Supporting Information

Catalytic, Diastereoselective 1,2 Difluorination of Alkenes

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Contents

General experimental procedures. All reactions for the preparation of substrates and catalysts were performed in standard, dry glassware fitted with rubber septa under an inert atmosphere of nitrogen unless otherwise described. All difluorination reactions were performed in low density polyethylene tubes sealed with a low density polyethylene cap under an atmosphere of air. Stainless steel gas-tight syringes or cannulae were used to transfer air- and moisture-sensitive liquids. Reported concentrations refer to solution volumes at room temperature. Concentration of organic solutions under reduced pressure was performed using house vacuum (ca. 40 mm Hg) at 30 °C. Column chromatography was performed with ZEOprep® 60 (40–63 micron) silica gel from American Scientific. Thin layer chromatography (TLC) was used for reaction monitoring and product detection was performed using pre-coated glass plates covered with 0.20 mm silica gel with fluorescent indicator; plates were visualized by exposure to UV light (λ_{ex} = 254 nm) or by staining with potassium permanganate or ninhydrin.

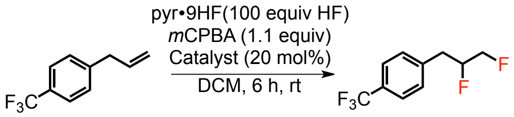
CAUTION: Pyridine•9HF is a corrosive and toxic substance that will corrode glassware. Safe handling can be conducted with plastic syringes and metal needles, with $NaHCO_3$ (aq.) or NaOH (aq.) employed to quench excess HF. Though reactions should not be conducted in glassware when employing pyridine•9HF, glassware may be used to quench reactions provided sufficient quantities of base are present. Always handle pyridine•9HF while wearing gloves and in a fumehood. As a precautionary measure, have calcium gluconate gel nearby and apply immediately and liberally on skin exposed to HF.

Materials. Reagents were purchased in reagent grade from commercial suppliers and used as received, unless otherwise described. Anhydrous solvents (benzene, dichloromethane, diethyl ether, *N*,*N*-dimethylformamide, tetrahydrofuran, and toluene) were prepared by passing the solvent through an activated alumina column. Triethylamine and diisopropylethylamine were distilled over calcium hydride at atmospheric pressure. The molarity of *n*-butyllithium solutions was determined by titration against diphenylacetic acid[1] (average of three titrations).

Instrumentation. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded on a Varian Mercury-400 or an Inova-500 spectrometer, are reported in parts per million downfield from tetramethylsilane, and are referenced to the residual protium resonances of the NMR solvent ($CDCl_3$: 7.26 [$CHCl_3$], acetone-d_6: 2.05 [acetone-d_5], DMSO-d_6: 2.50 [DMSO-d_5]). Proton-decoupled carbon-13 nuclear magnetic resonance (^{13}C {^{1}H} NMR) spectra were recorded on an Inova-500 spectrometer, are reported in parts per million downfield from tetramethylsilane, and are referenced to the carbon resonances of the NMR solvent ($CDCl_3$: 77.23, acetone-d_6: 29.92, DMSO-d_6: 39.61). Chemical shifts for fluorine-19 nuclear magnetic resonance (^{19}F NMR) were recorded on a Varian Mercury-400 or an Inova-500 spectrometer, are reported in parts per million downfield from chlorotrifluoromethane, and are referenced to the fluorine resonance of chlorotrifluoromethane ($\delta = 0$). Data are represented as follows: chemical shift, multiplicity (br = broad, s = singlet, d = doublet, t = triplet, q = quartet, quin = quintet, sept = septet, m = multiplet), coupling constants in Hertz (Hz), integration. Optical rotations were measured using a 1 mL cell with a 5 cm path length on a Jasco P-2000 digital polarimeter. Infrared spectra were recorded using a Bruker Tensor 27 FT-IR spectrometer. Data are represented as follows: frequency of absorption (cm^{-1}), intensity of absorption (s = strong, m = medium, w = weak, br = broad). High-resolution mass spectrometric data were obtained on an Agilent 6210 time-of-flight HPLC/MS spectrometer (ESI-TOF). Low-resolution mass spectrometric data were obtained on a Waters Quattro Micro GCMS (EI^+). Chiral GC analysis was performed using an Agilent 7890A GC system using commercially available CHIRALDEX columns.

General procedure for catalyst and reaction condition optimization:

Catalyst (2.6 µmol−10.4 µmol, 5.0–20.0 mol%) and *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 12.8−17.4 mg, 57.2–78.0 µmol, 1.10−1.50 equiv), and dichloromethane (0.52–2.60 mL) were combined in a polyethylene tube at room temperature. Pyridinium poly(hydrogen fluoride) (pyr•9HF, 0.0400 mL–0.140 mL, 25.0–100.0 equiv HF) was added via micropipette, followed by **2a** (9.6 mg, 52.0 µmol, 1 equiv) and dodecane (11.4 µL, 52.0 µmol, 1.00 equiv). The reaction was stirred for 6–12 hours at room temperature. The reaction was cooled to −78 ˚C and basic alumina (approximately 750 mg) was added slowly. The reaction was allowed to warm to room temperature with stirring and was filtered. The crude mixture was analyzed by GC to determine starting material conversion and yield of product.



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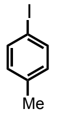
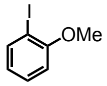
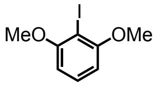
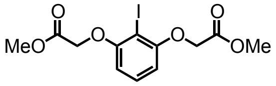
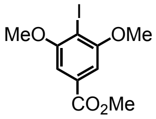
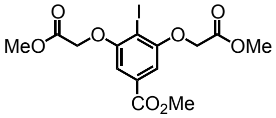
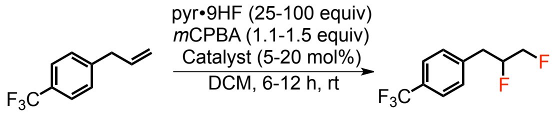
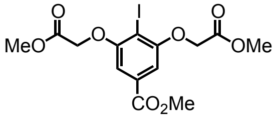
1		100%	70%
2		100%	46%
3		100%	45%
4		100%	32%
5		100%	57%
6		100%	70%
7	none	100%	0%

Table S1: Catalyst optimization. [a] Determined by GC using dodecane as an internal standard.

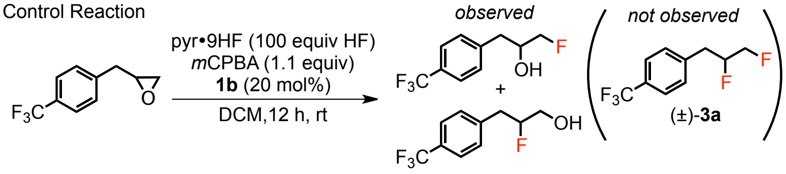


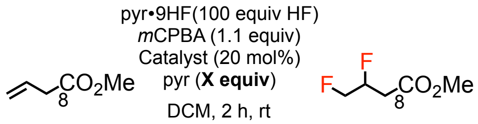


1b

Entry	Mol% Catalyst	Equiv. *m*CPBA (HF)	[Substrate]/ (M)	Conversion[a]	Yield[a]
1	20	1.5 (5)	0.1	75%	1%
2	20	1.5 (10)	0.1	80%	18%
3	20	1.5 (100)	0.1	100%	58%
4	5	1.5 (25)	0.1	100%	44%
5	10	1.5 (25)	0.1	100%	50%
6	20	1.1 (25)	0.1	100%	60%
7	20	1.5 (25)	0.05	100%	62%
8[b]	10	1.1 (25)	0.05	98%	61%
9[b]	20	1.1 (100)	0.05	100%	70%

Table S2. Reaction condition optimization. [a] Determined by GC using dodecane as an internal standard. [b] Reaction run for 12 hours.





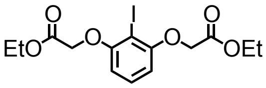
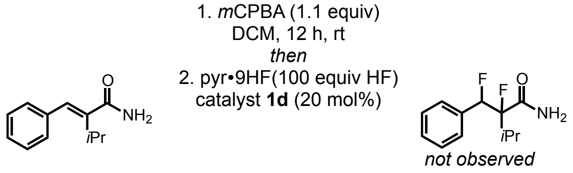
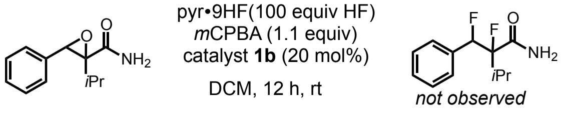
Entry	Catalyst	Equiv Pyr	Conversion[a]	Yield[a]
1		0.5	98%	13%
2	"	1.0	81%	18%
3	"	2.0	77%	20%
4	"	4.0	70%	28%
5	**"**	**6.0**	**75%**	**67%**
6	"	8.0	10%	0%

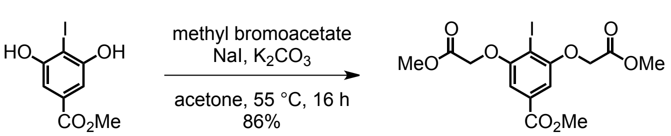
Table S3. Pyridine additive optimization for isolated alkenes. [a] Determined by GC using dodecane as an internal standard.

Enantioselective Reaction Control Experiments:



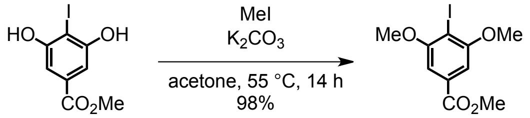


Synthesis and Characterization of Catalysts and Substrates



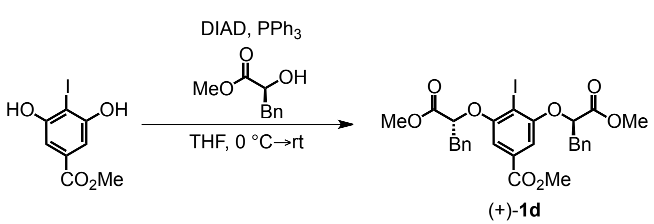
1b

1b: Methyl bromoacetate (6.43 mL, 68.0 mmol, 4.00 equiv) was added via syringe to a vigorously stirred mixture of methyl 3,5-dihydroxy-4-iodobenzoate[2] (5.00 g, 17.0 mmol, 1 equiv), K_2CO_3 (9.39 g, 68.0 mmol, 4.00 equiv), and NaI (2.55 g, 17.0 mmol, 1.00 equiv) in acetone (160 mL) at room temperature. The resulting mixture was warmed to 55 °C in an oil bath. After 16 h, the reaction mixture was cooled to room temperature and was concentrated under reduced pressure. The resulting solids were dissolved in ethyl acetate (250 mL) and water (150 mL). The organic layer was separated, and the aqueous layer was extracted with ethyl acetate (250 mL). The combined organic layers were dried over anhydrous $MgSO_4$, were filtered, and were concentrated under reduced pressure. The resulting solid was recrystallized twice from ethyl acetate to give **1b** (6.40 g, 86%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.07 (s, 2H), 4.78 (s, 4H), 3.90 (s, 3H), 3.81 (s, 6H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 168.6, 166.1, 158.4, 132.1, 106.7, 86.0, 66.5, 52.7, 52.6; FTIR (thin film) ν 3002 (w), 1758 (s), 1719 (s), 1581 (m), 1435 (m), 1417 (s), 1241 (s), 1209 (s), 1077 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{14}H_{15}IO_8$ $[M+H]^+$: 438.9884; found 438.9889.



1c

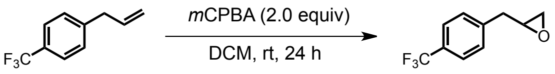
1c: Iodomethane (8.51 mL, 136 mmol, 4.00 equiv) was added via syringe to a vigorously stirred mixture of methyl 3,5-dihydroxy-4-iodobenzoate[2] (10.0 g, 34.0 mmol, 1 equiv), and K_2CO_3 (18.8 g, 136 mmol, 4.00 equiv) in acetone (170 mL) at room temperature. The resulting mixture was warmed to 55 °C in an oil bath. After 14 h, the reaction mixture was cooled to room temperature, diethyl ether (400 mL) was added, and the resulting mixture was filtered. The filtrate was washed sequentially with water (200 mL) and brine (100 mL), was dried over anhydrous $MgSO_4$, was filtered, and was concentrated under reduced pressure to give **1c** (10.7 g, 98%) as a white powder. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.10 (s, 2H), 3.89 (s, 6H), 3.87 (s, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 166.7, 159.7, 132.0, 104.9, 84.4, 57.0, 52.6; FTIR (thin film) ν 3090 (w), 2949 (w), 1712 (s), 1581 (m), 1452 (m), 1404 (s), 1325 (s), 1240 (s), 1229 (s), 1116 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{12}IO_4$ $[M+H]^+$: 322.9775; found 322.9780.



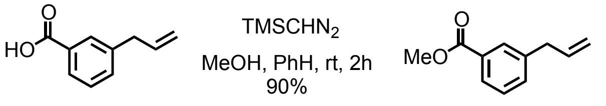
(+)-**1d**
65%

1d: Diisopropyl azodicarboxylate (1.55 mL, 7.90 mmol, 2.31 equiv) was added dropwise via syringe over 30 minutes to a stirred suspension of methyl 3,5-dihydroxy-4-iodobenzoate[2] (500 mg, 3.42 mmol, 1 equiv), triphenylphosphine (2.44 g, 9.30 mmol, 2.70 equiv), and benzyl (*S*)-methyl 2-hydroxy-3-phenylpropanoate (1.29 g, 7.18 mmol, 2.10 equiv) in tetrahydrofuran (32.0

mL) at 0 °C. The reaction mixture was warmed to room temperature. After 12 hours, the reaction mixture was concentrated under reduced pressure. The residue was was purified by flash column chromatography on a column composed of basic alumina layered on top of silica gel (1:1 w/w) (5 to 60% diethyl ether in hexanes) to give **1d** as a white solid (1.38 g, 65%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 (d, *J* = 7.6 Hz, 4H), 7.32 (t, *J* = 7.3 Hz, 4H), 7.27–7.23 (m, 2H), 6.88 (s, 2H), 4.94 (dd, *J* = 4.9, 7.8 Hz, 2H), 3.85 (s, 3H), 3.70 (s, 6H), 3.37 (dd, *J* = 7.8, 14.2 Hz, 2H), 3.33 (dd, *J* = 4.9, 14.2 Hz, 6H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 170.7, 166.1, 158.2, 136.1, 131.8, 130.1, 128.6, 127.3, 106.6, 86.3, 78.9, 52.6, 52.6, 39.2; FTIR (thin film) ν 3028 (w), 2952 (w), 1753 (s), 1721 (s), 1577 (m), 1434 (m), 1417 (s), 1325 (m), 1243 (s), 1197 (s), 1113 (s), 1011 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{28}H_{28}IO_8$ $[M+H]^+$: 619.0823; found 619.0817; $[\alpha]_D^{22}$ = +58.0 (c = 0.80, $CHCl_3$).

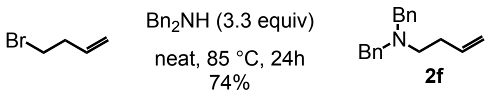


2-(4-(trifluoromethyl)benzyl)oxirane: *meta*-Chloroperoxybenzoic acid (77%) (*m*CPBA, 241 mg, 1.07 mmol, 2.00 equiv) and 1-allyl-4-trifluoromethyl benzene (100 mg, 0.54 mmol, 1 equiv) were dissolved in dichloromethane (5 mL) and the reaction mixture was stirred at room temperature for 24 hours. The reaction mixture was poured into saturated aqueous $NaHCO_3$ solution (15 mL) and the organic layer was separated. The aqueous layer was further extracted with dichloromethane (10 mL), and the combined organic layers were dried with anhydrous $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by flash column chromatography on silica gel (0% to 20% diethyl ether in hexanes) to give 2-(4-(trifluoromethyl)benzyl)oxirane (64 mg, 59%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) 7.57 (d, *J* = 8.3 Hz, 2H), 7.38 (d, *J* = 7.8 Hz, 2H), 3.19–3.12 (m, 1H), 3.00–2.87 (m, 2H), 2.81 (dd, *J* = 7.8, 7.8 Hz, 1H), 2.54 (dd, *J* = 4.9, 2.4 Hz, 1H); ^{13}C NMR (125.7 MHz, $CDCl_3$) 141.5, 129.6, 129.3 (q, *J* = 32.6 Hz), 125.6 (q, *J* = 3.8 Hz), 124.4 (q, *J* = 271.4 Hz), 52.1, 46.8, 38.6; ^{19}F NMR (470.4 MHz, $CDCl_3$) −62.5; FTIR (thin film) ν 3055 (w), 2997 (w), 2922 (w), 1323 (s), 1105 (s), 1066 (s); HRMS (ESI-TOF) Calc'd for $C_{10}H_9F_3O$ $[M+H]^+$: 203.0684; found 203.0678.



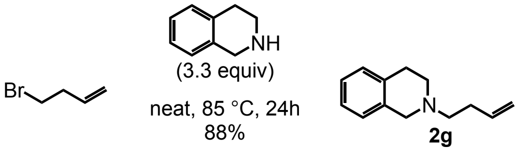
2c

2c: (Trimethylsilyl)diazomethane solution (2 M in hexanes, 1.35 mL, 2.71 mmol, 1.10 equiv) was added dropwise via syringe to a stirred mixture of 3-allylbenzoic acid (400 mg, 2.47 mmol, 1 equiv) in methanol (5.4 mL) and benzene (13 mL) at room temperature. After 2 hours, HCl solution (2.0 M in diethyl ether, 1.00 mL) was added via syringe, and the mixture was concentrated under reduced pressure. The resulting residue was purified by flash column chromatography on silica gel (0% to 30% diethyl ether in hexanes) to give **2c** (392 mg, 90%) as a colorless oil. The spectral data for **2c** were in accordance with literature data.[3]

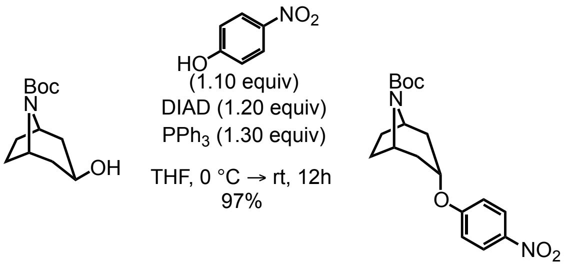


2f

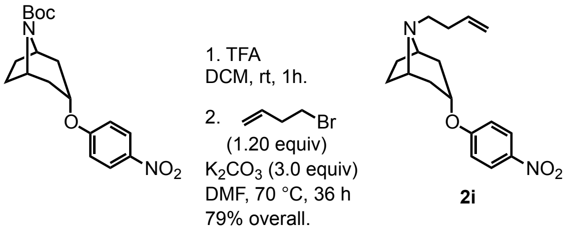
2f: *N,N*-dibenzylamine (3.85 mL, 20.0 mmol, 3.33 equiv) and 4-bromo-1-butene (1.02 mL, 6.80 mmol, 1 equiv) were combined at room temperature, and the resulting mixture was warmed to 85 °C in an oil bath and stirred for 24 hours. The resulting mixture was cooled to room temperature and purified by flash column chromatography on silica gel (0% to 20% ethyl acetate in hexanes) to give **2f** (1.26 g, 74%) as a pale brown oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43–7.42 (m, 4H), 7.36 (t, *J* = 7.6 Hz, 4H), 7.29–7.26 (m, 2H), 5.84–5.79 (m, 1H), 5.08–5.00 (m, 2H), 3.63 (s, 4H), 2.57 (t, *J* = 7.3 Hz, 2H), 2.34 (q, *J* = 7.0 Hz, 2H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 140.0, 137.2, 129.0, 128.3, 127.0, 115.5, 58.3, 53.1, 31.8; FTIR (thin film) ν 2793 (w), 1493 (m), 1452 (m), 908 (m), 731 (m), 696 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{18}H_{21}N$ [M+H]$^+$: 252.1747; found 252.1753.



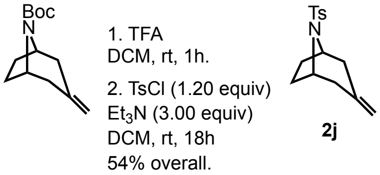
2g: 1,2,3,4-tetrahydroisoquinoline (2.50 mL, 20.0 mmol, 3.33 equiv) and 4-bromo-1-butene (1.02 mL, 6.80 mmol, 1 equiv) were combined at room temperature, and the resulting mixture was warmed to 85 °C in an oil bath and stirred for 24 hours. The resulting mixture was cooled to room temperature and purified by flash column chromatography on silica gel (0% to 80% diethyl ether in hexanes) to give **2g** (1.12 g, 88%) as a pale brown oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.16–7.11 (m, 3H), 7.06–7.04 (m, 1H), 5.94–5.86 (m, 1H), 5.16–5.05 (m, 2H), 3.68 (s, 2H), 2.94 (t, *J* = 5.9 Hz, 2H), 2.78 (t, *J* = 5.9 Hz, 2H), 2.65–2.62 (m, 2H), 2.43–2.38 (m, 2H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 136.7, 134.9, 134.4, 128.8, 126.7, 126.2, 125.7, 115.8, 57.9, 56.2, 51.0, 31.9, 29.2; FTIR (thin film) ν 2919 (w), 1097 (m), 936 (m), 738 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{13}H_{17}N$ [M+H]$^+$: 188.1434; found 188.1429.



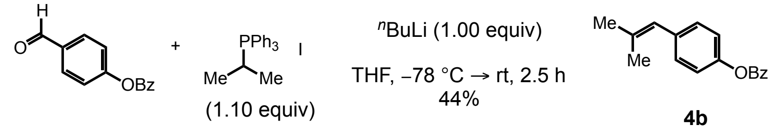
***tert*-Butyl 3-(4-nitrophenoxy)-8-azabicyclo[3.2.1]octane-8-carboxylate:** Diisopropyl azodicarboxylate (DIAD, 0.877 mL, 4.48 mmol, 1.20 equiv) was added dropwise over 45 minutes via syringe to a stirred mixture of *tert*-butyl 3-hydroxy-8-azabicyclo[3.2.1]octane-8-carboxylate (850 mg, 3.73 mmol, 1 equiv), triphenylphosphine (1.27 g, 4.85 mmol, 1.30 equiv), and 4-nitrophenol (571 mg, 4.10 mmol, 1.10 equiv) in tetrahydrofuran (30 mL) at 0 °C, and the resulting mixture was warmed to room temperature. After 12 hours, the reaction mixture was concentrated under reduced pressure, and the residue was purified by flash column chromatography on silica gel (0% to 40% ethyl acetate in hexanes) to give *tert*-butyl 3-(4-nitrophenoxy)-8-azabicyclo[3.2.1]octane-8-carboxylate (1.26 g, 97%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (d, *J* = 9.4 Hz, 2H), 6.86 (d, *J* = 9.4 Hz, 2H), 4.73–4.71 (m, 1H), 4.25–4.18 (m, 2H), 2.22–2.15 (m, 2H), 2.35–1.90 (m, 6H), 1.46 (s, 9H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 162.6, 153.5, 141.4, 126.2, 115.2, 79.6, 71.7, 52.8, 52.0, 35.0, 34.3, 28.7, 28.5, 27.8; FTIR (thin film) ν 3086 (w), 1686 (s), 1607 (m), 1591 (m), 1297 (m), 1251 (m), 1162 (m), 1033 (s), 820 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{18}H_{24}N_2O_5$ [M+H]$^+$: 349.1769; found 349.1758.



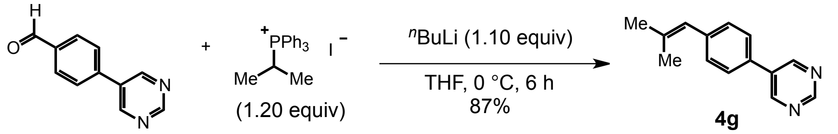
2i: Trifluoroacetic acid (8.4 mL) was added via syringe to a stirred solution of *tert*-butyl 3-(4-nitrophenoxy)-8-azabicyclo[3.2.1]octane-8-carboxylate (1.17 g, 3.36 mmol, 1 equiv) in dichloromethane (8.4 mL) at room temperature. After 1 hour, the reaction mixture was concentrated under reduced pressure. K_2CO_3 (1.39 g, 10.0 mmol, 3.00 equiv) was added as a solid under a nitrogen atmosphere, and *N*,*N*-dimethylformamide (19 mL) and 4-bromo-1-butene (0.410 mL, 4.00 mmol, 1.20 equiv) were added sequentially via syringe. The resulting mixture was warmed to 70 °C in an oil bath. After 36 hours, the reaction mixture was cooled to room temperature, was diluted with 100 mL ethyl acetate and washed with water (5 × 100 mL). The organic layer was dried with anhydrous $MgSO_4$ and was concentrated under reduced pressure. The resulting residue was purified by flash column chromatography (25% to 100% ethyl acetate in hexanes) to give **2i** (801 mg, 79% over 2 steps) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13–8.10 (m, 2H), 6.83–6.80 (m, 2H), 5.80–5.77 (m, 1H) 5.03–4.93 (m, 2H), 4.60–4.58 (m, 1H), 3.22 (s, 2H), 2.41–2.38 (m, 2H), 2.20–2.15 (m, 4H), 1.94–1.84 (m, 6H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 162.7, 141.1, 136.6, 126.1, 115.7, 115.1, 71.4, 58.0, 51.8, 35.4, 33.5, 26.1; FTIR (thin film) ν 2925 (w), 1606 (m), 1590 (m), 1336 (s), 1249 (s), 1108 (m), 1037 (m), 843 (w) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{22}N_2O_3$ $[M+H]^+$: 303.1703; found 303.1712.



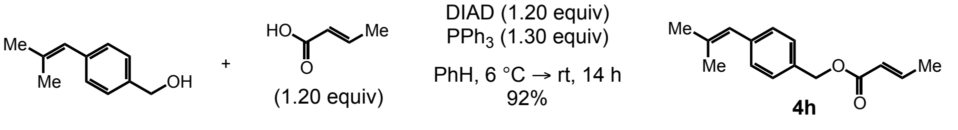
2j: Trifluoroacetic acid (10 mL) was added via syringe to a stirred solution of *tert*-Butyl 3-methylene-8-azabicyclo[3.2.1]octane-8-carboxylate (900 mg, 3.86 mmol, 1 equiv) in dichloromethane (10 mL) at room temperature. After 1 hour, the reaction mixture was concentrated under reduced pressure. Dichloromethane (20 mL) and triethylamine (1.63 mL, 11.57 mmol, 3.00 equiv) were added sequentially via syringe, then tosyl chloride (883 mg, 4.63 mmol, 1.20 equiv) was added as a solid under a nitrogen atmosphere. After 18 hours, aqueous HCl solution (1 M, 30 mL) was added. The organic layer was separated and was washed sequentially with saturated aqueous $NaHCO_3$ solution (30 mL) and water (30 mL). The organic layer was dried over anhydrous $MgSO_4$ and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0% to 20% ethyl acetate in hexanes) to give **2j** (578 mg, 54% over 2 steps) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.75 (d, *J* = 8.3 Hz, 2H), 7.27 (d, *J* = 8.3 Hz, 2H), 4.83 (s, 2H), 4.26 (s, 2H), 2.56 (d, *J* = 13.7 Hz, 2H), 2.42 (s, 3H), 2.12 (d, *J* = 13.7 Hz, 2H), 1.43 (s, 4H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 143.5, 141.2, 137.5, 129.8, 127.4, 114.5, 57.5, 42.5, 28.4, 21.7; FTIR (thin film) ν 2976 (w), 1304 (s), 1252 (s), 1150 (s), 678 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{15}H_{19}NO_2S$ $[M+H]^+$: 278.1209; found 278.1216.



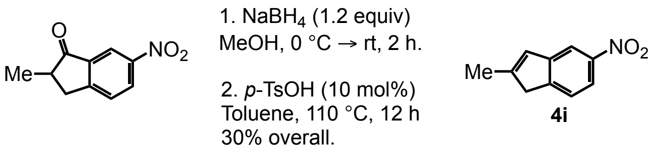
4b: A solution of *n*-butyllithium (2.38 M in hexanes, 3.05 mL, 7.25 mmol, 1.00 equiv) was added via syringe to a stirred suspension of isopropyltriphenylphosphonum iodide (3.45 g, 7.97 mmol, 1.10 equiv) in tetrahydrofuran (18.1 mL) at 0 °C. After 30 min, the reaction mixture was cooled to −78 °C. After 15 min, a solution of 4-formylphenyl benzoate[4] (1.64 g, 7.25 mmol, 1 equiv) in tetrahydrofuran (18.1 mL) was added via cannula. The resulting mixture was allowed to warm to −50 °C over 90 min and then warmed to room temperature. After 1 h, pH 7 buffer (20 mL) was added followed by diethyl ether (100 mL). The organic layer was washed sequentially with water (100 mL) and brine (100 mL), was dried over anhydrous $MgSO_4$, and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 2% ethyl acetate in hexanes) to give 4-(2-methylprop-1-en-1-yl)phenyl benzoate (**4b**, 805 mg, 44%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.22 (d, J = 8.3 Hz, 2H), 7.64 (t, J = 7.6 Hz, 1H), 7.52 (t, J = 7.8 Hz, 2H), 7.29 (d, J = 8.3 Hz, 2H), 7.18 (d, J = 8.3 Hz, 2H), 6.29 (s, 1H), 1.93 (d, J = 1.0 Hz, 3H), 1.89 (d, J = 1.0 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 165.5, 149.0, 136.7, 136.0, 133.7, 130.4, 129.9, 129.9, 128.7, 124.5, 121.4, 27.0, 19.6; FTIR (thin film) ν 2978 (w), 1728 (s), 1503 (m), 1451 (m), 1264 (s), 1201 (s), 1064 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{17}O_2$ [M+H]$^+$: 253.1223; found 253.1227.



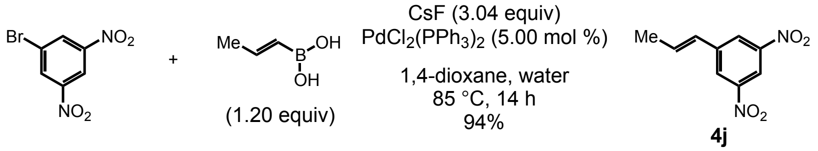
4g: A solution of *n*-butyllithium in (2.50 M in hexanes, 2.40 mL, 5.97 mmol, 1.10 equiv) was added via syringe to a stirred suspension of isopropyltriphenylphosphonium iodide (2.82 g, 6.52 mmol, 1.20 equiv) in tetrahydrofuran (20 mL) at 0 °C. After 1 hour, a solution of 4-(pyrimidin-5-yl)benzaldehyde (1.00 g, 5.42 mmol, 1 equiv) in tetrahydrofuran (5 mL) was added dropwise via cannula. After 5 hours, hexanes (50 mL) was added. The resulting heterogeneous mixture was filtered, and the filtrate was diluted with ethyl acetate (50 mL) and washed with water (50 mL). The organic layer was separated, and the aqueous layer was washed with ethyl acetate (50 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 80% ethyl acetate in hexanes) to give **4g** (991 mg, 87%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.15 (s, 1H), 8.92 (s, 2H), 7.50 (d, J = 7.8 Hz, 2H), 7.33 (d, J = 7.8 Hz, 2H), 6.27 (s, 1H), 1.91 (s, 3H), 1.88 (s, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 157.4, 154.8, 139.7, 137.1, 134.2, 131.5, 129.8, 126.6, 124.4, 27.1, 19.7; FTIR (thin film) ν 3017 (w), 1413 (m), 853 (m), 731 (m), 561 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{14}H_{14}N_2$ [M+H]$^+$: 211.1227; found 211.1230.



4h: Diisopropyl azodicarboxylate (DIAD, 2.45 mL, 12.6 mmol, 1.20 equiv) was added via syringe to a stirred solution of (4-(2-methylprop-1-en-1-yl)phenyl)methanol[5] (1.70 g, 10.5 mmol, 1 equiv), crotonic acid (1.08 g, 12.6 mmol, 1.20 equiv), and triphenylphosphine (3.57 g, 13.6 mmol, 1.30 equiv) in benzene (52.4 mL) at 6 °C, and the resulting mixture was warmed to room temperature. After 14 h, the reaction mixture was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 1% ethyl acetate in hexanes) to give **4h** (2.21 g, 92%) as a colorless oil. ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.33 (d, *J* = 8.3 Hz, 2H), 7.23 (d, *J* = 8.3 Hz, 2H), 7.03 (qd, *J* = 6.8, 15.6 Hz, 1H), 6.27 (s, 1H), 5.91 (qd, *J* = 2.0, 15.6 Hz, 1H), 5.16 (s, 2H), 1.92 (d, *J* = 1.5 Hz, 3H), 1.88 (dd, *J* = 6.8, 2.0 Hz, 3H), 1.87 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 166.5, 145.2, 138.8, 136.0, 133.7, 129.0, 128.2, 124.9, 122.7, 66.0, 27.0, 19.5, 18.1; FTIR (thin film) ν 2968 (w), 2911 (w), 1718 (s), 1657 (m), 1442 (m), 1260 (m), 1171 (s), 1012 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{15}H_{19}O_2$ [M+H]$^+$: 248.1645; found 248.1642.

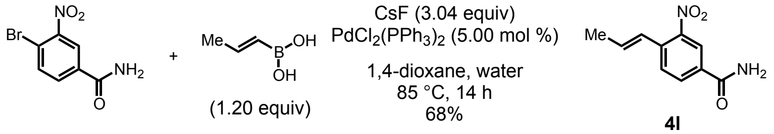


4i: NaBH$_4$ (310 mg, 8.16 mmol, 1.2 equiv) was added as a solid under a nitrogen atmosphere in portions over 20 minutes to a stirred solution of 2-methyl-6-nitro-2,3-dihydro-1*H*-inden-1-one[6] (1.30 g, 6.80 mmol, 1 equiv) in methanol (20 mL) at 0 °C, and the resulting mixture was allowed to warm to room temperature. After 2 hours, saturated aqueous NH$_4$Cl solution (50 mL) was added, and the mixture was extracted with dichloromethane (3 × 100 mL). The combined organic layers were dried over anhydrous MgSO$_4$ and were concentrated under reduced pressure to give a pale green solid. To this solid was added *p*-toluenesulfonic acid monohydrate (129 mg, 0.680 mmol, 0.100 equiv) and toluene (20 mL). The resulting mixture was warmed to 110 °C in an oil bath and stirred for 12 hours. The resulting mixture was cooled to room temperature and saturated aqueous NaHCO$_3$ solution (50 mL) was added. The aqueous layer was extracted with ethyl acetate (3 × 100 mL), and the combined organic layers were dried over anhydrous MgSO$_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography (0 to 20% ether in hexanes) to give a mixture of 2-methyl-5-nitro-1*H*-indene (**4i**) and 2-methyl-6-nitro-1*H*-indene. This mixture was recrystallized from hexanes to give pure 2-methyl-5-nitro-1*H*-indene (**4i**, 362 mg, 30% over 2 steps) as pale yellow needles. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.02 (d, *J* = 2.0 Hz, 1H), 7.99–7.97 (m, 1H), 7.43 (d, *J* = 7.8 Hz, 1H), 6.53 (s, 1H), 3.38 (s, 2H), 2.19 (s, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 150.5, 149.8, 147.6, 147.3, 126.6, 123.5, 119.3, 114.5, 43.0, 17.0; FTIR (thin film) ν 1606 (m), 1345 (s), 823 (s), 734 (s), 416 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_9NO_2$ [M+H]$^+$: 175.0706; found 176.0714.

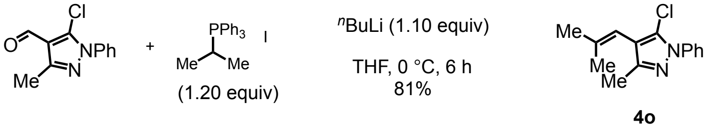


4j: Bis(triphenylphosphine)palladium(II) dichloride (284 mg, 405 μmol, 5.00 mol %) was added as a solid under a nitrogen atmosphere to a vigorously stirred biphasic mixture of 1-bromo-3,5-dinitrobenzene[7] (2.00 g, 8.10 mmol, 1 equiv), (*E*)-prop-1-en-1-ylboronic acid (835 mg, 9.72 mmol, 1.20 equiv), and CsF (3.74 g, 24.6 mmol, 3.04 equiv) in 1,4-dioxane (45.4 mL) and water (22.7 mL) at room temperature. The resulting mixture was warmed to 85 °C. After 14 h, the reaction mixture was cooled to room temperature, and ethyl acetate (200 mL) was added. The organic layer was washed with brine (150 mL), was dried over anhydrous Na$_2$SO$_4$, was filtered, and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 15% dichloromethane in hexanes) to give **4j** (1.58 g, 94%) as a yellow solid. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.84 (d, *J* = 2.0 Hz, 1H), 8.46 (d, *J* = 2.0 Hz, 2H), 6.60 (qd, *J* = 6.4, 15.7 Hz, 1H), 6.53 (d, *J* = 15.7 Hz, 1H), 2.00 (dd, *J* = 6.4, 1.5 Hz, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 149.0, 141.9, 133.3, 127.6, 125.6, 116.5, 18.8; FTIR (thin film) ν

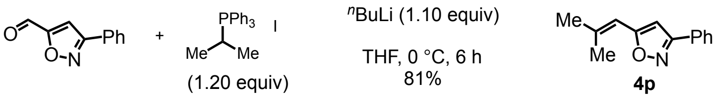
3104 (w), 2916 (w), 1540 (s), 1341 (s), 1292 (m), 1073 (w), 974 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_9H_9N_2O_4$ [M+H]$^+$: 209.0557; found 209.0547.



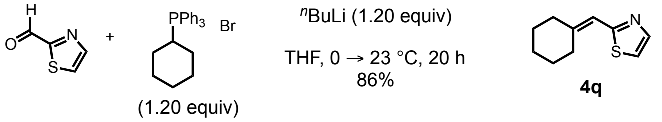
4l: Bis(triphenylphosphine)palladium(II) dichloride (274 mg, 391 μmol, 5.00 mol %) was added as a solid under a nitrogen atmosphere to a vigorously stirred biphasic mixture of 4-bromo-3-nitrobenzamide[8] (1.91 g, 7.81 mmol, 1 equiv), (*E*)-prop-1-en-1-ylboronic acid (805 mg, 9.38 mmol, 1.20 equiv), and CsF (3.61 g, 23.8 mmol, 3.04 equiv) in 1,4-dioxane (43.8 mL) and water (21.9 mL) at room temperature. The resulting mixture was warmed to 85 °C. After 14 h, the reaction mixture was cooled to room temperature, and ethyl acetate (200 mL) was added. The organic layer was washed with brine (150 mL), was dried over anhydrous Na_2SO_4, was filtered, and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 70% ethyl acetate in hexanes) to give **4l** (1.10 g, 68%) as a tan solid. ^{1}H NMR (500 MHz, acetone-d_6) δ 8.40 (d, J = 2.0 Hz, 1H), 8.16 (dd, J = 8.3, 2.0 Hz, 1H), 7.83 (d, J = 8.3 Hz, 1H), 7.84–7.68 (br-s, 1H), 7.14–6.91 (br-s, 1H), 6.79 (qd, J = 2.0, 15.6 Hz, 1H), 6.52 (qd, J = 6.8, 15.6 Hz, 1H), 1.94 (d, J = 2.0, 6.8 Hz, 3H); ^{13}C NMR (125.7 MHz, acetone-d_6) δ 166.8, 148.6, 135.9, 134.7, 134.3, 132.4, 129.1, 125.9, 124.3, 19.1; FTIR (thin film) ν 3353 (br-m), 3196 (br-m), 2972 (w), 2912 (w), 1660 (s), 1617 (s), 1527 (s), 1445 (w), 1405 (m), 1344 (m), 958 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{11}N_2O_3$ [M+H]$^+$: 207.0764; found 207.0755.



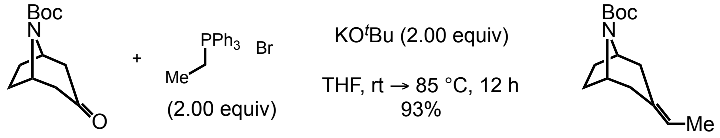
4o: A solution of *n*-butyllithium (2.50 M in hexanes, 2.00 mL, 4.98 mmol, 1.10 equiv) was added dropwise via syringe to a stirred suspension of isopropyltriphenylphosphonium iodide (2.35 g, 5.44 mmol, 1.20 equiv) in tetrahydrofuran (18 mL) at 0 °C. After 1 h, a solution of 5-chloro-3-methyl-1-phenyl-1*H*-pyrazole-4-carbaldehyde (1.00 g, 4.53 mmol, 1 equiv) in tetrahydrofuran (5 mL) was added dropwise via cannula. After 5 hours, hexanes (50 mL) was added. The resulting heterogeneous mixture was filtered, and the filtrate was diluted with ethyl acetate (50 mL) and washed with water (50 mL). The aqueous layer was extracted with ethyl acetate (50 mL), and the combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0% to 20% ethyl acetate in hexanes) to give **4o** (906 mg, 81%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 (d, J = 8.3 Hz, 2H), 7.46–7.43 (m, 2H), 7.36–7.32 (m, 1H), 5.84 (s, 1H), 2.23 (s, 3H), 1.92 (s, 3H), 1.69 (s, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 148.9, 139.5, 138.7, 129.0, 127.8, 124.0, 124.8, 116.9, 113.0, 25.8, 20.2, 13.4; FTIR (thin film) ν 2970 (w), 1500 (s), 1719 (s), 1358 (m), 992 (m), 758 (s), 692 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{14}H_{15}ClN_2$ [M+H]$^+$: 247.0997; found 247.1000.



4p: A solution of *n*-butyllithium (2.50 M in hexanes, 2.54 mL, 6.35 mmol, 1.10 equiv) was added dropwise via syringe to a stirred suspension of isopropyltriphenylphosphonium iodide (3.00 g, 6.93 mmol, 1.20 equiv) in tetrahydrofuran (21 mL) at 0 °C. After 1 hour, a solution of 3-phenylisoxazole-5-carbaldehyde (1.00 g, 5.77 mmol, 1 equiv) in tetrahydrofuran (5 mL) was added dropwise via cannula. After 5 hours, hexanes (50 mL) was added. The resulting heterogeneous mixture was filtered, and the filtrate was diluted with ethyl acetate (50 mL) and washed with water (50 mL). The aqueous layer was extracted with ethyl acetate (50 mL), and the combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0% to 20% ethyl acetate in hexanes) to give **4p** (936 mg, 81%) as a white solid. ^1H NMR (500 MHz, $CDCl_3$) δ 7.83–7.81 (m, 2H), 7.44–7.41 (m, 3H), 6.36 (s, 1H), 6.19 (s, 1H), 2.07 (s, 3H), 1.95 (s, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 169.5, 162.2, 144.1, 129.8, 129.5, 128.9, 126.8, 111.8, 99.5, 27.3, 20.7; FTIR (thin film) ν 2912 (w), 2149 (m), 1403 (s), 761 (s), 691 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{13}H_{13}NO$ $[M+H]^+$: 200.1070; found 200.1066.

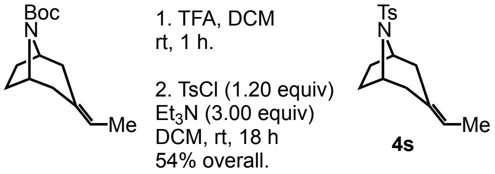


4q: A solution of *n*-butyllithium (2.41 M in hexanes, 2.20 mL, 5.30 mmol, 1.20 equiv) was added via syringe to a stirred suspension of cyclohexyltriphenylphosphonum bromide (2.26 g, 5.30 mmol, 1.20 equiv) in tetrahydrofuran (22.1 mL) at 0 °C. After 30 min, thiazole 2-carbaldehyde (388 μL, 4.42 mmol, 1 equiv) was added via syringe, and the resulting mixture was warmed to room temperature. After 20 h, saturated aqueous NH_4Cl solution (10 mL) and diethyl ether (100 mL) were added sequentially. The organic layer was washed sequentially with water (100 mL) and brine (100 mL), was dried over anhydrous $MgSO_4$, and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 7% ethyl acetate in hexanes) to give **4q** (678 mg, 86%) as a yellow oil. ^1H NMR (500 MHz, $CDCl_3$) δ 7.73 (d, J = 3.4 Hz, 1H), 7.18 (d, J = 3.4 Hz, 1H), 6.41 (s, 1H), 2.78 (t, J = 5.6 Hz, 2H), 2.28 (t, J = 6.1 Hz, 2H), 1.70–1.58 (m, 6H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 165.9, 150.3, 142.6, 117.6, 115.6, 38.0, 30.7, 28.7, 27.6, 26.5; FTIR (thin film) ν 2925 (m), 2852 (w), 1639 (m), 1489 (m), 1446 (m), 1140 (m), 1070 (s), 800 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{14}NS$ $[M+H]^+$: 180.0841; found 180.0846.

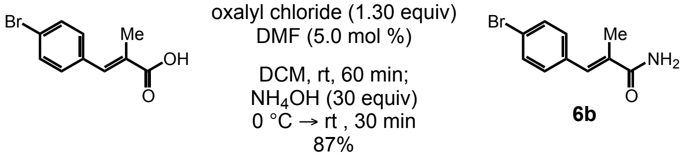


***tert*-Butyl 3-ethylidene-8-azabicyclo[3.2.1]octane-8-carboxylate:** Potassium *tert*-butoxide (2.00 g, 17.7 mmol, 2.00 equiv) was added as a solid under a nitrogen atmosphere to a stirred suspensions of ethyltriphenylphosphonium bromide (5.70 g, 17.7 mmol, 2.00 equiv) in tetrahydrofuran (80 mL) at room temperature. After 2 hours, a solution of *N*-Boc nortropinone (2.00 g, 8.87 mmol, 1 equiv) in tetrahydrofuran (10 mL) was added dropwise via cannula, and the resulting mixture has warmed to 85 °C in an oil bath. After 12 hours, the reaction mixture was cooled to room temperature, hexanes (100 mL) was added, and the resulting suspension was filtered. The filtrate was diluted with ethyl acetate (100 mL) and washed with saturated aqueous NH_4Cl solution (100 mL). The organic layer was separated, was washed with water (100 mL), was dried with anhydrous $MgSO_4$, and was concentrated under reduced pressure. The residue was purified by flash column chromatography (0% to 40% ethyl acetate in hexanes) to give *tert*-butyl 3-ethylidene-8-azabicyclo[3.2.1]octane-8-carboxylate (1.95 g, 93%) as a white solid. ^1H NMR (500 MHz, $CDCl_3$) δ 5.36–5.32 (m, 1H), 4.27–4.13 (m, 2H), 2.51–2.37 (m, 1H), 2.35 (d, J = 14.2 Hz, 1H), 2.19–2.09 (m, 1H), 1.93 (d, J = 13.7, 1H), 1.92–1.82 (m, 2H), 1.58–1.33 (m, 14H); ^{13}C

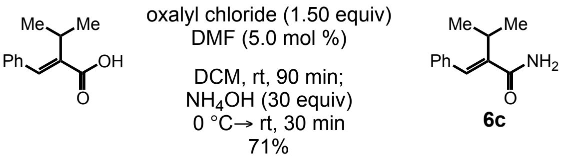
NMR (125.7 MHz, $CDCl_3$) δ153.8, 132.6, 122.1, 79.3, 54.8, 54.4, 54.2, 53.7, 42.5, 41.8, 34.8, 34.1, 29.0, 28.7, 28.5, 28.3, 27.9, 13.0; FTIR (thin film) ν 2974 (w), 1693 (s), 1390 (s), 1170 (s), 1123 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{14}H_{23}NO_2$ $[M+Na]^+$: 260.1621; found 260.1617.



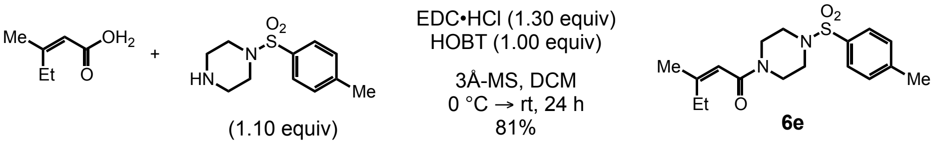
4s: Trifluoroacetic acid (10 mL) was added via syringe to a stirred solution of *tert*-butyl 3-ethylidene-8-azabicyclo[3.2.1]octane-8-carboxylate (800 mg, 3.37 mmol, 1 equiv) in dichloromethane (10 mL) at room temperature. After 1 hour, the reaction mixture was concentrated under reduced pressure. Dichloromethane (14 mL) and triethylamine (1.40 mL, 10.1 mmol, 3.00 equiv) were added sequentially via syringe, then tosyl chloride (1.28 mg, 6.74 mmol, 2.00 equiv) was added as a solid under a nitrogen atmosphere. After 18 hours, aqueous HCl solution (1 M, 30 mL) was added. The organic layer was separated and was washed sequentially with saturated aqueous $NaHCO_3$ solution (30 mL) and water (30 mL). The organic layer was dried over anhydrous $MgSO_4$ and was concentrated under reduced pressure. The residue was purified by flash column chromatography (0% to 20% ethyl acetate in hexanes) to give **4s** (531 mg, 54% over 2 steps) as a white solid. ^1H NMR (500 MHz, $CDCl_3$) δ 7.76 (d, J = 8.3 Hz, 2H), 7.27 (d, J = 8.3 Hz, 2H), 5.34 (q, J = 6.8 Hz, 1H), 4.28–4.22 (m, 2H), 2.58 (d, J = 13.7 Hz, 1H), 2.44–2.41 (m, 4H), 2.22 (d, J = 13.7 Hz, 1H), 2.01 (d, J = 13.7, 1H), 1.56–1.54 (m, 3H), 1.42–1.31 (m, 4H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ143.4, 137.6, 131.3, 129.7, 127.5, 123.1, 57.7, 57.2, 43.7, 36.1, 28.7, 28.3, 21.7, 13.0; FTIR (thin film) ν 2973 (w), 1340 (s), 1160 (s), 1096 (m), 709 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{16}H_{21}NO_2S$ $[M+H]^+$: 292.1366; found 292.1369.



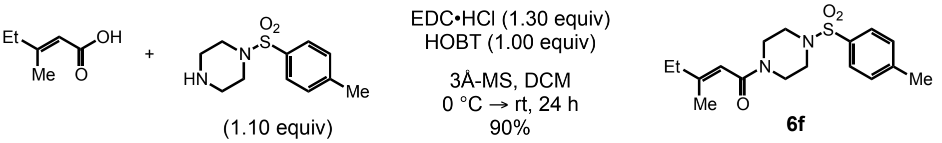
6b: *N*,*N*-Dimethylformamide (16 μL, 210 μmol, 5.0 mol %) was added via syringe to a stirred solution of (*E*)-3-(4-bromophenyl)-2-methylacrylic acid[9] (1.00 g, 4.15 mmol, 1 equiv) and oxalyl chloride (472 μL, 5.39 mmol, 1.30 equiv) in dichloromethane (13.8 mL) at room temperature. After 60 minutes, the resulting mixture was concentrated under reduced pressure. Dichloromethane (13.8 mL) was added via syringe, and the resulting mixture was transferred via cannula to a vigorously stirred aqueous solution of ammonia (30% weight/weight, 7.9 mL, 120 mmol, 30 equiv) at 0 °C. The resulting biphasic mixture was warmed to room temperature. After 30 minutes, diethyl ether (200 mL) was added. The organic layer was washed with (2 × 200 mL), was dried over anhydrous $MgSO_4$, was filtered, and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (20 to 100% ethyl acetate in hexanes) to give **6b** (867 mg, 87%) as a light tan solid. ^1H NMR (500 MHz, DMSO-d_6) δ 7.59 (d, J = 7.8 Hz, 2H), 7.59–7.50 (br-s, 1H), 7.33 (d, J = 8.3 Hz, 2H), 7.22 (s, 1H), 7.18–7.06 (br-s, 1H), 1.97 (s, 3H); ^{13}C NMR (125.7 MHz, DMSO-d_6) δ 170.3, 135.4, 133.1, 131.4, 131.3, 131.3, 120.9, 14.2; FTIR (thin film) ν 3358 (br-m), 3175 (br-m), 1653 (s), 1609 (m), 1484 (m), 1410 (m), 1073 (m), 1008 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{11}BrNO$ $[M+H]^+$: 240.0019; found 240.0024.



6c: *N*,*N*-dimethylformamide (20 μL, 260 μmol, 5.0 mol %) was added via syringe to a stirred solution of (*E*)-2-benzylidene-3-methylbutanoic acid[10] (1.00 g, 5.26 mmol, 1 equiv) and oxalyl chloride (598 μL, 6.83 mmol, 1.50 equiv) in dichloromethane (17.5 mL) at room temperature. After 90 minutes, the resulting mixture was concentrated under reduced pressure. Dichloromethane (17.5 mL) was added via syringe, and the resulting mixture was transferred via cannula to a vigorously stirred aqueous solution of ammonia (30% weight/weight, 10 mL, 160 mmol, 30 equiv) at 0 °C. The resulting biphasic mixture was warmed to room temperature. After 30 minutes, diethyl ether (200 mL) was added. The organic layer was washed with (2 × 200 mL), was dried over anhydrous $MgSO_4$, was filtered, and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 70% ethyl acetate in hexanes) to give **6c** (707 mg, 71%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36 (t, *J* = 7.3 Hz, 2H), 7.31–7.26 (m, 3H), 6.90 (s, 1H), 6.48–6.02 (br-s, 1H), 6.02–5.55 (br-s, 1H), 3.09 (sep, *J* = 6.8 Hz, 1H), 1.26 (d, *J* = 6.8 Hz, 6H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 173.1, 144.6, 136.0, 130.5, 128.9, 128.6, 127.7, 28.1, 21.7; FTIR (thin film) ν 3399 (br-m), 3169 (br-m), 2983 (w), 2966 (w), 1645 (s), 1608 (s), 1449 (m), 1405 (m), 1077 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{12}H_{16}NO$ $[M+H]^+$: 190.1226; found 190.1227.

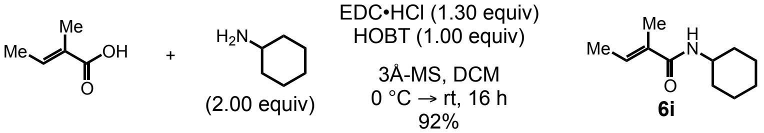


6e: 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrogen chloride (EDC•HCl, 2.18 g, 11.4 mmol, 1.30 equiv) was added as a solid under a nitrogen atmosphere to a stirred mixture of (*Z*)-3-methylpent-2-enoic acid[11] (1.00 mg, 8.76 mmol, 1 equiv), 1-tosylpiperazine (2.32 g, 9.64 mmol, 1.10 equiv), *N*-hydroxybenzotriazole hydrate (HOBT, 1.34 g, 8.76 mmol, 1.00 equiv), and powdered 3 Å molecular sieves (1.0 g) in dichloromethane (50.0 mL) at 0 °C. The resulting mixture was warmed to room temperature. After 24 hours, diethyl ether (200 mL) was added. The organic layer was washed sequentially with aqueous HCl solution (1 M, 2 × 100 mL), saturated aqueous $NaHCO_3$ solution (100 mL), and brine (100 mL); was dried over anhydrous $MgSO_4$; was filtered; and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 30% ethyl acetate in hexanes) to give **6e** (2.39 g, 81%) as a white solid. The olefin geometry was assigned using additional information from a NOESY experiment. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.2 Hz, 2H), 7.33 (d, *J* = 8.2 Hz, 2H), 5.63 (s, 1H), 3.76–3.67 (m, 2H), 3.62–3.53 (m, 2H), 3.02–2.91 (m, 4H), 2.44 (s, 3H), 2.22 (q, *J* = 7.4 Hz, 2H), 1.79 (s, 3H), 0.99 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 167.0, 152.5, 144.2, 132.4, 129.9, 127.9, 116.8, 46.4, 46.0, 45.7, 40.6, 27.0, 23.2, 21.7, 12.6; FTIR (thin film) ν 2972 (w), 2918 (w), 1624 (s), 1453 (m), 1424 (m), 1346 (s), 1234 (s), 1117 (m), 924 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{25}N_2O_3S$ $[M+H]^+$: 337.1580; found 337.1594.

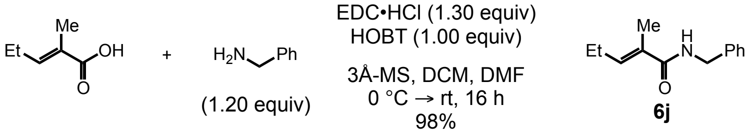


6f: 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrogen chloride (EDC•HCl, 1.09 g, 5.69 mmol, 1.30 equiv) was added as a solid under a nitrogen atmosphere to a stirred mixture of (*E*)-3-

methylpent-2-enoic acid[12] (500 mg, 4.38 mmol, 1 equiv), 1-tosylpiperazine (1.16 g, 4.82 mmol, 1.10 equiv), *N*-hydroxybenzotriazole hydrate (HOBT, 671 mg, 4.38 mmol, 1.00 equiv), and powdered 3 Å molecular sieves (500 mg) in dichloromethane (21.9 mL) at 0 °C. The resulting mixture was warmed to room temperature. After 24 hours, diethyl ether (130 mL) was added. The organic layer was washed sequentially with aqueous HCl solution (1 M, 2 × 50 mL), saturated aqueous $NaHCO_3$ solution (50 mL), and brine (50 mL); was dried over anhydrous $MgSO_4$; was filtered; and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 30% ethyl acetate in hexanes) to give **6f** (1.33 g, 90%) as a white solid. The olefin geometry was assigned using additional information from a NOESY experiment. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 7.8 Hz, 2H), 7.34 (d, *J* = 7.8 Hz, 2H), 5.65 (s, 1H), 3.79–3.67 (m, 2H), 3.64–3.53 (m, 2H), 3.04–2.91 (m, 4H), 2.44 (s, 3H), 2.09 (q, *J* = 7.6 Hz, 2H), 1.81 (s, 3H), 1.03 (t, *J* = 7.6 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 167.5, 152.4, 144.2, 132.5, 130.0, 127.9, 115.5, 46.5, 46.1, 45.7, 40.7, 32.5, 21.7, 18.8, 12.1; FTIR (thin film) ν 2970 (w), 2913 (w), 1624 (s), 1426 (m), 1347 (s), 1239 (m), 1164 (s), 1056 (m), 725 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{25}N_2O_3S$ $[M+H]^+$: 337.1580; found 337.1594.



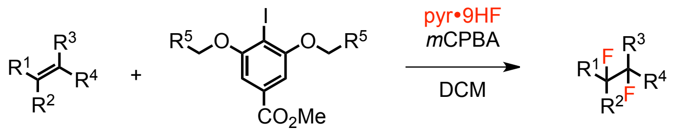
6i: 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrogen chloride (EDC•HCl, 2.45 g, 13.0 mmol, 1.30 equiv) was added as a solid under a nitrogen atmosphere to a stirred mixture of tiglic acid (1.00 g, 9.99 mmol, 1 equiv), cyclohexylamine (2.29 mL, 20.0 mmol, 2.00 equiv), *N*-hydroxybenzotriazole hydrate (HOBT, 1.53 g, 10.0 mmol, 1.00 equiv), and powdered 3 Å molecular sieves (500 mg) in dichloromethane (33.3 mL) at 0 °C. The resulting mixture was warmed to room temperature. After 16 hours, diethyl ether (250 mL) was added. The organic layer was washed sequentially with aqueous HCl solution (1 M, 2 × 100 mL), saturated aqueous $NaHCO_3$ solution (100 mL), and brine (100 mL); was dried over anhydrous $MgSO_4$; was filtered; and was concentrated under reduced pressure to give **6i** (1.66 g, 91%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.31 (q, *J* = 6.8 Hz, 1H), 5.75–5.55 (br-s, 1H), 3.81–3.68 (m, 1H), 1.93–1.82 (m, 2H), 1.77 (s, 3H), 1.67 (d, *J* = 6.8 Hz, 3H), 1.67–1.61 (m, 2H), 1.60–1.51 (m, 1H), 1.39–1.25 (m, 2H), 1.20–1.03 (m, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 168.6, 132.3, 129.9, 48.2, 33.2, 25.7, 25.0, 13.9, 12.5; FTIR (thin film) ν 3303 (br-m), 2928 (w), 2853 (w), 1660 (m), 1613 (s), 1527 (s), 1449 (m), 1318 (m), 1080 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{11}H_{20}NO$ $[M+H]^+$: 182.1539; found 182.1542.



6j: 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrogen chloride (EDC•HCl, 2.18 g, 11.4 mmol, 1.30 equiv) was added as a solid under a nitrogen atmosphere to a stirred mixture of (*E*)-2-methylpent-2-enoic acid (1.00 g, 8.76 mmol, 1 equiv), benzylamine (1.15 mL, 10.5 mmol, 1.20 equiv), *N*-hydroxybenzotriazole hydrate (HOBT, 1.34 g, 8.76 mmol, 1.00 equiv), and powdered 3 Å molecular sieves (700 mg) in dichloromethane (20.0 mL) and *N*,*N*-dimethylformamide (15.0 mL) at 0 °C. The resulting mixture was warmed to room temperature. After 16 hours, diethyl ether (175 mL) was added. The organic layer was washed sequentially with aqueous HCl solution (1 M, 2 × 100 mL), saturated aqueous $NaHCO_3$ solution (100 mL), and brine (100 mL); was dried over anhydrous $MgSO_4$; was filtered; and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 30% ethyl acetate in hexanes) to give **6j** (1.75 g, 98%) as a yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39–7.24 (m, 5H), 6.35 (t, *J* = 6.8 Hz, 1H), 6.04–5.90 (br-s, 1H), 4.51 (d, *J* = 5.4 Hz, 2H), 2.16 (quin, *J* = 7.3 Hz, 2H), 1.86 (s, 3H), 1.03 (t, *J* = 7.6 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 169.5, 138.8, 138.1, 130.4, 128.9, 128.1, 127.7, 44.1, 21.8, 13.5, 12.8; FTIR (thin film) ν 3307 (br-m), 2965 (w), 2931 (w), 1658 (m), 1617 (s), 1523 (s), 1496 (m), 1453 (m) 1308 (m), 1029 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{13}H_{18}NO$ $[M+H]^+$: 204.1383; found 204.1386.

Procedures for 1,2-Difluorination and Characterization of Products

Catalytic Difluorination Reactions:



1e: R = CO_2Me
1f: R = H

General Procedure A: A 75 mL low density polyethylene tube equipped with a stir bar was charged with catalyst **1b** (92.0 mg, 0.210 mmol, 20.0 mol %), *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 260 mg, 1.11 mmol, 1.10 equiv), and dichloromethane (20 mL), and the resulting mixture was vigorously stirred. Pyridinium poly(hydrogen fluoride) (pyr•9HF, 2.72 mL, 104 mmol, 100 equiv HF) was added via plastic syringe, and the tube was sealed with a low density polyethylene snap top. A solution of the alkene substrate (1.04 mmol, 1 equiv) in dichloromethane (2 mL) was added dropwise via syringe pump to the reaction mixture through a low density polyethylene snap top by syringe pump over 2 hours. After 12 hours, the reaction mixture was cooled to −78 °C, and basic alumina (15 grams) was added slowly to the rapidly stirred mixture. Upon completion of addition, the slurry was allowed to warm to room temperature and was filtered through a short plug of basic alumina. The alumina plug was extracted with dichloromethane (250 mL). The filtrate was concentrated under reduced pressure, and the residue was purified by flash column chromatography on silica gel (0% to 20% diethyl ether in hexanes).

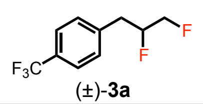
General Procedure B: A 75 mL low density polyethylene tube equipped with a stir bar was charged with the alkene substrate (1.04 mmol, 1 equiv), catalyst **1b** (92.0 mg, 0.210 mmol, 20.0 mol %), and dichloromethane (20 mL), the resulting mixture was vigorously stirred. Pyridinium poly(hydrogen fluoride) (pyr•9HF, 2.72 mL, 104 mmol, 100 equiv HF) was added via plastic syringe, then *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 303 mg, 1.35 mmol, 1.30 equiv) was added as a solid under an air atmosphere. The tube was sealed with a low density polyethylene snap top. After 20 hours, the reaction mixture was cooled to −78 °C and 4 M aqueous NaOH solution was added until pH = 14, and the mixture was allowed to warm to room temperature. The biphasic mixture was diluted with water (150 mL) and was extracted with ethyl acetate (3 × 150 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The resulting residue was purified by flash column chromatography on silica gel (0% to 30% ethyl acetate in dichloromethane). The product-containing fractions were concentrated and ^{1}H NMR showed ~10% of an inseparable chlorobenzoate ester byproduct. **Byproduct reduction with LAH:** The product mixture was dissolved in tetrahydrofuran (2 mL), and lithium aluminum hydride (3.9 mg, 0.1 mmol) was added as a solid under a nitrogen atmosphere. After 12 hours, the reaction mixture was cooled to 0 °C, and water (1.0 mL) was added dropwise via syringe. The resulting mixture was extracted with ethyl acetate (3 × 5 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0% to 30% ethyl acetate in dichloromethane).

General Procedure C: A low density polyethylene tube equipped with a stir bar was charged with catalyst **1b** (20.0 mol %), *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 1.30 equiv), pyridinium poly(hydrogen fluoride) (pyr•9HF, 100 equiv HF), and dichloromethane (20.0 mL per mmol of substrate) at room temperature, and the tube was sealed with a low density polyethylene snap top. The resulting biphasic mixture was vigorously stirred, and a solution of the alkene substrate (1 equiv) in dichloromethane (2.0 mL per mmol of substrate) was added via syringe pump over 2 h. After 1 h, the resulting biphasic mixture was transferred carefully into a vigorously stirred suspension of basic alumina (15 g per mmol of substrate) in ethyl acetate at 0 °C. The resulting suspension was filtered, and the filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel.

General Procedure D: A low density polyethylene tube equipped with a stir bar was charged with the alkene substrate (1 equiv), catalyst **1b** (20.0 mol %), and pyridinium poly(hydrogen fluoride) (pyr•9HF, 100 equiv HF) at room temperature. The resulting mixture was vigorously stirred, and *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 1.30 equiv) was added as a solid under an air atmosphere. The tube was sealed with a low density polyethylene snap top, and after 12 h, the resulting heterogeneous mixture was transferred carefully into a vigorously stirred suspension of basic alumina (15 g per mmol of substrate) in ethyl acetate at 0 °C. The resulting suspension was filtered, and the filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel.

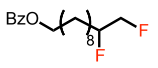
General Procedure E: A low density polyethylene tube equipped with a stir bar was charged with the alkene substrate (1 equiv), catalyst **1b** (20.0 mol %), pyridinium poly(hydrogen fluoride) (pyr•9HF, 100 equiv HF), and dichloromethane (6.0 mL per mmol of substrate) at room temperature. The resulting biphasic mixture was vigorously stirred, and *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 1.30 equiv) was added as a solid under an air atmosphere. The tube was sealed with a low density polyethylene snap top, and after 12 h, the resulting biphasic mixture was transferred carefully into a vigorously stirred suspension of basic alumina (15 g per mmol of substrate) in ethyl acetate at 0 °C. The resulting suspension was filtered, and the filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel.

General Procedure F: A low density polyethylene tube equipped with a stir bar was charged with the alkene substrate (1 equiv), catalyst **1c** (20.0 mol %), and pyridinium poly(hydrogen fluoride) (pyr•9HF, 100 equiv HF) at room temperature. The resulting mixture was vigorously stirred, and *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 1.30 equiv) was added as a solid under an air atmosphere. The tube was sealed with a low density polyethylene snap top, and after 12 h, the resulting heterogeneous mixture was transferred carefully into a vigorously stirred suspension of basic alumina (15 g per mmol of substrate) in ethyl acetate at 0 °C. The resulting suspension was filtered, and the filtrate was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel.



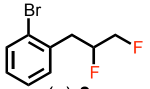
(±)-3a

(±)-3a: Prepared according to general procedure A. 4-(Trifluoromethyl)allylbenzene (**2a**, 194 mg, 1.04 mmol) was reacted to give (±)-**3a** (142 mg, 61%) as a colorless oil. ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.60 (d, *J* = 8.3 Hz, 2H), 7.38 (d, *J* = Hz, 2H), 4.94–4.79 (m, 1H), 4.62–4.38 (m, 2H), 3.17–3.00 (m, 2H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 140.1 (d, *J* = 4.1 Hz), 129.9, 129.6 (q, *J* = 32.5 Hz), 125.8 (m), 124.4 (q, *J* = 271.4 Hz), 91.6 (dd, *J* = 176.9, 20.3 Hz), 83.1 (dd, *J* = 174.8, 23.4 Hz), 36.7–36.5 (m); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −62.6 (s, 3F), −187.5–−187.8 (m, 1c), −232.3 (tdd, *J* = 47.5, 18.8, 15.0 Hz, 1c); FTIR (thin film) ν 1322 (s), 1162 (m), 1111 (s), 1066 (s), 1019 (m) cm^{-1}; GCMS (EI$^+$) Calc'd for $C_{10}H_9F_5$ [M]$^+$: 224.1; found 224.1. Note: HRMS was not possible for this compound.

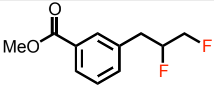

(±)-**3b**

(±)-3b: Prepared according to general procedure A with the following modifications: pyridine (0.500 mL, 6.24 mmol, 6.00 equiv) was added to the reaction mixture prior to the addition of pyr•9HF, the substrate was added in a single portion via syringe as a solution in dichloromethane (2.0 mL), and **1b** (46.0 mg, 0.105 mmol, 10.0 mol %) was used. Undec-10-en-1-yl benzoate[13] (**2b**, 285 mg, 1.04 mmol) was reacted, and after work-up, the crude residue was purified by flash column chromatography on silica gel to give (±)-**3b** (165 mg, 51%) as a colorless oil. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.04 (d, J = 7.3 Hz, 2H), 7.56–7.53 (m, 1H), 7.43 (t, J = 7.8 Hz, 2H), 4.74–4.36 (m, 3H), 4.32–4.30 (m, 2H), 1.79–1.26 (m, 16H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 166.8, 133.0, 130.7, 129.7, 128.5, 92.0 (dd, J = 172.6, 19.2 Hz), 84.3 (dd, J = 173.6, 23.0 Hz), 65.2, 30.3–30.1 (m), 29.5(2), 29.4(7), 29.4(6), 29.4, 28.9, 26.2, 24.9 (d, J = 4.8 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −188.8−−189.1 (m, 1c), −229.9 (tdd, J = 47.7, 20.3, 13.1 Hz, 1F); FTIR (thin film) ν 2928 (m), 2856 (w), 1716 (s), 1273 (s), 1112 (s), 712 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{18}H_{26}F_2O_2$ [M+H]$^+$: 313.1974; found 313.1979.

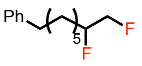
Reaction using 1a: The above procedure was repeated using *p*-iodotoluene as a catalyst (22.7 mg, 0.105 mmol, 10.0 mol %) to give (±)-**3b** (94 mg, 29%) as a colorless oil.


(±)-**3c**

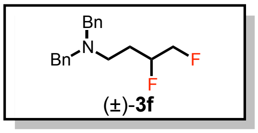
(±)-3c: Prepared according to general procedure A using 1-allyl-2-bromobenzene (**2c**, 205 mg, 1.04 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel to give (±)-**3c** (157 mg, 67%) as a colorless oil. ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.58–7.56 (m, 1H), 7.31–7.26 (m, 2H), 7.16–7.14 (m, 1H), 5.06–4.88 (m, 1H), 4.70–4.39 (m, 2H), 3.21–3.12 (m, 2H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 135.5 (d, J = 5.8 Hz), 133.2, 132.1, 129.0, 127.9, 124.8, 90.7 (dd, J = 176.9, 19.2 Hz), 83.5 (dd, J = 175.8, 22.1 Hz), 37.0–36.8 (m); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −187.5−−188.0 (m, 1F), −232.0 (tdd, J = 47.7, 22.7, 13.1 Hz, 1F); FTIR (thin film) ν 2954 (w), 1472 (m), 1441 (w), 1076 (m), 1026 (s), 750 (s) cm^{-1}; GCMS (EI$^+$) Calc'd for $C_9H_9BrF_2$ [M]$^+$: 234.0; found 234.0. Note: HRMS was not possible for this compound.


(±)-**3d**

(±)-3d: Prepared according to general procedure A using methyl 3-allylbenzoate (**2d**, 183 mg, 1.04 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel to give (±)-**3d** (136 mg, 61%) as a colorless oil. ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.94–7.92 (m, 2H), 7.44–7.37 (m, 2H), 4.93–4.78 (m, 1H), 4.60–4.36 (m, 2H), 3.90 (s, 3H), 3.13–2.97 (m, 2H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 167.0, 136.3 (d, J = 5.8 Hz), 134.1, 130.7, 130.5, 128.9, 128.4, 91.8 (dd, J = 19.2, 176.5 Hz), 83.2 (dd, J = 174.5, 23.0 Hz), 52.3, 36.5 (dd, J = 22.1, 6.7 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −187.2−−187.6 (m, 1F), −232.2 (tdd, J = 47.7, 21.5, 13.1 Hz, 1F); FTIR (thin film) ν 2954 (w), 1716 (s), 1278 (s), 1200 (s), 1086 (m), 749 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{11}H_{12}F_2O_2$ [M]$^+$: 215.0878; found 215.0886.

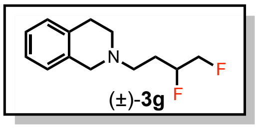

(±)-**3e**

(±)-3e: Prepared according to general procedure A with the following modifications: pyridine (0.500 mL, 6.24 mmol, 6.00 equiv) was added to the reaction mixture prior to the addition of pyr•9HF, the substrate was added in a single portion via syringe as a solution in dichloromethane (2.0 mL), and **1b** (46.0 mg, 0.105 mmol, 10.0 mol %) was used. Oct-7-en-1-ylbenzene[14] (**2e**, 196 mg, 1.04 mmol) was reacted, and after work-up, the crude residue was purified by flash column chromatography on silica gel to give (±)-**3e** (104 mg, 44%) as a colorless oil. ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.32–7.29 (m, 2H), 7.22–7.20 (m, 3H), 4.77–4.38 (m, 3H), 2.64 (t, J = 7.8 Hz, 2H), 1.76–1.30 (m, 10H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 142.9, 128.6, 128.5, 125.8, 92.0 (dd, *J* = 172.6, 19.2 Hz), 84.4 (dd, *J* = 173.6, 23.0 Hz), 36.1, 31.5, 30.3–30.1 (m), 29.3, 29.2, 24.9 (d, *J* = 4.8 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −188.8–−189.1 (m, 1F), −229.9 (tdd, *J* = 47.7, 20.3, 13.1, 1F); FTIR (thin film) ν 2930 (m), 2857 (w), 1496 (w), 1029 (m), 748 (m), 698 (s) cm^{-1}; GCMS (EI$^+$) Calc'd for $C_{14}H_{20}F_2$ [M]$^+$: 226.2; found 226.2. Note: HRMS was not possible for this compound.



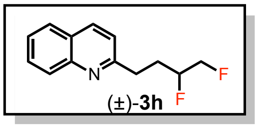
(±)-**3f**

(±)-3f: Prepared according to general procedure B with the following modification: flash column chromatography was conducted with 0% to 15% diethyl ether in hexanes. *N*,*N*-Dibenzylbut-3-en-1-amine (**2f**, 261 mg, 1.04 mmol) was reacted, and, after work-up, the crude residue was purified by flash column chromatography on silica gel to give (±)-**3f** (181 mg, 60%) as a colorless oil which solidified on standing. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41–7.30 (m, 10H), 4.88–4.75 (m, 1H), 4.49–4.25 (m, 2H), 3.66–3.60 (m, 4H), 2.69–2.59 (m, 2H), 1.99–1.77 (m, 2H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 139.5, 129.0, 128.5, 127.2, 90.5 (dd, *J* = 172.6, 18.2 Hz), 84.1 (dd, *J* = 173.6, 22.0 Hz), 58.7, 49.1 (d, *J* = 5.8 Hz), 28.0 (dd, *J* = 21.1, 5.75 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −189.0–−189.3 (m, 1F), −230.6 (tdd, *J* = 47.7, 22.7, 13.1 Hz, 1F); FTIR (thin film) ν 2799 (w), 1452 (w), 745 (m), 732 (w), 697 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{18}H_{21}F_2N$ [M+H]$^+$: 290.1715; found 290.1722.



(±)-**3g**

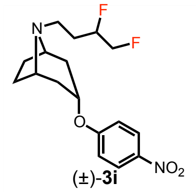
(±)-3g: Prepared according to general procedure B using 2-(but-3-en-1-yl)-1,2,3,4-tetrahydroisoquinoline (**2g**, 194 mg, 1.04 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel to give (±)-**3g** (122 mg, 52%) as a pale brown oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.16–7.05 (m, 4H), 4.96–4.79 (m, 1H), 4.67–4.44 (m, 2H), 3.69–3.62 (m, 2H), 2.93–2.91 (m, 2H), 2.79–2.69 (m, 4H), 2.07–1.86 (m, 2H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 134.8, 134.4, 128.8, 126.7, 126.4, 125.8, 90.6 (dd, *J* = 172.6, 19.2 Hz), 84.4 (dd, *J* = 173.6, 22.0 Hz), 56.3, 53.5 (d, *J* = 4.8 Hz), 51.1, 29.3, 28.0 (m); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −189.6–−189.9 (m, 1F), −230.1 (tdd, *J* = 47.7, 21.5, 13.1 Hz, 1F); FTIR (thin film) ν 2953 (w), 2778 (w), 1089 (m), 741 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{13}H_{17}F_2N$ [M+H]$^+$: 226.1402; found 226.1404.



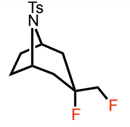
(±)-**3h**

(±)-3h: Prepared according to general procedure B with the following modifications: flash column chromatography was conducted with 0% to 100% ethyl acetate in hexanes and the *m*-chlorobenzoate ester byproduct was hydrolyzed by dissolving the product mixture obtained after the first column in a 1:1:1 mixture of methanol:tetrahydrofuran:aqueous 2.0 M NaOH solution (1.2 mL total) and stirring for 12 hours. The mixture was diluted with water (5 mL) and was extracted with ethyl acetate (3 × 20 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 20% diethyl ether in hexanes). 2-(But-3-en-1-yl)quinolone[15] (**2h**, 191 mg, 1.04 mmol) was reacted to give (±)-**3h** (140 mg, 61%) as a pale yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.3 Hz, 1H), 8.03 (d, *J* = 8.3 Hz, 1H), 7.77 (d, *J* = 8.3 Hz, 1H), 7.68 (t, *J* = 7.8, 1H), 7.50–7.47 (m, 1H), 7.28 (d, *J* = 8.3 Hz, 1H), 4.89–4.71 (m, 1H), 4.64–4.41 (m, 2H), 3.21–3.07 (m, 2H), 2.29–2.14 (m, 2H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 160.9, 148.1, 136.6, 129.6, 129.0, 127.7, 127.0, 126.1, 121.6, 91.4 (dd, *J* = 172.6, 19.2 Hz), 84.2 (dd, *J* = 173.6, 22.1 Hz), 34.0 (d, *J* = 3.8 Hz), 29.6 (dd, *J* = 20.1, 6.7 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −190.3–−190.6 (m, 1F), −230.1 (tdd, *J* = 47.7, 21.5, 13.1 Hz, 1F); FTIR (thin film) ν 2953 (w), 1503 (m), 1085 (m), 1031 (m), 825 (s), 751 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{13}H_{13}F_2N$ [M+H]$^+$: 222.1089; found 222.1091.

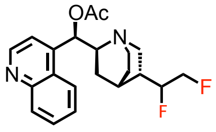
Reaction using 1a: The above procedure was repeated using *p*-iodotoluene as a catalyst (45.4 mg, 0.20 mmol, 20.0 mol %) to give (±)-**3h** (130 mg, 57%) as a pale yellow oil.


(±)-**3i**

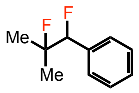
(±)-3i: Prepared according to general procedure B with the following modifications: no additional byproduct degradation step was necessary, and flash column chromatography was conducted on silica gel with a gradient of 0% to 10% methanol in dichloromethane. 8-(But-3-en-1-yl)-3-(4-nitrophenoxy)-8-azabicyclo[3.2.1]octane (**2i**, 314 mg, 1.04 mmol) was reacted to give (±)-**3i** (209 mg, 59%) as a pale brown oil. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.17 (d, *J* = 9.3 Hz, 2H), 6.85 (d, *J* = 9.3 Hz, 2H), 5.00–4.79 (m, 1H), 4.66–4.44 (m, 3H), 3.24 (s, 2H), 2.60–2.48 (m, 2H), 2.22–2.16 (m, 2H), 2.03–1.75 (m, 8H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 162.9, 141.2, 126.2, 115.2, 90.7 (dd, *J* = 172.6, 19.2 Hz), 84.5 (dd, *J* = 173.6, 23.0 Hz), 71.5, 58.7, 58.1, 48.0 (d, *J* = 4.8 Hz), 36.0 (d, *J* = 8.6 Hz), 29.9–29.7 (m), 26.2 (d, *J* = 35.5 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −189.6–−189.9 (m, 1F), −229.4 (tdd, *J* = 47.7, 21.5, 13.1 Hz, 1F); FTIR (thin film) ν 2946 (w), 1591 (m), 1336 (m), 1250 (m), 1109 (s), 1037 (m), 843 (m), 751 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{22}F_2N_2O_3$ [M+H]$^+$: 341.1671; found 341.1686.


3j

3j: Prepared according to general procedure A with the following modification: the substrate was added in a single portion via syringe as a solution in dichloromethane (2.0 mL). 3-Methylene-8-tosyl-8-azabicyclo[3.2.1]octane (**2i**, 288 mg, 1.04 mmol) was reacted to give a 4:1 diastereomeric mixture prior to purification as determined by ^{1}H and ^{19}F NMR analysis. After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 20% diethyl ether in hexanes) to give **3j** (81 mg, 25%) as a white crystalline solid. The diastereomeric ratio of the purified product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of **3j** were secured by X-ray diffraction analysis of a single crystal (page S40, vide infra).[16] ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.75 (d, *J* = 8.3 Hz, 2H), 7.29 (d, *J* = 7.8 Hz, 2H), 4.30 (s, 2H), 4.18 (dd, *J* = 46.9, 17.6 Hz, 1H), 2.48 (s, 3H), 2.14–1.90 (m, 6H), 1.54–1.52 (m, 2H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 143.9, 137.1, 129.9, 127.5, 93.4 (dd, *J* = 173.6, 18.2 Hz), 87.3 (dd, *J* = 178.4, 26.9 Hz), 55.2, 38.7(m), 27.9 (d, *J* = 3.8 Hz), 21.7; ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −152.9–−153.2 (m, 1F), −229.9 (tdd, *J* = 47.7, 20.3, 13.1, 1F); FTIR (thin film) ν 2978 (w), 1383 (m), 1184 (s), 1102 (m), 1088 (s), 680 (s), 573 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{15}H_{19}F_2NO_2S$ [M+H]$^+$: 316.1177; found 316.1190.


(−)-**3k**

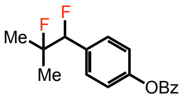
(−)-3k: Prepared according to general procedure B with the following modification: flash column chromatography was conducted on silica gel with a gradient of 50% ethyl acetate in dichloromethane to 100% dichloromethane to 10% methanol in dichloromethane. (−)-Cinchonidine-9-acetate (**2k**[17], 351 mg, 1.04 mmol) was reacted to give (−)-**3k** (238 mg, 61%) as a sticky, pale brown solid. The diastereomeric ratios of the crude and purified products were independently determined to be 10:1 by ^{1}H and ^{19}F NMR analysis. ^{1}H NMR (500 MHz, CDCl$_3$, *denotes minor diastereomer resonance) δ 8.89 (d, *J* = 4.4 Hz, 1H), 8.21 (d, *J* = 8.3 Hz, 1H), 8.13 (d, *J* = 8.3 Hz, 1H), 7.73–7.70 (m, 1H), 7.61–7.58 (m, 1H), 7.38 (d, *J* = 4.4 Hz, 1H), 6.52 (d, *J* = 7.3 Hz, 1H), 4.57–4.32 (m, 3H), 3.46–3.44* (m, 1H), 3.34–3.32 (m, 1H), 3.14–3.10 (m, 1H), 2.97–2.91 (m, 1H), 2.85–2.82* (m, 1H), 2.65–2.59 (m, 1H), 2.31–2.27 (m, 1H), 2.15–2.11 (m, 4H), 1.94–1.91 (m, 2H), 1.79–1.70 (m, 1H), 1.63–1.43 (m, 2H); ^{13}C NMR (125.7 MHz, CDCl$_3$, *denotes minor diastereomer resonance) δ 170.1, 150.1, 148.8, 145.2, 130.7, 129.4, 127.1, 126.1, 123.5, 119.0, 94.4* (dd, *J* = 174.5, 13.4 Hz), 92.9 (dd, *J* = 178.4, 19.2 Hz), 83.4* (dd, *J* = 174.5, 24.0 Hz), 82.9 (dd, *J* = 175.5, 23.4 Hz), 74.1, 60.1, 59.6*, 53.0 (d, *J* = 6.7 Hz), 42.5, 42.4*, 36.1–36.0* (m), 35.3 (dd, *J* = 18.2, 5.8 Hz), 29.9*, 28.3*, 27.4, 25.3*, 24.9* (d, *J* = 6.7 Hz), 24.7, 22.1 (d, *J* = 2.9 Hz), 21.2; ^{19}F NMR (470.4 MHz, $CDCl_3$, *denotes minor diastereomer resonance) δ −187.2−−187.5 (m, 1F), −196.7−−197.0* (m, 1F), −230.8 (tdd, *J* = 46.5, 22.6, 14.3 Hz, 1F), −232.5* (tdd, *J* = 47.7, 22.7, 13.1 Hz, 1F); FTIR (thin film) ν 2948 (w), 1743 (s), 1229 (s), 1022 (s), 729 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{21}H_{24}F_2N_2O_2$ [M+H]$^+$: 375.1879; found 375.1895. $[\alpha]_D^{23}$ = −24.2 (c = 1.0, $CHCl_3$).



(±)-**5a**

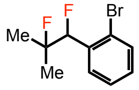
(±)-5a. Prepared according to general procedure C using 2-Methyl-1-phenyl-1-propene (**4a**, 137 mg, 1.04 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (hexanes) to give (±)-**5a** (108 mg, 61%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40–7.37 (m, 5H), 5.34 (dd, *J* = 44.9, 13.7 Hz, 1H), 1.41 (dd, *J* = 21.5, 2.0 Hz, 3H), 1.36 (dd, *J* = 21.5, 1.0 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 136.0–135.8 (m), 128.9 (d, *J* = 1.9 Hz), 128.3, 127.2–127.1 (m), 97.7–96.1 (m), 96.1–94.5 (m), 23.0 (dd, *J* = 24.0, 3.8 Hz), 22.8 (dd, *J* = 24.0, 3.8 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −149.9−−150.3 (m, 1F), −187.9 (dd, *J* = 45.3, 10.7 Hz, 1F); FTIR (thin film) ν 3036 (w), 1023 (m), 740 (s), 699 (s) cm^{-1}; GCMS (EI$^+$) Calc'd for $C_{10}H_{12}F_2$ [M]$^+$: 170.1; found 170.1. Note: HRMS was not possible for this compound.

Reaction using 1a: The above procedure was repeated using *p*-iodotoluene as a catalyst (45.4 mg, 0.20 mmol, 20.0 mol %) to give (±)-**5a** (61 mg, 34%) as a colorless oil.



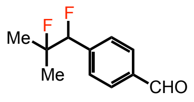
(±)-**5b**

(±)-5b: Prepared according to general procedure C using 4-(2-methylprop-1-en-1-yl)phenyl benzoate (**4b**, 300 mg, 1.19 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 2% ethyl acetate in hexanes) to give (±)-**5b** (235 mg, 68%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.22 (dd, *J* = 8.3, 1.5 Hz, 2H), 7.65 (t, *J* = 7.6 Hz, 1H), 7.53 (t, *J* = 7.8 Hz, 2H), 7.45 (d, *J* = 8.3 Hz, 2H), 7.27 (d, *J* = 8.3 Hz, 2H), 5.36 (dd, *J* = 44.9, 13.7 Hz, 1H), 1.43 (dd, *J* = 22.0, 2.0 Hz, 3H), 1.38 (dd, *J* = 22.5, 1.0 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 165.1, 151.4, 133.9, 133.5 (dd, *J* = 2.9, 21.1 Hz), 130.4, 129.6, 128.8, 128.4 (d, *J* = 7.7 Hz), 121.6, 96.3 (dd, *J* = 181.2, 25.9 Hz), 95.1 (dd, *J* = 173.6, 24.0 Hz), 22.9 (d, *J* = 24.0 Hz), 22.9 (d, *J* = 24.0 Hz); ^{19}F NMR (376.3 MHz, $CDCl_3$) δ −150.3−−150.8 (m, 1F), −186.9 (dd, *J* = 44.9, 10.5 Hz, 1F); FTIR (thin film) ν 3065 (w), 2989 (w), 1734 (s), 1509 (m), 1262 (s), 1202 (s), 1169 (m), 1061 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{17}F_2O_2$ [M+H]$^+$: 291.1191; found 291.1195.



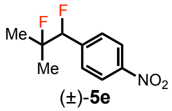
(±)-**5c**

(±)-5c. Prepared according to general procedure C using 1-Bromo-2-(2-methylprop-1-en-1-yl)benzene[18] (**4c**, 220 mg, 1.04 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 20% diethyl ether in hexanes) to give (±)-**5c** (159 mg, 61%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62–7.57 (m, 2H), 7.38 (t, *J* = 7.3 Hz, 1H), 7.23 (m, 1H), 5.82 (dd, *J* = 44.1, 18.3 Hz, 1H), 1.54 (dd, *J* = 21.5, 1.5 Hz, 3H), 1.37 (dd, *J* = 1.5, 21.5 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 135.4 (d, *J* = 13.4 Hz), 132.8, 130.5, 130.1 (dd, *J* = 7.7, 3.8 Hz), 127.7, 123.5 (d, *J* = 5.8 Hz), 96.5–95.4 (m), 95.1–93.9 (m), 23.7–23.5 (m), 23.1 (dd, *J* = 24.0, 3.8 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −153.4−−153.8 (m, 1F), −184.4 (dd, J = 44.1, 10.7 Hz, 1F); FTIR (thin film) ν 2989 (w), 1015 (m), 802 (m), 750 (s), 570 (m) cm^{-1}; GCMS (EI$^+$) Calc'd for $C_{10}H_{11}BrF_2$ [M]$^+$: 248.0; found 248.0. Note: HRMS was not possible for this compound.



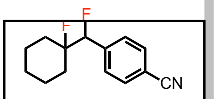
(±)-**5d**

(±)-5d: Prepared according to general procedure C using 4-(2-methylprop-1-en-1-yl)benzaldehyde[19] (**4d**, 180 mg, 1.11 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 5% ethyl acetate in hexanes) to give (±)-**5d** (155 mg, 70%) as a light yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 10.03 (s, 1H), 7.90 (d, J = 8.3 Hz, 2H), 7.54 (d, J = 7.8 Hz, 2H), 5.38 (dd, J = 45.5, 12.7 Hz, 1H), 1.42 (dd, J = 21.5, 2.0 Hz, 3H), 1.33 (dd, J = 21.4, 1.5 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 192.0, 142.3 (dd, J = 21.0, 1.9 Hz), 136.7, 129.6, 127.7 (dd, J = 8.6, 1.9 Hz), 96.0 (dd, J = 182.1, 26.7 Hz), 94.9 (dd, J = 174.5, 24.8 Hz), 23.4 (dd, J = 23.8, 2.9 Hz), 22.5 (dd, J = 23.8, 2.9 Hz); ^{19}F NMR (376.3 MHz, $CDCl_3$) δ −150.5–−150.9 (m, 1F), −189.3 (dd, J = 45.8, 9.1 Hz, 1F); FTIR (thin film) ν 2989 (w), 2937 (w), 1701 (s), 1612 (m), 1387 (m), 1209 (s), 1034 (s) cm^{-1}; GCMS (EI$^+$) Calc'd for $C_{11}H_{12}F_2O$ [M]$^+$: 198.1; found 198.1. Note: HRMS was not possible for this compound.



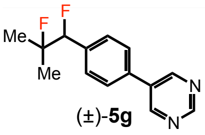
(±)-**5e**

(±)-5e. Prepared according to general procedure C using 1-(2-Methylprop-1-en-1-yl)-4-nitrobenzene[20] (**4e**, 184 mg, 1.04 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 20% diethyl ether in hexanes) to give (±)-**5e** (171 mg, 76%) as a pale yellow oil which solidified on standing. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.23 (d, J = 8.8, 2H), 7.55 (d, J = 8.3 Hz, 2H), 5.44–5.34 (dd, J = 45.5, 12.2 Hz, 1H), 1.45 (dd, J = 22.0, 2.0 Hz, 3H), 1.33 (dd, J = 21.5, 1.5 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 148.2, 142.8 (dd, J = 21.1, 1.9 Hz), 128.1–128.0 (m), 123.4, 95.5 (dd, J = 182.2, 26.9 Hz), 94.6 (dd, J = 174.5, 24.0 Hz), 23.7 (dd, J = 23.0, 2.9 Hz), 22.3 (dd, J = 24.0, 3.8 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −151.2–−151.5 (m, 1F), −189.4 (dd, J = 45.3, 8.3 Hz, 1F); FTIR (thin film) ν 2991 (w), 1522 (s), 1346 (s), 1037 (m), 739 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{11}F_2NO_2$ [M+H]$^+$: 216.0831; found 216.0805.



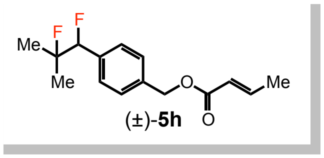
(±)-**5f**

(±)-5f: Prepared according to general procedure C using 4-(cyclohexylidenemethyl)benzonitrile[21] (**4f**, 200 mg, 1.01 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 40% dichloromethane in hexanes) to give (±)-**5f** (162 mg, 68%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, J = 8.3 Hz, 2H), 7.46 (d, J = 8.3 Hz, 2H), 5.29 (dd, J = 44.8, 14.2 Hz, 1H), 1.86–1.77 (m, 1H), 1.75–1.35 (m, 8H), 1.27–1.12 (m, 1H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 140.8 (d, J = 21.1 Hz), 132.0, 128.0 (dd, J = 8.6, 2.9 Hz), 118.6, 112.7, 95.7 (dd, J = 181.2, 25.9 Hz), 94.9 (dd, J = 178.4, 23.0 Hz), 31.6 (dd, J = 22.1, 2.9 Hz), 30.3 (dd, J = 23.0, 3.8 Hz), 25.0, 21.2 (d, J = 1.9 Hz), 21.2 (d, J = 2.2 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −170.7–−171.5 (m, 1F), −191.6 (dd, J = 44.8, 8.3 Hz, 1F); FTIR (thin film) ν 2936 (m), 2229 (m), 1444 (w), 1026 (s), 1017 (m), 949 (m), 850 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{14}H_{16}F_2N$ [M+H]$^+$: 236.1245; found 236.1236.



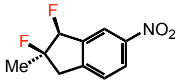
(±)-**5g**

(±)-5g. Prepared according to general procedure C using 5-(4-(2-methylprop-1-en-1-yl)phenyl)pyrimidine (**4g**, 219 mg, 1.04 mmol) with the following modifications: after the indicated time, the reaction mixture was cooled to −78 °C and 4 M aqueous NaOH solution was added until pH = 14. Upon completion of addition, the mixture was allowed to warm to room temperature with stirring. The biphasic mixture was added to a 500 mL separatory funnel, diluted with water (150 mL), and extracted with ethyl acetate (3 × 150 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography (0% to 50% ethyl acetate in hexanes). 5-(4-(2-methylprop-1-en-1-yl)phenyl)pyrimidine (**4g**, 219 mg, 1.04 mmol) was reacted to give a pale yellow oil which solidified on standing (173 mg, 70%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.17 (s, 1H), 8.92 (s, 2H), 7.57 (d, J = 8.3, 2H), 7.49 (d, J = 7.8 Hz, 2H), 5.34 (dd, J = 44.9, 13.7 Hz, 1H), 1.41–1.37 (m, 3H), 1.33 (d, J = 22.0 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 157.8, 155.0, 136.8–136.6 (m), 134.7, 133.8, 128.2 (dd, J = 7.7, 1.9 Hz), 126.8, 96.2 (dd, J = 163.0, 25.9 Hz), 94.9 (dd, J = 174.5, 24.0 Hz), 23.2 (dd, J = 24.0, 2.9 Hz), 22.7 (dd, J = 24.0, 2.9 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −150.8–−151.2 (m, 1F), −188.4 (dd, J = 45.3, 9.5 Hz, 1F); FTIR (thin film) ν 2989 (w), 1551 (m), 1413 (s), 724 (s), 573 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{14}H_{14}F_2N_2$ $[M+H]^+$: 249.1198; found 249.1208.



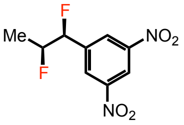
(±)-**5h**

(±)-5h: Prepared according to general procedure C using (*E*)-4-(2-methylprop-1-en-1-yl)benzyl but-2-enoate (**4h**, 300 mg, 1.30 mmol) with the following modifications: addition of the substrate solution was carried out over 1 h via syringe pump, the reaction was carried out at 0 °C, and *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 321 mg, 1.43 mmol, 1.10 equiv) was used. After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 2% ethyl acetate in hexanes) to give (±)-**5h** (271 mg, 78%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40–7.34 (m, 4H), 7.03 (qd, J = 6.9, 15.7 Hz, 1H), 5.90 (qd, J = 1.5, 15.7 Hz, 1H), 5.32 (dd, J = 45.0, 13.7 Hz, 1H), 5.18 (s, 2H), 1.89 (dd, J = 6.9, 1.5 Hz, 3H), 1.39 (dd, J = 21.5, 1.5 Hz, 3H), 1.33 (dd, J = 21.6, 1.5 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 166.4, 145.5, 137.0, 135.8 (dd, J = 21.0, 2.9 Hz), 128.0, 127.4 (dd, J = 7.6, 1.9 Hz), 122.6, 96.6 (dd, J = 181.2, 25.7 Hz), 95.1 (dd, J = 173.6, 23.2 Hz), 65.6, 23.0 (t, J = 3.3 Hz), 22.8 (t, J = 3.3 Hz), 18.2; ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −150.1–−150.5 (m, 1F), −187.9 (dd, J = 44.8, 10.0 Hz, 1F); FTIR (neat) ν 2985 (w), 2940 (w), 1718 (s), 1657 (m), 1261 (m), 1172 (s), 1014 (s), 967 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{15}H_{19}F_2O_2$ $[M+H]^+$: 269.1348; found 269.1338.



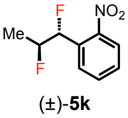
(±)-**5i**

(±)-5i. Prepared according to general procedure C using 2-Methyl-5-nitro-1*H*-indene (**4i**, 273 mg, 1.56 mmol) with the following modifications: *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 390 mg, 1.72 mmol, 1.10 equiv) was used. After work-up, the diastereomeric ratio of the crude product was determined to be 5:1 by ^{1}H and ^{19}F NMR analysis. The crude product was purified by flash column chromatography on silica gel (0 to 20% diethyl ether in hexanes) to give (±)-**5i** (200 mg, 60%) as a pale yellow oil. The diastereomeric ratio of the purified product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**5i** were secured by X-ray diffraction analysis of a single crystal of (±)-**S5i**, obtained by chemical synthesis from (±)-**5i** (page S45, vide infra).[22] ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.27 (s, 1H), 8.20 (d, *J* = 8.3, 1H), 7.41 (d, *J* = 8.3 Hz, 1H), 5.62 (dd, *J* = 53.2, 12.2, 1H), 3.40 (t, *J* = 17.6 Hz, 1H), 3.07 (dd, *J* = 23.9, 17.1 Hz, 1H), 1.68 (d, *J* = 22.0 Hz, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 148.0, 146.9 (dd, *J* = 5.8, 1.9 Hz), 139.8 (d, *J* = 19.2 Hz), 126.4, 125.4, 120.8, 100.3 (dd, *J* = 189.9, 14.4 Hz), 96.7–95.0 (m), 42.3 (d, *J* = 24.0 Hz), 21.8 (d, *J* = 24.9 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −163.8–−164.1 (m, 1F), −196.1 (d, *J* = 53.7 Hz, 1F); FTIR (thin film) ν 2991 (w), ν 1523 (s), 1346 (s), 1078 (m), 799 (m), 737 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_9F_2NO_2$ [M+H]$^+$: 214.0674; found 214.0676.



(±)-**5j**

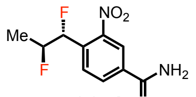
(±)-5j: Prepared according to general procedure C using (*E*)-1,3-dinitro-5-(prop-1-en-1-yl)benzene (**4j**, 250 mg, 1.20 mmol) with the following modification: a solution of the substrate in dichloromethane (6.0 mL) was added over 2 h via syringe pump to a biphasic mixture of *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 350 mg, 1.56 mmol, 1.30 equiv), pyridinium poly(hydrogen fluoride) (pyr•9HF, 3.12 mL, 120 mmol, 100 equiv HF), catalyst **1b** (105 mg, 0.240 mmol, 20.0 mol %), and dichloromethane (6.0 mL) at room temperature. The resulting biphasic mixture was vigorously stirred for 10 h prior to work-up. After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 25% dichloromethane in hexanes) to give (±)-**5j** (106 mg, 36%) as a colorless oil. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**5j** were secured by X-ray diffraction analysis of a single crystal of (±)-**S5j**, obtained by chemical synthesis from (±)-**5j** (page S56, vide infra).[23] ^{1}H NMR (500 MHz, CDCl$_3$) δ 9.07 (d, *J* = 2.0 Hz, 1H), 8.58 (d, *J* = 2.0 Hz, 2H), 5.66 (ddd, *J* = 45.0, 19.1, 2.9 Hz, 1H), 4.98 (qddd, *J* = 6.3, 46.0, 19.6, 2.9 Hz, 1H), 1.49 (ddd, *J* = 23.9, 6.3, 1.0 Hz, 1H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 148.8, 140.5 (dd, *J* = 23.0, 2.9 Hz), 126.6 (d, *J* = 8.6 Hz), 119.2, 92.0 (dd, *J* = 185.1, 22.1 Hz), 89.4 (dd, *J* = 179.3, 24.9 Hz), 16.1 (dd, *J* = 23.0, 4.8 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −189.6–−190.0 (m, 1F), −197.4 (ddd, *J* = 45.0, 19.6, 11.6 Hz, 1F); FTIR (thin film) ν 3108 (w), 2919 (w), 1545 (s), 1526 (s), 1344 (s), 1276 (s), 992 (m), 730 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_9H_8F_2N_2O_4$ [M+Cl]$^-$: 281.0146; found 281.0133.



(±)-**5k**

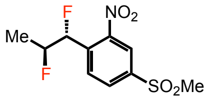
(±)-5k: Prepared according to general procedure C using (*E*)-1-nitro-2-(prop-1-en-1-yl)benzene[24] (**4k**, 200 mg, 1.23 mmol) with the following modification: after addition of the substrate solution over 2 h via syringe pump, the resulting biphasic mixture was vigorously stirred for 10 h prior to work-up. After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 1% ethyl acetate in hexanes) to give (±)-**5k** (194 mg, 79%) as a light yellow oil. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.13 (d, *J* = 8.3 Hz, 1H), 7.77 (t, *J* = 7.3 Hz, 1H), 7.74 (td, *J* = 7.8, 1.0 Hz, 1H), 7.56 (td, *J* = 8.3, 1.5 Hz, 1H), 6.41 (ddd, *J* = 48.4, 13.6, 2.9 Hz, 1H), 5.00 (qddd, *J* = 6.8, 46.0, 21.0, 2.9 Hz, 1H), 1.36 (ddd, *J* = 24.5, 6.8, 1.5 Hz, 1H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 147.2, 134.2, 131.7 (dd, *J* = 22.1, 7.7 Hz), 129.8, 128.4 (d, *J* = 14.4 Hz), 125.2, 90.5 (dd, *J* =

180.3, 24.9 Hz), 90.2 (dd, J = 176.4, 24.9 Hz), 14.6 (dd, J = 23.0, 6.7 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −179.7−−180.0 (m, 1F), −195.2−−195.5 (m, 1F); FTIR (thin film) ν 2994 (w), 2927 (w), 1527 (s), 1347 (s), 1197 (m), 1069 (m), 981 (m), 739 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_9H_9F_2NO_2$ [M−F]$^+$: 182.0612; found 182.0609.



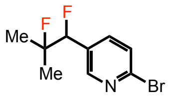
(±)-**5l**

(±)-5l: Prepared according to general procedure C using (*E*)-3-Nitro-4-(prop-1-en-1-yl)benzamide (**4l**, 400 mg, 1.94 mmol) with the following modification: instead of adding the substrate solution via syringe pump, (*E*)-3-Nitro-4-(prop-1-en-1-yl)benzamide (**4l**) was added as a solid in five equal portions over 2 h, and the resulting biphasic mixture was vigorously stirred for 10 h prior to work-up. After work-up, the crude residue was purified by flash column chromatography on silica gel (10 to 40% ethyl acetate in hexanes) to give (±)-**5l** (310 mg, 65%) as an off-white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**5l** were secured by X-ray diffraction analysis of a single crystal (page S65, vide infra).[25] ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.57 (s, 1H), 8.18 (dd, J = 8.3, 1.5 Hz, 1H), 7.89 (d, J = 7.8 Hz, 1H), 6.44 (ddd, J = 48.3, 12.7, 2.9 Hz, 1H), 6.58–6.07 (br-s, 2H), 4.96 (qddd, J = 7.3, 45.9, 19.5, 2.9 Hz, 1H), 1.38 (ddd, J = 24.9, 7.3, 1.0 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 166.5, 147.3, 135.2, 135.1 (dd, J = 22.1, 6.7 Hz), 132.7, 129.2 (dd, J = 16.3, 1.9 Hz), 124.2, 90.3 (dd, J = 181.2, 25.9 Hz), 90.1 (dd, J = 177.4, 25.9 Hz), 15.1 (dd, J = 23.0, 6.7 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −180.5−−180.9 (m, 1F), −194.4 (ddd, J = 48.1, 19.9, 14.9 Hz, 1F); FTIR (thin film) ν 3350 (br-m), 3196 (br-m), 2992 (w), 1664 (s), 1623 (m), 1535 (s), 1349 (s), 1068 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{11}F_2N_2O_3$ [M+H]$^+$: 245.0732; found 245.0731.



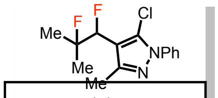
(±)-**5m**

(±)-5m: Prepared according to general procedure D using (*E*)-4-(methylsulfonyl)-2-nitro-1-(prop-1-en-1-yl)benzene[26] (**4m**, 150 mg, 0.622 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 100% dichloromethane in hexanes) to give (±)-**5m** (120 mg, 69%) as a white solid. The diastereomeric ratio of the product was determined to be 16:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**5m** were secured by X-ray diffraction analysis of a single crystal (page S69, vide infra).[27] ^{1}H NMR (500 MHz, $CDCl_3$, * denotes minor diastereomer resonance) δ 8.66* (s, 1H), 8.64 (s, 1H), 8.26 (dd, J = 7.8, 1.5 Hz, 1H), 8.26–8.23* (m, 1H), 8.04* (d, J = 8.3 Hz, 1H), 8.01 (d, J = 8.3 Hz, 1H), 6.43 (ddd, J = 47.8, 12.2, 3.4 Hz, 1H), 6.13* (dd, J = 45.4, 23.4 Hz, 1H), 5.14–4.94* (m, 1H), 5.04–4.84 (m, 1H), 3.14 (s, 3H), 3.14* (s, 3H), 1.61* (dd, J = 23.9, 6.3 Hz, 3H), 1.38 (ddd, J = 24.4, 5.9, 1.0 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$, * denotes minor diastereomer resonance) δ 147.5 (d, J = 3.8 Hz), 146.8*, 142.6, 142.3*, 138.2* (d, J = 23.0 Hz), 137.0 (d, J = 5.8, 21.1 Hz), 132.3 (d, J = 1.9 Hz), 132.2*, 131.4* (d, J = 15.3 Hz), 130.2 (dd, J = 15.4, 1.9 Hz), 124.6, 124.4*, 90.0 (dd, J = 181.2, 24.9 Hz), 89.9 (dd, J = 177.4, 25.9 Hz), 89.7* (dd, J = 183.2, 18.3 Hz), 89.1* (dd, J = 178.4, 21.1 Hz), 44.4, 44.4*, 16.9* (dd, J = 23.0, 4.8 Hz), 15.3 (dd, J = 23.0, 5.8 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$, * denotes minor diastereomer resonance) δ −181.2−−181.5 (m, 1F), −193.0−−193.3* (m, 1F), −193.3 (ddd, J = 48.1, 18.3, 15.0 Hz, 1F), −199.1* (ddd, J = 46.4, 24.9, 10.0 Hz, 1F); FTIR (thin film) ν 3085 (w), 2928 (w), 1536 (s), 1351 (s), 1314 (s), 1152 (s), 1068 (m), 777 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{12}F_2NO_4S$ [M+H]$^+$: 280.0450; found 280.0441.



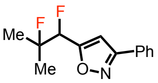
(±)-**5n**

(±)-5n: Prepared according to general procedure D using 2-bromo-5-(2-methylprop-1-en-1-yl)pyridine[28] (**4n**, 200 mg, 0.943 mmol) with the following modification: instead of the standard work-up, the reaction mixture was diluted with dichloromethane (20 mL) and was cooled to −78 °C. Aqueous NaOH solution (4 M, 30 mL) was added, and the resulting biphasic mixture was allowed to warm to room temperature with vigorous stirring. The layers were separated, and the aqueous layer was extracted with diethyl ether (2 × 100 mL). The combined organic layers were sequentially washed with a saturated aqueous copper sulfate solution (100 mL) and brine (100 mL), were dried over anhydrous $MgSO_4$, were filtered, and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0 to 5% ethyl acetate in hexanes) to give (±)-**5n** (192 mg, 81%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.34 (s, 1H), 7.61 (d, *J* = 8.3 Hz, 1H), 7.53 (d, *J* = 8.3 Hz, 1H), 5.29 (dd, *J* = 44.4, 13.7 Hz, 1H), 1.41 (dd, *J* = 9.8, 2.0 Hz, 3H), 1.36 (dd, *J* = 9.8, 1.9 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 148.8 (d, *J* = 6.7 Hz), 142.9, 137.4 (dd, *J* = 6.7, 2.9 Hz), 130.9 (d, *J* = 22.1 Hz), 128.0, 94.5 (dd, *J* = 173.6, 24.0 Hz), 94.1 (dd, *J* = 181.2, 26.7 Hz), 23.6 (dd, *J* = 24.0, 2.9 Hz), 22.3 (dd, *J* = 24.0, 2.9 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −152.9−−153.2 (m, 1F), −190.4 (dd, *J* = 44.8, 10.0 Hz, 1F); FTIR (thin film) ν 2988 (w), 2939 (w), 1585 (m), 1563 (m), 1457 (s), 1387 (m), 1088 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_9H_{11}BrF_2N$ $[M+H]^+$: 250.0037; found 250.0037.



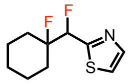
(±)-**5o**

(±)-5o. A modified procedure was used. An 8 mL low density polyethylene tube equipped with a stir bar was charged with **4o** (257 mg, 1 equiv, 1.04 mmol), **1b** (92.0 mg, 0.21 mmol, 20 mol %), *m*CPBA (303 mg, 1.30 equiv, 1.35 mmol) and pyr•9HF (2.72 mL, 100 equiv of HF, 104.0 mmol). The resulting mixture was vigorously stirred for 12 hours, after which it was cooled to −78 °C and 4 M aqueous NaOH was added until pH = 14. Upon completion of addition, the mixture was allowed to warm to room temperature with stirring. The biphasic mixture was added to a 500 mL separatory funnel, diluted with water (150 mL), and washed with ethyl acetate (3 × 150 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The resulting residue was purified by flash column chromatography on silica gel (0% to 70% ether in hexanes) to give a colorless oil which solidified on standing (151 mg, 51%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54–7.38 (m, 5H), 5.32 (dd, *J* = 20.5, 43.0 Hz, 1H), 2.39 (s, 3H), 1.55 (dd, *J* = 21.5, 1.5 Hz, 3H), 1.38 (dd, *J* = 21.0, 1.0 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 149.5, 138.2, 129.2, 128.5, 126.5 (d, *J* = 7.7 Hz), 125.2, 112.7 (m), 96.4 (dd, *J* = 175.5, 24.0 Hz), 91.3 (dd, *J* = 177.4, 24.0 Hz), 23.4–23.1 (m), 23.4–23.1 (m), 14.21–14.17 (m); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −151.4−−151.9 (m, 1F), −192.6 (dd, *J* = 44.1, 13.1 Hz, 1F); FTIR (thin film) ν 2987 (w), 1555 (m), 1502 (m), 1008 (m), 760 (s), 692 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{14}H_{15}ClF_2N_2$ $[M+H]^+$: 285.0965; found 285.0970.



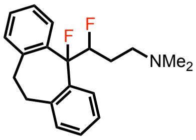
(±)-**5p**

(±)-5p. A modified procedure was used. An 8 mL low density polyethylene tube equipped with a stir bar was charged with **4p** (207 mg, 1.04 mmol, 1 equiv), **1b** (92.0 mg, 0.210 mmol, 20.0 mol %), *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 303 mg, 1.35 mmol, 1.30 equiv) and pyridinium poly(hydrogen fluoride) (pyr•9HF, 2.72 mL, 104 mmol, 100 equiv HF). The resulting mixture was vigorously stirred for 24 hours, after which additional *m*CPBA (77% by weight, 152 mg, 0.65 equiv, 0.68 mmol) was added as a solid. After 12 hours, the reaction was cooled to −78 °C and 4 M aqueous NaOH solution was added until pH = 14. Upon completion of addition, the mixture was allowed to warm to room temperature with stirring. The biphasic mixture was added to a 500 mL separatory funnel, diluted with water (150 mL), and extracted with ethyl acetate (3 × 150 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel with a short plug of alumina loaded on top of the silica gel (0% to 70% ether in hexanes) to give (±)-**5p** (65 mg, 26%) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84–7.82 (m, 2H), 7.49–7.46 (m, 3H), 6.76 (s, 1H), 5.50 (dd, *J* = 45.4, 15.6 Hz, 1H), 1.54–1.46 (m, 6H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 167.1–166.8 (m), 162.7, 130.5, 129.2, 128.6, 127.1, 102.5–102.4 (m), 94.3 (dd, *J* = 176.5, 22.1), 89.6 (dd, *J* = 182.2, 25.9 Hz), 23.0 (dd, *J* = 24.0, 4.8 Hz), 22.6–22.4 (m); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −150.9–−151.3 (m, 1F), −189.8 (dd, *J* = 42.9, 11.9 Hz, 1F); FTIR (thin film) ν 2991 (w), 1610 (w), 768 (s), 692 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{13}H_{13}F_2NO$ $[M+H]^+$: 238.1038; found 238.1044.



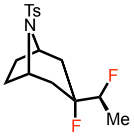
(±)-**5q**

(±)-5q: Prepared according to general procedure D using 2-(cyclohexylidenemethyl)thiazole (**4q**, 200 mg, 1.12 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 10% ethyl acetate in hexanes) to give (±)-**5q** (133 mg, 55%) as a light yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85–7.81 (m, 1H), 7.46 (d, *J* = 3.4 Hz, 1H), 5.64 (dd, *J* = 44.5, 19.1 Hz, 1H), 2.19–2.09 (m, 1H), 1.80–1.39 (m, 8H), 1.32–1.20 (m, 1H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 164.4 (dd, *J* = 26.1, 4.2 Hz), 142.5, 121.1, 95.1 (dd, *J* = 180.3, 21.4 Hz), 94.3 (dd, *J* = 180.3, 22.1 Hz), 31.1 (dd, *J* = 22.1, 4.8 Hz), 30.7 (dd, *J* = 21.1, 2.9 Hz), 25.2, 21.4 (d, *J* = 2.9 Hz), 21.2 (d, *J* = 2.0 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −170.4–−171.5 (m, 1F), −184.6 (dd, *J* = 44.8, 11.6 Hz, 1F); FTIR (thin film) ν 2935 (m), 2865 (w), 1449 (m), 1205 (w), 1146 (m), 1023 (m), 970 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{14}F_2SN$ $[M+H]^+$: 218.0810; found 218.0811.



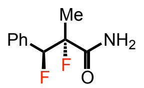
(±)-**5r**

(±)-5r: A modified procedure was used. An 8 mL low density polyethylene tube equipped with a stir bar was charged with **4r** (288 mg, 1.04 mmol, 1 equiv), **1b** (92.0 mg, 0.210 mmol, 20.0 mol %), and pyridinium poly(hydrogen fluoride) (pyr•9HF, 2.72 mL, 104 mmol, 100 equiv HF). The resulting mixture was vigorously stirred and *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 152 mg, 0.680 mmol, 0.650 equiv) was added as a solid. After 30 minutes, additional *m*CPBA (77% by weight, 152 mg, 0.680 mmol, 0.650 equiv) was added as a solid. After 12 hours, the reaction was cooled to −78 °C and 4 M aqueous NaOH solution was added until pH = 14. Upon completion of addition, the mixture was allowed to warm to room temperature with stirring. The biphasic mixture was added to a 500 mL separatory funnel, diluted with water (150 mL), and extracted with ethyl acetate (2 × 200 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel with a short plug of alumina loaded on top of the silica gel (0% to 10% methanol in dichloromethane) to give (±)-**5r** (135 mg, 41%) as a light brown oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (dd, *J* = 13.7, 7.3 Hz, 2H), 7.31–7.25 (m, 4H), 7.19–7.16 (m, 2H), 5.45 (dddd, *J* = 46.4, 24.9, 9.8, 2.0 Hz, 1H), 3.53–3.41 (m, 2H), 3.04–2.97 (m, 2H), 2.49–2.43 (m, 1H), 2.28–2.19 (m, 1H), 2.12 (s, 6H), 1.96–1.91 (m, 1H), 1.70–1.60 (m, 1H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 137.8–137.2 (m), 130.7–130.6, 128.5 (d, *J* = 46.0 Hz), 127.4–127.2 (m), 126.7 (d, *J* = 3.8 Hz), 126.1 (d, *J* = 3.8 Hz), 126.0 (d, *J* = 23.0 Hz), 99.1 (dd, *J* = 184.1, 20.1 Hz), 93.9 (dd, *J* = 185.1, 26.9 Hz), 55.5 (d, *J* = 2.9 Hz), 45.4, 33.7, 27.6–27.4 (m); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −150.9–−151.3 (m, 1F), −189.7–−189.8 (m, 1F); FTIR (thin film) ν 2941 (w), 2766 (w), 1444 (w), 753 (s), 724 (w) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{20}H_{23}F_2N$ $[M+H]^+$: 316.1871; found 316.1879.



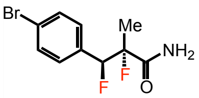
(±)-**5s**

(±)-5s. A modified procedure was used. An 8 mL low density polyethylene tube equipped with a stir bar was charged with **4s** (152 mg, 0.520 mmol, 1 equiv), **1b** (46.0 mg, 0.100 mmol, 20.0 mol %), and pyridinium poly(hydrogen fluoride) (pyr•9HF, 0.300 mL, 11.5 mmol, 22.0 equiv HF). The resulting mixture was vigorously stirred and *m*-chloroperbenzoic acid (*m*CPBA, 77% by weight, 64 mg, 0.29 mmol, 0.55 equiv) was added as a solid. After 30 minutes, additional *m*CPBA (77% by weight, 64 mg, 0.29 mmol, 0.55 equiv) was added as a solid. After 24 hours, the reaction mixture was cooled to −78 °C, and approximately 7.5 grams of basic alumina was added slowly to the rapidly stirred mixture. Upon completion of addition, the slurry was allowed to warm to room temperature with stirring and was filtered through a plug of basic alumina. The filter cake was extracted with dichloromethane. The filtrate was concentrated under reduced pressure, and the diastereomeric ratio of the crude product was determined to be 10:1 by ^{1}H and ^{19}F NMR analysis. The crude product was purified by flash column chromatography on silica gel (5 to 40% ethyl acetate in hexanes) to give (±)-**5s** (46 mg, 27%) as a white crystalline solid. The diastereomeric ratio of the purified product was determined to be 10:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**5s** were secured by X-ray diffraction analysis of a single crystal (page S73, vide infra).[29] ^{1}H NMR (500 MHz, CDCl$_3$, * denotes minor diastereomer resonance) δ 7.80* (d, J = 7.8 Hz, 2H), 7.76 (d, J = 8.3 Hz, 2H), 7.30 (d, J = 7.8 Hz, 2H), 4.38–4.25 (m, 3H), 2.44 (s, 3H), 2.19–1.36 (m, 8H), 1.29 (dd, J = 24.4, 6.3 Hz, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$, * denotes minor diastereomer resonance) δ 143.8, 137.2, 129.9, 127.6*, 127.5, 95.3–93.8 (m), 93.1 (dd, J = 176.5, 25.9 Hz), 56.2*, 55.3 (dd, J = 15.3, 1.9 Hz), 39.2–38.6 (m), 32.5*, 29.9*, 29.2*, 28.0*, 28.0–27.9 (m), 21.8, 14.2 (dd, J = 23.0, 3.8 , 23.0 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$, * denotes minor diastereomer resonance) δ −140.9–−141.1* (m, 1F), −160.4–−160.6 (m, 1F), −182.1–−182.4* (m, 1F), −185.6–−185.9 (m, 1F); FTIR (thin film) ν 2928 (w), 1338 (m), 1159 (s), 686 (m), 673 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for C$_{16}$H$_{21}$F$_2$NO$_2$S [M+H]$^+$: 330.1334; found 330.1341.



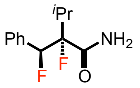
(±)-**7a**

(±)-7a: Prepared according to general procedure E using (*E*)-2-methyl-3-phenylacrylamide[30] (**6a**, 540 mg, 3.35 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 5% ethyl acetate in dichloromethane) to give (±)-**7a** (470 mg, 70%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**7a** were secured by X-ray diffraction analysis of a single crystal (page S78, vide infra).[31] ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.40–7.34 (m, 5H), 6.01–5.90 (br-s, 1H), 5.71 (dd, J = 44.0, 25.4 Hz, 1H), 5.25–5.10 (br-s, 1H), 1.81 (dd, J = 22.0, 1.5 Hz, 3H); ^{13}C NMR (125.7 MHz, DMSO-d_6) δ 170.9 (dd, J = 21.1, 6.7 Hz), 134.3 (d, J = 21.1 Hz), 128.9, 128.0, 127.3 (d, J = 6.7 Hz), 96.9 (dd, J = 195.6, 22.1 Hz), 95.2 (dd, J = 179.3, 20.1 Hz), 40.7 (dd, J = 24.9, 5.8 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −168.8–−169.2 (m, 1F), −195.8 (dd, J = 44.8, 10.0 Hz, 1F); FTIR (thin film) ν 3394 (br-m), 3209 (w), 1659 (s), 1455 (m), 1192 (w), 1113 (m), 1038 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for C$_{10}$H$_{12}$F$_2$NO [M+H]$^+$: 200.0881; found 200.0881.

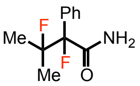


(±)-**7b**

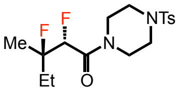
(±)-7b: Prepared according to general procedure E using (*E*)-3-(4-Bromophenyl)-2-methylacrylamide (**6b**, 300 mg, 1.25 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 10% ethyl acetate in dichloromethane) to give (±)-**7b** (261 mg, 75%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**7b** were secured by conversion of (±)-**7b** to (±)-**7a** by free radical debromination.[32] ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.49 (d, J = 8.3 Hz, 2H), 7.24 (d, J = 8.3 Hz, 2H), 6.05–5.95 (br-s, 1H), 5.67 (dd, J = 43.5, 25.0 Hz, 1H), 5.58–5.48 (br-s, 1H), 1.79 (dd, J = 22.5, 1.5 Hz, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 172.0 (dd, J = 21.1, 6.7 Hz), 133.0 (dd, J = 23.0, 1.9 Hz), 131.6, 129.2 (d, J = 7.7 Hz), 123.6, 98.0 (dd, J = 197.5, 24.0 Hz), 93.7 (dd, J = 185.1, 19.2 Hz), 20.3 (dd, J = 24.9, 5.8 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −169.1–−169.4 (m, 1F), −196.3 (dd, J = 43.1, 10.0 Hz, 1F); FTIR (thin film) ν 3397 (br-m), 3209 (br-m), 2987 (w), 1664 (s), 1492 (m), 1406 (m), 1112 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{11}BrF_2NO$ [M+H]$^+$: 277.9987; found 277.9981.


(±)-**7c**

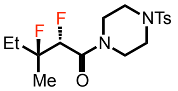
(±)-7c: Prepared according to general procedure E using (*E*)-2-benzylidene-3-methylbutanamide (**6c**, 200 mg, 1.06 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 20% ethyl acetate in hexanes) to give (±)-**7c** (149 mg, 62%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**7c** were secured by X-ray diffraction analysis of a single crystal (page S82, vide infra).[33] ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40–7.36 (m, 2H), 7.36–7.33 (m, 3H), 5.96 (dd, *J* = 44.0, 26.9 Hz, 1H), 5.95–5.90 (br-s, 1H), 5.40–5.30 (br-s, 1H), 2.63–2.49 (m, 1H), 1.28 (d, *J* = 6.9 Hz, 3H), 1.09 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 170.5 (dd, *J* = 21.1, 7.7 Hz), 134.5 (d, *J* = 21.1 Hz), 129.1, 128.3, 127.8 (d, *J* = 5.8 Hz), 102.5 (dd, *J* = 198.5, 23.0 Hz), 92.8 (dd, *J* = 184.1, 19.2 Hz), 32.6 (dd, *J* = 23.0, 3.8 Hz), 17.8 (d, *J* = 8.6 Hz), 17.1 (d, *J* = 1.9 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −174.1–−174.3 (m, 1F), −197.3 (dd, *J* = 44.8, 10.0 Hz, 1F); FTIR (thin film) ν 3480 (br-m), 3311 (br-m), 2973 (w), 1681 (s), 1417 (m), 1136 (m), 1044 (m), 1020 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{12}H_{16}F_2NO$ [M+H]$^+$: 228.1194; found 228.1189.


(±)-**7d**

(±)-7d: Prepared according to general procedure E using 3-methyl-2-phenylbut-2-enamide[34] (**6d**, 1.00 g, 5.71 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 20% ethyl acetate in hexanes) to give (±)-**7d** (1.00 g, 82%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77–7.73 (m, 2H), 7.39–7.35 (m, 3H), 6.62–6.47 (br-s, 1H), 6.43–6.28 (br-s, 1H), 1.56 (dd, *J* = 21.5, 1.0 Hz, 3H), 1.45 (dd, *J* = 22.0, 1.5 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 171.0 (dd, *J* = 22.9, 3.8 Hz), 134.4 (dd, *J* = 22.9, 2.9 Hz), 129.1, 128.1 (d, *J* = 1.9 Hz), 126.3 (dd, *J* = 12.4, 1.9 Hz), 99.1 (dd, *J* = 195.5, 22.9 Hz), 97.1 (dd, *J* = 181.2, 23.8 Hz), 23.1 (dd, *J* = 11.4, 4.8 Hz), 22.9 (dd, *J* = 12.4, 5.7 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −148.6 (sepd, *J* = 22.1, 10.0 Hz, 1F), −162.0–−162.2 (m, 1F); FTIR (thin film) ν 3489 (br-m), 3293 (br-m), 2988 (w), 1691 (s), 1449 (m), 1385 (m), 1048 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{11}H_{14}F_2NO$ [M+H]$^+$: 214.1038; found 214.1041.

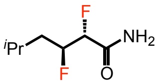

(±)-**7e**

(±)-7e: Prepared according to general procedure E using (*Z*)-3-methyl-1-(4-tosylpiperazin-1-yl)pent-2-en-1-one (**6e**, 200 mg, 0.594 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 25% ethyl acetate in hexanes) to give (±)-**7e** (165 mg, 74%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.3 Hz, 2H), 4.91 (dd, *J* = 48.4, 25.9 Hz, 1H), 3.82–3.65 (m, 4H), 3.09–2.94 (m, 4H), 2.44 (s, 3H), 1.83 (quindd, J = 7.8, 15.7, 2.0 Hz, 1H), 1.64 (quind, J = 7.3, 15.2 Hz, 1H), 1.35 (dd, *J* = 22.0, 1.0 Hz, 3H), 0.96 (t, *J* = 7.6 Hz, 3H); ^{13}C NMR (125.7 MHz, $CDCl_3$) δ 164.6 (d, *J* = 18.2 Hz), 144.1, 132.5, 130.0, 127.8, 97.0 (dd, *J* = 175.5, 19.2 Hz), 94.7 (dd, *J* = 197.5, 24.0 Hz), 46.5, 46.0, 45.3, 42.3, 28.6 (dd, *J* = 24.0, 6.7 Hz), 21.6, 19.9 (dd, *J* = 24.0, 3.8 Hz), 7.7 (d, *J* = 7.7 Hz); ^{19}F NMR (470.4 MHz, $CDCl_3$) δ −154.6–−155.0 (m, 1F), −190.7 (dd, *J* = 48.1, 14.9 Hz, 1F); FTIR (thin film) ν 2973 (w), 2921 (w), 1651 (s), 1446 (m), 1349 (m), 1165 (s), 1055 (m), 725 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{25}F_2N_2O_3S$ [M+H]$^+$: 375.1548; found 375.1561.



(±)-**7f**

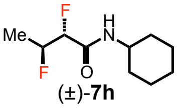
(±)-7f: Prepared according to general procedure E using (*E*)-3-methyl-1-(4-tosylpiperazin-1-yl)pent-2-en-1-one (**6f**, 200 mg, 0.594 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 10% ethyl acetate in dichloromethane) to give (±)-**7f** (146 mg, 66%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**7f** were secured by X-ray diffraction analysis of a single crystal (page S87, vide infra).[35] ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.58 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.3 Hz, 2H), 4.93 (dd, *J* = 47.8, 20.0 Hz, 1H), 3.78–3.57 (m, 4H), 3.07–2.90 (m, 4H), 2.39 (s, 3H), 1.73 (quind, *J* = 7.5, 15.1 Hz, 1H), 1.64 (quind, *J* = 7.3, 14.6 Hz, 1H), 1.35 (d, *J* = 22.5 Hz, 3H), 0.92 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 164.6 (d, *J* = 22.0 Hz), 144.1, 132.5, 129.9, 127.8, 96.9 (dd, *J* = 174.5, 20.1 Hz), 93.1 (dd, *J* = 193.7, 26.9 Hz), 46.4, 45.9, 45.3, 42.1, 29.3 (dd, *J* = 23.0, 2.9 Hz), 21.6, 19.3 (dd, *J* = 24.9, 6.7 Hz), 7.5 (d, *J* = 6.7 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −156.3–−156.7 (m, 1F), −191.3 (dd, *J* = 48.1, 13.3 Hz, 1F); FTIR (thin film) ν 2984 (w), 2924 (w), 1665 (s), 1448 (m), 1349 (m), 1166 (s), 725 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{17}H_{25}F_2N_2O_3S$ [M+H]$^+$: 375.1548; found 375.1564.



(±)-**7g**

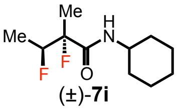
(±)-7g: Prepared according to general procedure F using (*E*)-5-methylhex-2-enamide[36] (**6g**, 300 mg, 2.36 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 20% ethyl acetate in dichloromethane) to give (±)-**7g** (350 mg, 90%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**7g** were secured by X-ray diffraction analysis of a single crystal (page S93, vide infra).[37] ^{1}H NMR (500 MHz, CDCl$_3$) δ 6.62–6.45 (br-s, 1H), 6.45–6.28 (br-s, 1H), 5.06 (dd, *J* = 49.8, 19.1 Hz, 1H), 4.98 (ddd, *J* = 47.4, 24.9, 10.3 Hz, 1H), 1.94–1.76 (m, 2H), 1.28 (dddd, *J* = 40.1, 14.2, 8.8, 2.9 Hz, 1H), 0.96 (d, *J* = 6.4 Hz, 3H), 0.93 (d, *J* = 6.4 Hz, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 169.3 (dd, *J* = 21.1, 10.5 Hz), 92.3 (dd, *J* = 193.7, 23.0 Hz), 91.2 (dd, *J* = 176.4, 19.2 Hz), 37.2 (dd, *J* = 21.1, 4.8 Hz), 24.5 (d, *J* = 1.9 Hz), 23.3, 21.7; ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −193.1–−193.4 (m, 1F), −198.1 (dddd, *J* = 49.8, 24.9, 13.3, 3.3 Hz, 1F); FTIR (thin film) ν 3389 (br-m), 3180 (br-m), 2959 (w), 2901 (w), 1669 (s), 1405 (m), 1393 (m), 1107 (m), 1058 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{11}H_{14}F_2NO$ [M+H]$^+$: 166.1038; found 166.1035.

Reaction using 1a: The above procedure was repeated using *p*-iodotoluene as a catalyst (102 mg, 0.47 mmol, 20.0 mol %) to give (±)-**7g** (235 mg, 60%) as a white solid.



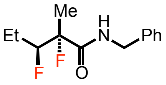
(±)-**7h**

(±)-7h: Prepared according to general procedure F using (*E*)-*N*-cyclohexylbut-2-enamide[38] (**6h**, 300 mg, 1.79 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 10% ethyl acetate in hexanes) to give (±)-**7h** (314 mg, 85%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. ^{1}H NMR (500 MHz, CDCl$_3$) δ 6.31–6.09 (br-s, 1H), 5.11 (qdd, *J* = 6.8, 46.0, 25.9 Hz, 1H), 5.07 (dd, *J* = 48.8, 16.6 Hz, 1H), 3.85–3.74 (m, 1H), 1.97–1.85 (m, 2H), 1.79–1.68 (m, 2H), 1.67–1.59 (m, 1H), 1.44–1.32 (m, 2H), 1.37 (dd, *J* = 23.5, 6.8 Hz, 3H), 1.27–1.13 (m, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 165.1 (dd, *J* = 19.2, 10.6 Hz), 92.2 (dd, *J* = 194.7, 22.1 Hz), 89.2 (dd, *J* = 174.5, 20.8 Hz), 48.1, 33.1, 32.8, 25.5, 24.9, 24.8, 14.0 (dd, *J* = 23.0, 6.7 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −185.2–−185.7 (m, 1F), −203.1 (ddd, *J* = 48.8, 25.9, 10.7 Hz, 1F); FTIR (thin film) ν 3310 (br-m), 2935 (w), 2854 (w), 1647 (s), 1553 (m), 1450 (m), 1099 (m), 1083 (m), 992 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{10}H_{18}F_2NO$ [M+H]$^+$: 206.1351; found 206.1357.



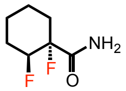
(±)-**7i**

(±)-7i: Prepared according to general procedure F using (*E*)-*N*-cyclohexyl-2-methylbut-2-enamide (**6i**, 100 mg, 0.552 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 50% dichloromethane in hexanes) to give (±)-**7i** (102 mg, 84%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. ^{1}H NMR (500 MHz, CDCl$_3$) δ 6.40–6.19 (br-s, 1H), 4.85 (qdd, *J* = 6.4, 47.0, 23.5 Hz, 1H), 3.80–3.68 (m, 1H), 1.94–1.84 (m, 2H), 1.77–1.66 (m, 2H), 1.65–1.58 (m, 1H), 1.59 (d, *J* = 23.0 Hz, 3H), 1.41–1.28 (m, 2H), 1.32 (dd, *J* = 24.0, 6.4 Hz, 3H), 1.25–1.11 (m, 3H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 168.8 (dd, *J* = 20.0, 6.7 Hz), 98.1 (dd, *J* = 191.7, 20.0 Hz), 91.3 (dd, *J* = 178.3, 21.0 Hz), 48.2, 33.1, 32.9, 25.6, 24.9, 24.9, 20.1 (dd, *J* = 23.8, 5.7 Hz), 14.9 (dd, *J* = 23.8, 6.7 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −170.0–−191.4 (m, 1F), −191.4 (qdd, *J* = 23.0, 47.0, 11.6 Hz, 1F); FTIR (thin film) ν 3322 (br-m), 2929 (w), 2856 (w), 1649 (s), 1540 (s), 1448 (m), 1110 (m), 1090 (m), 1065 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{11}H_{20}F_2NO$ [M+H]$^{+}$: 220.1507; found 220.1515.



(±)-**7j**

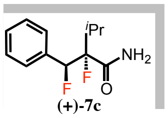
(±)-7j: Prepared according to general procedure F using (*E*)-*N*-benzyl-2-methylpent-2-enamide (**6j**, 112 mg, 0.551 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 10% ethyl acetate in hexanes) to give (±)-**7j** (106 mg, 80%) as a white solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.38–7.25 (m, 5H), 6.81–6.68 (br-s, 1H), 4.63 (dddd, *J* = 47.4, 23.5, 10.8, 2.5 Hz, 1H), 4.51–4.42 (m, 2H), 1.91–1.78 (m, 1H), 1.65 (dd, *J* = 23.0, 2.0 Hz, 3H), 1.51 (sextdd, *J* = 7.4, 39.7, 2.5 Hz, 1H), 1.04 (t, *J* = 7.6 Hz, 1H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 169.9 (dd, *J* = 20.1, 6.7 Hz), 137.6, 129.0, 128.0, 127.9, 98.3 (dd, *J* = 191.8, 20.1 Hz), 96.1 (dd, *J* = 181.2, 20.1 Hz), 43.4, 22.6 (dd, *J* = 22.1, 4.8 Hz), 20.5 (dd, *J* = 24.0, 5.8 Hz), 10.1 (d, *J* = 3.8 Hz); ^{19}F NMR (376.3 MHz, CDCl$_3$) δ −167.9–−168.3 (m, 1F), −201.2 (tdd, *J* = 47.4, 39.7, 13.0 Hz, 1F); FTIR (thin film) ν 3325 (br-m), 2974 (w), 2936 (w), 1662 (s), 1531 (m), 1454 (m), 1078 (m), 966 (m) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_{13}H_{18}F_2NO$ [M+H]$^{+}$: 242.1351; found 242.1358.



(±)-**7k**

(±)-7k: Prepared according to general procedure F using cyclohex-1-enecarboxamide[39] (**6k**, 200 mg, 1.60 mmol). After work-up, the crude residue was purified by flash column chromatography on silica gel (0 to 10% ethyl acetate in dichloromethane) to give (±)-**7k** (156 mg, 60%) as a light yellow solid. The diastereomeric ratio of the product was determined to be >19:1 by ^{1}H and ^{19}F NMR analysis. The connectivity and relative stereochemistry of (±)-**7k** were secured by X-ray diffraction analysis of a single crystal (page S97, vide infra).[40] ^{1}H NMR (500 MHz, CDCl$_3$) δ 6.53–6.22 (br-s, 1H), 6.21–5.84 (br-s, 1H), 4.62 (dddd, *J* = 49.4, 13.7, 9.8, 4.9 Hz, 1H), 2.29–2.10 (m, 2H), 2.07–1.95 (m, 1H), 1.95–1.74 (m, 2H), 1.74–1.58 (m, 2H), 1.42–1.31 (m, 1H); ^{13}C NMR (125.7 MHz, CDCl$_3$) δ 172.0 (d, *J* = 23.8 Hz), 95.8 (dd, *J* = 187.9, 21.9 Hz), 93.1 (dd, *J* = 182.2, 24.8 Hz), 32.6 (d, *J* = 19.1 Hz), 28.5 (dd, *J* = 18.1, 5.7 Hz), 21.9 (d, *J* = 8.6 Hz), 21.7 (d, *J* = 7.6 Hz); ^{19}F NMR (470.4 MHz, CDCl$_3$) δ −150.5–−152.8 (m, 1F), −187.7 (d, *J* = 49.4 Hz, 1F); FTIR (thin film) ν 3417 (br-m), 3193 (br-m), 2943 (w), 1681 (s), 1451 (m), 1408 (m), 1070 (m), 1038 (s) cm^{-1}; HRMS (ESI-TOF) Calc'd for $C_7H_{11}F_2NO$ [M+H]$^{+}$: 164.0881; found 164.0878.

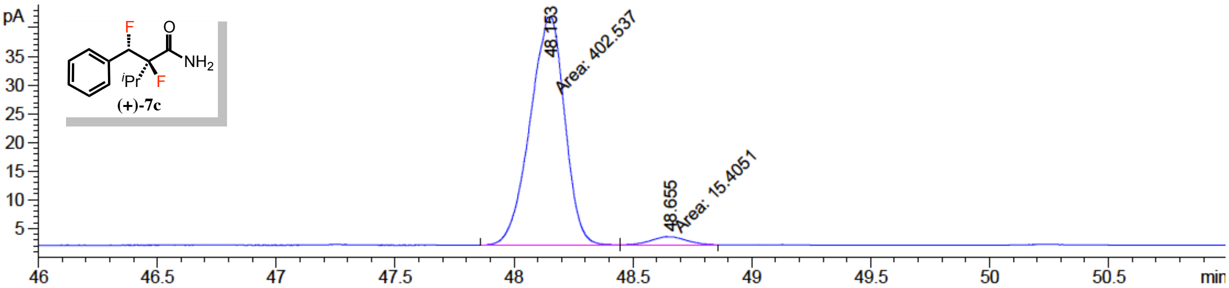
Enantioselective Difluorination of 6c:



(+)-7c

(+)-7c: (*E*)-2-benzylidene-3-methylbutanamide (**6c**, 197 mg, 1.04 mmol, 1 equiv), catalyst **1d** (128 mg, 0.21 mmol, 20 mol%) and *m*CPBA (307 mg, 1.35 mmol, 1.30 equiv) were dissolved in dichloromethane (2.0 mL). The reaction mixture was cooled to −78° C, and pyr•9HF (2.72 mL, 104.0 mmol, 100 equiv HF) was added. The reaction vessel was transferred to a 4° C refridgerator and stirred for 72 hours. After 72 hours, the reaction mixture was cooled to −78° C, and was slowly added to a sturred slurry of silica gel (20 grams) and ethyl acetate (100 mL). The mixture was allowed to warm to room temperature with stirring, and was then filtered and the silica gel washed with 150 mL ethyl acetate. To the combined filtrate was added 100 mL saturated aqueous $NaHCO_3$, and the organic layer was separated. The resulting solution was dried with anhydrous $MgSO_4$ and concentrated. The resulting residue was purified by flash column chromatography on silica gel (0 to 10% diethyl ether in dichloromethane) to give (+)-**7c** (121 mg, 51%) as a white solid. These solvent conditions for purification enabled greater separation between the product and the catalyst. (+)-**7c** was determined to be of 93% e.e. by chiral GC analysis (β-Cyclosil, 120→200 °C, 1°/min, 7 psi, t_r(major)= 48.153 min, t_r(minor)= 48.655 min) and >19:1 d.r. by F^{19} NMR. The spectral data for (+)-**7c** were in accordance with **(±)-7c** (*vide supra*). $[\alpha]_D^{23}$ = +6.2 (c = 1.0, $CHCl_3$). The absolute stereochemistry of (+)-**7c** was confirmed by X-ray diffraction analysis of a single crystal.[41]

Chiral GC Trace of (+)-7c



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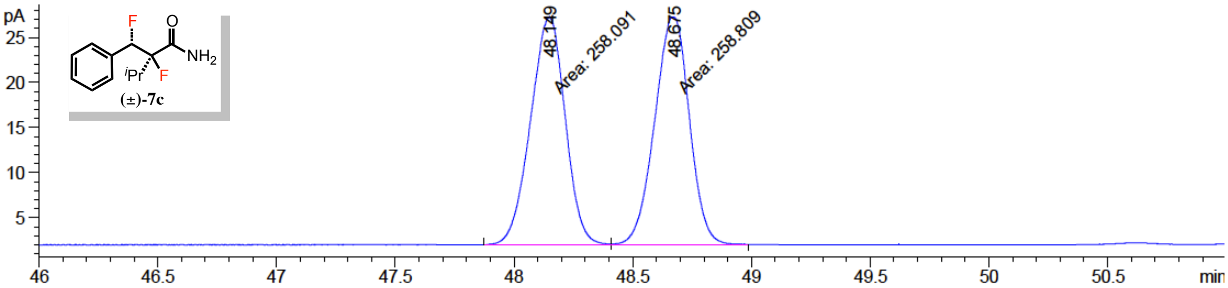

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  1   48.149 MF    0.1696  258.09058   25.35552 49.93055
  2   48.675 FM    0.1703  258.80856   25.33195 50.06945
```

Computational Details: Calculations were executed using the Gaussian 09[42] program at the M06-2X level of theory. The SDD basis set was used for iodine and the 6-31+G(d) basis set for all other atoms. Default optimization convergence criteria, tight SCF convergence criteria, and default integration settings were used. Optimized structures correspond to gas-phase (298 K) structures unless noted. Solvation energies were evaluated by a self-consistent reaction field (SCRF) using the CPCM model with UFF radii. Stationary points were characterized by the presence of all positive eigenvalues of the Hessian for minima. All molecular structures were rendered in CYLView.[43]

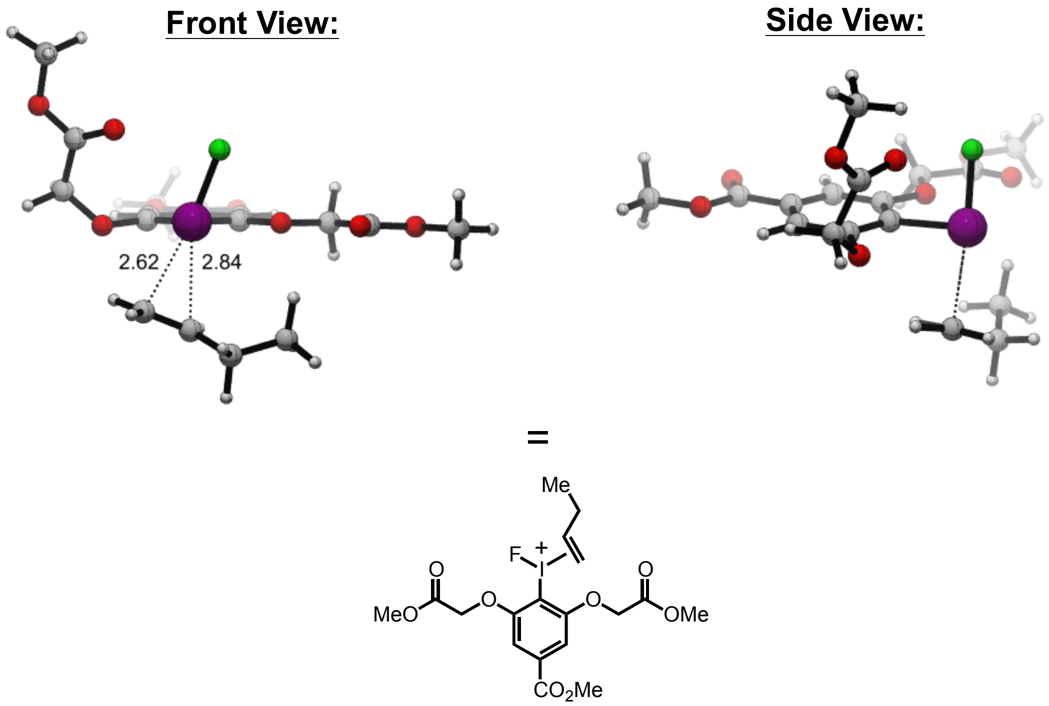


Figure S1: Computed binding mode of butene to aryl iodonium derived from catalyst **1b**. Structures calculated at the M06-2X/6-31+G(d,p)[SDD, for I] level of theory in DCM.

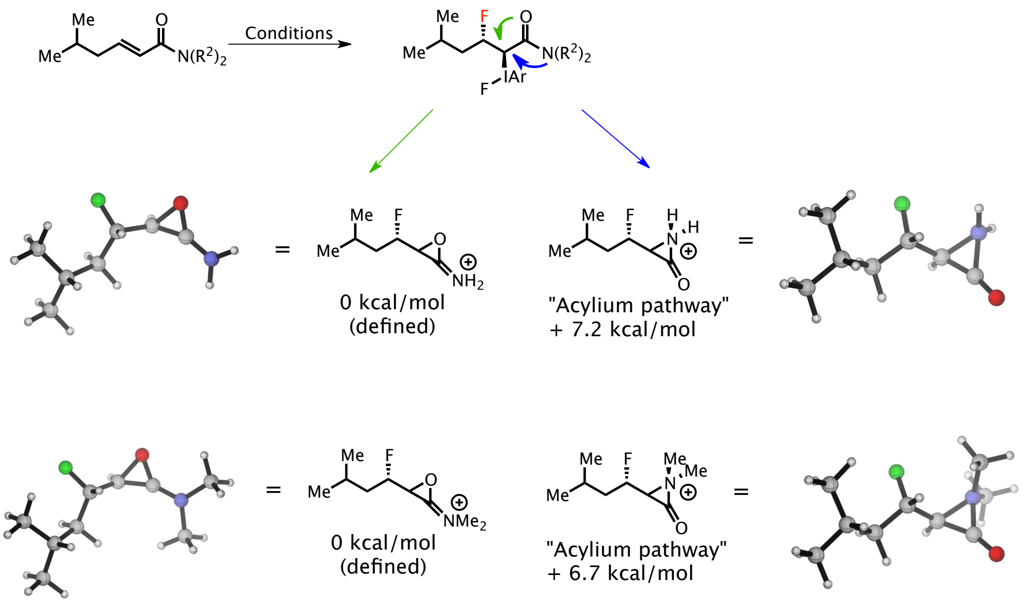
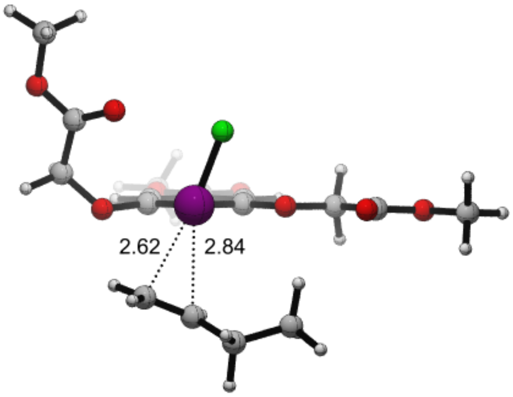


Figure S2: Computed models of anchimeric assistance in acrylamide difluorination. Structures calculated at the M06-2X/6-31+G(d,p) level of theory.



Charge = 1 Multiplicity = 1
Electronic Energy (AU)= -1411.96511794
Solvent: DCM
Imaginary Frequencies: 0

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C	2.31368	1.21358	0.74854
C	1.66039	-0.01742	0.70146
C	0.31728	-0.04216	0.32898
C	-0.4065	1.12151	0.02667
C	0.25912	2.34315	0.06316
H	3.34973	1.28171	1.05867
H	-0.23613	3.27845	-0.17308
I	-0.67734	-1.85296	0.01624
O	-1.6987	0.94069	-0.27988
O	2.25357	-1.18397	1.0763
C	3.48397	-1.51332	0.44998
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C	3.22287	-1.96279	-0.98028
C	-3.81517	1.44844	-1.15744
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H	3.63531	-3.61522	-2.99352
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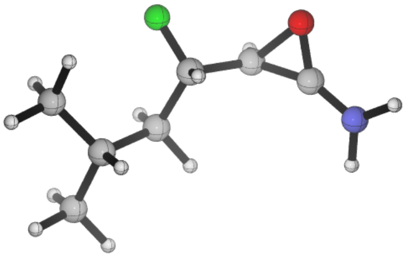
H	-5.82443	1.18975	-2.85076
C	-0.31901	-2.39552	2.64758
H	-0.56571	-3.45616	2.63178
H	0.73314	-2.12498	2.67525
C	-1.29549	-1.46488	2.82453
H	-0.99384	-0.41712	2.90266
F	-0.69276	-1.51257	-1.89688
C	-2.75487	-1.74388	2.97903
H	-2.95547	-1.70627	4.05985
H	-2.97961	-2.76873	2.66214
C	-3.64735	-0.72194	2.26796
H	-4.69754	-0.92064	2.48998
H	-3.41932	0.29243	2.61192
H	-3.52398	-0.74529	1.18167
H	4.19287	-0.68017	0.4579
H	-2.56817	2.81936	-0.07164
C	2.26606	3.7205	0.44628
O	1.67224	4.74077	0.19739
O	3.55503	3.65167	0.76973
C	4.24612	4.91239	0.81145
H	5.27372	4.67254	1.07379
H	4.19331	5.39478	-0.1658
H	3.79046	5.55931	1.56272



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Solvent: gas phase
Imaginary Frequencies: 0

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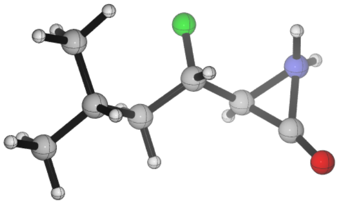
H	-1.22747	3.51366	-0.80105
C	-3.34327	3.24544	-1.06675
H	-3.56417	4.28991	-0.98809
H	-3.26074	2.97587	-2.09891
H	-4.12928	2.67853	-0.61223
C	-2.13618	3.33448	1.13751
H	-2.92391	2.76852	1.58955
H	-1.21415	3.1258	1.63838
H	-2.35628	4.37881	1.21661
C	-1.69418	1.44355	-0.46208
H	-0.77189	1.23536	0.03867
H	-2.48056	0.87606	-0.01061
C	-1.57003	1.0571	-1.94684
C	-1.25073	-0.44456	-2.0633
H	-2.22112	-0.58591	-1.63532

C	-1.43161	-1.43733	-3.15792
O	-0.77957	-0.25261	-3.54661
N	-1.89762	-2.59081	-3.51582
H	-2.35032	-3.17717	-2.84327
H	-1.80478	-2.8957	-4.46361
H	-0.7833	1.62478	-2.39817
F	-2.73341	1.31959	-2.5794



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Solvent: gas phase
Imaginary Frequencies: 0

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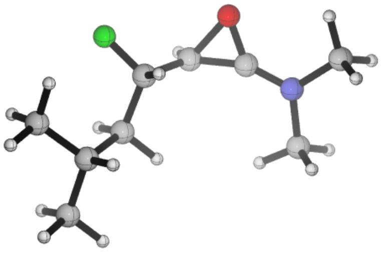
H	-2.23349	-0.37515	1.21566
C	-2.64385	1.39612	0.07145
H	-3.55199	1.61693	0.59245
H	-1.84016	1.95556	0.50273
H	-2.75046	1.6619	-0.95952
C	-3.49681	-0.91455	-0.43604
H	-3.60342	-0.64877	-1.467
H	-3.28576	-1.96057	-0.35735
H	-4.40495	-0.69374	0.08496
C	-1.03307	-0.42716	-0.56516
H	-0.82201	-1.47319	-0.48648
H	-1.13967	-0.16138	-1.59613
C	0.12365	0.37801	0.05557
C	1.43068	0.06022	-0.69428
H	1.47006	1.10041	-0.94197
C	2.86886	0.02561	-0.25448
O	4.05092	0.39171	-0.4831
N	1.98818	-0.76949	0.55368
H	1.43191	-1.58193	0.37907
H	2.71305	-1.44878	0.66828
F	-0.14263	1.69776	-0.04371
H	0.23026	0.11223	1.08654



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Solvent: gas phase
Imaginary Frequencies: 0

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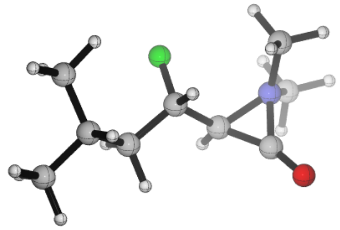
C	-3.34327	3.24544	-1.06675
H	-3.56417	4.28991	-0.98809
H	-3.26074	2.97587	-2.09891
H	-4.12928	2.67853	-0.61223
C	-2.13618	3.33448	1.13751
H	-2.92391	2.76852	1.58955
H	-1.21415	3.1258	1.63838
H	-2.35628	4.37881	1.21661
C	-1.69418	1.44355	-0.46208
H	-0.77189	1.23536	0.03867
H	-2.48056	0.87606	-0.01061
C	-1.57003	1.0571	-1.94684
C	-1.25073	-0.44456	-2.0633
H	-2.22112	-0.58591	-1.63532
C	-1.43161	-1.43733	-3.15792
O	-0.77957	-0.25261	-3.54661
N	-1.89762	-2.59081	-3.51582
C	-2.56273	-3.4523	-2.5277
H	-3.48998	-3.00702	-2.23303
H	-2.74994	-4.41279	-2.9605
H	-1.93241	-3.56415	-1.67034
C	-1.76114	-3.03902	-4.90915
H	-2.30615	-2.37895	-5.55116
H	-0.72761	-3.03318	-5.18609
H	-2.15031	-4.03117	-5.00441
H	-0.7833	1.62478	-2.39817
F	-2.73341	1.31959	-2.5794



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Solvent: gas phase
Imaginary Frequencies: 0

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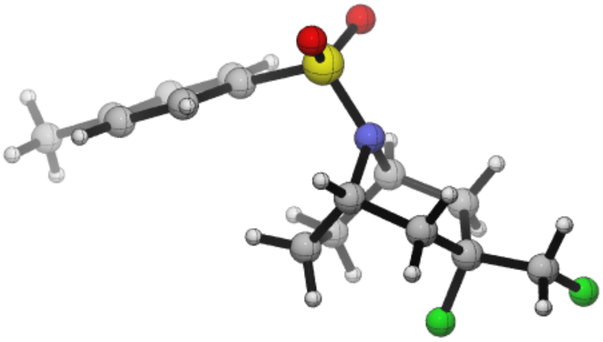
H	-1.73455	3.54546	-1.39098
C	-3.61629	3.01002	-0.50365
H	-3.96734	4.01937	-0.4501
H	-3.99295	2.54806	-1.39226
H	-3.95837	2.46752	0.35285
C	-1.53452	3.66784	0.74445
H	-1.87659	3.12534	1.60094
H	-0.46474	3.66294	0.72303
H	-1.88557	4.67719	0.79799
C	-1.57137	1.55025	-0.61154
H	-0.5016	1.54535	-0.63297
H	-1.91345	1.00775	0.24495
C	-2.11347	0.88537	-1.89047
C	-1.60823	-0.56734	-1.96753
H	-2.63675	-0.86178	-1.94877
C	-1.28568	-1.4681	-3.12839
O	-1.44316	-2.59589	-3.66397
N	-0.6175	-0.19808	-3.167
C	-1.30085	0.26257	-4.38427
H	-0.99012	1.26089	-4.61163
H	-1.05069	-0.38331	-5.19984
H	-2.35914	0.24543	-4.22737
C	0.79218	-0.54683	-2.9388
H	1.15191	-1.13267	-3.75873
H	1.37259	0.34847	-2.85841
H	0.87814	-1.11014	-2.03316
F	-3.46319	0.89155	-1.86344
H	-1.7714	1.42787	-2.74697

X-Ray Crystallographic Data

X-Ray Crystal Structure of 1,2-Difluoride 3j.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD diffractometer (Mo$_{K_\alpha}$ radiation, λ=0.71073 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 0.5° scans in *ω* at 28° in *2θ*. Data integration down to 0.78 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S4. Experimental details

	SMB-8-161
Crystal data	
Chemical formula	$C_{15}H_{19}F_2NO_2S$
M_r	315.37
Crystal system, space group	Triclinic, *P*-1
Temperature (K)	100
a, *b*, *c* (Å)	6.134 (2), 10.761 (4), 12.298 (5)
a, b, g (°)	70.442 (6), 75.711 (7), 89.132 (7)
V (Å^3)	739.3 (5)
Z	2
Radiation type	Mo *K*a
m (mm^{-1})	0.25
Crystal size (mm)	0.24 × 0.16 × 0.06

Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan TWINABS
T_{min}, T_{max}	0.663, 0.746
No. of measured, independent and observed [$I > 2s(I)$] reflections	2529, 2529, 1445
R_{int}	0.0664
(sin q/l)$_{\mathrm{max}}$ (Å^{-1})	0.597
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.050, 0.099, 0.84
No. of reflections	2529
No. of parameters	191
H-atom treatment	H-atom parameters constrained
Dρ$_{\mathrm{max}}$, Dρ$_{\mathrm{min}}$ (e Å^{-3})	0.36, -0.35

Table S5. Geometric parameters (Å, º)

C1—C2	1.383 (5)	C9—H9	1.0000
C1—C6	1.384 (5)	C10—C11	1.554 (4)
C1—H1	0.9500	C10—H10A	0.9900
C2—C3	1.389 (4)	C10—H10B	0.9900
C2—H2	0.9500	C11—C12	1.542 (4)
C3—C4	1.385 (5)	C11—H11A	0.9900
C3—S1	1.753 (3)	C11—H11B	0.9900
C4—C5	1.389 (5)	C12—N1	1.493 (4)
C4—H4	0.9500	C12—C13	1.520 (5)
C5—C6	1.393 (5)	C12—H12	1.0000
C5—H5	0.9500	C13—C14	1.519 (5)
C6—C7	1.504 (5)	C13—H13A	0.9900
C7—H7A	0.9800	C13—H13B	0.9900
C7—H7B	0.9800	C14—F1	1.432 (3)
C7—H7C	0.9800	C14—C15	1.491 (5)
C8—C9	1.514 (4)	C15—F2	1.402 (4)
C8—C14	1.525 (4)	C15—H15A	0.9900
C8—H8A	0.9900	C15—H15B	0.9900

C8—H8B	0.9900	N1—S1	1.633 (3)
C9—N1	1.476 (4)	O1—S1	1.437 (2)
C9—C10	1.549 (4)	O2—S1	1.444 (2)
C2—C1—C6	121.0 (3)	H10A—C10—H10B	109.0
C2—C1—H1	119.5	C12—C11—C10	105.2 (2)
C6—C1—H1	119.5	C12—C11—H11A	110.7
C1—C2—C3	119.9 (3)	C10—C11—H11A	110.7
C1—C2—H2	120.1	C12—C11—H11B	110.7
C3—C2—H2	120.1	C10—C11—H11B	110.7
C4—C3—C2	120.2 (3)	H11A—C11—H11B	108.8
C4—C3—S1	120.0 (3)	N1—C12—C13	104.9 (3)
C2—C3—S1	119.7 (3)	N1—C12—C11	103.3 (3)
C3—C4—C5	119.0 (3)	C13—C12—C11	113.3 (3)
C3—C4—H4	120.5	N1—C12—H12	111.6
C5—C4—H4	120.5	C13—C12—H12	111.6
C4—C5—C6	121.5 (3)	C11—C12—H12	111.6
C4—C5—H5	119.2	C14—C13—C12	113.7 (3)
C6—C5—H5	119.2	C14—C13—H13A	108.8
C1—C6—C5	118.3 (3)	C12—C13—H13A	108.8
C1—C6—C7	120.4 (4)	C14—C13—H13B	108.8
C5—C6—C7	121.3 (4)	C12—C13—H13B	108.8
C6—C7—H7A	109.5	H13A—C13—H13B	107.7
C6—C7—H7B	109.5	F1—C14—C15	105.5 (3)
H7A—C7—H7B	109.5	F1—C14—C13	107.7 (3)
C6—C7—H7C	109.5	C15—C14—C13	110.1 (3)
H7A—C7—H7C	109.5	F1—C14—C8	106.9 (2)
H7B—C7—H7C	109.5	C15—C14—C8	113.3 (3)
C9—C8—C14	113.0 (3)	C13—C14—C8	112.8 (3)
C9—C8—H8A	109.0	F2—C15—C14	110.3 (3)
C14—C8—H8A	109.0	F2—C15—H15A	109.6
C9—C8—H8B	109.0	C14—C15—H15A	109.6
C14—C8—H8B	109.0	F2—C15—H15B	109.6
H8A—C8—H8B	107.8	C14—C15—H15B	109.6
N1—C9—C8	105.5 (3)	H15A—C15—H15B	108.1
N1—C9—C10	104.3 (2)	C9—N1—C12	103.6 (2)
C8—C9—C10	113.4 (3)	C9—N1—S1	120.0 (2)
N1—C9—H9	111.1	C12—N1—S1	121.6 (2)
C8—C9—H9	111.1	O1—S1—O2	119.81 (14)
C10—C9—H9	111.1	O1—S1—N1	105.81 (14)
C9—C10—C11	104.0 (2)	O2—S1—N1	106.35 (14)
C9—C10—H10A	110.9	O1—S1—C3	107.24 (15)
C11—C10—H10A	110.9	O2—S1—C3	108.30 (16)
C9—C10—H10B	110.9	N1—S1—C3	108.97 (15)

C11—C10—H10B	110.9		
C6—C1—C2—C3	0.9 (5)	C9—C8—C14—C13	−38.6 (4)
C1—C2—C3—C4	−2.3 (5)	F1—C14—C15—F2	63.3 (3)
C1—C2—C3—S1	176.7 (3)	C13—C14—C15—F2	179.2 (3)
C2—C3—C4—C5	2.1 (5)	C8—C14—C15—F2	−53.3 (4)
S1—C3—C4—C5	−176.9 (3)	C8—C9—N1—C12	−77.0 (3)
C3—C4—C5—C6	−0.6 (5)	C10—C9—N1—C12	42.8 (3)
C2—C1—C6—C5	0.5 (5)	C8—C9—N1—S1	143.4 (2)
C2—C1—C6—C7	−179.1 (3)	C10—C9—N1—S1	−96.9 (3)
C4—C5—C6—C1	−0.7 (5)	C13—C12—N1—C9	76.0 (3)
C4—C5—C6—C7	178.9 (3)	C11—C12—N1—C9	−42.9 (3)
C14—C8—C9—N1	57.9 (3)	C13—C12—N1—S1	−145.2 (2)
C14—C8—C9—C10	−55.7 (4)	C11—C12—N1—S1	95.9 (3)
N1—C9—C10—C11	−25.3 (3)	C9—N1—S1—O1	−51.7 (3)
C8—C9—C10—C11	88.9 (3)	C12—N1—S1—O1	176.0 (2)
C9—C10—C11—C12	−0.8 (3)	C9—N1—S1—O2	179.9 (2)
C10—C11—C12—N1	26.2 (3)	C12—N1—S1—O2	47.6 (3)
C10—C11—C12—C13	−86.8 (3)	C9—N1—S1—C3	63.3 (3)
N1—C12—C13—C14	−56.6 (3)	C12—N1—S1—C3	−69.0 (3)
C11—C12—C13—C14	55.4 (3)	C4—C3—S1—O1	−157.6 (3)
C12—C13—C14—F1	−79.3 (3)	C2—C3—S1—O1	23.4 (3)
C12—C13—C14—C15	166.1 (3)	C4—C3—S1—O2	−27.0 (3)
C12—C13—C14—C8	38.4 (4)	C2—C3—S1—O2	154.1 (3)
C9—C8—C14—F1	79.6 (3)	C4—C3—S1—N1	88.3 (3)
C9—C8—C14—C15	−164.6 (3)	C2—C3—S1—N1	−90.6 (3)

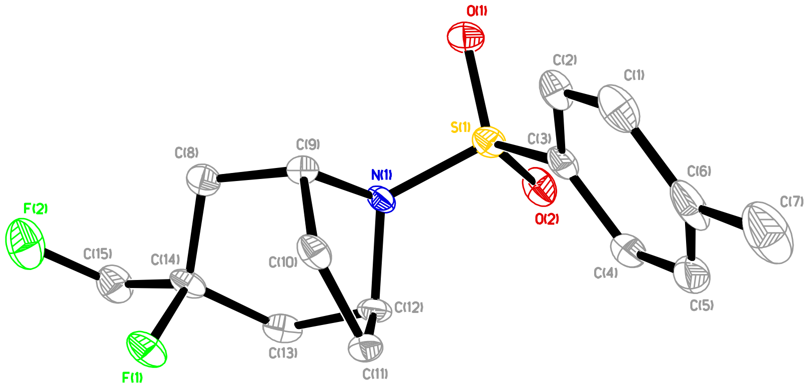
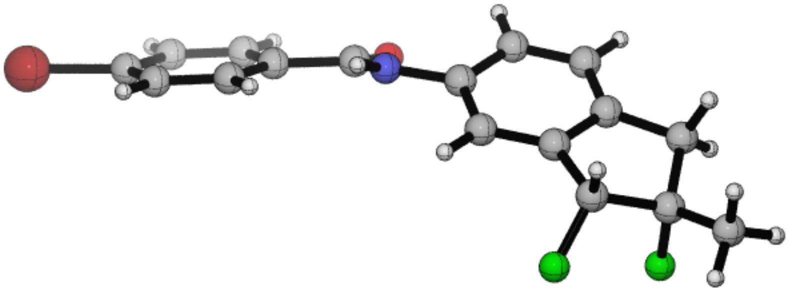


Figure S3. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-S5i.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD diffractometer (Mo$_{K_\alpha}$ radiation, λ=0.71073 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 0.5° scans in ω at 28° in 2θ. Data integration down to 0.80 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program.[48]

Table S6. Experimental details

	SMB-p-Br-amide
Crystal data	
Chemical formula	$C_{17}H_{14}BrF_2NO$
M_r	366.20
Crystal system, space group	Monoclinic, *I*2/*c*
Temperature (K)	100
a, *b*, *c* (Å)	9.9432 (7), 9.5857 (6), 94.148 (6)
b (°)	91.086 (4)
V (Å^3)	8971.9 (10)
Z	24
Radiation type	Mo *K*a
m (mm^{-1})	2.77
Crystal size (mm)	0.16 × 0.14 × 0.04

Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
$T_{\min}$, $T_{\max}$	0.622, 0.746
No. of measured, independent and observed [$I > 2s(I)$] reflections	59166, 10000, 7890
R_{int}	0.060
(sin q/l)$_{\max}$ (Å^{-1})	0.644
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.090, 0.196, 1.17
No. of reflections	10000
No. of parameters	610
No. of restraints	182
H-atom treatment	H-atom parameters constrained
Dρ$_{\max}$, Dρ$_{\min}$ (e Å^{-3})	1.55, -1.42

Table S6. Geometric parameters (Å, º)

C1—F1	1.451 (7)	N2—H2	0.8800
C1—C2	1.500 (9)	C32—C33	1.3900
C1—C9	1.537 (9)	C32—C37	1.3900
C1—H1	1.0000	C33—C34	1.3900
C2—C3	1.382 (8)	C33—H33	0.9500
C2—C7	1.383 (9)	C34—C35	1.3900
C3—C4	1.393 (8)	C34—H34	0.9500
C3—H3	0.9500	C35—C36	1.3900
C4—C5	1.393 (9)	C35—Br2	1.875 (3)
C4—N1A	1.413 (8)	C36—C37	1.3900
C4—N1	1.413 (8)	C36—H36	0.9500
C5—C6	1.377 (10)	C37—H37	0.9500
C5—H5	0.9500	C31A—O2A	1.23 (2)
C6—C7	1.383 (10)	C31A—N2A	1.35 (2)
C6—H6	0.9500	C31A—C32A	1.52 (2)
C7—C8	1.510 (9)	N2A—H2A	0.8800
C8—C9	1.536 (10)	C32A—C33A	1.3900
C8—H8A	0.9900	C32A—C37A	1.3900

C8—H8B	0.9900	C33A—C34A	1.3900
C9—F2	1.424 (7)	C33A—H33A	0.9500
C9—C10	1.496 (10)	C34A—C35A	1.3900
C10—H10A	0.9800	C34A—H34A	0.9500
C10—H10B	0.9800	C35A—C36A	1.3900
C10—H10C	0.9800	C35A—Br2A	1.863 (19)
C11—O1	1.239 (11)	C36A—C37A	1.3900
C11—N1	1.364 (11)	C36A—H36A	0.9500
C11—C12	1.512 (10)	C37A—H37A	0.9500
N1—H1A	0.8800	C41—F5	1.455 (7)
C12—C13	1.3900	C41—C42	1.497 (8)
C12—C17	1.3900	C41—C49	1.546 (9)
C13—C14	1.3900	C41—H41	1.0000
C13—H13	0.9500	C42—C43	1.386 (8)
C14—C15	1.3900	C42—C47	1.395 (9)
C14—H14	0.9500	C43—C44	1.389 (8)
C15—C16	1.3900	C43—H43	0.9500
C15—Br1	1.886 (6)	C44—C45	1.405 (8)
C16—C17	1.3900	C44—N3A	1.409 (7)
C16—H16	0.9500	C44—N3	1.409 (7)
C17—H17	0.9500	C45—C46	1.373 (9)
C11A—O1A	1.232 (14)	C45—H45	0.9500
C11A—N1A	1.344 (14)	C46—C47	1.387 (9)
C11A—C12A	1.502 (14)	C46—H46	0.9500
N1A—H1AA	0.8800	C47—C48	1.499 (8)
C12A—C13A	1.3900	C48—C49	1.522 (10)
C12A—C17A	1.3900	C48—H48A	0.9900
C13A—C14A	1.3900	C48—H48B	0.9900
C13A—H13A	0.9500	C49—F6	1.432 (7)
C14A—C15A	1.3900	C49—C50	1.512 (9)
C14A—H14A	0.9500	C50—H50A	0.9800
C15A—C16A	1.3900	C50—H50B	0.9800
C15A—Br1A	1.863 (9)	C50—H50C	0.9800
C16A—C17A	1.3900	C51—O3	1.239 (9)
C16A—H16A	0.9500	C51—N3	1.354 (7)
C17A—H17A	0.9500	C51—C52	1.501 (7)
C21—F3	1.462 (7)	N3—H3A	0.8800
C21—C22	1.509 (8)	C52—C53	1.3900
C21—C29	1.535 (9)	C52—C57	1.3900
C21—H21	1.0000	C53—C54	1.3900
C22—C23	1.377 (8)	C53—H53	0.9500
C22—C27	1.381 (9)	C54—C55	1.3900
C23—C24	1.406 (8)	C54—H54	0.9500

C23—H23	0.9500	C55—C56	1.3900
C24—C25	1.391 (8)	C55—Br3	1.878 (3)
C24—N2A	1.416 (8)	C56—C57	1.3900
C24—N2	1.416 (8)	C56—H56	0.9500
C25—C26	1.382 (9)	C57—H57	0.9500
C25—H25	0.9500	C51A—O3A	1.24 (2)
C26—C27	1.385 (8)	C51A—N3A	1.36 (2)
C26—H26	0.9500	C51A—C52A	1.51 (2)
C27—C28	1.506 (8)	N3A—H3AA	0.8800
C28—C29	1.525 (9)	C52A—C53A	1.390 (2)
C28—H28A	0.9900	C52A—C57A	1.3900 (10)
C28—H28B	0.9900	C53A—C54A	1.3900
C29—F4	1.423 (7)	C53A—H53A	0.9500
C29—C30	1.502 (9)	C54A—C55A	1.3900
C30—H30A	0.9800	C54A—H54A	0.9500
C30—H30B	0.9800	C55A—C56A	1.390 (2)
C30—H30C	0.9800	C55A—Br3A	1.890 (19)
C31—O2	1.228 (8)	C56A—C57A	1.3900
C31—N2	1.342 (7)	C56A—H56A	0.9500
C31—C32	1.519 (7)	C57A—H57A	0.9500
F1—C1—C2	114.3 (5)	N2—C31—C32	117.3 (5)
F1—C1—C9	110.0 (5)	C31—N2—C24	125.8 (5)
C2—C1—C9	104.6 (5)	C31—N2—H2	117.1
F1—C1—H1	109.3	C24—N2—H2	117.1
C2—C1—H1	109.3	C33—C32—C37	120.0
C9—C1—H1	109.3	C33—C32—C31	123.5 (3)
C3—C2—C7	120.9 (6)	C37—C32—C31	116.4 (3)
C3—C2—C1	129.7 (6)	C34—C33—C32	120.0
C7—C2—C1	109.4 (6)	C34—C33—H33	120.0
C2—C3—C4	118.8 (6)	C32—C33—H33	120.0
C2—C3—H3	120.6	C33—C34—C35	120.0
C4—C3—H3	120.6	C33—C34—H34	120.0
C3—C4—C5	120.1 (6)	C35—C34—H34	120.0
C3—C4—N1A	117.8 (5)	C36—C35—C34	120.0
C5—C4—N1A	122.1 (6)	C36—C35—Br2	120.1 (2)
C3—C4—N1	117.8 (5)	C34—C35—Br2	119.8 (2)
C5—C4—N1	122.1 (6)	C35—C36—C37	120.0
C6—C5—C4	120.3 (6)	C35—C36—H36	120.0
C6—C5—H5	119.8	C37—C36—H36	120.0
C4—C5—H5	119.8	C36—C37—C32	120.0
C5—C6—C7	119.7 (6)	C36—C37—H37	120.0
C5—C6—H6	120.2	C32—C37—H37	120.0

C7—C6—H6	120.2	O2A—C31A—N2A	137 (10)
C6—C7—C2	120.1 (6)	O2A—C31A—C32A	116 (8)
C6—C7—C8	129.2 (6)	N2A—C31A—C32A	99 (3)
C2—C7—C8	110.7 (6)	C31A—N2A—C24	107.4 (16)
C7—C8—C9	103.7 (5)	C31A—N2A—H2A	126.3
C7—C8—H8A	111.0	C24—N2A—H2A	126.3
C9—C8—H8A	111.0	C33A—C32A—C37A	120.00 (6)
C7—C8—H8B	111.0	C33A—C32A—C31A	126 (6)
C9—C8—H8B	111.0	C37A—C32A—C31A	114 (6)
H8A—C8—H8B	109.0	C34A—C33A—C32A	120.00 (7)
F2—C9—C10	107.7 (6)	C34A—C33A—H33A	120.0
F2—C9—C8	106.4 (5)	C32A—C33A—H33A	120.0
C10—C9—C8	116.2 (6)	C33A—C34A—C35A	120.0
F2—C9—C1	106.0 (5)	C33A—C34A—H34A	120.0
C10—C9—C1	116.1 (6)	C35A—C34A—H34A	120.0
C8—C9—C1	103.7 (5)	C36A—C35A—C34A	120.00 (5)
C9—C10—H10A	109.5	C36A—C35A—Br2A	116 (4)
C9—C10—H10B	109.5	C34A—C35A—Br2A	124 (4)
H10A—C10—H10B	109.5	C35A—C36A—C37A	120.00 (6)
C9—C10—H10C	109.5	C35A—C36A—H36A	120.0
H10A—C10—H10C	109.5	C37A—C36A—H36A	120.0
H10B—C10—H10C	109.5	C36A—C37A—C32A	120.0
O1—C11—N1	118.6 (17)	C36A—C37A—H37A	120.0
O1—C11—C12	119.4 (14)	C32A—C37A—H37A	120.0
N1—C11—C12	121.7 (9)	F5—C41—C42	114.5 (5)
C11—N1—C4	129.4 (8)	F5—C41—C49	110.4 (5)
C11—N1—H1A	115.3	C42—C41—C49	104.0 (5)
C4—N1—H1A	115.3	F5—C41—H41	109.3
C13—C12—C17	120.0	C42—C41—H41	109.3
C13—C12—C11	122.2 (7)	C49—C41—H41	109.3
C17—C12—C11	117.8 (7)	C43—C42—C47	121.3 (6)
C14—C13—C12	120.0	C43—C42—C41	129.6 (6)
C14—C13—H13	120.0	C47—C42—C41	109.1 (5)
C12—C13—H13	120.0	C42—C43—C44	118.7 (6)
C13—C14—C15	120.0	C42—C43—H43	120.6
C13—C14—H14	120.0	C44—C43—H43	120.6
C15—C14—H14	120.0	C43—C44—C45	120.0 (6)
C16—C15—C14	120.0	C43—C44—N3A	118.9 (5)
C16—C15—Br1	119.3 (5)	C45—C44—N3A	121.1 (5)
C14—C15—Br1	120.6 (5)	C43—C44—N3	118.9 (5)
C17—C16—C15	120.0	C45—C44—N3	121.1 (5)
C17—C16—H16	120.0	C46—C45—C44	120.5 (6)
C15—C16—H16	120.0	C46—C45—H45	119.8

C16—C17—C12	120.0	C44—C45—H45	119.8
C16—C17—H17	120.0	C45—C46—C47	120.0 (6)
C12—C17—H17	120.0	C45—C46—H46	120.0
O1A—C11A—N1A	130 (2)	C47—C46—H46	120.0
O1A—C11A—C12A	120 (2)	C46—C47—C42	119.4 (6)
N1A—C11A—C12A	110.2 (11)	C46—C47—C48	129.2 (6)
C11A—N1A—C4	118.7 (9)	C42—C47—C48	111.3 (5)
C11A—N1A—H1AA	120.7	C47—C48—C49	103.6 (5)
C4—N1A—H1AA	120.7	C47—C48—H48A	111.0
C13A—C12A—C17A	120.0	C49—C48—H48A	111.0
C13A—C12A—C11A	124.2 (12)	C47—C48—H48B	111.0
C17A—C12A—C11A	115.6 (11)	C49—C48—H48B	111.0
C12A—C13A—C14A	120.0	H48A—C48—H48B	109.0
C12A—C13A—H13A	120.0	F6—C49—C50	106.9 (5)
C14A—C13A—H13A	120.0	F6—C49—C48	106.7 (5)
C15A—C14A—C13A	120.0	C50—C49—C48	116.4 (6)
C15A—C14A—H14A	120.0	F6—C49—C41	105.5 (5)
C13A—C14A—H14A	120.0	C50—C49—C41	115.7 (6)
C14A—C15A—C16A	120.0	C48—C49—C41	104.9 (5)
C14A—C15A—Br1A	121.6 (7)	C49—C50—H50A	109.5
C16A—C15A—Br1A	118.4 (7)	C49—C50—H50B	109.5
C17A—C16A—C15A	120.0	H50A—C50—H50B	109.5
C17A—C16A—H16A	120.0	C49—C50—H50C	109.5
C15A—C16A—H16A	120.0	H50A—C50—H50C	109.5
C16A—C17A—C12A	120.0	H50B—C50—H50C	109.5
C16A—C17A—H17A	120.0	O3—C51—N3	124.0 (7)
C12A—C17A—H17A	120.0	O3—C51—C52	119.1 (6)
F3—C21—C22	113.8 (5)	N3—C51—C52	116.9 (6)
F3—C21—C29	110.2 (5)	C51—N3—C44	124.5 (5)
C22—C21—C29	104.0 (5)	C51—N3—H3A	117.8
F3—C21—H21	109.6	C44—N3—H3A	117.8
C22—C21—H21	109.6	C53—C52—C57	120.0
C29—C21—H21	109.6	C53—C52—C51	123.3 (4)
C23—C22—C27	121.5 (5)	C57—C52—C51	116.5 (4)
C23—C22—C21	129.1 (6)	C52—C53—C54	120.0
C27—C22—C21	109.4 (5)	C52—C53—H53	120.0
C22—C23—C24	118.5 (5)	C54—C53—H53	120.0
C22—C23—H23	120.7	C53—C54—C55	120.0
C24—C23—H23	120.7	C53—C54—H54	120.0
C25—C24—C23	120.1 (6)	C55—C54—H54	120.0
C25—C24—N2A	121.8 (5)	C56—C55—C54	120.0
C23—C24—N2A	118.0 (5)	C56—C55—Br3	118.8 (2)
C25—C24—N2	121.8 (5)	C54—C55—Br3	121.2 (2)

C23—C24—N2	118.0 (5)	C55—C56—C57	120.0
C26—C25—C24	120.0 (6)	C55—C56—H56	120.0
C26—C25—H25	120.0	C57—C56—H56	120.0
C24—C25—H25	120.0	C56—C57—C52	120.0
C25—C26—C27	119.9 (6)	C56—C57—H57	120.0
C25—C26—H26	120.0	C52—C57—H57	120.0
C27—C26—H26	120.0	O3A—C51A—N3A	101 (9)
C22—C27—C26	119.9 (6)	O3A—C51A—C52A	122 (10)
C22—C27—C28	110.6 (5)	N3A—C51A—C52A	131 (4)
C26—C27—C28	129.5 (6)	C51A—N3A—C44	142 (4)
C27—C28—C29	103.9 (5)	C51A—N3A—H3AA	109.2
C27—C28—H28A	111.0	C44—N3A—H3AA	109.2
C29—C28—H28A	111.0	C53A—C52A—C57A	120.0
C27—C28—H28B	111.0	C53A—C52A—C51A	115 (6)
C29—C28—H28B	111.0	C57A—C52A—C51A	124 (5)
H28A—C28—H28B	109.0	C52A—C53A—C54A	120.00 (7)
F4—C29—C30	107.7 (5)	C52A—C53A—H53A	120.0
F4—C29—C28	107.0 (5)	C54A—C53A—H53A	120.0
C30—C29—C28	117.0 (6)	C55A—C54A—C53A	120.00 (17)
F4—C29—C21	105.8 (5)	C55A—C54A—H54A	120.0
C30—C29—C21	114.6 (6)	C53A—C54A—H54A	120.0
C28—C29—C21	104.1 (5)	C54A—C55A—C56A	120.00 (7)
C29—C30—H30A	109.5	C54A—C55A—Br3A	118 (4)
C29—C30—H30B	109.5	C56A—C55A—Br3A	121 (4)
H30A—C30—H30B	109.5	C55A—C56A—C57A	120.00 (6)
C29—C30—H30C	109.5	C55A—C56A—H56A	120.0
H30A—C30—H30C	109.5	C57A—C56A—H56A	120.0
H30B—C30—H30C	109.5	C56A—C57A—C52A	120.00 (16)
O2—C31—N2	123.0 (6)	C56A—C57A—H57A	120.0
O2—C31—C32	119.5 (5)	C52A—C57A—H57A	120.0

F1—C1—C2—C3	41.3 (9)	C23—C24—N2—C31	−140.7 (7)
C9—C1—C2—C3	161.6 (6)	O2—C31—C32—C33	170.1 (6)
F1—C1—C2—C7	−138.8 (6)	N2—C31—C32—C33	−5.3 (8)
C9—C1—C2—C7	−18.4 (7)	O2—C31—C32—C37	−8.4 (9)
C7—C2—C3—C4	0.8 (9)	N2—C31—C32—C37	176.2 (5)
C1—C2—C3—C4	−179.3 (6)	C37—C32—C33—C34	0.0
C2—C3—C4—C5	−2.8 (9)	C31—C32—C33—C34	−178.5 (6)
C2—C3—C4—N1A	177.2 (5)	C32—C33—C34—C35	0.0
C2—C3—C4—N1	177.2 (5)	C33—C34—C35—C36	0.0
C3—C4—C5—C6	2.6 (10)	C33—C34—C35—Br2	−177.3 (4)
N1A—C4—C5—C6	−177.4 (6)	C34—C35—C36—C37	0.0
N1—C4—C5—C6	−177.4 (6)	Br2—C35—C36—C37	177.3 (4)

C4—C5—C6—C7	−0.3 (10)	C35—C36—C37—C32	0.0
C5—C6—C7—C2	−1.8 (10)	C33—C32—C37—C36	0.0
C5—C6—C7—C8	178.3 (7)	C31—C32—C37—C36	178.6 (5)
C3—C2—C7—C6	1.6 (10)	O2A—C31A—N2A—C24	−31 (21)
C1—C2—C7—C6	−178.4 (6)	C32A—C31A—N2A—C24	−179 (6)
C3—C2—C7—C8	−178.5 (6)	C25—C24—N2A—C31A	43 (7)
C1—C2—C7—C8	1.5 (7)	C23—C24—N2A—C31A	−137 (7)
C6—C7—C8—C9	−164.2 (7)	O2A—C31A—C32A—C33A	165 (12)
C2—C7—C8—C9	16.0 (7)	N2A—C31A—C32A—C33A	−39 (13)
C7—C8—C9—F2	85.3 (6)	O2A—C31A—C32A—C37A	−5 (17)
C7—C8—C9—C10	−154.8 (6)	N2A—C31A—C32A—C37A	151 (7)
C7—C8—C9—C1	−26.2 (6)	C37A—C32A—C33A—C34A	0.00 (8)
F1—C1—C9—F2	38.6 (7)	C31A—C32A—C33A—C34A	−170 (10)
C2—C1—C9—F2	−84.5 (6)	C32A—C33A—C34A—C35A	0.00 (8)
F1—C1—C9—C10	−80.9 (7)	C33A—C34A—C35A—C36A	0.00 (7)
C2—C1—C9—C10	156.0 (6)	C33A—C34A—C35A—Br2A	−176 (7)
F1—C1—C9—C8	150.4 (5)	C34A—C35A—C36A—C37A	0.00 (7)
C2—C1—C9—C8	27.3 (6)	Br2A—C35A—C36A—C37A	176 (6)
O1—C11—N1—C4	−9 (4)	C35A—C36A—C37A—C32A	0.00 (8)
C12—C11—N1—C4	165.5 (13)	C33A—C32A—C37A—C36A	0.00 (9)
C3—C4—N1—C11	−139.5 (18)	C31A—C32A—C37A—C36A	171 (9)
C5—C4—N1—C11	40.5 (19)	F5—C41—C42—C43	42.6 (9)
O1—C11—C12—C13	163 (3)	C49—C41—C42—C43	163.1 (6)
N1—C11—C12—C13	−11 (3)	F5—C41—C42—C47	−138.1 (5)
O1—C11—C12—C17	−16 (4)	C49—C41—C42—C47	−17.6 (6)
N1—C11—C12—C17	169.8 (18)	C47—C42—C43—C44	0.7 (9)
C17—C12—C13—C14	0.0	C41—C42—C43—C44	179.9 (6)
C11—C12—C13—C14	−179.2 (16)	C42—C43—C44—C45	−2.4 (9)
C12—C13—C14—C15	0.0	C42—C43—C44—N3A	177.9 (5)
C13—C14—C15—C16	0.0	C42—C43—C44—N3	177.9 (5)
C13—C14—C15—Br1	−176.8 (8)	C43—C44—C45—C46	1.9 (9)

C14—C15—C16—C17	0.0	N3A—C44—C45—C46	−178.5 (6)
Br1—C15—C16—C17	176.9 (8)	N3—C44—C45—C46	−178.5 (6)
C15—C16—C17—C12	0.0	C44—C45—C46—C47	0.6 (9)
C13—C12—C17—C16	0.0	C45—C46—C47—C42	−2.4 (9)
C11—C12—C17—C16	179.2 (15)	C45—C46—C47—C48	178.1 (6)
O1A—C11A—N1A—C4	−4 (6)	C43—C42—C47—C46	1.8 (9)
C12A—C11A—N1A—C4	175.0 (16)	C41—C42—C47—C46	−177.6 (6)
C3—C4—N1A—C11A	−146 (2)	C43—C42—C47—C48	−178.6 (6)
C5—C4—N1A—C11A	34 (2)	C41—C42—C47—C48	2.0 (7)
O1A—C11A—C12A—C13A	148 (4)	C46—C47—C48—C49	−165.7 (6)
N1A—C11A—C12A—C13A	−31 (4)	C42—C47—C48—C49	14.7 (7)
O1A—C11A—C12A—C17A	−27 (5)	C47—C48—C49—F6	87.0 (6)
N1A—C11A—C12A—C17A	154 (2)	C47—C48—C49—C50	−153.8 (6)
C17A—C12A—C13A—C14A	0.0	C47—C48—C49—C41	−24.7 (6)
C11A—C12A—C13A—C14A	−174 (2)	F5—C41—C49—F6	36.8 (6)
C12A—C13A—C14A—C15A	0.0	C42—C41—C49—F6	−86.4 (6)
C13A—C14A—C15A—C16A	0.0	F5—C41—C49—C50	−81.1 (7)
C13A—C14A—C15A—Br1A	178.9 (11)	C42—C41—C49—C50	155.6 (6)
C14A—C15A—C16A—C17A	0.0	F5—C41—C49—C48	149.3 (5)
Br1A—C15A—C16A—C17A	−178.9 (11)	C42—C41—C49—C48	26.0 (6)
C15A—C16A—C17A—C12A	0.0	O3—C51—N3—C44	−3.5 (13)
C13A—C12A—C17A—C16A	0.0	C52—C51—N3—C44	175.5 (5)
C11A—C12A—C17A—C16A	175 (2)	C43—C44—N3—C51	−144.1 (7)
F3—C21—C22—C23	42.6 (9)	C45—C44—N3—C51	36.2 (9)
C29—C21—C22—C23	162.5 (6)	O3—C51—C52—C53	147.4 (7)
F3—C21—C22—C27	−138.0 (5)	N3—C51—C52—C53	−31.6 (8)
C29—C21—C22—C27	−18.1 (7)	O3—C51—C52—C57	−27.3 (10)
C27—C22—C23—C24	0.8 (9)	N3—C51—C52—C57	153.6 (5)
C21—C22—C23—C24	−179.9 (6)	C57—C52—C53—C54	0.0
C22—C23—C24—C25	−2.7 (9)	C51—C52—C53—C54	−174.6 (5)
C22—C23—C24—N2A	177.4 (5)	C52—C53—C54—C55	0.0

C22—C23—C24—N2	177.4 (5)	C53—C54—C55—C56	0.0
C23—C24—C25—C26	2.8 (9)	C53—C54—C55—Br3	178.2 (3)
N2A—C24—C25—C26	−177.3 (6)	C54—C55—C56—C57	0.0
N2—C24—C25—C26	−177.3 (6)	Br3—C55—C56—C57	−178.2 (3)
C24—C25—C26—C27	−1.0 (9)	C55—C56—C57—C52	0.0
C23—C22—C27—C26	1.0 (9)	C53—C52—C57—C56	0.0
C21—C22—C27—C26	−178.4 (6)	C51—C52—C57—C56	174.9 (5)
C23—C22—C27—C28	−179.4 (6)	O3A—C51A—N3A—C44	−2 (20)
C21—C22—C27—C28	1.2 (7)	C52A—C51A—N3A—C44	149 (8)
C25—C26—C27—C22	−0.9 (9)	C43—C44—N3A—C51A	−147 (10)
C25—C26—C27—C28	179.5 (6)	C45—C44—N3A—C51A	34 (10)
C22—C27—C28—C29	16.3 (7)	O3A—C51A—C52A—C53A	179 (15)
C26—C27—C28—C29	−164.1 (6)	N3A—C51A—C52A—C53A	33 (17)
C27—C28—C29—F4	85.3 (6)	O3A—C51A—C52A—C57A	−13 (21)
C27—C28—C29—C30	−154.0 (6)	N3A—C51A—C52A—C57A	−159 (11)
C27—C28—C29—C21	−26.5 (6)	C57A—C52A—C53A—C54A	0.0
F3—C21—C29—F4	37.0 (6)	C51A—C52A—C53A—C54A	169 (8)
C22—C21—C29—F4	−85.3 (5)	C52A—C53A—C54A—C55A	0.0
F3—C21—C29—C30	−81.5 (7)	C53A—C54A—C55A—C56A	0.0
C22—C21—C29—C30	156.2 (6)	C53A—C54A—C55A—Br3A	−169 (5)
F3—C21—C29—C28	149.6 (5)	C54A—C55A—C56A—C57A	0.0
C22—C21—C29—C28	27.2 (6)	Br3A—C55A—C56A—C57A	168 (6)
O2—C31—N2—C24	−7.4 (12)	C55A—C56A—C57A—C52A	0.0
C32—C31—N2—C24	167.9 (5)	C53A—C52A—C57A—C56A	0.00 (6)
C25—C24—N2—C31	39.4 (9)	C51A—C52A—C57A—C56A	−168 (9)

Table S7. Hydrogen-bond geometric parameters (Å, º)

D—H···A	D—H	H···A	D···A	D—H···A
N1—H1A···O1^{i}	0.88	2.05	2.90 (3)	161
N1A—H1AA···O1A^{i}	0.88	2.02	2.83 (4)	153

N2—H2···O2^{i}	0.88	2.03	2.865 (8)	157
N2A—H2A···O2A^{i}	0.88	1.96	2.72 (11)	145
N3—H3A···O3^{ii}	0.88	2.06	2.889 (7)	158

Symmetry codes: (i) x−1/2, −y+3/2, z; (ii) x+1/2, −y+3/2, z.

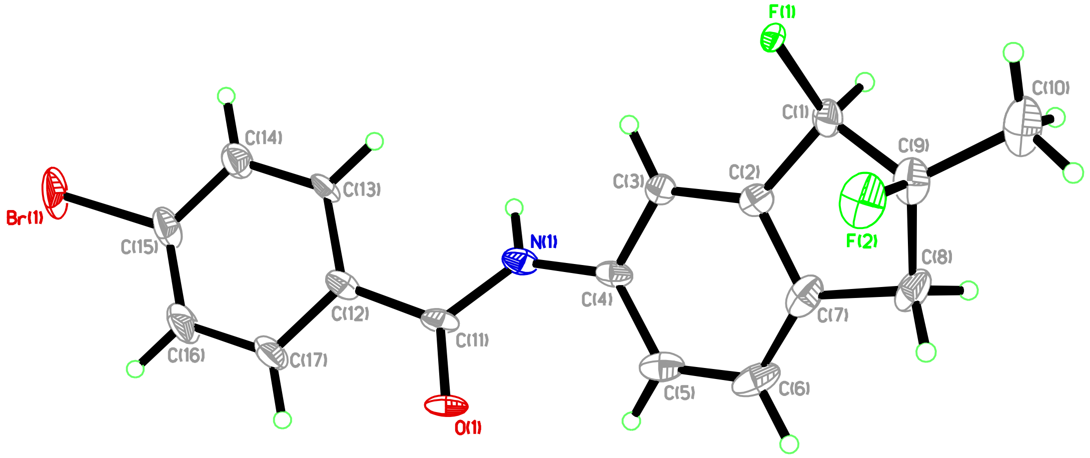
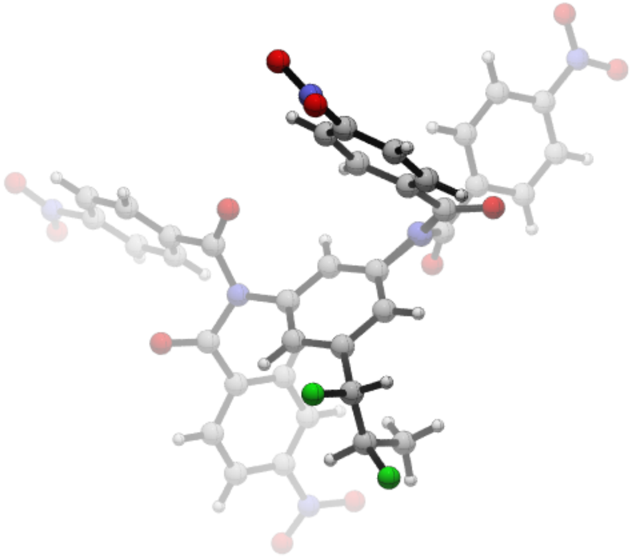


Figure S4. Perspective views showing 50% probability displacement

X-Ray Crystal Structure of 1,2-Difluoride (±)-S5j.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II DUO CCD diffractometer (Cu$_{K_\alpha}$ radiation, λ=1.54178 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 1.0° scans in ω at -30°, -55°, -80°, 30°, 55°, 80° and 115° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimisation. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S8. Experimental details

	JWM-VI-188A
Crystal data	
Chemical formula	$C_{37}H_{24}F_2N_6O_{12}$
M_r	782.62
Crystal system, space group	Triclinic, *P*-1
Temperature (K)	100
a, *b*, *c* (Å)	8.3123 (3), 12.8636 (5), 16.7610 (6)
a, b, g (°)	83.207 (2), 86.721 (3), 85.465 (3)
V (Å^3)	1771.96 (11)
Z	2
Radiation type	Cu *K*a
m (mm^{-1})	1.02
Crystal size (mm)	0.24 × 0.18 × 0.05
Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
$T_{\min}$, $T_{\max}$	0.699, 0.864
No. of measured, independent and observed [$I > 2s(I)$] reflections	26788, 5963, 4189
R_{int}	0.054
(sin q/l)$_{\max}$ (Å^{-1})	0.596
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.062, 0.197, 1.04
No. of reflections	5963
No. of parameters	542
No. of restraints	19
H-atom treatment	H-atom parameters constrained
Dρ$_{\max}$, Dρ$_{\min}$ (e Å^{-3})	0.41, -0.38

Table S9. Geometric parameters (Å, º)

C1—C6	1.384 (5)	C22—C23	1.378 (5)
C1—C2	1.386 (4)	C22—H22	0.9500
C1—H1	0.9500	C23—H23	0.9500
C2—C3	1.386 (4)	C24—O7	1.210 (4)
C2—N1	1.435 (4)	C24—N4A	1.427 (19)
C3—C4	1.379 (4)	C24—N4	1.432 (5)
C3—H3	0.9500	C24—C25	1.472 (6)
C4—C5	1.389 (5)	C25—C30	1.396 (5)
C4—N4	1.432 (4)	C25—C26	1.401 (5)
C4—N4A	1.444 (16)	C26—C27	1.371 (5)
C5—C6	1.388 (5)	C26—H26	0.9500
C5—H5	0.9500	C27—C28	1.376 (5)
C6—C7A	1.504 (5)	C27—H27	0.9500
C6—C7	1.504 (5)	C28—C29	1.390 (5)
C7—F1	1.356 (6)	C28—N5	1.450 (5)
C7—C8	1.420 (8)	C29—C30	1.366 (6)
C7—H7	1.0000	C29—H29	0.9500
C8—F2	1.45 (4)	C30—H30	0.9500
C8—C9	1.473 (18)	N4A—C31A	1.36 (7)
C8—H8	1.0000	O10A—C31A	1.22 (2)
C9—H9A	0.9800	C31A—C32A	1.487 (19)
C9—H9B	0.9800	C32A—C33A	1.3900
C9—H9C	0.9800	C32A—C37A	1.3900
C7A—F1A	1.322 (7)	C33A—C34A	1.3900
C7A—C8A	1.402 (8)	C33A—H33A	0.9500
C7A—H7A	1.0000	C34A—C35A	1.3900
C8A—F2A	1.45 (4)	C34A—H34A	0.9500
C8A—C9A	1.480 (18)	C35A—C36A	1.3900
C8A—H8A	1.0000	C35A—N6A	1.473 (17)
C9A—H9AA	0.9800	C36A—C37A	1.3900
C9A—H9AB	0.9800	C36A—H36A	0.9500
C9A—H9AC	0.9800	C37A—H37A	0.9500
C10—O1	1.205 (3)	N6A—O11A	1.218 (19)
C10—N1	1.406 (4)	N6A—O12A	1.23 (2)
C10—C11	1.496 (4)	N4—C31	1.389 (11)
C11—C16	1.377 (4)	O10—C31	1.222 (6)
C11—C12	1.393 (4)	C31—C32	1.487 (5)
C12—C13	1.378 (5)	C32—C33	1.373 (5)
C12—H12	0.9500	C32—C37	1.3900
C13—C14	1.376 (5)	C33—C34	1.367 (4)
C13—H13	0.9500	C33—H33	0.9500

C14—C15	1.379 (4)	C34—C35	1.3900
C14—N2	1.474 (4)	C34—H34	0.9500
C15—C16	1.386 (4)	C35—C36	1.3900
C15—H15	0.9500	C35—N6	1.448 (4)
C16—H16	0.9500	C36—C37	1.3900
C17—O4	1.205 (4)	C36—H36	0.9500
C17—N1	1.441 (3)	C37—H37	0.9500
C17—C18	1.480 (5)	N6—O11	1.210 (5)
C18—C23	1.393 (4)	N6—O12	1.222 (5)
C18—C19	1.396 (5)	N2—O2	1.224 (4)
C19—C20	1.381 (5)	N2—O3	1.232 (4)
C19—H19	0.9500	N3—O6	1.224 (4)
C20—C21	1.370 (5)	N3—O5	1.235 (4)
C20—H20	0.9500	N5—O9	1.219 (4)
C21—C22	1.382 (5)	N5—O8	1.222 (4)
C21—N3	1.474 (5)		
C6—C1—C2	120.1 (3)	C23—C22—H22	120.8
C6—C1—H1	119.9	C21—C22—H22	120.8
C2—C1—H1	119.9	C22—C23—C18	120.8 (3)
C3—C2—C1	120.8 (3)	C22—C23—H23	119.6
C3—C2—N1	118.8 (3)	C18—C23—H23	119.6
C1—C2—N1	120.4 (2)	O7—C24—N4A	118.7 (11)
C4—C3—C2	118.6 (3)	O7—C24—N4	121.0 (4)
C4—C3—H3	120.7	O7—C24—C25	122.8 (3)
C2—C3—H3	120.7	N4A—C24—C25	118.5 (11)
C3—C4—C5	121.3 (3)	N4—C24—C25	116.2 (3)
C3—C4—N4	120.1 (3)	C30—C25—C26	119.3 (4)
C5—C4—N4	118.5 (3)	C30—C25—C24	119.2 (3)
C3—C4—N4A	122.1 (12)	C26—C25—C24	121.2 (3)
C5—C4—N4A	116.6 (12)	C27—C26—C25	121.2 (3)
C6—C5—C4	119.6 (3)	C27—C26—H26	119.4
C6—C5—H5	120.2	C25—C26—H26	119.4
C4—C5—H5	120.2	C26—C27—C28	117.9 (3)
C1—C6—C5	119.6 (3)	C26—C27—H27	121.1
C1—C6—C7A	121.1 (3)	C28—C27—H27	121.1
C5—C6—C7A	119.3 (3)	C27—C28—C29	122.6 (4)
C1—C6—C7	121.1 (3)	C27—C28—N5	118.0 (3)
C5—C6—C7	119.3 (3)	C29—C28—N5	119.4 (3)
F1—C7—C8	118.0 (5)	C30—C29—C28	119.0 (3)
F1—C7—C6	112.0 (3)	C30—C29—H29	120.5
C8—C7—C6	113.1 (4)	C28—C29—H29	120.5
F1—C7—H7	103.9	C29—C30—C25	120.0 (3)
C8—C7—H7	103.9	C29—C30—H30	120.0

C6—C7—H7	103.9	C25—C30—H30	120.0
C7—C8—F2	105 (2)	C31A—N4A—C24	125 (2)
C7—C8—C9	120.5 (15)	C31A—N4A—C4	118 (2)
F2—C8—C9	107 (2)	C24—N4A—C4	116.2 (14)
C7—C8—H8	108.2	O10A—C31A—N4A	124 (6)
F2—C8—H8	108.2	O10A—C31A—C32A	117 (10)
C9—C8—H8	108.2	N4A—C31A—C32A	119 (5)
C8—C9—H9A	109.5	C33A—C32A—C37A	120.0
C8—C9—H9B	109.5	C33A—C32A—C31A	119 (5)
H9A—C9—H9B	109.5	C37A—C32A—C31A	120 (5)
C8—C9—H9C	109.5	C34A—C33A—C32A	120.0
H9A—C9—H9C	109.5	C34A—C33A—H33A	120.0
H9B—C9—H9C	109.5	C32A—C33A—H33A	120.0
F1A—C7A—C8A	120.0 (6)	C33A—C34A—C35A	120.0
F1A—C7A—C6	110.6 (4)	C33A—C34A—H34A	120.0
C8A—C7A—C6	118.7 (5)	C35A—C34A—H34A	120.0
F1A—C7A—H7A	101.0	C36A—C35A—C34A	120.0
C8A—C7A—H7A	101.0	C36A—C35A—N6A	105 (3)
C6—C7A—H7A	101.0	C34A—C35A—N6A	134 (2)
C7A—C8A—F2A	107 (3)	C37A—C36A—C35A	120.0
C7A—C8A—C9A	120.4 (15)	C37A—C36A—H36A	120.0
F2A—C8A—C9A	106 (3)	C35A—C36A—H36A	120.0
C7A—C8A—H8A	107.7	C36A—C37A—C32A	120.0
F2A—C8A—H8A	107.7	C36A—C37A—H37A	120.0
C9A—C8A—H8A	107.7	C32A—C37A—H37A	120.0
C8A—C9A—H9AA	109.5	O11A—N6A—O12A	120 (3)
C8A—C9A—H9AB	109.5	O11A—N6A—C35A	132 (3)
H9AA—C9A—H9AB	109.5	O12A—N6A—C35A	108 (3)
C8A—C9A—H9AC	109.5	C31—N4—C24	121.4 (5)
H9AA—C9A—H9AC	109.5	C31—N4—C4	119.4 (4)
H9AB—C9A—H9AC	109.5	C24—N4—C4	116.7 (4)
O1—C10—N1	122.0 (3)	O10—C31—N4	121.9 (7)
O1—C10—C11	121.7 (3)	O10—C31—C32	122.2 (12)
N1—C10—C11	116.2 (2)	N4—C31—C32	115.7 (7)
C16—C11—C12	120.2 (3)	C33—C32—C37	118.47 (17)
C16—C11—C10	118.5 (3)	C33—C32—C31	124.0 (7)
C12—C11—C10	121.2 (3)	C37—C32—C31	117.6 (7)
C13—C12—C11	120.0 (3)	C34—C33—C32	122.9 (3)
C13—C12—H12	120.0	C34—C33—H33	118.5
C11—C12—H12	120.0	C32—C33—H33	118.5
C14—C13—C12	118.4 (3)	C35—C34—C33	118.6 (2)
C14—C13—H13	120.8	C35—C34—H34	120.7
C12—C13—H13	120.8	C33—C34—H34	120.7

C13—C14—C15	123.1 (3)	C34—C35—C36	120.0
C13—C14—N2	118.6 (3)	C34—C35—N6	119.9 (3)
C15—C14—N2	118.4 (3)	C36—C35—N6	120.1 (3)
C14—C15—C16	117.7 (3)	C35—C36—C37	120.0
C14—C15—H15	121.1	C35—C36—H36	120.0
C16—C15—H15	121.1	C37—C36—H36	120.0
C11—C16—C15	120.6 (3)	C36—C37—C32	120.0
C11—C16—H16	119.7	C36—C37—H37	120.0
C15—C16—H16	119.7	C32—C37—H37	120.0
O4—C17—N1	119.9 (3)	O11—N6—O12	124.2 (4)
O4—C17—C18	122.9 (3)	O11—N6—C35	117.3 (4)
N1—C17—C18	117.1 (2)	O12—N6—C35	118.5 (4)
C23—C18—C19	118.9 (3)	C10—N1—C2	118.0 (2)
C23—C18—C17	118.2 (3)	C10—N1—C17	120.0 (2)
C19—C18—C17	122.9 (3)	C2—N1—C17	118.7 (2)
C20—C19—C18	120.7 (3)	O2—N2—O3	124.5 (3)
C20—C19—H19	119.6	O2—N2—C14	118.1 (3)
C18—C19—H19	119.6	O3—N2—C14	117.4 (3)
C21—C20—C19	118.7 (3)	O6—N3—O5	124.0 (4)
C21—C20—H20	120.7	O6—N3—C21	118.1 (3)
C19—C20—H20	120.7	O5—N3—C21	117.9 (3)
C20—C21—C22	122.4 (3)	O9—N5—O8	123.2 (4)
C20—C21—N3	118.3 (3)	O9—N5—C28	118.6 (3)
C22—C21—N3	119.3 (3)	O8—N5—C28	118.2 (3)
C23—C22—C21	118.5 (3)		
C6—C1—C2—C3	−1.1 (5)	C3—C4—N4A—C31A	−53 (7)
C6—C1—C2—N1	−178.9 (3)	C5—C4—N4A—C31A	128 (7)
C1—C2—C3—C4	−1.0 (5)	C3—C4—N4A—C24	129.0 (17)
N1—C2—C3—C4	176.9 (3)	C5—C4—N4A—C24	−50 (3)
C2—C3—C4—C5	1.7 (5)	C24—N4A—C31A—O10A	168 (10)
C2—C3—C4—N4	−175.1 (3)	C4—N4A—C31A—O10A	−10 (17)
C2—C3—C4—N4A	−177.2 (13)	C24—N4A—C31A—C32A	−12 (15)
C3—C4—C5—C6	−0.3 (5)	C4—N4A—C31A—C32A	169 (8)
N4—C4—C5—C6	176.5 (4)	O10A—C31A—C32A—C33A	130 (11)
N4A—C4—C5—C6	178.6 (12)	N4A—C31A—C32A—C33A	−50 (14)
C2—C1—C6—C5	2.4 (5)	O10A—C31A—C32A—C37A	−40 (15)
C2—C1—C6—C7A	−175.5 (3)	N4A—C31A—C32A—C37A	141 (8)
C2—C1—C6—C7	−175.5 (3)	C37A—C32A—C33A—C34A	0.0

C4—C5—C6—C1	−1.8 (5)	C31A—C32A—C33A—C34A	−169 (6)
C4—C5—C6—C7A	176.2 (3)	C32A—C33A—C34A—C35A	0.0
C4—C5—C6—C7	176.2 (3)	C33A—C34A—C35A—C36A	0.0
C1—C6—C7—F1	−55.6 (6)	C33A—C34A—C35A—N6A	−165 (4)
C5—C6—C7—F1	126.4 (5)	C34A—C35A—C36A—C37A	0.0
C1—C6—C7—C8	80.7 (5)	N6A—C35A—C36A—C37A	169 (3)
C5—C6—C7—C8	−97.3 (5)	C35A—C36A—C37A—C32A	0.0
F1—C7—C8—F2	−63 (4)	C33A—C32A—C37A—C36A	0.0
C6—C7—C8—F2	163 (4)	C31A—C32A—C37A—C36A	169 (7)
F1—C7—C8—C9	177.1 (16)	C36A—C35A—N6A—O11A	−4 (6)
C6—C7—C8—C9	43.7 (17)	C34A—C35A—N6A—O11A	163 (5)
C1—C6—C7A—F1A	−94.4 (5)	C36A—C35A—N6A—O12A	179 (3)
C5—C6—C7A—F1A	87.6 (5)	C34A—C35A—N6A—O12A	−14 (6)
C1—C6—C7A—C8A	121.1 (6)	O7—C24—N4—C31	−29.8 (9)
C5—C6—C7A—C8A	−56.9 (7)	C25—C24—N4—C31	147.3 (8)
F1A—C7A—C8A—F2A	54 (6)	O7—C24—N4—C4	132.1 (4)
C6—C7A—C8A—F2A	−165 (6)	C25—C24—N4—C4	−50.8 (5)
F1A—C7A—C8A—C9A	175 (2)	C3—C4—N4—C31	−65.4 (9)
C6—C7A—C8A—C9A	−44 (2)	C5—C4—N4—C31	117.7 (9)
O1—C10—C11—C16	−41.1 (4)	C3—C4—N4—C24	132.3 (4)
N1—C10—C11—C16	143.1 (3)	C5—C4—N4—C24	−44.5 (6)
O1—C10—C11—C12	135.4 (3)	C24—N4—C31—O10	154.9 (12)
N1—C10—C11—C12	−40.4 (4)	C4—N4—C31—O10	−6.5 (19)
C16—C11—C12—C13	−1.1 (4)	C24—N4—C31—C32	−30.6 (16)
C10—C11—C12—C13	−177.5 (3)	C4—N4—C31—C32	168.0 (9)
C11—C12—C13—C14	−0.5 (4)	O10—C31—C32—C33	133.3 (13)
C12—C13—C14—C15	1.8 (4)	N4—C31—C32—C33	−41.1 (16)
C12—C13—C14—N2	−177.1 (3)	O10—C31—C32—C37	−45.8 (18)
C13—C14—C15—C16	−1.3 (4)	N4—C31—C32—C37	139.8 (9)
N2—C14—C15—C16	177.6 (2)	C37—C32—C33—C34	−1.4 (7)
C12—C11—C16—C15	1.6 (4)	C31—C32—C33—C34	179.6 (8)
C10—C11—C16—C15	178.1 (2)	C32—C33—C34—C35	1.4 (7)

C14—C15—C16—C11	–0.4 (4)	C33—C34—C35—C36	–0.7 (3)
O4—C17—C18—C23	−17.4 (6)	C33—C34—C35—N6	178.9 (5)
N1—C17—C18—C23	165.5 (3)	C34—C35—C36—C37	0.0
O4—C17—C18—C19	159.8 (4)	N6—C35—C36—C37	−179.5 (4)
N1—C17—C18—C19	−17.3 (5)	C35—C36—C37—C32	0.0
C23—C18—C19—C20	−2.0 (6)	C33—C32—C37—C36	0.6 (3)
C17—C18—C19—C20	−179.2 (3)	C31—C32—C37—C36	179.8 (8)
C18—C19—C20—C21	0.7 (6)	C34—C35—N6—O11	177.9 (4)
C19—C20—C21—C22	1.9 (7)	C36—C35—N6—O11	–2.5 (6)
C19—C20—C21—N3	179.4 (4)	C34—C35—N6—O12	–2.1 (6)
C20—C21—C22—C23	−3.1 (7)	C36—C35—N6—O12	177.4 (4)
N3—C21—C22—C23	179.5 (4)	O1—C10—N1—C2	–9.4 (4)
C21—C22—C23—C18	1.7 (6)	C11—C10—N1—C2	166.4 (3)
C19—C18—C23—C22	0.8 (6)	O1—C10—N1—C17	149.9 (3)
C17—C18—C23—C22	178.1 (4)	C11—C10—N1—C17	–34.3 (4)
O7—C24—C25—C30	–26.7 (5)	C3—C2—N1—C10	–54.9 (4)
N4A—C24—C25—C30	154.6 (12)	C1—C2—N1—C10	122.9 (3)
N4—C24—C25—C30	156.3 (3)	C3—C2—N1—C17	145.5 (3)
O7—C24—C25—C26	147.0 (3)	C1—C2—N1—C17	–36.7 (4)
N4A—C24—C25—C26	−31.7 (13)	O4—C17—N1—C10	–28.1 (5)
N4—C24—C25—C26	−30.0 (4)	C18—C17—N1—C10	149.1 (3)
C30—C25—C26—C27	2.8 (5)	O4—C17—N1—C2	131.1 (4)
C24—C25—C26—C27	−170.8 (3)	C18—C17—N1—C2	–51.7 (4)
C25—C26—C27—C28	−2.7 (5)	C13—C14—N2—O2	−176.0 (3)
C26—C27—C28—C29	0.6 (5)	C15—C14—N2—O2	5.1 (4)
C26—C27—C28—N5	179.8 (3)	C13—C14—N2—O3	4.5 (4)
C27—C28—C29—C30	1.4 (5)	C15—C14—N2—O3	−174.4 (3)
N5—C28—C29—C30	−177.8 (3)	C20—C21—N3—O6	18.1 (6)
C28—C29—C30—C25	−1.3 (5)	C22—C21—N3—O6	−164.3 (4)
C26—C25—C30—C29	−0.7 (5)	C20—C21—N3—O5	−161.9 (4)
C24—C25—C30—C29	173.0 (3)	C22—C21—N3—O5	15.7 (6)
O7—C24—N4A—C31A	−43 (8)	C27—C28—N5—O9	–23.1 (4)
C25—C24—N4A—C31A	136 (8)	C29—C28—N5—O9	156.2 (3)
O7—C24—N4A—C4	135.6 (17)	C27—C28—N5—O8	156.0 (3)
C25—C24—N4A—C4	−46 (3)	C29—C28—N5—O8	–24.7 (4)

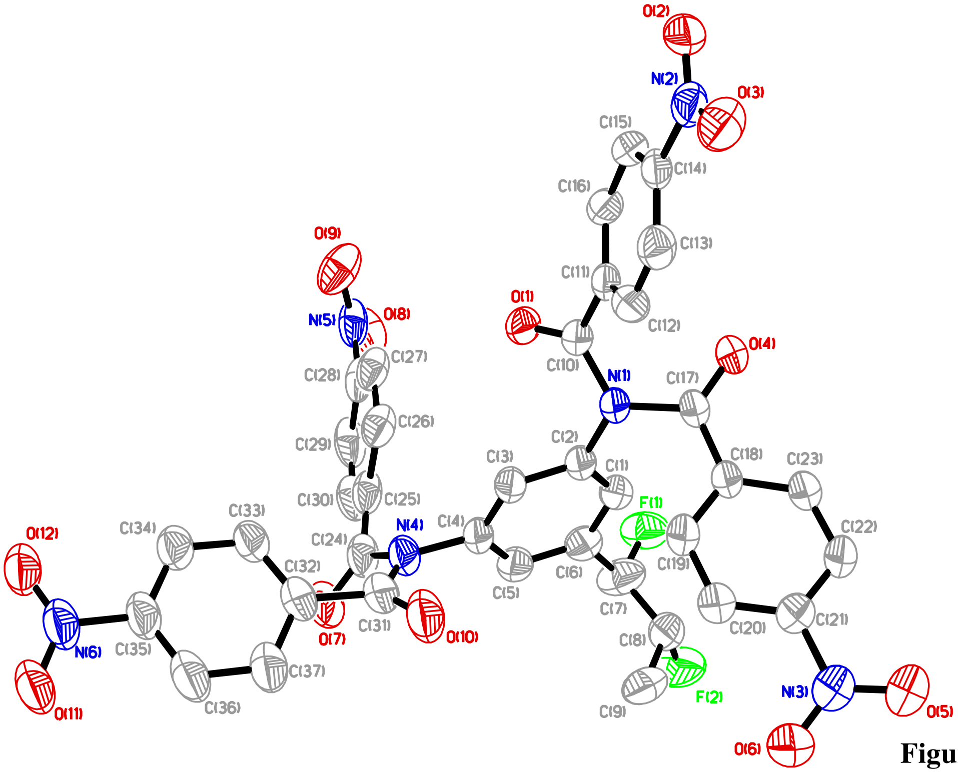
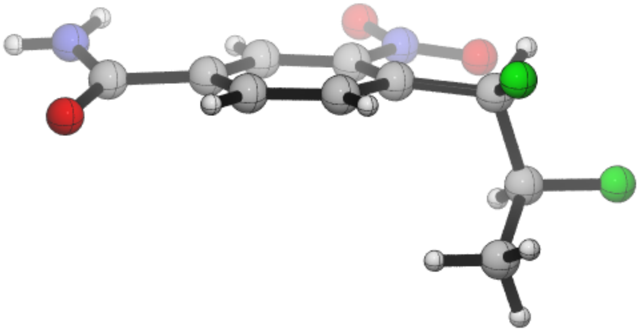


Figure S5.

Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-5l.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD diffractometer (Mo_{K_α} radiation, λ=0.71073 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 0.5° scans in ω at 28° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S10. Experimental details

	JWM-VI-159-II
Crystal data	
Chemical formula	$C_{10}H_{10}F_2N_2O_3$
M_r	244.20
Crystal system, space group	Monoclinic, $P2_1/c$
Temperature (K)	100
a, b, c (Å)	10.4220 (8), 9.9549 (8), 9.6965 (7)
b (°)	91.8774 (15)
V (Å^3)	1005.47 (13)
Z	4
Radiation type	Mo Ka
m (mm^{-1})	0.14
Crystal size (mm)	0.14 × 0.10 × 0.08

Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
T_{min}, T_{max}	0.828, 0.862
No. of measured, independent and observed [$I > 2s(I)$] reflections	17104, 2228, 1727
R_{int}	0.041
(sin q/l)$_{max}$ (Å^{-1})	0.641
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.033, 0.091, 1.09
No. of reflections	2228
No. of parameters	163
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
Dρ$_{max}$, Dρ$_{min}$ (e Å^{-3})	0.33, -0.26

Table S11. Geometric parameters (Å, º)

C1—C2	1.3872 (18)	C7—H7	1.0000
C1—C6	1.4058 (19)	C8—F2	1.4084 (15)
C1—N1	1.4721 (18)	C8—C9	1.505 (2)
C2—C3	1.387 (2)	C8—H8	1.0000
C2—H2	0.9500	C9—H9A	0.9800
C3—C4	1.3877 (19)	C9—H9B	0.9800
C3—C10	1.5051 (18)	C9—H9C	0.9800
C4—C5	1.3804 (19)	C10—O3	1.2299 (16)
C4—H4	0.9500	C10—N2	1.3314 (19)
C5—C6	1.390 (2)	N1—O2	1.2262 (14)
C5—H5	0.9500	N1—O1	1.2283 (14)
C6—C7	1.5197 (17)	N2—H2A	0.852 (19)
C7—F1	1.4024 (15)	N2—H2B	0.88 (2)
C7—C8	1.5160 (19)		
C2—C1—C6	122.77 (12)	C6—C7—H7	109.6
C2—C1—N1	115.36 (12)	F2—C8—C9	107.93 (11)
C6—C1—N1	121.87 (12)	F2—C8—C7	107.31 (10)

C1—C2—C3	119.16 (12)	C9—C8—C7	114.96 (12)
C1—C2—H2	120.4	F2—C8—H8	108.8
C3—C2—H2	120.4	C9—C8—H8	108.8
C2—C3—C4	119.05 (12)	C7—C8—H8	108.8
C2—C3—C10	123.32 (12)	C8—C9—H9A	109.5
C4—C3—C10	117.61 (12)	C8—C9—H9B	109.5
C5—C4—C3	121.09 (13)	H9A—C9—H9B	109.5
C5—C4—H4	119.5	C8—C9—H9C	109.5
C3—C4—H4	119.5	H9A—C9—H9C	109.5
C4—C5—C6	121.54 (13)	H9B—C9—H9C	109.5
C4—C5—H5	119.2	O3—C10—N2	122.80 (13)
C6—C5—H5	119.2	O3—C10—C3	119.41 (12)
C5—C6—C1	116.32 (12)	N2—C10—C3	117.79 (13)
C5—C6—C7	118.20 (12)	O2—N1—O1	122.96 (12)
C1—C6—C7	125.41 (12)	O2—N1—C1	118.37 (11)
F1—C7—C8	108.38 (11)	O1—N1—C1	118.67 (11)
F1—C7—C6	108.33 (11)	C10—N2—H2A	118.3 (12)
C8—C7—C6	111.33 (10)	C10—N2—H2B	123.0 (12)
F1—C7—H7	109.6	H2A—N2—H2B	118.7 (18)
C8—C7—H7	109.6		
C6—C1—C2—C3	−0.89 (19)	C5—C6—C7—C8	95.33 (14)
N1—C1—C2—C3	178.51 (11)	C1—C6—C7—C8	−81.25 (16)
C1—C2—C3—C4	2.12 (19)	F1—C7—C8—F2	−73.70 (13)
C1—C2—C3—C10	−176.07 (12)	C6—C7—C8—F2	167.26 (11)
C2—C3—C4—C5	−1.0 (2)	F1—C7—C8—C9	46.34 (15)
C10—C3—C4—C5	177.34 (12)	C6—C7—C8—C9	−72.70 (15)
C3—C4—C5—C6	−1.6 (2)	C2—C3—C10—O3	162.16 (13)
C4—C5—C6—C1	2.72 (19)	C4—C3—C10—O3	−16.06 (19)
C4—C5—C6—C7	−174.17 (12)	C2—C3—C10—N2	−18.4 (2)
C2—C1—C6—C5	−1.51 (19)	C4—C3—C10—N2	163.34 (13)
N1—C1—C6—C5	179.13 (12)	C2—C1—N1—O2	8.35 (17)
C2—C1—C6—C7	175.12 (12)	C6—C1—N1—O2	−172.25 (11)
N1—C1—C6—C7	−4.2 (2)	C2—C1—N1—O1	−172.22 (11)
C5—C6—C7—F1	−23.75 (16)	C6—C1—N1—O1	7.18 (18)
C1—C6—C7—F1	159.67 (12)		

Table S12. Hydrogen-bond geometric parameters (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N2—H2*A*···O2^{i}	0.852 (19)	2.298 (19)	3.0763 (17)	151.9 (16)
N2—H2*B*···O3^{ii}	0.88 (2)	2.26 (2)	3.0189 (17)	143.4 (17)

Symmetry codes: (i) −*x*+2, *y*+1/2, −*z*+1/2; (ii) −*x*+2, *y*−1/2, −*z*+1/2.

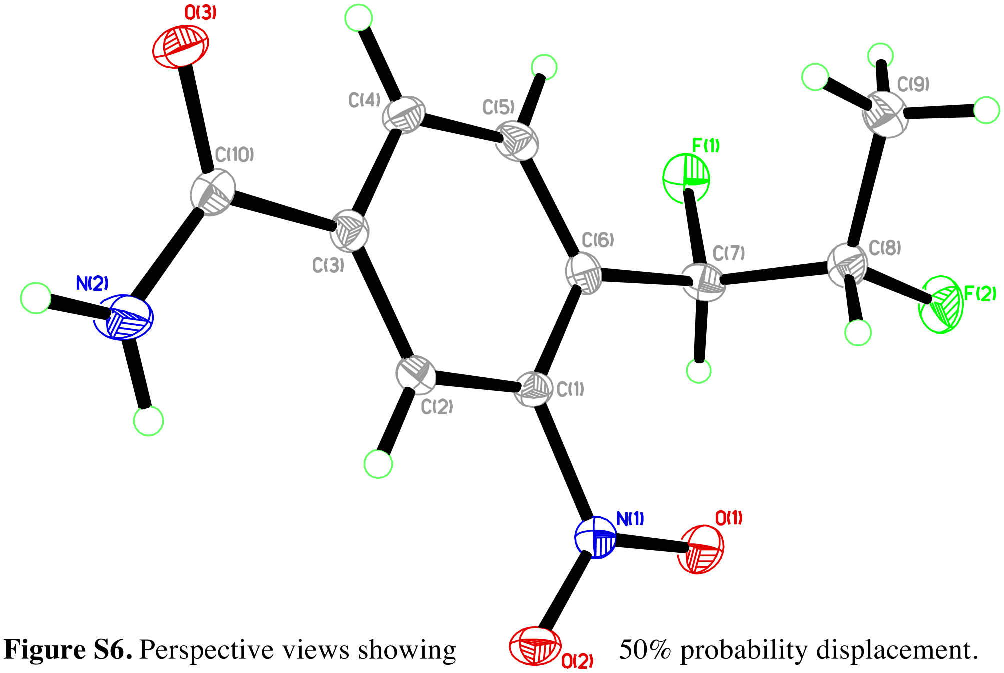
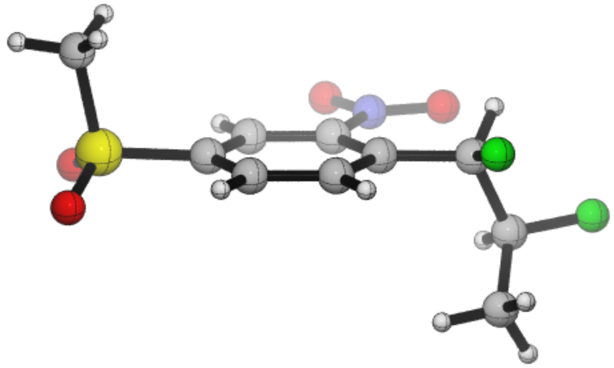


Figure S6. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-5m.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II DUO CCD diffractometer (Cu$_{K\alpha}$ radiation, λ=1.54178 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 1.0° scans in ω at -30°, -55°, -80°, 30°, 55°, 80° and 115° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S13. Experimental details

	JWM-VI-25-II
Crystal data	
Chemical formula	$C_{10}H_{11c2}NO_4S$
M_r	279.26
Crystal system, space group	Monoclinic, $P2_1/c$
Temperature (K)	100
a, b, c (Å)	5.5641 (3), 5.4741 (3), 38.7991 (19)
b (°)	92.9922 (18)
V (Å^3)	1180.15 (11)
Z	4
Radiation type	Cu Ka
m (mm^{-1})	2.80
Crystal size (mm)	0.20 × 0.18 × 0.06

Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
T_{min}, T_{max}	0.717, 0.864
No. of measured, independent and observed [I > 2s(I)] reflections	22755, 2128, 2086
R_{int}	0.057
(sin q/l)$_{\mathrm{max}}$ (Å^{-1})	0.595
Refinement	
R[F^2 > 2s(F^2)], wR(F^2), S	0.054, 0.134, 1.08
No. of reflections	2128
No. of parameters	166
H-atom treatment	H-atom parameters constrained
Dρ$_{\mathrm{max}}$, Dρ$_{\mathrm{min}}$ (e Å^{-3})	0.33, -0.32

Table S14. Geometric parameters (Å, º)

C1—C2	1.384 (6)	C8—F2	1.405 (4)
C1—C6	1.403 (6)	C8—C9	1.497 (6)
C1—N1	1.478 (5)	C8—H8	1.0000
C2—C3	1.383 (6)	C9—H9A	0.9800
C2—H2	0.9500	C9—H9B	0.9800
C3—C4	1.391 (6)	C9—H9C	0.9800
C3—S1	1.772 (4)	C10—S1	1.748 (4)
C4—C5	1.392 (6)	C10—H10A	0.9800
C4—H4	0.9500	C10—H10B	0.9800
C5—C6	1.399 (6)	C10—H10C	0.9800
C5—H5	0.9500	N1—O4	1.226 (5)
C6—C7	1.525 (5)	N1—O3	1.231 (4)
C7—F1	1.402 (4)	O1—S1	1.437 (3)
C7—C8	1.528 (6)	O2—S1	1.445 (3)
C7—H7	1.0000		
C2—C1—C6	122.9 (4)	C9—C8—C7	114.4 (4)
C2—C1—N1	114.9 (3)	F2—C8—H8	109.1
C6—C1—N1	122.2 (3)	C9—C8—H8	109.1

C3—C2—C1	118.8 (4)	C7—C8—H8	109.1
C3—C2—H2	120.6	C8—C9—H9A	109.5
C1—C2—H2	120.6	C8—C9—H9B	109.5
C2—C3—C4	120.7 (4)	H9A—C9—H9B	109.5
C2—C3—S1	119.1 (3)	C8—C9—H9C	109.5
C4—C3—S1	120.2 (3)	H9A—C9—H9C	109.5
C3—C4—C5	119.3 (4)	H9B—C9—H9C	109.5
C3—C4—H4	120.4	S1—C10—H10A	109.5
C5—C4—H4	120.4	S1—C10—H10B	109.5
C4—C5—C6	122.0 (4)	H10A—C10—H10B	109.5
C4—C5—H5	119.0	S1—C10—H10C	109.5
C6—C5—H5	119.0	H10A—C10—H10C	109.5
C5—C6—C1	116.3 (4)	H10B—C10—H10C	109.5
C5—C6—C7	118.2 (4)	O4—N1—O3	123.1 (4)
C1—C6—C7	125.5 (4)	O4—N1—C1	118.1 (3)
F1—C7—C6	107.5 (3)	O3—N1—C1	118.8 (3)
F1—C7—C8	108.0 (3)	O1—S1—O2	118.05 (19)
C6—C7—C8	113.0 (3)	O1—S1—C10	109.01 (19)
F1—C7—H7	109.4	O2—S1—C10	109.42 (18)
C6—C7—H7	109.4	O1—S1—C3	107.73 (18)
C8—C7—H7	109.4	O2—S1—C3	108.15 (17)
F2—C8—C9	109.1 (3)	C10—S1—C3	103.47 (19)
F2—C8—C7	105.9 (3)		
C6—C1—C2—C3	0.4 (6)	C1—C6—C7—C8	−78.3 (5)
N1—C1—C2—C3	−177.7 (3)	F1—C7—C8—F2	−74.4 (4)
C1—C2—C3—C4	−0.2 (6)	C6—C7—C8—F2	166.8 (3)
C1—C2—C3—S1	177.3 (3)	F1—C7—C8—C9	45.7 (5)
C2—C3—C4—C5	−0.2 (6)	C6—C7—C8—C9	−73.1 (5)
S1—C3—C4—C5	−177.8 (3)	C2—C1—N1—O4	−2.8 (5)
C3—C4—C5—C6	0.5 (6)	C6—C1—N1—O4	179.1 (3)
C4—C5—C6—C1	−0.4 (6)	C2—C1—N1—O3	176.7 (3)
C4—C5—C6—C7	179.4 (4)	C6—C1—N1—O3	−1.5 (6)
C2—C1—C6—C5	−0.1 (6)	C2—C3—S1—O1	26.1 (4)
N1—C1—C6—C5	177.8 (3)	C4—C3—S1—O1	−156.3 (3)
C2—C1—C6—C7	−179.9 (4)	C2—C3—S1—O2	154.8 (3)
N1—C1—C6—C7	−2.0 (6)	C4—C3—S1—O2	−27.7 (4)
C5—C6—C7—F1	−17.2 (5)	C2—C3—S1—C10	−89.2 (3)
C1—C6—C7—F1	162.6 (3)	C4—C3—S1—C10	88.3 (3)
C5—C6—C7—C8	101.9 (4)		

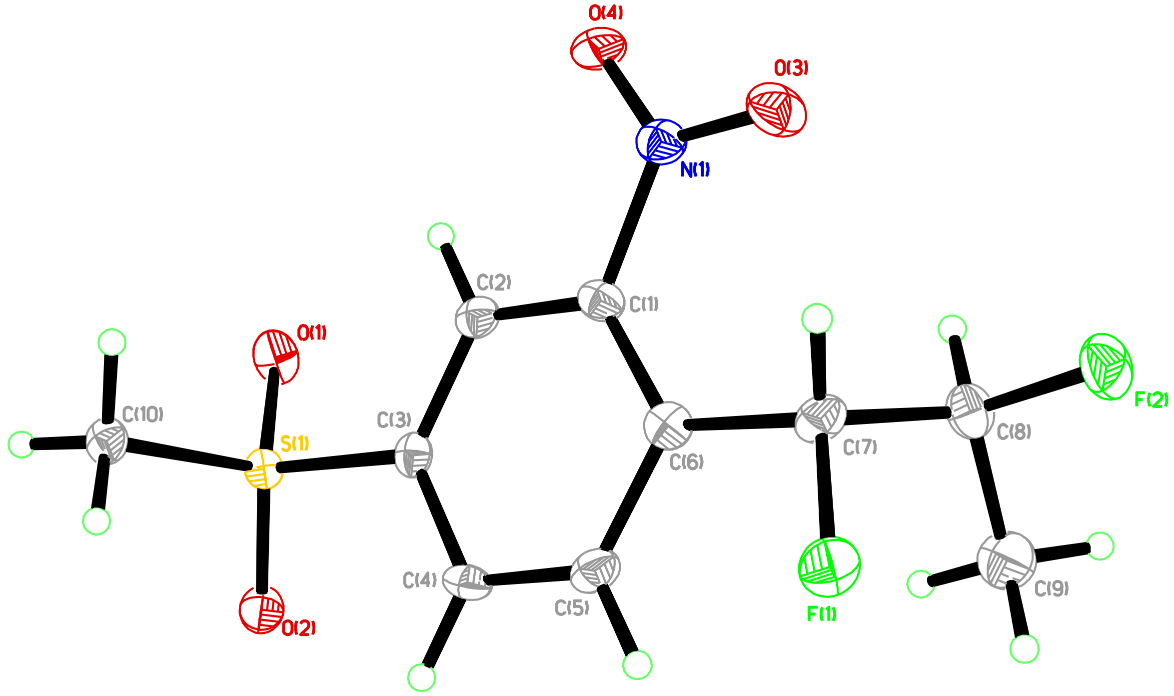
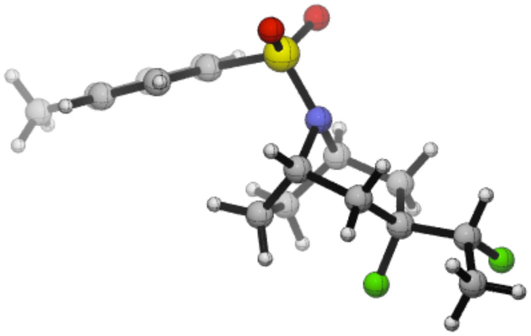


Figure S7. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-5s.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD diffractometer (Mo$_{K_\alpha}$ radiation, λ=0.71073 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 0.5° scans in ω at 28° in 2θ. Data integration down to 0.78 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S15. Experimental details

	SMB-trisub-OTS
Crystal data	
Chemical formula	$C_{16}H_{21c2}NO_2S$
M_r	329.40
Crystal system, space group	Triclinic, *P*-1
Temperature (K)	100
a, *b*, *c* (Å)	6.1242 (2), 10.9040 (3), 12.8468 (4)
a, b, g (°)	109.6287 (6), 101.8115 (6), 91.5446 (6)
V (Å^3)	786.65 (4)
Z	2
Radiation type	Mo *K*a
m (mm^{-1})	0.23
Crystal size (mm)	0.24 × 0.18 × 0.10
Data collection	

Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
T_{min}, T_{max}	0.725, 0.746
No. of measured, independent and observed [$I > 2\mathrm{s}(I)$] reflections	58823, 3479, 3141
R_{int}	0.048
$(\sin \mathrm{q}/\mathrm{l})_{\mathrm{max}}$ (Å^{-1})	0.642
Refinement	
$R[F^2 > 2\mathrm{s}(F^2)]$, $wR(F^2)$, S	0.031, 0.086, 1.06
No. of reflections	3479
No. of parameters	201
H-atom treatment	H-atom parameters constrained
$\mathrm{D}\rho_{\mathrm{max}}$, $\mathrm{D}\rho_{\mathrm{min}}$ (e Å^{-3})	0.38, -0.40

Table S16. Geometric parameters (Å, º)

C1—C2	1.5283 (18)	C8—H8	1.0000
C1—C7	1.5291 (18)	C9—H9A	0.9800
C1—H1A	0.9900	C9—H9B	0.9800
C1—H1B	0.9900	C9—H9C	0.9800
C2—N1	1.4830 (14)	C10—C11	1.386 (2)
C2—C3	1.5432 (17)	C10—C15	1.394 (2)
C2—H2	1.0000	C10—H10	0.9500
C3—C4	1.5472 (17)	C11—C12	1.3926 (19)
C3—H3A	0.9900	C11—H11	0.9500
C3—H3B	0.9900	C12—C13	1.3933 (18)
C4—C5	1.5417 (17)	C12—S1	1.7605 (13)
C4—H4A	0.9900	C13—C14	1.385 (2)
C4—H4B	0.9900	C13—H13	0.9500
C5—N1	1.4854 (15)	C14—C15	1.392 (2)
C5—C6	1.5315 (18)	C14—H14	0.9500
C5—H5	1.0000	C15—C16	1.506 (2)
C6—C7	1.5321 (17)	C16—H16A	0.9800
C6—H6A	0.9900	C16—H16B	0.9800
C6—H6B	0.9900	C16—H16C	0.9800
C7—F1	1.4241 (13)	N1—S1	1.6240 (11)
C7—C8	1.5205 (19)	O1—S1	1.4378 (9)

C8—F2	1.4164 (15)	O2—S1	1.4356 (9)
C8—C9	1.505 (2)		

C2—C1—C7	113.06 (10)	C9—C8—C7	114.93 (12)
C2—C1—H1A	109.0	F2—C8—H8	108.6
C7—C1—H1A	109.0	C9—C8—H8	108.6
C2—C1—H1B	109.0	C7—C8—H8	108.6
C7—C1—H1B	109.0	C8—C9—H9A	109.5
H1A—C1—H1B	107.8	C8—C9—H9B	109.5
N1—C2—C1	105.55 (10)	H9A—C9—H9B	109.5
N1—C2—C3	104.08 (9)	C8—C9—H9C	109.5
C1—C2—C3	113.52 (10)	H9A—C9—H9C	109.5
N1—C2—H2	111.1	H9B—C9—H9C	109.5
C1—C2—H2	111.1	C11—C10—C15	121.67 (14)
C3—C2—H2	111.1	C11—C10—H10	119.2
C2—C3—C4	104.45 (9)	C15—C10—H10	119.2
C2—C3—H3A	110.9	C10—C11—C12	118.75 (13)
C4—C3—H3A	110.9	C10—C11—H11	120.6
C2—C3—H3B	110.9	C12—C11—H11	120.6
C4—C3—H3B	110.9	C11—C12—C13	120.51 (13)
H3A—C3—H3B	108.9	C11—C12—S1	119.92 (10)
C5—C4—C3	104.87 (10)	C13—C12—S1	119.51 (10)
C5—C4—H4A	110.8	C14—C13—C12	119.75 (13)
C3—C4—H4A	110.8	C14—C13—H13	120.1
C5—C4—H4B	110.8	C12—C13—H13	120.1
C3—C4—H4B	110.8	C13—C14—C15	120.75 (14)
H4A—C4—H4B	108.8	C13—C14—H14	119.6
N1—C5—C6	105.12 (10)	C15—C14—H14	119.6
N1—C5—C4	104.10 (9)	C14—C15—C10	118.55 (13)
C6—C5—C4	113.09 (10)	C14—C15—C16	120.46 (15)
N1—C5—H5	111.4	C10—C15—C16	120.98 (16)
C6—C5—H5	111.4	C15—C16—H16A	109.5
C4—C5—H5	111.4	C15—C16—H16B	109.5
C5—C6—C7	113.06 (10)	H16A—C16—H16B	109.5
C5—C6—H6A	109.0	C15—C16—H16C	109.5
C7—C6—H6A	109.0	H16A—C16—H16C	109.5
C5—C6—H6B	109.0	H16B—C16—H16C	109.5
C7—C6—H6B	109.0	C2—N1—C5	103.31 (9)
H6A—C6—H6B	107.8	C2—N1—S1	120.90 (8)
F1—C7—C8	106.47 (10)	C5—N1—S1	121.50 (8)
F1—C7—C1	107.22 (10)	O2—S1—O1	119.88 (6)
C8—C7—C1	111.51 (11)	O2—S1—N1	106.03 (5)
F1—C7—C6	107.85 (10)	O1—S1—N1	106.29 (5)

C8—C7—C6	110.52 (10)	O2—S1—C12	107.73 (6)
C1—C7—C6	112.93 (10)	O1—S1—C12	107.16 (6)
F2—C8—C9	108.68 (11)	N1—S1—C12	109.48 (6)
F2—C8—C7	107.21 (10)		

C7—C1—C2—N1	57.19 (12)	C12—C13—C14—C15	0.1 (2)
C7—C1—C2—C3	−56.17 (13)	C13—C14—C15—C10	0.7 (2)
N1—C2—C3—C4	−26.42 (13)	C13—C14—C15—C16	−179.32 (13)
C1—C2—C3—C4	87.81 (12)	C11—C10—C15—C14	–0.8 (2)
C2—C3—C4—C5	0.92 (13)	C11—C10—C15—C16	179.25 (14)
C3—C4—C5—N1	24.84 (13)	C1—C2—N1—C5	–77.03 (11)
C3—C4—C5—C6	−88.69 (12)	C3—C2—N1—C5	42.75 (12)
N1—C5—C6—C7	−57.48 (12)	C1—C2—N1—S1	142.85 (9)
C4—C5—C6—C7	55.44 (14)	C3—C2—N1—S1	–97.36 (11)
C2—C1—C7—F1	80.62 (12)	C6—C5—N1—C2	77.02 (11)
C2—C1—C7—C8	−163.20 (10)	C4—C5—N1—C2	–42.10 (12)
C2—C1—C7—C6	−38.04 (14)	C6—C5—N1—S1	–143.17 (9)
C5—C6—C7—F1	−79.98 (12)	C4—C5—N1—S1	97.70 (10)
C5—C6—C7—C8	164.01 (10)	C2—N1—S1—O2	−179.52 (9)
C5—C6—C7—C1	38.32 (14)	C5—N1—S1—O2	47.53 (10)
F1—C7—C8—F2	63.21 (12)	C2—N1—S1—O1	–50.91 (10)
C1—C7—C8—F2	−53.43 (13)	C5—N1—S1—O1	176.14 (9)
C6—C7—C8—F2	−179.92 (10)	C2—N1—S1—C12	64.52 (10)
F1—C7—C8—C9	−57.71 (13)	C5—N1—S1—C12	–68.43 (10)
C1—C7—C8—C9	−174.35 (10)	C11—C12—S1—O2	–27.12 (12)
C6—C7—C8—C9	59.16 (14)	C13—C12—S1—O2	155.68 (10)
C15—C10—C11—C12	0.0 (2)	C11—C12—S1—O1	−157.37 (10)
C10—C11—C12—C13	0.8 (2)	C13—C12—S1—O1	25.43 (12)
C10—C11—C12—S1	−176.36 (10)	C11—C12—S1—N1	87.75 (11)
C11—C12—C13—C14	–0.9 (2)	C13—C12—S1—N1	–89.44 (11)
S1—C12—C13—C14	176.30 (10)		

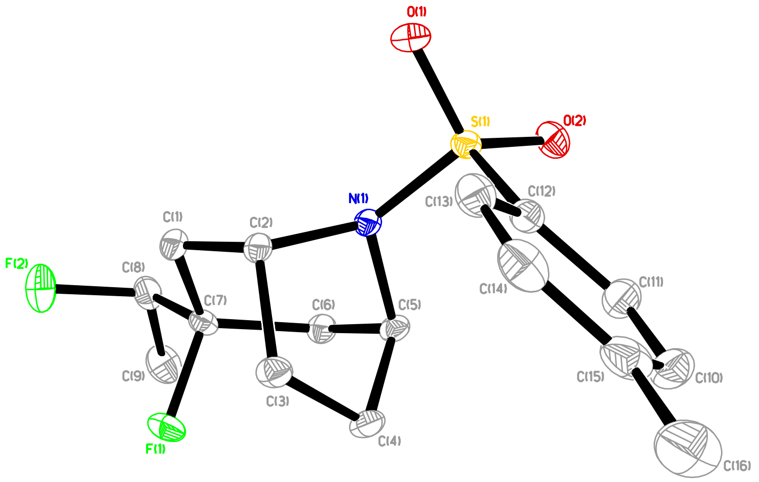
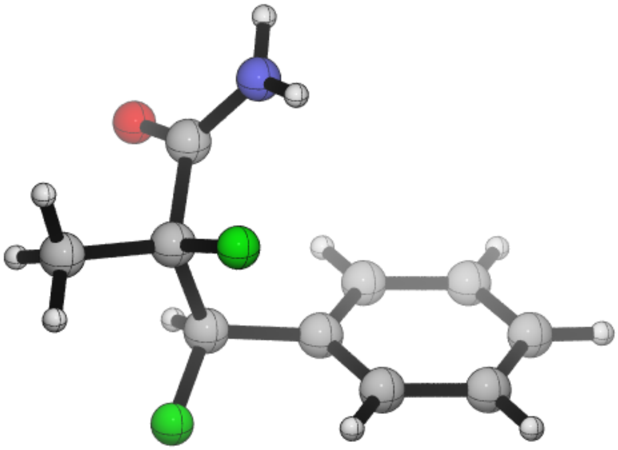


Figure S8. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-7a.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD along with the D8 Diffractometer (30 KeV, l = 0.40651 Å), and equipped with an Oxford Cryosystems nitrogen open flow apparatus. The collection method involved 0.5° scans in Phi at -5° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S17. Experimental details

	JWM-V-194-II
Crystal data	
Chemical formula	$C_{10}H_{11c2}NO$
M_r	199.20
Crystal system, space group	Monoclinic, $P2_1/c$
Temperature (K)	100
a, b, c (Å)	7.9650 (11), 5.1021 (7), 22.815 (3)
b (°)	96.225 (1)
V (Å^3)	921.7 (2)

Z	4
Radiation type	Synchrotron, l = 0.40651 Å
m (mm^{-1})	0.02
Crystal size (mm)	0.08 × 0.01 × 0.01
Data collection	
Diffractometer	Three-circle goniometer with fixed chi diffractometer
Absorption correction	Multi-scan *SADABS*
T_{min}, T_{max}	0.745, 0.762
No. of measured, independent and observed [$I > 2$s(I)] reflections	6597, 1568, 1379
R_{int}	0.045
(sin q/l)$_{\text{max}}$ (Å^{-1})	0.595
Refinement	
$R[F^2 > 2\text{s}(F^2)]$, $wR(F^2)$, S	0.041, 0.097, 1.12
No. of reflections	1568
No. of parameters	136
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
Dρ$_{\text{max}}$, Dρ$_{\text{min}}$ (e Å^{-3})	0.23, -0.21

Table S18. Geometric parameters (Å, º)

C1—C6	1.377 (3)	C7—C8	1.530 (3)
C1—C2	1.382 (3)	C7—H7	1.0000
C1—H1	0.9500	C8—F2	1.401 (2)
C2—C3	1.369 (3)	C8—C10	1.504 (3)
C2—H2	0.9500	C8—C9	1.518 (3)
C3—C4	1.372 (3)	C9—O1	1.238 (2)
C3—H3	0.9500	C9—N1	1.310 (2)
C4—C5	1.390 (3)	C10—H10A	0.9800
C4—H4	0.9500	C10—H10B	0.9800
C5—C6	1.377 (3)	C10—H10C	0.9800
C5—H5	0.9500	N1—H1A	0.92 (2)
C6—C7	1.501 (3)	N1—H1B	0.87 (3)
C7—F1	1.387 (2)		

C6—C1—C2	120.2 (2)	F1—C7—H7	108.9
C6—C1—H1	119.9	C6—C7—H7	108.9
C2—C1—H1	119.9	C8—C7—H7	108.9
C3—C2—C1	120.1 (2)	F2—C8—C10	107.61 (15)
C3—C2—H2	119.9	F2—C8—C9	108.26 (14)
C1—C2—H2	119.9	C10—C8—C9	110.56 (16)
C2—C3—C4	120.2 (2)	F2—C8—C7	107.74 (15)
C2—C3—H3	119.9	C10—C8—C7	113.44 (16)
C4—C3—H3	119.9	C9—C8—C7	109.07 (15)
C3—C4—C5	119.9 (2)	O1—C9—N1	124.35 (18)
C3—C4—H4	120.0	O1—C9—C8	118.34 (16)
C5—C4—H4	120.0	N1—C9—C8	117.30 (16)
C6—C5—C4	119.9 (2)	C8—C10—H10A	109.5
C6—C5—H5	120.0	C8—C10—H10B	109.5
C4—C5—H5	120.0	H10A—C10—H10B	109.5
C1—C6—C5	119.65 (18)	C8—C10—H10C	109.5
C1—C6—C7	120.33 (18)	H10A—C10—H10C	109.5
C5—C6—C7	119.99 (18)	H10B—C10—H10C	109.5
F1—C7—C6	109.25 (15)	C9—N1—H1A	121.1 (13)
F1—C7—C8	107.86 (15)	C9—N1—H1B	119.4 (15)
C6—C7—C8	112.82 (15)	H1A—N1—H1B	119 (2)
C6—C1—C2—C3	0.3 (3)	F1—C7—C8—F2	74.85 (17)
C1—C2—C3—C4	−1.8 (3)	C6—C7—C8—F2	−45.9 (2)
C2—C3—C4—C5	1.8 (3)	F1—C7—C8—C10	−44.2 (2)
C3—C4—C5—C6	−0.3 (3)	C6—C7—C8—C10	−164.91 (16)
C2—C1—C6—C5	1.2 (3)	F1—C7—C8—C9	−167.86 (14)
C2—C1—C6—C7	−176.75 (17)	C6—C7—C8—C9	71.4 (2)
C4—C5—C6—C1	−1.2 (3)	F2—C8—C9—O1	−175.96 (15)
C4—C5—C6—C7	176.77 (18)	C10—C8—C9—O1	−58.3 (2)
C1—C6—C7—F1	−34.4 (2)	C7—C8—C9—O1	67.1 (2)
C5—C6—C7—F1	147.66 (17)	F2—C8—C9—N1	3.3 (2)
C1—C6—C7—C8	85.6 (2)	C10—C8—C9—N1	120.93 (18)
C5—C6—C7—C8	−92.4 (2)	C7—C8—C9—N1	−113.67 (18)

Table S19. Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N1—H1*B*···O1^{i}	0.87 (3)	2.06 (3)	2.908 (2)	164 (2)

Symmetry code: (i) −*x*, *y*−1/2, −*z*+3/2.

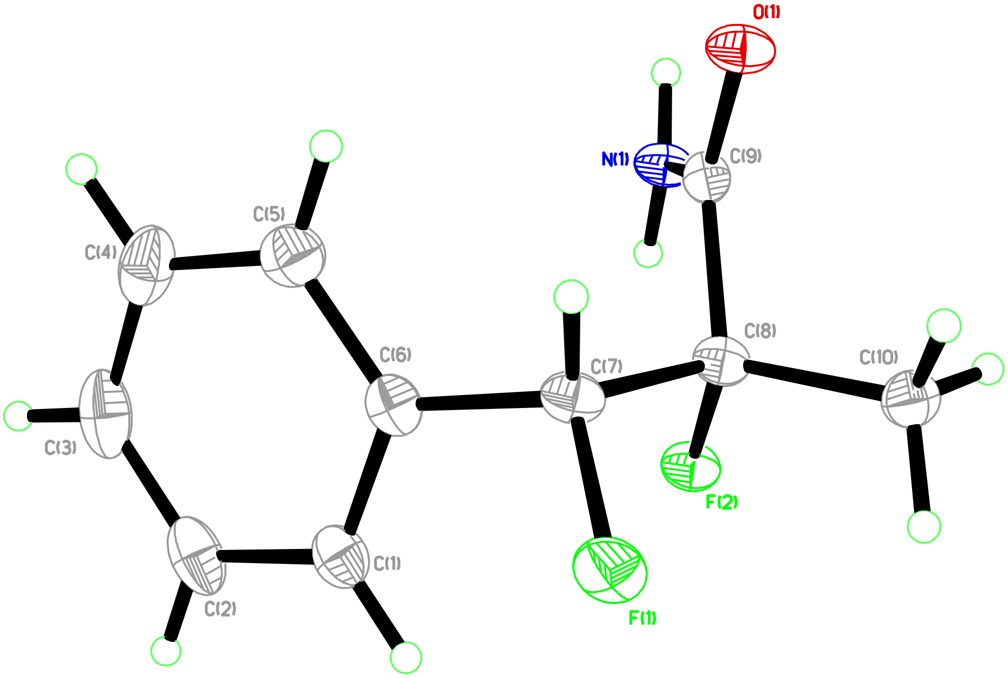
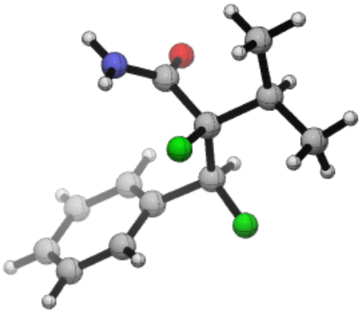


Figure S9. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-7c.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II DUO CCD diffractometer ($Cu_{K\alpha}$ radiation, λ=1.54178 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 1.0° scans in ω at -30°, -55°, -80°, 30°, 55°, 80° and 115° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S20. Experimental details

	JWM-V-223-II
Crystal data	
Chemical formula	$C_{24}H_{30}F_4N_2O_2$
M_r	454.50
Crystal system, space group	Monoclinic, $P2_1/c$
Temperature (K)	100
a, b, c (Å)	5.1700 (5), 35.663 (4), 13.1106 (15)
b (°)	100.433 (9)
V (Å^3)	2377.3 (4)
Z	4
Radiation type	Cu Ka
m (mm^{-1})	0.86
Crystal size (mm)	0.18 × 0.01 × 0.01
Data collection	

Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
$T_{\min}$, $T_{\max}$	0.656, 0.753
No. of measured, independent and observed [$I > 2s(I)$] reflections	23289, 4062, 1798
R_{int}	0.176
(sin q/l)$_{\max}$ (Å^{-1})	0.595
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.105, 0.257, 1.10
No. of reflections	4062
No. of parameters	306
No. of restraints	6
H-atom treatment	H-atom parameters constrained
D$\rho_{\max}$, D$\rho_{\min}$ (e Å^{-3})	0.39, -0.35

Table S21. Geometric parameters (Å, º)

C1—C2	1.377 (10)	C26—C27	1.506 (17)
C1—C6	1.385 (9)	C27—F3	1.426 (18)
C2—C3	1.374 (12)	C27—C28	1.515 (18)
C3—C4	1.376 (12)	C21A—C22A	1.3900
C4—C5	1.374 (10)	C21A—C26A	1.3900
C5—C6	1.346 (8)	C22A—C23A	1.3900
C6—C7	1.502 (8)	C23A—C24A	1.3900
C7—F1	1.378 (7)	C24A—C25A	1.3900
C7—C8	1.538 (9)	C25A—C26A	1.3900
C8—F2	1.399 (6)	C26A—C27A	1.507 (10)
C8—C9	1.525 (8)	C27A—F3A	1.424 (10)
C8—C10	1.547 (8)	C27A—C28	1.517 (11)
C9—O1	1.226 (6)	C28—F4	1.403 (7)
C9—N1	1.314 (7)	C28—C29	1.525 (8)
C10—C11	1.512 (9)	C28—C30	1.538 (9)
C10—C12	1.521 (9)	C28—C30A	1.563 (17)
C21—C22	1.3900	C29—O2	1.236 (6)
C21—C26	1.3900	C29—N2	1.307 (6)
C22—C23	1.3900 (13)	C30—C32	1.518 (12)

C23—C24	1.3900	C30—C31	1.525 (12)
C24—C25	1.3900	C30A—C32A	1.513 (18)
C25—C26	1.3900 (17)	C30A—C31A	1.520 (18)
C2—C1—C6	120.9 (8)	C26—C27—C28	113 (6)
C3—C2—C1	119.8 (9)	C22A—C21A—C26A	120.0
C2—C3—C4	119.2 (9)	C21A—C22A—C23A	120.0
C5—C4—C3	120.0 (8)	C24A—C23A—C22A	120.0
C6—C5—C4	121.7 (8)	C25A—C24A—C23A	120.0
C5—C6—C1	118.4 (7)	C24A—C25A—C26A	120.0
C5—C6—C7	122.0 (7)	C25A—C26A—C21A	120.0
C1—C6—C7	119.6 (6)	C25A—C26A—C27A	120 (2)
F1—C7—C6	107.8 (5)	C21A—C26A—C27A	120 (2)
F1—C7—C8	109.7 (5)	F3A—C27A—C26A	103.5 (17)
C6—C7—C8	114.9 (5)	F3A—C27A—C28	112.2 (12)
F2—C8—C9	109.1 (5)	C26A—C27A—C28	116 (2)
F2—C8—C7	106.4 (4)	F4—C28—C27	104 (4)
C9—C8—C7	107.2 (5)	F4—C28—C27A	107.1 (14)
F2—C8—C10	108.3 (5)	F4—C28—C29	108.5 (4)
C9—C8—C10	111.0 (5)	C27—C28—C29	112.7 (17)
C7—C8—C10	114.7 (5)	C27A—C28—C29	105.4 (8)
O1—C9—N1	124.9 (6)	F4—C28—C30	115.1 (6)
O1—C9—C8	118.1 (5)	C27—C28—C30	109 (3)
N1—C9—C8	117.0 (5)	C29—C28—C30	108.1 (6)
C11—C10—C12	111.1 (6)	F4—C28—C30A	90.9 (10)
C11—C10—C8	114.1 (6)	C27A—C28—C30A	129.9 (14)
C12—C10—C8	109.1 (5)	C29—C28—C30A	112.5 (12)
C22—C21—C26	120.00 (10)	O2—C29—N2	124.2 (6)
C23—C22—C21	120.00 (7)	O2—C29—C28	117.6 (5)
C24—C23—C22	120.0	N2—C29—C28	118.2 (5)
C25—C24—C23	120.00 (12)	C32—C30—C31	110.3 (11)
C26—C25—C24	120.00 (9)	C32—C30—C28	115.7 (8)
C25—C26—C21	120.0	C31—C30—C28	106.2 (9)
C25—C26—C27	123 (6)	C32A—C30A—C31A	110 (2)
C21—C26—C27	117 (6)	C32A—C30A—C28	108.5 (15)
F3—C27—C26	120 (6)	C31A—C30A—C28	119 (3)
F3—C27—C28	98 (2)		
C6—C1—C2—C3	0.6 (13)	C22A—C23A—C24A—C25A	0.0
C1—C2—C3—C4	−0.7 (14)	C23A—C24A—C25A—C26A	0.0
C2—C3—C4—C5	0.8 (14)	C24A—C25A—C26A—C21A	0.0
C3—C4—C5—C6	−0.8 (13)	C24A—C25A—C26A—	177 (2)

		C27A	
C4—C5—C6—C1	0.7 (11)	C22A—C21A—C26A—C25A	0.0
C4—C5—C6—C7	−177.4 (7)	C22A—C21A—C26A—C27A	−177 (2)
C2—C1—C6—C5	−0.6 (11)	C25A—C26A—C27A—F3A	−41 (2)
C2—C1—C6—C7	177.5 (7)	C21A—C26A—C27A—F3A	136.0 (17)
C5—C6—C7—F1	38.4 (9)	C25A—C26A—C27A—C28	82.4 (17)
C1—C6—C7—F1	−139.6 (6)	C21A—C26A—C27A—C28	−101 (3)
C5—C6—C7—C8	−84.2 (8)	F3—C27—C28—F4	66 (5)
C1—C6—C7—C8	97.7 (8)	C26—C27—C28—F4	−61 (5)
F1—C7—C8—F2	−58.4 (6)	F3—C27—C28—C29	−177 (3)
C6—C7—C8—F2	63.2 (7)	C26—C27—C28—C29	56 (6)
F1—C7—C8—C9	−175.0 (4)	F3—C27—C28—C30	−57 (6)
C6—C7—C8—C9	−53.4 (7)	C26—C27—C28—C30	176 (5)
F1—C7—C8—C10	61.2 (6)	F3A—C27A—C28—F4	64 (2)
C6—C7—C8—C10	−177.1 (5)	C26A—C27A—C28—F4	−55 (2)
F2—C8—C9—O1	−176.6 (5)	F3A—C27A—C28—C29	179.1 (19)
C7—C8—C9—O1	−61.8 (7)	C26A—C27A—C28—C29	61 (2)
C10—C8—C9—O1	64.2 (7)	F3A—C27A—C28—C30A	−42 (4)
F2—C8—C9—N1	2.8 (7)	C26A—C27A—C28—C30A	−161 (2)
C7—C8—C9—N1	117.6 (5)	F4—C28—C29—O2	177.6 (5)
C10—C8—C9—N1	−116.4 (6)	C27—C28—C29—O2	63 (4)
F2—C8—C10—C11	58.7 (7)	C27A—C28—C29—O2	63.1 (16)
C9—C8—C10—C11	178.4 (6)	C30—C28—C29—O2	−56.9 (8)
C7—C8—C10—C11	−59.9 (7)	C30A—C28—C29—O2	−83.4 (10)
F2—C8—C10—C12	−66.1 (6)	F4—C28—C29—N2	−3.5 (7)
C9—C8—C10—C12	53.6 (7)	C27—C28—C29—N2	−118 (4)
C7—C8—C10—C12	175.3 (5)	C27A—C28—C29—N2	−117.9 (15)
C26—C21—C22—C23	0.0	C30—C28—C29—N2	122.0 (6)
C21—C22—C23—C24	0.00 (5)	C30A—C28—C29—N2	95.5 (10)
C22—C23—C24—C25	0.00 (5)	F4—C28—C30—C32	−69.6 (10)
C23—C24—C25—C26	0.0	C27—C28—C30—C32	46 (3)
C24—C25—C26—C21	0.00 (8)	C29—C28—C30—C32	168.9 (7)
C24—C25—C26—C27	179 (7)	F4—C28—C30—C31	53.2 (13)
C22—C21—C26—C25	0.0	C27—C28—C30—C31	169 (3)
C22—C21—C26—C27	−179 (6)	C29—C28—C30—C31	−68.3 (13)
C25—C26—C27—F3	−36 (7)	F4—C28—C30A—C32A	−159 (2)
C21—C26—C27—F3	143 (4)	C27A—C28—C30A—C32A	−45 (3)
C25—C26—C27—C28	78 (5)	C29—C28—C30A—C32A	91 (2)
C21—C26—C27—C28	−103 (7)	F4—C28—C30A—C31A	74 (3)

C26A—C21A—C22A—C23A	0.0	C27A—C28—C30A—C31A	−172 (3)
C21A—C22A—C23A—C24A	0.0	C29—C28—C30A—C31A	−36 (3)

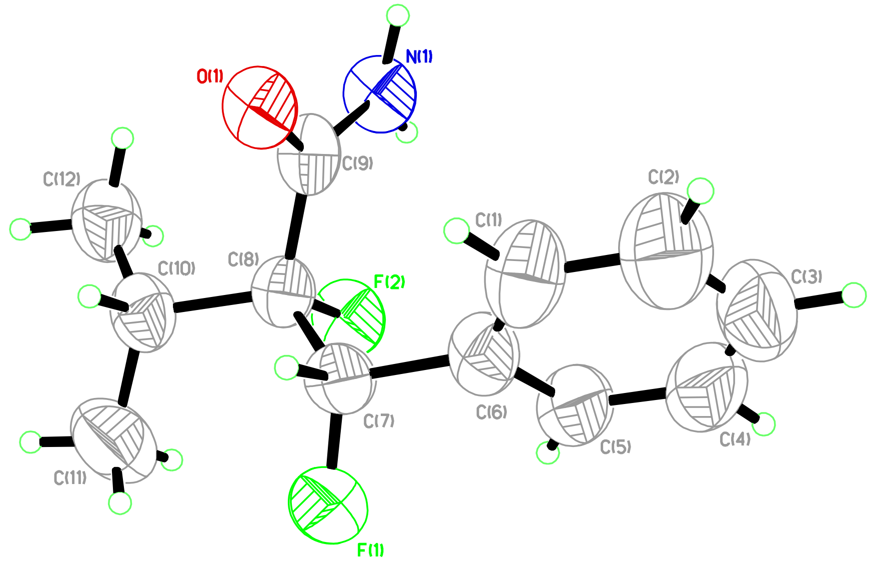
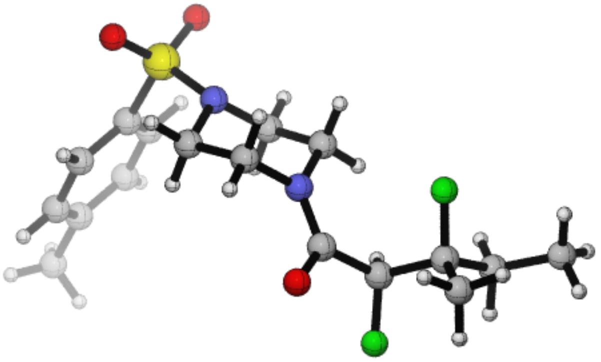


Figure S10. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-7f.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD diffractometer ($Mo_{K\alpha}$ radiation, λ=0.71073 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 0.5° scans in ω at 28° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S22. Experimental details

	JWM-VI-20-II
Crystal data	
Chemical formula	$C_{17}H_{24}F_2N_2O_3S$
M_r	374.44
Crystal system, space group	Monoclinic, $P2_1$
Temperature (K)	100
a, b, c (Å)	9.4625 (7), 6.1999 (4), 15.9168 (11)
b (°)	107.1497 (18)
V (Å^3)	892.27 (11)
Z	2
Radiation type	Mo Ka
m (mm^{-1})	0.22

Crystal size (mm)	0.26 × 0.14 × 0.12
Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
T_{min}, T_{max}	0.782, 0.862
No. of measured, independent and observed $[I > 2s(I)]$ reflections	22701, 3920, 3234
R_{int}	0.052
$(\sin q/l)_{\text{max}}$ (Å^{-1})	0.641
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.071, 0.185, 1.13
No. of reflections	3920
No. of parameters	236
No. of restraints	4
H-atom treatment	H-atom parameters constrained
Dρ_{max}, Dρ_{min} (e Å^{-3})	0.81, -0.39
Absolute structure	Refined as an inversion twin.

Table S23. Geometric parameters (Å, º)

C1—C2	1.3900	C10—H10B	0.9900
C1—C6	1.3900	C11—N1	1.479 (7)
C1—H1	0.9500	C11—H11A	0.9900
C2—C3	1.3900	C11—H11B	0.9900
C2—H2	0.9500	C12—O3	1.244 (8)
C3—C4	1.3900	C12—N2	1.328 (8)
C3—S1	1.769 (5)	C12—C13	1.530 (9)
C4—C5	1.3900	C13—F1	1.400 (7)
C4—H4	0.9500	C13—C14A	1.502 (10)
C5—C6	1.3900	C13—C14	1.502 (10)
C5—H5	0.9500	C13—H13	1.0000
C6—C7	1.527 (11)	C13—H13A	1.0000
C7—H7A	0.9800	C14—F2	1.410 (7)
C7—H7B	0.9800	C14—C17	1.474 (11)
C7—H7C	0.9800	C14—C15	1.555 (11)

C1A—C2A	1.3900	C15—C16	1.481 (15)
C1A—C6A	1.3900	C15—H15A	0.9900
C1A—H1A	0.9500	C15—H15B	0.9900
C2A—C3A	1.3900	C16—H16A	0.9800
C2A—H2A	0.9500	C16—H16B	0.9800
C3A—C4A	1.3900	C16—H16C	0.9800
C3A—S1	1.711 (16)	C14A—F2	1.410 (7)
C4A—C5A	1.3900	C14A—C17	1.474 (11)
C4A—H4A	0.9500	C14A—C15A	1.56 (2)
C5A—C6A	1.3900	C15A—C16A	1.49 (2)
C5A—H5A	0.9500	C15A—H15C	0.9900
C6A—C7A	1.45 (4)	C15A—H15D	0.9900
C7A—H7AA	0.9800	C16A—H16D	0.9800
C7A—H7AB	0.9800	C16A—H16E	0.9800
C7A—H7AC	0.9800	C16A—H16F	0.9800
C8—N1	1.488 (7)	C17—H17A	0.9800
C8—C9	1.520 (8)	C17—H17B	0.9800
C8—H8A	0.9900	C17—H17C	0.9800
C8—H8B	0.9900	C17—H17D	0.9800
C9—N2	1.459 (8)	C17—H17E	0.9800
C9—H9A	0.9900	C17—H17F	0.9800
C9—H9B	0.9900	N1—S1	1.632 (5)
C10—N2	1.451 (7)	O1—S1	1.431 (4)
C10—C11	1.526 (9)	O2—S1	1.445 (5)
C10—H10A	0.9900		
C2—C1—C6	120.0	F1—C13—C14A	106.0 (6)
C2—C1—H1	120.0	F1—C13—C14	106.0 (6)
C6—C1—H1	120.0	F1—C13—C12	109.0 (5)
C1—C2—C3	120.0	C14A—C13—C12	113.9 (5)
C1—C2—H2	120.0	C14—C13—C12	113.9 (5)
C3—C2—H2	120.0	F1—C13—H13	109.3
C4—C3—C2	120.0	C14—C13—H13	109.3
C4—C3—S1	119.7 (7)	C12—C13—H13	109.3
C2—C3—S1	120.2 (7)	F1—C13—H13A	109.3
C5—C4—C3	120.0	C14A—C13—H13A	109.3
C5—C4—H4	120.0	C12—C13—H13A	109.3
C3—C4—H4	120.0	F2—C14—C17	109.3 (6)
C6—C5—C4	120.0	F2—C14—C13	104.2 (5)
C6—C5—H5	120.0	C17—C14—C13	114.2 (6)
C4—C5—H5	120.0	F2—C14—C15	101.9 (6)
C5—C6—C1	120.0	C17—C14—C15	119.9 (7)
C5—C6—C7	119.9 (6)	C13—C14—C15	105.6 (6)
C1—C6—C7	120.1 (6)	C16—C15—C14	113.0 (9)

C6—C7—H7A	109.5	C16—C15—H15A	109.0
C6—C7—H7B	109.5	C14—C15—H15A	109.0
H7A—C7—H7B	109.5	C16—C15—H15B	109.0
C6—C7—H7C	109.5	C14—C15—H15B	109.0
H7A—C7—H7C	109.5	H15A—C15—H15B	107.8
H7B—C7—H7C	109.5	C15—C16—H16A	109.5
C2A—C1A—C6A	120.0	C15—C16—H16B	109.5
C2A—C1A—H1A	120.0	H16A—C16—H16B	109.5
C6A—C1A—H1A	120.0	C15—C16—H16C	109.5
C1A—C2A—C3A	120.0	H16A—C16—H16C	109.5
C1A—C2A—H2A	120.0	H16B—C16—H16C	109.5
C3A—C2A—H2A	120.0	F2—C14A—C17	109.3 (6)
C4A—C3A—C2A	120.0	F2—C14A—C13	104.2 (5)
C4A—C3A—S1	123 (3)	C17—C14A—C13	114.2 (6)
C2A—C3A—S1	117 (3)	F2—C14A—C15A	115.4 (12)
C3A—C4A—C5A	120.0	C17—C14A—C15A	92.8 (10)
C3A—C4A—H4A	120.0	C13—C14A—C15A	120.6 (12)
C5A—C4A—H4A	120.0	C16A—C15A—C14A	110.2 (17)
C6A—C5A—C4A	120.0	C16A—C15A—H15C	109.6
C6A—C5A—H5A	120.0	C14A—C15A—H15C	109.6
C4A—C5A—H5A	120.0	C16A—C15A—H15D	109.6
C5A—C6A—C1A	120.0	C14A—C15A—H15D	109.6
C5A—C6A—C7A	119 (2)	H15C—C15A—H15D	108.1
C1A—C6A—C7A	121 (2)	C15A—C16A—H16D	109.5
C6A—C7A—H7AA	109.5	C15A—C16A—H16E	109.5
C6A—C7A—H7AB	109.5	H16D—C16A—H16E	109.5
H7AA—C7A—H7AB	109.5	C15A—C16A—H16F	109.5
C6A—C7A—H7AC	109.5	H16D—C16A—H16F	109.5
H7AA—C7A—H7AC	109.5	H16E—C16A—H16F	109.5
H7AB—C7A—H7AC	109.5	C14—C17—H17A	109.5
N1—C8—C9	108.3 (4)	C14—C17—H17B	109.5
N1—C8—H8A	110.0	H17A—C17—H17B	109.5
C9—C8—H8A	110.0	C14—C17—H17C	109.5
N1—C8—H8B	110.0	H17A—C17—H17C	109.5
C9—C8—H8B	110.0	H17B—C17—H17C	109.5
H8A—C8—H8B	108.4	C14A—C17—H17D	109.5
N2—C9—C8	110.3 (5)	C14A—C17—H17E	109.5
N2—C9—H9A	109.6	H17D—C17—H17E	109.5
C8—C9—H9A	109.6	C14A—C17—H17F	109.5
N2—C9—H9B	109.6	H17D—C17—H17F	109.5
C8—C9—H9B	109.6	H17E—C17—H17F	109.5
H9A—C9—H9B	108.1	C11—N1—C8	112.5 (5)
N2—C10—C11	110.6 (5)	C11—N1—S1	116.9 (4)

N2—C10—H10A	109.5	C8—N1—S1	115.5 (4)
C11—C10—H10A	109.5	C12—N2—C10	121.0 (5)
N2—C10—H10B	109.5	C12—N2—C9	127.2 (5)
C11—C10—H10B	109.5	C10—N2—C9	111.8 (5)
H10A—C10—H10B	108.1	O1—S1—O2	119.0 (3)
N1—C11—C10	107.0 (5)	O1—S1—N1	106.7 (3)
N1—C11—H11A	110.3	O2—S1—N1	107.3 (3)
C10—C11—H11A	110.3	O1—S1—C3A	106.7 (19)
N1—C11—H11B	110.3	O2—S1—C3A	112.6 (15)
C10—C11—H11B	110.3	N1—S1—C3A	103.2 (17)
H11A—C11—H11B	108.6	O1—S1—C3	109.3 (6)
O3—C12—N2	122.8 (6)	O2—S1—C3	106.0 (4)
O3—C12—C13	116.8 (6)	N1—S1—C3	108.1 (5)
N2—C12—C13	120.4 (6)		
C6—C1—C2—C3	0.0	F1—C13—C14A—C17	−53.2 (7)
C1—C2—C3—C4	0.0	C12—C13—C14A—C17	66.6 (8)
C1—C2—C3—S1	−177.8 (10)	F1—C13—C14A—C15A	56.0 (13)
C2—C3—C4—C5	0.0	C12—C13—C14A—C15A	175.9 (12)
S1—C3—C4—C5	177.8 (10)	F2—C14A—C15A—C16A	−72 (2)
C3—C4—C5—C6	0.0	C17—C14A—C15A—C16A	175 (2)
C4—C5—C6—C1	0.0	C13—C14A—C15A—C16A	55 (2)
C4—C5—C6—C7	−178.9 (8)	C10—C11—N1—C8	59.5 (6)
C2—C1—C6—C5	0.0	C10—C11—N1—S1	−163.3 (4)
C2—C1—C6—C7	178.9 (8)	C9—C8—N1—C11	−59.0 (7)
C6A—C1A—C2A—C3A	0.0	C9—C8—N1—S1	163.2 (4)
C1A—C2A—C3A—C4A	0.0	O3—C12—N2—C10	2.1 (10)
C1A—C2A—C3A—S1	178 (3)	C13—C12—N2—C10	−178.5 (6)
C2A—C3A—C4A—C5A	0.0	O3—C12—N2—C9	−178.1 (6)
S1—C3A—C4A—C5A	−178 (4)	C13—C12—N2—C9	1.3 (9)
C3A—C4A—C5A—C6A	0.0	C11—C10—N2—C12	−120.4 (6)
C4A—C5A—C6A—C1A	0.0	C11—C10—N2—C9	59.8 (7)
C4A—C5A—C6A—C7A	−179 (2)	C8—C9—N2—C12	121.9 (6)
C2A—C1A—C6A—C5A	0.0	C8—C9—N2—C10	−58.2 (6)
C2A—C1A—C6A—C7A	179 (3)	C11—N1—S1—O1	44.4 (5)
N1—C8—C9—N2	56.1 (7)	C8—N1—S1—O1	−179.7 (4)
N2—C10—C11—N1	−58.5 (7)	C11—N1—S1—O2	173.1 (4)
O3—C12—C13—F1	26.8 (8)	C8—N1—S1—O2	−51.1 (5)
N2—C12—C13—F1	−152.6 (6)	C11—N1—S1—C3A	−67.8 (18)
O3—C12—C13—C14A	−91.3 (8)	C8—N1—S1—C3A	68.0 (18)
N2—C12—C13—C14A	89.2 (7)	C11—N1—S1—C3	−73.0 (6)
O3—C12—C13—C14	−91.3 (8)	C8—N1—S1—C3	62.8 (7)

N2—C12—C13—C14	89.2 (7)	C4A—C3A—S1—O1	−33 (3)
F1—C13—C14—F2	−172.4 (5)	C2A—C3A—S1—O1	148.9 (13)
C12—C13—C14—F2	−52.6 (7)	C4A—C3A—S1—O2	−165.4 (17)
F1—C13—C14—C17	−53.2 (7)	C2A—C3A—S1—O2	17 (2)
C12—C13—C14—C17	66.6 (8)	C4A—C3A—S1—N1	79 (3)
F1—C13—C14—C15	80.6 (7)	C2A—C3A—S1—N1	−98.8 (15)
C12—C13—C14—C15	−159.5 (7)	C4—C3—S1—O1	−30.4 (8)
F2—C14—C15—C16	71.8 (10)	C2—C3—S1—O1	147.4 (4)
C17—C14—C15—C16	−49.0 (13)	C4—C3—S1—O2	−159.8 (5)
C13—C14—C15—C16	−179.6 (8)	C2—C3—S1—O2	18.0 (6)
F1—C13—C14A—F2	−172.4 (5)	C4—C3—S1—N1	85.4 (7)
C12—C13—C14A—F2	−52.6 (7)	C2—C3—S1—N1	−96.8 (5)

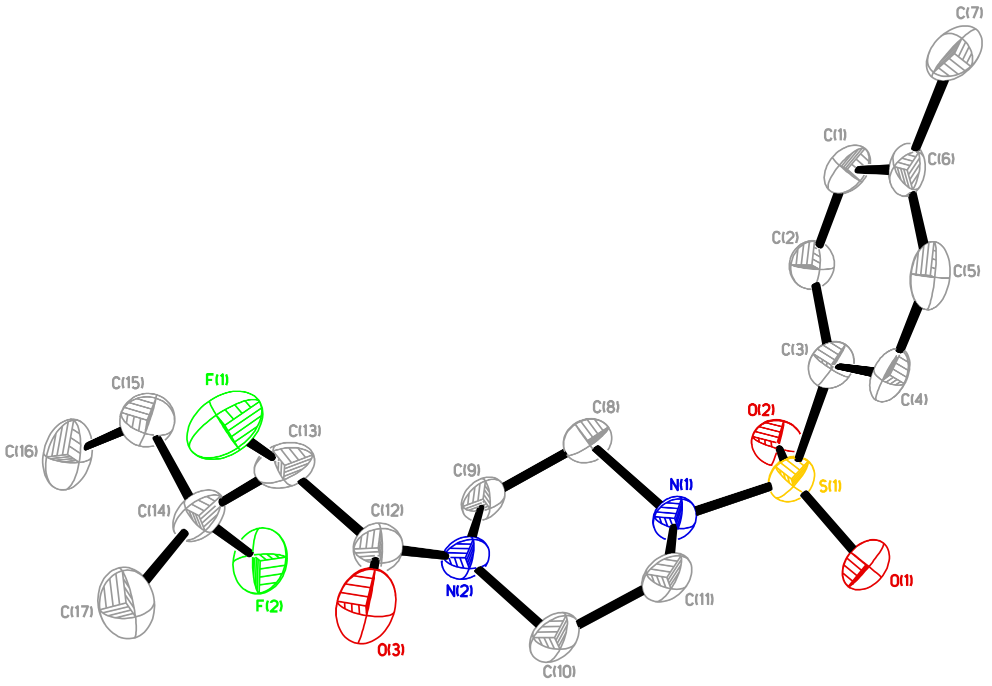
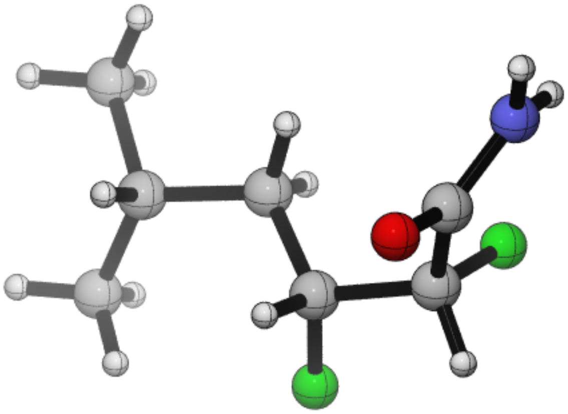


Figure S11. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-7g.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II CCD diffractometer (Mo$_{K_\alpha}$ radiation, λ=0.71073 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 0.5° scans in ω at 28° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S24. Experimental details

	JWM-V-216
Crystal data	
Chemical formula	$C_7H_{13}F_2NO$
M_r	165.18
Crystal system, space group	Monoclinic, $P2_1/c$
Temperature (K)	100
a, *b*, *c* (Å)	16.353 (3), 5.1206 (10), 10.1150 (18)
b (°)	90.805 (5)
V (Å^3)	846.9 (3)
Z	4
Radiation type	Mo *K*a
m (mm^{-1})	0.12

Crystal size (mm)	0.26 × 0.18 × 0.14
Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan *SADABS*
$T_{\min}$, $T_{\max}$	0.699, 0.862
No. of measured, independent and observed [$I > 2s(I)$] reflections	11749, 1489, 1232
R_{int}	0.070
(sin q/l)$_{\max}$ (Å^{-1})	0.596
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.085, 0.238, 1.13
No. of reflections	1489
No. of parameters	118
No. of restraints	5
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
Dρ$_{\max}$, Dρ$_{\min}$ (e Å^{-3})	0.55, -0.76

Table S25. Geometric parameters (Å, º)

C1—O1	1.236 (4)	C6—H6A	0.9800
C1—N1	1.315 (4)	C6—H6B	0.9800
C1—C2	1.528 (5)	C6—H6C	0.9800
C2—F1	1.397 (4)	C7—H7A	0.9800
C2—C3	1.513 (5)	C7—H7B	0.9800
C2—H2	1.0000	C7—H7C	0.9800
C3—F2	1.414 (4)	C5A—C7A	1.53 (2)
C3—C4	1.511 (6)	C5A—C6A	1.58 (2)
C3—H3	1.0000	C5A—H5A	1.0000
C4—C5A	1.513 (19)	C6A—H6AA	0.9800
C4—C5	1.525 (7)	C6A—H6AB	0.9800
C4—H4AA	0.9900	C6A—H6AC	0.9800
C4—H4AB	0.9900	C7A—H7AA	0.9800
C4—H4BC	0.9900	C7A—H7AB	0.9800
C4—H4BD	0.9900	C7A—H7AC	0.9800

C5—C7	1.519 (7)	N1—H1A	0.86 (4)
C5—C6	1.593 (8)	N1—H1B	0.91 (5)
C5—H5	1.0000		
O1—C1—N1	125.1 (3)	C5—C6—H6A	109.5
O1—C1—C2	117.4 (3)	C5—C6—H6B	109.5
N1—C1—C2	117.4 (3)	H6A—C6—H6B	109.5
F1—C2—C3	110.5 (3)	C5—C6—H6C	109.5
F1—C2—C1	109.9 (3)	H6A—C6—H6C	109.5
C3—C2—C1	111.7 (3)	H6B—C6—H6C	109.5
F1—C2—H2	108.2	C5—C7—H7A	109.5
C3—C2—H2	108.2	C5—C7—H7B	109.5
C1—C2—H2	108.2	H7A—C7—H7B	109.5
F2—C3—C4	109.7 (3)	C5—C7—H7C	109.5
F2—C3—C2	104.8 (3)	H7A—C7—H7C	109.5
C4—C3—C2	115.3 (3)	H7B—C7—H7C	109.5
F2—C3—H3	109.0	C4—C5A—C7A	103 (2)
C4—C3—H3	109.0	C4—C5A—C6A	108.1 (16)
C2—C3—H3	109.0	C7A—C5A—C6A	111.1 (18)
C3—C4—C5A	127.8 (12)	C4—C5A—H5A	111.4
C3—C4—C5	114.1 (4)	C7A—C5A—H5A	111.4
C3—C4—H4AA	108.7	C6A—C5A—H5A	111.4
C5—C4—H4AA	108.7	C5A—C6A—H6AA	109.5
C3—C4—H4AB	108.7	C5A—C6A—H6AB	109.5
C5—C4—H4AB	108.7	H6AA—C6A—H6AB	109.5
H4AA—C4—H4AB	107.6	C5A—C6A—H6AC	109.5
C3—C4—H4BC	105.4	H6AA—C6A—H6AC	109.5
C5A—C4—H4BC	105.4	H6AB—C6A—H6AC	109.5
C3—C4—H4BD	105.4	C5A—C7A—H7AA	109.5
C5A—C4—H4BD	105.4	C5A—C7A—H7AB	109.5
H4BC—C4—H4BD	106.0	H7AA—C7A—H7AB	109.5
C7—C5—C4	116.4 (4)	C5A—C7A—H7AC	109.5
C7—C5—C6	110.4 (4)	H7AA—C7A—H7AC	109.5
C4—C5—C6	106.8 (5)	H7AB—C7A—H7AC	109.5
C7—C5—H5	107.7	C1—N1—H1A	129 (3)
C4—C5—H5	107.7	C1—N1—H1B	118 (3)
C6—C5—H5	107.7	H1A—N1—H1B	113 (4)

Table S26. Hydrogen-bond geometric parameters (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N1—H1*B*···O1^{i}	0.91 (5)	2.02 (5)	2.922 (4)	170 (4)
N1—H1*A*···O1^{ii}	0.86 (4)	2.08 (4)	2.860 (4)	151 (4)

Symmetry codes: (i) $-x+1, y+1/2, -z+1/2$; (ii) $x, y+1, z$.

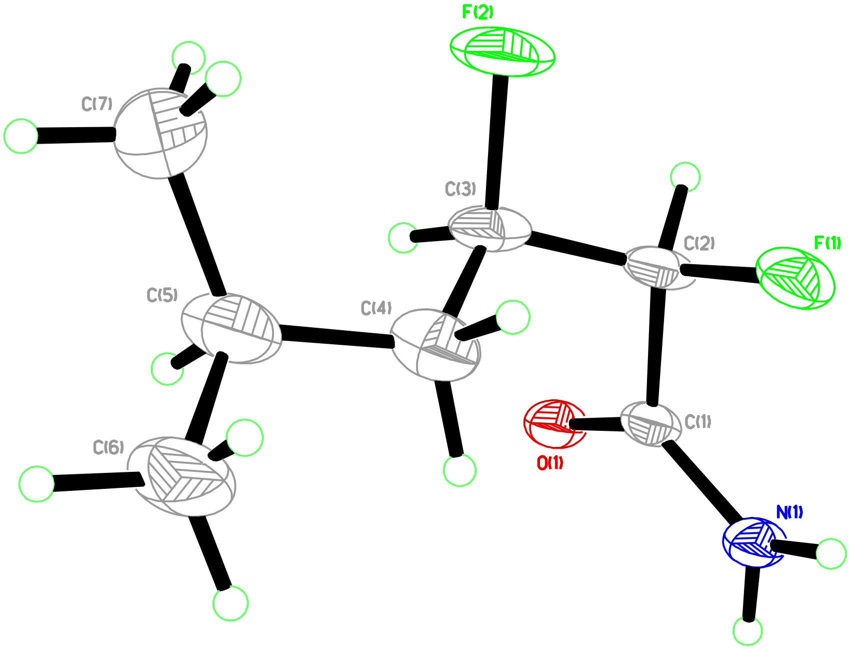
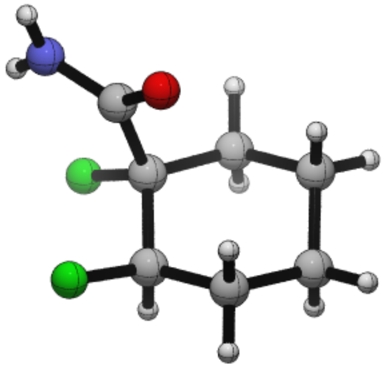


Figure 12. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (±)-7k.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II DUO CCD diffractometer ($Cu_{K\alpha}$ radiation, λ=1.54178 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 1.0° scans in ω at -30°, -55°, -80°, 30°, 55°, 80° and 115° in 2θ. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.0.[48]

Table S27. Experimental details

	JWM-V-232
Crystal data	
Chemical formula	$C_7H_{11c2}NO$
M_r	163.17
Crystal system, space group	Orthorhombic, $Pca2_1$
Temperature (K)	100
a, b, c (Å)	23.3079 (12), 6.1672 (3), 10.5727 (5)
V (Å^3)	1519.77 (13)
Z	8
Radiation type	Cu Ka
m (mm^{-1})	1.11
Crystal size (mm)	0.18 × 0.16 × 0.14
Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector diffractometer
Absorption correction	Multi-scan

	SADABS
T_{min}, T_{max}	0.749, 0.864
No. of measured, independent and observed [$I > 2s(I)$] reflections	25359, 2680, 2653
R_{int}	0.039
(sin q/l)$_{max}$ (Å^{-1})	0.595
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.032, 0.108, 1.06
No. of reflections	2680
No. of parameters	216
No. of restraints	1
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
Dρ$_{max}$, Dρ$_{min}$ (e Å^{-3})	0.22, -0.21
Absolute structure	Flack x determined using 1193 quotients [(I+)-(I-)]/[(I+)+(I-)] (Parsons, Flack and Wagner, Acta Cryst. B69 (2013) 249-259).
Absolute structure parameter	0.03 (5)

Table S28. Geometric parameters (Å, º)

C1—F1	1.409 (4)	C11—F3	1.412 (4)
C1—C2	1.508 (5)	C11—C12	1.514 (5)
C1—C6	1.520 (4)	C11—C16	1.525 (4)
C2—C3	1.535 (5)	C12—C13	1.532 (5)
C3—C4	1.522 (5)	C13—C14	1.526 (5)
C4—C5	1.532 (5)	C14—C15	1.531 (5)
C5—C6	1.530 (5)	C15—C16	1.517 (5)
C6—F2	1.418 (4)	C16—F4	1.413 (4)
C6—C7	1.532 (4)	C16—C17	1.528 (5)
C7—O1	1.236 (4)	C17—O2	1.234 (4)
C7—N1	1.329 (5)	C17—N2	1.331 (5)
F1—C1—C2	110.0 (3)	F3—C11—C12	109.8 (3)
F1—C1—C6	108.6 (3)	F3—C11—C16	108.2 (3)
C2—C1—C6	113.8 (3)	C12—C11—C16	114.6 (3)
C1—C2—C3	109.9 (3)	C11—C12—C13	109.3 (3)
C4—C3—C2	111.6 (3)	C14—C13—C12	110.2 (3)
C3—C4—C5	111.0 (3)	C13—C14—C15	109.9 (3)
C6—C5—C4	113.3 (3)	C16—C15—C14	113.7 (3)

F2—C6—C1	106.8 (3)	F4—C16—C15	107.3 (3)
F2—C6—C5	106.7 (3)	F4—C16—C11	105.7 (2)
C1—C6—C5	110.8 (3)	C15—C16—C11	111.7 (3)
F2—C6—C7	107.3 (3)	F4—C16—C17	106.8 (3)
C1—C6—C7	112.4 (3)	C15—C16—C17	111.9 (3)
C5—C6—C7	112.5 (3)	C11—C16—C17	112.9 (3)
O1—C7—N1	123.8 (3)	O2—C17—N2	123.9 (3)
O1—C7—C6	119.6 (3)	O2—C17—C16	119.4 (3)
N1—C7—C6	116.6 (3)	N2—C17—C16	116.7 (3)
F1—C1—C2—C3	−178.0 (3)	F3—C11—C12—C13	−176.5 (3)
C6—C1—C2—C3	−55.9 (4)	C16—C11—C12—C13	−54.5 (4)
C1—C2—C3—C4	56.6 (4)	C11—C12—C13—C14	59.7 (4)
C2—C3—C4—C5	−55.1 (4)	C12—C13—C14—C15	−59.7 (4)
C3—C4—C5—C6	52.4 (4)	C13—C14—C15—C16	54.0 (4)
F1—C1—C6—F2	−68.5 (3)	C14—C15—C16—F4	−163.1 (3)
C2—C1—C6—F2	168.6 (3)	C14—C15—C16—C11	−47.6 (4)
F1—C1—C6—C5	175.7 (3)	C14—C15—C16—C17	80.0 (4)
C2—C1—C6—C5	52.8 (4)	F3—C11—C16—F4	−72.2 (3)
F1—C1—C6—C7	48.9 (4)	C12—C11—C16—F4	164.9 (3)
C2—C1—C6—C7	−74.0 (4)	F3—C11—C16—C15	171.4 (3)
C4—C5—C6—F2	−166.3 (3)	C12—C11—C16—C15	48.5 (4)
C4—C5—C6—C1	−50.4 (4)	F3—C11—C16—C17	44.2 (4)
C4—C5—C6—C7	76.3 (3)	C12—C11—C16—C17	−78.7 (4)
F2—C6—C7—O1	−174.6 (3)	F4—C16—C17—O2	176.2 (3)
C1—C6—C7—O1	68.3 (4)	C15—C16—C17—O2	−66.6 (4)
C5—C6—C7—O1	−57.5 (4)	C11—C16—C17—O2	60.4 (4)
F2—C6—C7—N1	5.2 (4)	F4—C16—C17—N2	−4.4 (4)
C1—C6—C7—N1	−111.9 (3)	C15—C16—C17—N2	112.7 (3)
C5—C6—C7—N1	122.2 (3)	C11—C16—C17—N2	−120.2 (3)

Table S29. Hydrogen-bond geometric parameters (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N1—H1*B*···F2	0.83 (5)	2.17 (4)	2.557 (4)	108 (4)
N1—H1*A*···O2^{i}	0.88 (5)	2.06 (5)	2.928 (4)	171 (4)
N1—H1*B*···F3^{ii}	0.83 (5)	2.43 (5)	3.175 (4)	150 (4)
N2—H2*C*···O1^{iii}	0.86 (5)	2.08 (5)	2.933 (4)	175 (4)
N2—H2*D*···O2^{iv}	0.86 (5)	2.31 (5)	3.173 (4)	173 (4)
N2—H2*D*···F4	0.86 (5)	2.16 (4)	2.542 (4)	106 (3)

Symmetry codes: (i) *x*−1/2, −*y*, *z*; (ii) −*x*+1, −*y*, *z*−1/2; (iii) *x*+1/2, −*y*, *z*; (iv) −*x*+3/2, *y*, *z*+1/2.

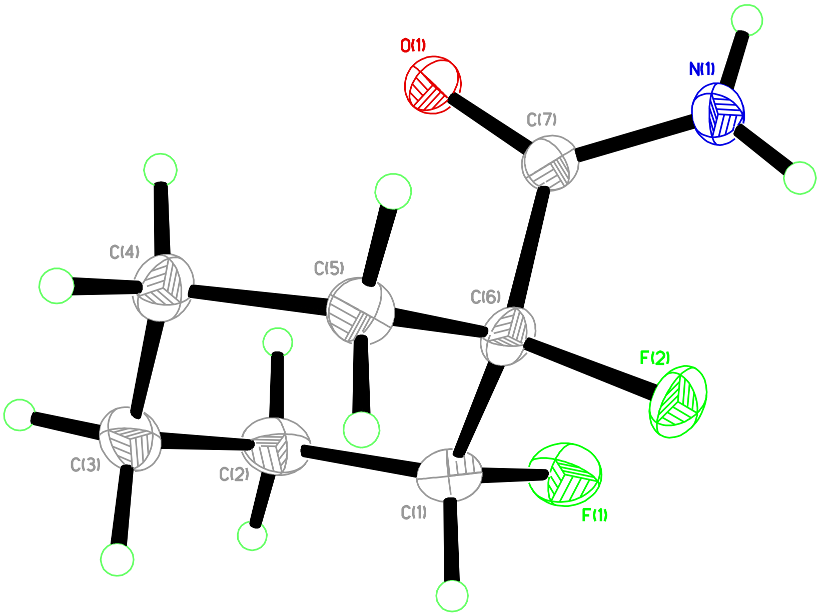
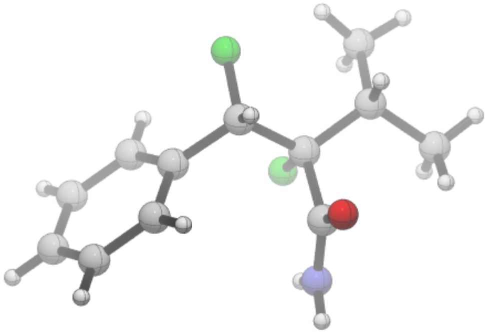


Figure S13. Perspective views showing 50% probability displacement.

X-Ray Crystal Structure of 1,2-Difluoride (+)-7c.



A crystal mounted on a diffractometer was collected data at 100 K. The intensities of the reflections were collected by means of a Bruker APEX II DUO CCD diffractometer (Cu_{K_α} radiation, λ=1.54178 Å), and equipped with an Oxford Cryosystems nitrogen flow apparatus. The collection method involved 1.0° scans in *ω* at -30°, -55°, -80°, 30°, 55°, 80° and 115° in *2θ*. Data integration down to 0.84 Å resolution was carried out using SAINT V8.34 C[44] with reflection spot size optimization. Absorption corrections were made with the program SADABS.[44] The structure was solved by the Intrinsic Phasing methods and refined by least-squares methods again F^2 using SHELXT-2014[45] and SHELXL-2014[46] with OLEX 2 interface.[47] Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were allowed to ride on the respective atoms. The Ortep plots produced with SHELXL-2014 program, and the other drawings were produced with Accelrys DS Visualizer 2.[48]

Table S30. Experimental details

	SMB-10-222
Crystal data	
Chemical formula	$C_{12}H_{15}F_2NO$
M_r	227.25
Crystal system, space group	Monoclinic, $P2_1$
Temperature (K)	100
a, b, c (Å)	5.13445 (9), 12.7905 (2), 17.8653 (3)
b (°)	95.3412 (9)
V (Å^3)	1168.16 (4)
Z	4
Radiation type	Cu *K*a
m (mm^{-1})	0.88
Crystal size (mm)	0.18 × 0.08 × 0.06

Data collection	
Diffractometer	Bruker D8 goniometer with CCD area detector
Absorption correction	Multi-scan *SADABS*
T_{min}, T_{max}	0.655, 0.753
No. of measured, independent and observed [$I > 2s(I)$] reflections	14247, 3828, 3709
R_{int}	0.031
(sin q/l)$_{\text{max}}$ (Å^{-1})	0.596
Refinement	
$R[F^2 > 2s(F^2)]$, $wR(F^2)$, S	0.027, 0.072, 1.05
No. of reflections	3828
No. of parameters	309
No. of restraints	1
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
Dρ_{max}, Dρ_{min} (e Å^{-3})	0.15, -0.15
Absolute structure	Flack x determined using 1574 quotients [(I+)-(I-)]/[(I+)+(I-)] (Parsons, Flack and Wagner, Acta Cryst. B69 (2013) 249-259).
Absolute structure parameter	-0.09 (6)

Table S31. Geometric parameters (Å, º)

F1—C7	1.398 (2)	F3—C27	1.403 (2)
F2—C8	1.407 (2)	F4—C28	1.408 (2)
O1—C9	1.245 (2)	O2—C29	1.242 (2)
N1—C9	1.317 (3)	N2—C29	1.318 (3)
N1—H1A	0.87 (3)	N2—H2A	0.89 (3)
N1—H1B	0.91 (3)	N2—H2B	0.88 (3)
C1—C2	1.392 (3)	C21—C22	1.386 (3)
C1—C6	1.393 (3)	C21—C26	1.393 (3)
C1—H1	0.9500	C21—H21	0.9500
C2—C3	1.387 (3)	C22—C23	1.389 (3)
C2—H2	0.9500	C22—H22	0.9500
C3—C4	1.386 (3)	C23—C24	1.387 (3)

C3—H3	0.9500	C23—H23	0.9500
C4—C5	1.384 (3)	C24—C25	1.394 (3)
C4—H4	0.9500	C24—H24	0.9500
C5—C6	1.395 (3)	C25—C26	1.392 (3)
C5—H5	0.9500	C25—H25	0.9500
C6—C7	1.510 (3)	C26—C27	1.513 (3)
C7—C8	1.541 (3)	C27—C28	1.543 (3)
C7—H7	1.0000	C27—H27	1.0000
C8—C9	1.535 (3)	C28—C29	1.535 (3)
C8—C10	1.544 (3)	C28—C30	1.543 (3)
C10—C11	1.525 (3)	C30—C32	1.533 (3)
C10—C12	1.535 (3)	C30—C31	1.537 (3)
C10—H10	1.0000	C30—H30	1.0000
C11—H11A	0.9800	C31—H31A	0.9800
C11—H11B	0.9800	C31—H31B	0.9800
C11—H11C	0.9800	C31—H31C	0.9800
C12—H12A	0.9800	C32—H32A	0.9800
C12—H12B	0.9800	C32—H32B	0.9800
C12—H12C	0.9800	C32—H32C	0.9800
C9—N1—H1A	120.3 (18)	C29—N2—H2A	121.4 (16)
C9—N1—H1B	115.9 (17)	C29—N2—H2B	117.4 (19)
H1A—N1—H1B	123 (2)	H2A—N2—H2B	121 (3)
C2—C1—C6	120.1 (2)	C22—C21—C26	120.3 (2)
C2—C1—H1	119.9	C22—C21—H21	119.8
C6—C1—H1	119.9	C26—C21—H21	119.8
C3—C2—C1	120.1 (2)	C21—C22—C23	120.3 (2)
C3—C2—H2	119.9	C21—C22—H22	119.9
C1—C2—H2	119.9	C23—C22—H22	119.9
C4—C3—C2	119.8 (2)	C24—C23—C22	119.7 (2)
C4—C3—H3	120.1	C24—C23—H23	120.1
C2—C3—H3	120.1	C22—C23—H23	120.1
C5—C4—C3	120.3 (2)	C23—C24—C25	120.3 (2)
C5—C4—H4	119.8	C23—C24—H24	119.9

C3—C4—H4	119.8	C25—C24—H24	119.9
C4—C5—C6	120.2 (2)	C26—C25—C24	119.99 (19)
C4—C5—H5	119.9	C26—C25—H25	120.0
C6—C5—H5	119.9	C24—C25—H25	120.0
C1—C6—C5	119.3 (2)	C25—C26—C21	119.5 (2)
C1—C6—C7	120.68 (19)	C25—C26—C27	120.32 (18)
C5—C6—C7	119.98 (18)	C21—C26—C27	120.18 (19)
F1—C7—C6	108.42 (17)	F3—C27—C26	108.30 (15)
F1—C7—C8	109.99 (15)	F3—C27—C28	109.80 (16)
C6—C7—C8	112.43 (17)	C26—C27—C28	112.20 (17)
F1—C7—H7	108.6	F3—C27—H27	108.8
C6—C7—H7	108.6	C26—C27—H27	108.8
C8—C7—H7	108.6	C28—C27—H27	108.8
F2—C8—C9	108.05 (16)	F4—C28—C29	108.50 (15)
F2—C8—C7	108.32 (16)	F4—C28—C30	107.77 (16)
C9—C8—C7	105.39 (15)	C29—C28—C30	109.68 (15)
F2—C8—C10	107.91 (15)	F4—C28—C27	107.95 (15)
C9—C8—C10	110.40 (16)	C29—C28—C27	105.52 (16)
C7—C8—C10	116.49 (17)	C30—C28—C27	117.15 (17)
O1—C9—N1	124.32 (19)	O2—C29—N2	124.27 (19)
O1—C9—C8	117.87 (17)	O2—C29—C28	117.93 (17)
N1—C9—C8	117.81 (18)	N2—C29—C28	117.80 (17)
C11—C10—C12	109.46 (17)	C32—C30—C31	109.13 (17)
C11—C10—C8	110.63 (17)	C32—C30—C28	113.31 (16)
C12—C10—C8	112.65 (18)	C31—C30—C28	109.72 (17)
C11—C10—H10	108.0	C32—C30—H30	108.2
C12—C10—H10	108.0	C31—C30—H30	108.2
C8—C10—H10	108.0	C28—C30—H30	108.2
C10—C11—H11A	109.5	C30—C31—H31A	109.5
C10—C11—H11B	109.5	C30—C31—H31B	109.5
H11A—C11—H11B	109.5	H31A—C31—H31B	109.5
C10—C11—H11C	109.5	C30—C31—H31C	109.5
H11A—C11—H11C	109.5	H31A—C31—H31C	109.5
H11B—C11—H11C	109.5	H31B—C31—H31C	109.5

C10—C12—H12A	109.5	C30—C32—H32A	109.5
C10—C12—H12B	109.5	C30—C32—H32B	109.5
H12A—C12—H12B	109.5	H32A—C32—H32B	109.5
C10—C12—H12C	109.5	C30—C32—H32C	109.5
H12A—C12—H12C	109.5	H32A—C32—H32C	109.5
H12B—C12—H12C	109.5	H32B—C32—H32C	109.5
C6—C1—C2—C3	-0.4 (4)	C26—C21—C22—C23	-0.2 (3)
C1—C2—C3—C4	0.0 (4)	C21—C22—C23—C24	0.0 (3)
C2—C3—C4—C5	0.3 (3)	C22—C23—C24—C25	0.2 (3)
C3—C4—C5—C6	-0.3 (3)	C23—C24—C25—C26	-0.3 (3)
C2—C1—C6—C5	0.4 (3)	C24—C25—C26—C21	0.1 (3)
C2—C1—C6—C7	-177.8 (2)	C24—C25—C26—C27	-178.09 (19)
C4—C5—C6—C1	0.0 (3)	C22—C21—C26—C25	0.1 (3)
C4—C5—C6—C7	178.1 (2)	C22—C21—C26—C27	178.31 (18)
C1—C6—C7—F1	-146.05 (19)	C25—C26—C27—F3	-146.64 (18)
C5—C6—C7—F1	35.8 (3)	C21—C26—C27—F3	35.2 (3)
C1—C6—C7—C8	92.1 (2)	C25—C26—C27—C28	92.0 (2)
C5—C6—C7—C8	-86.0 (2)	C21—C26—C27—C28	-86.2 (2)
F1—C7—C8—F2	-74.5 (2)	F3—C27—C28—F4	-73.08 (19)
C6—C7—C8—F2	46.5 (2)	C26—C27—C28—F4	47.4 (2)
F1—C7—C8—C9	170.07 (16)	F3—C27—C28—C29	171.06 (15)
C6—C7—C8—C9	-69.0 (2)	C26—C27—C28—C29	-68.4 (2)
F1—C7—C8—C10	47.3 (2)	F3—C27—C28—C30	48.7 (2)
C6—C7—C8—C10	168.25 (18)	C26—C27—C28—C30	169.19 (16)
F2—C8—C9—O1	-178.51 (17)	F4—C28—C29—O2	179.77 (16)

C7—C8—C9—O1	-62.9 (2)	C30—C28—C29—O2	62.3 (2)
C10—C8—C9—O1	63.7 (2)	C27—C28—C29—O2	-64.7 (2)
F2—C8—C9—N1	0.4 (2)	F4—C28—C29—N2	-0.8 (2)
C7—C8—C9—N1	116.05 (19)	C30—C28—C29—N2	-118.28 (19)
C10—C8—C9—N1	-117.4 (2)	C27—C28—C29—N2	114.68 (19)
F2—C8—C10—C11	-72.9 (2)	F4—C28—C30—C32	53.5 (2)
C9—C8—C10—C11	45.0 (2)	C29—C28—C30—C32	171.43 (17)
C7—C8—C10—C11	165.09 (18)	C27—C28—C30—C32	-68.4 (2)
F2—C8—C10—C12	50.0 (2)	F4—C28—C30—C31	-68.75 (19)
C9—C8—C10—C12	167.85 (18)	C29—C28—C30—C31	49.2 (2)
C7—C8—C10—C12	-72.0 (2)	C27—C28—C30—C31	169.37 (16)

Table S32. Hydrogen-bond parameters

D—H···*A*	*D*—H (Å)	H···*A* (Å)	*D*···*A* (Å)	*D*—H···*A* (°)
N2—H2A···O2^{i}	0.89 (3)	2.09 (3)	2.890 (2)	149 (2)

Symmetry code(s): (i) $x+1, y, z$

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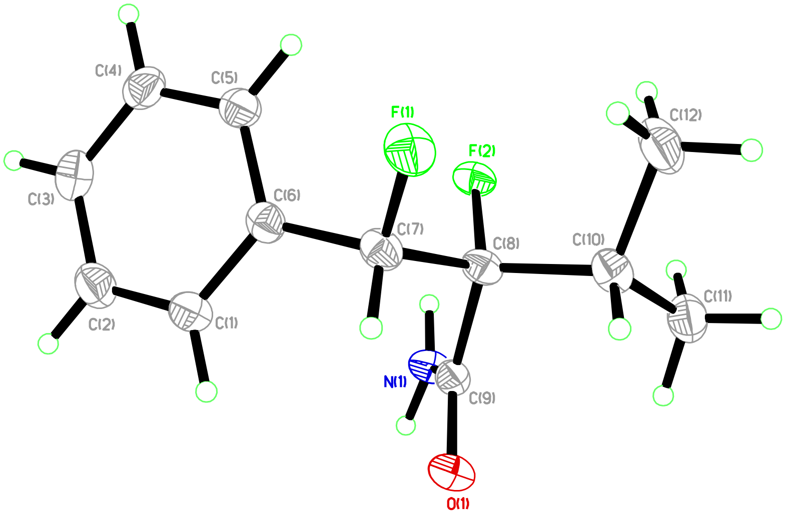

Figure S14. Perspective views showing 50% probability displacement

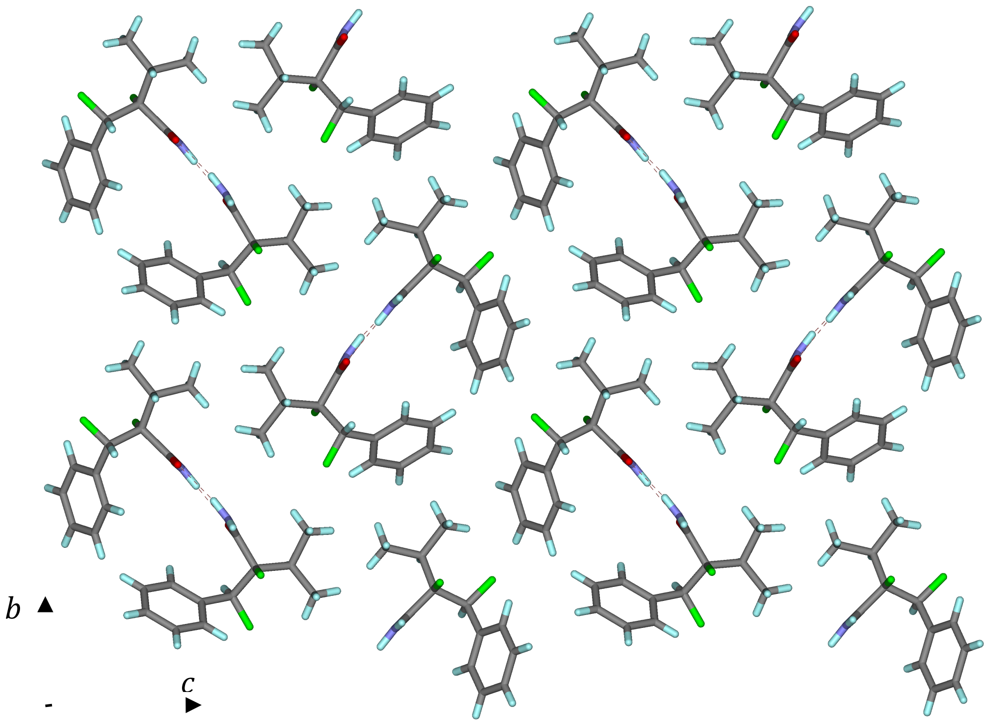

Figure S15. Three-dimensional supramolecular architecture viewed along the *a*-axis direction.

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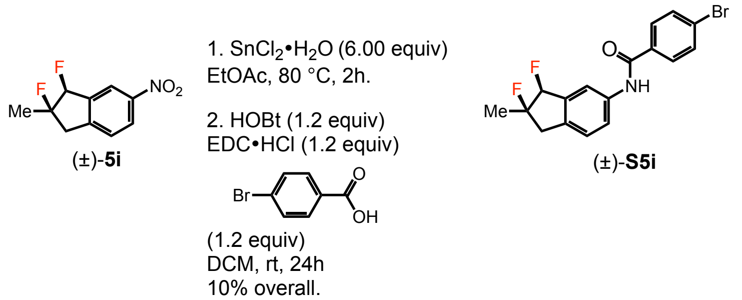
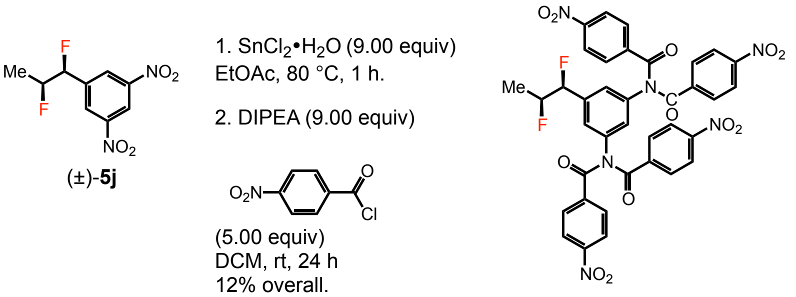


Ethyl acetate (2.3 mL) was added via syringe to a stirred mixture of (±)-**5i** (50.0 mg, 0.230 mmol, 1 equiv) and $SnCl_2$•2 H_2O (318 mg, 1.38 mmol, 6.00 equiv) at room temperature, and the resulting mixture was stirred for warmed to 80 °C in an oil bath. After 2 hours, the reaction mixure was cooled to room temperature and diluted with water (2.3 mL). The organic layer was separated, and the aqueous layer was extracted with ethyl acetate (2 × 5 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and were concentrated under reduced pressure. The residue was dissolved in dichlorometane (2.3 mL) at room temperature, and *N*-hydroxybenzotriazole hydrate (HOBt, 43 mg, 0.28 mmol, 1.2 equiv), 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrogen chloride (EDC•HCl, 54 mg, 0.28 mg, 0.28 mmol, 1.2 equiv), and 4-bromobenzoic acid (56 mg, 0.28 mmol, 1.2 equiv) were added as solids under a nitrogen atmosphere. The resulting mixture was stirred for 24 hours and was then diluted with water (3 mL). The organic layer was separated and washed sequentially with aqueous HCl solution (1 M, 3 mL), saturated aqueous $NaHCO_3$ solution (3 mL), and water (3 mL). The organic layer was dried over anhydrous $MgSO_4$ and was concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (0% to 50% diethyl ether in hexanes) to give crude (±)-**S5i** as a solid that was recrystallized twice from dichloromethane to give (±)-**S5i** (8.4 mg, 10%)as colorless crystals suitable for X-Ray diffraction. For a thermal ellipsoid representation of (±)-**S5i**, see page S45. 1H NMR (500 MHz, Acetone-*d*6) δ 9.65 (s, 1H), 8.80 (s, 1H), 7.97–7.94 (m, 2H), 7.77–7.70 (m, 3H), 7.29 (d, *J* = 8.3 Hz, 1H), 5.70 (dd, *J* = 10.7, 54.2 Hz, 1H), 3.28–3.21 (m, 1H), 3.11–3.03 (m, 1H), 1.63 (d, *J* = 22.5 Hz, 3H) ; 13C NMR (125.7 MHz, Acetone-*d*6) δ 165.4, 139.8 (d, *J* = 18.2 Hz), 139.5, 136.3–136.2 (m), 135.4, 132.5, 130.4, 126.5, 126.4, 122.8 (m), 117.9, 101.8–100.2 (m), 93.9 (dd, *J* = 17.3, 191.8 Hz), 42.4 (d, *J* = 24.0 Hz), 22.2 (d, *J* = 25.9 Hz); 19F NMR (470.4 MHz, Acetone-*d*6) δ −163.5-−163.8 (m, 1F), −194.7 (d, *J* = 54.8 Hz, 1F); FTIR (thin film) ν 3292 (w), 1649 (s), 1535 (s), 1492 (s), 1011 (m) cm−1; HRMS (ESI-TOF) Calc'd for C17H14BrF2NO[M+H]+: 366.0300; found 366.0301.

23.



(±)-**5j**

(±)-**S5j**

$SnCl_2$•2 H_2O (866 mg, 3.84 mmol, 9.00 equiv) was added under a nitrogen atmosphere to a solution of (±)-**5j** (105 mg, 0.427 mmol, 1 equiv) in ethyl acetate (4.3 mL) at room temperature. The resulting slurry was placed in an oil bath and warmed to 80 °C. After 1 hour, the reaction mixture was allowed to cool to room temperature and was poured into water (60 mL). K_2CO_3 was added until the pH of the aqueous layer was 9. The layers were separated, and the aqueous layer was extracted with ethyl acetate (60 mL). The combined organic layers were dried over anhydrous Na_2SO_4, were filtered through a short plug of silica, and were concentrated under reduced pressure to give the crude dianiline product (102 mg) as a light yellow oil. The crude dianiline (20.0 mg, 0.107 mmol, 1 equiv) was dissolved in dichloromethane (1 mL) at room temperature, and diisopropylethylamine (DIPEA, 169 µL, 0.967 mmol, 9.00 equiv) was added via syringe. 4-Nitrobenzoyl chloride (100 mg, 0.537 mmol, 5.00 equiv) was added as a solid under a nitrogen atmosphere. After 2 hours, ethyl acetate (30 mL) was added. The organic layer was washed sequentially with aqueous HCl solution (1 M, 2 15 mL), saturated aqueous $NaHCO_3$ solution (15 mL), and brine (15 mL). The organic layer was dried over anhydrous Na_2SO_4, was filtered, and was concentrated under reduced pressure. The residue was purified by flash column

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chromatography on silica gel (0 to 30% ethyl acetate in hexanes) to give diimide (±)-**S5j** (9.9 mg, 12%) as a white solid. Slow evaporation of a solution of (±)-**S5j** in 3:1 hexanes:ethyl acetate gave crystals suitable for X-ray diffraction. For a thermal ellipsoid representation of (±)-**S5j**, see page S56.

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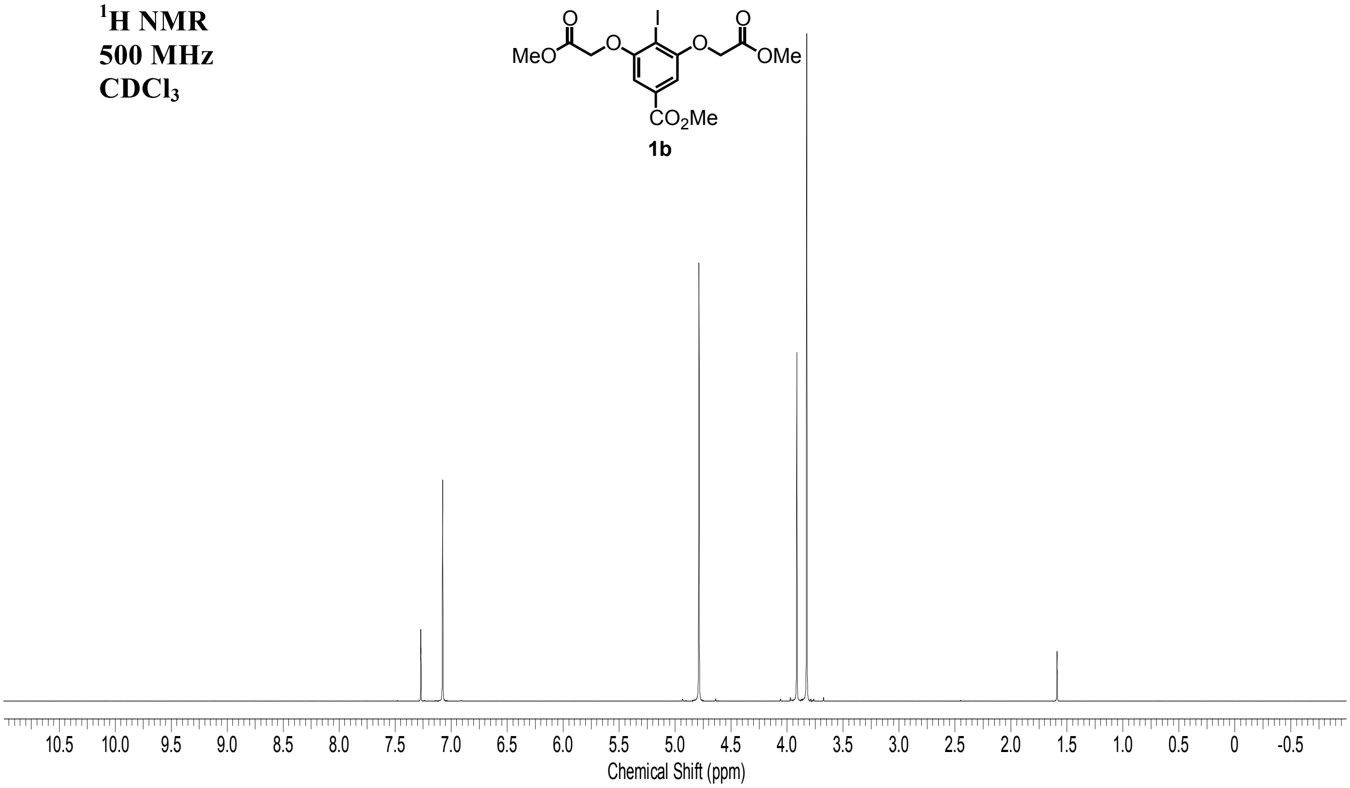
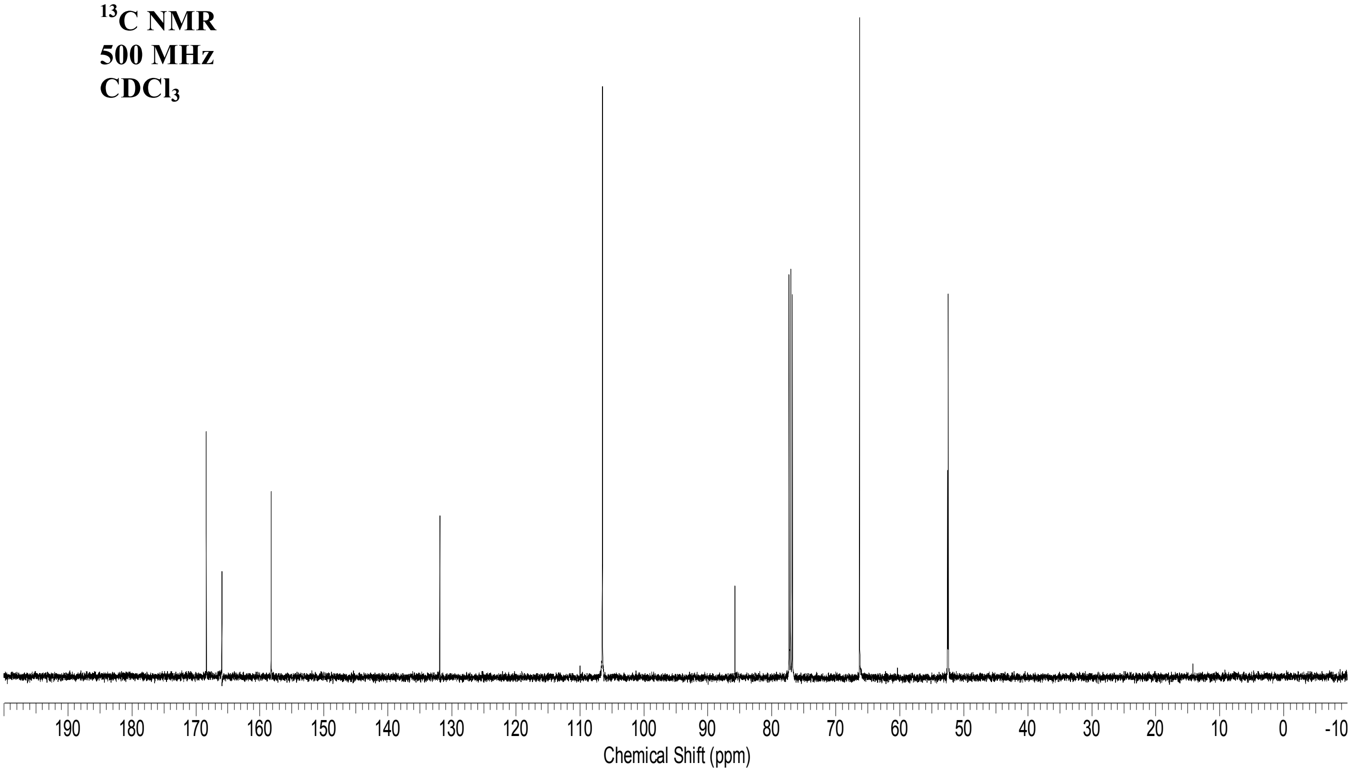
^{1}H, ^{13}C, and ^{19}F NMR Spectra of Substrates, Catalysts, and 1,2-Difluorination Products

^{1}H NMR
500 MHz
$CDCl_3$

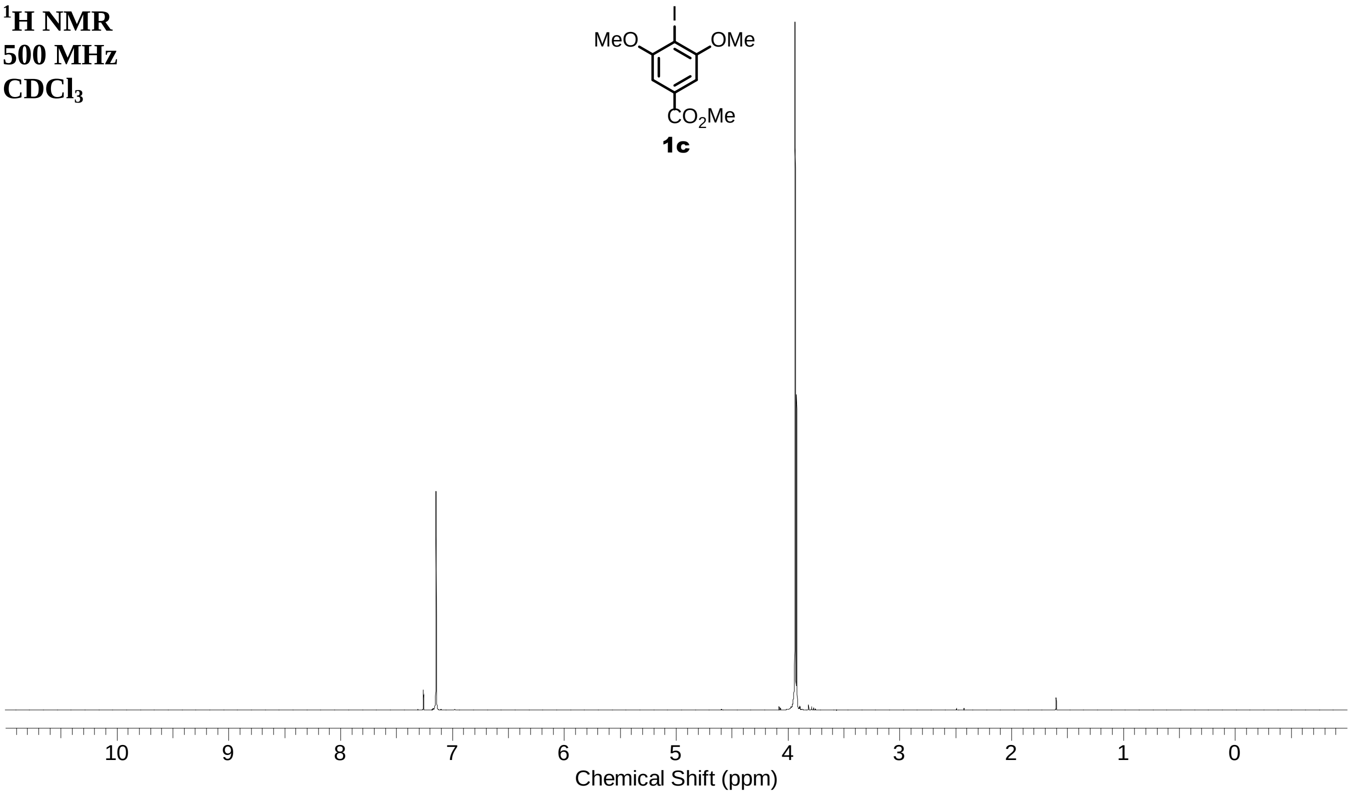


1b

^{13}C NMR
500 MHz
$CDCl_3$

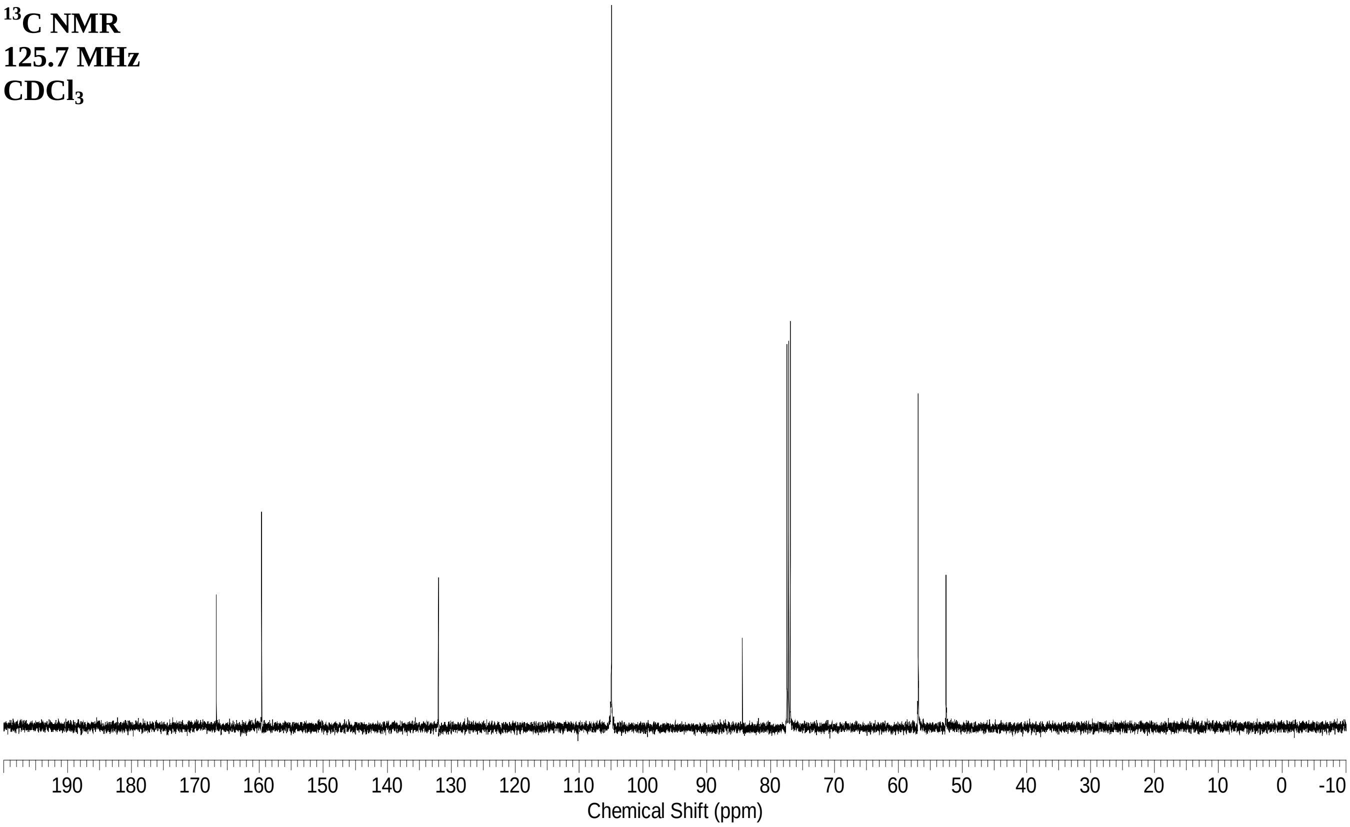


^{1}H NMR
500 MHz
$CDCl_3$



1c

^{13}C NMR
125.7 MHz
$CDCl_3$



^{1}H NMR
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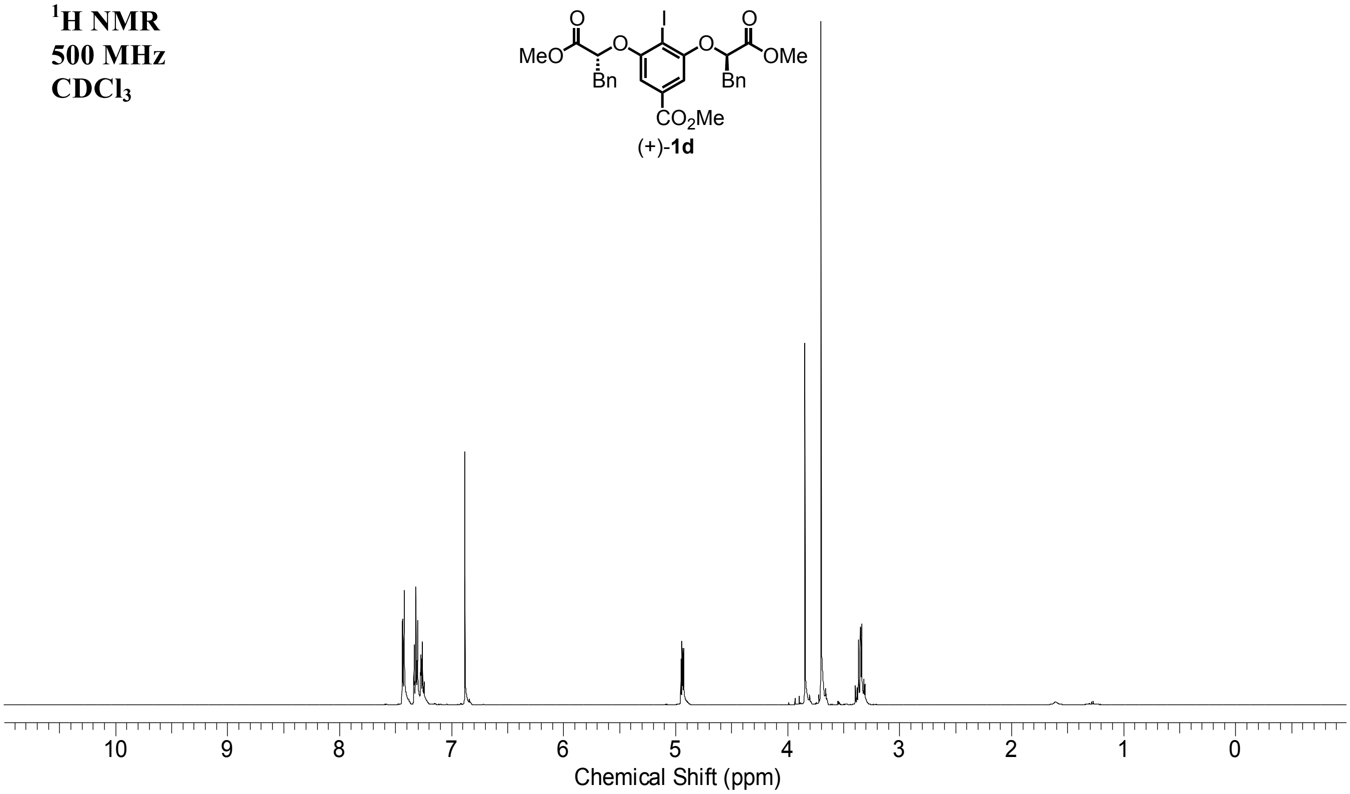
$CDCl_3$



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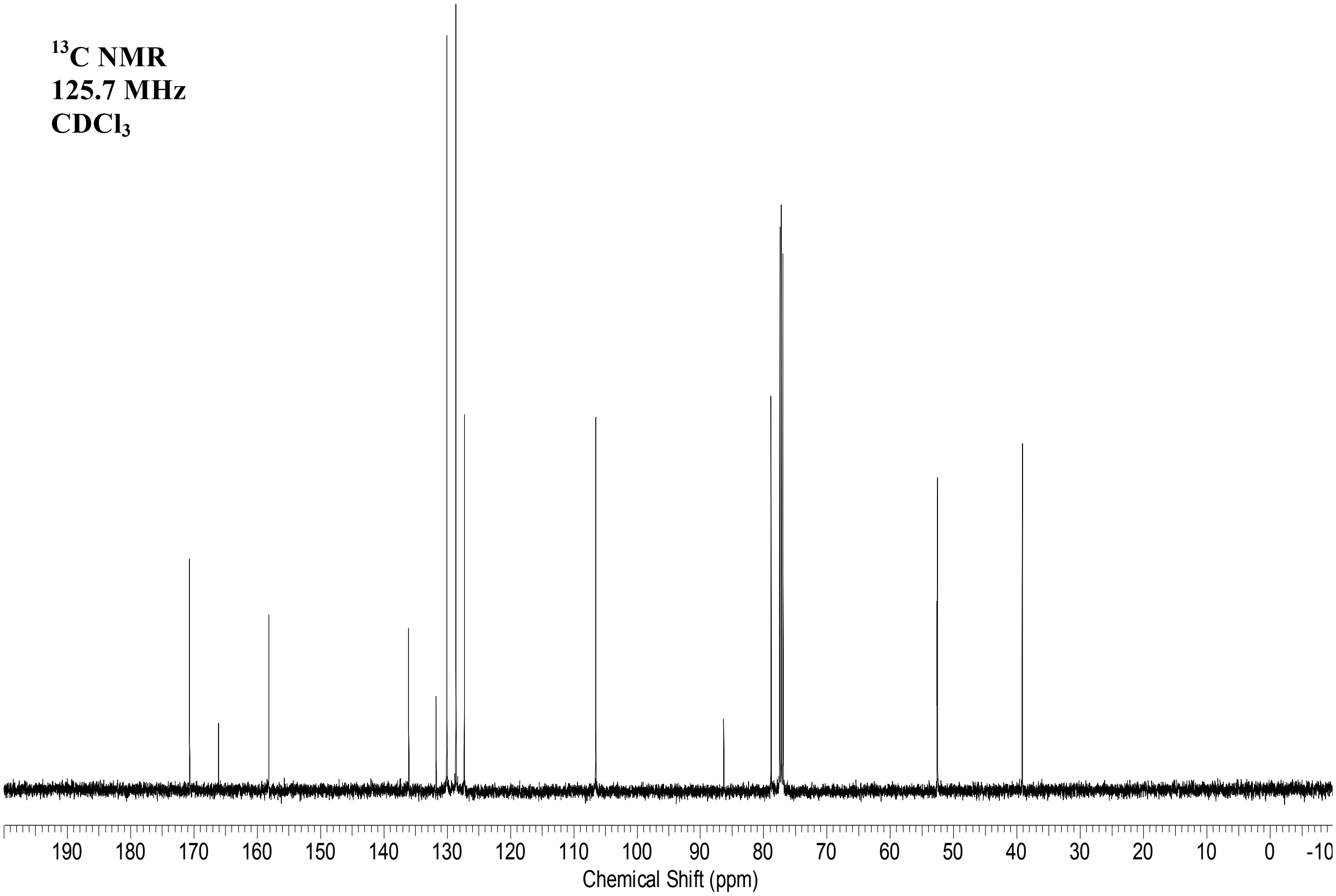
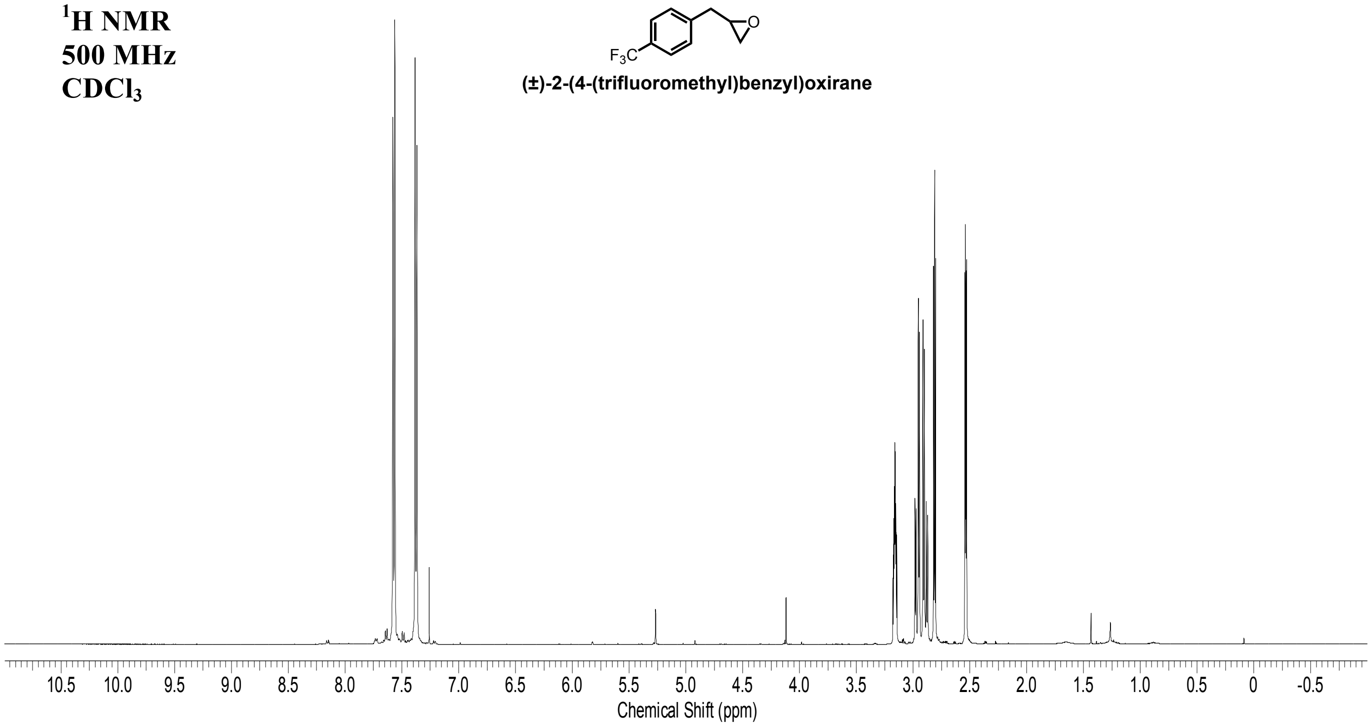
$CDCl_3$



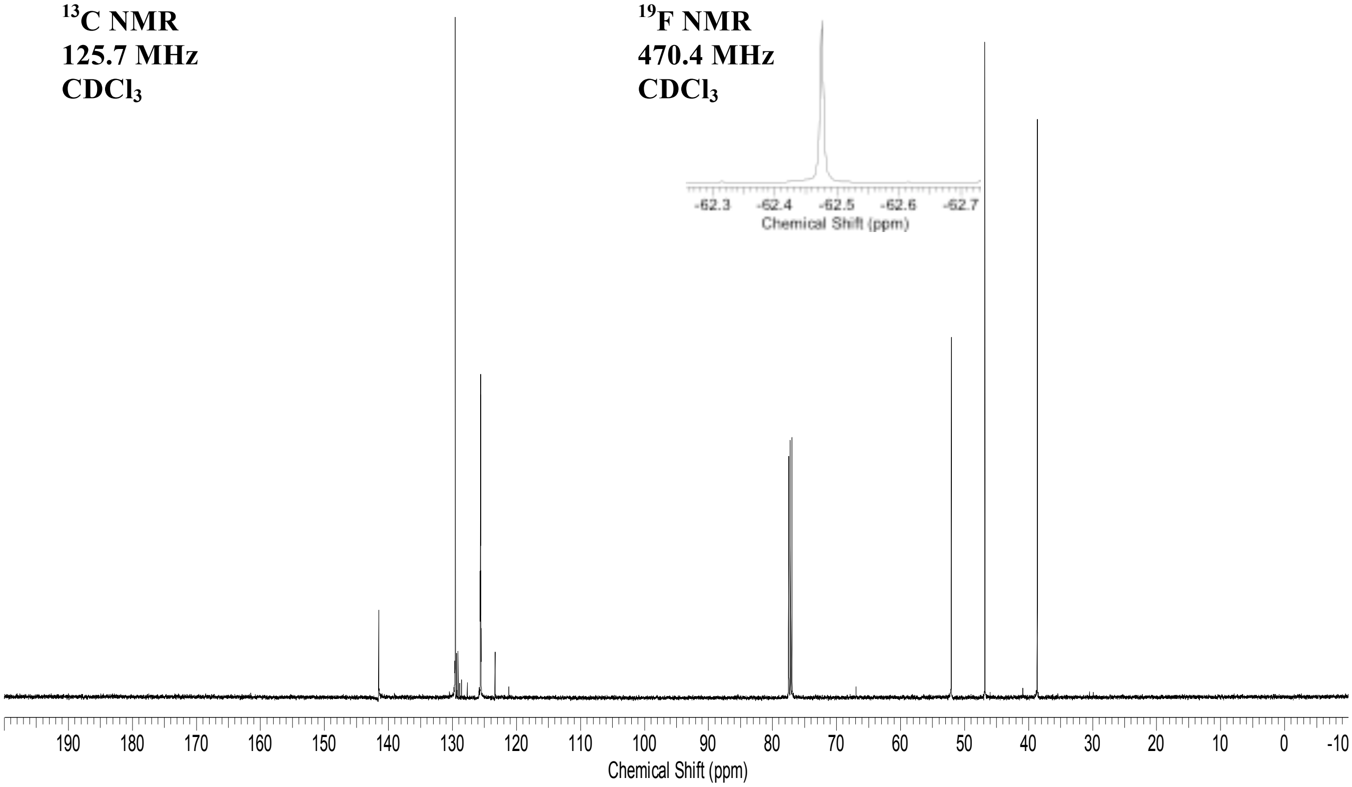
^{1}H NMR
500 MHz
$CDCl_3$



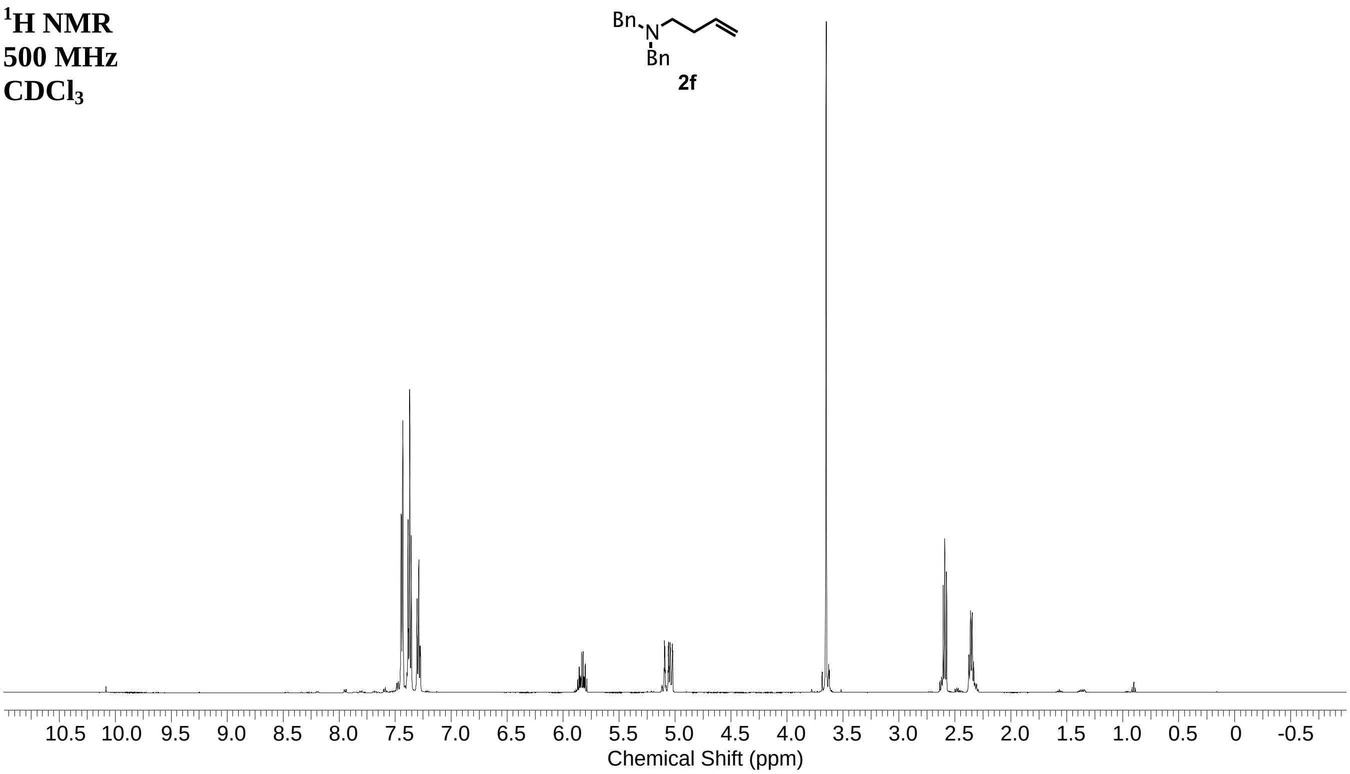
(±)-2-(4-(trifluoromethyl)benzyl)oxirane

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$

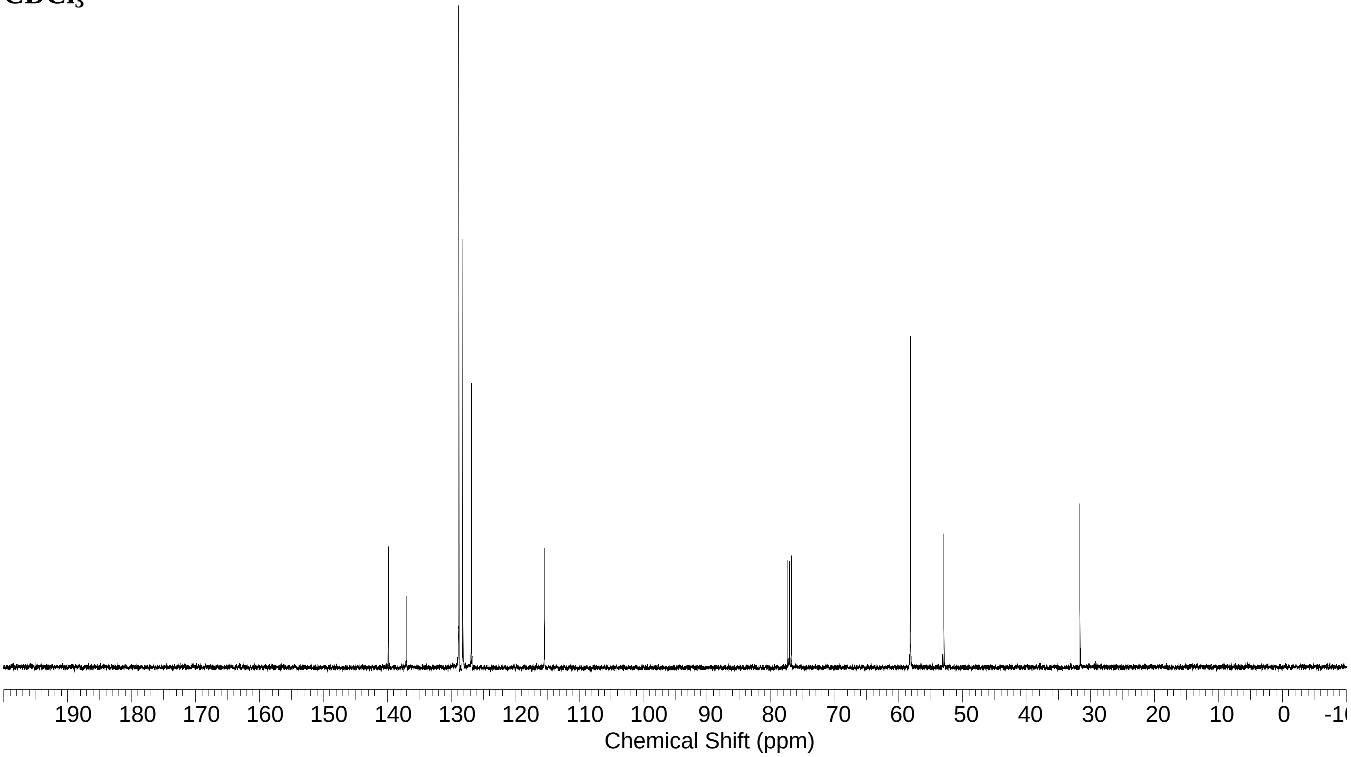


^{1}H NMR
500 MHz
CDCl$_3$

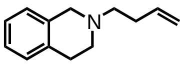


2f

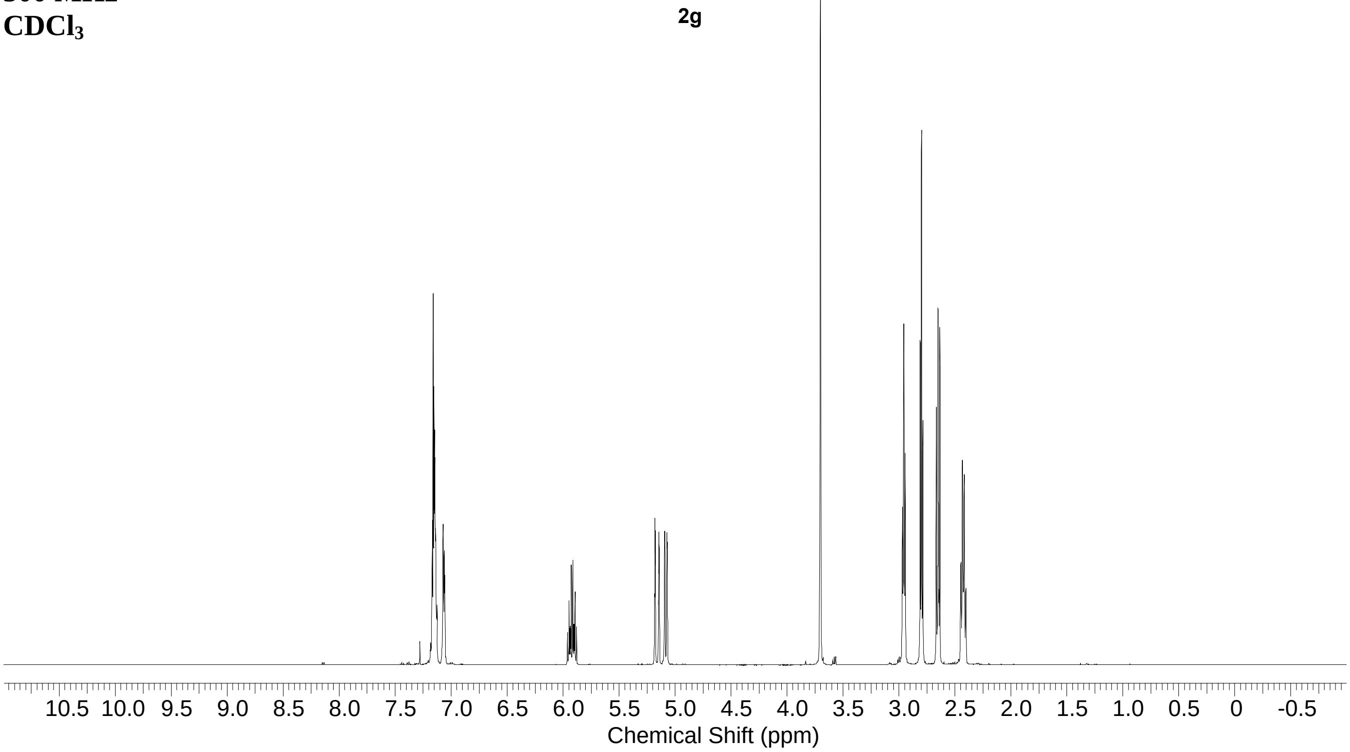
^{13}C NMR
125.7 MHz
CDCl$_3$



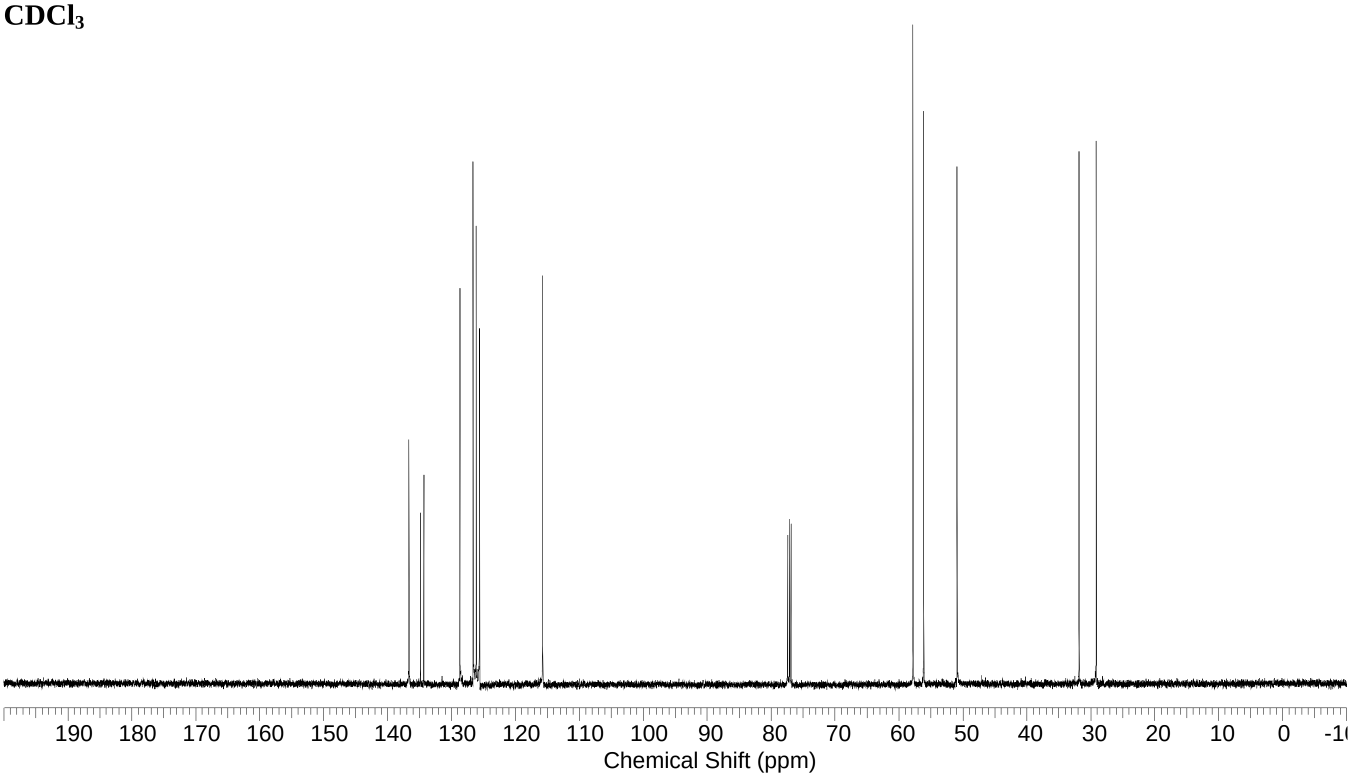
^{1}H NMR
500 MHz
CDCl$_3$



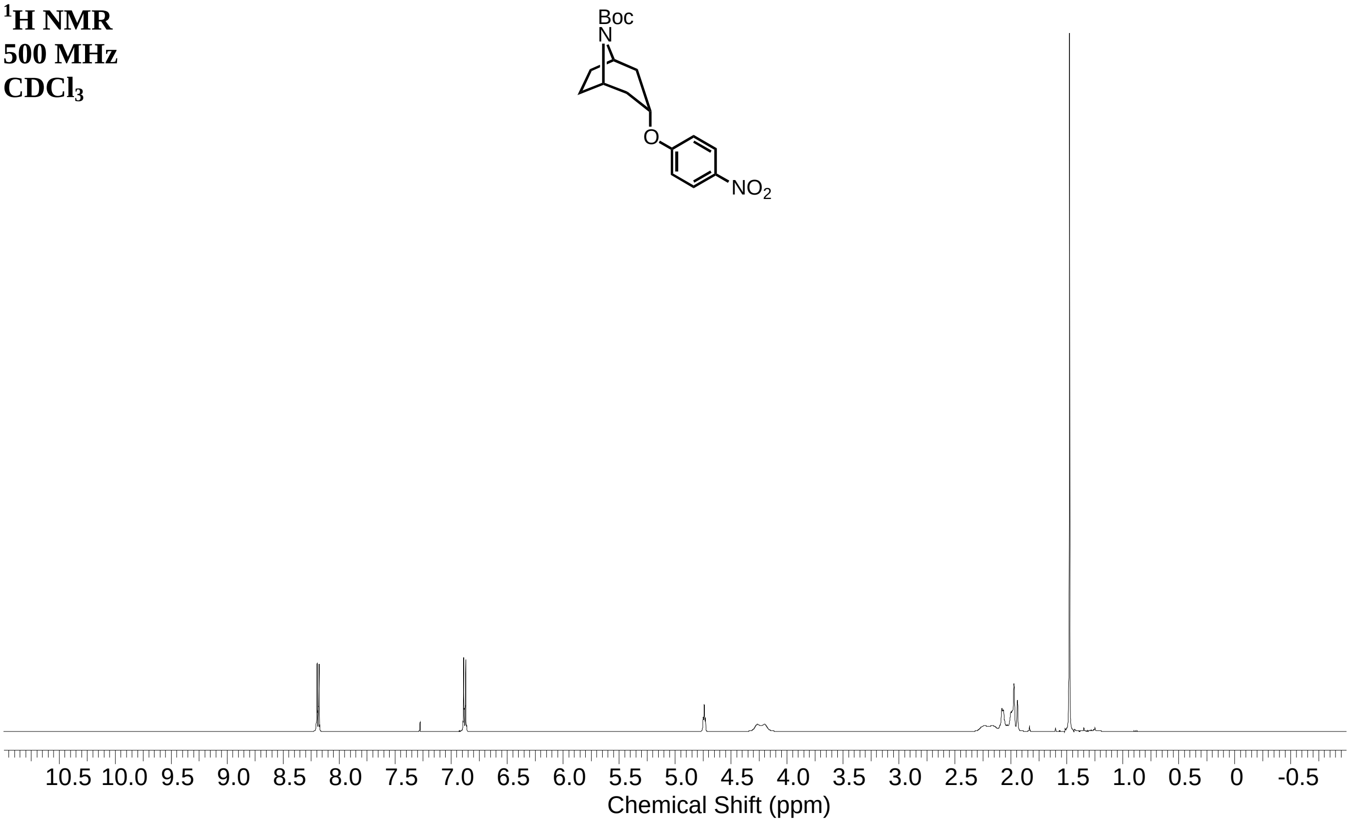
2g



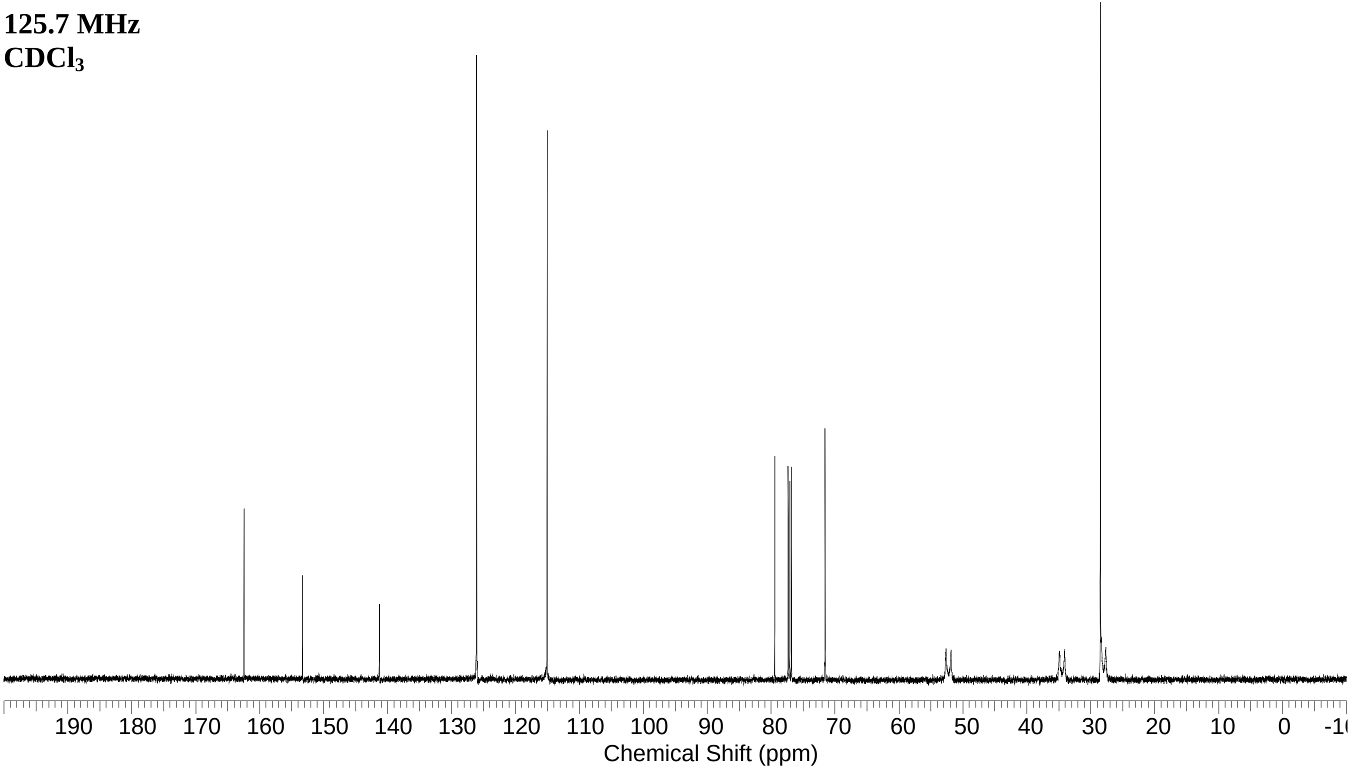
^{13}C NMR
125.7 MHz
CDCl$_3$



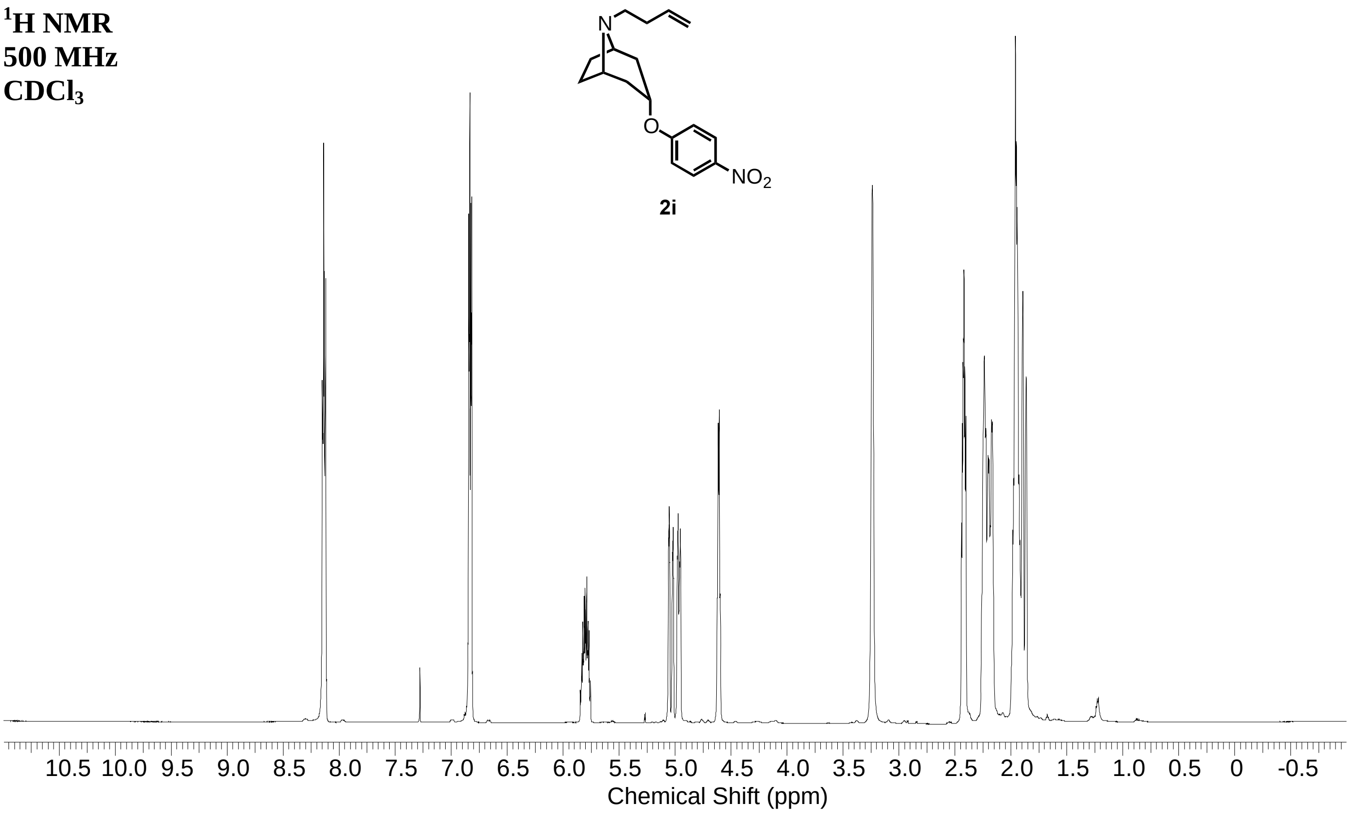
^{1}H NMR
500 MHz
CDCl$_3$



^{13}C NMR
125.7 MHz
CDCl$_3$

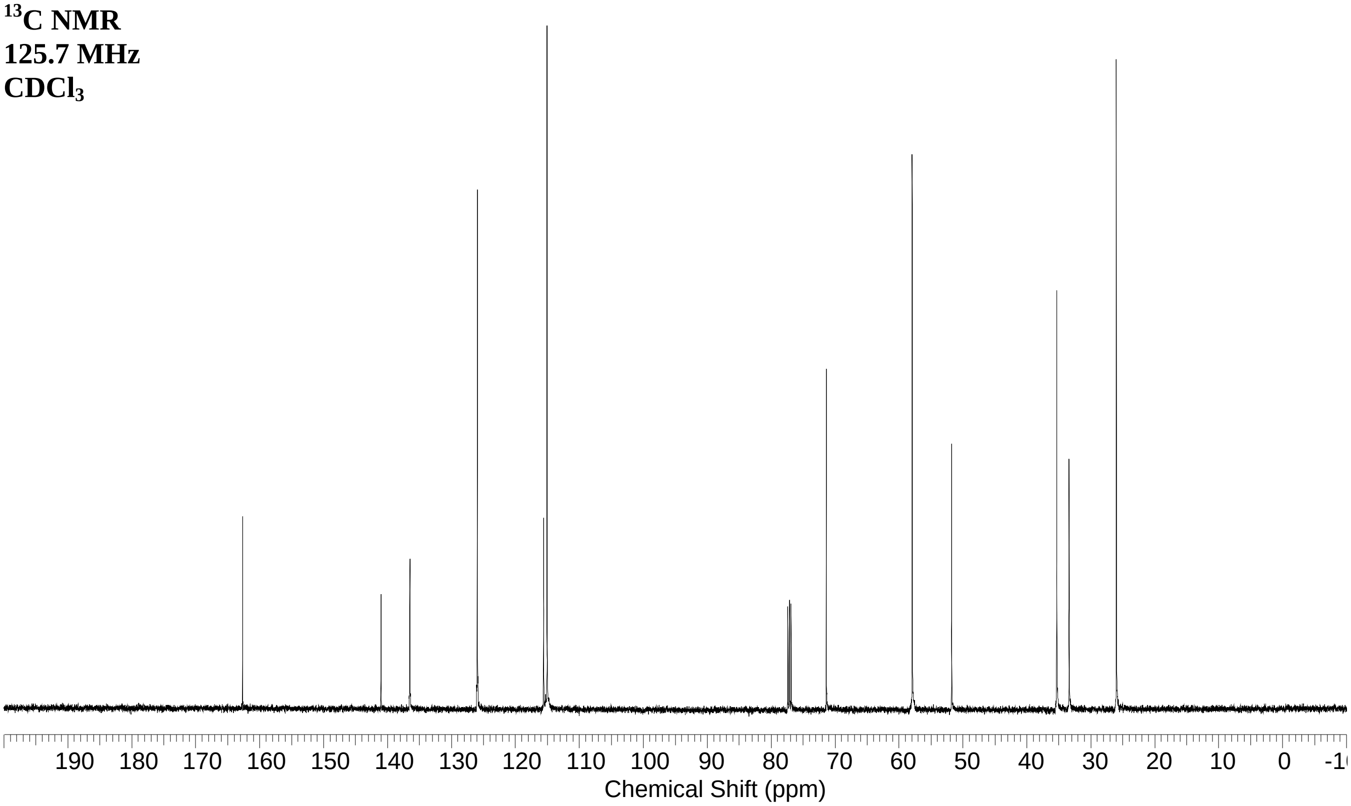


^{1}H NMR
500 MHz
$CDCl_3$

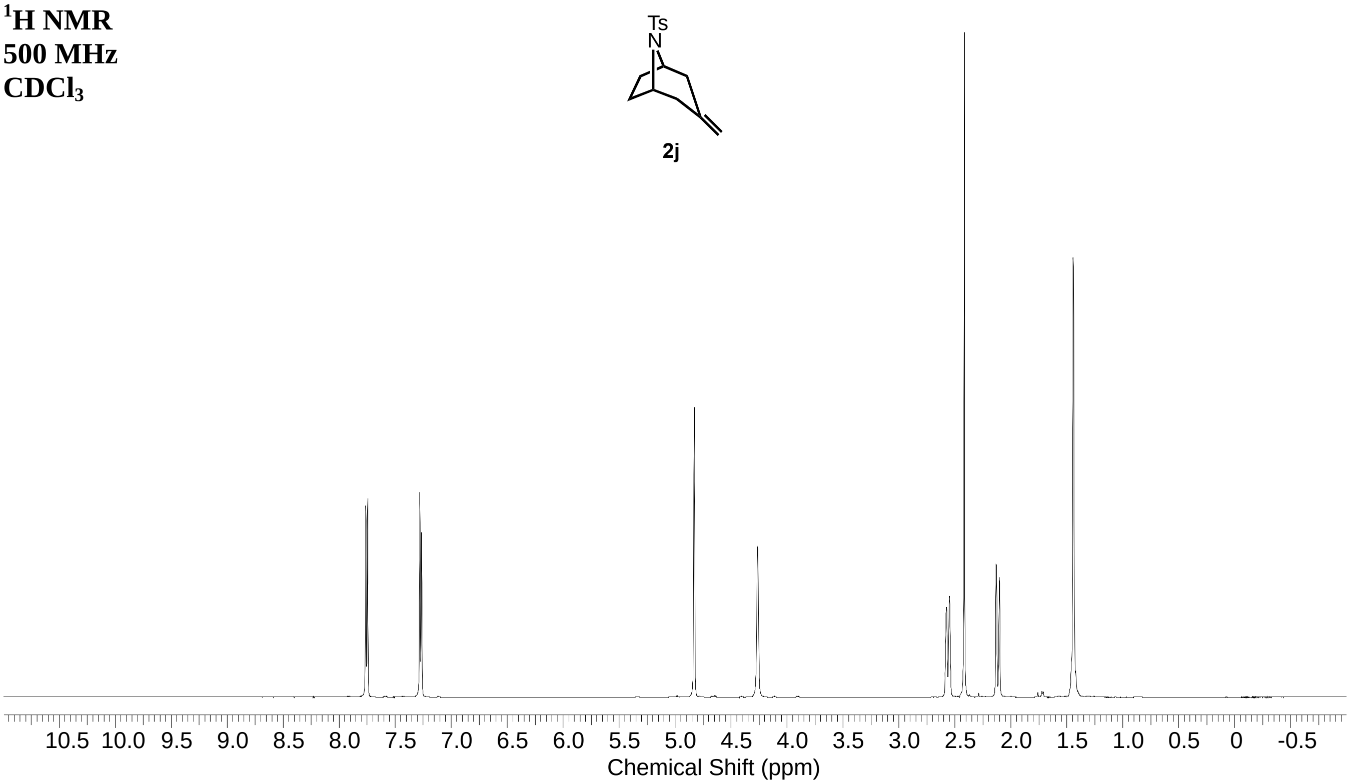


2i

^{13}C NMR
125.7 MHz
$CDCl_3$

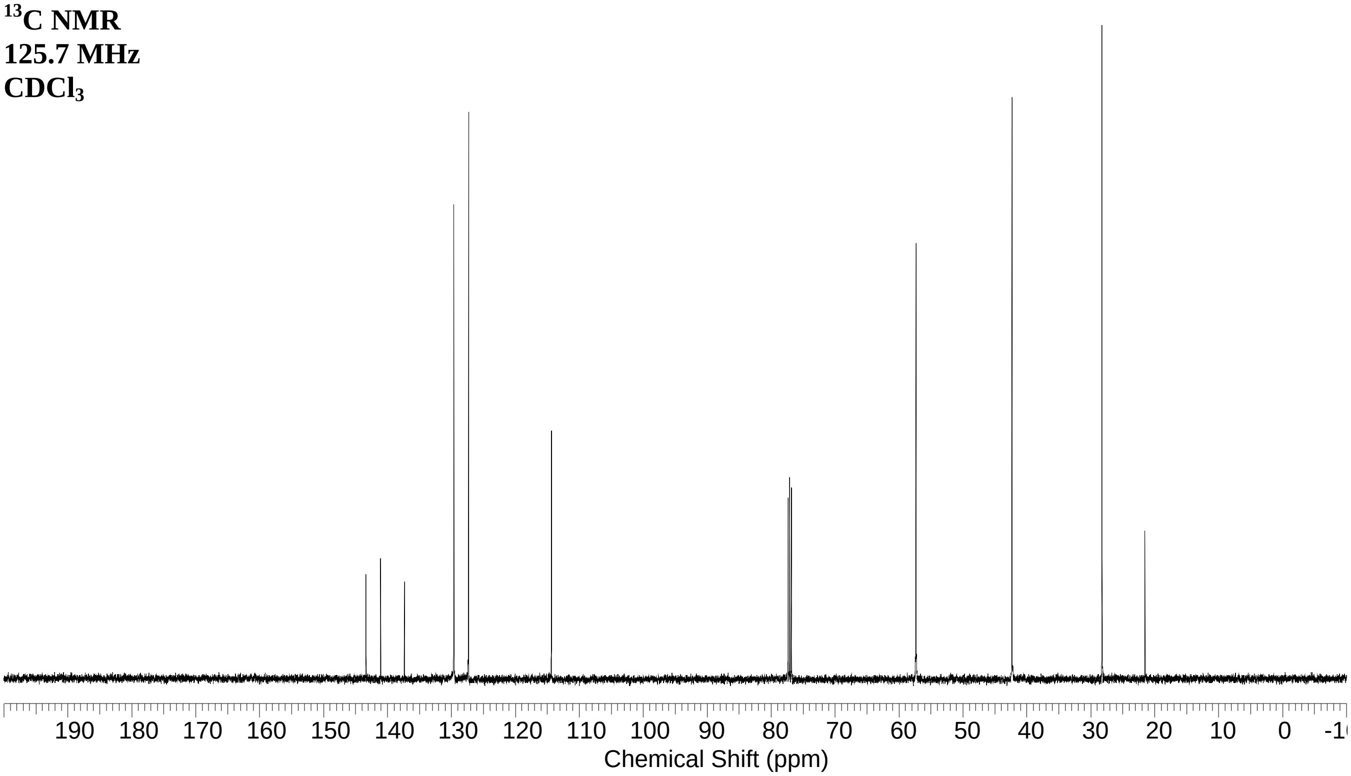


^{1}H NMR
500 MHz
$CDCl_3$

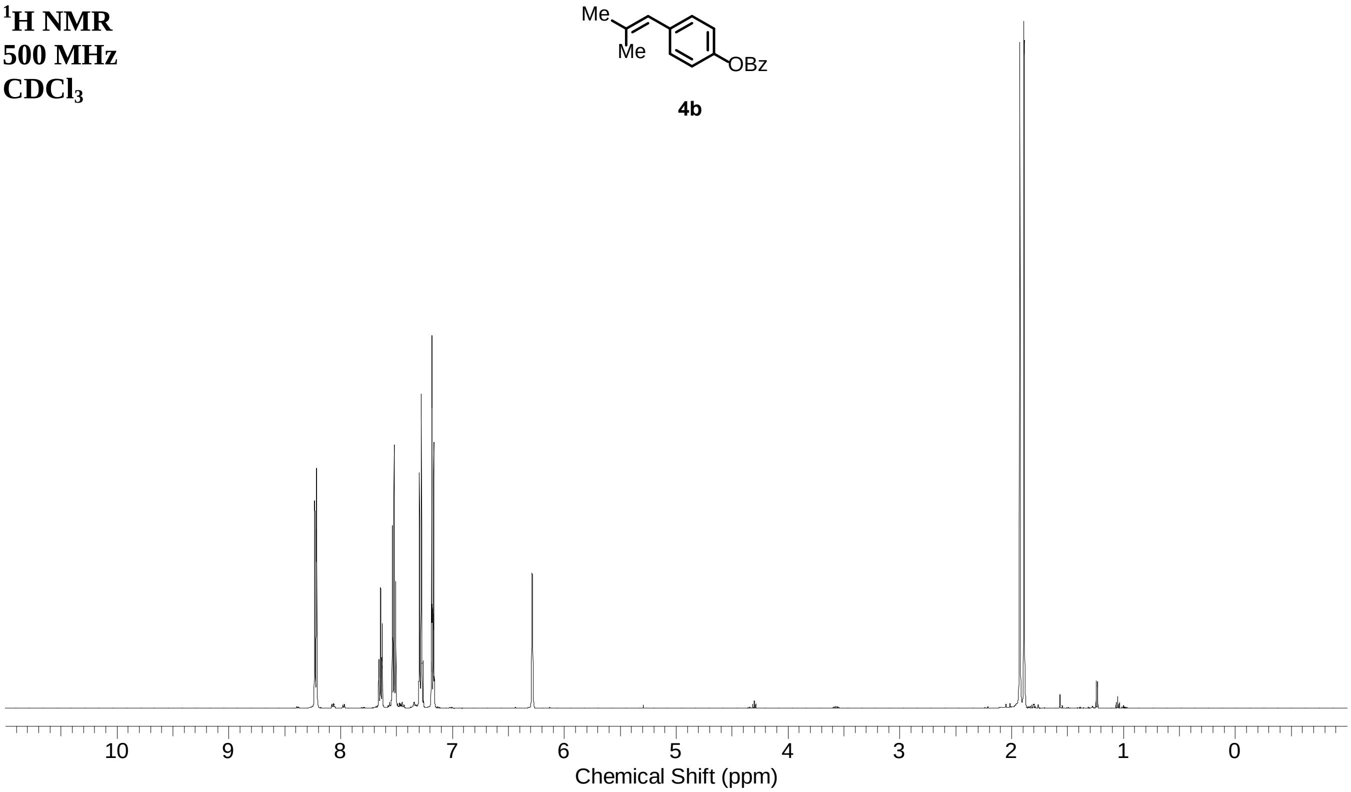


2j

^{13}C NMR
125.7 MHz
$CDCl_3$

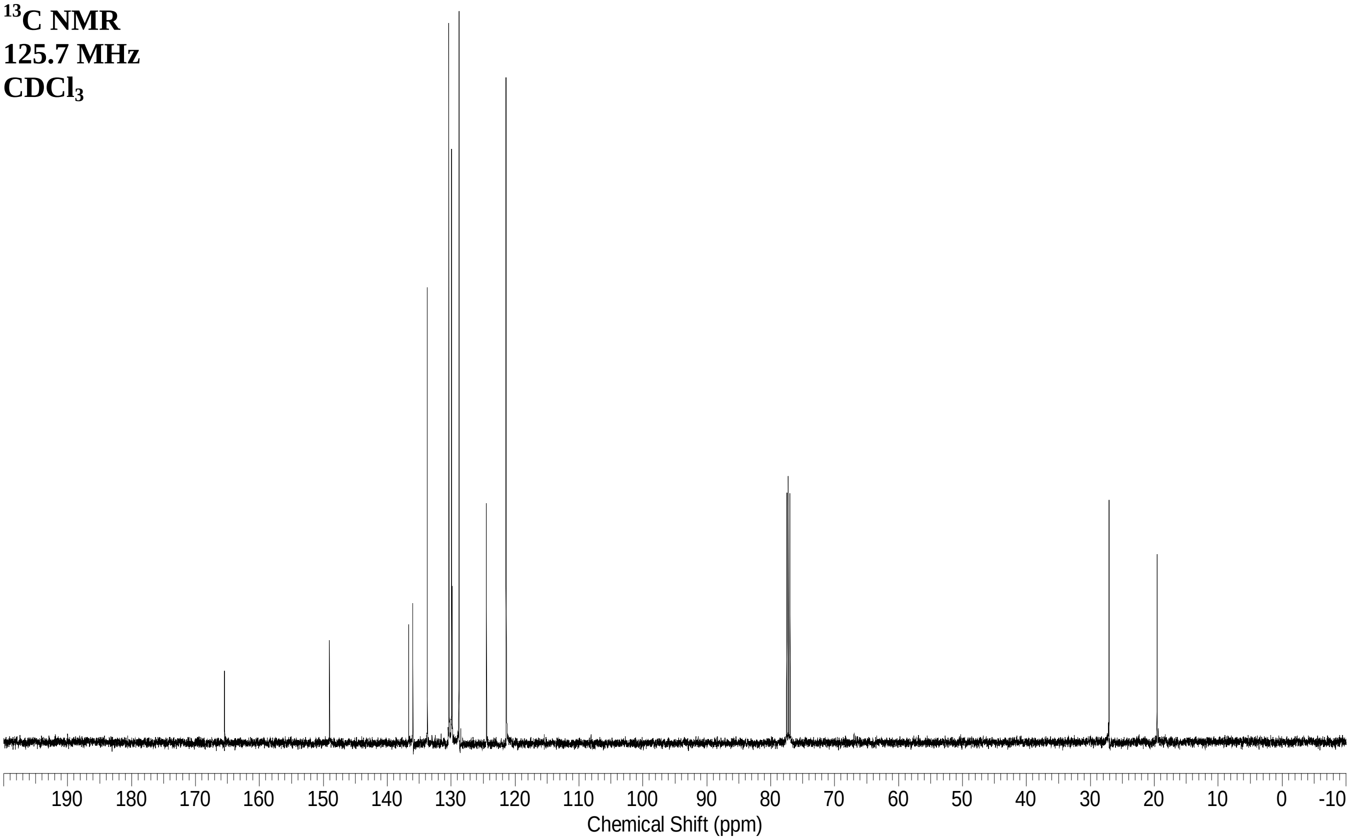


^{1}H NMR
500 MHz
CDCl$_3$

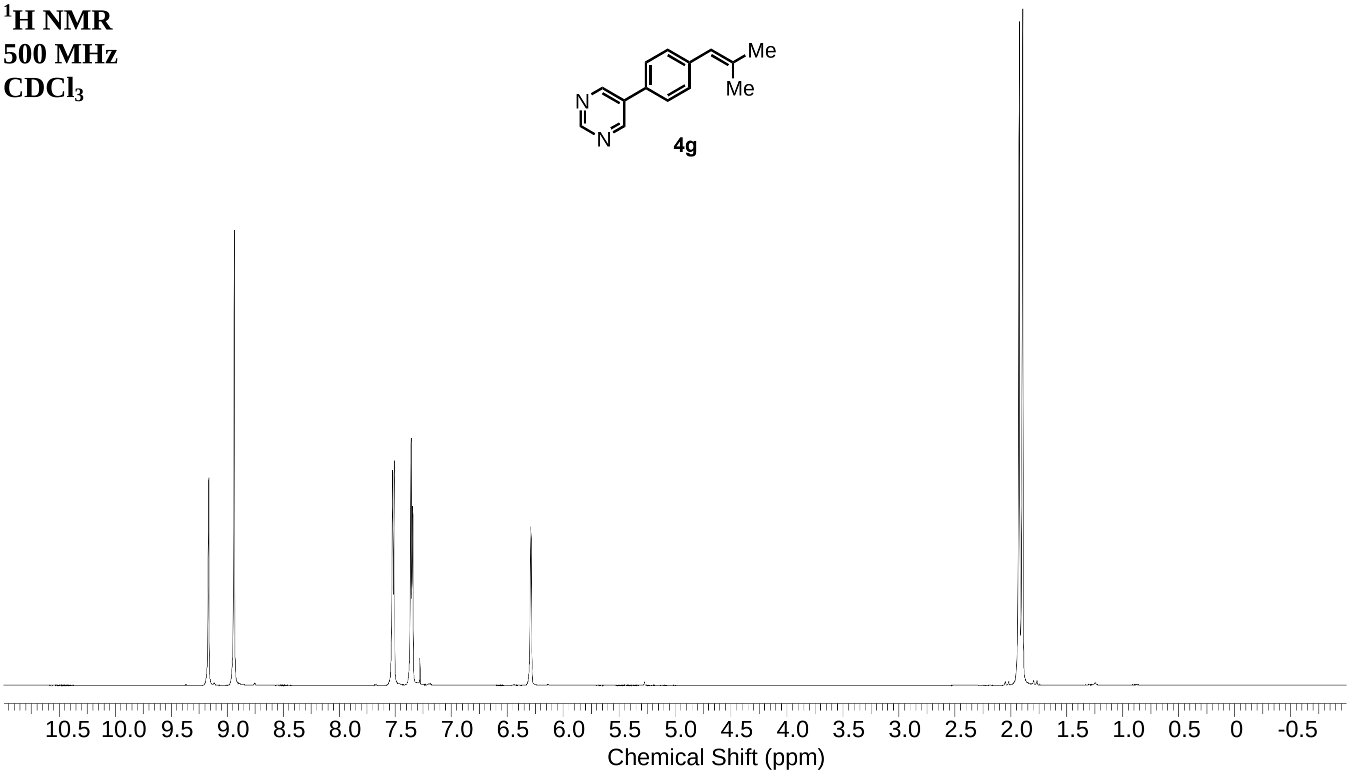


4b

^{13}C NMR
125.7 MHz
CDCl$_3$

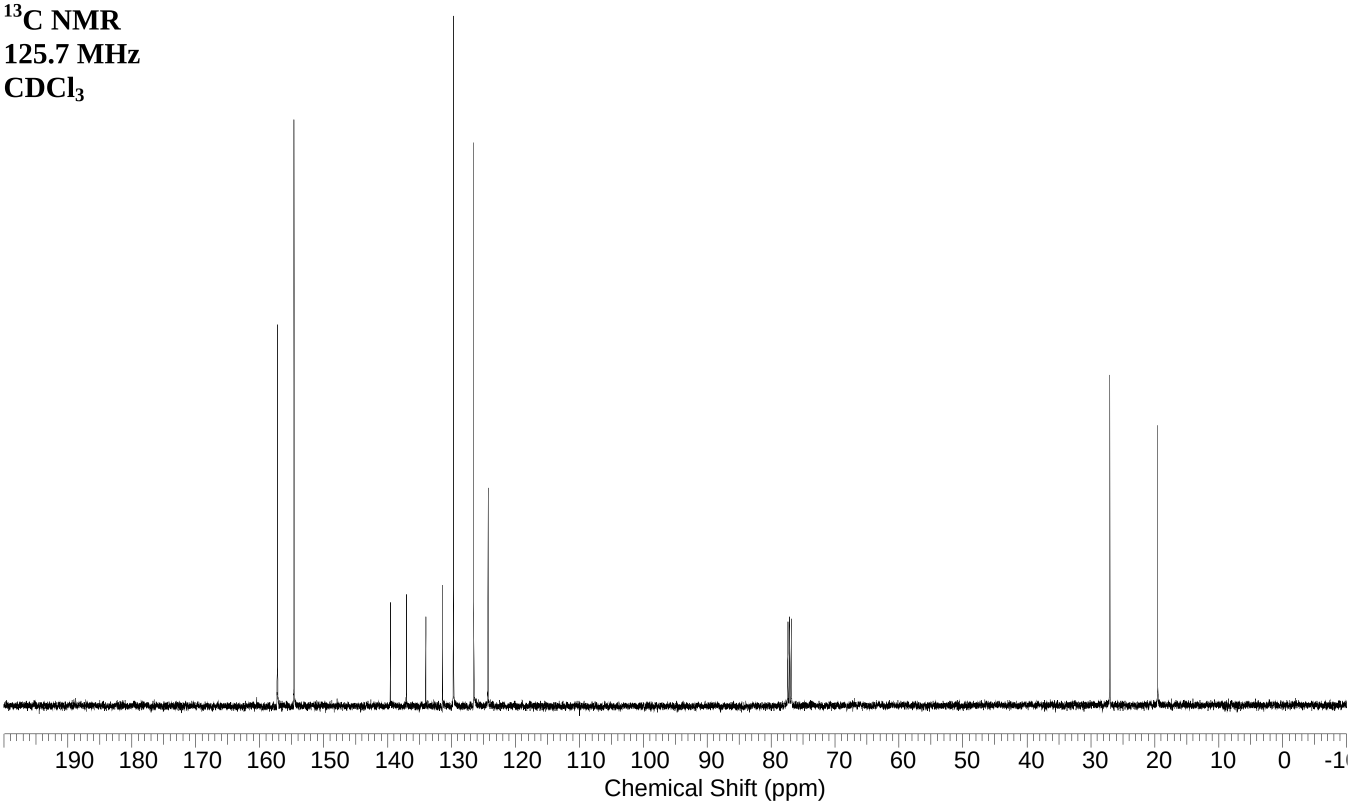


^{1}H NMR
500 MHz
CDCl$_3$

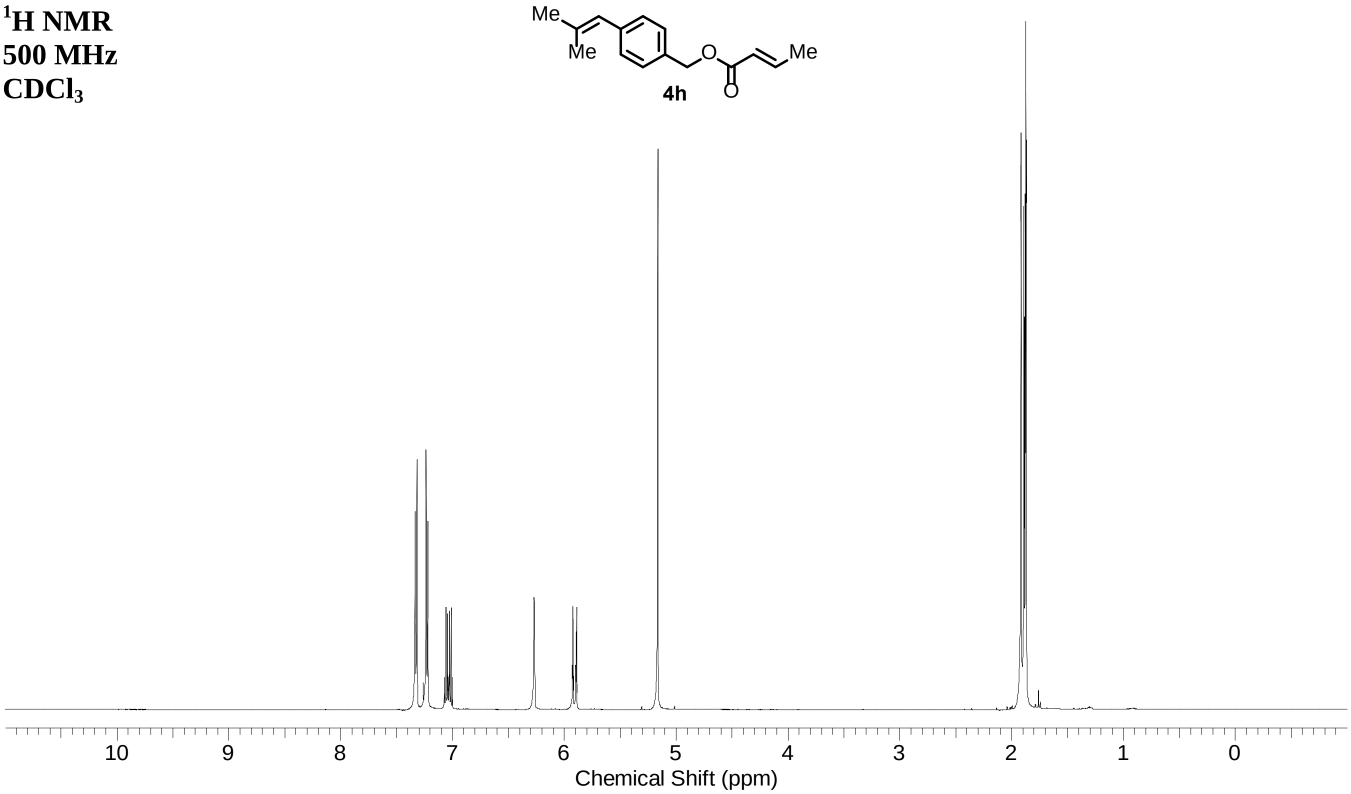


4g

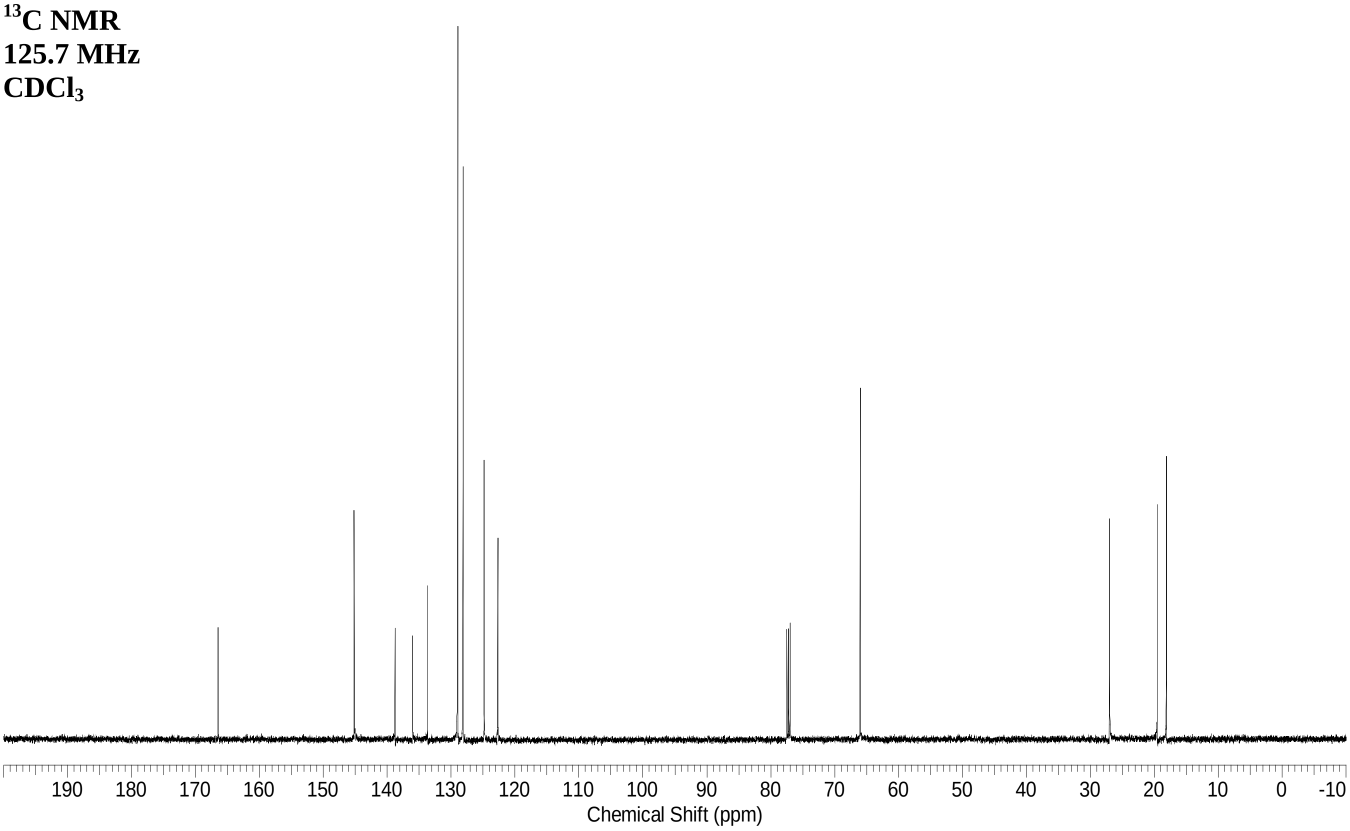
^{13}C NMR
125.7 MHz
CDCl$_3$



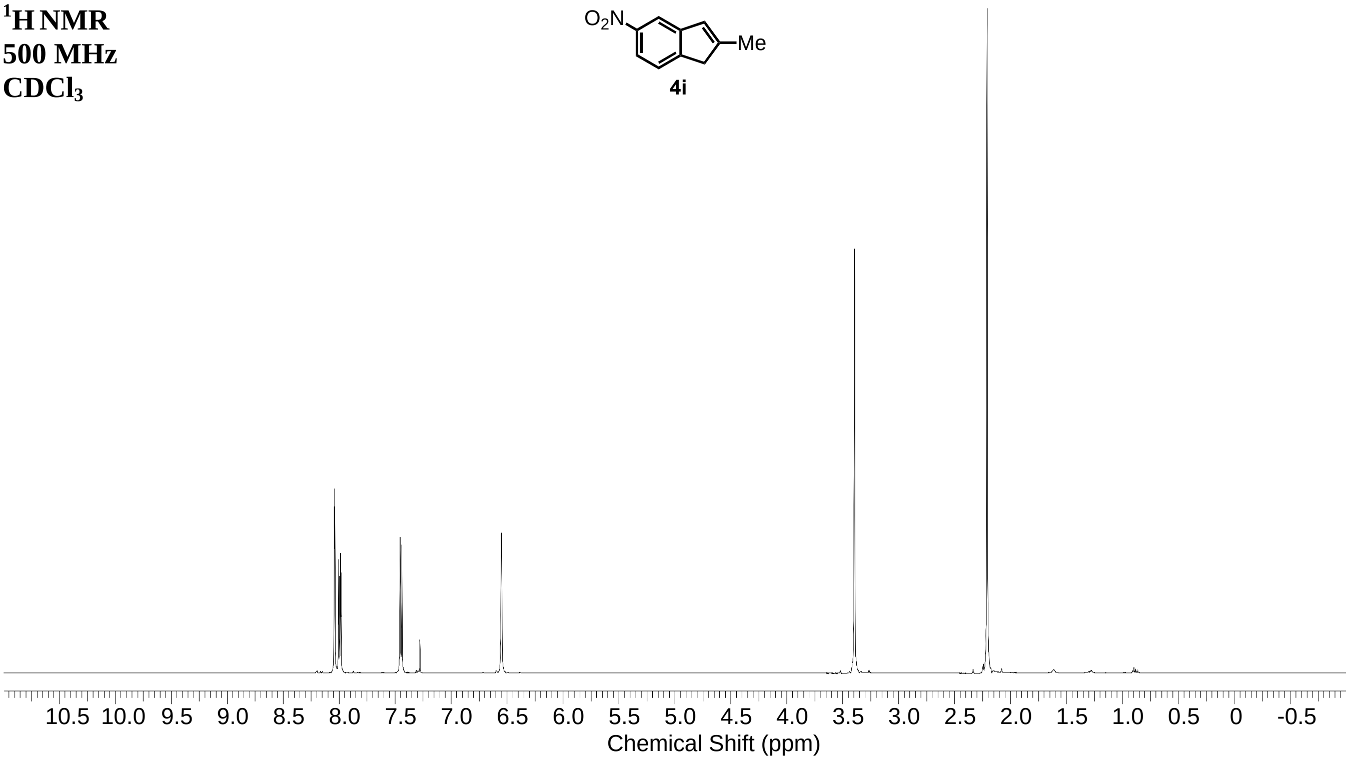
^{1}H NMR
500 MHz
$CDCl_3$



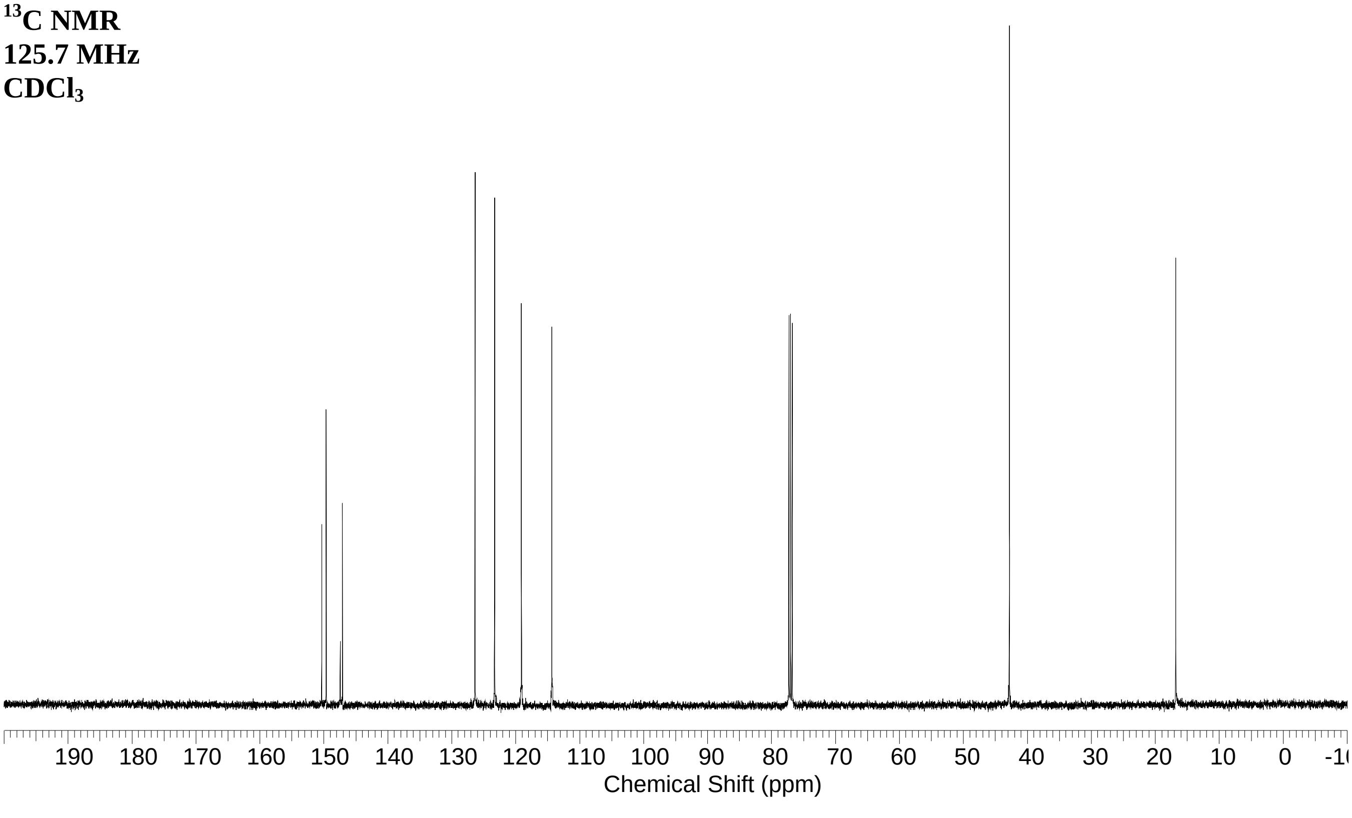
^{13}C NMR
125.7 MHz
$CDCl_3$



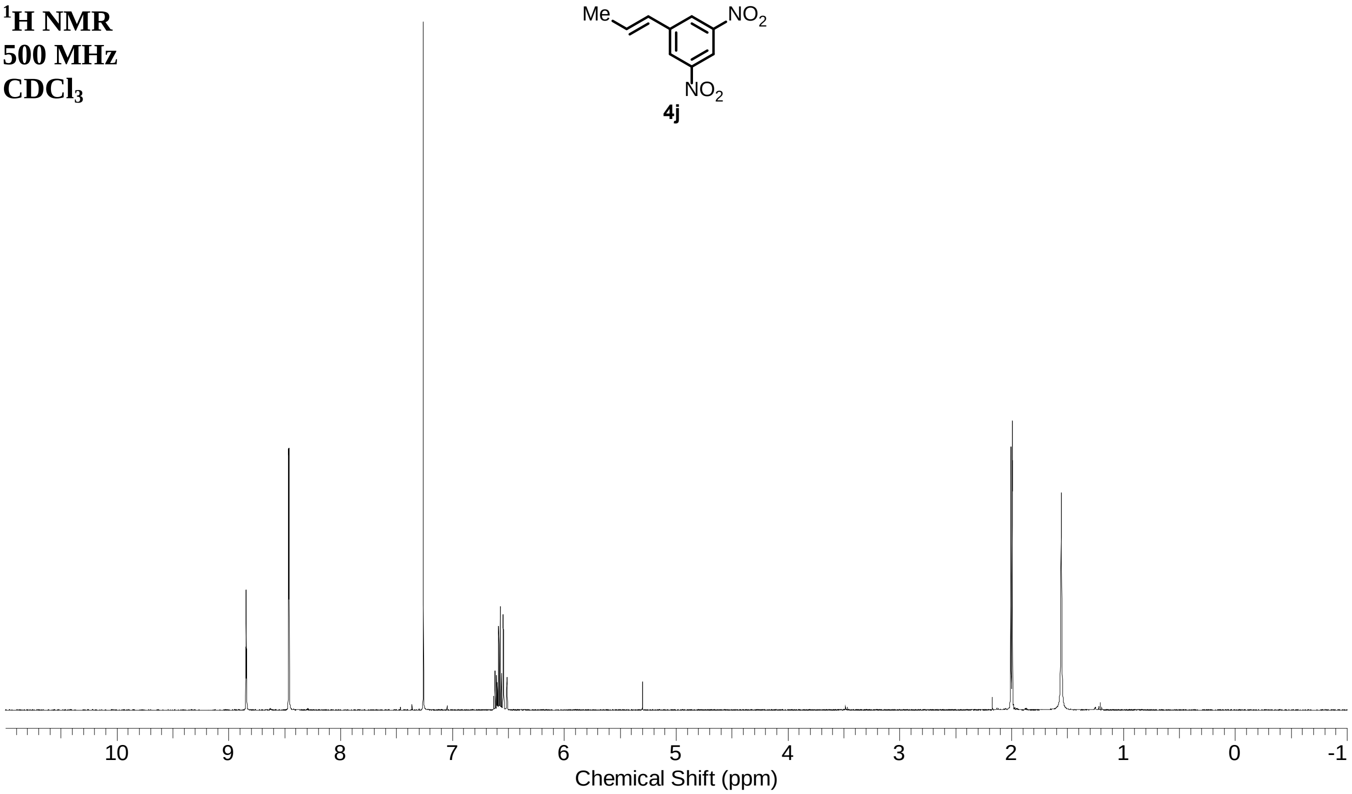
^{1}H NMR
500 MHz
$CDCl_3$



^{13}C NMR
125.7 MHz
$CDCl_3$

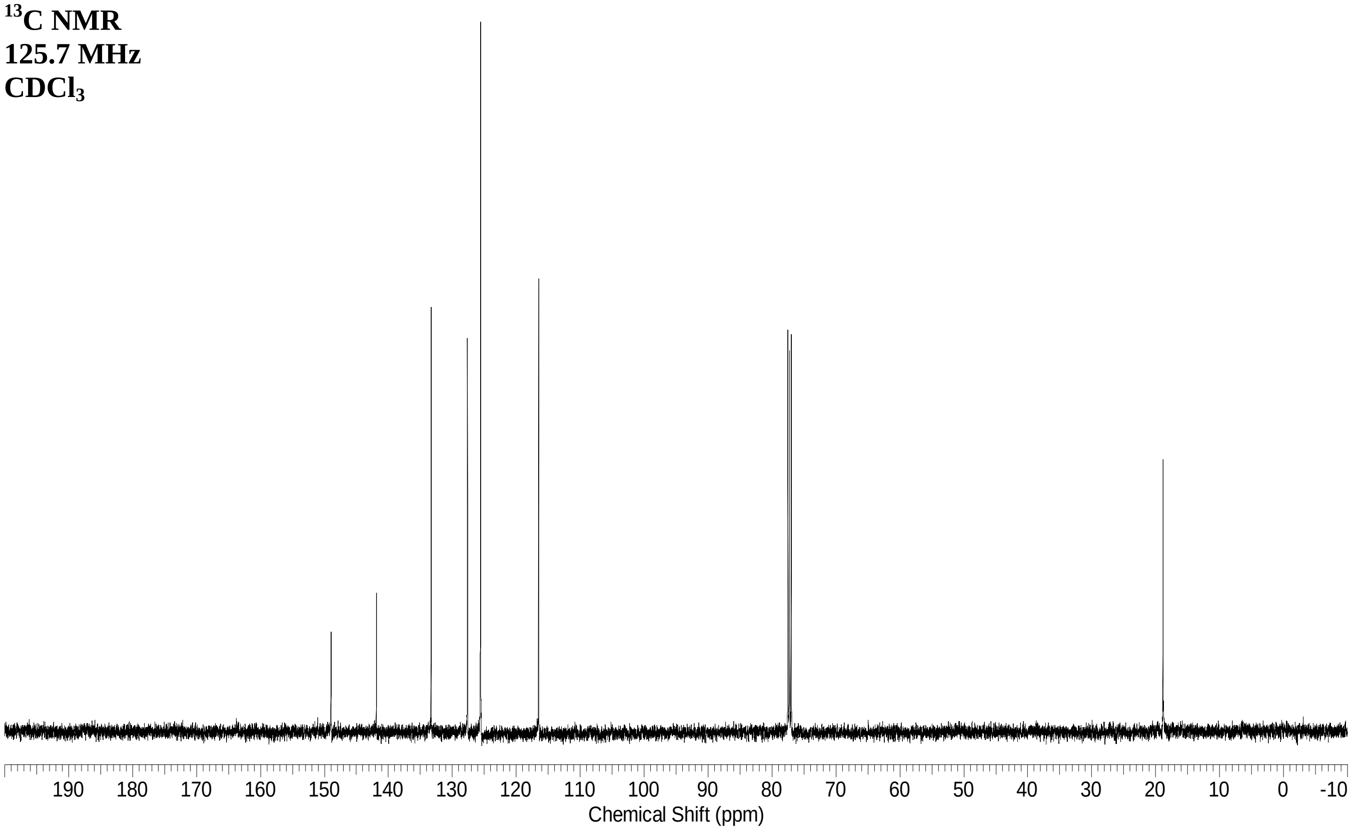


^{1}H NMR
500 MHz
$CDCl_3$

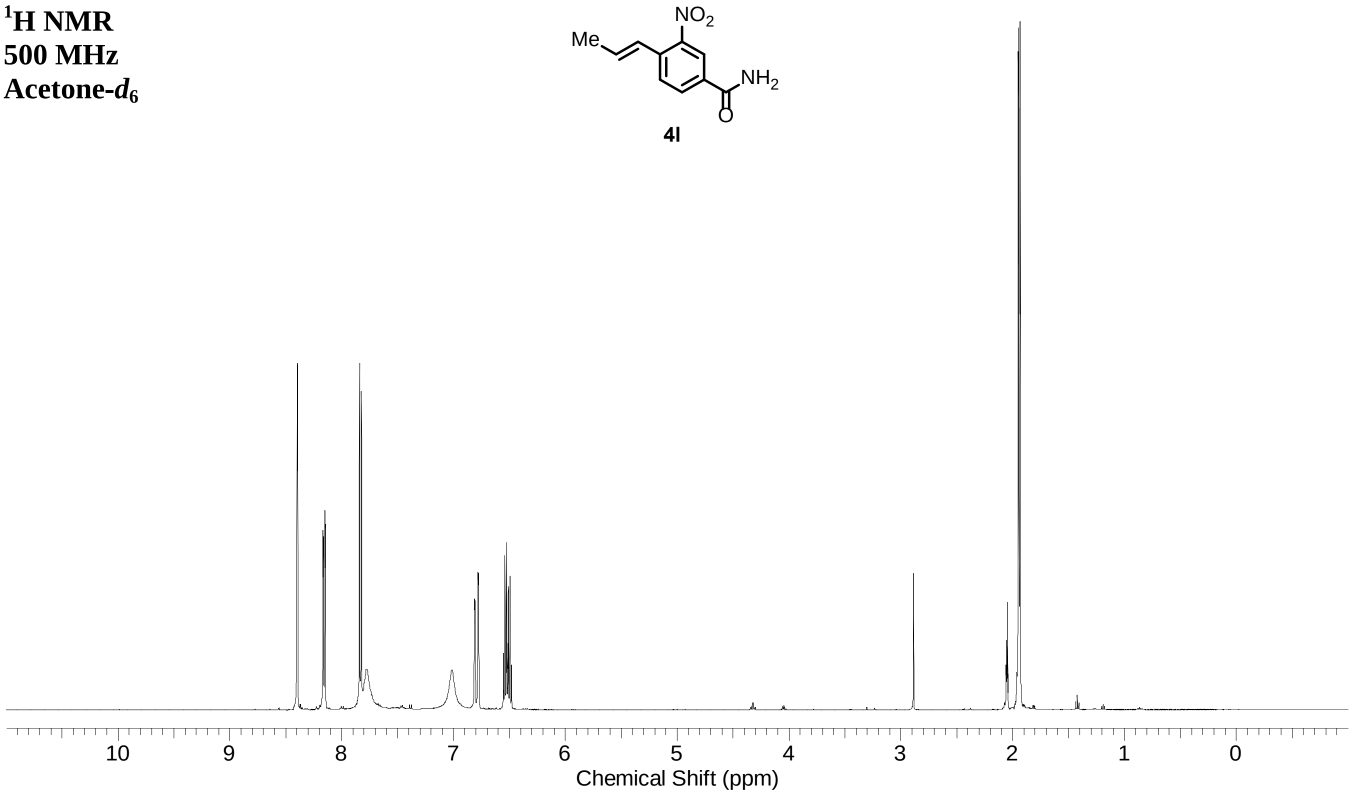


4j

^{13}C NMR
125.7 MHz
$CDCl_3$

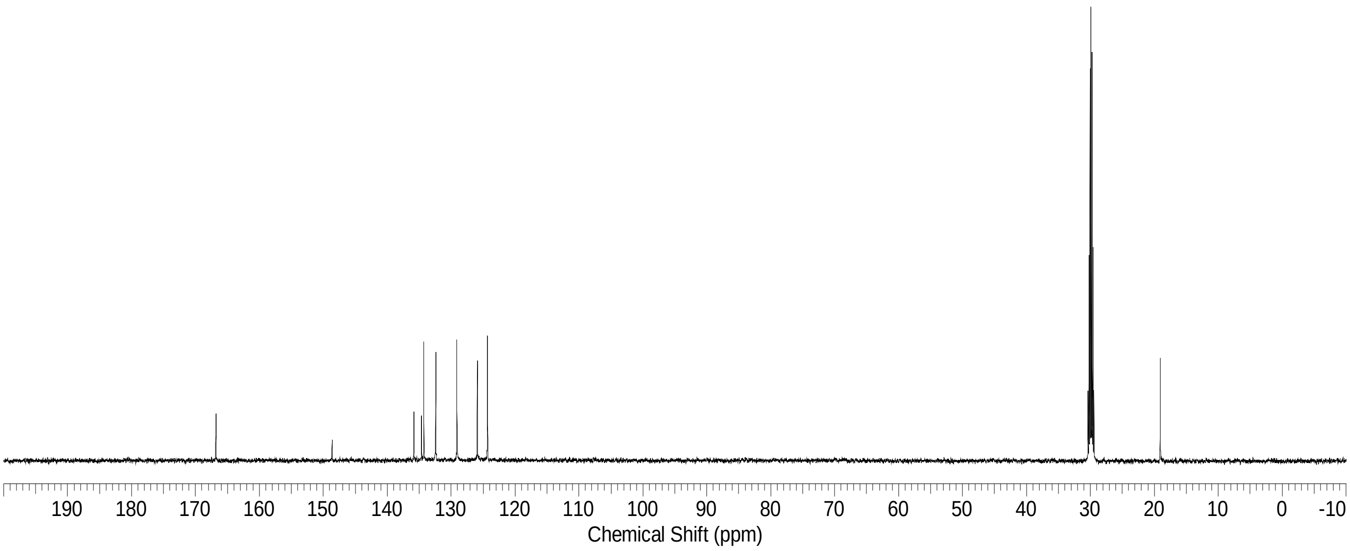


^{1}H NMR
500 MHz
Acetone-d_6

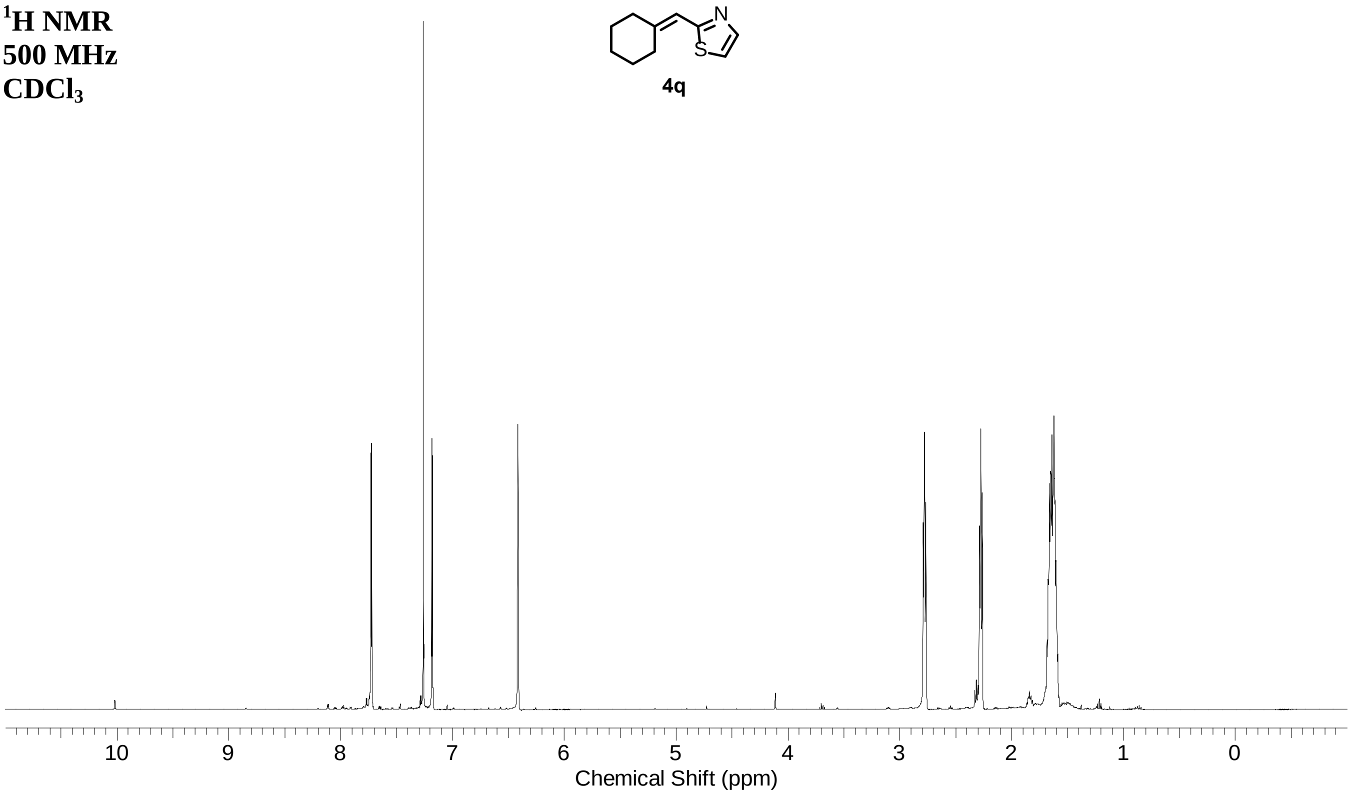


4l

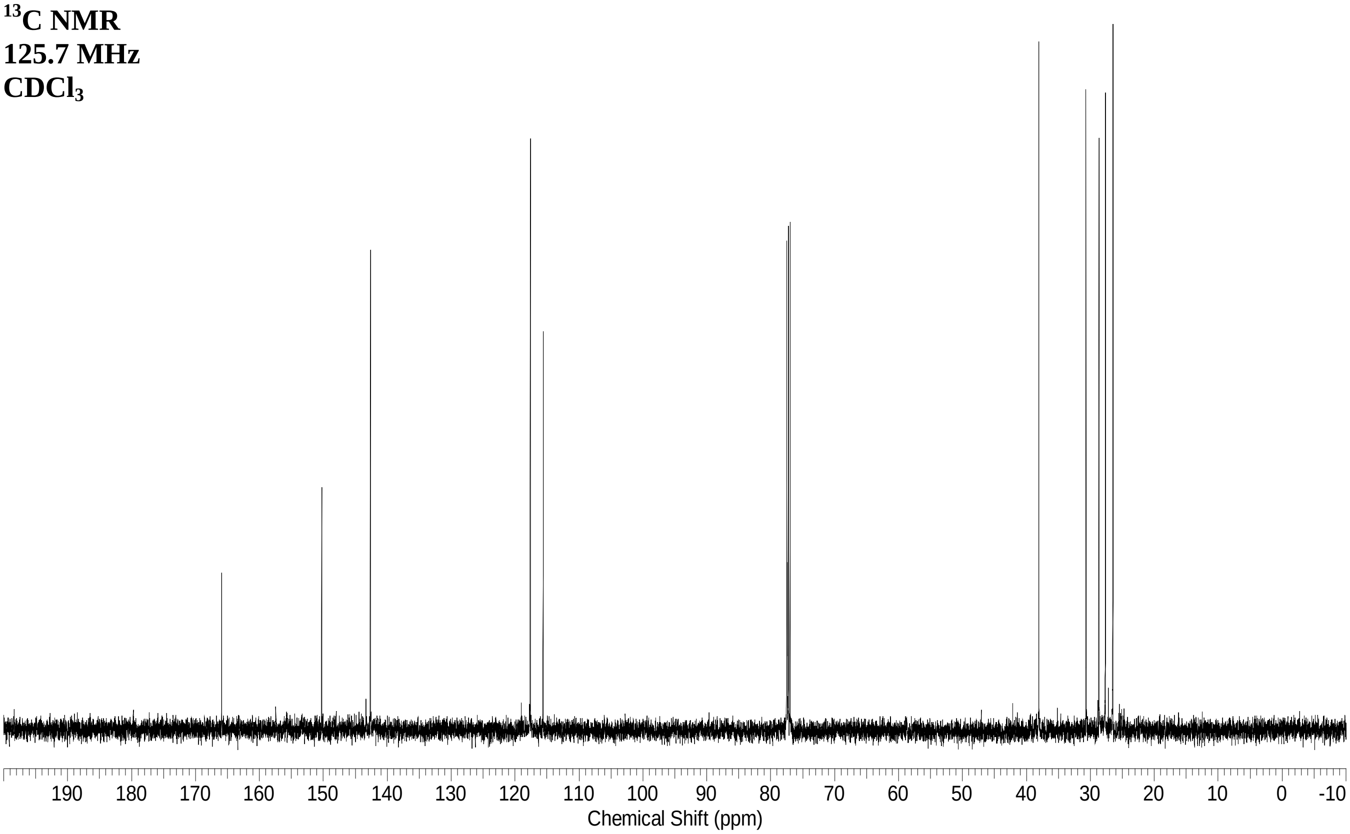
^{13}C NMR
125.7 MHz
Acetone-d_6



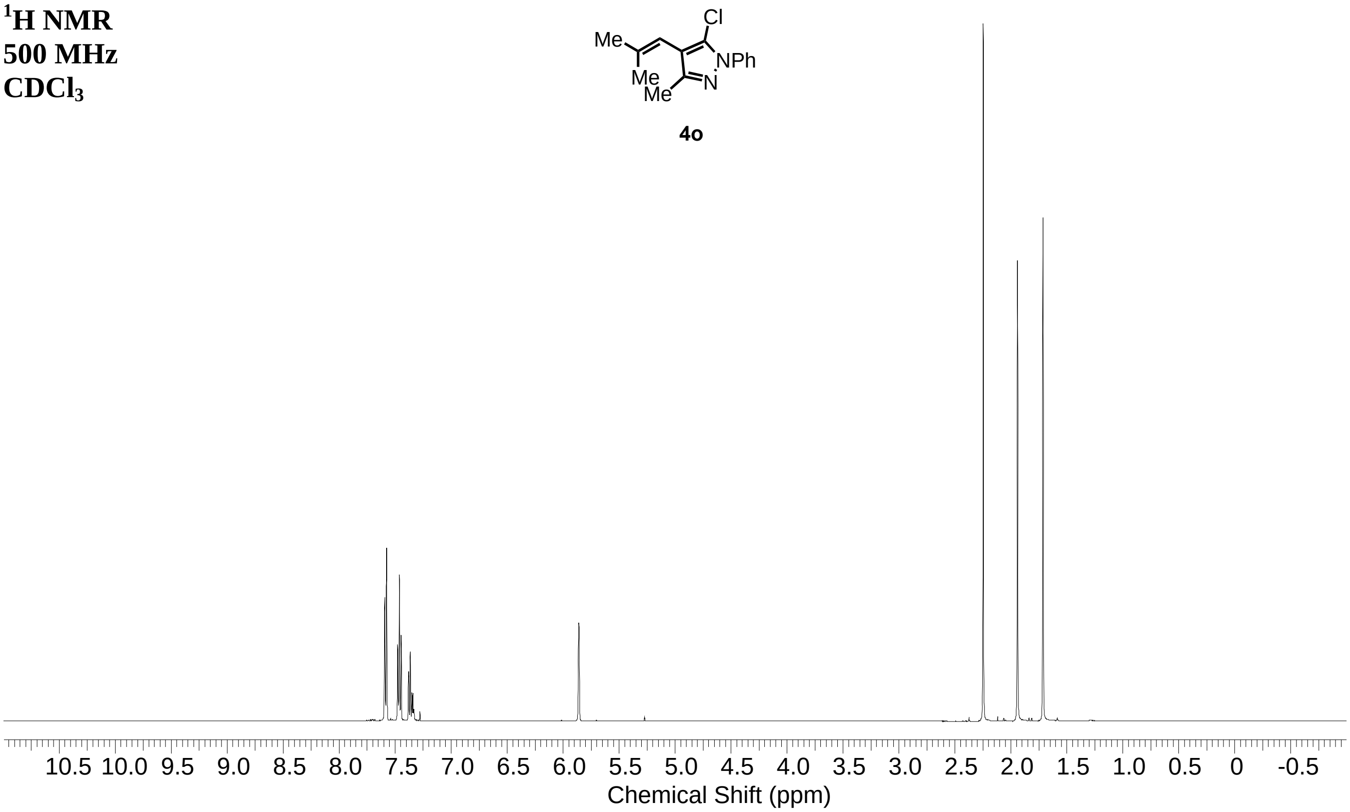
^{1}H NMR
500 MHz
$CDCl_3$


4q

^{13}C NMR
125.7 MHz
$CDCl_3$

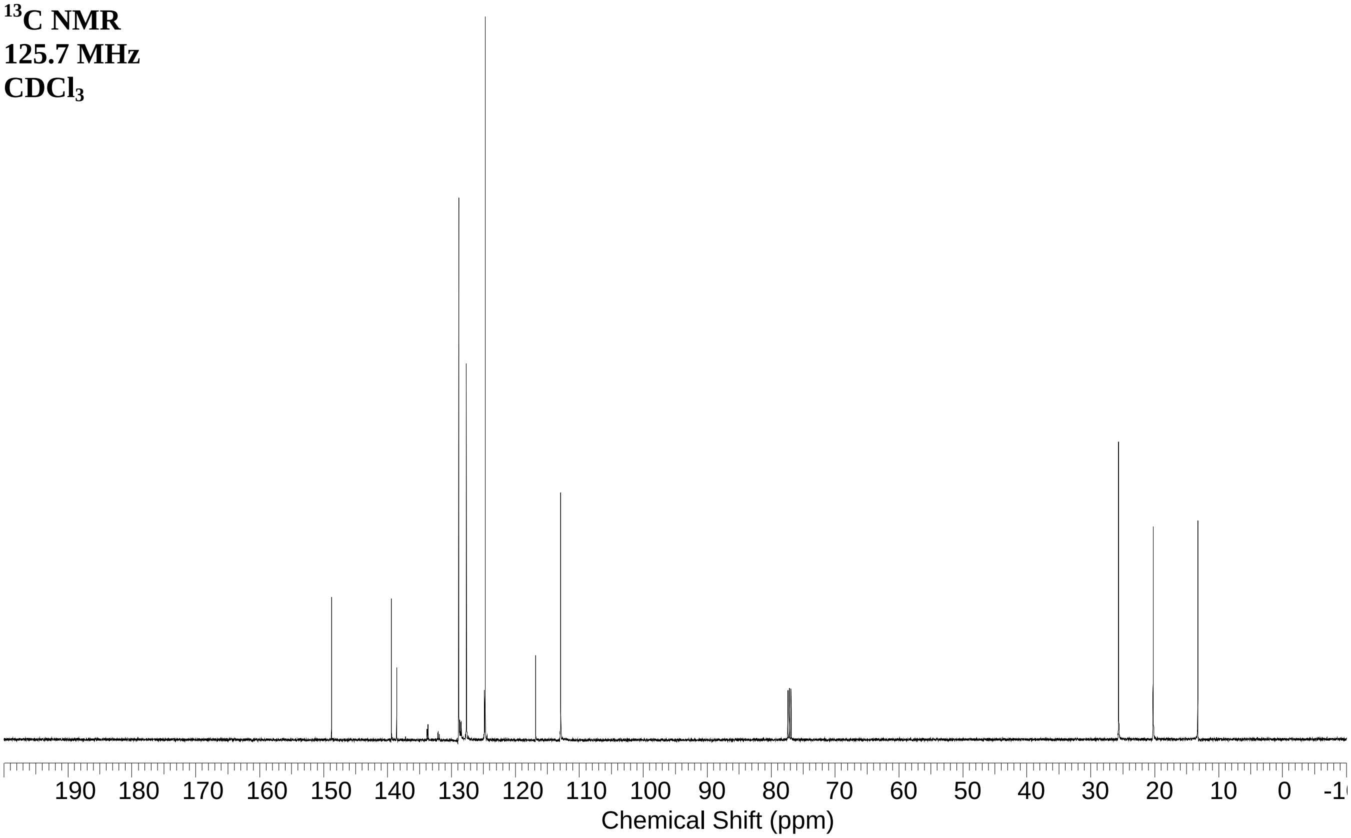


^{1}H NMR
500 MHz
$CDCl_3$

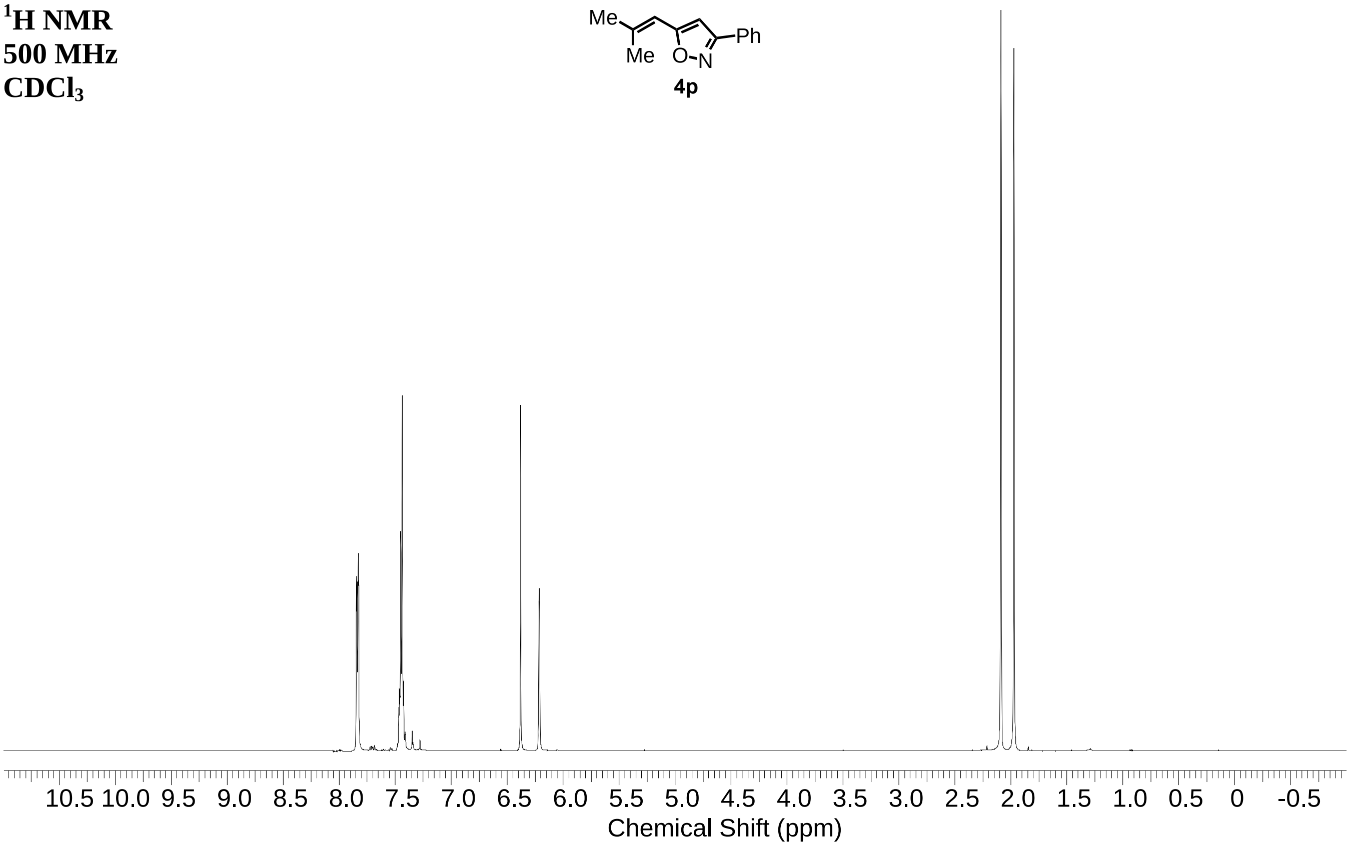


4o

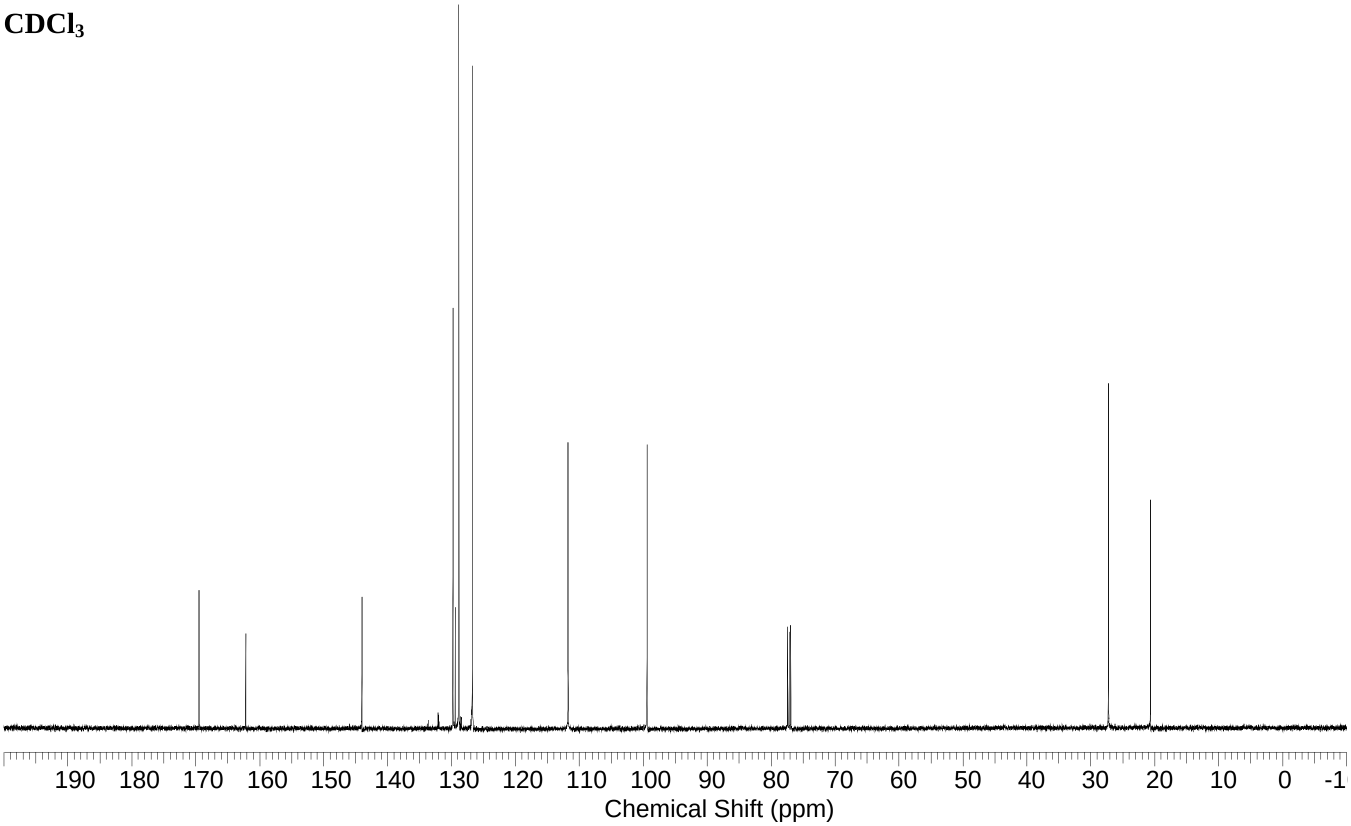
^{13}C NMR
125.7 MHz
$CDCl_3$



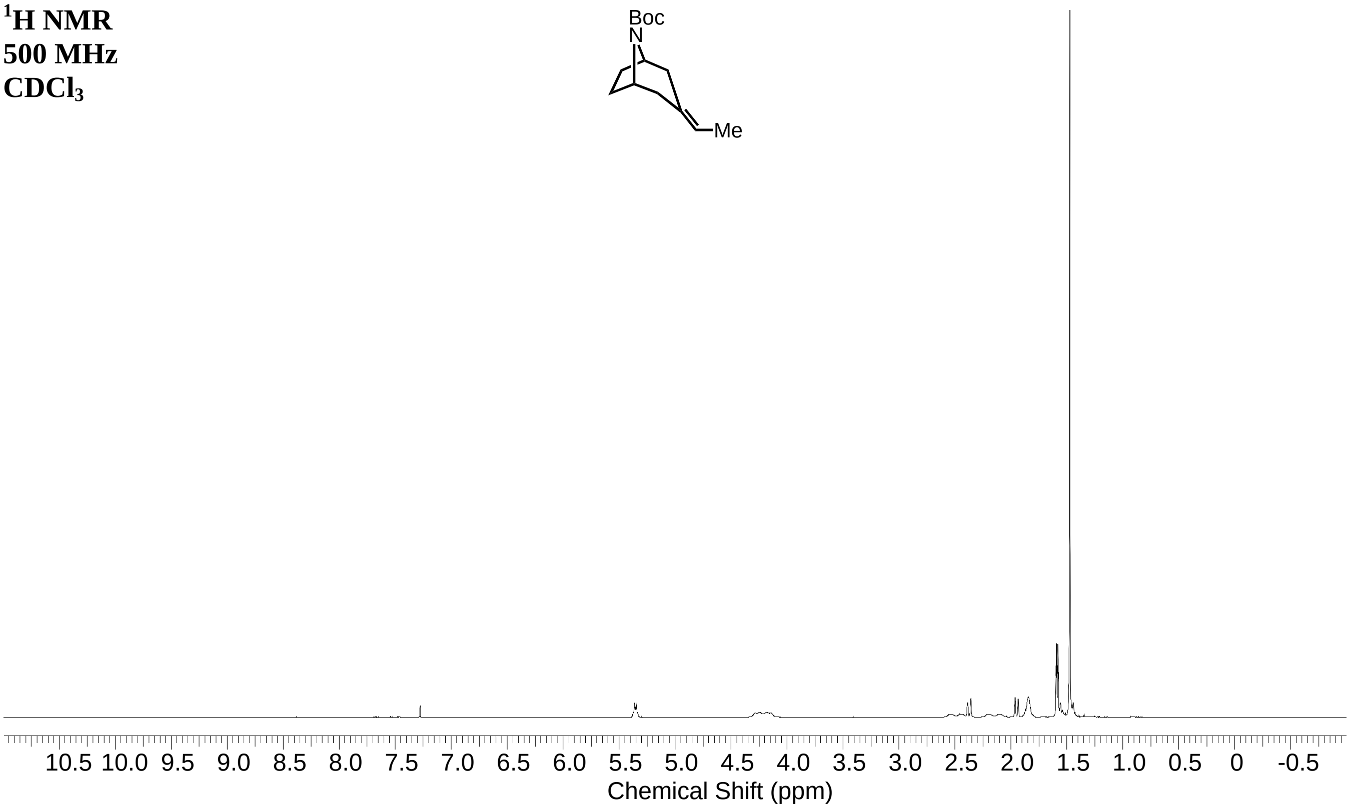
^{1}H NMR
500 MHz
CDCl$_3$



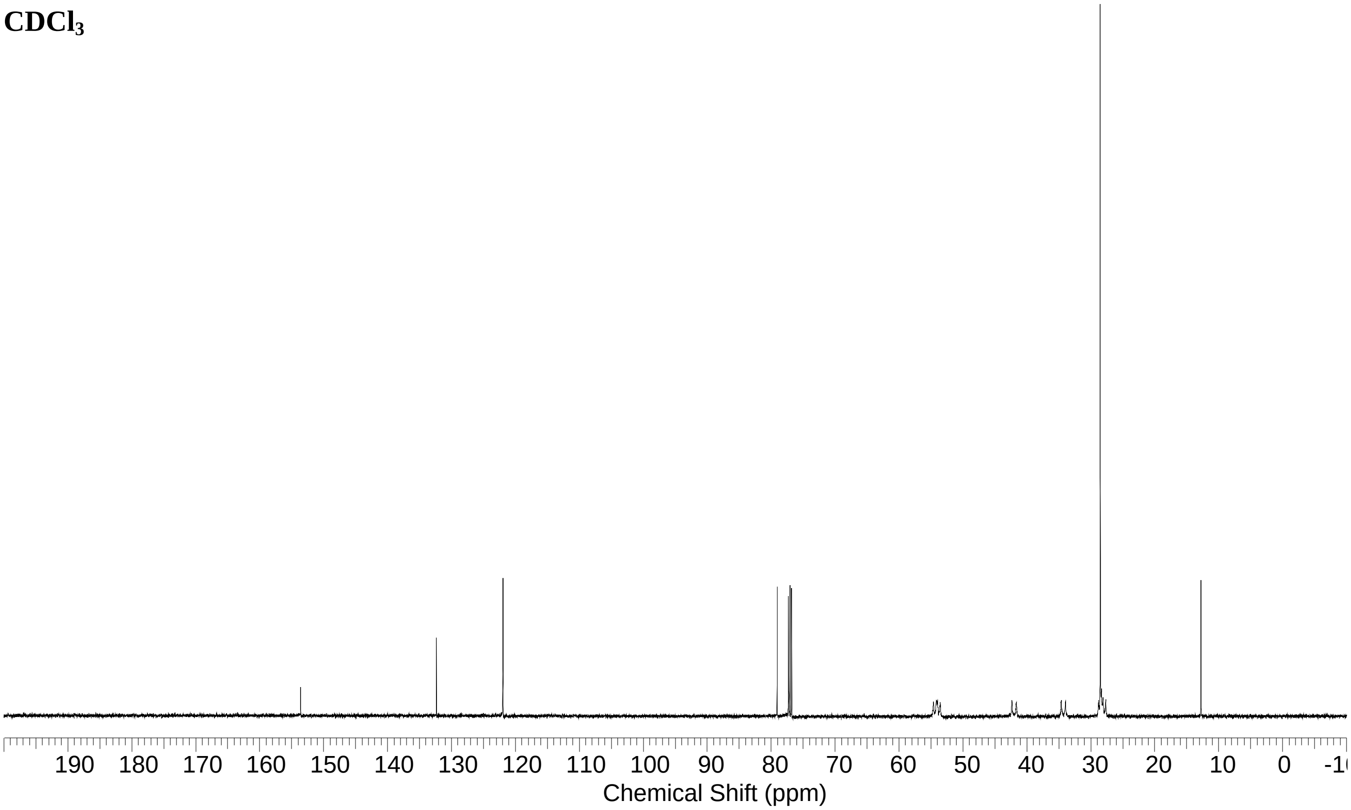
^{13}C NMR
125.7 MHz
CDCl$_3$



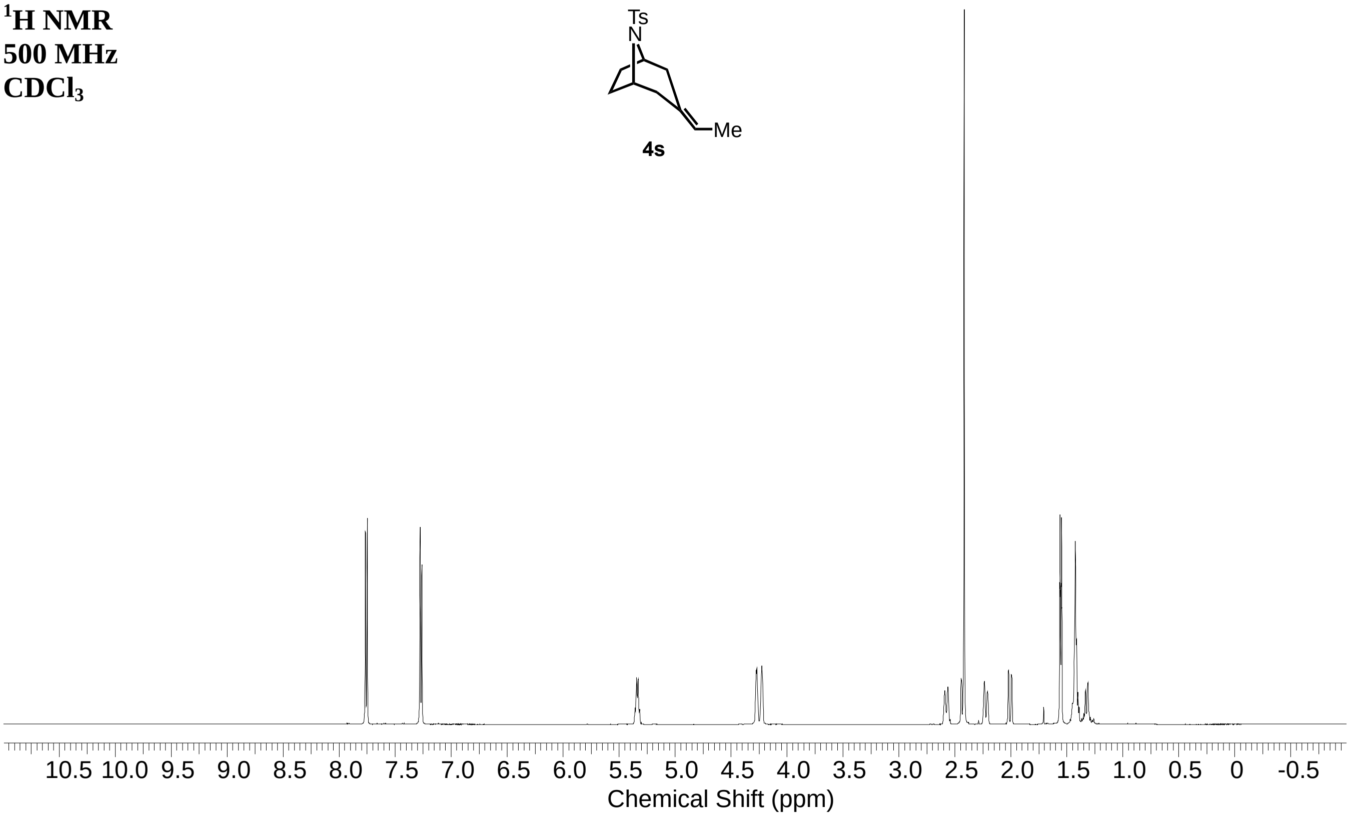
^{1}H NMR
500 MHz
$CDCl_3$



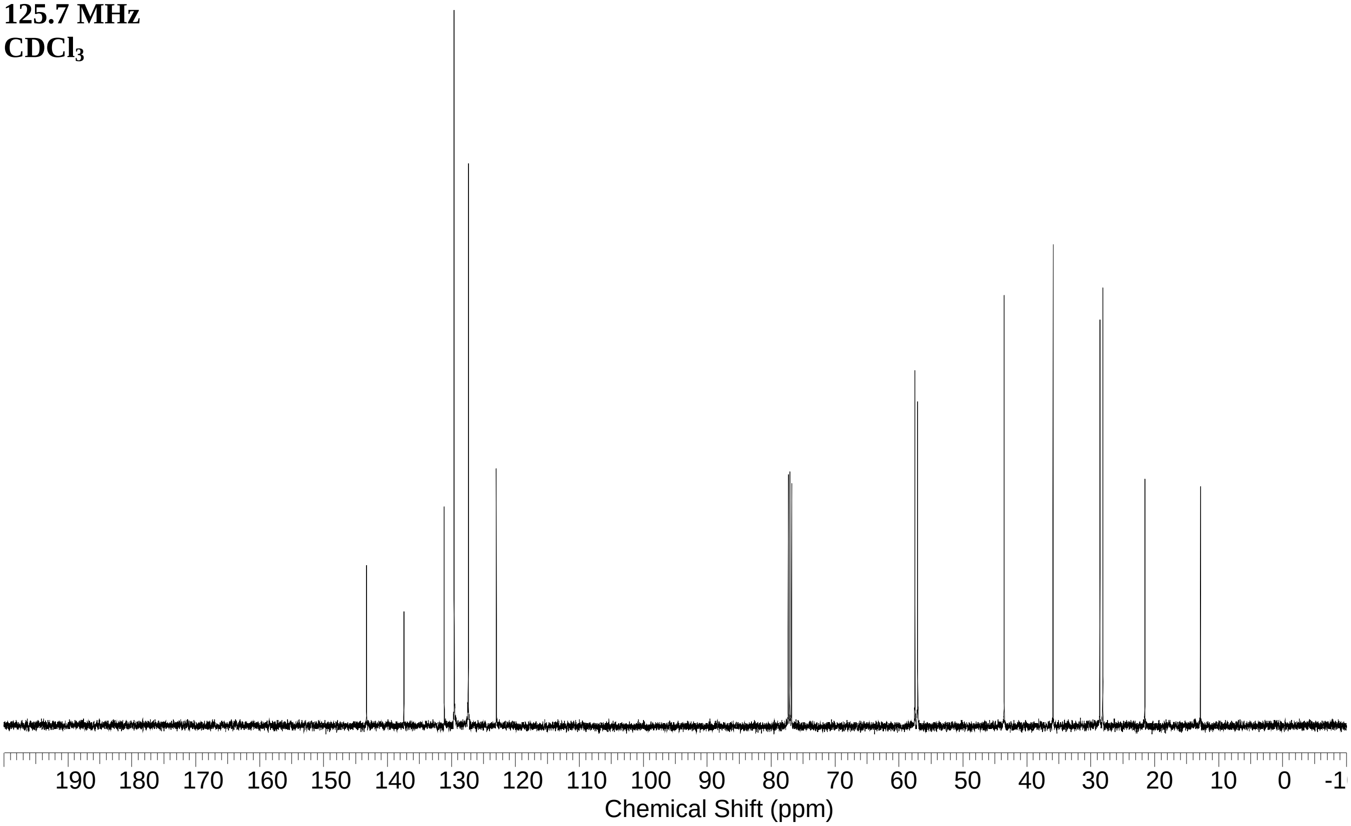
^{13}C NMR
125.7 MHz
$CDCl_3$



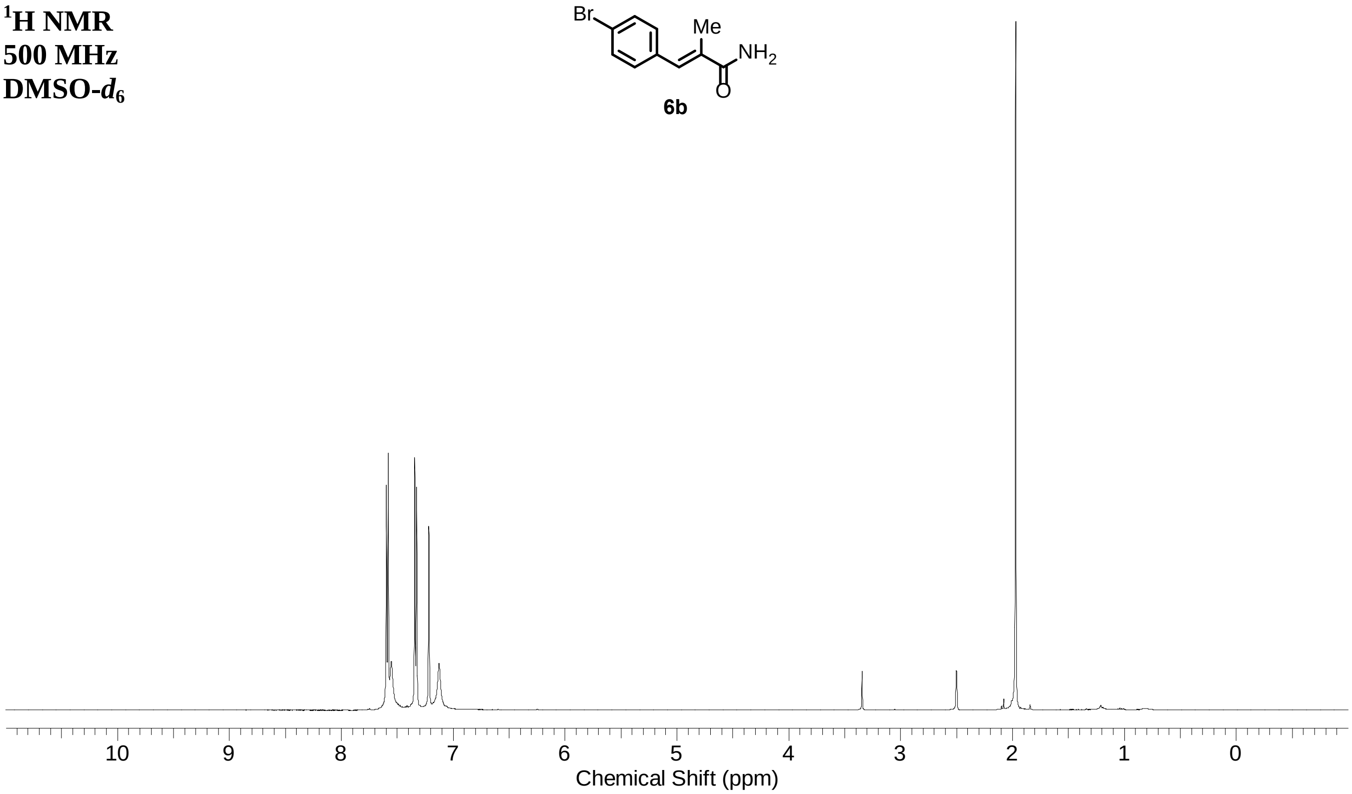
^{1}H NMR
500 MHz
CDCl$_3$



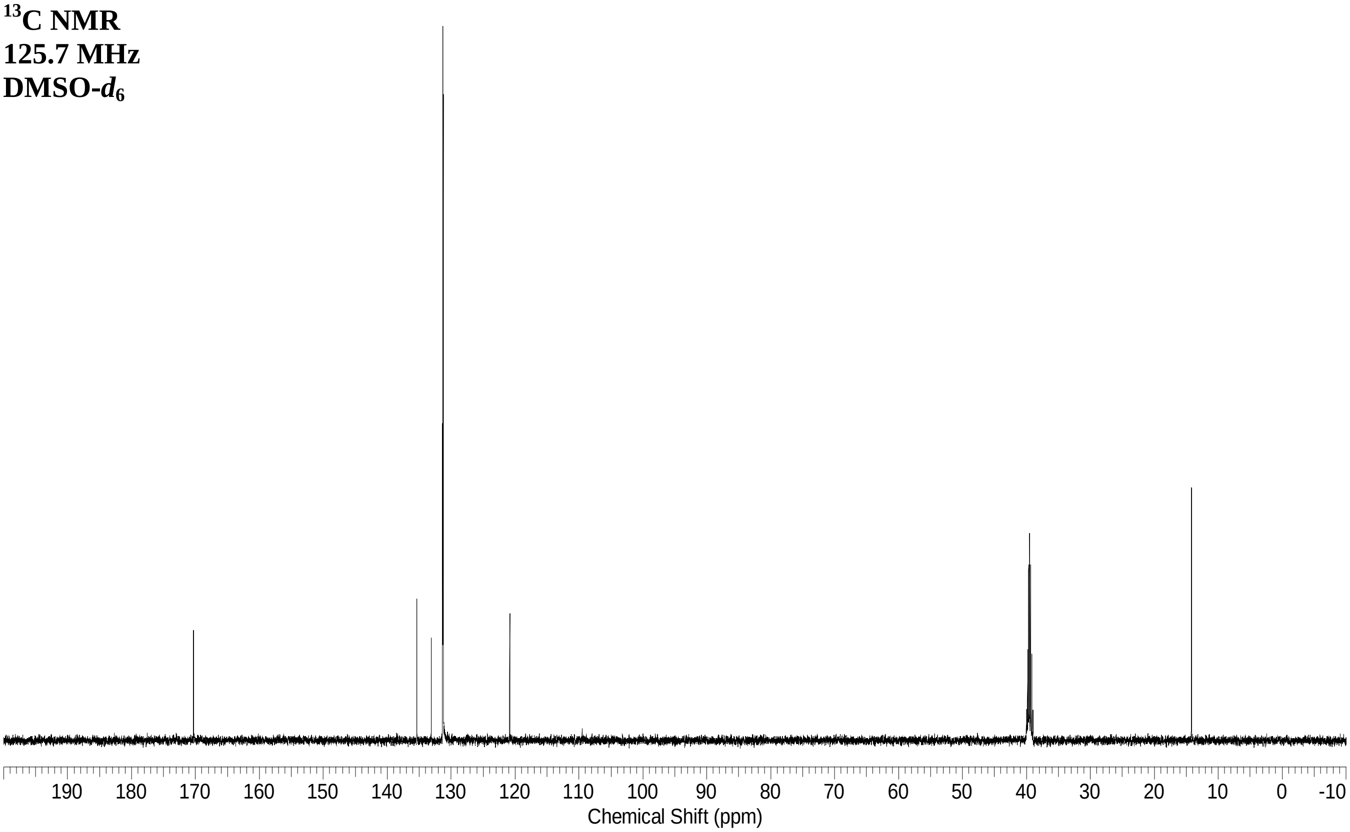
^{13}C NMR
125.7 MHz
CDCl$_3$



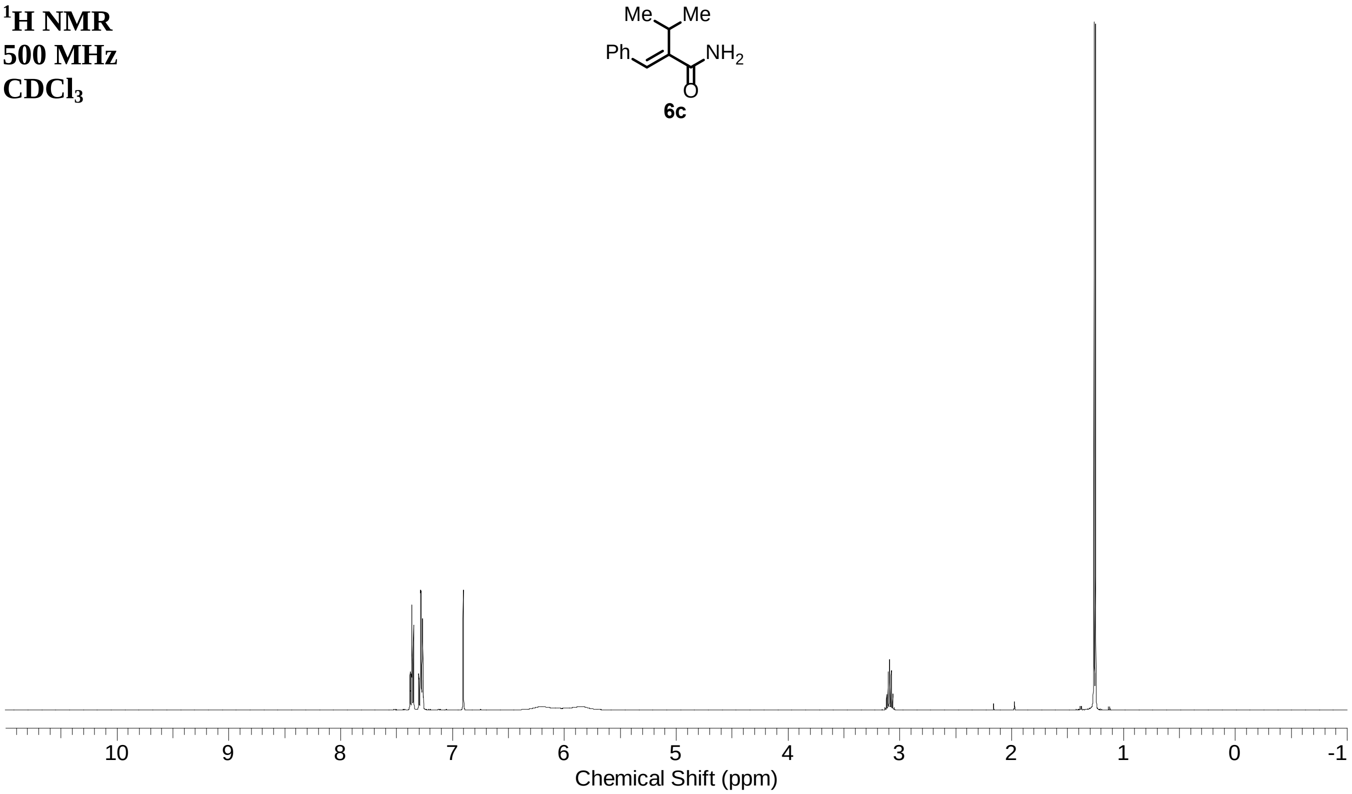
^{1}H NMR
500 MHz
DMSO-d_6



^{13}C NMR
125.7 MHz
DMSO-d_6

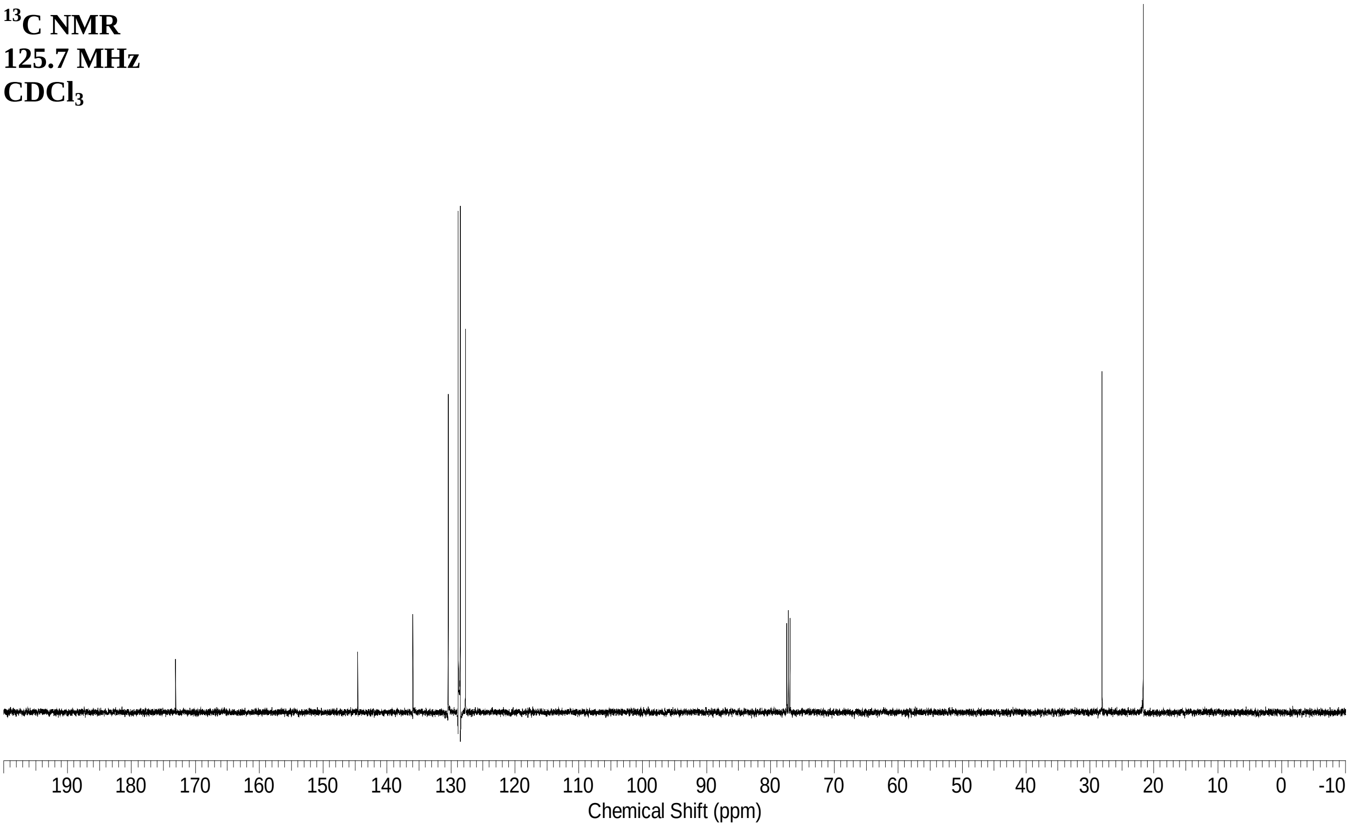


^{1}H NMR
500 MHz
$CDCl_3$

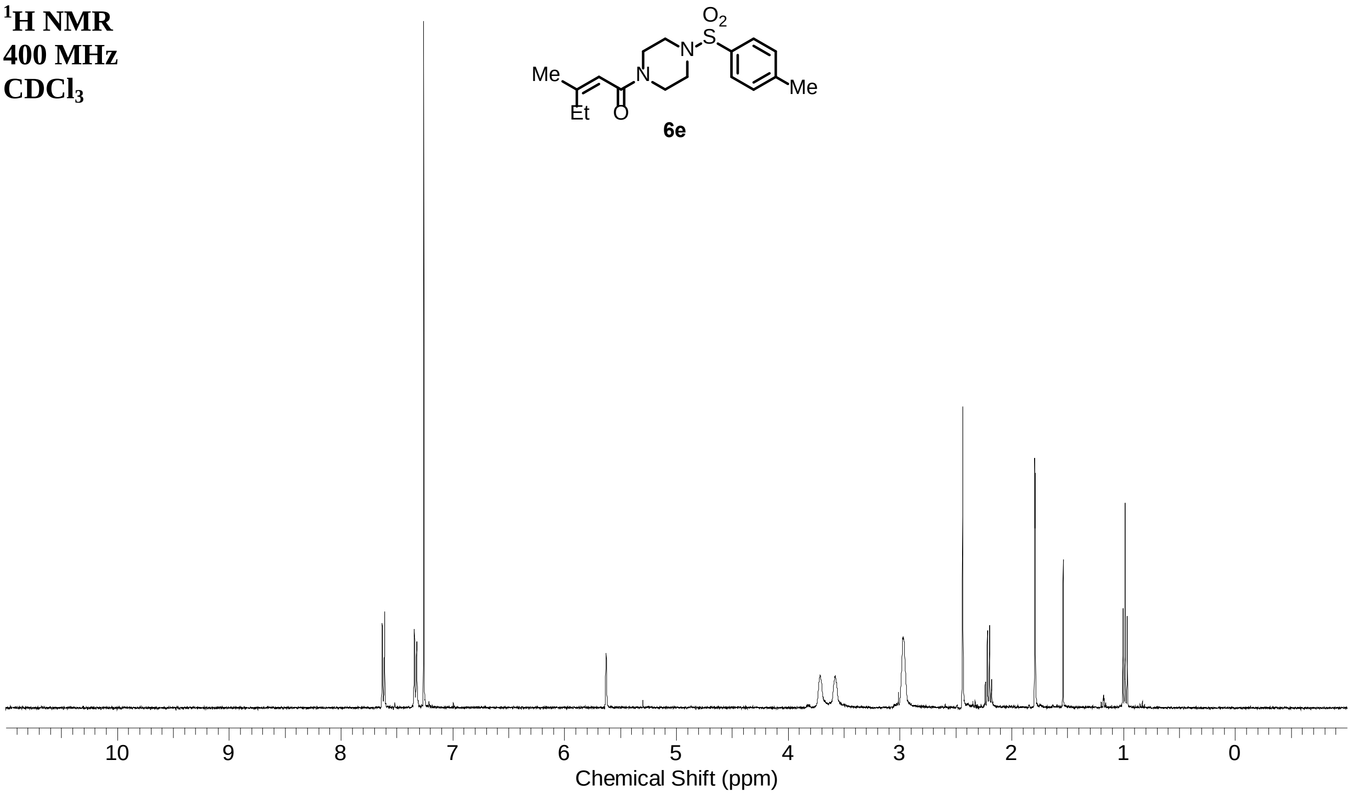


6c

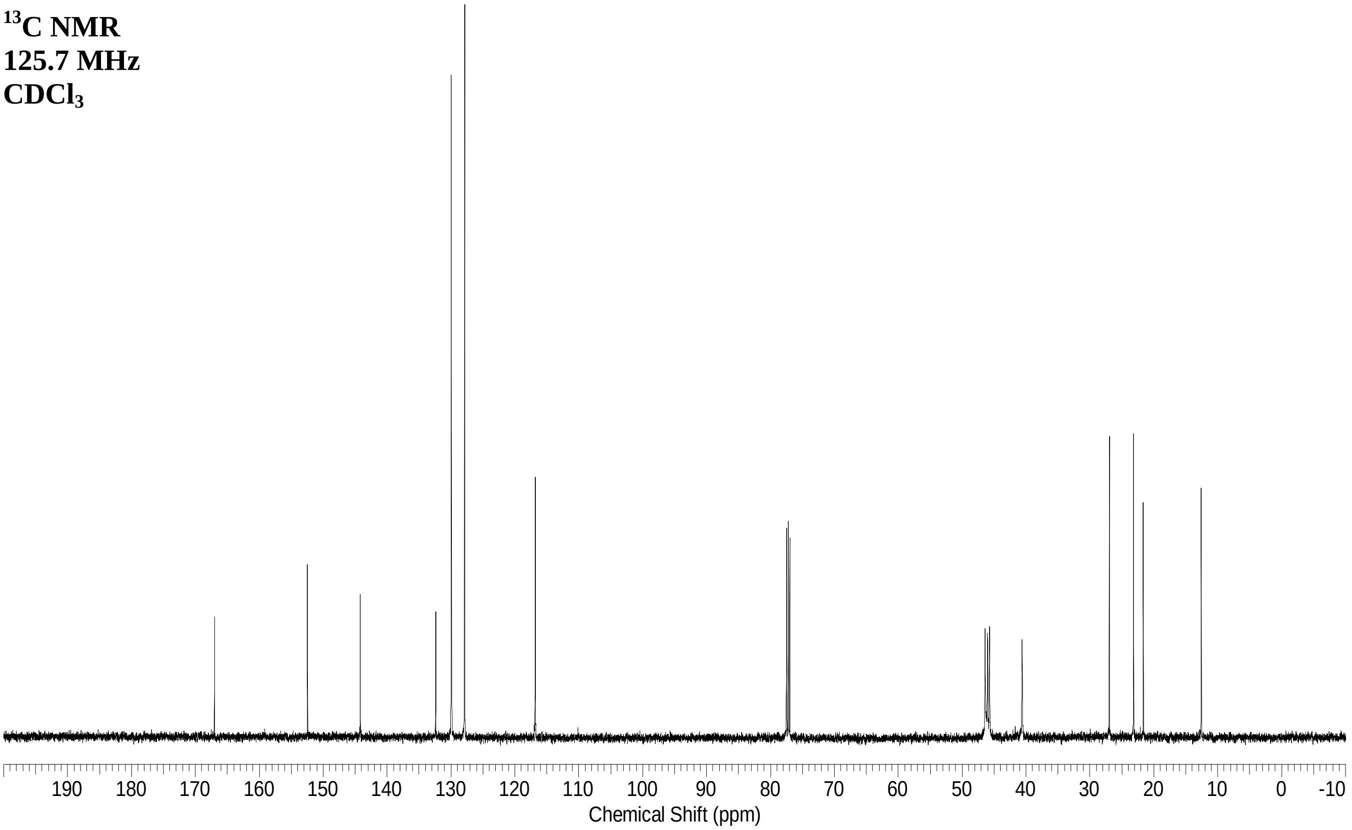
^{13}C NMR
125.7 MHz
$CDCl_3$



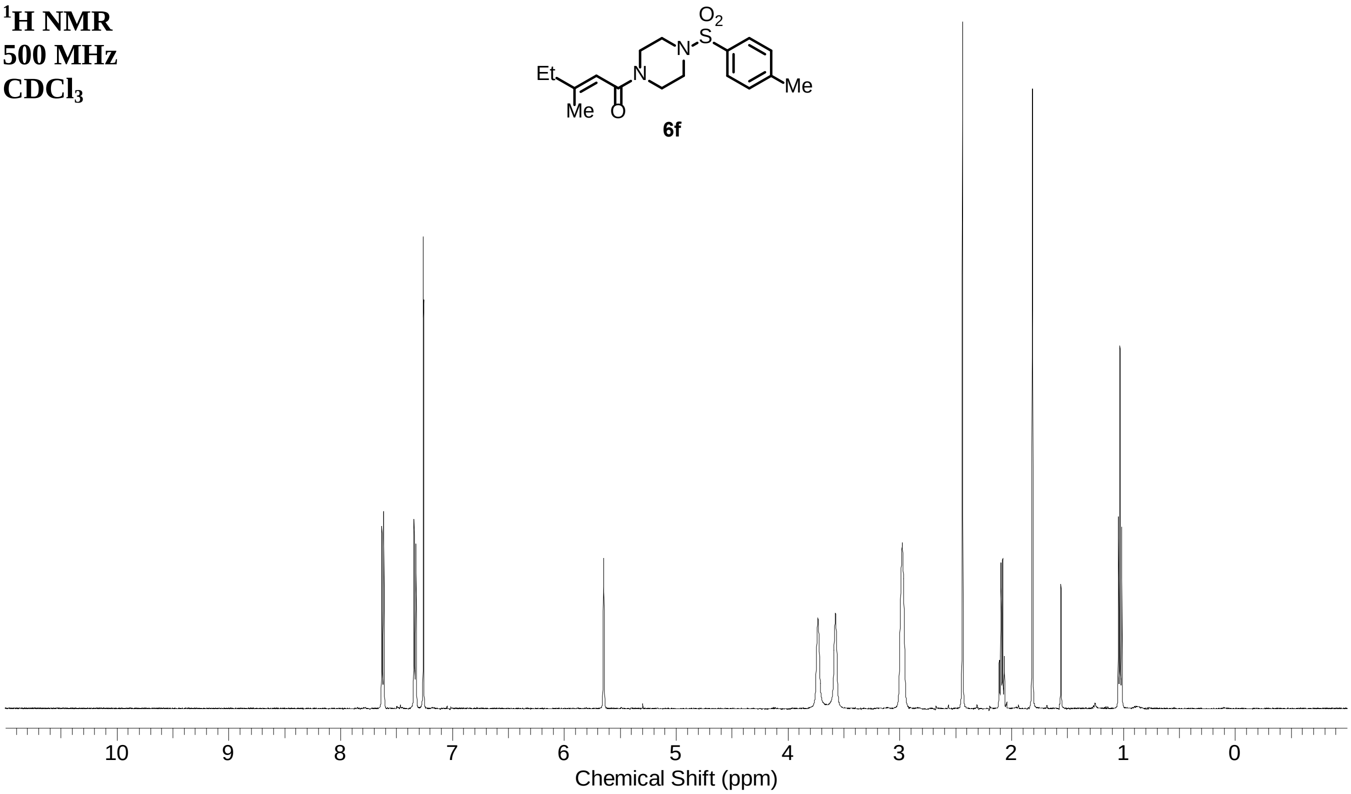
^{1}H NMR
400 MHz
$CDCl_3$



^{13}C NMR
125.7 MHz
$CDCl_3$

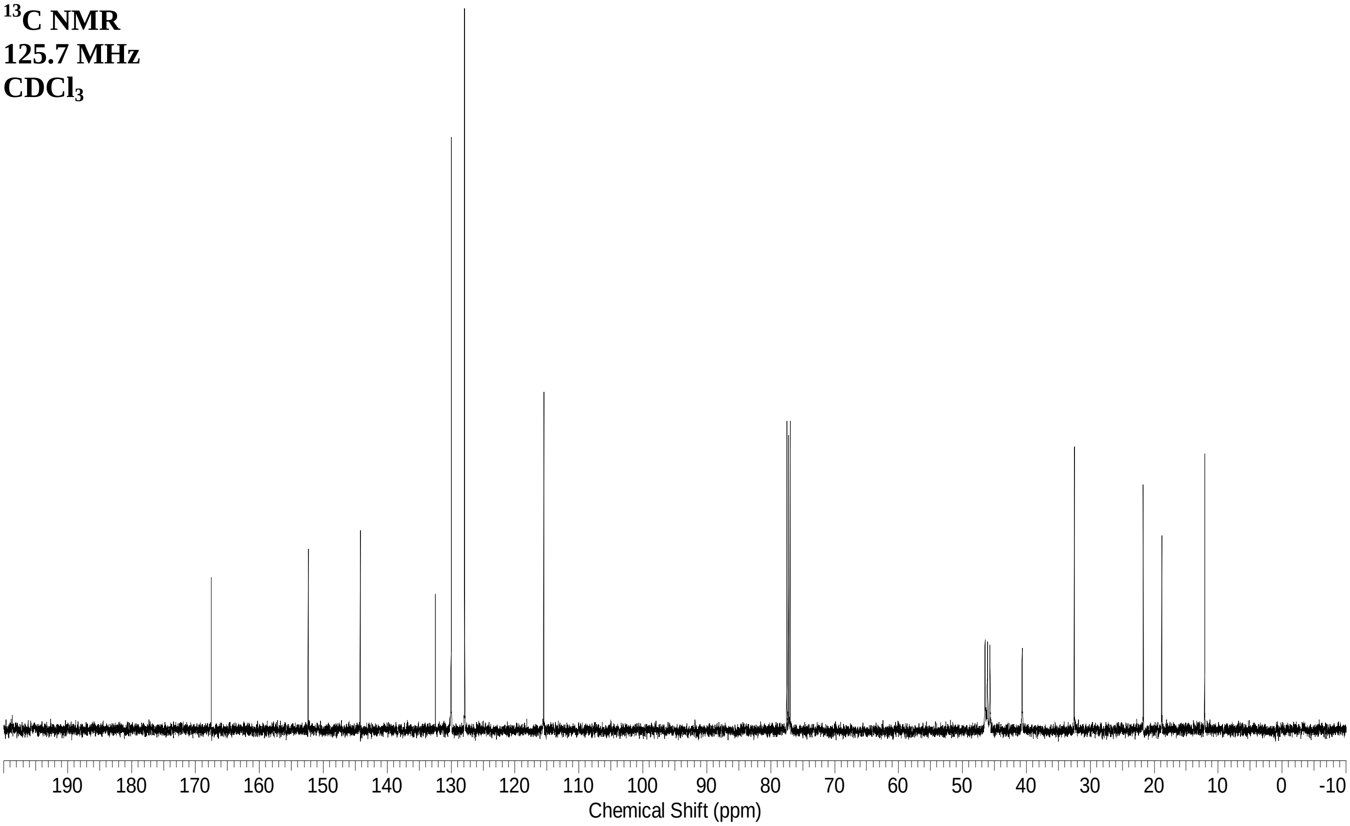


^{1}H NMR
500 MHz
$CDCl_3$

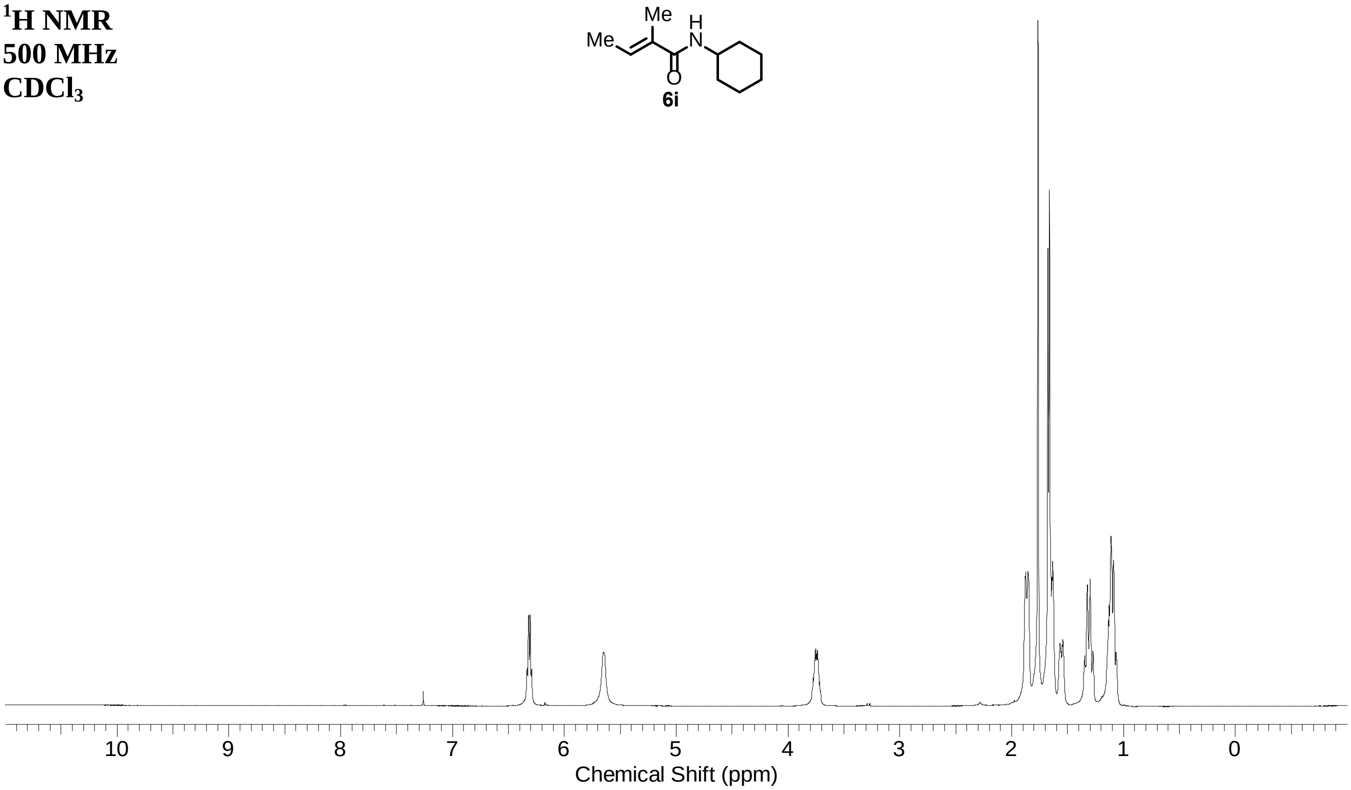


6f

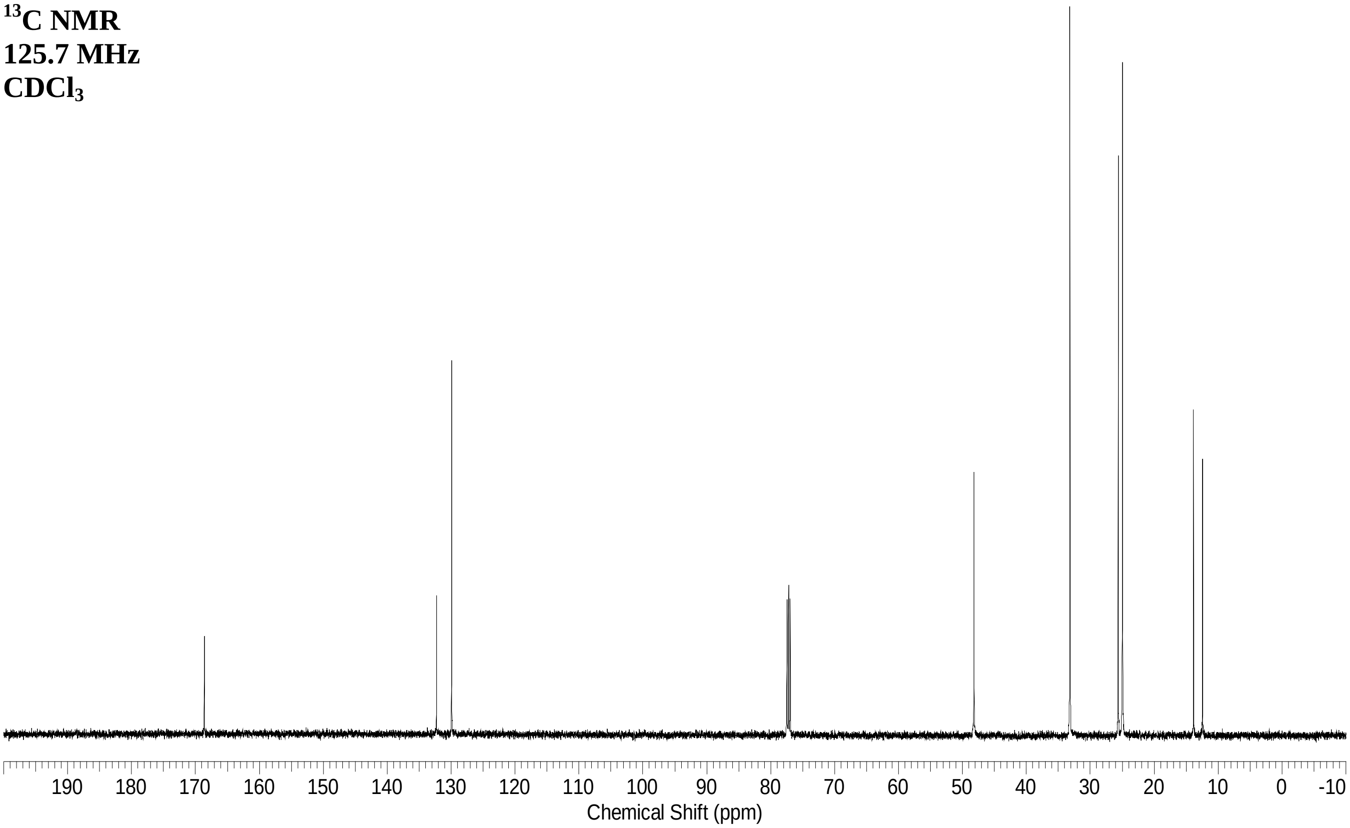
^{13}C NMR
125.7 MHz
$CDCl_3$



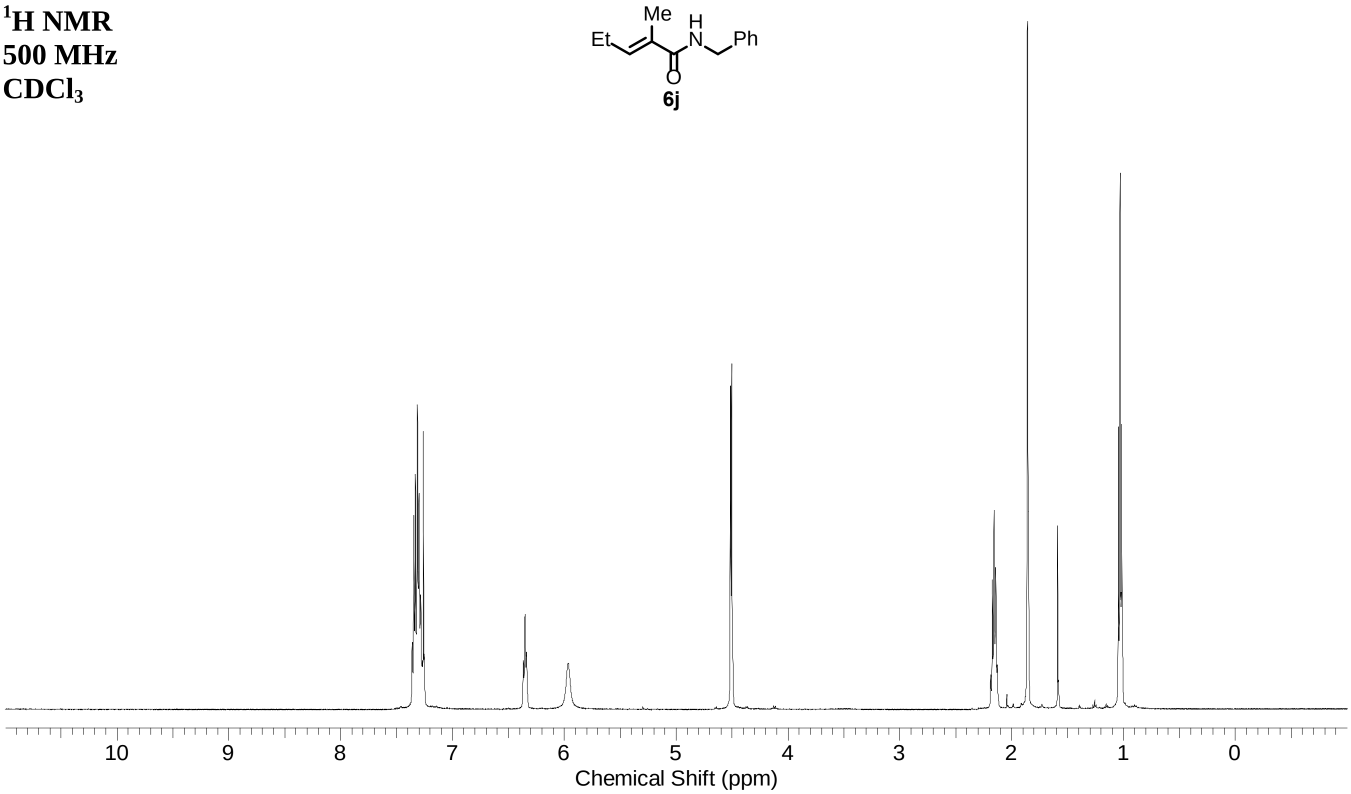
^{1}H NMR
500 MHz
CDCl$_3$



^{13}C NMR
125.7 MHz
CDCl$_3$

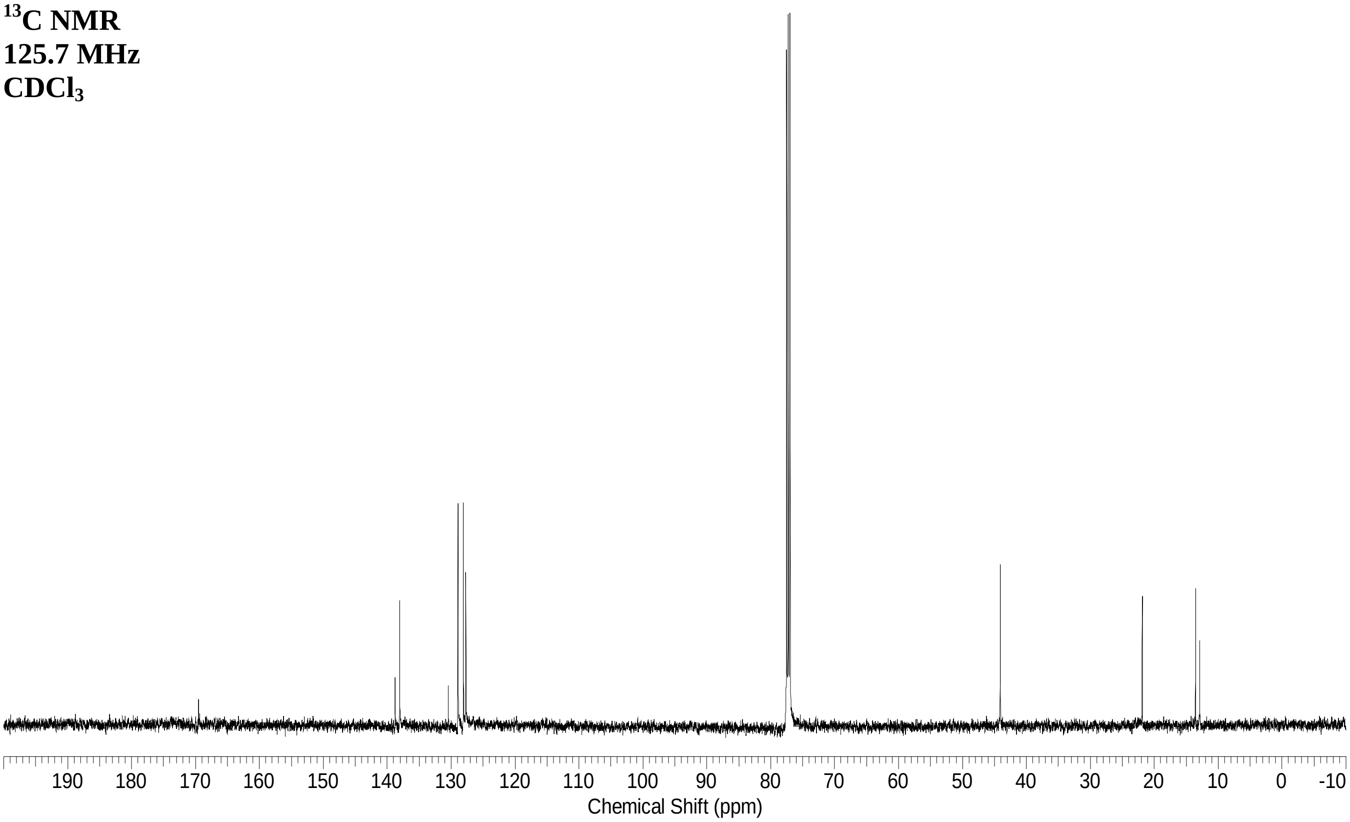


^{1}H NMR
500 MHz
$CDCl_3$

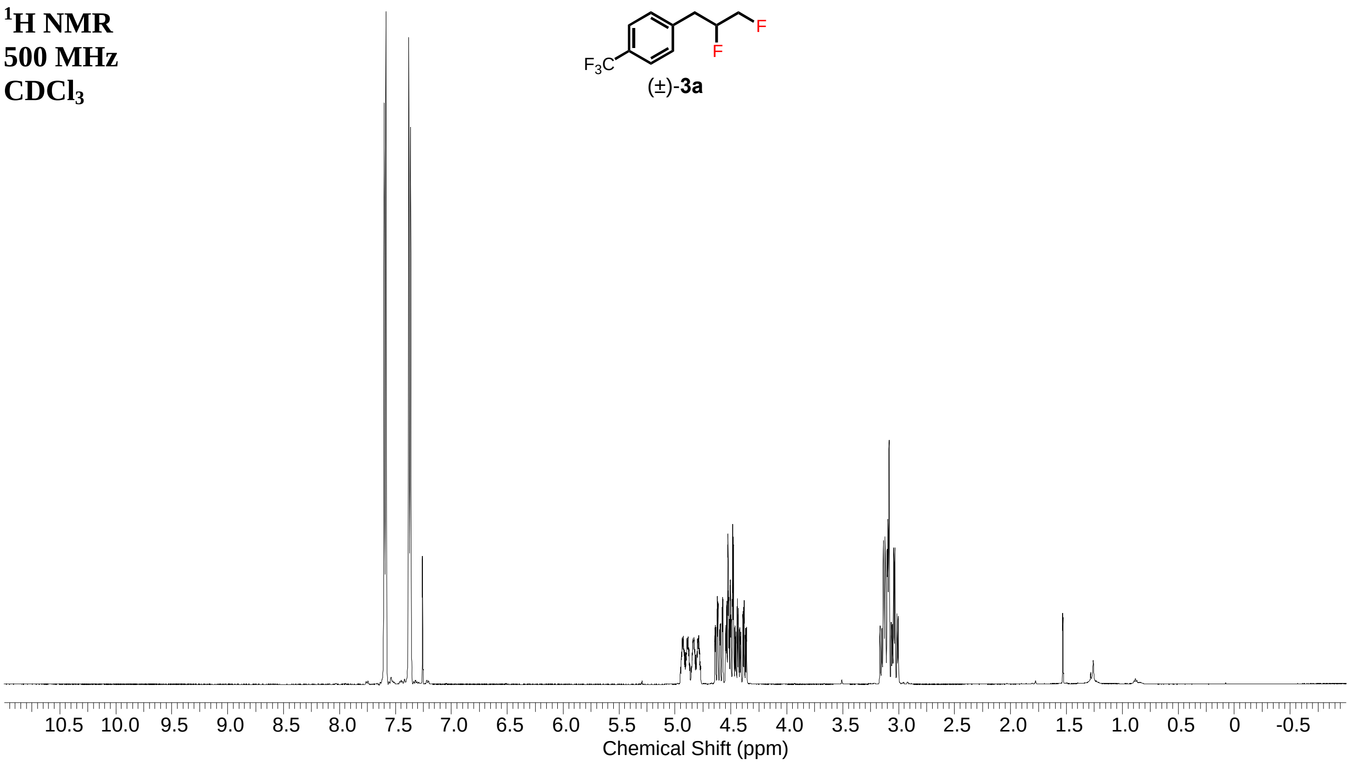


6j

^{13}C NMR
125.7 MHz
$CDCl_3$

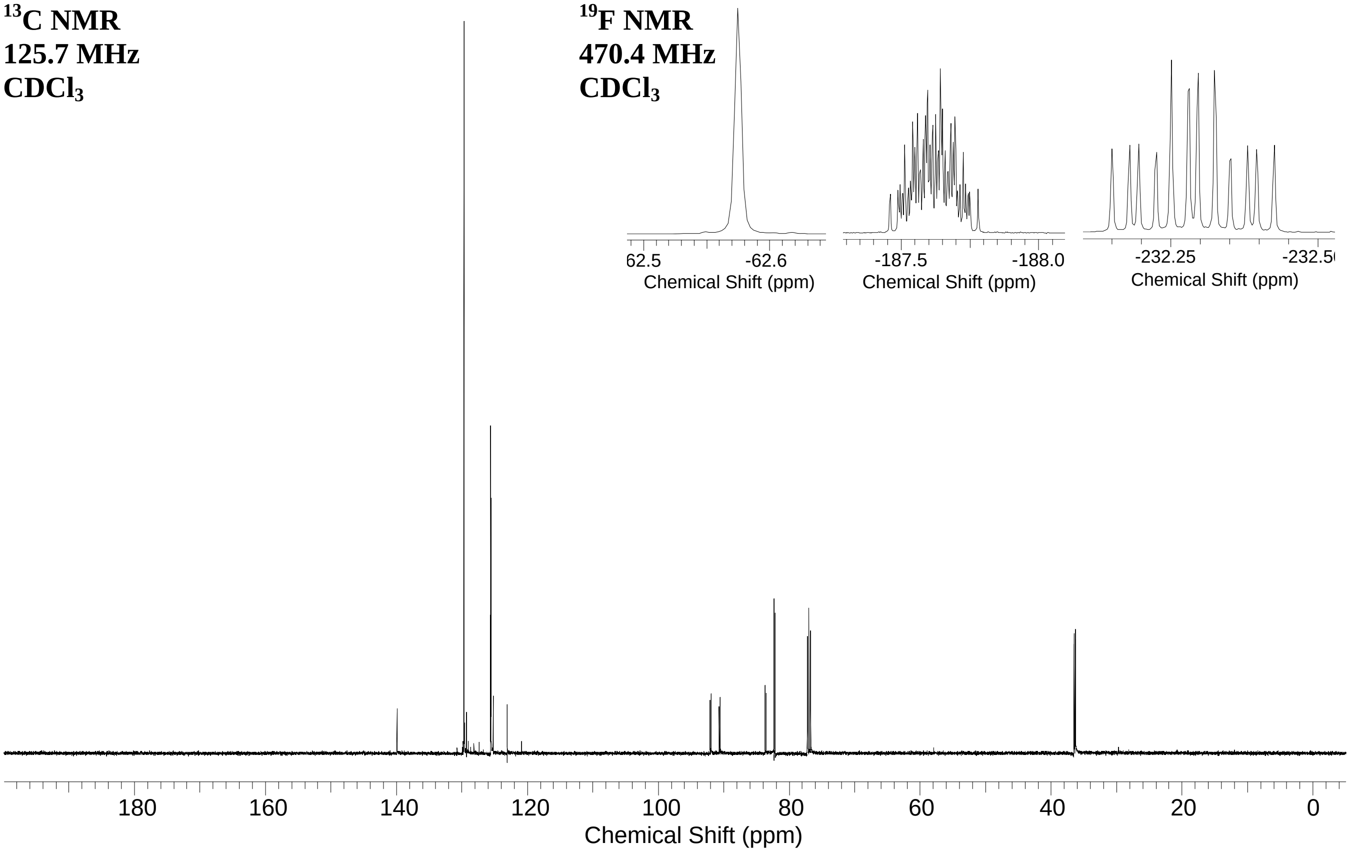


^{1}H NMR
500 MHz
$CDCl_3$

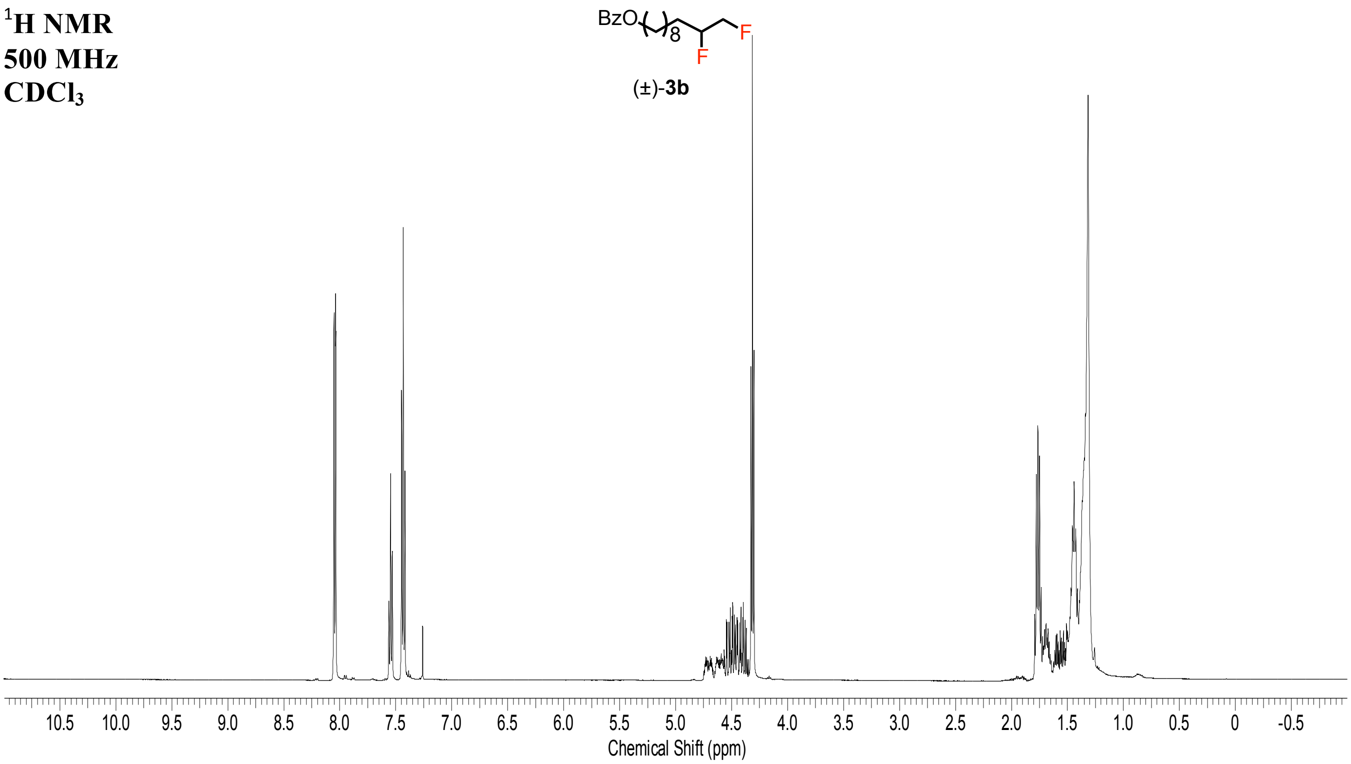


^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$

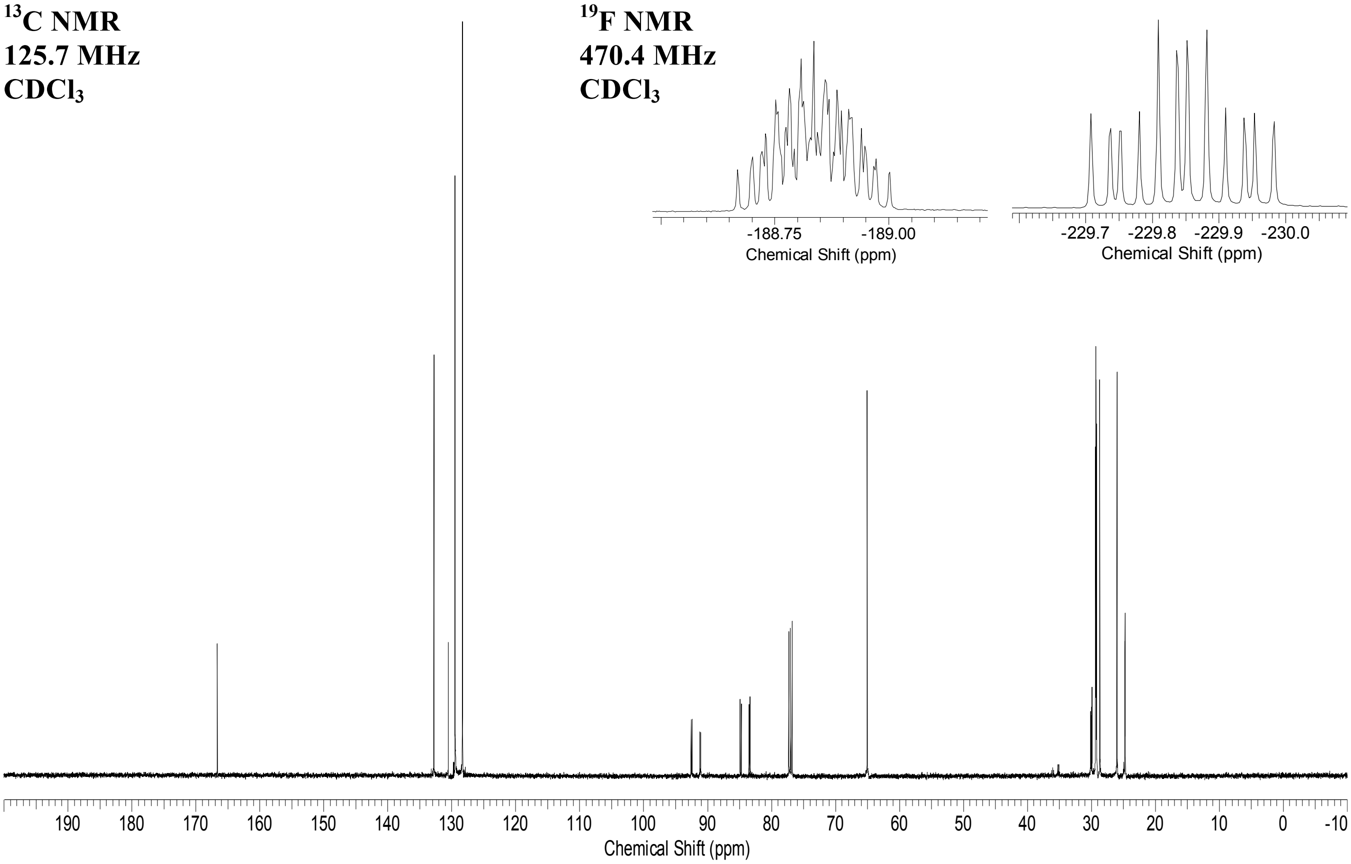


^{1}H NMR
500 MHz
CDCl$_3$

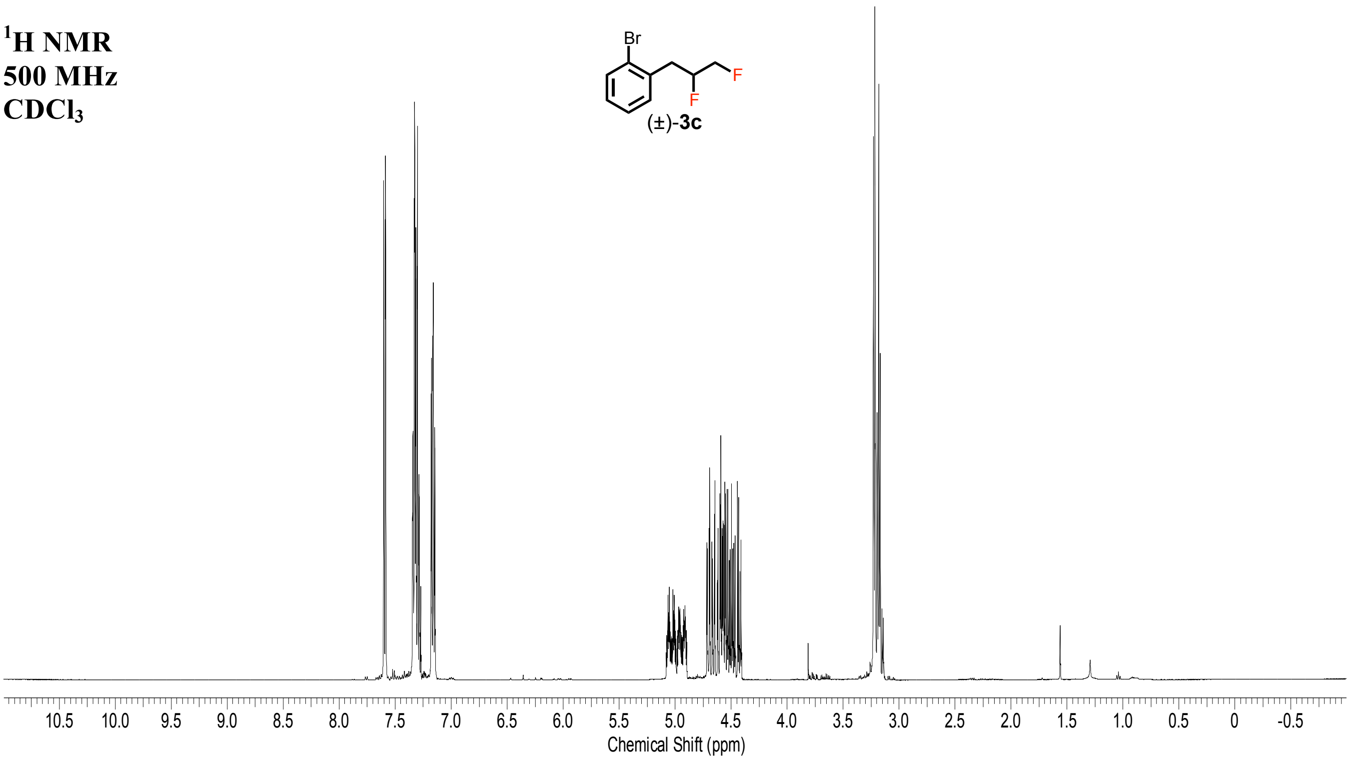


^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



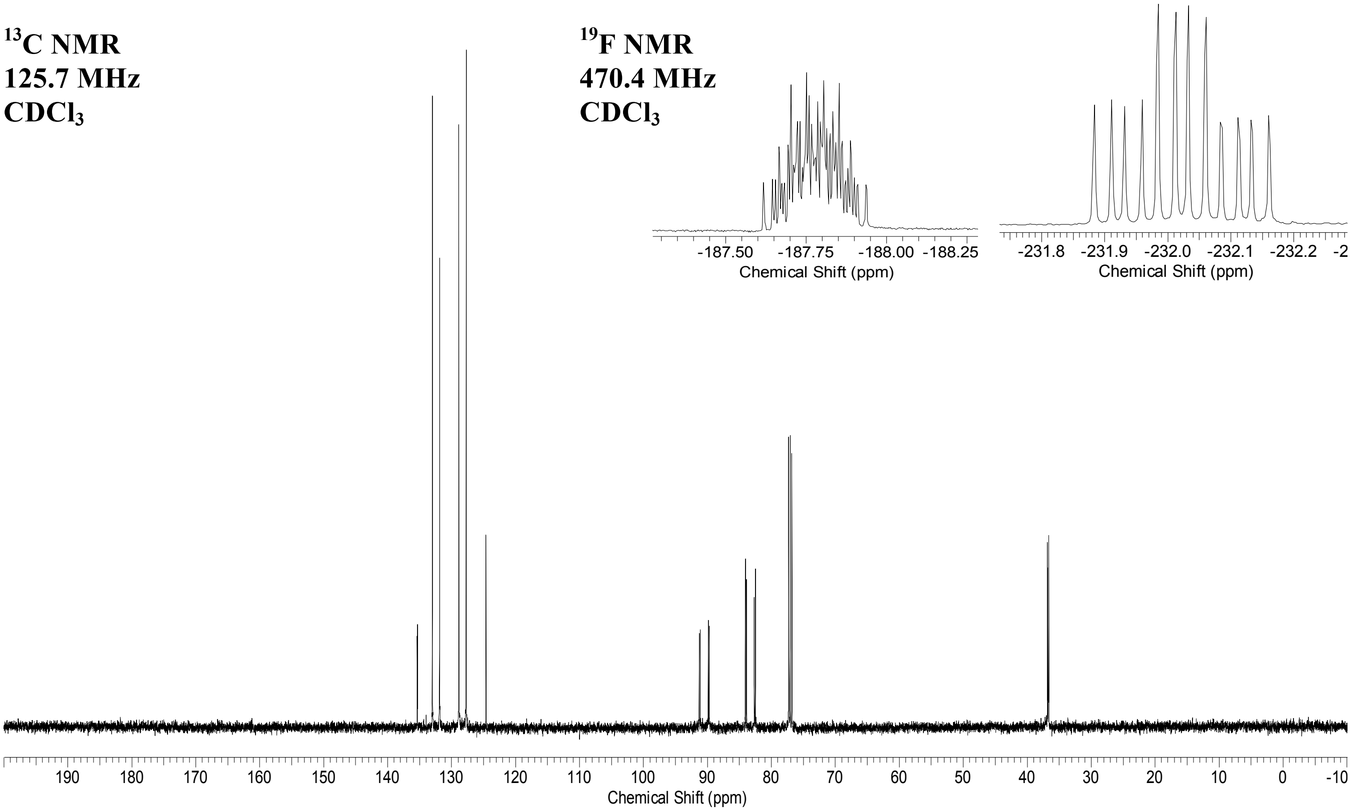
^{1}H NMR
500 MHz
$CDCl_3$



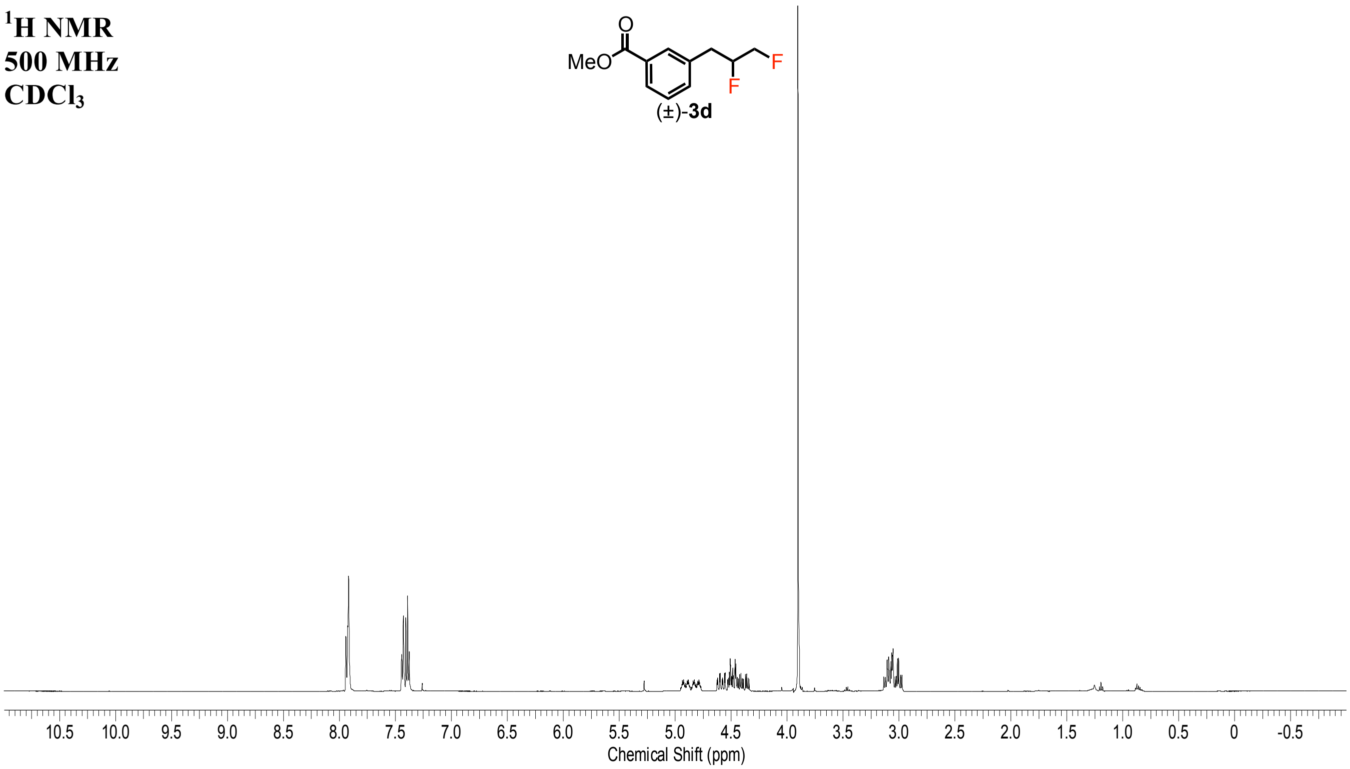
(±)-**3c**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



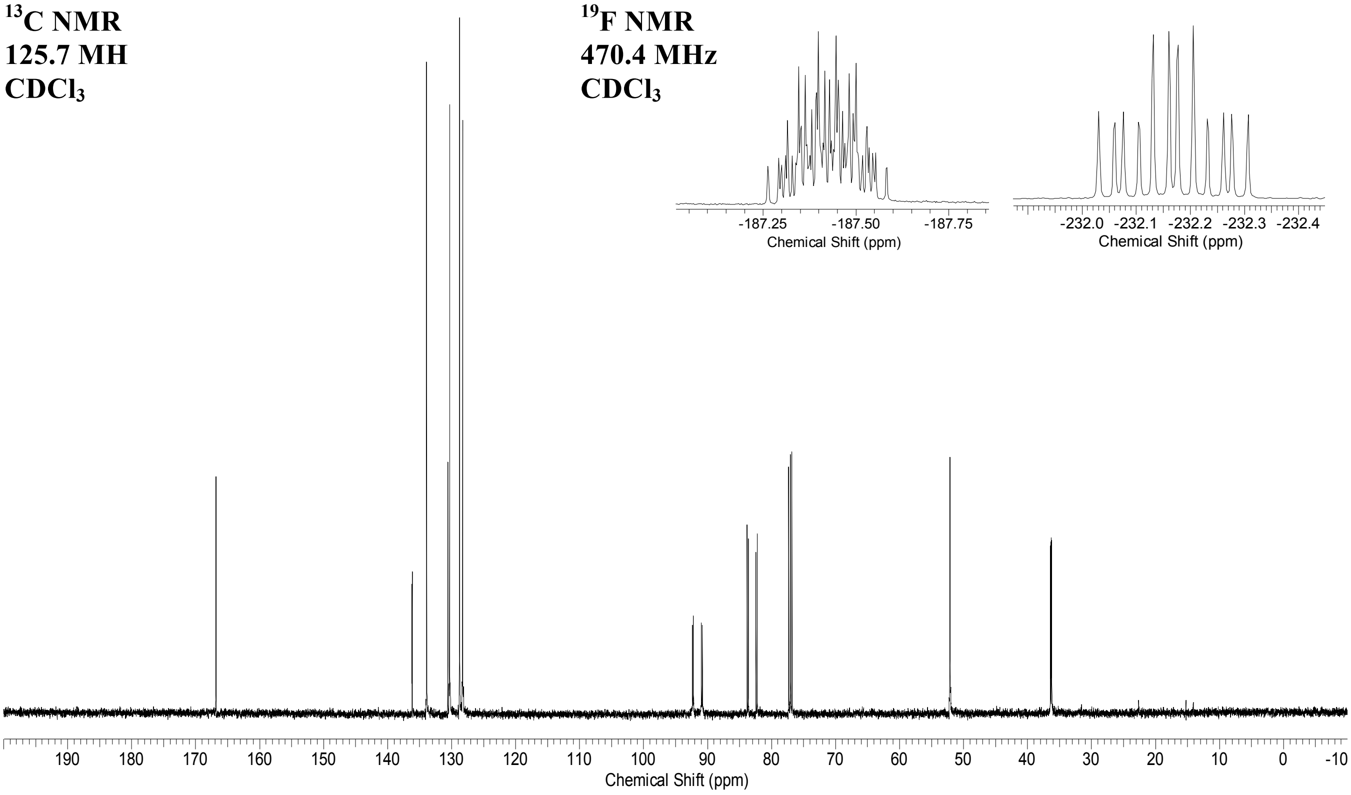
^{1}H NMR
500 MHz
$CDCl_3$



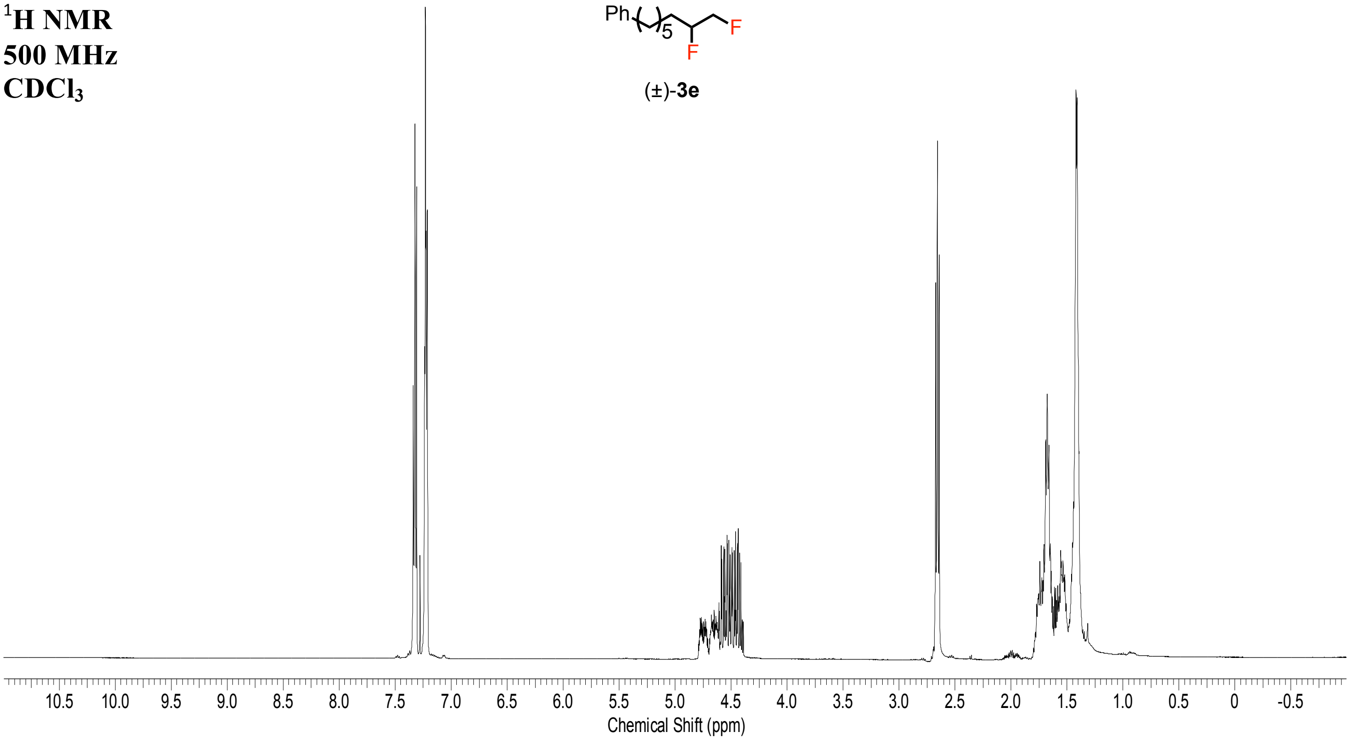
(±)-**3d**

^{13}C NMR
125.7 MH
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



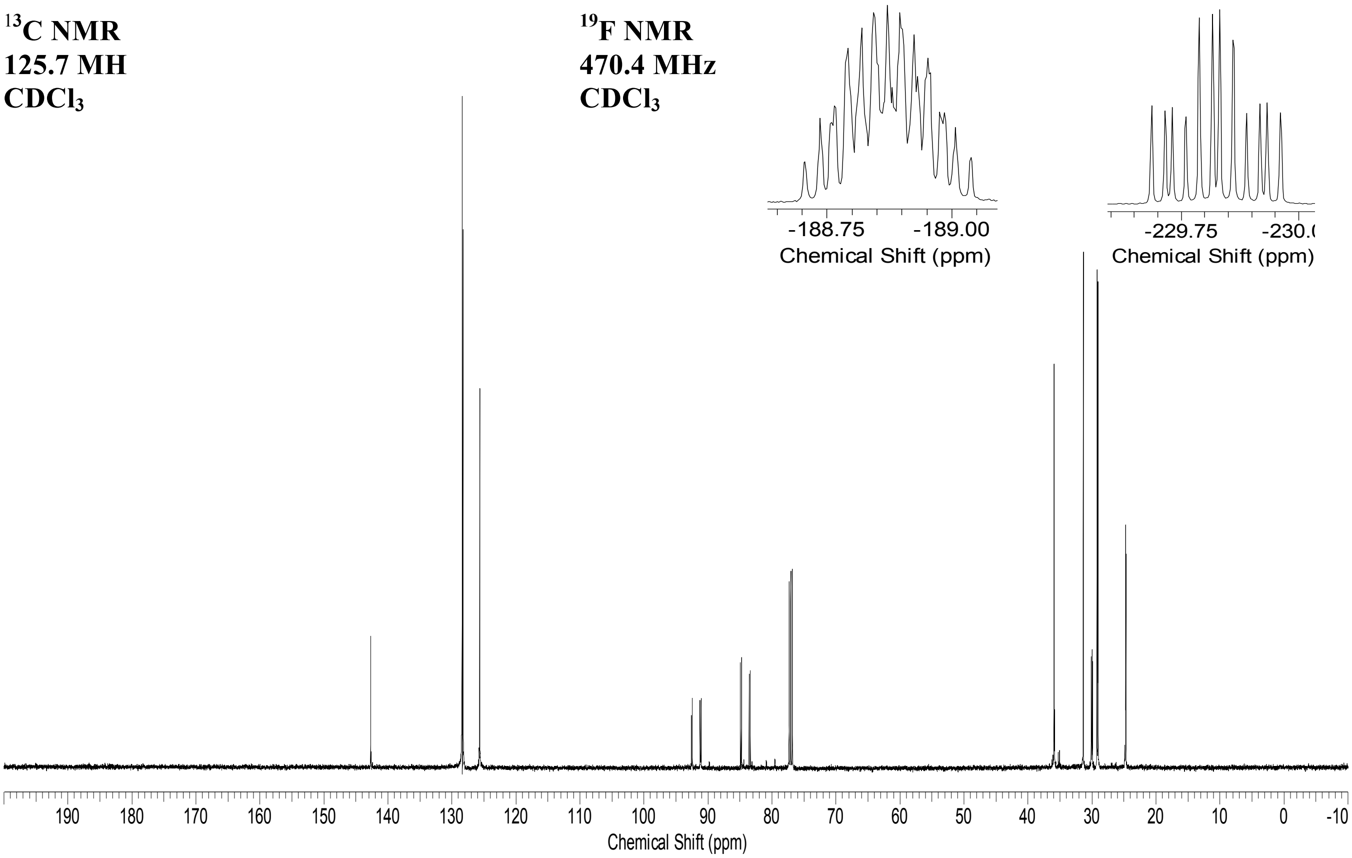
^{1}H NMR
500 MHz
CDCl$_3$



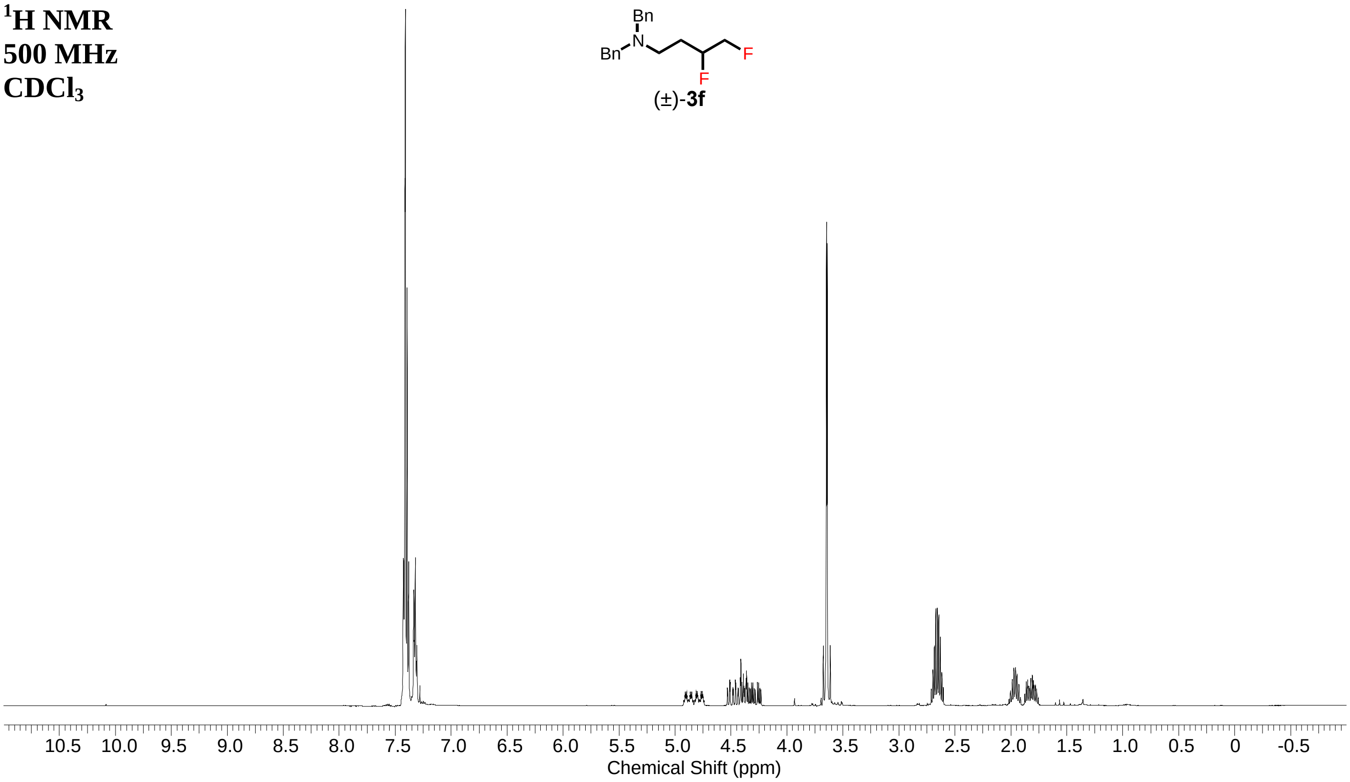
(±)-**3e**

^{13}C NMR
125.7 MH
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



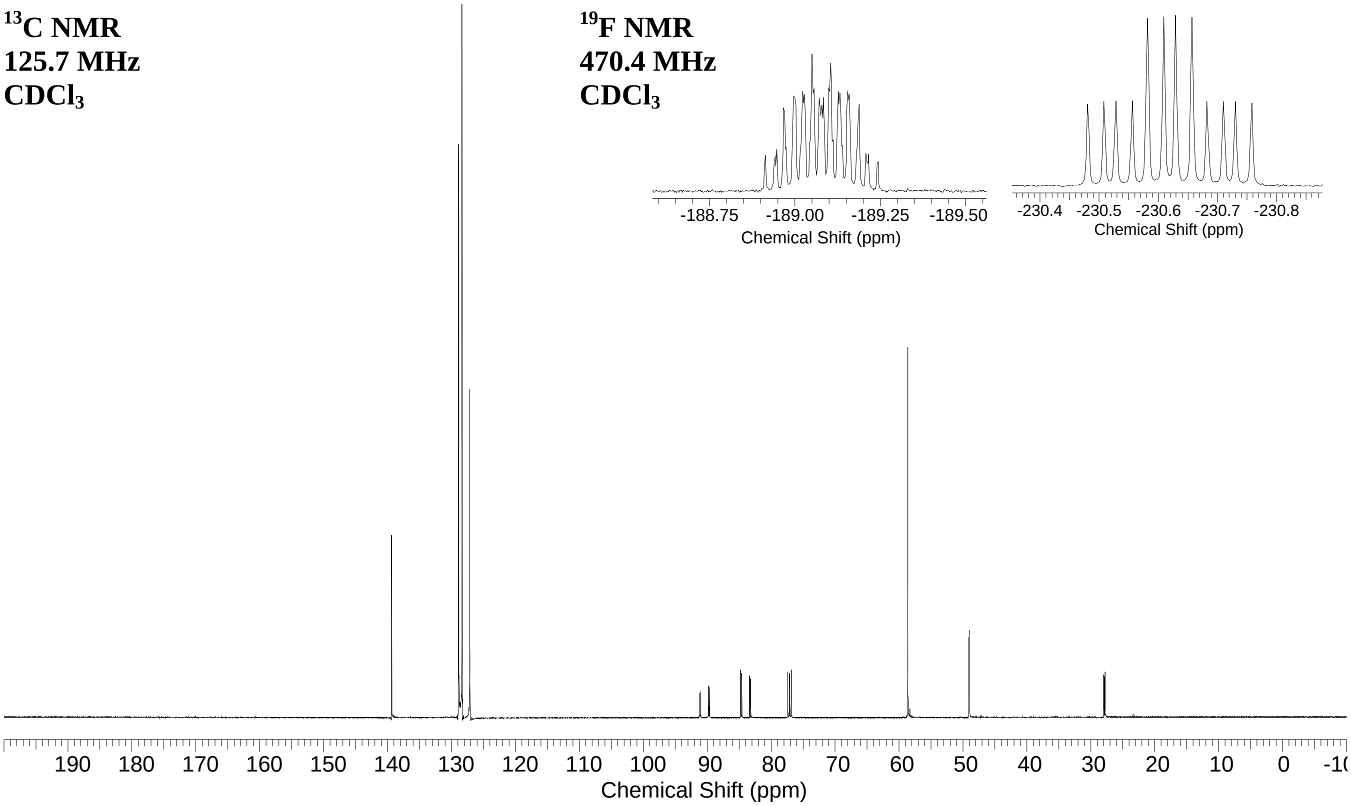
^{1}H NMR
500 MHz
$CDCl_3$



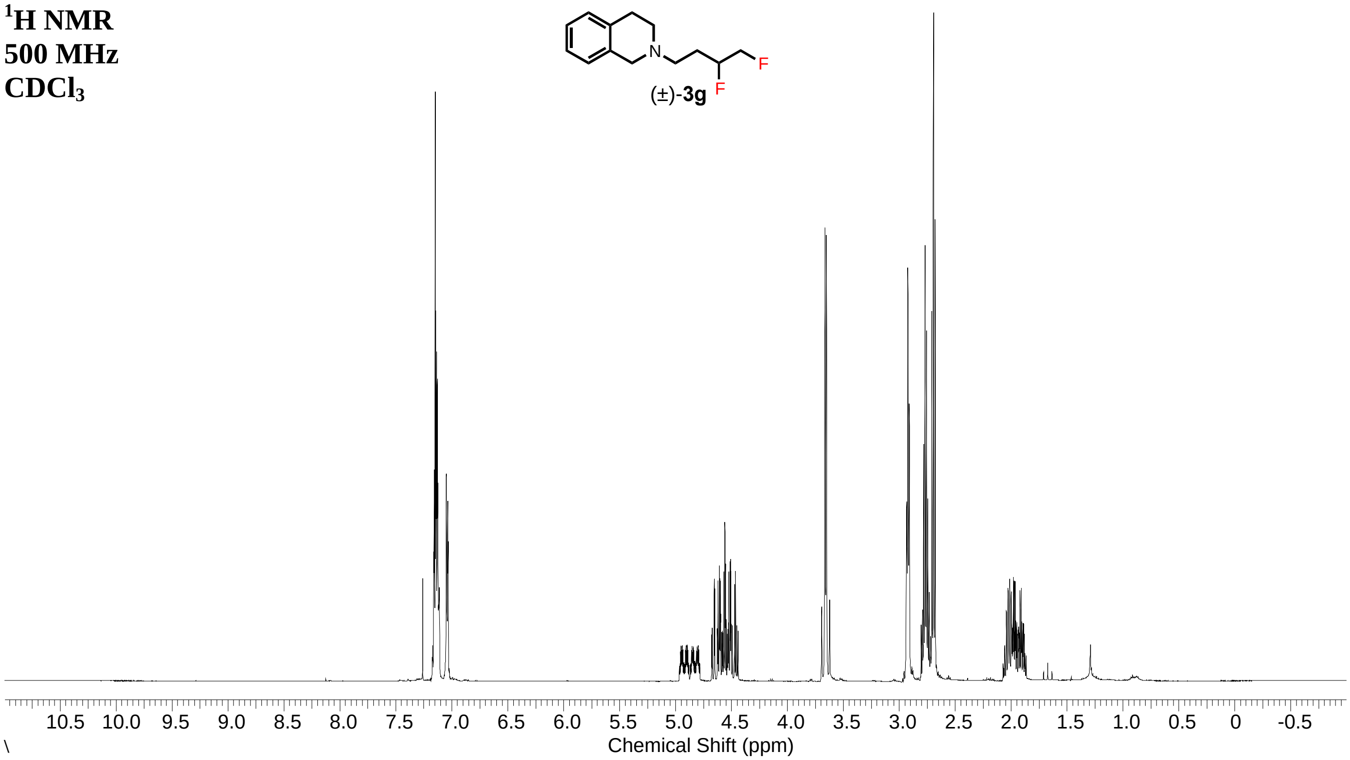
(±)-**3f**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



^{1}H NMR
500 MHz
$CDCl_3$



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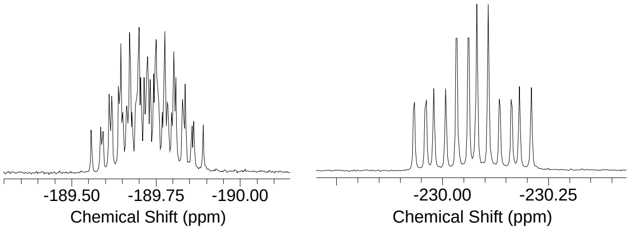
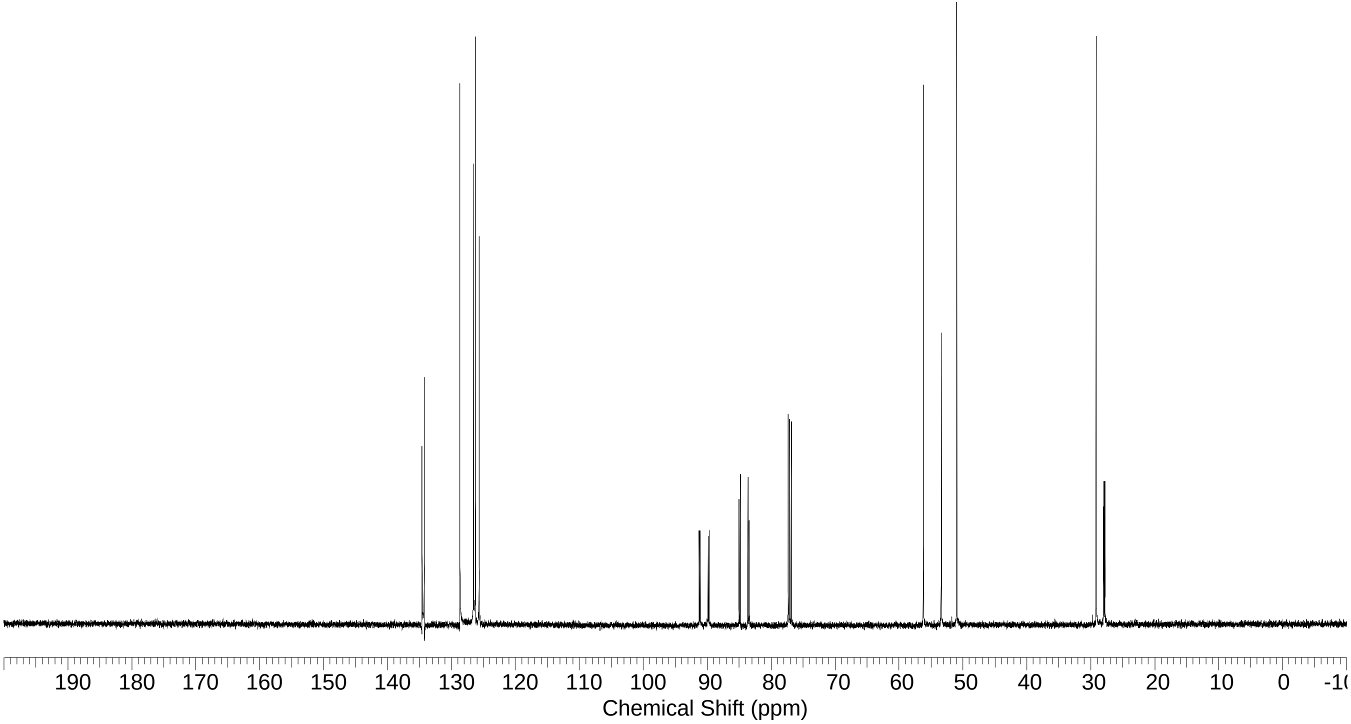
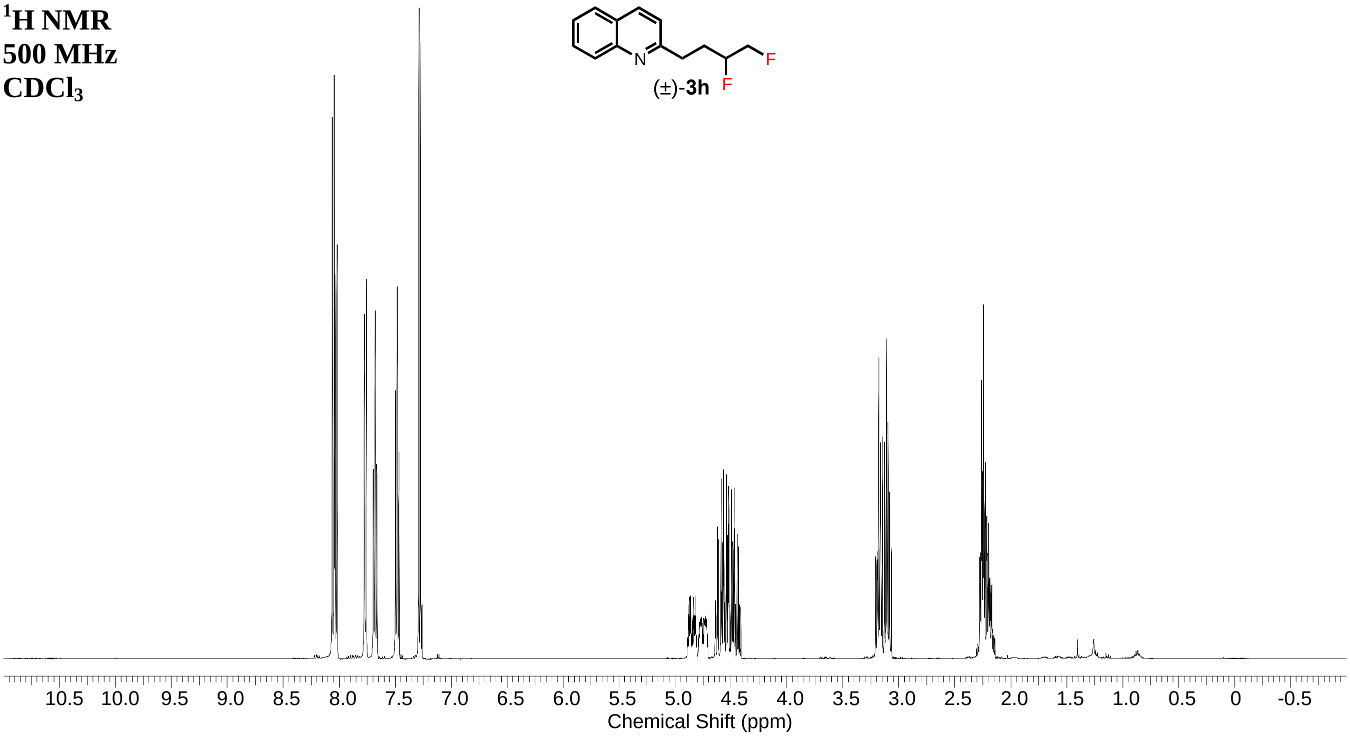
^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



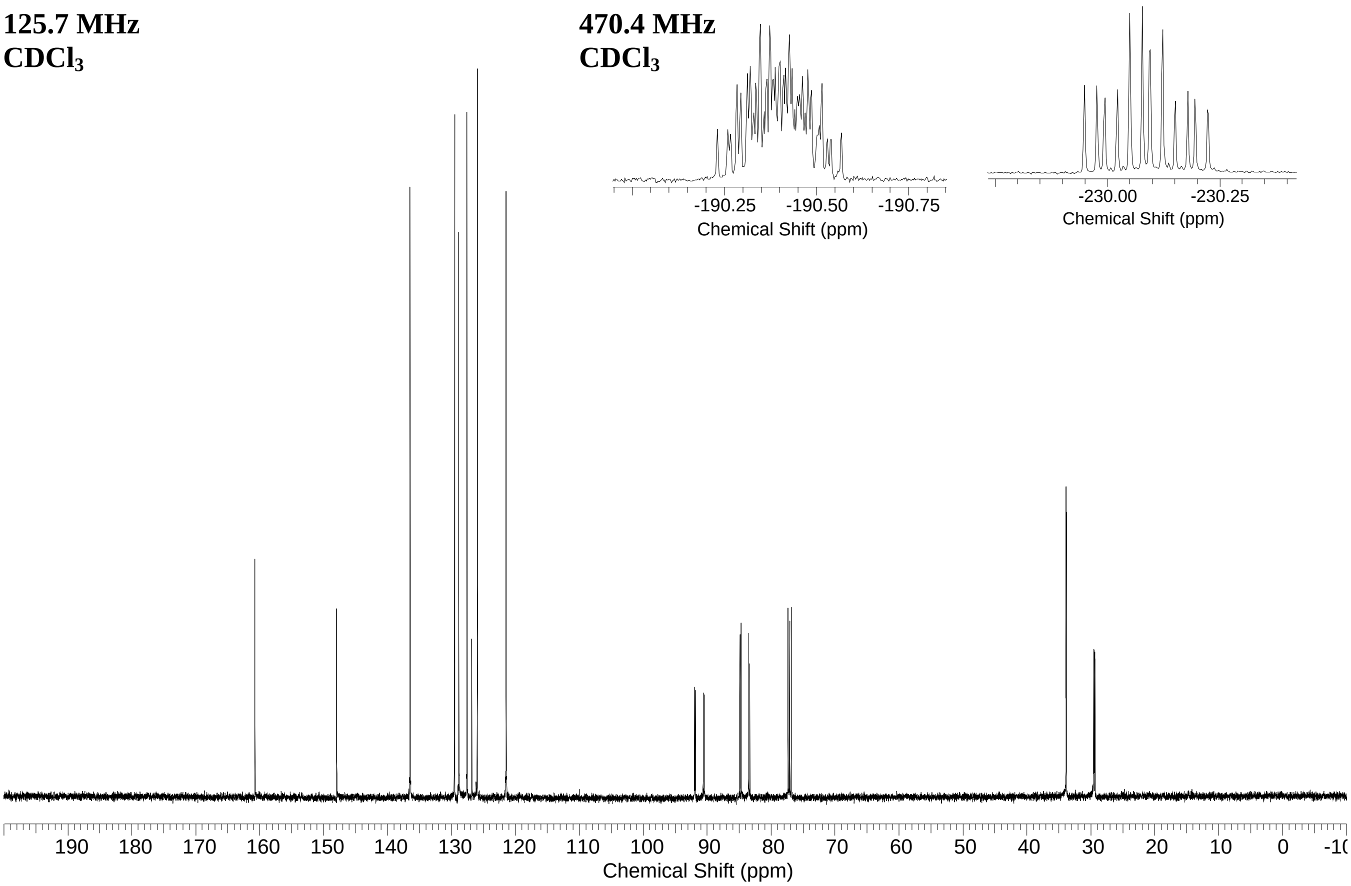


^{1}H NMR
500 MHz
CDCl$_3$

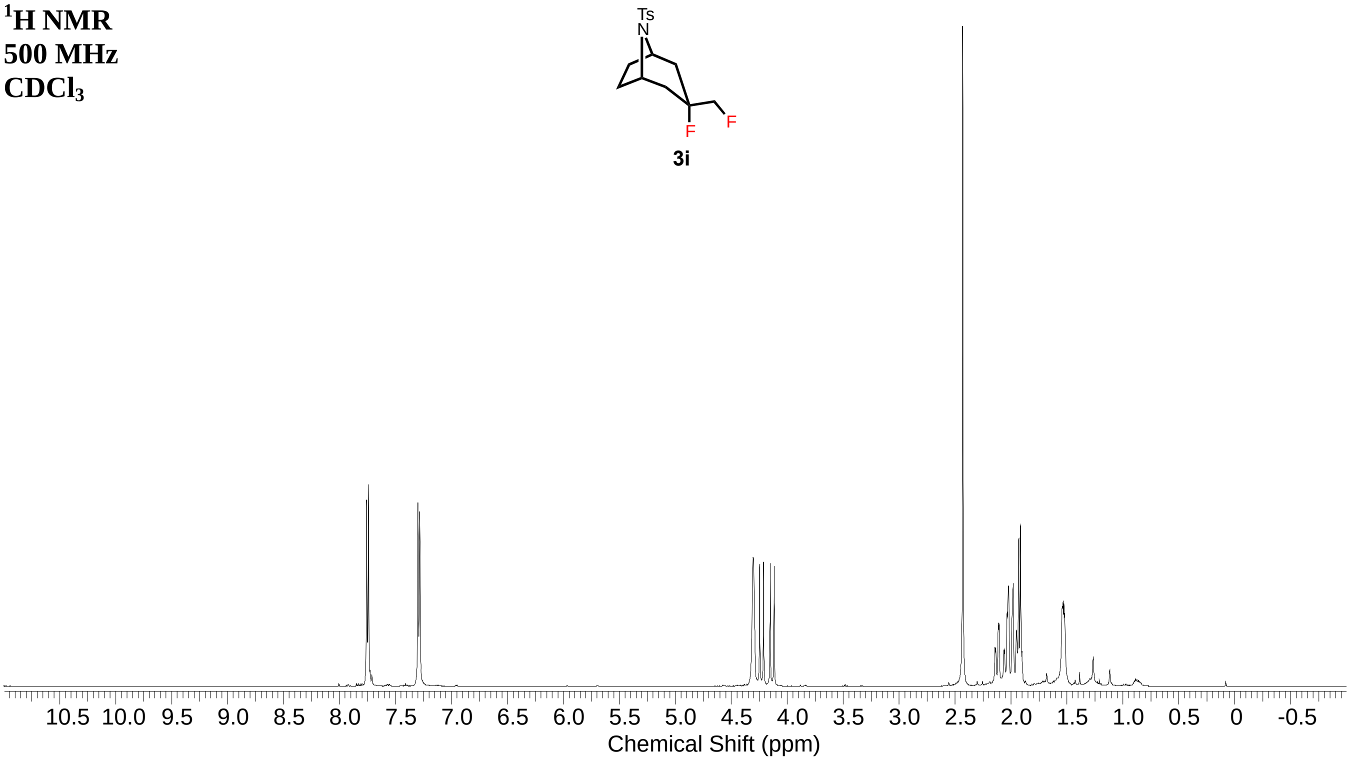


^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$

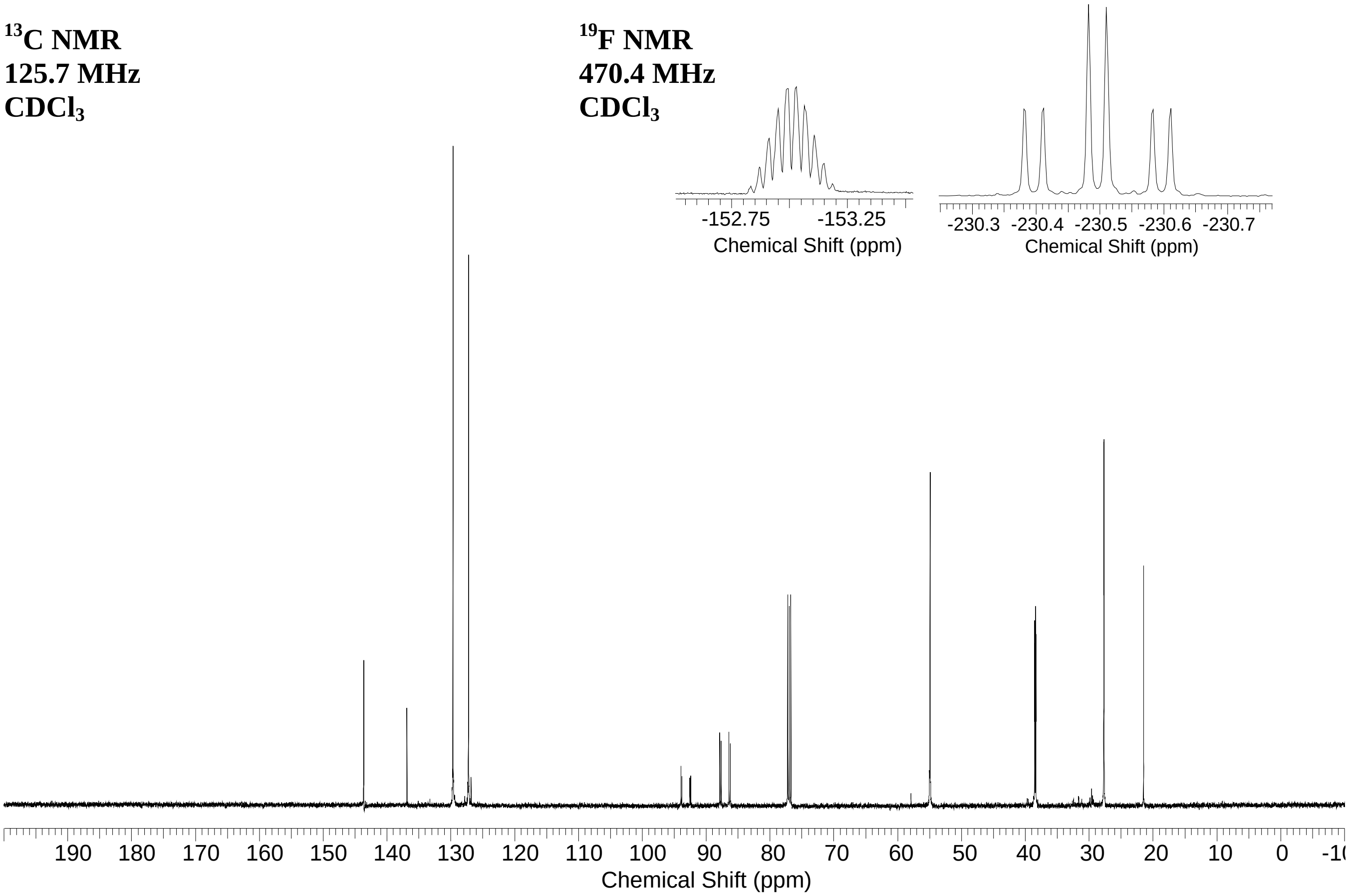


^{1}H NMR
500 MHz
$CDCl_3$

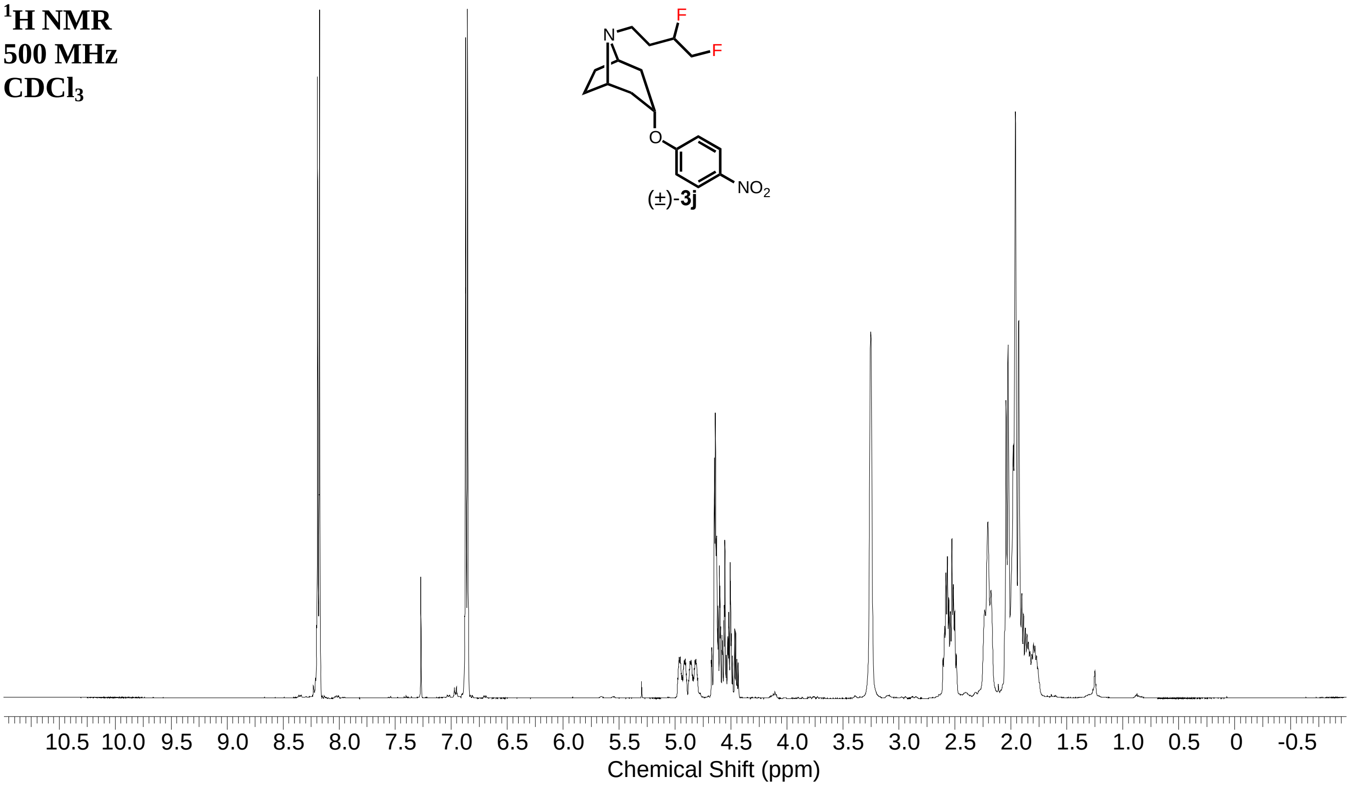


^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



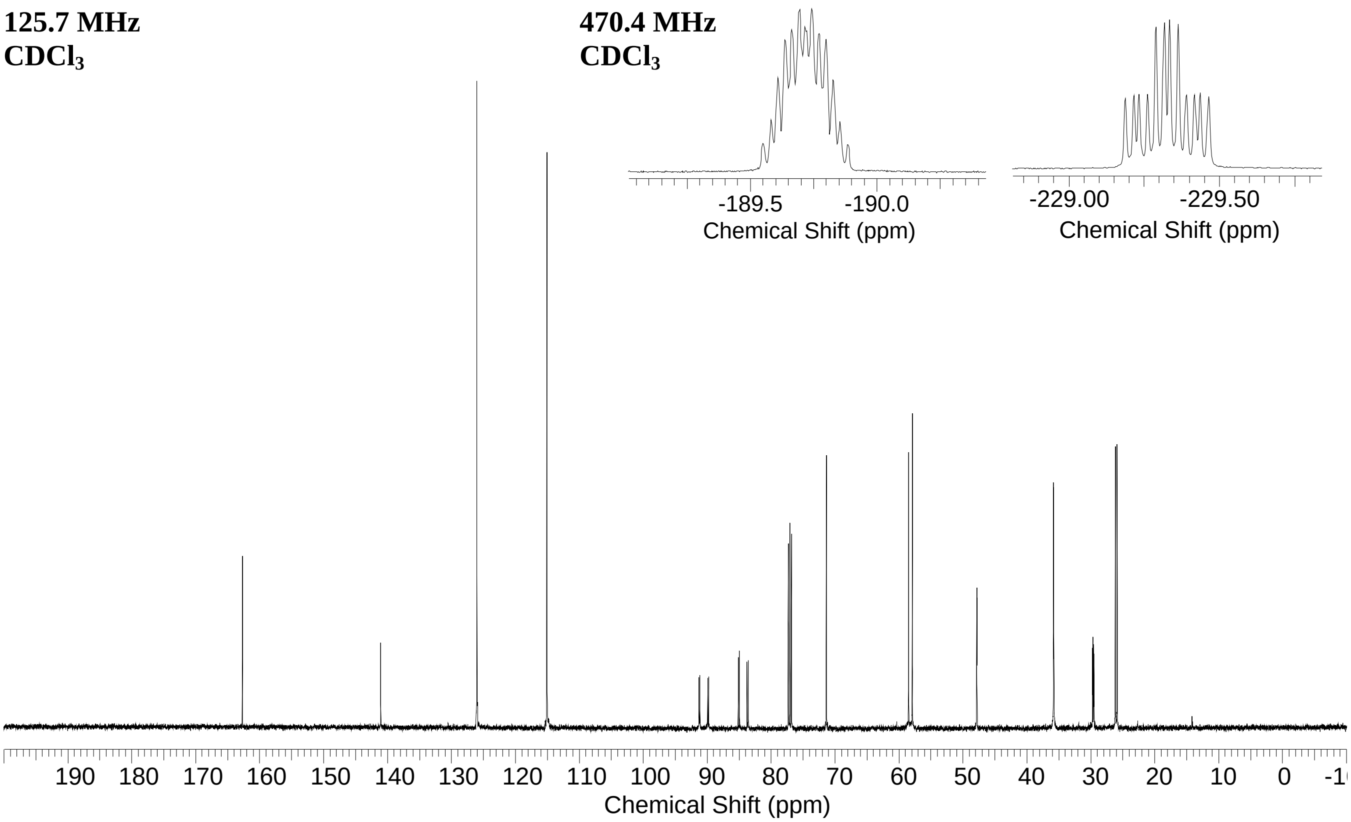
^{1}H NMR
500 MHz
CDCl$_3$



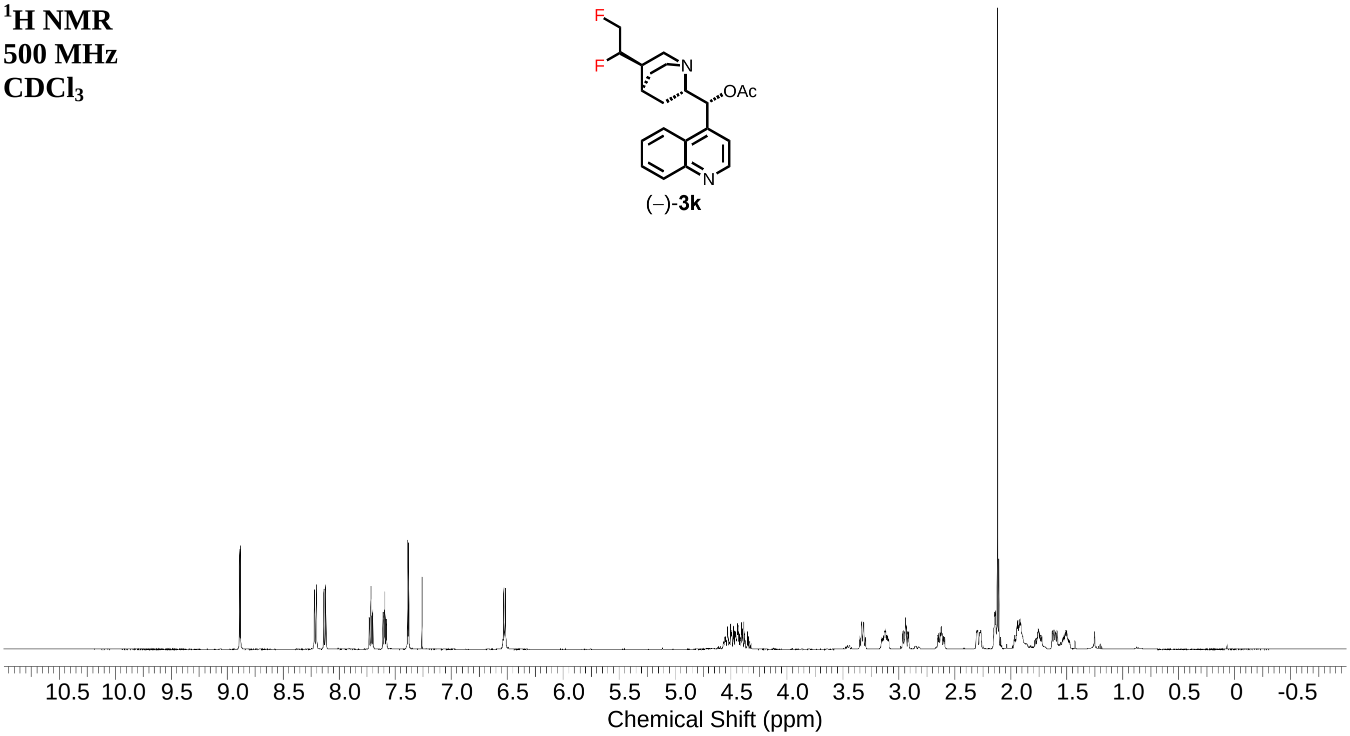
(±)-**3j**

^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



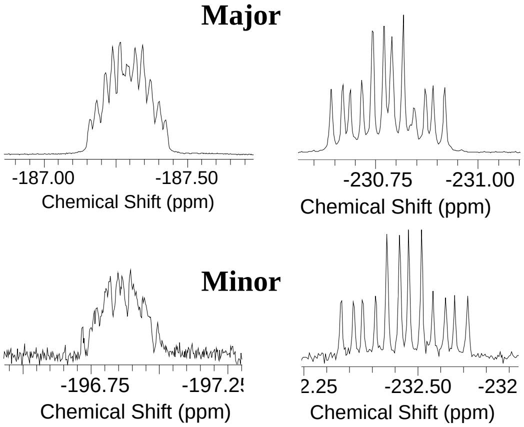
^{1}H NMR
500 MHz
$CDCl_3$

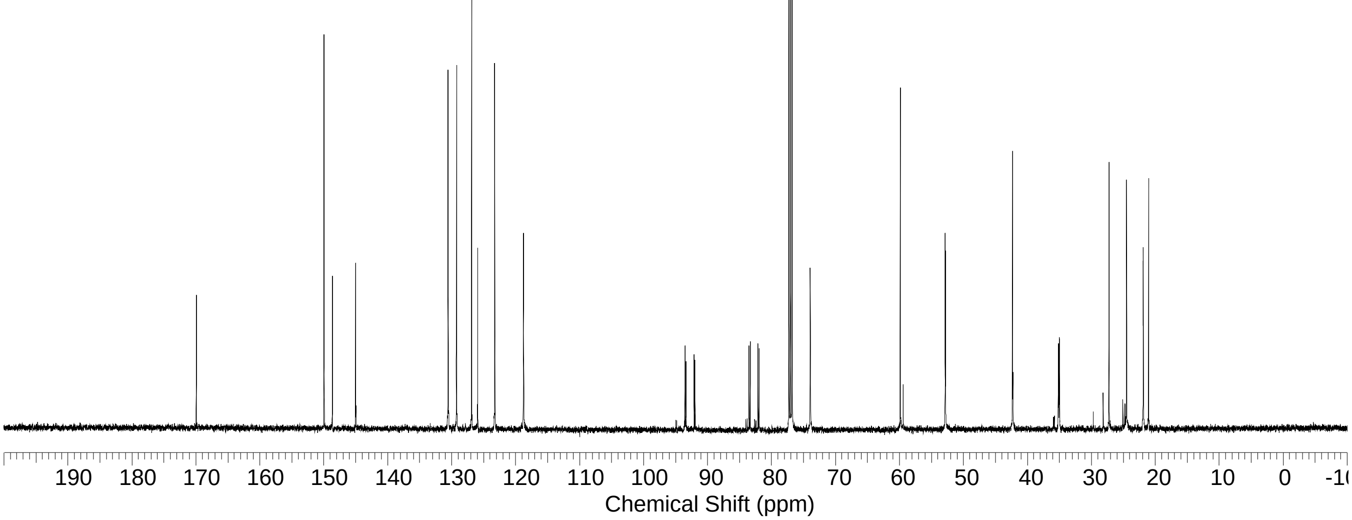


(–)-**3k**

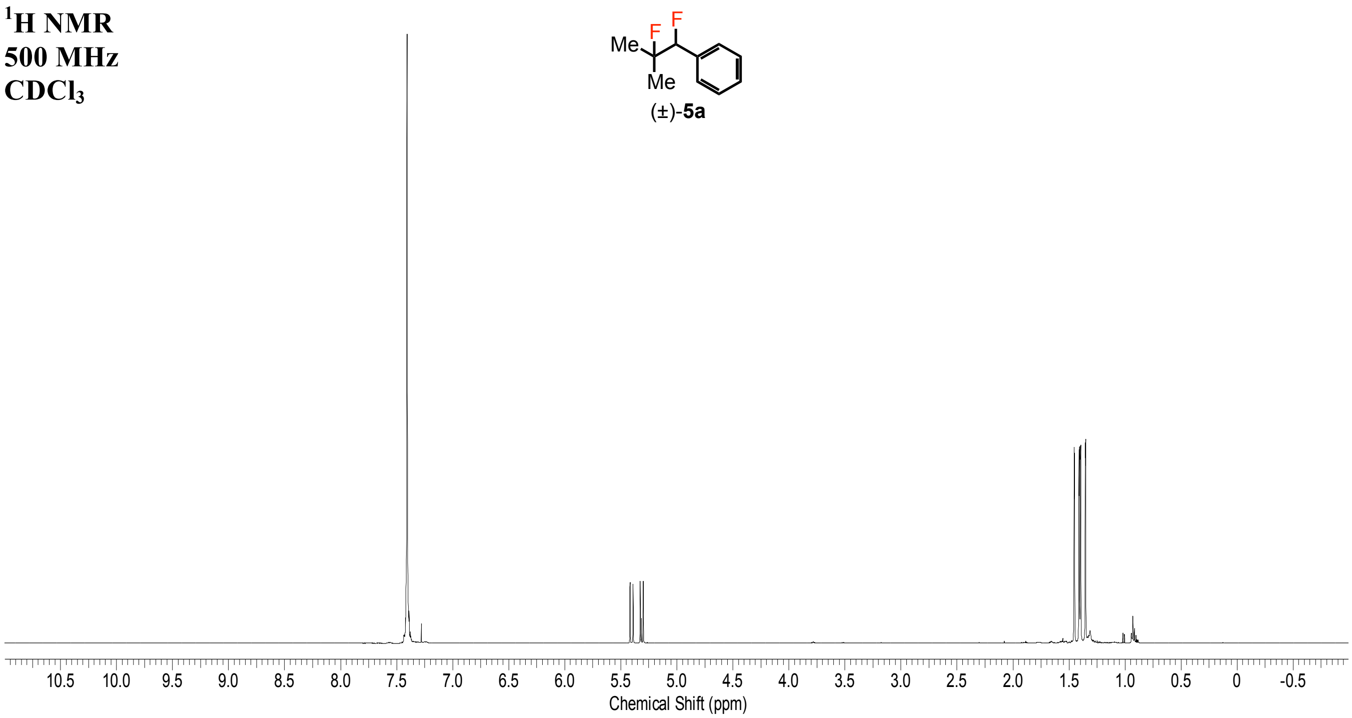
^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$





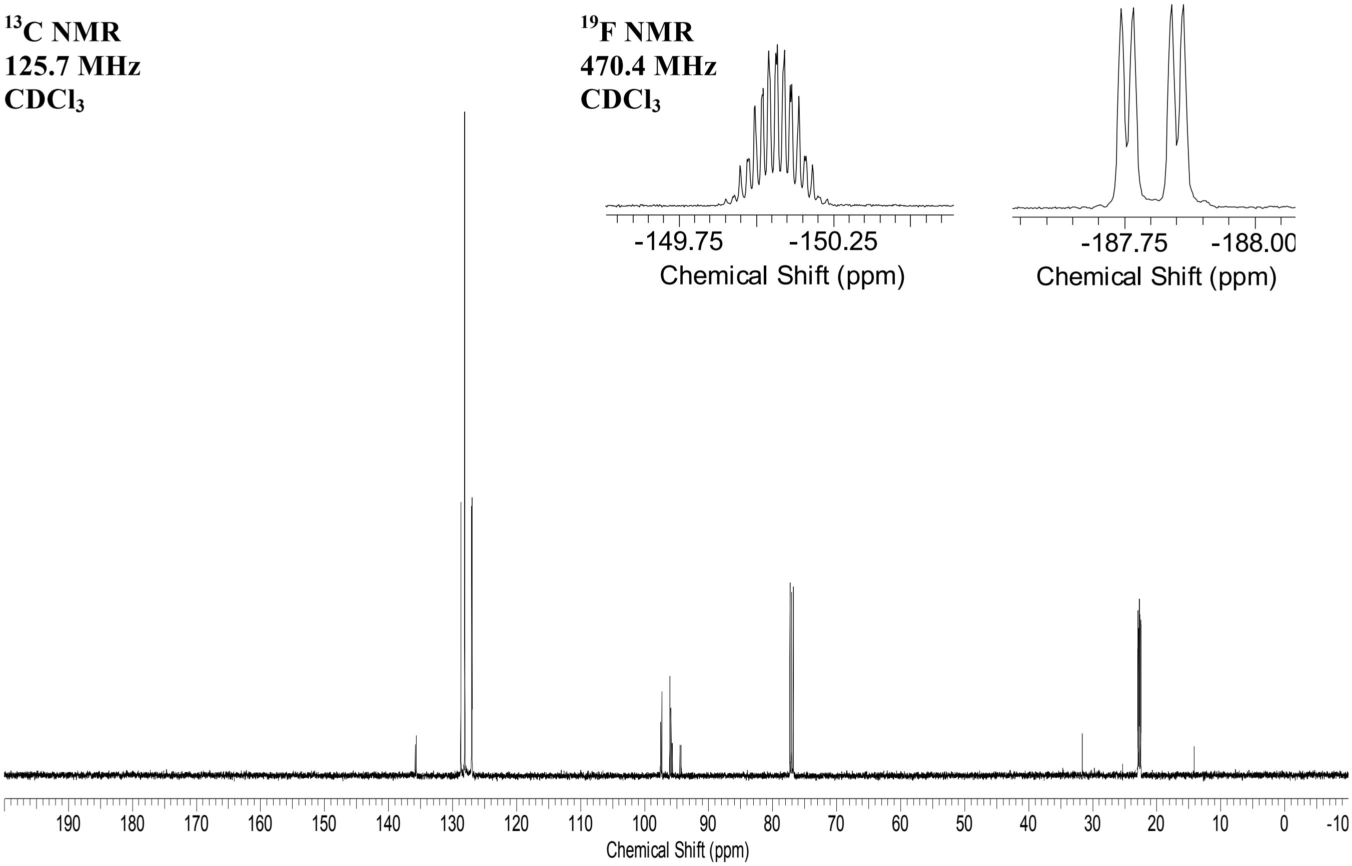
^{1}H NMR
500 MHz
CDCl$_3$



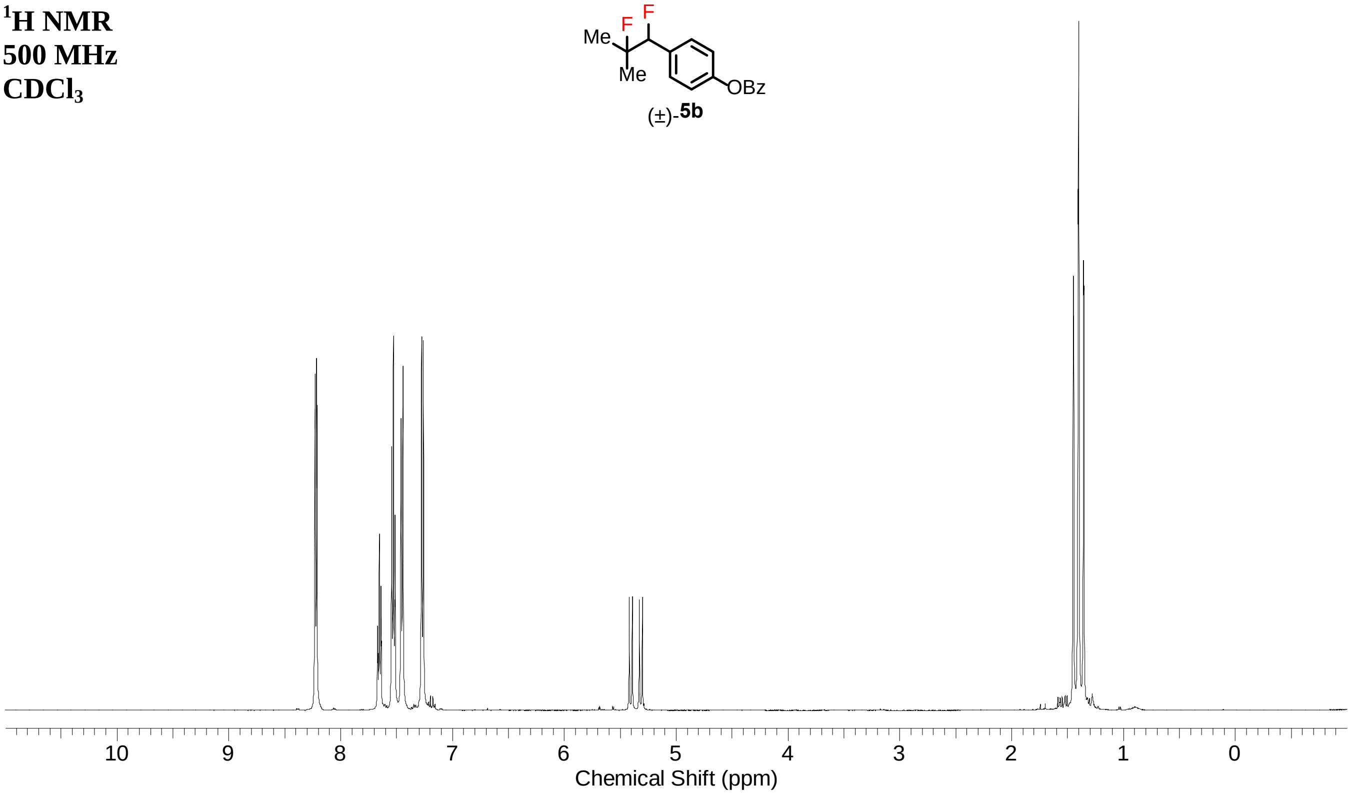
(±)-**5a**

^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$

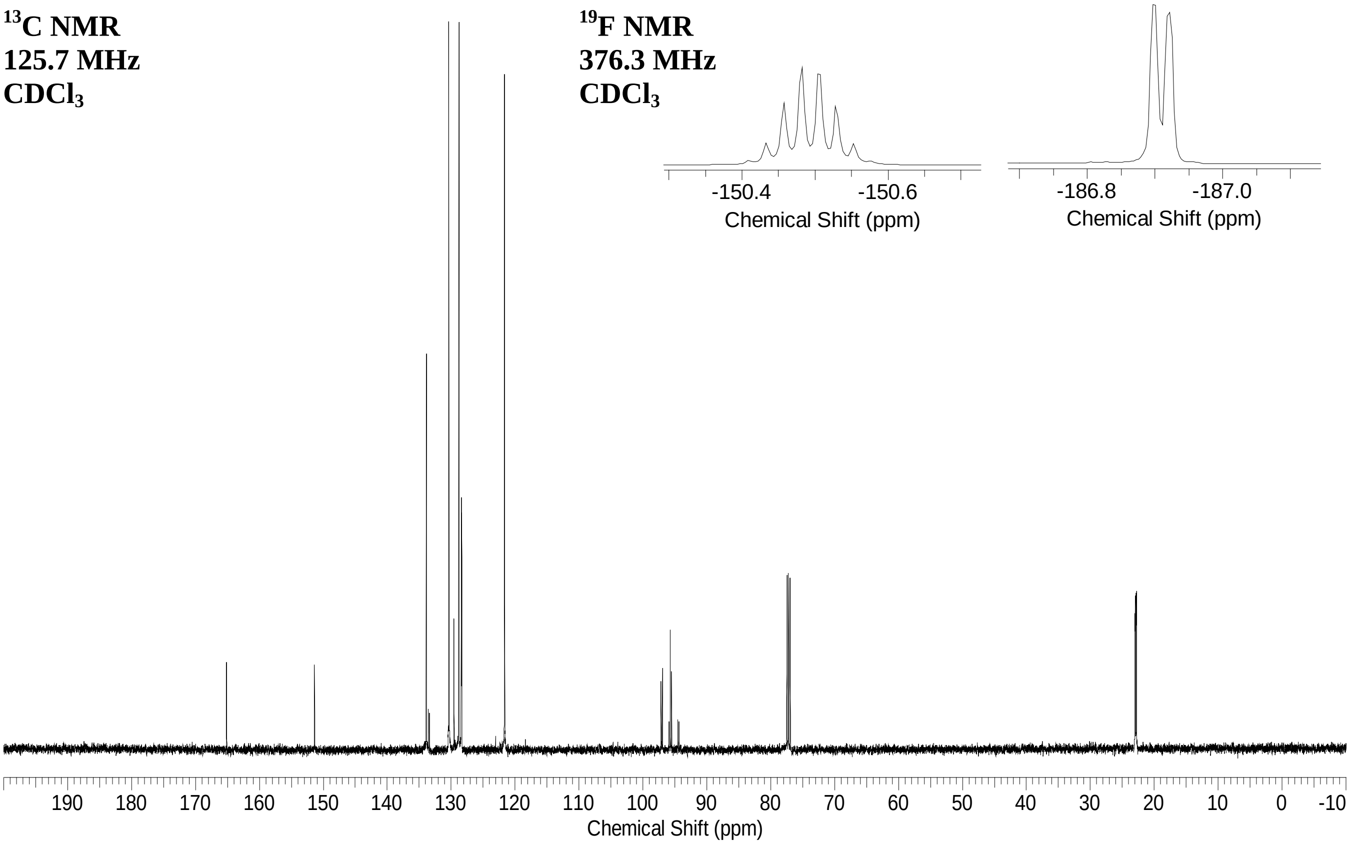


^{1}H NMR
500 MHz
$CDCl_3$

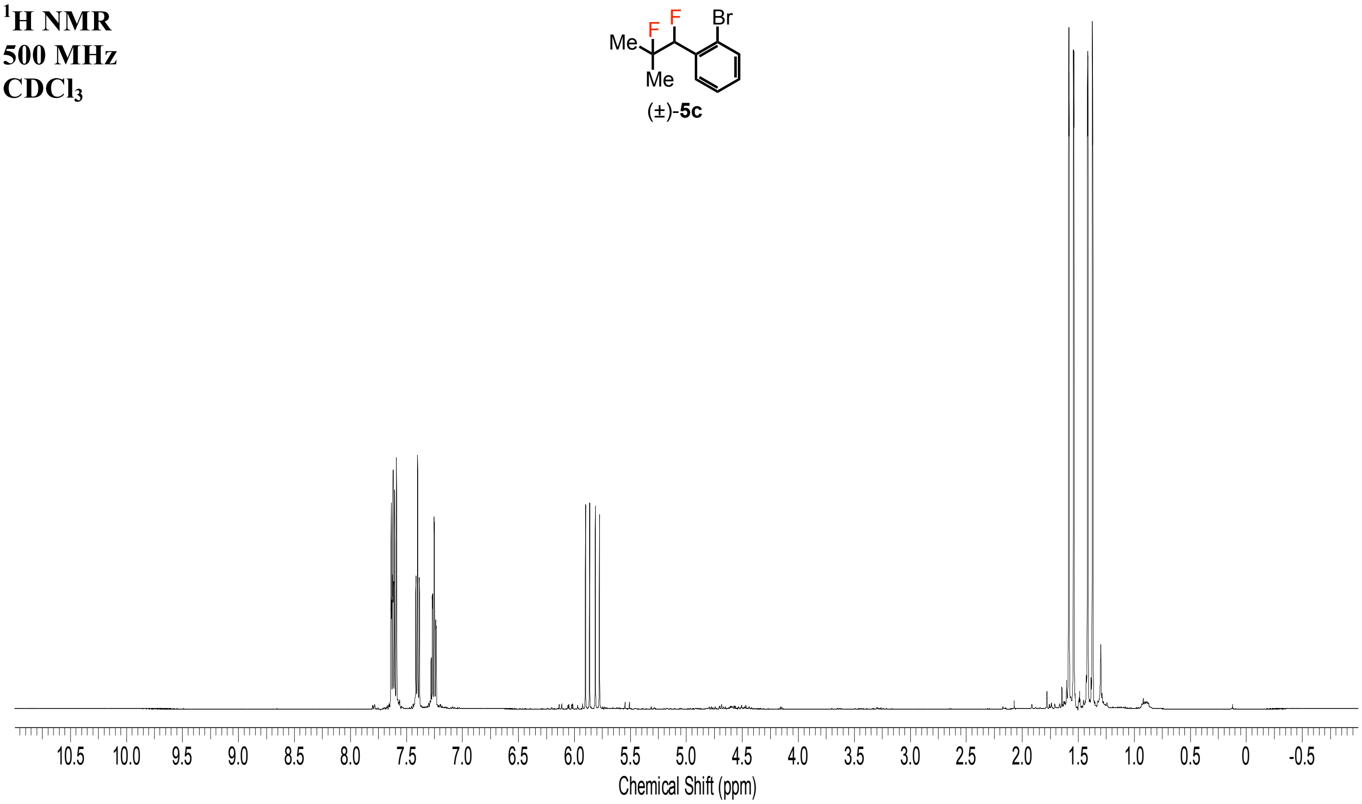


^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
376.3 MHz
$CDCl_3$

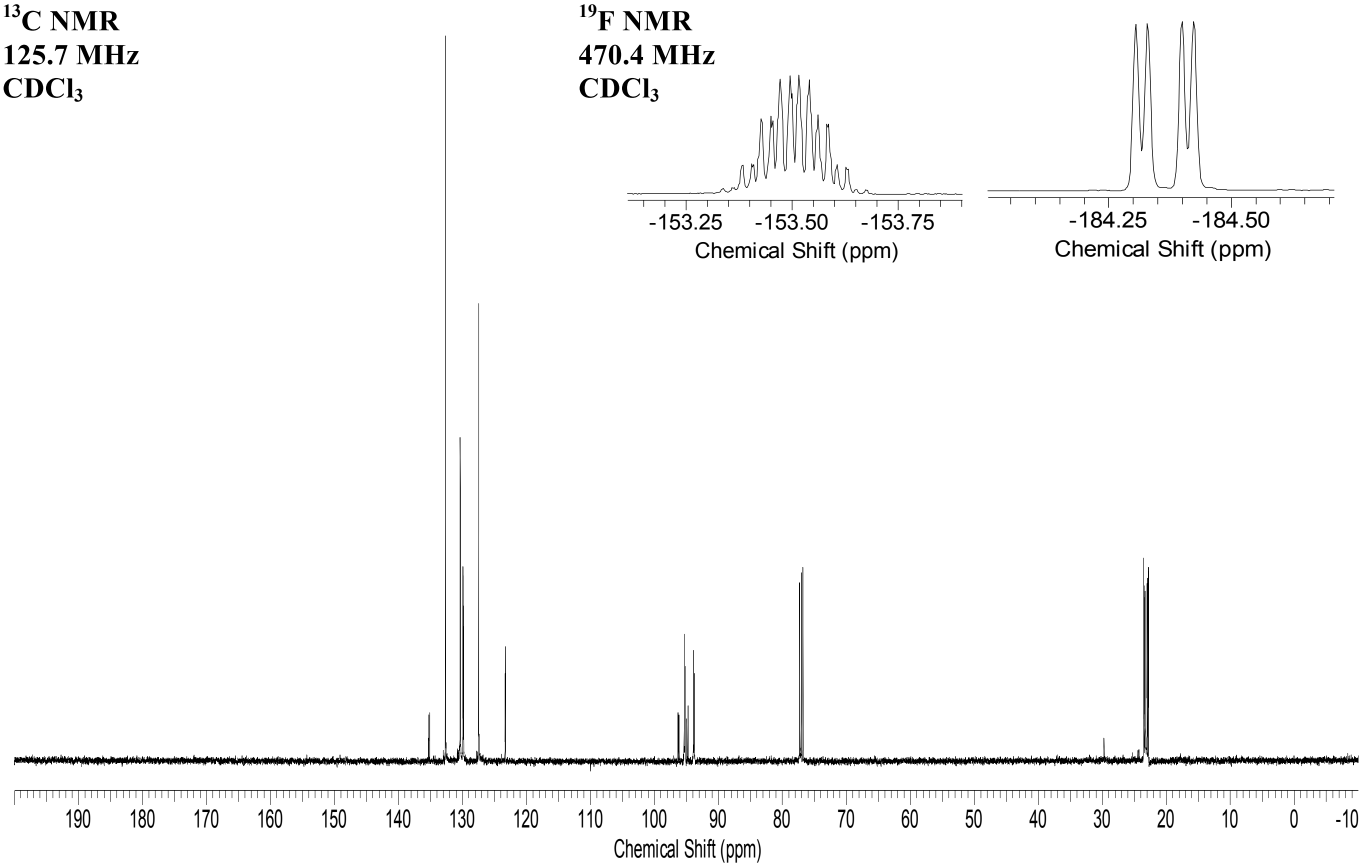


^{1}H NMR
500 MHz
CDCl$_3$

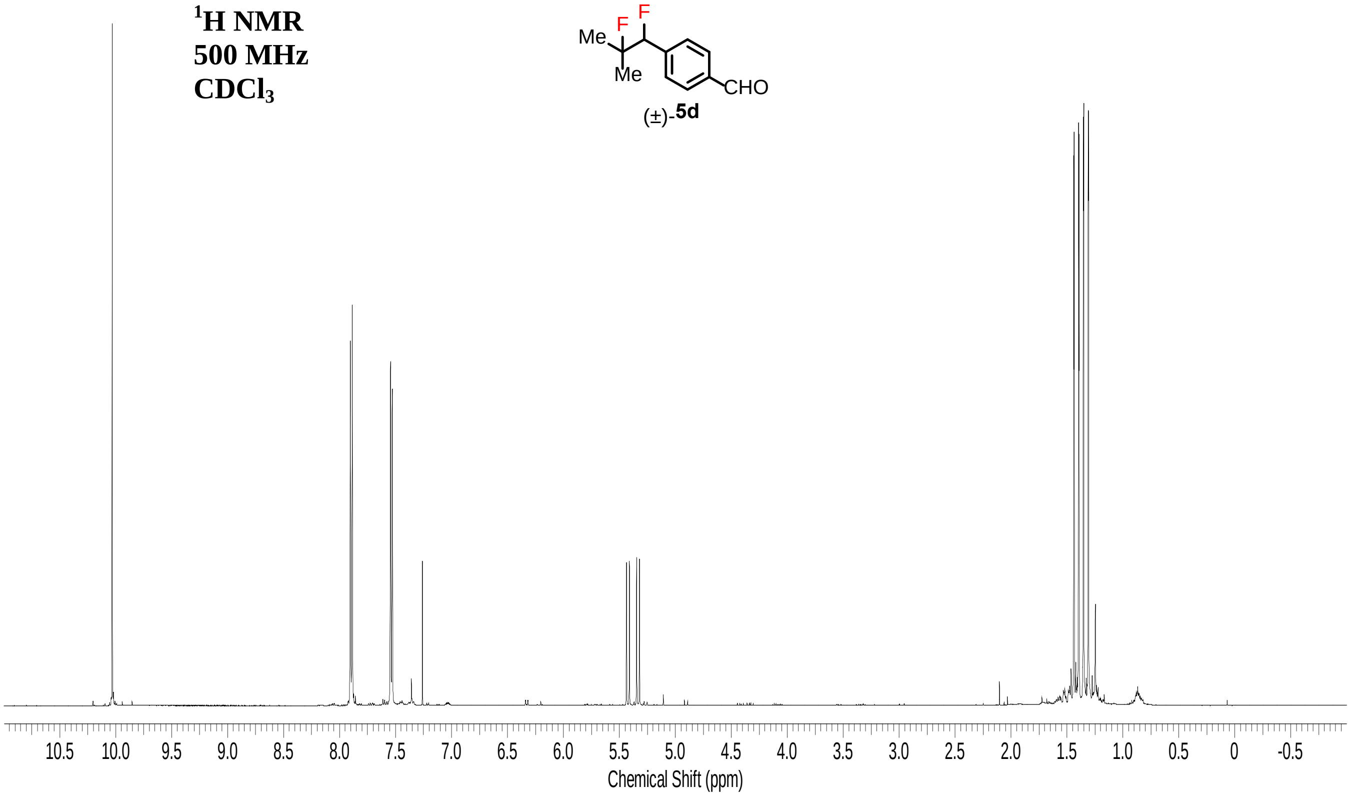


^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



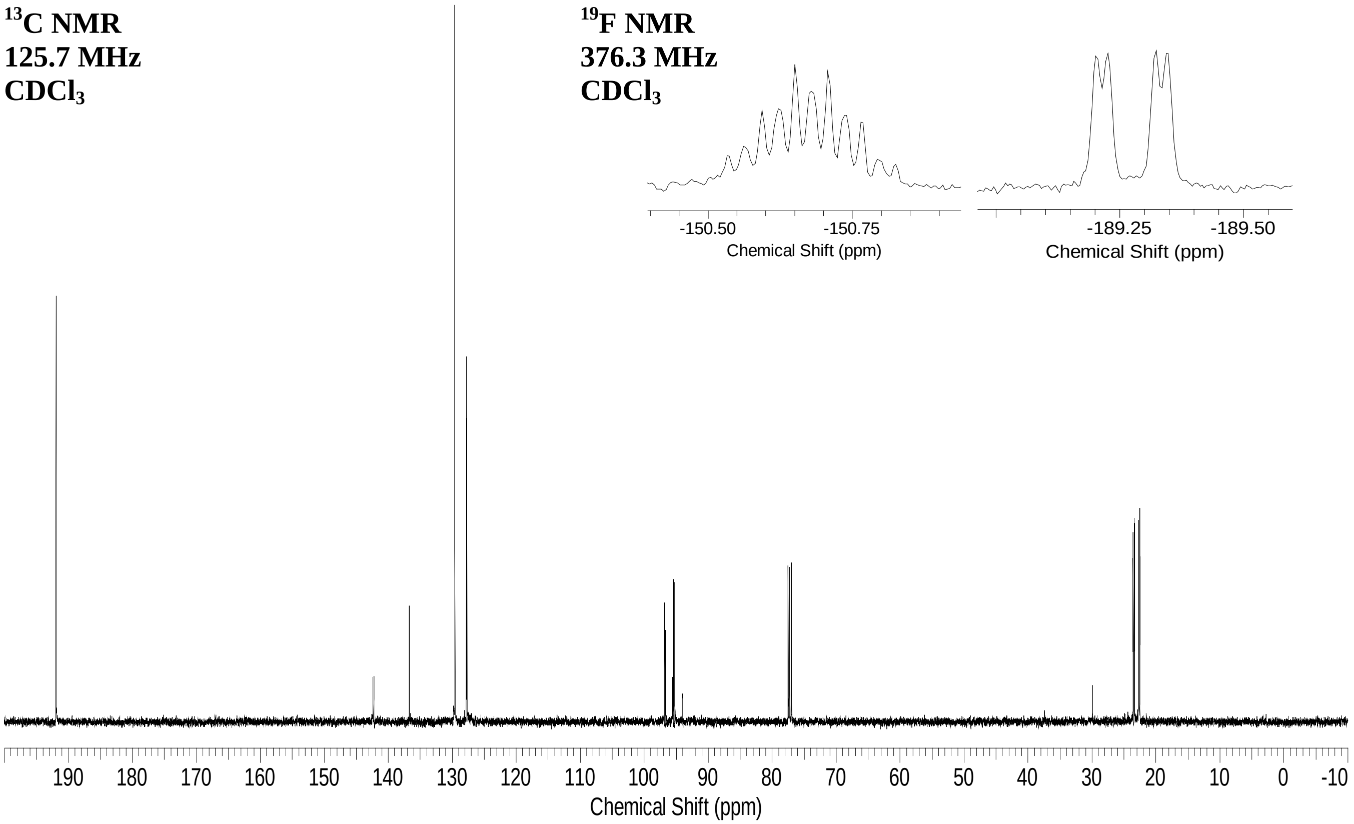
^{1}H NMR
500 MHz
$CDCl_3$



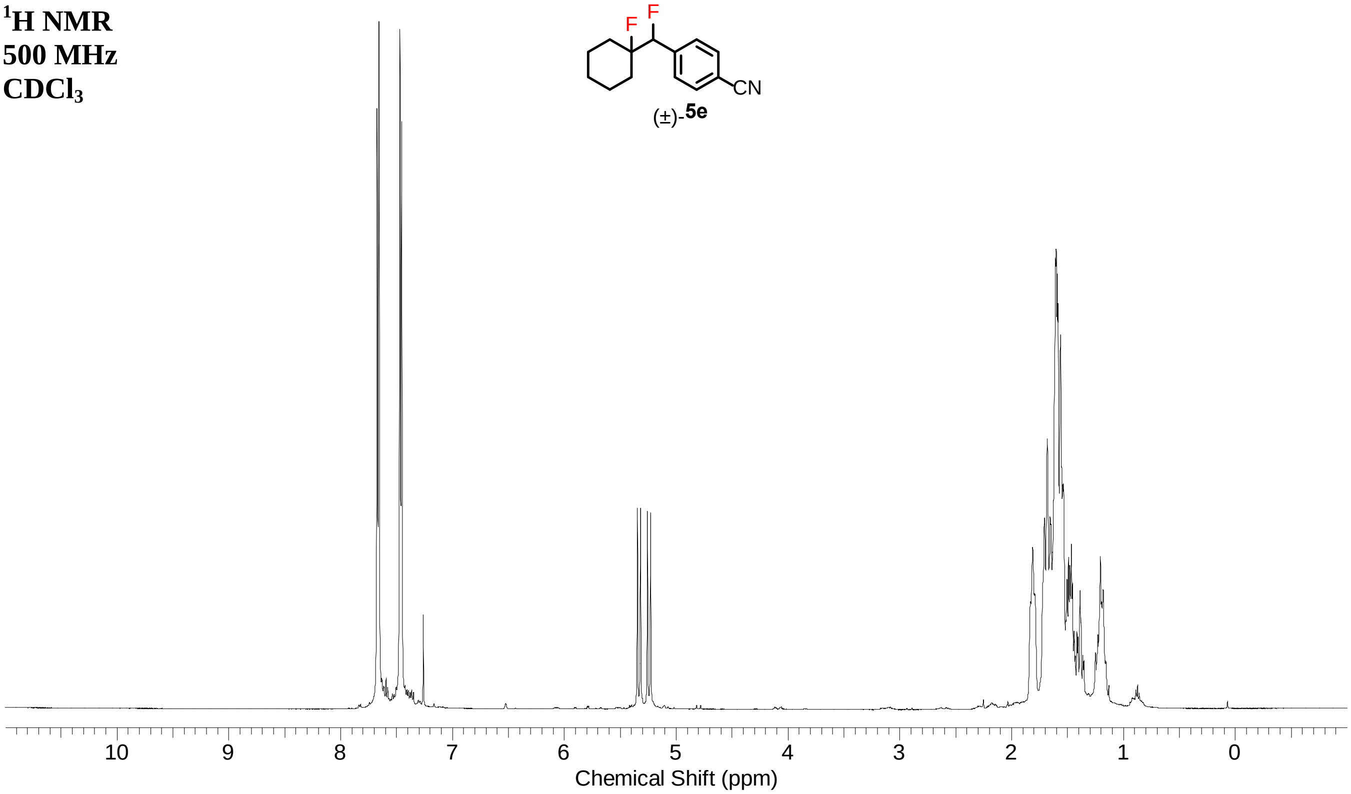
(±)-**5d**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
376.3 MHz
$CDCl_3$

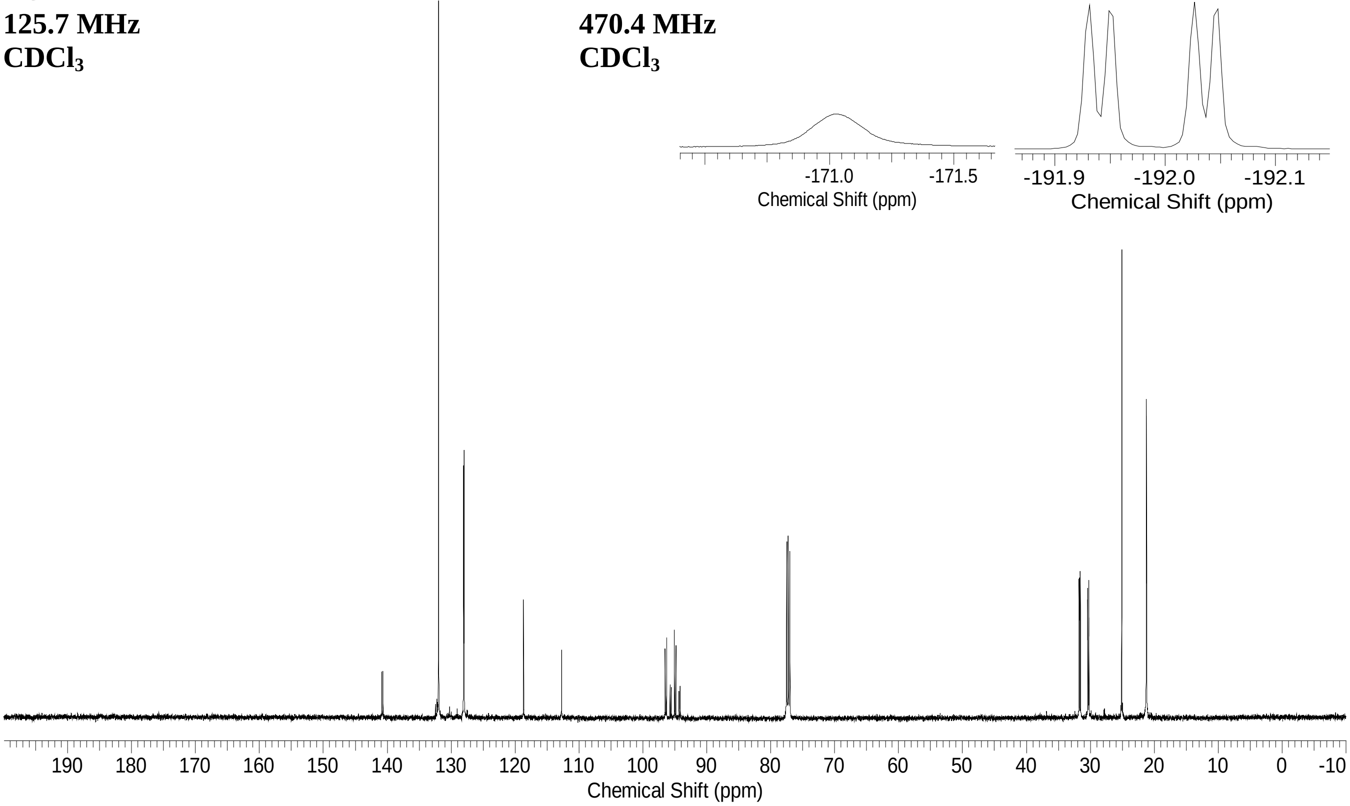


^{1}H NMR
500 MHz
$CDCl_3$

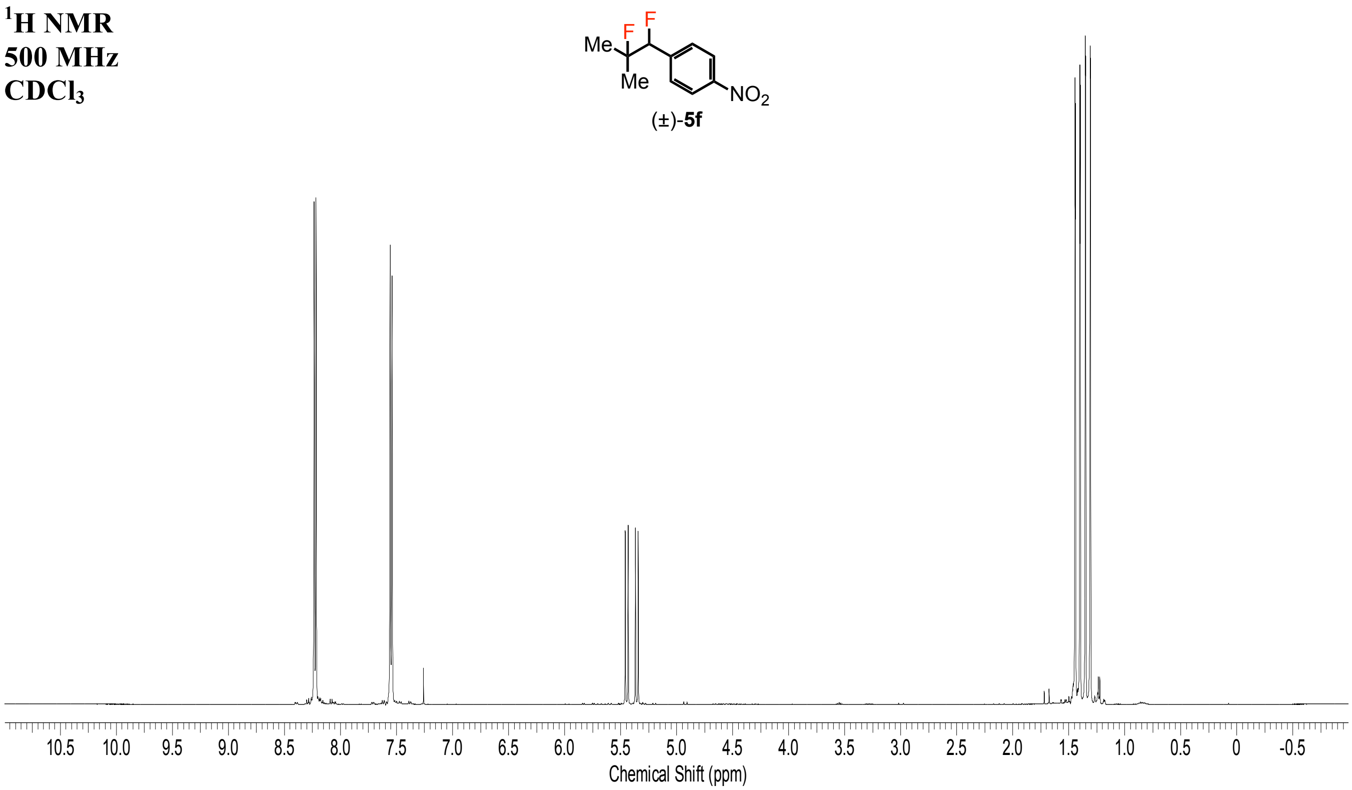


^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$

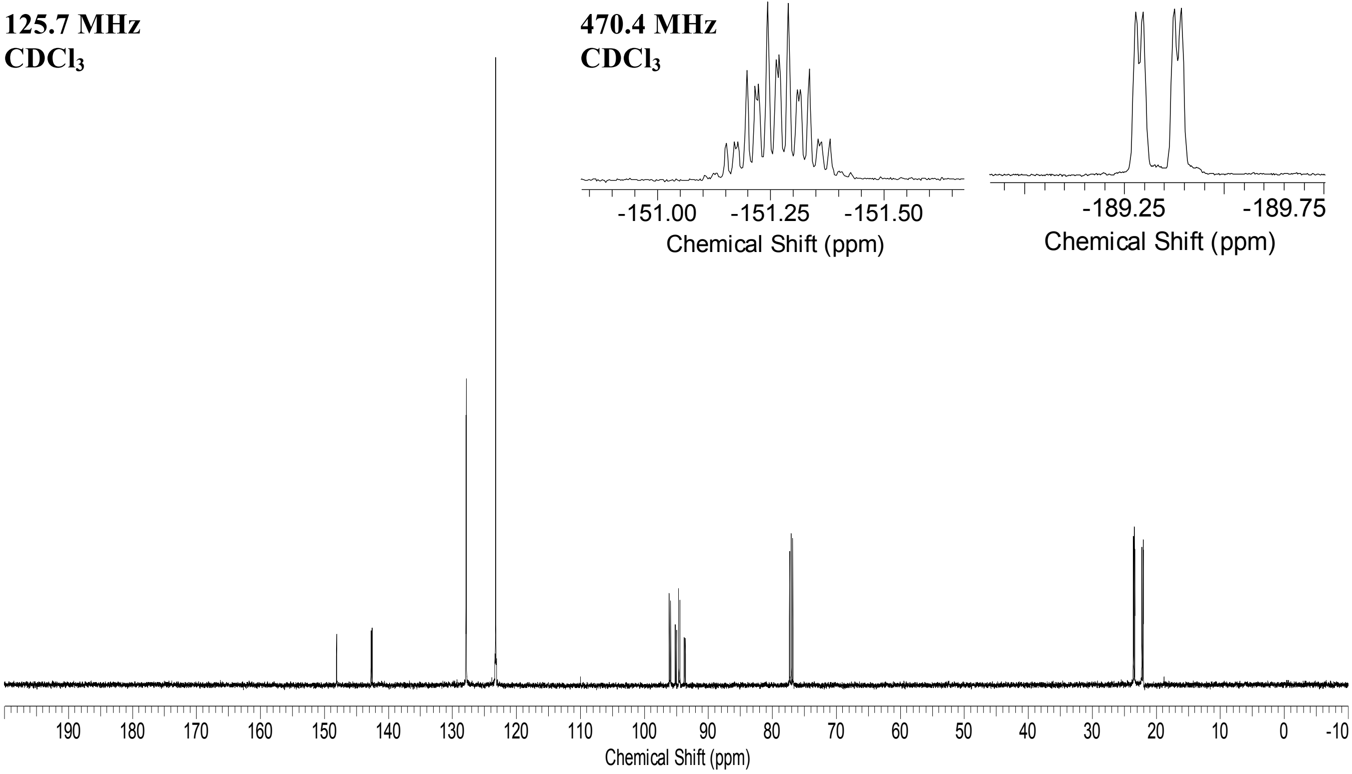


^{1}H NMR
500 MHz
$CDCl_3$

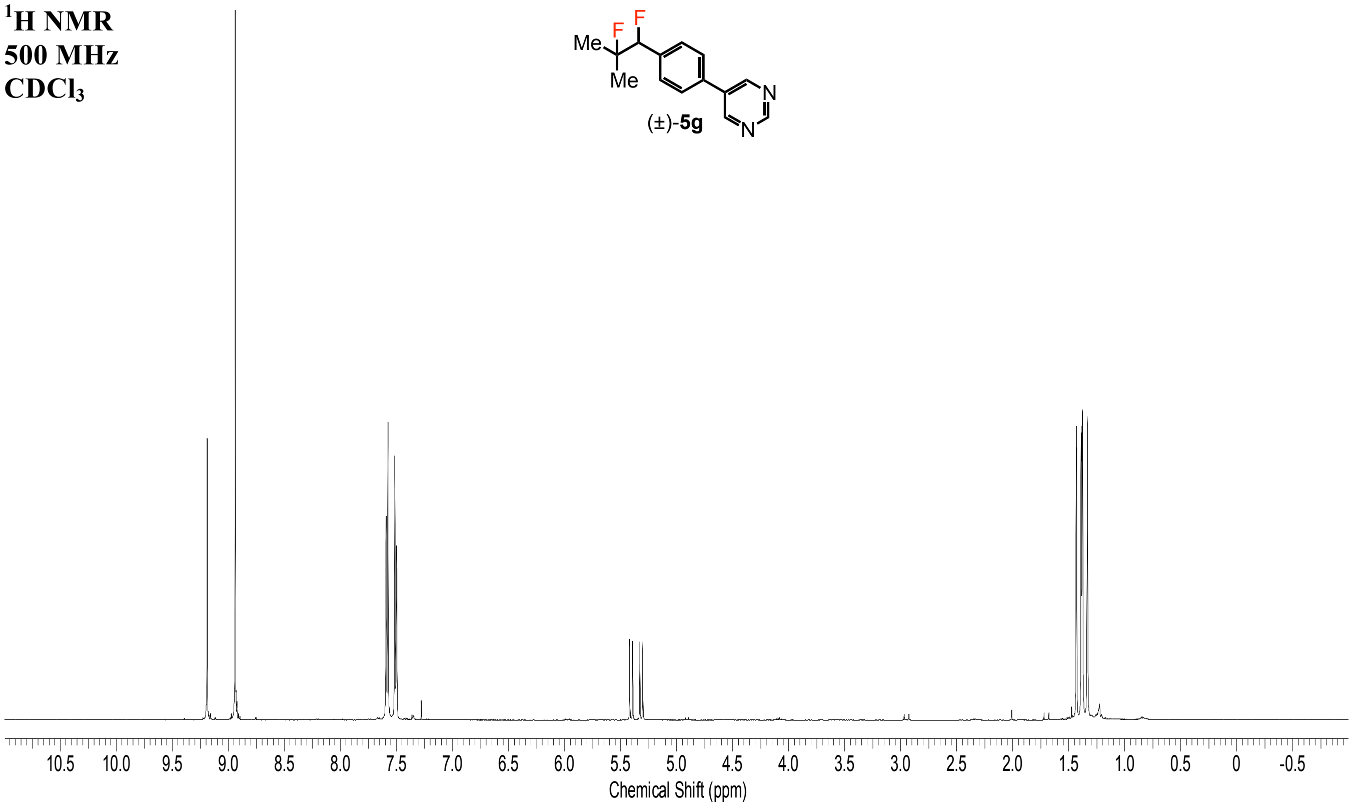


^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



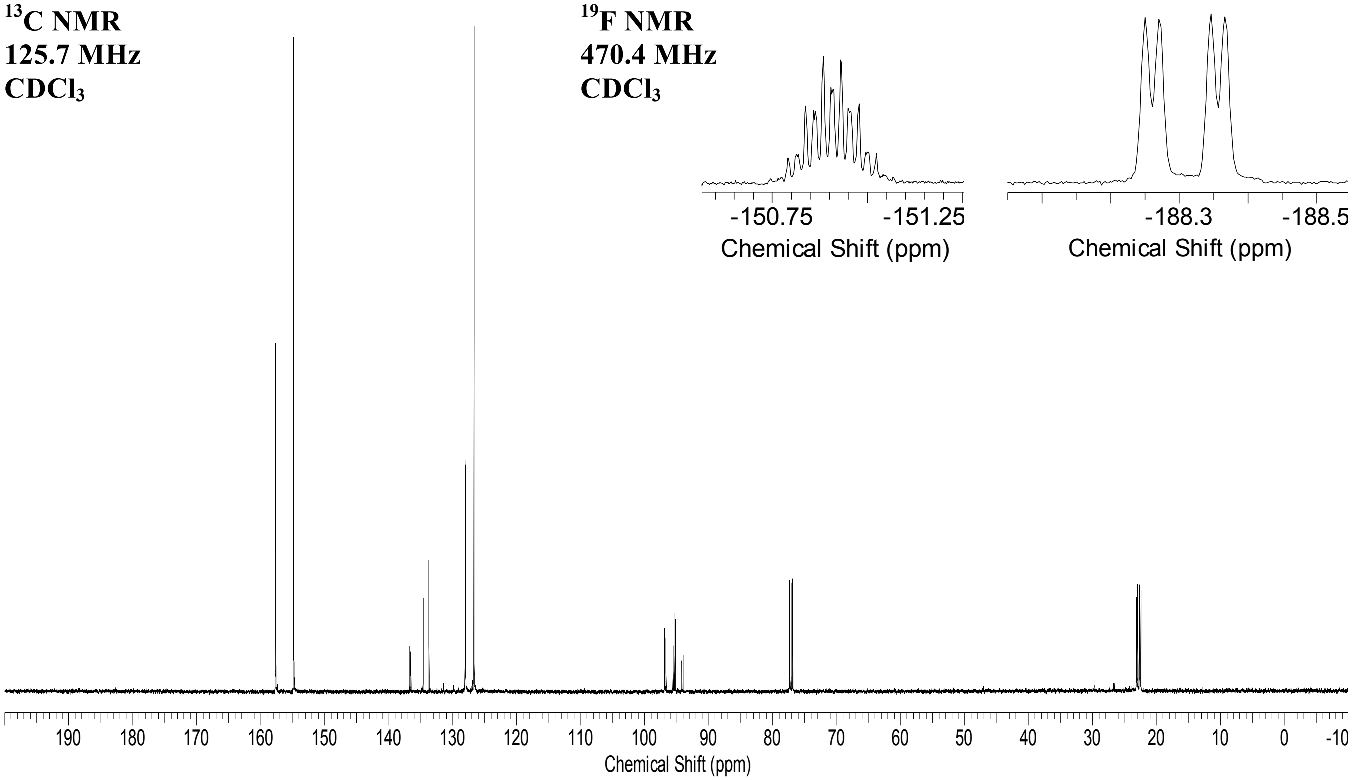
^{1}H NMR
500 MHz
CDCl$_3$



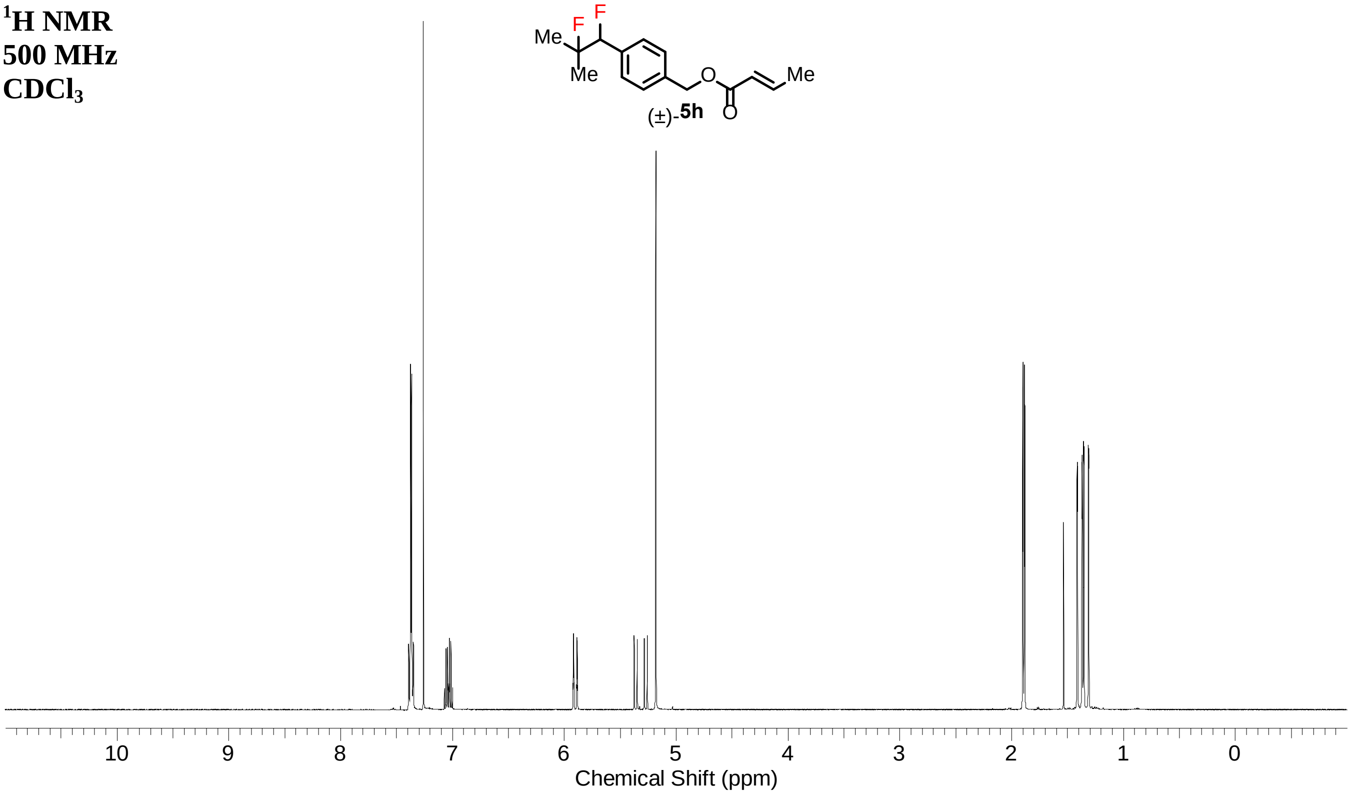
(±)-**5g**

^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



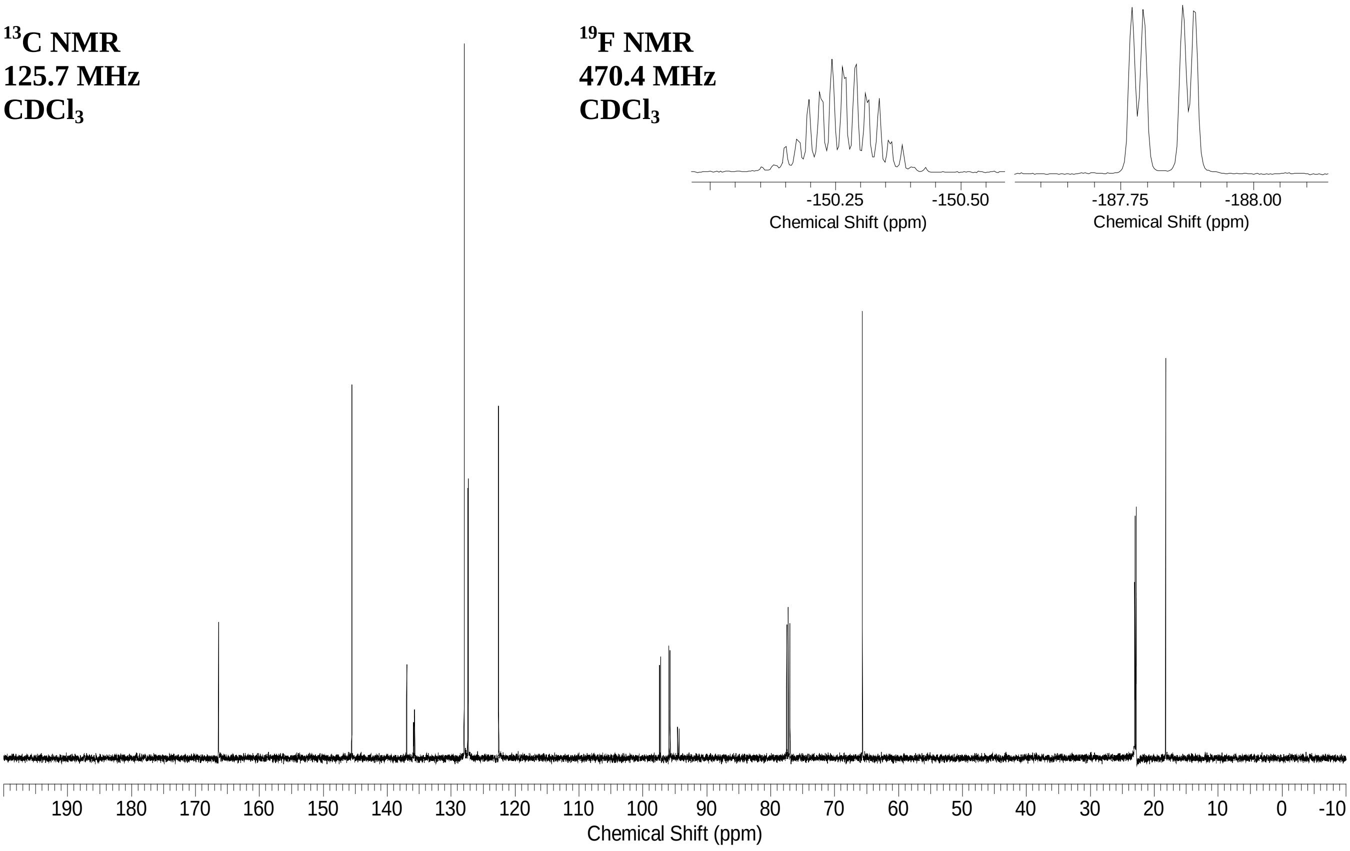
^{1}H NMR
500 MHz
$CDCl_3$



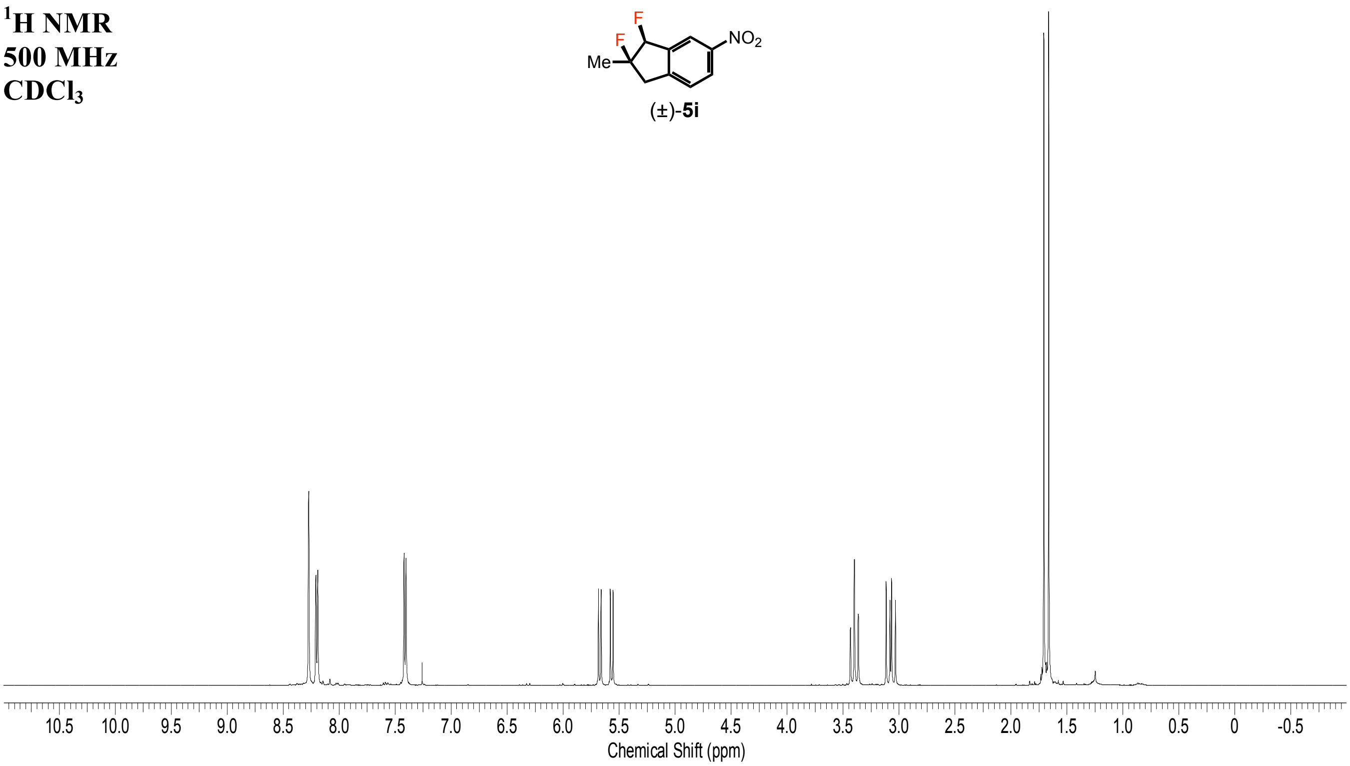
(±)-**5h**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



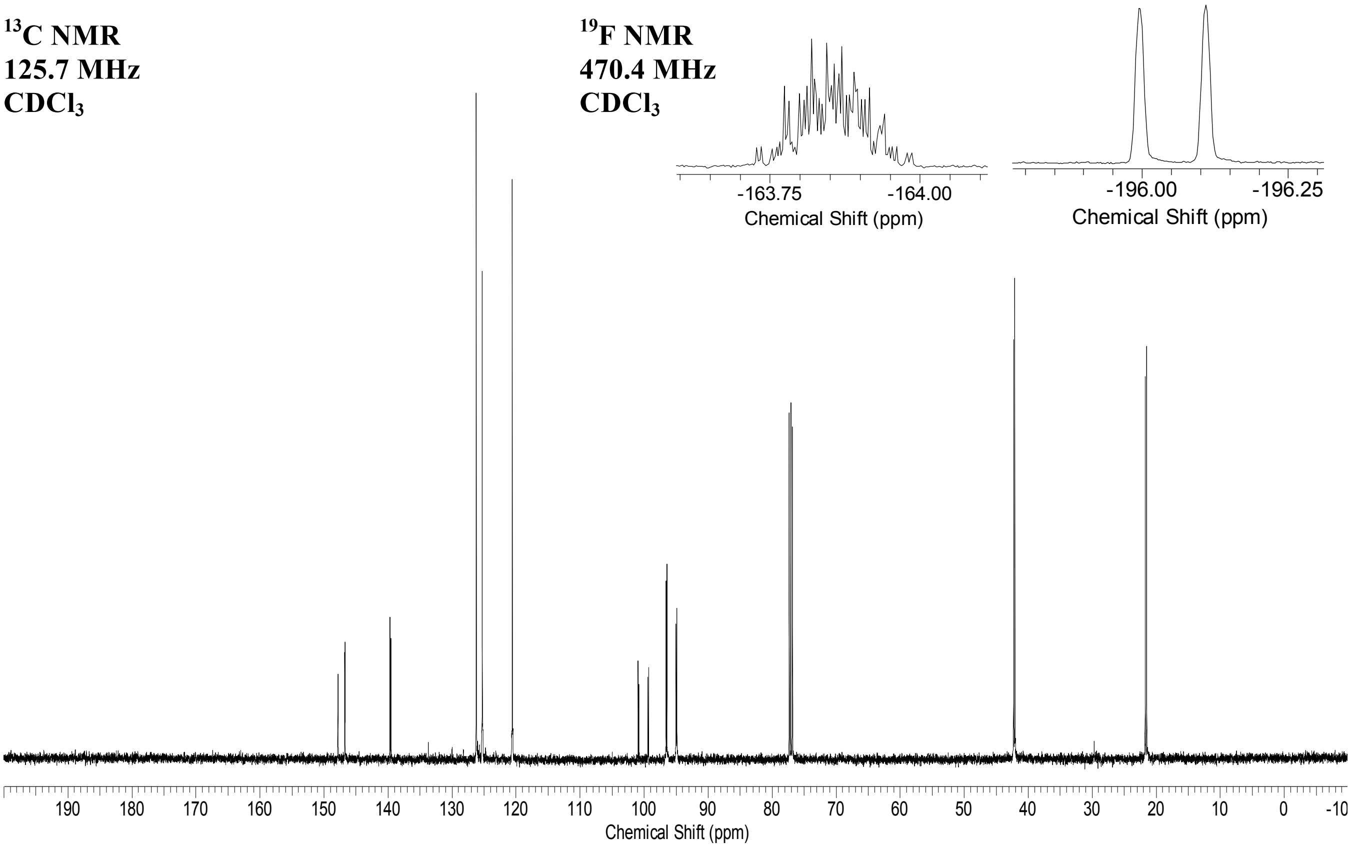
^{1}H NMR
500 MHz
$CDCl_3$



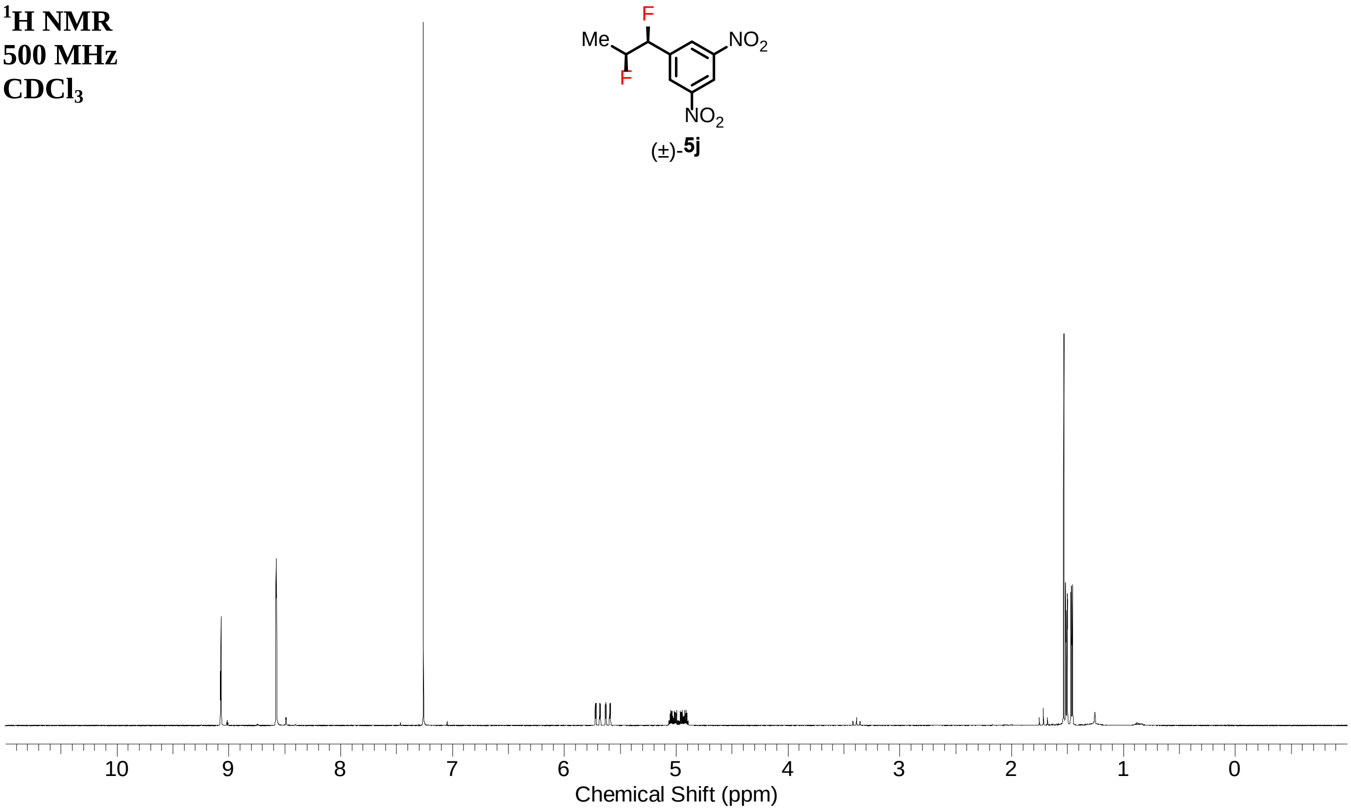
(±)-**5i**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



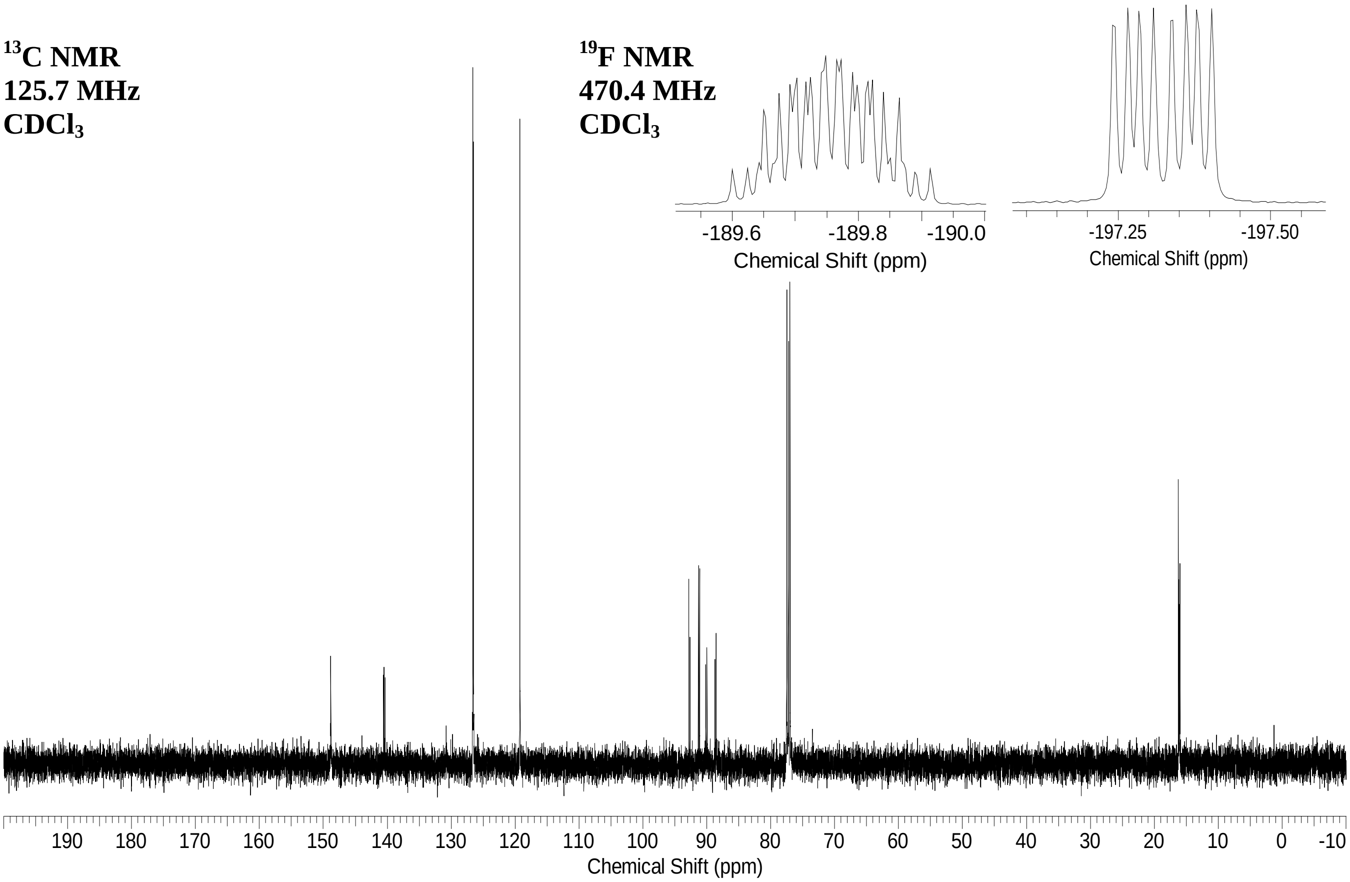
^{1}H NMR
500 MHz
CDCl$_3$



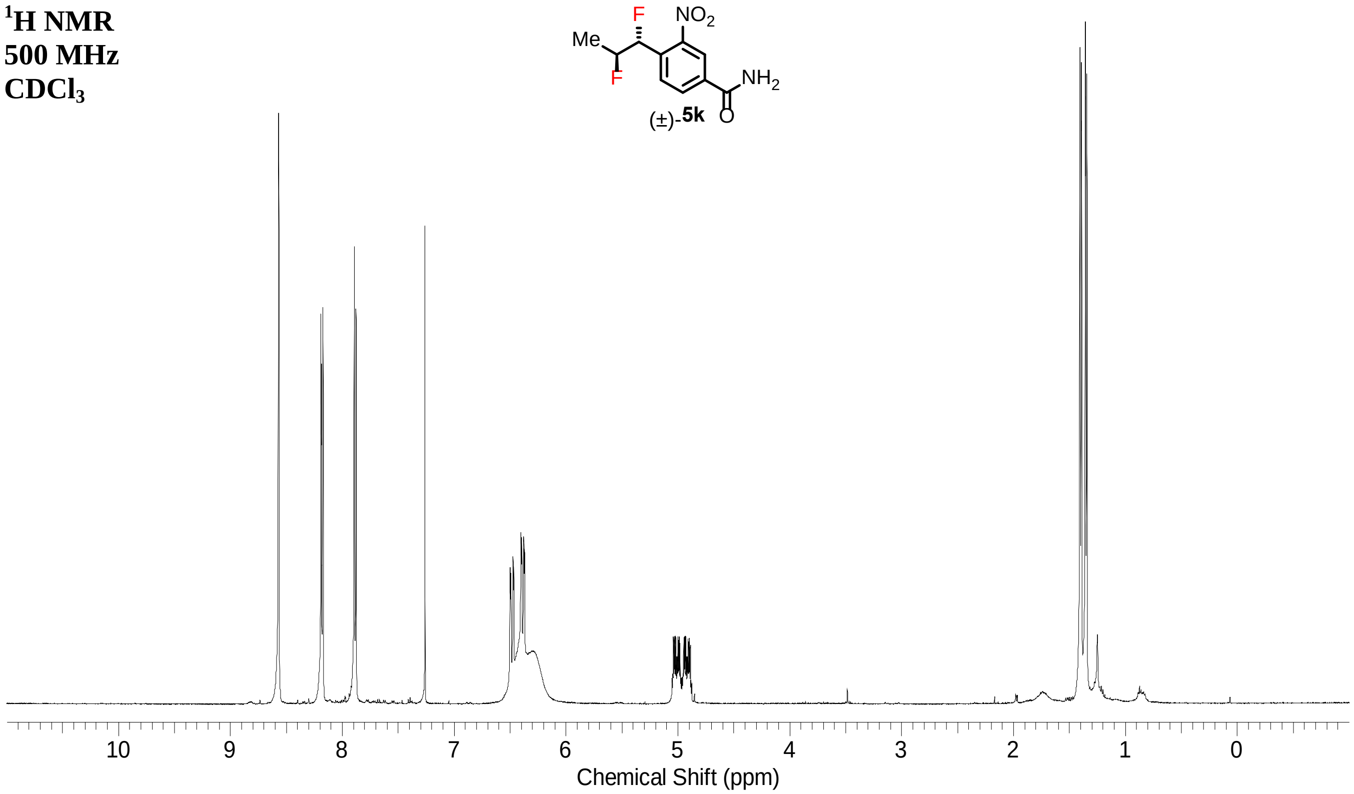
(±)-**5j**

^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$

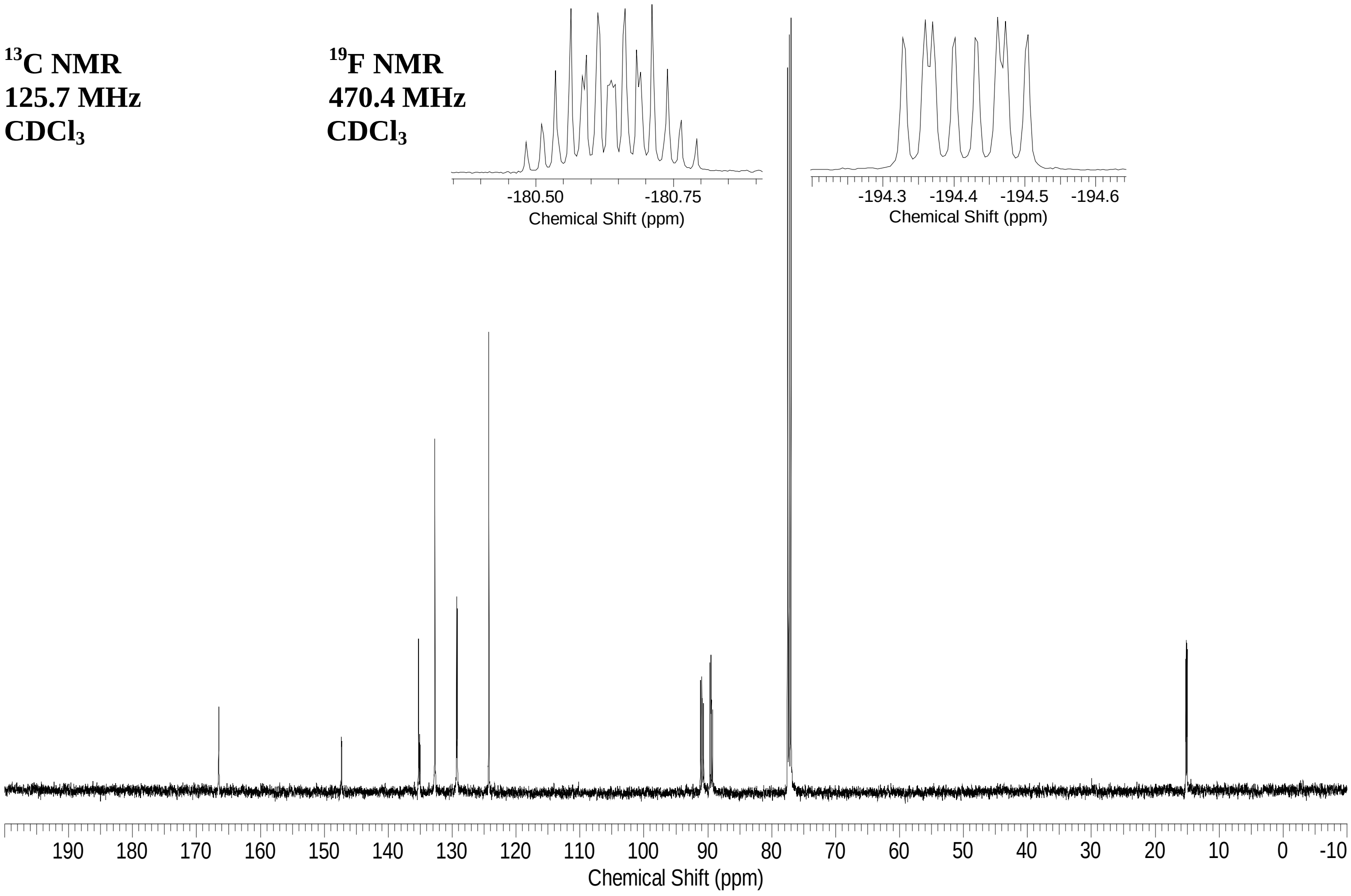


^{1}H NMR
500 MHz
CDCl$_3$

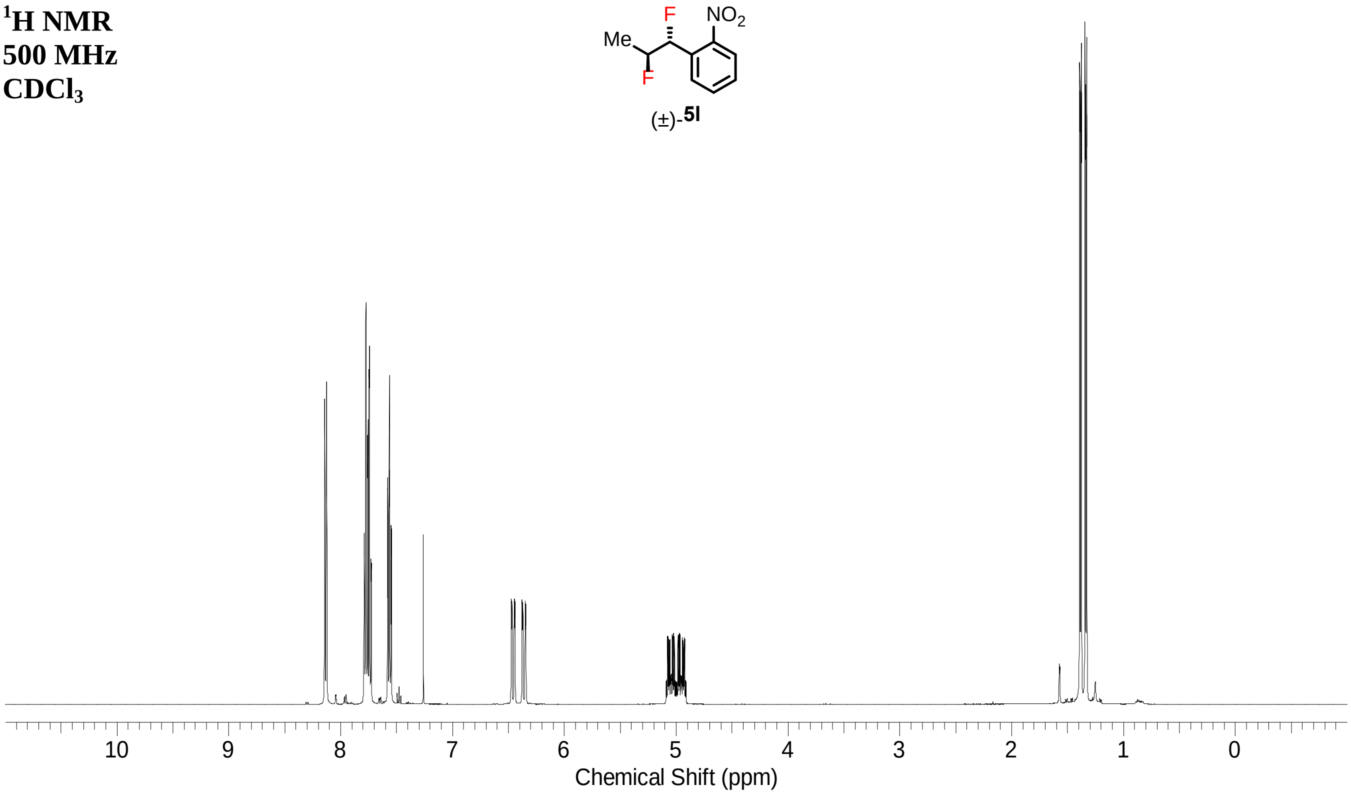


^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



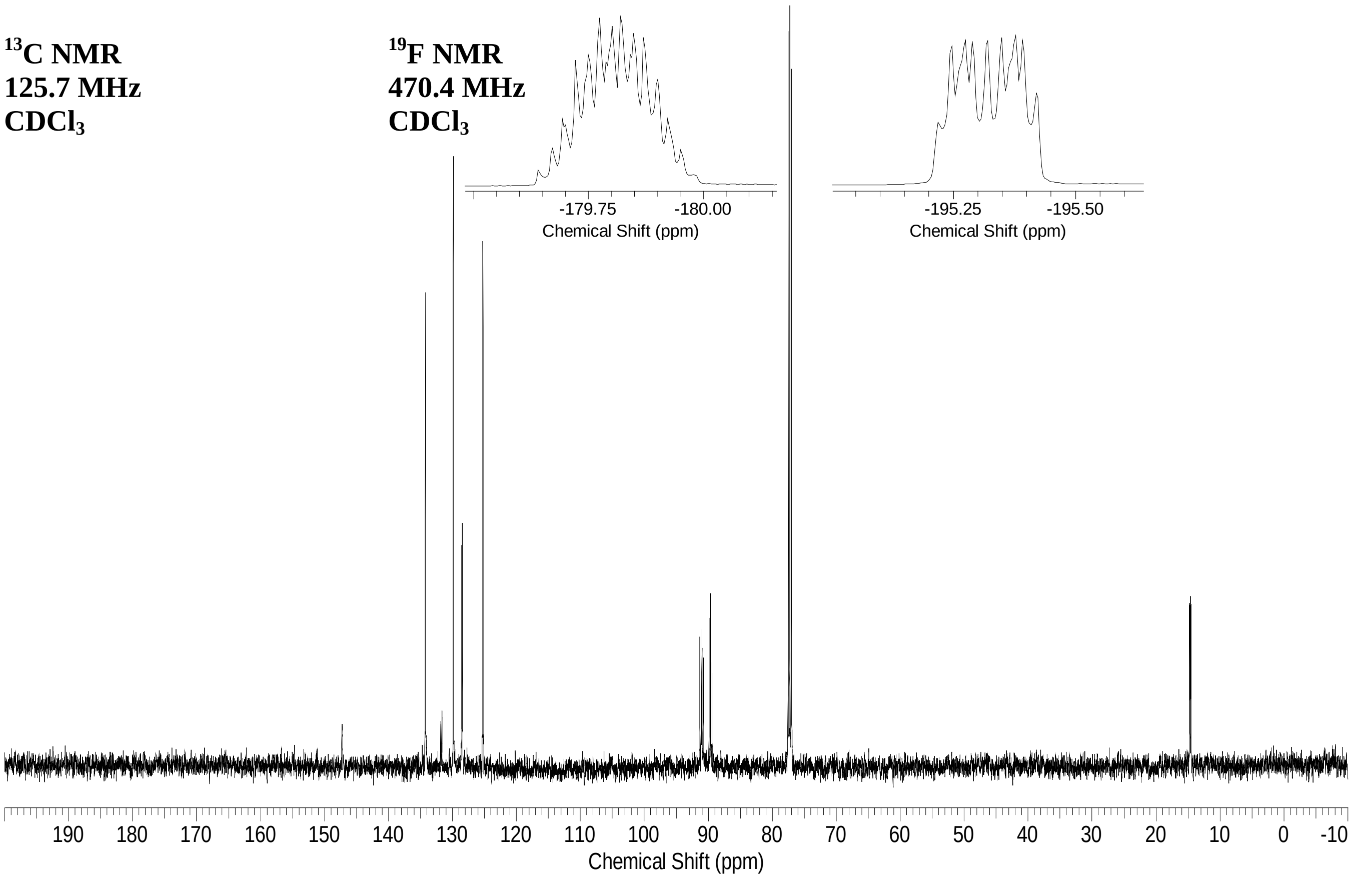
^{1}H NMR
500 MHz
$CDCl_3$



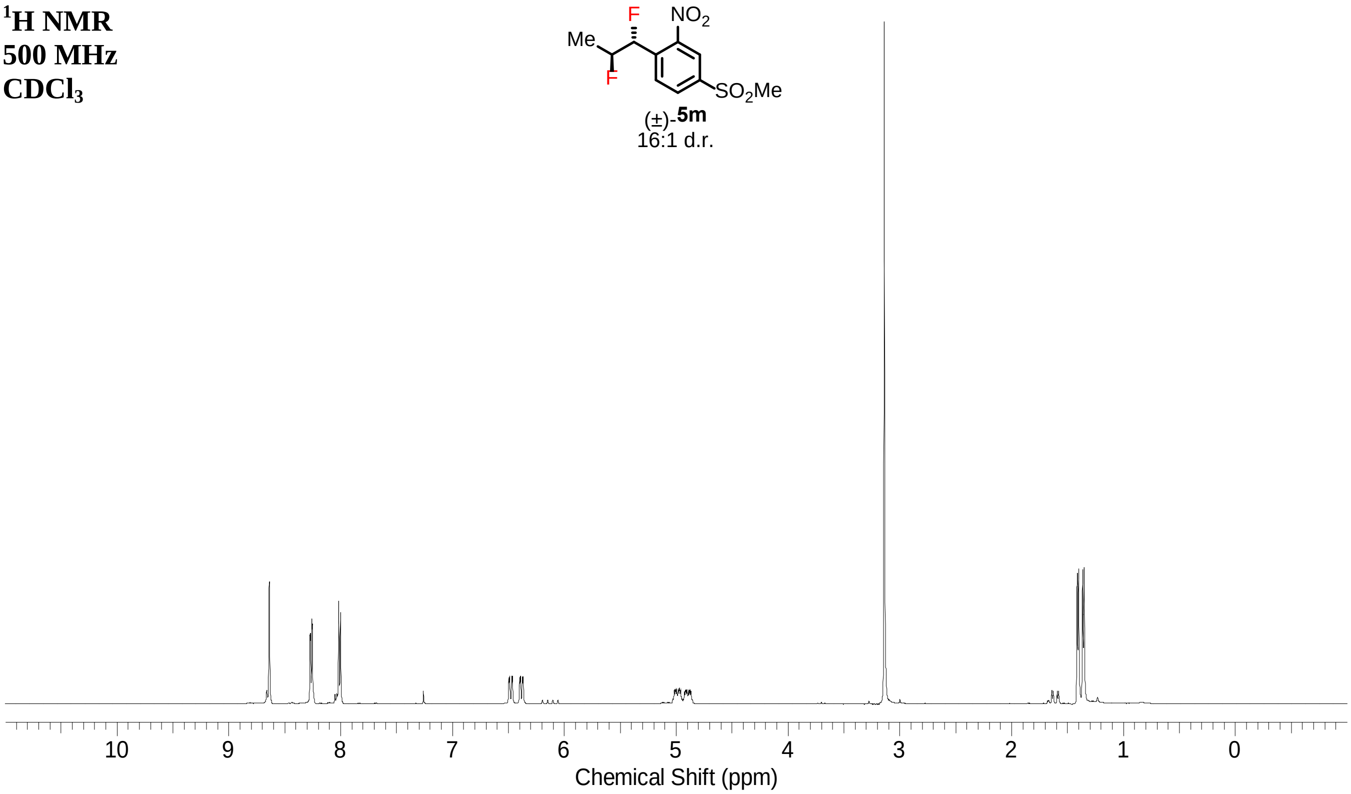
(±)-**5l**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



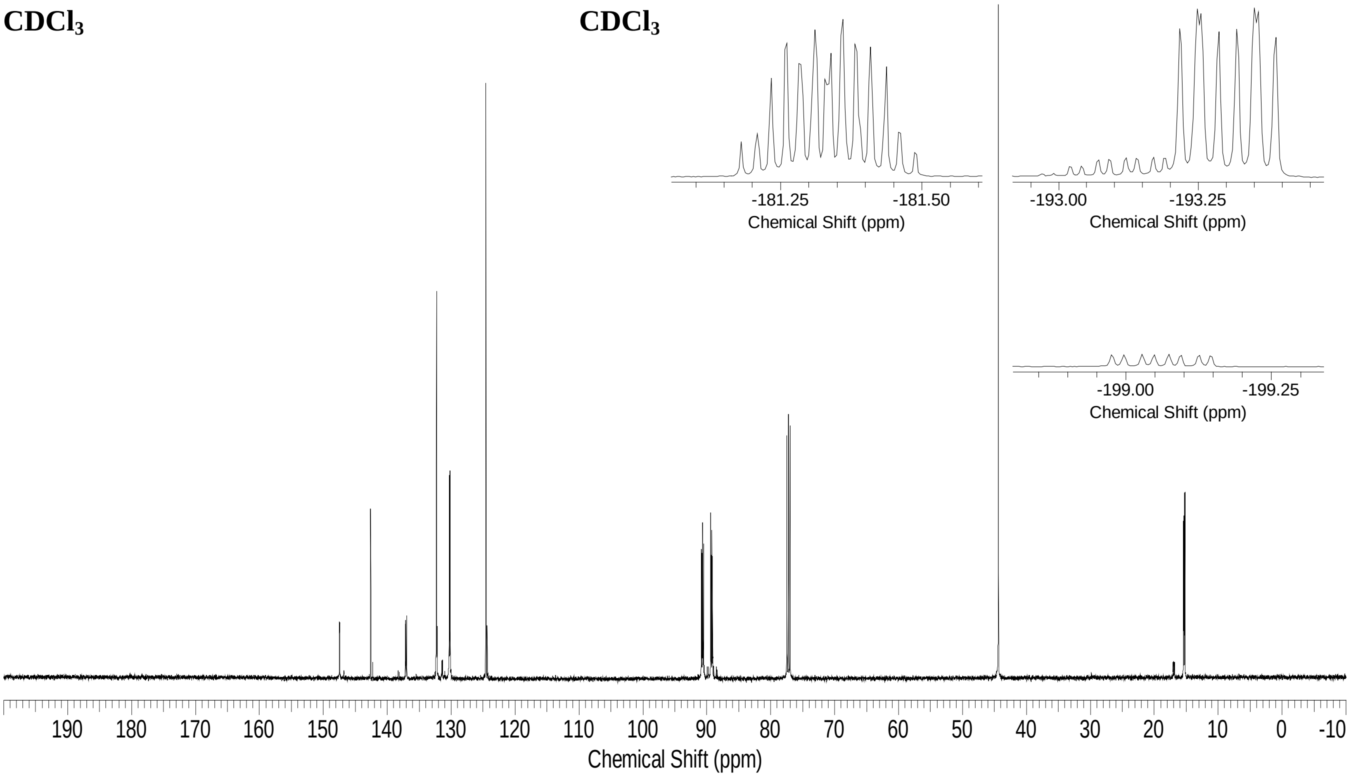
^{1}H NMR
500 MHz
$CDCl_3$



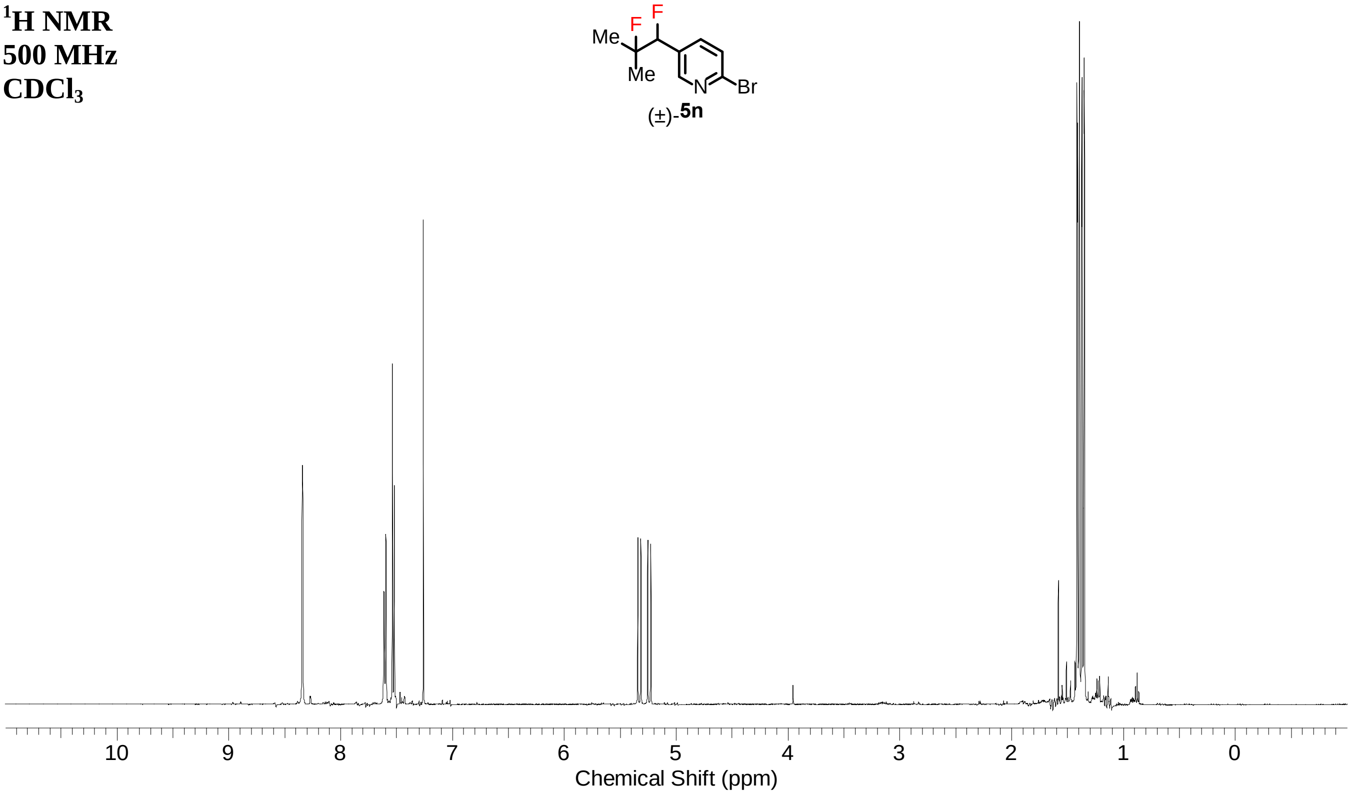
(±)-**5m**
16:1 d.r.

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$

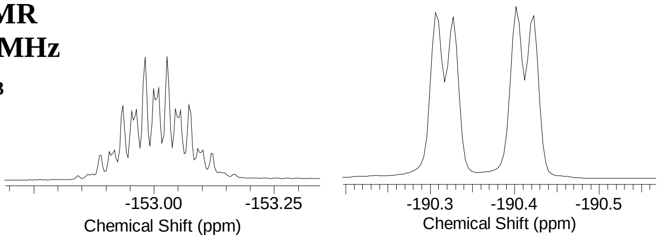


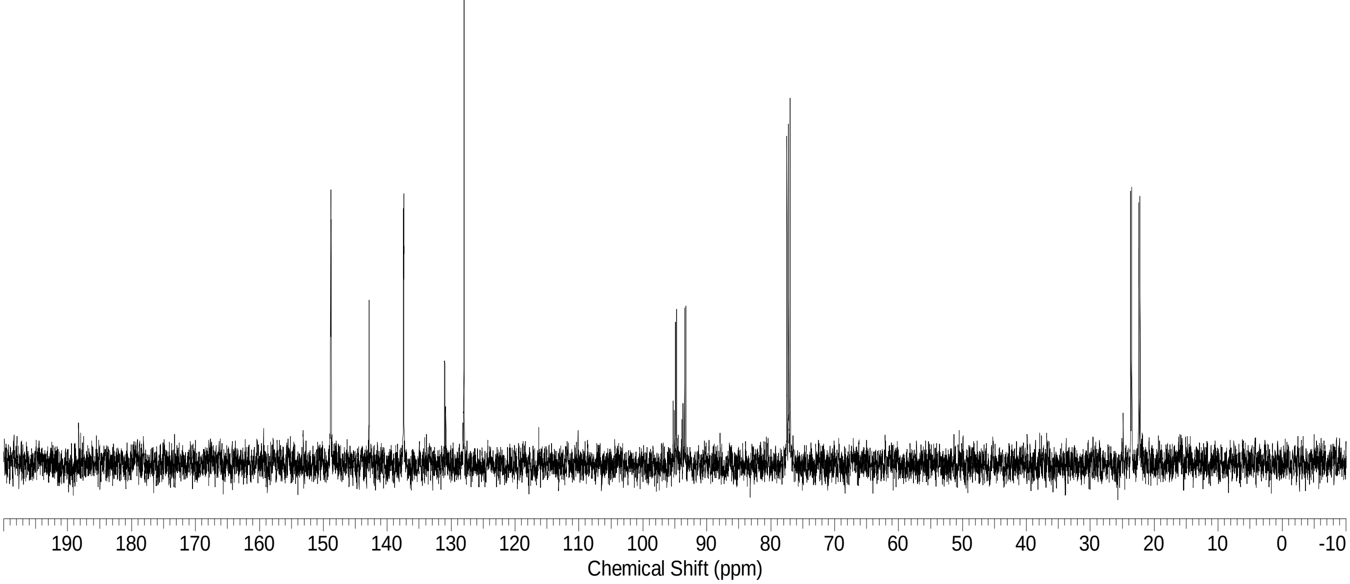
^{1}H NMR
500 MHz
$CDCl_3$



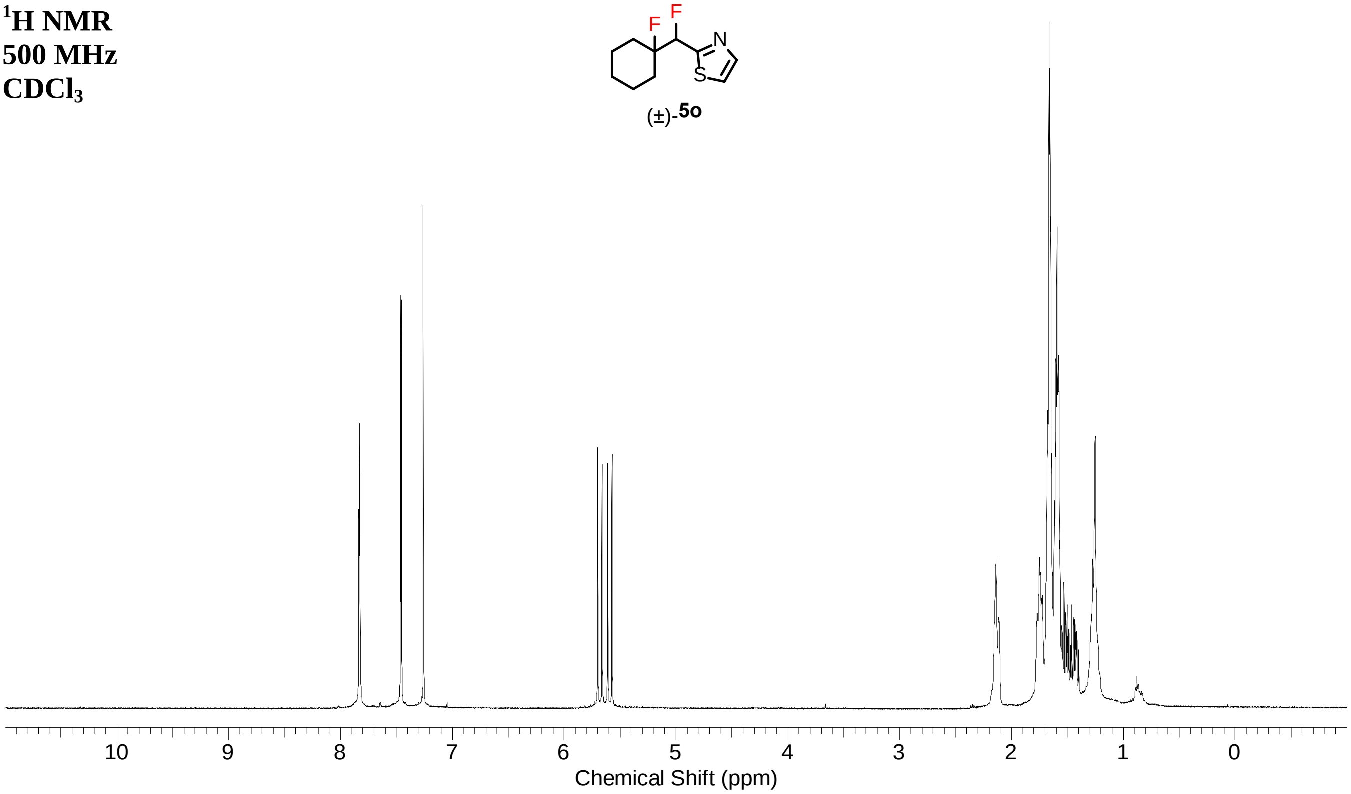
^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



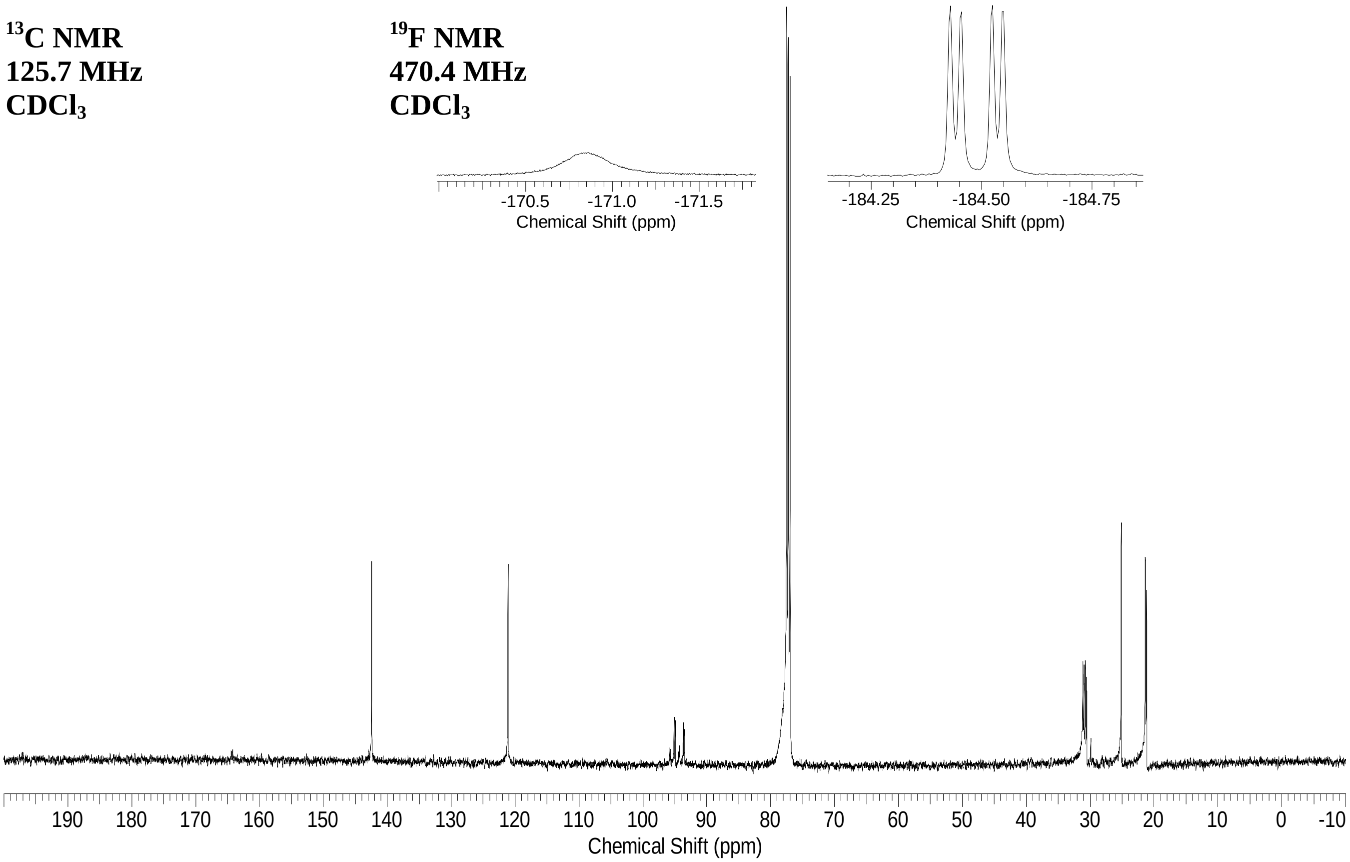


^{1}H NMR
500 MHz
CDCl$_3$

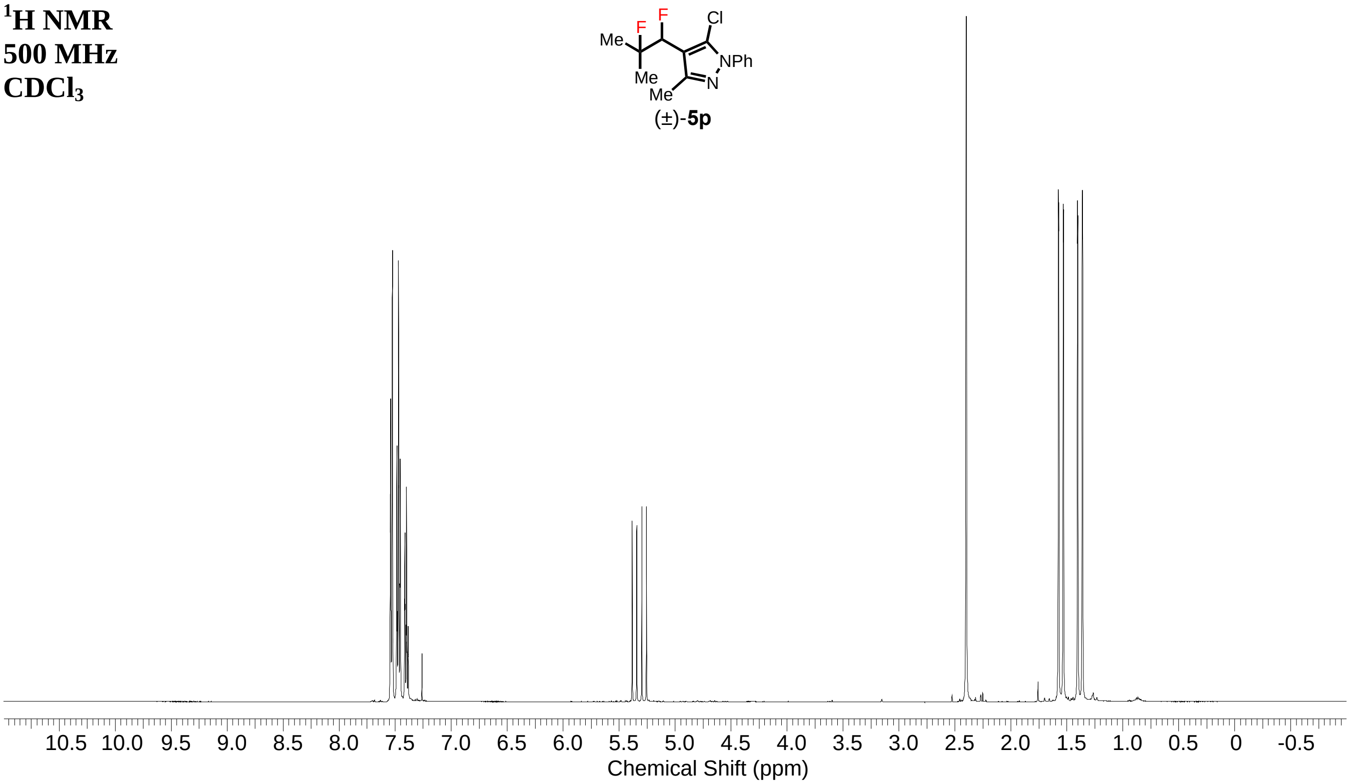


^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



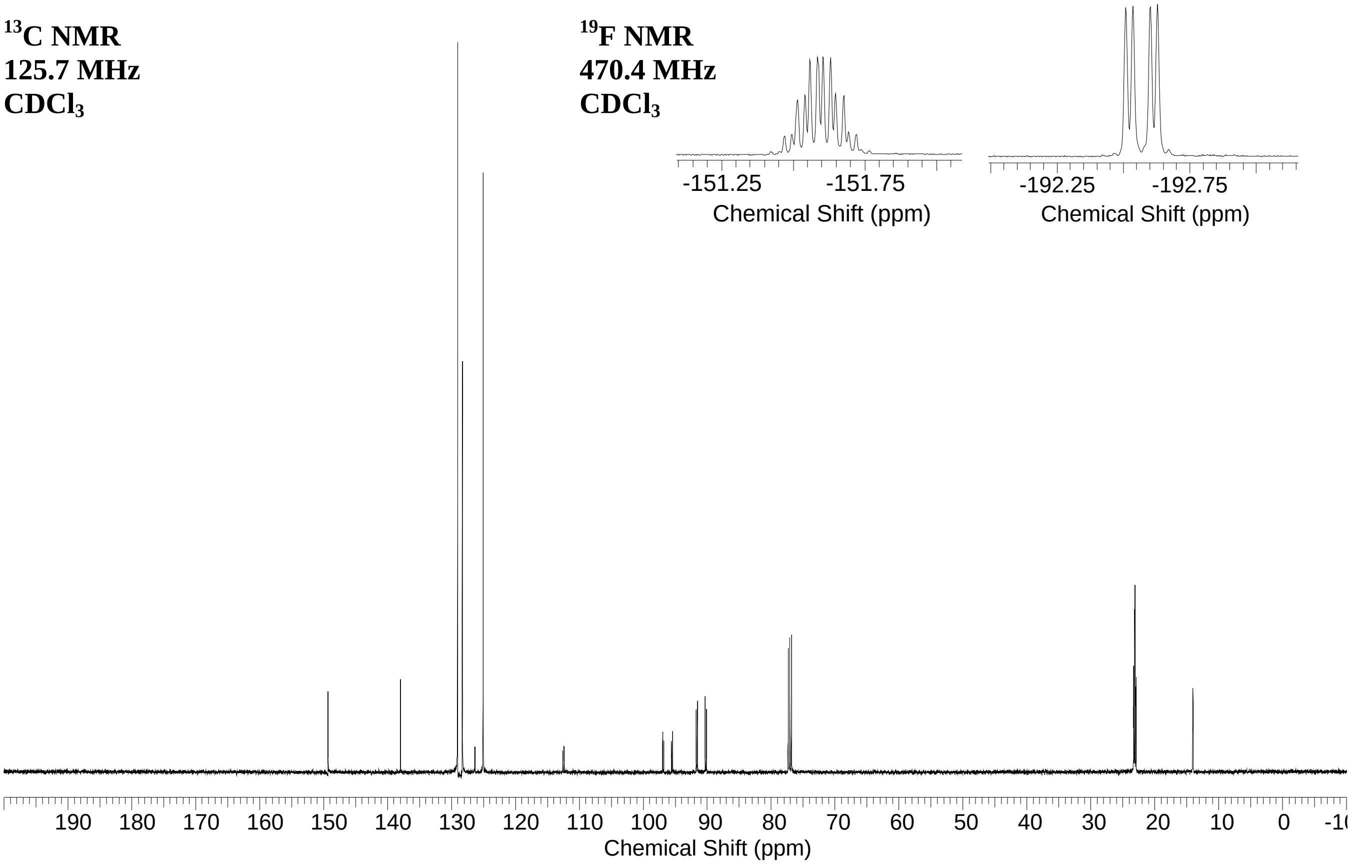
^{1}H NMR
500 MHz
CDCl$_3$



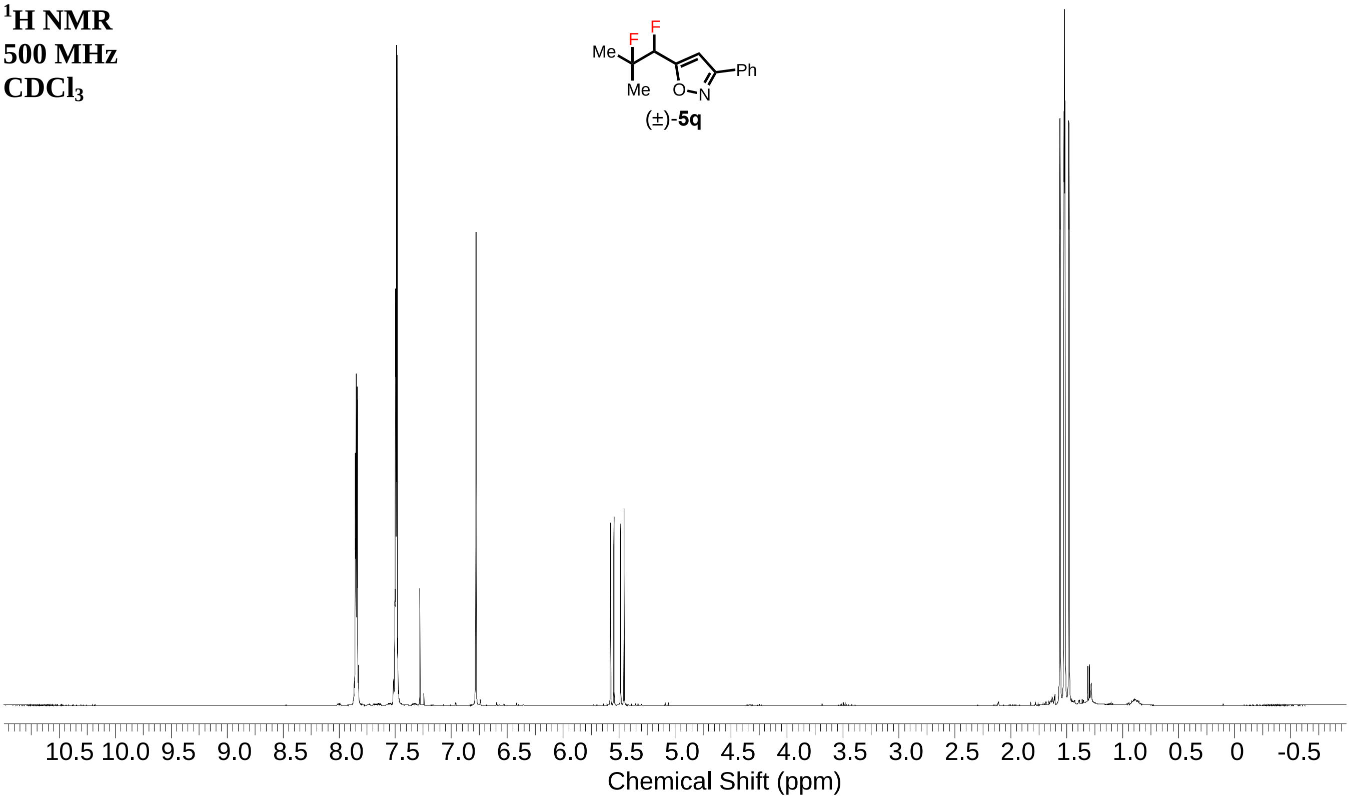
(±)-**5p**

^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



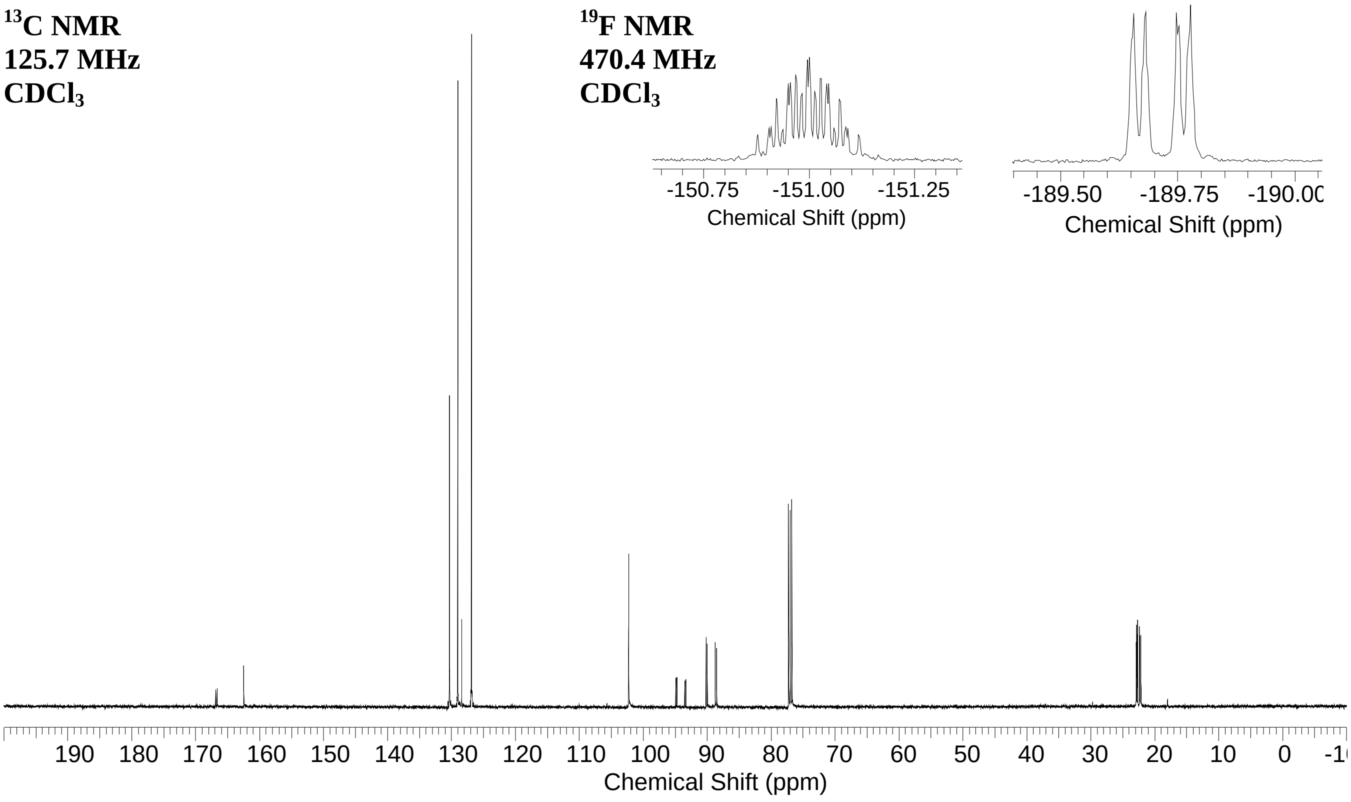
^{1}H NMR
500 MHz
CDCl$_3$

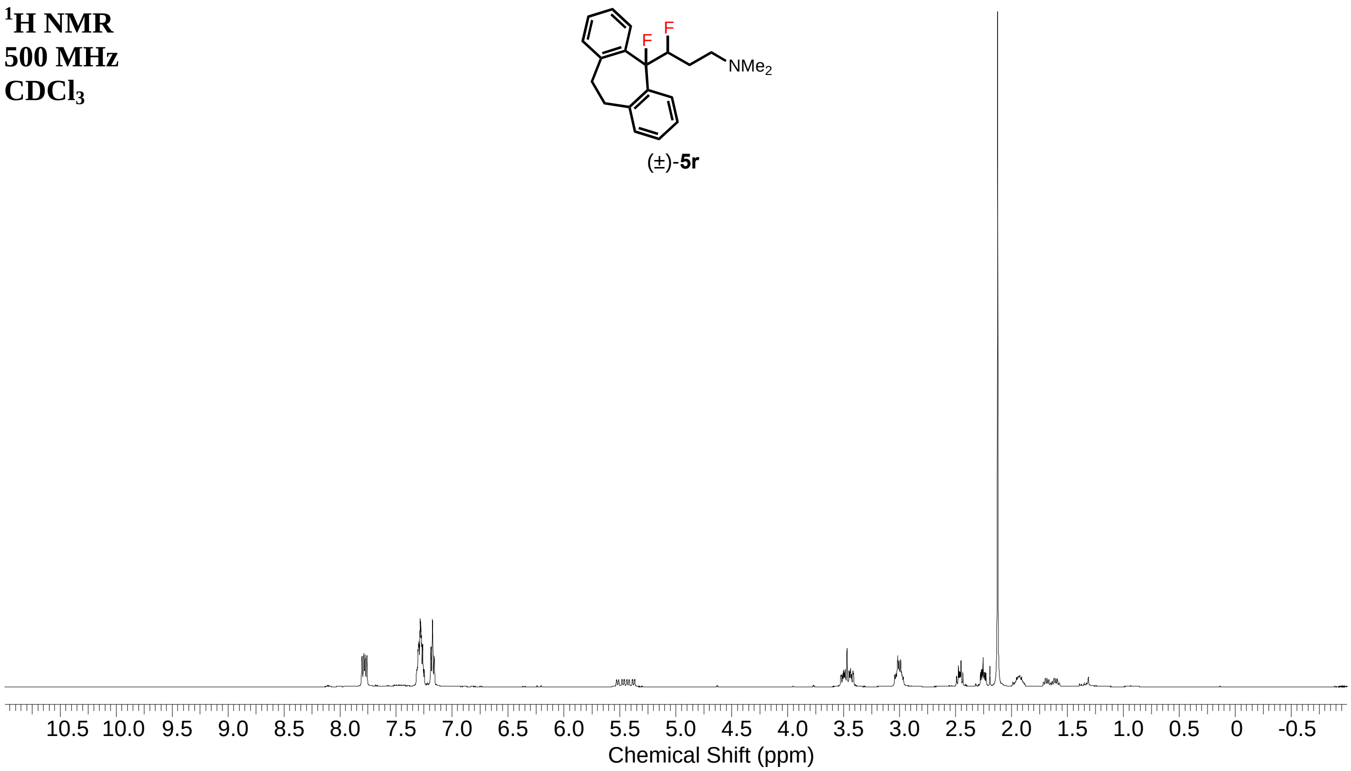


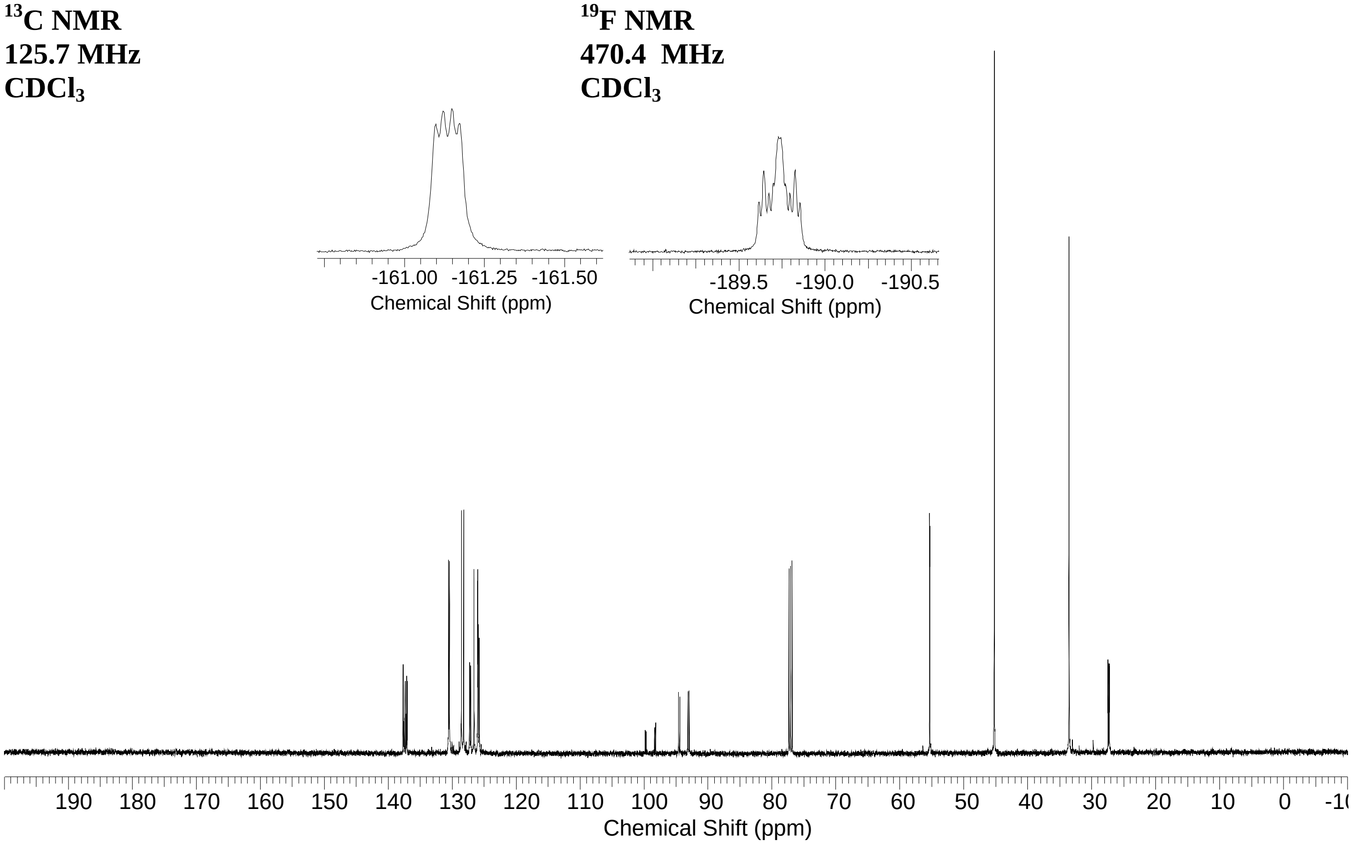
(±)-**5q**

^{13}C NMR
125.7 MHz
CDCl$_3$

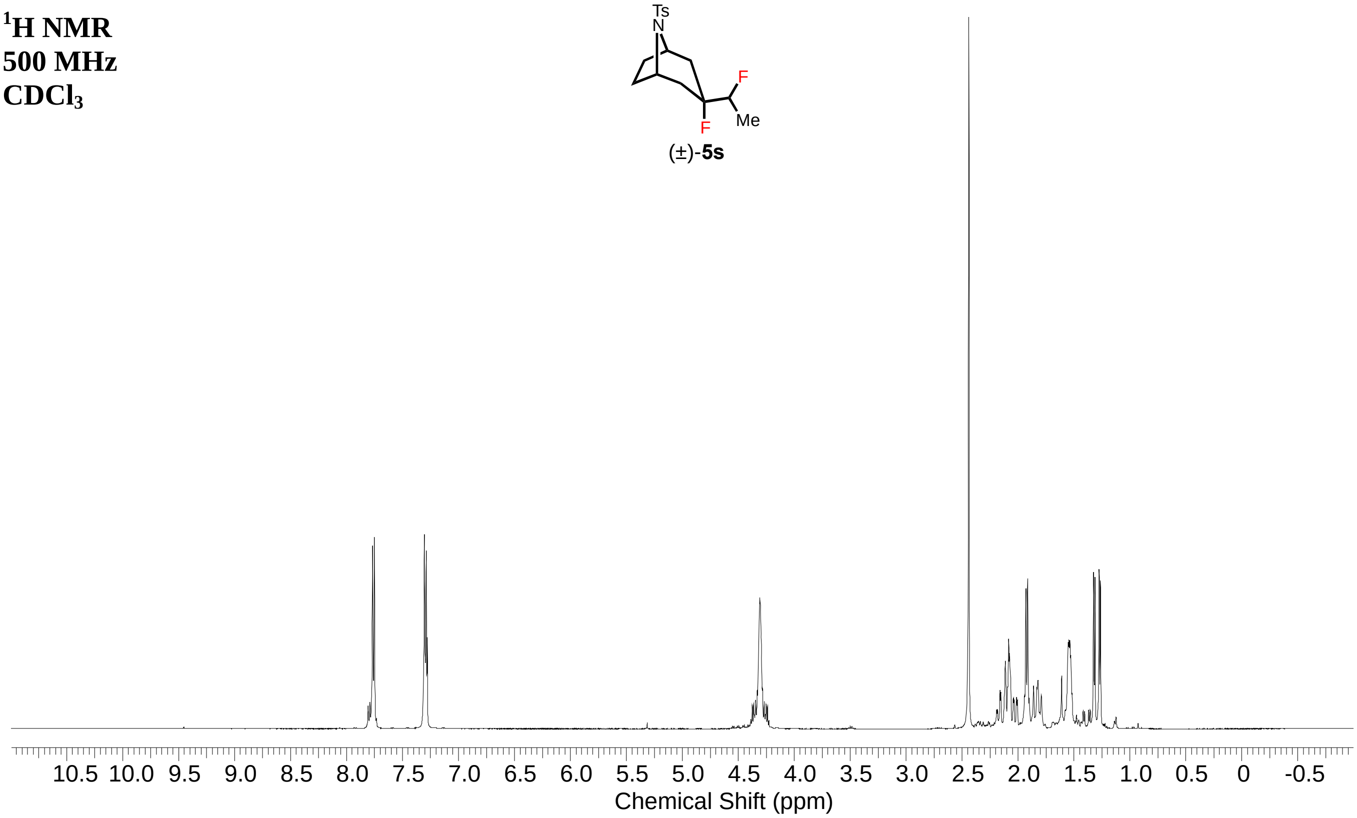
^{19}F NMR
470.4 MHz
CDCl$_3$




^{1}H NMR
500 MHz
$CDCl_3$
F
F
NMe_2
(±)-**5r**
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0 -0.5
Chemical Shift (ppm)


^{13}C NMR
125.7 MHz
$CDCl_3$
^{19}F NMR
470.4 MHz
$CDCl_3$
-161.00 -161.25 -161.50
Chemical Shift (ppm)
-189.5 -190.0 -190.5
Chemical Shift (ppm)
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
Chemical Shift (ppm)

^{1}H NMR
500 MHz
$CDCl_3$



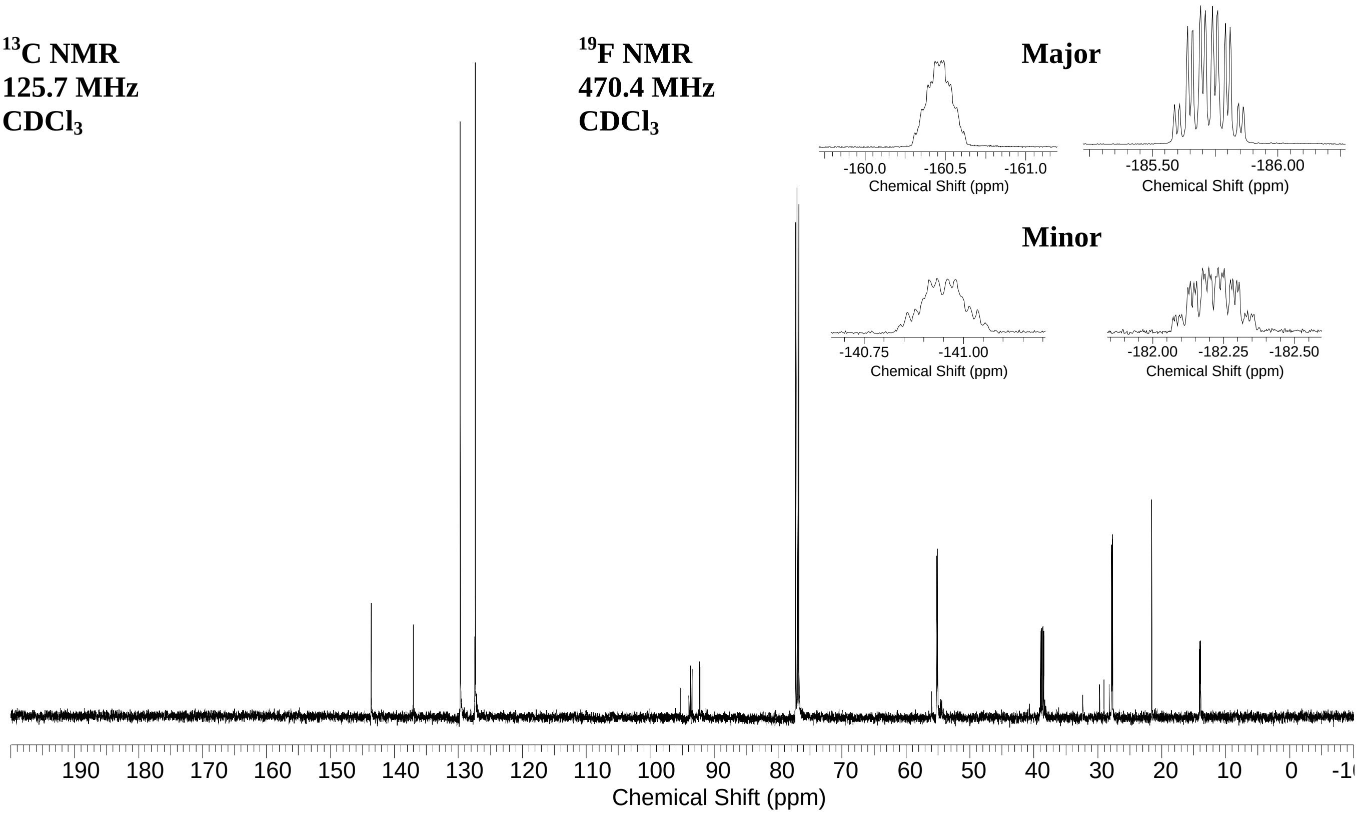
(±)-**5s**

^{13}C NMR
125.7 MHz
$CDCl_3$

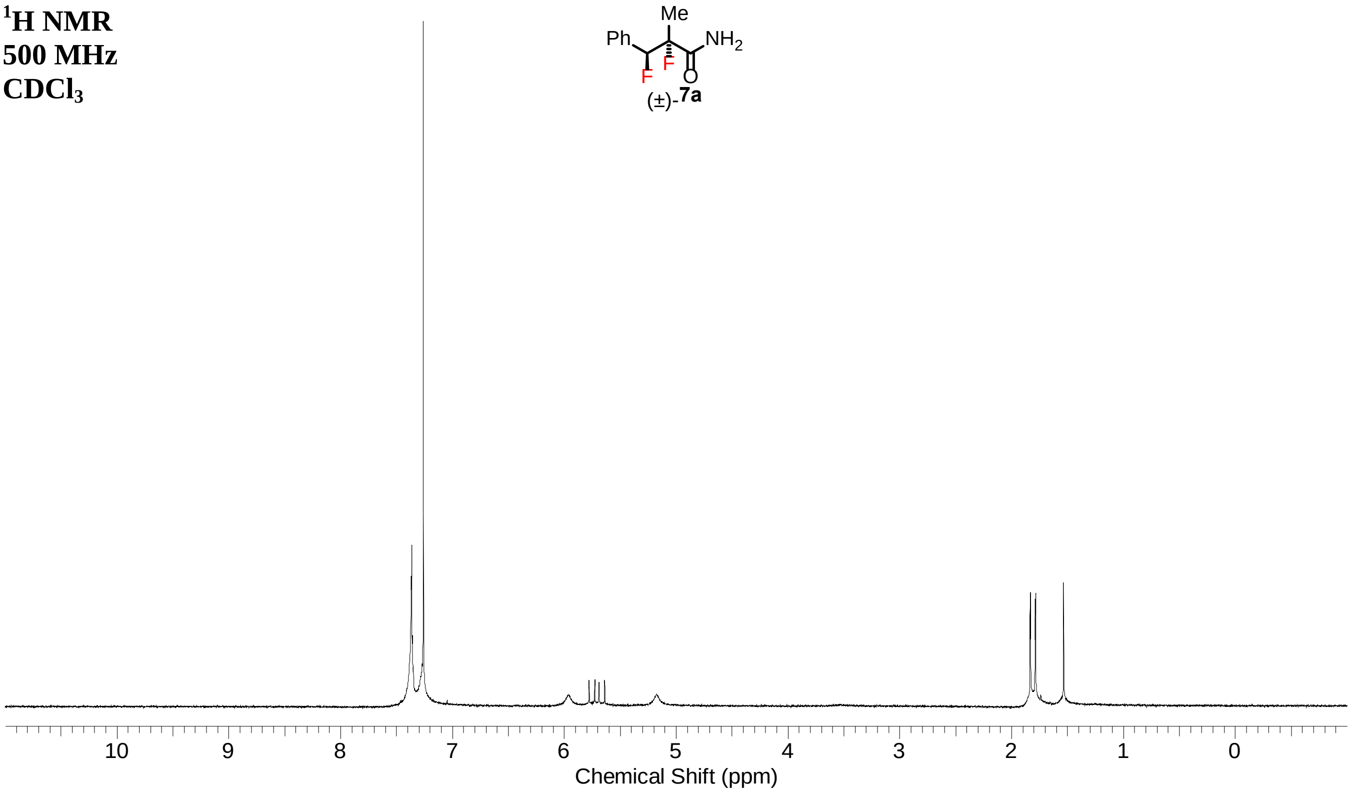
^{19}F NMR
470.4 MHz
$CDCl_3$

Major

Minor

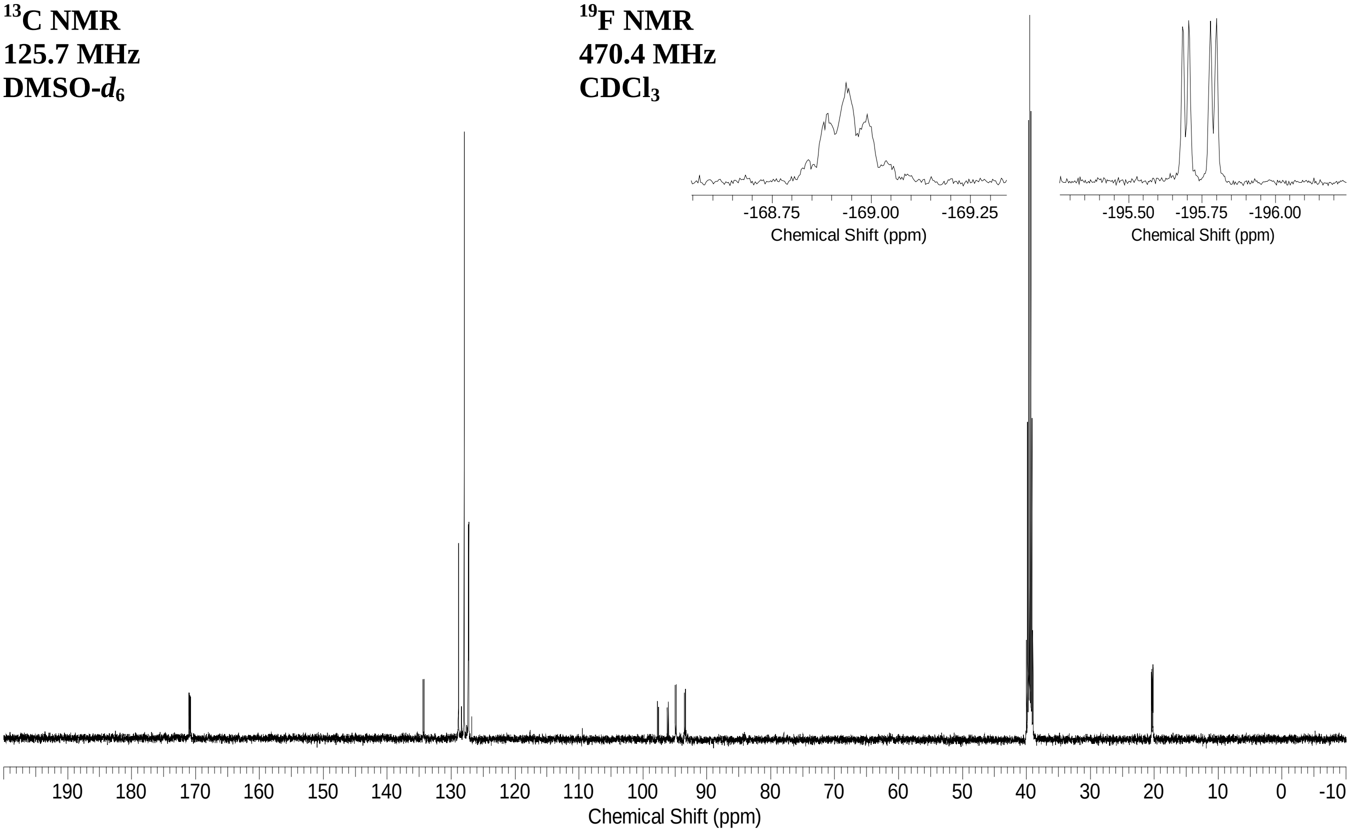


^{1}H NMR
500 MHz
$CDCl_3$



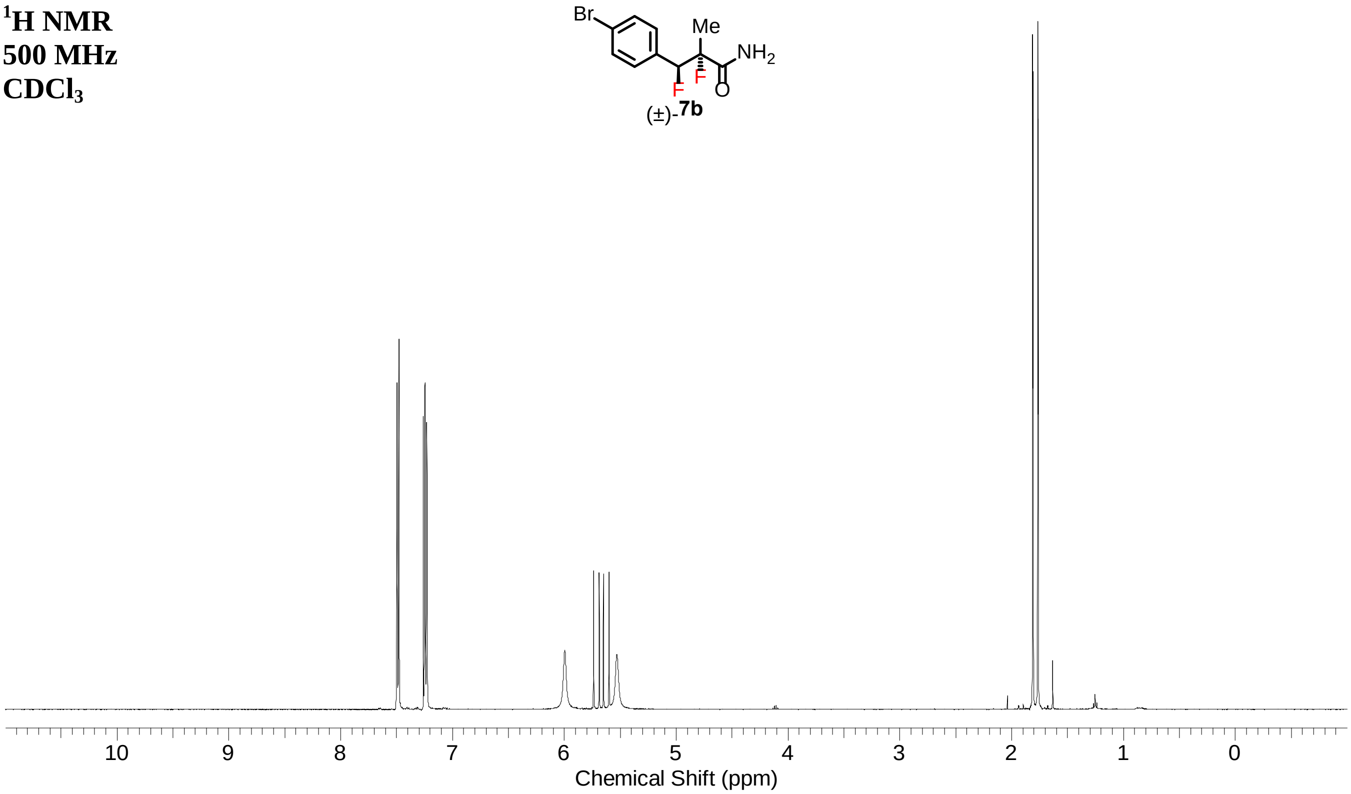
(±)-**7a**

^{13}C NMR
125.7 MHz
DMSO-d_6



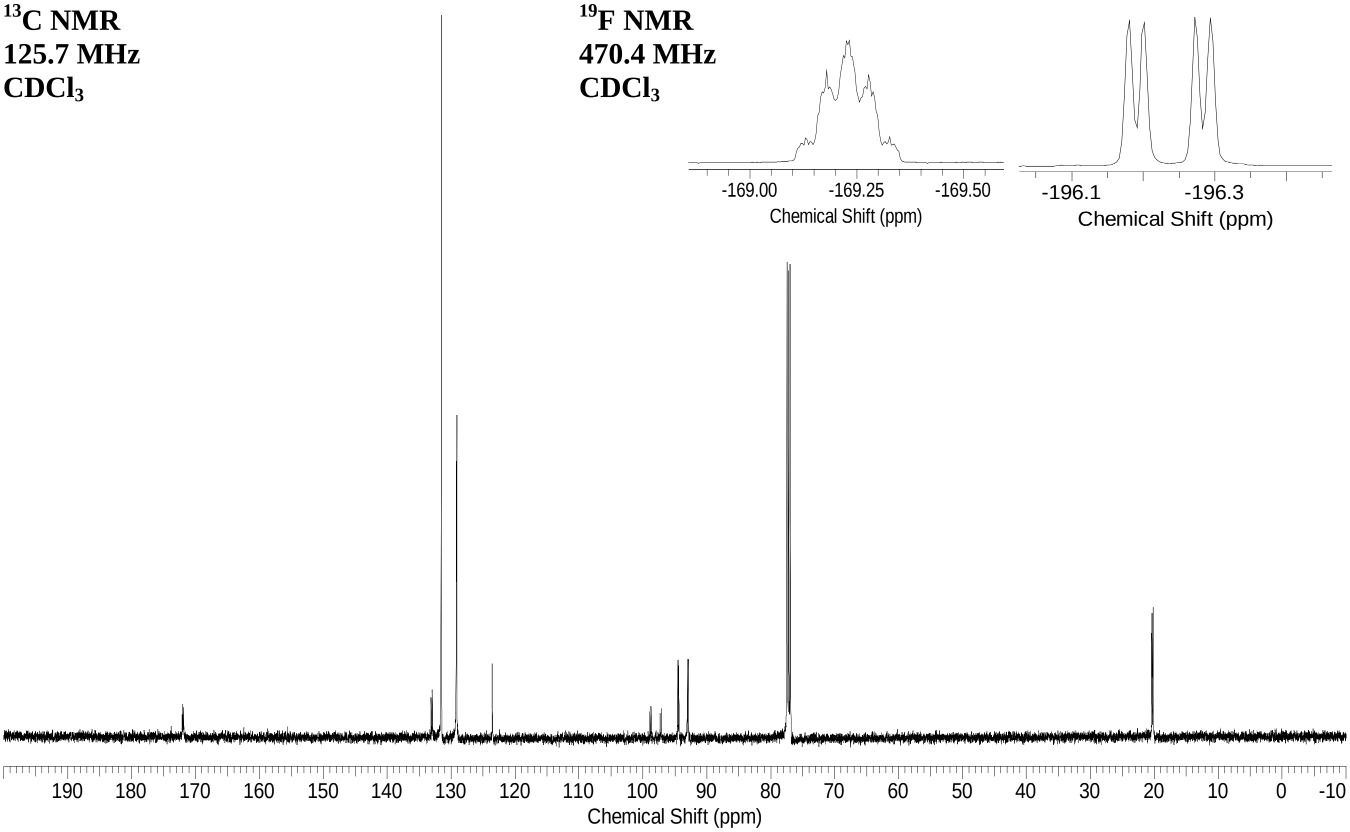
^{19}F NMR
470.4 MHz
$CDCl_3$

^{1}H NMR
500 MHz
$CDCl_3$

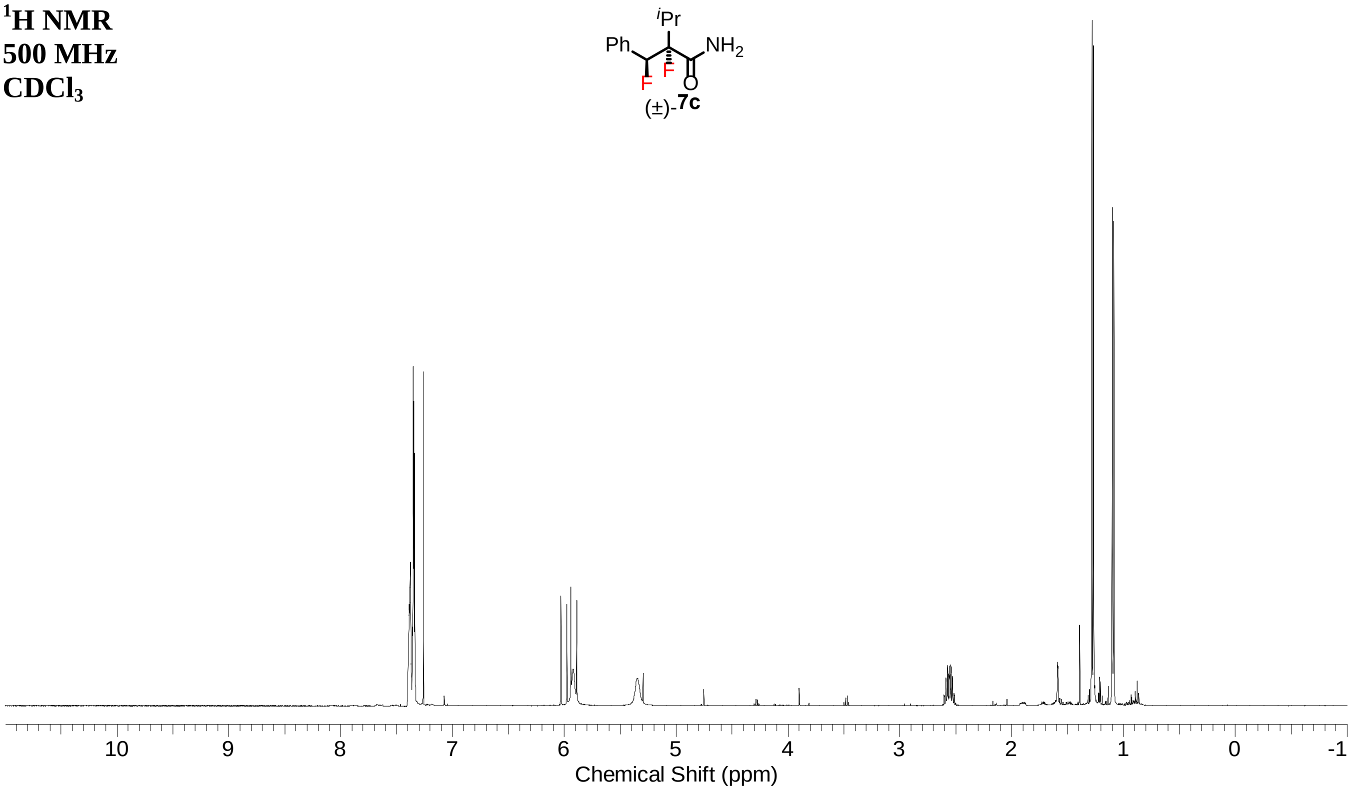


^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$

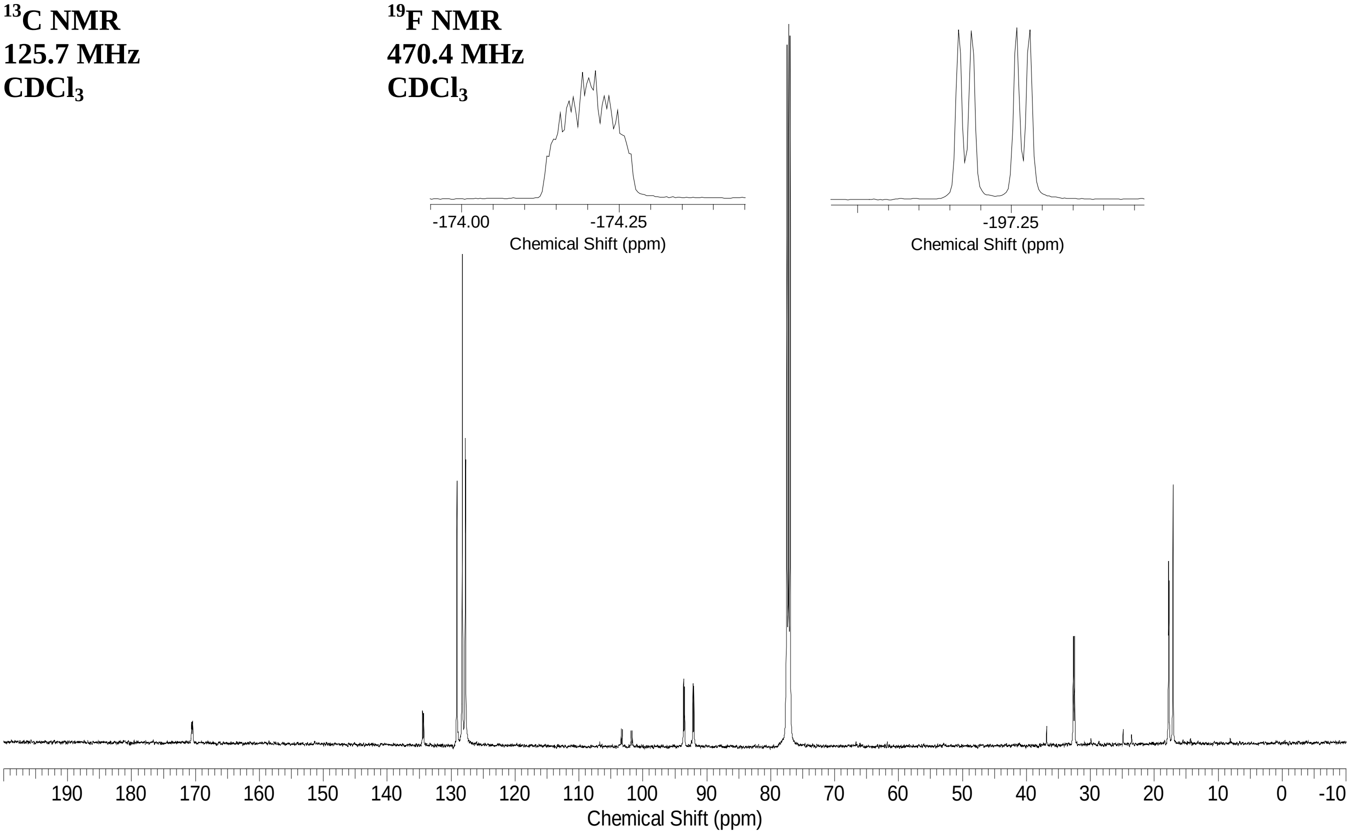


^{1}H NMR
500 MHz
CDCl$_3$

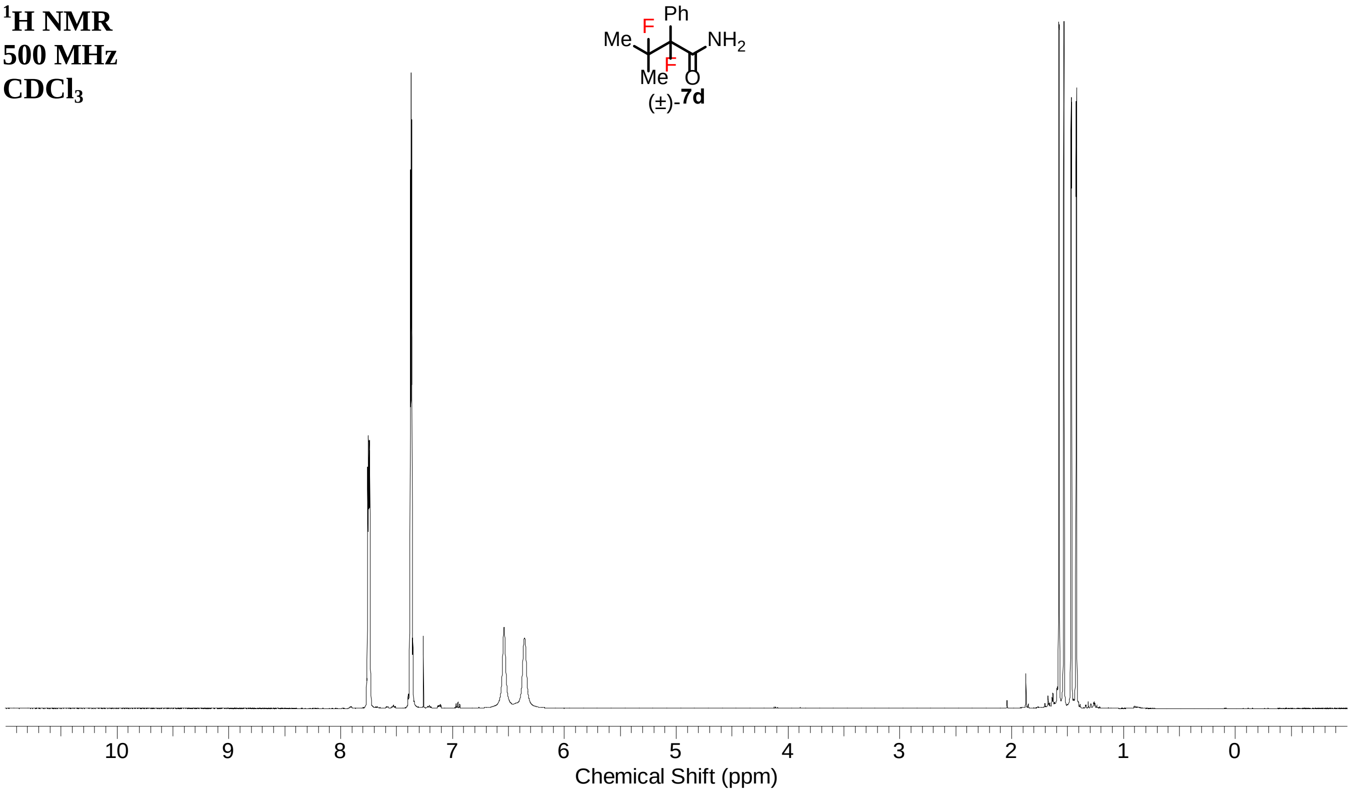


^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



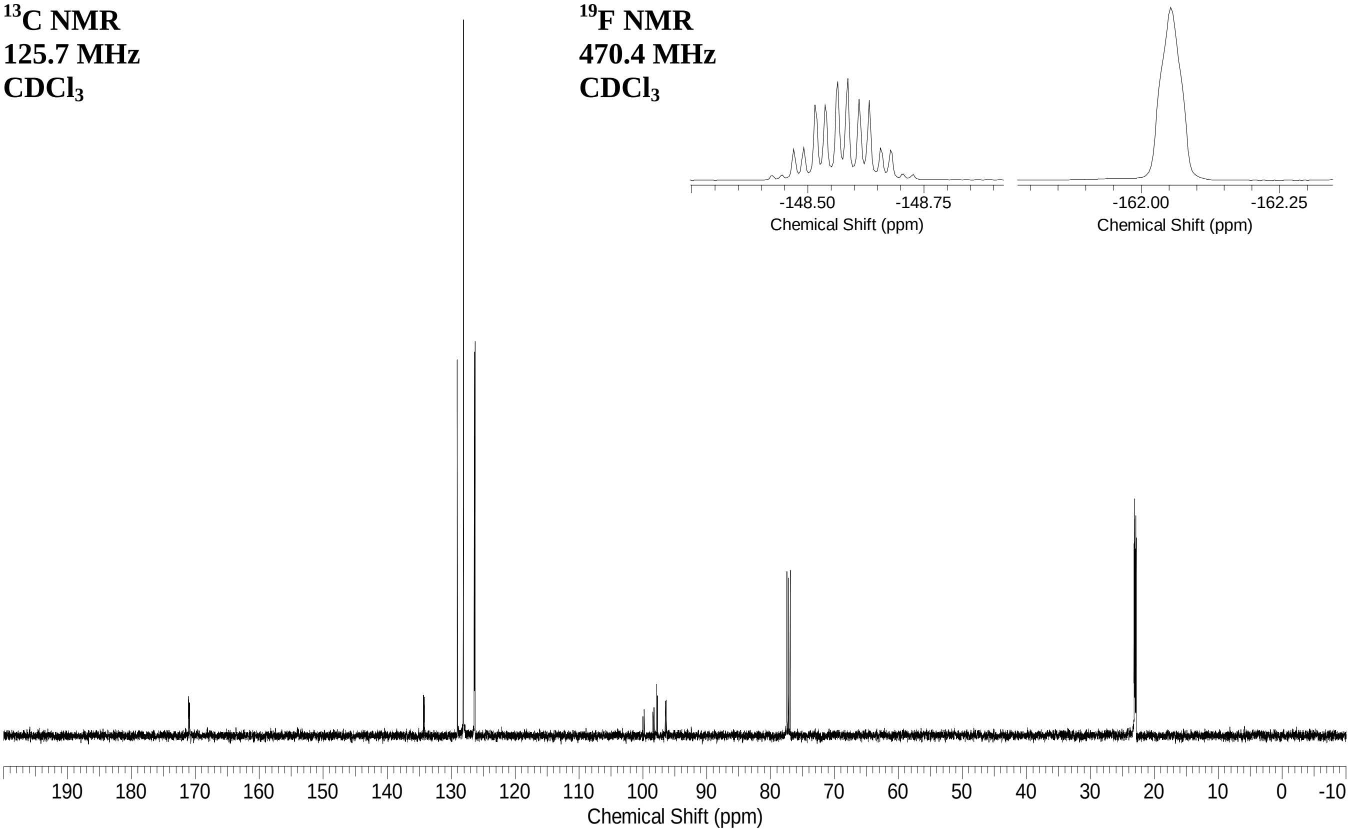
^{1}H NMR
500 MHz
CDCl$_3$



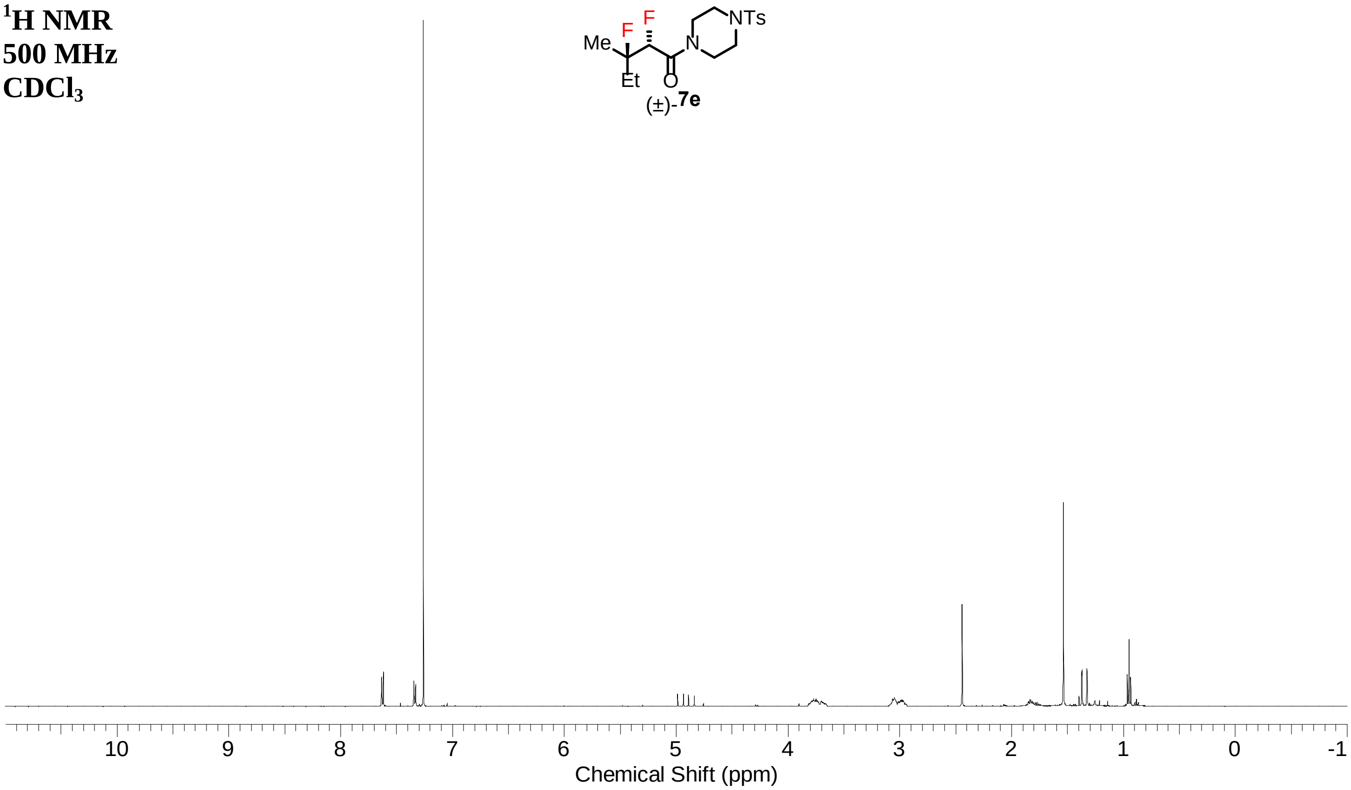
(±)-**7d**

^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$



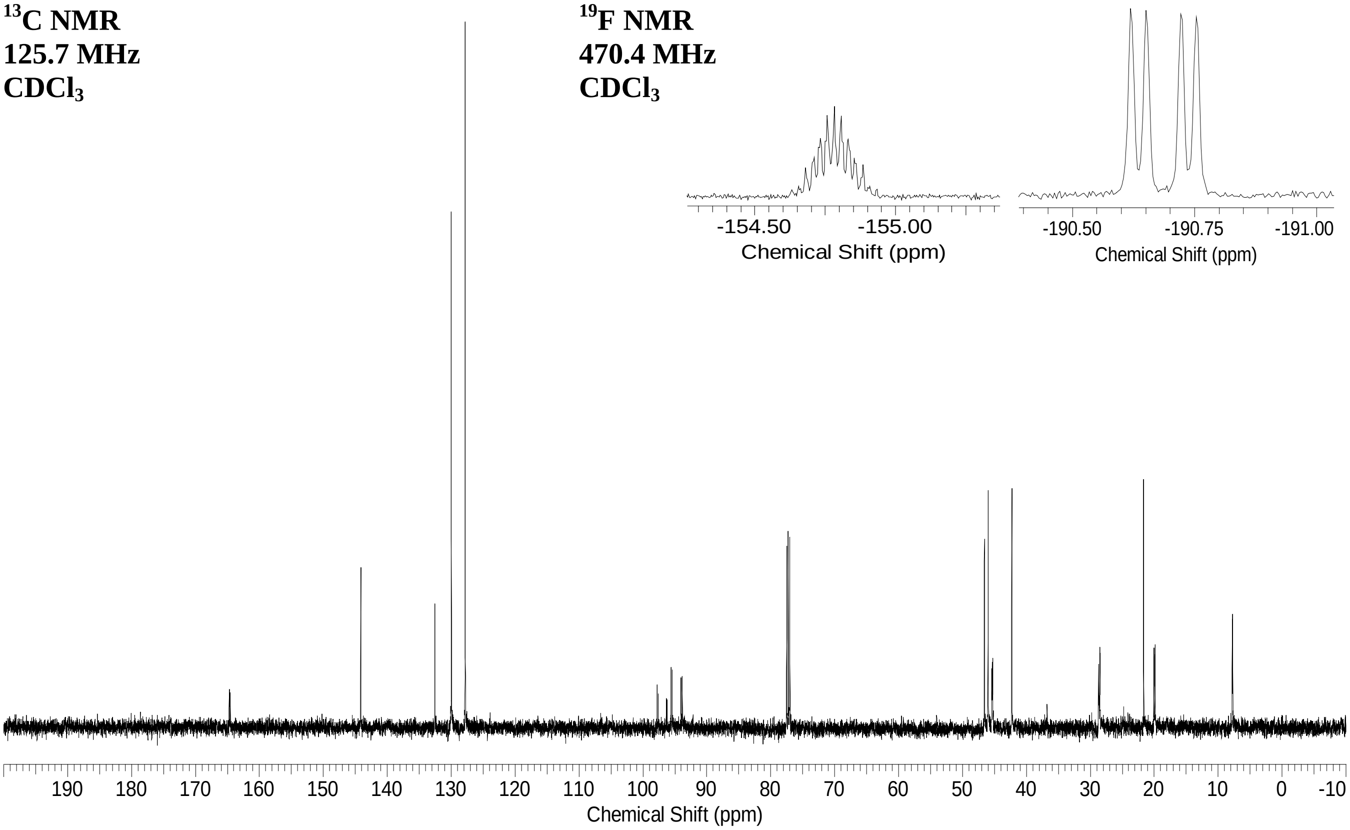
^{1}H NMR
500 MHz
CDCl$_3$



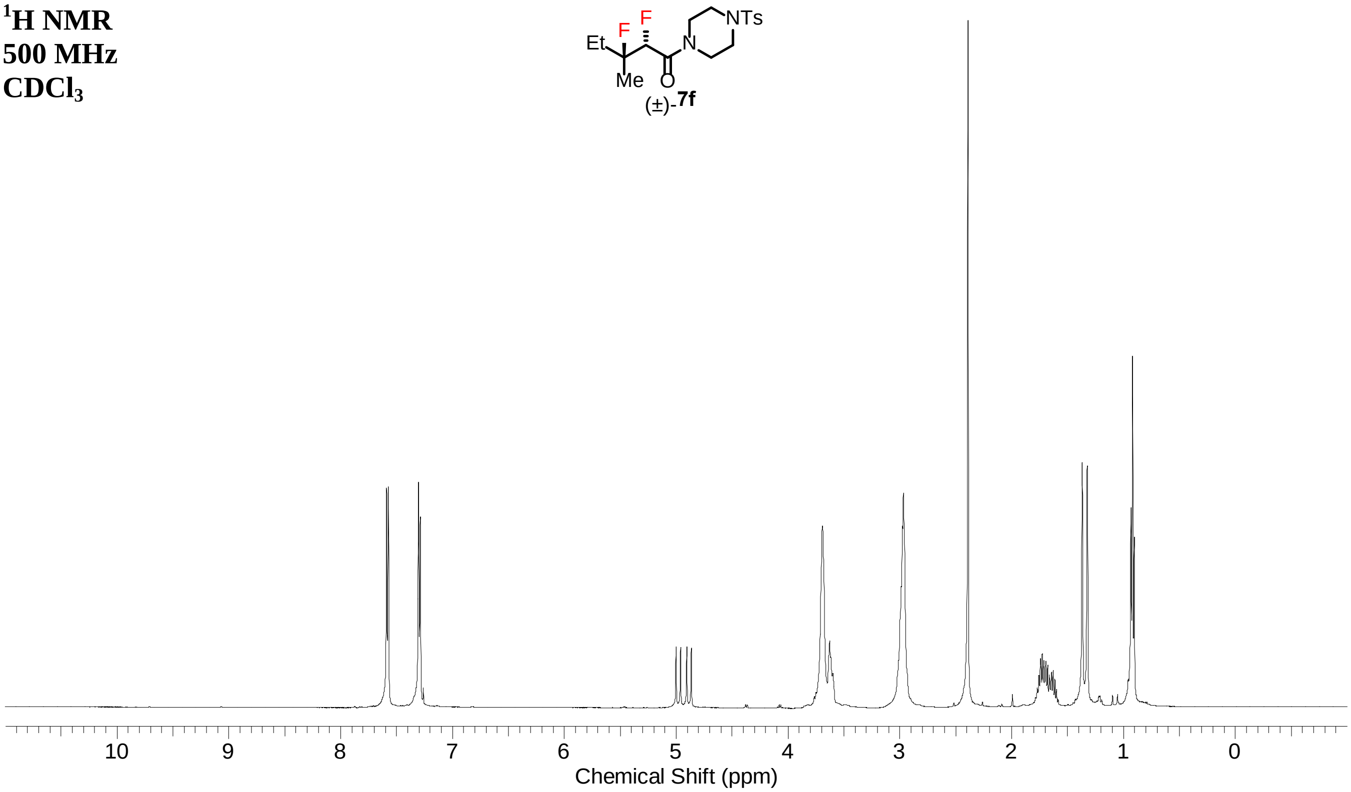
(±)-**7e**

^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
470.4 MHz
CDCl$_3$

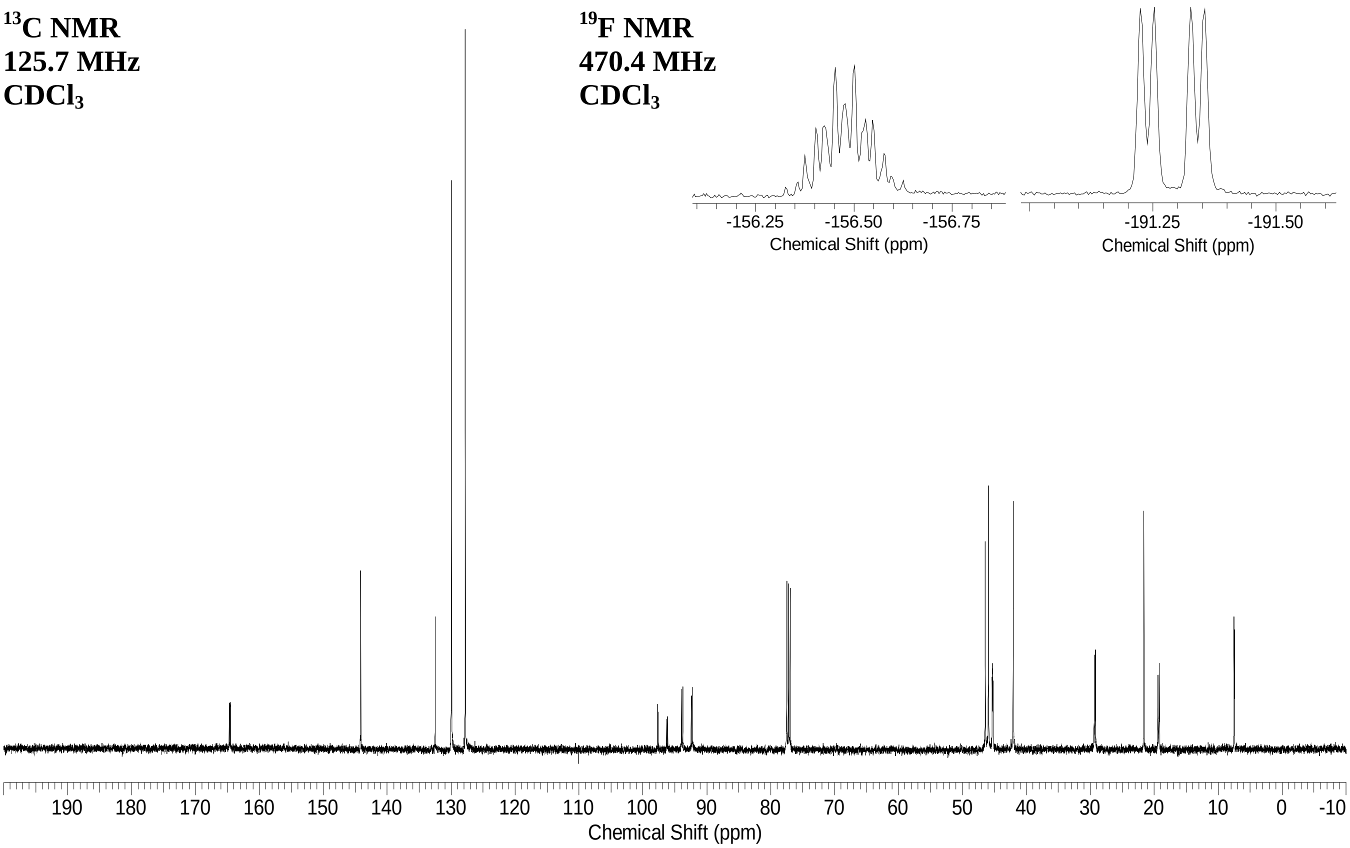


^{1}H NMR
500 MHz
$CDCl_3$

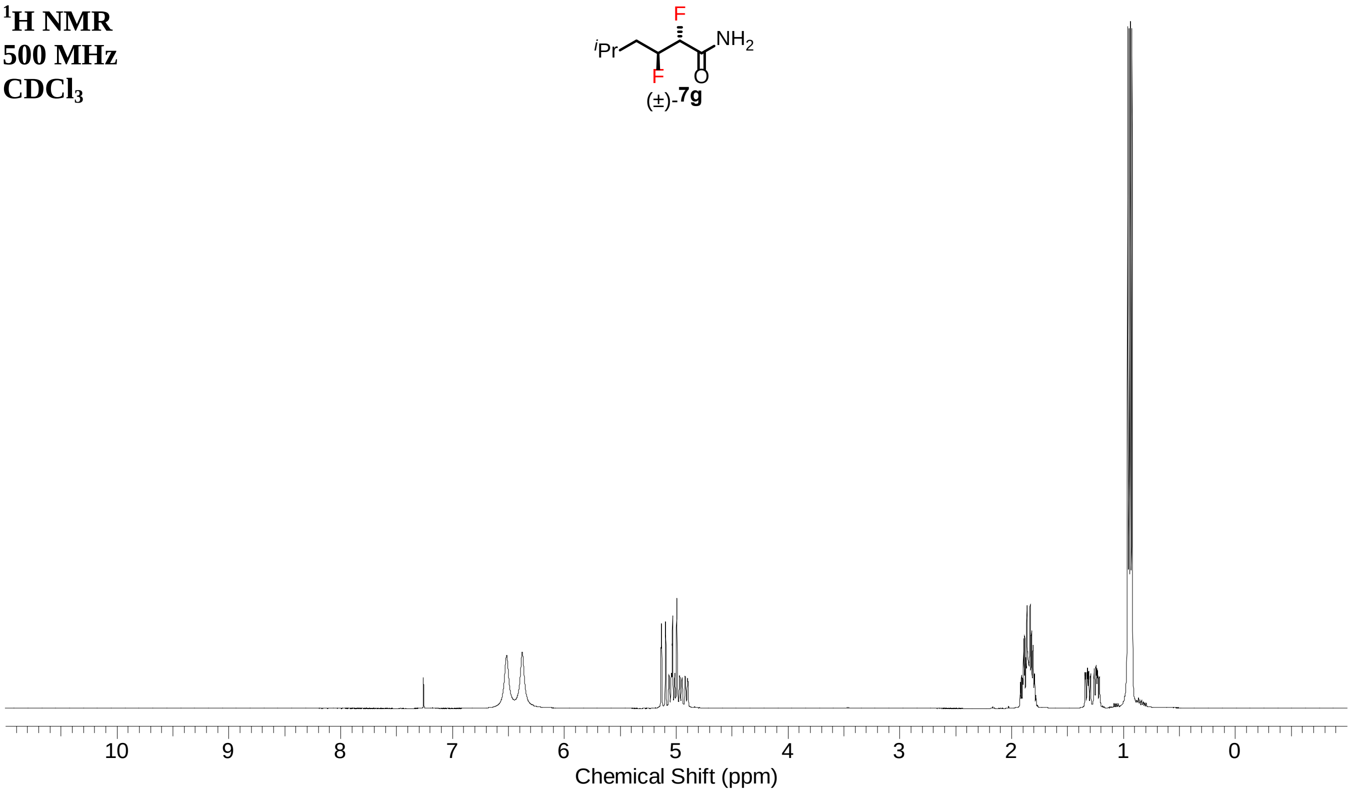

(±)-**7f**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



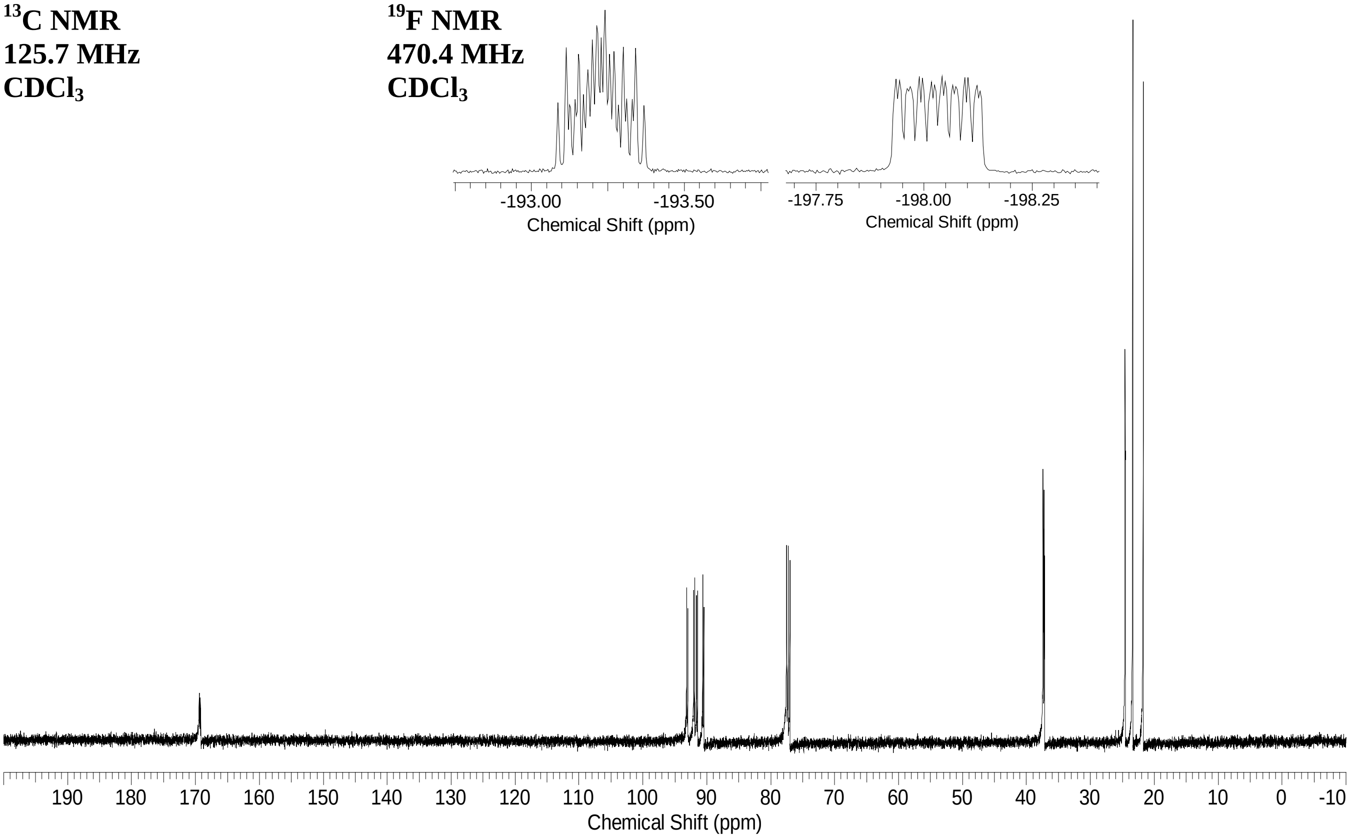
^{1}H NMR
500 MHz
$CDCl_3$



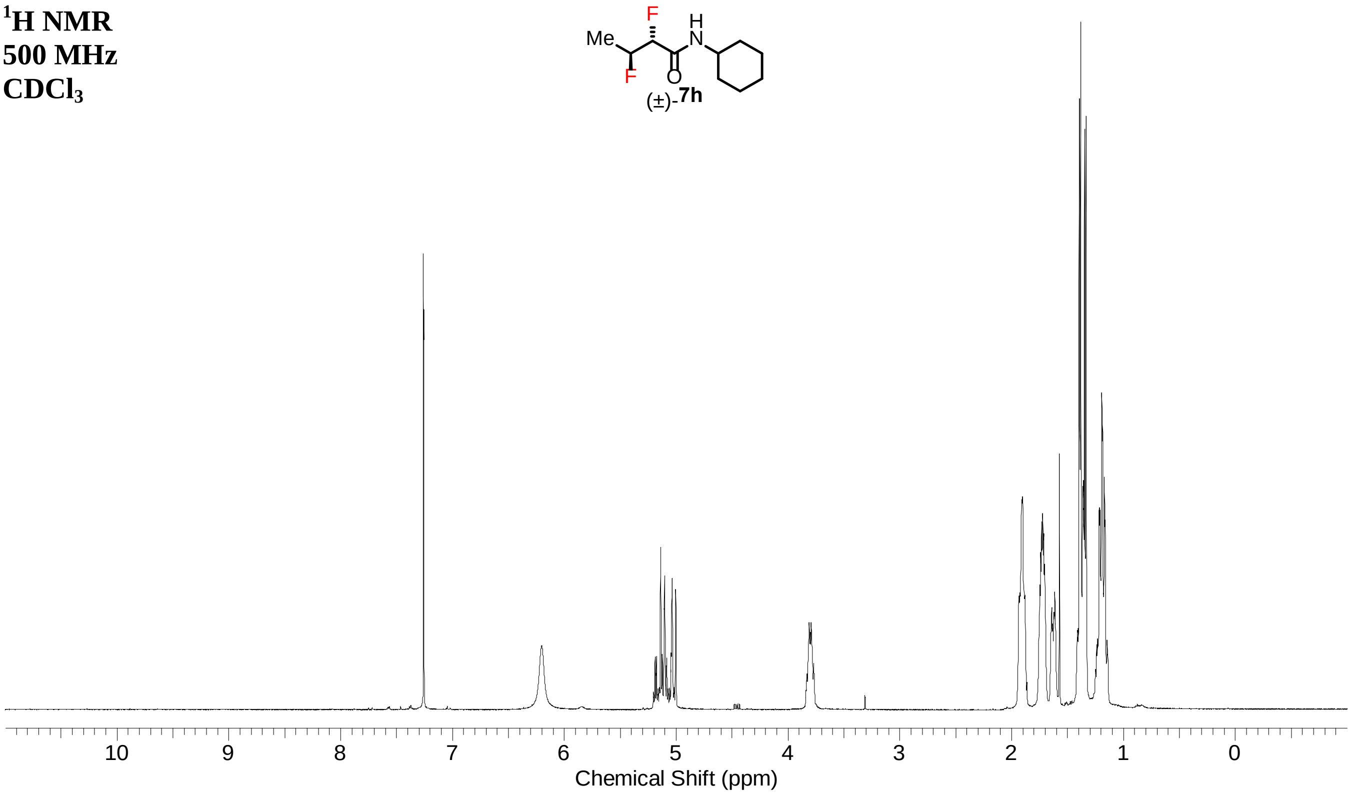
(±)-**7g**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$

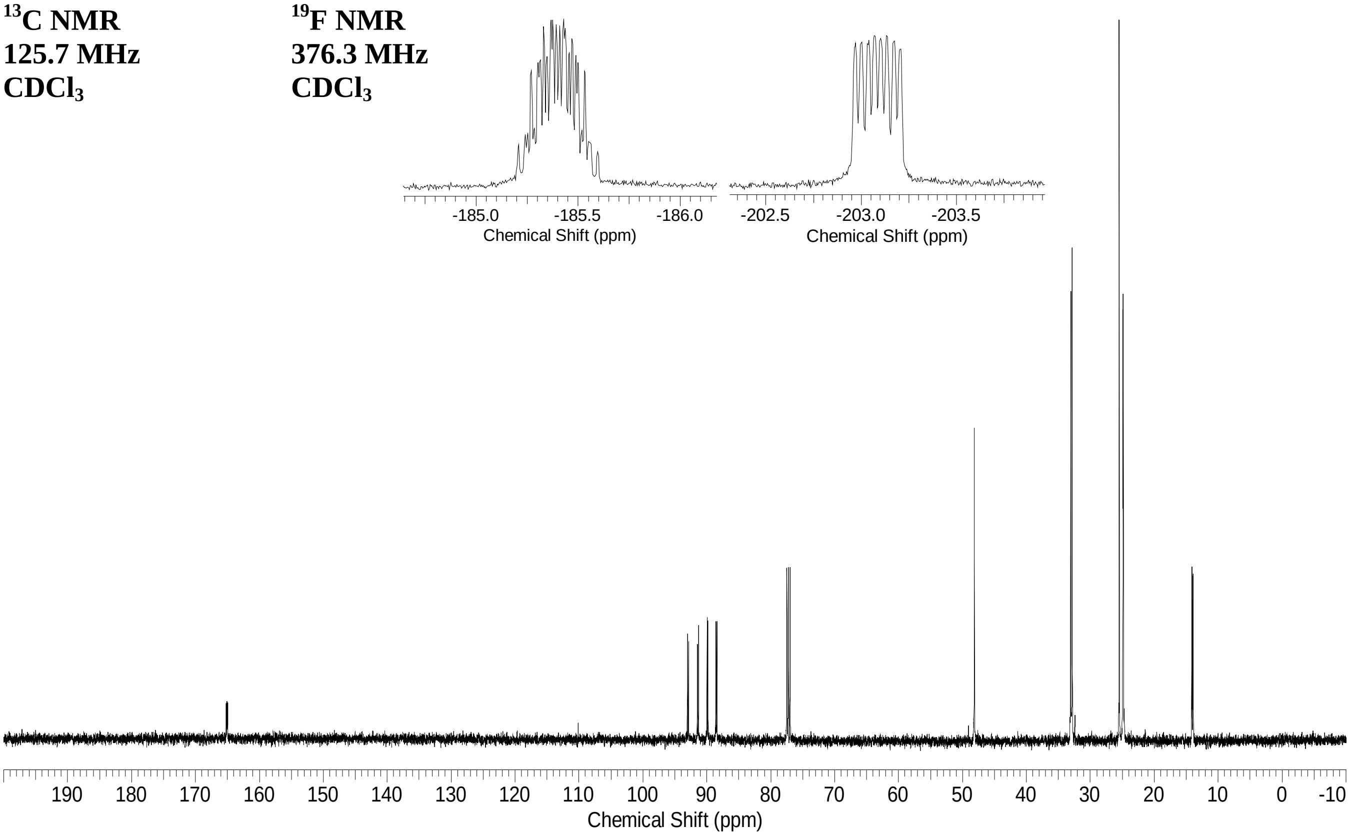


^{1}H NMR
500 MHz
CDCl$_3$

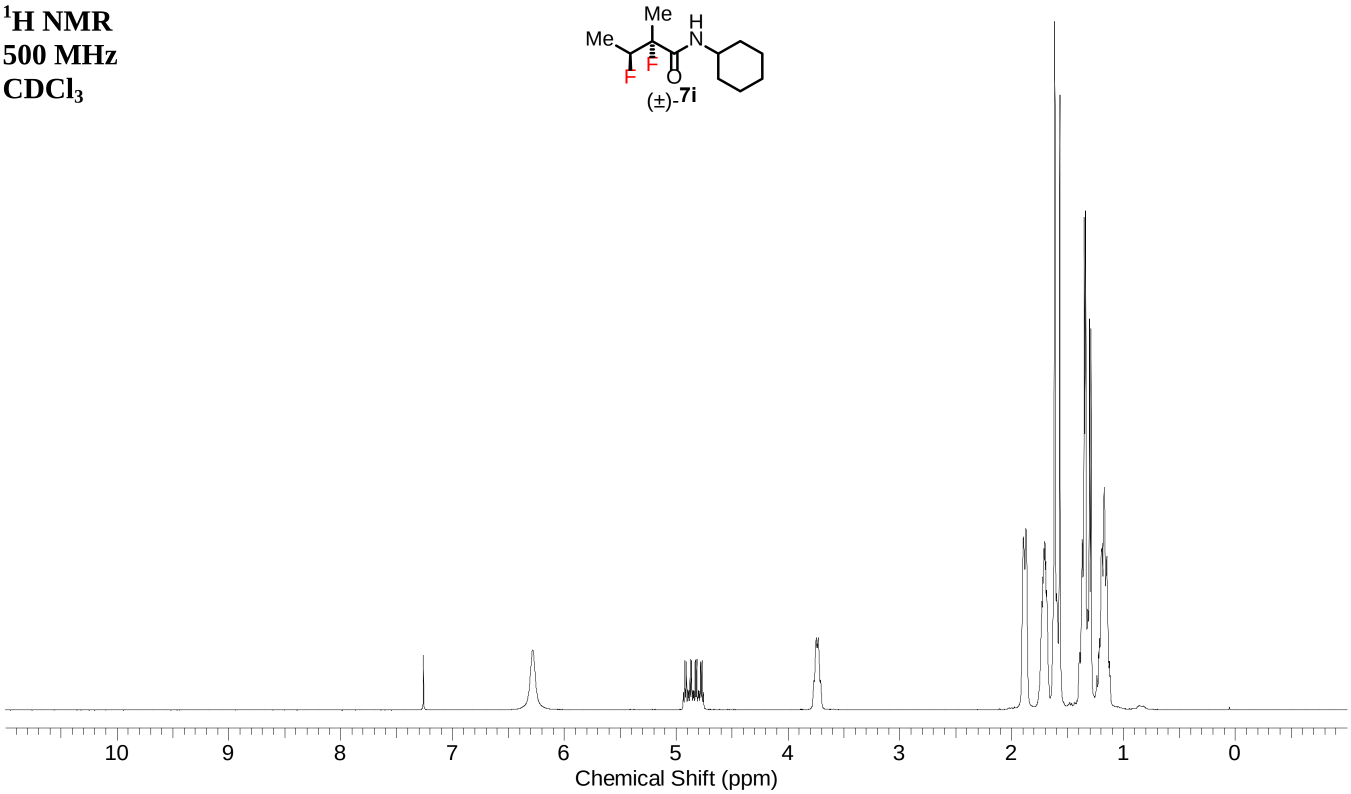


^{13}C NMR
125.7 MHz
CDCl$_3$

^{19}F NMR
376.3 MHz
CDCl$_3$



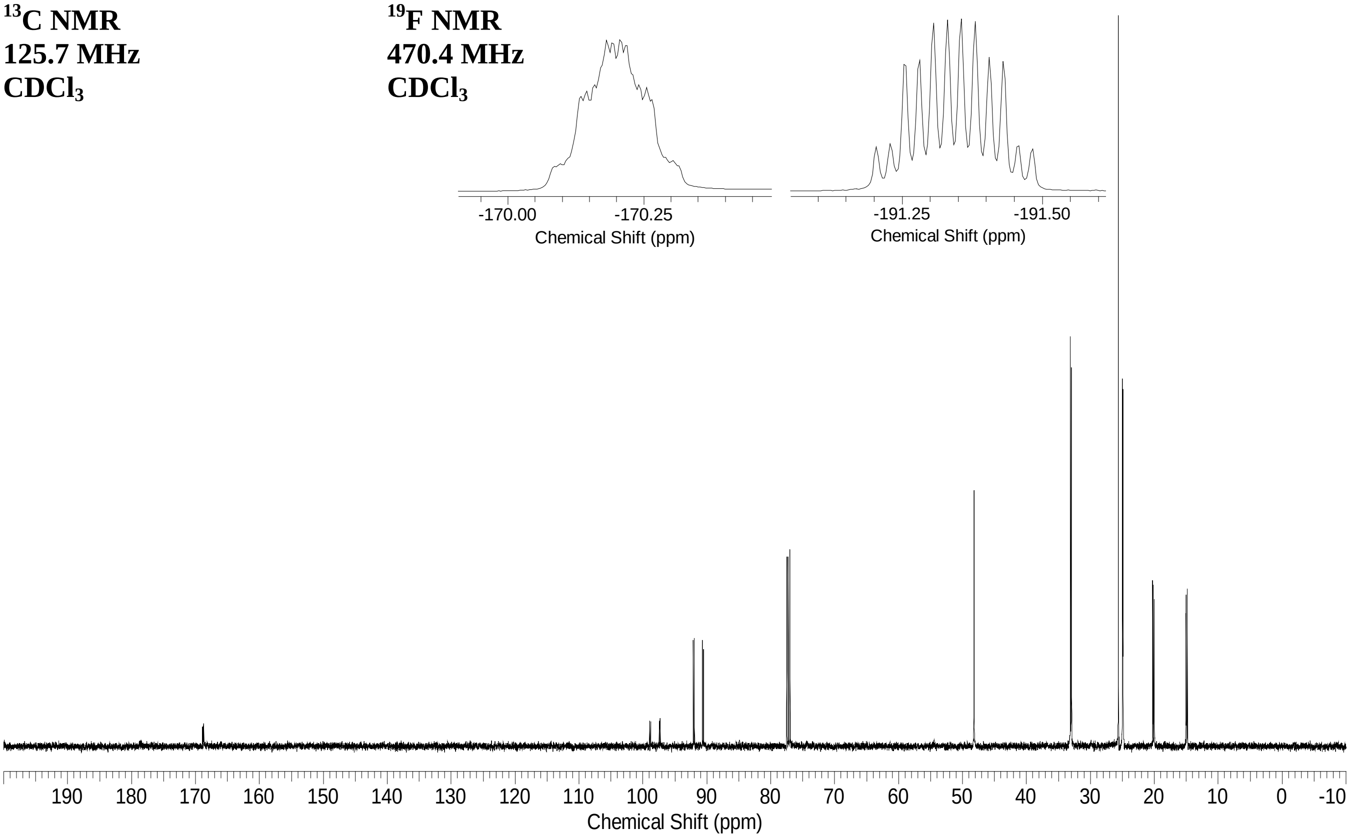
^{1}H NMR
500 MHz
$CDCl_3$



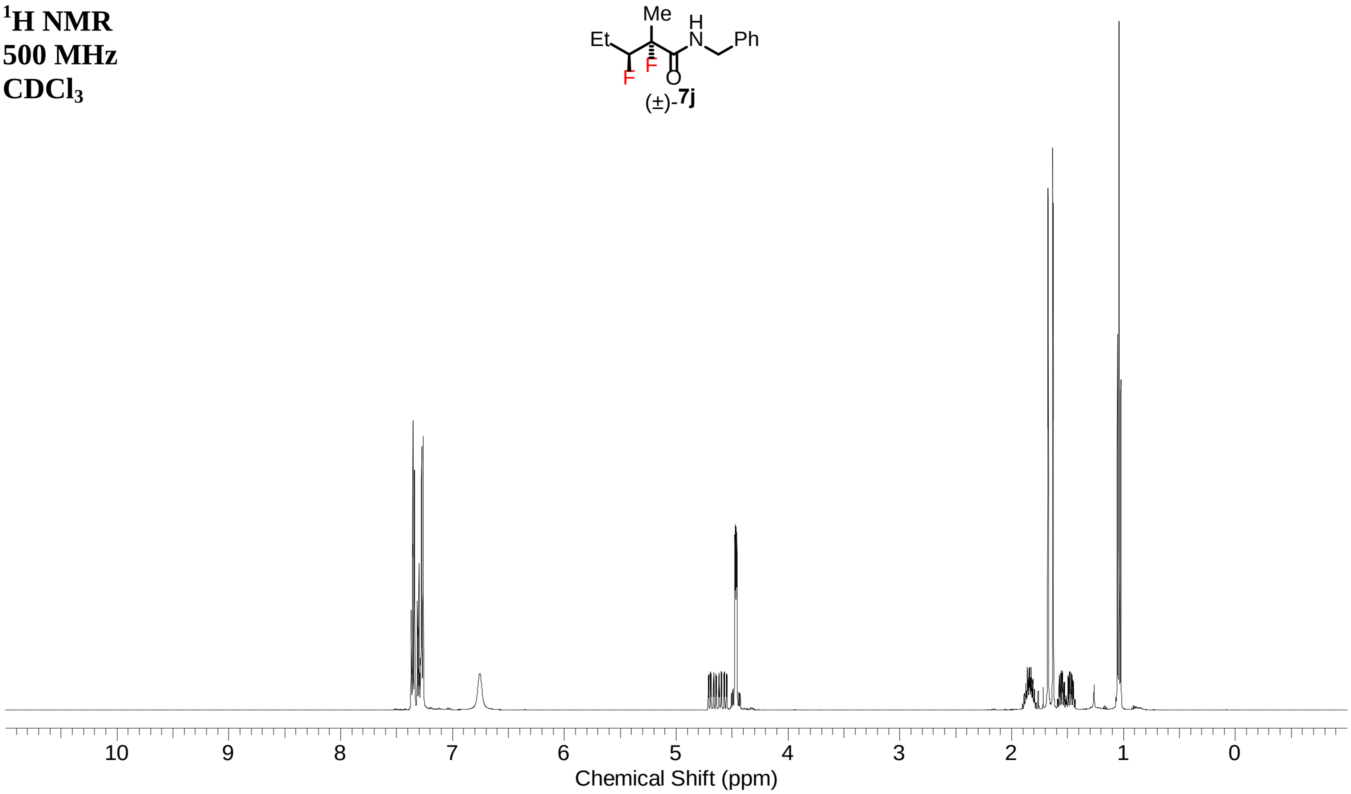
(±)-**7i**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
470.4 MHz
$CDCl_3$



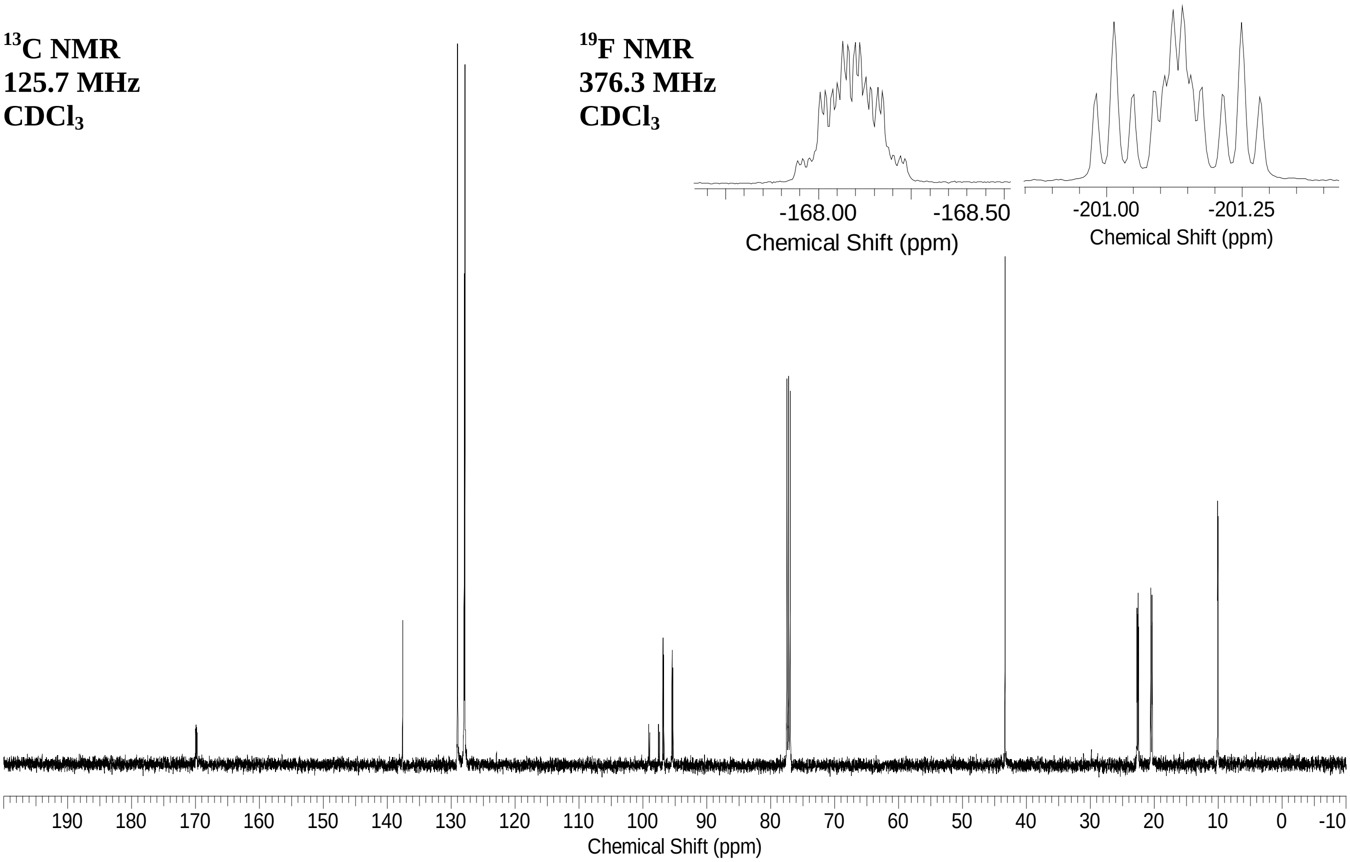
^{1}H NMR
500 MHz
$CDCl_3$

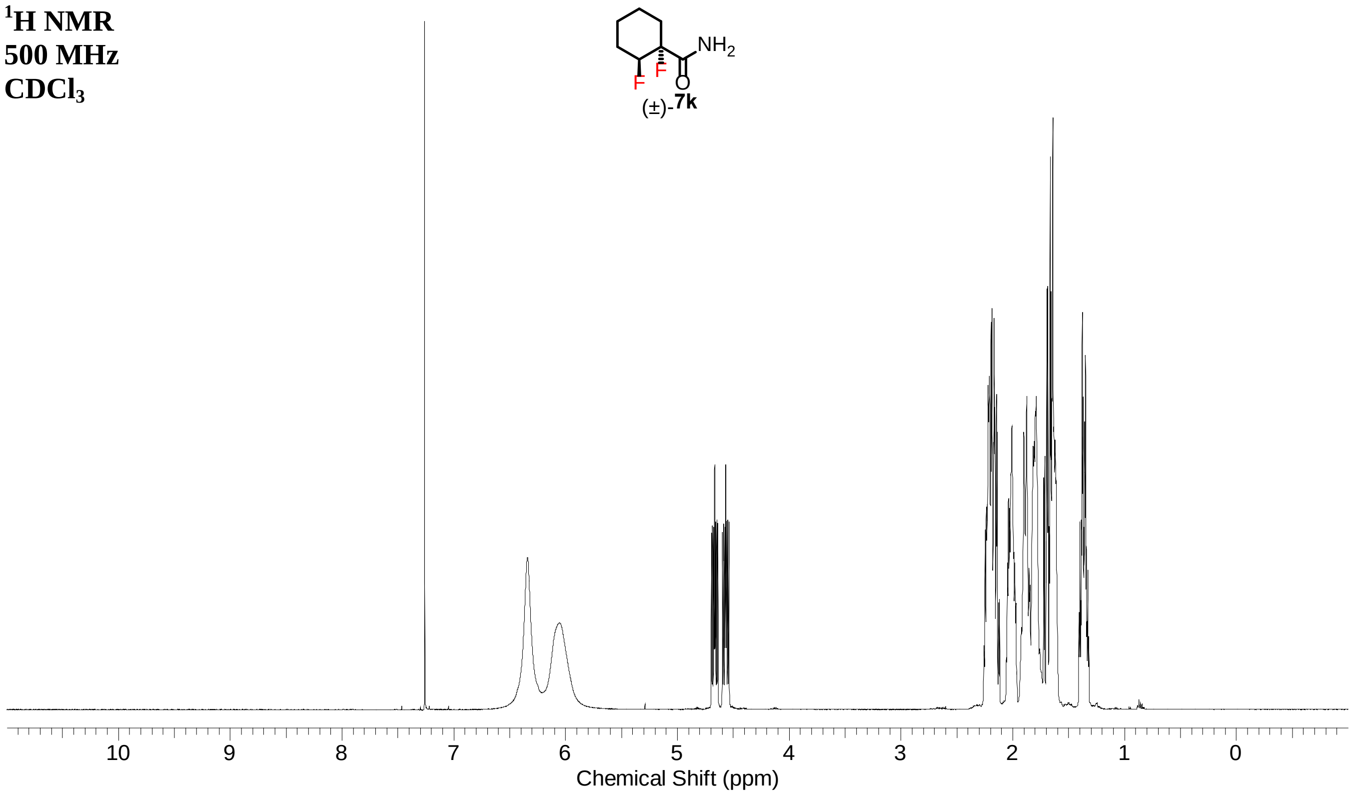


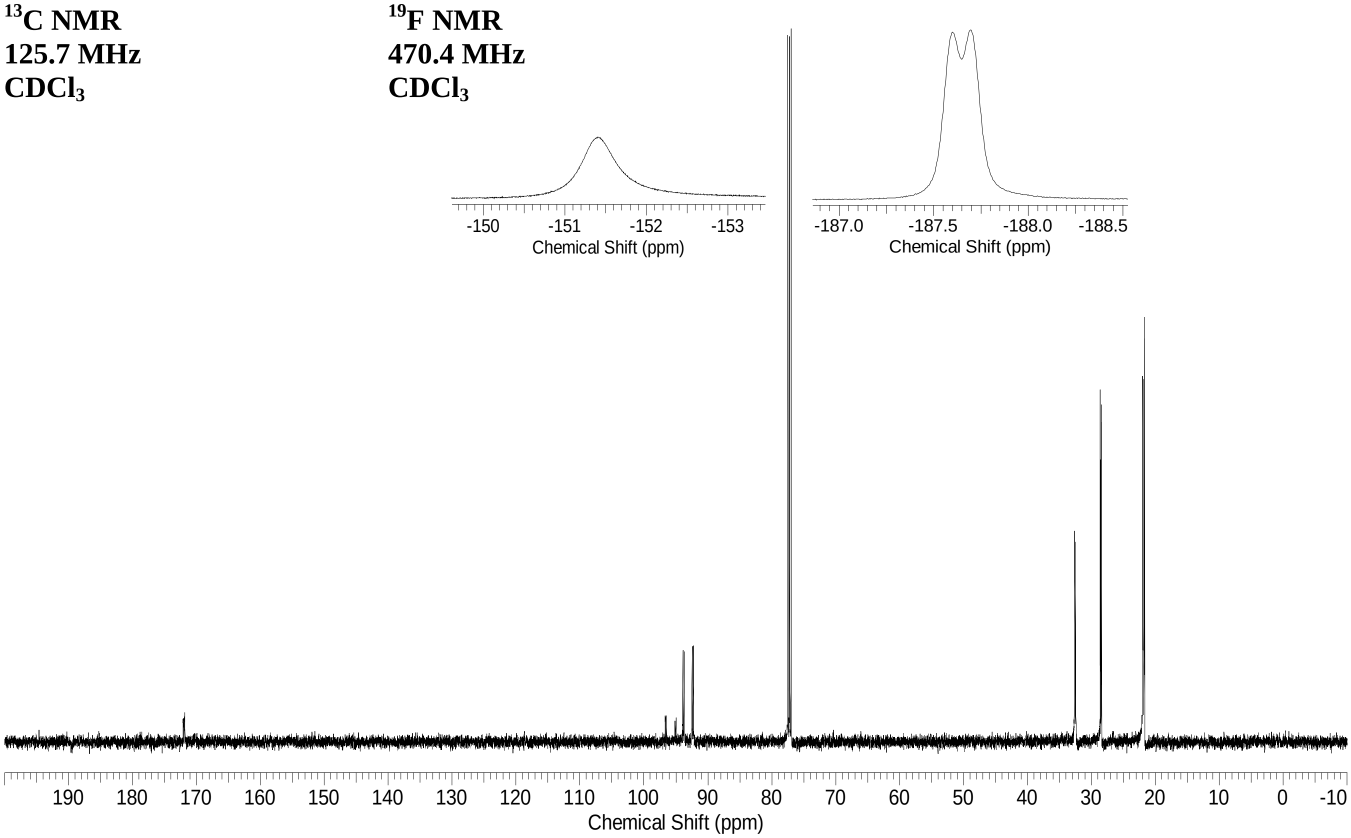
(±)-**7j**

^{13}C NMR
125.7 MHz
$CDCl_3$

^{19}F NMR
376.3 MHz
$CDCl_3$




^{1}H NMR
500 MHz
CDCl$_3$
NH$_2$
F
F
O
(±)-7k
10
9
8
7
6
5
4
3
2
1
0
Chemical Shift (ppm)


^{13}C NMR
125.7 MHz
CDCl$_3$
^{19}F NMR
470.4 MHz
CDCl$_3$
-150
-151
-152
-153
Chemical Shift (ppm)
-187.0
-187.5
-188.0
-188.5
Chemical Shift (ppm)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
Chemical Shift (ppm)