Electronic Supplementary Material (ESI) for ChemComm.

Merging C-C σ-Bond Activation of Cyclobutanones with CO_2 Fixation via Ni-Catalysis.

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General Methods.

^{1}H-NMR spectra were recorded on Varian 400 (400 MHz) spectrometers. Chemical shifts are reported in ppm from TMS with the solvent resonance as the internal standard (deuterochloroform: 7.24 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, dd= doublet doublet, t = triplet, td = triple doublet, dt = double triplet, q = quartet, sext = sextet, sept = septet, p = pseudo, b = broad, m = multiplet), coupling constants (Hz). ^{13}C-NMR spectra were recorded on a Varian 400 (100 MHz) spectrometers with complete proton decoupling. Chemical shifts are reported in ppm from TMS with the solvent as the internal standard (deuterochloroform: 77.0 ppm).

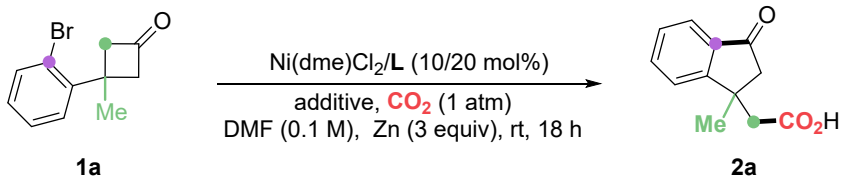
GC-MS spectra were taken by EI ionization at 70 eV on a Hewlett-Packard 5971 with GC injection. They are reported as: *m/z* (rel. intense). LC-electrospray ionization mass spectra were obtained with Agilent Technologies MSD1100 single-quadrupole mass spectrometer.

Chromatographic purification was done with 240-400 mesh silica gel. Other anhydrous solvents were supplied by Sigma Aldrich in Sureseal® bottles and used without any further purification. Commercially available chemicals were purchased from Sigma Aldrich, Stream and TCI and used without any further purification. Melting points were determined with Bibby Stuart Scientific Melting Point Apparatus SMP 3 and are not corrected.

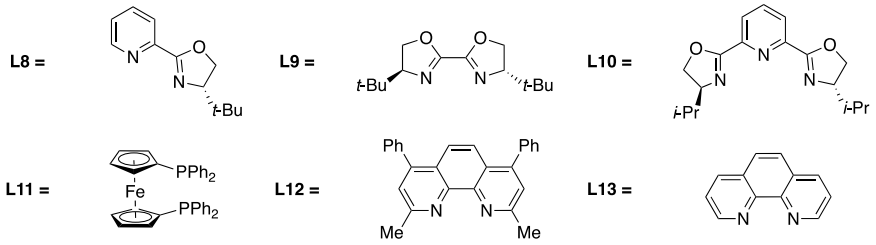
CO_2 ≥ 99.5% purity, purchased from SIAD, was used in the Ni-catalyzed tandem C-C σ-bond carboxylation reaction.

Anhydrous DMF, THF and CH_2Cl_2 were purchased from Merck and used as received. Zn dust refers to a particle size <10 μm and was purchased from Merck, having ≥98% purity. All other commercially available starting materials and (non-anhydrous) solvents were purchased from Merck, TCI chemicals, Fluorochem or Alfa Aesar and were used as such without further purification. Ligands **L1** and **L2** are commercially available and **L6** is a known compound (see ref. 5).

Table S1. Optimization of reaction conditions, additional data.



1a **2a**



Entry[a]	L	Additive (equiv)	Yield (%)[b]
1	**L8**	None	NR
2	**L8**	TMSCl (1.5)	NR
3	**L8**	$MgCl_2$ (1.5)	25 (27)[c]
4	**L8**	$MgCl_2$[d] (1.5)	22 (29)
5	**L8**	LiCl (1.5)	NR
6	**L8**	$AlCl_3$ (1.5)	43 (19)
7	**L8**	$Al(OTf)_3$ (1.5)	NR
8	**L8**	$Al(OTf)_3$ + LiCl (1.5 + 4.5)	NR
9	**L9**	$AlCl_3$ (1.5)	NR
10	**L10**	$AlCl_3$ (1.5)	NR
11	**L11**	$AlCl_3$ (1.5)	NR
12	**L12**	$AlCl_3$ (1.5)	22
13	**L13**	$AlCl_3$ (1.5)	NR
14	**L7**	$AlCl_3$ (0.5)	38
15	**L7**	$AlCl_3$ (2.0)	56
16	**L7**	$InCl_3$ (1.5)	NR
17	**L7**	$ZnCl_2$ (1.5)	NR

(a) Reaction conditions: **1a** (0.1 mmol, 0.1 M), additive (0.15 mmol), Zn (0.3 mmol), CO_2 (1 atm), Ni(dme)Cl_2 (10 mol%), **L** (20 mol%). (b) Isolated yield after flash chromatography. (c) The number in brackets refers to the yield of dehalogenated starting material **7a**. (d) 20 mol% of TBAI was also added.

Limitation of the methodology: unsuccessful substrates.

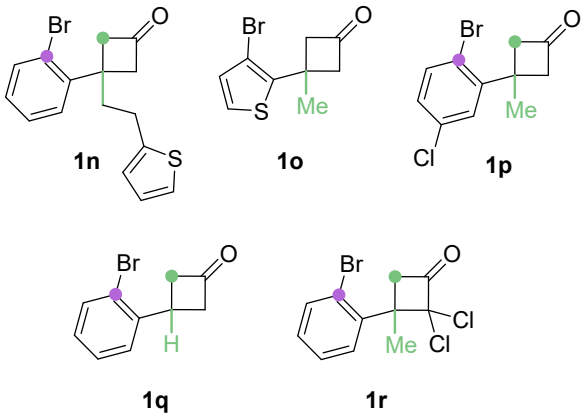
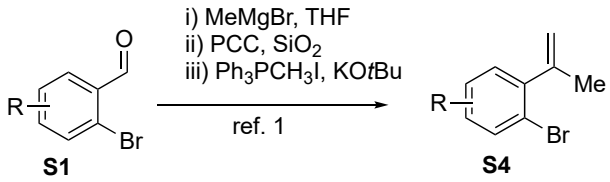


Figure S1

Substrates **1n-1r** were tested under the optimal reaction conditions but failed to give the desired products. Compounds **1n** and **1o** were recovered untouched while in the case od **1p-1r** a complex mixture was observed by ^{1}H NMR spectroscopy on the reaction crudes.

Preparation and Characterization of the cyclobutanones 1

Cyclobutanones **1** were synthesized from the corresponding 2-bromobenzaldehydes **S1** following literature procedures. Addition of methylmagnesium bromide to **S1** provided alcohols **S2** that, upon PCC mediated oxidation afforded ketones **S3**. Wittig olefination of **S3** served for the preparation of α-methylstyrenes **S4**. All compounds **S2**, **S3** and **S4** are known and the characterization, as well as the above-described preparation is reported in the literature.[1]

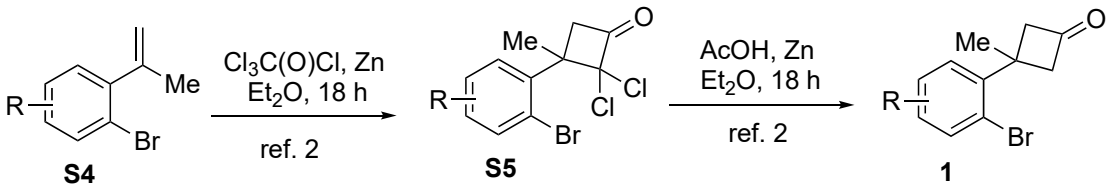


Conversion of **S4** to cyclobutanones **1** was conducted following a modified literature procedure.[2] In a flame-dried round bottom flask equipped with a reflux condenser and a magnetic stirring bar, anhydrous Et_2O (30 mL), **S4** (5.0 mmol) and Zn dust (1.30 g, 20 mmol) were added in this order under a N_2 atmosphere. Then, trichloroacetyl chloride (15 mmol, 1.7 mL) was added dropwise and the reaction mixture was stirred at room temperature for 18 h.

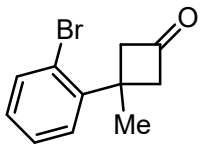
Caution! A highly exothermic reaction is generally observed within 5-20 min, bringing the solvent to a vigorous boil.

The mixture was then filtered over a Celite pad, concentrated *in vacuo* and filtered over a short silica plug (*c*Hex:EtOAc 10:1), affording crudes α,α-dichlorocyclobutanones **S5** that were used in the following step without further purification.

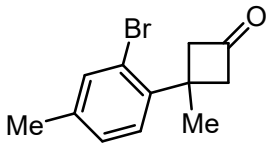
In a round bottom flask equipped with a magnetic stirring bar, crude **S5** (5 mmol) and Zn dust (650 mg, 10 mmol) were vigorously stirred in glacial AcOH (20 mL) at 60 °C for 5 h. Then, additional Zn dust (650 mg, 10 mmol) was added, and the reaction mixture stirred at 60 °C for 18 h. The reaction was monitored *via* GC-MS analysis and additional Zn was be added if completion is not reached. Excess of AcOH was then removed *in vacuo* and the resulting solid was suspended in EtOAc (50 mL), filtered over a Celite pad (washing with EtOAC, 50 mL), concentrated *in vacuo* and purified by flash chromatography (*c*Hex:EtOAc) to afford cyclobutanones **1**. A two-step combined yield is provided. In case of known compounds, the recorded spectroscopic data matched the one reported in literature.[2b]



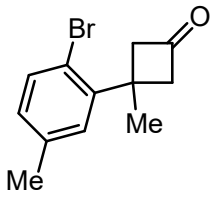
Characterization of compounds 1a-1n



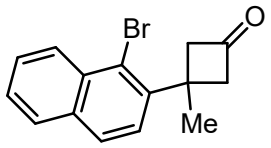
1a. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 15:1. Yield = 70% (3.5 mmol, 833 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.61 (dt, *J* = 7.6, 3.1 Hz, 1H), 7.38 – 7.30 (m, 2H), 7.14 (ddt, *J* = 11.3, 8.2, 4.0 Hz, 1H), 3.60 – 3.52 (m, 2H), 3.27 – 3.20 (m, 2H), 1.65 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 206.5, 145.9, 134.3, 128.3, 128.2, 127.6, 122.2, 59.2 (2C), 36.2, 27.7; **GC-MS**: 238 [^{79}Br] and 240 [^{81}Br] (5), 196 [^{79}Br] and 198 [^{81}Br] (100), 181 [^{79}Br] and 183 [^{81}Br] (20).



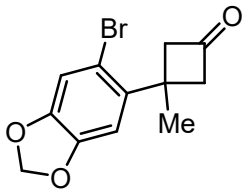
1b. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 15:1. Yield = 66% (3.3 mmol, 832 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.41 – 7.39 (m, 1H), 7.16 (d, *J* = 7.9 Hz, 1H), 7.10 (ddd, *J* = 7.9, 1.7, 0.7 Hz, 1H), 3.53 – 3.45 (m, 2H), 3.23 – 3.13 (m, 2H), 2.31 (s, 3H), 1.59 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 206.8, 142.8, 138.4, 134.7, 128.3, 127.8, 121.9, 59.2 (2C), 35.8, 27.8, 20.4; **GC-MS**: 252 [^{79}Br] and 254 [^{81}Br] (5), 210 [^{79}Br] and 212 [^{81}Br] (100), 195 [^{79}Br] and 197 [^{81}Br] (25).



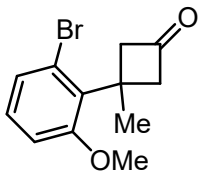
1c. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 15:1. Yield = 64% (3.2 mmol, 806 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.43 (d, *J* = 8.1 Hz, 1H), 7.08 (d, *J* = 1.9 Hz, 1H), 6.94 – 6.90 (m, 1H), 3.56 – 3.47 (m, 2H), 3.22 – 3.13 (m, 2H), 2.31 (s, 3H), 1.60 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 207.0, 145.5, 137.5, 134.0, 129.1, 128.9, 118.8, 59.1 (2C), 36.1, 27.8, 21.0; **GC-MS**: 252 [^{79}Br] and 254 [^{81}Br] (5), 210 [^{79}Br] and 212 [^{81}Br] (100), 131 (85), 115 (90).



1d. White solid. Mp = 100 -103 °C. FC eluent: *n*Hex:EtOAc: 10:1. Yield = 50% (2.5 mmol, 720 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 8.38 (d, *J* = 8.6 Hz, 1H), 7.81 (*pseudo*d, *J* = 8.4 Hz, 2H), 7.60 (t, *J* = 7.7 Hz, 1H), 7.51 (t, *J* = 7.5 Hz, 1H), 7.40 (d, *J* = 8.6 Hz, 1H), 3.71 – 3.61 (m, 2H), 3.36 – 3.26 (m, 2H), 1.70 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 206.6, 143.7, 133.2, 132.8, 128.1, 128.0, 127.8, 127.1, 126.5, 125.5, 122.2, 59.6 (2C), 37.3, 27.5; **GC-MS**: 288 [^{79}Br] and 290 [^{81}Br] (15), 246 [^{79}Br] and 248 [^{81}Br] (90), 165 (100), 152 (95).

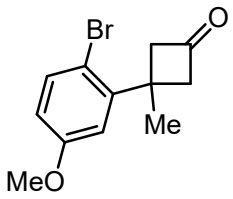


1e. White solid. Mp = 113 - 115 °C. FC eluent: *n*Hex:EtOAc: 10:1 then *n*Hex:EtOAc 5:1. Yield = 35% (1.75 mmol, 492 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.00 (s, 1H), 6.76 (s, 1H), 5.96 (s, 2H), 3.49 – 3.39 (m, 2H), 3.20 – 3.11 (m, 2H), 1.56 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 206.4, 147.5, 147.1, 139.2, 113.9, 112.4, 108.0, 101.9, 59.3 (2C), 36.2, 27.7; **GC-MS**: 282 [^{79}Br] and 284 [^{81}Br] (25), 240 [^{79}Br] and 242 [^{81}Br] (100), 225 [^{79}Br] and 227 [^{81}Br] (10).

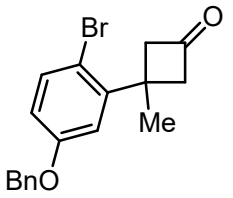


1f. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 8:1. Yield = 68% (3.4 mmol, 911 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.18 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.05 (t, *J* = 8.1 Hz, 1H), 6.84 (dd, *J* = 8.2, 1.0 Hz, 1H), 3.80 (s, 3H), 3.56 – 3.47 (m, 2H), 3.24 – 3.14 (m, 2H), 1.53 (s, 3H); **^{13}C NMR** (100 MHz,

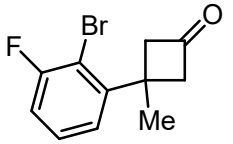
$CDCl_3$) δ = 210.1, 158.7, 134.1, 128.3, 126.5, 123.1, 110.3, 60.5 (2C), 55.6, 34.6, 25.6; **GC-MS**: 268 [^{79}Br] and 270 [^{81}Br] (5), 240 [^{79}Br] and 242 [^{81}Br] (5), 226 [^{79}Br] and 228 [^{81}Br] (20), 211 [^{79}Br] and 213 [^{81}Br] (20), 132 (100).



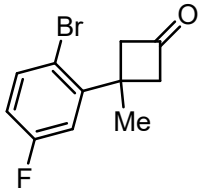
1g. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 8:1. Yield = 75% (3.75 mmol, 1.0 g). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.46 (d, *J* = 8.7 Hz, 1H), 6.83 (d, *J* = 3.0 Hz, 1H), 6.67 (dd, *J* = 8.7, 3.0 Hz, 1H), 3.80 (s, 3H), 3.57 – 3.47 (m, 2H), 3.24 – 3.10 (m, 2H), 1.61 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 201.7, 154.2, 142.2, 130.2, 110.1, 108.2, 107.8, 54.3 (2C), 50.7, 31.5, 22.9; **GC-MS**: 268 [^{79}Br] and 270 [^{81}Br] (15), 226 [^{79}Br] and 228 [^{81}Br] (25), 211 [^{79}Br] and 213 [^{81}Br] (25), 132 (100).



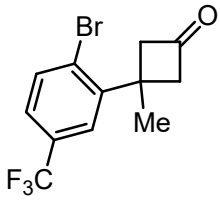
1h. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 9:1. Yield = 55% (2.75 mmol, 946 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.45 (d, *J* = 8.7 Hz, 1H), 7.42 – 7.30 (m, 5H), 6.90 (d, *J* = 3.0 Hz, 1H), 6.73 (dd, *J* = 8.7, 3.0 Hz, 1H), 5.03 (s, 2H), 3.52 – 3.43 (m, 2H), 3.21 – 3.12 (m, 2H), 1.59 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 206.4, 158.1, 147.0, 136.3, 134.9, 128.7 (2C), 128.2 (2C), 127.5, 115.8, 113.9, 112.8, 70.3, 59.1 (2C), 36.2, 27.6; **GC-MS**: 344 [^{79}Br] and 346 [^{81}Br] (5), 302 [^{79}Br] and 304 [^{81}Br] (5), 265 (5), 91 (100).



1i. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 20:1. Yield = 35% (1.75 mmol, 446 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.28 (td, *J* = 8.0, 5.6 Hz, 1H), 7.08 (dt, *J* = 7.9, 1.3 Hz, 1H), 7.03 (td, *J* = 8.2, 1.5 Hz, 1H), 3.59 – 3.49 (m, 2H), 3.30 – 3.17 (m, 2H), 1.65 – 1.61 (m, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.9, 159.6 (d, *J* = 246.5 Hz), 148.4, 128.6 (d, *J* = 8.4 Hz), 123.3 (d, *J* = 3.2 Hz), 114.6 (d, *J* = 23.5 Hz), 109.6 (d, *J* = 21.0 Hz), 59.3 (2C), 36.4 (d, *J* = 2.1 Hz), 27.6 (2C); **^{19}F NMR** (376 MHz, $CDCl_3$) δ = -103.46 (dd, *J* = 8.1, 5.5 Hz, 1F); **GC-MS**: 256 [^{79}Br] and 258 [^{81}Br] (2), 214 [^{79}Br] and 216 [^{81}Br] (95), 177 (50), 133 (100), 135 (95).

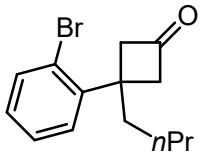


1j. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 20:1. Yield = 41% (2.1 mmol, 523 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.52 (dd, *J* = 8.7, 5.4 Hz, 1H), 7.01 (dd, *J* = 9.7, 3.0 Hz, 1H), 6.91 – 6.80 (m, 1H), 3.54 – 3.45 (m, 2H), 3.25 – 3.16 (m, 2H), 1.61 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.6, 162.0 (d, *J* = 247.6 Hz), 148.1 (d, *J* = 6.6 Hz), 135.6 (d, *J* = 8.0 Hz), 116.2 (d, *J* = 3.0 Hz), 115.6 (d, *J* = 2.4 Hz), 115.3 (d, *J* = 3.4 Hz), 59.0 (2C), 36.3 (d, *J* = 1.4 Hz), 27.5; **^{19}F NMR** (376 MHz, $CDCl_3$) δ = -114.21 – -114.32 (m, 1F); **GC-MS**: 256 [^{79}Br] and 258 [^{81}Br] (5), 214 [^{79}Br] and 216 [^{81}Br] (100), 177 (15).

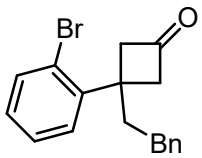


1k. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 20:1. Yield = 23% (1.2 mmol, 367 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.71 (d, *J* = 8.2 Hz, 1H), 7.51 (d, *J* = 2.2 Hz, 1H), 7.37 (dd, *J* = 8.3, 2.2 Hz, 1H), 3.59 – 3.48 (m, 2H), 3.31 – 3.20 (m, 2H), 1.64 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.1, 147.0, 135.0, 130.2 (q, *J* = 33.1 Hz), 126.1 (q, *J* = 1.6 Hz), 125.1 (q, *J* = 3.6 Hz), 124.9 (q, *J* = 3.6 Hz), 123.6 (q, *J* = 259.4 Hz) 59.1 (2C), 36.4, 27.5. **^{19}F NMR**

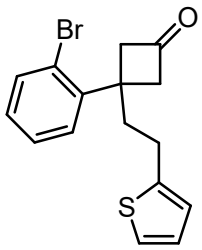
(376 MHz, $CDCl_3$) δ = -62.66 (s, 3F); **GC-MS**: 287 [^{79}Br] and 289 [^{81}Br] (10), 264 [^{79}Br] and 266 [^{81}Br] (100), 227 (60), 165 (90).



1l. Synthesized according to the general methodology from benzaldehyde **S1a** using *n*-BuLi (instead of MeMgBr) in the first step. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 20:1. Yield = 73% (3.65 mmol, 1.0 g). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.57 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.28 (td, *J* = 7.6, 1.3 Hz, 1H), 7.19 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.10 (td, *J* = 7.6, 1.3 Hz, 1H), 3.50 – 3.40 (m, 2H), 3.28 – 3.17 (m, 2H), 1.94 (bs, 2H), 1.26 – 1.16 (m, 2H), 1.06 - 0.95 (m, 2H), 0.80 (t, *J* = 7.3 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 209.5, 143.8, 134.3, 129.8, 128.3, 127.0, 122.3, 57.8 (b, 2C), 39.8, 38.4, 27.7, 22.7, 13.8; **GC-MS**: 238 [^{79}Br] and 240 [^{81}Br] (5), 196 [^{79}Br] and 198 [^{81}Br] (100), 115 (95).

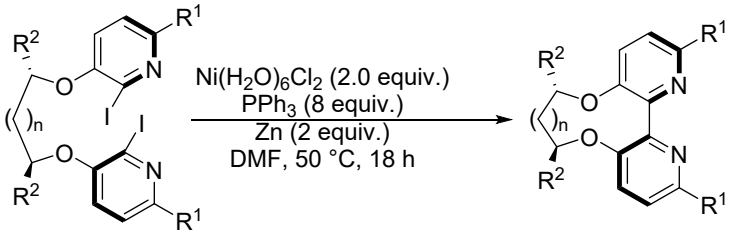


1m. Synthesized according to the general methodology using 2-bromohydrochalcone as the **S3m**.[3] The last two steps of the synthesis were conducted on 1 mmol scale. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 15:1. Yield = 61% (0.61 mmol, 200 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.62 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.33 (td, *J* = 7.5, 1.3 Hz, 1H), 7.28 (dd, *J* = 7.8, 1.9 Hz, 1H), 7.23 – 7.19 (m, 2H), 7.18 – 7.11 (m, 2H), 7.08 – 7.02 (m, 2H), 3.58 – 3.50 (m, 2H), 3.36 – 3.25 (m, 2H), 2.48 – 2.19 (m, 4H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 206.2, 143.1, 141.2, 134.6, 129.9, 128.6, 128.4 (2C), 128.2 (2C), 127.2, 126.0, 122.4, 65.8 (2C), 40.5, 39.9, 32.1; **GC-MS**: 328 [^{79}Br] and 330 [^{81}Br] (2), 286 [^{79}Br] and 288 [^{81}Br] (15), 259 (10), 91 (100).



1n. Synthesized according to the general methodology using 1-(2-bromophenyl)-3-(thiophen-2-yl)propan-1-one as **S3o**.[3] The last two steps of the synthesis were conducted on 1 mmol scale. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 20:1. Yield = 57% (0.57 mmol, 190 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.61 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.37 – 7.30 (m, 1H), 7.26 (dd, *J* = 7.8, 1.8 Hz, 1H), 7.15 (ddd, *J* = 7.9, 7.2, 1.8 Hz, 1H), 7.06 (dd, *J* = 5.2, 1.2 Hz, 1H), 6.85 (dd, *J* = 5.1, 3.4 Hz, 1H), 6.69 (dd, *J* = 3.4, 1.1 Hz, 1H), 3.62 – 3.48 (m, 2H), 3.38 – 3.25 (m, 2H), 2.56 (t, *J* = 8.2 Hz, 2H), 2.44 (bs, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.9, 143.9, 142.8, 134.6, 129.8, 128.7, 127.2, 126.8, 124.1, 123.1, 122.5, 57.9 (b, 2C), 40.3, 39.8, 26.2; **GC-MS**: 334 [^{79}Br] and 336 [^{81}Br] (10), 292 [^{79}Br] and 294 [^{81}Br] (100), 223 [^{79}Br] and 225 [^{81}Br] (10).

Preparation and Characterization of Optimal Ligand L7 and Ligands L3-5



S6 (n = 2, R^1 = R^2 = Me)
S7 (n = 1, R^1 = R^2 = Me)
S8 (n = 0, R^1 = R^2 = Me)
S9 (n = 2, R^1 = Me, R^2 = H)

L7 (n = 2, R^1 = R^2 = Me)
L3 (n = 1, R^1 = R^2 = Me)
L4 (n = 0, R^1 = R^2 = Me)
L5 (n = 2, R^1 = Me, R^2 = H)

L7 was prepared by intramolecular reductive homocoupling of **S6** (prepared form 2-iodo-6-methylpyridin-3-ol[4] and commercially available (2*S*,5*S*)-2,5-hexanediol following and unmodified literature procedure.[5]

In a flame-dried, nitrogen-filled Schlenk tube equipped with a magnetic stirring bar, $NiCl_2 \cdot 6H_2O$ (855 mg, 3.6 mmol) and PPh_3 (3.78 g, 14.4 mmol) were stirred in DMF (20 mL) at room temperature until a clear dark blue solution was obtained (ca. 10 min). Then, Zn dust (234 mg, 3.6 mmol) was added, and the resulting mixture was stirred at 50 °C for 1 h, leading to the formation of a red-brown slurry. The mixture was then cooled to room temperature and a solution of **S6** (1.0 g, 1.8 mmol) in DMF (3 mL) was added dropwise. The resulting black mixture was then stirred at 50 °C for 18 h and then cooled to room temperature. A concentrated aqueous NH_3 solution (28% wt., 30 mL) and CH_2Cl_2 (50 mL) were added, and the biphasic mixture was moved to a separatory funnel and vigorously shaken (the formation of the violet NH_3-Ni complex in the aqueous phase was observed). The organic layer was separated and washed with the NH_3 solution again (15 mL each time) until the washings became colorless, dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. Once all DMF was removed, the residue was re-dissolved in CH_2Cl_2 (30 mL) placed in a separatory funnel and treated with an aqueous HCl solution (3 M, 2 x 15 mL). The combined aqueous layers (containing **L7***2HCl) were washed with CH_2Cl_2 (2 x 15 mL), moved to a beaker, and cooled to 0 °C. Solid NaOH (pellets) was added until pH = 12-14 and the precipitation of a white solid was observed. CH_2Cl_2 (30 mL) was added, and the biphasic mixture was moved to a separatory funnel. The organic layer was separated, and the aqueous layer was extracted with CH_2Cl_2 (2 x 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude residue was purified by FC on silica gel (CH_2Cl_2:Et_2O 2:1) to afford **L7** as a white powder in 55% yield (297 mg, 0.99 mmol). Mp = 216 - 218 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.18 (d, *J* = 8.4 Hz, 2H), 7.08 (d, *J* = 8.4 Hz, 2H), 4.34 – 4.23 (m, 2H), 2.56 (s, 6H), 1.87 – 1.77 (m, 2H), 1.77 – 1.66 (m, 2H), 1.38 (d, *J* = 6.3 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 152.1, 150.7, 145.7, 123.4, 121.4, 80.4, 35.5, 23.8, 22.3; **GC-MS**: 298 (75), 216 (90), 199 (100); **Anal. Calc.** for ($C_{18}H_{12}N_2O_2$: 298.17): C, 72.46; H, 7.43; found: C, 72.79; H, 7.37. $[\alpha]_D^{25}$ = + 159° (*c* = 0.25, CH_2Cl_2).

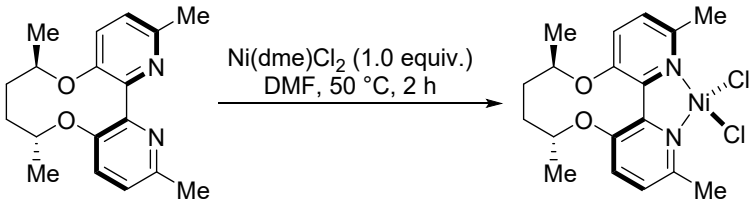
L3 was prepared by intramolecular reductive homocoupling of **S7** (prepared form 2-iodo-6-methylpyridin-3-ol and commercially available (2*S*,4*S*)-2,4-pentanediol) following the same

procedure employed for **L7**. Yield = 60% (performed on 1.2 mmol scale, 0.72 mmol, 204 mg). FC on silica gel (EtOAc 100%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.29 (d, *J* = 8.3 Hz, 2H), 7.09 (d, *J* = 8.3 Hz, 2H), 4.58 – 4.47 (m, 2H), 2.57 (s, 6H), 1.89 (t, *J* = 4.2 Hz, 2H), 1.37 (d, *J* = 6.5 Hz, 6H); **GC-MS**: 284 (70), 202 (95), 185 (100).

L4 was prepared by intramolecular reductive homocoupling of **S8** (prepared form 2-iodo-6-methylpyridin-3-ol and commercially available (2*S*,3*S*)-2,3-butanediol) following the same procedure employed for **L7**. Yield = 52% (performed on 0.8 mmol scale, 0.42 mmol, 112 mg). FC on silica gel (EtOAc 100%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.32 (d, *J* = 8.3 Hz, 2H), 7.16 (d, *J* = 8.3 Hz, 2H), 3.91 – 3.81 (m, 2H), 2.62 (s, 6H), 1.42 – 1.33 (m, 6H); **GC-MS**: 270 (65), 188 (85), 171 (100).

L5 was prepared by intramolecular reductive homocoupling of **S9** (prepared form 2-iodo-6-methylpyridin-3-ol and commercially available 1,4-butanediol) following the same procedure employed for **L7**. Yield = 31% (performed on 1.0 mmol scale, 0.31 mmol, 88 mg). FC on silica gel (EtOAc 100%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.28 (d, *J* = 8.4 Hz, 2H), 7.12 (d, *J* = 8.4 Hz, 2H), 4.41 (bs, 2H), 4.11 (bs, 2H), 2.58 (s, 6H); **GC-MS**: 284 (55), 202 (80), 185 (100).

Preparation and Characterization of Precatalyst [Ni(L7)Cl_2]



L7 **[Ni(L7)Cl_2]**

In a flame-dried, nitrogen-filled Schlenk tube equipped with a magnetic stirring bar, Ni(dme)Cl_2 (110 mg, 0.5 mmol) was stirred in anhydrous DMF (1 mL) at room temperature until a clear blue solution was obtained (10 min). Then, ligand **L7** (150 mg, 0.5 mmol) was added in one portion, resulting almost immediately in a dark brown slurry. The mixture was stirred at 50 °C for 2 h to ensure complete complexation, then cooled to room temperature and evaporated *in vacuo* to dryness. The residue was suspended in Et_2O (5 mL) and stirred vigorously for 2 h until a thick brown solid precipitate is obtained. The solid was filtered, washed several times with Et_2O and dried *in vacuo* to yield [Ni(**L7**)Cl_2] as a light brown bench-stable powder in 90% yield (186 mg, 0.45 mmol). Mp > 400 °C (decomposition). $[\alpha]_D^{25}$ = + 246° (*c* = 0.20, DMF). Crystals suitable for X-ray diffraction analysis were obtained by layering a solution of [Ni(**L7**)Cl_2] in THF with *c*Hex.

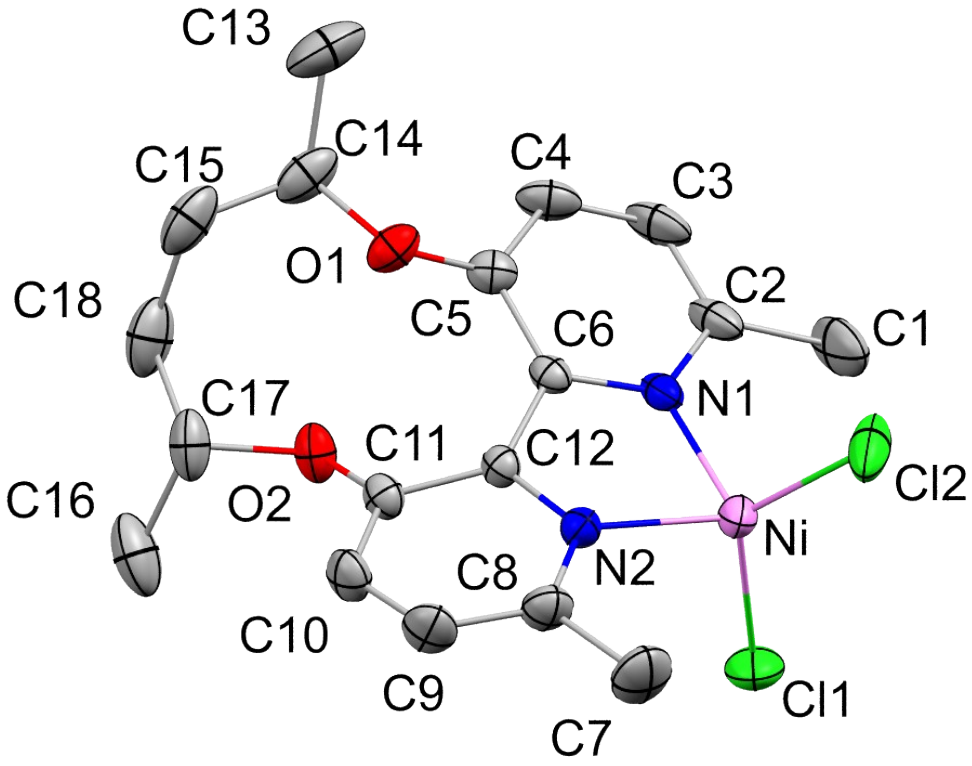
The X-ray intensity data were measured on a Bruker Apex III CCD diffractometer. Cell dimensions and the orientation matrix were initially determined from a least-squares refinement on reflections measured in four sets of 20 exposures, collected in three different ω regions, and eventually refined against all data. A full sphere of reciprocal space was scanned by 0.5° ω steps. The software SMART[3] was used for collecting frames of data, indexing reflections and determination of lattice parameters. The collected frames were then processed for integration by the SAINT program,[6] and an empirical absorption correction was applied using SADABS.[7] The structures were solved by direct methods (SIR 2014)[8] and subsequent Fourier syntheses and refined by full-matrix least-squares on F^2 (SHELXTL)[9] using anisotropic thermal parameters for all non-hydrogen atoms. The aromatic, methyl, methylene and methine hydrogen atoms were placed in calculated positions, refined with isotropic thermal parameters *U(H)* = 1.2 *Ueq*(C) and allowed to ride on their carrier carbons.
Crystal data and details of the data collection for compound [Ni(**L7**)Cl_2] are reported in **Table S2**.[10] Crystallographic data have been deposited with the Cambridge Crystallographic Data Centre (CCDC) as supplementary publication number CCDC 2129543. Copies of the data can be obtained free of charge via www.ccdc.cam.ac.uk/getstructures.

Table S2. Crystal data and structure refinement for compound [Ni(**L7**)Cl_2]

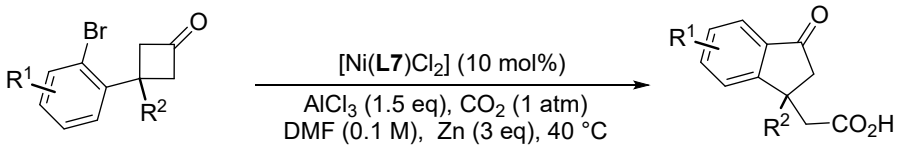
Compound	**[Ni(L7)Cl_2]**
Formula	$C_{18}H_{22}O_2N_2NiCl_2$
Fw	427.98
T, K	296
λ, Å	0.71073
Crystal symmetry	Orthorhombic
Space group	$P2_12_12_1$
a, Å	8.797(3)
b, Å	12.158(4)
c, Å	19.362(7)
α	90.00
β	90.00
γ	90.00
Cell volume, Å^3	2070.8(1)
Z	4
Dc, Mg m^{-3}	1.373
μ(Mo-K_α), mm^{-1}	1.207
F(000)	888
Crystal size/ mm	0.81 x 0.09 x 0.07
θ limits, °	3.129 to 25.496
Reflections collected	26173
Unique obs. Reflections [$F_o > 4\sigma(F_o)$]	3843 [R(int) = 0.0372]
Goodness-of-fit-on F^2	1.005
R_1 (F)[a], wR_2 (F^2)[b] [I > 2σ(I)]	R1 = 0.0379, wR2 =
Largest diff. peak and hole, e. Å^{-3}	0.311 and -0.231

a) $R_1 = \Sigma||F_o|-|F_c||/\Sigma|F_o|$. b $wR_2 = [\Sigma w(F_o^2-F_c^2)^2/\Sigma w(F_o^2)^2]^{1/2}$ where $w = 1/[\sigma^2(F_o^2) + (aP)^2 + bP]$ where $P = (F_o^2 + F_c^2)/3$.

Figure S2. Molecular structure of [Ni(**L7**)Cl_2] with the atom labelling. Hydrogen atoms omitted for clarity. Thermal ellipsoids are drawn at 30% of probability level.

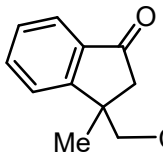


Optimized general procedure for the Ni-Catalyzed Tandem C-C σ-Bond Activation-CO_2 Fixation.



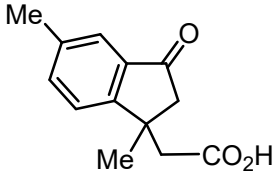
1 **2**

A flame-dried, nitrogen-filled Schlenk tube equipped with a magnetic stirring bar was charged with Nickel pre-catalyst [Ni(**L7**)Cl_2] (10 mol%, 4.3 mg), zinc dust (0.3 mmol, 19.8 mg) and $AlCl_3$ (0.15 mmol, 20.0 mg). The nitrogen atmosphere was evacuated, and the tube was backfilled with CO_2 (1 bar). This operation was repeated three times. Then DMF (1 mL, 0.1 M) was added under a flow of CO_2, and the reaction mixture was stirred for 5 min. Under a flow of CO_2, substrate **1** (0.1 mmol) was added, CO_2 was bubbled in the solution, the Schlenk flask was closed, and the reaction mixture was stirred (1000 rpm) for 16 h at 40 °C. The reaction was quenched with HCl (5 mL, 2.0 M), and extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with HCl (3 x 10 mL, 0.2 M), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography (FC) on silica gel [*n*Hex:EtOAc + 1% HCOOH] to afford desired products **2**.

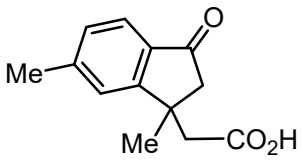


2a. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 70:30 +1% HCOOH. Yield = 70% (0.070 mmol, 14.3 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.70 (d, *J* = 7.6 Hz, 1H), 7.61 (t, *J* = 7.5 Hz, 1H), 7.47 (d, *J* = 7.8 Hz, 1H), 7.38 (t, *J* = 7.4 Hz, 1H), 3.02 (d, *J* = 19.0 Hz, 1H), 2.80 (d, *J* = 15.4 Hz, 1H), 2.66 (d, *J* = 15.3 Hz, 1H), 2.56 (d, *J* = 19.0 Hz, 1H), 1.47 (s, 3H), the -COOH peak appears as a very broad singlet around 7.8 – 6.9 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 200.0, 170.7, 155.6, 130.5, 129.9, 122.8, 118.4, 118.4, 45.0, 40.0, 34.9, 23.4; **LC-MS**: $[M\text{-}H^+]^-$ = 203; **Anal. Calc.** for ($C_{12}H_{12}O_3$: 204.08): C, 70.58; H, 5.92; found: C, 70.76; H, 6.07.

2a is a known compound and the reported spectroscopic data match with the ones reported in the literature.[11]

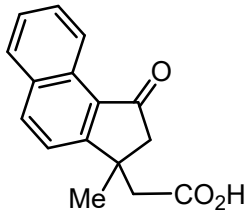


2b. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 70:30 +1% HCOOH. Yield = 76% (0.076 mmol, 16.6 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.49 (s, 1H), 7.43 (d, *J* = 7.9 Hz, 1H), 7.35 (d, *J* = 7.9 Hz, 1H), 3.02 (d, *J* = 19.0 Hz, 1H), 2.78 (d, *J* = 15.3 Hz, 1H), 2.64 (d, *J* = 15.3 Hz, 1H), 2.55 (d, *J* = 19.0 Hz, 1H), 2.38 (s, 3H), 1.45 (s, 3H), the -COOH peak appears as a very broad singlet around 7.7 – 6.9 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.2, 176.0, 158.2, 138.1, 136.3, 135.9, 123.5, 123.3, 50.5, 45.2, 39.8, 28.6, 21.0; **LC-MS**: $[M\text{-}H^+]^-$ = 217; **Anal. Calc.** for ($C_{13}H_{14}O_3$: 218.09): C, 71.54; H, 6.47; found: C, 71.36; H, 6.77.

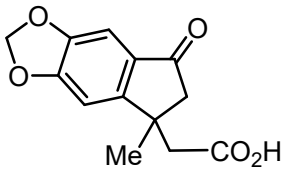


2c. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 67:33 +1% HCOOH. Yield = 64% (0.064 mmol, 14.1 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.59 (d, *J* = 7.8 Hz, 1H), 7.26 (s, 1H, overlapped with the $CHCl_3$ peak), 7.18 (d, *J* = 7.8 Hz, 1H), 6.26 (bs, 1H), 3.01 (d, *J*

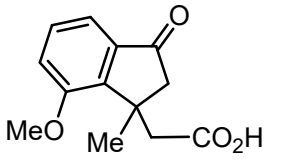
= 19.0 Hz, 1H), 2.79 (d, *J* = 15.4 Hz, 1H), 2.64 (d, *J* = 15.4 Hz, 1H), 2.54 (d, *J* = 19.0 Hz, 1H), 2.43 (s, 3H), 1.46 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 204.8, 175.9, 161.3, 146.3, 133.4, 129.3, 123.9, 123.4, 50.4, 45.1, 39.9, 28.5, 22.2; **LC-MS**: $[M\text{-}H^+]^-$ = 217; **Anal. Calc.** for ($C_{13}H_{14}O_3$: 218.09): C, 71.54; H, 6.47; found: C, 71.69; H, 6.30.



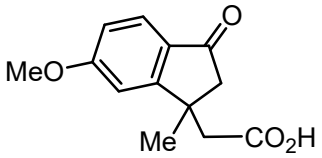
2d. White solid. Mp = 177 - 180 °C. FC eluent: *n*Hex:EtOAc: 75:25 +1% HCOOH. Yield = 43% (0.043 mmol, 10.9 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 9.13 (d, *J* = 8.3 Hz, 1H), 8.07 (d, *J* = 8.5 Hz, 1H), 7.87 (d, *J* = 8.1 Hz, 1H), 7.66 (ddd, *J* = 8.3, 7.0, 1.1 Hz, 1H), 7.55 (ddd, *J* = 6.9, 6.2, 1.6 Hz, 1H) partially overlapped with 7.52 (d, *J* = 8.5 Hz, 1H), 3.14 (d, *J* = 18.8 Hz, 1H), 2.86 (d, *J* = 15.2 Hz, 1H), 2.71 (d, *J* = 15.2 Hz, 1H) partially overlapped with 2.67 (d, *J* = 18.8 Hz, 1H), 1.52 (s, 3H) the -COOH peak appears as a very broad singlet around 6.7 – 4.4 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.5, 175.7, 163.2, 136.3, 132.7, 129.5, 129.2, 129.0, 128.1, 126.9, 124.4, 120.5, 50.7, 44.8, 39.8, 28.2; **LC-MS**: $[M\text{-}H^+]^-$ = 253; **Anal. Calc.** for ($C_{16}H_{14}O_3$: 254.09): C, 75.58; H, 5.55; found: C, 75.32; H, 5.81.



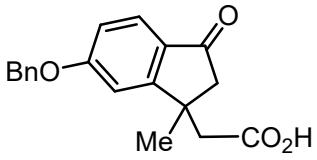
2e. White solid. Mp = 164 - 165 °C. FC eluent: *n*Hex:EtOAc: 70:30 +1% HCOOH, then *n*Hex:EtOAc: 60:40 +1% HCOOH. Yield = 50% (0.050 mmol, 12.3 mg). **^{1}H NMR** (400 MHz, acetone-d_6) δ = 7.25 (s, 1H), 7.02 (s, 1H), 6.24 (s, 2H), 3.09 (d, *J* = 18.6 Hz, 1H), 2.91 (d, *J* = 15.5 Hz, 1H), 2.81 (d, *J* = 15.5 Hz, 1H), 2.55 (d, *J* = 18.6 Hz, 1H), 1.53 (s, 3H) the -COOH peak appears as a very broad singlet around 4.3 – 3.3 ppm; **^{13}C NMR** (100 MHz, acetone-d_6) δ = 204.2, 174.5, 161.4, 156.8, 151.2, 133.3, 106.2, 105.3, 103.6, 52.9, 46.9, 42.4, 30.8; **LC-MS**: $[M\text{-}H^+]^-$ = 247; **Anal. Calc.** for ($C_{13}H_{12}O_5$: 248.07): C, 62.90; H, 4.87; found: C, 62.72; H, 5.04.



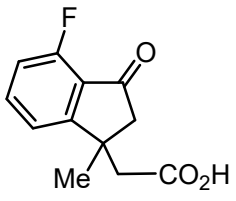
2f. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 75:25 +1% HCOOH. Yield = 73% (0.073 mmol, 17.0 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.34 (t, *J* = 7.6 Hz, 1H), 7.29 (d, *J* = 6.9 Hz, 1H), 7.04 (d, *J* = 7.3 Hz, 1H), 3.87 (s, 3H), 3.03 (d, *J* = 15.6 Hz, 1H), 2.98 (d, *J* = 19.2 Hz, 1H), 2.90 (d, *J* = 15.6 Hz, 1H), 2.53 (d, *J* = 19.2 Hz, 1H), 1.52 (s, 3H), the -COOH peak appears as a very broad singlet around 8.1 – 6.4 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.5, 176.8, 157.1, 147.4, 138.0, 130.0, 116.3, 115.3, 55.4, 50.8, 42.4, 40.3, 26.3; **LC-MS**: $[M\text{-}H^+]^-$ = 233; **Anal. Calc.** for ($C_{13}H_{14}O_4$: 234.09): C, 66.66; H, 6.02; found: C, 66.68; H, 5.87.



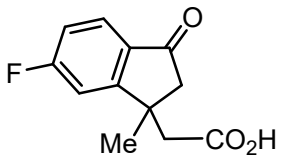
2g. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 64:36 +1% HCOOH, then *n*Hex:EtOAc 60:40 + 1% HCOOH. Yield = 65% (0.065 mmol, 15.1 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.64 (d, *J* = 8.5 Hz, 1H), 6.90 (dd, *J* = 8.5, 2.1 Hz, 1H), 6.87 (d, *J* = 2.0 Hz, 1H), 3.87 (s, 3H), 3.01 (d, *J* = 18.9 Hz, 1H), 2.78 (d, *J* = 15.3 Hz, 1H), 2.65 (d, *J* = 15.3 Hz, 1H), 2.55 (d, *J* = 18.9 Hz, 1H), 1.46 (s, 3H), the -COOH peak appears as a very broad singlet around 8.0 – 6.2 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 200.9, 173.2, 163.0, 161.2, 126.4, 122.9, 112.8, 104.8, 53.1, 47.9, 42.5, 37.4, 25.9; **LC-MS**: $[M\text{-}H^+]^-$ = 233; **Anal. Calc.** for ($C_{13}H_{14}O_4$: 234.09): C, 66.66; H, 6.02; found: C, 66.73; H, 6.20.



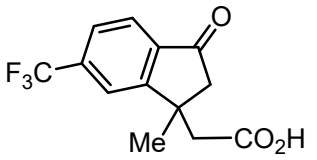
2h. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 70:30 +1% HCOOH, then *n*Hex:EtOAc 62:38 + 1% HCOOH. Yield = 64% (0.064 mmol, 20.3 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.64 (d, *J* = 8.7 Hz, 1H), 7.45 – 7.31 (m, 5H), 7.00 – 6.94 (m, 2H), 5.12 (s, 2H), 3.01 (d, *J* = 18.9 Hz, 1H), 2.75 (d, *J* = 15.3 Hz, 1H), 2.63 (d, *J* = 15.3 Hz, 1H), 2.54 (d, *J* = 18.9 Hz, 1H), 1.45 (s, 3H), the -COOH peak appears as a very broad singlet around 5.3 – 4.3 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 203.5, 175.3, 164.7, 163.8, 135.8, 129.2, 128.7 (2C), 128.3, 127.6 (2C), 125.5, 115.9, 108.5, 70.4, 50.5, 45.1, 40.0, 28.4; **LC-MS**: $[M\text{-}H^+]^-$ = 309; **Anal. Calc.** for ($C_{19}H_{18}O_4$: 310.12): C, 75.53; H, 5.85; found: C, 75.81; H, 5.68.



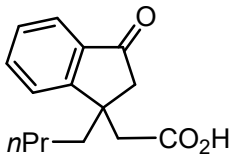
2i. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 75:25 +1% HCOOH. Yield = 45% (0.045 mmol, 10.0 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.61 (dt, *J* = 12.6, 6.3 Hz, 1H), 7.27 (d, *J* = 7.5 Hz, 1H, overlapped with the $CHCl_3$ peak), 7.03 (t, *J* = 8.6 Hz, 1H), 3.07 (d, *J* = 18.9 Hz, 1H), 2.84 (d, *J* = 15.6 Hz, 1H), 2.74 (d, *J* = 15.6 Hz, 1H), 2.61 (d, *J* = 18.9 Hz, 1H), 1.51 (s, 3H), the -COOH peak appears as a very broad singlet around 4.8 – 3.1 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 201.1, 174.7, 162.9 (d, *J* = 2.1 Hz), 158.4 (d, *J* = 264.6 Hz), 137.0 (d, *J* = 8.3 Hz), 123.7 (d, *J* = 12.7 Hz), 119.3 (d, *J* = 4.1 Hz), 114.9 (d, *J* = 19.3 Hz) 50.6, 44.7, 40.1 (d, *J* = 1.5 Hz, 1H), 28.8; **^{19}F NMR** (376 MHz, $CDCl_3$) δ = -114.44 (dd, *J* = 9.1, 4.9 Hz, 1F); **LC-MS**: $[M\text{-}H^+]^-$ = 221; **Anal. Calc.** for ($C_{12}H_{11}FO_3$: 222.07): C, 64.86; H, 4.99; found: C, 64.89; H, 4.87.



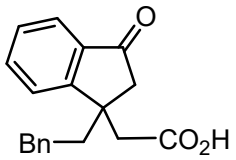
2j. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 75:25 +1% HCOOH. Yield = 45% (0.045 mmol, 10.0 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.71 (dd, *J* = 8.4, 5.3 Hz, 1H), 7.14 – 7.04 (m, 2H), 3.02 (d, *J* = 19.0 Hz, 1H), 2.79 (d, *J* = 15.6 Hz, 1H), 2.68 (d, *J* = 15.6 Hz, 1H), 2.58 (d, *J* = 19.0 Hz, 1H), 1.47 (s, 3H), the -COOH peak appears as a very broad singlet around 7.7 – 6.0 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 203.0, 175.3, 167.3 (d, *J* = 256.9 Hz), 163.6 (d, *J* = 8.9 Hz), 132.2 (d, *J* = 1.9 Hz), 126.1 (d, *J* = 10.4 Hz), 116.3 (d, *J* = 23.8 Hz), 110.5 (d, *J* = 22.5 Hz), 50.4, 44.7, 40.0 (d, *J* = 2.0 Hz), 28.6; **^{19}F NMR** (376 MHz, $CDCl_3$) δ = -101.49 - -101.59 (m, 1F); **LC-MS**: $[M\text{-}H^+]^-$ = 221; **Anal. Calc.** for ($C_{12}H_{11}FO_3$: 222.07): C, 64.86; H, 4.99; found: C, 64.91; H, 5.11.



2k. Viscous colorless oil. FC eluent: CH_2Cl_2:MeOH: 30:1. Yield = 25% (0.025 mmol, 6.8 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.84 (d, *J* = 7.9 Hz, 1H), 7.76 (s, 1H), 7.68 (d, *J* = 7.9 Hz, 1H), 3.10 (d, *J* = 19.2 Hz, 1H), 2.88 (d, *J* = 15.8 Hz, 1H), 2.77 (d, *J* = 15.8 Hz, 1H), 2.66 (d, *J* = 19.1 Hz, 1H), 1.55 (s, 3H), the -COOH peak appears as a very broad singlet around 4.3 – 3.5 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 203.7, 172.1, 160.6, 138.5 (q, *J* = 1.5 Hz) , 136.3 (q, *J* = 32.1 Hz), 125.3 (q, *J* = 3.6 Hz), 123.5 (q, *J* = 273.7 Hz), 124.2, 120.8 (q, *J* = 3.8 Hz), 50.4, 40.2, 29.7, 28.7; **^{19}F NMR** (376 MHz, $CDCl_3$) δ = -62.93 (s, 3F) **LC-MS**: $[M\text{-}H^+]^-$ = 269; **Anal. Calc.** for ($C_{13}H_{11}F_3O_3$: 272.07): C, 57.36; H, 4.07; found: C, 57.55; H, 3.93.



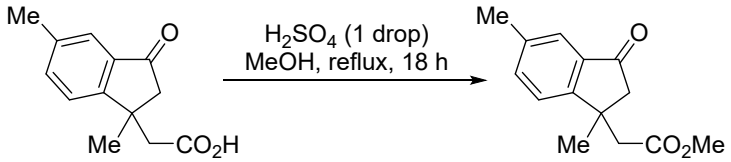
2l. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 75:25 +1% HCOOH. Yield = 76% (0.076 mmol, 18.7 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.69 (d, *J* = 7.6 Hz, 1H), 7.63 – 7.57 (m, 1H), 7.42 (d, *J* = 7.8 Hz, 1H), 7.38 (t, *J* = 7.4 Hz, 1H), 2.92 (d, *J* = 19.1 Hz, 1H), 2.83 (d, *J* = 15.3 Hz, 1H), 2.70 (d, *J* = 15.3 Hz, 1H), 2.63 (d, *J* = 19.1 Hz, 1H), 1.88 – 1.78 (m, 1H), 1.74 – 1.63 (m, 1H), 1.30 – 1.04 (m, 4H), 0.78 (t, *J* = 7.2 Hz, 3H), the -COOH peak appears as a very broad singlet around 6.6 – 4.2 ppm; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.2, 175.7, 159.1, 136.7, 134.9, 128.0, 123.8, 123.5, 47.6, 44.0, 43.6, 40.6, 26.5, 22.9, 13.8; **LC-MS**: $[M\text{-}H^+]^-$ = 259; **Anal. Calc.** for ($C_{16}H_{20}O_3$: 260.14): C, 73.82; H, 7.74; found: C, 74.00; H, 7.97.



2m. Viscous colorless oil. FC eluent: *n*Hex:EtOAc: 75:25 +1% HCOOH. Yield = 60% (0.060 mmol, 17.7 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.72 (dd, *J* = 7.5, 1.1 Hz, 1H), 7.62 (td, *J* = 7.5, 1.2 Hz, 1H), 7.47 (d, *J* = 7.7 Hz, 1H), 7.39 (t, *J* = 7.4 Hz, 1H), 7.23 – 7.18 (m, 2H), 7.16 – 7.10 (m, 1H), 7.05 – 7.00 (m, 2H), 2.99 (d, *J* = 19.1 Hz, 1H), 2.88 (d, *J* = 15.4 Hz, 1H), 2.78 – 2.65 (m, 2H), 2.48 – 2.40 (m, 1H), 2.16 (td, *J* = 9.9, 3.4 Hz, 2H), 2.05 – 1.98 (m, 1H), the -COOH peak was not detected; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.0, 175.5, 158.7, 141.1, 136.8, 135.1, 128.5 (2C), 128.2, 128.1 (2C), 126.0, 123.9, 123.6, 47.5, 44.2, 43.7, 42.6, 30.9; **LC-MS**: $[M\text{-}H^+]^-$ = 293; **Anal. Calc.** for ($C_{19}H_{18}O_3$: 294.13): C, 77.53; H, 6.16; found: C, 77.39; H, 5.94.

Transformations of compound 2b

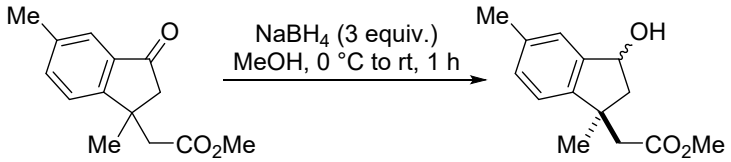
➢ Esterification of acid 2b



2b **2b-methyl ester**

A nitrogen-filled Schlenk tube equipped with a stirring bar was charged with acid **2b** (64.4 mg, 0.3 mmol), MeOH (4 mL) and 1 droplet of concentrated H_2SO_4. The resulting mixture was heated to reflux for 18 h, then cooled to room temperature, diluted with EtOAc (10 mL), saturated aqueous $NaHCO_3$ (15 mL) was added. The organic phase was separated, and the aqueous phase was extracted with EtOAc (2 x 10 mL). The combined organic phases were washed with brine (10 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography (FC) on silica gel [*n*Hex:EtOAc 4:1] to afford product **2b-methyl ester** as a colorless oil (46.1 mg, 0.2 mmol, 66% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.52 (s, 1H), 7.44 (d, *J* = 8.0 Hz, 1H), 7.37 (d, *J* = 7.9 Hz, 1H), 3.57 (s, 3H), 3.03 (d, *J* = 18.9 Hz, 1H), 2.78 (d, *J* = 15.0 Hz, 1H), 2.64 (d, *J* = 14.9 Hz, 1H), 2.56 (d, *J* = 18.9 Hz, 1H), 2.40 (s, 3H), 1.58 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 205.0, 171.3, 158.2, 138.0, 136.1, 136.0, 123.4, 123.3, 51.5, 50.8, 45.5, 40.0, 28.5, 21.1. **GC-MS**: 232 (40), 159 (100), 115 (35); **Anal. Calc.** for ($C_{14}H_{16}O_3$: 232.11): C, 72.39; H, 6.94; found: C, 72.44; H, 7.05.

➢ Preparation of Alcohol 3b

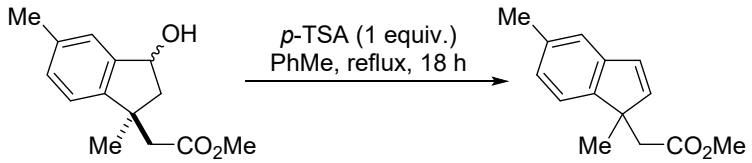


2b-methyl ester **3b**

In a screw-capped vial equipped with a magnetic stirring bar **2b-methyl ester** (23.2 mg, 0.1 mmol) was dissolved in MeOH (1 mL). The resulting solution was cooled to 0 °C and $NaBH_4$ (3 equiv., 11.4 mg, 0.3 mmol) was added. The reaction mixture was then stirred at room temperature for 1 h then quenched with saturated aqueous NH_4Cl (5 mL), diluted with EtOAc (5 mL) and moved to a separatory funnel. The organic phase was separated, and the aqueous phase was back-extracted with EtOAc (2 x 5 mL). The combined organic phases were washed with brine (5 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure to afford analytically pure **3b** as a white foam in quantitative yield (*dr* = 1.1:1). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.22 (s, 1H minor), 7.19 (s, 1H major), 7.13 – 7.08 (m, 1H minor + 1H major), 7.07 (d, *J* = 7.8 Hz, 1H major), 7.03 (d, *J* = 7.8 Hz, 1H minor), 5.23 (t, *J* = 6.4 Hz, 1H major), 5.17 (dd, *J* = 7.5, 4.1 Hz, 1H minor), 3.59 (s, 3H major), 3.56 (s, 3H minor), 2.76 (dd, *J* = 13.5, 7.2 Hz, 1H minor) partially overlapped with 2.73 (d, *J* = 15.2 Hz, 1H minor), 2.58 (d, *J* = 15.2 Hz,

1H minor), 2.52 (d, *J* = 14.2 Hz, 1H major), 2.46 – 2.38 (m, 2H major), 2.34 (s, 3H major + 3H minor), 2.22 (dd, *J* = 14.1, 4.1 Hz, 1H minor), 1.82 (dd, *J* = 13.5, 5.8 Hz, 1H major), 1.45 (s, 3H major), 1.29 (s, 3H minor), the -OH peak was not detected; **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 172.7 (minor), 172.0 (major), 146.4 (minor), 146.2 (major), 144.2 (major), 144.1 (minor), 137.4 (minor), 137.3 (major), 129.7 (major), 129.5 (minor), 125.3 (minor), 124.8 (major), 122.6 (minor), 122.2 (major), 74.4 (minor), 74.2 (major), 51.4 (minor), 51.3 (major), 49.6 (major), 49.3 (minor), 46.4 (minor), 45.9 (major), 44.3 (major), 44.0 (minor), 29.0 (minor), 28.2 (major) 21.3 (major), 21.2 (minor); **GC-MS**: 234 (15), 161 (100), 143 (50); **Anal. Calc.** for ($C_{14}H_{18}O_3$: 234.13): C, 71.77; H, 7.74; found: C, 71.66; H, 7.92.

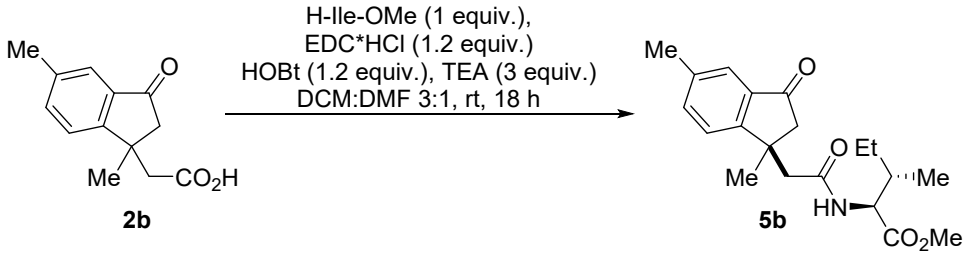
- **Preparation of indene 4b**



3b **4b**

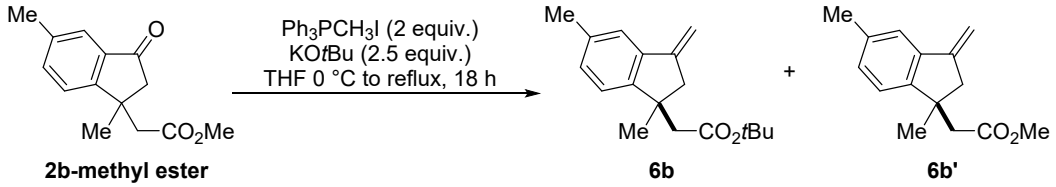
In a screw-capped vial equipped with a magnetic stirring bar **3b** (23.4 mg, 0.1 mmol) and *p*-toluenesulfonic acid monohydrate (1 equiv., 19.0 mg, 0.1 mmol) were suspended in toluene (1 mL) and heated to reflux for 18 h. The reaction mixture was then cooled to room temperature, quenched with saturated aqueous $NaHCO_3$ (5 mL), diluted with EtOAc (5 mL) and moved to a separatory funnel. The organic phase was separated, and the aqueous phase was back-extracted with EtOAc (2 x 5 mL). The combined organic phases were washed with brine (5 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography (FC) on silica gel [*n*Hex:EtOAc 40:1] to afford product **4b** as a colorless oil (14.0 mg, 0.065 mmol, 65% yield). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.18 (d, *J* = 7.6 Hz, 1H), 7.11 (s, 1H), 7.00 (d, *J* = 7.7 Hz, 1H), 6.63 (d, *J* = 5.5 Hz, 1H), 6.56 (d, *J* = 5.5 Hz, 1H), 3.62 (s, 3H), 2.75 (d, *J* = 14.4 Hz, 1H), 2.37 (d, *J* = 14.3 Hz, 1H) partially overlapped with 2.35 (s, 3H), 1.35 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 171.9, 148.3, 144.6, 142.9, 136.6, 129.0, 125.9, 122.2, 121.2, 51.4, 50.5, 42.5, 22.2, 21.4; **GC-MS**: 216 (70), 156 (100), 141 (80), 128 (70), 115 (60); **Anal. Calc.** for ($C_{14}H_{16}O_2$: 216.12): C, 77.75; H, 7.46; found: C, 77.54; H, 7.66.

- **Preparation of amide 5b**



A nitrogen-filled Schlenk tube equipped with a stirring bar was charged with acid **2b** (21.8 mg, 0.1 mmol), HOBt (1.2 equiv., 18.4 mg, 0.12 mmol), CH_2Cl_2 (1.2 mL) and DMF (0.4 mL). The resulting solution is stirred for 10 min. at room temperature, then EDC hydrochloride (1.2 equiv., 21.0 mg, 0.12 mmol) and isoleucine methyl ester (H-Ile-Ome, 1.0 equiv., 13.2 mg, 0.1 mmol) were added in this order. Finally, TEA (3.0 equiv., 42 µL, 0.3 mmol) was added dropwise and the resulting mixture was stirred at room temperature for 18 h. The reaction was then diluted with EtOAc (10 mL), treated with saturated aqueous NH_4Cl (15 mL) and moved to a separatory funnel. The organic phase was separated, and the aqueous phase was back-extracted with EtOAc (2 x 10 mL). The combined organic phases were washed with brine (10 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography (FC) on silica gel [*n*Hex:EtOAc 1.5:1] to afford product **5b** as a colorless oil (dr = 1.5:1, 17.9 mg, 0.052 mmol, 52% yield). Partial separation of the diastereoisomers was possible *via* FC. Two fractions of the column were thus obtained. The first (7.6 mg) containing the pure major diastereoisomer and the second (10.3 mg) containing a 1.3:1 diastereomeric mixture in favor of the minor diastereoisomer. **^{1}H NMR of major diastereoisomer** (400 MHz, $CDCl_3$) δ = 7.51 (s, 1H), 7.43 (dd, *J* = 8.0, 1.7 Hz, 1H), 7.38 (d, *J* = 7.9 Hz, 1H), 5.70 (d, *J* = 8.4 Hz, 1H), 4.44 (dd, *J* = 8.4, 4.8 Hz, 1H), 3.66 (s, 3H), 3.07 (d, *J* = 19.0 Hz, 1H), 2.63 – 2.59 (m, 3H), 2.38 (s, 3H), 1.78 (ddt, *J* = 9.3, 6.9, 4.7 Hz, 1H), 1.47 (s, 3H), 1.34 – 1.20 (m, 1H), 1.02 (ddt, *J* = 13.8, 9.0, 7.1 Hz, 1H), 0.85 (t, *J* = 7.4 Hz, 3H), 0.80 (d, *J* = 6.9 Hz, 3H). **^{1}H NMR of minor diastereoisomer** (400 MHz, $CDCl_3$) δ = 7.52 (s, 1H), 7.46 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.39 (d, *J* = 7.7 Hz, 1H), 5.64 (d, *J* = 8.6 Hz, 1H), 4.44 (dd, *J* = 8.7, 4.8 Hz, 1H), 3.68 (s, 3H), 3.16 (d, *J* = 19.1 Hz, 1H), 2.64 – 2.58 (m, 2H), 2.54 (d, *J* = 19.0 Hz, 1H), 2.38 (s, 3H), 1.78 (ddt, *J* = 9.5, 7.0, 4.8 Hz, 1H), 1.47 (s, 3H), 1.34 – 1.25 (m, 1H), 1.17 – 1.07 (m, 1H), 0.85 (t, *J* = 7.3 Hz, 3H), 0.60 (d, *J* = 6.9 Hz, 3H). **^{13}C NMR of major diastereoisomer** (100 MHz, $CDCl_3$) δ = 205.1, 172.1, 169.8, 158.5, 138.0, 136.1, 136.0, 123.6, 123.2, 56.3, 52.0, 50.5, 47.8, 40.5, 37.7, 28.9, 25.2, 21.0, 15.4, 11.5; **^{13}C NMR of minor diastereoisomer** (100 MHz, $CDCl_3$) δ = ^{13}C NMR (101 MHz, $cdcl_3$) δ 205.0, 172.4, 169.6, 158.3, 138.0, 136.3, 136.1, 123.7, 123.2, 56.1, 52.1, 50.1, 47.9, 40.7, 37.8, 29.3, 24.8, 21.0, 15.1, 11.4; **LC-MS**: [M+H$^+$] = 346, [M+Na$^+$] = 368.

- **Wittig olefination for the preparation of 6b and 6b'**



2b-methyl ester **6b** **6b'**

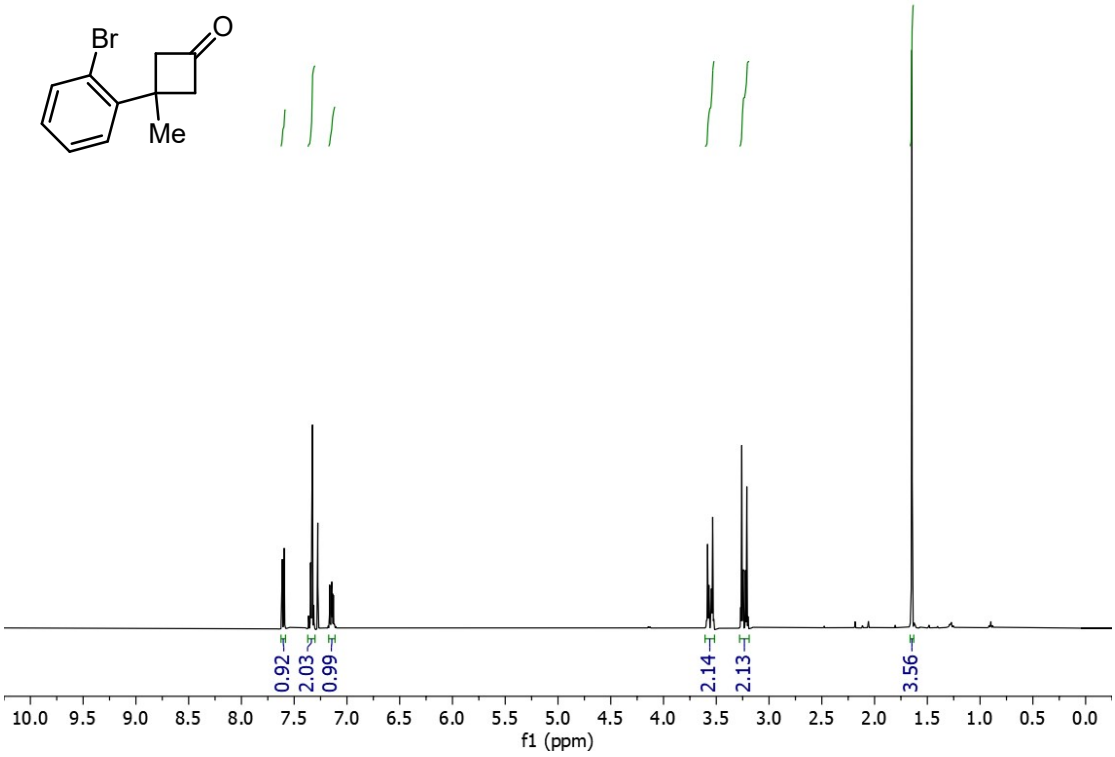
A nitrogen-filled Schlenk tube equipped with a stirring bar was charged with methyl triphenylphosphonium iodide (2.0 equiv., 80.8 mg, 0.2 mmol), KO*t*Bu (2.5 equiv., 28.0 mg, 0.25 mmol) and THF (0.5 mL) in this order. The resulting bright yellow suspension was stirred at room temperature for 1 h and then cooled to 0 °C. A solution of **2b-methyl ester** (23.2 mg, 0.1 mmol), in THF (0.5 mL) was then added dropwise, the mixture was immediately heated to reflux and stirred at that temperature for 18 h. The reaction was then cooled to room temperature and diluted with EtOAc (5 mL), treated with saturated aqueous NH_4Cl (10 mL) and moved to a separatory funnel. The organic phase was separated, and the aqueous phase was back-extracted with EtOAc (2 x 5 mL). The combined organic phases were washed with brine (5 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography (FC) on silica gel [*n*Hex:EtOAc 40:1] to afford product **6b** (colorless oil, 10.9 mg, 0.040 mmol) and **6b'** (colorless oil, 2.3 mg, 0.010 mmol) in 50% combined yield.

6b: **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.25 (s, 1H), 7.09 (d, *J* = 7.8 Hz, 1H), 7.05 (d, *J* = 7.9 Hz, 1H), 5.41 (t, *J* = 2.5 Hz, 1H), 5.00 (t, *J* = 2.4 Hz, 1H), 3.08 (dt, *J* = 16.5, 2.3 Hz, 1H), 2.61 (dt, *J* = 16.5, 2.2 Hz, 1H), 2.49 (d, *J* = 13.8 Hz, 1H), 2.42 (d, *J* = 13.8 Hz, 1H), 2.33 (s, 3H), 1.34 (s, 9H), 1.32 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 171.0, 150.1, 148.0, 139.8, 136.7, 129.5, 122.9, 120.9, 103.0, 80.2, 47.2, 45.9, 43.8, 28.0, 27.9 (3C), 21.3; **GC-MS**: 272 (35), 157 (25), 57 (100); **Anal. Calc.** for ($C_{18}H_{24}O_2$: 272.18): C, 79.37; H, 8.88; found: C, 79.56; H, 9.00.

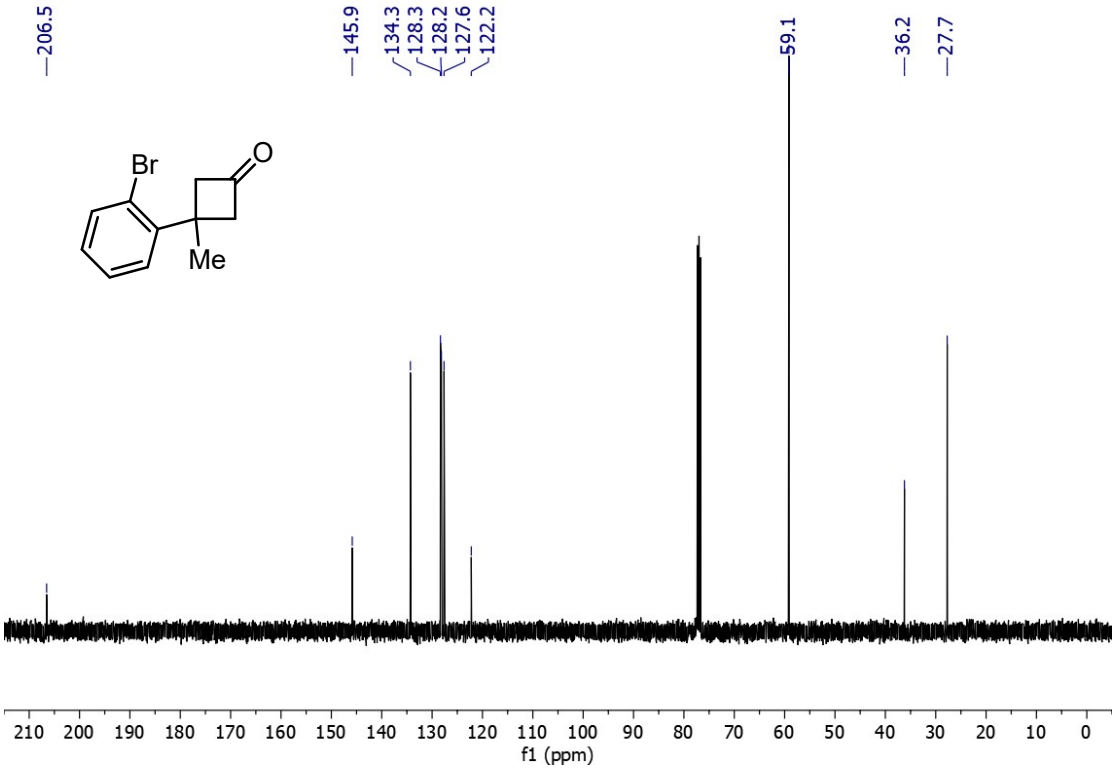
6b': **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.27 (s, 1H), 7.10 – 7.04 (m, 2H), 5.42 (t, *J* = 2.1 Hz, 1H), 5.01 (t, *J* = 2.1 Hz, 1H), 3.60 (s, 3H), 3.02 (dt, *J* = 16.3, 2.2 Hz, 1H), 2.64 (dt, *J* = 16.4, 2.1 Hz, 1H) partially overlapped with 2.59 (d, *J* = 14.2 Hz, 1H), 2.48 (d, *J* = 14.3 Hz, 1H), 2.34 (s, 3H), 1.34 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ = 172.1, 149.8, 147.7, 139.8, 136.9, 129.6, 122.7, 121.1, 103.2, 51.3, 46.2, 45.7, 43.6, 27.3, 21.3; **GC-MS**: 230 (25), 157 (55), 142 (100); **Anal. Calc.** for ($C_{15}H_{18}O_2$: 230.13): C, 78.23; H, 7.88; found: C, 78.08; H, 7.65.

^{1}H, ^{13}C and ^{19}F NMR spectra

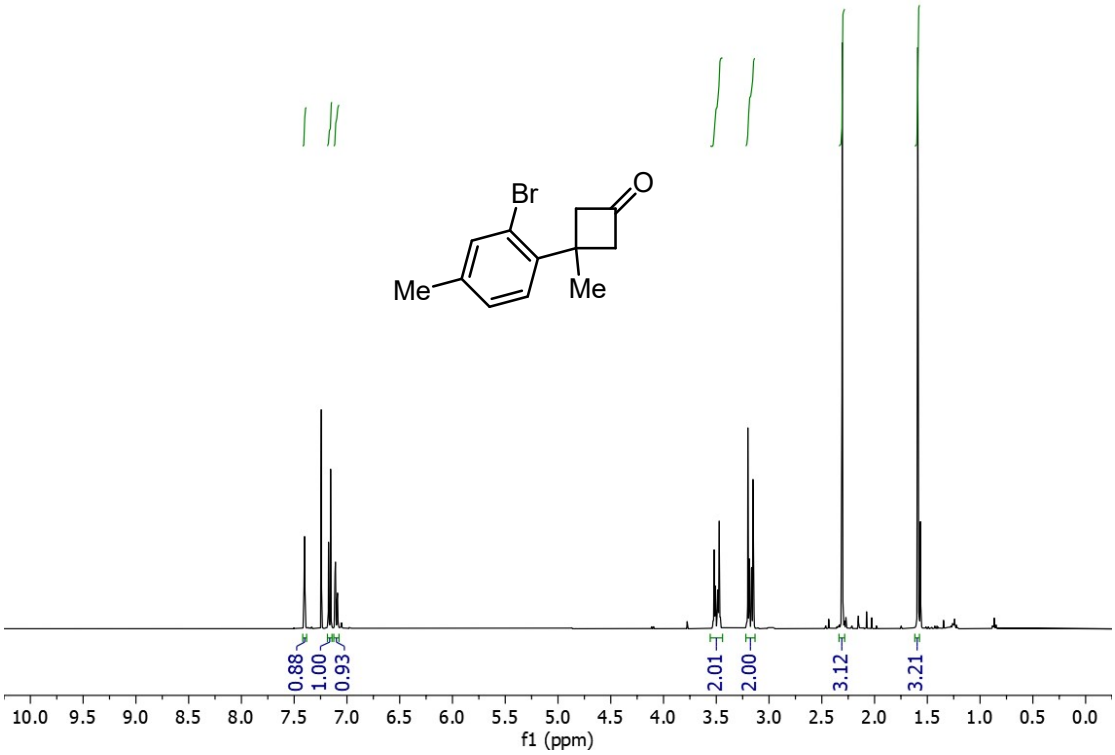
1a ^{1}H NMR (400 MHz, $CDCl_3$)



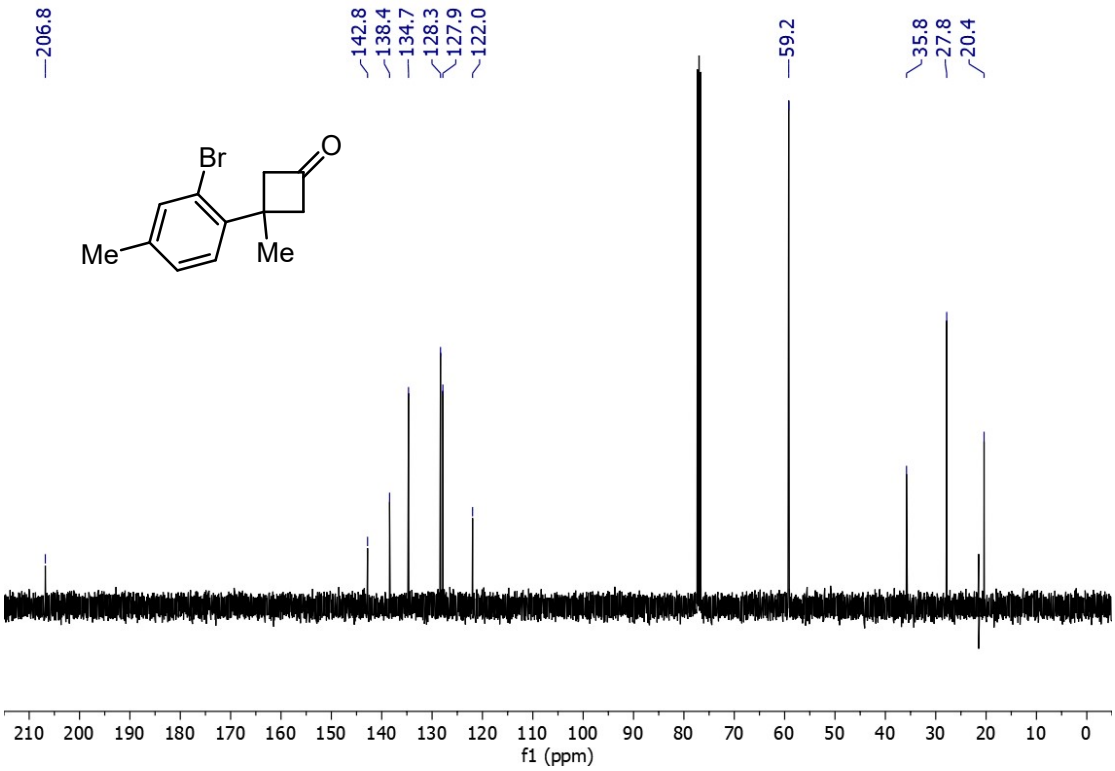
1a ^{13}C NMR (100 MHz, $CDCl_3$)



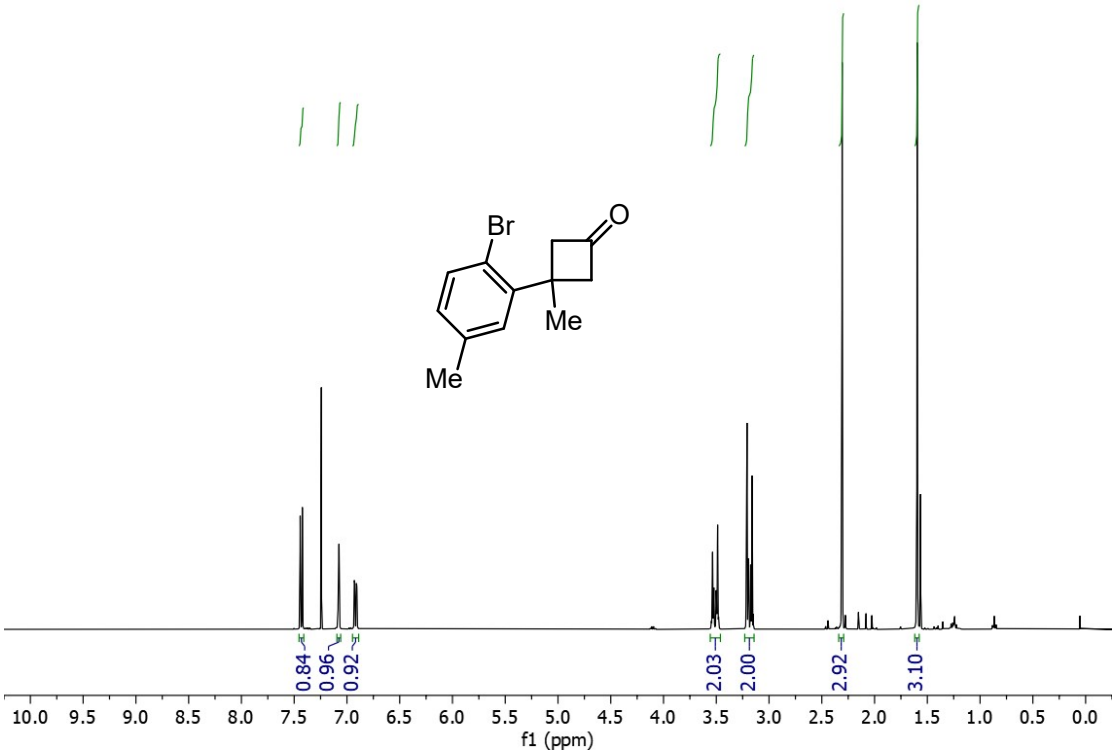
1b ^{1}H NMR (400 MHz, $CDCl_3$)



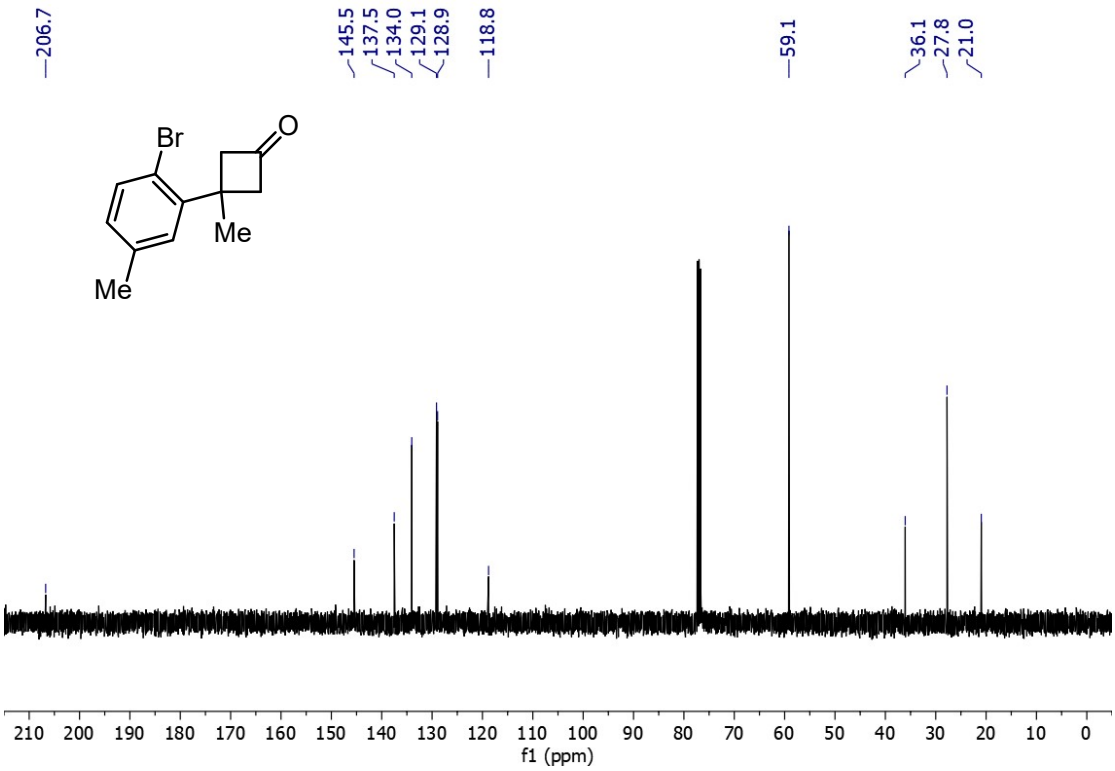
1a ^{13}C NMR (100 MHz, $CDCl_3$)



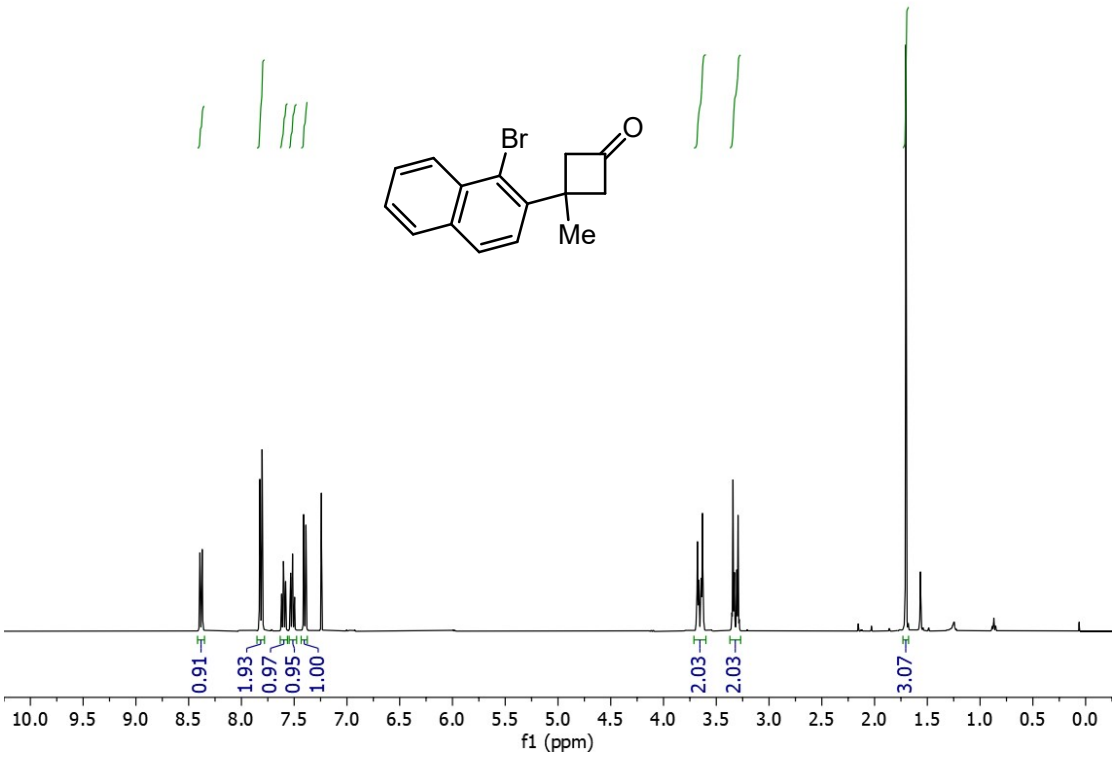
1c ^{1}H NMR (400 MHz, $CDCl_3$)



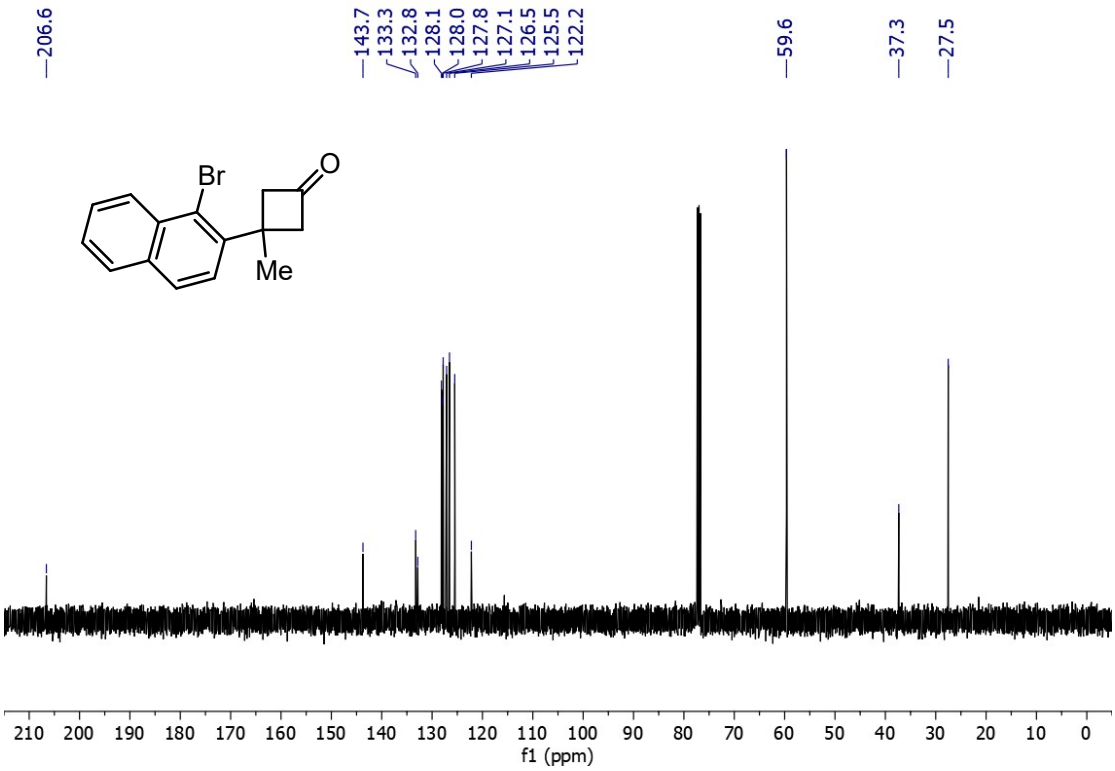
1c ^{13}C NMR (100 MHz, $CDCl_3$)



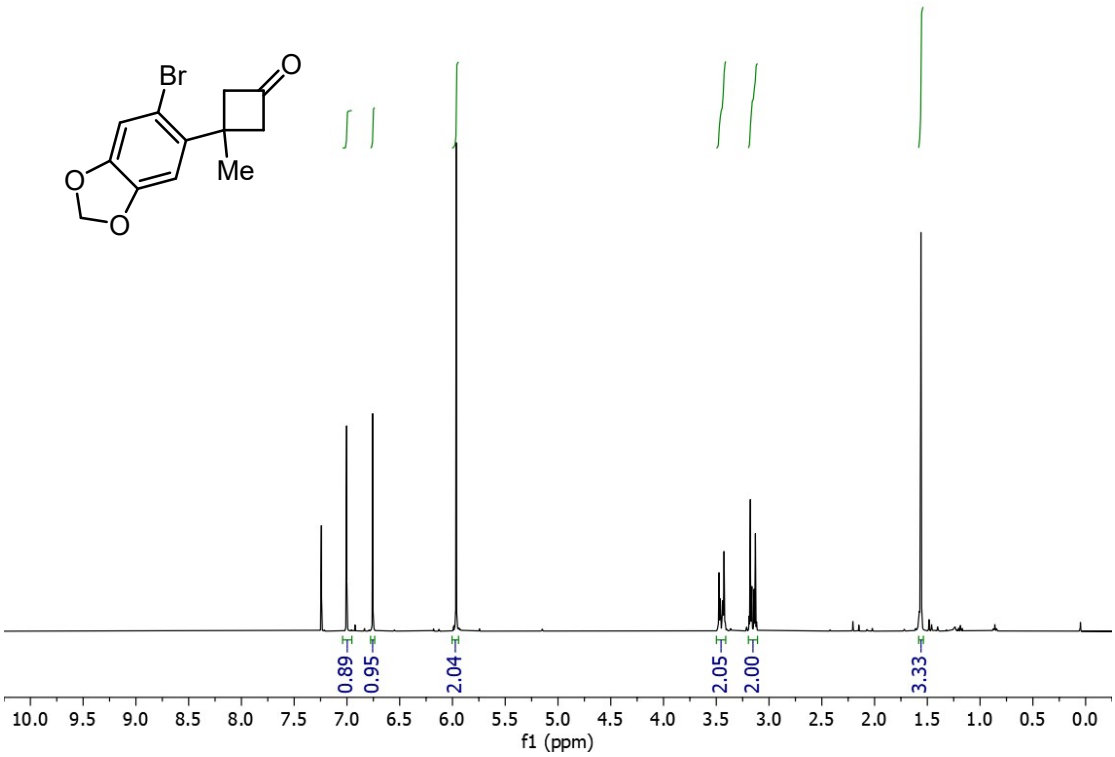
1d ^{1}H NMR (400 MHz, $CDCl_3$)



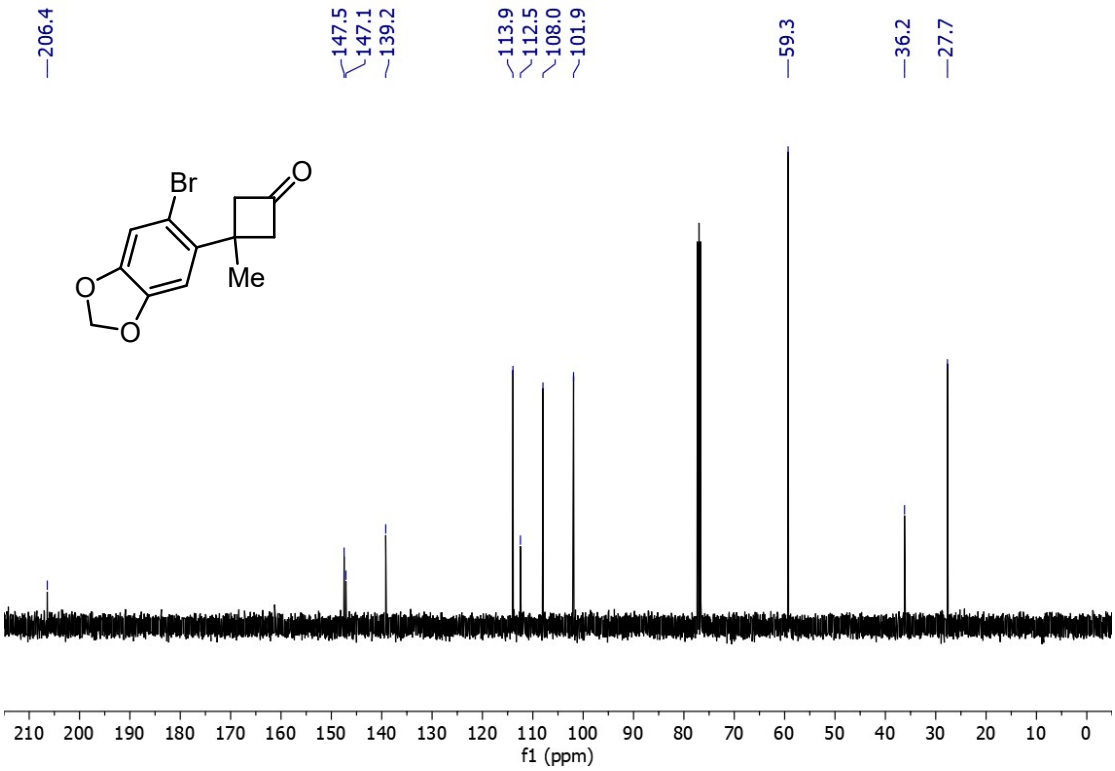
1d ^{13}C NMR (100 MHz, $CDCl_3$)



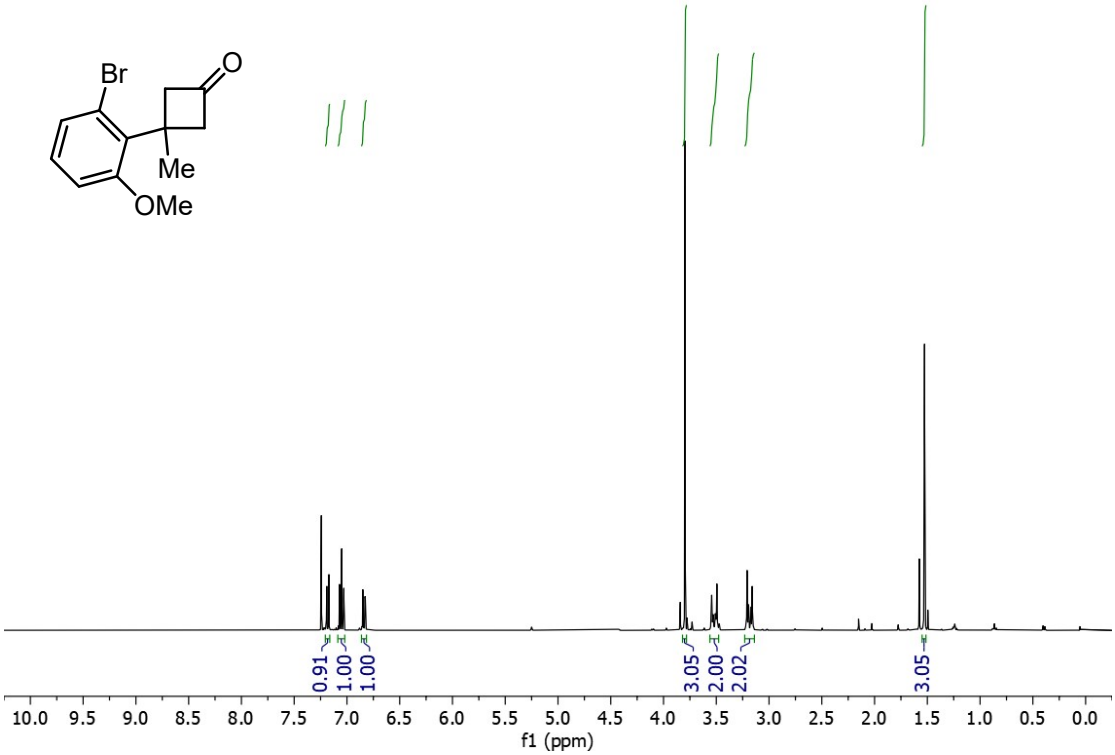
1e ^{1}H NMR (400 MHz, $CDCl_3$)



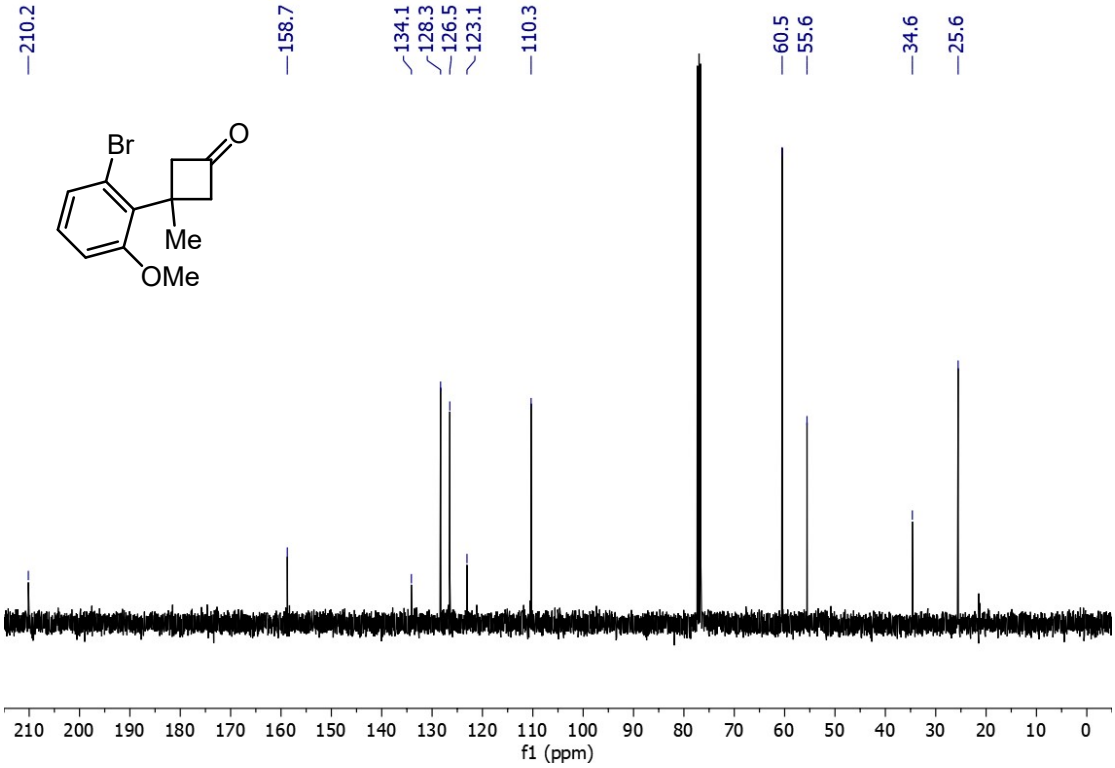
1e ^{13}C NMR (100 MHz, $CDCl_3$)



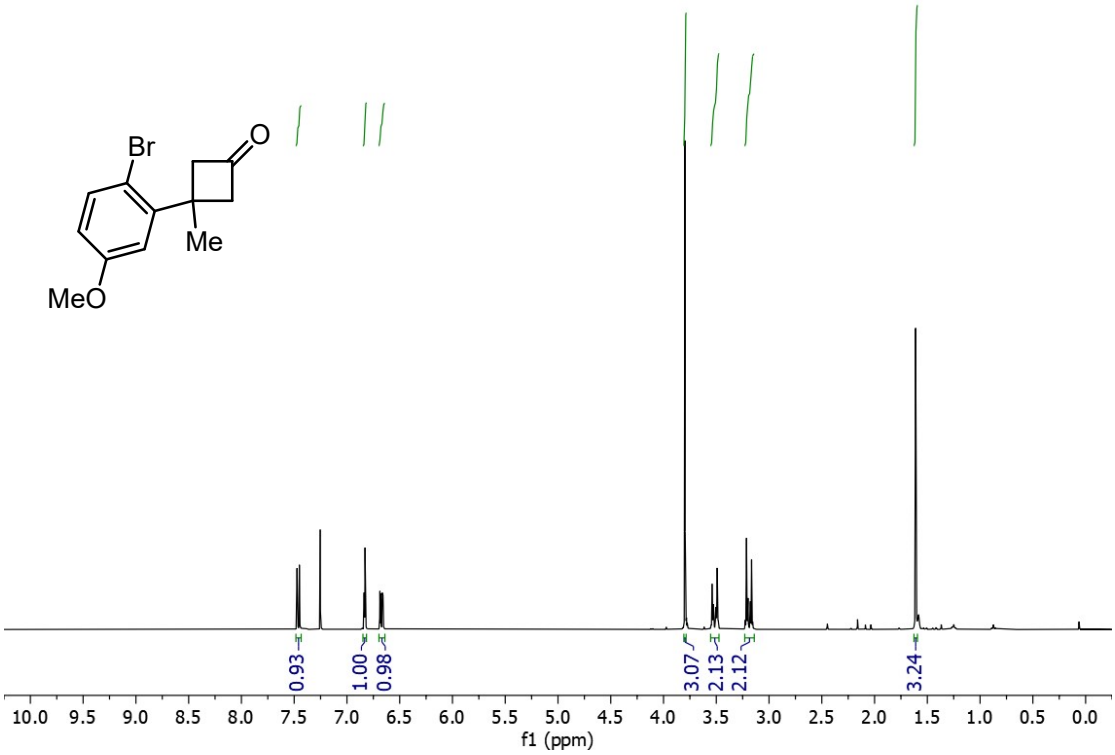
1f ^{1}H NMR (400 MHz, $CDCl_3$)



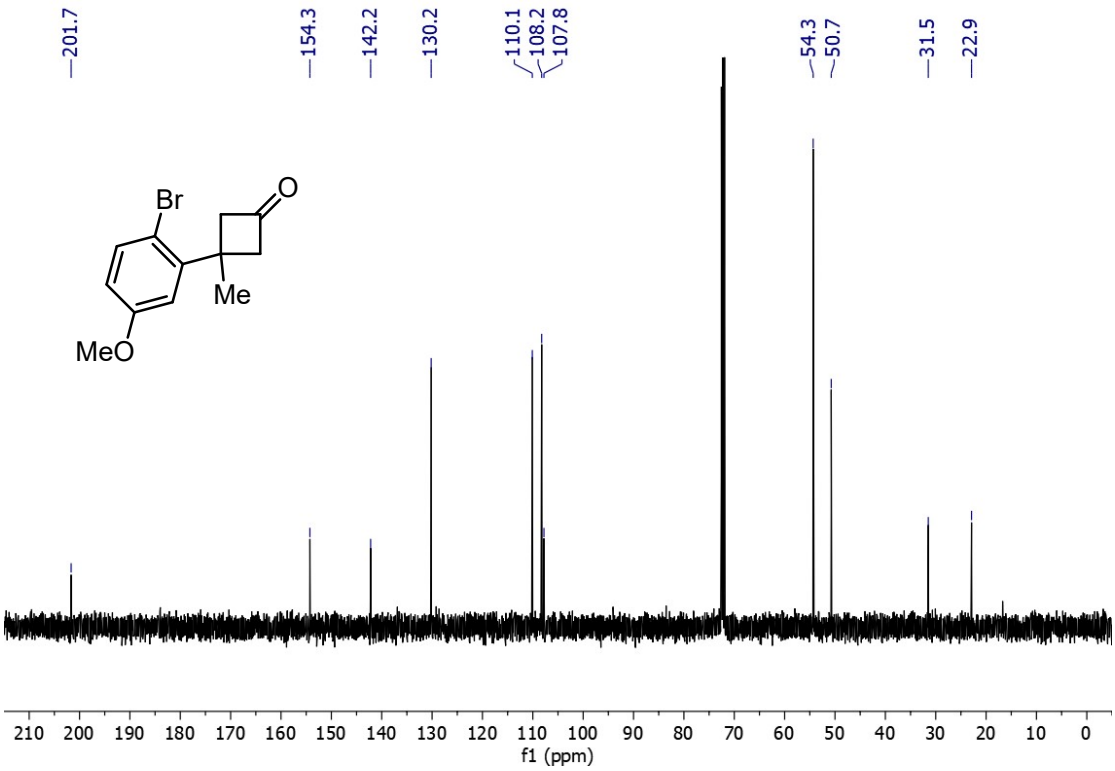
1f ^{13}C NMR (100 MHz, $CDCl_3$)



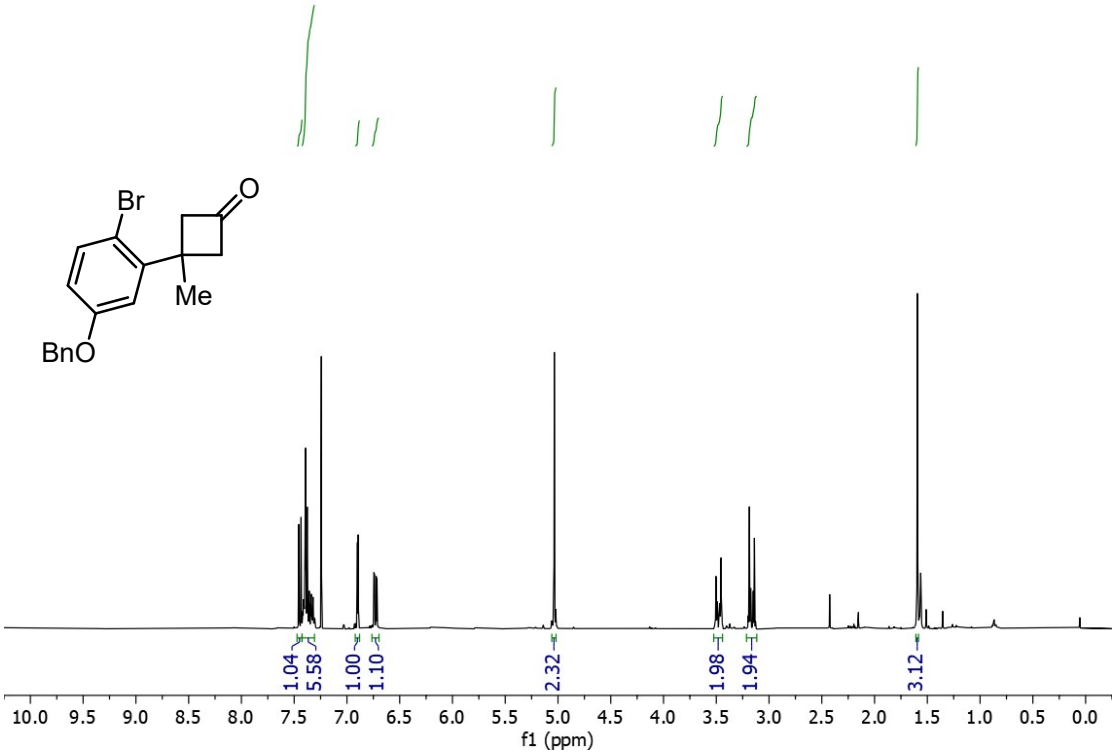
1g ^{1}H NMR (400 MHz, $CDCl_3$)



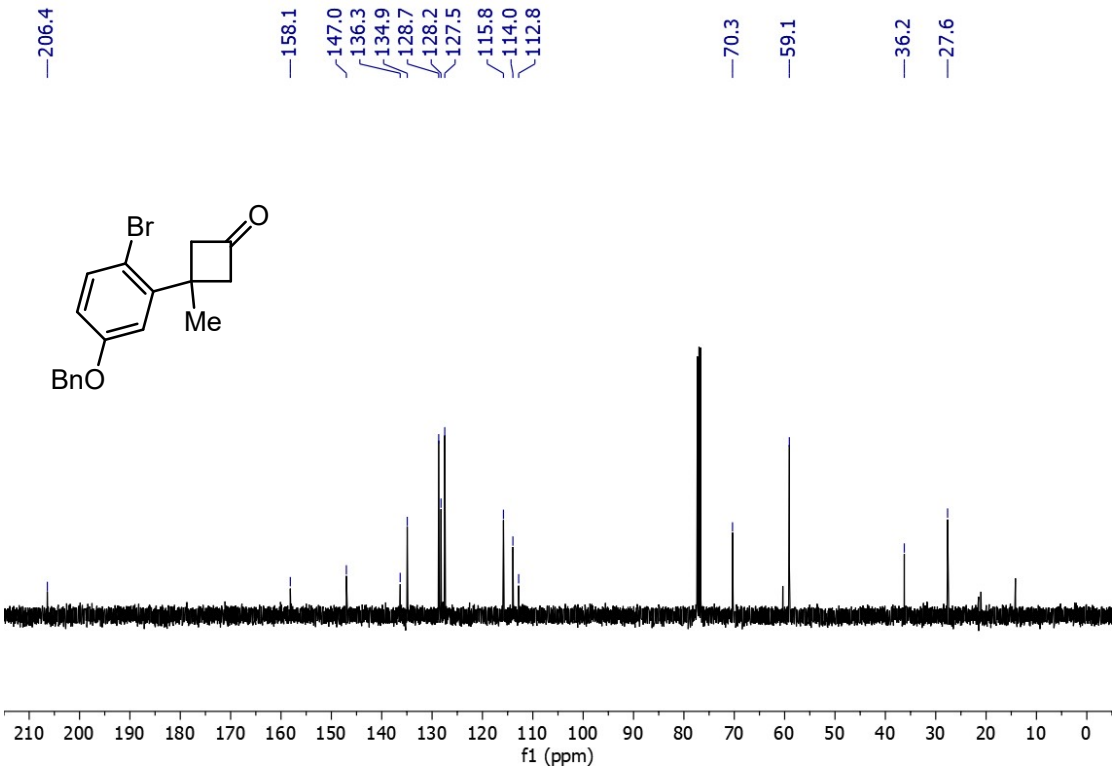
1g ^{13}C NMR (100 MHz, $CDCl_3$)



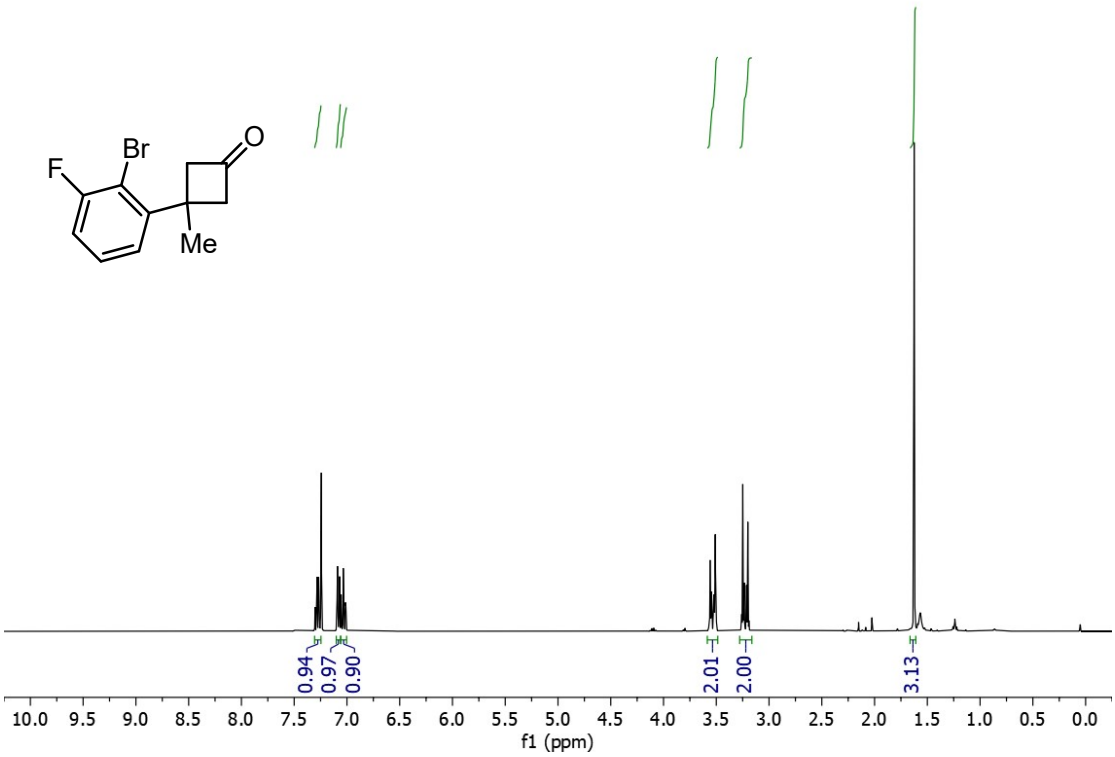
1h ^{1}H NMR (400 MHz, $CDCl_3$)



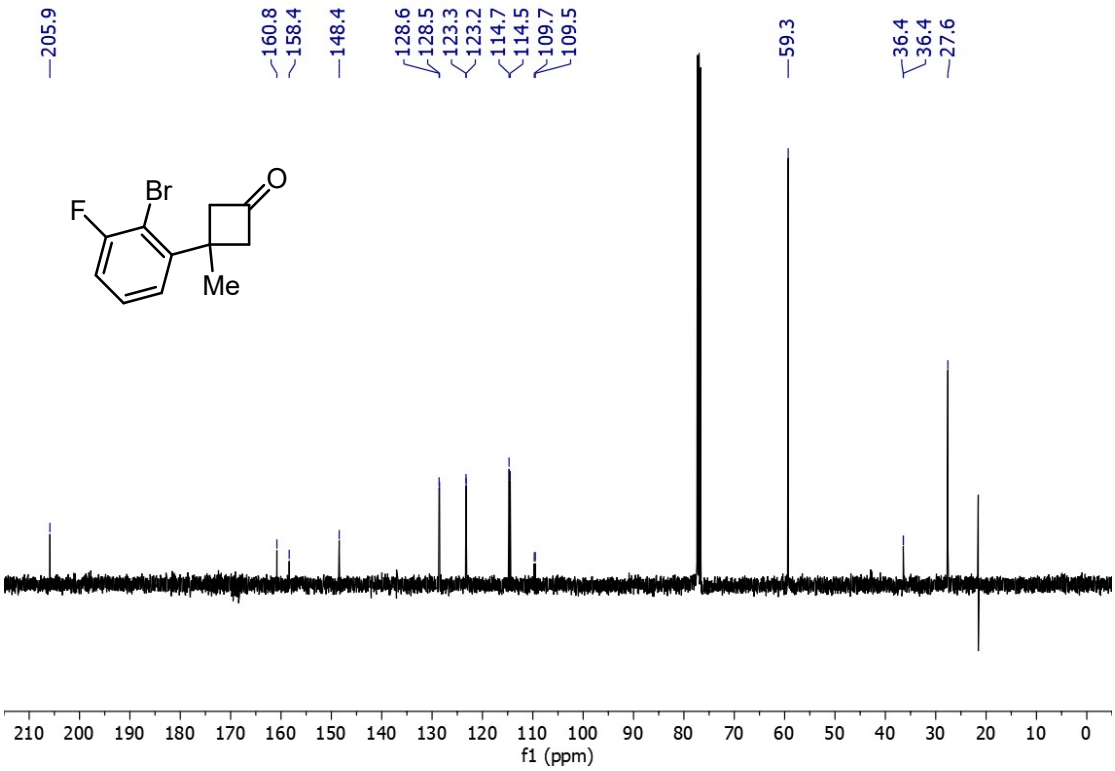
1h ^{13}C NMR (100 MHz, $CDCl_3$)



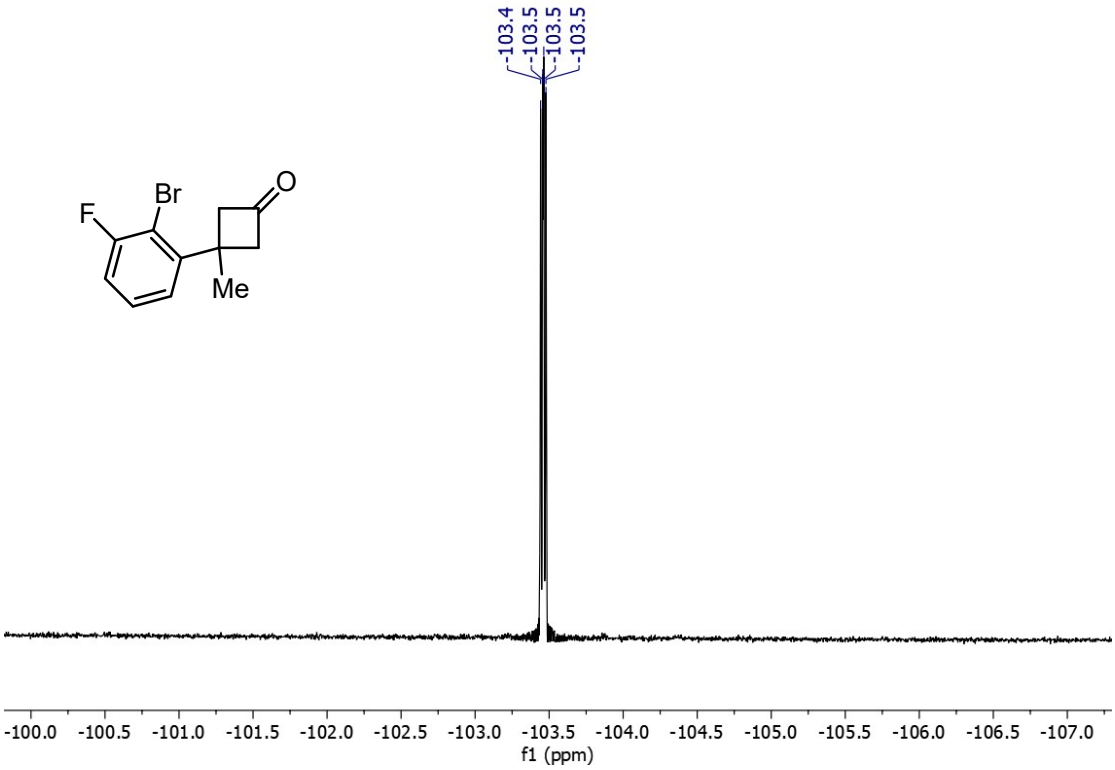
1i ^{1}H NMR (400 MHz, $CDCl_3$)



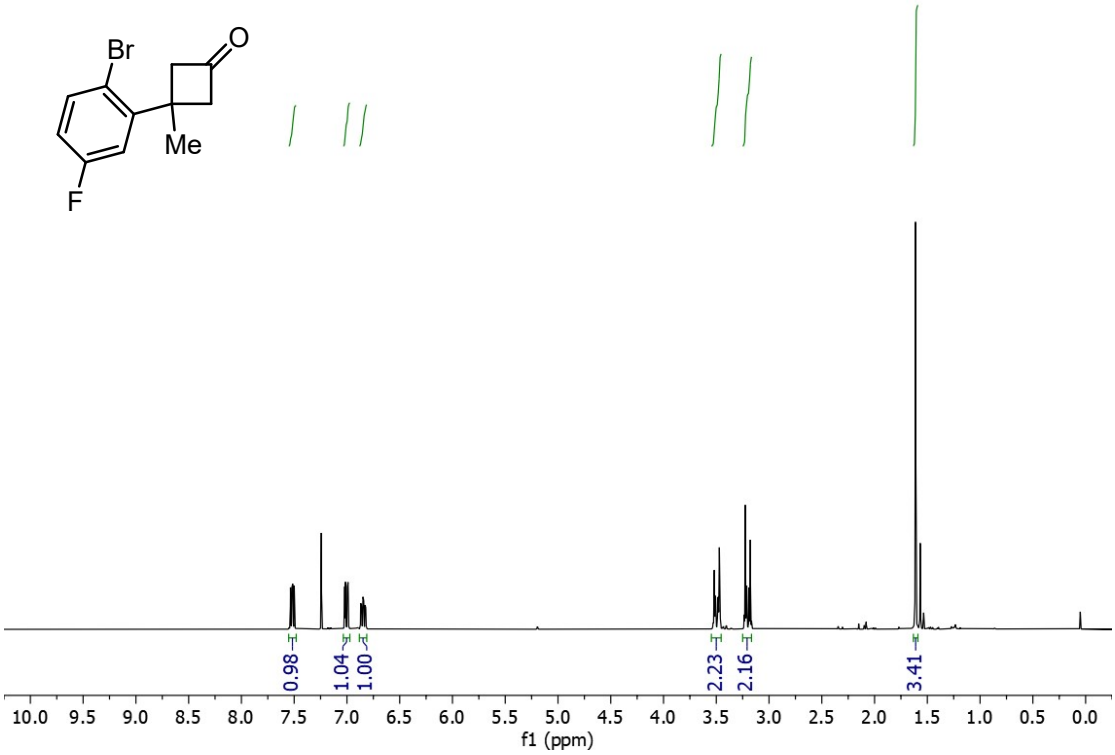
1i ^{13}C NMR (100 MHz, $CDCl_3$)



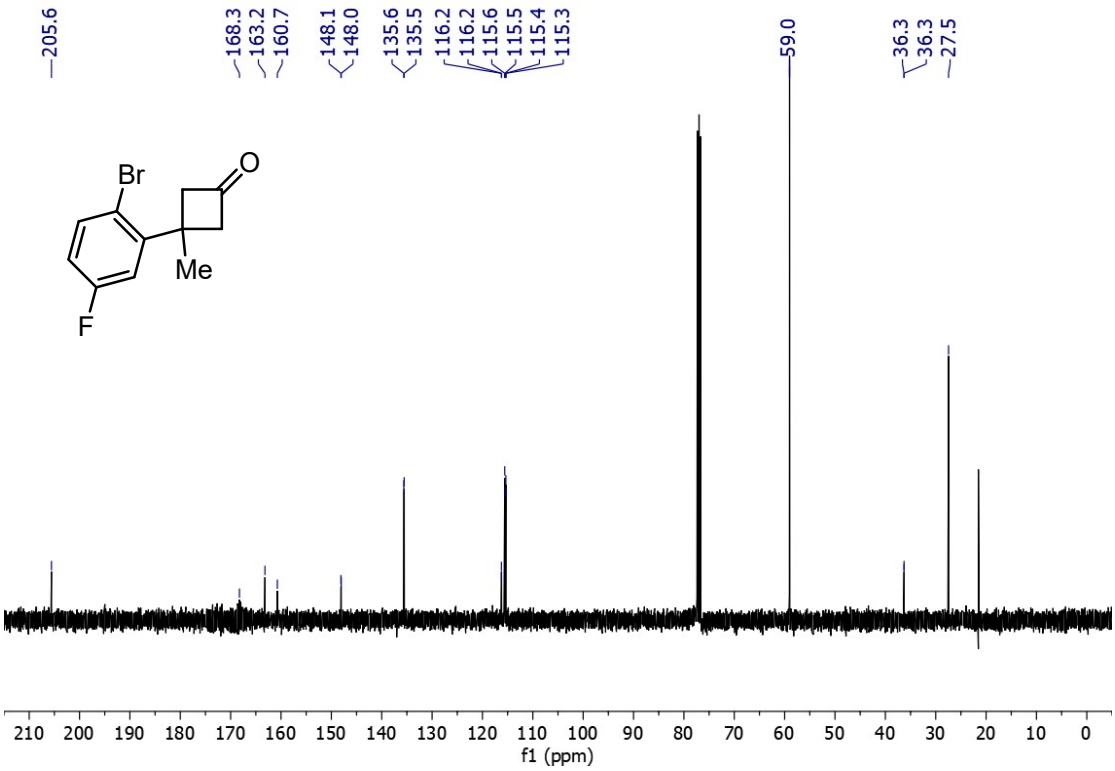
1i ^{19}F NMR (376 MHz, $CDCl_3$)



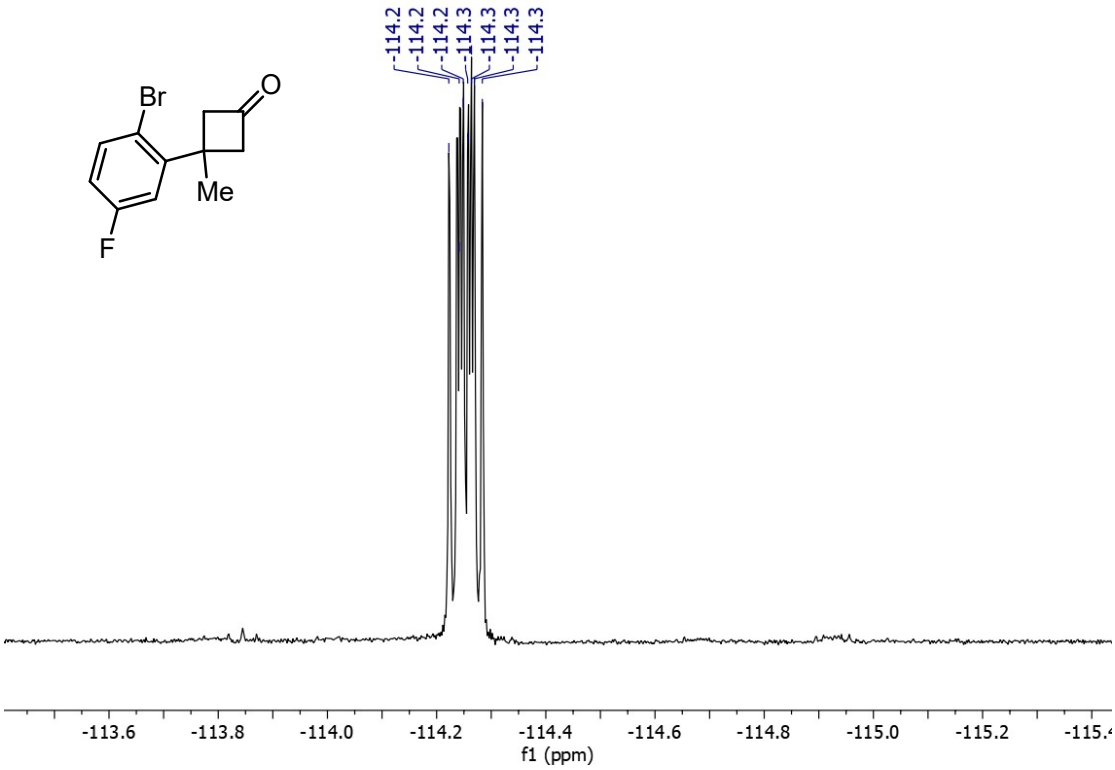
1j ^{1}H NMR (400 MHz, $CDCl_3$)



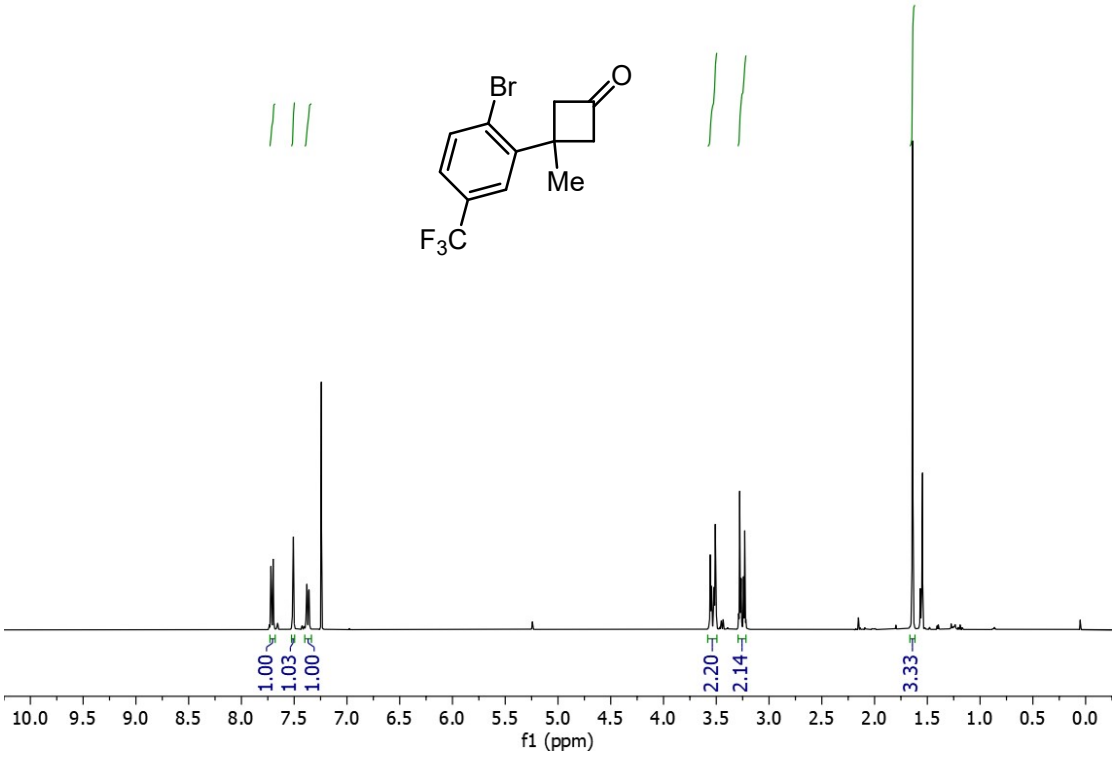
1j ^{13}C NMR (100 MHz, $CDCl_3$)



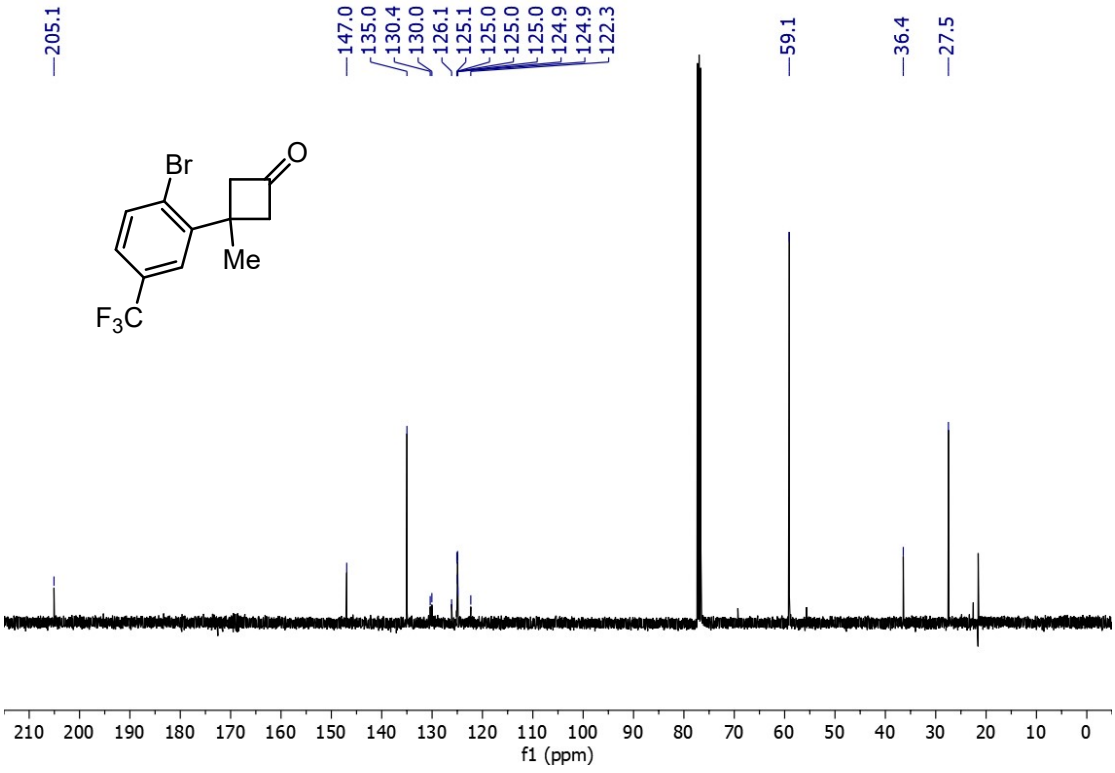
1j ^{19}F NMR (376 MHz, $CDCl_3$)



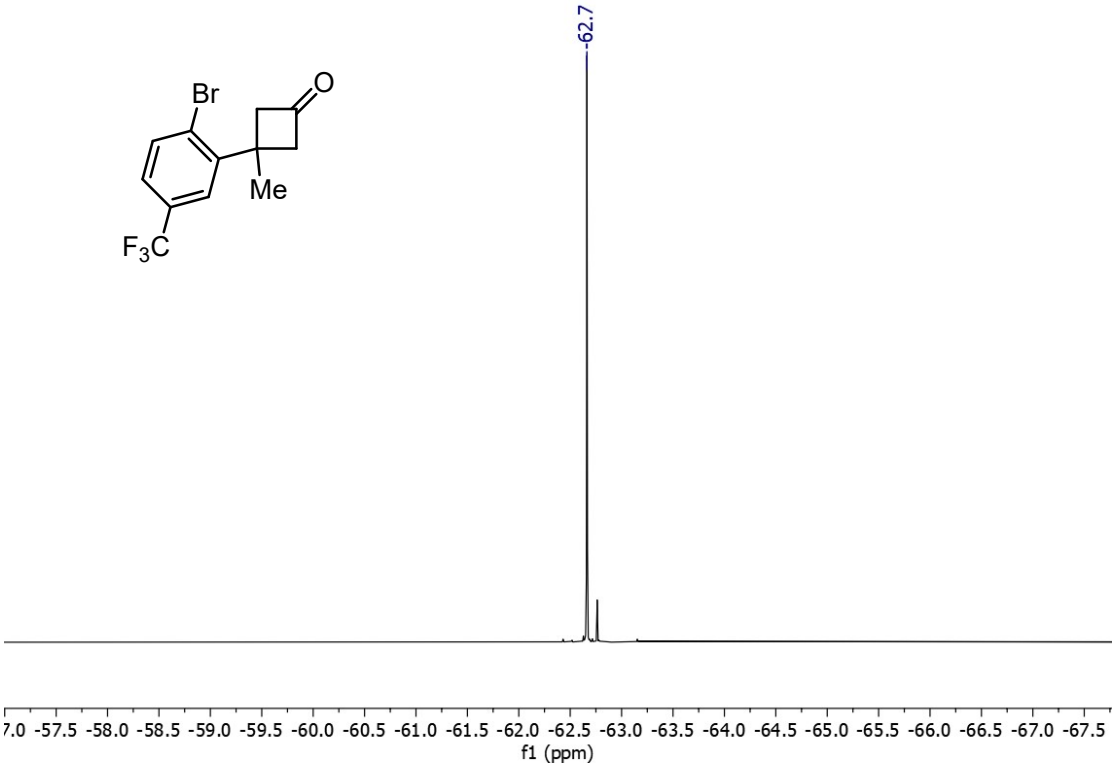
1k ^{1}H NMR (400 MHz, $CDCl_3$)



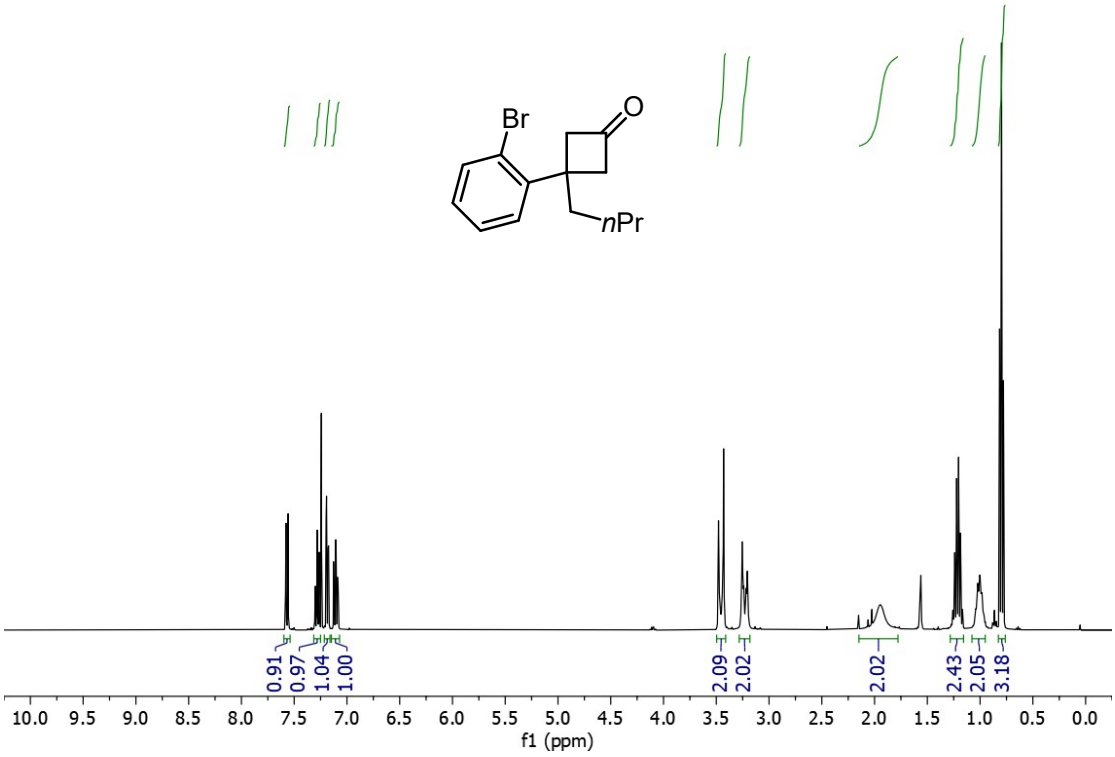
1k ^{13}C NMR (100 MHz, $CDCl_3$)



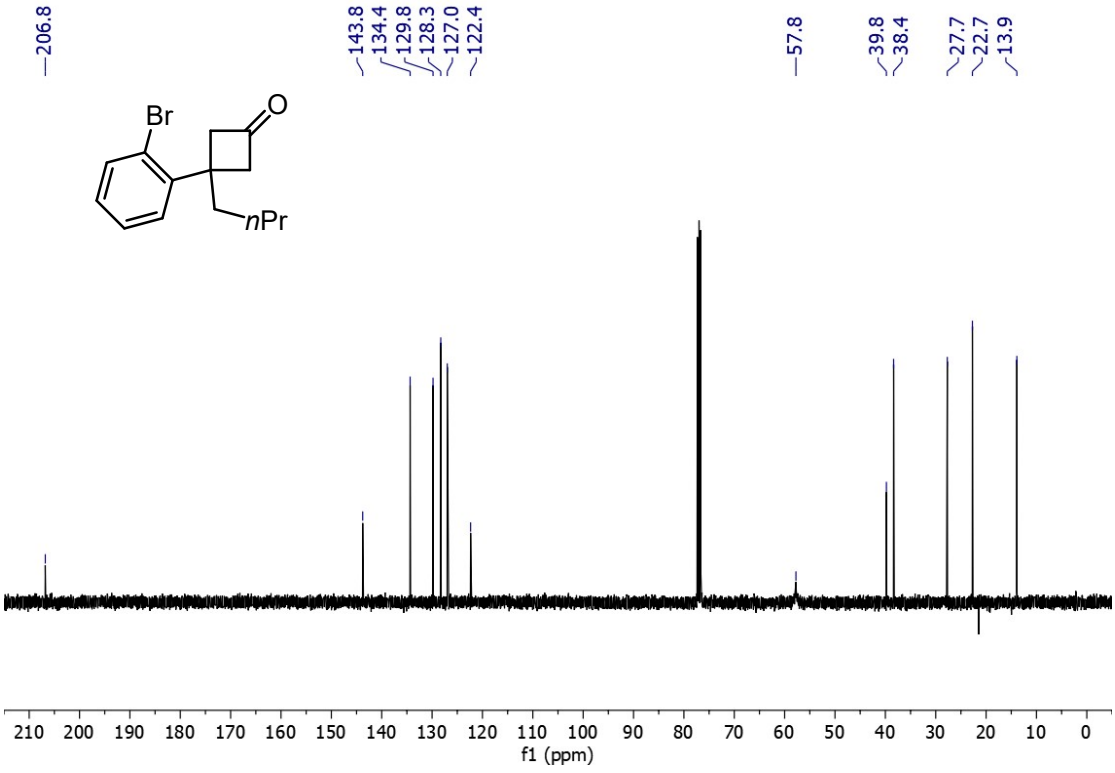
1k ^{19}F NMR (376 MHz, $CDCl_3$)



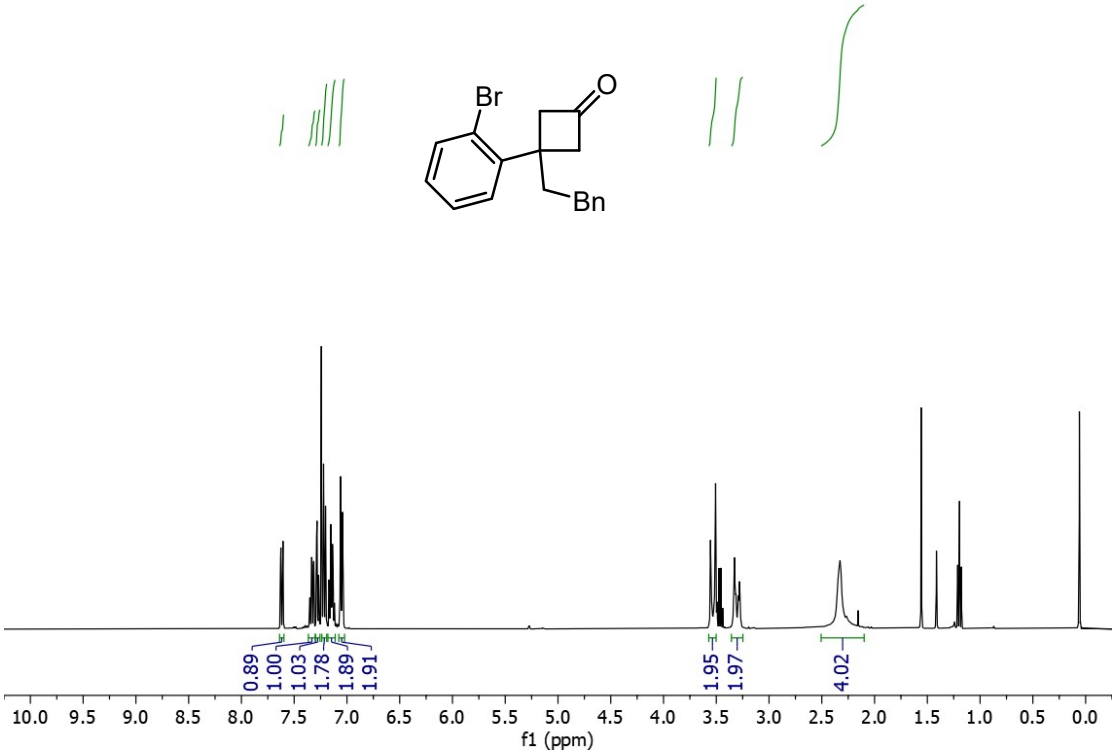
1l ^{1}H NMR (400 MHz, $CDCl_3$)



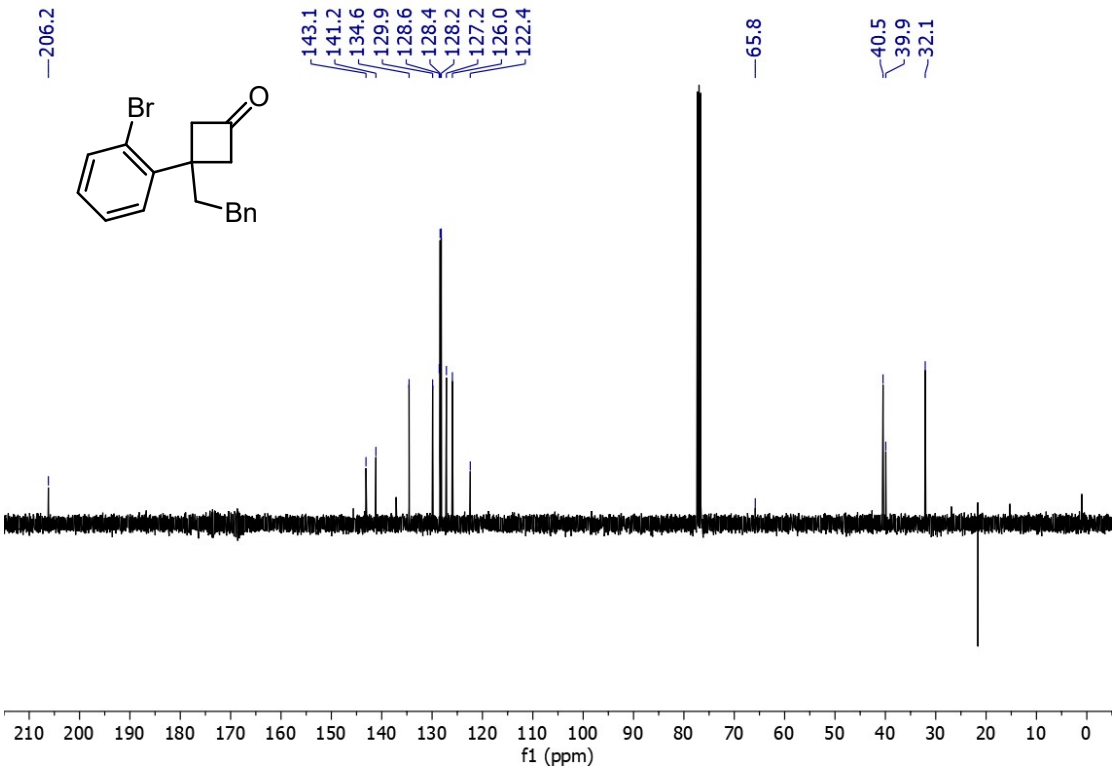
1l ^{13}C NMR (100 MHz, $CDCl_3$)



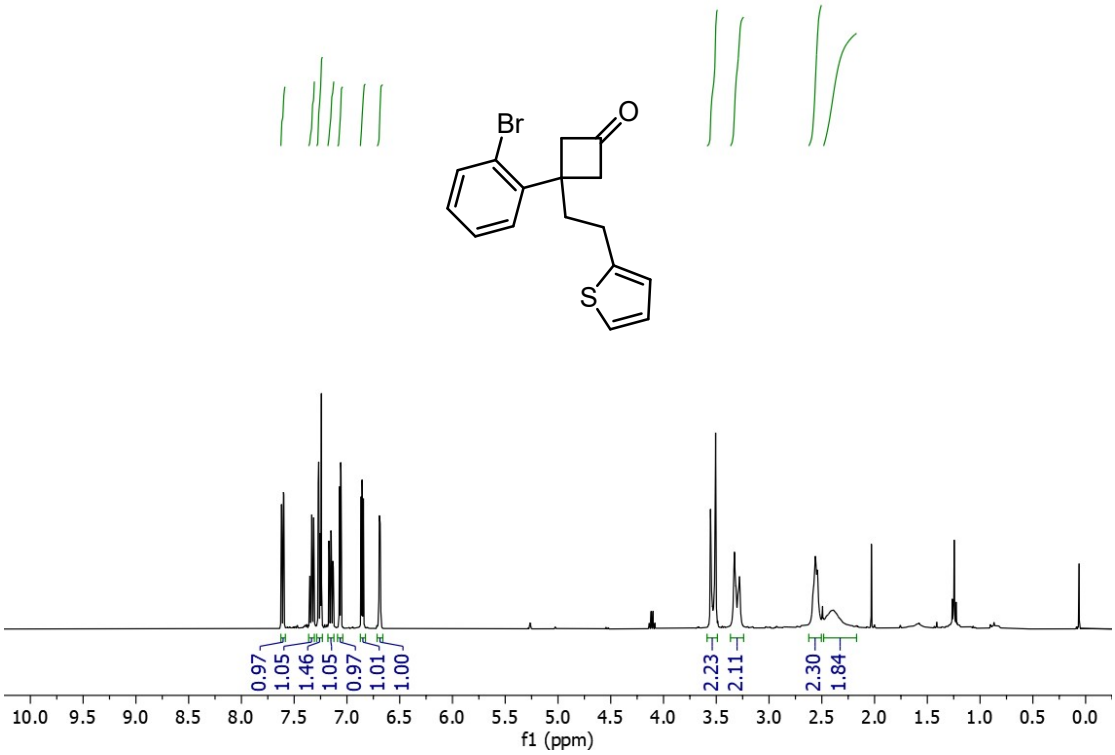
1m ^{1}H NMR (400 MHz, $CDCl_3$)



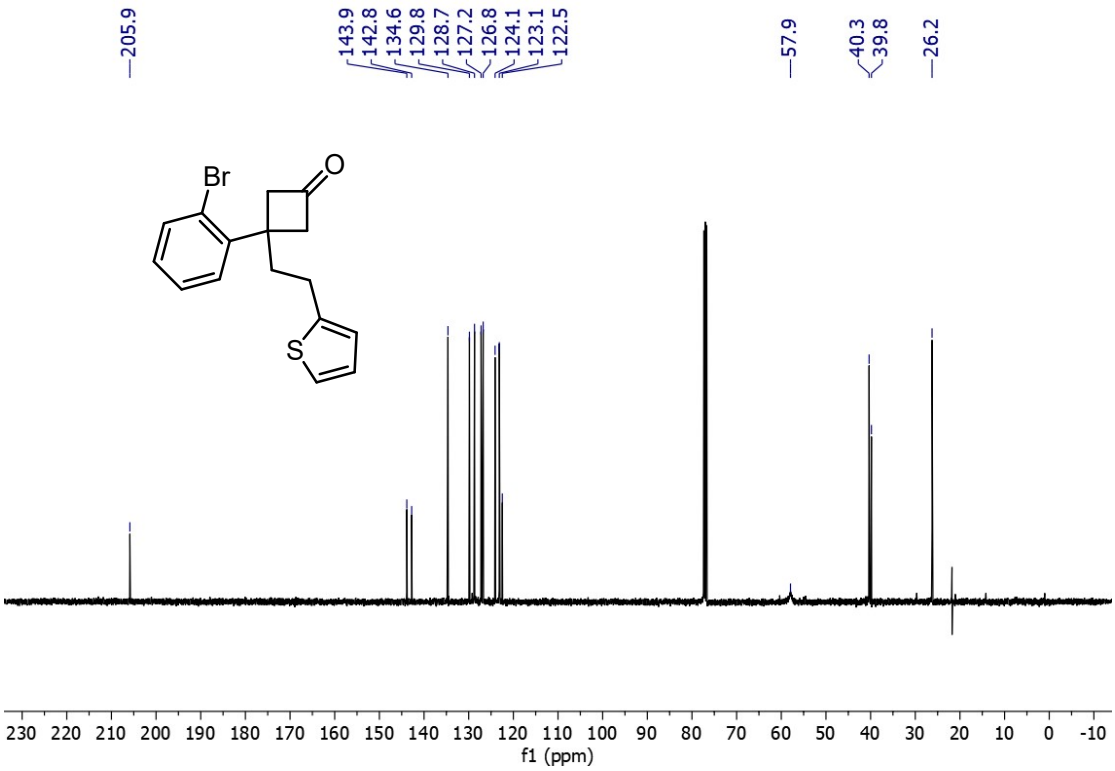
1m ^{13}C NMR (100 MHz, $CDCl_3$)



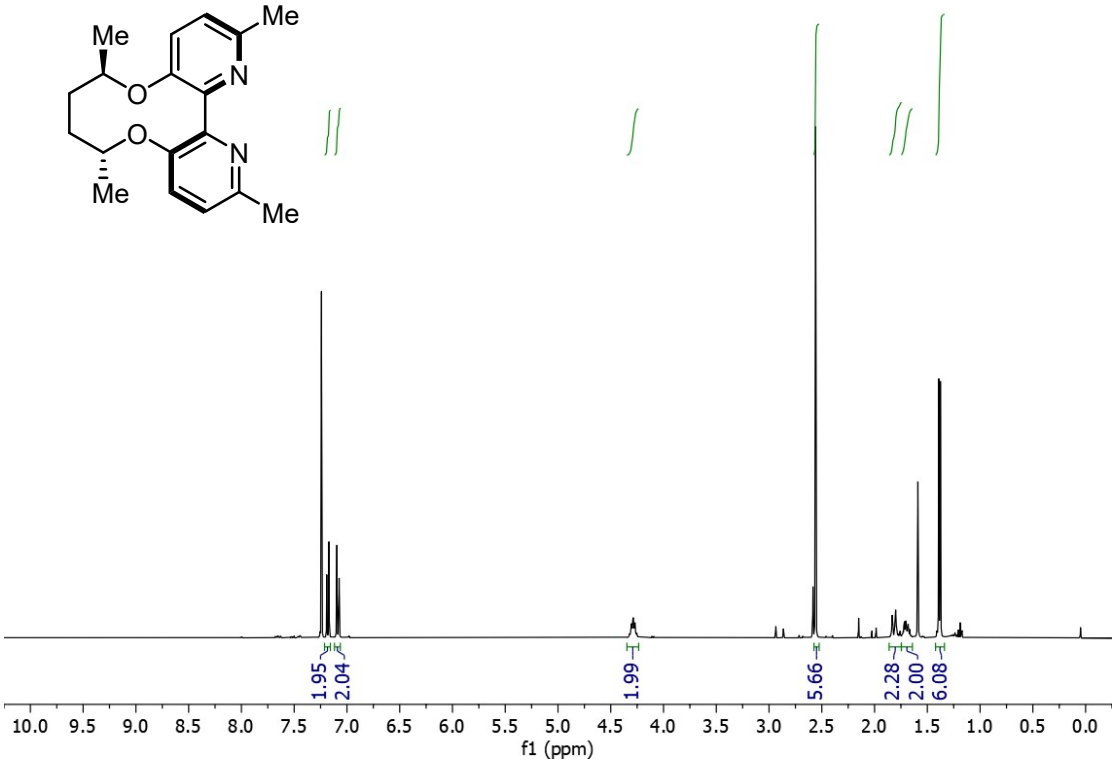
1n ^{1}H NMR (400 MHz, $CDCl_3$)



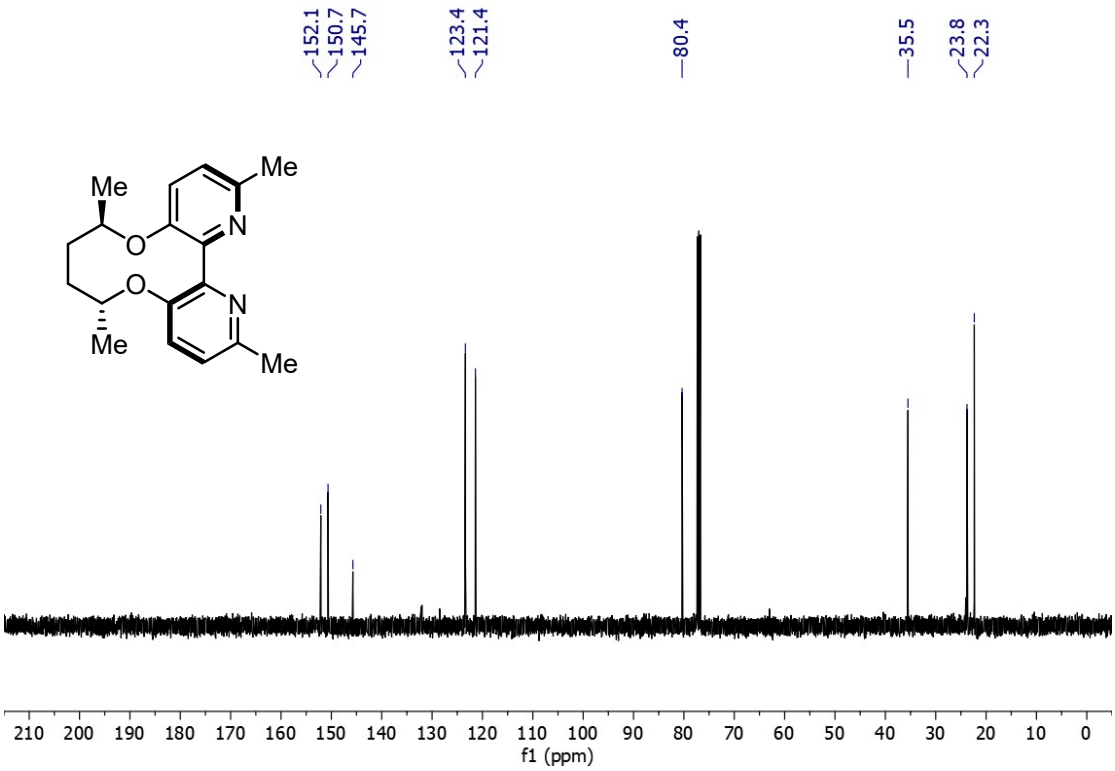
1n ^{13}C NMR (100 MHz, $CDCl_3$)



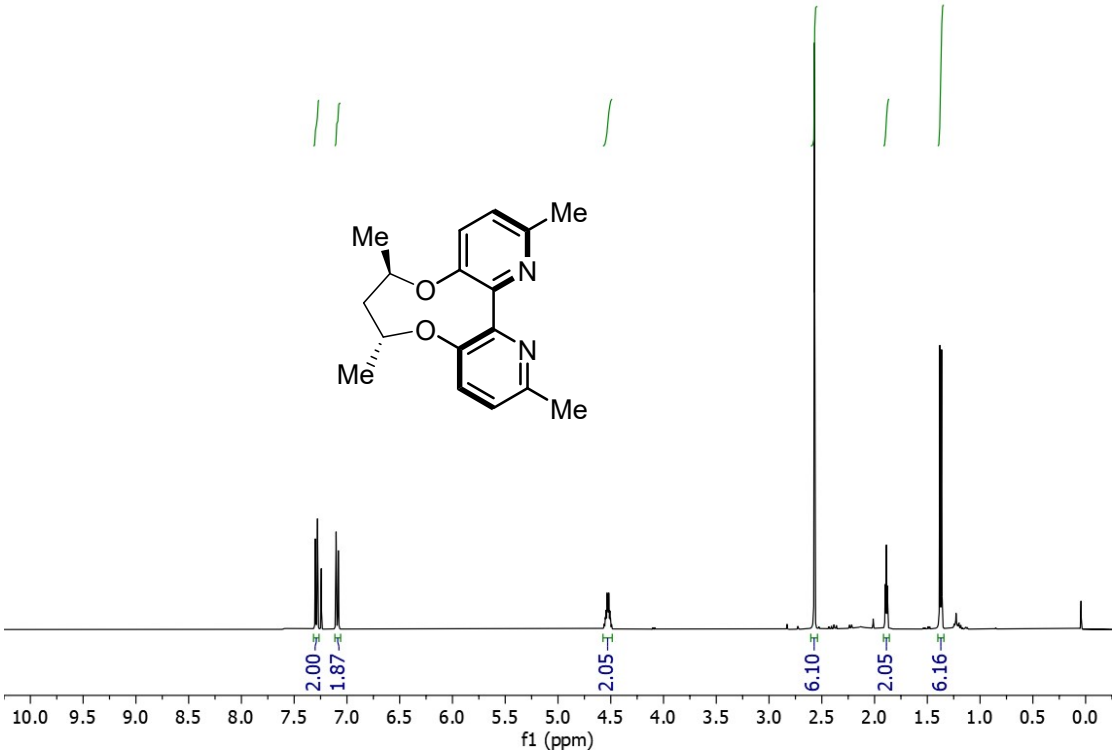
L7 ^{1}H NMR (400 MHz, $CDCl_3$)



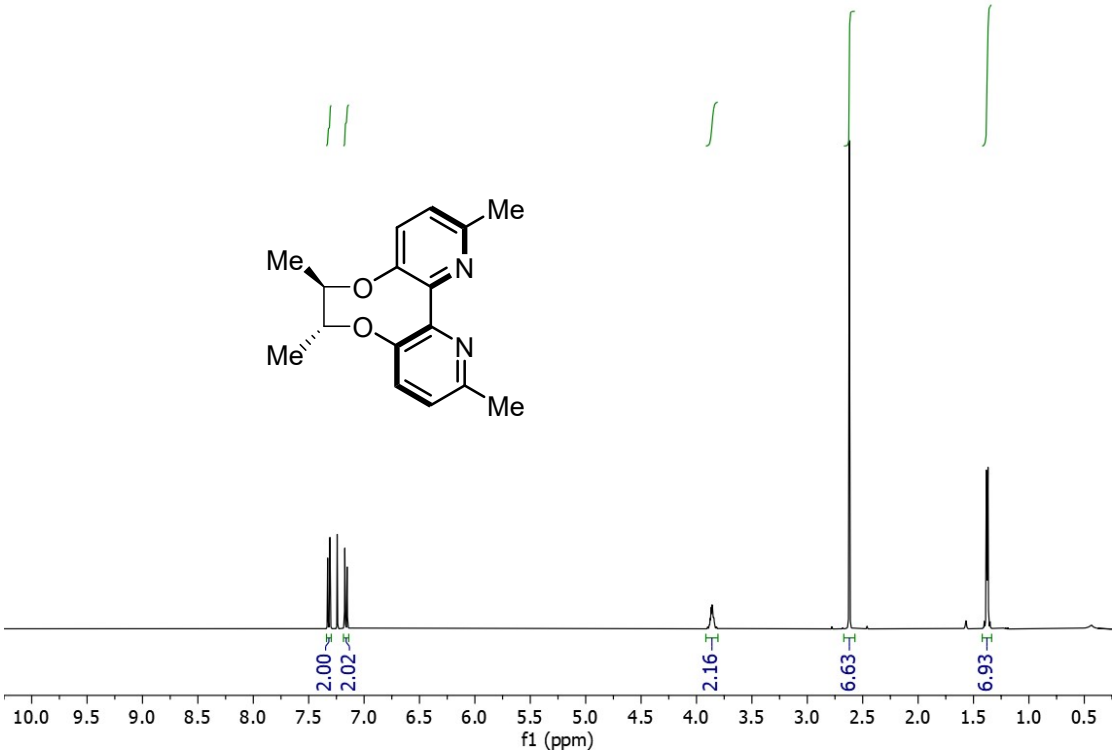
L7 ^{13}C NMR (100 MHz, $CDCl_3$)



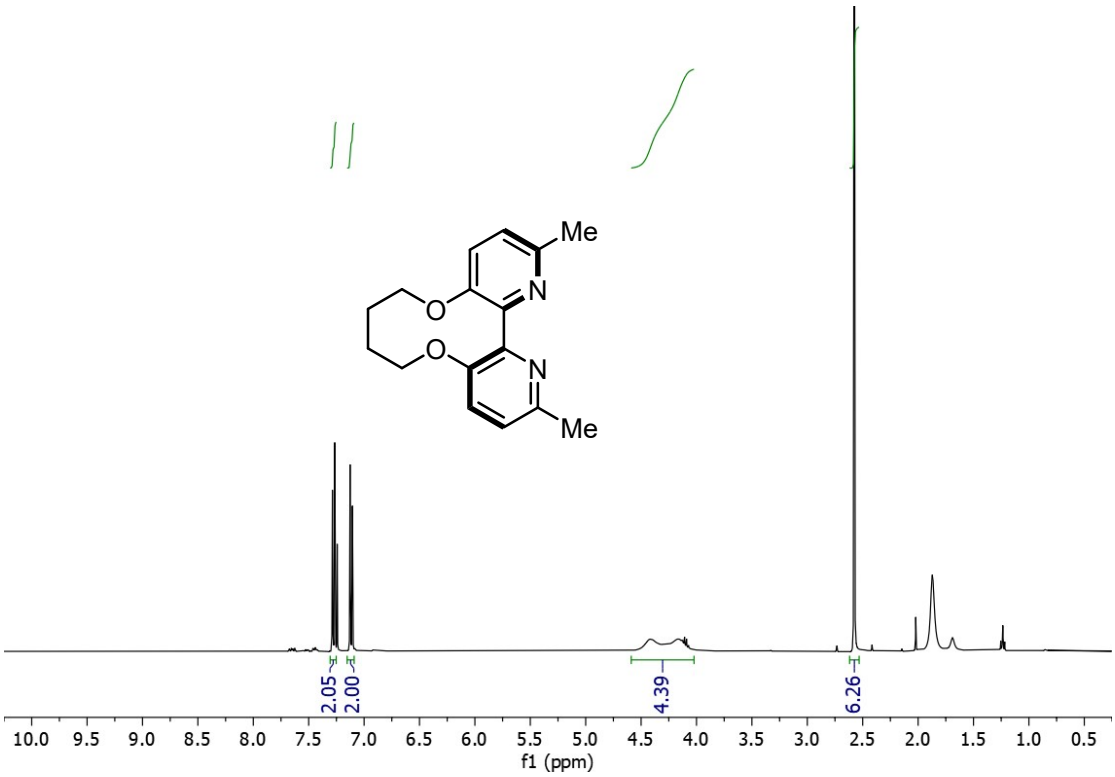
L3 ^{1}H NMR (400 MHz, $CDCl_3$)



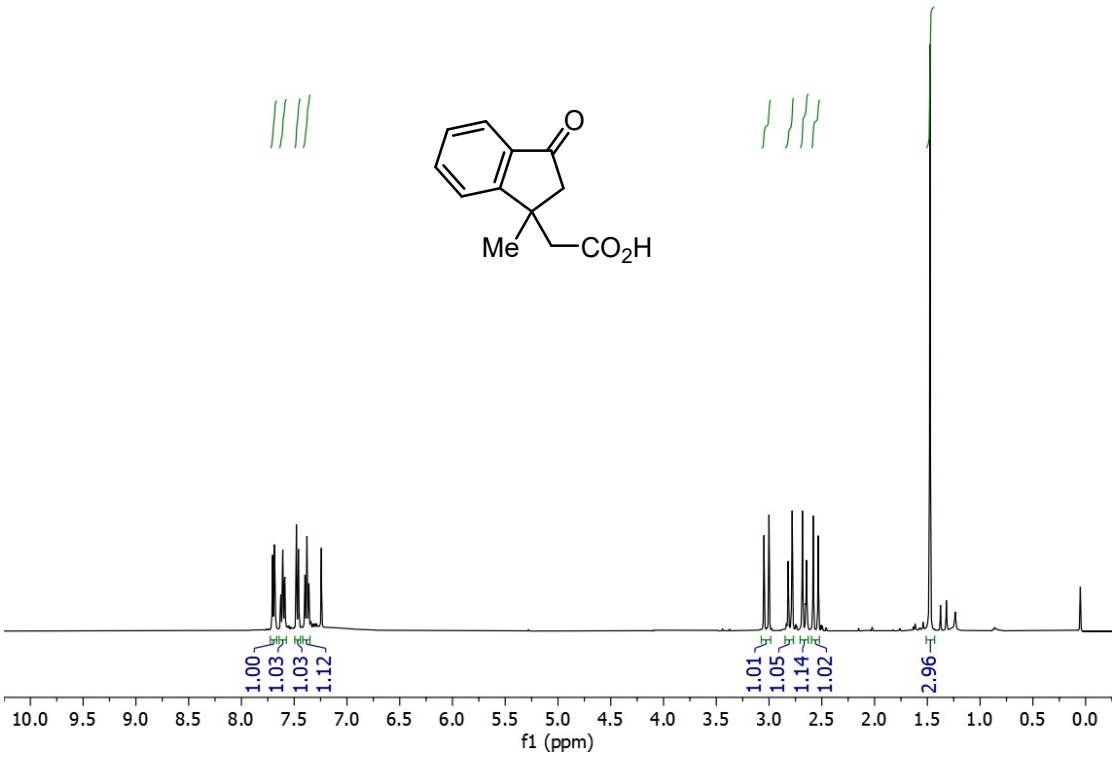
L4 ^{1}H NMR (400 MHz, $CDCl_3$)



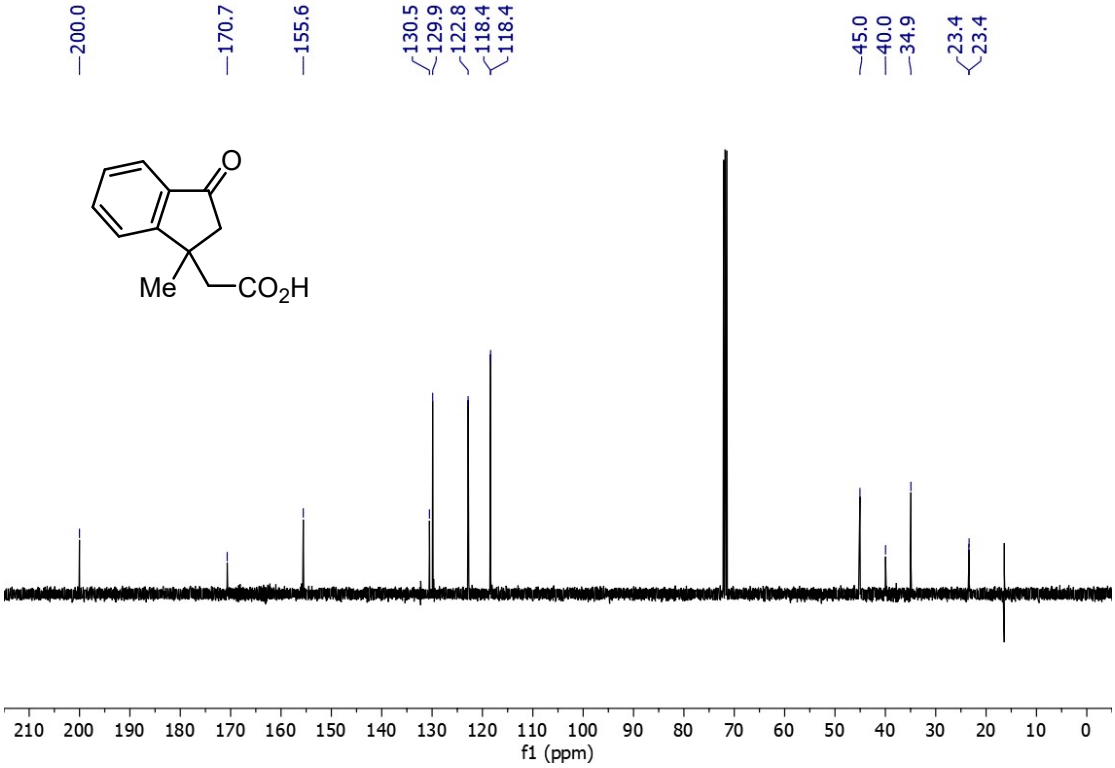
L5 ^{1}H NMR (400 MHz, $CDCl_3$)



2a ^{1}H NMR (400 MHz, $CDCl_3$)



2a ^{13}C NMR (100 MHz, $CDCl_3$)



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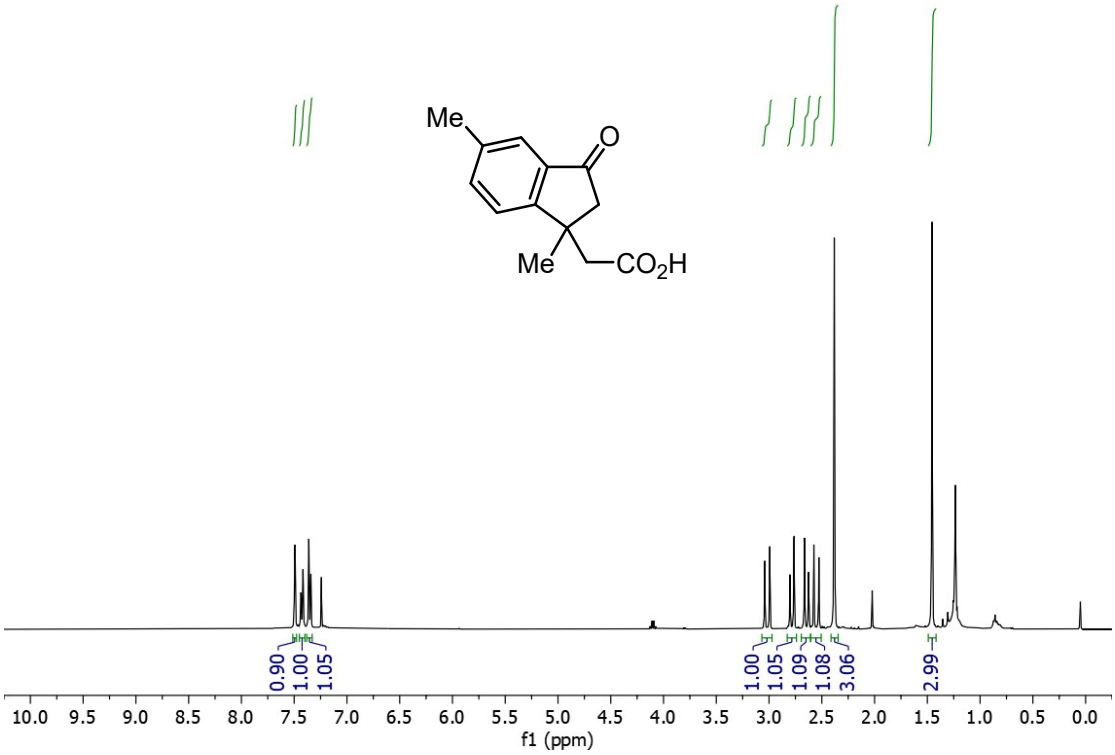

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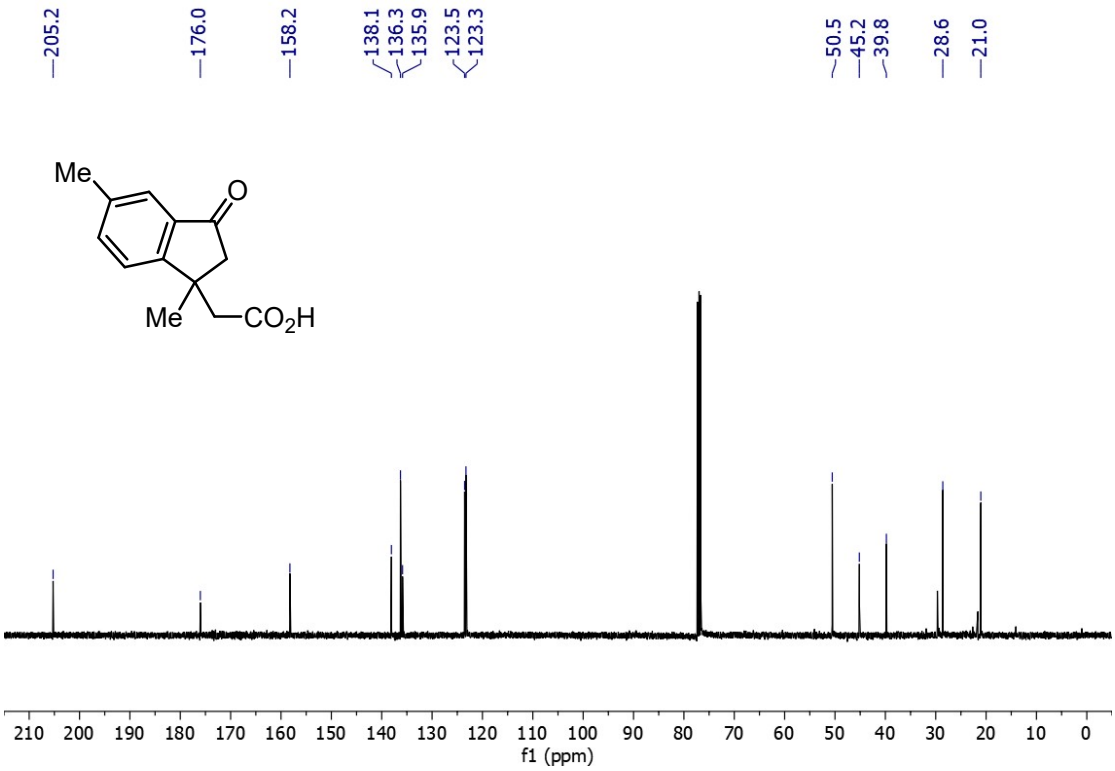

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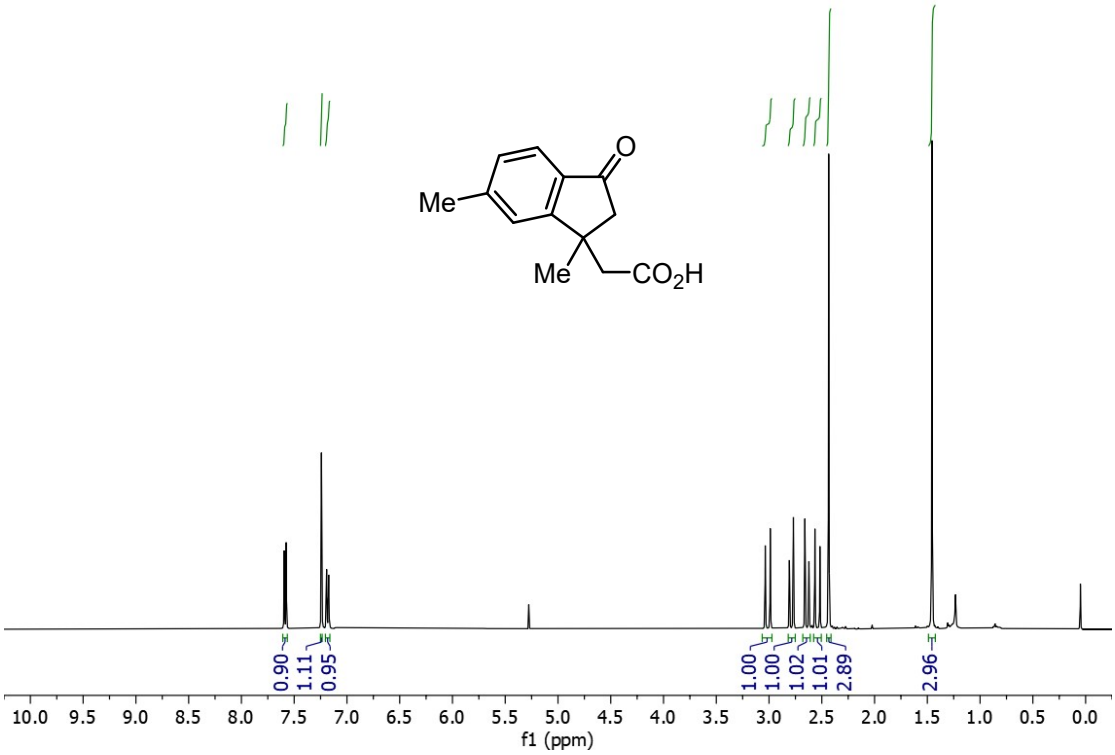
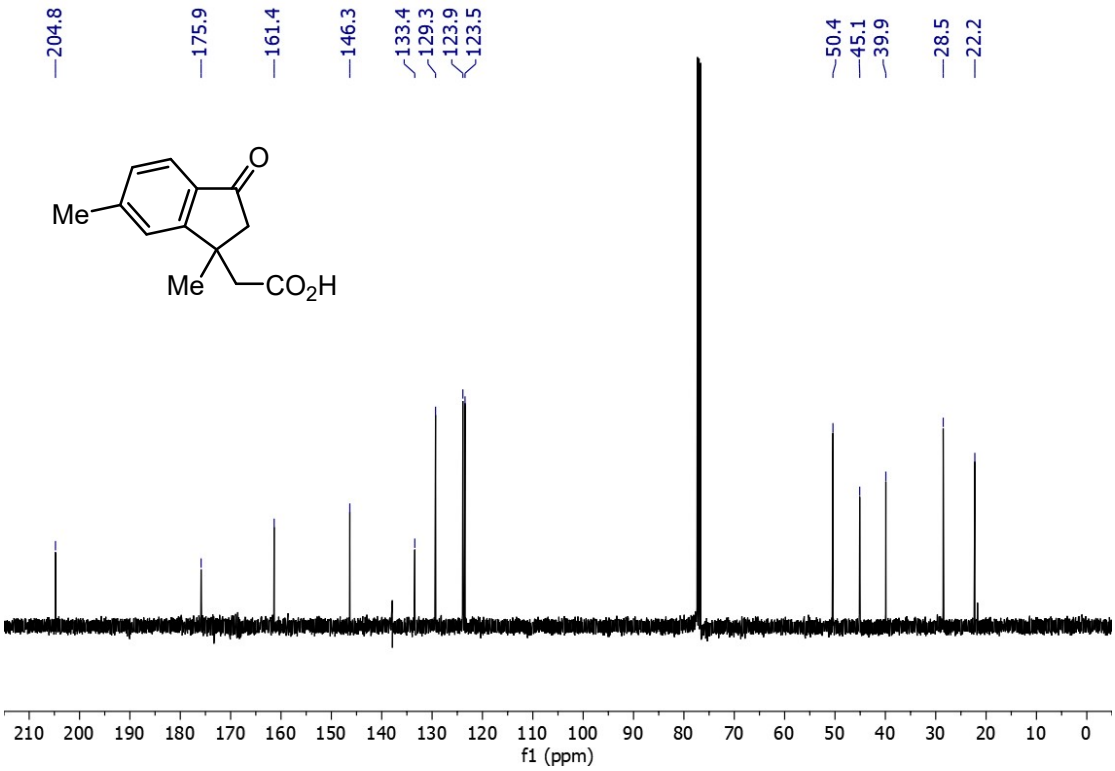
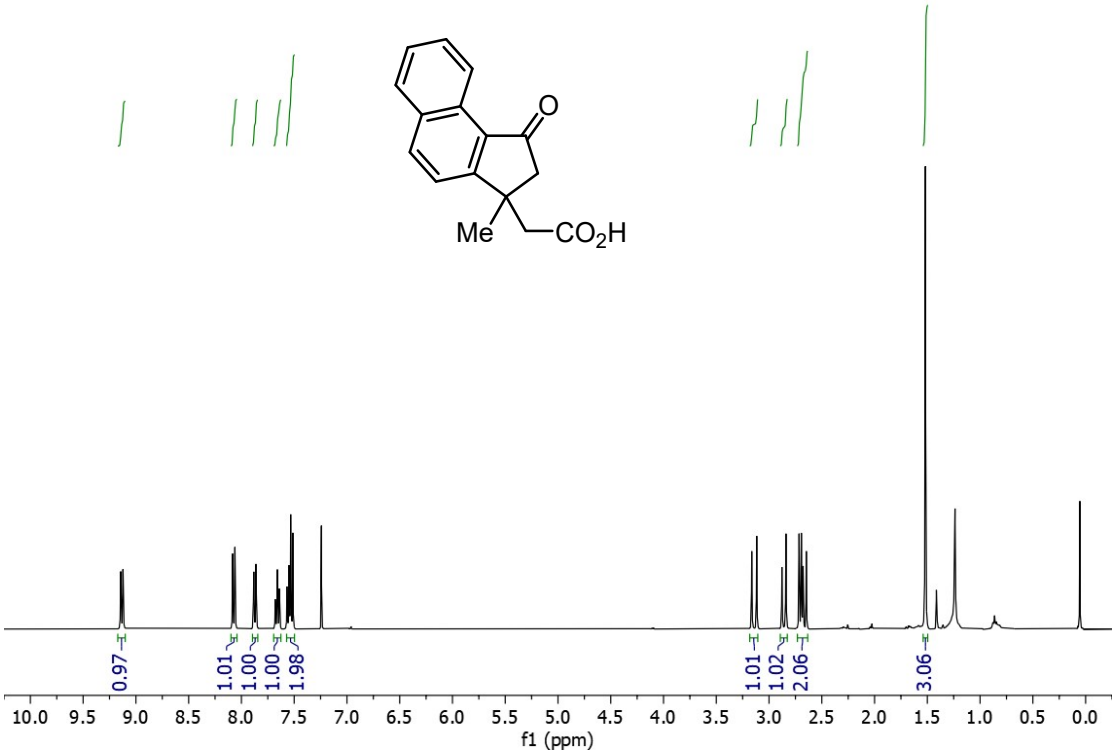


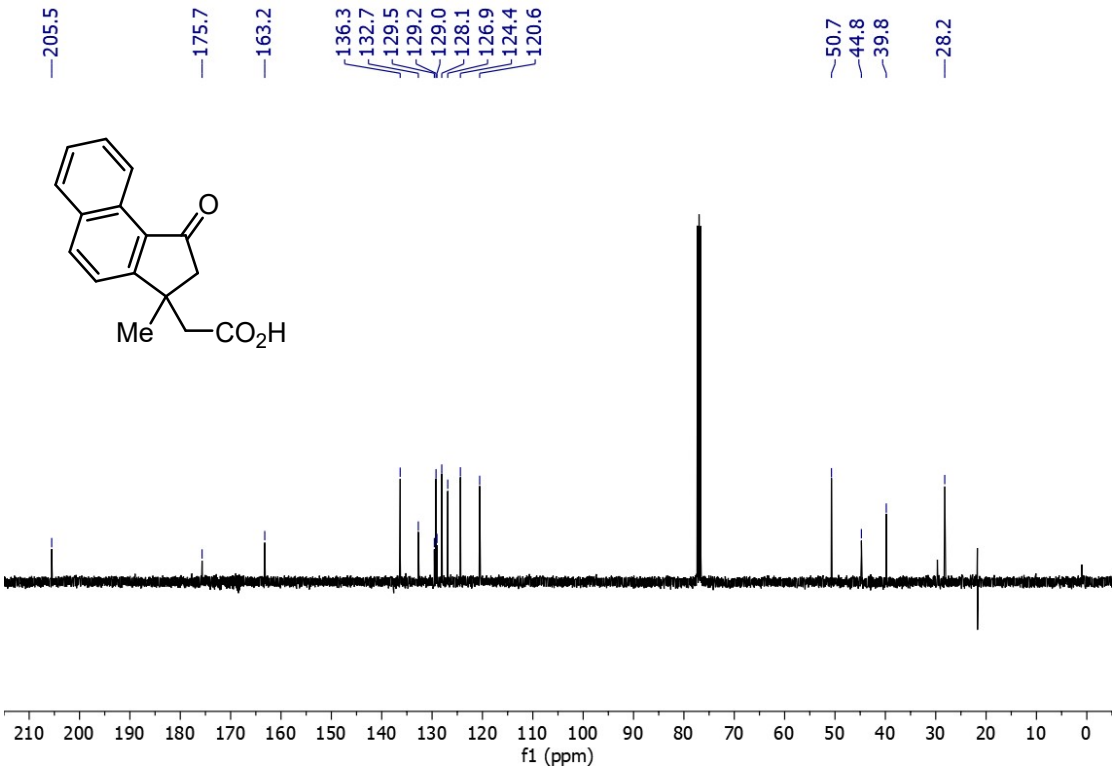
2c ^{13}C NMR (100 MHz, $CDCl_3$)



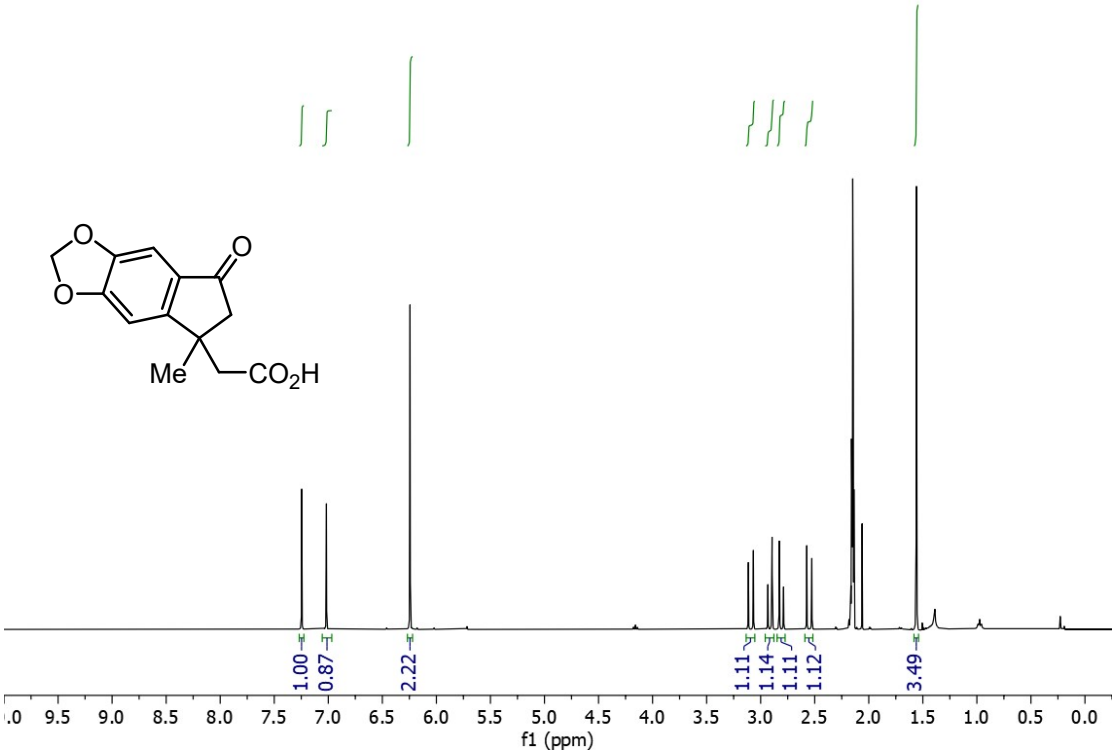
2d ^{1}H NMR (400 MHz, $CDCl_3$)



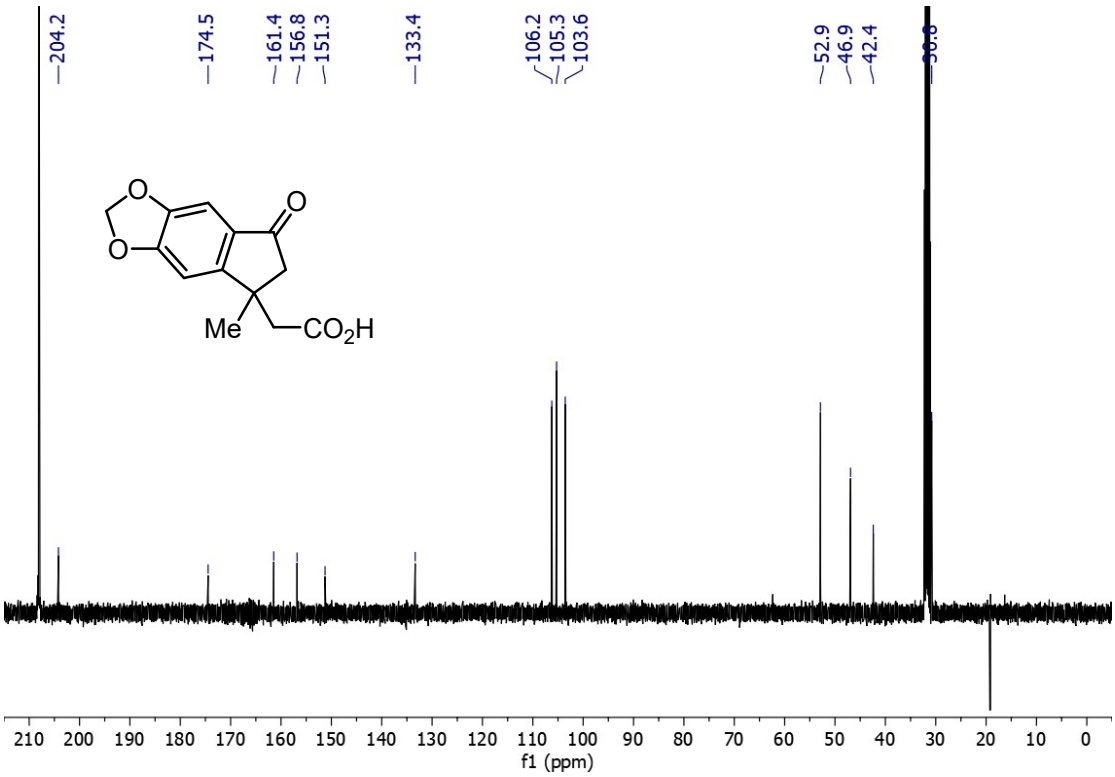
2d ^{13}C NMR (100 MHz, $CDCl_3$)



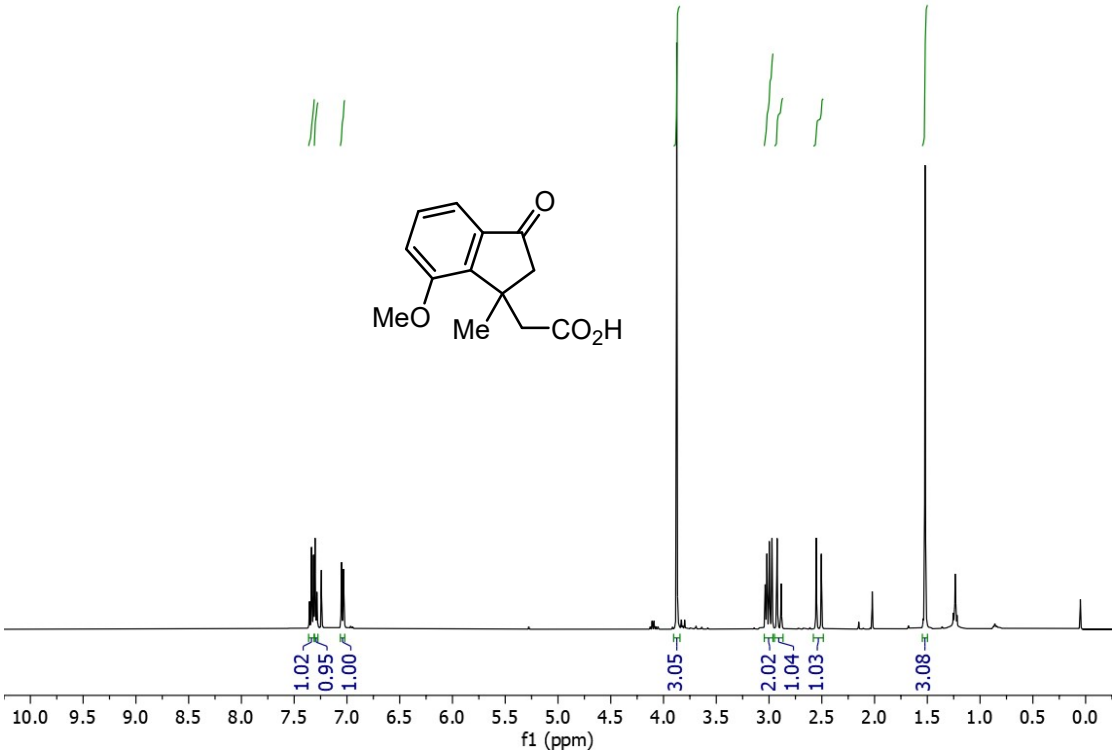
2e ^{1}H NMR (400 MHz, acetone-d_6)



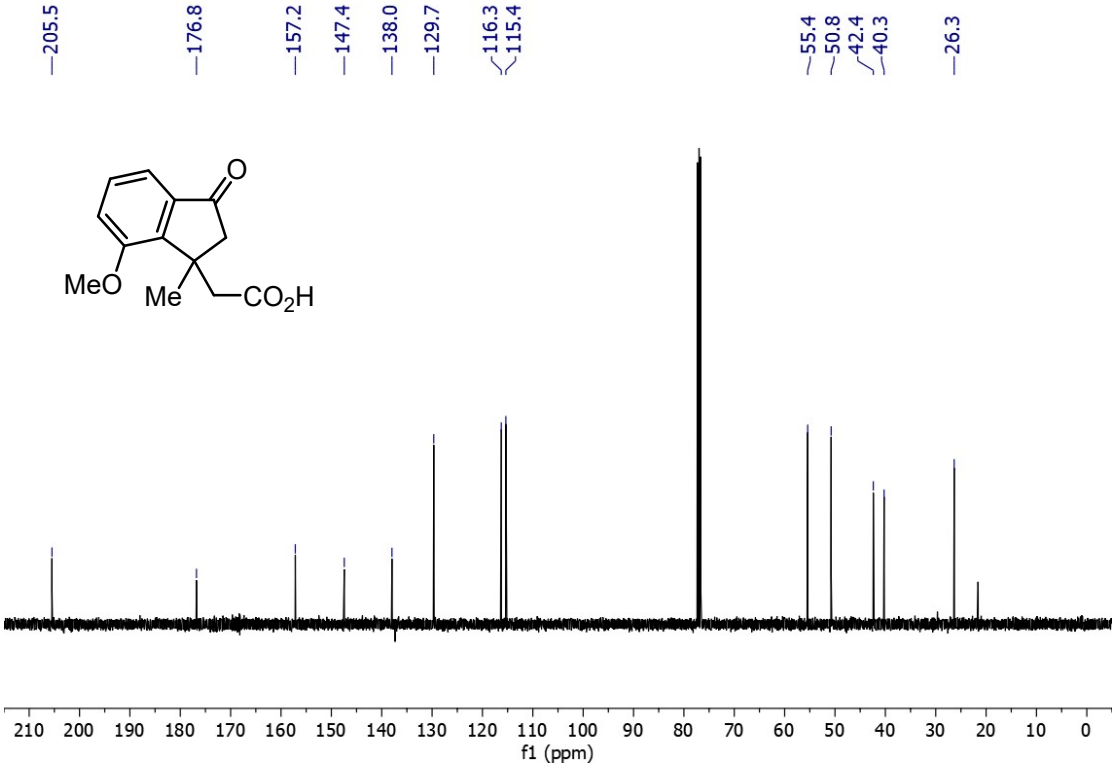
2e ^{13}C NMR (100 MHz, acetone-d_6)



2f ^{1}H NMR (400 MHz, $CDCl_3$)



2f ^{13}C NMR (100 MHz, $CDCl_3$)



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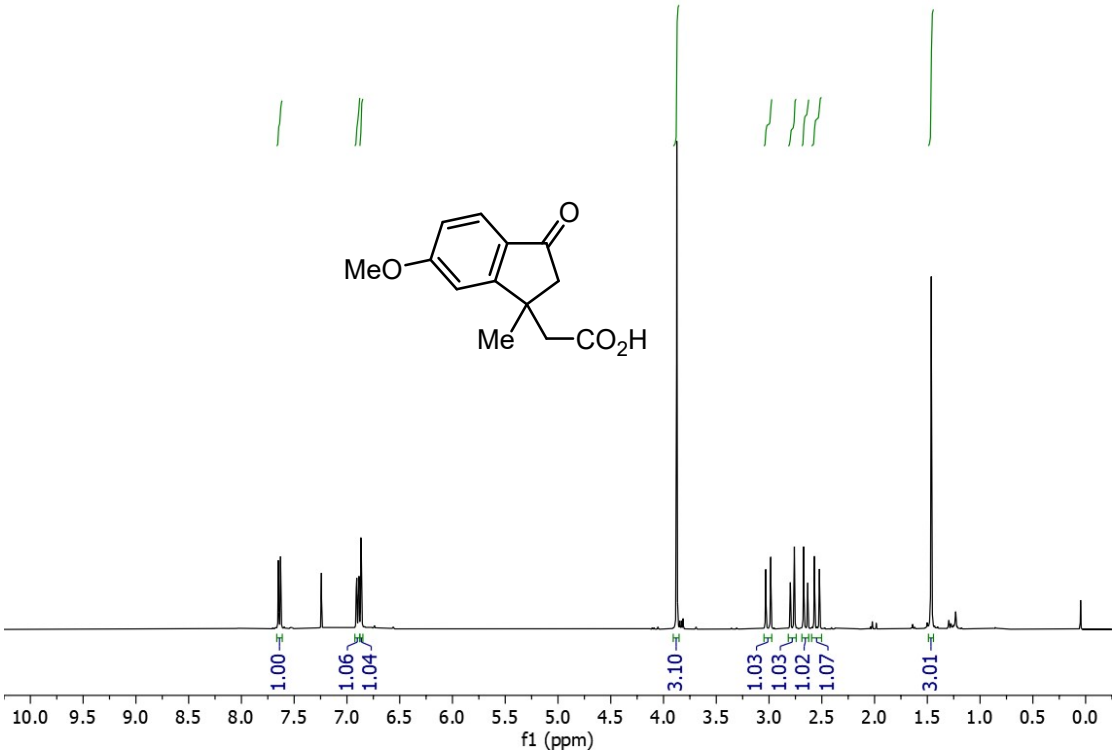
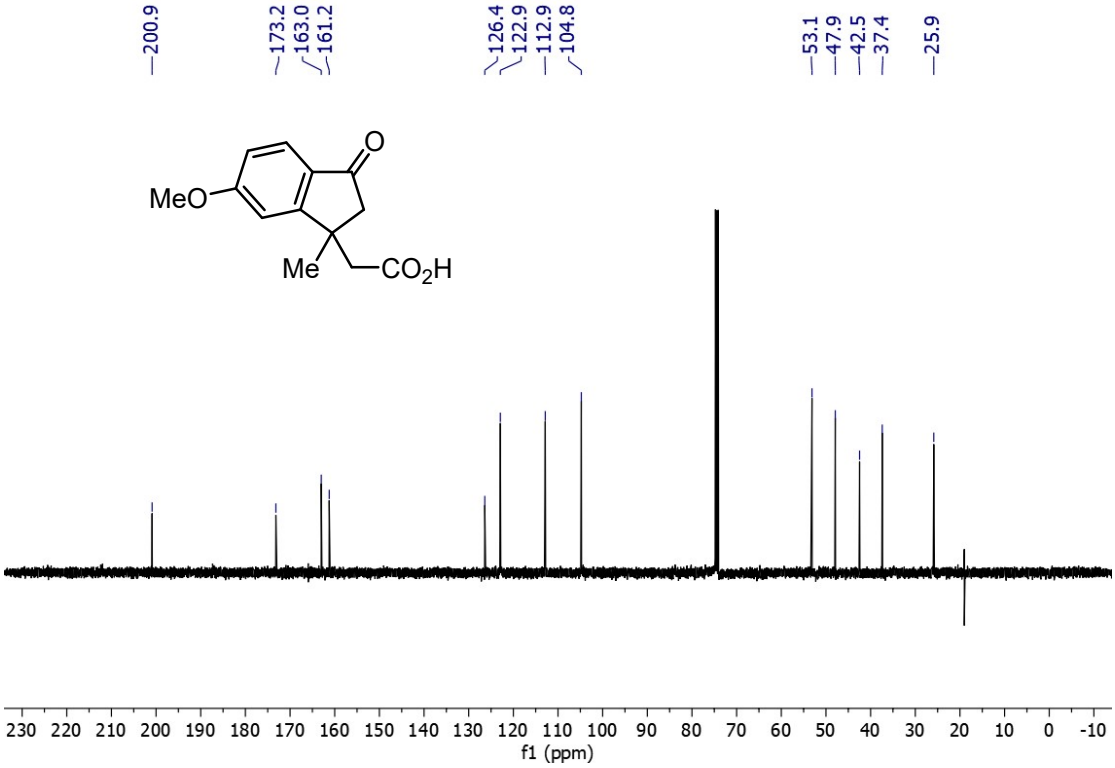


2g ^{13}C NMR (100 MHz, $CDCl_3$)



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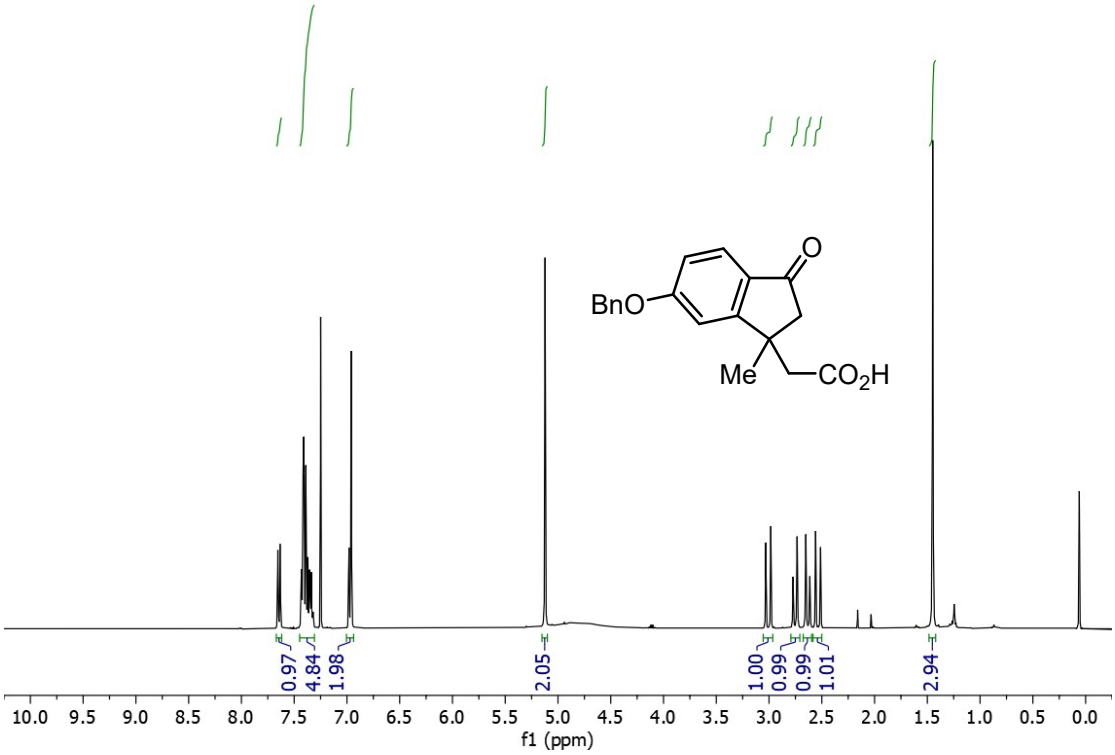
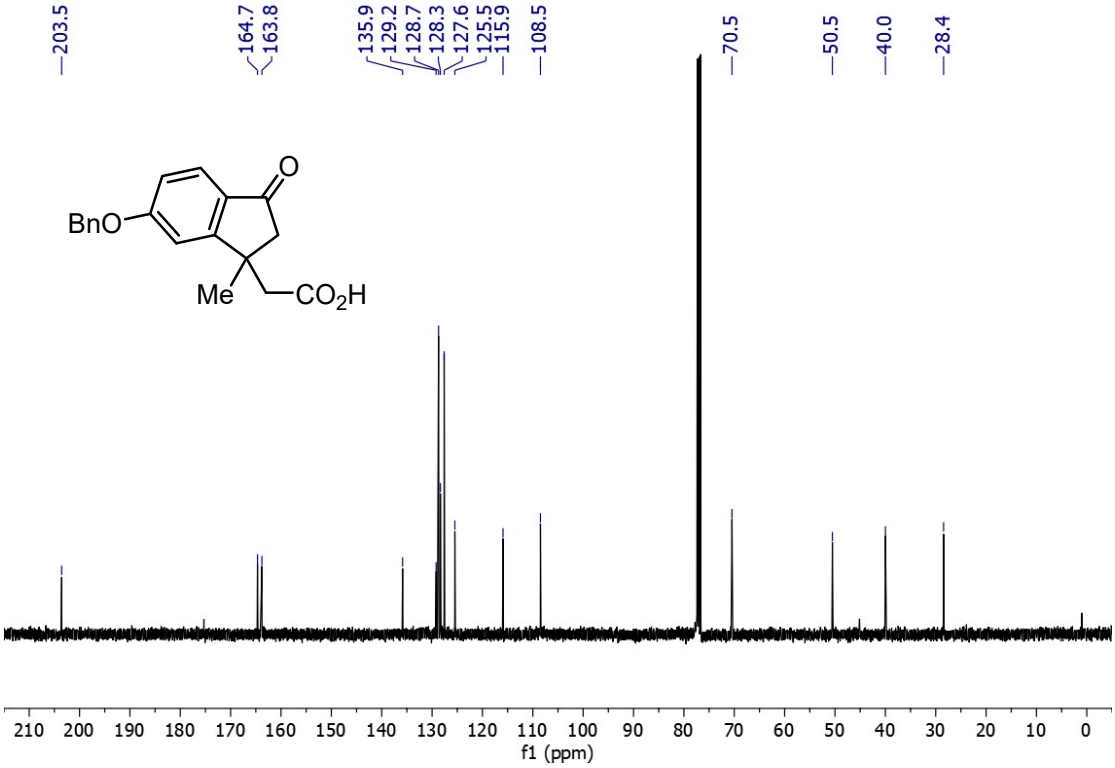
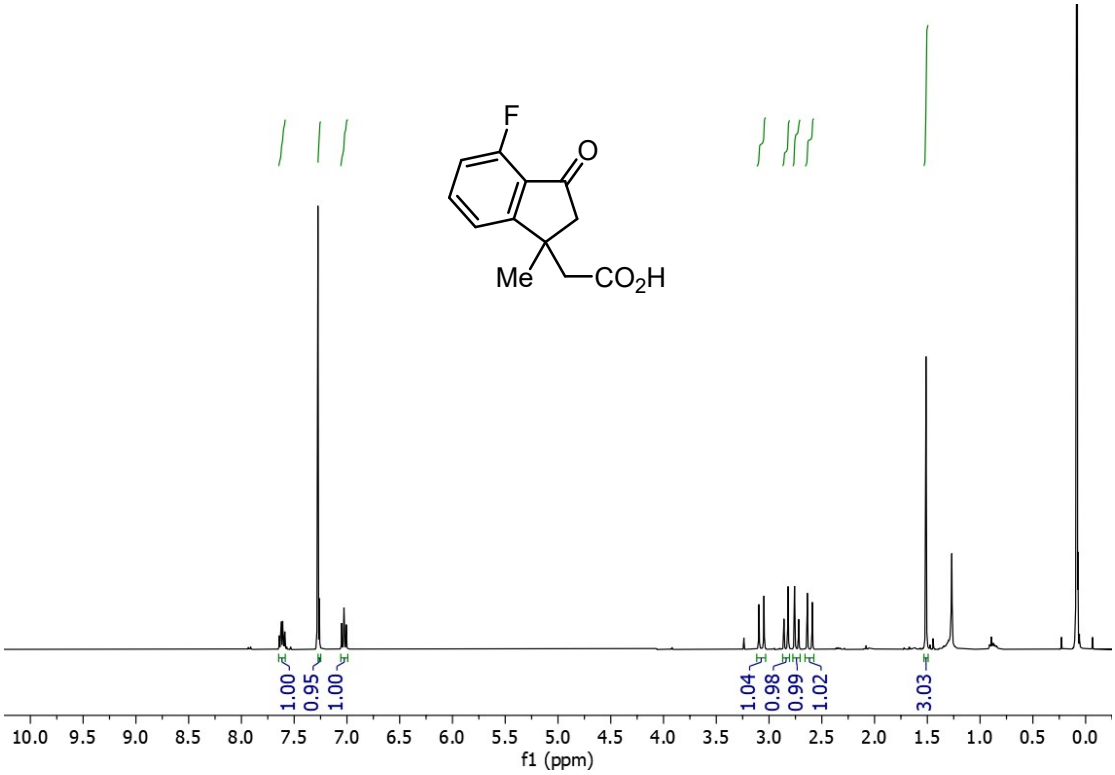


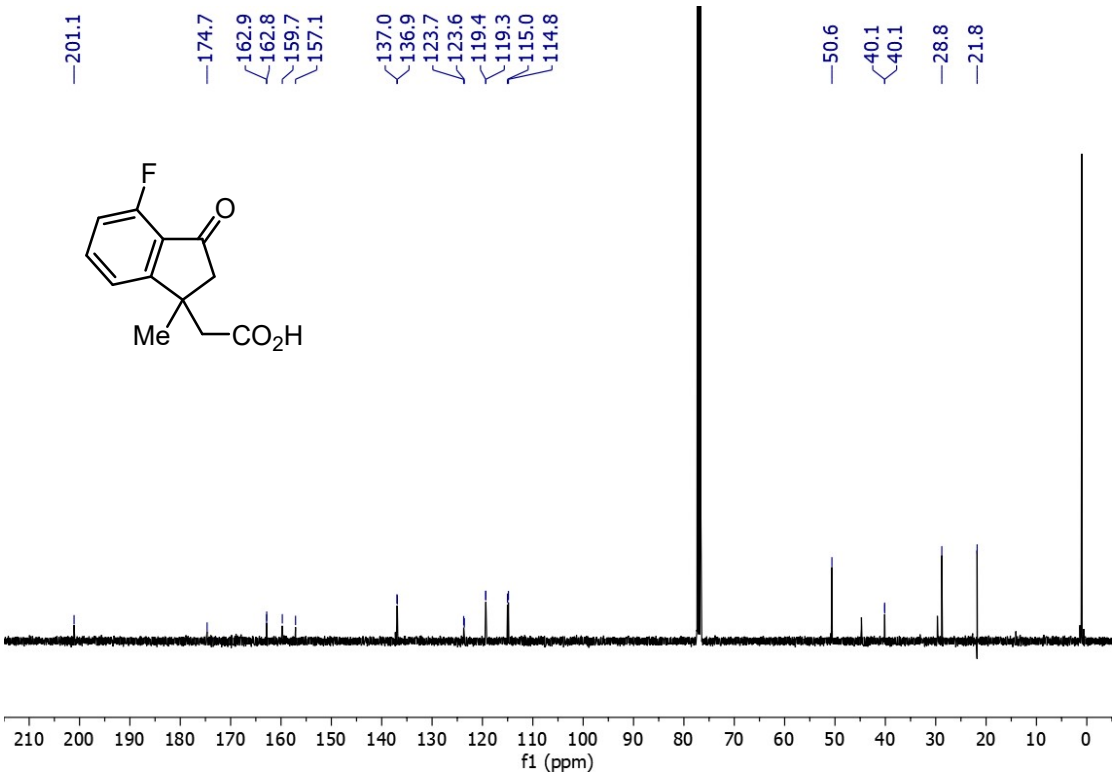
2h ^{13}C NMR (100 MHz, $CDCl_3$)



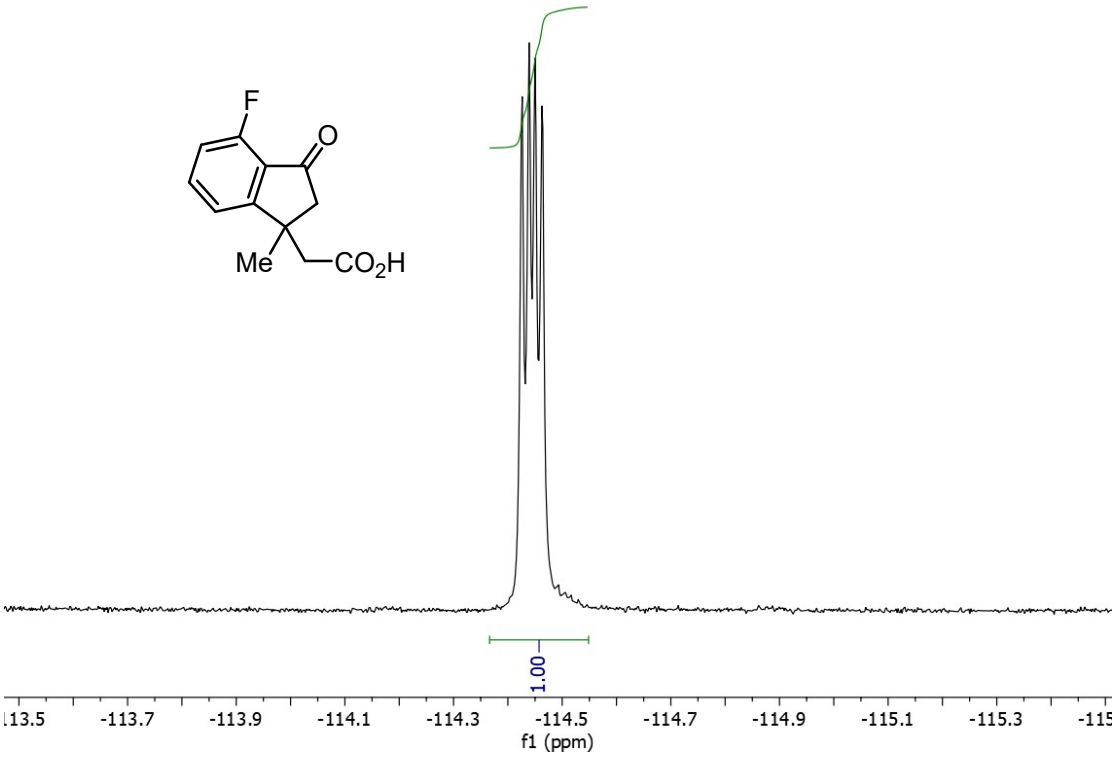
2i ^{1}H NMR (400 MHz, $CDCl_3$)



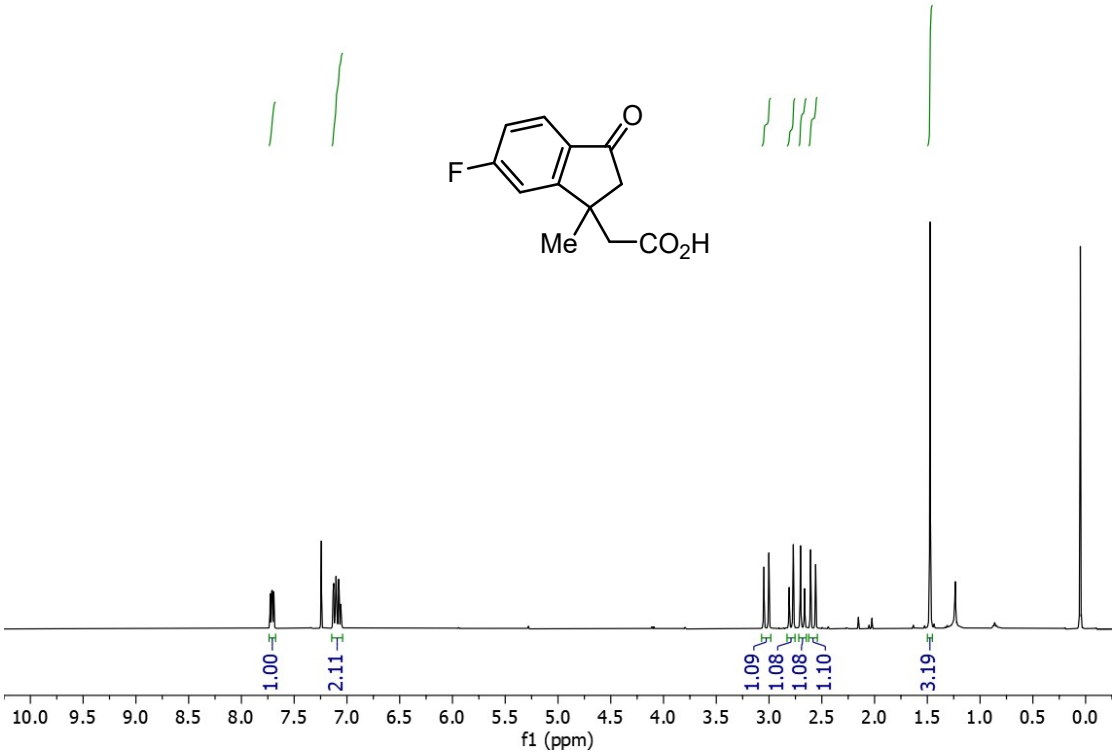
2i ^{13}C NMR (100 MHz, $CDCl_3$)



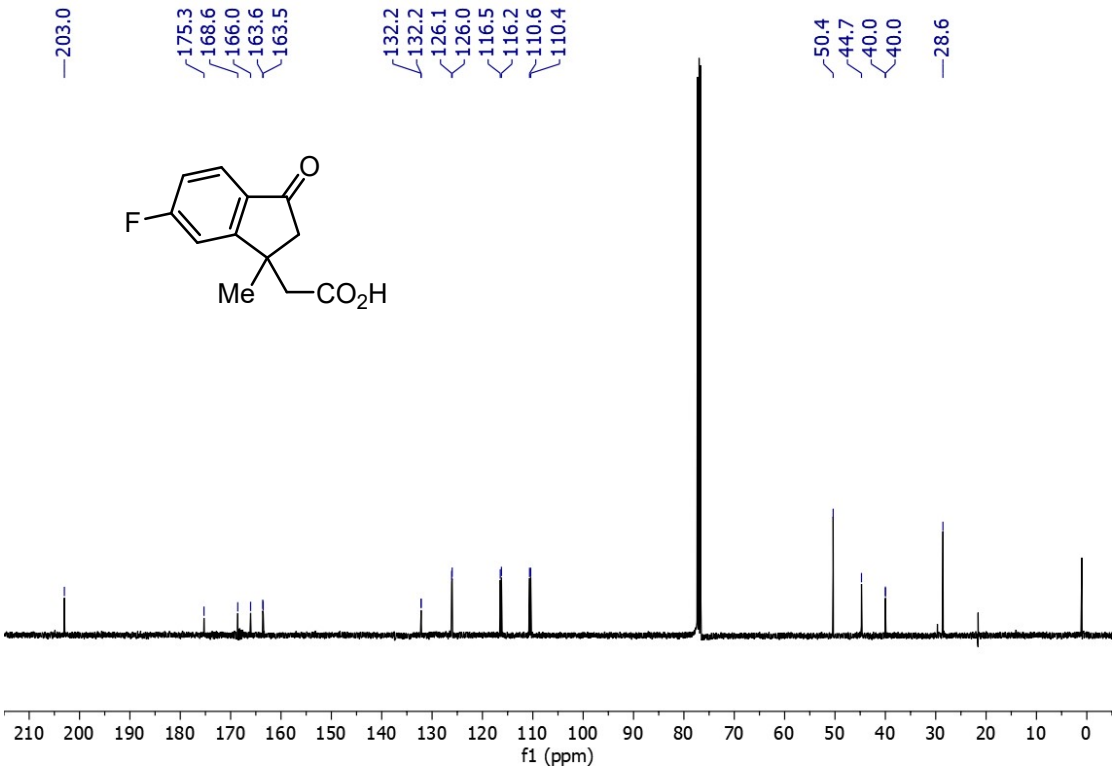
2i ^{19}F NMR (376 MHz, $CDCl_3$)



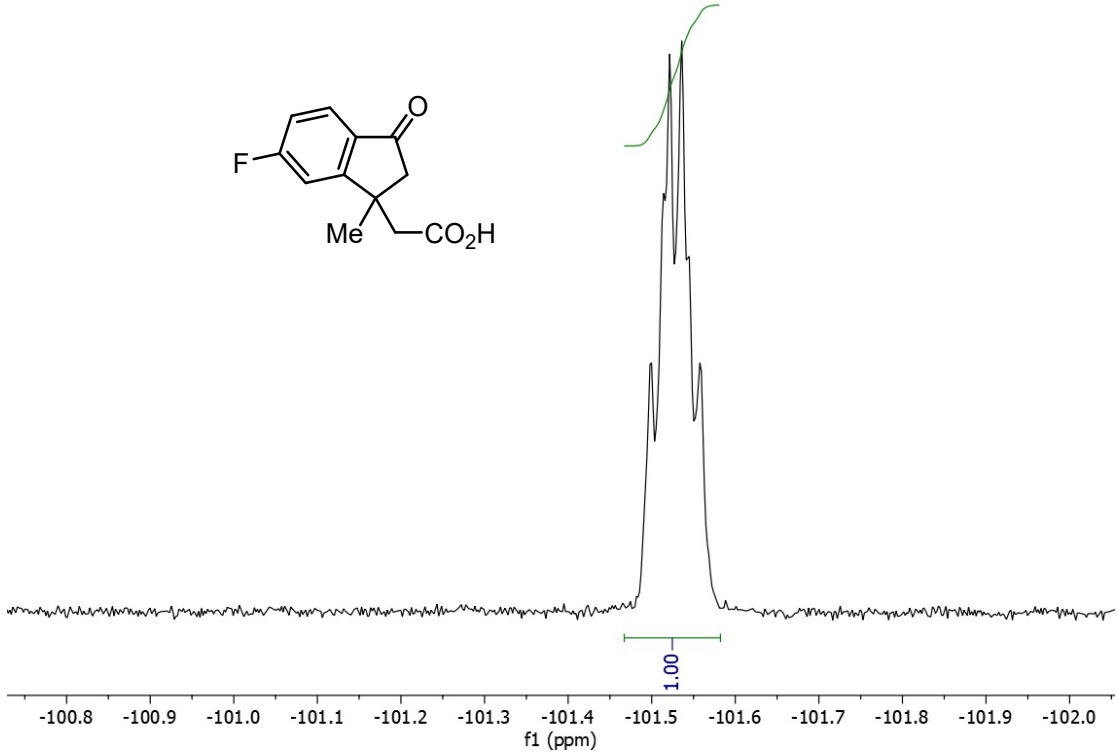
2j ^{1}H NMR (400 MHz, $CDCl_3$)



2j ^{13}C NMR (100 MHz, $CDCl_3$)



2j ^{19}F NMR (376 MHz, $CDCl_3$)



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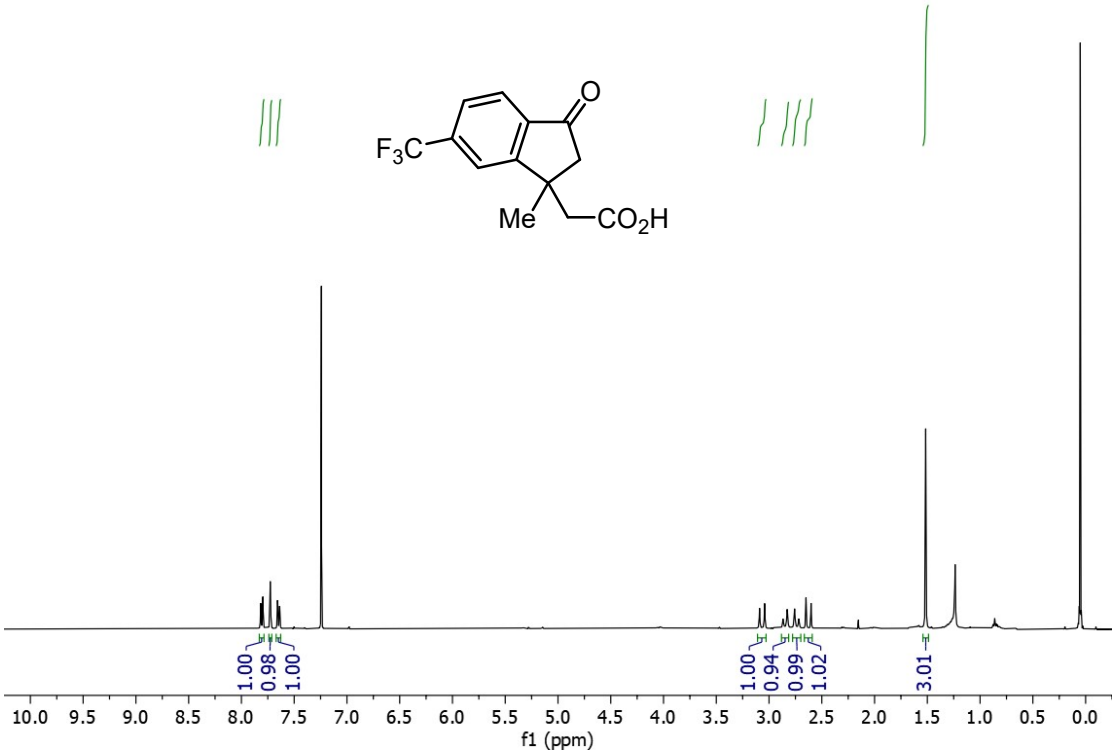
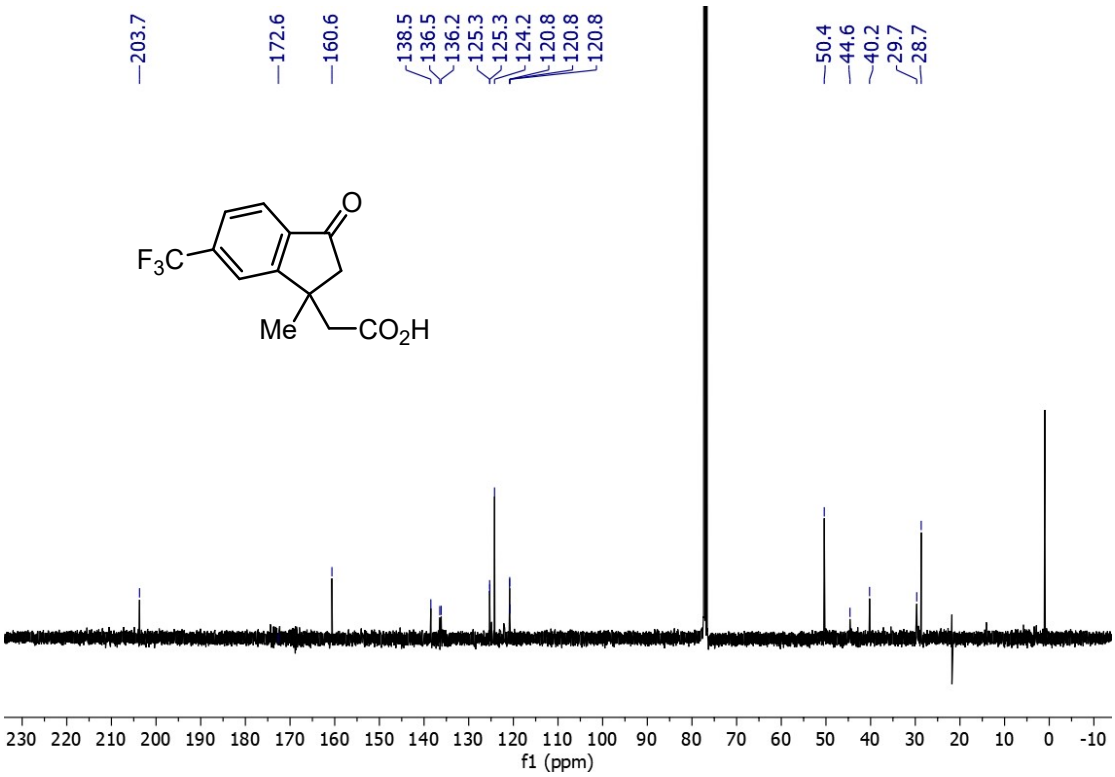
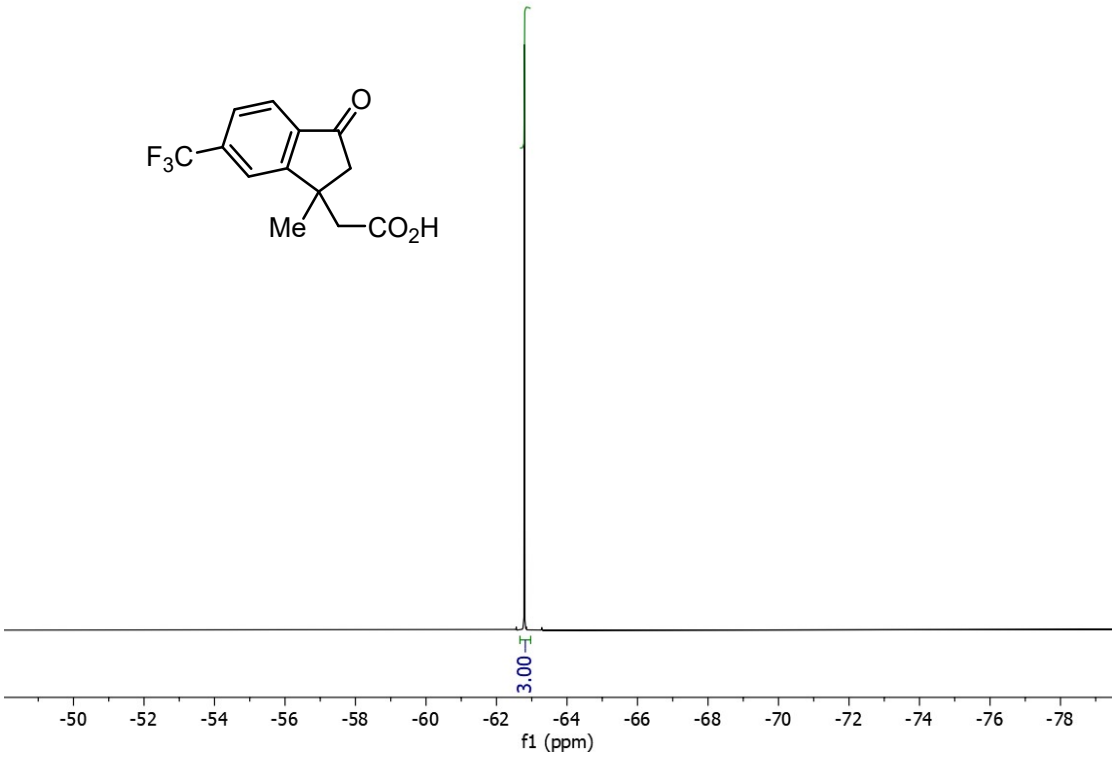


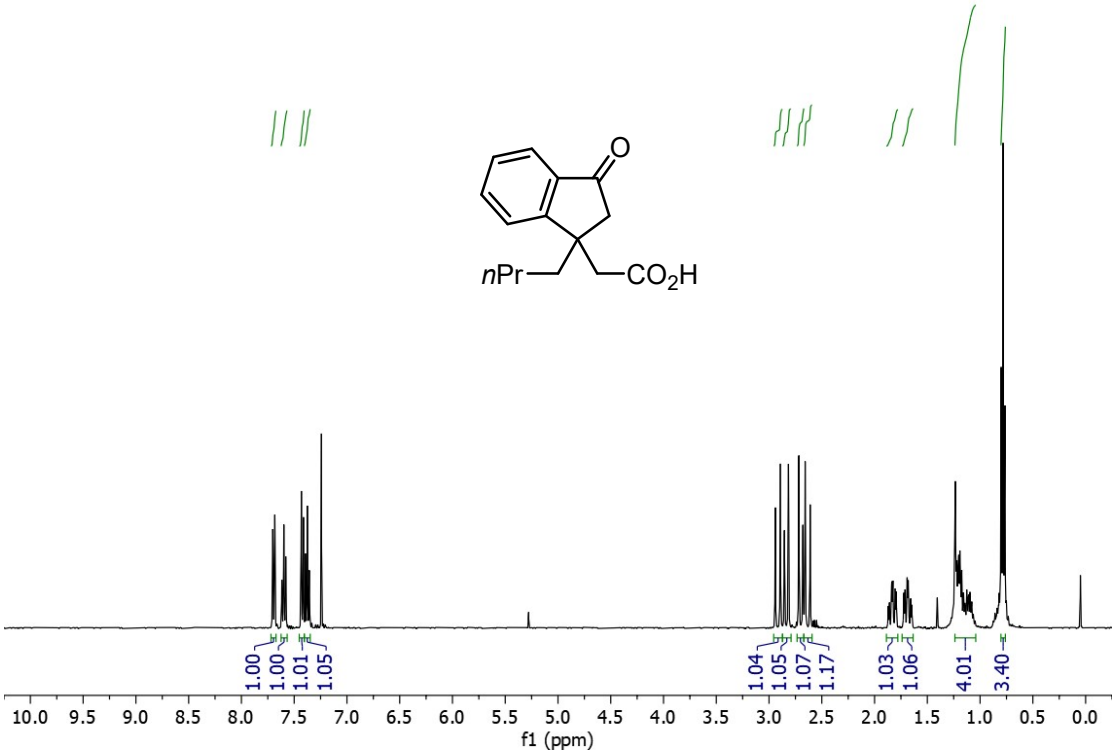
2k ^{13}C NMR (100 MHz, $CDCl_3$)



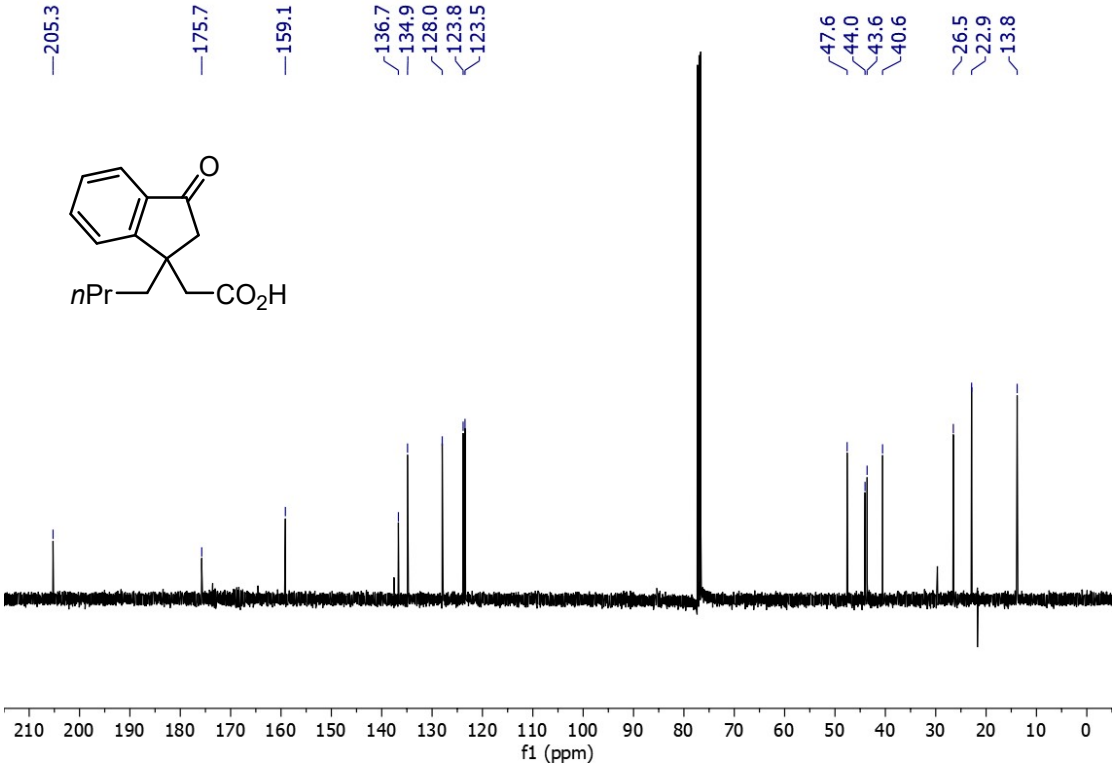
2k ^{19}F NMR (376 MHz, $CDCl_3$)



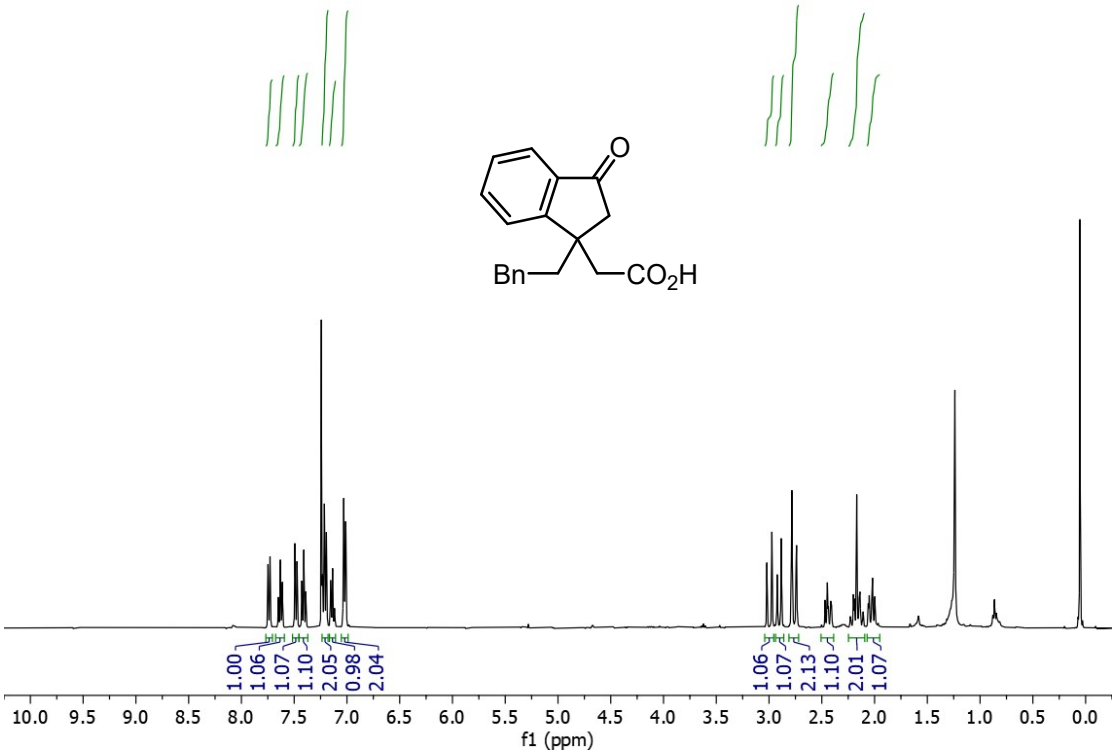
2l ^{1}H NMR (400 MHz, $CDCl_3$)



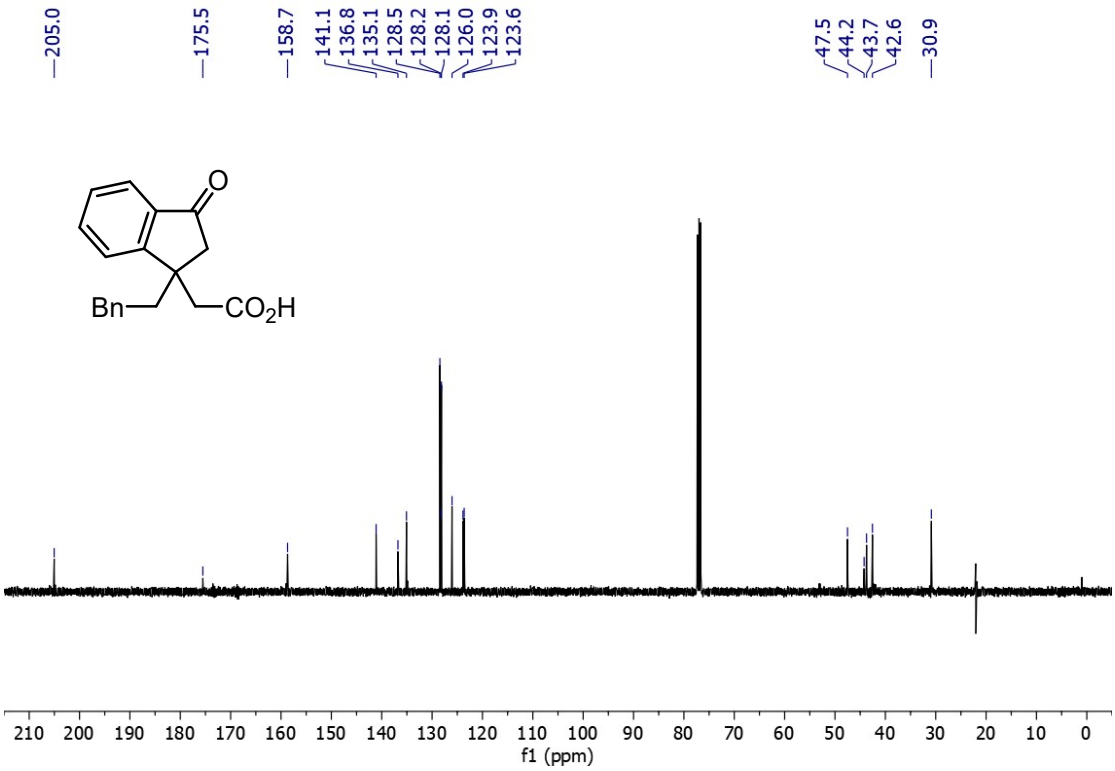
2l ^{13}C NMR (100 MHz, $CDCl_3$)



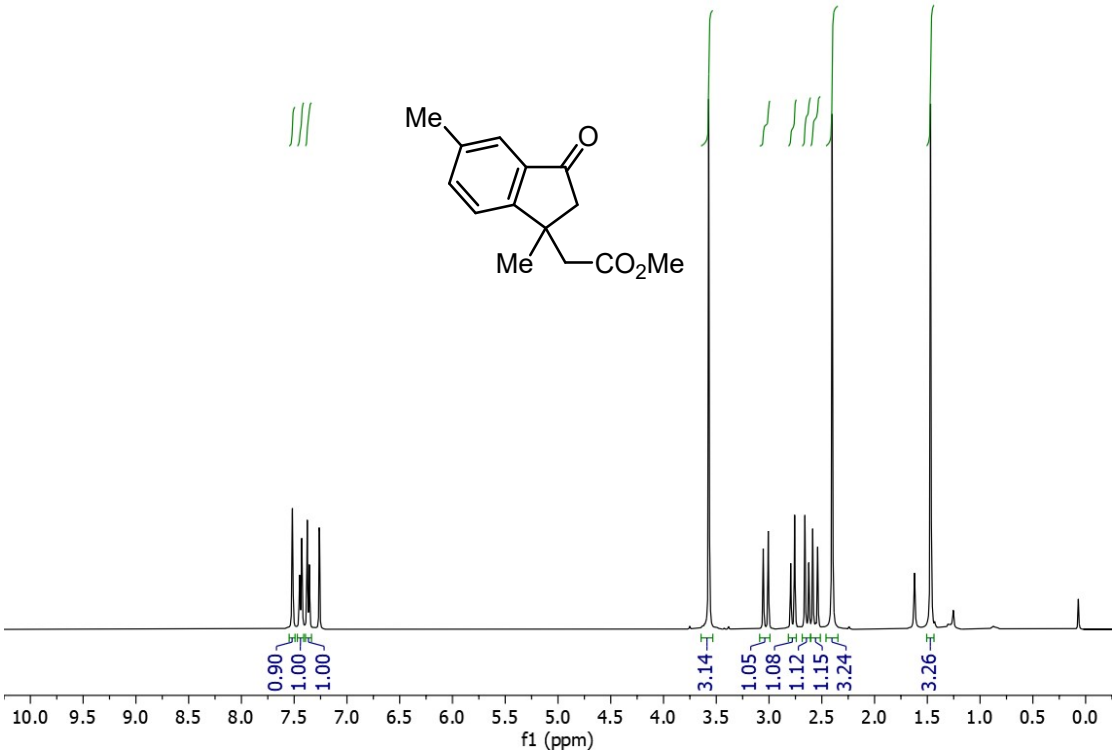
2m ^{1}H NMR (400 MHz, $CDCl_3$)



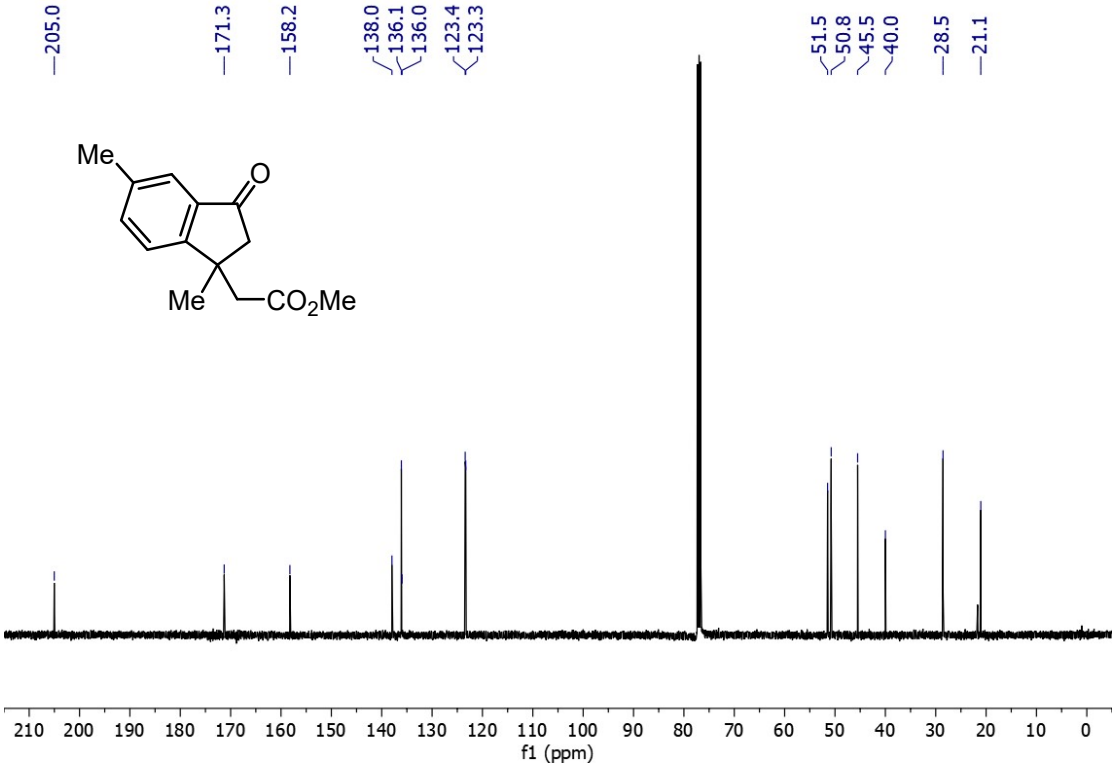
2m ^{13}C NMR (100 MHz, $CDCl_3$)



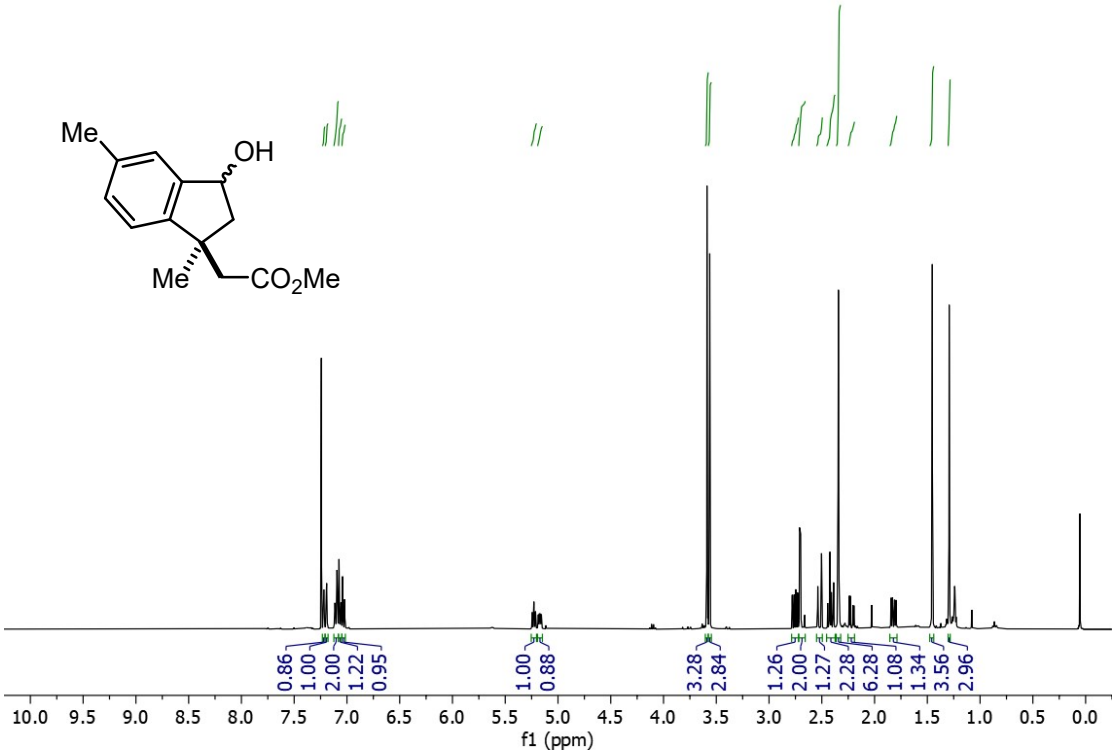
2b-methyl ester ^{1}H NMR (400 MHz, $CDCl_3$)



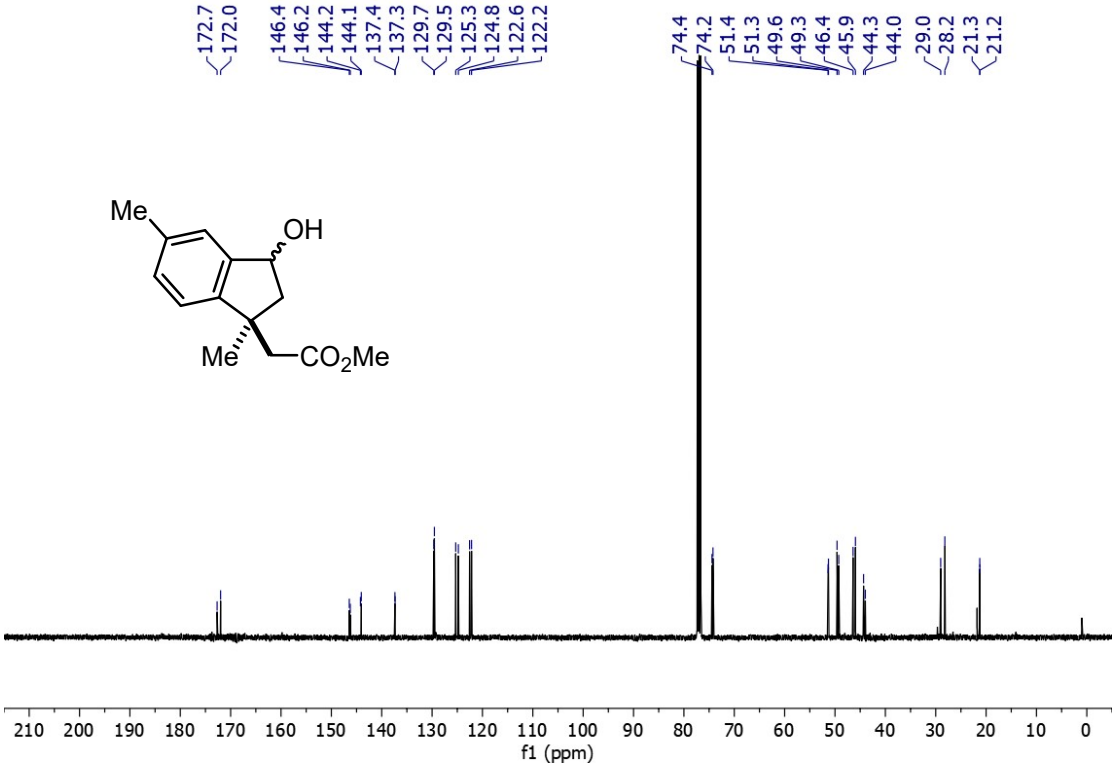
2b-methyl ester ^{13}C NMR (100 MHz, $CDCl_3$)



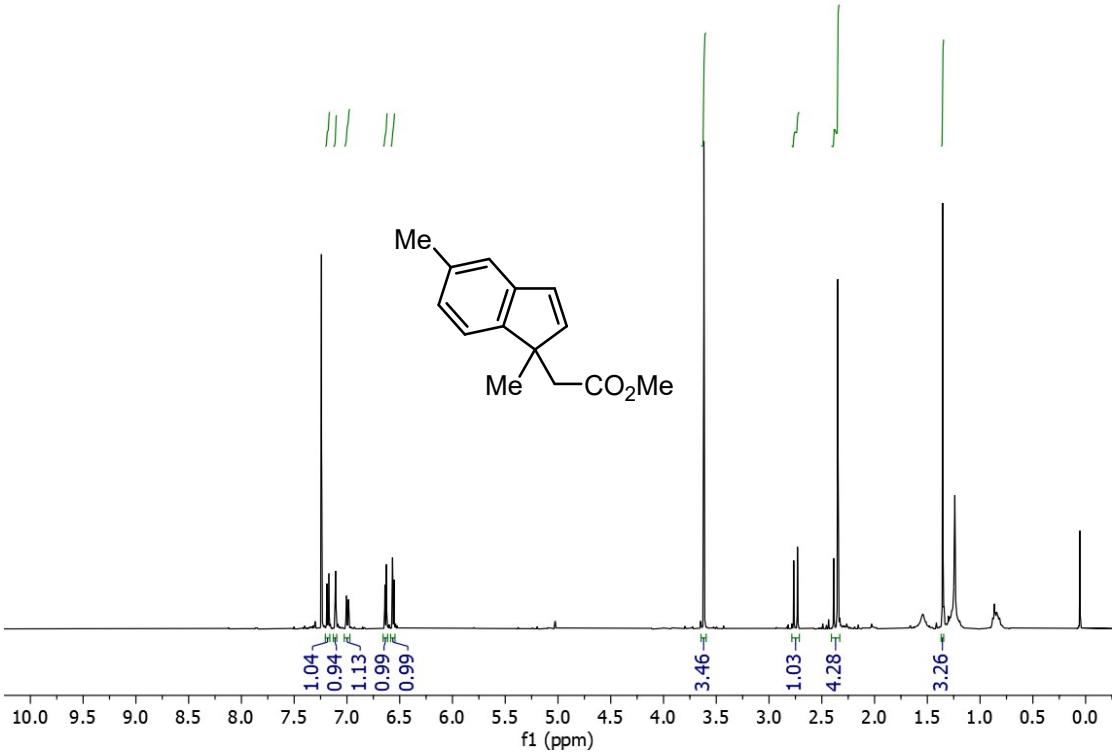
3b ^{1}H NMR (400 MHz, $CDCl_3$)



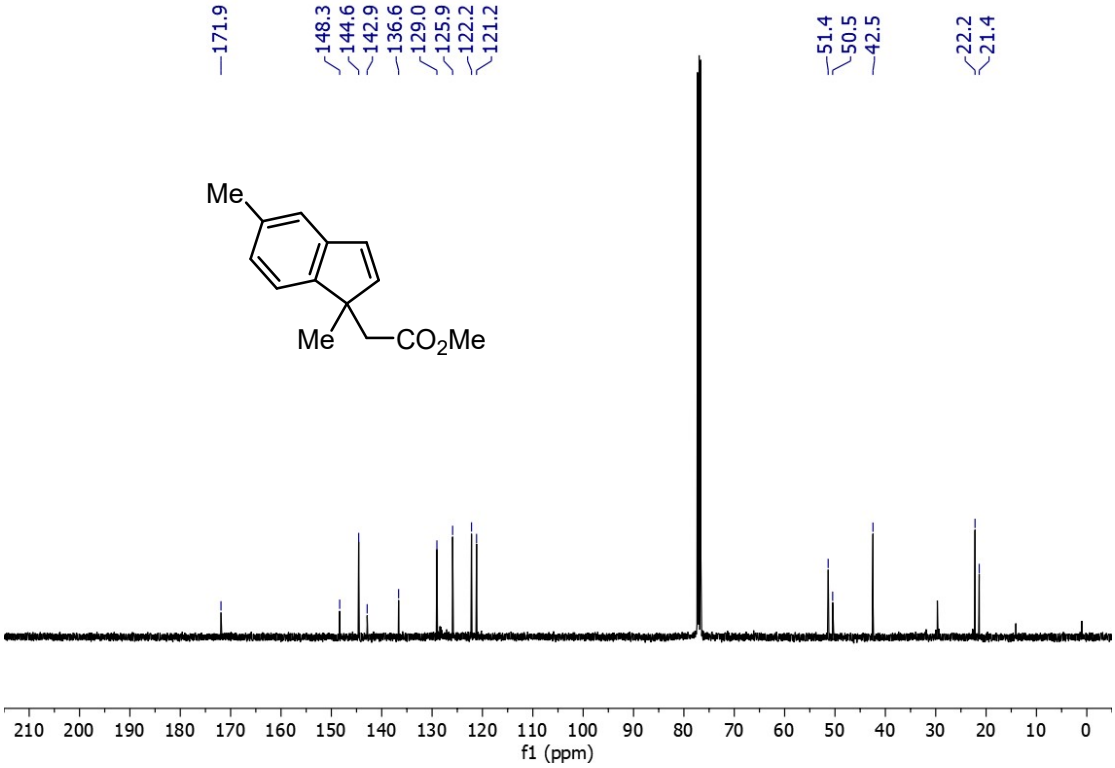
3b ^{13}C NMR (100 MHz, $CDCl_3$)



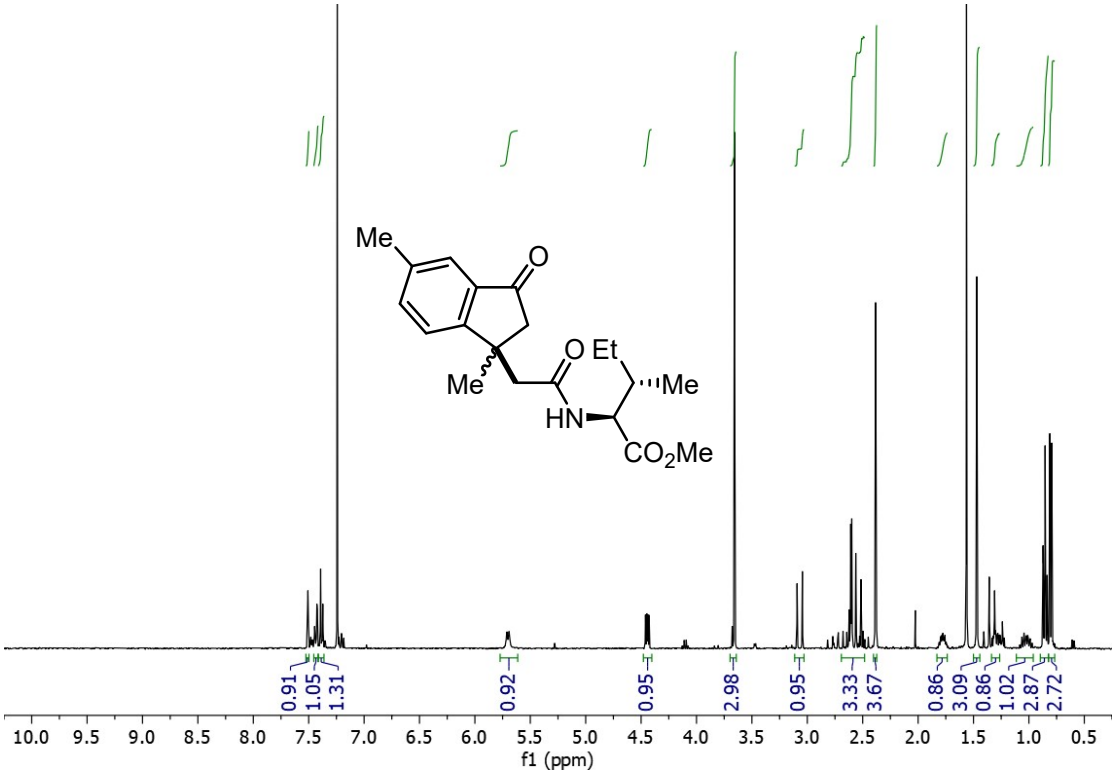
4b ^{1}H NMR (400 MHz, $CDCl_3$)



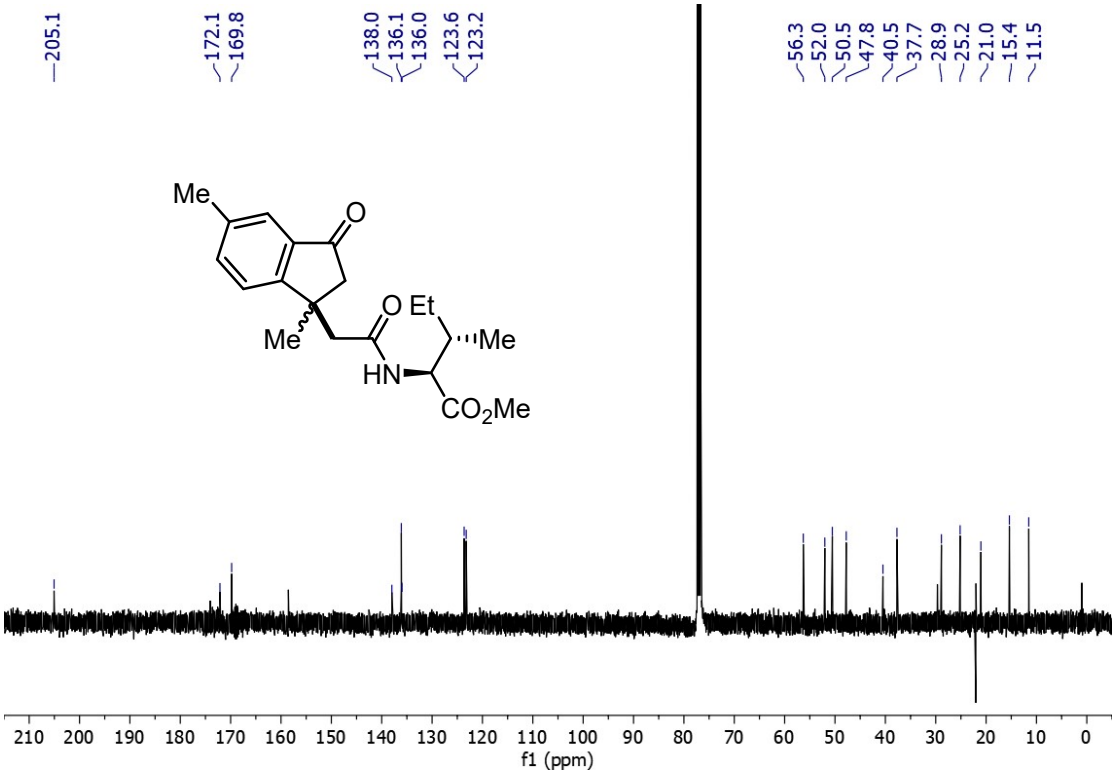
4b ^{13}C NMR (100 MHz, $CDCl_3$)



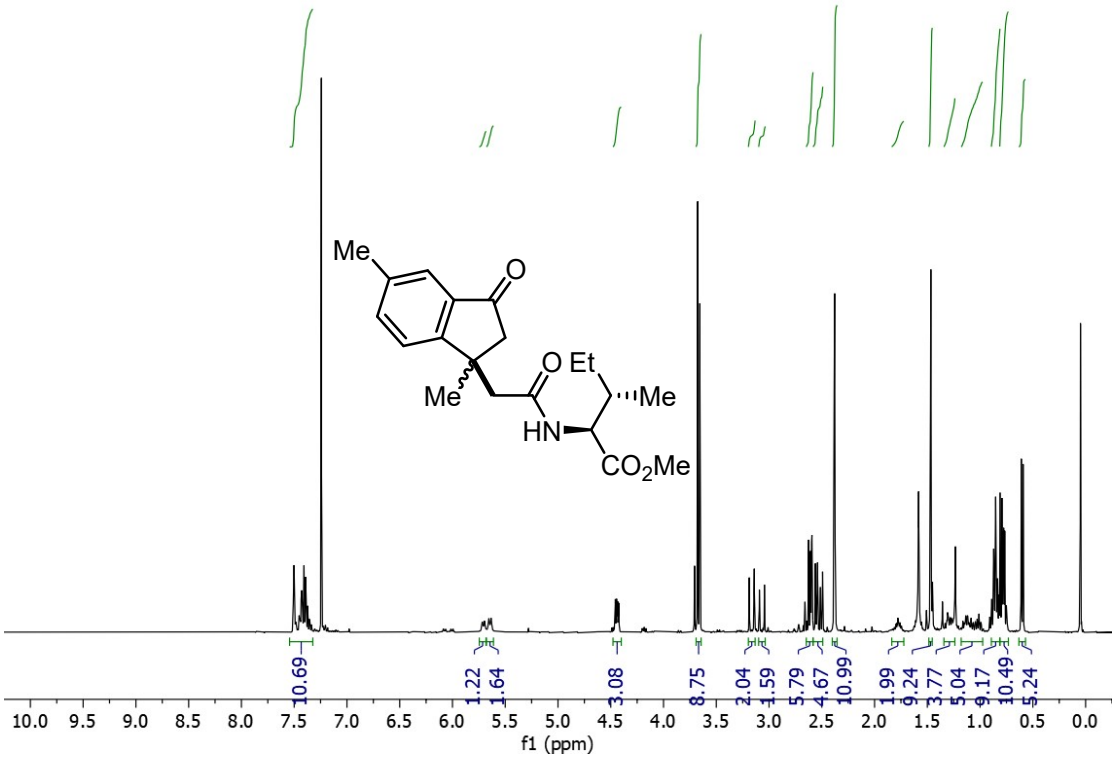
5b-major diastereoisomer ^{1}H NMR (400 MHz, $CDCl_3$)



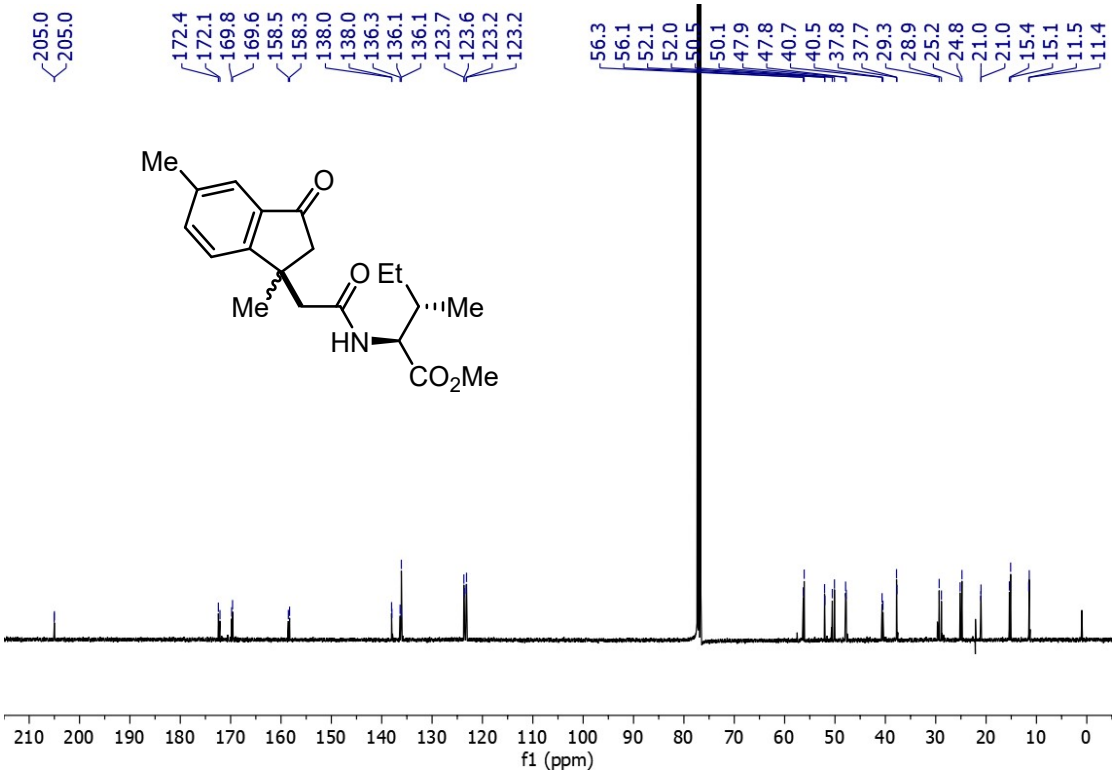
5b-major diastereoisomer ^{13}C NMR (100 MHz, $CDCl_3$)



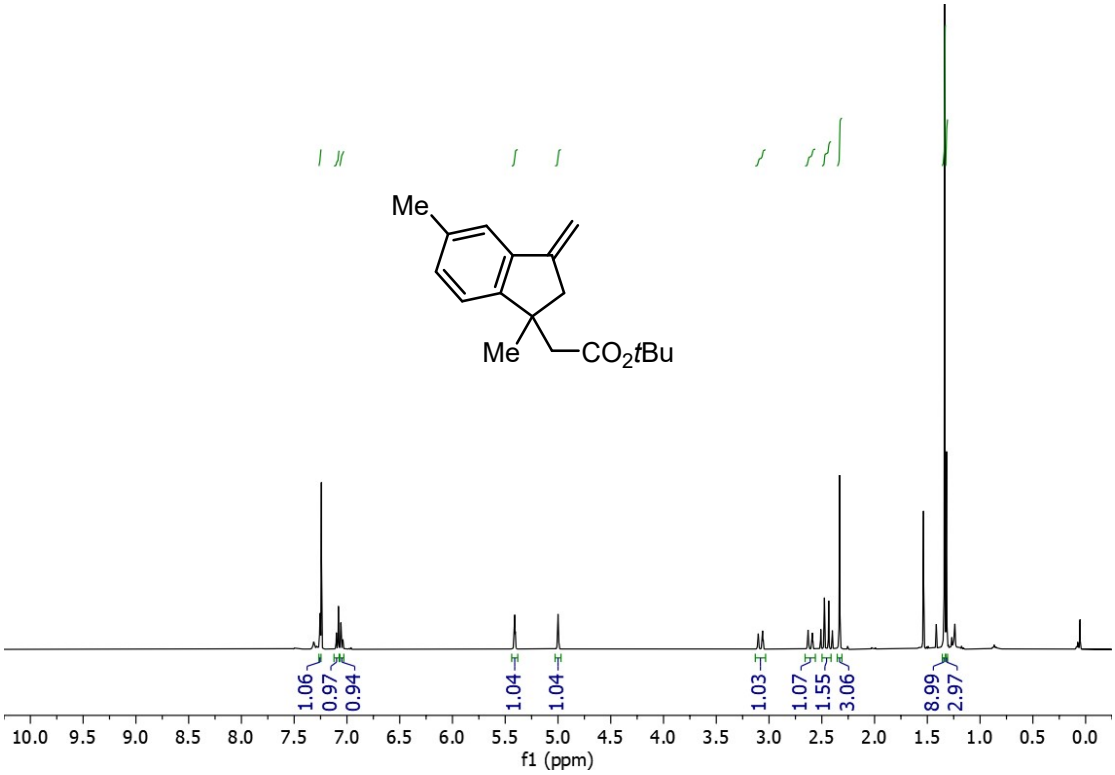
5b-diastereomeric mixture ^{1}H NMR (400 MHz, $CDCl_3$)



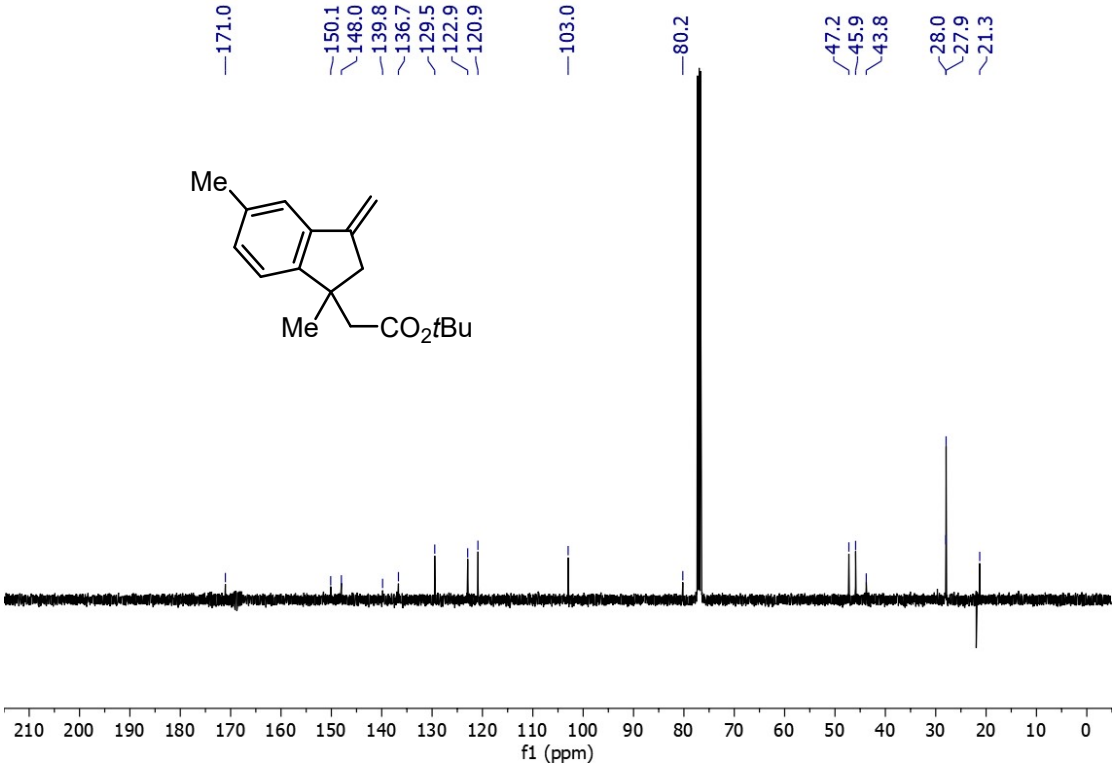
5b-diastereomeric mixture ^{13}C NMR (100 MHz, $CDCl_3$)



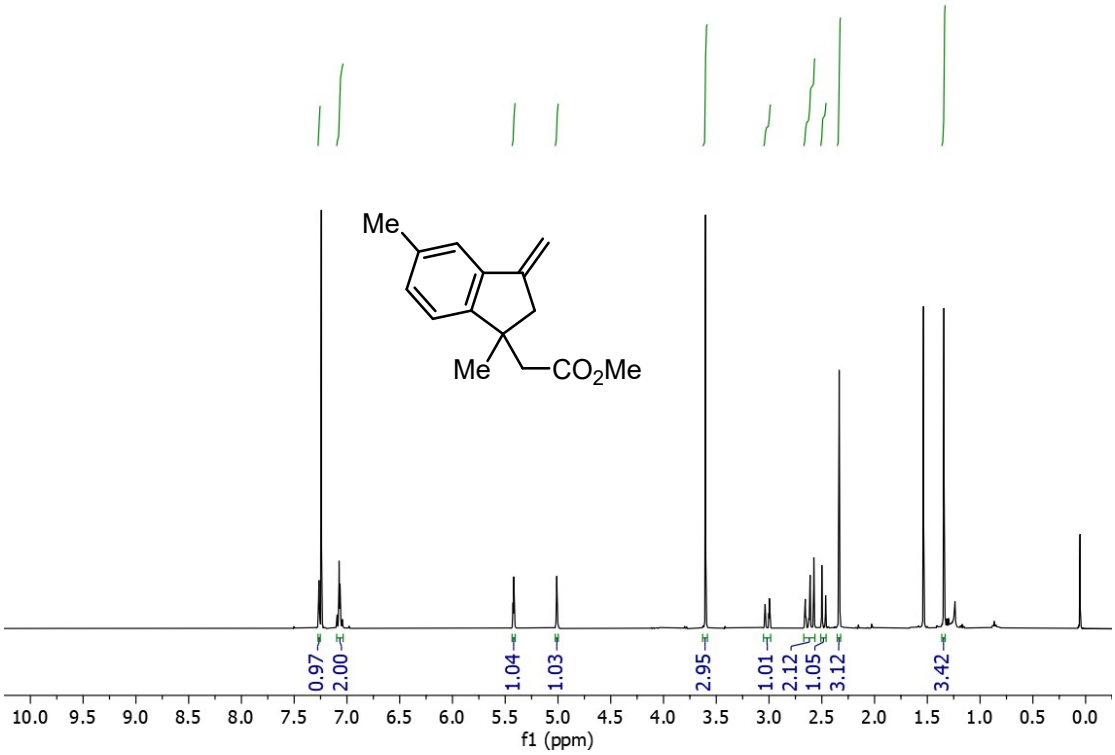
6b ^{1}H NMR (400 MHz, $CDCl_3$)



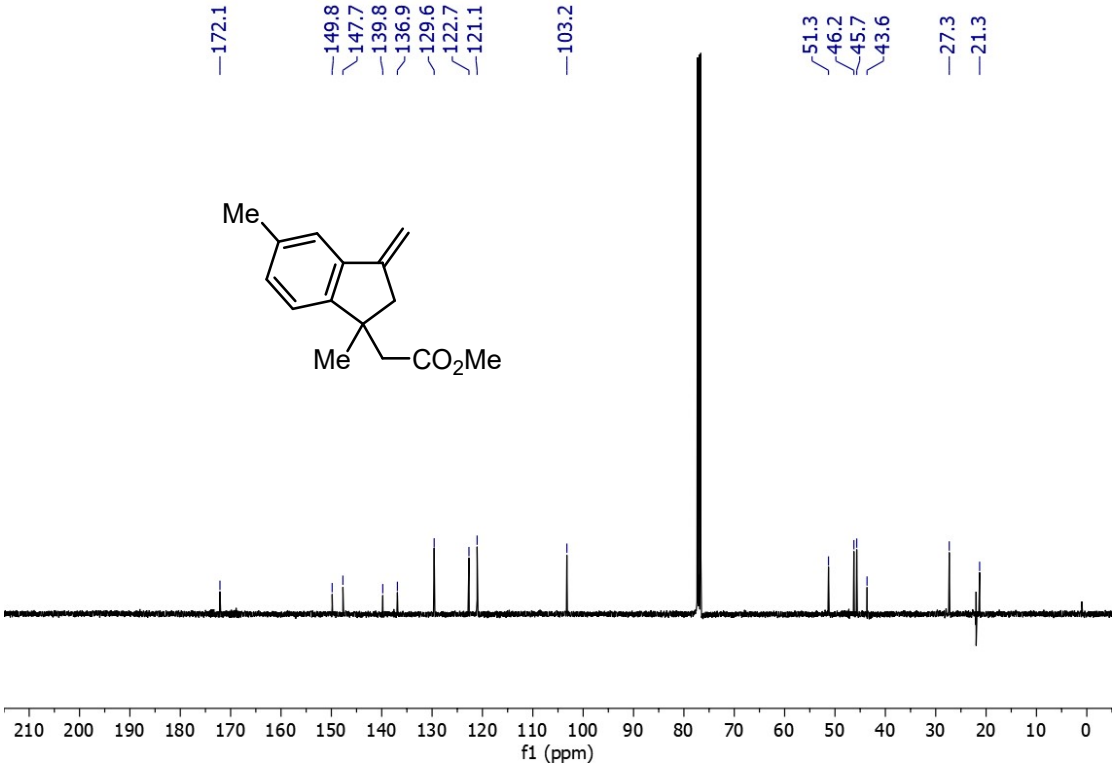
6b ^{13}C NMR (100 MHz, $CDCl_3$)



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



6b' ^{13}C NMR (100 MHz, $CDCl_3$)



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