Cu-Catalyzed Tandem Reactions of Fluorinated Alkynes with Sulfonyl Azides en Route to 2-Trifluoromethylquinolines†

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General Information

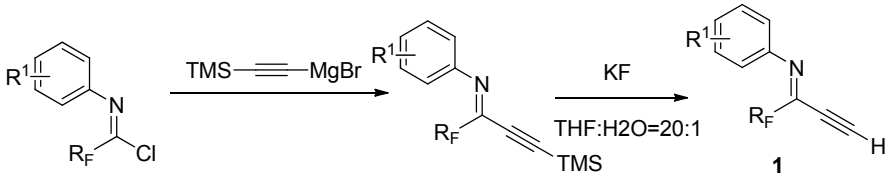
Melting points were measured on a Melt-Temp apparatus and were uncorrected. ^{1}H NMR spectra were recorded in $CDCl_3$ or d_6-DMSO on a Bruker AM-300 spectrometer (300 MHz) or an Agilent spectrometer (400 MHz) with TMS as an internal standard. ^{19}F NMR spectra were taken on a Bruker AM-300 spectrometer (282 MHz) using $PhCF_3$ as external standard. ^{13}C NMR spectra were taken on a Bruker AM-400 (100 MHz) spectrometer. IR spectra were obtained with a Nicolet AV-360 spectrophotometer. Mass spectra and elemental analyses were recorded in this institute. Solvents were purchased form commercial sources and purified before used by standard procedures. Unless otherwise specified, all reactions were carried out under a nitrogen atmosphere in a flame-dried Schlenk tube and magnetic stirring. TLC analysis was performed on silica gel plates, column chromatography over silica gel (mesh 300-400) and petroleum ethyl acetate combination was used as the eluent.

Experimental Details

N-aryl-(tri or di or mono-halogen-di)fluoroacetimidoyl chlorides[1] were prepared according to literature

A 250-mL two-necked flask equipped with a septum cap, a condenser, and a Teflon-coated magnetic stir bar was charged with PPh_3 (48.1 g, 184 mmol), Et_3N (10.4 mL, 75 mmol), CCl_4 (50 mL), and fluorocarboxylic acid (61 mmol). After the solution was stirred for about 15 min in an ice bath, aromatic amine (70 mmol) was added. The mixture was then refluxed under stirring (3 h). Solvents were removed under reduced pressure, and the residue was diluted with hexane and filtered. Residue was washed with hexane several times. The filtrate was concentrated under reduced pressure, and the residue was purified by distillation or flash column chromatography to afford the target product.

Preparation of Substrates 1



General procedure for one pot preparation of fluorinated terminal alkynes **1**: A solution of 2,2,2-trifluoro-N-phenylacetimidoyl chloride (5 mmol) in THF (10 ml) was stirred at 0 °C for 15 min, and then ((trimethylsilyl)ethynyl)magnesium bromide (6 mmol) was added dropwise in 20 min. After stirred at rt for 15 min, the mixture was then stirred at 40 °C until reaction was finished determined by TLC. To the mixture saturated ammonium chloride solution was added, then extracted with ethyl acetate, and dried over anhydrous magnesium sulfate. After filtration the resulting solution was evaporated in vacuo and the crude residue was dissolved in THF and H_2O (20:1). KF (6 mmol) was added in one portion, and the mixture was stirred at rt for 1h. The reaction mixture was diluted with water, and extracted with ethyl acetate. The combined organic layers were washed with water and brine and dried over anhydrous magnesium sulfate. After the removal of the solvent, the resulting residue was purified by chromatography (silica gel, ethyl

acetate and petrol ether) to give **1a** as a yellow liquid (740 mg, 75%).

Preparation of products 3 and 5

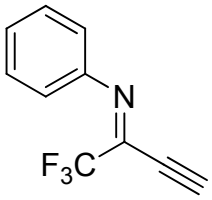
General procedure for preparation of products **3** and **5**: To an over dried Schlenk tube was added CuCl (0.1 eq.), K_2CO_3 (1.5 eq.), fluorinated terminal alkyne (0.4 mmol, if solid) and sulfonyl azide (1.2eq, if solid). Then toluene was added along with other reagents (fluorinated terminal alkyne (0.4 mmol, if liquid) and/or sulfonyl azide (1.2eq, if liquid)). The mixture was stirred at rt for 24h under nitrogen atmosphere. The reaction mixture was diluted with water, and extracted with ethyl acetate. The combined organic layers were washed with water and brine and dried over anhydrous magnesium sulfate. After filtration the resulting solution was evaporated in vacuo and the crude residue was purified by column chromatography (silica gel, ethyl acetate and petrol ether) to give **3** and **5** as a solid.

Reference:

1. T. Kenji, M. Hiromichi, M. Kazuhiro, W. Hisayuki and U. Kenji, *J. Org. Chem.*, 1993, **58**, 32.

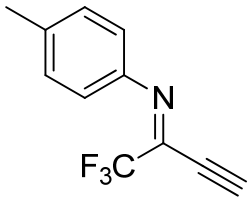
Characterization data for the substrates and Products

1a, N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



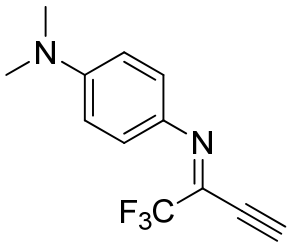
Yellow liquid, yield 75%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.43 (t, *J* = 7.6 Hz, 2H), 7.32-7.23 (m, 3H), 3.42 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -71.72 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.85, 138.41 (q, *J* = 38.7 Hz), 128.92, 127.82, 121.00, 118.44 (q, *J* = 277.2 Hz), 88.04, 72.48; IR (film, cm^{-1}): ν 3192, 3000, 2084, 1276, 1261, 764, 750; MS (EI) m/z (relative intensity) 197 [M^+], 128 (100); HRMS (EI) calcd. For $C_{10}H_6F_3N$: 197.0452, Found: 197.0448.

1b, 4-methyl-N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



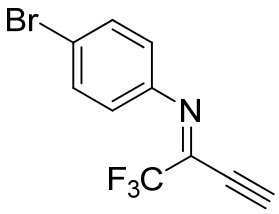
Yellow liquid, yield 57%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.25-7.23 (m, 4H), 3.44 (s, 1H), 2.38 (s, 3H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -71.98 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.15, 138.48, 137.05 (q, *J* = 38.6 Hz), 129.51, 121.68, 118.64 (q, *J* = 277.0 Hz), 87.89, 72.87, 21.05; IR (film, cm^{-1}): ν 2916, 2096, 1505, 1324, 1195, 1148, 1063, 832; MS (EI) m/z (relative intensity) 211 [M^+], 142 (100); HRMS (EI) calcd. For $C_{11}H_8F_3N$: 211.0609, Found: 211.0613.

1c, N^1,N^1-dimethyl-N^4-(1,1,1-trifluorobut-3-yn-2-ylidene)benzene-1,4-diamine



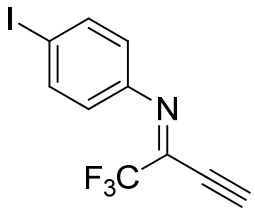
Yellow solid, yield 18%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.69 (d, *J* = 8.7 Hz, 2H), 6.69 (d, *J* = 8.6 Hz, 2H), 3.60 (s, 1H), 3.05 (s, 6H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -70.87 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.25, 134.67, 128.83 (q, *J* = 38.2 Hz), 126.43, 119.56 (q, *J* = 276.1 Hz), 111.17, 87.64, 74.99, 40.06; IR (KBr, cm^{-1}): ν 3191, 2886, 2084, 1561, 1518, 1172, 1131, 1058, 824; MS (EI) m/z (relative intensity) 240 [M^+, 100]; HRMS (EI) calcd. For $C_{12}H_{11}F_3N_2$: 240.0874, Found: 240.0873.

1d, 4-bromo-N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



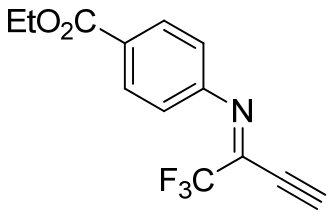
Yellow liquid, yield 80%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.55 (d, J = 8.5 Hz, 2H), 7.13 (d, J = 8.6 Hz, 2H), 3.50 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -72.14 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.66, 138.86 (q, J = 39.2 Hz), 132.10, 122.80, 121.50, 118.28 (q, J = 277.3 Hz), 88.87, 72.29; IR (film, cm^{-1}): ν 3287, 2102, 1620, 1481, 1323, 1232, 1153, 1065, 838, 765; MS (EI) m/z (relative intensity) 275 (51, ^{79}Br) [M^+], 277 (50, ^{81}Br) [M^+], 208 (100); HRMS (EI) calcd. For $C_{10}H_5F_3NBr$: 274.9557, Found: 274.9560.

1e, 4-iodo-N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



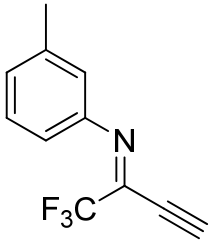
Yellow liquid, yield 64%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.75 (d, J = 8.5 Hz, 2H), 6.99 (d, J = 8.5 Hz, 2H), 3.49 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -72.15 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.35, 138.93 (q, J = 39.1 Hz), 138.09, 122.91, 118.27 (q, J = 277.4 Hz), 92.89, 88.96, 72.28; IR (film, cm^{-1}): ν 3275, 2964, 2102, 1622, 1478, 1324, 1153, 1066, 764, 750; MS (EI) m/z (relative intensity) 323 [M^+, 100]; HRMS (EI) calcd. For $C_{10}H_5F_3NI$: 322.9415, Found: 322.9415.

1f, ethyl 4-((1,1,1-trifluorobut-3-yn-2-ylidene)amino)benzoate



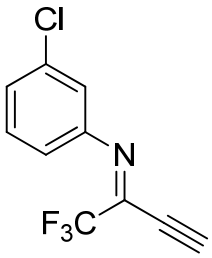
Yellow liquid, yield 37%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.11 (d, J = 8.7 Hz, 2H), 7.17 (d, J = 8.6 Hz, 2H), 4.39 (q, J = 7.1 Hz, 2H), 3.47 (s, 1H), 1.41 (t, J = 7.1 Hz, 3H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -72.31 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.77, 150.87, 140.15 (q, J = 39.4 Hz), 130.50, 129.14, 119.97, 118.05 (q, J = 277.4 Hz), 89.29, 71.87, 61.06, 14.17; IR (film, cm^{-1}): ν 3234, 2994, 2096, 1719, 1599, 1276, 1067, 751; MS (EI) m/z (relative intensity) 269 [M^+, 72], 200 (100); HRMS (EI) calcd. For $C_{11}H_8F_3N$: 211.0609, Found: 211.0613.

1g, 3-methyl-N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



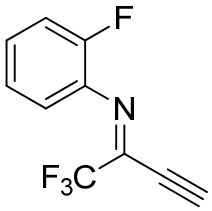
Yellow liquid, yield 57%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.30 (t, J = 8.0 Hz, 1H), 7.11 (d, J = 7.5 Hz, 1H), 7.04 (m, 2H), 3.42 (s, 1H), 2.38 (s, 3H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -72.15 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.89, 138.94, 138.17 (q, J = 38.7 Hz), 128.74, 128.58, 121.77, 118.50 (q, J = 277.1 Hz), 117.76, 87.94, 72.54, 21.15; IR (film, cm^{-1}): ν 3000, 2096, 1276, 1260, 750; MS (EI) m/z (relative intensity) 211 [M^+, 66], 142 (100); HRMS (EI) calcd. For $C_{11}H_8F_3N$: 211.0609, Found: 211.0611.

1h, 3-chloro-N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



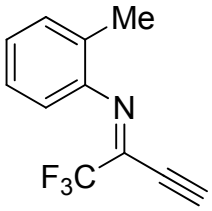
Yellow liquid, yield 67%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.36 (t, J = 7.9 Hz, 1H), 7.27 (d, J = 8.1 Hz, 1H), 7.22 (s, 1H), 7.08 (d, J = 7.8 Hz, 1H), 3.50 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -72.24 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.98, 139.76 (q, J = 39.3 Hz), 134.65, 130.05, 127.52, 120.85, 119.00, 118.18 (q, J = 277.4 Hz), 89.07, 72.02; IR (film, cm^{-1}): ν 3296, 2102, 1587, 1470, 1326, 1196, 1154, 1066, 766, 679; MS (EI) m/z (relative intensity) 231 [M^+, 48], 162 (100); HRMS (EI) calcd. For $C_{10}H_5F_3NCl$: 231.0063, Found: 231.0061.

1i, 2-fluoro-N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



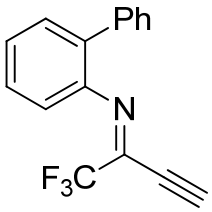
Yellow liquid, yield 55%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42 – 6.79 (m, 4H), 3.49 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -72.13 (s, 3F), -122.96 - -123.02 (m, 1F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.81 (d, J = 251.1 Hz), 141.55 (q, J = 40.8 Hz), 135.18 (d, J = 11.5 Hz), 128.70 (d, J = 7.6 Hz), 124.15 (d, J = 4.0 Hz), 121.54, 118.11 (q, J = 277.3 Hz), 116.38 (d, J = 19.6 Hz), 89.02, 72.21; IR (film, cm^{-1}): ν 3299, 2103, 1490, 1330, 1216, 1067, 750; MS (EI) m/z (relative intensity) 215 [M^+, 38], 146 (100); HRMS (EI) calcd. For $C_{10}H_5F_4N$: 215.0358, Found: 215.0361.

1j, 2-methyl-N-(1,1,1-trifluorobut-3-yn-2-ylidene)aniline



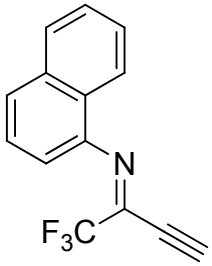
Yellow liquid, yield, 61%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.24 (m, 1H), 7.24 – 7.14 (m, 2H), 7.06 – 7.02 (m, 1H), 3.37 (s, 1H), 2.22 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -71.68 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.02, 138.59 (q, J = 38.8 Hz), 130.67, 130.45, 127.37, 126.06, 118.38 (q, J = 277.1 Hz), 117.99, 87.86, 72.37, 17.40; IR (film, cm^{-1}): ν 3301, 3066, 2946, 2099, 1633, 1484, 1326, 1233, 1204, 1151, 1064, 744; MS (EI) m/z (relative intensity) 211 [M^+, 100]; HRMS (EI) calcd. For $C_{11}H_8F_3N$: 211.0609, Found: 211.0611.

1k, N-(1,1,1-trifluorobut-3-yn-2-ylidene)-[1,1'-biphenyl]-2-amine



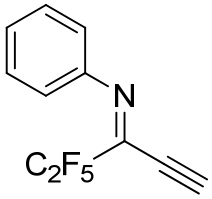
Yellow solid, yield 52%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.468-7.45 (m, 1H), 7.40 – 7.27 (m, 7H), 7.09-7.07 (m, 1H), 3.35 (s, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -71.89 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.12, 139.90 (q, J = 39.1 Hz), 138.28, 134.01, 130.57, 129.62, 128.04, 127.73, 127.42, 127.40, 118.81, 118.19 (q, J = 277.4 Hz), 88.32, 72.58; IR (KBr, cm^{-1}): ν 3218, 2093, 1475, 1326, 1187, 1145, 1069, 741, 698; MS (EI) m/z (relative intensity) 273 [M^+, 82], 204 (100); HRMS (EI) calcd. For $C_{16}H_{10}F_3N$: 273.0765, Found: 273.0764.

1l, N-(1,1,1-trifluorobut-3-yn-2-ylidene)naphthalen-1-amine



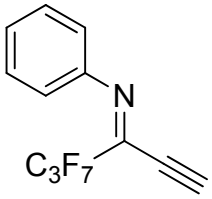
White solid, mp 49-51 ^{o}C, yield 55%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.99 (d, J = 8.8 Hz, 1H), 7.87 (d, J = 8.9 Hz, 1H), 7.80 (d, J = 8.3 Hz, 1H), 7.59 – 7.51 (m, 2H), 7.48 (t, J = 7.8 Hz, 1H), 7.32 (d, J = 7.4 Hz, 1H), 3.39 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -71.76 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.26, 138.68 (q, J = 39.1 Hz), 133.98, 128.20, 127.95, 127.48, 126.86, 126.63, 125.11, 123.18, 118.63 (q, J = 277.3 Hz), 114.39, 88.20, 72.60; IR (KBr, cm^{-1}): ν 3275, 3060, 2102, 1321, 1205, 1149, 749; MS (EI) m/z (relative intensity) 247 [M^+, 100]; HRMS (EI) calcd. For $C_{14}H_8F_3N$: 247.0609, Found: 247.0611.

1m, N-(4,4,5,5,5-pentafluoropent-1-yn-3-ylidene)aniline



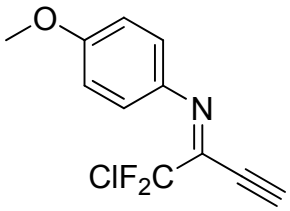
Yellow liquid, yield 57%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (t, *J* = 7.7 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.27 – 7.22 (m, 2H), 3.46 (s, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -81.68 (m, 3F), -116.78 (m, 2F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.10, 138.97 (t, *J* = 28.9 Hz), 128.89, 127.93, 121.00, 118.53 (qt, *J* = 286.8, 36.0 Hz), 109.01 (tq, *J* = 257.9, 37.6 Hz), 88.57, 72.52; IR (film, cm^{-1}): ν 3302, 2963, 2104, 1593, 1332, 1212, 1106, 750; MS (EI) m/z (relative intensity) 247 [M^+, 40], 128 (100); HRMS (EI) calcd. For $C_{11}H_6F_5N$: 247.0420, Found: 247.0418.

1n, N-(4,4,5,5,6,6,6-heptafluorohex-1-yn-3-ylidene)aniline



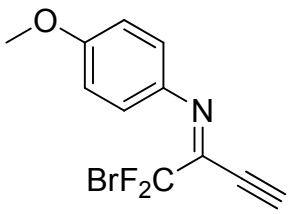
Yellow liquid, yield 51%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (t, *J* = 7.8 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.23 (d, *J* = 7.5 Hz, 2H), 3.47 (s, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -80.33 (t, *J* = 8.8 Hz, 3F), -114.61 (m, 2F), -125.82 (m, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.22, 139.16 (t, *J* = 28.3 Hz), 128.89, 127.86, 120.85, 117.75 (qt, *J* = 287.5, 33.6 Hz), 110.32 (tt, *J* = 259.9, 29.8 Hz), 113.94 – 104.43 (m), 88.63, 72.76; IR (film, cm^{-1}): ν 3311, 2922, 2096, 1350, 1275, 1260, 1119, 764, 750; MS (EI) m/z (relative intensity) 297 [M^+, 35], 128 (100); HRMS (EI) calcd. For $C_{12}H_6F_7N$: 297.0388, Found: 297.0389.

1o, N-(1-chloro-1,1-difluorobut-3-yn-2-ylidene)-4-methoxyaniline



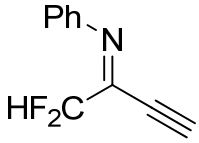
Yellow liquid, yield 24%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 9.0 Hz, 2H), 6.94 (d, *J* = 9.0 Hz, 2H), 3.84 (s, 3H), 3.52 (s, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -58.42 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.93, 139.08, 138.18 (t, *J* = 31.4 Hz), 124.55, 122.29 (t, *J* = 293.4 Hz), 113.98, 88.16, 73.30, 55.36; IR (film, cm^{-1}): ν 3293, 2958, 2102, 1613, 1504, 1257, 1062, 926, 750; MS (EI) m/z (relative intensity) 243 [M^+, 26], 158 (100); HRMS (EI) calcd. For $C_{11}H_8F_2NOCl$: 243.0262, Found: 243.0264.

1p, N-(1-bromo-1,1-difluorobut-3-yn-2-ylidene)-4-methoxyaniline



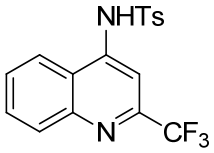
Yellow liquid, yield 44%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.48 (d, J = 8.9 Hz, 2H), 6.94 (d, J = 8.9 Hz, 2H), 3.85 (s, 3H), 3.54 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -54.43 (s, 2F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.04, 139.22 (t, J = 28.3 Hz), 138.93, 124.71, 115.33 (t, J = 307.7 Hz), 114.06, 88.62, 73.12, 55.39; IR (film, cm^{-1}): ν 3289, 2964, 2832, 2095, 1614, 1575, 1504, 1302, 1253, 898; MS (EI) m/z (relative intensity) 287 (14.9, ^{79}Br) [M^+], 289 (14.6, ^{81}Br) [M^+], 158 (100); HRMS (EI) calcd. For $C_{11}H_8F_2NOBr$: 286.9756, Found: 286.9753.

1q, N-(1,1-difluorobut-3-yn-2-ylidene)aniline



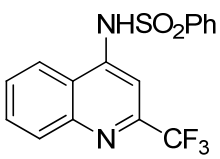
Yellow liquid, yield 53%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42-7.38 (m, 2H), 7.32 – 7.22 (m, 1H), 7.20-7.18 (m, 2H), 6.19 (t, J = 55.1 Hz, 1H), 3.36 (s, 1H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -119.26 (d, J = 55.1 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.81, 144.40 (t, J = 29.7 Hz), 128.87, 127.22, 120.87, 112.89 (t, J = 245.0 Hz), 87.80, 72.86; IR (film, cm^{-1}): ν 3295, 3054, 2104, 1628, 1486, 1351, 1245, 1054, 789, 690; MS (EI) m/z (relative intensity) 179 [M^+, 45], 128 (100); HRMS (EI) calcd. For $C_{10}H_7F_2N$: 179.0547, Found: 179.0542.

3aa, 4-methyl-N-(2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



White solid, mp 176-178 ^{o}C, yield 94%; ^{1}H NMR (400 MHz, DMSO) δ 8.52 (d, J = 8.5 Hz, 1H), 8.12 (d, J = 8.4 Hz, 1H), 7.85-7.78 (m, 3H), 7.79 (t, J = 7.5 Hz, 1H), 7.72 (s, 1H), 7.42 (d, J = 8.0 Hz, 2H), 2.34 (s, 3H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -67.94 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 147.41, 144.74, 136.61, 132.11, 130.42, 129.73, 128.92, 127.22, 123.14, 121.64 (q, J = 275.3 Hz), 121.41, 104.50, 21.32; IR (KBr, cm^{-1}): ν 3302, 1522, 1438, 1280, 1129, 941, 759, 669; MS (EI) m/z (relative intensity) 366 [M^+, 2], 91 (100); Anal. Calcd. For $C_{17}H_{13}F_3N_2O_2S$: C, 55.73; H, 3.58; N, 7.65. Found: C, 55.78; H, 3.60; N, 7.67.

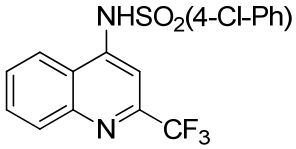
3ab, N-(2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



White solid, mp 186-188 ^{o}C, yield, 90%; ^{1}H NMR (400 MHz, DMSO) δ 8.40 (d, J = 8.4 Hz, 1H),

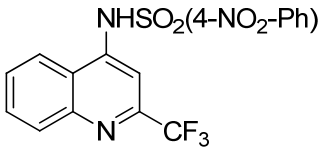
8.02 (d, J = 8.4 Hz, 1H), 7.93 – 7.86 (m, 2H), 7.85-7.81 (m, 1H), 7.69 (t, J = 7.7 Hz, 1H), 7.65 – 7.58 (m, 2H), 7.56-7.53 (m, 2H); ^{19}F NMR (376 MHz, DMSO) δ -66.70 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 147.21, 139.61, 134.05, 132.14, 130.00, 129.48, 128.88, 127.13, 123.19, 121.64, 121.59 (q, J = 275.3 Hz), 104.89; IR (KBr, cm^{-1}): ν 3278, 1518, 1353, 1281, 1169, 1137, 939, 758, 581; MS (EI) m/z (relative intensity) 352 [M$^+$, 15], 77 (100); Anal. Calcd. For $C_{16}H_{11}F_3N_2O_2S$: C, 54.54; H, 3.15; N, 7.95. Found: C, 54.49; H, 3.14; N, 7.96.

3ac, 4-chloro-N-(2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



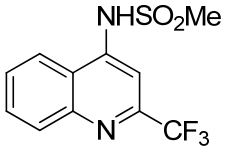
White solid, mp 201-202 °C, yield, 82%; ^{1}H NMR (400 MHz, DMSO) δ 8.42 (d, J = 8.3 Hz, 1H), 8.11 (d, J = 8.4 Hz, 1H), 7.97-7.09 (m, , 3H), 7.77 (t, J = 7.4 Hz, 1H), 7.69 (d, J = 8.7 Hz, 2H), 7.66 (s, 1H); ^{19}F NMR (376 MHz, DMSO) δ -66.53 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 146.76, 138.89, 138.76, 132.26, 130.07, 129.00, 128.81, 123.30, 121.88, 121.51 (q, J = 275.3 Hz), 105.09; IR (KBr, cm^{-1}): ν 3096, 2985, 1482, 1449, 1285, 1136, 1077, 826, 624; MS (EI) m/z (relative intensity) 386 [M$^+$, 10], 111 (100); Anal. Calcd. For $C_{16}H_{11}ClF_3N_2O_2S$: C, 49.69; H, 2.61; N, 7.24. Found: C, 49.56; H, 2.65; N, 7.22.

3ad, 4-nitro-N-(2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



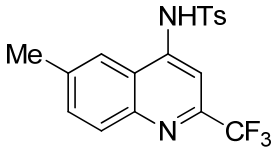
Yellow solid, mp 215-216 °C, yield 93%; ^{1}H NMR (300 MHz, DMSO) δ 8.40-8.36 (m, 3H), 8.17 (d, J = 8.6 Hz, 2H), 8.06 (d, J = 8.4 Hz, 1H), 7.91 (t, J = 7.6 Hz, 1H), 7.79 – 7.67 (m, 1H), 7.65 (s, 1H); ^{19}F NMR (376 MHz, DMSO) δ -66.27 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 150.31, 146.11, 132.84, 128.71, 128.54, 125.20, 123.69, 122.43, 121.29 (q, J = 275.3 Hz), 104.96; IR (KBr, cm^{-1}): ν 3103, 2968, 1606, 1533, 1449, 1274, 1156, 1138, 1078, 829, 563; MS (EI) m/z (relative intensity) 397 [M$^+$, 16], 43 (100); HRMS (EI) calcd. For $C_{16}H_{10}F_3N_3O_4S$: 397.0344, Found: 397.0342.

3ae, N-(2-(trifluoromethyl)quinolin-4-yl)methanesulfonamide



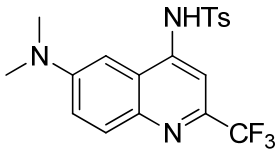
White solid, mp 200-202 °C, yield 44%; ^{1}H NMR (400 MHz, DMSO) δ 8.46 (d, J = 8.5 Hz, 1H), 8.09 (d, J = 8.4 Hz, 1H), 7.88 (t, J = 7.3 Hz, 1H), 7.79 (s, 1H), 7.74 (t, J = 7.6 Hz, 1H), 3.29 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.41 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 147.57, 132.00, 129.77, 128.76, 123.22, 121.32, 121.29 (q, J = 275.3 Hz), 104.20, 41.15; IR (KBr, cm^{-1}): ν 3314, 1523, 1430, 1278, 1193, 1152, 939, 764; MS (EI) m/z (relative intensity) 290 [M$^+$, 52], 184 (100); HRMS (EI) calcd. For $C_{11}H_9F_3N_2O_2S$: 290.0337, Found: 290.0335.

3ba, 4-methyl-N-(6-methyl-2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



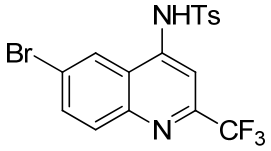
White solid, mp 203-205 °C, yield 94%; ^{1}H NMR (400 MHz, DMSO) δ 8.29 (s, 1H), 7.98 (d, *J* = 8.6 Hz, 1H), 7.85 (d, *J* = 8.3 Hz, 2H), 7.74 (d, *J* = 8.6, 1H), 7.61 (s, 1H), 7.41 (d, *J* = 8.2 Hz, 2H), 2.53 (s, 3H), 2.34 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.54 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 146.03, 144.70, 138.92, 136.57, 133.99, 130.37, 129.51, 127.26, 121.83, 121.76 (q, *J* = 275.1 Hz), 121.20, 21.75, 21.27; IR (KBr, cm^{-1}): ν 3304, 1572, 1513, 1426, 1347, 1181, 1139, 944, 881, 667, 563; MS (EI) m/z (relative intensity) 380 [M^{+}, 9], 91 (100); Anal. Calcd. For $C_{18}H_{15}F_3N_2O_2S$: C, 56.84; H, 3.97; N, 7.36. Found: C, 56.91; H, 3.91; N, 7.40.

3ca, N-(6-(dimethylamino)-2-(trifluoromethyl)quinolin-4-yl)-4-methylbenzenesulfonamide



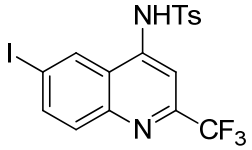
Yellow solid, mp 246-248 °C, yield 89%; ^{1}H NMR (400 MHz, DMSO) δ 7.86 (d, *J* = 9.4 Hz, 1H), 7.78 (d, *J* = 8.3 Hz, 2H), 7.53 (s, 1H), 7.51 (d, *J* = 9.3 Hz, 1H), 7.37 (d, *J* = 8.2 Hz, 2H), 7.15 (s, 1H), 3.08 (s, 6H), 2.32 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -65.77 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 150.05, 144.55, 141.24, 140.88, 136.85, 130.93, 130.40, 127.14, 123.43, 122.26 (q, *J* = 275.7 Hz), 121.02, 105.93, 98.93, 40.52, 21.37; IR (KBr, cm^{-1}): ν 3281, 2922, 1623, 1523, 1420, 1288, 1165, 1112, 939, 808, 668, 564; MS (EI) m/z (relative intensity) 409 [M^{+}, 8], 254 (100); HRMS (EI) calcd. For $C_{19}H_{18}F_3N_3O_2S$: 409.1072, Found: 409.1067.

3da, N-(6-bromo-2-(trifluoromethyl)quinolin-4-yl)-4-methylbenzenesulfonamide



White solid, mp 188-190 °C, yield 46%; ^{1}H NMR (400 MHz, DMSO) δ 8.77 (s, 1H), 8.02 (s, 2H), 7.85 (d, *J* = 8.3 Hz, 2H), 7.66 (s, 1H), 7.42 (d, *J* = 8.0 Hz, 2H), 2.35 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.81 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 146.25, 144.97, 136.28, 135.16, 132.03, 130.53, 127.30, 125.52, 122.49, 122.38, 121.66 (q, *J* = 275.7 Hz), 104.71, 21.41; IR (KBr, cm^{-1}): ν 3300, 1566, 1505, 1402, 1344, 1274, 1169, 938, 882, 668, 562; MS (EI) m/z (relative intensity) 444 [M^{79+}, 3], 446 [M^{81+}, 3], 91 (100); HRMS (EI) calcd. For $C_{17}H_{12}F_3N_2O_2SBr$: 443.9755, Found: 443.9759.

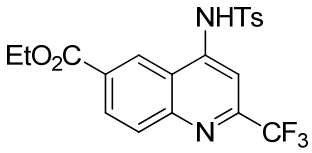
3ea, N-(6-iodo-2-(trifluoromethyl)quinolin-4-yl)-4-methylbenzenesulfonamide



White solid, mp 191-192 °C, yield 42%; ^{1}H NMR (400 MHz, DMSO) δ 8.85 (s, 1H), 8.09 (d, *J* = 8.8

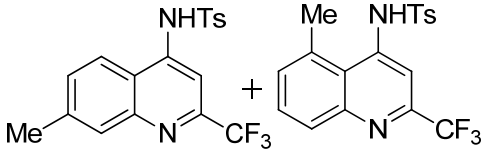
Hz, 1H), 7.79-7.76 (m, 3H), 7.57 (s, 1H), 7.37 (d, J = 8.1 Hz, 2H), 2.35 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.79 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 146.53, 144.90, 140.39, 136.35, 131.71, 130.51, 127.27, 122.71, 121.66 (q, J = 275.7 Hz),104.62, 96.02, 21.42; IR (KBr, cm^{-1}): ν 3303, 1568, 1400, 1348, 1290, 1167, 938, 885, 660, 562; MS (ESI) m/z 491 [M-H$^+$]; HRMS (ESI) *m/e* calcd. for $C_{17}H_{11}F_3IN_2O_2S^-$ [M-H$^+$] 490.9543, Found: 490.9555.

3fa, ethyl 4-(4-methylphenylsulfonamido)-2-(trifluoromethyl)quinoline-6-carboxylate



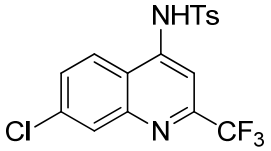
Yellow solid, mp 172-173 °C, yield 33%; ^{1}H NMR (400 MHz, DMSO) δ 9.16 (s, 1H), 8.30 (dd, J = 8.8, 1.5 Hz, 1H), 8.14 (d, J = 8.8 Hz, 1H), 7.88 (d, J = 8.3 Hz, 2H), 7.64 (s, 1H), 7.43 (d, J = 8.3 Hz, 2H), 4.45 (q, J = 7.1 Hz, 2H), 2.35 (s, 3H), 1.42 (t, J = 7.1 Hz, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.99 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 165.30, 148.94, 144.78, 136.60, 130.88, 130.44, 129.94, 129.51, 127.25, 126.08, 121.37 (q, J = 275.7 Hz), 120.77, 104.37, 61.81, 21.32, 14.56; IR (KBr, cm^{-1}): ν 3291, 2976, 1727, 1515, 1358, 1248, 1165, 860, 667; MS (EI) m/z (relative intensity) 438 [M$^+$, 2], 91 (100); Anal. Calcd. For $C_{20}H_{17}F_3N_2O_4S$: C, 54.79; H, 3.91; N, 6.39. Found: C, 54.44; H, 3.88; N, 6.39.

3ga+3ga', 4-methyl-N-(7-methyl-2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide and 4-methyl-N-(5-methyl-2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



White solid, yield 75%; ^{1}H NMR (400 MHz, DMSO) δ 8.39 (d, J = 8.7 Hz, 0.5H), 7.87-7.85 (m, 2H), 7.80-7.78 (m, 2H), 7.72 (t, J = 7.7 Hz, 1H), 7.64 (s, 0.5H), 7.60 (d, J = 8.2 Hz, 0.5H), 7.44-7.40 (m, 4.5H), 2.87 (s, 3H), 2.52 (s, 1H), 2.40 (s, 3H), 2.33 (s, 1H); ^{19}F NMR (282 MHz, $CDCl_3$) δ -67.97, -68.17; ^{13}C NMR (100 MHz, DMSO) δ 144.67, 143.40, 142.49, 136.69, 132.31, 130.96, 130.39, 129.98, 127.18, 126.89, 122.83, 121.69 (q, J = 276.1 Hz), 120.90 (q, J = 273.8 Hz), 119.41, 103.86, 24.90, 21.44, 21.33; IR (KBr, cm^{-1}): ν 3078, 2981, 1622, 1486, 1270, 1130, 847, 663; MS (EI) m/z (relative intensity) 380 [M$^+$, 8], 91 (100); Anal. Calcd. For $C_{18}H_{15}F_3N_2O_2S$: C, 56.84; H, 3.97; N, 7.36. Found: C, 57.01; H, 4.31; N, 7.41. (note: ratio of the product changed after recrystallization.)

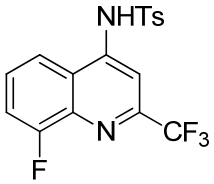
3ha, N-(7-chloro-2-(trifluoromethyl)quinolin-4-yl)-4-methylbenzenesulfonamide



White solid, yield 45%; ^{1}H NMR (400 MHz, DMSO) δ 8.52 (d, J = 9.2 Hz, 1H), 8.16 (d, J = 2.1 Hz, 1H), 7.86 (d, J = 8.3 Hz, 2H), 7.82 (dd, J = 9.2, 2.1 Hz, 1H), 7.67 (s, 1H), 7.42 (d, J = 8.0 Hz, 2H), 2.35 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.90 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 148.14, 144.88, 136.91, 136.45, 130.50, 129.39, 128.46, 127.25, 125.33, 121.47 (q, J = 275.6 Hz), 120.04, 104.57,

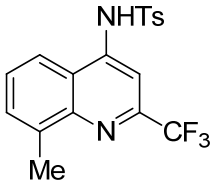
21.38; MS (EI) m/z (relative intensity) 400 [M^+, 3], 91 (100); Anal. Calcd. For $C_{17}H_{12}ClF_3N_2O_2S$: C, 50.49; H, 3.02; N, 6.99. Found: C, 50.88; H, 3.13; N, 6.91. (note: only pure **3ha** obtained after recrystallization.)

3ia, N-(8-fluoro-2-(trifluoromethyl)quinolin-4-yl)-4-methylbenzenesulfonamide



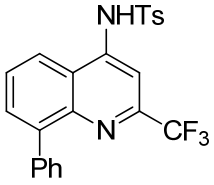
White solid, mp 208-209 °C, yield 21%; ^{1}H NMR (400 MHz, DMSO) δ 8.38 – 8.21 (m, 1H), 7.86 (d, *J* = 8.3 Hz, 2H), 7.84-7.74 (m, 2H), 7.74 (s, 1H), 7.43 (d, *J* = 8.2 Hz, 2H), 2.35 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.85 (s, 3F), -105.23 – -132.91 (m, 1F); ^{13}C NMR (100 MHz, DMSO) δ 159.01, 156.46, 147.06 (q, *J* = 34.3 Hz), 144.97, 144.86 (d, *J* = 3.6 Hz), 138.15 (d, *J* = 12.6 Hz), 136.26, 130.48, 129.03 (d, *J* = 8.3 Hz), 127.28, 122.82, 121.51 (q, *J* = 275.5 Hz), 119.05 (d, *J* = 4.8 Hz), 116.11 (d, *J* = 18.3 Hz), 21.31; IR (KBr, cm^{-1}): ν 3297, 1598, 1522, 1424, 1345, 1167, 980, 665, 561; MS (EI) m/z (relative intensity) 384 [M^+, 6], 91 (100); Anal. Calcd. For $C_{17}H_{12}F_4N_2O_2S$: C, 53.12; H, 3.15; N, 7.29. Found: C, 53.01; H, 3.10; N, 7.33.

3ja, 4-methyl-N-(8-methyl-2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



White solid, mp 206-208 °C, yield 83%; ^{1}H NMR (400 MHz, DMSO) δ 8.29 (d, *J* = 8.4 Hz, 1H), 7.83 (d, *J* = 8.3 Hz, 2H), 7.76 (d, *J* = 7.0 Hz, 1H), 7.69 (s, 1H), 7.67 – 7.58 (m, 1H), 7.40 (d, *J* = 8.0 Hz, 2H), 2.68 (s, 3H), 2.33 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.65 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 146.81, 145.74 (q, *J* = 33.7 Hz), 144.75, 144.58, 137.96, 136.46, 131.79, 130.39, 128.59, 127.23, 121.76 (q, *J* = 275.2 Hz), 121.48, 120.76, 21.28, 18.02; IR (KBr, cm^{-1}): ν 3288, 1521, 1421, 1346, 1281, 1164, 958, 662, 561; MS (EI) m/z (relative intensity) 380 [M^+, 16], 225 (100); Anal. Calcd. For $C_{18}H_{15}F_3N_2O_2S$: C, 56.84; H, 3.97; N, 7.36. Found: C, 56.65; H, 4.04; N, 7.33.

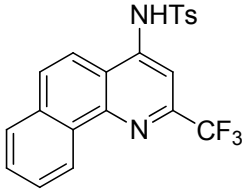
3ka, 4-methyl-N-(8-phenyl-2-(trifluoromethyl)quinolin-4-yl)benzenesulfonamide



White solid, mp 216-218 °C, yield 91%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (s, 1H), 7.94-7.89 (m, 3H), 7.87 – 7.77 (m, 2H), 7.76 – 7.63 (m, 3H), 7.47-7.38 (m, 3H), 7.34 – 7.17 (m, 2H), 2.37 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -67.99 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 146.31 (q, *J* = 34.0 Hz), 145.31, 144.85, 144.76, 141.06, 138.58, 136.49, 132.54, 131.04, 130.50, 128.85, 128.16, 127.92, 127.28, 122.52, 122.05, 121.66 (q, *J* = 275.5 Hz), 21.37; IR (KBr, cm^{-1}): ν 3284, 1515, 1407, 1343,

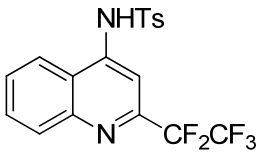
1269, 1168, 945, 764, 560; MS (EI) m/z (relative intensity) 442 [M^+, 15], 287 (100); Anal. Calcd. For $C_{23}H_{17}F_3N_2O_2S$: C, 62.44; H, 3.87; N, 6.33. Found: C, 62.32; H, 3.89; N, 6.33.

3la, 4-methyl-N-(2-(trifluoromethyl)benzo[h]quinolin-4-yl)benzenesulfonamide



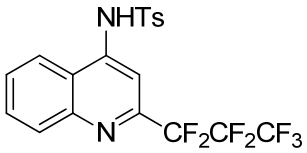
White solid, mp 234-235 °C, yield 96%; ^{1}H NMR (400 MHz, DMSO) δ 9.52 – 8.63 (m, 1H), 8.28 (d, *J* = 9.3 Hz, 1H), 8.12 (s, 1H), 8.09 (t, *J* = 4.5 Hz, 1H), 7.98 – 7.60 (m, 5H), 7.40 (d, *J* = 8.2 Hz, 2H), 2.33 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -66.41 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 146.59, 145.49 (q, *J* = 33.9 Hz), 144.74, 144.31, 136.59, 133.67, 130.43, 129.86, 128.39, 128.32, 127.22, 124.59, 121.91 (q, *J* = 274.9 Hz), 119.92, 119.50, 107.52, 21.31; IR (KBr, cm^{-1}): ν 3303, 1573, 1431, 1339, 1285, 1161, 974, 666, 563; MS (EI) m/z (relative intensity) 416 [M^+, 14], 91 (100); Anal. Calcd. For $C_{21}H_{15}F_3N_2O_2S$: C, 60.57; H, 3.63; N, 6.73. Found: C, 60.19; H, 3.66; N, 6.70.

3ma, 4-methyl-N-(2-(perfluoroethyl)quinolin-4-yl)benzenesulfonamide



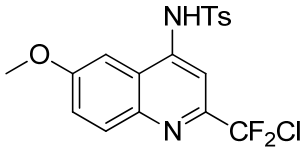
White solid, mp 136-137 °C, yield 84%; ^{1}H NMR (400 MHz, DMSO) δ 8.45 (d, *J* = 8.4 Hz, 1H), 8.04 (d, *J* = 8.2 Hz, 1H), 7.94 – 7.81 (m, 1H), 7.77 (d, *J* = 8.3 Hz, 2H), 7.73 (t, *J* = 7.8 Hz, 1H), 7.61 (s, 1H), 7.34 (d, *J* = 8.0 Hz, 2H), 2.27 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -82.35 (m, 3F), -116.14 (m, 2F); ^{13}C NMR (100 MHz, DMSO) δ 147.75, 146.20 (t, *J* = 23.7 Hz), 144.79, 136.33, 132.04, 130.36, 130.11, 129.09, 127.27, 123.11, 121.20, 123.90 – 113.83 (m), 115.37 – 107.47 (m), 105.49, 21.26; IR (KBr, cm^{-1}): ν 3321, 1520, 1444, 1355, 1169, 916, 563; MS (EI) m/z (relative intensity) 416 [M^+, 6], 91 (100); Anal. Calcd. For $C_{18}H_{13}F_5N_2O_2S$: C, 51.92; H, 3.15; N, 6.73. Found: C, 51.84; H, 3.11; N, 6.78.

3na, 4-methyl-N-(2-(perfluoropropyl)quinolin-4-yl)benzenesulfonamide



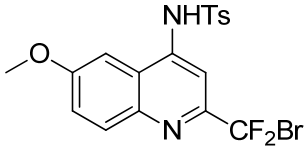
White solid, mp 135-136 °C, yield 81%; ^{1}H NMR (400 MHz, DMSO) δ 8.45 (d, *J* = 8.4 Hz, 1H), 8.05 (d, *J* = 8.3 Hz, 1H), 7.85 (dd, *J* = 11.3, 4.1 Hz, 1H), 7.80 – 7.67 (m, 3H), 7.58 (s, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 2.26 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -79.91 (t, *J* = 8.7 Hz, 3F), -114.16 (m, 2F), -126.28 (m, 3F); ^{13}C NMR (100 MHz, DMSO) δ 147.81, 146.23 (t, *J* = 24.5 Hz), 144.70, 136.35, 131.92, 130.26, 129.05, 127.23, 123.11, 120.38 – 107.86 (m, 3C), 121.20, 105.93, 21.12; IR (KBr, cm^{-1}): ν 3291, 1521, 1352, 1241, 1170, 1118, 762; MS (EI) m/z (relative intensity) 466 [M^+, 4], 91 (100); Anal. Calcd. For $C_{19}H_{13}F_7N_2O_2S$: C, 48.93; H, 2.81; N, 6.01. Found: C, 49.00; H, 2.84; N, 6.05.

3oa, N-(2-(chlorodifluoromethyl)-6-methoxyquinolin-4-yl)-4-methylbenzenesulfonamide



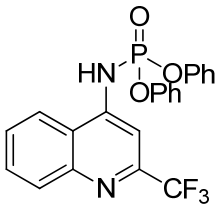
White solid, mp 158-160 °C, yield 62%; ^{1}H NMR (400 MHz, DMSO) δ 7.92 (d, *J* = 9.2 Hz, 1H), 7.76 (d, *J* = 8.3 Hz, 2H), 7.73 (d, *J* = 2.6 Hz, 1H), 7.59 (s, 1H), 7.46 (dd, *J* = 9.2, 2.6 Hz, 1H), 7.35 (d, *J* = 8.0 Hz, 2H), 3.89 (s, 3H), 2.27 (s, 3H); ^{19}F NMR (376 MHz, DMSO) δ -53.60 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 159.41, 148.81 (t, *J* = 27.7 Hz), 144.83, 143.43, 142.83, 136.34, 131.81, 130.49, 127.27, 125.05 (t, *J* = 290.2 Hz), 124.52, 104.57, 101.25, 56.55, 21.39; IR (KBr, cm^{-1}): ν 3303, 1625, 1485, 1243, 1164, 979, 661; MS (EI) m/z (relative intensity) 412 [M^{+}, 23], 257 (100); Anal. Calcd. For $C_{18}H_{15}ClF_3N_2O_3S$: C, 52.37; H, 3.66; N, 6.79. Found: C, 52.18; H, 3.92; N, 6.75.

3pa, N-(2-(bromodifluoromethyl)-6-methoxyquinolin-4-yl)-4-methylbenzenesulfonamide



White solid, mp 180-182 °C, yield 54%; ^{1}H NMR (300 MHz, DMSO) δ 7.92 (d, *J* = 9.2 Hz, 1H), 7.79-7.74 (m, 3H), 7.58 (s, 1H), 7.46 (dd, *J* = 9.2, 2.4 Hz, 1H), 7.35 (d, *J* = 8.1 Hz, 2H), 3.90 (s, 3H), 2.28 (s, 3H); ^{19}F NMR (282 MHz, DMSO) δ -50.86 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 159.39, 150.34 (t, *J* = 22.9 Hz), 144.81, 136.32, 131.71, 130.48, 127.28, 124.47, 122.22, 117.49 (t, *J* = 302.7 Hz), 104.27, 101.29, 56.55, 21.39; IR (KBr, cm^{-1}): ν 3300, 1626, 1490, 1253, 1160, 985, 666; MS (EI) m/z (relative intensity) 456 [M^{79+}, 7], 458 [M^{81+}, 7], 222 (100); HRMS (EI) calcd. For $C_{18}H_{15}F_2N_2O_3SBr$: 455.9955, Found: 455.9951.

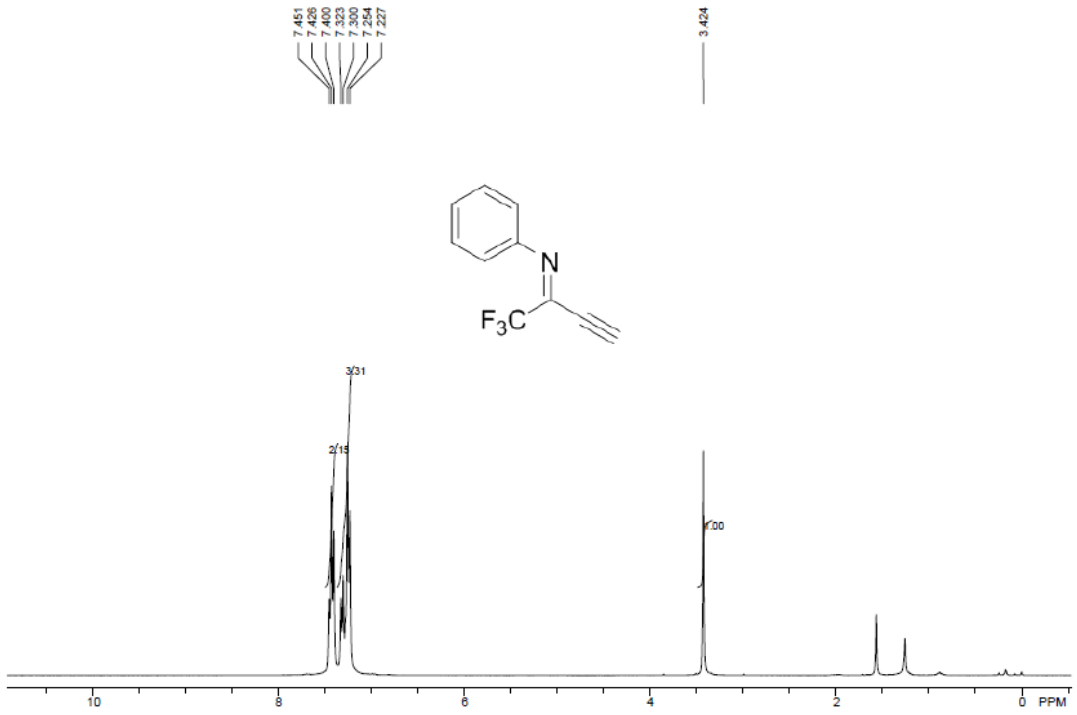
5a, diphenyl (2-(trifluoromethyl)quinolin-4-yl)phosphoramidate

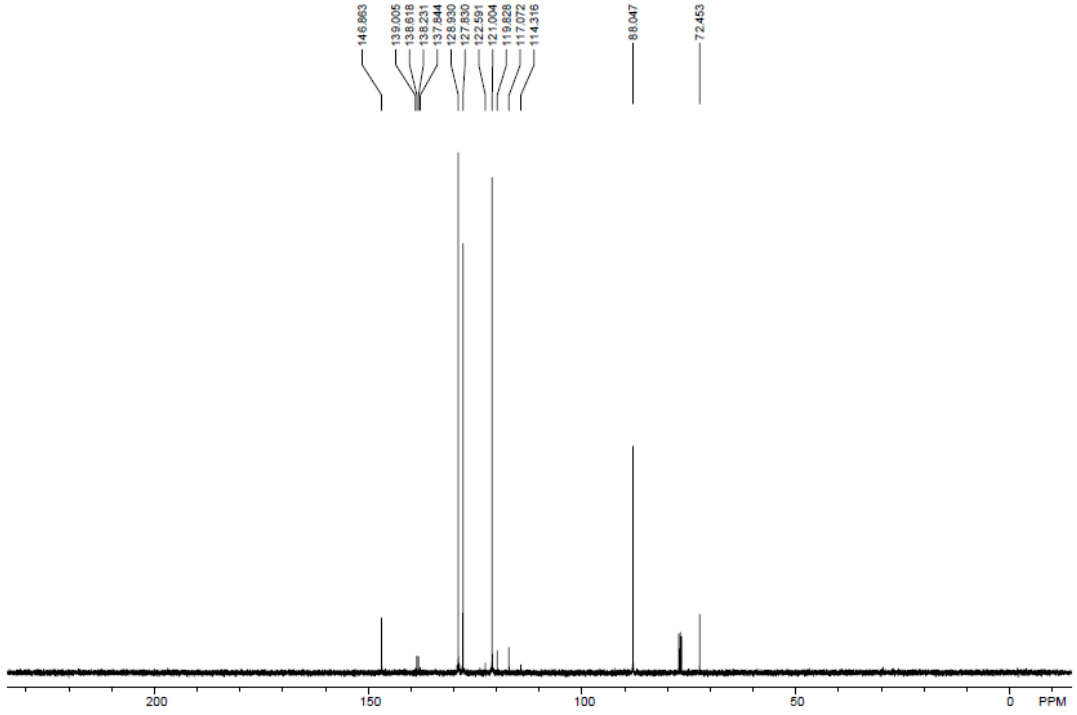


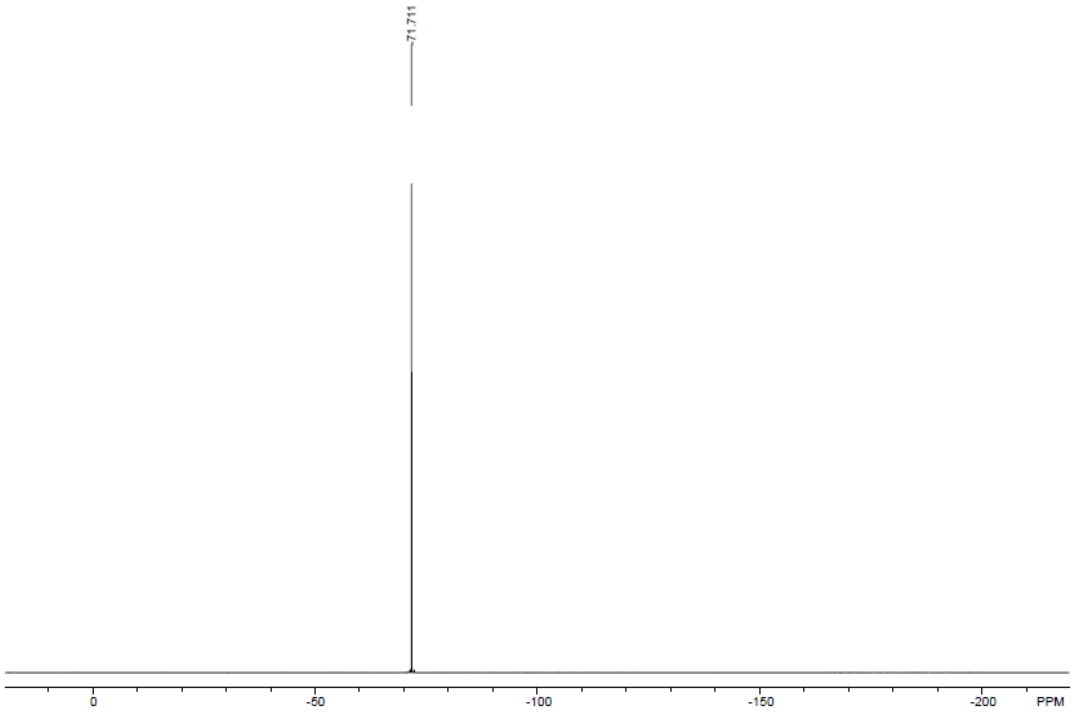
White solid, mp 158-159 °C, yield 62%; ^{1}H NMR (400 MHz, DMSO) δ 10.11 (s, 1H), 8.44 (d, *J* = 8.4 Hz, 2H), 8.19 (d, *J* = 8.4 Hz, 2H), 7.96 (t, *J* = 7.7 Hz, 2H), 7.79 (t, *J* = 7.3 Hz, 2H), 7.60 – 7.39 (m, 4H), 7.35 (dd, *J* = 13.3, 7.5 Hz, 1H), 7.22 (dd, *J* = 13.6, 7.5 Hz, 1H), 6.86 (d, *J* = 8.3 Hz, 1H); ^{19}F NMR (376 MHz, DMSO) δ -66.55 (s, 3F); ^{13}C NMR (100 MHz, DMSO) δ 151.12, 149.07, 148.50, 147.56 (q, *J* = 33.7 Hz), 134.83, 131.90, 130.31, 130.20, 129.99, 129.50, 128.33, 127.00, 125.85, 123.74, 122.46, 122.17, 121.92 (q, *J* = 275.3 Hz), 120.76, 120.72, 105.58; IR (KBr, cm^{-1}): ν 1567, 1531, 1391, 1289, 1145, 937, 764; MS (EI) m/z (relative intensity) 444 [M^{+}, 2], 407 (100); HRMS (EI) calcd. For $C_{22}H_{16}F_3N_2O_3P$: 444.0851, Found: 444.0850.

^{1}H, ^{19}F, ^{13}C NMR Spectra for the Substrates and Products

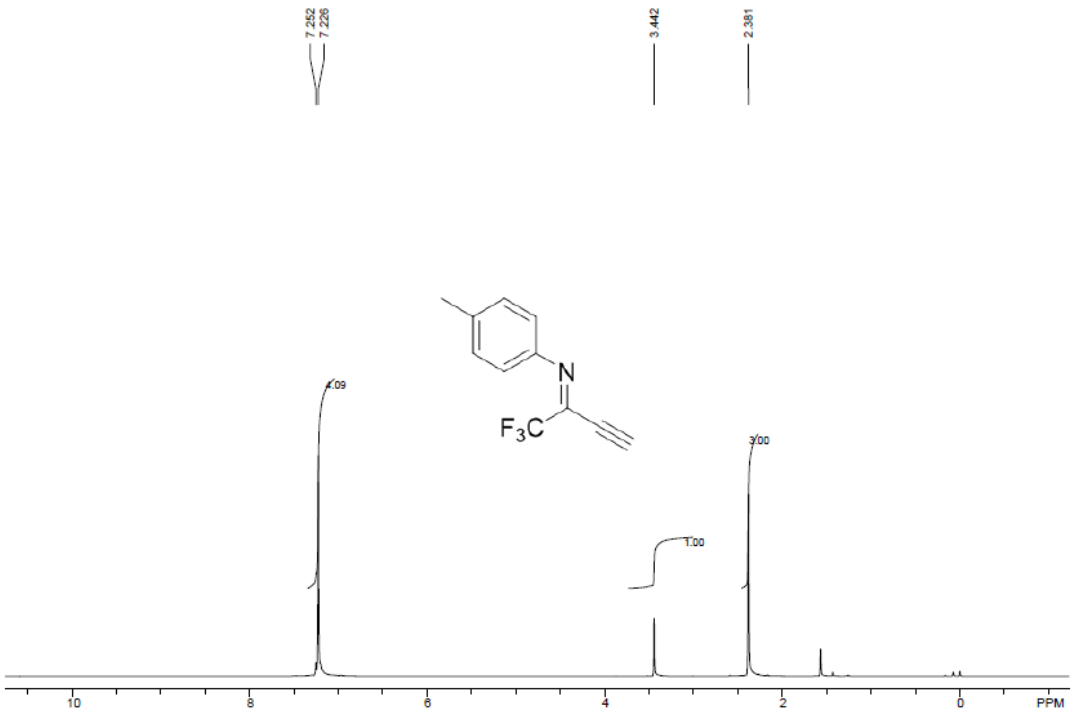
1a

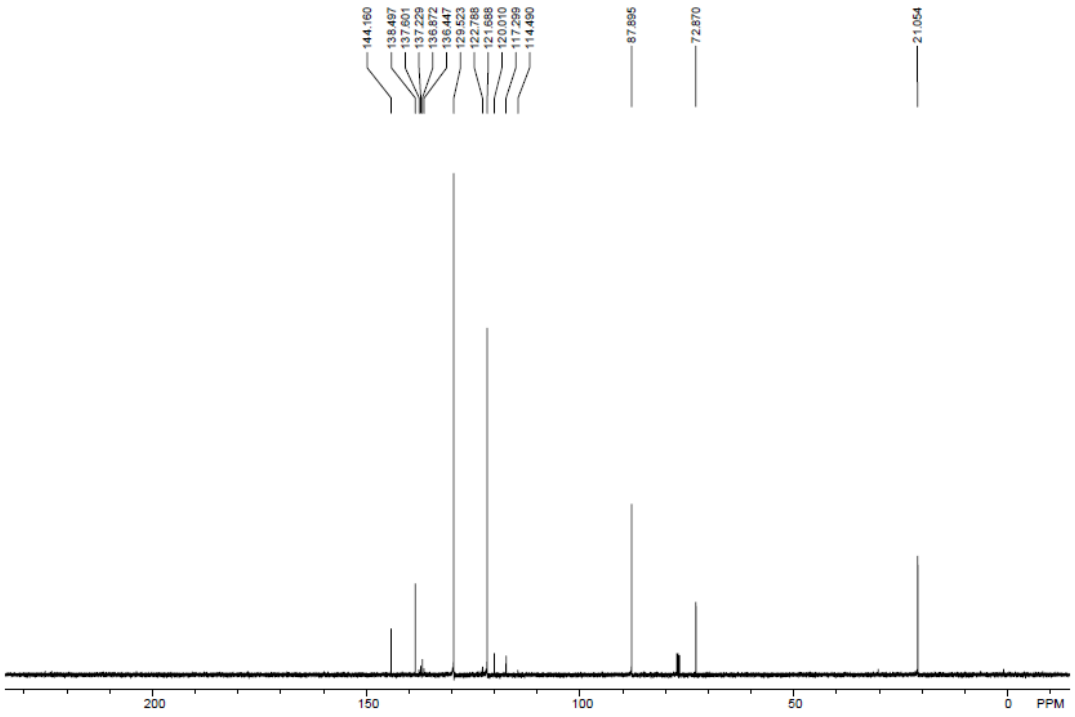


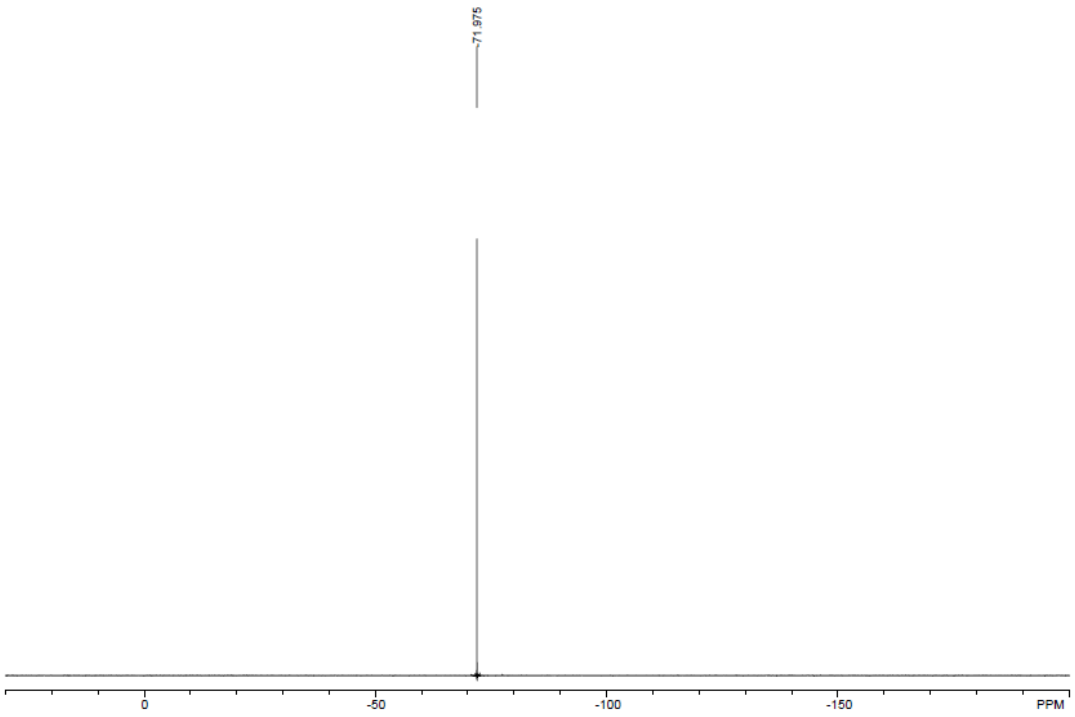




1b







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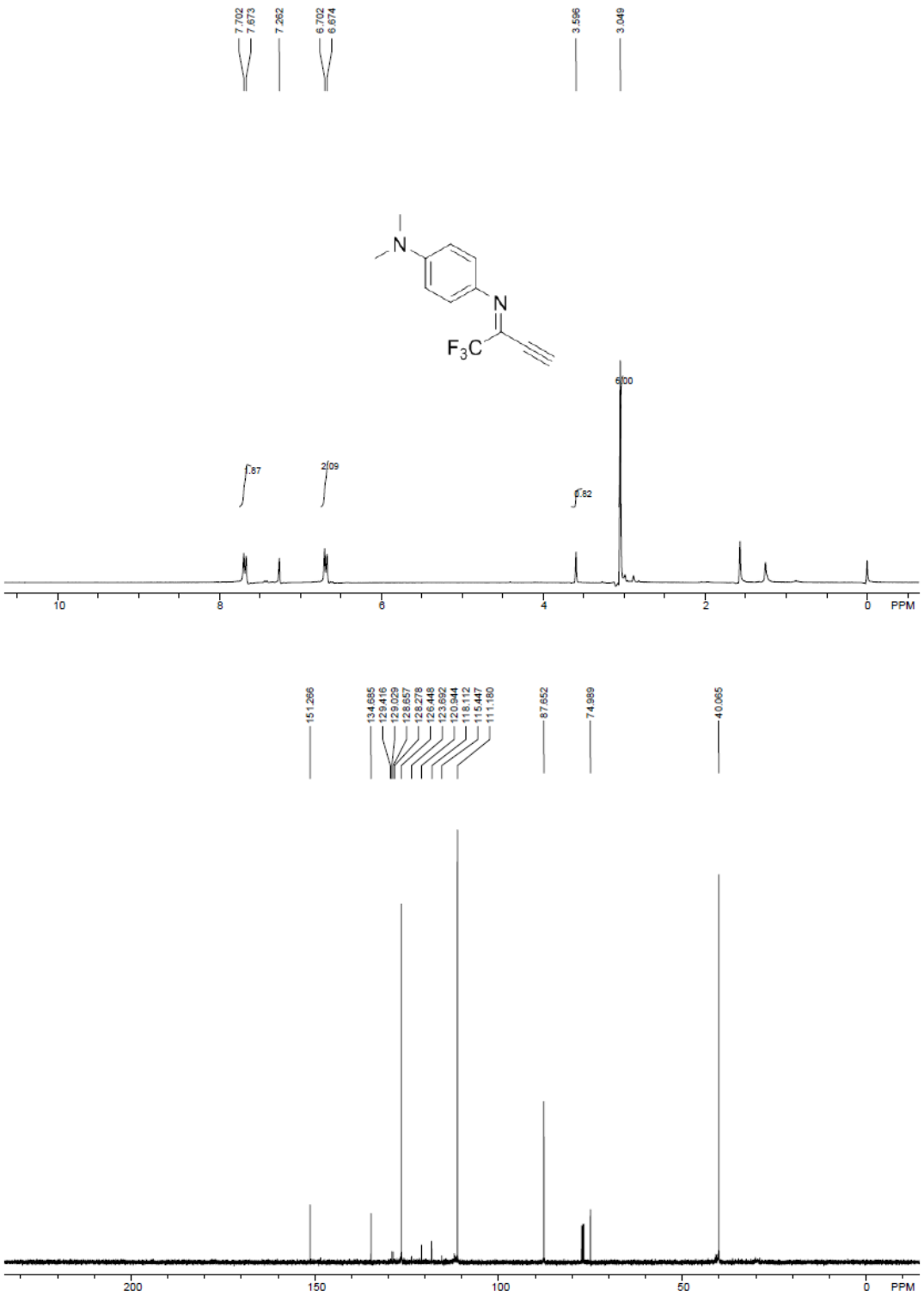
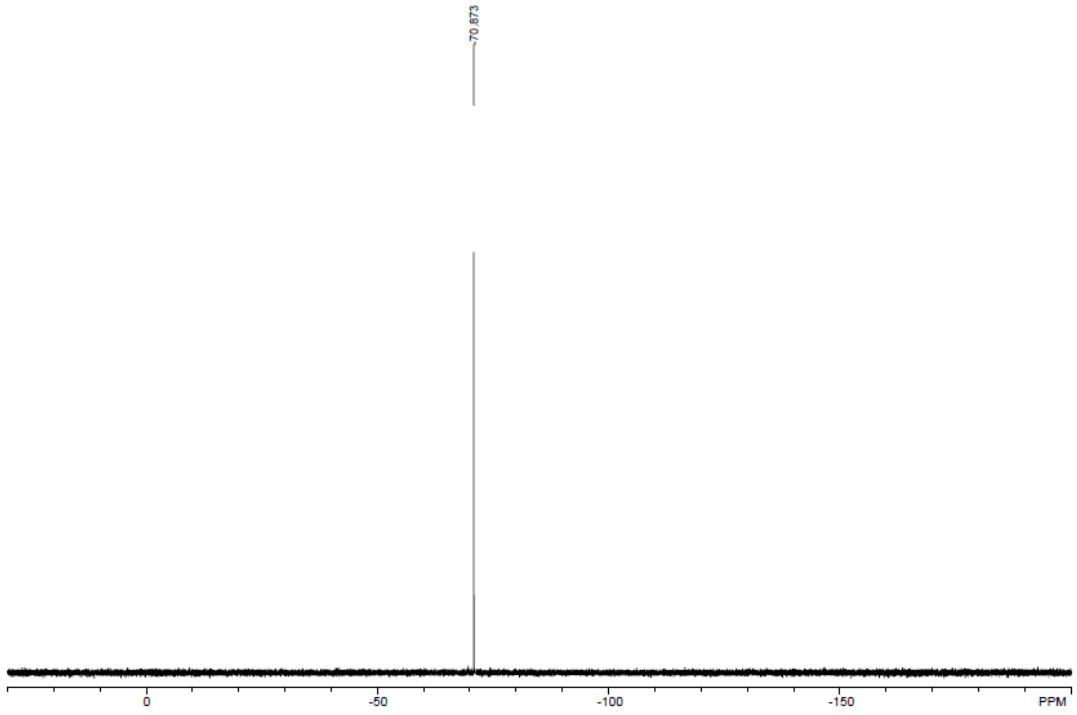
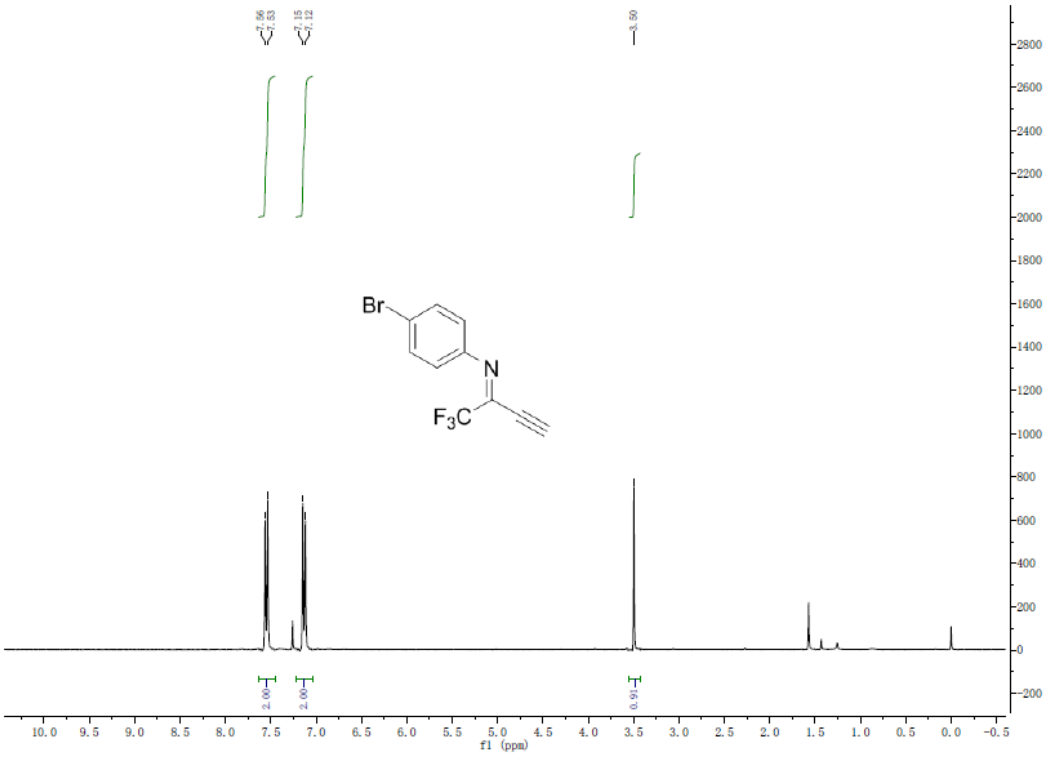
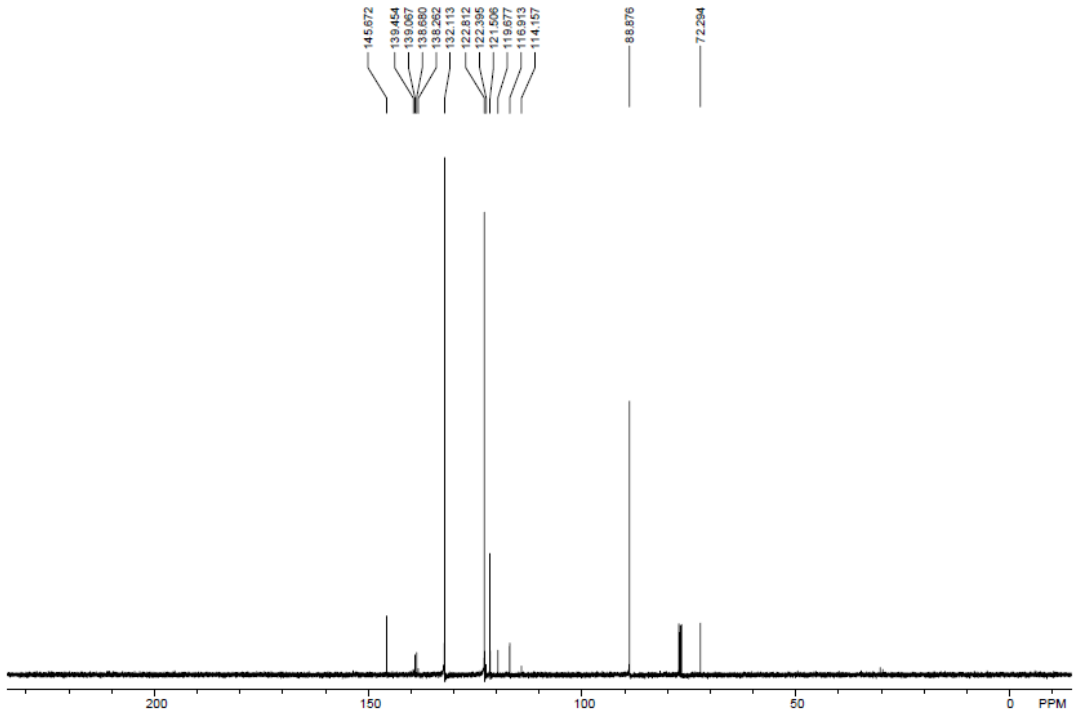
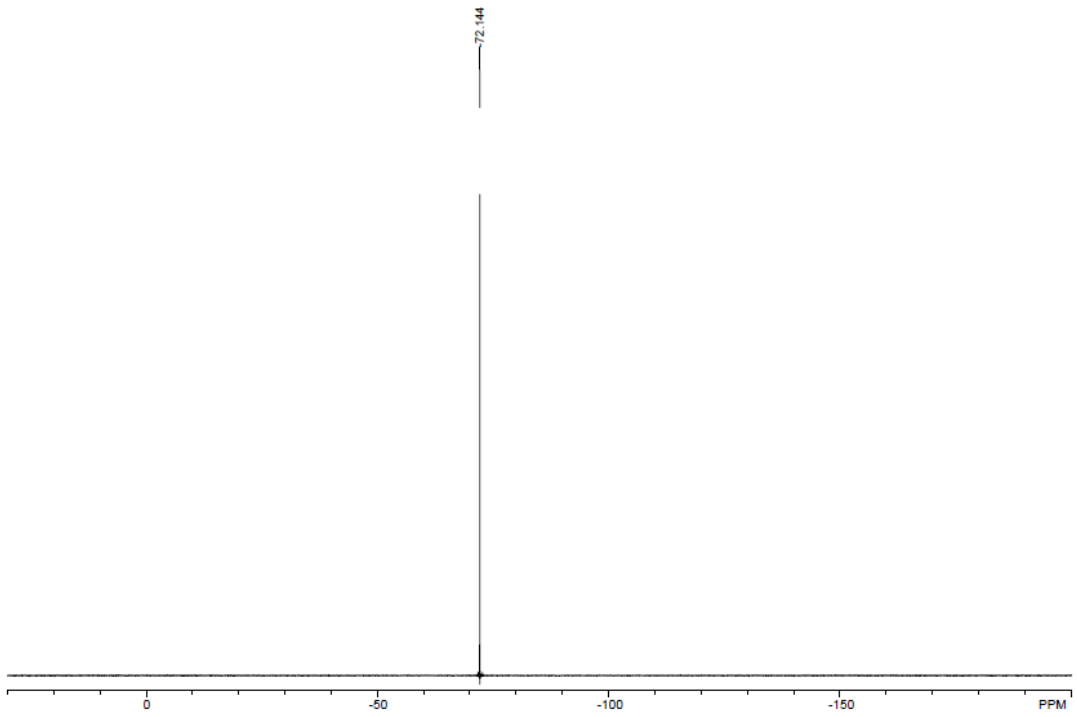




1d







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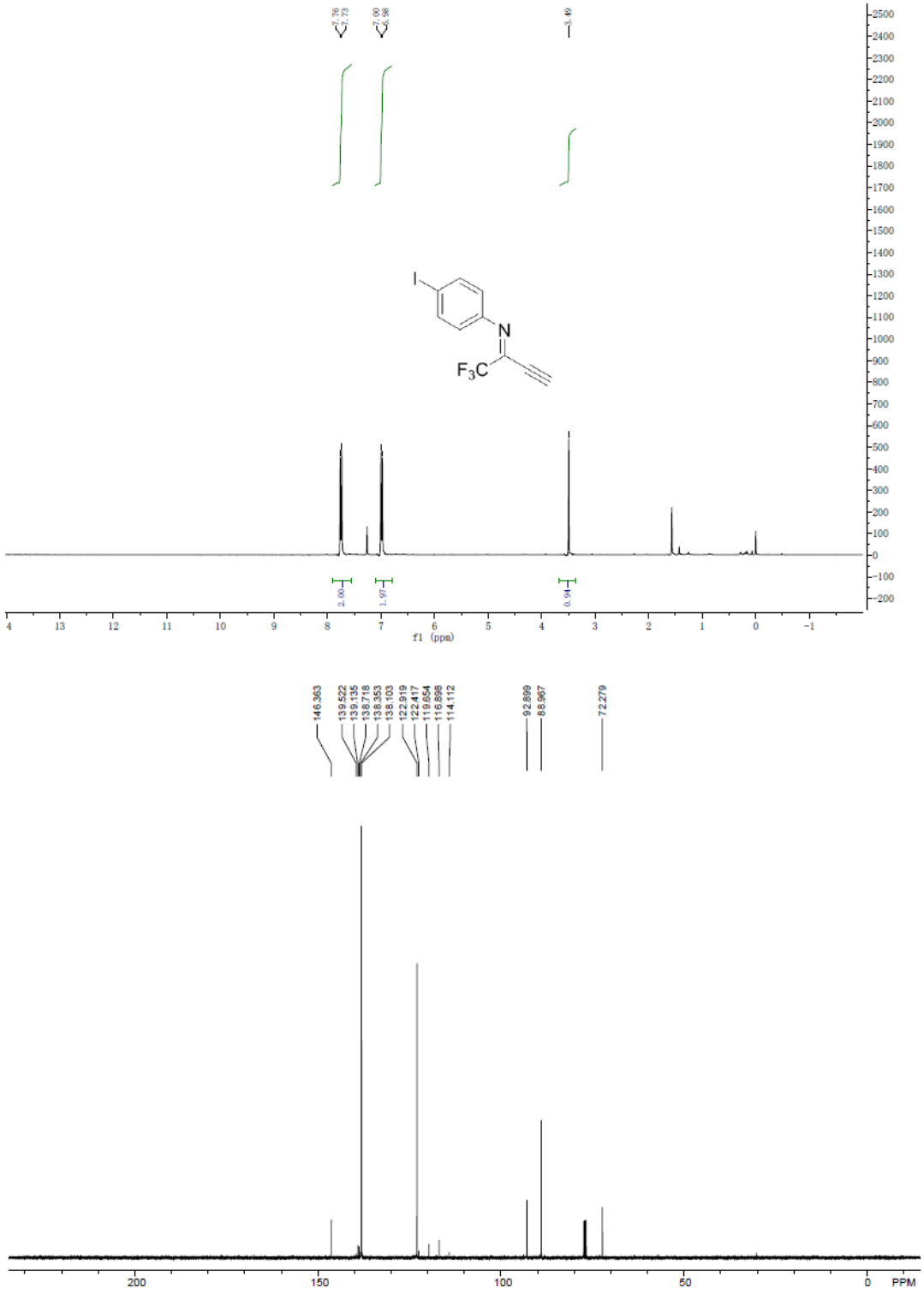

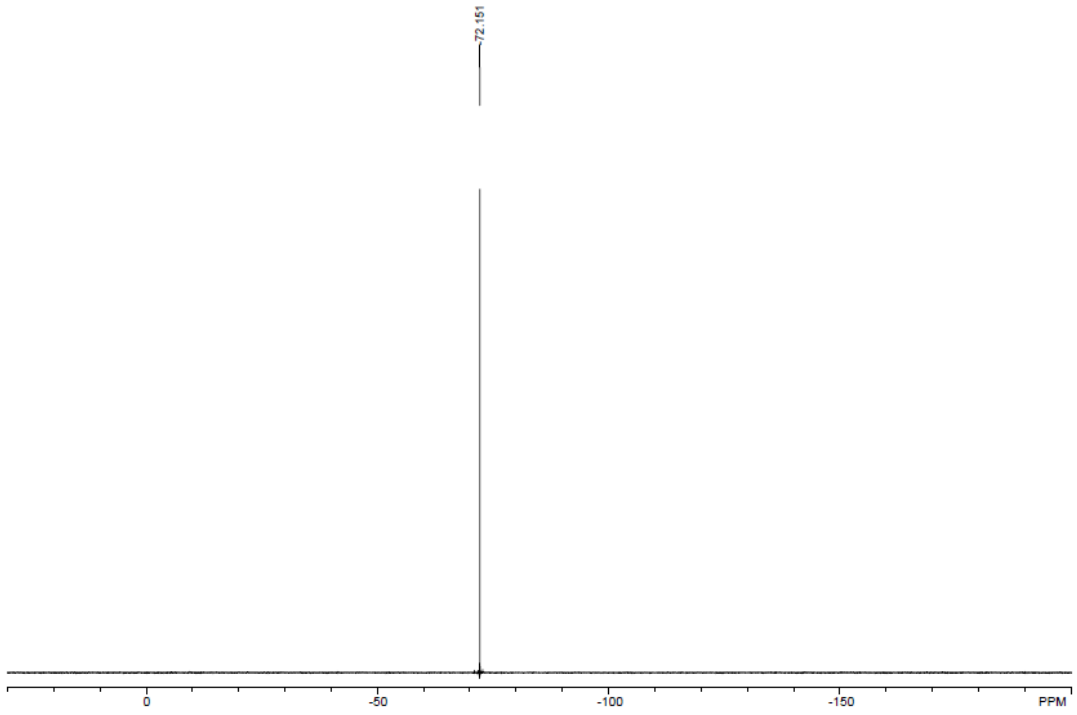

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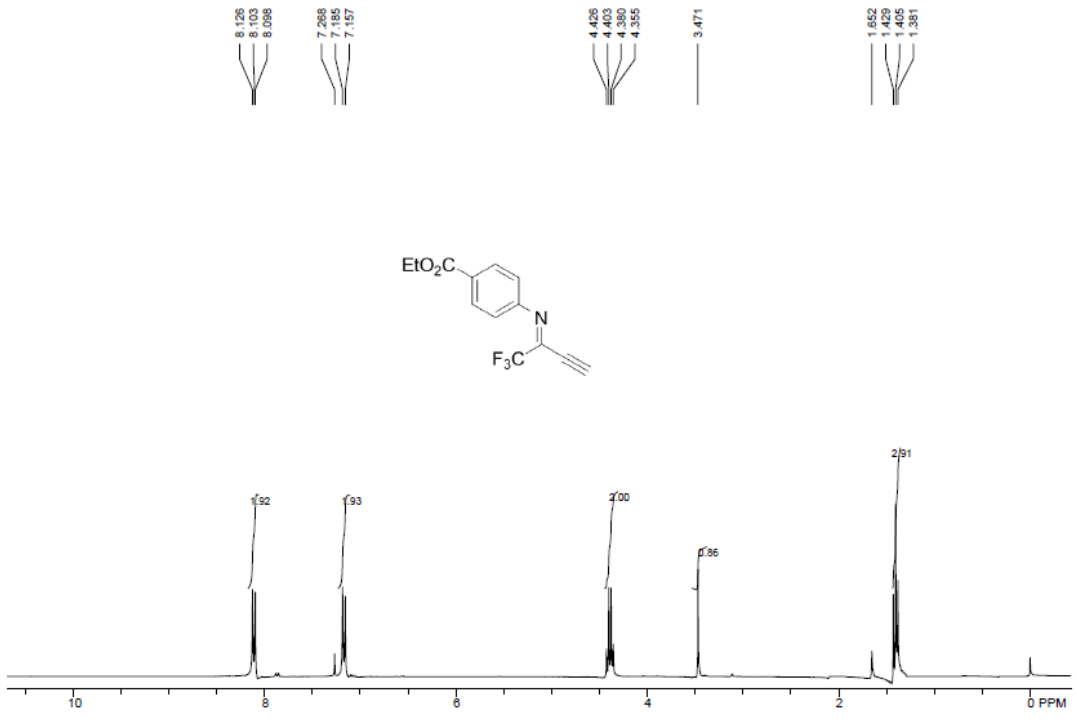

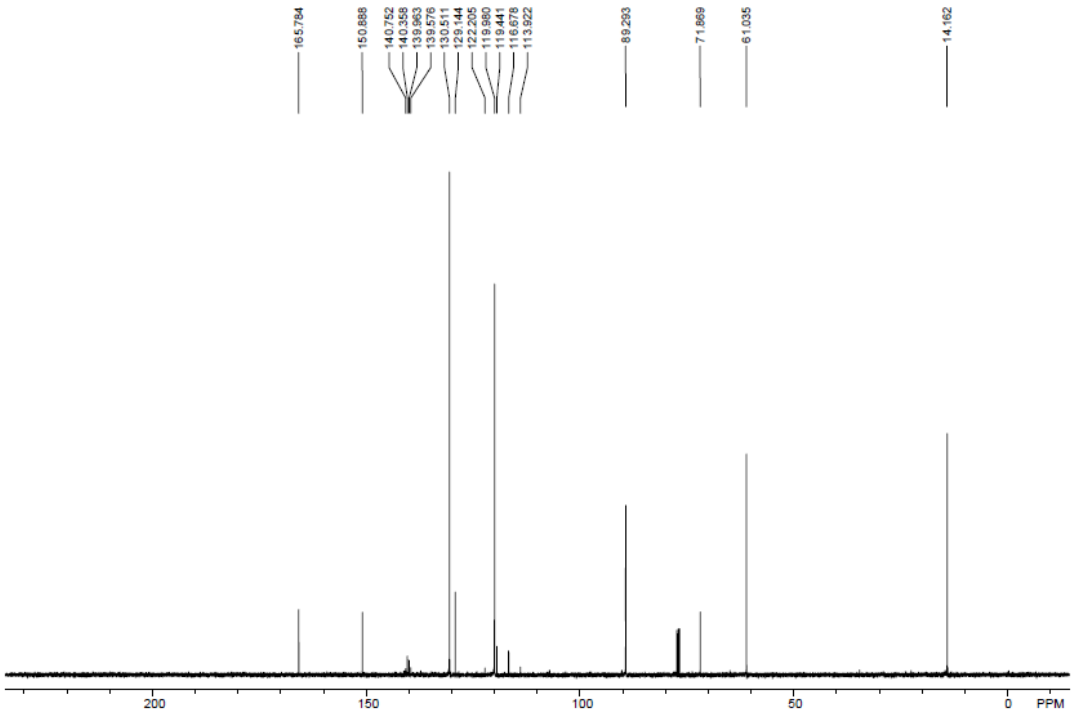

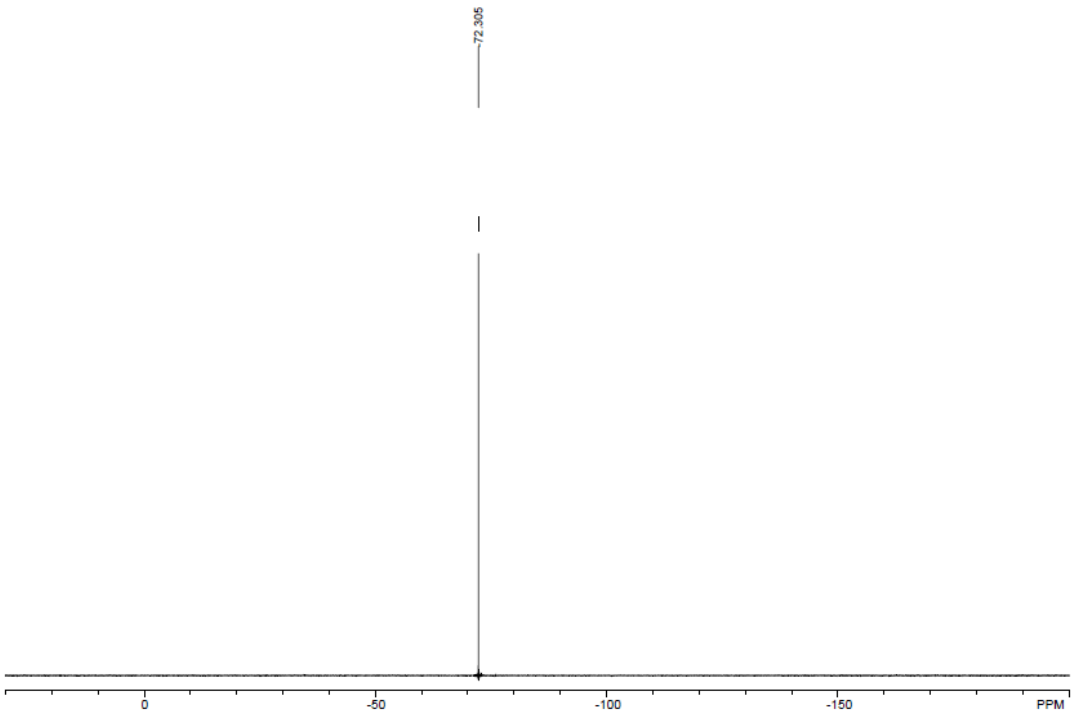

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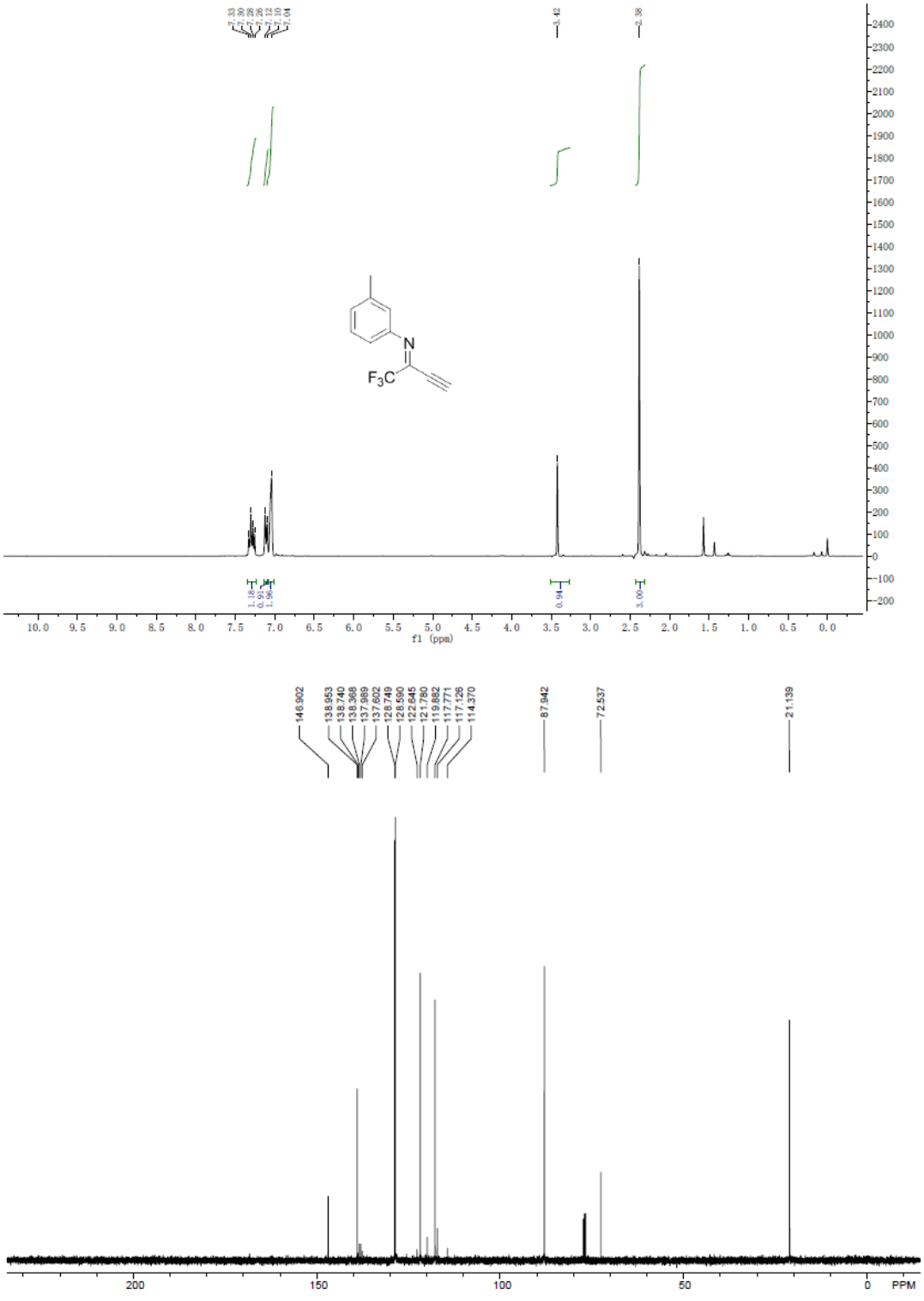

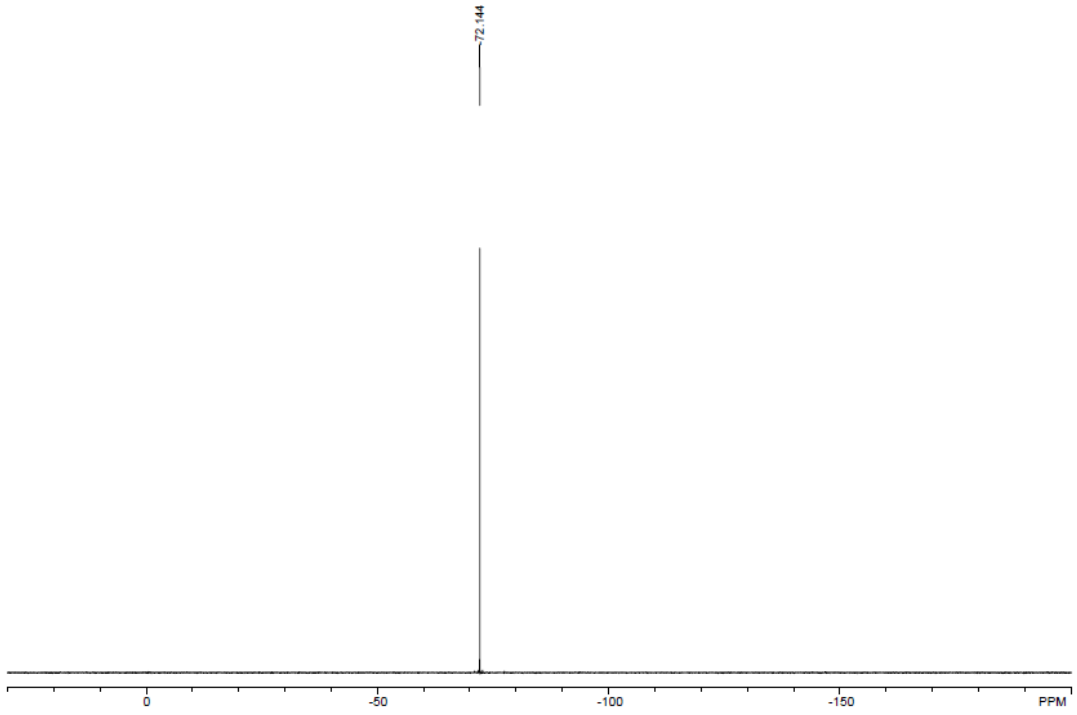

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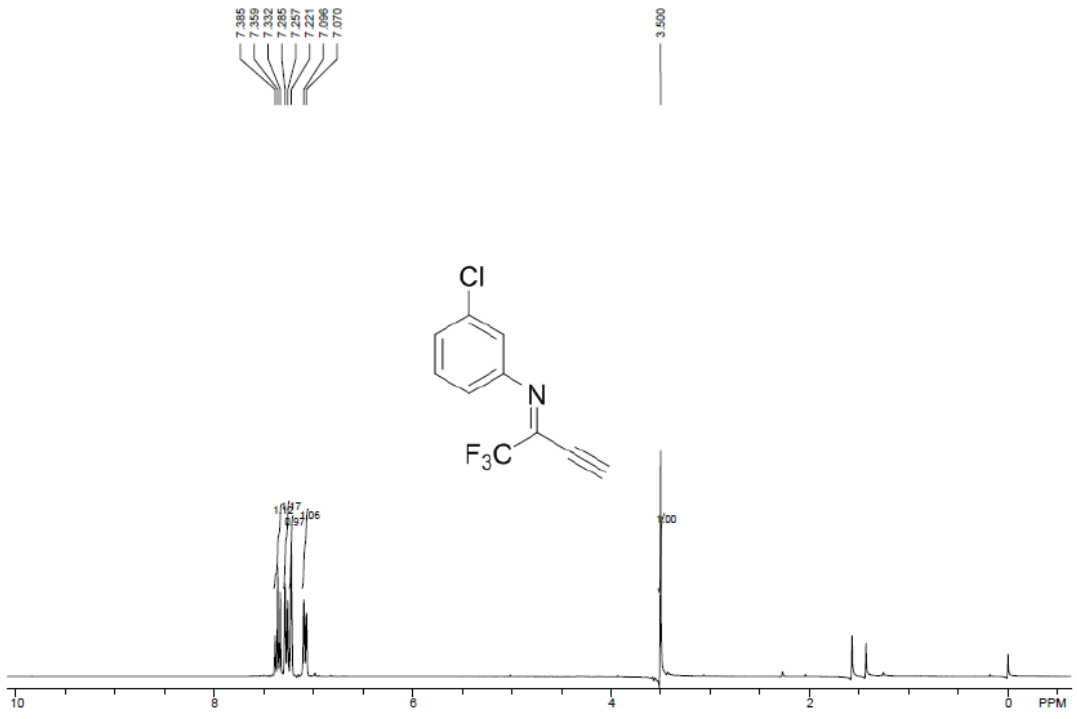

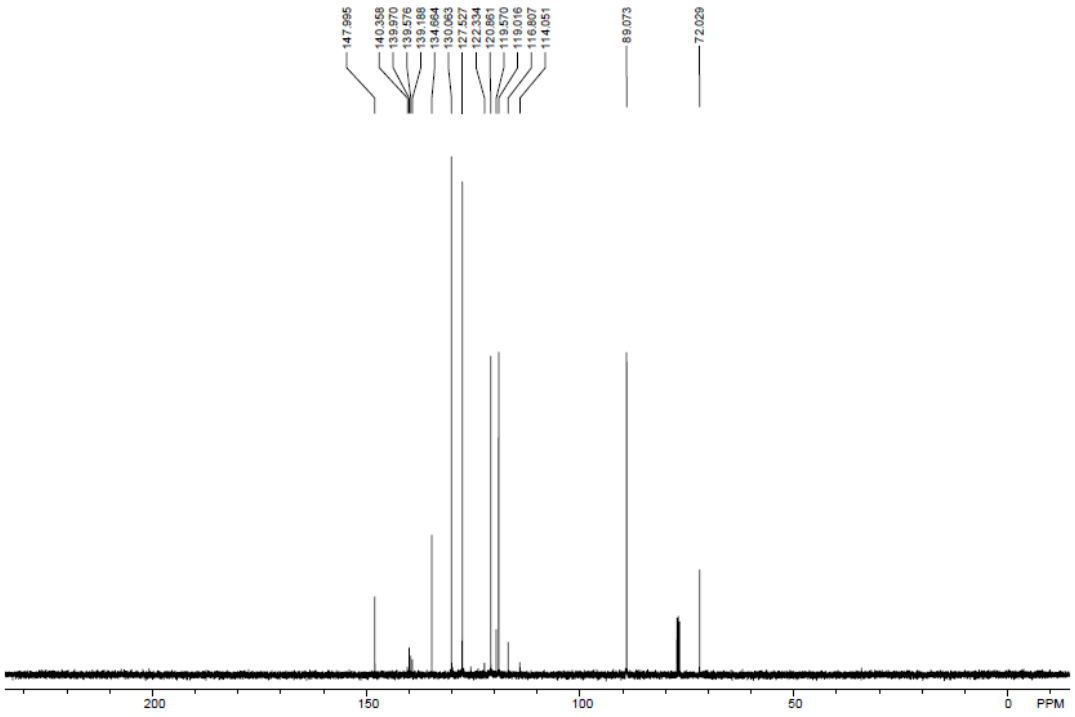

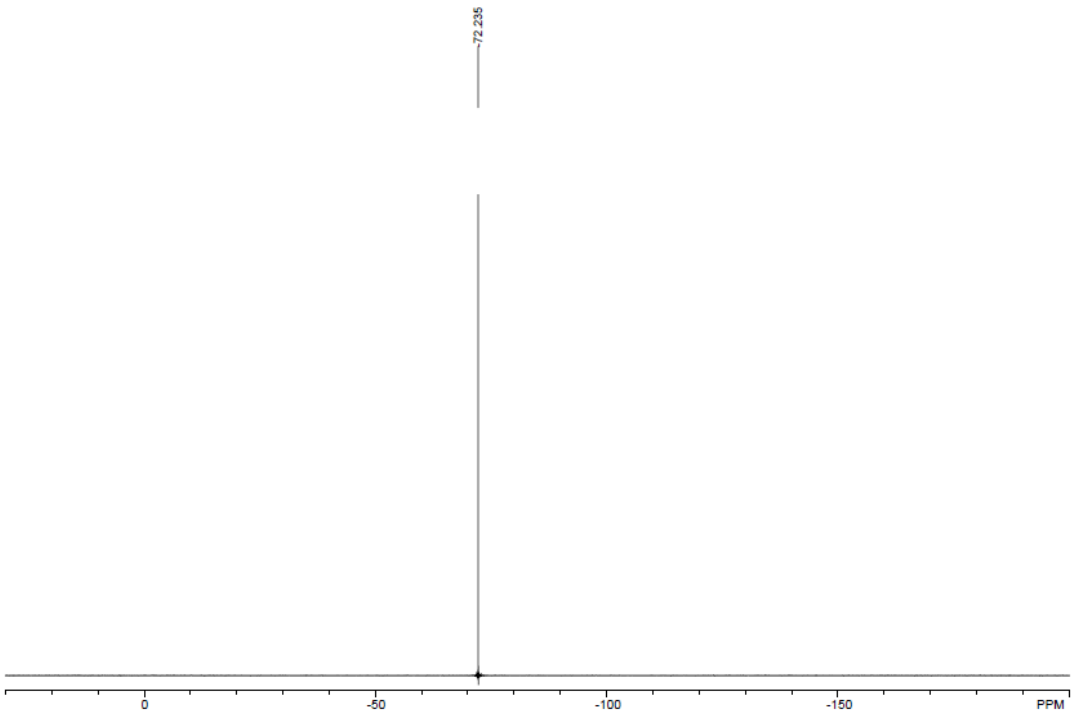

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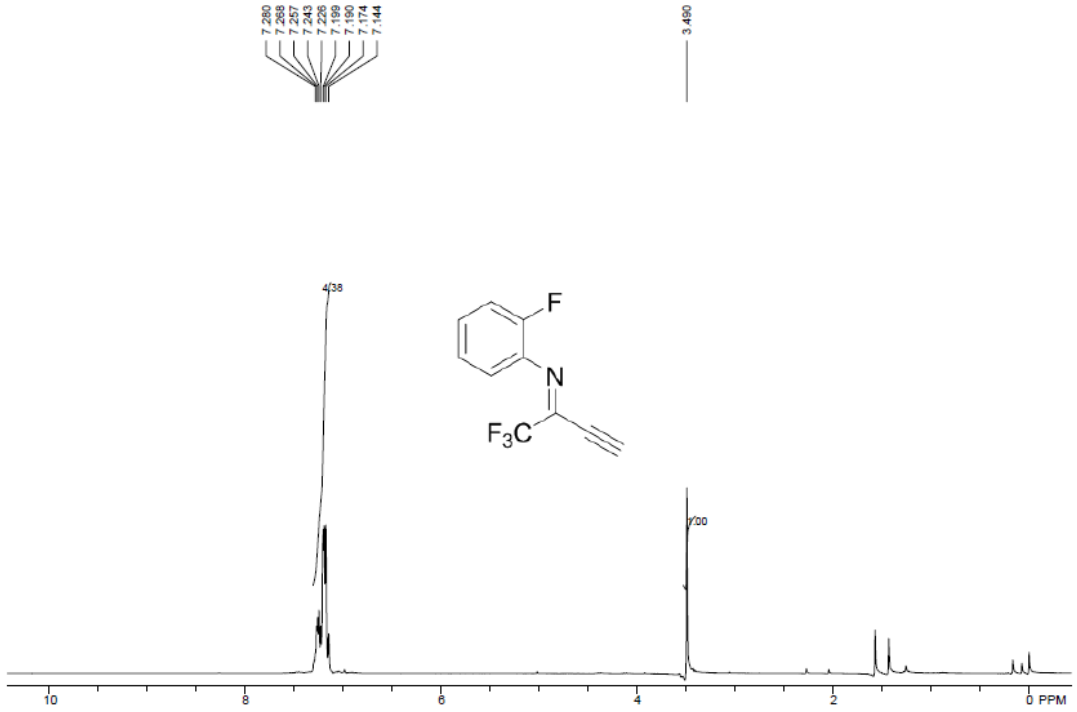

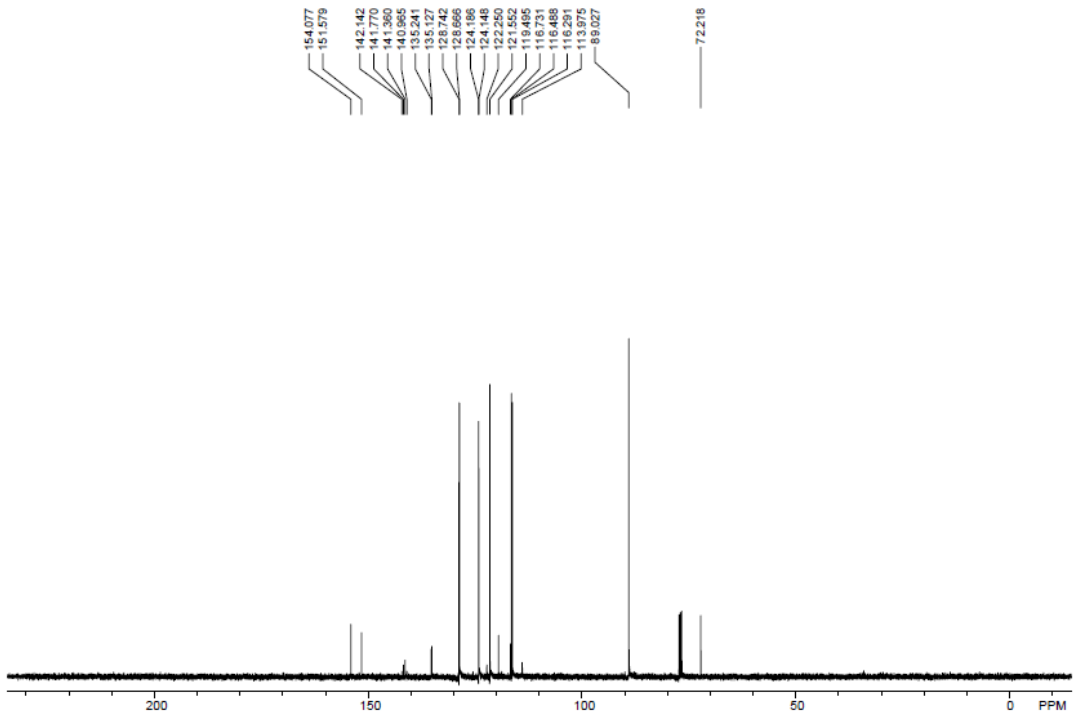

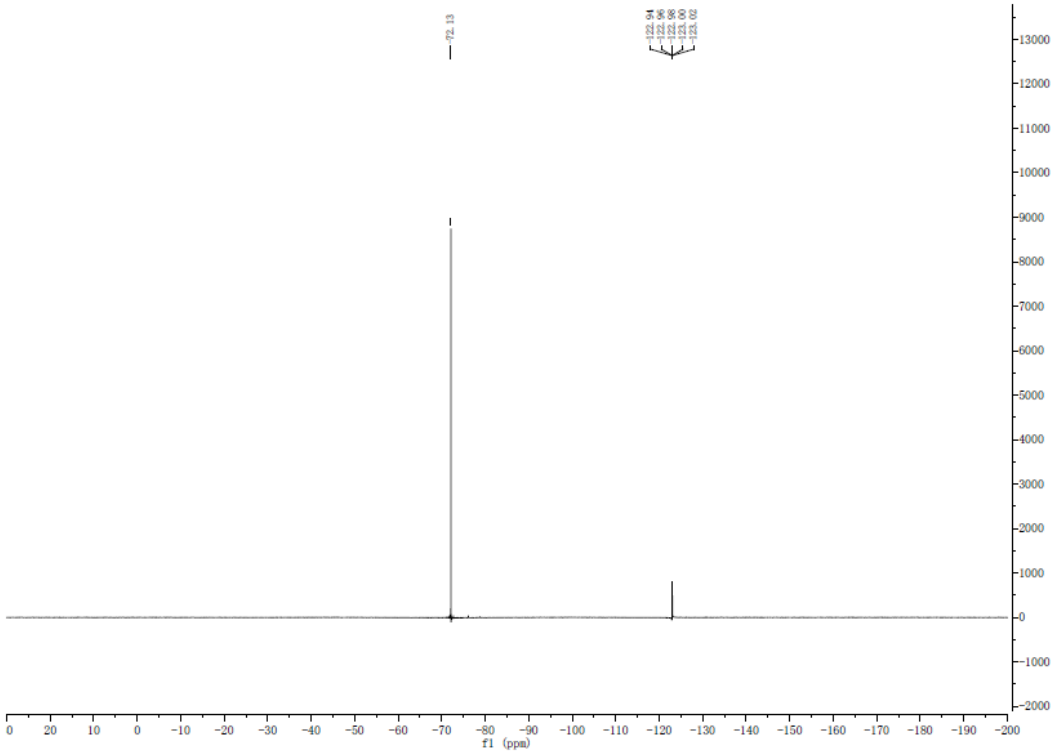

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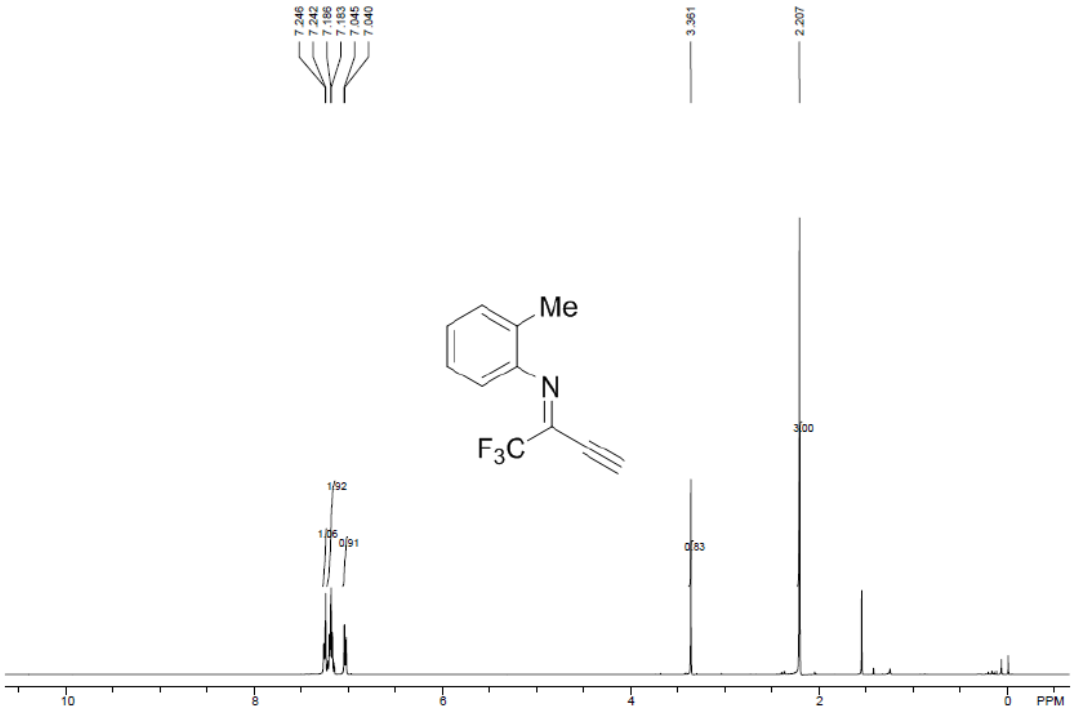
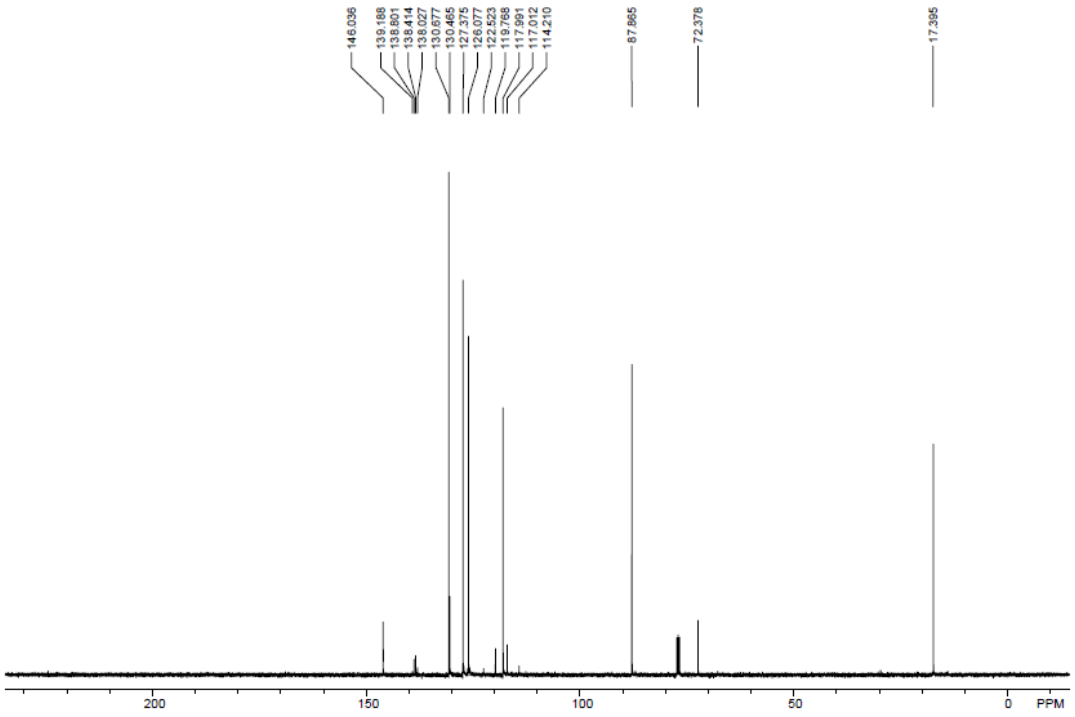
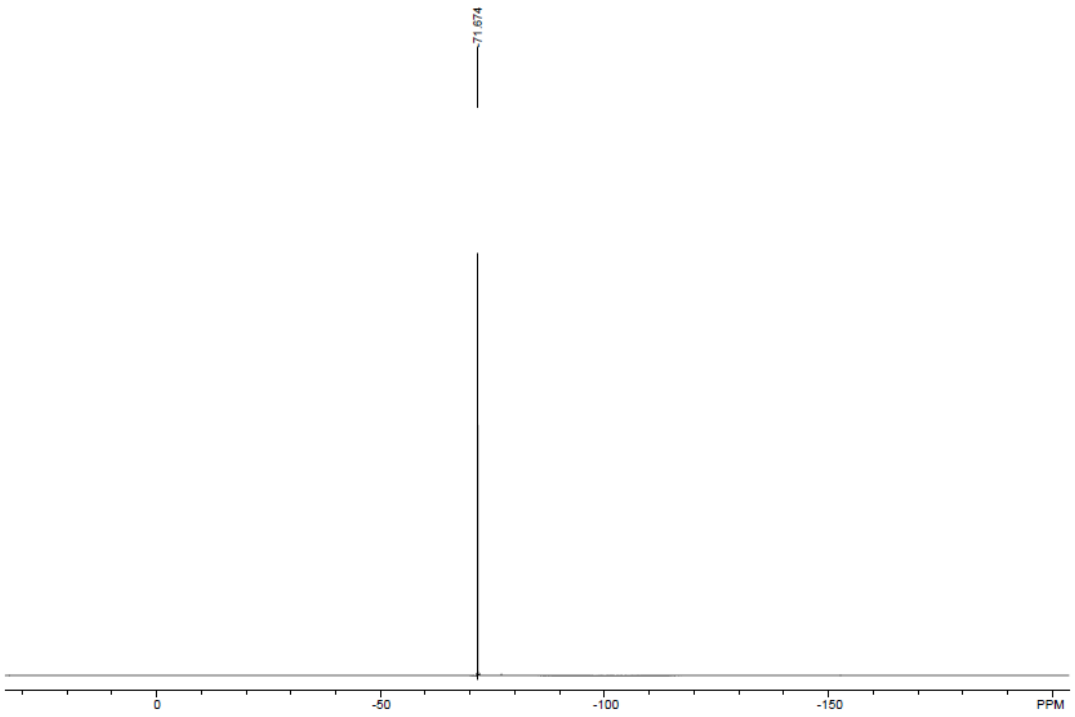
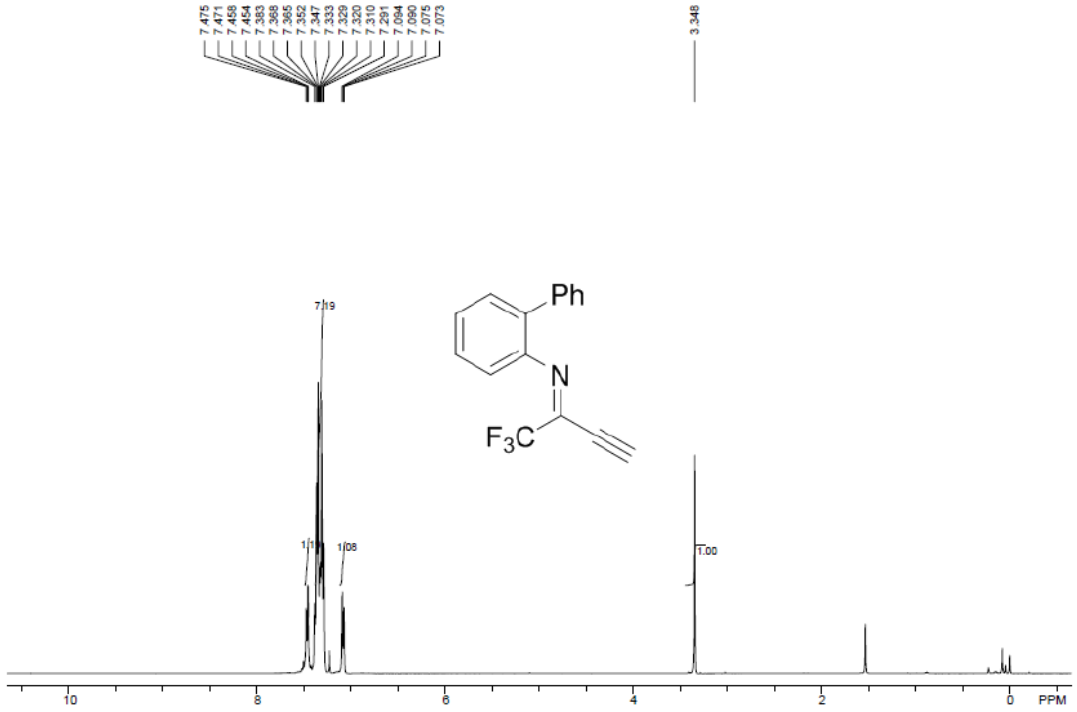






1k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7.073
3.348
7.19
Ph
N
F3C
1.11
1.08
1.00
10
8
6
4
2
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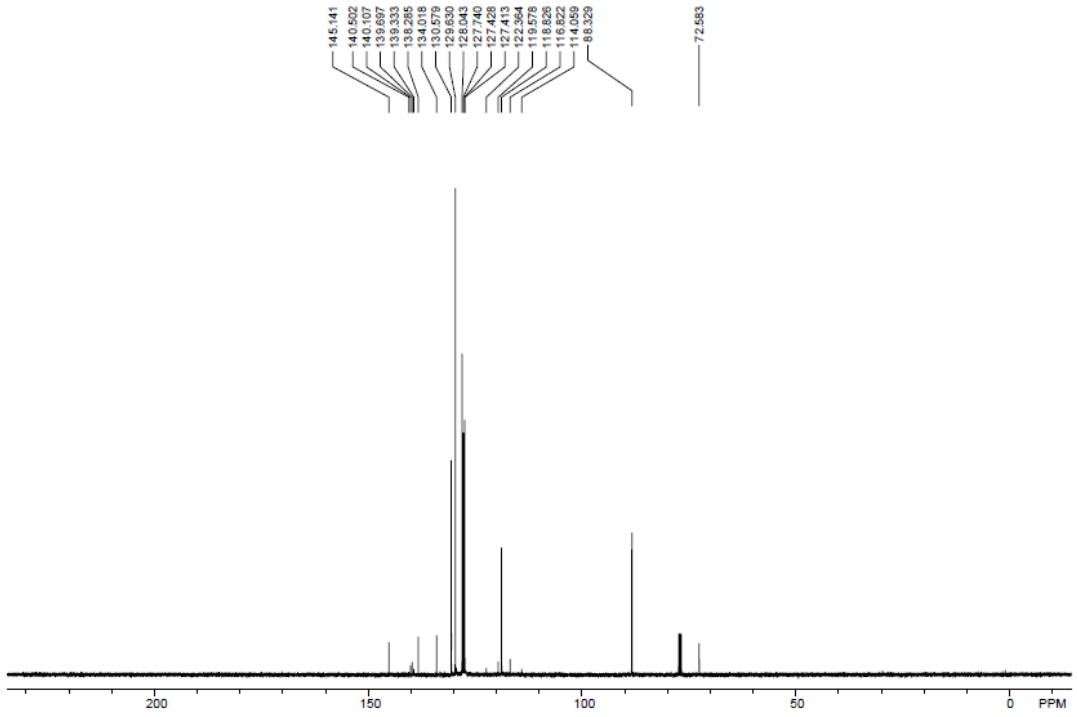
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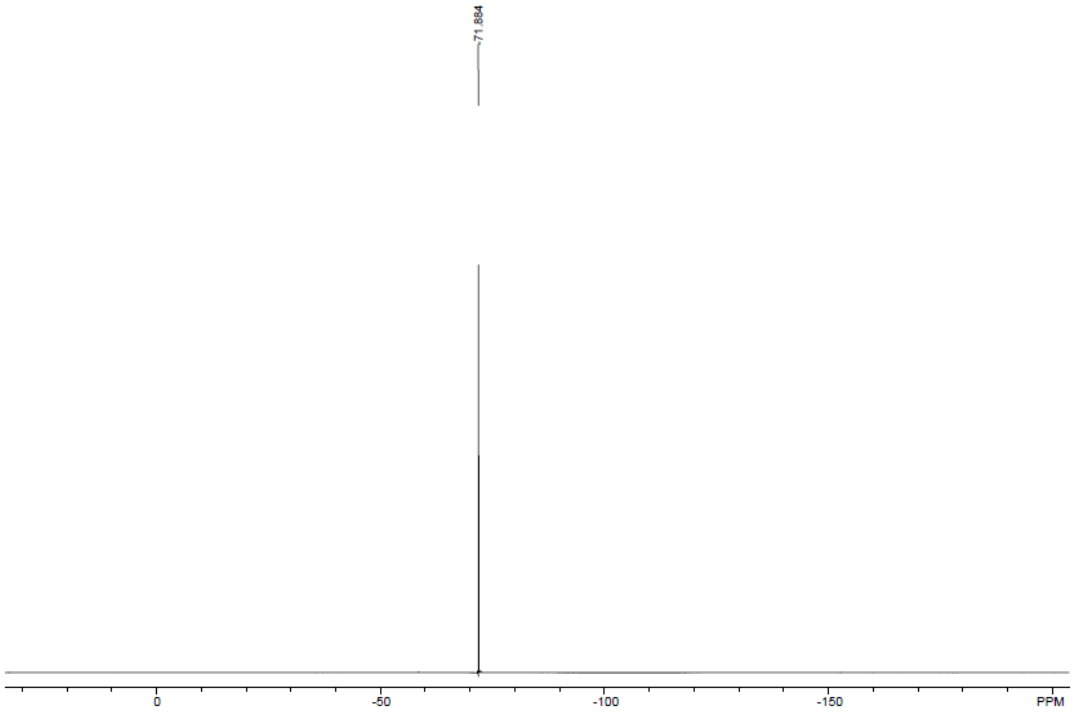

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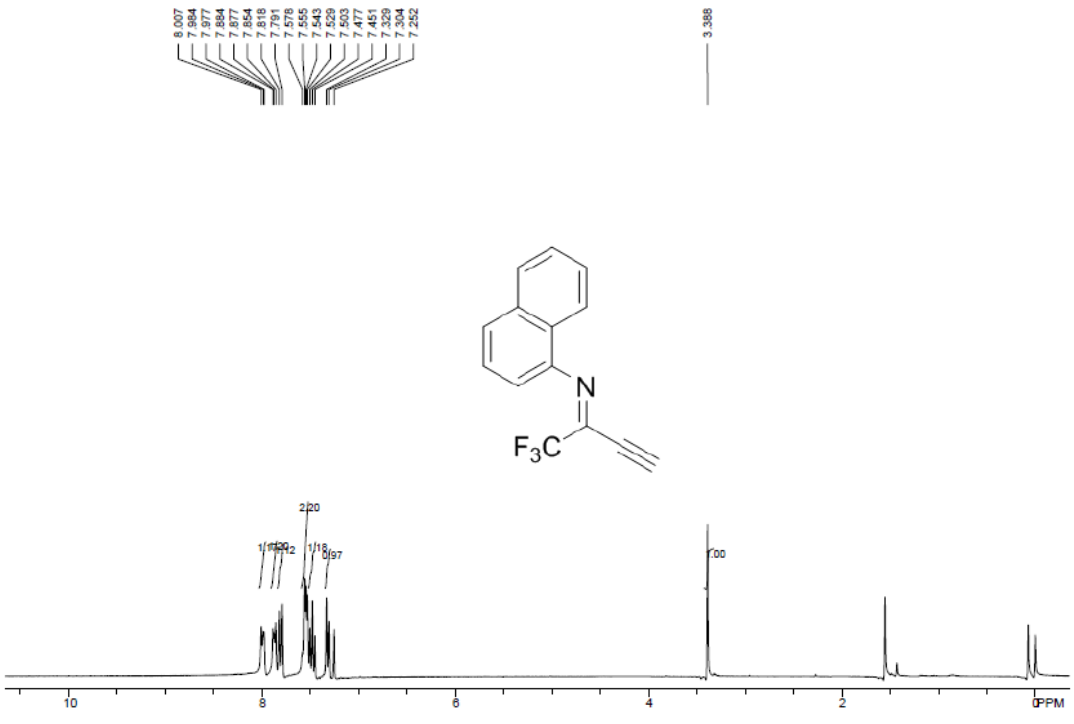

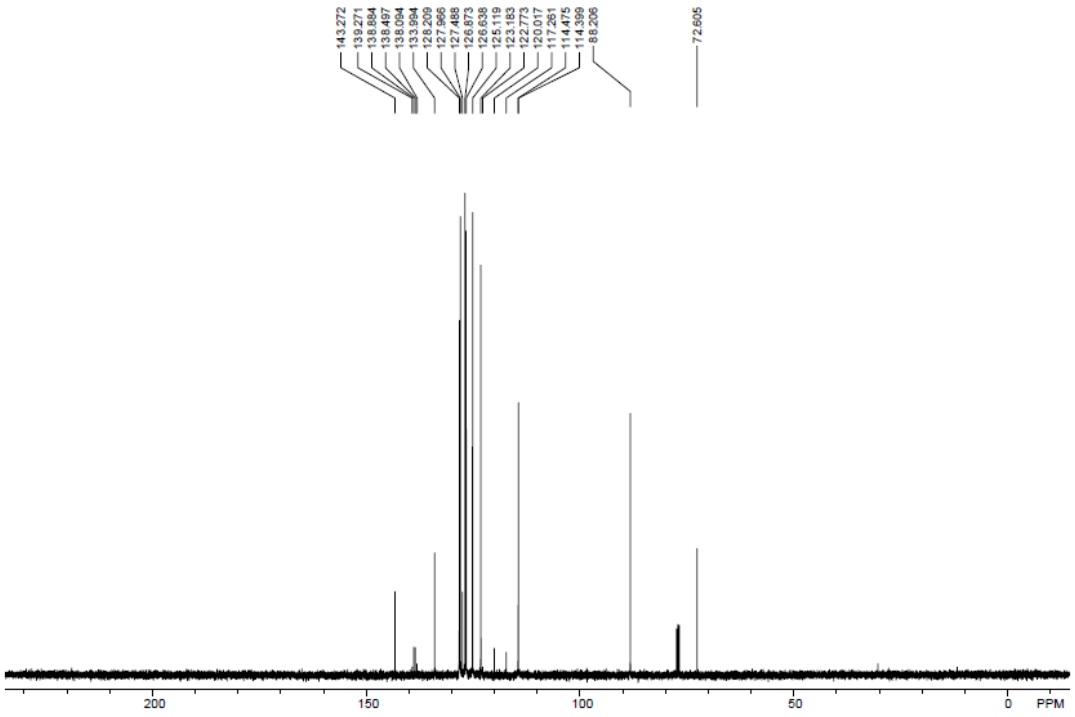

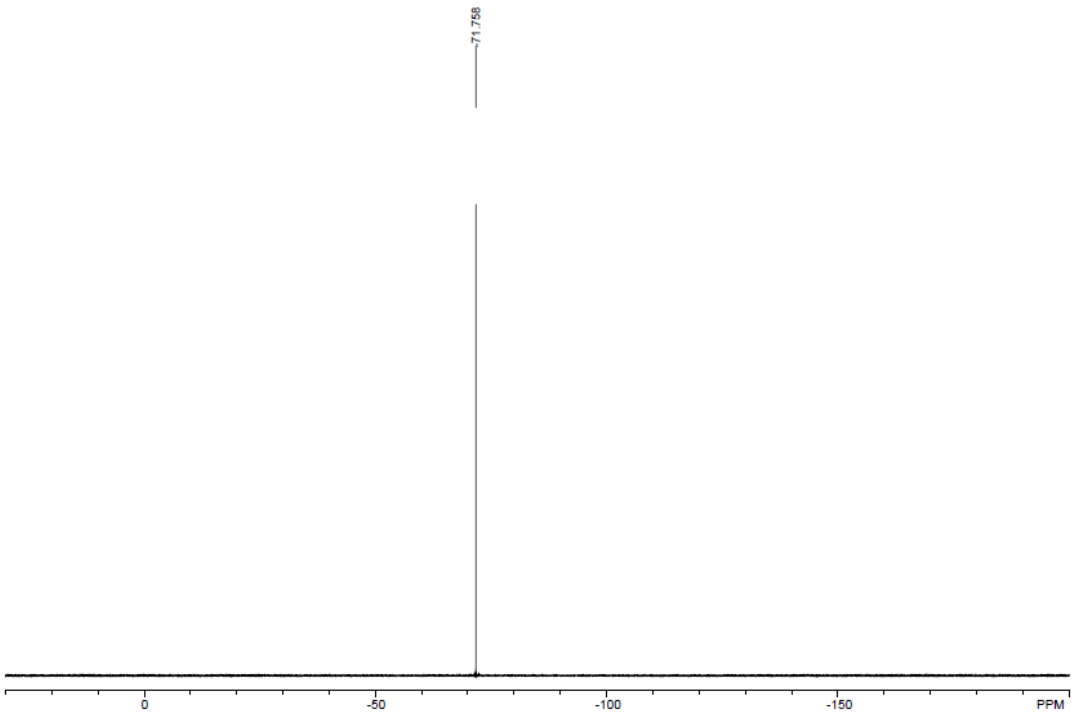

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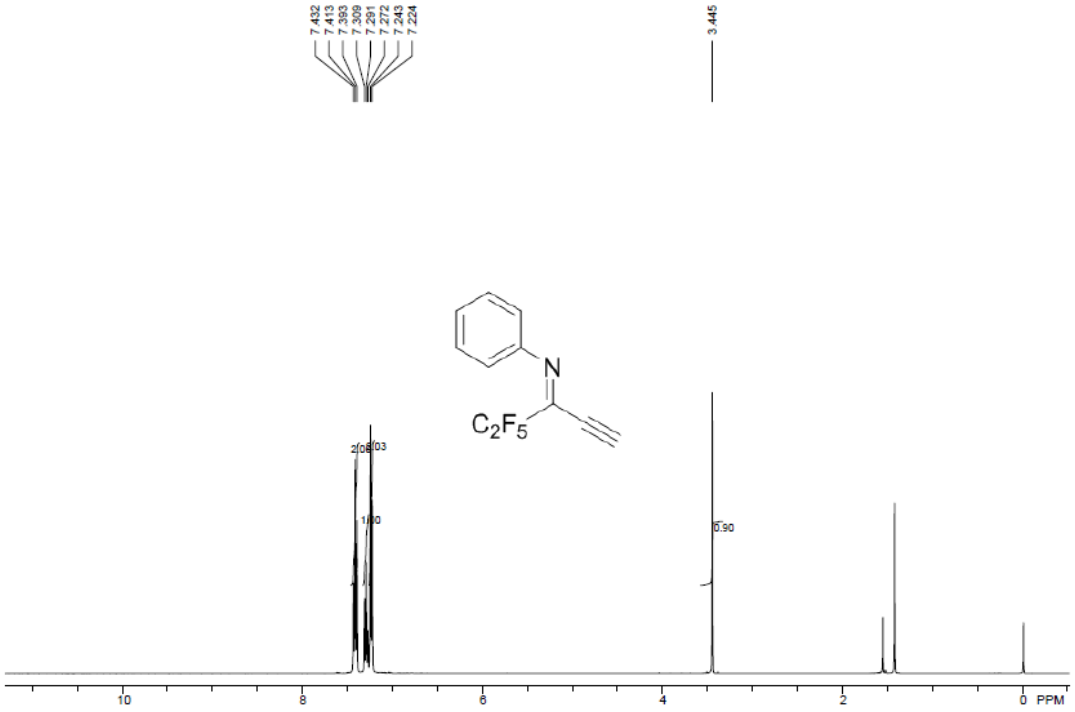

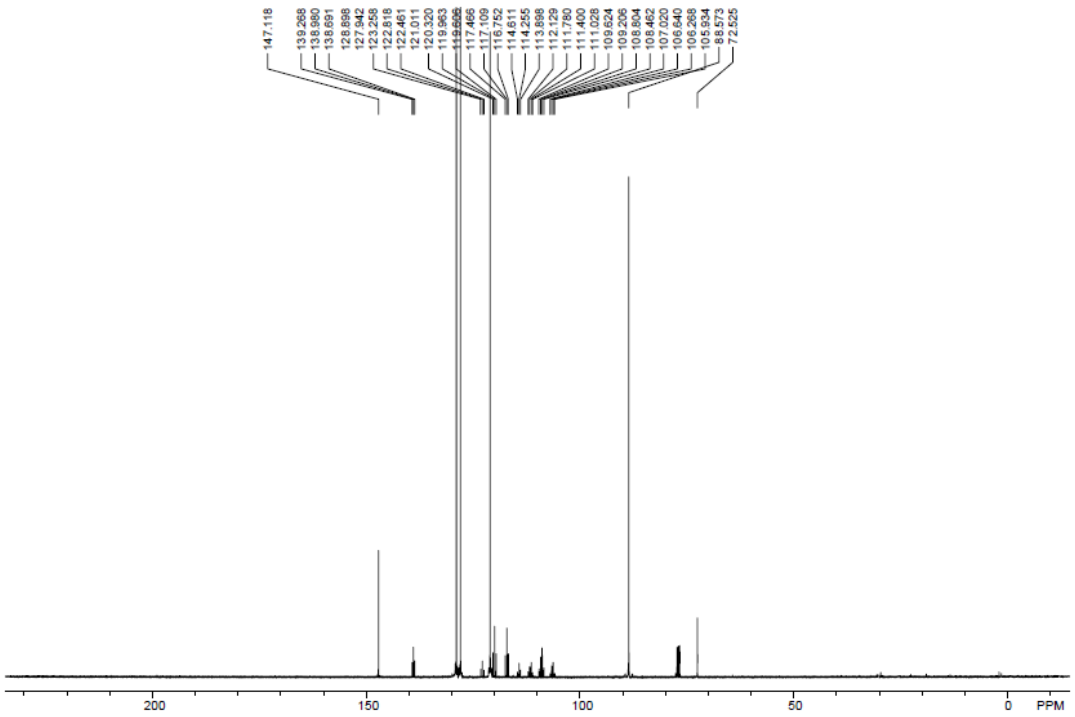

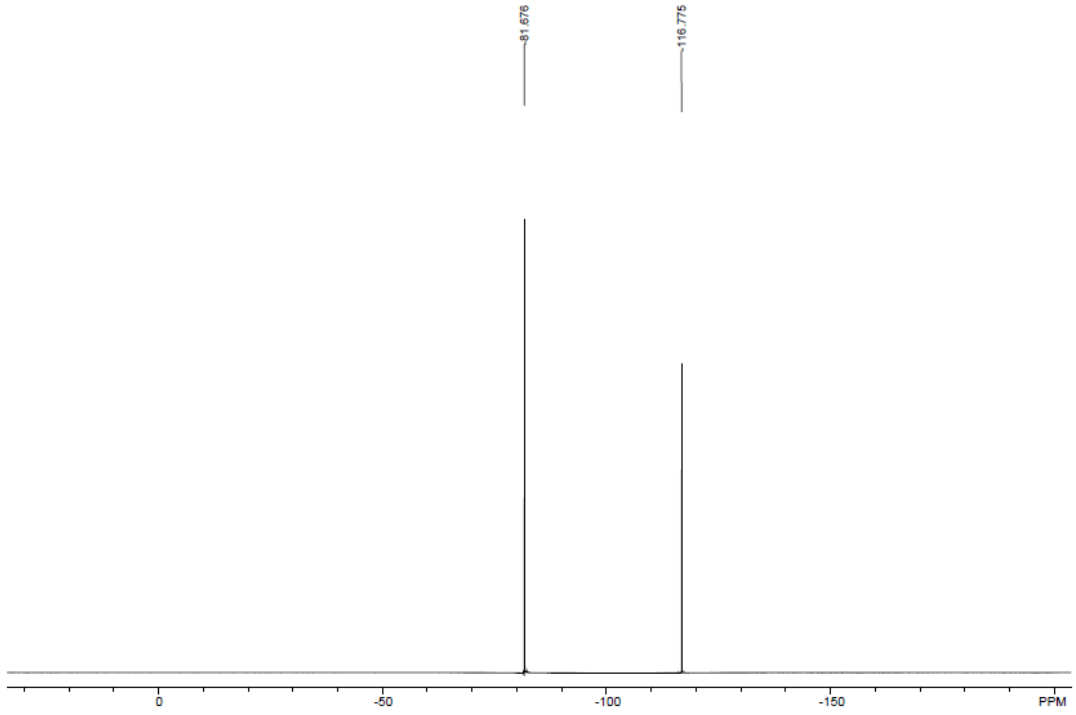

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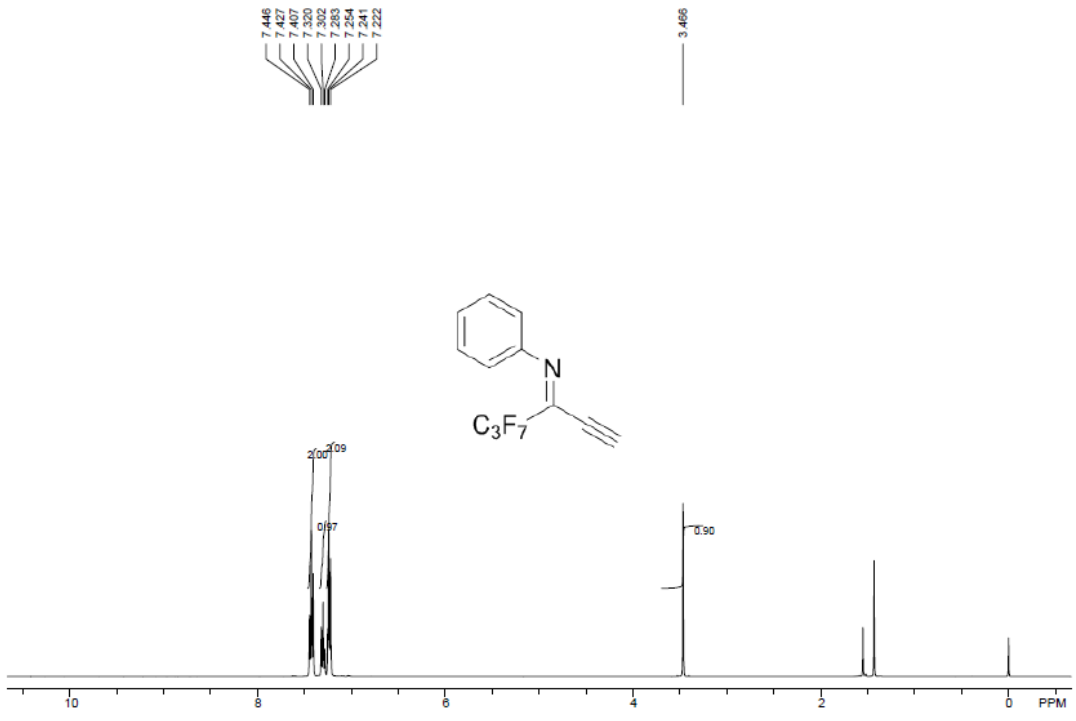

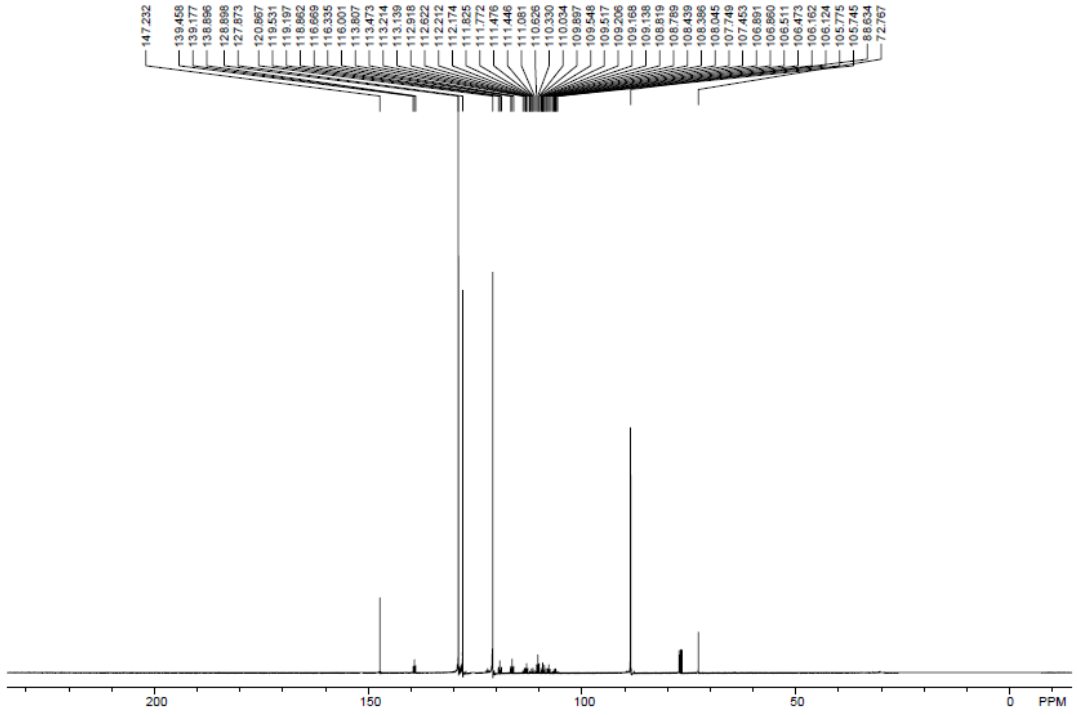

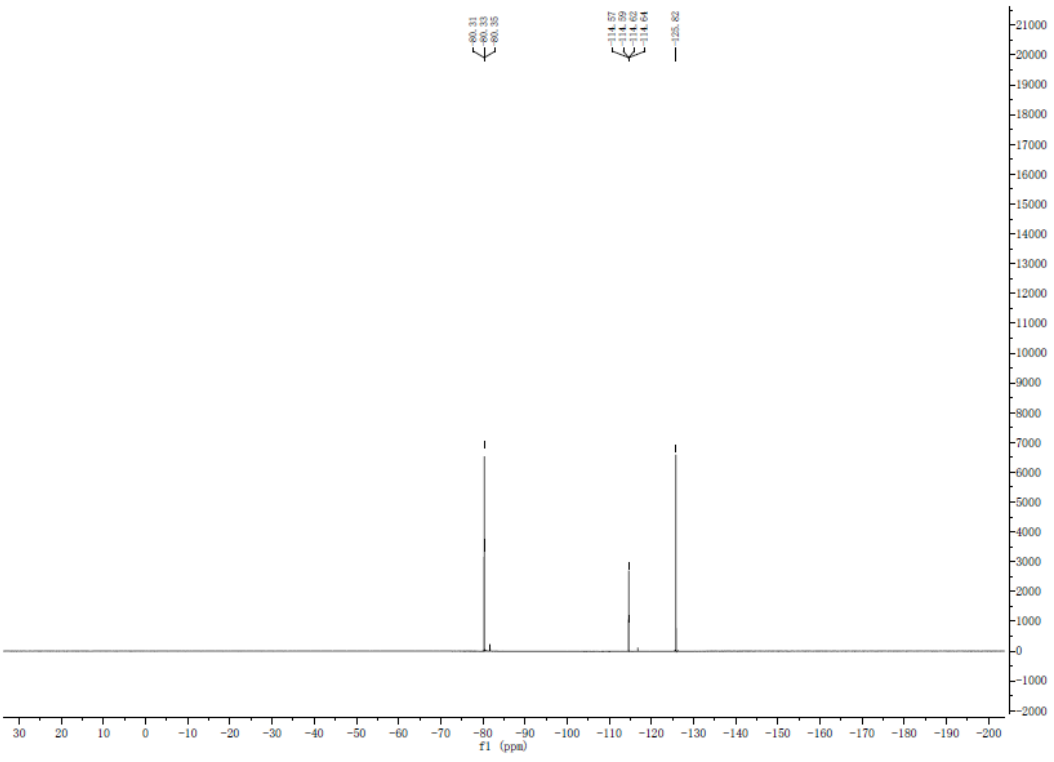

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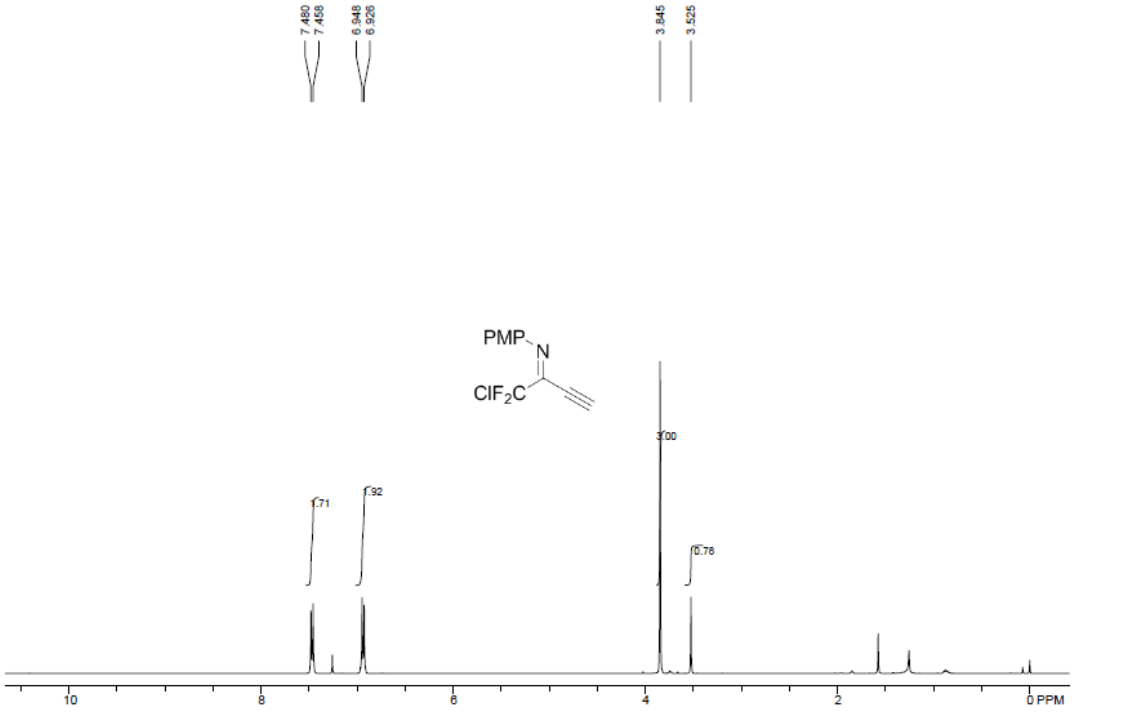

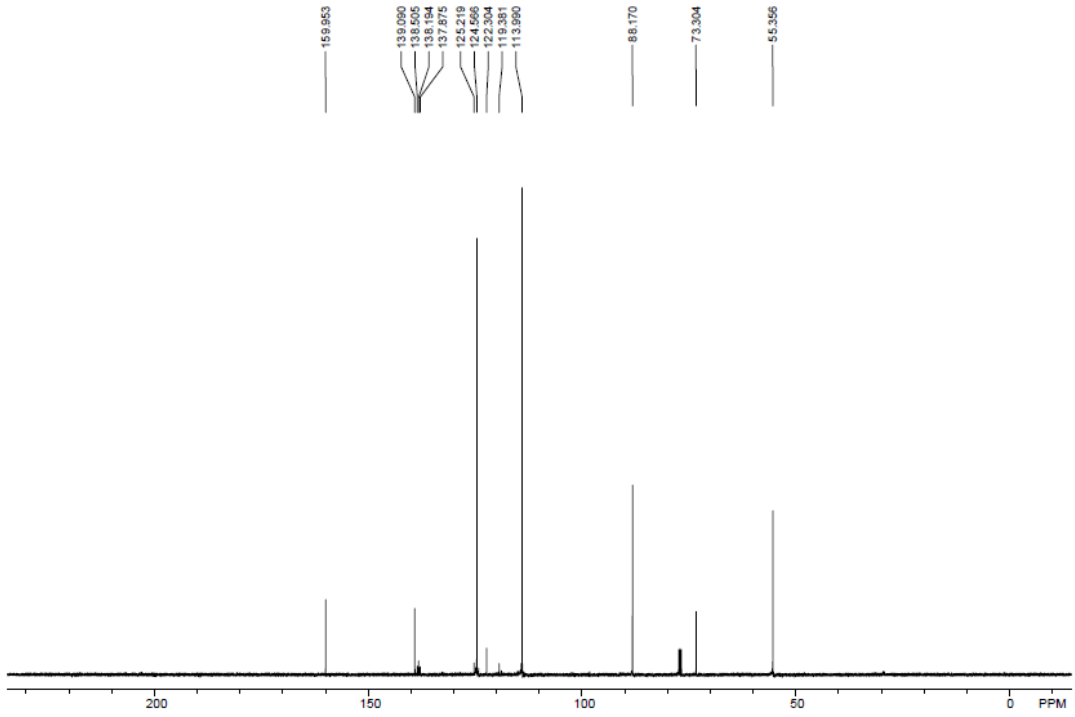

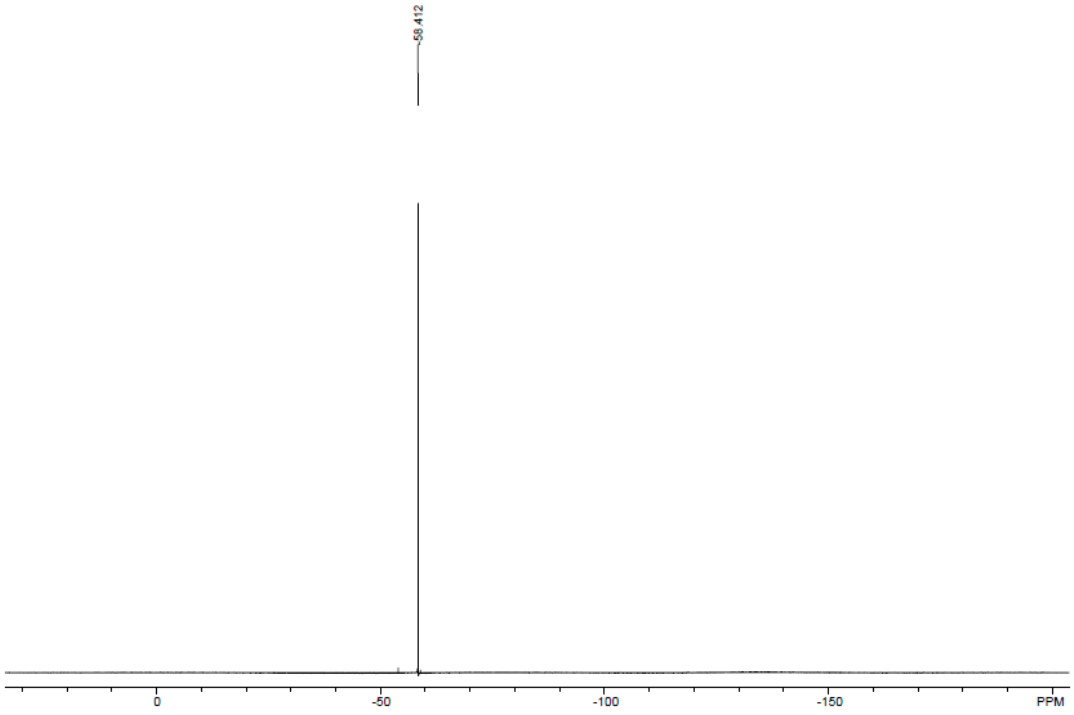

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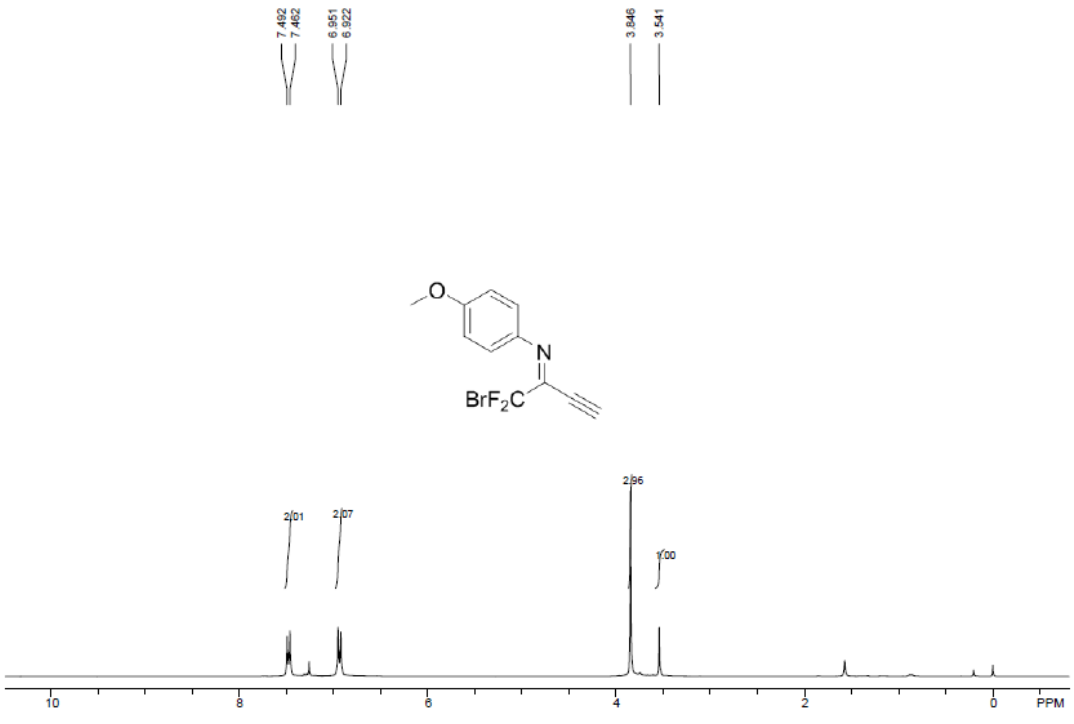

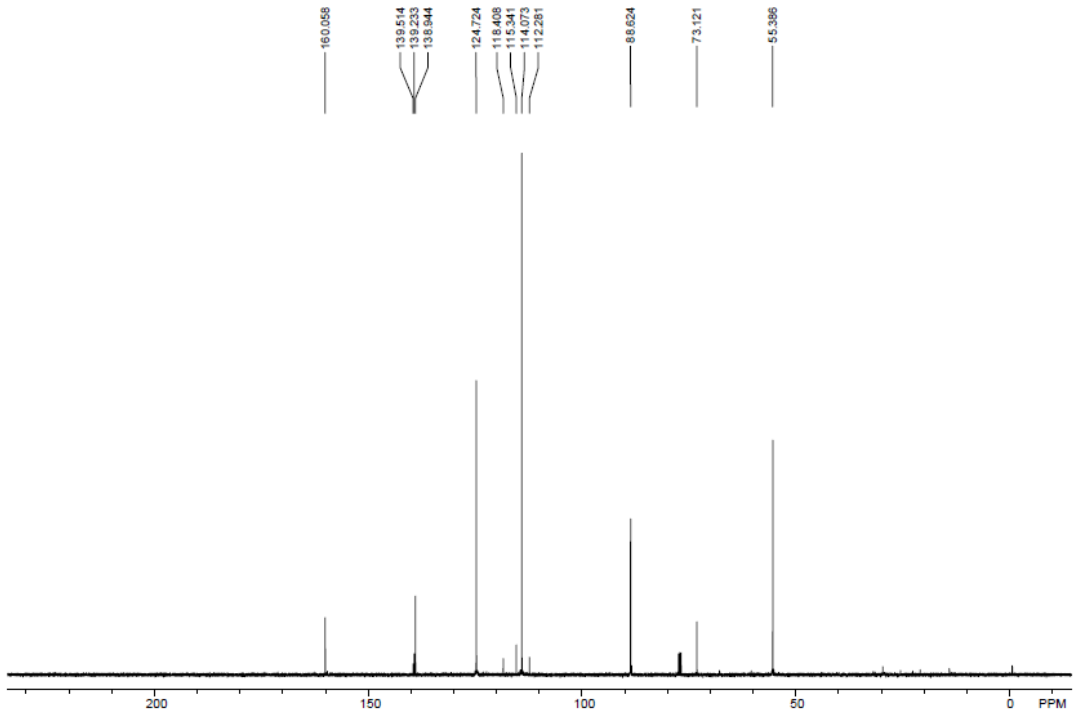

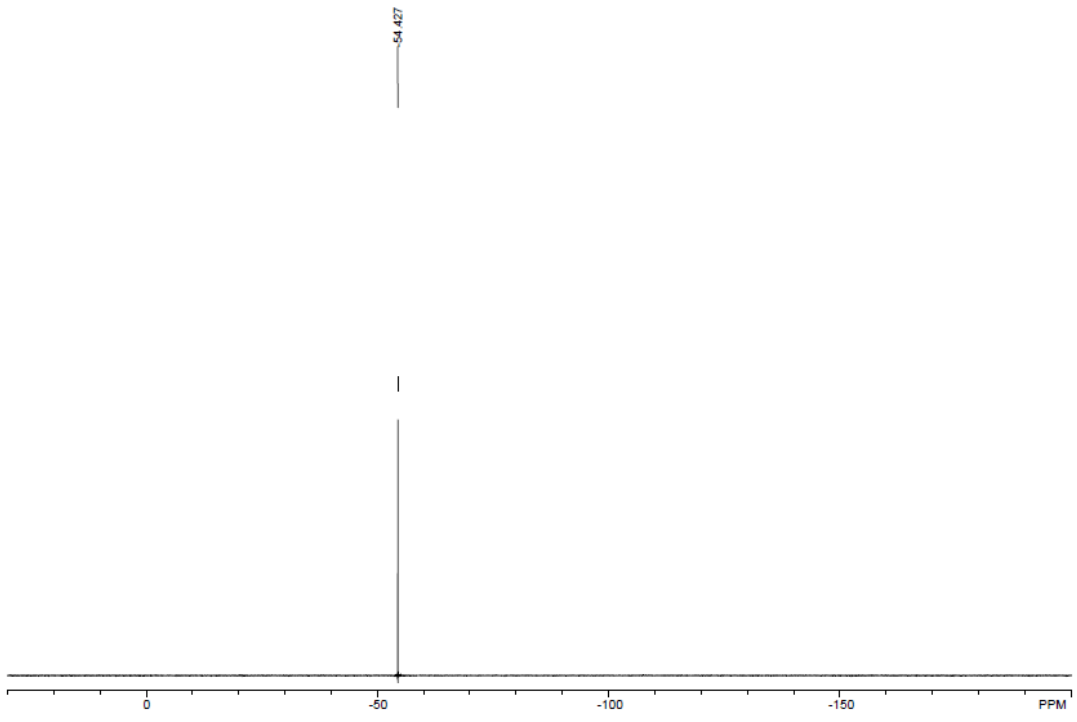

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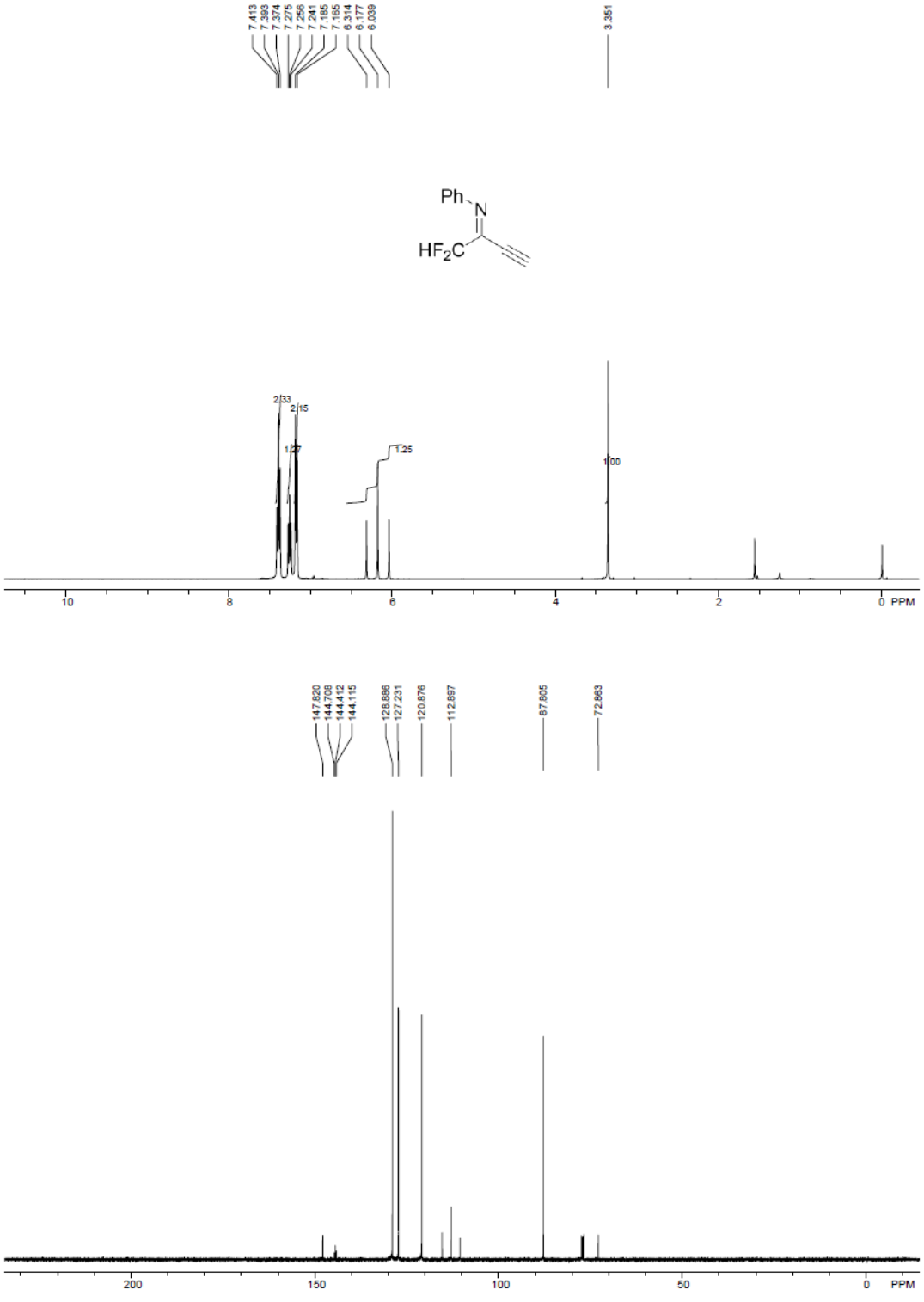

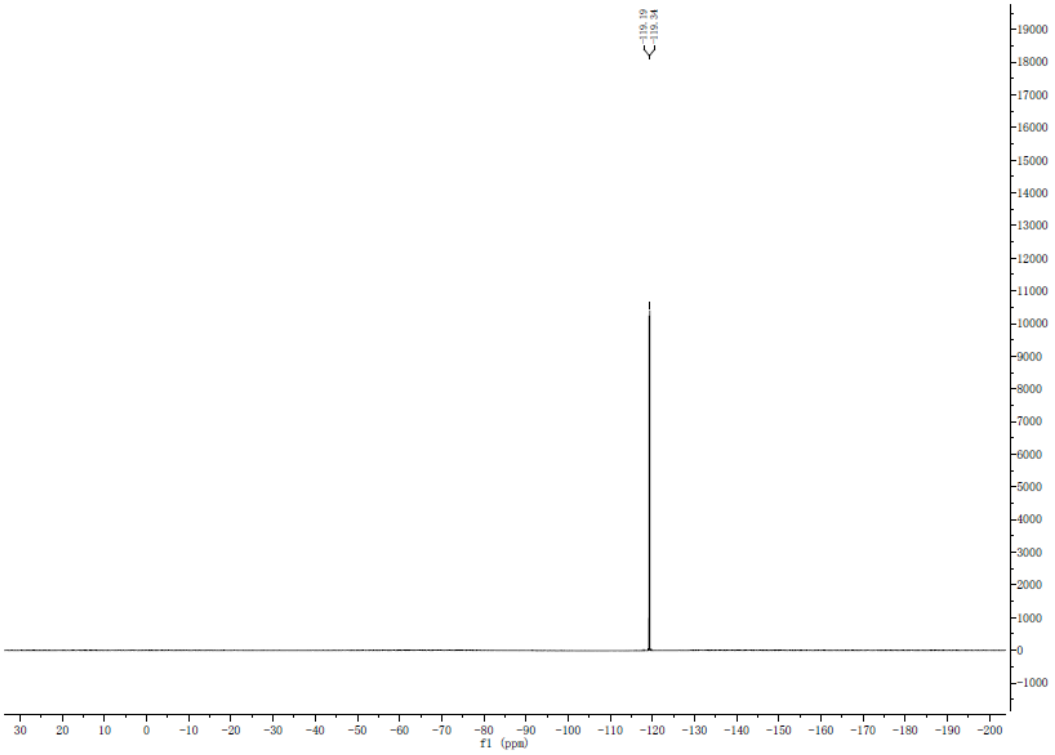

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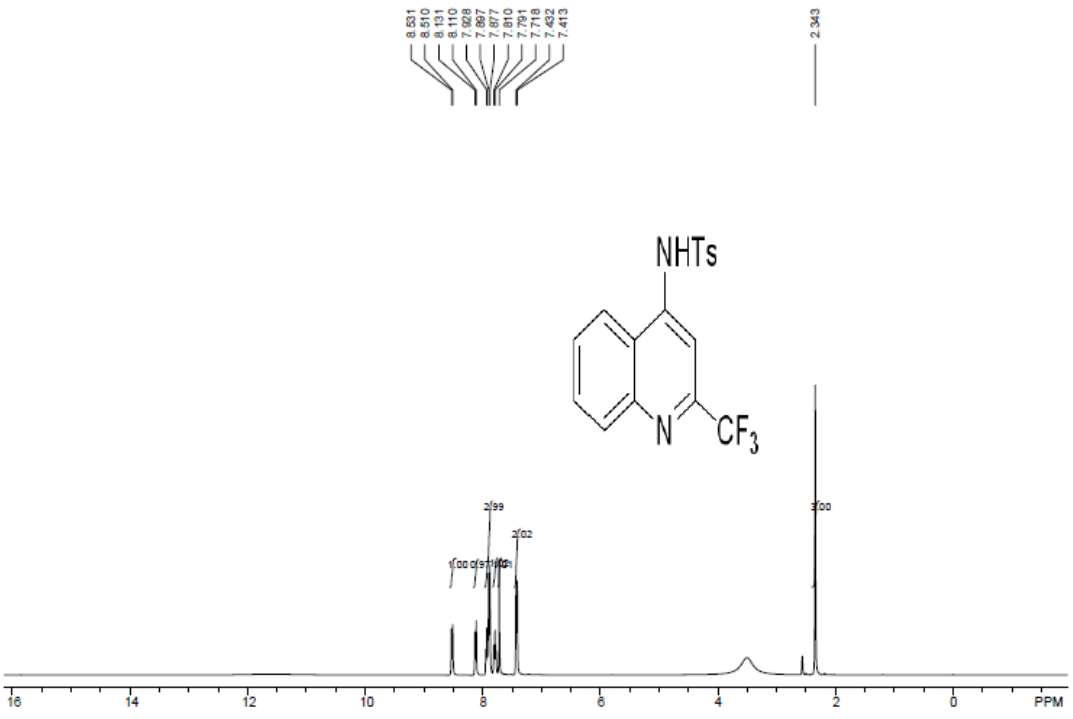

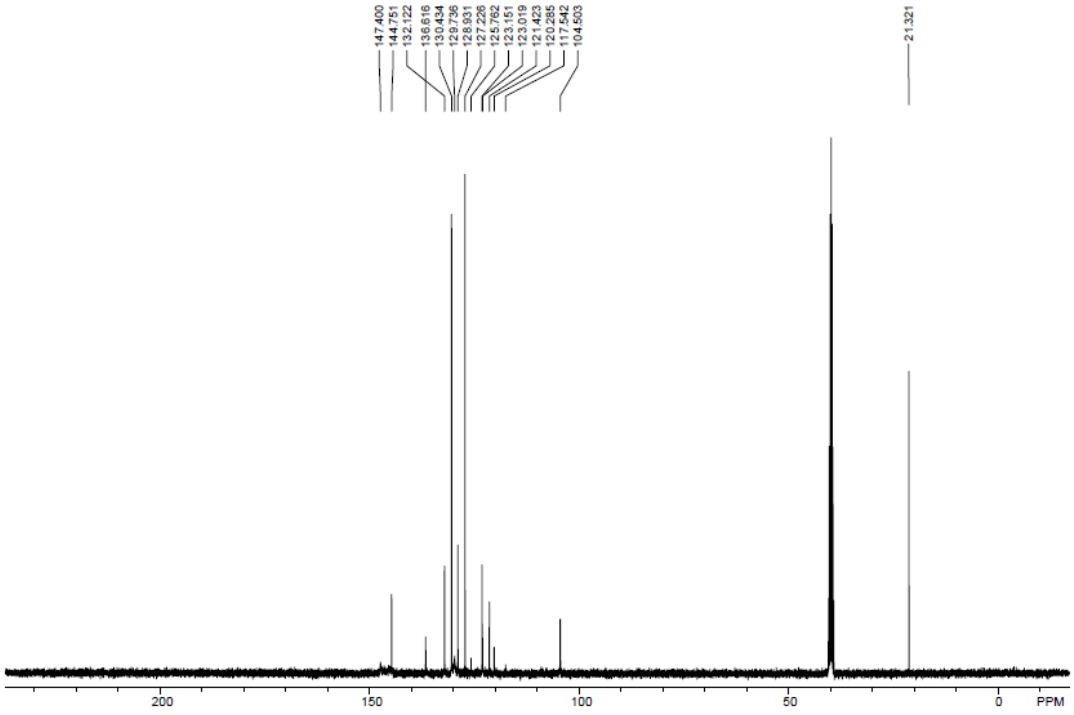

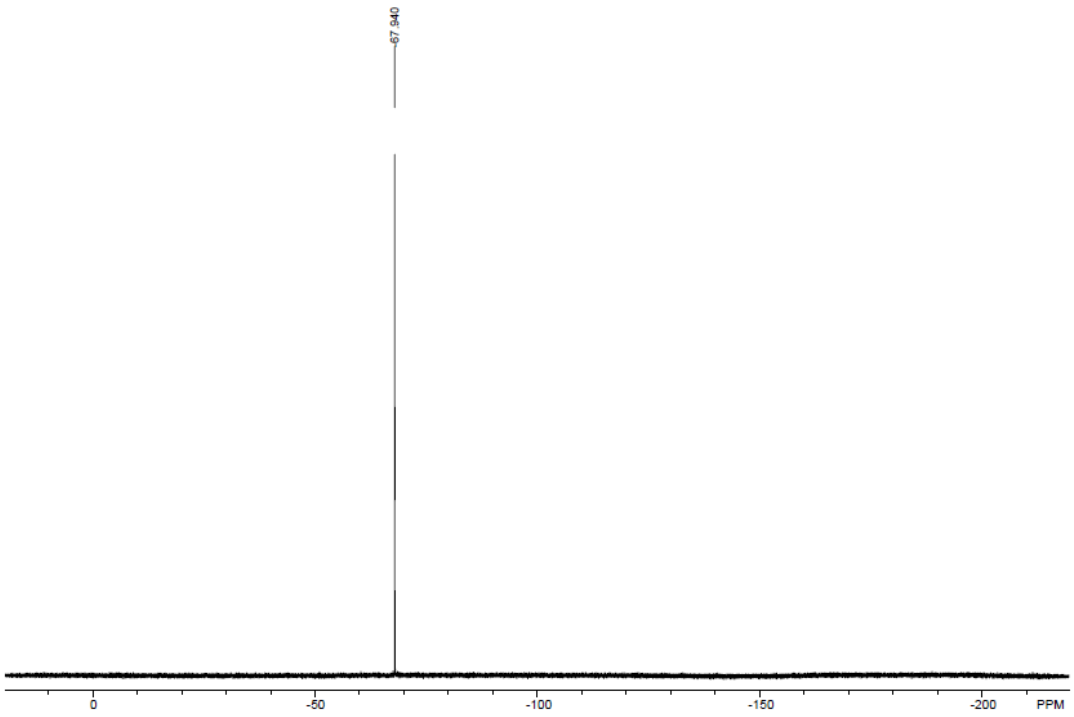

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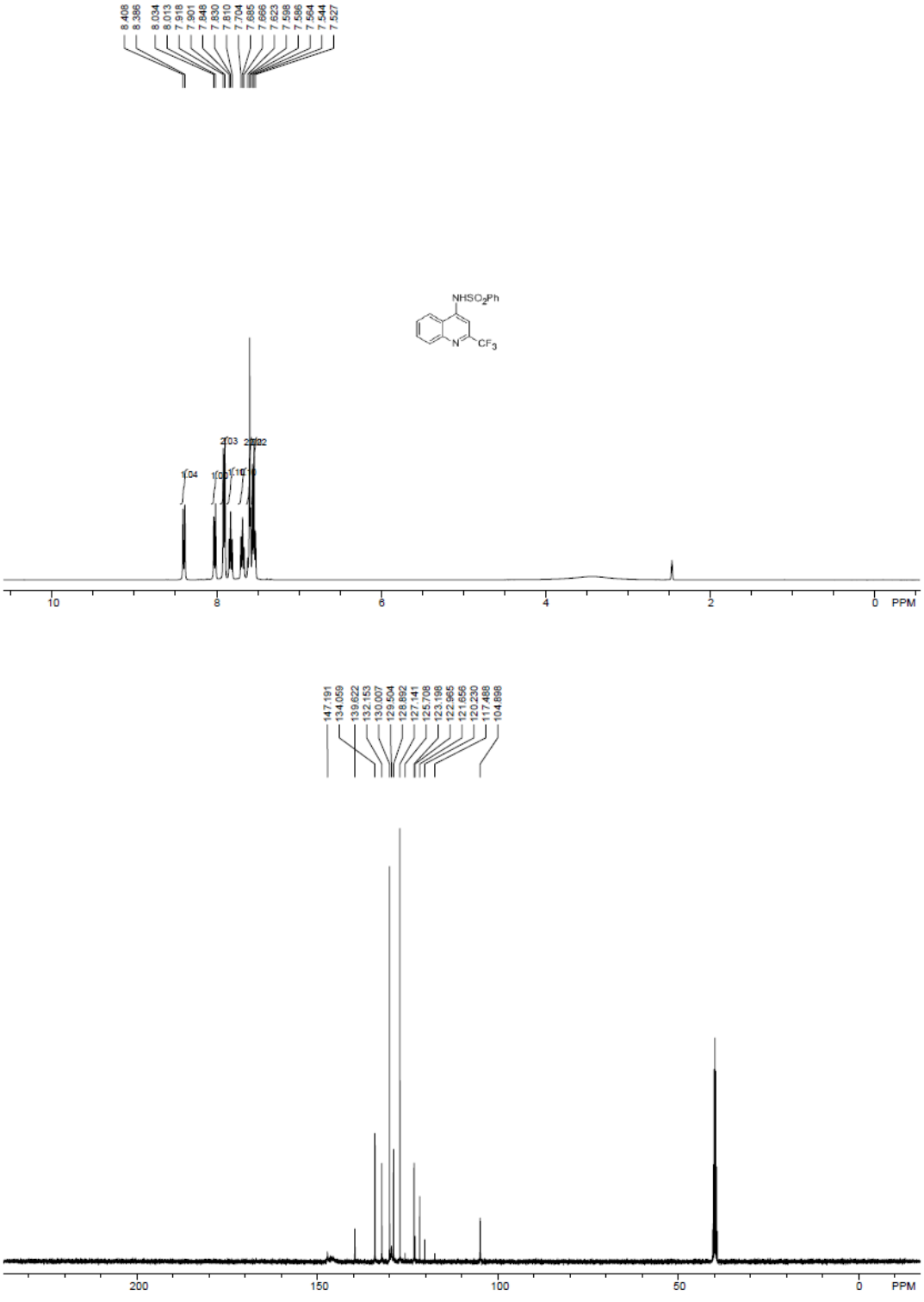

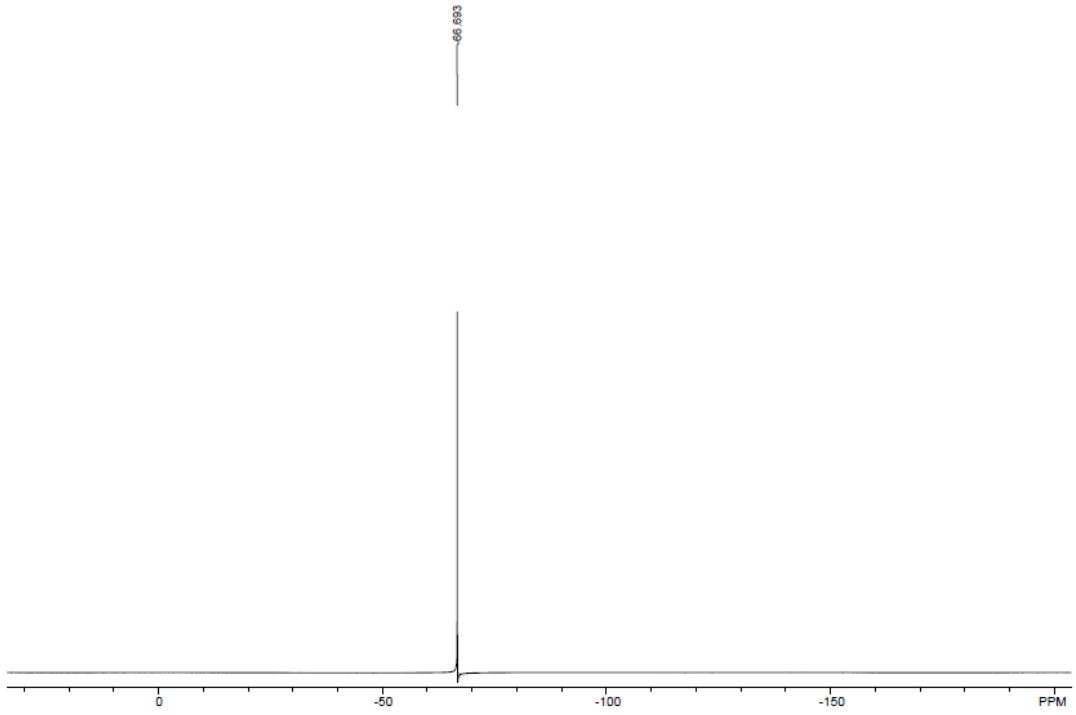

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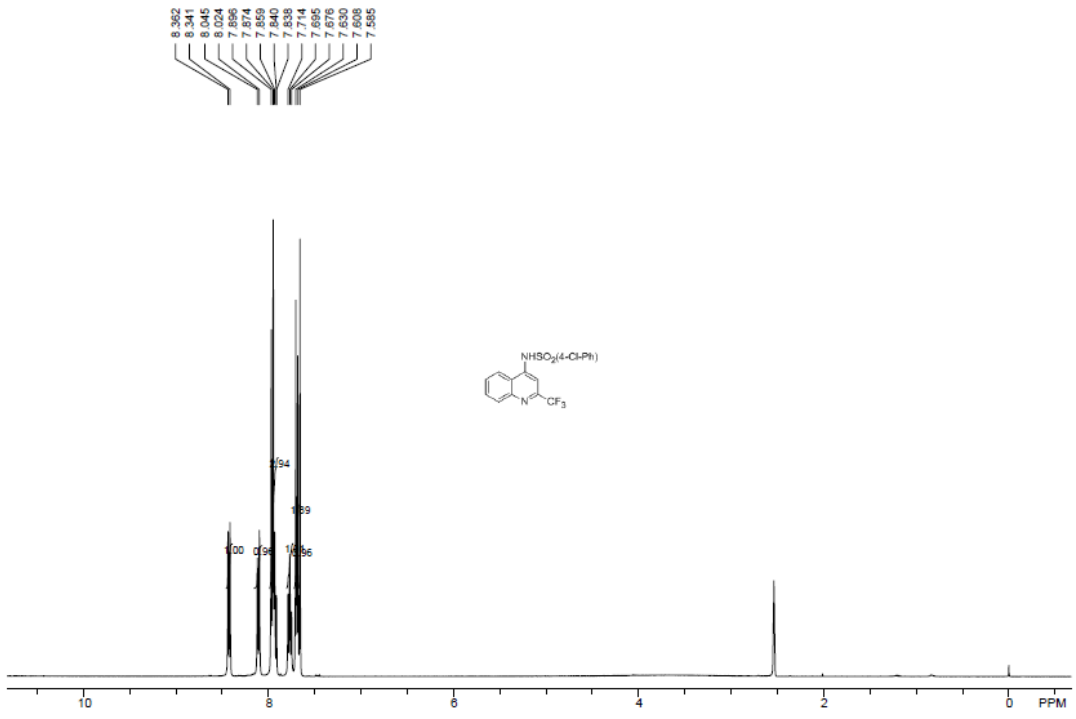

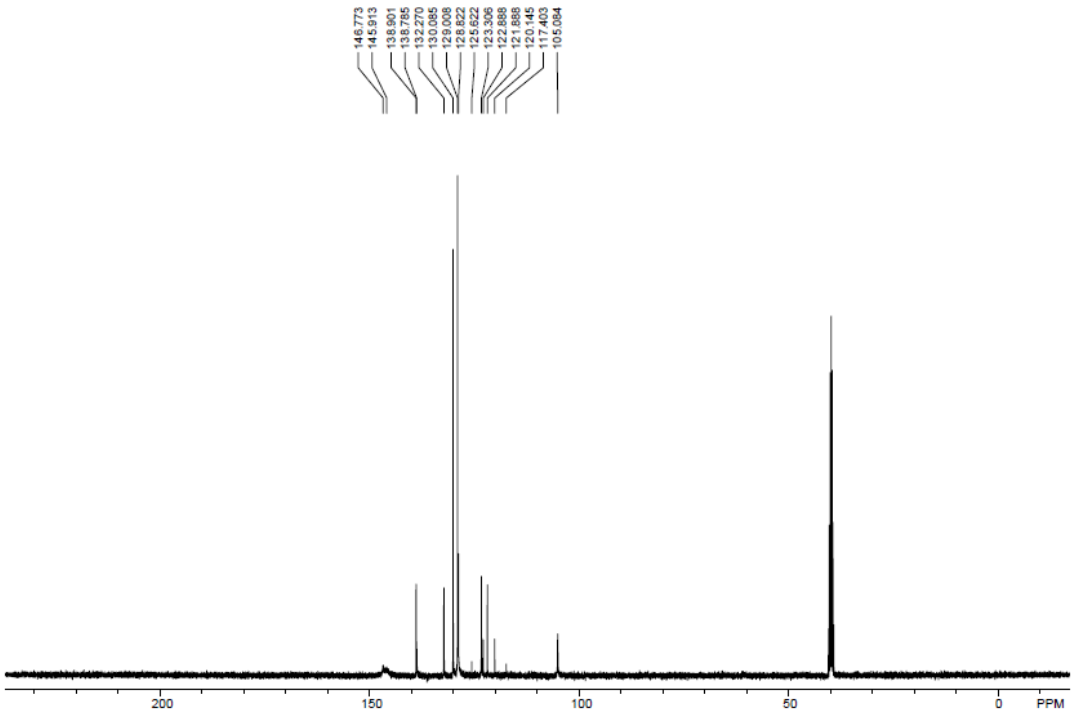

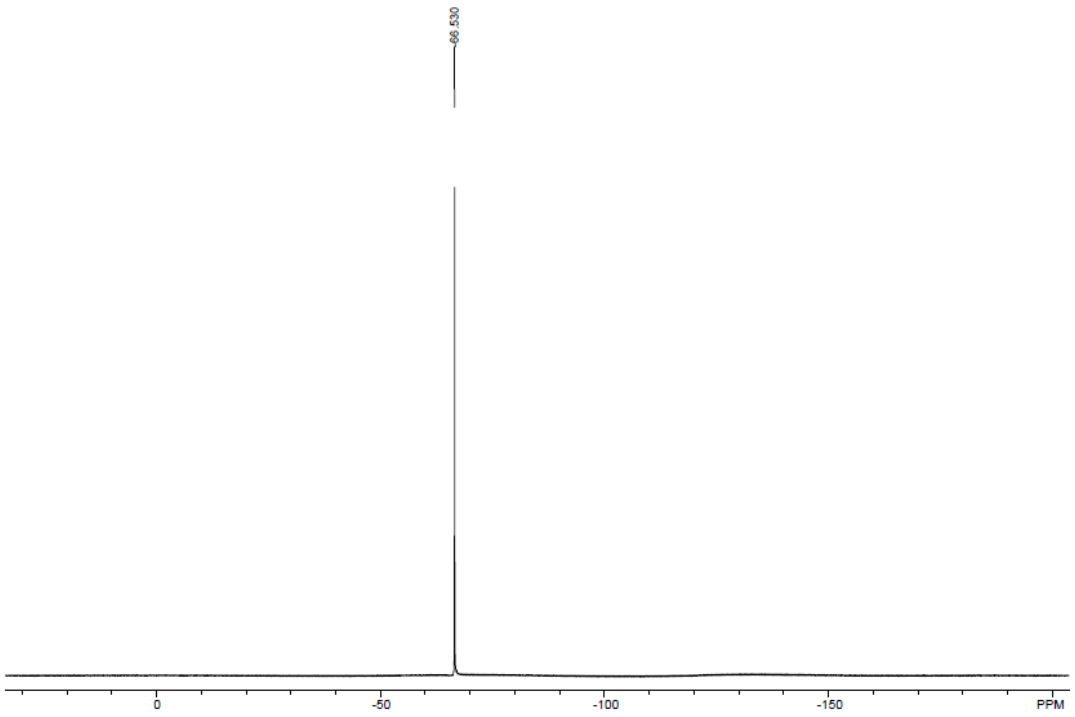

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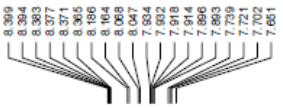

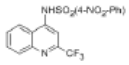

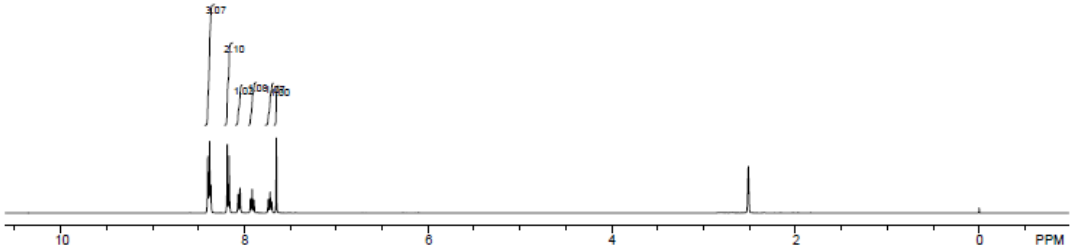

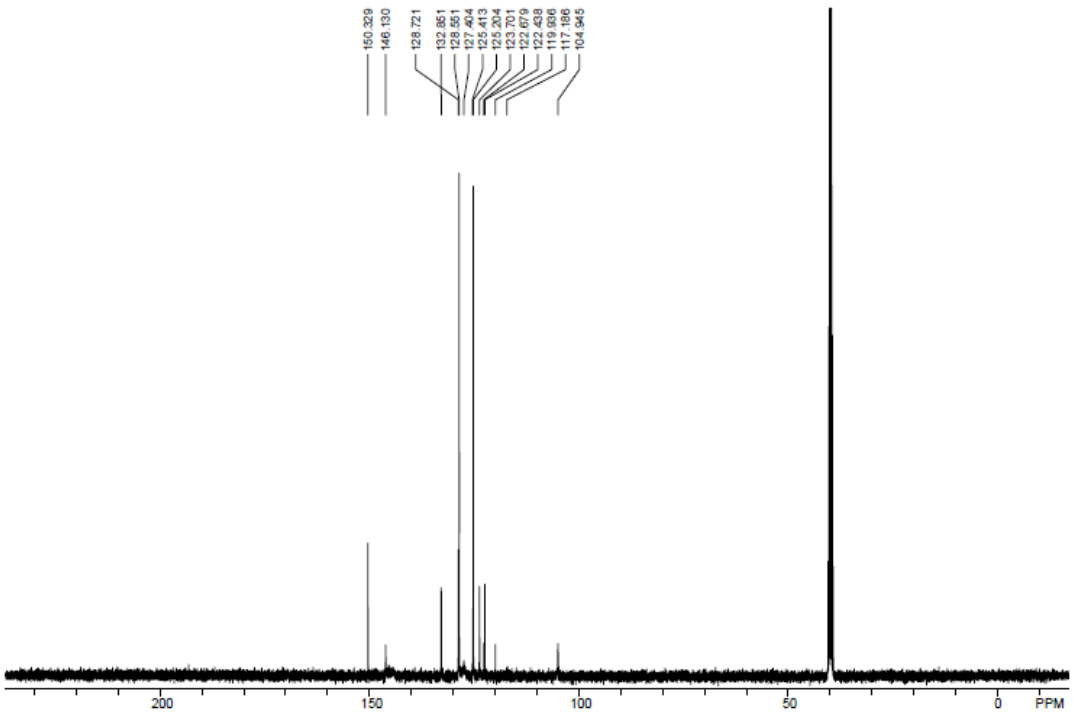

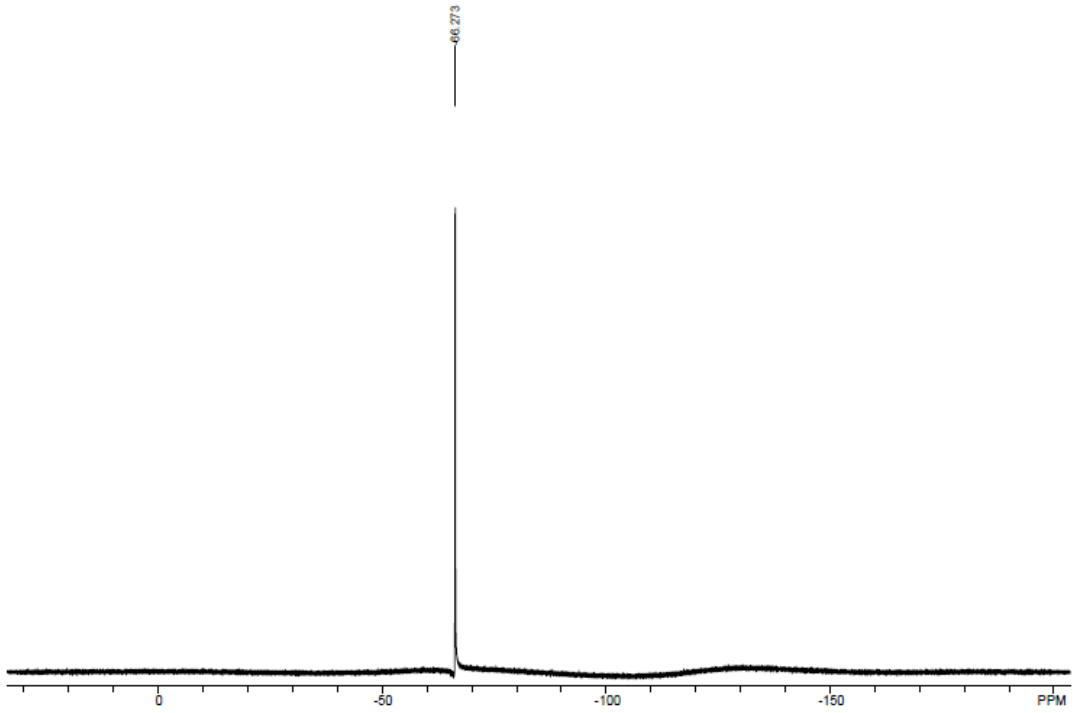

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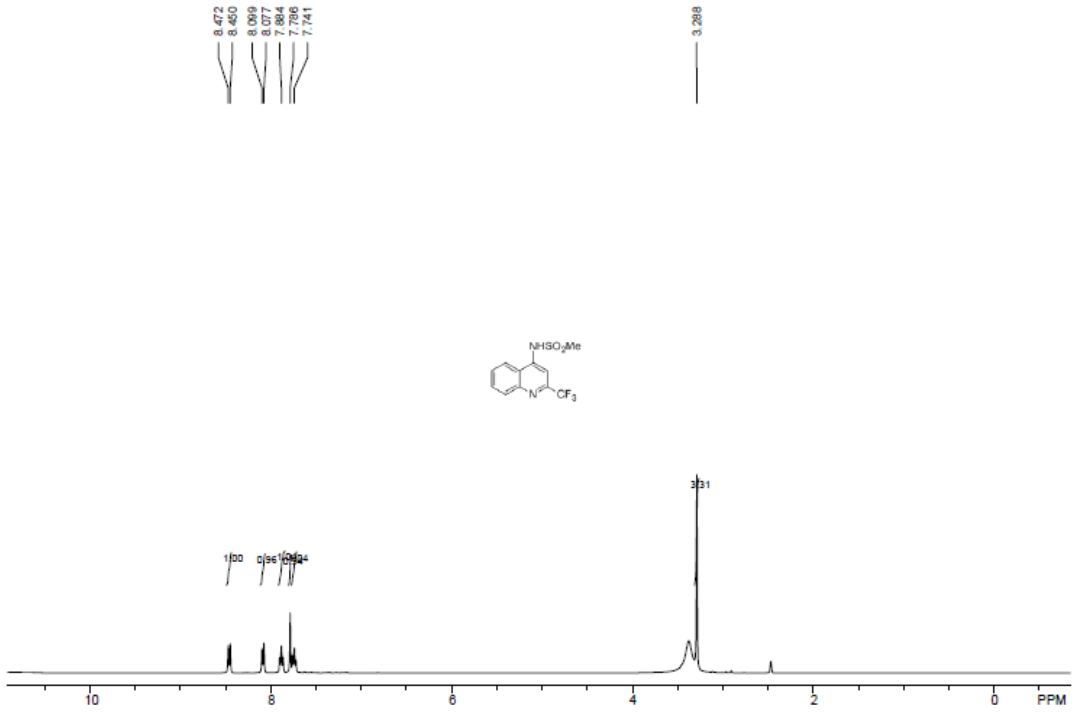

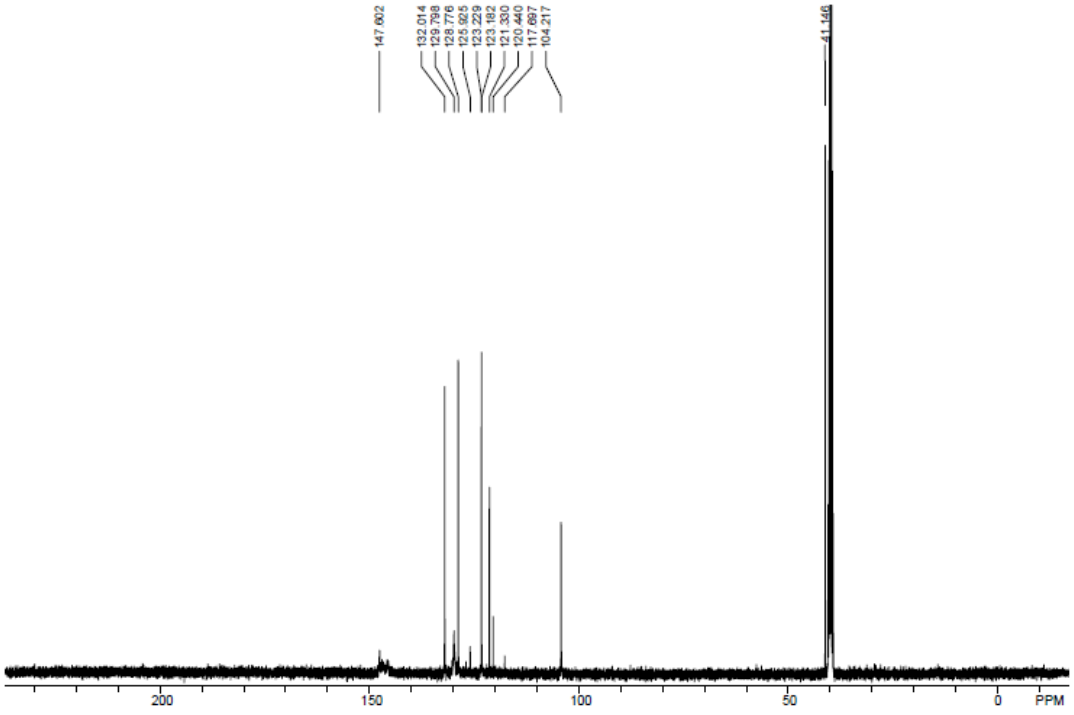

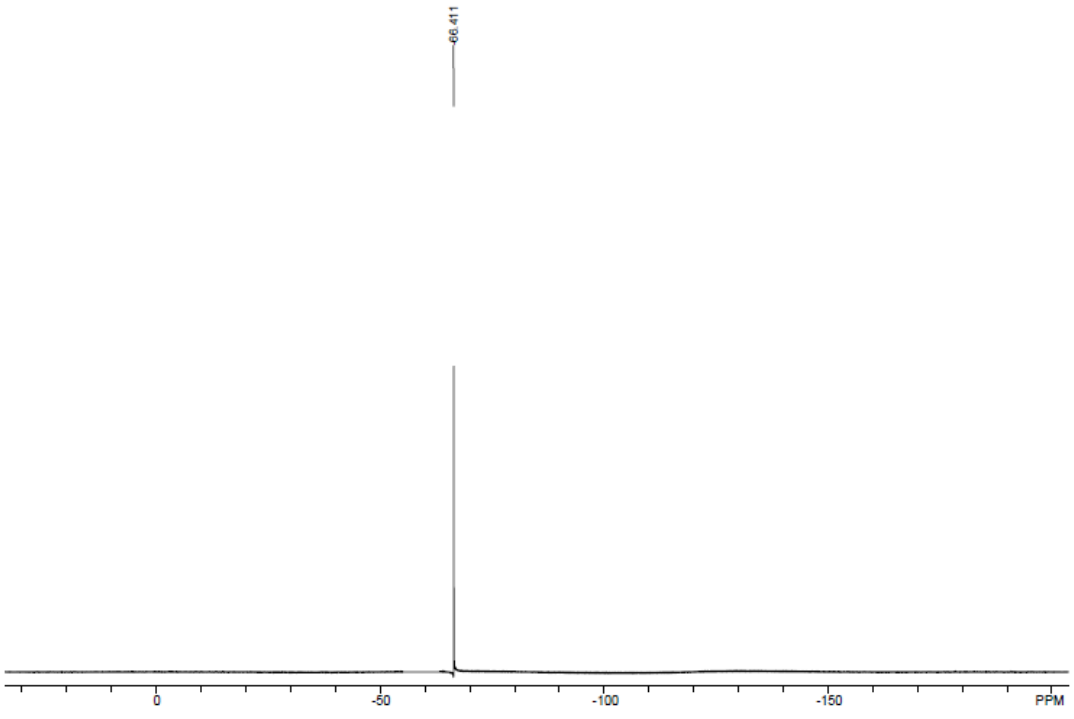

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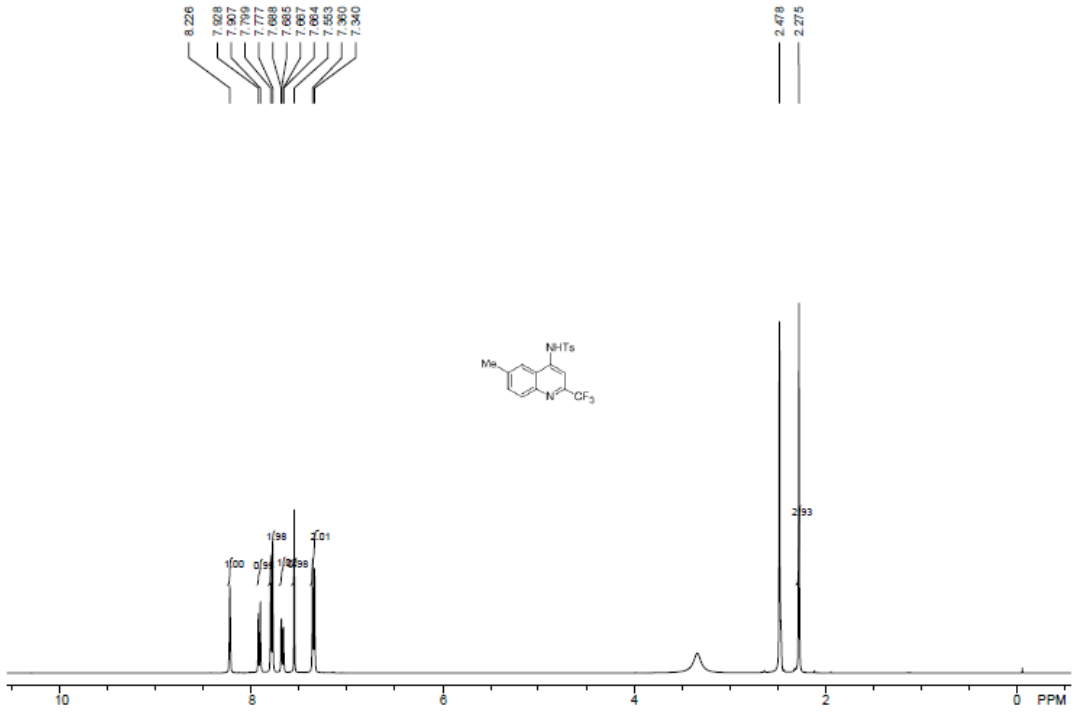

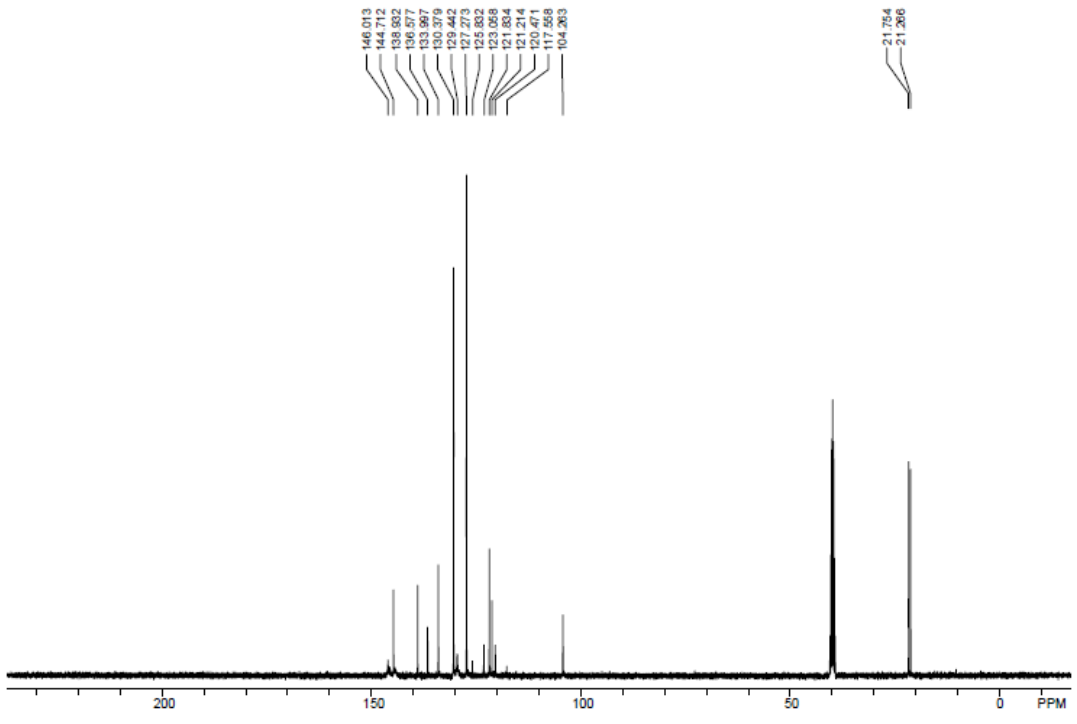

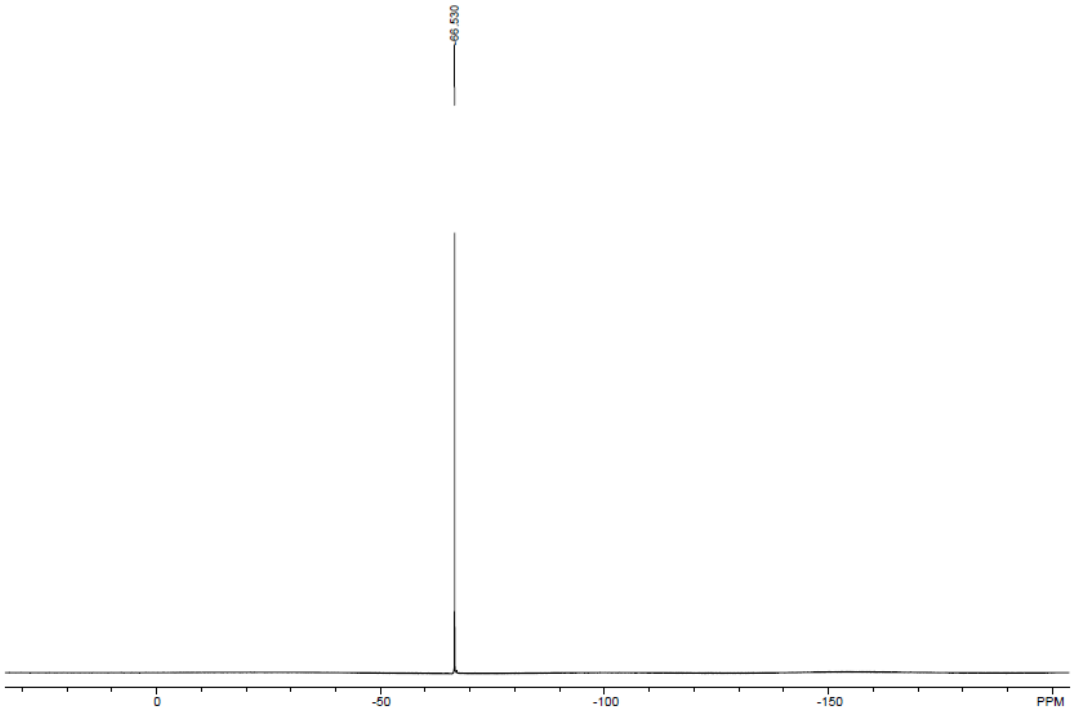

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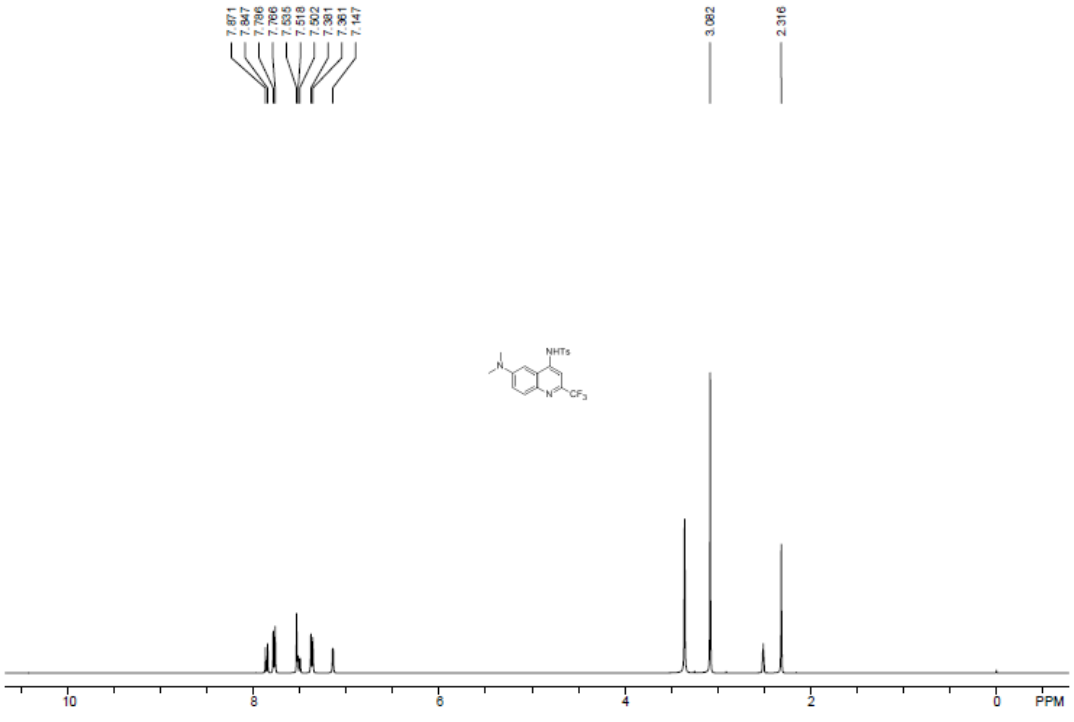

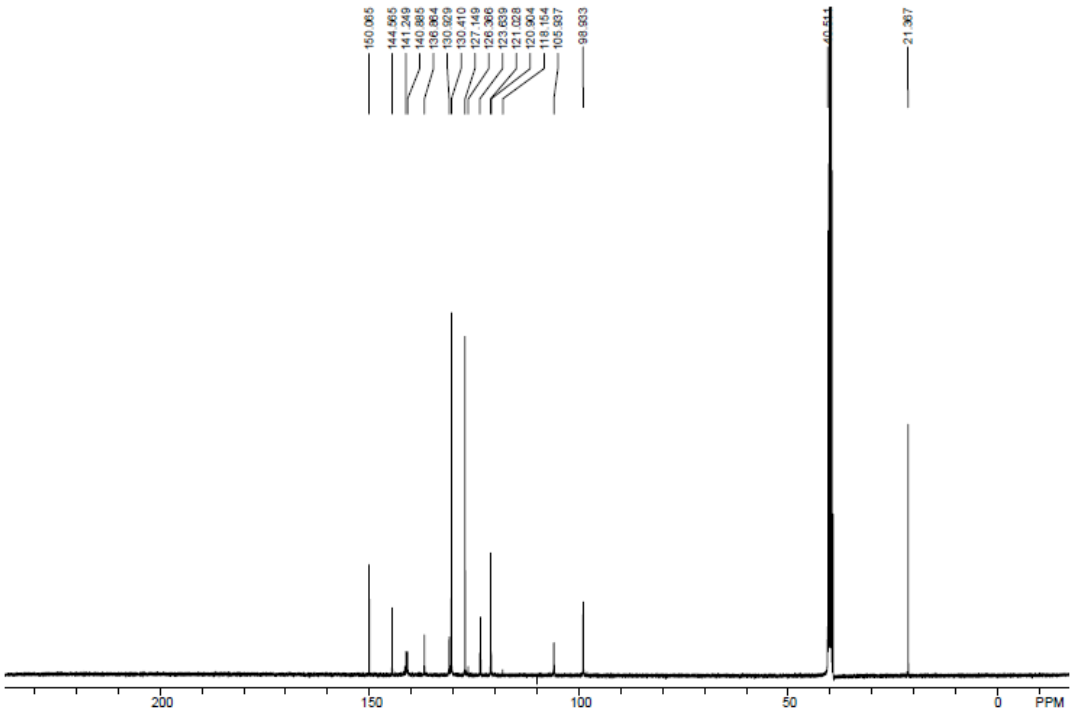

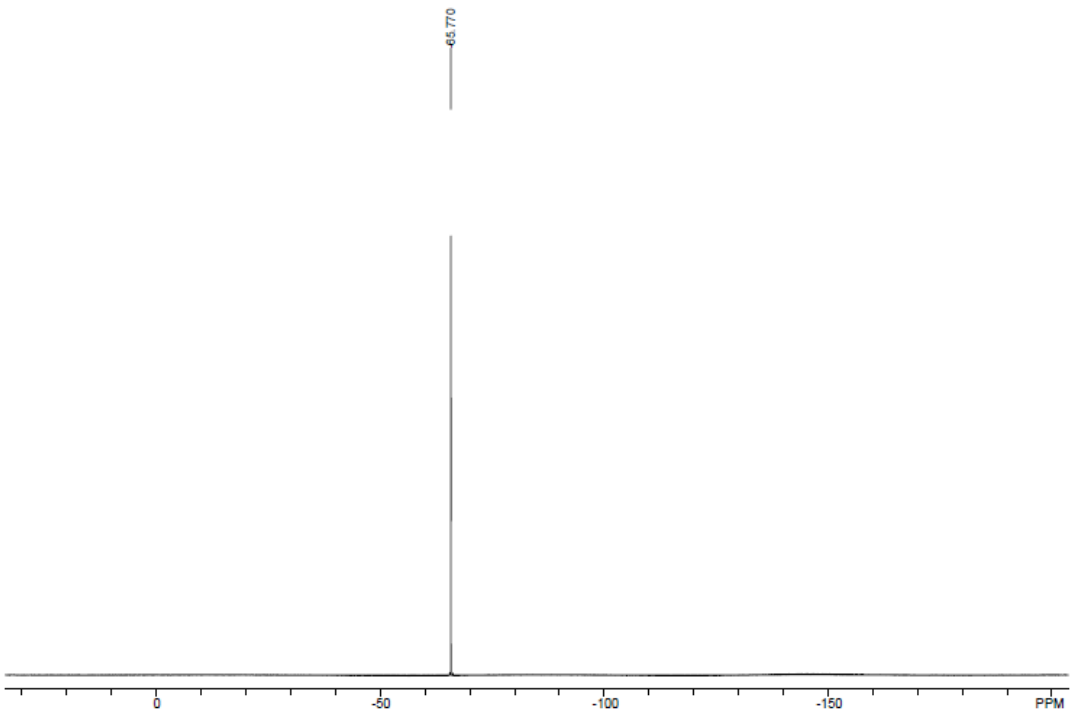

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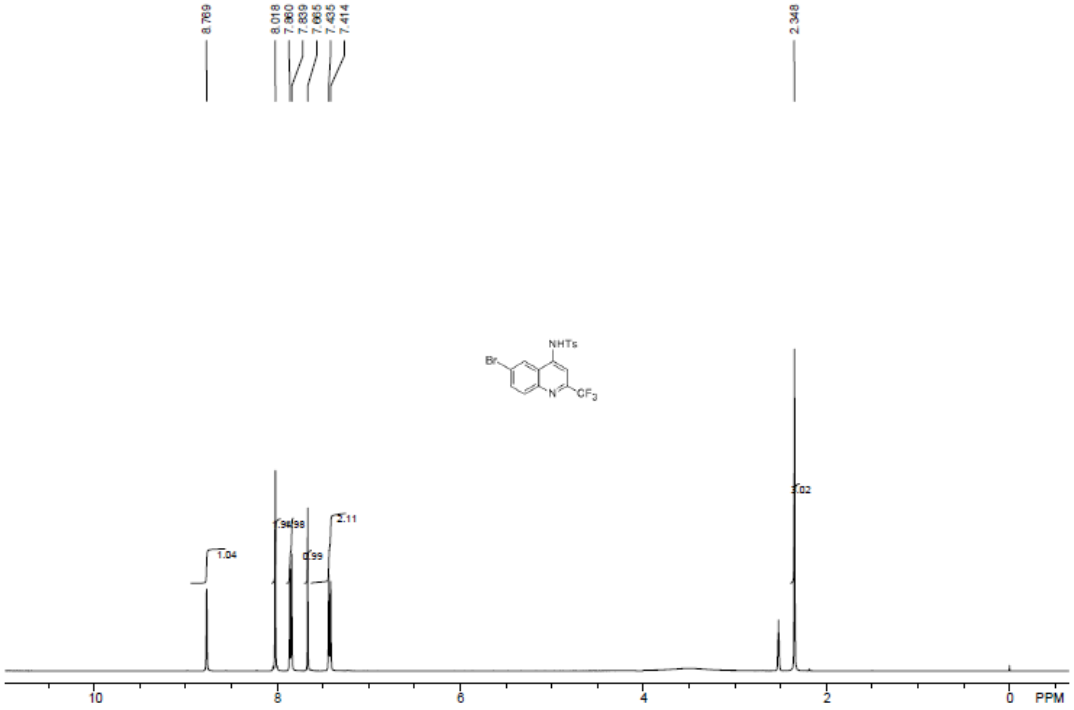

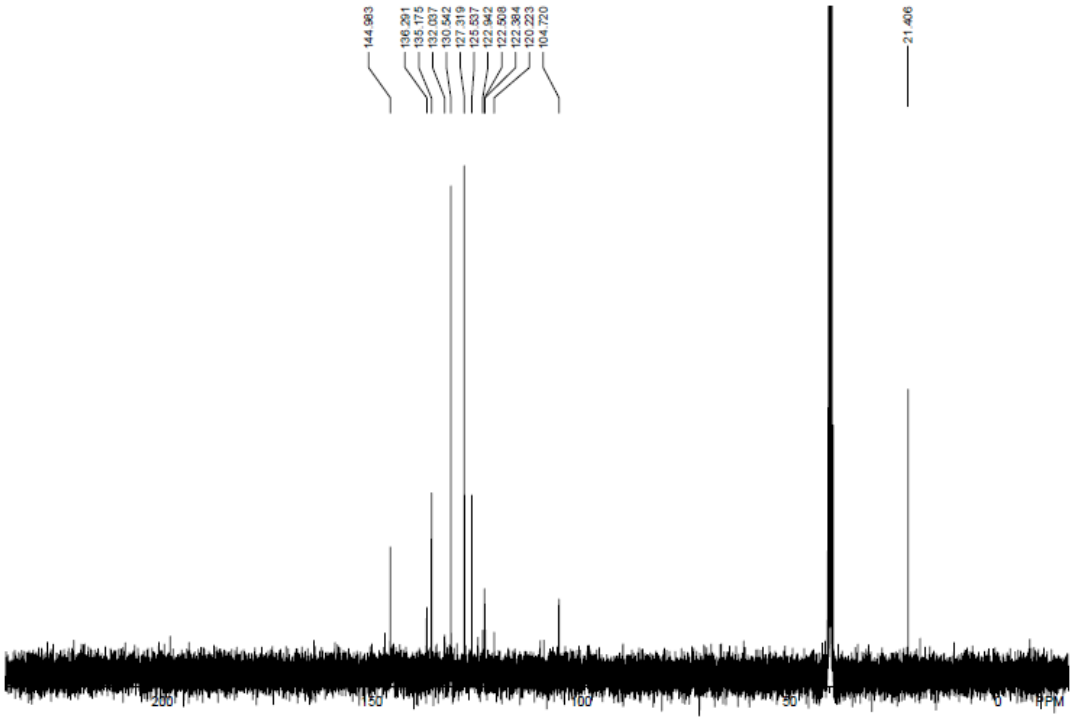

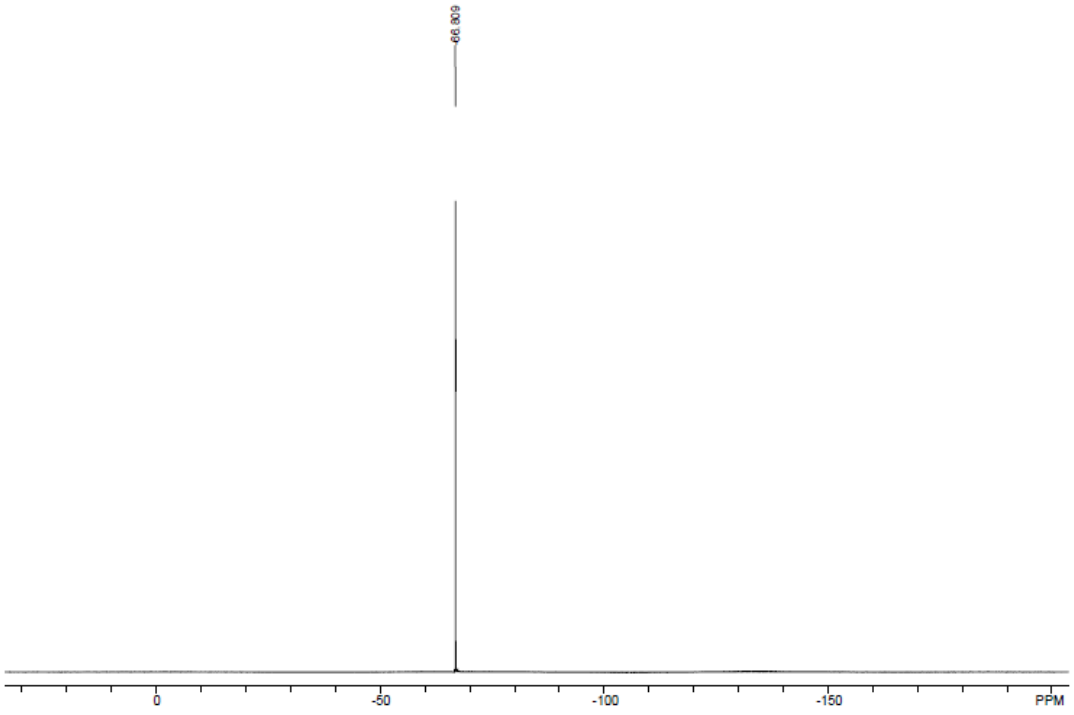

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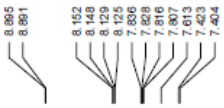

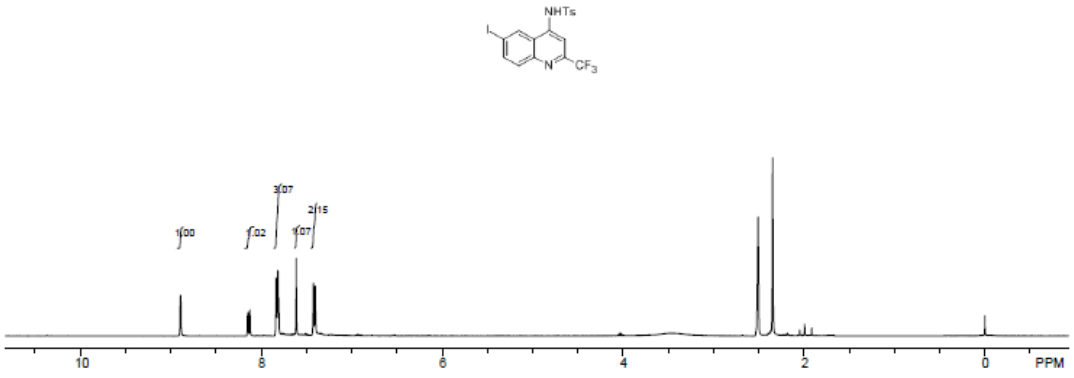

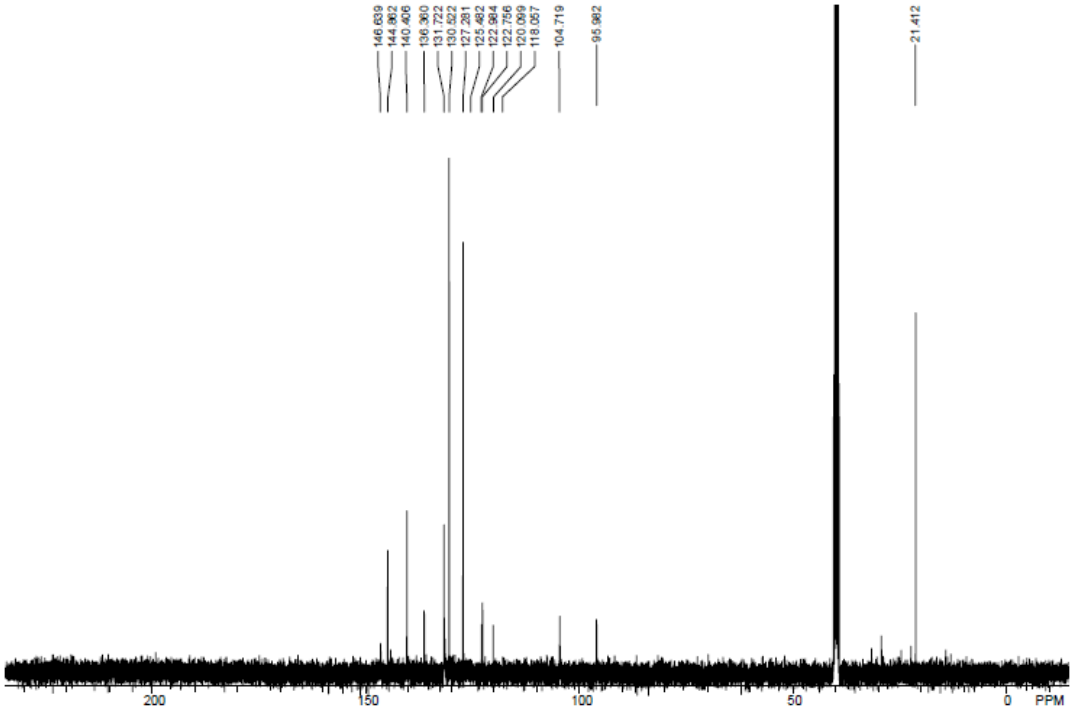

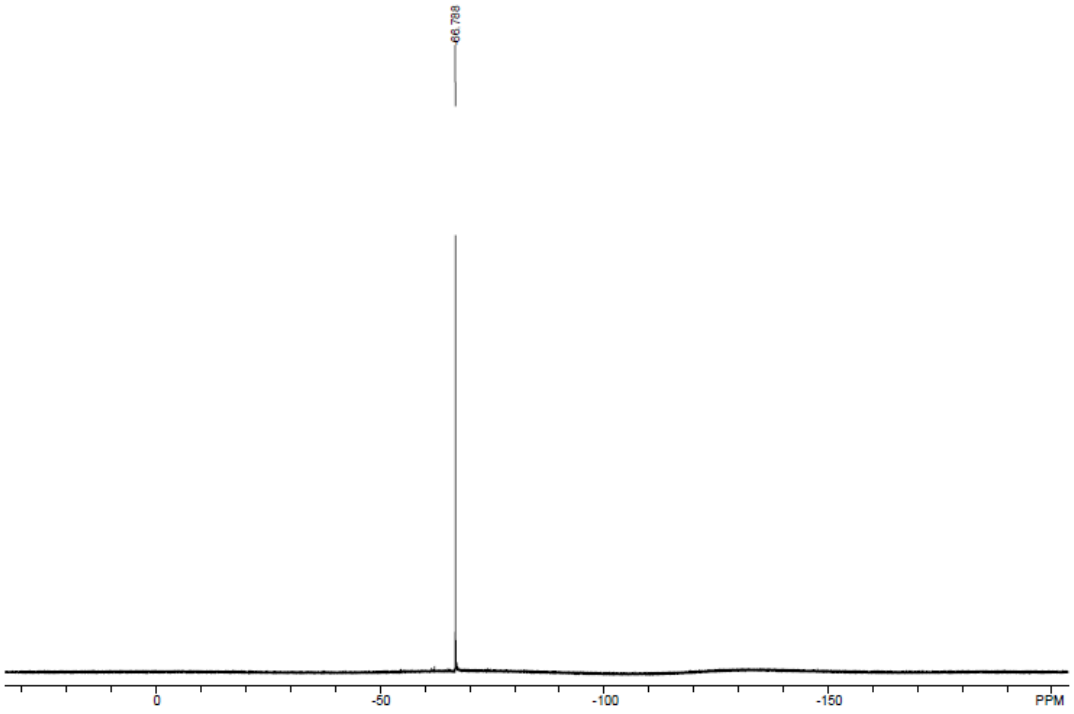

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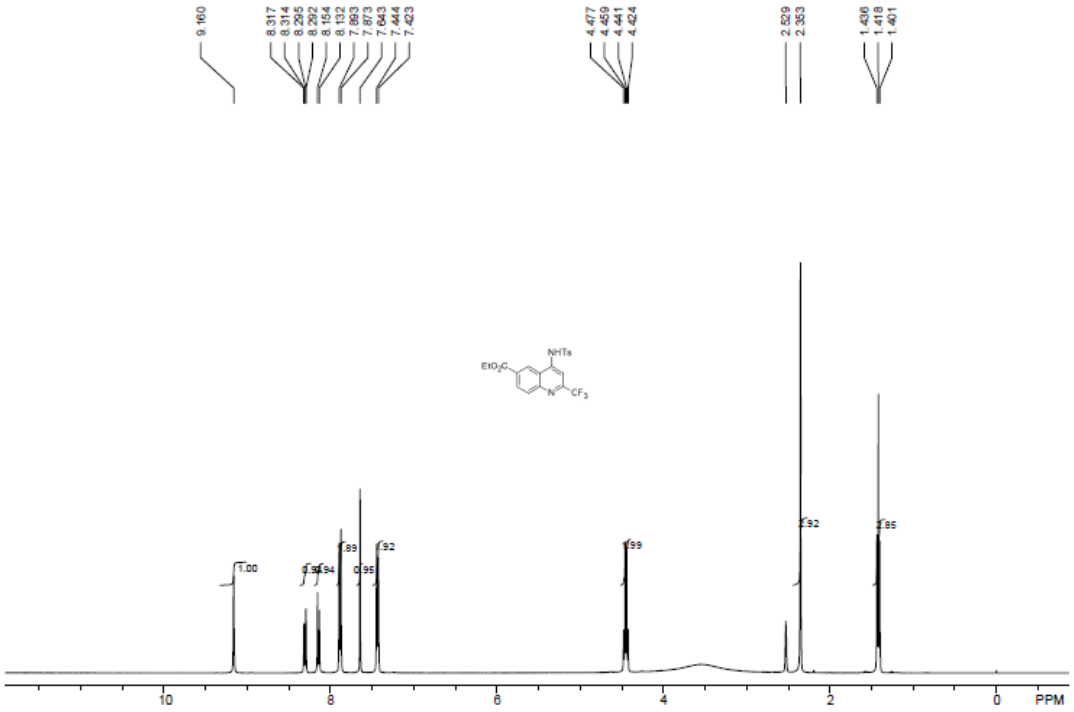

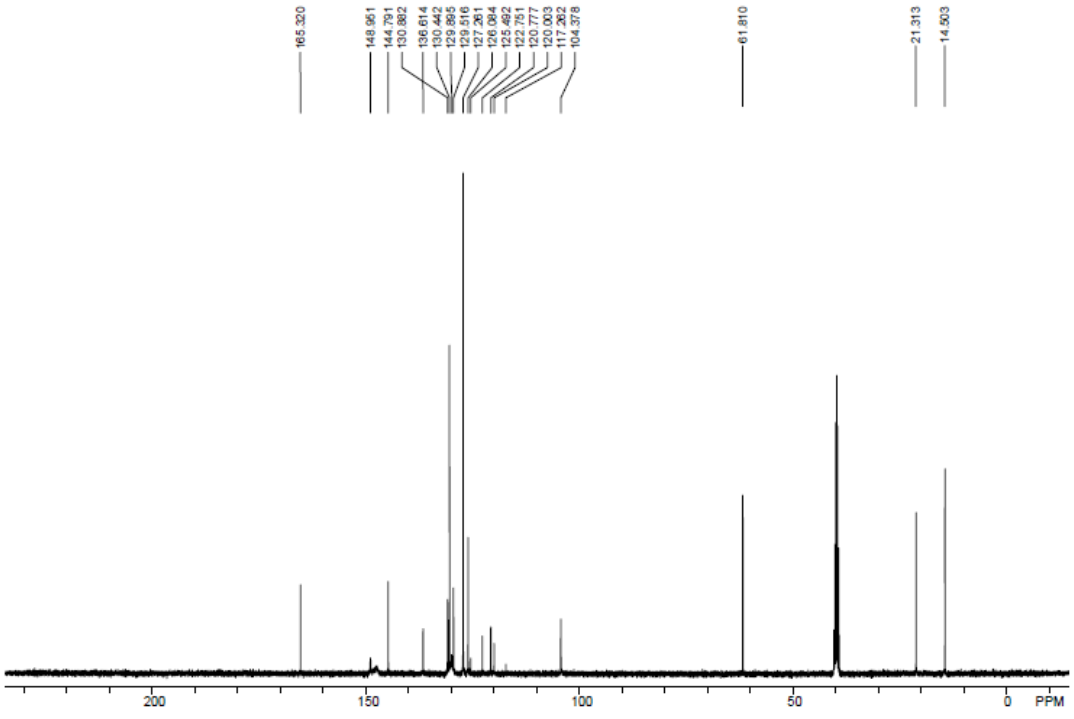

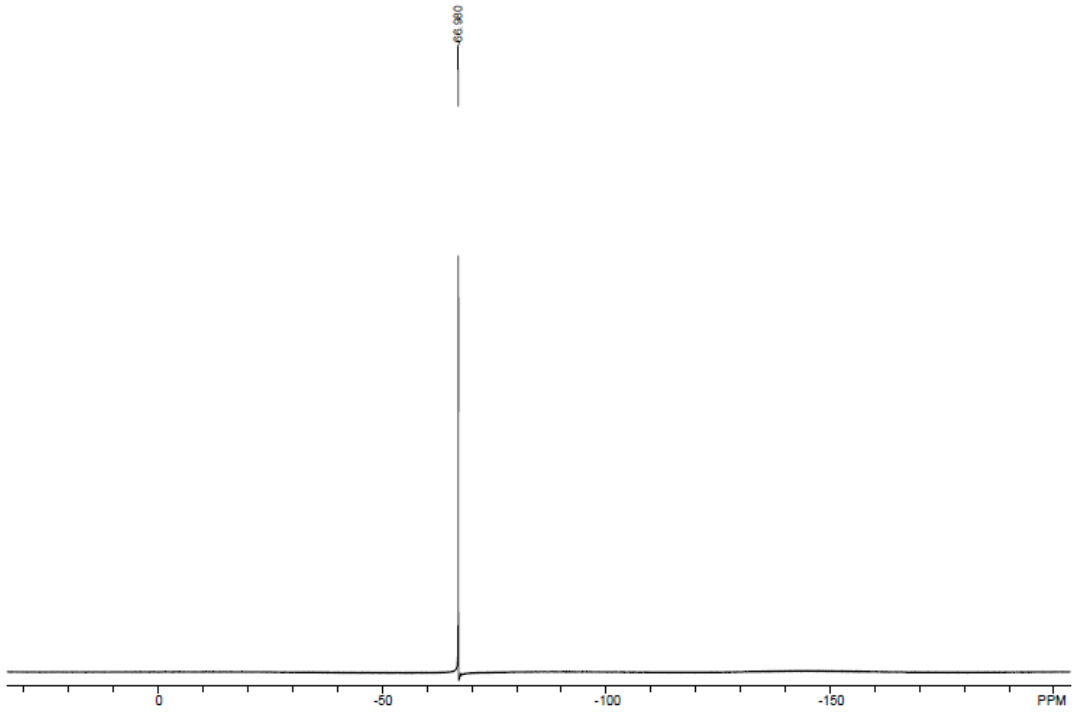

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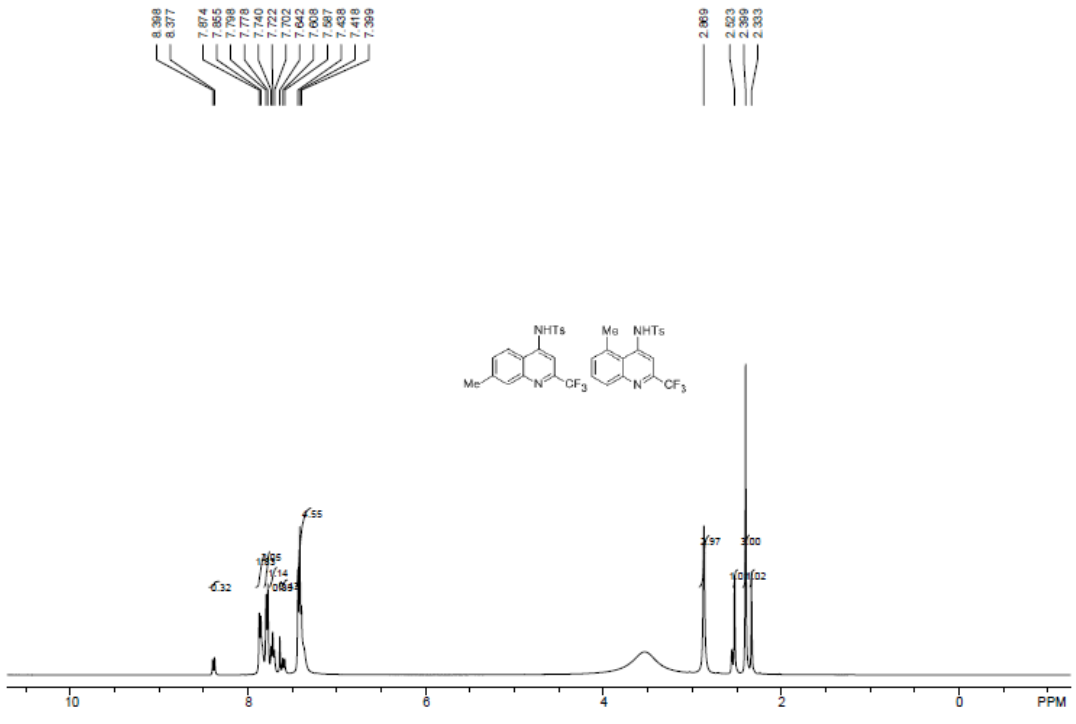

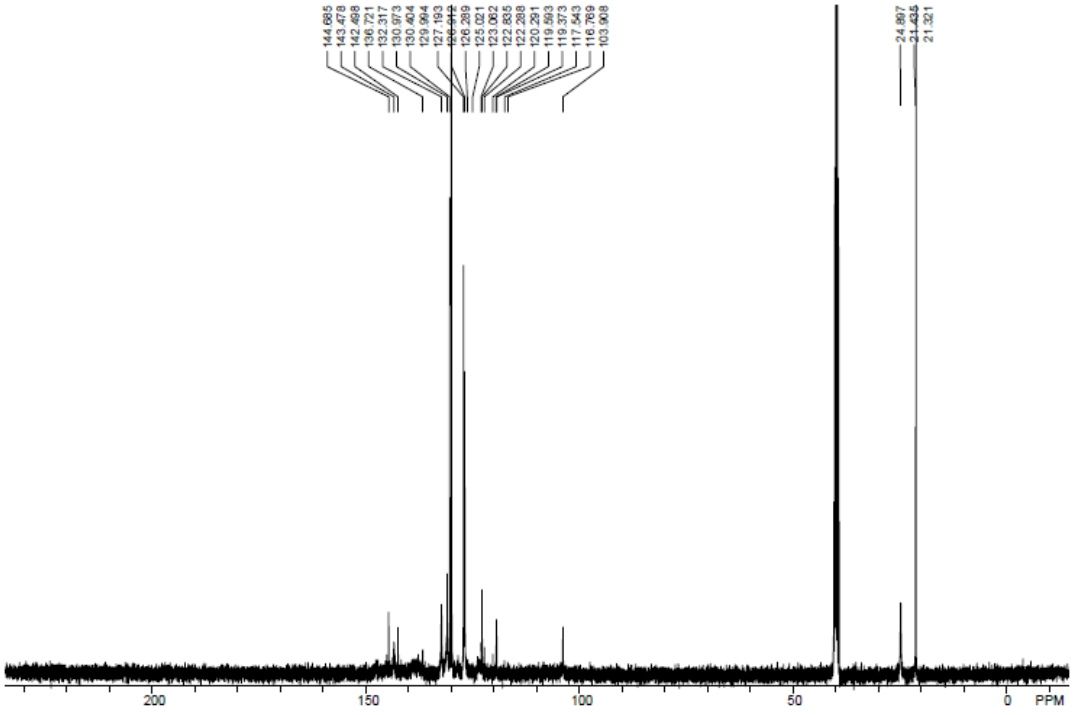

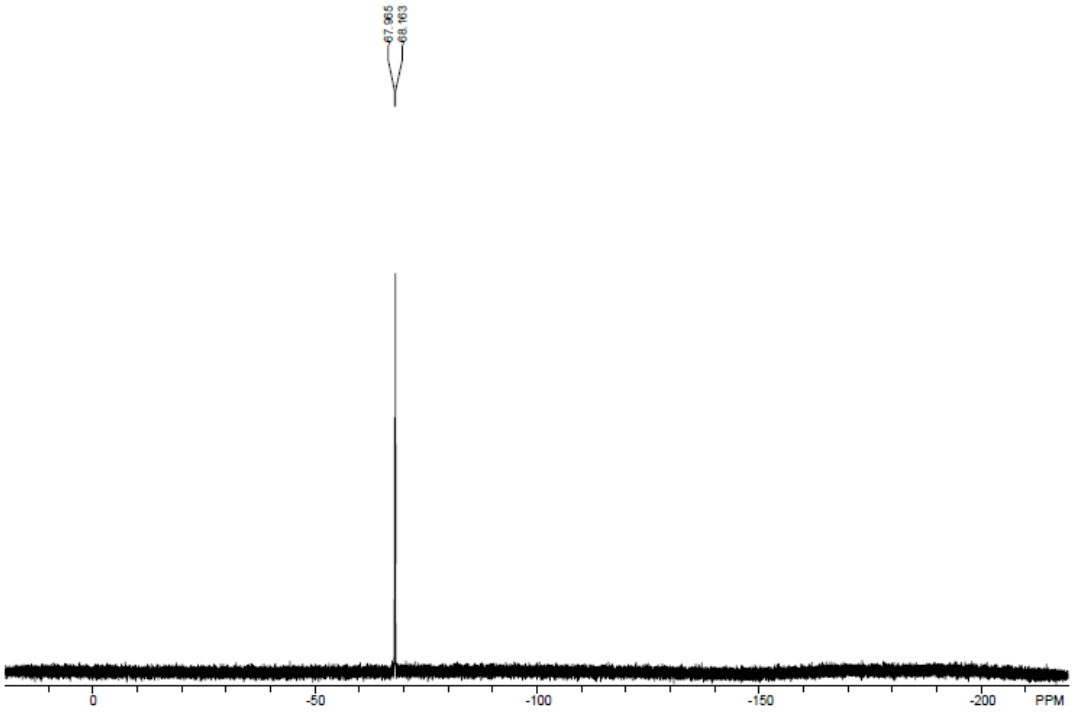

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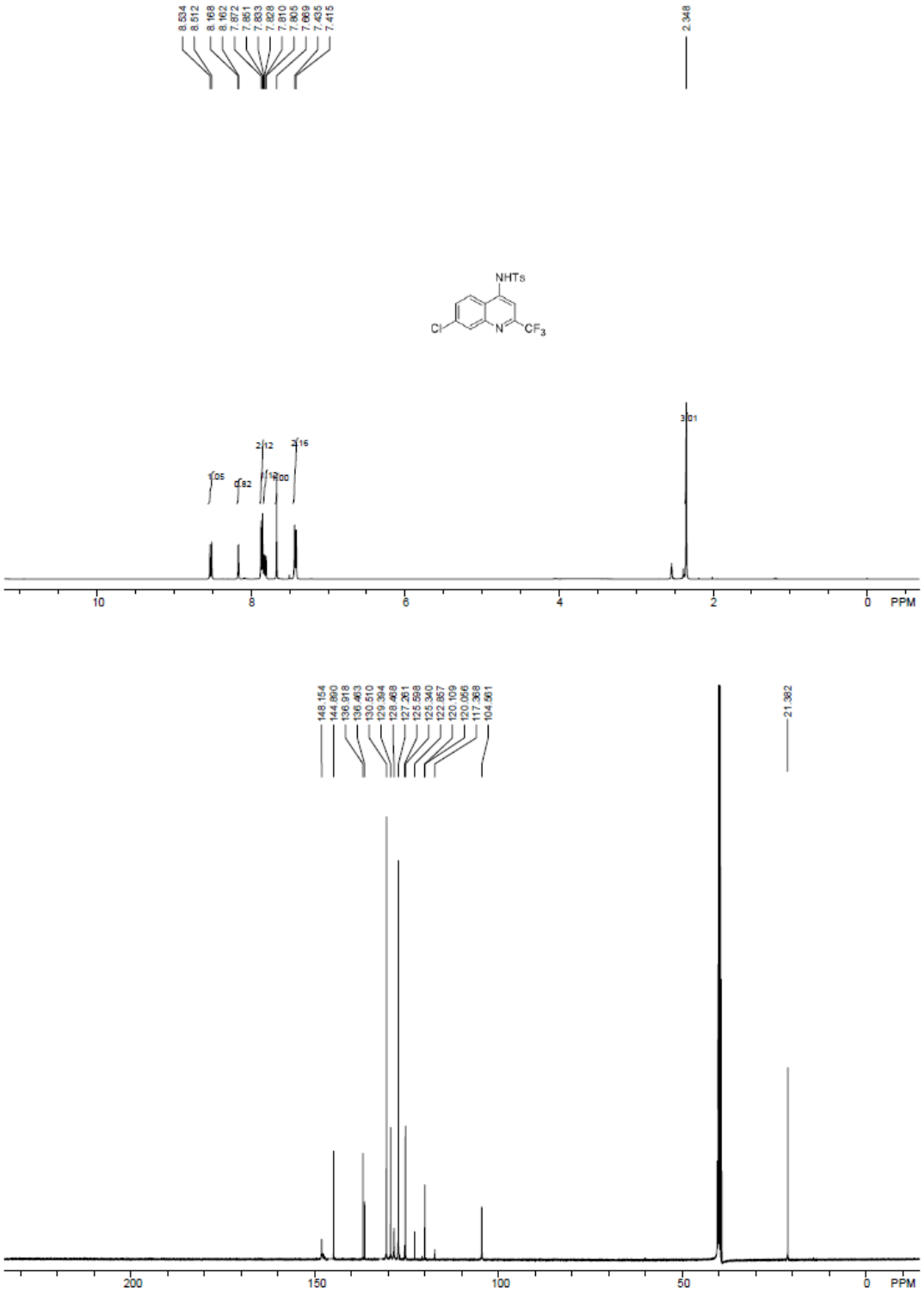

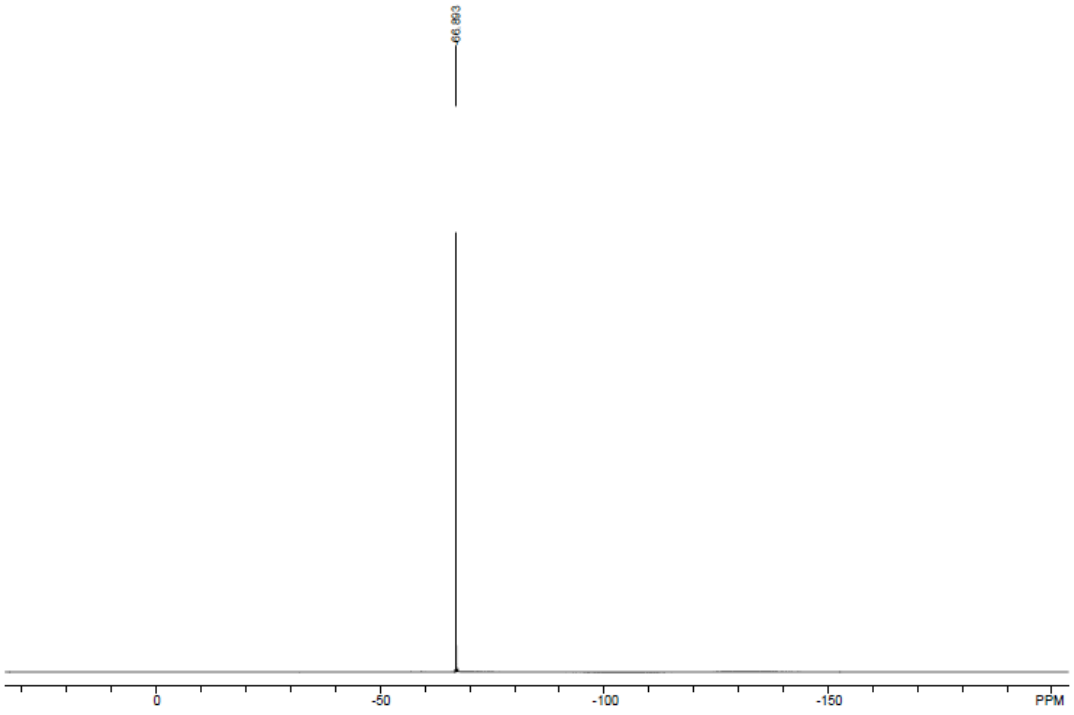

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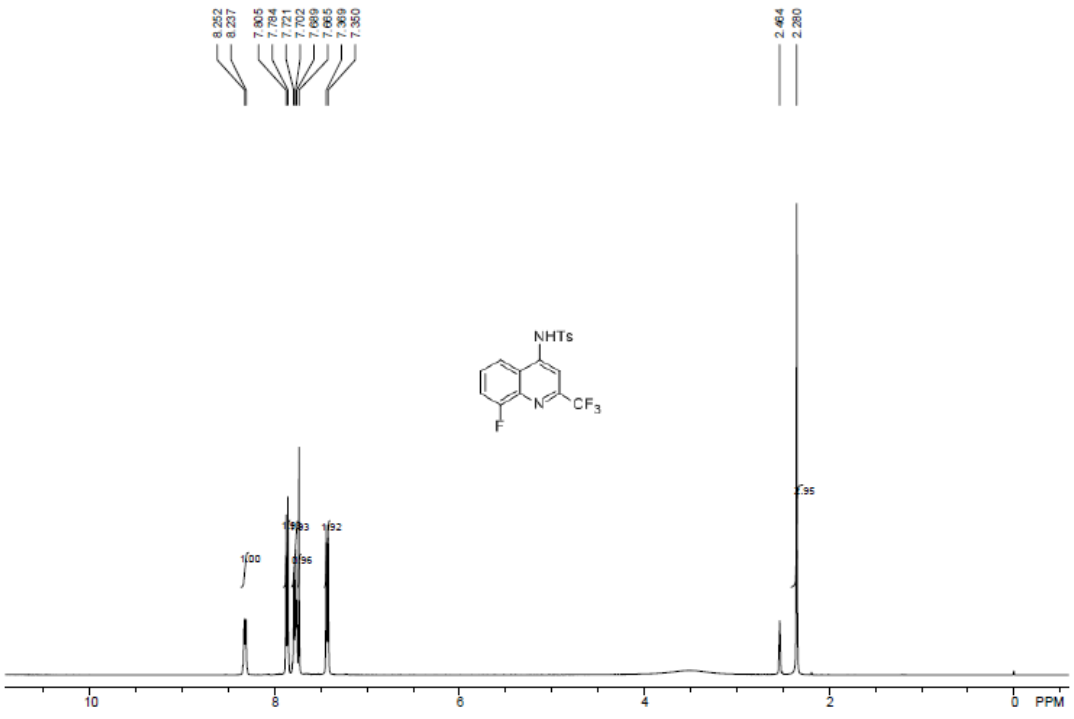

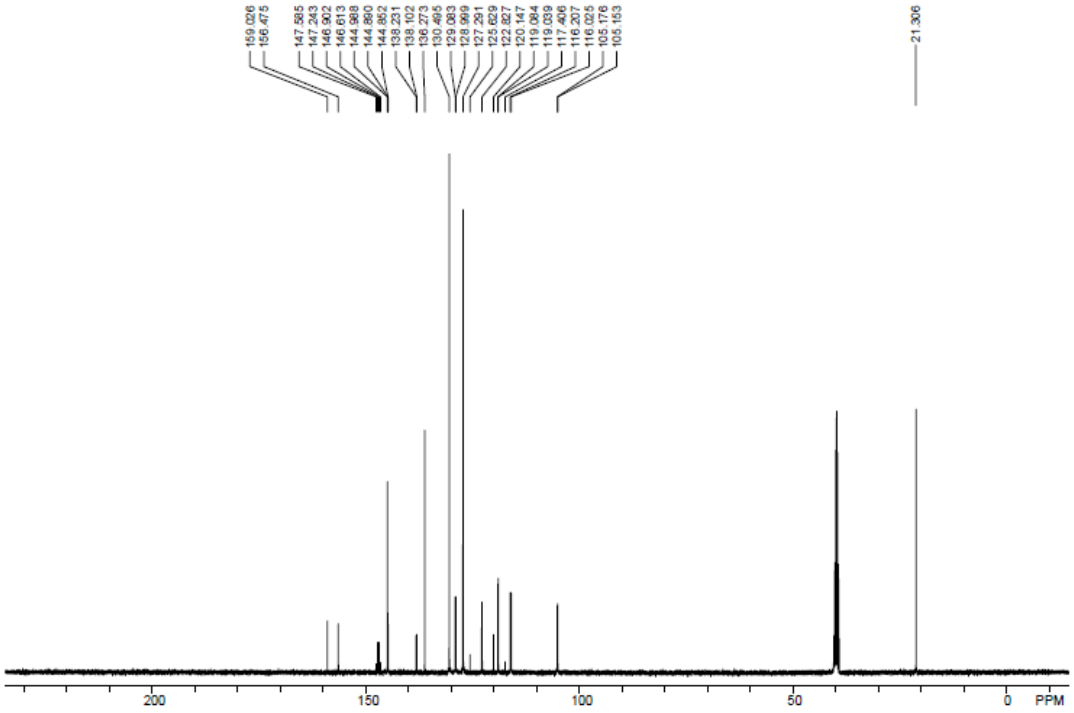

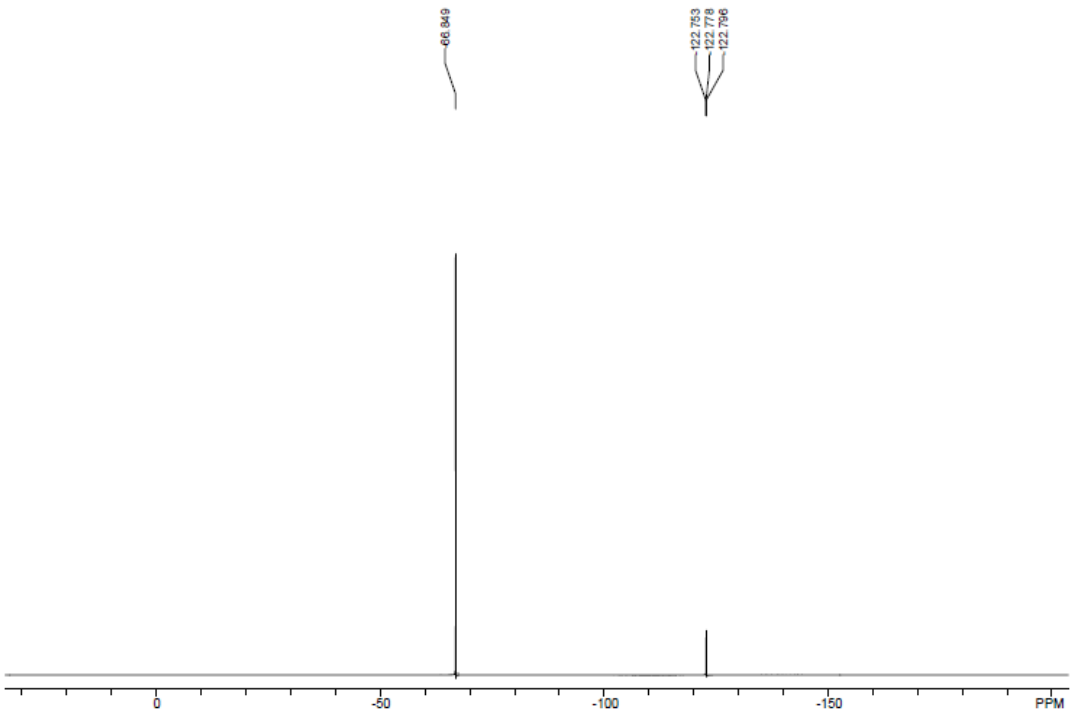

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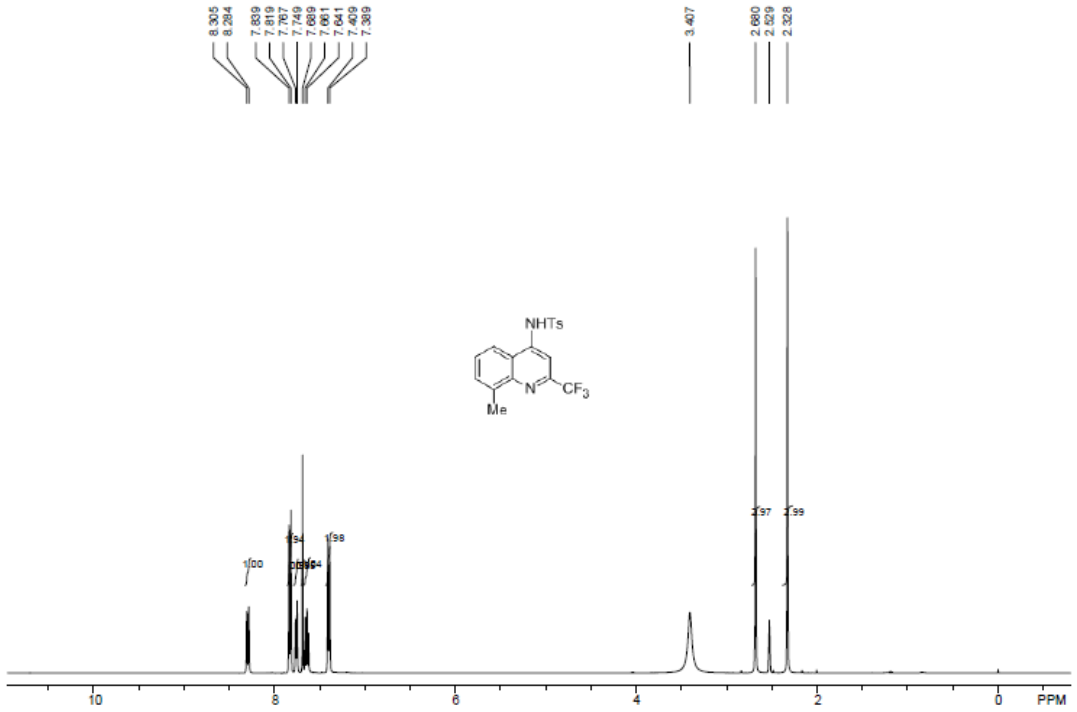

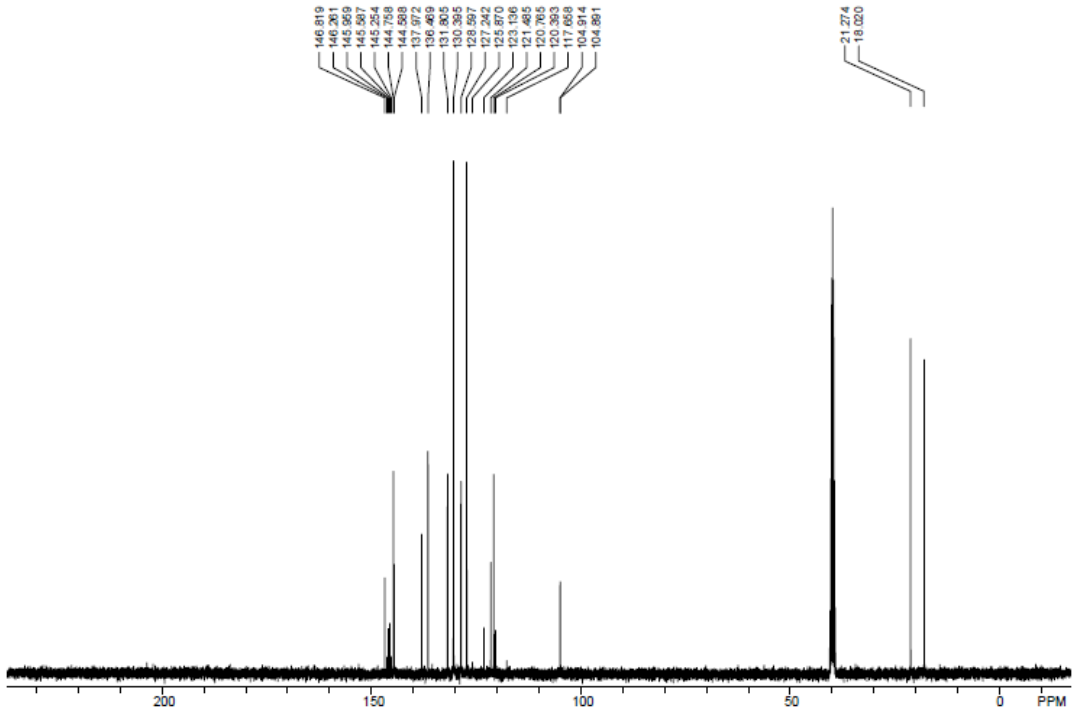

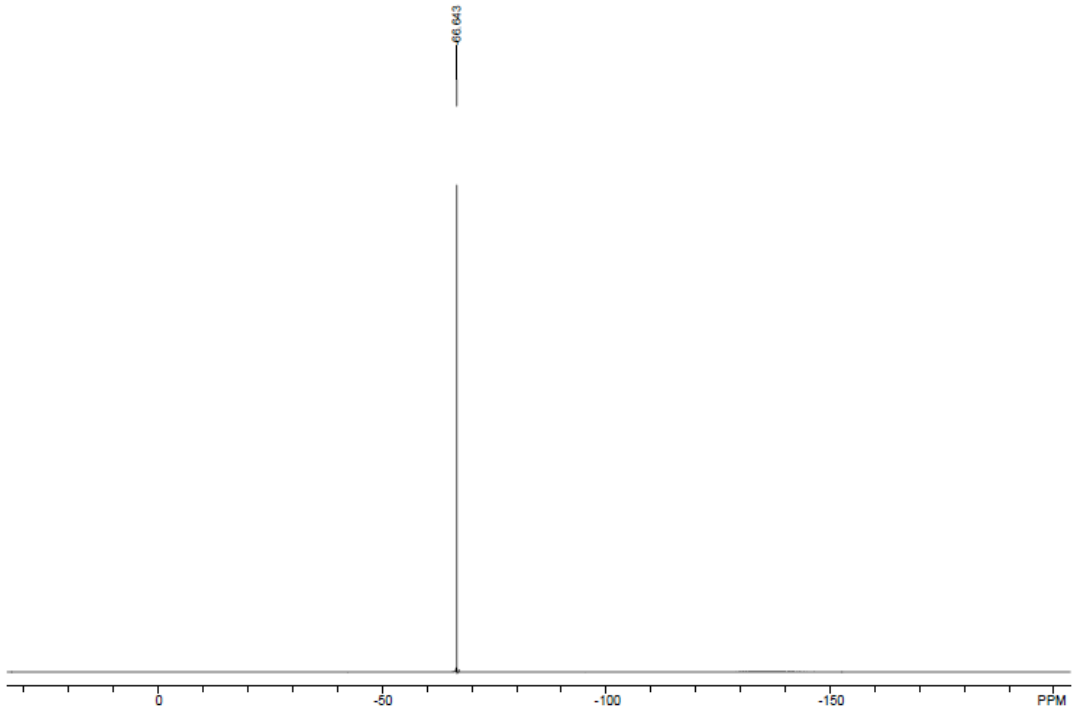

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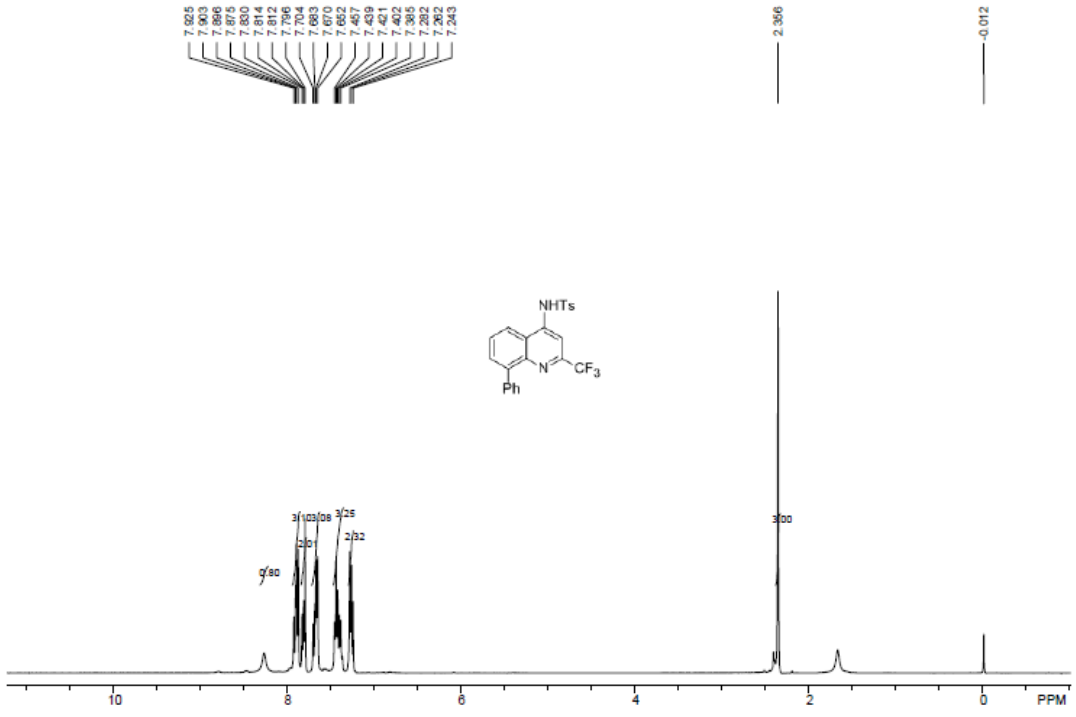

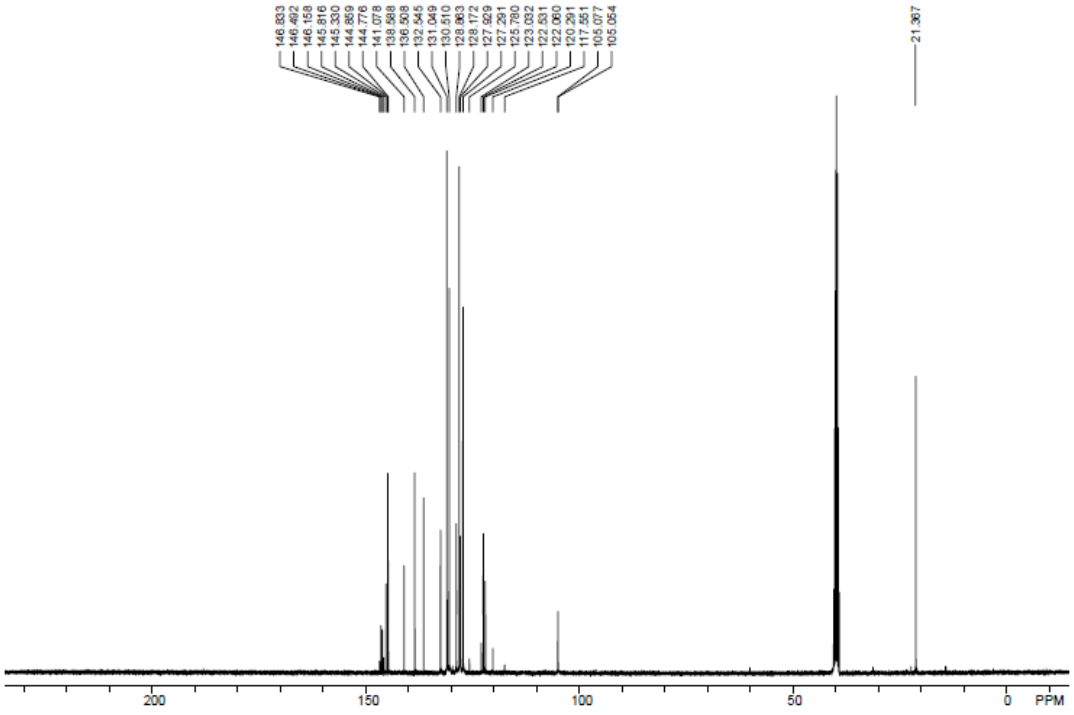

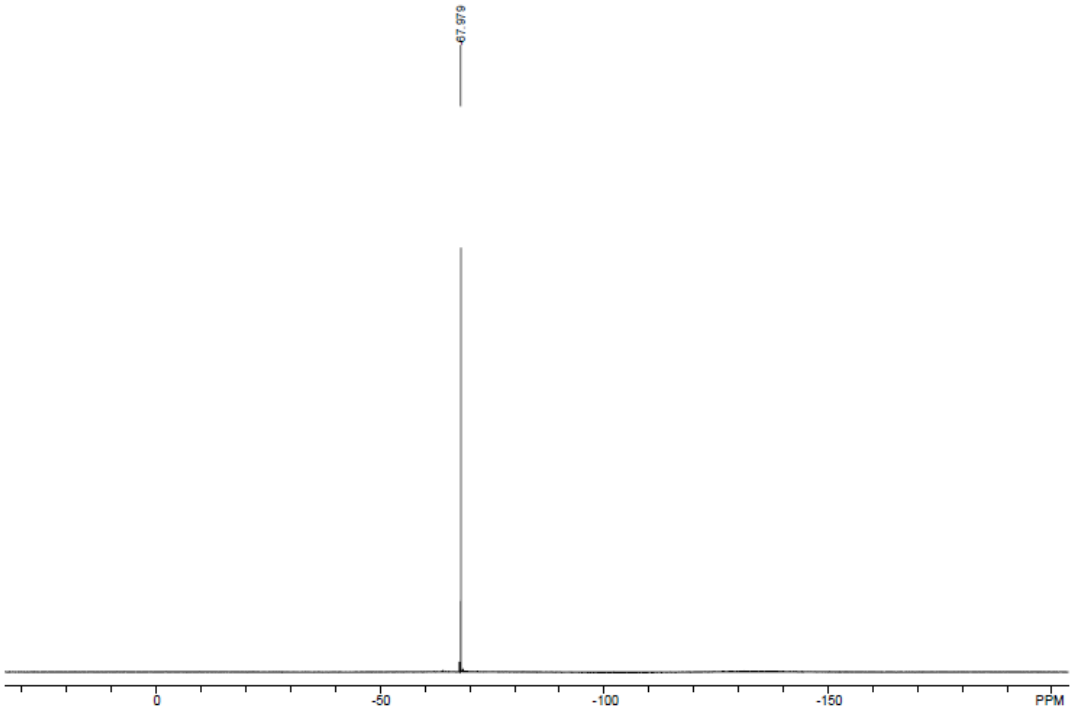

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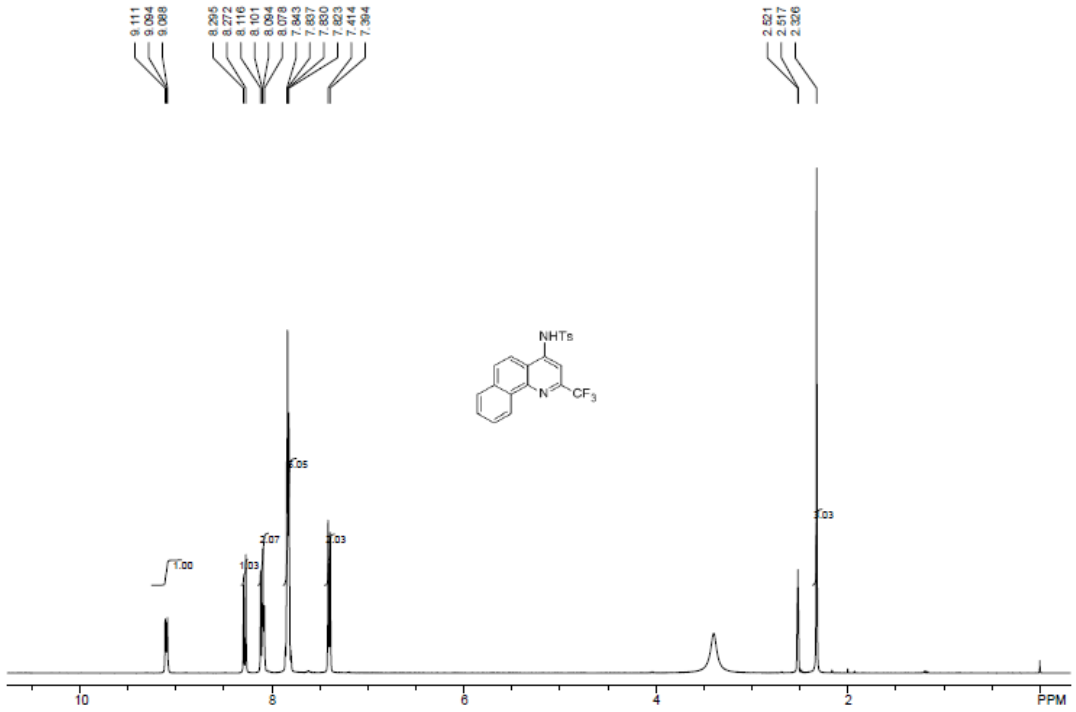

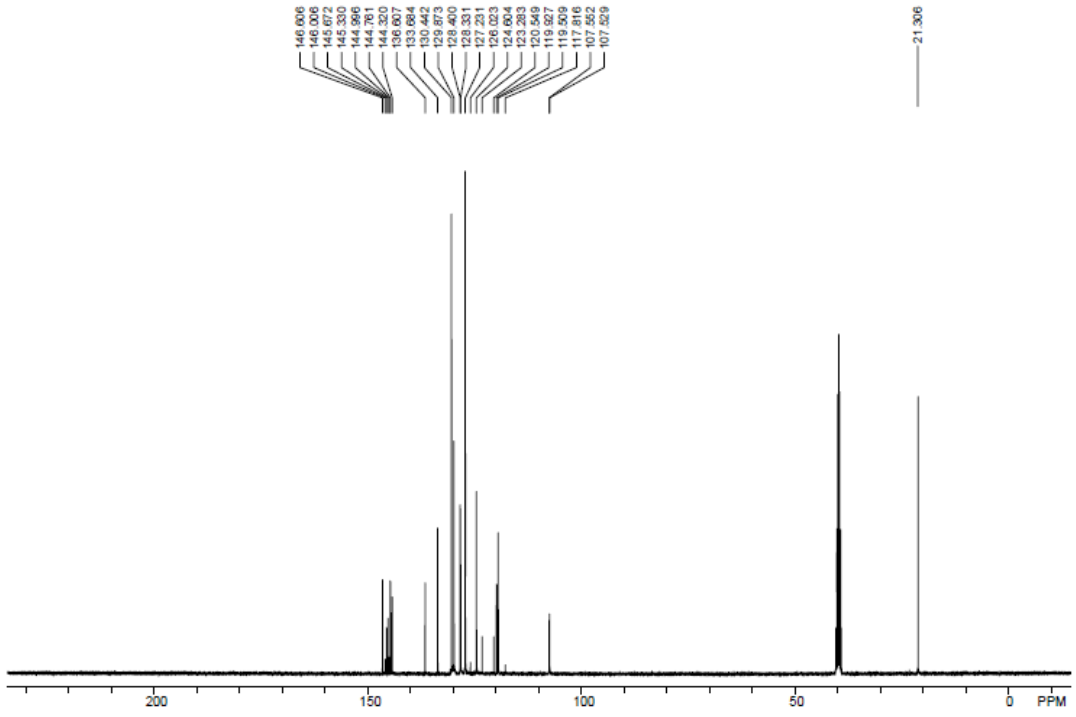

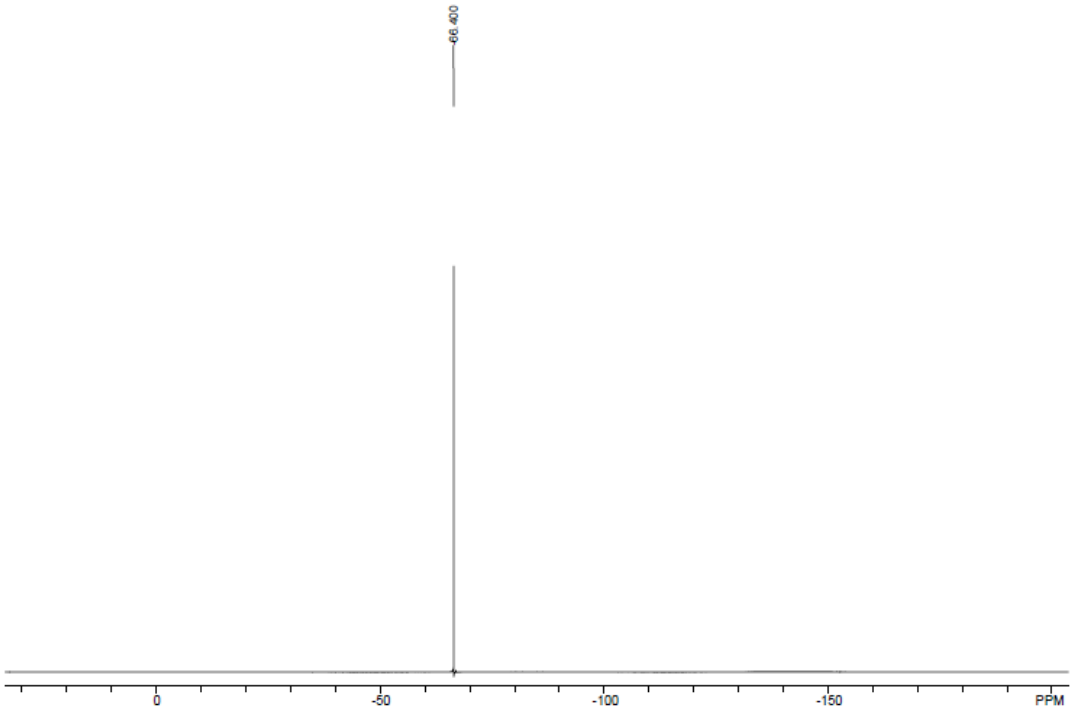

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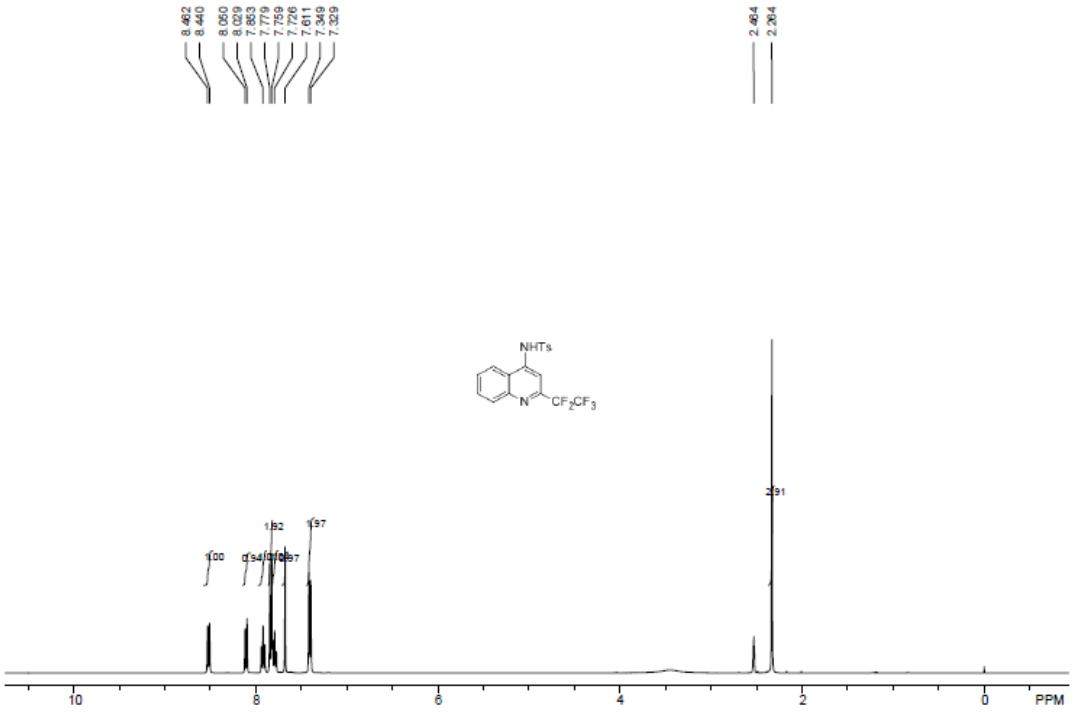

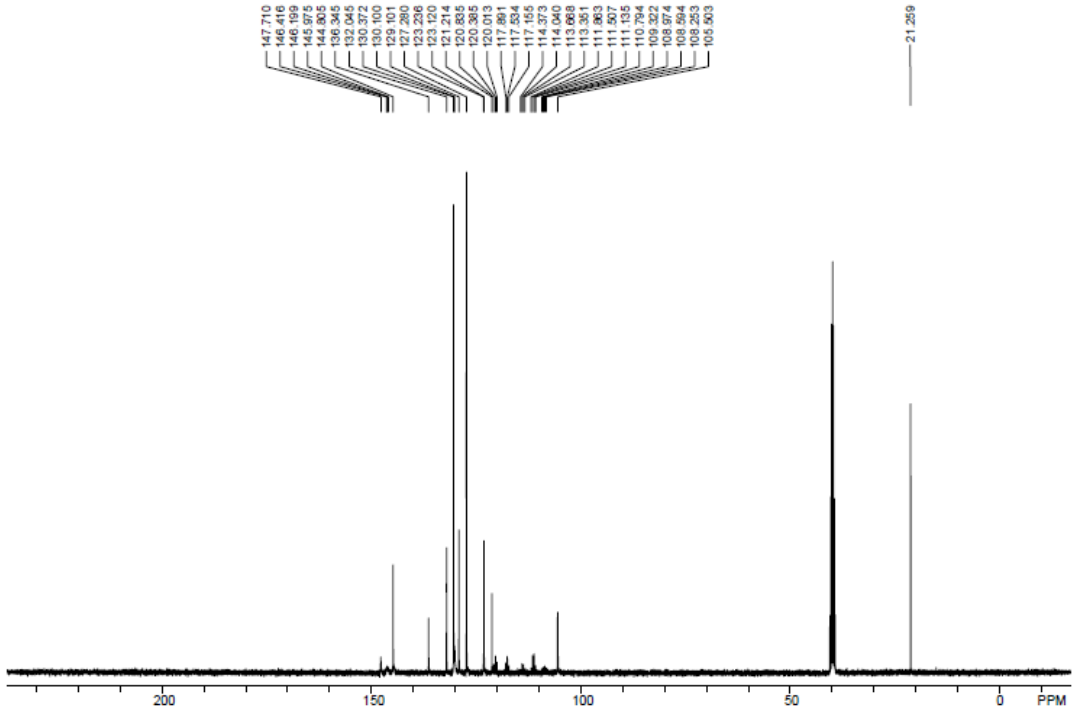

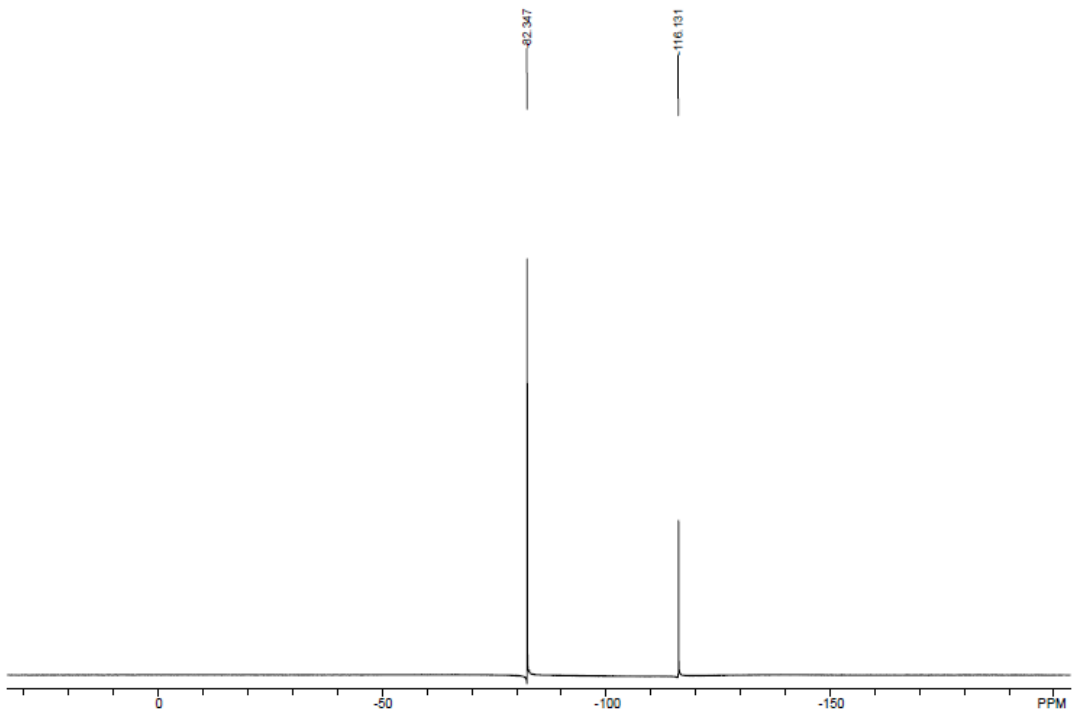

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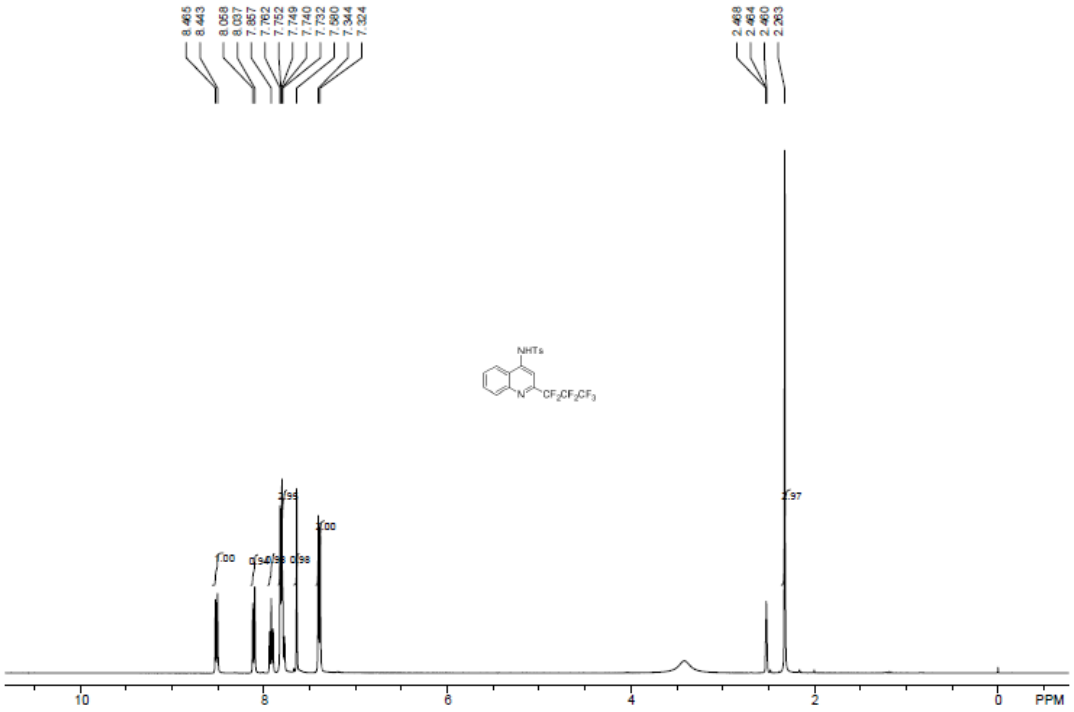

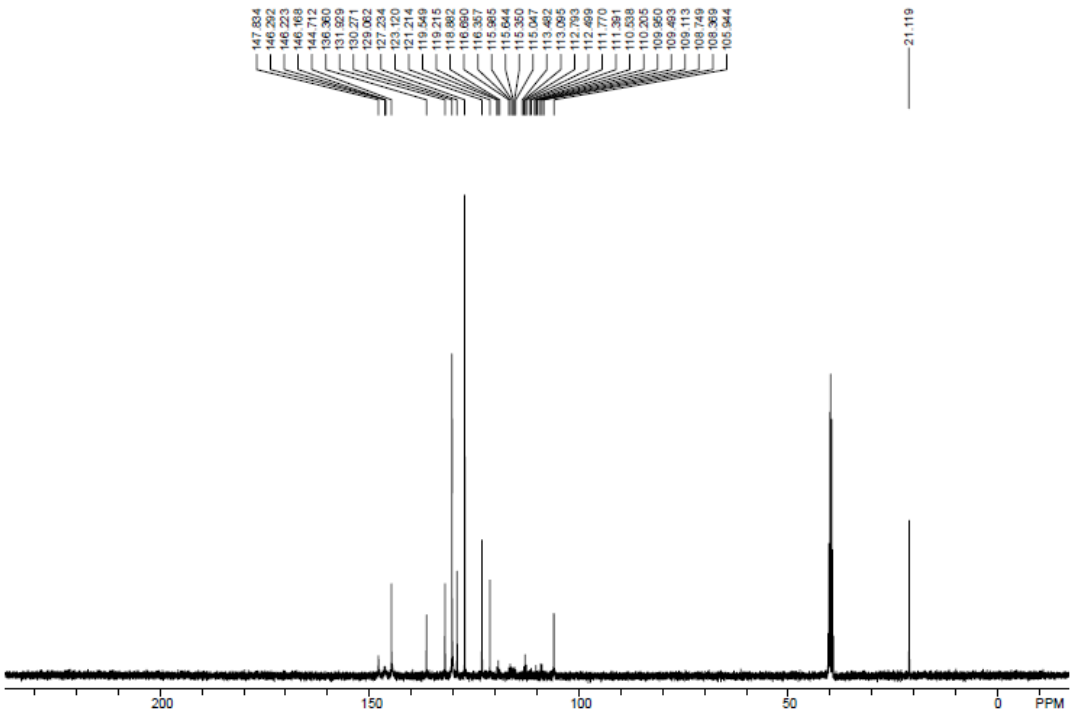

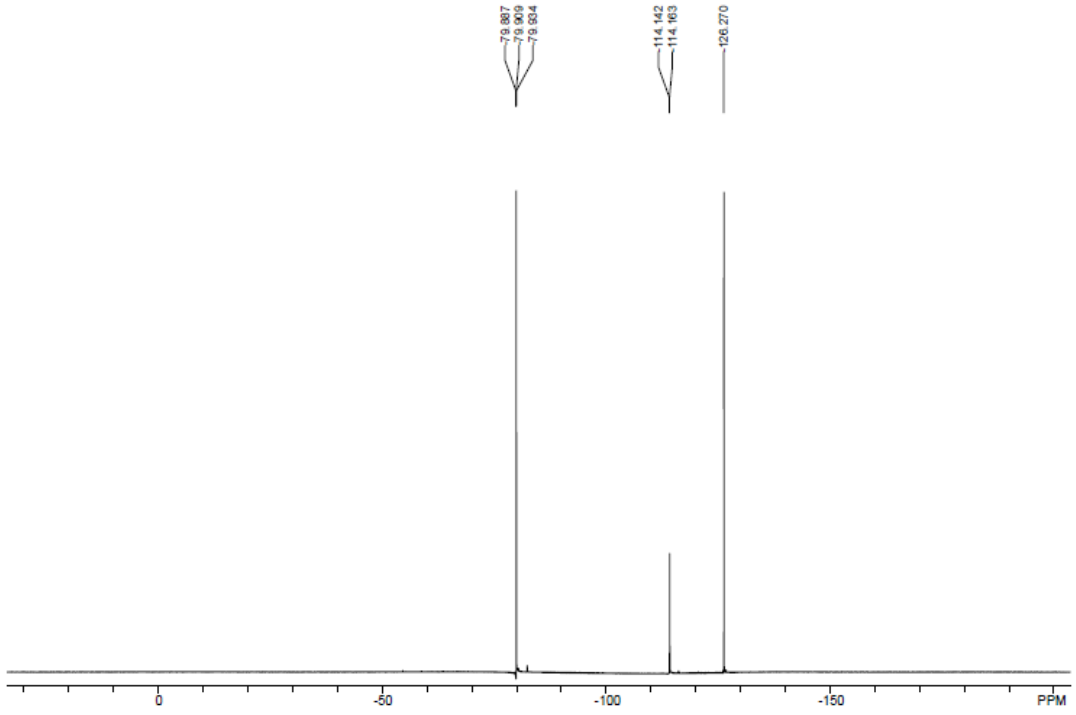

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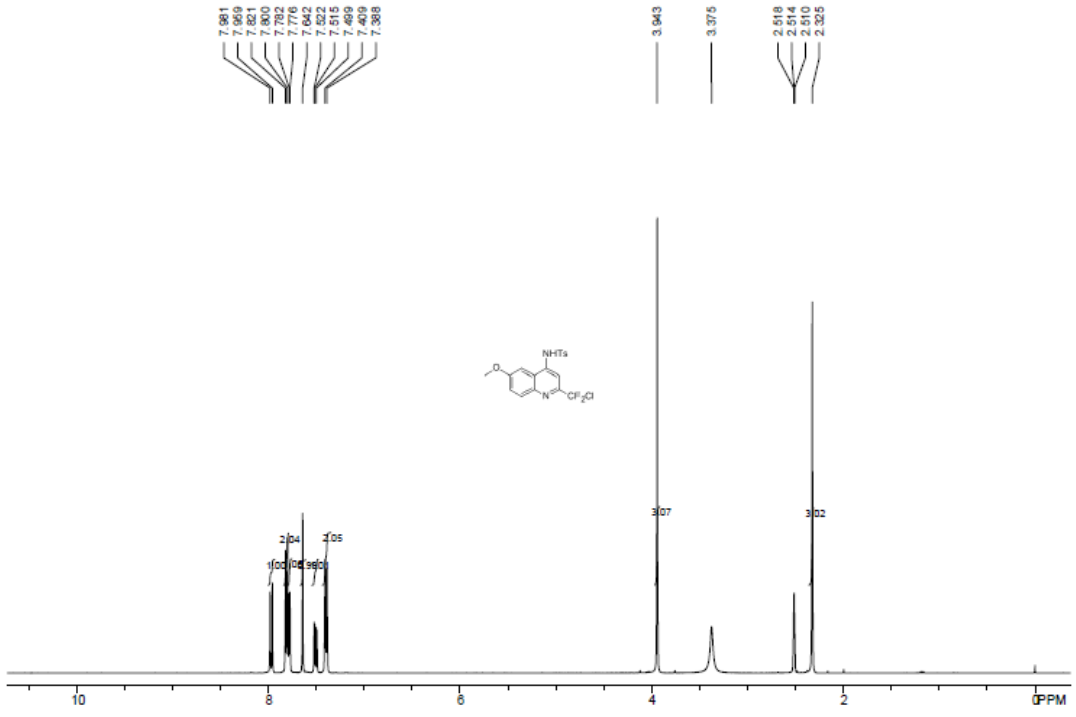

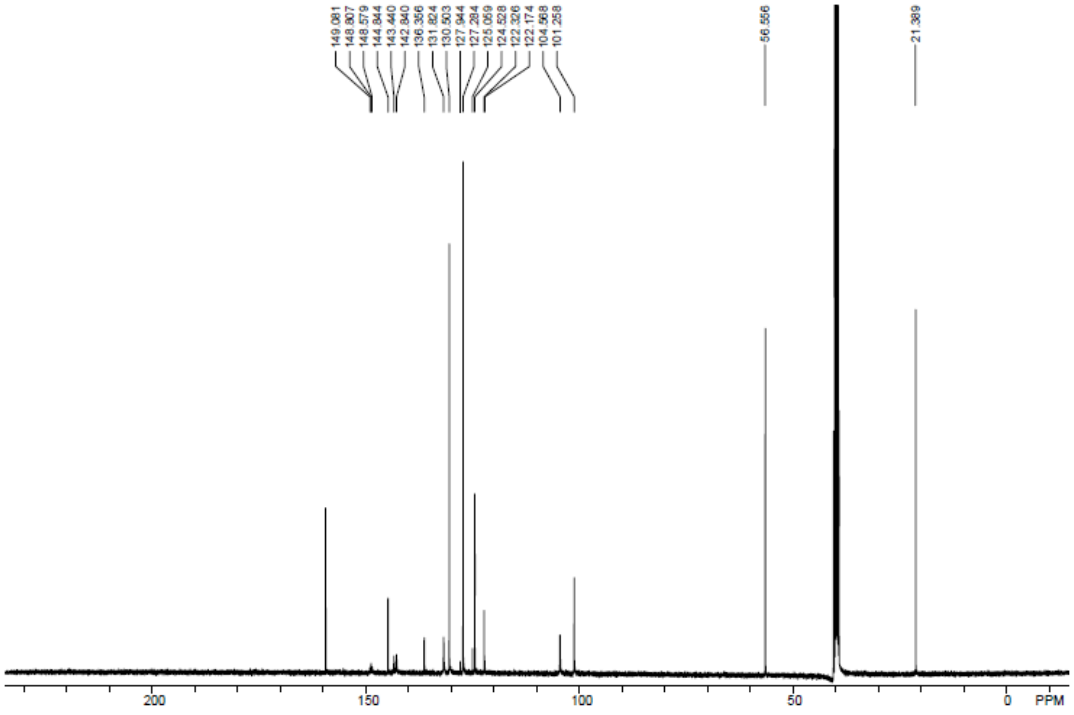

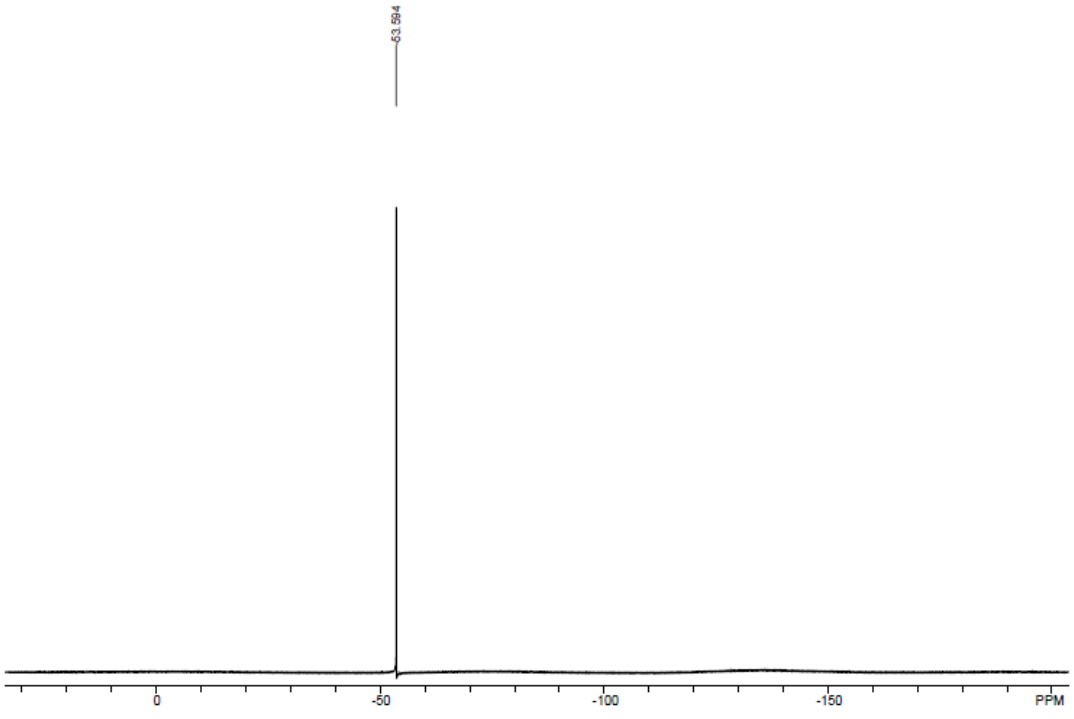

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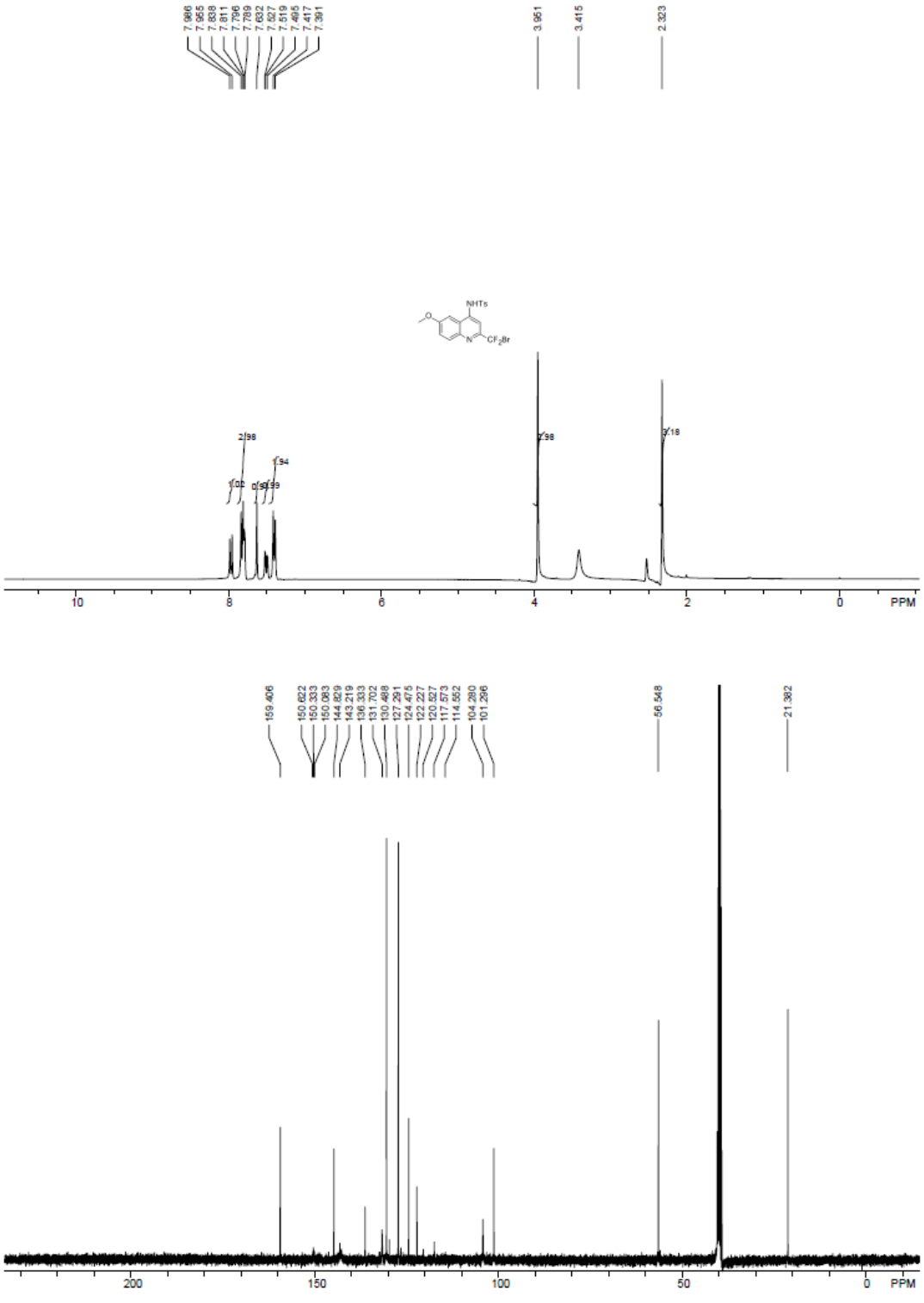

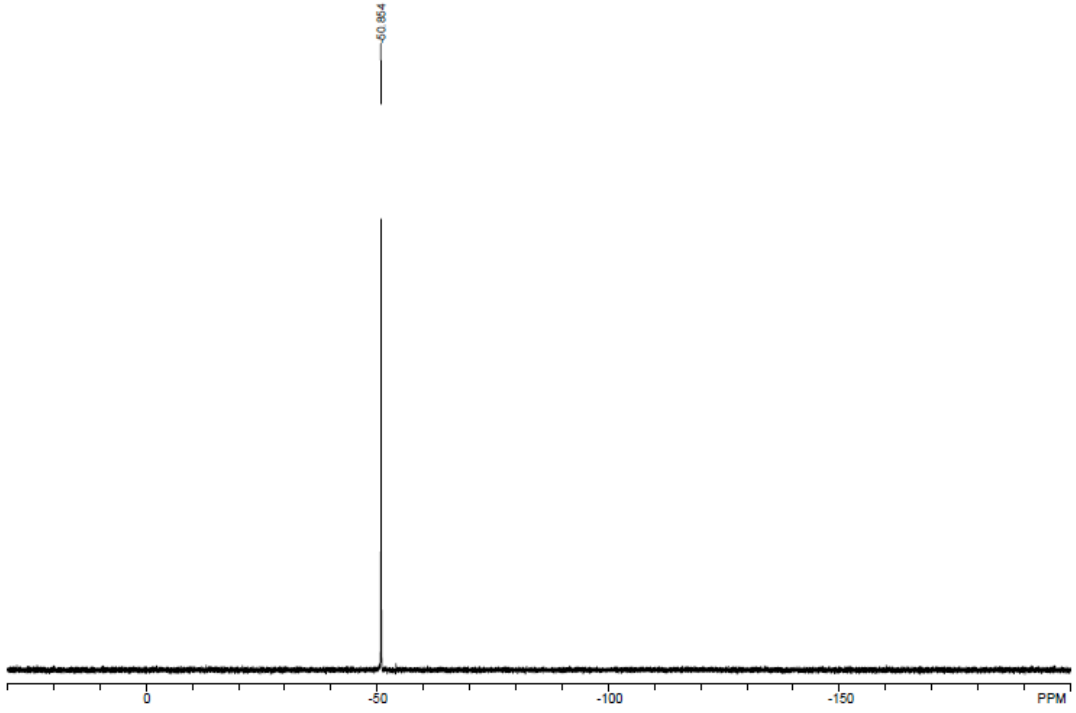

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