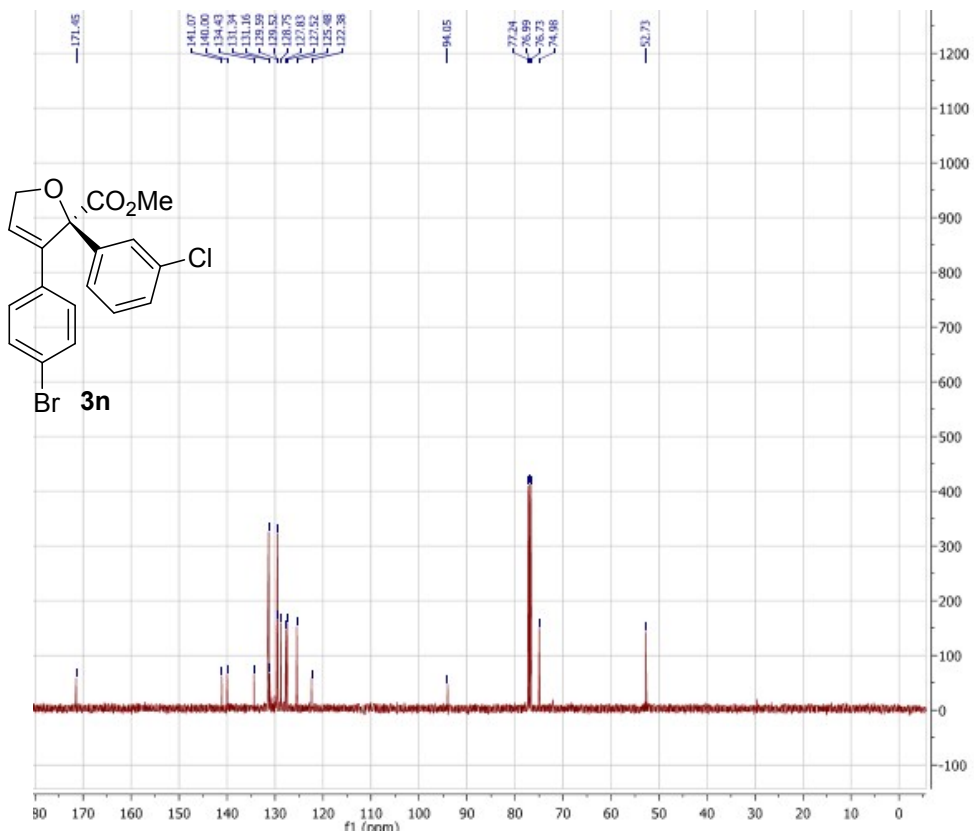
std-s3-173

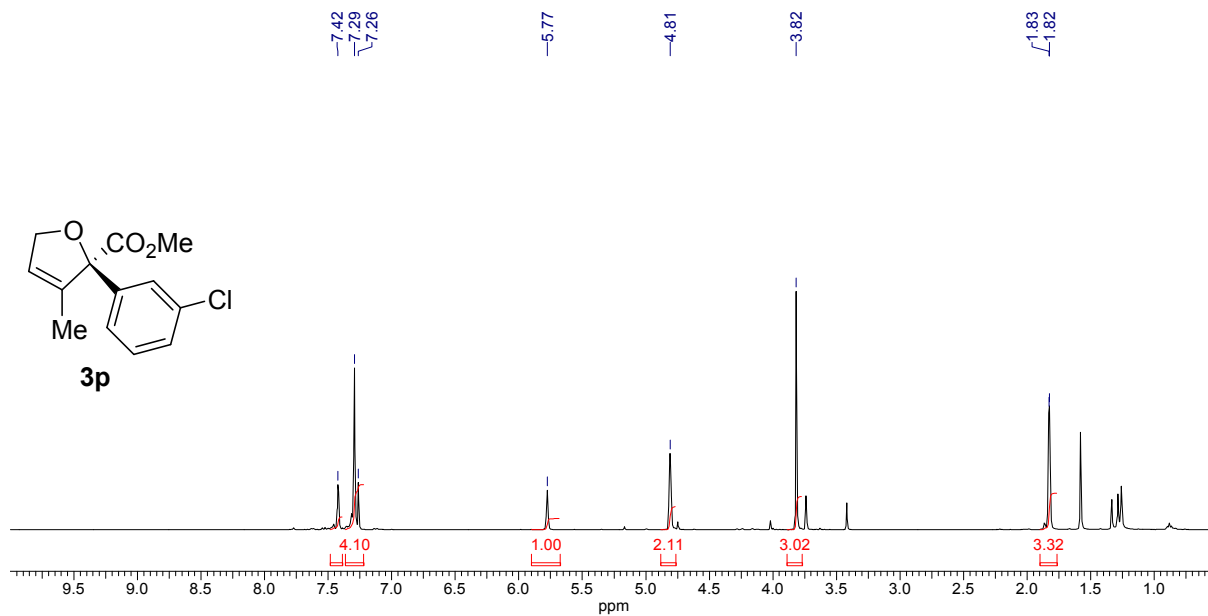
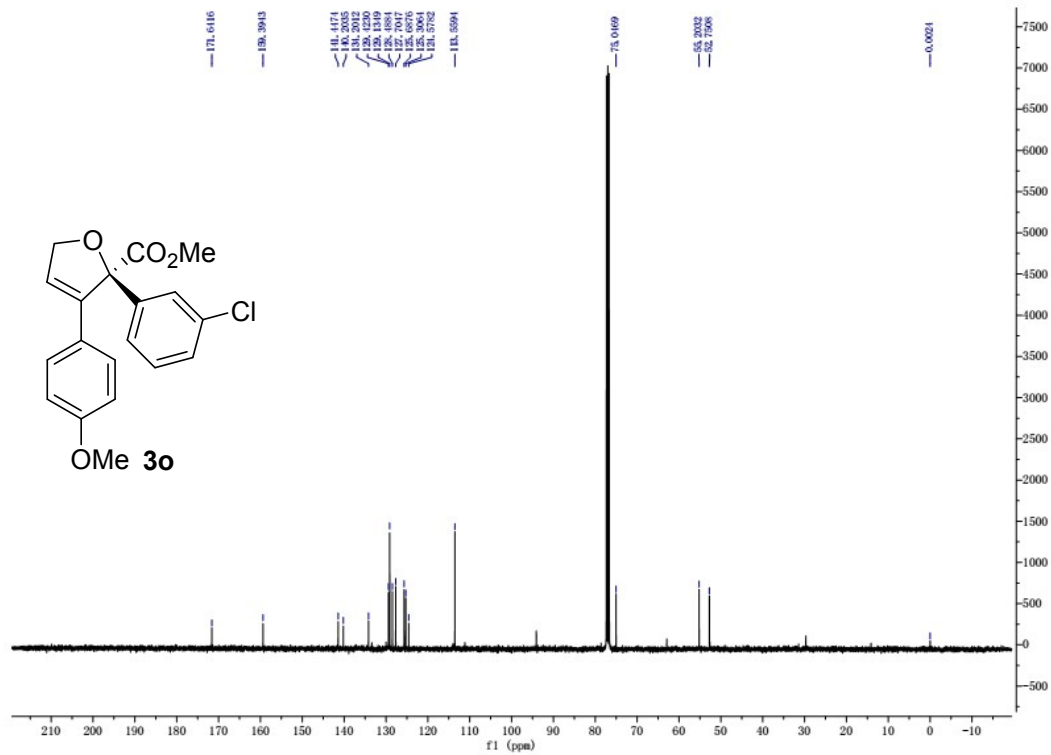


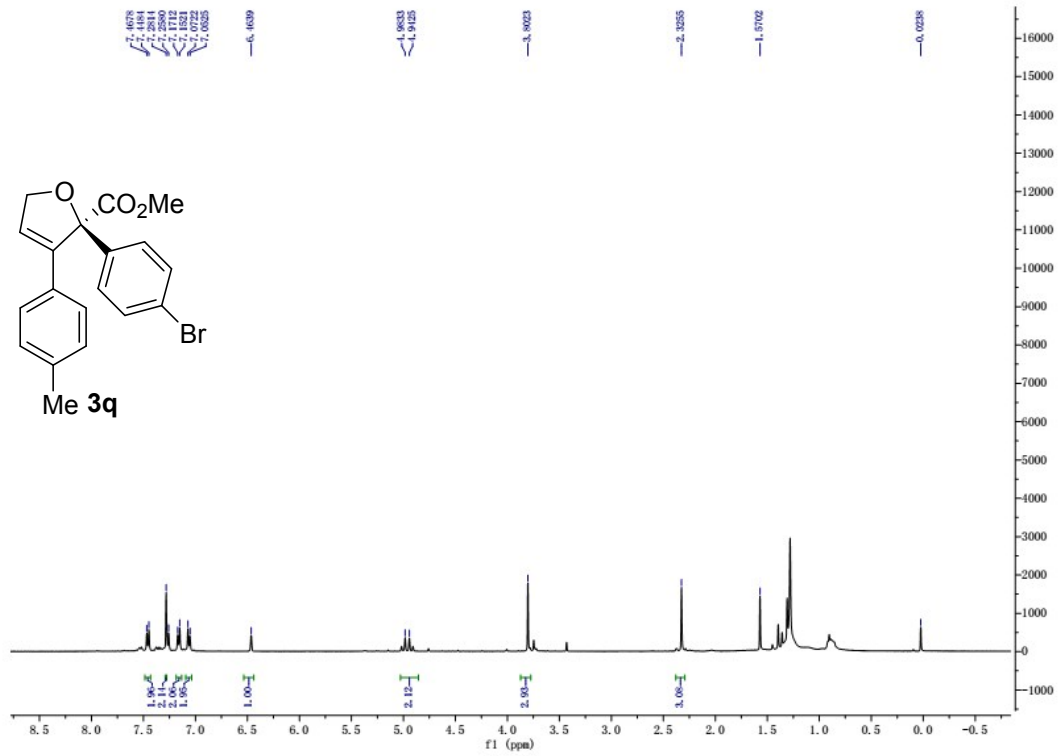
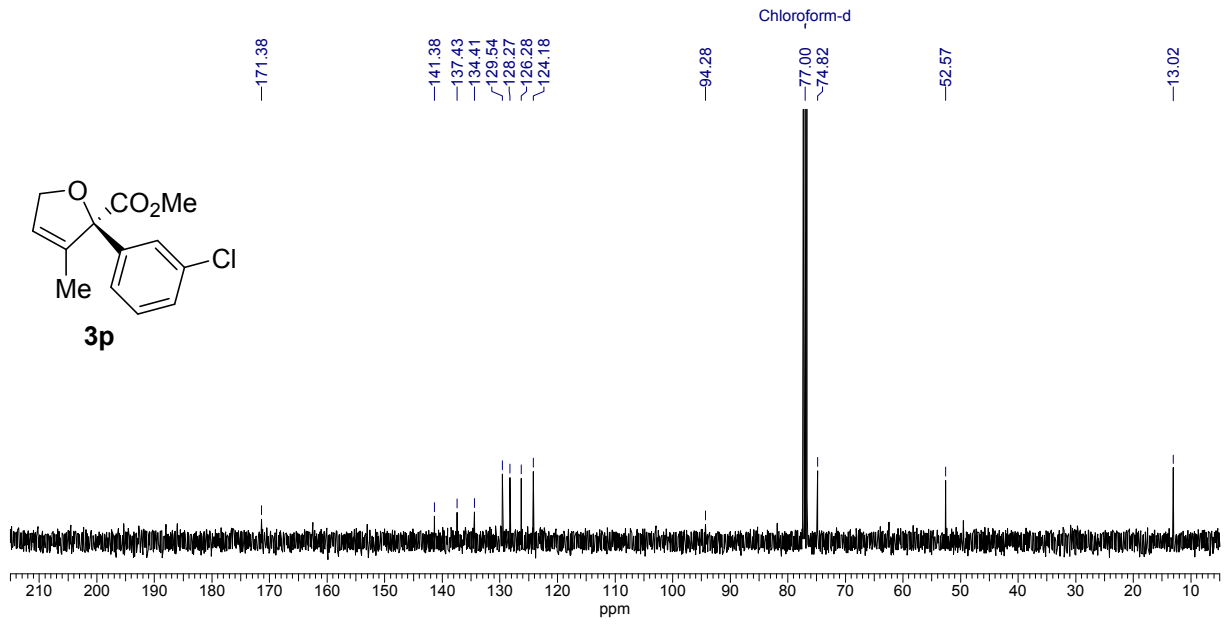


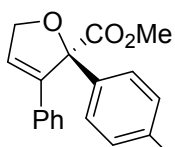
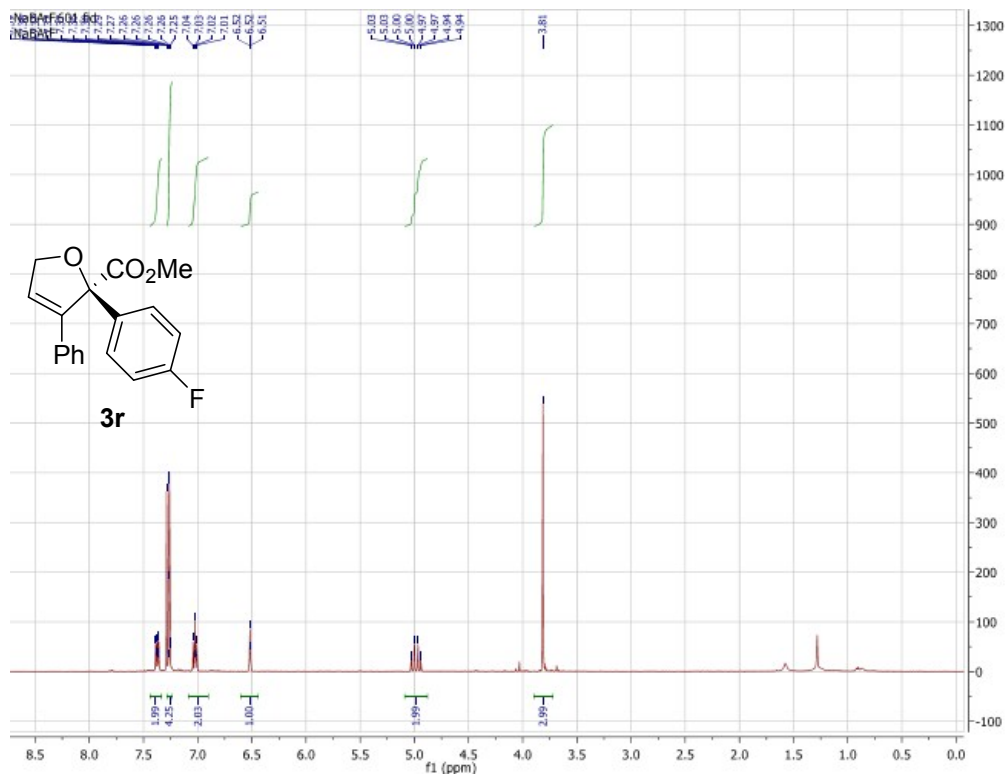
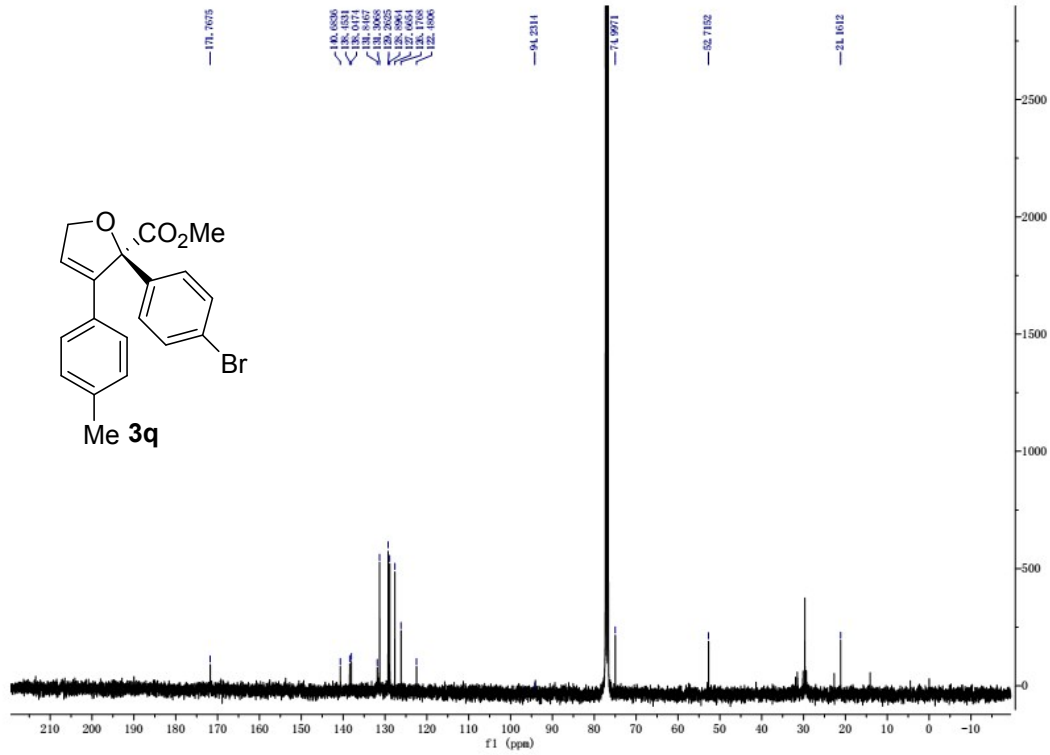


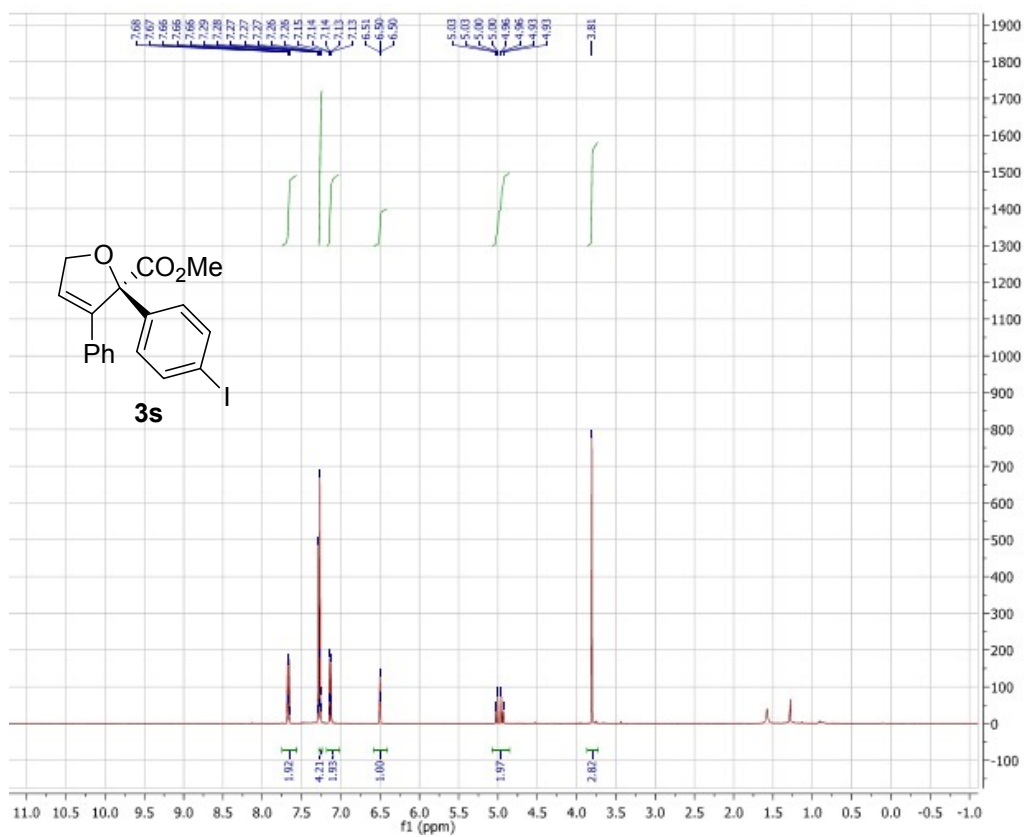
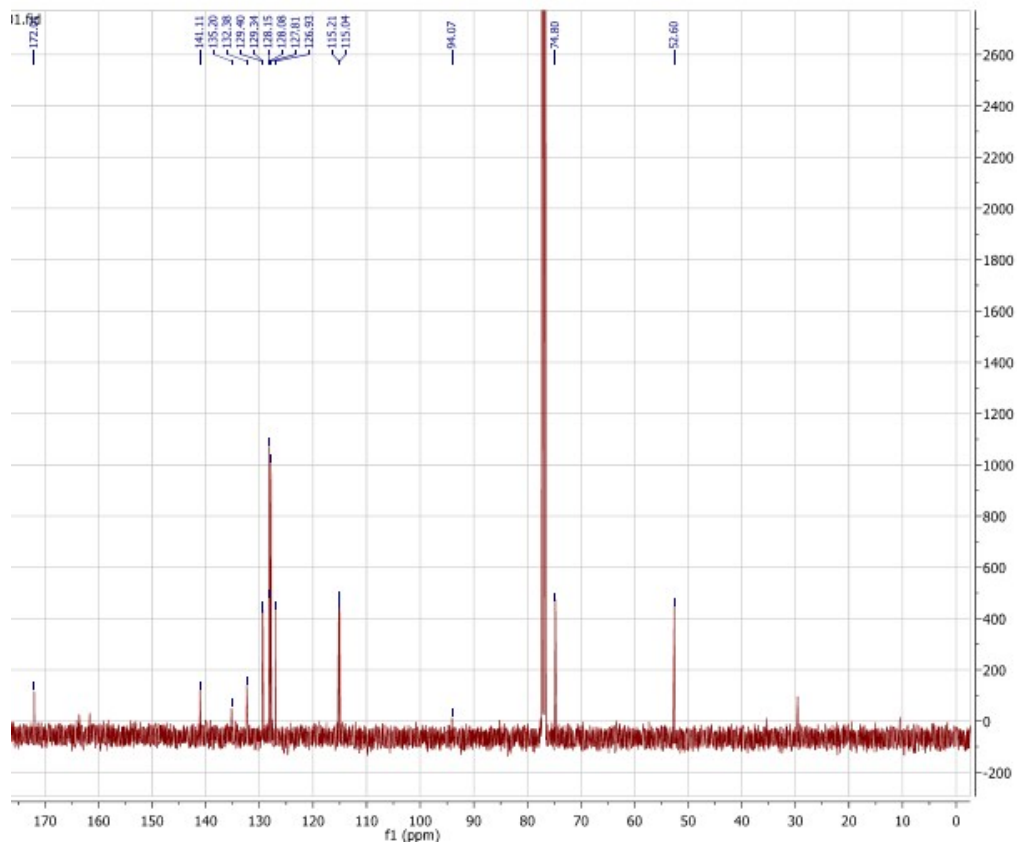


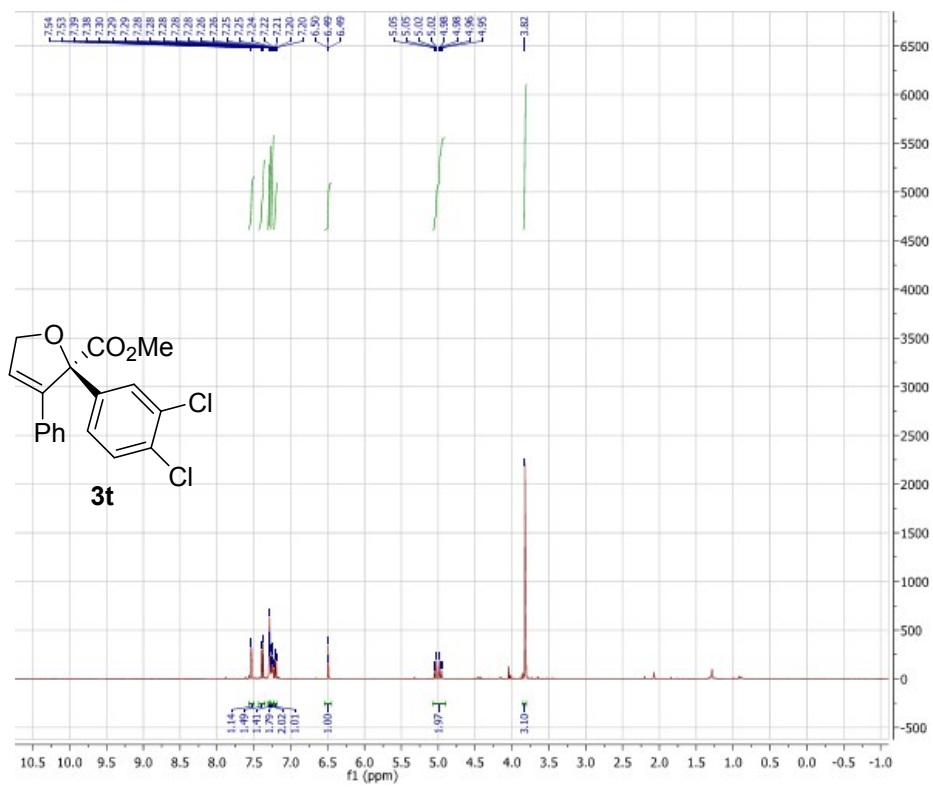
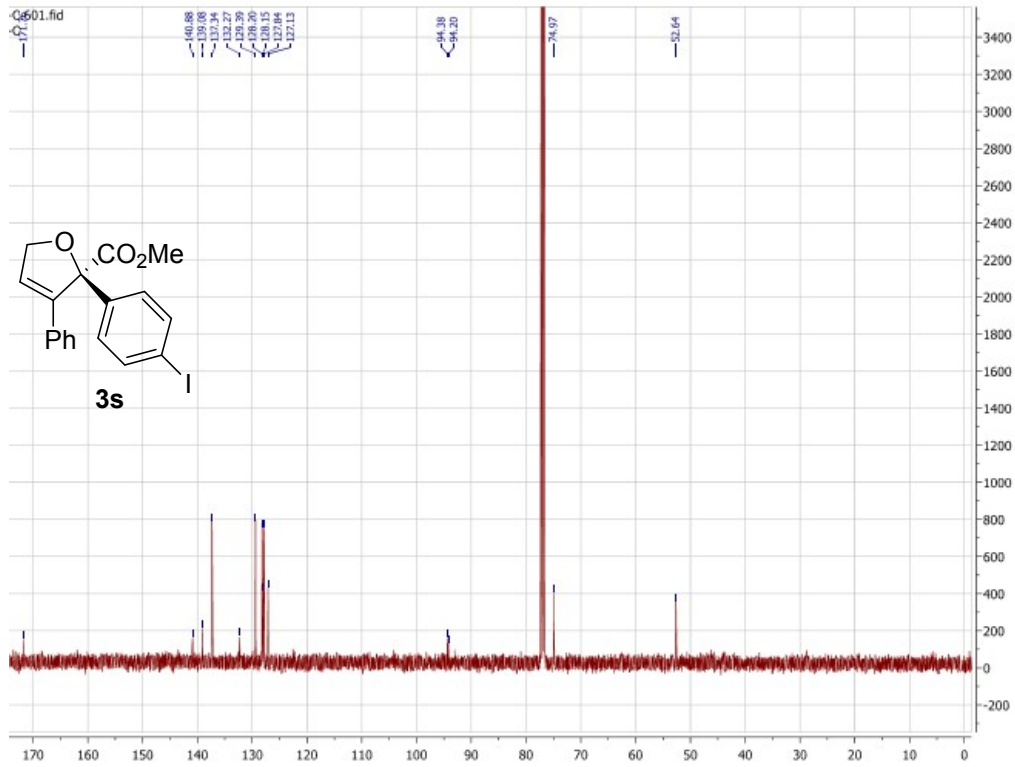


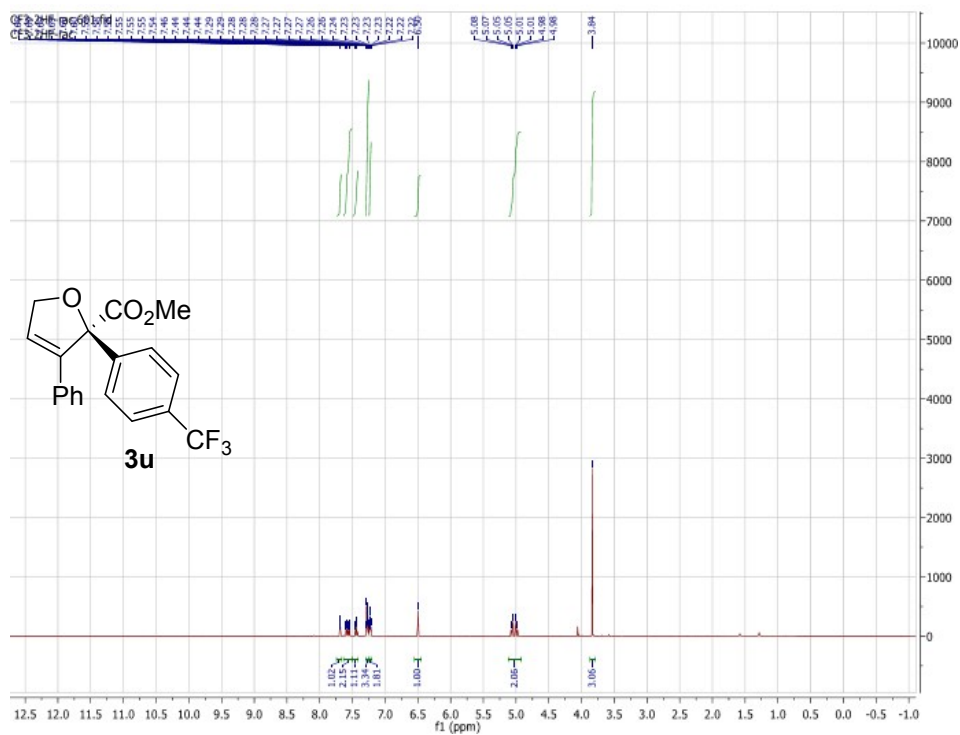
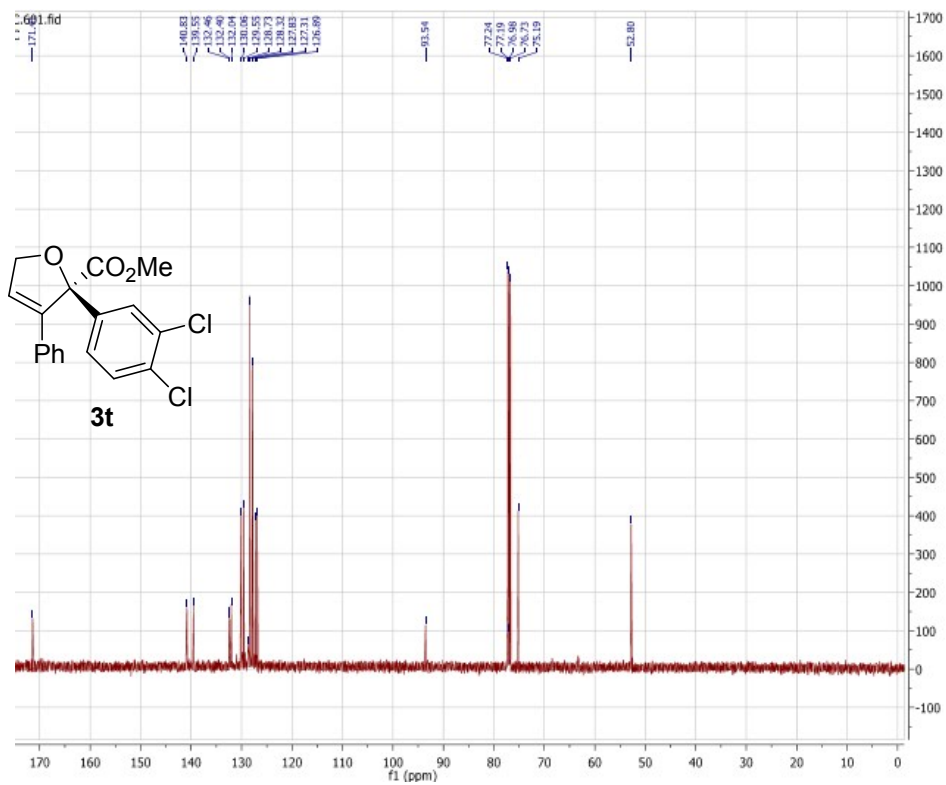


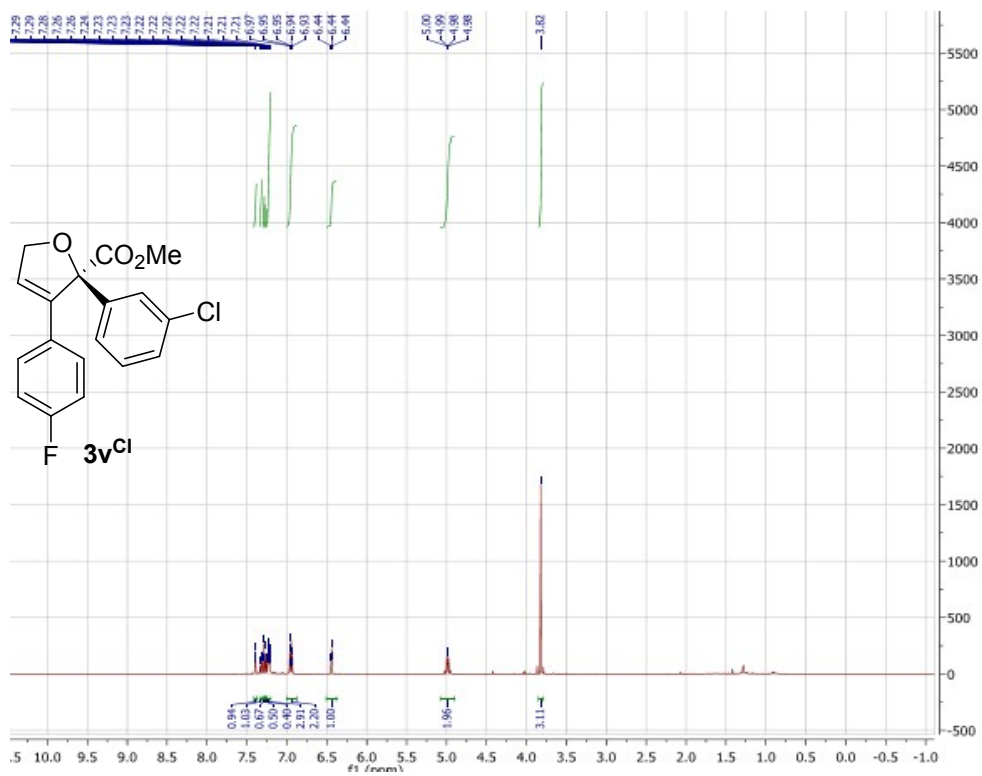
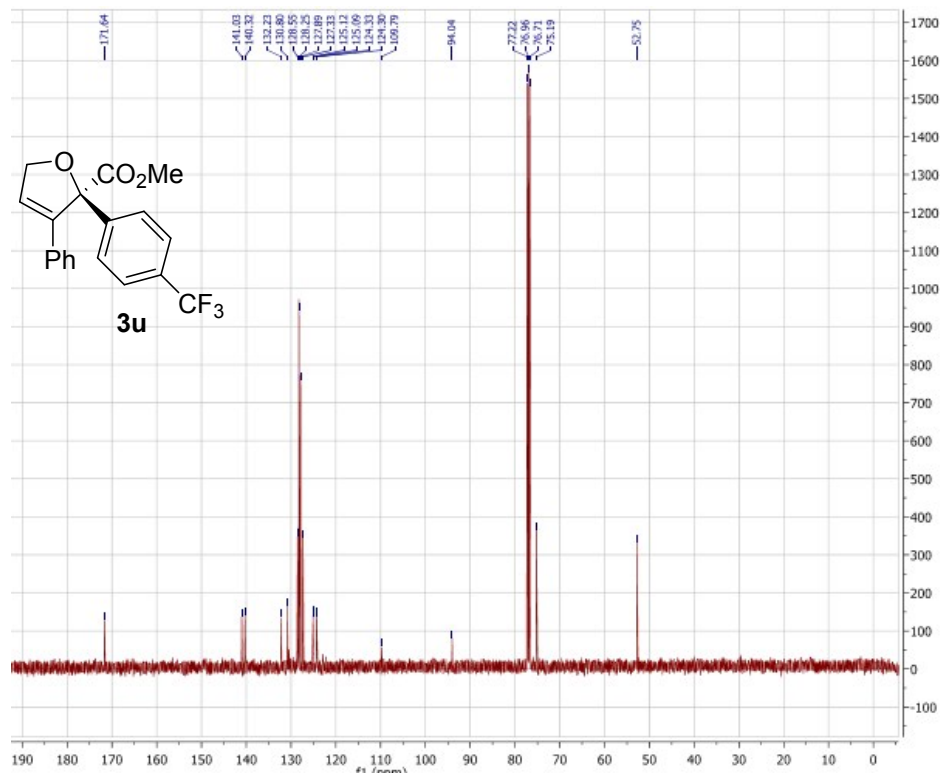


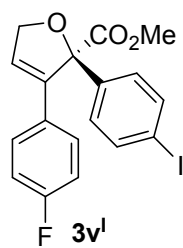
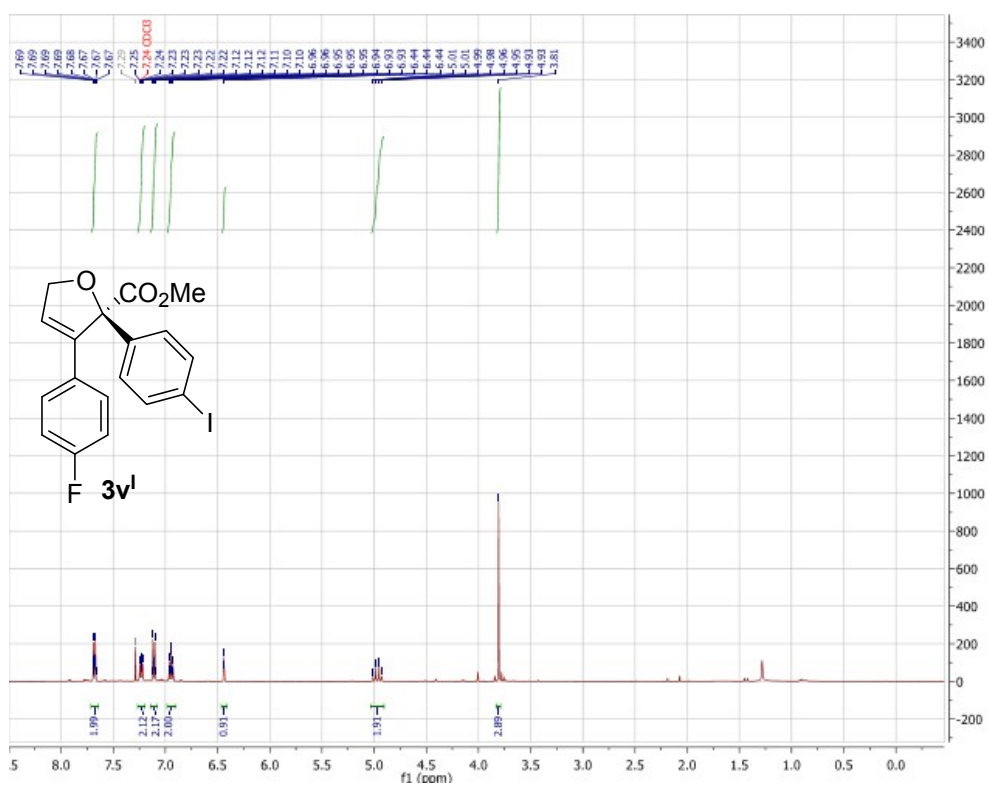
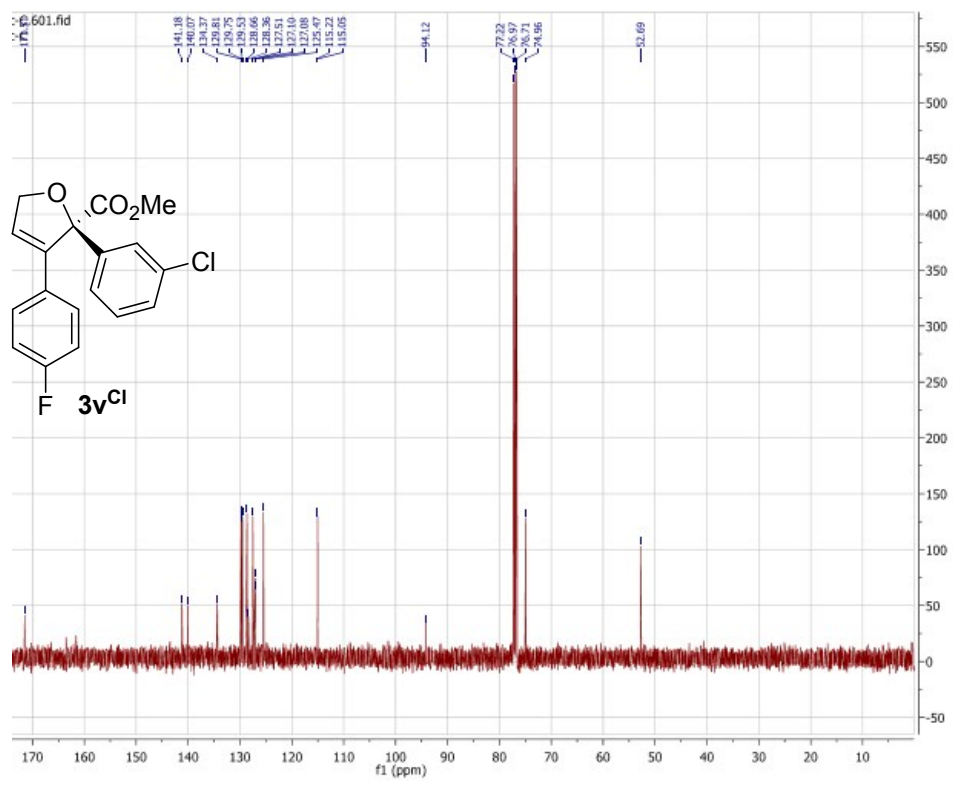


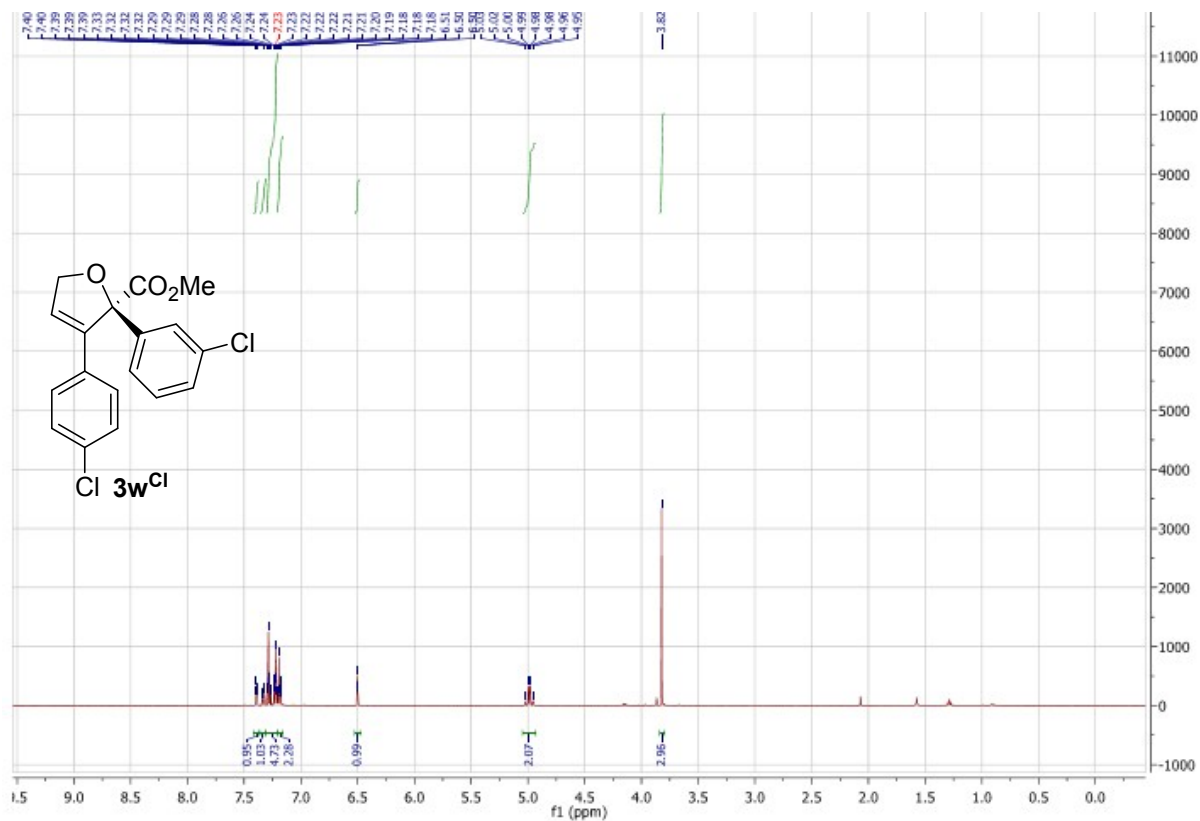
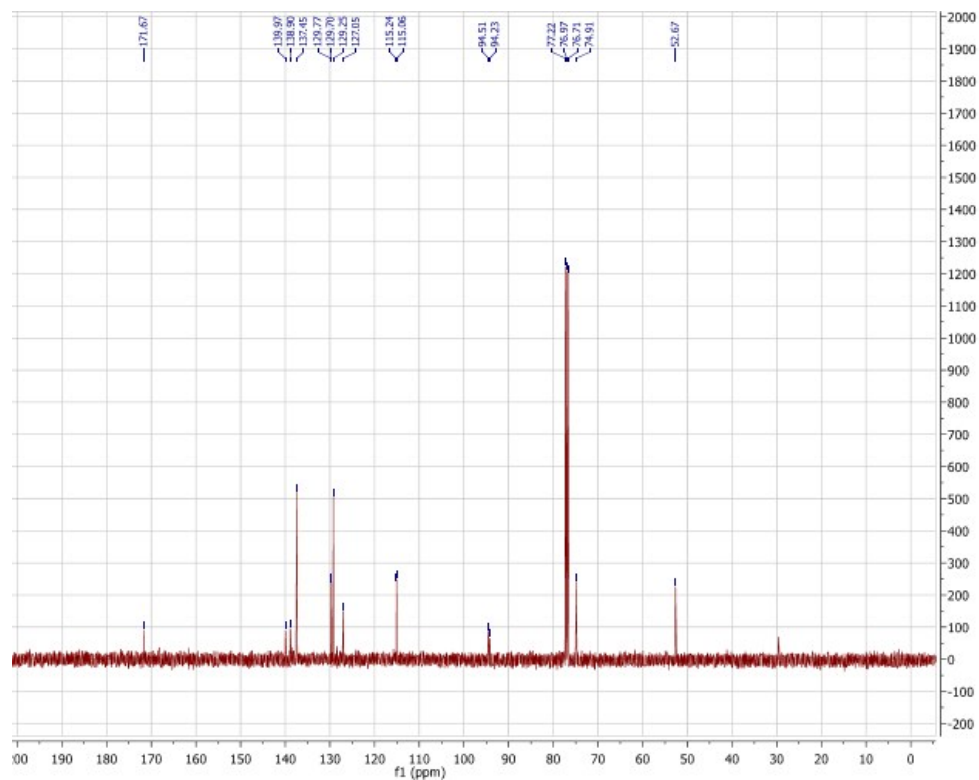


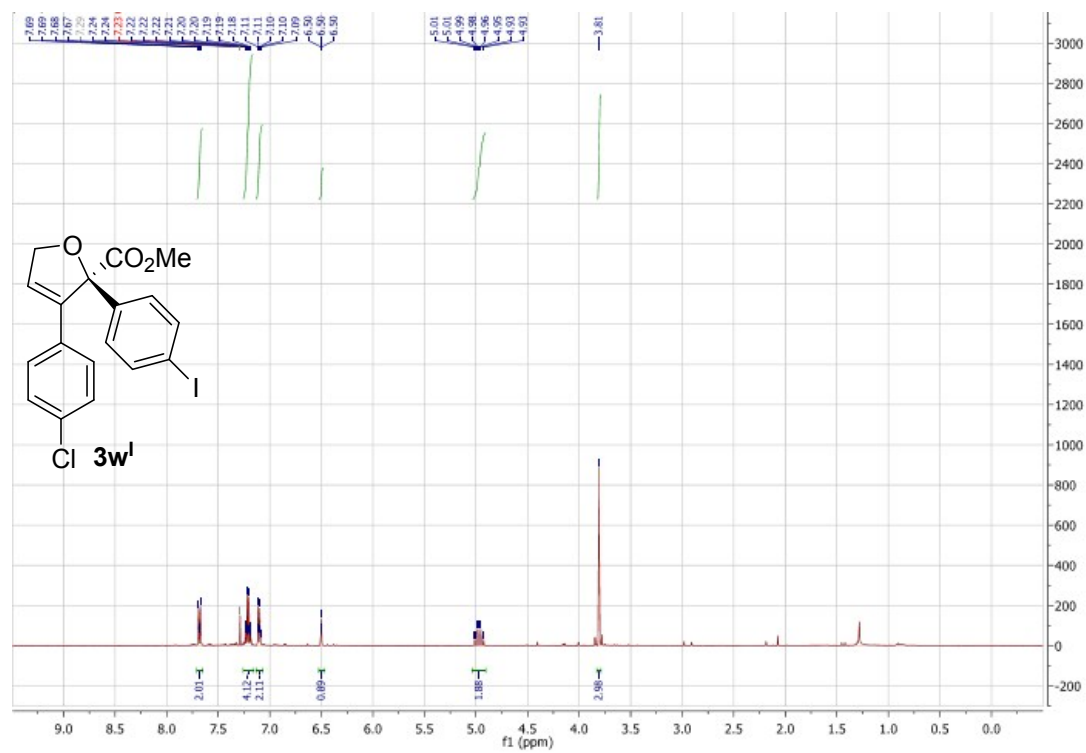
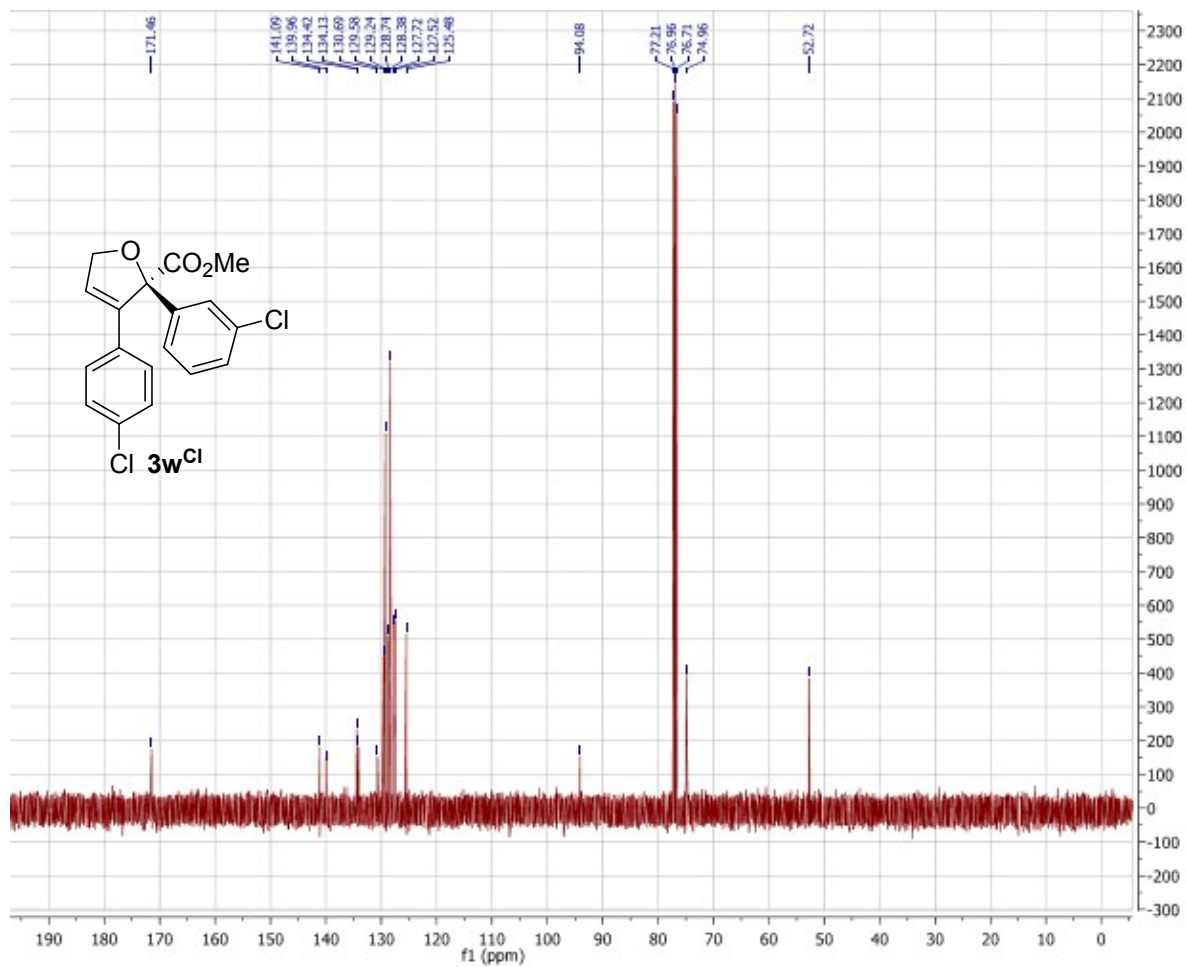


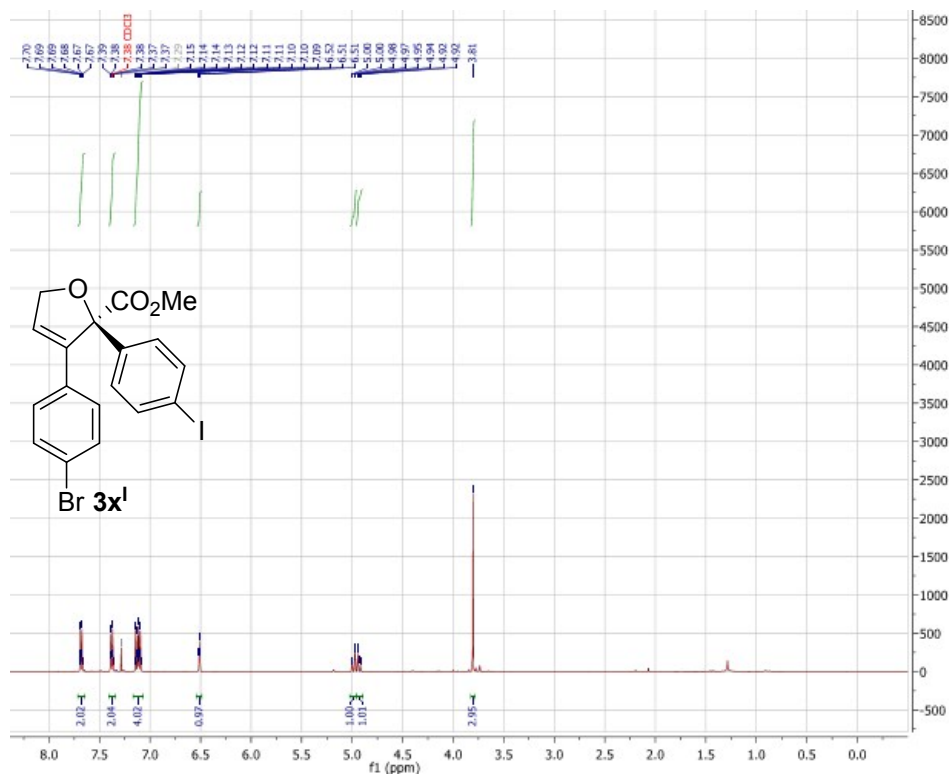
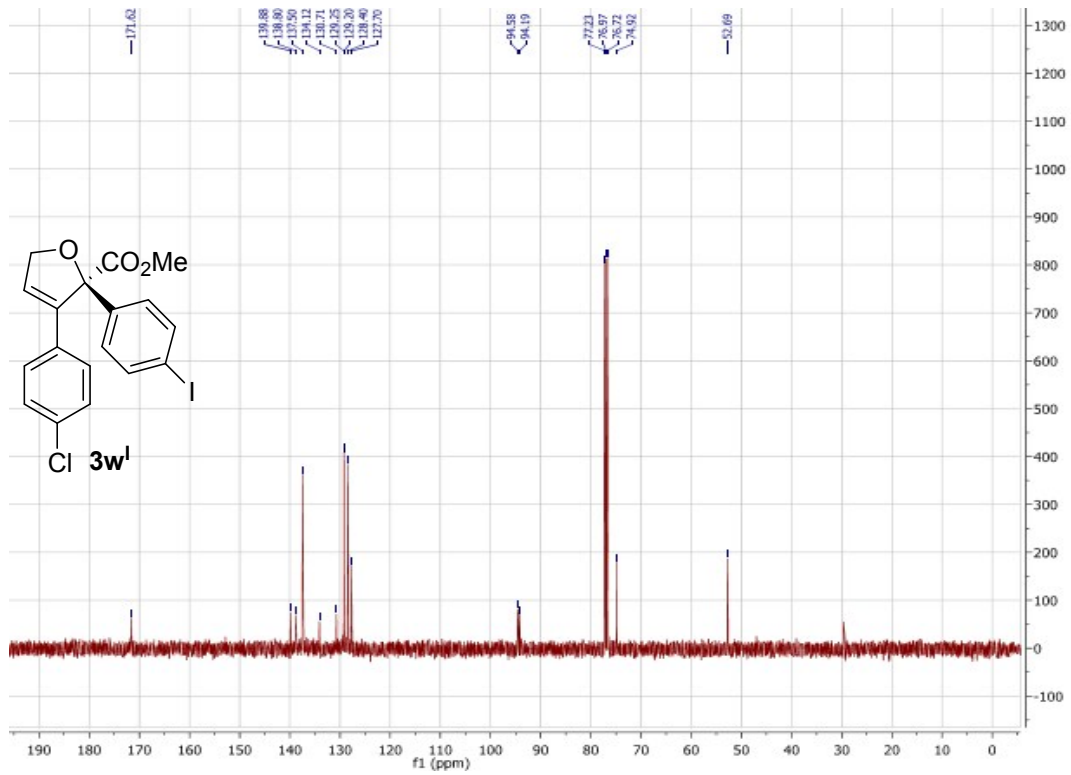


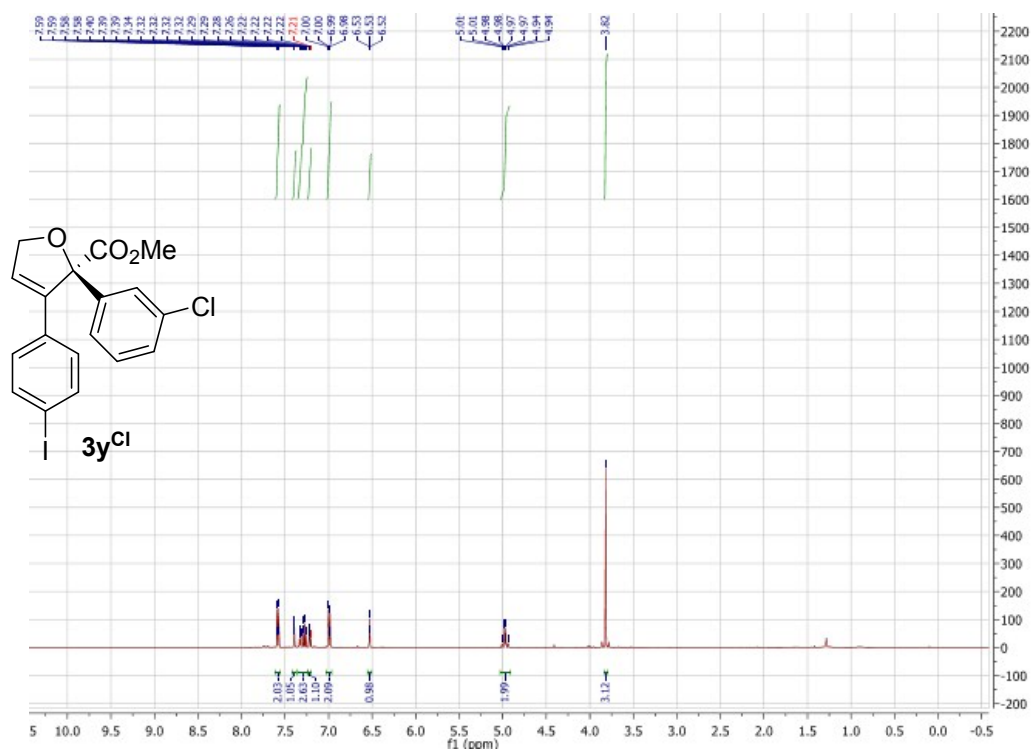
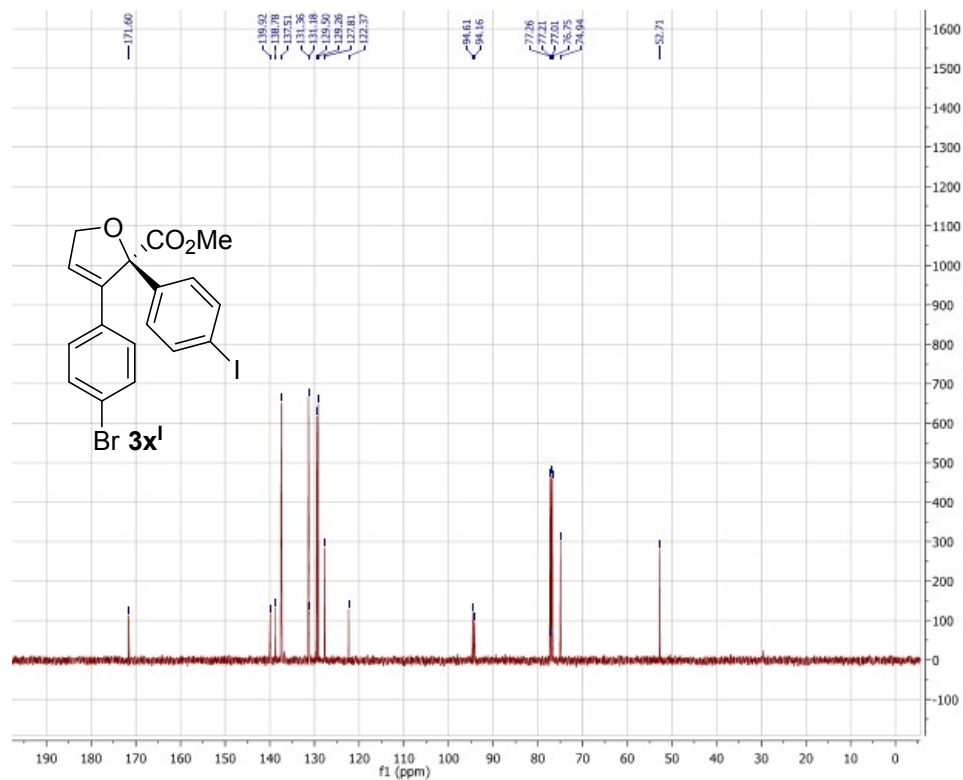


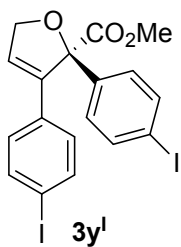
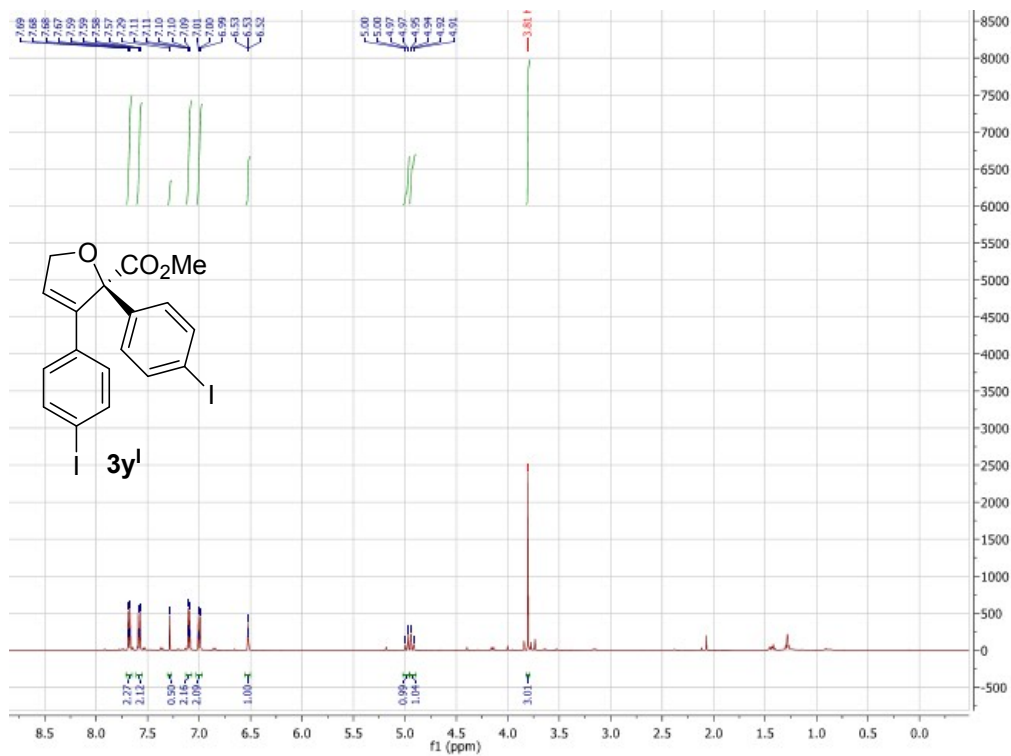
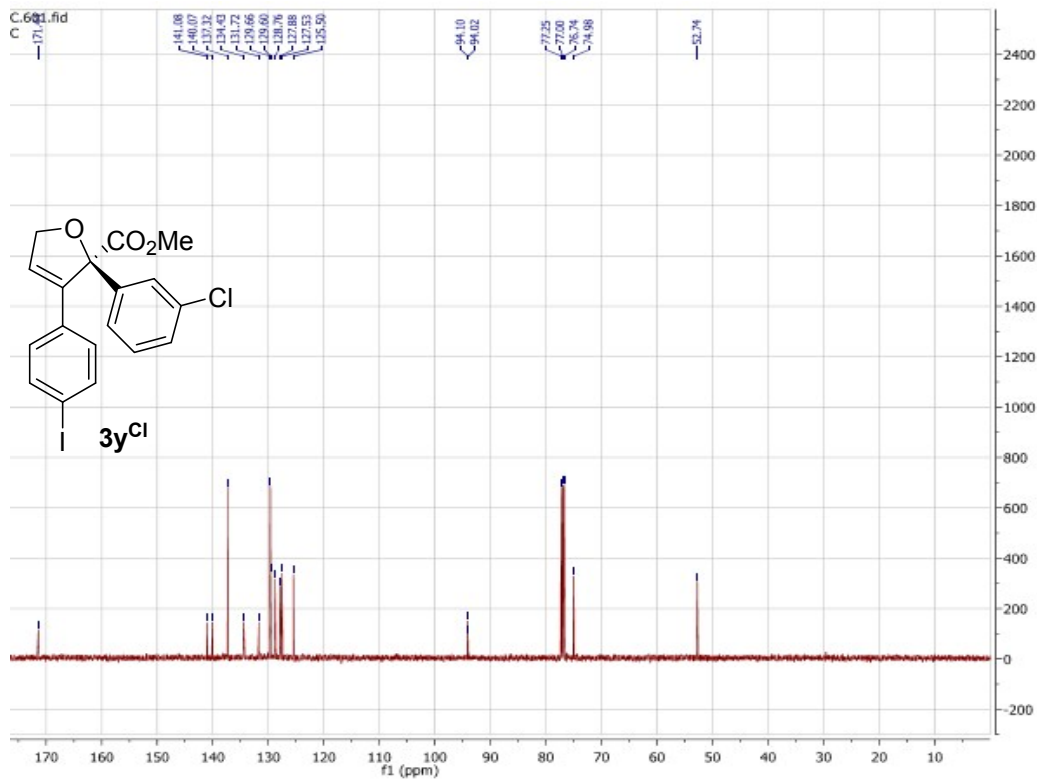


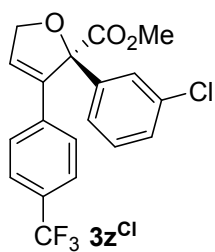
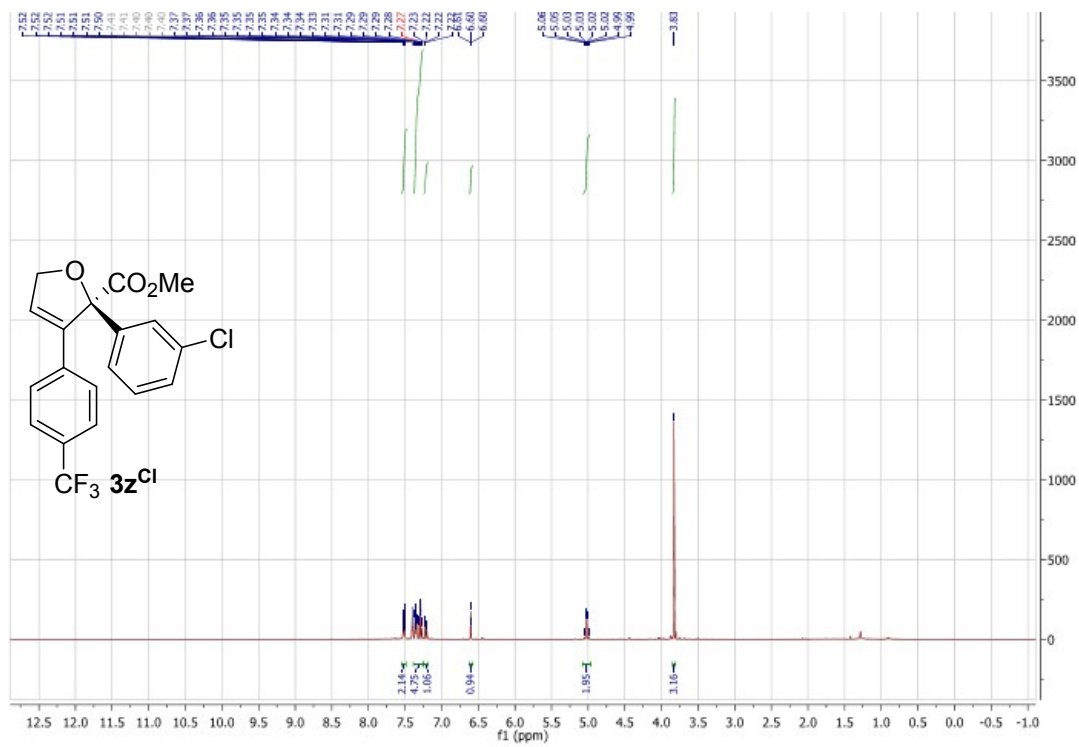
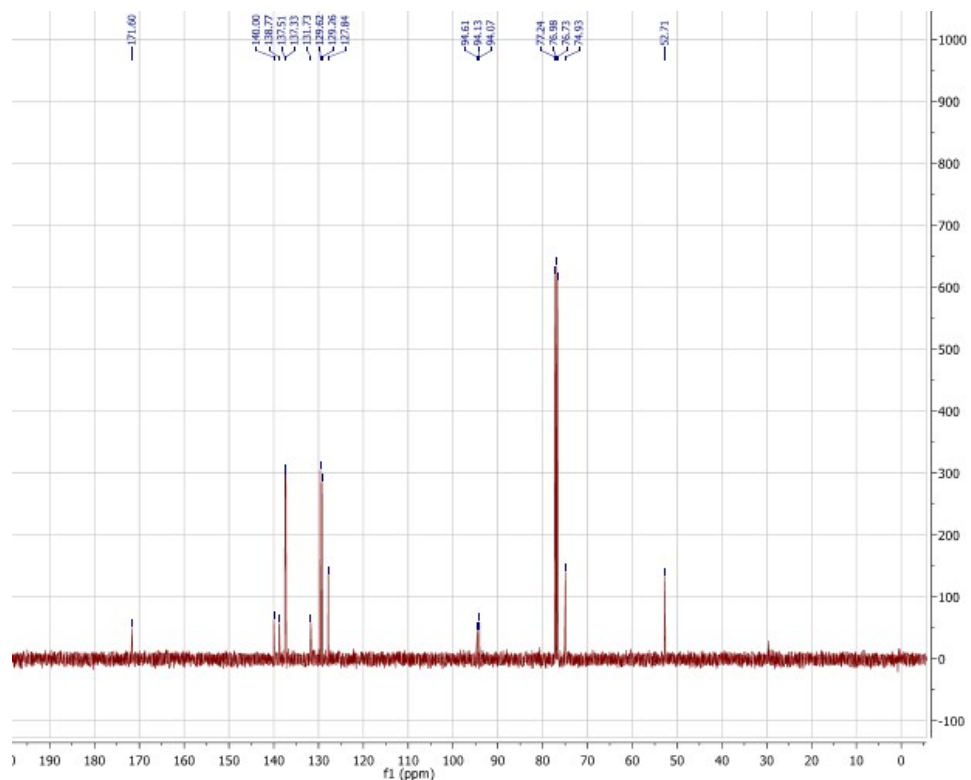


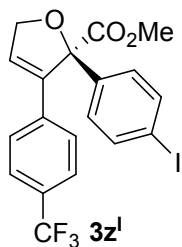
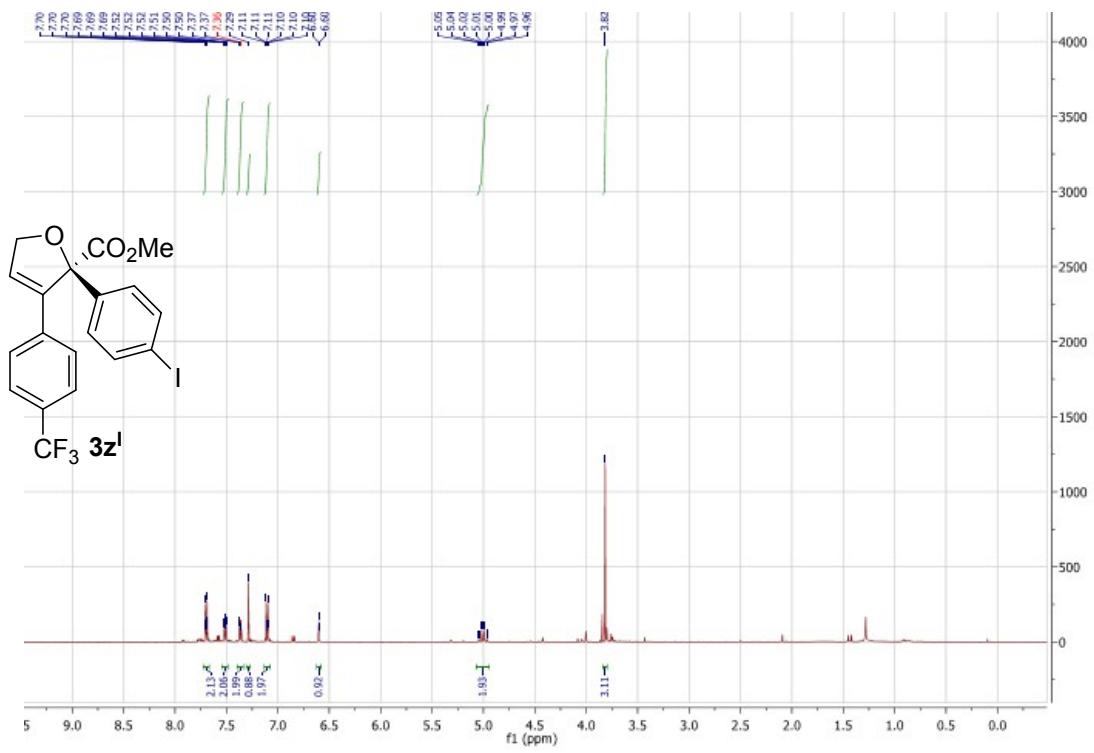
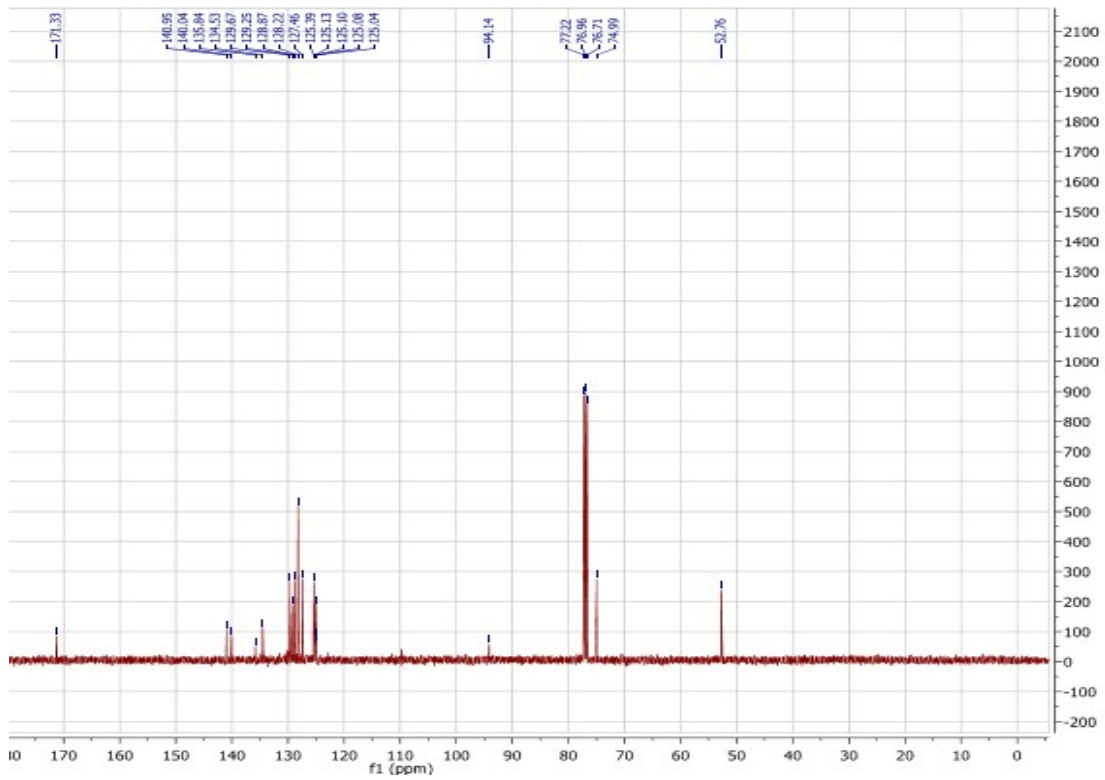


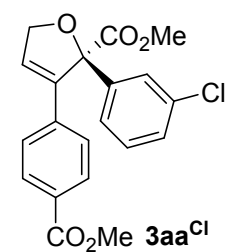
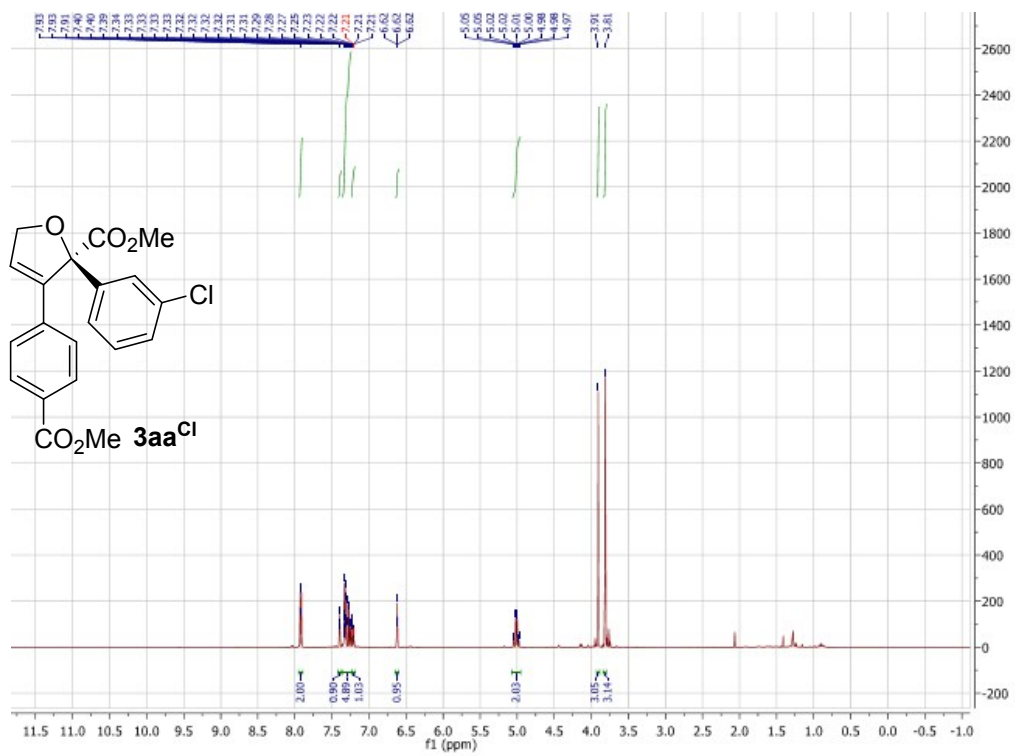
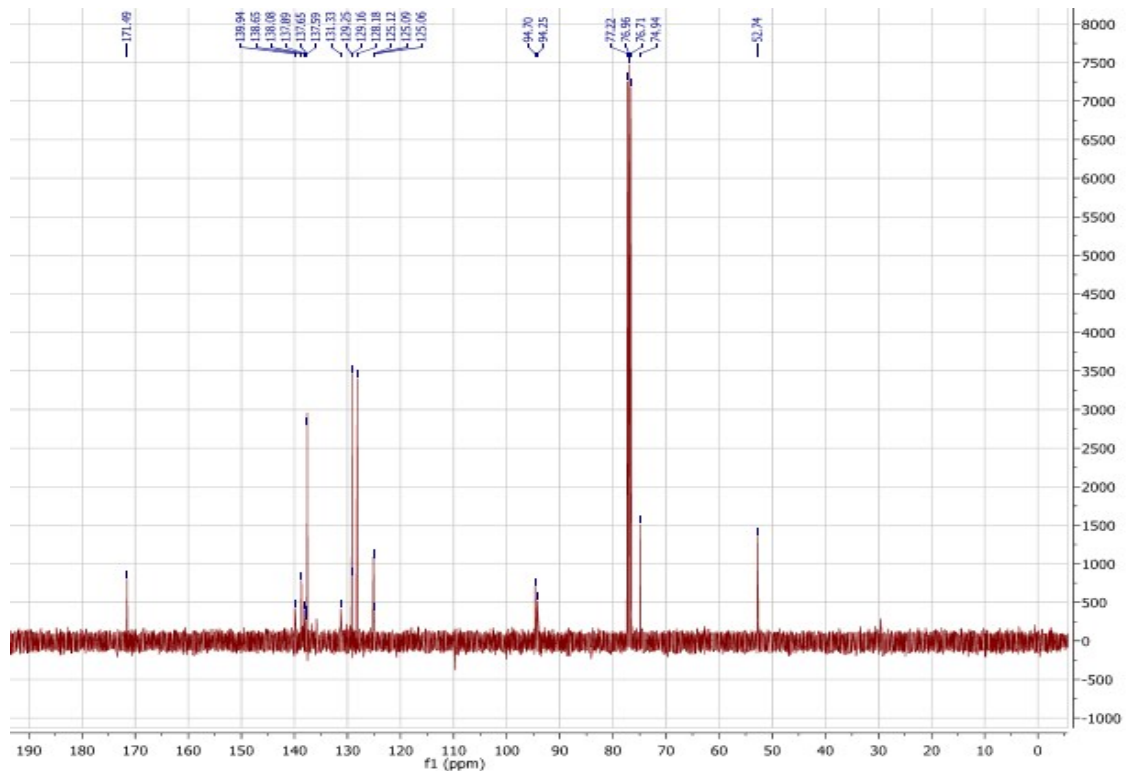


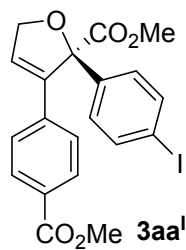
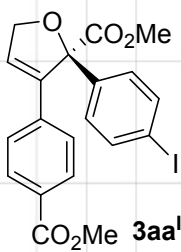
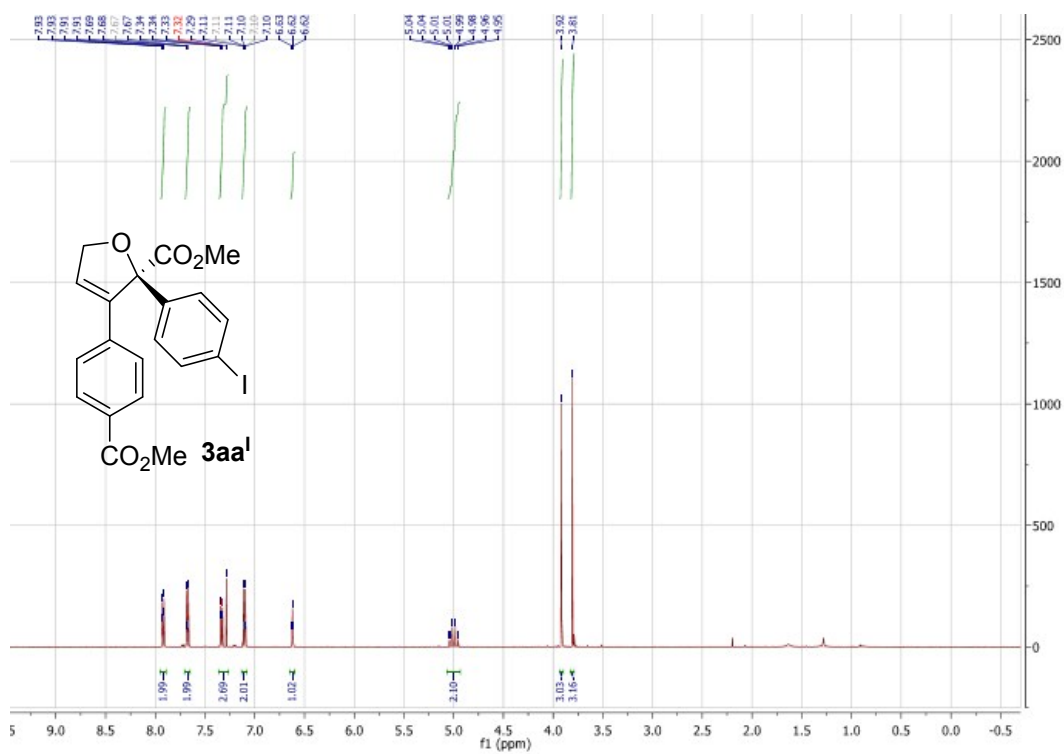
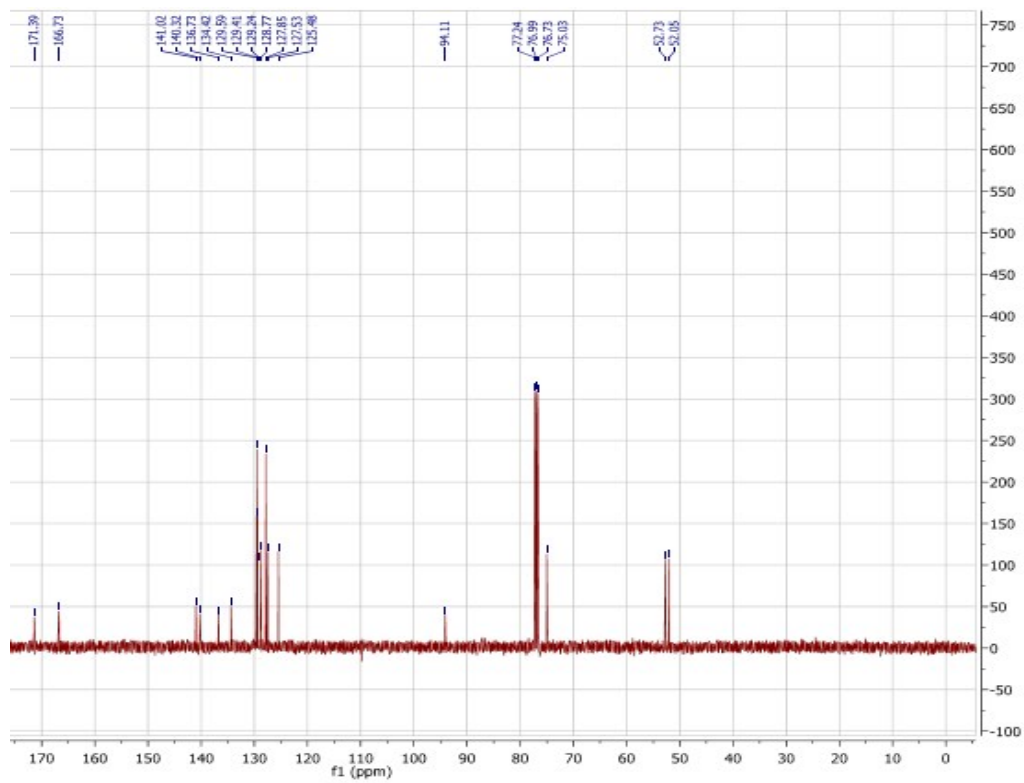


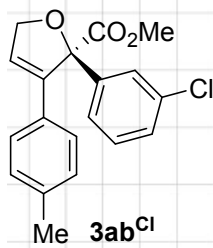
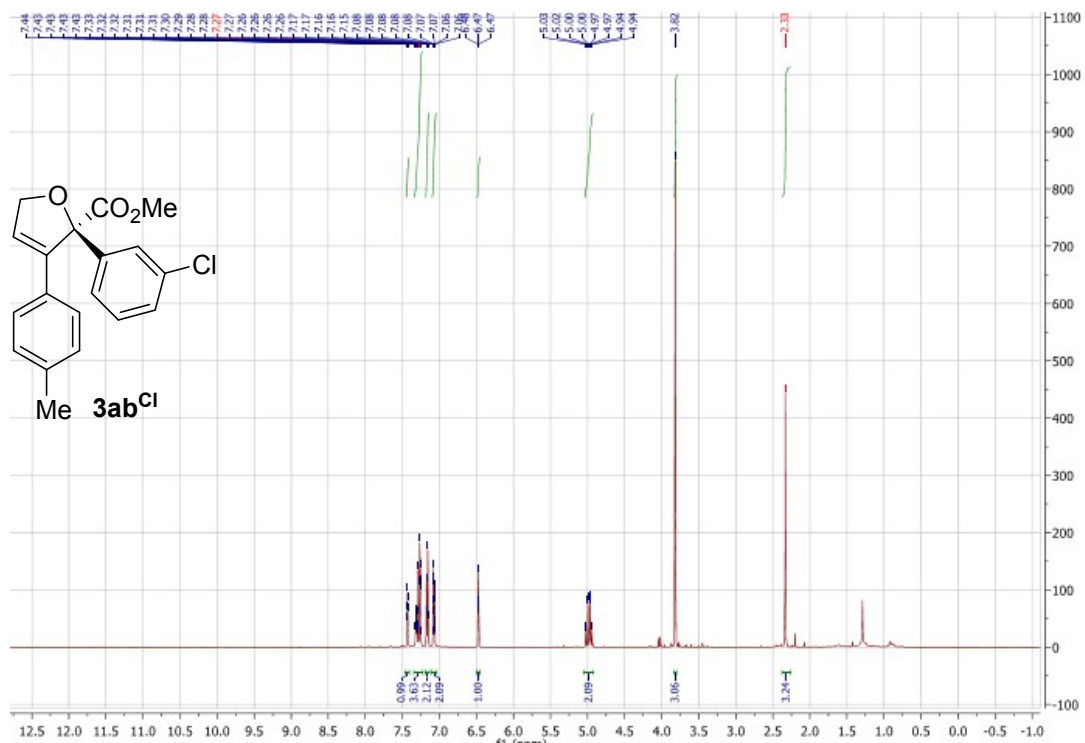
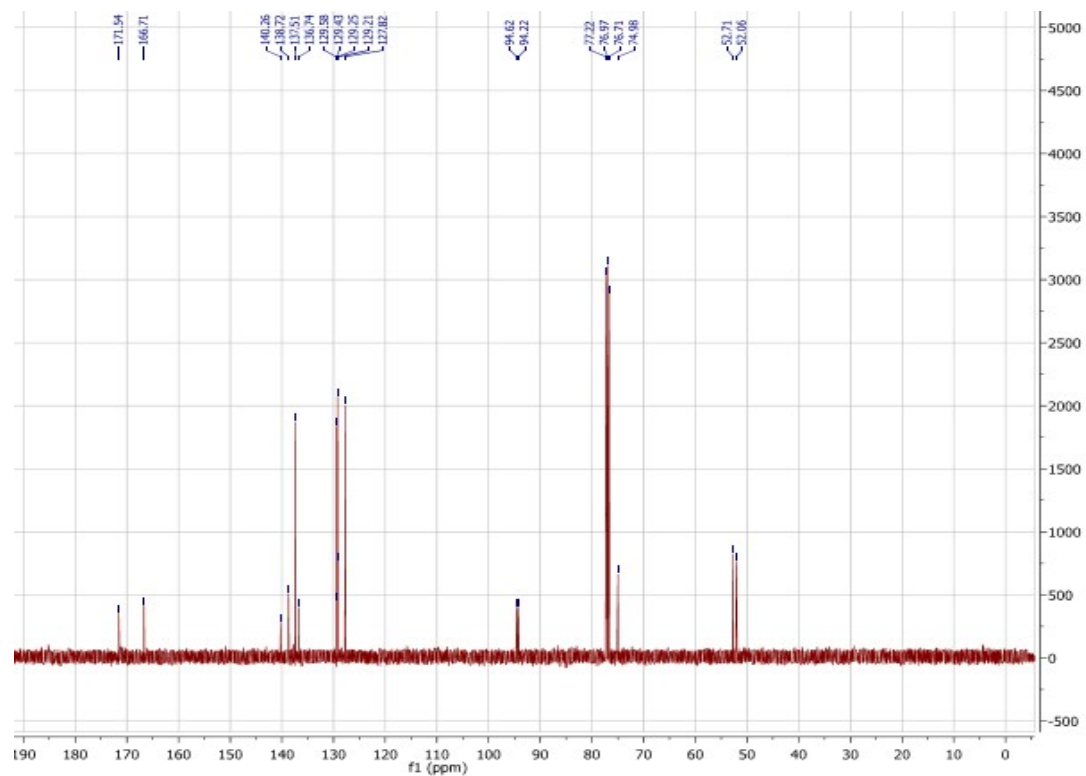


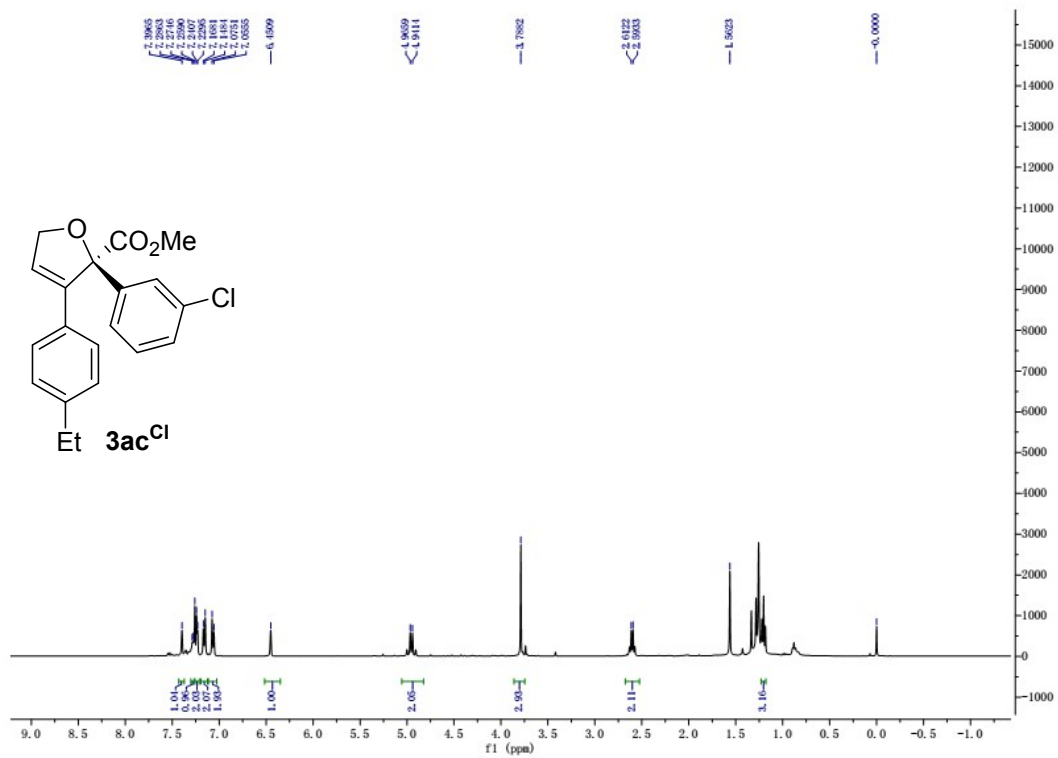
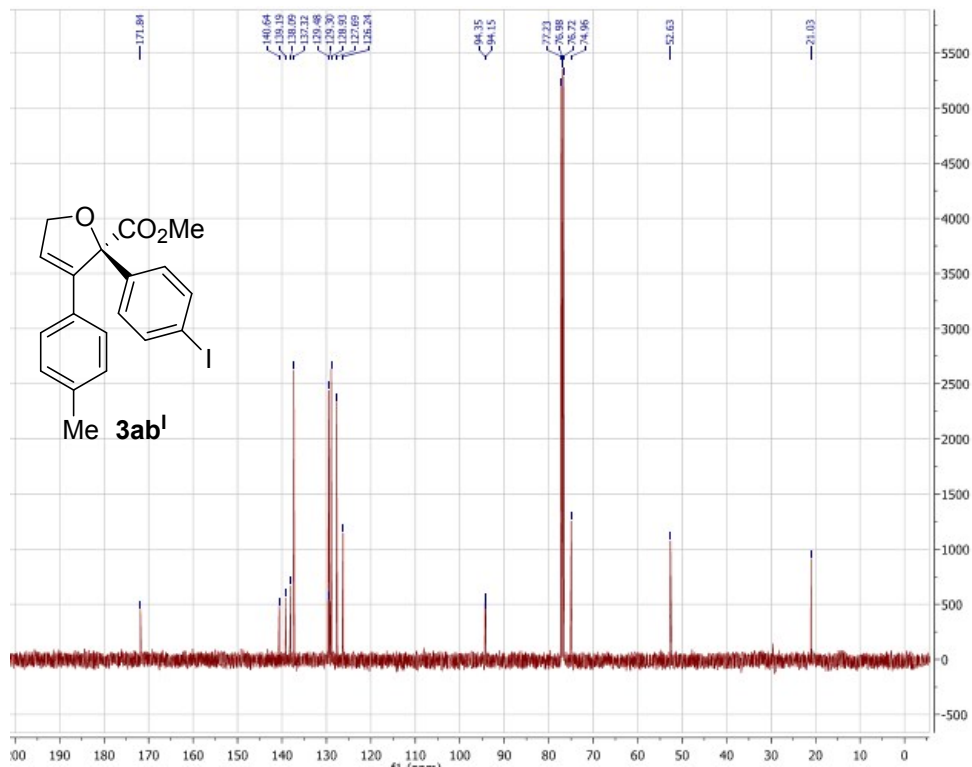


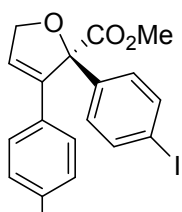
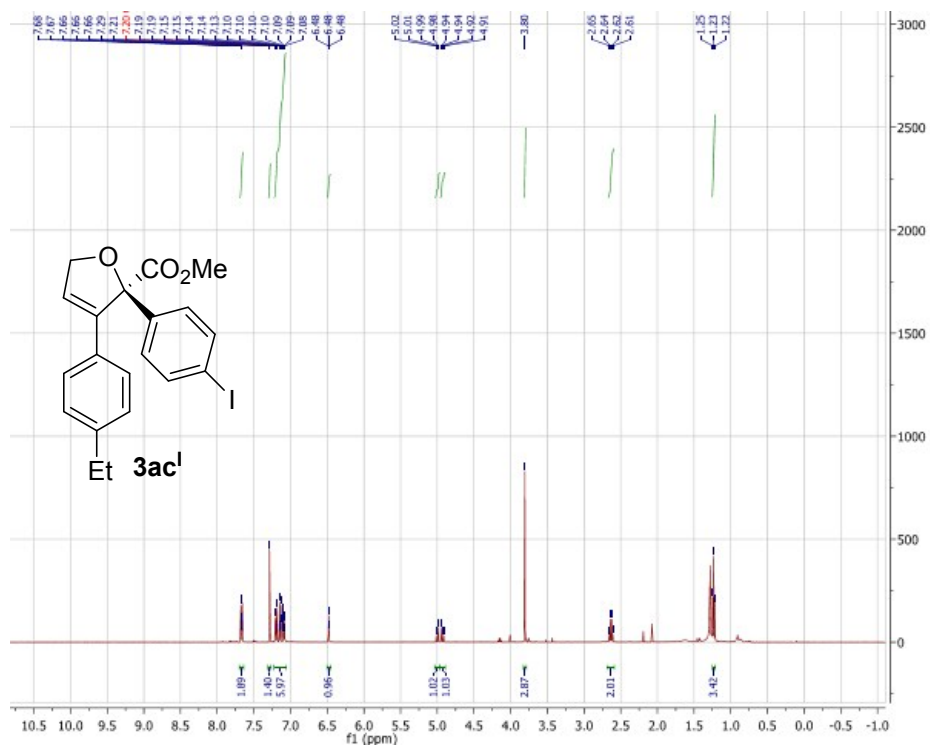
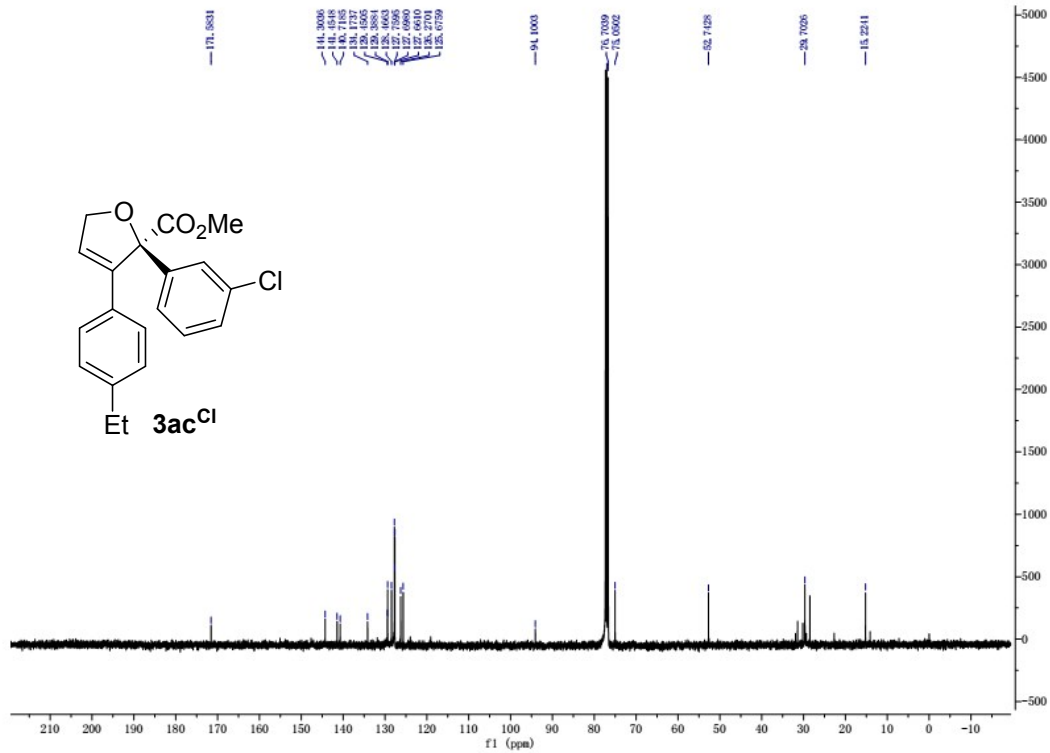


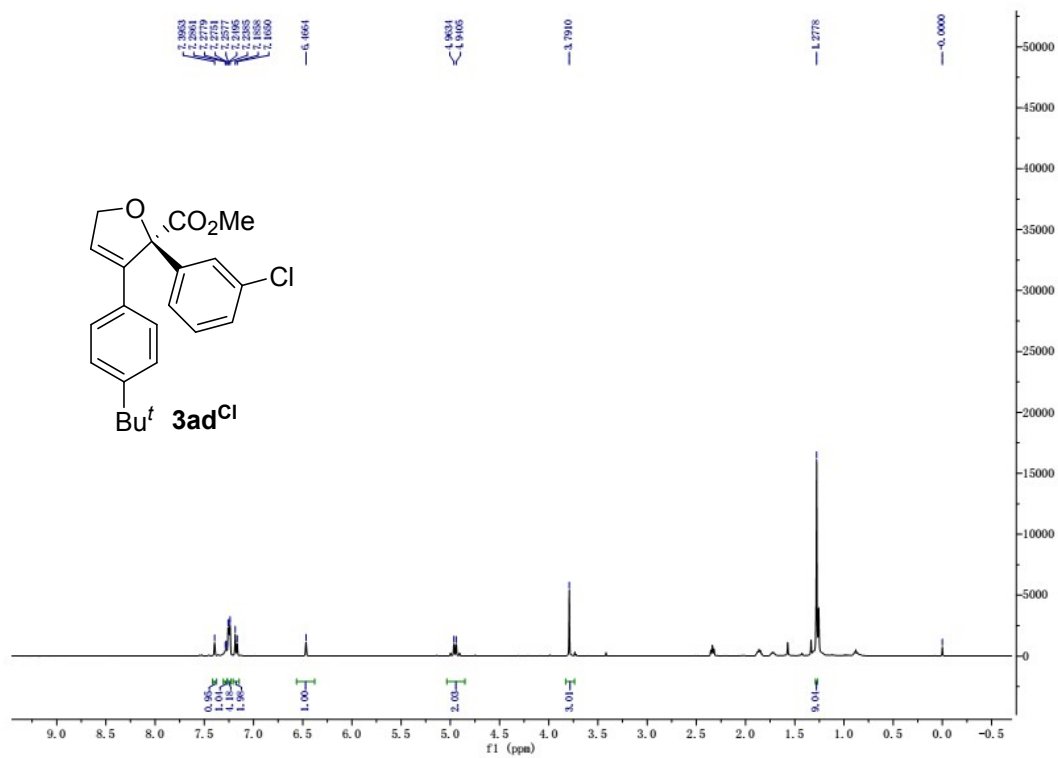
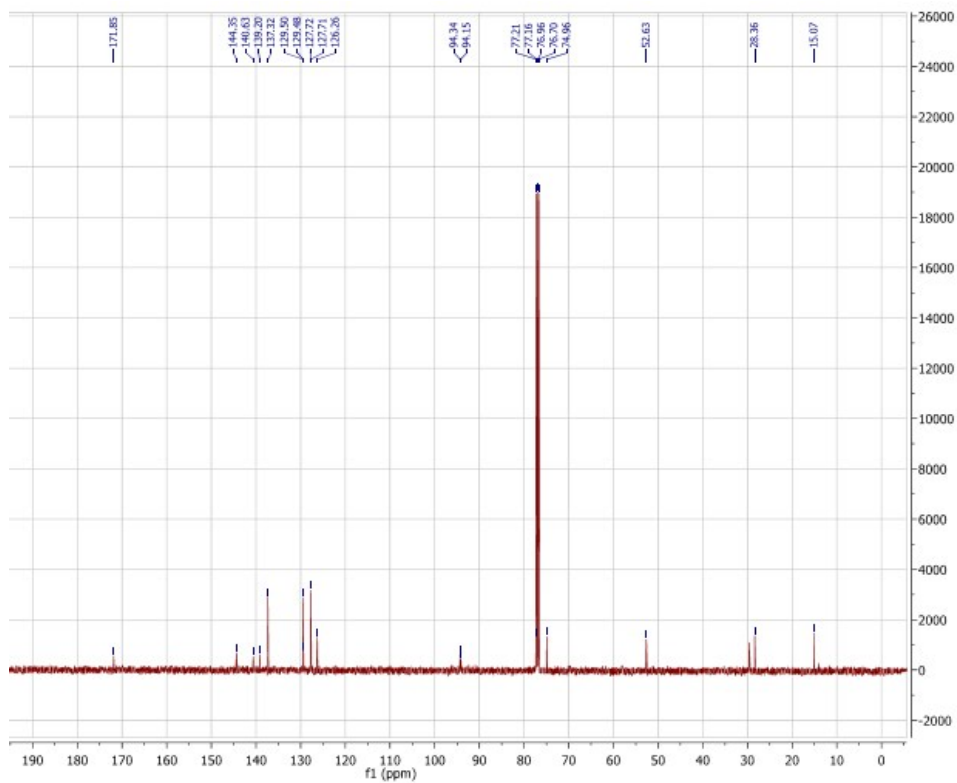


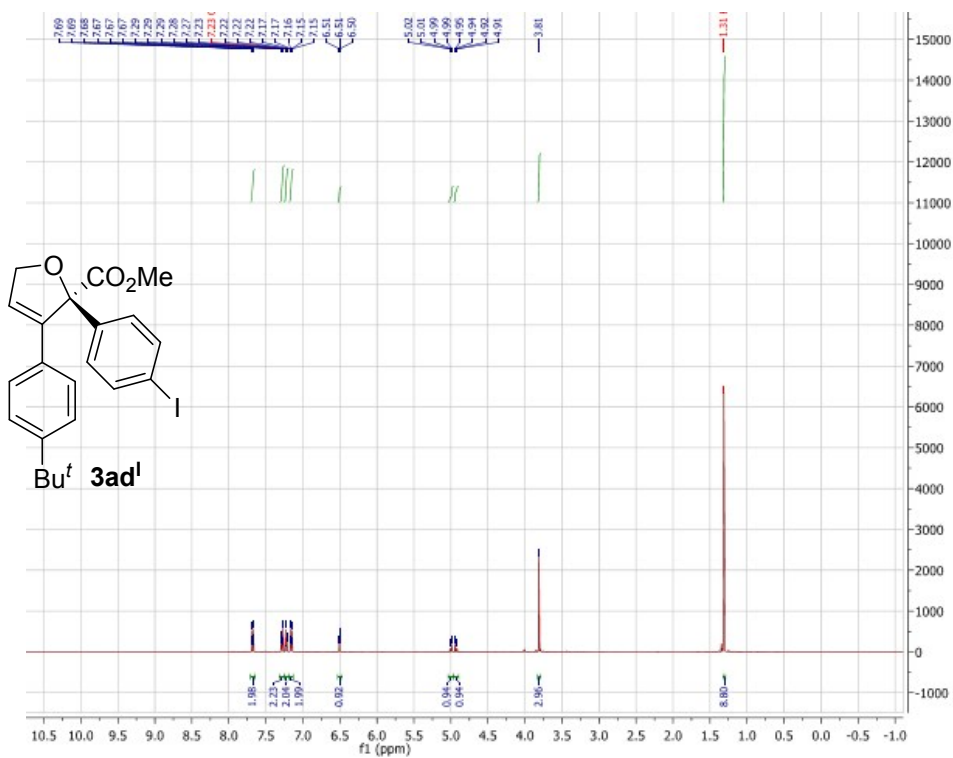
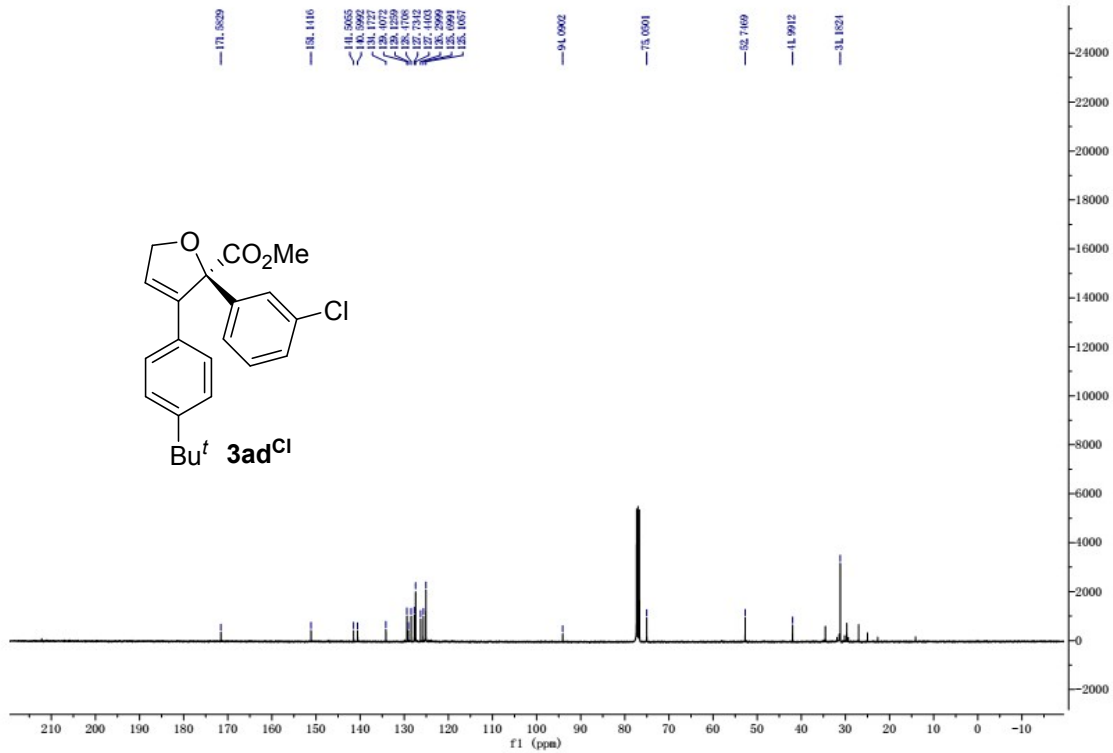


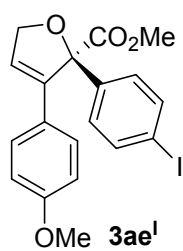
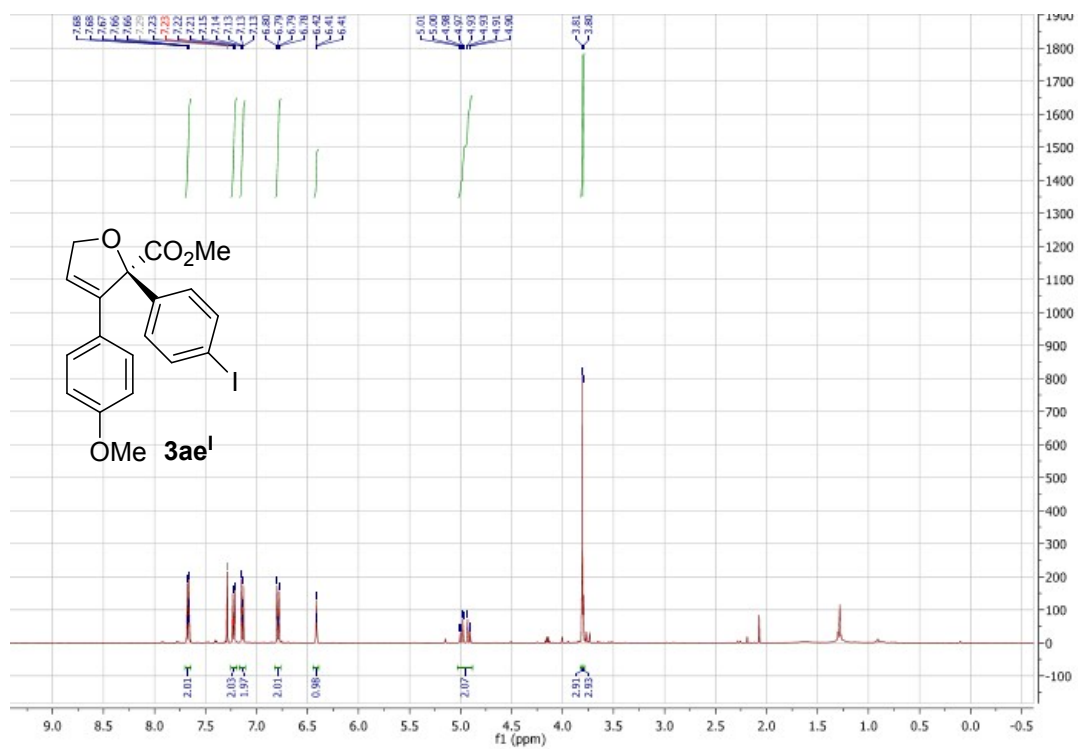
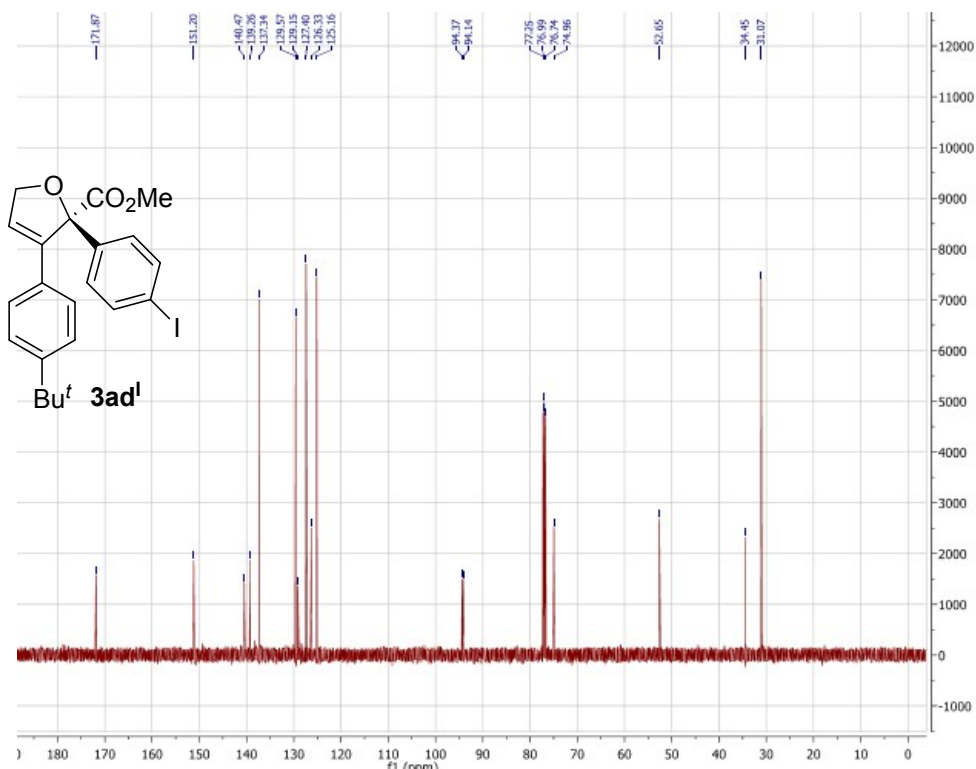


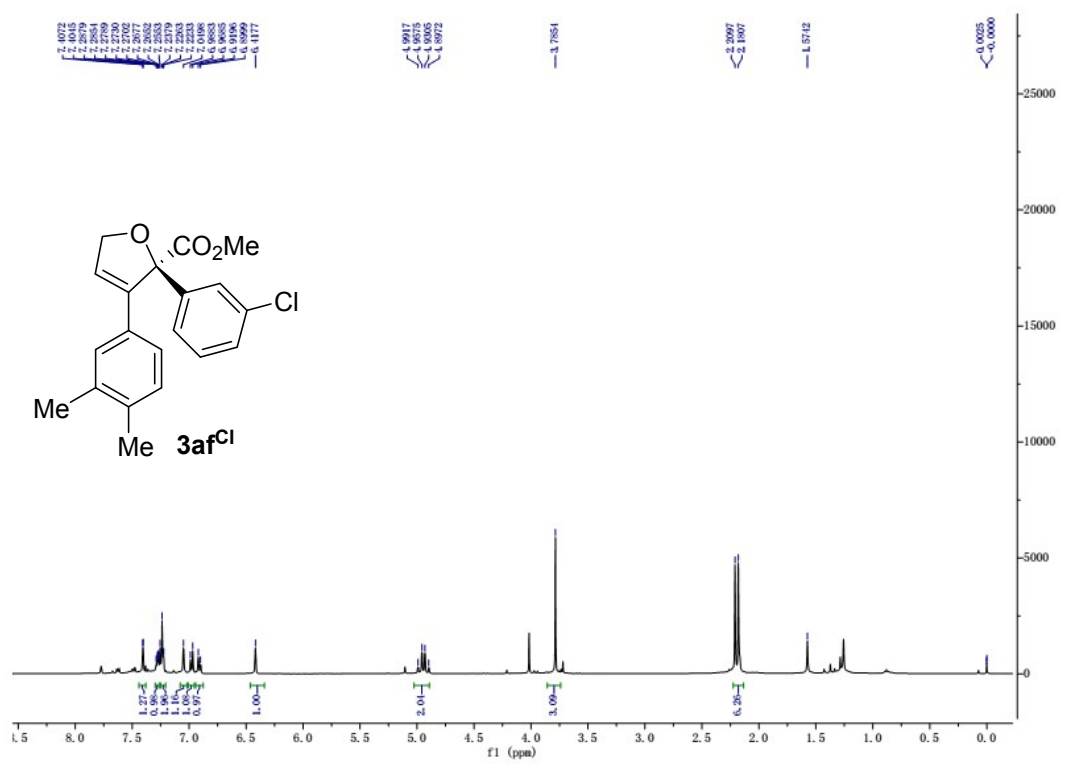
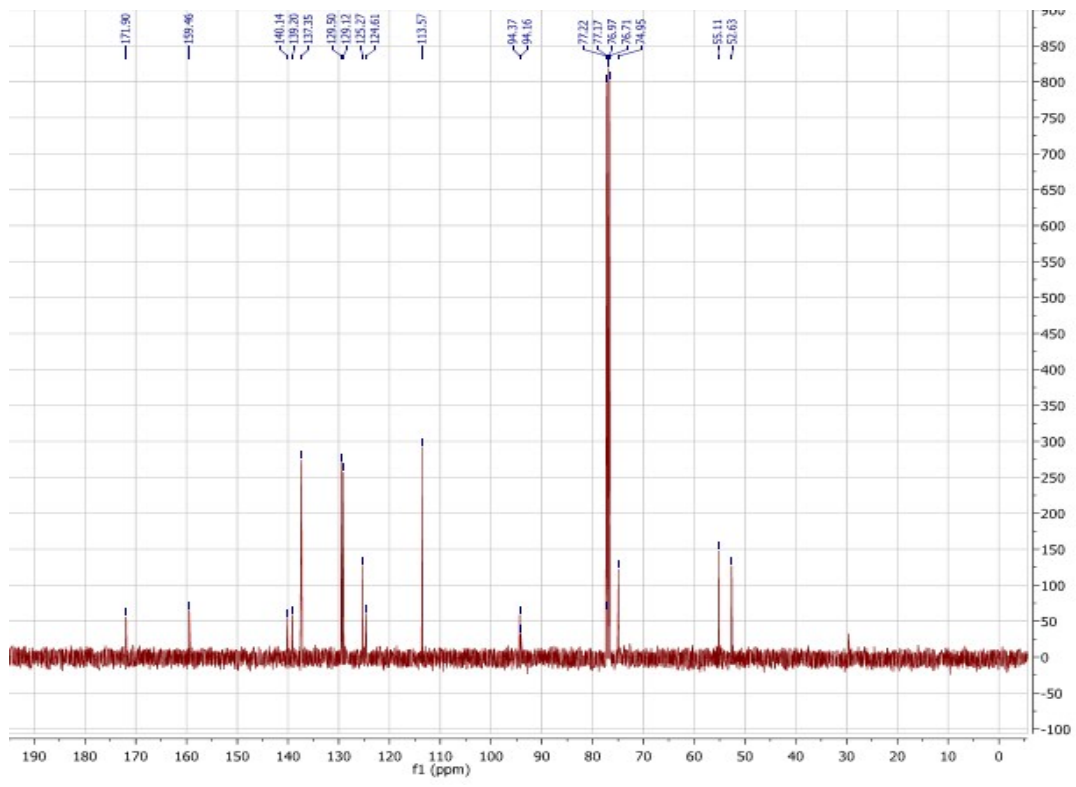


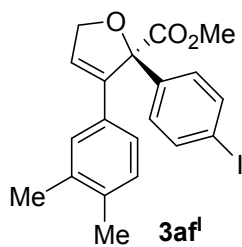
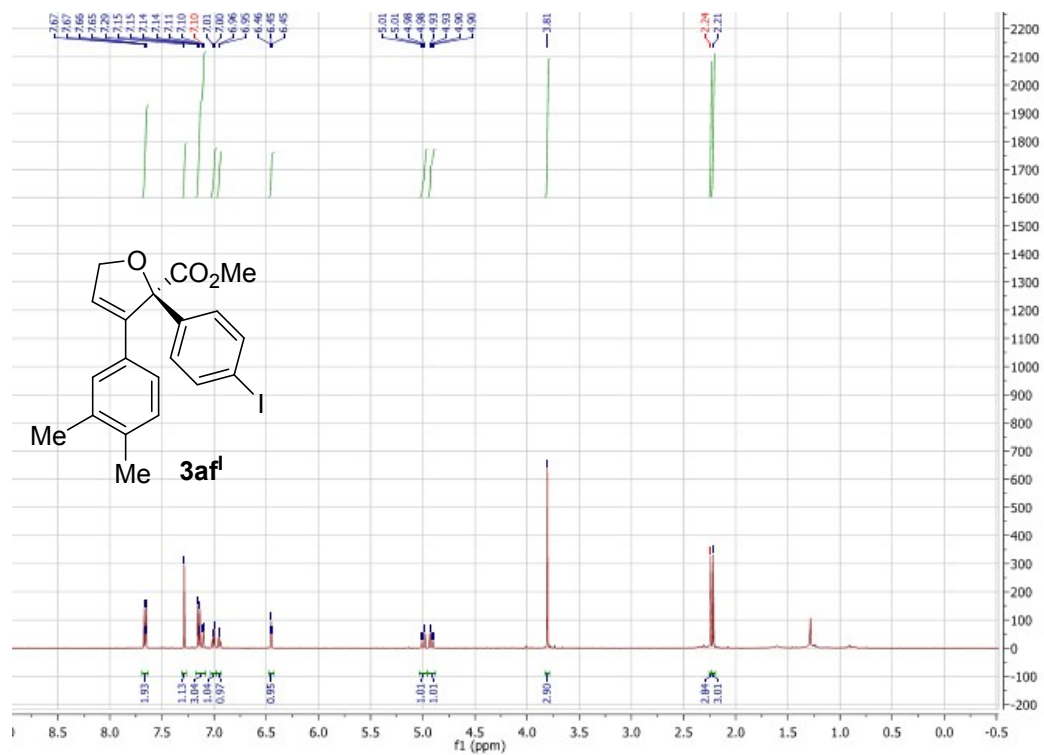
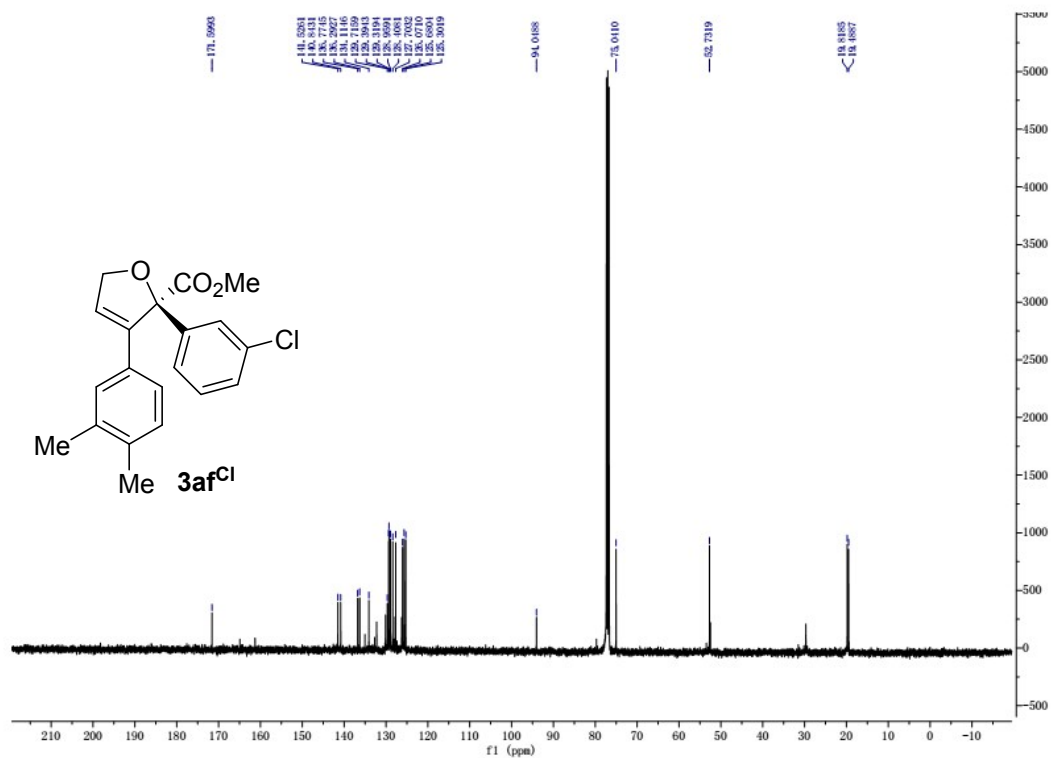


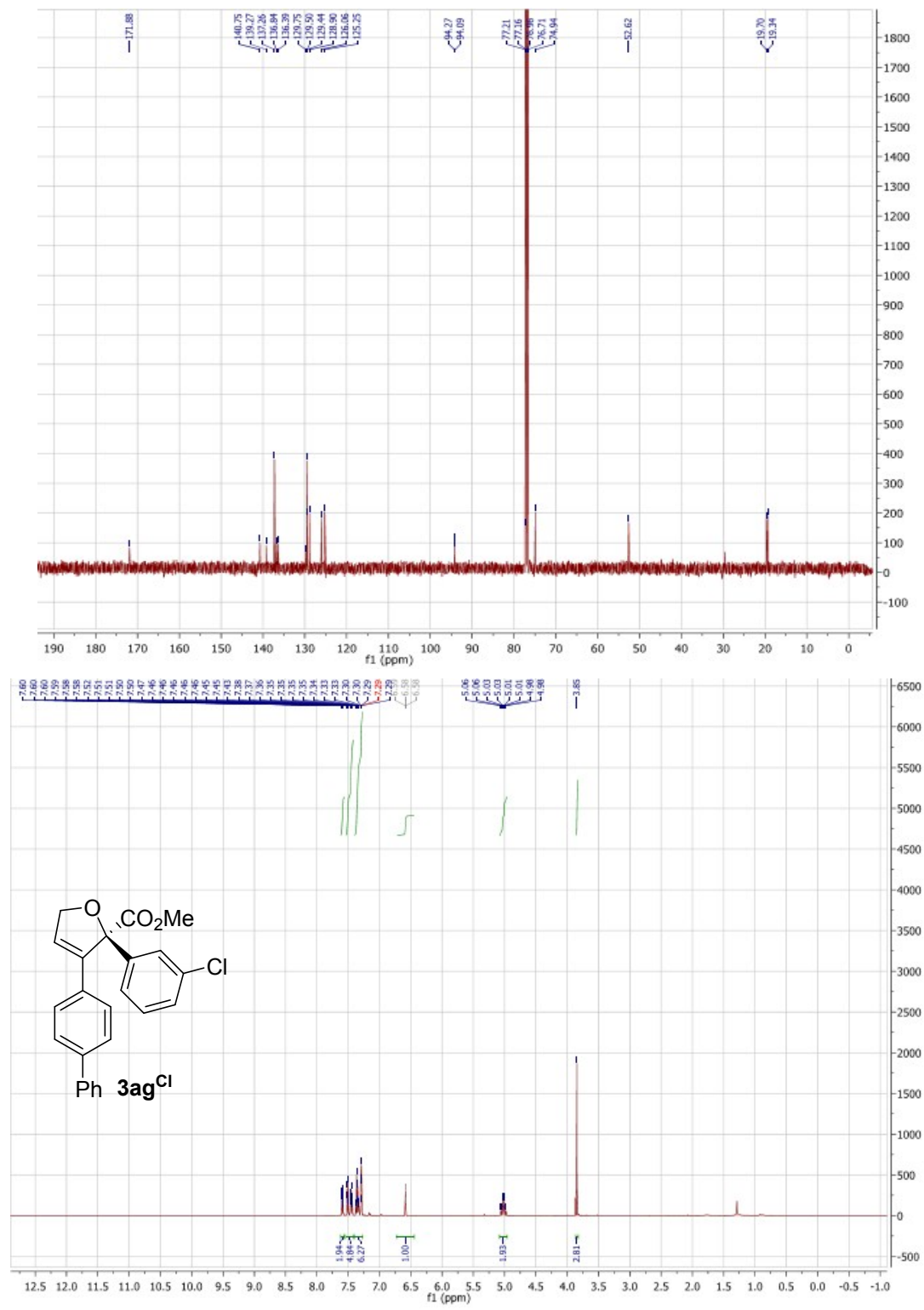


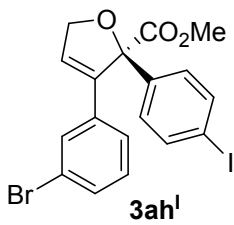
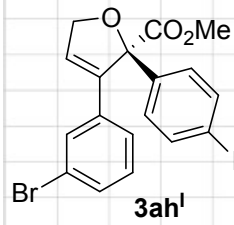
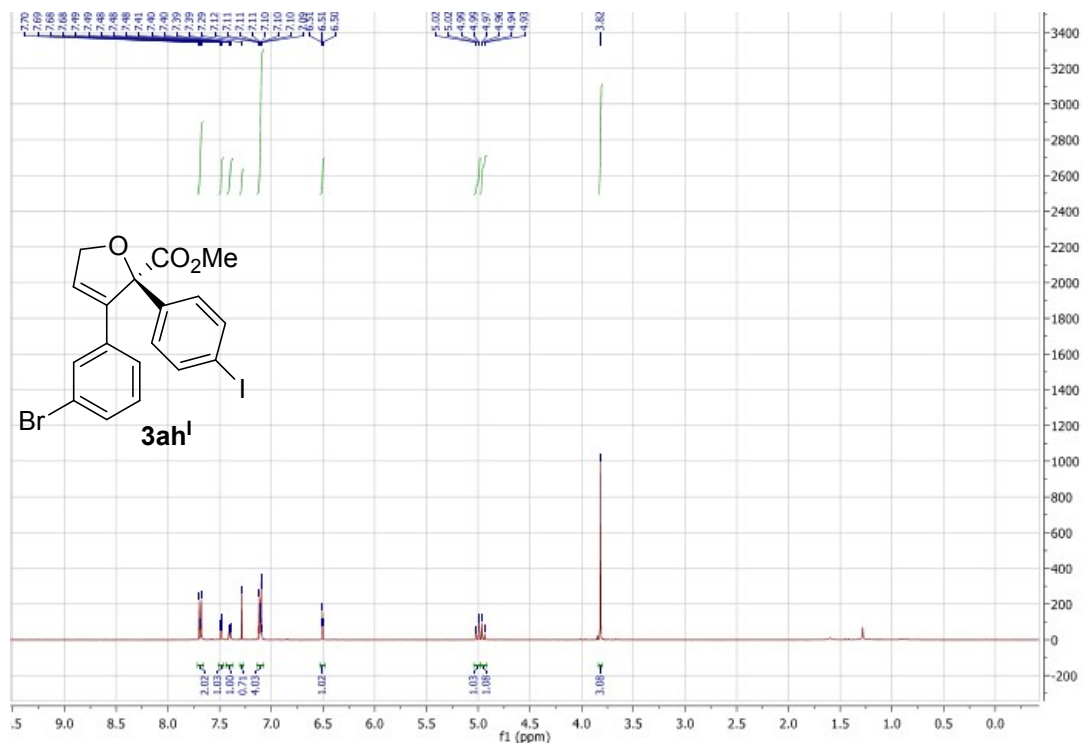
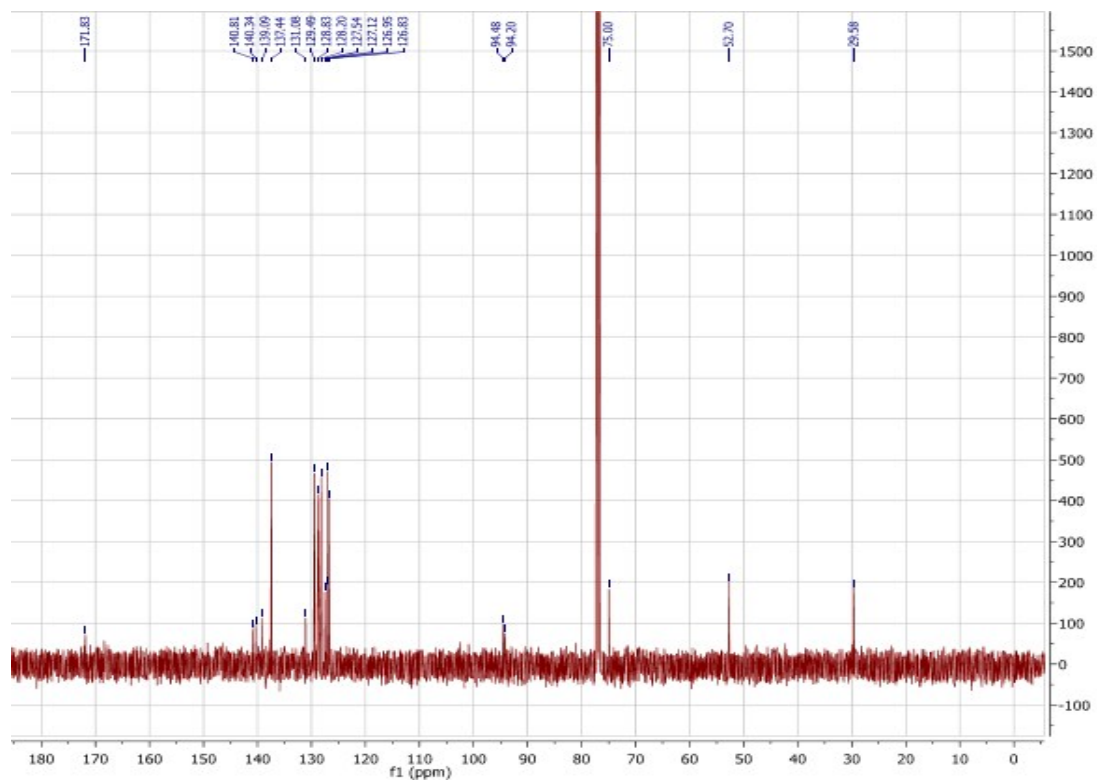


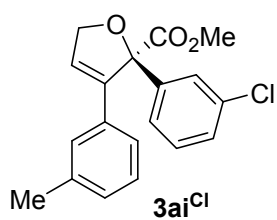
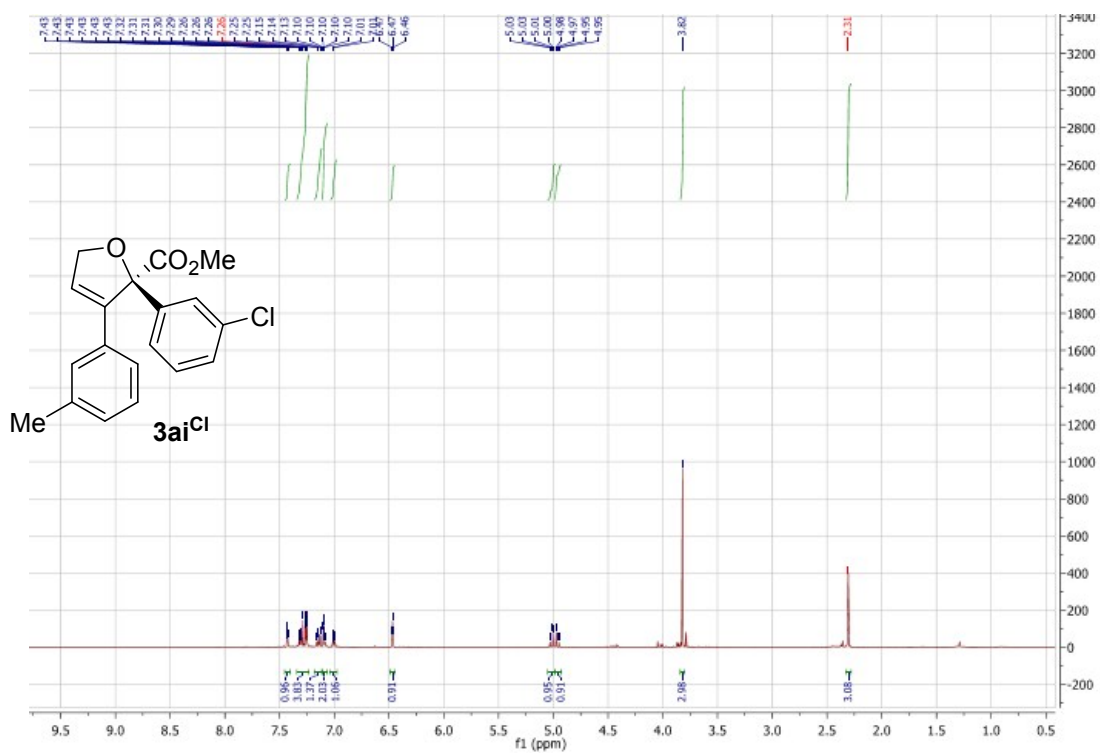
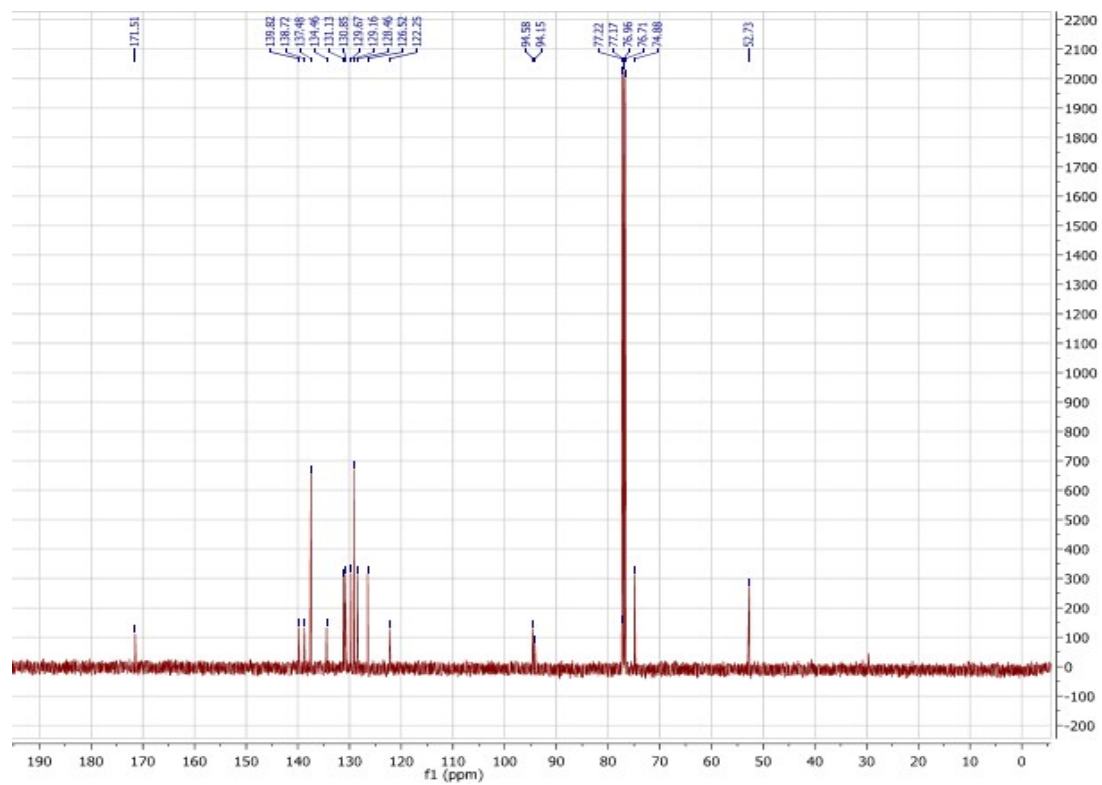


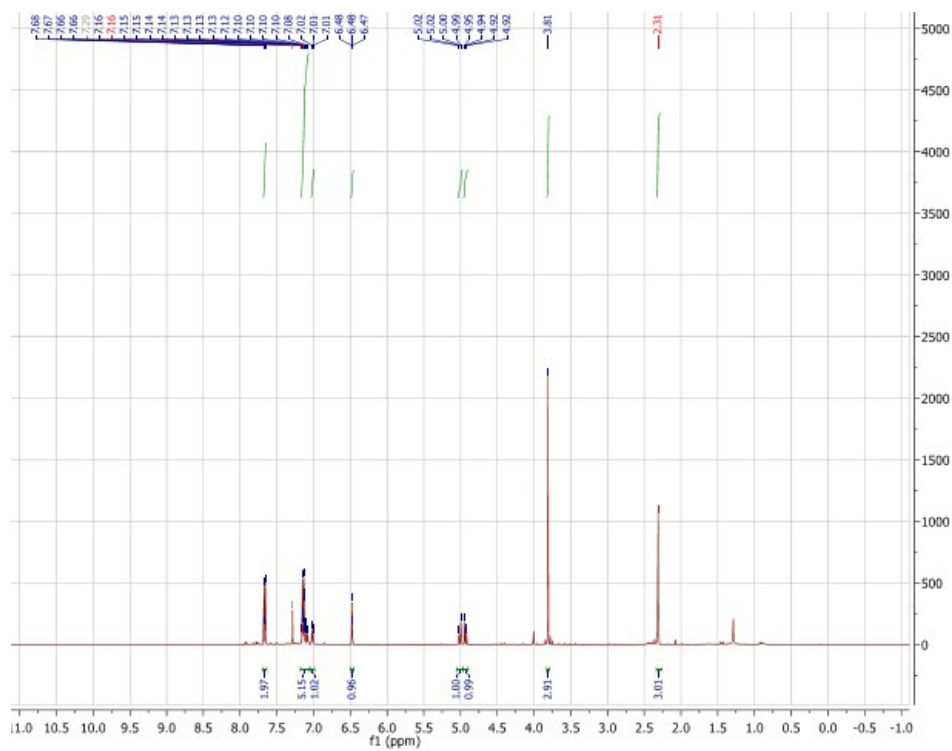
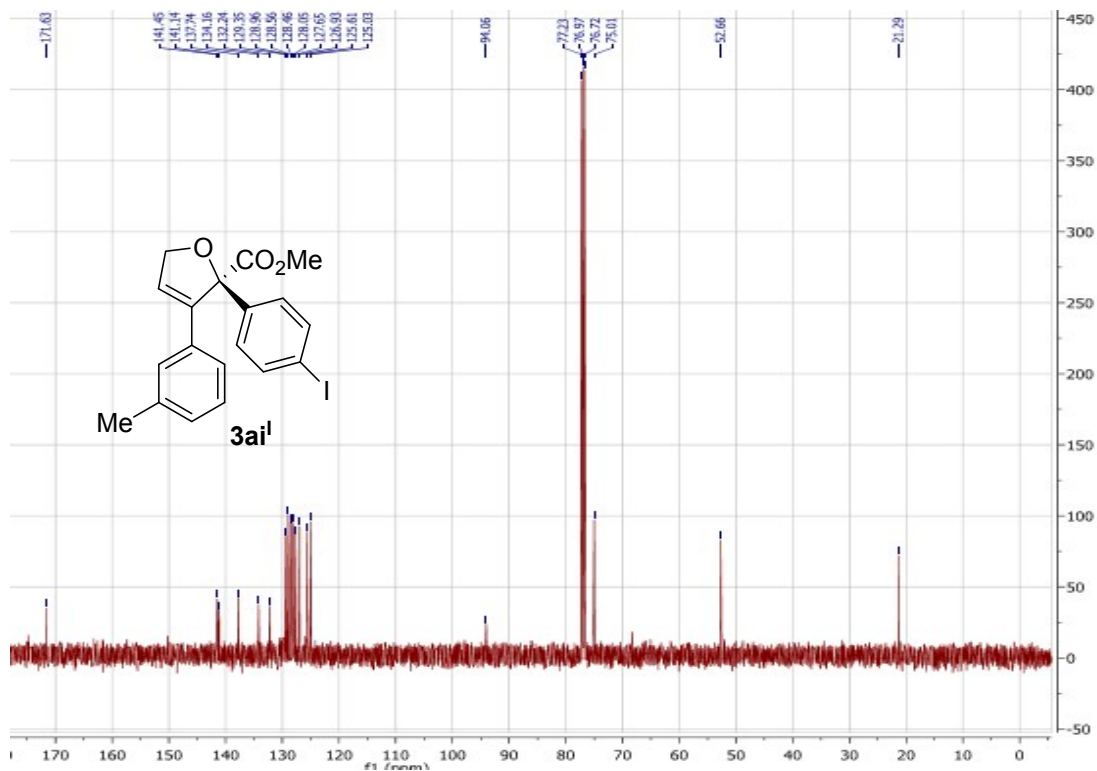


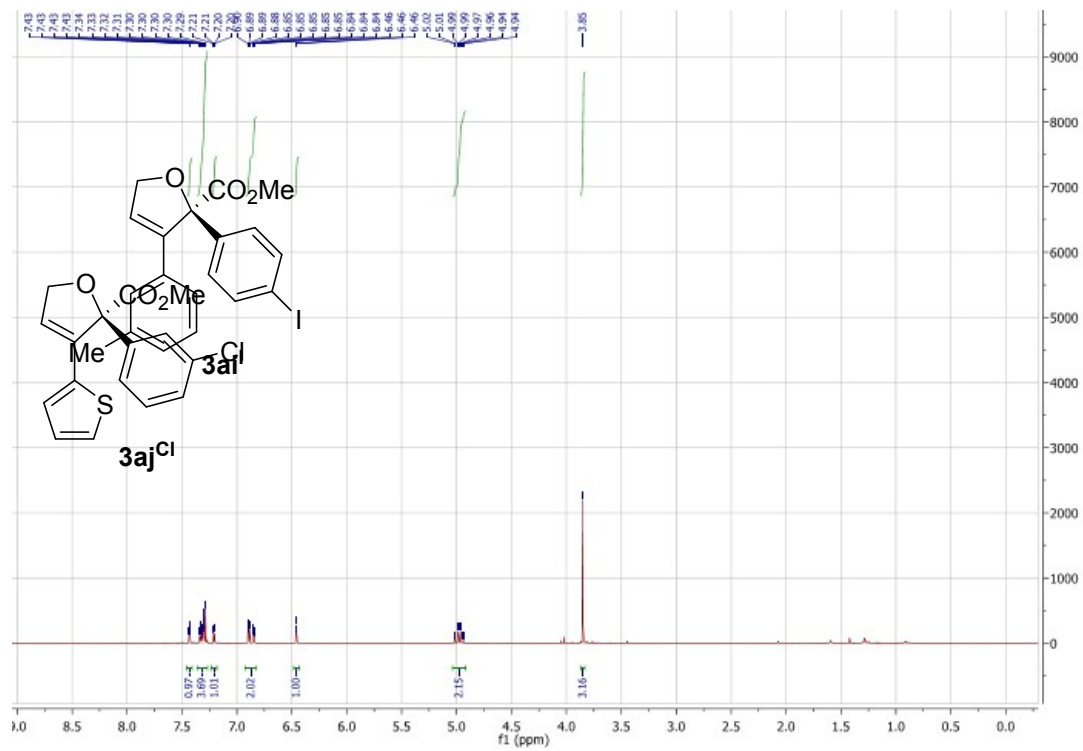
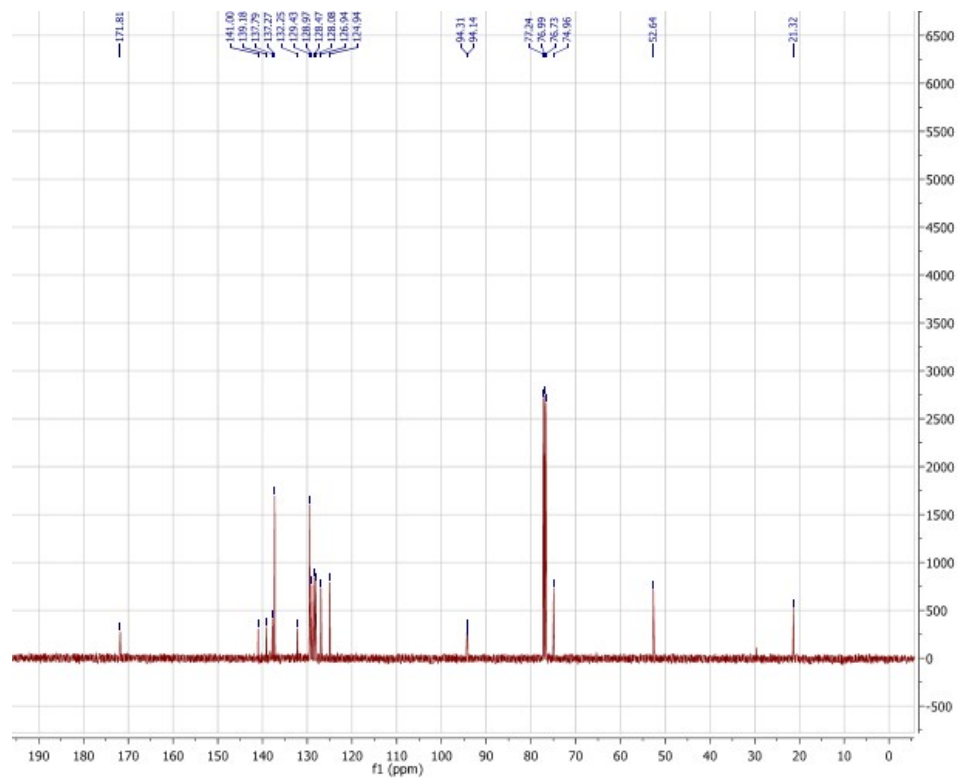


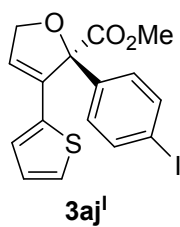
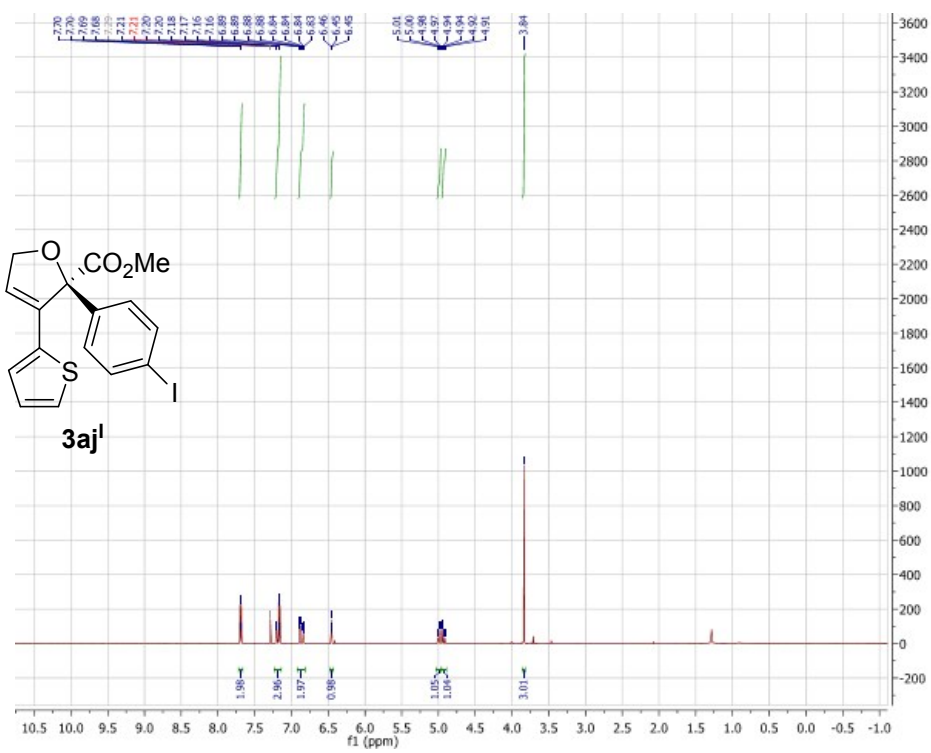
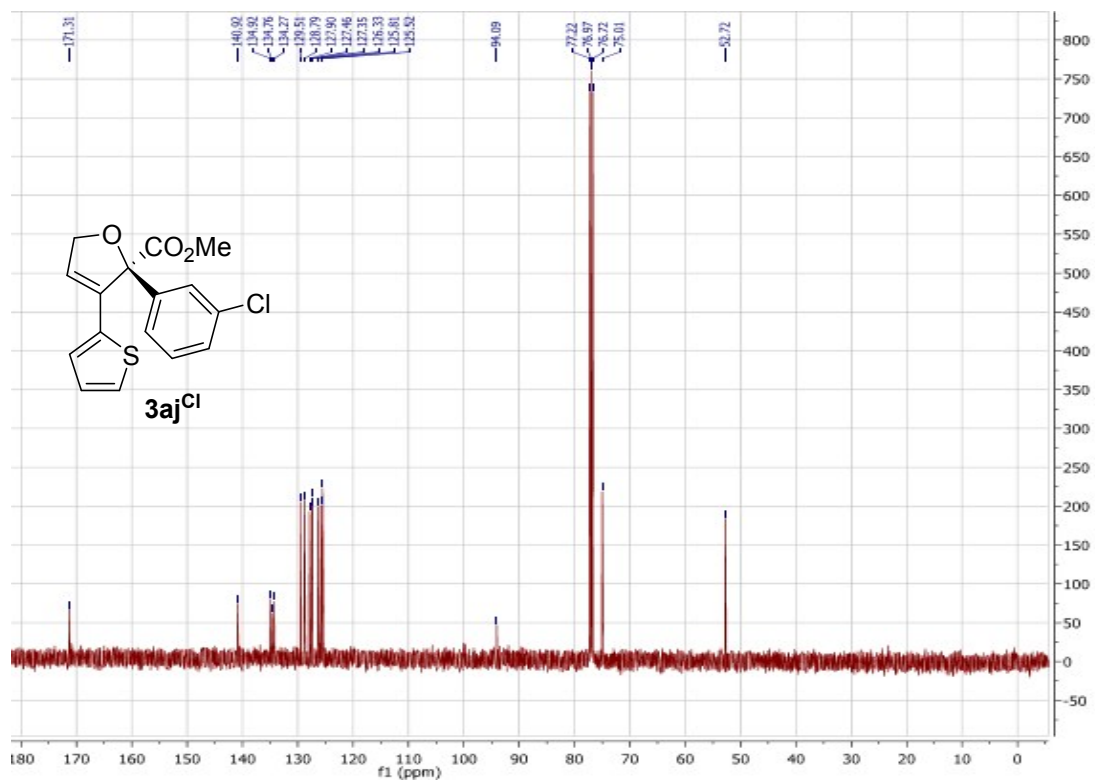


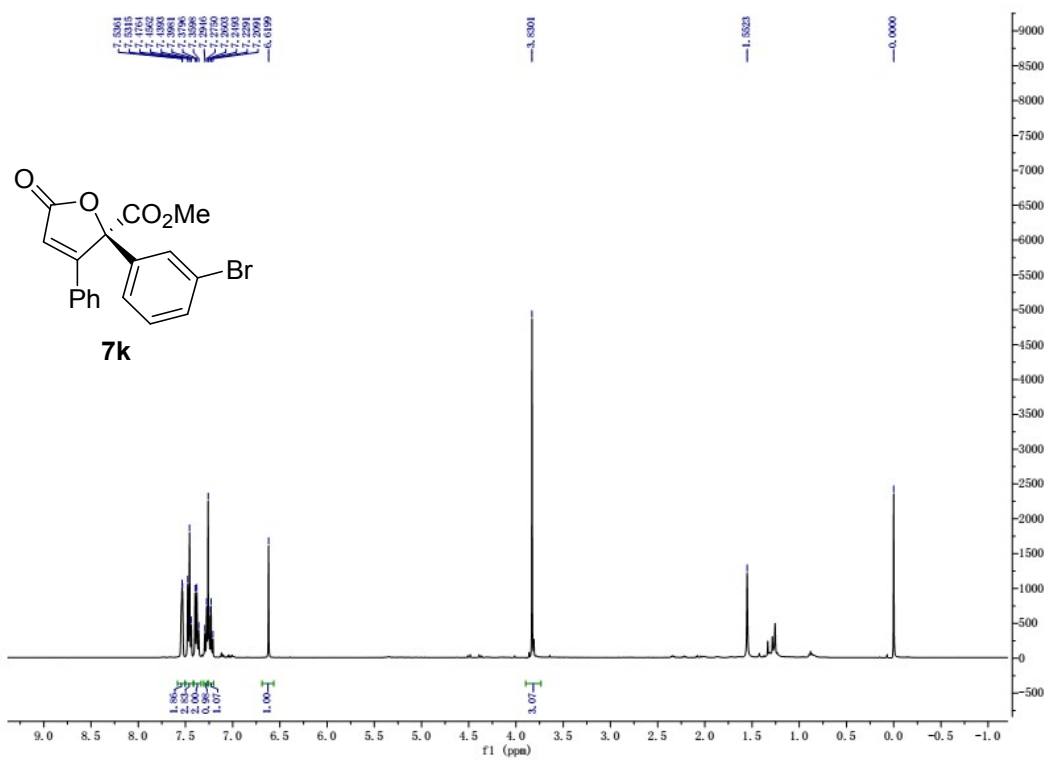
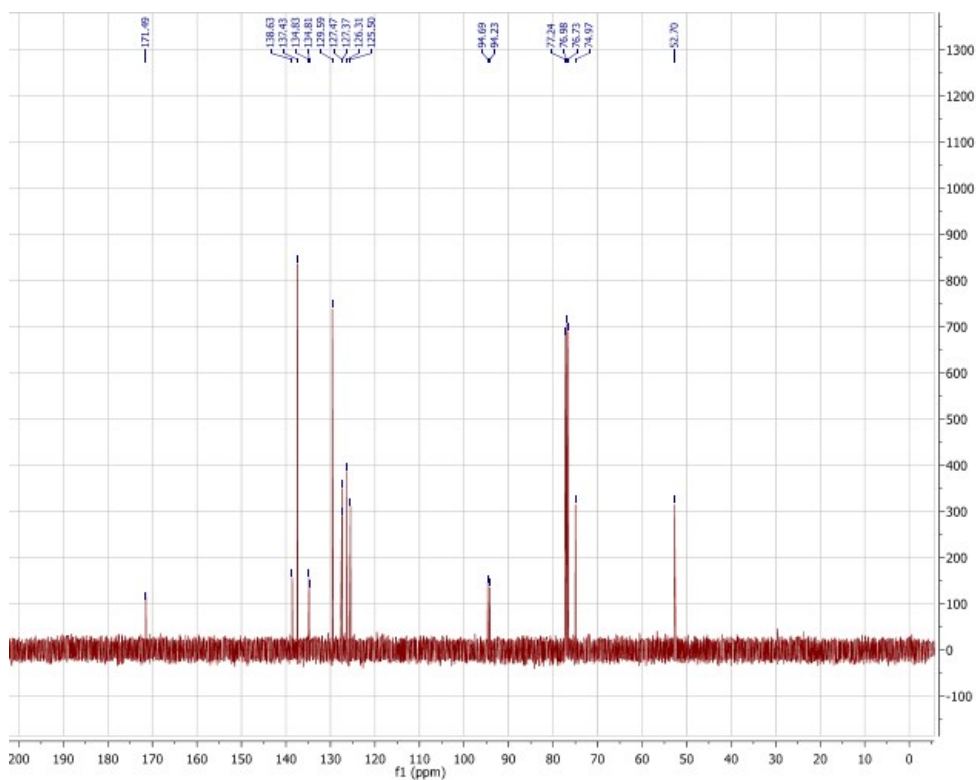


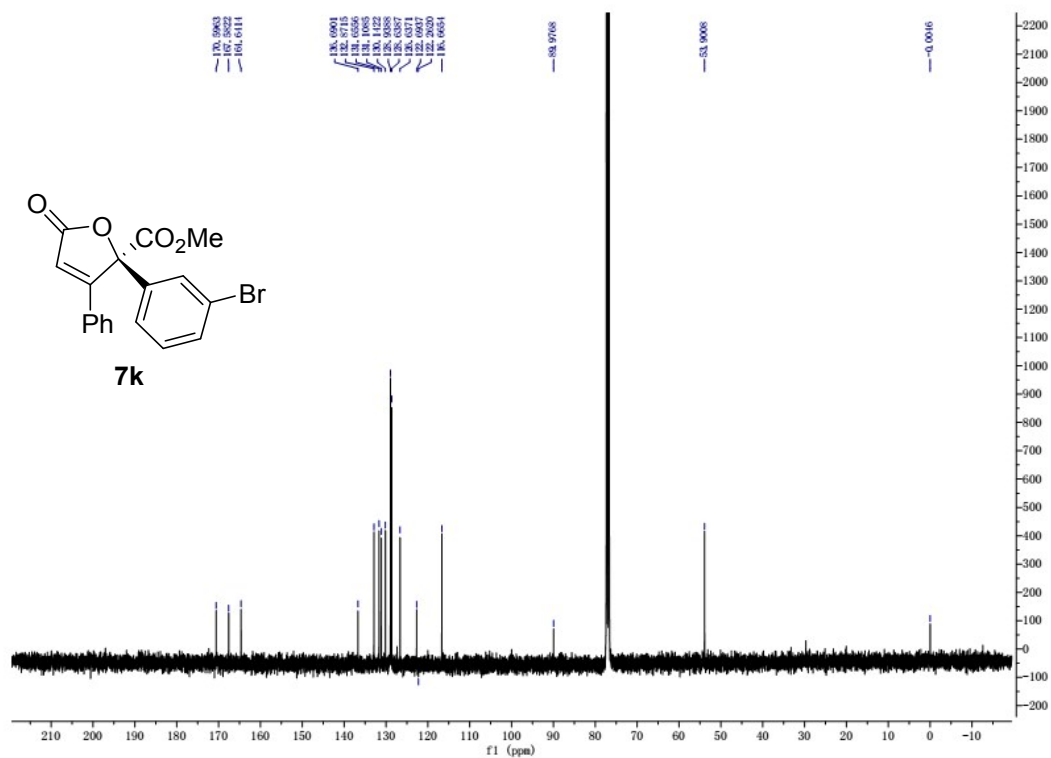




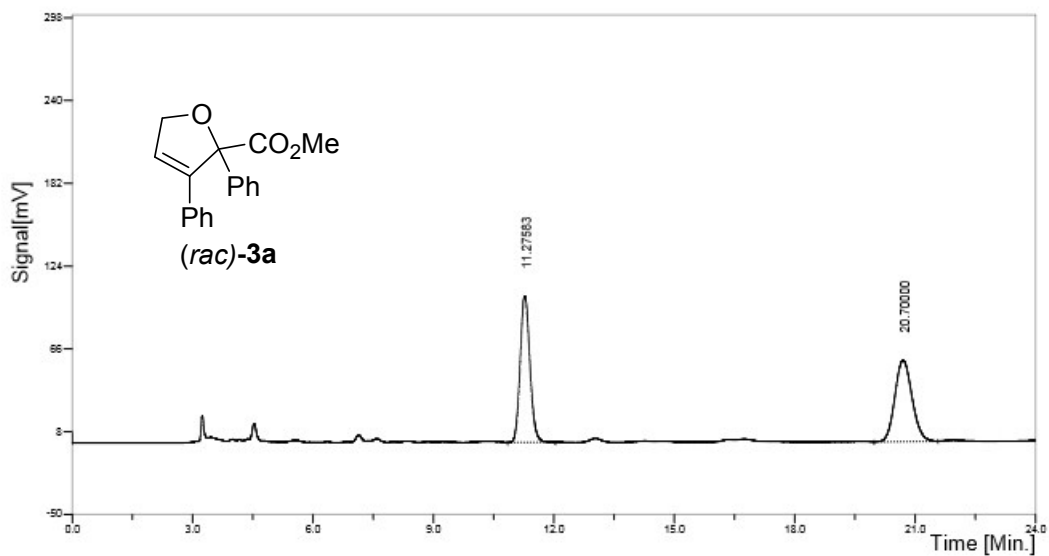




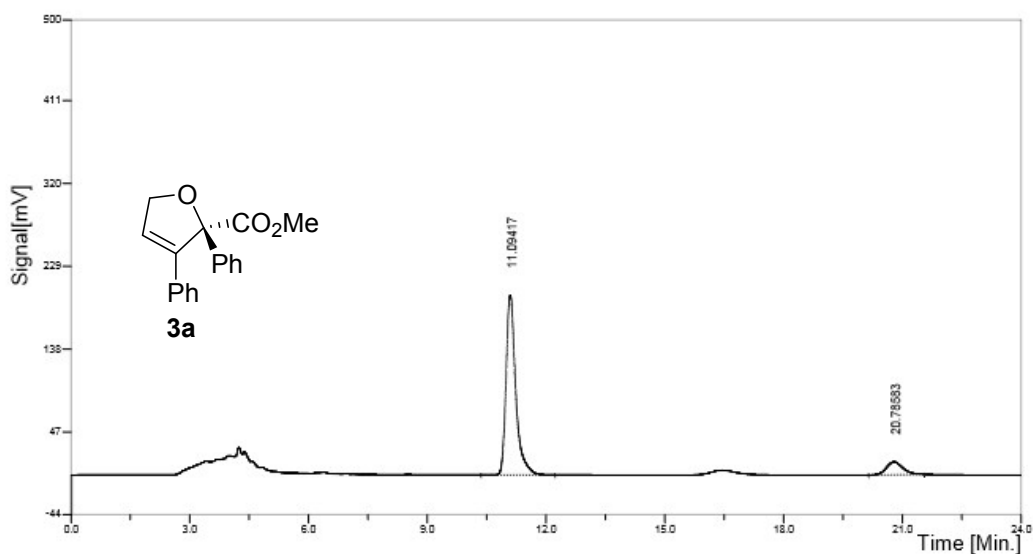




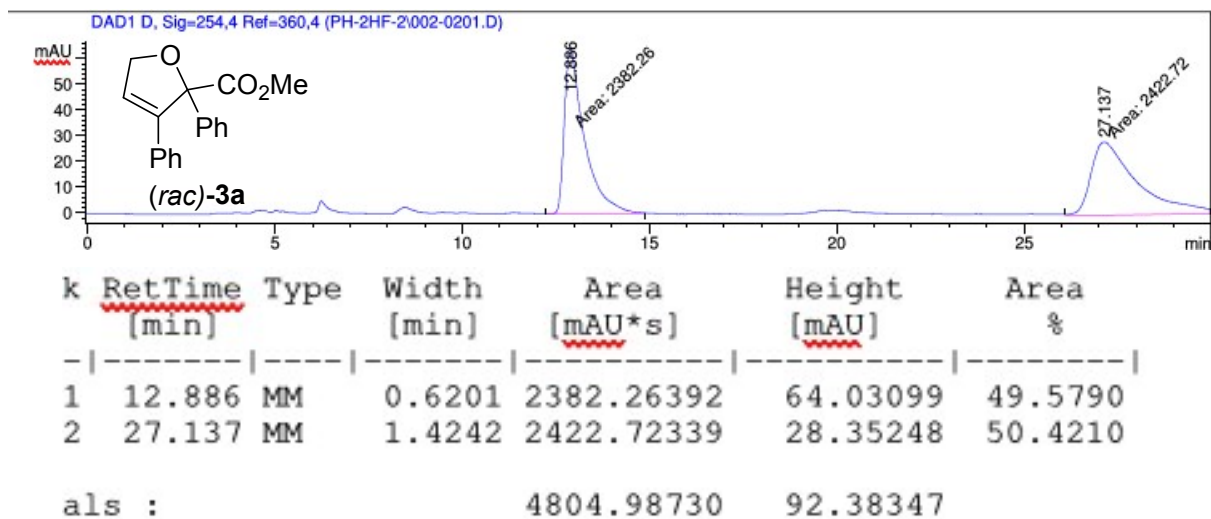
I. HPLC of 2,5-dihydrofurans

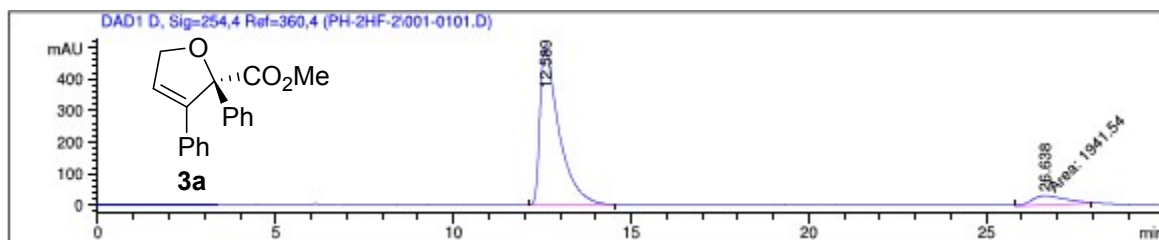


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	11.27583	1692.14	50.2867
2	20.70000	1672.84	49.7133
total		3364.98	100



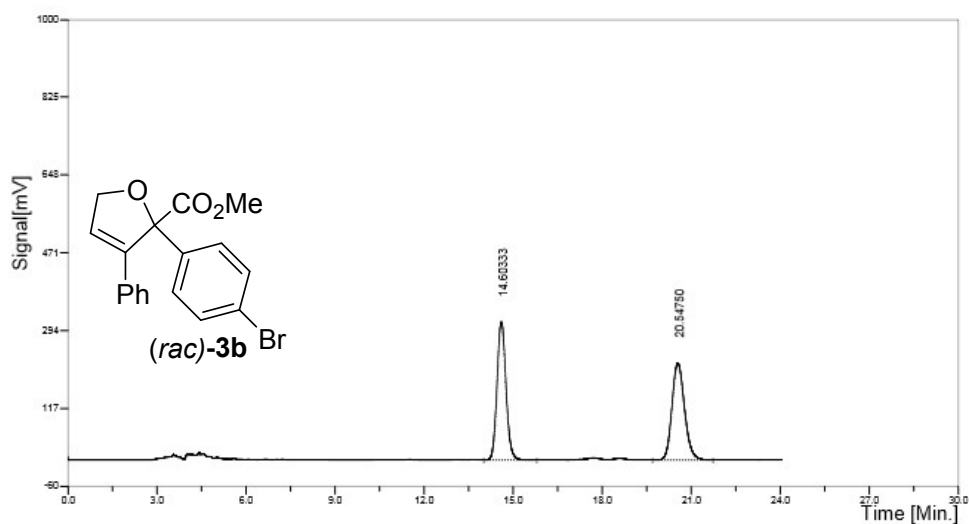
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	11.09417	3289.07	89.0713
2	20.78583	403.56	10.9287
total		3692.63	100



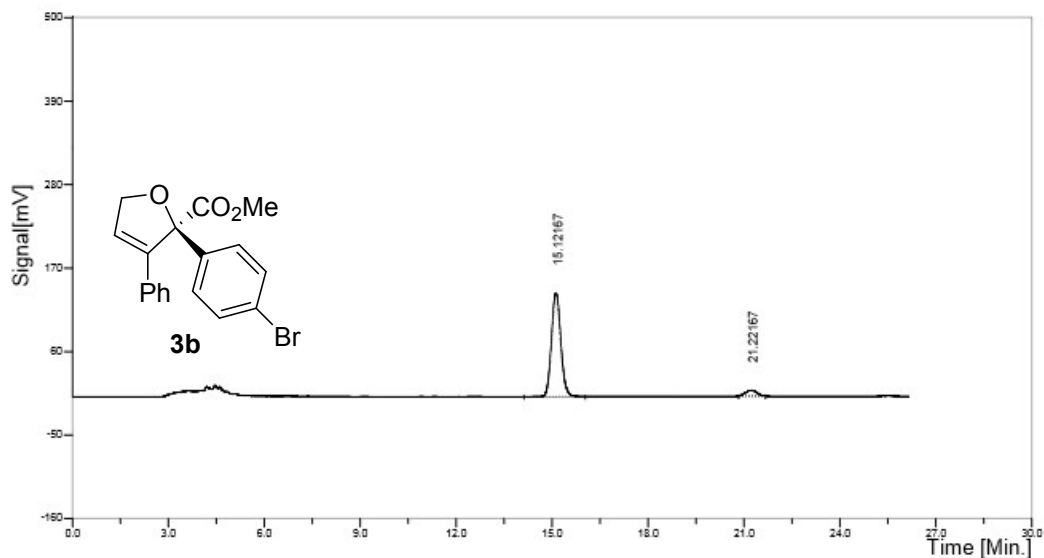


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.589	PB	0.5300	1.86596e4	499.29446	90.5756
2	26.638	MM	1.0843	1941.53723	29.84433	9.4244

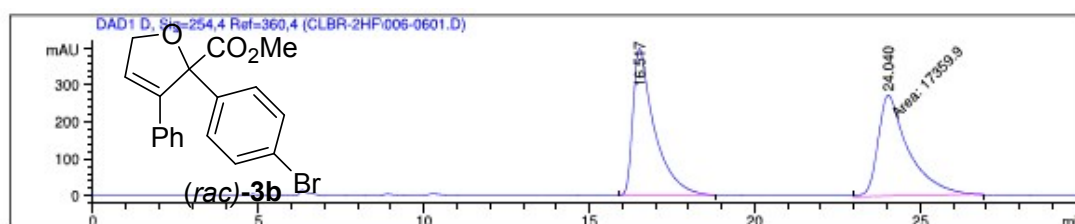
Totals : 2.06011e4 529.13879



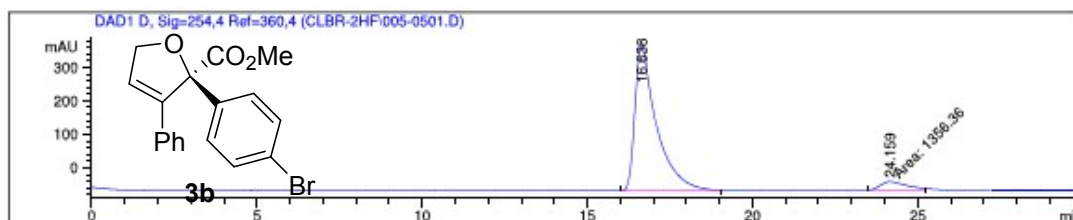
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	14.60333	6417.80	50.2508
2	20.54750	6353.75	49.7492
total		12771.55	100



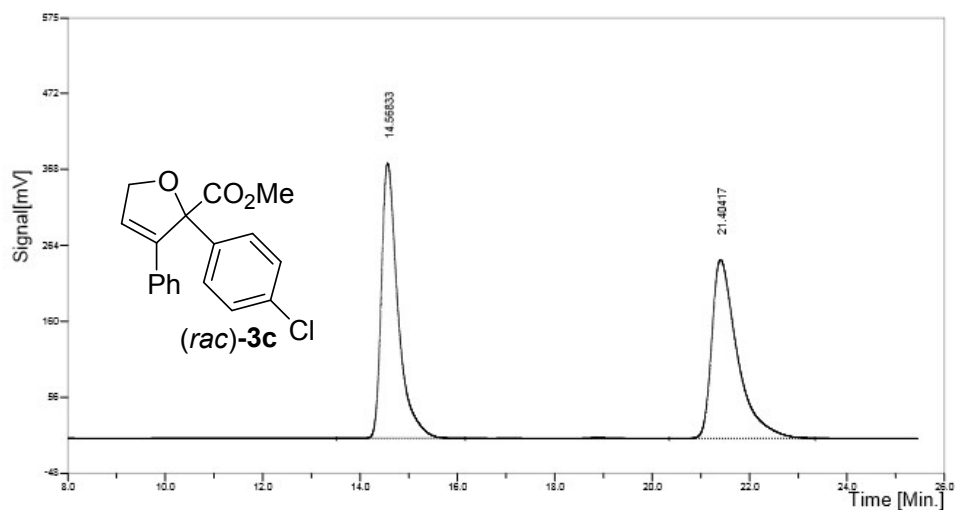
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	15.12167	2700.66	93.4937
2	21.22167	187.94	6.5063
total		2888.61	100



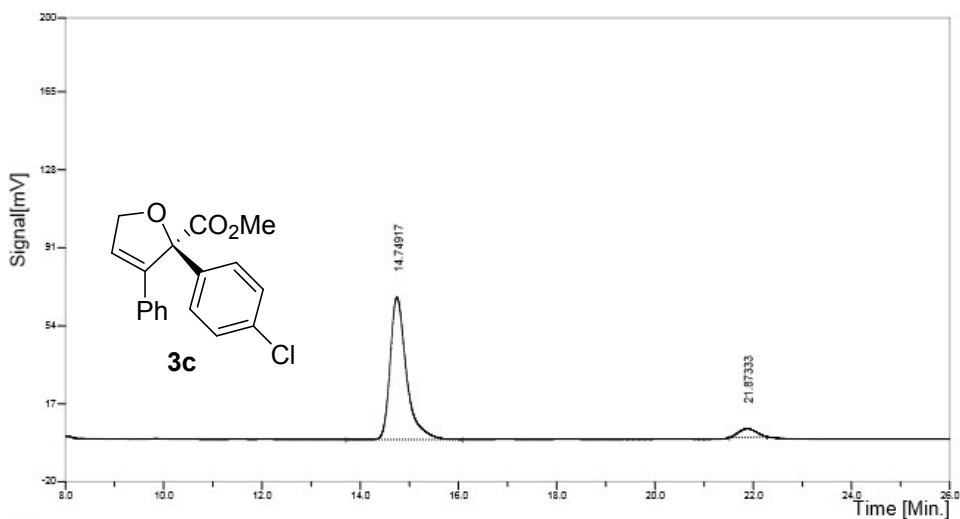
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.517	BB	0.6398	1.79112e4	397.43658	50.7815
2	24.040	MM	1.0642	1.73599e4	271.86606	49.2185
Totals :				3.52711e4	669.30264	



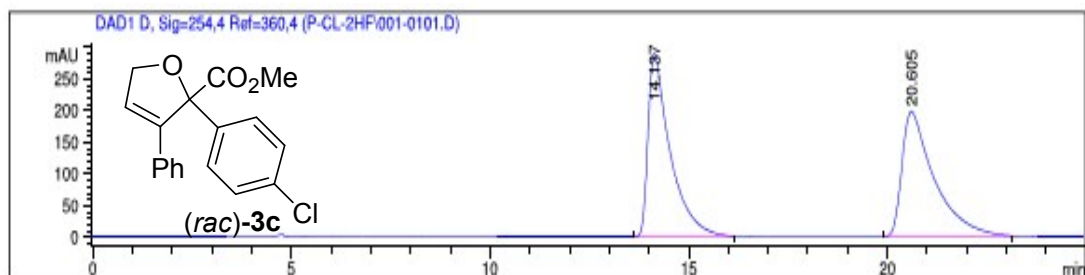
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.638	BB	0.6428	1.97020e4	436.33389	93.5590
2	24.159	MM	0.8871	1356.36487	25.48320	6.4410
Totals :				2.10584e4	461.81710	



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	14.56833	8788.07	50.0014
2	21.40417	8787.60	49.9986

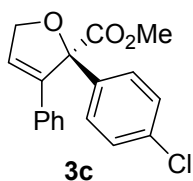


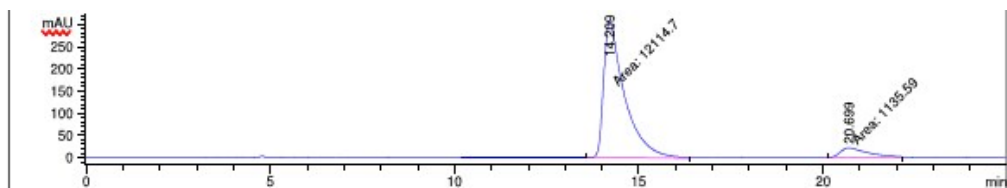
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	14.74917	1523.67	93.9648
2	21.87333	97.86	6.0352
total		1621.54	100



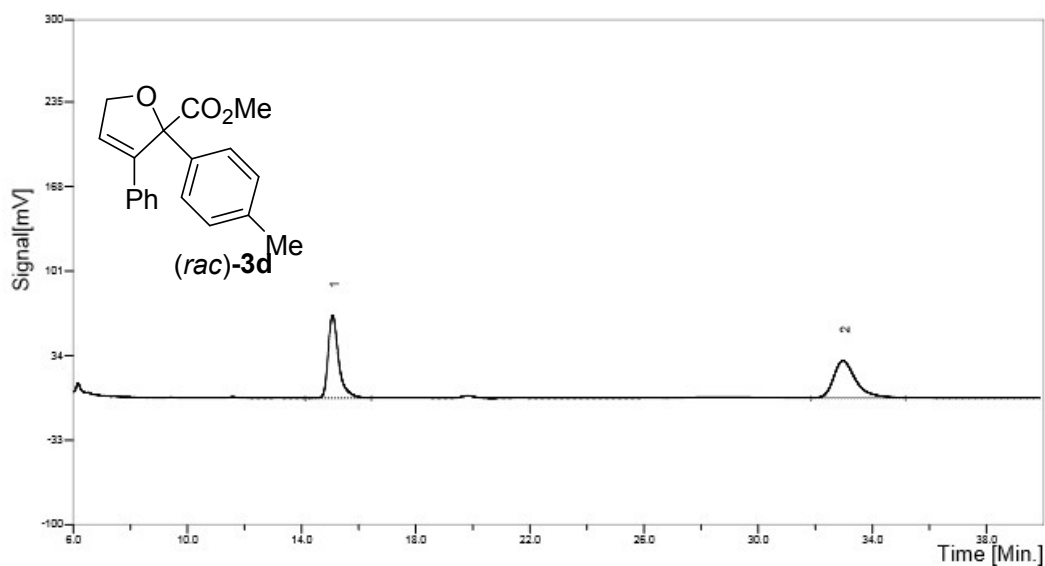
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.137	BB	0.5483	1.12307e4	289.69943	50.1026
2	20.605	BB	0.8010	1.11847e4	198.01602	49.8974

Totals : 2.24153e4 487.71545

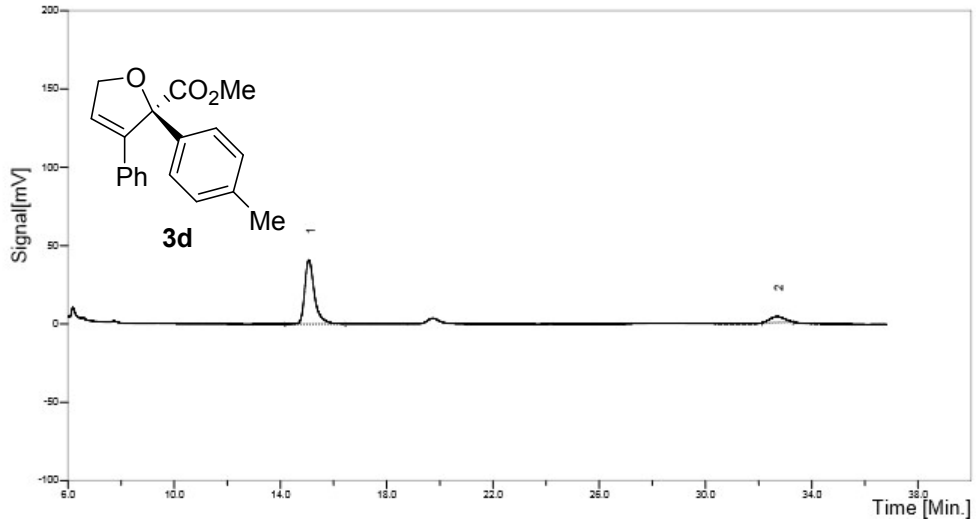




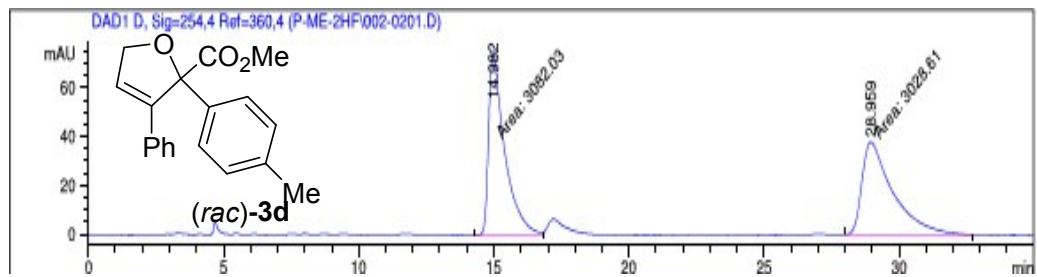
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.209	MM	0.6572	1.21147e4	307.21481	91.4297
2	20.699	MM	0.8684	1135.59058	21.79458	8.5703
Totals :				1.32503e4	329.00939	



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	15.0900	1617.22	50.84
2	32.97250	1563.51	49.16
total		3180.74	100

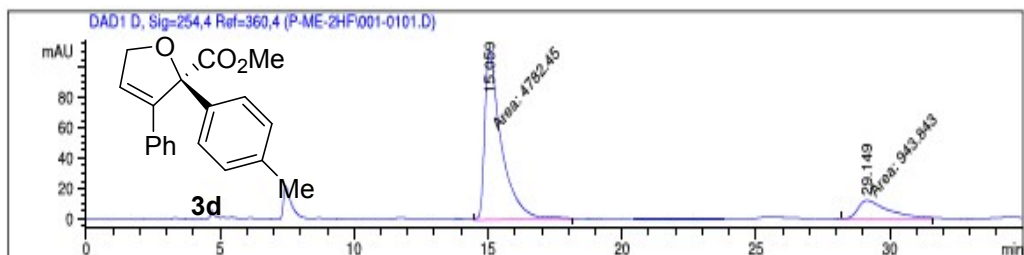


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	15.07417	1008.42	87.826
2	32.69750	139.76	12.1720
total		1148.17	100



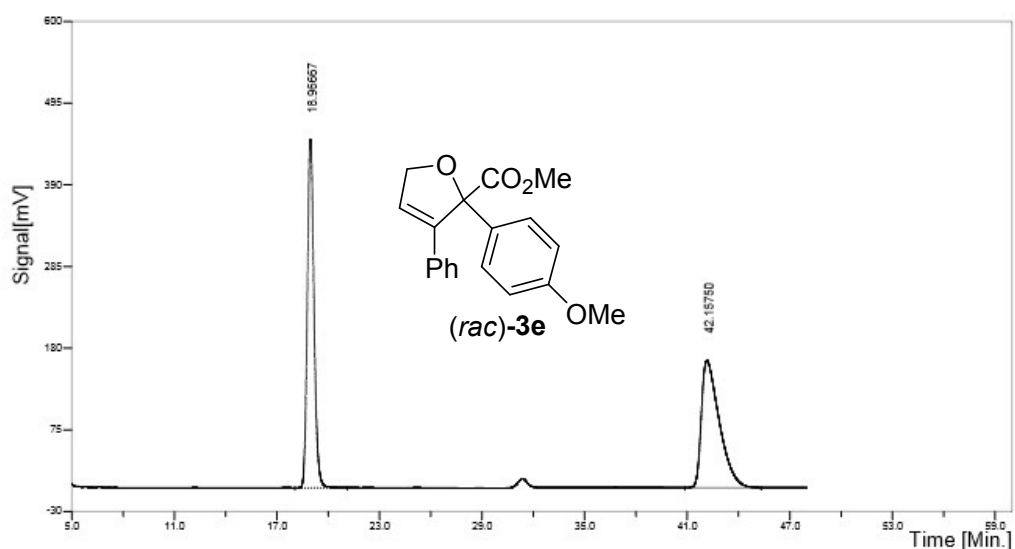
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.982	MM	0.6822	3082.02734	75.29202	50.4371
2	28.959	MM	1.3227	3028.61255	38.16206	49.5629

Totals : 6110.63989 113.45407



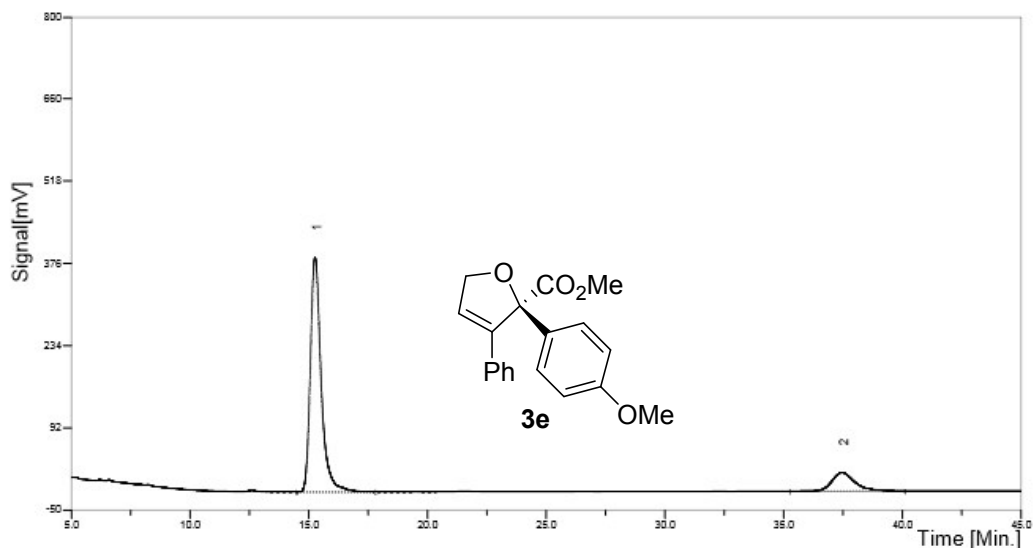
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.059	MM	0.7117	4782.45361	111.99453	83.5174
2	29.149	MM	1.2811	943.84296	12.27935	16.4826

Totals : 5726.29657 124.27388

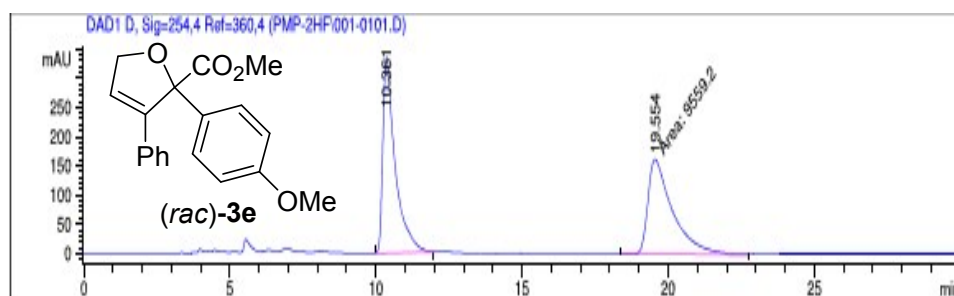


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area
----------	----------------------	--------------------	--------------------

			(%)
1	18.96667	11745.68	49.8801
2	42.15750	11802.16	50.1199
total		23547.84	100

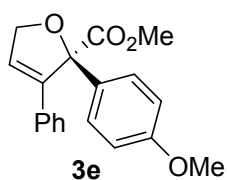


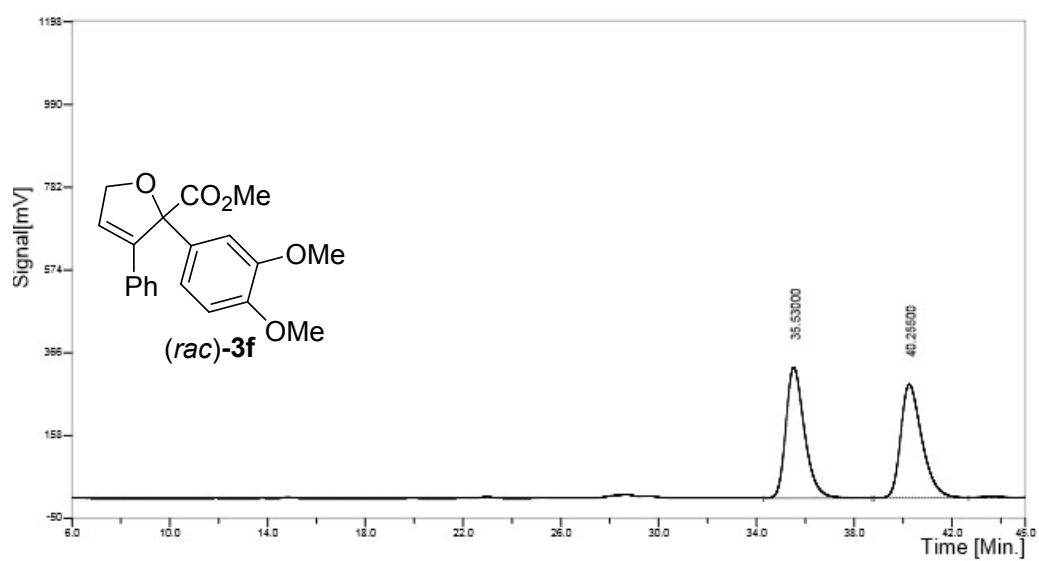
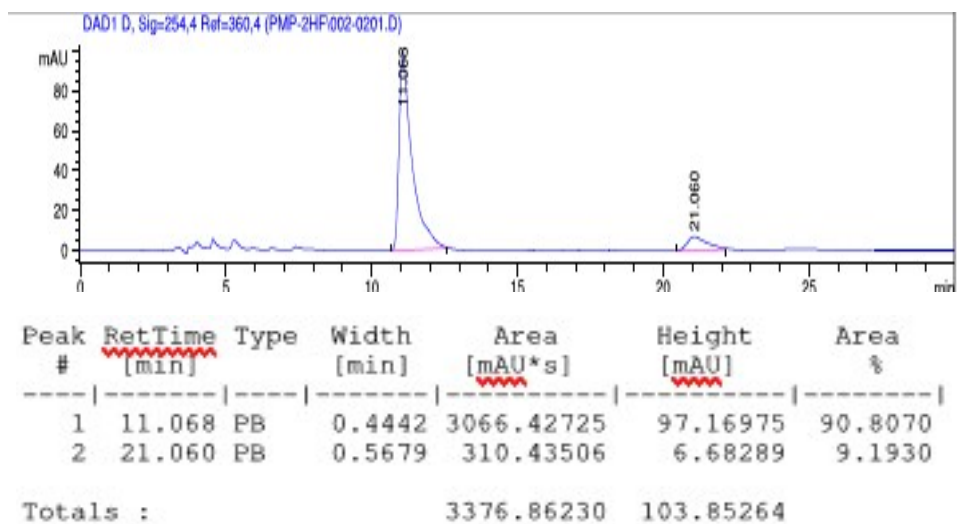
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	15.26250	12538.32	85.3815
2	37.45500	2146.73	14.6185
total		14685.05	100



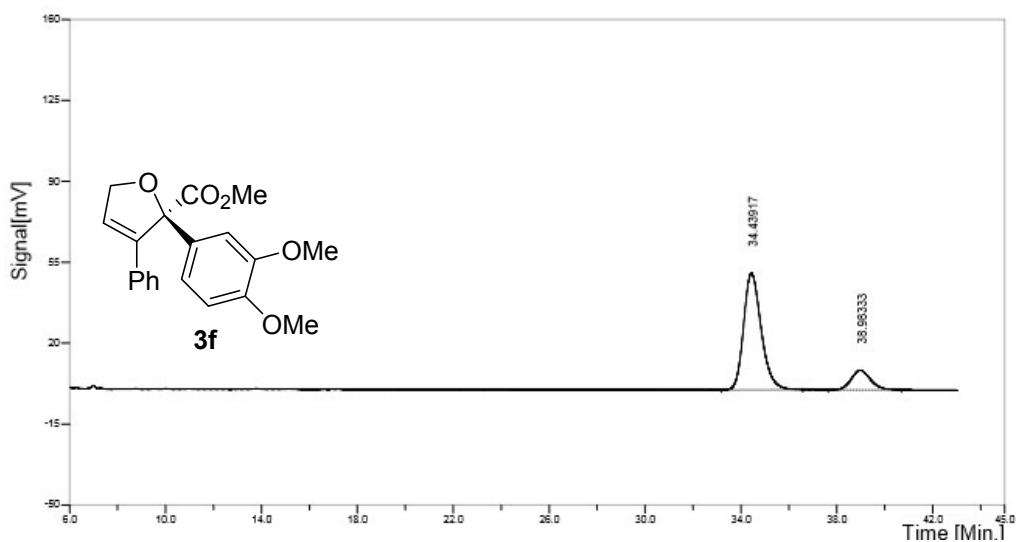
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.361	BB	0.4148	9783.11914	334.94330	50.5788
2	19.554	MM	0.9815	9559.20020	162.32405	49.4212

Totals : 1.93423e4 497.26735

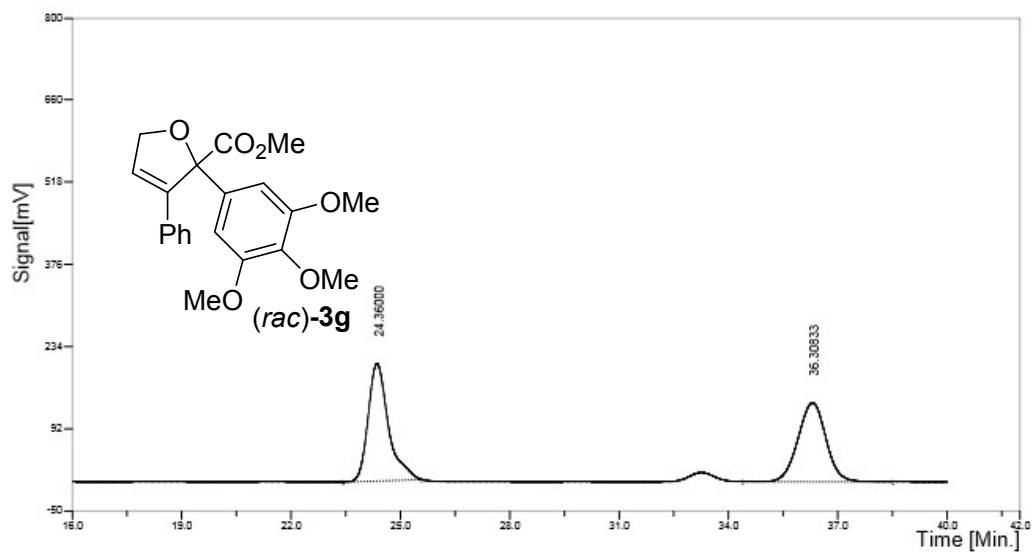




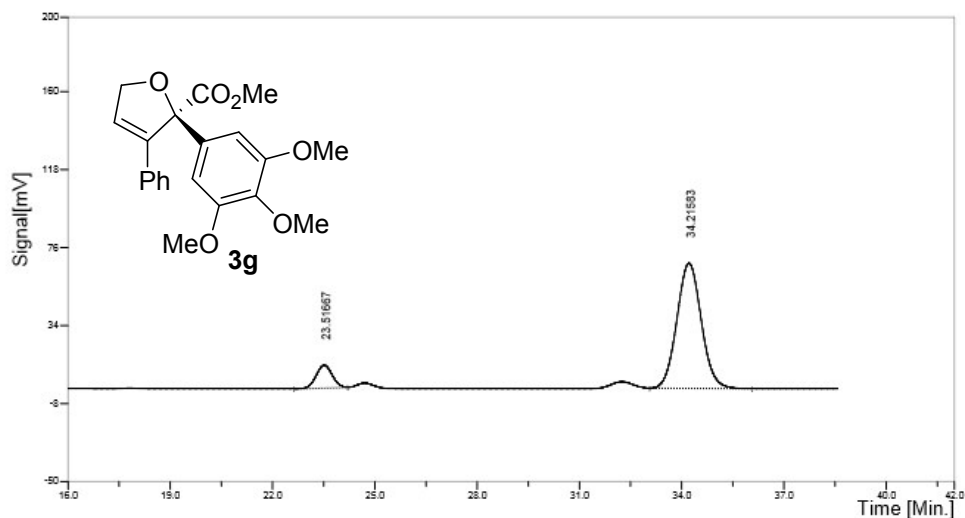
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	35.53000	17204.81	50.2179
2	40.255500	17055.52	49.7821
total		34260.33	100



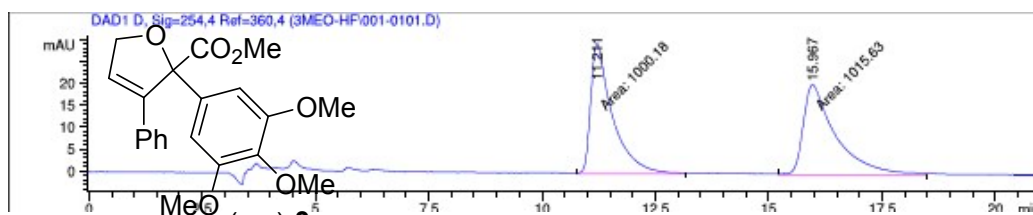
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	34.43917	2547.98	84.3564
2	38.98333	472.51	15.6436
total		3020.49	100



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	24.36000	7766.39	51.7724
2	36.30833	7234.64	48.2276
total		15001.03	100

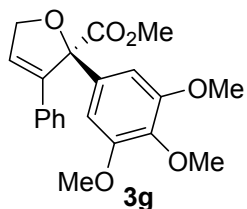


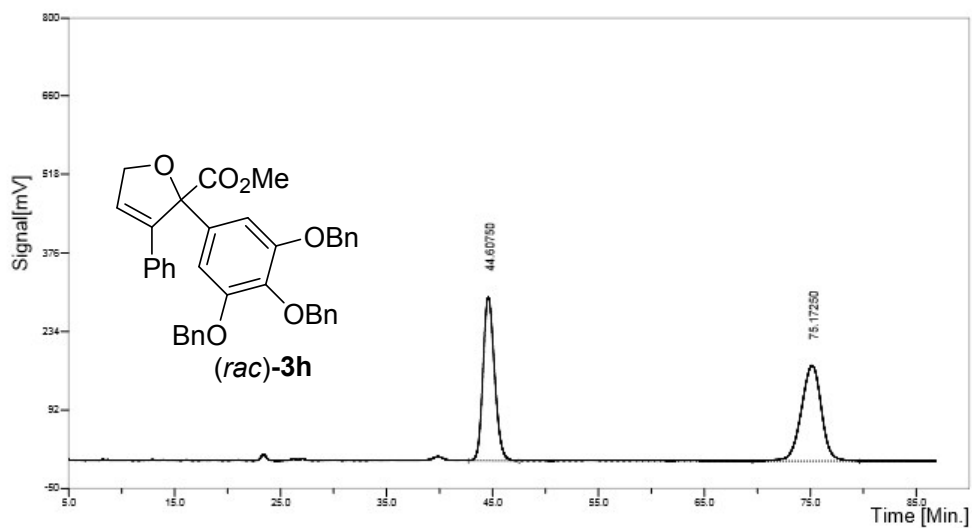
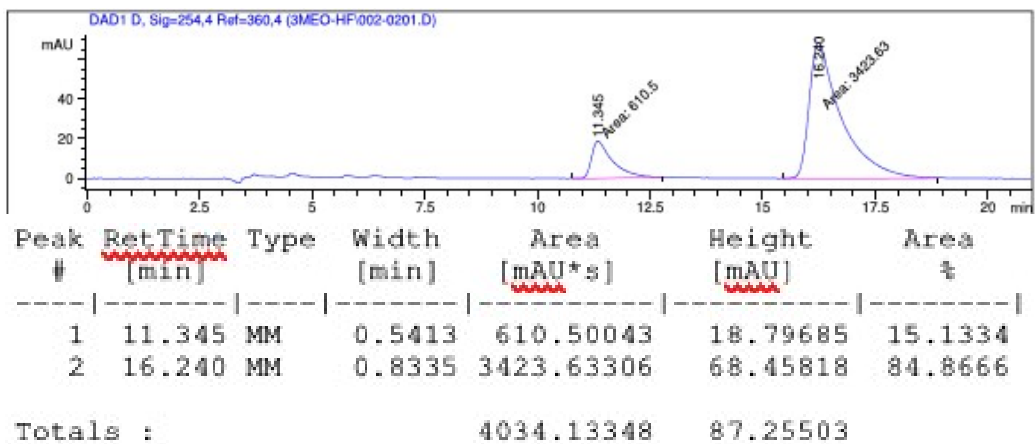
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	23.51667	396.60	10.6443
2	34.21583	3329.32	89.3557
total		3725.92	100



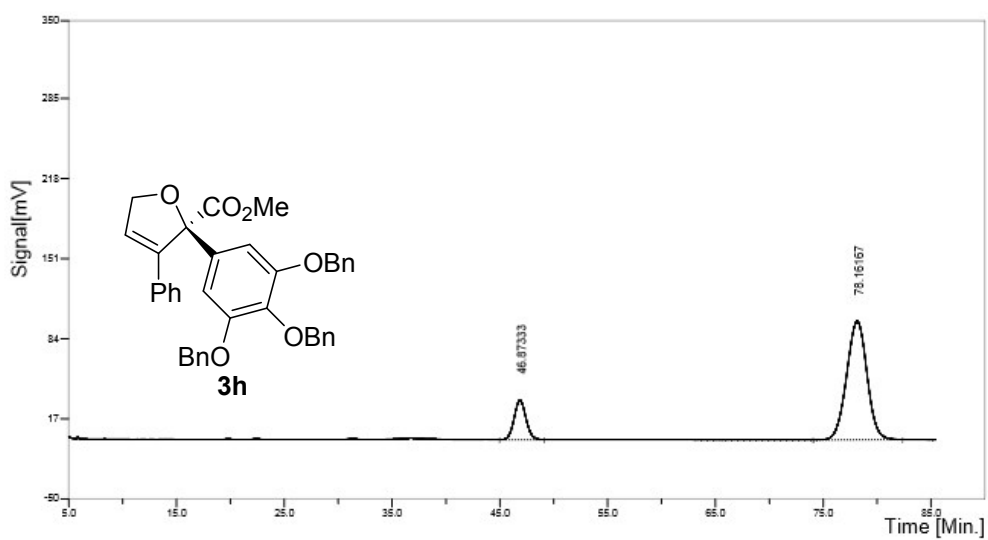
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.211	MM	0.5603	1000.18292	29.74970	49.6168
2	15.967	MM	0.8269	1015.63086	20.47054	50.3832

Totals : 2015.81378 50.22024

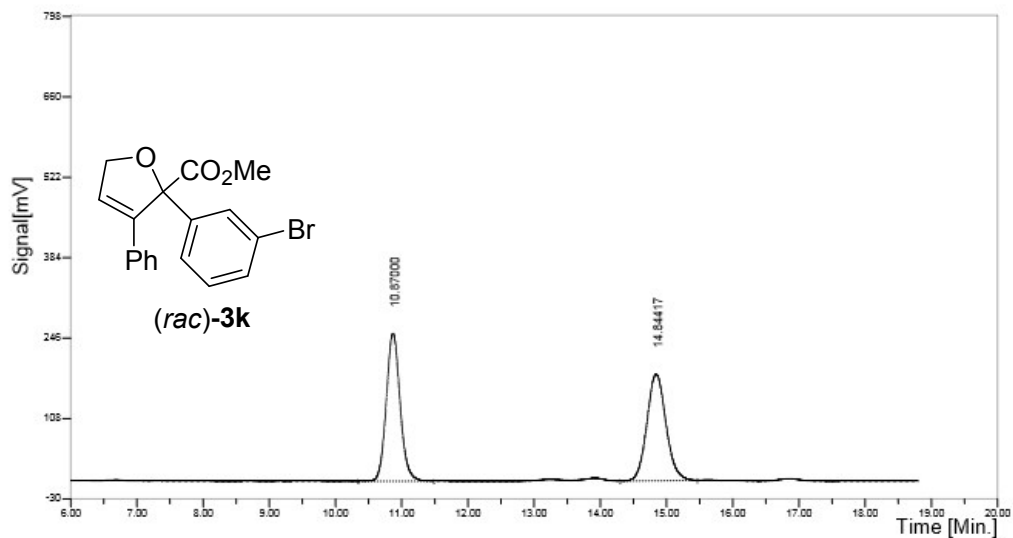




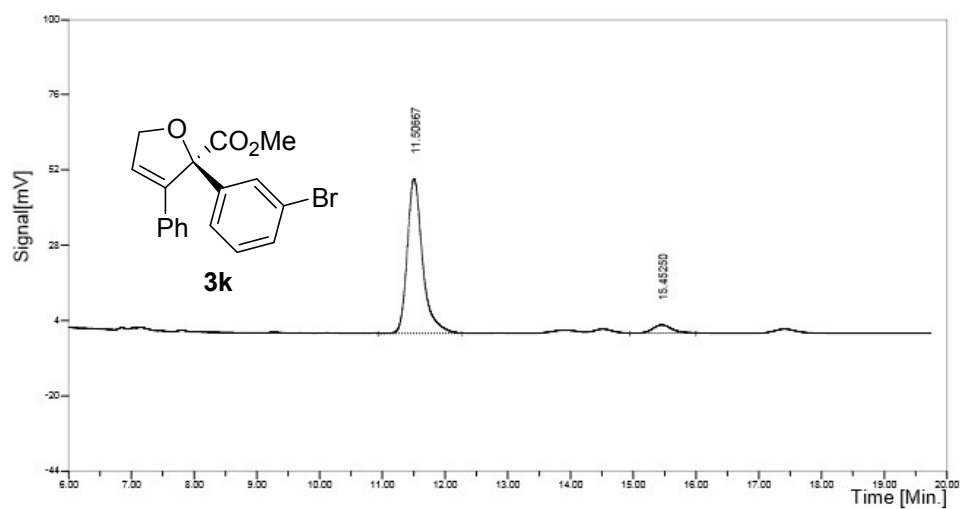
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	44.60750	21969.15	49.3153
2	75.17250	22579.16	50.6847
total		44548.31	100



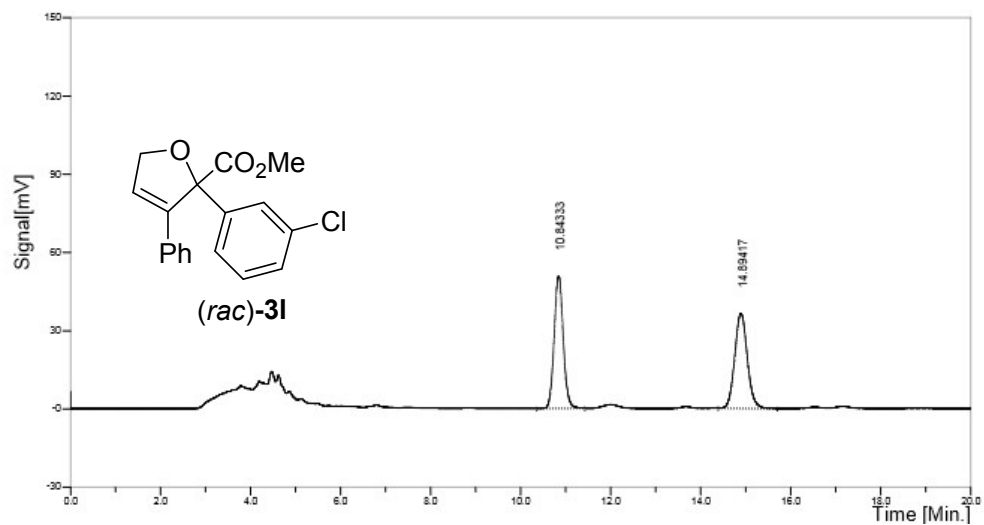
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	46.87333	2494.37	16.1111
2	78.16167	12987.94	83.8889
total		15482.32	100



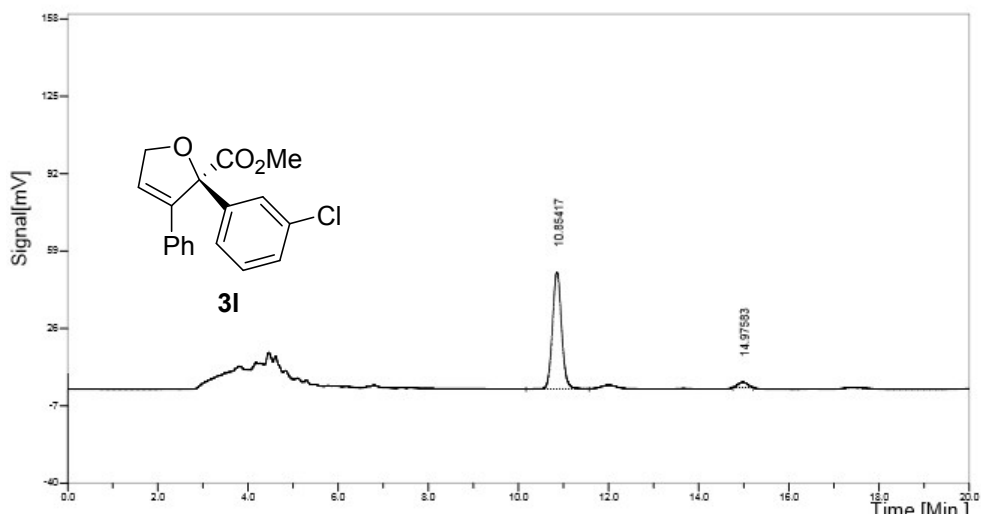
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	10.87000	3628.98	50.0720
2	14.84417	3618.53	49.9280
total		7247.51	100



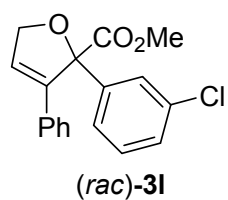
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	11.50667	820.22	94.0869
2	15.45250	51.55	5.9131
total		871.77	100

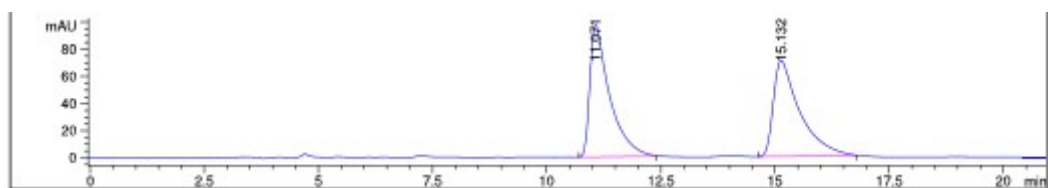


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	10.84333	693.46	50.0540
2	14.89417	691.96	49.9460
total		1385.96	100



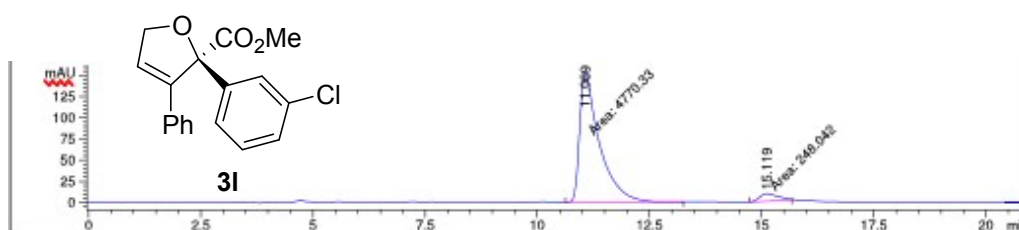
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	10.85417	679.18	95.2978
2	14.97583	33.51	4.7022
total		712.69	100





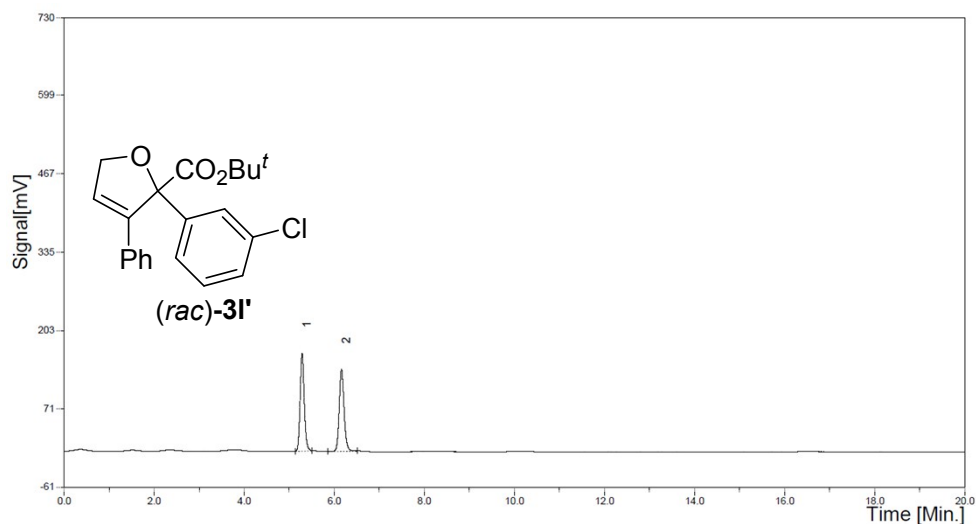
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.071	BB	0.4208	2928.32251	97.38730	50.4768
2	15.132	PB	0.5696	2873.00220	71.07188	49.5232

Totals : 5801.32471 168.45918

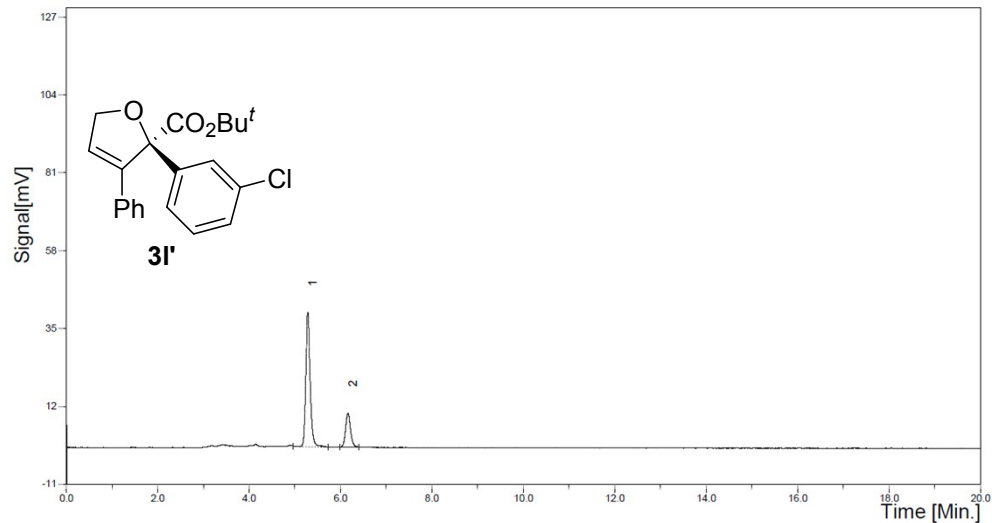


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.069	MM	0.5157	4770.33398	154.17871	95.0573
2	15.119	MM	0.4750	248.04237	8.70309	4.9427

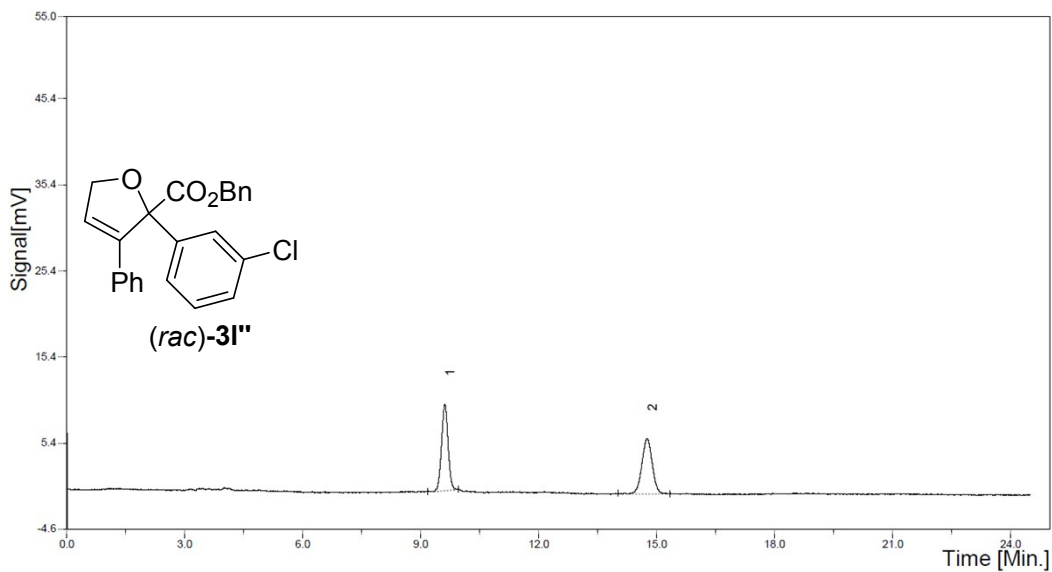
Totals : 5018.37636 162.88180



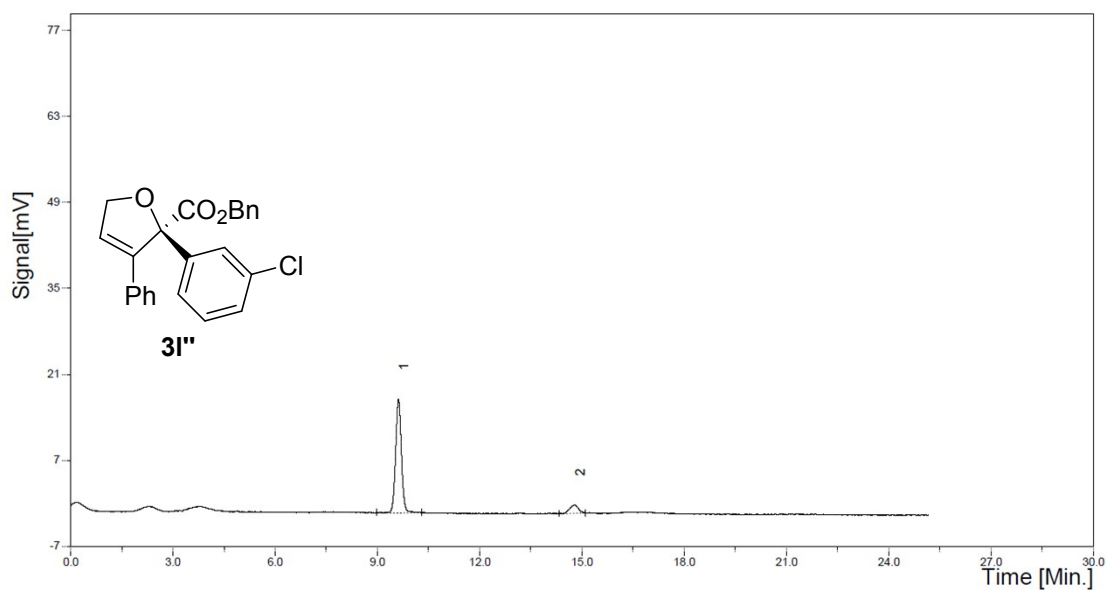
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	5.28417	1044.22	50.4962
2	6.15917	1023.69	49.5038
total		2067.91	100



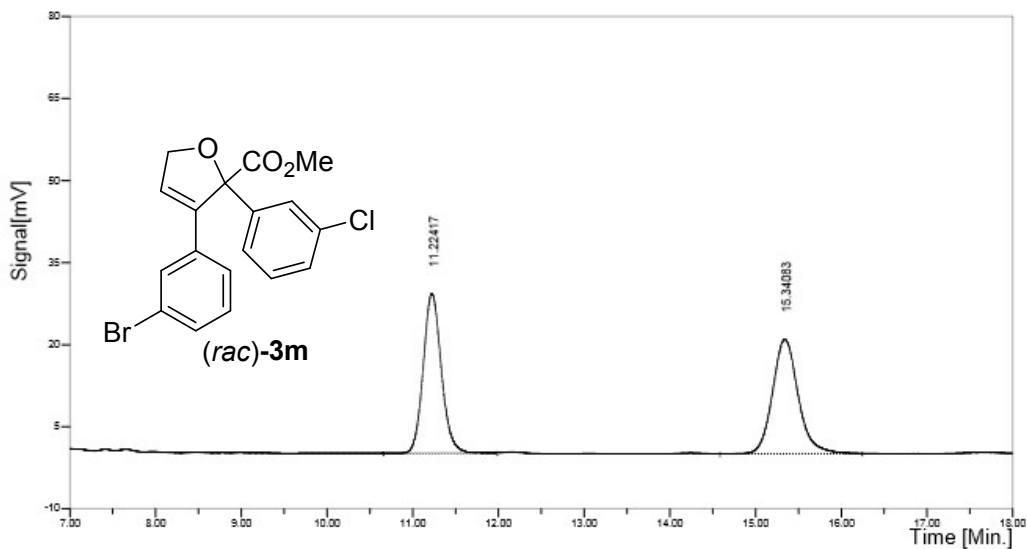
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	5.28333	259.71	77.8760
2	6.16000	73.78	22.1240
total		333.50	100



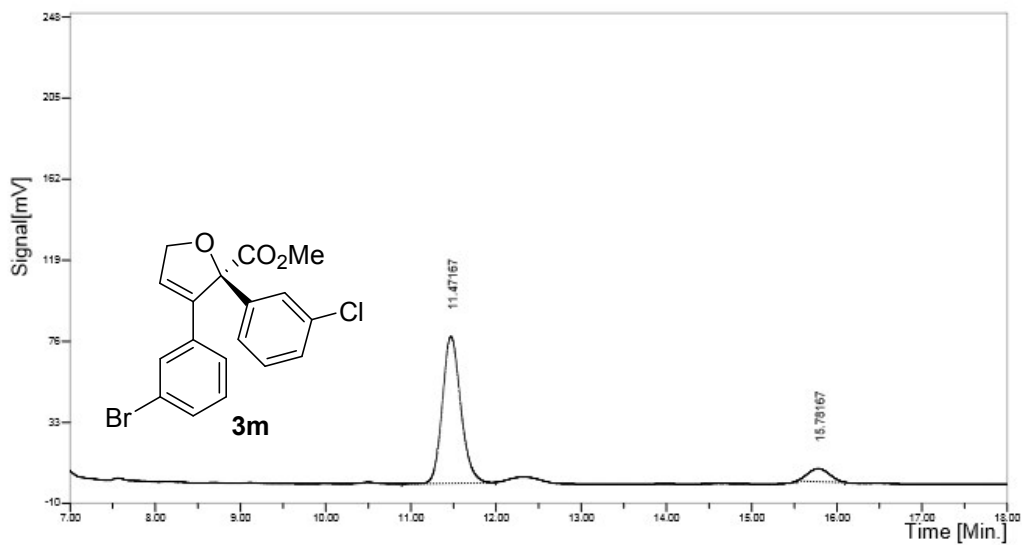
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	9.61667	114.19	49.7749
2	14.76250	115.22	50.2251
total		229.41	100



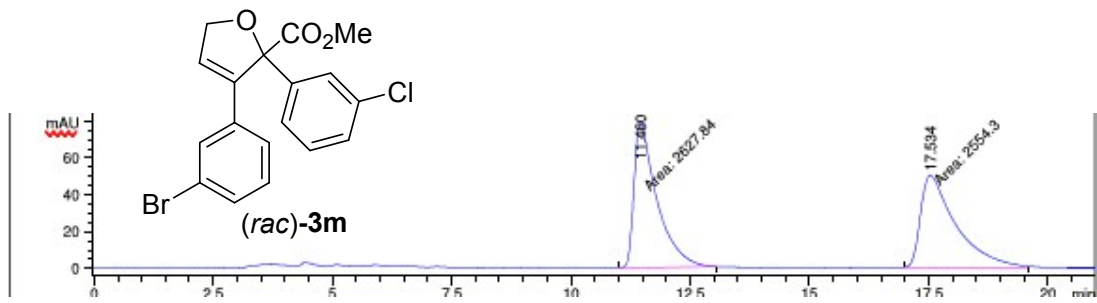
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	9.61083	217.10	90.8588
2	14.78500	21.84	9.1412
total		333.50	100



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	8.42417	421.13	49.4675
2	11.95083	430.19	50.5325
total		851.32	100

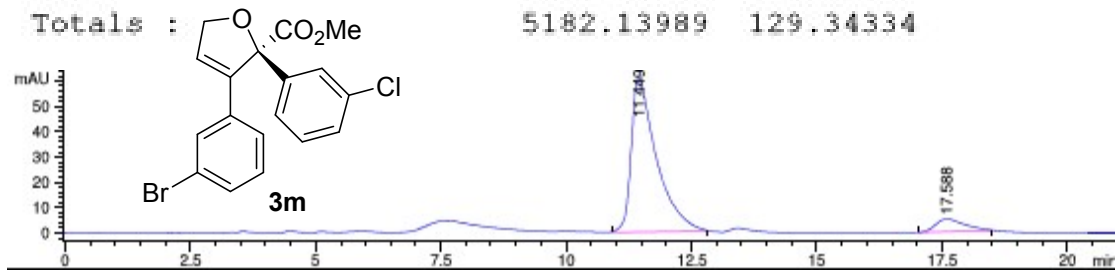


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	11.47167	1152.63	90.5986
2	15.78167	119.61	9.4014
total		1272.23	100



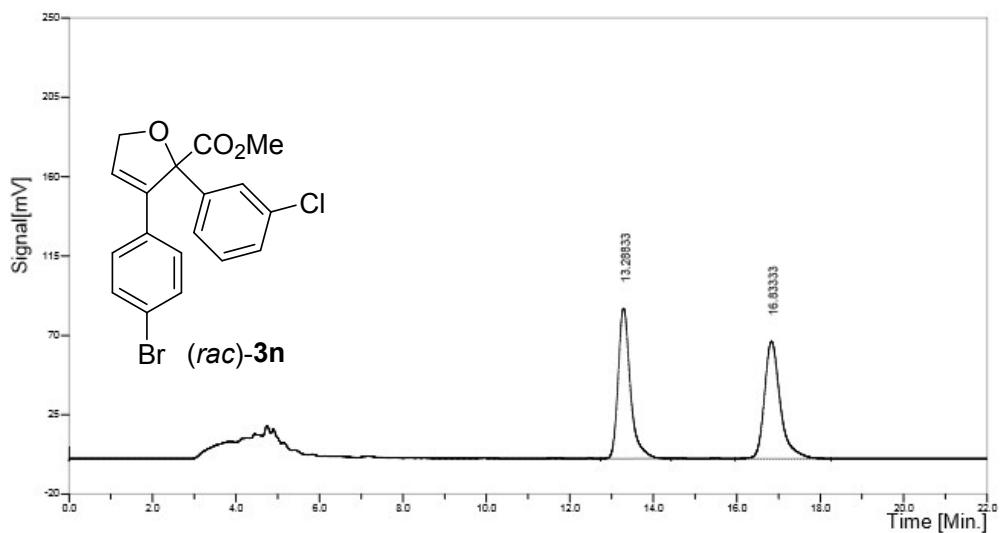
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.460	MM	0.5517	2627.83936	79.39070	50.7095
2	17.534	MM	0.8522	2554.30054	49.95264	49.2905

Totals : 5182.13989 129.34334

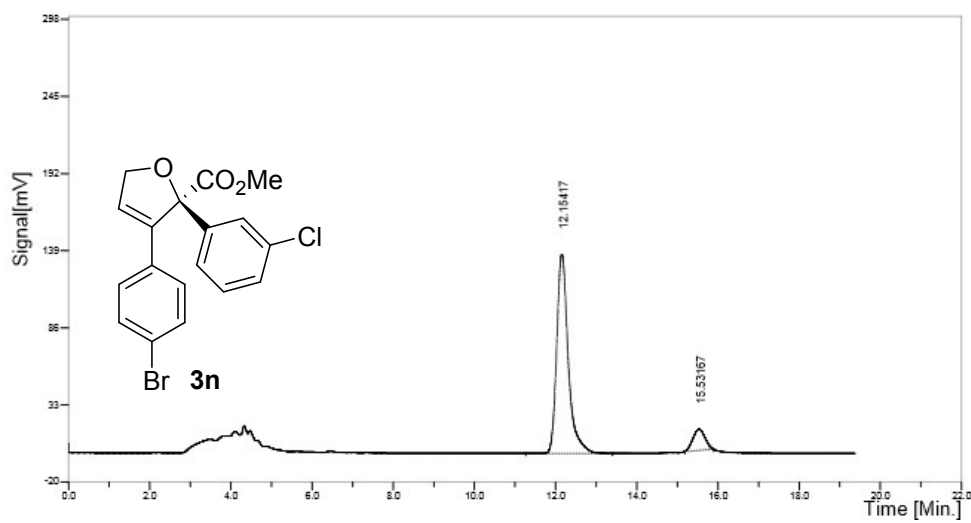


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.449	BB	0.4976	2138.91284	61.21994	91.2183
2	17.588	PB	0.5105	205.91641	5.06311	8.7817

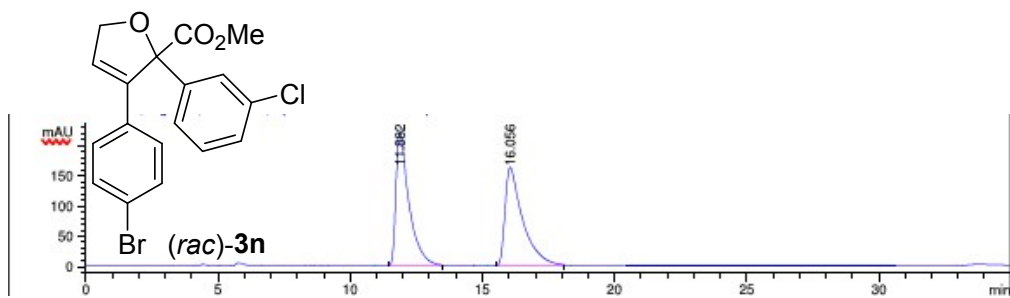
Totals : 2344.82925 66.28305



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	13.28833	1703.62	49.6799
2	16.83333	1725.57	50.3201
total		3429.19	100

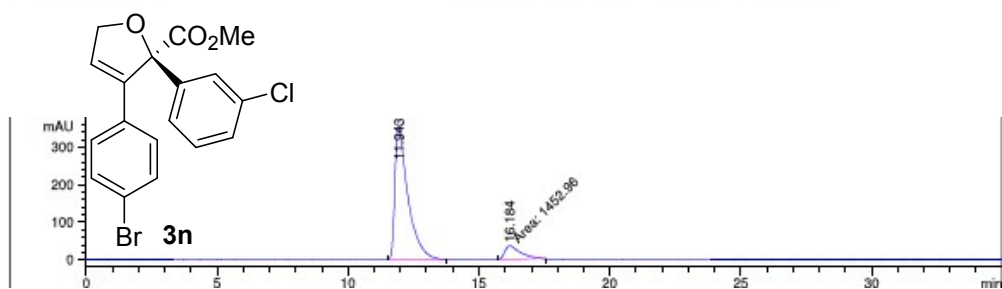


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	12.15417	2648.59	89.9086
2	15.53167	297.28	10.0914
total		2945.86	100



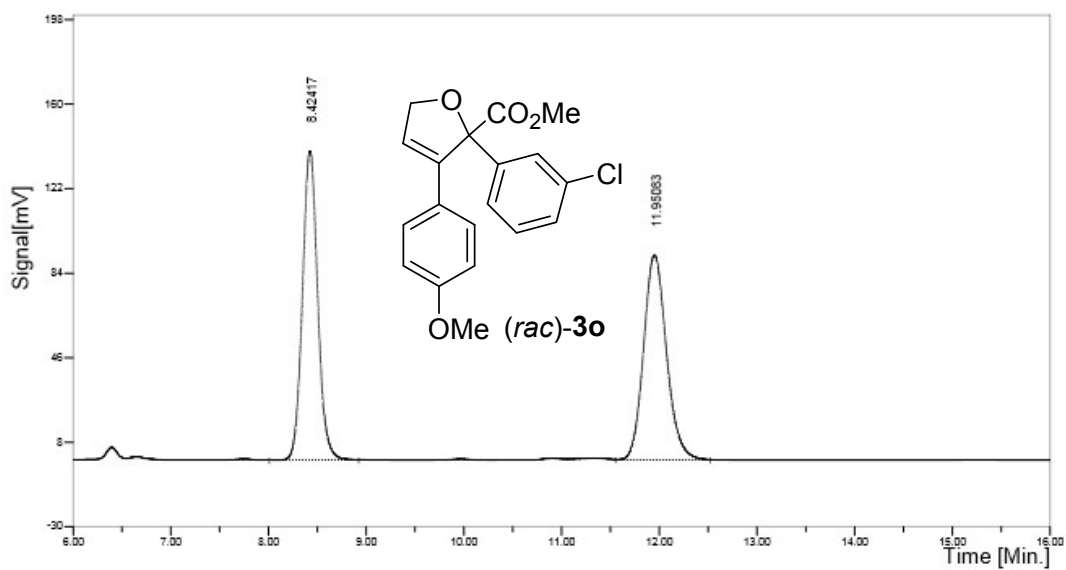
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.882	BB	0.4862	7648.73096	224.07246	50.3896
2	16.056	BB	0.6552	7530.44678	162.94998	49.6104

Totals : 1.51792e4 387.02245

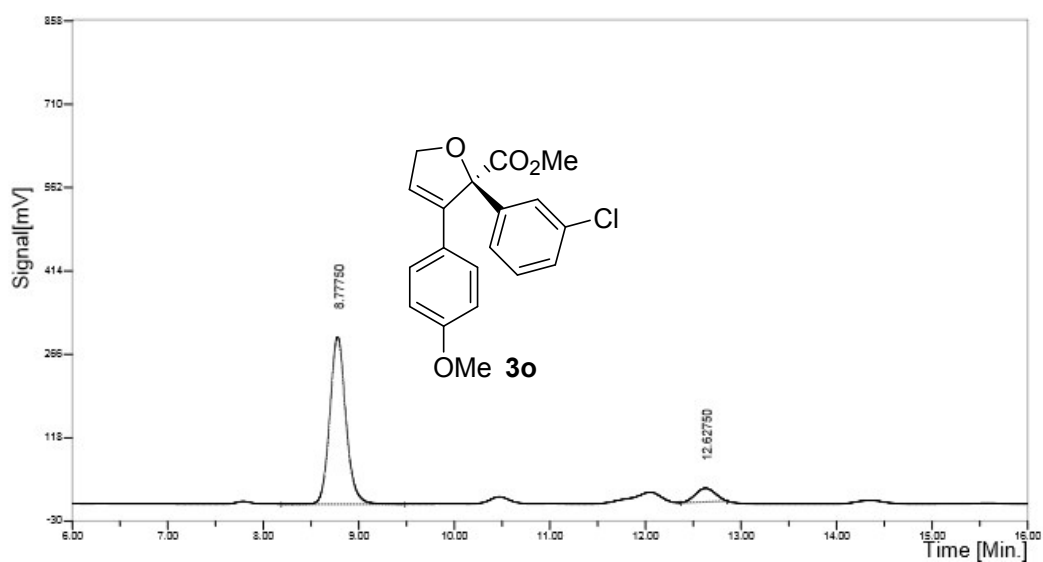


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.943	BB	0.5004	1.23972e4	359.45667	89.5094
2	16.184	MM	0.6838	1452.96375	35.41357	10.4906

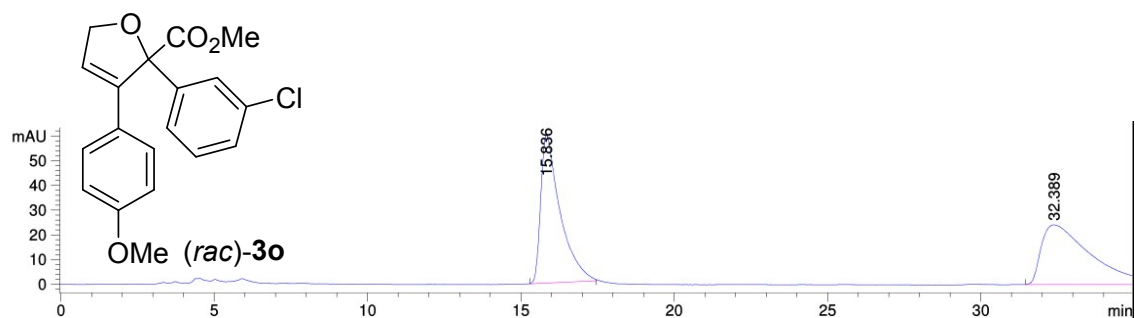
Totals : 1.38501e4 394.87024



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	8.42417	1488.34	50.3907
2	11.95083	1465.26	49.6093
total		1953.60	100

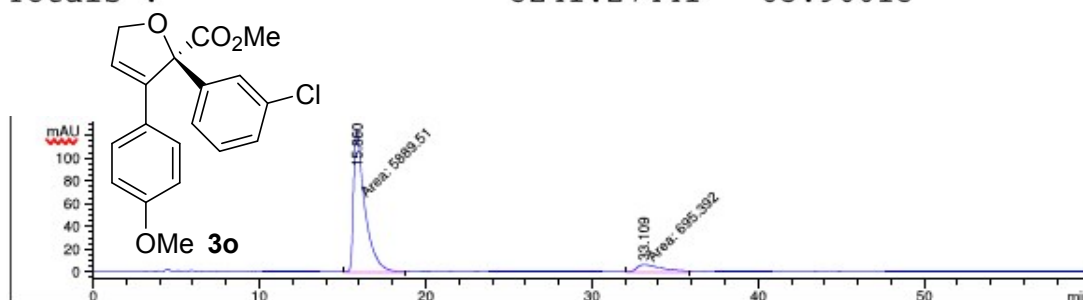


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	8.77750	3422.79	90.9497
2	12.62750	340.60	9.0503
total		3763.39	100



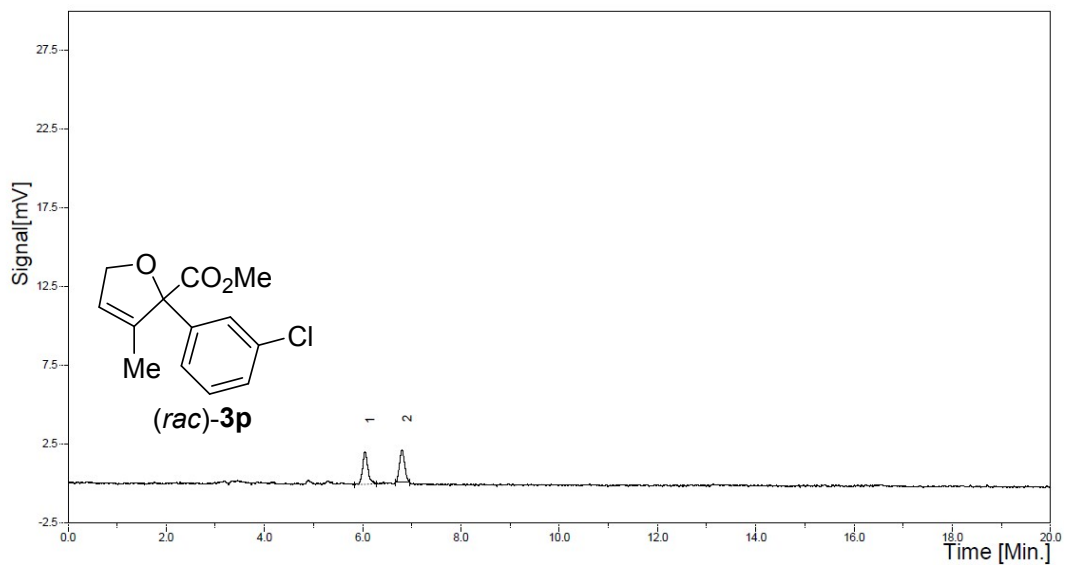
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.836	BB	0.6254	2634.53369	59.86848	50.2651
2	32.389	PBA	1.2863	2606.74072	24.09167	49.7349

Totals : 5241.27441 83.96015

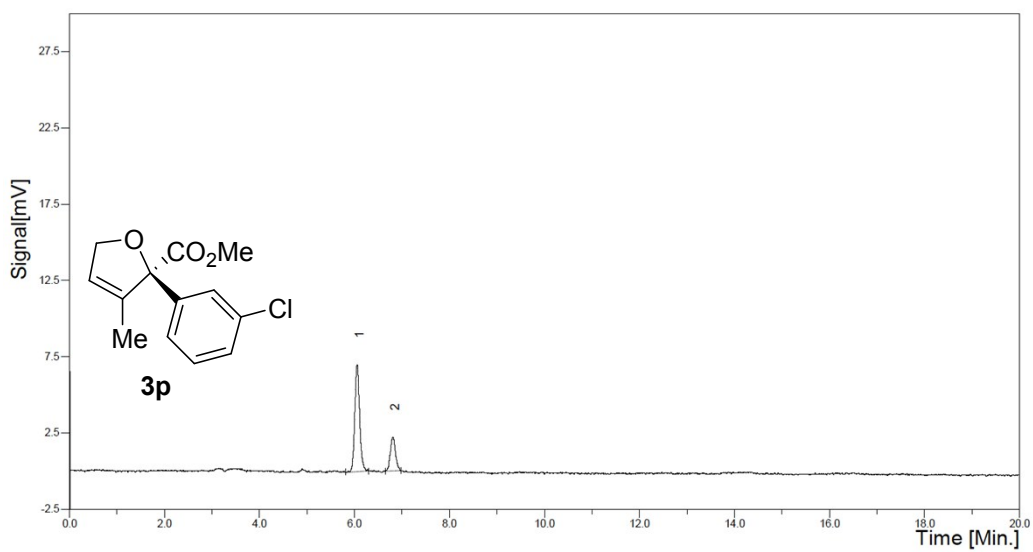


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.860	MM	0.7846	5889.51465	125.10153	89.4396
2	33.109	MM	1.8168	695.39197	6.37936	10.5604

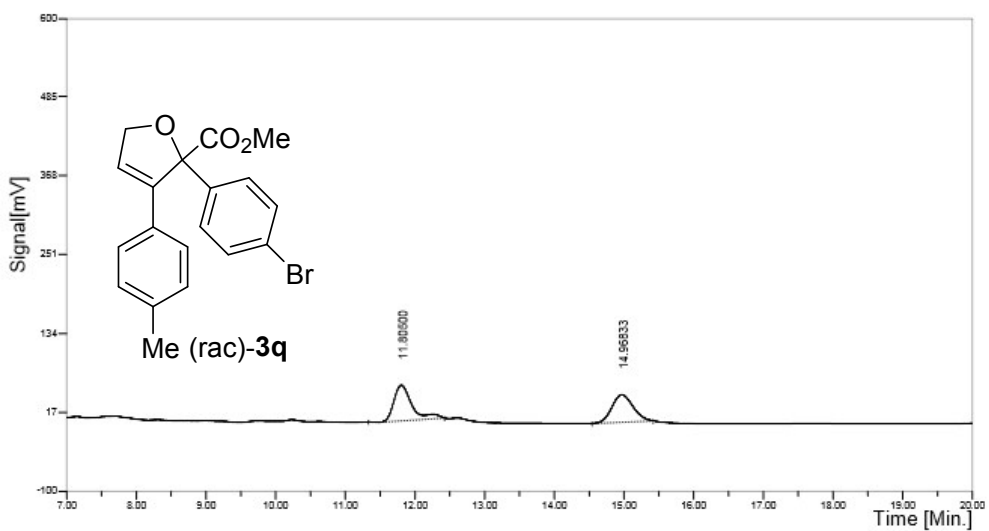
Totals : 6584.90662 131.48090



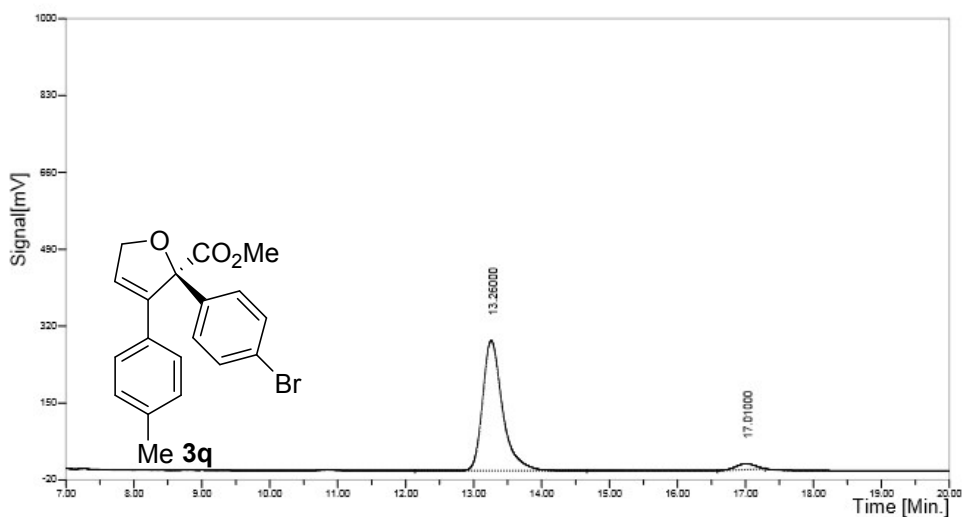
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	6.04667	15.38	50.6261
2	6.79917	15.00	49.3739
total		3763.39	100



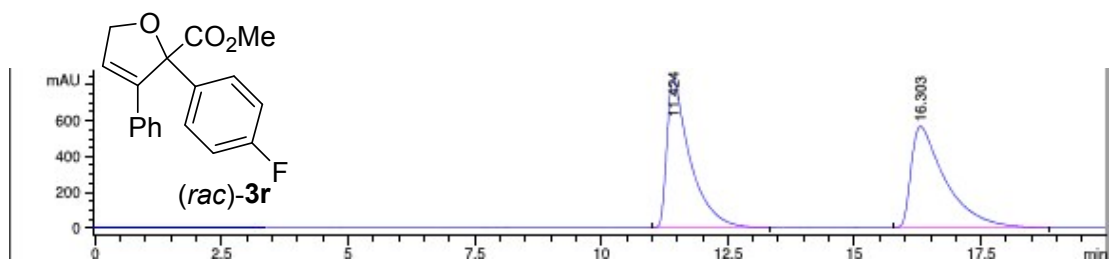
Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	6.05417	49.81	74.6891
2	6.80583	16.88	25.3109
total		3763.39	100



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	11.80500	896.50	51.2879
2	14.96833	851.48	48.7121
total		1747.98	100

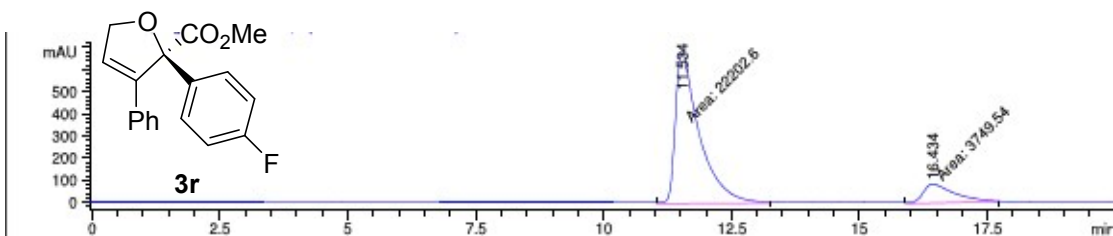


Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	13.26000	5781.87	95.9735
2	17.01000	242.57	4.0265
total		6024.45	100



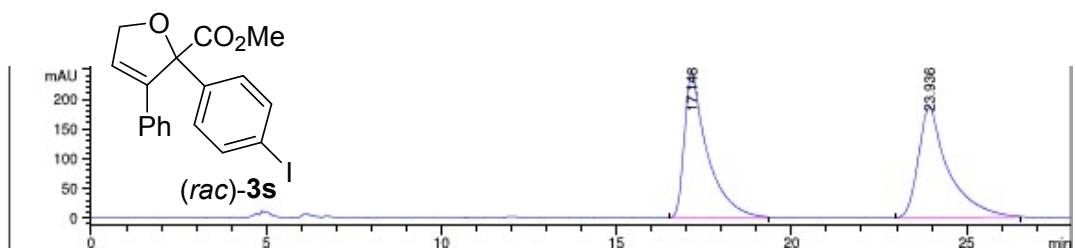
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.424	BB	0.4514	2.65999e4	835.46490	49.7973
2	16.303	BB	0.6751	2.68164e4	567.72009	50.2027

Totals : 5.34164e4 1403.18500



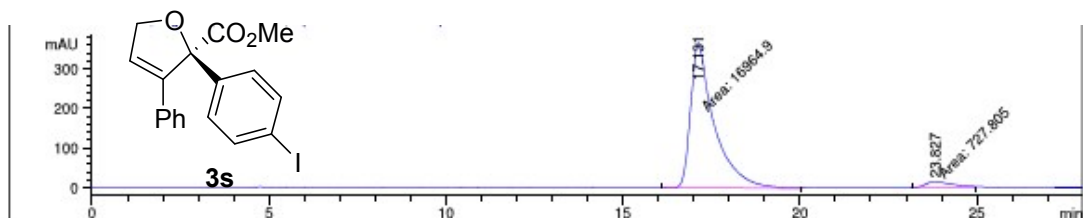
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.534	MM	0.5358	2.22026e4	690.65497	85.5521
2	16.434	MM	0.7261	3749.54297	86.06681	14.4479

Totals : 2.59522e4 776.72178



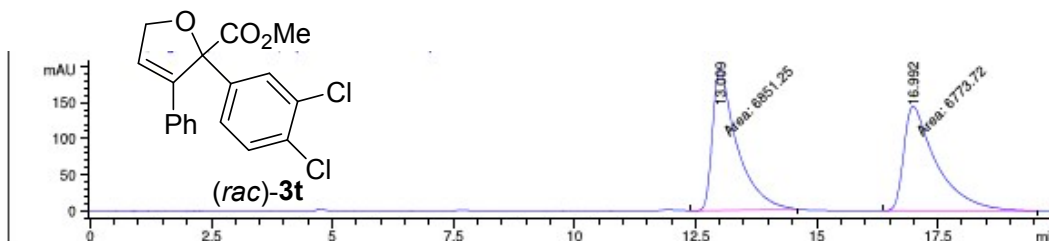
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.148	BB	0.6386	1.10927e4	241.18089	50.2338
2	23.936	BB	0.8247	1.09894e4	185.61333	49.7662

Totals : 2.20821e4 426.79422



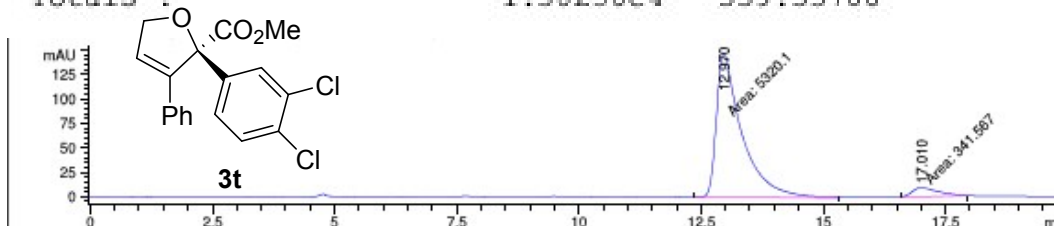
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.131	MM	0.7718	1.69649e4	366.34326	95.8864
2	23.827	MM	0.8487	727.80493	14.29185	4.1136

Totals : 1.76927e4 380.63511



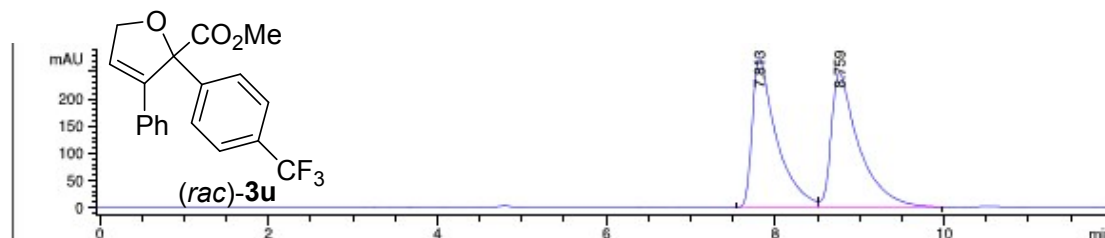
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.009	MM	0.5845	6851.24658	195.34415	50.2845
2	16.992	MM	0.7840	6773.72461	143.99345	49.7155

Totals : 1.36250e4 339.33760



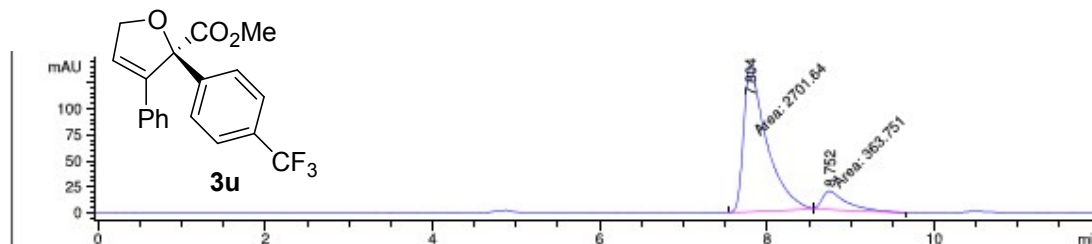
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.970	MM	0.6048	5320.10352	146.59758	93.9670
2	17.010	MM	0.6183	341.56696	9.20763	6.0330

Totals : 5661.67047 155.80521



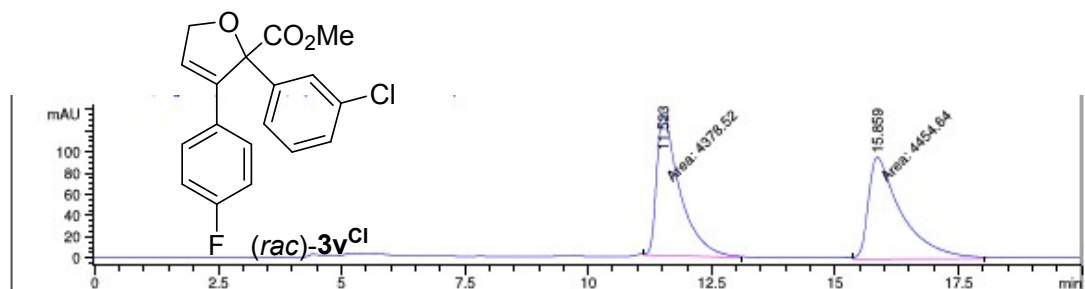
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.813	PV	0.2774	5468.34863	275.71201	49.1826
2	8.759	VB	0.3228	5650.10547	247.04898	50.8174

Totals : 1.11185e4 522.76099



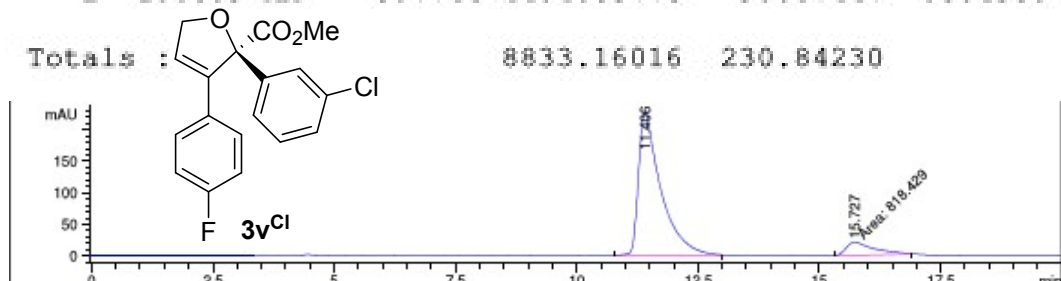
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.804	MM	0.3186	2701.63989	141.31232	88.1336
2	8.752	MM	0.3420	363.75064	17.72688	11.8664

Totals : 3065.39053 159.03920



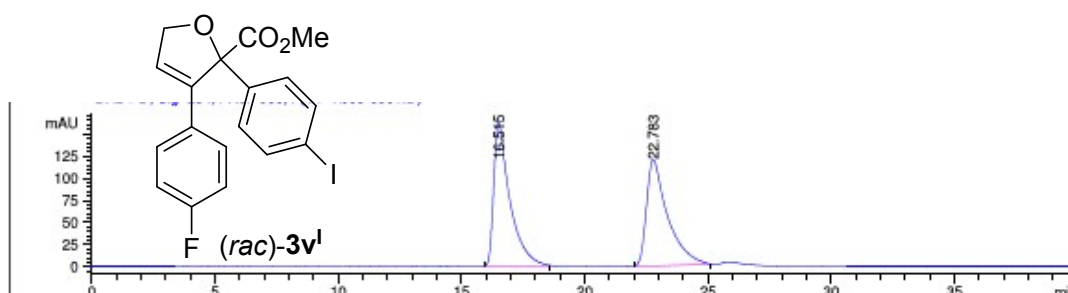
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.523	MM	0.5407	4378.52246	134.96783	49.5692
2	15.859	MM	0.7744	4454.63770	95.87447	50.4308

Totals : 8833.16016 230.84230

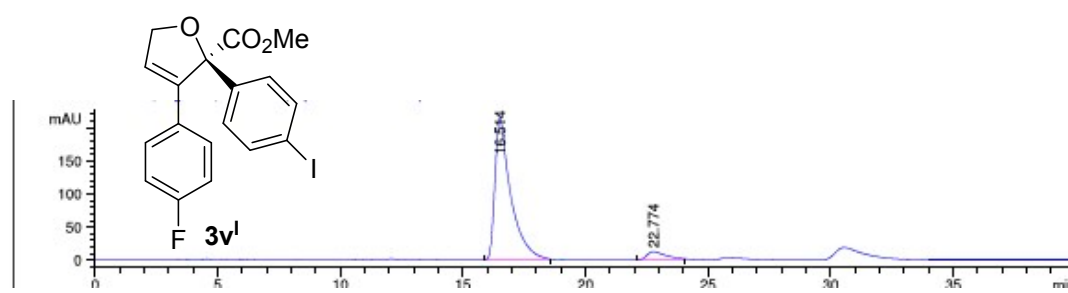


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.406	BB	0.4579	7280.71143	225.96733	89.8949
2	15.727	MM	0.6699	818.42944	20.36209	10.1051

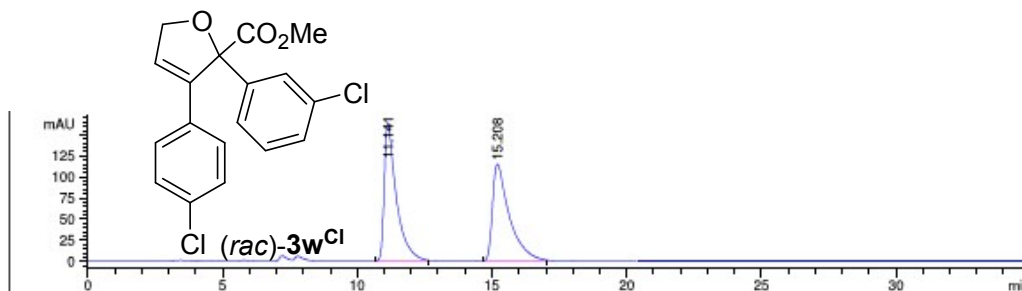
Totals : 8099.14087 246.32942



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.515	BB	0.6420	7355.46582	163.14612	50.7547
2	22.783	BB	0.8382	7136.71777	119.93546	49.2453
Totals :				1.44922e4	283.08157	

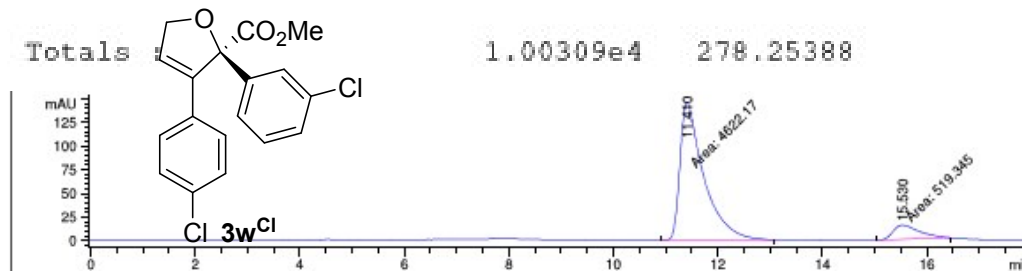


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.514	BB	0.6313	9627.69629	215.44711	93.8316
2	22.774	BB	0.6124	632.91589	12.33924	6.1684
Totals :				1.02606e4	227.78636	



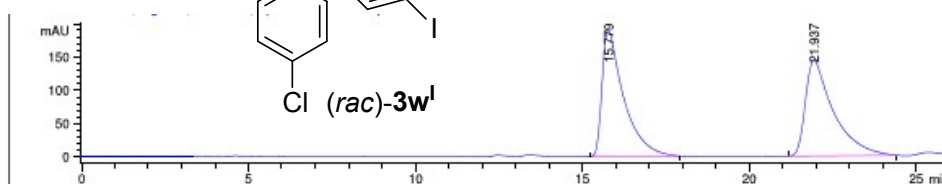
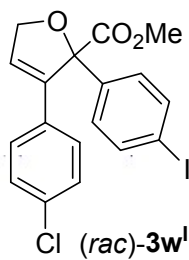
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.141	BB	0.4401	5086.66504	163.87410	50.7097
2	15.208	BB	0.6103	4944.28320	114.37978	49.2903

Totals : COC(=O)C1=CC=C(C=C1)C2=CC=C(C=C2)Cl 1.00309e4 278.25388

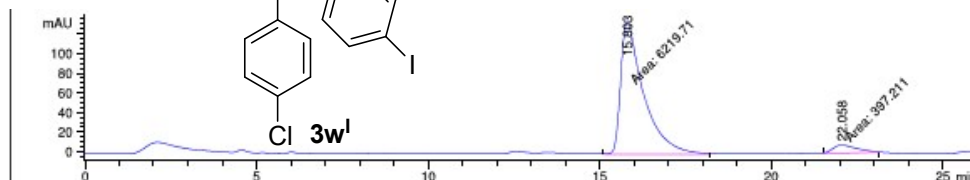
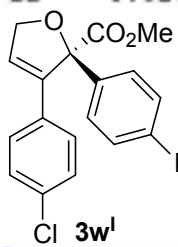


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.410	MM	0.5289	4622.16992	145.65225	89.8990
2	15.530	MM	0.5746	519.34460	15.06500	10.1010

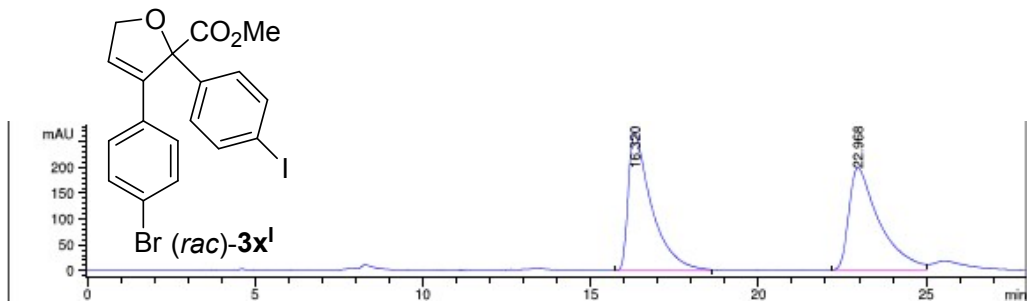
Totals : 5141.51453 160.71725



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.779	BB	0.6459	8556.36523	190.53479	50.5355
2	21.937	BB	0.8207	8375.02734	143.53569	49.4645
Totals :				1.69314e4	334.07048	

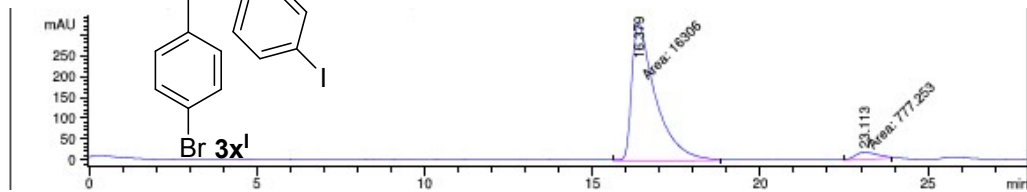


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.803	MM	0.7699	6219.70752	134.63850	93.9970
2	22.058	MM	0.7992	397.21100	8.28314	6.0030
Totals :				6616.91852	142.92164	



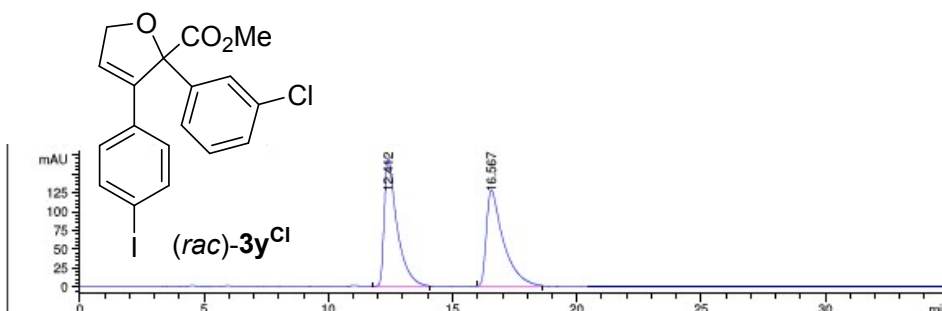
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.320	BB	0.6827	1.28081e4	267.45074	50.5410
2	22.968	BB	0.9008	1.25339e4	198.47818	49.4590

Totals : COC(=O)C1=C(C=C1)C2=CC=C(C=C2)Br 2.53421e4 465.92892

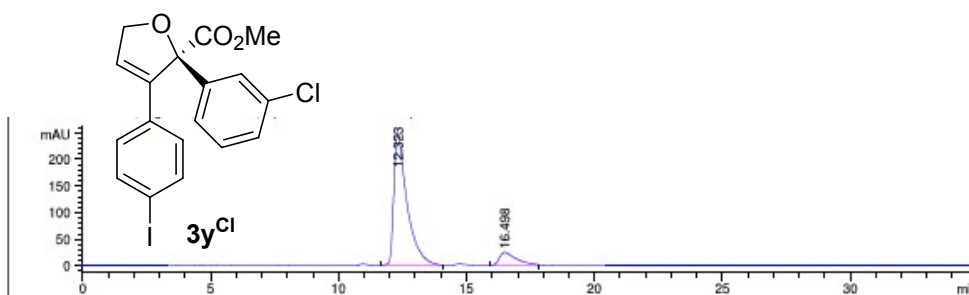


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.379	MM	0.8215	1.63060e4	330.81659	95.4502
2	23.113	MM	0.7655	777.25287	16.92294	4.5498

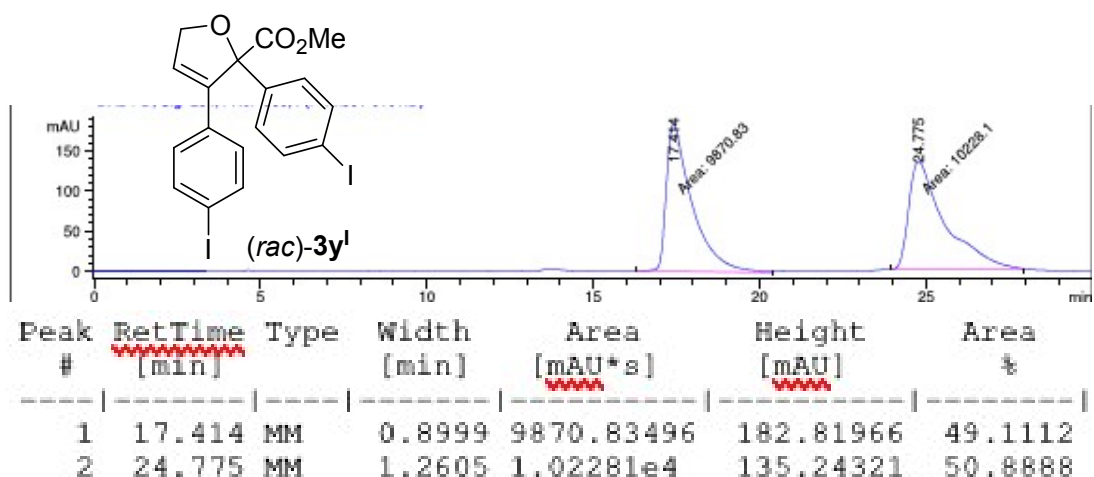
Totals : 1.70832e4 347.73953



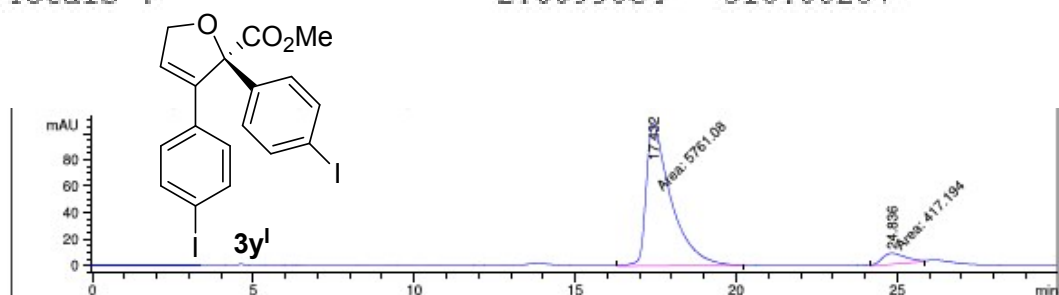
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.412	BB	0.5139	6097.26221	170.22220	50.1268
2	16.567	BB	0.6767	6066.41455	127.58616	49.8732
Totals :				1.21637e4	297.80836	



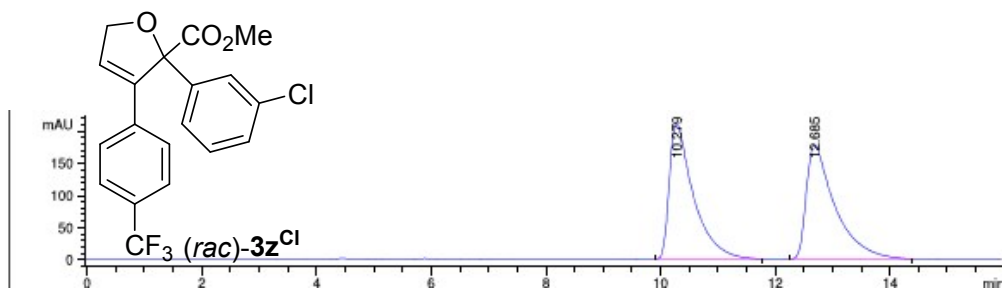
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.323	BB	0.5112	8919.56934	248.26727	89.0456
2	16.498	PB	0.6321	1097.29016	24.05755	10.9544
Totals :				1.00169e4	272.32482	



Totals : 2.00990e4 318.06287

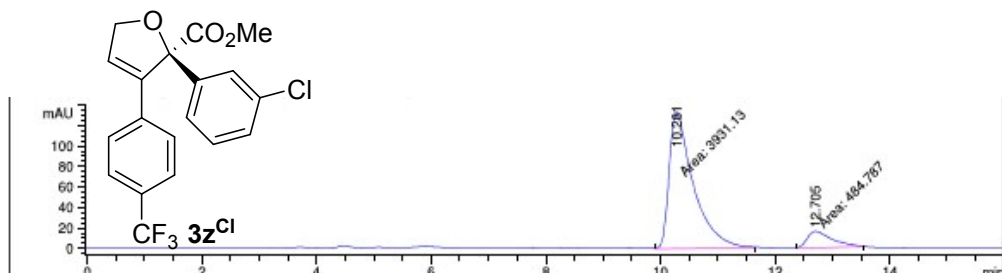


Totals : 6178.26932 115.93857



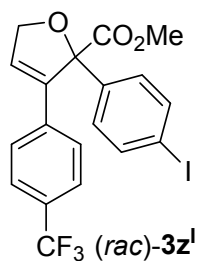
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.279	BB	0.4180	6217.50586	212.08061	50.0433
2	12.685	BB	0.5002	6206.75781	178.28883	49.9567

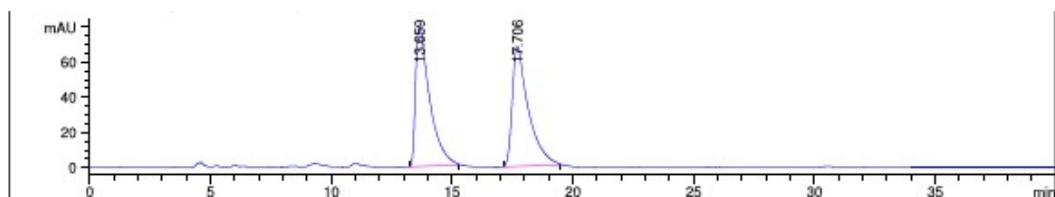
Totals : 1.24243e4 390.36945



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.281	MM	0.4898	3931.13330	133.77592	89.0218
2	12.705	MM	0.5044	484.78699	16.01945	10.9782

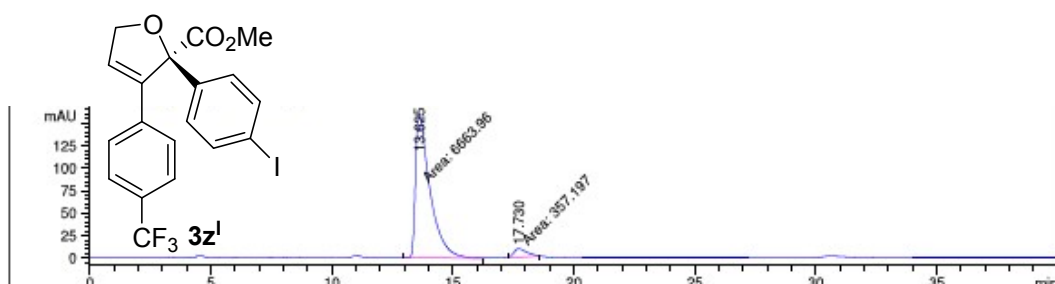
Totals : 4415.92029 149.79537





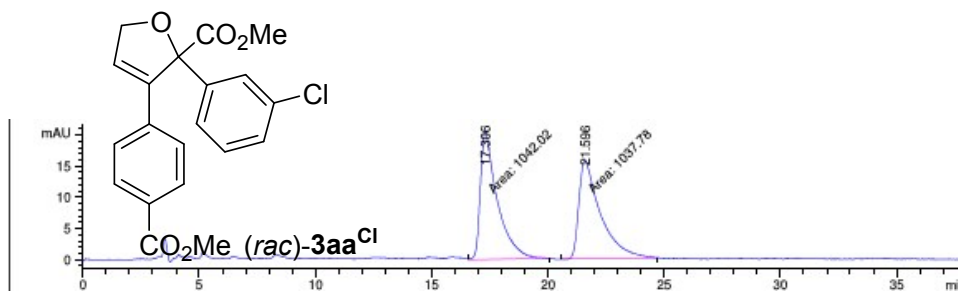
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.659	BB	0.5765	3235.79297	79.56165	50.5974
2	17.706	BB	0.6436	3159.38696	68.06228	49.4026

Totals : 6395.17993 147.62393

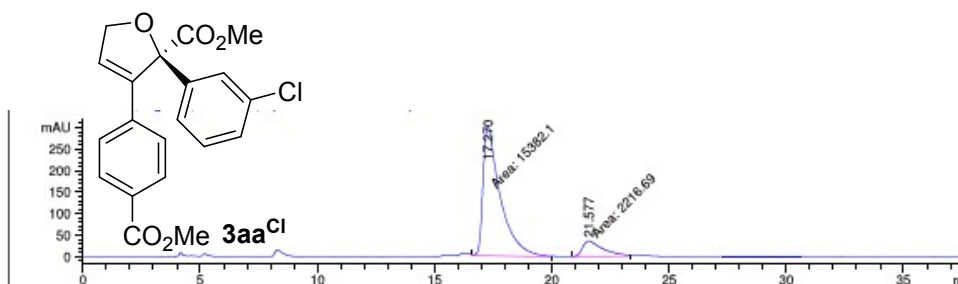


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.625	MM	0.6955	6663.96289	159.68738	94.9126
2	17.730	MM	0.6304	357.19739	9.44297	5.0874

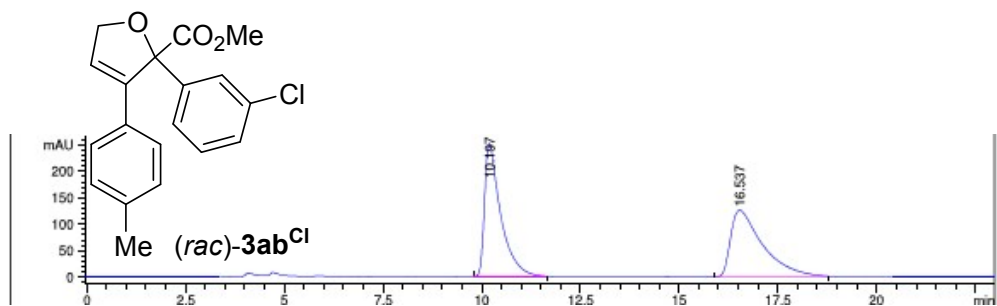
Totals : 7021.16028 169.13035



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.306	MM	0.8455	1042.02454	20.53952	50.1020
2	21.596	MM	1.0974	1037.77991	15.76123	49.8980
Totals :				2079.80444	36.30075	

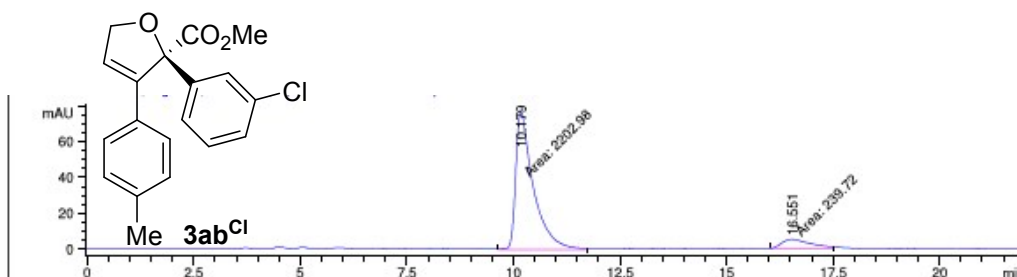


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.270	MM	0.8521	1.53821e4	300.86414	87.4043
2	21.577	MM	1.0152	2216.68750	36.39233	12.5957
Totals :				1.75988e4	337.25647	



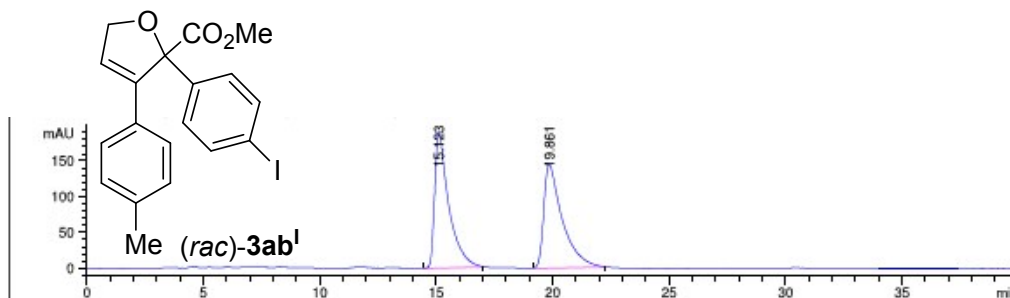
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.197	BB	0.4138	7152.69775	251.47589	50.2581
2	16.537	BB	0.8074	7079.24658	125.64143	49.7419

Totals : 1.42319e4 377.11732

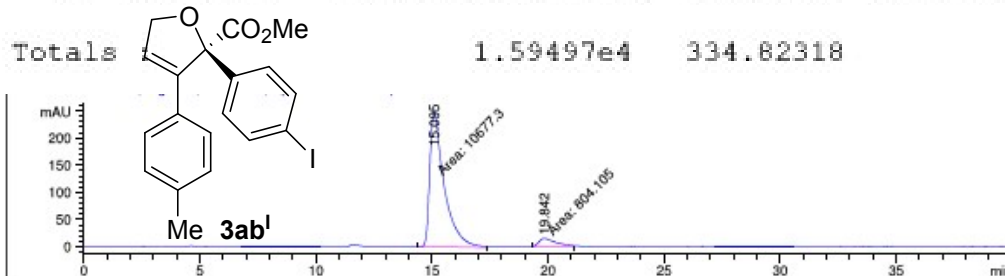


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.179	MM	0.4795	2202.97656	76.57000	90.1863
2	16.551	MM	0.7843	239.71956	5.09402	9.8137

Totals : 2442.69612 81.66402

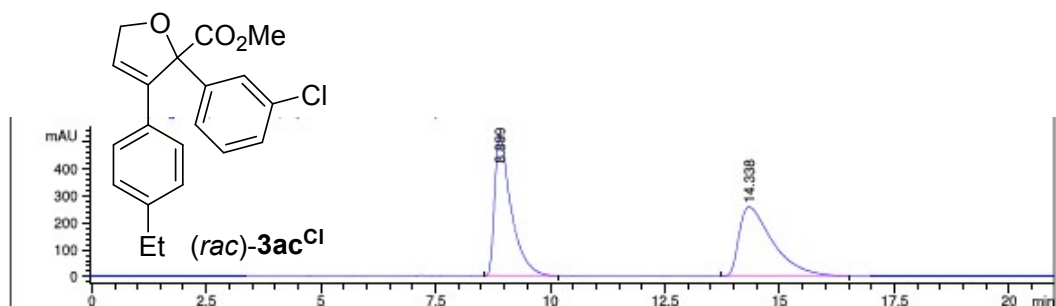


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.123	PB	0.5824	7953.88330	189.97961	49.8687
2	19.861	BB	0.7800	7995.76807	144.84357	50.1313



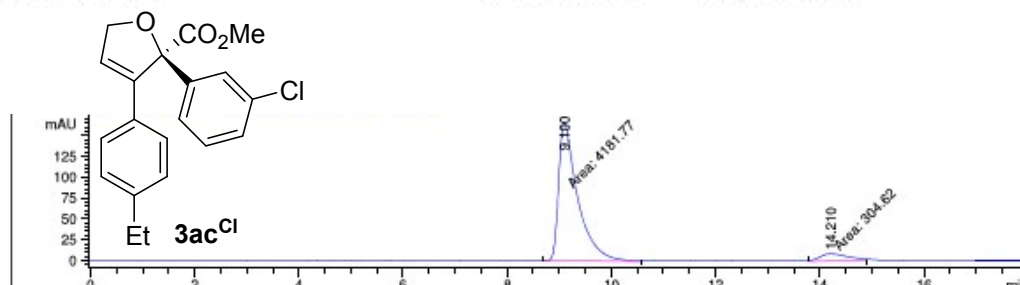
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.095	MM	0.7106	1.06773e4	250.44604	92.9965
2	19.842	MM	0.8710	804.10510	15.38731	7.0035

Totals : 1.14814e4 265.83336



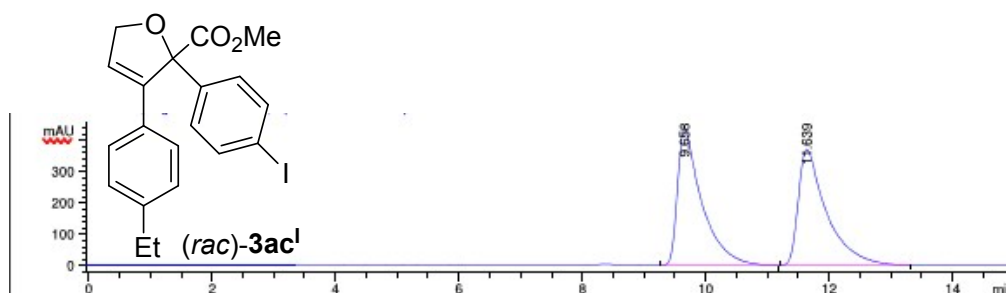
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.899	VB	0.3628	1.32531e4	528.05212	49.9456
2	14.338	PB	0.7546	1.32819e4	258.01193	50.0544

Totals : 2.65350e4 786.06406

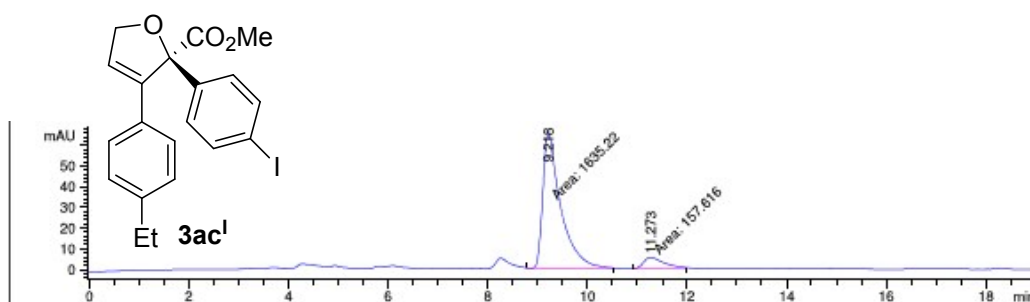


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.100	MM	0.4208	4181.77393	165.64491	93.2101
2	14.210	MM	0.6025	304.61981	8.42634	6.7899

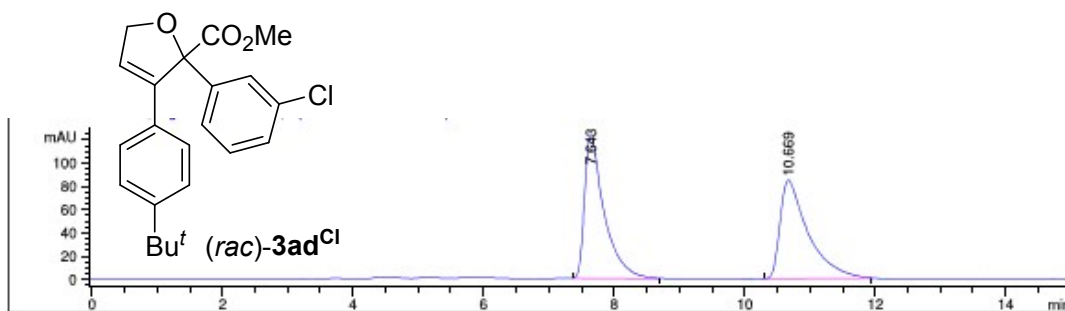
Totals : 4486.39374 174.07125



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.658	BP	0.3877	1.19543e4	433.48761	50.3688
2	11.639	BB	0.4502	1.17793e4	369.23737	49.6312
Totals :				2.37336e4	802.72498	

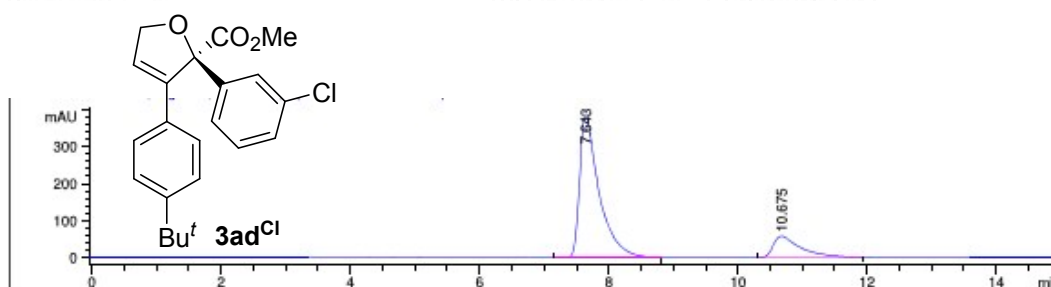


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.218	MM	0.4202	1635.21936	64.85749	91.2086
2	11.273	MM	0.4718	157.61609	5.56835	8.7914
Totals :				1792.83545	70.42584	



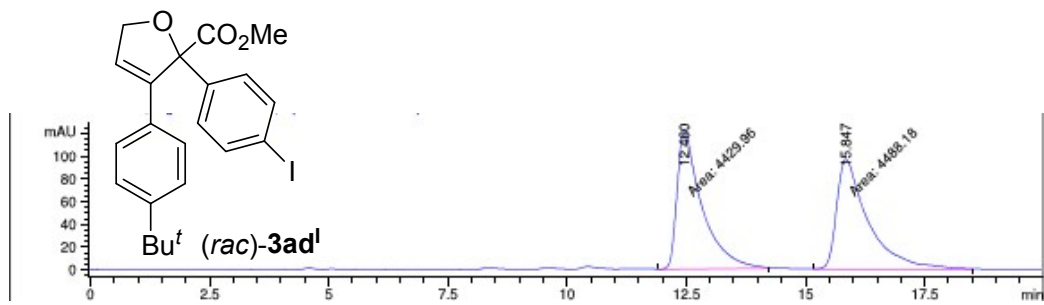
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.643	BB	0.2991	2551.74487	122.46594	50.2172
2	10.669	BB	0.4253	2529.67334	84.49617	49.7828

Totals : 5081.41821 206.96211



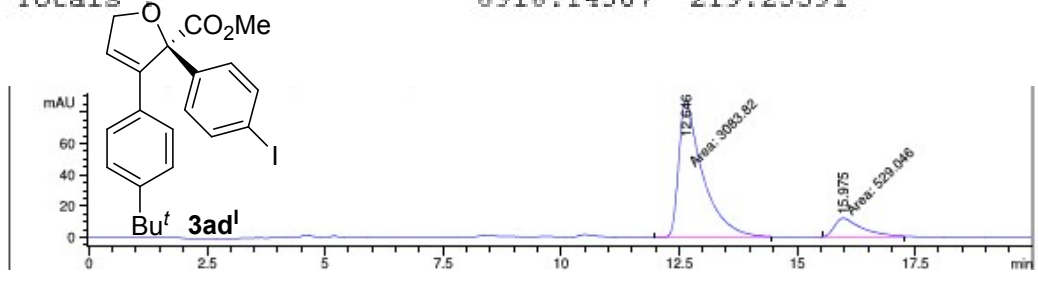
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.643	BB	0.3004	8040.16211	383.85760	82.3718
2	10.675	BB	0.4238	1720.65759	57.71673	17.6282

Totals : 9760.81970 441.57434



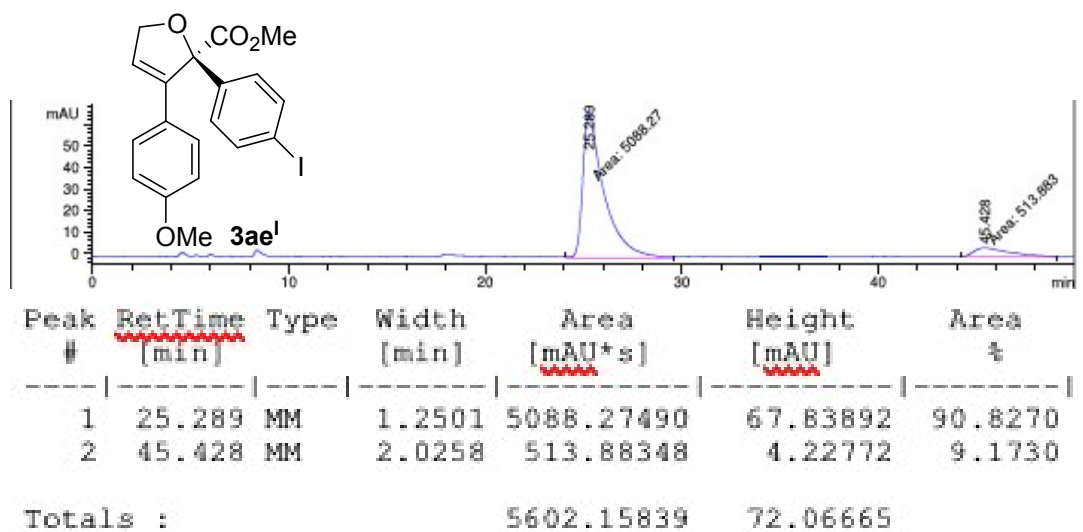
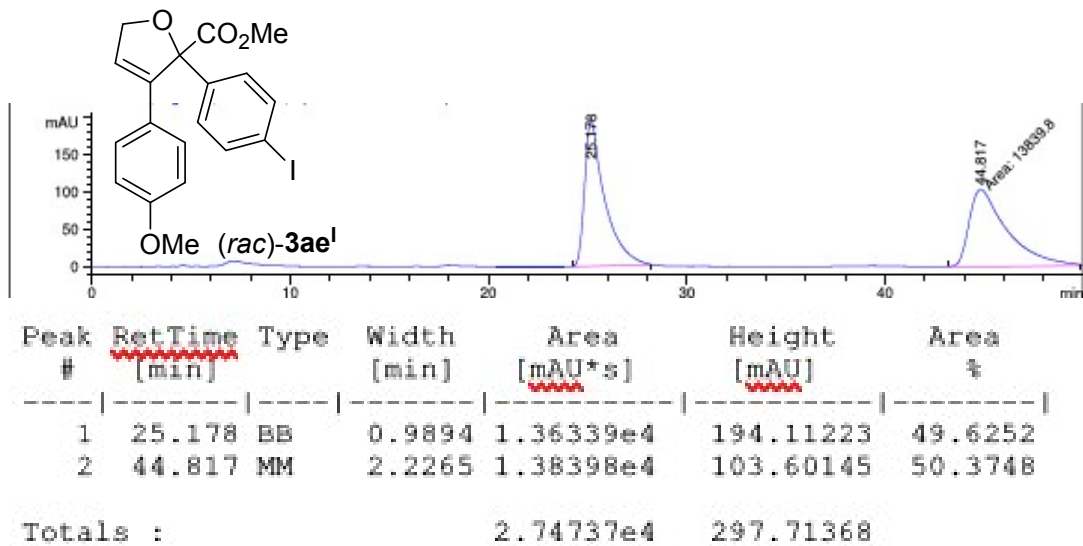
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.460	MM	0.6032	4429.96094	122.40429	49.6736
2	15.847	MM	0.7723	4488.18213	96.85162	50.3264

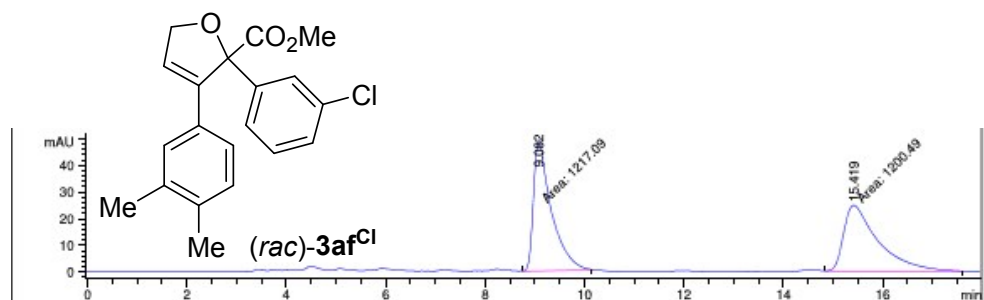
Totals : 8918.14307 219.25591



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.646	MM	0.5907	3083.81763	87.01206	85.3566
2	15.975	MM	0.7161	529.04559	12.31371	14.6434

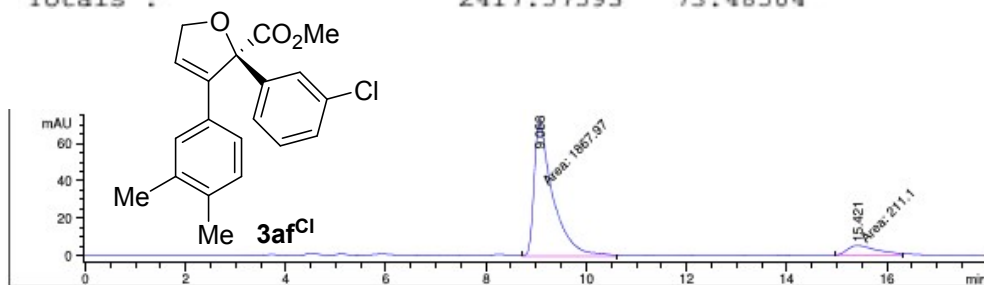
Totals : 3612.86322 99.32577





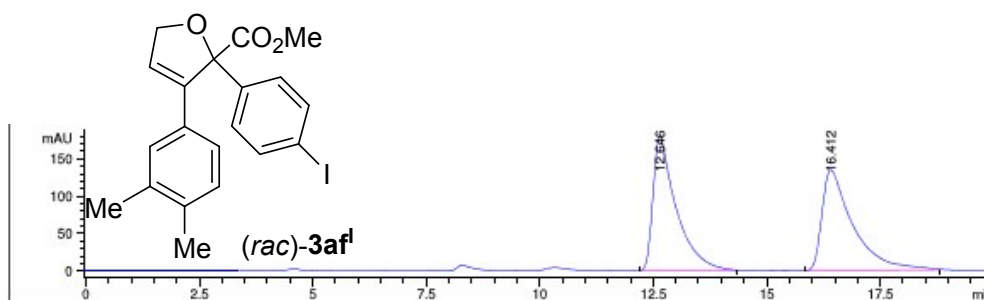
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.082	MM	0.4156	1217.08984	48.80845	50.3434
2	15.419	MM	0.8108	1200.48608	24.67659	49.6566

Totals : 2417.57593 73.48504



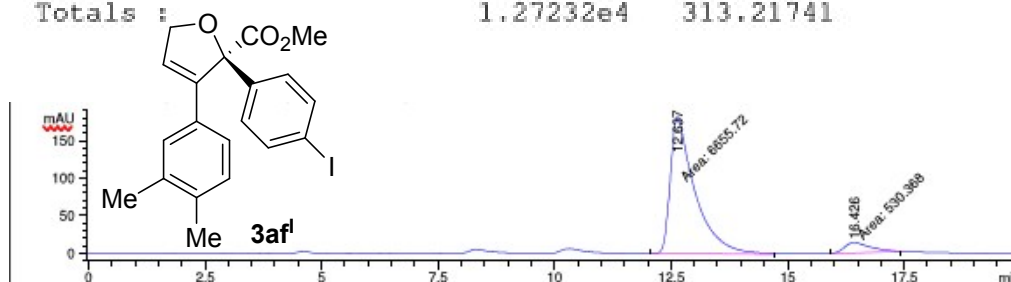
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.068	MM	0.4346	1867.97070	71.63638	89.8464
2	15.421	MM	0.6821	211.09995	5.15815	10.1536

Totals : 2079.07065 76.79452



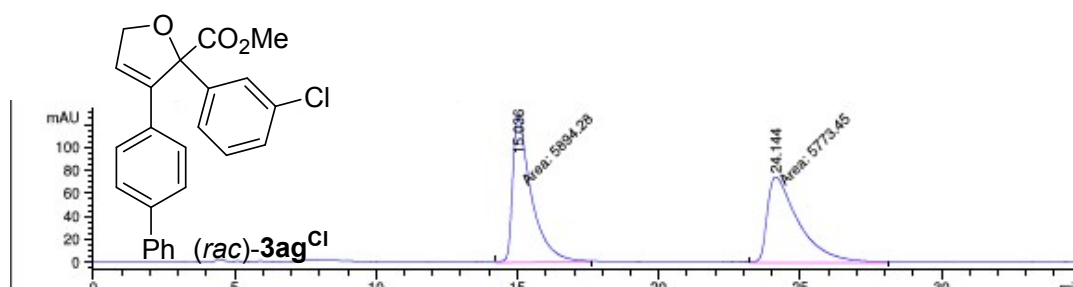
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.646	BB	0.4984	6383.18555	178.84732	50.1696
2	16.412	BB	0.6725	6340.02002	134.37009	49.8304

Totals : 1.27232e4 313.21741



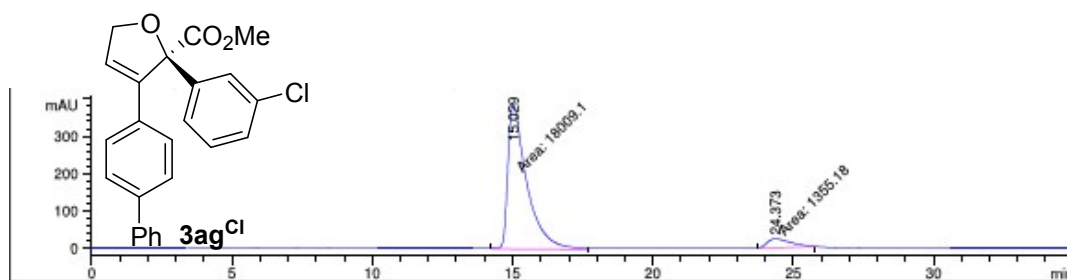
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.637	MM	0.6109	6655.72314	181.58607	92.6195
2	16.426	MM	0.6477	530.36755	13.64783	7.3805

Totals : 7186.09070 195.23391



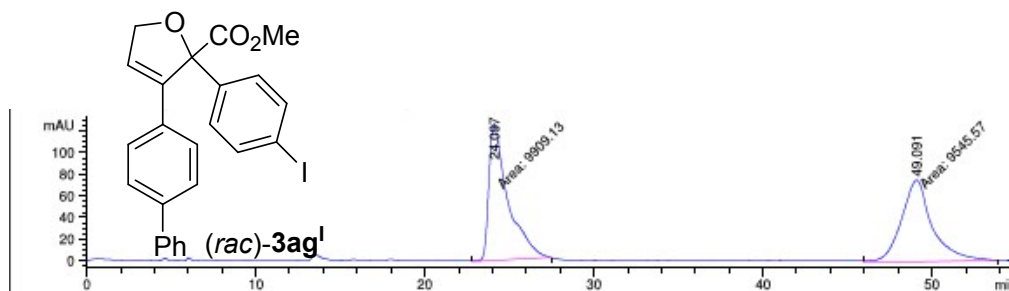
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.036	MM	0.7702	5894.27783	127.54149	50.5178
2	24.144	MM	1.2912	5773.44873	74.52562	49.4822

Totals : 1.16677e4 202.06711



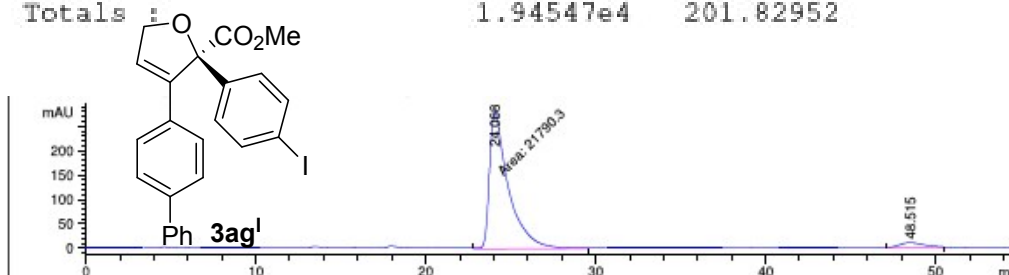
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.029	MM	0.7749	1.80091e4	387.34140	93.0017
2	24.373	MM	0.9484	1355.17798	23.81606	6.9983

Totals : 1.93643e4 411.15746



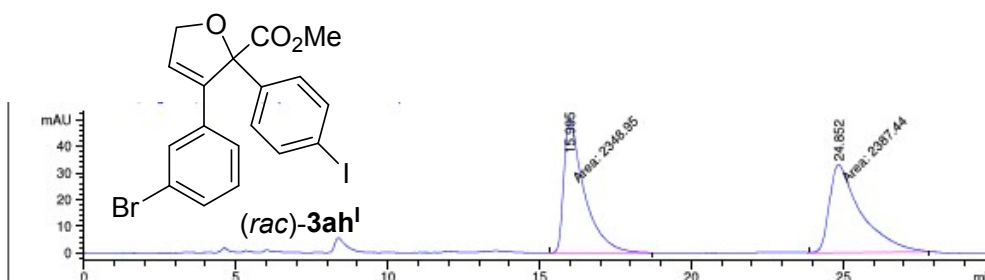
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.097	MM	1.3060	9909.12500	126.45602	50.9344
2	49.091	MM	2.1107	9545.57227	75.37350	49.0656

Totals : 1.94547e4 201.82952

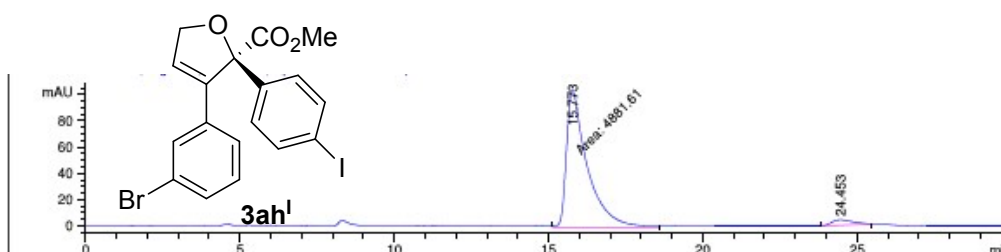


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.068	MM	1.2836	2.17903e4	282.92865	95.7695
2	48.515	BB	1.1549	962.55469	9.84308	4.2305

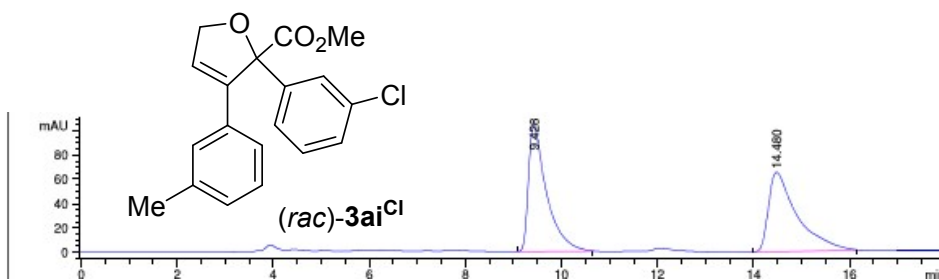
Totals : 2.27528e4 292.77173



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.995	MM	0.7781	2348.95410	50.31637	49.5937
2	24.852	MM	1.2123	2387.44092	32.82201	50.4063
Totals :				4736.39502	83.13837	

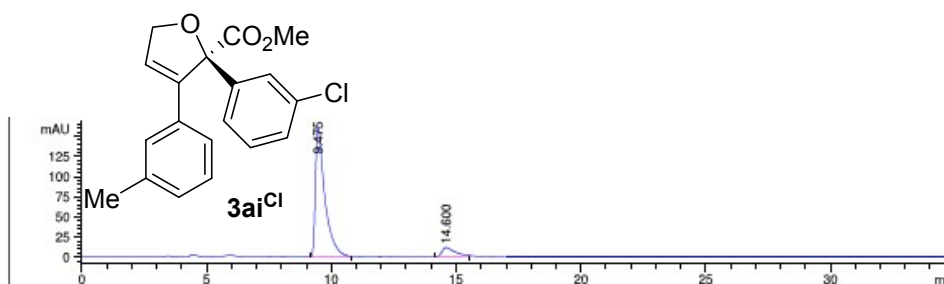


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.773	MM	0.7797	4881.60596	104.35300	96.2496
2	24.453	BB	0.5645	190.21117	4.03127	3.7504
Totals :				5071.81712	108.38427	



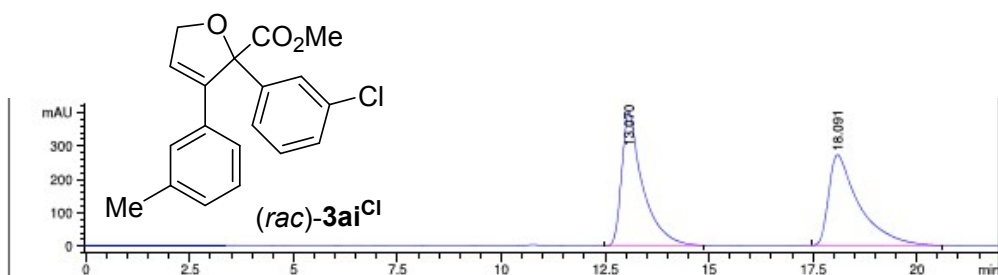
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.428	BB	0.3709	2713.41406	104.52685	50.2210
2	14.480	PB	0.5800	2689.52881	65.09391	49.7790

Totals : 5402.94287 169.62076



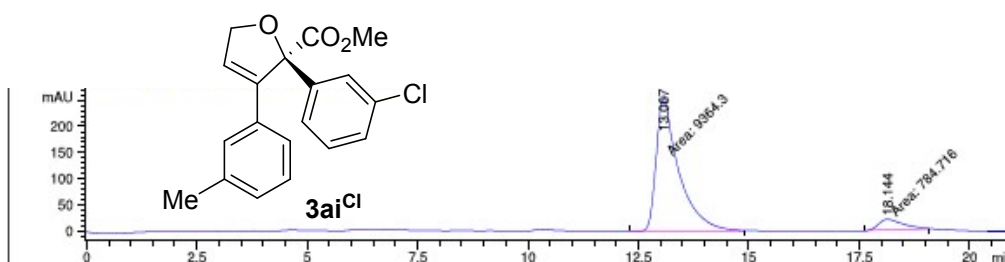
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.475	BB	0.3752	4184.53906	159.97960	91.4640
2	14.600	PB	0.4895	390.52911	11.23664	8.5360

Totals : 4575.06818 171.21624



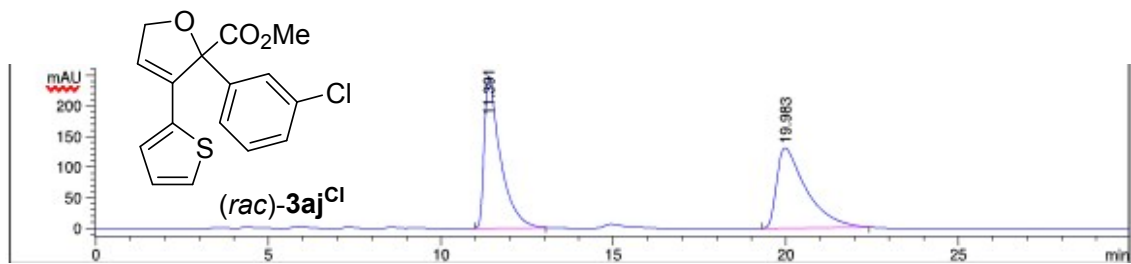
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.070	BB	0.5021	1.41542e4	404.59039	50.1517
2	18.091	BB	0.7222	1.40686e4	273.48682	49.8483

Totals : 2.82229e4 678.07721



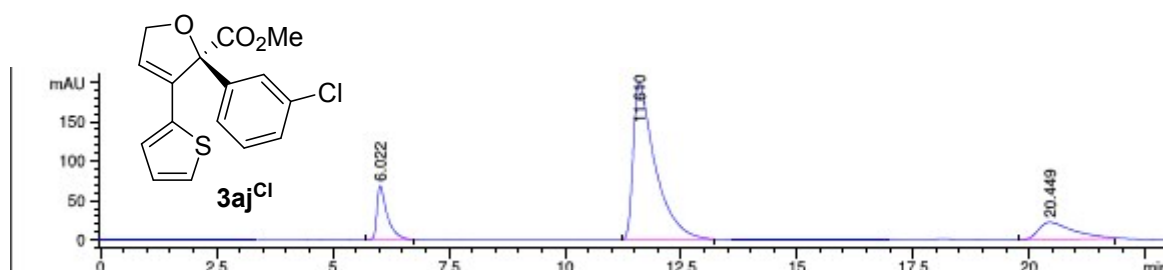
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.067	MM	0.5983	9364.30176	260.85406	92.2681
2	18.144	MM	0.6452	784.71606	20.27131	7.7319

Totals : 1.01490e4 281.12537



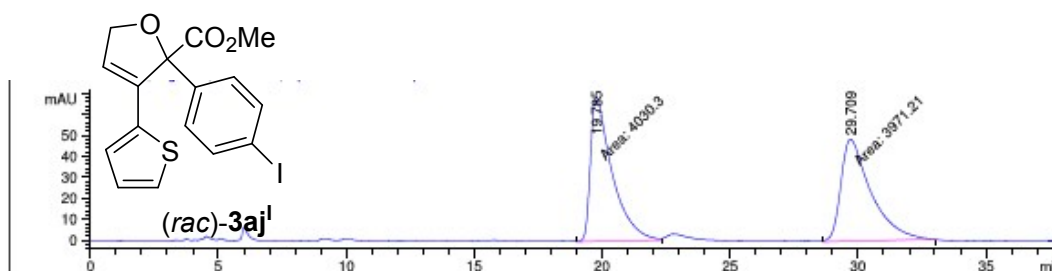
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.391	BB	0.4637	8058.70264	248.91983	50.6684
2	19.983	BB	0.8588	7846.08789	130.99600	49.3316

Totals : 1.59048e4 379.91583



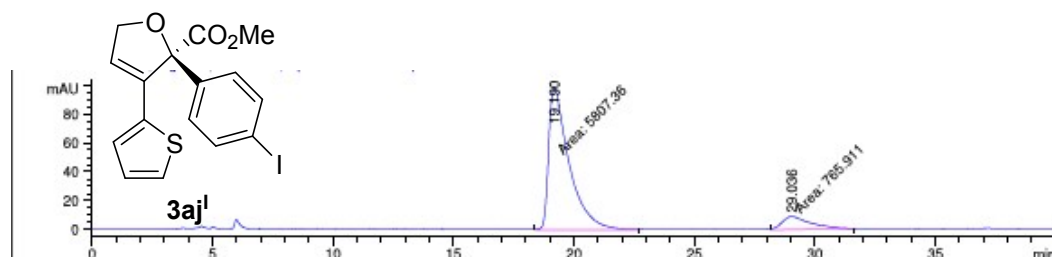
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	6.022	MM	0.5550	5180.91992	155.58571	85.7233
2	11.610	MM	0.8385	862.84869	17.14973	14.2767

Totals : 6043.76862 172.73544



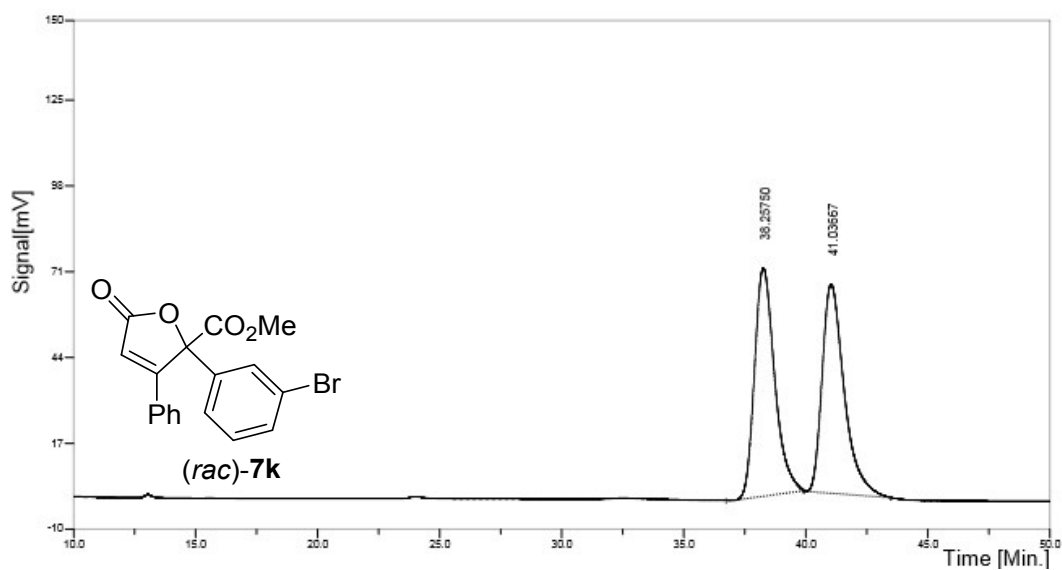
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.785	MM	0.9806	4030.30469	68.50259	50.3693
2	29.709	MM	1.3622	3971.20532	48.58732	49.6307

Totals : 8001.51001 117.08990

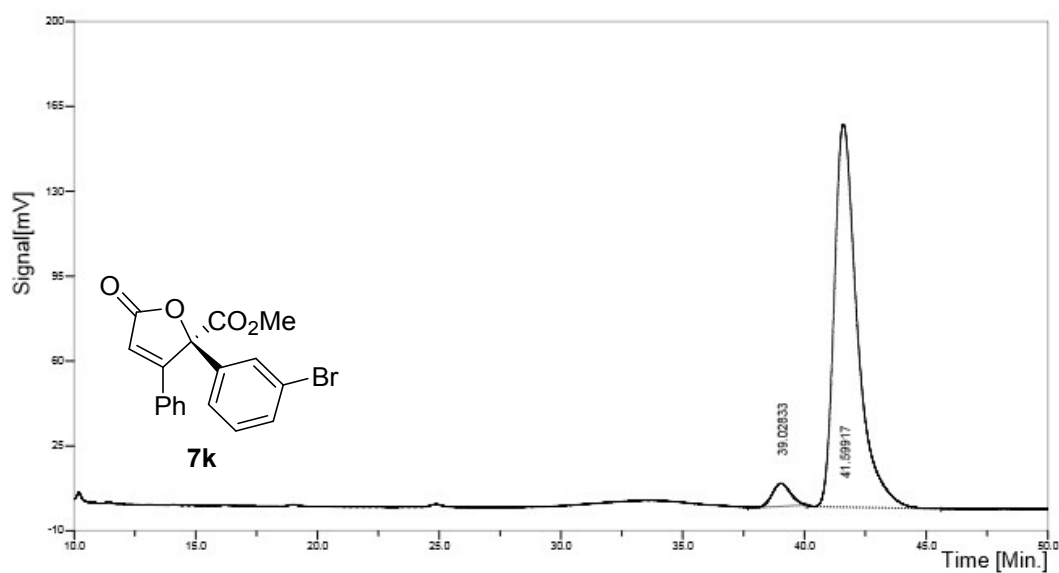


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.190	MM	0.9831	5807.36328	98.44942	88.3481
2	29.036	MM	1.4229	765.91125	8.97093	11.6519

Totals : 6573.27454 107.42036



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	38.25750	4044.27	50.0411
2	41.03667	4037.63	49.9589
total		8081.90	100



Peak NO.	Retention time (min)	Peak area (mV.sec)	Percentage of area (%)
1	39.02833	468.68	4.3928
2	41.59917	10200.67	95.6072
total		10669.35	100

J. Structural determination by X-ray

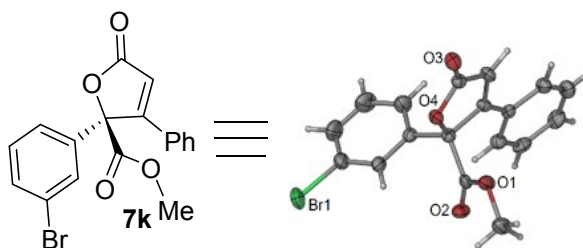


Figure S5 X-ray diffraction parameters and data for 7k (CCDC: 1432486).

Bond precision:	C-C = 0.0042 Å	Wavelength=0.71073	
Cell:	a=8.8995 (4)	b=12.8103 (6)	c=13.9893 (6)
	alpha=90	beta=90	gamma=90
Temperature:	173 K		
	Calculated	Reported	
Volume	1594.85 (12)	1594.85 (12)	
Space group	P 21 21 21	P2 (1) 2 (1) 2 (1)	
Hall group	P 2ac 2ab	?	
Moiety formula	C18 H13 Br O4	?	
Sum formula	C18 H13 Br O4	C18 H13 Br O4	
Mr	373.18	373.19	
Dx, g cm ⁻³	1.554	1.554	
Z	4	4	
Mu (mm ⁻¹)	2.595	2.595	
F000	752.0	752.0	
F000'	751.22		
h, k, lmax	10, 15, 16	10, 15, 16	
Nref	2811 [1627]	2801	
Tmin, Tmax	0.409, 0.509	0.455, 0.552	
Tmin'	0.378		
Correction method=	# Reported T Limits: Tmin=0.455 Tmax=0.552		
AbsCorr =	MULTI-SCAN		
Data completeness=	1.72/1.00	Theta (max)= 25.010	
R(reflections)=	0.0297 (2486)	wR2(reflections)= 0.0679 (2801)	
S =	1.058	Npar= 208	