Supporting Information

Rapid Access to Azetidines via Allylation of Azabicyclo[1.1.0]butanes by Dual Copper/Photoredox Catalysis

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1 General information

Unless otherwise noted, all reactions of substrates preparation were conducted in flame – dried glassware under a nitrogen atmosphere using anhydrous solvent passed through an activated alumina column (Innovative Technology). Commercially available reagents were used without further purification. Thin layer chromatography (TLC) was performed using Huanghai TLC silica gel plates HSG F254 and visualized using UV light, anisaldehyde or potassium permanganate. The photocatalytic reactions were performed on WATTCAS Parallel Light Reactor (WP – TEC – 1020L) with 10W LED. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker 400M spectrometer. Chemical shifts in ^{1}H NMR spectra were reported in parts per million (ppm) on the δ scale from an internal standard of residual $CDCl_3$ (7.26 ppm). Data for ^{1}H NMR were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), coupling constant in Hertz (Hz) and integration. Data for ^{13}C NMR spectra were reported in terms of chemical shift in ppm from the central peak of $CDCl_3$ (77.00 ppm). HP 8453 spectrometer was used as the light source for the UV-Vis data. The fluorescence emission spectra were collected on an Edinburgh FLS1000.

2 Picture of reaction set up

The photocatalytic reactions were performed on WATTCAS Parallel Light Reactor (WP – TEC – 1020L).

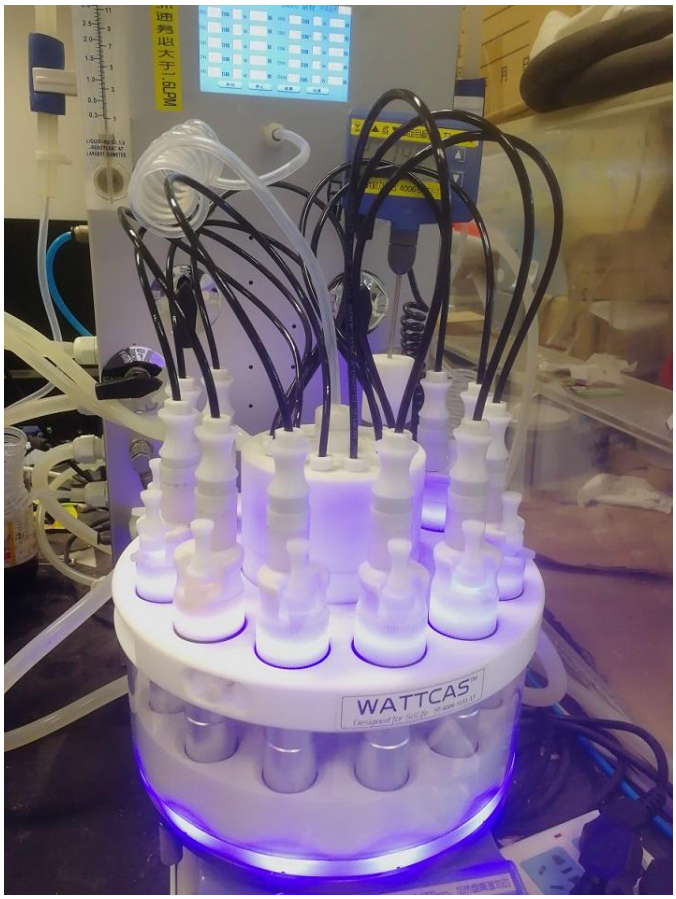


Figure 1 Picture of the photoreactor

Emission spectra of the 10 W blue LED lamp (maximum emission at λ = 450 nm). Distance between light source and quartz tube was approximately 0.5 cm and no filter was used for the reaction.

3 Preparation of 1-azabicyclo[1.1.0]butane

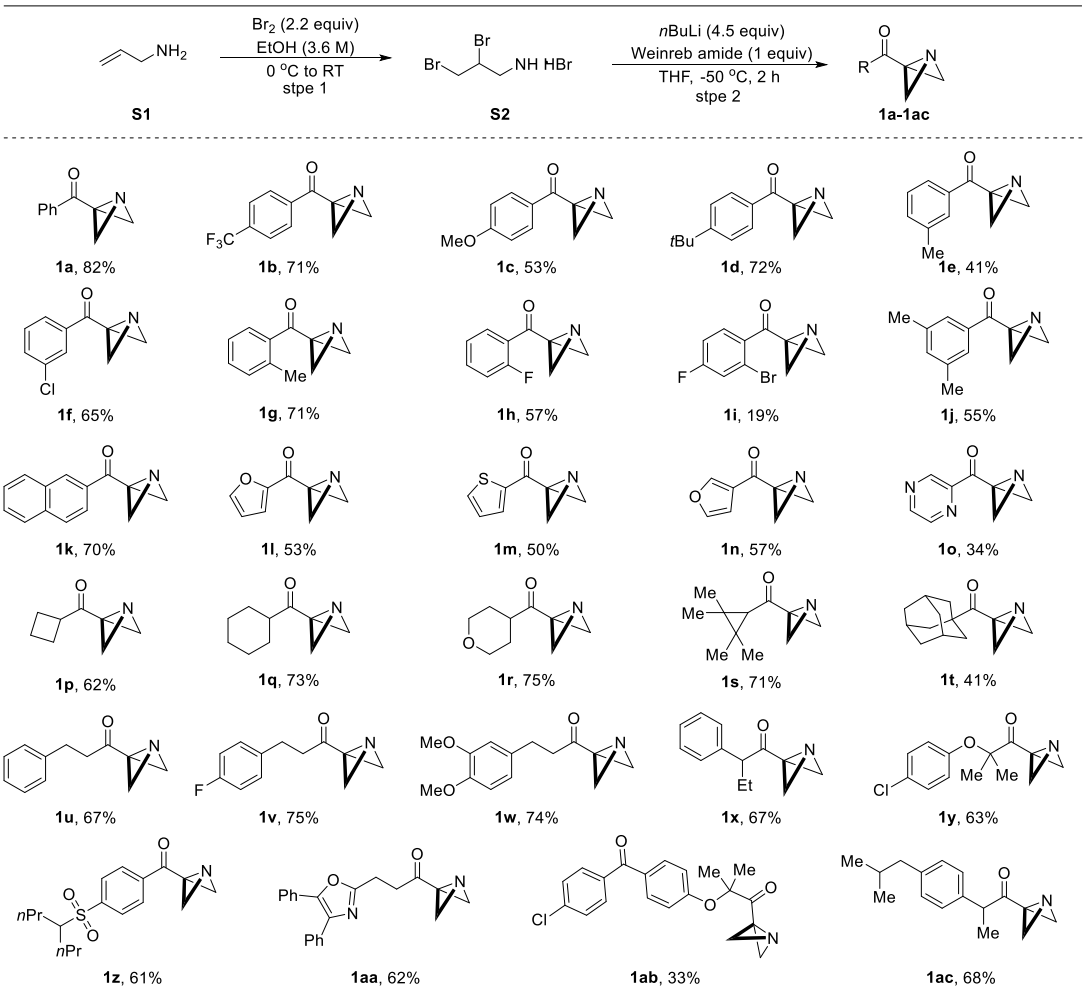


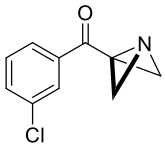
Table S1 Preparation of 1-azabicyclo[1.1.0]butane

Step 1. According to a literature procedure[1], an oven-dried Schlenk tube (100 mL) equipped with a magnetic stir bar was cooled to 0 °C under N_2 protection, and add EtOH (25 mL). The mixture was subsequently stirred for 15 minutes at same temperature. Next, Br_2 (10.0 mL, 196 mmol, 2.2 equiv.) was added slowly dropwise to a vigorously stirring ethanol. After the addition was completed, allylamine **S1** (6.7 mL, 90 mmol, 1.0 equiv.) was then added slowly dropwise into the reaction mixture. The ice bath was removed following the addition, and the mixture was stirred at room temperature for 16 h. The resulting precipitate was collected via suction filtration and washed with Et_2O. The crude residue was subsequently dissolved in the methanol (10 mL) followed by a small amount of Et_2O (50 mL) was added until a white precipitate formed. After the complete precipitation, the desired ammonium salt **S2** (21 g, 79%) was collected as a white solid via suction filtration and thoroughly dried under high vacuum.

Step 2. An oven-dried Schlenk tube (50 mL) equipped with a magnetic stir bar was charged with the ammonium salt S2 (1.3 equiv.) and add dry THF (23 mL) under N_2 protection. n-BuLi (2.5 M in Hexane, 4.5 equiv.) was added slowly dropwise (at a rate of 3 mL/h) to a suspension of ammonium salt solution at -50 °C. After the addition was completed, the resulting solution was stirred for 2 h at -50 °C. Then, the Weinreb amide (2.3 mmol, 1.0 equiv.), in dry THF (5 mL), was added slowly dropwise (at a rate of 5.0

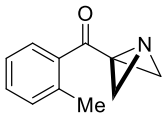
mL/h, syringe pump) into the mixture. After the addition was completed, the reaction flask was removed from cooling bath, and the resulting solution was stirred at room temperature for 2 h. The reaction was quenched with water (15 mL) and then extracted with ethyl acetate (25.0 mL x 3). The combined organic phase was washed with brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude residue was purified by silica gel column chromatography (PE:EA = 10:1 to 2:1) to obtain the desired products **1**.

The characterization data for 1-azabicyclo[1.1.0]butanes **1a**, **1b**, **1c**, **1d**, **1e**, **1k**, **1l**, **1m**, **1q** and **1r** were consistent with respective reported literature.[1]



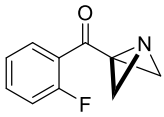
1f

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (s, 1H), 7.83 (dt, *J* = 7.7, 1.3 Hz, 1H), 7.55 (ddd, *J* = 8.0, 2.2, 1.1 Hz, 1H), 7.41 (t, *J* = 7.9 Hz, 1H), 3.05 (s, 2H), 1.76 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 196.0, 137.8, 134.8, 133.3, 129.9, 128.6, 126.8, 56.7, 28.5. **HRMS**: calculated for $C_{10}H_9ClNO$ $[M+H]^+$ 194.0367; found 194.0369.



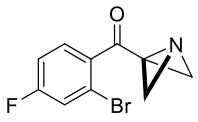
1g

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (dd, *J* = 7.7, 1.7 Hz, 1H), 7.38 (td, *J* = 7.5, 1.5 Hz, 1H), 7.25 (d, *J* = 7.7 Hz, 2H), 2.95 (s, 2H), 2.46 (s, 3H), 1.71 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 201.0, 137.7, 136.2, 131.5, 131.4, 129.0, 125.3, 56.6, 30.1, 20.2. **HRMS**: calculated for $C_{11}H_{12}NO$ $[M+H]^+$ 174.0913; found 174.0916.



1h

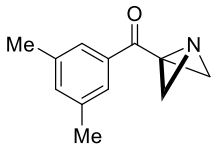
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.63 (m, 1H), 7.60 – 7.47 (m, 1H), 7.24 – 7.20 (m, 1H), 7.18 – 7.09 (m, 1H), 3.02 (s, 2H), 1.77 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 196.9 (d, *J* = 2.6 Hz), 160.9 (d, *J* = 254.4 Hz), 134.5 (d, *J* = 8.7 Hz), 130.2 (d, *J* = 2.3 Hz), 125.3 (d, *J* = 13.8 Hz), 124.4 (d, *J* = 3.6 Hz), 116.4 (d, *J* = 21.9 Hz), 56.7 (d, *J* = 2.8 Hz), 30.4, 30.4. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -110.8. **HRMS**: calculated for $C_{10}H_9FNO$ $[M+H]^+$ 178.0663; found 178.0665.



1i

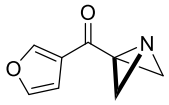
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (dd, *J* = 8.5, 6.0 Hz, 1H), 7.36 (dd, *J* = 8.2, 2.1 Hz, 1H), 7.09 (td, *J* = 8.3, 2.2 Hz, 1H), 2.92 (s, 2H), 1.78 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.6, 163.5 (d, *J* = 256.4

Hz), 131.2, 131.1, 120.8 (d, J = 24.6 Hz), 120.8, 114.8 (d, J = 21.3 Hz), 57.1, 30.2. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -106.0. **HRMS**: calculated for $C_{10}H_8BrFNO$ $[M+H]^+$ 255.9768; found 255.9772.



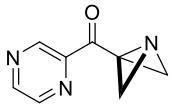
1j

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (s, 2H), 7.39 – 7.14 (s, 1H), 3.05 (s, 2H), 2.38 (s, 6H), 1.74 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 197.3, 138.2, 136.5, 135.1, 126.4, 56.6, 28.6, 21.1. **HRMS**: calculated for $C_{12}H_{14}NO$ $[M+H]^+$ 188.1070; found 188.1073.



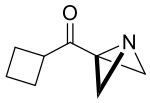
1n

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 (s, 1H), 7.44 (d, J = 1.6 Hz, 1H), 6.78 (d, J = 1.8 Hz, 1H), 3.03 (s, 2H), 1.63 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 190.3, 148.0, 144.2, 126.5, 108.6, 55.6, 29.5. **HRMS**: calculated for $C_8H_8NO_2$ $[M+H]^+$ 150.0550; found 150.0551.



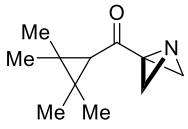
1o

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.27 – 9.14 (m, 1H), 8.79 – 8.69 (m, 1H), 8.60 (dd, J = 4.5, 2.2 Hz, 1H), 3.41 (s, 2H), 1.76 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 196.7, 147.9, 147.6, 144.2, 143.1, 57.6, 29.0. **HRMS**: calculated for $C_8H_7N_3NaO$ $[M+Na]^+$ 184.0481; found 184.0481.



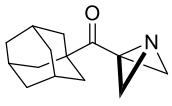
1p

^{1}H NMR (500 MHz, $CDCl_3$) δ 3.44 (t, J = 8.5 Hz, 1H), 2.86 (s, 2H), 2.44 – 2.27 (m, 2H), 2.21 – 2.09 (m, 2H), 1.99 (dp, J = 10.4, 8.4 Hz, 1H), 1.87 (tq, J = 10.0, 5.1, 4.6 Hz, 1H), 1.50 (s, 2H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 207.1, 55.0, 42.5, 24.3, 17.9. **HRMS**: calculated for $C_8H_{12}NO$ $[M+H]^+$ 138.0913; found 138.0915.



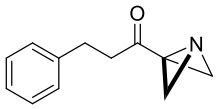
1s

^{1}H NMR (400 MHz, $CDCl_3$) δ 2.87 (t, J = 1.2 Hz, 2H), 1.62 (s, 1H), 1.46 (t, J = 1.2 Hz, 2H), 1.21 (s, 6H), 1.20 (s, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 203.8, 55.0, 41.2, 35.8, 32.0, 23.7, 16.3. **HRMS**: calculated for $C_{11}H_{18}NO$ $[M+H]^+$ 180.1383; found 180.1386.



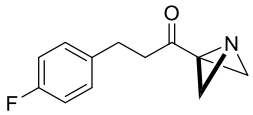
1t

^{1}H NMR (400 MHz, $CDCl_3$) δ 2.90 (s, 2H), 2.18 – 1.99 (m, 3H), 1.90 (d, *J* = 3.0 Hz, 6H), 1.71 (qd, *J* = 15.3, 13.6, 3.3 Hz, 6H), 1.45 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 209.0, 55.8, 47.5, 37.8, 36.3, 27.6. **HRMS**: calculated for $C_{14}H_{20}NO$ $[M+H]^+$ 218.1539; found 218.1543.



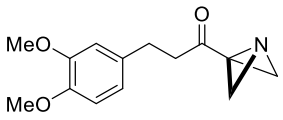
1u

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 – 7.26 (m, 2H), 7.23 – 7.15 (m, 3H), 2.97 – 2.92 (m, 4H), 2.88 – 2.84 (m, 2H), 1.54 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 205.3, 140.5, 128.5, 128.2, 126.2, 55.3, 40.8, 29.8, 29.2. **HRMS**: calculated for $C_{12}H_{14}NO$ $[M+H]^+$ 188.1070; found 188.1071.



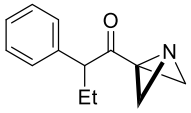
1v

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 (dd, *J* = 8.5, 5.5 Hz, 2H), 6.98 – 6.93 (m, 2H), 2.92 – 2.88 (m, 4H), 2.86 – 2.79 (m, 2H), 1.54 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 205.1, 161.3 (d, *J* = 244.1 Hz), 136.1 (d, *J* = 3.3 Hz), 129.6 (d, *J* = 8.0 Hz), 115.2 (d, *J* = 21.5 Hz), 55.3, 40.7, 29.7, 28.3. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -117.0. **HRMS**: calculated for $C_{12}H_{13}FNO$ $[M+H]^+$ 206.0976; found 206.0981.



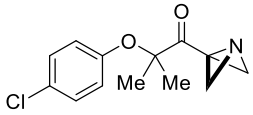
1w

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.78 (d, *J* = 8.2 Hz, 1H), 6.70 (d, *J* = 6.5 Hz, 2H), 3.85 (s, 3H), 3.84 (s, 3H), 2.93 (s, 2H), 2.85 (dp, *J* = 10.4, 5.3, 4.3 Hz, 4H), 1.54 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 205.4, 148.8, 147.3, 133.1, 120.0, 111.5, 111.2, 55.8, 55.7, 55.3, 41.0, 29.8, 28.8. **HRMS**: calculated for $C_{14}H_{18}NO_3$ $[M+H]^+$ 248.1281; found 248.1284.



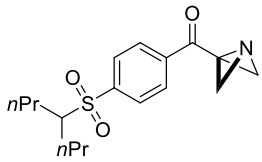
1x

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (td, *J* = 8.0, 7.6, 3.1 Hz, 2H), 7.29 – 7.22 (m, 1H), 7.21 – 7.15 (m, 2H), 3.70 (td, *J* = 7.4, 2.0 Hz, 1H), 2.85 (s, 2H), 2.06 (ddd, *J* = 17.3, 8.5, 5.5 Hz, 1H), 1.80 – 1.63 (m, 1H), 1.40 (s, 2H), 0.81 (td, *J* = 7.4, 3.3 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 205.7, 138.0, 128.9, 128.4, 127.3, 56.9, 55.7, 55.4, 29.9, 25.7, 11.8. **HRMS**: calculated for $C_{13}H_{16}NO$ $[M+H]^+$ 202.1226; found 202.1229.



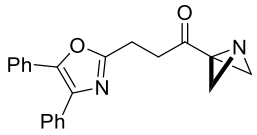
1y

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (dd, *J* = 9.0, 0.9 Hz, 2H), 6.77 (d, *J* = 8.8 Hz, 2H), 3.12 (d, *J* = 1.4 Hz, 2H), 1.53 (s, 6H), 1.48 (d, *J* = 1.4 Hz, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 209.3, 153.6, 129.3, 127.5, 120.1, 84.7, 56.1, 27.3, 24.5. **HRMS**: calculated for $C_{13}H_{15}ClNO_2$ $[M+H]^+$ 252.0786; found 252.0790.



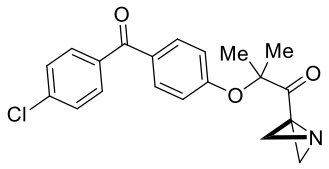
1z

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.2 Hz, 2H), 7.87 (d, *J* = 8.0 Hz, 2H), 3.09 – 3.04 (m, 6H), 1.78 (s, 2H), 1.51 (dt, *J* = 14.8, 7.4 Hz, 4H), 0.81 (dt, *J* = 16.4, 8.0 Hz, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 196.5, 144.3, 139.0, 129.1, 127.0, 127.0, 56.7, 56.7, 49.8, 28.6, 21.8, 21.8, 11.0, 11.0. **HRMS**: calculated for $C_{17}H_{24}NO_3S$ $[M+H]^+$ 322.1471; found 322.1476.



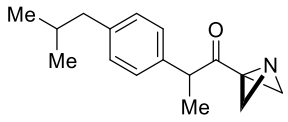
1aa

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.60 (m, 2H), 7.59 – 7.53 (m, 2H), 7.42 – 7.27 (m, 6H), 3.17 (s, 4H), 3.01 (s, 2H), 1.59 (s, 2H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 204.1, 161.7, 145.3, 135.0, 132.3, 128.8, 128.5, 128.4, 128.3, 127.9, 127.8, 126.3, 55.4, 35.7, 29.7, 21.7. **HRMS**: calculated for $C_{21}H_{19}N_2O_2$ $[M+H]^+$ 331.1441; found 331.1445.



1ab

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 – 7.64 (m, 4H), 7.49 – 7.41 (m, 2H), 6.93 – 6.83 (m, 2H), 3.09 (s, 2H), 1.62 (s, 6H), 1.46 (s, 2H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 209.1, 194.0, 159.2, 138.4, 136.1, 132.1, 131.1, 130.9, 128.5, 117.4, 85.0, 56.0, 27.3, 24.7. **HRMS**: calculated for $C_{20}H_{19}ClNO_3$ $[M+H]^+$ 356.1048; found 356.1052.

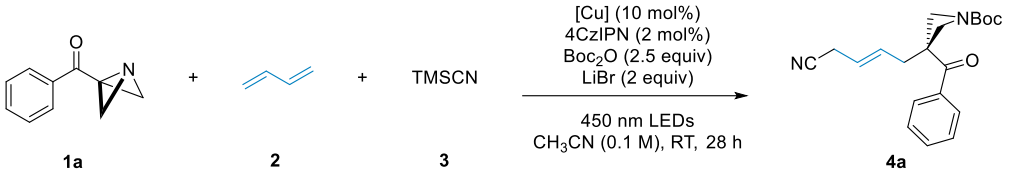


1ac

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.09 (s, 4H), 3.93 (q, *J* = 6.9 Hz, 1H), 2.97 – 2.77 (m, 2H), 2.44 (d, *J* = 7.2 Hz, 2H), 1.84 (dt, *J* = 13.5, 6.8 Hz, 1H), 1.48 – 1.31 (m, 5H), 0.89 (s, 3H), 0.87 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 206.2, 140.7, 136.9, 129.7, 127.5, 55.8, 55.3, 49.2, 44.9, 30.0, 29.5, 22.3, 18.2. **HRMS**: calculated for $C_{16}H_{22}NO$ $[M+H]^+$ 244.1696; found 244.1699.

4 Optimization of reaction conditions

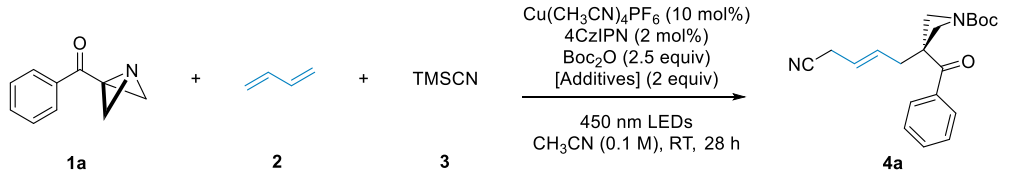
4.1 The effect of copper salts



Entry [a]	[**Cu**]	Yield of **4a** (%)[b]
1	CuCl	74
2	CuCN	79
3	$Cu(CH_3CN)_4PF_6$	84

[a] Reaction conditions: **1a** (0.2 mmol, 1 equiv.), **2** (2 equiv.), **3** (1.5 equiv.), 28 h. [b] Yields were determined by ^{1}H NMR analysis with 1,3,5-trimethoxybenzene as the internal standard.

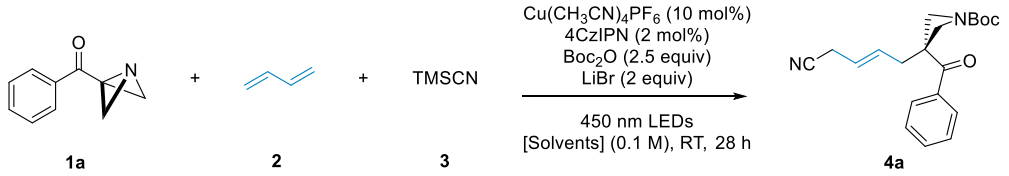
4.2 The effect of additives



Entry [a]	[**additives**]	Yield of **4a** (%)[b]
1	LiCl	71
2	KI	38
3	LiBr	84

[a] Reaction conditions: **1a** (0.2 mmol, 1 equiv.), **2** (2 equiv.), **3** (1.5 equiv.), 28 h. [b] Yields were determined by ^{1}H NMR analysis with 1,3,5-trimethoxybenzene as the internal standard.

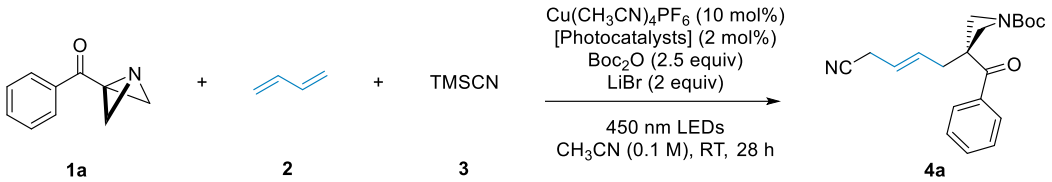
4.3 The effect of solvents

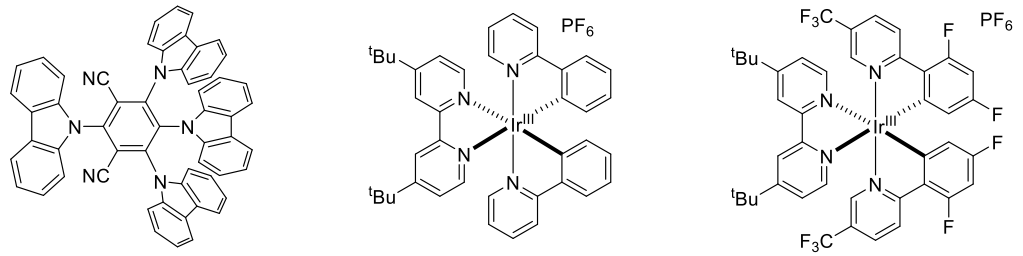


Entry [a]	[**Solvents**]	Yield of **4a** (%)[b]
1	CH_3CN	84
2	THF	57
3	DCM	64

[a] Reaction conditions: **1a** (0.2 mmol, 1 equiv.), **2** (2 equiv.), **3** (1.5 equiv.), 28 h. [b] Yields were determined by ^{1}H NMR analysis with 1,3,5-trimethoxybenzene as the internal standard.

4.4 The effect of photocatalysts



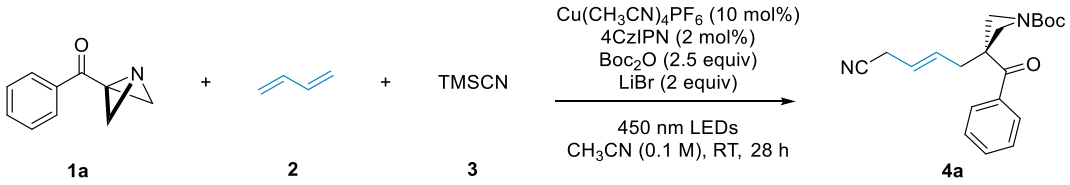


4CzIPN | $Ir(ppy)_2(dtbbpy)PF_6$ | $Ir[dF(CF_3)ppy_2](dtbbpy)PF_6$

Entry [a]	[Photocatalysts]	Yield of **4a** (%)[b]
1	4CzIPN	84
2	$Ir(ppy)_2(dtbbpy)PF_6$	77
3	$Ir[dF(CF_3)ppy_2](dtbbpy)PF_6$	80

[a] Reaction conditions: **1a** (0.2 mmol, 1 equiv.), **2** (2 equiv.), **3** (1.5 equiv.), 28 h. [b] Yields were determined by ^1H NMR analysis with 1,3,5-trimethoxybenzene as the internal standard.

4.5 Control Experiments



Entry [a]	[**variation from standard conditions**]	Yield of **4a** (%)[b]
1	none	84 (82)[c]
2	no $Cu(CH_3CN)_4PF_6$	15
3	no LiBr	31
4	no 4CzIPN	<5
5	no light	0

[a] Reaction conditions: **1a** (0.2 mmol, 1 equiv.), **2** (2 equiv.), **3** (1.5 equiv.), 28 h. [b] Yields were determined by ^1H NMR analysis with 1,3,5-trimethoxybenzene as the internal standard. [c] Isolated yield.

5 Stern-Volmer luminescence quenching analysis

Emission intensities were recorded using Edinburgh FLS1000 Fluorescense Spectrophotometer for all experiments. All samples used in the luminescence quenching-based screening studies were prepared under oxygen-free conditions. The quenchers were weighed into vials and placed inside a glovebox under a positive pressure of argon. CH_3CN was degassed by argon sparging for one hour and also placed inside along with micropipettes and their tips, cuvettes, empty vials, waste containers and parafilm. The solutions were irradiated at 374 nm and the emission intensity was collected at 450-700 nm. The excited state lifetime of the 4CzIPN is 5.1μs.[2]

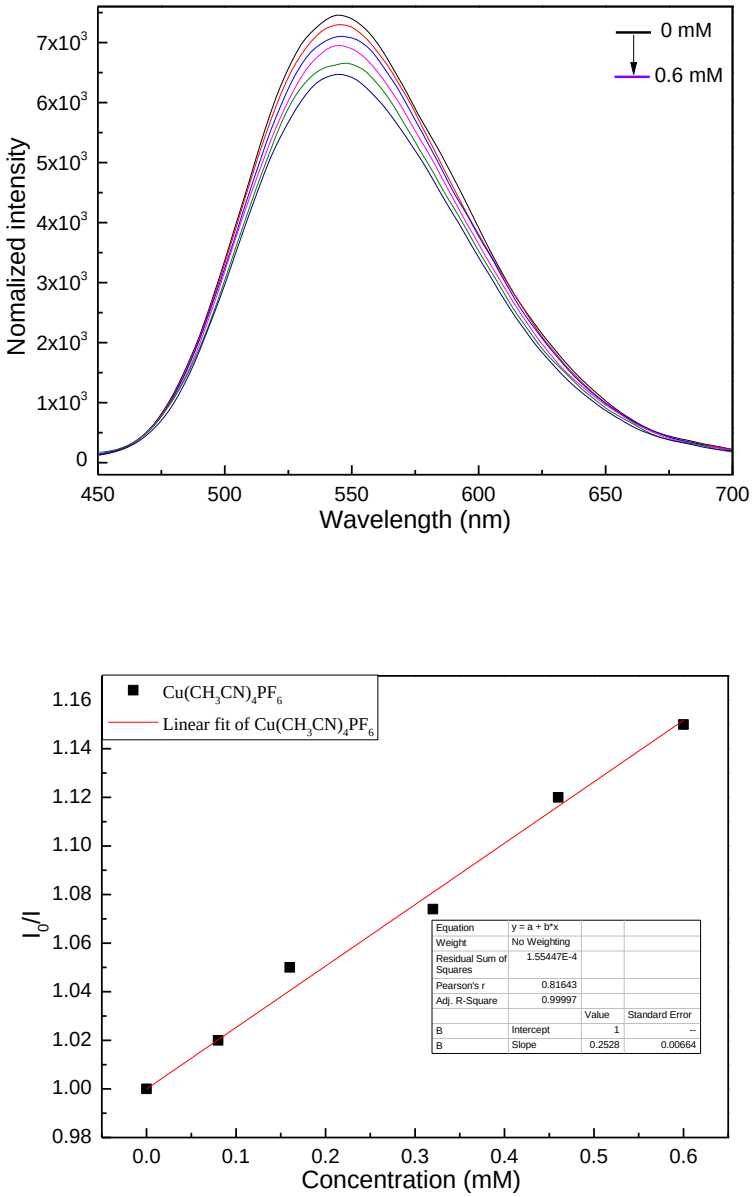
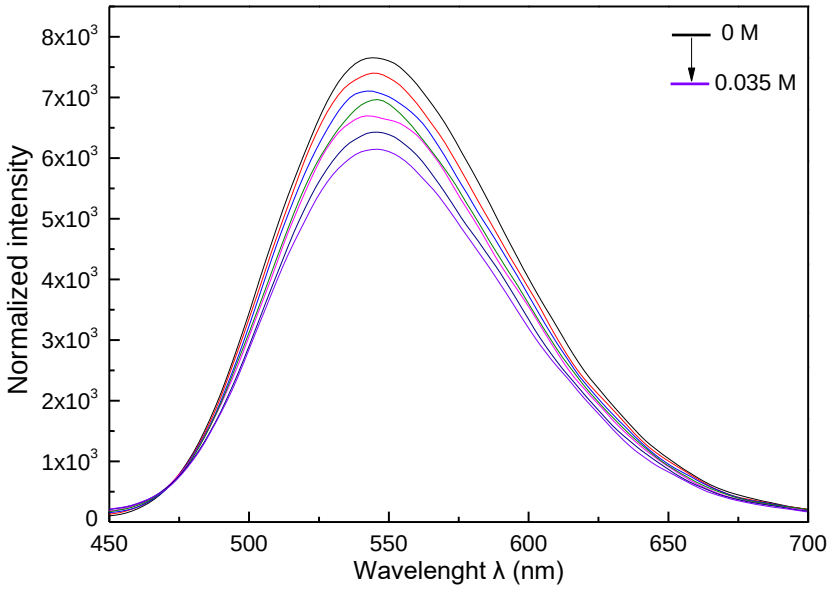


Figure S2 4CzIPN emission quenching by $Cu(CH_3CN)_4PF_6$.



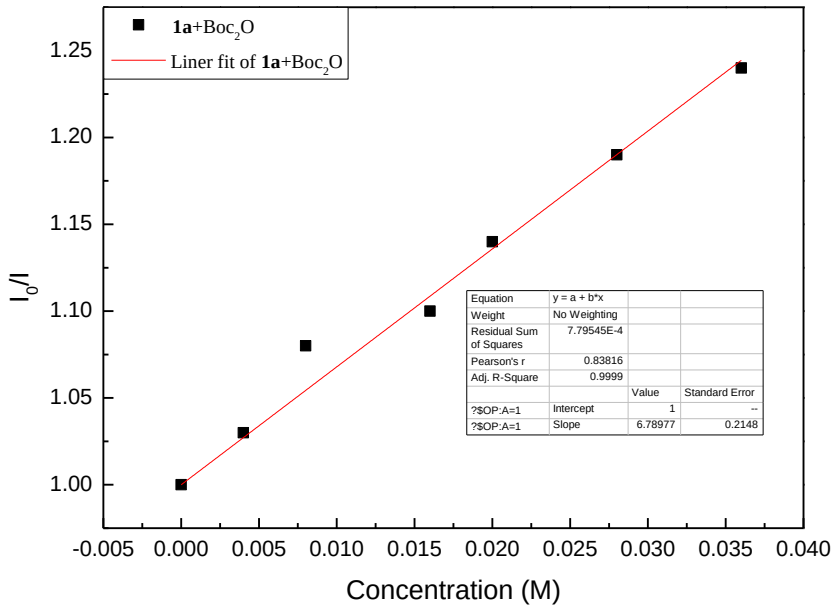
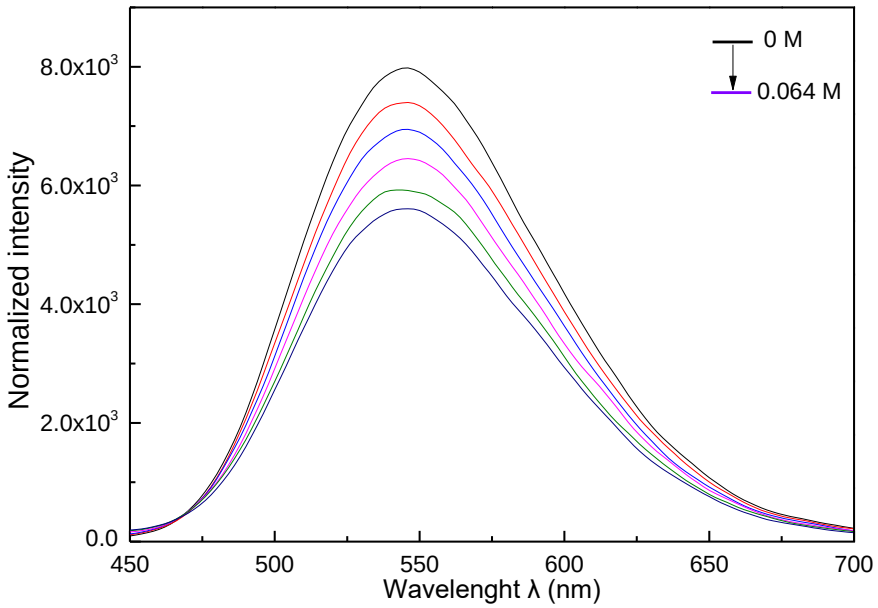


Figure S3 4CzIPN emission quenching by **1a**+Boc_2O adduct.



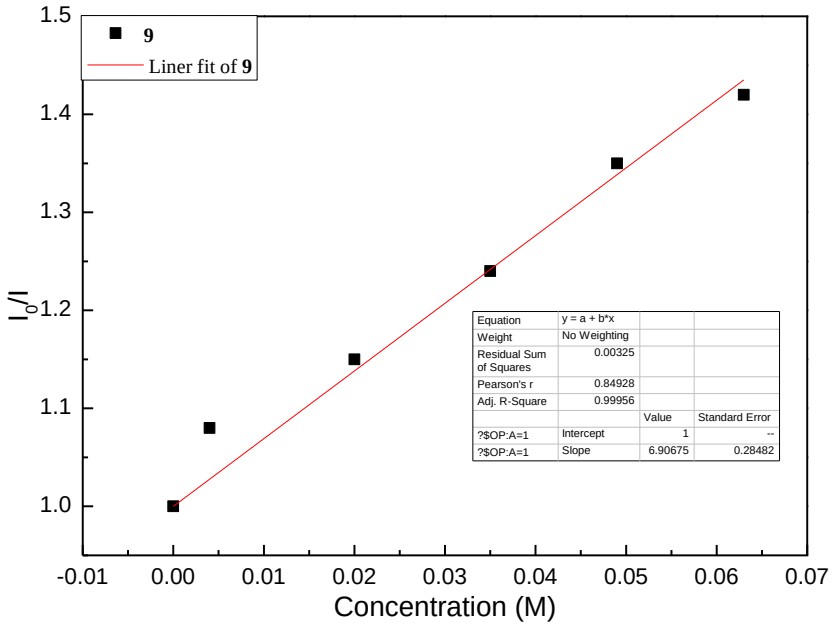
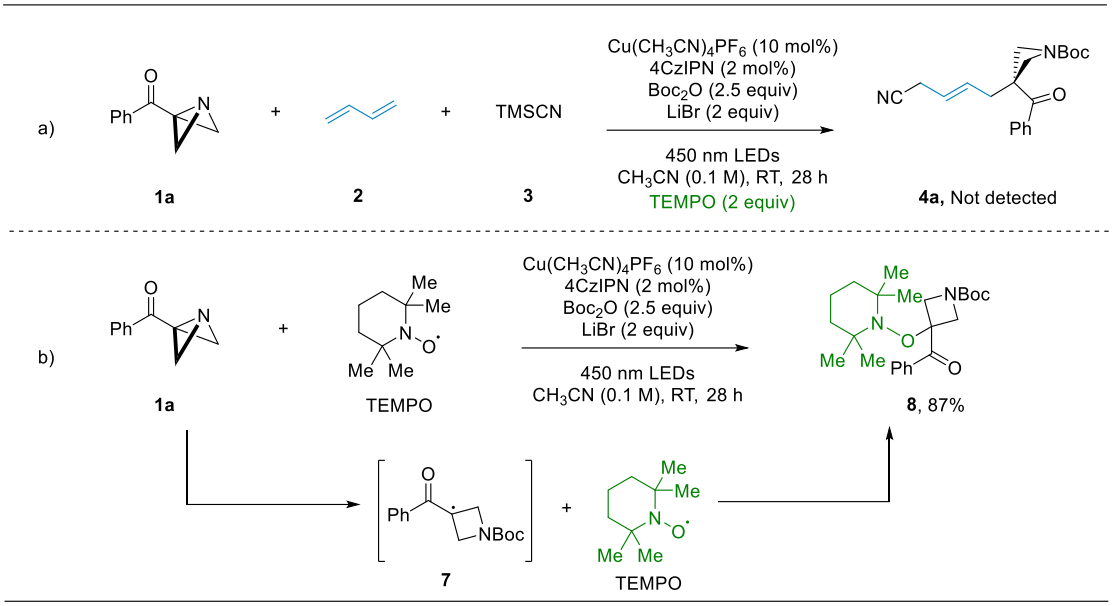


Figure S4 4CzIPN emission quenching by 3-brominated azetidine **9**.

6 Mechanistic Studies

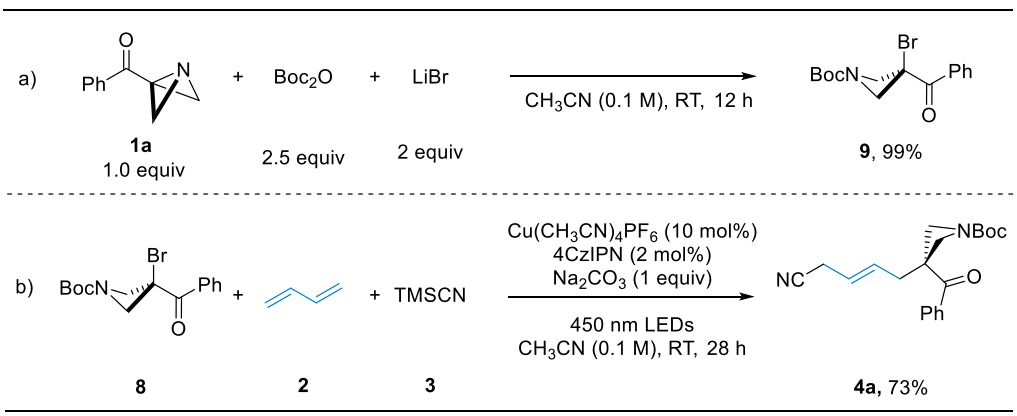
6.1 Radical trapping experiments



Scheme S1 Radical trapping experiments

In a flame-dried 10 mL reaction tube equipped with a magnetic stirrer bar was added with $Cu(CH_3CN)_4PF_6$ (0.1 equiv.), 4CzIPN (0.02 equiv.), Boc_2O (2.5 equiv.), LiBr (2 equiv.) and **1a** (0.2 mmol, 1.0 equiv.). The reaction tube was transferred to an argon-filled glovebox and followed by the addition of CH_3CN (0.1 M), 1,3-butadiene **2** (2 M in THF, 2 equiv.), TMSCN **3** (1.5 equiv.) and TEMPO (0.4 mmol, 2 equiv.). The resulting mixture was removed out the glovebox. Then, the reaction mixture was stirred at room temperature with irradiation of 10 W 450 nm LED for 28 h. The reaction solution was detected by ^1H NMR analysis and the **4a** was not found. However, when ABB **1a** reacted without 1,3-butadiene and TMSCN, the radical-trapping adduct **8** was derived in 87% yield.

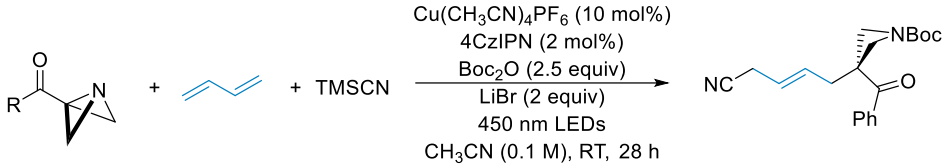
6.2 The evidence for the presence 3-brominated azetidine



Scheme S2 The evidence for the presence 3-brominated azetidine

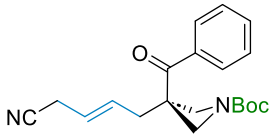
To a solution of **1a** (0.5 mmol, 1 equiv.) in dry CH_3CN (0.1 M) was added Boc_2O (2.5 equiv.) and LiBr (2 equiv.) under N_2 protection. Then, the reaction mixture was stirred at room temperature for 12 h. The solvent was evaporated in vacuo and the crude material was purified by flash column chromatography to furnish the product **9**. Then, in a flame-dried 10 mL reaction tube equipped with a magnetic stirrer bar was added with $Cu(CH_3CN)_4PF_6$ (0.1 equiv.), 4CzIPN (0.02 equiv.), Na_2CO_3 (1 equiv.) and **1a** (0.2 mmol, 1.0 equiv.). The reaction tube was transferred to an argon-filled glovebox and followed by the addition of CH_3CN (0.1 M), 1,3-butadiene **2** (2 M in THF, 2 equiv.) and TMSCN **3** (1.5 equiv.). Then, the resulting mixture was removed out the glovebox and stirred at room temperature with irradiation of 10 W 450 nm LED for 28 h. The product **4a** was derived in 73% yield

7 General procedure and characterization data



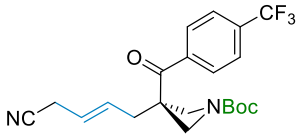
1 2 3 4

In a flame-dried 10 mL reaction tube equipped with a magnetic stirrer bar was added with $Cu(CH_3CN)_4PF_6$ (0.1 equiv.), 4CzIPN (0.02 equiv.), Boc_2O (2.5 equiv.), LiBr (2 equiv.) and **1a** (0.2 mmol, 1.0 equiv.). The reaction tube was transferred to an argon-filled glovebox and followed by the addition of CH_3CN (0.1 M), 1,3-butadiene **2** (2 M in THF, 2 equiv.) and TMSCN **3** (1.5 equiv.). Then, the reaction mixture was stirred at room temperature with irradiation of 10 W 450 nm LED for 28 h. After the reaction completed, the solvent was evaporated in vacuo and the crude material was purified by flash column chromatography to furnish the desired azetidine products.



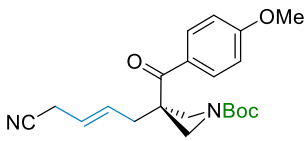
4a

4a, Rf = 0.25 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 82% yield (56 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.76 – 7.64 (m, 2H), 7.64 – 7.52 (m, 1H), 7.47 (dd, *J* = 8.3, 7.0 Hz, 2H), 5.75 – 5.57 (m, 1H), 5.39 (dtt, *J* = 15.3, 5.7, 1.3 Hz, 1H), 4.37 (d, *J* = 8.7 Hz, 2H), 3.92 (d, *J* = 8.8 Hz, 2H), 3.03 (dd, *J* = 5.6, 1.6 Hz, 2H), 2.86 (dd, *J* = 7.2, 1.4 Hz, 2H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.5, 156.2, 133.5, 133.1, 128.8, 128.8, 128.7, 122.2, 117.0, 79.9, 56.0, 47.0, 40.3, 28.2, 20.3. **HRMS**: calculated for $C_{20}H_{24}N_2NaO_3$ $[M+Na]^+$ 363.1685; found 363.1685.



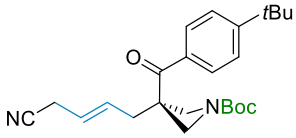
4b

4b, Rf = 0.33 (PE:EA = 4:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 75% yield (61 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.81 (d, *J* = 8.3 Hz, 2H), 7.74 (d, *J* = 8.3 Hz, 2H), 5.76 – 5.58 (m, 1H), 5.40 (dt, *J* = 15.3, 5.6 Hz, 1H), 4.37 (d, *J* = 8.8 Hz, 2H), 3.95 (d, *J* = 8.8 Hz, 2H), 3.04 (dd, *J* = 5.6, 1.5 Hz, 2H), 2.93 – 2.78 (m, 2H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 198.5, 156.2, 135.9, 134.7 (q, *J* = 32.9 Hz), 129.1, 128.4, 125.9 (q, *J* = 3.8 Hz), 123.2 (q, *J* = 272.9 Hz), 122.5, 116.9, 80.1, 55.9, 47.1, 40.0, 28.2, 20.3. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -63.2. **HRMS**: calculated for $C_{21}H_{23}F_3N_2NaO_3$ $[M+Na]^+$ 431.1558; found 431.1559.



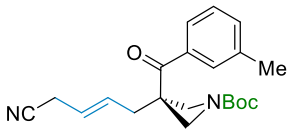
4c

4c, Rf = 0.35 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 80% yield (59 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.82 – 7.54 (m, 2H), 7.04 – 6.76 (m, 2H), 5.83 – 5.53 (m, 1H), 5.39 (dt, *J* = 15.2, 5.7 Hz, 1H), 4.34 (d, *J* = 8.7 Hz, 2H), 3.93 – 3.84 (m, 5H), 3.13 – 2.95 (m, 2H), 2.83 (d, *J* = 7.3 Hz, 2H), 1.41 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 198.1, 163.6, 156.3, 131.1, 129.1, 126.0, 122.0, 117.0, 113.9, 79.8, 56.2, 55.4, 46.8, 40.5, 28.2, 20.3. **HRMS**: calculated for $C_{21}H_{26}N_2NaO_4$ $[M+Na]^+$ 393.1790; found 393.1788.



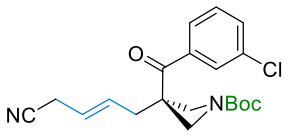
4d

4d, Rf = 0.31 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 85% yield (67 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.76 – 7.57 (m, 2H), 7.56 – 7.43 (m, 2H), 5.77 – 5.58 (m, 1H), 5.50 – 5.36 (m, 1H), 4.37 (d, *J* = 8.8 Hz, 2H), 3.92 (d, *J* = 8.9 Hz, 2H), 3.04 (dd, *J* = 5.7, 1.5 Hz, 2H), 2.94 – 2.78 (m, 2H), 1.42 (s, 9H), 1.33 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.2, 157.4, 156.3, 130.4, 129.1, 128.8, 125.8, 122.1, 117.1, 79.8, 56.1, 47.0, 40.4, 35.1, 30.9, 28.2, 20.3. **HRMS**: calculated for $C_{24}H_{32}N_2NaO_3$ $[M+Na]^+$ 419.2311; found 419.2311.



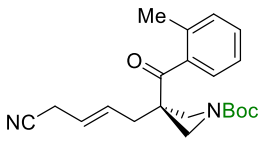
4e

4e, Rf = 0.48 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 82% yield (58 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.54 (s, 1H), 7.47 – 7.31 (m, 3H), 5.82 – 5.55 (m, 1H), 5.40 (dt, *J* = 15.3, 5.7 Hz, 1H), 4.37 (d, *J* = 8.8 Hz, 2H), 3.92 (d, *J* = 8.8 Hz, 2H), 3.03 (dd, *J* = 5.7, 1.5 Hz, 2H), 2.86 (d, *J* = 7.3 Hz, 2H), 2.40 (s, 3H), 1.43 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.7, 156.3, 138.8, 134.3, 133.2, 129.3, 129.0, 128.6, 125.9, 122.1, 117.0, 79.9, 56.1, 47.1, 40.4, 28.2, 21.4, 20.3. **HRMS**: calculated for $C_{21}H_{26}N_2NaO_3$ $[M+Na]^+$ 377.1841; found 377.1838.



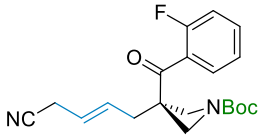
4f

4f, Rf = 0.46 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 87% yield (65 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.70 (t, *J* = 1.9 Hz, 1H), 7.54 (ddt, *J* = 12.4, 7.7, 1.2 Hz, 2H), 7.42 (t, *J* = 7.9 Hz, 1H), 5.85 – 5.54 (m, 1H), 5.40 (dt, *J* = 15.3, 5.6 Hz, 1H), 4.35 (d, *J* = 8.8 Hz, 2H), 3.92 (d, *J* = 8.7 Hz, 2H), 3.04 (dd, *J* = 5.6, 1.5 Hz, 2H), 2.85 (d, *J* = 7.4 Hz, 2H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 198.2, 156.2, 135.2, 134.7, 133.4, 130.1, 128.8, 128.5, 126.7, 122.4, 116.9, 80.0, 56.1, 47.1, 40.1, 28.2, 20.3. **HRMS**: calculated for $C_{20}H_{23}ClN_2NaO_3$ $[M+Na]^+$ 397.1295; found 397.1295.



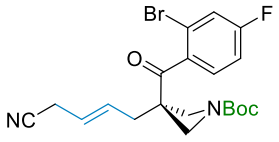
4g

4g, Rf = 0.5 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 77% yield (55 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.39 (td, *J* = 7.5, 1.4 Hz, 1H), 7.30 (d, *J* = 7.6 Hz, 1H), 7.27 – 7.20 (m, 1H), 7.17 (dd, *J* = 7.8, 1.4 Hz, 1H), 5.84 – 5.59 (m, 1H), 5.41 – 5.24 (m, 1H), 4.36 (d, *J* = 8.7 Hz, 2H), 3.85 (d, *J* = 8.6 Hz, 2H), 3.02 (dd, *J* = 5.6, 1.6 Hz, 2H), 2.86 – 2.76 (m, 2H), 2.44 (s, 3H), 1.43 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 203.0, 156.3, 139.4, 134.2, 132.7, 131.6, 129.0, 127.5, 125.3, 121.9, 116.9, 79.9, 56.1, 47.8, 40.2, 28.2, 21.3, 20.3. **HRMS**: calculated for $C_{21}H_{26}N_2NaO_3$ $[M+Na]^+$ 377.1841; found 377.1840.



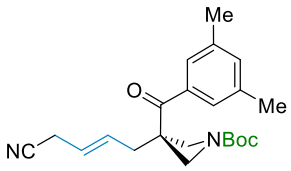
4h

4h, Rf = 0.35 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 76% yield (54 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.81 (td, *J* = 7.6, 1.8 Hz, 1H), 7.56 (tdd, *J* = 7.4, 5.1, 1.8 Hz, 1H), 7.30 – 7.25 (m, 1H), 7.12 (dd, *J* = 11.3, 8.3 Hz, 1H), 5.66 (dt, *J* = 14.8, 7.2 Hz, 1H), 5.33 (dt, *J* = 15.3, 5.6 Hz, 1H), 4.27 (dd, *J* = 9.2, 2.1 Hz, 2H), 3.85 (dd, *J* = 9.2, 2.1 Hz, 2H), 3.16 – 2.97 (m, 2H), 2.73 (d, *J* = 7.2 Hz, 2H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 197.9 (d, *J* = 2.3 Hz), 160.3 (d, *J* = 252.2 Hz), 156.2, 135.1 (d, *J* = 9.0 Hz), 131.7 (d, *J* = 3.4 Hz), 129.0, 123.2 (d, *J* = 14.6 Hz), 122.1, 117.0, 116.4 (d, *J* = 24.0 Hz), 79.7, 55.0, 48.0, 37.6, 37.6, 28.2, 20.3. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -108.6. **HRMS**: calculated for $C_{20}H_{23}FN_2NaO_3$ $[M+Na]^+$ 381.1590; found 381.1587.



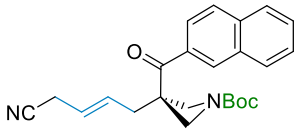
4i

4i, Rf = 0.35 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 65% yield (57 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.40 (dd, *J* = 8.2, 2.4 Hz, 1H), 7.19 (dd, *J* = 8.6, 5.7 Hz, 1H), 7.11 (td, *J* = 8.1, 2.4 Hz, 1H), 5.95 – 5.61 (m, 1H), 5.39 (dt, *J* = 15.3, 5.5 Hz, 1H), 4.29 (d, *J* = 8.7 Hz, 2H), 3.83 (d, *J* = 8.7 Hz, 2H), 3.07 (dd, *J* = 5.4, 1.6 Hz, 2H), 2.79 (d, *J* = 7.1 Hz, 2H), 1.43 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 202.5, 163.0 (d, *J* = 256.5 Hz), 156.2, 135.1 (d, *J* = 3.7 Hz), 129.4 (d, *J* = 8.8 Hz), 129.0, 122.3, 121.6 (d, *J* = 24.6 Hz), 120.4 (d, *J* = 9.5 Hz), 116.9, 114.8 (d, *J* = 21.5 Hz), 80.2, 56.0, 47.5, 38.7, 28.2, 20.4. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -106.2. **HRMS**: calculated for $C_{20}H_{22}BrFN_2NaO_3$ $[M+Na]^+$ 459.0696; found 459.0693.



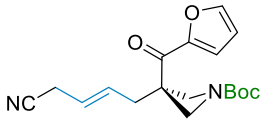
4j

4j, Rf = 0.4 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 70% yield (52 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.27 (s, 2H), 7.21 (s, 1H), 5.83 – 5.56 (m, 1H), 5.40 (dt, *J* = 15.3, 5.7 Hz, 1H), 4.35 (d, *J* = 8.8 Hz, 2H), 3.90 (d, *J* = 8.7 Hz, 2H), 3.03 (dd, *J* = 5.7, 1.5 Hz, 2H), 2.85 (d, *J* = 7.2 Hz, 2H), 2.35 (s, 6H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.9, 156.3, 138.4, 135.1, 133.3, 129.0, 126.4, 122.0, 117.0, 79.8, 56.3, 47.1, 40.4, 28.2, 21.2, 20.3. **HRMS**: calculated for $C_{22}H_{28}N_2NaO_3$, $[M+Na]^+$ 391.1998; found 391.1997.



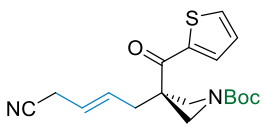
4k

4k, Rf = 0.28 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 91% yield (71 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 1.7 Hz, 1H), 8.07 – 7.83 (m, 3H), 7.79 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.60 (dddd, *J* = 22.3, 8.2, 6.9, 1.3 Hz, 2H), 5.82 – 5.63 (m, 1H), 5.40 (dt, *J* = 15.2, 5.7 Hz, 1H), 4.47 (d, *J* = 8.7 Hz, 2H), 4.02 (d, *J* = 8.7 Hz, 2H), 3.16 – 2.98 (m, 2H), 2.95 (d, *J* = 7.2 Hz, 2H), 1.44 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.6, 156.3, 135.5, 132.2, 130.5, 130.5, 129.6, 128.9, 128.8, 127.7, 127.0, 124.1, 122.2, 117.0, 79.9, 56.0, 47.2, 40.6, 28.2, 20.3. **HRMS**: calculated for $C_{24}H_{26}N_2NaO_3$, $[M+Na]^+$ 413.1841; found 413.1843.



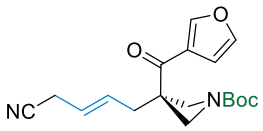
4l

4l, Rf = 0.31 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 2:1) to provide the title compound as a colorless oil in 65% yield (43 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 1.7 Hz, 1H), 7.21 (d, *J* = 3.6 Hz, 1H), 6.56 (dd, *J* = 3.6, 1.7 Hz, 1H), 5.81 – 5.59 (m, 1H), 5.42 (dt, *J* = 15.3, 5.7 Hz, 1H), 4.29 (d, *J* = 9.1 Hz, 2H), 3.84 (d, *J* = 9.1 Hz, 2H), 3.03 (dd, *J* = 5.6, 1.5 Hz, 2H), 2.92 – 2.72 (m, 2H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 188.6, 156.3, 150.9, 146.4, 129.1, 122.0, 118.6, 117.0, 112.5, 79.8, 55.2, 46.4, 39.1, 2.2, 20.3. **HRMS**: calculated for $C_{18}H_{22}N_2NaO_4$, $[M+Na]^+$ 353.1477; found 353.1474.



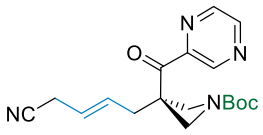
4m

4m, Rf = 0.33 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 2:1) to provide the title compound as a colorless oil in 71% yield (49 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 4.8 Hz, 1H), 7.43 (d, *J* = 3.7 Hz, 1H), 7.14 (ddd, *J* = 4.9, 3.8, 1.1 Hz, 1H), 5.78 – 5.60 (m, 1H), 5.53 – 5.34 (m, 1H), 4.35 (d, *J* = 8.7 Hz, 2H), 3.89 (d, *J* = 8.7 Hz, 2H), 3.14 – 2.99 (m, 2H), 2.85 (d, *J* = 7.3 Hz, 2H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.9, 156.2, 140.3, 134.4, 132.1, 128.9, 128.3, 122.2, 117.0, 79.9, 56.0, 47.2, 40.6, 28.2, 20.3. **HRMS**: calculated for $C_{18}H_{22}N_2NaO_3S$, $[M+Na]^+$ 369.1249; found 369.1253.



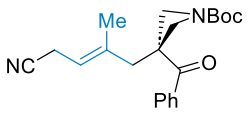
4n

4n, Rf = 0.31 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 2:1) to provide the title compound as a colorless oil in 83% yield (55 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.89 (s, 1H), 7.45 (t, *J* = 1.7 Hz, 1H), 6.65 (dd, *J* = 1.9, 0.9 Hz, 1H), 5.78 – 5.58 (m, 1H), 5.53 – 5.32 (m, 1H), 4.28 (d, *J* = 8.8 Hz, 2H), 3.82 (d, *J* = 8.7 Hz, 2H), 3.04 (dd, *J* = 5.5, 1.5 Hz, 2H), 2.82 – 2.69 (m, 2H), 1.41 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 194.6, 156.2, 147.1, 144.2, 128.8, 123.4, 122.2, 117.0, 108.8, 80.0, 55.6, 47.4, 39.9, 28.2, 20.3. **HRMS**: calculated for $C_{18}H_{22}N_2NaO_4$, $[M+Na]^+$ 353.1477; found 353.1480.



4o

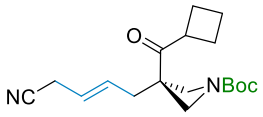
4o, Rf = 0.29 (PE:EA = 1.5:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 1.5:1) to provide the title compound as a pale yellow oil in 51% yield (35 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.24 (d, *J* = 1.5 Hz, 1H), 8.78 (d, *J* = 2.4 Hz, 1H), 8.60 (dd, *J* = 2.5, 1.5 Hz, 1H), 5.78 – 5.61 (m, 1H), 5.38 (dtt, *J* = 15.3, 5.6, 1.3 Hz, 1H), 4.33 (d, *J* = 9.3 Hz, 2H), 3.94 (d, *J* = 9.3 Hz, 2H), 3.03 (dd, *J* = 5.5, 1.6 Hz, 2H), 3.00 – 2.95 (m, 2H), 1.43 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 199.7, 156.4, 148.1, 145.4, 145.0, 143.0, 129.3, 121.8, 117.0, 79.8, 55.9, 47.4, 39.6, 28.3, 20.3. **HRMS**: calculated for $C_{18}H_{22}N_4NaO_3$, $[M+Na]^+$ 365.1590; found 365.1589.



4p

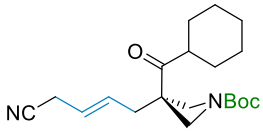
4p, Rf = 0.34 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 54% yield (38 mg)**.** **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.70 (d, J = 8.4 Hz, 2H), 7.62 – 7.55 (m, 1H), 7.48 (t, J = 7.8 Hz, 2H), 5.02 – 4.95 (m, 1H), 4.46 (d, J = 8.7 Hz, 2H), 3.98 (d, J = 8.7 Hz, 2H), 2.96 (s, 2H), 2.93 (d, J = 7.0 Hz, 2H), 1.50 (s, 3H), 1.43 (s, 9H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 199.8, 156.3, 137.6, 133.6, 133.5, 128.9,

128.7, 117.7, 116.3, 80.0, 57.0, 47.8, 47.3, 28.3, 17.0, 16.1. **HRMS**: calculated for $C_{21}H_{26}N_2NaO_3$, $[M+Na]^+$ 377.1841; found 377.1834.



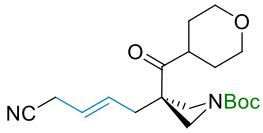
5a

5a, Rf = 0.21 (PE:EA = 4:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 70% yield (45 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.59 (dt, *J* = 14.6, 7.0 Hz, 1H), 5.42 (dd, *J* = 13.5, 7.5 Hz, 1H), 4.00 (d, *J* = 8.8 Hz, 2H), 3.62 (d, *J* = 8.9 Hz, 2H), 3.49 – 3.38 (m, 1H), 3.03 (d, *J* = 5.5 Hz, 2H), 2.57 (d, *J* = 6.9 Hz, 2H), 2.29 – 2.17 (m, 2H), 2.11 – 2.02 (m, 2H), 2.01 – 1.93 (m, 1H), 1.88 – 1.78 (m, 1H), 1.39 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 210.2, 156.1, 129.3, 121.7, 116.9, 79.8, 54.7, 47.1, 41.0, 37.8, 28.1, 25.1, 20.3, 17.9. **HRMS**: calculated for $C_{18}H_{26}N_2NaO_3$, $[M+Na]^+$ 341.1841; found 341.1838.



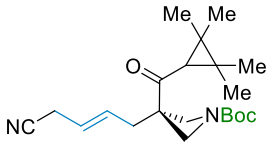
5b

5b, Rf = 0.28 (PE:EA = 4:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 84% yield (57 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.73 – 5.55 (m, 1H), 5.45 (dt, *J* = 15.3, 5.6 Hz, 1H), 4.08 (d, *J* = 8.8 Hz, 2H), 3.66 (d, *J* = 8.9 Hz, 2H), 3.06 (dd, *J* = 5.5, 1.5 Hz, 2H), 2.75 – 2.48 (m, 3H), 1.93 – 1.72 (m, 2H), 1.67 (d, *J* = 11.5 Hz, 3H), 1.50 – 1.34 (m, 11H), 1.33 – 1.10 (m, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 212.5, 156.2, 129.4, 121.8, 117.0, 79.9, 54.8, 47.8, 46.2, 38.0, 29.3, 28.2, 25.4, 25.4, 20.4. **HRMS**: calculated for $C_{20}H_{30}N_2NaO_3$, $[M+Na]^+$ 369.2154; found 369.2153.



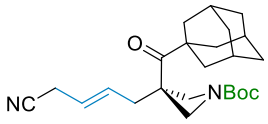
5c

5c, Rf = 0.22 (PE:EA = 1:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 1:1) to provide the title compound as a colorless oil in 86% yield (60 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.73 – 5.59 (m, 1H), 5.47 (dt, *J* = 15.3, 5.5 Hz, 1H), 4.10 (d, *J* = 8.7 Hz, 2H), 4.00 (ddd, *J* = 11.7, 4.5, 2.0 Hz, 2H), 3.71 (d, *J* = 8.9 Hz, 2H), 3.42 (td, *J* = 11.9, 2.2 Hz, 2H), 3.16 – 3.02 (m, 2H), 2.87 (tt, *J* = 11.4, 3.8 Hz, 1H), 2.68 (d, *J* = 6.8 Hz, 2H), 1.89 – 1.70 (m, 2H), 1.65 – 1.51 (m, 2H), 1.43 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 210.5, 156.2, 129.2, 122.1, 116.9, 80.2, 66.8, 54.6, 47.8, 43.3, 38.0, 28.9, 28.2, 20.4. **HRMS**: calculated for $C_{19}H_{28}N_2NaO_4$, $[M+Na]^+$ 371.1947; found 371.1943.



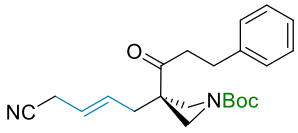
5d

5d, Rf = 0.39 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 68% yield (49 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.63 (dtt, *J* = 15.5, 7.0, 1.6 Hz, 1H), 5.55 – 5.39 (m, 1H), 4.09 (d, *J* = 8.7 Hz, 2H), 3.65 (d, *J* = 8.7 Hz, 2H), 3.07 (dd, *J* = 5.6, 1.5 Hz, 2H), 2.63 (dd, *J* = 7.0, 1.5 Hz, 2H), 1.43 (s, 9H), 1.35 (s, 1H), 1.23 (s, 6H), 1.22 (s, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 207.6, 156.4, 129.6, 121.5, 117.0, 79.8, 54.7, 48.7, 40.7, 38.8, 35.8, 28.3, 23.7, 20.4, 16.2. **HRMS**: calculated for $C_{21}H_{32}N_2NaO_3$, $[M+Na]^+$ 383.2311; found 383.2309.



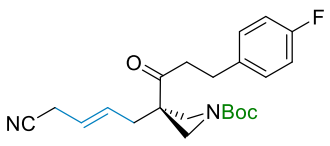
5e

5e, Rf = 0.41 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a white solid in 75% yield (60 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.59 (dt, *J* = 15.3, 6.7 Hz, 1H), 5.49 (dt, *J* = 15.3, 5.4 Hz, 1H), 4.22 (d, *J* = 8.9 Hz, 2H), 3.64 (d, *J* = 8.8 Hz, 2H), 3.11 – 2.98 (m, 2H), 2.74 (d, *J* = 6.8 Hz, 2H), 2.07 – 1.97 (m, 3H), 1.86 (d, *J* = 3.0 Hz, 6H), 1.81 – 1.60 (m, 6H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 213.5, 156.5, 129.5, 122.0, 117.1, 79.9, 55.9, 48.5, 47.1, 39.1, 38.9, 36.3, 28.2, 27.8, 20.4. **HRMS**: calculated for $C_{24}H_{34}N_2NaO_3$, $[M+Na]^+$ 421.2467; found 421.2469.



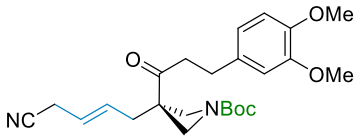
5f

5f, Rf = 0.32 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a pale colorless oil in 80% yield (60 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.33 – 7.24 (m, 2H), 7.23 – 7.11 (m, 3H), 5.51 (dtt, *J* = 15.5, 6.9, 1.6 Hz, 1H), 5.42 – 5.23 (m, 1H), 4.00 (d, *J* = 8.8 Hz, 2H), 3.64 (d, *J* = 8.8 Hz, 2H), 2.98 (dd, *J* = 5.6, 1.6 Hz, 2H), 2.93 (t, *J* = 7.2 Hz, 2H), 2.77 (t, *J* = 7.1 Hz, 2H), 2.66 – 2.46 (m, 2H), 1.42 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 208.2, 156.1, 140.6, 129.0, 128.5, 128.4, 126.3, 121.8, 117.0, 80.0, 54.7, 47.7, 39.3, 38.0, 29.5, 28.2, 20.3. **HRMS**: calculated for $C_{22}H_{28}N_2NaO_3$, $[M+Na]^+$ 391.1998; found 391.1998.



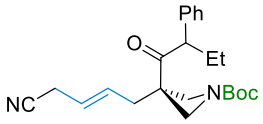
5g

5g, Rf = 0.22 (PE:EA = 3:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 83% yield (64 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.21 – 7.06 (m, 2H), 7.04 – 6.89 (m, 2H), 5.70 – 5.46 (m, 1H), 5.46 – 5.29 (m, 1H), 3.98 (d, *J* = 8.8 Hz, 2H), 3.63 (d, *J* = 8.9 Hz, 2H), 3.00 (dd, *J* = 5.4, 1.5 Hz, 2H), 2.89 (t, *J* = 7.2 Hz, 2H), 2.74 (t, *J* = 7.2 Hz, 2H), 2.64 – 2.44 (m, 2H), 1.41 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 208.1, 161.3 (d, *J* = 244.2 Hz), 156.1, 136.2 (d, *J* = 3.1 Hz), 129.8 (d, *J* = 8.0 Hz), 128.9, 121.8, 116.9, 115.2 (d, *J* = 21.4 Hz), 80.0, 54.7, 47.7, 39.4, 37.9, 28.6, 28.2, 20.3. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -116.6. **HRMS**: calculated for $C_{22}H_{27}FN_2NaO_3$, $[M+Na]^+$ 409.1903; found 409.1902.



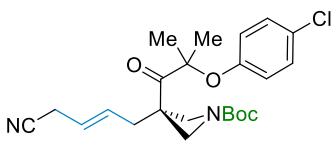
5h

5h, Rf = 0.22 (PE:EA = 1.5:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 1.5:1) to provide the title compound as a colorless oil in 78% yield (57 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.77 (d, *J* = 8.7 Hz, 1H), 6.70 (dd, *J* = 6.3, 2.1 Hz, 2H), 5.64 – 5.47 (m, 1H), 5.35 (dt, *J* = 15.3, 5.4 Hz, 1H), 4.00 (d, *J* = 8.9 Hz, 2H), 3.85 (s, 3H), 3.83 (s, 3H), 3.63 (d, *J* = 8.9 Hz, 2H), 2.99 (dd, *J* = 5.5, 1.5 Hz, 2H), 2.86 (t, *J* = 7.2 Hz, 2H), 2.74 (t, *J* = 7.0 Hz, 2H), 2.63 – 2.52 (m, 2H), 1.41 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 208.3, 156.1, 148.7, 147.4, 133.1, 128.9, 121.8, 120.1, 116.9, 111.7, 111.2, 79.9, 55.8, 54.7, 47.7, 39.6, 38.0, 29.1, 28.1, 20.2. **HRMS**: calculated for $C_{24}H_{32}N_2NaO_5$, $[M+Na]^+$ 451.2209; found 451.2209.



5i

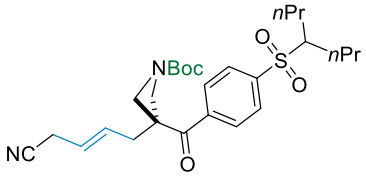
5i, Rf = 0.25 (PE:EA = 4:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 85% yield (65 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.32 – 7.29 (m, 2H), 7.28 – 7.16 (m, 3H), 5.35 (s, 1H), 5.21 – 4.85 (m, 1H), 4.10 (d, *J* = 8.9 Hz, 1H), 4.00 (s, 1H), 3.74 (t, *J* = 7.4 Hz, 1H), 3.63 (d, *J* = 8.9 Hz, 1H), 3.54 (d, *J* = 8.9 Hz, 1H), 3.02 – 2.78 (m, 2H), 2.58 (d, *J* = 6.7 Hz, 1H), 2.50 (dd, *J* = 14.7, 7.2 Hz, 1H), 1.98 (dt, *J* = 14.2, 7.1 Hz, 1H), 1.76 (dt, *J* = 13.9, 7.4 Hz, 1H), 1.41 (s, 9H), 0.80 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 208.8, 156.1, 137.8, 128.8, 128.2, 127.4, 121.5, 116.9, 79.9, 55.7, 54.8, 48.7, 38.2, 28.2, 27.8, 20.3, 12.1. **HRMS**: calculated for $C_{23}H_{30}N_2NaO_3$, $[M+Na]^+$ 405.2154; found 405.2157.



5j

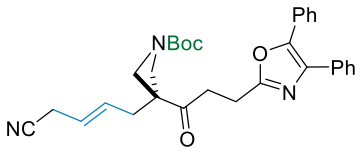
5j, Rf = 0.27 (PE:EA = 4:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 81% yield (70 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.43 – 7.18 (m, 2H), 6.90 (d, *J* = 8.5 Hz, 2H), 5.68 (dt, *J* = 14.5, 7.0 Hz,

1H), 5.53 (dt, *J* = 15.4, 5.7 Hz, 1H), 4.30 (d, *J* = 9.2 Hz, 2H), 3.75 (d, *J* = 9.2 Hz, 2H), 3.08 (d, *J* = 5.6 Hz, 2H), 2.95 (d, *J* = 6.9 Hz, 2H), 1.42 (s, 15H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 211.7, 156.3, 151.5, 129.7, 129.6, 129.3, 124.6, 121.9, 117.0, 87.5, 79.7, 55.6, 48.2, 38.5, 28.2, 25.4, 20.4. **HRMS**: calculated for $C_{23}H_{29}ClN_2NaO_4$, $[M+Na]^+$ 455.1714; found 455.1717.



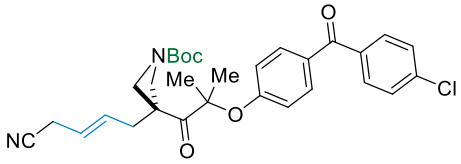
6a

6a，Rf = 0.38 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 3:1) to provide the title compound as a colorless oil in 76% yield (74 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 7.9 Hz, 2H), 7.80 (d, *J* = 8.2 Hz, 2H), 5.64 (dt, *J* = 14.8, 7.1 Hz, 1H), 5.39 (dt, *J* = 15.4, 5.7 Hz, 1H), 4.35 (d, *J* = 8.7 Hz, 2H), 3.94 (d, *J* = 8.8 Hz, 2H), 3.27 – 2.97 (m, 6H), 2.85 (d, *J* = 7.2 Hz, 2H), 1.54 (q, *J* = 7.6 Hz, 5H), 1.41 (s, 9H), 0.85 (t, *J* = 7.3 Hz, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 198.4, 156.2, 144.5, 135.8, 129.3, 128.3, 127.4, 122.6, 116.8, 80.1, 55.9, 49.9, 47.1, 40.0, 28.2, 21.9, 20.3, 11.0. **HRMS**: calculated for $C_{27}H_{38}N_2NaO_5S$, $[M+Na]^+$ 525.2399; found 525.2401.



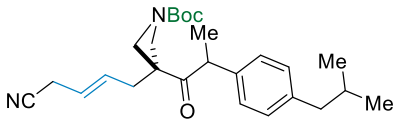
6b

6b，Rf = 0.21 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 2:1) to provide the title compound as a yellow oil in 73% yield (75 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.57 (ddt, *J* = 11.0, 6.0, 1.6 Hz, 4H), 7.45 – 7.27 (m, 6H), 5.66 (dtt, *J* = 15.4, 7.0, 1.6 Hz, 1H), 5.53 – 5.38 (m, 1H), 4.25 (d, *J* = 8.8 Hz, 2H), 3.74 (d, *J* = 8.9 Hz, 2H), 3.18 (t, *J* = 6.4 Hz, 2H), 3.08 (t, *J* = 7.0 Hz, 2H), 2.90 (dd, *J* = 5.5, 1.5 Hz, 2H), 2.79 – 2.60 (m, 2H), 1.43 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 207.2, 161.8, 156.2, 145.4, 134.9, 132.3, 129.3, 128.8, 128.6, 128.5, 128.4, 128.0, 127.7, 126.4, 121.9, 117.0, 80.0, 55.0, 47.7, 38.1, 33.7, 28.2, 21.8, 20.2. **HRMS**: calculated for $C_{31}H_{33}N_3NaO_4$, $[M+Na]^+$ 534.2369; found 534.2370.



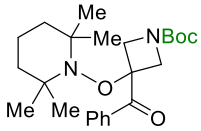
6c

6c, Rf = 0.49 (PE:EA = 2:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 58% yield (62 mg)**.** **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.91 – 7.75 (m, 2H), 7.73 (d, *J* = 8.5 Hz, 2H), 7.53 – 7.42 (m, 2H), 7.14 – 6.99 (m, 2H), 5.81 – 5.65 (m, 1H), 5.55 (dt, *J* = 15.3, 5.6 Hz, 1H), 4.33 (d, *J* = 9.2 Hz, 2H), 3.80 (d, *J* = 9.2 Hz, 2H), 3.10 (dd, *J* = 5.7, 1.5 Hz, 2H), 2.97 (d, *J* = 6.6 Hz, 2H), 1.55 (s, 6H), 1.44 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 211.4, 194.1, 157.4, 156.3, 138.8, 135.8, 132.7, 131.8, 131.2, 129.5, 128.6, 122.1, 121.9, 117.0, 88.0, 79.9, 55.7, 48.2, 38.6, 28.3, 25.5, 20.5. **HRMS**: calculated for $C_{30}H_{33}ClN_2NaO_5$, $[M+Na]^+$ 559.1976; found 559.1975.



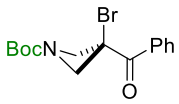
6d

6d, Rf = 0.34 (PE:EA = 4:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 4:1) to provide the title compound as a colorless oil in 85% yield (72 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.13 (d, *J* = 7.9 Hz, 2H), 7.08 (d, *J* = 7.9 Hz, 2H), 5.40 (s, 1H), 5.13 (s, 1H), 4.14 (d, *J* = 8.8 Hz, 1H), 3.96 (dt, *J* = 14.3, 7.3 Hz, 2H), 3.62 (d, *J* = 8.8 Hz, 1H), 3.52 (d, *J* = 8.9 Hz, 1H), 2.98 – 2.81 (m, 2H), 2.64 – 2.55 (m, 1H), 2.50 (dd, *J* = 14.7, 7.1 Hz, 1H), 2.42 (d, *J* = 7.2 Hz, 2H), 1.82 (dt, *J* = 13.5, 6.8 Hz, 1H), 1.41 – 1.36 (m, 12H), 0.87 (s, 3H), 0.86 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 209.5, 156.1, 141.0, 136.6, 129.6, 129.1, 127.5, 121.5, 116.9, 79.9, 55.0, 48.5, 47.6, 44.8, 38.4, 30.1, 28.2, 22.2, 22.2, 20.3, 20.1. **HRMS**: calculated for $C_{26}H_{36}N_2NaO_3$, $[M+Na]^+$ 447.2624; found 447.2628.



8

8, Rf = 0.36 (PE:EA = 9:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 15:1) to provide the title compound as a colorless oil in 87% yield (72 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.03 – 7.88 (m, 2H), 7.68 – 7.51 (m, 1H), 7.49 – 7.42 (m, 2H), 4.58 (d, *J* = 9.8 Hz, 2H), 4.29 (s, 2H), 1.47 (s, 5H), 1.43 (s, 9H), 1.35 – 1.23 (m, 1H), 1.06 – 0.93 (m, 6H), 0.90 (s, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 196.4, 156.3, 133.5, 133.1, 129.8, 128.3, 82.8, 79.5, 59.3, 55.1, 54.6, 39.9, 32.6, 28.2, 20.6, 16.8. **HRMS**: calculated for $C_{24}H_{36}N_2NaO_4$, $[M+Na]^+$ 439.2573; found 439.2573.



9

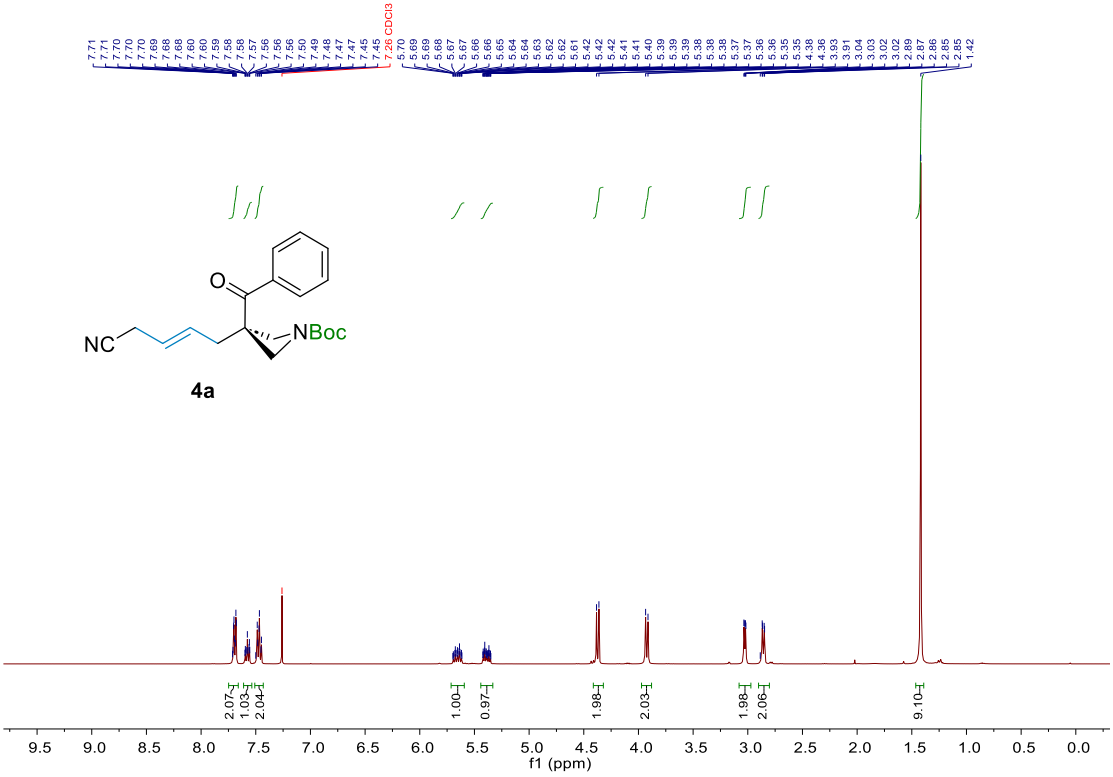
9, Rf = 0.28 (PE:EA = 12:1). The crude material was purified by flash column chromatography (using petroleum ether/EtOAc = 12:1) to provide the title compound as a colorless oil in 99% yield (168 mg). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 8.0, 1.5 Hz, 2H), 7.66 – 7.56 (m, 1H), 7.49 (t, *J* = 7.6 Hz, 2H), 4.91 – 4.76 (m, 2H), 4.57 – 4.38 (m, 2H), 1.43 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 191.7, 155.8, 134.1, 131.2, 129.9, 128.8, 80.6, 62.0, 48.8, 28.2. **HRMS**: calculated for $C_{15}H_{18}BrNNaO_3$, $[M+Na]^+$ 362.0368; found 362.0370.

8 References

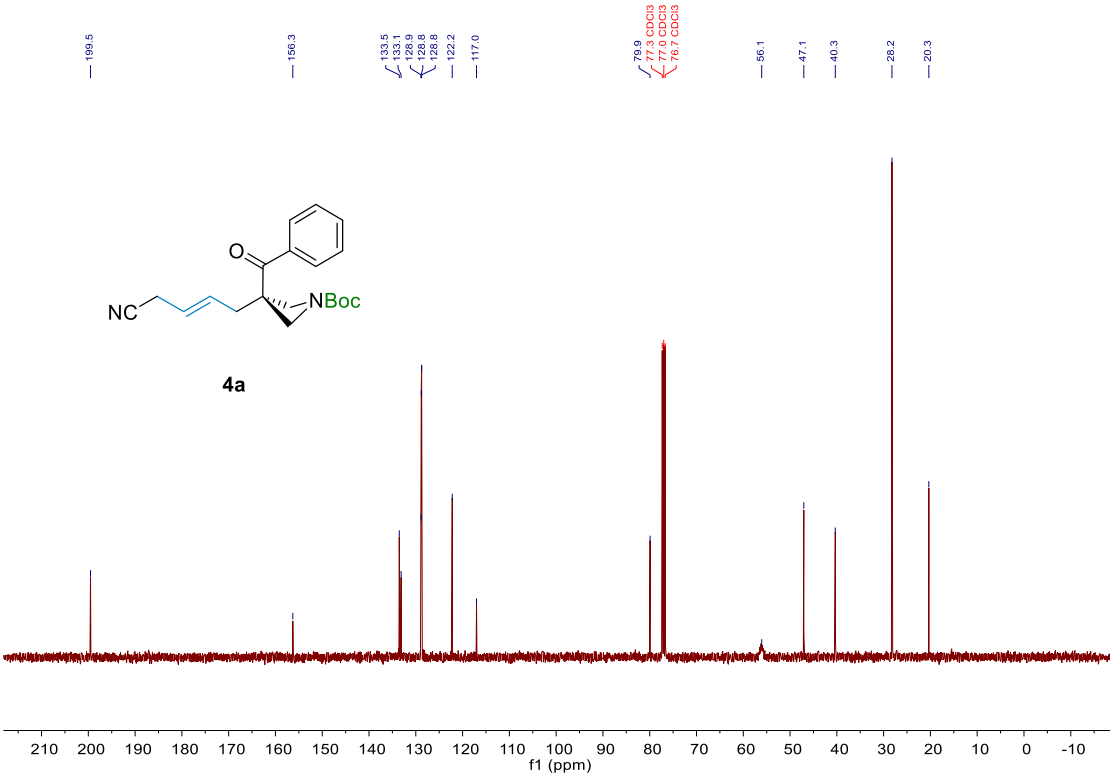
1. Hsu, C.-M.; Lin, H.-B.; Hou, X.-Z.; Tapales, R. V. P. P.; Shih, C.-K.; Miñoza, S.; Tsai, Y.-S.; Tsai, Z.-N.; Chan, C.-L.; Liao, H.-H. Azetidines with all-carbon quaternary centers: merging relay catalysis with strain release functionalization. *J. Am. Chem. Soc.* **2023**, *145*, 19049-19059.
2. Phelan, J. P.; Lang, S. B.; Compton, J. S.; Kelly, C. B.; Dykstra, R.; Gutierrez, O.; Molander, G. A. Redox-Neutral Photocatalytic Cyclopropanation via Radical/Polar Crossover. *J. Am. Chem. Soc.* **2018**, *140*, 8037-8047.

9 NMR Spectra

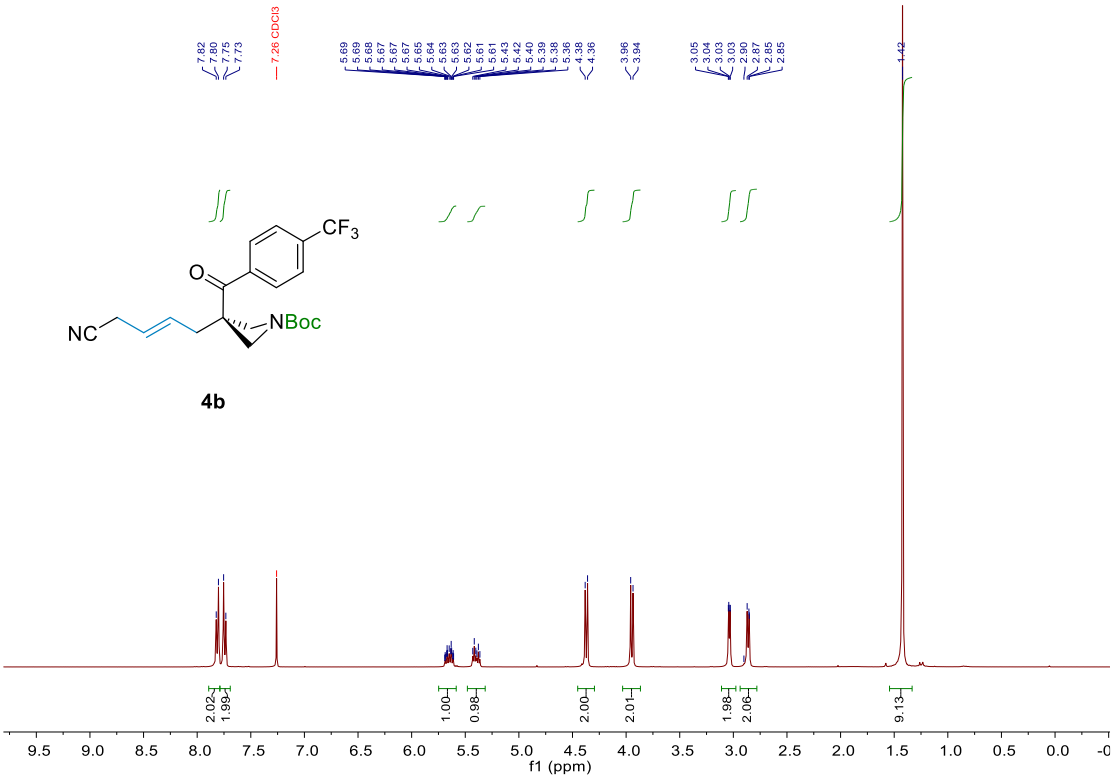
^{1}H NMR (400 MHz, $CDCl_3$)



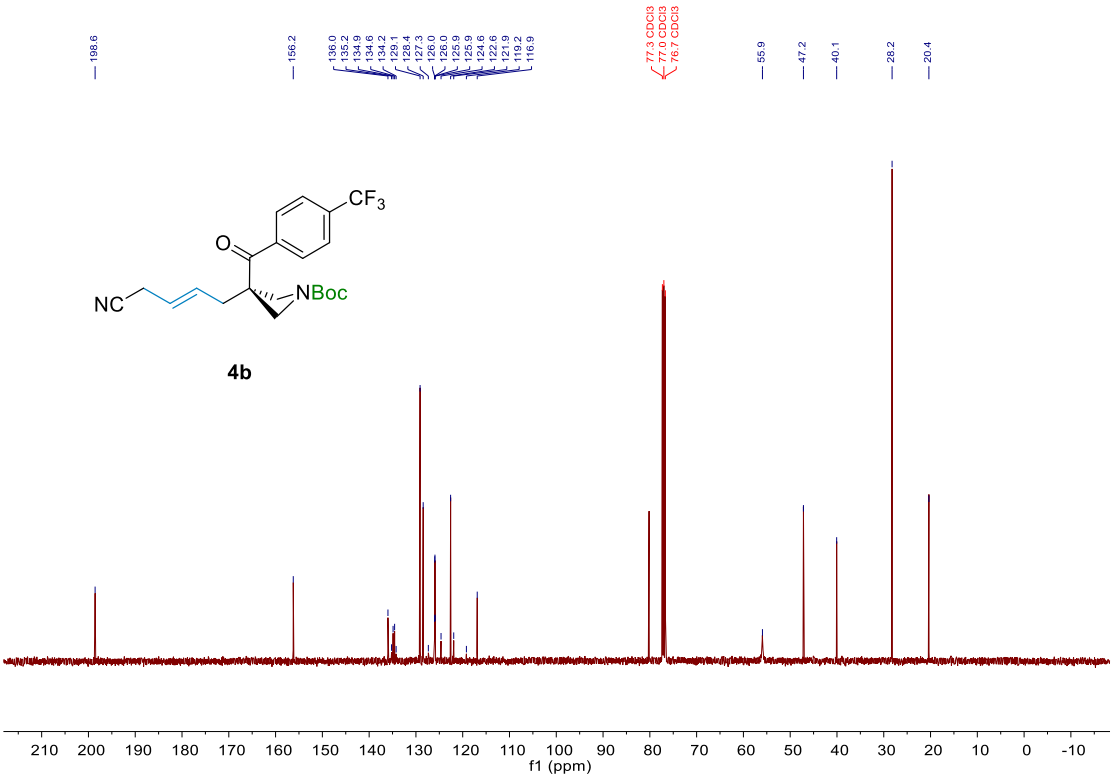
^{13}C NMR (101 MHz, $CDCl_3$)



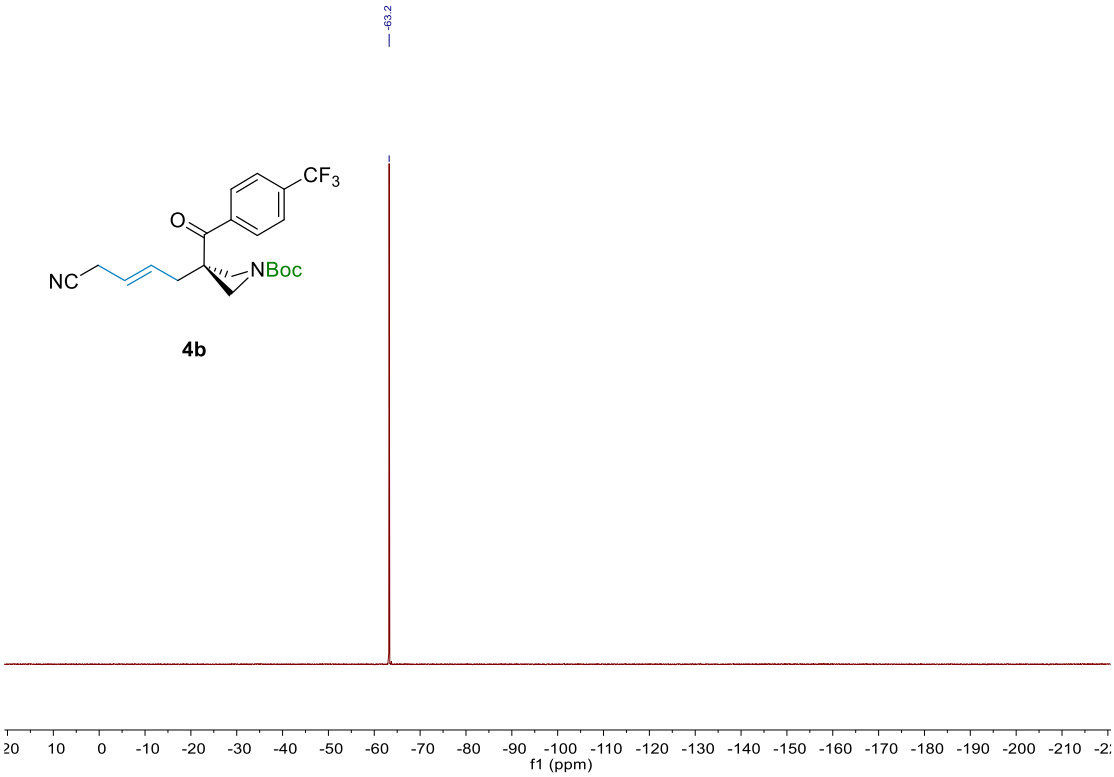
^{1}H NMR (400 MHz, $CDCl_3$)



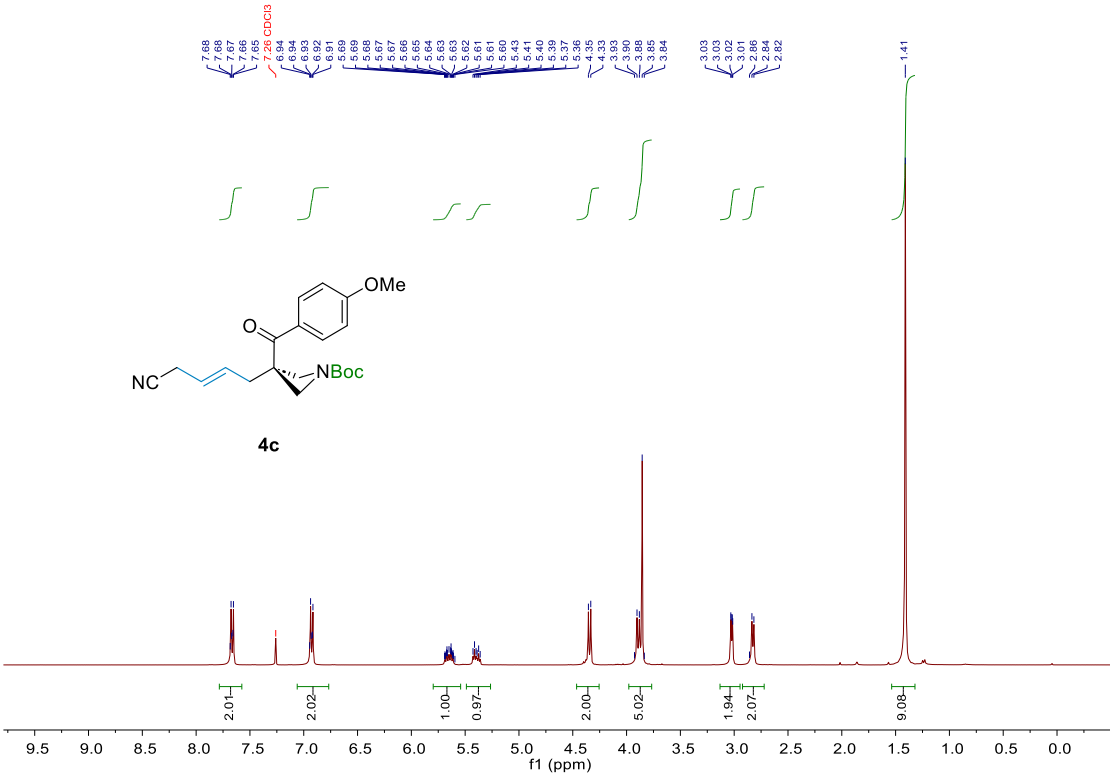
^{13}C NMR (101 MHz, $CDCl_3$)



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



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



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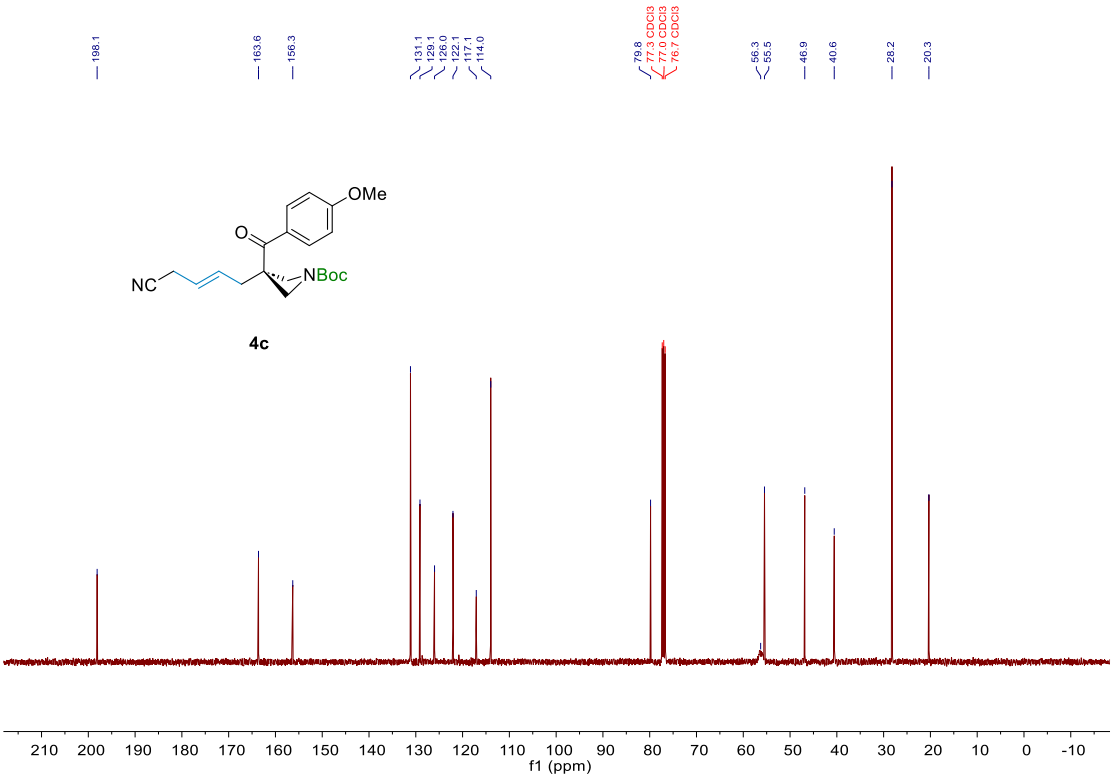

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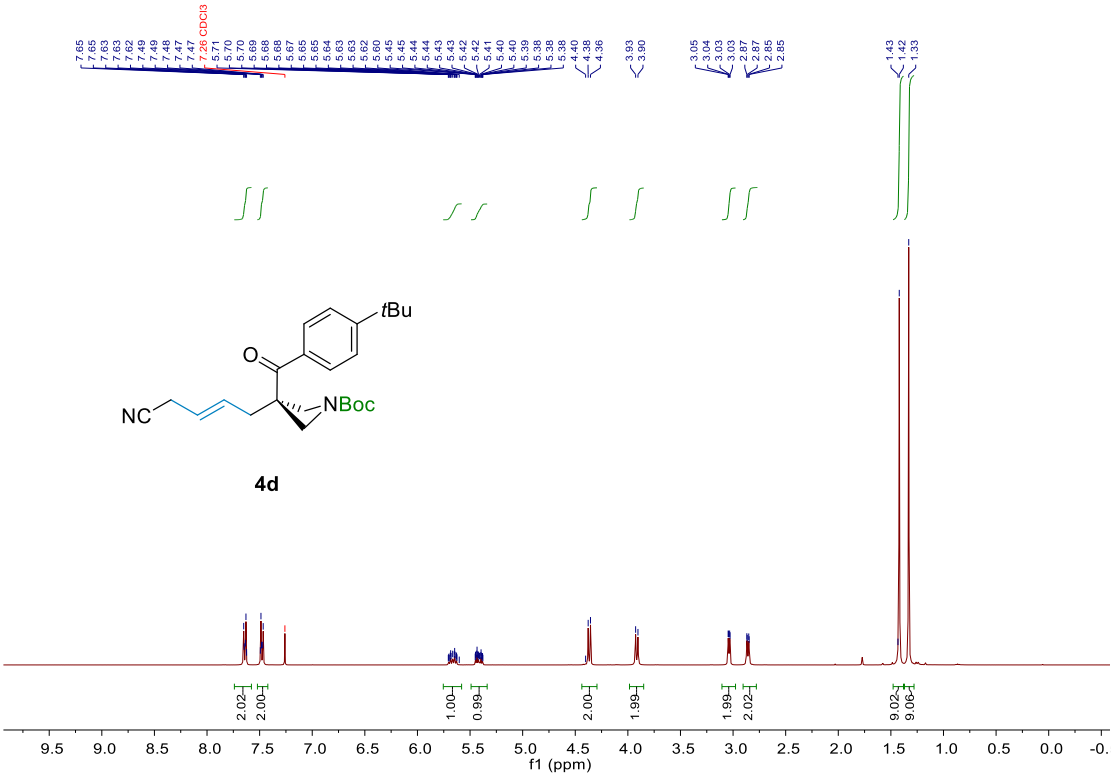

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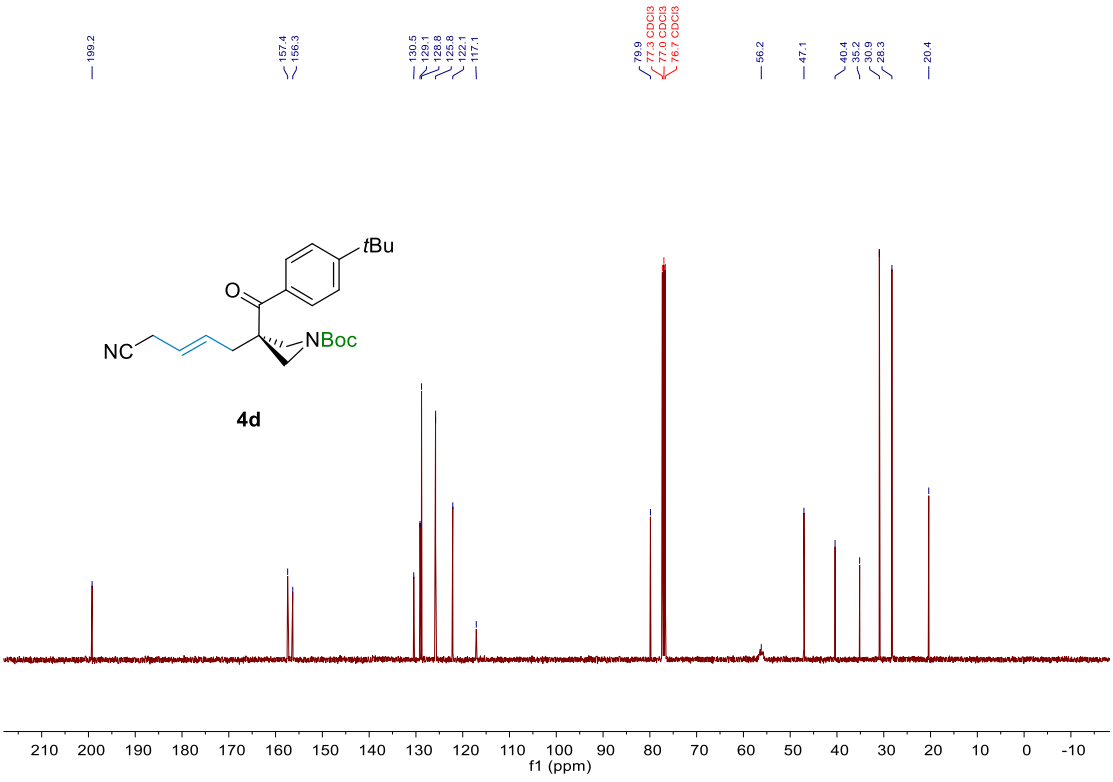

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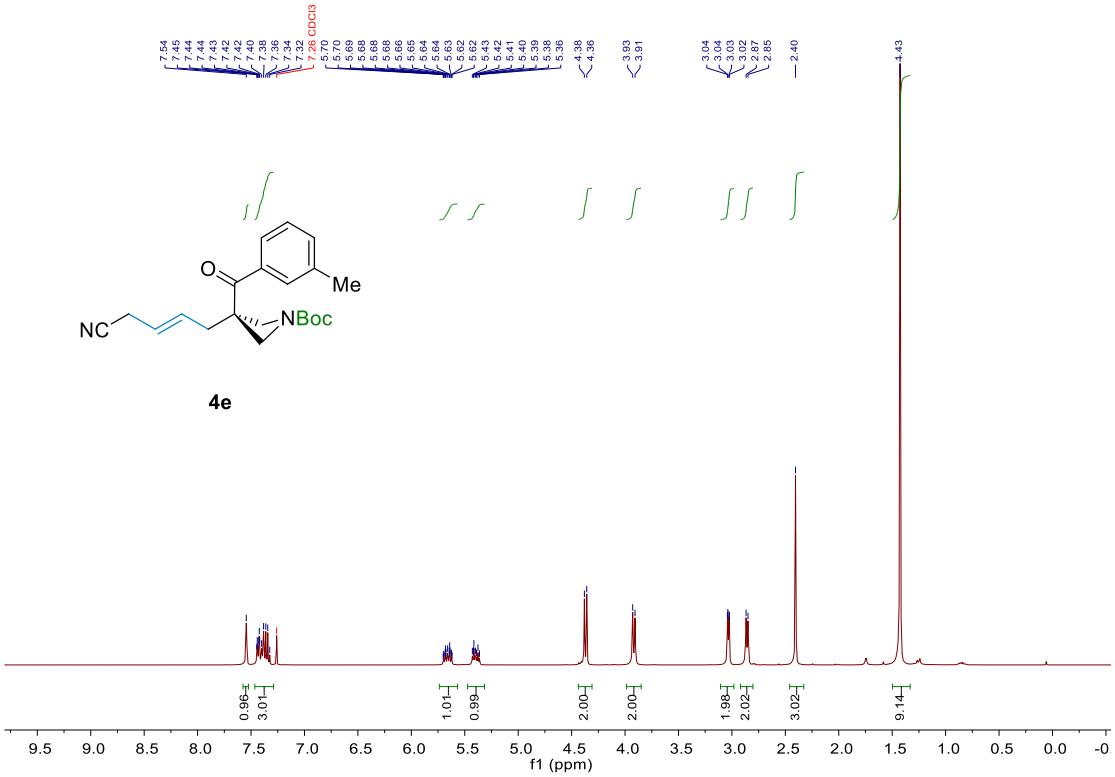

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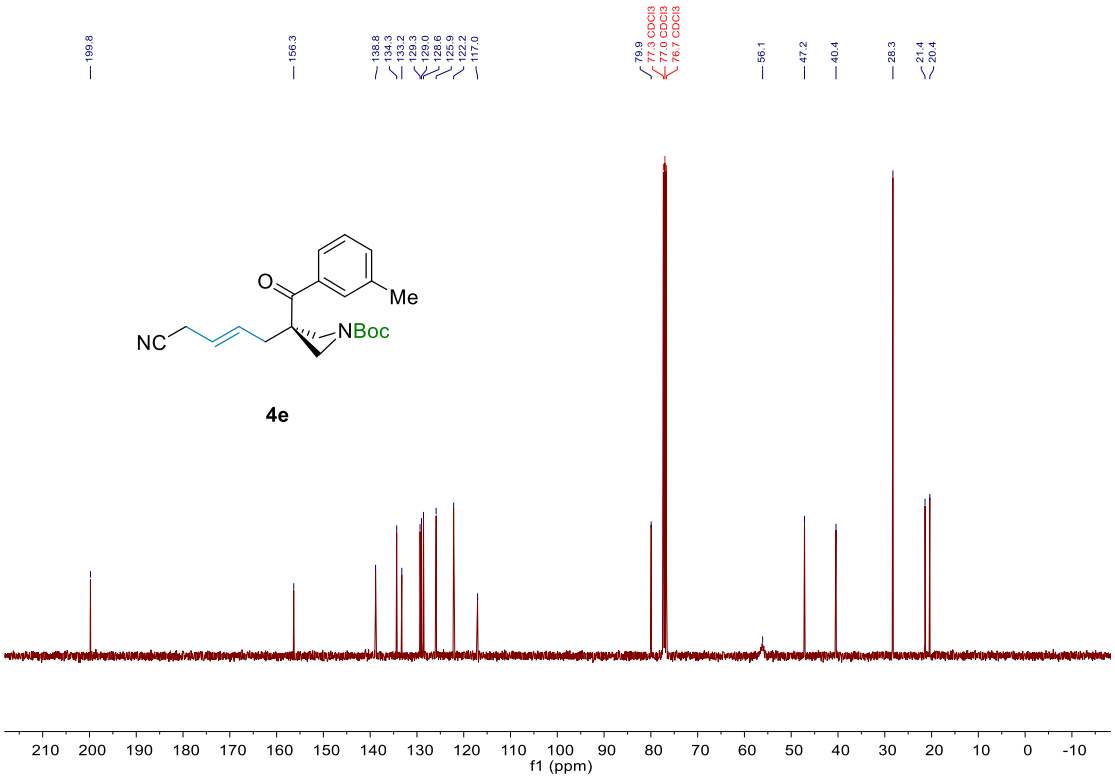
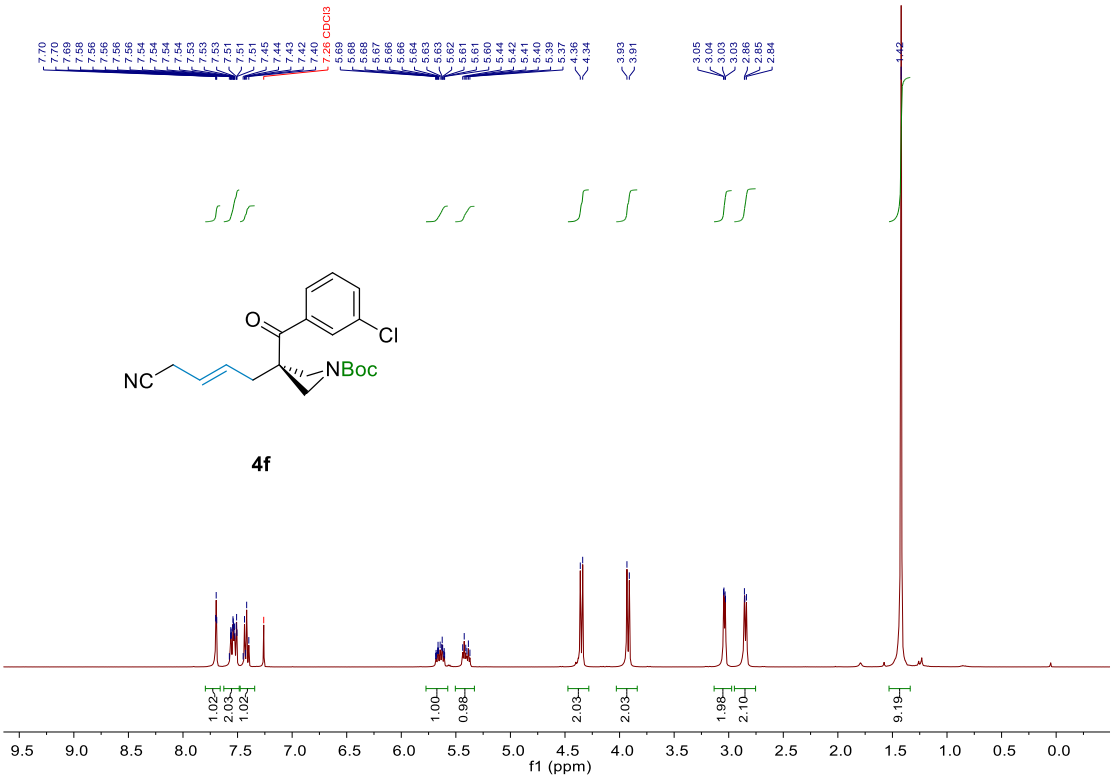


^{1}H NMR (400 MHz, $CDCl_3$)



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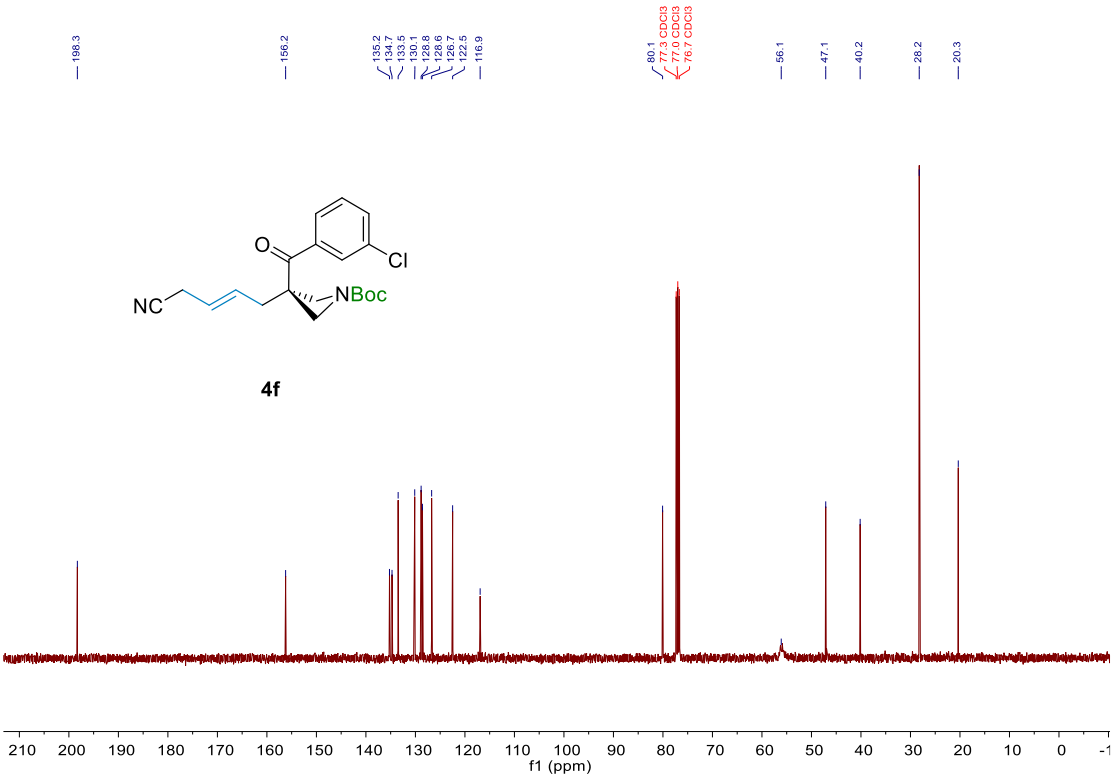
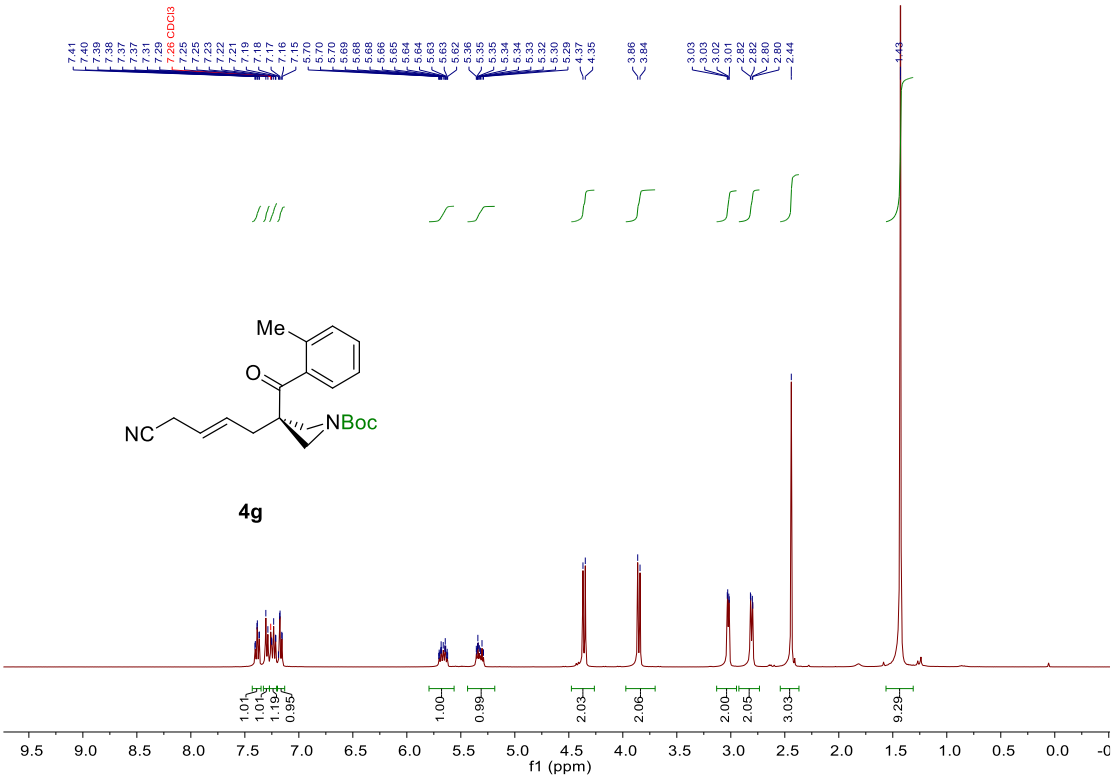


^{1}H NMR (400 MHz, $CDCl_3$)



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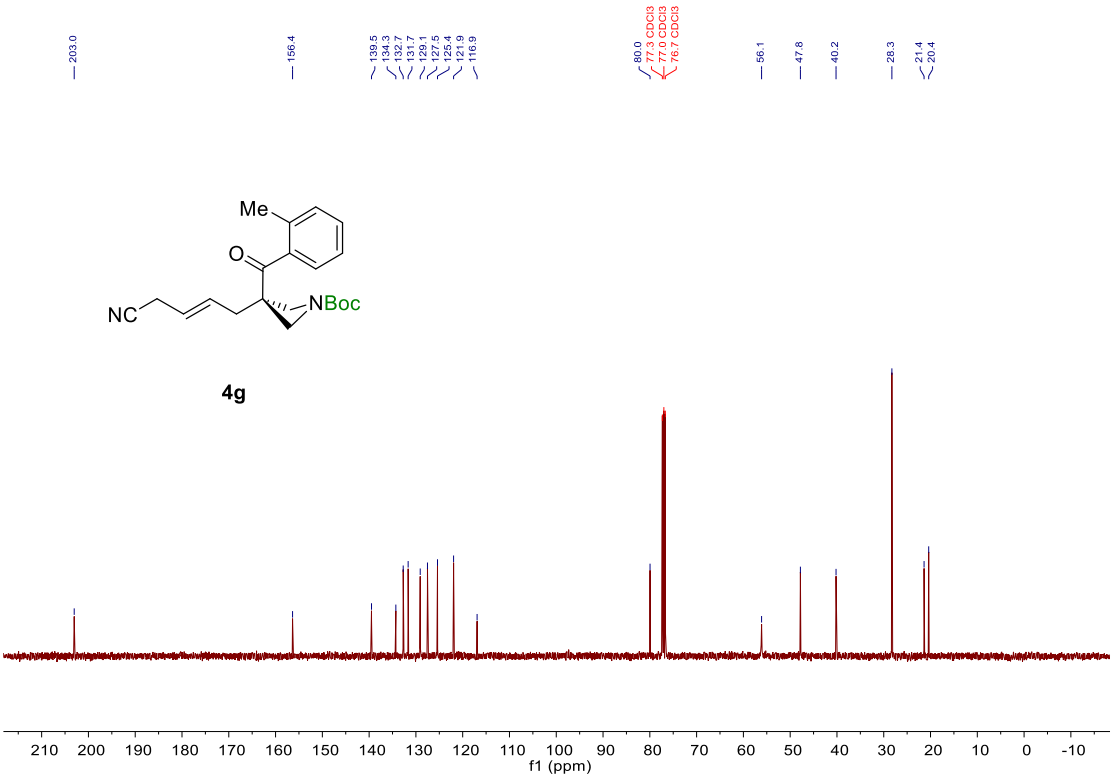

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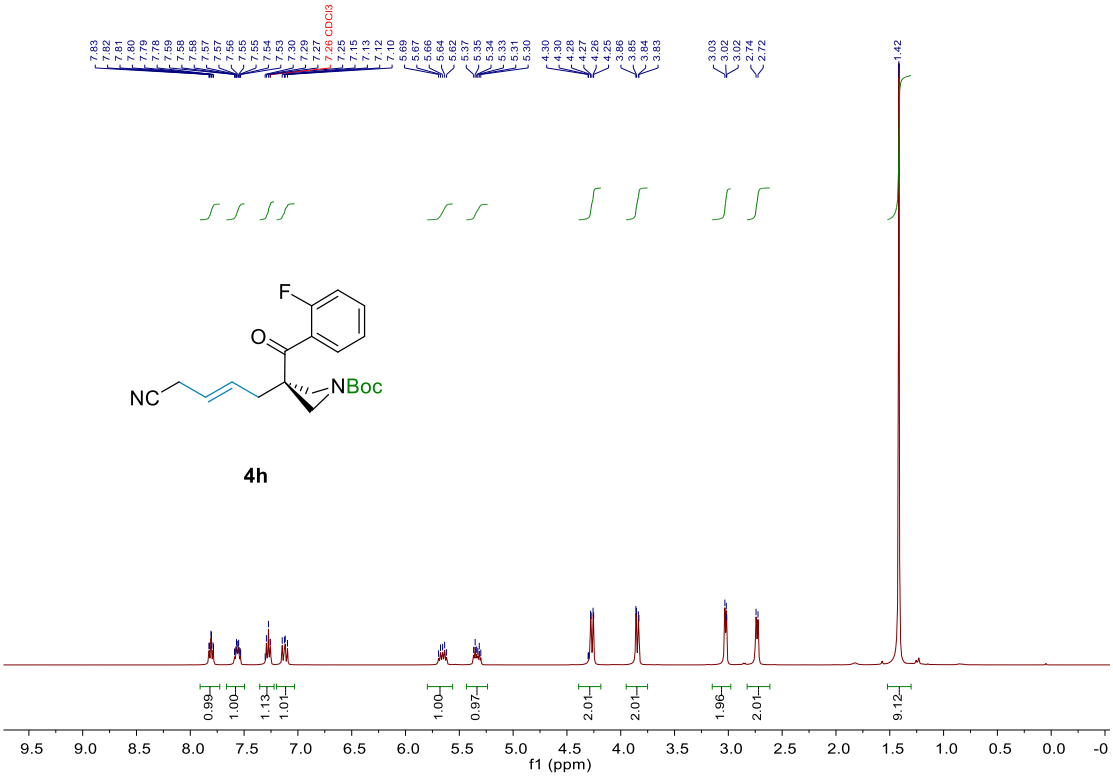
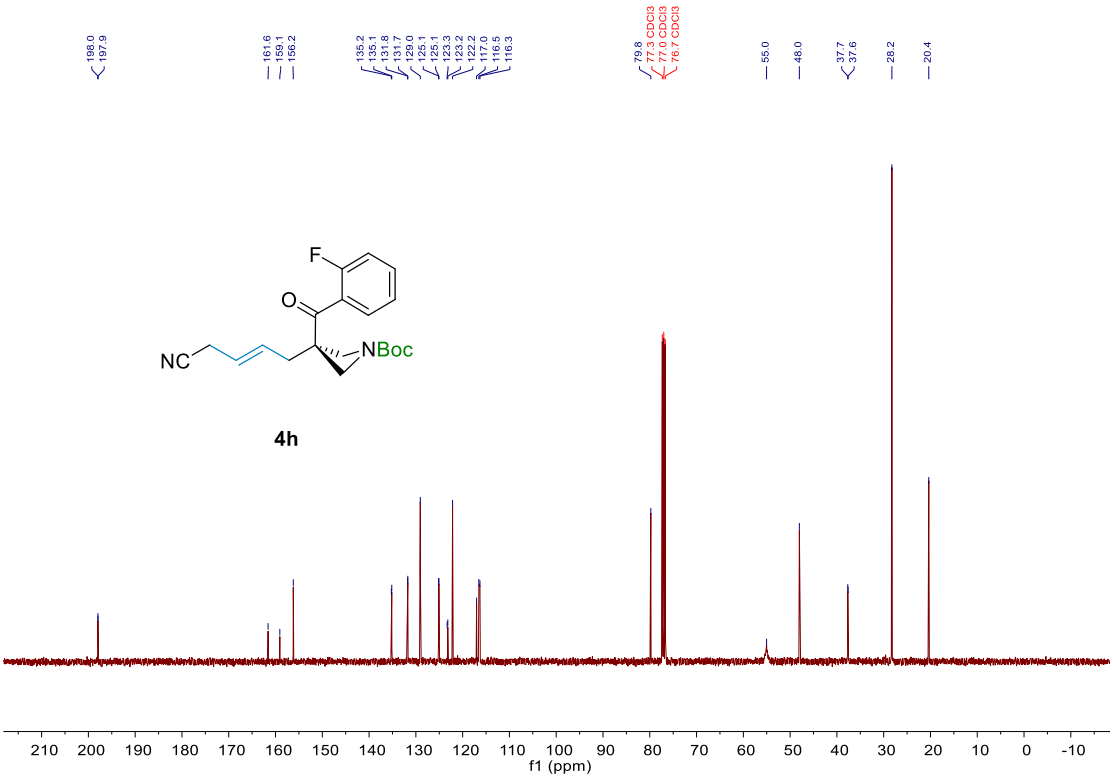
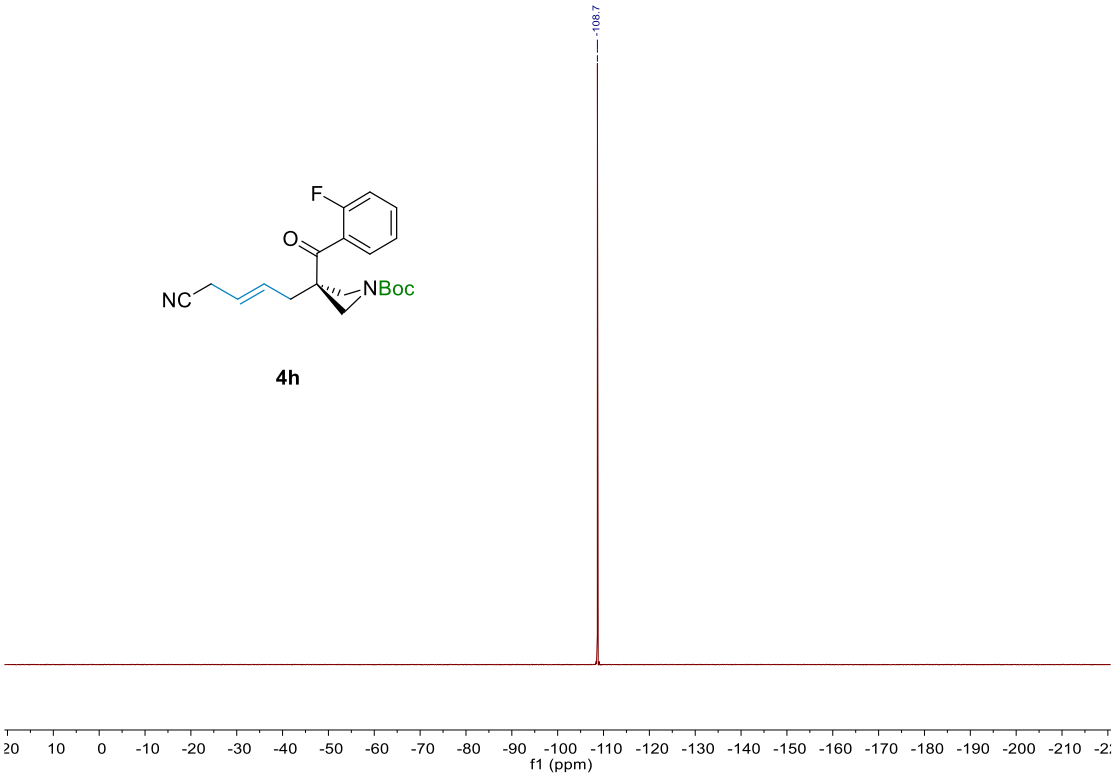


^{13}C NMR (101 MHz, $CDCl_3$)

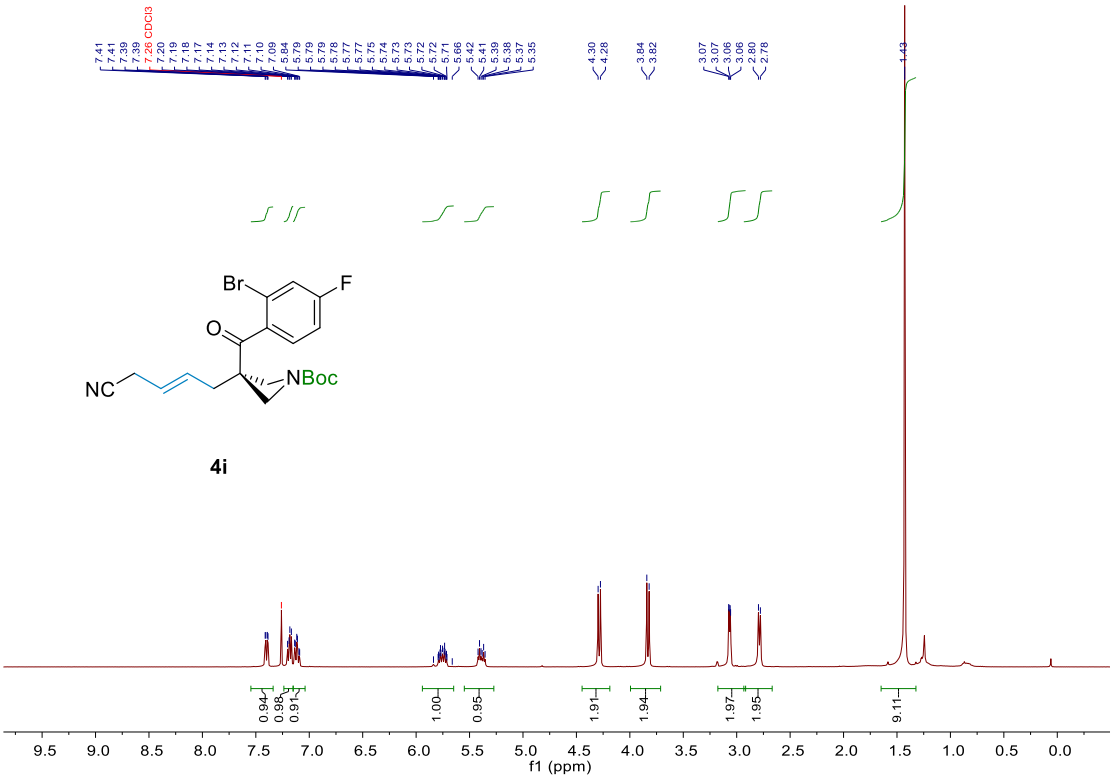


^{19}F NMR (377 MHz, $CDCl_3$)

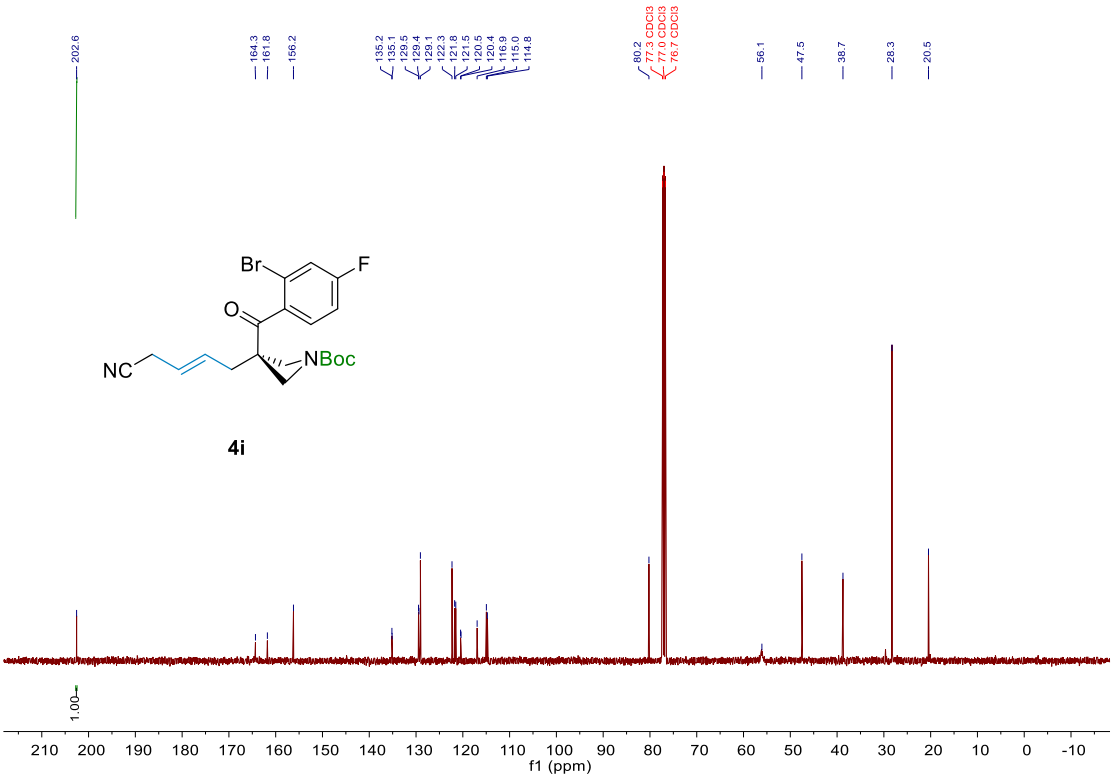


4h

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



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



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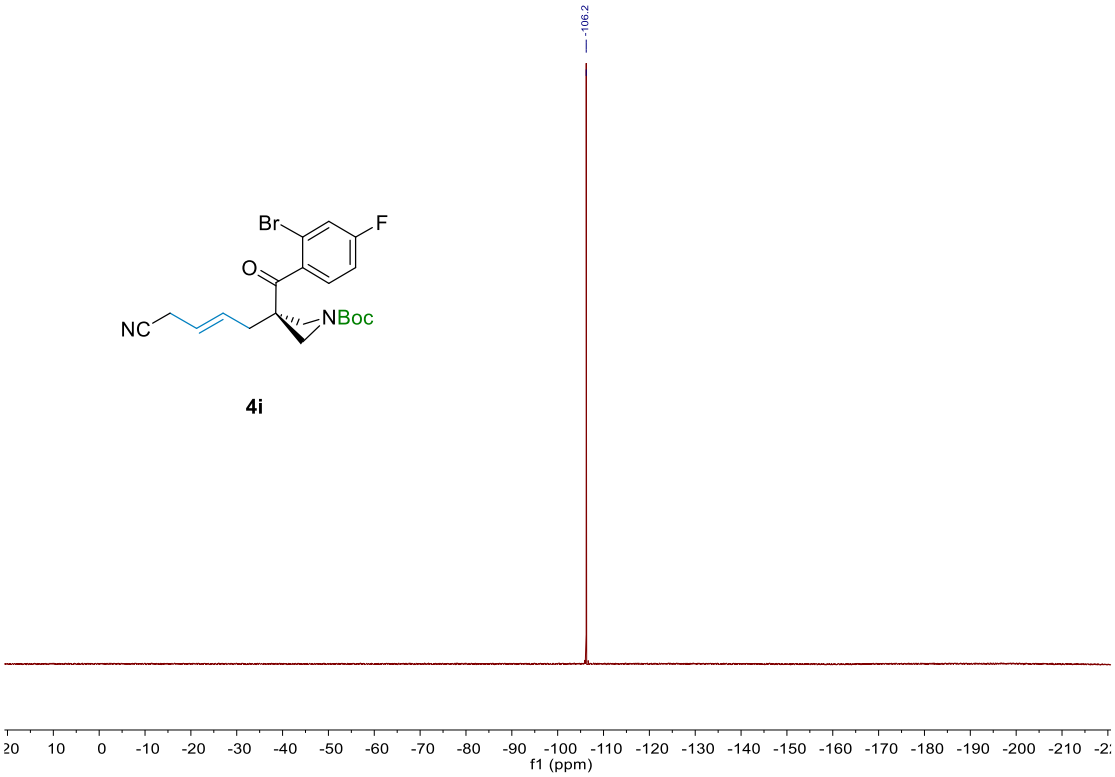
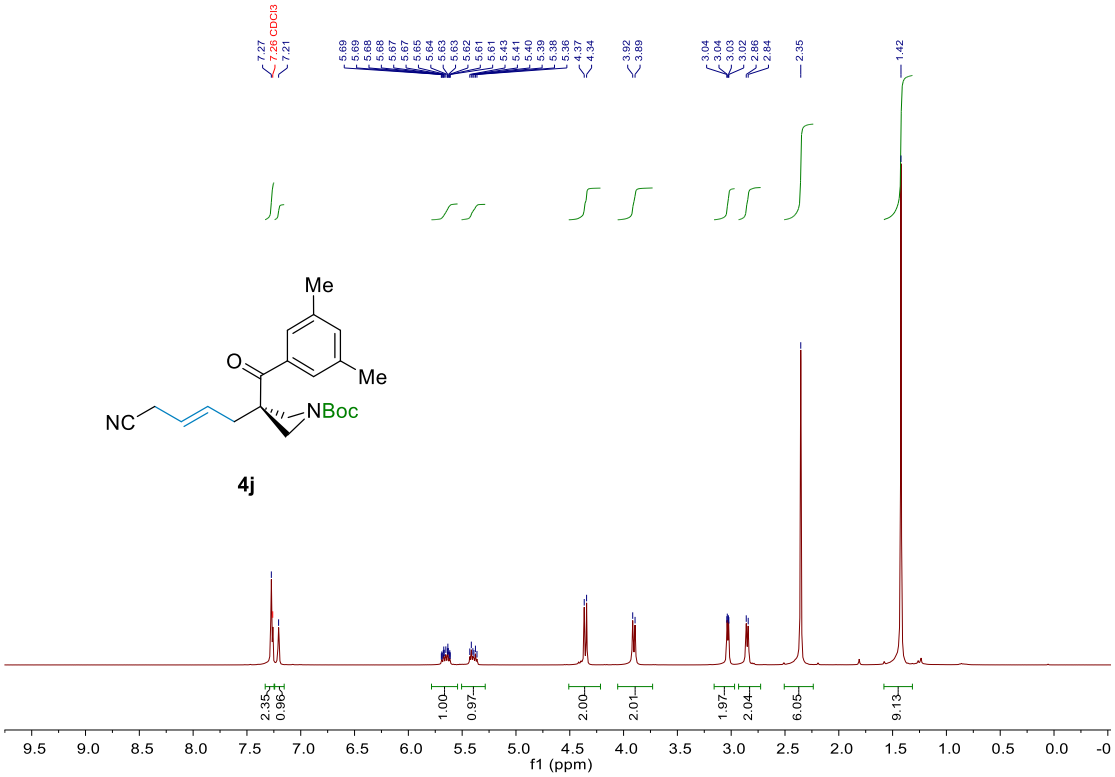
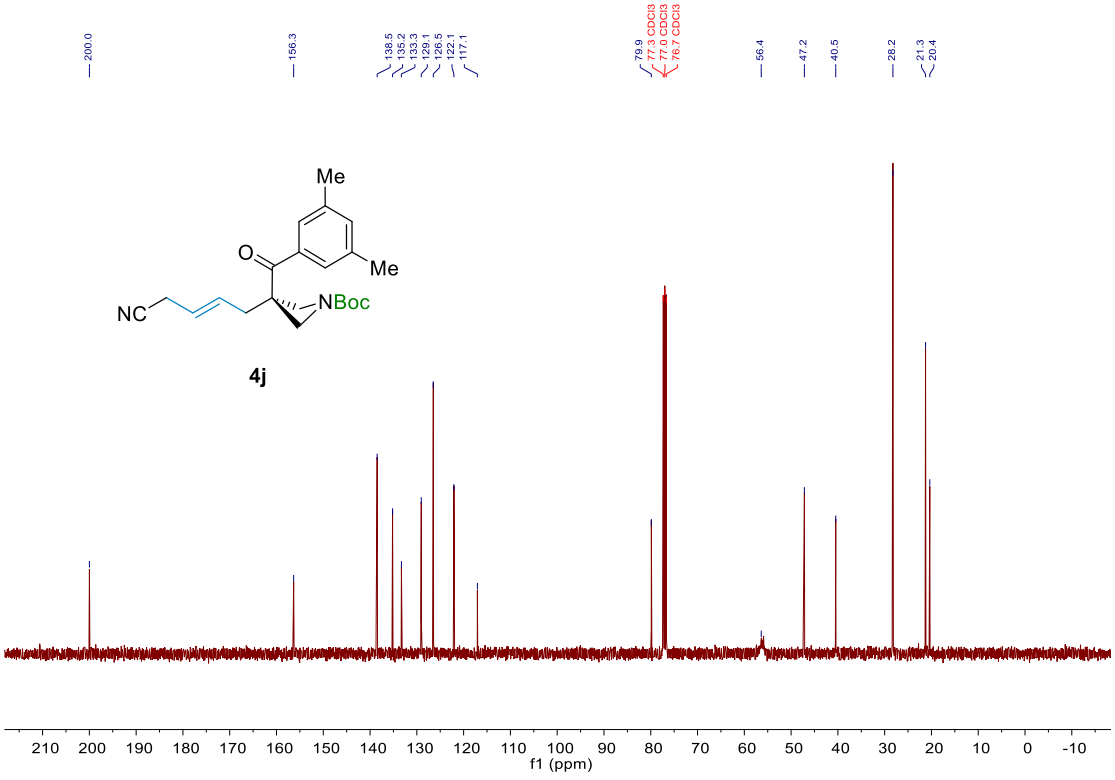


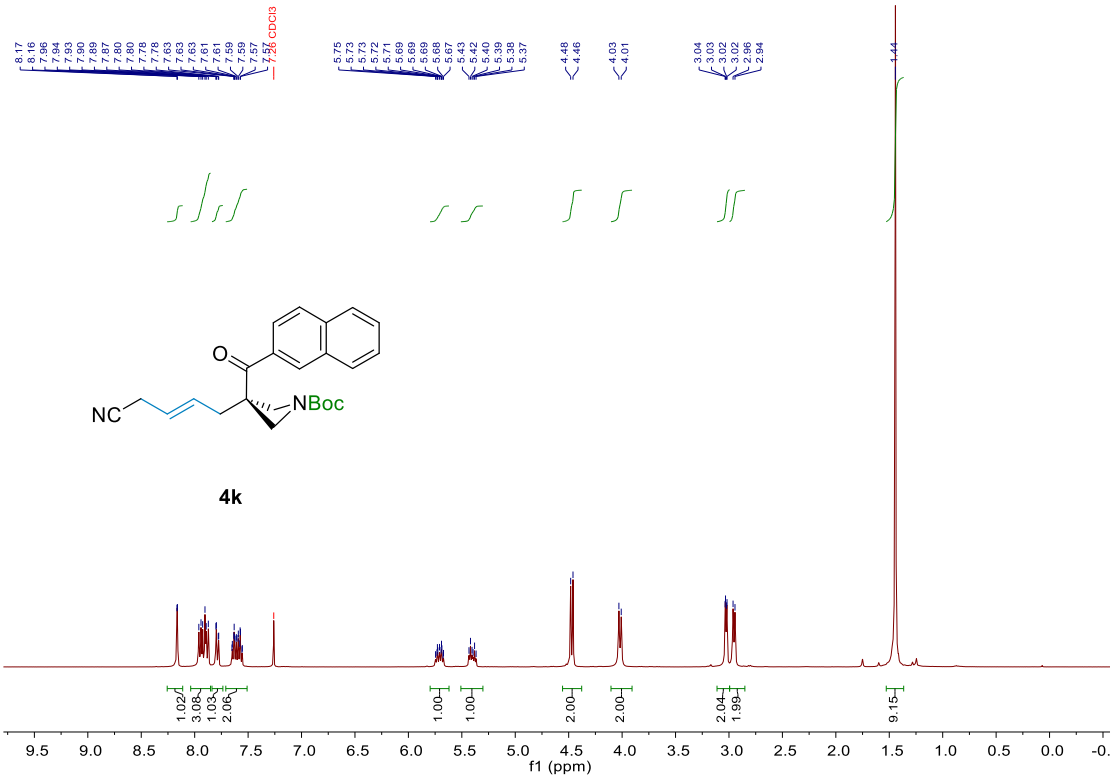
^{1}H NMR (400 MHz, $CDCl_3$)



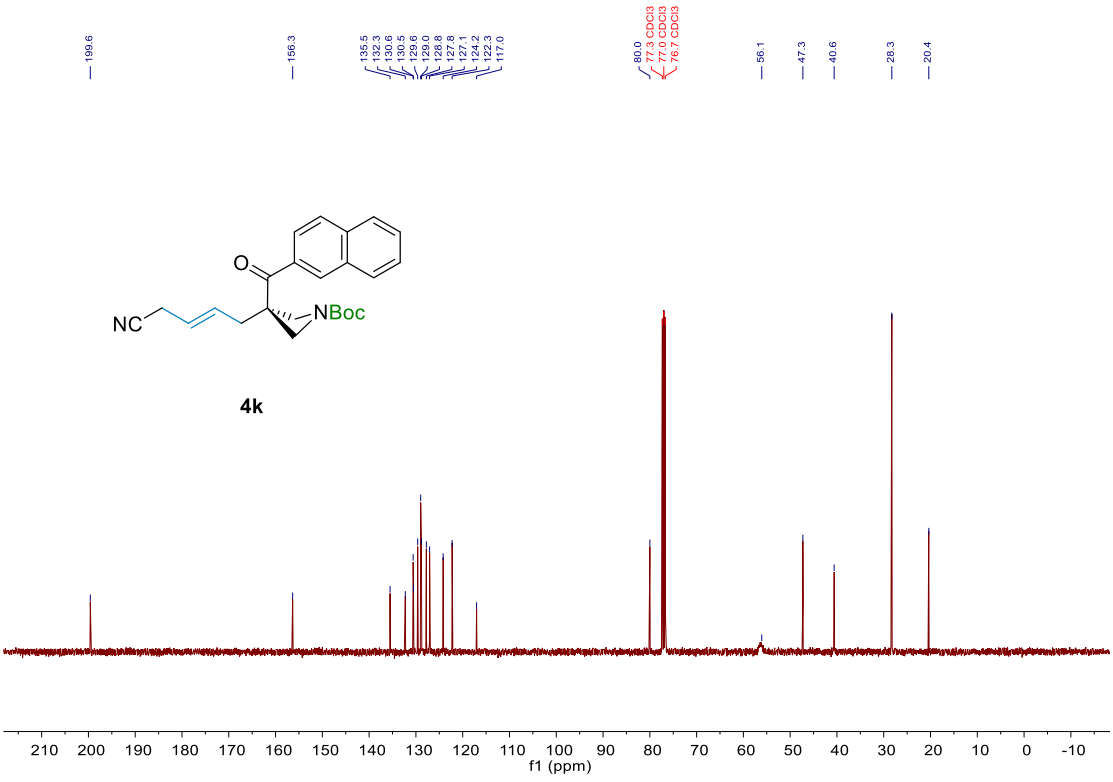
^{13}C NMR (101 MHz, $CDCl_3$)



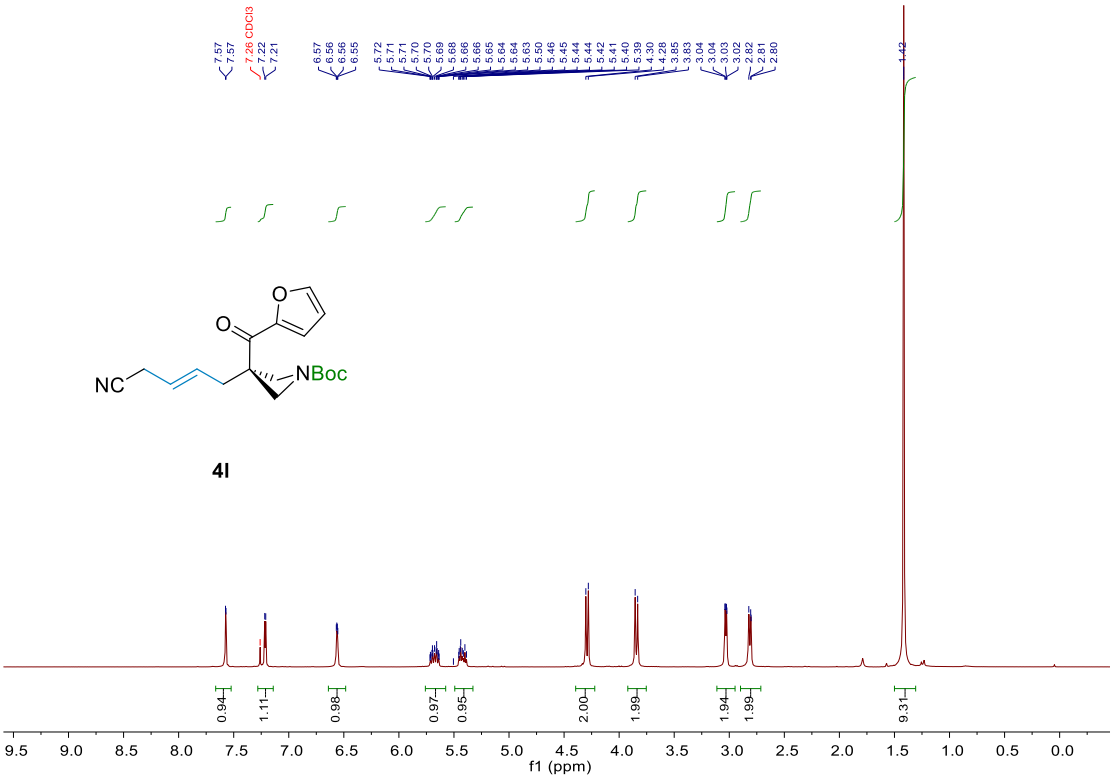
^{1}H NMR (400 MHz, $CDCl_3$)



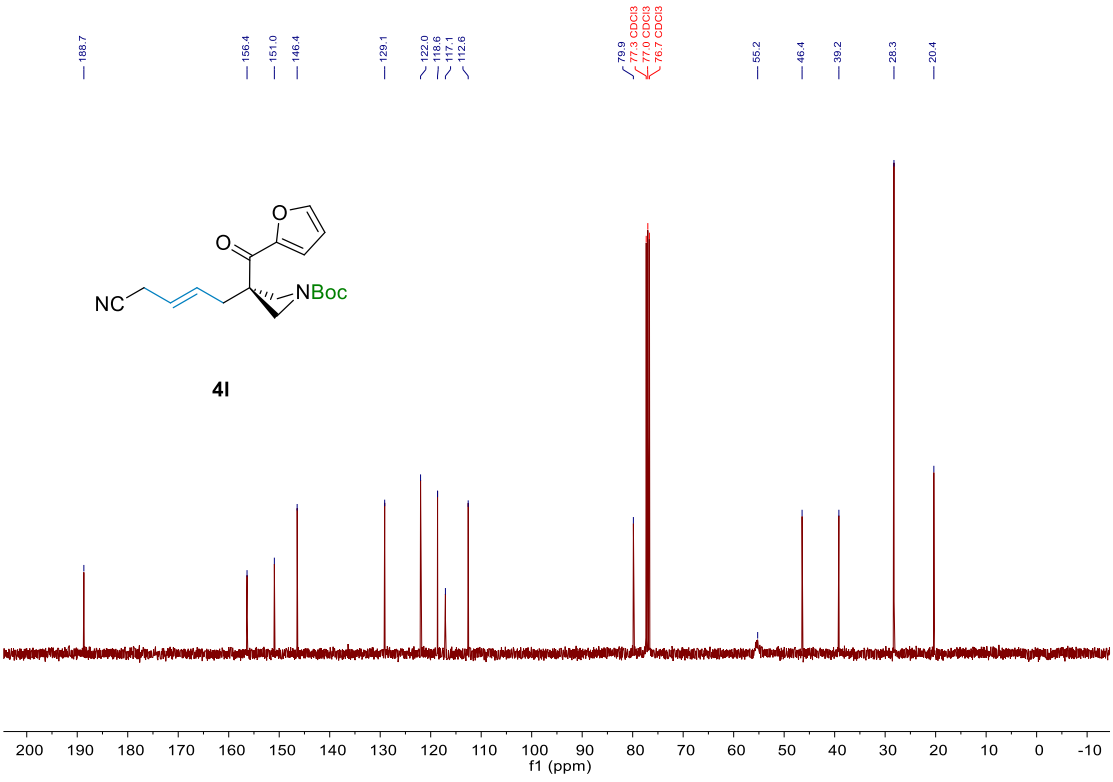
^{13}C NMR (101 MHz, $CDCl_3$)



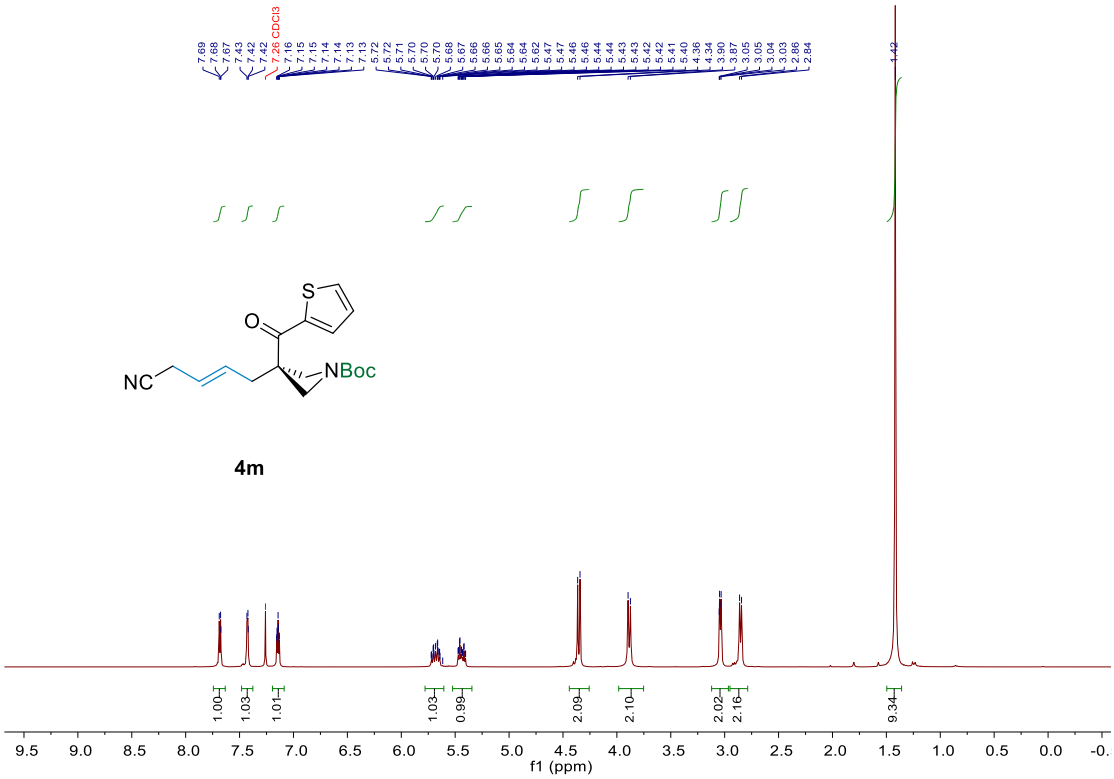
^{1}H NMR (400 MHz, $CDCl_3$)



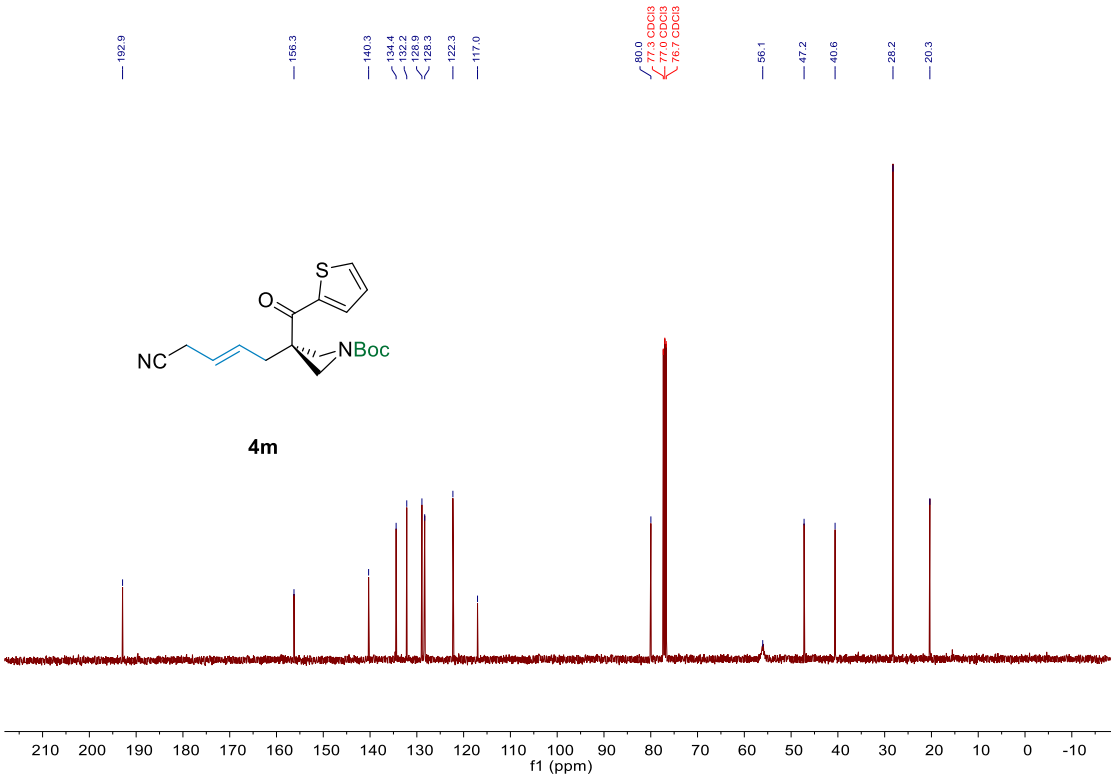
^{13}C NMR (101 MHz, $CDCl_3$)



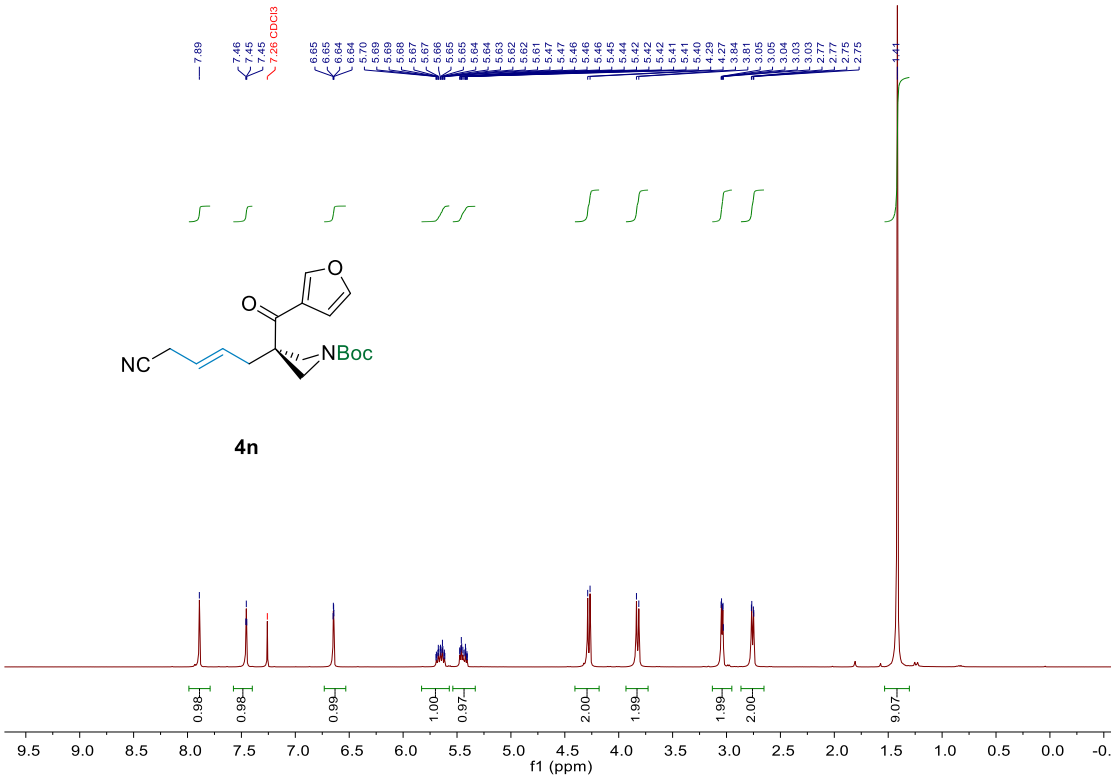
^{1}H NMR (400 MHz, $CDCl_3$)



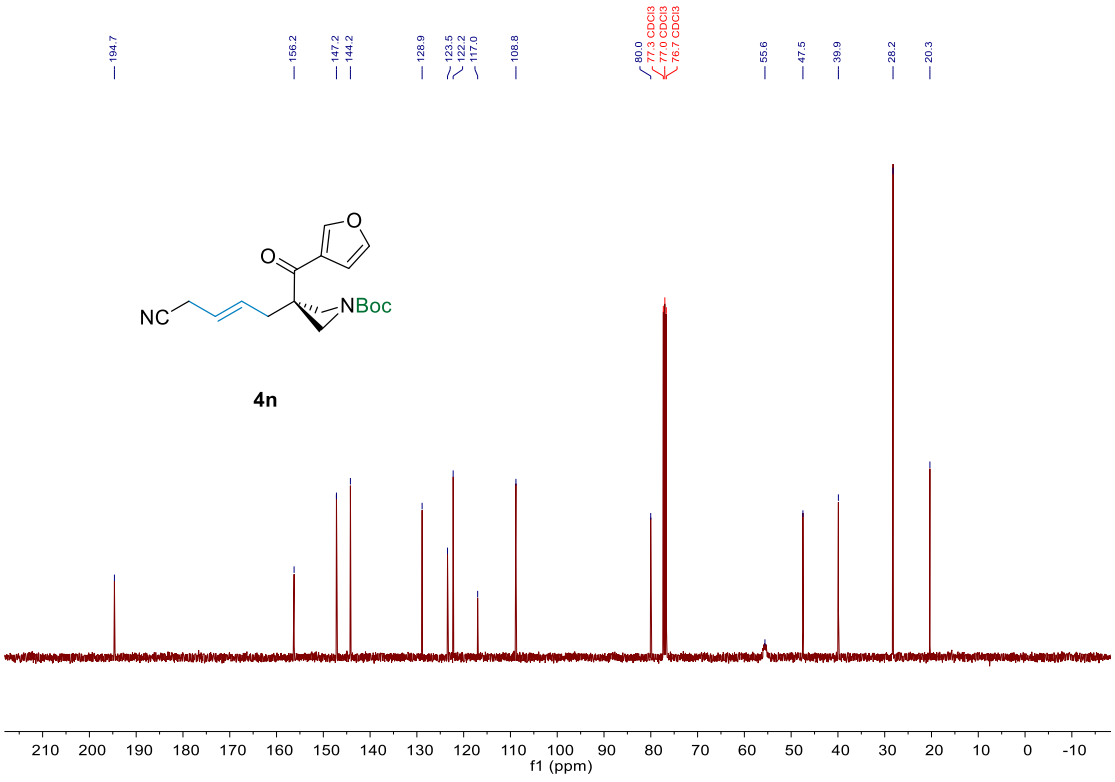
^{13}C NMR (101 MHz, $CDCl_3$)



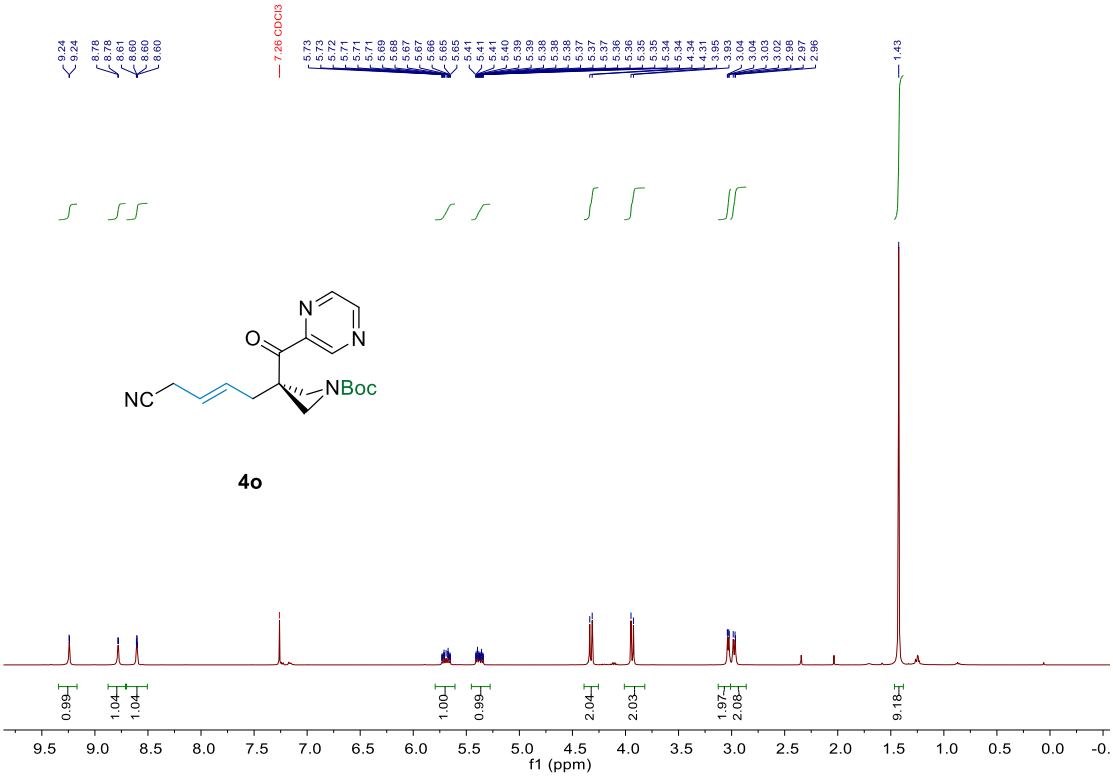
^{1}H NMR (400 MHz, $CDCl_3$)



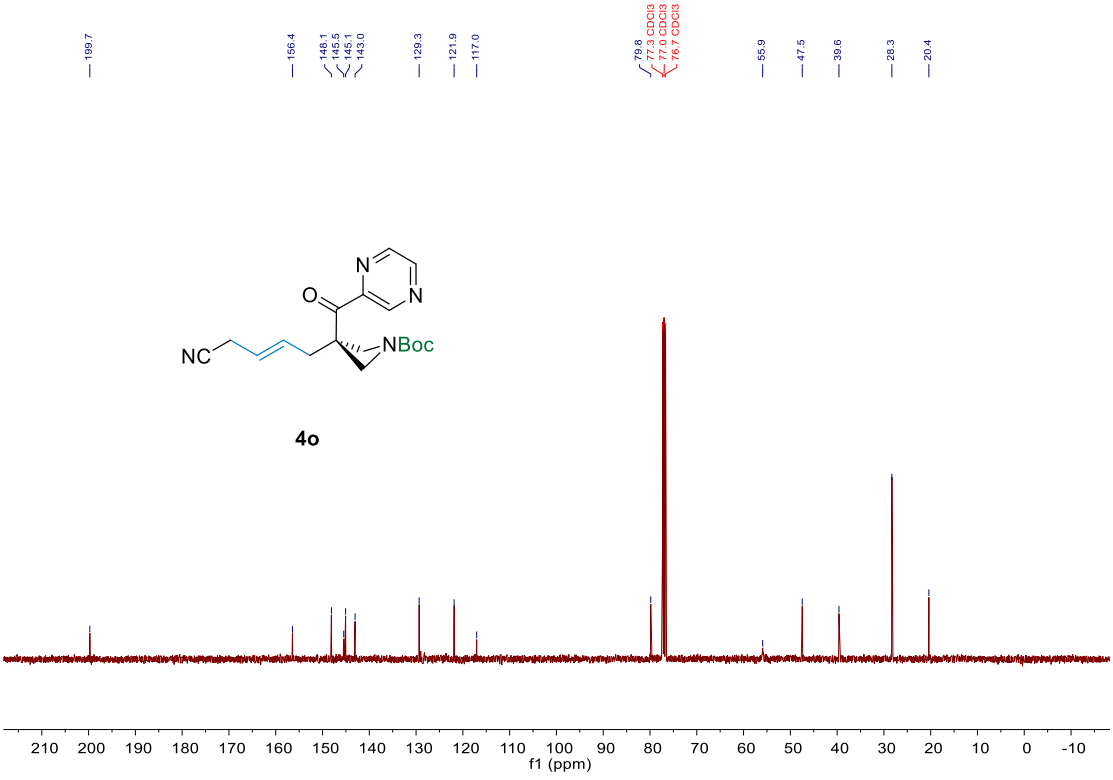
^{13}C NMR (101 MHz, $CDCl_3$)



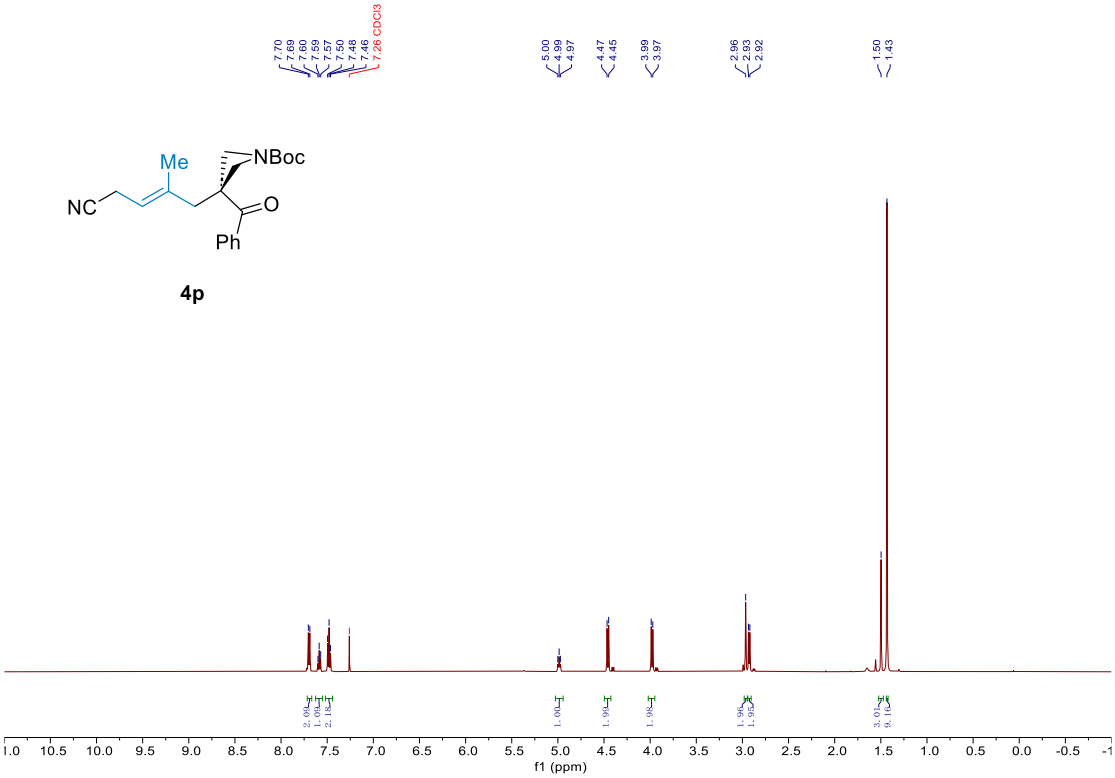
^{1}H NMR (400 MHz, $CDCl_3$)



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

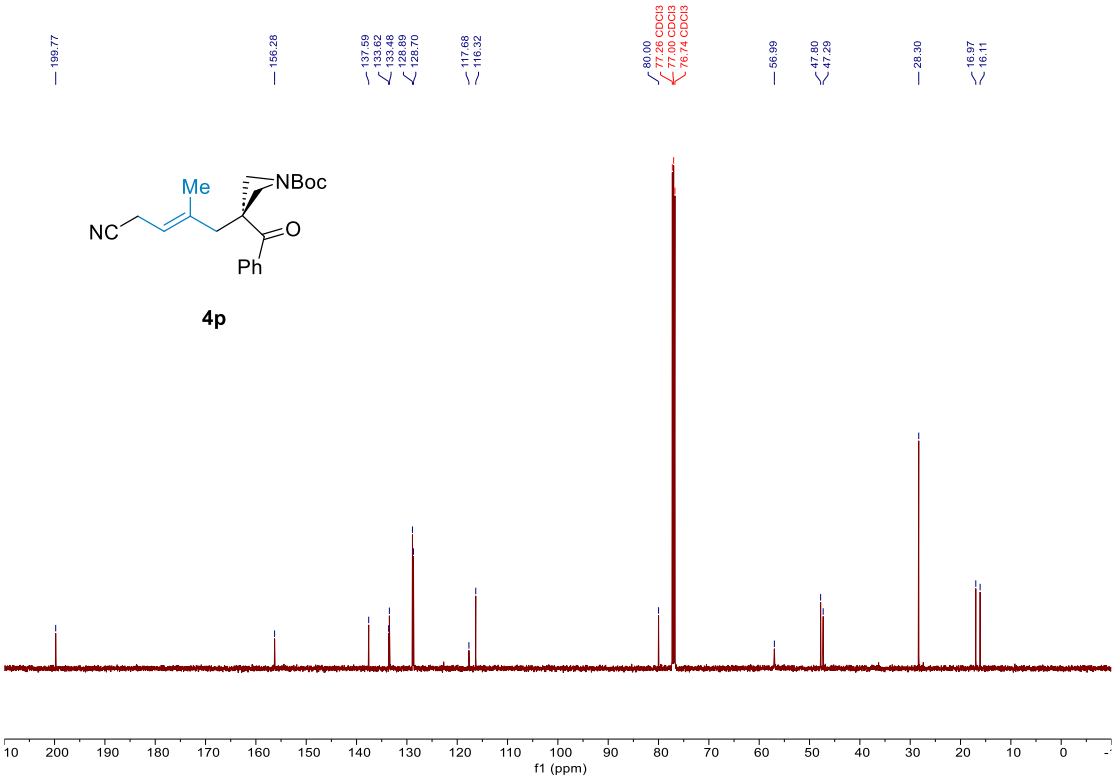


^{1}H NMR (500 MHz, $CDCl_3$)

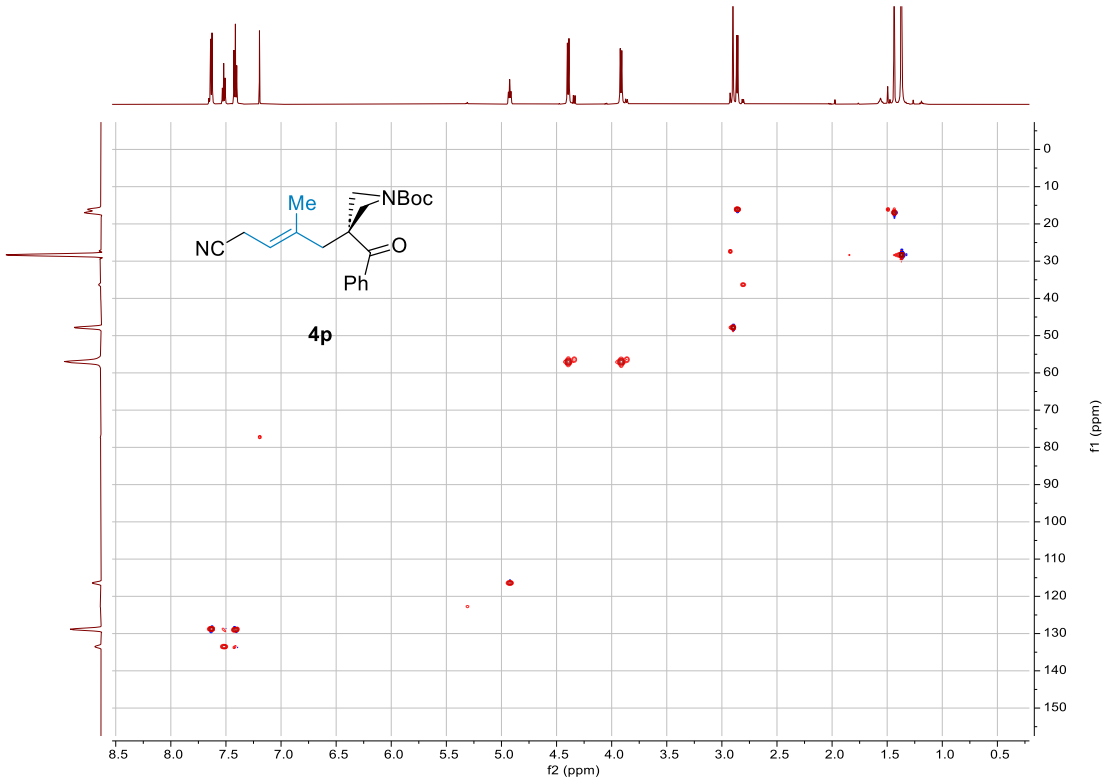


4p

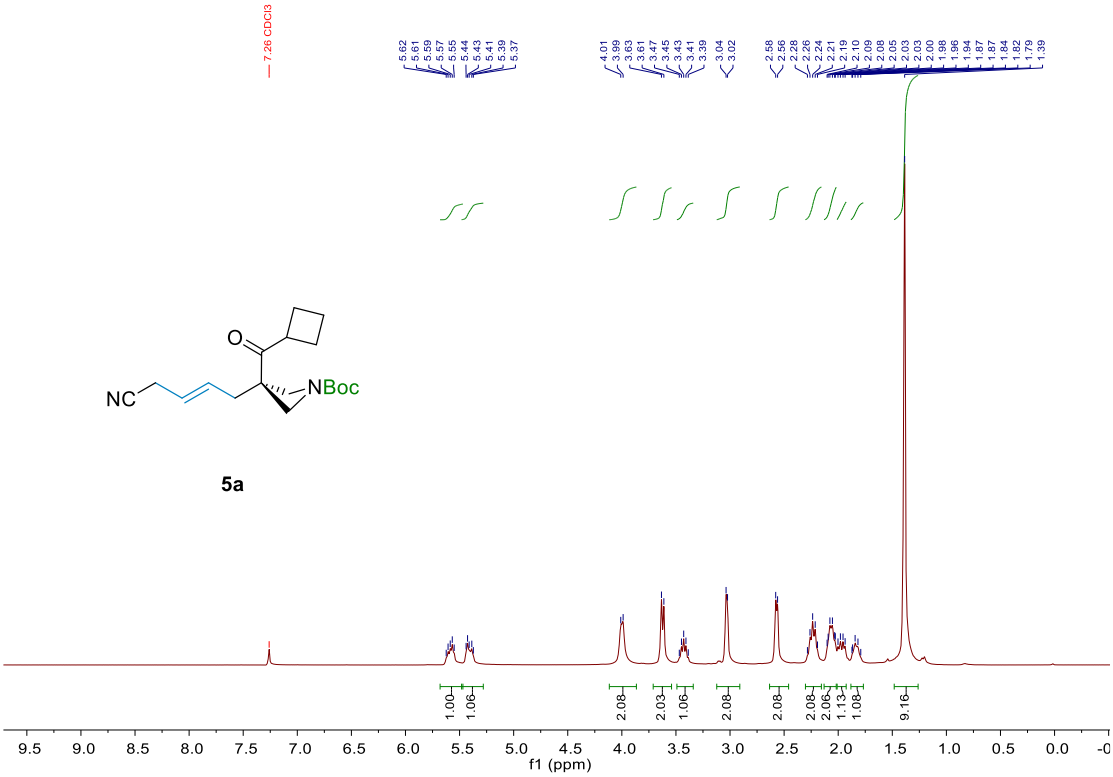
^{13}C NMR (126 MHz, $CDCl_3$)



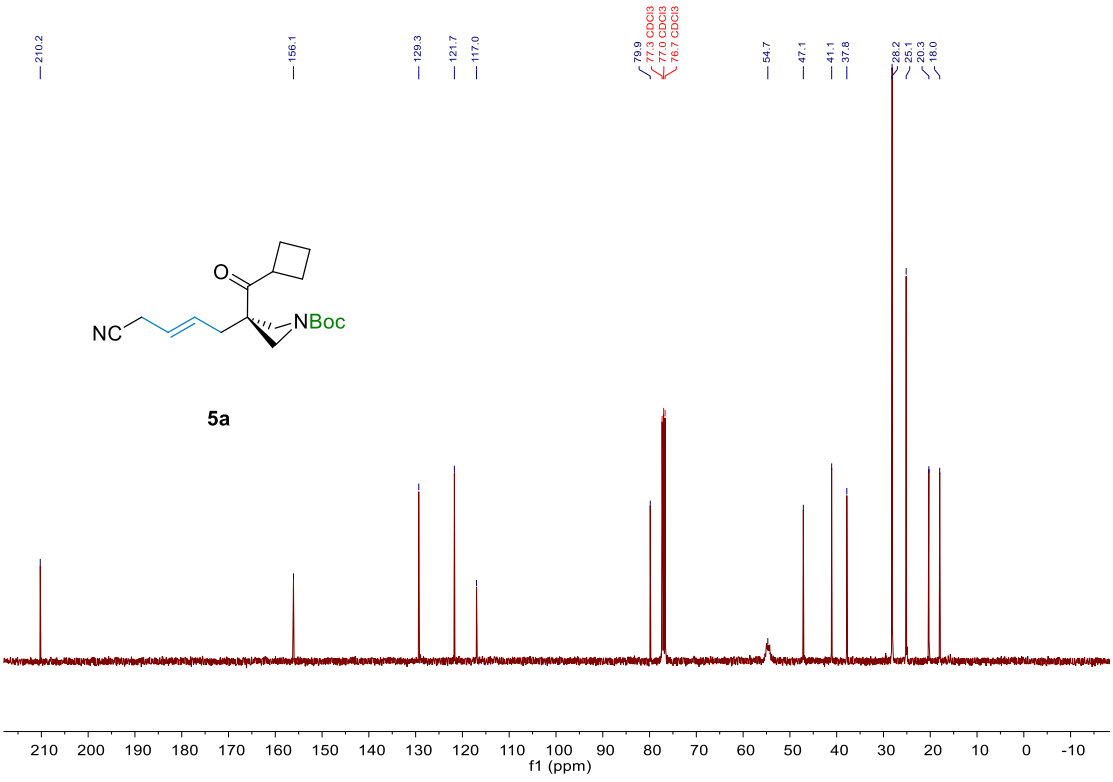
4p


Me
NBoc
NC
O
Ph
4p
f2 (ppm)
f1 (ppm)

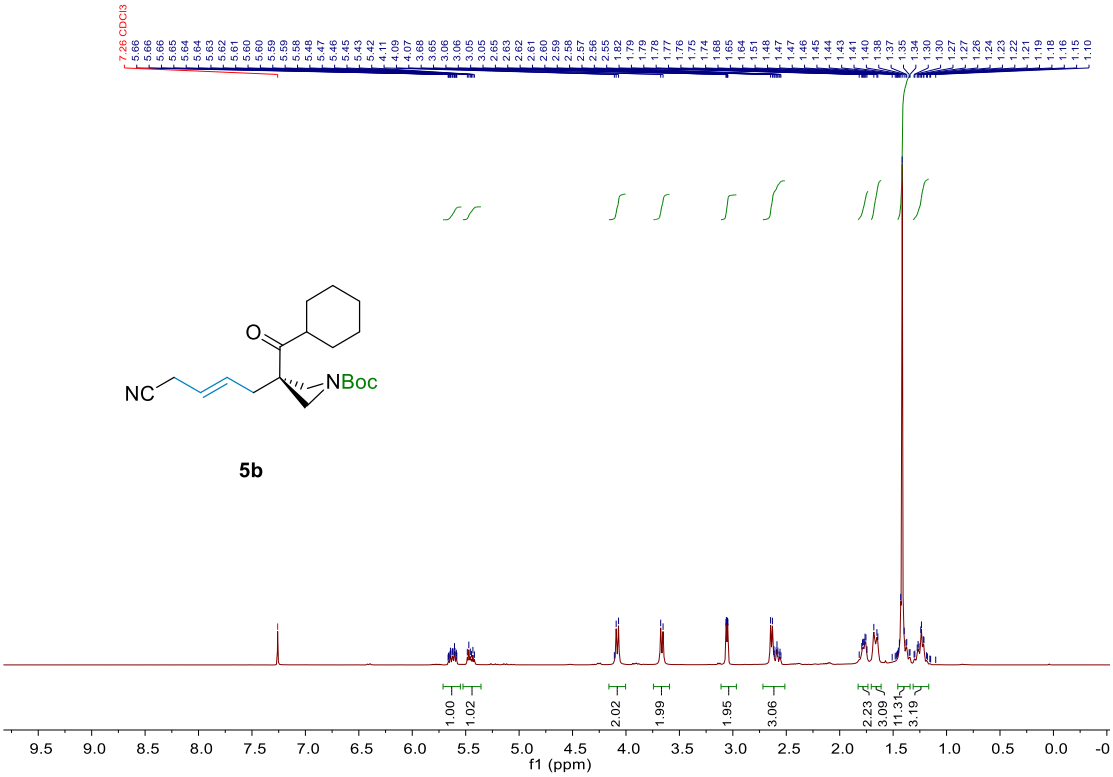
^{1}H NMR (400 MHz, $CDCl_3$)



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

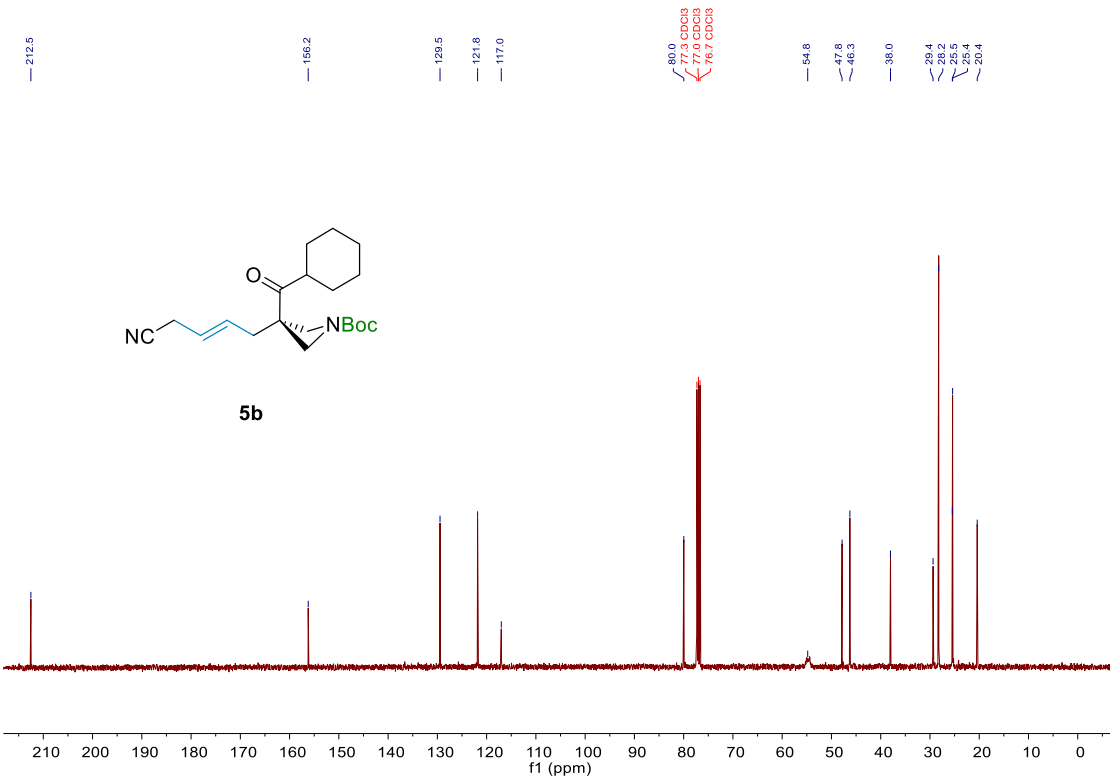


^{1}H NMR (400 MHz, $CDCl_3$)



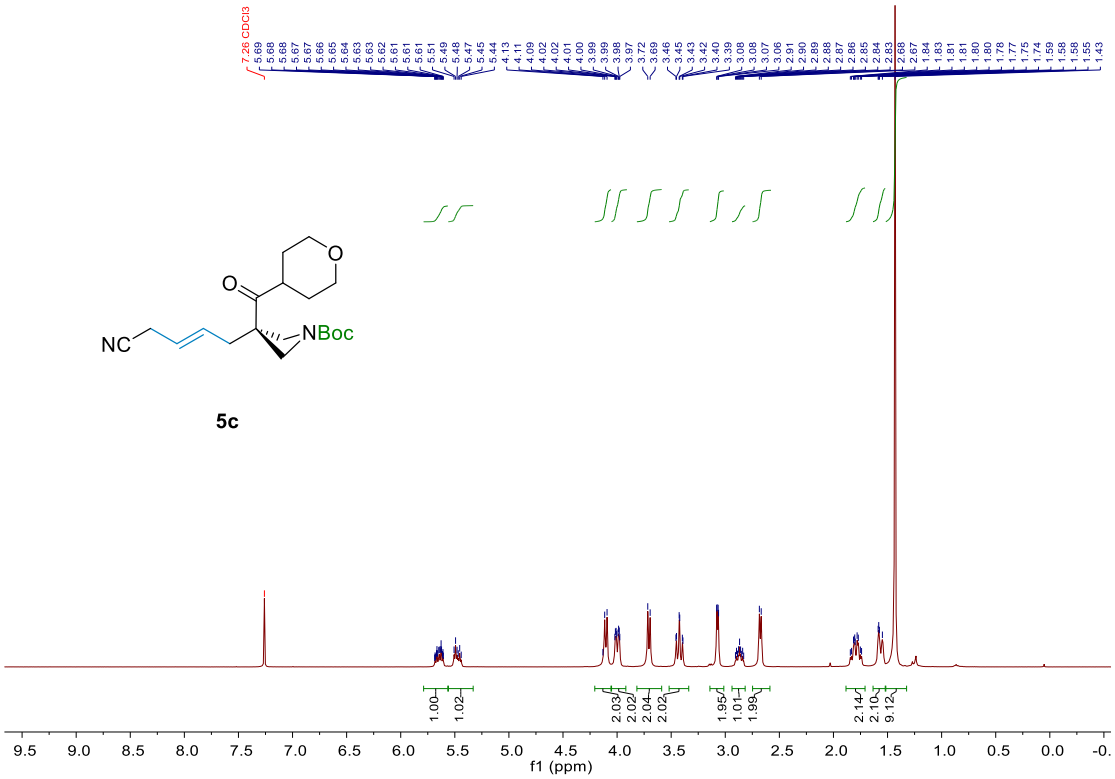
5b

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



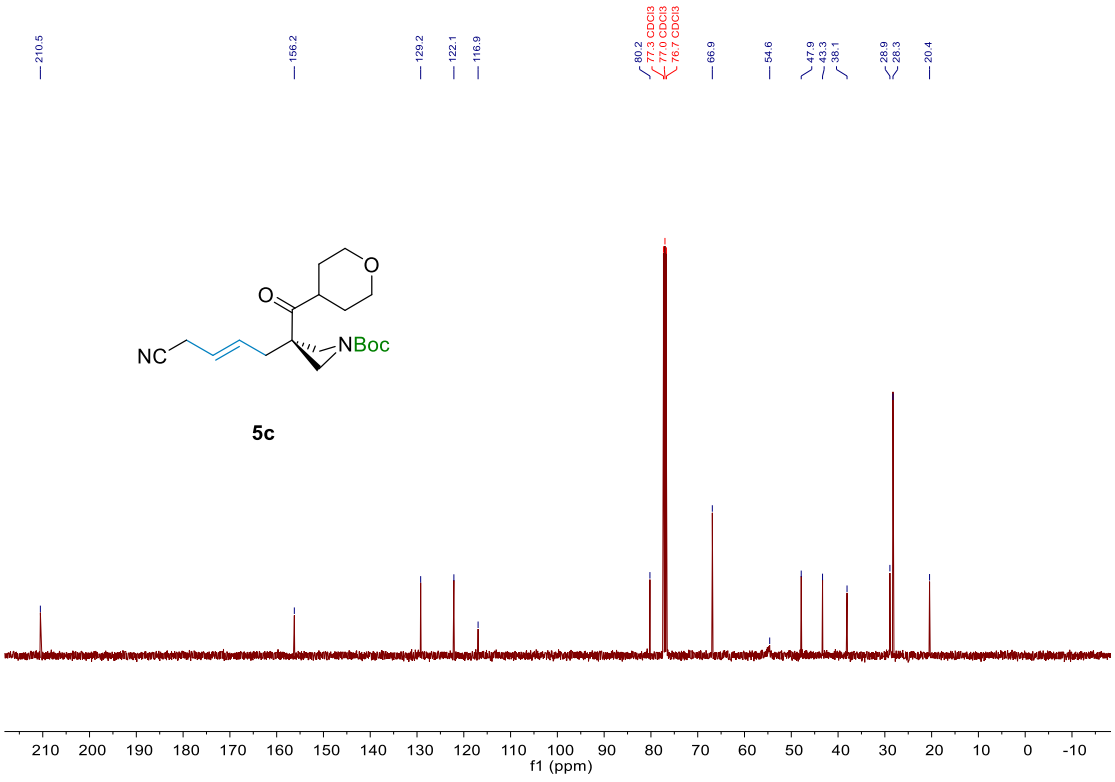
5b

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



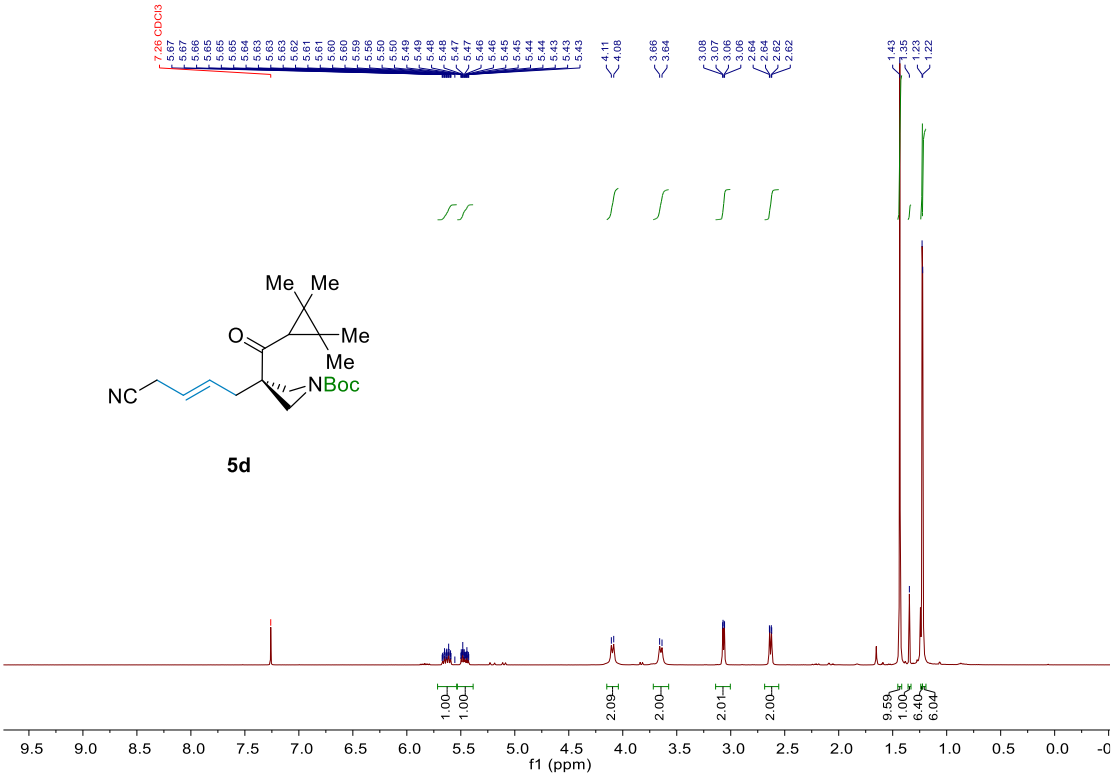
5c

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

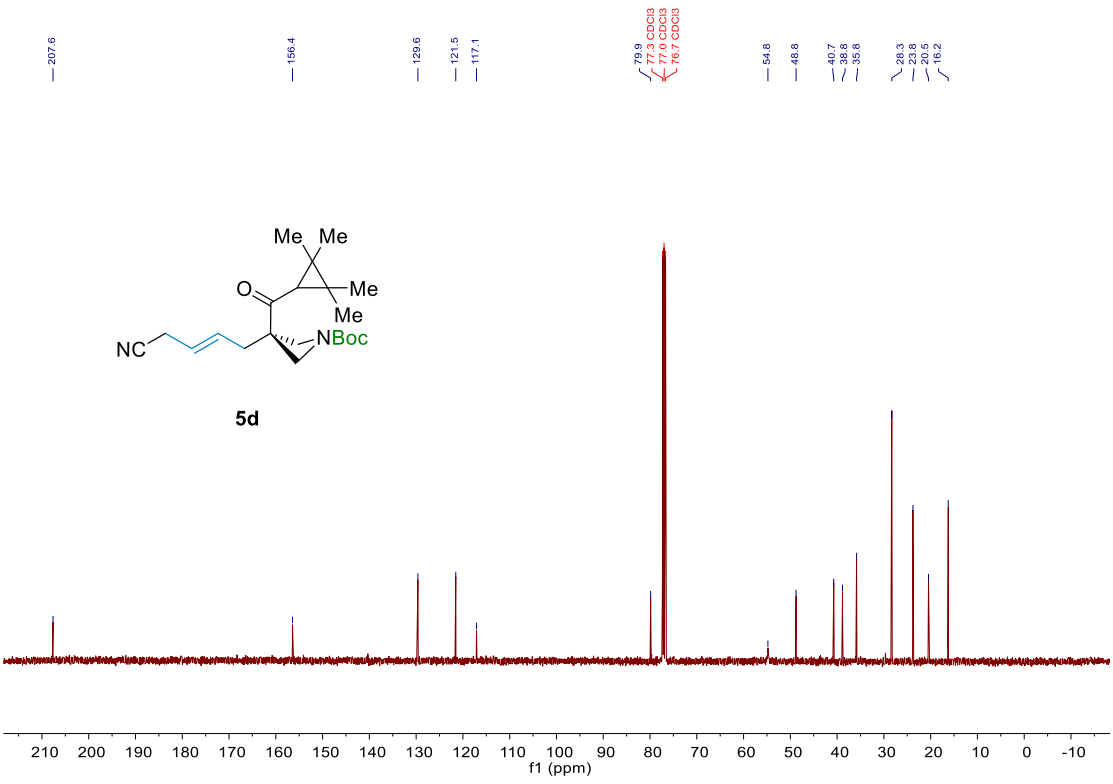


5c

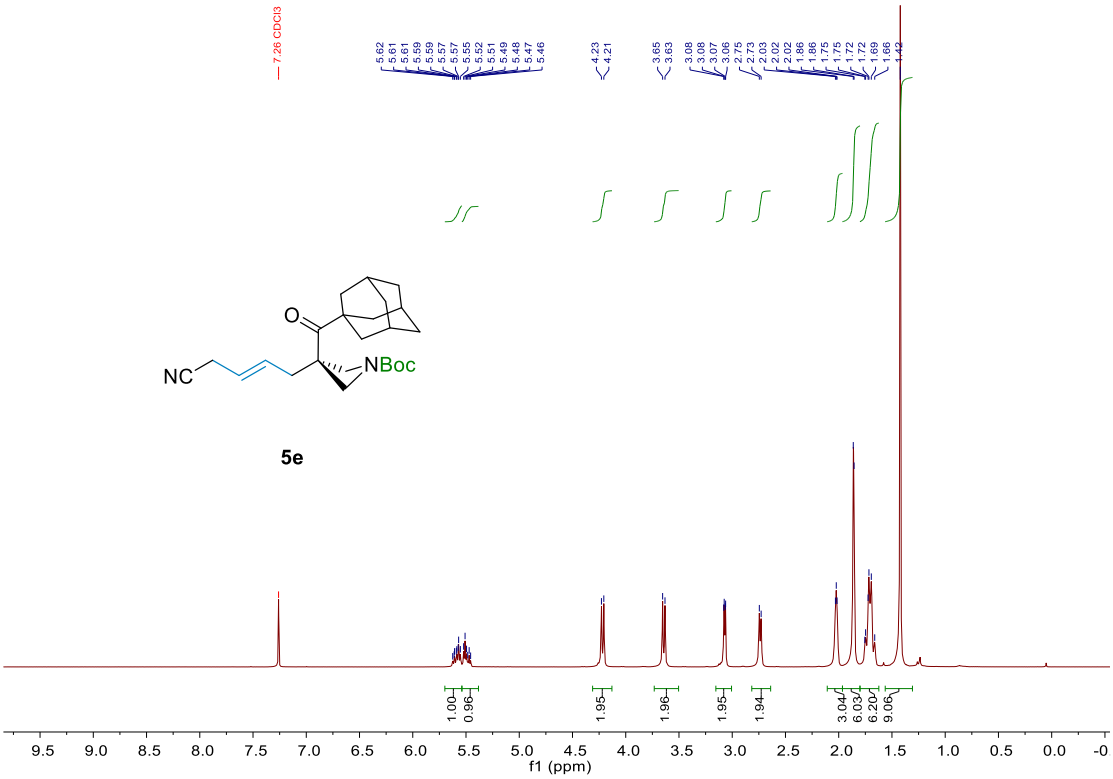
^{1}H NMR (400 MHz, $CDCl_3$)



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

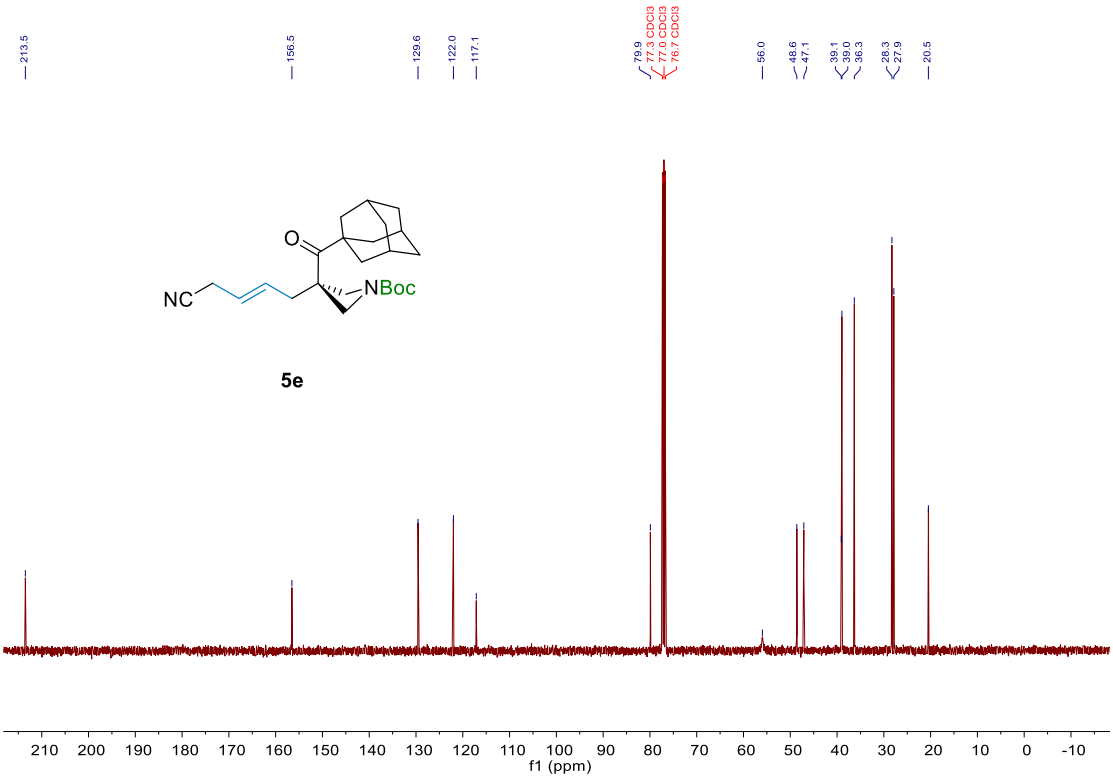


^{1}H NMR (400 MHz, $CDCl_3$)



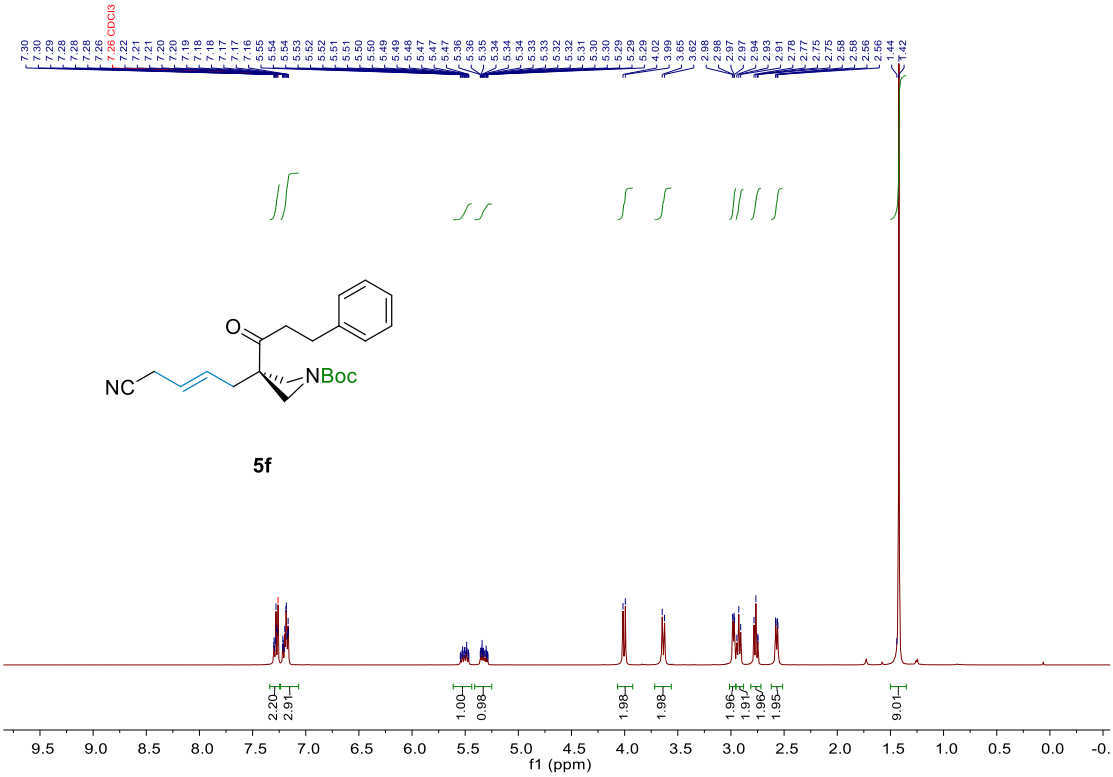
5e

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

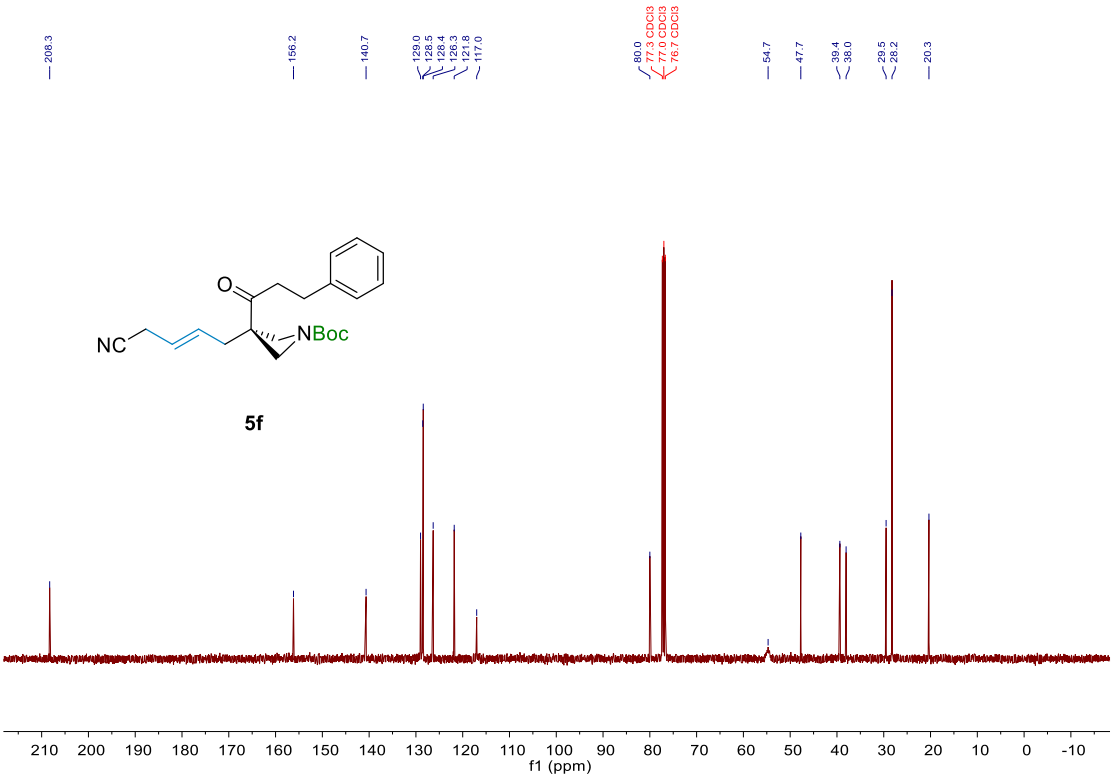


5e

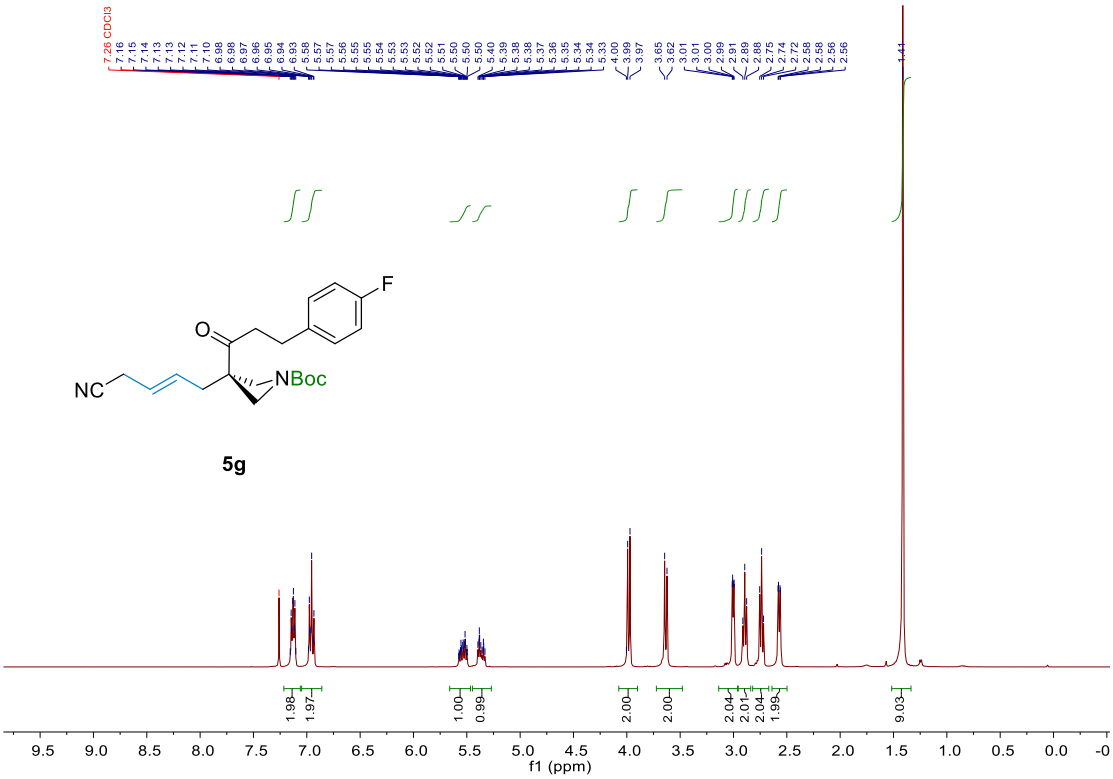
^{1}H NMR (400 MHz, $CDCl_3$)



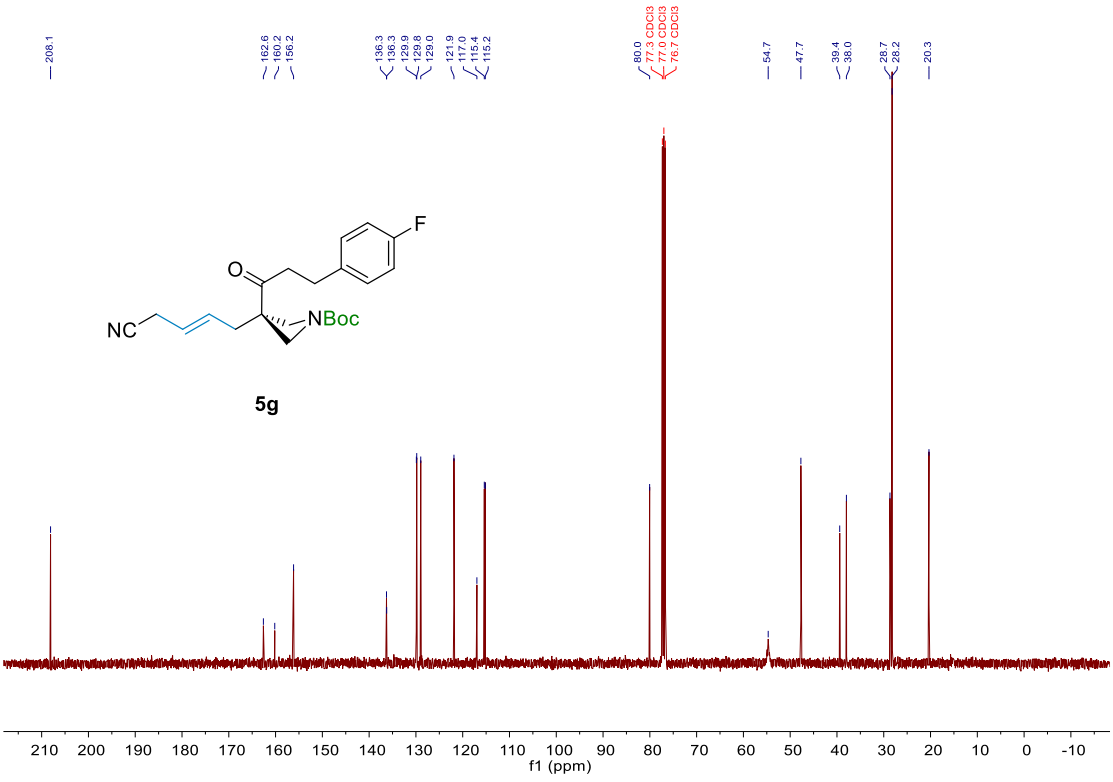
^{13}C NMR (101 MHz, $CDCl_3$)



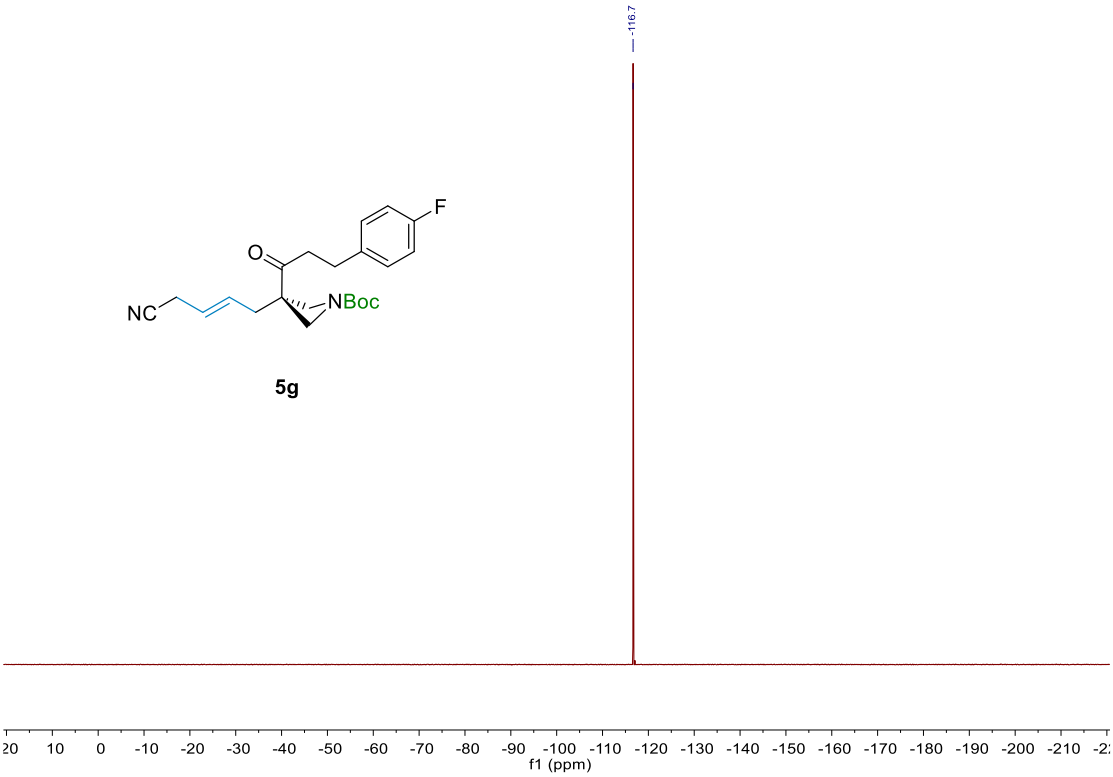
^{1}H NMR (400 MHz, $CDCl_3$)



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

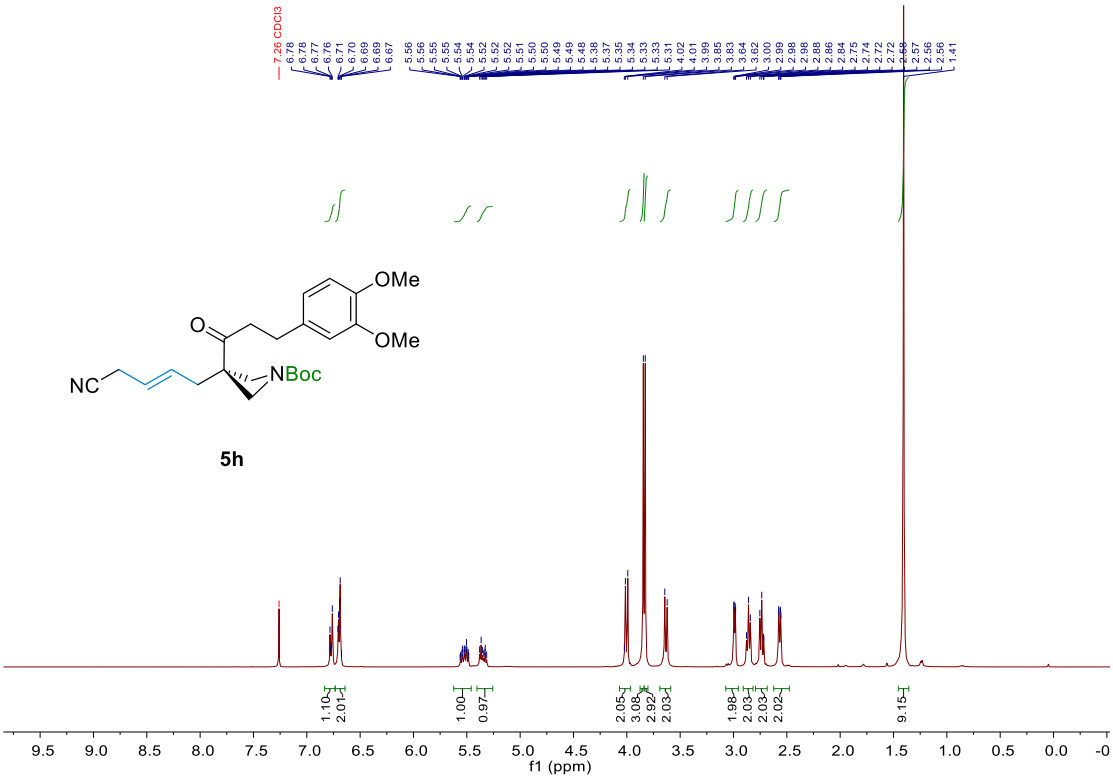


^{19}F NMR (377 MHz, $CDCl_3$)

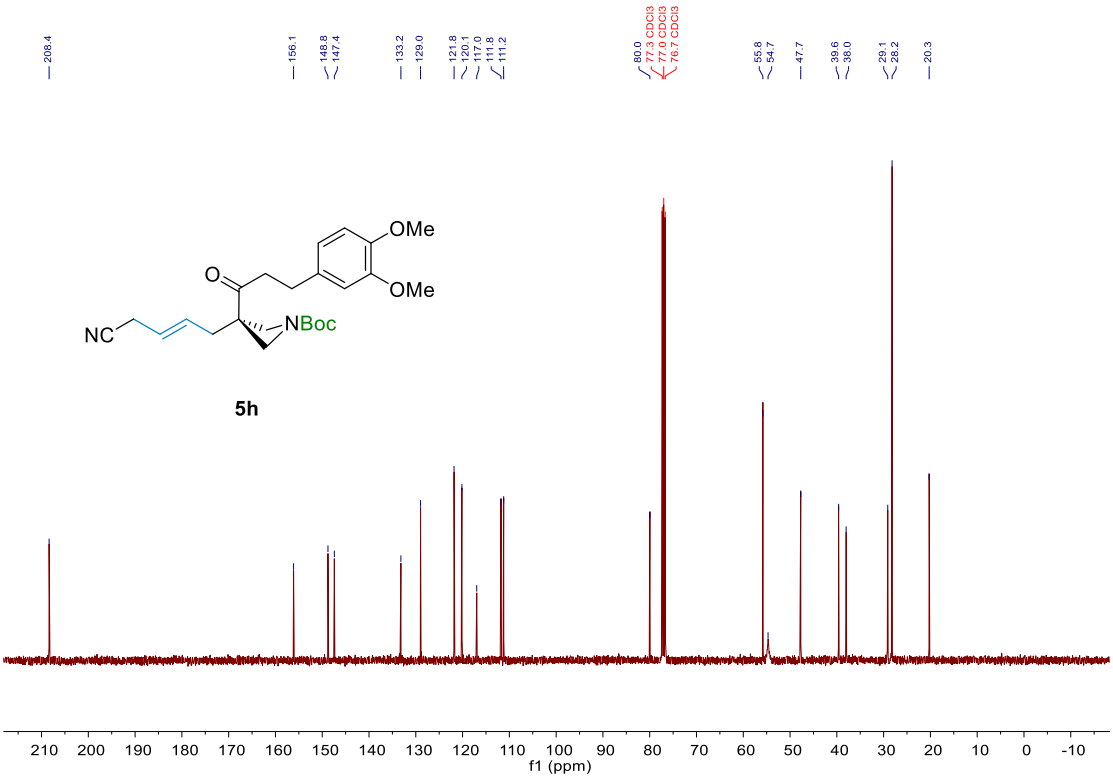


5g

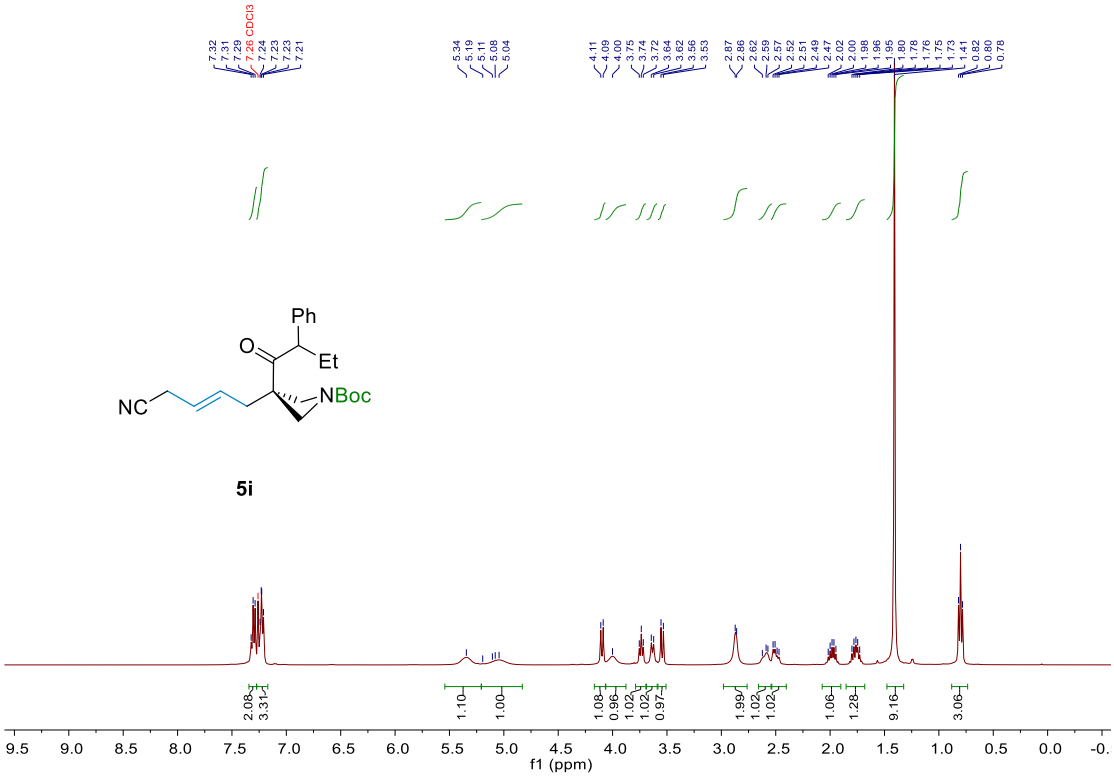
^{1}H NMR (400 MHz, $CDCl_3$)



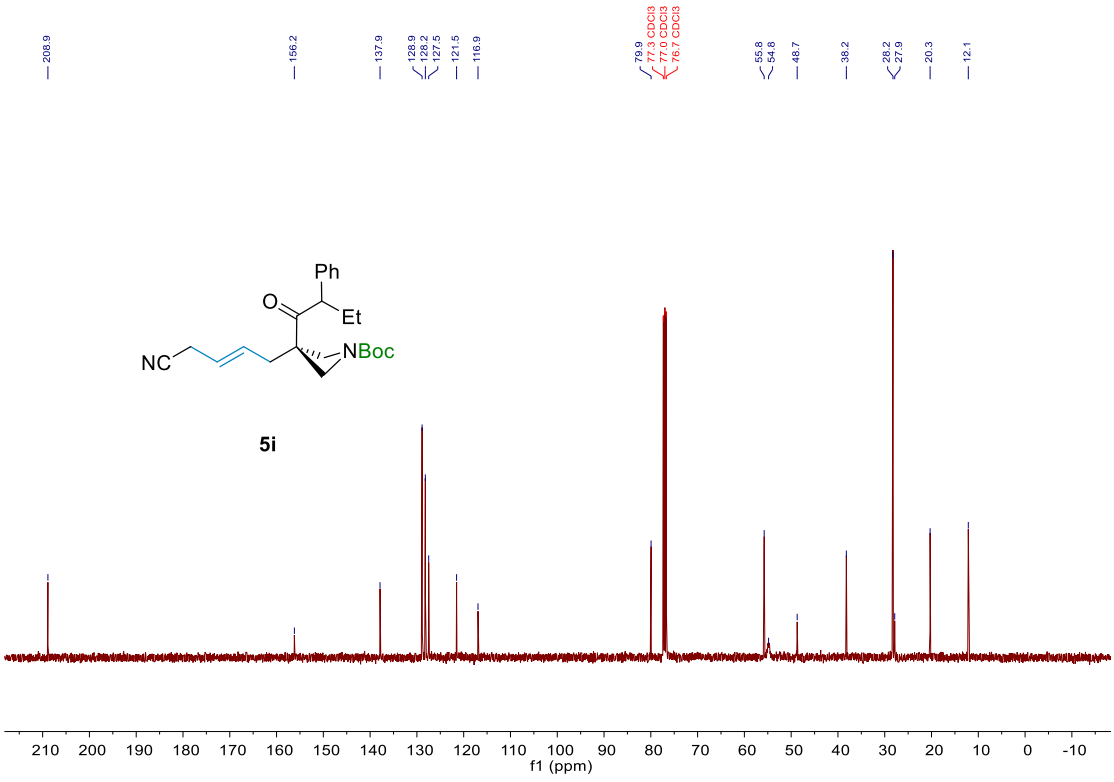
^{13}C NMR (101 MHz, $CDCl_3$)



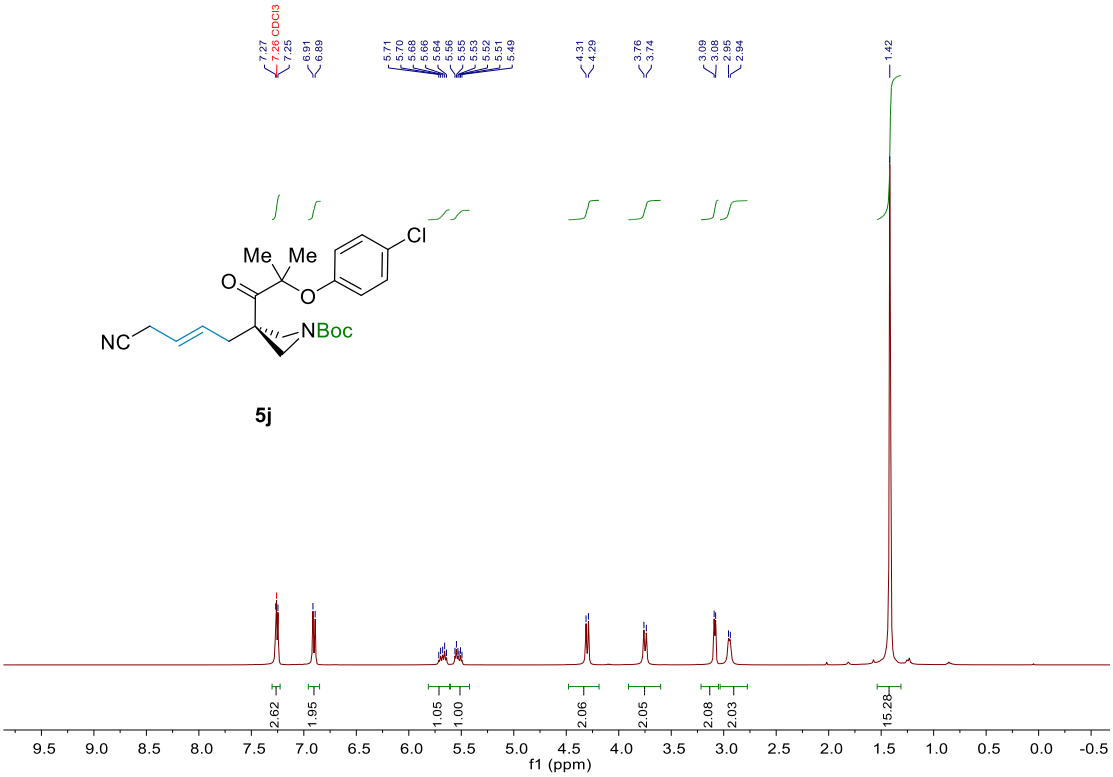
^{1}H NMR (400 MHz, $CDCl_3$)



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

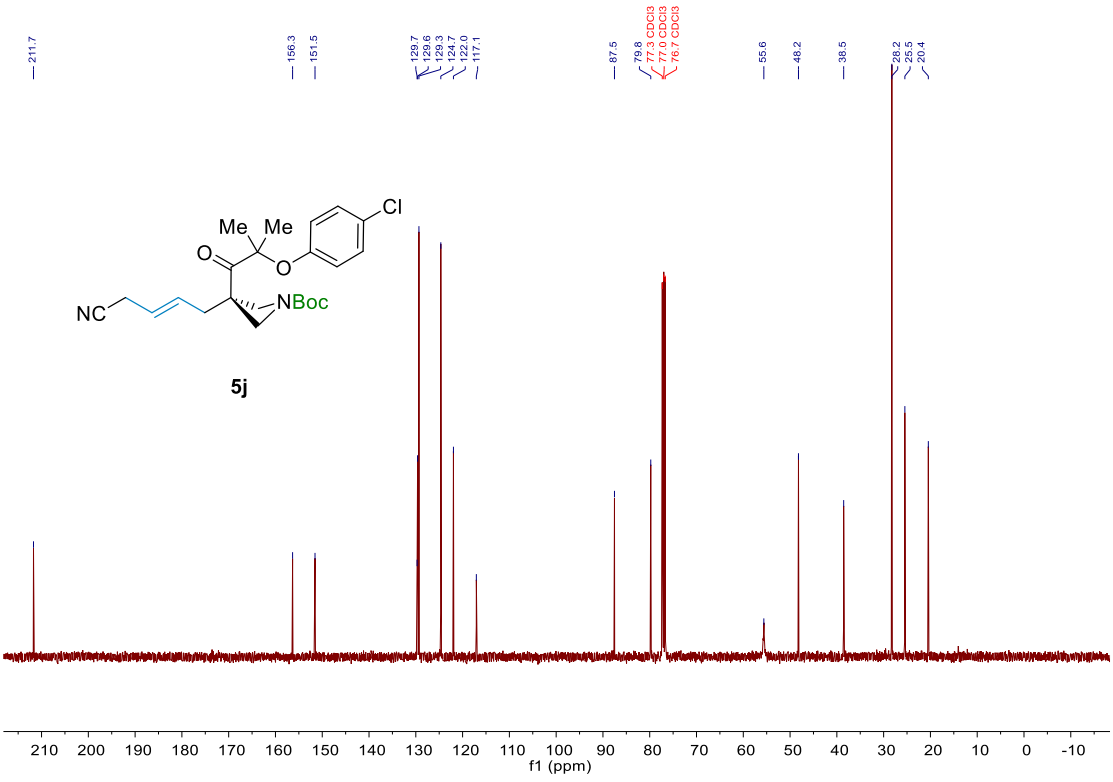


^{1}H NMR (400 MHz, $CDCl_3$)



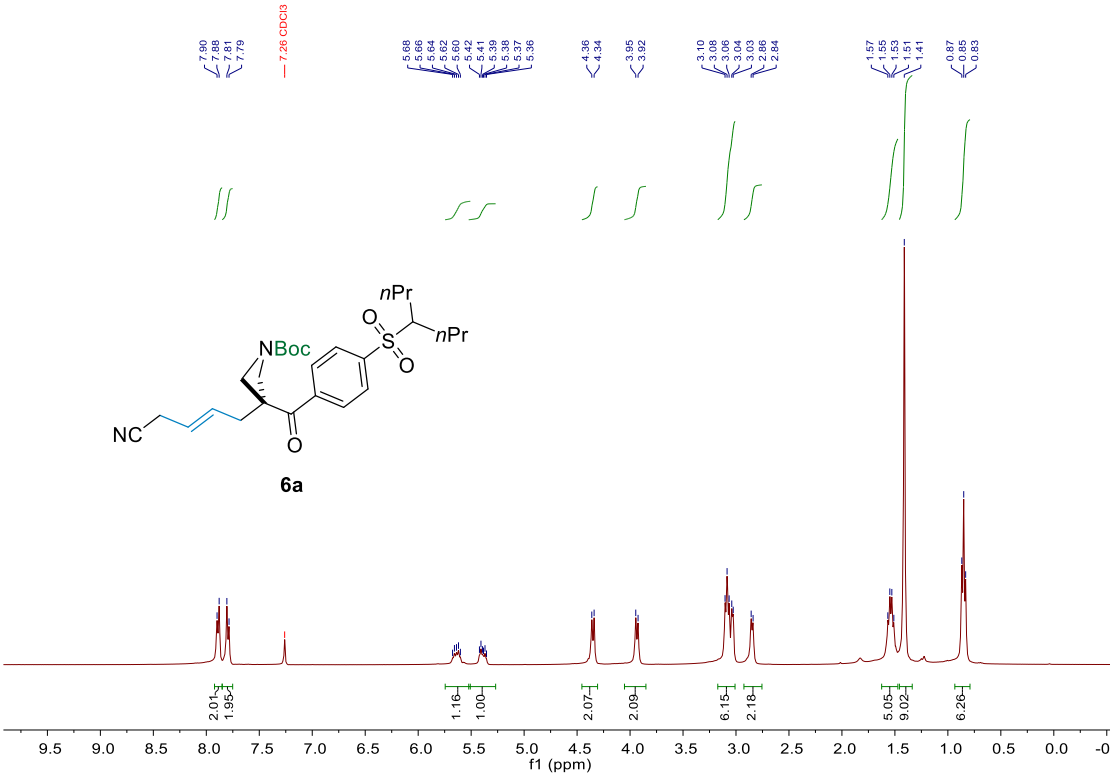
5j

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

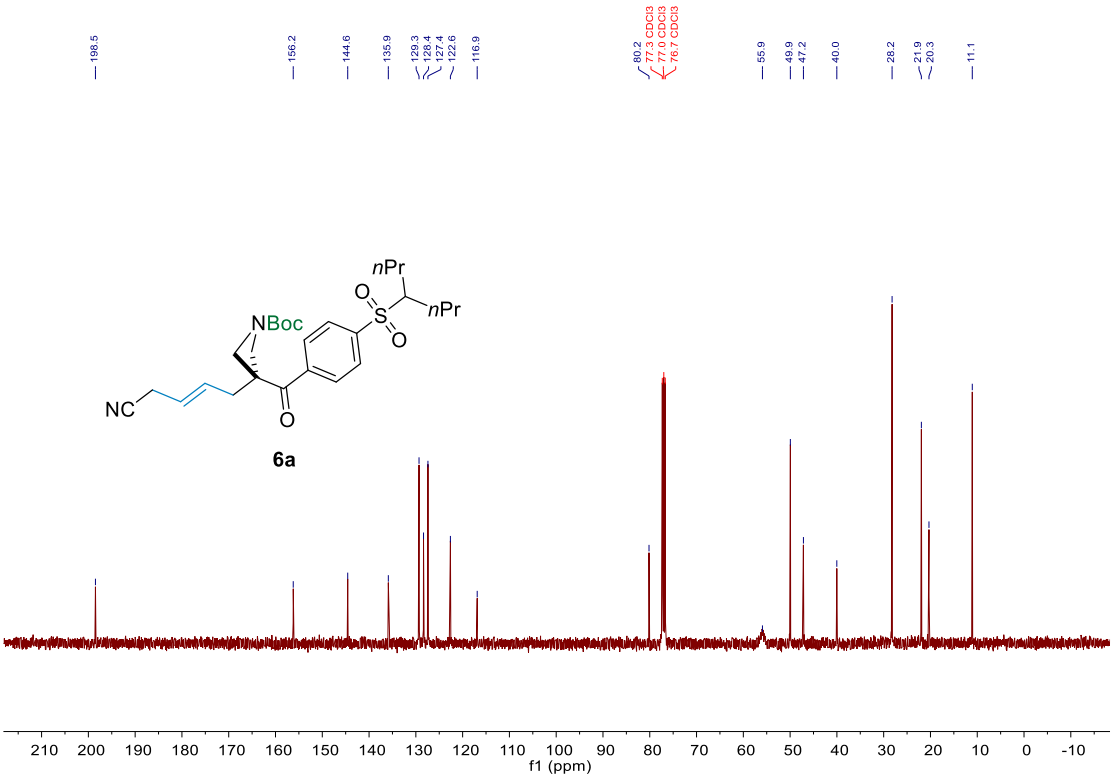


5j

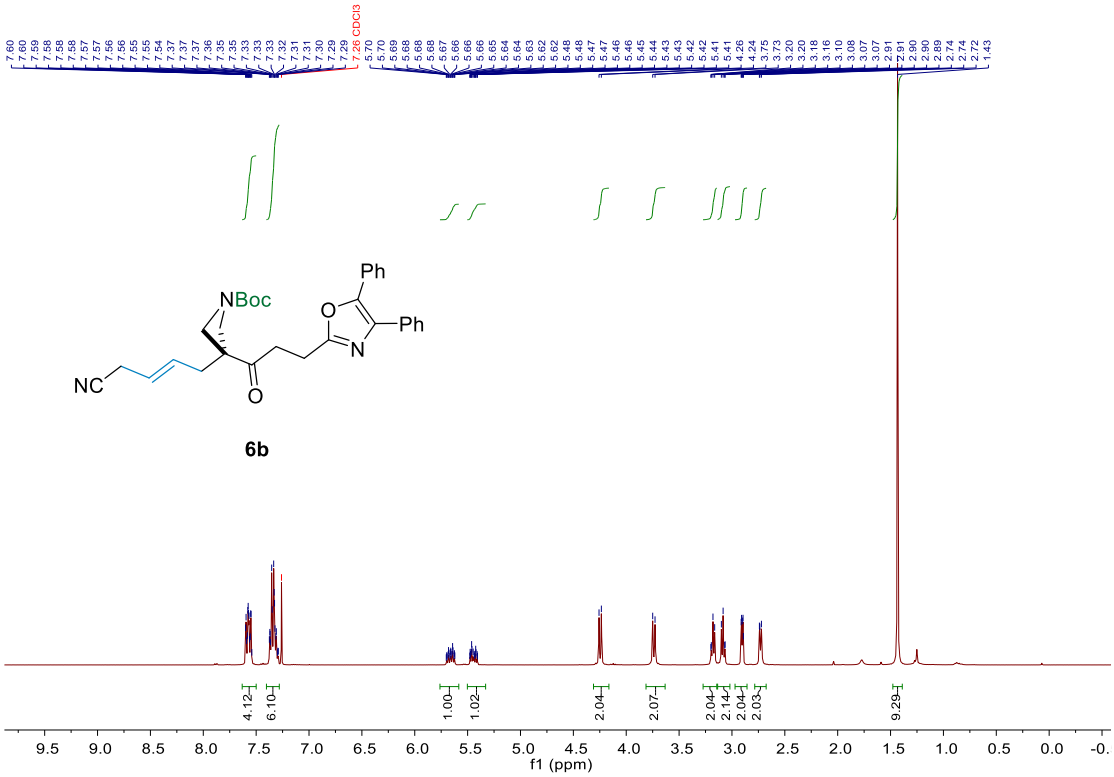
^{1}H NMR (400 MHz, $CDCl_3$)



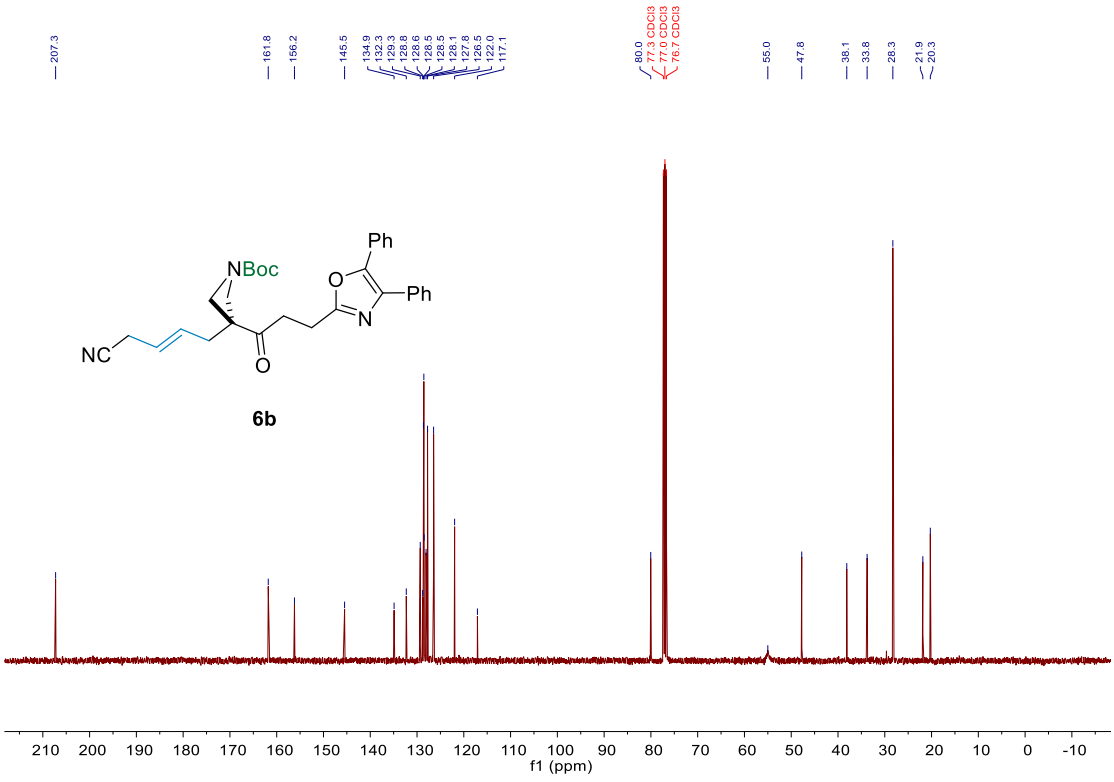
^{13}C NMR (101 MHz, $CDCl_3$)



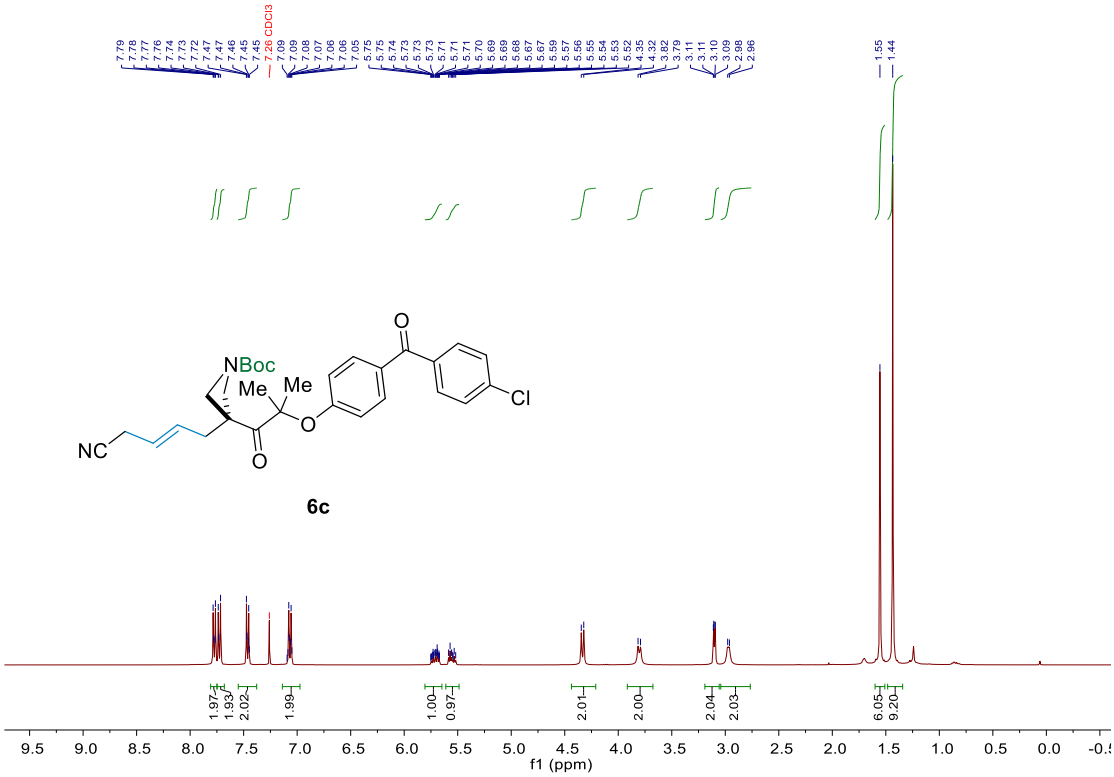
^{1}H NMR (400 MHz, $CDCl_3$)



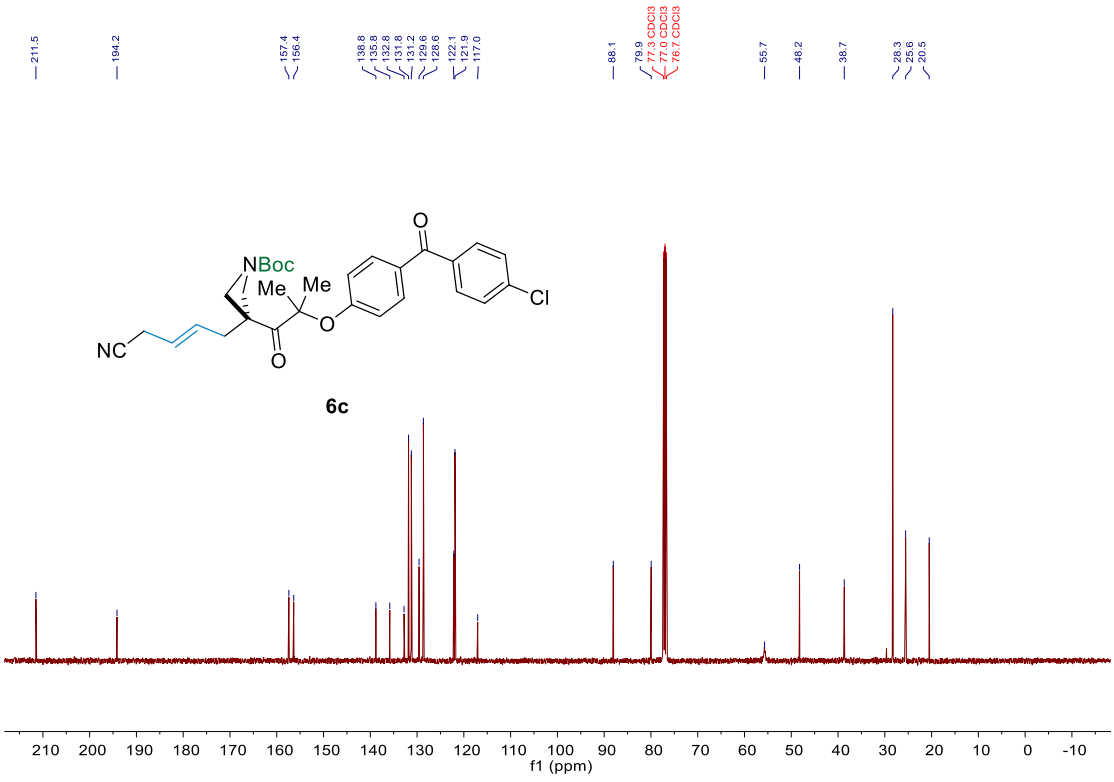
^{13}C NMR (101 MHz, $CDCl_3$)



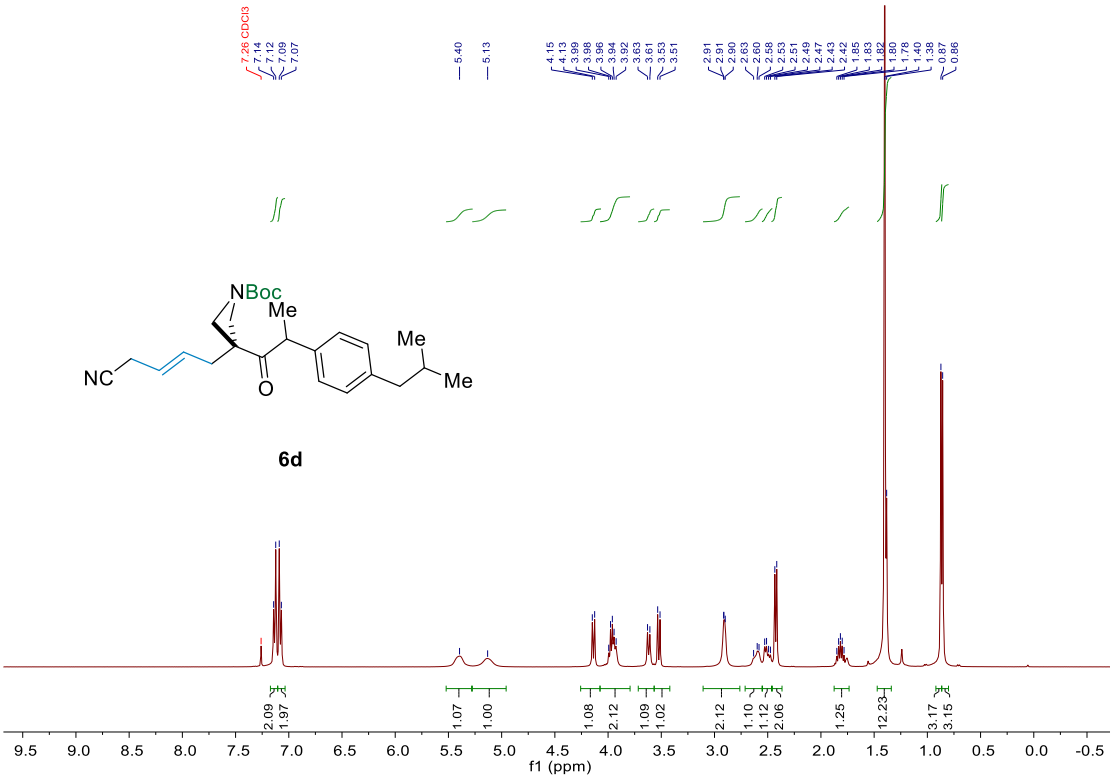
^{1}H NMR (400 MHz, $CDCl_3$)



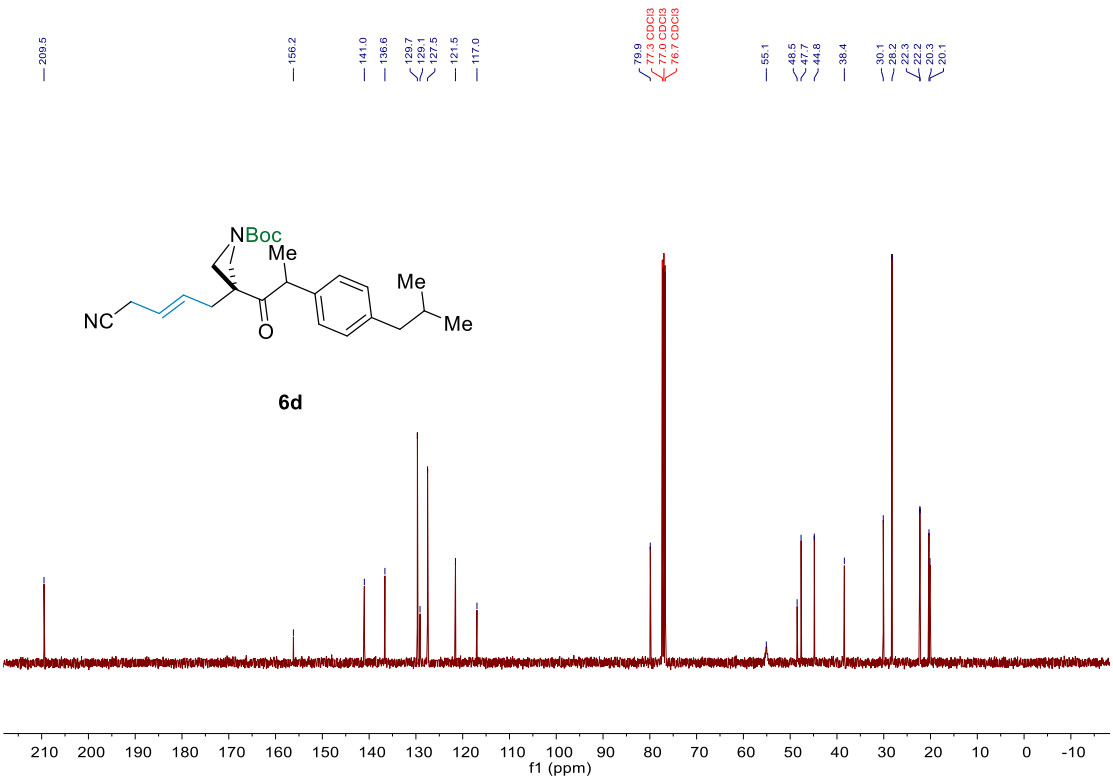
^{13}C NMR (101 MHz, $CDCl_3$)



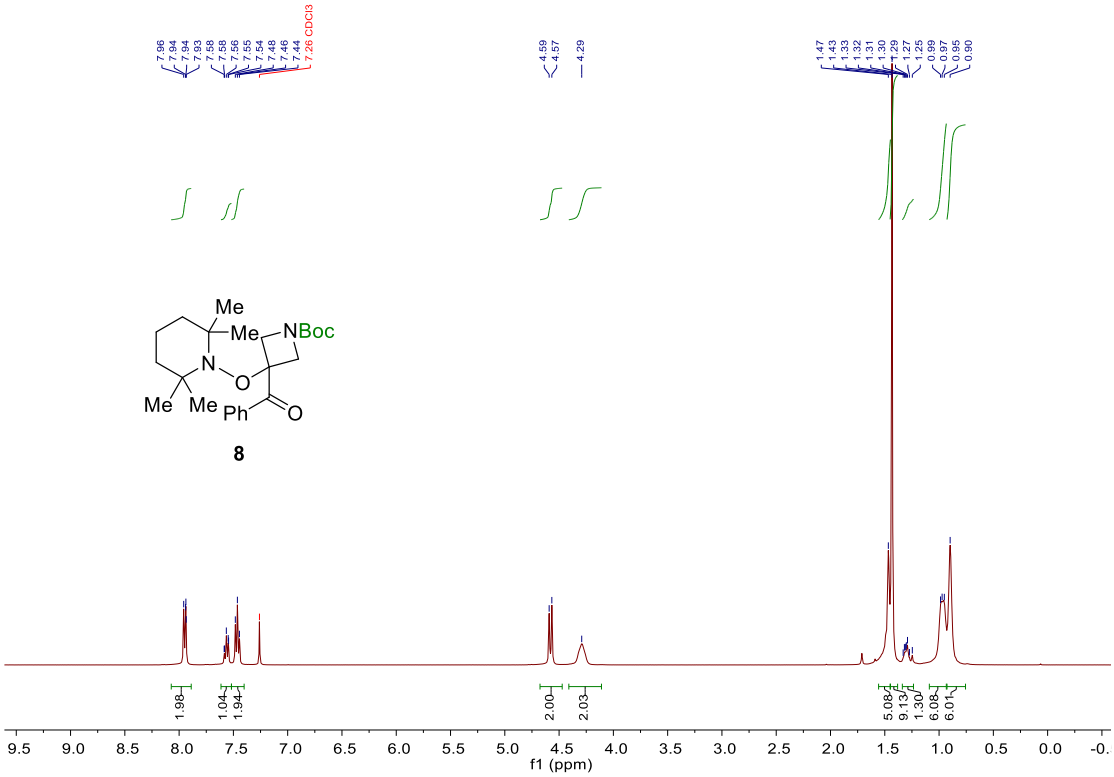
^{1}H NMR (400 MHz, $CDCl_3$)



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

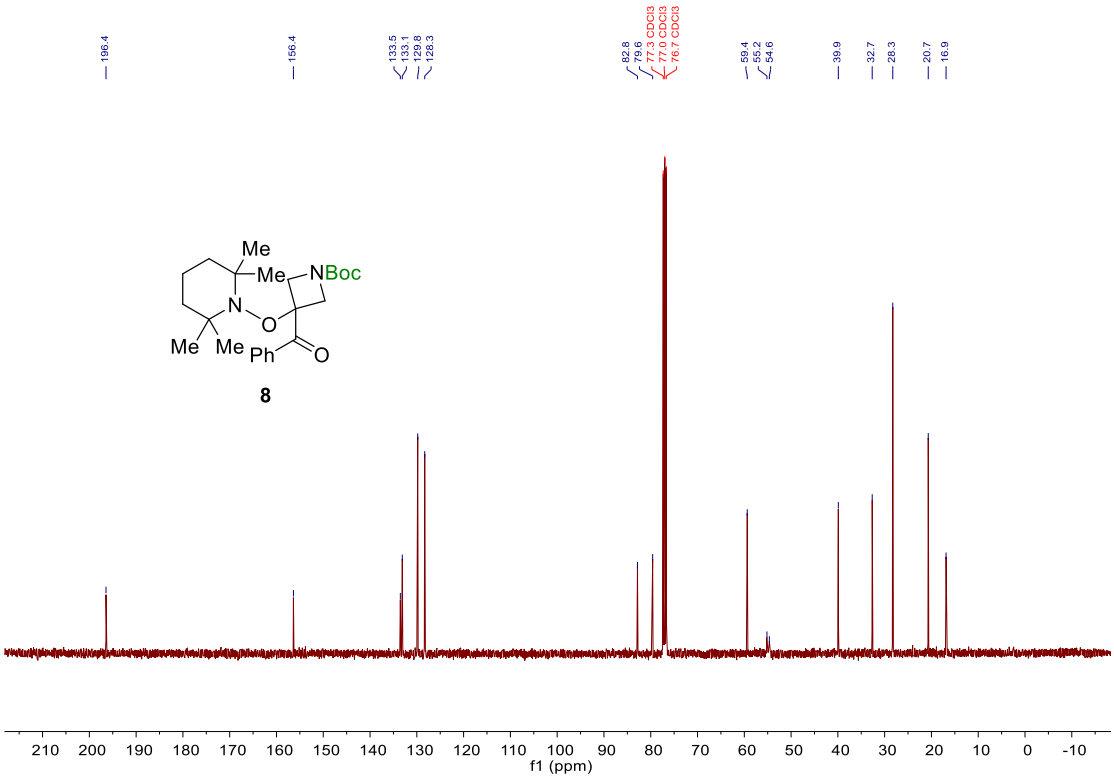


^{1}H NMR (400 MHz, $CDCl_3$)



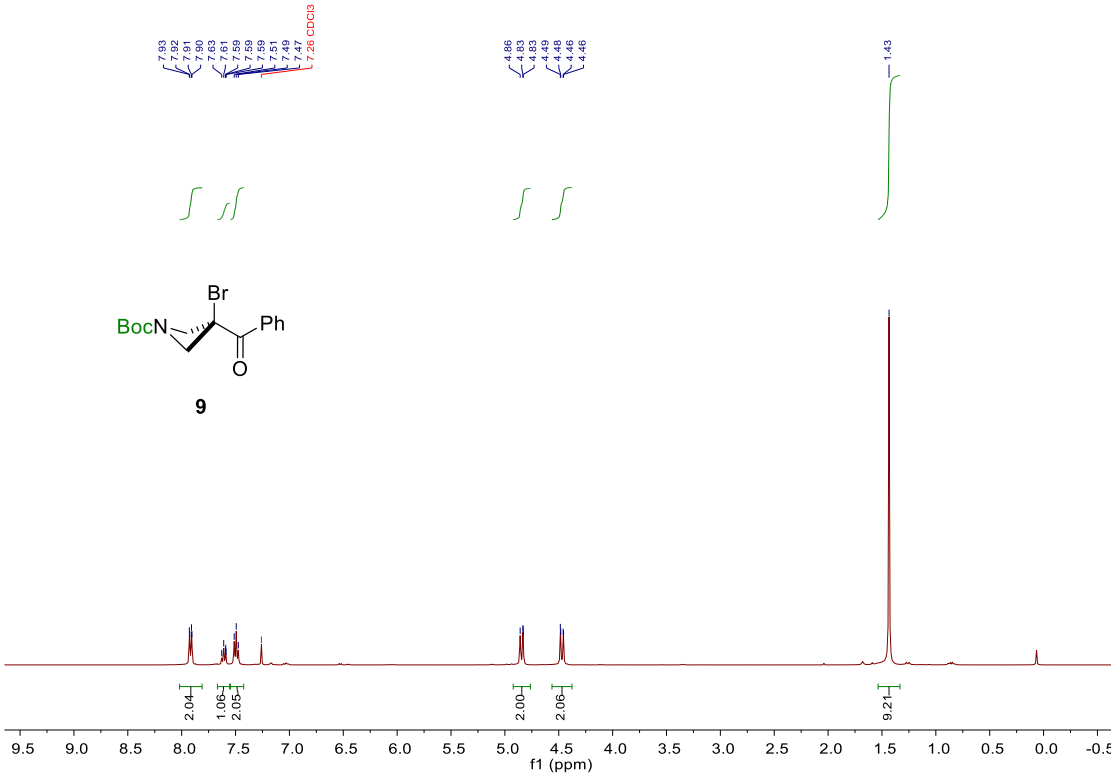
8

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



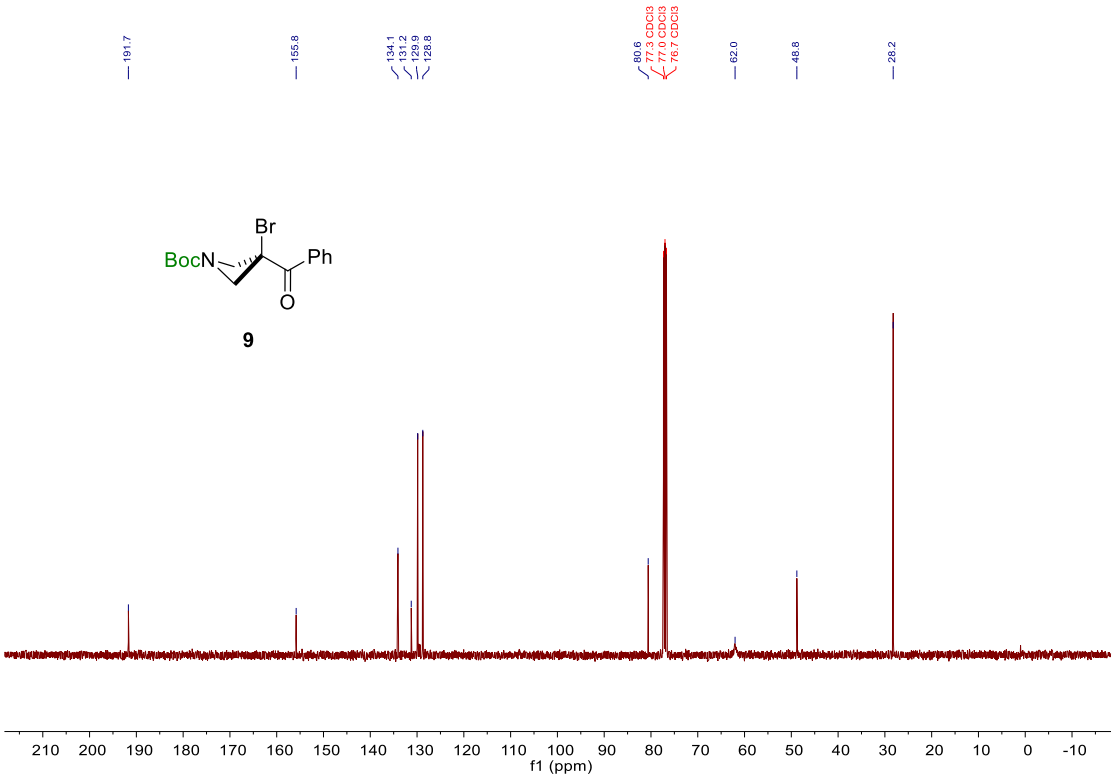
8

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



9

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



9