A Single Cu(II) Catalyst for the Three-Component Coupling of Diverse Nitrogen Sources with Aldehydes and Alkynes

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General Procedural and Reagent Information

All reactions were set up on the benchtop in test tubes, closed with Teflon seal insert screw caps, and carried out under an atmosphere of argon ("test tube" in general procedures A-D). Column chromatography was performed using florisil purchased from Alfa Aesar. Toluene was purchased from Aldrich in Sure-Seal bottles and used as received. Copper(II) trifluoromethanesulfonate, $Cu(OTf)_2$, was purchased from Alfa Aesar and used as supplied. Amines were purchased from Acros Organics, Alfa Aesar, or Aldrich and flushed through alumina before used. All aldehydes and alkynes were purchased from Acros Organics, Alfa Aesar, or TCI America and were purified by distillation before use as in Amerengo, W. L. F.; Perrin, D. D. *Purification of Laboratory Chemicals*. 4th ed.; Butterworth-Heinemann: Oxford, U.K. 1996.

General Analytical Information

^1H and ^{13}C NMR spectra were measured on a Varian Inova 400 (400 MHz) spectrometer using $CDCl_3$, acetone-d6, or CD_3CN as a solvent at room temperature. Some spectra include tetramethylsilane as an internal standard. The following abbreviations are used singularly or in combination to indicate the multiplicity of signals: s - singlet, d - doublet, t - triplet, q - quartet, m - multiplet and br - broad. NMR spectra were acquired at 300 K. Gas chromatography spectra were obtained on an Agilent Technologies 6850 GC System using dodecane as an internal standard. IR spectra of solids were recorded on Perkin Elmer Spectrum One FT-IR Spectrometer. Attenuated total reflection infrared (ATR-IR) was used for analysis with selected absorption maxima reported in wavenumbers (cm^{-1}). No sample preparation was necessary for ATR analysis. ATR-IR is based on the propagation of the infrared radiation through an internal reflection element (crystal) with a high refractive index, and its reflection at the interface between the crystal and the solid material. Mass spectrometric data was collected on a HP 5989A GC/MS quadrupole instrument. Exact masses were recorded on a Waters GCT Premier ToF instrument

using direct injection of samples in acetonitrile into the electrospray source (ESI) and either positive or negative ionization.

General Procedures

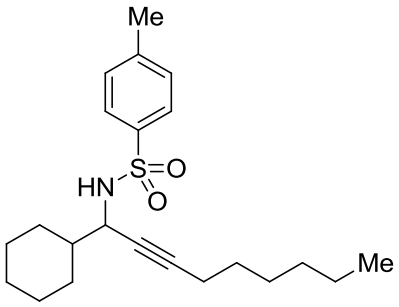
A. To an oven-dried test tube and magnetic stir bar was added amine (1.0 equiv.) and 10 mol % $Cu(OTf)_2$. The flask was purged with argon for 15 minutes. Aldehyde (1.1 equiv), alkyne (1.5 equiv), and toluene (1 mL) were added, and the reaction was stirred at the designated temperature for the indicated time. Upon completion (as judged by GC), the mixture was cooled to room temperature and diluted with 5 mL diethyl ether (Et_2O). Combined organics were washed with 1M aqueous HCl and sat. aq. $NaHCO_3$, dried over Na_2SO_4 for 30 minutes, and reduced *in vacuo*. Then 20 mL chloroform and 1.0 g florisil were added and concentrated under vacuum for dry loading atop a florisil gel column. Chromatography with ethyl acetate (EtOAc) or Et_2O in hexanes as eluent afforded the desired product.

B. To an oven-dried test tube and magnetic stir bar was added amine (1.0 equiv), Na_2SO_4 if specified, and 10 mol % $Cu(OTf)_2$. The flask was purged with argon for 15 minutes. Aldehyde (1.1 equiv), alkyne (1.5 equiv), and toluene (1 mL) were added, and the reaction was stirred at the designated temperature for the indicated time. Upon completion (as judged by GC), the mixture was cooled to room temperature and diluted with 20 mL chloroform and reduced *in vacuo*. Resulting oil was loaded directly onto column for chromatography with EtOAc or Et_2O in hexanes as eluent afforded the desired product.

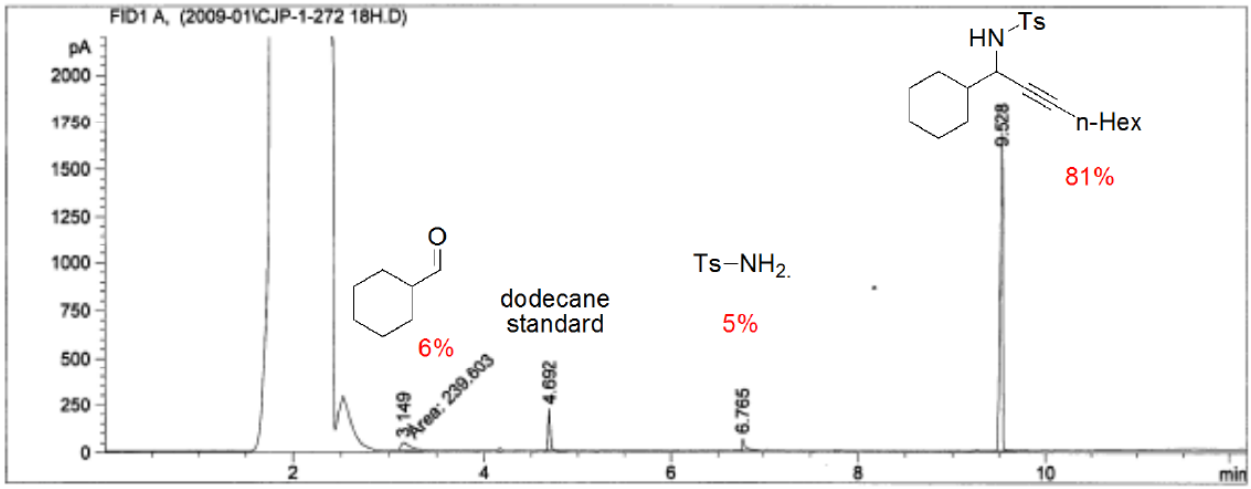
C. To an oven-dried test tube and magnetic stir bar was added amine (1.0 equiv), Na_2SO_4 (1.0 equiv), and 10 mol % $Cu(OTf)_2$. The flask was purged with argon for 15 minutes. Aldehyde (1.1 equiv), alkyne (1.5 equiv), and toluene (1 mL) were added, and the reaction was stirred at the designated temperature for the indicated time. Upon completion (as judged by GC), the mixture was cooled to room temperature and diluted with 5 mL diethyl ether (Et_2O). Combined organics were washed with 1M aqueous HCl and sat. aq. $NaHCO_3$, dried over Na_2SO_4 for 30 minutes, and reduced *in vacuo*. Then 20 mL chloroform and 1.0 g florisil were added and concentrated under vacuum for dry loading atop a florisil gel column. Chromatography with EtOAc or Et_2O in hexanes as eluent afforded the desired product.

D. To an oven-dried test tube and magnetic stir bar was added amine (1.0 equiv), Na_2SO_4 (1.0 equiv), 10 mol % Cs_2CO_3, and 10 mol % $Cu(OTf)_2$. The flask was purged with argon for 15 minutes. Aldehyde (1.1 equiv), alkyne (1.5 equiv), and toluene (1 mL) were added, and the reaction was stirred at the designated temperature for the indicated time. Upon completion (as judged by GC), the mixture was cooled to room temperature and diluted with 5 mL diethyl ether (Et_2O). Combined organics were washed with sat. aq. $NaHCO_3$, dried over Na_2SO_4 for 30 minutes, and reduced *in vacuo*. Then 20 mL chloroform and 1.0 g florisil were added and concentrated under vacuum for dry loading atop a florisil gel column. Chromatography with EtOAc or Et_2O in hexanes as eluent afforded the desired product.

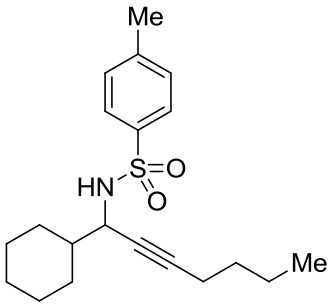
(3a) N-(1-cyclohexylnon-2-yn-1-yl)-4-methylbenzene-1-sulfonamide



Prepared according to general procedure A: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 100 °C for 2h to afford the title compound as a white crystalline powder in 79% yield (0.285 g, 0.79 mmol) after column chromatography on florisil gel (2-4-6-8-10-12-15% Et_2O in hexanes). IR (film) 3285, 2928, 2854, 1599, 1427, 1332, 1299, 1158, 1094, 1049, 1020, 929, 812, 742, 679 cm^{-1}. ^1H NMR (400 MHz, acetone, 25°C) δ 7.74 (d, J = 8.3 Hz, 2H), 7.36 (d, J = 8.0 Hz, 2H), 6.53 (d, J = 9.3 Hz, 1H), 3.81 (ddt, J = 8.5, 6.3, 2.1 Hz, 1H), 2.40 (s, 3H), 2.03 (dt, J = 4.4, 2.2 Hz, 1H), 1.92 – 1.76 (m, 4H), 1.69 (s, 2H), 1.62 (d, J = 10.9 Hz, 1H), 1.53 – 1.40 (m, 1H), 1.32 – 0.97 (m, 12H), 0.86 (t, J = 7.0 Hz, 3H).^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 143.26, 137.84, 129.55, 127.62, 85.93, 51.43, 43.49, 31.45, 29.31, 28.64, 28.58, 28.36, 26.38, 26.03, 25.93, 22.71, 21.70, 18.58, 14.22, 0.19. HRMS calculated requires $[M]^+$: 375.2232. Found *m/z*: 375.2227. GC trace of aliquot taken near reaction completion and flushed through celite plug is shown below:



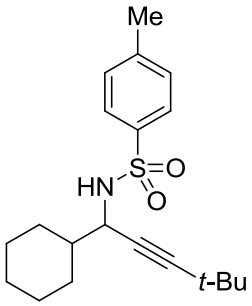
(3b) N-(1-cyclohexylhept-2-yn-1-yl)-4-methylbenzene-1-sulfonamide



Prepared according to general procedure A: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), 1-hexyne (174 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 60 °C for 42 hours to afford the title compound as a white crystalline powder in 70% yield (0.242 g, 0.70 mmol) after column chromatography on florisil gel (5-10-15-20% EtOAc in hexanes). IR (film) 3282, 2927, 2855, 1680, 1598, 1496, 1433, 1332, 1302, 1289, 1211, 1157, 1093, 1054, 1024, 941, 910 cm^{-1}. ^1H NMR (400 MHz, CD_3CN, 25°C) δ 7.73 (dd, J = 17.6, 8.0 Hz, 2H), 7.38 (d, J = 7.9 Hz, 2H), 5.76 (d, J = 9.3 Hz, 1H), 3.88 – 3.71 (m, 1H), 2.43 (s, 3H), 1.88 (t, J = 5.8 Hz, 2H), 1.77 (dd, J = 21.9, 12.6 Hz, 3H), 1.65 (d, J = 11.9 Hz, 2H), 1.45 (s, 2H), 1.30 – 0.95 (m, 8H), 0.86 (t, J = 6.7 Hz, 2H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 143.45, 138.50, 129.58, 127.36, 85.44, 77.16, 51.14, 43.41, 30.57, 29.22,

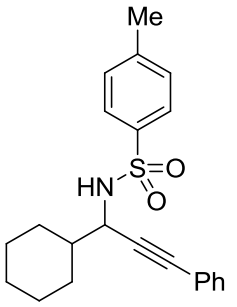
28.52, 26.25, 25.85, 25.77, 21.74, 20.78, 17.79, 13.10. HRMS calculated requires $[M+Na]^+$: 370.1817. Found *m*/*z*: 370.1811.

(3c) N-(1-cyclohexyl-4,4-dimethylpent-2-yn-1-yl)-4-methylbenzene-1-sulfonamide



Prepared according to general procedure A: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), 3,3-dimethylbutyne (185 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 100 °C for 4 hours to afford the title compound as a yellow crystalline powder in 88% yield (0.305 g, 0.88 mmol) after column chromatography on florisil gel (5-10-15-20-30% EtOAc in hexanes). IR (film) 3289, 2925, 2853, 1703, 1599, 1495, 1449, 1333, 1302, 1289, 1158, 1093, 1053, 1020, 930, 909, 880, 813, 718, 666 cm^{-1}. ^1H NMR (400 MHz, CD_3CN, 25°C) δ 7.73 (d, J = 8.3 Hz, 2H), 7.37 (d, J = 8.3 Hz, 2H), 5.74 (d, J = 9.5 Hz, 1H), 3.73 (dd, J = 9.5, 6.0 Hz, 1H), 2.41 (s, 3H), 1.95 (dt, J = 4.9, 2.5 Hz, 1H), 1.82 – 1.70 (m, 4H), 1.64 (d, J = 10.9 Hz, 1H), 1.41 (tdd, J = 12.1, 6.2, 3.1 Hz, 1H), 1.23 – 1.03 (m, 4H), 0.95 (s, 9H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 143.50, 138.51, 129.71, 127.35, 93.52, 75.69, 50.95, 43.60, 30.17, 29.22, 28.40, 26.95, 26.26, 25.87, 25.79, 20.71. HRMS calculated requires $[M+Na]^+$: 370.1817. Found *m*/*z*: 370.1822.

(3d) N-(1-cyclohexyl-3-phenylprop-2-yn-1-yl)-4-methylbenzene-1-sulfonamide



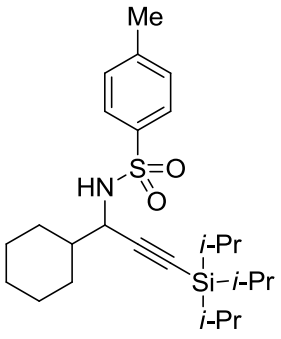
Prepared according to general procedure C: *p*-toluene sulfonamide (172 mg, 1.0 mmol), Na_2SO_4 (142 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), phenylacetylene (165 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 60 °C for 72 hours to afford the title compound as a light yellow powder in 76% yield (0.279 g, 0.76 mmol) after column chromatography on florisil gel (2-4-6-8-10-15-20% Et_2O in hexanes). IR (film) 3278, 2923, 2852, 1597, 1490, 1432, 1330, 1153, 1090, 1039, 921, 816, 762, 738, 692, 670 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.73 (d, J = 8.3 Hz, 2H), 7.28 – 7.08 (m, 5H), 6.97 (dd, J = 8.1, 1.5 Hz, 2H), 4.51 (d, J = 9.9 Hz, 1H), 4.04 (dd, J = 9.9, 5.9 Hz, 1H), 2.31 – 2.17 (m, 3H), 1.83 (d, J = 11.6 Hz, 1H), 1.76 – 1.68 (m, 2H), 1.63 – 1.53 (m, 2H), 1.21 – 1.02 (m, 5H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 143.61, 137.63, 131.67, 129.74, 128.47, 128.24, 127.67, 122.46, 86.41, 85.37, 51.71, 43.42, 29.40, 28.64, 26.34, 26.02, 25.94, 21.62, 0.20. HRMS calculated requires $[M+Na]^+$: 390.1504. Found *m*/*z*: 390.1498. These value match those previously reported:

1) Zani, L.; Alesi, S.; Cozzi, P. G.; Bolm, C. *J. Org. Chem.* **2006**, *71*, 1558.

2) Blay, G.; Cardona, L.; Climent, E.; Pedro, J. R. *Angew. Chem., Int. Ed.* **2008**, *47*, 5593.

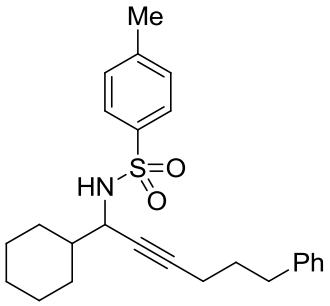
(3e) N-{1-cyclohexyl-3-[tris(propan-2-yl)silyl]prop-2-yn-1-yl}-4-methylbenzene-1-sulfonamide

Prepared according to general procedure D: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), triisopropyl silyl acetylene (337 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol), Cs_2CO_3 (33 mg, 10 mol %) were stirred at 80 °C for 18



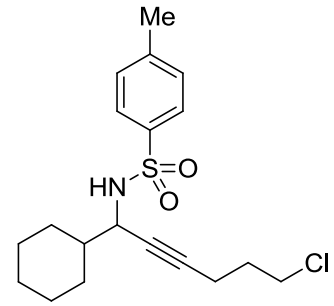
hours to afford the title compound as a white crystalline powder in 78% yield (0.349 g, 0.78 mmol) after column chromatography on florisil gel (5-10-20-30-40-50% EtOAc in hexanes, each with 1% triethylamine added). IR (film) 3263, 2929, 2862, 2170, 1598, 1447, 1428, 1326, 1160, 1083, 1036, 1001, 932, 883, 815, 707 cm^{-1}. ^{1}H NMR (400 MHz, CD_3CN, 25°C) δ 7.72 (dd, J = 8.4, 1.8 Hz, 2H), 7.31 (t, J = 10.2 Hz, 2H), 5.96 (d, J = 9.2 Hz, 1H), 3.89 (dd, J = 9.1, 5.7 Hz, 1H), 2.39 (d, J = 7.4 Hz, 3H), 1.83 – 1.69 (m, 4H), 1.64 (d, J = 11.4 Hz, 1H), 1.50 (dtd, J = 9.0, 6.5, 3.3 Hz, 2H), 1.23 (dt, J = 23.5, 9.2 Hz, 4H), 1.15 – 1.05 (m, 2H), 0.94 (s, 18H), 0.90 – 0.82 (m, 2H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 143.49, 138.49, 129.86, 127.11, 104.90, 85.13, 51.37, 43.83, 29.23, 28.24, 26.28, 25.87, 25.75, 20.79, 18.11, 11.11. HRMS calculated requires $[M+Na]^+$: 470.2525. Found *m*/*z*: 470.2519.

(3f) N-(1-cyclohexyl-6-phenylhex-2-yn-1-yl)-4-methylbenzene-1-sulfonamide



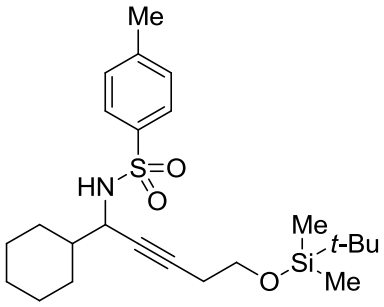
Prepared according to general procedure C: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), 5-phenyl-1-pentyne (228 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol) were stirred at 60 °C for 28 hours to afford the title compound as a white crystalline powder in 80% yield (0.327 g, 0.80 mmol) after column chromatography on florisil gel (10-20-30-40-50% Et_2O in hexanes). IR (film) 3282, 2925, 2853, 1599, 1496, 1451, 1429, 1331, 1301, 1289, 1158, 1093, 1038, 1021, 935, 909, 881, 816 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.73 (dd, J = 18.7, 8.2 Hz, 2H), 7.46 – 7.12 (m, 5H), 7.09 (d, J = 7.2 Hz, 2H), 4.59 (d, J = 9.5 Hz, 1H), 3.93 – 3.80 (m, 1H), 2.50 (t, J = 7.6 Hz, 2H), 2.31 (s, 3H), 1.89 (td, J = 7.0, 1.8 Hz, 2H), 1.84 – 1.68 (m, 4H), 1.63 (d, J = 11.1 Hz, 1H), 1.54 (td, J = 14.7, 7.3 Hz, 2H), 1.27 – 0.98 (m, 5H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 143.38, 141.61, 137.83, 129.59, 128.62, 128.56, 127.60, 126.15, 85.36, 77.74, 51.40, 43.52, 34.96, 30.24, 29.36, 28.45, 26.40, 26.04, 25.94, 21.63, 18.10. HRMS calculated requires $[M+Na]^+$: 432.1973. Found *m*/*z*: 432.1985.

(3g) N-(6-chloro-1-cyclohexylhept-2-yn-1-yl)-4-methylbenzene-1-sulfonamide



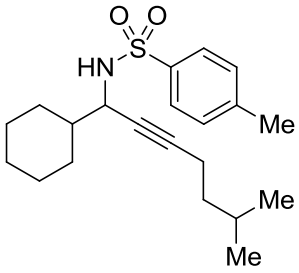
Prepared according to general procedure A: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), 5-chloro-1-pentyne (161 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 100 °C for 2 hours to afford the title compound as an off-white crystalline powder in 81% yield (0.307 g, 0.81 mmol) after column chromatography on florisil gel (10-20-30% Et_2O in hexanes). IR (film) 3275, 2926, 2855, 1692, 1599, 1495, 1435, 1333, 1305, 1289, 1273, 1160, 1094, 1055, 1032, 938, 912, 880 cm^{-1}. ^{1}H NMR (400 MHz, CD_3CN, 25°C) δ 7.77 – 7.69 (m, 2H), 7.41 – 7.32 (m, 2H), 5.75 (d, J = 9.5 Hz, 1H), 3.83 – 3.74 (m, 1H), 3.50 – 3.41 (m, 2H), 2.42 (s, 3H), 2.07 – 2.00 (m, 2H), 1.81 – 1.70 (m, 4H), 1.64 – 1.60 (m, 2H), 1.25 – 0.97 (m, 6H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 143.59, 138.43, 129.64, 127.37, 83.53, 78.16, 51.02, 43.98, 43.36, 31.20, 29.16, 28.55, 26.21, 25.83, 25.75, 20.78, 15.52. HRMS calculated requires $[M+H]^+$: 368.1451. Found *m*/*z*: 368.1446.

(3h) N-{5-[(tert-butyldimethylsilyl)oxy]-1-cyclohexylpent-2-yn-1-yl}-4-methylbenzene-1-sulfonamide



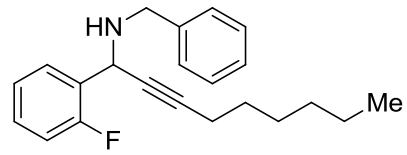
Prepared according to general procedure D: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), 4-(tert-butyldimethylsiloxy)-1-butyne (310 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol), Cs_2CO_3 (32 mg, 10 mol %) were stirred at 80 °C for 18 hours to afford the title compound as an orange crystalline powder in 80% yield (0.359 g, 0.80 mmol) after column chromatography on florisil gel (2-5-10-15-20-25-30-35% EtOAc in hexanes, each a 1% solution of triethylamine). IR (film) 3264, 2926, 2852, 1710, 1599, 1494, 1449, 1335, 1303, 1290, 1258, 1165, 1093, 1052, 1032, 927, 918, 877 cm^{-1}. ^1H NMR (400 MHz, CD_3CN, 25°C) δ 7.73 (d, J = 8.3 Hz, 2H), 7.35 (d, J = 8.1 Hz, 2H), 5.72 (d, J = 6.9 Hz, 1H), 3.76 (s, 1H), 3.50 – 3.36 (m, 2H), 2.41 (s, J = 5.9 Hz, 3H), 2.23 (s, J = 32.0 Hz, 2H), 2.03 (td, J = 6.8, 2.1 Hz, 2H), 1.75 (dd, J = 24.8, 12.2 Hz, 4H), 1.67 – 1.48 (m, 2H), 1.46 – 1.31 (m, 2H), 1.26 – 0.92 (m, 6H), 0.87 (s, 9H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 143.46, 143.43, 138.48, 129.55, 127.44, 82.76, 78.11, 61.68, 51.16, 43.20, 29.23, 28.56, 26.20, 25.85, 25.78, 25.48, 22.71, 20.84, 18.10, -5.84. HRMS calculated requires $[M+H]^+$: 450.2498. Found *m*/*z*: 450.2493.

(3i) N-(1-cyclohexyl-6-methylhept-2-yn-1-yl)-4-methylbenzene-1-sulfonamide



Prepared according to general procedure A: *p*-toluene sulfonamide (172 mg, 1.0 mmol), cyclohexanecarboxaldehyde (134 µL, 1.1 mmol), 5-methyl-1-hexyne (198 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 100 °C for 3 hours to afford the title compound as a white crystalline powder in 79% yield (0.285 g, 0.79 mmol) after column chromatography on florisil gel (10-20-30-40-50% Et_2O in hexanes). IR (film) 3265, 2923, 2852, 1738, 1598, 1439, 1331, 1211, 1156, 1092, 1054, 1020, 933, 882, 815, 670 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.78 (d, J = 8.4 Hz, 2H), 7.29 (d, J = 8.4 Hz, 2H), 4.65 (d, J = 9.2 Hz, 1H), 3.86 (m, J = 7.6 Hz, 1H), 2.42 (s, 3H), 1.88 (m, 2H), 1.80-1.58 (m, 5H), 1.52-1.42 (m, 2H), 1.25-1.01 (m, 6H), 0.80 (d, 6H). ^{13}C NMR (100 MHz, acetone, 25°C) 142.71, 139.37, 129.35, 127.43, 85.07, 77.32, 51.12, 43.47, 37.54, 27.06, 26.35, 25.87, 21.75, 21.67, 20.78, 16.23. HRMS calculated requires $[M+Na]^+$: 384.1968. Found *m*/*z*: 384.1973.

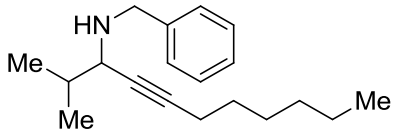
(7a) Benzyl[1-(2-fluorophenyl)non-2-yn-1-yl]amine



Prepared according to general procedure B: benzylamine (110 µL, 1.0 mmol), 2-fluorobenzaldehyde (128 µL, 1.2 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 72 hours to afford the title compound as a dark yellow oil in 88% yield (0.284 g, 0.88 mmol) after column chromatography on florisil gel (50% Et_2O in hexanes). Methylene chloride (1 mL) was added before loading onto florisil column. IR (film) 3029, 2955, 2928, 2857, 1716, 1490, 1455, 1231, 1095, 1029, 754, 731, 697 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.62 (td, J=1.6 Hz, 7.6 Hz, 1H), 7.36-7.26 (m, 4H), 7.25-7.22 (m, 2H), 7.14 (td, J = 1.2

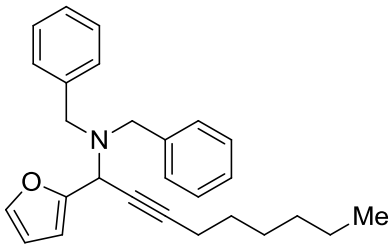
Hz, 7.2 Hz, 1H), 7.03 (td, J = 1.2 Hz, 8.4 Hz, 1H), 4.87 (t, J = 2.4 Hz, 1H), 3.93 (d, J = 12.8 Hz, 1H), 3.87 (d, J = 12.8, 1H), 2.26 (td, J = 2 Hz, 6.8 Hz, 2H), 1.72 (bs, 1H), 1.55 (quin, J = 7.2 Hz, 2H), 1.45-1.38 (m, 2H), 1.35-1.26 (m, 4H), 0.89 (t, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 161.7, 159.2, 139.7, 129.3, 128.4, 127.0, 124.1, 115.6-115.4 (J = 23.5 Hz), 85.7, 78.9, 51.3, 47.4, 31.3, 28.8, 28.6, 22.6, 18.8, 14.1. HRMS calculated requires $[M]^+$: 323.1998. Found *m*/*z*: 323.2000.

(7b) Benzyl(2-methylundec-4-yn-3-yl)amine



Prepared according to general procedure B: benzylamine (55 µL, 0.50 mmol), isobutyraldehyde (55 µL, 0.60 mmol), 1-octyne (110 µL, 0.75 mmol), $Cu(OTf)_2$ (18 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol) were stirred at 80 °C for 72 hours to afford the title compound as a yellow oil in 94% yield (0.127 g, 0.47 mmol) after column chromatography on florisil gel (50% Et_2O in hexanes). Methylene chloride (1 mL) was added before loading onto florisil column. IR (film) 3063, 3029, 2957, 2928, 2858, 1740, 1605, 1495, 1455, 1366, 1098, 1029, 842, 731, 697 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.37-7.29 (m, 4H), 7.25-7.22 (m, 1H), 4.03 (d, J = 12.8 Hz, 1H), 3.80 (d, J = 13.2, 1H), 3.17 (dt, J = 2.4 Hz, 5.6 Hz, 1H), 2.24 (td, J = 2 Hz, 6.8 Hz, 2H), 1.86-1.78 (m, 1H), 1.57-1.39 (m, 4H), 1.33-1.27 (m, 4H), 1.26 (bs, 1H), 0.98 (d, J = 6.8, 6H), 0.89 (t, J = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 140.4, 128.4, 128.3, 126.8, 84.7, 79.8, 55.8, 51.7, 32.8, 31.4, 29.1, 28.5, 19.8, 18.7, 17.8, 14.1. HRMS calculated requires $[M+H]^+$: 272.2378. Found *m*/*z*: 272.2386.

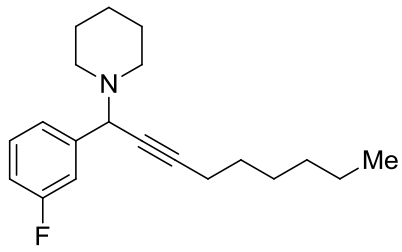
(7c) Dibenzyl[1-(furan-2-yl)non-2-yn-1-yl]amine



Prepared according to general procedure B: dibenzylamine (194 µL, 1.0 mmol), 2-furaldehyde (100 µL, 1.2 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 24 hours to afford the title compound as a yellow oil in 76% yield (0.229 g, 0.76 mmol) after column chromatography on florisil gel (0-2% Et_2O in hexanes). IR (film) 3063, 3028, 2955, 2929, 2857, 2808, 1741, 1603, 1495, 1454, 1371, 1300, 1147, 1128, 1072, 1029, 1008, 967, 815, 789, 730, 696 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.42 (d, J = 7.2 Hz, 4H), 7.39 (s, 1H), 7.29 (t, J = 6.8 Hz, 4H), 7.21 (t, J = 7.2 Hz, 2H), 6.42 (d, J = 3.2 Hz, 1H), 6.29 (dd, J = 2 Hz, 1H), 4.70 (s, 1H), 3.72 (d, J = 14 Hz, 2H), 3.52 (d, J = 14 Hz, 2H), 2.34 (td, J = 2 Hz, 6.4 Hz, 2H), 1.61 (quin, J = 6.4 Hz, 2H), 1.54-1.47 (m, 2H), 1.38-1.33 (m, 4H), 0.93 (t, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 153.2, 142.3, 139.6, 128.7, 128.2, 126.8, 109.9, 108.8, 86.5, 73.9, 54.5, 50.5, 31.4, 29.0, 28.6, 22.6, 18.8, 14.1. HRMS calculated requires $[M+Na]^+$: 408.2298. Found *m*/*z*: 408.2299.

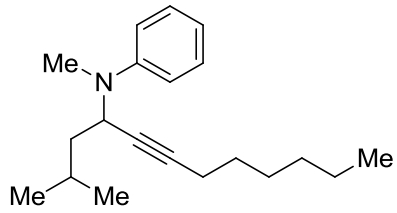
(7d) 1-{1-[3-(trifluoromethyl)phenyl]non-2-yn-1-yl}piperidine

Prepared according to general procedure B: piperidine (50 µL, 0.50 mmol), 3-fluorobenzaldehyde (59 µL, 0.55 mmol), 1-octyne (111 µL, .75 mmol), $Cu(OTf)_2$ (18 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol) were stirred at 100 °C for 1 hour to afford the title compound as a pale yellow oil in 90% yield (0.316 g, 0.45 mmol) after column chromatography on florisil gel (0-10% EtOAc in hexanes). IR (film) 2930, 2856, 2907, 1695, 1614, 1589, 1484, 1442, 1318, 1266, 1239, 1155, 1141, 1113, 992, 947, 912, 881, 865, 795, 771,



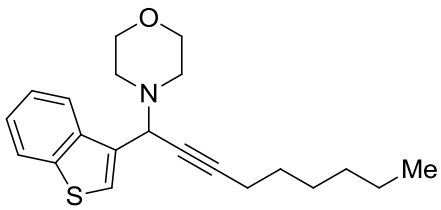
686 cm^{-1}. ^{1}H NMR (400 MHz, acetone, 25°C) δ 7.50 – 7.29 (m, 3H), 7.05 – 6.92 (m, 1H), 4.59 (s, 1H), 2.51 – 2.38 (m, 4H), 2.34 (td, J = 6.8, 2.1 Hz, 2H), 1.63 – 1.27 (m, 14H), 0.90 (t, J = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, acetone, 25°C) δ 164.14, 161.72, 143.11, 129.71, 124.12, 115.07, 114.11, 88.59, 75.31, 61.28, 50.49, 31.43, 29.14, 28.64, 26.30, 24.60, 22.67, 18.51, 13.73. HRMS calculated requires $[M-H]^-$: 300.2122. Found *m*/*z*: 300.2127.

(7e) Benzyl(methyl)(2-methyldodec-5-yn-4-yl)amine



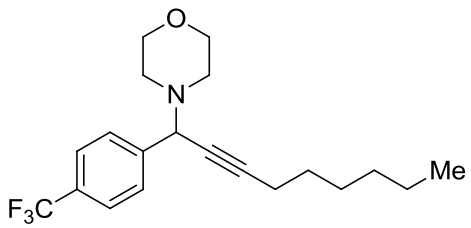
Prepared according to general procedure B: N-methylaniline (110 µL, 1.0 mmol), isovaleraldehyde (130 µL, 1.2 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 24 hours to afford the title compound as a pale yellow oil in 72% yield (0.204 g, 0.72 mmol) after column chromatography on florisil gel (0-5% Et_2O in hexanes). IR (film) 2955, 2929, 2869, 1739, 1650, 1598, 1500, 1466, 1366, 1315, 1288, 1229, 1217, 1146, 1116, 1095, 1034, 924, 870, 946, 690 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.25-7.21 (m, 2H), 7.07 (td, J = 1.6 Hz, 7.6 Hz, 1H), 6.93 (dd, J = 1.2, 7.2, 1H), 6.85 (d, J = 8.4 Hz, 2H), 6.75 (t, J = 7.6 Hz, 1H), 6.63 (t, J = 7.6 Hz, 1H), 6.48 (d, J = 8 Hz, 1H), 6.16 (s, 1H), 4.51 (m, 1H), 3.81 (dd, J = 4.4 Hz, 6.4 Hz, 1H), 2.99 (s, 3H), 2.83 (s, 3H), 2.32-2.25 (m, 1H), 2.17 (td, J = 2 Hz, 6.4 Hz, 2H), 1.80-1.72 (m, 1H), 1.69-1.43 (m, 6H), 1.39-1.24 (m, 6H), 1.19 (d, J = 6.8 Hz, 3H), 1.14 (d, J = 6.8 Hz, 3H), 0.95-0.83 (m, 12H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 150.3, 144.9, 143.5, 129.0, 127.8, 126.2, 123.4, 117.7, 117.2, 116.6, 114.7, 110.9, 84.5, 7.6, 60.6, 50.5, 42.6, 41.2, 38.2, 32.9, 31.7, 31.3, 28.9, 28.5, 25.2, 25.0, 23.6, 23.0, 22.9, 22.7, 22.6, 22.2, 20.6, 18.7, 14.0. HRMS calculated requires $[M+Na]^+$: 286.2529. Found *m*/*z*: 286.2533.

(7f) 4-[1-(1-benzothiophen-3-yl)non-2-yn-1-yl]morpholine



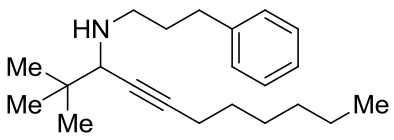
Prepared according to general procedure C: morpholine (88 µL, 1.0 mmol), 1-benzothiophene-3-carbaldehyde (179 mg, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol) were stirred at 80 °C for 16 hours to afford the title compound as a white crystalline powder in 74% yield (0.253 g, 0.74 mmol) after column chromatography on florisil gel (1-2-3-4-5-7-10-15-20% EtOAc in hexanes). IR (film) 2954, 2927, 2853, 1455, 1427, 1319, 1252, 1115, 1072, 997, 870, 772, 753, 730, 666 cm^{-1}. ^{1}H NMR (400 MHz, CD_3CN, 25°C) δ 8.15 (dd, J = 7.1, 2.2 Hz, 1H), 7.88 (dd, J = 6.8, 1.8 Hz, 1H), 7.63 (s, 1H), 7.42-7.31 (m, 2H), 4.90 (s, 1H), 3.69-3.43 (m, 4H), 2.63-2.40 (m, 4H), 2.34 (td, J = 6.9, 2.1 Hz, 2H), 1.95 (dq, J = 4.9, 2.3 Hz, 2H), 1.62-1.52 (m, 2H), 1.52- 1.42 (m, 2H), 1.36-1.30 (m, 2H), 0.95-0.84 (m, 3H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 141.03, 137.95, 134.25, 125.95, 124.76, 124.05, 123.80, 122.86, 88.26, 74.90, 66.90, 56.76, 49.64, 31.29, 28.94, 28.54, 22.57, 18.37, 13.63. HRMS calculated requires $[M-H]^-$: 340.1741. Found *m*/*z*: 340.1743.

(7g) 4-{1-[4-(trifluoromethyl)phenyl]non-2-yn-1-yl}morpholine



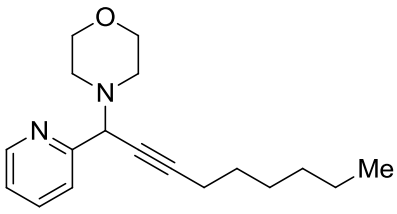
Prepared according to general procedure B: morpholine (88 µL, 1.0 mmol), 4-trifluoromethanebenzaldehyde (164 µL, 1.2 mmol), 1-octyne (222µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 24 hours to afford the title compound as a pale yellow oil in 97% yield (0.343 g, 0.97 mmol) after column chromatography on florisil gel (0-10% Et_2O in hexanes). IR (film) 2959, 2931, 2857, 1619, 1455, 1412, 1323, 1288, 1272, 1247, 1162, 1116, 1103, 1066, 1019, 1002, 933, 862, 784, 758, 731, 667 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.71 (d, J = 8.4 Hz, 2H), 7.59 (t, J = 8.4 Hz, 2H), 4.57 (s, 1H), 3.72-3.69 (m, 4H), 2.52 (bs, 4H), 2.32 (td, J = 2 Hz, 7.2 Hz, 2H), 1.64-1.55 (m, J = 7.2, 2H), 1.45 (quin, J = 7.2 Hz, 2H), 1.36-1.30 (m, 4H), 0.91 (t, J=7.2, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 142.7, 128.8, 125.0, 89.7, 74.4, 67.1, 61.3, 49.7, 31.3, 28.9, 28.6, 22.6, 18.8, 14.0. HRMS calculated requires $[M-H]^-$: 352.1883. Found *m*/*z*: 352.1890.

(7h) (2,2-dimethylundec-4-yn-3-yl)(3-phenylpropyl)amine



Prepared according to general procedure C: 3-phenyl-1-propylamine (143 µL, 1.0 mmol), trimethylacetaldehyde (120 µL, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol) were stirred at 80 °C for 18 hours to afford the title compound as a white crystalline powder in 78% yield (0.244 g, 0.78 mmol) after column chromatography on florisil gel (1-2-3-4-5-6-7-8-10% EtOAc in hexanes). IR (film) 3277, 2926, 2853, 1731, 1597, 1491, 1445, 1329, 1154, 816, 762, 740, 695, 671 cm^{-1}. ^1H NMR (400 MHz, CD_3CN, 25°C) δ 7.45 – 7.04 (m, 5H), 2.89 (t, J = 2.1 Hz, 2H), 2.67 (t, J = 7.9 Hz, 2H), 2.48 (ddd, J = 11.4, 7.5, 6.3 Hz, 1H), 2.18 (td, J = 6.7, 2.0 Hz, 2H), 1.95 (dt, J = 5.0, 2.5 Hz, 2H), 1.82-1.63 (m, 2H), 1.47-1.40 (m, 4H), 1.30 (m, J = 6.6, 2.9 Hz, 3H), 0.96 (s, 9H), 0.92-0.86 (m, 3H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 142.94, 128.63, 128.46, 125.81, 83.94, 81.12, 60.52, 47.93, 34.69, 33.47, 31.83, 31.30, 29.06, 28.43, 26.05, 22.59, 18.37, 13.62. HRMS calculated requires $[M+Na]^+$: 336.2667. Found *m*/*z*: 336.2650.

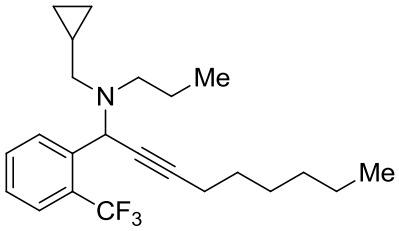
(7i) 4-[1-(pyridin-2-yl)non-2-yn-1-yl]morpholine



Prepared according to general procedure C: morpholine (88 µL, 1.0 mmol), 2-pyridinecarboxaldehyde (105 µL, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (142 mg, 1.0 mmol) were stirred at 100 °C for 4 hours to afford the title compound as a brown oil in 88**%** yield (0.252 g, 0.88 mmol) after column chromatography on florisil gel (5-10-15-20-30-40-50% EtOAc in hexanes). IR (film) 3290, 2924, 2853, 1703, 1599, 1495, 1449, 1430, 1333, 1303, 1289, 1158, 1093, 1053, 1020, 929, 909, 880, 813 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.57 (s, 1H), 7.36 (d, J = 9.0 Hz, 1H), 6.43 (d, J = 19.2 Hz, 3H), 3.96-3.79 (m, 4H), 3.00 (s, 4H), 2.73 (s, 2H), 1.78-1.63 (m, 2H), 1.47-1.17 (m, 6H), 1.00-0.79 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 128.14, 123.56, 122.18, 121.26, 117.58,

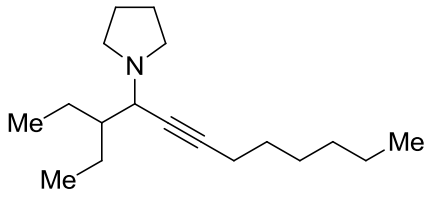
113.21, 110.18, 103.54, 67.68, 54.48, 31.87, 29.49, 27.41, 26.20, 22.82, 14.29. HRMS calculated requires $[M]^+$: 286.2045. Found *m*/*z*: 286.2037.

(7j) (cyclopropylmethyl)(propyl){1-[2-(trifluoromethyl)phenyl]non-2-yn-1-yl}amine



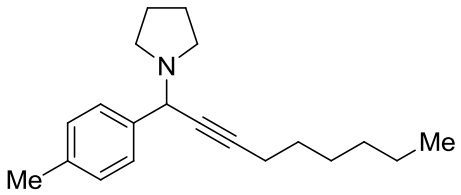
Prepared according to general procedure A: N-cyclopropylpropanemethylamine (86 µL, 1.0 mmol), 2-trifluoromethylbenzaldehyde (146 µL, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 80°C for 22 hours to afford a clear orange oil in 77% yield (0.292 g, 0.77 mmol) after column chromatography on florisil gel (0-1% ethyl acetate in hexanes). IR (film) 3028, 2949, 2931, 2852, 1721 1493, 1461, 1236, 1090, 1027, 755, 734, 696 cm^{-1}. ^1H NMR (400 MHz, acetone) δ 8.05 (d, J = 7.8 Hz, 1H), 7.71 (d, J = 7.8 Hz, 1H), 7.62 (t, J = 7.6 Hz, 1H), 7.48 (t, J = 7.6 Hz, 1H), 5.35 (t, J = 2.1 Hz, 1H), 2.82 (s, 1H), 2.64 (dd, J = 13.1, 5.5 Hz, 1H), 2.54 (ddt, J = 12.5, 9.1, 6.2 Hz, 1H), 2.39-2.25 (m, 3H), 2.21 (dd, J = 13.1, 7.6 Hz, 1H), 1.51-1.26 (m, 9H), 0.91-0.85 (m, 3H), 0.72-0.59 (m, 3H), 0.53-0.34 (m, 2H), 0.24-0.03 (m, 2H), -0.04 (dt, J = 9.4, 5.2 Hz, 1H). ^{13}C NMR (100 MHz, acetone) δ 139.56, 131.70, 131.57, 128.60, 128.30, 128.05, 126.71, 126.65, 126.28, 123.56, 88.42, 76.38, 56.44, 54.71, 52.34, 31.36, 22.61, 20.68, 18.42, 13.63, 11.29, 9.07, 4.47, 2.61. HRMS calculated requires $[M]^+$: 378.2400. Found *m*/*z*: 378.2403.

(7k) 1-(3-ethyldodec-5-yn-4-yl)pyrrolidine



Prepared according to general procedure B: pyrrolidine (84 µL, 1.0 mmol), 2-ethylbutyraldehyde (150 µL, 1.2 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 80 °C for 24 hours to afford the title compound as a pale yellow oil in 71% yield (0.187 g, 0.71 mmol) after column chromatography on florisil gel (0-5% Et_2O in hexanes). IR (film) 3456, 2959, 2929, 2874, 2859, 2809, 1739, 1457, 1366, 1217, 1116, 1033, 908, 882, 795, 725 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 3.21-3.20 (m, 1H), 2.63-2.59 (m, 2H), 2.56-2.53 (m, 2H), 2.20 (td, J = 2 Hz, 7.2 Hz, 2H), 1.76-1.66 (m, 5H), 1.53-1.26 (m, 12H), 0.91-0.84 (m, 9H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 85.2, 77.9, 58.2, 50.4, 43.9, 31.4, 29.1, 28.5, 23.5, 22.6, 22.2, 22.0, 18.7, 14.1, 11.0. HRMS calculated requires $[M+H]^+$: 264.2686. Found *m*/*z*: 264.2688.

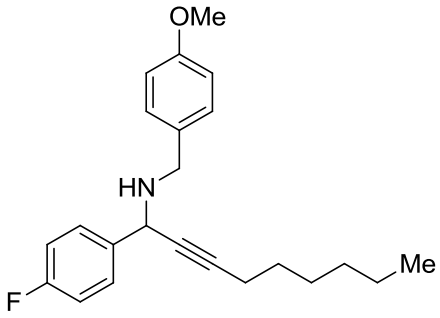
(7l) 1-[1-(4-methylphenyl)non-2-yn-1-yl]pyrrolidine



Prepared according to general procedure A: pyrrolidine (84 µL, 1.0 mmol), p-tolualdehyde (131 µL, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 100 °C for 6 hours to afford the title compound as a white crystalline powder in 89% yield (0.252 g, 0.89 mmol) after column chromatography on florisil gel (1-3-5-10-15-20-25-30-40-50% ethyl acetate in hexanes). IR (film) 2956, 2928, 2858, 2809, 1686, 1608, 1511, 1458, 1326, 1177, 1135, 1109, 1032, 1022, 966, 878, 815, 766, 724, 673 cm^{-1}. ^1H NMR (400 MHz, CD_3CN, 25°C) δ 7.37 (d, J = 7.9 Hz, 2H), 7.15 (d, J = 7.8 Hz, 2H), 4.57 (s, 1H), 2.52 (d, J = 5.0 Hz, 5H), 2.32 (s, 3H), 2.27 (td, J = 6.7, 1.4 Hz, 2H), 1.75-1.66 (m, 3H), 1.63 –

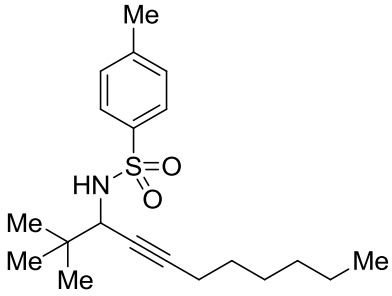
1.17 (m, 8H), 0.90 (t, J = 6.9 Hz, 3H). ^{13}C NMR (100 MHz, CD_3CN, 25°C) δ 137.80, 137.18, 128.86, 128.12, 87.01, 77.37, 58.09, 49.88, 31.25, 28.90, 28.43, 23.39, 22.54, 20.32, 18.33, 13.56. HRMS calculated requires $[M+H]^+$: 284.2378. Found *m*/*z*: 284.2373.

(7m) 1-(4-fluorophenyl)-N-[(4-methoxyphenyl)methyl]non-2-yn-1-amine



Prepared according to general procedure B: 4-methoxybenzylamine (131 µL, 1.0 mmol), 4-fluorobenzaldehyde (130 µL, 1.2 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 48 hours to afford the title compound as a yellow oil in 72% yield (0.256 g, 0.72 mmol) after column chromatography on florisil gel (0-20% Et_2O in hexanes). Methylene chloride (1 mL) was added before loading onto florisil column. IR (film) 2929, 2857, 1603, 1507, 1245, 1221, 1036, 825, 738 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.51-7.48 (m, J = 6.3 Hz, 2H), 7.28 (d, J = 8.8 Hz, 2H), 7.03-6.99 (m, J = 6.3 Hz, 2H), 6.86 (d, J = 8.4 Hz, 2H), 4.51 (s, 1H), 3.82 (d, J = 2.8 Hz, 2H), 3.79 (s, 3H), 2.28 (td, J = 2.4 Hz, 2H), 1.56 (q, 2H), 1.43 (q, 2H), 1.35-1.27 (m, 4H), 0.90 (t, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 163.6, 161.2, 158.9, 137.1, 132.2, 129.9, 129.8, 129.5, 129.4, 115.4, 115.2, 114.0, 86.5, 7.9, 55.5, 52.6, 50.6, 31.6, 29.1, 28.8, 22.8, 19.0, 14.3. HRMS calculated requires $[M-H]^-$: 352.2071. Found *m*/*z*: 352.2082.

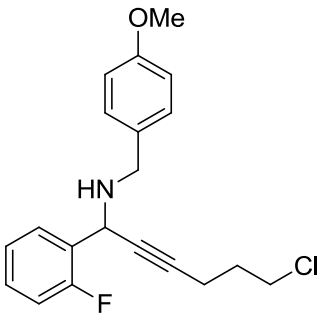
(7n) N-(2,2-dimethylundec-4-yn-3-yl)-4-methylbenzene-1-sulfonamide



Prepared according to general procedure A: *p*-toluene sulfonamide (172 mg, 1.0 mmol), trimethylacetaldehyde (120 µL, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %) were stirred at 100 °C for 4 hours to afford the title compound as a yellow powder in 72% yield (0.256 g, 0.72 mmol) after column chromatography on florisil gel (0-20% EtOAc in hexanes). IR (film) 3285, 2928, 2854, 1599, 1427, 1332, 1299, 1158, 1094, 1049, 1020, 929, 812, 742, 679 cm^{-1}. ^{1}H NMR (400 MHz, acetone, 25°C) δ 7.74 (d, J = 8.2 Hz, 2H), 7.35 (d, J = 8.3 Hz, 2H), 6.44 (d, J = 10.0 Hz, 1H), 3.69 (dt, J = 10.1, 2.1 Hz, 1H), 2.40 (s, 3H), 2.03 (dt, J = 4.3, 2.2 Hz, 1H), 1.94-1.71 (m, 2H), 1.34-1.10 (m, 7H), 0.96 (s, 9H), 0.86 (t, J = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, acetone, 25°C) δ 142.72, 139.14, 129.29, 127.54, 85.17, 77.24, 55.81, 35.39, 31.33, 25.77, 25.72, 22.51, 20.75, 18.13, 13.60. HRMS calculated requires $[M+H]^+$: 348.1992. Found *m*/*z*: 348.1995.

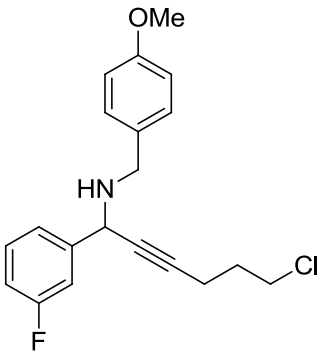
(8a) [6-Chloro-1-(2-fluorophenyl)hex-2-yn-1-yl][(4-methoxyphenyl)methyl]amine

Prepared according to general procedure B: 4-methoxybenzylamine (131 µL, 1.0 mmol), 2-fluorobenzaldehyde (128 µL, 1.2 mmol), 5-chloro-1-pentyne (160 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 48 hours to afford the title compound as a yellow oil in 73% yield (0.252 g, 0.73 mmol) after column chromatography on florisil gel (0-20% Et_2O in hexanes). Methylene chloride (1 mL) was added before loading onto florisil column. IR (film) 3003, 2970, 2970, 2836, 1738, 1611, 1586, 1511, 1489, 1455, 1365, 1231, 1173, 1093, 1033, 825, 803, 755 cm^{-1}. ^{1}H



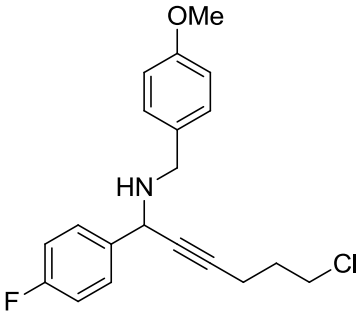
NMR (400 MHz, $CDCl_3$, 25°C) δ 7.57 (td, J = 2 Hz, 8 Hz, 1H), 7.30-7.24 (m, 3H), 7.16-7.13 (t, J = 7.6 Hz, 1H), 7.04 (t, J = 10 Hz, 1H), 6.86 (d, J = 8.4 Hz, 2H), 4.83 (t, J = 2 Hz, 1H), 3.82 (dd, J = 12.8 Hz, 23.6 Hz, 2H), 3.80 (s, 3H), 3.67 (t, J = 6.8 Hz, 2H), 2.47 (td, J = 2.4 Hz, 6.8 Hz, 2H), 1.99 (quint, J = 6.8 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 161.6, 158.7, 131.6, 129.5, 129.4, 129.3, 129.1, 124.2, 115.7, 115.5, 113.8, 83.3, 80.1, 55.3, 50.7, 47.3, 31.4, 16.3. HRMS calculated requires $[M+Na]^+$: 368.1188. Found *m*/*z*: 368.1191.

(8b) [6-Chloro-1-(3-fluorophenyl)hex-2-yn-1-yl][(4-methoxyphenyl)methyl]amine



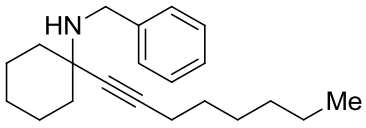
Prepared according to general procedure B: 4-methoxybenzylamine (131 µL, 1.0 mmol), 3-fluorobenzaldehyde (128 µL, 1.2 mmol), 5-chloro-1-pentyne (160 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 48 hours to afford the title compound as a yellow oil in 71% yield (0.249 g, 0.71 mmol) after column chromatography on florisil gel (0-20% Et_2O in hexanes). Methylene chloride (1 mL) was added before loading onto florisil column. IR (film) 2999, 2933, 2836, 1612, 1587, 1511, 1484, 1441, 1355, 1301, 1244, 1173, 1034, 824, 773, 691 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.31-7.24 (m, 6H), 6.87 (d, J = 8.4 Hz, 2H), 4.53 (t, J = 1.6 Hz, 1H), 3.82 (d, J = 3.6 Hz, 2H), 3.80 (s, 3H), 2.50 (td, J = 2.4 Hz, 6.8 Hz, 2H), 2.02 (quint, J = 6.4 Hz, 2H), 1.62 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 164.1, 161.7, 158.8, 143.5, 143.4, 131.7, 129.9, 129.8, 129.5, 123.1, 114.6, 114.4, 113.8, 84.1, 80.6, 55.3, 52.5, 50.4, 43.7, 31.5, 16.3. HRMS calculated requires $[M-H]^-$: 344.1221. Found *m*/*z*: 344.1225.

(8c) [6-Chloro-1-(4-fluorophenyl)hex-2-yn-1-yl][(4-methoxyphenyl)methyl]amine



Prepared according to general procedure B: 4-methoxybenzylamine (131 µL, 1.0 mmol), 4-fluorobenzaldehyde (130 µL, 1.2 mmol), 5-chloro-1-pentyne (160 µL, 1.5 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Na_2SO_4 (285 mg, 2.0 mmol) were stirred at 80 °C for 48 hours to afford the title compound as a yellow oil in 72% yield (0.248 g, 0.72 mmol) after column chromatography on florisil gel (0-20% Et_2O in hexanes). Methylene chloride (1 mL) was added before loading onto florisil column. IR (film) 3000, 2957, 2836, 1610, 1506, 1441, 1355, 1301, 1244, 1220, 1173, 1155, 1091, 1034, 825, 725 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$, 25°C) δ 7.50-7.46 (m, 2H), 7.29-7.25 (m, 2H), 7.02 (tt, J = 3.2 Hz, 8.4 Hz, 2H), 6.87 (dt, J = 2.8 Hz, 9.2 Hz, 2H), 4.51 (s, 1H), 3.81 (dd, J = 13.2 Hz, 18.4 Hz, 2H), 3.80 (s, 3H), 3.68 (t, J = 6.4 Hz, 2H), 2.49 (td, J = 1.6 Hz, 6.4 Hz, 2H), 2.01 (quint, J = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$, 25°C) δ 163.5, 161.0, 158.8, 136.6, 131.8, 129.5, 129.2, 129.1, 84.0, 80.9, 55.3, 52.3, 50.5, 43.7, 31.5, 16.3. HRMS calculated requires $[M-H]^-$: 344.1221. Found *m*/*z*: 344.1212.

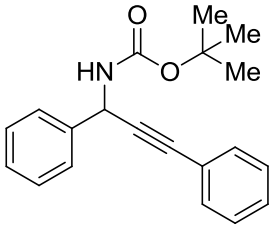
(9) N-benzyl-1-(oct-1-yn-1-yl)cyclohexan-1-amine



Prepared according to general procedure A: $Cu(OTf)_2$ (36 mg, 10 mol %), benzylamine (110 µL, 1.0 mmol), cyclohexanone (114 µL, 1.1 mmol), 1-octyne (222 µL, 1.5 mmol) were stirred at 110°C for 22 hours to afford a clear yellow oil in 80% yield (0.238 g, 0.80 mmol) after column chromatography on florisil gel (0-1-2-3% EtOAc in hexanes). IR (film) 2928, 2854, 1495, 1452, 1343, 1282, 1173, 1116, 1028, 905, 731, 690 cm^{-1}. ^1H NMR (400 MHz, acetone) δ 7.35 (d, J = 7.3 Hz, 2H), 7.27 (t, J = 7.5 Hz, 2H), 7.18 (t, J = 7.3 Hz, 1H), 3.86 (s, J = 2H), 2.26 (t, J = 6.6 Hz, 2H), 1.85-1.75 (m, 2H), 1.67-1.37 (m, 11H), 1.36-1.25 (m, 5H), 0.91-0.85 (m, 3H). ^{13}C NMR (100 MHz, acetone) δ 142.14, 128.36, 128.23, 126.59, 84.33, 84.03, 54.51, 47.72, 38.51, 31.42, 26.10, 22.88, 22.63, 18.46, 13.64. HRMS calculated requires $[M-H]^-$: 296.2373. Found *m*/*z*: 296.2369.

The following compound is included to demonstrate that the full range of reactivity with $Cu(OTf)_2$ does include carbamate as determined by GC, ^1H NMR of crude reaction, and HRMS. However, the limitations of these propargylamine products are that they proved difficult to isolate.

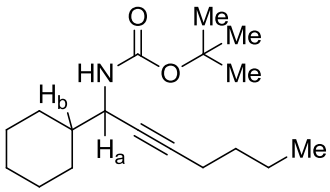
(7o) *tert*-butyl N-(1,3-diphenylprop-2-yn-1-yl)carbamate



Prepared according to general procedure A: *tert*-butyl carbamate (71 mg, 0.5 mmol), benzaldehyde (51 µL, 0.6 mmol), phenylacetylene (166 µL, 0.75 mmol), $Cu(OTf)_2$ (18 mg, 10 mol %) were stirred at 100 °C for 18 hours. HRMS calculated requires $[M+H]^+$: 308.1450. Found *m*/*z*: 308.1456.

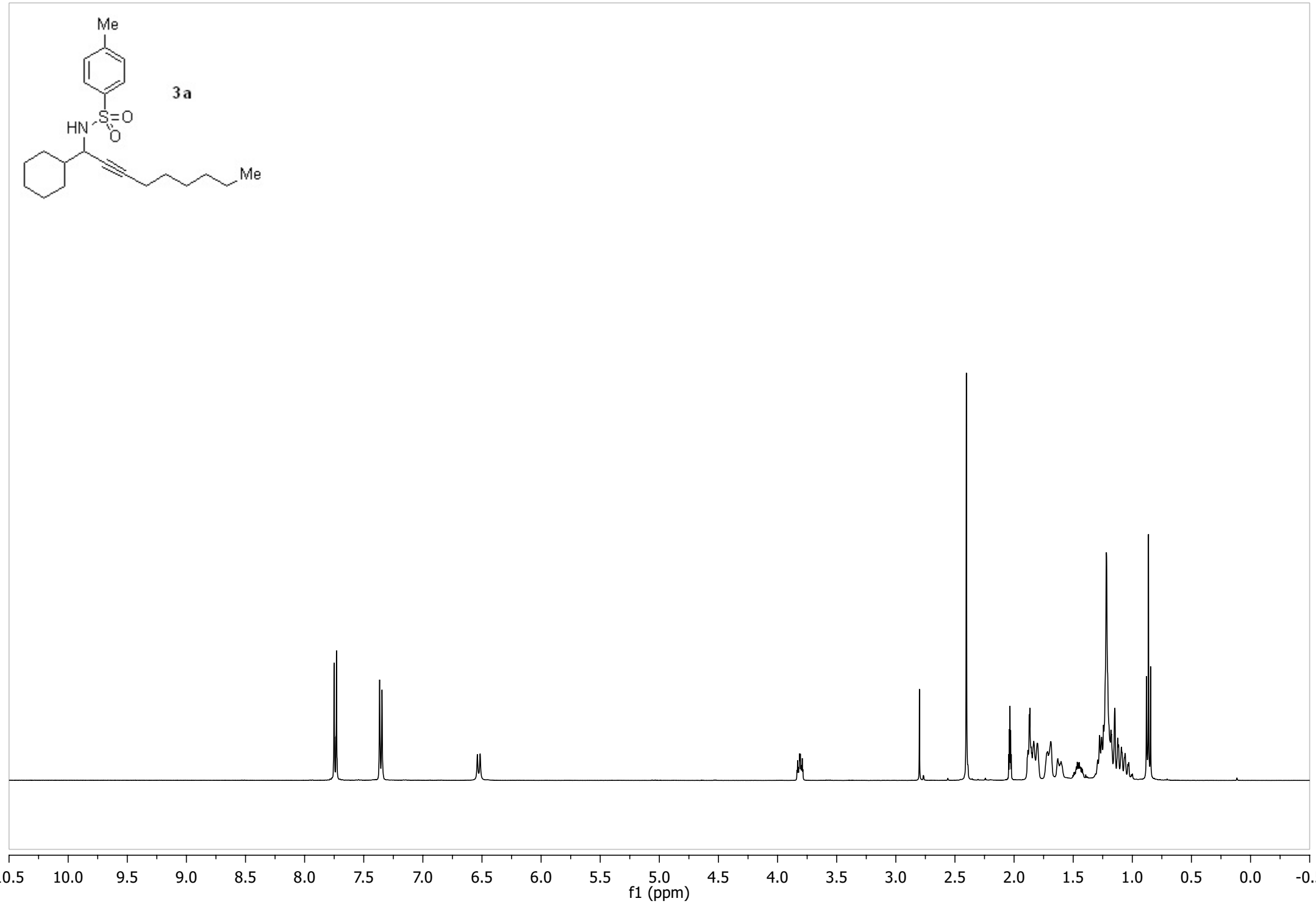
3) Compare commercially available, stable unsubstituted *N*-Boc propargylamine versus sole report of 16% yield of an α-substituted *N*-Boc propargylamine: Hatano, M.; Asai, T.; Ishihara, K. *Tetrahedron Lett*. **2008**, *49*, 379.

tert-butyl N-(1-cyclohexylhept-2-yn-1-yl)carbamate



Prepared from preformed imine[4] (211 mg, 1.0 mmol), $Cu(OTf)_2$ (36 mg, 10 mol %), Cs_2CO_3 (33 mg, 10 mol %) in 2 mL 1:1 $CHCl_3$:hexanes stirred at 60 °C for 15 minutes, followed by addition of 1-hexyne (138 µL, 1.2 mmol) and stirred for 6 days at 60 °C. Best attempt to isolate product by column chromatography on basic alumina (0-50% EtOAc in hexanes) resulted in deprotection, decomposition, and some fractions of clean product with diagnostic peaks H_a and H_b in ^1H NMR (400 MHz, $CDCl_3$) δ 3.76 (m, $1H_a$), 1.86 (m, $1H_b$).

4) Wenzel, A.; Jacobsen, E. N. *J. Am. Chem. Soc.* **2002**, *124*, 12964.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O
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10.0
9.5
9.0
8.5
8.0
7.5
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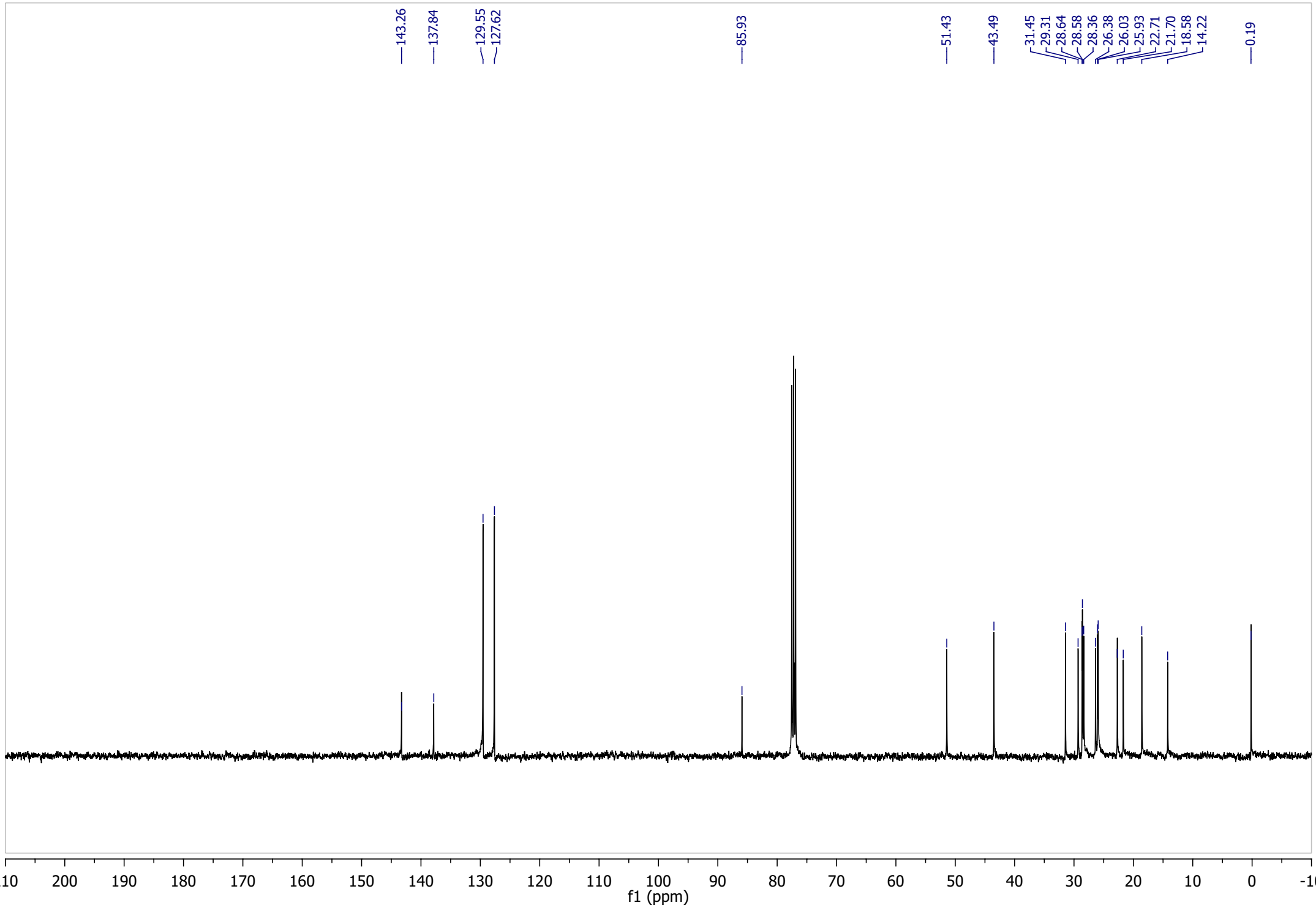
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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129.55
127.62
85.93
51.43
43.49
31.45
29.31
28.64
28.58
28.36
26.38
26.03
25.93
22.71
21.70
18.58
14.22
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200
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180
170
160
150
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120
110
100
90
80
70
60
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40
30
20
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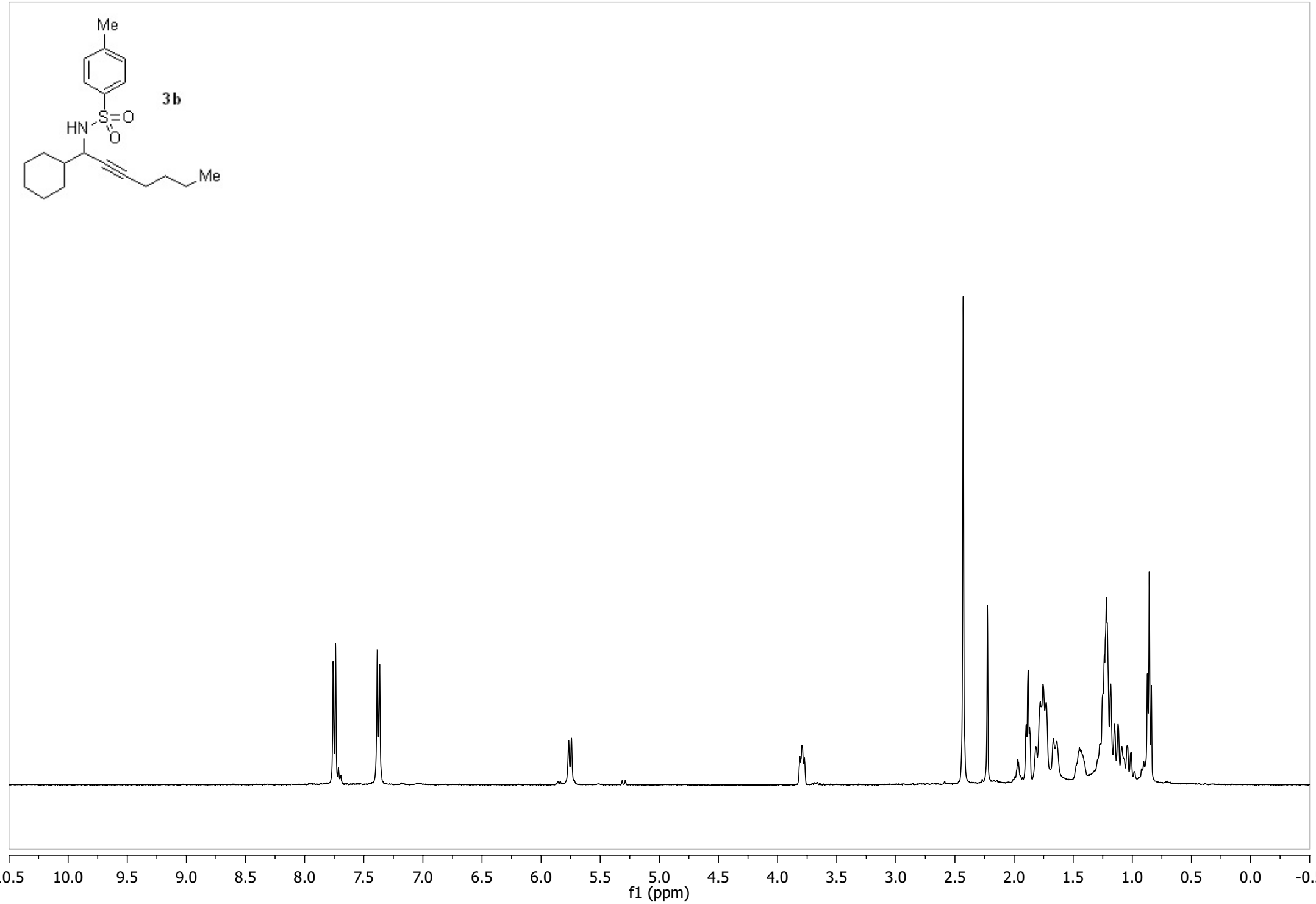
f1 (ppm)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6.0
5.5
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2.5
2.0
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0.5
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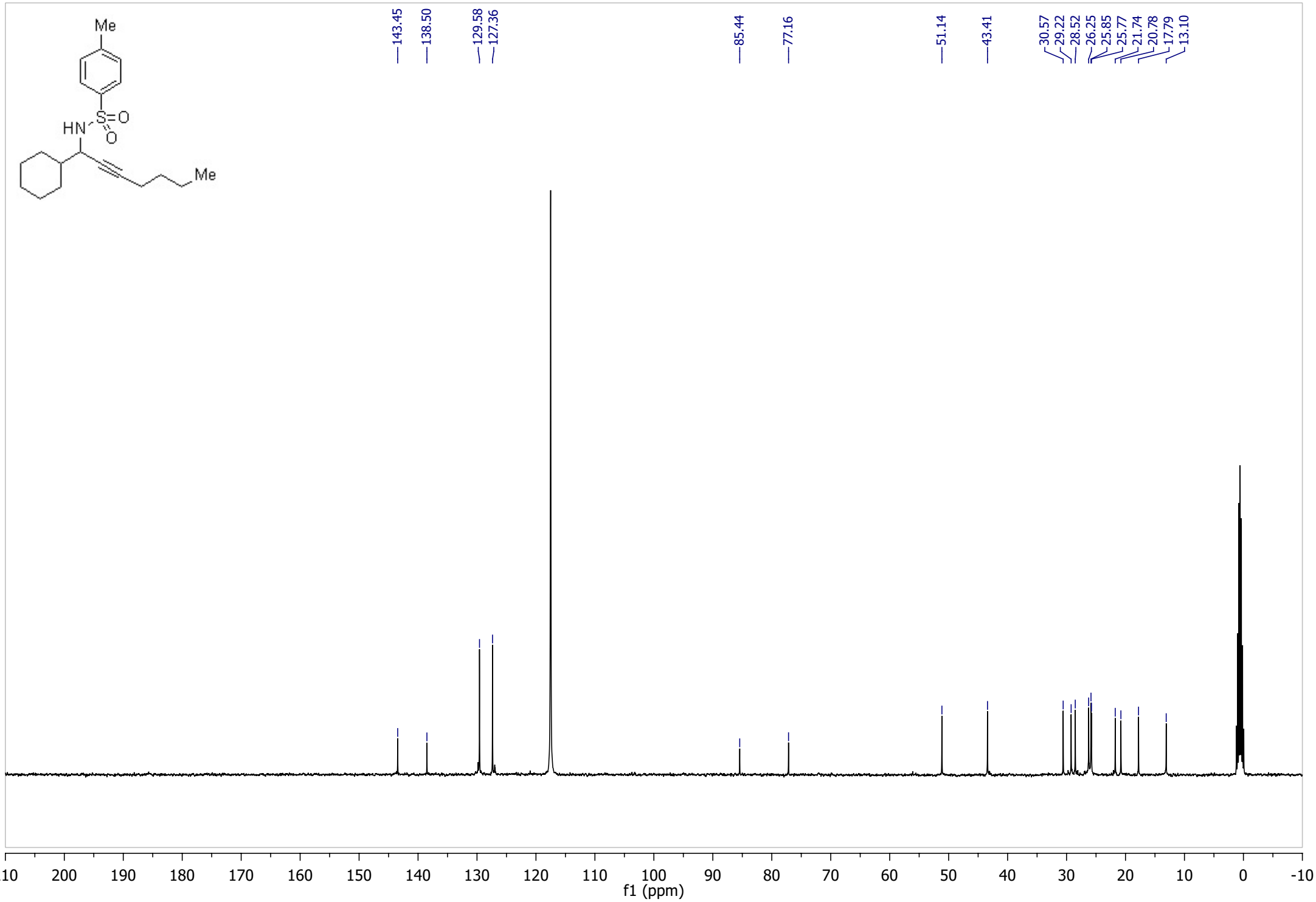
f1 (ppm)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O
Me
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129.58
127.36
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43.41
30.57
29.22
28.52
26.25
25.85
25.77
21.74
20.78
17.79
13.10
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200
190
180
170
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80
70
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40
30
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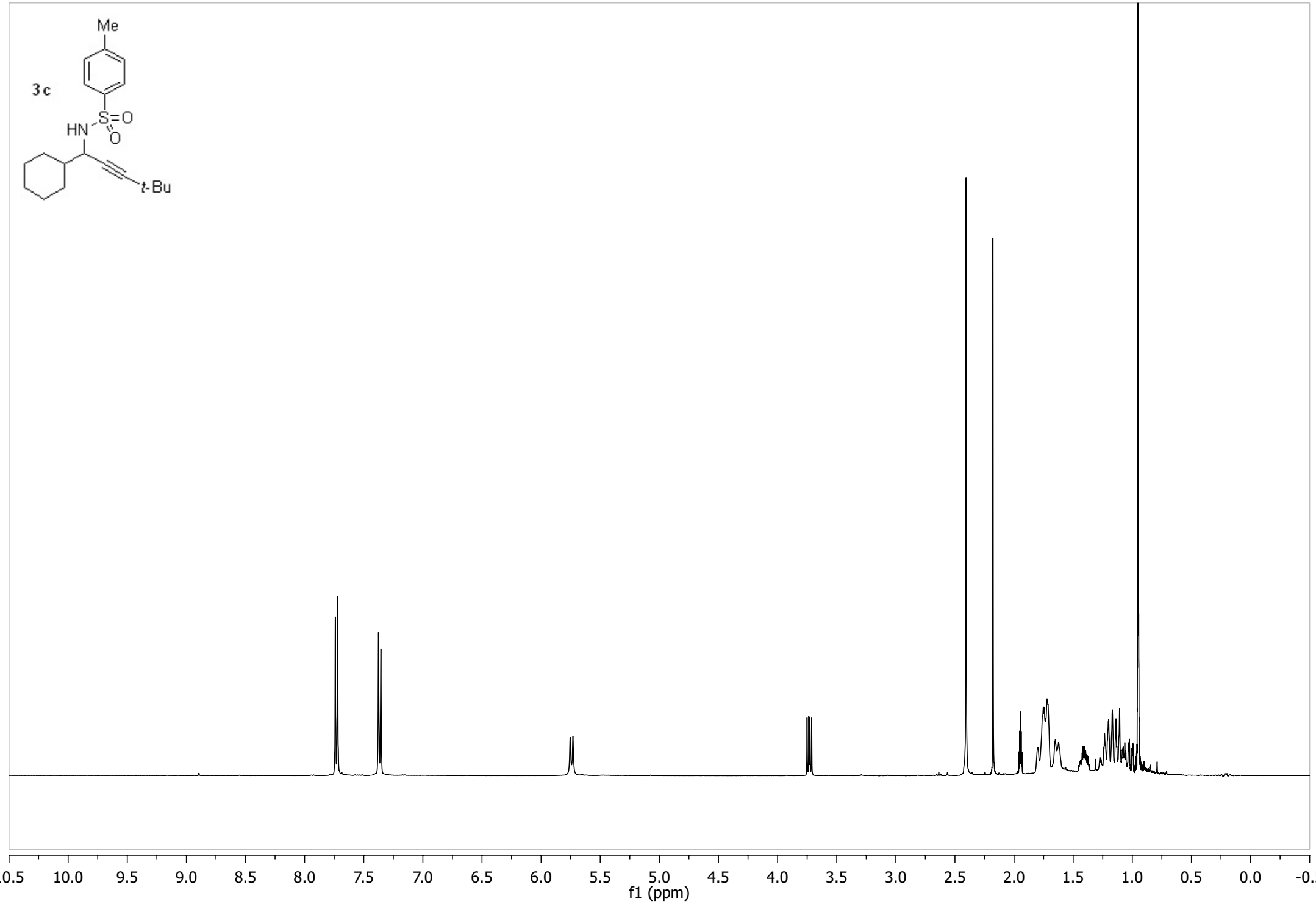
f1 (ppm)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6.5
6.0
5.5
5.0
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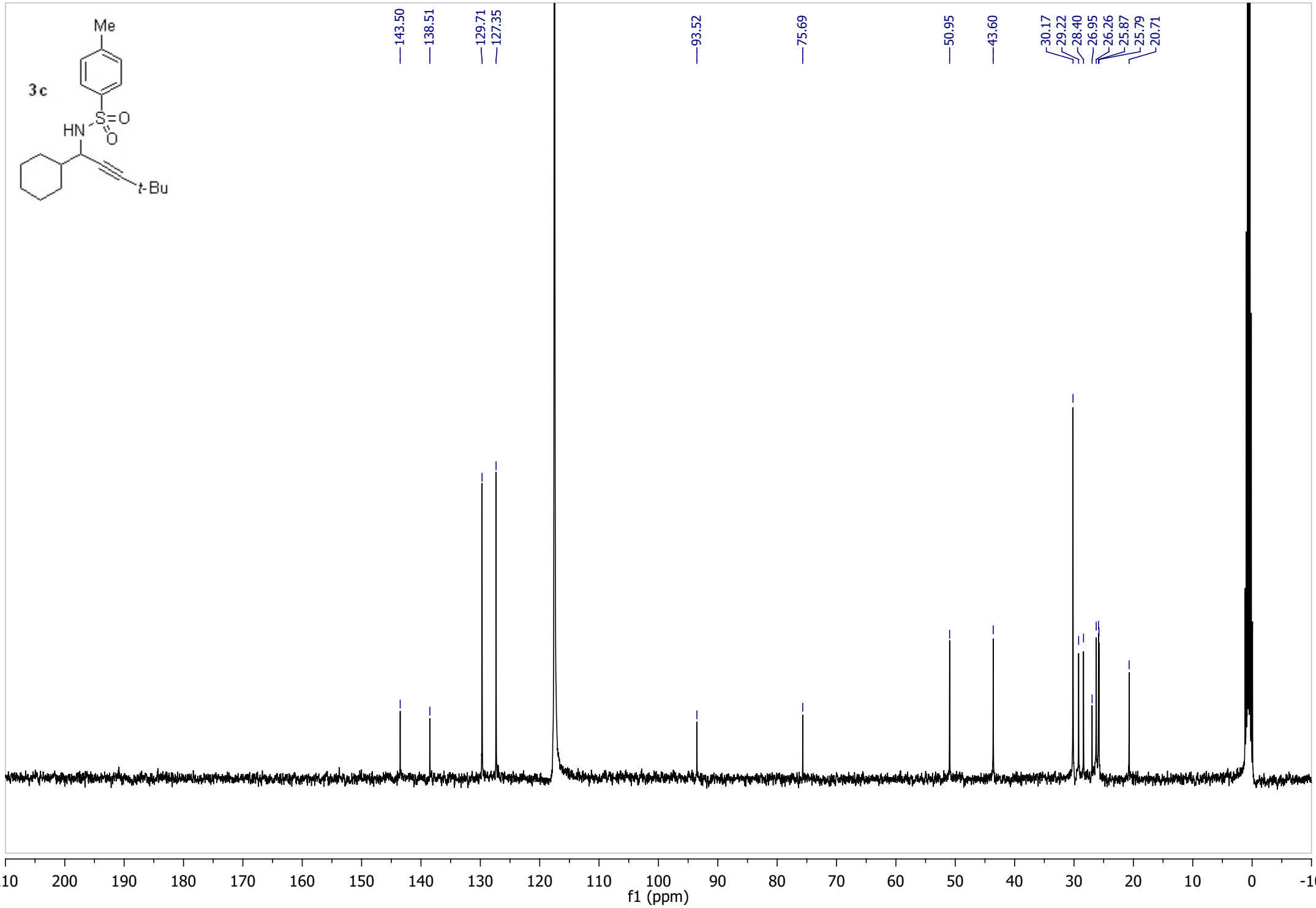
f1 (ppm)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200
190
180
170
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110
100
90
80
70
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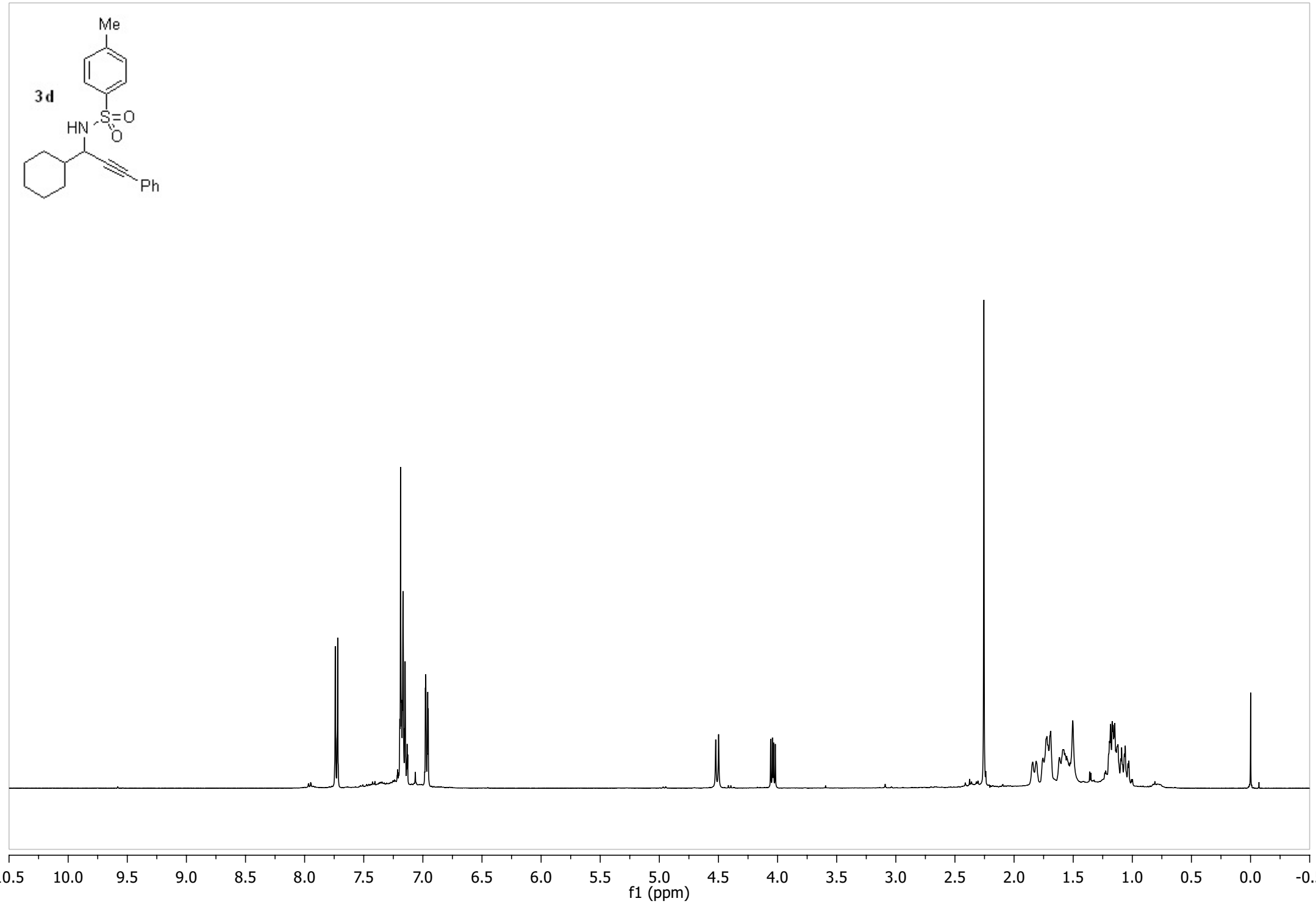
40
30
20
10
0
-10
f1 (ppm)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O
Ph
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9.5
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8.0
7.5
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6.5
6.0
5.5
5.0
4.5
4.0
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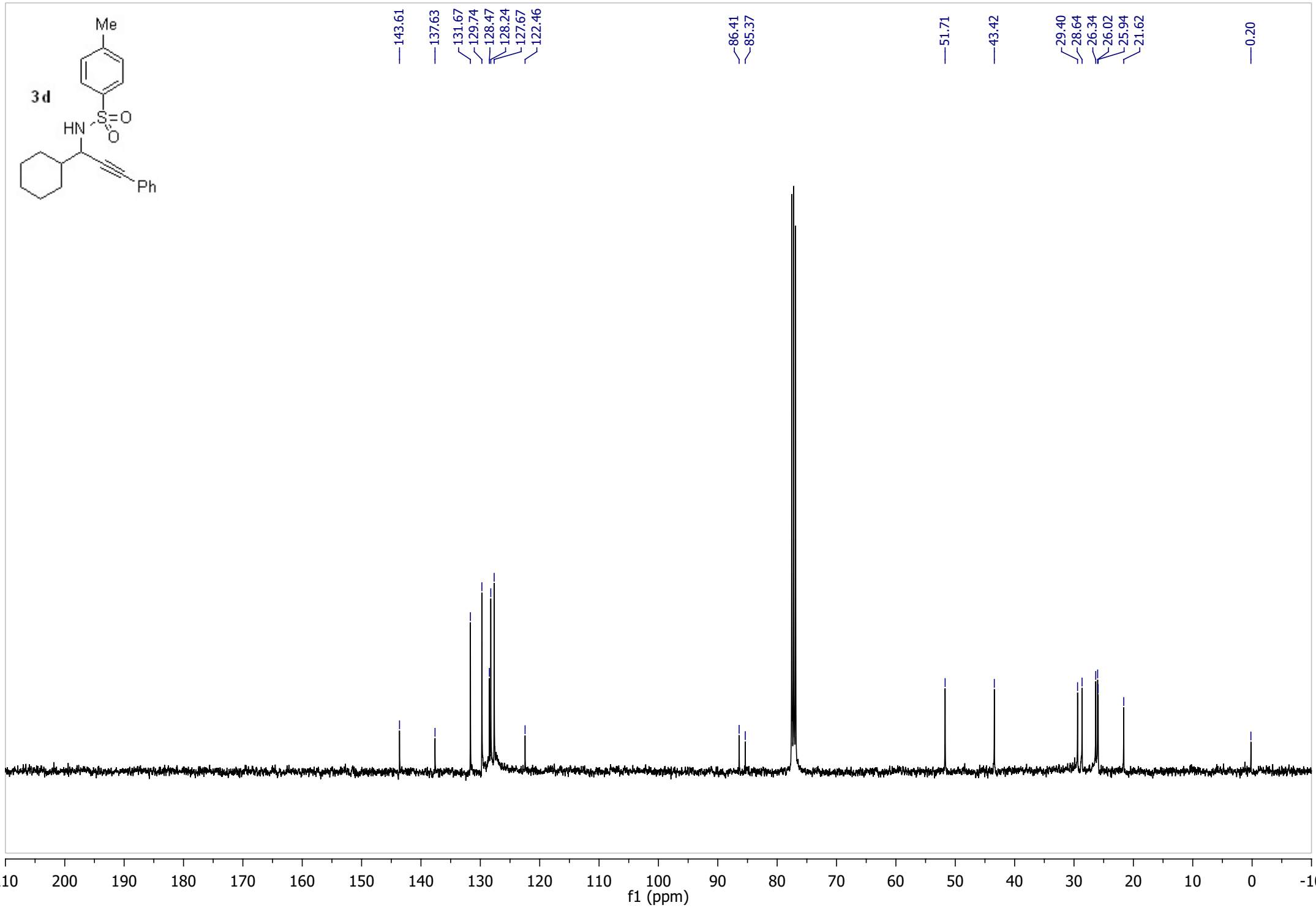
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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O
Ph
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128.24
127.67
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86.41
85.37
51.71
43.42
29.40
28.64
26.34
26.02
25.94
21.62
0.20
210
200
190
180
170
160
150
140
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120
110
100
90
80
70
60
50
40
30
20
10
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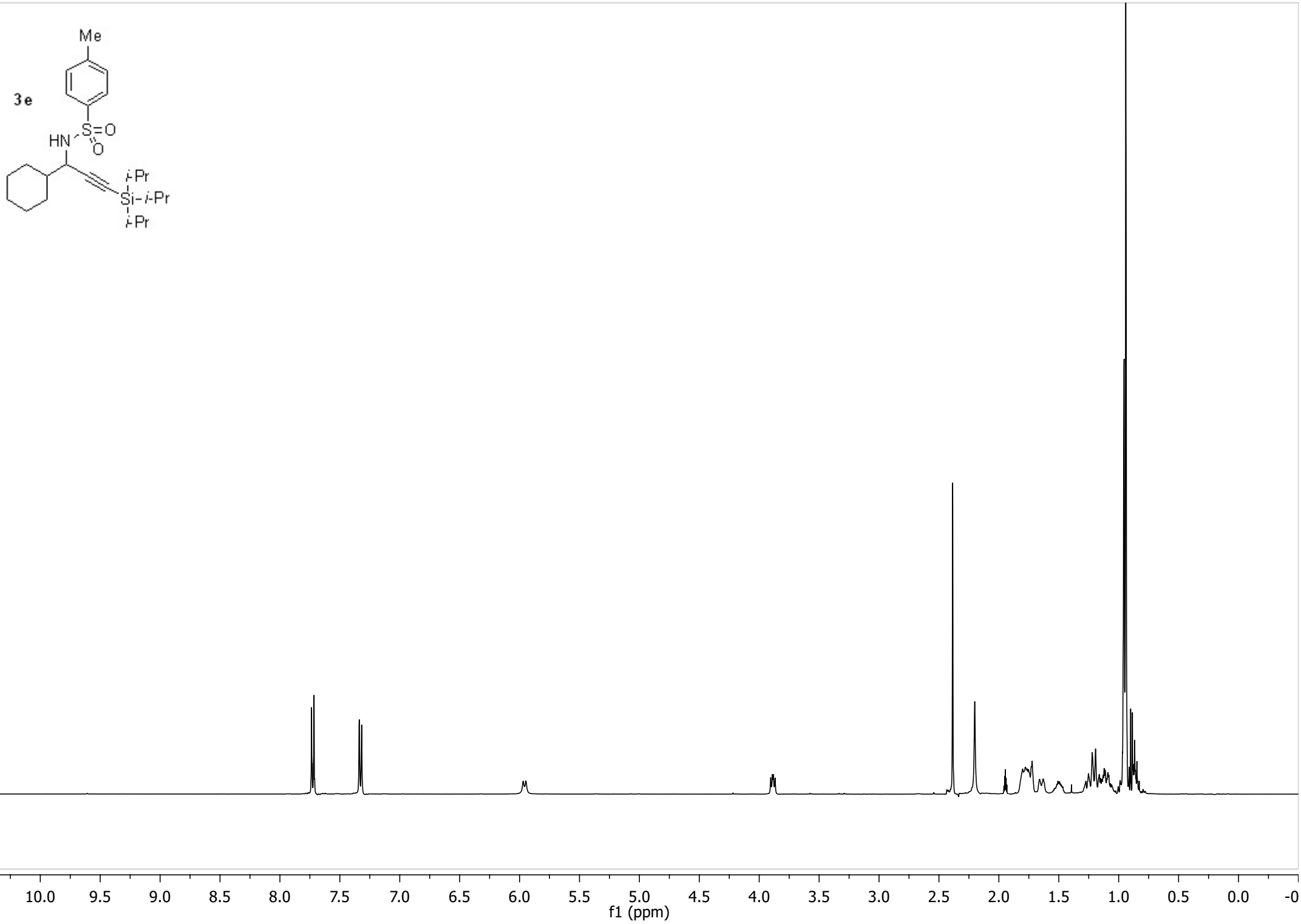
-10
f1 (ppm)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HN
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O
i-Pr
Si-i-Pr
i-Pr
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9.5
9.0
8.5
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7.0
6.5
6.0
5.5
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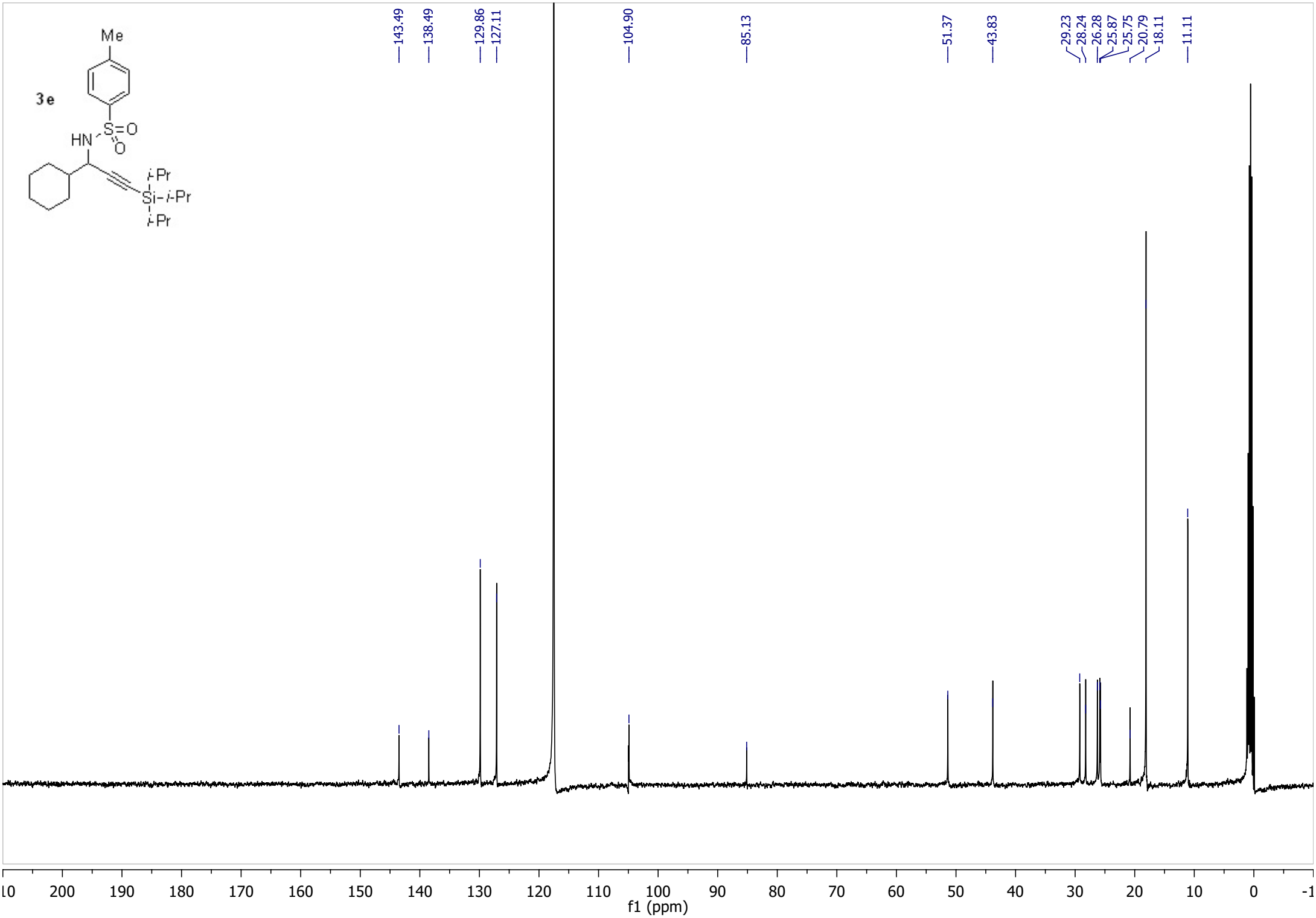
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


3e
Me
HN
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O
i-Pr
Si-i-Pr
i-Pr
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138.49
129.86
127.11
104.90
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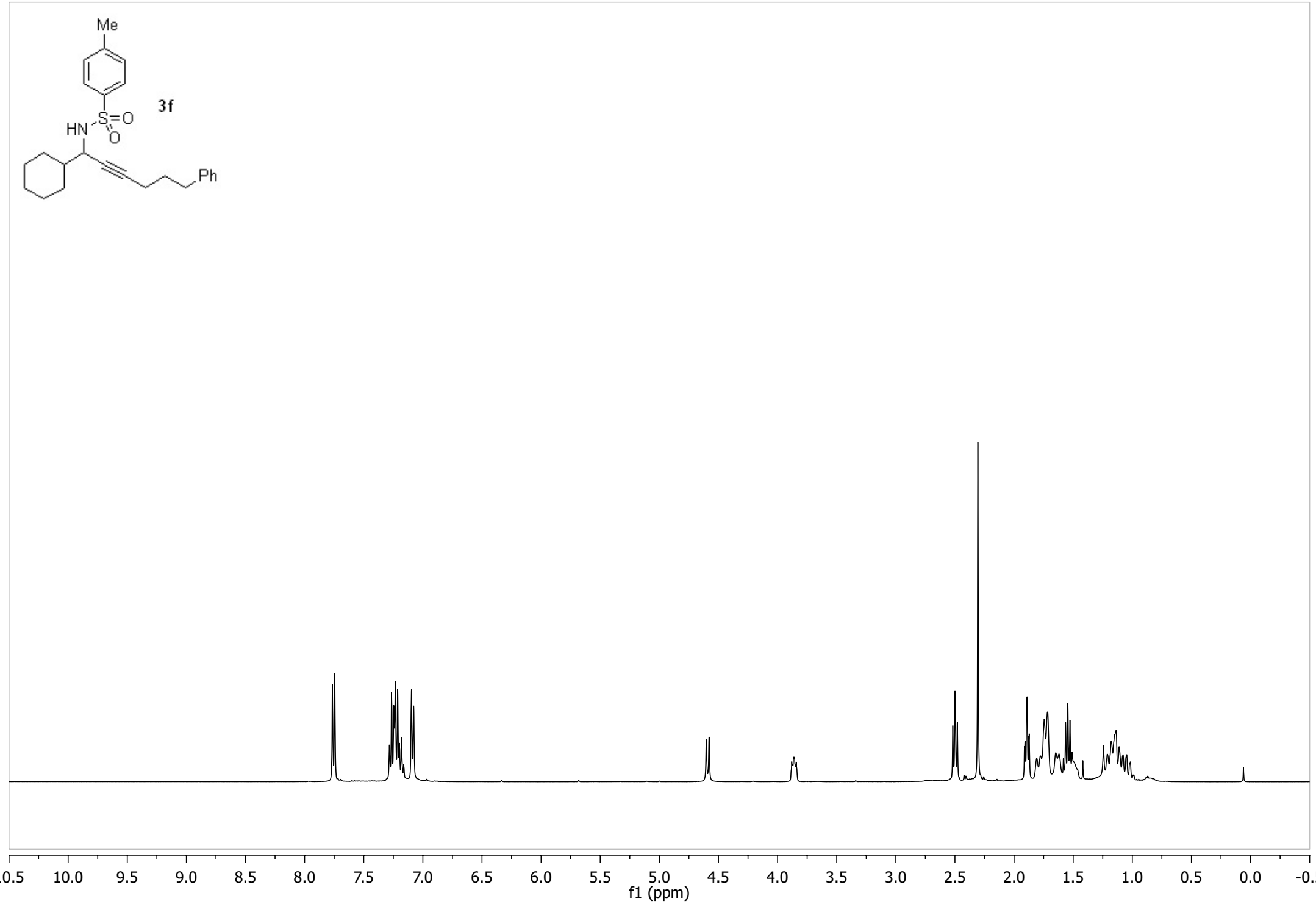
25.75
20.79
18.11
11.11
f1 (ppm)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Ph
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6.5
6.0
5.5
5.0
4.5
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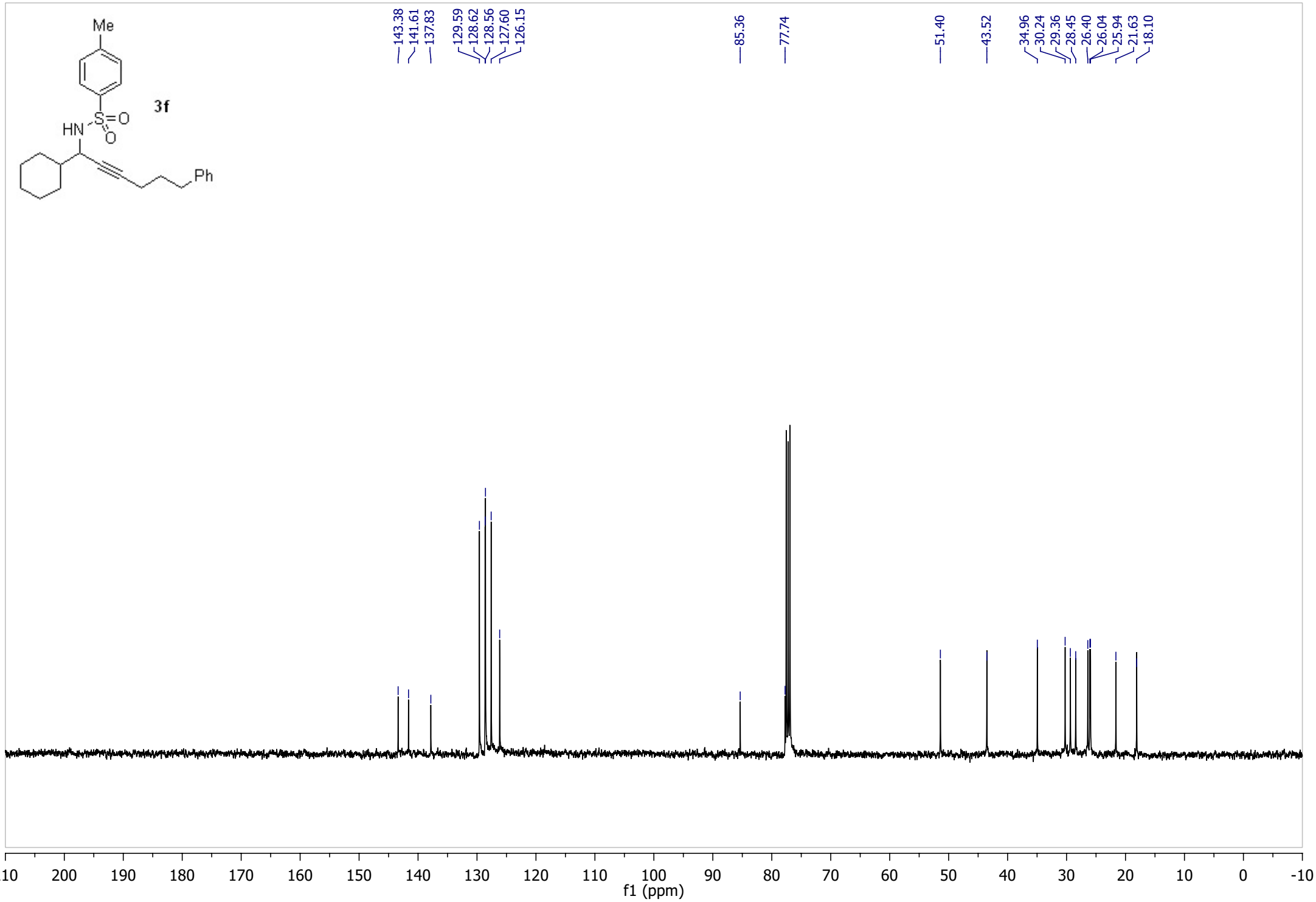
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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3f
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O
Ph
143.38
141.61
137.83
129.59
128.62
128.56
127.60
126.15
85.36
77.74
51.40
43.52
34.96
30.24
29.36
28.45
26.40
26.04
25.94
21.63
18.10
210
200
190
180
170
160
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140
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120
110
100
90
80
70
60
50
40
30
20
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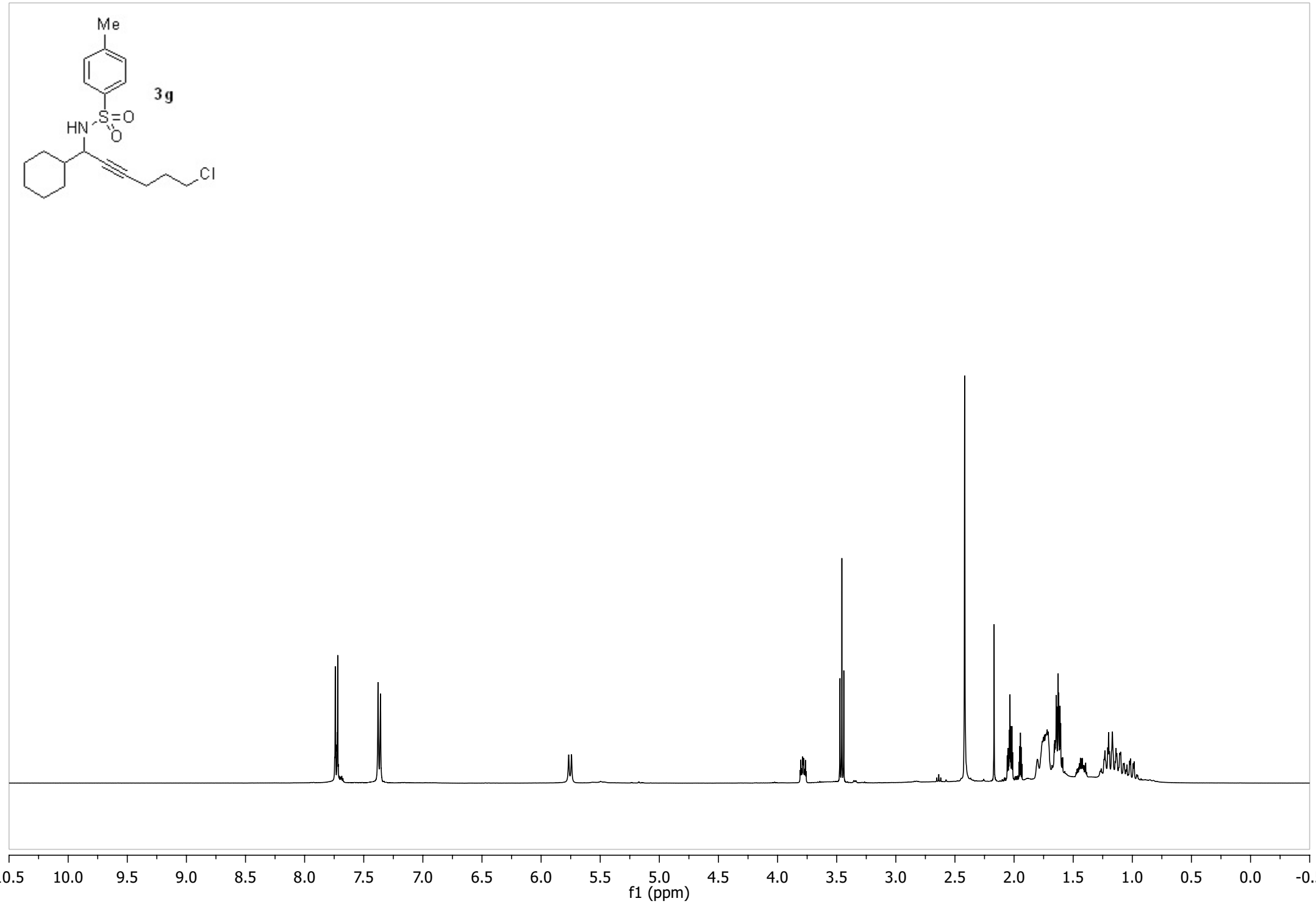
0
-10
f1 (ppm)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3g
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O
Cl
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9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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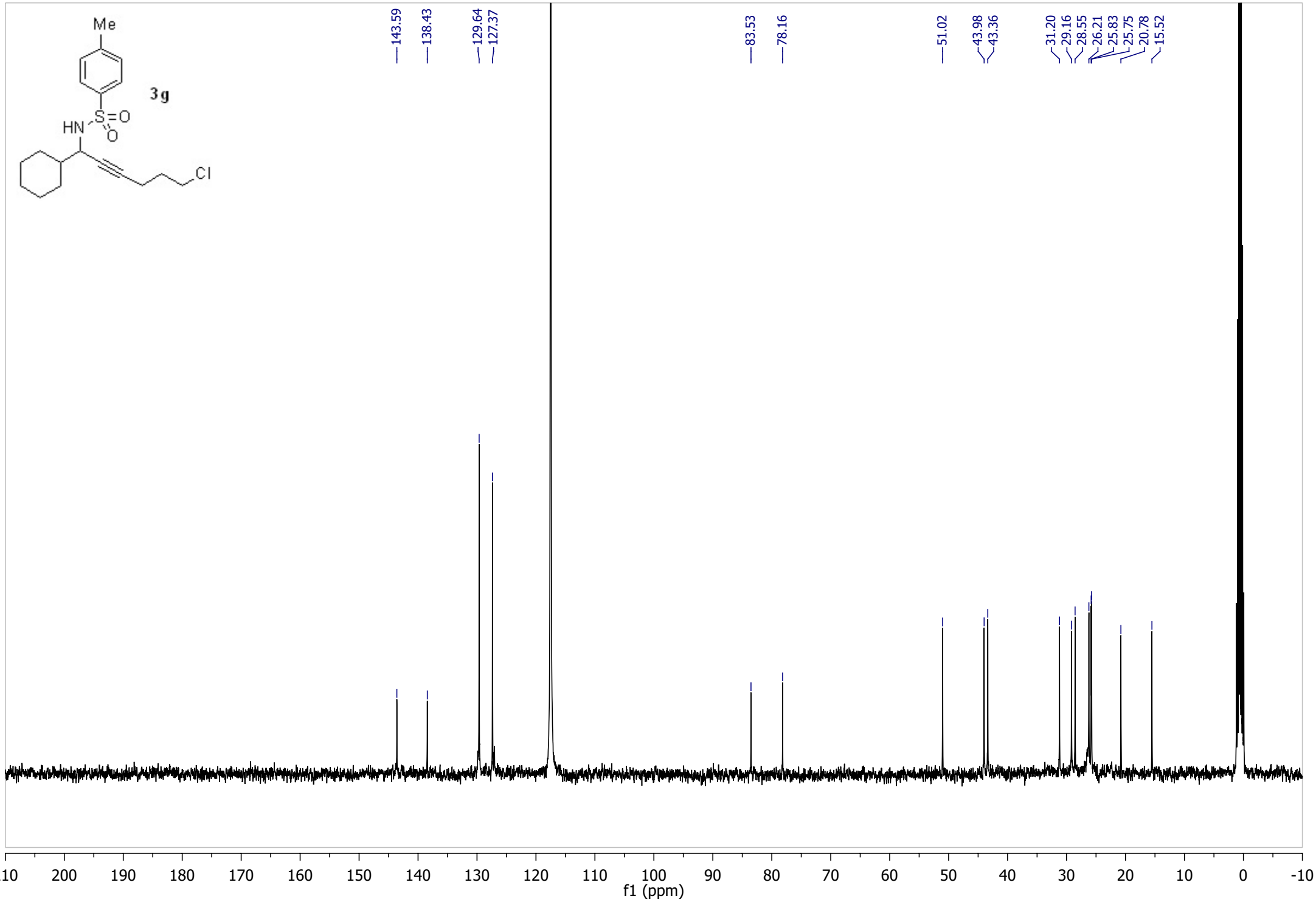
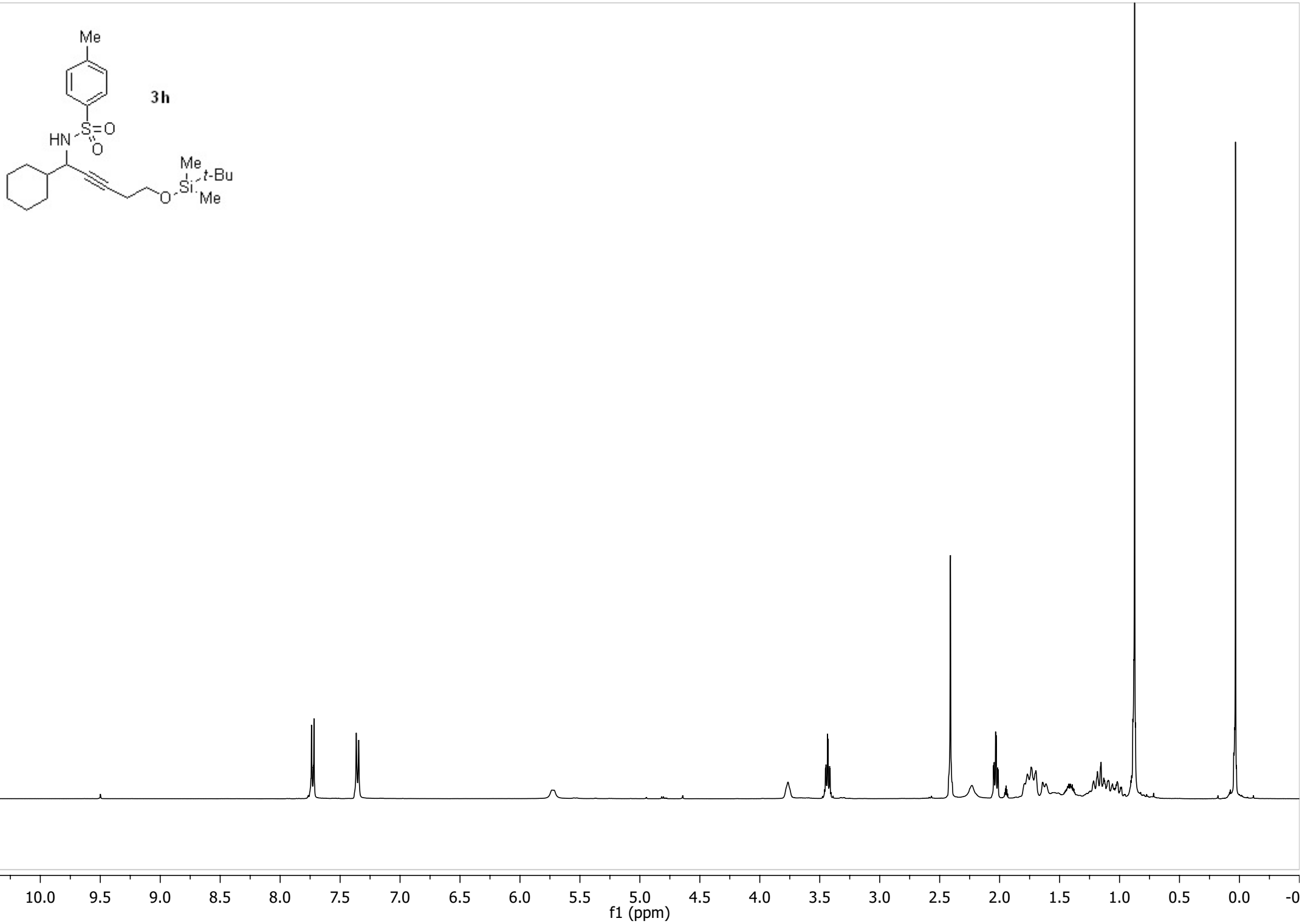
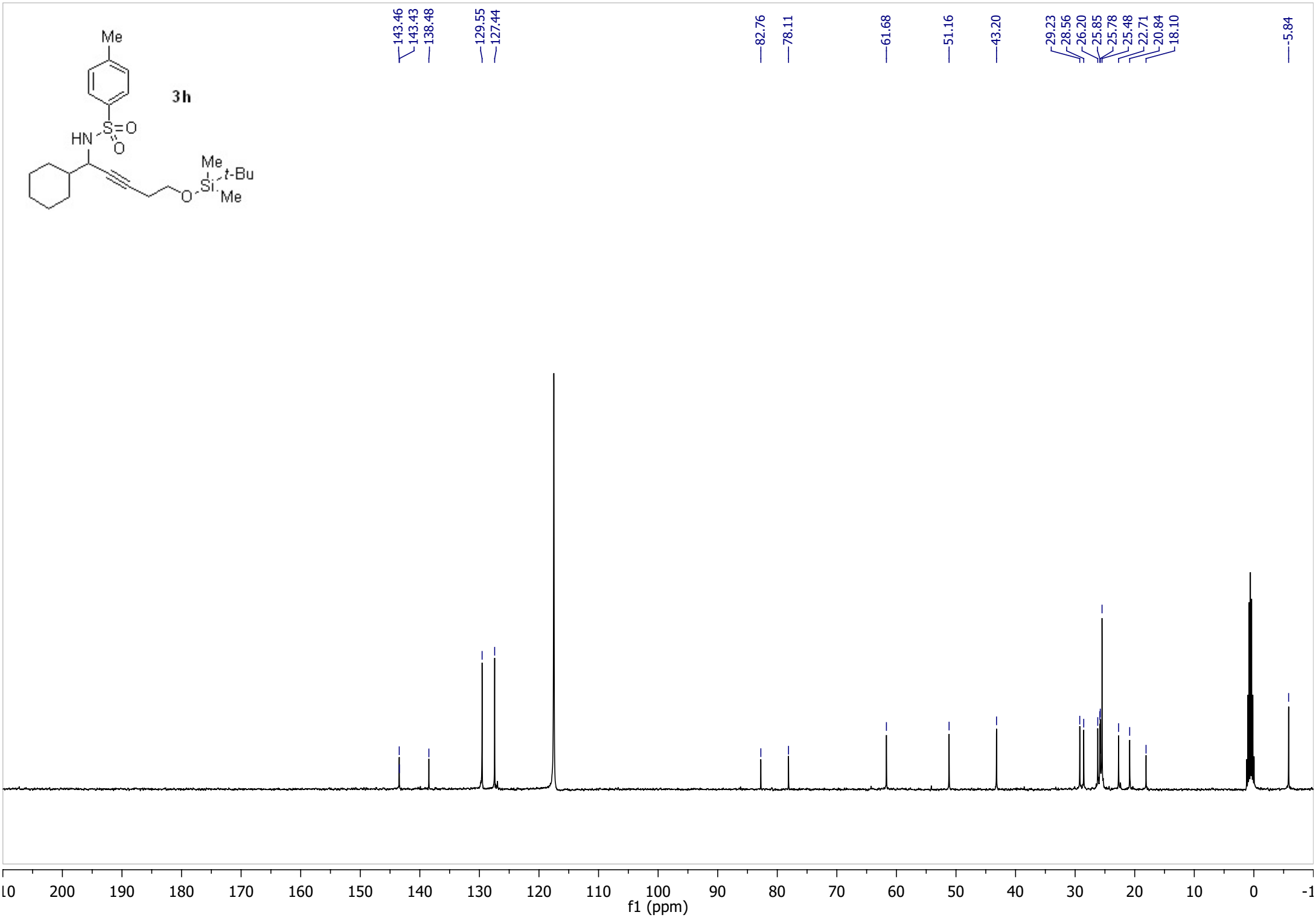
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


Me
3g
HN
S
O
O
Cl
143.59
138.43
129.64
127.37
83.53
78.16
51.02
43.98
43.36
31.20
29.16
28.55
26.21
25.83
25.75
20.78
15.52
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


Me
3h
HN
S=O
O
Me
t-Bu
Si
Me
O
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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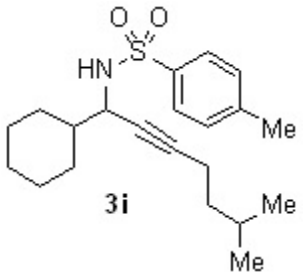
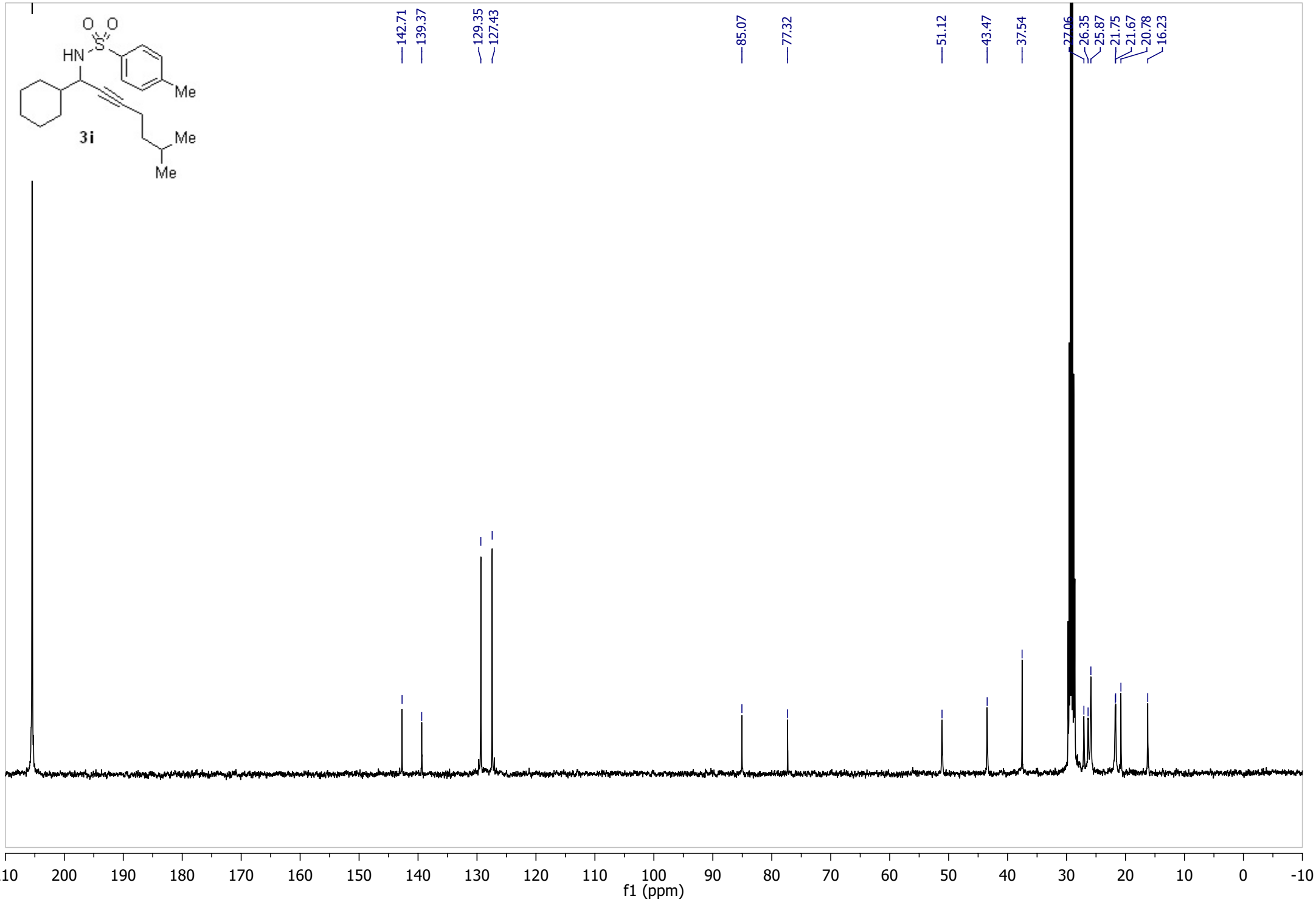
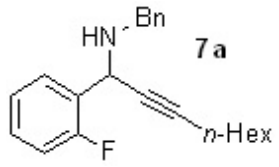
143.43
138.48
129.55
127.44
82.76
78.11
61.68
51.16
43.20
29.23
28.56
26.20
25.85
25.78
25.48
22.71
20.84
18.10
-5.84
Me
3h
HN
S=O
O
Me
Si
t-Bu
Me
O
f1 (ppm)


O
O
S
HN
Me
Me
Me

3i

10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


HN
O
O
S
Me
Me
Me
3i
142.71
139.37
129.35
127.43
85.07
77.32
51.12
43.47
37.54
27.06
26.35
25.87
21.75
21.67
20.78
16.23
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


HN
Bn
7a
F
n-Hex

10.5
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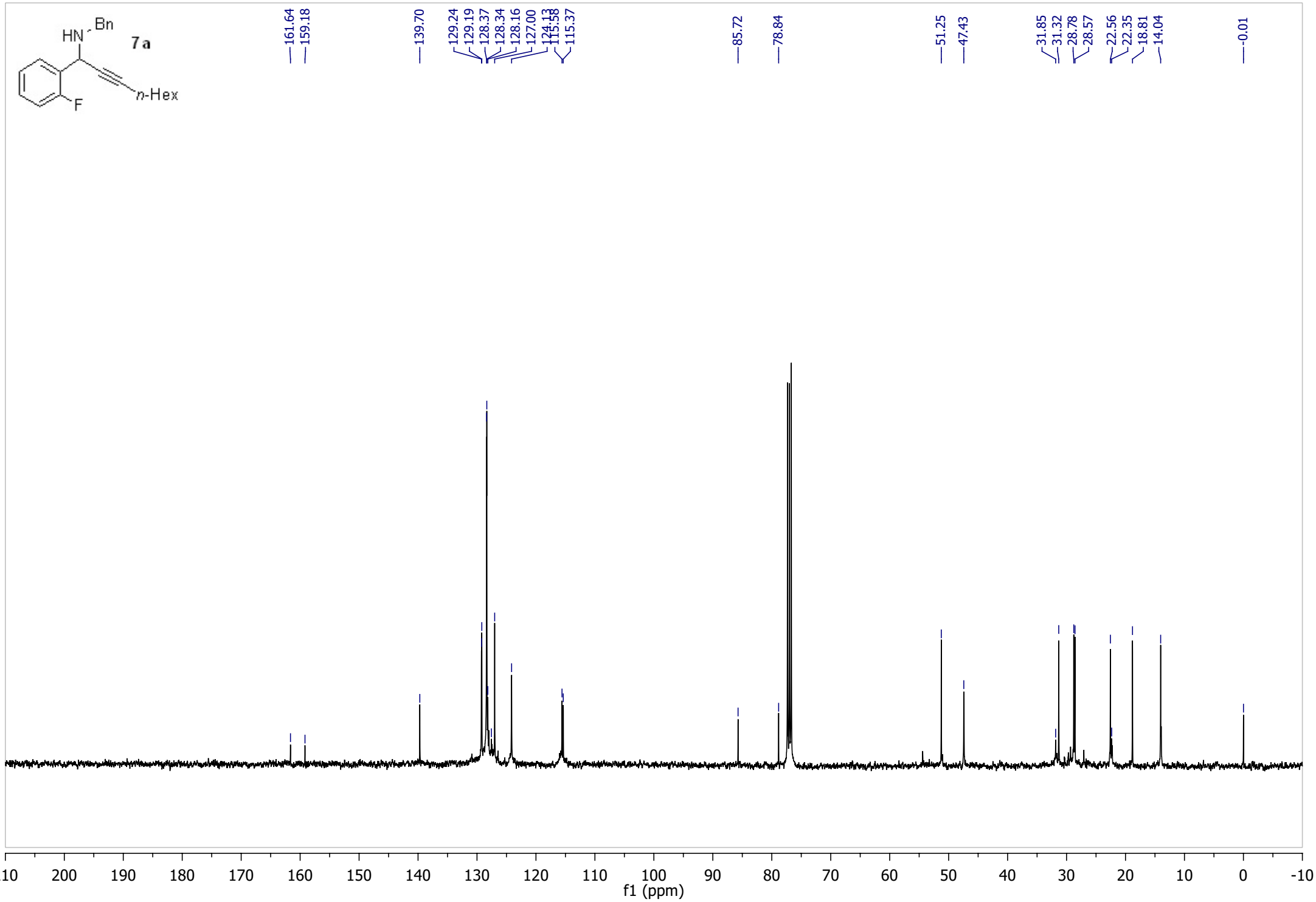
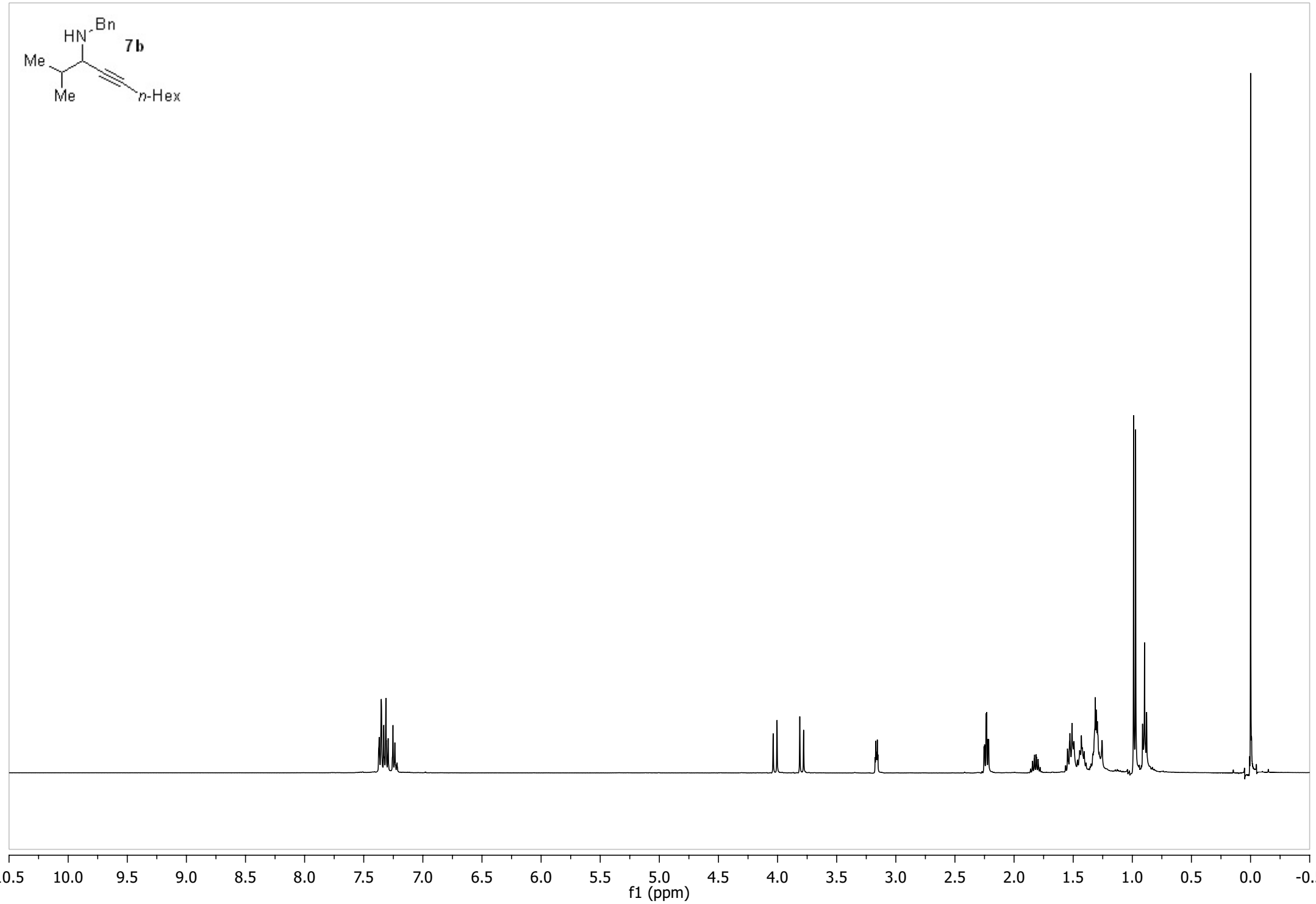
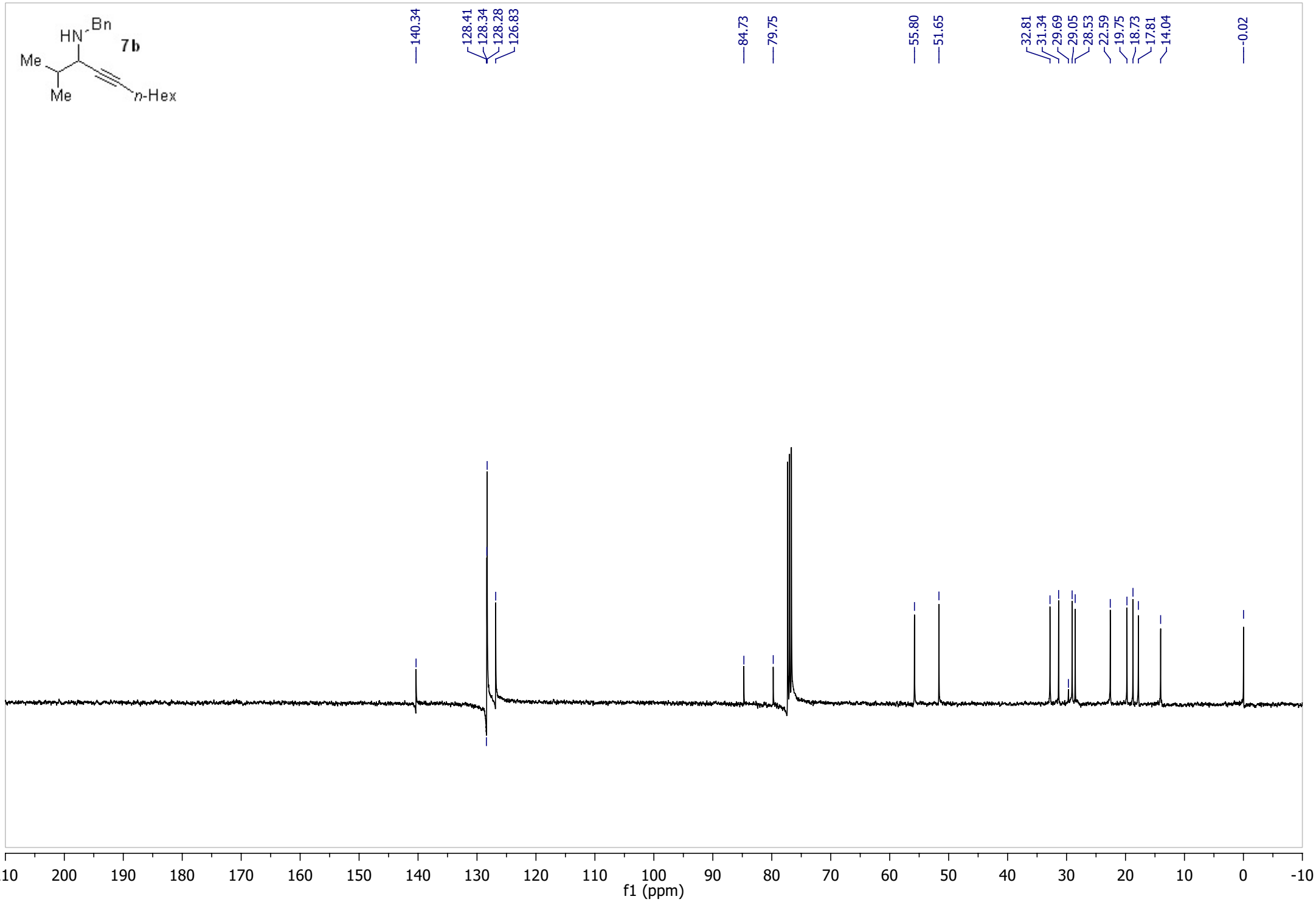
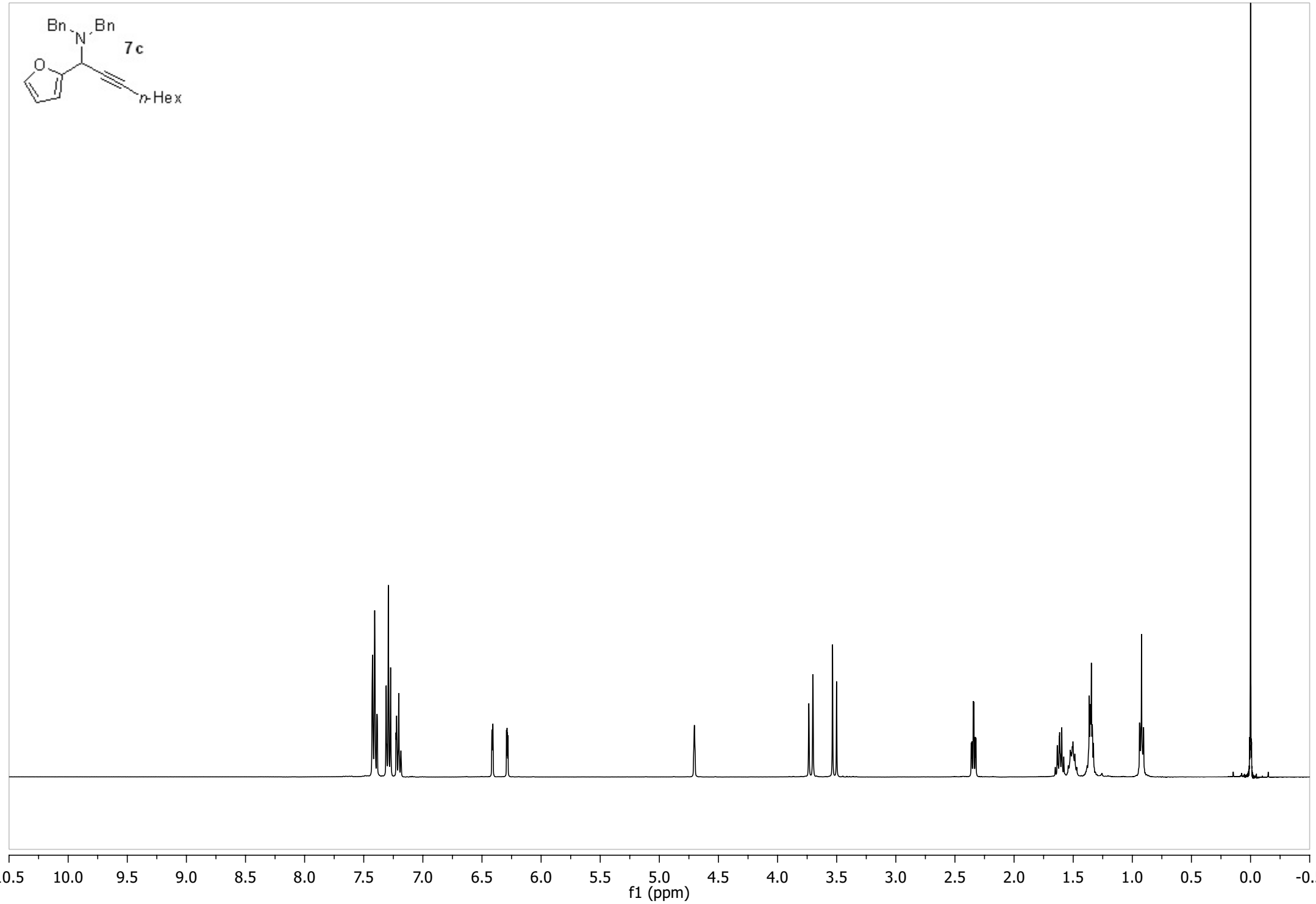
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


HN
Bn
7a
F
n-Hex
161.64
159.18
139.70
129.24
129.19
128.37
128.34
128.16
127.00
124.13
115.58
115.37
85.72
78.84
51.25
47.43
31.85
31.32
28.78
28.57
22.56
22.35
18.81
14.04
-0.01
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


HN
Bn
7b
Me
Me
n-Hex
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


HN
Bn
7b
Me
Me
n-Hex
140.34
128.41
128.34
128.28
126.83
84.73
79.75
55.80
51.65
32.81
31.34
29.69
29.05
28.53
22.59
19.75
18.73
17.81
14.04
-0.02
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


Bn
N
Bn
7c
O
n-Hex
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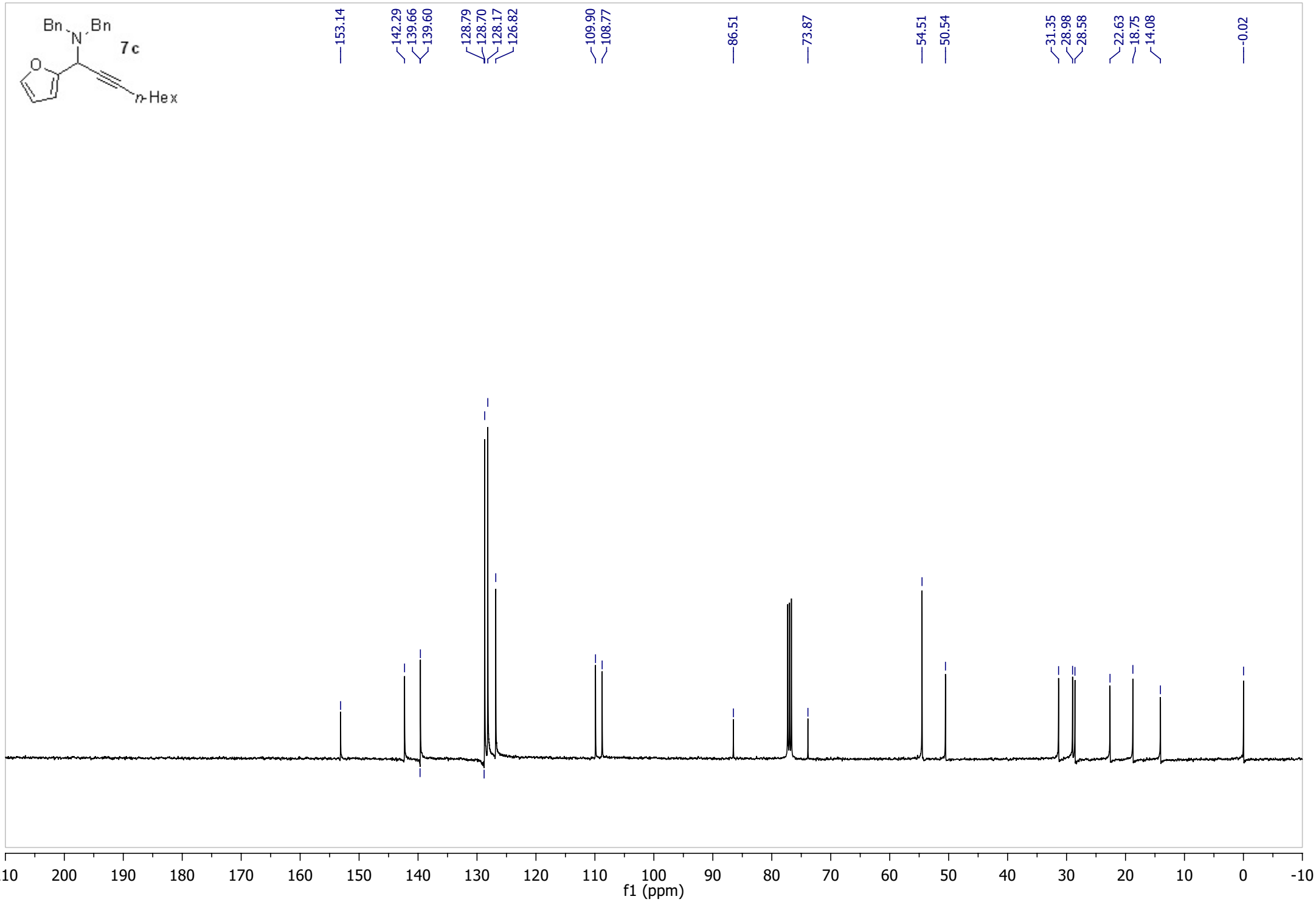
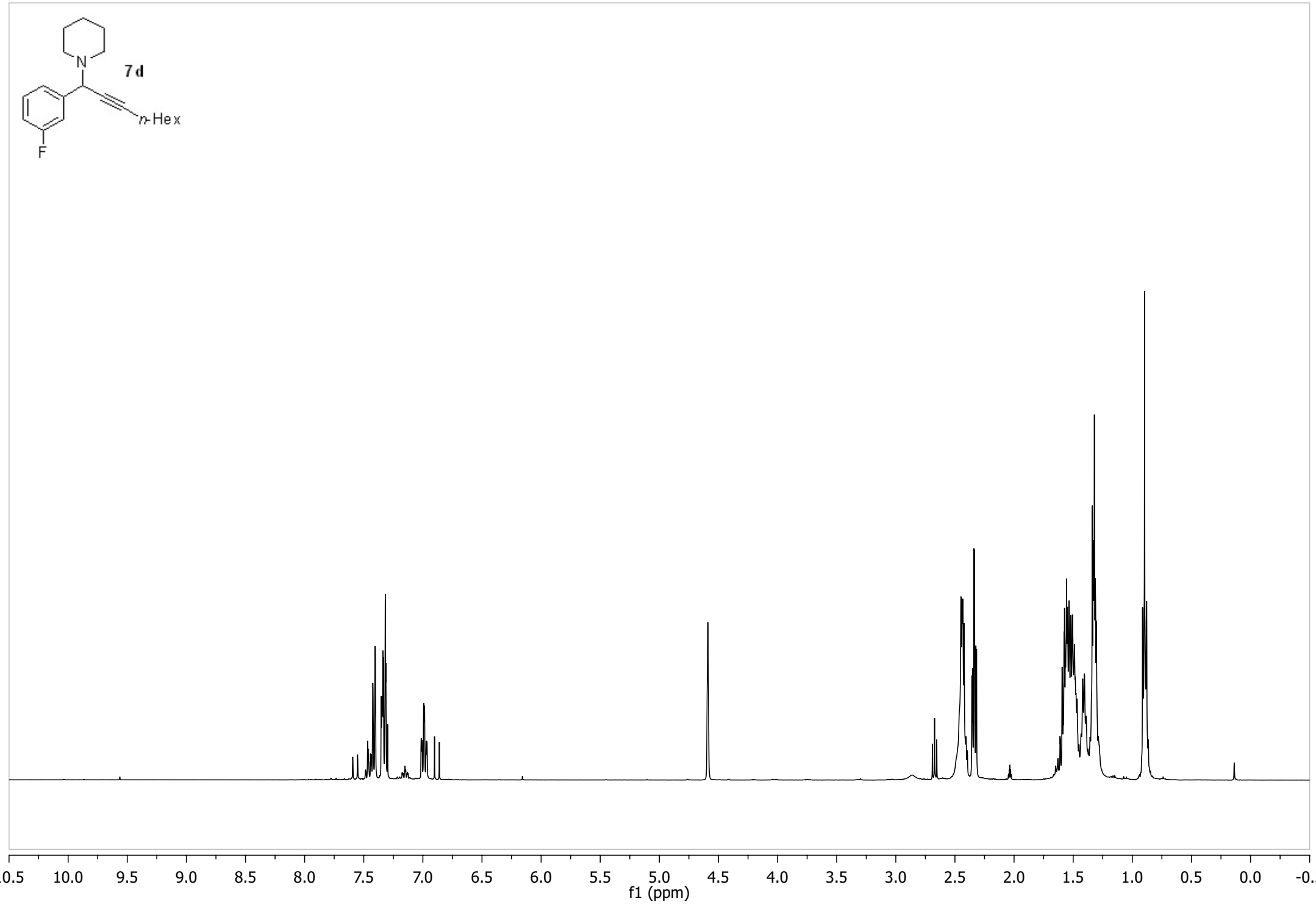
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


Bn
Bn
N
7c
O
n-Hex
153.14
142.29
139.66
139.60
128.79
128.70
128.17
126.82
109.90
108.77
86.51
73.87
54.51
50.54
31.35
28.98
28.58
22.63
18.75
14.08
-0.02
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7d
N
n-Hex
F
10.5
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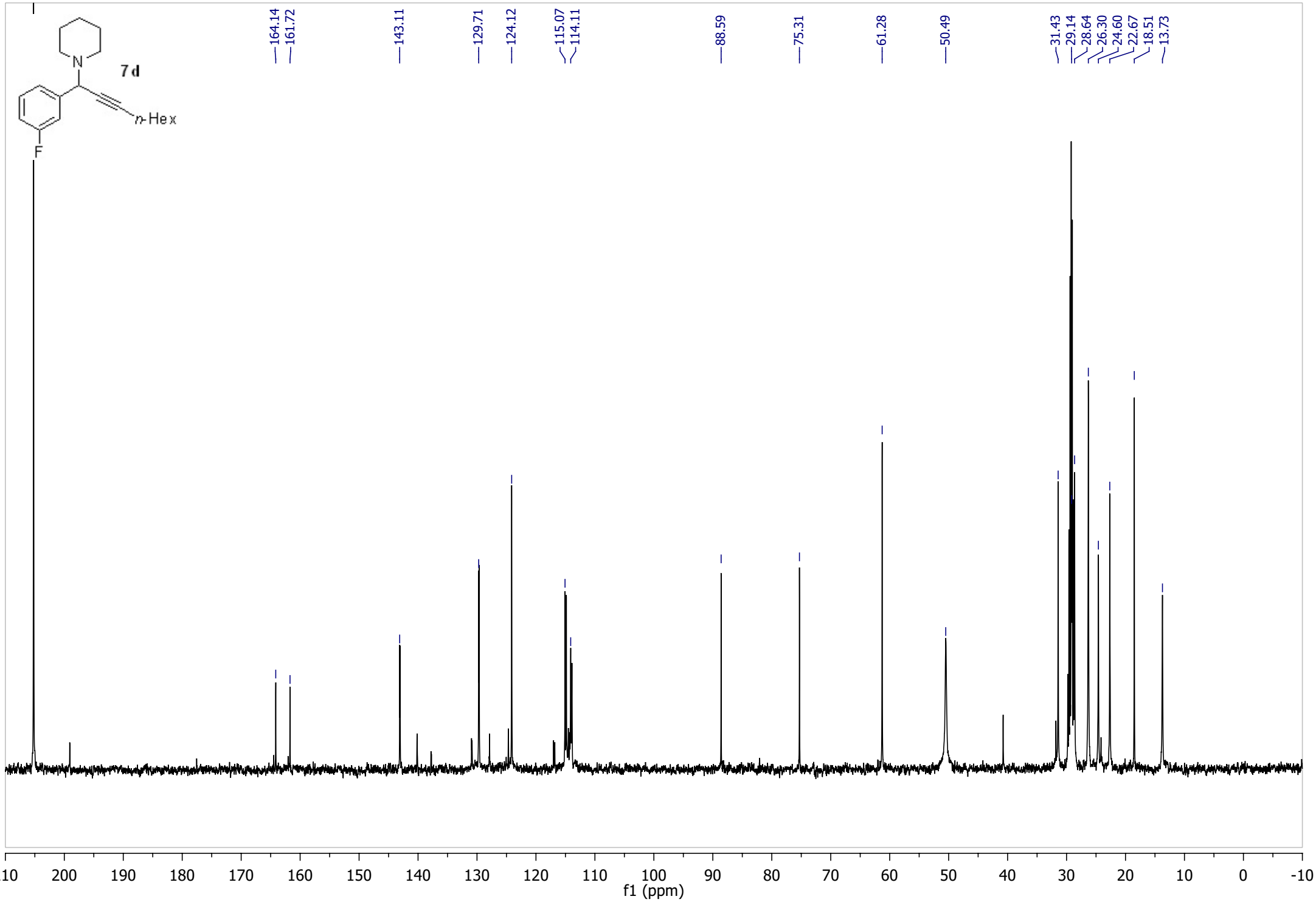
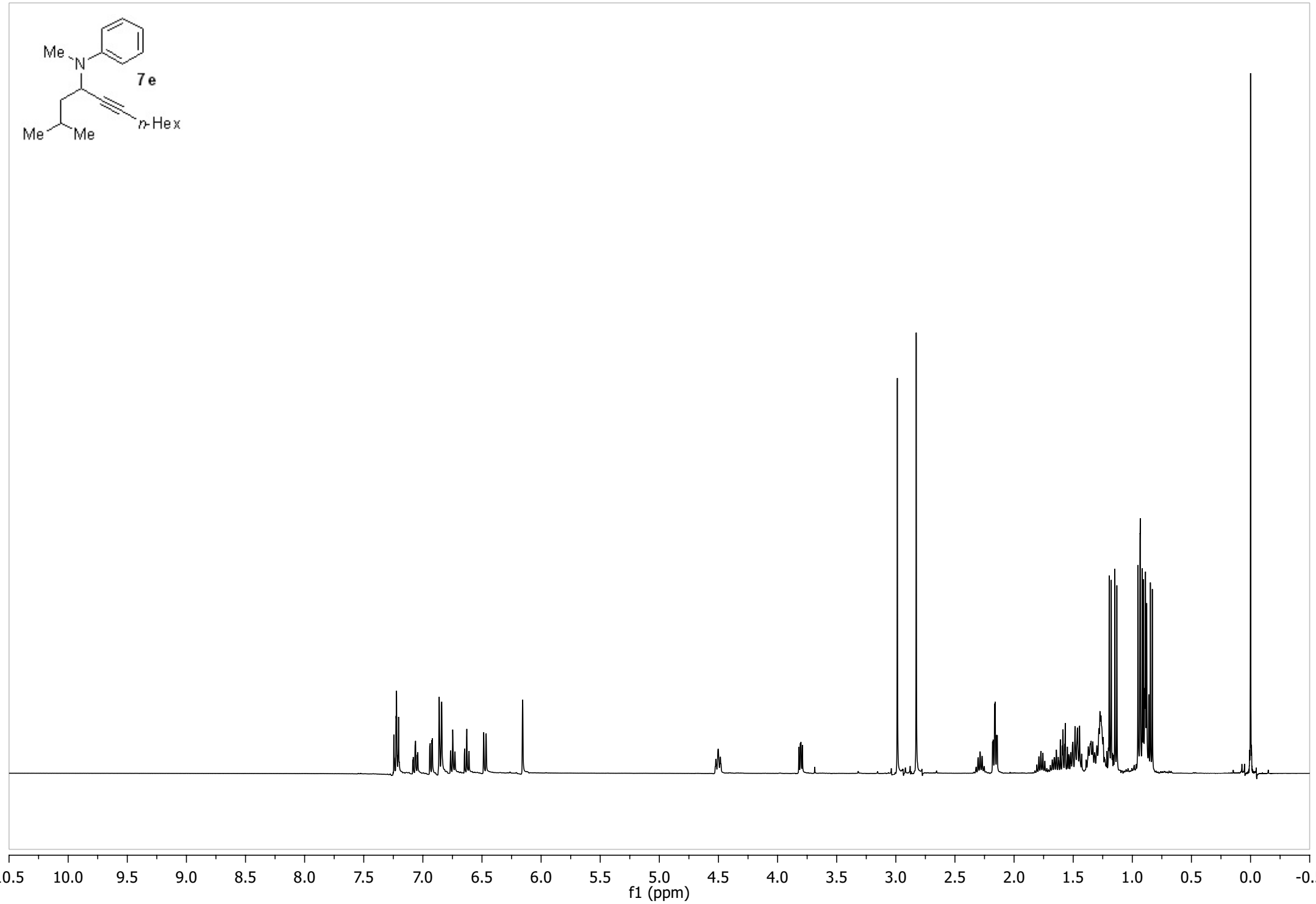
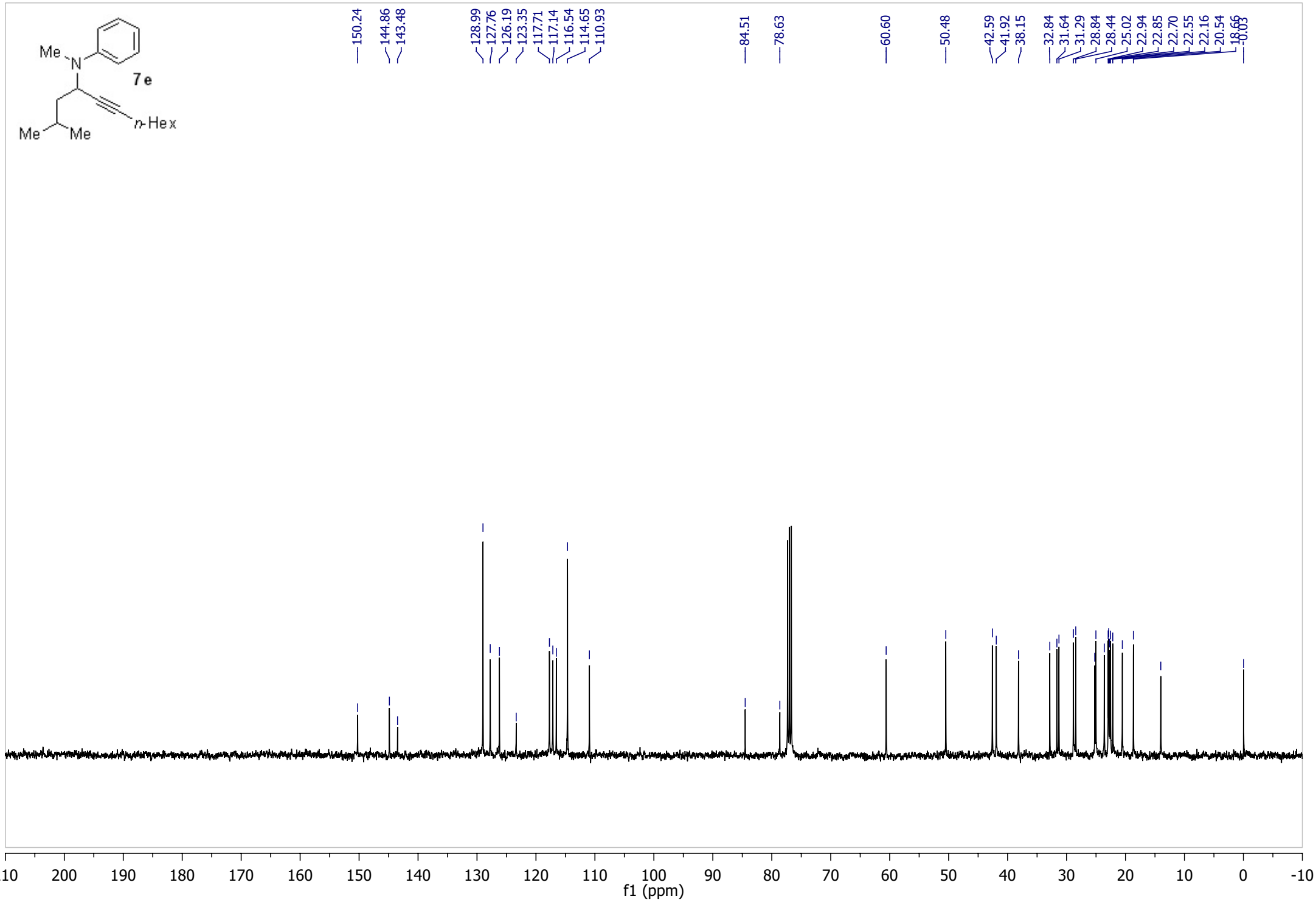
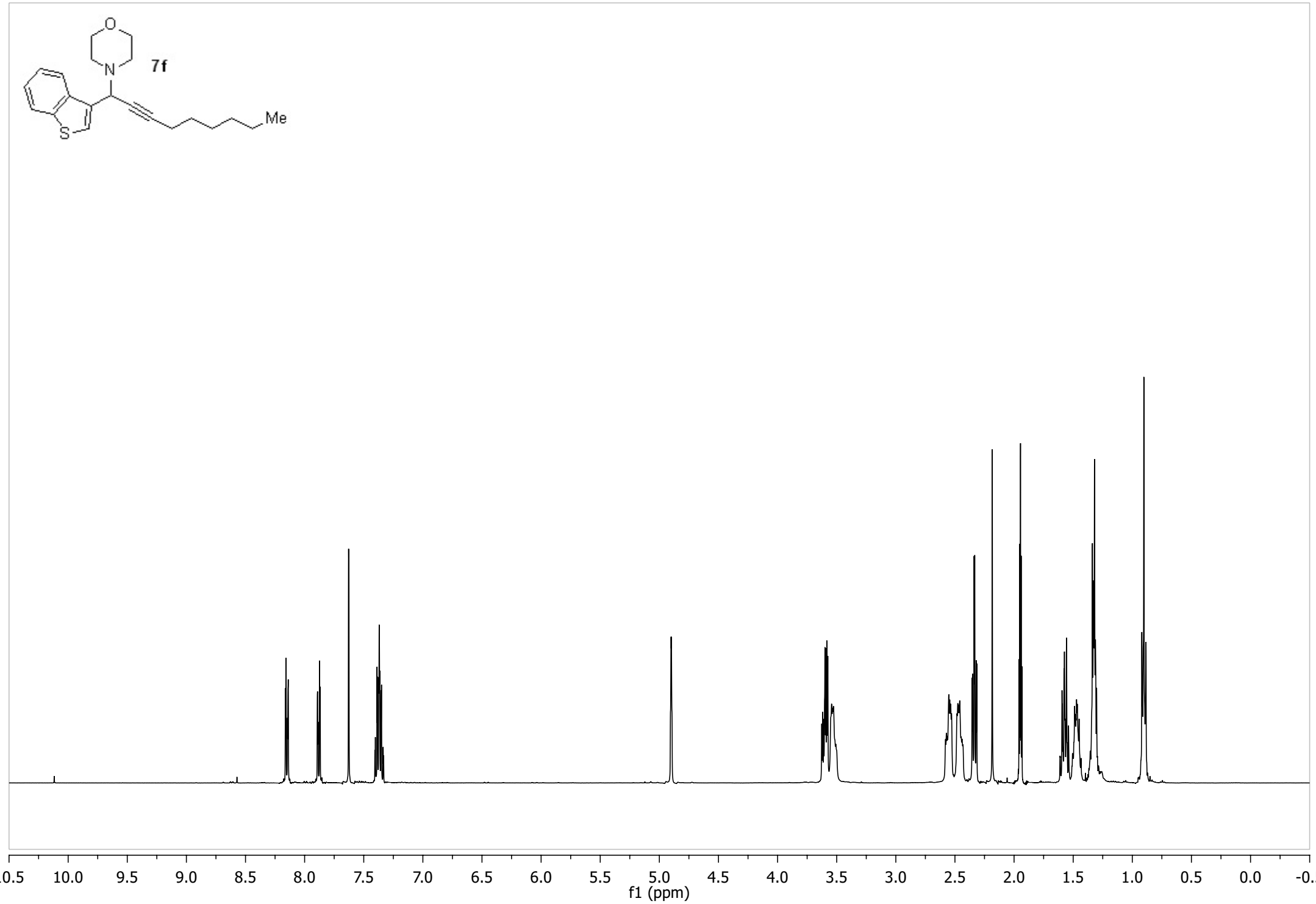
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


7d
n-Hex
F
164.14
161.72
143.11
129.71
124.12
115.07
114.11
88.59
75.31
61.28
50.49
31.43
29.14
28.64
26.30
24.60
22.67
18.51
13.73
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


Me
N
7e
Me
Me
n-Hex
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


Me
N
7e
Me
Me
n-Hex
150.24
144.86
143.48
128.99
127.76
126.19
123.35
117.71
117.14
116.54
114.65
110.93
84.51
78.63
60.60
50.48
42.59
41.92
38.15
32.84
31.64
31.29
28.84
28.44
25.02
22.94
22.85
22.70
22.55
22.16
20.54
18.66
0.03
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


O
N
7f
S
Me
10.5
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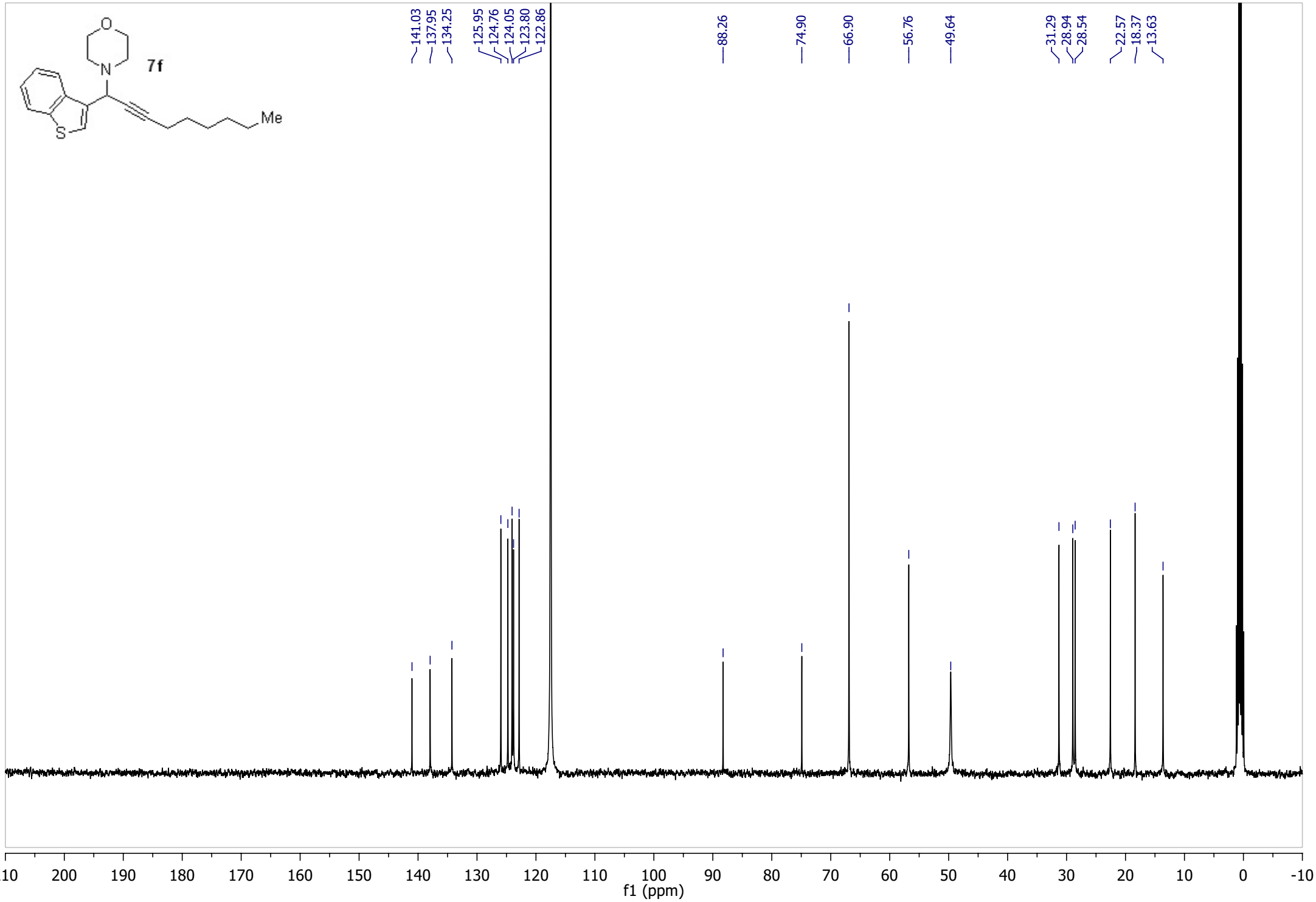
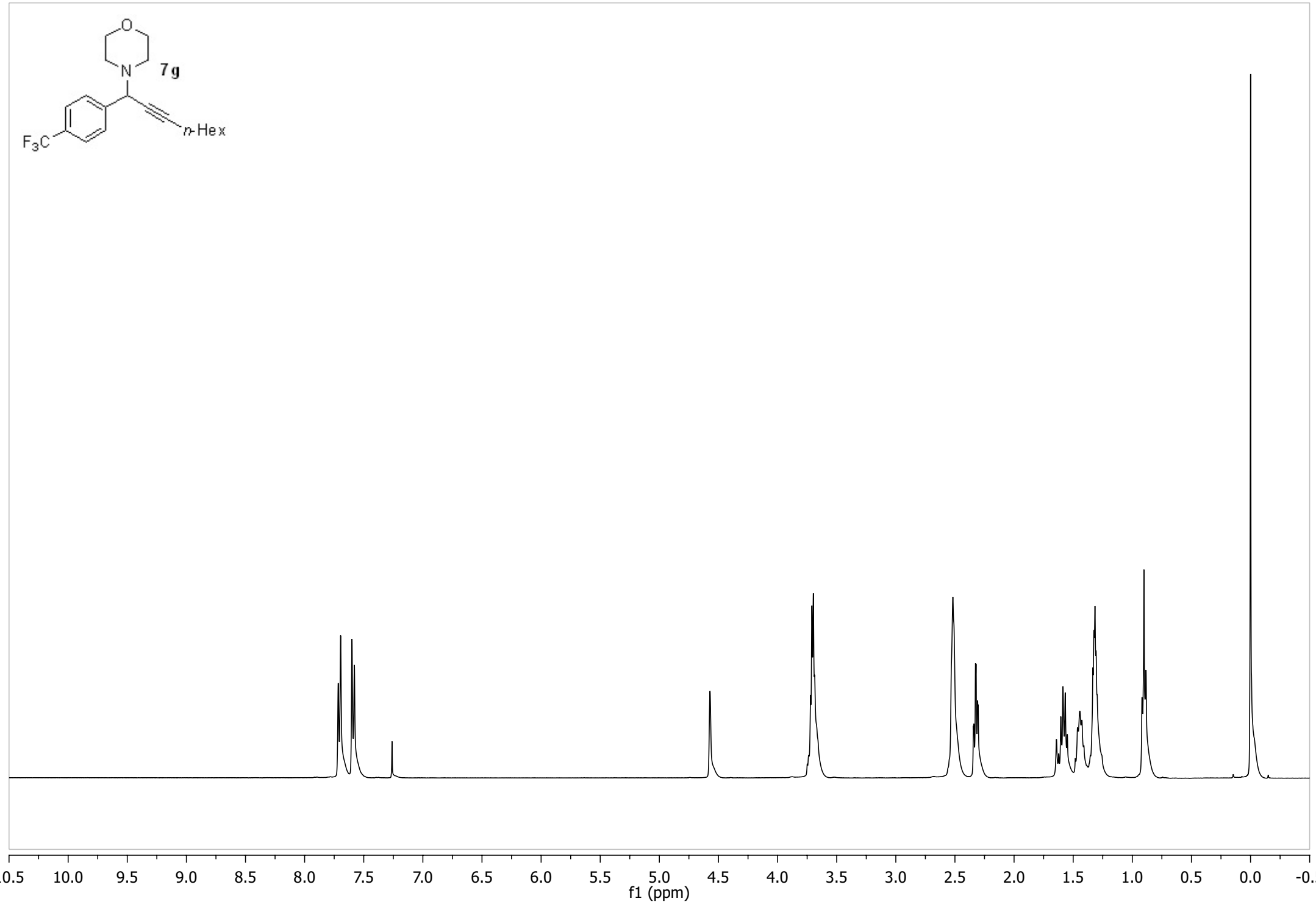
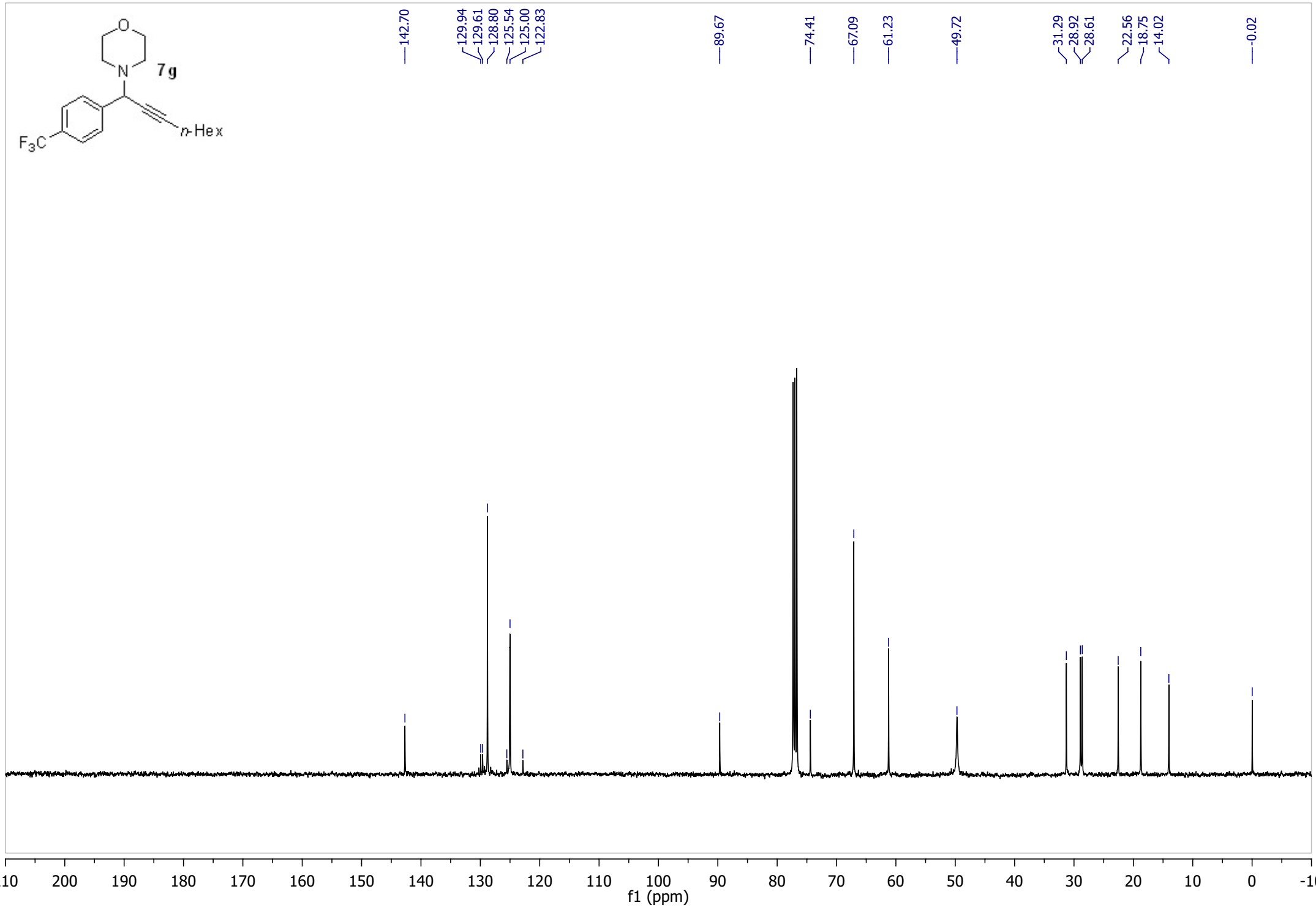
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


7f
O
N
S
Me
141.03
137.95
134.25
125.95
124.76
124.05
123.80
122.86
88.26
74.90
66.90
56.76
49.64
31.29
28.94
28.54
22.57
18.37
13.63
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


O
N
7g
F3C
n-Hex
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


7g
n-Hex
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129.94
129.61
128.80
125.54
125.00
122.83
89.67
74.41
67.09
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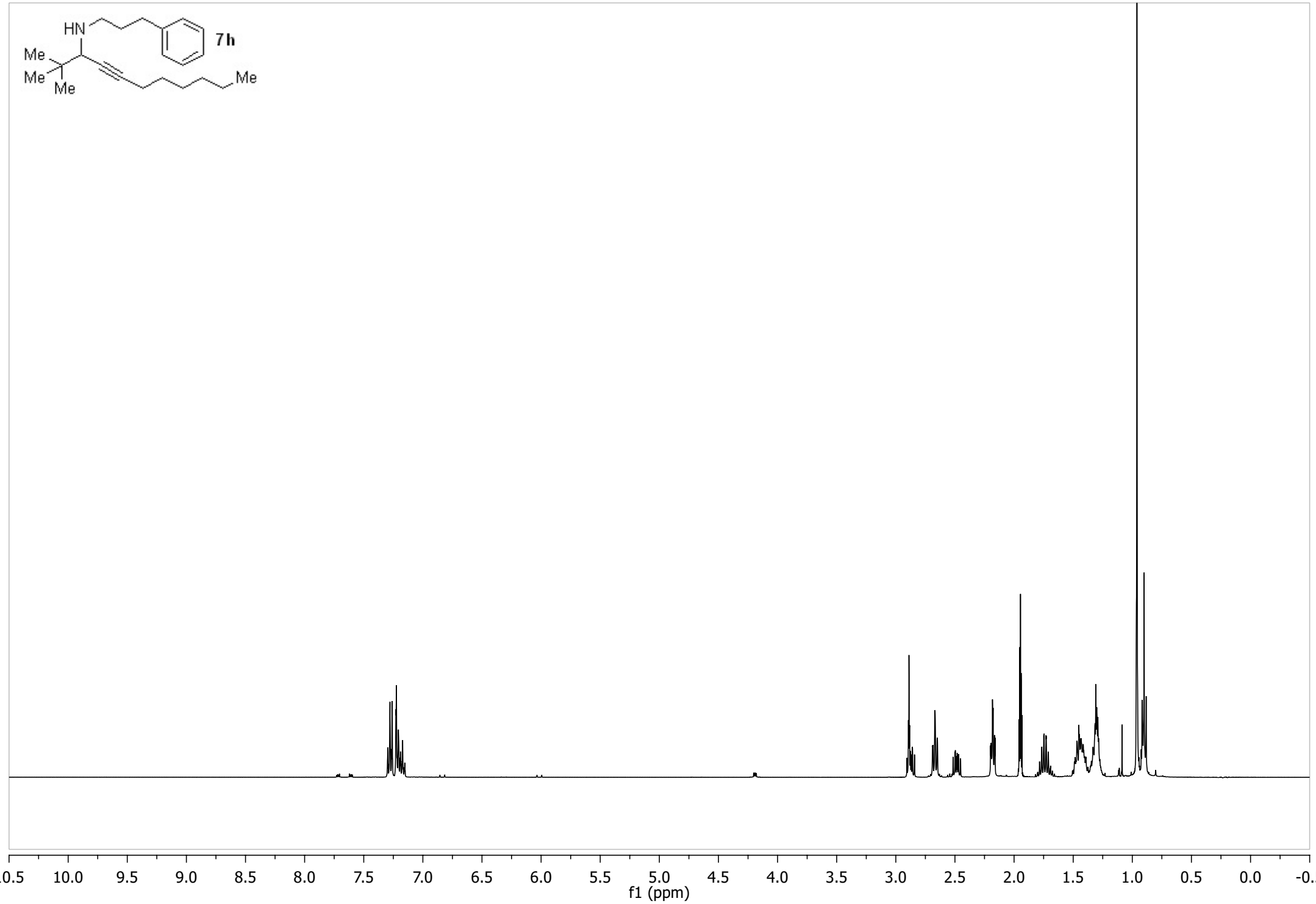
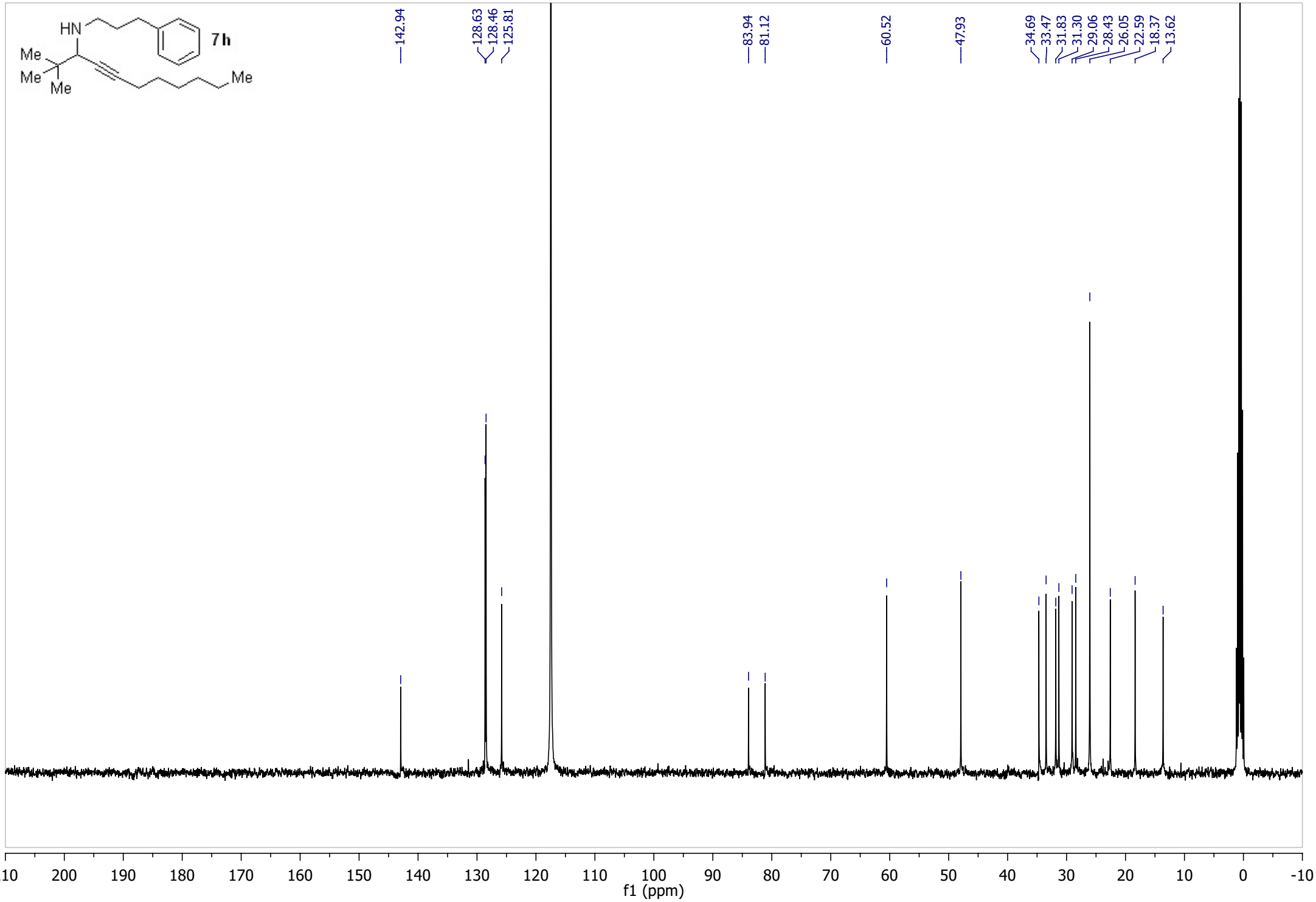
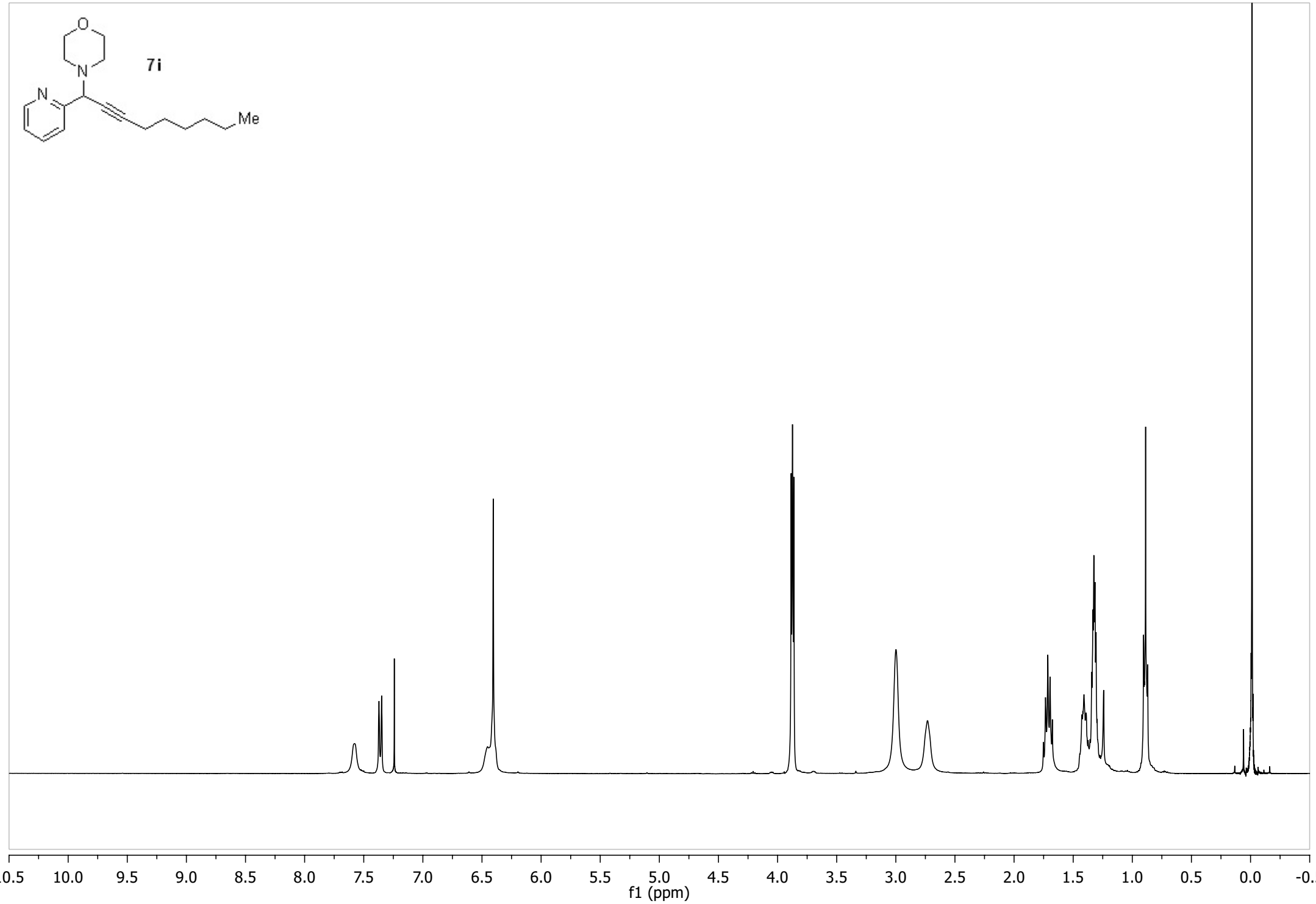
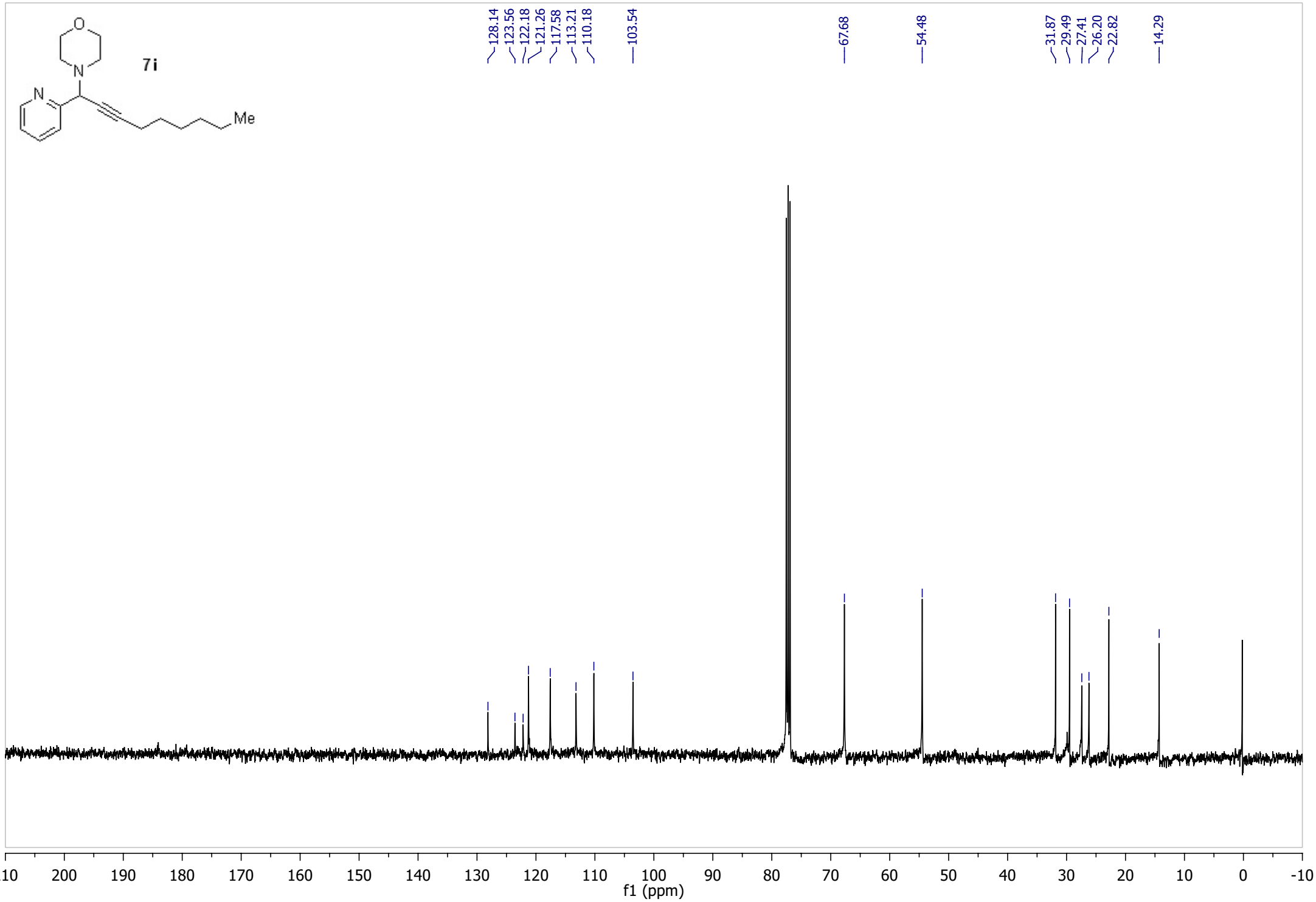
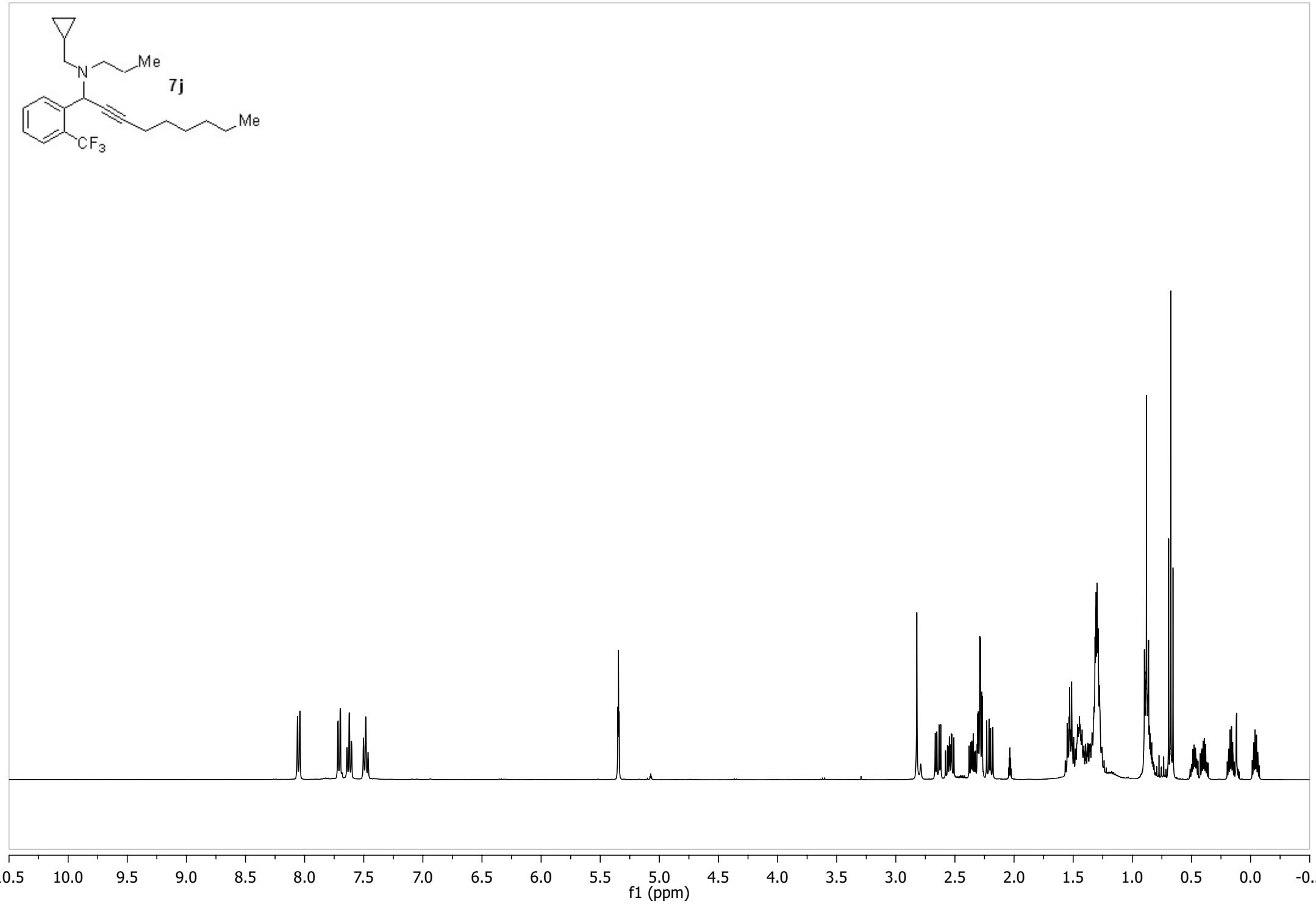
49.72
31.29
28.92
28.61
22.56
18.75
14.02
-0.02
f1 (ppm)

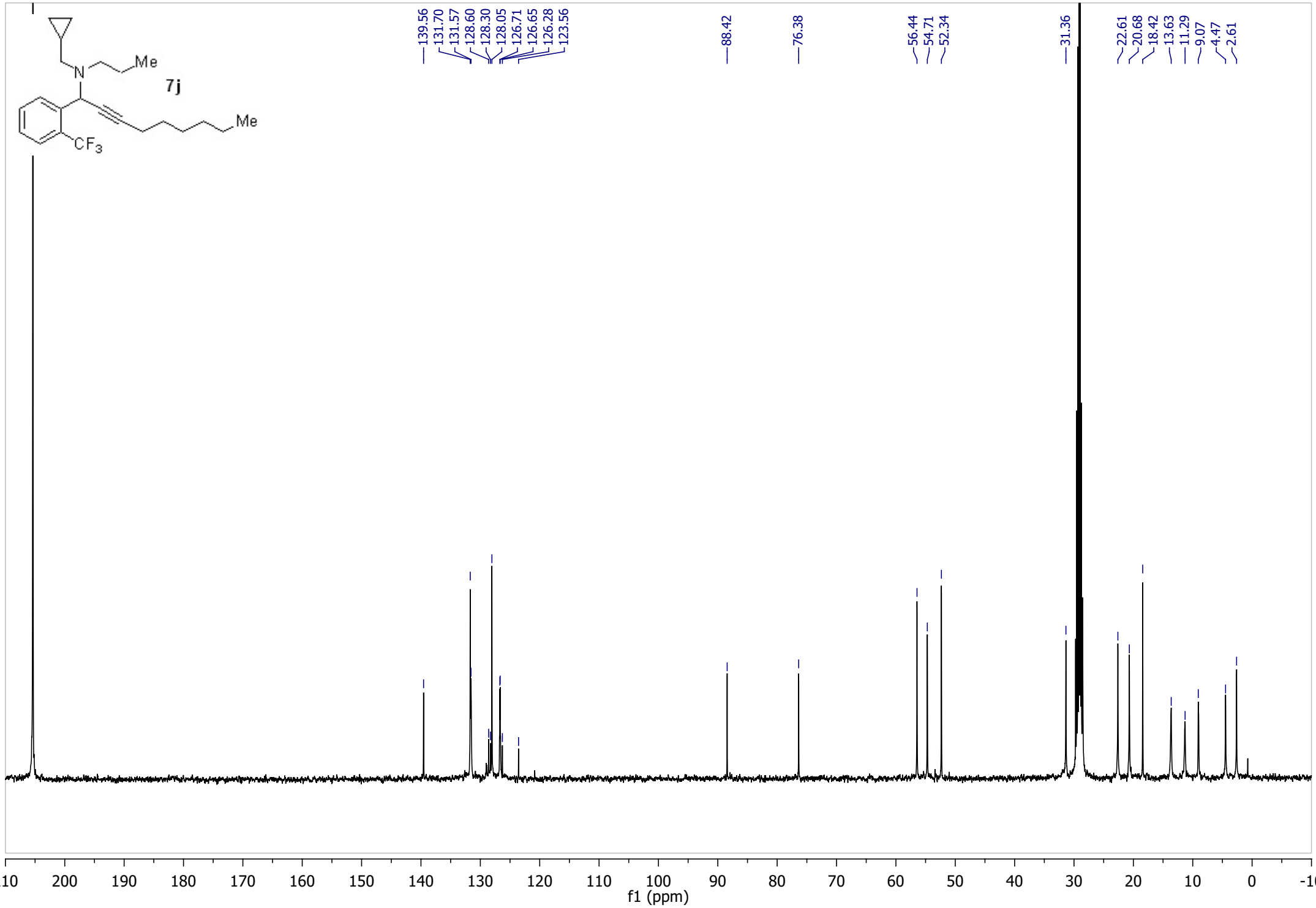

HN
7h
Me
Me
Me
Me
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

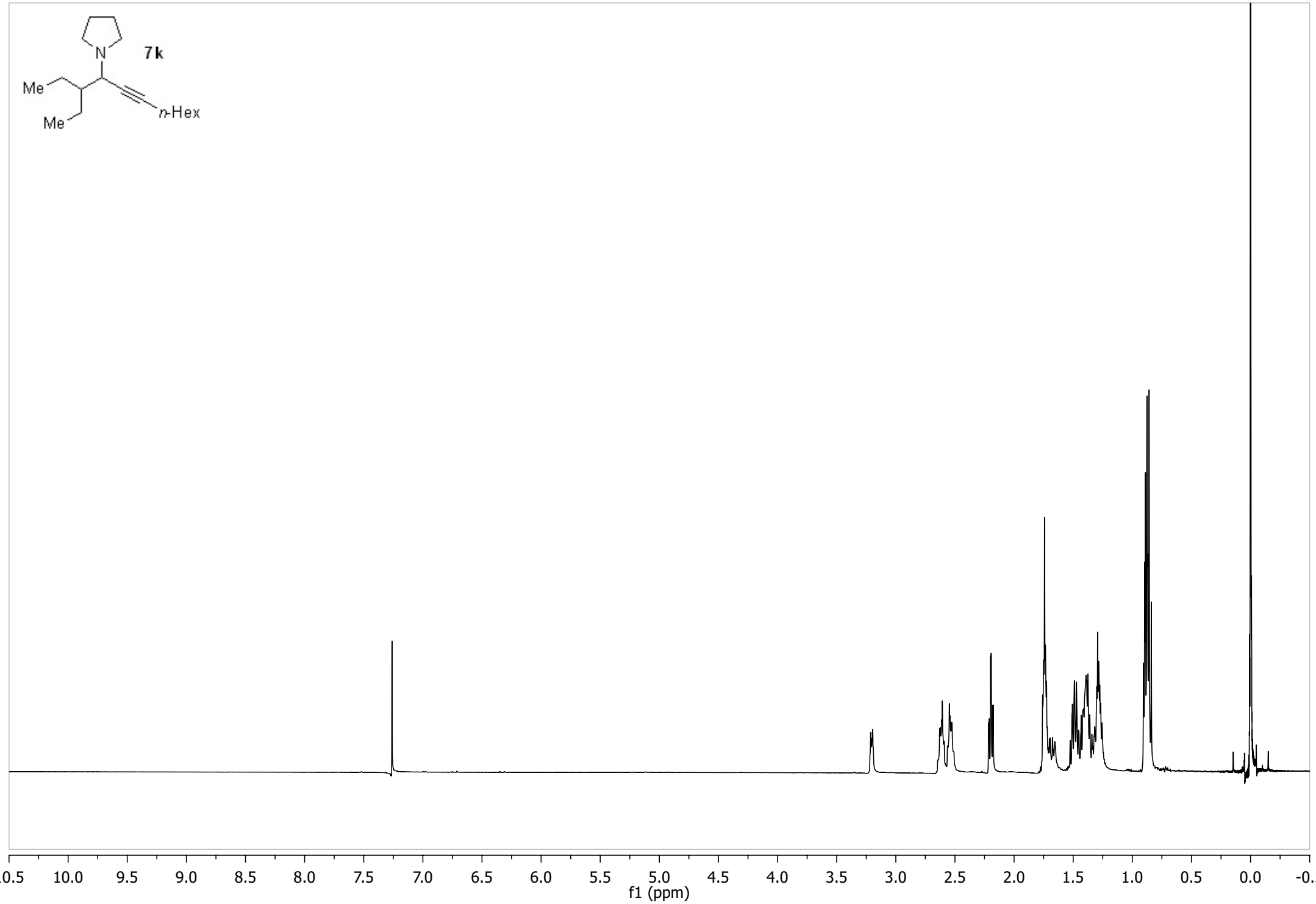

HN
Me
Me
Me
Me
7h
142.94
128.63
128.46
125.81
83.94
81.12
60.52
47.93
34.69
33.47
31.83
31.30
29.06
28.43
26.05
22.59
18.37
13.62
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


O
N
N
Me
7i
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


7i
O
N
N
Me
128.14
123.56
122.18
121.26
117.58
113.21
110.18
103.54
67.68
54.48
31.87
29.49
27.41
26.20
22.82
14.29
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


Me
N
7j
Me
CF3
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


7j
Me
N
Me
CF3
139.56
131.70
131.57
128.60
128.30
128.05
126.71
126.65
126.28
123.56
88.42
76.38
56.44
54.71
52.34
31.36
22.61
20.68
18.42
13.63
11.29
9.07
4.47
2.61
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7k
N
Me
Me
n-Hex
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9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
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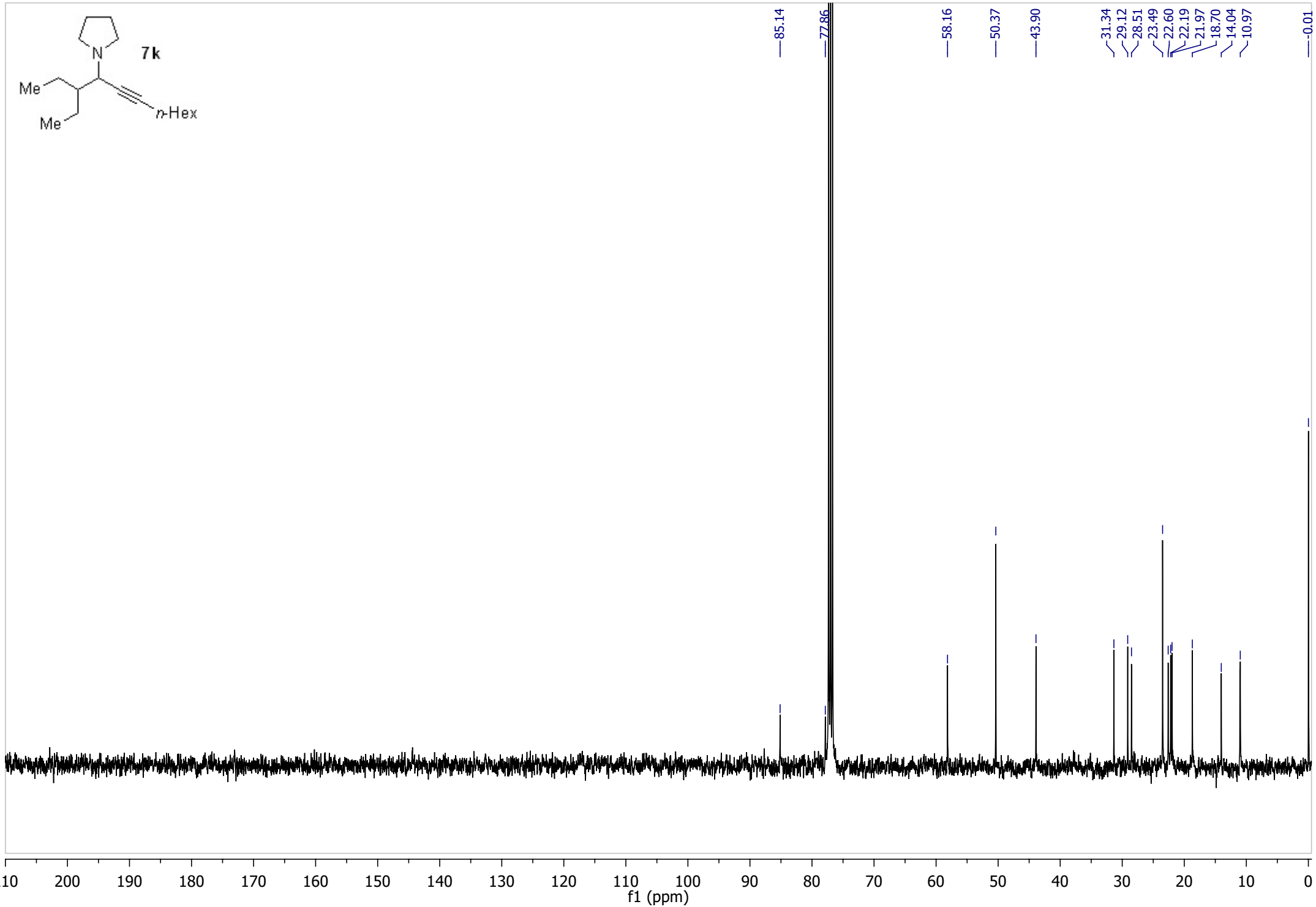
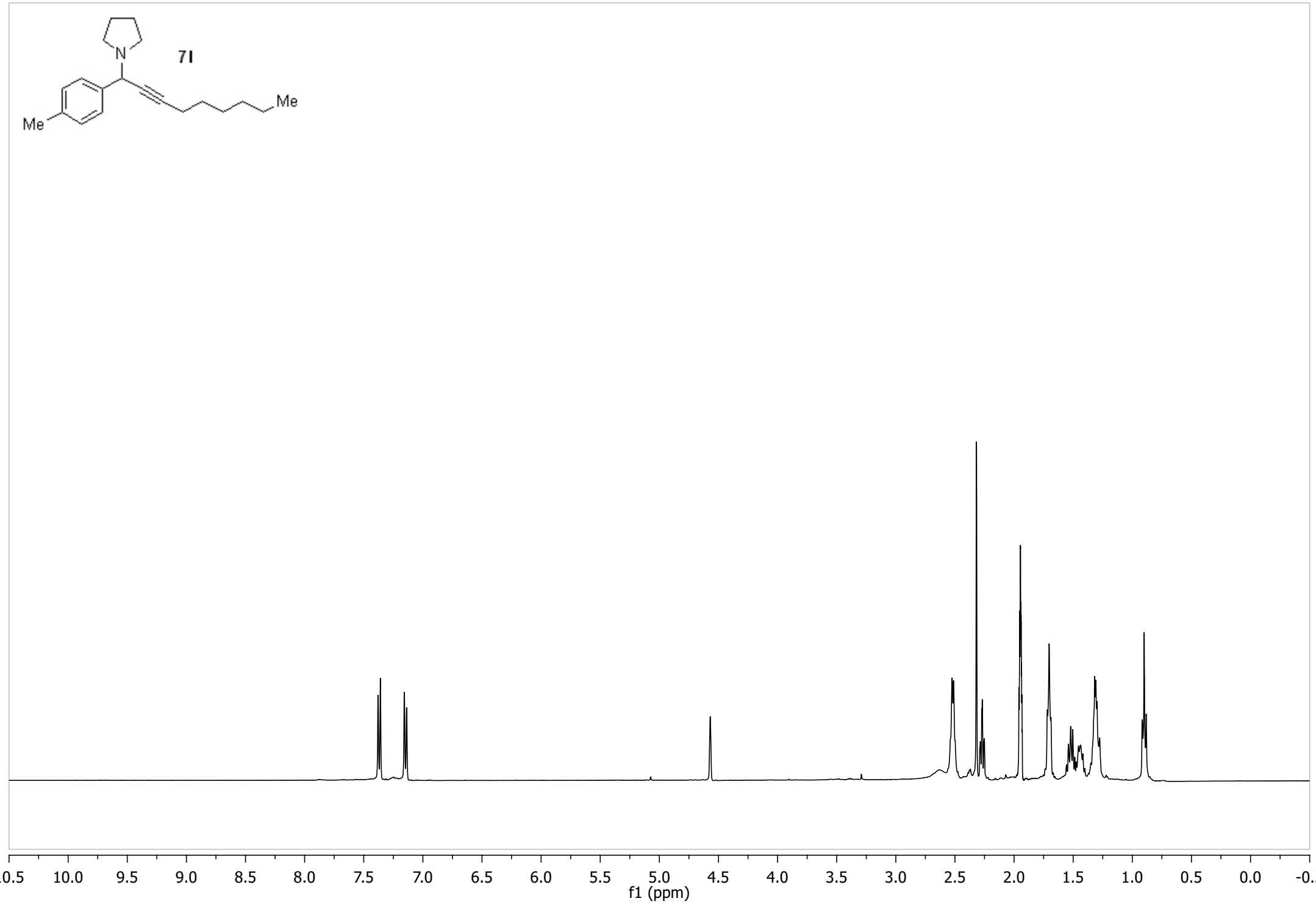
-0.5
f1 (ppm)


7k
N
Me
Me
n-Hex
85.14
77.86
58.16
50.37
43.90
31.34
29.12
28.51
23.49
22.60
22.19
21.97
18.70
14.04
10.97
-0.01
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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N
Me
Me
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9.5
9.0
8.5
8.0
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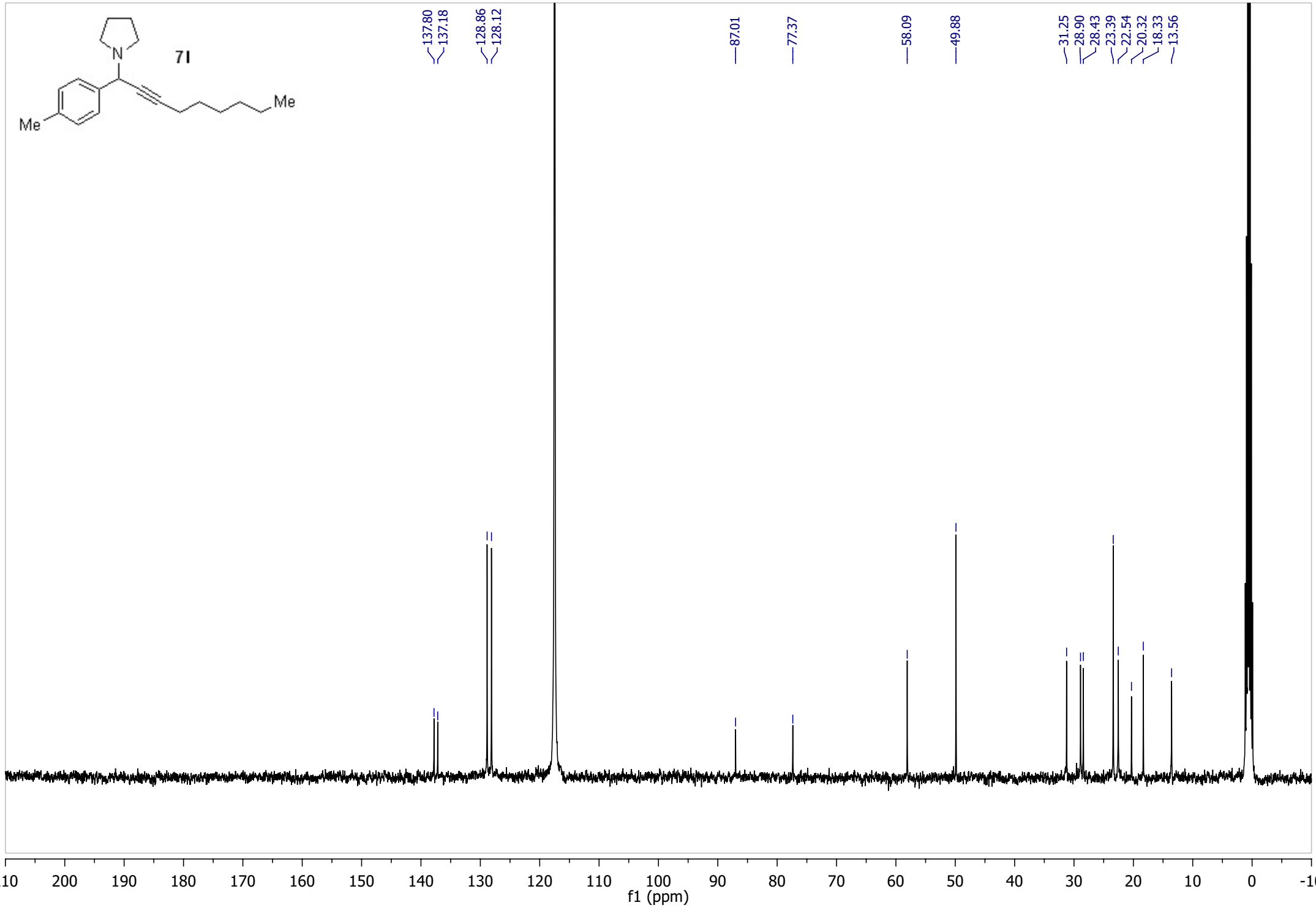
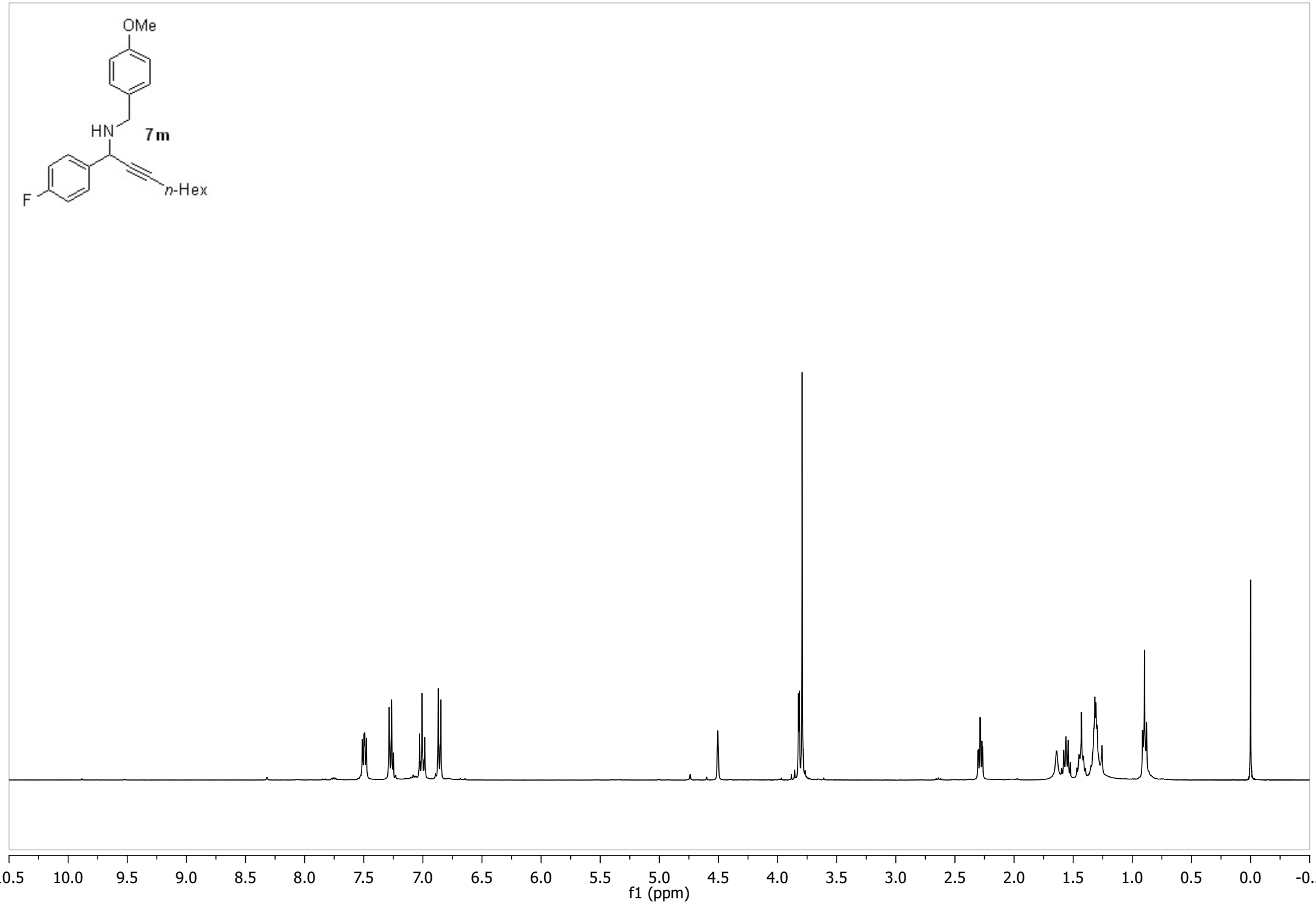
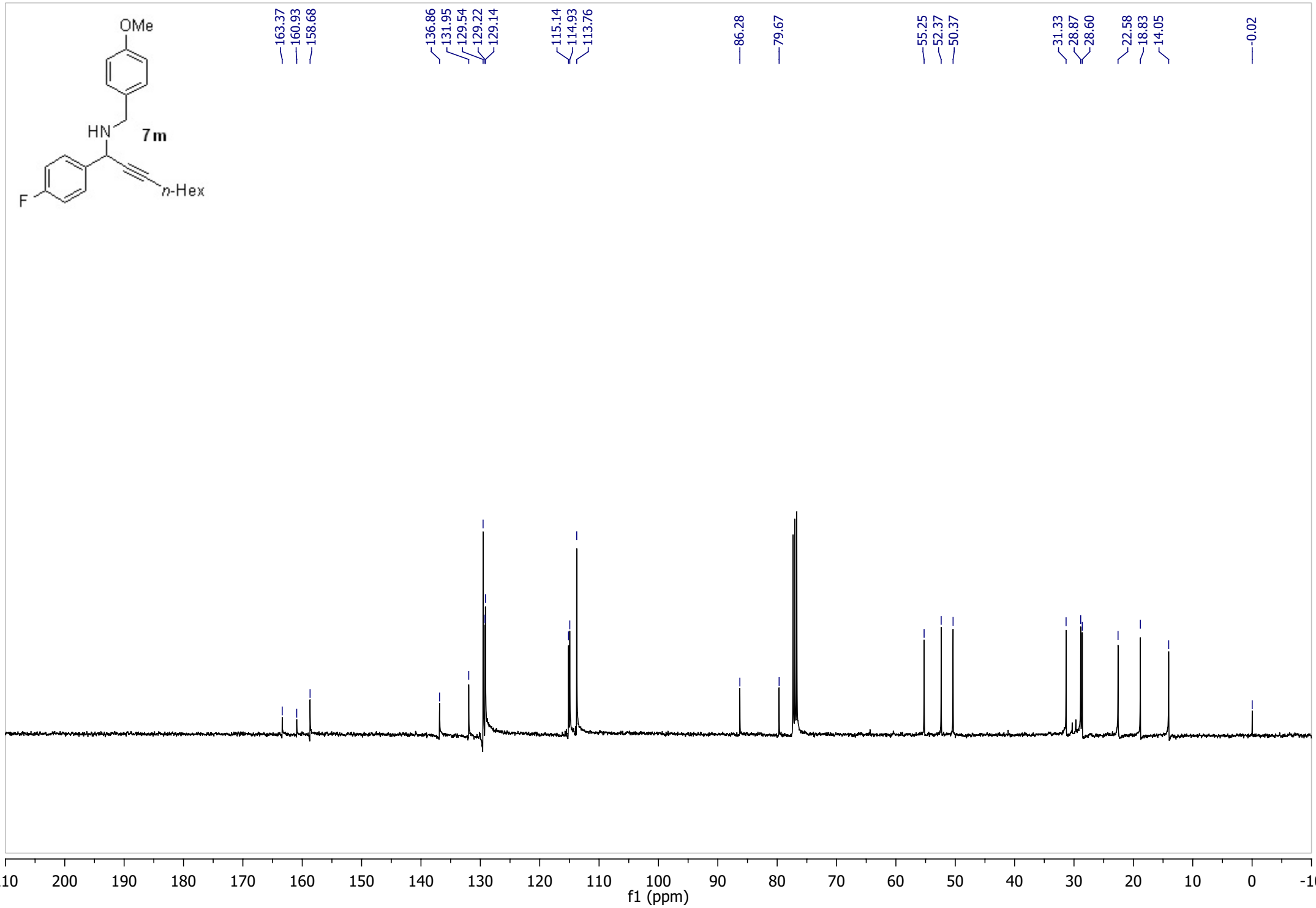
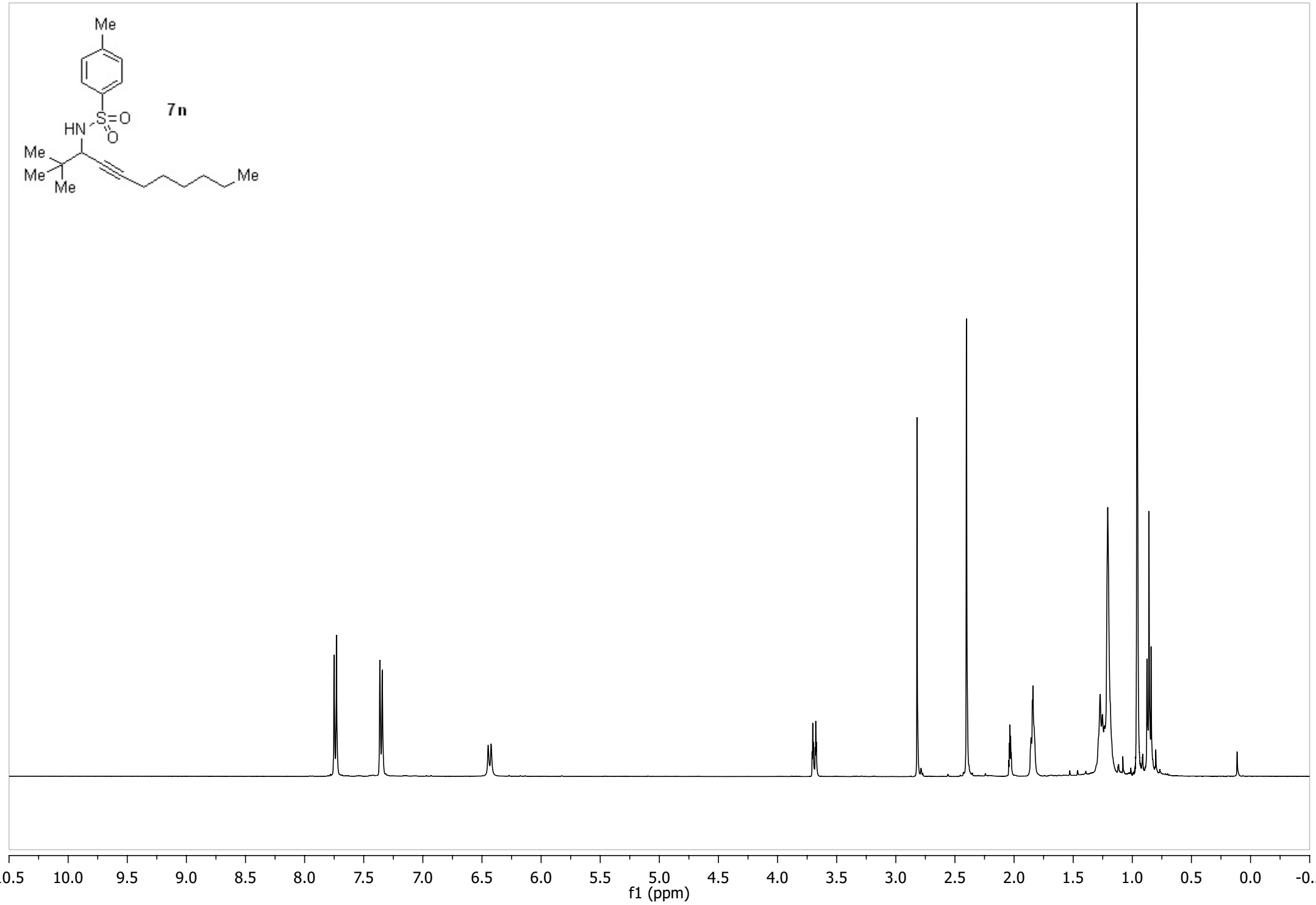
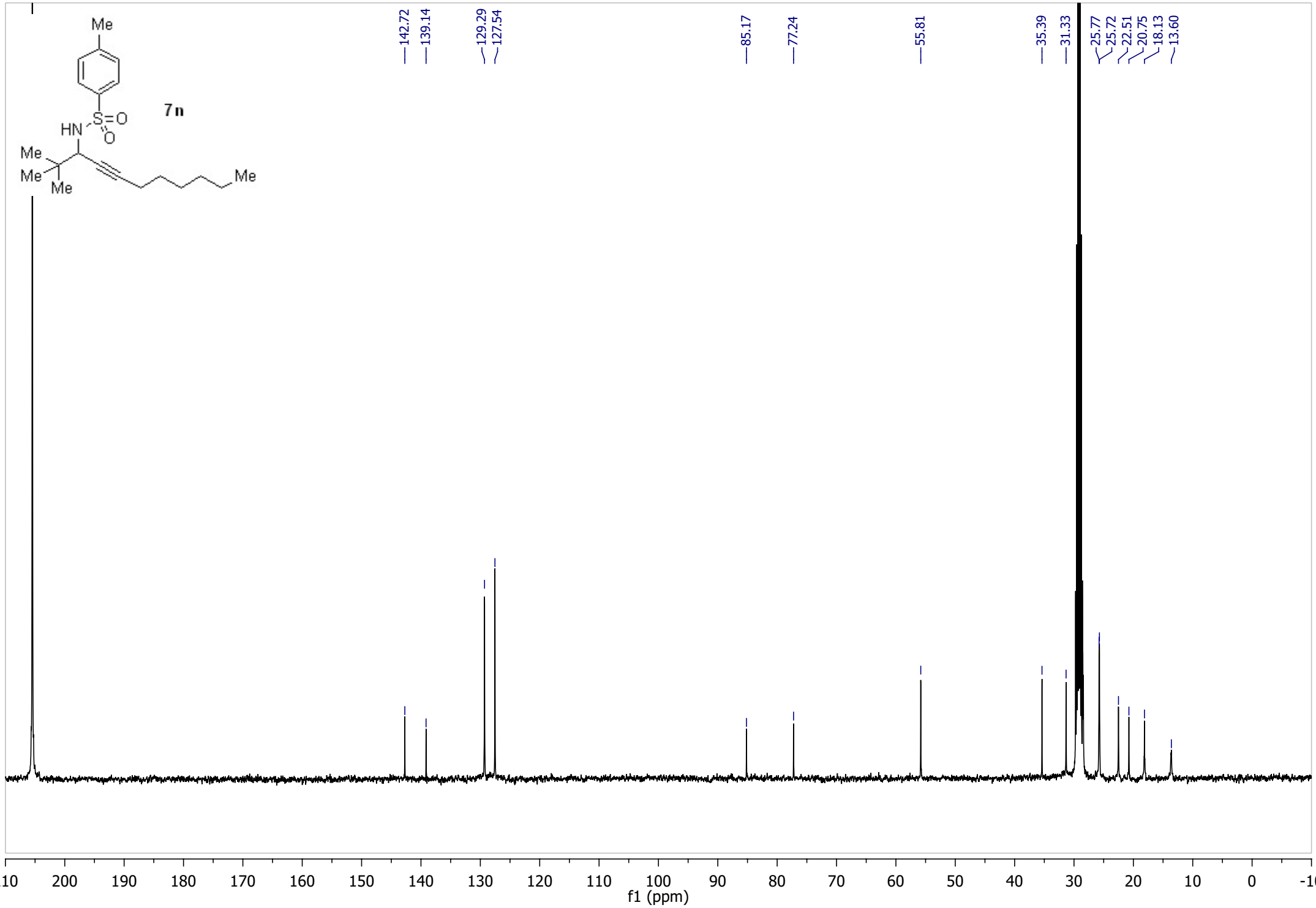
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

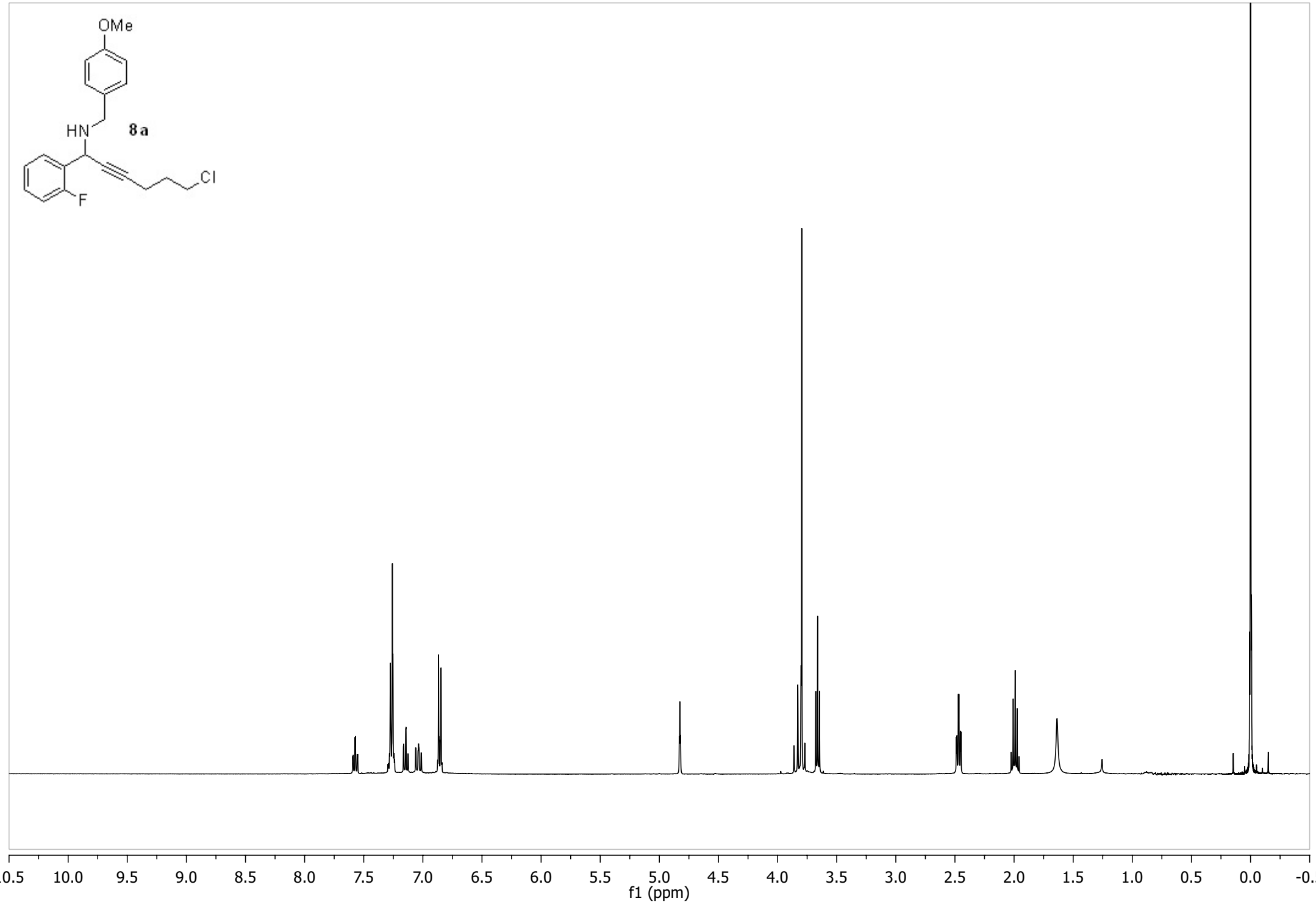

71
N
Me
Me
137.80
137.18
128.86
128.12
87.01
77.37
58.09
49.88
31.25
28.90
28.43
23.39
22.54
20.32
18.33
13.56
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

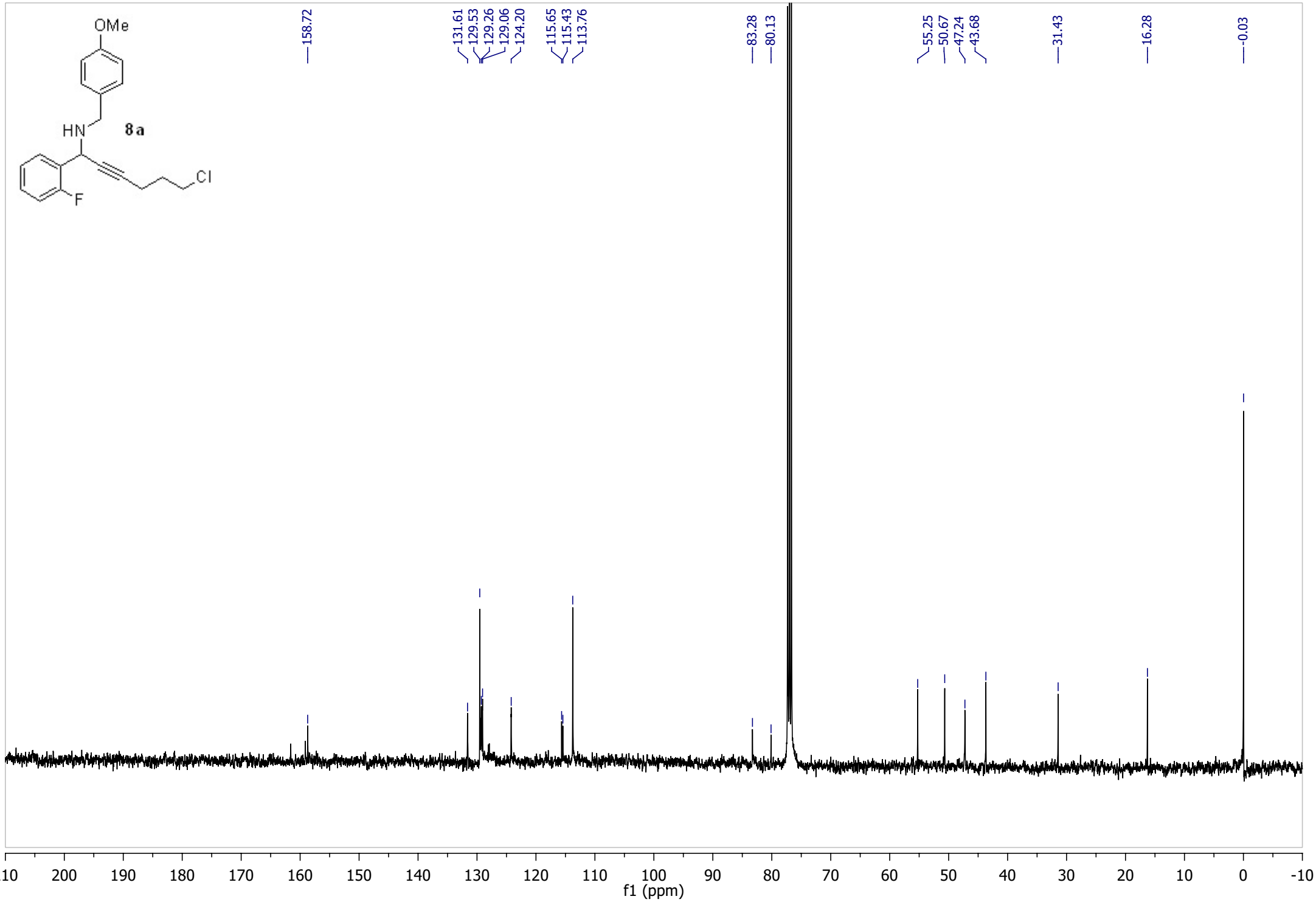

OMe
HN
7m
F
n-Hex
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

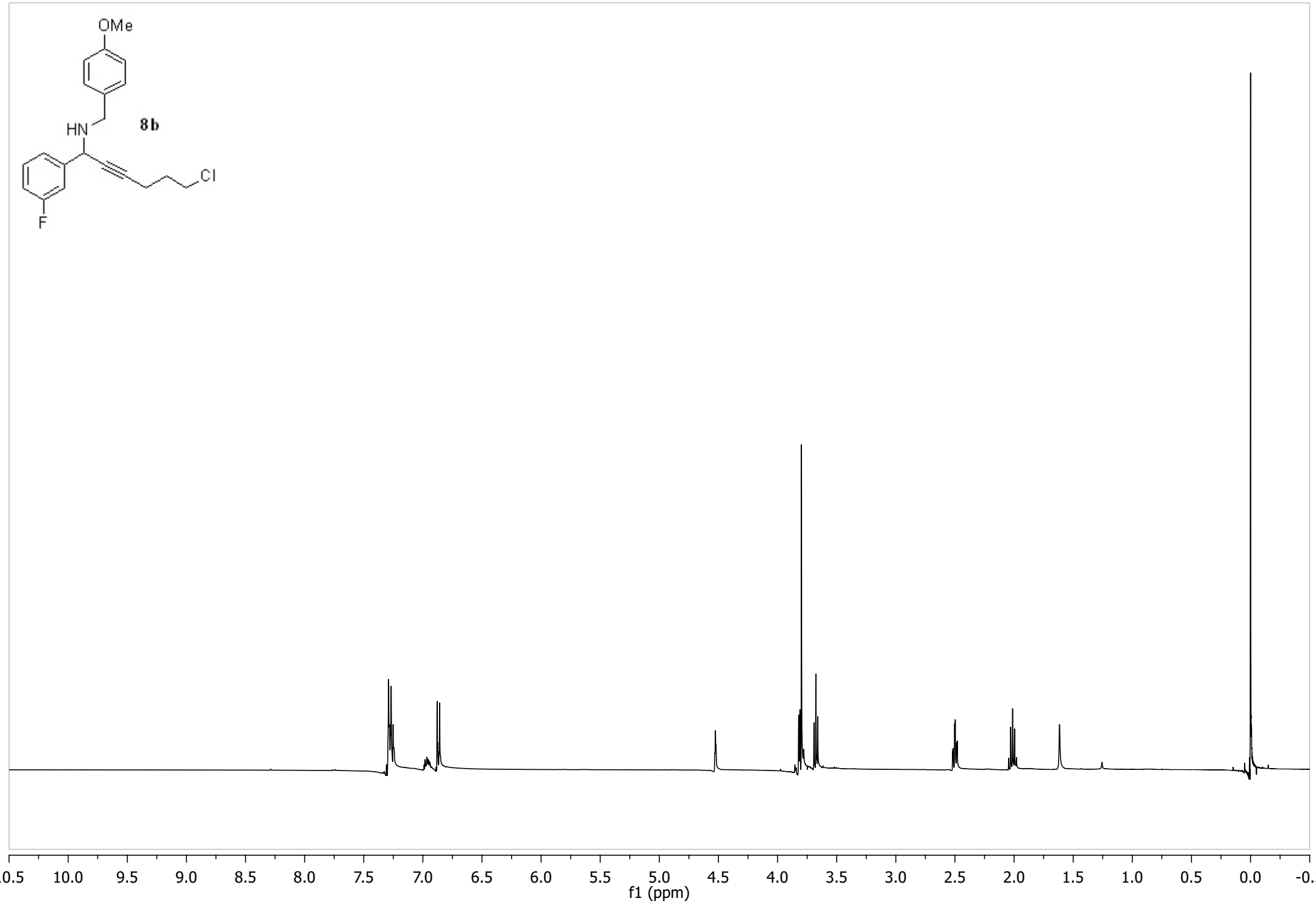

OMe
HN
7m
F
n-Hex
163.37
160.93
158.68
136.86
131.95
129.54
129.22
129.14
115.14
114.93
113.76
86.28
79.67
55.25
52.37
50.37
31.33
28.87
28.60
22.58
18.83
14.05
-0.02
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

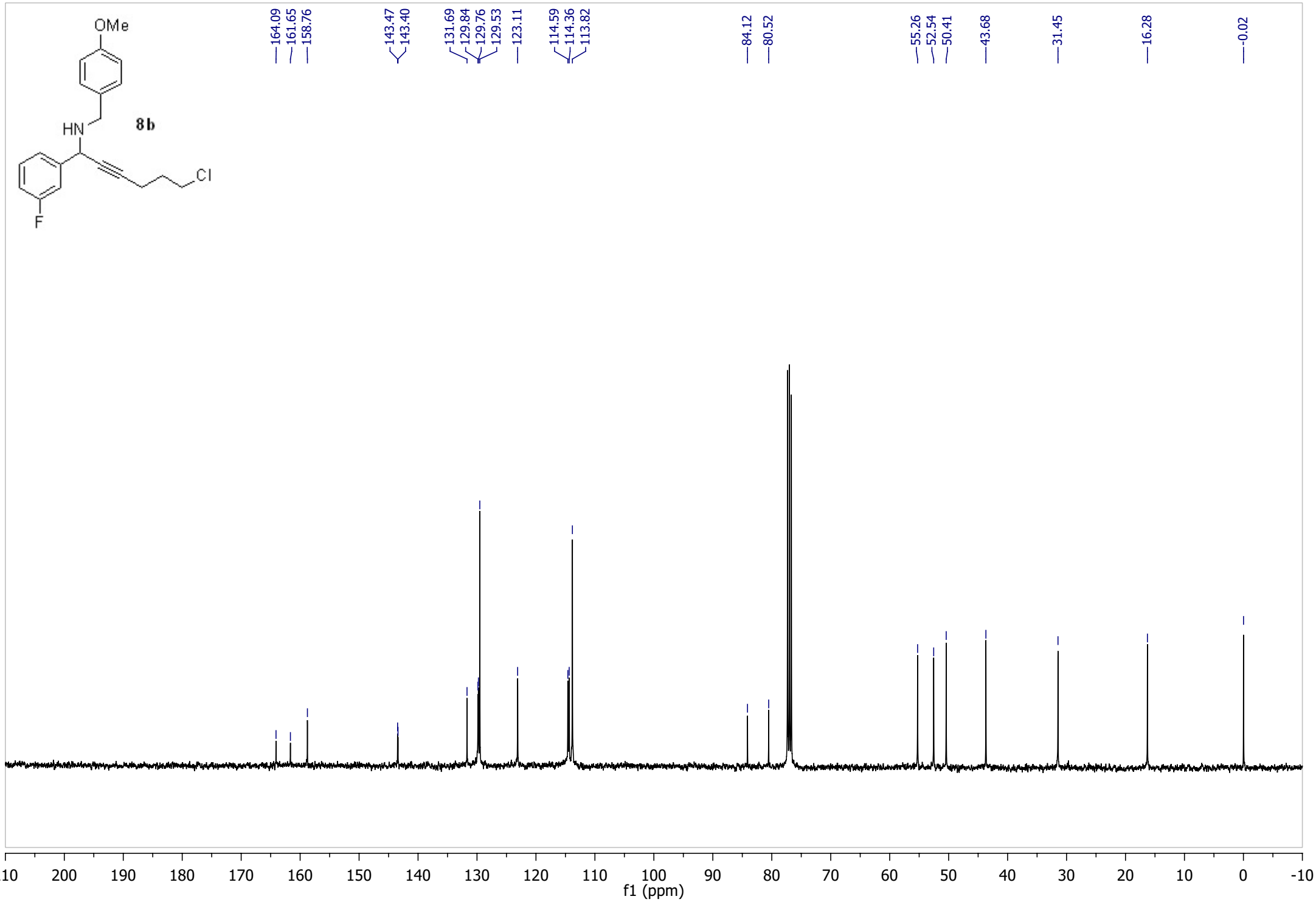

Me
S=O
HN
O
7n
Me
Me
Me
Me
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

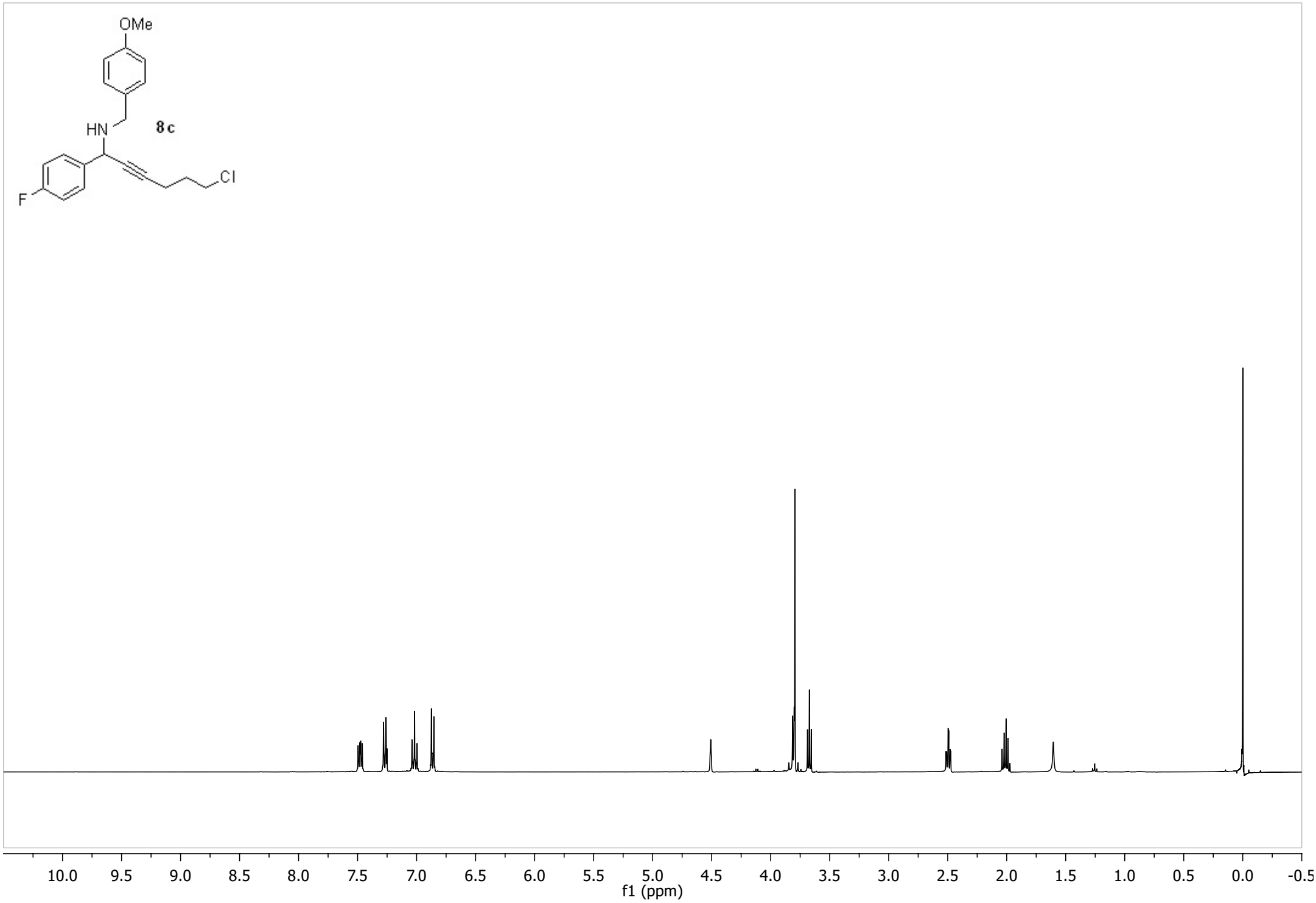

Me
HN
S
O
O
Me
Me
Me
Me
7n
142.72
139.14
129.29
127.54
85.17
77.24
55.81
35.39
31.33
25.77
25.72
22.51
20.75
18.13
13.60
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

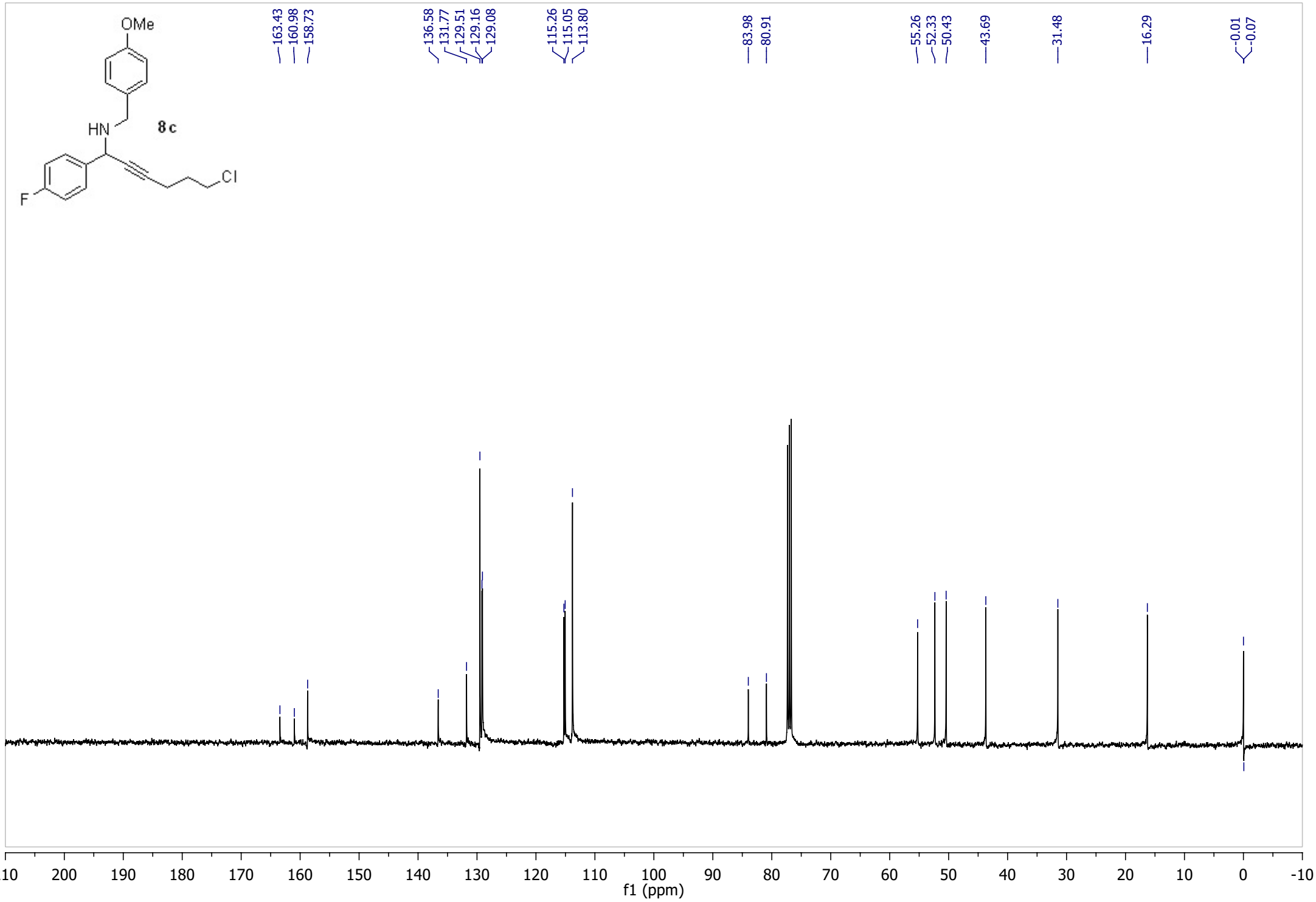

OMe
HN
8a
Cl
F
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

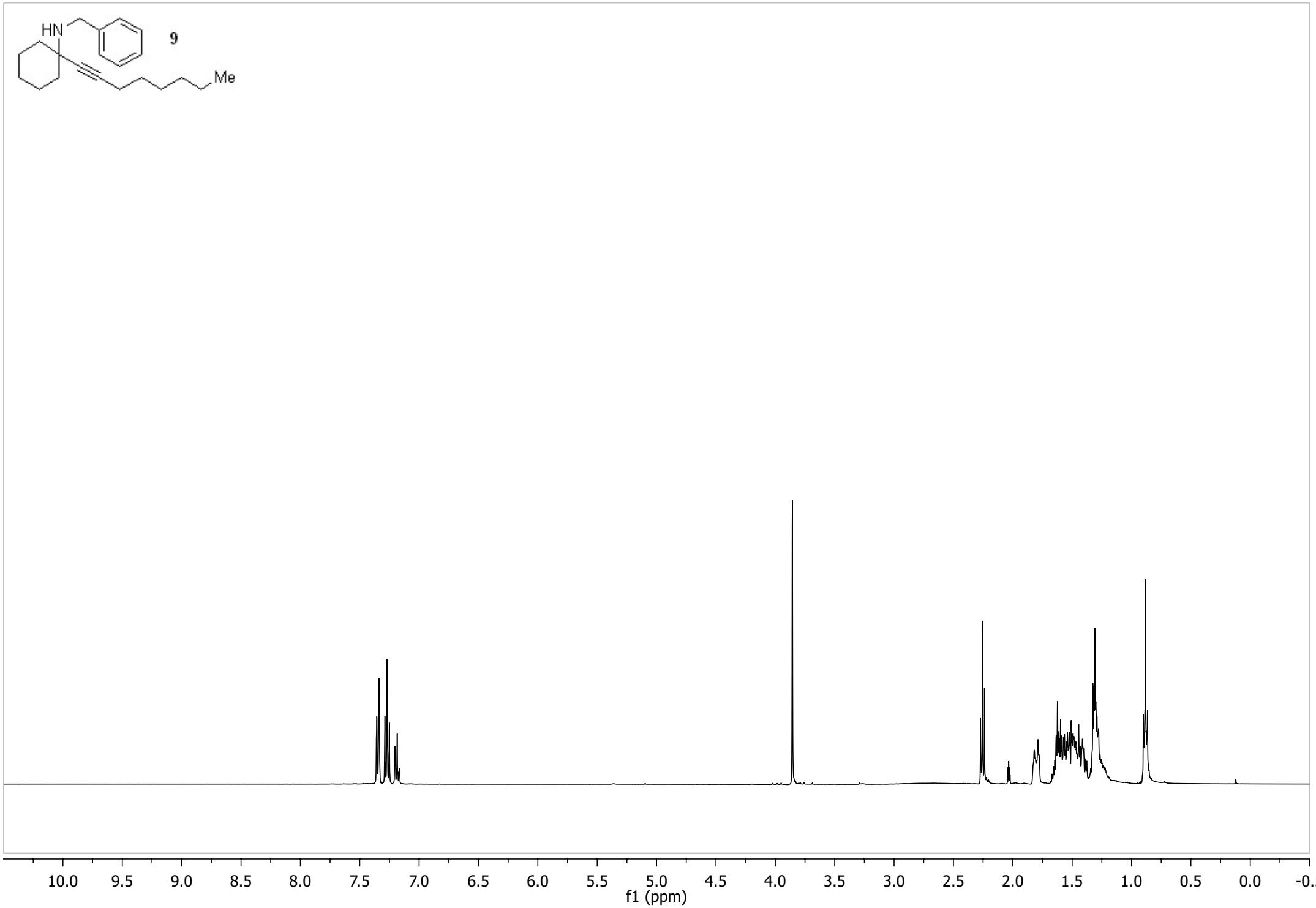

OMe
HN
8a
F
Cl
158.72
131.61
129.53
129.26
129.06
124.20
115.65
115.43
113.76
83.28
80.13
55.25
50.67
47.24
43.68
31.43
16.28
-0.03
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

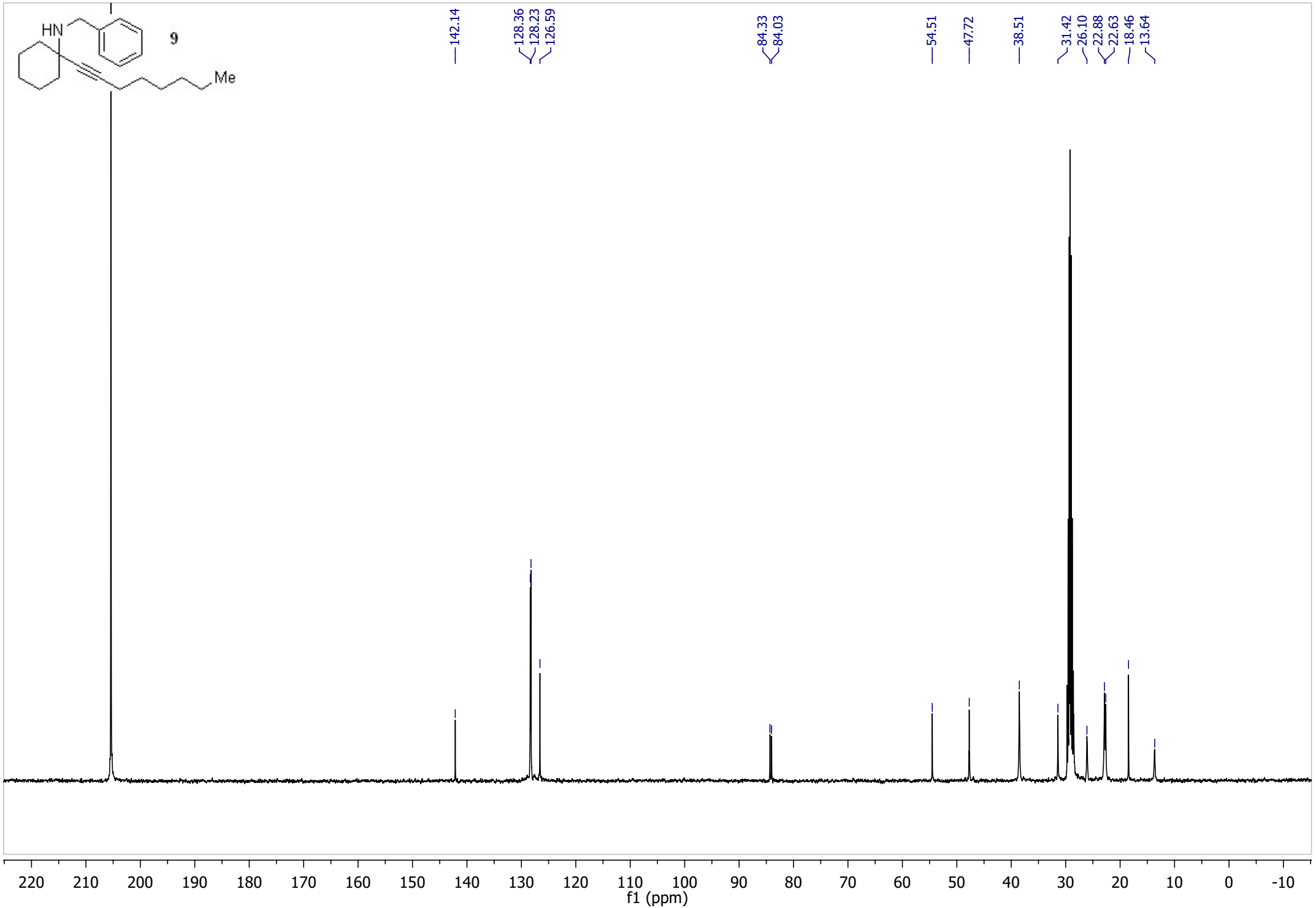

OMe
HN
8b
Cl
F
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


OMe
HN
8b
Cl
F
164.09
161.65
158.76
143.47
143.40
131.69
129.84
129.76
129.53
123.11
114.59
114.36
113.82
84.12
80.52
55.26
52.54
50.41
43.68
31.45
16.28
-0.02
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


OMe
HN
8c
F
Cl
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


OMe
HN
8c
F
Cl
163.43
160.98
158.73
136.58
131.77
129.51
129.16
129.08
115.26
115.05
113.80
83.98
80.91
55.26
52.33
50.43
43.69
31.48
16.29
-0.01
-0.07
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


HN
9
Me
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


HN
9
Me
142.14
128.36
128.23
126.59
84.33
84.03
54.51
47.72
38.51
31.42
26.10
22.88
22.63
18.46
13.64
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)