



Supporting Information

for

Synthesis of spiro-1,2-dihydropyridine derivatives via cycloisomerization of 3-aza-1,5-enynes catalyzed by gold(I) complex/polyoxometalate hybrids

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Experimental procedures, characterization data and copies of spectra

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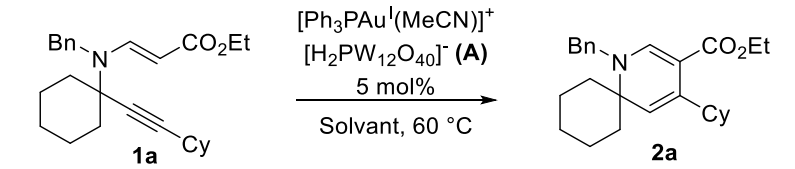
1. Organic synthesis

1.1 General information

All chemicals were of the best commercially available grade and used without further purification. Reactions taking place in screw cap tubes were flushed with argon before sealing. Reactions were monitored by thin layer chromatography carried out on silica (silica gel 60 F254, Merck) plates using UV-light, KMnO₄, vanillin (especially for carbonyls) and ninhydrine (for amines and imines) stains for visualization. Column chromatographies were performed on silica gel 60 (40–63 μm, Merck). Further abbreviations were used to consider solvents: EtOAc for ethyl acetate and DCM for dichloromethane. IR spectra were recorded neat on a Bruker Alpha II Fourier transform spectrometer. NMR spectra were recorded on a Bruker Avance III spectrometer operating at specified power (Bruker Corporation, Billerica, MA, USA). ¹H and ¹³C NMR spectra were recorded at 500 MHz for ¹H and 126 MHz for ¹³C NMR experiments at 298 K. Chemical shifts (δ) and coupling constants (*J*) are given in parts per million (ppm) and Hertz (Hz), respectively. Chemical shifts (δ) are reported relative to the residual solvent as an internal standard (CDCl₃: δ 7.26 ppm for ¹H and δ 77.16 ppm for ¹³C). Assignments were determined based on chemical shifts, multiplicities and coupling constants. COSY, HSQC and HMBC experiments were sometimes used to interpret spectra for related compounds. Low-(MS) and high-resolution mass spectra (HRMS) data were recorded on a MicroTOF spectrometer (Broker Corporation, Billerica, MA, USA) equipped with an orthogonal electro spray interface (ESI) or with atmospheric pressure chemical ionisation (APCI). The parent ions [M + H]⁺ or [M + Na]⁺ are indicated. Mass spectra were obtained from the « Service de Spectroscopie de Masse » of the Fédération de Chimie « Le Bel » (FR2010). Gold(I)-polyoxometalate catalysts were synthesized following described procedures.¹

1.2 Optimization of the reaction conditions (Table S1)

Table S1. Solvents Optimization of Azaspiro-1,5-enyne **1a** Cycloisomerization into Dihydropyridine **2a** using 5 mol% of catalyst **A**.



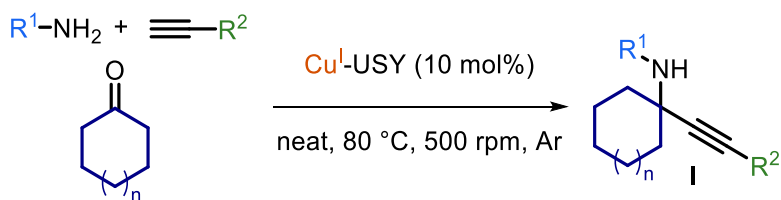
Entry	Solvent	Time (h)	Yield ^a (%)
1	DCE	2	79
2	Toluene	24	71
3	HFIP	2	68
4	EtOH	8	61
5	2-MeTHF	4	73
6	AcOEt	24	77
7	MeCN	2	90

^aCalculated yield by ¹H NMR integration relative to an internal standard (MeNO₂).

¹ For the synthesis of NHC-gold(I) polyoxometalate catalysts, see: F. Sirindil *et al.* *Chem. Eur. J.* **2018**, *24*, 12630. For the synthesis of phosphines-gold(I) polyoxometalate catalysts, see: D. Hueber *et al.* *Organometallics* **2010**, *34*, 5065.

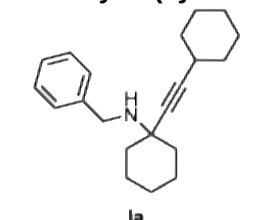
1.3 Preparation of propargylamines (I)

General procedure A: synthesis of propargylamines (I) via KA² reaction



Ketone (1.0 mmol, 1 equiv), alkyne (1.2 mmol, 1.2 equiv) and Cu^I-USY (36 mg, 10 mol %) were successively added to a screw cap tube (10 mL) and stirred at room temperature and 500 rpm for 15 min. Next, amine (1.0 mmol, 1.0 equiv) was added, and the mixture was progressively heated to 80 °C and left to stir for 48 h. Once cooled to room temperature, the reaction mixture was diluted with DCM (2 mL), filtered over Celite and washed with DCM (3 x 20 mL). The filtrate was concentrated under reduced pressure and the crude product was purified by flash chromatography over silica gel (cyclohexane/EtOAc).

N-Benzyl-1-(cyclohexylethynyl)cyclohexan-1-amine (Ia).

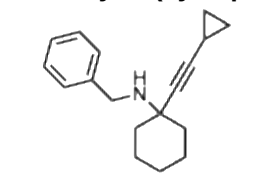


Chemical Formula: C₂₁H₂₉N
Molecular Weight: 295.47

Following the **General Procedure A** starting from cyclohexanone (207 μL, 2.0 mmol), cyclohexylacetylene (265 μL, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μL, 2.0 mmol), the title compound **Ia** was obtained (272 mg, 0.92 mmol, 46% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.55 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2926, 2851, 1604, 1495, 1447, 1345, 1115, 734, 697 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.37-7.34 (m, 2H), 7.33-7.29 (m, 2H), 7.25-7.21 (m, 1H), 3.89 (s, 2H), 2.48 (m, 1H), 1.88-1.13 (m, 20H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.5, 128.7, 128.5, 126.9, 89.2, 83.9, 55.0, 48.1, 38.7, 33.4, 29.1, 26.2, 26.2, 24.9, 23.3 ppm.

HRMS: 296.2370 [M+H]⁺, calcd 296.2373.

N-Benzyl-1-(cyclopropylethynyl)cyclohexan-1-amine (Ib).

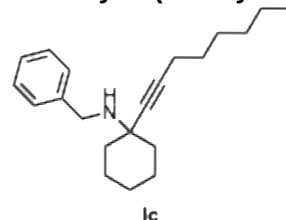


Chemical Formula: C₁₈H₂₃N
Molecular Weight: 253.39

Following the **General Procedure A** starting from cyclohexanone (207 μL, 2.0 mmol), cyclopropylacetylene (203 μL, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μL, 2.0 mmol), the title compound **Ib** was obtained (178 mg, 0.70 mmol, 35% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.48 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2928, 2852, 1450, 1112, 1027, 911, 734 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.37-7.34 (m, 2H), 7.33-7.29 (m, 2H), 7.25-7.21 (m, 1H), 3.86 (s, 2H), 1.84-1.77 (m, 2H), 1.67-1.52 (m, 5H), 1.44-1.36 (m, 2H), 1.30 (tt, *J* = 8.2, 5.0 Hz, 1H), 1.24-1.17 (m, 1H), 0.78 (dd, *J* = 8.3, 2.6 Hz, 2H), 0.66 (dd, *J* = 8.2, 2.6 Hz, 2H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.4, 128.6, 128.5, 126.9, 87.9, 79.2, 54.9, 48.0, 38.5, 26.1, 23.1, 8.7, 0.3 ppm.

HRMS: 254.1902 [M+H]⁺, calcd 254.1903.

N-Benzyl-1-(oct-1-yn-1-yl)cyclohexan-1-amine (Ic).

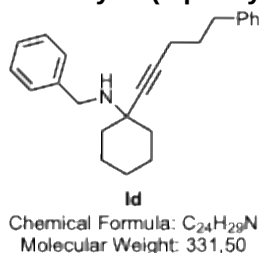


Chemical Formula: C₂₁H₃₁N
Molecular Weight: 297.49

Following the **General Procedure A** starting from cyclohexanone (207 μL, 2.0 mmol), 1-octyne (354 μL, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μL, 2.0 mmol), the title compound **Ic** was obtained (263 mg, 0.88 mmol, 44% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.59 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2927, 2854, 1462, 1448, 1116, 833, 735, 694 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.39-7.35 (m, 2H), 7.34-7.30 (m, 2H), 7.26-7.22 (m, 1H), 3.89 (s, 2H), 2.27 (t, *J* = 7.0 Hz, 2H), 1.87-1.81 (m, 2H), 1.69-1.58 (m, 5H), 1.58-1.52 (m, 2H), 1.48-1.38 (m, 4H), 1.35-1.30 (m, 5H), 1.24-1.18 (m, 1H), 0.93-0.88 (m, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.5, 128.6, 128.5, 126.9, 84.7, 84.0, 55.0, 48.1, 38.6, 31.5, 29.4, 28.7, 26.1, 23.1, 22.8, 18.9, 14.2 ppm.

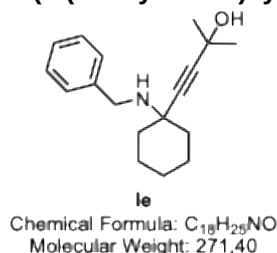
HRMS: 298.2542 [M+H]⁺, calcd 298.2529.

N-Benzyl-1-(5-phenylpent-1-yn-1-yl)cyclohexan-1-amine (Id).



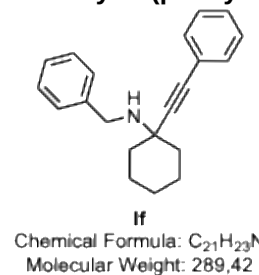
Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), 5-phenyl-1-pentyne (364 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Id** was obtained (234 mg, 0.70 mmol, 35% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.46 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2928, 2852, 1495, 1451, 1113, 738, 694 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.39-7.37 (m, 2H), 7.34-7.28 (m, 4H), 7.26-7.19 (m, 4H), 3.92 (s, 2H), 2.80-2.77 (m, 2H), 2.30 (t, *J* = 6.9 Hz, 2H), 1.91-1.84 (m, 4H), 1.72-1.50 (m, 5H), 1.49-1.42 (m, 2H), 1.29-1.20 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 142.0, 141.4, 128.7, 128.6, 128.5, 128.5, 126.9, 126.0, 84.6, 84.2, 55.0, 48.1, 38.6, 35.1, 31.1, 26.1, 23.2, 18.4 ppm. **HRMS**: 332.2384 [M+H]⁺, calcd 332.2373.

4-(1-(Benzylamino)cyclohexyl)-2-methylbut-3-yn-2-ol (Ie).



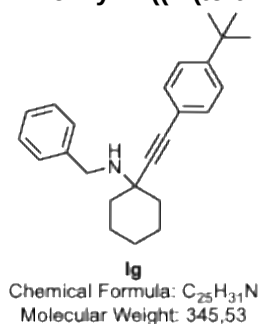
Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), 2-methyl-3-butyne-2-ol (233 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Ie** was obtained (48 mg, 0.18 mmol, 8% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.08 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2980, 2931, 2856, 1452, 1273, 1163, 1112, 733, 702 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.38-7.29 (m, 4H), 7.26-7.22 (m, 1H), 3.87 (s, 2H), 1.89-1.82 (m, 2H), 1.71-1.57 (m, 6H), 1.56 (s, 6H), 1.47-1.40 (m, 2H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.2, 128.6, 128.6, 127.0, 89.7, 86.0, 65.6, 54.7, 48.1, 38.3, 32.1, 26.0, 23.1 ppm. **HRMS**: 272.2022 [M+H]⁺, calcd 272.2009.

N-Benzyl-1-(phenylethynyl)cyclohexan-1-amine (If).



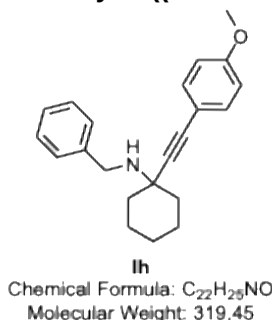
Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), phenylacetylene (264 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **If** was obtained (477 mg, 1.65 mmol, 83% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.57 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2936, 2917, 2856, 1596, 1489, 1443, 1285, 1116, 734, 696 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.61-7.45 (m, 2H), 7.44-7.39 (m, 2H), 7.37-7.30 (m, 5H), 7.29-7.23 (m, 1H), 4.00 (s, 2H), 2.05-1.95 (m, 2H), 1.79-1.63 (m, 5H), 1.61-1.49 (m, 2H), 1.36-1.22 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.2, 131.8, 128.6, 128.6, 128.4, 127.9, 123.8, 93.7, 84.9, 55.5, 48.2, 38.4, 26.1, 23.2 ppm. **HRMS**: 290.1895 [M+H]⁺, calcd 290.1903.

N-Benzyl-1-((4-(tert-butyl)phenyl)ethynyl)cyclohexan-1-amine (Ig).



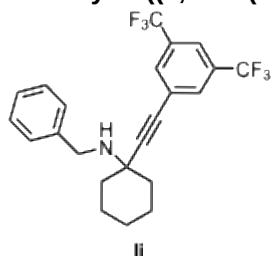
Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), 4-*tert*-butylphenylacetylene (433 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Ig** was obtained (325 mg, 0.94 mmol, 47% yield) as a white solid after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.48 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2932, 2854, 1464, 1268, 1117, 833, 768, 736, 696, 564 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.42-7.37 (m, 4H), 7.35-7.29 (m, 4H), 7.25-7.21 (m, 1H), 3.97 (s, 2H), 2.01-1.93 (m, 2H), 1.75-1.62 (m, 5H), 1.57-1.47 (m, 2H), 1.32 (s, 9H), 0.89-0.77 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 151.2, 141.3, 131.5, 128.7, 128.6, 127.0, 125.4, 121.8, 93.0, 84.9, 55.5, 48.2, 38.4, 34.9, 31.4, 26.1, 23.2 ppm. **HRMS**: 346.2523 [M+H]⁺, calcd 346.2529.

N-Benzyl-1-((4-methoxyphenyl)ethynyl)cyclohexan-1-amine (Ih).



Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), 4-methoxyphenylacetylene (311 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Ih** was obtained (211 mg, 0.66 mmol, 33% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.43 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2929, 2851, 1605, 1507, 1441, 1284, 1245, 1209, 830, 699 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.42-7.37 (m, 4H), 7.36-7.29 (m, 2H), 7.27-7.21 (m, 1H), 6.88-6.82 (m, 2H), 3.97 (s, 2H), 3.82 (s, 3H), 2.01-1.92 (m, 2H), 1.77-1.60 (m, 7H), 1.34-1.19 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 159.4, 141.3, 133.2, 128.6, 128.6, 127.0, 116.0, 114.0, 92.1, 84.6, 55.5, 55.5, 48.2, 38.4, 26.1, 23.2 ppm. **HRMS**: 320.2018 [M+H]⁺, calcd 320.2009.

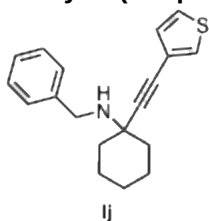
***N*-Benzyl-1-((3,5-bis(trifluoromethyl)phenyl)ethynyl)cyclohexan-1-amine (Ii).**



Chemical Formula: $C_{23}H_{21}F_6N$
Molecular Weight: 425.42

Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), 1-ethynyl-3,5-bis(trifluoromethyl)benzene (425 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Ii** was obtained (462 mg, 1.08 mmol, 54% yield) as a yellow solid after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **Rf** = 0.54 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2934, 2855, 1614, 1461, 1379, 1276, 1131, 896, 683 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.85-7.82 (bs, 2H) 7.80-7.77 (bs, 1H), 7.40-7.38 (m, 2H), 7.35-7.32 (m, 2H), 7.27-7.24 (m, 1H), 3.96 (s, 2H), 2.02-1.98 (m, 2H), 1.79-1.74 (m, 2H), 1.71-1.53 (m, 5H), 1.35-1.26 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 140.9, 132.0 (q, J = 33.6 Hz), 131.7 (d, J = 3.93 Hz), 128.6, 128.5, 127.2, 126.1, 121.6 (m), 97.9, 82.1, 55.4, 48.2, 38.1, 27.1, 25.6, 23.0 ppm. **¹⁹F NMR** (282 MHz, CDCl₃) δ -63.1 ppm. **HRMS**: 426.1670 [M+H]⁺, calcd 426.1651.

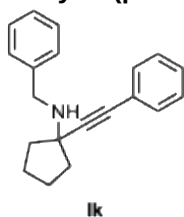
***N*-Benzyl-1-(thiophen-3-ylethynyl)cyclohexan-1-amine (Ij).**



Chemical Formula: $C_{19}H_{21}NS$
Molecular Weight: 295.44

Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), 3-ethynylthiophene (269 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Ij** was obtained (501 mg, 1.70 mmol, 85% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **Rf** = 0.36 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3313, 3085, 2928, 2851, 1449, 1335, 1114, 815, 715, 626 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.43-7.37 (m, 3H), 7.35-7.30 (dd, J = 8.3, 6.9 Hz, 2H), 7.29-7.22 (m, 2H), 7.13 (dd, J = 5.0, 1.2 Hz, 1H), 3.96 (s, 2H), 2.01-1.93 (m, 2H), 1.76-1.62 (m, 5H), 1.53 (td, 11.9, 4.0 Hz, 2H), 1.32-1.29 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.2, 130.3, 128.6, 128.6, 128.0, 127.0, 125.3, 122.8, 93.2, 79.7, 55.5, 48.2, 38.2, 26.1, 23.1 ppm. **HRMS**: 296.1470 [M+H]⁺, calcd 296.1467.

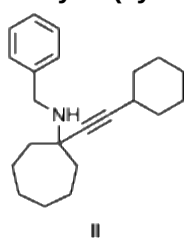
***N*-Benzyl-1-(phenylethynyl)cyclopentan-1-amine (Ik).**



Chemical Formula: $C_{20}H_{21}N$
Molecular Weight: 275.39

Following the **general procedure A** starting from cyclopentanone (177 μ L, 2.0 mmol), cyclohexylacetylene (265 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Ik** was obtained (36 mg, 65.4 μ mol, 7% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **Rf** = 0.52 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2958, 2867, 1597, 1489, 1452, 1196, 1069, 754, 691 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.47-7.43 (m, 2H), 7.41-7.38 (m, 2H), 7.36-7.29 (m, 5H), 7.27-7.23 (m, 1H), 3.96 (s, 2H), 2.11-2.01 (m, 2H), 1.92-1.79 ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.1, 131.8, 128.6, 128.5, 128.4, 127.9, 127.0, 123.8, 94.6, 83.1, 61.4, 50.0, 40.9, 23.9 ppm. **HRMS**: 276.1734 [M+H]⁺, calcd 276.1747.

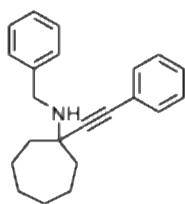
***N*-Benzyl-1-(cyclohexylethynyl)cycloheptan-1-amine (II).**



Chemical Formula: $C_{22}H_{31}N$
Molecular Weight: 309.50

Cycloheptanone (117 μ L, 1.0 mmol), benzylamine (109 μ L, 1 mmol), dry DCM (0.5 mL) and molecular sieves 4 Å (72 mg) were successively added to a round bottom flask and stirred at room temperature. After completion, the mixture was filtrated over Celite and dried with MgSO₄. The filtrate was concentrated under reduced pressure and dry THF was added to the crude product. BF₃·OEt₂ (209 μ L, 2 mmol) was added to the solution of imine (0.1 M) and cooled down to -78 °C for 10 min. In another round bottom flask, *n*-BuLi (1.8 mL, 3.2 mmol, 1.6 M in hexane) was added to a solution of cyclohexylacetylene (331 μ L, 3 mmol) in dry THF (0.5 M) at -78 °C. The solution of lithium acetylide is then added to the solution of activated imine and after 30 min, the mixture is progressively heated to room temperature for 2 h. The reaction mixture is then quenched with NH₄Cl (20 mL) and THF was removed under reduced pressure. The organic phase is extracted with DCM (3 $\times$ 20 mL) and then concentrated under reduced pressure. The title compound **II** was obtained (61.7 mg, 0.20 mmol, 20% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **Rf** = 0.60 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2924, 2851, 1708, 1495, 1447, 1360, 1203, 1071, 1028, 728, 697 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.38-7.35 (m, 2H), 7.33-7.29 (m, 2H), 7.25-7.22 (m, 1H), 3.86 (s, 2H), 2.51-2.44 (m, 1H), 1.91-1.78 (m, 5H), 1.77-1.70 (m, 2H), 1.70-1.60 (m, 9H), 1.58-1.44 (m, 6H), 1.40-1.33 (m, 2H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.5, 128.7, 128.5, 126.9, 88.3, 84.9, 58.1, 48.7, 41.2, 33.3, 29.1, 28.2, 26.2, 24.9, 22.8 ppm. **HRMS**: 310.2521 [M+H]⁺, calcd 310.2529.

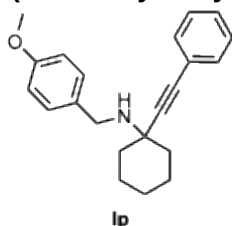
***N*-Benzyl-1-(phenylethynyl)cycloheptan-1-amine (Im).**



Im
Chemical Formula: C₂₂H₂₅N
Molecular Weight: 303.45

Following de **General Procedure A** starting from cycloheptanone (235 μ L, 2.0 mmol), cyclohexylacetylene (265 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Im** was obtained (248.2 mg, 0.82 mmol, 67% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.56 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2922, 2853, 1597, 1489, 1453, 1287, 1028, 754, 691 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.48-7.44 (m, 2H), 7.42-7.38 (m, 2H), 7.35-7.29 (m, 5H), 7.27-7.22 (m, 1H), 3.96 (s, 2H), 2.07-1.99 (m, 2H), 1.841.56 (m, 10H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 141.3, 131.8, 128.6, 128.6, 128.4, 127.9, 127.0, 123.9, 94.9, 83.9, 58.5, 49.8, 40.9, 28.4, 22.8 ppm. **HRMS**: 304.2046 [M+H]⁺, calcd 304.2060.

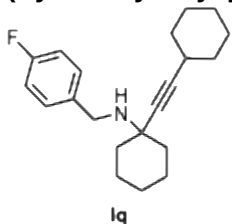
***N*-(4-Methoxybenzyl)-1-(phenylethynyl)cyclohexan-1-amine (Ip).**



Ip
Chemical Formula: C₂₂H₂₅NO
Molecular Weight: 319.45

Following de **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), cyclohexylacetylene (265 μ L, 2.4 mmol), Cu^I-USY (72 mg) and 4-methoxybenzylamine (261 μ L, 2.0 mmol), the title compound **Ip** was obtained (493.4 mg, 1.5 mmol, 77% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.33 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2996, 2929, 2852, 2834, 1611, 1598, 1585, 1510, 1442, 1172, 1034, 822 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.48-7.45 (m, 2H), 7.34-7.29 (m, 5H), 6.88-6.84 (m, 2H), 3.92 (s, 2H), 3.80 (s, 3H), 2.01-1.93 (m, 2H), 1.77-1.62 (m, 5H), 1.52 (ddd, *J* = 12.6, 10.9, 4.4 Hz, 2H), 1.34-1.21 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 158.7, 133.4, 131.8, 129.8, 128.4, 127.9, 123.9, 114.0, 93.9, 84.8, 55.4, 47.6, 38.4, 26.1, 23.2 ppm. **HRMS**: 320.2005 [M+H]⁺, calcd 320.2009.

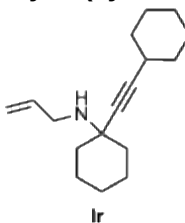
1-(Cyclohexylethynyl)-*N*-(4-fluorobenzyl)cyclohexan-1-amine (Iq).



Iq
Chemical Formula: C₂₁H₂₈FN
Molecular Weight: 313.46

Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), cyclohexylacetylene (265 μ L, 2.4 mmol), Cu^I-USY (72 mg) and 4-fluorobenzylamine (229 μ L, 2.0 mmol), the title compound **Iq** was obtained (124 mg, 0.40 mmol, 19% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.71 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2926, 2852, 1602, 1608, 1446, 1220, 1113, 824, 739 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.38-7.35 (m, 2H), 6.99 (t, *J* = 8.7 Hz, 2H), 3.85 (s, 2H), 2.47 (tt, *J* = 8.6, 3.7, 1H), 1.88-1.13 (m, 20H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 162.0 (d, *J* = 244.3 Hz), 137.2 (d, *J* = 3.1 Hz), 130.2 (d, *J* = 7.9 Hz), 115.3 (d, *J* = 21.2 Hz), 89.3, 83.8, 55.0, 47.4, 38.7, 33.3, 29.1, 26.1, 24.9, 23.2 ppm. **¹⁹F NMR** (282 MHz, CDCl₃) δ -116.5 ppm. **HRMS**: 314.2271 [M+H]⁺, calcd 314.2279.

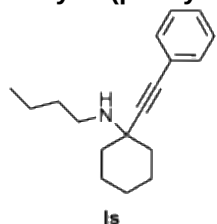
***N*-Allyl-1-(cyclohexylethynyl)cyclohexan-1-amine (Ir).**



Ir
Chemical Formula: C₁₇H₂₇N
Molecular Weight: 245.41

Following the **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), cyclohexylacetylene (265 μ L, 2.4 mmol), Cu^I-USY (72 mg) and benzylamine (218 μ L, 2.0 mmol), the title compound **Ir** was obtained (239 mg, 0.97 mmol, 24% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.45 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2932, 2852, 1643, 1447, 1346, 1282, 1117, 994, 747 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 5.97 (ddt, *J* = 17.2, 10.2, 6.1 Hz, 1H), 5.19 (dq, *J* = 17.1, 1.7 Hz, 1H), 5.06 (dq, *J* = 10.2, 1.4 Hz, 1H), 3.36 (dt, *J* = 6.1, 1.5 Hz, 2H), 2.42 (dt, *J* = 6.6, 4.7 Hz, 1H), 1.82-1.73 (m, 4H), 1.72-1.66 (m, 2H), 1.65-1.58 (m, 4H), 1.51-1.40 (m, 3H), 1.37-1.28 (m, 5H), 1.19-1.11 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 137.7, 115.6, 89.3, 83.4, 54.7, 46.4, 38.7, 33.2, 29.1, 26.1, 26.1, 24.8, 23.3 ppm. **HRMS**: 246.2204 [M+H]⁺, calcd 246.2216.

***N*-Butyl-1-(phenylethynyl)cyclohexan-1-amine (Is).**

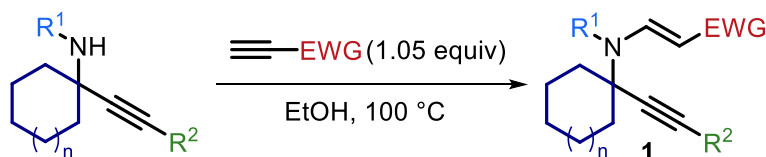


Is
Chemical Formula: C₁₈H₂₅N
Molecular Weight: 255.40

Following de **General Procedure A** starting from cyclohexanone (207 μ L, 2.0 mmol), cyclohexylacetylene (265 μ L, 2.4 mmol), Cu^I-USY (72 mg) and butylamine (199 μ L, 2.0 mmol), the title compound **Is** was obtained (439 mg, 1.72 mmol, 86% yield) as a yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.29 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2928, 2853, 1597, 1488, 1459, 1443, 1289, 1126, 1069, 753, 690 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.44-7.40 (m, 2H), 7.32-7.26 (m, 3H), 2.80 (t, *J* = 7.3 Hz, 2H), 1.98-1.89 (m, 2H), 1.75-1.60 (m, 5H), 1.55-1.36 (m, 6H), 1.29-1.20 (m, 1H), 0.94 (t, *J* = 7.3 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 131.7, 128.3, 127.8, 123.9, 93.9, 84.5, 55.1, 43.1, 38.4, 33.0, 26.1, 23.2, 20.8, 14.2 ppm. **HRMS**: 256.2068 [M+H]⁺, calcd 256.2060.

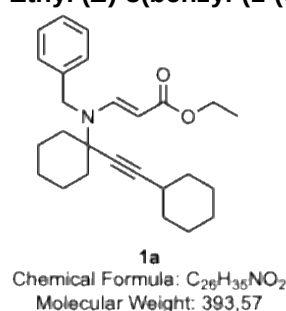
1.4 Preparation of 3-aza-1,5-enynes (**1**)

General procedure B: synthesis of aza-1,5-enynes (**1**)



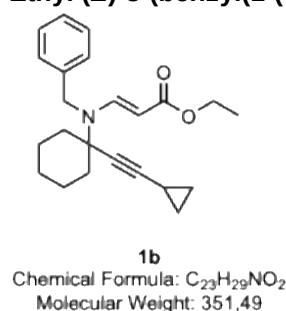
Activated alkyl propiolate (1.05 equiv) was added to a solution of propargylamine (**I**) (1.0 equiv) in EtOH (1 M) in a screw cap tube (3 mL) equipped with a stirring bar. The reaction flask was flushed with argon before sealing. Next, the mixture was placed into a pre-heated aluminium block at 100 °C and stirred until completion. All volatiles were removed under reduced pressure and the crude product was used without further purification unless otherwise stated.

Ethyl (E)-3-(benzyl(1-(cyclohexylethynyl)cyclohexyl)amino)acrylate (**1a**).



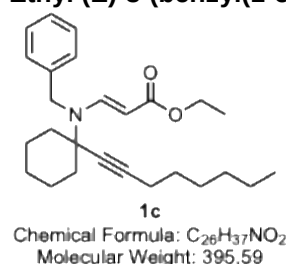
Following **General Procedure B** starting from **1a** (295.5 mg, 1 mmol), the title compound **1a** was obtained in quantitative yield as a pale-yellow solid. **R_f** = 0.46 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2928, 2853, 1686, 1604, 1448, 1328, 1120, 1105, 726 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.17 (d, *J* = 12.9 Hz, 1H), 7.30-7.26 (m, 2H), 7.21-7.17 (m, 3H), 4.51 (s, 2H), 4.47 (d, *J* = 12.9 Hz, 1H), 4.04 (q, *J* = 7.1 Hz, 2H), 2.37 (m, 1H), 1.91 (d, 2H), 1.77-1.59 (m, 10H), 1.53-1.25 (m, 6H), 1.17 (t, *J* = 7.1 Hz, 3H), 1.16-1.05 (m, 1H), 0.86-0.78 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.0, 148.1, 137.6, 128.5, 126.8, 126.4, 93.3, 87.2, 79.9, 62.8, 59.0, 50.2, 37.8, 32.6, 29.1, 26.0, 25.3, 24.8, 24.0, 14.7 ppm. **HRMS**: 394.2748 [M+H]⁺, calcd 394.2741.

Ethyl (E)-3-(benzyl(1-(cyclopropylethynyl)cyclohexyl)amino)acrylate (**1b**).

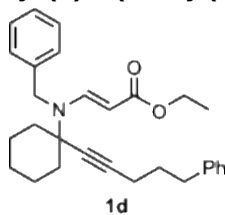


Following **General Procedure B** starting from **1b** (90.7 mg, 0.36 mmol), the title compound **1b** was obtained in quantitative yield as a pale-yellow solid. **R_f** = 0.44 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2932, 1683, 1626, 1443, 1327, 1290, 1138, 973, 793 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.16 (d, *J* = 12.9, 1H), 7.31-7.26 (m, 2H), 7.22-7.15 (m, 3H), 4.52 (s, 2H), 4.49 (d, *J* = 12.9 Hz, 1H), 4.08 (q, *J* = 7.1 Hz, 2H), 1.96-1.90 (m, 2H), 1.75-1.58 (m, 8H), 1.21 (t, *J* = 7.1 Hz, 3H), 1.13-1.05 (m, 1H), 0.74-0.69 (m, 2H), 0.56-0.52 (m, 2H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.0, 148.0, 137.6, 128.5, 128.6, 126.3, 92.0, 87.3, 75.0, 62.7, 59.1, 50.2, 37.7, 25.2, 23.9, 14.7, 8.4, 0.4 ppm. **HRMS**: 374.2091 [M+Na]⁺, calcd 374.2091.

Ethyl (E)-3-(benzyl(1-oct-1-yn-1-yl)cyclohexyl)amino)acrylate (**1c**).



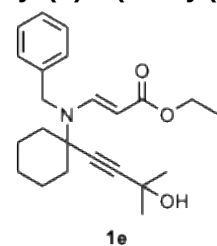
Following **General Procedure B** starting from **1c** (298 mg, 1 mmol), the title compound **1c** was obtained in quantitative yield as a pale-yellow oil. **R_f** = 0.58 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2930, 2857, 1687, 1559, 1328, 1139, 1106, 726 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.18 (d, *J* = 13.0 Hz, 2H), 7.30-7.26 (m, 2H), 7.22-7.17 (m, 3H), 4.55 (s, 2H), 4.51 (d, *J* = 12.9 Hz, 2H), 4.08 (q, *J* = 7.1 Hz, 2H), 2.19 (t, *J* = 7.0 Hz, 2H), 1.99-1.93 (m, 2H), 1.75-1.59 (m, 7H), 1.37-1.24 (m, 6H), 1.21 (t, *J* = 7.1 Hz, 3H), 1.15-1.06 (m, 1H), 0.88 (t, *J* = 7.0 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.0, 148.0, 137.6, 128.5, 126.8, 126.3, 88.9, 87.3, 80.0, 62.7, 59.0, 37.7, 31.4, 28.7, 28.7, 25.2, 23.9, 22.7, 18.8, 14.7, 14.2 ppm. **HRMS**: 418.2696 [M+Na]⁺, calcd 418.2717.

Ethyl (E)-3-(benzyl(1-(5-phenylpent-1-yn-1-yl)cyclohexyl)amino)acrylate (1d).

Chemical Formula: $C_{29}H_{35}NO_2$
Molecular Weight: 429.60

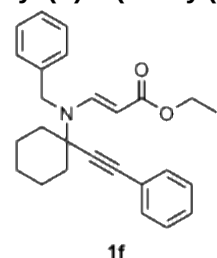
Following **General Procedure B** starting from **Id** (88 mg, 0.26 mmol), the title compound **1d** was obtained in quantitative yield as a pale-yellow oil. **Rf** = 0.48 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2931, 2857, 1686, 1590, 1452, 1328, 1142, 1107, 728, 698 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.20 (d, *J* = 12.9 Hz, 1H), 7.30-7.26 (m, 4H), 7.22-7.17 (m, 4H), 7.16-7.12 (m, 2H), 4.56 (s, 2H), 4.52 (d, *J* = 12.9 Hz, 1H), 2.67 (dd, *J* = 8.4 ; 6.8 Hz, 2H), 2.22 (t, *J* = 7.0 Hz, 2H), 2.02-1.95 (m, 2H), 1.80-1.62 (m, 9H), 1.21 (t, *J* = 7.1 Hz, 3H), 1.16-1.08 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.0, 148.0, 141.6, 137.6, 128.6, 128.6, 128.6, 126.9, 126.3, 126.1, 88.3, 87.5, 80.6, 62.7, 59.1, 50.3, 37.7, 35.0, 30.5, 25.2, 23.9, 18.3, 14.7 ppm.

HRMS: 452.2541 [M+Na]⁺, calcd 452.2560.

Ethyl (E)-3-(benzyl(1-(3-hydroxy-3-methylbut-1-yn-1-yl)cyclohexyl)amino)acrylate (1e).

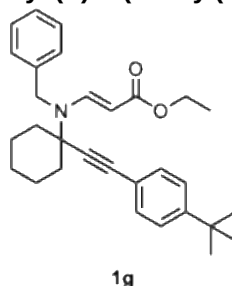
Chemical Formula: $C_{23}H_{31}NO_3$
Molecular Weight: 369.50

Following **General Procedure B** starting from **1e** (50.2 mg, 0.19 mmol), the title compound **1e** was obtained in quantitative yield as a pale-yellow solid. **Rf** = 0.10 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3377, 2979, 2933, 2858, 1669, 1594, 1452, 1329, 1261, 1147, 1106, 794, 728, 695 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.15 (d, *J* = 13.0 Hz, 1H), 7.32-7.28 (m, 2H), 7.23-7.17 (m, 3H), 4.54 (d, *J* = 13.0 Hz, 1H), 4.54 (s, 2H), 4.08 (q, *J* = 7.1 Hz, 2H), 2.03-1.98 (m, 2H), 1.77-1.63 (m, 8H), 1.42 (s, 6H), 1.21 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.0, 147.7, 137.4, 128.6, 127.0, 126.2, 93.1, 87.6, 81.9, 65.2, 62.4, 59.2, 50.3, 37.4, 31.4, 25.2, 23.9, 14.7 ppm. **HRMS**: 392.2174 [M+Na]⁺, calcd 392.2196.

Ethyl (E)-3-(benzyl(1-(phenylethynyl)cyclohexyl)amino)acrylate (1f).

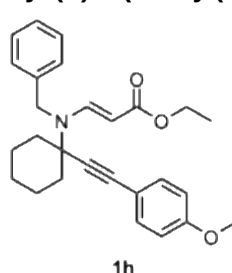
Chemical Formula: $C_{25}H_{29}NO_2$
Molecular Weight: 387.52

Following **General Procedure B** starting from **1f** (290.7 mg, 1 mmol), the title compound **1f** was obtained in quantitative yield as a pale-brown solid. **Rf** = 0.39 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2933, 2855, 1679, 1626, 1451, 1329, 1288, 1138, 654 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.22 (d, *J* = 12.9 Hz, 1H), 7.33-7.26 (m, 7H), 7.25-7.20 (m, 3H), 4.63 (s, 2H), 4.58 (d, *J* = 12.9 Hz, 1H), 4.09 (q, *J* = 7.1 Hz, 2H), 2.16-2.10 (m, 2H), 1.85-1.69 (m, 8H), 1.22 (t, *J* = 7.2, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.9, 147.7, 137.5, 131.7, 128.6, 128.6, 128.4, 126.9, 126.4, 122.6, 89.2, 88.2, 87.9, 63.0, 59.1, 50.5, 37.7, 25.2, 23.9, 14.7 ppm. **HRMS**: 410.2107 [M+Na]⁺, calcd 410.2090.

Ethyl (E)-3-(benzyl(1-((4-(tert-butyl)phenyl)ethynyl)cyclohexyl)amino)acrylate (1g).

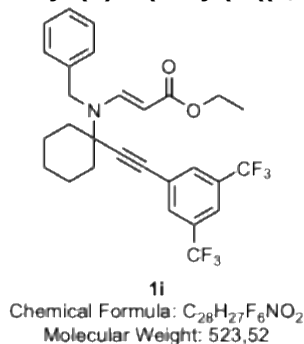
Chemical Formula: $C_{30}H_{37}NO_2$
Molecular Weight: 443.63

Following **General Procedure B** starting from **1g** (236 mg, 0.68 mmol), the title compound **1g** was obtained in quantitative yield as a pale-yellow oil. **Rf** = 0.42 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2934, 2860, 1684, 1626, 1328, 1208, 1106, 730 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.21 (d, *J* = 13.0 Hz, 1H), 7.32-7.28 (m, 4H), 7.27-7.21 (m, 5H), 4.63 (s, 2H), 4.57 (d, *J* = 13.0 Hz, 1H), 4.09 (q, *J* = 7.1 Hz, 2H), 2.13 (m, 2H), 1.82-1.68 (m, 8H), 1.30 (s, 9H), 1.22 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.9, 151.9, 147.7, 137.5, 131.5, 128.6, 126.9, 126.4, 125.4, 119.6, 88.5, 88.3, 87.8, 63.1, 59.1, 50.6, 37.7, 34.9, 31.3, 25.2, 23.9, 14.7 ppm. **HRMS**: 466.2704 [M+Na]⁺, calcd 466.2717.

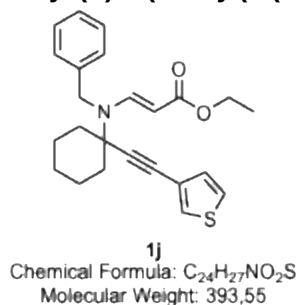
Ethyl (E)-3-(benzyl(1-((4-methoxyphenyl)ethynyl)cyclohexyl)amino)acrylate (1h).

Chemical Formula: $C_{27}H_{31}NO_3$
Molecular Weight: 417.55

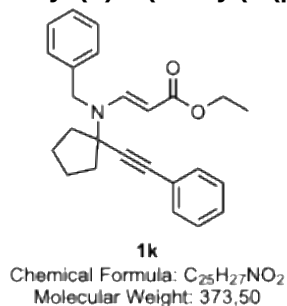
Following **General Procedure B** starting from **1h** (90.5 mg, 0.28 mmol), the title compound **1h** was obtained in quantitative yield as a pale-yellow oil. **Rf** = 0. (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2933, 2857, 1683, 1626, 1509, 1452, 1226, 1106, 731 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.23 (d, *J* = 13.0 Hz, 1H), 7.33-7.28 (m, 2H), 7.26-7.21 (m, 5H), 6.80 (d, *J* = 8.8 Hz, 2H), 4.62 (s, 2H), 4.57 (d, *J* = 12.9 Hz, 1H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.80 (s, 3H), 2.14-2.08 (m, 2H), 1.87-1.71 (m, 7H), 1.22 (t, *J* = 7.2 Hz, 3H), 1.19-1.13 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.9, 159.8, 147.8, 137.5, 133.1, 128.6, 126.0, 126.4, 114.7, 114.0, 88.1, 87.7, 87.6, 63.1, 59.1, 55.4, 50.5, 37.7, 25.2, 23.9, 14.7 ppm. **HRMS**: 418.2366 [M+H]⁺, calcd 418.2377.

Ethyl (E)-3-(benzyl(1-((3,5-bis(trifluoromethyl)phenyl)ethynyl)cyclohexyl)amino)acrylate (1i).

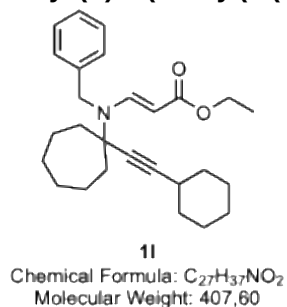
Following **General Procedure B** starting from **1i** (302 mg, 0.70 mmol), the title compound **1i** was obtained in quantitative yield as a pale-yellow oil. **R_f** = 0.42 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2937, 1687, 1600, 1380, 1268, 1110, 987, 682 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.14 (d, *J* = 13.0 Hz, 1H), 7.79-7.75 (bs, 1H), 7.57-7.55 (m, 2H), 7.34-7.29 (bs, 2H), 7.26-7.20 (m, 3H), 4.63 (d, *J* = 13.0 Hz, 1H), 4.62 (s, 2H), 4.10 (q, *J* = 7.1 Hz, 2H), 2.23-2.17 (m, 1H), 1.89-1.68 (m, 7H), 1.12 (t, *J* = 7.1 Hz, 3H), 1.20-1.16 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.8, 147.1, 137.2, 132.0 (q, *J* = 33.8 Hz), 131.6 (d, *J* = 3.2 Hz), 128.7, 127.2, 126.2, 124.8, 124.1, 122.0 (m), 93.1, 88.5, 84.7, 62.6, 59.3, 50.7, 37.4, 25.1, 23.9, 14.7 ppm. **¹⁹F NMR** (282 MHz, CDCl₃) δ -63.1 ppm. **HRMS**: 546.1833 [M+Na]⁺, calcd 546.1838.

Ethyl (E)-3-(benzyl(1-(thiophen-3-ylethynyl)cyclohexyl)amino)acrylate (1j).

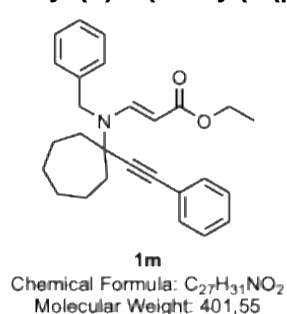
Following **General Procedure B** starting from **1j** (178 mg, 0.60 mmol), the title compound **1j** was obtained in quantitative yield as a pale-brown oil. **R_f** = 0.43 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2976, 2932, 2857, 1683, 1596, 1451, 1327, 1241, 1139, 963, 782, 694 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.20 (d, *J* = 13.0 Hz, 1H), 7.32-7.28 (m, 3H), 7.24-7.20 (m, 4H), 6.98 (dd, *J* = 5.0, 1.2 Hz, 1H), 4.59 (s, 2H), 4.58 (d, *J* = 13.0 Hz, 1H), 4.09 (q, *J* = 7.2 Hz, 2H), 2.15-2.08 (m, 2H), 1.83-1.68 (m, 7H), 1.21 (t, *J* = 7.1 Hz, 3H), 1.19-1.12 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.0, 147.7, 137.4, 129.9, 129.0, 128.6, 126.9, 126.3, 125.5, 121.5, 88.7, 87.7, 83.1, 63.0, 59.1, 50.5, 37.6, 25.2, 23.9, 14.7 ppm. **HRMS**: 394.1836 [M+H]⁺, calcd 394.1835.

Ethyl (E)-3-(benzyl(1-(phenylethynyl)cyclopentyl)amino)acrylate (1k).

Following **General Procedure B** starting from **1k** (34.3 mg, 0.12 mmol), the title compound **1k** was obtained in quantitative yield as an orange oil. **R_f** = 0.42 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2950, 2928, 2861, 1687, 1601, 1490, 1452, 1244, 1145, 1043, 756, 728, 692 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.02 (d, *J* = 13.1 Hz, 1H), 7.36-7.33 (m, 2H), 7.32-7.28 (m, 5H), 7.25-7.21 (m, 3H), 4.62 (d, *J* = 13.1 Hz, 1H), 4.56 (s, 2H), 4.10 (q, *J* = 7.1 Hz, 2H), 2.32-2.26 (m, 2H), 2.11-2.04 (m, 2H), 1.97-1.91 (m, 2H), 1.87-1.81 (m, 2H), 1.22 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.7, 149.5, 137.4, 131.8, 128.7, 128.5, 128.4, 127.1, 126.3, 122.8, 91.2, 88.8, 84.4, 67.9, 59.2, 52.1, 40.0, 22.8, 14.7 ppm. **HRMS**: 396.1931 [M+Na]⁺, calcd 396.1934.

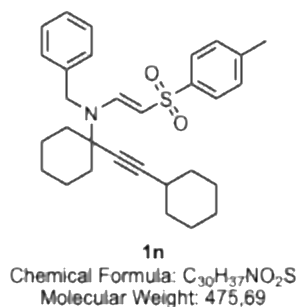
Ethyl (E)-3-(benzyl(1-(cyclohexylethynyl)cycloheptyl)amino)acrylate (1l).

Following **General Procedure B** starting from **1l** (48.8 mg, 0.16 mmol), the title compound **1l** was obtained in quantitative yield as a pale-yellow oil. **R_f** = 0.35 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2927, 2853, 1689, 1601, 1449, 1330, 1241, 1146, 1096, 712 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.20 (d, *J* = 13.0 Hz, 1H), 7.30-7.26 (m, 2H), 7.21-7.18 (m, 3H), 4.53 (s, 2H), 4.46 (d, *J* = 13.0 Hz, 1H), 4.07 (q, *J* = 7.1 Hz, 2H), 2.42-2.35 (m, 1H), 2.05-1.98 (m, 2H), 1.93 (ddd, *J* = 13.5, 10.2, 3.0 Hz, 2H), 1.65-1.58 (m, 10H), 1.57-1.50 (m, 2H), 1.38-1.25 (m, 6H), 1.22 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.9, 148.4, 137.6, 128.5, 126.8, 126.3, 3.0, 87.5, 80.5, 66.1, 59.0, 50.7, 40.9, 32.5, 29.1, 27.2, 26.0, 24.8, 23.4, 14.7 ppm. **HRMS**: 408.2885 [M+H]⁺, calcd 408.2897.

Ethyl (E)-3-(benzyl(1-(phenylethynyl)cycloheptyl)amino)acrylate (1m).

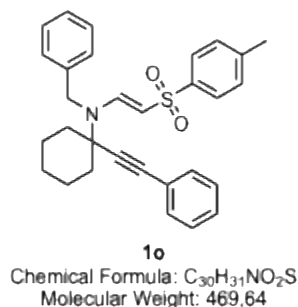
Following **General Procedure B** starting from **1m** (303.5 mg, 1 mmol), the title compound **1m** was obtained in quantitative yield as an orange oil. **R_f** = 0.57 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2931, 2859, 1678, 1595, 1444, 1334, 1292, 1152, 1095, 965, 756, 724, 693 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.21 (d, *J* = 12.9 Hz, 1H), 7.33-7.26 (m, 4H), 7.26-7.20 (m, 6H), 4.61 (s, 2H), 4.55 (d, *J* = 13.0 Hz, 1H), 4.09 (q, *J* = 7.1 Hz, 2H), 2.19 (ddt, *J* = 14.0, 6.9, 1.7 Hz, 2H), 2.06 (ddd, *J* = 13.7, 10.3, 3.0 Hz, 2H), 1.87-1.68 (m, 6H), 1.63-1.55 (m, 2H), 1.22 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.9, 148.1, 137.5, 131.6, 128.6, 128.6, 128.4, 126.9, 126.3, 122.6, 89.9, 88.1, 87.8, 66.3, 59.1, 51.2, 40.8, 27.4, 23.4, 14.7 ppm. **HRMS**: 402.2438 [M+H]⁺, calcd 402.2428.

(E)-N-Benzyl-1-(cyclohexylethynyl)-N-(2-tosylvinyl)cyclohexan-1-amine (1n).



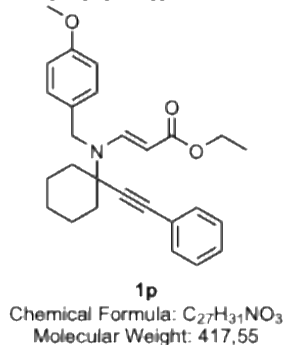
Following **General Procedure B** starting from **1a** (113.3 mg, 0.38 mmol), the title compound **1n** was obtained in quantitative yield as a pale-yellow solid. **R_f** = 0.32 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3080, 3060, 2928, 2853, 1600, 1448, 1326, 1283, 1133, 1082, 876, 733, 707, 660, 539, 559 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.06 (d, *J* = 12.7 Hz, 1H), 7.57 (d, *J* = 8.3 Hz, 2H), 7.27-7.22 (m, 2H), 7.21-7.11 (m, 5H), 4.82 (d, *J* = 12.7 Hz, 1H), 4.51 (s, 2H), 2.42 (td, *J* = 6.1, 5.2, 3.3 Hz, 1H), 2.37 (s, 3H), 1.99-1.93 (m, 2H), 1.78-1.59 (m, 12H), 1.42-1.36 (m, 2H), 1.33-1.29 (m, 2H), 1.17-1.06 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 146.3, 142.5, 142.0, 136.6, 129.4, 128.6, 127.1, 126.3, 126.1, 95.4, 93.8, 79.5, 63.1, 53.6, 50.4, 37.7, 32.6, 29.0, 26.0, 25.2, 23.9, 21.6 ppm. **HRMS**: 476.2607 [M+H]⁺, calcd 476.2682.

(E)-N-Benzyl-1-(phenylethynyl)-N-(2-tosylvinyl)cyclohexan-1-amine (1o).



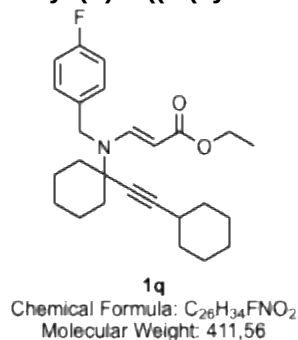
Following **General Procedure B** starting from **1f** (289.4 mg, 1 mmol), the title compound **1o** was obtained (372.5 mg, 7.9 mmol, 79% yield) as a white solid after purification by column chromatography of the crude residue (cyclohexane/EtOAc 98/2 to 94/6). **R_f** = 0.27 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3060, 3029, 2930, 2857, 1598, 1491, 1451, 1327, 1280, 1131, 1080, 874, 691, 655, 556, 536 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.09 (d, *J* = 12.6 Hz, 1H), 7.59 (d, *J* = 8.3 Hz, 2H), 7.36-7.24 (m, 7H), 7.23-7.15 (m, 5H), 4.91 (d, *J* = 12.6 Hz, 1H), 4.60 (s, 2H), 2.37 (s, 3H), 2.19-2.11 (m, 2H), 1.84-1.72 (m, 7H), 1.21-1.19 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 145.9, 142.2, 142.1, 136.5, 131.7, 129.4, 128.7, 128.7, 128.5, 127.2, 126.3, 126.2, 122.3, 96.1, 88.6, 88.6, 63.3, 50.8, 37.6, 25.1, 23.9, 21.6 ppm. **HRMS**: 470.2138 [M+H]⁺, calcd 470.2148.

Ethyl (E)-3-((4-methoxybenzyl)(1-(phenylethynyl)cyclohexyl)amino)acrylate (1p).



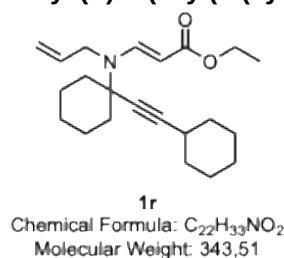
Following **General Procedure B** starting from **1p** (303.5 mg, 1 mmol), the title compound **1p** was obtained in quantitative yield as an orange oil. **R_f** = 0.40 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3059, 2933, 2858, 2836, 1685, 1597, 1328, 1139, 1099, 755, 691 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.20 (d, *J* = 13.0 Hz, 1H), 7.36-7.33 (m, 2H), 7.32-7.28 (m, 3H), 7.18-7.14 (m, 2H), 6.86-6.82 (m, 2H), 4.60 (d, *J* = 13.0 Hz, 1H), 4.57 (s, 2H), 4.10 (q, *J* = 7.1 Hz, 2H), 3.79 (s, 3H), 2.15-2.08 (m, 2H), 1.89-1.63 (m, 7H), 1.22 (t, *J* = 7.1 Hz, 3H), 1.20-1.13 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.0, 158.6, 147.7, 131.7, 129.5, 128.6, 128.4, 127.5, 122.6, 114.1, 89.2, 88.2, 87.8, 63.0, 59.1, 55.4, 50.0, 37.7, 25.2, 23.9, 14.7 ppm. **HRMS**: 440.2193 [M+Na]⁺, calcd 440.2196.

Ethyl (E)-3-((1-(cyclohexylethynyl)cyclohexyl)(4-fluorobenzyl)amino)acrylate (1q).



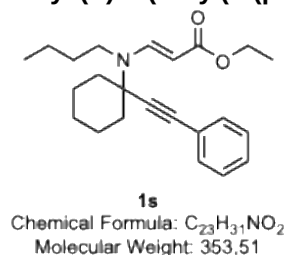
Following **General Procedure B** starting from **1q** (345 mg, 1.10 mmol), the title compound **1q** was obtained in quantitative yield as a pale-yellow solid. **R_f** = 0.46 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2929, 2854, 1683, 1608, 1508, 1328, 1222, 1107, 1093, 732 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.16 (d, *J* = 13.0 Hz, 1H), 7.18-7.13 (m, 2H), 6.97 (t, *J* = 8.7 Hz, 2H), 4.51 (s, 2H), 4.47 (d, *J* = 13.0 Hz, 1H), 4.08 (q, *J* = 7.1 Hz, 2H), 2.44-2.37 (m, 1H), 1.96-1.91 (m, 2H), 1.76-1.57 (m, 12H), 1.42-1.25 (m, 5H), 1.21 (t, *J* = 7.1 Hz, 1H), 1.15-1.06 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 169.9, 161.8 (d, *J* = 244.5 Hz), 141.7, 133.2 (d, *J* = 3.1 Hz), 127.9 (d, *J* = 7.9 Hz), 115.4 (d, *J* = 21.5 Hz), 93.3, 87.5, 79.8, 62.8, 59.1, 49.6, 37.8, 32.6, 29.0, 26.0, 25.2, 24.8, 23.9, 14.7 ppm. **¹⁹F NMR** (282 MHz, CDCl₃) δ -116.5 ppm. **HRMS**: 434.2454 [M+Na]⁺, calcd 434.2466.

Ethyl (E)-3-(allyl(1-(cyclohexylethynyl)cyclohexyl)amino)acrylate (**1r**).



Following **general procedure B** starting from **1r** (128 mg, 0.50 mmol), the title compound **1r** was obtained in quantitative yield as a pale-brown oil. **Rf** = 0.50 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2928, 2854, 1729, 1688, 1598, 1447, 1238, 1141, 966, 790 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.07 (d, *J* = 13.0 Hz, 1H), 5.74 (ddt, *J* = 17.2, 10.2, 5.0 Hz, 1H), 5.16-5.13 (m, 2H), 4.60 (d, *J* = 13.0 Hz, 1H), 4.11 (q, *J* = 7.1 Hz, 2H), 3.91 (dt, *J* = 5.0, 1.9 Hz, 2H), 2.45 (dt, *J* = 8.9, 4.8 Hz, 1H), 1.92-1.87 (m, 2H), 1.82-1.75 (m, 2H), 1.74-1.62 (m, 8H), 1.62-1.54 (m, 2H), 1.51-1.43 (m, 3H), 1.35-1.31 (m, 2H), 1.24 (t, *J* = 7.1 Hz, 3H), 1.15-1.04 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.1, 147.6, 133.4, 116.6, 99.0, 86.0, 79.8, 62.3, 59.0, 48.6, 37.6, 32.8, 29.1, 26.0, 25.2, 24.8, 23.9, 14.8 ppm. **HRMS**: 344.2603 [M+H]⁺, calcd 344.2584.

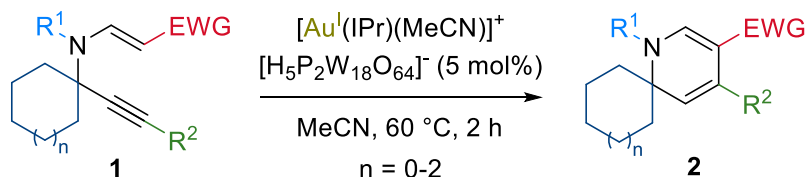
Ethyl (E)-3-(butyl(1-(phenylethynyl)cyclohexyl)amino)acrylate (**1s**).



Following **general procedure B** starting from **1s** (303.5 mg, 1 mmol), the title compound **1s** was obtained in quantitative yield as an orange oil. **Rf** = 0.45 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3057, 2933, 2860, 1686, 1591, 1330, 1236, 1123, 1075, 755, 691 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 8.02 (d, *J* = 13.0 Hz, 1H), 7.46-7.41 (m, 2H), 7.34-7.30 (m, 3H), 4.65 (d, *J* = 13.0 Hz, 1H), 4.15 (q, *J* = 7.1 Hz, 2H), 3.33-3.27 (m, 2H), 2.11-2.02 (m, 2H), 1.83-1.75 (m, 4H), 1.75-1.60 (m, 5H), 1.38-1.30 (m, 2H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.23-1.14 (m, 1H), 0.94 (t, *J* = 7.4 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 170.2, 147.2, 131.7, 128.6, 128.5, 122.8, 89.3, 87.8, 85.3, 62.3, 59.0, 46.8, 37.6, 29.8, 25.2, 23.9, 20.6, 14.9, 14.0 ppm. **HRMS**: 354.2439 [M+H]⁺, calcd 354.2428.

1.5 Synthesis of 1,2-dihydropyridines (**2**)

General procedure C: synthesis of 1,2-dihydropyridines **2** from **1**

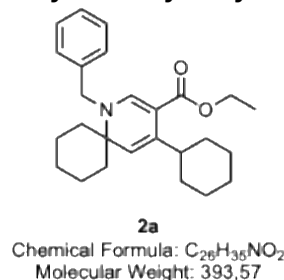


[Au^I(IPr)(MeCN)][H₅P₂W₁₈O₆₂] (5 mol %) was added to a solution of enyne (**1**) in MeCN (1 M) in a screw cap tube (3 mL) equipped with a stirring bar. The reaction flask was flushed with argon before sealing. The mixture was placed into a pre-heated aluminum block at 60 °C and stirred until completion. The catalyst was filtered off through a short pad of Celite and the residue was washed with Et₂O (3 × 20 mL). The filtrate was concentrated under reduced pressure and the crude product was purified by column chromatography over silica gel (cyclohexane/EtOAc) to afford the product (**2**).

Recycling procedure of gold(I)-polyoxometallate complex catalysts

After completion, the reaction mixture is diluted in Et₂O (2 mL) and after centrifugation and decantation, the supernatant was taken out. This operation was repeated 3 times. The decanted catalyst was dried under reduced pressure and directly engaged for the next cycle. This procedure was repeated up to 3 consecutive times.

Ethyl 1-benzyl-4-cyclohexyl-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (**2a**).



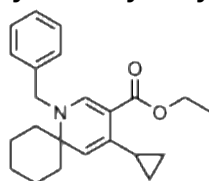
Following **General Procedure C** starting from **1a** (50 mg, 0.13 mmol), the title compound **2a** was obtained (42.1 mg, 1.07 mmol, 82% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **Rf** = 0.60 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2925, 2851, 1674, 1553, 1450, 1287, 1218, 1134, 1071, 907, 750 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.50 (s, 1H), 7.34-7.29 (m, 2H), 7.25-7.19 (m, 3H) 5.00 (d, *J* = 1.2 Hz, 1H), 4.49 (s, 2H), 4.13 (q, *J* = 7.1 Hz, 2H), 3.04 (m, 1H), 1.91-1.04 (m, 19H), 1.26 (t, *J* = 7.1 Hz, 3H), 0.92-0.78 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 167.0, 150.5, 140.1, 139.7, 128.8, 127.4, 126.6, 110.8, 99.5, 59.9, 59.0, 53.4, 38.9, 34.7, 33.8, 27.3, 26.9, 25.7, 21.7, 14.7 ppm. **HRMS**: 393.2657 [M]⁺, calcd 393.2662.

2a was also obtained at gram-scale (665 mg, 1.7 mmol, 67%) from **1a** (1 g, 2.54 mmol)

2a can be obtained via one-pot process from **1a**. Activated alkyl propiolate (1.05 equiv) was added to a solution of propargylamine **1a** (1.0 equiv) in EtOH (1 M) in a screw cap tube (3 mL) equipped with a stirring bar. The reaction flask was flushed with argon before sealing. Next, the mixture was placed into a pre-heated aluminium block at 100 °C and stirred until completion. The temperature is reduced to 60 °C and [Au^I(IPr)(MeCN)][H₅P₂W₁₈O₆₂] (5 mol %) was then added to the reaction mixture. The reaction flask was flushed with argon before sealing and stirred until completion. The catalyst was filtered off through a short pad of Celite and the residue was washed with Et₂O (3 × 20 mL). The filtrate was concentrated under reduced pressure and the crude product was purified by column chromatography over silica gel (cyclohexane/EtOAc 8/2) to afford the product **2a** (28.5 mg, 74.1 μmol, 57% yield).

Following the **Recycling procedure**, **2a** (50 mg, 0.13 mmol) with 5 mol % of catalyst [Au^I(IPr)(MeCN)][H₅P₂W₁₈O₆₂] (25.8 mg) was obtained with 66% yield (33 mg) after RUN 1 (2 h), 63% yield (31.5 mg) after RUN 2 (2 h), 42% yield (21 mg) after RUN 3 (5 h) and 10% yield (5 mg) after RUN 4 (30 h). [Au^I(IPr)(MeCN)][H₅P₂W₁₈O₆₂] was recovered up to 95% (RUN 1, m_{cat} = 22.4 mg), 82% (RUN 2, m_{cat} = 21.0 mg) and 77% (RUN 3, m_{cat} = 18.3 mg). It was not recovered after RUN 4 since it was not effective anymore.

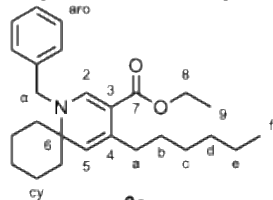
Ethyl 1-benzyl-4-cyclopropyl-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (**2b**).



2b
Chemical Formula: C₂₃H₂₉NO₂
Molecular Weight: 351.49

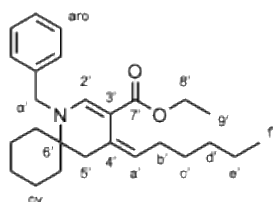
Following **General Procedure C** starting from **1b** (45.7 mg, 0.13 mmol), the title compound **2b** was obtained (32.4 mg, 92.3 μmol, 71% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.52 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2928, 1677, 1626, 1554, 1291, 1207, 1130, 1070, 654 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.50 (s, 1H), 7.36-7.32 (m, 2H), 7.29-7.21 (m, 3H), 4.90 (m, 1H), 4.50 (s, 2H), 4.18 (q, J = 7.1 Hz, 2H), 2.16-2.10 (m, 1H), 1.86-1.80 (m, 2H), 1.65-1.59 (m, 1H), 1.52-1.38 (m, 6H), 1.28 (t, J = 7.1 Hz, 3H), 1.10-1.05 (m, 1H), 0.77-0.72 (m, 2H), 0.51-0.47 (td, J = 6.0, 4.0, 2H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 167.1, 149.8, 139.4, 135.9, 128.8, 127.4, 126.6, 110.2, 100.2, 60.0, 59.0, 53.3, 34.8, 25.5, 21.5, 14.7, 14.3, 7.0 ppm. **HRMS**: 374.2085 [M+Na]⁺, calcd 374.2091.

Ethyl 1-benzyl-4-hexyl-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (**2c**) and Ethyl (Z)-1-benzyl-4-hexylidene-1-azaspiro[5.5]undec-2-ene-3-carboxylate (**2c'**).



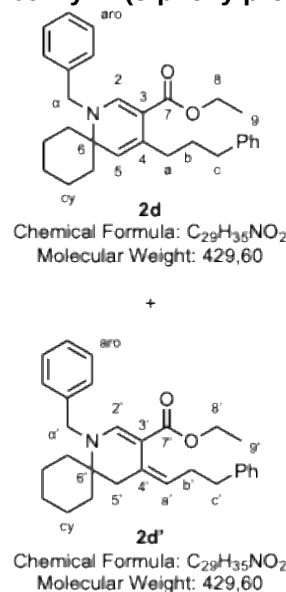
2c
Chemical Formula: C₂₉H₃₇NO₂
Molecular Weight: 395.59

Following **General Procedure C** starting from **1c** (50.0 mg, 0.13 mmol), the title compound **2c** was obtained (12 mg, 30.3 μmol, 23% yield, **2c:2c'** 40:60) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.60 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2925, 2854, 1679, 1581, 1452, 1363, 1162, 1069, 730 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.49 (s, 1H, H₂), 7.42 (s, 1H, H₂'), 7.37-7.29 (m, 3H x2, H_{aro}), 7.28-7.18 (m, 2H x2, H_{aro}), 6.32 (t, J = 7.3 Hz, 1H, H_a), 4.98 (s, 1H, H₅), 4.49 (s, 2H, H_a), 4.46 (s, 2H, H_a'), 4.14 (q, J = 7.1 Hz, 2H x2, H₇ and H₇'), 2.55 (s, 2H, H₅'), 2.50 (t, J = 7.5 Hz, 2H, H_a), 2.17 (q, J = 7.3 Hz, 2H, H_b'), 1.87-1.78 (m, 2H, H_{cy}), 1.71-1.29 (m, 15H x2, H_{cy} and H_{hex}), 1.26 (t, J = 7.1 Hz, 3H x2, H₈ and H₈'), 1.16-1.08 (m, 1H x2, H_{cy}), 0.90-0.86 (m, 3H x2, H_r and H_r') ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 167.55, 166.99, 150.43, 147.80, 139.84, 139.66, 134.67, 128.79, 127.41, 127.37, 126.64, 126.56, 125.00, 123.96, 115.07, 113.75, 99.30, 98.36, 60.21, 59.10, 59.00, 58.96, 53.36, 53.24, 34.92, 34.41, 32.95, 32.25, 32.08, 31.92, 30.24, 29.89, 29.28, 28.11, 25.70, 25.64, 22.95, 22.84, 22.74, 21.66, 14.75, 14.72, 14.30, 14.25 ppm. **HRMS**: 396.2894 [M+H]⁺, calcd 396.2897.



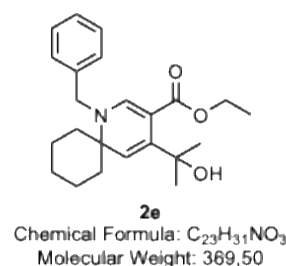
2c'
Chemical Formula: C₂₈H₃₇NO₂
Molecular Weight: 395.59

Ethyl 1-benzyl-4-(3-phenylpropyl)-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2d) and Ethyl (Z)-1-benzyl-4-(3-phenylpropylidene)-1-azaspiro[5.5]undec-2-ene-3-carboxylate (2d').



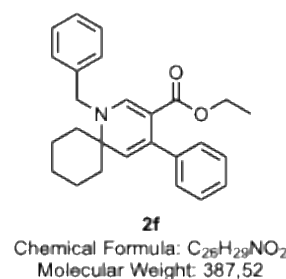
Following **General Procedure C** starting from **1d** (71.2 mg, 0.17 mmol), the title compound **2d** was obtained (16.8 mg, 39.1 μ mol, 16% yield, **2d:2d'** 43:57) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.54 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3026, 2928, 2856, 1679, 1581, 1557, 1452, 1288, 1222, 1131, 1067, 1028, 729, 697 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.51 (s, 1H, H₂), 7.44 (s, 1H, H₂), 7.36-7.26 (m, 5H x 2, H_{aro}), 7.25-7.15 (m, 5H x 2, H_{aro}), 6.40 (t, *J* = 7.2 Hz, 1H, H_{a'}), 4.98 (s, 1H), 4.50 (s, 2H), 4.45 (s, 2H), 4.14 (q, *J* = 7.1 Hz, 2H x 2, H₇ and H_{7'}), 2.77-2.73 (m, 2H, H_c), 2.69-2.64 (m, 2H, H_c), 2.62-2.57 (m, 2H, H_a), 2.52-2.46 (m, 2H, H_b), 2.51 (s, 2H, H₅), 1.86-1.82 (m, 2H, H_{cy}), 1.79 (td, *J* = 7.3, 7.0, 3.4 Hz, 2H, H_b), 1.65-1.61 (m, 2H, H_{cy}), 1.58-1.30 (m, 7H x 2, H_{cy}), 1.06 (dt, *J* = 12.9, 3.8 Hz, 1H x 2, H_{cy}) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 167.5, 166.9, 150.6, 148.0, 143.3, 142.8, 139.7, 139.6, 134.2, 128.8, 128.8, 128.7, 128.7, 128.4, 128.3, 127.5, 127.4, 126.6, 126.5, 125.9, 125.8, 125.6, 122.6, 114.1, 99.1, 98.2, 60.3, 59.2, 59.0, 59.0, 53.4, 53.3, 37.0, 35.9, 34.9, 34.1, 32.9, 32.2, 31.8, 30.7, 25.6, 25.6, 22.7, 21.6, 14.8, 14.8 ppm. **HRMS**: 430.2731 [M+H]⁺, calcd 430.274.

Ethyl 1-benzyl-4-(2-hydroxypropan-2-yl)-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2e).



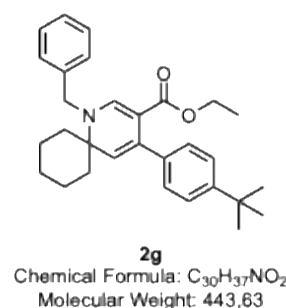
Following **General Procedure C** starting from **1e** (36.3 mg, 98.2 μ mol), the title compound **2e** was obtained (4.5 mg, 12.2 μ mol, 12% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.17 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3312, 2977, 2929, 2856, 1646, 1628, 1556, 1411, 1347, 1287, 1223, 1167, 1135, 1074, 1054, 715 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.67 (s, 1H), 7.38-7.27 (m, 3H), 7.24-7.17 (m, 2H), 7.11 (s, 1H), 5.27 (s, 1H), 4.52 (s, 2H), 4.14 (q, *J* = 7.1 Hz, 2H), 1.92-1.82 (m, 2H), 1.70-1.47 (m, 8H), 1.45 (s, 6H), 1.24 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 168.5, 152.8, 139.4, 138.7, 128.8, 127.6, 126.5, 112.2, 97.6, 70.4, 59.9, 59.8, 53.4, 34.6, 29.5, 25.4, 21.6, 14.5 ppm. **HRMS**: 370.2370 [M+H]⁺, calcd 370.2377.

Ethyl 1-benzyl-4-phenyl-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2f).

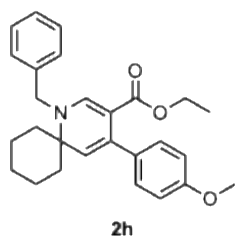


Following **General Procedure C** starting from **1f** (50.4 mg, 0.13 mmol), the title compound **2f** was obtained (38.4 mg, 99.1 μ mol, 76% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.39 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2929, 1676, 1615, 1550, 1451, 1291, 1207, 1138, 1070, 907, 654 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.63 (s, 1H), 7.35-7.23 (m, 10H), 5.10 (s, 1H), 4.57 (s, 2H), 3.96 (q, *J* = 7.1 Hz, 2H), 2.00-1.96 (m, 2H), 1.68-1.63 (m, 1H), 1.57-1.52 (m, 4H), 1.49-1.43 (m, 2H), 1.15-1.05 (m, 1H), 0.95 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.7, 150.3, 142.0, 139.3, 136.1, 128.9, 127.9, 127.6, 127.5, 126.7, 126.6, 116.5, 100.1, 60.8, 59.1, 53.6, 34.4, 25.6, 21.8, 14.2 ppm. **HRMS**: 388.2295 [M+H]⁺, calcd 388.2271.

Ethyl 1-benzyl-4-(4-(tert-butyl)phenyl)-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2g).

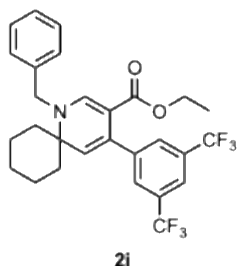


Following **General Procedure C** starting from **1g** (62.5 mg, 0.14 mmol), the title compound **2g** was obtained (50.9 mg, 0.11 mmol, 82% yield) as a pale-yellow solid after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.43 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2933, 2852, 1676, 1617, 1551, 1293, 1221, 1133, 1066, 919, 729 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.63 (s, 1H), 7.34-7.30 (m, 4H), 7.27-7.24 (m, 3H), 7.22-7.1 (m, 2H), 5.10 (s, 1H), 4.57 (s, 2H), 3.96 (q, *J* = 7.1 Hz, 2H), 1.99-1.93 (m, 2H), 1.68-1.62 (m, 1H), 1.59-1.50 (m, 4H), 1.45 (td, *J* = 12.2, 4.9 Hz, 2H), 1.33 (s, 9H), 1.15-1.04 (m, 1H), 0.92 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.7, 150.2, 149.4, 139.2, 138.8, 135.7, 128.7, 127.4, 127.4, 126.5, 124.3, 116.1, 100.0, 60.7, 59.9, 34.5, 34.2, 31.5, 25.5, 21.7, 13.9 ppm. **HRMS**: 444.2886 [M+H]⁺, calcd 444.2897.

Ethyl 1-benzyl-4-(4-methoxyphenyl)-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2h).

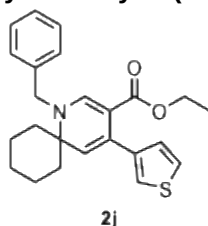
2h
Chemical Formula: C₂₇H₃₁NO₃
Molecular Weight: 417.55

Following **General Procedure C** starting from **1h** (50.0 mg, 0.12 mmol), the title compound **2h** was obtained (32.6 mg, 78.0 μmol, 65% yield) as a pale-yellow solid after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.32 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2930, 2855, 1676, 1610, 1551, 1502, 1290, 1206, 1173, 1029, 728 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.62 (s, 1H), 7.35-7.31 (m, 2H), 7.28-7.24 (m, 3H), 7.22-7.18 (m, 2H), 6.86-6.83 (m, 2H), 5.05 (s, 1H), 4.56 (s, 2H), 3.99 (q, *J* = 7.1 Hz, 2H), 3.82 (s, 3H), 1.99-1.94 (m, 2H), 1.68-1.62 (m, 1H), 1.56-1.51 (m, 4H), 1.49-1.41 (m, 2H), 1.15-1.06 (m, 1H), 1.02 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.7, 156.7, 150.3, 139.2, 135.5, 134.4, 129.0, 128.9, 127.6, 126.7, 115.8, 113.0, 100.0, 60.8, 59.1, 55.4, 53.9, 34.4, 25.6, 21.8, 14.4 ppm. **HRMS**: 418.2365 [M+H]⁺, calcd 418.2377.

Ethyl 1-benzyl-4-(3,5-bis(trifluoromethyl)phenyl)-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2i).

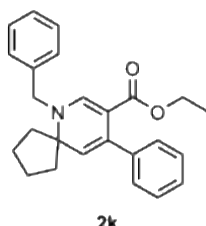
2i
Chemical Formula: C₂₈H₂₇F₆NO₂
Molecular Weight: 523.52

Following **General Procedure C** starting from **1i** (67.3 mg, 0.13 mmol) heated at 80 °C, the title compound **2i** was obtained (33.4 mg, 63.8 μmol, 50% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.46 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2980, 2934, 2859, 1679, 1612, 1553, 1364, 1275, 1209, 1171, 1128, 907, 724 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.81-7.76 (bs, 1H), 7.71 (s, 1H), 7.70-7.68 (bs, 2H), 7.42-7.30 (m, 4H), 5.11 (s, 1H), 4.61 (s, 2H), 3.96 (q, *J* = 7.1 Hz, 2H), 2.08-1.95 (m, 2H), 1.78-1.67 (m, 1H), 1.66-1.50 (m, 6H), 1.20-1.07 (m, 1H), 0.94 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.1, 151.1, 144.2, 138.7, 134.3, 130.7 (q, *J* = 33.1 Hz), 129.0, 128.2, 127.8, 126.8, 124.8, 122.6, 120.4 (m), 117.8, 98.9, 61.2, 59.3, 53.8, 34.4, 25.4, 21.7, 14.0 ppm. **¹⁹F NMR** (282 MHz, CDCl₃) δ -62.6 ppm. **HRMS**: 524.2005 [M+H]⁺, calcd 524.2019.

Ethyl 1-benzyl-4-(thiophen-3-yl)-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2j).

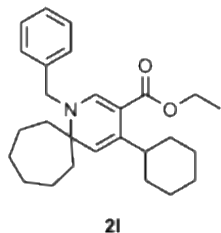
2j
Chemical Formula: C₂₄H₂₇NO₂S
Molecular Weight: 393.55

Following **General Procedure C** starting from **1j** (51.2 mg, 0.13 mmol), the title compound **2j** was obtained (39.4 mg, 0.10 mmol, 77% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.43 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2927, 2854, 1675, 1612, 1551, 1495, 1451, 1361, 1289, 1210, 1136, 1070, 732, 697 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.61 (s, 1H), 7.35-7.32 (m, 2H), 7.28-7.24 (m, 3H), 7.21 (dd, *J* = 4.9, 3.0 Hz, 1H), 7.15 (dd, *J* = 3.0, 1.3 Hz, 1H), 7.01 (dd, *J* = 5.0, 1.3 Hz, 1H), 5.20 (s, 1H), 4.56 (s, 2H), 4.02 (q, *J* = 7.1 Hz, 2H), 1.98-1.95 (m, 2H), 1.69-1.62 (m, 2H), 1.58-1.52 (m, 6H), 1.06 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.6, 150.2, 142.5, 139.2, 130.8, 128.9, 128.7, 127.6, 126.7, 123.7, 121.0, 116.0, 99.9, 60.6, 59.2, 53.7, 34.3, 25.8, 21.8, 14.3 ppm. **HRMS**: 394.1824 [M+H]⁺, calcd 394.1835.

Ethyl 1-benzyl-4-phenyl-1-azaspiro[4.5]dodeca-2,4-diene-3-carboxylate (2k).

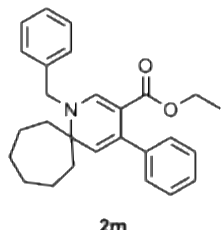
2k
Chemical Formula: C₂₅H₂₇NO₂
Molecular Weight: 373.50

Following **General Procedure C** starting from **1k** (44.8 mg, 0.12 mmol), the title compound **2k** was obtained (19.3 mg, 51.6 μmol, 43% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.42 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2955, 2901, 2872, 1679, 1613, 1549, 1442, 1288, 1219, 1145, 1084, 1032, 754, 730, 697 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.56 (s, 1H), 7.39-7.33 (m, 2H), 7.32-7.24 (m, 8H), 4.90 (s, 1H), 4.52 (s, 2H), 3.93 (q, *J* = 7.1 Hz, 2H), 1.94-1.80 (m, 4H), 1.73-1.63 (m, 4H), 0.93 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.6, 150.1, 141.8, 138.9, 134.4, 129.0, 127.8, 127.7, 127.5, 126.6, 126.5, 121.0, 99.4, 68.3, 59.0, 53.9, 39.5, 23.2, 13.2 ppm. **HRMS**: 374.2091 [M+H]⁺, calcd 374.2115.

Ethyl 1-benzyl-4-cyclohexyl-1-azaspiro[5.6]dodeca-2,4-diene-3-carboxylate (2l).**2l**

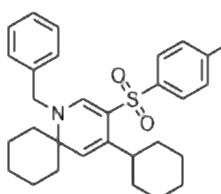
Chemical Formula: $C_{27}H_{37}NO_2$
Molecular Weight: 407.60

Following **General Procedure C** starting from **1l** (52.9 mg, 0.13 mmol), the title compound **2l** was obtained (19.8 mg, 48.6 μ mol, 37% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.60 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2921, 2849, 1677, 1630, 1555, 1450, 1284, 1217, 1140, 1065, 729 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.40 (s, 1H), 7.35-7.31 (m, 2H), 7.28-7.24 (m, 1H), 7.22-7.19 (m, 2H), 4.84 (s, 1H), 4.51 (s, 2H), 4.10 (q, *J* = 7.1 Hz, 2H), 3.03 (ttd, *J* = 11.6, 3.0, 1.1 Hz, 1H), 1.83 (q, *J* = 5.2, 5.0 Hz, 4H), 1.80-1.74 (m, 2H), 1.74-1.68 (m, 1H), 1.55-1.45 (m, 9H), 1.44-1.34 (m, 3H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.15-1.06 (m, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.9, 149.5, 139.4, 139.4, 128.9, 127.5, 126.8, 114.4, 99.2, 62.9, 58.9, 53.5, 39.4, 38.6, 33.8, 29.7, 27.3, 26.9, 22.5, 14.7 ppm. **HRMS**: 408.2887 [M+H]⁺, calcd 408.2897.

Ethyl 1-benzyl-4-phenyl-1-azaspiro[5.6]dodeca-2,4-diene-3-carboxylate (2m).**2m**

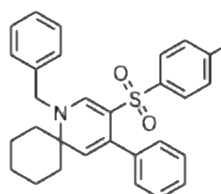
Chemical Formula: $C_{27}H_{31}NO_2$
Molecular Weight: 401.55

Following **General Procedure C** starting from **1m** (53.8 mg, 0.13 mmol), the title compound **2m** was obtained (30.5 mg, 74.1 μ mol, 57% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.57 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2977, 2924, 2853, 1677, 1616, 1552, 1452, 1287, 1212, 1148, 1071, 757, 725, 697 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.52 (s, 1H), 7.38-7.33 (m, 2H), 7.31-7.24 (m, 8H), 4.97 (s, 1H), 4.59 (s, 2H), 3.94 (q, *J* = 7.1 Hz, 2H), 2.04-1.96 (m, 2H), 1.92-1.85 (m, 2H), 1.62-1.50 (m, 8H), 0.94 (t, *J* = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.6, 149.5, 142.0, 139.1, 135.6, 129.0, 127.9, 127.7, 127.5, 126.9, 126.7, 120.0, 99.9, 63.8, 59.1, 53.7, 39.0, 29.6, 22.4, 14.2 ppm. **HRMS**: 402.2423 [M+H]⁺, calcd 402.2428.

1-Benzyl-4-cyclohexyl-3-tosyl-1-azaspiro[5.5]undeca-2,4-diene (2n).**2n**

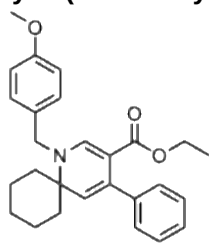
Chemical Formula: $C_{30}H_{37}NO_2S$
Molecular Weight: 475.69

Following **General Procedure C** starting from **1n** (64 mg, 0.14 mmol), the title compound **2n** was obtained (26.6 mg, 55.9 μ mol, 42% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.38 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2922, 2850, 1624, 1554, 1449, 1281, 1129, 1089, 908, 729, 675, 659, 537 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.72-7.68 (m, 2H), 7.49 (s, 1H), 7.38-7.32 (m, 2H), 7.30-7.20 (m, 5H), 5.02 (s, 1H), 4.52 (s, 2H), 2.48-2.42 (m, 1H), 2.40 (s, 3H), 1.86-1.82 (m, 2H), 1.64-1.53 (m, 6H), 1.52-1.39 (m, 5H), 1.12-0.93 (m, 6H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 148.7, 142.3, 142.0, 139.1, 137.5, 129.4, 128.9, 127.7, 126.8, 126.6, 112.4, 107.3, 60.4, 53.3, 37.9, 35.1, 34.4, 27.1, 26.4, 25.5, 21.6, 21.5 ppm. **HRMS**: 498.2454 [M+Na]⁺, calcd 498.2437.

1-Benzyl-4-phenyl-3-tosyl-1-azaspiro[5.5]undeca-2,4-diene (2o).**2o**

Chemical Formula: $C_{30}H_{31}NO_2S$
Molecular Weight: 469.64

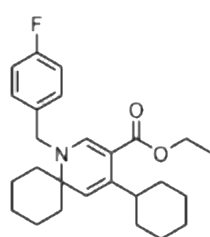
Following **General Procedure C** starting from **1o** (61.0 mg, 0.13 mmol), the title compound **2o** was obtained (38.6 mg, 82.2 μ mol, 63% yield) as a white solid after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **R_f** = 0.31 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 3059, 3027, 2935, 2858, 1619, 1597, 1547, 1452, 1417, 1291, 1242, 1163, 1130, 1088, 907, 728, 711, 695, 656, 577, 529 cm^{-1} . **¹H NMR** (500 MHz, CDCl₃) δ 7.58 (s, 1H), 7.41-7.37 (m, 2H), 7.34-7.28 (m, 3H), 7.22-7.17 (m, 1H), 7.15-7.08 (m, 4H), 7.06-6.99 (m, 2H), 6.97-6.93 (m, 2H), 5.02 (s, 1H), 4.59 (s, 2H), 2.34 (s, 3H), 2.00-1.94 (m, 2H), 1.62-1.56 (m, 1H), 1.54-1.44 (m, 6H), 1.12-1.01 (m, 1H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 148.0, 141.9, 140.9, 138.9, 138.3, 133.5, 130.0, 129.0, 128.9, 127.8, 127.2, 127.2, 127.1, 126.7, 117.6, 108.5, 61.2, 53.4, 35.1, 27.1, 25.4, 21.6, 21.4 ppm. **HRMS**: 470.2138 [M+H]⁺, calcd 470.2148.

Ethyl 1-(4-methoxybenzyl)-4-phenyl-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2p).**2p**

Chemical Formula: $C_{27}H_{31}NO_3$
Molecular Weight: 417,55

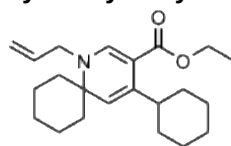
Following **General Procedure C** starting from **1p** (62 mg, 0.15 mmol), the title compound **2p** was obtained (46.3 mg, 0.11 mmol, 75% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **Rf** = 0.45 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2931, 2978, 2850, 1662, 1606, 1545, 1511, 1456, 1357, 1287, 1251, 1195, 1129, 1032, 954, 832, 753, 702 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.63 (s, 1H), 7.30-7.25 (m, 5H), 7.20-7.16 (m, 2H), 6.89-6.85 (m, 2H), 5.08 (s, 1H), 4.50 (s, 2H), 3.95 (q, J = 7.1 Hz, 2H), 3.80 (s, 3H), 2.01-1.92 (m, 2H), 1.69-1.62 (m, 1H), 1.59-1.52 (m, 4H), 1.47 (td, J = 12.0, 5.2 Hz, 2H), 1.15-1.05 (m, 1H), 0.94 (t, J = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.8, 159.1, 150.2, 142.1, 136.1, 131.0, 128.1, 127.9, 127.5, 126.7, 116.3, 114.3, 99.9, 60.8, 59.0, 55.4, 53.1, 34.3, 25.6, 21.8, 14.2 ppm.

HRMS: 440.2196 [M+Na]⁺, calcd 440.2179.

Ethyl 4-cyclohexyl-1-(4-fluorobenzyl)-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2q).**2q**

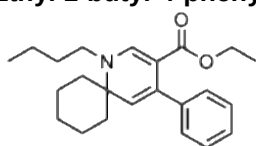
Chemical Formula: $C_{26}H_{34}FNO_2$
Molecular Weight: 411,56

Following **General Procedure C** starting from **1q** (53.8 mg, 0.13 mmol), the title compound **2q** was obtained (38.4 mg, 93.3 μ mol, 71% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **Rf** = 0.54 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2925, 2851, 1677, 1554, 1509, 1219, 1134, 1070, 731 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.47 (s, 1H), 7.16 (m, 2H), 7.05-6.96 (m, 2H), 5.00 (s, 1H), 4.44 (s, 2H), 4.14 (q, J = 7.1 Hz, 2H), 3.08-2.96 (m, 1H), 1.92-1.30 (m, 20H), 1.26 (t, J = 7.1 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.2, 162.2 (d, J = 245.5 Hz), 150.2, 140.1, 135.4 (d, J = 3.2 Hz), 128.2 (d, J = 8.0 Hz), 115.7 (d, J = 21.5 Hz), 110.9, 99.9, 59.9, 59.1, 52.7, 38.9, 34.7, 33.8, 27.3, 27.1, 25.7, 21.7, 14.7 ppm. **¹⁹F NMR** (282 MHz, CDCl₃) δ -115.5 ppm. **HRMS**: 412.2641 [M+H]⁺, calcd 412.2646.

Ethyl 1-allyl-4-cyclohexyl-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2r).**2r**

Chemical Formula: $C_{22}H_{33}NO_2$
Molecular Weight: 343,51

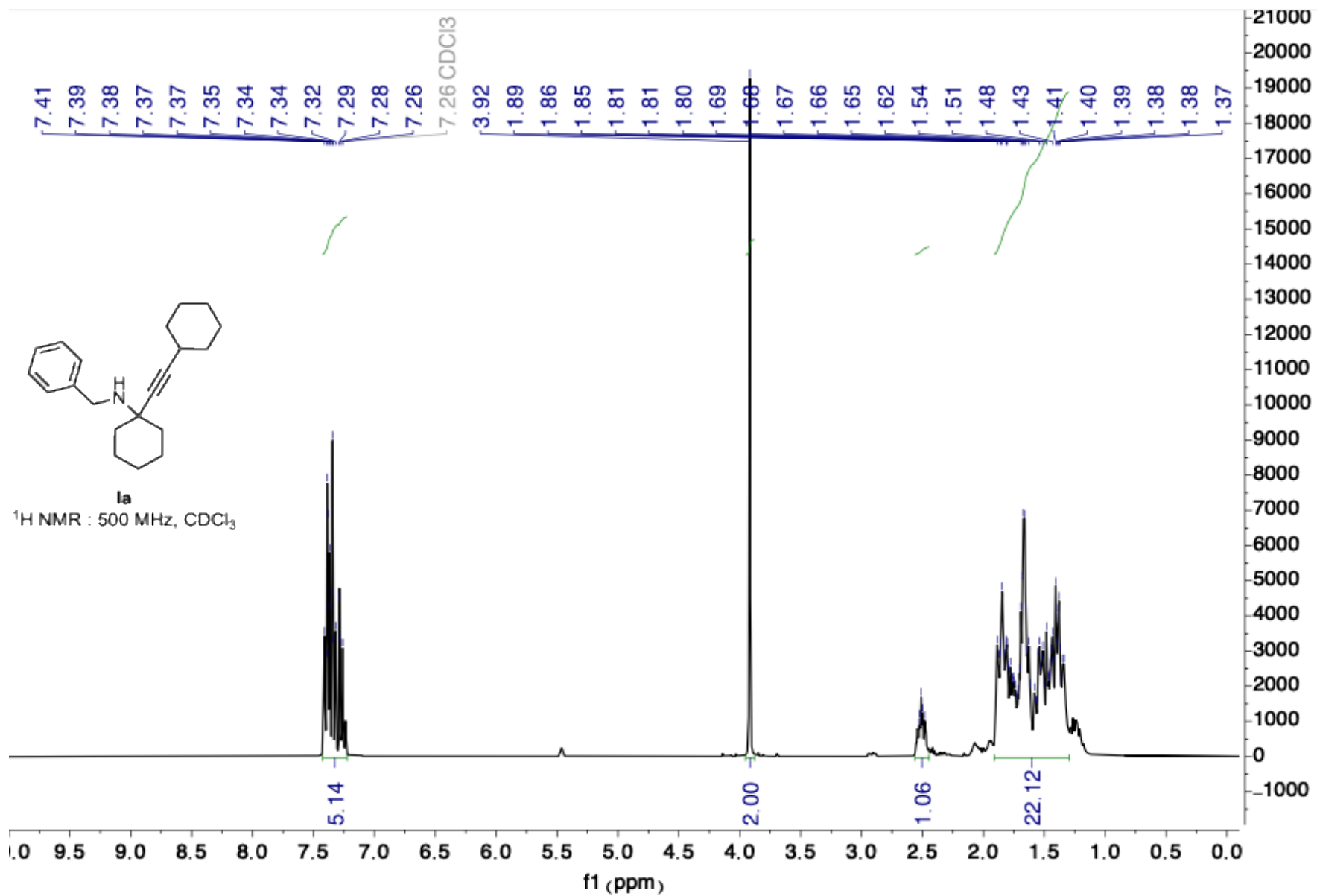
Following **General Procedure C** starting from **1r** (44.6 mg, 0.13 mmol), the title compound **2r** was obtained (26.8 mg, 78.0 μ mol, 60% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **Rf** = 0.59 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2924, 2851, 1726, 1682, 1555, 1448, 1365, 1284, 1221, 988, 765 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.41 (s, 1H), 5.84 (ddt, J = 17.1, 10.5, 5.4 Hz, 1H), 5.23-5.12 (m, 2H), 4.97 (s, 1H), 4.13 (q, J = 7.1 Hz, 2H), 3.84 (d, J = 5.4 Hz, 2H), 3.04-2.94 (m, 1H), 1.93-1.80 (m, 4H), 1.79-1.59 (m, 6H), 1.56-1.32 (m, 8H), 1.27 (t, J = 7.1 Hz, 3H), 1.14-1.03 (m, 2H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 167.0, 149.7, 139.8, 136.0, 117.2, 110.3, 98.8, 59.6, 58.9, 51.8, 38.8, 34.7, 33.8, 27.2, 26.9, 25.7, 21.7, 14.8 ppm. **HRMS**: 344.2576 [M+H]⁺, calcd 344.2584.

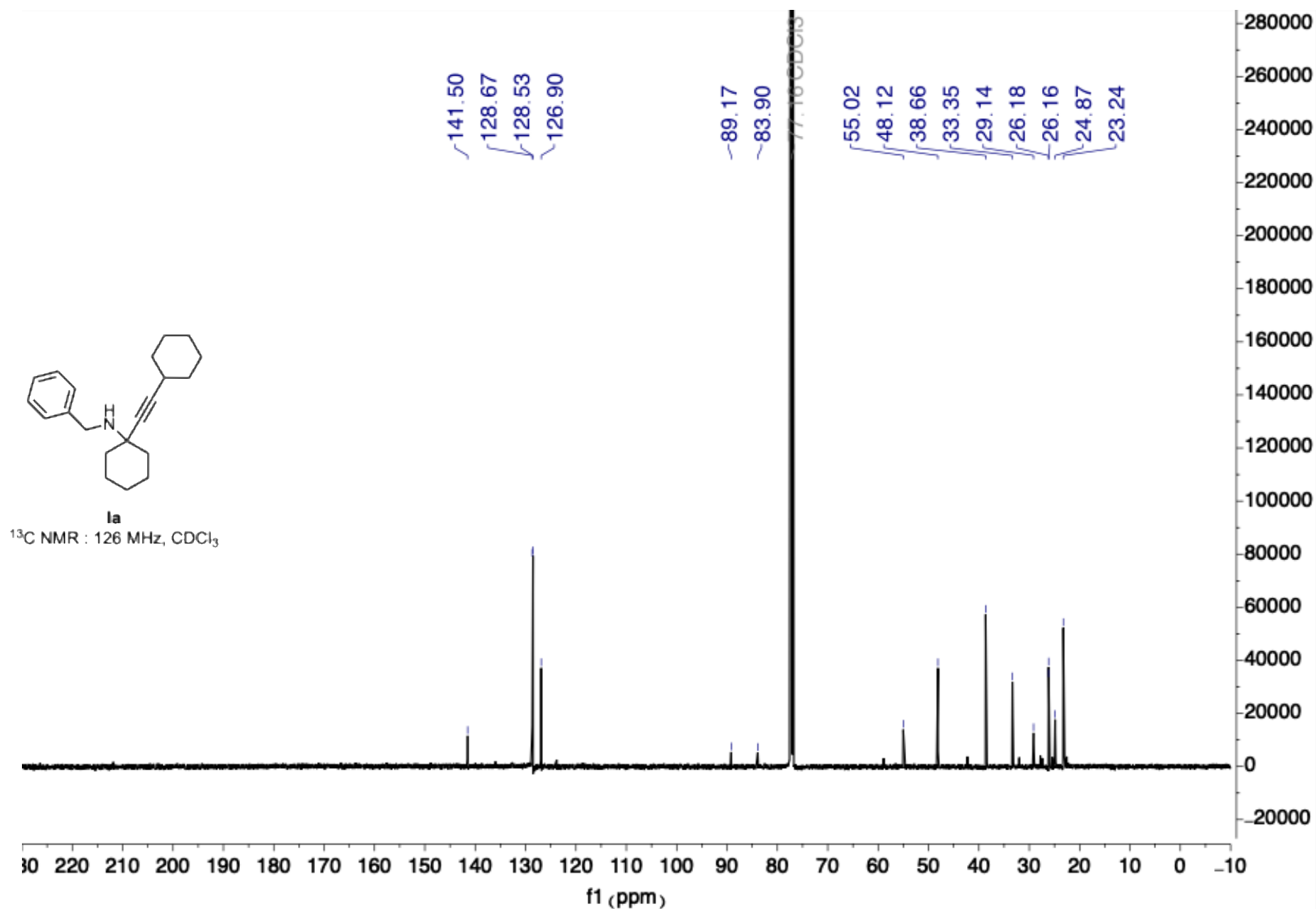
Ethyl 1-butyl-4-phenyl-1-azaspiro[5.5]undeca-2,4-diene-3-carboxylate (2s).**2s**

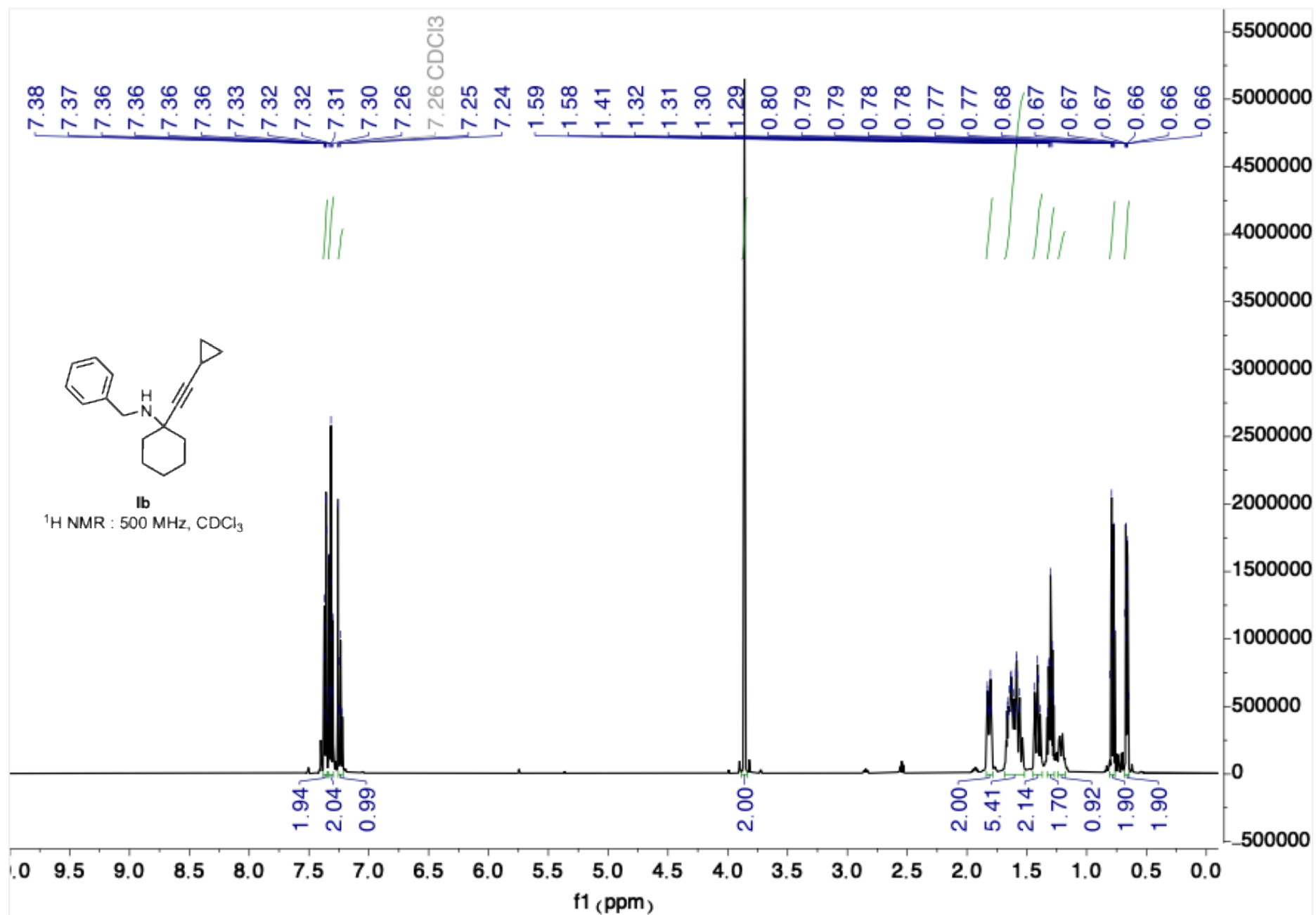
Chemical Formula: $C_{23}H_{31}NO_2$
Molecular Weight: 353,51

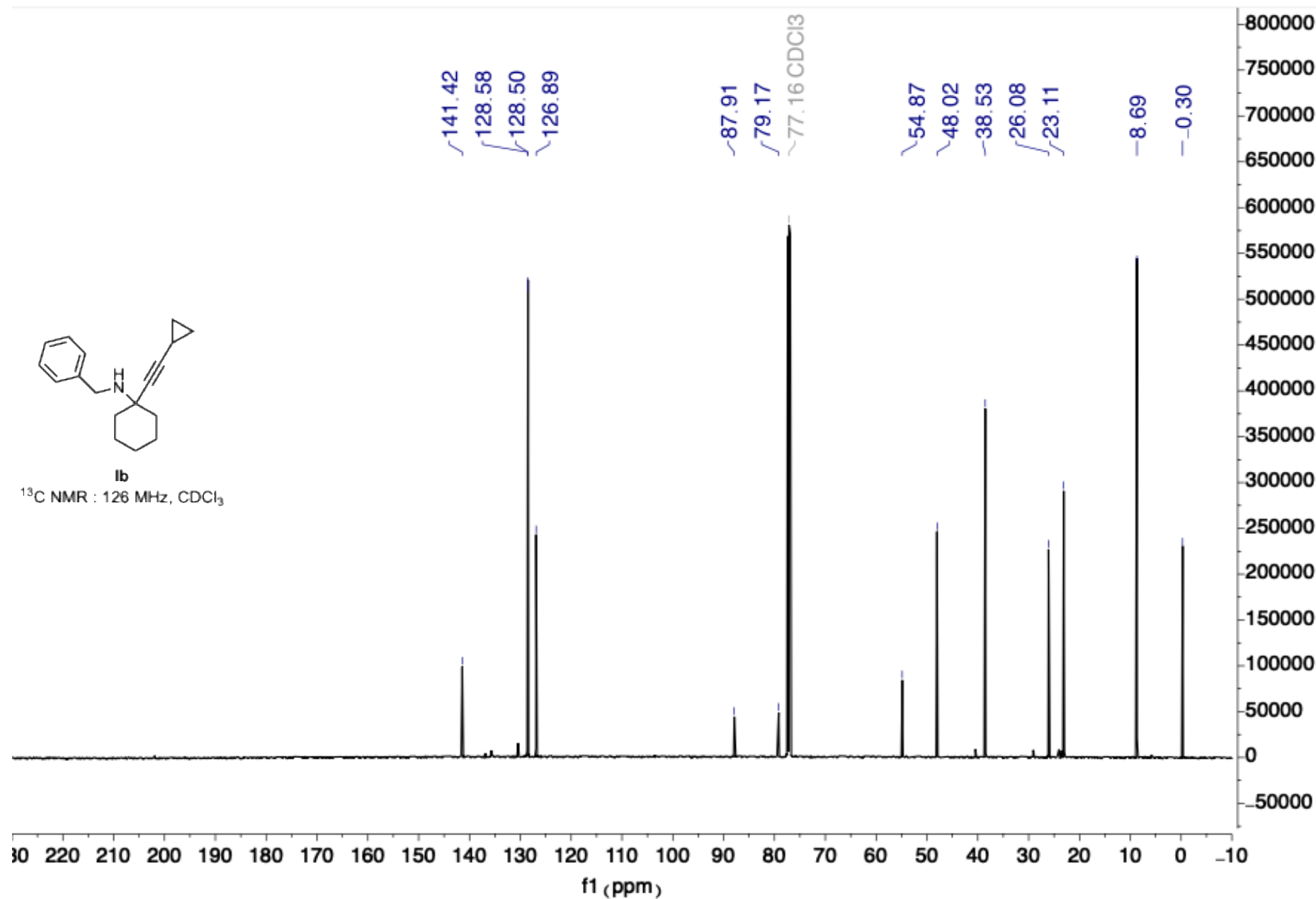
Following **General Procedure C** starting from **1s** (45.4 mg, 0.13 mmol), the title compound **2s** was obtained (27.1 mg, 78 μ mol, 60% yield) as a pale-yellow oil after purification by column chromatography of the crude residue (cyclohexane/EtOAc 95/5). **Rf** = 0.45 (SiO₂, cyclohexane/EtOAc 8/2). **ATR FTIR** ν = 2928, 2857, 1677, 1614, 1551, 1445, 1362, 1275, 1201, 1146, 1069, 908, 756, 731, 698 cm⁻¹. **¹H NMR** (500 MHz, CDCl₃) δ 7.55 (s, 1H), 7.29-7.21 (m, 5H), 5.02 (s, 1H), 3.95 (q, J = 7.1 Hz, 2H), 3.29-3.25 (m, 2H), 2.06-2.03 (m, 2H), 1.73-1.66 (m, 1H), 1.65-1.56 (m, 6H), 1.53-1.45 (m, 2H), 1.39-1.34 (m, 2H), 1.19-1.12 (m, 1H), 0.96 (t, J = 7.1 Hz, 3H), 0.93 (t, J = 7.4 Hz, 3H) ppm. **¹³C NMR** (126 MHz, CDCl₃) δ 166.9, 149.8, 142.2, 136.0, 127.9, 127.4, 126.6, 115.7, 98.8, 60.4, 58.9, 49.8, 34.6, 34.4, 25.7, 21.8, 20.2, 14.2, 14.0 ppm. **HRMS**: 354.2431 [M+H]⁺, calcd 354.2428.

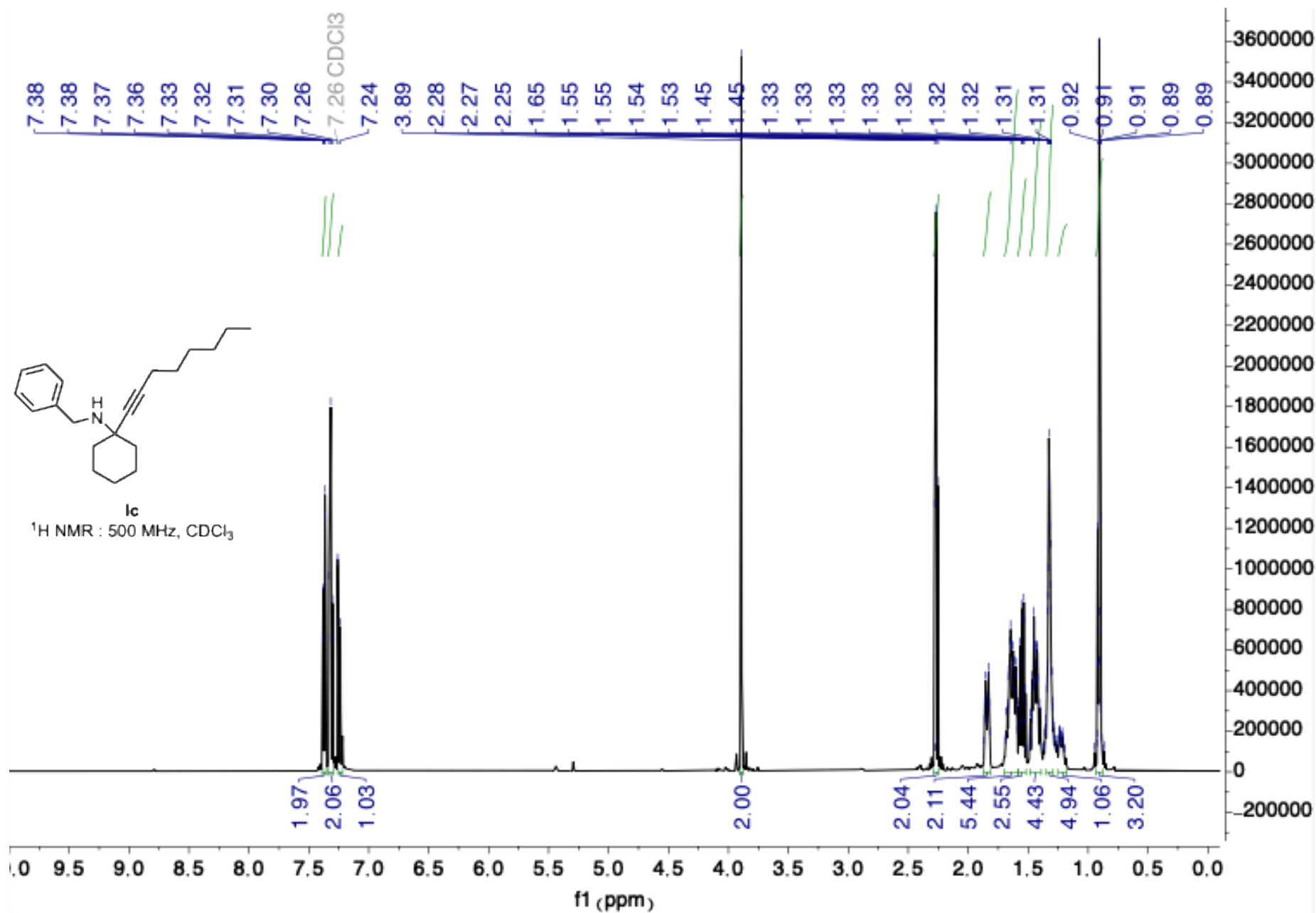
2. ^1H and ^{13}C NMR spectra

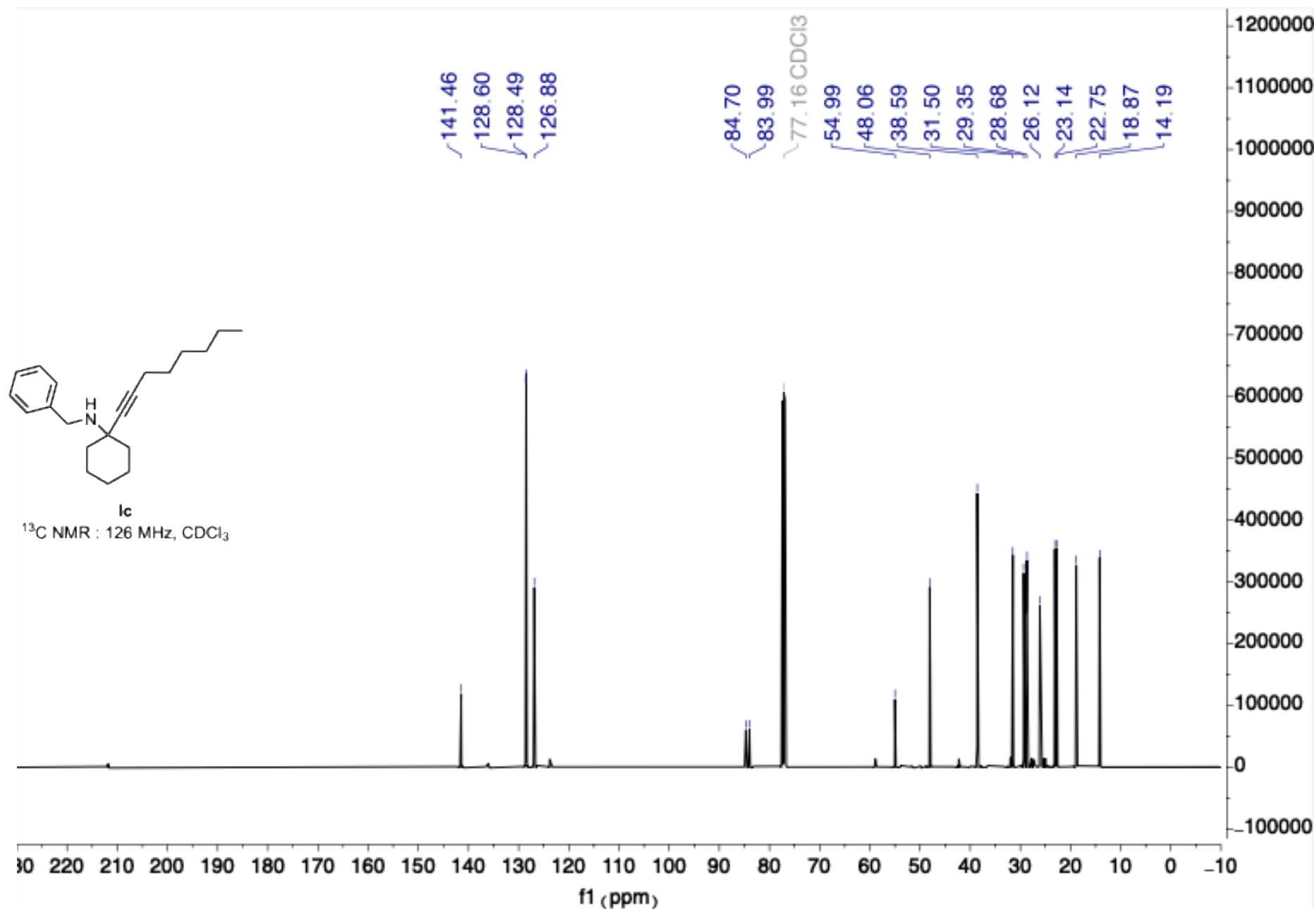


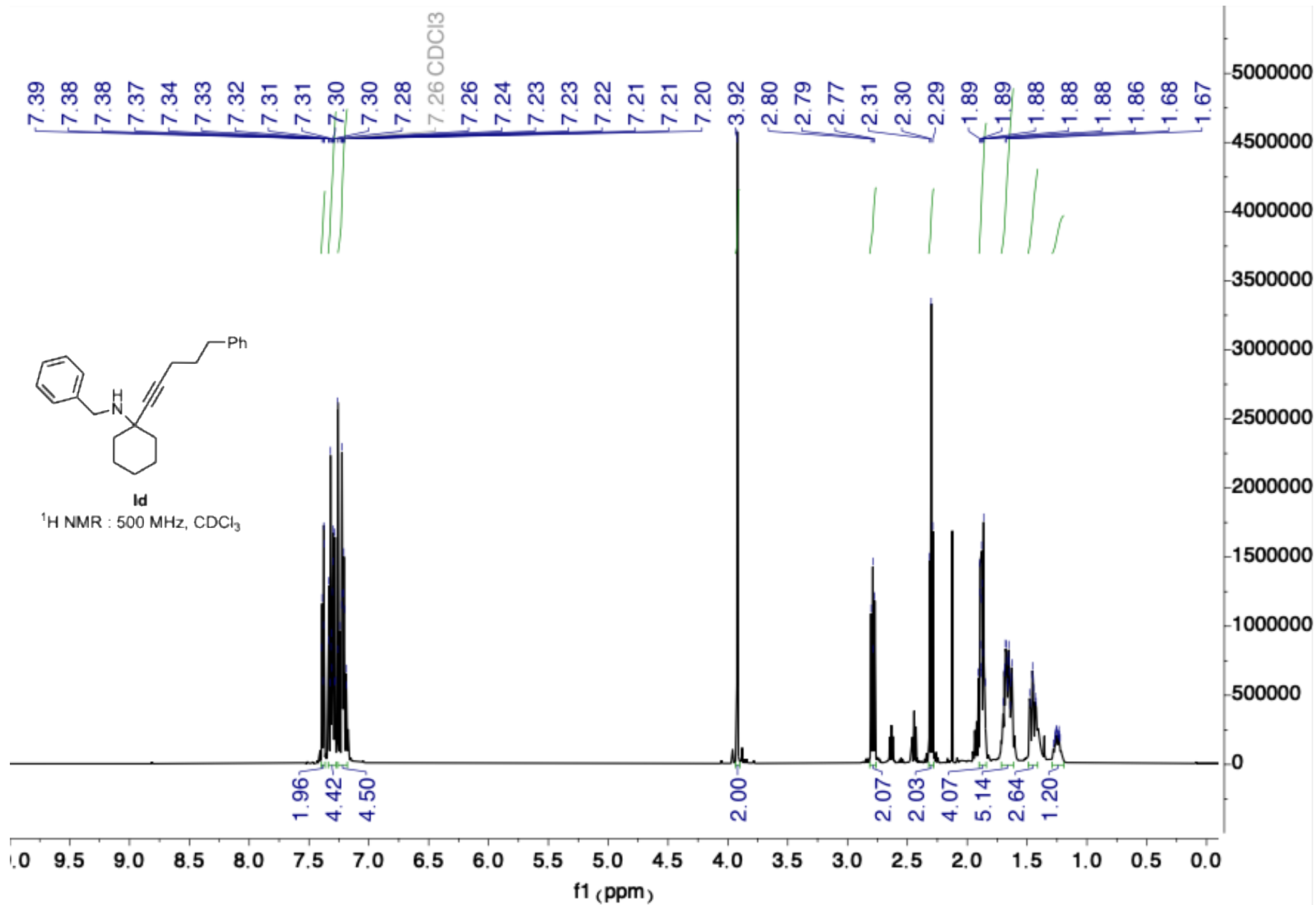


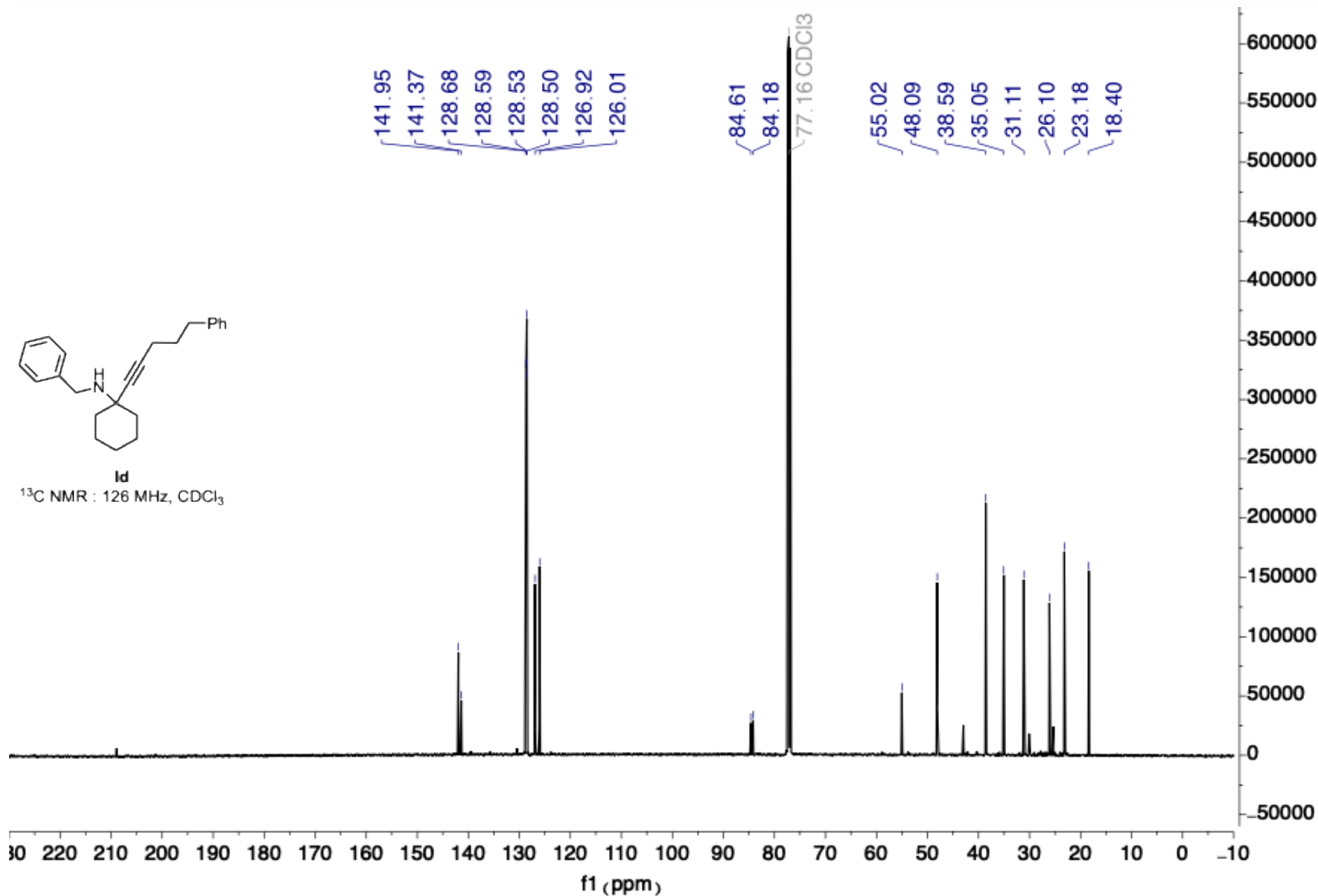


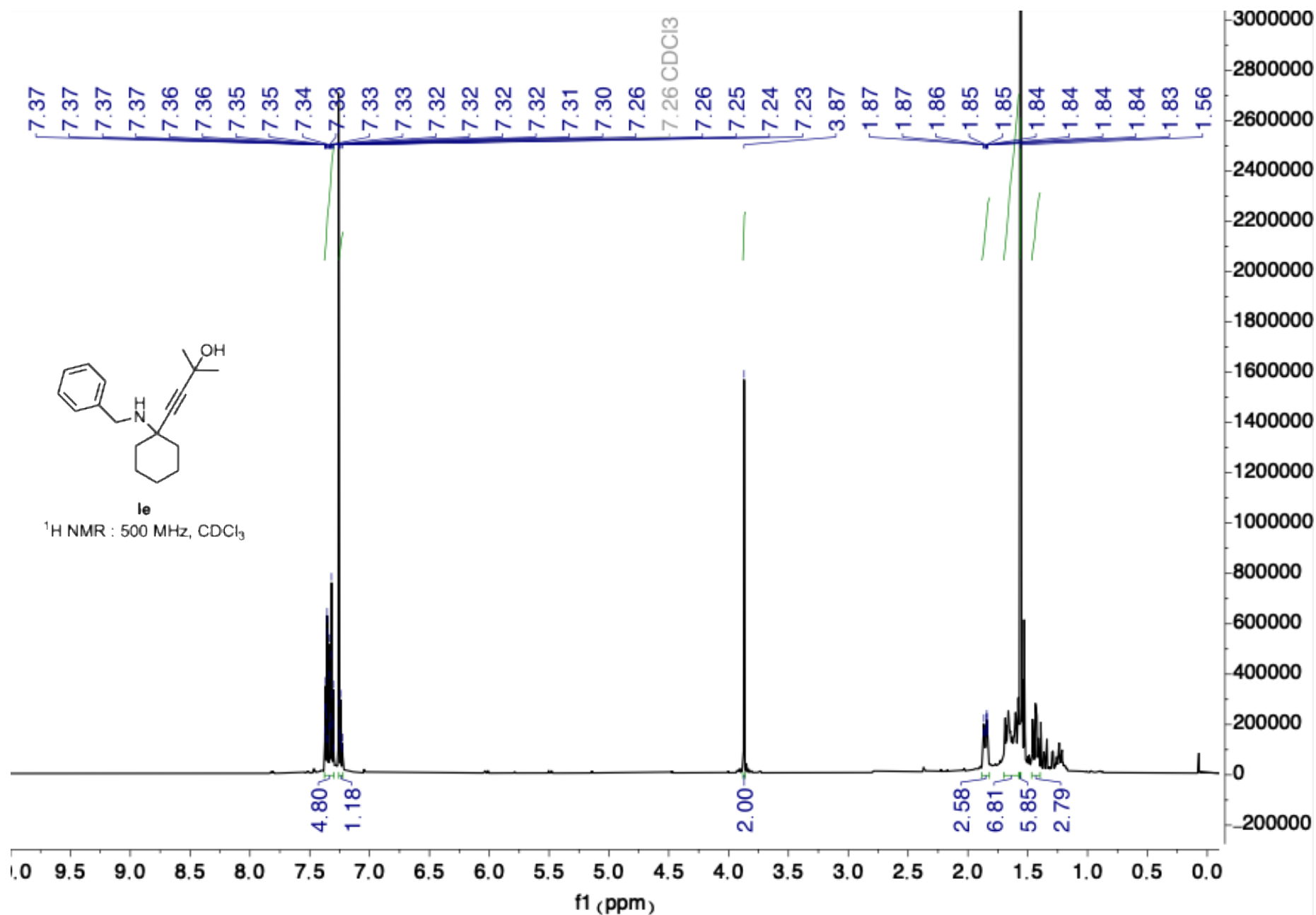


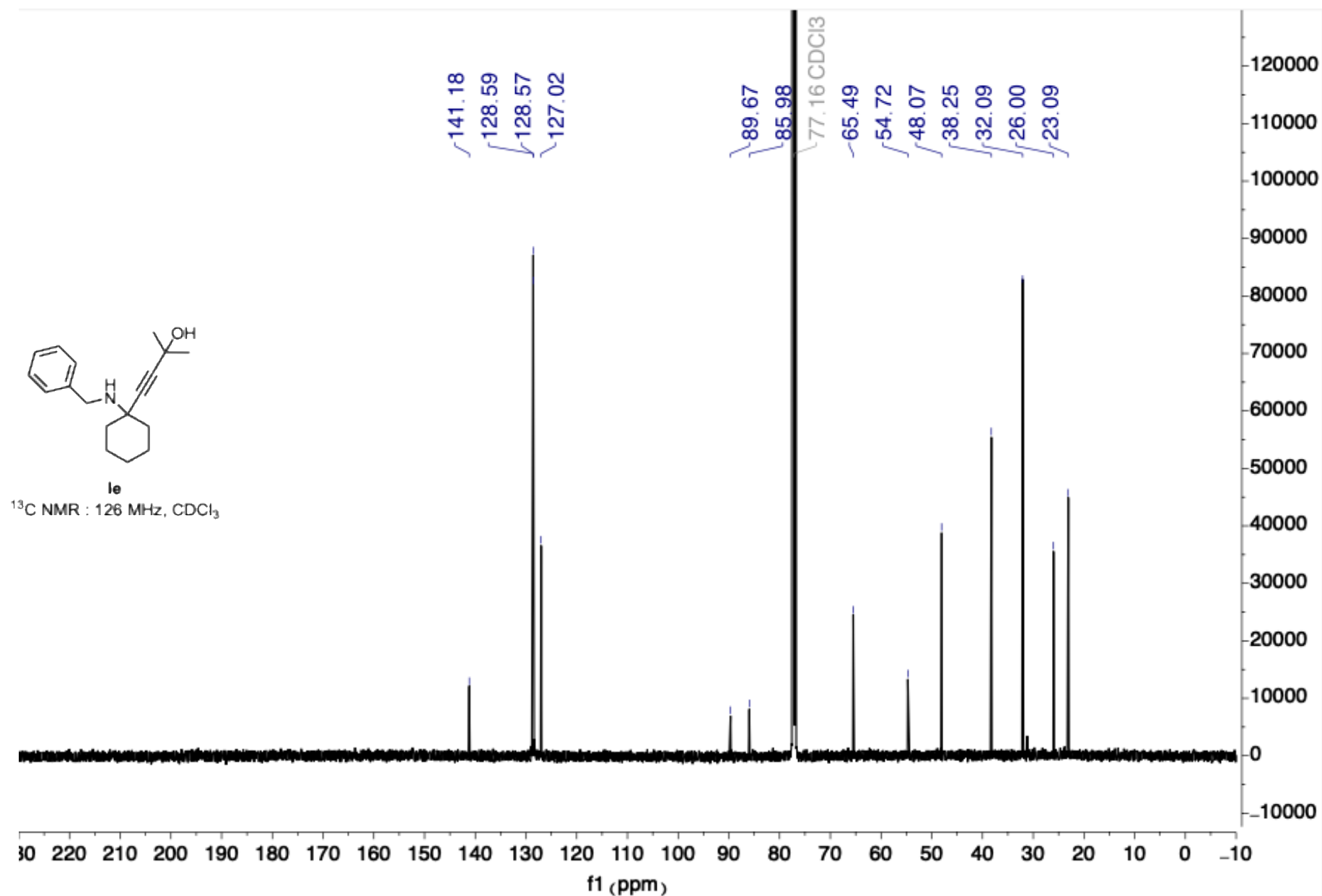


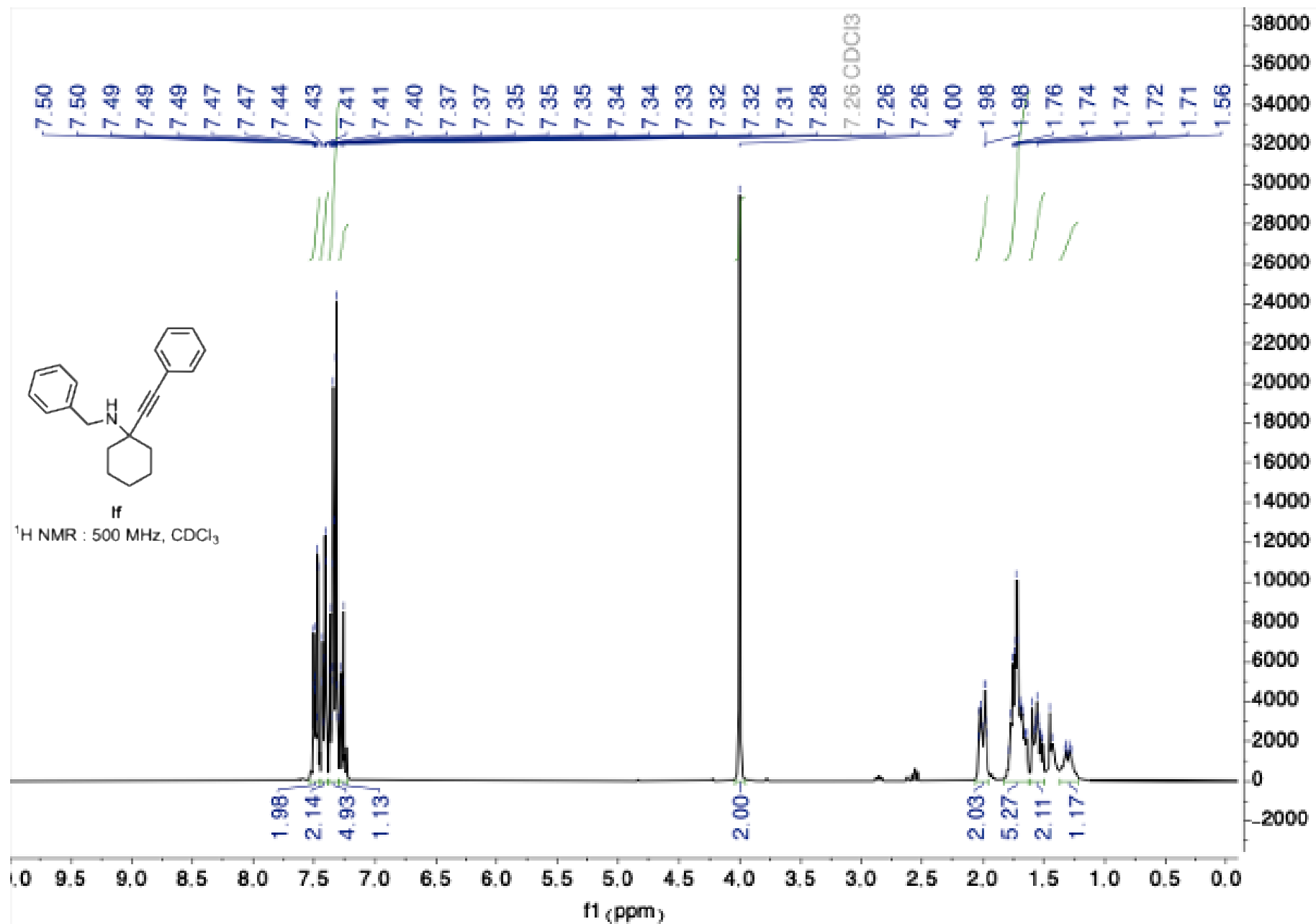


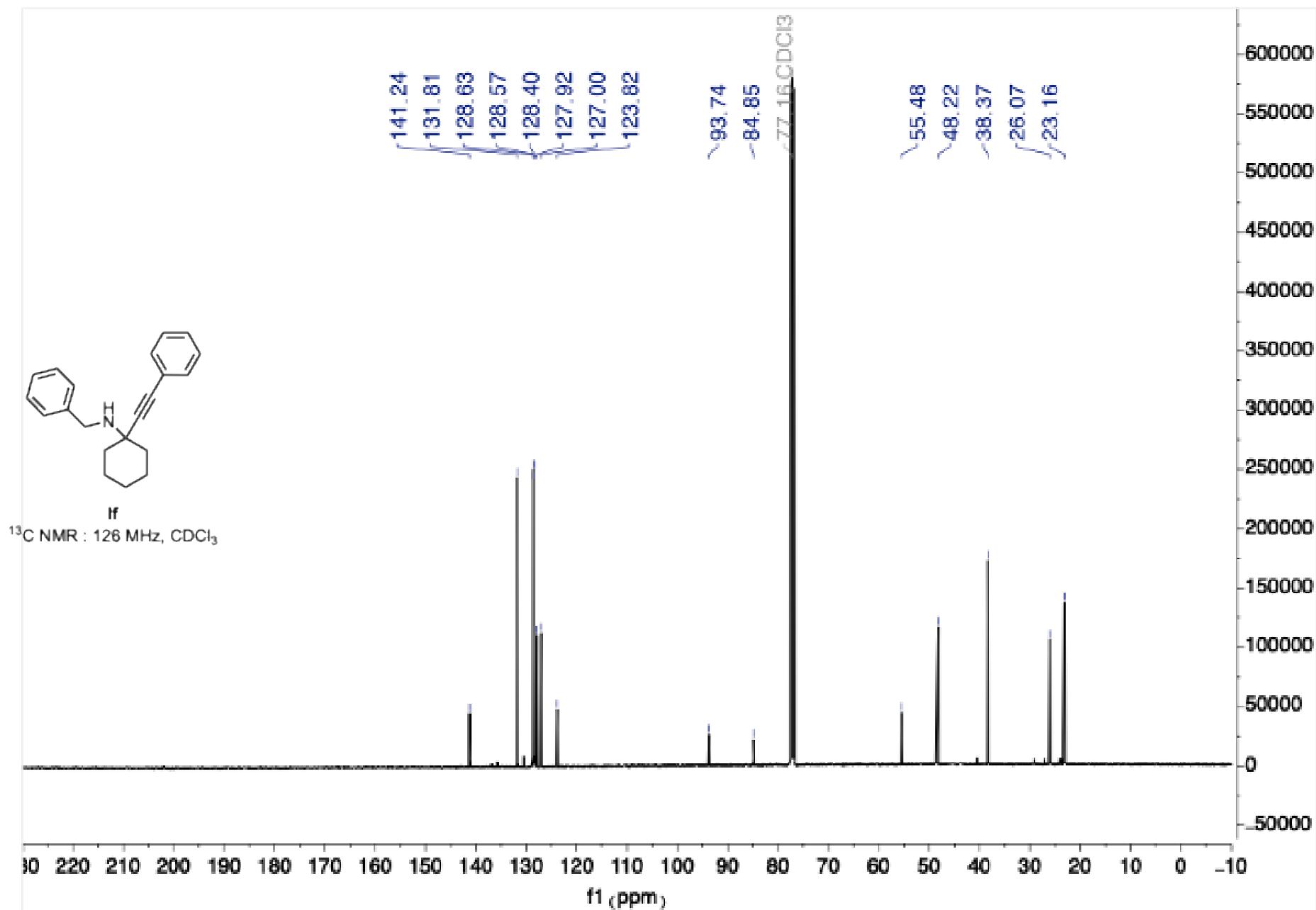


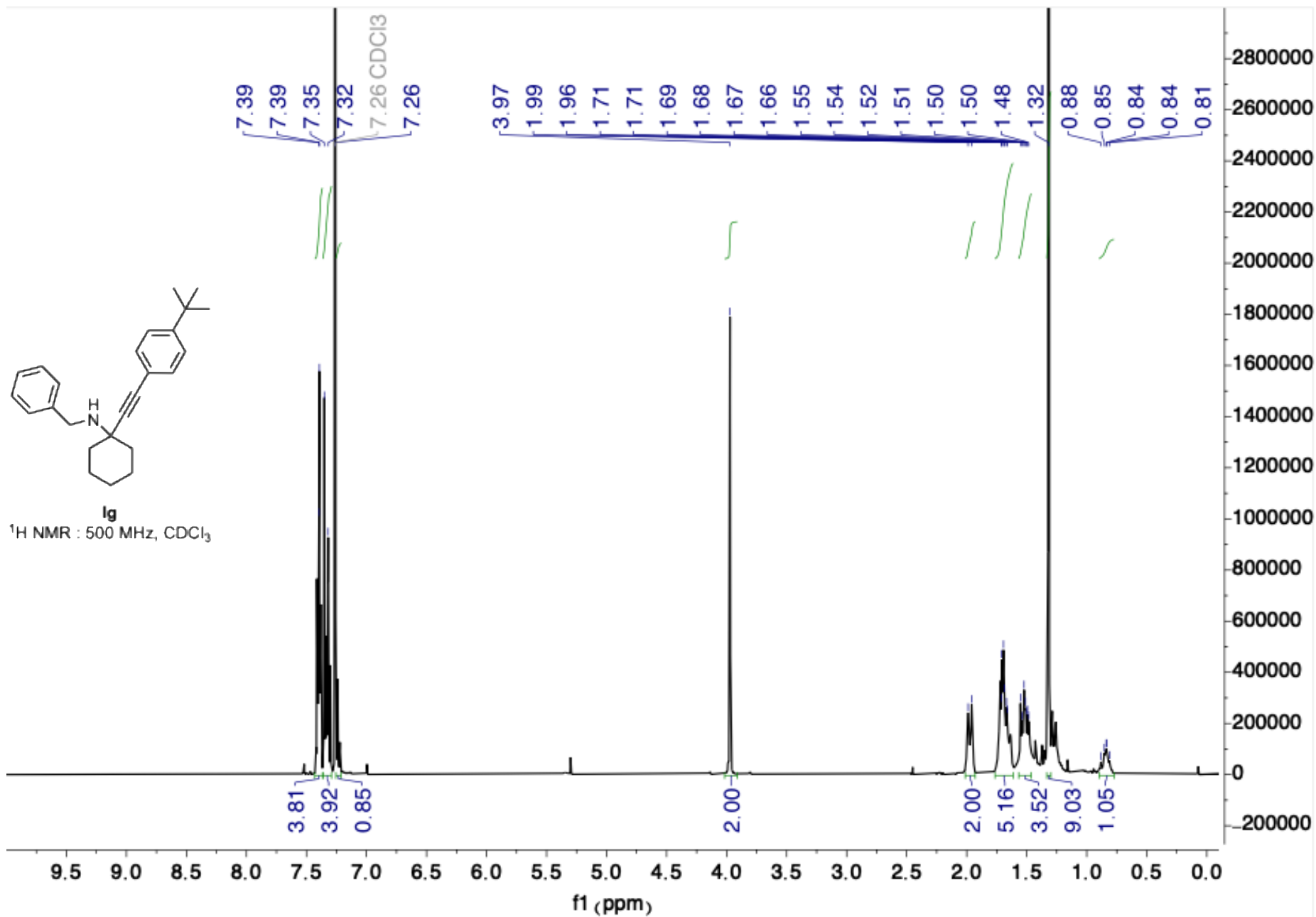


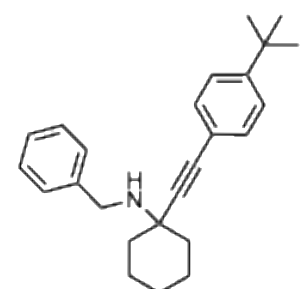






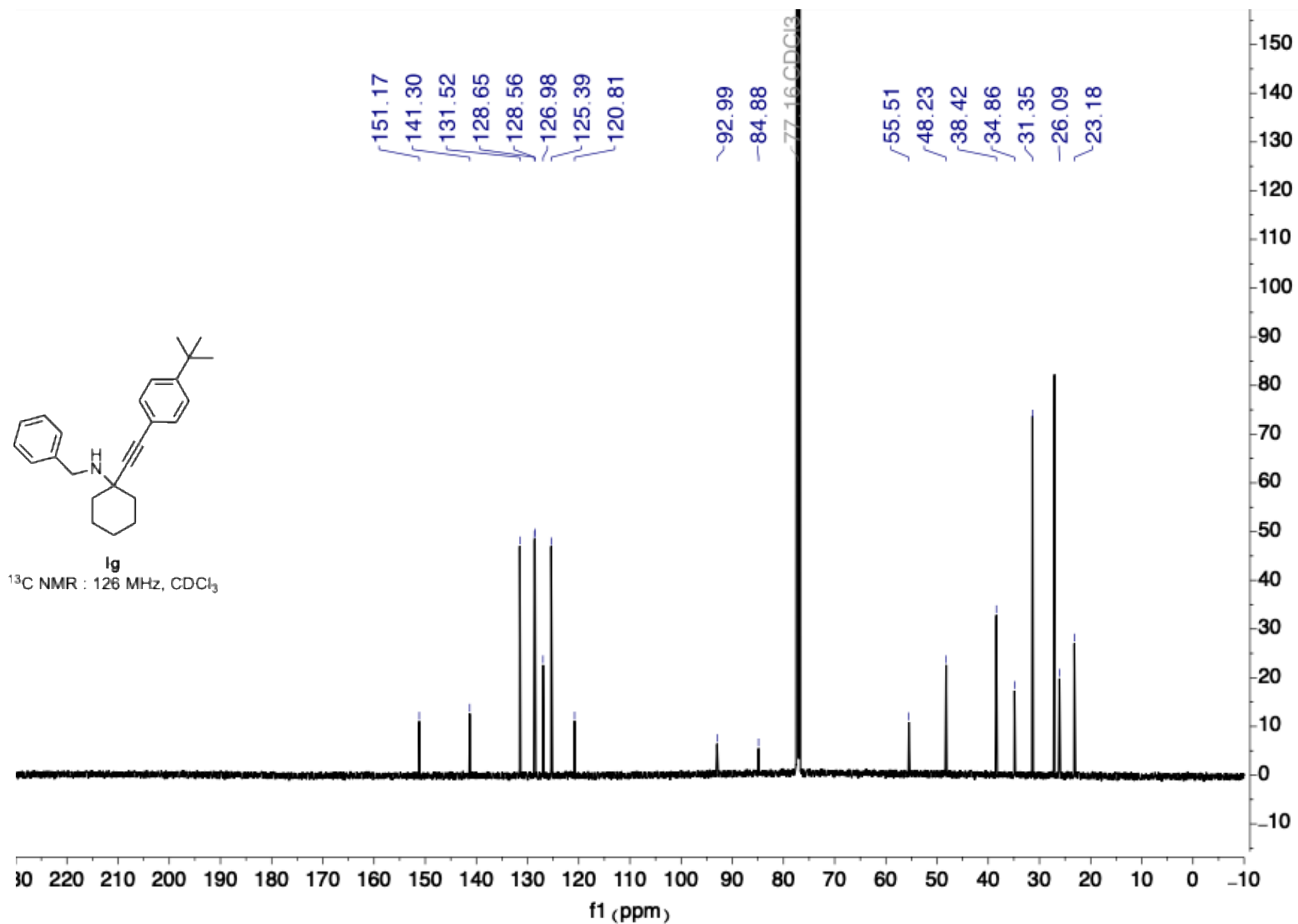


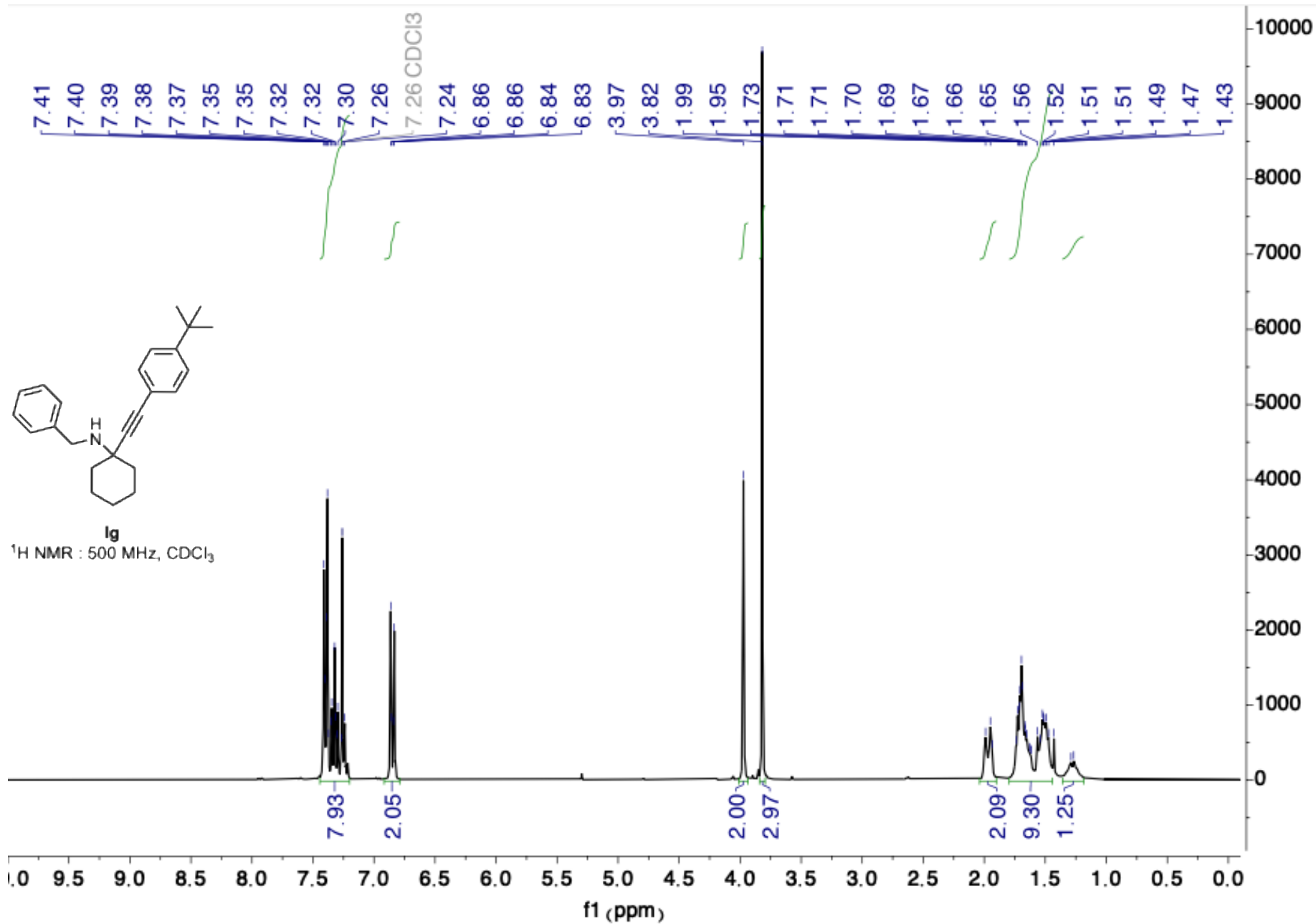


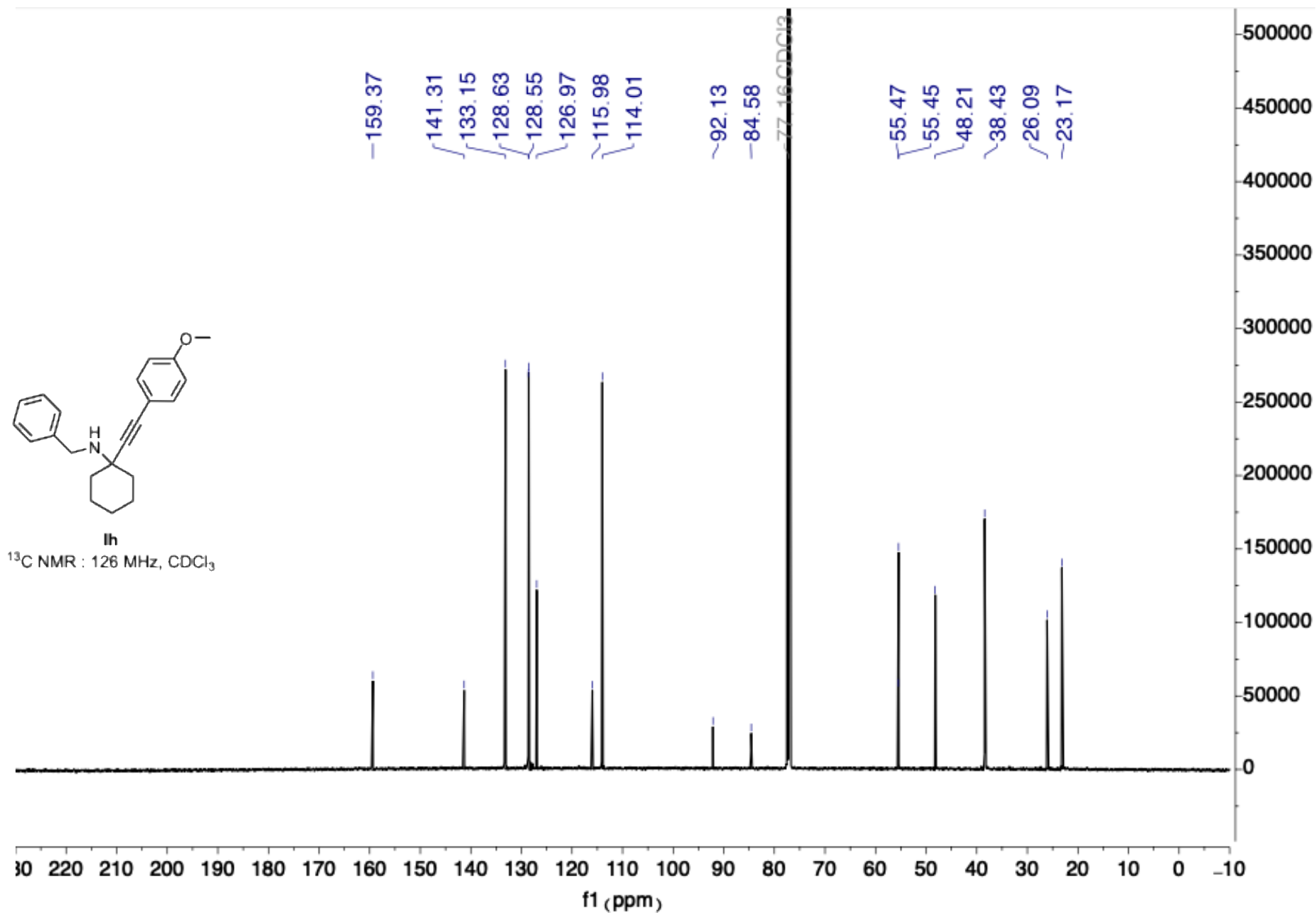


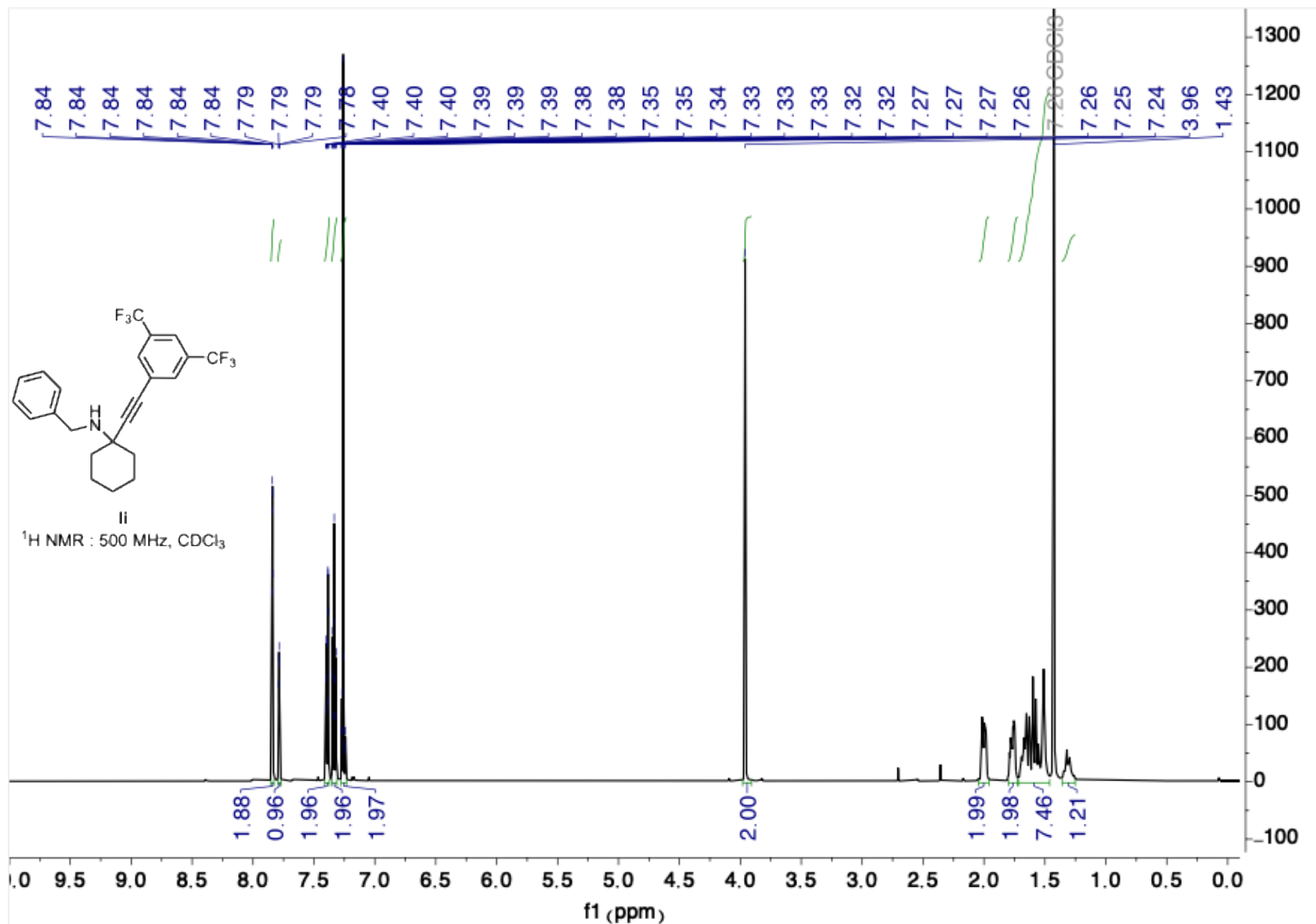
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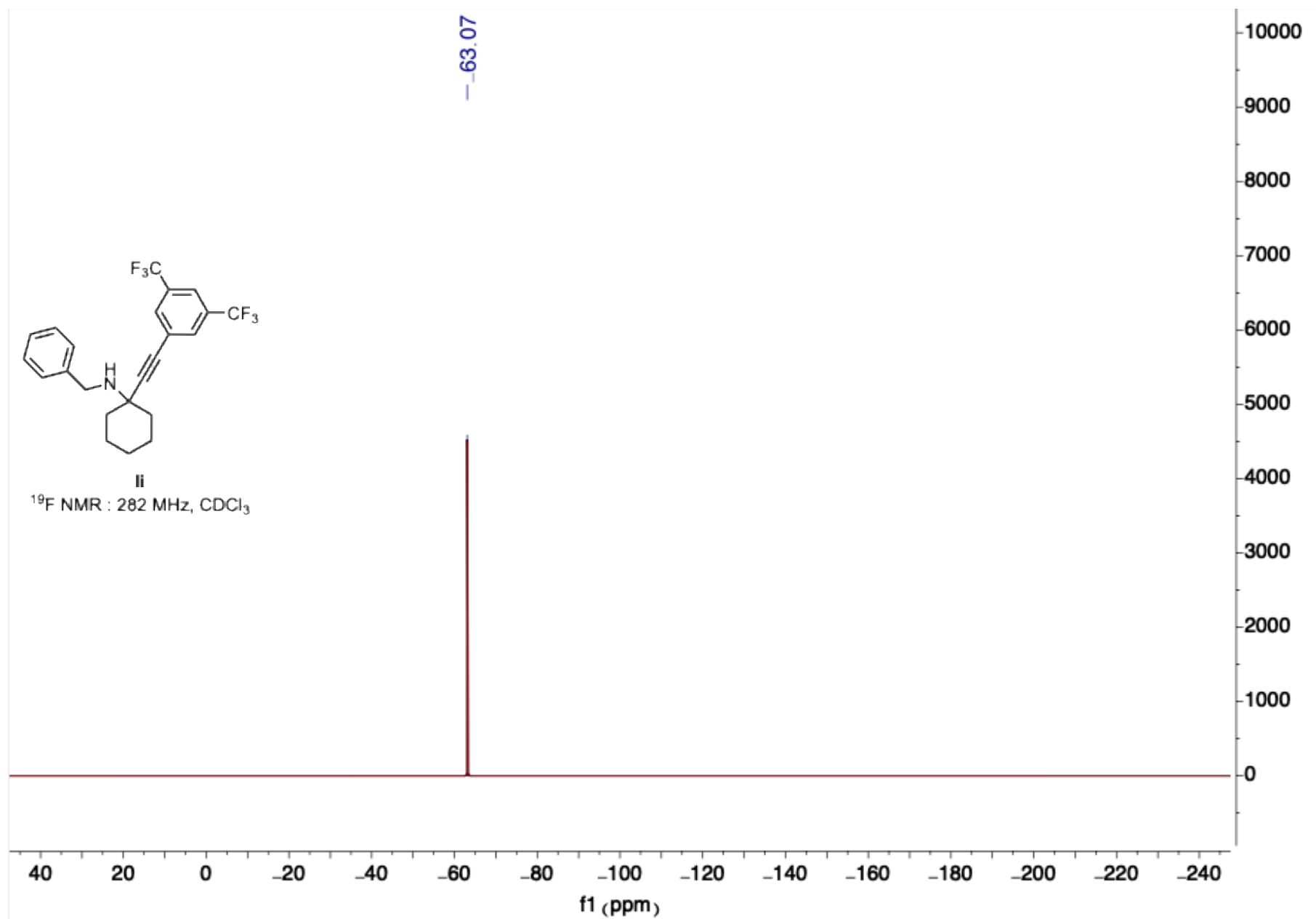
^{13}C NMR : 126 MHz, CDCl_3

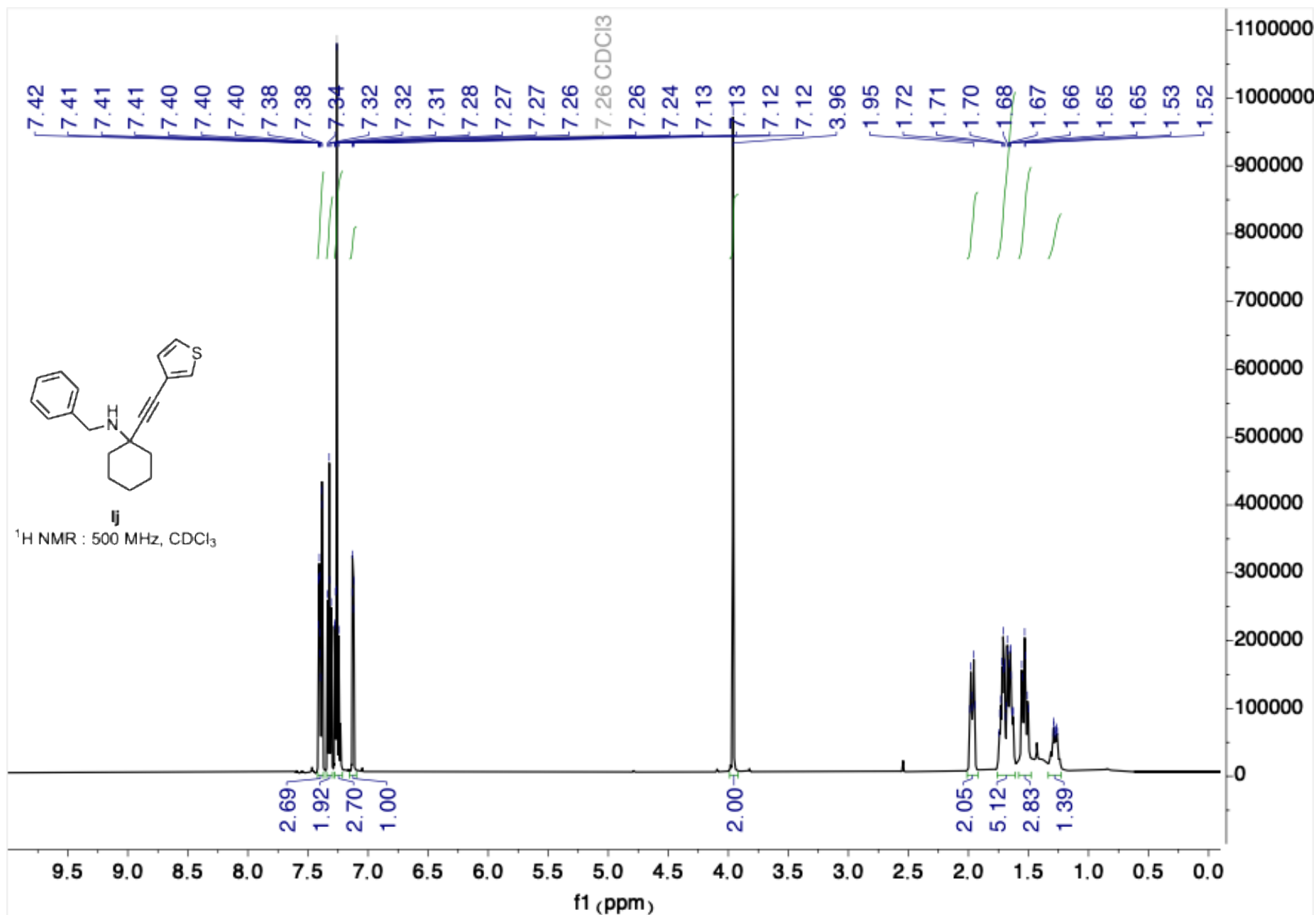


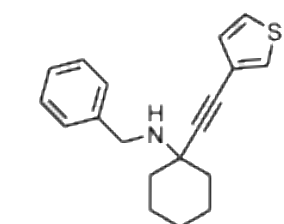






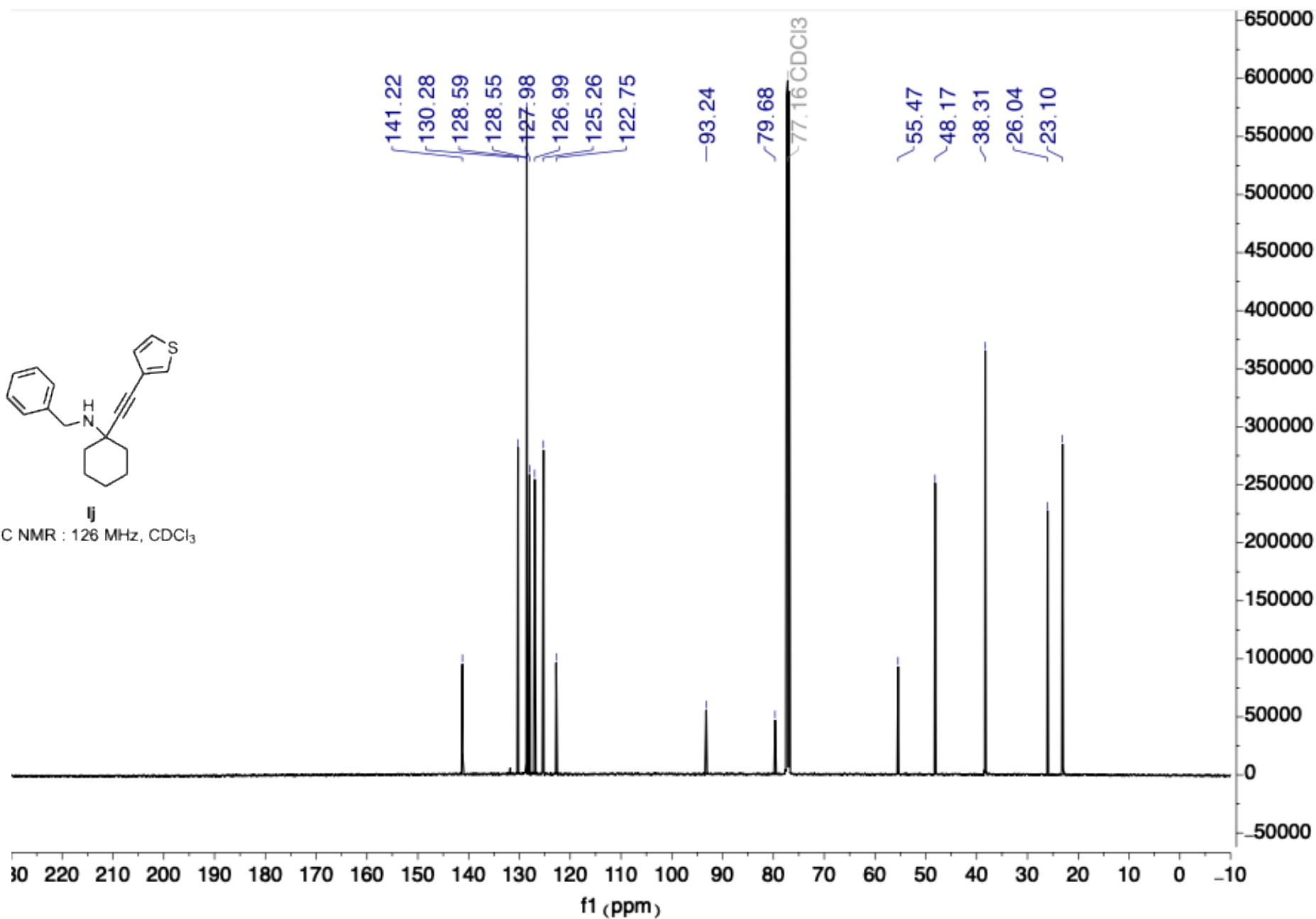


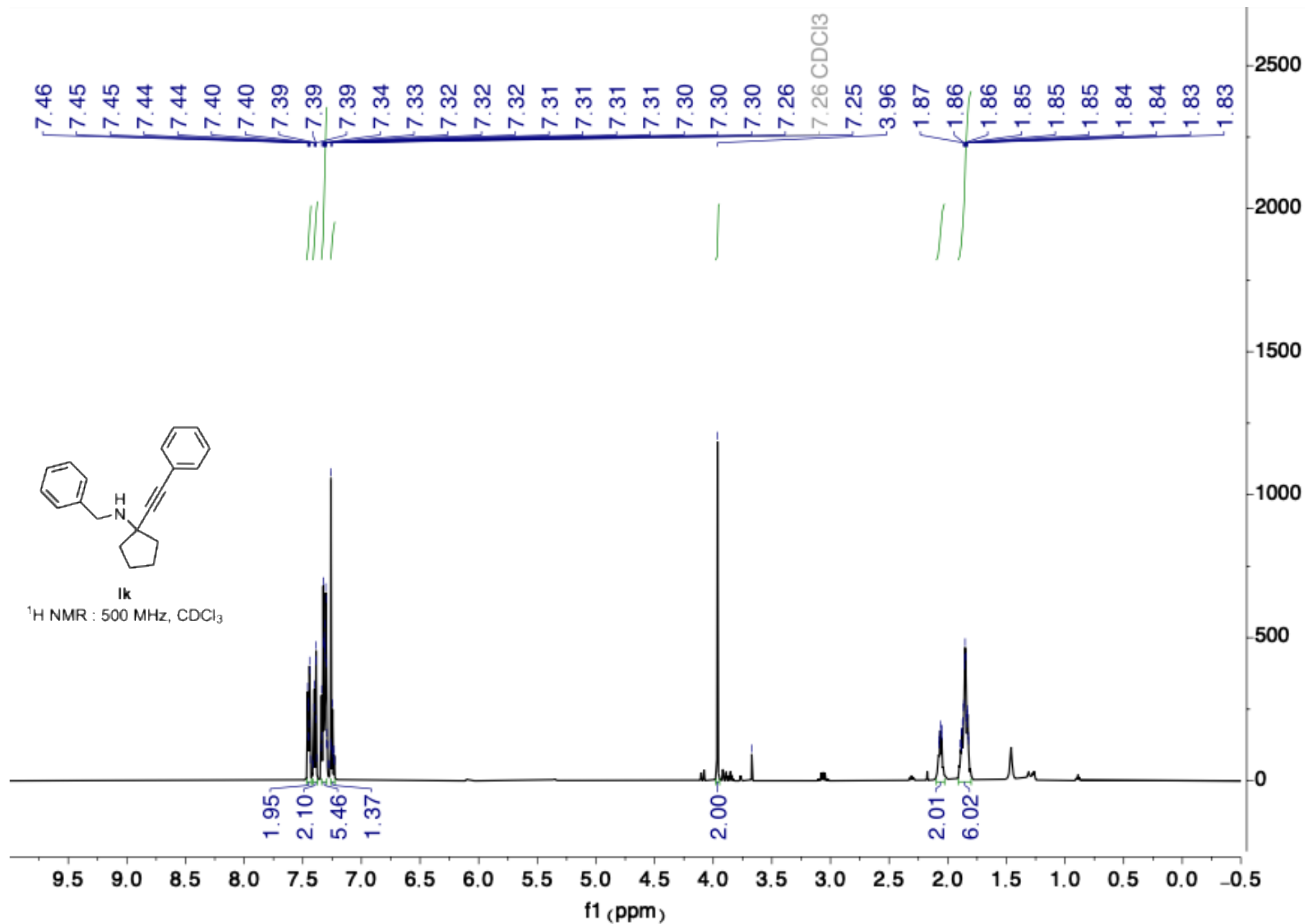


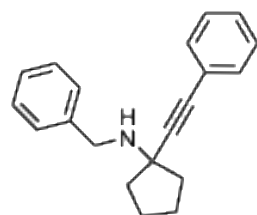


1j

^{13}C NMR : 126 MHz, CDCl_3

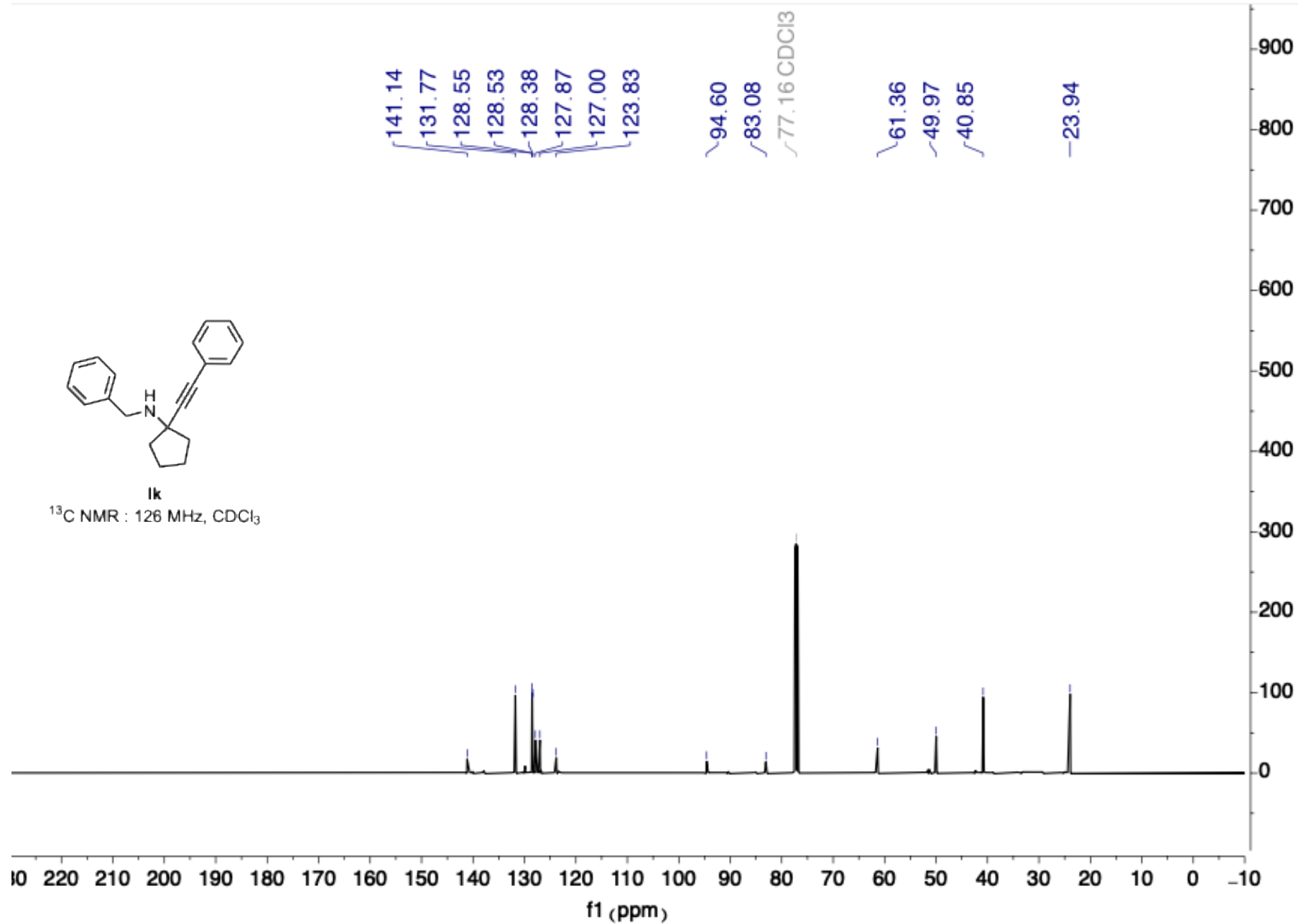


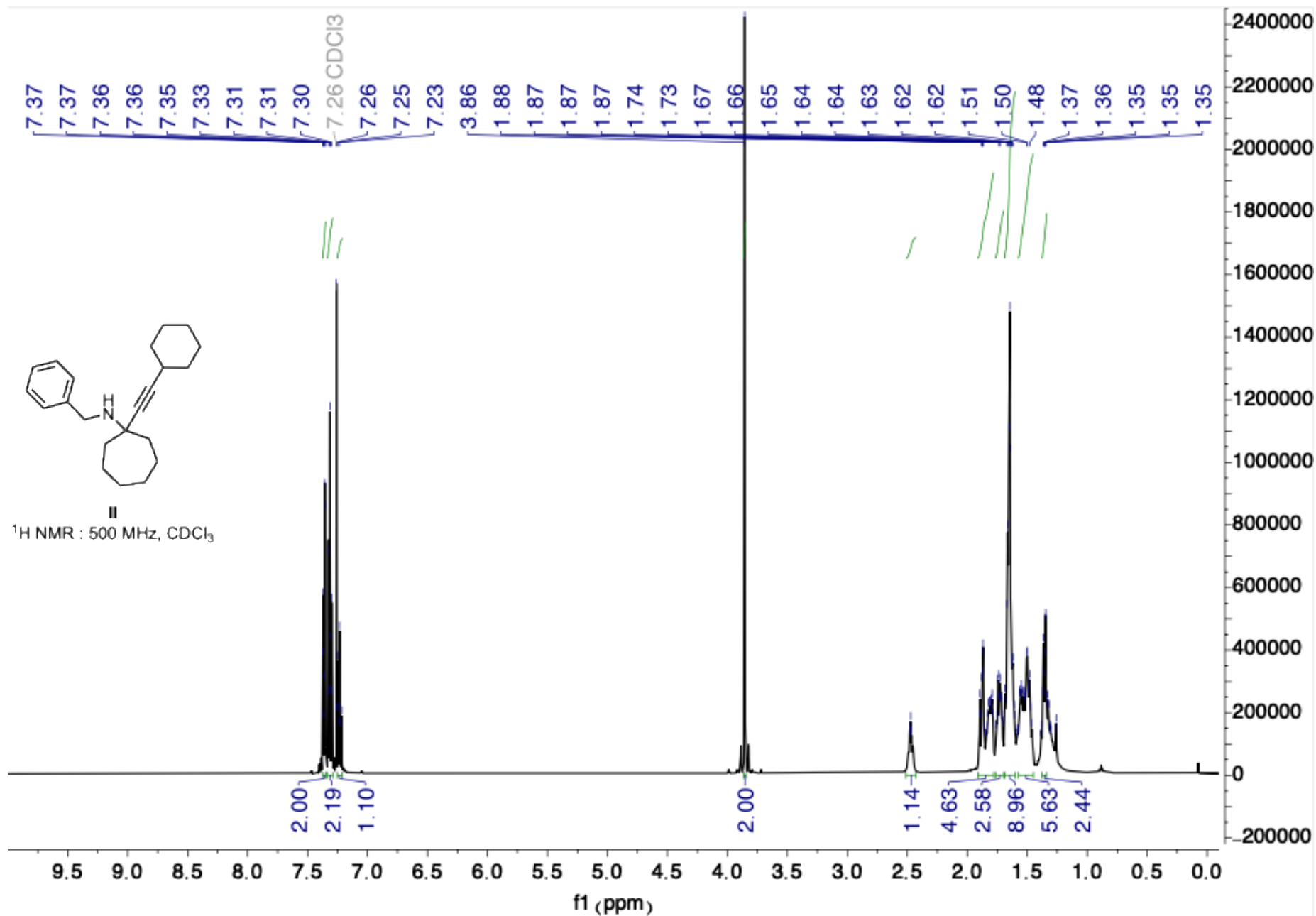


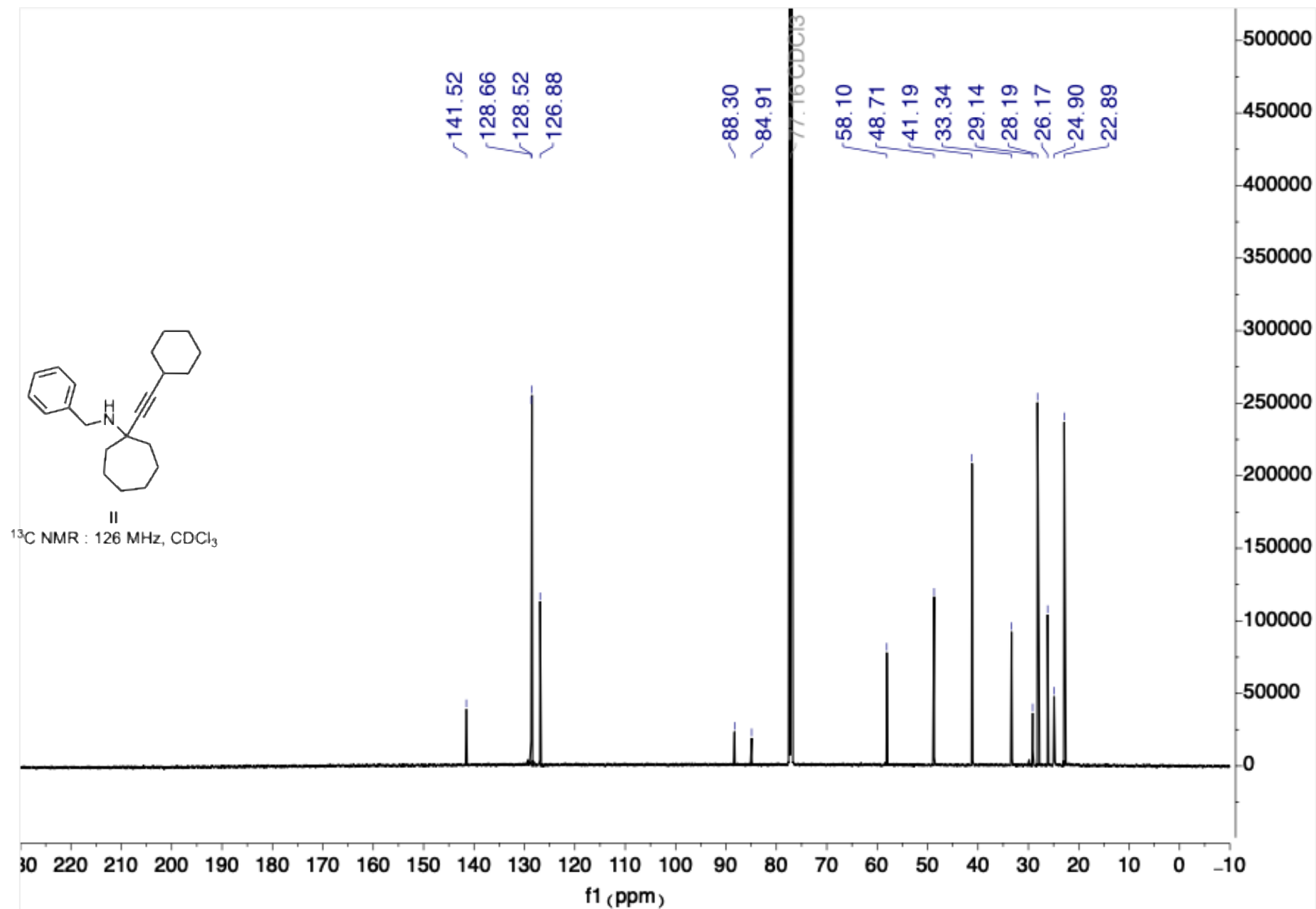


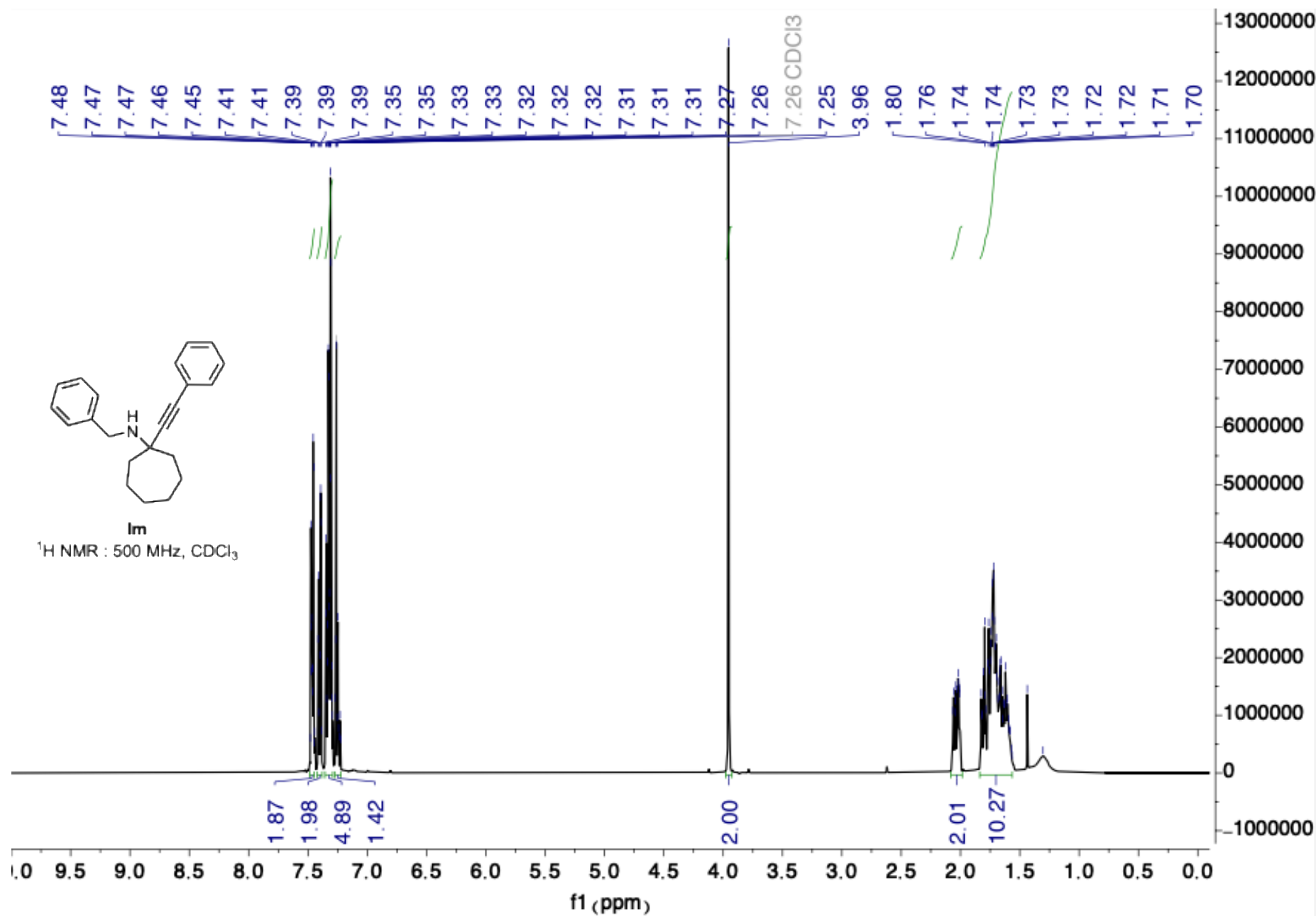
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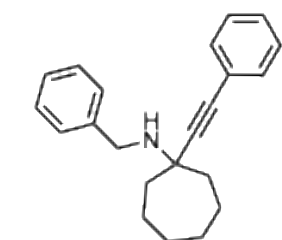
^{13}C NMR : 126 MHz, CDCl_3





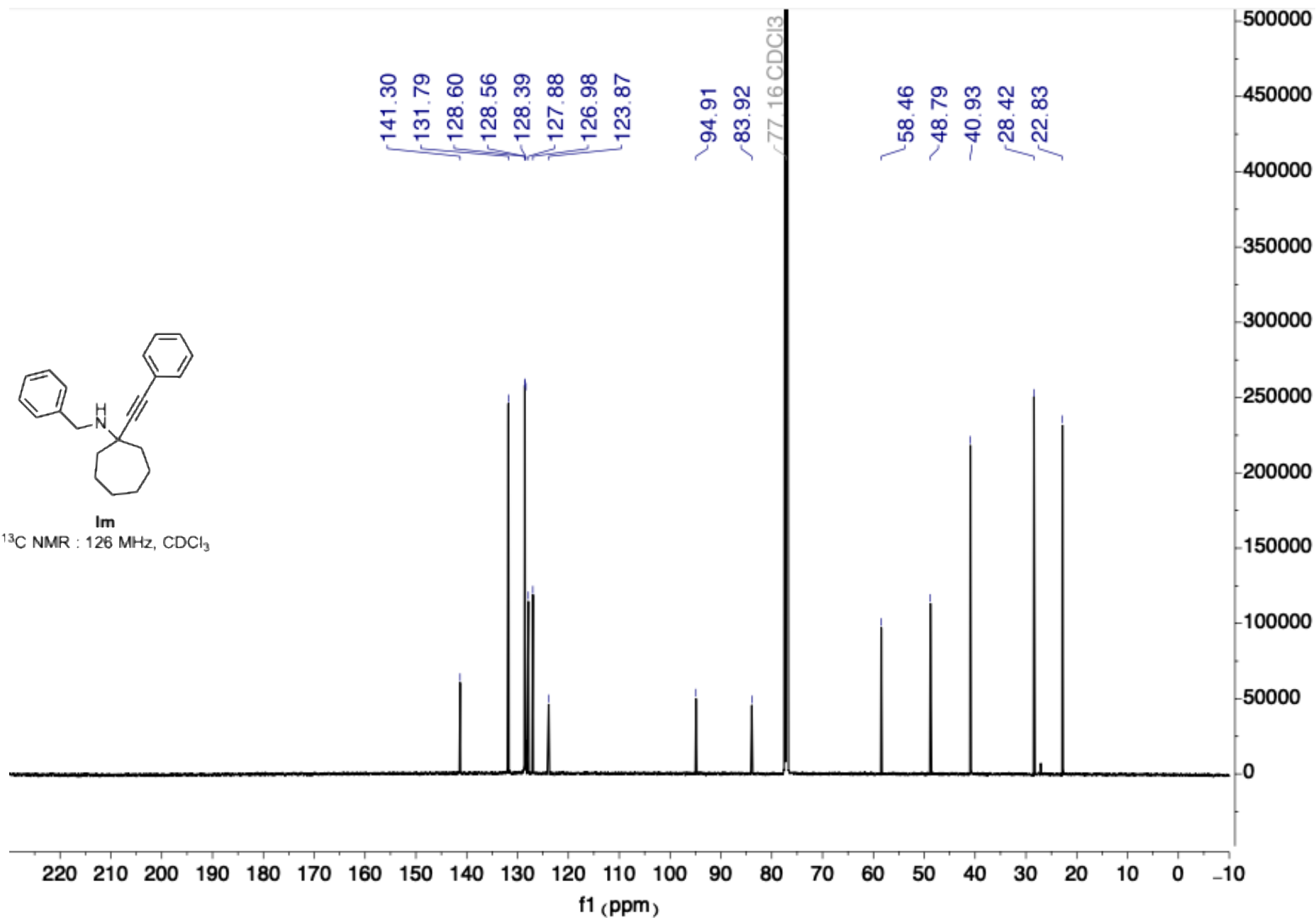


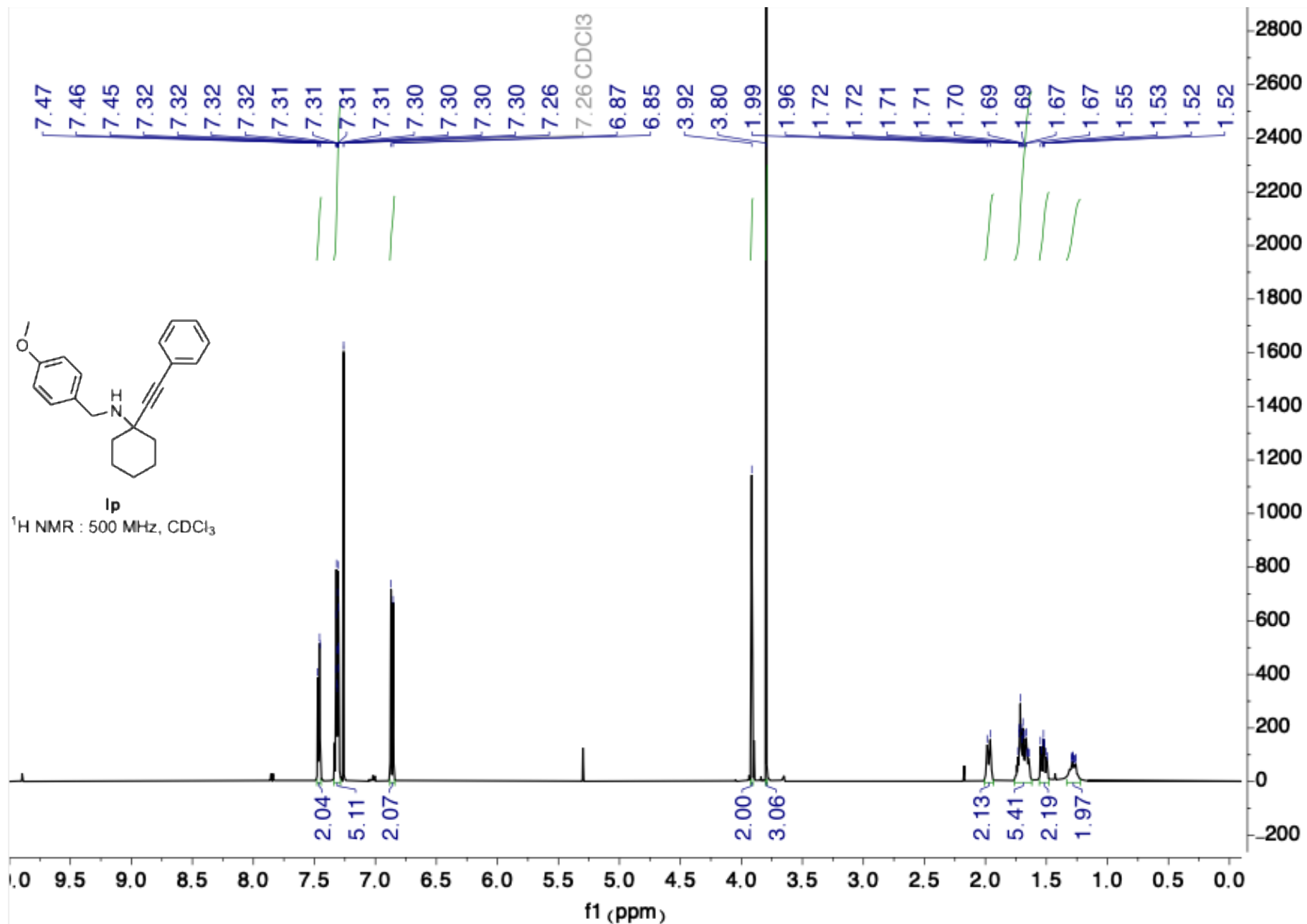


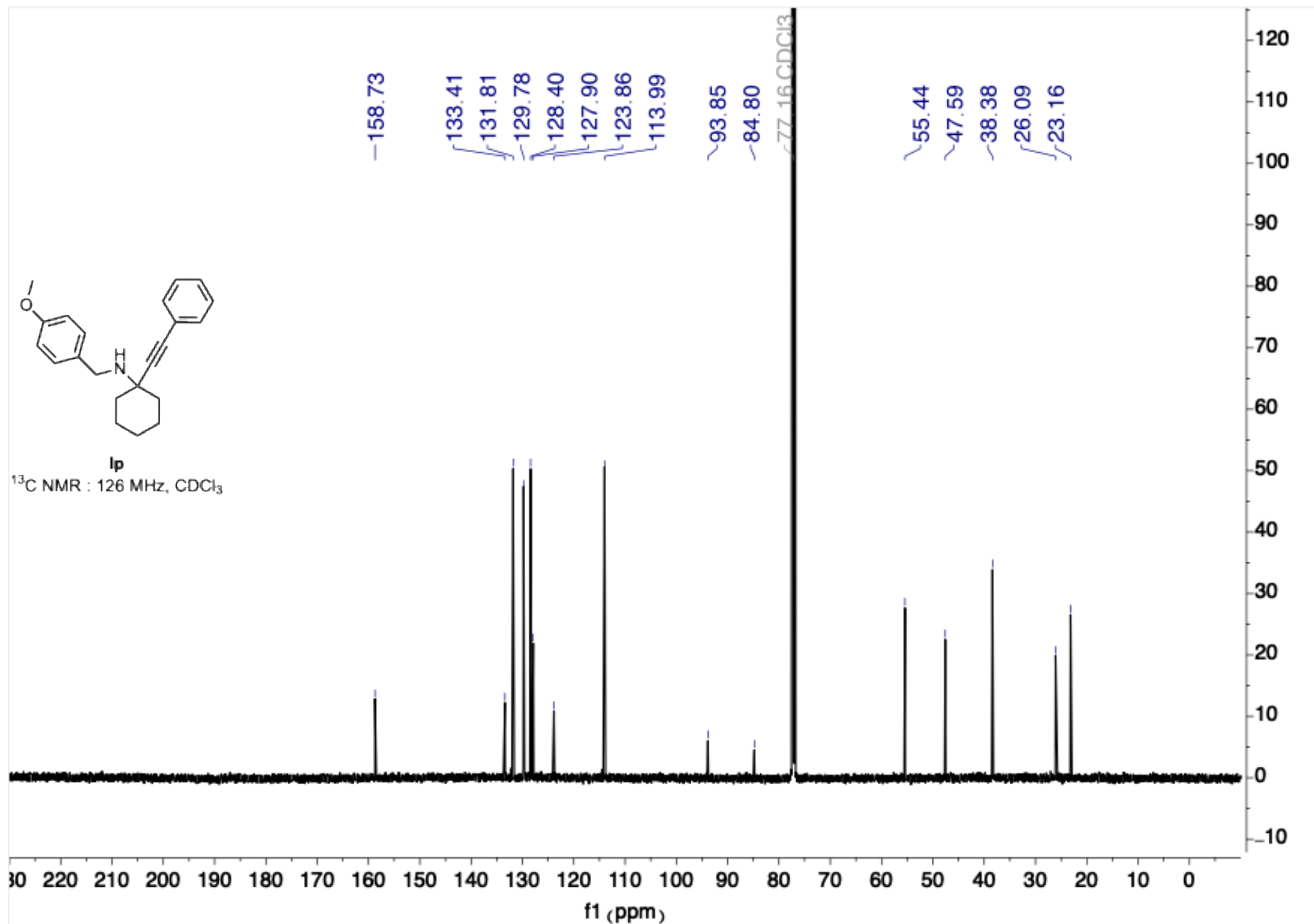


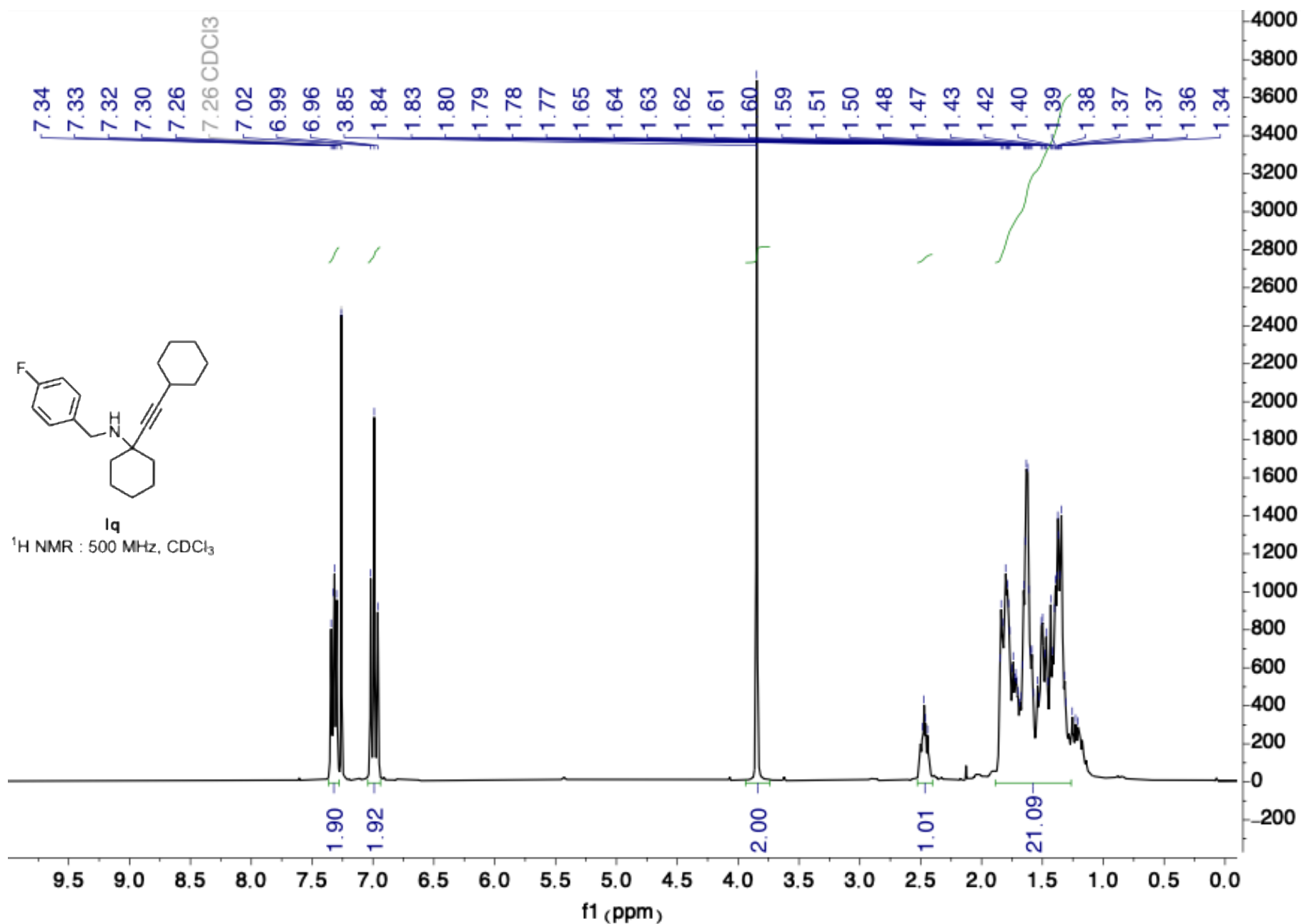
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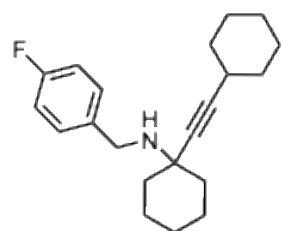
^{13}C NMR : 126 MHz, CDCl_3





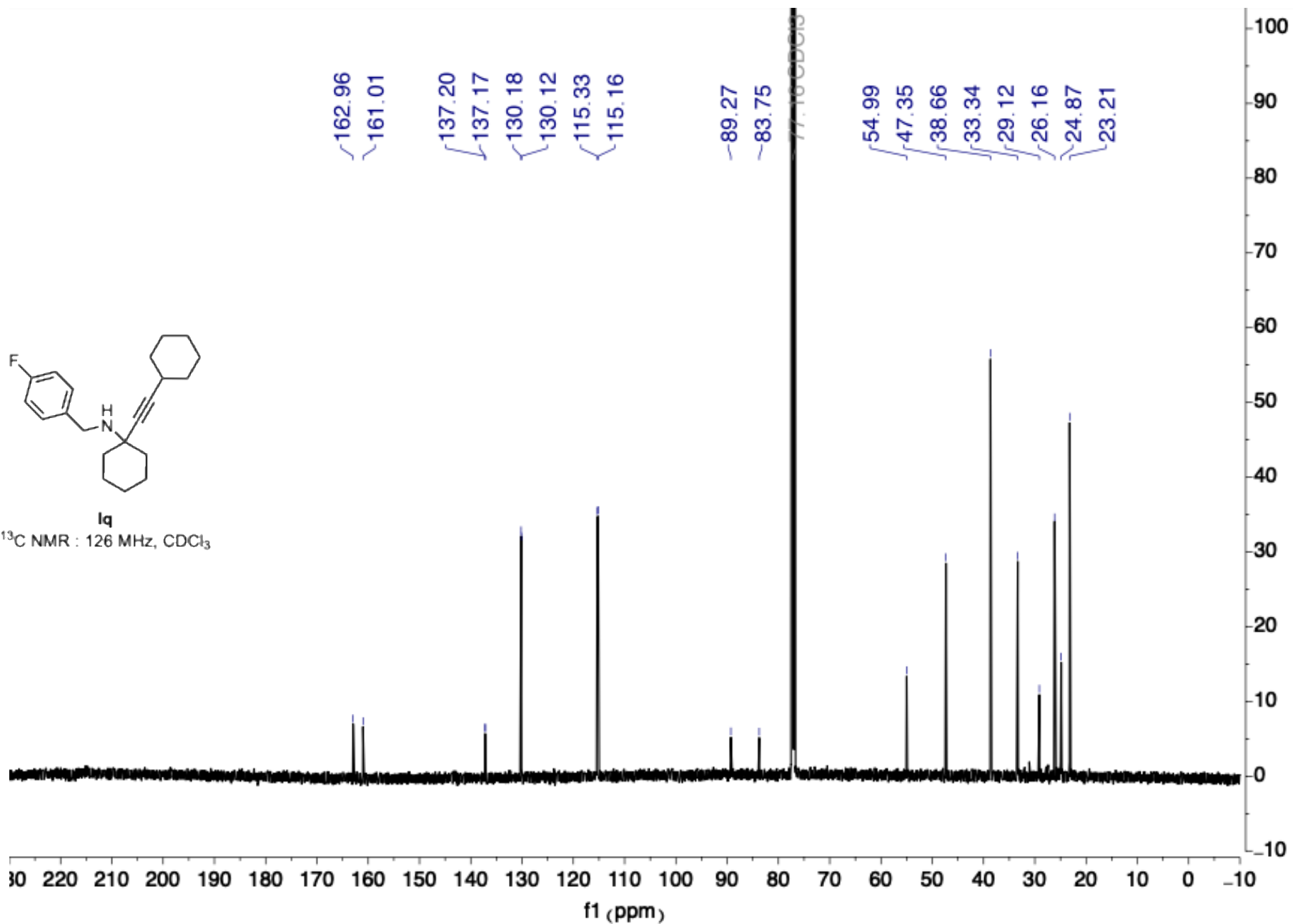


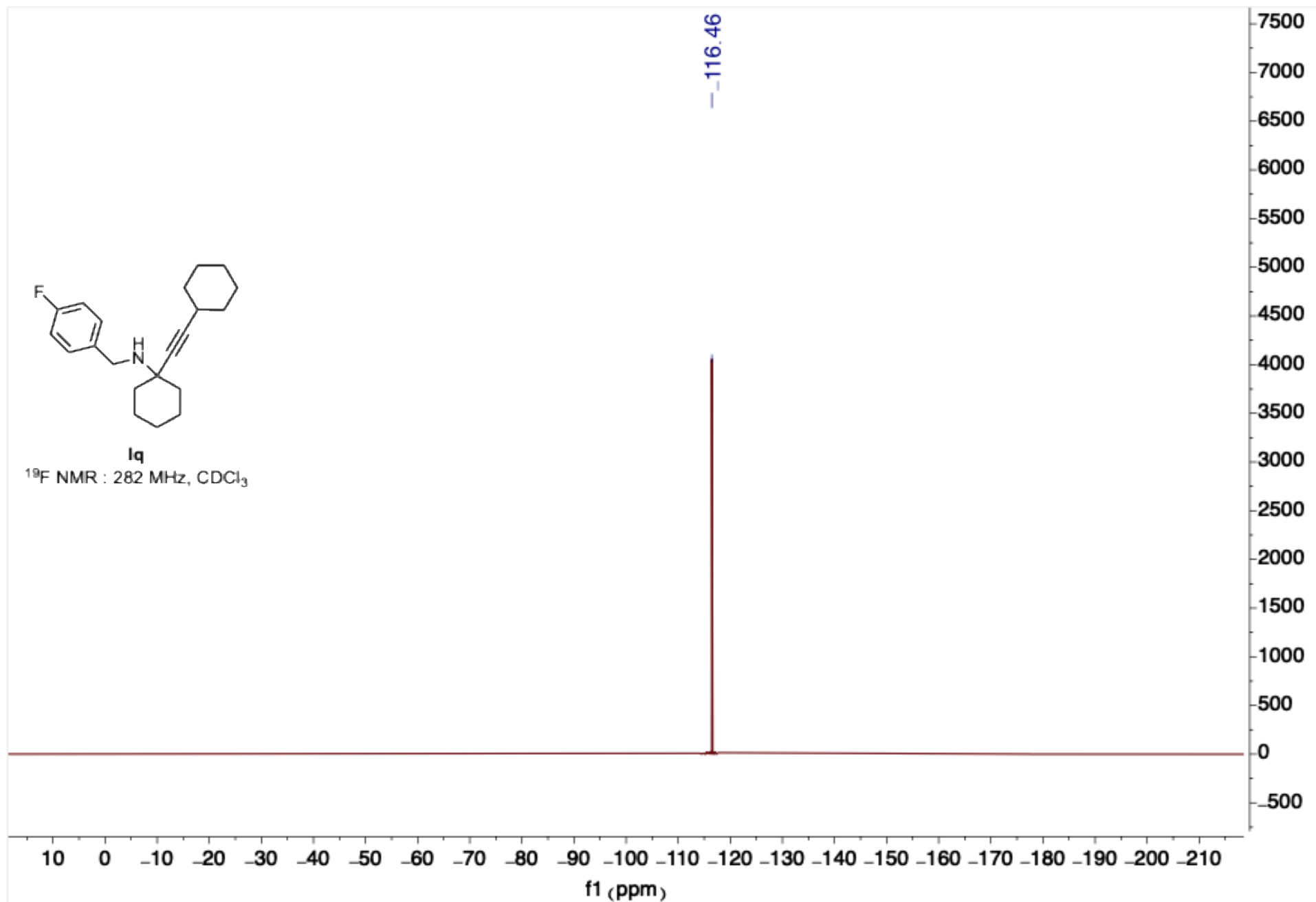


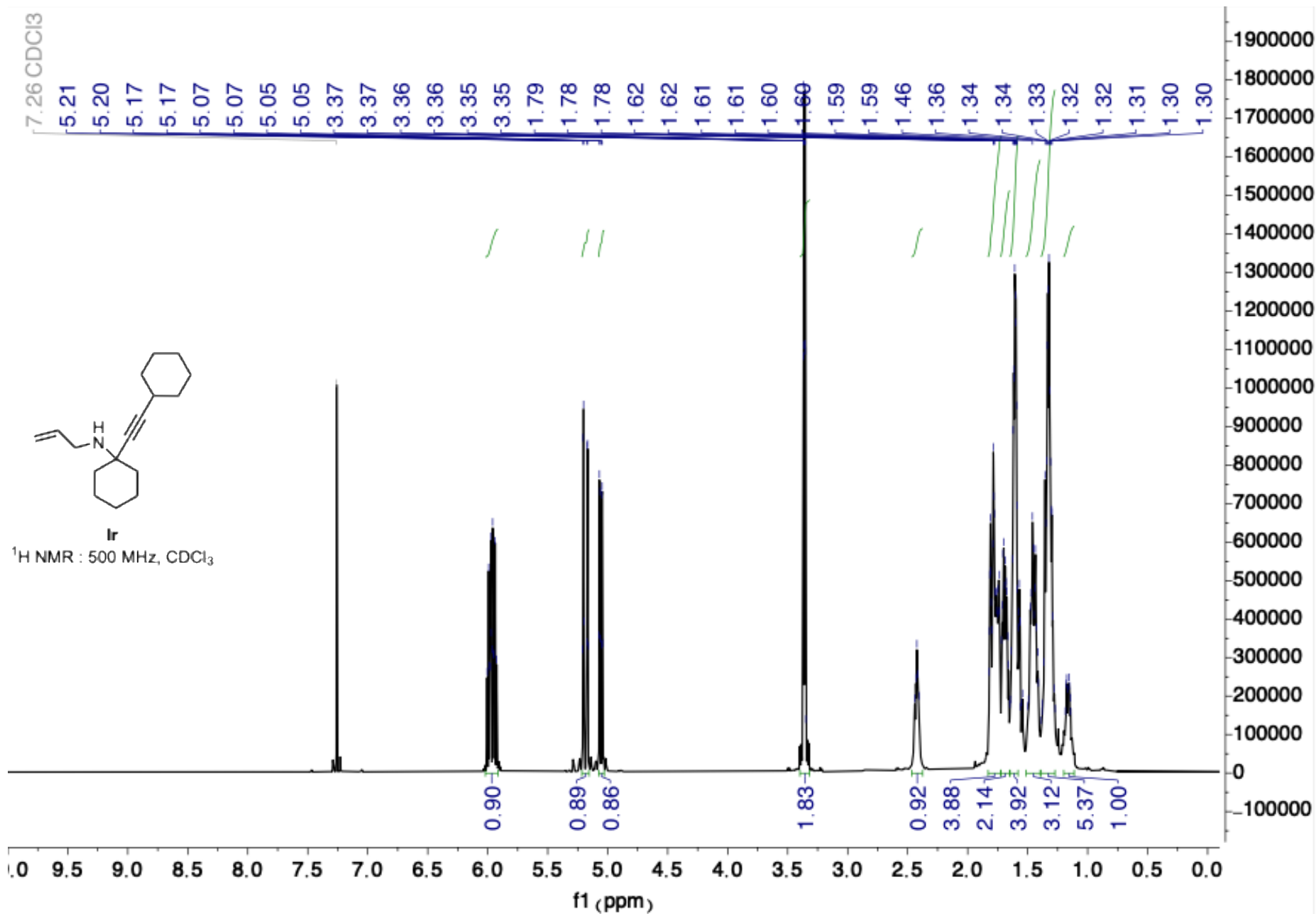


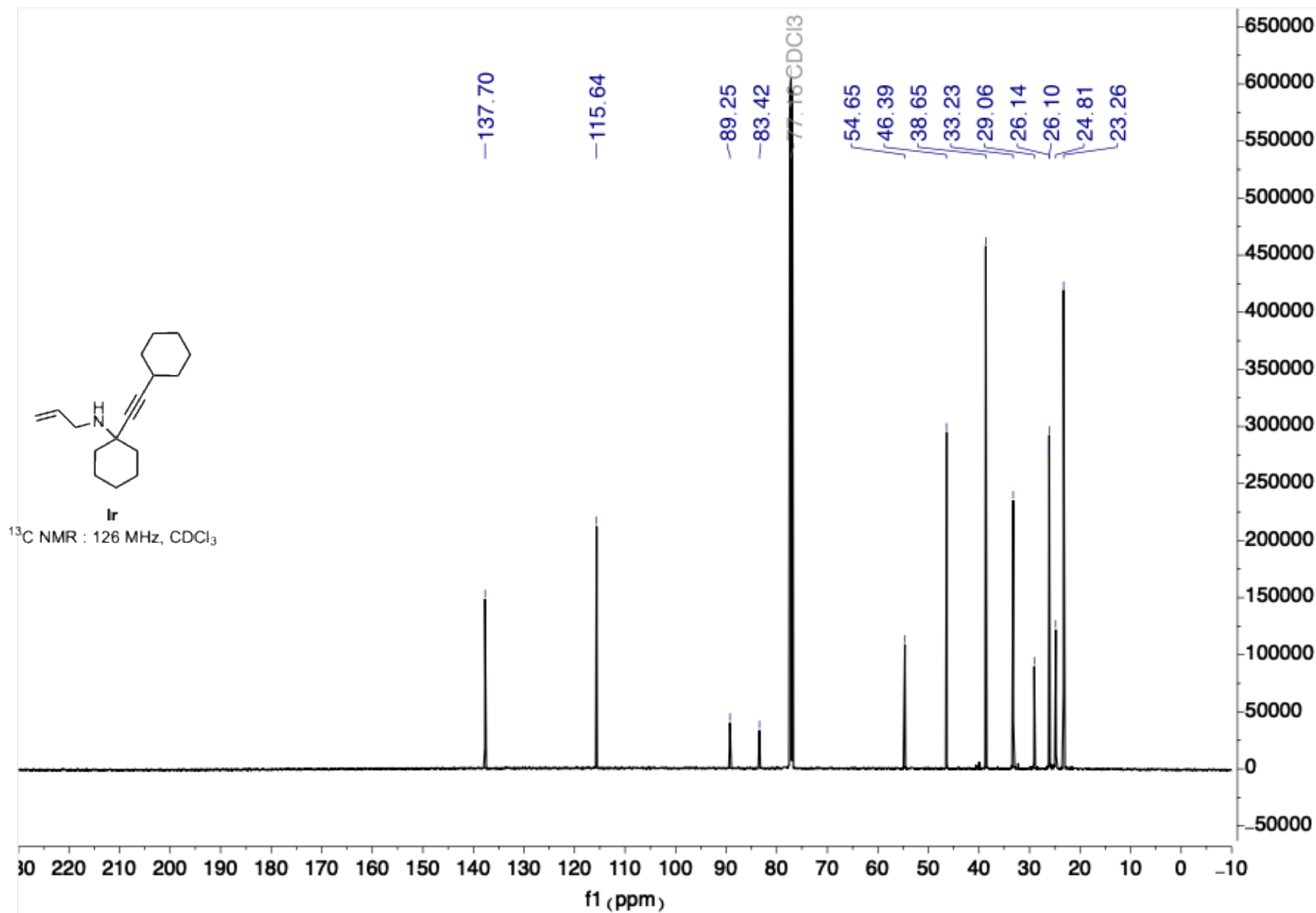
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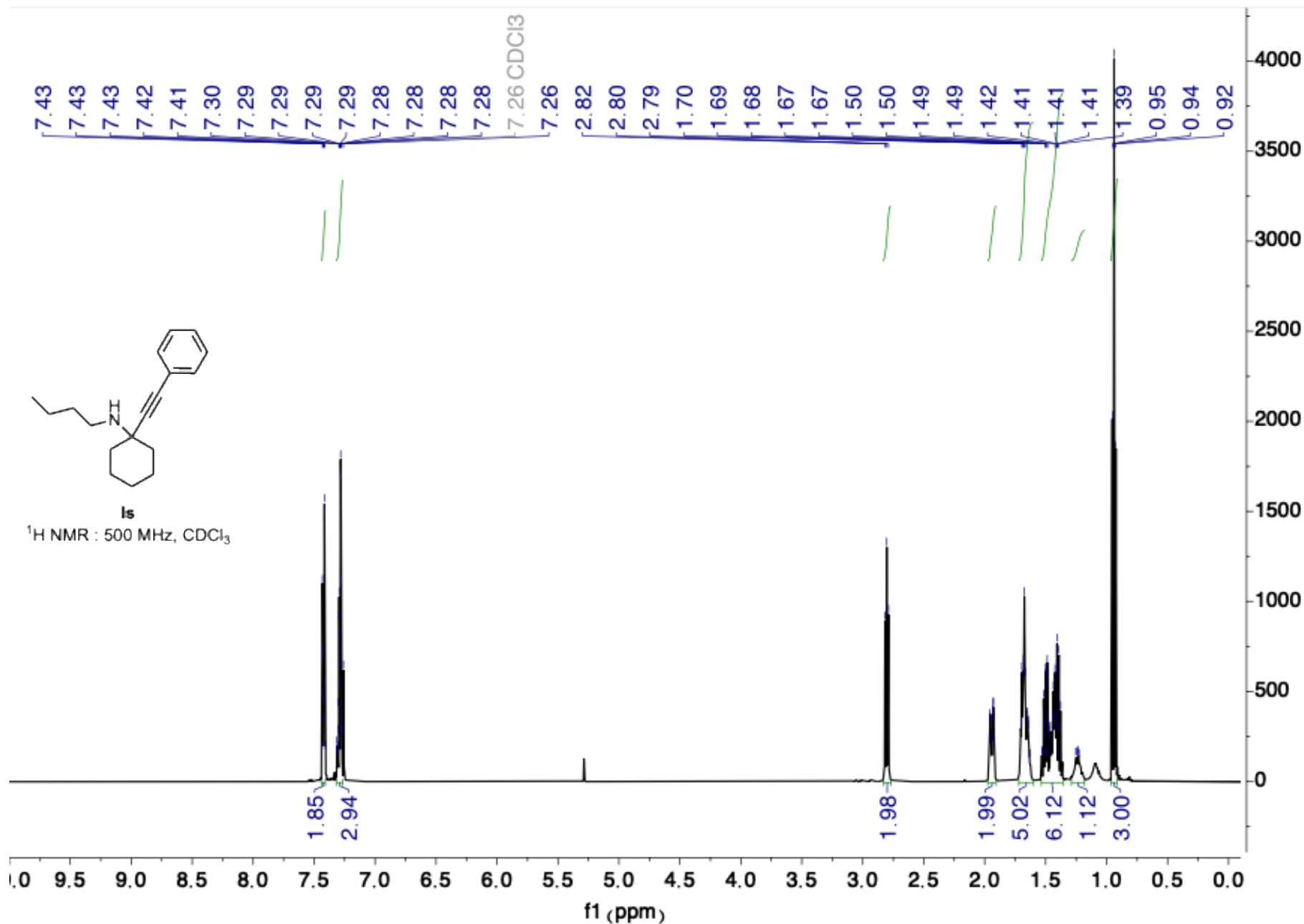
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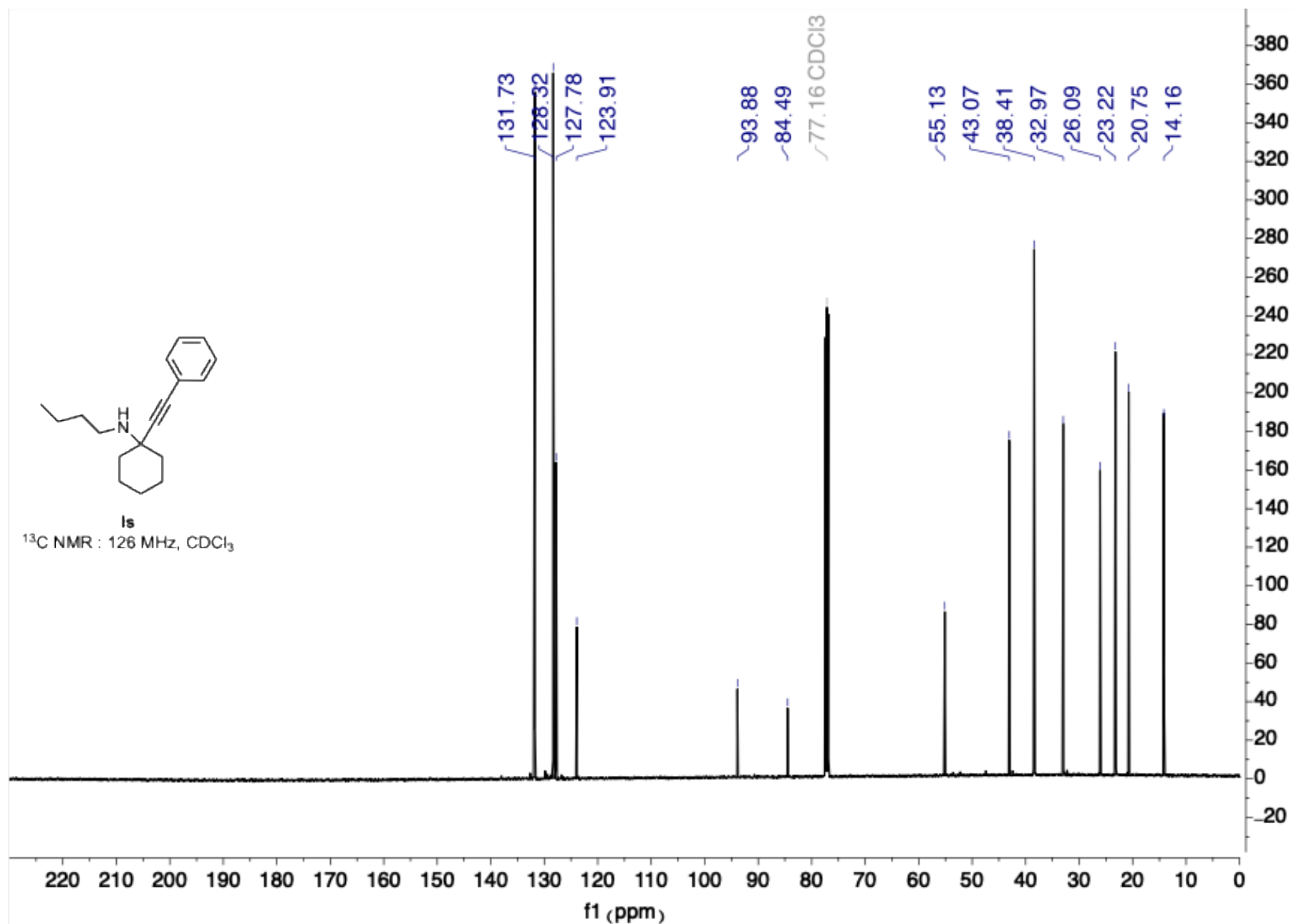


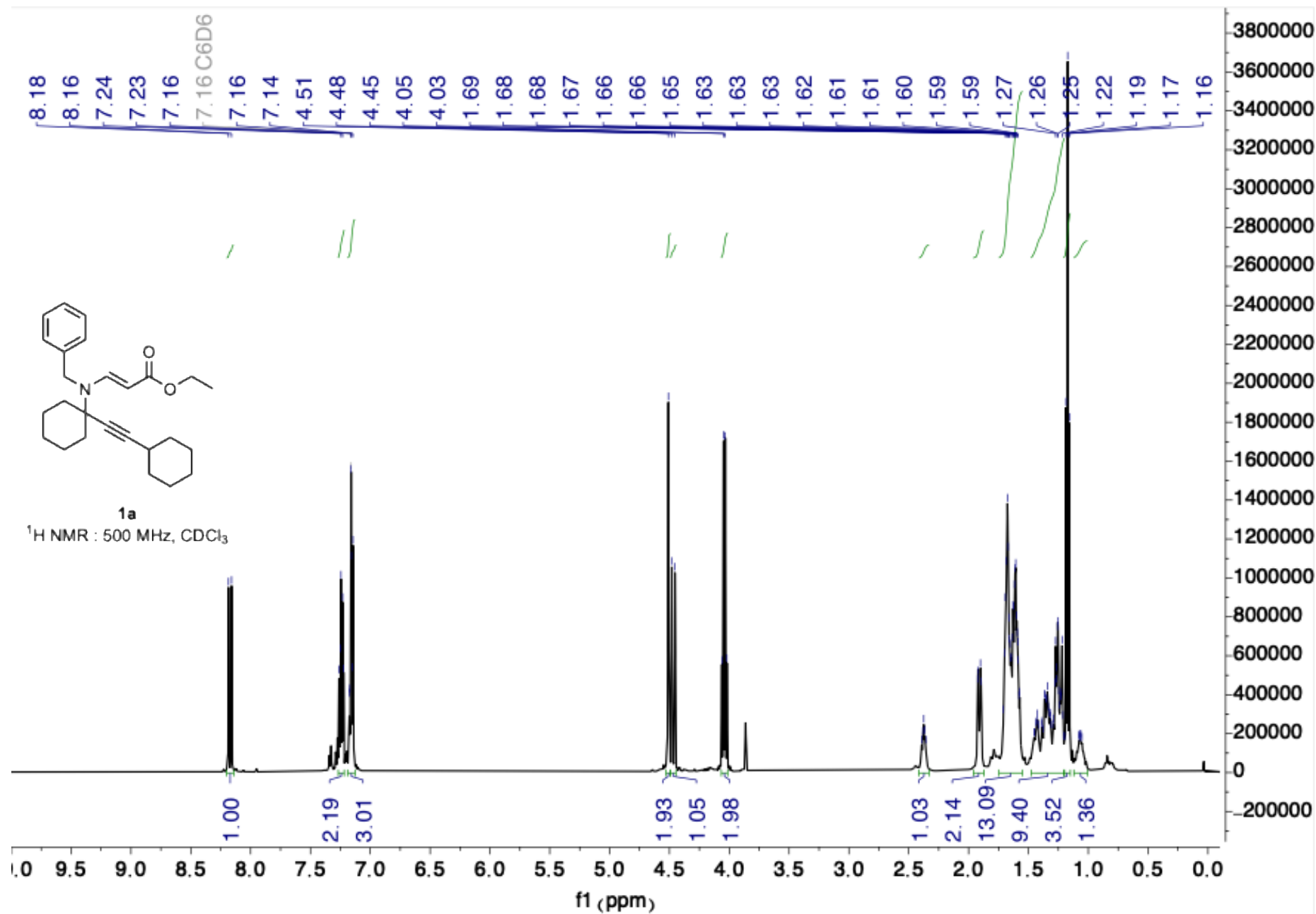


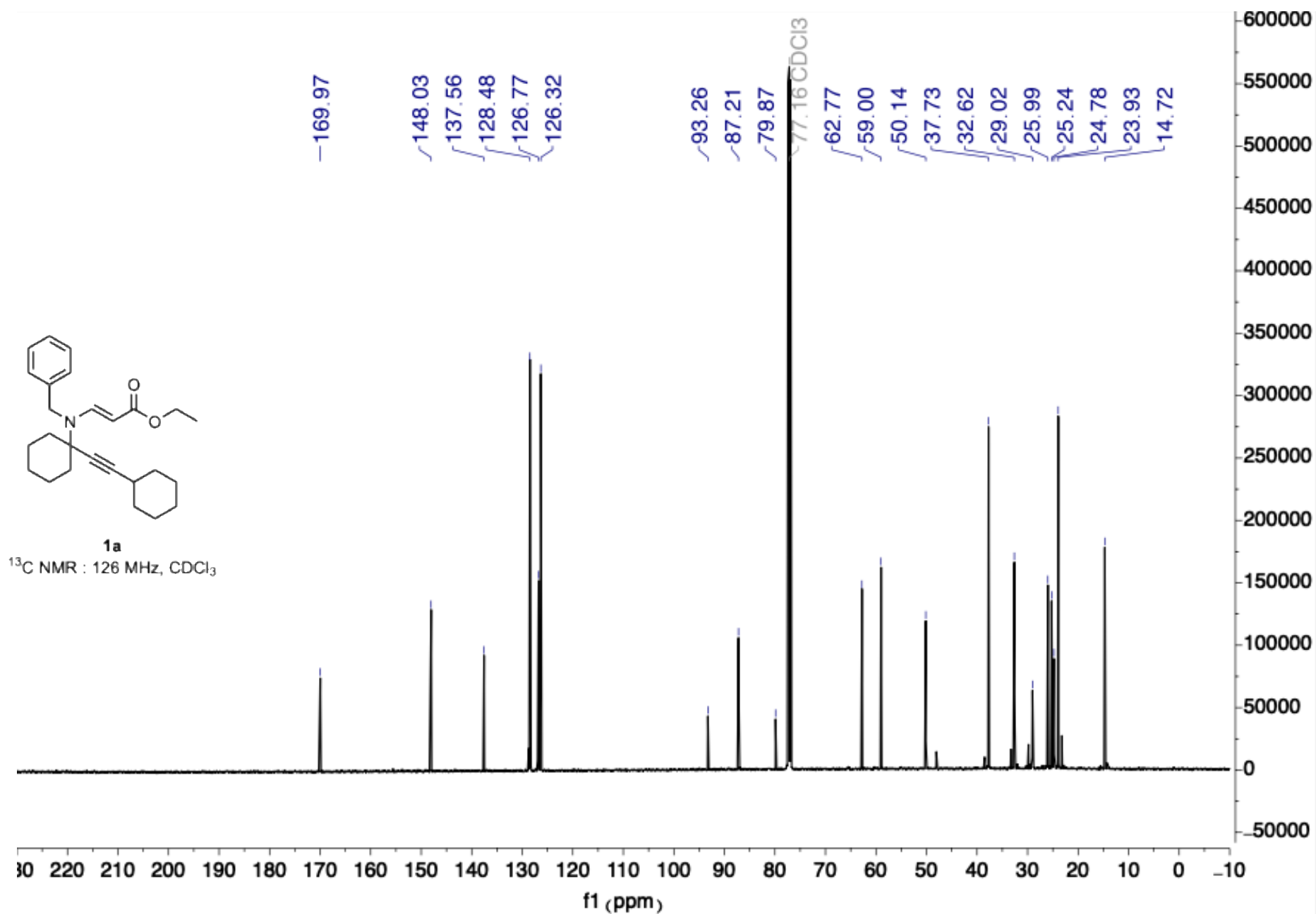


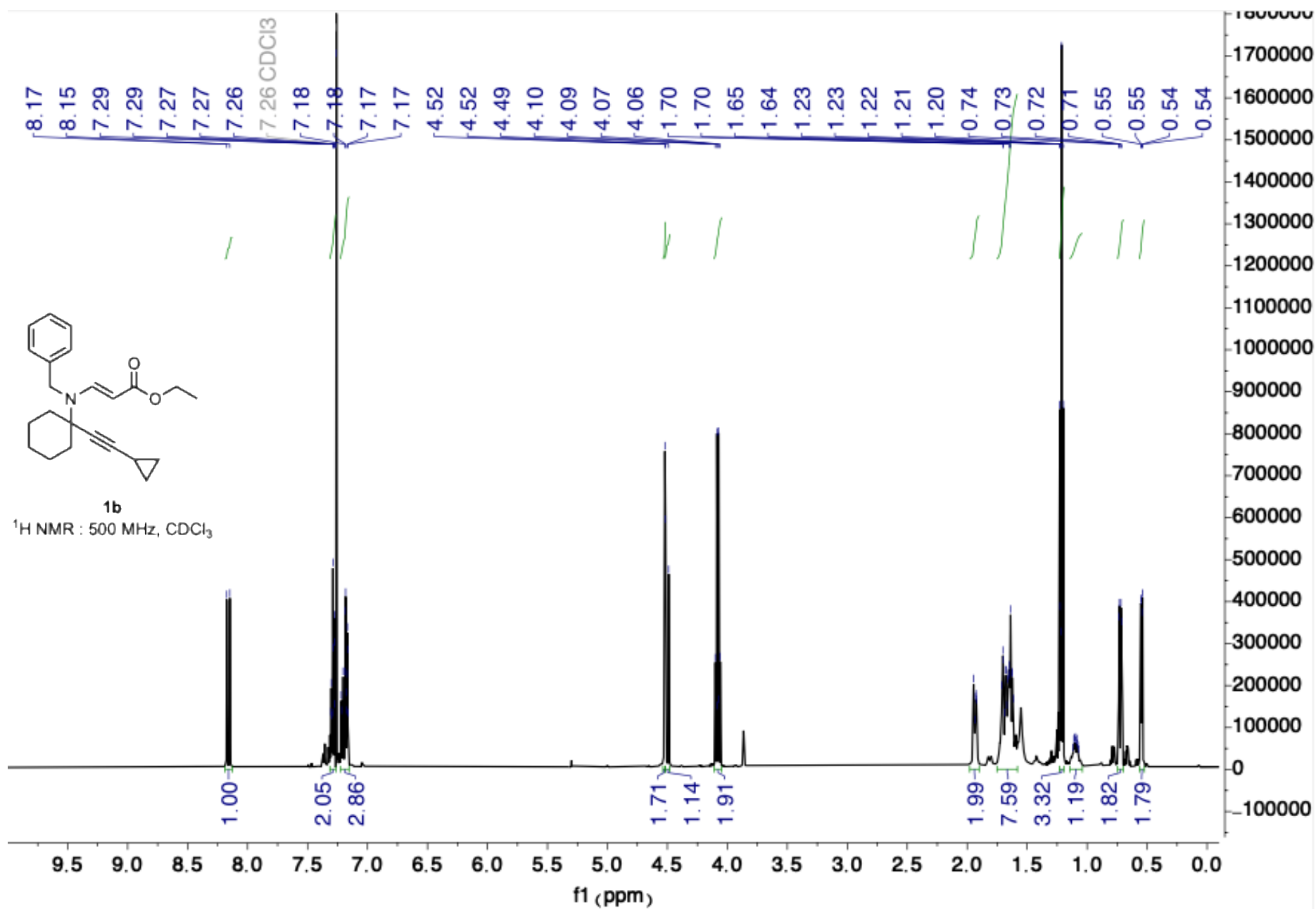


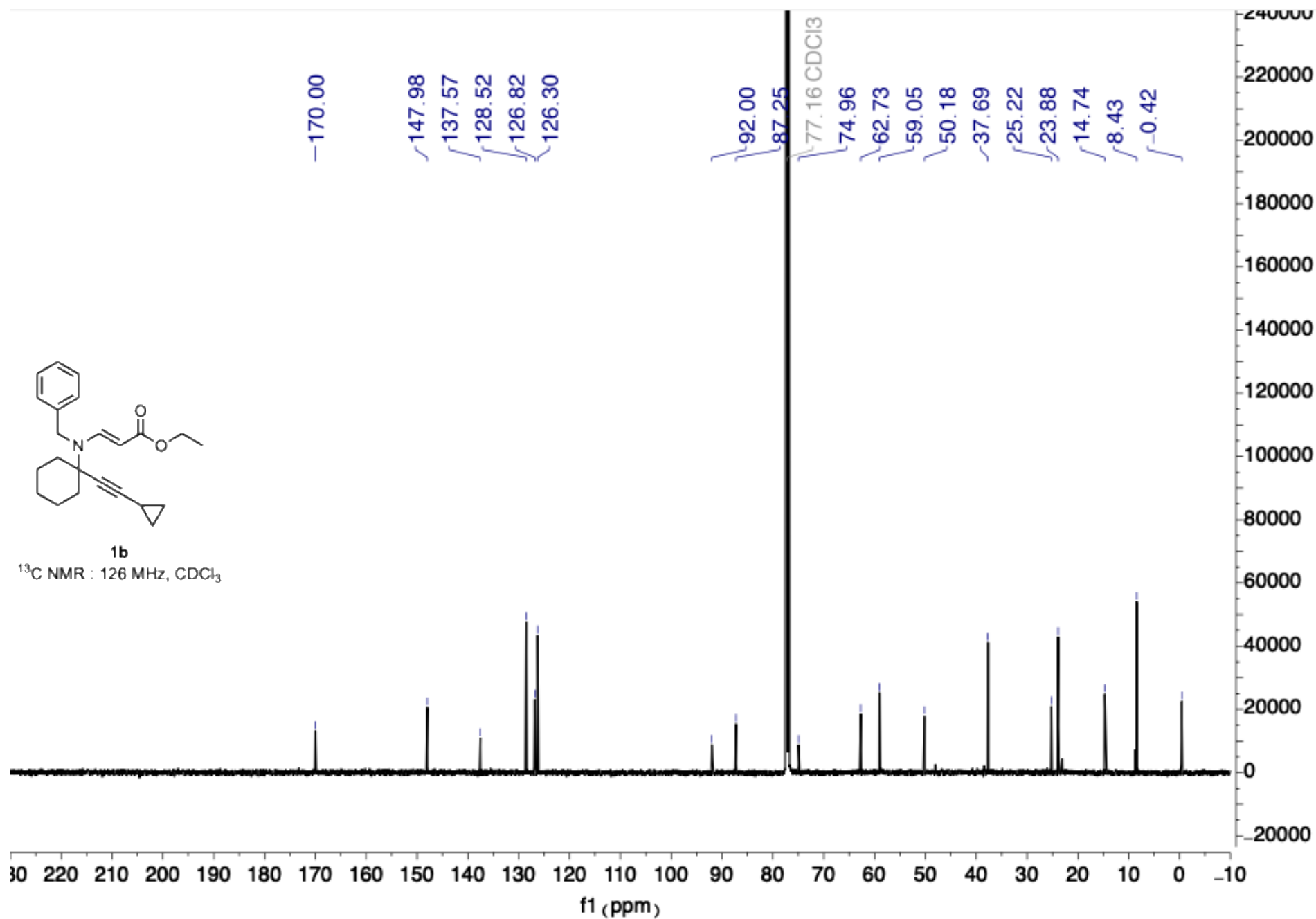


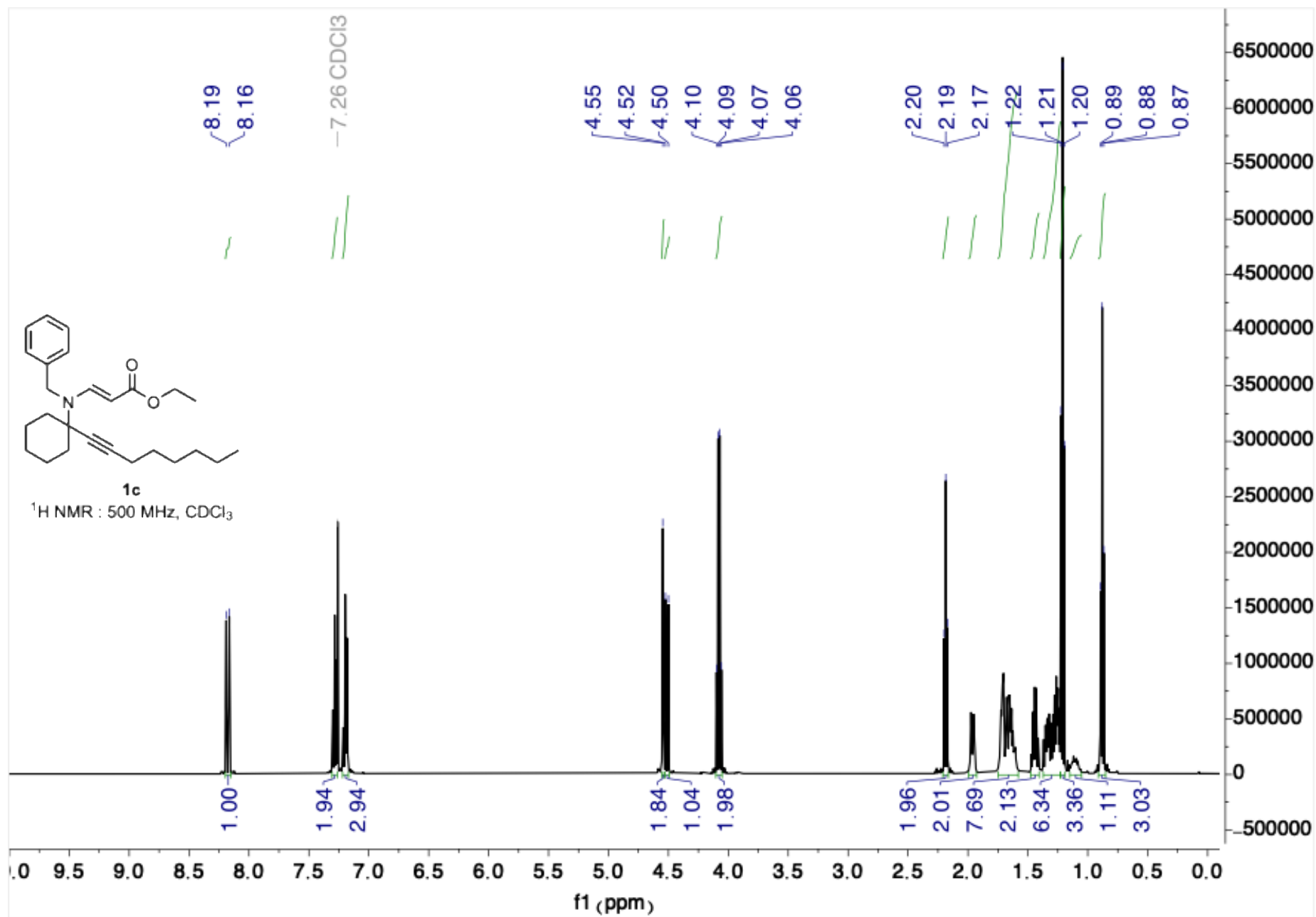


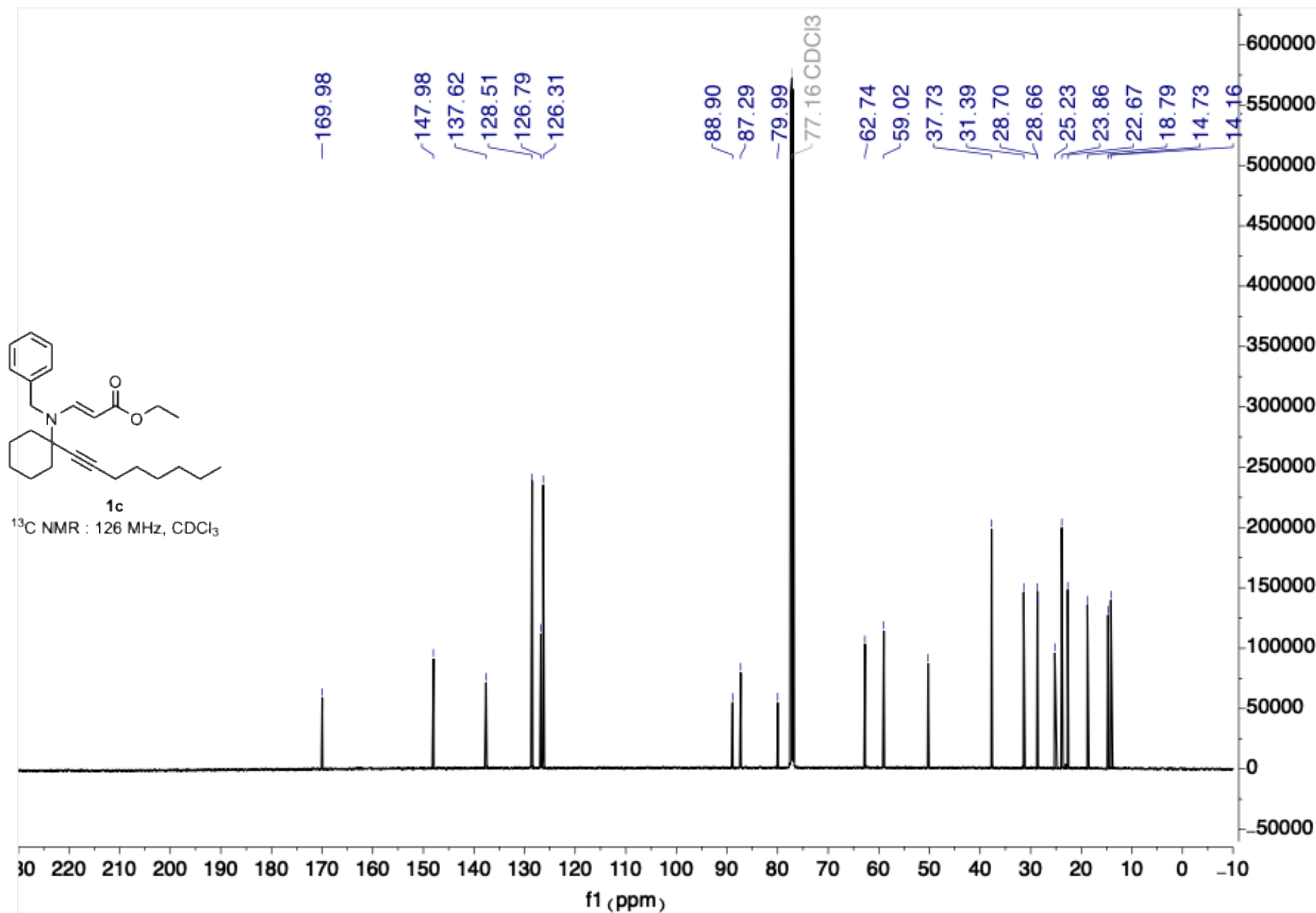


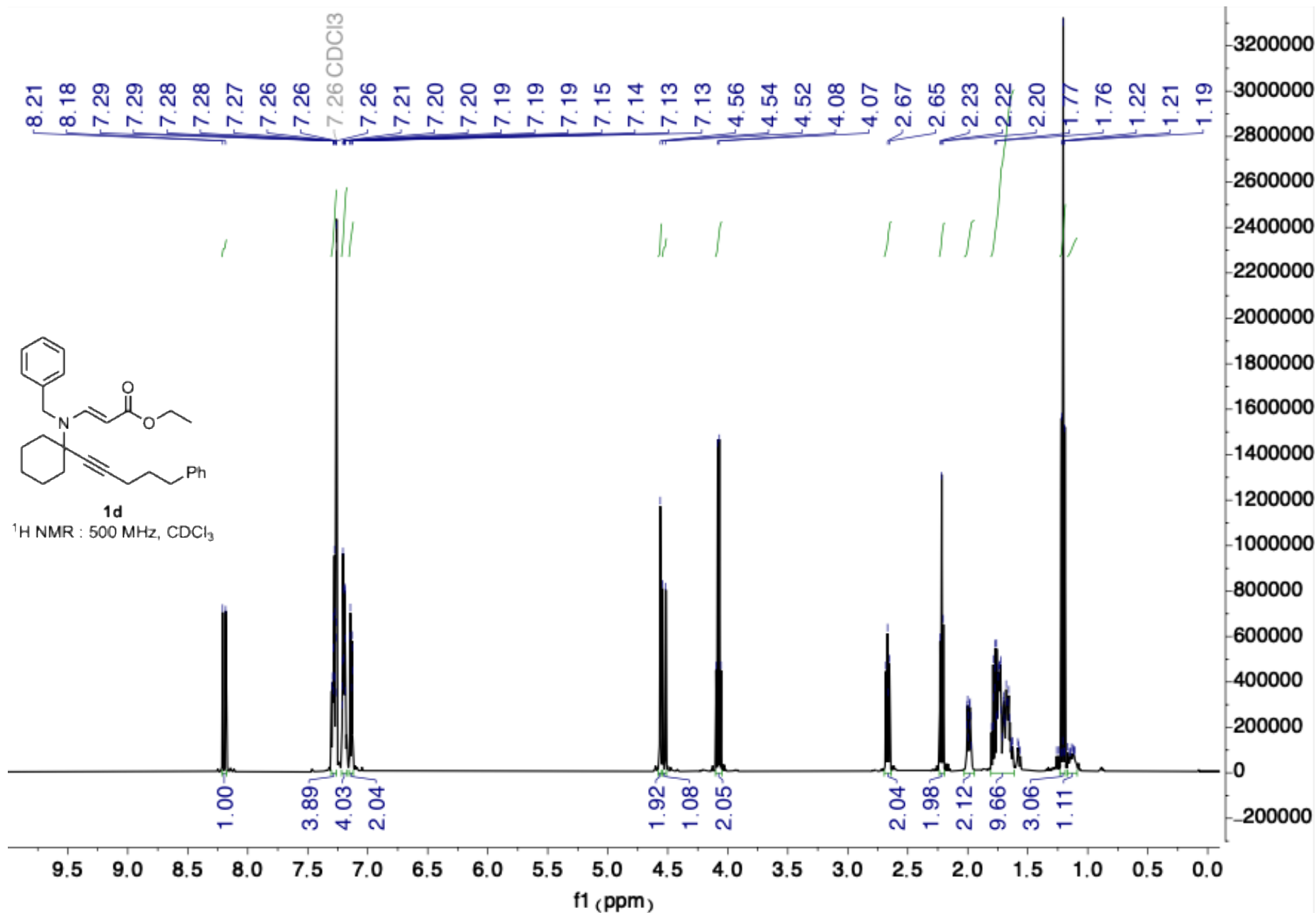


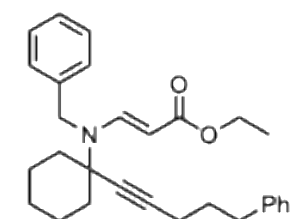






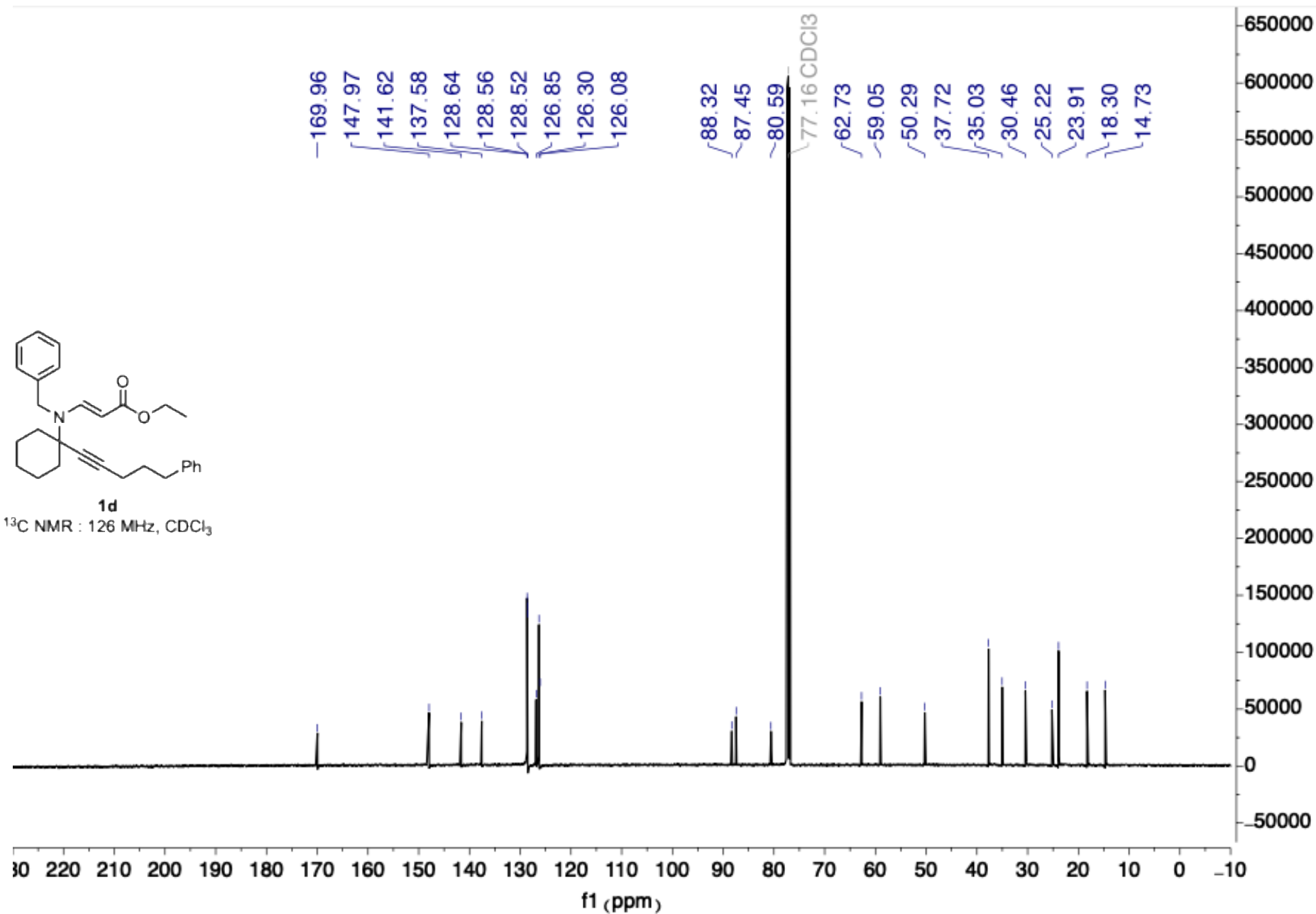


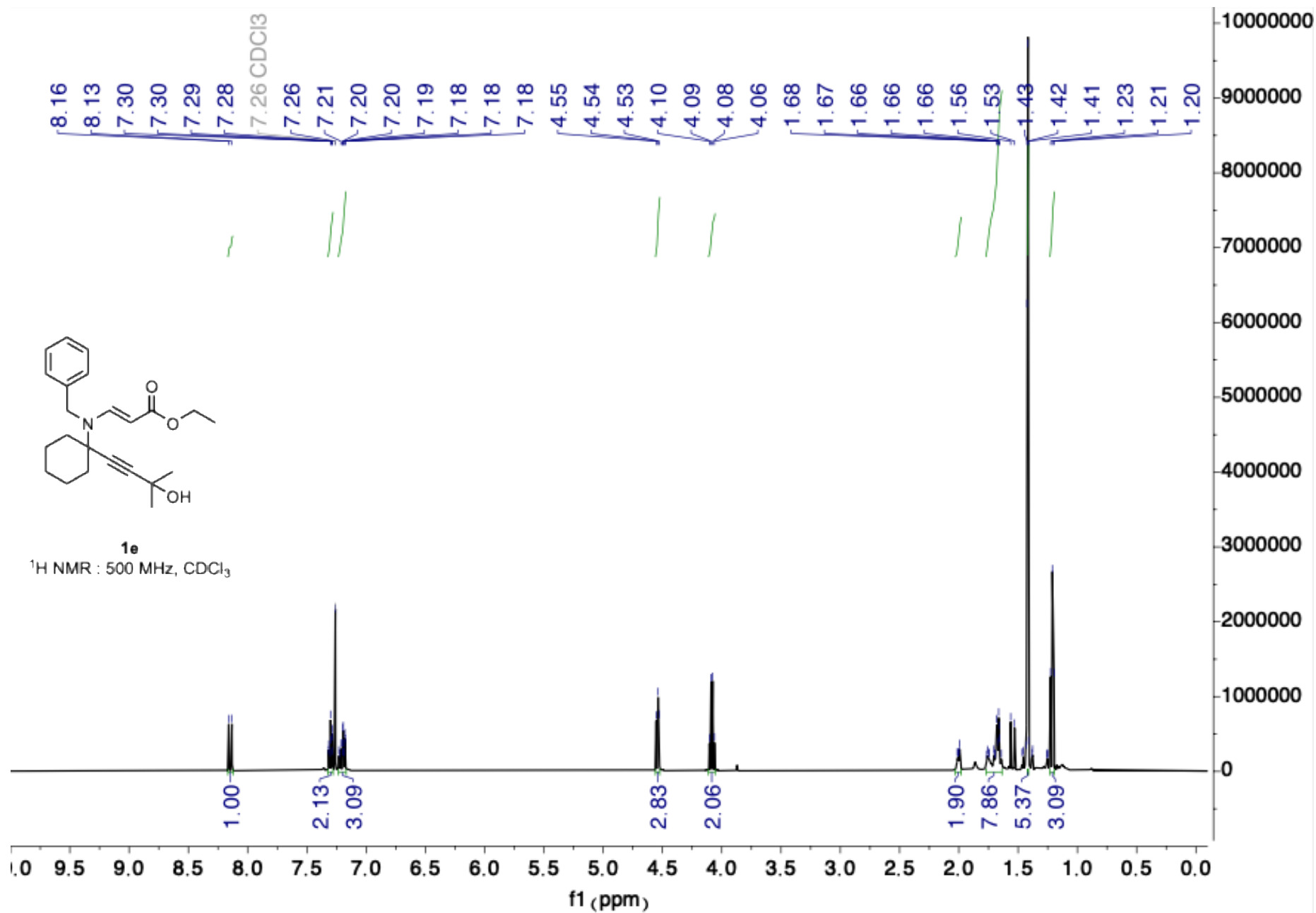


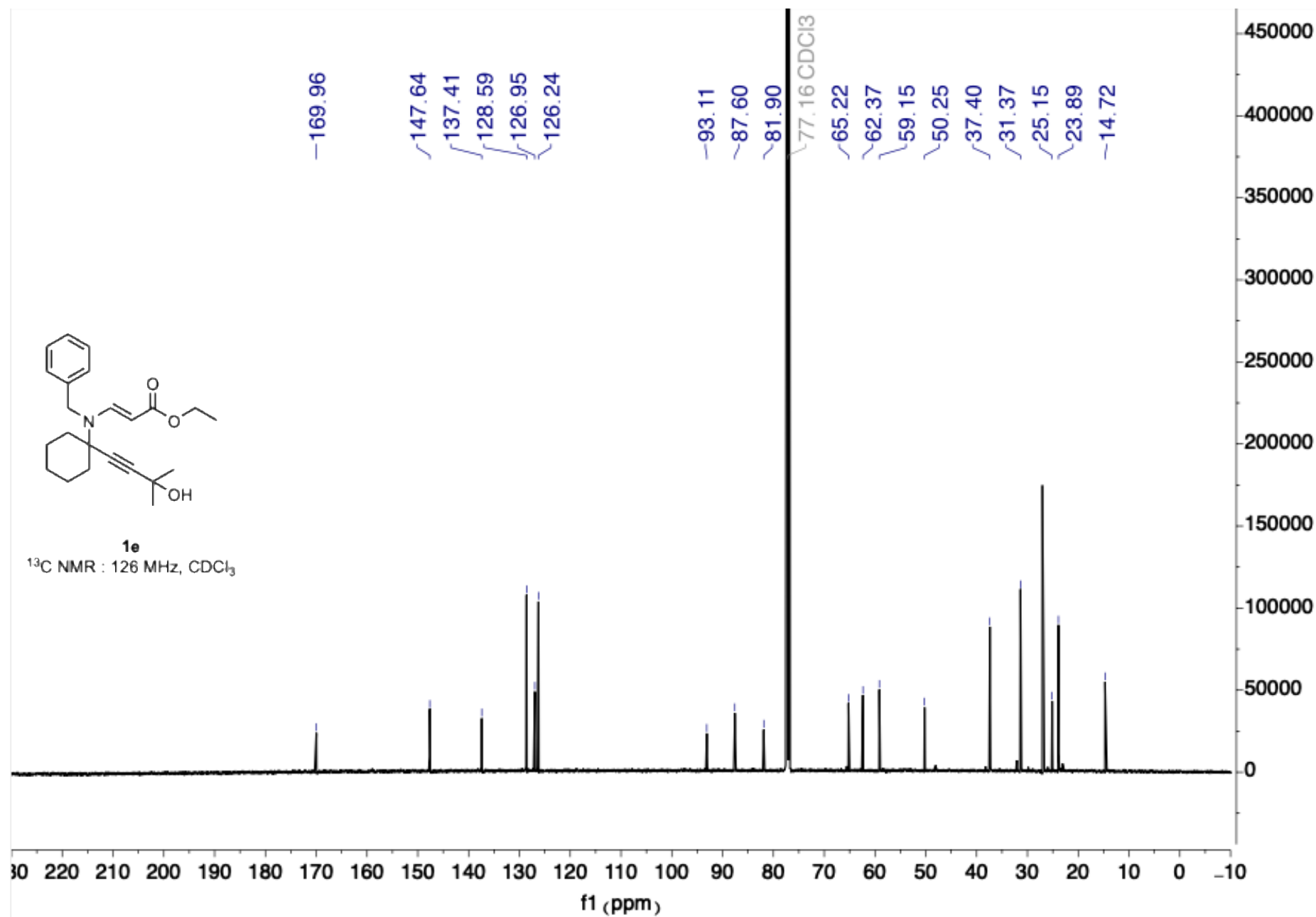


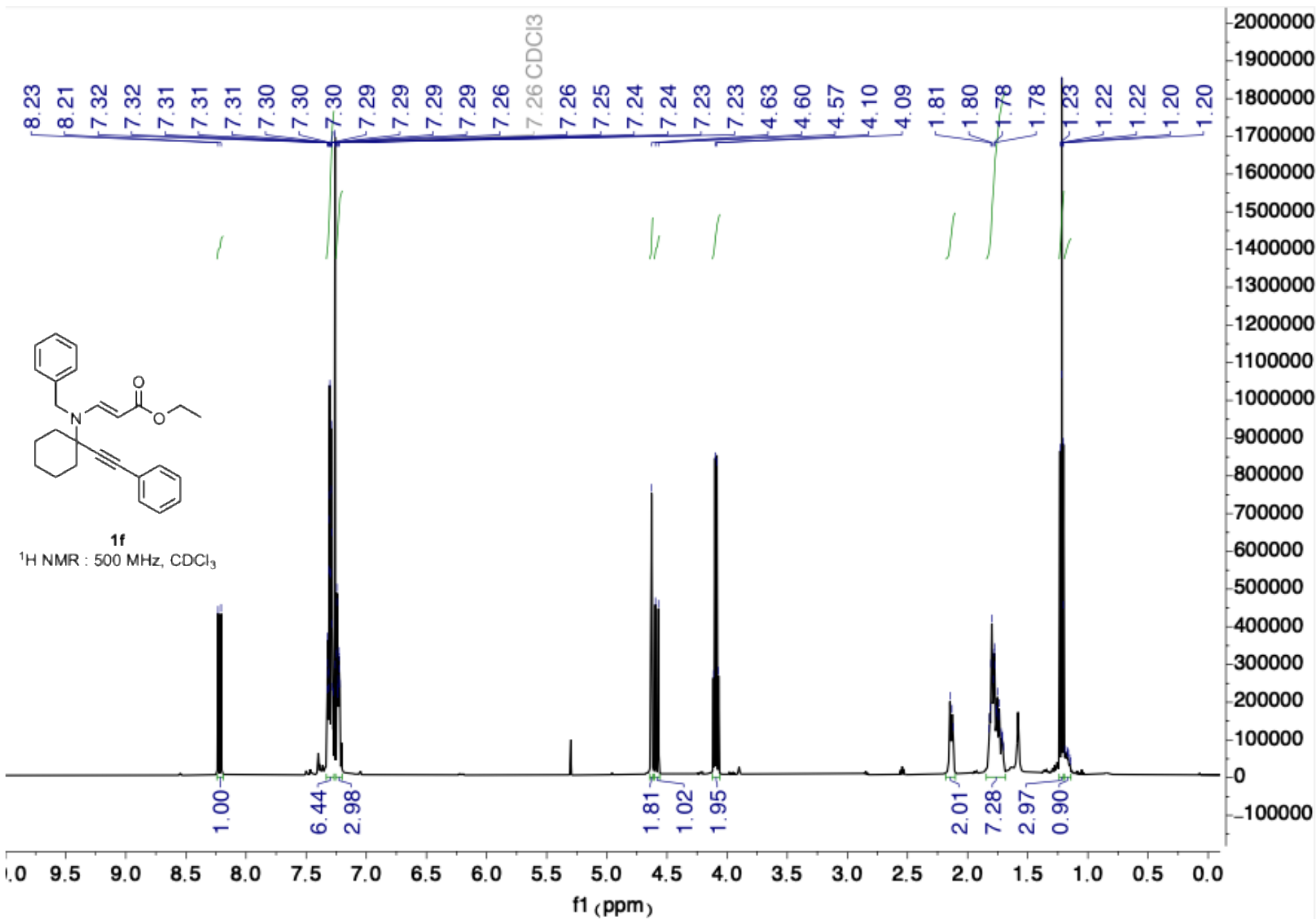
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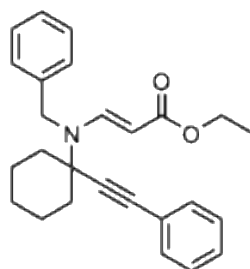
^{13}C NMR : 126 MHz, CDCl_3





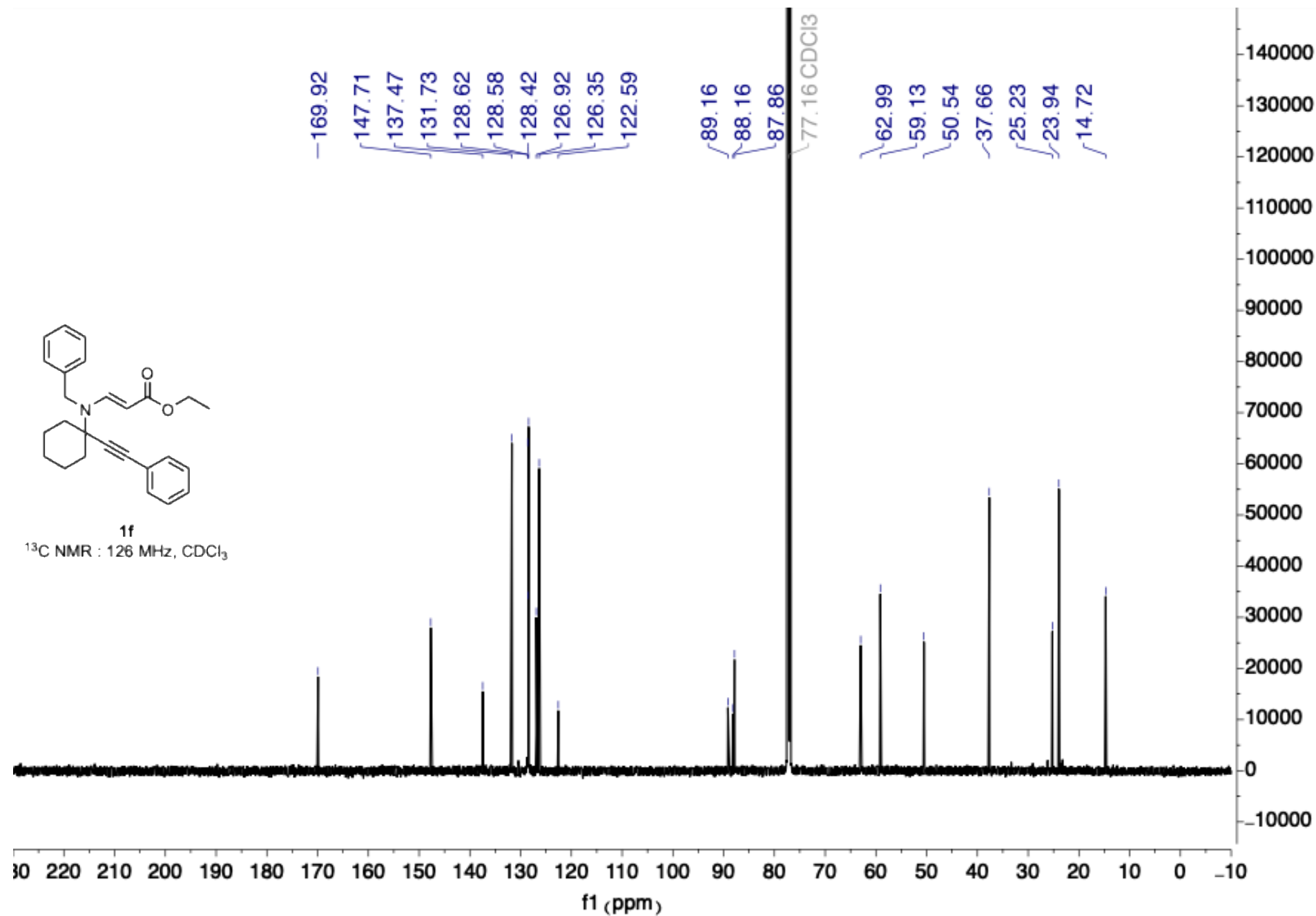


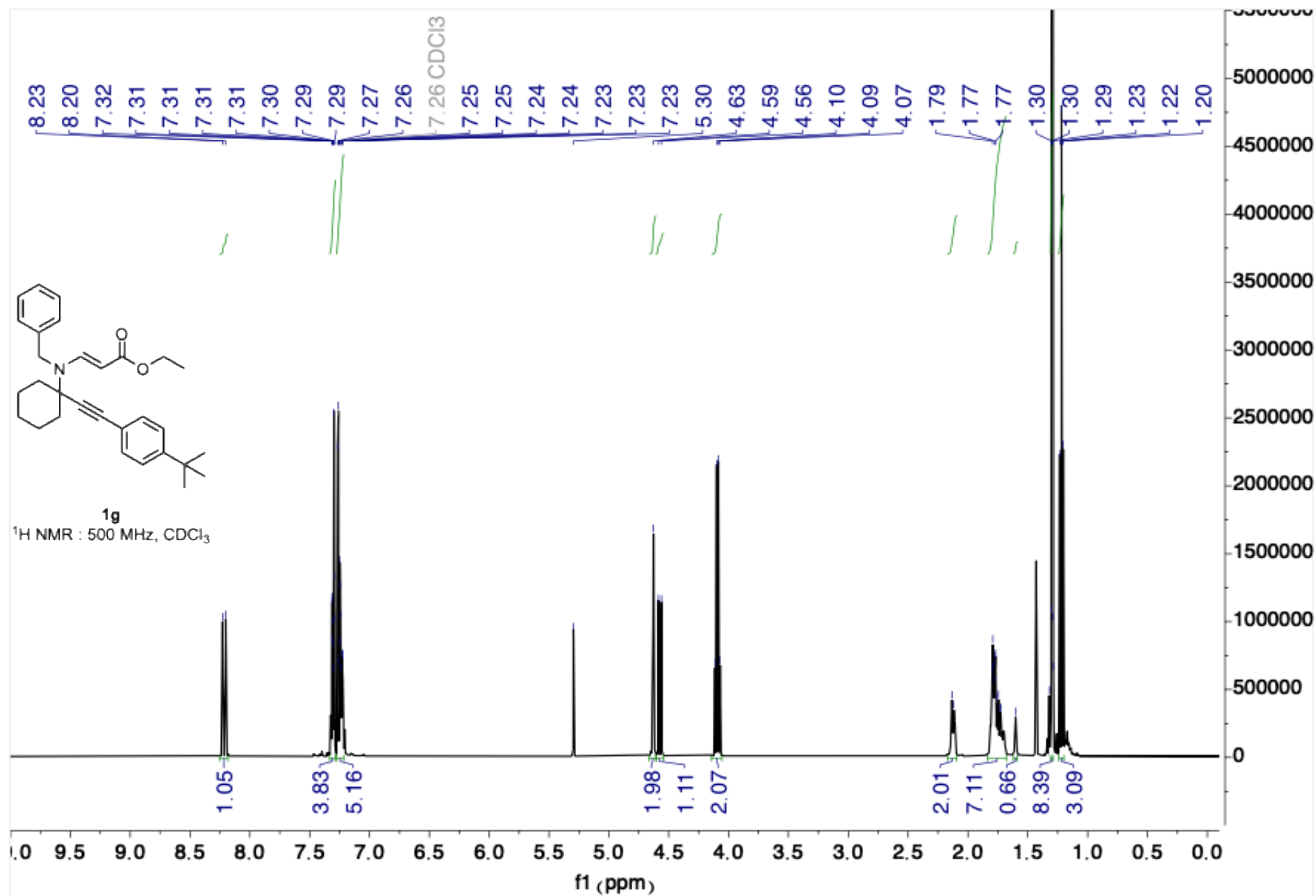


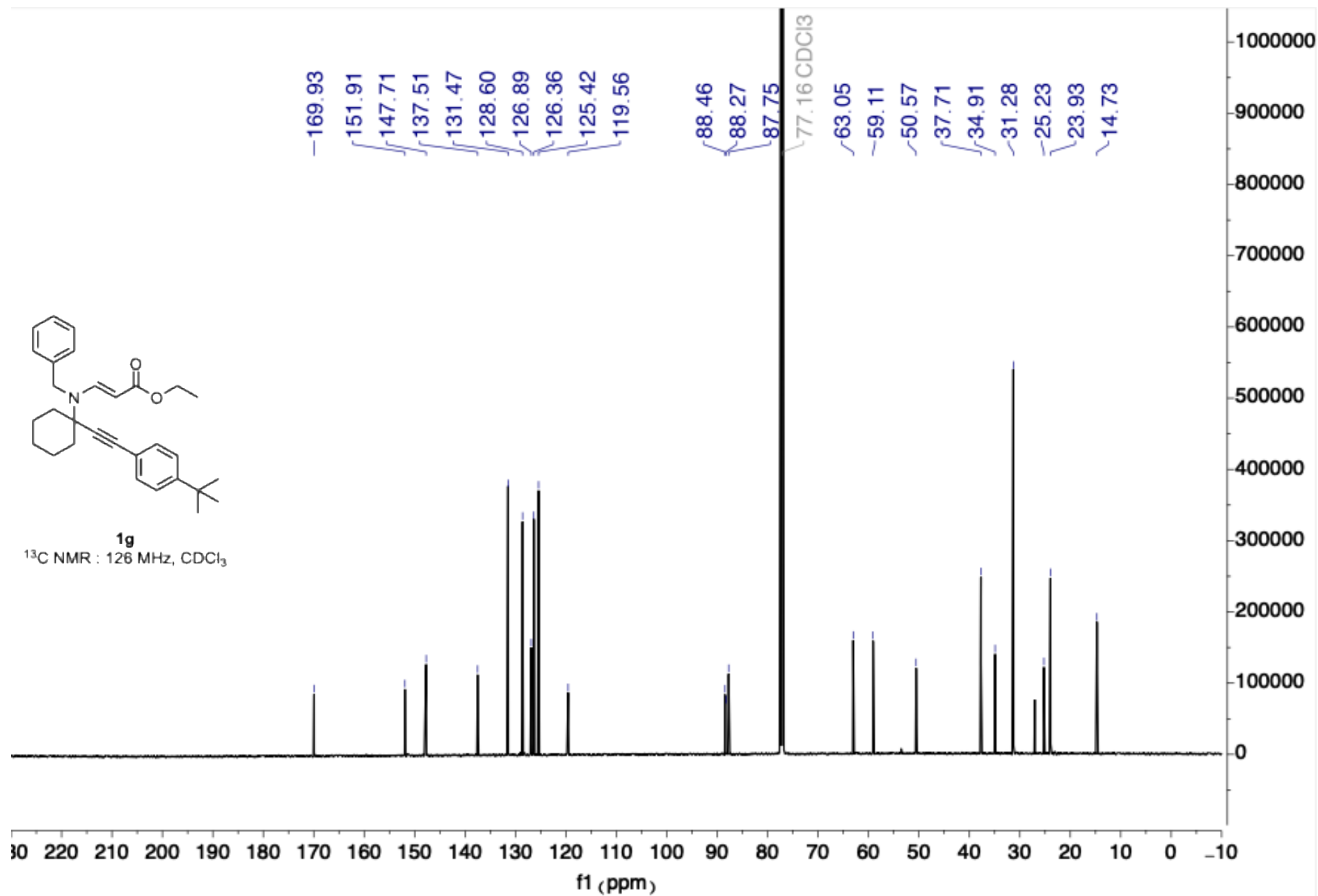


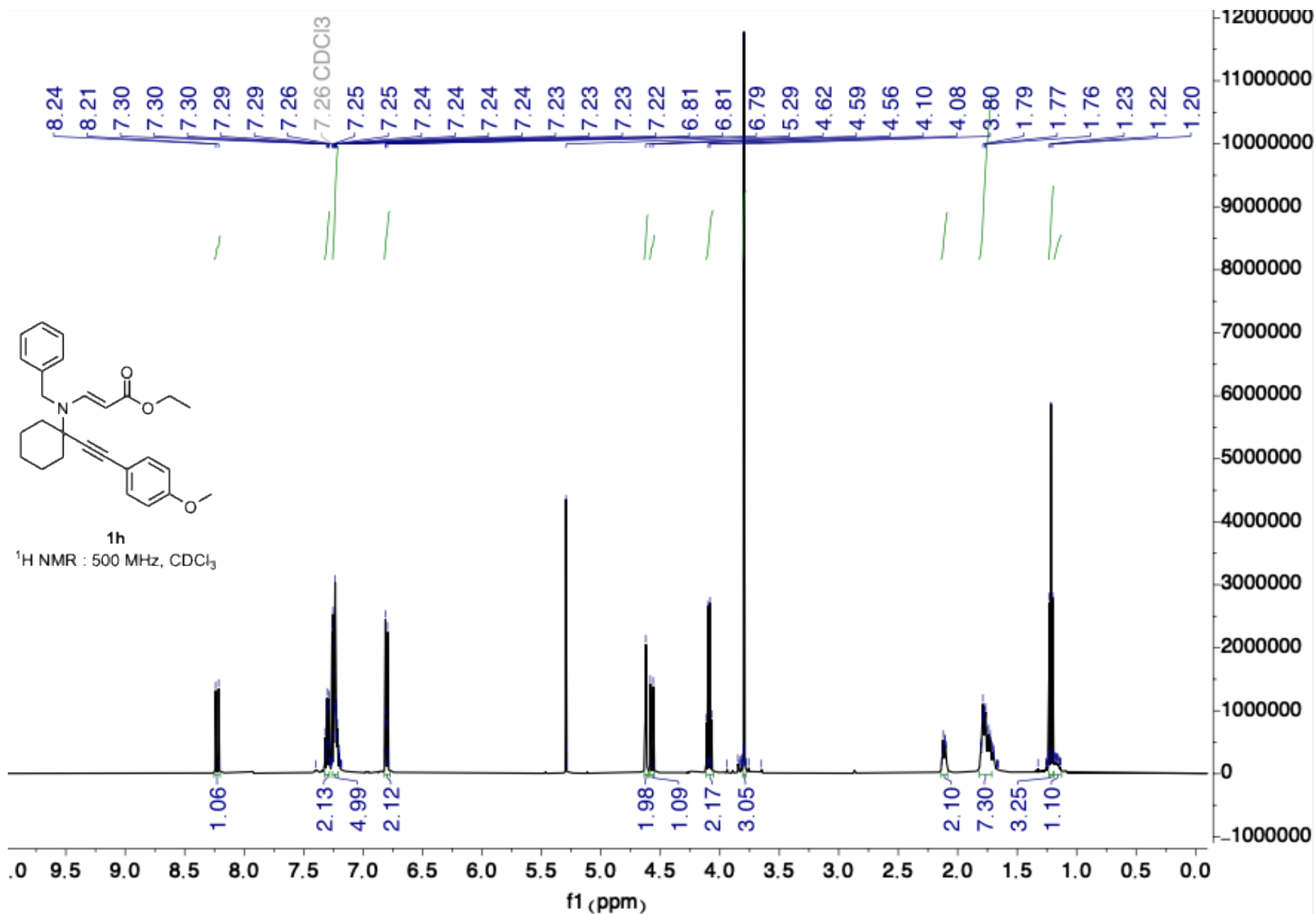
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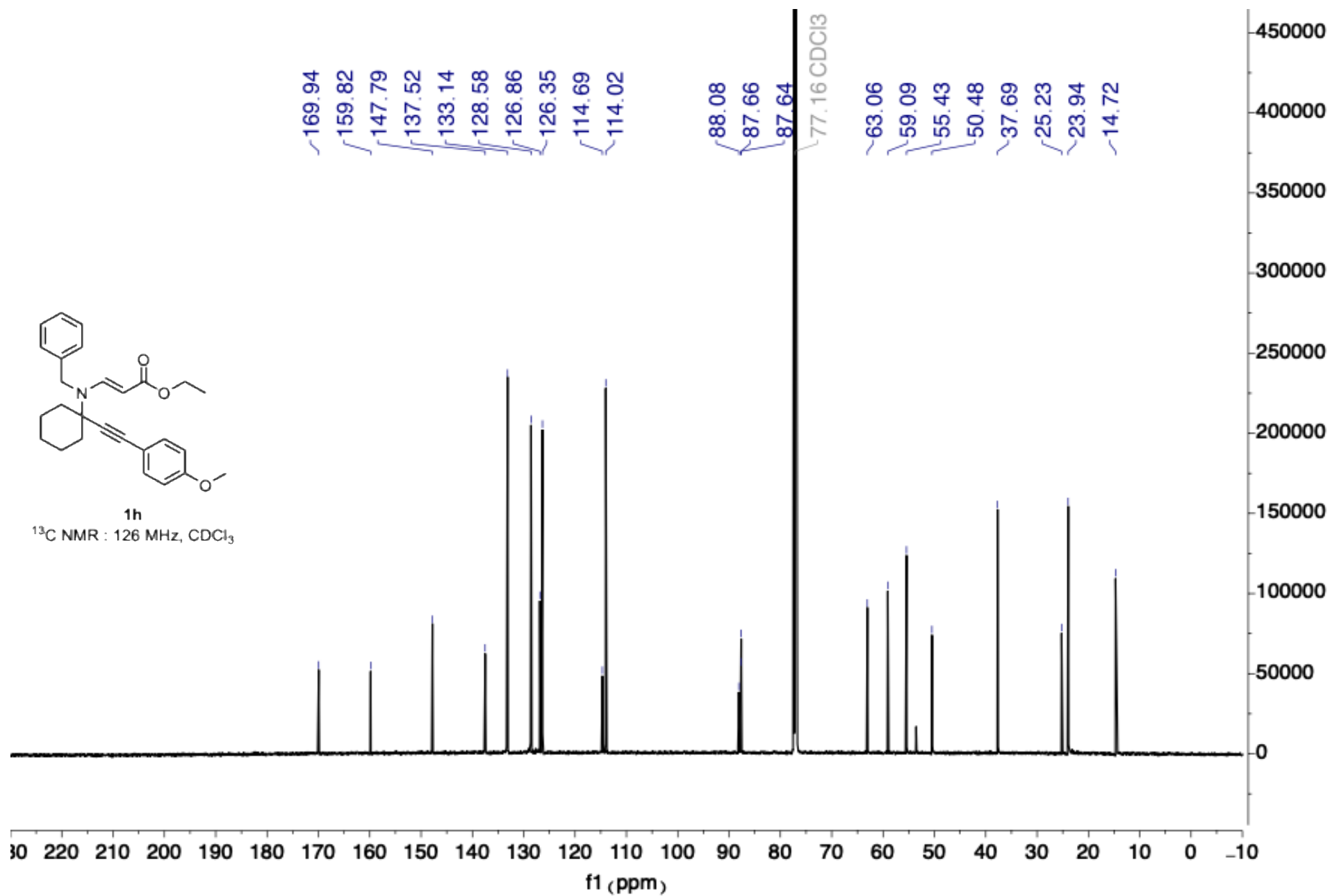
^{13}C NMR : 126 MHz, CDCl_3

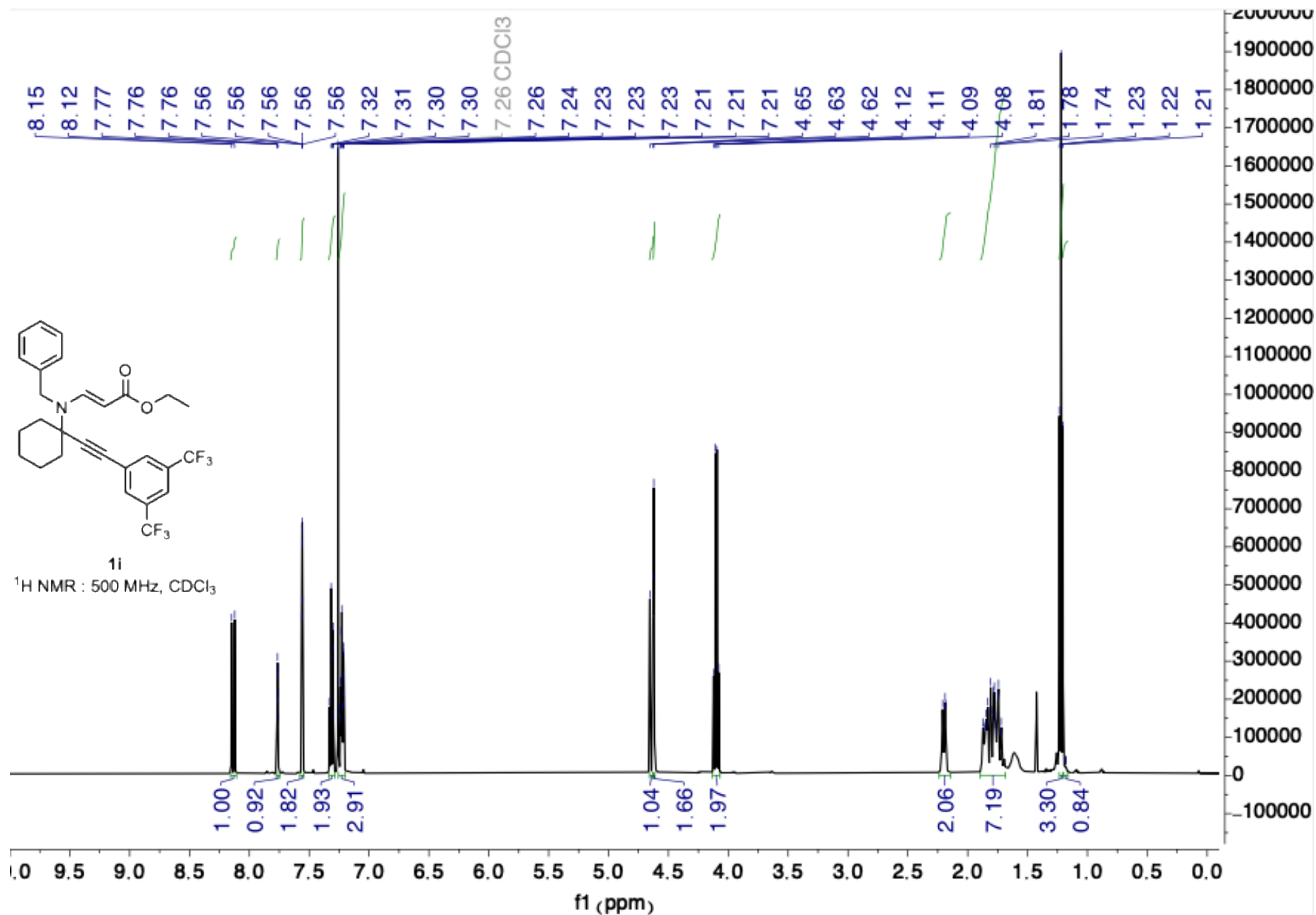


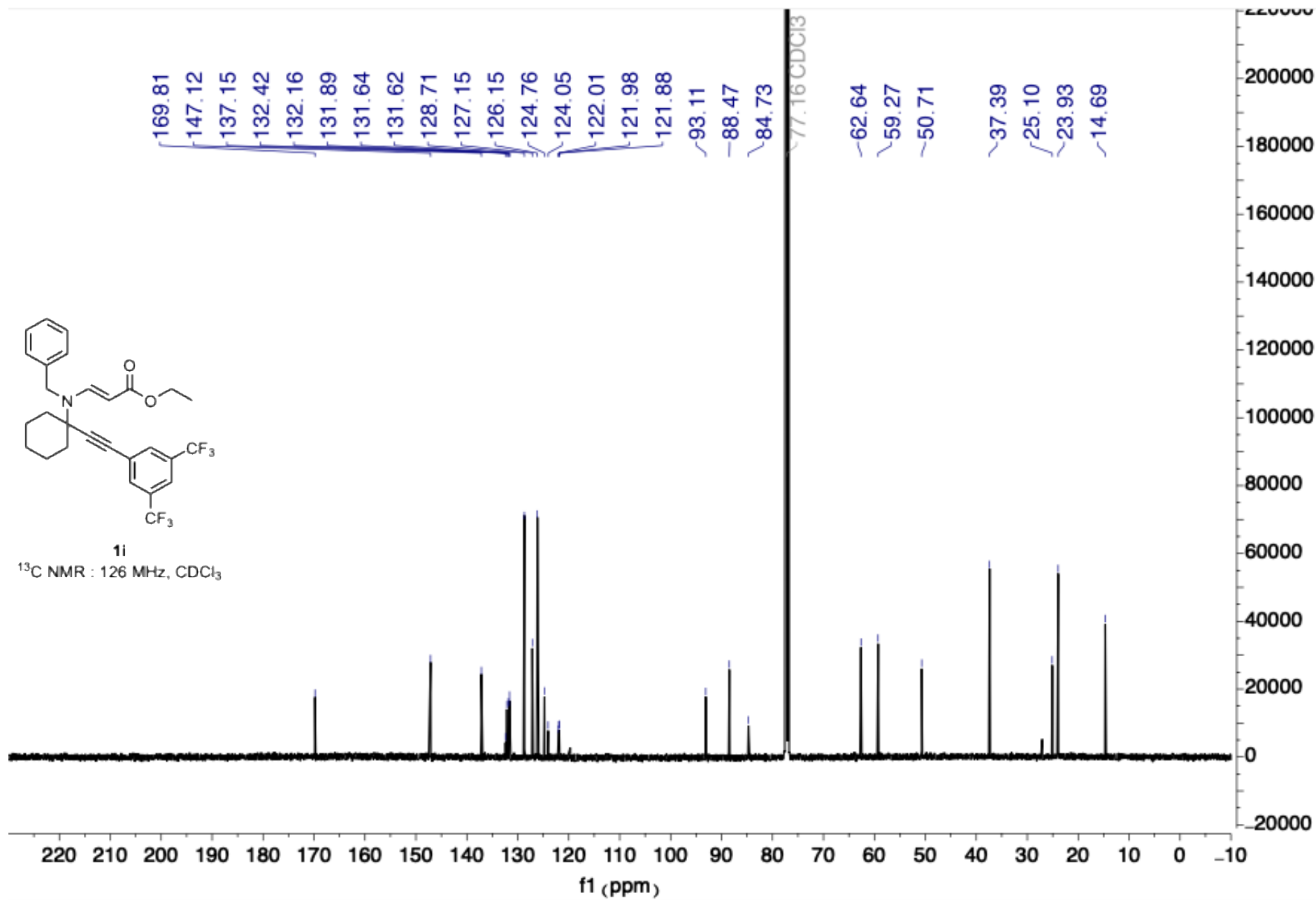


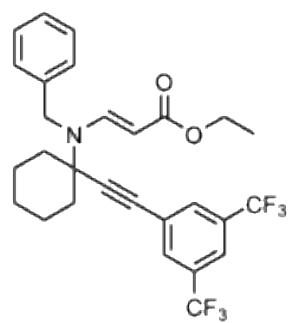






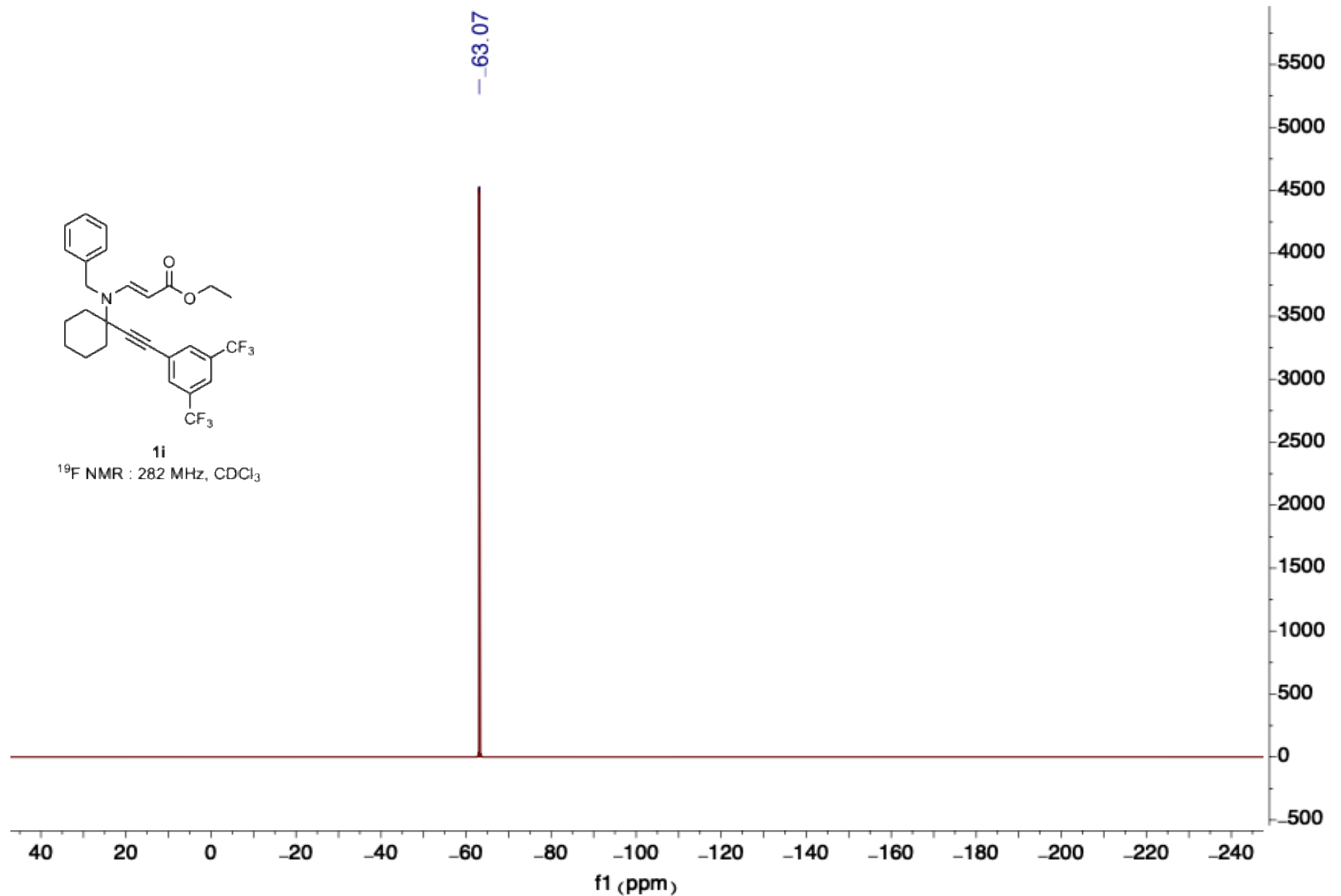


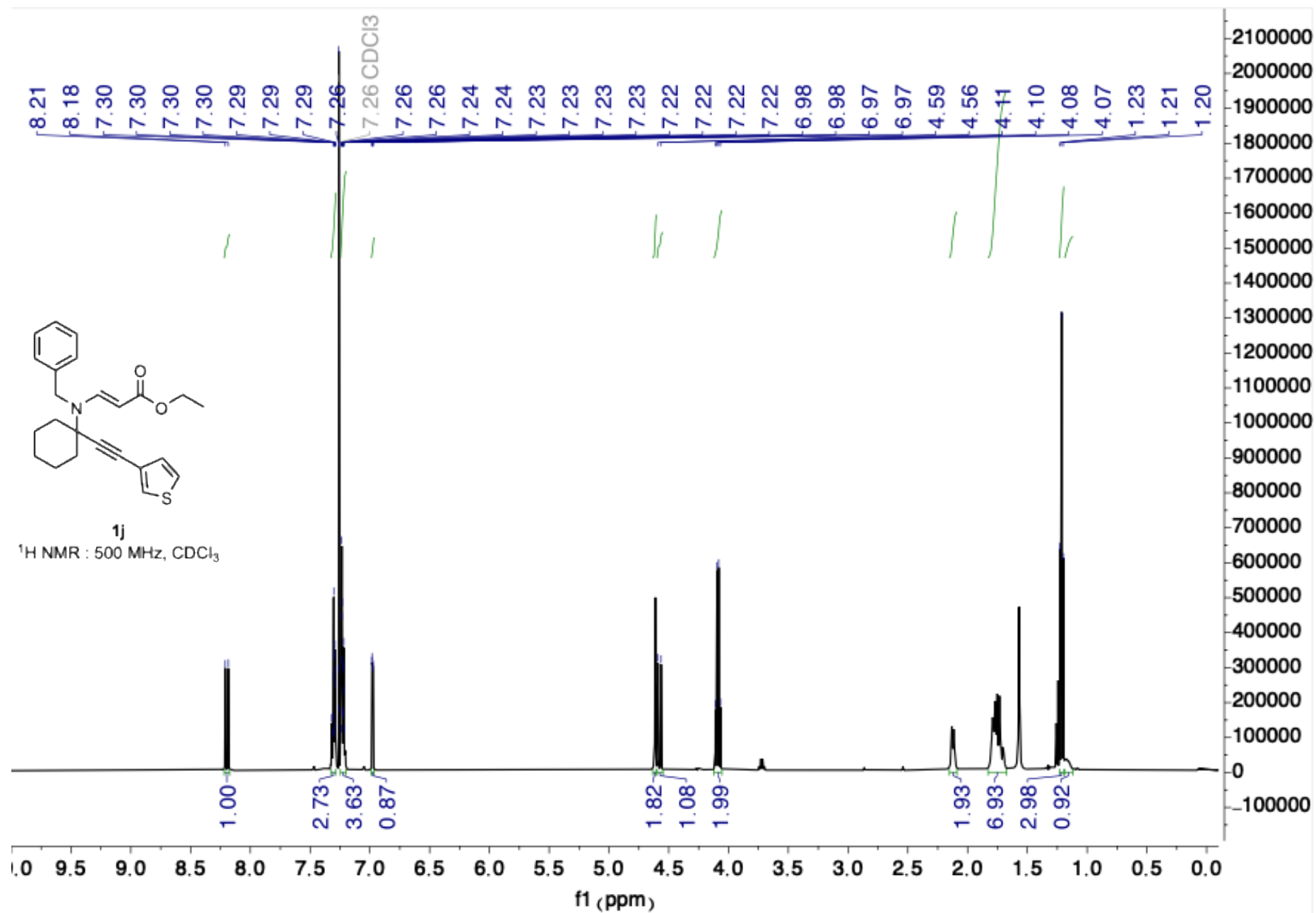


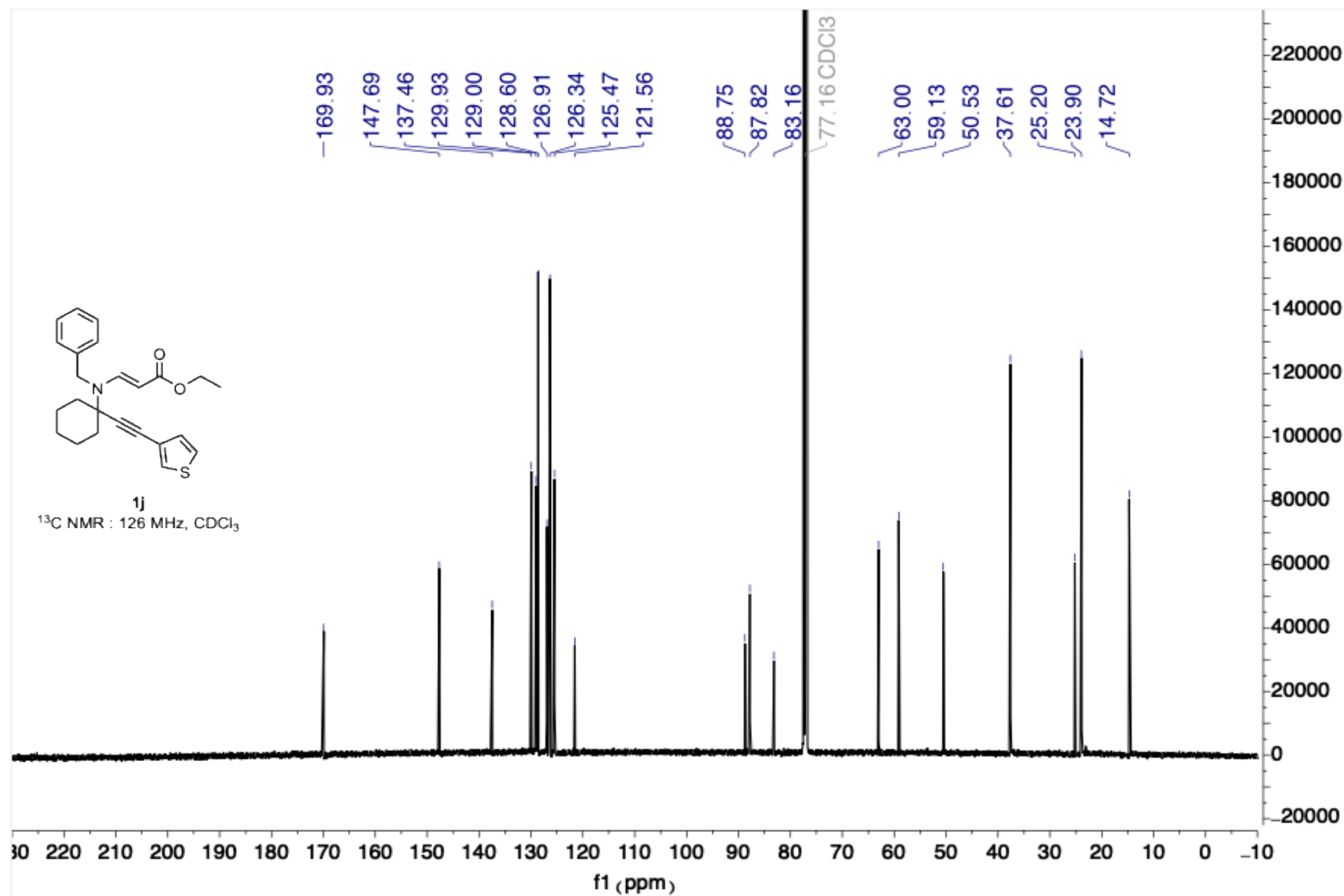


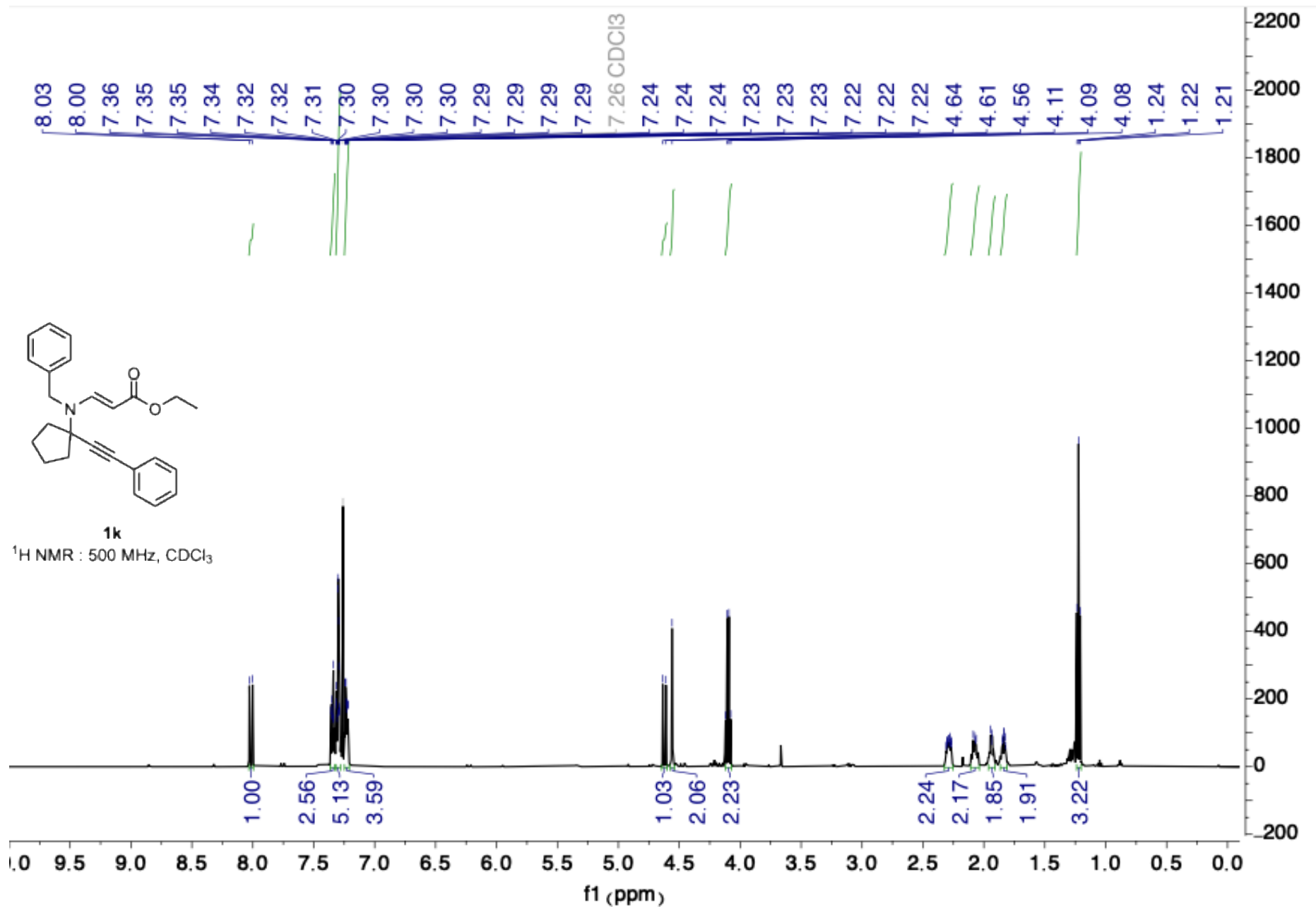
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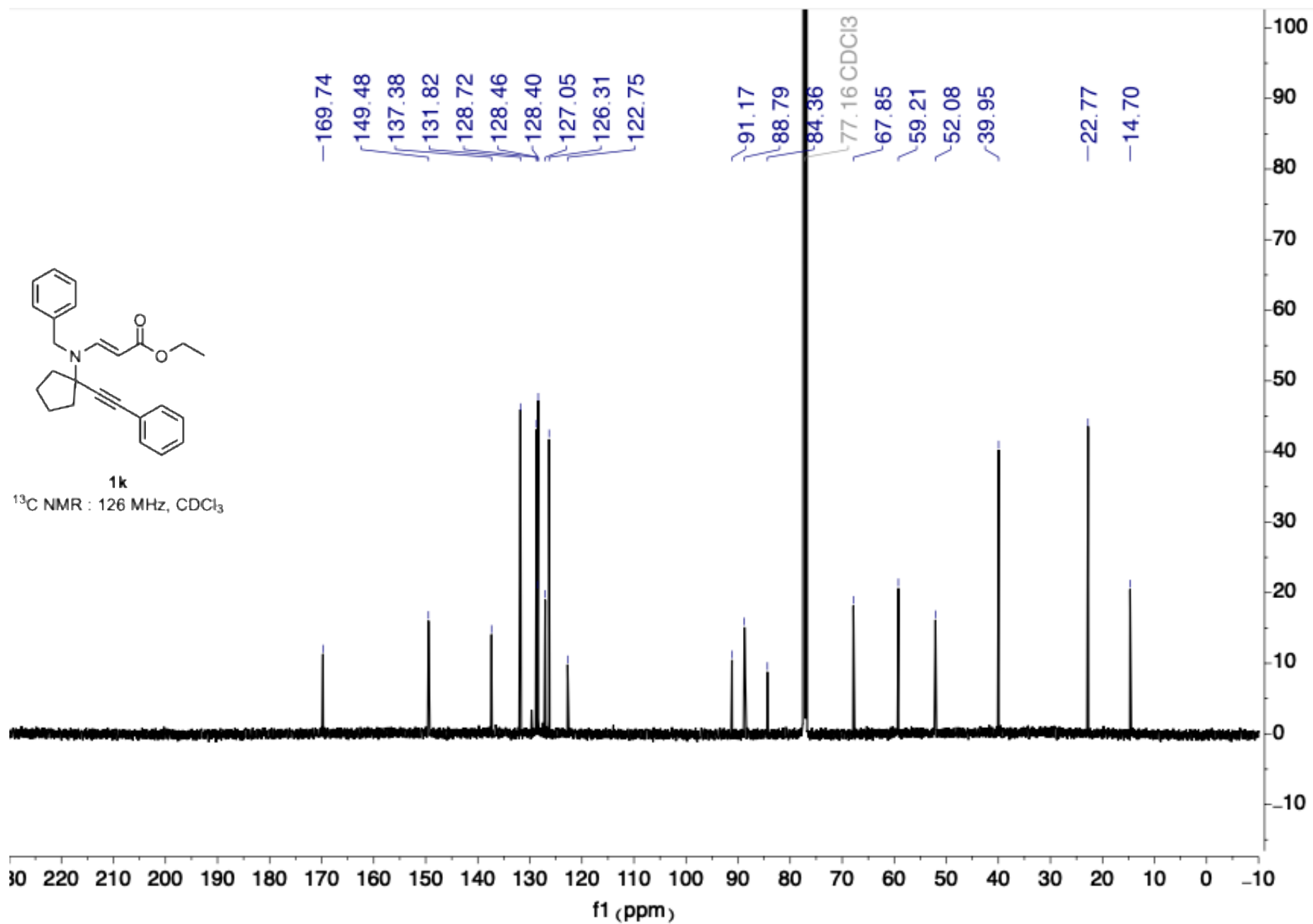
^{19}F NMR : 282 MHz, CDCl_3

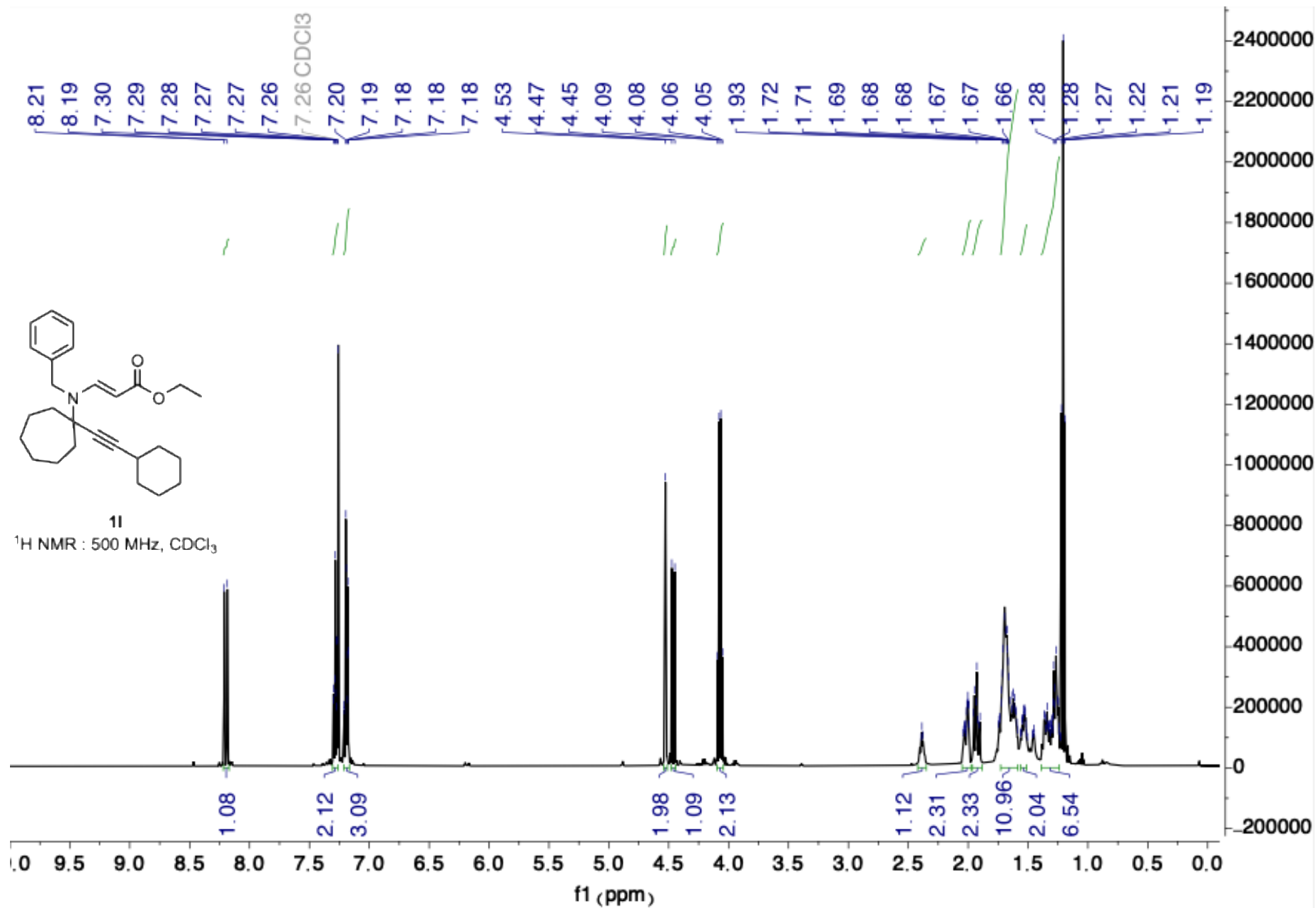


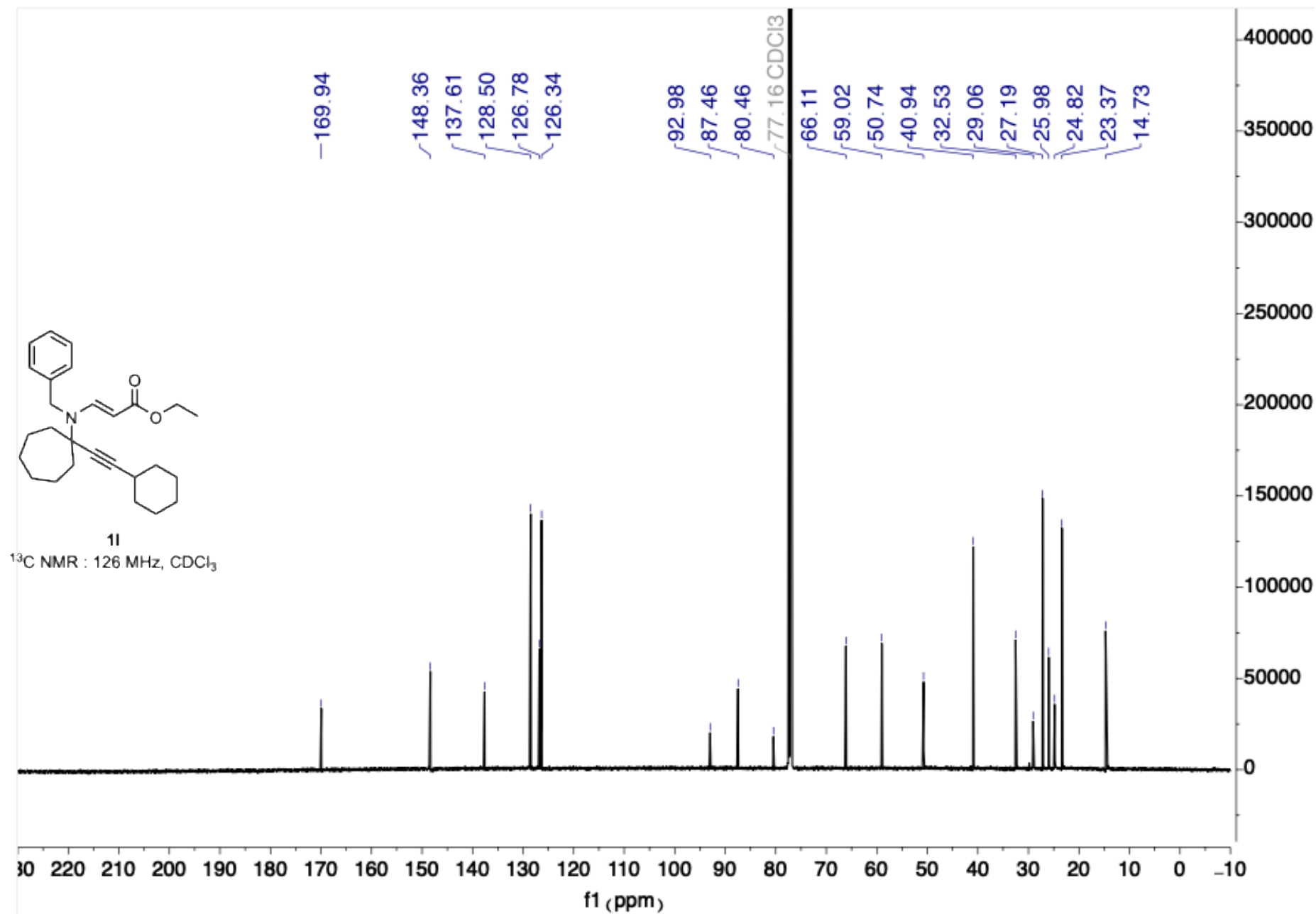


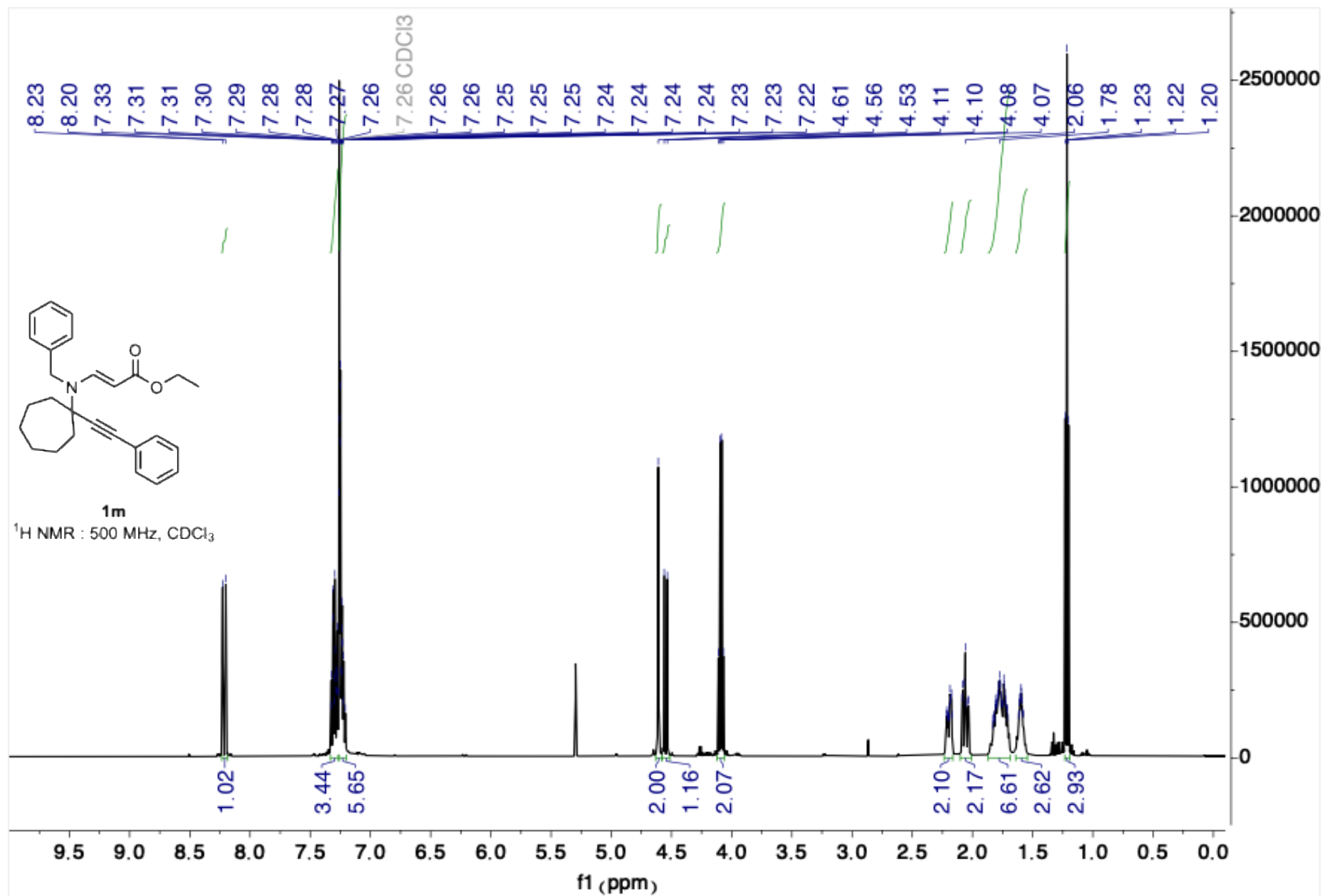


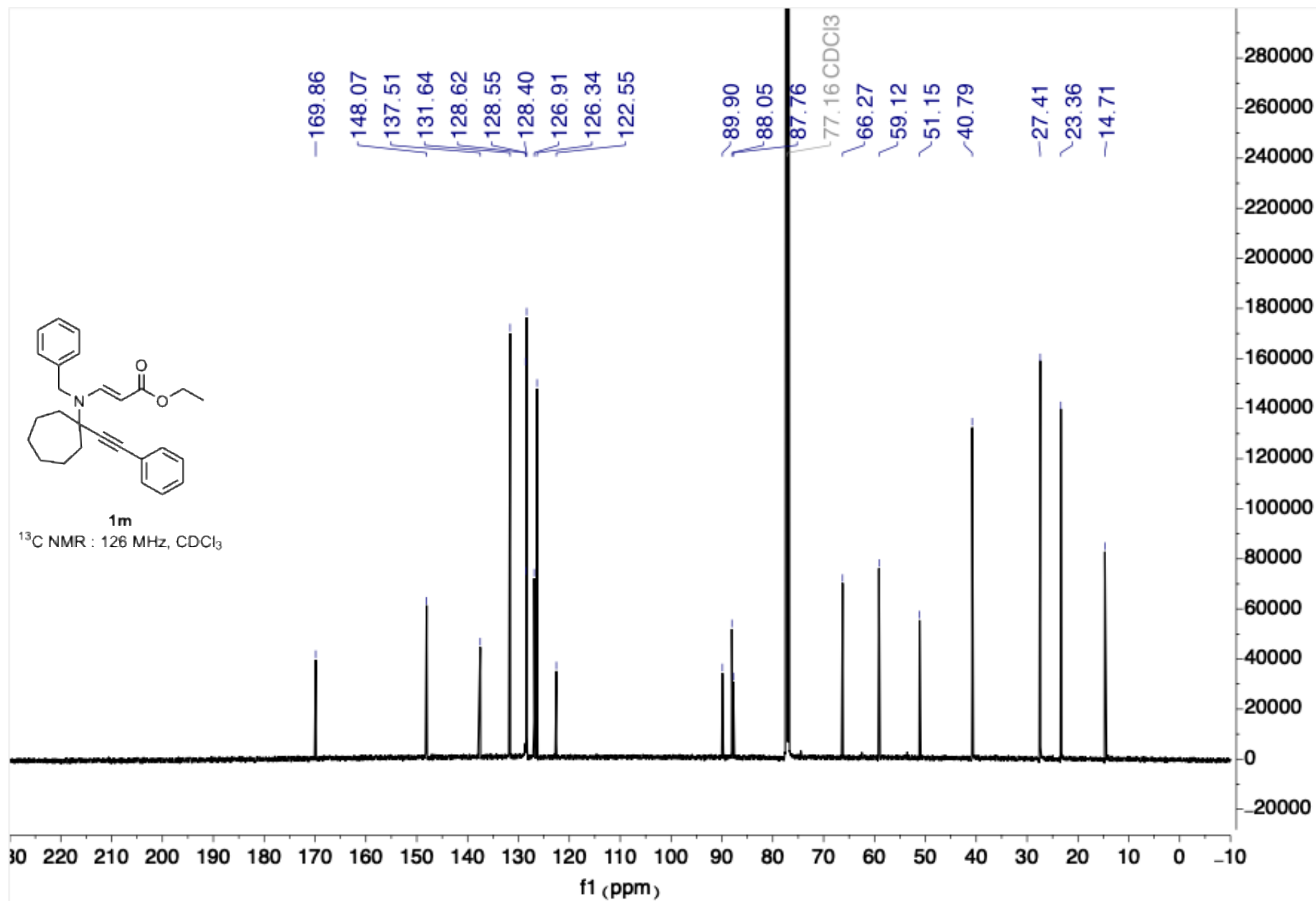


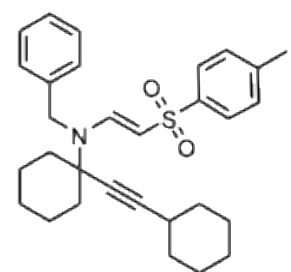






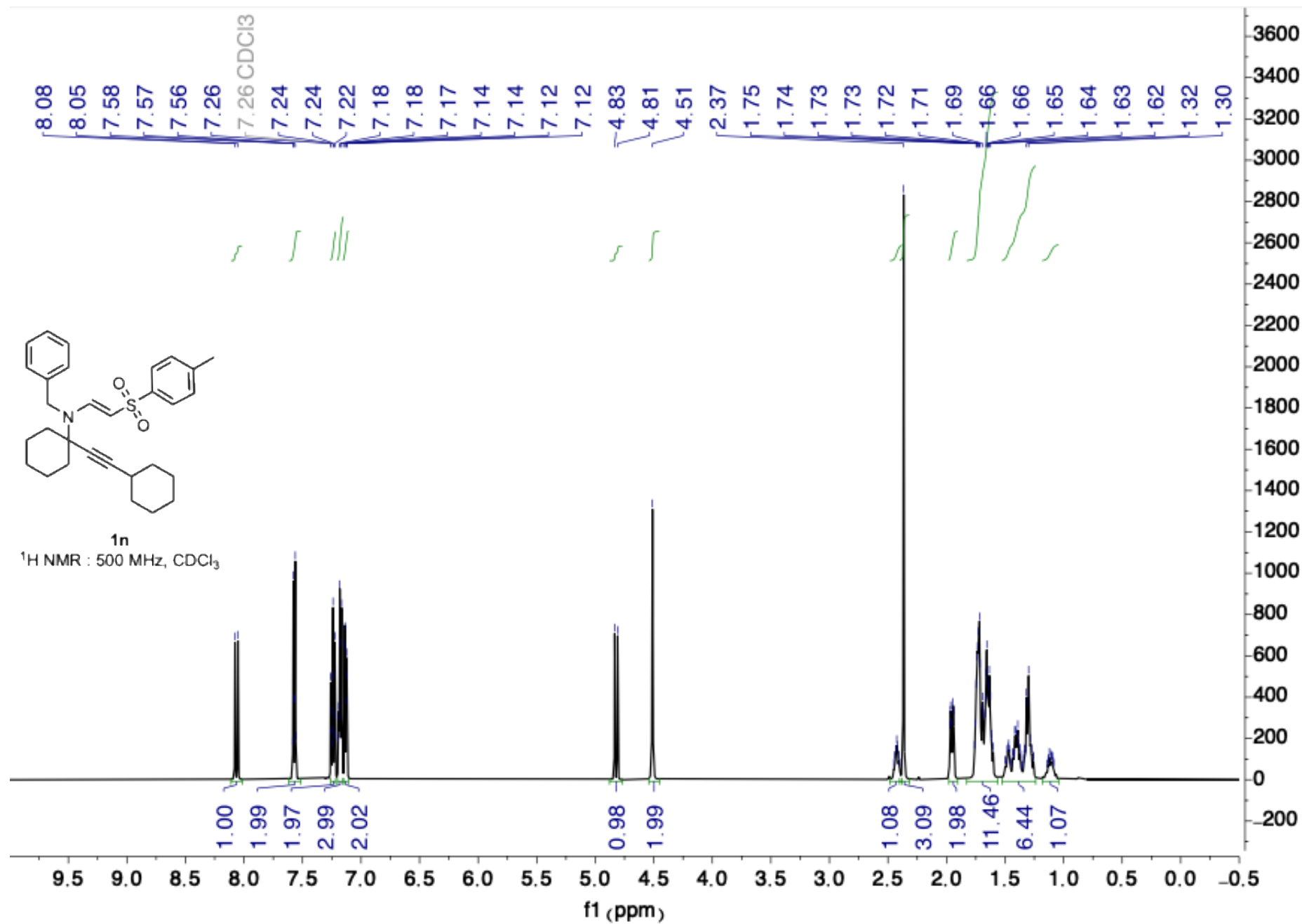


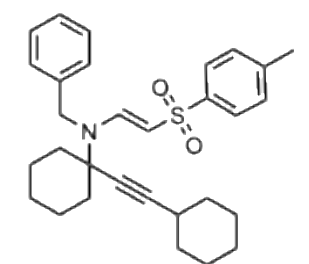




1n

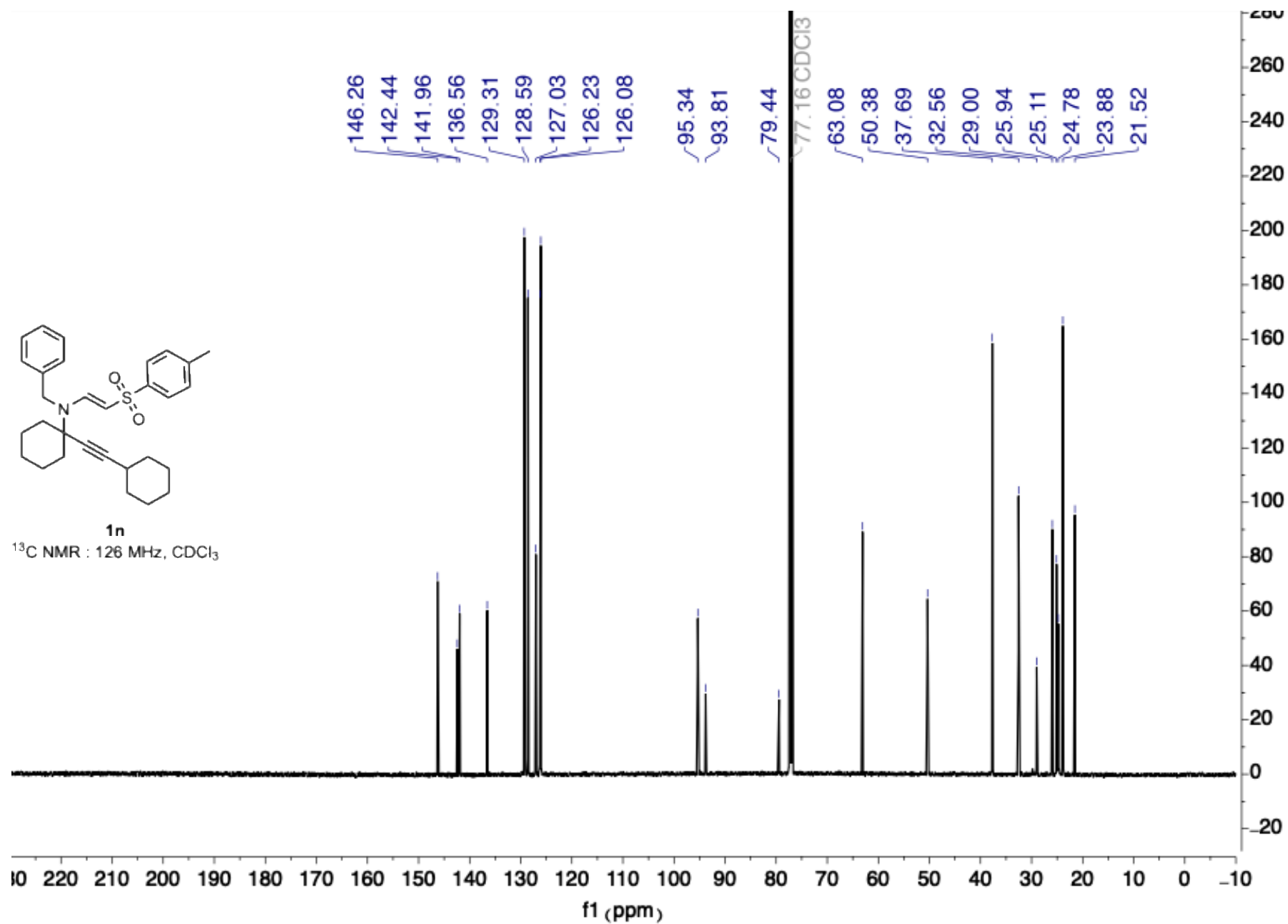
^1H NMR : 500 MHz, CDCl_3

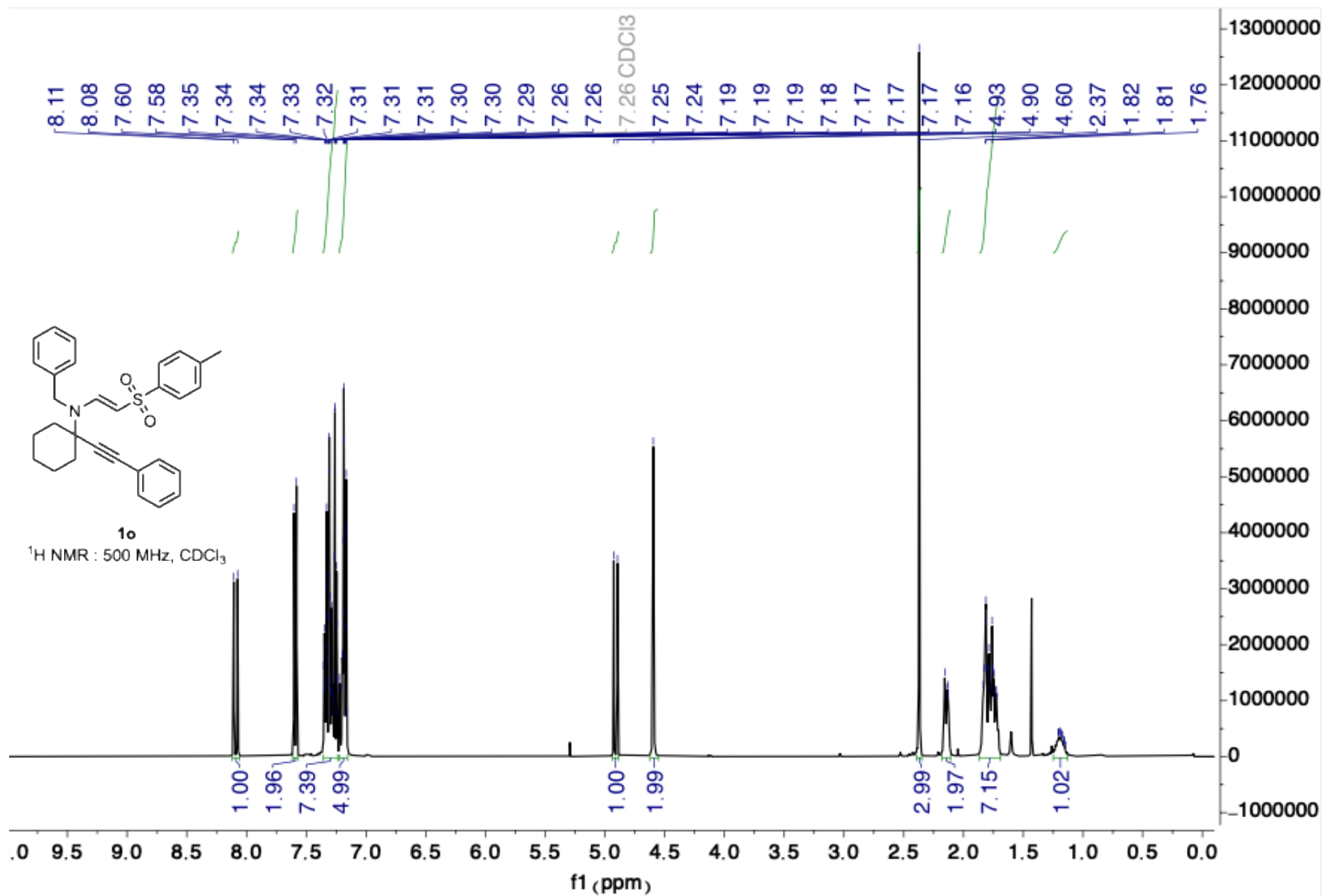


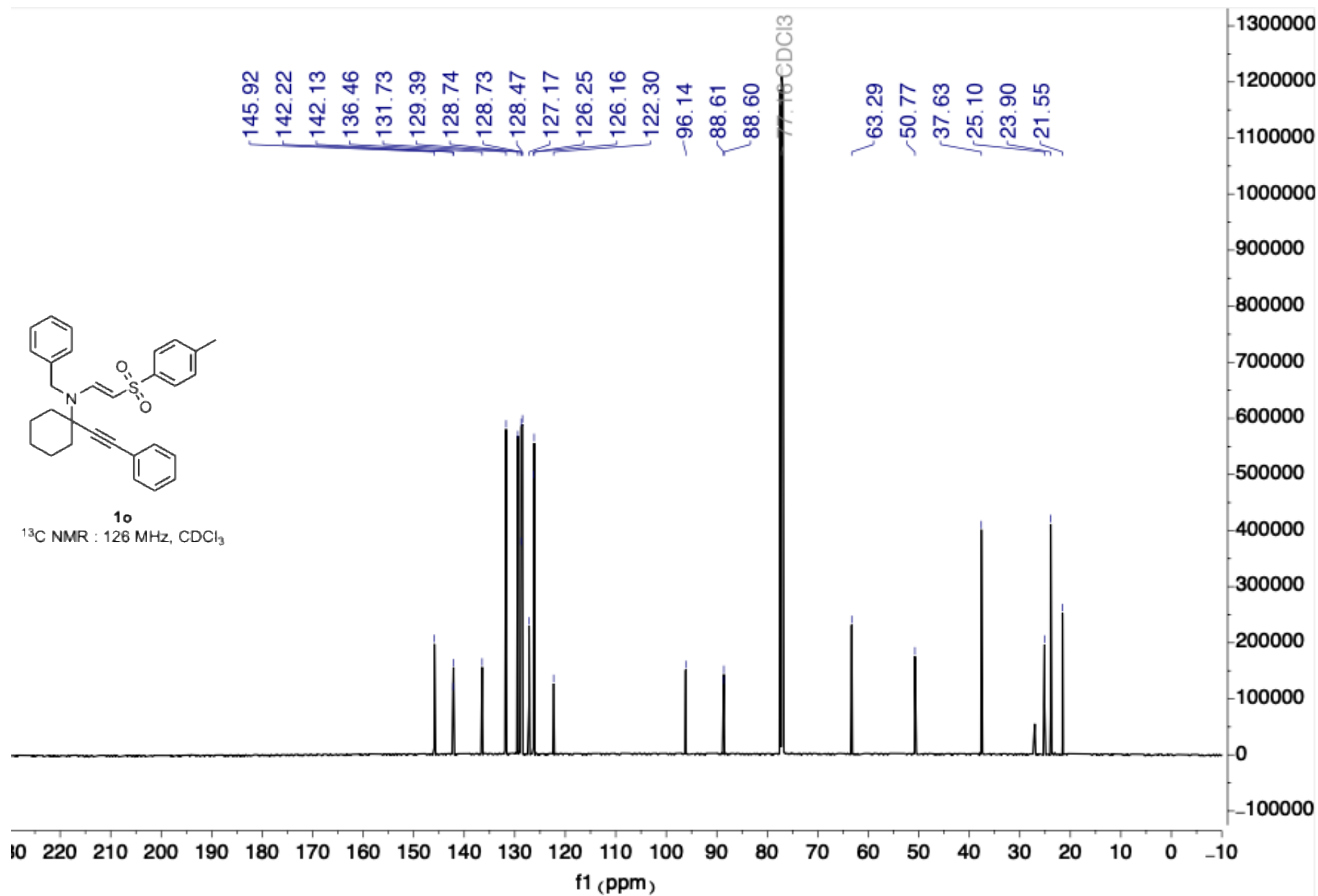


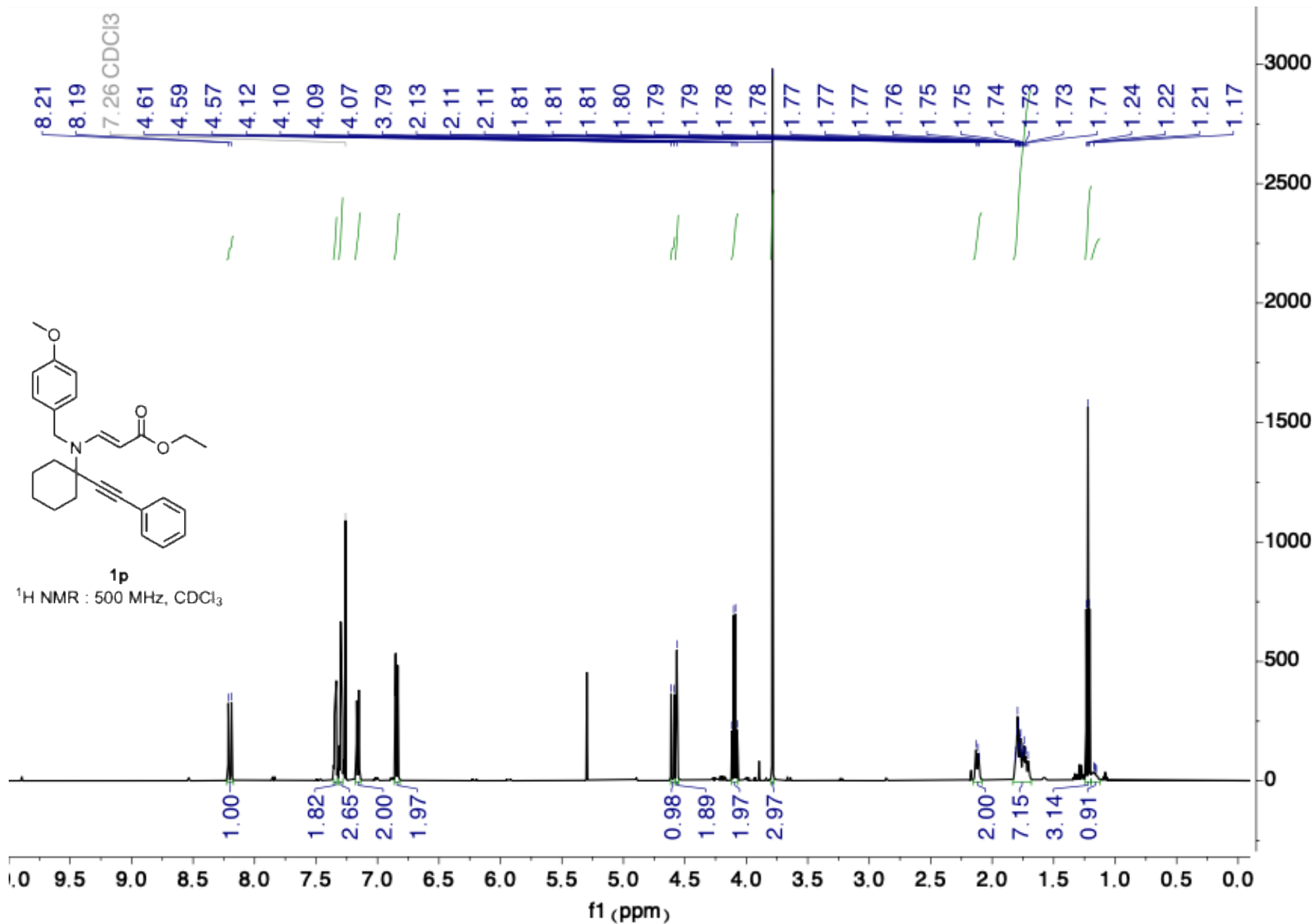
1n

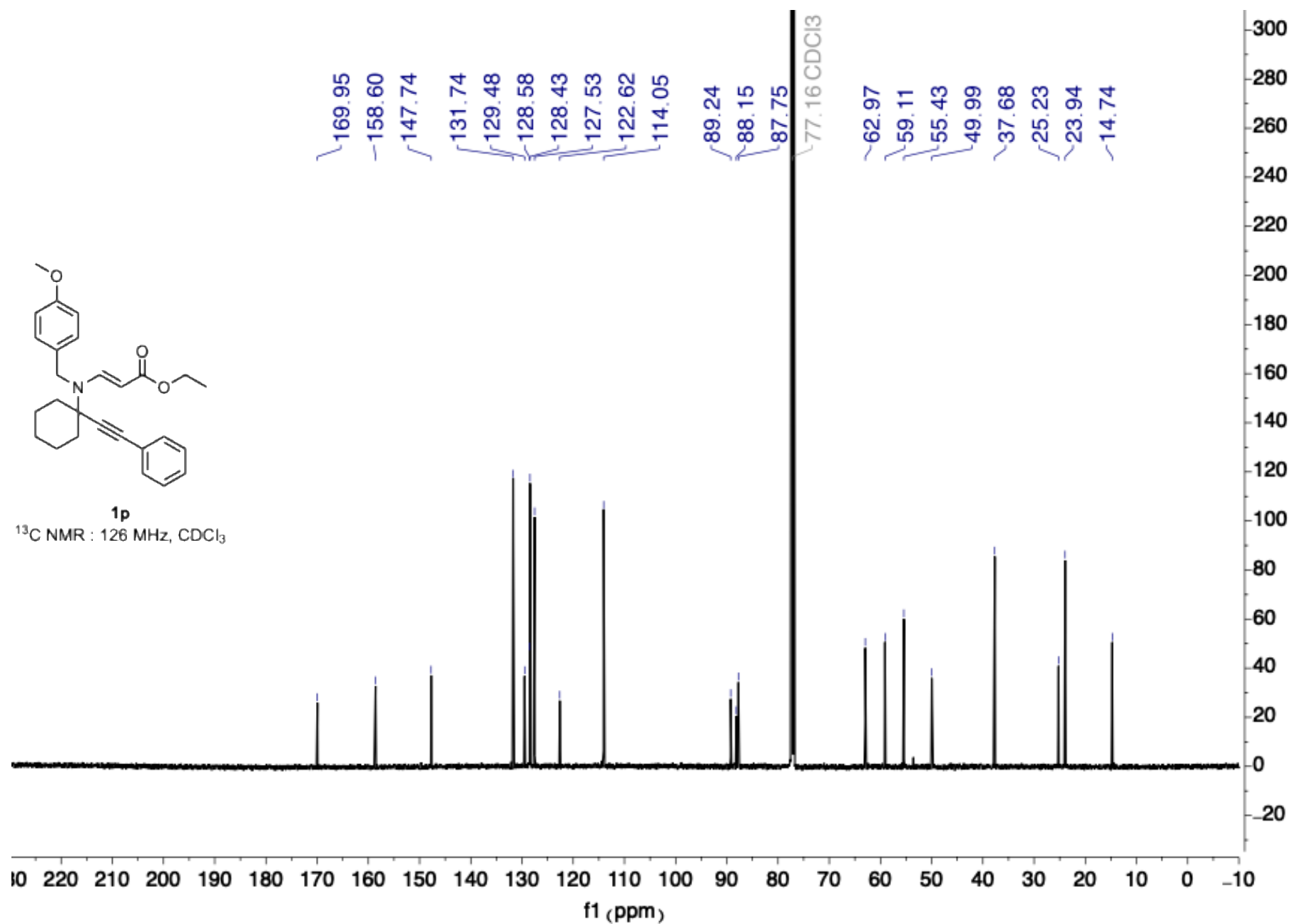
^{13}C NMR : 126 MHz, CDCl_3

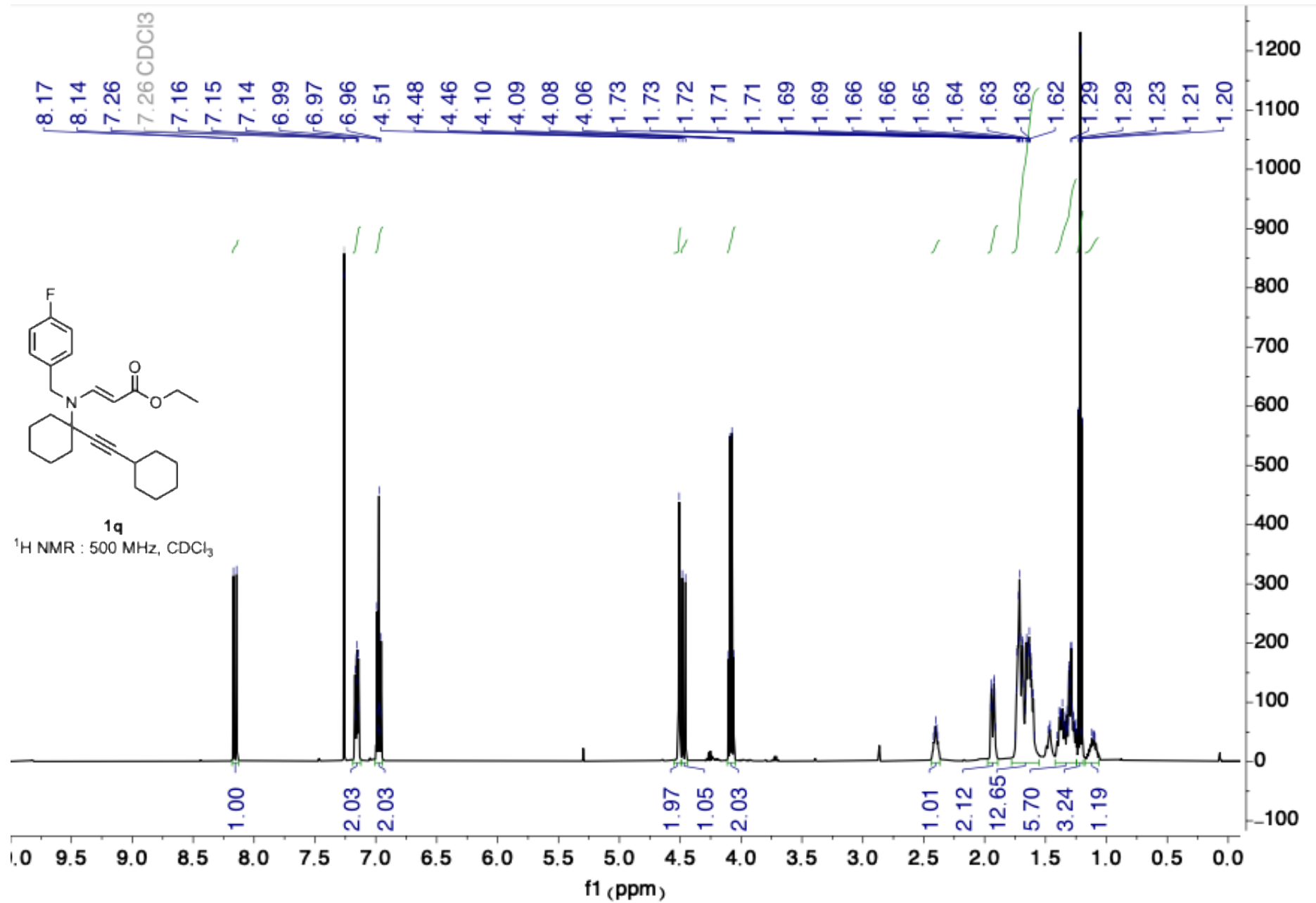


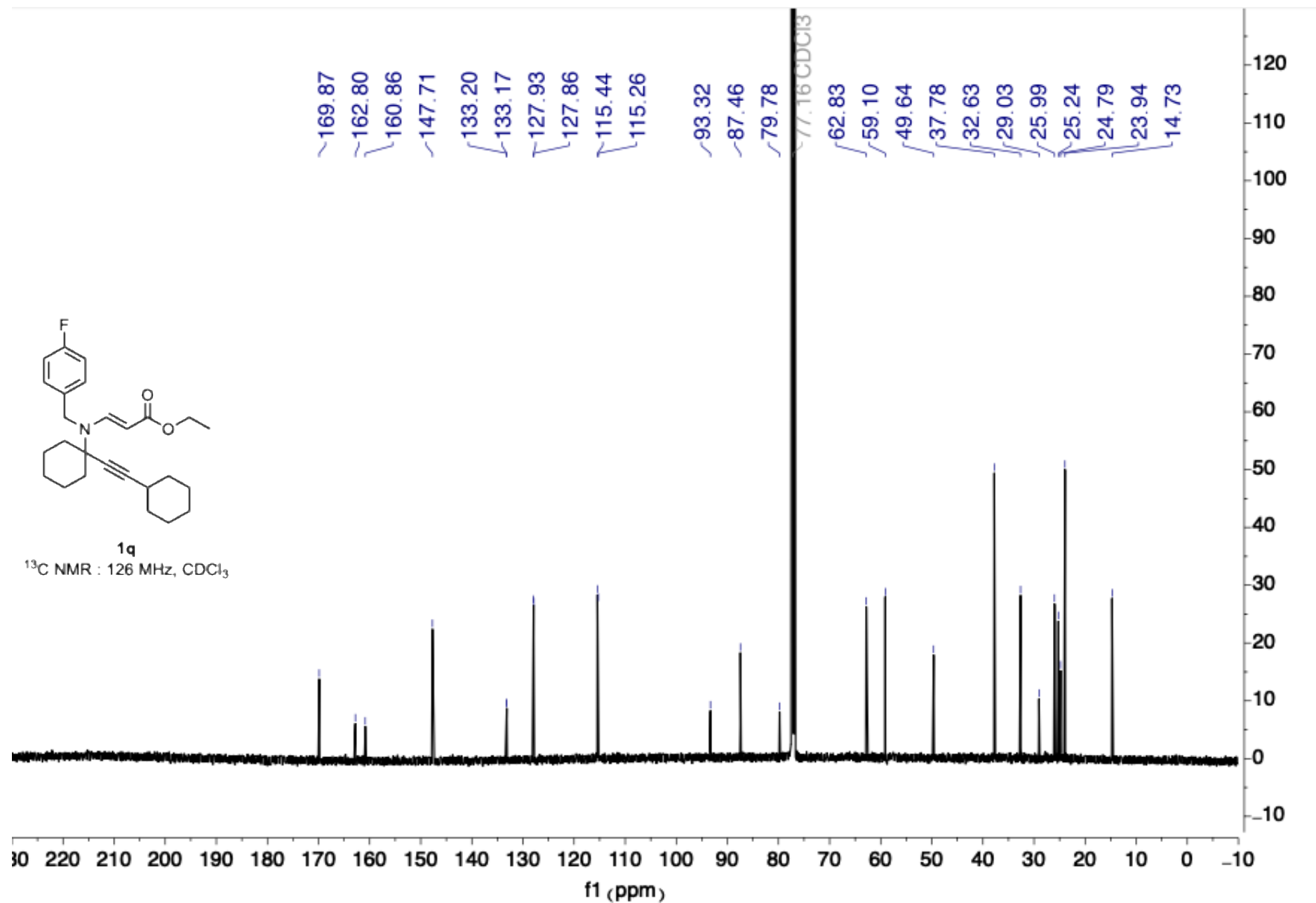


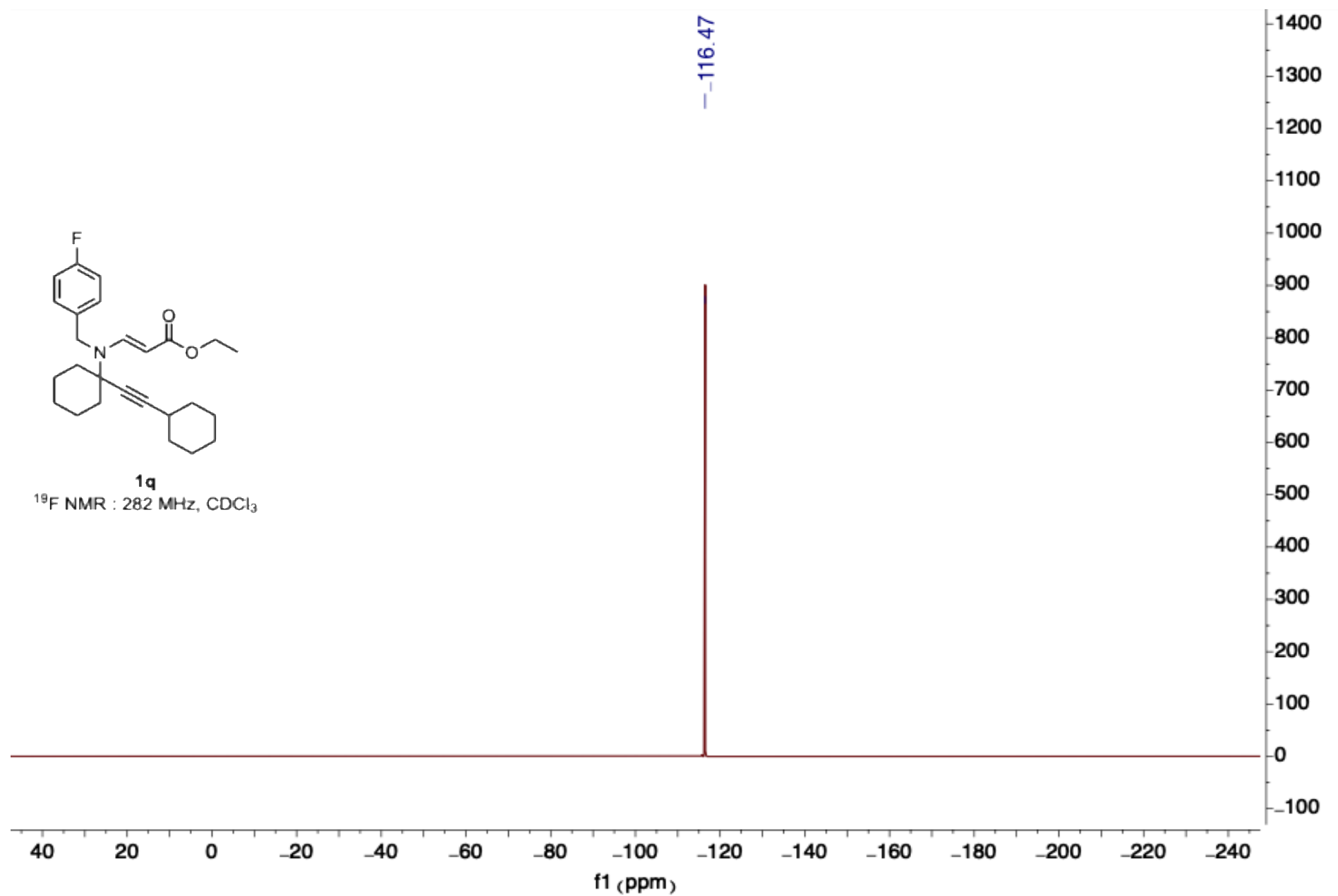


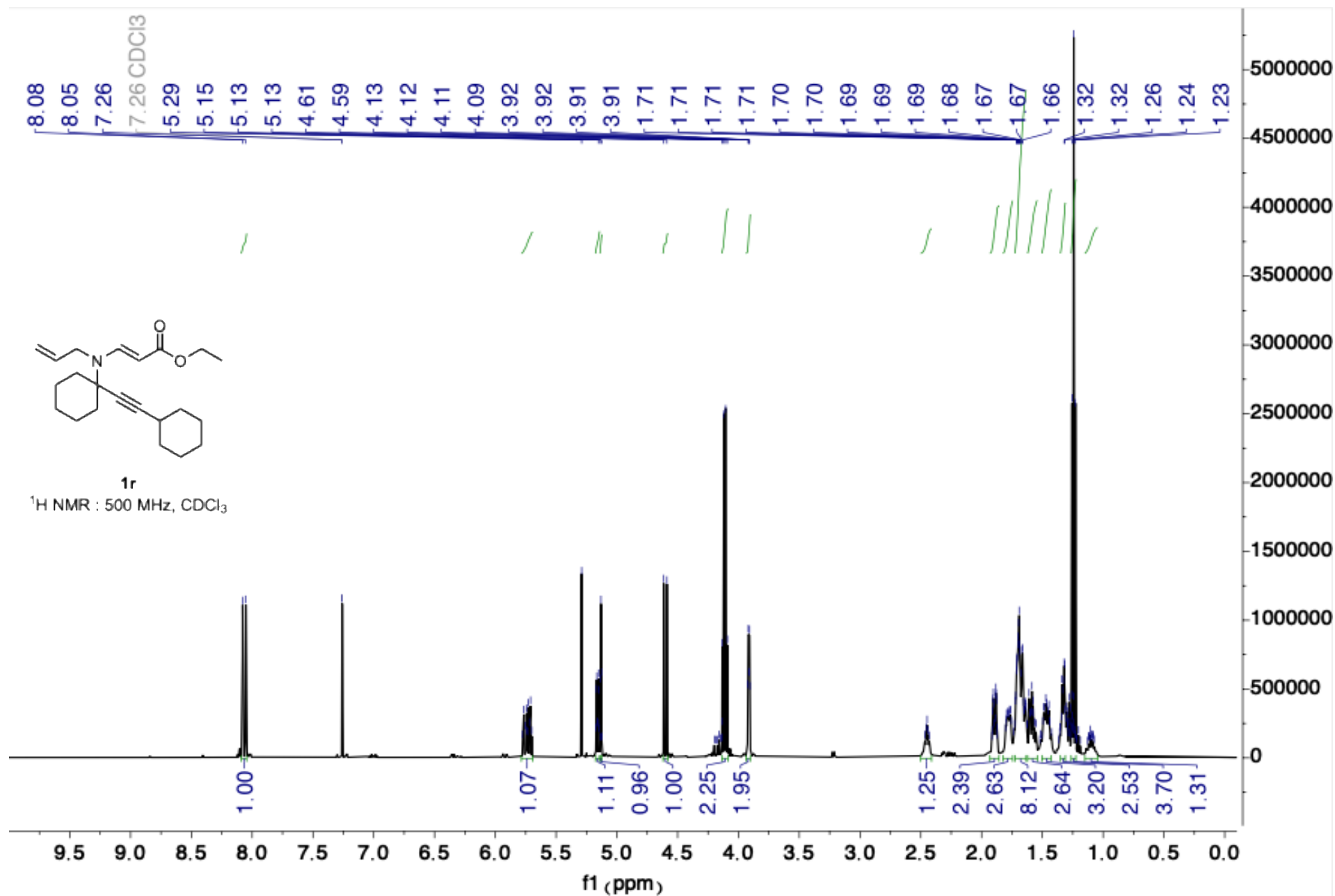


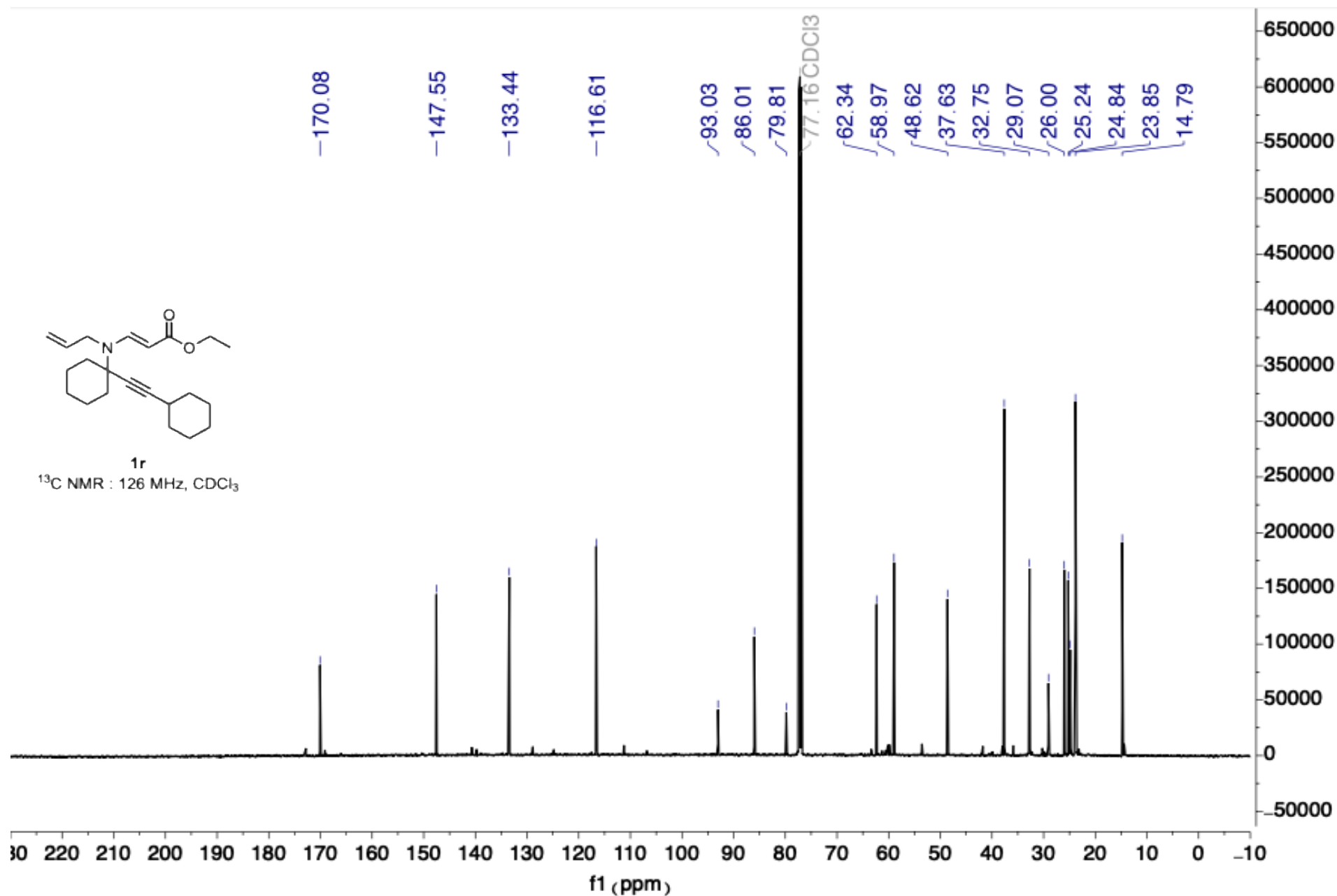


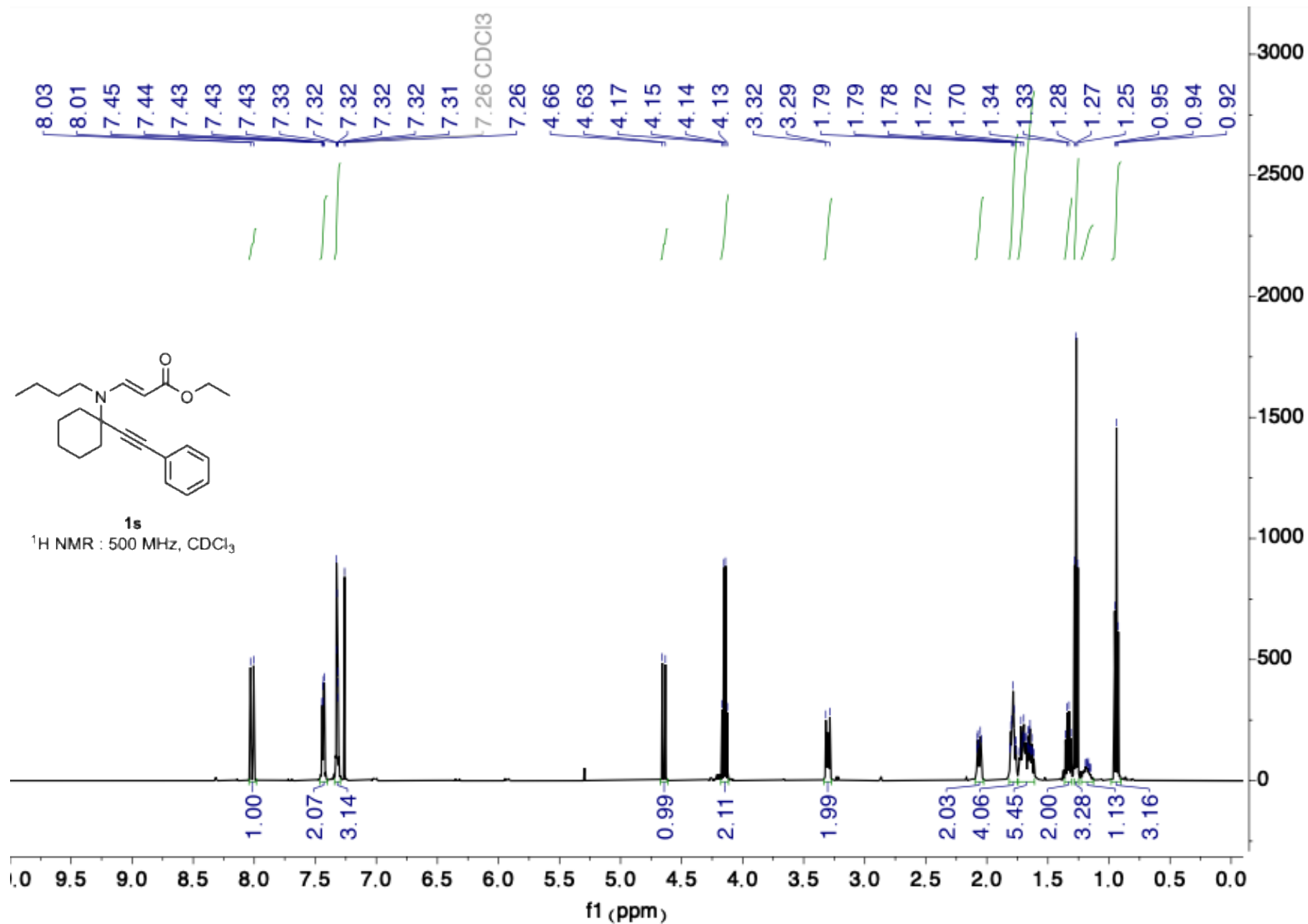


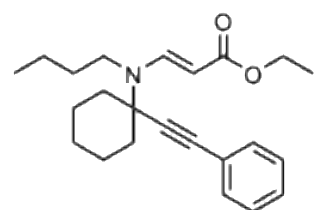






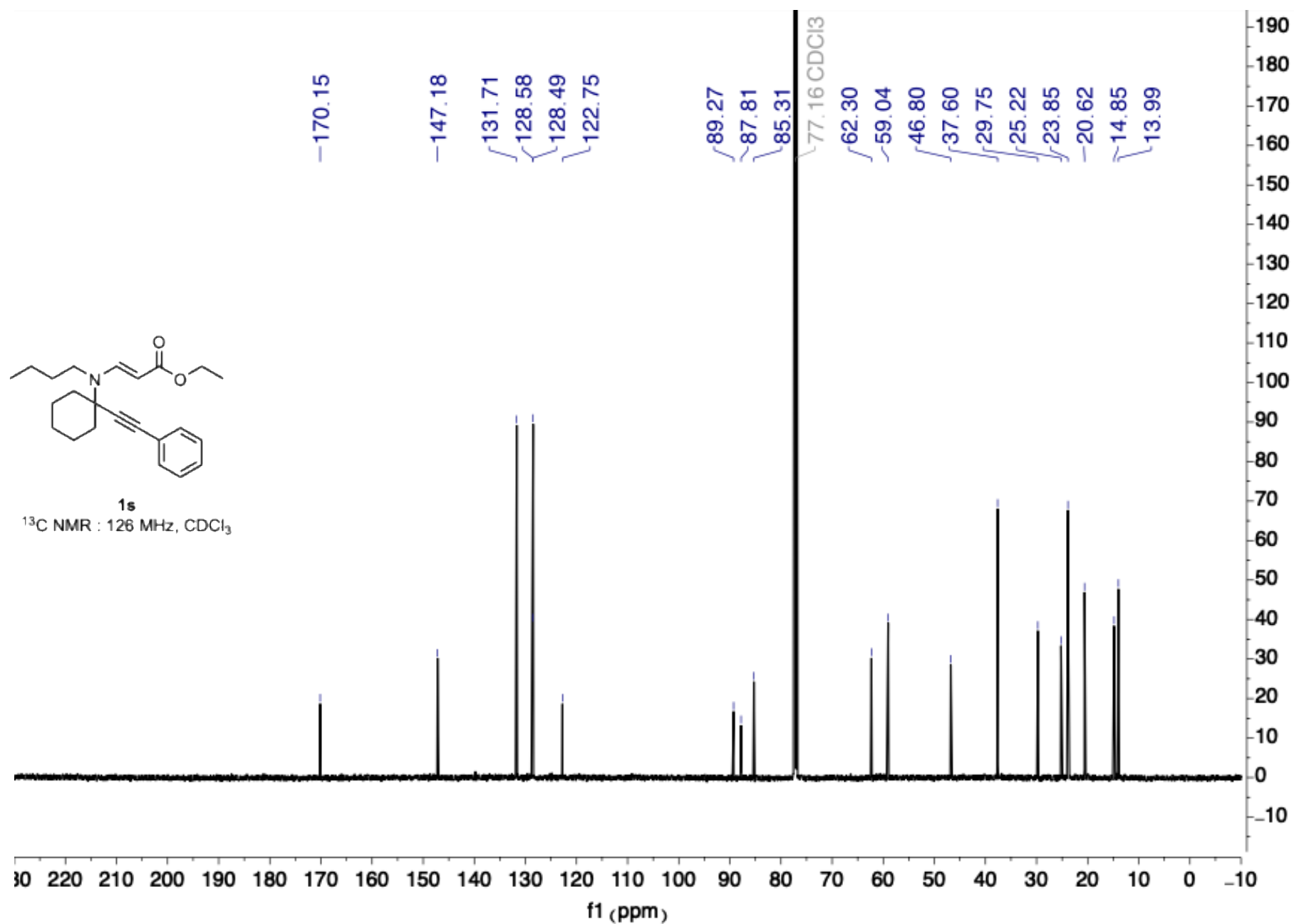


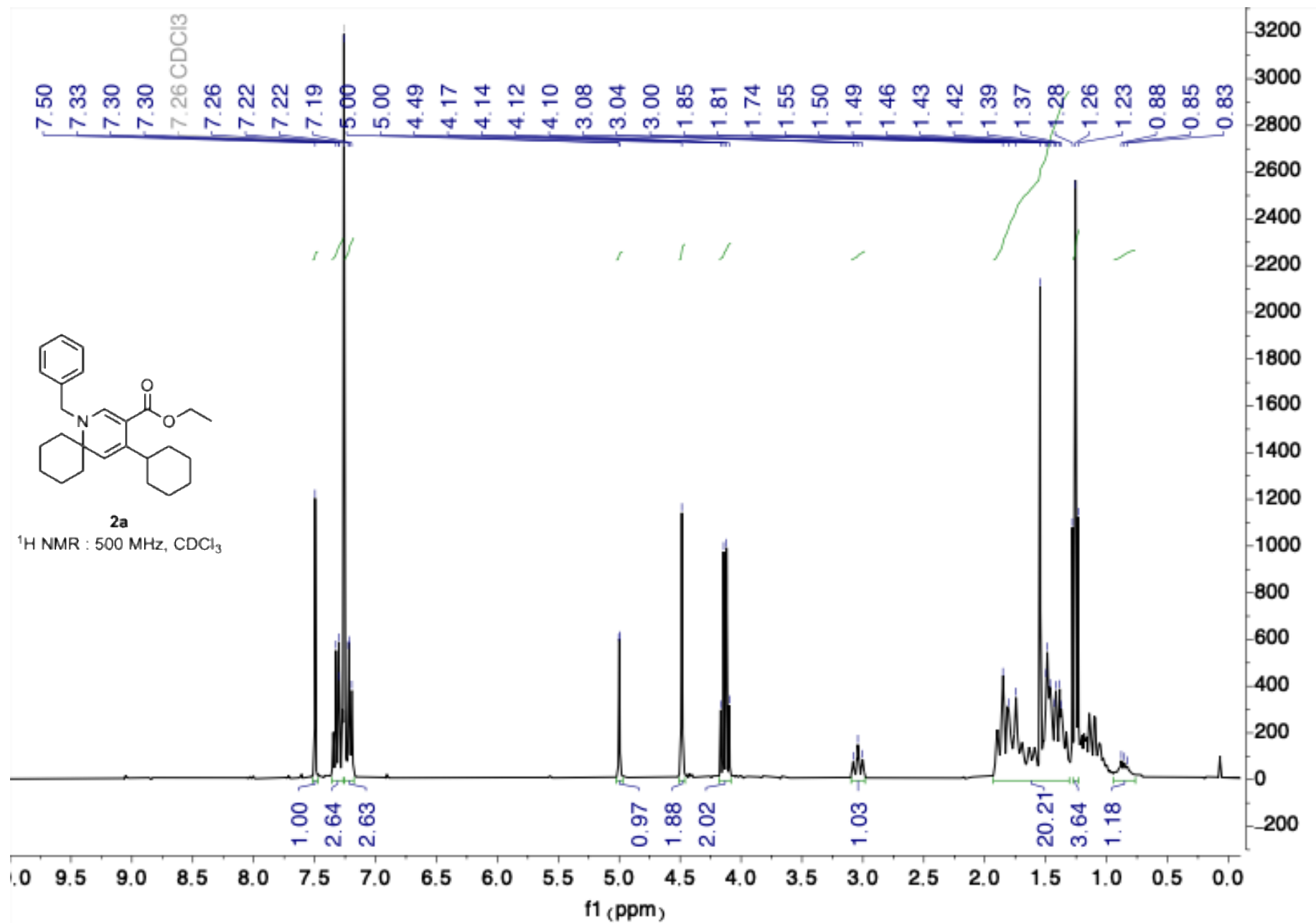


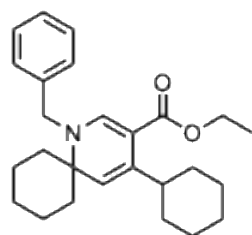


1s

^{13}C NMR : 126 MHz, CDCl_3

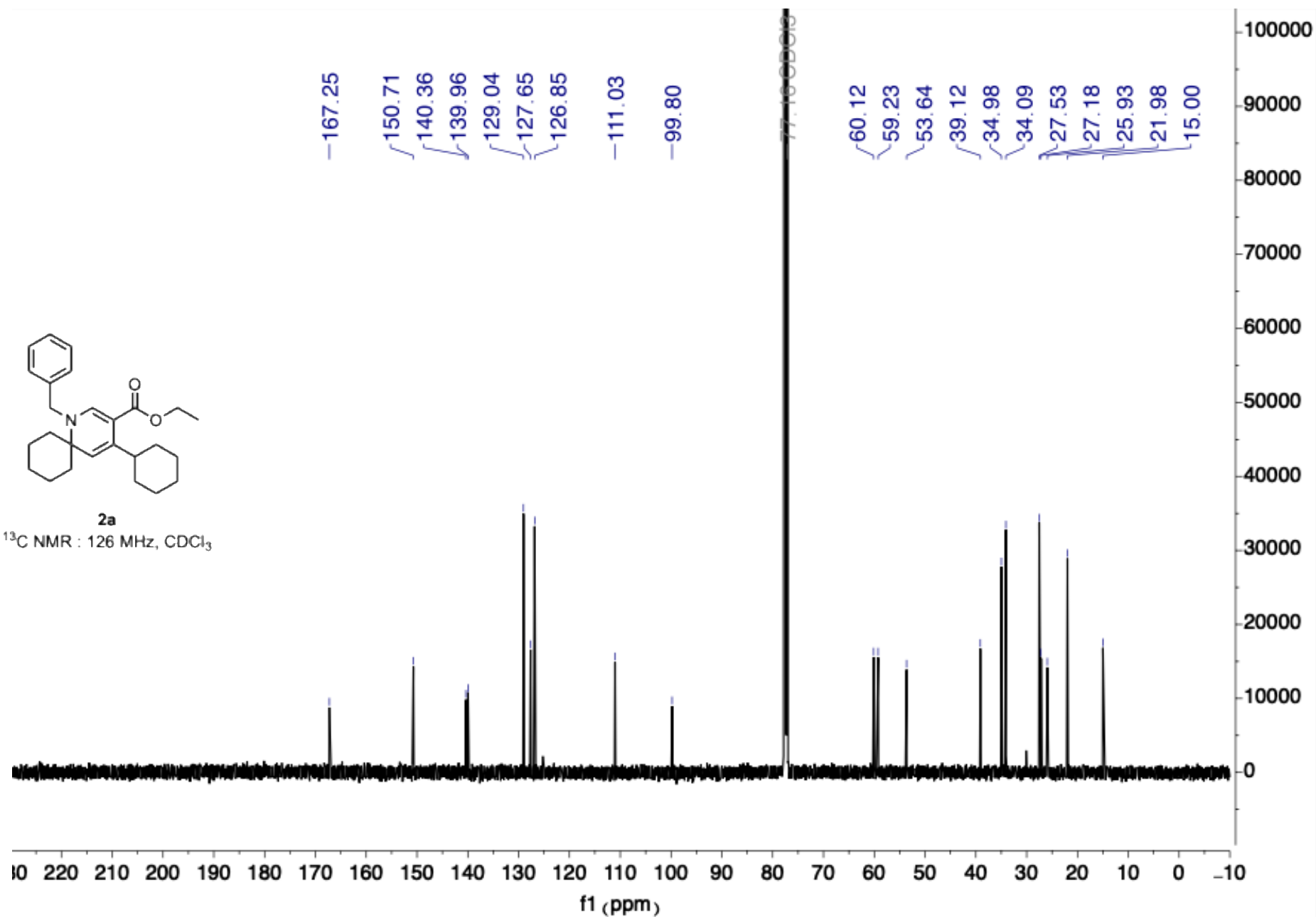


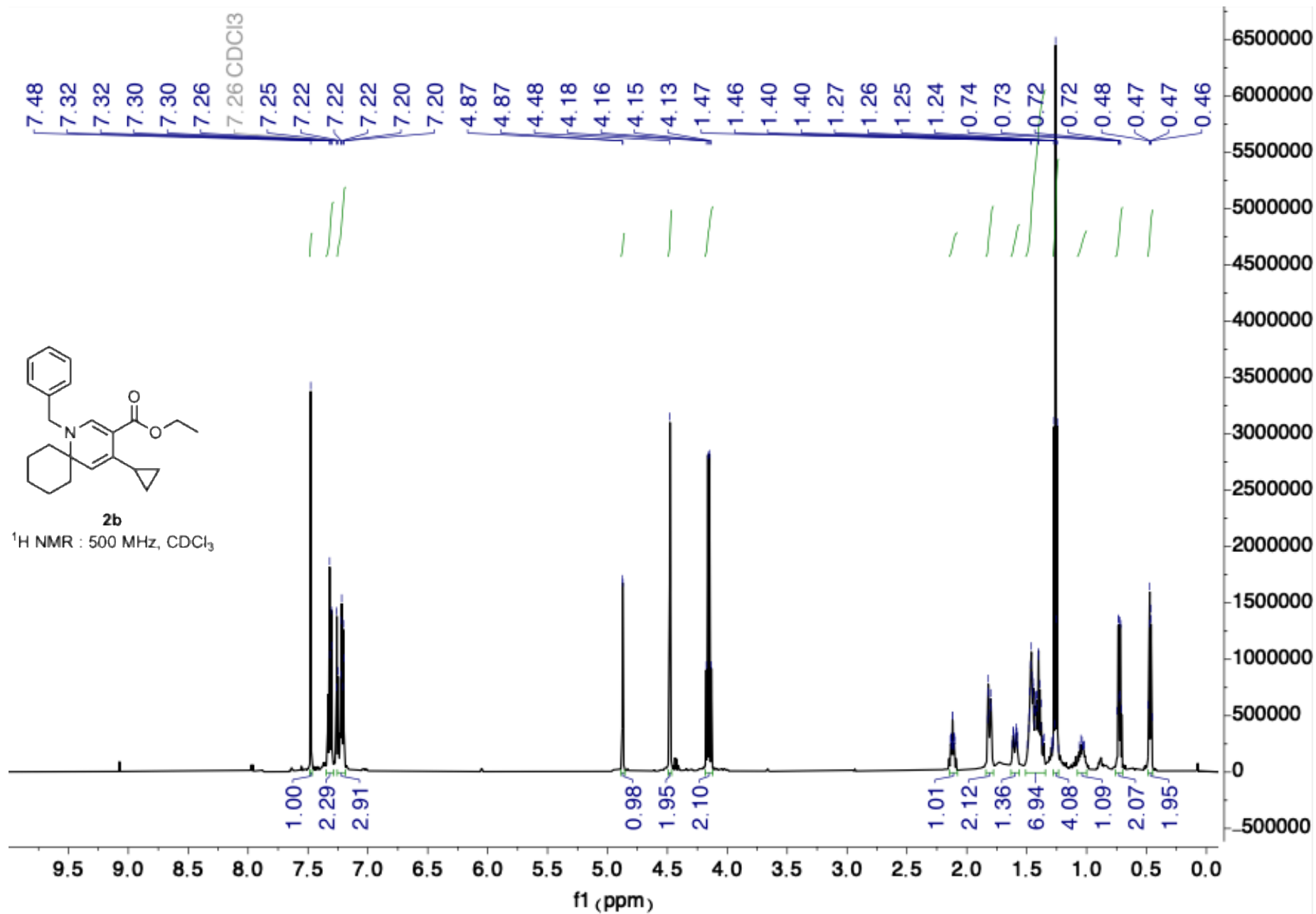


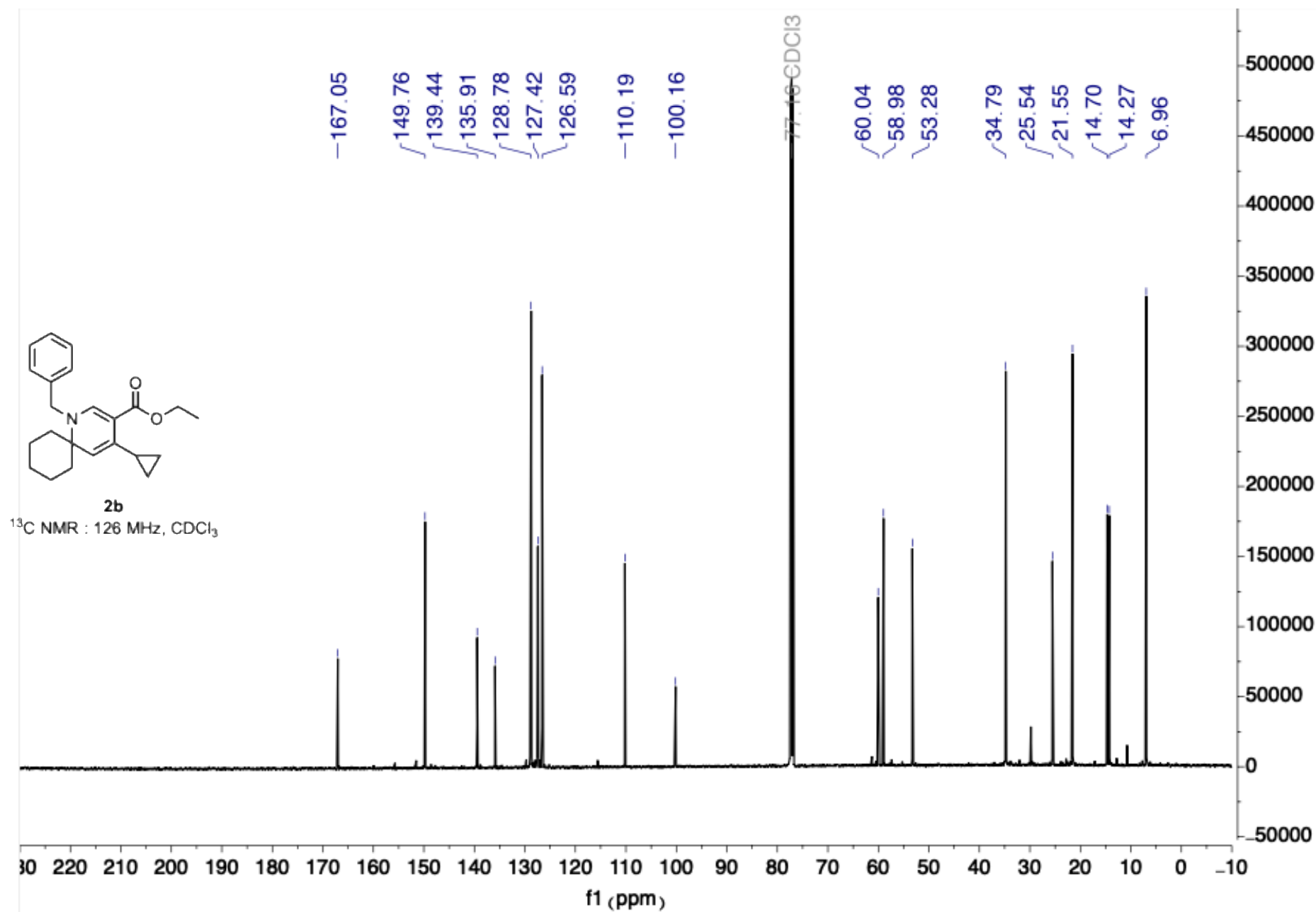


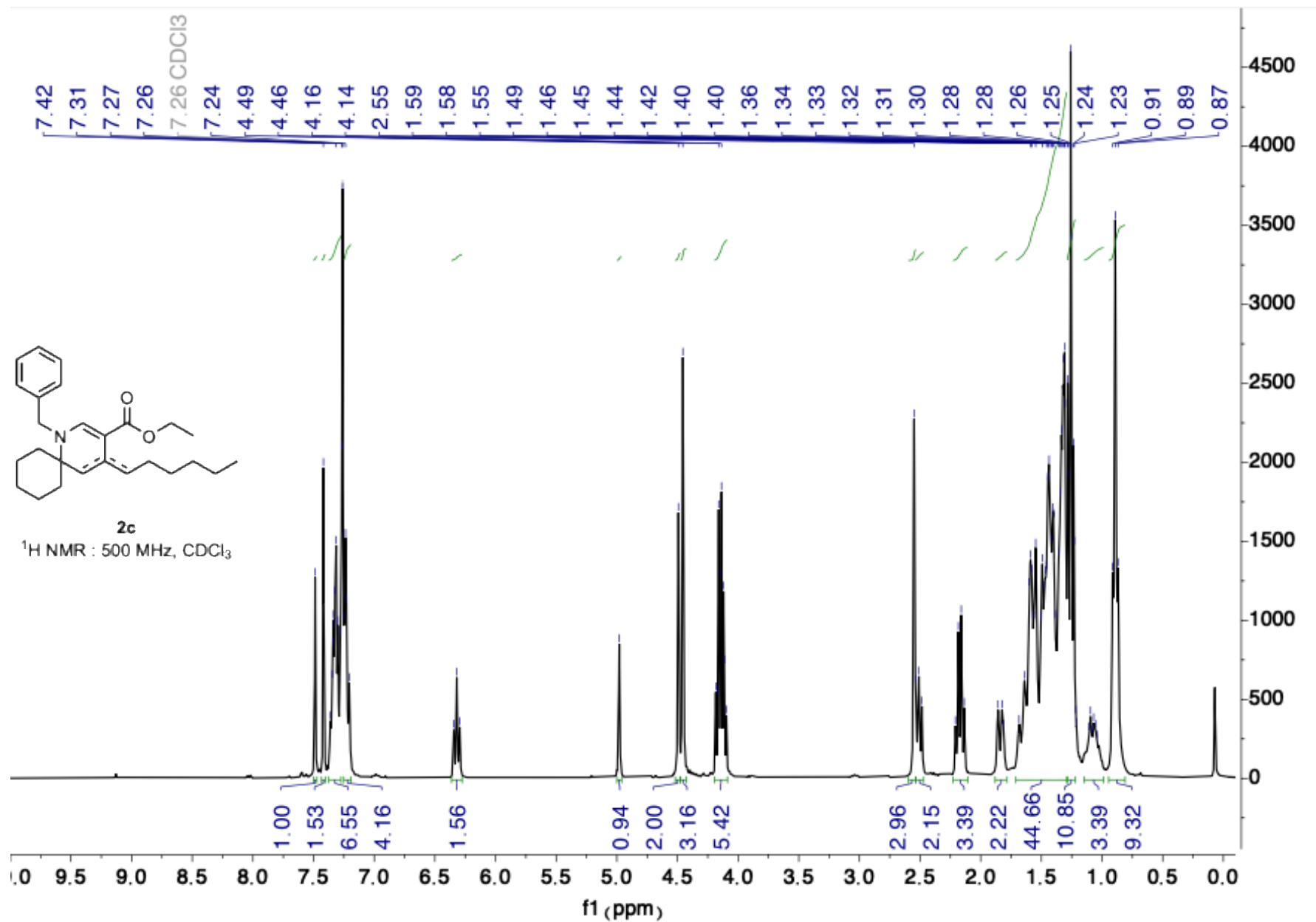
2a

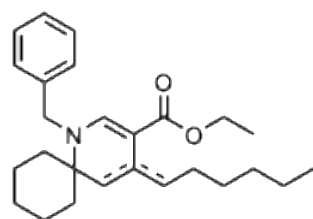
^{13}C NMR : 126 MHz, CDCl_3





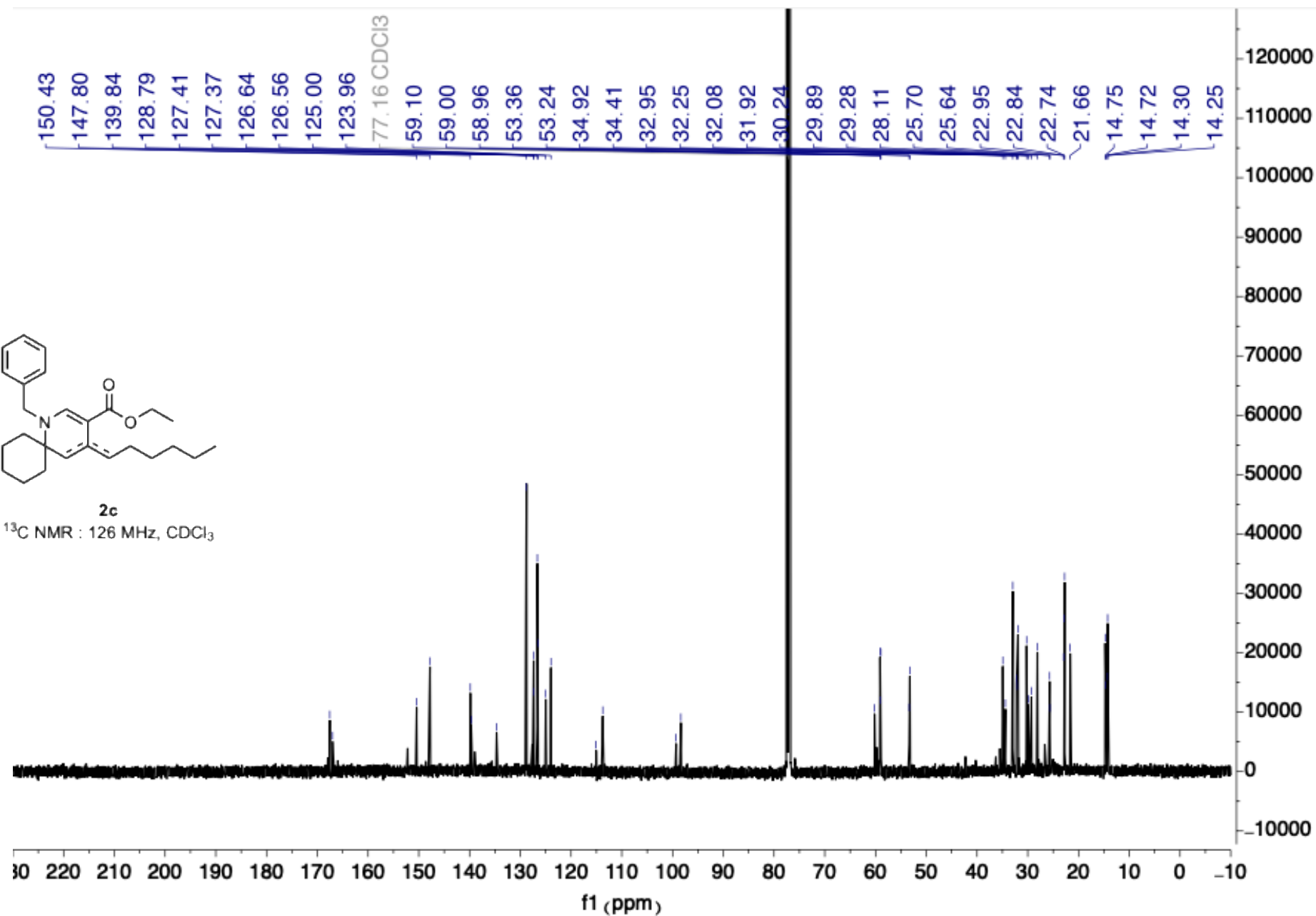


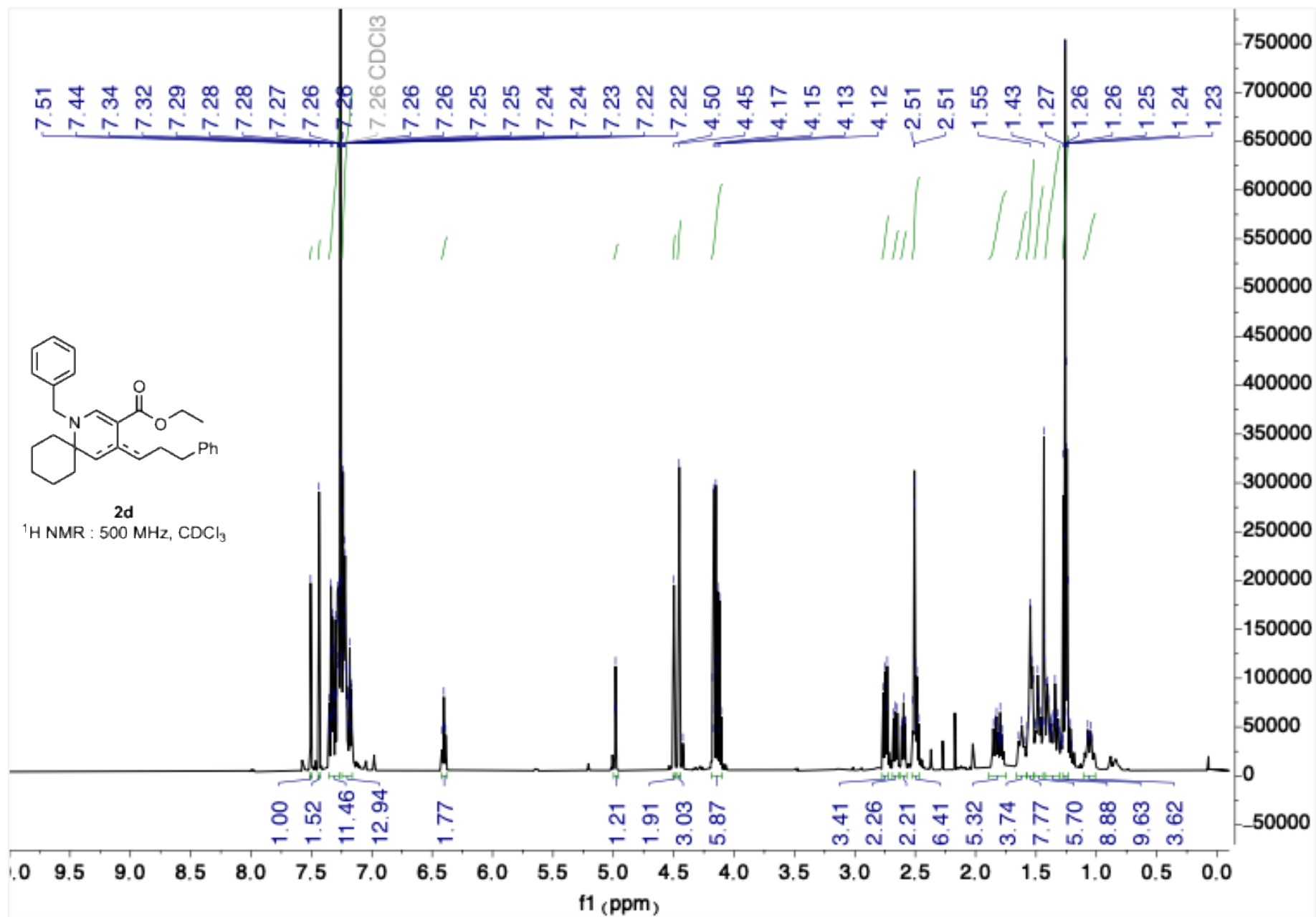


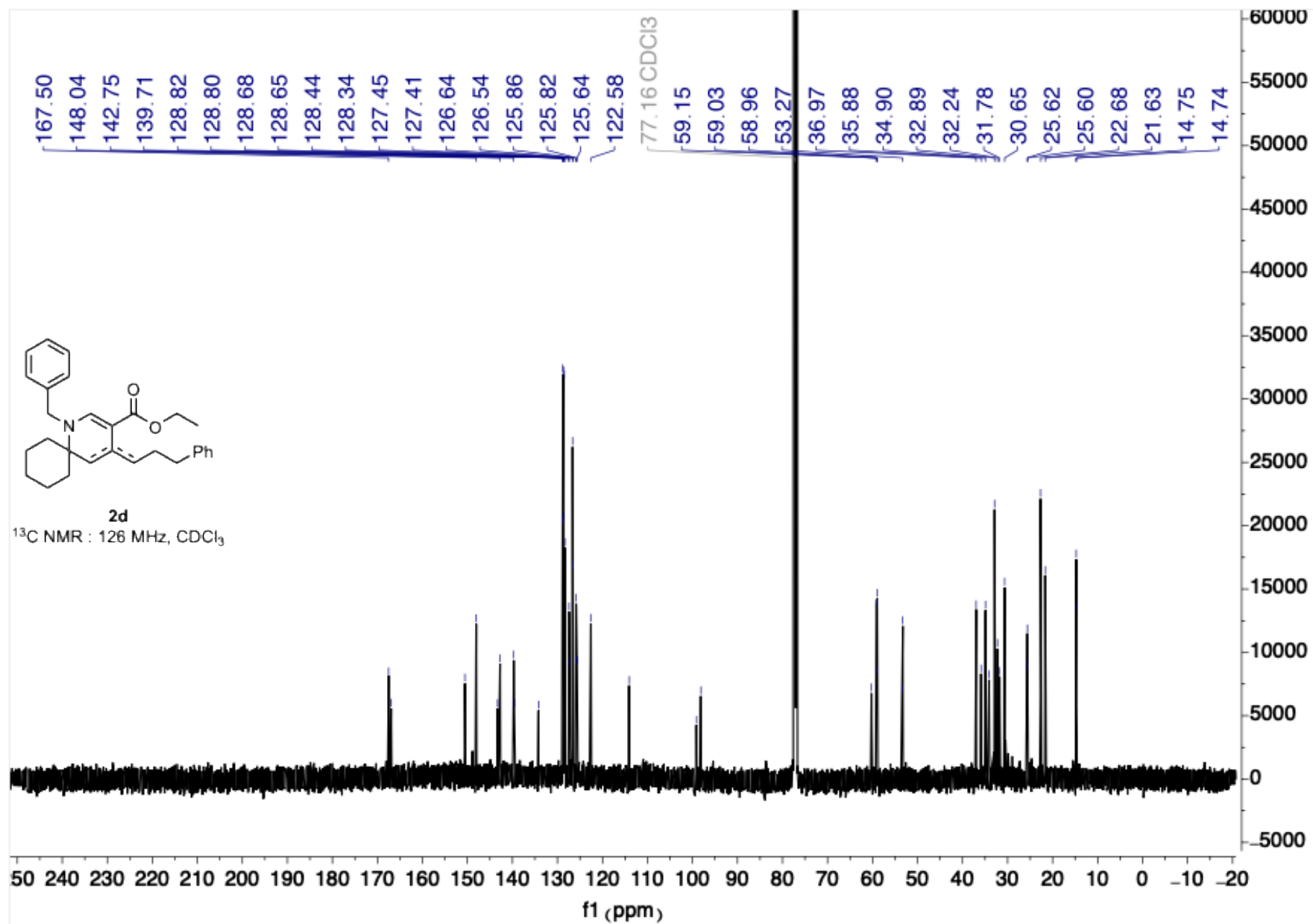


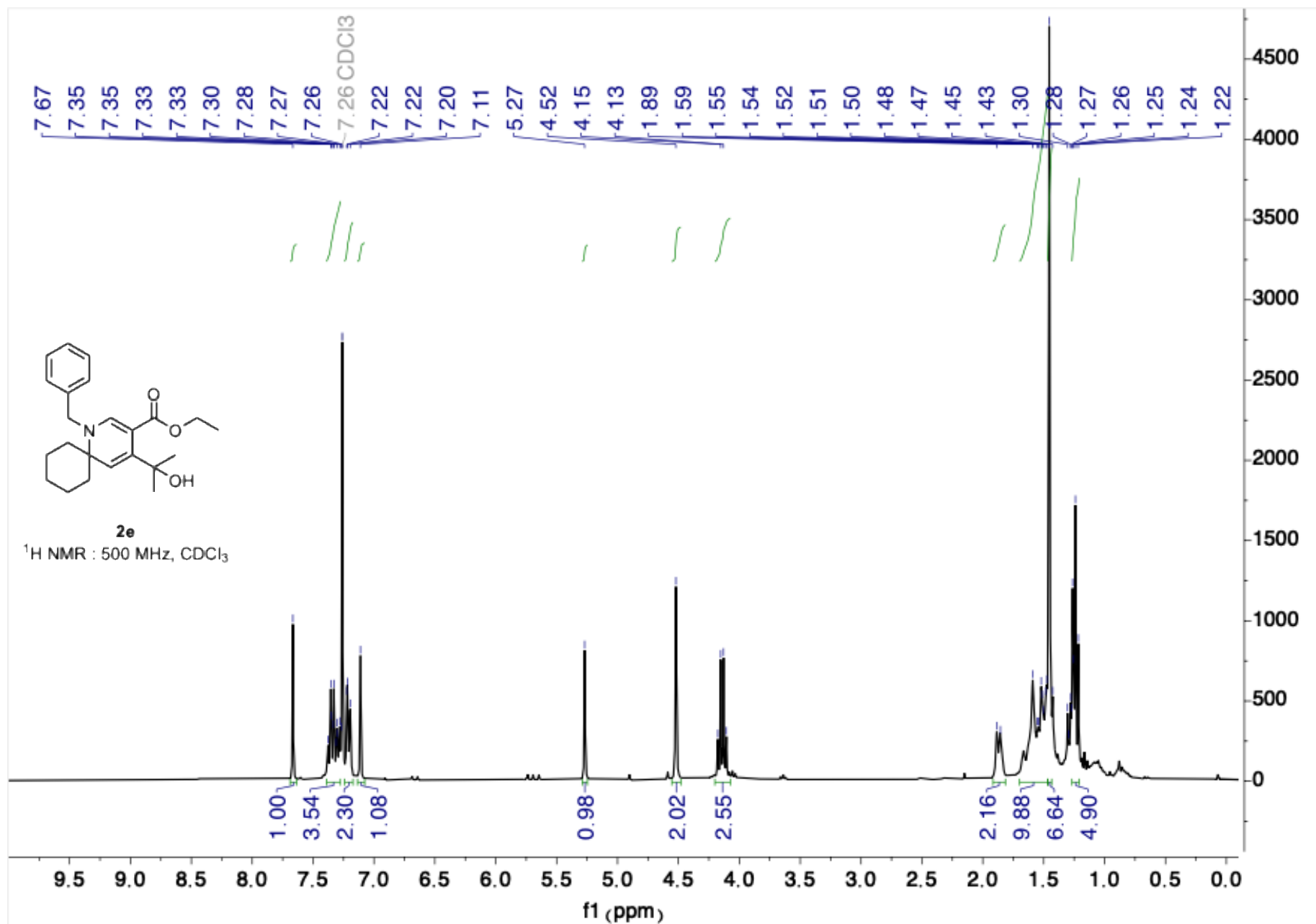
2c

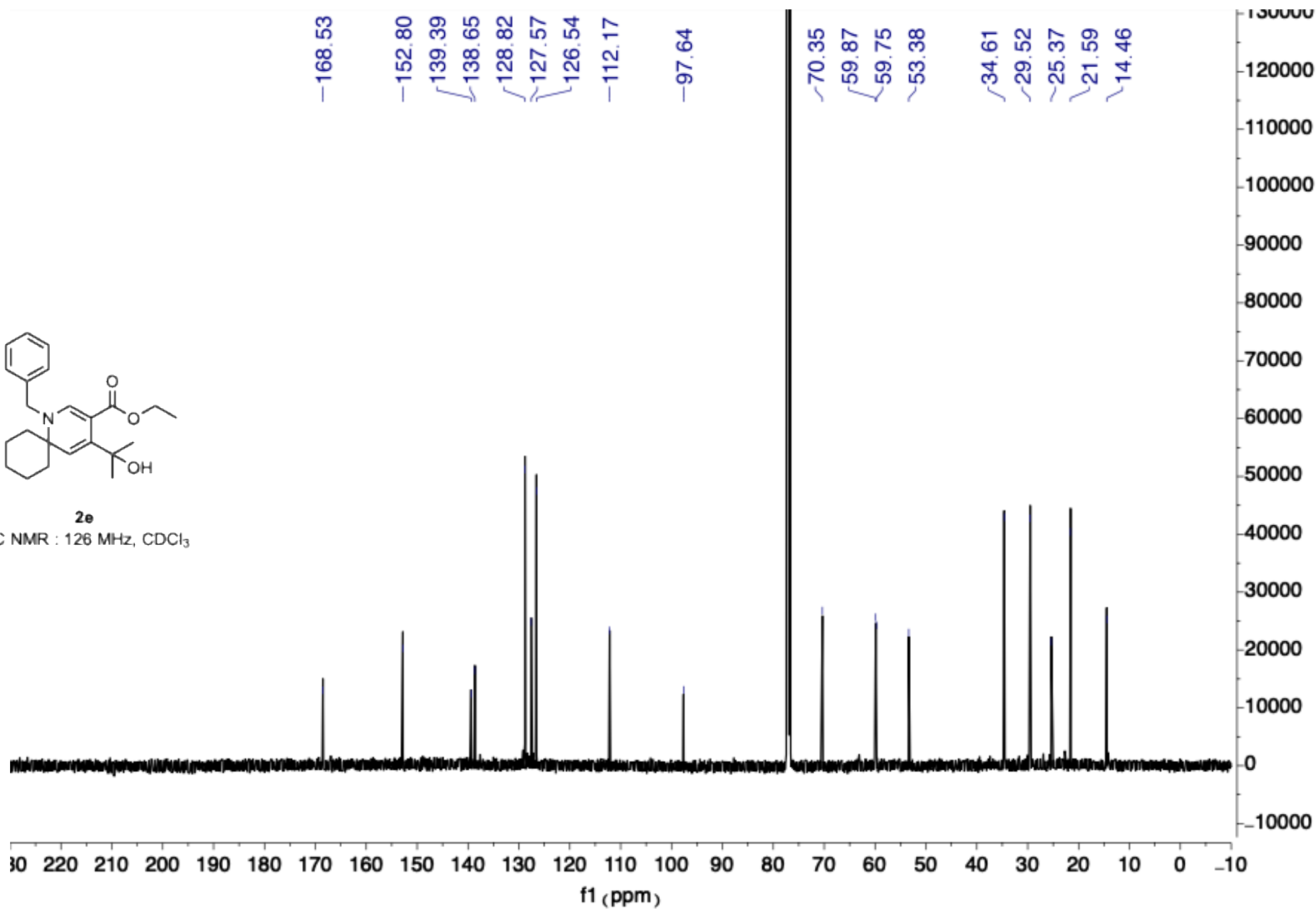
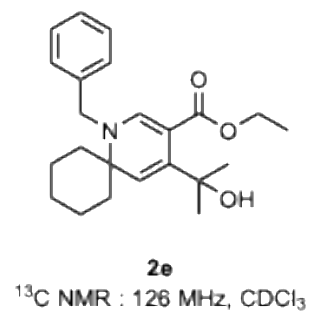
^{13}C NMR : 126 MHz, CDCl_3

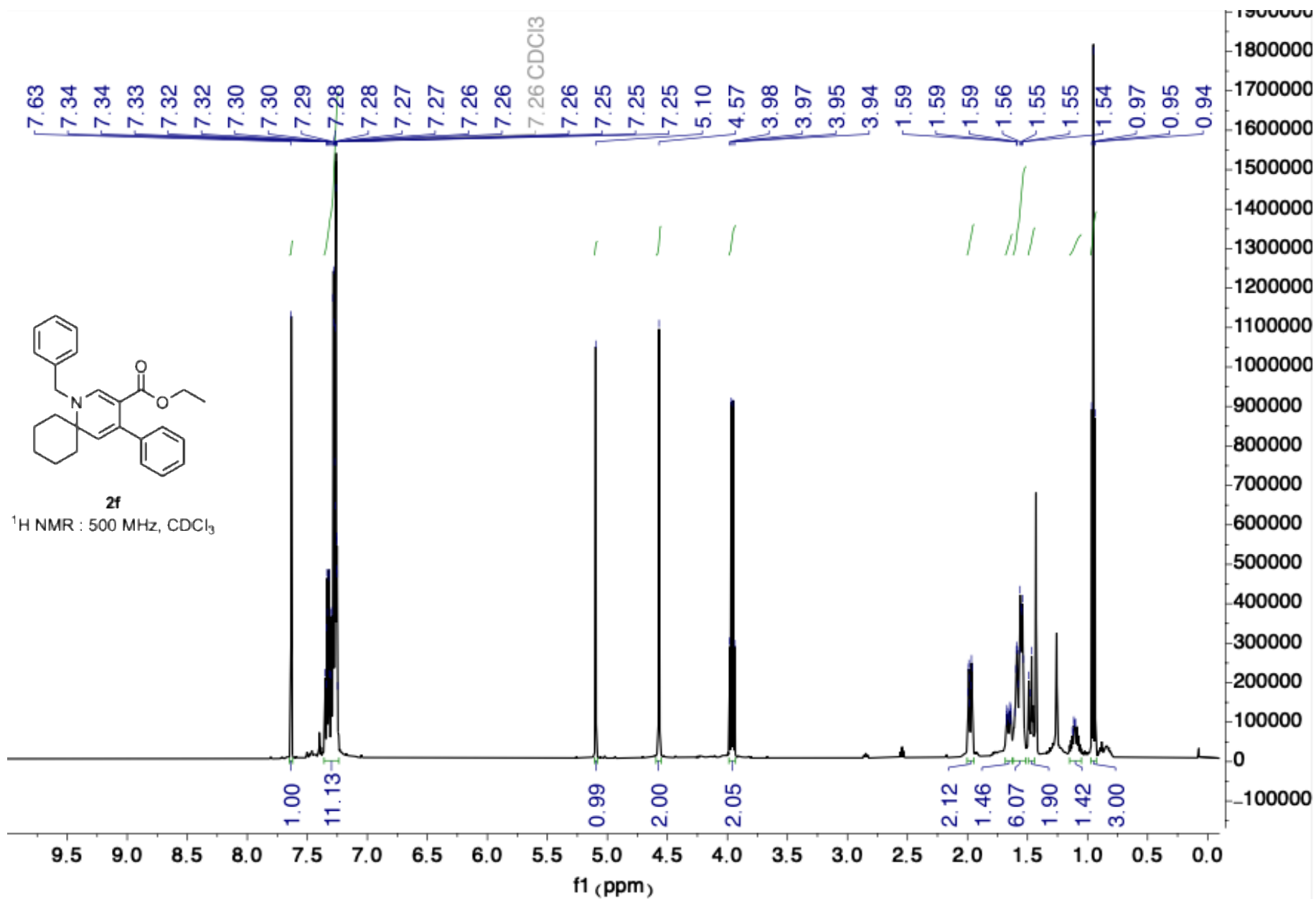


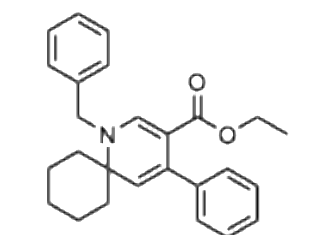






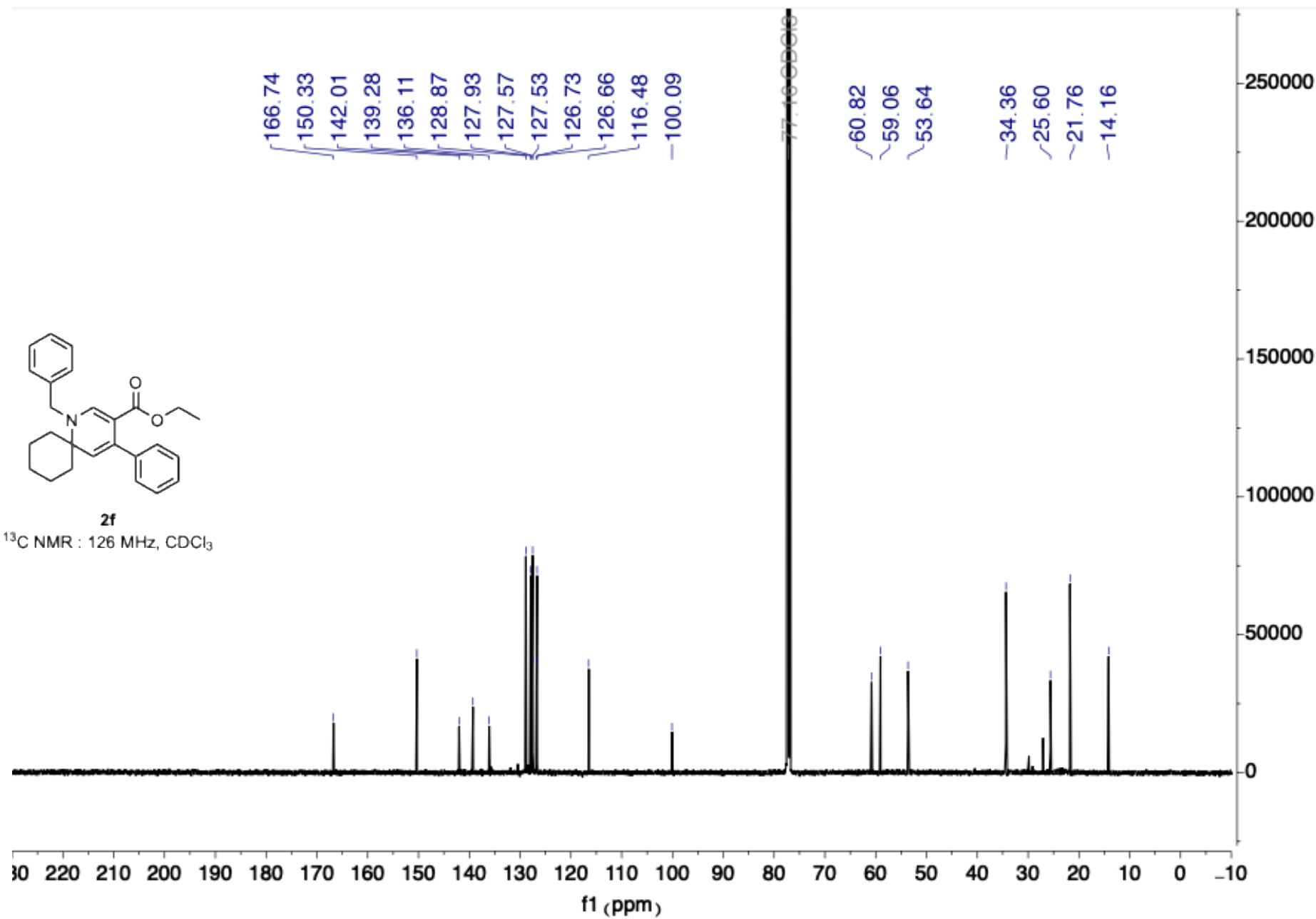


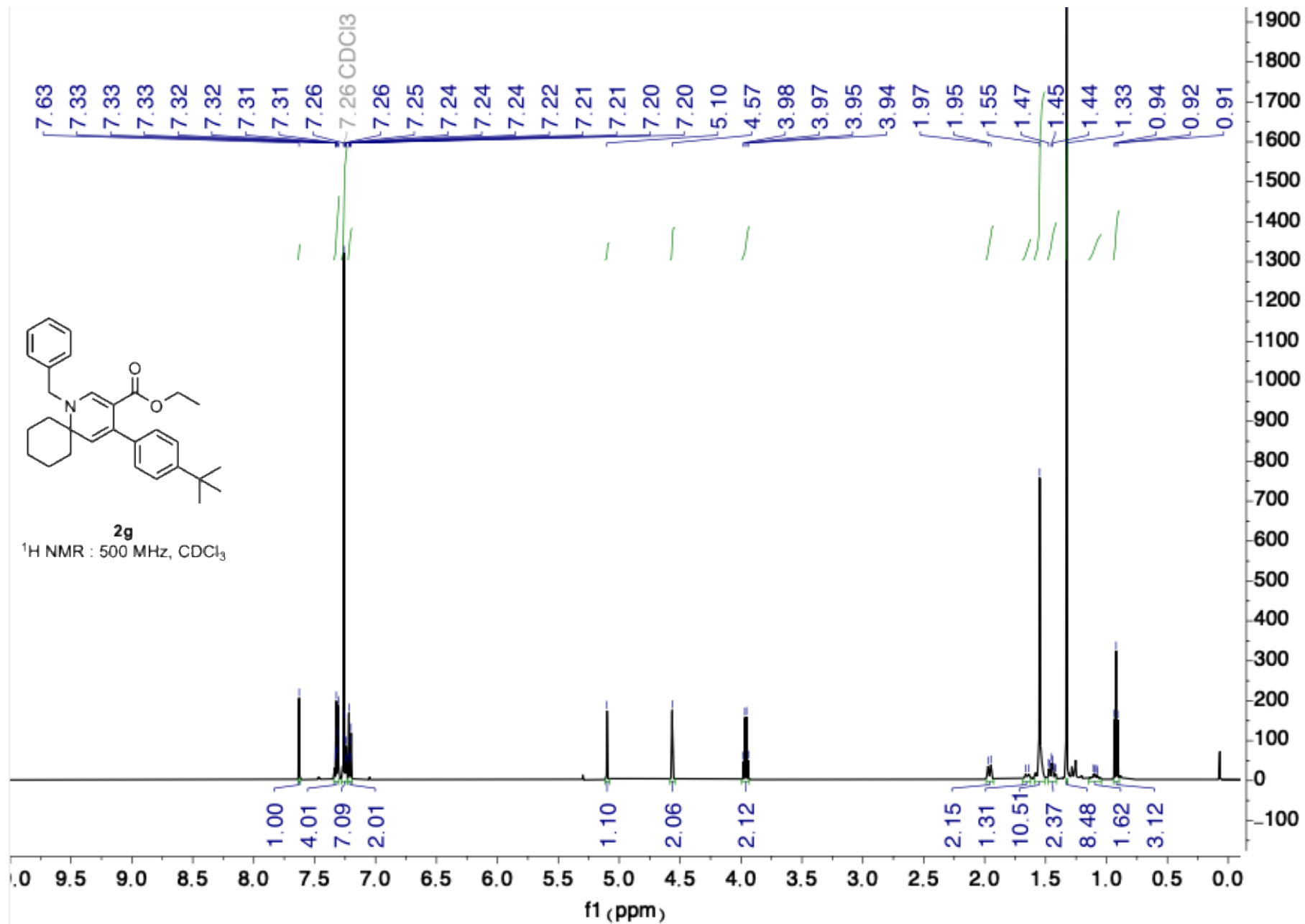


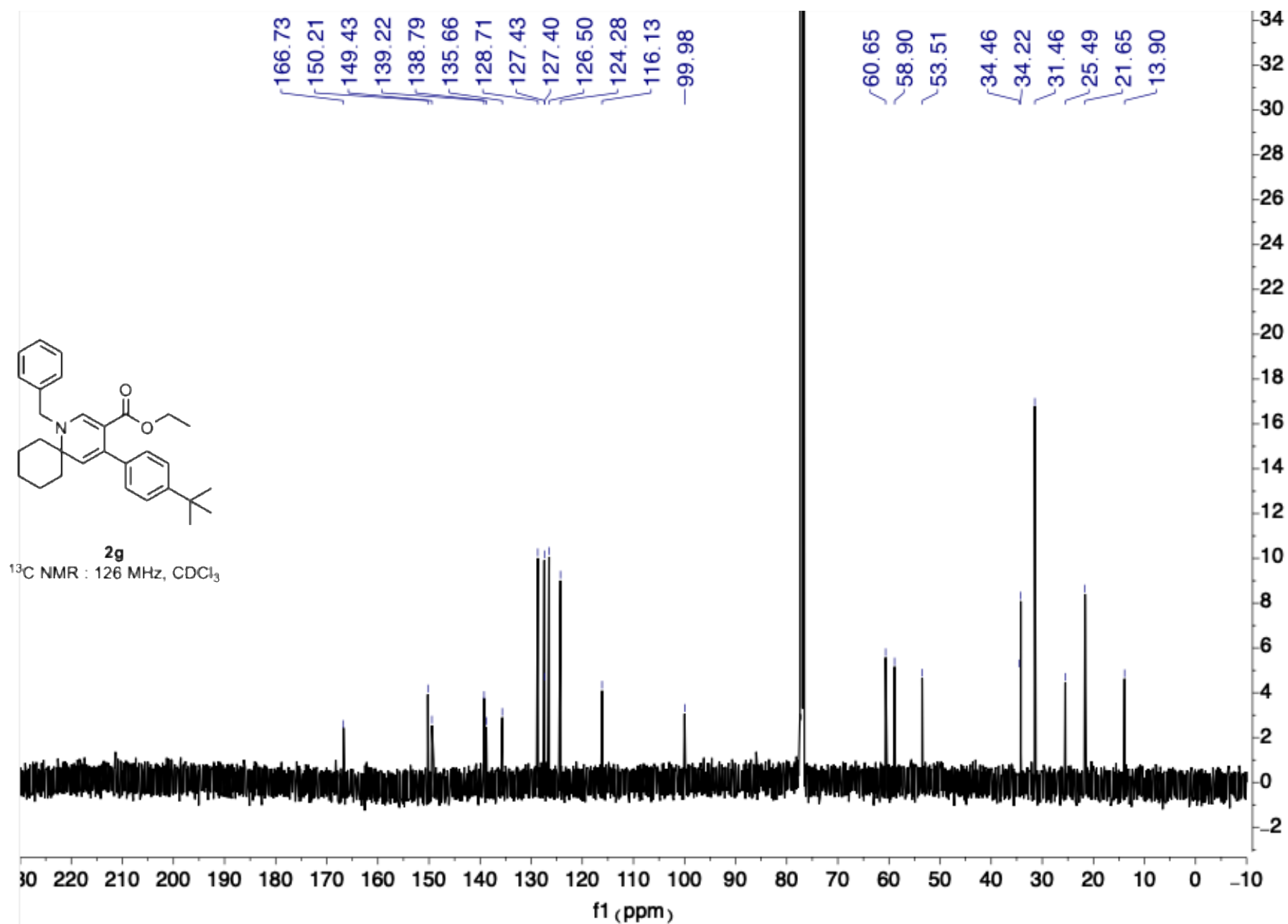


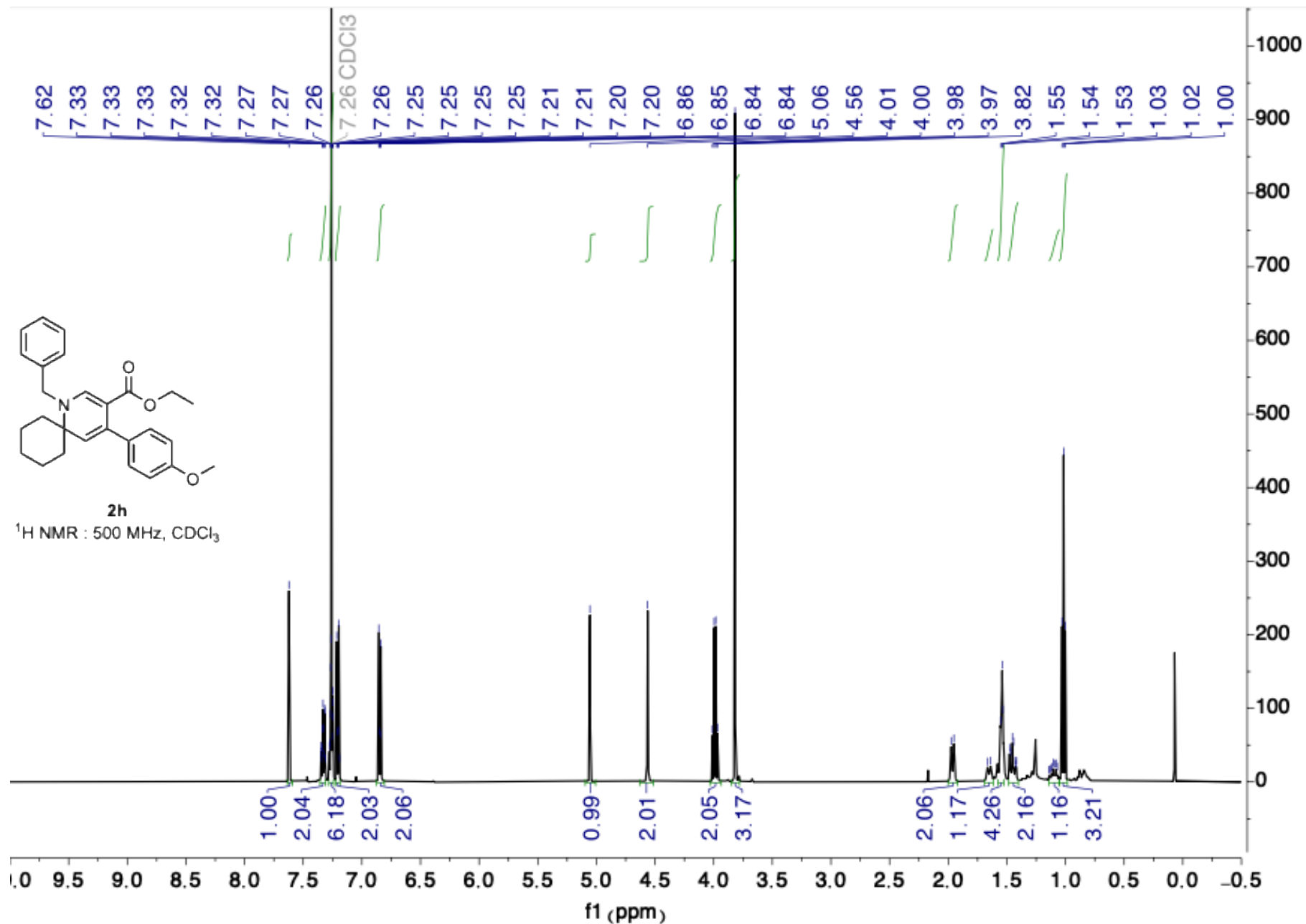
2f

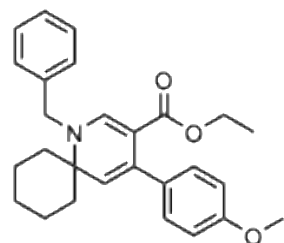
^{13}C NMR : 126 MHz, CDCl_3











2h

^{13}C NMR : 126 MHz, CDCl_3

