Supporting Information

Umpolung of Donor-Aceptor Cyclopropanes through N-Heterocyclic Carbene Organocatalysis

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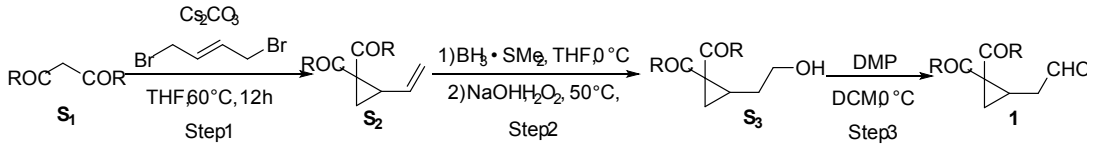
Ⅰ. General information

Commercially available materials purchased from Energy Chemical or Aladdin were used as received. All reactions were carried out using dry chloroform as the solvent under an atmosphere in 10 mL dry Schlenk tube. NMR spectra were measured on a Bruker ASCEND (AVANCE III HD 400 MHz) or on a JEOL-ECX-500 (500 MHz) spectrometer. The chemical shift values were corrected to 7.26 ppm (^{1}H NMR) and 77.16 ppm (^{13}C NMR) for $CHCl_3$. ^{1}H NMR splitting patterns were designated as singlet (s), double (d), triplet (t), quartet (q), doublet of doublets (dd), multiplets (m), and etc. All first-order splitting patterns were assigned on the base of the appearance of the multiplet. Splitting patterns that could not be easily interpreted are designated as multiplet (m) or broad (br). High resolution mass spectrometer analysis (HRMS) was performed on Thermo Fisher Q Exactive mass spectrometer. HPLC analyses were measured on Waters systems with Empower3 system controller, Alliance 2695, and 2998 Diode Array Waters 2489 UV/Vis detector. Chiralcel brand chiral columns from Daicel Chemical Industries were used with models IA, IB, ID, AD-H in 4.6 x 250 mm size. The racemic products used to determine the er values were synthesized using racemic catalyst. Optical rotations were measured on an Insmark IP-digi Polarimeter in a 1 dm cuvette. The concentration (*c*) is given in g/100 mL. Melting Point (MP): Melting points were measured on an uncorrected Beijing Tech Instrument X-4 digital display micro melting point apparatus. Analytical thin-layer chromatography (TLC) was carried out on pre-coated silica gel plate (0.2 mm thickness). Visualization was performed using a UV lamp.

Ⅱ. Preparation of substrates

1. Preparation of cyclopropanyl aldehyde 1[1]

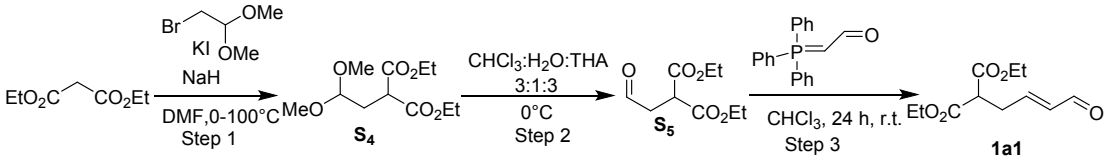


Step 1: To a solution of the corresponding malonate **S_1** (60.5 mmol, 1.0 equiv.) and 1,4-dibromodibutene (60.5 mmol, 1.0 equiv.) were dissolved in dry THF (300 mL) and added cesium carbonate (25 mmol, 2.5 equiv.). The reaction mixture was then heated to 60 ºC and reacted overnight. After cooling down to r.t., the reaction was filtered over celite and washed with EtOAc. The organic phase was washed with satuated $NaHCO_3$ (120 mL) water (120 mL) and brine (120 mL), respectively. The organic phase was dried over anhydrous sodium sulfate, and filtered. The solvent was removed under reduced pressure to afford the product **S_2** which was used for the next step without purification

Step 2: To the corresponding vinylcyclopropane (1 equiv.) in dry THF at 0 °C borane dimethylsulfide complex (10 M in THF, 1.2 equiv.) was added slowly. The reaction mixture was stirred at 0 ºC for 3 h. Then NaOH (3 M, 1.2 equiv.) was added dropwisefollowed by H_2O_2 (30%, 1.2 equiv.), and reacted overnight. The reaction was quenched with H_2O (5 mL) and extracted with EtOAc. The organic extracts were washed with brine (20 mL), dried over anhydrous sodium sulfate and filtered, and the solvent was removed under reduced pressure. The crude product was purified by column chromatography on silica gel with PE/EtOAc (5:1) as the eluent to afford the desired product **S_3**.

Step 3: To a solution of **S_3** in DCM at 0 °C was added DMP (1.5 equiv.). After stirring for 3-8 h, the reaction mixture was filtered over celite and the solvent was removed on rotary evaporator. The crude product was purified by column chromatography on silica gel with PE/EtOAc (20:1) as the eluent to afford the desired product **1a**.

2. Preparation of olefine aldehyde 1a1[2]



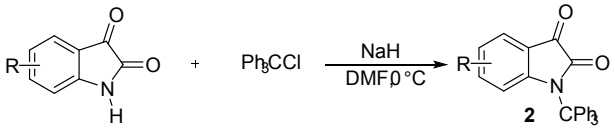
Step 1: In a 50 mL Schlenk tube, NaH (60 % in mineral oil, 63 mmol, 1.0 equiv.) was dissolved in DMF (100 mL) at 0 ºC. The resultant mixture was stirred for 10 min. Then malonate ester (63 mmol, 1.0 equiv.) was added slowly and stirring was continued for another 1 h. At the same temperature, KI (13 mmol, 0.2 equiv.) and 2-bromo-1,1-dimethoxy ethane (63 mmol, 1.0 equiv.) were added carefully.The reaction mixture was heated to 100 ºC and stirred for 24 h. The reaction was quenched by adding saturated NH_4Cl (aq., 10 mL) and diluted with EtOAc (30 mL) Organic phase obtained here was separated and washed with water and brine (10 mL), respectively, dried over $MgSO_4$. The solvent was removed on a rotary evaporator. The crude product was purified by column chromatography on silica gel with PE/EtOAc (30:1) as the eluent to afford the desired product **S_4**.

Step 2: In a 25 ml round-bottom flask, **S_4** (25 mmol) was dissolved in $CHCl_3$ (32 mL) and

H_2O (10 mL) at 0 ºC. To the solution of **S_4** was added slowly TFA (32 mL) and the mixture was stirred for 1 h. Then the reaction solution was neutralized with 1 M K_2CO_3 and DCM (30 mL) was added, the organic phase was separated and the aqueous phase was extracted with DCM. The combined organic phase was dried over anhydrous $MgSO_4$ and concentrated. The crude product was purified by column chromatography on silica gel with PE/EtOAc (10:1) as the eluent to afford the desired product **S_5**.

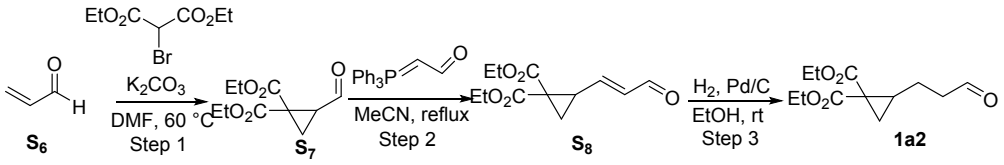
Step 3: In a 25 ml dry Schlenk round-bottom flask, **S_5** (5 mmol) was dissolved in $CHCl_3$ (14 mL), to this solution triphenyl phophonium ylide (6 mmol) was added and the reaction mixture was stirred for 24 h at ambient temperature. The crude product was purified by column chromatography on silica gel with PE/EtOAc (10:1) as the eluent to afford the desired product **1a1**.

3. General procedure for the preparation of *N*-protection isatin 2[3]



To a solution of isatins (1.0 equiv.) in DMF at 0 ℃ was added sodium hydride (1.2 equiv., 60% dispersion in mineral oil) in portions. After stirring for 15 minutes, triphenylmethyl chloride (1.2 equiv.) was added. When TLC showed the reaction was finished, cooled water was added to the reaction mixture to afford a suspension and the resultant mixture was filtered, washed with water and petroleum ether, respectively. The solid was recrystallized from ethanol to afford **2**.

4. Preparation of 3-(2,2-dipropionylcyclopropyl)propanal 1a2[4]



Step 1: To a solution of the corresponding acrolein **S_6** (89.2 mmol, 1.0 equiv.) and Ethyl Bromomalonate (89.2 mmol, 1.0 equiv.) were dissolved in DMF (100 mL) and added potassium carbonate (133.8 mmol, 1.5 equiv.). The reaction mixture was then heated to 60 ºC and reacted overnight. The organic phase was washed with satuated $NaHCO_3$ (120 mL) water (120 mL) and brine (120 mL), respectively. The organic phase was dried over anhydrous sodium sulfate, and filtered. The solvent was removed under reduced pressure to afford the product **S_7** which was used for the next step without purification

Step 2: In a 200 ml dry Schlenk round-bottom flask, **S_7** (30.0 mmol, 1.0 equiv.) was dissolved in MeCN (100 mL), to this solution triphenyl phophonium ylide (36.0 mmol, 1.2 equiv.) was added and the reaction mixture was stirred for 4 h at 100 °C. The crude product was purified by column chromatography on silica gel with PE/EtOAc (10:1) as the eluent to afford the desired product **S_8**.

Step 3: To a 100 mL flame-dry Schlenk reaction tube equipped with a magnetic stir bar was added compound **S_8** (5.0 mmol) and excess Pd/C, the Schlenk tube was sealed with a septum, evacuated and refilled with H_2 (3 cycles, balloon). THF (30 mL) was then added via syringe. The reaction mixture was allowed to stir for 4 h at room temperature. The mixture was concentrated

under reduced pressure, the resulting crude residue was purified via column chromatography on silica gel to afford the desired product **1c**.

Refrences:

[1] E. S. Diez, D. L. Vesga, E. Reyes, U. Uria, L. Carrillo, J. L. Vicario. *Org. Lett.* **2016**, *18*, 1270-1273.

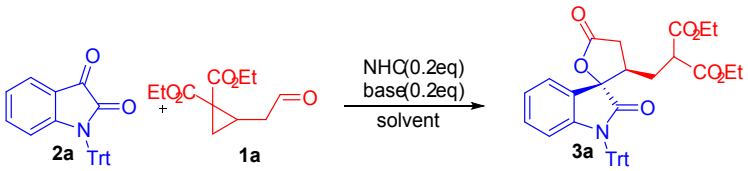
[2] S. Bera, C. G. Daniliuc, A. Studer. *Org. Lett.* **2015**, *17*, 4940-4943.

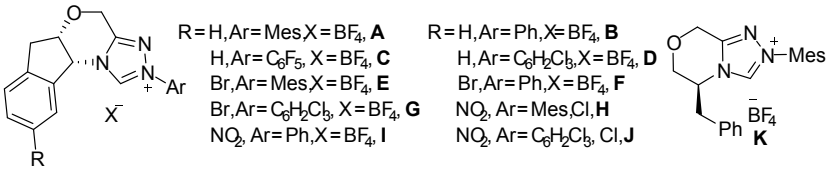
[3] R.S. Ding, Z. A. D. Santos, C. Wolf. *ACS.* Catal. **2019,** *9*, 2169-2176.

[4] S. B. Poh, J. Y. Ong, S. Lu, Y. Zhao, *Angew. Chem. Int. Ed.* **2018**, *57*, 1645-1649.

Ⅲ. Condition optimization

Table 1. Screening of different carbene catalysts, bases and solvents[a]

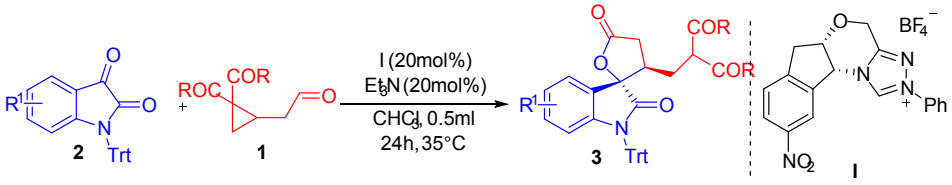




entry	NHC	base	solvent	yield (%)[b]	er[c]	dr[d]
1	**A**	Et_3N	$CHCl_3$	47	58:42	3:1
2	**B**	Et_3N	$CHCl_3$	48	81:19	5:1
3	**C**	Et_3N	$CHCl_3$	37	46:54	2:1
4	**D**	Et_3N	$CHCl_3$	30	37:63	2:1
5	**E**	Et_3N	$CHCl_3$	40	79:21	2:1
6	**F**	Et_3N	$CHCl_3$	50	94:6	8:1
7	**G**	Et_3N	$CHCl_3$	25	88:12	9:1
8	**H**	Et_3N	$CHCl_3$	45	93:7	5:1
9	**I**	Et_3N	$CHCl_3$	47	98:2	>20:1
10	**J**	Et_3N	$CHCl_3$	49	94:6	6:1
11	**K**	Et_3N	$CHCl_3$	33	45:55	9:1
12	**I**	DMAP	$CHCl_3$	<10	-	-
13	**I**	DABCO	$CHCl_3$	<10	-	-
14	**I**	t-BuOK	$CHCl_3$	19	99:1	1:1
15	**I**	NaOAc	$CHCl_3$	16	99:1	2:1
16	**I**	Et_3N	MeCN	15	90:10	4:1
17	**I**	Et_3N	PhMe	<5	-	-
18	**I**	Et_3N	DCM	26	94:6	4:1
19	**I**	Et_3N	DCE	18	97:3	4:1
20[e]	**I**	Et_3N	$CHCl_3$(0.1 M)	67	98:2	>20:1
21[e]	**I**	Et_3N	$CHCl_3$(0.2 M)	82	98:2	>20:1
22[e]	**I**	Et_3N	$CHCl_3$(0.5 M)	63	98:2	>20:1

[a]General conditions: **2a** (0.10mmol), **1a** (0.15mmol), NHC (0.02mmol), base (0.02mmol), $CHCl_3$ (2.0 mL), 35°C, 24 h. [b]Isolated yield of **3a**. [c]er values were determined via HPLC on chiral stationary phase (ID column, 0.8 mL/min, hexanes / iPrOH = 90 / 10). [d]dr values were determined by ^1H NMR on the crude product. [e]**2a** (0.10mmol), **1a** (0.2 mmol), **I** (0.02 mmol), base (0.02mmol), $CHCl_3$ (0.5 mL), 35 °C, 24 h. Trt = Triphenylmethyl, DMAP = 4-Dimethylaminopyridine, DABCO = Triethylenediamine, DCM = Dichloromethane, DCE = 1,2-Dichloroethane.

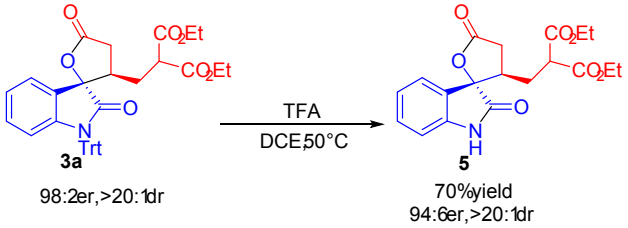
Ⅳ. General procedure



To a 4 mL vial equipped with a magnetic stir bar was added chiral pre-catalyst triazolium salt **I** (20 mol %, 0.02 mmol, 8.4 mg), isatin **2** (0.1 mmol), Cyclopropanyl aldehyde **1** (0.2 mmol) and Et_3N (20 mol %, 0.02 mmol, 2.8 μL), dry chloroform (0.5 mL)was added via syringe. The reaction mixture was allowed to stir for 24 hours at 35 °C, and then completion of the reaction monitored by TLC, the mixture was concentrated under reduced pressure, and the residue was purified via column chromatography on silica gel with Hexane/EtOAc (10:1) to afford the desired product **3**.

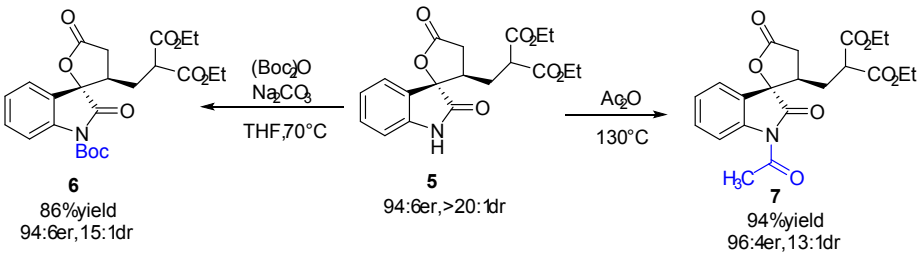
Ⅴ. Synthetic transformations of product 3a.

1. Preparation of **5** from product **3a**.



Compound **3a** (200 mg, 0.3 mmol) was dissolved in dry DCE (5 mL), then TFA (3 mmol) was added dropwise at 50 °C, after that the mixture was stirred for 24 h. The mixture was neutralized with saturated $NaHCO_3$ and extracted with DCM. The combined organic layerwas dried over Na_2SO_4, filtrated and concentrated to give crude product. The crude product was purified by column chromatography on silica gel with Hexane/EtOAc (5:1) as the eluent to afford the desired product **5** (85 mg, 70% yield).

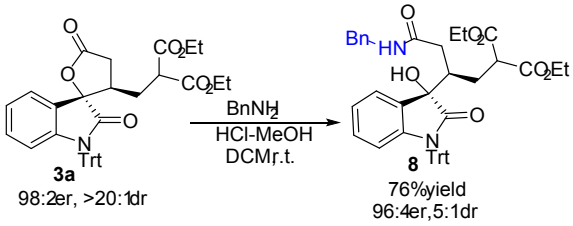
2. Preparation of both product **6** and **7** from **5**.



Both compound **5** (20 mg, 0.05 mmol) and Na_2CO_3 (45 mg, 0.42 mmol) were placed in a dry flask (10 mL) and dissolved in dry THF (1 mL), then di-tert-butyl decarbonate (0.5 mmol) was added dropwise and the resultant mixture was stirred for 7 h at 70 °C. The reaction was quenched with water and neutralized with saturated $NaHCO_3$, extracted with EtOAc. The combined the organic layer was dried over Na_2SO_4, filtrated and concentrated to give crude product. The crude product was purified by column chromatography on silica gel with Hexane/EtOAc (8:1) to afford the desired product **6** (22 mg, 86% yield).

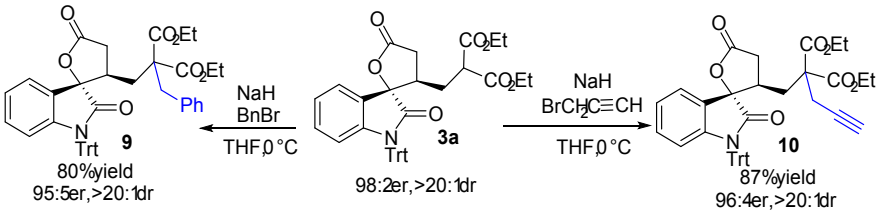
Compound **5** (20 mg, 0.05 mmol) was placed in a dry flask (10 mL) and acetic anhydride (0.5 mmol) was added dropwise and the resultant mixture was stirred for 4 h at at 130 °C. The mixture was quenched with water and neutralized with saturated $NaHCO_3$, extracted with EtOAc. The combined organic layer was dried over Na_2SO_4, filtrated and concentrated to give crude product. The crude product was purified by column chromatography on silica gel with Hexane/EtOAc (8:1) as the eluent to afford the desired product **7** (21 mg, 94% yield).

3. Preparation of product **8** from **3a.**



To a stirred solution of this **3a** (90 mg, 0.15 mmol) in DCM (2 mL) was added benzylamine (47 mg, 0.44 mmol) and HCl in MeOH (0.5 ml, HCl/MeOH = 1/10), the mixture was stirred at ambine temperature for 2 h. The solvent was evaporated and the residue was purified by column chromatography on silica gel with Hexane/EtOAc (3:1) to afford the desired product **8** (80 mg, 76% yield).

4. Preparation of both **9** and **10** from **3a**.

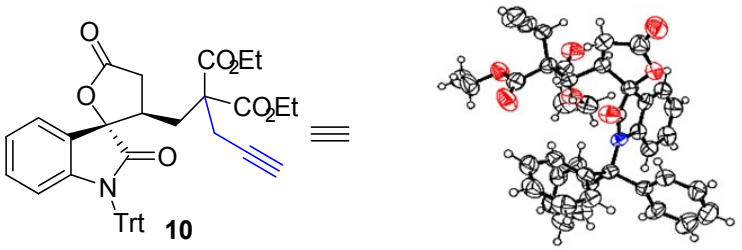


To the slurry of NaH (3.03 mg, 0.075 mmol) in THF (1 mL) was added dropwise a mixture of both **3a** and THF at 0 °C. After 20 min, to the above reaction system the solution combining 0.5 mL of THF with benzyl bromide (9.97 mg, 0.06 mmol) was added and further stirred for 30 min at room temperature. Then the reaction mixture was treated with saturated ammonium chloride solution to eliminate redundant NaH, extracted with EtOAc. The combined organic layer was dried over Na_2SO_4, filtrated and concentrated to give crude product. The crude product was purified by column chromatography on silica gel with Hexane/EtOAc (3:1) to afford the desired product **9** (27.5 mg, 80% yield).

Compound **3a** (30 mg, 0.05 mmol) dissolved in dry THF (1 mL) was added dropwise to the slurry of NaH (3.03 mg, 0.075 mmol) in THF (1 mL) at 0 °C. After 20 min, to the above reaction system the solution combining 0.5 mL of THF with 3-bromorpropyne (7 mg, 0.06 mmol) was added and further stirred at room temperature for 30 min. Then the mixture was treated with saturated ammonium chloride solution to eliminate redundant NaH, extracted with EtOAc.The combined the organic layer was dried over Na_2SO_4, filtrated and concentrated to give crude product. The crude product was purified by column chromatography on silica gel with Hexane/EtOAc (10:1) to afford the desired product **10** (28 mg, 87% yield).

VI. *X*-ray crystallography of compound

Good quality crystal of **10** (Colorless needle crystals) was obtained by vaporization of a dichloromethane / petroleum ether solution of compound **10** (~50 mg). CCDC 1962651 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre via https://www.ccdc.cam.ac.uk/.



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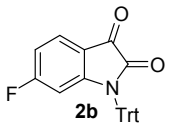
VII. Characterization of intermediates & products

6-fluoro-1-tritylindoline-2, 3-dione (2b):



2b

Yellow solid, 2.8 g, yield 75%; m.p. 193-195 ℃;

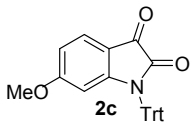
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.61 (dd, *J* = 8.5, 6.0 Hz, 1H), 7.45 – 7.42 (m, 6H), 7.32 – 7.24 (m, 9H), 6.68 (td, *J* = 8.5, 2.0 Hz, 1H), 6.07 (dd, *J* = 10.5, 2.0 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 180.8, 167.5 (d, *J* = 259.3 Hz), 159.5, 154.7 (d, *J* = 13.6 Hz), 140.8 , 129.2, 128.2, 127. 6, 127.2 (d, *J* = 11.9 Hz), 115.6 (d, *J* = 2.0 Hz), 110.7 (d, *J* = 23.3 Hz), 106.3 (d, *J* = 29.9 Hz), 75.7.

^{19}F NMR (565 MHz, $CDCl_3$) δ -93.6.

HRMS (ESI, m/z): Mass calcd. for $C_{27}H_{18}O_2NFNa^+$ $[M+Na]^+$, 430.1214; found: 430.1205.

6-methoxy-1-tritylindoline-2, 3-dione (2c):



2c

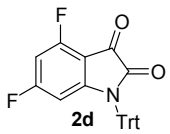
Yellow solid, 2.5 g, yield 70%; m.p. 221-223 ℃;

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.0f Hz, 1H), 7.46 – 7.42 (m, 6H), 7.30 – 7.23 (m, 9H), 6.46 (dd, *J* = 8.5, 2.0 Hz, 1H), 5.85 (d, *J* = 2.0 Hz, 1H), 3.54 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 180.1, 166.6, 160.7, 154.6, 141.3, 129.3, 127.9, 127.3, 127.0, 112.9, 108.7, 104.2, 75.3, 55.7.

HRMS (ESI, m/z): Mass calcd. for $C_{28}H_{21}O_3NNa^+$ $[M+Na]^+$, 442.1414; found: 442.1415.

4,6-difluoro-1-tritylindoline-2,3-dione (2d):



2d

Yellow solid, 2.5 g, yield 71%; m.p. 189-191 ℃;

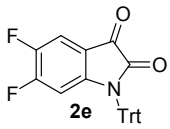
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 – 7.39 (m, 5H), 7.32 – 7.26 (m, 10H), 6.42 – 6.36 (m, 1H), 5.91 (dd, *J* = 10.0, 1.5 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.7, 168.3 (dd, *J* = 261.3, 13.4 Hz), 159.7 (dd, *J* = 269.0, 16.1 Hz), 158.9, 154.1 (dd, *J* = 15.7, 7.3 Hz), 140.5, 129.1, 128.2, 128.0, 127.3, 104.5 (dd, *J* = 18.2, 2.6 Hz), 102.8 (d, *J* = 29.9, 3.5 Hz), 99.5 (d, *J* = 27.0, 22.9 Hz), 76.1.

^{19}F NMR (565 MHz, CDCl3) δ -89.6 (d, *J* = 15.8), -103.0 (d, *J* = 16.0).

HRMS (ESI, m/z): Mass calcd. for $C_{27}H_{17}O_2NF_2Na^+$ $[M+Na]^+$, 448.1119; found: 448.1109.

5,6-difluoro-1-tritylindoline-2,3-dione (2e):



2e

Brownish yellow solid, 1.2 g, yield 34%; m.p. 190-192 ℃;

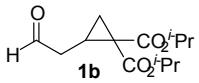
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.45 – 7.40 (m, 7H), 7.33 – 7.27 (m, 9H), 6.22 (dd, *J* = 11.5, 6.0 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 180.5, 158.8, 155.1 (dd, *J* = 261,5, 13.9 Hz), 149.7 (d, *J* = 13.3 Hz), 147.0 (dd, *J* = 250.0, 13.7 Hz), 140.5, 129.1, 128.1, 127.7, 114.7(dd, *J* = 4.0, 3.9 Hz), 113.4 (dd, *J* = 19.6, 3.0 Hz), 108.0 (d, *J* = 25.7 Hz), 75, 8.

^{19}F NMR (565 MHz, $CDCl_3$) δ-118.2 (d, *J* = 20.1 Hz), -142.6 (d, *J* = 20.1 Hz).

HRMS (ESI, m/z): Mass calcd. for $C_{27}H_{17}O_2NF_2Na^+$ $[M+Na]^+$, 448.1119; found: 448.1114.

diisopropyl 2-(2-oxoethyl)cyclopropane-1,1-dicarboxylate (1b):



1b

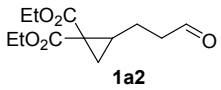
Light yellow oil, 1.2 g, yield 48%;

^{1}H NMR (500 MHz, $CDCl_3$) δ 9.72 (s, 1H), 5.05 – 4.97 (m, 2H), 2.54 – 2.49 (m, 1H), 2.43 – 2.38 (m, 1H), 2.15 – 2.09 (m, 1H), 1.43 (dd, *J* = 9.0, 4.8 Hz, 1H), 1.30 (dd, *J* = 9.5, 5.0 Hz, 1H), 1.22 – 1.16 (m, 12H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 199.8, 169.2, 167.6, 69.2, 69.2, 42.7, 33.5, 21.7, 21.6, 21.6, 21. 6, 20. 6, 19.9.

HRMS (ESI, m/z): Mass calcd.for $C_{13}H_{21}O_5^+$ $[M+H]^+$,256.1305; found: 256.1294.

3-(2,2-dipropionylcyclopropyl)propanal (1a2):



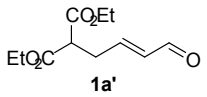
1a2

Colorless oil, 600 mg, yield 60%;

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.82 – 9.73 (m, 1H), 4.23 – 4.16 (m, 4H), 2.62 (td, *J* = 7.2, 1.2 Hz, 1H), 2.46 (td, *J* = 7.2, 1.2 Hz, 1H), 1.96 – 1.86 (m, 2H), 1.71 – 1.63 (m, 2H), 1.40 – 1.30 (m, 1H), 1.30 – 1.20 (m, 6H).

HRMS (ESI, m/z): Mass calcd.for $C_{12}H_{18}O_5Na^+$ $[M+Na]^+$, 265.1046; found: 265.1047.

Diethyl (E)-2-(4-oxobut-2-en-1-yl)malonate (1a'):



1a'

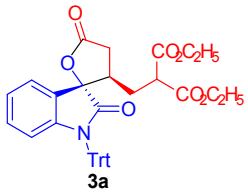
Light yellow oil, 0.6 g, yield 17%;

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.44 (d, *J* = 8.0 Hz, 1H), 6.76 (dt, *J* = 15.8, 6.8 Hz, 1H), 6.13 – 6.06 (m, 1H), 4.17 – 4.14 (m, 4H), 3.48 (t, *J* = 7.2 Hz, 1H), 2.85 (td, *J* = 6.8, 1.2 Hz, 2H), 1.21 (t, *J* = 6.8 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 192.5, 167.2, 151.9, 133. 6, 60.9, 49.4, 30.4, 13.0.

HRMS (ESI, m/z): Mass calcd. for $C_{11}H_{16}O_5Na^+$ $[M+Na]^+$, 251.0890; found: 251.0893.

Diethyl 2-(((2*R*,3*S*)-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl) malonate (3a):



3a

Colorless solid, 51 mg, yield 82%; m.p. 76-78 ℃;

[α]^{26}D = 14.0 (*c* 1.0 $CHCl_3$);

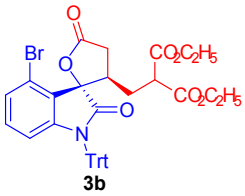
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 7.6 Hz, 6H), 7.29 – 7.22 (m, 10H), 7.04 – 6.96 (m, 2H), 6.38 – 6.31 (m, 1H), 4.21 – 4.09 (m, 4H), 3.20 (dd, *J* = 8.8, 6.8 Hz, 1H), 3.00 – 2.83 (m, 2H), 2.68 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.13 – 2.05 (m , 1H), 1.99 – 1.88 (m, 1H), 1.21 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.7, 174.2, 168.2, 144.6, 141.3, 129.9, 129.4, 127.9, 127.2, 124.6, 123.9, 123.3, 116.7, 84.8, 75.2, 61.8, 50.3, 43.3, 33.3, 27.7, 13.9.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{35}O_7NNa^+$ $[M+Na]^+$, 640.2306; found: 640.2309.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.9 mL/min, λ = 254 nm), Rt (minor) = 37.9 min, Rt (major) = 51.9 min.

Diethyl 2-(((2*R*,3*S*)-4'-bromo-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3b):



3b

Colorless solid, 51 mg, yield 73%; m.p. 64-66 ℃;

[α]^{26}D = 8.9 (*c* 1.0 $CHCl_3$).

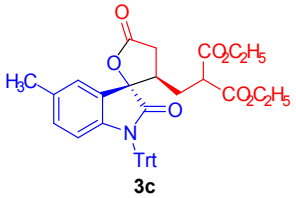
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.35 (m, 6H), 7.30– 7.22 (m, 9H), 7.14 – 7.07 (m, 1H), 6.87 – 6.82 (m, 1H), 6.42 – 6.31 (m, 1H), 4.24 –4.15 (m, 4H), 3.65 – 3.46 (m, 1H), 3.34 – 3.23 (m, 1H), 2.92 – 2.82 (m, 1H), 2.79 – 2.71 (m, 1H), 2.24 – 2.06 (m, 2H), 1.26 – 1.21 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.3, 174.0, 168.2, 146.4, 140.9, 130.9, 129.4, 127.9, 127.6, 127.4, 122.5, 119.3, 115.9, 85.6, 75.6, 62.3, 50.5, 38.9, 32.6, 28.5, 14.1.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{34}O_7NBrNa^+$ $[M+Na]^+$, 718.1410; found: 718.1410.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 53.7 min, Rt (major) = 59.6 min.

Diethyl 2-(((2*R*,3*S*)-5'-methyl-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3c):



3c

Colorless solid, 42 mg, yield 66%; m.p. 83-85 ℃;

[α]^{26}D = 2.2 (*c* 1.0 $CHCl_3$).

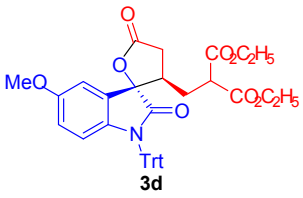
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.39 (m, 6H) 7.29– 7.19 (m, 9H), 7.02 (s, 1H), 6.78 (dd, *J* = 8.8, 2.0 Hz, 1H), 6.22 (d, *J* = 8.4 Hz, 1H), 4.22 – 4.09 (m, 4H), 3.24 – 3.12 (m, 1H), 3.01 – 2.82 (m, 2H), 2.74 – 2.56 (m, 1H), 2.22 (s, 3H), 2.15–2.08 (m, 1H), 2.00 – 1.91 (m, 1H), 1.25 – 1.18 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.7, 174.2, 168.2, 142.1, 141.4, 133.7, 130.5, 129.4, 127.8, 127.2, 124.6, 124.5, 116.5, 84.9, 75.1, 61.8, 50.4, 43.3, 33.4, 27.7, 20.8, 14.0.

HRMS (ESI, m/z): Mass calcd. for $C_{39}H_{38}O_7N^+$ $[M+H]^+$, 632.2642; found: 632.2622.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 38.2 min, Rt (major) = 58.4 min.

Diethyl 2-(((2*R*,3*S*)-5'-methoxy-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3d):



3d

Colorless solid, 50 mg, yield 77%; m.p. 82-84 ℃;

[α]^{26}D = 7.7 (*c* 0.7 $CHCl_3$).

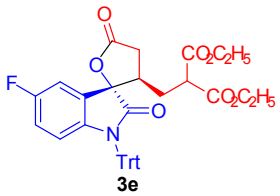
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.39 (m, 6H), 7.30 – 7.19 (m, 9H), 6.81 (d, *J* = 2.8 Hz, 1H), 6.53 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.24 (d, *J* = 8.8 Hz, 1H), 4.24 – 4.05 (m, 4H), 3.70 (s, 3H), 3.20 (dd, *J* = 8.8, 7.2 Hz, 1H), 3.00 – 2.82 (m, 2H), 2.68 (dd, *J* = 15.6, 7.6 Hz, 1H), 2.15 – 2.08 (m, 1H), 2.00 – 1.92 (m, 1H), 1.25 – 1.20 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.7, 174.1, 168.2, 156.0, 141.3, 137.5, 129.4, 127.8, 127.2, 125.8, 117.5, 115.2, 109.9, 84.9, 75.2, 61.8, 55.6, 50.4, 43.4, 33.4, 27.6, 14.1.

HRMS (ESI, m/z): Mass calcd. for $C_{39}H_{37}O_8NNa^+$ $[M+Na]^+$, 670.2411; found: 670.2415.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 75.7 min, Rt (major) = 87.1 min.

Diethyl 2-(((2*R*,3*S*)-5'-fluoro-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3e):



3e

Colorless solid, 53 mg, yield 83%; m.p. 74-76 ℃;

[α]^{26}D = 13.8 (*c* 1.0 $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40–7.38 (m, 6H), 7.30– 7.22 (m, 9H), 6.98 (dd, *J* = 7.2, 2.4 Hz, 1H), 6.71 (td, *J* = 8.8, 2.8 Hz, 1H), 6.30 (dd, *J* = 8.8, 4.0 Hz, 1H), 4.22 – 4.12 (m, 4H), 3.19 (dd, *J* = 8.8, 6.8 Hz, 1H), 2.99 – 2.81 (m, 2H), 2.69 (dd, *J* = 15.6, 7.4 Hz, 1H), 2.15– 2.07 (m, 1H), 2.00 – 1.92 (m, 1H), 1.31– 1.23 (m, 6H).

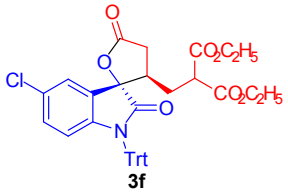
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.2, 174.1, 168.1, 159.0 (d, *J* = 240.4 Hz), 141.0, 140.3 (d, *J* = 9.1 Hz), 129.3, 127.9, 127.4, 126.4 (d, *J* = 8.1 Hz), 117.7 (d, *J* = 8.1 Hz), 116.7 (d, *J* = 23.2 Hz), 111.6 (d, *J* = 24.2 Hz), 84.4, 75.3, 61.9, 50.1, 43.2, 33.2, 27.6, 13.7.

^{19}F NMR (565 MHz, $CDCl_3$) δ -118.7.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{34}O_7NF^+$ $[M+Na]^+$, 658.2212; found: 658.2213.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 30.8 min, Rt (major) = 35.7 min.

Diethyl 2-(((2*R*,3*S*)-5'-chloro-2',5-dioxo-1'-trityl-4,5-dihydro-3H-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3f):



3f

Colorless solid, 45 mg, yield 69%; m.p. 85-87 ℃;

[α]^{26}D = 2.4 (*c* 1.0 $CHCl_3$).

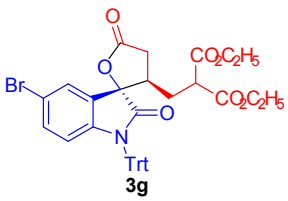
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.37 (m, 6H), 7.30 – 7.22 (m, 10H), 6.97 (dd, *J* = 7.6, 5.2 Hz, 1H), 6.29 (d, *J* = 8.8 Hz, 1H), 4.25 – 4.08 (m, 4H), 3.19 (dd, *J* = 8.4, 7.2 Hz, 1H), 2.98 – 2.80 (m, 2H), 2.69 (dd, *J* = 14.8, 6.8 Hz, 1H), 2.15 – 2.08 (m, 1H), 2.00 – 1.91 (m, 1H), 1.25 – 1.21 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.1, 173.8, 168.1, 143.1, 140.9, 130.0, 129.3, 129.0, 128.0, 127.4, 126.4, 124.3, 117.7, 84.3, 75.4, 61.9, 50.3, 43.3, 33.2, 27.6, 14.1.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{34}O_7NClNa^+$ $[M+Na]^+$, 674.1916; found: 674.1918.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 94:6 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 50.3 min, Rt (major) = 58.9 min.

Diethyl 2-(((2*R*,3*S*)-5'-bromo-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3g):



3g

Colorless solid, 50 mg, yield 72%; m.p. 94-96 ℃;

[α]^{26}D = 0.3 (*c* 1.0 $CHCl_3$).

^{1}H NMR (400 MHz, CDCl3) δ 7.39 – 7.37 (m, 7H), 7.30 – 7.22 (m, 9H), 7.12 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.23 (d, *J* = 8.8 Hz, 1H), 4.25 – 4.09 (m, 4H), 3.19 (dd, *J* = 8.4, 7.2 Hz, 1H), 2.98 – 2.80 (m, 2H), 2.69 (dd, *J* = 14.8, 6.4 Hz, 1H), 2.15 – 2.08 (m, , 1H), 1.99 – 1.93 (m, 1H), 1.25 – 1.21 (m, 6H).

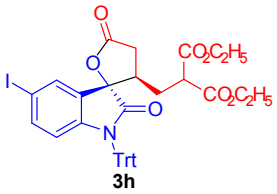
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.1, 173.7, 168.2, 143.6, 140.9, 132.9 129.3, 127.9, 127.4, 127.1, 126.7, 118.1, 116.3, 84.2, 75.4, 61.9, 50.3, 43.3, 33.2, 27.6, 14.1.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{35}O_7NBr^+$ $[M+H]^+$, 696.1591; found: 696.1582.

HPLC analysis: 94:6 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ =

254 nm), Rt (minor) = 26.1 min, Rt (major) = 30.7 min.

Diethyl 2-(((2*R*,3*S*)-5'-iodo-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3h):



3h

Colorless solid, 43 mg, yield 58%; m.p. 77-79 ℃;

[α]^{26}D = -4.7 (*c* 1.0 $CHCl_3$).

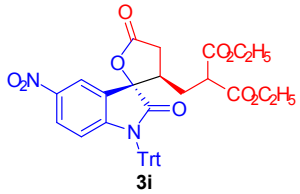
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, *J* = 1.6 Hz, 1H), 7.40 7.37 (m, 6H), 7.31 – 7.21 (m, 7H), 6.12 (d, *J* = 8.4 Hz, 1H), 4.24 – 4.11 (m, 4H), 3.20 (t, *J* = 8.0 Hz, 1H), 2.97 – 2.80 (m, 2H), 2.68 (dd, *J* = 14.4, 6.4 Hz, 1H) , 2.18 – 2.08 (m, 1H), 2.00 – 1.93 (m, 1H), 1.27 – 1.21 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.2, 173.6, 168.1, 144.5, 140.9, 138.6, 132.8, 129.3, 129.2, 128.0, 127.4, 127.0, 118.6, 86.6, 84.1, 77.3, 62.0, 50.4, 33.2, 27.9, 14.4.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{34}O_7NINa^+$ $[M+Na]^+$, 766.1272; found: 766.1274.

UPLC analysis: 98:2 er (Daicel Chiralcel ID column, 94:6 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (major) = 56.4 min, Rt (minor) = 69.7 min.

Diethyl2-(((2*R*,3*S*)-5'-nitro-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3i):



3i

Colorless solid, 50 mg, yield 75%; m.p. 103-105 ℃;

[α]^{26}D = 3.7 (*c* 1.0 $CHCl_3$).

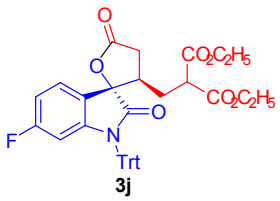
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 2.4 Hz, 1H), 7.95 (dd, J = 8.8, 2.0 Hz, 1H), 7.39 – 7.37 (m, 6H), 7.34 – 7.27 (m, 9H), 6.50 (d, *J* = 8.8 Hz, 1H), 4.18 (m, 4H), 3.20 (dd, *J* = 8.8, 6.4 Hz, 1H), 2.99 – 2.87 (m, 2H), 2.80– 2.65 (m, 1H), 2.15 – 2.04 (m, 1H), 1.99 – 1.89 (m, 1H), 1.25– 1.23 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.3, 174.1, 168.1, 168.1, 145.8, 140.8, 135.9, 129.3, 128.0, 127.5, 124.8, 123.4, 123.0, 117.1, 84.1, 75.5, 61.9, 50.2, 43.2, 33.2, 27.6, 14.0.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{35}O_9N_2^+$ $[M+H]^+$, 663.2257; found: 663.2272.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 47.2 min, Rt (major) = 63.1 min.

Diethyl 2-(((2*R*,3*S*)-6'-fluoro-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3j):



3j

Colorless solid, 48 mg, yield 76%; m.p. 77-79 ℃;

[α]^{26}D = 1.9 (*c* 1.0 $CHCl_3$).

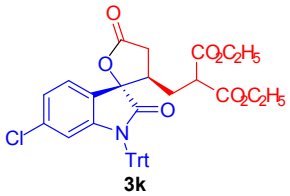
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.37 (m, 6H), 7.32 – 7.20 (m, 10H), 6.71 (td, *J* = 10.8, 2.4 Hz, 1H), 6.08 (dd, *J* = 10.4, 6.4 Hz, 1H), 4.24 – 4.08 (m, 4H), 3.18 (dd, *J* = 8.8, 6.4 Hz, 1H), 3.00 – 2.82 (m, 2H), 2.68 (dd, *J* = 14.8, 6.4 Hz, 1H), 2.09 – 2.01 (m, 1H), 1.94 – 1.85 (m, 1H), 1.25– 1.20 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.4,174.3, 168.2, 158.1, 163.3 (d, *J* = 248.5 Hz), 146.4 (d, *J* = 12.1 Hz), 140.9, 129.3, 128.0, 127.4, 125.2 (d, *J* = 10.1 Hz), 120.1 (d, *J* = 3.0 Hz), 110.1 (d, *J* = 23.2 Hz), 105.4 (d, *J* = 30.3 Hz), 84.2, 75.5, 61.9 , 50.2, 43.2, 33.3, 27.6, 14.1.

^{19}F NMR (565 MHz, $CDCl_3$) δ -106.9.

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{34}O_7NFNa^+$ $[M+Na]^+$, 658.2211; found: 658.2215.
HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 36.2 min, Rt (major) = 41.9 min.

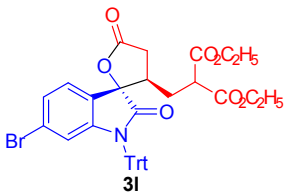
Diethyl 2-(((2*R*,3*S*)-6'-chloro-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3k):



3k

Colorless solid, 46 mg, yield 71%; m.p. 78-80 °C;
[α]^{26}D = 6.6 (*c* 1.0 $CHCl_3$).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.36 (m, 6H), 7.33 – 7.19 (m, 10H), 7.00 (dd, *J* = 8.0, 1.6 Hz, 1H), 6.29 (d, *J* = 1.6 Hz, 1H), 4.24 – 4.07 (m, 4H), 3.18 (dd, *J* = 8.8, 6.4 Hz, 1H), 2.97 – 2.80 (m, 2H), 2.68 (dd, *J* = 14.8, 6.4 Hz, 1H), 2.09 – 1.98 (m, 1H), 1.94 – 1.84 (m, 1H), 1.25 – 1.23 (m, 6H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.3, 174.1, 168.1, 145.7, 140.8, 135.9, 129.3, 128.0, 127.5, 124.8, 123.5, 123.0, 117.1, 84.1, 75.5, 61.9, 50.2, 43.2, 33.2, 27.6, 14.1.
HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{34}O_7NClNa^+$ $[M+Na]^+$, 674.1915; found: 674.1916.
HPLC analysis: 99:1 er (Daicel Chiralcel AD-H column, 70:30 hexanes/*i*-PrOH, 0.5 mL/min, λ = 254 nm), Rt (minor) = 51.9 min, Rt (major) = 81.0 min.

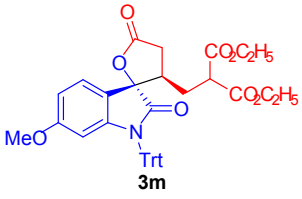
Diethyl 2-(((2*R*,3*S*)-6'-bromo-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3l):



3l

Colorless solid, 50 mg, yield 72%; m.p. 85-87 °C;
[α]^{26}D = 5.8 (*c* 1.0 $CHCl_3$).
^{1}H NMR (400 MHz, $CDCl_3$) 7.40 – 7.38 (m, 7H), 7.31 – 7.23 (m, 8H), 7.17 – 7.10 (m, 2H), 6.43 (d, *J* = 1.2 Hz, 1H), 4.20 – 4.11 (m, 4H), 3.18 (dd, *J* = 8.8, 6.8 Hz, 1H), 2.98 – 2.84 (m, 2H), 2.65 (dt, *J* = 14.4, 6.0 Hz, 1H), 2.07 – 1.98 (m, 1H), 1.93 – 1.84 (m, 1H), 1.26– 1.21 (m, 6H)
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.3, 173.9, 168.1, 145.8, 140.8, 129.3, 128.1, 127.5, 126.4, 125.1, 123.9, 123.5, 119.8, 84.2, 75.5, 61.9, 50.2, 43.1, 33.2, 27.6, 14.1.
HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{34}O_7NBrNa^+$ $[M+Na]^+$, 718.1410; found: 718.1418.
HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 92:8 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 48.1 min, Rt (major) = 53.5 min.

Diethyl 2-(((2*R*,3*S*)-6'-methoxy-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3m):



3m

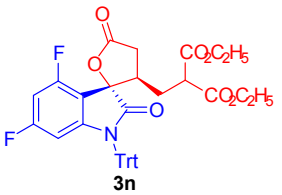
Colorless solid, 25 mg, yield 37%; m.p. 77-79 °C;
[α]^{26}D = 13.3 (*c* 1.0 $CHCl_3$).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.40 (m, 6H), 7.31 – 7.19 (m, 8H), 7.12 (d, *J* = 8.4 Hz, 1H), 6.49 (dd, *J* = 8.4, 2.4 Hz, 1H), 5.91 (d, *J* = 2.0 Hz, 1H), 4.22 – 4.09 (m, 4H), 3.48 (s, 3H), 3.23 – 3.12 (m, 1H), 3.00 – 2.80 (m, 2H), 2.71 – 2.52 (m, 1H), 2.07 – 1.98 (m, 1H), 1.92 – 1.83 (m, 1H), 1.26– 1.20 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.8, 174.5, 168.3, 160.9, 146.0, 141.3, 129.4, 129.3, 127.8, 127.3, 124.8, 116.2, 108.0, 104.3, 84.8, 75.2, 61.8, 55.3, 50.3, 43.1, 33.2, 27.6, 14.2.

HRMS (ESI, m/z): Mass calcd. for $C_{39}H_{38}O_8N^+$ $[M+H]^+$, 634.2421; found: 634.2435.

HPLC analysis: 98:2 er (Daicel Chiralcel AD-H column, 80:20 hexanes/*i*-PrOH, 0.5 mL/min, λ = 254 nm), Rt (minor) = 25.2 min, Rt (major) = 32.3 min.

Diethyl 2-(((2*R*,3*S*)-4',6'-difluoro-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3n):



3n

Colorless solid, 44 mg, yield 67%; m.p. 72-74 ℃;

[α]^{26}D = 10.9 (*c* 1.0 $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 – 7.33 (m, 6H), 7.33 – 7.19 (m, 9H), 6.50 – 6.23 (m, 1H), 5.96 – 5.87 (m, 1H), 4.25 – 4.12 (m, 4H), 3.27 – 2.98 (m, 2H), 2.89 (dt, *J* =16.8, 12.8 Hz, 1H), 2.76 – 2.59 (m, 1H), 2.10 – 2.06 (m, 1H), 1.99 – 1.91 (m, 1H), 1.26 – 1.21 (m, 6H).

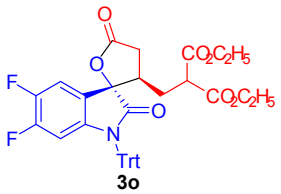
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.0, 173.6, 168.1, 168.1, 163.9 (dd, *J* = 250.5, 13.1 Hz), 159.7 (dd, *J* = 253.5, 14.11 Hz), 147.3 (dd, *J* = 14.1, 9.1 Hz), 140.6, 129.2, 128.1, 127.6, 106.6 (dd, *J* = 17.1, 3.0 Hz), 102.0 (dd, *J* = 30.3, 4.0 Hz), 99.2 (dd, *J* = 26.5, 23.9 Hz), 83.6, 75.9, 61.7, 52.5, 40.3, 33.0, 27.9, 14.0.

^{19}F NMR (377 MHz, $CDCl_3$) δ -102.93 (d, *J* = 8.4 Hz), -114.64 (d, *J* = 8.4 Hz).

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{33}O_7NF_2Na^+$ $[M+Na]^+$, 676.2117; found: 676.2121.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 92:8 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 28.3 min, Rt (major) = 35.2 min.

Diethyl 2-(((2*R*,3*S*)-5',6'-difluoro-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3o):



3o

Colorless solid, 43 mg, yield 66%; m.p. 76-78 ℃;

[α]^{26}D = 10.4 (*c* 1.0 $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.34 (m, 6H), 7.32 – 7.23 (m, 9H), 7.14 – 7.04 (m, 1H), 6.20 (dd, *J* = 11.6, 6.4 Hz, 1H), 4.25 – 4.11 (m, 4H), 3.24 – 3.12 (m, 1H), 2.98 – 2.88 (m, 1H), 2.88 – 2.77 (m, 1H), 2.68 (dd, *J* = 15.6, 7.6 Hz, 1H), 2.20 – 1.97 (m, 1H), 1.97 – 1.86 (m, 1H), 1.25 – 1.22 (m, 6H).

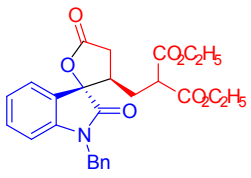
^{13}C NMR (101 MHz, $CDCl_3$) δ 174.0, 168.1, 150.8 (dd, *J* = 250.2, 13.6 Hz), 146.9 (dd, *J* = 247.3, 13.7 Hz), 141.1 (dd, *J* = 9.9, 2.6 Hz), 140.6, 129.2, 128.1, 127.6, 120.3 (dd, *J* = 5.7, 3.8 Hz), 113.3 (d, *J* = 20.2 Hz), 107.1 (d, *J* = 25.0 Hz), 84.0, 75.6, 62.0, 50.1, 43.3, 33.1, 27.6, 14.1.

^{19}F NMR (565 MHz, $CDCl_3$) δ -131.52 (d, *J* = 21.5 Hz), -143.03 (d, *J* = 20.7 Hz).

HRMS (ESI, m/z): Mass calcd. for $C_{38}H_{33}O_7NF_2Na^+$ $[M+Na]^+$, 676.2117; found: 676.2125.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 92:8 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 27.6 min, Rt (major) = 29.5 min.

Diethyl 2-(((2R,3S)-1'-benzyl-2',5-dioxo-4,5-dihydro-3H-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3p):



3p

Colorless solid, 30 mg, yield 64%; m.p. 63-65 ℃;

[α]^{26}D = 14.9 (*c* 0.7 $CHCl_3$).

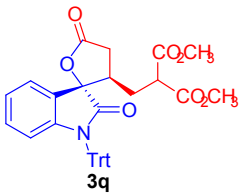
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.25 (m, 7H), 7.10 (t, *J* = 7.6 Hz, 1H), 6.76 (d, *J* = 7.6 Hz, 1H), 5.01 – 4.78 (m, 2H), 4.21 – 4.04 (m, 4H), 3.19 – 3.04 (m, 2H), 3.01 – 2.89 (m, 1H), 2.79 (dd, *J* = 16.0, 7.6 Hz, 1H), 2.16 – 2.03 (m, 1H), 1.94 – 1.84 (m, 1H), 1.25 – 1.17 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.6, 172.9, 168.2, 168.1, 135.0, 134. 7, 131.5, 129.0, 128.0, 127.3, 124.5, 124.4, 123.8, 110.1, 84.7, 62.0,49.9, 44.3, 43.3, 33.5, 27.7,13.6.

HRMS (ESI, m/z): Mass calcd. for $C_{26}H_{28}O_7N^+$ $[M+H]^+$, 466.1860; found: 466.1853.

HPLC analysis: 87:13 er (Daicel Chiralcel AD-H column, 80:20 hexanes/*i*-PrOH, 0.5 mL/min, λ = 254 nm), Rt (major) = 57.9 min, Rt (minor) = 41.4 min.

Dimethyl 2-(((2*R*,3*S*)-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3q):



3q

Colorless solid, 38 mg, yield 64%; m.p. 67-69 ℃;

[α]^{26}D = 14.3 (*c* 1.0 $CHCl_3$).

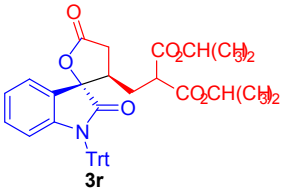
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.39 (m, 6H), 7.30 – 7.21 (m, 10H), 7.04 – 6.97 (m, 2H), 6.37 – 6.33 (m, 1H), 3.69 (d, *J* = 5.2 Hz, 6H), 3.19 (dd, *J* = 8.0, 6.8 Hz, 1H), 3.00 – 2.81 (m, 2H), 2.67 (dd, *J* = 15.2, 7.2 Hz, 1H), 2.13 – 2.02 (m, 1H), 1.94 – 1.84 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.6, 174.0, 168.6, 144.55, 141.3, 130.1, 129.3, 127.9, 127.2, 124.5, 123.9, 123.3, 116.7, 84.7, 75.2, 52.8, 49.9, 43.2, 33.3, 27.6.

HRMS (ESI, m/z): Mass calcd. for $C_{36}H_{31}O_7NNa^+$ $[M+Na]^+$, 612.1992; found: 612.2002.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 57.8 min, Rt (major) = 74.6 min.

Diisopropyl 2-(((2*R*,3*S*)-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3r):



3r

Colorless solid, 41 mg, yield 63%; m.p. 57-59 ℃;

[α]^{26}D = 16.6 (*c* 1.0 $CHCl_3$).

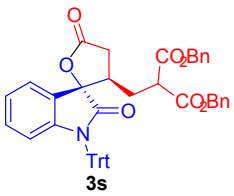
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.40 (m, 7H), 7.29– 7.21 (m, 9H), 7.01 – 6.96 (m, 2H), 6.37 – 6.34 (m, 1H), 5.05 – 4.98 (m, 2H), 3.17 (dd, *J* = 9.2, 6.4 Hz, 1H), 3.05 – 2.86 (m, 2H), 2.80 – 2.63 (m, 1H), 2.16 – 2.08 (m, 1H), 2.01 – 1.95 (m, 1H), 1.31 – 1.14 (m, 12H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.7, 174.4, 167.8, 144.6, 141.3, 129.9, 129.4, 127.9, 127.3, 124.6, 123.9, 123.3, 116.8, 84.9, 75.2, 69.5, 50.8, 43.4, 33.3, 27.6, 21.6.

HRMS (ESI, m/z): Mass calcd. for $C_{40}H_{39}O_7NNa^+$ $[M+Na]^+$, 668.2619; found: 668.2625.

HPLC analysis: 98:2er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 36.4 min, Rt (major) = 44.1 min.

Dibenzyl 2-(((2*R*,3*S*)-2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (3s):



3s

Colorless solid, 46 mg, yield 59%; m.p. 67-69 ℃;

[α]^{26}D = 29.3 (*c* 1.0 $CHCl_3$).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.34 (m, 7H), 7.36 – 7.28 (m, 7H), 7.26 – 7.17 (m, 13H), 7.08 – 7.01 (m, 1H), 6.99 – 6.88 (m, 2H), 6.40 – 6.27 (m, 1H), 5.16 – 5.01 (m, 4H), 3.34 – 3.15 (m, 1H), 2.95 – 2.81 (m, 1H),

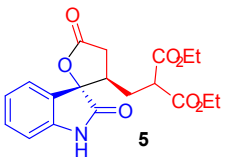
2.82 – 2.65 (m, 1H), 2.66 – 2.48 (m, 1H), 2.18 – 2.01 (m, 1H), 2.01 – 1.89 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.5, 174.1, 167.0, 167.8, 144.6, 141.2, 134.9, 130.0, 129.4, 128.7, 128.7, 128.6, 128.5, 128.4, 127.9, 127.2, 124.4, 124.0, 123.3, 116.7, 84.6, 75.2, 67.6, 50.36, 43.1, 33.3, 29.8, 27.7.

HRMS (ESI, m/z): Mass calcd. for $C_{48}H_{39}O_7NNa^+$ $[M+Na]^+$, 764.2619; found: 764.2628.

HPLC analysis: 98:2 er (Daicel Chiralcel ID column, 90:10 hexanes/*i*-PrOH, 0.8 mL/min, λ = 254 nm), Rt (minor) = 36.4 min, Rt (major) = 44.1 min.

Diethyl 2-((2',5-dioxo-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl)malonate (5):



5

Light yellow oil, 85 mg, yield 70%

[α]^{26}D = 0.4 (*c* 1.0 $CHCl_3$).

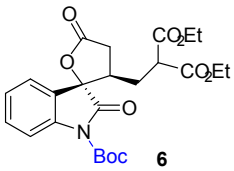
^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (s, 1H), 7.35 (td, *J* = 7.5, 1.0 Hz, 1H), 7.30 (dd, *J* = 7.5, 1.0 Hz, 1H), 7.12 (td, *J* = 8.0, 1.0 Hz, 1H), 6.91 (d, *J* = 8.0 Hz, 1H), 4.17 – 4.07 (m, 4H), 3.17 (dd, *J* = 8.5, 7.0 Hz, 1H), 2.99 (dd, *J* = 16.0, 7.0 Hz, 1H), 2.94 – 2.86 (m, 1H), 2.76 (dd, *J* = 16.0, 7.5 Hz, 1H), 2.12 – 2.06 (m, 1H), 1.95 – 1.86 (m, 1H), 1.22 – 1.17(m, 6H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 174.6, 174.4, 168.3, 141.5, 131.6, 124.8 , 124.8, 123.8, 110.8, 85.1, 61.9, 50.2, 43.0, 33.2, 27.4, 14.0.

HRMS (ESI, m/z): Mass calcd. for $C_{19}H_{22}O_7N^+$ $[M+H]^+$, 376.1391; found: 376.1390.

HPLC analysis: 94:6 er (Daicel Chiralcel AD-H column, 85:15 hexanes/*i*-PrOH, 0.6 mL/min, λ = 254 nm), Rt (minor) = 37.5 min, Rt (major) = 24.8 min.

Diethyl 2-((1'-(tert-butoxycarbonyl)-2',5-dioxo-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin] -3-yl)methyl)malonate (6):



6

Colorless solid, 22 mg, yield 86%; m.p. 94-96 ℃;

[α]^{26}D = 2.1 (*c* 1.0 $CHCl_3$)

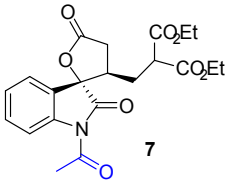
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 8.0 Hz, 1H), 7.42 – 7.38 (m, 1H), 7.29 (dd, *J* = 7.6, 1.2 Hz, 1H), 7.21– 7.17 (m, 1H), 4.11 – 3.99 (m, 4H), 3.07 (dd, *J* = 8.8, 6.8 Hz, 1H), 2.96– 2.79 (m, 2H), 2.70 (dd, *J* = 15.2, 7.2 Hz, 1H), 2.01– 1.94 (m, 1H), 1.83 – 1.76 (m, 1H), 1.57 (s, 9H), 1.16 – 1.10 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ174.0, 171.5, 168.2, 168.1, 148.4, 140.8, 131.8, 125.5, 124.3, 123.3, 115.8, 85.4, 84.6, 61.9, 50.1, 43.8, 33.2, 28.0, 27.2, 14.0

HRMS (ESI, m/z): Mass calcd. for $C_{24}H_{29}O_9NNa^+$ $[M+Na]^+$, 498.1735; found: 498.1732.

HPLC analysis: 94:6 er (Daicel Chiralcel AD-H column,80:20 hexanes/*i*-PrOH, 0.5 mL/min, λ = 254 nm), Rt (minor) = 14.7 min, Rt (major) = 12.6 min.

Diethyl 2-((1'-acetyl-2',5-dioxo-4,5-dihydro-3H-spiro[furan-2,3'-indolin]-3-yl) methyl)malonate (7):



7

Light yellow oil, 21 mg, yield 94%

[α]^{26}D = 1.0 (*c* 0.5 $CHCl_3$)

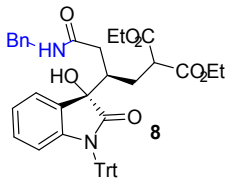
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 8.4 Hz, 1H), 7.44 – 7.38 (m, 1H), 7.32 (dd, *J* = 7.6, 1.0 Hz, 1H), 7.23 (td, *J* = 7.6, 0.8 Hz, 1H), 4.08 – 3.97 (m, 4H), 3.04 (dd, *J* = 8.0, 6.8 Hz, 1H), 2.91 – 2.82 (m, 2H), 2.79 – 2.71 (m, 1H), 2.61 (s, 3H), 2.01 – 1.92 (m, 1H), 1.83 – 1.75 (m, 1H), 1.15 – 1.08 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 174.6, 174.4, 168.3, 168.2, 139.0, 129.9, 124.2, 122.1, 121.6, 15.1, 82.8, 59.9, 48.0, 41.9, 31.2, 25.3, 24.5, 11.9.

HRMS (ESI, m/z): Mass calcd. for $C_{21}H_{24}O_8N^+$ $[M+H]^+$, 418.1496; found: 418.1490.

HPLC analysis: 96:4 er (Daicel Chiralcel AD-H column, 80:20 hexanes/*i*-PrOH, 0.5 mL/min, λ = 254 nm), Rt (minor) = 32.7 min, Rt (major) = 42.2 min.

Diethyl 2-(4-(benzylamino)-2-(3-hydroxy-2-oxo-1-tritylindolin-3-yl)-4-oxobutyl)malonate (8):



Colorless solid, 80 mg, yield 76%; m.p. 68-70 ℃;

[α]^{26}D = -19.0 (*c* 1.0 $CHCl_3$)

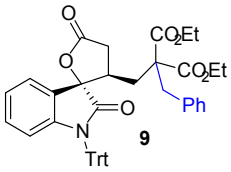
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.42 (m, 6H), 7.33 – 7.15(m, 16H), 6.97 – 6.91 (m, 2H), 6.26 (d, *J* = 7.6 Hz, 1H), 5.97 (t, *J* = 5.6 Hz, 1H), 4.37 (d, *J* = 5.6 Hz, 2H), 4.16 – 4.11 (m, 4H), 3.46 (dd, *J* = 10.4, 5.6 Hz, 1H), 2.81 (dd, *J* = 15.6, 4.8 Hz, 1H), 2.53 – 2.51 (m, 1H), 2.02 (dd, *J* = 13.6, 2.8 Hz, 1H), 1.95 – 1.90 (m, 1H), 1.79 – 1.72 (m, 1H), 1.22 – 1.09 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.9, 176.5, 167.5, 166.5, 141.7, 140.5, 139.5, 127.7, 127.6, 127.1, 126.2, 126.1, 125.6, 125.3, 122.2, 121.9, 121.2, 114.3, 73.1, 59.9, 57.0, 48.7, 42.3, 39.6, 34.1, 28.0.

HRMS (ESI, m/z): Mass calcd. for $C_{45}H_{44}O_7N_2Na^+$ $[M+Na]^+$, 747.3041; found: 747.3036.

HPLC analysis: 96:4 er (Daicel Chiralcel IA column, 90:10 hexanes/*i*-PrOH, 0.5 mL/min, λ = 254 nm), Rt (minor) = 21.9 min, Rt (major) = 19.1 min.

Diethyl 2-benzyl-2-((2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin] -3-yl)methyl)malonate (9):



Colorless solid, 27.5 mg, yield 80%; m.p. 62-64 ℃;

[α]^{26}D = -27.7 (*c* 1.0 $CHCl_3$)

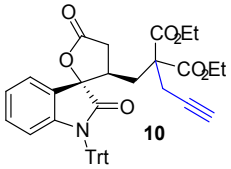
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.33 (m, 1H), 7.25 – 7.20 (m, 7H), 7.13 – 7.00 (m, 11H), 7.39 – 7.33 (t, *J* = 7.6 Hz, 2H), 6.48 – 6.40 (m, 2H), 6.39 – 6.32 (m, 1H), 4.29 – 4.21 (m, 1H), 4.07 – 3.96 (m, 3H), 3.22 (d, *J* = 14.0 Hz, 1H), 2.94 – 2.91 (m, 2H), 2.76 (dd, *J* = 16.8, 12.0 Hz, 1H), 2.55 (dd, *J* = 16.8, 8.4 Hz, 1H), 2.26 (dd, *J* = 14.0, 11.2 Hz, 1H), 2.06 – 1.96 (m, 1H), 1.19 (t, *J* = 7.2 Hz, 3H).), 1.05 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.8, 172.7, 169.0, 167.8, 142.7, 139.0, 132.7, 127.8, 127.7, 127.2, 126.3, 125.7, 125.0, 124.8, 122.8, 121.8, 121.3, 114.9, 83.1, 73.1, 56.0, 55.0, 39.0, 35.3, 31.2, 28.8, 11.6.

HRMS (ESI, m/z): Mass calcd. for $C_{45}H_{41}O_7NNa^+$ $[M+Na]^+$, 730.2775; found: 730.2778.

HPLC analysis: 95:5 er (Daicel Chiralcel IB column, 90:10 hexanes/*i*-PrOH, 0.4 mL/min, λ = 254 nm), Rt (minor) = 27.1 min, Rt (major) = 36.3 min.

Diethyl 2-((2',5-dioxo-1'-trityl-4,5-dihydro-3*H*-spiro[furan-2,3'-indolin]-3-yl)methyl) -2-(prop-2-yn-1-yl)malonate (10):



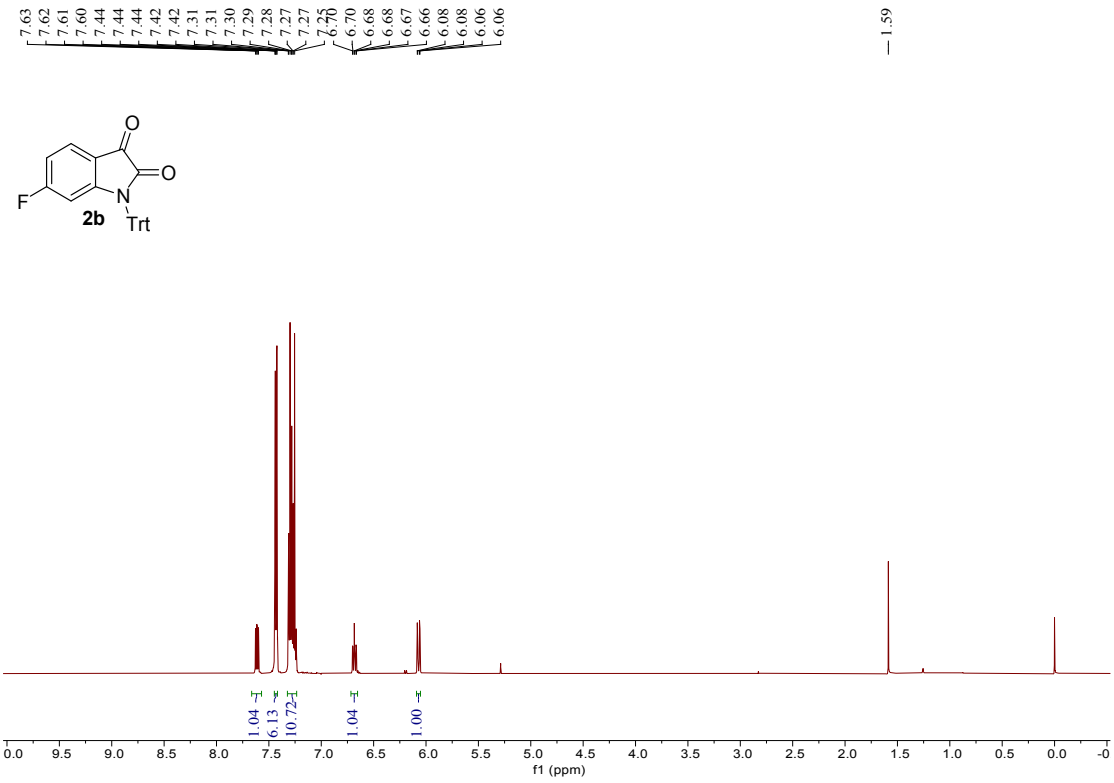
Colorless solid, 28 mg, yield 87%; m.p. 64-66 ℃;

[α]^{26}D = 4.5 (*c* 1.0 $CHCl_3$).

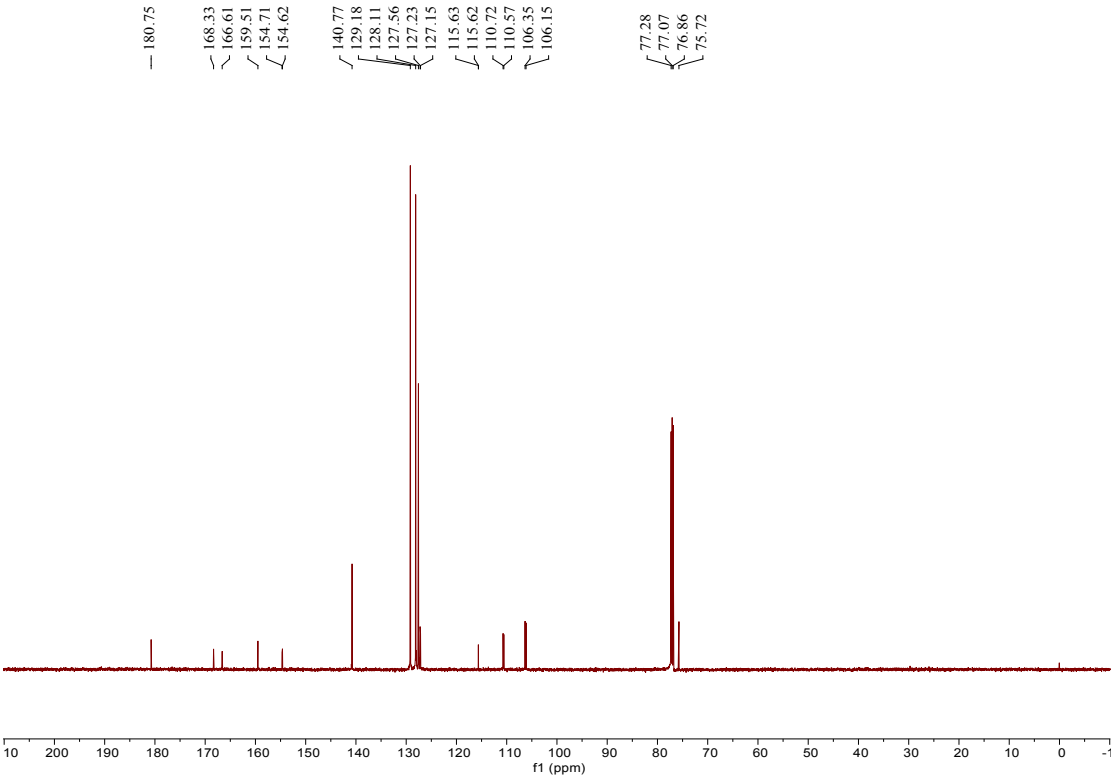
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.35 (m, 6H), 7.24 – 7.13 (m, 10H), 6.94 – 6.86 (m, 2H), 6.29 (dd, *J* = 6.8, 2.4 Hz, 1H), 4.13 – 4.03 (m, 3H), 3.92 – 3.92 (m, 1H), 2.88 (dd, *J* = 15.6, 11.2 Hz, 1H), 2.78 – 2.56 (m, 4H), 2.38 (dd, *J* = 14.0, 10.0 Hz, 1H), 2.29 – 2.23 (m, 1H), 1.63 (t, *J* = 2.4 Hz, 1H), 1.15 (t, *J* = 7.2 Hz, 3H), 1.02 (t, *J* = 7.2 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 173.6, 173.0, 168.0, 167.70, 143.20, 139.8, 128.1, 128.0, 126.3, 125.7, 123.0, 122.4, 121.6, 115.1, 83.8, 73.7, 70.8, 60.6, 54.2, 39.8, 32.7, 30.2, 21.5, 12.5, 12.4.
HRMS (ESI, m/z): Mass calcd. for $C_{41}H_{37}O_7NNa^+$ $[M+Na]^+$, 678.2462; found: 678.2473.
HPLC analysis: 96:4 er (Daicel Chiralcel IB column, 80:20 hexanes/*i*-PrOH, 0.5 mL/min, λ = 254 nm), Rt (minor) = 12.8 min, Rt (major) = 17.5 min.

Ⅷ. NMR spectra of intermediates & products

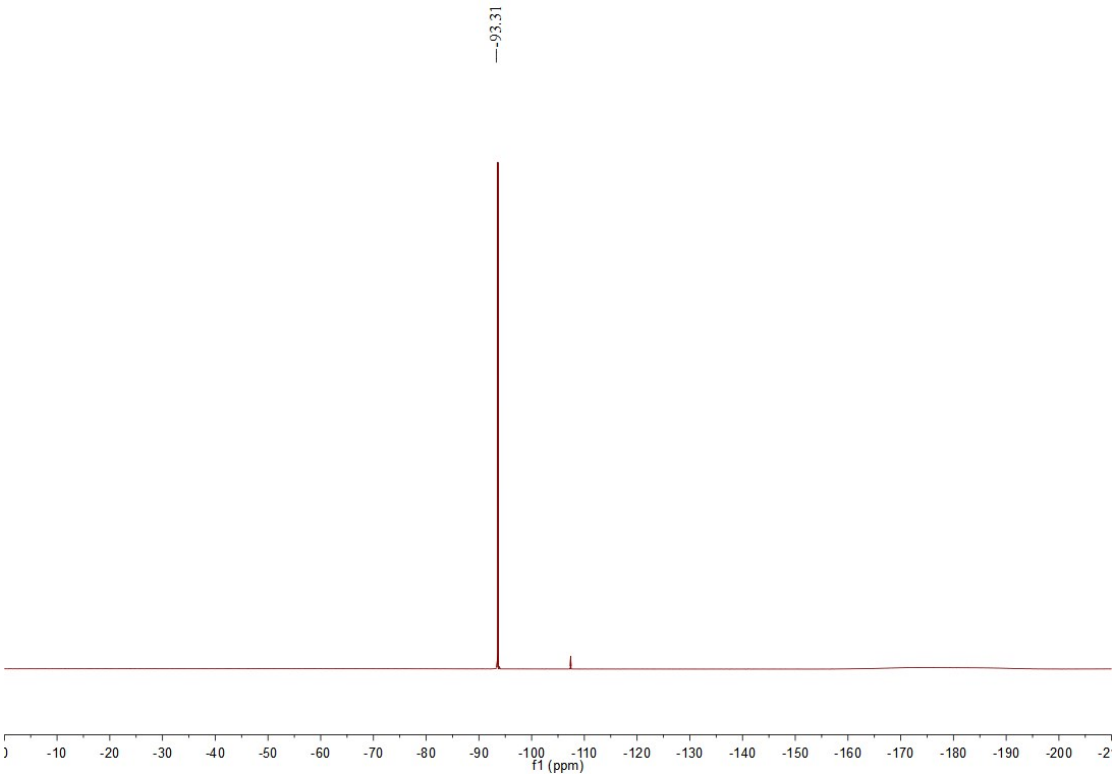
2b ^{1}H NMR (500 MHz, $CDCl_3$)



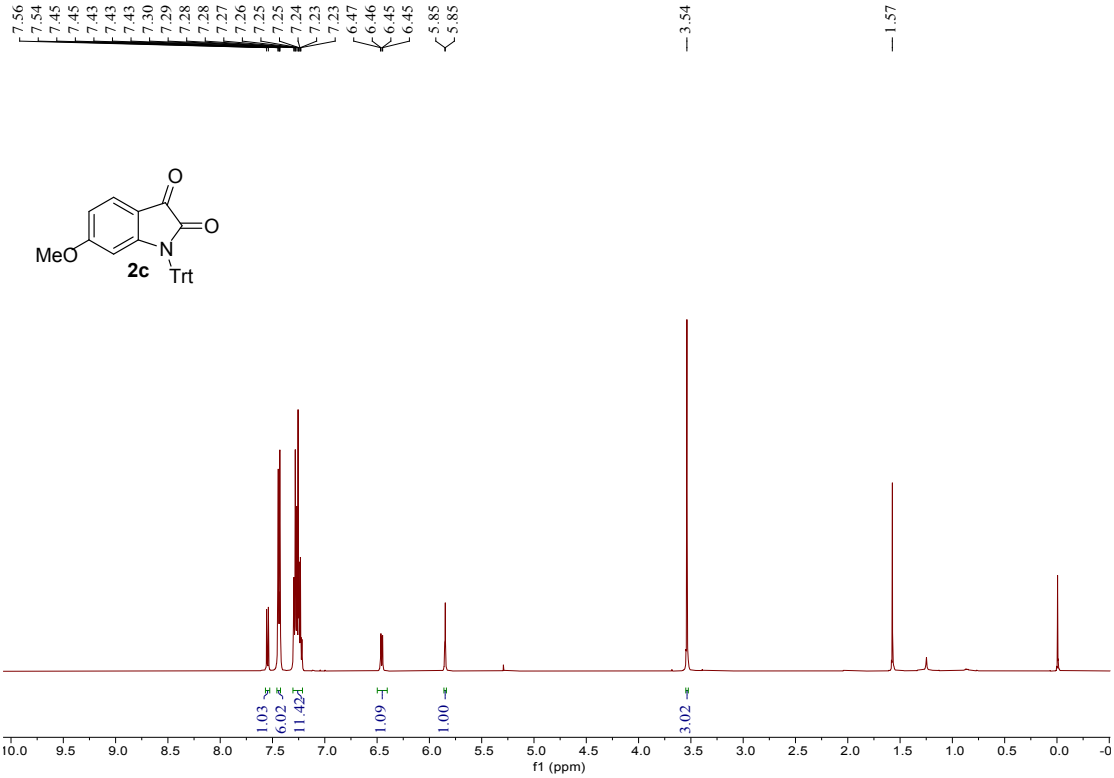
2b ^{13}C NMR (151 MHz, $CDCl_3$)



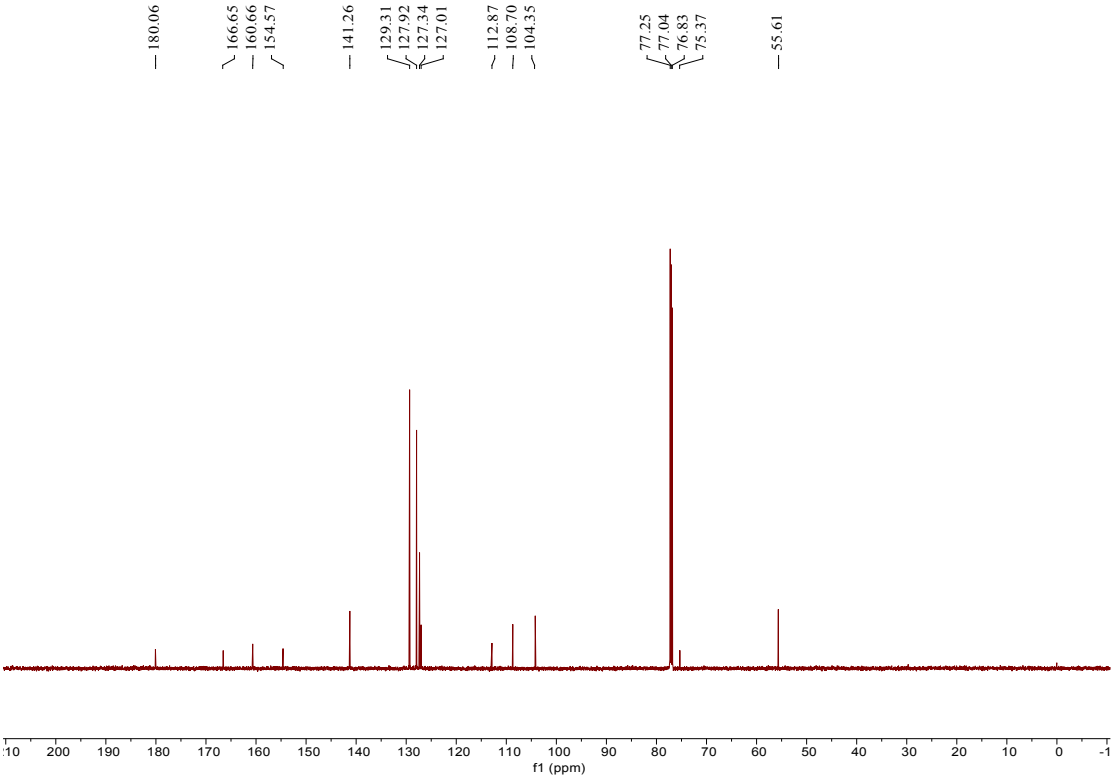
2b ^{19}F NMR (565 MHz, $CDCl_3$)



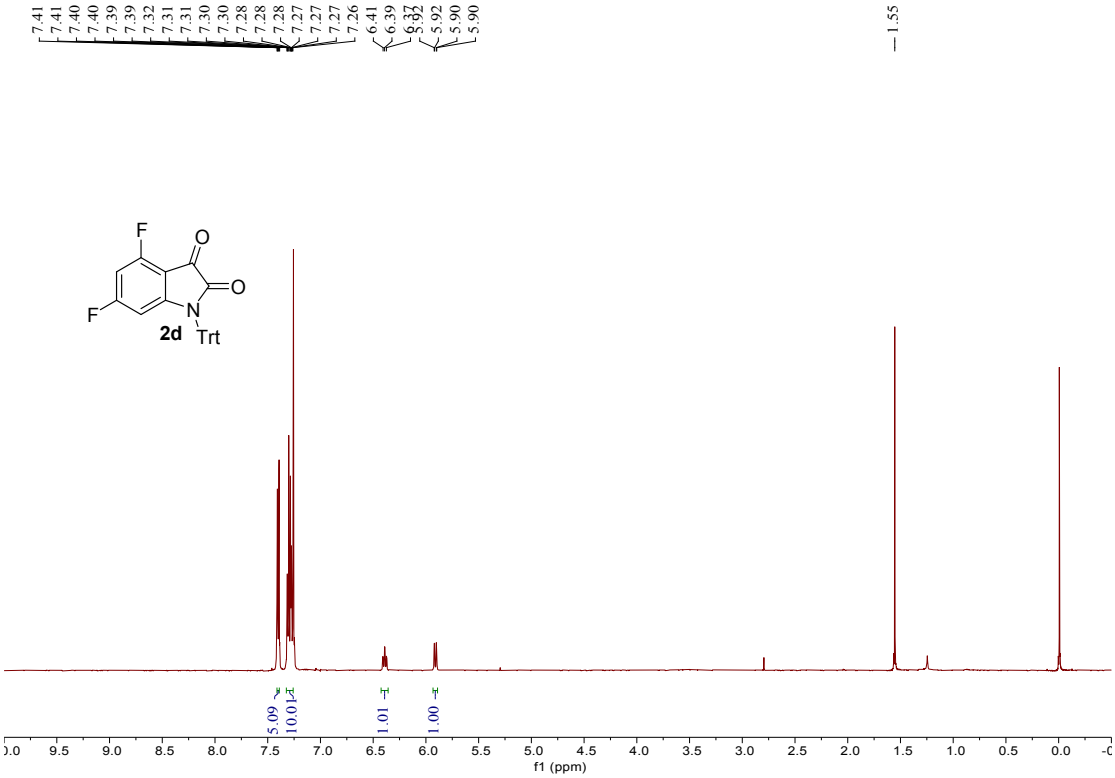
2c ^{1}H NMR (500 MHz, $CDCl_3$)



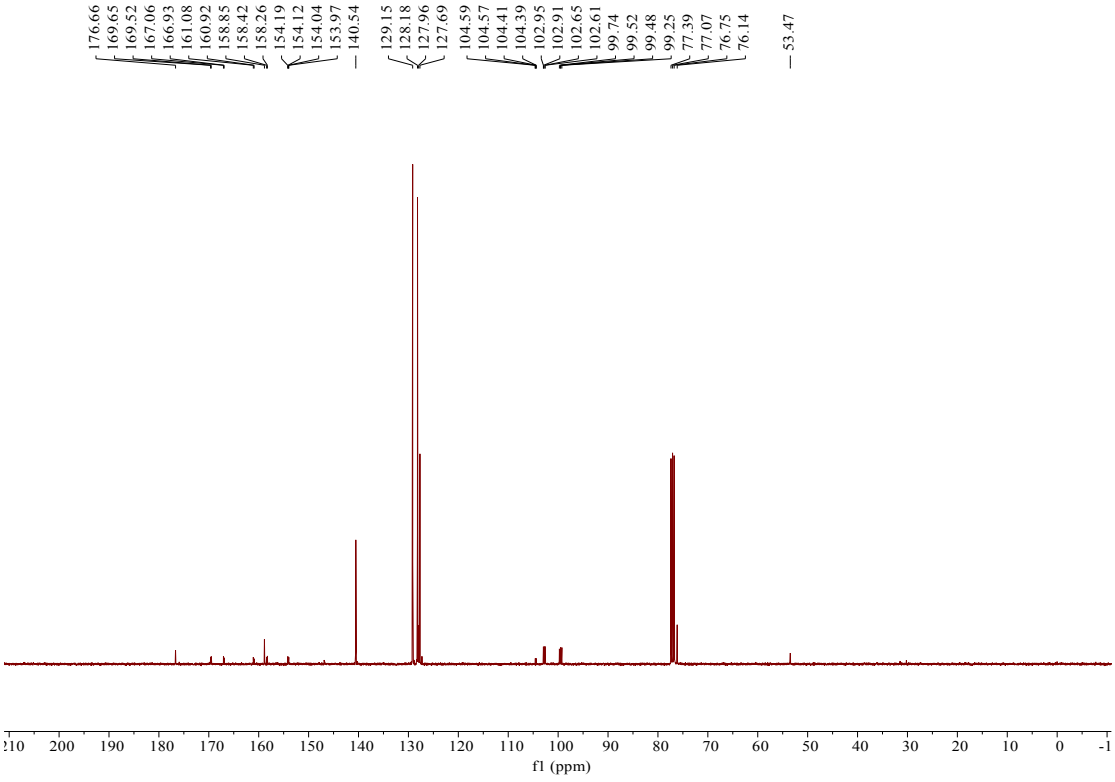
2c ^{13}C NMR (151 MHz, $CDCl_3$)



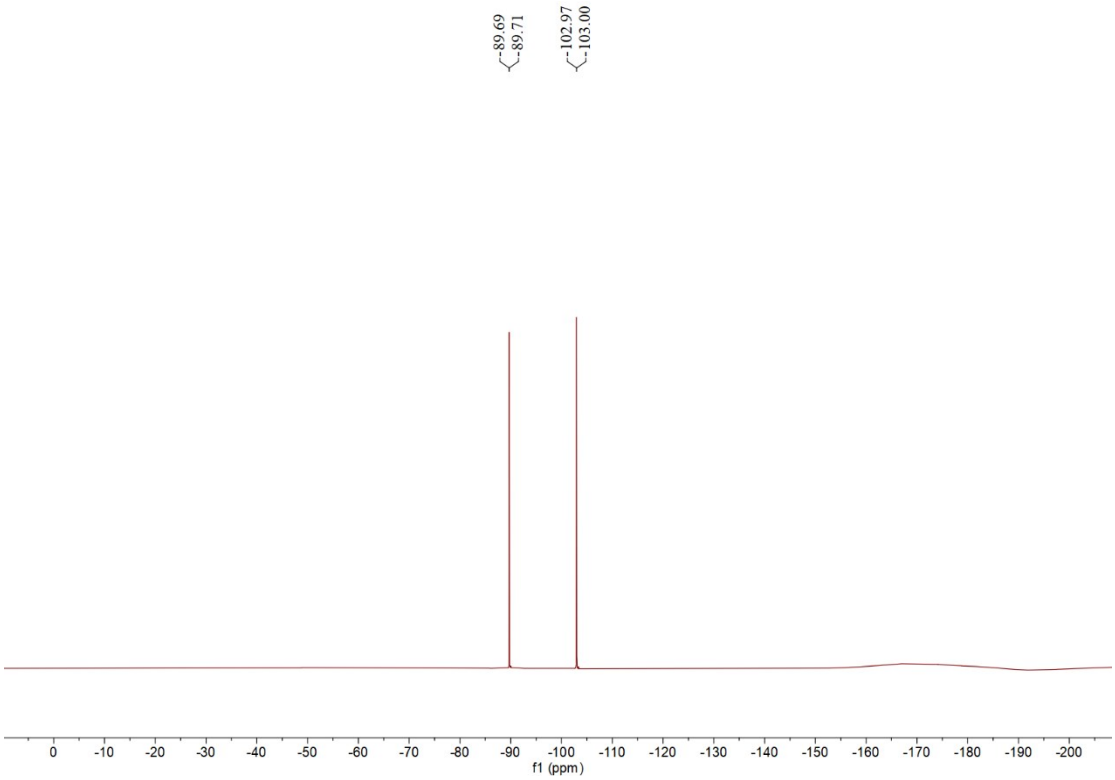
2d ^{1}H NMR (500 MHz, $CDCl_3$)



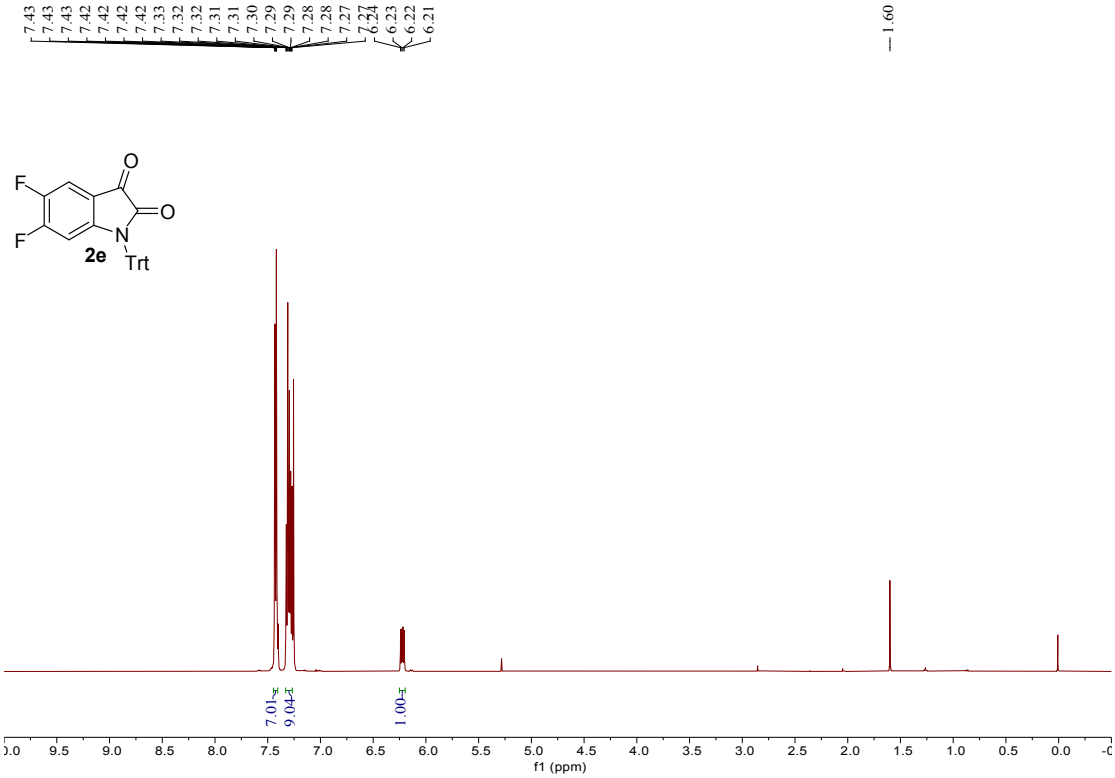
2d ^{13}C NMR (101 MHz, $CDCl_3$)



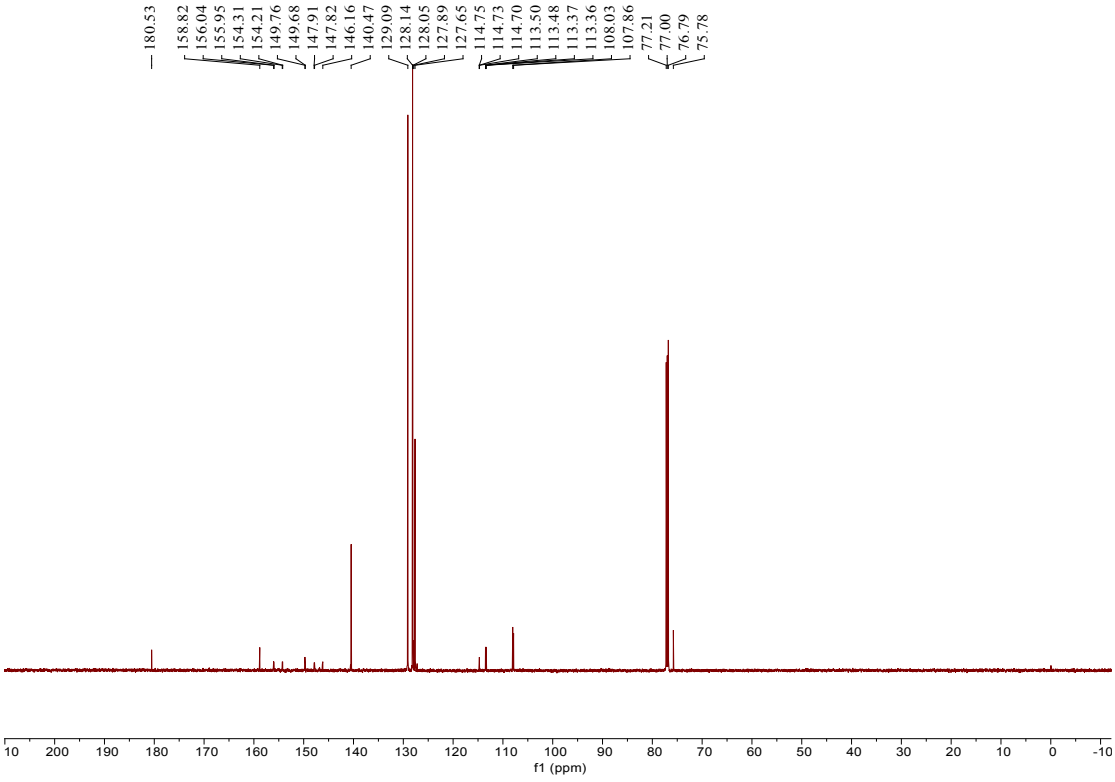
2d ^{19}F NMR (565 MHz, $CDCl_3$)



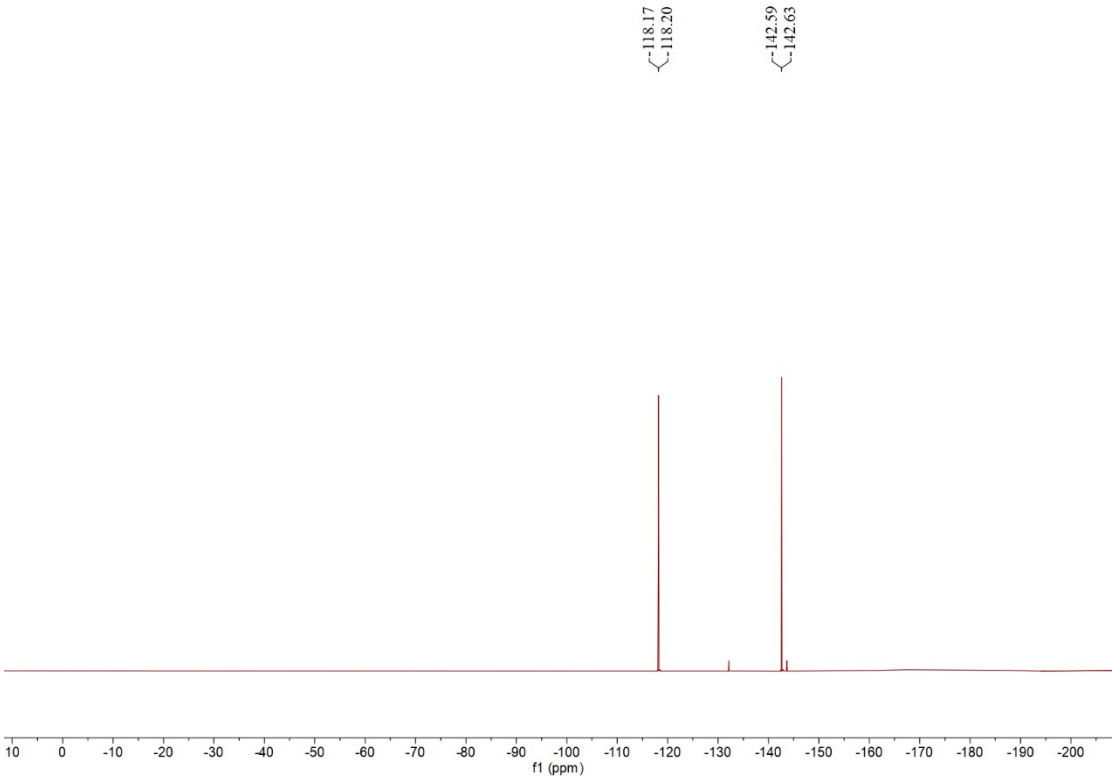
2e ^{1}H NMR (500 MHz, $CDCl_3$)



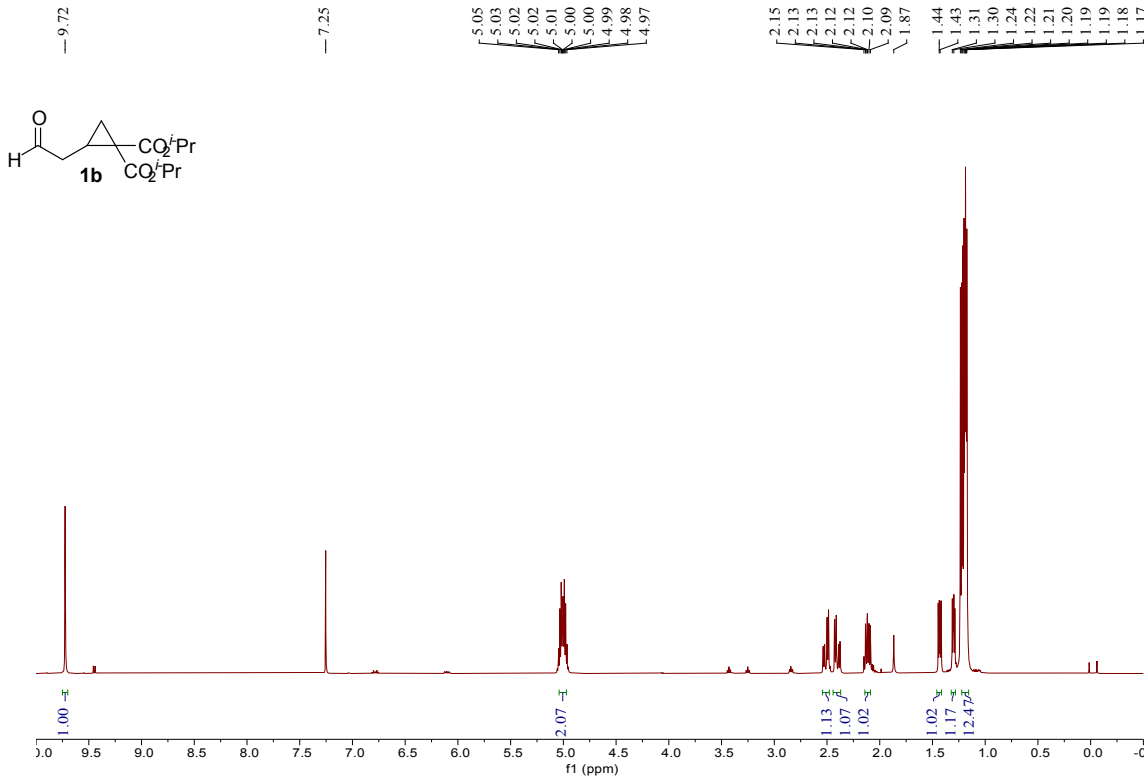
2e ^{13}C NMR (151 MHz, $CDCl_3$)



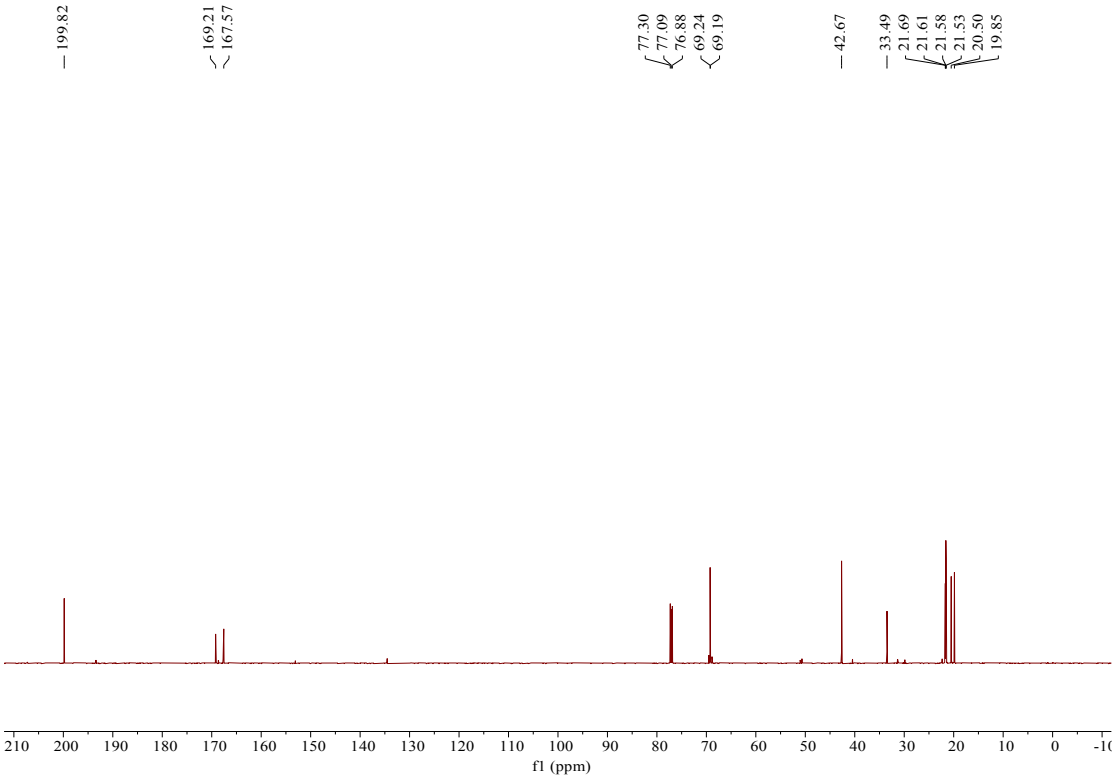
2e ^{19}F NMR (565 MHz, $CDCl_3$)



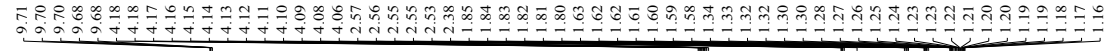
1b ^{1}H NMR (500 MHz, $CDCl_3$)

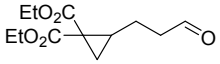


1b ^{13}C NMR (151 MHz, $CDCl_3$)

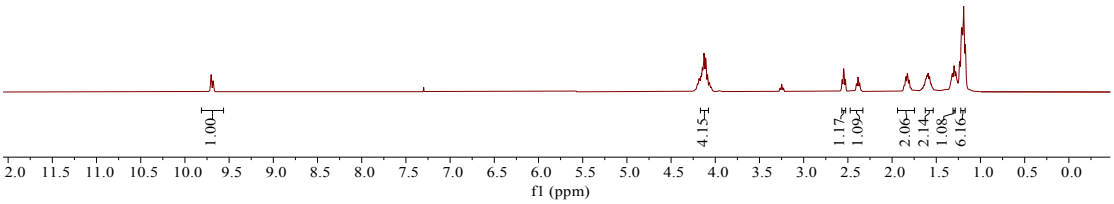


1c ^{1}H NMR (400 MHz, $CDCl_3$)

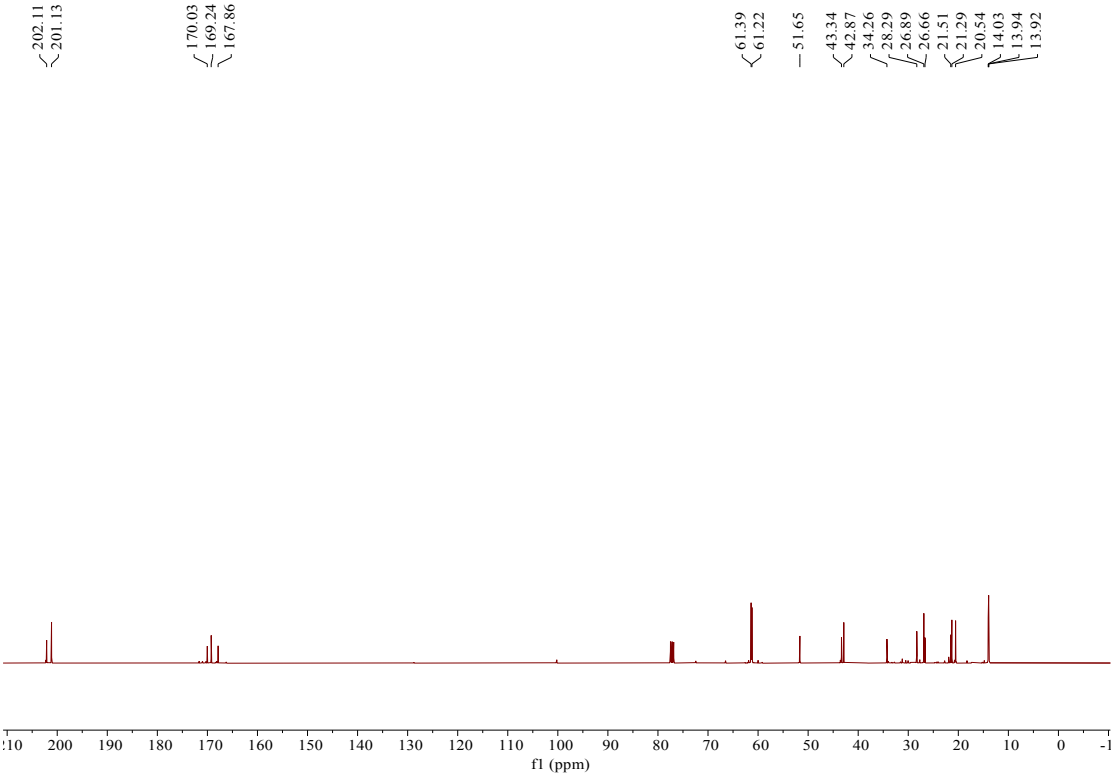




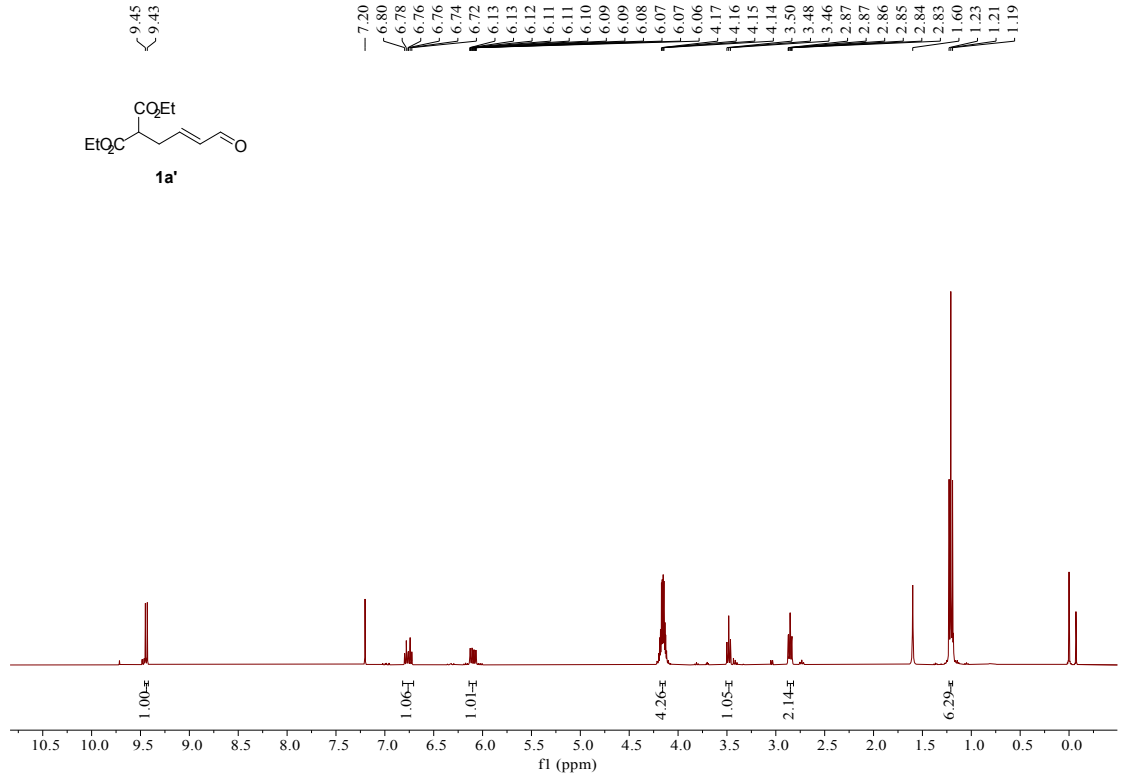
1c



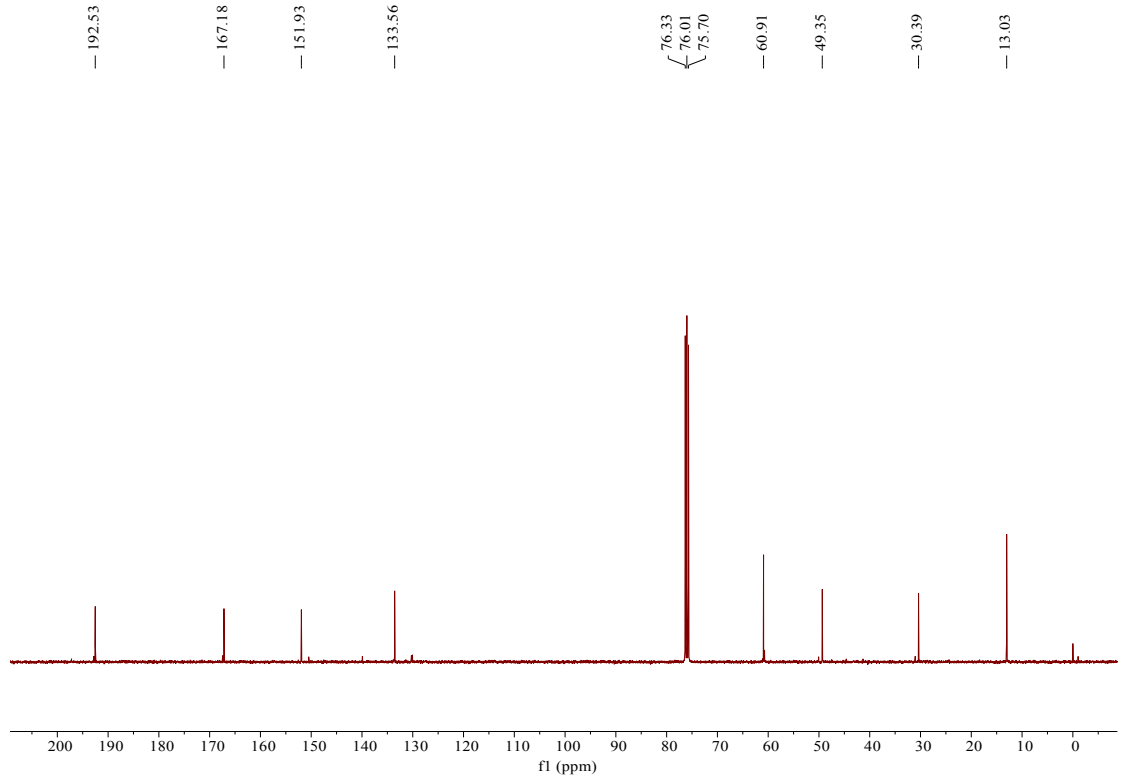
1c ^{1}H NMR (101 MHz, $CDCl_3$)



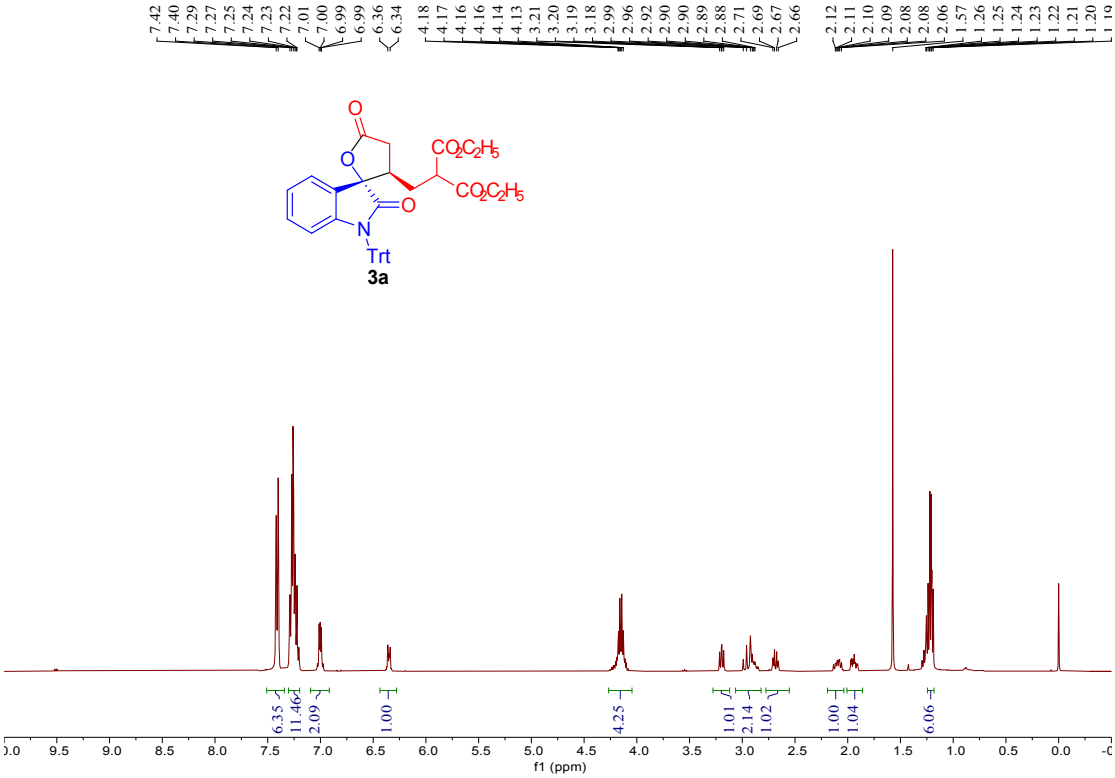
1a′ ^{1}H NMR (400 MHz, $CDCl_3$)



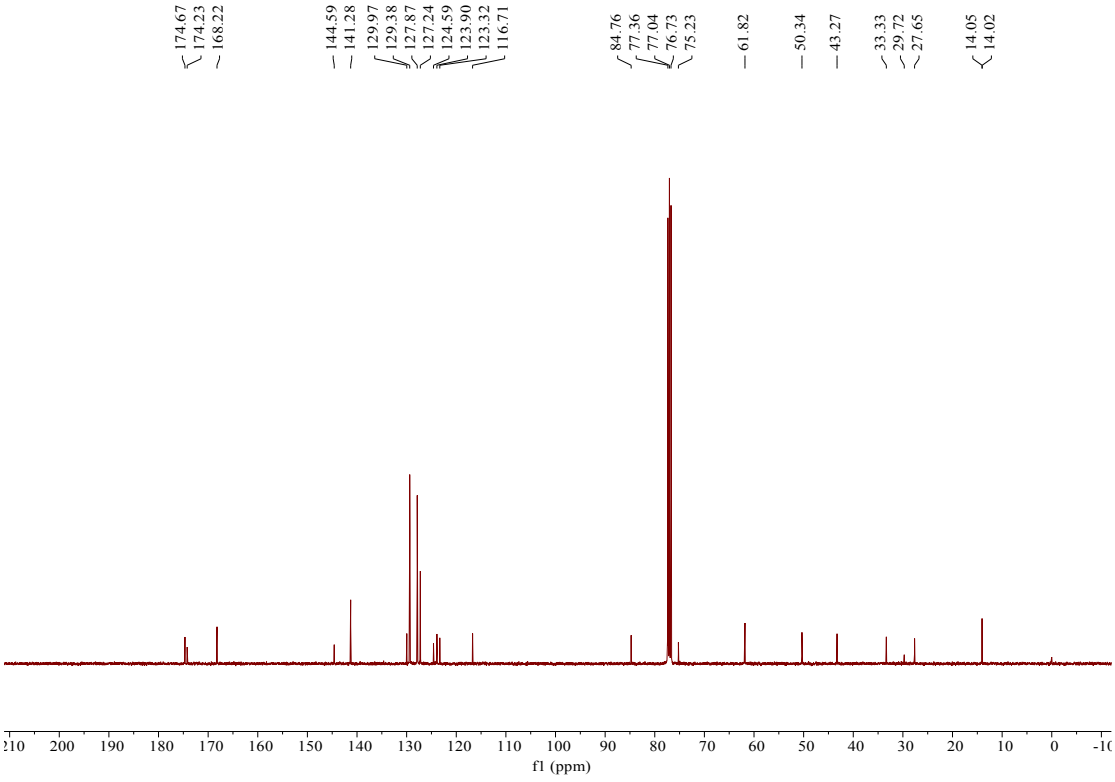
1a′ ^{13}C NMR (101 MHz, $CDCl_3$)



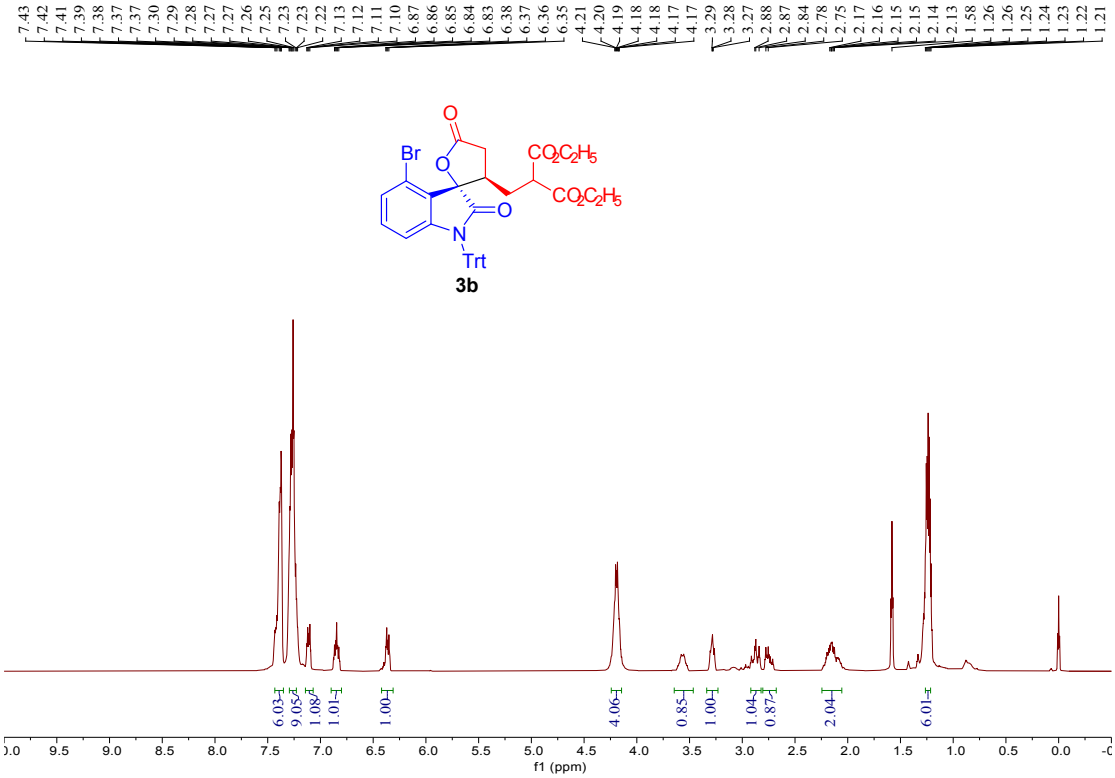
3a ^{1}H NMR (400 MHz, $CDCl_3$)



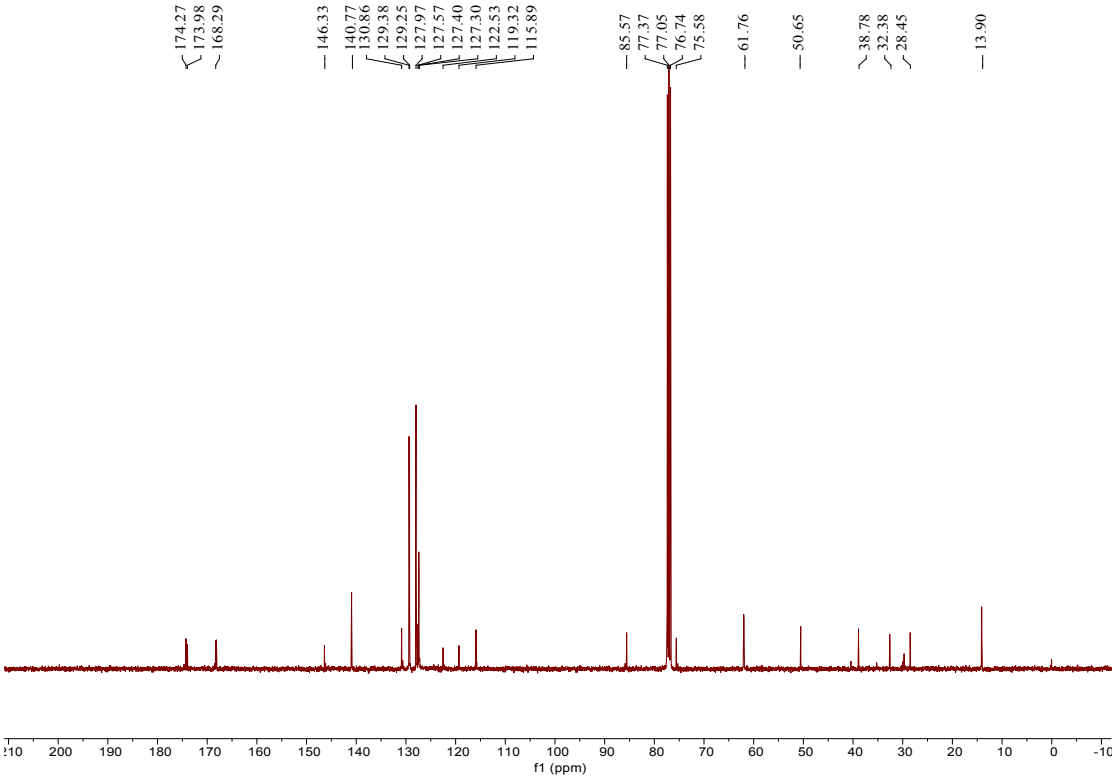
3a ^{13}C NMR (101 MHz, $CDCl_3$)



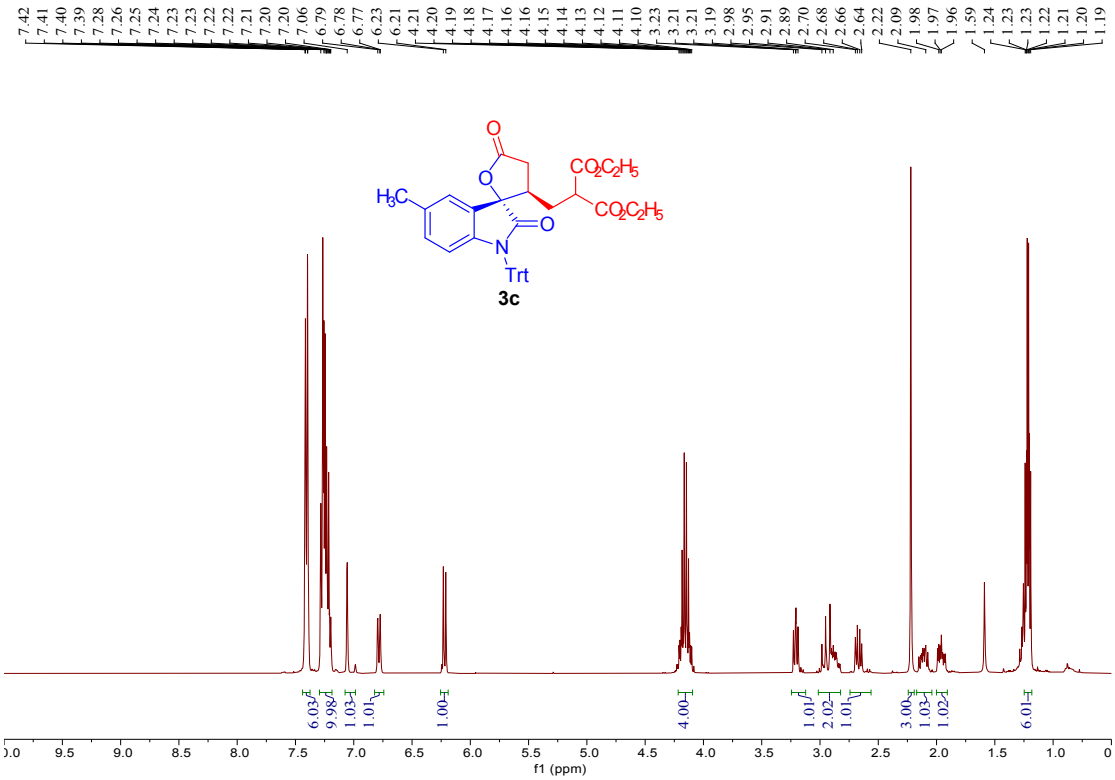
3b ^{1}H NMR (400 MHz, $CDCl_3$)



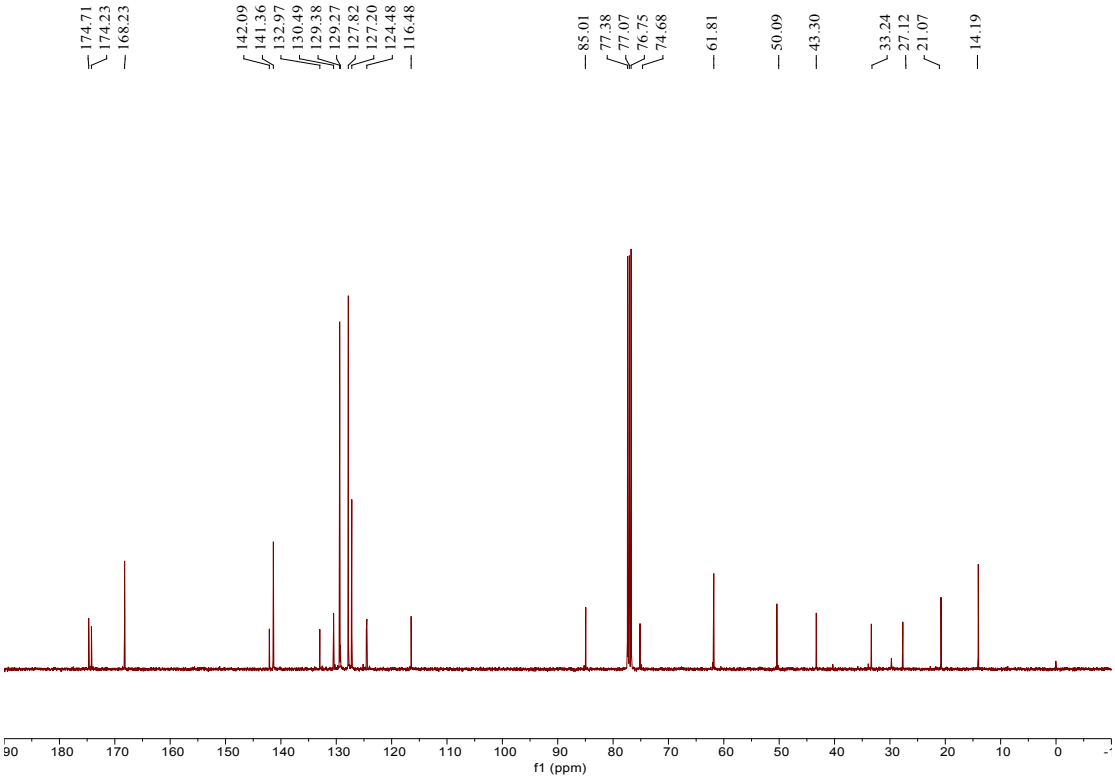
3b ^{13}C NMR (101 MHz, $CDCl_3$)



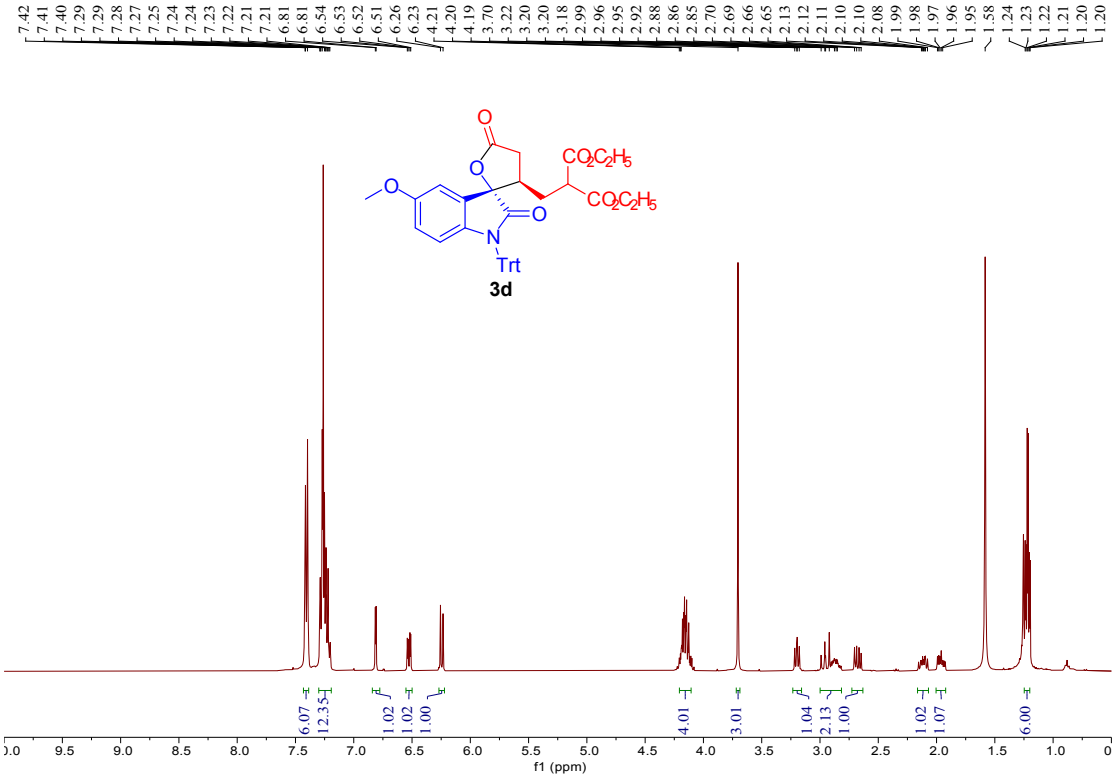
3c ^{1}H NMR (400 MHz, $CDCl_3$)



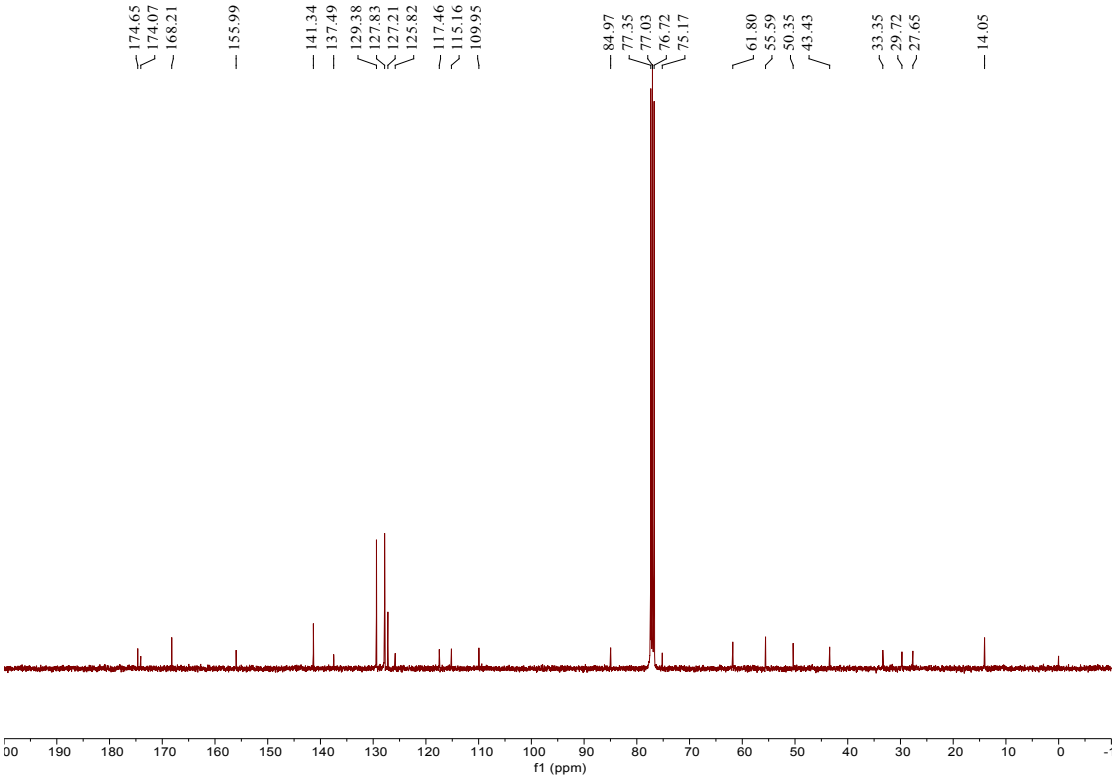
3c ^{13}C NMR (101 MHz, $CDCl_3$)



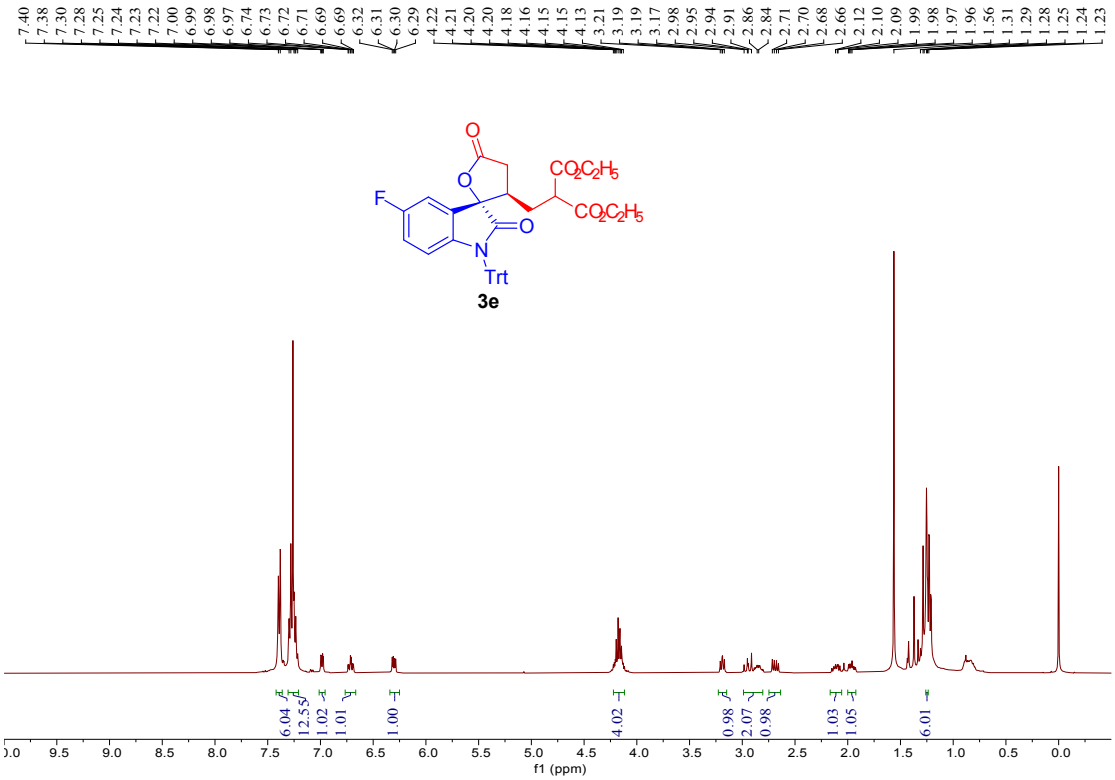
3d ^{1}H NMR (400 MHz, $CDCl_3$)



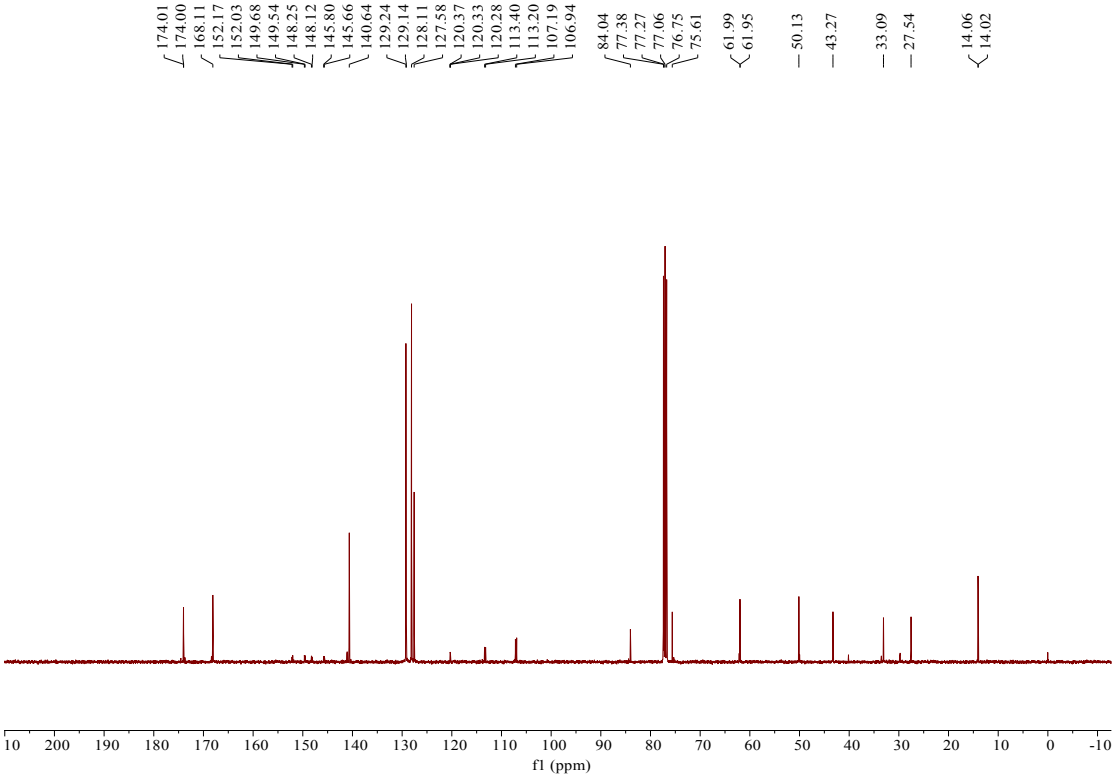
3d ^{13}C NMR (101 MHz, $CDCl_3$)



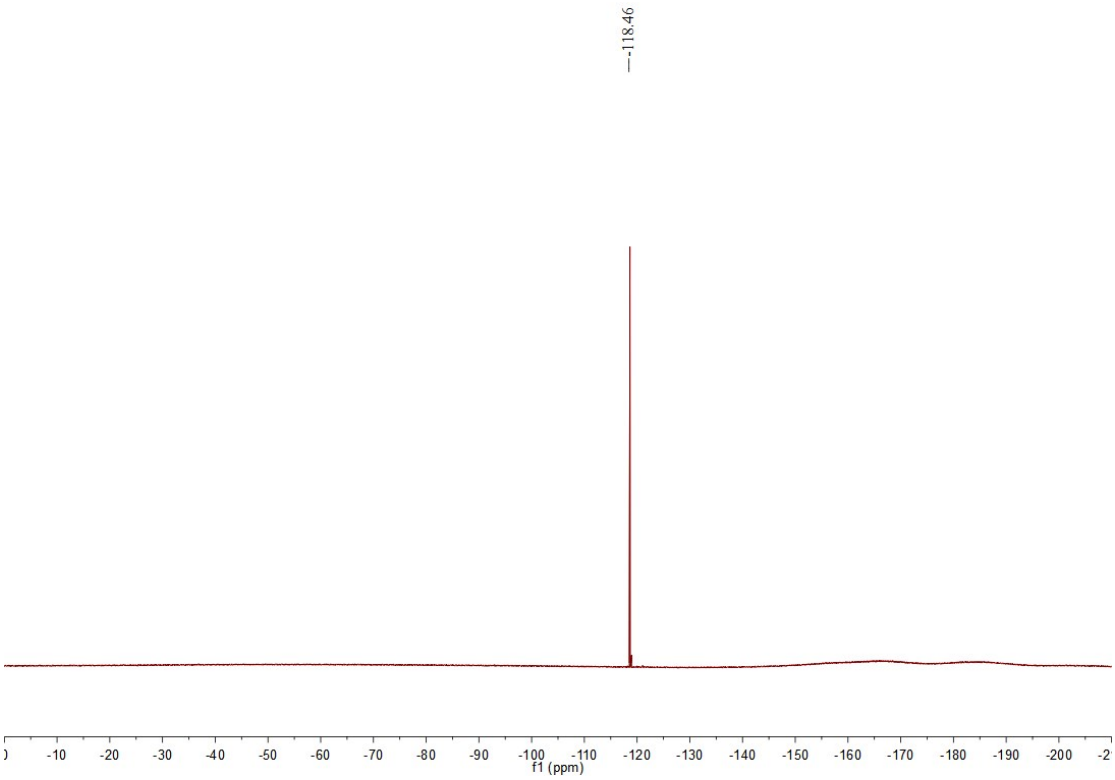
3e ^{1}H NMR (400 MHz, $CDCl_3$)



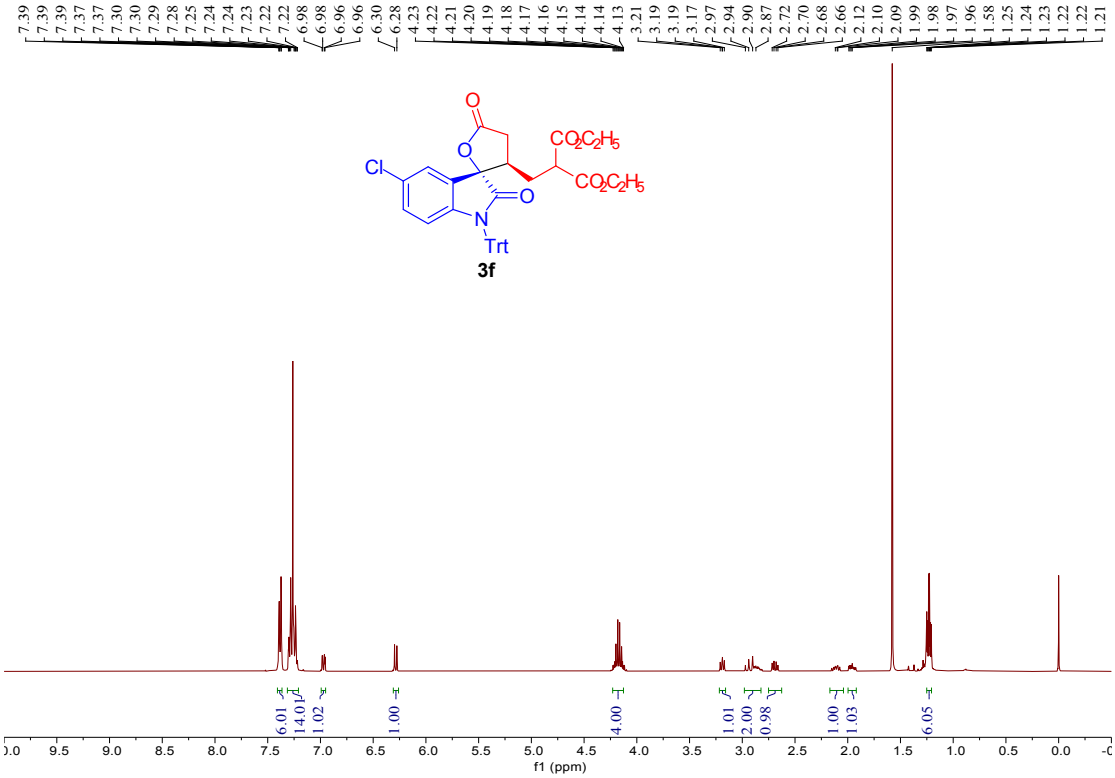
3e ^{13}C NMR (101 MHz, $CDCl_3$)



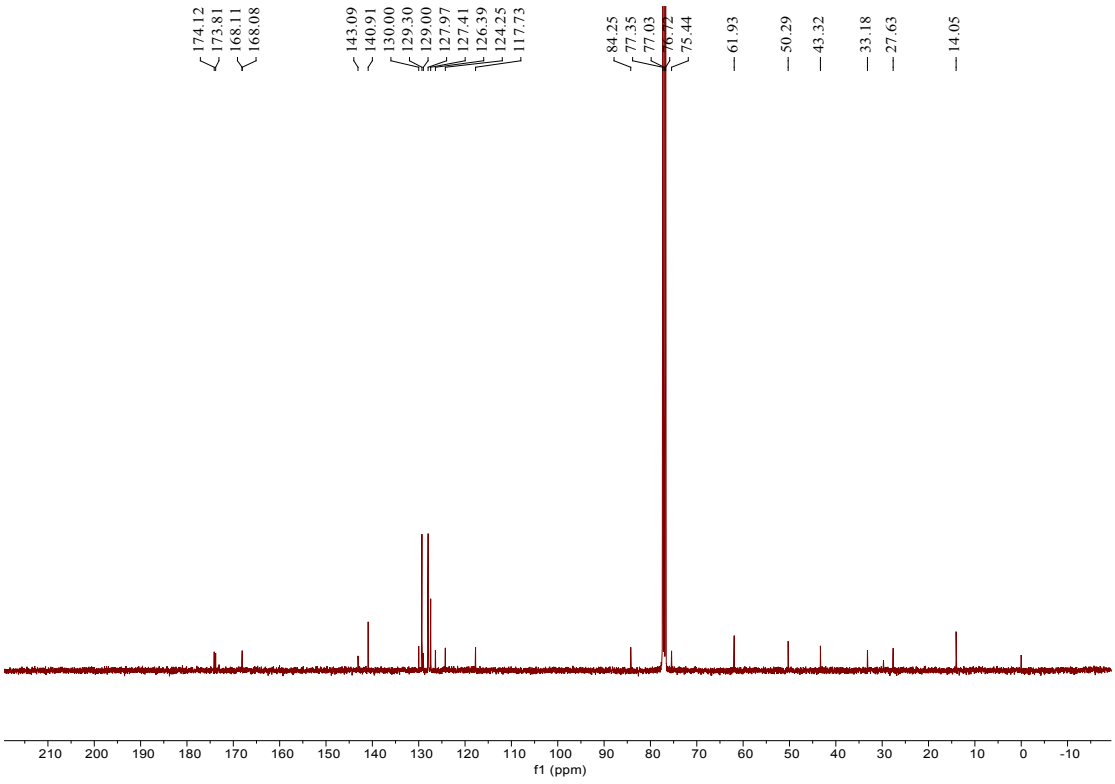
3e ^{19}F NMR (565 MHz, $CDCl_3$)



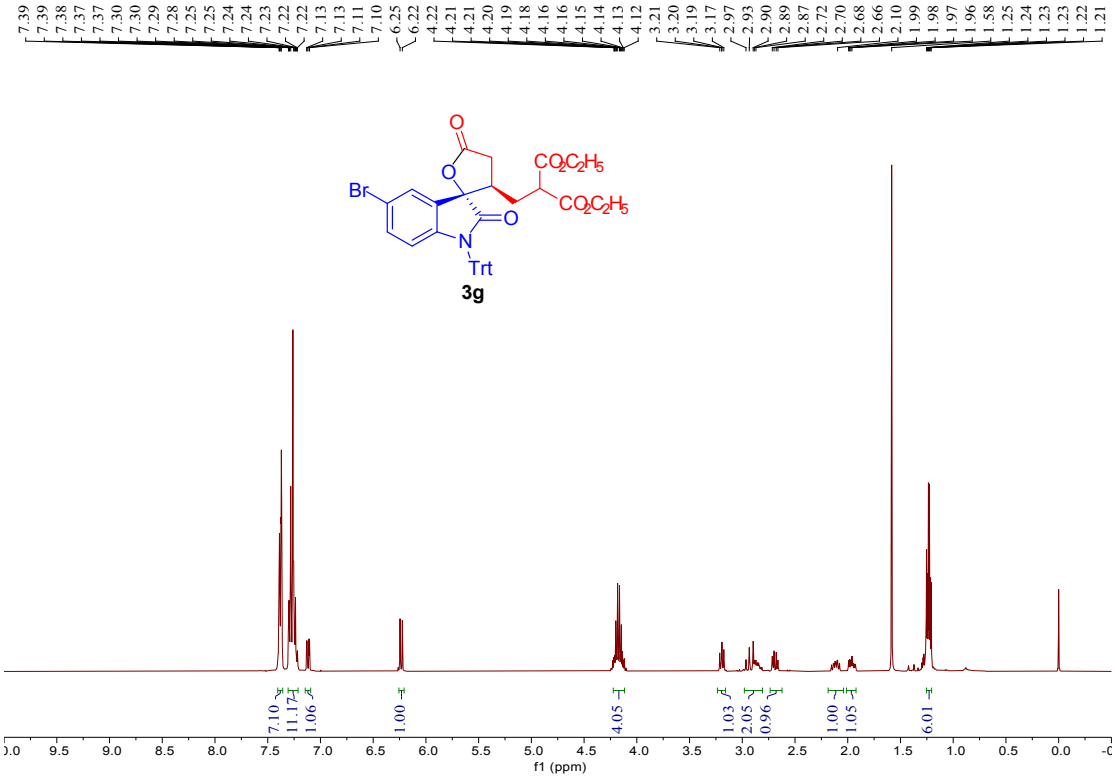
3f ^{1}H NMR (400 MHz, $CDCl_3$)



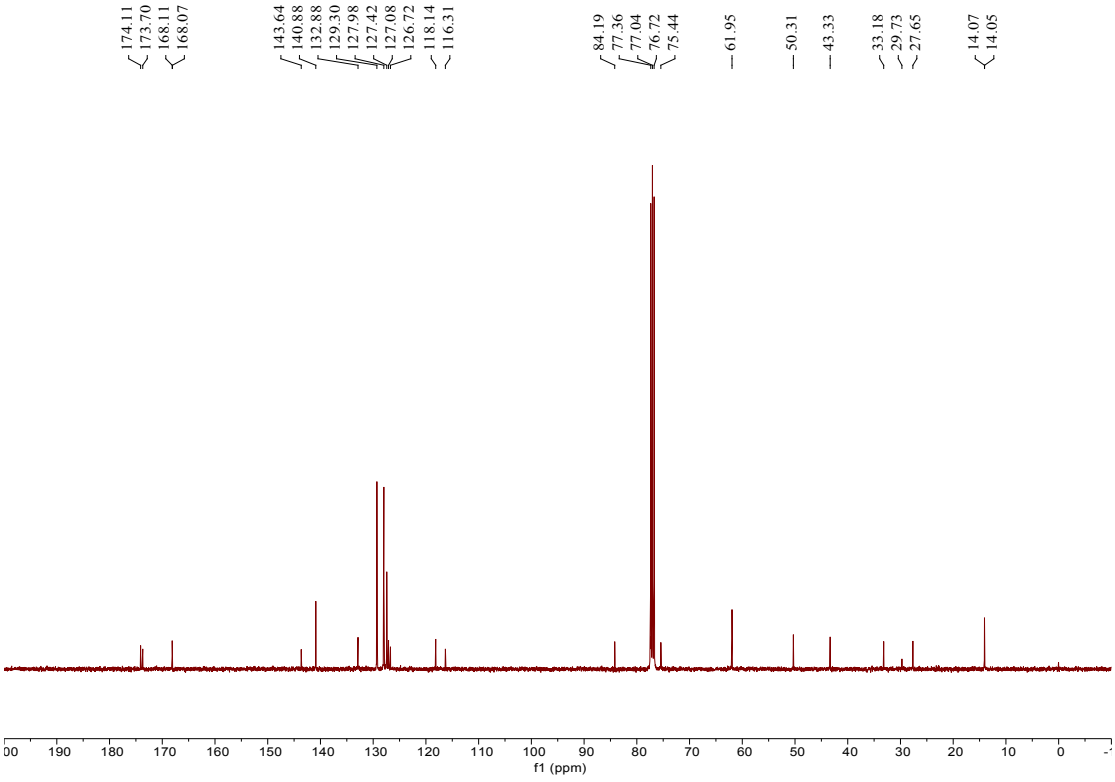
3f ^{13}C NMR (101 MHz, $CDCl_3$)



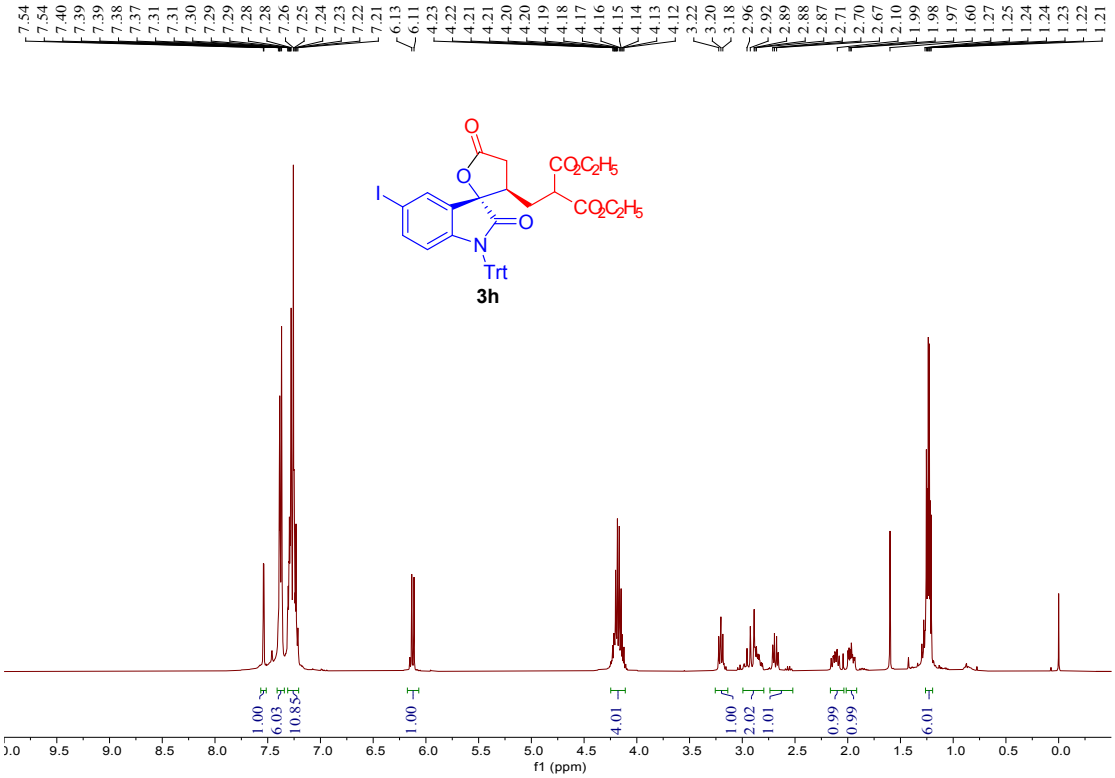
3g ^{1}H NMR (400 MHz, $CDCl_3$)



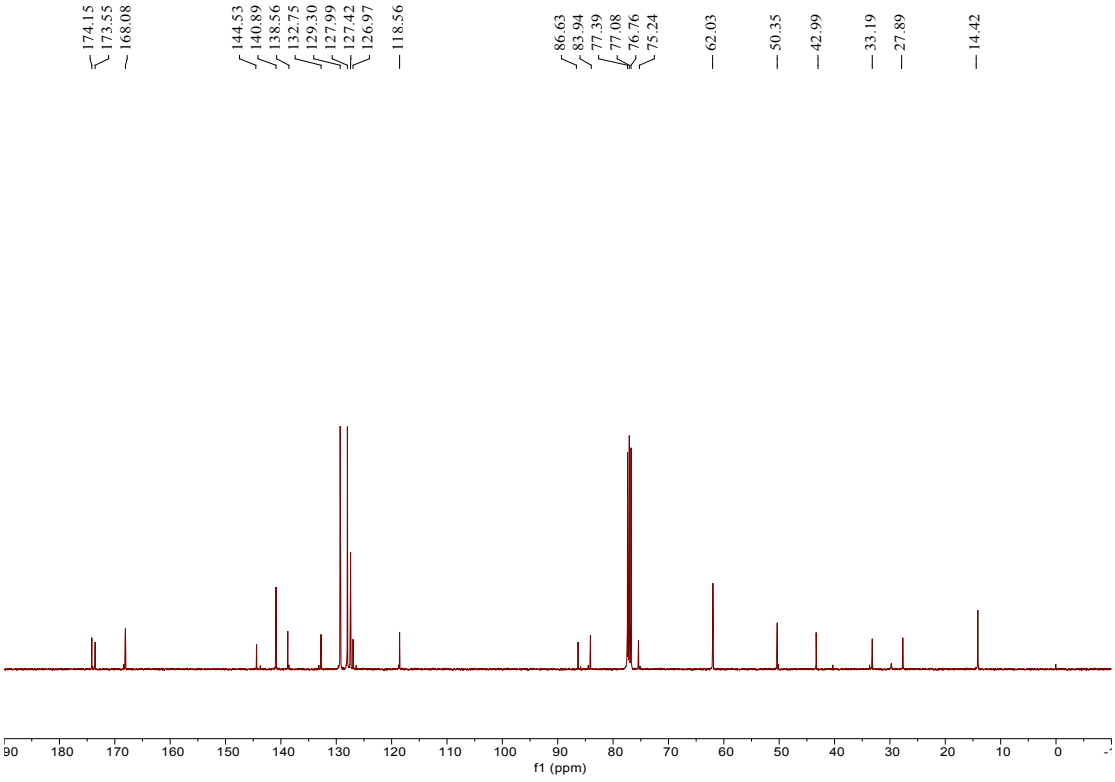
3g ^{13}C NMR (101 MHz, $CDCl_3$)



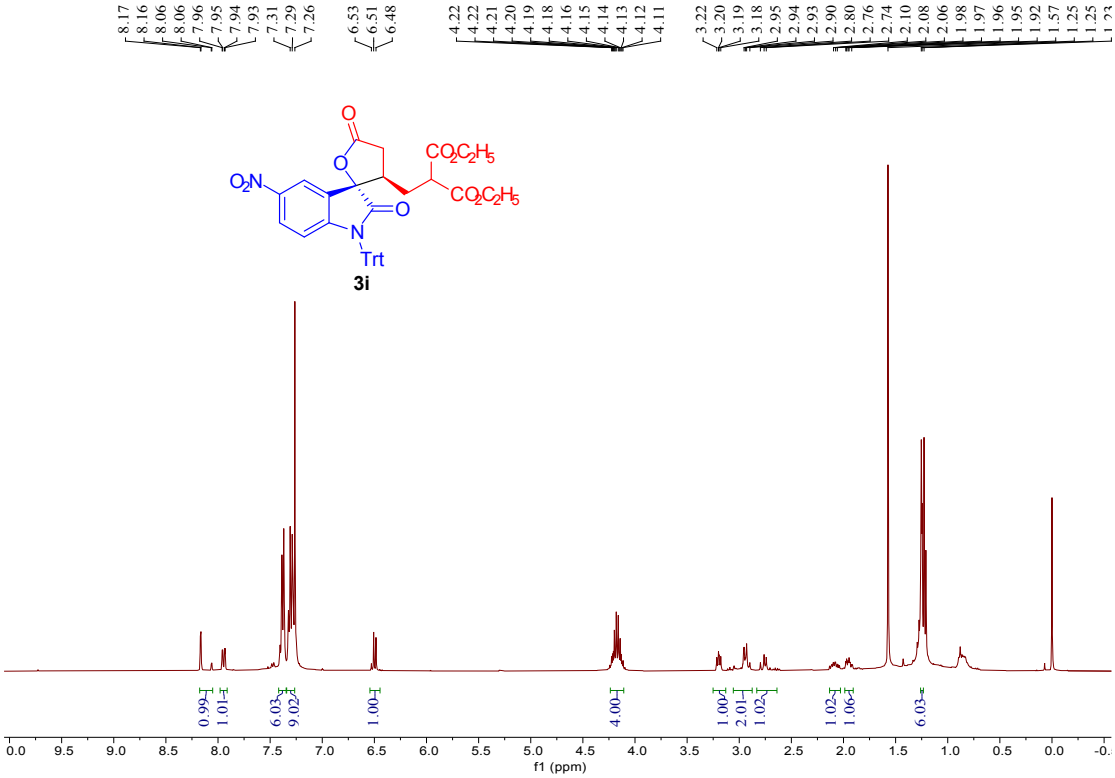
3h ^{1}H NMR (400 MHz, $CDCl_3$)



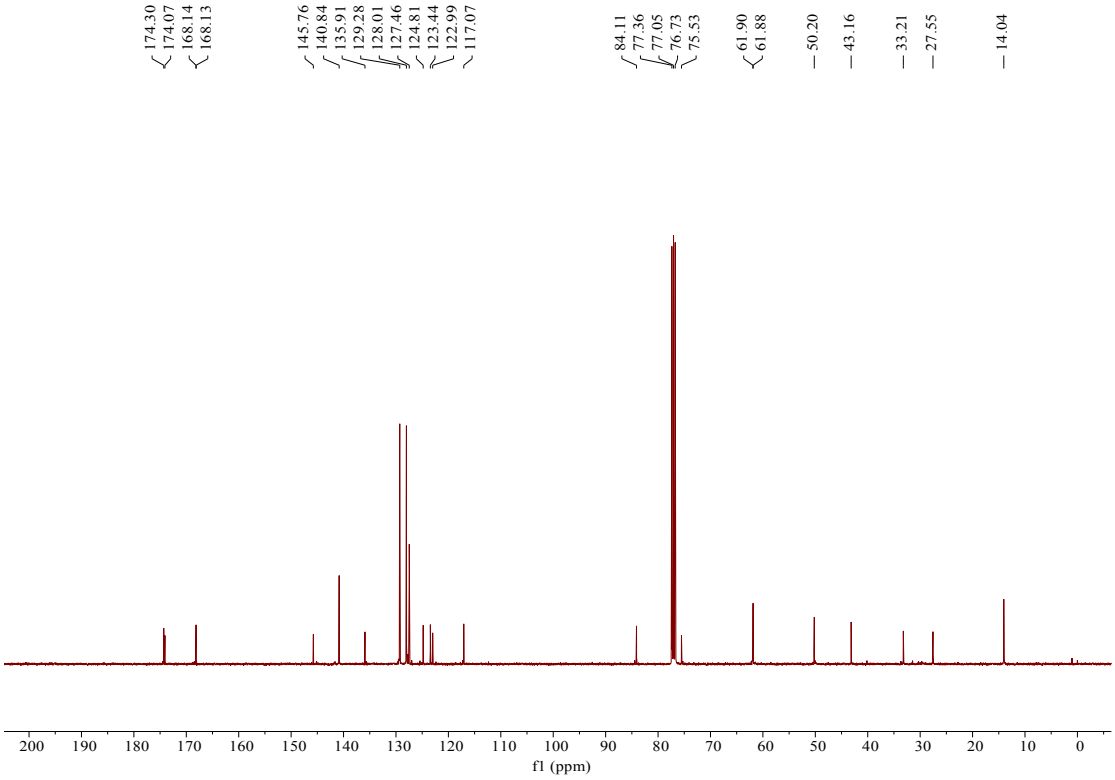
3h ^{13}C NMR (101 MHz, $CDCl_3$)



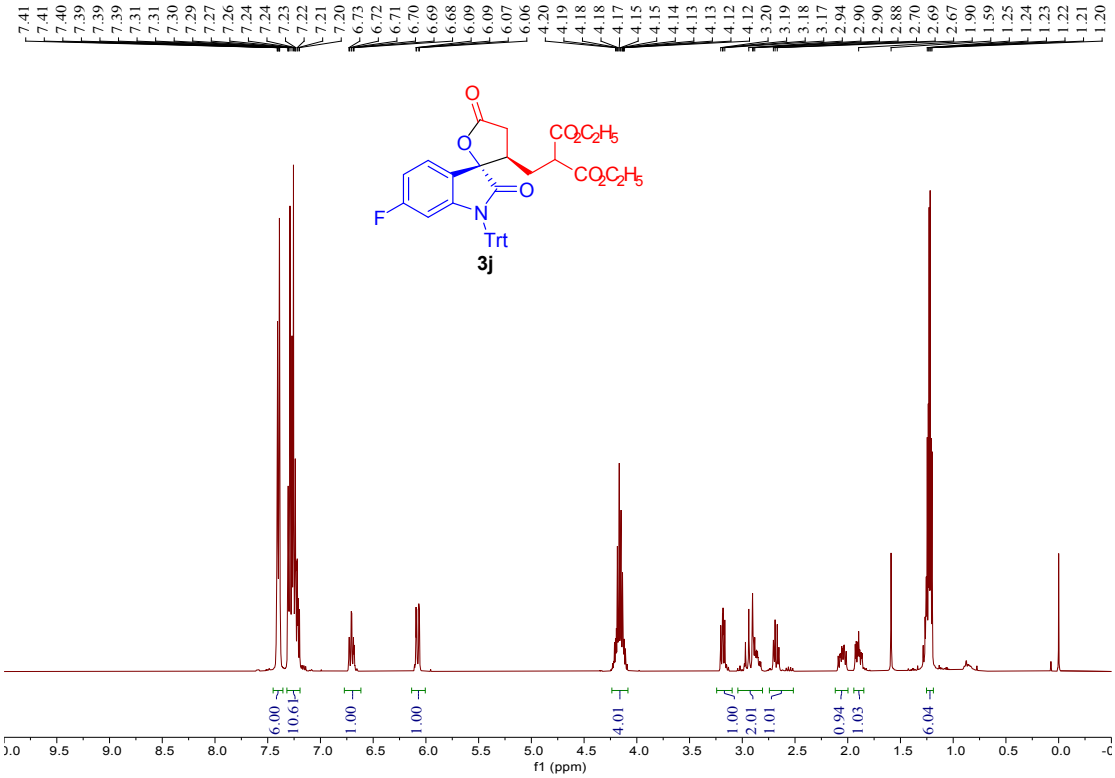
3i ^{1}H NMR (400 MHz, $CDCl_3$)



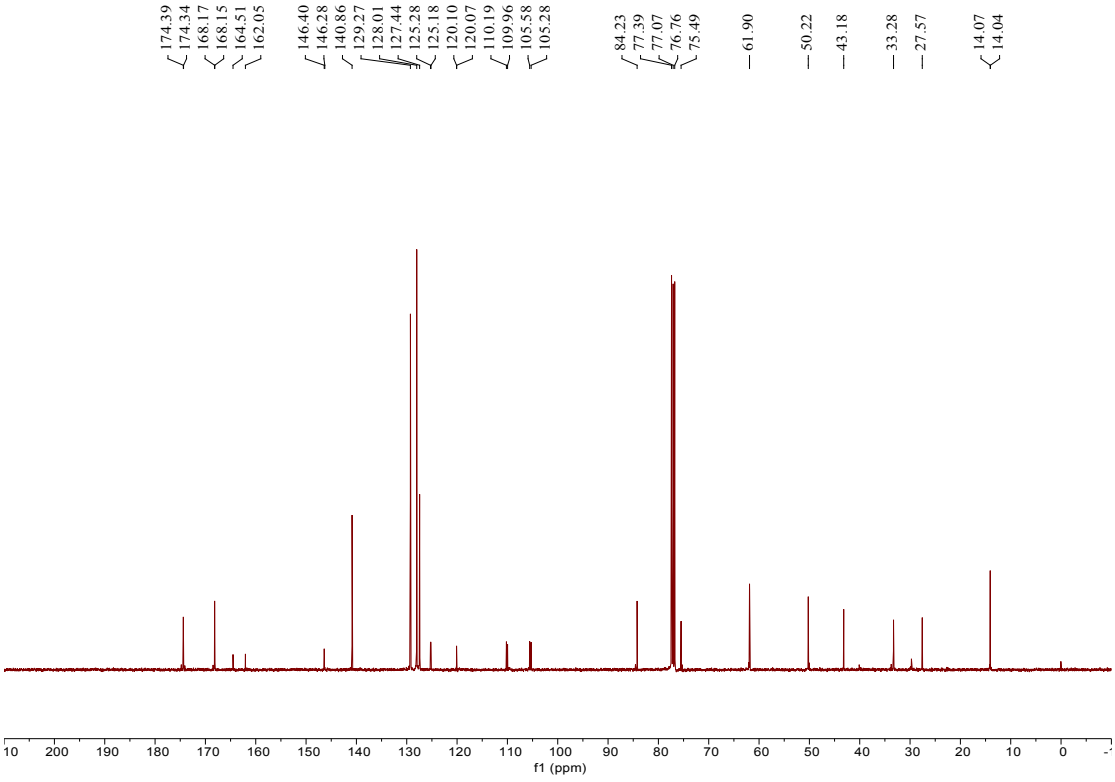
3i ^{13}C NMR (101 MHz, $CDCl_3$)



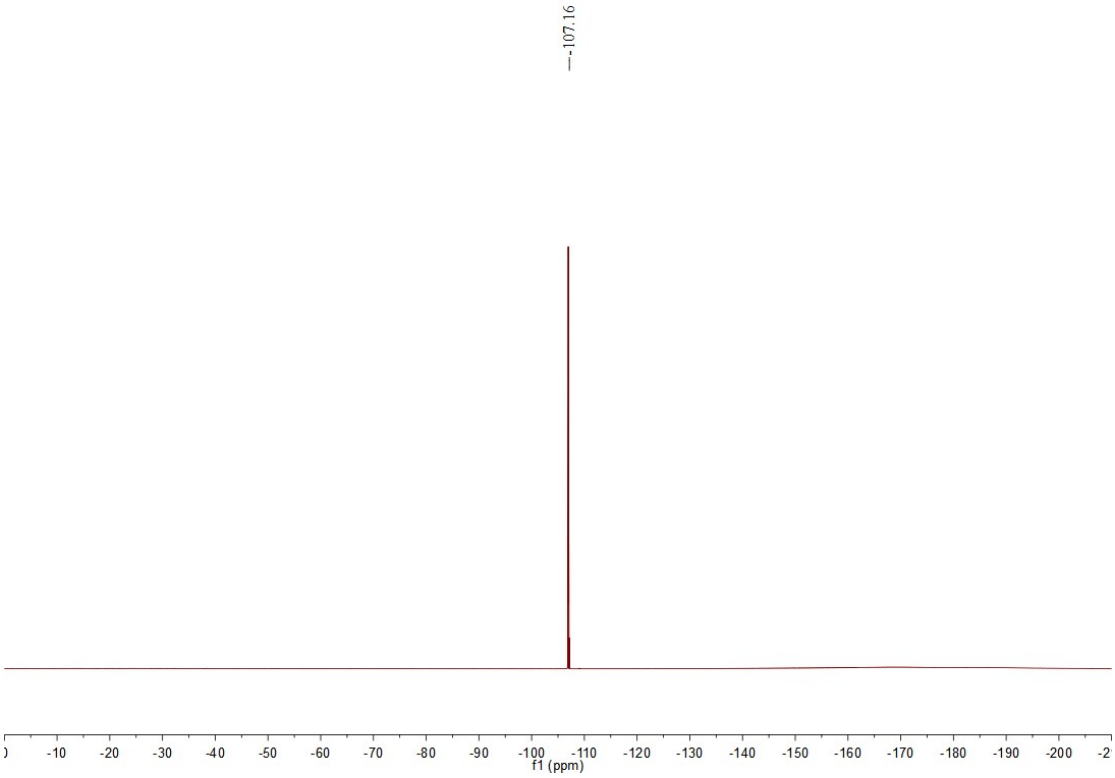
3j ^{1}H NMR (400 MHz, $CDCl_3$)



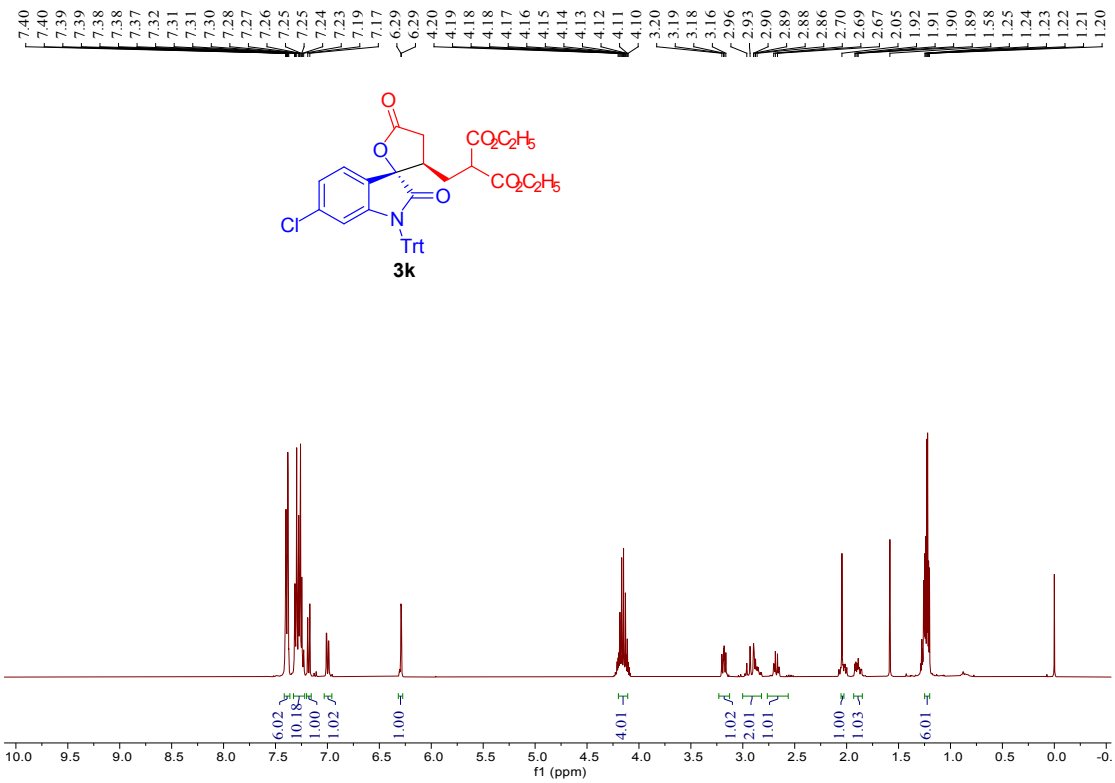
3j ^{13}C NMR (101 MHz, $CDCl_3$)



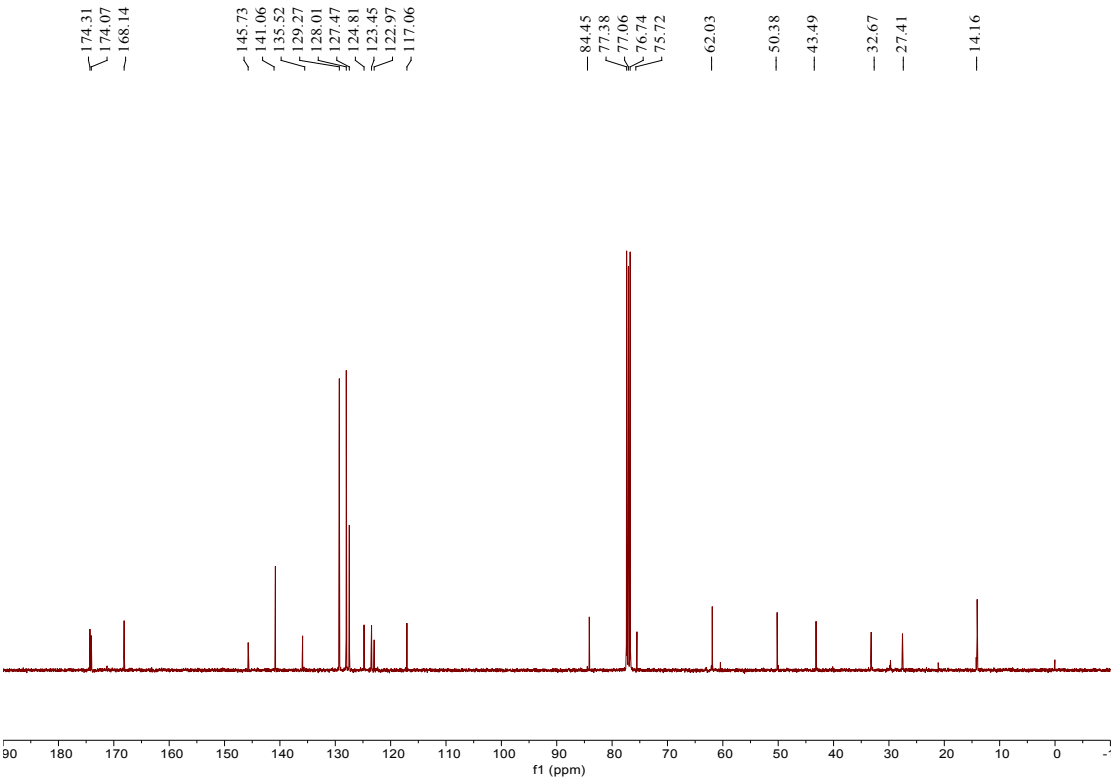
3j ^{19}F NMR (565 MHz, $CDCl_3$)



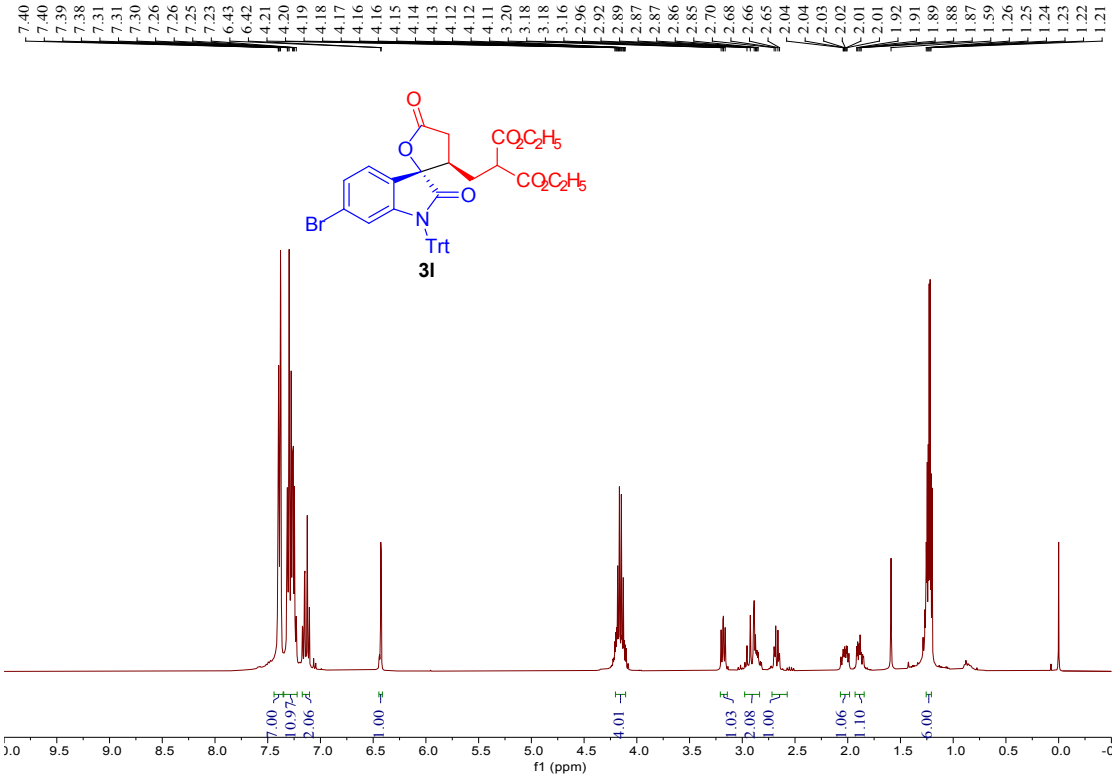
3k ^{1}H NMR (400 MHz, $CDCl_3$)



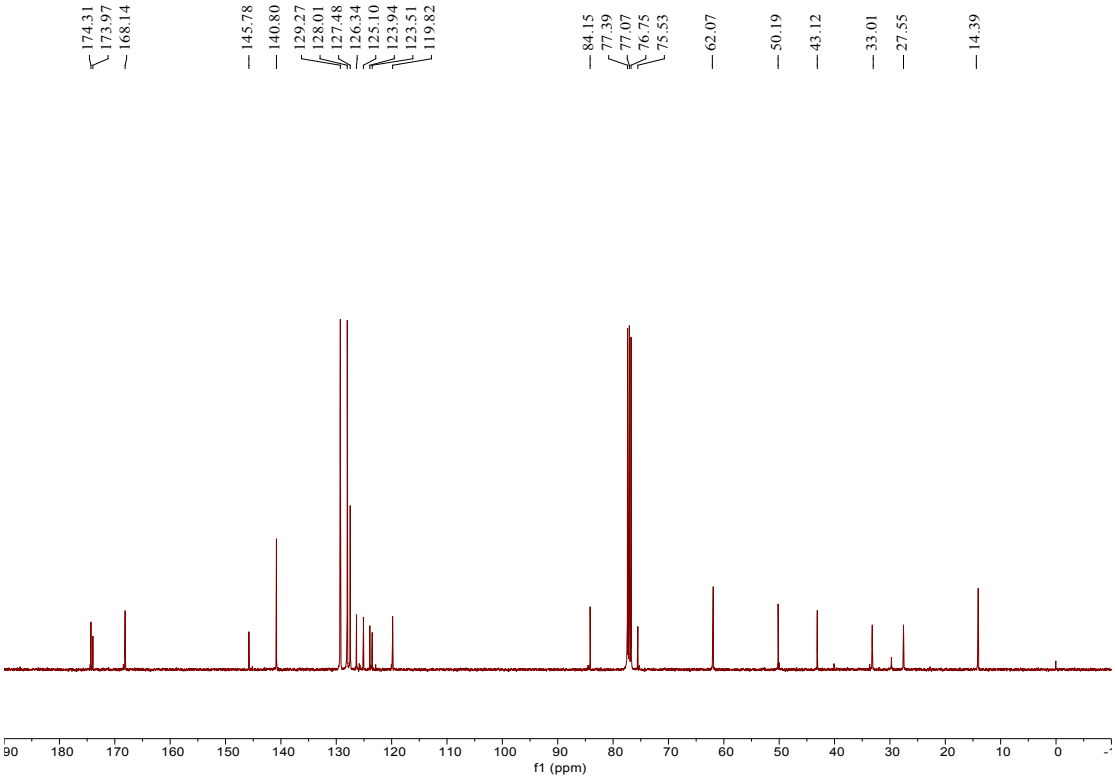
3k ^{13}C NMR (101 MHz, $CDCl_3$)



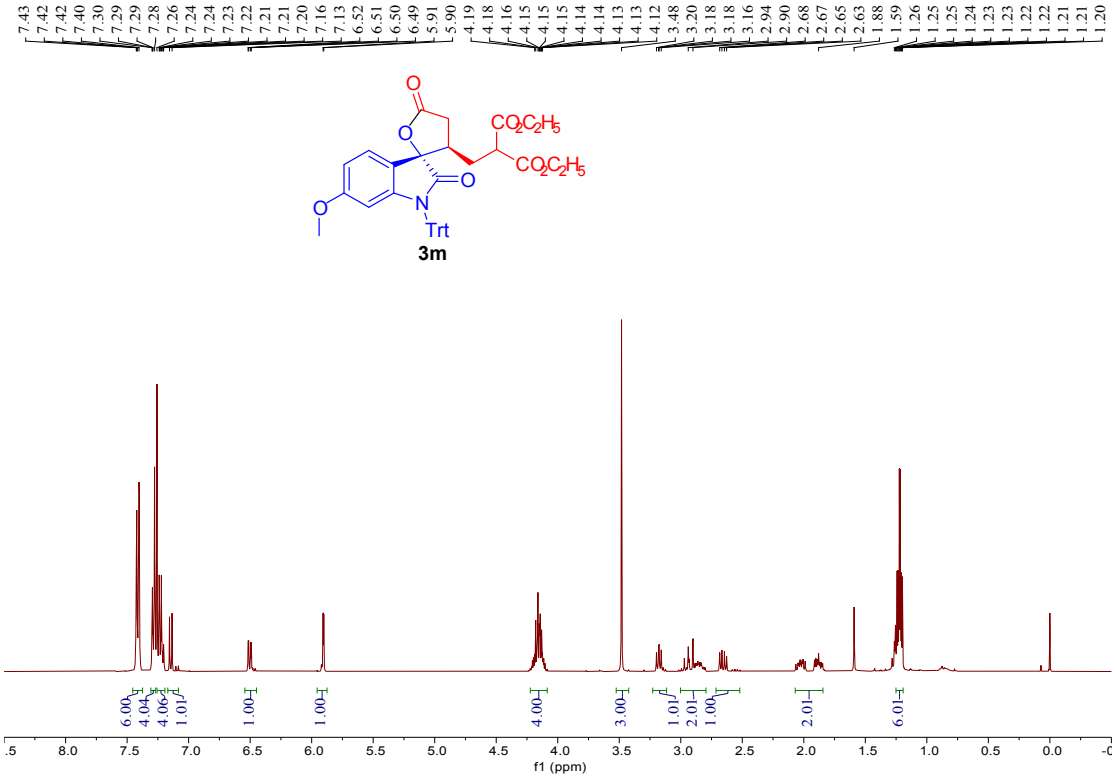
3l ^{1}H NMR (400 MHz, $CDCl_3$)



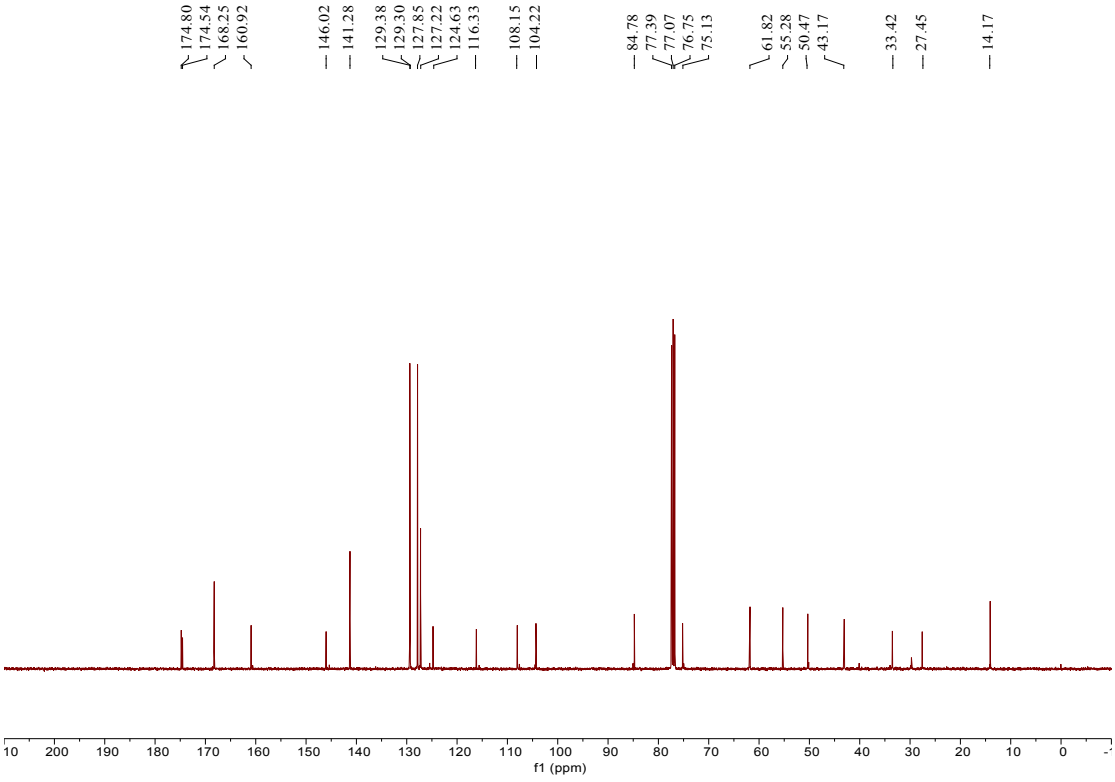
3l ^{13}C NMR (101 MHz, $CDCl_3$)



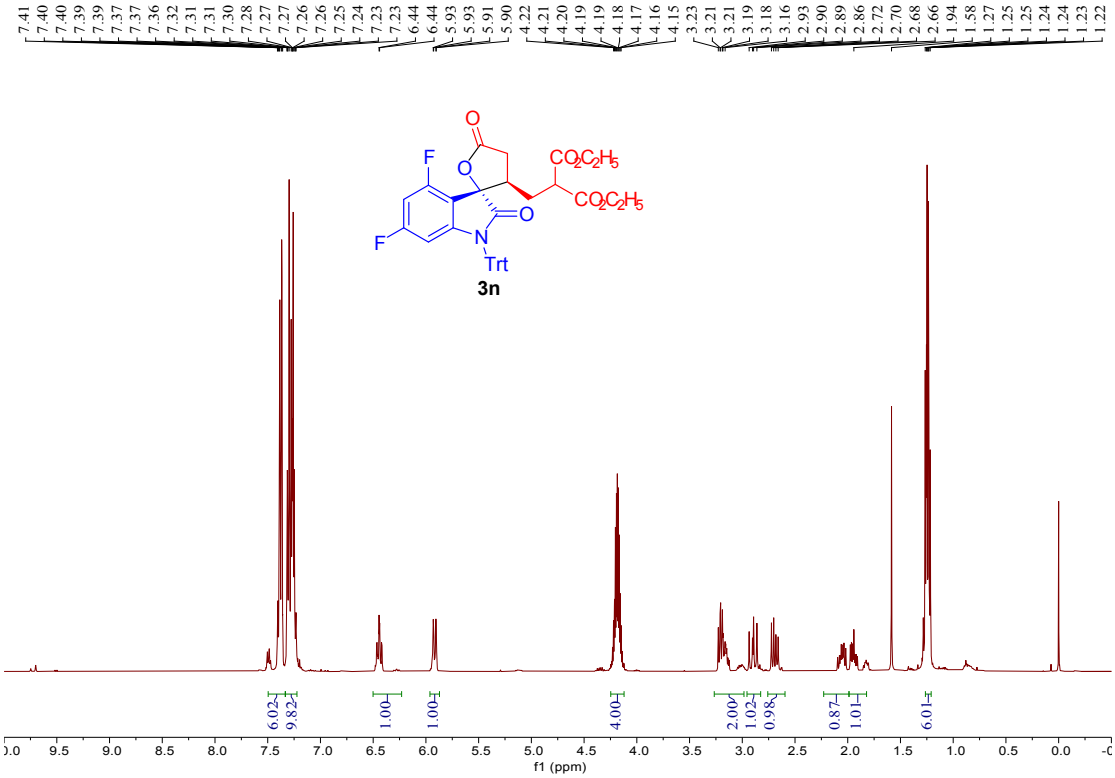
3m ^{1}H NMR (400 MHz, $CDCl_3$)



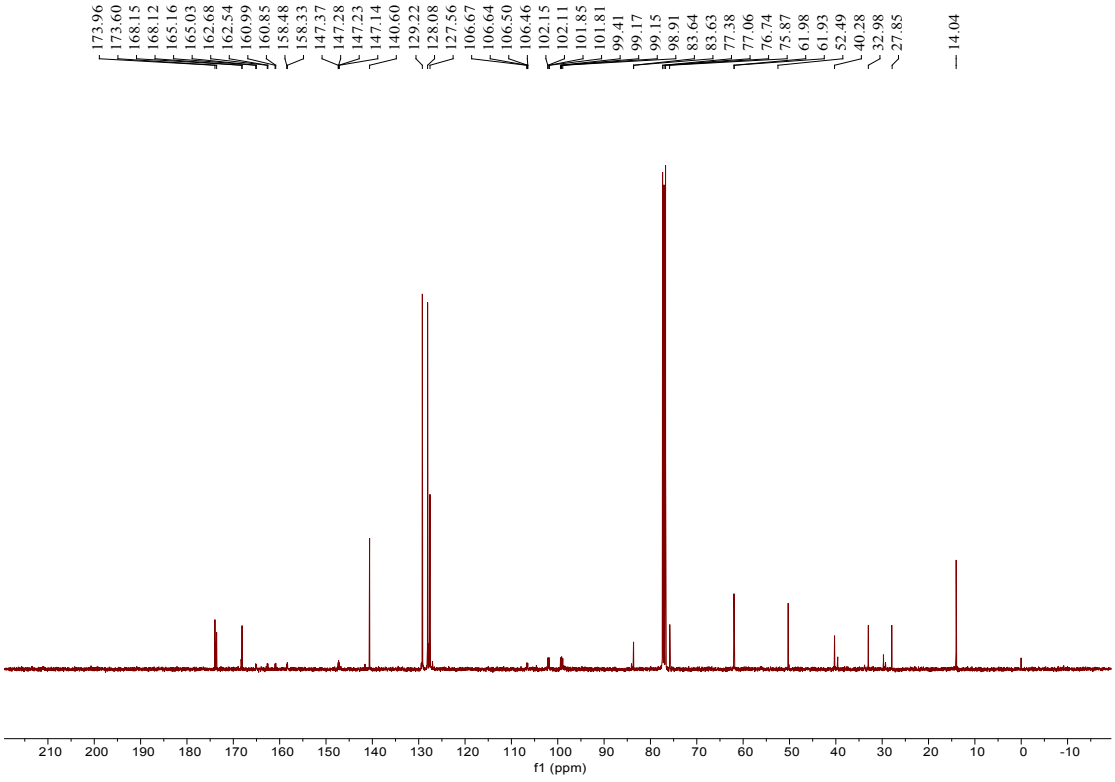
3m ^{13}C NMR (101 MHz, $CDCl_3$)



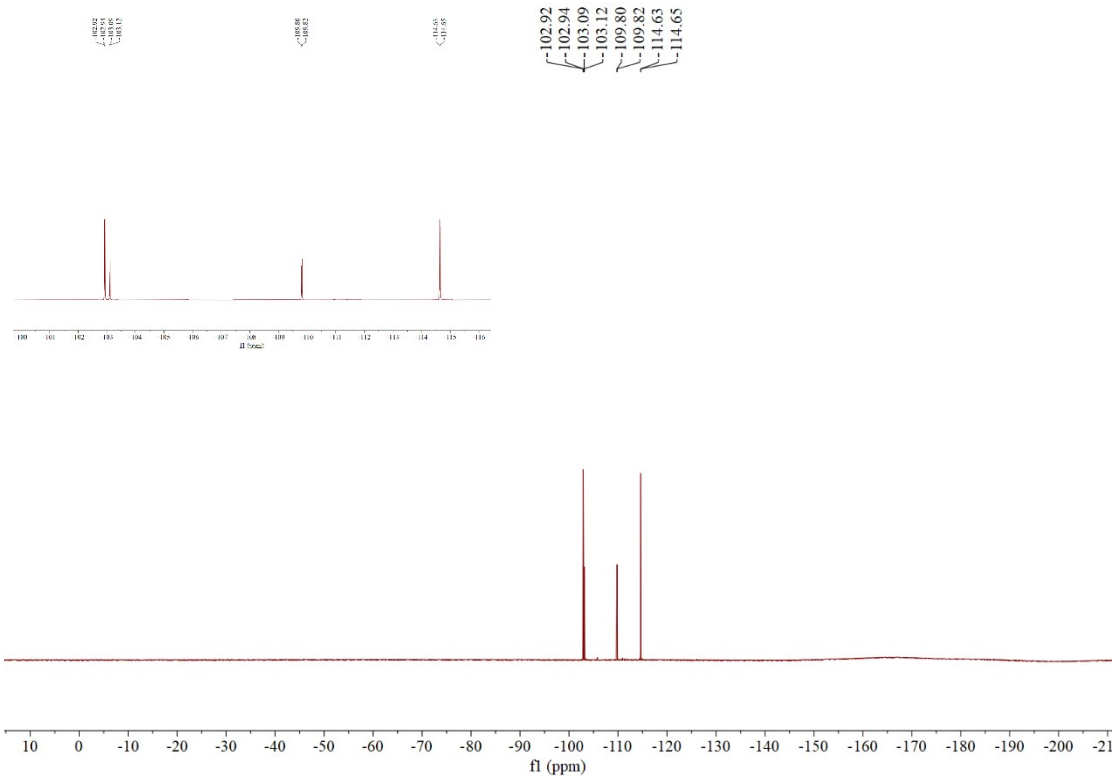
3n ^{1}H NMR(400 MHz, $CDCl_3$)



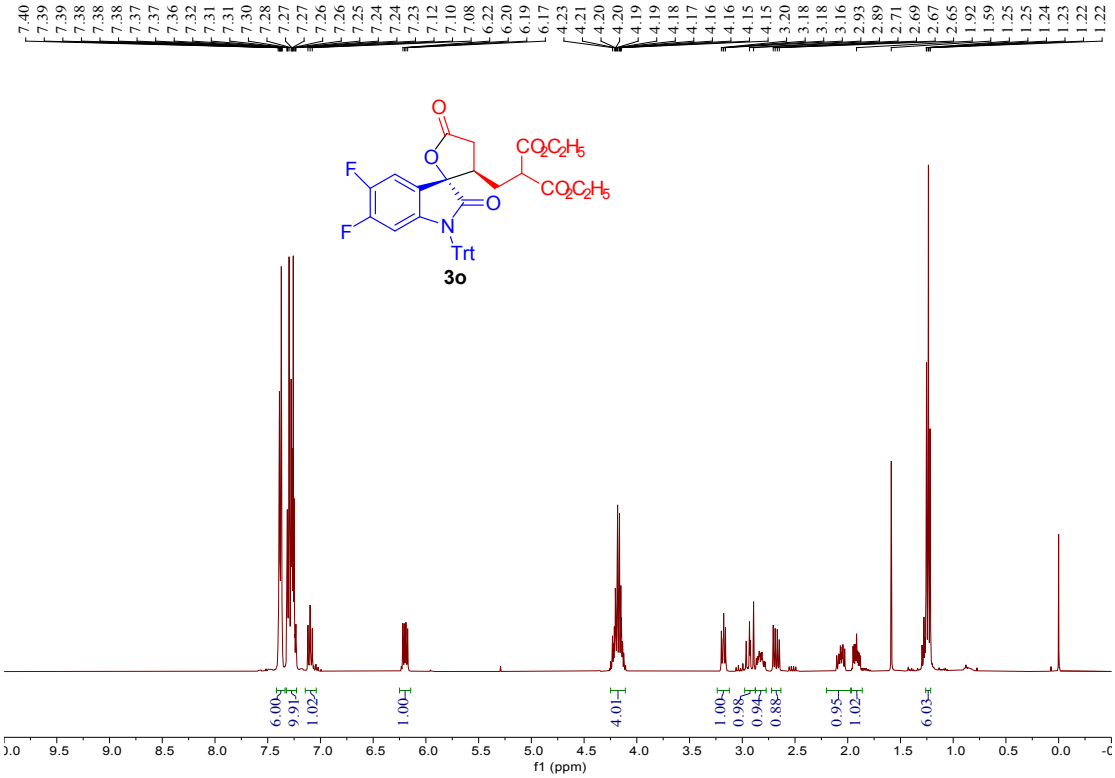
3n ^{13}C NMR (101 MHz, $CDCl_3$)



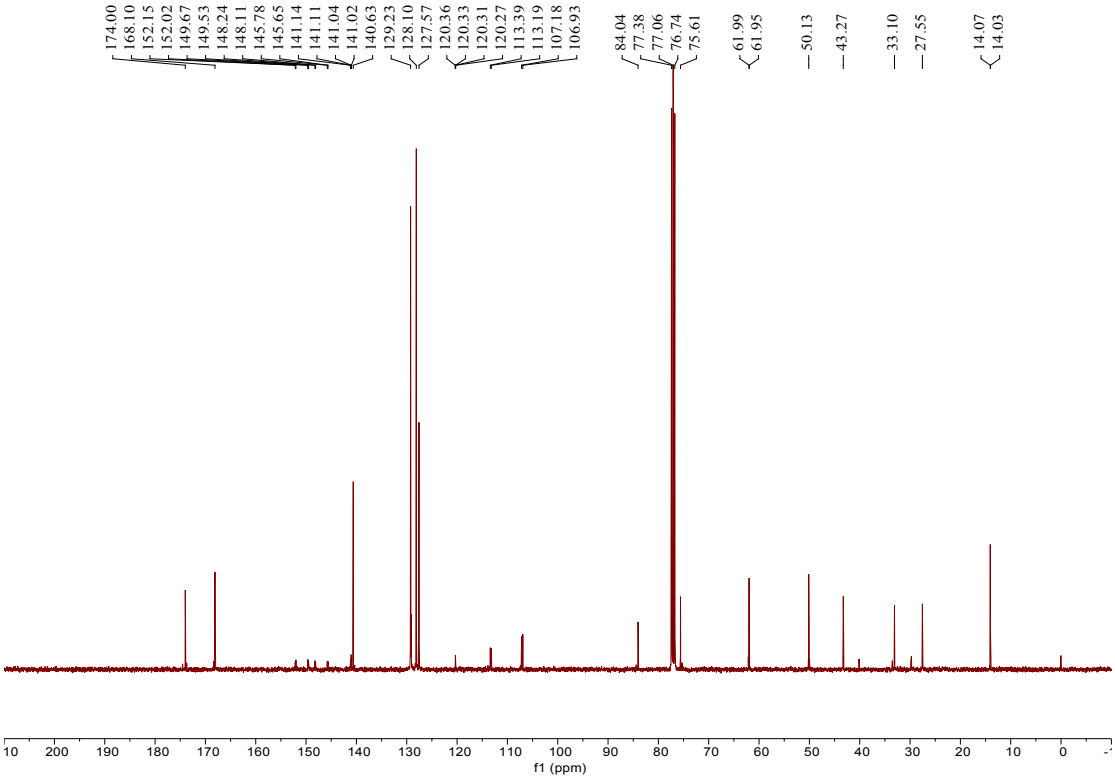
3n ^{19}F NMR (377 MHz, $CDCl_3$)



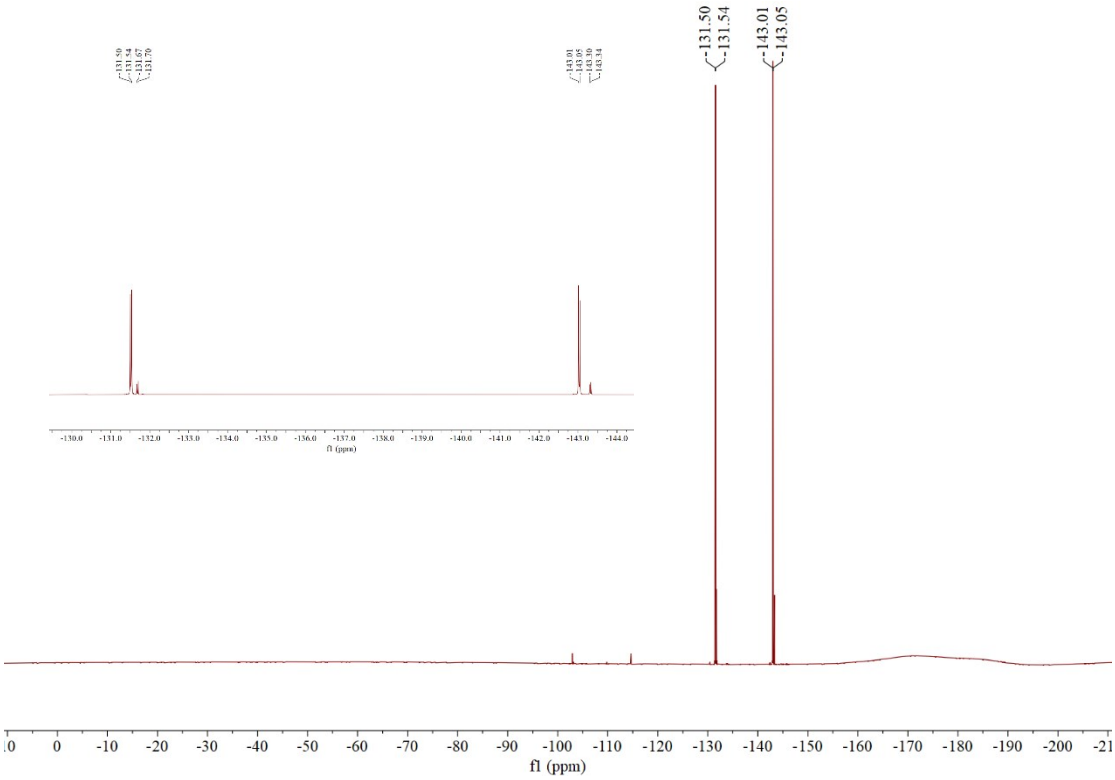
3o ^{1}H NMR (400 MHz, $CDCl_3$)



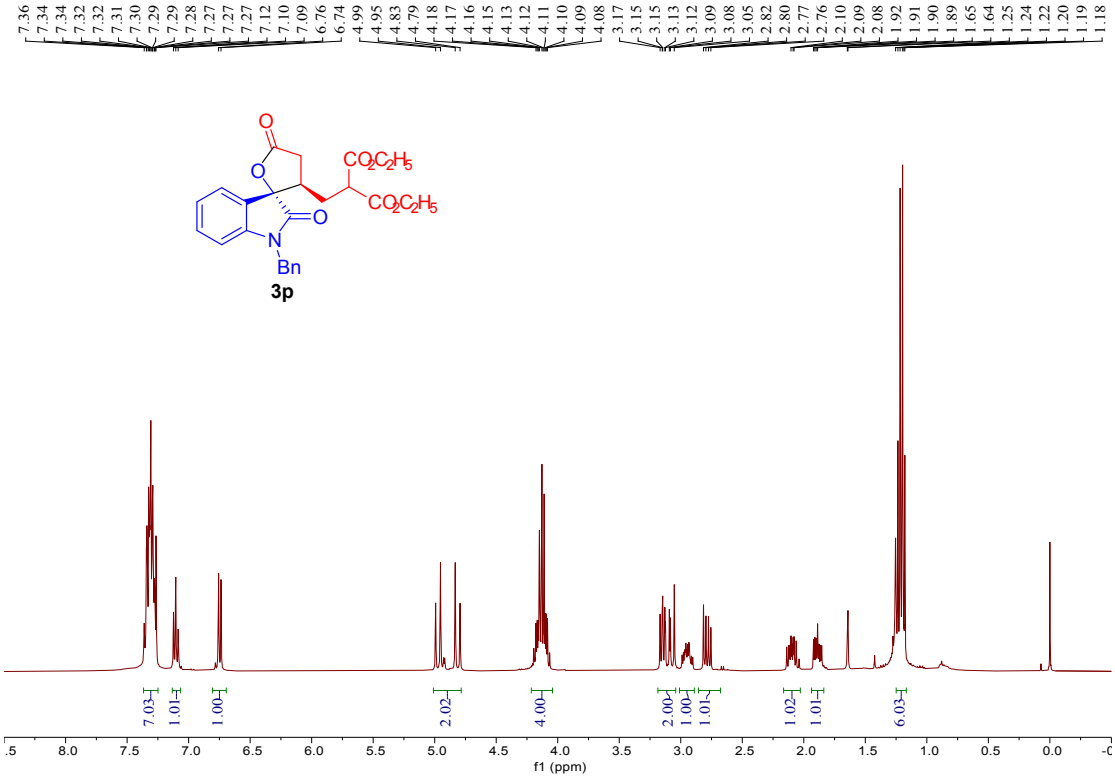
3o ^{13}C NMR (101 MHz, $CDCl_3$)



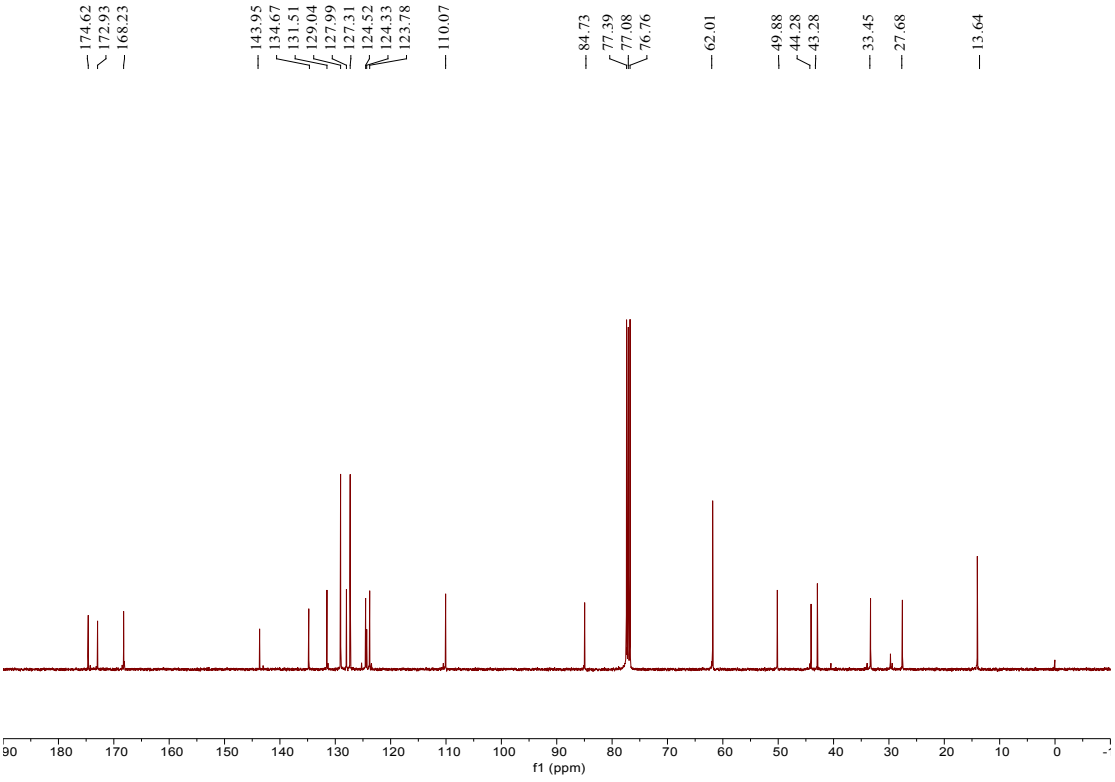
3o ^{19}F NMR (565 MHz, $CDCl_3$)



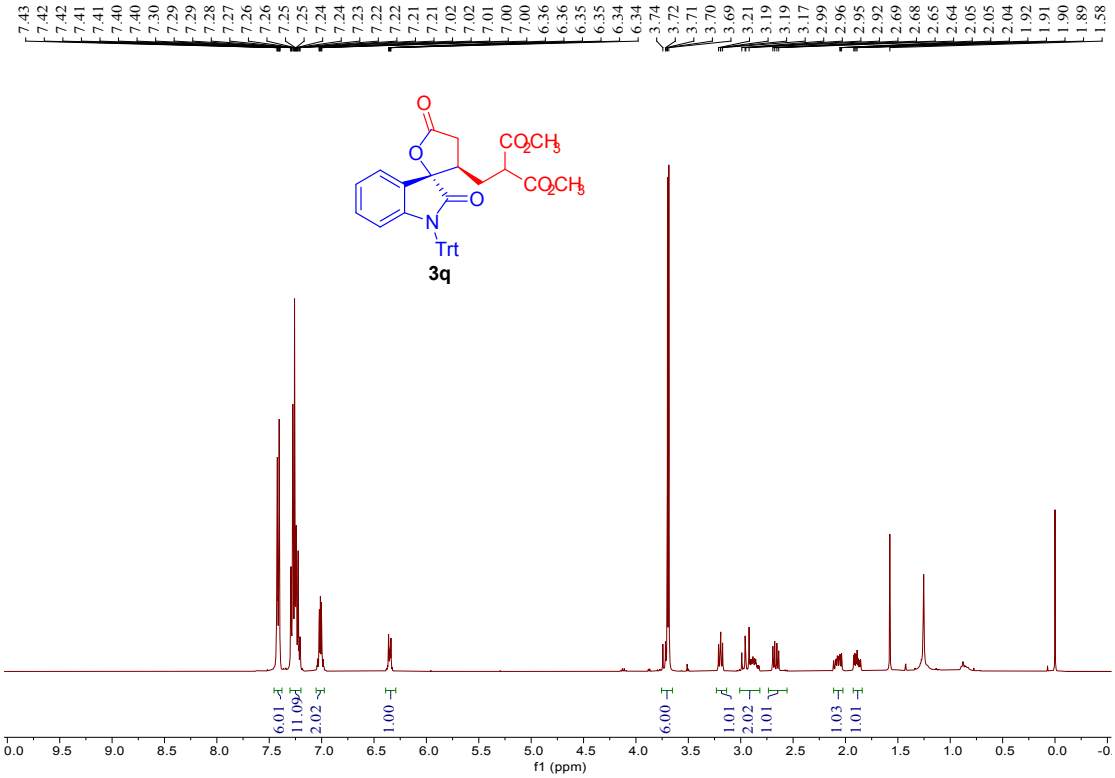
3p ^{1}H NMR (400 MHz, $CDCl_3$)



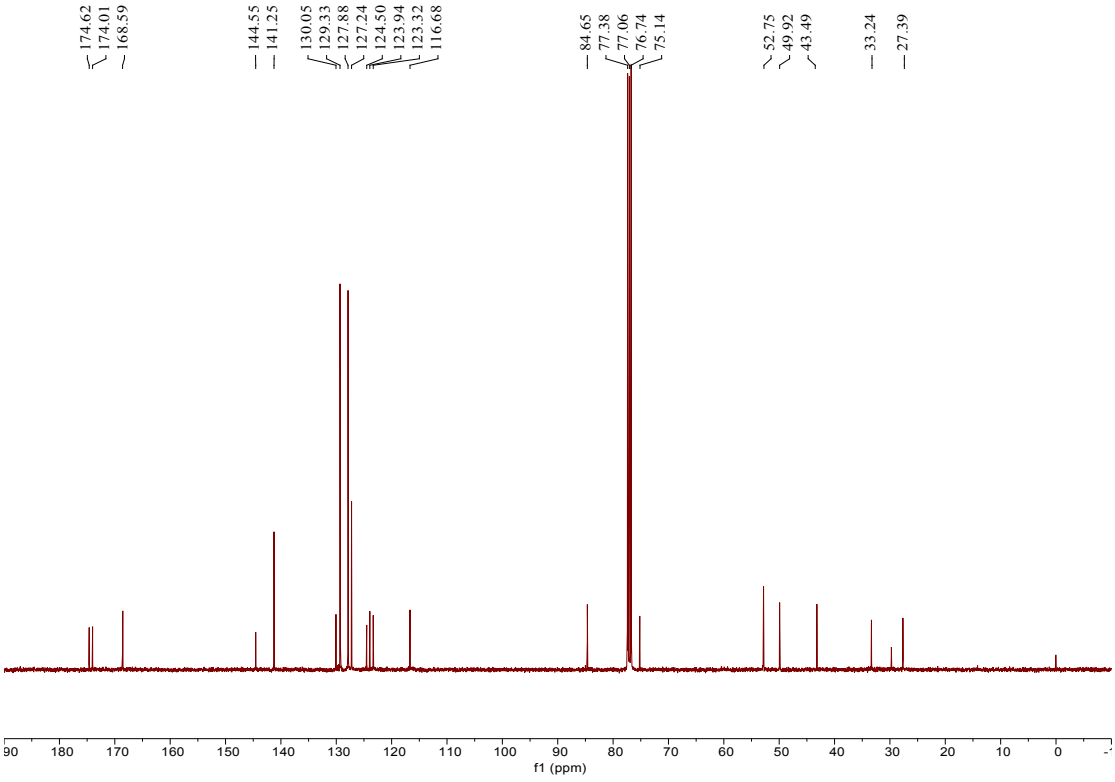
3p ^{13}C NMR(101 MHz, $CDCl_3$)



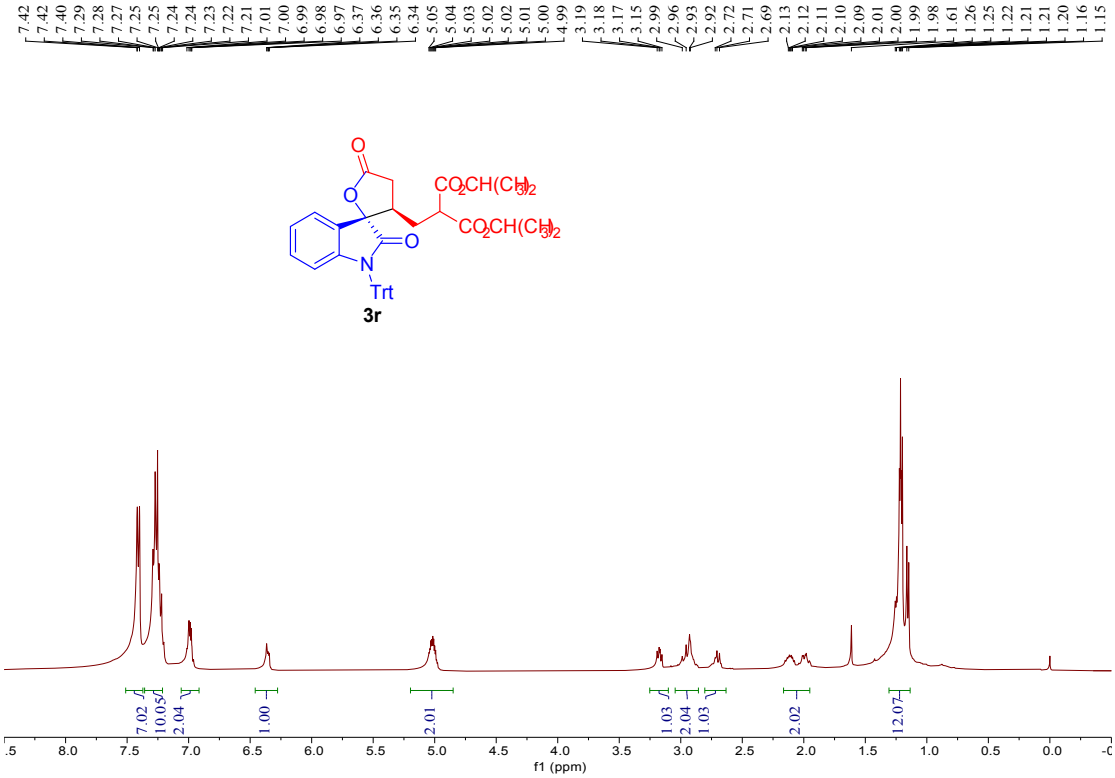
3q ^{1}H NMR (400 MHz, $CDCl_3$)



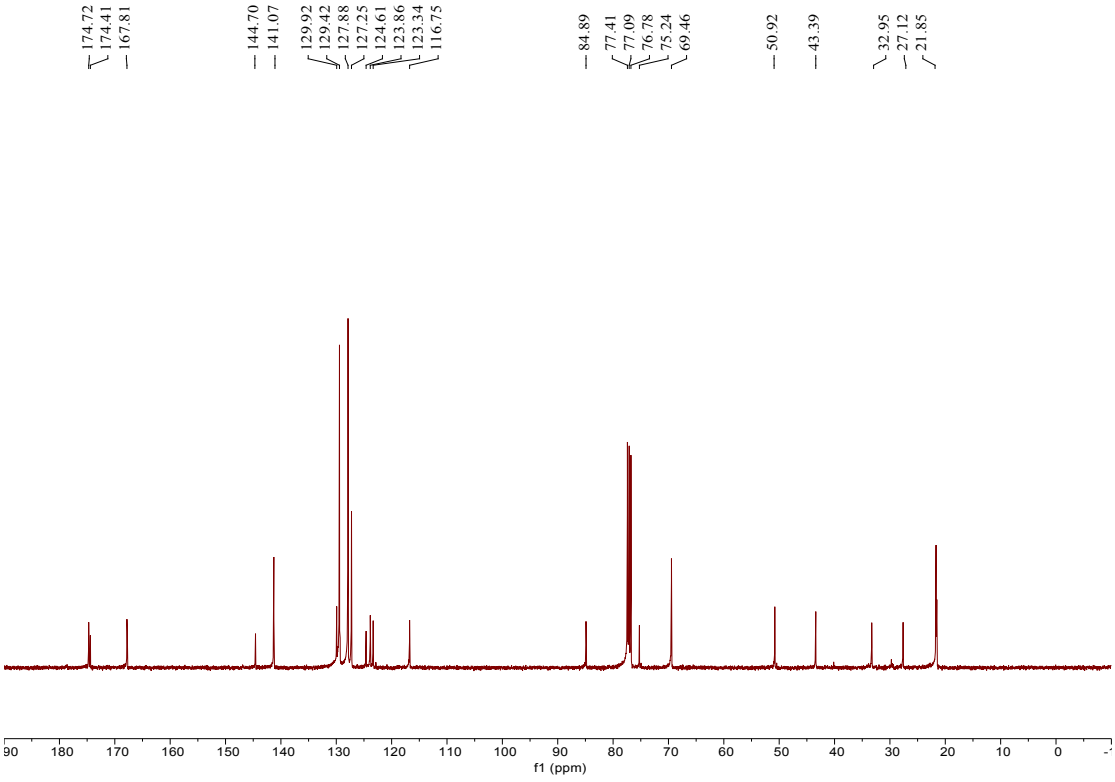
3q ^{13}C NMR (101 MHz, $CDCl_3$)



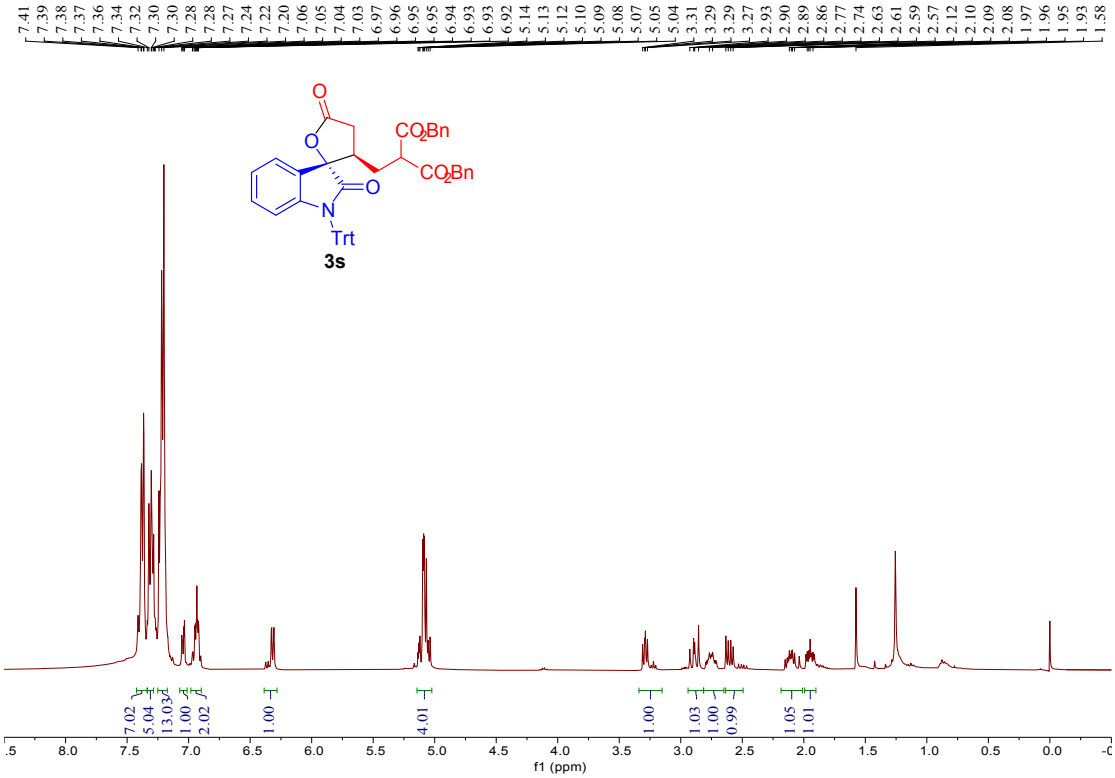
3r ^{1}H NMR (400 MHz, $CDCl_3$)



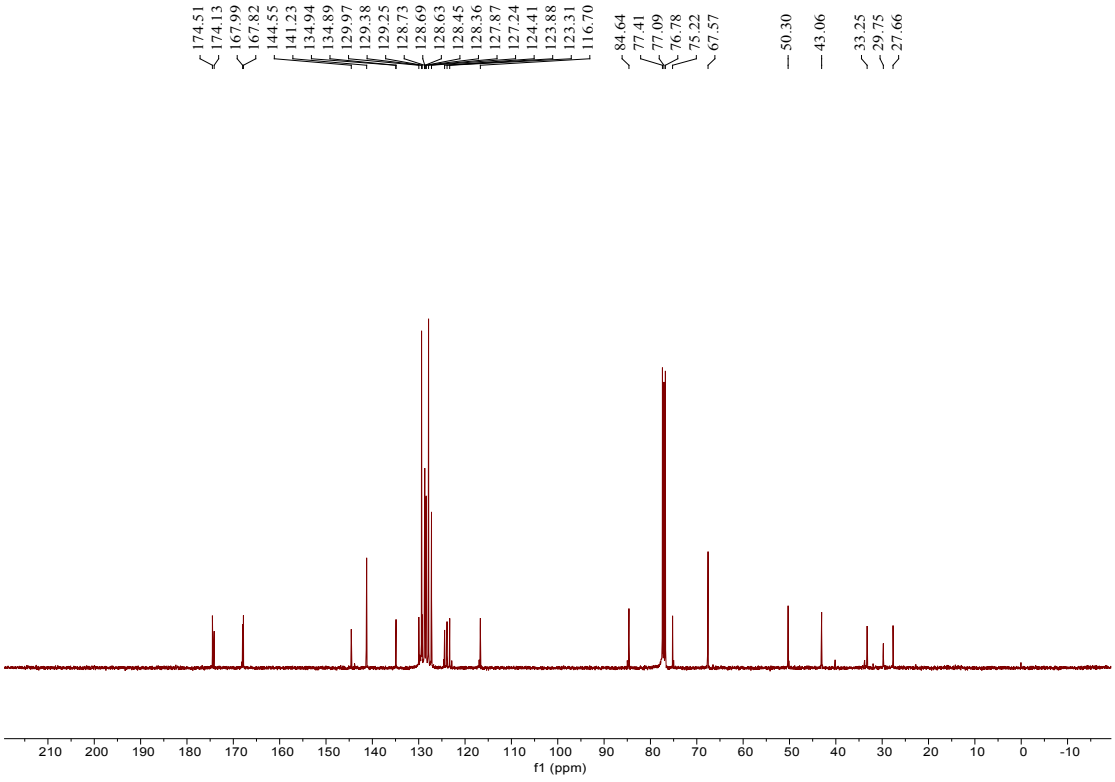
3r ^{13}C NMR (101 MHz, $CDCl_3$)



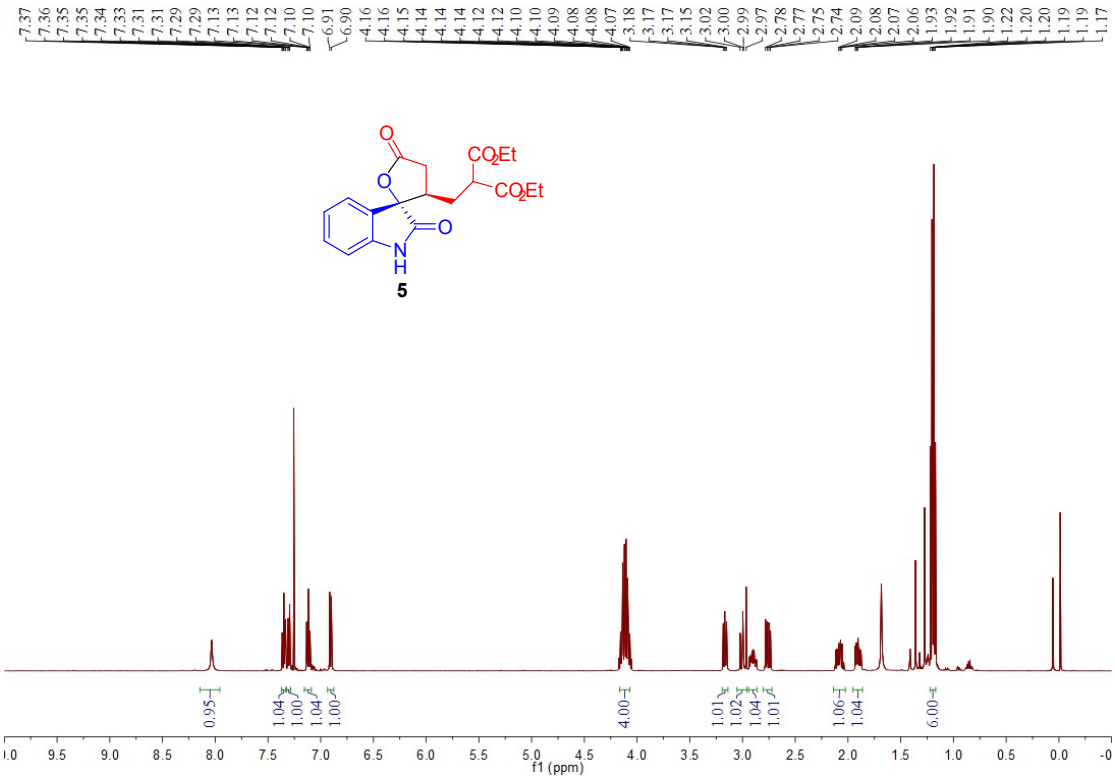
3s ^{1}H NMR (400 MHz, $CDCl_3$)



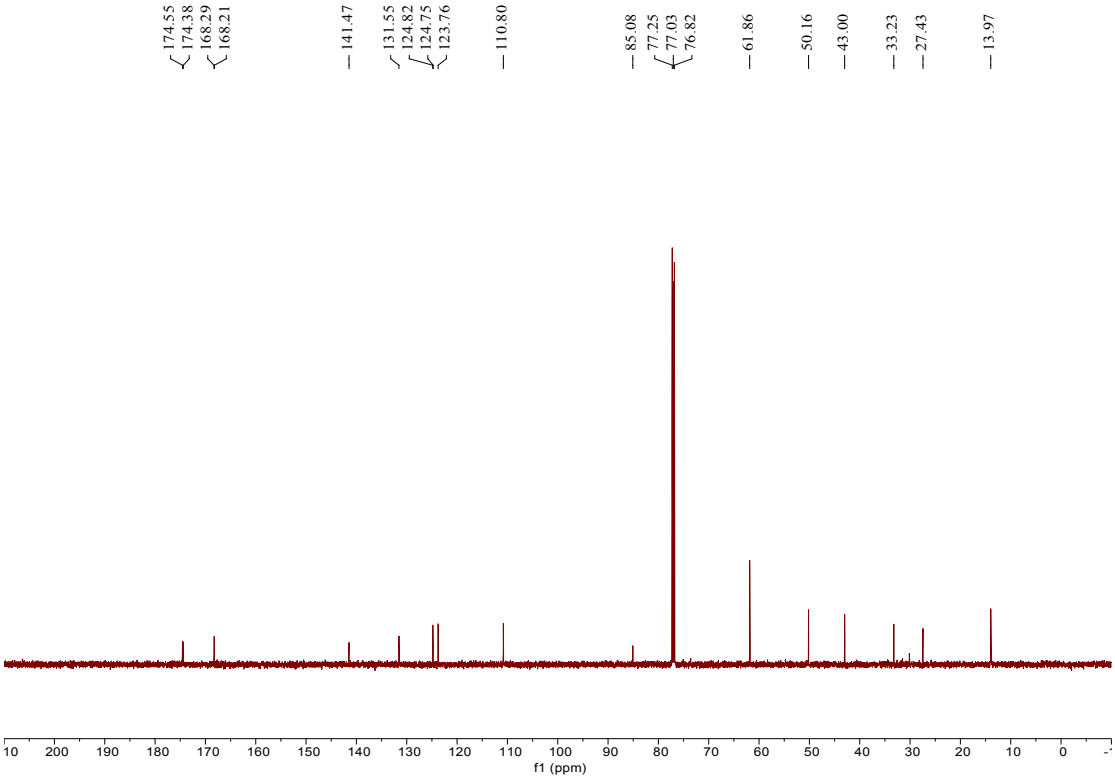
3s ^{13}C NMR (101 MHz, $CDCl_3$)



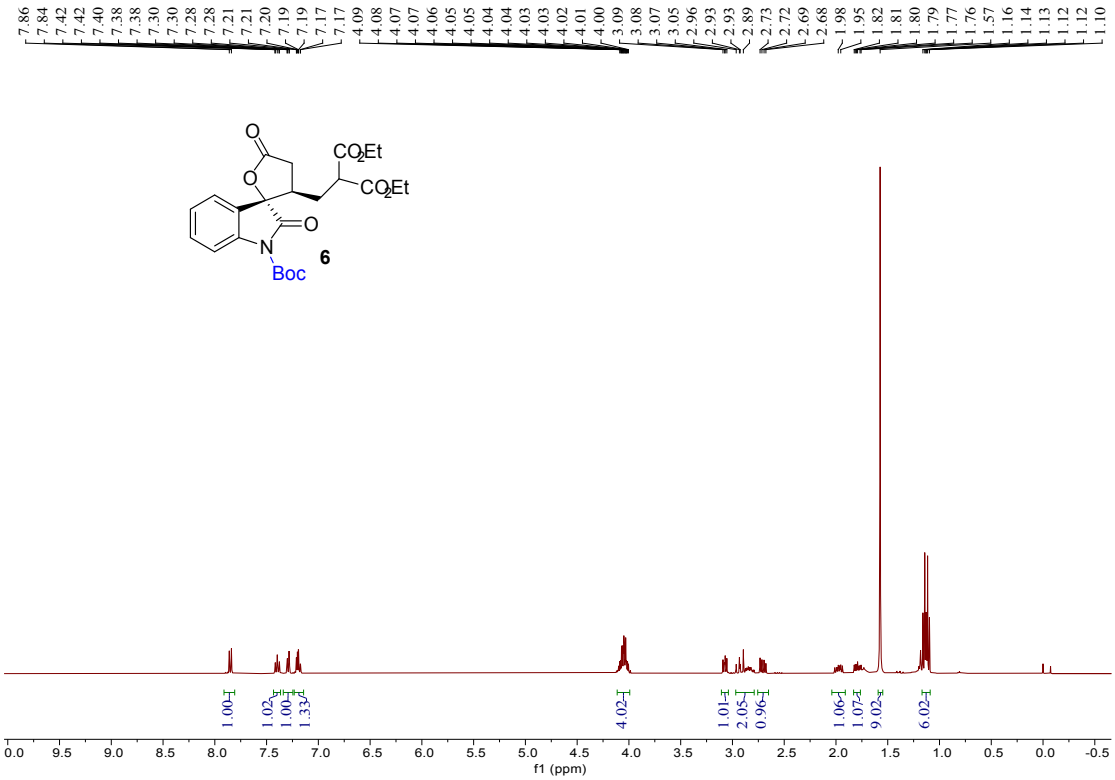
5 ^{1}H NMR (500 MHz, $CDCl_3$)



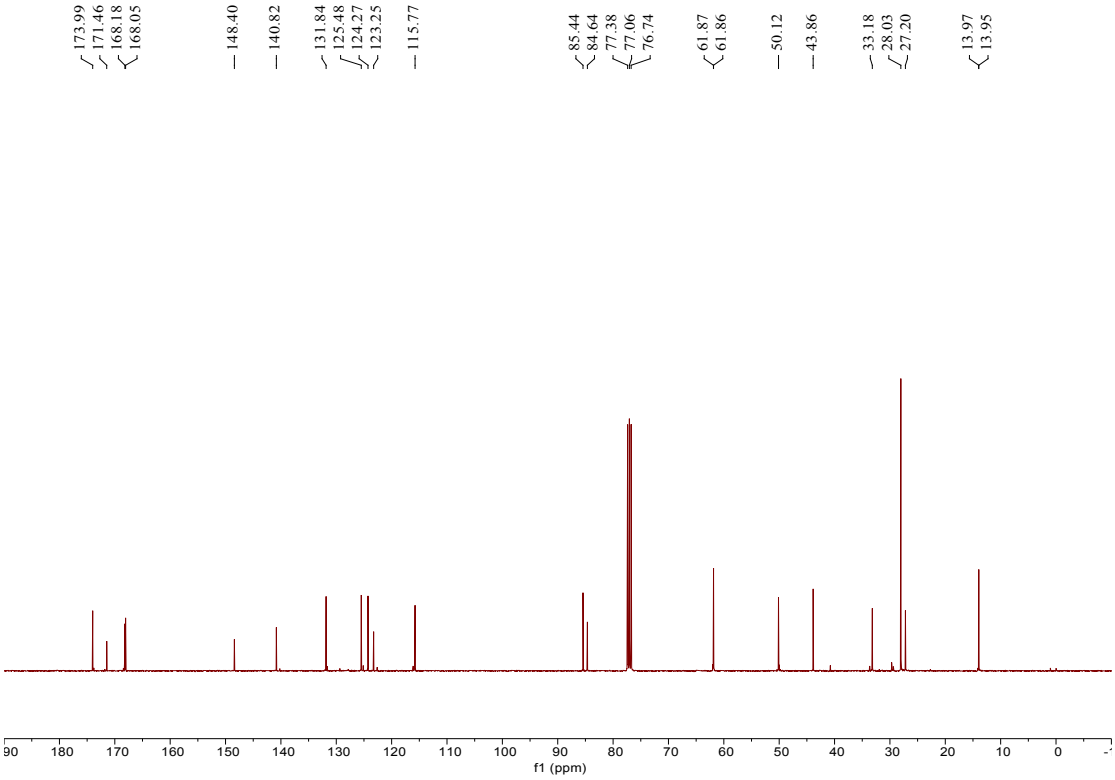
5 ^{13}C NMR (151 MHz, $CDCl_3$)



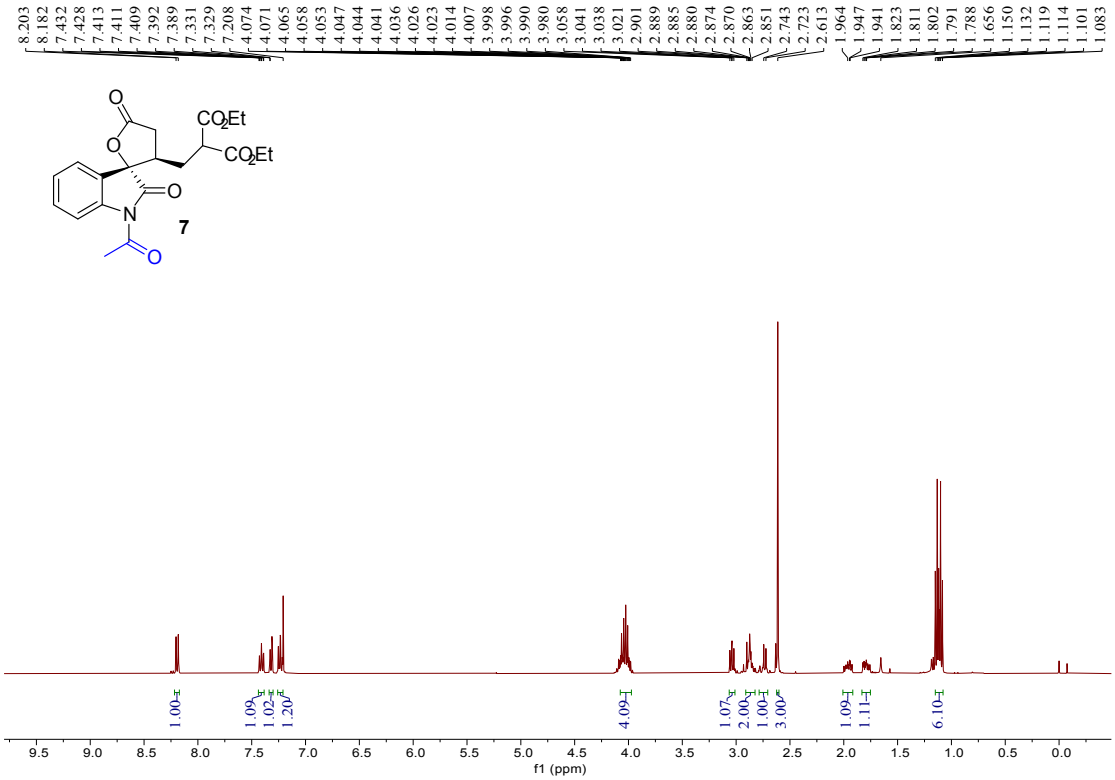
6 ^{1}H NMR (400 MHz, $CDCl_3$)



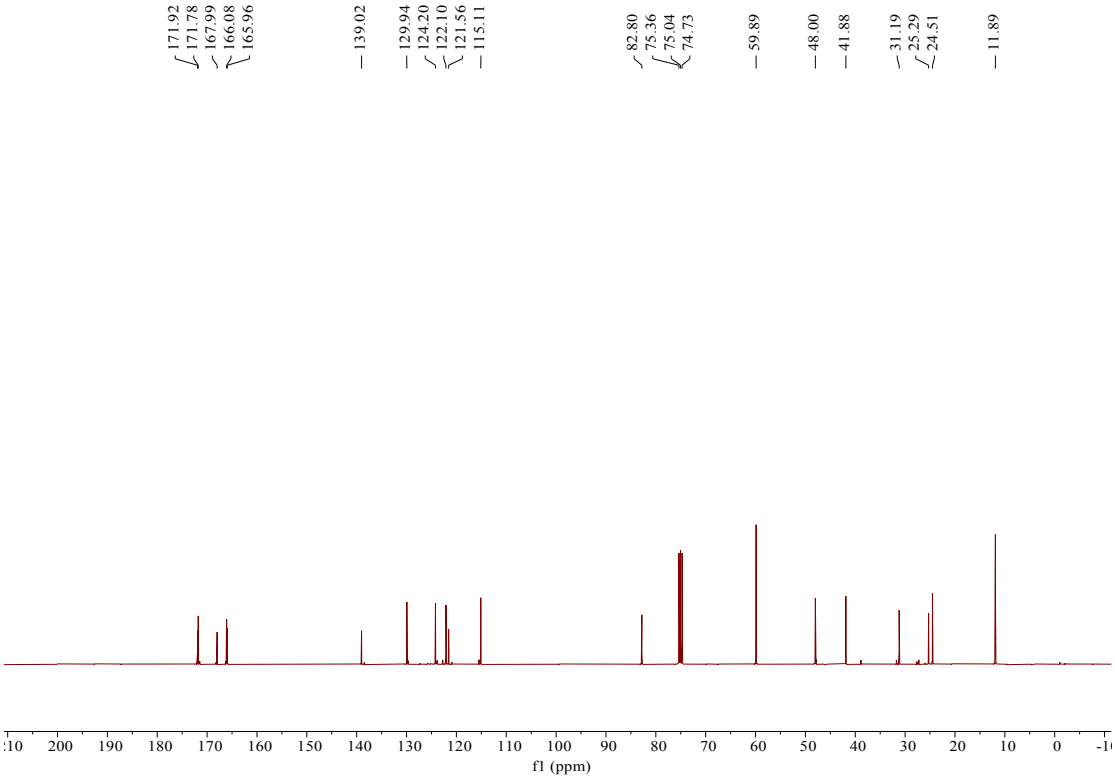
6 ^{13}C NMR (101 MHz, $CDCl_3$)



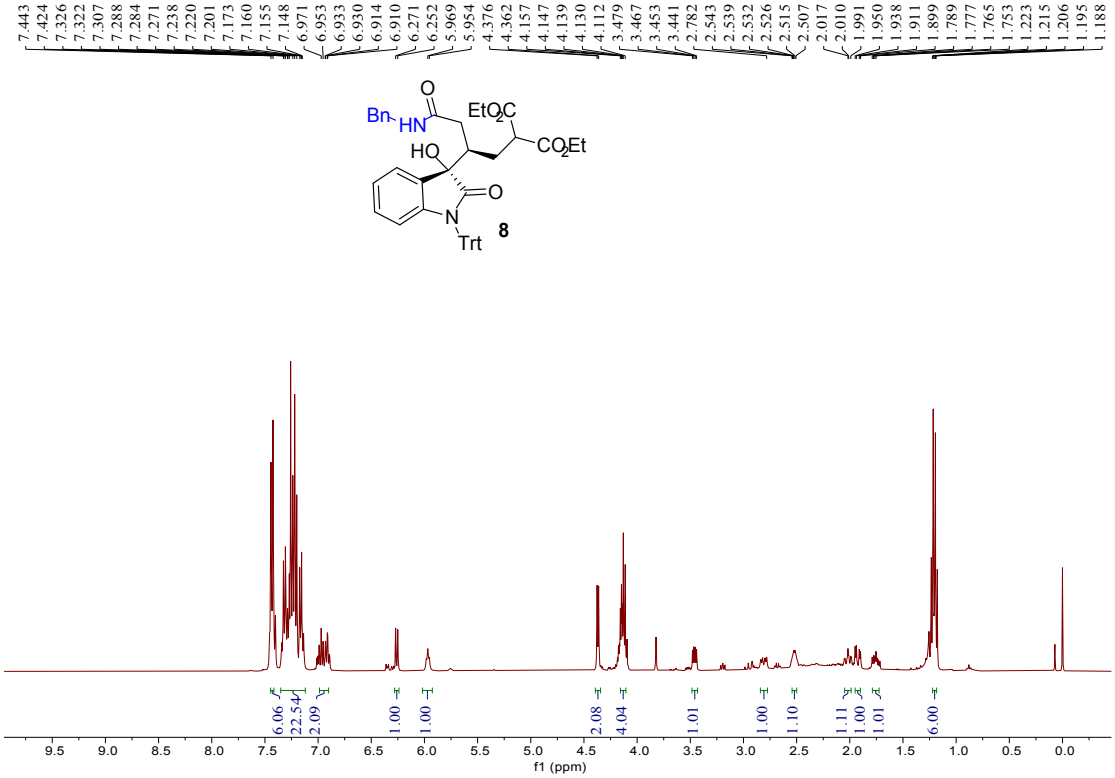
7 ^{1}H NMR (400 MHz, $CDCl_3$)



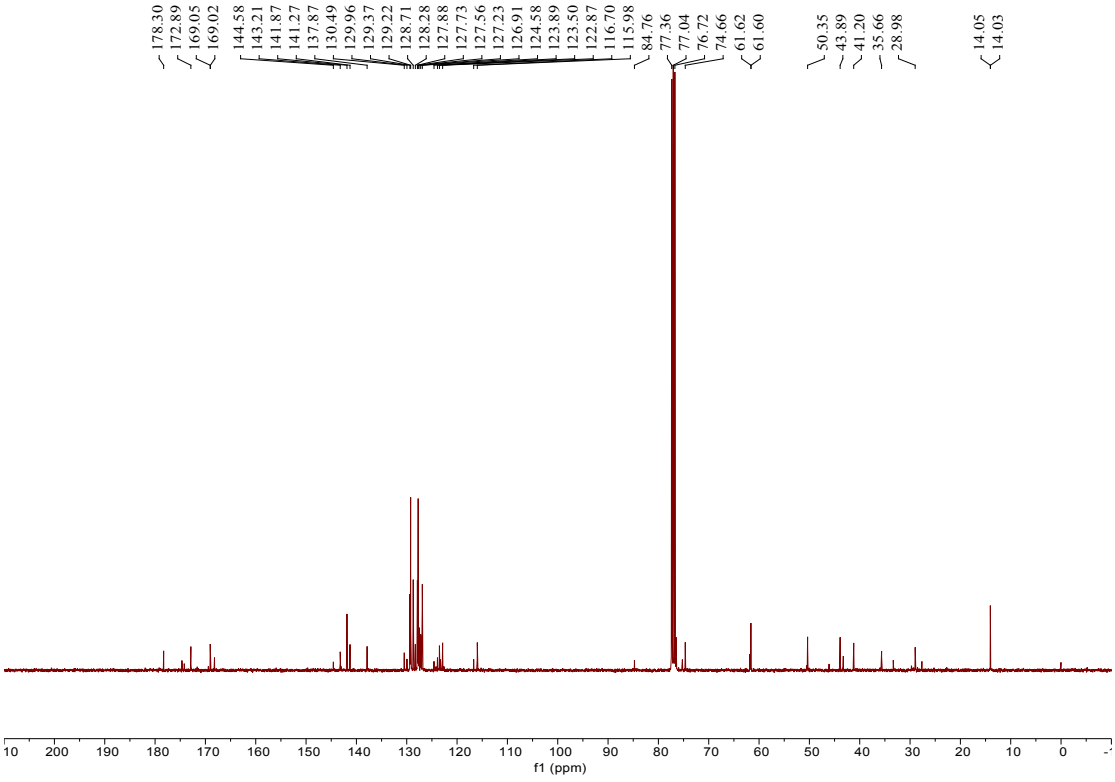
7 ^{13}C NMR (101 MHz, $CDCl_3$)



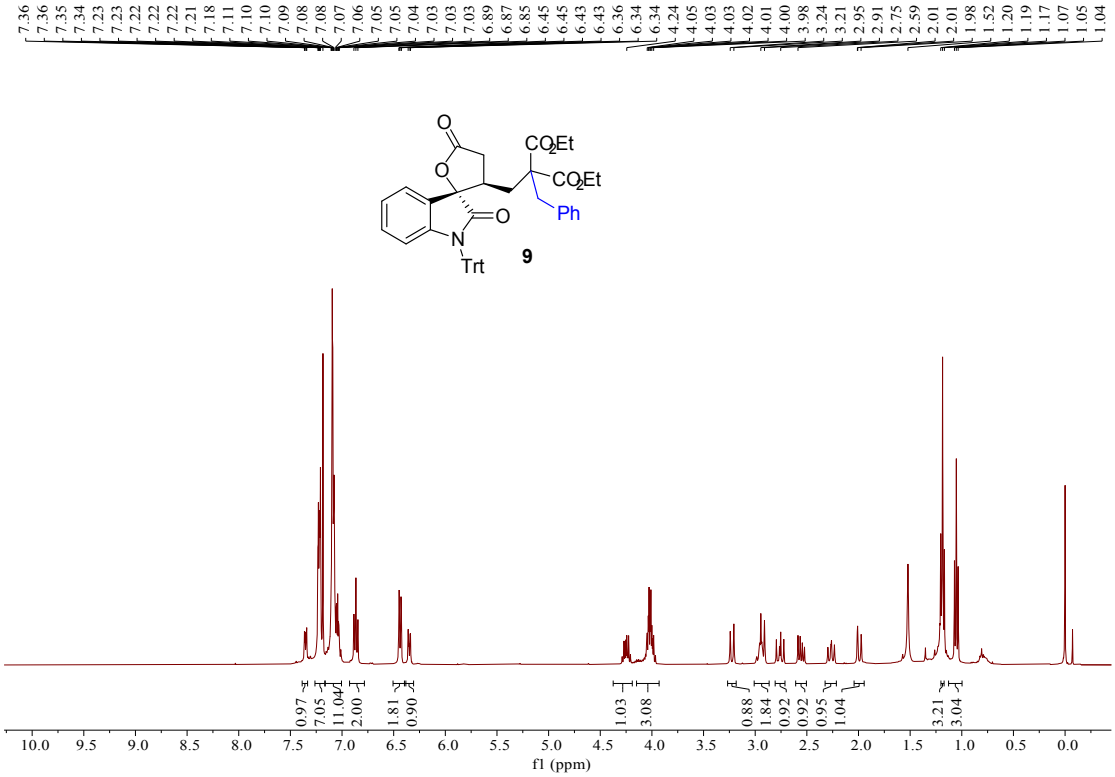
8 ^{1}H NMR (400 MHz, $CDCl_3$)



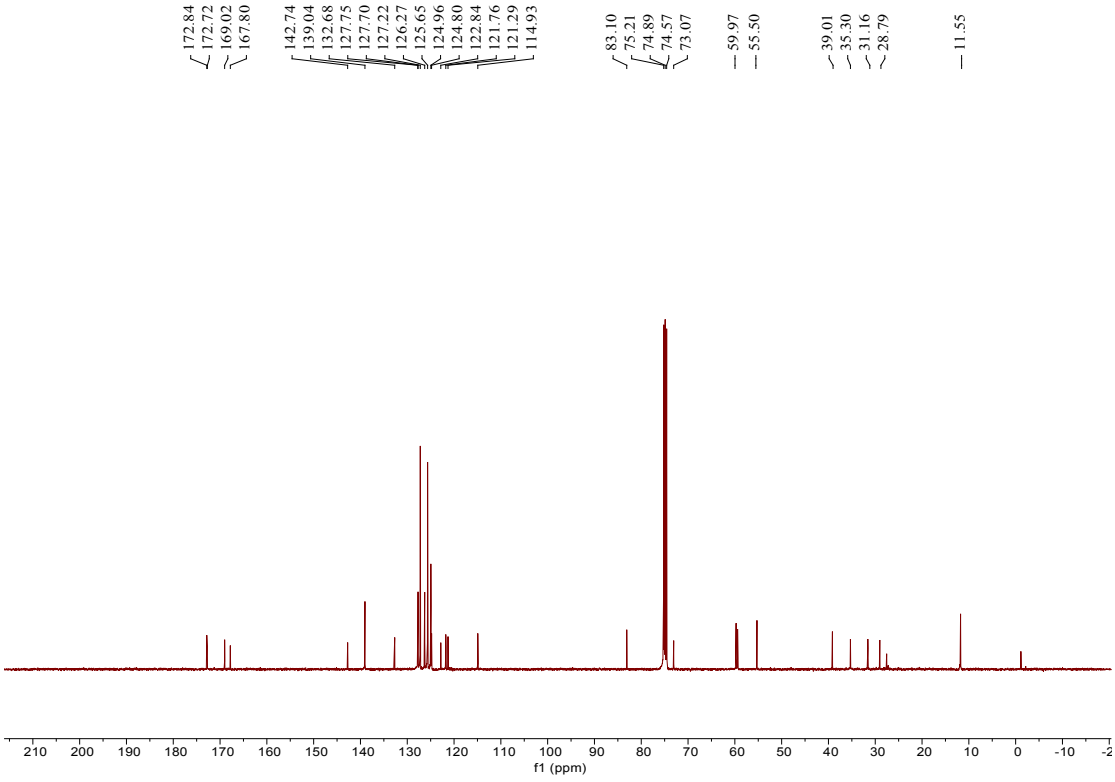
8 ^{13}C NMR (101 MHz, $CDCl_3$)



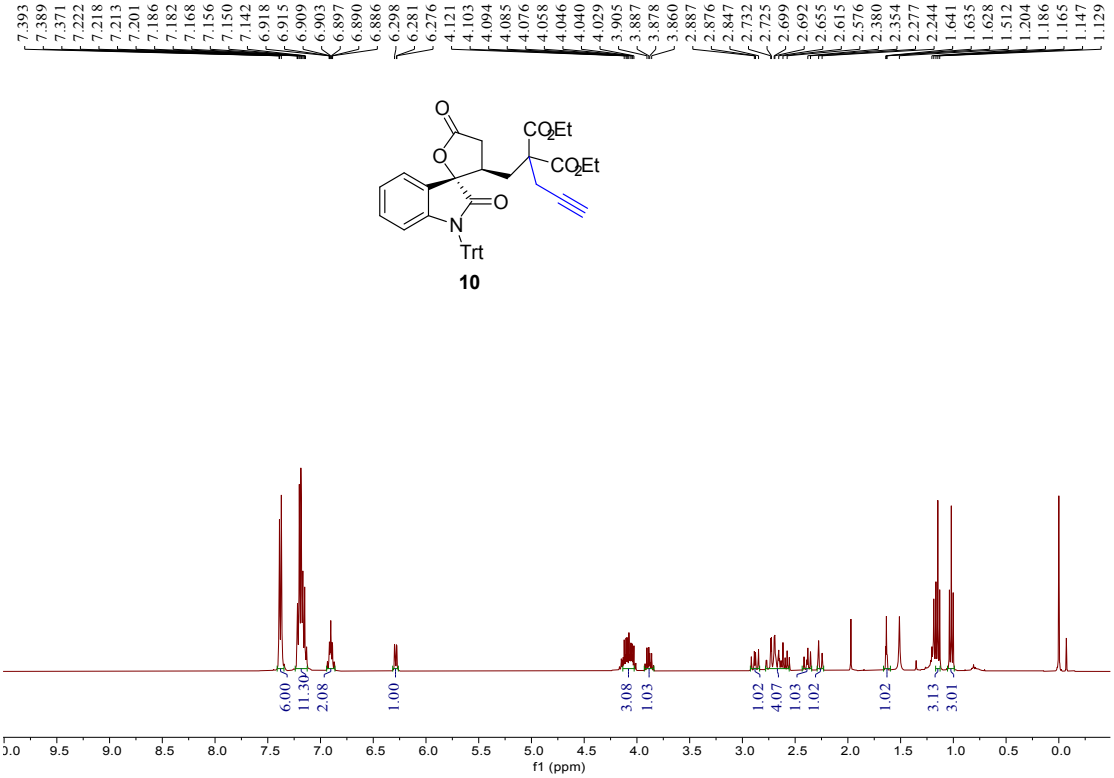
9 ^{1}H NMR (400 MHz, $CDCl_3$)



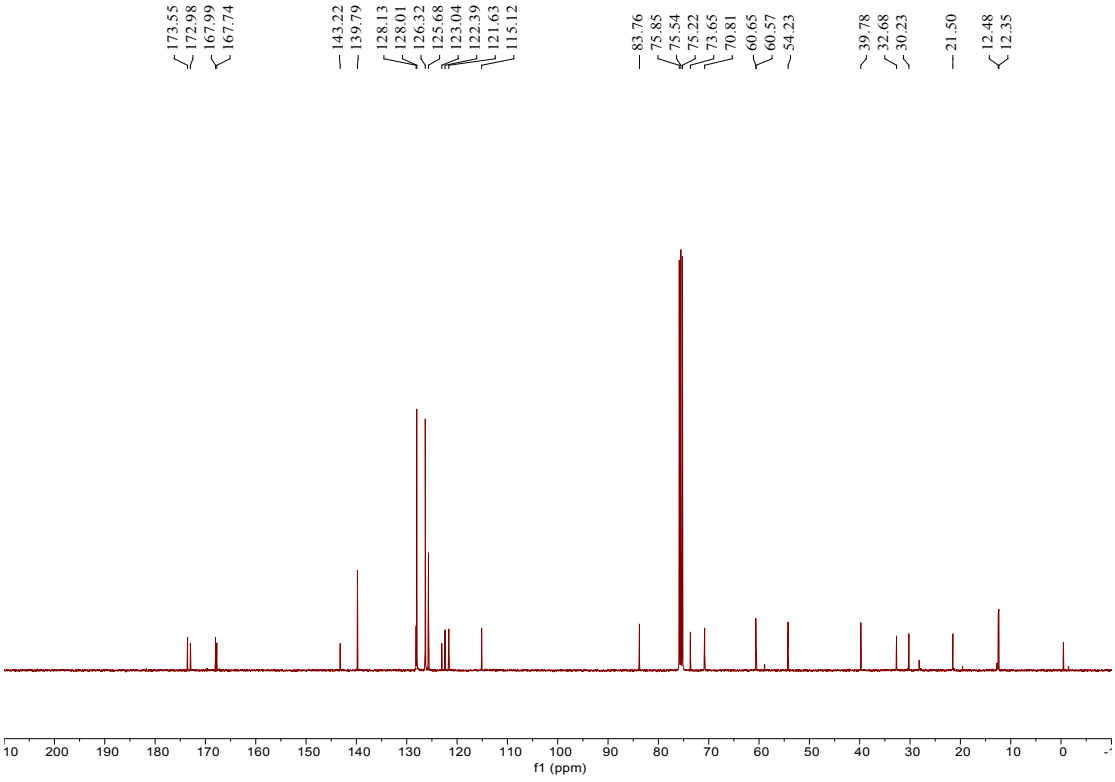
9 ^{13}C NMR (101 MHz, $CDCl_3$)



10 ^{1}H NMR (400 MHz, $CDCl_3$)

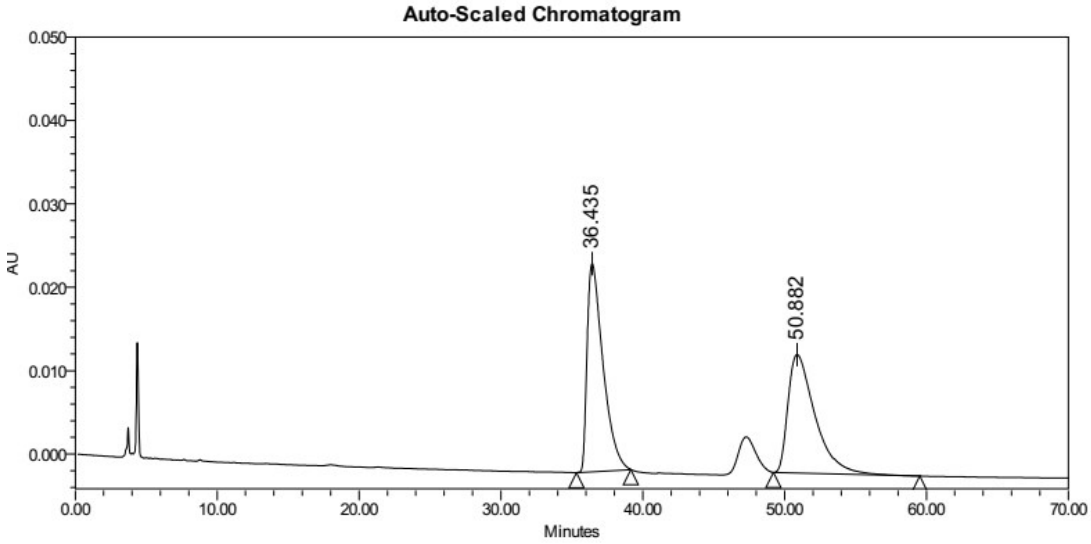


10 ^{13}C NMR (101 MHz, $CDCl_3$)



IX. HPLC spectra of products

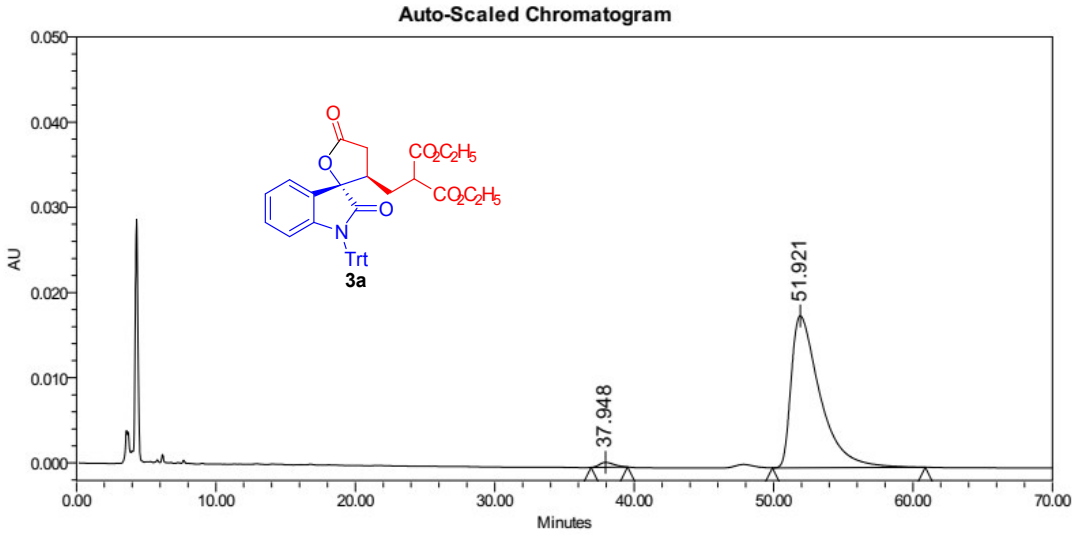
Racemic 3a



Peak Results

	RT	Area	% Area	Height
1	36.435	1947080	50.75	24967
2	50.882	1889388	49.25	14210

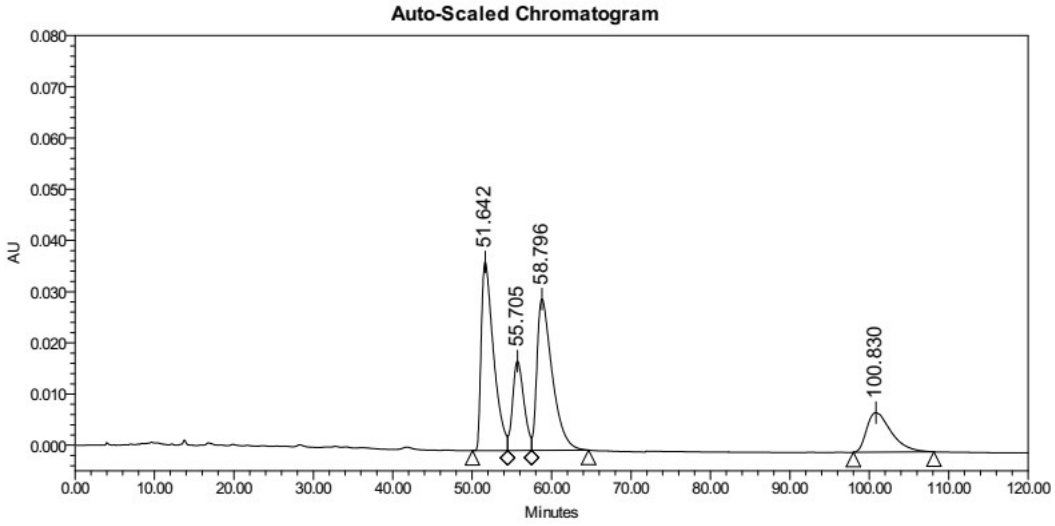
Enantioenriched 3a



Peak Results

	RT	Area	% Area	Height
1	37.948	42235	1.62	578
2	51.921	2564266	98.38	17825

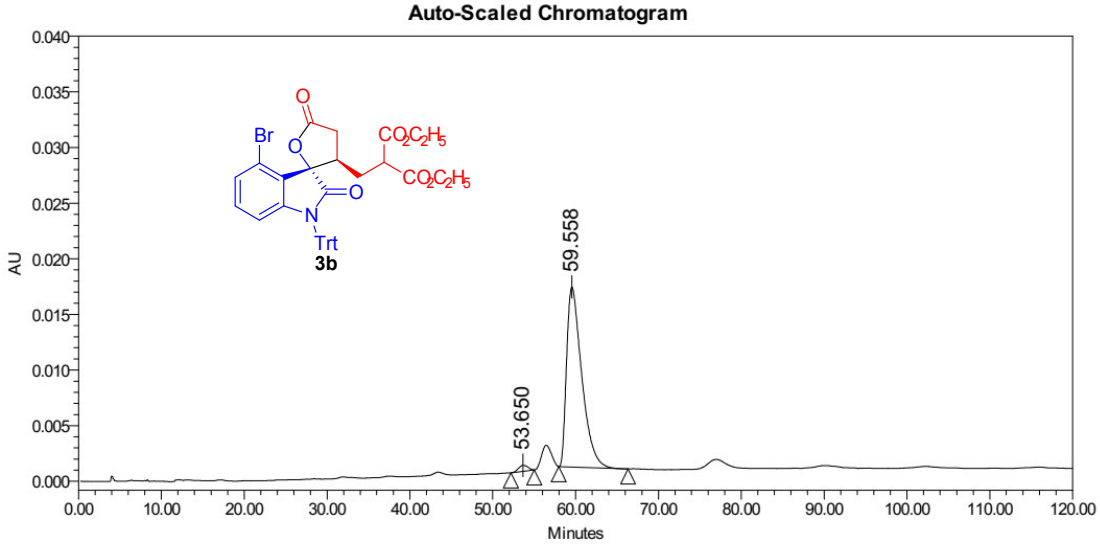
Racemic 3b



Peak Results

	Name	RT	Area	Height	% Area
1		51.642	3959645	36846	35.02
2		55.705	1726094	17449	15.27
3		58.796	3962629	29553	35.04
4		100.830	1658921	7730	14.67

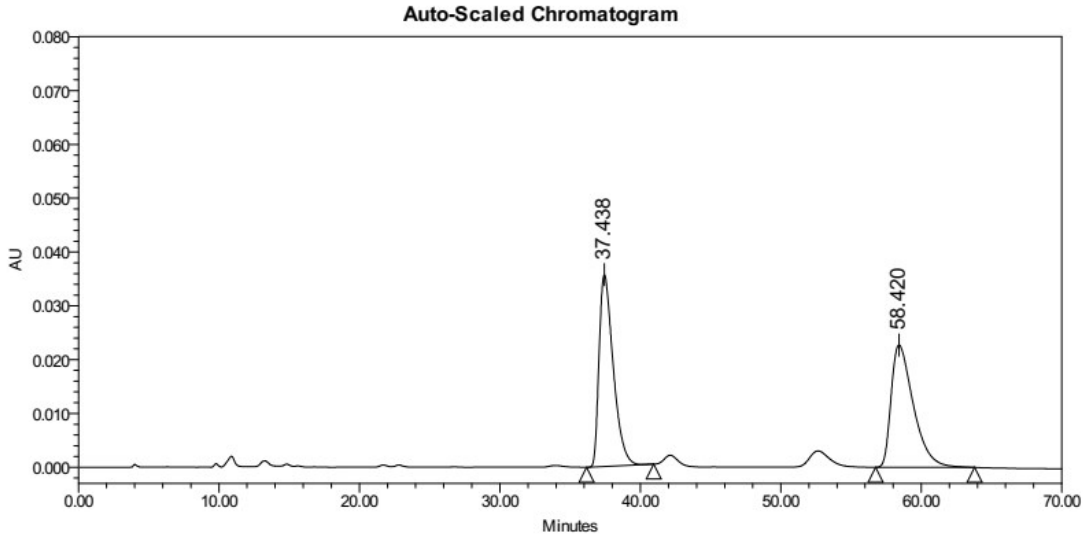
Enantioenriched 3b



Peak Results

	Name	RT	Area	Height	% Area
1		53.650	42868	546	2.04
2		59.558	2054046	16198	97.96

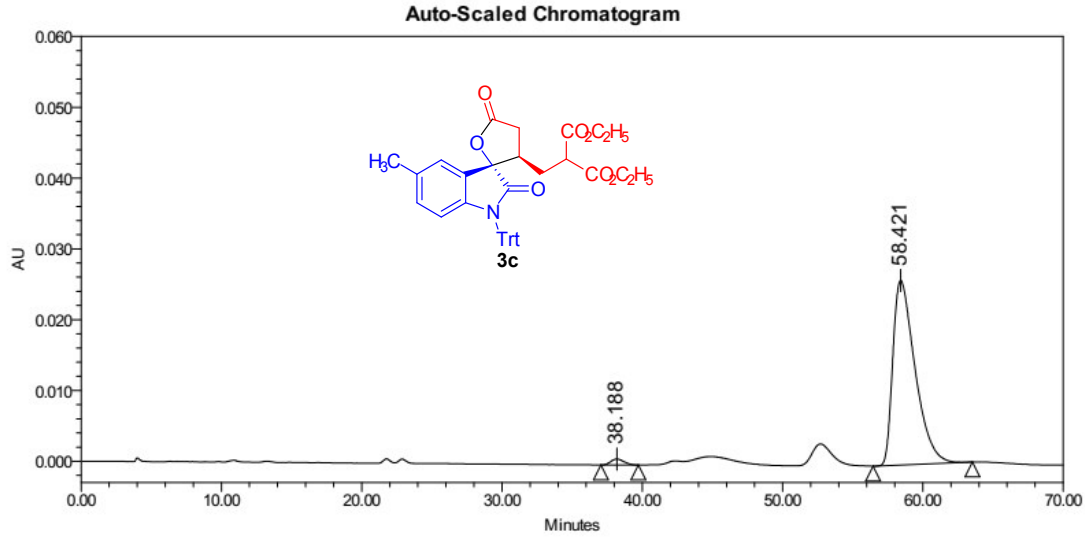
Racemic 3c



Peak Results

	Name	RT	Area	Height	% Area
1		37.438	2495629	35617	49.89
2		58.420	2506972	22756	50.11

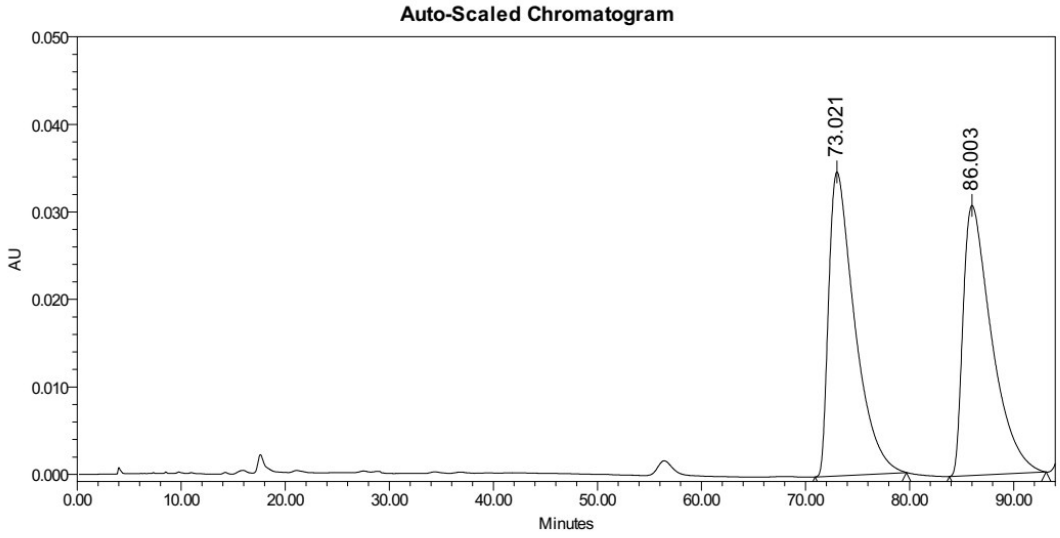
Enantioenriched 3c



Peak Results

	Name	RT	Area	Height	% Area
1		38.188	54826	836	1.87
2		58.421	2871751	26074	98.13

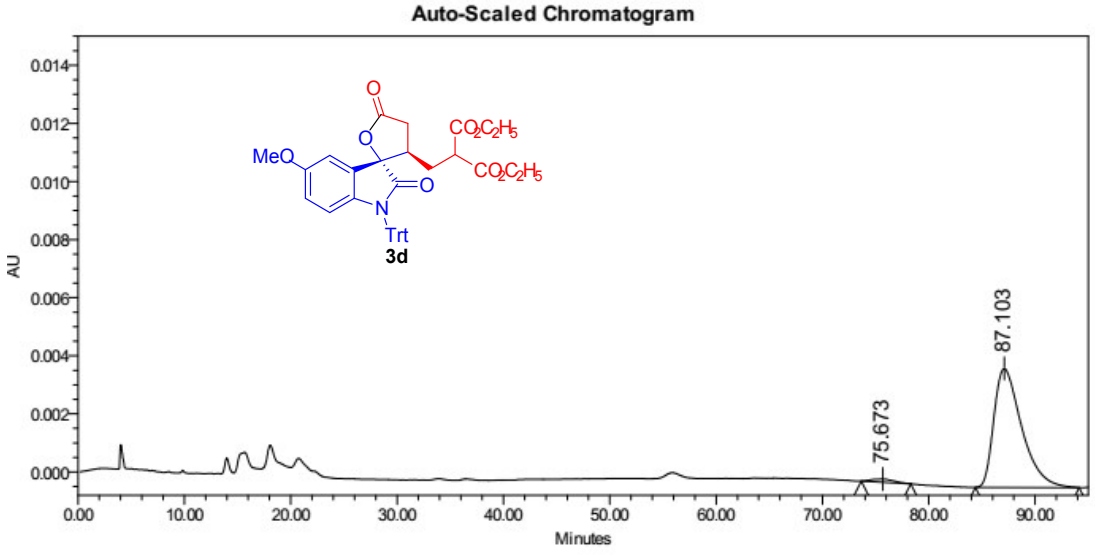
Racemic 3d



Peak Results

	Name	RT	Area	Height	% Area
1		73.021	6023597	34719	50.54
2		86.003	5894597	30853	49.46

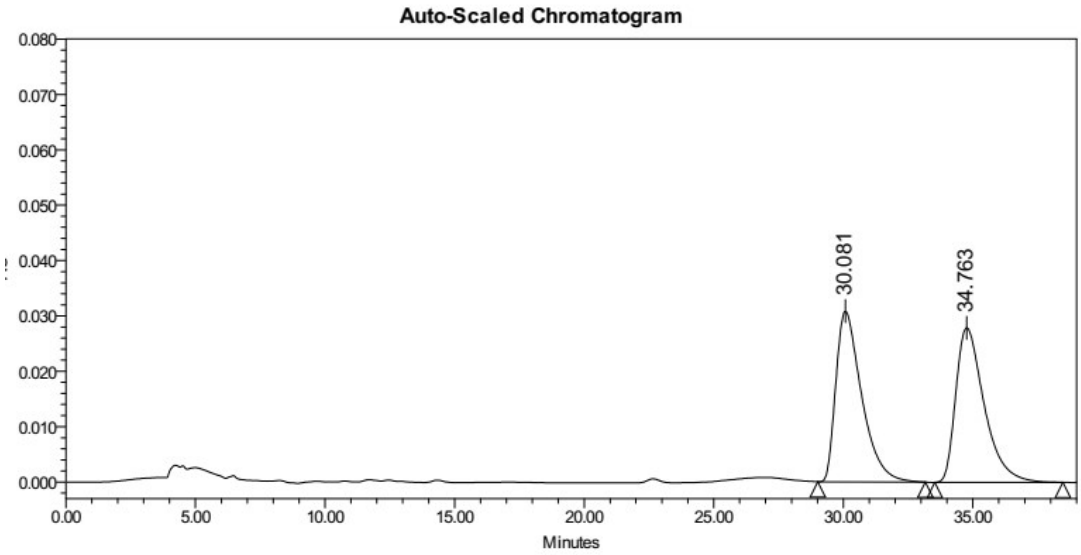
Enantioenriched 3d



Peak Results

	Name	RT	Area	Height	% Area
1		75.673	15765	112	2.07
2		87.103	744726	4100	97.93

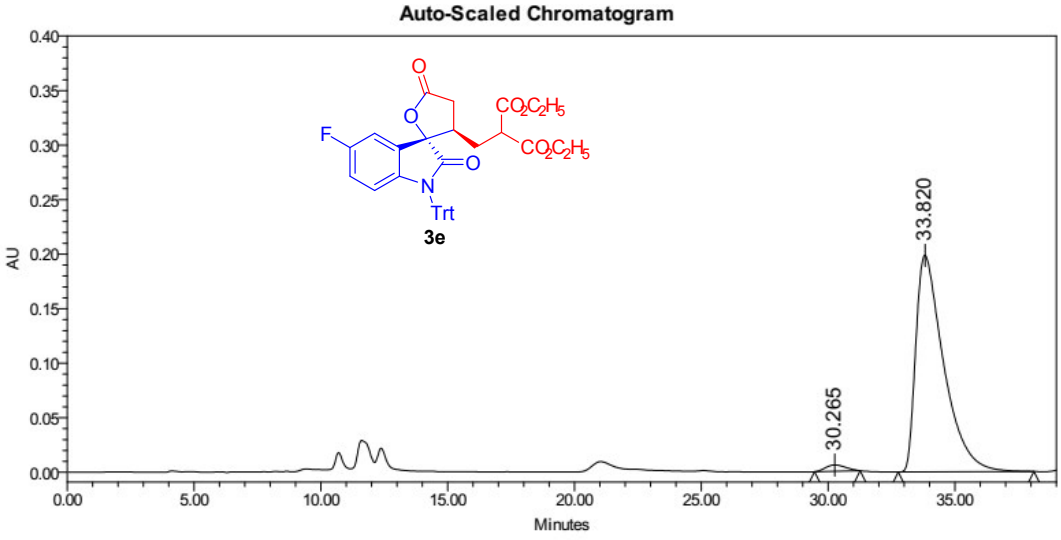
Racemic 3e



Peak Results

	Name	RT	Area	Height	% Area
1		30.081	2134512	30825	50.05
2		34.763	2130211	27909	49.95

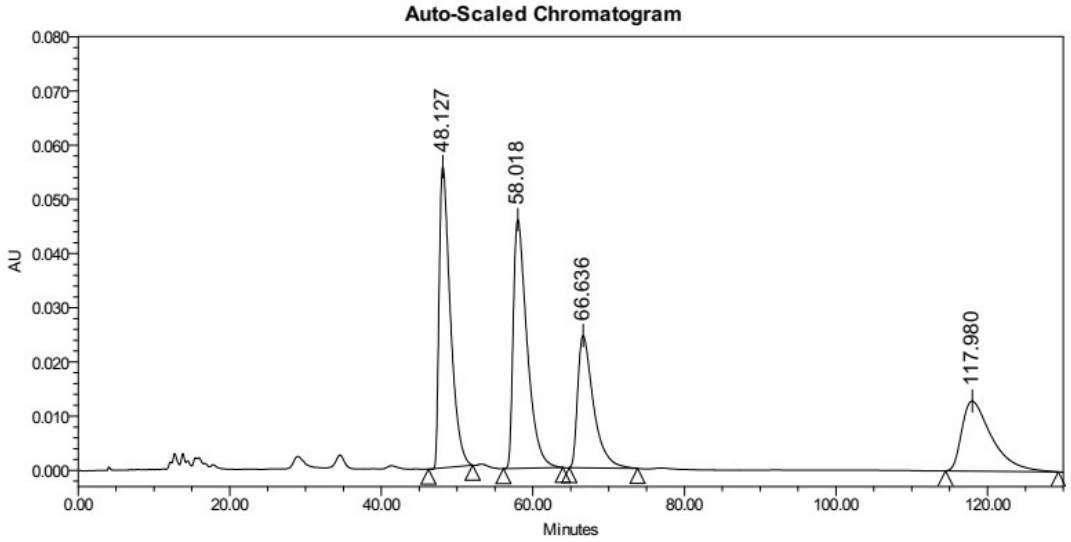
Enantioenriched 3e



Peak Results

	Name	RT	Area	Height	% Area
1		30.265	323912	5852	2.08
2		33.820	15224997	198591	97.92

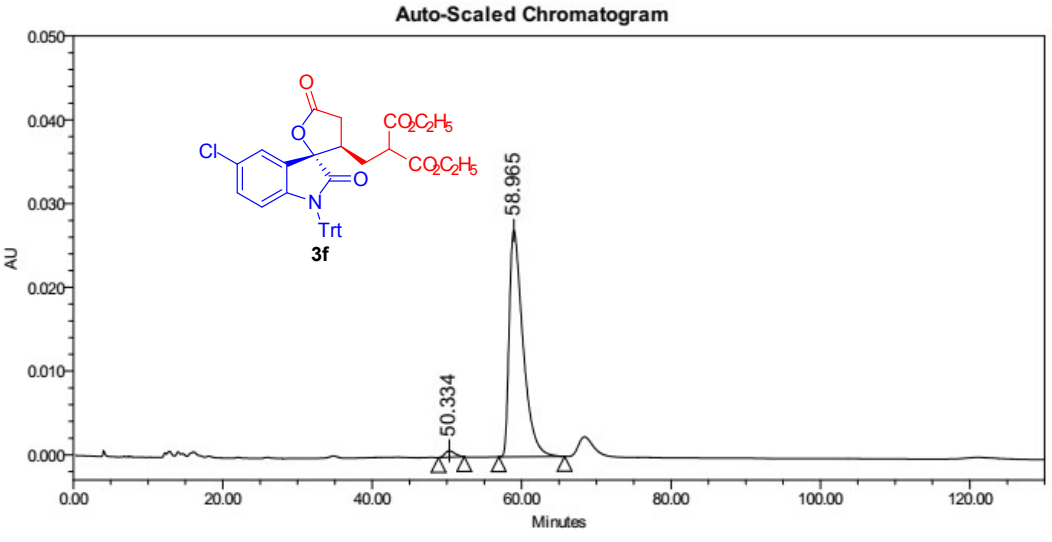
Racemic 3f



Peak Results

	Name	RT	Area	Height	% Area
1		48.127	5722727	55594	30.76
2		58.018	5818266	45885	31.27
3		66.636	3529134	24402	18.97
4		117.980	3534398	12925	19.00

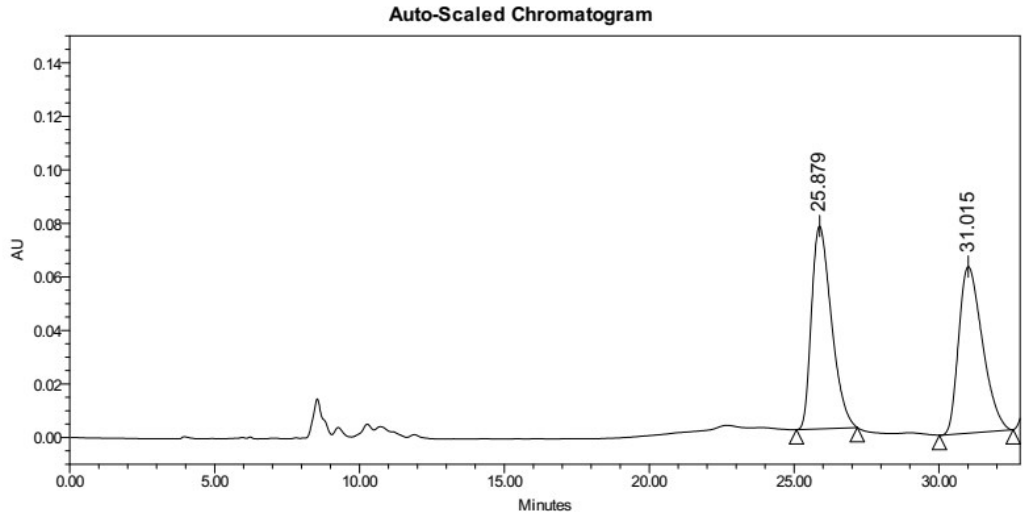
Enantioenriched 3f



Peak Results

	Name	RT	Area	Height	% Area
1		50.334	71142	761	2.01
2		58.965	3470760	27036	97.99

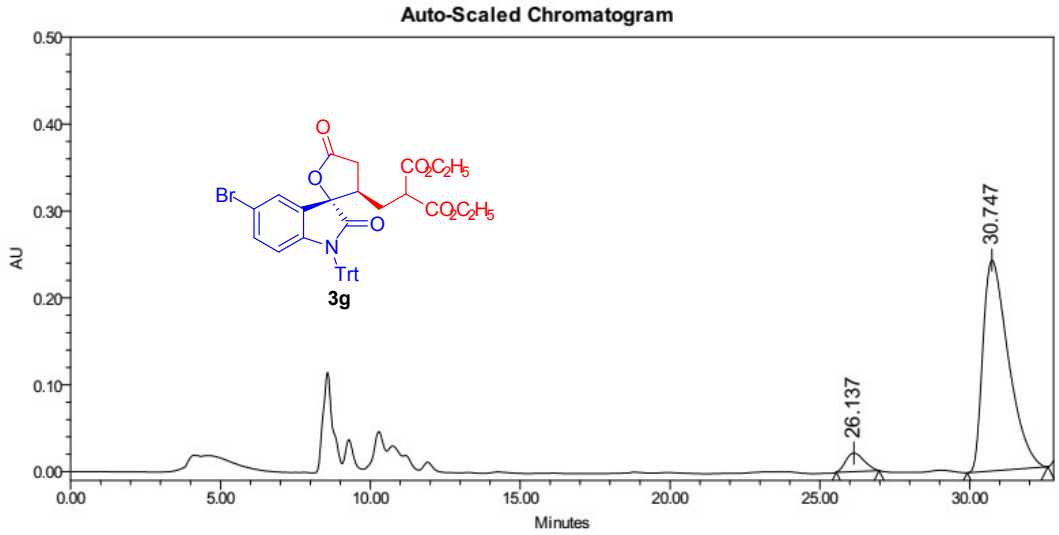
Racemic 3g



Peak Results

	Name	RT	Area	Height	% Area
1		25.879	3625816	75781	50.62
2		31.015	3537127	62208	49.38

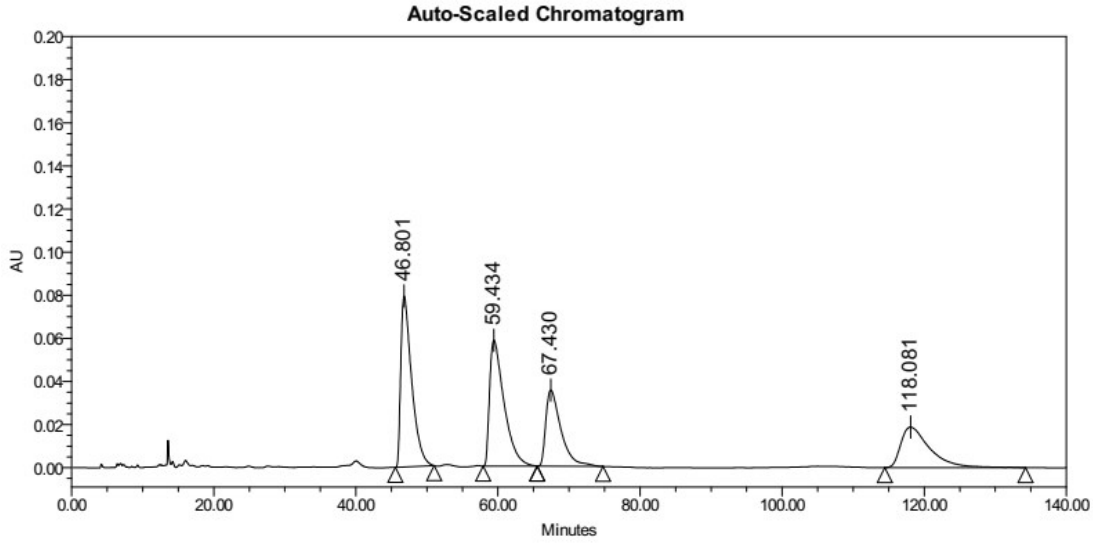
Enantioenriched 3g



Peak Results

	Name	RT	Area	Height	% Area
1		26.137	906017	21274	5.93
2		30.747	14377444	242632	94.07

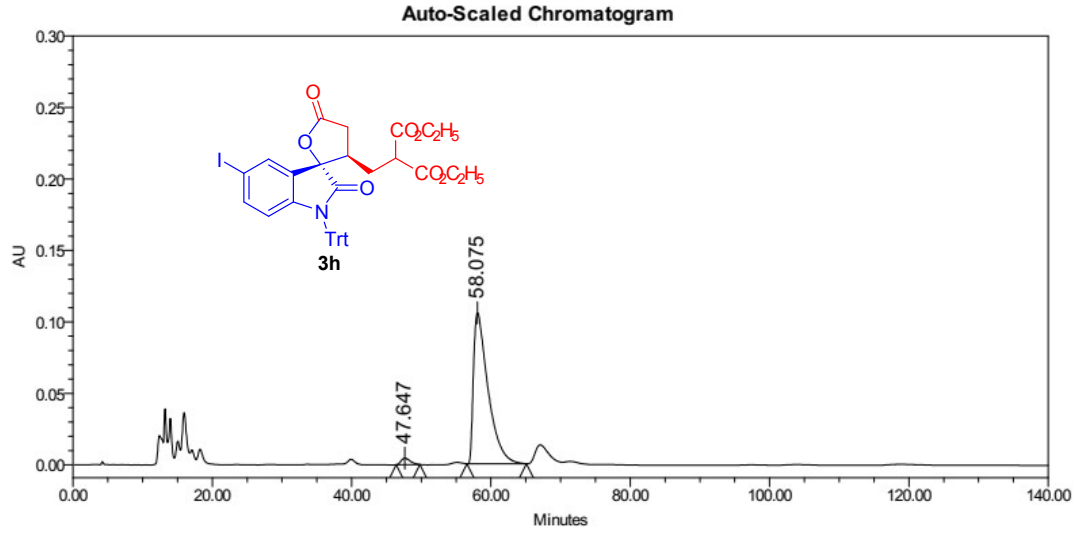
Racemic 3h



Peak Results

	Name	RT	Area	Height	% Area
1		46.801	8438425	79308	30.91
2		59.434	8303465	58458	30.41
3		67.430	5263184	35322	19.28
4		118.081	5296150	18780	19.40

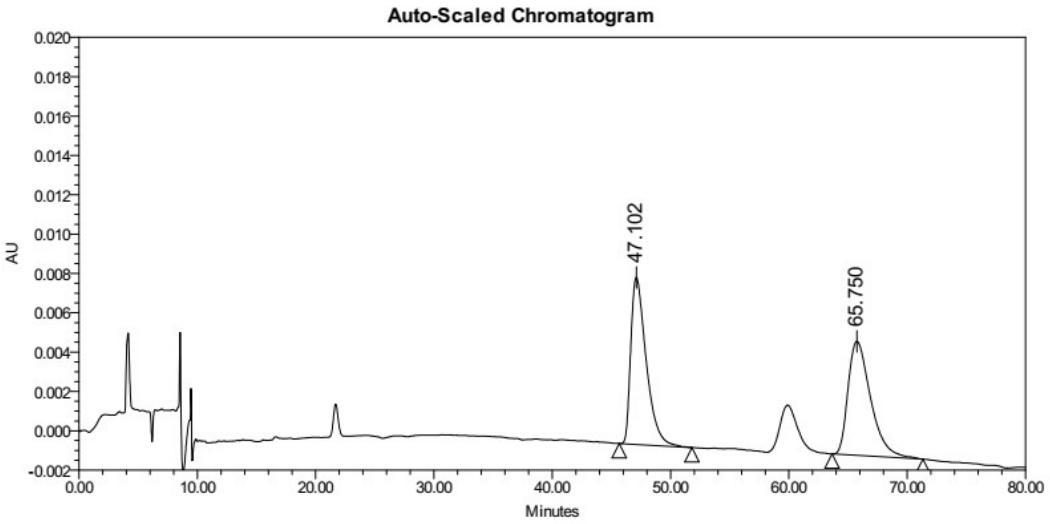
Enantioenriched 3h



Peak Results

	Name	RT	Area	Height	% Area
1		47.647	421653	4573	2.67
2		58.075	15387866	105763	97.33

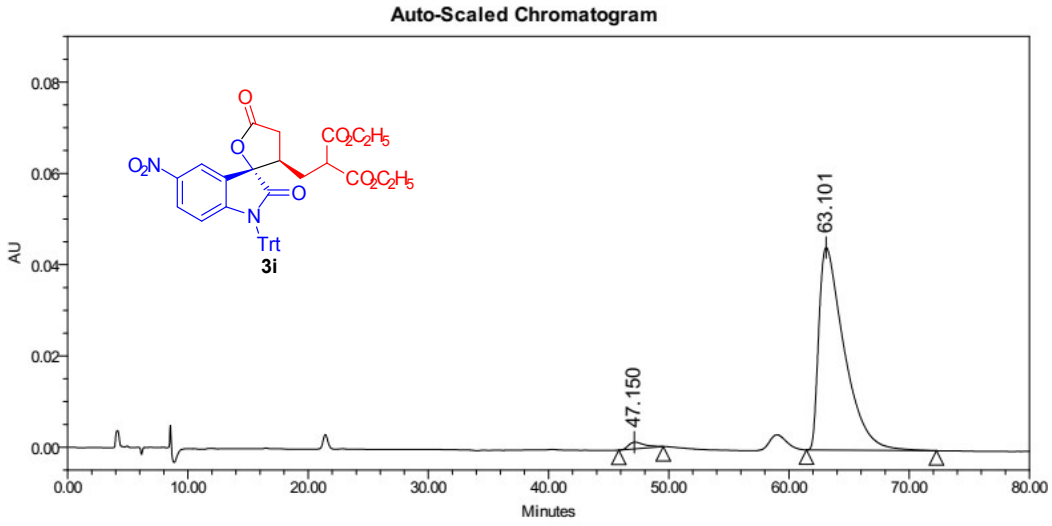
Racemic 3i



Peak Results

	Name	RT	Area	Height	% Area
1		47.102	768461	8490	50.04
2		65.750	767122	5797	49.96

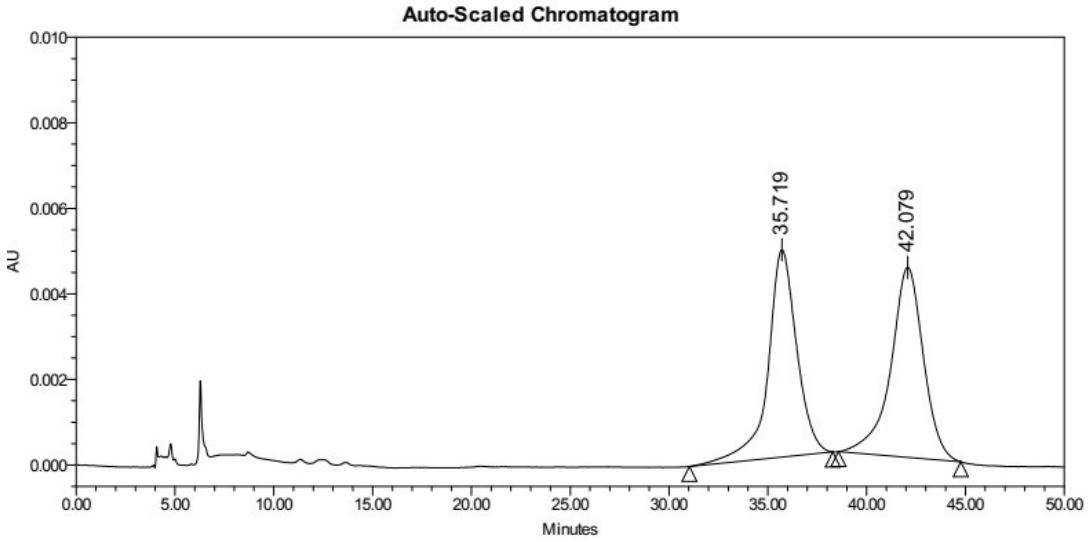
Enantioenriched 3i



Peak Results

	Name	RT	Area	Height	% Area
1		47.150	136489	1480	2.05
2		63.101	6517026	44384	97.95

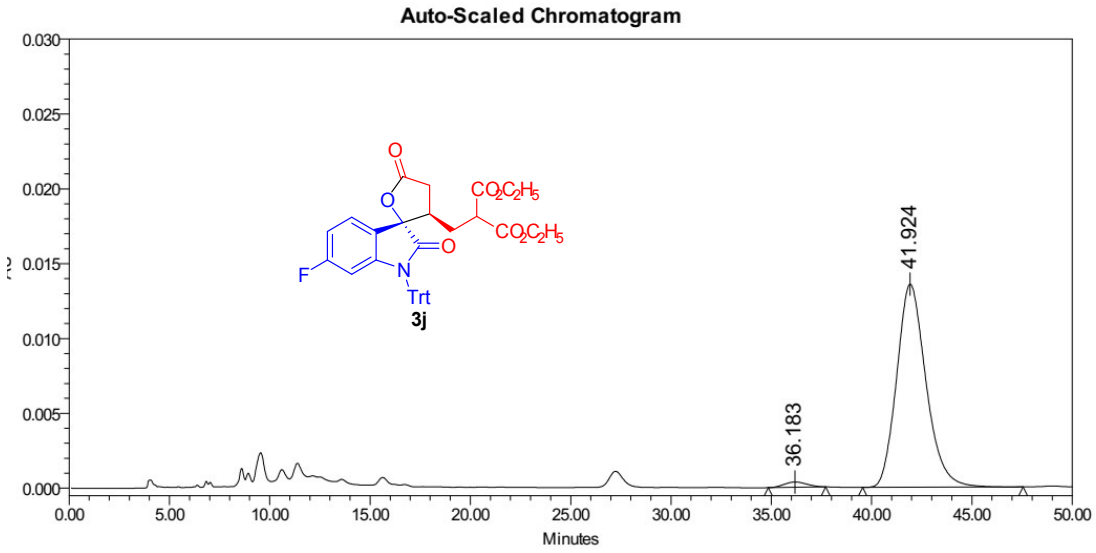
Racemic 3j



Peak Results

	Name	RT	Area	Height	% Area
1		35.719	490816	4849	49.01
2		42.079	510716	4445	50.99

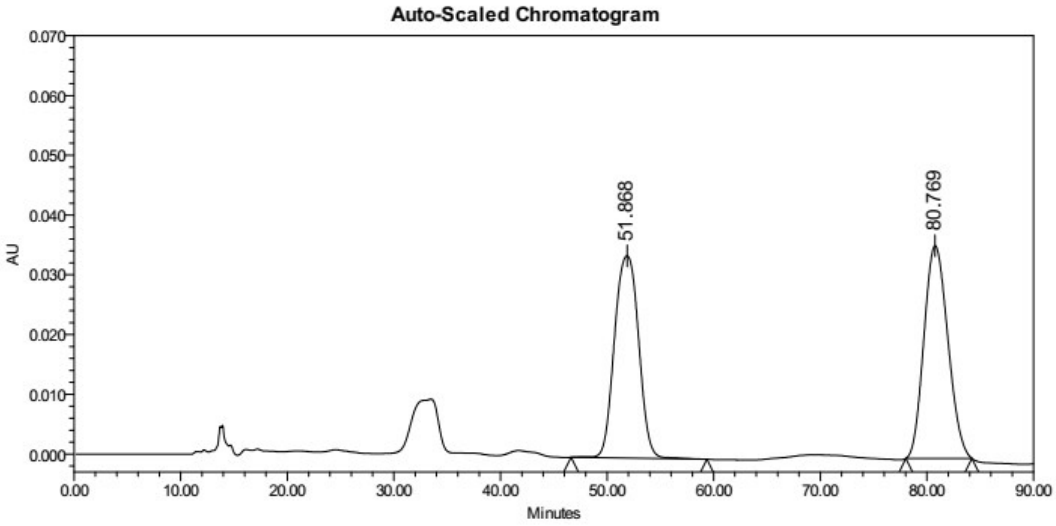
Enantioenriched 3j



Peak Results

	Name	RT	Area	Height	% Area
1		36.183	28413	360	2.02
2		41.924	1380713	13579	97.98

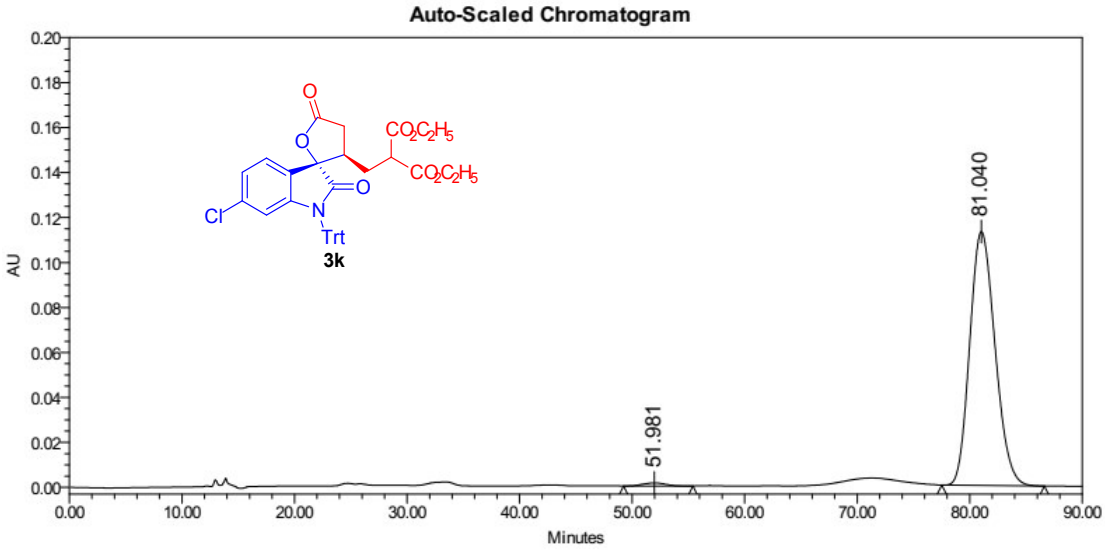
Racemic 3k



Peak Results

	Name	RT	Area	Height	% Area
1		51.868	5355141	33866	49.12
2		80.769	5546903	35616	50.88

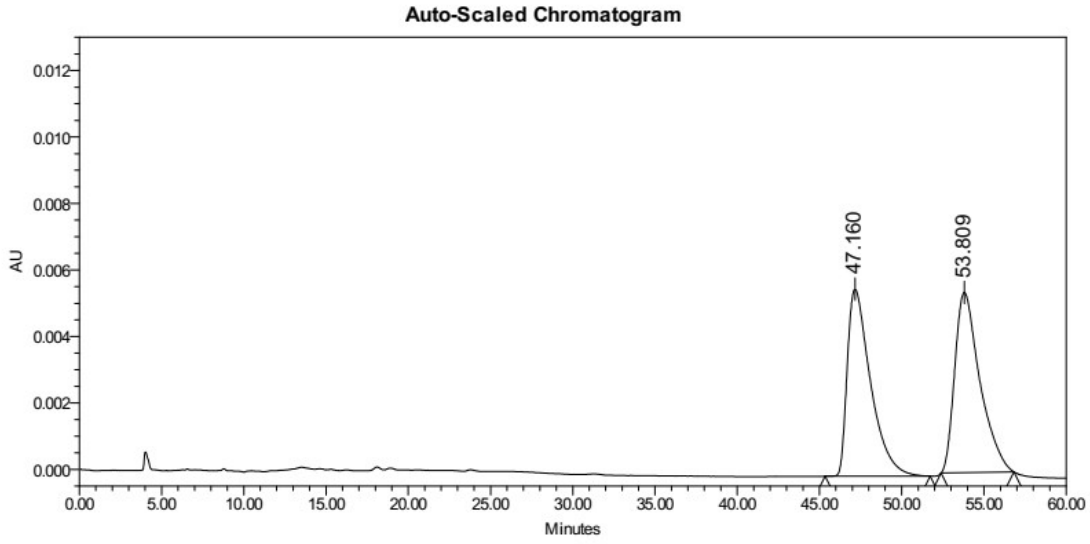
Enantioenriched 3k



Peak Results

	Name	RT	Area	Height	% Area
1		51.981	184900	1321	1.04
2		81.040	17610988	112887	98.96

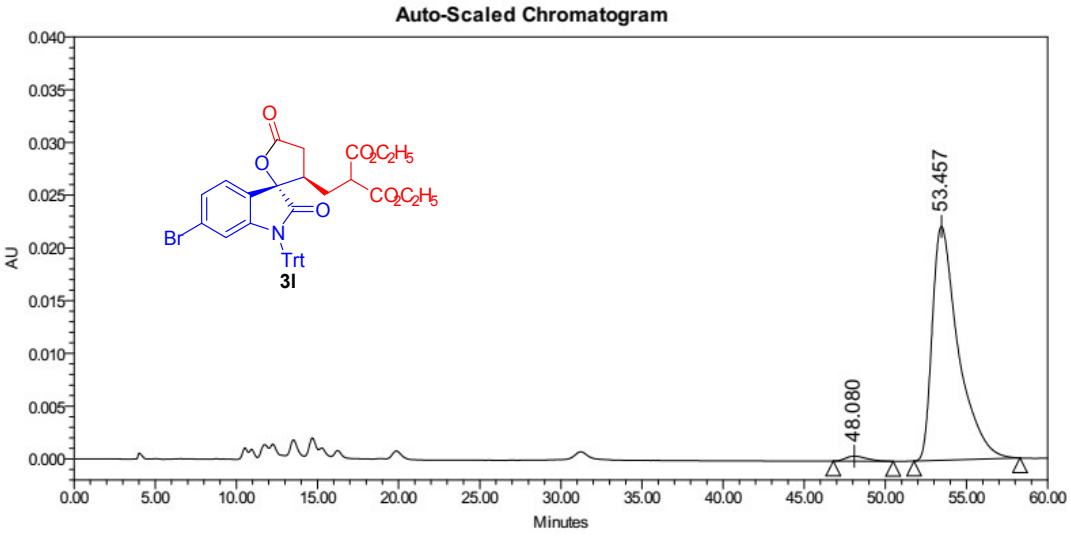
Racemic 3l



Peak Results

	Name	RT	Area	Height	% Area
1		47.160	554922	5632	49.05
2		53.809	576414	5420	50.95

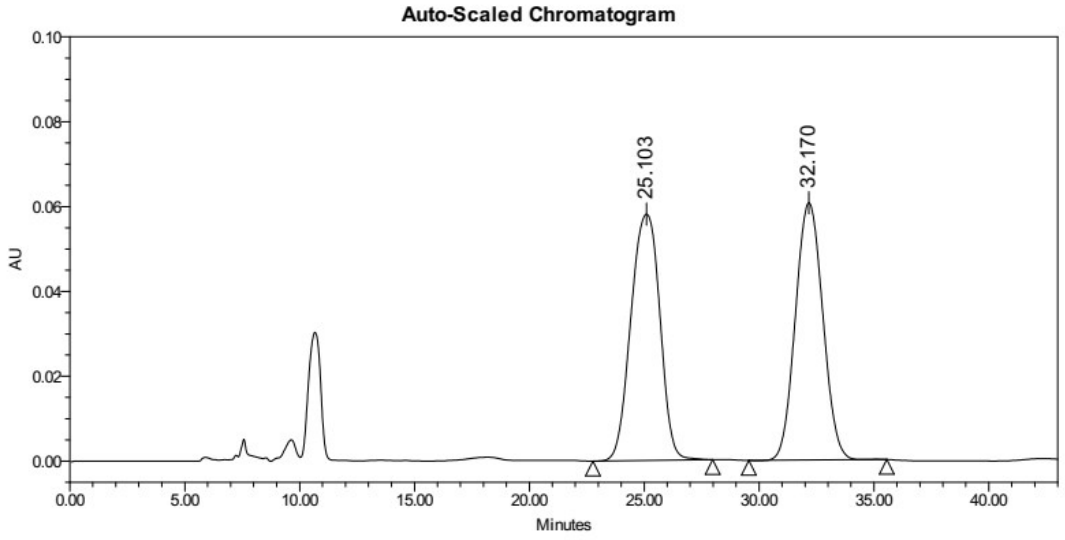
Enantioenriched 3l



Peak Results

	Name	RT	Area	Height	% Area
1		48.080	44737	482	1.77
2		53.457	2476302	22172	98.23

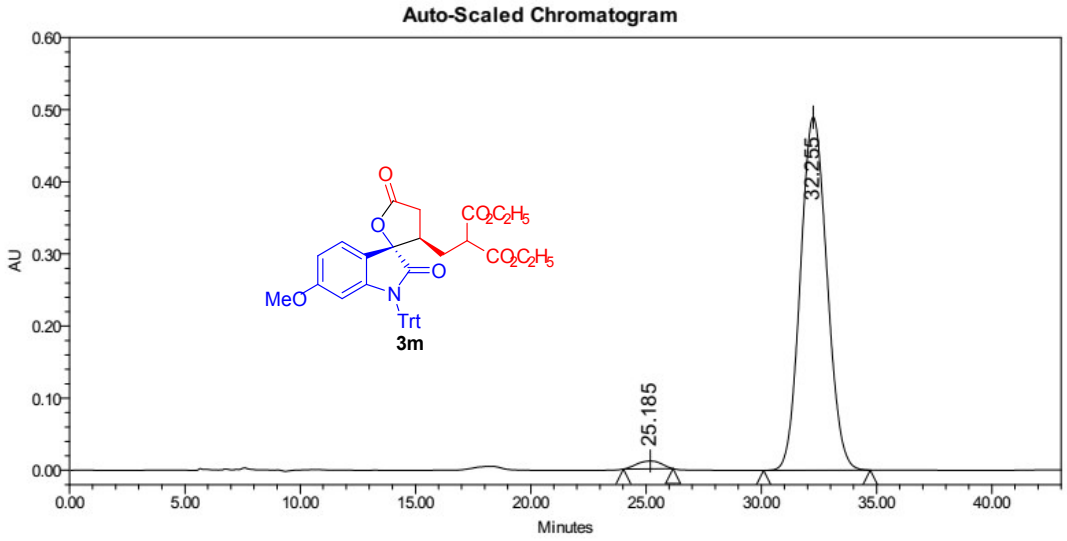
Racemic 3m



Peak Results

	Name	RT	Area	Height	% Area
1		25.103	5099948	58092	50.31
2		32.170	5036644	60662	49.69

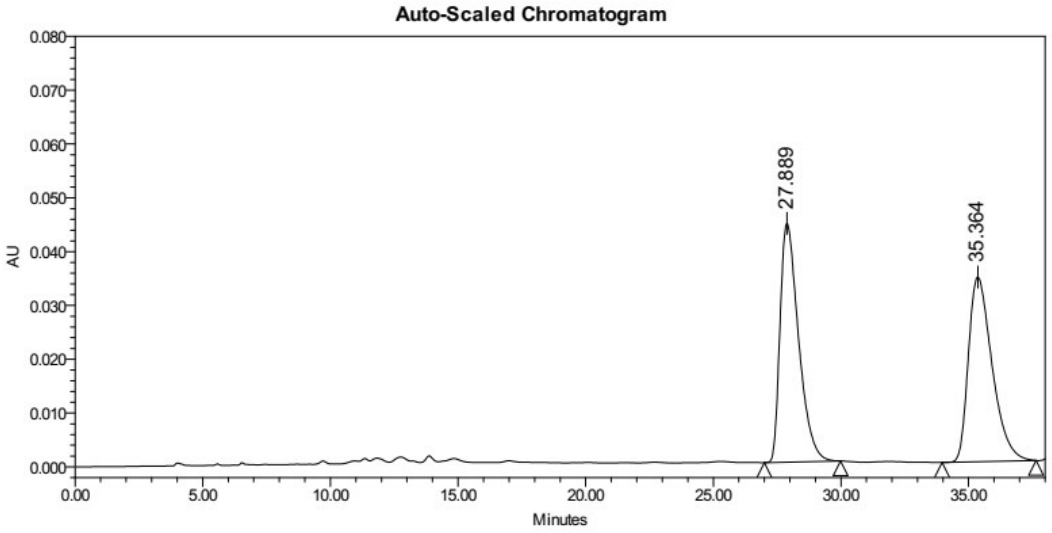
Enantioenriched 3m



Peak Results

	Name	RT	Area	Height	% Area
1		25.185	807960	10875	2.02
2		32.255	39167215	489632	97.98

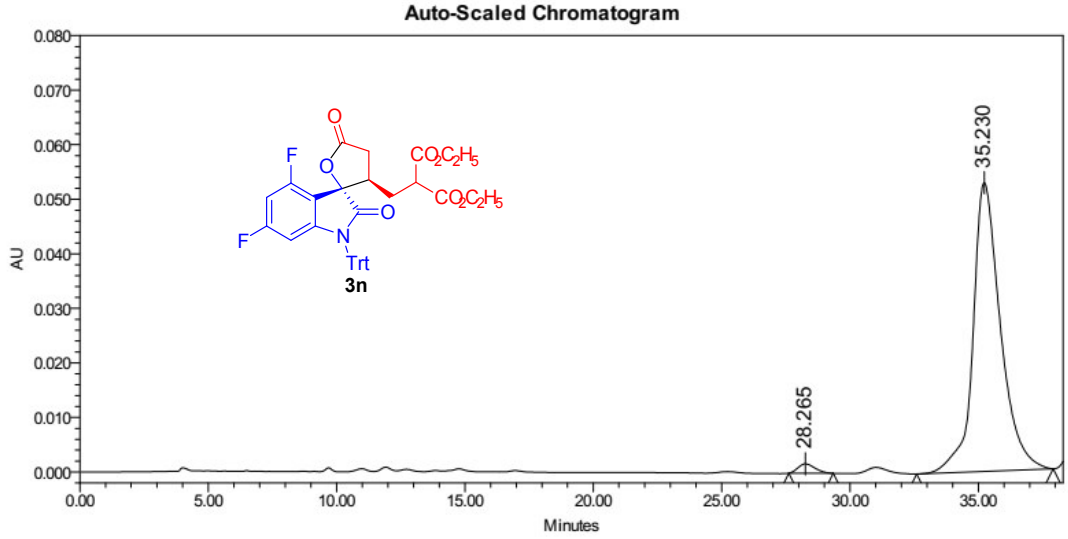
Racemic 3n



Peak Results

	Name	RT	Area	Height	% Area
1		27.889	2237246	44403	50.30
2		35.364	2210393	34329	49.70

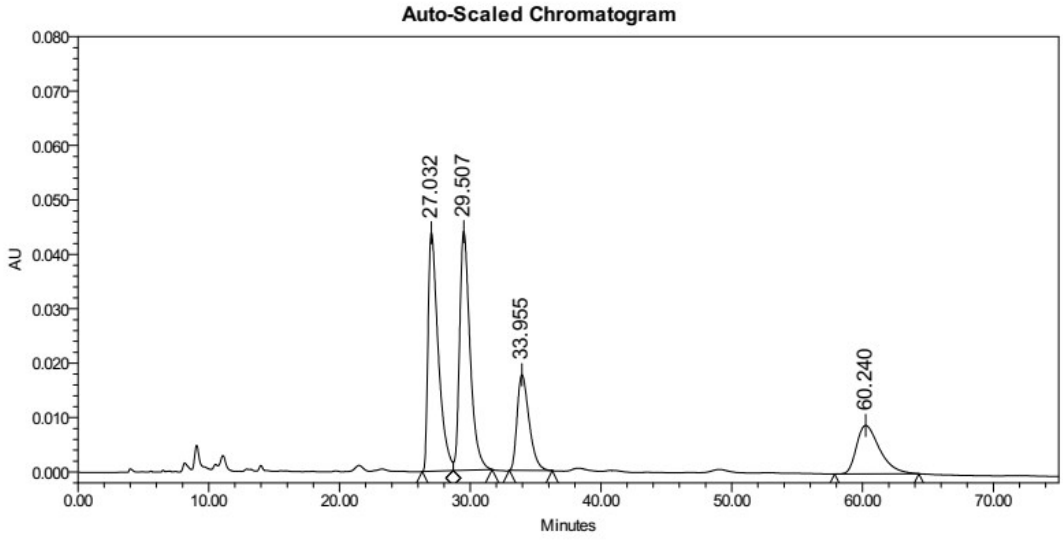
Enantioenriched 3n



Peak Results

	Name	RT	Area	Height	% Area
1		28.265	79404	1712	1.98
2		35.230	3934721	52952	98.02

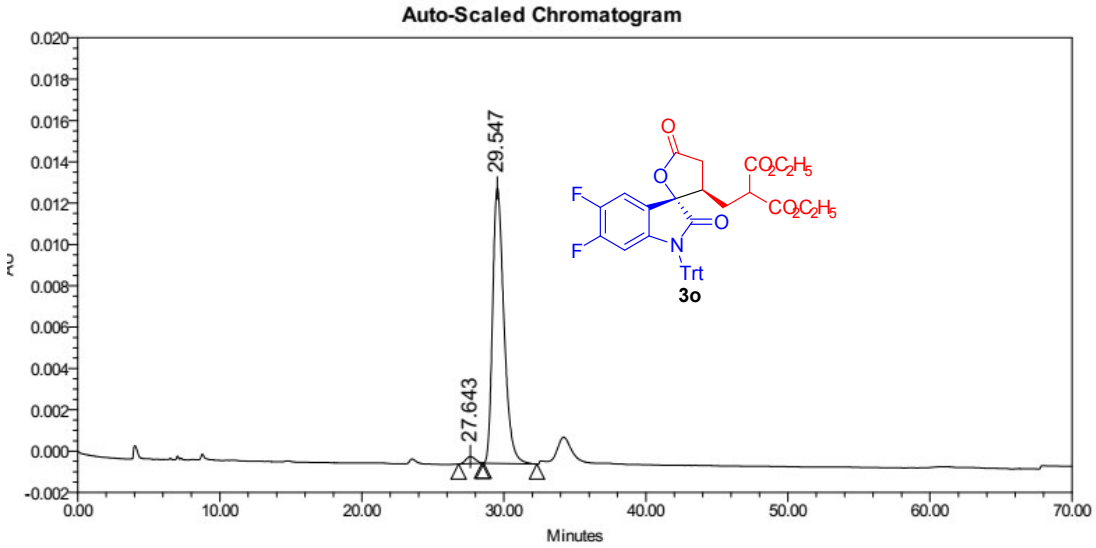
Racemic 3o



Peak Results

	Name	RT	Area	Height	% Area
1		27.032	2386793	43861	33.90
2		29.507	2437221	43891	34.62
3		33.955	1121851	17610	15.93
4		60.240	1094620	8902	15.55

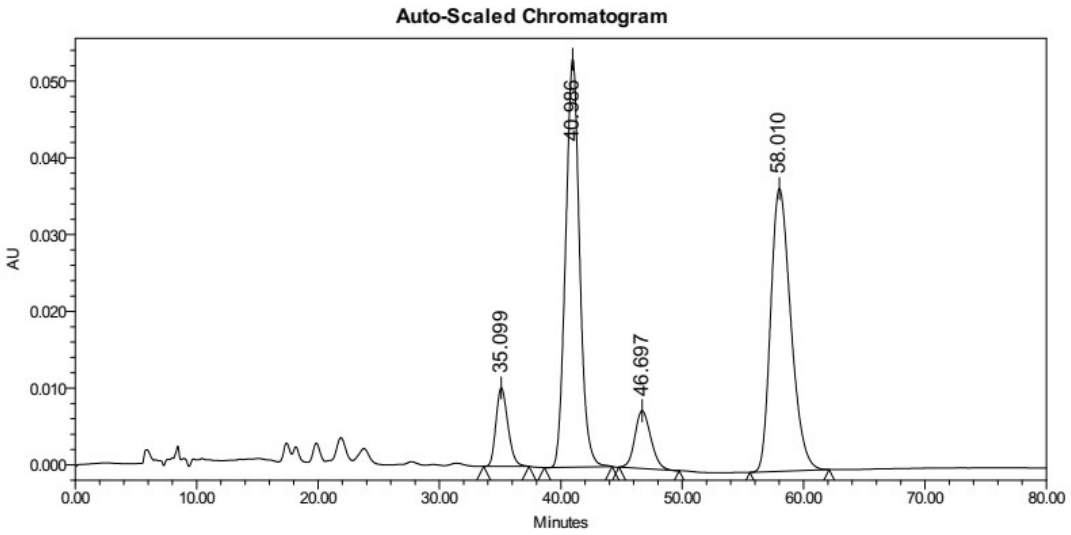
Enantioenriched 3o



Peak Results

	Name	RT	Area	Height	% Area
1		27.643	15613	339	2.06
2		29.547	742401	13329	97.94

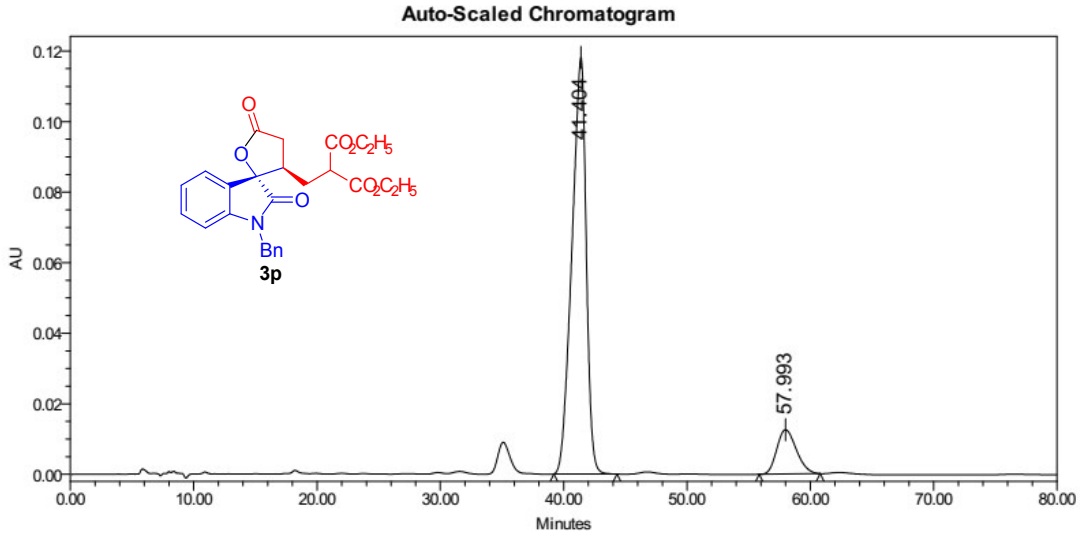
Racemic 3p



Peak Results

	Name	RT	Area	Height	% Area
1		35.099	697217	10230	7.05
2		40.986	4249598	53144	42.99
3		46.697	687539	7529	6.96
4		58.010	4251180	36822	43.00

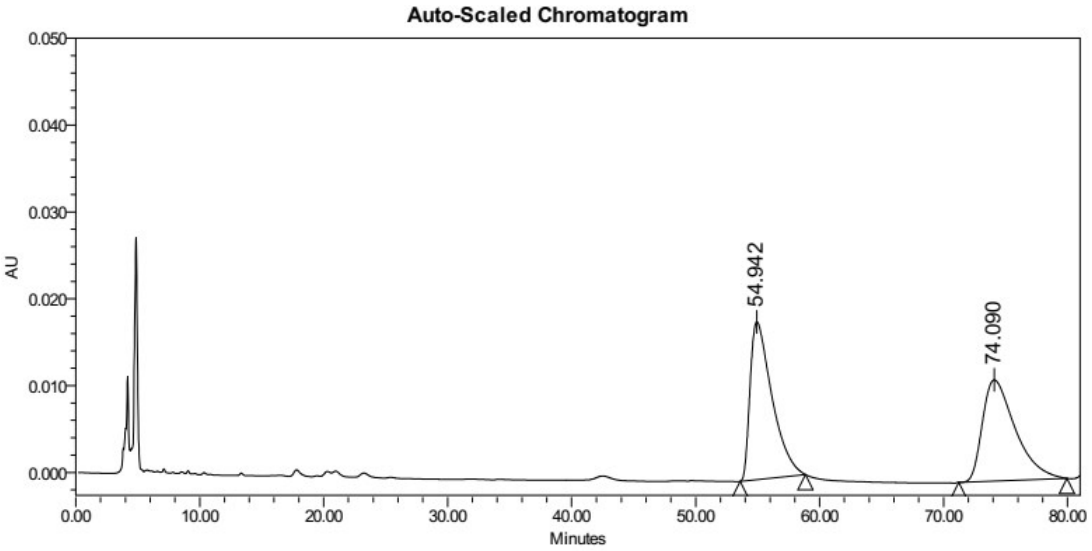
Enantioenriched 3p



Peak Results

	Name	RT	Area	Height	% Area
1		41.404	9505199	118070	87.25
2		57.993	1388404	12585	12.75

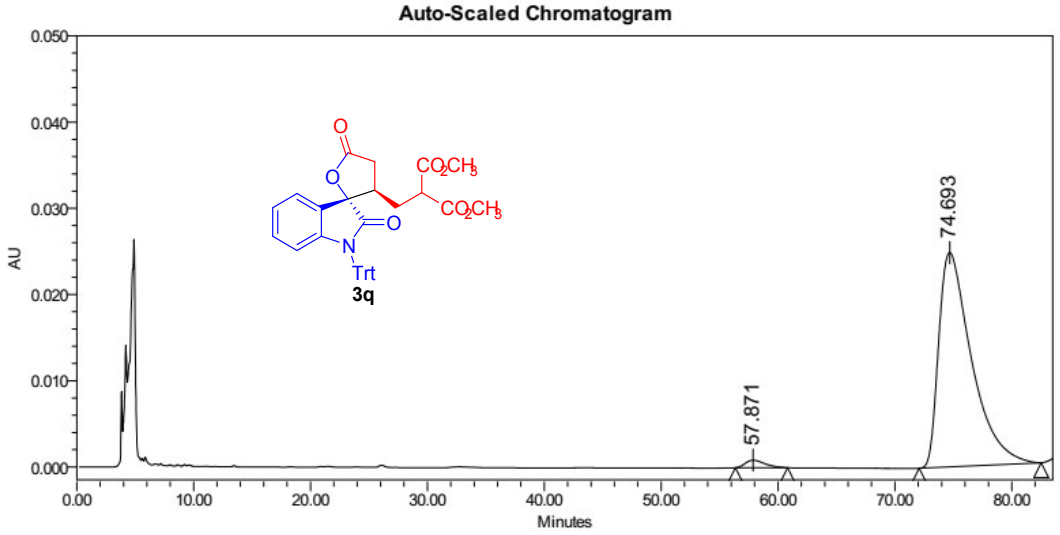
Racemic 3q



Peak Results

	RT	Area	% Area	Height
1	54.942	2230736	51.00	18171
2	74.090	2143537	49.00	11654

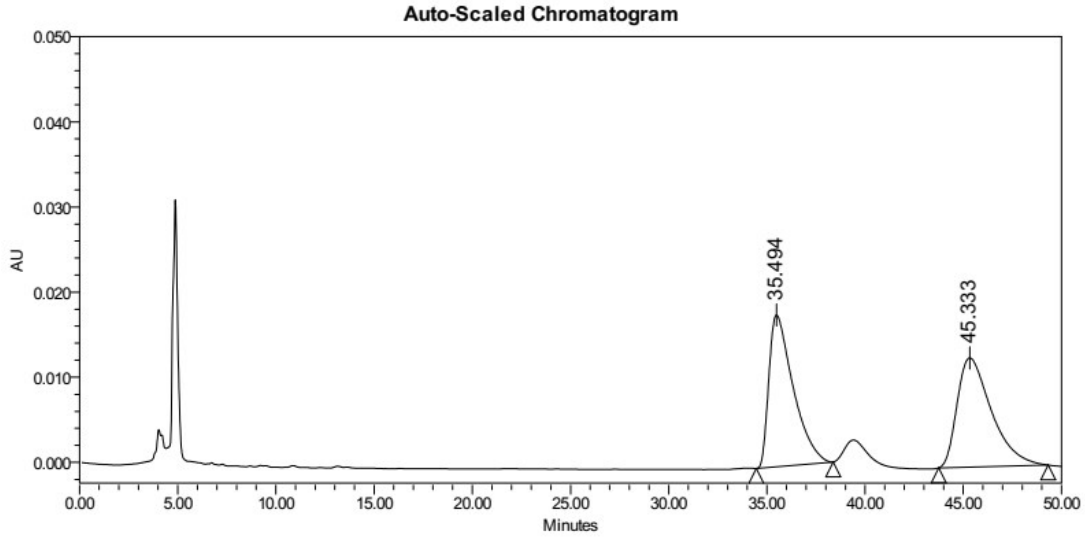
Enantioenriched 3q



Peak Results

	RT	Area	% Area	Height
1	57.871	102534	2.07	880
2	74.693	4839936	97.93	24861

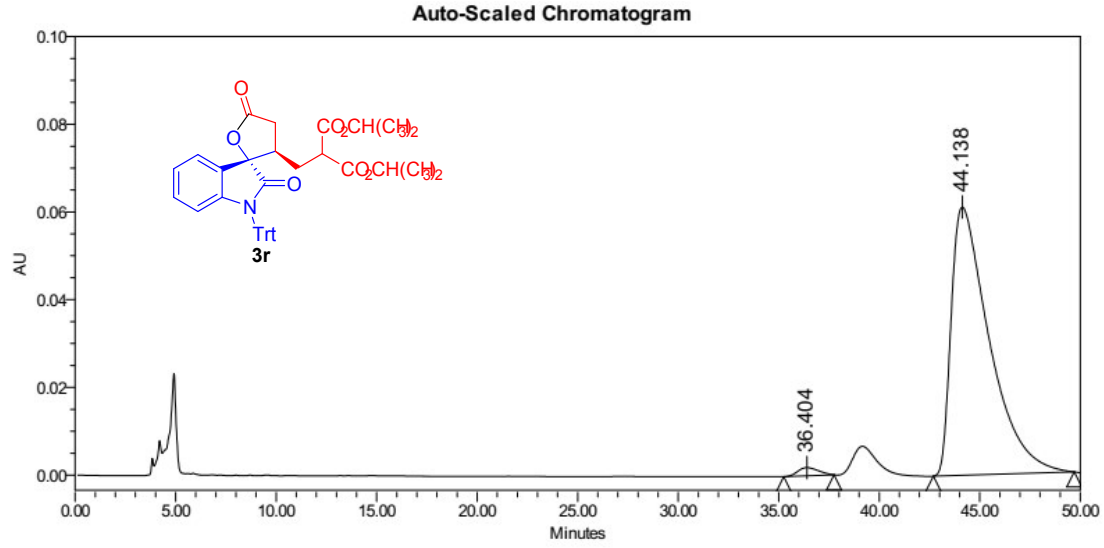
Racemic 3r



Peak Results

	RT	Area	% Area	Height
1	35.494	1533037	49.59	17824
2	45.333	1558137	50.41	12831

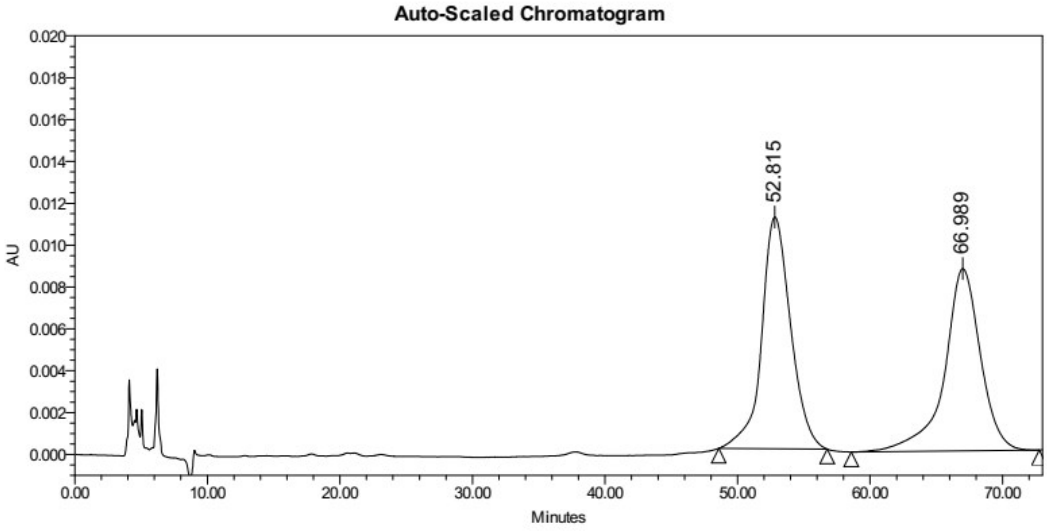
Enantioenriched 3r



Peak Results

	RT	Area	% Area	Height
1	36.404	132817	1.62	1876
2	44.138	8063888	98.38	61168

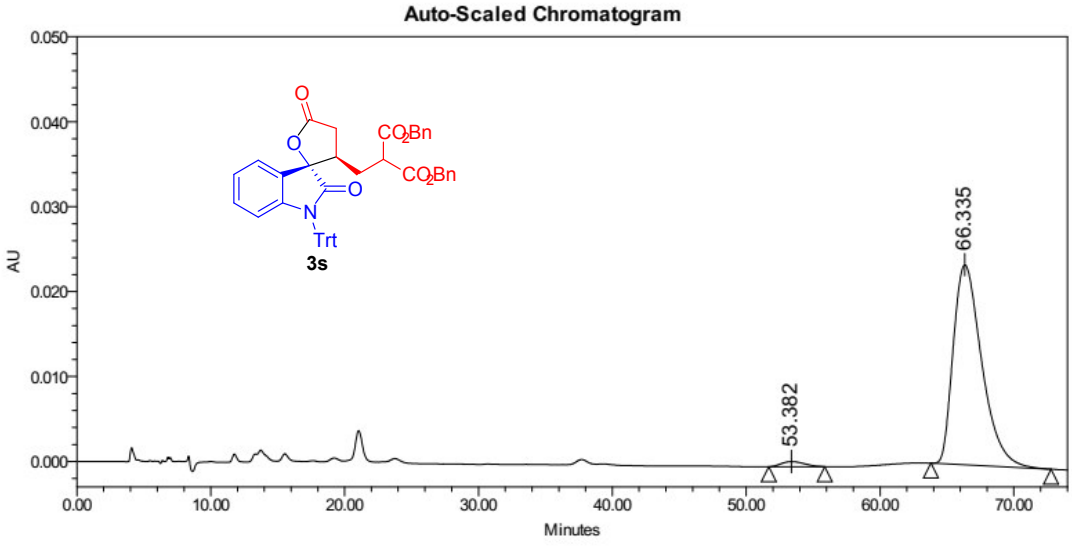
Racemic 3s



Peak Results

	Name	RT	Area	Height	% Area
1		52.815	1685433	11069	50.66
2		66.989	1641235	8710	49.34

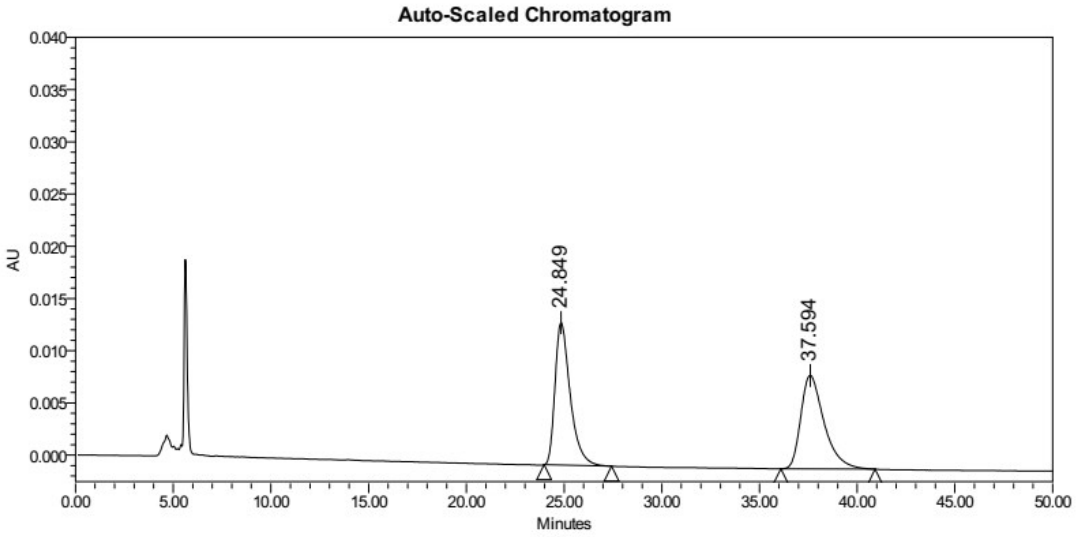
Enantioenriched 3s



Peak Results

	Name	RT	Area	Height	% Area
1		53.382	71541	595	2.01
2		66.335	3487954	23559	97.99

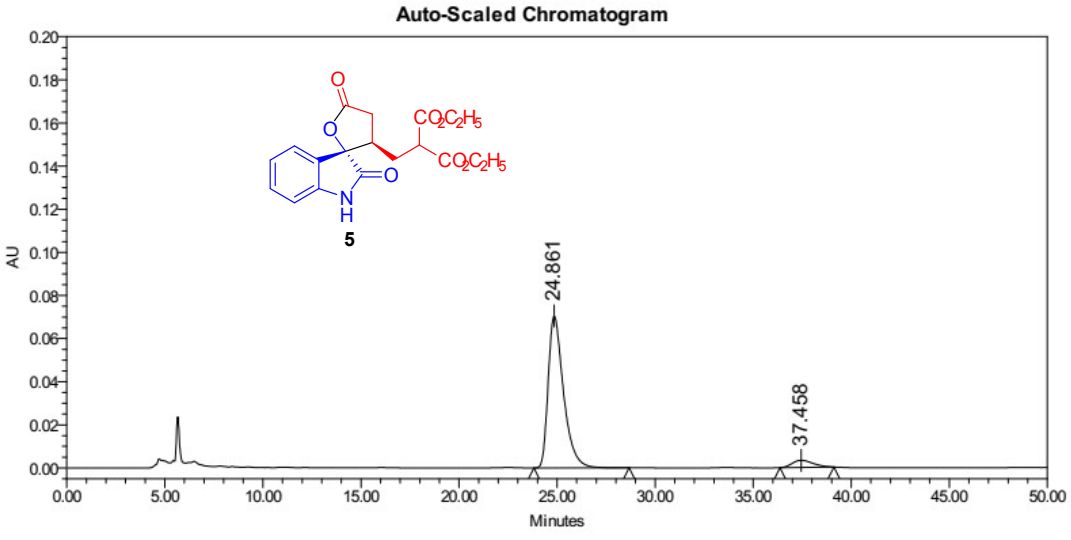
Racemic 5



Peak Results

	RT	Area	% Area	Height
1	24.849	737689	49.82	13633
2	37.594	742966	50.18	8957

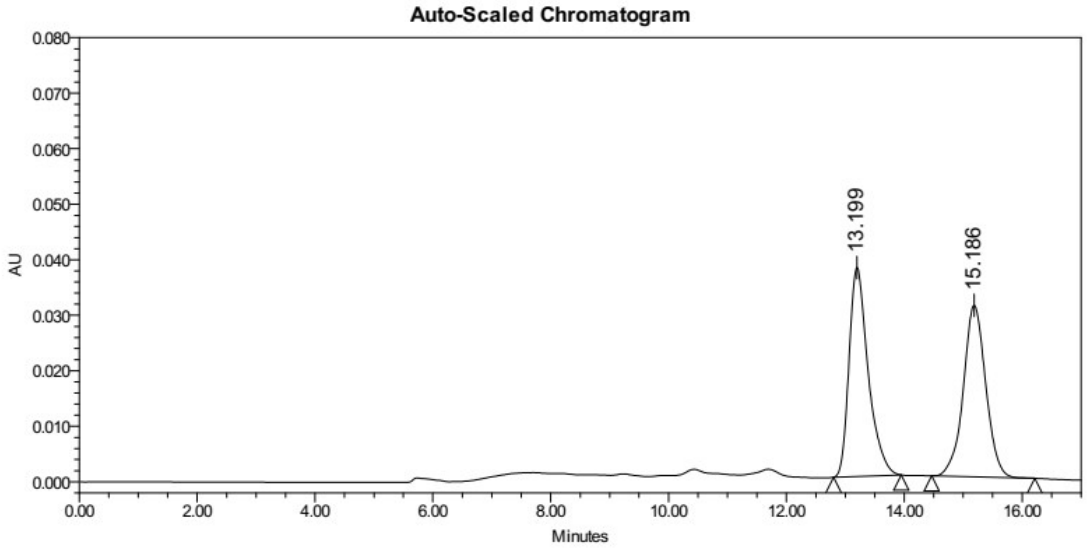
Enantioenriched 5



Peak Results

	Name	RT	Area	Height	% Area
1		24.861	3833779	70461	93.97
2		37.458	246070	3319	6.03

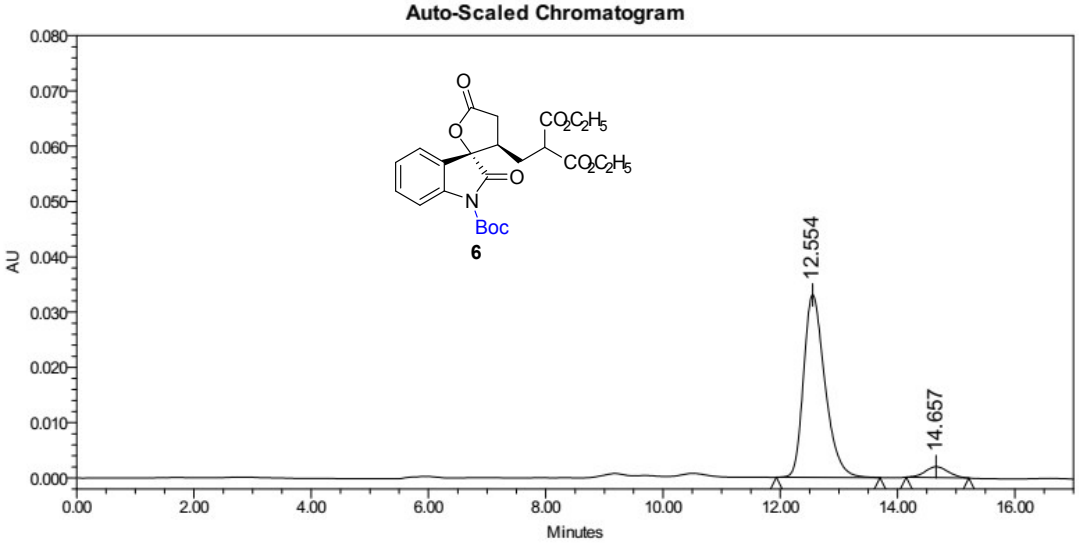
Racemic 6



Peak Results

	Name	RT	Area	Height	% Area
1		13.199	846848	37644	50.90
2		15.186	817062	30915	49.10

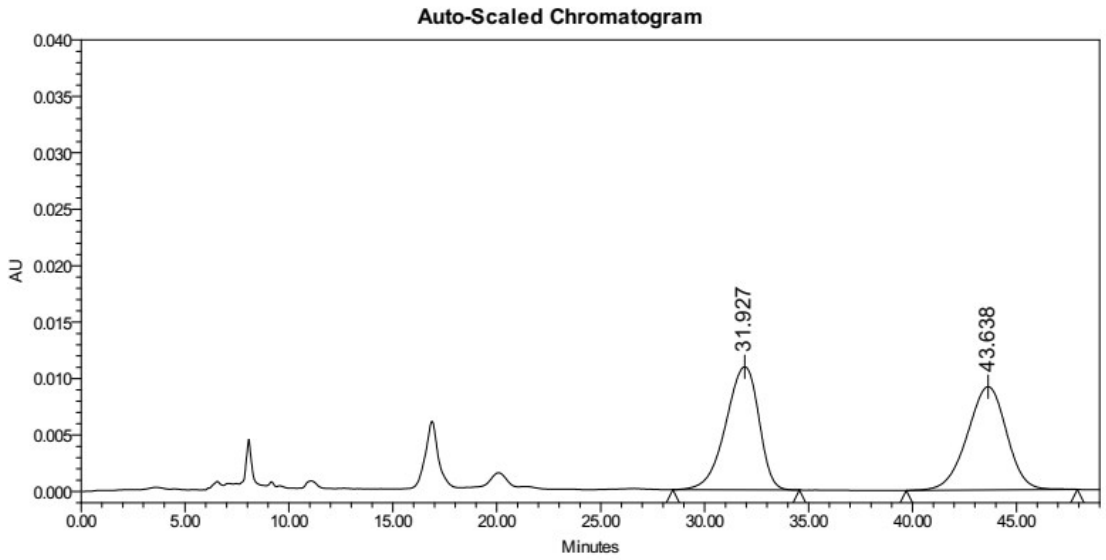
Enantioenriched 6



Peak Results

	Name	RT	Area	Height	% Area
1		12.554	841242	33064	94.01
2		14.657	53636	1964	5.99

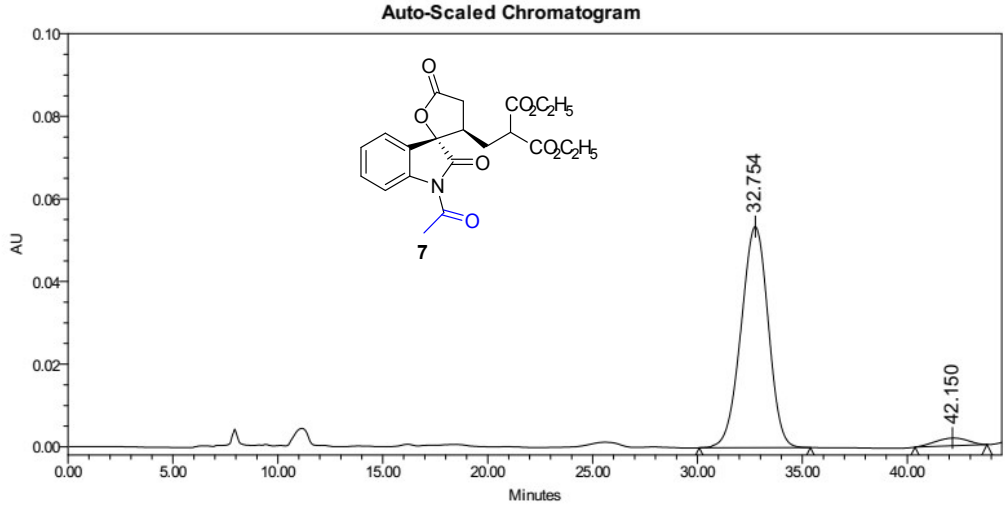
Racemic 7



Peak Results

	Name	RT	Area	Height	% Area
1		31.927	1211167	10912	50.16
2		43.638	1203207	9147	49.84

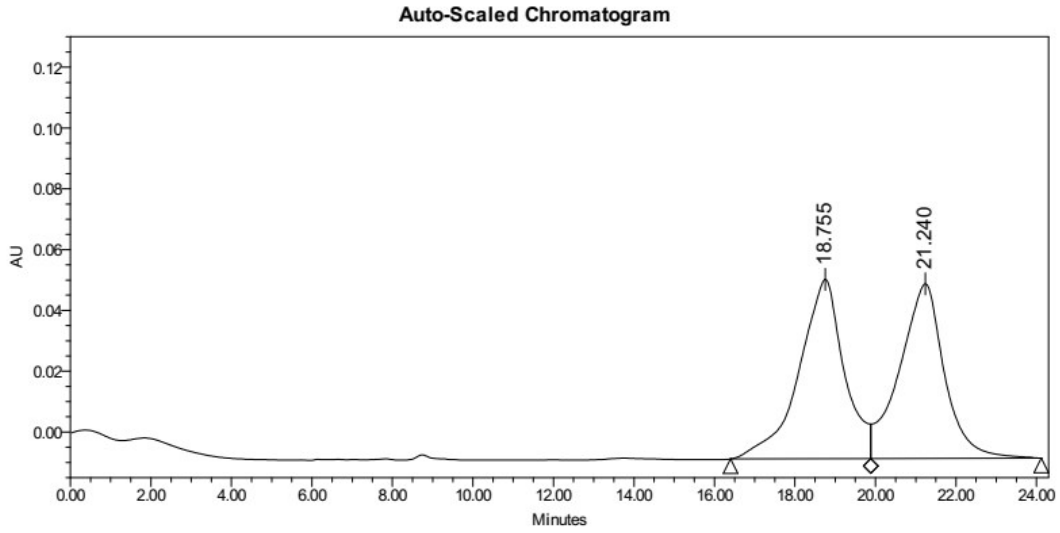
Enantioenriched 7



Peak Results

	Name	RT	Area	Height	% Area
1		32.754	4817284	53519	95.95
2		42.150	203375	1887	4.05

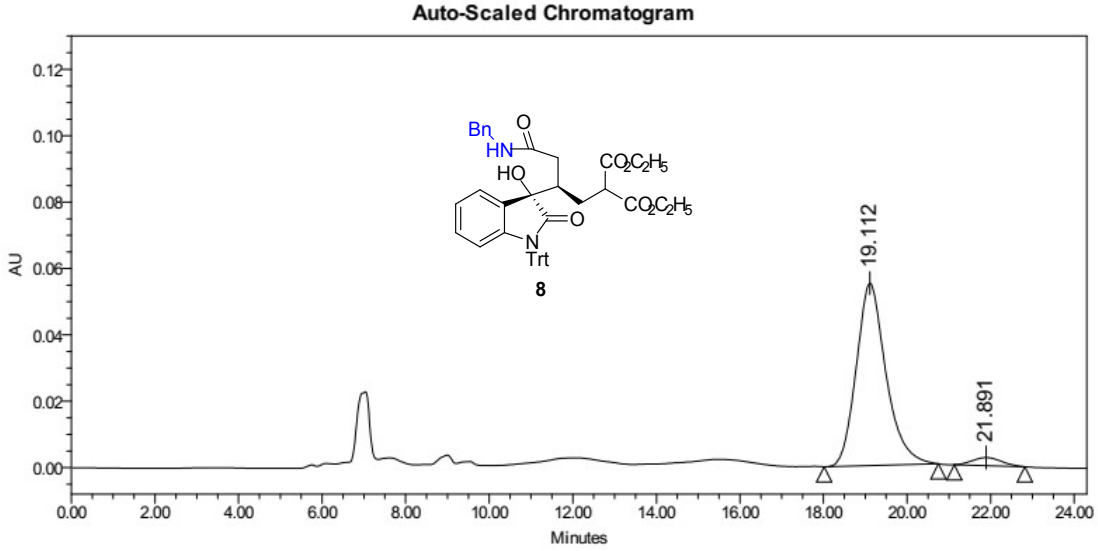
Racemic 8



Peak Results

	Name	RT	Area	Height	% Area
1		18.755	4579981	59028	50.76
2		21.240	4443290	57488	49.24

Enantioenriched 8



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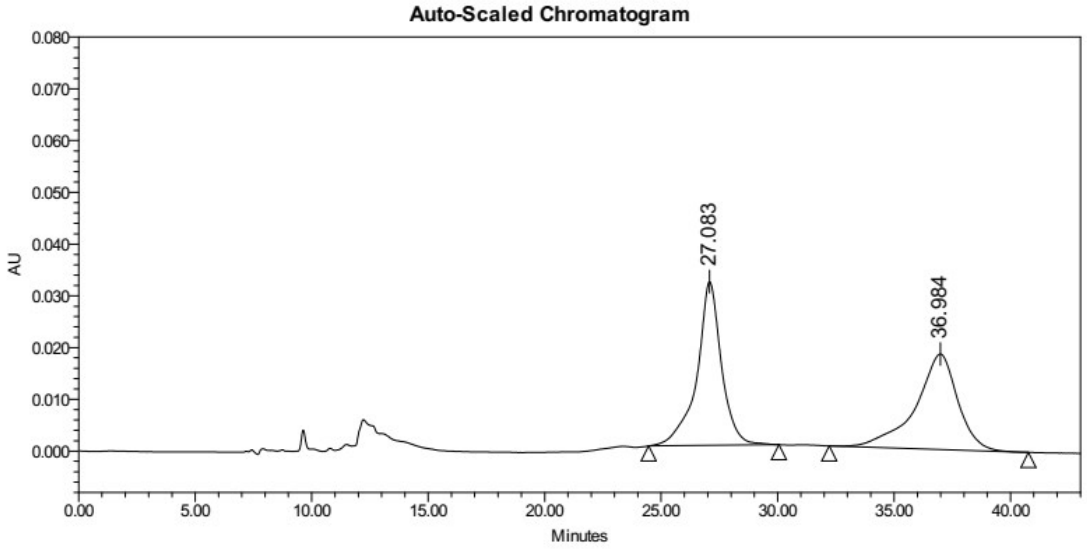
Peak Results

	Name	RT	Area	Height	% Area
1		19.112	2709109	54938	95.92
2		21.891	115234	2403	4.08

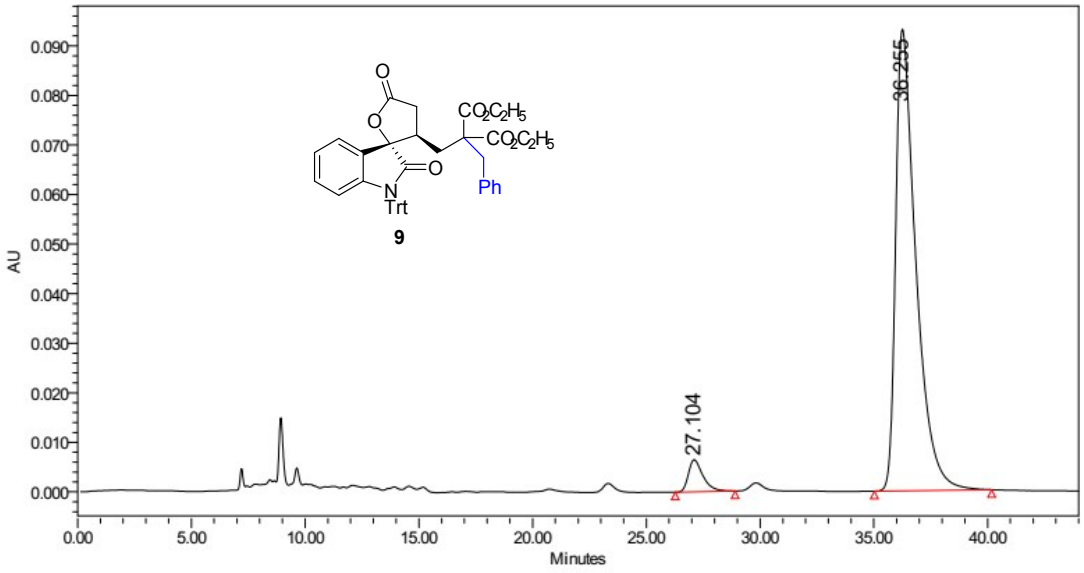
Racemic 9



Peak Results

	Name	RT	Area	Height	% Area
1		27.083	2331119	31670	50.13
2		36.984	2318765	18450	49.87

Enantioenriched 9



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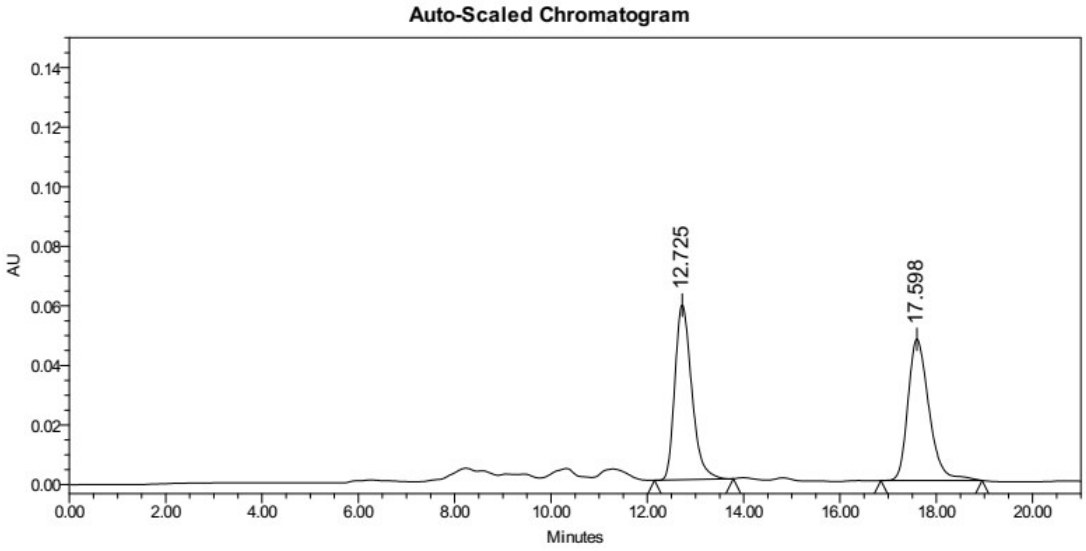
Peak Report

	RT	Area	% Area	Height
1	27.104	288652	4.76	6452
2	36.255	5774355	95.24	93129

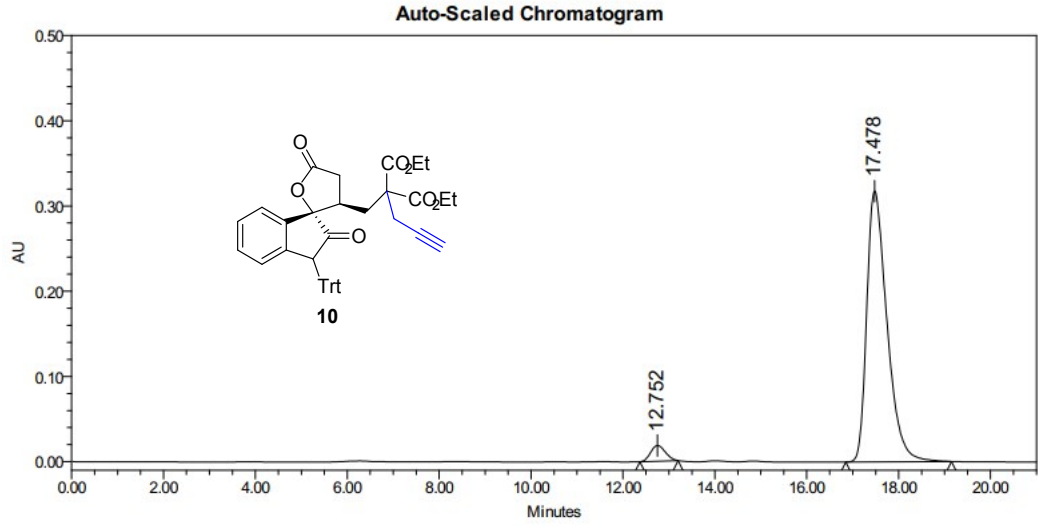
Racemic 10



Peak Results

	Name	RT	Area	Height	% Area
1		12.725	1435376	58754	49.89
2		17.598	1441686	47429	50.11

Enantioenriched 10



Peak Results

	Name	RT	Area	Height	% Area
1		12.752	410898	18476	4.06
2		17.478	9716637	317852	95.94