SUPPORTING INFORMATION

Trifluoromethyl Radical Triggered Radical Cyclization of N-Benzoyl Ynamides leading to Isoindolinones

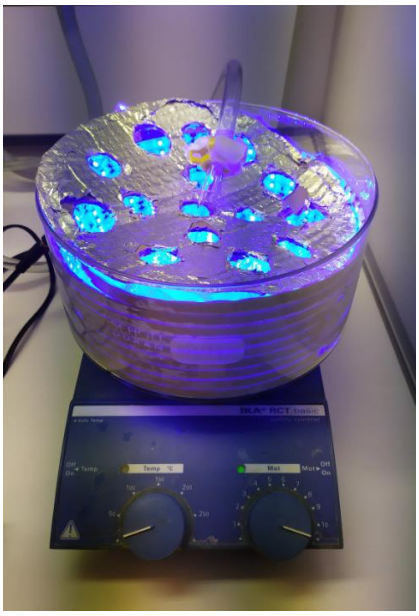
Maud Cassé [1, 2], Christian Nisole [2], Héloïse Dossmann [1], Yves Gimbert [1, 3], Jean-Marie Fourquez [2], Laure Haberkorn [2], Cyril Ollivier [1*] & Louis Fensterbank [1*]

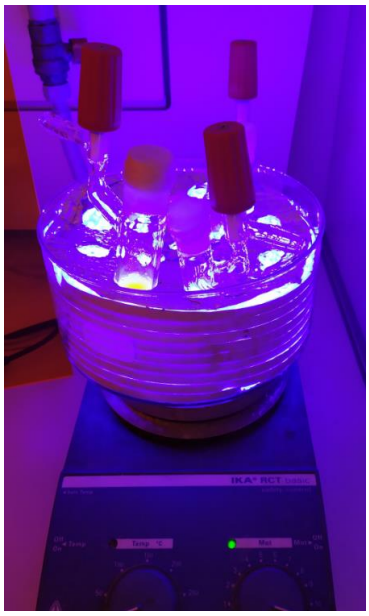
[1]*Sorbonne Université, CNRS, Institut Parisien de Chimie Moléculaire, IPCM, 75005 Paris, France*
[2]*Institut de Recherches Servier, 78290 Croissy-sur-Seine, France*
[3]*Département de Chimie Moléculaire, CNRS, Université Grenoble Alpes, 38610 Gières, France*
E-mail : cyril.ollivier@sorbonne-universite.fr
louis.fensterbank@sorbonne-universite.fr

Table of contents

General informations

Photocatalyzed reactions were irradiated under a blue LED light array homemade apparatus. Reactions were carried out in Schlenk tubes at a distance of approximately 2 cm from the LEDs and an average temperature of 27°C was maintained by an air cooling system.





If there were issues with solubility (syntheses of compounds **4j** and **4k**), reactions were heated at 40°C in an oil bath and irradiation occurred with a 365 nm Evoluchem^{TM} LED.

All reactions were performed under an atmosphere of argon unless otherwise stated, and monitored by thin layer chromatography (T.L.C.) or UPLC-MS. T.L.C. were carried out on ready for use plates of silica gel 60 F254 (Merck) and visualization was performed under an U.V. lamp at 254 nm. Reaction monitoring was conducted with Waters Acquity® instrument, fitted with PDA and SQD2 detectors (ESI source in positive mode). Injection volumes were 0.5 or 1 µL, the column was a Waters Acquity UPLC® BEH C_{18} 1.7 µm and temperature was kept at 40°C. Mobile phase A consisted of H_2O/MeCN/formic acid (98/2/0.1) and mobile phase B of MeCN/ H_2O /formic acid (98/2/0.1). Gradient ran from 100% A to 100% B in 3 min. Products were purified by flash chromatography using packed silica gel columns. Unless otherwise specified, all commercially available reagents were used as received.

All the analyses were conducted by Servier analysis department. ^{1}H and ^{13}C NMR spectra were recorded on Brüker 400 or 500 MHz machine operating at ambient temperature probe, in DMSO-d_6 or $CDCl_3$. ^{1}H NMR spectra were recorded at 400 MHz or 500 MHz, ^{13}C NMR spectra were recorded at 75 MHz or 100 MHz and ^{19}F spectra were recorded at 376 MHz on a Brüker 400 M Hz machine

Chemical shifts (δ) were quoted in parts per million (ppm). For ^{1}H NMR spectra, the chemical shifts were attributed relative to residual $CHCl_3$ (7.26 ppm) or residual DMSO (2.50 ppm).For ^{13}C NMR spectra (JMOD), the attributions were done relative to residual $CHCl_3$ (77.16 ppm) or residual DMSO (40 ppm). Coupling constants (*J*) were quoted in Hertz (Hz). The following abbreviations were used to give the multiplicity of the NMR signals: s: singlet, bs: broad singlet, d: doublet, t: triplet, q: quartet, quint: quintet, dd: doublet – doublet… Infrared spectra were recorded with the ATR technic on a

Brüker Tensor 27 spectrometer. Mass spectrometry (HRMS) was performed with a Thermo-Fischer Scientific spectrometer (by ESI+: Orbitrap Velos Pro or by EI: HREIGC, HRMS magnetic Sector Ms DFS). In a few cases, the mass spectrometry was done on an Agilent Technologies (ESI; LC/MSD TOF). Melting points were measured on the Büchi Melting point B-540 apparatus.

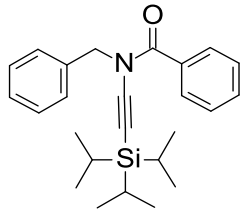
General procedure 1 for the synthesis of protected ynamides 2a-q

Amides **1a-q** were synthesized according to the literature. [1]

In a sealed tube (Radley) was loaded the amide **1** (1 equiv.), $CuSO_4.5H_2O$ (0.2 equiv.), 1,10-phenanthroline (0.4 equiv.) and K_3PO_4 (2.2 equiv.) under argon. To this mixture was added the 2-bromoethynyl(triisopropyl)silane[2,3] (1.1 equiv., 0.1M) in toluene. The reaction mixture was capped and heated at 75°C for a given reaction time. The reaction mixture was cooled down to room temperature, filtrated through Celite (rinced with DCM). The filtrate was concentrated under vacuum. The crude product was purified by silica gel flash column chromatography (liquid deposit in Heptane/ CH_2Cl_2 50/50; gradient eluent, CH_2Cl_2 in heptane/pentane or diethyl ether in pentane).

General procedure 1': use of $CuSO_4.5H_2O$ (0.1 equiv.), 1,10-phenanthroline (0.2 equiv.), K_3PO_4 (2 equiv.) and 2-bromoethynyl(triisopropyl)silane (1.2 equiv., 0.1M).

N-benzyl-N-(2-triisopropylsilylethynyl)benzamide 2a



Starting from N-benzylbenzamide **1a** (2.83 g, 13.5 mmol), $CuSO_4.5H_2O$ (335 mg, 1.4 mmol), 1,10-phenanthroline (485 mg, 2.7 mmol), K_3PO_4 (5.71 g, 26.9 mmol) and 2-bromoethynyl(triisopropyl)silane (4.21 g, 16.0 mmol) under argon, using **General procedure 1'** and heating at 75°C for 3.5 days. The crude was purified to afford N-benzyl-N-(2-triisopropylsilylethynyl)benzamide **2a** as a yellow oil (3.10 g, 59 % yield). Spectral data are in accordance with those reported in the literature.[4]

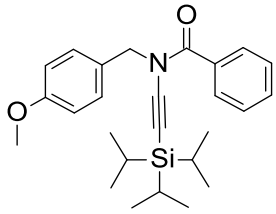
IR (neat): 2167, 1676, 881, 745 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.7 (d, *J* = 7.7 Hz, 2 H), 7.55 (tt, *J* = 7.5, 1.5 Hz, 1 H), 7.45 (t, *J* = 7.6 Hz, 2 H), 7.4 (m, 5 H), 4.85 (s, 2 H), 0.8 (s, 21 H)

[1] For the synthesis of the amides, see: Couty S, Liegault B, Meyer C, Cossy J. *Tetrahedron* **2006**, *62*, 3882-3895
[2] Nicolai S, Sedigh-Zadeh R, Waser J. *J. Org. Chem.* **2013**, 78, 3783-3801
[3] Rubin Y, Lin SS, Knobler CB, Anthony J, Boldi AM, Diederich F. *J. Am. Chem. Soc.* **1991**, 113, 6943-6949
[4] Zhang X, Zhang Y, Huang J, Hsung RP, Tracey MR, Kurtz KCM, Oppenheimer J, Petersen ME, Sagamanova IK, Shen L, Tracey MR. *J. Org. Chem.* **2006**, *71*, 4170-4177

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.6, 136.2, 133.8, 131.7, 128.9 (2C), 128.8 (2C), 128.6 (2C), 128.5 (2C), 128.4, 99.4, 71.5, 52.3, 18.7 (6C), 11 (3C)

N-[(4-methoxyphenyl)methyl]-N-(2-triisopropylsilylethynyl)benzamide 2b



Starting from N-[(4-methoxyphenyl)methyl]benzamide **1b** (6.04 g, 25 mmol), $CuSO_4.5H_2O$ (445 mg, 2.5 mmol), 1,10-phenanthroline (902 mg, 5.0 mmol), K_3PO_4 (6.71 g, 50.1 mmol) and 2-bromoethynyl(triisopropyl)silane (7.85 g, 30.0 mmol) under argon, using **General procedure 1'** and heating at 75°C for 4.5 days. The crude was purified to afford N-[(4-methoxyphenyl)methyl]-N-(2-triisopropylsilylethynyl)benzamide **2b** as a yellow oil (1.87 g, 18 % yield).

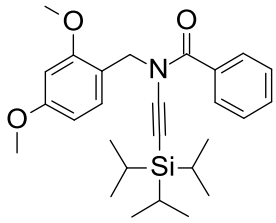
IR (neat): 2171, 1678 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.69 (d, *J* = 7.5 Hz, 2 H), 7.52 (t, *J* = 7.5 Hz, 1 H), 7.43 (t, *J* = 7.5 Hz, 2 H), 7.32 (d, *J* = 8.0 Hz, 2 H), 6.92 (d, *J* = 8.0 Hz, 2 H), 4.75 (s, 2 H), 3.74 (s, 3 H), 0.82 (s, 18 H), 0.82 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.9, 160, 134.2, 132.2, 130.5 (2C), 128.5 (2C), 128.3 (2C), 128.1, 114.3 (2C), 100, 71.6, 55.6, 51.9, 18.8 (6C), 11.1 (3C)

HRMS (ESI): calcd. for $C_{26}H_{36}NO_2Si$ ($[M+H]^+$) 422.2510, found 422.2511

N-[(2,4-dimethoxyphenyl)methyl]-N-(2-triisopropylsilylethynyl)benzamide 2c



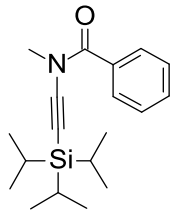
Starting from N-[(2,4-dimethoxyphenyl)methyl]benzamide **1c** (940 mg, 3 mmol), CuI (57 mg, 0.3 mmol), 1,10-phenanthroline (108 mg, 0.6 mmol), K_3PO_4 (1.27 g, 6 mmol) and 2-bromoethynyl(triisopropyl)silane (941 mg, 3.6 mmol) under argon, using **General procedure 1'** and heating at 75°C for 4 days. The crude was purified to afford N-[(2,4-dimethoxyphenyl)methyl]-N-(2-triisopropylsilylethynyl)benzamide **2c** as a yellow oil (423 mg, 30 % yield).
IR (neat): 2170, 1681, 1612, 1591, 1512 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.65 (dd, *J* = 7.6, 1.4 Hz, 2 H), 7.5 (tt, *J* = 7.4, 1.3 Hz, 1 H), 7.42 (t, *J* = 7.5 Hz, 2 H), 7.2 (d, *J* = 8.4 Hz, 1 H), 6.58 (d, *J* = 2.4 Hz, 1 H), 6.49 (dd, *J* = 8.3, 2.4 Hz, 1 H), 4.71 (s, 2 H), 3.77/3.75 (2 s, 6 H), 0.76 (d, 18 H), 0.75 (m, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.7, 161.3, 159, 134.4, 131.8, 131.5, 128.5 (2C), 128.4 (2C), 115.6, 105.01, 99.3, 98.8, 71.3, 56, 55.7, 47.1, 18.7 (6C), 11.02 (3C)

HRMS (ESI): calcd. for $C_{27}H_{37}NO_3Si$ ($[M]^+$) 451.2537, found 451.2518

N-methyl-N-(2-triisopropylsilylethynyl)benzamide 2d



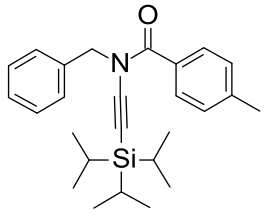
Starting from N-methyl-N-(2-triisopropylsilylethynyl)benzamide **1d** (700 mg, 5.18 mmol), $CuSO_4.5H_2O$ (129 mg, 0.52 mmol), 1,10-phenanthroline (187 mg, 1.0 mmol), K_3PO_4 (2.20 g, 10.4 mmol) and 2-bromoethynyl(triisopropyl)silane (1.49 g, 5.7 mmol, 1.1 equiv.) under argon, using **General procedure 1'** and heating at 75°C for 4 days. The crude was purified to afford N-methyl-N-(2-triisopropylsilylethynyl)benzamide **2d** as a yellow oil (682 mg, 42 % yield). Spectral data are in accordance with those reported in the literature[4].

IR (neat): 2167, 1680, 1603, 1580 cm^{-1}

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.81-7.76 (m, 2 H), 7.48-7.41 (m, 1 H), 7.40-7.33 (m, 2 H), 3.35 (s, 3 H), 0.94 (s, 21 H)

^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 171.4, 133.8, 131.7, 128.7 (2C), 127.9 (2C), 100.3, 70.0, 37.9, 18.6 (6C), 11.4 (3C)

N-benzyl-4-methyl-N-(2-triisopropylsilylethynyl)benzamide 2e



Starting from N-benzyl-4-methyl-benzamide **1e** (406 mg, 1.8 mmol), $CuSO_4.5H_2O$ (71 mg, 0.3 mmol, 0.15 equiv.), 1,10-phenanthroline (144 mg, 0.8 mmol), K_3PO_4 (1.02 g, 4.8 mmol) and 2-bromoethynyl(triisopropyl)silane (523 mg, 2.0 mmol) under argon, using **General procedure 1** and heating at 75°C for 4.5 days. The crude was purified to afford N-benzyl-4-methyl-N-(2-triisopropylsilylethynyl)benzamide **2e** as a colorless oil (335 mg, 41 % yield).

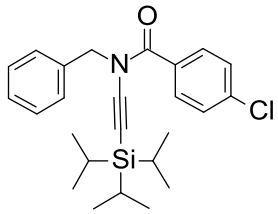
IR (neat): 2166, 1676, 749, 675 cm^{-1}

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.76 (d, *J* = 8.1 Hz, 2 H), 7.44 (d, *J* = 7.5 Hz, 2 H), 7.35 (m, 3 H), 7.15 (d, *J* = 7.9 Hz, 2 H), 4.85 (s, 2 H), 2.35 (s, 3 H), 0.88 (s, 18 H), 0.87 (s, 3 H)

^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 170.5, 141.5, 136.2, 130.6, 128.8, 128.4, 128.4, 127.8, 99.4, 72.1, 53.1, 41.6, 21.5, 18.4 (6C), 11.4 (3C)

HRMS (EI): calcd. for C_{26} H_{35} N O Si ($[M]^+$) 405.2482, found 405.2479

N-benzyl-4-chloro-N-(2-triisopropylsilylethynyl)benzamide 2f



Starting from N-benzyl-4-chloro-benzamide **1f** (310 mg, 1.3 mmol), $CuSO_4.5H_2O$ (70 mg, 0.3 mmol), 1,10-phenanthroline (100 mg, 0.6 mmol), K_3PO_4 (0.71 g, 3.0 mmol) and 2-bromoethynyl(triisopropyl)silane (370 mg, 1.4 mmol) under argon, using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford N-benzyl-4-chloro-N-(2-triisopropylsilylethynyl)benzamide **2f** as a colorless oil (366 mg, 67 % yield).

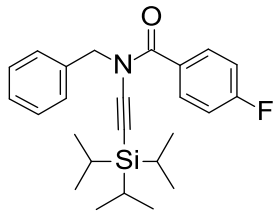
IR (neat): 2168, 1681, 752, 699, 676 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.73 (d, *J* = 8.3 Hz, 2 H), 7.51 (d, *J* = 8.3 Hz, 2 H), 7.35 (m, 5 H), 4.82 (s, 2 H), 0.81 (s, 18 H), 0.81 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 168.9, 135.4, 135, 131.2, 129.4 (2C), 127.8 (2C), 127.7 (2C), 127.6 (2C), 127.3, 98.6, 71, 51.4, 17.8 (6C), 10.1 (3C)

HRMS (EI): calcd. for C_{25} H_{32} Cl N O Si ($[M]^+$) 425.1936, found 425.1939

N-benzyl-4-fluoro-N-(2-triisopropylsilylethynyl)benzamide 2g



Starting from N-benzyl-4-fluoro-benzamide **1g** (2.1 g, 9.1 mmol), $CuSO_4.5H_2O$ (161 mg, 0.9 mmol), 1,10-phenanthroline 327 mg, 1.8 mmol), K_3PO_4 (2.43 g, 18.2 mmol) and 2-bromoethynyl(triisopropyl)silane (2.61 g, 10.0 mmol, 1.1 equiv.) under argon, using **General procedure 1'** and heating at 75°C for 3.5 days. The crude was purified to afford N-benzyl-4-fluoro-N-(2-triisopropylsilylethynyl)benzamide **2g** as a colorless oil (1.72 g, 46 % yield).

IR (neat): 2166, 1677, 1604 cm^{-1}

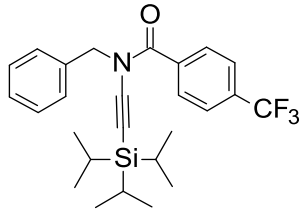
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.8 (m, 2 H), 7.4 (m, 5 H), 7.3 (m, 2 H), 4.8 (s, 2 H), 0.8 (m, 21 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169.7, 164.1 (d, *J* = 250 Hz), 136.1, 131.4 (d, *J* = 9.0 Hz, 2C), 130.4 (d, *J* = 3.1 Hz), 128.9 (2C), 128.9 (2C), 128.5, 115.6 (d, *J* = 22.3 Hz, 2C), 99.3, 71.7, 52.3, 18.7 (6C), 11 (3C)

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -108.5

HRMS (EI): calcd. for C_{25} H_{32} F N O Si ($[M]^+$) 409.2232, found 409.2223

N-benzyl-4-(trifluoromethyl)-N-(2-triisopropylsilylethynyl)benzamide 2h



Starting from N-benzyl-4-(trifluoromethyl)benzamide **1h** (350 mg, 1.3 mmol), $CuSO_4.5H_2O$ (70 mg, 0.3 mmol), 1,10-phenanthroline (100 mg, 0.6 mmol), K_3PO_4 (0.71 g, 3.0 mmol) and 2-bromoethynyl(triisopropyl)silane (370 mg, 1.4 mmol) under argon using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford N-benzyl-4-(trifluoromethyl)-N-(2-triisopropylsilylethynyl)benzamide **2h** as a colorless oil (355 mg, 61 % yield).

IR (neat): 2169, 1684, 1170, 1131, 744, 698, 676 cm^{-1}

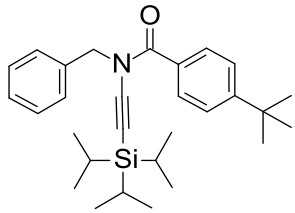
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.87 (d, *J* = 8.3 Hz, 2 H), 7.81 (d, *J* = 8.3 Hz, 2 H), 7.44-7.31 (m, 5 H), 4.85 (s, 2 H), 0.75 (s, 18 H), 0.75 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169.8, 138.3, 135.9, 131.4 (q, *J* = 32 Hz), 129.0 (4C), 129.0 (2C), 128.4, 125.7 (q, *J* = 3.8 Hz, 2C), 124.4 (q, *J* = 273 Hz), 98.7, 72.4, 51.8, 18.2 (6C), 10.9 (3C)

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -61.7

HRMS (ESI): calcd. for C_{26} H_{33} F_3 N O Si ($[M+H]^+$) 460.2278, found 460.228

N-benzyl-4-tert-butyl-N-(2-triisopropylsilylethynyl)benzamide 2i



Starting from N-benzyl-4-tert-butyl-benzamide **1i** (340 mg, 1.3 mmol), $CuSO_4.5H_2O$ (70 mg, 0.3 mmol), 1,10-phenanthroline (100 mg, 0.6 mmol), K_3PO_4 (0.71 g, 3.0 mmol) and 2-bromoethynyl(triisopropyl)silane (370 mg, 1.4 mmol) under argon, using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford N-benzyl-4-tert-butyl-N-(2-triisopropylsilylethynyl)benzamide **2i** as a colorless oil (215 mg, 38 % yield).

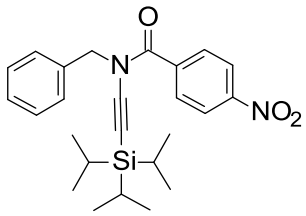
IR (neat): 2167, 1678, 770, 747, 697 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.64 (d, *J* = 8.3 Hz, 2 H), 7.44 (d, *J* = 8.3 Hz, 2 H), 7.41-7.30 (m, 5 H), 4.81 (s, 2 H), 1.28 (s, 9 H), 0.8 (s, 18 H), 0.8 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.7, 154.3, 136.1, 130.5, 128.8 (2C), 128.7 (2C), 128.3 (2C), 128.2, 125.2 (2C), 99, 71.4, 52.2, 34.6, 31.1 (3C), 18.8 (6C), 10.9 (3C)

HRMS (EI): calcd. for C_{29} H_{41} N O Si ($[M]^+$) 447.2952, found 447.2942

N-benzyl-4-nitro-N-(2-triisopropylsilylethynyl)benzamide 2j



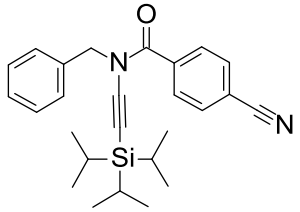
Starting from N-benzyl-4-nitro-benzamide **1j** (320 mg, 1.3 mmol), $CuSO_4.5H_2O$ (70 mg, 0.3 mmol), 1,10-phenanthroline (100 mg, 0.6 mmol), K_3PO_4 (0.71 g, 3.0 mmol) and 2-bromoethynyl(triisopropyl)silane (370 mg, 1.4 mmol) under argon, using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford N-benzyl-4-nitro-N-(2-triisopropylsilylethynyl)benzamide **2j** as a colorless oil (408 mg, 73 % yield).

IR (neat): 2169, 1680, 1525, 1346, 851, 719, 698 cm^{-1}
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.3 (d, *J* = 8.5 Hz, 2 H), 7.95 (d, *J* = 8.5 Hz, 2 H), 7.43-7.37 (m, 4 H), 7.36 (t, *J* = 6.9 Hz, 1 H), 4.85 (s, 2 H), 0.75 (s, 18 H), 0.75 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 168.3, 148, 139.4, 134.7, 128.7 (2C), 127.9 (2C), 127.9 (2C), 127.4, 122.8 (2C), 97.4, 71.7, 50.9, 17.5 (6C), 9.9 (3C)

HRMS (EI): calcd. for C_{25} H_{32} N_2 O_3 Si ($[M]^+$) 436.2177, found 436.2179

N-benzyl-4-cyano-N-(2-triisopropylsilylethynyl)benzamide 2k



Starting from N-benzyl-4-cyano-N-ethynyl-benzamide **1k** (360 mg, 1.5 mmol), $CuSO_4.5H_2O$ (53 mg, 0.3 mmol), 1,10-phenanthroline (110 mg, 0.6 mmol), K_3PO_4 (0.48 g, 3.6 mmol, 2.4 equiv.) and 2-bromoethynyl(triisopropyl)silane (390 mg, 30.0 mmol, 0.8 equiv.) under argon, using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford N-benzyl-4-cyano-N-(2-triisopropylsilylethynyl)benzamide **2k** as a colorless oil (232 mg, 37 % yield).

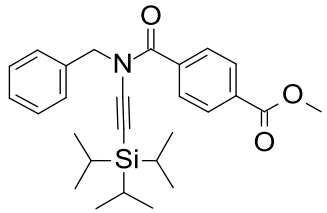
IR (neat): 2231, 2169, 1679, 1609, 1273 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.97 (d, *J* = 8.4 Hz, 2 H), 7.88 (d, *J* = 8.4 Hz, 2 H), 7.35 (m, 5 H), 4.82 (s, 2 H), 0.8 (m, 21 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169.6, 138.7, 135.8, 132.8, 129.1 (2C), 129.0 (2C), 128.9 (2C), 128.5, 128.5, 118.5, 113.8, 98.5, 72.6, 52, 18.7 (6C), 11 (3C)

HRMS (EI): calcd. for $C_{26}H_{32}N_2OSi$ ([M]$^+$) 416.2278, found 416.2279

methyl 4-[benzyl(2-triisopropylsilylethynyl)carbamoyl]benzoate 2l



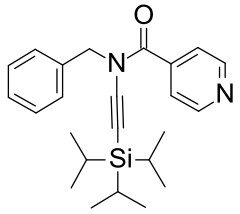
Starting from methyl 4-(benzylcarbamoyl)benzoate **1l** (340 mg, 1.3 mmol), $CuSO_4.5H_2O$ (70 mg, 0.3 mmol), 1,10-phenanthroline (100 mg, 0.6 mmol), K_3PO_4 (0.71 g, 3.0 mmol) and 2-bromoethynyl(triisopropyl)silane (370 mg, 1.4 mmol) under argon, using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford methyl 4-[benzyl(2-triisopropylsilylethynyl)carbamoyl]benzoate **2l** as a colorless oil (315 mg, 55 % yield).

IR (neat): 2168, 1728, 1678, 1271, 1106, 727, 699, 675 cm^{-1}
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.00/7.82 (2d, *J* = 8.2 Hz, 4 H), 7.43-7.31 (m, 5 H), 4.84 (s, 2 H), 3.88 (s, 3 H), 0.78 (s, 18 H), 0.78 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 169, 164.9, 137.5, 135, 131.1, 128.3 (2C), 127.9 (2C), 127.8 (2C), 127.6 (2C), 127.4, 97.8, 71.4, 51.9, 51, 17.5 (6C), 10.9 (3C)

HRMS (EI): calcd. for $C_{27}H_{35}NO_3Si$ ([M]$^+$) 449.2381, found 449.2378

N-benzyl-N-(2-triisopropylsilylethynyl)pyridine-4-carboxamide 2m



Starting from N-benzylpyridine-4-carboxamide **1m** (382 mg, 1.8 mmol), $CuSO_4.5H_2O$ (71 mg, 0.3 mmol, 0.15 equiv.), 1,10-phenanthroline (144 mg, 0.8 mmol), K_3PO_4 (1.02 g, 4.8 mmol) and 2-bromoethynyl(triisopropyl)silane (523 mg, 2.0 mmol) under argon, using **General procedure 1** and heating at 75°C for 4.5 days. The crude was purified to afford N-benzyl-N-(2-triisopropylsilylethynyl)pyridine-4-carboxamide **2m** as a yellow oil (514 mg, 73 % yield).

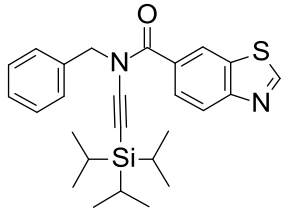
IR (neat): 2170, 1683, 753, 673 cm^{-1}

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 8.68 (d, *J* = 4.9 Hz, 2 H), 7.6 (d, *J* = 4.8 Hz, 2 H), 7.43 (dd, *J* = 7.6, 1.8 Hz, 2 H), 7.35 (m, 3 H), 4.86 (s, 2 H), 0.89 (s, 18 H), 0.89 (s, 3 H)

^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 168.6, 149.8 (2C), 141.4, 135.2, 129.0 (2C), 128.7 (2C), 128.3, 122.9 (2C), 97.7, 73.9, 52.9, 18.9 (6C), 11.6 (3C)

HRMS (EI): calcd. for $C_{24}H_{32}N_2OSi$ ([M]$^+$) 392.2278, found 392.228

N-benzyl-N-(2-triisopropylsilylethynyl)-1,3-benzothiazole-6-carboxamide 2n



Starting from N-benzyl-1,3-benzothiazole-6-carboxamide **1n** (340 mg, 1.3 mmol), $CuSO_4.5H_2O$ (70 mg, 0.3 mmol), 1,10-phenanthroline (100 mg, 0.6 mmol), K_3PO_4 (0.71 g, 3.0 mmol) and 2-bromoethynyl(triisopropyl)silane (370 mg, 1.4 mmol) under argon, using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford N-benzyl-N-(2-triisopropylsilylethynyl)-1,3-benzothiazole-6-carboxamide **2n** as a colorless oil (401 mg, 70 % yield).

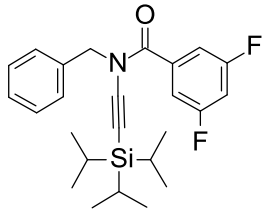
IR (neat): 2167, 1674, 877, 740, 698, 675 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 9.53 (s, 1 H), 8.6 (d, *J* = 1.4 Hz, 1 H), 8.13 (d, *J* = 8.5 Hz, 1 H), 7.83 (dd, *J* = 8.5, 1.6 Hz, 1 H), 7.44 (d, *J* = 7.4 Hz, 2 H), 7.39 (t, *J* = 7.3 Hz, 2 H), 7.34 (t, *J* = 7.3 Hz, 1 H), 4.88 (s, 2 H), 0.74 (s, 18 H), 0.74 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.3, 159.5, 154.9, 136.1, 133.6, 130.9, 129.0 (2C), 128.9 (2C), 128.4, 126.5, 123.5, 123.1, 99.3, 71.8, 52.3, 18.6 (6C), 11 (3C)

HRMS (EI): calcd. for $C_{26}H_{32}N_2OSSi$ ($[M]^+$) 448.1999, found 448.1977

N-benzyl-3,5-difluoro-N-(2-triisopropylsilylethynyl)benzamide 2o



Starting from N-benzyl-3,5-difluoro-benzamide **1o** (310 mg, 1.3 mmol), $CuSO_4.5H_2O$ (70 mg, 0.3 mmol), 1,10-phenanthroline (100 mg, 0.6 mmol), K_3PO_4 (0.71 g, 3.0 mmol) and 2-bromoethynyl(triisopropyl)silane (370 mg, 1.4 mmol) under argon, using **General procedure 1** and heating at 75°C for 3 days. The crude was purified to afford N-benzyl-3,5-difluoro-N-(2-triisopropylsilylethynyl)benzamide **2o** as a colorless oil (333 mg, 61 % yield).

IR (neat): 2169, 1680, 1594, 751, 698, 675 cm^{-1}

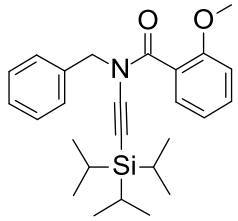
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.46 (m, 2 H), 7.39 (m, 1 H), 7.36 (m, 5 H), 4.82 (s, 2 H), 0.81 (s, 18 H), 0.81 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 168.5, 162.4 (dd, *J* = 247.9, 12.4 Hz, 2 C), 137.5 (t, *J* = 9.2 Hz), 135.8, 129.2 (4C), 128.5, 112.1 (d, *J* = 27.2 Hz, 2C), 107.0 (t, *J* = 25.9 Hz), 98.6, 72.7, 52.2, 18.8 (6C), 11.1 (3C)

^{19}F NMR (376 MHz, DMSO-d_6) δ -108.9 ppm

HRMS (EI): calcd. for C_{25} H_{31} F_2 N O Si ($[M]^+$) 427.2137, found 427.2135

N-benzyl-2-methoxy-N-(2-triisopropylsilylethynyl)benzamide 2p



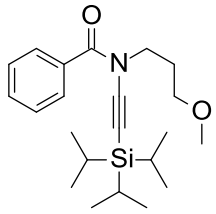
Starting from N-benzyl-2-methoxy-benzamide **1p** (434 mg, 1.8 mmol), $CuSO_4.5H_2O$ (71 mg, 0.3 mmol, 0.15 equiv.), 1,10-phenanthroline (144 mg, 0.8 mmol), K_3PO_4 (1.02 g, 4.8 mmol) and 2-bromoethynyl(triisopropyl)silane (523 mg, 2.0 mmol) under argon, using **General procedure 1** and heating at 75°C for 9.5 days. The crude was purified to afford N-benzyl-2-methoxy-N-(2-triisopropylsilylethynyl)benzamide **2p** as a colorless oil (447 mg, 59 % yield).
IR (neat): 2172, 1686, 1251, 750, 675 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.38 (m, 5 H), 7.33 (m, 1 H), 7.29 (dd, *J* = 8.4, 1.5 Hz, 1 H), 7.08 (d, *J* = 8.0 Hz, 1 H), 6.97 (t, *J* = 7.7 Hz, 1 H), 4.82 (s, 2 H), 3.79 (s, 3 H), 0.73 (s, 18 H), 0.73 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 170.1, 156.1, 136.2, 131.8, 128.8 (2C), 128.4 (2C), 128.1, 127.9, 125.2, 120.7, 111.9, 99.1, 70, 56.1, 51.3, 18.6 (6C), 11 (3C)

HRMS (EI): calcd. for C_{26} H_{35} N O_2 Si ($[M]^+$) 421.2432, found 421.2416

N-(3-methoxypropyl)-N-(2-triisopropylsilylethynyl)benzamide 2q



Starting from N-(3-methoxypropyl)benzamide **1q** (500 mg, 2.6 mmol), $CuSO_4.5H_2O$ (129 mg, 0.5 mmol), 1,10-phenanthroline (187 mg, 1.0 mmol), K_3PO_4 (0.69 g, 5.2 mmol, 2.0 equiv.) and 2-bromoethynyl(triisopropyl)silane (0.74 g, 2.8 mmol) under argon, using **General procedure 1** and heating at 75°C for 5 days. The crude was purified to afford N-(3-methoxypropyl)-N-(2-triisopropylsilylethynyl)benzamide **2q** as a yellow oil (189 mg, 20 % yield).

IR (neat): 2165, 1678, 1278, 1118, 709, 673 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.67 (d, *J* = 7.6 Hz, 2 H), 7.52 (t, *J* = 7.5 Hz, 1 H), 7.43 (t, *J* = 7.4 Hz, 2 H), 3.7 (t, *J* = 6.8 Hz, 2 H), 3.44 (t, *J* = 6.3 Hz, 2 H), 3.24 (s, 3 H), 1.95 (quint, *J* = 6.6 Hz, 2 H), 0.9 (s, 18 H), 0.9 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 170.9, 134.2, 131.6, 128.5 (2C), 128.4 (2C), 99.6, 71.3, 69.5, 58.6, 46.4, 27.7, 18.8 (6C), 11.2 (3C)

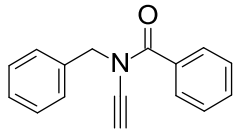
HRMS (ESI): calcd. for C_{22} H_{36} N O_2 Si ($[M+H]^+$) 374.2437, found 374.2512

General procedure 2 for the synthesis of ynamides 3a-q

To a solution of the protected ynamide **2** (1 equiv.) in tetrahydrofuran (0.2 M) under argon at 0°C/-5°C was added tetrabutylammonium fluoride (1M in THF, 1.2 equiv.) dropwise.

The reaction mixture was stirred at 0°C for the given amount of time.
After completion of the reaction, a mixture of an aqueous solution of NH_4Cl (10 % w/w) was added, the aqueous phase was extracted three times with diethyl ether. After washing with a saturated solution of NaCl, the organic phases were dried over Na_2SO_4 and concentrated.
The crude was purified either by trituration in pentane at -20°C (if 400 mg of crude obtained, 4 mL of pentane was added) or by silica gel flash column chromatography (gradient eluent, EtOAc in heptane).

N-benzyl-N-ethynyl-benzamide 3a



Starting from N-benzyl-N-(2-triisopropylsilylethynyl)benzamide **2a** (1.33 g, 3.4 mmol), TBAF 1M/THF (4.1 mL, 4.1 mmol) under argon, using **General procedure 2** and stirring at 0°C for 1 h. The crude was purified by silica gel flash column chromatography to afford N-benzyl-N-ethynyl-benzamide **3a** as a white solid (699 mg, 87 % yield). Spectral data are in accordance with those reported in the literature. [5]

IR (neat): 3242, 2146, 1649 cm^{-1}

^{1}H NMR (400MHz, DMSO-d_6) δ ppm 7.73 (d, *J* = 7.7 Hz, 2 H), 7.55 (t, *J* = 7.5 Hz, 1 H), 7.48 (t, *J* = 7.5 Hz, 2 H), 7.4 (m, 4 H), 7.32 (m, 1 H), 4.82 (s, 2 H), 3.82 (s, 1 H)

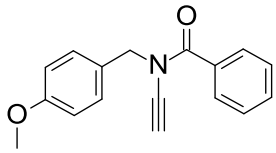
^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.6, 136.5, 133.7, 132, 129.0 (2C), 128.6 (2C), 128.5 (2C), 128.4 (2C), 128.3, 78.9, 64.2, 52.3

HRMS (ESI): calcd. for C_{16} H_{14} N O ($[M+H]^+$) 236.1070, found 236.1071

mp: 45.5-48°C

[5] B. Witulski, T. Stengel, *Angew. Chem. Int. Ed.* **1998**, *37*, 489

N-ethynyl-N-[(4-methoxyphenyl)methyl]benzamide 3b



Starting from N-[(4-methoxyphenyl)methyl]-N-(2-triisopropylsilylethynyl)benzamide **2b** (1.87 g, 4.4 mmol), TBAF 1M/THF (5.3 mL, 5.3 mmol) under argon, using **General procedure 2** and stirring at 0°C for 10 min. The crude was purified by silica gel flash column chromatography to afford N-ethynyl-N-[(4-methoxyphenyl)methyl]benzamide **3b** as a white solid (806 mg, 69 % yield).

IR (neat): 3242, 2142, 1645 cm^{-1}

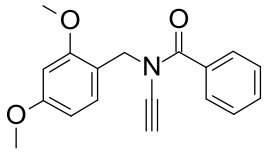
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.8 (d, *J* = 7.6 Hz, 2 H), 7.48 (t, *J* = 7.4 Hz, 1 H), 7.39 (m, 4 H), 6.9 (d, *J* = 8.2 Hz, 2 H), 4.8 (s, 2 H), 3.81 (s, 3 H), 2.75 (s, 1 H)

^{13}C NMR (125 MHz, $CDCl_3$) δ ppm 170.75, 159.51, 133.41, 131.45, 130.26 (2C), 128.68 (2C), 128.06, 127.8 (2C), 113.9 (2C), 78.62, 61.7, 55.27, 52.25

HRMS (ESI): calcd. for $C_{17}H_{16}NO_2$ ($[M+H]^+$) 266.1176, found 266.1177

mp: 86.8-88.7°C

N-[(2,4-dimethoxyphenyl)methyl]-N-ethynyl-benzamide 3c



Starting from N-[(2,4-dimethoxyphenyl)methyl]-N-(2-triisopropylsilylethynyl)benzamide **2c** (405 mg, 0.90 mmol), TBAF 1M/THF (1.08 mL, 1.08 mmol) under argon, using **General procedure 2** and stirring at 0°C for 30 min. The crude was purified by trituration in pentane to afford N-[(2,4-dimethoxyphenyl)methyl]-N-ethynyl-benzamide **3c** as a beige solid (198 mg, 75 % yield).

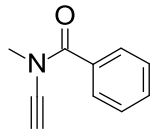
IR (neat): 3244, 2131, 1660 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.67 (d, *J* = 7.4 Hz, 2 H), 7.54 (t, *J* = 7.4 Hz, 1 H), 7.47 (t, *J* = 7.4 Hz, 2 H), 7.18 (d, *J* = 8.3 Hz, 1 H), 6.6 (d, *J* = 2.3 Hz, 1 H), 6.53 (dd, *J* = 8.3, 2.3 Hz, 1 H), 4.7 (s, 2 H), 3.78 (s, 3 H), 3.77 (s, 3 H), 3.65 (s, 1 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.6, 161, 158.9, 134, 131.8, 130.9, 128.5 (4C), 116, 105, 99, 78.7, 64, 56, 55.6, 47.3

HRMS (EI): calcd. for $C_{18}H_{17}NO_3$ ($[M]^+$) 295.1203, found 295.1201

N-ethynyl-N-methyl-benzamide 3d



Starting from N-methyl-N-(2-triisopropylsilylethynyl)benzamide **2d** (500 mg, 1.6 mmol), TBAF 1M/THF (2.10 mL, 2.1 mmol, 1.3 equiv.) under argon, using **General procedure 2** and stirring at 0°C for 60 min. The crude was purified by silica gel flash column chromatography to afford N-ethynyl-N-methyl-benzamide **3d** as a yellow oil (180 mg, 71 % yield).

IR (neat): 2138, 1647, 704 cm^{-1}

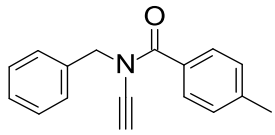
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.7 (d, *J* =7.6 Hz, 2 H), 7.56 (t, *J* = 7.4 Hz, 1 H), 7.48 (t, *J* = 7.6 Hz, 2 H), 3.85 (s, 1 H), 3.25 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.9, 134.2, 132, 128.6 (2C), 128.5 (2C), 62.9, 62.9, 37.8

HRMS (ESI): calcd. for C_{10} H_9 N O ($[M+H]^+$) 160.0757, found 160.0757

mp: 42.1-45.5°C

N-benzyl-N-ethynyl-4-methyl-benzamide 3e



Starting from N-benzyl-4-methyl-N-(2-triisopropylsilylethynyl)benzamide **2e** (335 mg, 0.83 mmol), TBAF 1M/THF (0.99 mL, 1.0 mmol) under argon, using **General procedure 2** and stirring at 0°C for 30 min. The crude was purified by silica gel flash column chromatography to afford N-benzyl-N-ethynyl-4-methyl-benzamide **3e** as a white solid (142 mg, 69 % yield).

IR (neat): 3246, 2138, 1664 cm^{-1}

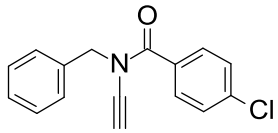
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.65 (d, *J* = 8.0 Hz, 2 H), 7.39 (m, 4 H), 7.34 (m, 1 H), 7.28 (d, *J* = 7.9 Hz, 2 H), 4.82 (s, 2 H), 3.81 (s, 1 H), 2.36 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 170.5, 142.2, 136.7, 130.9, 129.2 (4C), 128.8 (2C), 128.4 (2C), 128.2, 79.3, 63.9, 52.1, 21

HRMS (ESI): calcd. for C_{17} H_{16} N O ($[M+H]^+$) 250.1226, found 250.1227

mp: 57.7-58.3°C

N-benzyl-4-chloro-N-ethynyl-benzamide 3f



Starting from N-benzyl-4-chloro-N-(2-triisopropylsilylethynyl)benzamide **2f** (366 mg, 0.86 mmol), TBAF 1M/THF (1.0 mL, 1.0 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by silica gel flash column chromatography to afford N-benzyl-4-chloro-N-ethynyl-benzamide **3f** as a white solid (145 mg, 63 % yield).

IR (neat): 3242, 2136, 1670 cm^{-1}

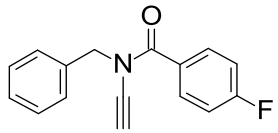
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.77 (d, *J* = 8.3 Hz, 2 H), 7.56 (d, *J* = 8.4 Hz, 2 H), 7.4/7.35 (2m, 5 H), 4.83 (s, 2 H), 3.87 (s, 1 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169.7, 136.7, 136.3, 132.4, 130.6 (2C), 129.4 (2C), 129.0 (2C), 128.7 (2C), 128.4, 78.6, 64.6, 52.3

HRMS (EI): calcd. for C_{16} H_{12} Cl N O ([M]+) 269.0602, found 269.0602

mp: 64-66°C

N-benzyl-N-ethynyl-4-fluoro-benzamide 3g



Starting from N-benzyl-4-fluoro-N-(2-triisopropylsilylethynyl)benzamide **2g** (1.72 g, 4.20 mmol), TBAF 1M/THF (5.0 mL, 5.0 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by trituration in pentane to afford N-benzyl-N-ethynyl-4-fluoro-benzamide **3g** as a white solid (742 mg, 70 % yield).

IR (neat): 3242, 2147, 1649, 1604 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.88 (dd, *J* = 8.9, 5.6 Hz, 2 H), 7.35 (m, 5 H), 7.35 (t, *J* = 8.8 Hz, 2 H), 4.86 (s, 2 H), 3.9 (s, 1 H)

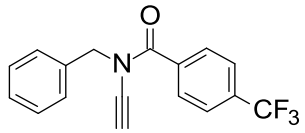
^{13}C NMR (100 MHz, dmso-d_6) δ ppm 169.6, 164.2 (d, *J* = 249.5 Hz), 136.4, 131.6 (d, *J* = 9.3 Hz, 2C), 130.1 (d, *J* = 3.0 Hz), 129.0 (2C), 128.5 (2C), 128.3, 115.6 (d, *J* = 22.1 Hz, 2C), 78.8, 64.4, 52.3

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -108.0

HRMS (EI): calcd. for C_{16} H_{12} F N O ($[M]^{+}$) 253.0897, found 253.0895

mp: 63.7-66.1°C

N-benzyl-N-ethynyl-4-(trifluoromethyl)benzamide 3h



Starting from N-benzyl-4-(trifluoromethyl)-N-(2-triisopropylsilylethynyl)benzamide **2h** (355 mg, 0.77 mmol), TBAF 1M/THF (0.93 mL, 0.9 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by silica gel flash column chromatography to afford N-benzyl-N-ethynyl-4-(trifluoromethyl)benzamide **3h** as a white solid (139 mg, 59 % yield).

IR (neat): 3238, 2135, 1664, 1319, 1136, 1124 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.93 (d, *J* = 7.9 Hz, 2 H), 7.87 (d, *J* = 7.9 Hz, 2 H), 7.4 (m, 4 H), 7.35 (m, 1 H), 4.85 (s, 2 H), 3.88 (s, 1 H)

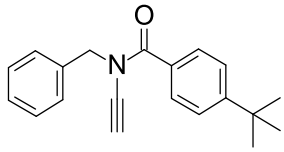
^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169.6, 137.8, 136.2, 131.6 (q, *J* = 32.0 Hz), 129.4 (2C), 129.1 (2C), 128.5 (2C), 128.4, 125.6 (q, *J* = 3.7 Hz, 2C), 124.0 (q, *J* = 271.9 Hz), 78.3, 64.9, 52.2

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm - 61.4

HRMS (EI): calcd. for $C_{17}H_{12}F_3NO$ ($[M]^+$) 303.0866, found 303.0869

mp: 67-69°C

N-benzyl-4-tert-butyl-N-ethynyl-benzamide 3i



Starting from N-benzyl-4-tert-butyl-N-(2-triisopropylsilylethynyl)benzamide **2i** (215 mg, 0.48 mmol), TBAF 1M/THF (0.58 mL, 0.6 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by silica gel flash column chromatography to afford N-benzyl-4-tert-butyl-N-ethynyl-benzamide **3i** as a colorless oil (82 mg, 59 % yield).

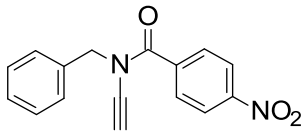
IR (neat): 3230, 2137, 1672 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.71 (d, *J* = 8.2 Hz, 2 H), 7.5 (d, *J* = 8.2 Hz, 2 H), 7.39 (m, 4 H), 7.34 (m, 1 H), 4.82 (s, 2 H), 3.85 (s, 1 H), 1.3 (s, 9 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 170.7, 155.1, 136.9, 131.1, 129.0 (2C), 128.8 (2C), 128.4 (2C), 128.2, 125.3 (2C), 79.4, 64, 52.3, 35.3, 31.4 (3C)

HRMS (EI): calcd. for $C_{20}H_{21}NO$ ($[M]^+$) 291.1618, found 291.1608

N-benzyl-N-ethynyl-4-nitro-benzamide 3j



Starting from N-benzyl-4-nitro-N-(2-triisopropylsilylethynyl)benzamide **2j** (408 mg, 0.93 mmol), TBAF 1M/THF (1.1 mL, 1.1 mmol) under argon, using **General procedure 2** and stirring at 0°C for 25 min. The crude was purified by silica gel flash column chromatography to afford N-benzyl-N-ethynyl-4-nitro-benzamide **3j** as a beige solid (170 mg, 65 % yield).

IR (neat): 3236, 2133, 1668, 1602, 1523, 1350 cm^{-1}

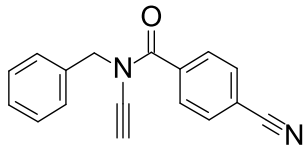
^{1}H NMR (400MHz, DMSO-d_6) δ ppm 8.32 (d, *J* = 8.5 Hz, 2 H), 7.98 (d, *J* = 8.6 Hz, 2 H), 7.41 (m, 4 H), 7.35 (m, 1 H), 4.86 (s, 2 H), 3.9 (s, 1 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 169.7, 149.3, 139.8, 136.1, 130.0 (2C), 129.1 (2C), 128.6 (2C), 128.4, 123.9 (2C), 78.6, 65.1, 52.3

HRMS (EI): calcd. for $C_{16}H_{12}N_2O_3$ ($[M]^+$) 280.0842, found 280.083

mp: 42.9-44.4°C

N-benzyl-4-cyano-N-ethynyl-benzamide 3k



Starting from N-benzyl-4-cyano-N-(2-triisopropylsilylethynyl)benzamide **2k** (239 mg, 0.57 mmol), TBAF 1M/THF (0.69 mL, 0.7 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by trituration in pentane to afford N-benzyl-4-cyano-N-ethynyl-benzamide **3k** as a white solid (116 mg, 78 % yield).

IR (neat): 3232, 2235, 2137, 1670, 1609 cm^{-1}

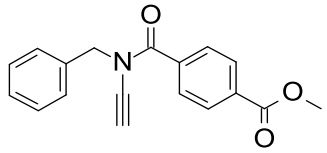
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.0 (d, *J* = 8.2 Hz, 2 H), 7.9 (d, *J* = 8.2 Hz, 2 H), 7.35 (m, 5 H), 4.86 (s, 2 H), 3.9 (s, 1 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169.5, 138.1, 135.9, 132.8 (2C), 129.3 (2C), 129.0 (2C), 128.5 (2C), 128.4, 118.6, 114.2, 78.1, 65, 52.2

HRMS (EI): calcd. for $C_{17}H_{12}N_2O$ ($[M]^+$) 260.0944, found 260.0929

mp: 114-118°C

methyl 4-[benzyl(ethynyl)carbamoyl]benzoate 3l



Starting from methyl 4-[benzyl(2-triisopropylsilylethynyl)carbamoyl]benzoate **2l** (315 mg, 0.70 mmol), TBAF 1M/THF (0.8 mL, 0.8 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by silica gel flash column chromatography to afford methyl 4-[benzyl(ethynyl)carbamoyl]benzoate **3l** as a yellow solid (121 mg, 59 % yield).

IR (neat): 3230, 2137, 1718, 1674 cm^{-1}

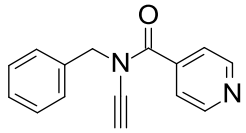
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.04 (d, *J* = 8.2 Hz, 2 H), 7.84 (d, *J* = 8.3 Hz, 2 H), 7.4 (m, 4 H), 7.35 (m, 1 H), 4.85 (s, 2 H), 3.89 (s, 3 H), 3.85 (s, 1 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 170.9, 166.6, 138.9, 136.2, 132.3, 129.4 (2C), 129.0 (2C), 128.9 (2C), 128.5 (2C), 128.2, 78.2, 64.7, 52.9, 52.3

HRMS (EI): calcd. for $C_{18}H_{15}NO_3$ ($[M]^+$) 293.1046, found 293.1034

mp: 93.3-95.3°C

N-benzyl-N-ethynyl-pyridine-4-carboxamide 3m



Starting from N-benzyl-N-(2-triisopropylsilylethynyl)pyridine-4-carboxamide **2m** (514 mg, 1.31 mmol), TBAF 1M/THF (1.6 mL, 1.6 mmol) under argon, using **General procedure 2** and stirring at 0°C for 30 min. The crude was purified by trituration in pentane to afford N-benzyl-N-ethynyl-pyridine-4-carboxamide **3m** as a white solid (179 mg, 58 % yield).

IR (neat): 3233, 2139, 1674, 831, 739, 696 cm^{-1}

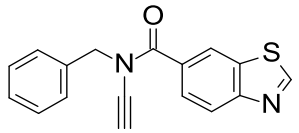
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.74 (d, *J* = 4.9 Hz, 2 H), 7.65 (d, *J* = 4.7 Hz, 2 H), 7.4 (m, 4 H), 7.35 (m, 1 H), 4.84 (s, 2 H), 3.9 (s, 1 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169.2, 150.2 (2C), 141.4, 136.2, 129.1 (2C), 128.5 (2C), 128.4, 122.1 (2C), 77.9, 64.8, 51.6

HRMS (ESI): calcd. for $C_{15}H_{13}N_2O$ ($[M+H]^+$) 237.1022, found 237.1022

mp: 62.5-64.5°C

N-benzyl-N-ethynyl-1,3-benzothiazole-6-carboxamide 3n



Starting from N-benzyl-N-(2-triisopropylsilylethynyl)-1,3-benzothiazole-6-carboxamide **2n** (401 mg, 0.89 mmol), TBAF 1M/THF (1.07 mL, 1.07 mmol) under argon, using **General procedure 2** and stirring at 0°C for 25 min. The crude was purified by silica gel flash column chromatography to N-benzyl-N-ethynyl-1,3-benzothiazole-6-carboxamide **3n** as a yellow solid (178 mg, 68 % yield).

IR (neat): 3234, 2137, 1668 cm^{-1}

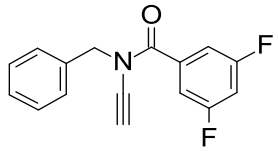
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 9.56 (s, 1 H), 8.62 (d, *J* = 1.5 Hz, 1 H), 8.17 (d, *J* = 8.5 Hz, 1 H), 7.88 (dd, *J* = 8.4, 1.7 Hz, 1 H), 7.42 (m, 4 H), 7.36 (m, 1 H), 4.88 (s, 2 H), 3.84 (s, 1 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 170.3, 160, 155, 136.4, 133.8, 130.7, 129.1 (2C), 128.5 (2C), 128.3, 126.6, 123.7, 122.9, 78.7, 64.3, 52.3

HRMS (EI): calcd. for $C_{17}H_{12}N_2OS$ ($[M]^+$) 292.0665, found 292.0657

mp: 125.7-127.7°C

N-benzyl-N-ethynyl-3,5-difluoro-benzamide 3o



Starting from N-benzyl-3,5-difluoro-N-(2-triisopropylsilylethynyl)benzamide **2o** (333 mg, 0.78 mmol), TBAF 1M/THF (0.93 mL, 0.9 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by silica gel flash column chromatography to afford N-benzyl-N-ethynyl-3,5-difluoro-benzamide **3o** as a white solid (73 mg, 35 % yield).

IR (neat): 3247, 2137, 1674, 1622, 1591 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.45 (m, 3 H), 7.4 (m, 4 H), 7.35 (m, 1 H), 4.83 (s, 2 H), 3.92 (s, 1 H)

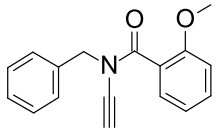
^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 168.3, 162.3 (dd, *J* = 248.2, 12.7 Hz, 2C), 137.3 (t, *J* = 9.2 Hz), 136.1, 129.0 (2C), 128.5 (2C), 128.2, 112.2 (d, *J* = 27.3 Hz, 2C), 107.2 (t, *J* = 25.6 Hz), 78.1, 65.1, 52.5

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -108.8

HRMS (EI): calcd. for $C_{16}H_{11}F_2NO$ ($[M]^+$) 271.0803, found 271.0775

mp: 87.7-91.4°C

N-benzyl-N-ethynyl-2-methoxy-benzamide 3p



Starting from N-benzyl-2-methoxy-N-(2-triisopropylsilylethynyl)benzamide **2p** (447 mg, 1.06 mmol), TBAF 1M/THF (1.27 mL, 1.3 mmol) under argon, using **General procedure 2** and stirring at 0°C for 40 min. The crude was purified by trituration in pentane to afford N-benzyl-N-ethynyl-2-methoxy-benzamide **3p** as a white solid (200 mg, 71 % yield).

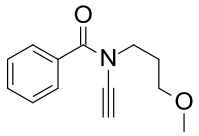
IR (neat): 3245, 2146, 1672, 751, 703 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.45 (ddd, *J* = 8.0, 7.7, 1.7 Hz, 1 H), 7.38 (m, 5 H), 7.31 (dd, *J* = 7.8, 1.6 Hz, 1 H), 7.12 (d, *J* = 8.2 Hz, 1 H), 7.01 (t, *J* = 7.5 Hz, 1 H), 4.82 (s, 2 H), 3.82 (s, 3 H), 3.55 (bs, 1 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 170.1, 156.4, 136.5, 132, 128.8 (2C), 127.9 (2C), 128.3, 127.9, 124.8, 120.8, 112.1, 78.2, 62.8, 56.3, 51

HRMS (EI): calcd. for $C_{17}H_{15}NO_2$ ($[M]^+$) 265.1097, found 265.1096

N-ethynyl-N-(3-methoxypropyl)benzamide 3q



Starting from N-(3-methoxypropyl)-N-(2-triisopropylsilylethynyl)benzamide **2q** (189 mg, 0.51 mmol), TBAF 1M/THF (0.61 mL, 0.6 mmol) under argon, using **General procedure 2** and stirring at 0°C for 1h30. The crude was purified by silica gel flash column chromatography to afford N-ethynyl-N-(3-methoxypropyl)benzamide **3q** as a yellow oil (86 mg, 78 % yield).

IR (neat): 2136, 1671, 1601 cm^{-1}

^{1}H NMR (500 MHz, dmso-d6) δ ppm 7.68 (d, *J* = 7.5 Hz, 2 H), 7.54 (t, *J* = 7.3 Hz, 1 H), 7.47 (t, *J* = 7.5 Hz, 2 H), 3.85 (s, 1 H), 3.69 (t, *J* = 6.9 Hz, 2 H), 3.42 (t, *J* = 6.2 Hz, 2 H), 3.24 (s, 3 H), 1.81 (quint, *J* = 6.6 Hz, 2 H)

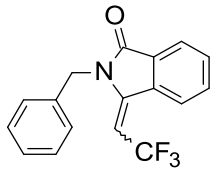
^{13}C NMR (100 MHz, dmso-d6) δ ppm 170.5, 134.2, 131.7 (2C), 128.3 (2C), 128.2, 78.7, 69.5, 63.7, 58.5, 46.5, 27.7

HRMS (ESI): calcd. for $C_{13}H_{15}NO_2$ ($[M+H]^+$) 218.1181, found 218.1176

General procedure 3 for the cascade processes: Synthesis of isoindolinones 4a-q

In a 10 mL Schlenk tube (prealably dried under vacuum) under argon, were loaded the ynamide **3** (1 equiv.), Togni I reagent (3,3-dimethyl-1-(trifluoromethyl)-1lambda3,2-benziodoxole) (1.2 equiv.) and $Ir(ppy)_3$ (0.025 equiv.). The tube was degassed with 3 vacuum/argon cycles. Anhydrous acetonitrile on molecular sieves (0.1M) followed by dichloromethane (5% v/v) were added under argon. The reaction mixture was freeze pumped once to deoxygenate the solvent. The reaction mixture was irradiated under blue LED at 27°C approximately for the given amount of time. After completion of the reaction, the reaction mixture was concentrated under vacuum. The crude was purified by silica gel flash column chromatography (solid deposit on Celite, gradient eluent using a mixture of EtOAc 2% /CH_2Cl_2 1% in heptane). The separation was tricky, the by-product of Togni I was eluted close to the expected product.

(3E/Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4a



In a 25 mL Schlenk tube, starting from N-benzyl-N-ethynyl-benzamide **3a** (250 mg, 1.06 mmol), Togni I reagent (421 mg, 1.3 mmol) and $Ir(ppy)_3$ (17.5 mg, 0.03 mmol), using **General procedure 3** and stirring at 27°C for 5 h. The crude was purified by silica gel flash column chromatography to afford a mixture of (3E/Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4a** as a pale yellow oil (213 mg, 64 % yield) (E/Z mixture 81/19).

(3E)-2-benzyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4aE

IR (neat): 1732, 1656, 1319, 1109 cm^{-1} (mixture 81/19 E/Z)

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.96/7.94 (2d, *J* = 8.2 Hz, 2 H), 7.85/7.77 (2t, *J* = 7.6 Hz, 2 H), 7.35 (m, 3 H), 7.27 (m, 2 H), 5.93 (q, *J* = 9.5 Hz, 1 H), 5.05 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 166.4, 144.5 (q, *J* = 6.3 Hz), 136, 134.1, 132.4, 131.9 (2C), 129.2 (2C), 127.5, 127.4 (2C), 125.5, 124.8 (q, *J* = 268.6 Hz), 124.1, 95.9 (q, *J* = 38.0 Hz), 42.6

167.7, 141.4, 136.9, 136.5, 132.2, 129/128.4, 125.7, 123.9, 122.2, 92.2, 44.7

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.87

HRMS (ESI): calcd. for $C_{17}H_{12}F_3NO$ ($[M+H]^+$) 304.0944, found 304.0942

mp: 94.6-101.9°C

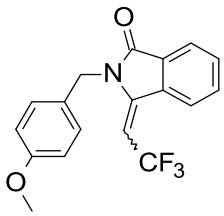
(3Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4aZ

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.23 (d, *J* = 7.8 Hz, 1 H), 7.89 (d, *J* = 7.6 Hz, 1 H), 7.73 (t, *J* = 7.5 Hz, 2 H), 7.31 (m, 3 H), 7.07 (d, *J* = 7.5 Hz, 2 H), 6.37 (q, *J* = 10.1 Hz, 1 H), 5.12 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 167.7, 141.4 (q, *J* = 6.6 Hz), 136.9 (2C), 136.5, 132.2 (2C), 129 (2C), 128.4, 125.7 (2C), 123.9, 122.9 (q, *J* = 268.6 Hz), 122.2, 92.2 (q, *J* = 38.0 Hz), 44.7

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.85

(3E/Z)-2-[(4-methoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4b



Starting from N-[(2,4-dimethoxyphenyl)methyl]-N-ethynyl-benzamide **3b** (106 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 5.5 h. The crude was purified by silica gel flash column chromatography to afford a mixture of (3E/Z)-2-[(4-methoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4b** as a pale yellow oil (78 mg, 59 % yield) (E/Z mixture 60/40).

(3E)-2-[(4-methoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4bE
IR (neat): 1728, 1655, 1244, 1086 cm^{-1} (mixture 60/40 E/Z)

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.95 (d, *J* = 8.1 Hz, 1 H), 7.93 (d, *J* = 8.1 Hz, 1 H), 7.84 (t, *J* = 7.7 Hz, 1 H), 7.76 (t, *J* = 7.5 Hz, 1 H), 7.23 (d, *J* = 8.3 Hz, 2 H), 6.91 (d, *J* = 8.5 Hz, 2 H), 5.95 (q, *J* = 9.4 Hz, 1 H), 4.97 (s, 2 H), 3.73 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 166.5, 159.1, 144.4 (q, *J* = 6.3 Hz), 134, 132.1, 132.1, 130.1, 128.7 (2C), 128.3, 123.7/125.8 (q, *J* = 267.9 Hz), 124.3, 124, 114.3 (2C), 95.9 (q, *J* = 37.9 Hz), 55.4, 42.1

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.8

HRMS (ESI): calcd. for $C_{18}H_{15}F_3NO_2$ ($[M+H]^+$) 334.1049, found 334.105

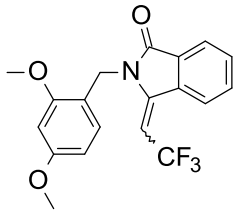
mp: 76.5-84.2°C (mixture 60/40 E/Z)

(3Z)-2-[(4-methoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4bZ
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.22 (d, *J* = 7.8 Hz, 1 H), 7.87 (d, *J* = 7.5 Hz, 1 H), 7.81 (t, *J* = 7.9 Hz, 1 H), 7.73 (t, *J* = 7.5 Hz, 1 H), 7 (d, *J* = 8.5 Hz, 2 H), 6.86 (d, *J* = 8.7 Hz, 2 H), 6.35 (q, *J* = 10.04 Hz, 1 H), 5.04 (s, 2 H), 3.71 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 168.4, 158.5, 142 (q, *J* = 6.5 Hz), 137.3, 134.2, 132, 128.8, 127.1, 127 (2C), 123.8 (q, *J* = 266.9 Hz), 123.8, 122, 114.4 (2C), 91.9 (q, *J* = 37.9 Hz), 55.5, 44.2

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.8

(3E/Z)-2-[(2,4-dimethoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4c



Starting from N-[(2,4-dimethoxyphenyl)methyl]-N-ethynyl-benzamide **3c** (82 mg, 0.28 mmol), Togni I reagent (110 mg, 0.33 mmol) and $Ir(ppy)_3$ (4.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 3 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-[(2,4-dimethoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4cE** as a white solid (39 mg) and (3Z)-2-[(2,4-dimethoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4cZ** as a white solid (18 mg) (E/Z ratio 70/30, 57 % overall yield).

(3E)-2-[(2,4-dimethoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4cE
IR (neat): 1723, 1659, 1614, 1258, 1093 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.97/7.93 (2d, *J* = 7.6 Hz, 2 H), 7.86/7.79 (2t, *J* = 7.6 Hz, 2 H), 6.9 (d, *J* = 8.5 Hz, 1 H), 6.63 (d, *J* = 2.4 Hz, 1 H), 6.5 (dd, *J* = 8.4 Hz, 1 H), 5.85 (q, *J* = 9.5 Hz, 1 H), 4.9 (s, 2 H), 3.85/3.75 (s, 6 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 166.4, 160.6, 157.9, 145 (q, *J* = 6.8 Hz), 134, 132.3, 132.1, 129.9, 129, 125 (q, *J* = 267.6 Hz), 124.6, 124 , 116, 105.6, 98.9, 95 (q, *J* = 37.8 Hz), 56, 55.7, 37.6

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.8

HRMS (ESI): calcd. for $C_{19}H_{17}F_3NO_3$ ($[M+H]^+$) 364.1155, found 364.1157

mp: 132.0-134.8°C

(3Z)-2-[(2,4-dimethoxyphenyl)methyl]-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4cZ
IR (neat): 1719, 1660, 1610, 1134, 1095 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.22 (d, *J* = 7.7 Hz, 1 H), 7.87 (d, *J* = 7.5 Hz, 1 H), 7.81 (tt, *J* = 7.7, 1.1 Hz, 1 H), 7.73 (t, *J* = 7.5 Hz, 1 H), 6.59 (df, *J* = 2.3 Hz, 1 H), 6.49 (d, *J* = 8.3 Hz, 1 H), 6.37 (dd, *J* = 8.4, 2.3 Hz, 1 H), 6.33 (q, *J* = 10.0 Hz, 1 H), 4.97 (sl, 2 H), 3.83 (s, 3 H), 3.71 (s, 3 H)

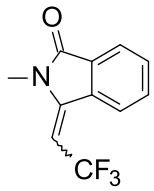
^{13}C NMR (75 MHz, DMSO-d_6) δ ppm 168.1, 159.6, 157.1, 141.9 (q, *J* = 6.4 Hz),, 137.3, 134, 132, 127, 125.4, 123.7 (q, *J* = 267.8 Hz), 123.7, 121.9, 116.5, 104.6, 98.5, 91.8 (q, *J* = 37.6 Hz), 56, 55.6, 40.3

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -49.3

HRMS (ESI): calcd. for $C_{19}H_{17}F_3NO_3$ ($[M+H]^+$) 364.1155, found 364.1157

mp: 137.0-139.5°C

(3E/Z)-2-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4d



Starting from N-ethynyl-N-methyl-benzamide **3d** (64 mg, 0.4 mmol), Togni I reagent (139 mg, 0.42 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 4 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **3dE** as a white solid (27 mg) and (3Z)-2-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **3dZ** as a white solid (16 mg) (E/Z ratio 63/37, 47 % overall yield).

(3E)-2-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4dE
IR (neat): 1716, 1654, 1336, 1124 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.95 (d, *J* = 7.8 Hz, 1 H), 7.85 (d, *J* = 7.5 Hz, 1 H), 7.8 (td, *J* = 7.5, 0.7 Hz, 1 H), 7.72 (td, *J* = 7.5, 0.7 Hz, 1 H), 5.99 (q, *J* = 9.4 Hz, 1 H), 3.21 (s, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 165.5, 145.1 (q, *J* = 6.5 Hz), 133.2, 131.6, 131.5, 129.7, 124.3 (q, *J* = 268.4 Hz), 123.9, 123.2, 94.6 (q, *J* = 37.6 Hz), 26

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.8

HRMS (ESI): calcd. for $C_{11}H_9F_3NO$ ($[M+H]^+$) 228.0631, found 228.0632

mp: 100.5-105.3°C

(3Z)-2-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4dZ
IR (neat): 1721, 1655, 1121, 1090 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.14 (d, *J* = 7.6 Hz, 1 H), 7.82 (d, *J* = 7.4 Hz, 1 H), 7.76 (td, *J* = 7.6, 1.1 Hz, 1 H), 7.68 (td, *J* = 7.5, 0.6 Hz, 1 H), 6.32 (q, *J* = 7.7 Hz, 1 H), 3.32 (q[6], , *J* = 2.3 Hz, 3 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 167.9, 143.3 (q, *J* = 6.3 Hz), 136.9, 133.8, 131.5, 127.4, 123.9 (q, *J* = 268.0 Hz), 123.2, 121.6, 91.4 (q, *J* = 37.3 Hz), 28.1

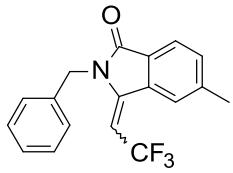
^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -47.1

HRMS (ESI): calcd. for $C_{11}H_9F_3NO$ ($[M+H]^+$) 228.0631, found 228.0632

mp: 105.5-107.0°C

[6] Through space coupling

(3E/Z)-2-benzyl-5-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4e



Starting from N-benzyl-N-ethynyl-4-methyl-benzamide **3e** (100 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 5.3 h. The crude was purified by silica gel flash column chromatography to afford a mixture of (3E/Z)-2-benzyl-5-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4e** as a white solid (66 mg, 52 % yield) (E/Z mixture 58/42).

(3E)-2-benzyl-5-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4eE
IR (neat): 1718, 1654, 1317, 1257, 1157, 1134 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.82 (d, *J* = 7.7 Hz, 1 H), 7.73 (s, 1 H), 7.59 (d, *J* = 7.7 Hz, 1 H), 7.38-7.22 (m, 5 H), 5.88 (q, *J* = 9.5 Hz, 1 H), 5.03 (s, 2 H), 2.5 (s, 3 H, under the DMSO peak)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 166.5, 144.6 (q, *J* = 6.4 Hz), 137.7, 136.5, 133, 132.5, 129.3 (4C), 125.9, 127.4, 126.8 (q, *J* = 268.8 Hz), 124.6, 123.9, 95.7 (q, *J* = 37.8 Hz), 42.4, 22.6

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.7

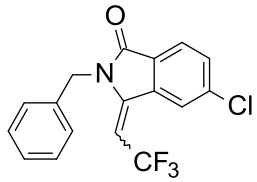
HRMS (ESI): calcd. for $C_{18}H_{15}F_3NO$ ($[M+H]^+$) 318.1111, found 318.1098

(3Z)-2-benzyl-5-methyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4eZ
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.06 (s, 1 H), 7.78 (d, *J* = 7.6 Hz, 1 H), 7.55 (d, *J* = 7.8 Hz, 1 H), 7.36-7.21 (m, 3 H), 7.06 (d, *J* = 7.5 Hz, 2 H), 6.29 (q, *J* = 9.9 Hz, 1 H), 5.09 (s, 2 H), 2.5 (s, 3 H, under the DMSO peak)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 168.4, 142.1 (q, *J* = 6.5 Hz), 137.6, 137.2, 137.1, 132.5, 129.0 (2C), 126.5, 125.2, 124.8 (q, *J* = 267.9 Hz), 124.7, 123.6, 122.2, 91.4 (q, *J* = 37.6 Hz), 44.8, 22.5

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.8

(3E/Z)-2-benzyl-5-chloro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4f



Starting from N-benzyl-4-chloro-N-ethynyl-benzamide **3f** (108 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 4.7 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-benzyl-5-chloro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4fE** as a white solid (50 mg) and (3Z)-2-benzyl-5-

chloro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4fZ** as a white solid (27 mg) (E/Z ratio 63/37, 57% overall yield).

(3E)-2-benzyl-5-chloro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4fE
IR (neat): 1309, 1654, 1309, 1269, 1249, 1128 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.97 (d, *J* = 8.1 Hz, 1 H), 7.86 (dd, *J* = 8.1, 1.7 Hz, 1 H), 7.83 (bs, 1 H), 7.35 (t, *J* = 7.5 Hz, 2 H), 7.31-7.25 (m, 3 H), 6.03 (q, *J* = 9.4 Hz, 1 H), 5.05 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 165.4, 143.3 (q, *J* = 6.4 Hz), 138.8, 136.1, 133.7, 132.6, 129.2 (2C), 128.8, 128.4, 127.7 (2C), 126, 124.6 (q, *J* = 269.1 Hz), 124.3, 96.9 (q, *J* = 37.5 Hz), 42.7

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.8

HRMS (ESI): calcd. for $C_{17}H_{12}ClF_3NO$ ($[M+H]^+$) 338.0554, found 338.0556

mp: 102.6-110.3°C

(3Z)-2-benzyl-5-chloro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4fZ
IR (neat): 1722, 1660, 1301, 1274, 1255, 1134 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.45 (df, *J* = 1.5 Hz, 1 H), 7.89 (d, *J* = 8.1 Hz, 1 H), 7.78 (dd, *J* = 8.1, 1.6 Hz, 1 H), 7.3 (t, *J* = 7.4 Hz, 2 H), 7.23 (t, *J* = 7.3 Hz, 1 H), 7.07 (t, *J* = 7.5 Hz, 2 H), 6.48 (q, *J* = 9.9 Hz, 1 H), 5.1 (s, 2 H)

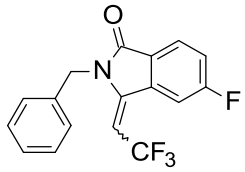
^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 168.2, 141.3 (q, *J* = 6.4 Hz), 139.8, 139.3, 137.6, 132.2, 128.9 (2C), 127.4, 126.1, 125.8 (2C), 125.5, 123.6 (q, *J* = 268.8 Hz), 122.4, 93.4 (q, *J* = 37.5 Hz), 44.9

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -49.1

HRMS (ESI): calcd. for $C_{17}H_{12}ClF_3NO$ ($[M+H]^+$) 338.0554, found 338.0556

mp: 138.2-146.4°C

(3E/Z)-2-benzyl-5-fluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4g



Starting from N-benzyl-N-ethynyl-4-fluoro-benzamide **3g** (101 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** (in CH_2Cl_2) and stirring at 27°C for 6.5 h. The crude was purified by silica gel flash column chromatography to afford a mixture of (3E/Z)-2-benzyl-5-fluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4g** as a yellow oil (74 mg, 58 % yield) (E/Z mixture 62/38).

(3E)-2-benzyl-5-fluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4gE
IR (neat): 1730, 1658, 1109 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.01 (dd, *J* = 8.4, 5.2 Hz, 1 H), 7.65 (td, *J* = 8.6 Hz, 1 H), 7.6 (d, *J* = 8.7 Hz, 1 H), 7.35 (t, *J* = 7.4 Hz, 2 H), 7.28 (m, 3 H), 6.02 (q, *J* = 9.4 Hz, 1 H), 5.05 (s, 2 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 165.5, 165.5 (d, *J* = 250.1 Hz), 143.4 (q, *J* = 6.3 Hz), 136.5, 134.3 (2C), 129.1 (2C), 127.7 (2C), 126.4, 126.2, 124.4 (q, *J* = 268.0 Hz), 119.9 (d, *J* = 23.5 Hz, 2C), 112.1, 96.5 (q, *J* = 37.7 Hz), 42.7

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.9, -105

HRMS (EI) : calcd. for $C_{17}H_{11}F_4NO$ ($[M]^+$) 321.0777, found 321.0772

(3Z)-2-benzyl-5-fluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4gZ

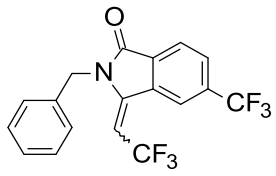
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.2 (dd, *J* = 8.8, 2.2 Hz, 1 H), 7.94 (dd, *J* = 8.5 Hz, 1 H), 7.57 (td, *J* = 8.6, 2.3 Hz, 1 H), 7.3 (t, *J* = 7.6 Hz, 2 H), 7.23 (t, *J* = 7.4 Hz, 1 H), 7.07 (d, *J* = 7.5 Hz, 2 H), 6.42 (q, *J* = 10.0 Hz, 1 H), 5.1 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 166.8, 165.5 (d, *J* = 249.9 Hz), 140.7 (q, *J* = 6.4 Hz), 139.9 (d, *J* = 11.1 Hz, 136.4, 128.7 (2C), 127.1, 126.5 (d, *J* = 10.1 Hz), 123.8 (2C), 123.8 (d, , 123.6 (q, *J* = 268.3 Hz), 119.6 (d, *J* = 24.1 Hz), 109.5 (d, *J* = 26.3 Hz), 93.1 (q, *J* = 37.8 Hz), 44.9

^{19}F NMR (376 MHz, dmso-d6) δ ppm -49.1, -105

HRMS (ESI): calcd. for $C_{17}H_{12}F_4NO$ ($[M+H]^+$) 322.0850, found 322.0852

(3E/Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)-5-(trifluoromethyl)isoindolin-1-one 4h



Starting from N-benzyl-N-ethynyl-4-(trifluoromethyl)benzamide **3h** (121 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 4.7 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-benzyl-3-(2,2,2-trifluoroethylidene)-5-(trifluoromethyl)isoindolin-1-one **4hE** as a colorless oil (65 mg) and (3Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)-5-(trifluoromethyl)isoindolin-1-one **4hZ** as a yellow oil (8 mg) (E/Z mixture 90/10, 45% overall yield).

(3E)-2-benzyl-3-(2,2,2-trifluoroethylidene)-5-(trifluoromethyl)isoindolin-1-one 4hE

IR (neat): 1733, 1313, 1120, 1103 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.17 (s, 2 H), 8.11 (sl, 1 H), 7.35 (t, *J* = 7.4 Hz, 2 H), 7.3 (m, 3 H), 6.13 (q, *J* = 9.3 Hz, 1 H), 5.1 (s, 2 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 165.5, 143.3 (q, *J* = 6.2 Hz), 136.2, 133.7, 133.5, 132.6, 129.7 (bq, *J* = 3.3 Hz), 129 (2C), 127.6 (2C), 127.6, 125, 124.5 (q, *J* = 268.6 Hz), 124 (q, *J* = 272.7 Hz), 120.7 (bq, *J* = 5.0 Hz), 97.4 (q, *J* = 37.6 Hz), 42.9

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.9, -61.6

HRMS (EI) : calcd. for C_{18} H_{11} F_6 N O ($[M]^+$) 371.0739, found 371.0730

(3Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)-5-(trifluoromethyl)isoindolin-1-one 4hZ
IR (neat): 1724, 1660, 1323, 1130, 1110, 1097 cm^{-1}

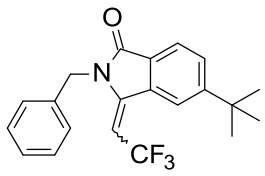
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.78 (s, 1 H), 8.08 (bs, 2 H), 7.3 (t, *J* = 7.5 Hz, 2 H), 7.24 (t, *J* = 7.3 Hz, 1 H), 7.1 (d, *J* = 765 Hz, 2 H), 6.69 (q, *J* = 10.09 Hz, 1 H), 5.14 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 167.1, 141 (q, *J* = 6.1 Hz), 138, 136.7, 133.9 (q, *J* = 32.0 Hz), 130.8, 128.8 (bq, *J* = 3.7 Hz), 128.6 (2C), 127, 126 (2C), 124.5, 124.2 (q, *J* = 272.8 Hz), 123.6 (q, *J* = 268.5 Hz), 119.4 (bq, *J* = 3.8 Hz), 93.8 (q, *J* = 37.6 Hz), 45

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -49.2, -61

HRMS (EI): calcd. for C_{18} H_{11} F_6 N O ($[M]^+$) 371.0739, found 371.0737

(3E/Z)-2-benzyl-5-tert-butyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4i



Starting from N-benzyl-4-tert-butyl-N-ethynyl-benzamide **3i** (77 mg, 0.26 mmol), Togni I reagent (105 mg, 0.32 mmol) and $Ir(ppy)_3$ (4.3 mg, 0.007 mmol), using **General procedure 3** and stirring at 27°C for 3.8 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-benzyl-5-tert-butyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4iE** as a pale yellow oil (25 mg) and (3Z)-2-benzyl-5-tert-butyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4iZ** as a pale yellow oil (18 mg) (E/Z mixture 56/44, 40 % overall yield).

(3E)-2-benzyl-5-tert-butyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4iE
IR (neat): 1726, 1654, 1313, 1253, 1126 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8 (sb, 1 H), 7.85 (d, *J* = 8.0 Hz, 1 H), 7.82 (d, *J* = 8.0, 1.5 Hz, 1 H), 7.4-7.2 (m, 5 H), 5.9 (q, *J* = 9.6 Hz, 1 H), 5.03 (s, 2 H), 1.32 (s, 9 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 166.5, 157.2, 144.7 (q, *J* = 6.1 Hz), 136.6, 132.4, 129.8, 129.2 (2C), 127.9, 127.4, 127.3 (2C), 123.9 (q, *J* = 268.3 Hz), 123.5, 121.3, 95.4 (q, *J* = 37.8 Hz), 42.5, 35.7, 31.2 (3C)

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.9

HRMS (ESI): calcd. for C_{21} H_{22} F_3 N O ($[M+H]^+$) 360.1570, found 360.157

(3Z)-2-benzyl-5-tert-butyl-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4iZ
IR (neat): 1728, 1660, 1267, 1251, 1197, 1128 cm^{-1}

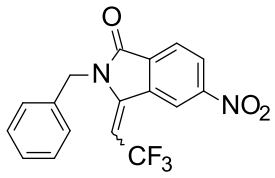
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.3 (sb, 1 H), 7.8 (db, *J* = 7.9 Hz, 1 H), 7.76 (dd, *J* = 8.0, 1.4 Hz, 1 H), 7.3 (t, *J* = 7.7 Hz, 2 H), 7.23 (t, *J* = 7.4 Hz, 1 H), 7.05 (d, *J* = 7.6 Hz, 2 H), 6.5 (q, *J* = 10.1 Hz, 1 H), 5.1 (s, 2 H), 1.4 (s, 9 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 169, 158, 142.2 (q, *J* = 6.5 Hz), 137.5, 137.2, 129, 128.9 (2C), 127.3, 125.8 (2C), 124.8, 124.0 (q, *J* = 268.3 Hz), 123.6, 119.3, 91.5 (q, *J* = 37.4 Hz), 44.5, 35.9, 31.5 (3C)

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.7

HRMS (ESI): calcd. for $C_{21}H_{21}F_3NO$ ($[M+H]^+$) 360.1570, found 360.157

(3E/Z)-2-benzyl-5-nitro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4j



Starting from N-benzyl-N-ethynyl-4-nitro-benzamide **3j** (112 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 22 h and then at 40°C for 5.5 h. The crude was purified by silica gel flash column chromatography to afford a mixture of (3E/Z)-2-benzyl-5-nitro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4j** as a white solid (80 mg, 52 % yield) (E/Z mixture 55/45).

(3E)-2-benzyl-5-nitro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4jE
IR (neat): 1730, 1656, 1533, 1340, 1116, 779, 738 cm^{-1} (mixture 70/30 E/Z)

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.63 (df, *J* = 1.5 Hz, 1 H), 8.59 (dd, *J* = 8.3, 1.8 Hz, 1 H), 8.19 (d, *J* = 8.3 Hz, 1 H), 7.39-7.3 (m, 5 H), 6.18 (q, *J* = 9.3 Hz, 1 H), 5.1 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 164.5, 151.1, 143 (q, *J* = 6.0 Hz), 134.6, 132.8, 128.9, 128.7 (2C), 127.6 (2C), 127.6, 125.9, 125.9, 124.4 (q, *J* = 268.9 Hz), 119.9, 97.6 (q, *J* = 37.8 Hz), 43.5

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.6

HRMS (ESI): calcd. for $C_{17}H_{11}F_3N_2O$ ($[M+H]^+$) 3498.0795, found 349.0796

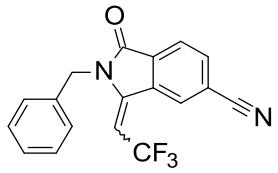
(3Z)-2-benzyl-5-nitro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4jZ
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 9.21 (df, *J* = 1.8 Hz, 1 H), 8.52 (dd, *J* = 8.26, 1.9 Hz, 1 H), 8.13 (d, *J* = 8.3 Hz, 1 H), 7.31 (m, 2 H), 7.23 (t, *J* = 7.3 Hz, 1 H), 7.11 (d, *J* = 7.4 Hz, 2 H), 6.81 (q, *J* = 10.0 Hz, 1 H), 5.14 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 167.1, 151.6, 140.6 (q, *J* = 6.5 Hz), 138.5, 135.9, 132.2, 128.0 (2C), 127.6, 127.2, 125.9 (2C), 125.3, 124.4 (q, *J* = 267.2 Hz), 117, 95 (q, *J* = 37.6 Hz), 45.6

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -49.3

HRMS (ESI): calcd. for $C_{17}H_{11}F_3N_2O$ ($[M+H]^+$) 3498.0795, found 349.0796

(3E/Z)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carbonitrile 4k



Starting from N-benzyl-4-cyano-N-ethynyl-benzamide **3k** (104 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 6 h and at 40°C for 15 h. The crude was purified by silica gel flash column chromatography to afford a mixture of (3E)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carbonitrile **4k** as a white solid (64 mg) (E/Z mixture 66/34, 56 % overall yield).

(3E)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carbonitrile 4kE
IR (neat): 2233, 1735, 1654, 1107, 704, 661 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.27 (d, *J* = 7.8 Hz, 1 H), 8.16 (bs, 1 H), 8.13 (d, *J* = 7.8 Hz, 1 H), 7.35 (t, *J* = 7.4 Hz, 2 H), 7.28 (m, 3 H), 6.13 (q, *J* = 9.3 Hz, 1 H), 5.09 (s, 2 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 165.1, 142.9 (q, *J* = 6.2 Hz), 136.4, 136.1, 133.9, 132.6, 129.1 (2C), 128.1, 127.4 (2C), 125.4, 125.3, 124.4 (q, *J* = 269.7 Hz), 118.5, 116.3, 97.6 (q, *J* = 37.7 Hz), 43

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.8

HRMS (EI): calcd. for $C_{18}H_{11}F_3N_2O$ ($[M]^+$) 328.0823, found 328.0818

mp: 122.6-132.0°C (mixture 65/35 E/Z)

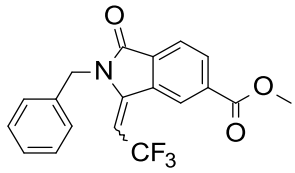
(3Z)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carbonitrile 4kZ
IR (neat): 2231, 1727, 1662, 1094 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.84 (bs, 1 H), 8.18 (dd, *J* = 7.9, 1.2 Hz, 1 H), 8.07 (d, *J* = 7.8 Hz, 1 H), 7.31 (t, *J* = 7.4 Hz, 2 H), 7.23 (t, *J* = 7.3 Hz, 1 H), 7.1 (d, *J* = 7.5 Hz, 2 H), 6.53 (q, *J* = 9.9 Hz, 1 H), 5.12 (s, 2 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 167, 140.8 (q, *J* = 6.5 Hz), 137.6, 136.6, 135.5, 130.6, 128.7 (2C), 127.3, 126.5, 125.9 (2C), 124.9, 123.5 (q, *J* = 268.9 Hz), 118.3, 116.2, 94.1 (q, *J* = 37.6 Hz), 43.8

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -49.2

methyl (3E/Z)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carboxylate 4l



Starting from methyl 4-[benzyl(ethynyl)carbamoyl]benzoate **3l** (107 mg, 0.36 mmol), Togni I reagent (145 mg, 0.44 mmol) and $Ir(ppy)_3$ (6 mg, 0.09 mmol), using **General procedure 3** and stirring at 27°C

for 22 h. The crude was purified by silica gel flash column chromatography to afford a mixture of methyl (3E/Z)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carboxylate **4l** as a yellow solid (81 mg, 61 % yield) (E/Z mixture 63/37).

methyl (3E)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carboxylate 4lE

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.52 (s, 1 H), 8.31 (dd, *J* = 7.9, 1.2 Hz, 1 H), 8.07 (d, *J* = 7.9 Hz, 1 H), 7.36 (t, *J* = 7.4 Hz, 2 H), 7.3 (m, 3 H), 6.08 (q, *J* = 9.4 Hz, 1 H), 5.08 (s, 2 H), 3.94 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 165.6, 165.6, 143.8 (q, *J* = 6.2 Hz), 136.3, 134.2, 133.5, 132.8, 132.2, 129.2 (2C), 128 (2C), 128, 125.1, 124.9 (q, *J* = 268.0 Hz), 124.9, 96.6 (q, *J* = 37.4 Hz), 52.8, 42.6

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.7

HRMS (ESI): calcd. for $C_{19}H_{15}F_3NO_3$ ($[M+H]^+$) 362.0999, found 362.1001

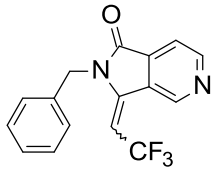
methyl (3Z)-2-benzyl-1-oxo-3-(2,2,2-trifluoroethylidene)isoindoline-5-carboxylate 4lZ

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.82 (s, 1 H), 8.26 (dd, *J* = 7.8, 1.2 Hz, 1 H), 8 (d, *J* = 7.9 Hz, 1 H), 7.3 (m, 2 H), 7.23 (t, *J* = 7.3 Hz, 1 H), 7.1 (d, *J* = 7.6 Hz, 2 H), 6.67 (q, *J* = 10.01 Hz, 1 H), 5.13 (s, 2 H), 3.95 (s, 3 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 167.6, 166, 141.1 (q, *J* = 6.4 Hz), 137.6, 136.8, 134.7, 132.5, 130.7, 129.1 (2C), 127.2, 125.5 (2C), 124.8, 124.0 (q, *J* = 268.3 Hz), 122.9, 94 (q, *J* = 37.4 Hz), 53.8, 44.7

^{19}F NMR (376 MHz, DMSO-d_6) δ -49.1 ppm

(3E/Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)pyrrolo[3,4-c]pyridin-1-one 4m



Starting from N-benzyl-N-ethynyl-pyridine-4-carboxamide **3m** (95 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 20 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-benzyl-3-(2,2,2-trifluoroethylidene)pyrrolo[3,4-c]pyridin-1-one **4mE** as a yellow solid (40 mg) and (3Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)pyrrolo[3,4-c]pyridin-1-one **4mZ** as a yellow oil (28 mg) (E/Z mixture 73/27, 54 % overall yield).

(3E)-2-benzyl-3-(2,2,2-trifluoroethylidene)pyrrolo[3,4-c]pyridin-1-one 4mE

IR (neat): 1728, 1660, 1334, 1105 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 9.15 (bs, 1 H), 9 (d, *J* = 4.8 Hz, 1 H), 7.97 (dd, *J* = 4.9, 1.2 Hz, 1 H), 7.36 (t, *J* = 7.2 Hz, 2 H), 7.3 (m, 3 H), 6.14 (q, *J* = 9.2 Hz, 1 H), 5.1 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 165.1, 152.9, 145.4, 142.7 (q, *J* = 6.3 Hz), 137.1, 136, 129.2 (2C), 128.0, 127.4 (2C), 127.3, 124.4 (q, *J* = 268.3 Hz), 117.7, 97.2 (q, *J* = 37.6 Hz), 42.8

^{19}F NMR (376 MHz, dmso-d6) δ ppm -52.5

HRMS (ESI): calcd. for $C_{16}H_{12}F_3N_2O$ ([M+H]$^+$) 305.0896, found 305.0894

(3Z)-2-benzyl-3-(2,2,2-trifluoroethylidene)pyrrolo[3,4-c]pyridin-1-one 4mZ
IR (neat): 1728, 1662, 1126-1100cm^{-1}

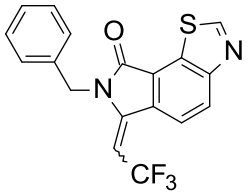
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 9.55 (s, 1 H), 9 (d, *J* = 4.9 Hz, 1 H), 7.9 (dd, *J* = 4.9, 1.1 Hz, 1 H), 7.35 (t, *J* = 7.5 Hz, 2 H), 7.27 (t, *J* = 7.4 Hz, 1 H), 7.11 (d, *J* = 7.4 Hz, 2 H), 6.5 (q, *J* = 10.0 Hz 1 H), 5.17 (s, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 167.4, 152.5, 144, 140.5 (q, *J* = 6.6 Hz), 136.5, 134.3, 131.9, 129 (2C), 127.5, 126 (2C), 123 (q, *J* = 268.9 Hz), 117.5, 94 (q, *J* = 37.6 Hz), 45

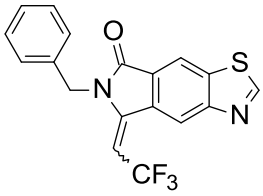
^{19}F NMR (376 MHz, dmso-d6) δ ppm -49.2

HRMS (ESI): calcd. for $C_{16}H_{12}F_3N_2O$ ([M+H]$^+$) 305.0896, found 305.0896

(6E/Z)-7-benzyl-6-(2,2,2-trifluoroethylidene)pyrrolo[3,4-g][1,3]benzothiazol-8-one 4n and (5E/Z)-6-benzyl-5-(2,2,2-trifluoroethylidene)pyrrolo[3,4-f][1,3]benzothiazol-7-one 4n'



4n



4n'

Starting from N-benzyl-N-ethynyl-1,3-benzothiazole-6-carboxamide **3n** (117 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and Ir(ppy)$_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 22 h. The crude was purified by silica gel flash column chromatography to afford (6E)-7-benzyl-6-(2,2,2-trifluoroethylidene)pyrrolo[3,4-g][1,3]benzothiazol-8-one **4nE** as a white solid (33 mg), (6Z)-7-benzyl-6-(2,2,2-trifluoroethylidene)pyrrolo[3,4-g][1,3]benzothiazol-8-one **4nZ** as a white solid (19 mg) (E/Z mixture 63/37, 36 % overall yield) and a mixture of (5E/Z)-6-benzyl-5-(2,2,2-trifluoroethylidene)pyrrolo[3,4-f][1,3]benzothiazol-7-one **4n'** as a white solid (22 mg, 15 % yield) (E/Z mixture 78/22).

(6E)-7-benzyl-6-(2,2,2-trifluoroethylidene)pyrrolo[3,4-g][1,3]benzothiazol-8-one 4nE
IR (neat): 3070, 1724, 1652, 1099, 717, 692, 675 cm^{-1}

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 9.79 (s, 1 H), 8.47 (d, *J* = 8.2 Hz, 1 H), 8.06 (d, *J* = 8.2 Hz, 1 H), 7.31 (t, *J* = 7.4 Hz, 2 H), 7.23 (t, *J* = 7.3 Hz, 1 H), 7.14 (d, *J* = 7.5 Hz, 2 H), 5.79 (q, *J* = 9.6 Hz, 1 H), 5.17 (s, 2 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 168, 160.2, 158.8, 142.5 (q, *J* = 6.3 Hz), 136.8, 132, 128.9 (2C), 127.4, 127.1, 126.8, 126.3 (q, *J* = 268.7 Hz), 125.8 (2C), 125.5, 121.7, 94.5 (q, *J* = 38.4 Hz), 45.2

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.9

HRMS (ESI): calcd. for $C_{18}H_{11}F_3OS$ ([M+H]$^+$) 361.0617, found 361.0619

mp: 171.7-174.9°C

(6Z)-7-benzyl-6-(2,2,2-trifluoroethylidene)pyrrolo[3,4-g][1,3]benzothiazol-8-one 4nZ
IR (neat): 3060, 1714, 1649, 1110, 777, 713, 678 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 9.7 (s, 1 H), 8.52 (d, *J* = 8.2 Hz, 1 H), 8.1 (d, *J* = 8.2 Hz, 1 H), 7.37 (t, *J* = 7.4 Hz, 2 H), 7.3 (m, 3 H), 6.09 (q, *J* = 9.9 Hz, 1 H), 5.16 (s, 2 H)

^{13}C NMR (75 MHz, DMSO-d_6) δ ppm 166, 159.8, 158.6, 143.1 (q, *J* = 6.2 Hz), 136.4, 130.2, 129.3 (2C), 129, 128.3 (2C), 128.1, 127.6, 127.5, 124.1 (q, *J* = 267.3 Hz), 121.8, 98.7 (q, *J* = 38.0 Hz), 43

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -46.8

HRMS (ESI): calcd. for $C_{18}H_{11}F_3OS$ ($[M+H]^+$) 361.0617, found 361.0618

mp: 181.5-185.7°C

(5E)-6-benzyl-5-(2,2,2-trifluoroethylidene)pyrrolo[3,4-f][1,3]benzothiazol-7-one 4n'E
IR (neat): 3076, 1724, 1651, 1132, 1099, 839, 732, 692 cm^{-1} (mixture 78/22 E/Z)

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 9.7 (s, 1 H), 8.86 (s, 1 H), 8.51 (s, 1 H), 7.36 (t, *J* = 7.4 Hz, 2 H), 7.3 (m, 3 H), 5.97 (q, *J* = 9.5 Hz, 1 H), 5.11 (s, 2 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 165.9, 161.9, 156.5, 144.1 (q, *J* = 6.2 Hz), 137.8, 136.7, 129.5 (2C), 129.5, 127.9 (2C), 127.7, 126.7, 125.1 (q, *J* = 268.9 Hz), 119.8, 119.3, 95.6 (q, *J* = 37.7 Hz), 43.1

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -52.1

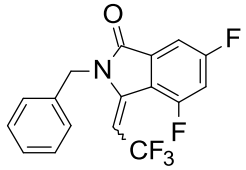
HRMS (ESI): calcd. for $C_{18}H_{11}F_3OS$ ($[M+H]^+$) 361.0617, found 361.0619

(5Z)-6-benzyl-5-(2,2,2-trifluoroethylidene)pyrrolo[3,4-f][1,3]benzothiazol-7-one 4n'Z
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 9.69 (s, 1 H), 9 (s, 1 H), 8.8 (s, 1 H), 7.32 (m, 2 H), 7.24 (t, *J* = 7.3 Hz, 1 H), 7.1 (d, *J* = 7.5 Hz, 2 H), 6.58 (q, *J* = 10.1 Hz, 1 H), 5.16 (s, 2 H)

^{13}C NMR (125 MHz, DMSO-d_6) δ ppm 168.1, 161.9, 156.9, 142 (q, *J* = 6.4 Hz), 137.6, 137, 135.1, 127.4 (2C), 127.4, 124.8 (2C), 124.5, 124 (q, *J* = 268.2 Hz), 119.6, 116.7, 91.4 (q, *J* = 37.7 Hz), 45.2

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.5

(3E/Z)-2-benzyl-4,6-difluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4o



Starting from N-benzyl-N-ethynyl-3,5-difluoro-benzamide **3o** (54 mg, 0.2 mmol), Togni I reagent (79 mg, 0.24 mmol) and $Ir(ppy)_3$ (3.3 mg, 0.005 mmol), using **General procedure 3** and stirring at 27°C for 12 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-benzyl-4,6-difluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4oE** as a colorless oil (22 mg) and (3Z)-2-benzyl-

4,6-difluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4oZ** as a colorless oil (22 mg) (E/Z mixture 50/50, 62 % overall yield).

(3E)-2-benzyl-4,6-difluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4oE
IR (neat): 1720, 1658, 1336, 1112 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.78 (td, *J* = 10.2, 2.3 Hz, 1 H), 7.73 (dd, *J* = 6.6, 2.3 Hz, 1 H), 7.36 (t, *J* = 7.4 Hz, 2 H), 7.28 (m, 3 H), 6 (q, *J* = 9.1 Hz, 1 H), 5.08 (s, 2 H)

^{13}C NMR (75 MHz, DMSO-d_6) δ ppm 165.1 (dd, *J* = 255.5, 10.9 Hz), 164.8, 157.5 (dd, *J* = 262.3, 13.0 Hz, 139.7 (bq, *J* = 5.7 Hz), 136.3, 134.7, 129.2 (2C), 127.9, 126.9 (2C), 123.7 (q, *J* = 267.7 Hz), 115.1, 110.1 (t, *J* = 27.6 Hz), 108.3 (dd, *J* = 24.1, 3.2 Hz), 99.4 (q, *J* = 38.9 Hz), 42.6

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -50.8, -100.4, -102.2

HRMS (EI): calcd. for $C_{17}H_{10}F_5NO$ ($[M]^+$) 339.0677, found 339.067

(3Z)-2-benzyl-4,6-difluoro-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4oZ
IR (neat): 3091, 3068, 3033, 1739, 1656, 1097, 761, 729, 692 cm^{-1}

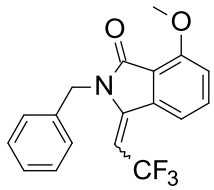
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.84 (td, *J* = 10.1, 2.1 Hz, 1 H), 7.73 (dd, *J* = 9.9, 2.1 Hz, 1 H), 7.31 (t, *J* = 7.4 Hz, 2 H), 7.24 (t, *J* = 7.2 Hz, 1 H), 7.11 (d, *J* = 7.5 Hz, 2 H), 6.02 (qd[7], *J* = 9.9, 4.2 Hz, 1 H), 5.11 (s, 2 H)

^{13}C NMR (75 MHz, DMSO-d_6) δ ppm 166.5, 164.9 (dd, *J* = 254.1, 11.0 Hz), 157.9 (dd, *J* = 258.5, 13.0 Hz), 138.8 (bq, *J* = 6.4 Hz), 136.3, 131.8, 128.6 (2C), 127.3, 125.5 (2C), 123.2 (q, *J* = 268.7 Hz), 119.2, 109.9 (t, *J* = 26.4 Hz), 108.1 (dd, *J* = 24.6, 4.2 Hz), 95.4 (bq, *J* = 37.8 Hz), 45.1

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -49.5, -103.2, -111.7

HRMS (EI): calcd. for $C_{17}H_{10}F_5NO$ ($[M+H]^+$) 339.0677, found 339.0675

(3E/Z)-2-benzyl-7-methoxy-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4p



Starting from N-benzyl-N-ethynyl-2-methoxy-benzamide **3p** (106 mg, 0.4 mmol), Togni I reagent (158 mg, 0.48 mmol) and $Ir(ppy)_3$ (6.6 mg, 0.01 mmol), using **General procedure 3** and stirring at 27°C for 20 h. The crude was purified by silica gel flash column chromatography to afford (3E)-2-benzyl-7-methoxy-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4pE** as a white solid (13 mg) and (3Z)-2-benzyl-7-methoxy-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4pZ** as a white solid (10 mg) (E/Z mixture 52/48, 24 % overall yield).

(3E)-2-benzyl-7-methoxy-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4pE

[7] Through space coupling

IR (neat): 1724, 1643, 1292/1249, 1105, 758, 700 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.75 (t, *J* = 7.9 Hz, 1 H), 7.49 (d, *J* = 7.3 Hz, 1 H), 7.45 (d, *J* = 8.4 Hz, 1 H), 7.35 (t, *J* = 7.4 Hz, 2 H), 7.30-7.21 (m,3 H), 5.68 (q, *J* = 9.6 Hz, 1 H), 5.05 (s, 2 H), 3.91 (s, 3 H)

^{13}C NMR (75 MHz, DMSO-d_6) δ ppm 166.4, 156, 141.7 (q, *J* = 6.6 Hz), 136.9, 134.8, 131.9, 129.0 (2C), 127.7, 127.2 (2C), 121.2 (q, *J* = 268.0 Hz), 119.4, 117.6, 115.8, 98.1 (q, *J* = 39.3 Hz), 55.9, 42.5

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.7

HRMS (ESI): calcd. for $C_{18}H_{15}F_3NO_2$ ($[M+H]^+$) 334.1049, found 334.105

mp: 124.0-127.1°C

(3Z)-2-benzyl-7-methoxy-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4pZ
IR (neat): 1726, 1651, 1247, 1080, 748, 731, 694 cm^{-1}

^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 7.71 (t, *J* = 7.8 Hz, 1 H), 7.50 (m, 2 H), 7.3 (t, *J* = 7.5 Hz, 2 H), 7.22 (t, *J* = 7.4 Hz, 1 H), 7.06 (d, *J* = 7.7 Hz, 2 H), 6.5 (q, *J* = 10.5 Hz, 1 H), 6.1 (s, 2 H), 4.04 (s, 3 H)

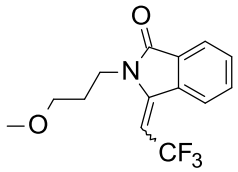
^{13}C NMR (75 MHz, DMSO-d_6) δ ppm 168.1, 156, 141.5 (q, *J* = 6.8 Hz), 136.8, 133.6, 132.7 (q, *J* = 267.2 Hz), 129.2, 127.8 (2C), 127.5, 126.4 (2C), 122, 117.4, 116, 94.6 (q, *J* = 37.6 Hz), 56.8, 44.7

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -48.6

HRMS (ESI): calcd. for $C_{18}H_{15}F_3NO_2$ ($[M+H]^+$) 334.1049, found 334.1049

mp: 135.4-136.8°C

(3E/Z)-2-(3-methoxypropyl)-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4q



Starting from N-ethynyl-N-(3-methoxypropyl)benzamide **3q** (80 mg, 0.37 mmol), Togni I reagent (146 mg, 0.44 mmol) and $Ir(ppy)_3$ (6.1 mg, 0.009 mmol), using **General procedure 3** and stirring at 27°C for 2.7 h. The crude was purified by silica gel flash column chromatography to afford a mixture of (3E/Z)-2-(3-methoxypropyl)-3-(2,2,2-trifluoroethylidene)isoindolin-1-one **4q** as a beige solid (60 mg, 57 % yield) (E/Z mixture 76/24).

(3E)-2-(3-methoxypropyl)-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4qE
IR (neat): 1728, 1655 cm^{-1} (mixture 78/22 E/Z)

^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 7.96 (d, *J* = 7.8 Hz, 1 H), 7.86 (d, *J* = 7.4 Hz, 1 H), 7.81 (m, 1 H), 7.73 (t, *J* = 7.5 Hz, 1 H), 6.04 (q, *J* = 9.5 Hz, 1 H), 3.82 (t, *J* = 7 Hz, 2 H), 3.35 (m, 2 H), 3.22 (s, 3 H), 1.81 (m, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 166.3, 144.4 (q, *J* = 6.2 Hz), 133.7, 132, 131.9, 130.1, 125.2 (q, *J* = 267.9 Hz), 124.5, 123.5, 94.8 (q, *J* = 37.6 Hz), 69.6, 58.3, 36.8, 28.1

^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -51.6

HRMS (ESI): calcd. for C_{14} H_{15} F_3 N O_2 ([M+H]+) 286.1049, found 286.1051

(3Z)-2-(3-methoxypropyl)-3-(2,2,2-trifluoroethylidene)isoindolin-1-one 4qZ

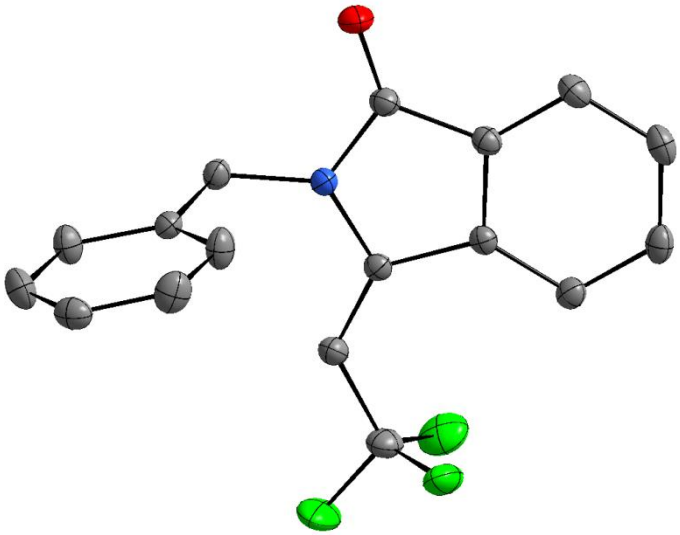
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.15 (d, *J* = 7.6 Hz, 1 H), 7.81 (m, 1 H), 7.76 (t, *J* = 7.6 Hz, 1 H), 7.68 (t, *J* = 7.4 Hz, 1 H), 6.29 (q, *J* = 10.2 Hz, 1 H), 3.88 (t, *J* = 7.6 Hz, 2 H), 3.35 (m, 2 H), 3.21 (s, 3 H), 1.8 (m, 2 H)

^{13}C NMR (100 MHz, DMSO-d_6) δ ppm 168.4, 142.1 (q, *J* = 6.5 Hz), 137, 133.3, 132, 127.4, 124.2 (q, *J* = 267.9 Hz), 123, 121.7, 91.1 (q, *J* = 37.6 Hz), 69.7, 58.3, 39.5, 28.1

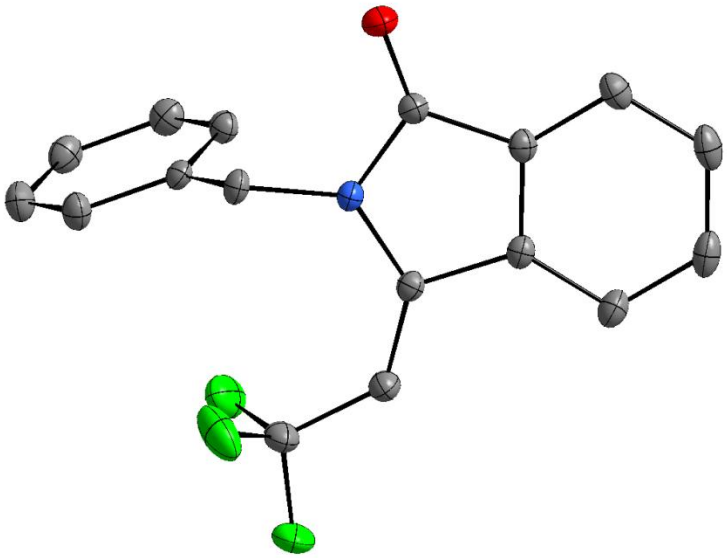
^{19}F NMR (376 MHz, DMSO-d_6) δ ppm -49

X-Ray crystal structure determination of compounds 4aE and 4aZ

A single crystal of each compound (**4aE** and **4aZ**) was selected, mounted onto a cryoloop and transferred into a cold nitrogen gas stream. Intensity data were collected with a Bruker Kappa-APEXII diffractometer using graphite-monochromated Mo-Kα radiation (λ = 0.71073 Å). Data collection was performed with the Bruker APEXII suite. Unit-cell parameters determination, integration and data reduction were carried out with SAINT program. SADABS was used for scaling and absorption corrections. The structures were solved with SHELXS-2014[1] for **4aZ** or SHELXT-2014[2] for **4aE**, and refined by full-matrix least-squares methods with SHELXL-2014[3] using the Olex2 software package[4]. All non-hydrogen atoms were refined anisotropically. The structures were deposited at the Cambridge Crystallographic Data Centre with numbers CCDC 1949295 to 1949296 and can be obtained free of charge via www.ccdc.cam.ac.uk.



X-Ray crystal structure of compound **4aE** (E isomer)



X-Ray crystal structure of compound **4aZ** (Z isomer)

Crystal data and structure refinement for 4aE

CCDC number	1949295
Empirical formula[a]	$C_{17}H_{12}F_3NO$
Moiety Formula	$C_{17}H_{12}F_3NO$
Formula weight (g/mol)	303.28
Temperature (K)	200
Crystal system	Monoclinic
Space group	C2/c
a (Å)	22.9645(6)
b (Å)	8.0352(2)
c (Å)	15.3941(4)
α (°)	90
β (°)	104.553(2)
γ (°)	90
Volume ($Å^3$)	2749.45(12)
Z	8
ρ_{calc} (g/cm^3)	1.465
Absorption coefficient μ (mm^{-1})	0.119 (MoKα)
F(000)	1248
Crystal size (mm^2)	0.39 x 0.28 x 0.20
Wavelength λ (Å)	0.71073
2Θ range (°)	5.39 – 61.16
Miller indexes ranges	-32 ≤ h ≤ 32, -11 ≤ k ≤ 11, -22 ≤ l ≤ 22
Measured reflections	21356
Unique reflections	4223
R_{int} / R_{sigma}	0.0223 / 0.0192
Completeness	0.999
Reflections [I ≥ 2σ(I)]	3239
Restraints	0
Parameters	199
Goodness-of-fit F^2	1.021
Final R indexes[b c] **[all data]**	R1 = 0.0611, wR2 = 0.1201
Final R indexes[b c] **[I ≥ 2σ(I)]**	R1 = 0.0438 wR2 = 0.1080
Largest diff. peak/hole ($e/Å^3$)	0.30/-0.25

[a] Including solvent molecules (if presence)

[b] $R1 = \sum\left||F_o| - |F_c|\right| / \sum |F_o|$ [c] $wR2 = \sqrt{\sum\left(w(F_o^2 - F_c^2)\right)/\sum(w(F_o^2)^2)}$

Crystal data and structure refinement for 4aZ

CCDC number	1949296
Empirical formula[a]	$C_{17}H_{12}F_3NO$
Moiety Formula	$C_{17}H_{12}F_3NO$
Formula weight (g/mol)	303.28
Temperature (K)	200
Crystal system	Monoclinic
Space group	$P2_1/c$
a (Å)	8.6387(3)
b (Å)	12.9185(4)
c (Å)	12.5678(4)
α (°)	90
β (°)	92.705(2)
γ (°)	90
Volume (Å^3)	1400.99(8)
Z	4
ρ_{calc} (g/cm^3)	1.438
Absorption coefficient μ (mm^{-1})	0.117 (MoKα)
F(000)	624
Crystal size (mm²)	0.34 x 0.32 x 0.26
Wavelength λ (Å)	0.71073
2Θ range (°)	4.524 – 61.314
Miller indexes ranges	-12 ≤ h ≤ 12, -18 ≤ k ≤ 18, -17 ≤ l ≤ 17
Measured reflections	38461
Unique reflections	4319
R_{int} / R_{sigma}	0.0464 / 0.0214
Completeness	1.000
Reflections [I ≥ 2σ(I)]	3394
Restraints	0
Parameters	199
Goodness-of-fit F²	1.052
Final R indexes[b c] **[all data]**	R1 = 0.0622, wR2 = 0.1329
Final R indexes[b c] **[I ≥ 2σ(I)]**	R1 = 0.0459 wR2 = 0.1175
Largest diff. peak/hole (e/Å^3)	0.39/-0.30

[a] Including solvent molecules (if presence)

[b] $R1 = \sum||F_o| - |F_c|| \ / \sum |F_o|$ [c] $wR2 = \sqrt{\sum\left(w(F_o^2 - F_c^2)\right)/\sum(w(F_o^2)^2)}$

DFT calculation method, energetics data and cartesian coordinates

All calculations were performed using the Gaussian 09 software package[8]. Optimization of geometries, frequency and single point energy calculations were done using the PBE0 functional including the D3BJ dispersion term[9,10] with the def2-TZVP basis set[11]. The effect of solvation (in MeCN) was modeled using the 'SMD' model[12]. The nature of all stationary points was confirmed by analyzing the harmonic vibrational frequencies.

Table 1. Energetics data (kcal/mol) relative to Scheme 5 obtained at the PBE0-D3BJ/def2-TZVP level of theory.

PBE0-D3BJ/ Def2-TZVP	ΔE	ΔE+ZPE	ΔG	ΔG_{MeCN}
$\mathbf{A}_E$	0.0	0.0	0.0	0.0
$\mathbf{A}_Z$ *a*	0.4	0.8	1.3	2.1
$\mathbf{TS}_{Ebz}$ *a*	5.5	4.9	6.3	5.7
$\mathbf{B}_{Ebz}$ *a*	-26.1	-25.4	-23.5	-26.1
$\mathbf{TS}_{Eb}$ *a*	12.3	10.9	13.5	12.8
$\mathbf{B}_{Eb}$ *a*	-12.5	-12.2	-9.8	-12.4
$\mathbf{TS}_{Zbz}$ *b*	9.4	8.4	9.1	6.9
$\mathbf{B}_{Zbz}$ *b*	-21.8	-21.6	-20.2	-24.9
$\mathbf{TS}_{Zb}$ *b*	13.7	12.7	14.8	12.0
$\mathbf{B}_{Zb}$ *b*	-10.6	-10.7	-8.3	-13.1

a energies relative to $\mathbf{A}_E$; *b* energies relative to $\mathbf{A}_Z$

[8] Gaussian 09, Revision **D.01**, Frisch MJ, Trucks GW, Schlegel HB, Scuseria GE, Robb MA, Cheeseman JR, Scalmani G, Barone V, Mennucci B, Petersson GA, Nakatsuji H, Caricato M, Li X, Hratchian HP, Izmaylov AF, Bloino J, Zheng G, Sonnenberg JL, Hada M, Ehara M, Toyota K, Fukuda R, Hasegawa J, Ishida M, Nakajima T, Honda Y, Kitao O, Nakai H, Vreven T, Montgomery JA, Jr. Peralta JE, Ogliaro F, Bearpark M, Heyd JJ, Brothers E, Kudin KN, Staroverov VN, Kobayashi R, Normand J, Raghavachari K, Rendell A, Burant JC, Iyengar SS, Tomasi J, Cossi M, Rega N, Millam JM, Klene M, Knox JE, Cross JB, Bakken V, Adamo C, Jaramillo J, Gomperts R, Stratmann RE, Yazyev O, Austin AJ, Cammi R, Pomelli C, Ochterski JW, Martin RL, Morokuma K, Zakrzewski VG, Voth GA, Salvador P, Dannenberg JJ, Dapprich S, Daniels AD, Farkas Ö, Foresman JB, Ortiz JV, Cioslowski J, Fox DJ. Gaussian, Inc., Wallingford CT, **2009**

[9] Perdew JP, Burke K, Ernzerhof M. *Phys. Rev. Lett.* **1996**, *77*, 3865-3868

[10] Adamo C, Barone V. *J. Chem. Phys*. **1999**, *110*, 6158

[11] Weigend F, Ahlrichs R, *Chem. Phys*., **2005**, *7*, 3297

[12] Marenich AV, Cramer CJ, Truhlar DG. *J. Phys. Chem.* **2009**,*113*, 6378

Cartesian coordinates of all compounds involved in this work

A_E

6	-3.365420	0.074014	0.406803
6	-2.455636	-0.957565	0.604963
6	-2.555934	-2.110505	-0.170126
6	-3.546940	-2.221952	-1.130720
6	-4.449927	-1.185406	-1.325824
6	-4.359371	-0.037839	-0.554360
1	-3.295008	0.974473	1.007441
1	-1.848302	-2.916816	-0.013204
1	-3.618446	-3.123429	-1.728301
1	-5.225425	-1.274422	-2.077780
1	-5.061276	0.774679	-0.701394
6	-1.360961	-0.828872	1.621984
1	-1.580888	-0.031411	2.332684
1	-1.224597	-1.760742	2.168840
7	-0.050643	-0.529786	1.009825
6	0.169828	0.691613	0.506142
6	-0.257366	1.913163	0.740477
6	0.828429	-1.596575	0.791873
8	0.490128	-2.729347	1.049702
6	2.162520	-1.276729	0.225915
6	2.714723	-2.207448	-0.649995
6	3.960479	-1.982842	-1.207420
6	4.674316	-0.840097	-0.872422
6	4.141367	0.074551	0.023115
6	2.885559	-0.137468	0.569004
1	2.150014	-3.101036	-0.885663
1	4.378588	-2.701452	-1.902291
1	5.652279	-0.665448	-1.305886
1	4.704145	0.958020	0.299608
1	2.484796	0.575486	1.278429
6	0.060554	3.052343	-0.158723
9	0.760811	4.005257	0.486489
9	0.773290	2.690448	-1.225342
9	-1.058262	3.651754	-0.603870
1	-0.842269	2.173924	1.621526

A_Z

6	-3.212168	-0.331151	-0.230761
6	-2.205029	-1.001811	0.453430
6	-2.128439	-2.389522	0.362491
6	-3.041424	-3.090516	-0.407707
6	-4.042230	-2.414169	-1.092315
6	-4.127798	-1.033950	-1.000594
1	-3.279531	0.748707	-0.159572
1	-1.346360	-2.913046	0.900794
1	-2.975719	-4.170705	-0.470455
1	-4.757423	-2.964619	-1.692660
1	-4.909688	-0.500441	-1.528674
6	-1.200005	-0.238123	1.264952
1	-1.562634	0.761448	1.495160
1	-0.977075	-0.756765	2.195818
7	0.098434	-0.096148	0.569331
6	0.176228	0.672676	-0.528341
6	-0.216484	1.860261	-0.936660
1	-0.159138	2.119073	-1.988139
6	1.103924	-1.016962	0.892741
8	0.890806	-1.909593	1.681104
6	2.421950	-0.840678	0.234932
6	3.121130	-1.994297	-0.108972
6	4.369331	-1.899711	-0.697597
6	4.939089	-0.653010	-0.919133
6	4.258681	0.497550	-0.550049
6	2.998804	0.407741	0.019852
1	2.670098	-2.958282	0.092023
1	4.903437	-2.799567	-0.978826
1	5.920501	-0.578911	-1.373252
1	4.710691	1.470332	-0.702955
1	2.479370	1.308777	0.319569
6	-0.706135	2.962914	-0.056699
9	-2.051832	3.049196	-0.032969
9	-0.310723	2.824736	1.216832
9	-0.258398	4.148325	-0.488353

TS_{Ebz} *Frequencies -- -367.5841*

6	3.560159	0.378455	-0.638144
6	2.573951	-0.589361	-0.499780
6	2.578946	-1.405438	0.627073
6	3.552536	-1.249382	1.599208
6	4.535507	-0.279434	1.454690
6	4.539602	0.533104	0.332415
1	3.560422	1.020520	-1.513559
1	1.817907	-2.170308	0.737178
1	3.546581	-1.889314	2.474002
1	5.295665	-0.157921	2.217480
1	5.302309	1.293860	0.213252
6	1.526337	-0.763507	-1.563875
1	1.609161	0.030838	-2.310010
1	1.643674	-1.727767	-2.062991
7	0.164645	-0.755043	-1.045042
6	-0.421359	0.378294	-0.589935
6	0.062502	1.586402	-0.361963
6	-0.548869	-1.951425	-0.949279
8	-0.073948	-3.025425	-1.228997
6	-1.882117	-1.683028	-0.379976
6	-2.387751	-2.493409	0.614783
6	-3.461786	-2.055086	1.382012
6	-4.004450	-0.791921	1.156591
6	-3.528009	0.015517	0.141570
6	-2.448968	-0.413323	-0.651293
1	-1.903064	-3.442065	0.814197
1	-3.858257	-2.684222	2.169465
1	-4.833521	-0.449440	1.765261
1	-3.997468	0.967912	-0.066266

1	-2.326984	0.039743	-1.630738
6	-0.776232	2.745259	0.032719
9	-2.042400	2.657232	-0.403349
9	-0.843049	2.913368	1.365928
9	-0.266665	3.884967	-0.464251
1	1.131674	1.786473	-0.385847

B$_{Ebz}$

6	3.565688	0.115946	-0.658995
6	2.476641	-0.713236	-0.425428
6	2.374448	-1.368403	0.796495
6	3.345850	-1.193337	1.768215
6	4.432641	-0.363865	1.528304
6	4.542162	0.289416	0.311023
1	3.649737	0.635124	-1.608863
1	1.529977	-2.022131	0.985814
1	3.255322	-1.708016	2.717793
1	5.190548	-0.225743	2.290474
1	5.385297	0.942249	0.116988
6	1.438439	-0.919460	-1.497065
1	1.553435	-0.164873	-2.281267
1	1.556684	-1.905552	-1.953876
7	0.082747	-0.884990	-1.010329
6	-0.563827	0.255399	-0.579439
6	0.033598	1.450597	-0.513473
6	-0.698111	-2.043534	-0.950438
8	-0.312850	-3.141675	-1.280425
6	-1.967226	-1.622861	-0.376305
6	-2.903485	-2.411189	0.224769
6	-3.837535	-1.818018	1.081603
6	-3.690050	-0.455280	1.448685
6	-2.771836	0.359627	0.870616
6	-2.006029	-0.135780	-0.310998
1	-2.851416	-3.488144	0.108618
1	-4.594362	-2.423403	1.564008
1	-4.313014	-0.062971	2.244738
1	-2.669751	1.388463	1.184379
1	-2.560260	0.229105	-1.201192
6	-0.634559	2.724499	-0.168317
9	0.055170	3.759804	-0.666293
9	-1.888298	2.818154	-0.653410
9	-0.735874	2.942547	1.160330
1	1.091543	1.546553	-0.713080

TS$_{Eb}$ *Frequencies -- -390.6123*

6	2.493770	-0.380783	-0.682944
6	2.188027	-1.707646	-0.291212
6	2.780906	-2.256753	0.822448
6	3.721632	-1.526135	1.548422
6	4.031559	-0.221877	1.173599
6	3.444176	0.346982	0.061178
1	2.296817	-0.066298	-1.704176
1	2.491255	-3.249119	1.151148
1	4.195084	-1.968376	2.416801
1	4.757028	0.344207	1.746243
1	3.715257	1.346682	-0.252121
6	0.960471	-2.255378	-0.926277
1	1.051838	-2.363318	-2.012053
1	0.646940	-3.213769	-0.517958
7	-0.075191	-1.246676	-0.611810
6	0.376183	0.031602	-0.516024
6	-0.159348	1.238362	-0.569884
6	-1.400344	-1.678166	-0.664384
8	-1.665512	-2.735881	-1.189110
6	-2.436649	-0.843508	-0.006617
6	-2.223648	-0.268813	1.242517
6	-3.244806	0.429164	1.863453
6	-4.473042	0.572590	1.232380
6	-4.688090	-0.003144	-0.011743
6	-3.676622	-0.724228	-0.624042
1	-1.259574	-0.369414	1.726331
1	-3.081094	0.866748	2.841055
1	-5.266774	1.130886	1.715138
1	-5.648716	0.102835	-0.501697
1	-3.834690	-1.204101	-1.582393
6	0.652760	2.474532	-0.415196
9	-0.121607	3.558095	-0.564930
9	1.246512	2.582679	0.786833
9	1.644728	2.579911	-1.324805
1	-1.221238	1.409852	-0.718683

B$_{Eb}$

6	1.921892	-0.217183	-0.643206
6	2.366934	-1.581360	-0.209283
6	3.665304	-1.886927	0.025627
6	4.657631	-0.891989	-0.069570
6	4.277304	0.448688	-0.290186
6	2.987194	0.815015	-0.507050
1	1.651556	-0.274370	-1.721788
1	3.936034	-2.890104	0.339702
1	5.696351	-1.141138	0.103326
1	5.041081	1.218320	-0.269600
1	2.741898	1.850911	-0.684779
6	1.165707	-2.419833	0.045734
1	0.943246	-3.135797	-0.753656
1	1.231495	-2.987777	0.977015
7	0.093501	-1.426200	0.116675
6	0.576005	-0.114080	0.057477
6	-0.069863	0.930882	0.578334
1	-0.992999	0.778509	1.118568
6	-1.191409	-1.895536	0.304756
8	-1.360285	-3.045646	0.652910
6	-2.346135	-1.011994	-0.013247
6	-3.453249	-1.048642	0.825605
6	-4.572140	-0.286194	0.531169
6	-4.600248	0.488883	-0.618779
6	-3.507703	0.500929	-1.475486
6	-2.379727	-0.239841	-1.170120
1	-3.425126	-1.680893	1.704964
1	-5.427327	-0.303675	1.196396
1	-5.477420	1.080977	-0.852452

1	-3.534001	1.093747	-2.382097
1	-1.522754	-0.220371	-1.832901
6	0.290182	2.362351	0.428352
9	0.613039	2.700364	-0.837353
9	-0.753261	3.128768	0.775516
9	1.322406	2.753227	1.197008

TS$_{Zbz}$ *Frequencies -- -338.5570*

6	1.597330	-1.261953	0.859718
6	2.005406	-0.910154	-0.417484
6	3.315683	-1.172296	-0.802731
6	4.202328	-1.773923	0.073767
6	3.788161	-2.124051	1.351285
6	2.483909	-1.866111	1.739590
1	0.582590	-1.059909	1.182294
1	3.644995	-0.903478	-1.801680
1	5.220075	-1.972223	-0.242138
1	4.479935	-2.596028	2.039031
1	2.150054	-2.134323	2.735337
6	1.088154	-0.246321	-1.412518
1	1.441057	0.757310	-1.651580
1	1.077742	-0.829395	-2.335763
7	-0.296806	-0.147718	-0.974016
6	-0.821298	0.898009	-0.305811
6	-0.509291	2.080926	0.190860
1	-1.298232	2.672440	0.642581
6	-1.119735	-1.273661	-1.158123
8	-0.726815	-2.283002	-1.682050
6	-2.440968	-1.026424	-0.549648
6	-3.021396	-1.963278	0.279384
6	-4.069904	-1.586854	1.113647
6	-4.511615	-0.266752	1.123174
6	-3.958601	0.672262	0.270536
6	-2.903943	0.308612	-0.580208
1	-2.615080	-2.967755	0.304274
1	-4.525658	-2.315930	1.772357
1	-5.321364	0.021384	1.783788
1	-4.358844	1.678270	0.232621
1	-2.701601	0.933700	-1.445055
6	0.826250	2.746090	0.195463
9	1.800350	1.994912	0.727826
9	1.250270	3.077647	-1.044933
9	0.773121	3.884024	0.898556

B$_{Zbz}$

6	1.419090	-1.624781	0.745710
6	1.911294	-0.985704	-0.381705
6	3.285638	-0.947528	-0.589234
6	4.152568	-1.539385	0.313226
6	3.654233	-2.177079	1.440728
6	2.286091	-2.216088	1.653579
1	0.351527	-1.664482	0.926900
1	3.680919	-0.439823	-1.463544
1	5.221692	-1.497365	0.139562
1	4.330874	-2.637916	2.150800
1	1.886448	-2.710454	2.531565
6	1.010880	-0.356869	-1.415855
1	1.406471	0.606140	-1.733538
1	0.977965	-1.008281	-2.293508
7	-0.363739	-0.197864	-1.002545
6	-0.931803	0.859193	-0.326176
6	-0.428145	2.012063	0.132676
1	-1.124943	2.686946	0.610082
6	-1.252453	-1.269106	-1.216149
8	-0.950412	-2.287938	-1.788696
6	-2.499523	-0.886190	-0.572193
6	-3.510776	-1.694242	-0.144061
6	-4.420425	-1.193618	0.795823
6	-4.195018	0.070954	1.401208
6	-3.200496	0.900195	0.995332
6	-2.416736	0.550289	-0.218665
1	-3.544952	-2.730274	-0.462237
1	-5.232566	-1.816019	1.149340
1	-4.821930	0.364068	2.235899
1	-3.037236	1.853702	1.482671
1	-2.869992	1.122966	-1.056313
6	0.945533	2.568228	0.062186
9	1.883751	1.794276	0.623309
9	1.362934	2.805199	-1.203247
9	0.982813	3.749120	0.696730

B$_{Zb}$

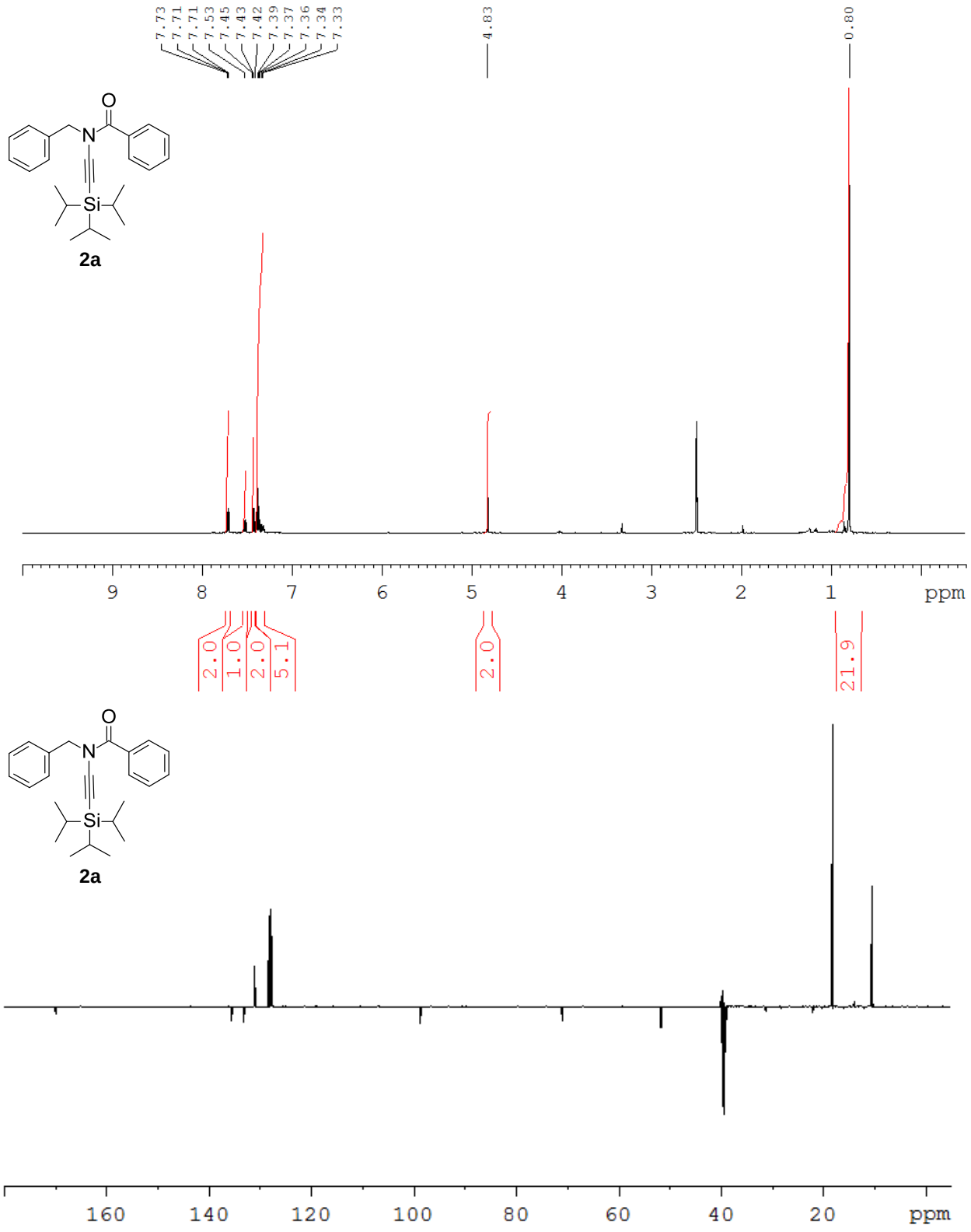
6	2.364082	0.783511	0.032339
6	2.848393	-0.390532	-0.749780
6	3.908373	-1.134812	-0.354237
6	4.525885	-0.870864	0.887453
6	3.938197	0.050462	1.783160
6	2.865281	0.808419	1.434819
1	2.729726	1.705929	-0.464447
1	4.240432	-1.978031	-0.951106
1	5.383693	-1.452452	1.199376
1	4.341767	0.132705	2.786427
1	2.416064	1.498461	2.139352
6	1.841887	-0.656355	-1.812673
1	1.991767	-0.045173	-2.712305
1	1.768469	-1.697526	-2.120701
7	0.608279	-0.254050	-1.120704
6	0.858711	0.770945	-0.221108
6	0.054962	1.717307	0.272176
1	0.489811	2.416720	0.975197
6	-0.540960	-0.999179	-1.353286
8	-0.668843	-1.589070	-2.402696
6	-1.508992	-1.165144	-0.239312
6	-1.089180	-1.292778	1.080086
6	-2.013428	-1.554033	2.077950
6	-3.358952	-1.671563	1.763728
6	-3.778813	-1.553060	0.445527
6	-2.854925	-1.315286	-0.555274
1	-0.038236	-1.202947	1.327458
1	-1.682184	-1.663710	3.103842
1	-4.082778	-1.862428	2.547708

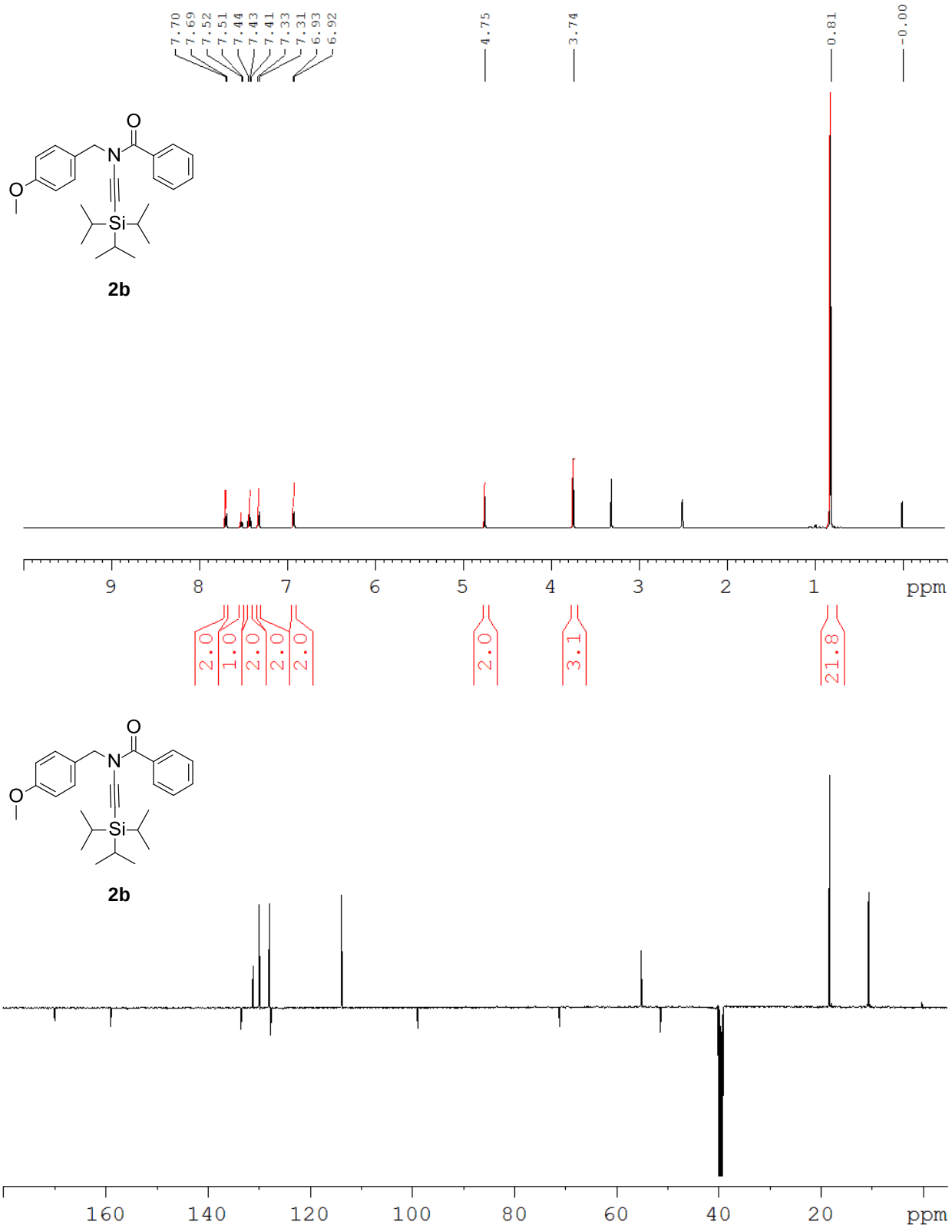
1	-4.829440	-1.650803	0.199085
1	-3.160289	-1.236746	-1.591319
6	-1.338977	2.067030	-0.091939
9	-1.450319	3.407427	-0.166330
9	-1.718285	1.582647	-1.282689
9	-2.254203	1.672426	0.807924

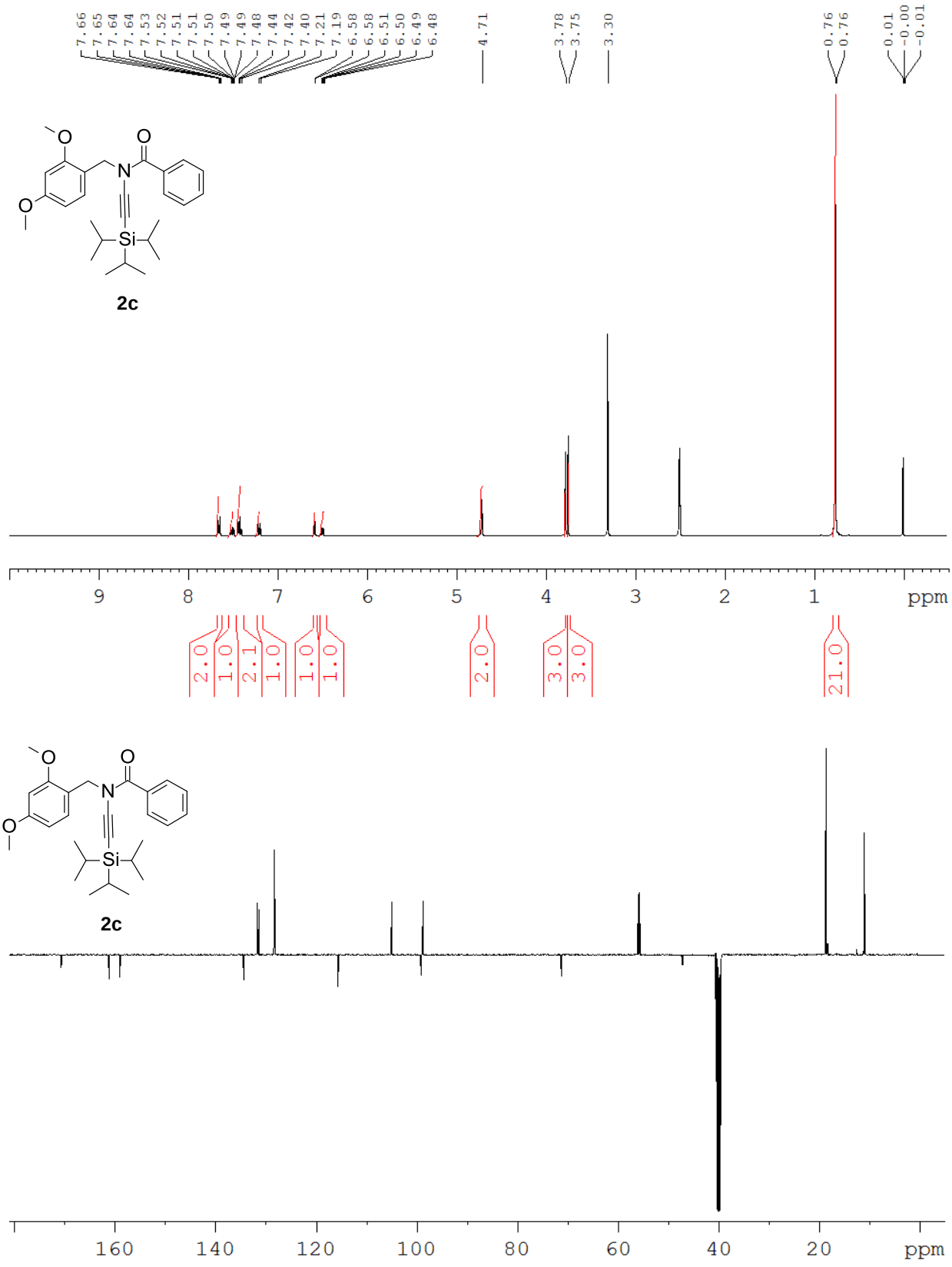
TS_{Zb} *Frequencies -- -412.0166*

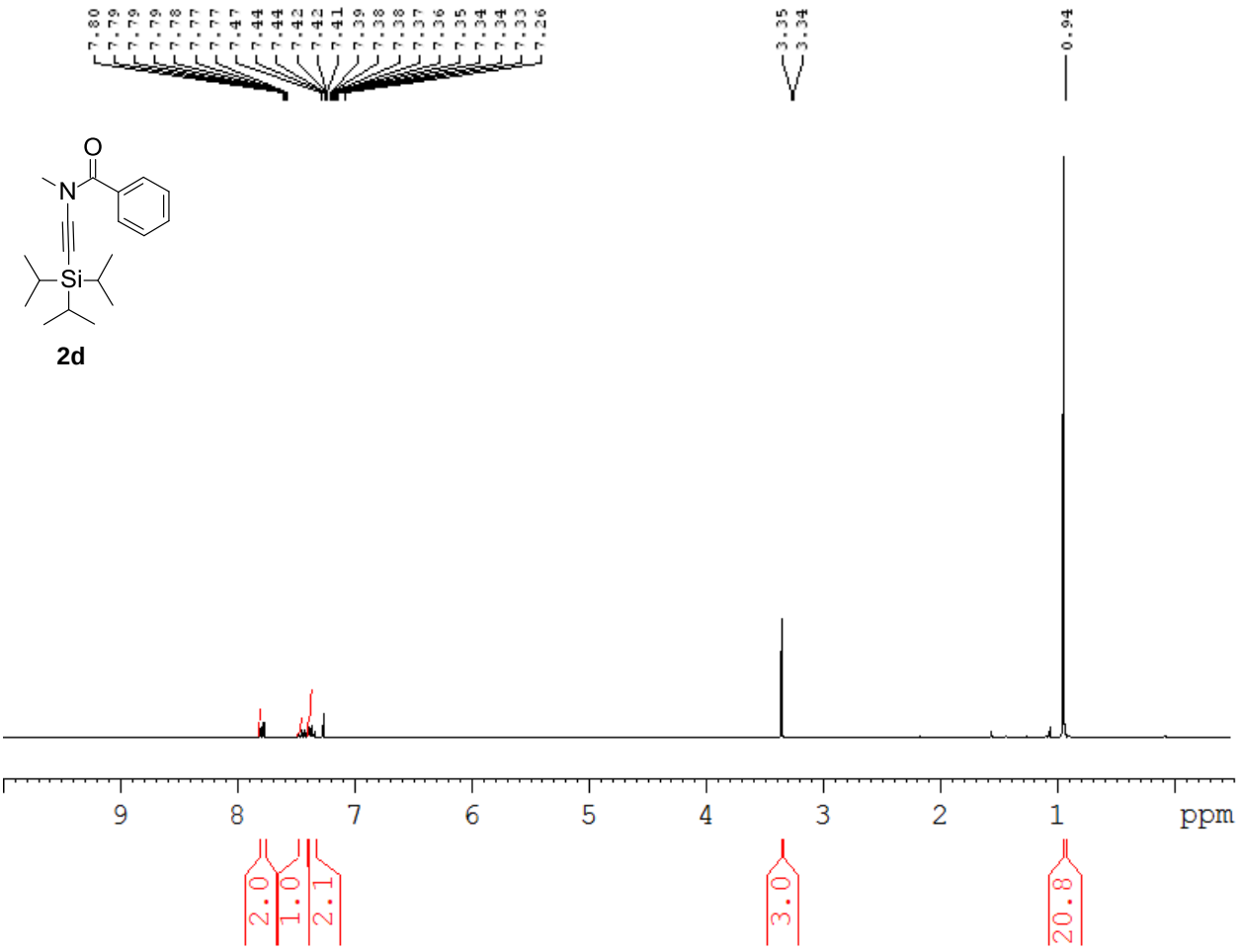
6	-2.841231	0.901798	0.122722
6	-2.881807	-0.354954	0.781322
6	-3.533409	-1.419406	0.203390
6	-4.199258	-1.259882	-1.013444
6	-4.167593	-0.032280	-1.670237
6	-3.519638	1.048871	-1.105630
1	-2.647216	1.796207	0.708645
1	-3.497305	-2.393982	0.678751
1	-4.723005	-2.098594	-1.455973
1	-4.680658	0.082556	-2.618200
1	-3.545219	2.016762	-1.592491
6	-1.834164	-0.496154	1.831979
1	-1.951517	0.221825	2.649786
1	-1.754770	-1.493953	2.256245
7	-0.586311	-0.204012	1.089042
6	-0.714139	0.773435	0.165574
6	0.016154	1.721953	-0.390120
1	-0.417828	2.319475	-1.185210
6	0.525161	-1.016549	1.344143
8	0.601773	-1.607432	2.395590
6	1.520265	-1.195891	0.259137
6	1.136168	-1.325435	-1.071170
6	2.086962	-1.594302	-2.041141
6	3.423030	-1.715535	-1.689093
6	3.806890	-1.592776	-0.360685
6	2.856167	-1.348932	0.613707
1	0.093009	-1.229539	-1.347371
1	1.784205	-1.706107	-3.075505
1	4.167600	-1.911906	-2.451948
1	4.849915	-1.692333	-0.084652
1	3.133818	-1.268521	1.657438
6	1.393411	2.141237	-0.005657
9	1.469513	3.483341	0.035502
9	1.758502	1.690355	1.201636
9	2.332111	1.741243	-0.878949

^{1}H, ^{13}C and ^{19}F NMR spectra

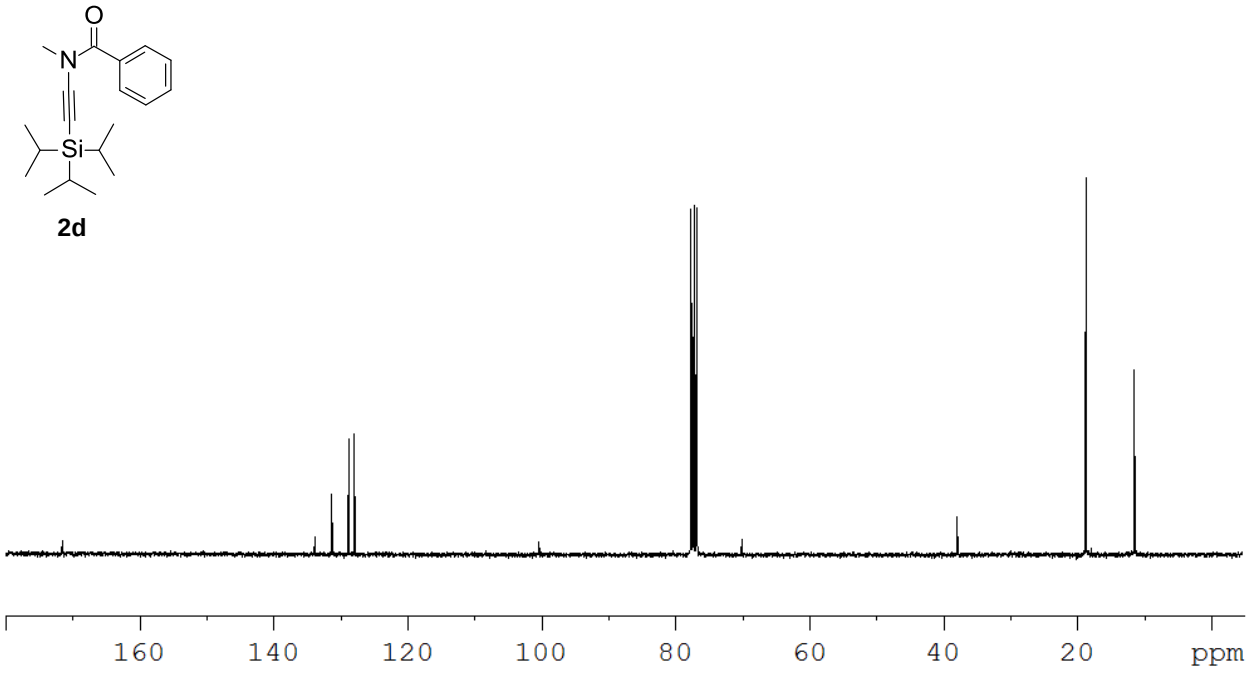



7.70
7.69
7.52
7.51
7.44
7.43
7.41
7.33
7.31
6.93
6.92
4.75
3.74
0.81
-0.00
O
N
O
Si
2b
9
8
7
6
5
4
3
2
1
ppm
2.0
1.0
2.0
2.0
2.0
2.0
3.1
21.8
O
N
O
Si
2b
160
140
120
100
80
60
40
20
ppm

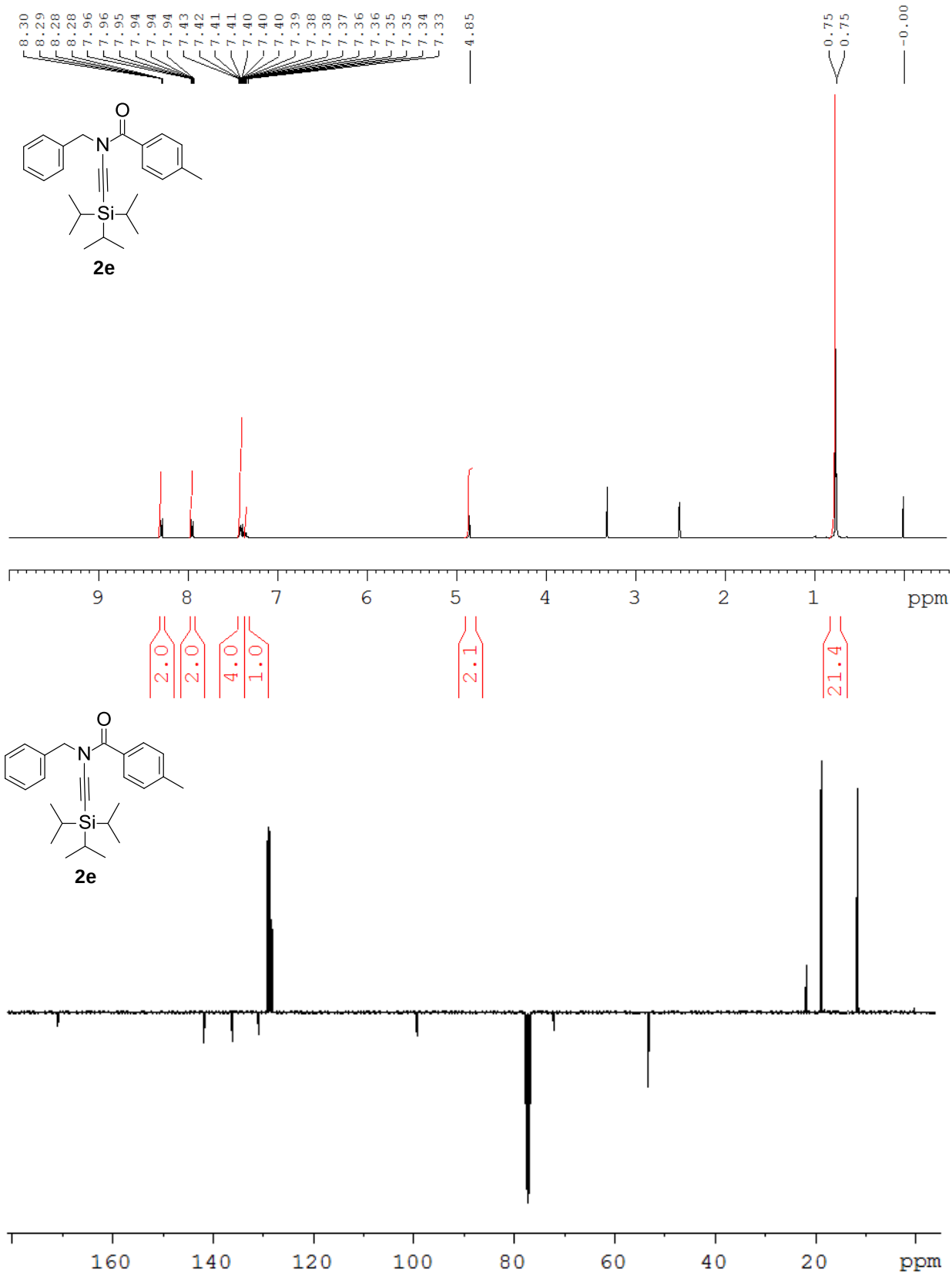

7.66
7.65
7.64
7.64
7.53
7.52
7.51
7.51
7.50
7.49
7.49
7.48
7.44
7.42
7.40
7.21
7.19
6.58
6.58
6.51
6.50
6.49
6.48
4.71
3.78
3.75
3.30
0.76
0.76
0.01
-0.00
-0.01
O
O
N
O
Si
2c
9
8
7
6
5
4
3
2
1
ppm
2.0
1.0
2.1
1.0
1.0
1.0
2.0
3.0
3.0
21.0
O
O
N
O
Si
2c
160
140
120
100
80
60
40
20
ppm

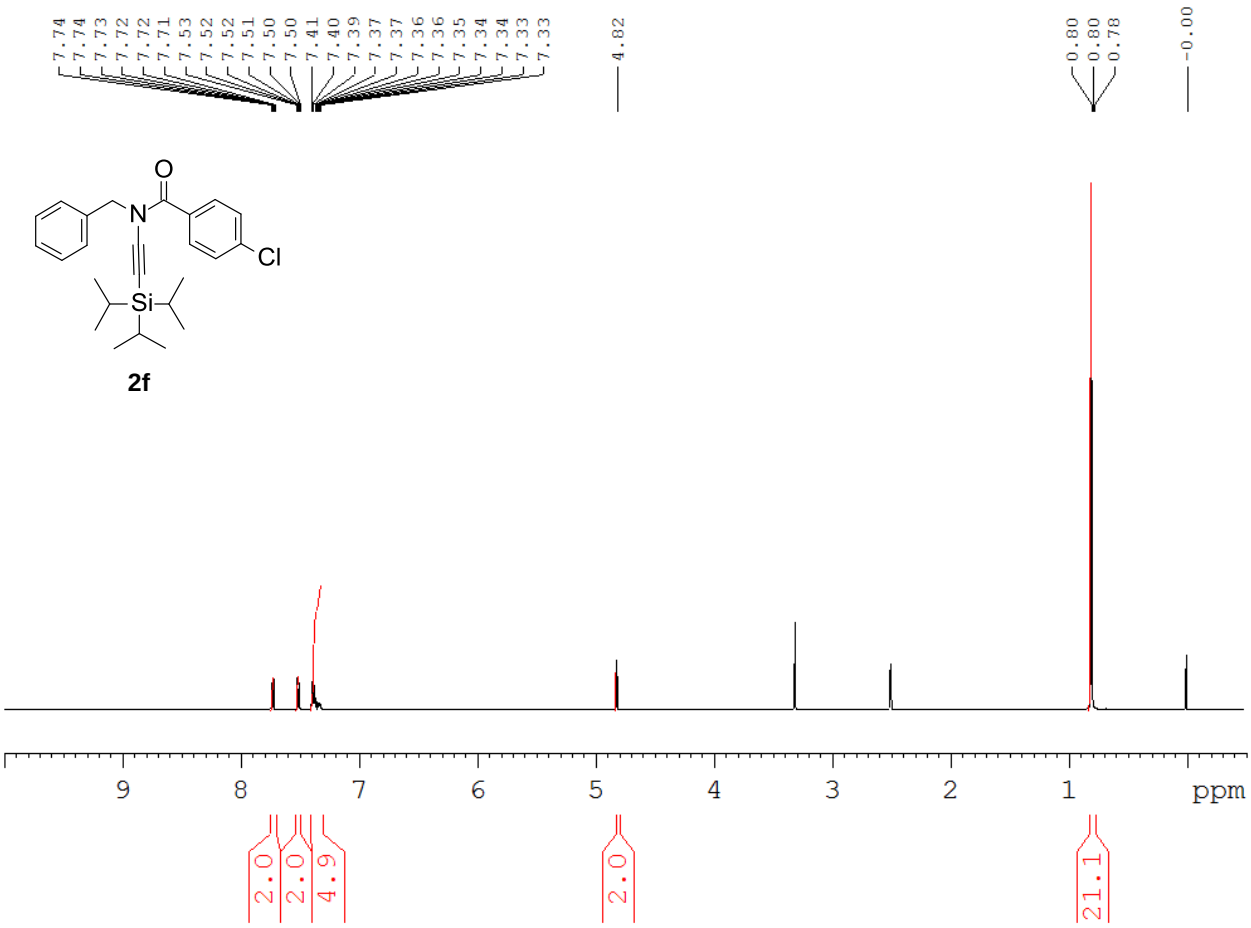

7.80
7.79
7.79
7.79
7.78
7.77
7.77
7.47
7.44
7.44
7.42
7.42
7.41
7.39
7.38
7.37
7.36
7.35
7.34
7.34
7.33
7.26
3.35
3.34
0.94
O
N
Si
9
8
7
6
5
4
3
2
1
ppm
2.0
1.0
2.1
3.0
20.8

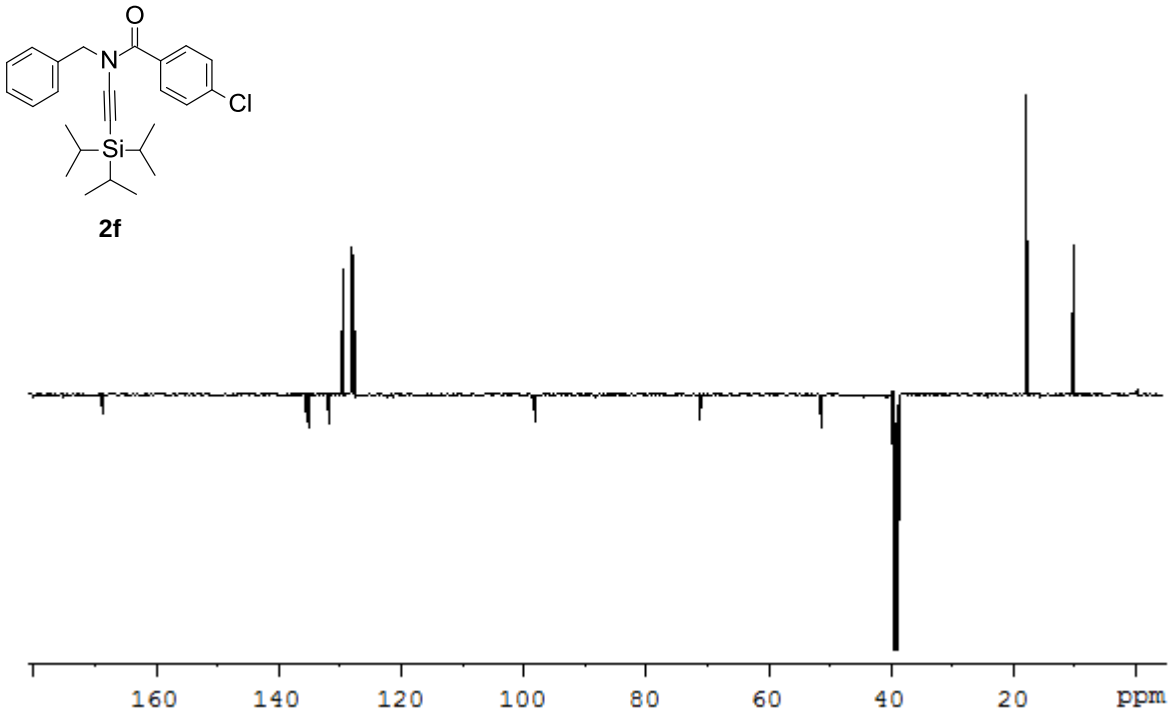
2d

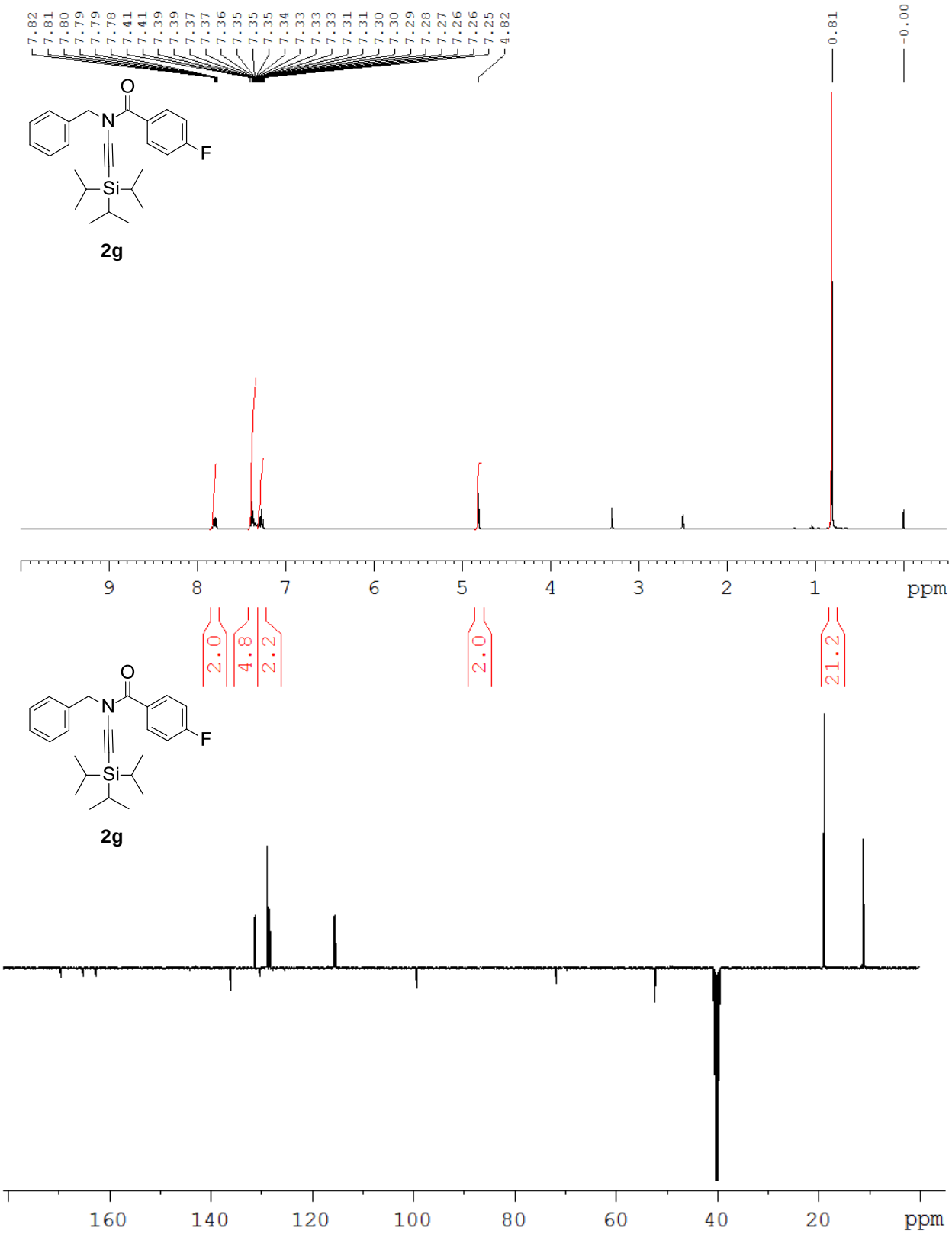

O
N
Si
160
140
120
100
80
60
40
20
ppm

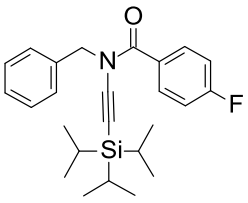
2d


8.30
8.29
8.28
8.28
7.96
7.96
7.95
7.94
7.94
7.94
7.43
7.42
7.41
7.41
7.40
7.40
7.40
7.39
7.38
7.38
7.37
7.36
7.36
7.35
7.35
7.34
7.33
4.85
0.75
0.75
-0.00
O
N
Si
2e
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
1.0
2.1
21.4
O
N
Si
2e
160
140
120
100
80
60
40
20
ppm


7.74
7.74
7.73
7.72
7.72
7.71
7.53
7.52
7.52
7.51
7.50
7.50
7.41
7.40
7.39
7.37
7.37
7.36
7.36
7.35
7.34
7.34
7.33
7.33
4.82
0.80
0.80
0.78
-0.00
O
N
Cl
Si
2f
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.9
2.0
21.1

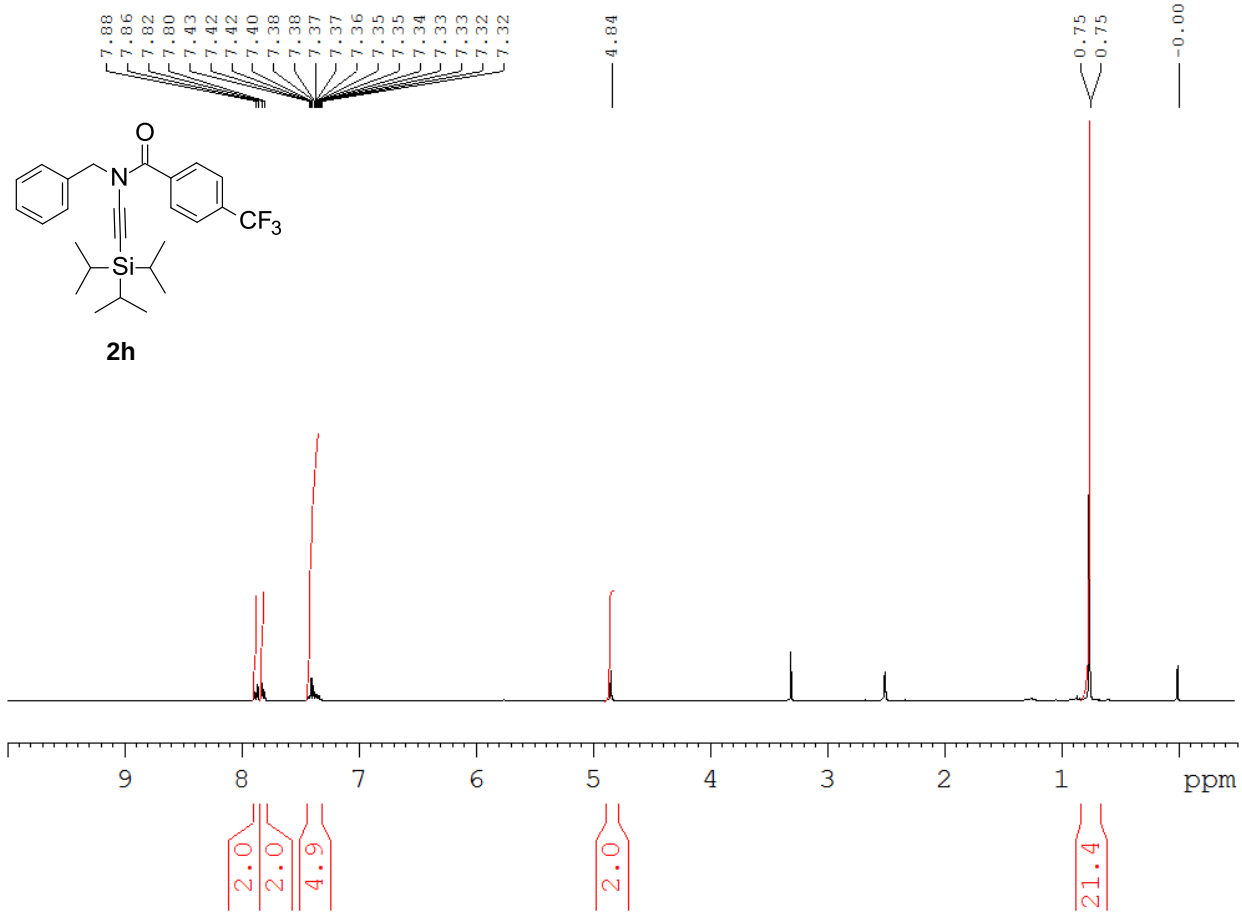

O
N
Cl
Si
2f
160
140
120
100
80
60
40
20
ppm


7.82
7.81
7.80
7.79
7.79
7.78
7.41
7.41
7.39
7.39
7.37
7.37
7.36
7.35
7.35
7.35
7.34
7.33
7.33
7.33
7.31
7.31
7.30
7.30
7.29
7.28
7.27
7.26
7.26
7.25
4.82
0.81
-0.00
O
N
F
Si
2g
9
8
7
6
5
4
3
2
1
ppm
2.0
4.8
2.2
2.0
21.2
O
N
F
Si
2g
160
140
120
100
80
60
40
20
ppm


O
N
F
Si

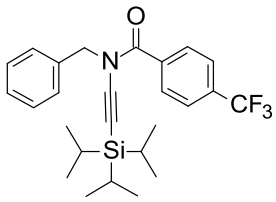
2g

-108.45
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.88
7.86
7.82
7.80
7.43
7.42
7.42
7.40
7.38
7.38
7.37
7.37
7.36
7.35
7.35
7.34
7.33
7.33
7.32
7.32
4.84
0.75
0.75
-0.00
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.9
2.0
21.4

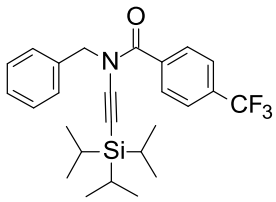
O
N
CF3
Si

2h


O
N
CF3
Si

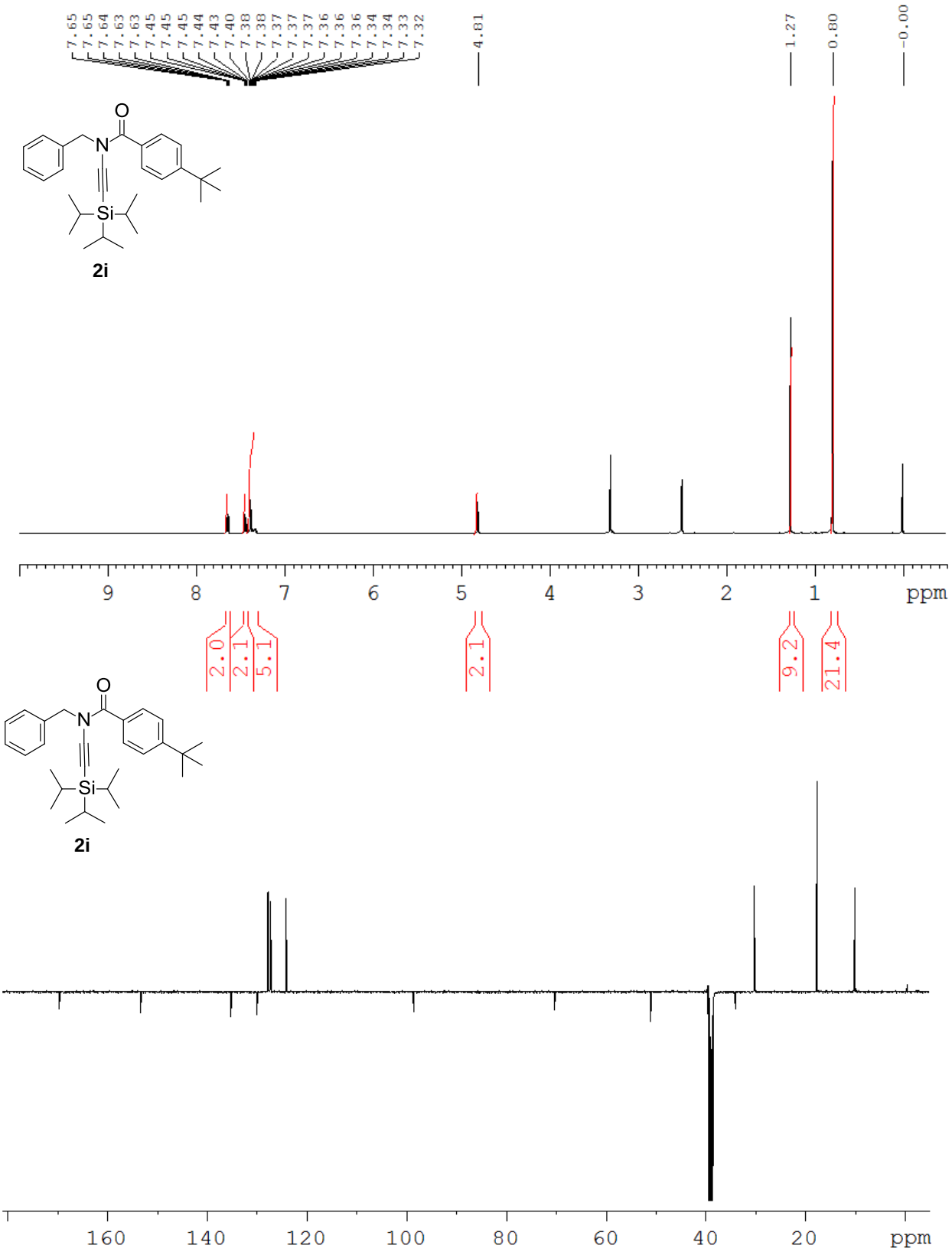
2h

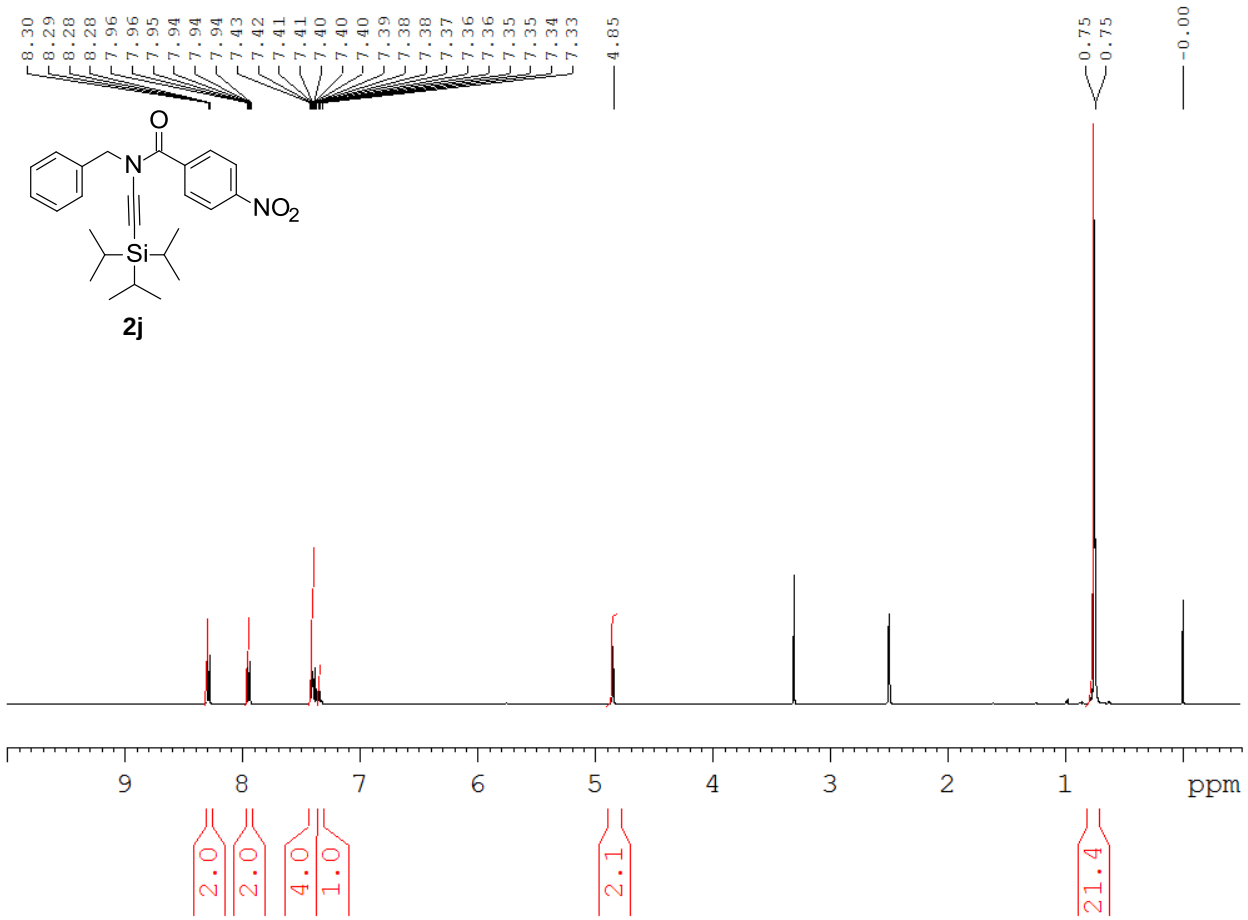
160
140
120
100
80
60
40
20
ppm

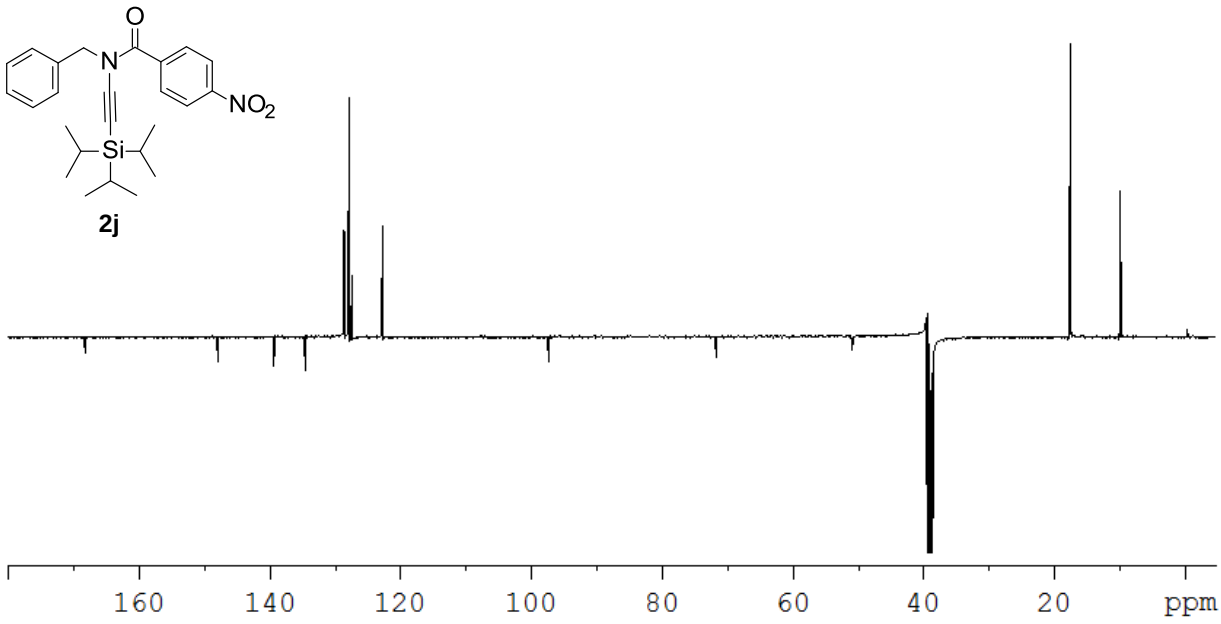

O
N
CF3
Si

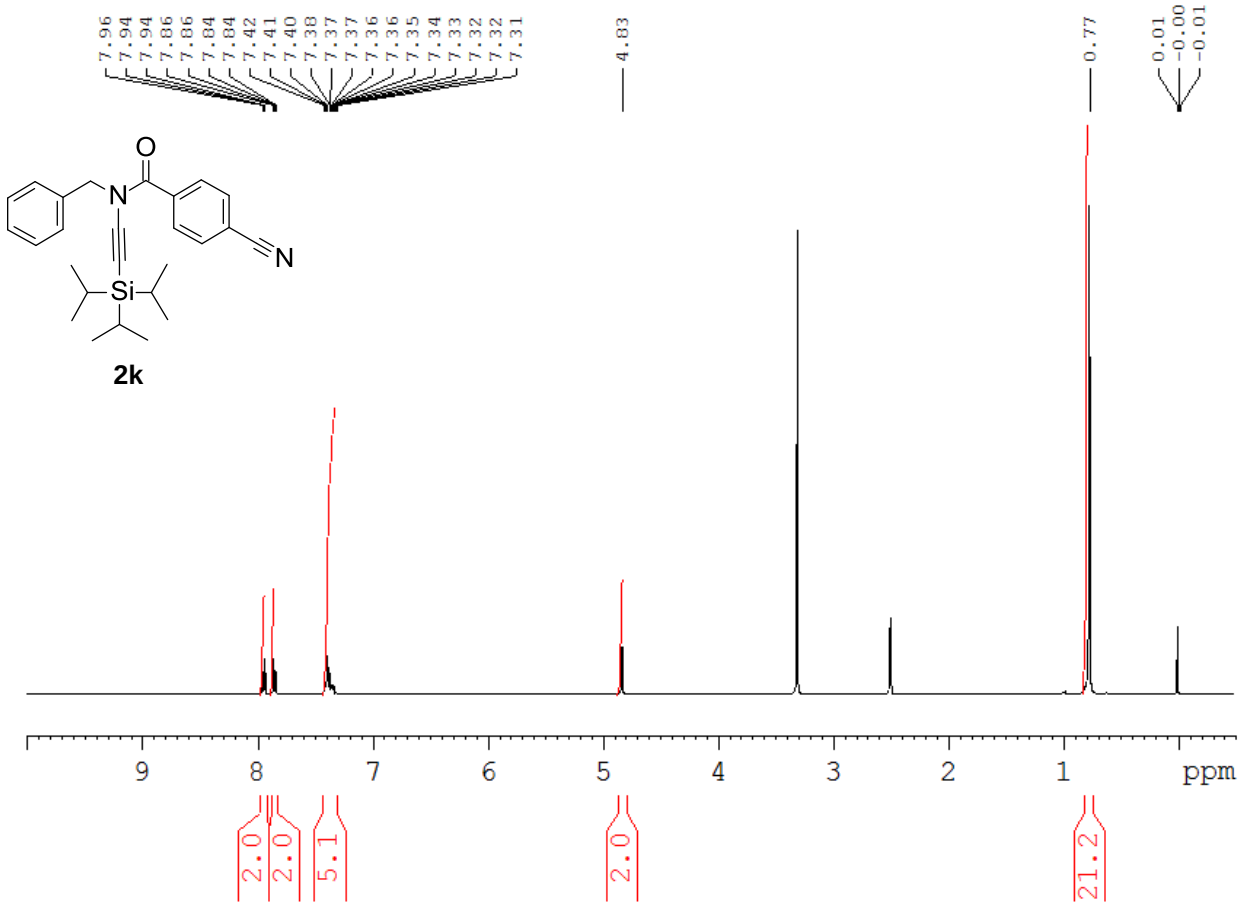
2h

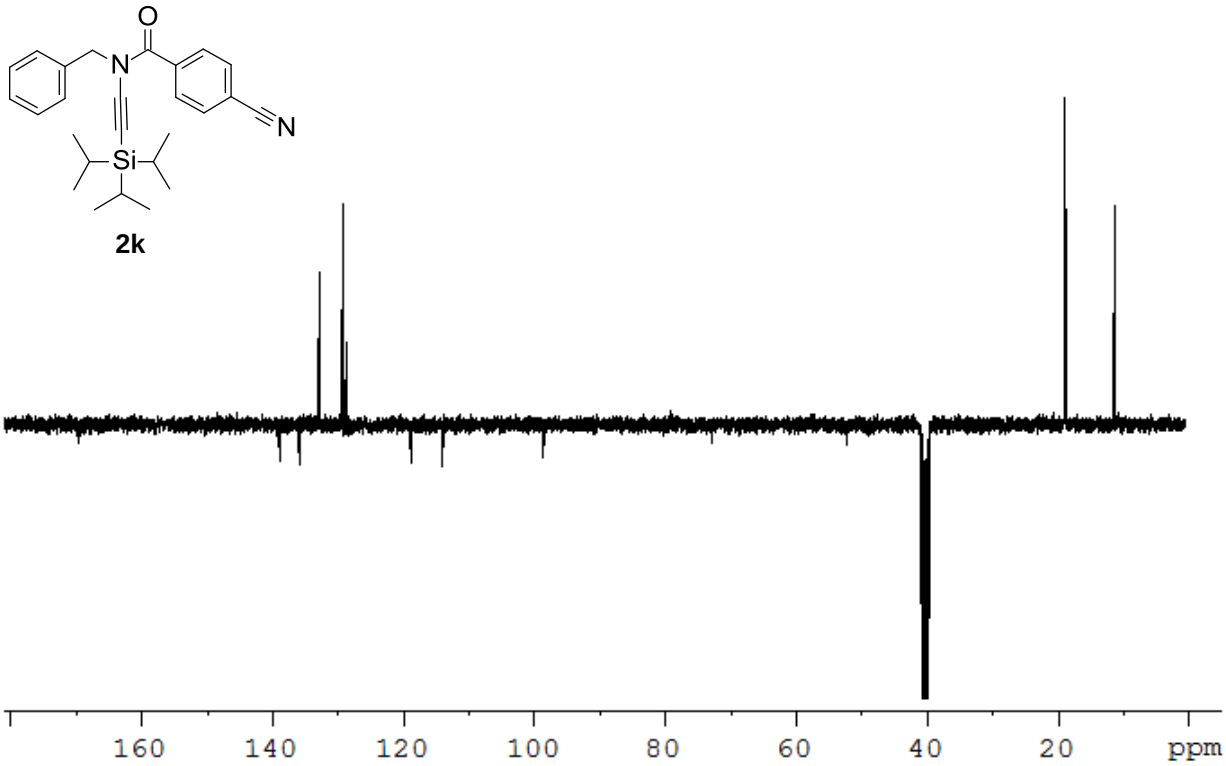
-61.74
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

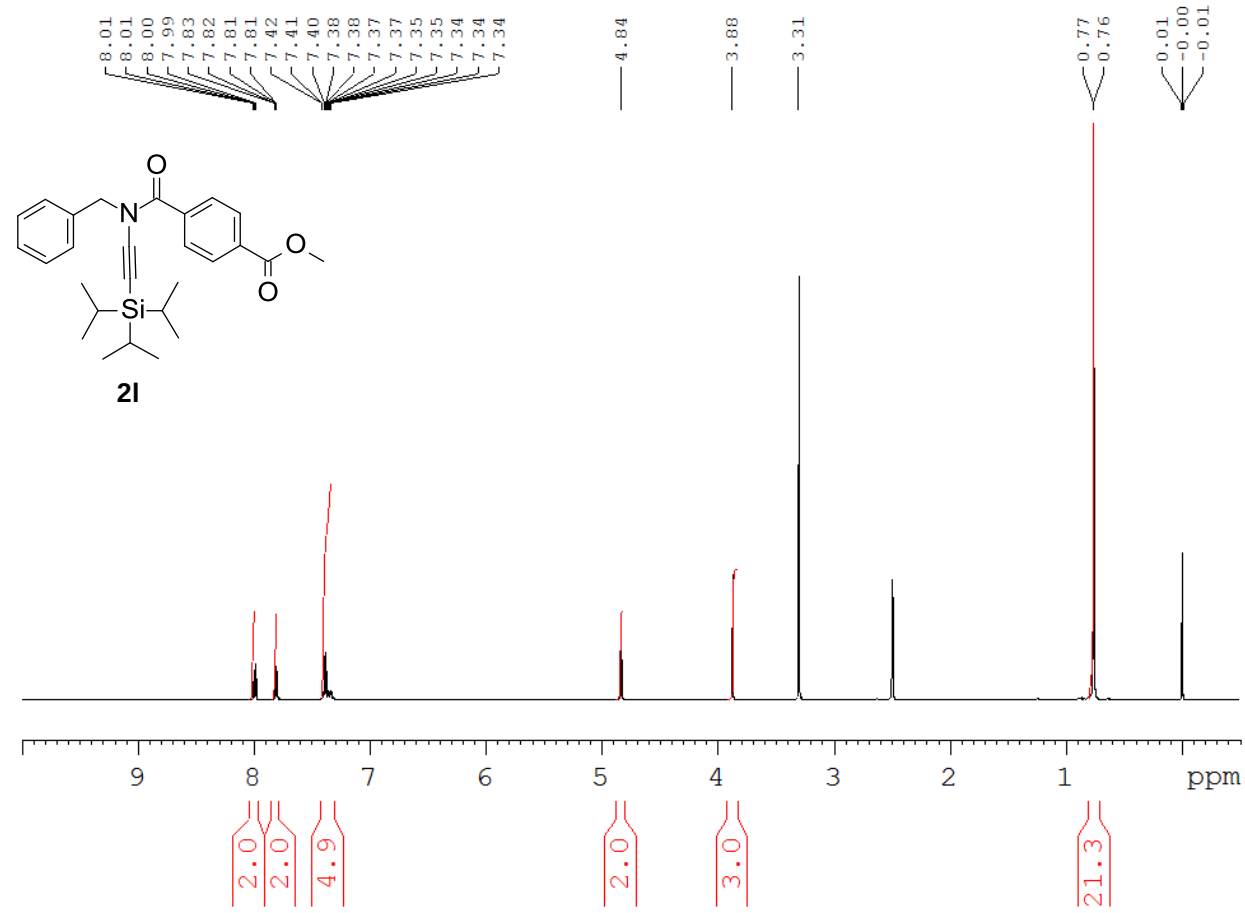

7.65
7.65
7.64
7.63
7.63
7.45
7.45
7.45
7.44
7.43
7.40
7.38
7.38
7.37
7.37
7.37
7.36
7.36
7.36
7.34
7.34
7.33
7.32
4.81
1.27
0.80
-0.00
O
N
Si
2i
9
8
7
6
5
4
3
2
1
ppm
2.0
2.1
5.1
2.1
9.2
21.4
O
N
Si
2i
160
140
120
100
80
60
40
20
ppm


8.30
8.29
8.28
8.28
7.96
7.96
7.95
7.94
7.94
7.94
7.43
7.42
7.41
7.41
7.40
7.40
7.40
7.39
7.38
7.38
7.37
7.36
7.36
7.35
7.35
7.34
7.33
4.85
0.75
0.75
-0.00
O
N
NO2
Si
2j
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
1.0
2.1
21.4

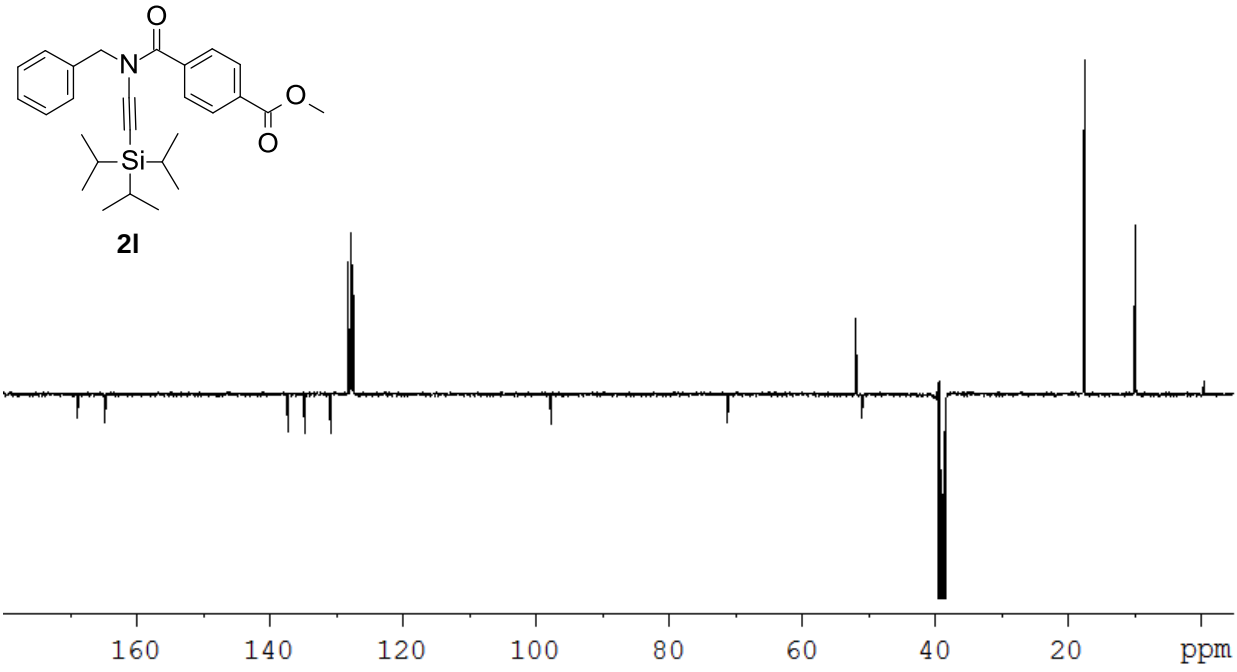

O
N
NO2
Si
2j
160
140
120
100
80
60
40
20
ppm


7.96
7.94
7.94
7.86
7.86
7.84
7.84
7.42
7.41
7.40
7.38
7.37
7.37
7.36
7.36
7.35
7.34
7.33
7.32
7.32
7.31
4.83
0.77
0.01
-0.00
-0.01
O
N
N
Si
2k
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
5.1
2.0
21.2

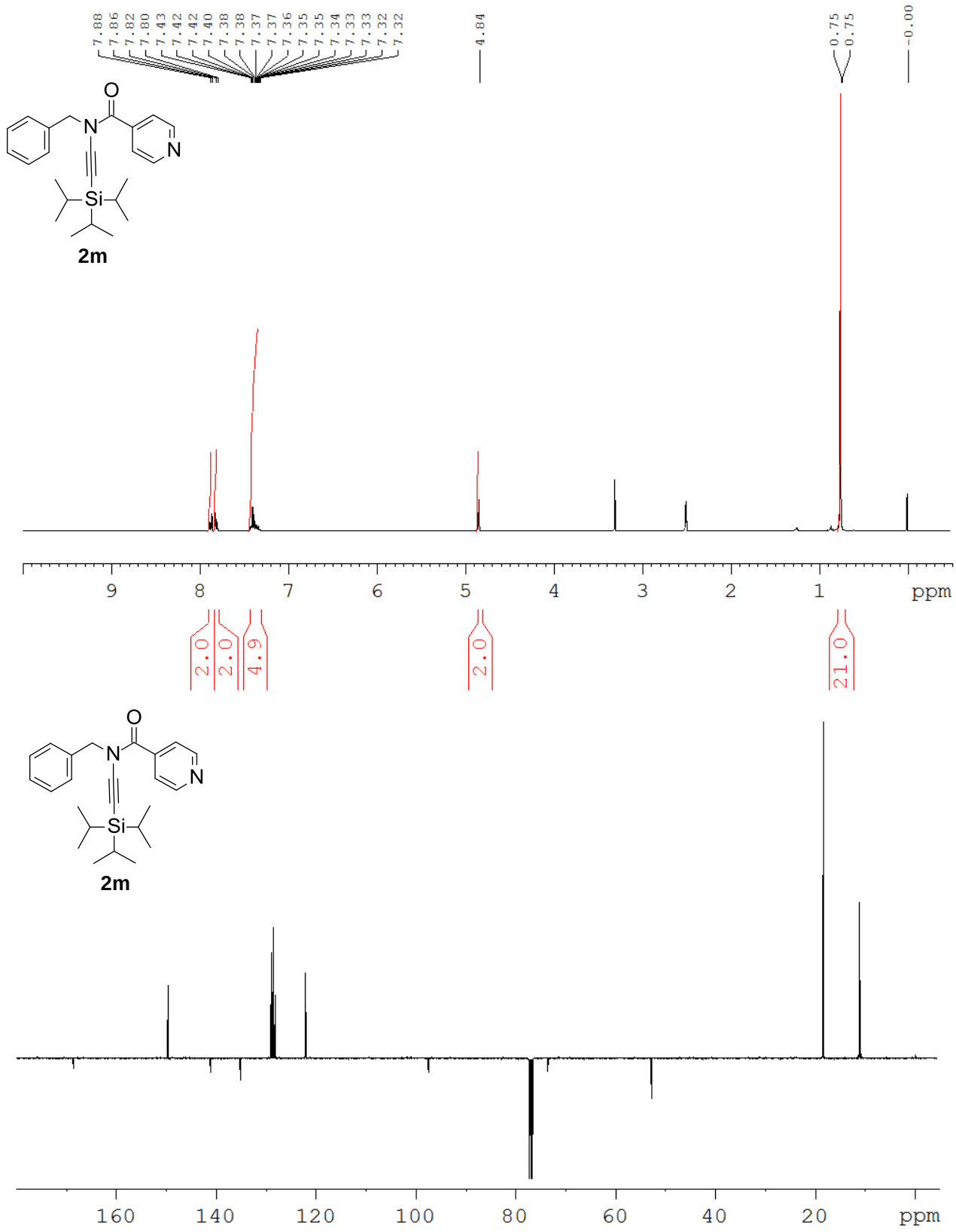

O
N
N
Si
2k
160
140
120
100
80
60
40
20
ppm

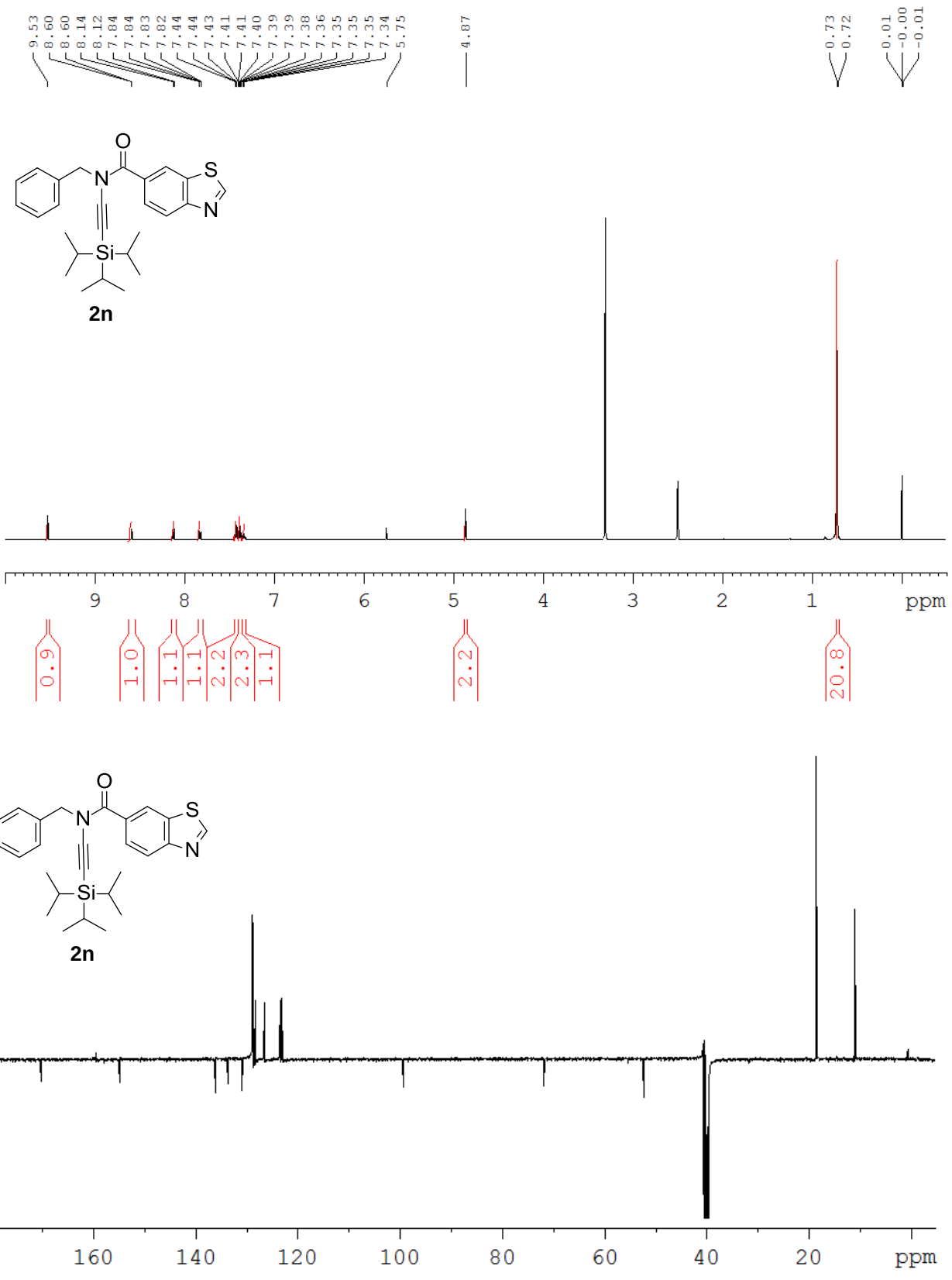

8.01
8.01
8.00
7.99
7.83
7.82
7.81
7.81
7.42
7.41
7.40
7.38
7.38
7.37
7.37
7.35
7.35
7.34
7.34
7.34
4.84
3.88
3.31
0.77
0.76
0.01
-0.00
-0.01
O
N
O
O
Si
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.9
2.0
3.0
21.3

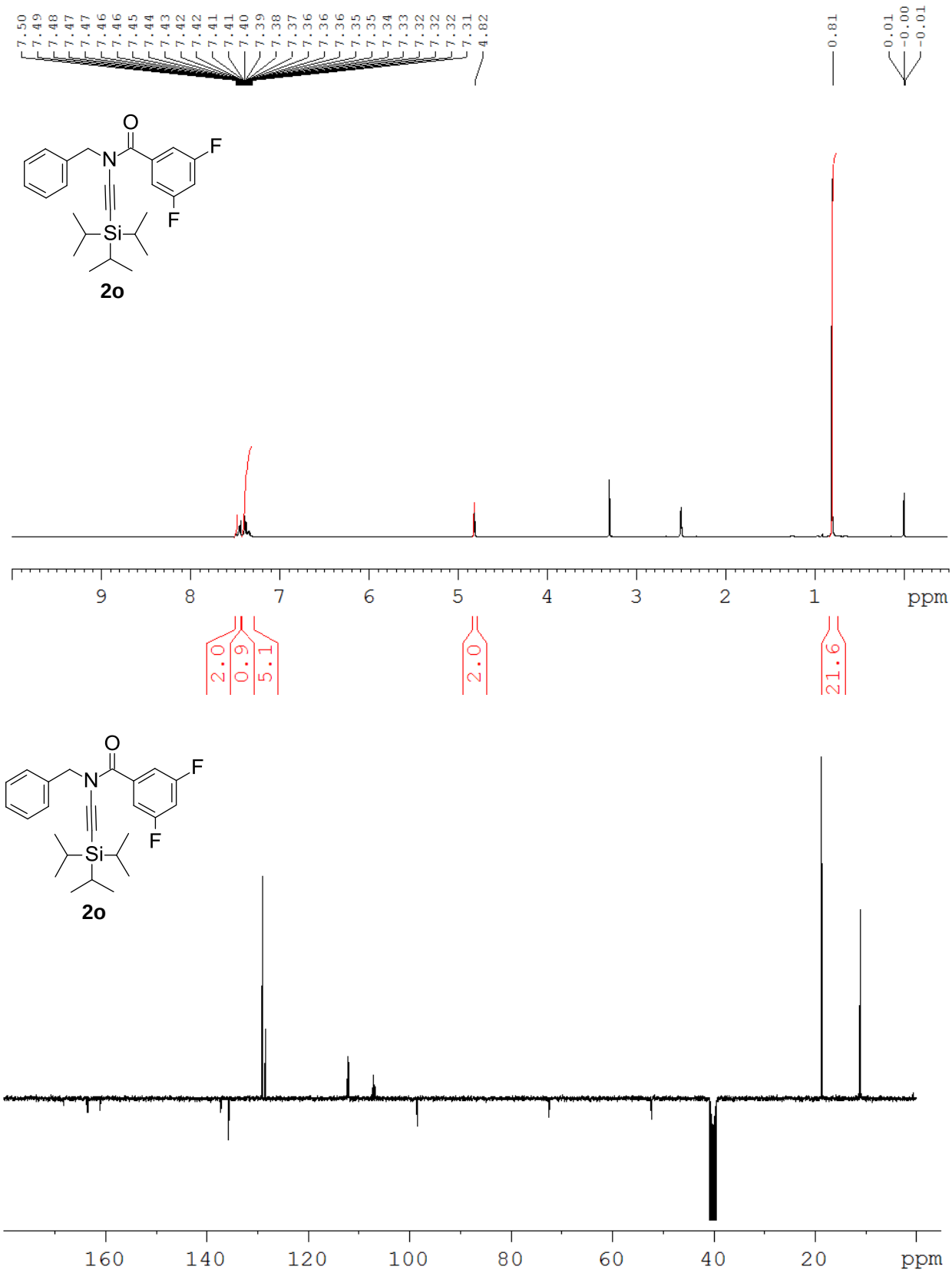
2l

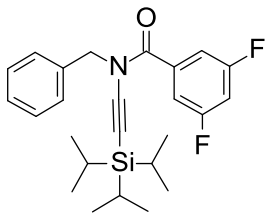

O
N
O
O
Si
160
140
120
100
80
60
40
20
ppm

2l


7.88
7.86
7.82
7.80
7.43
7.42
7.42
7.40
7.38
7.38
7.37
7.37
7.36
7.35
7.35
7.34
7.33
7.33
7.32
7.32
4.84
0.75
0.75
0.00
O
N
N
Si
2m
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.9
2.0
21.0
O
N
N
Si
2m
160
140
120
100
80
60
40
20
ppm

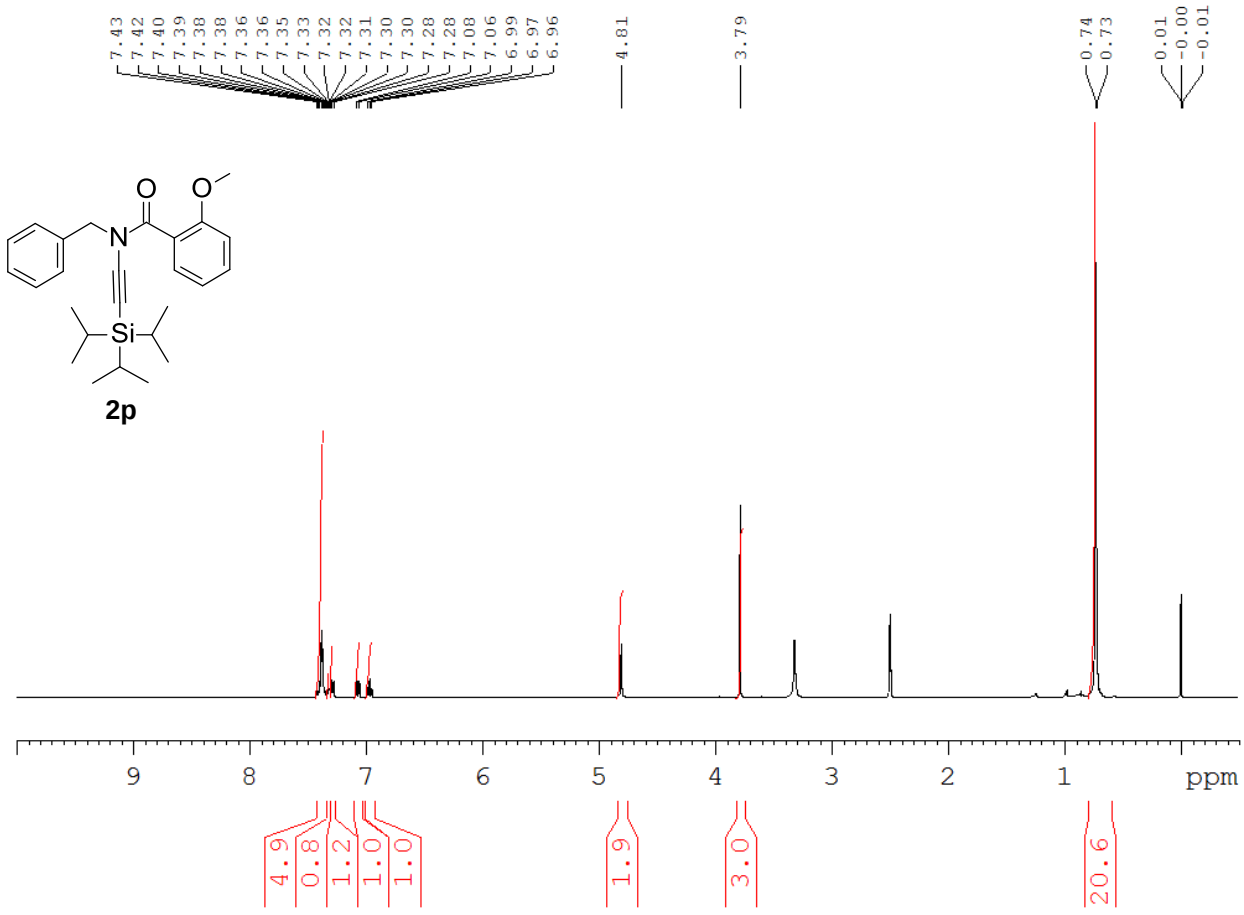

9.53
8.60
8.60
8.14
8.12
7.84
7.84
7.83
7.82
7.44
7.44
7.43
7.41
7.41
7.40
7.39
7.39
7.38
7.36
7.35
7.35
7.35
7.34
5.75
4.87
0.73
0.72
0.01
-0.00
-0.01
O
N
S
N
Si
2n
9
8
7
6
5
4
3
2
1
ppm
0.9
1.0
1.1
1.1
2.2
2.3
1.1
2.2
20.8
O
N
S
N
Si
2n
160
140
120
100
80
60
40
20
ppm


7.50
7.49
7.48
7.47
7.47
7.46
7.46
7.45
7.44
7.43
7.42
7.42
7.41
7.41
7.40
7.39
7.38
7.37
7.36
7.36
7.35
7.35
7.34
7.33
7.32
7.32
7.31
4.82
0.81
0.01
-0.00
-0.01
O
N
F
F
Si
2o
9
8
7
6
5
4
3
2
1
ppm
2.0
0.9
5.1
2.0
21.6
O
N
F
F
Si
2o
160
140
120
100
80
60
40
20
ppm


O
N
F
F
Si

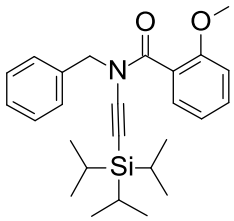
2o

-108.86
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.43
7.42
7.40
7.39
7.38
7.38
7.36
7.36
7.35
7.33
7.32
7.32
7.31
7.30
7.30
7.28
7.08
7.06
6.99
6.97
6.96
4.81
3.79
0.74
0.73
0.01
-0.00
-0.01
9
8
7
6
5
4
3
2
1
ppm
4.9
0.8
1.2
1.0
1.0
1.9
3.0
20.6

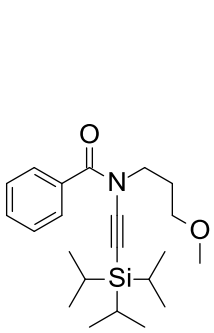
O
O
N
Si

2p

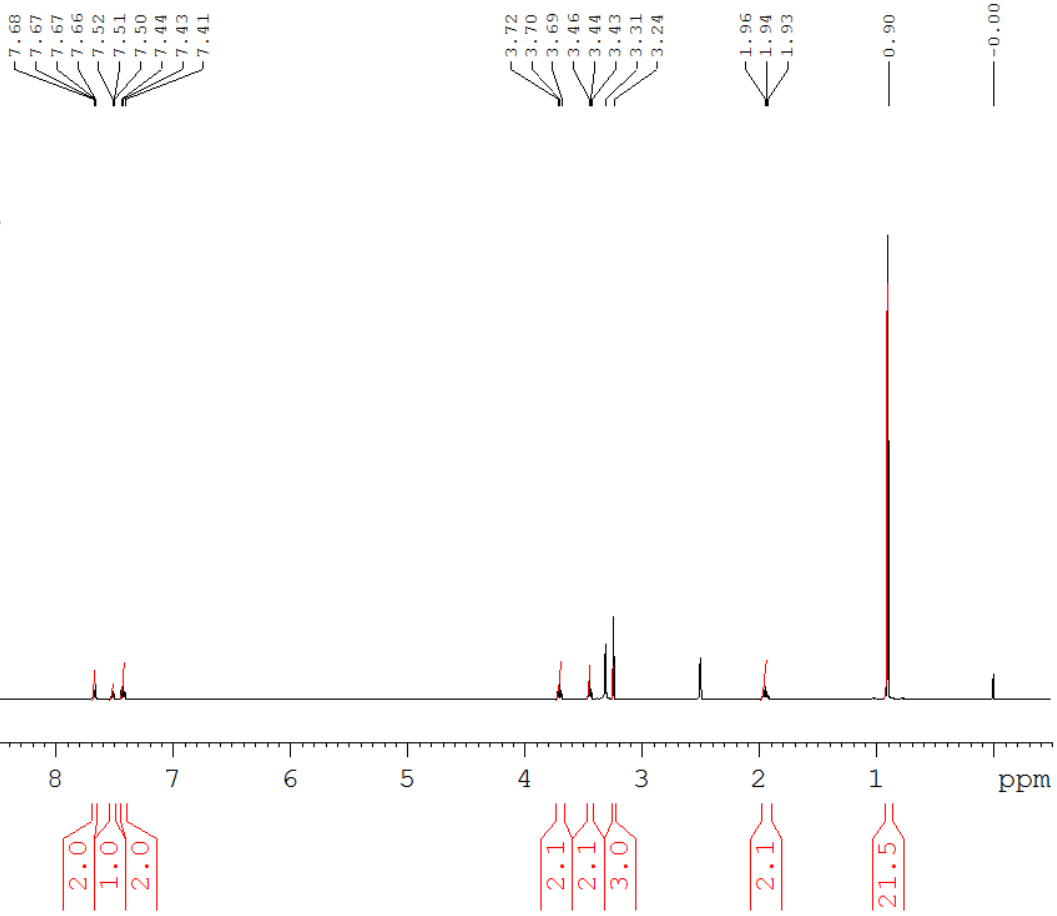

O
O
N
Si

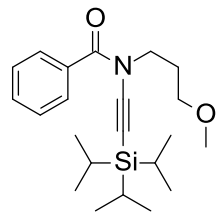
2p

160
140
120
100
80
60
40
20
ppm


O
N
O
Si

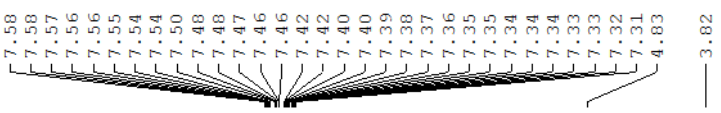
2q

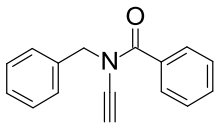

7.68
7.67
7.67
7.66
7.52
7.51
7.50
7.44
7.43
7.41
3.72
3.70
3.69
3.46
3.44
3.43
3.31
3.24
1.96
1.94
1.93
0.90
-0.00
9
8
7
6
5
4
3
2
1
ppm
2.0
1.0
2.0
2.1
2.1
3.0
2.1
21.5


O
N
O
Si

2q

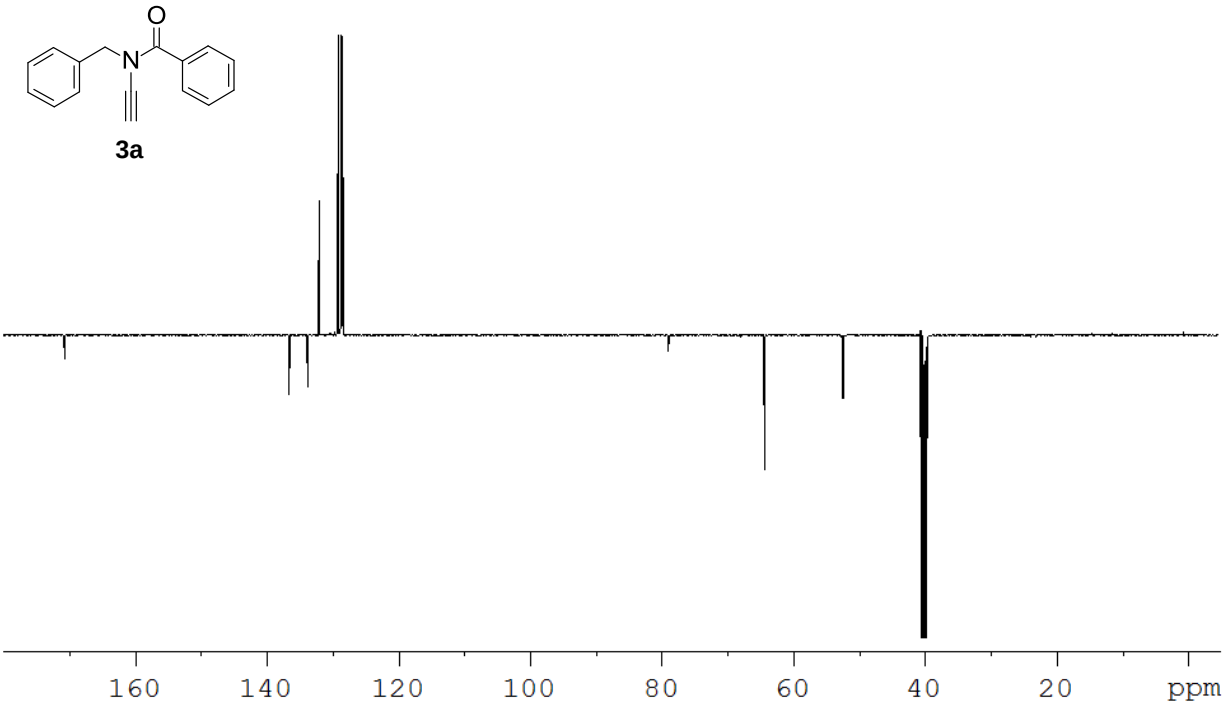
160
140
120
100
80
60
40
20
ppm

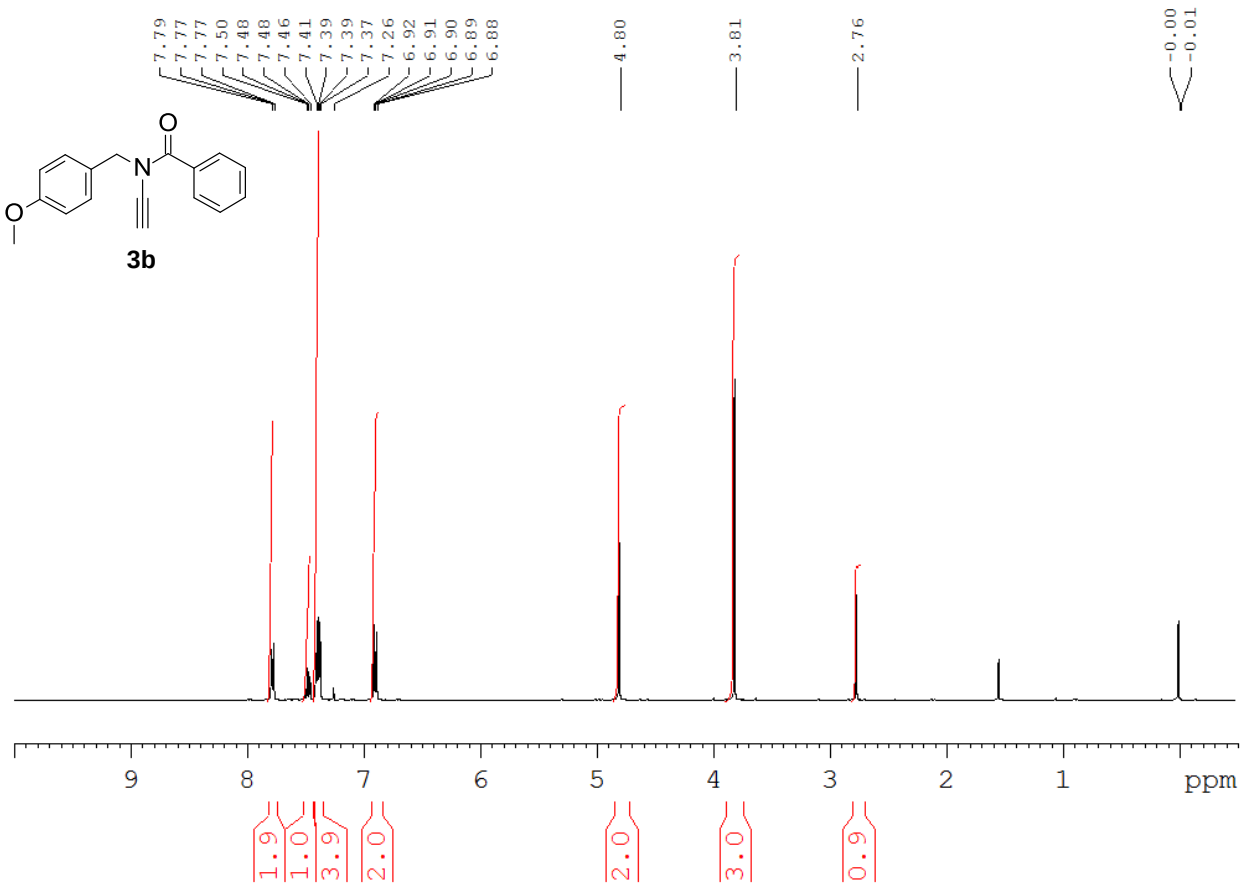

7.58
7.58
7.57
7.56
7.56
7.55
7.54
7.54
7.50
7.48
7.48
7.47
7.46
7.46
7.42
7.42
7.40
7.40
7.39
7.38
7.37
7.36
7.35
7.35
7.34
7.34
7.34
7.33
7.32
7.31
4.83
3.82
0.01
0.00
-0.01

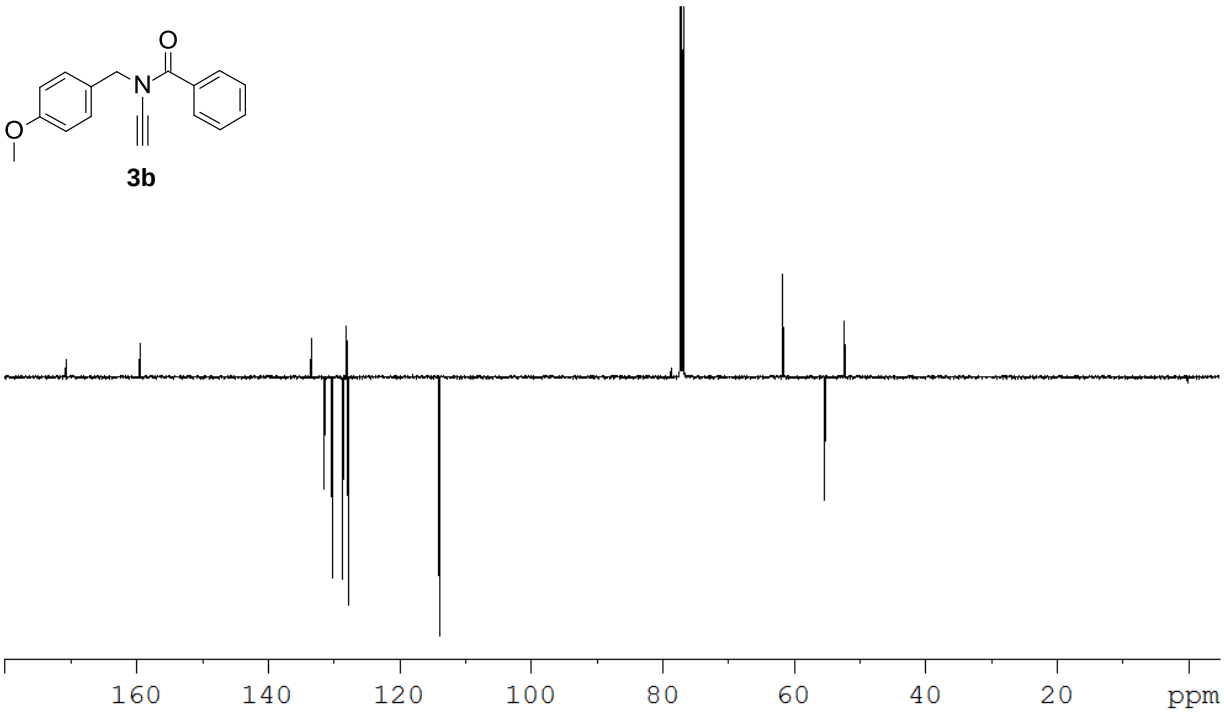

O
N

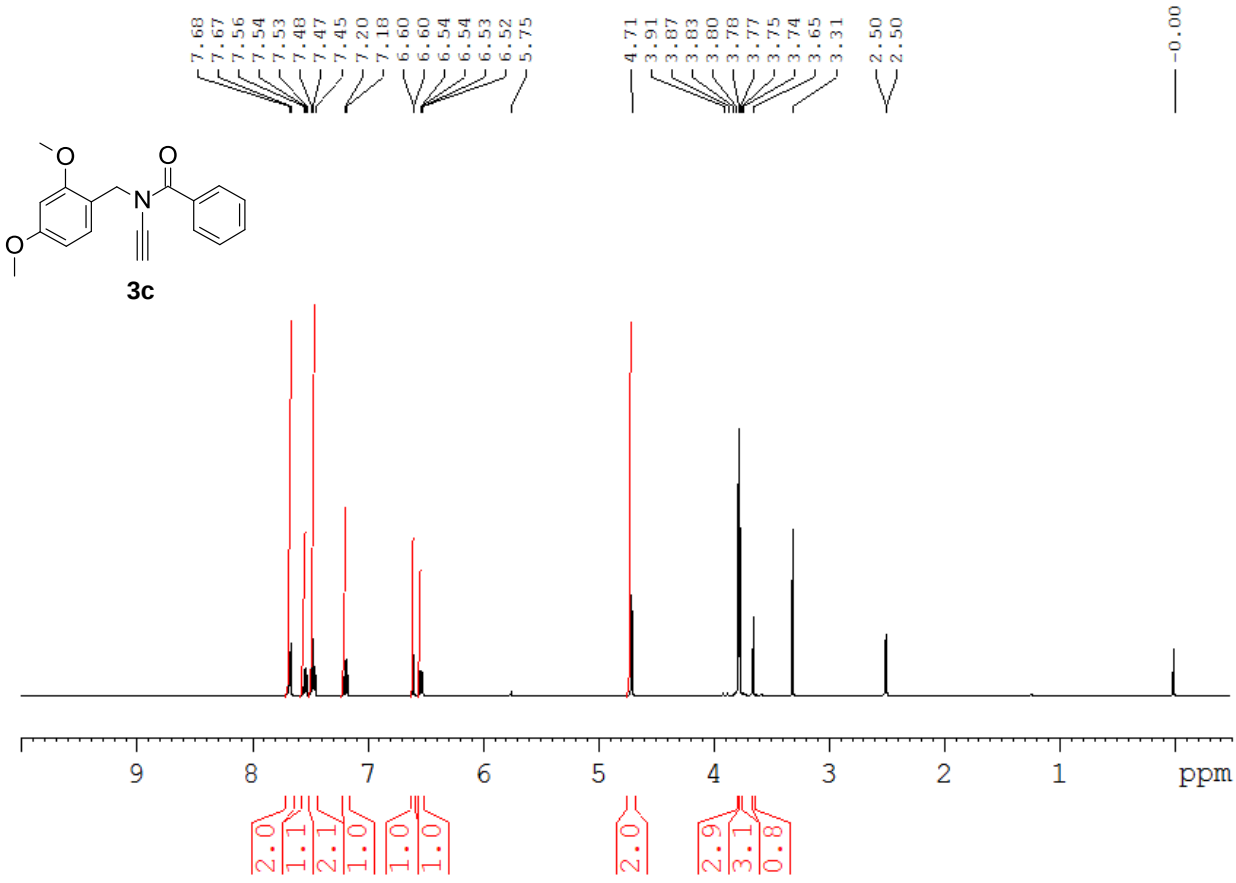
3a

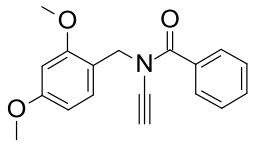
9
8
7
6
5
4
3
2
1
ppm
2.0
1.0
2.1
4.1
1.0
2.1
0.9


O
N
3a
160
140
120
100
80
60
40
20
ppm


7.79
7.77
7.77
7.50
7.48
7.48
7.46
7.41
7.39
7.39
7.37
7.26
6.92
6.91
6.90
6.89
6.88
4.80
3.81
2.76
-0.00
-0.01
O
N
O
3b
9
8
7
6
5
4
3
2
1
ppm
1.9
1.0
3.9
2.0
2.0
3.0
0.9

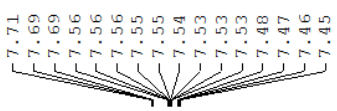

O
N
O
3b
160
140
120
100
80
60
40
20
ppm

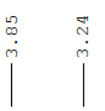

7.68
7.67
7.56
7.54
7.53
7.48
7.47
7.45
7.20
7.18
6.60
6.60
6.54
6.54
6.53
6.52
5.75
4.71
3.91
3.87
3.83
3.80
3.78
3.77
3.75
3.74
3.65
3.31
2.50
2.50
-0.00
O
O
N
O
3c
9
8
7
6
5
4
3
2
1
ppm
2.0
1.1
2.1
1.0
1.0
1.0
2.0
2.9
3.1
0.8

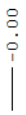


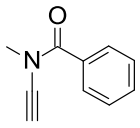
3c

160
140
120
100
80
60
40
20
ppm

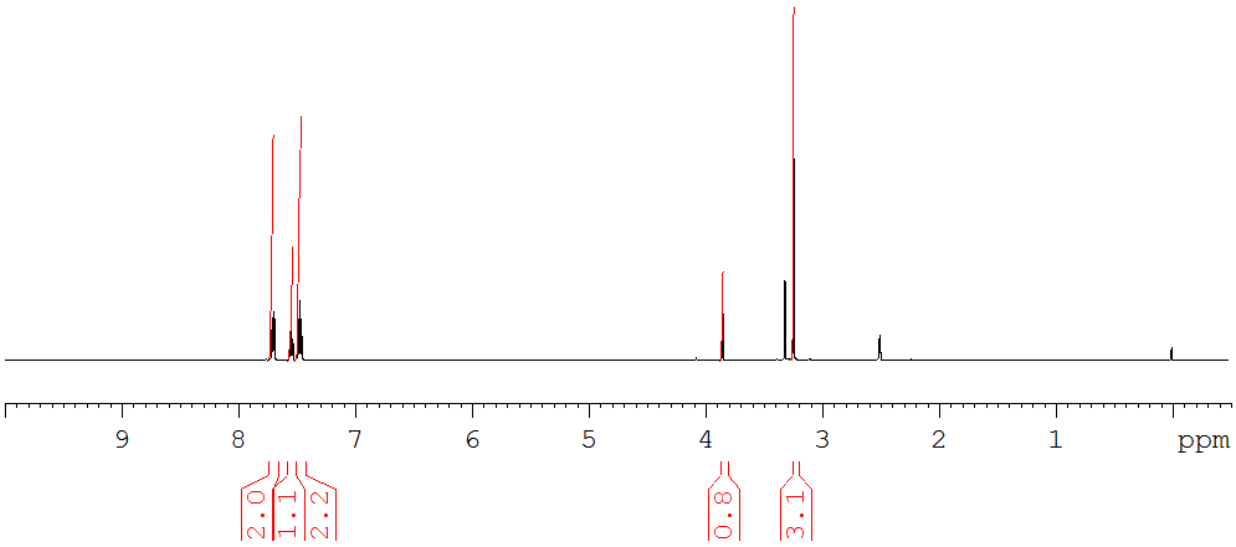

7.71
7.69
7.69
7.56
7.56
7.56
7.55
7.55
7.54
7.53
7.53
7.53
7.48
7.47
7.46
7.45

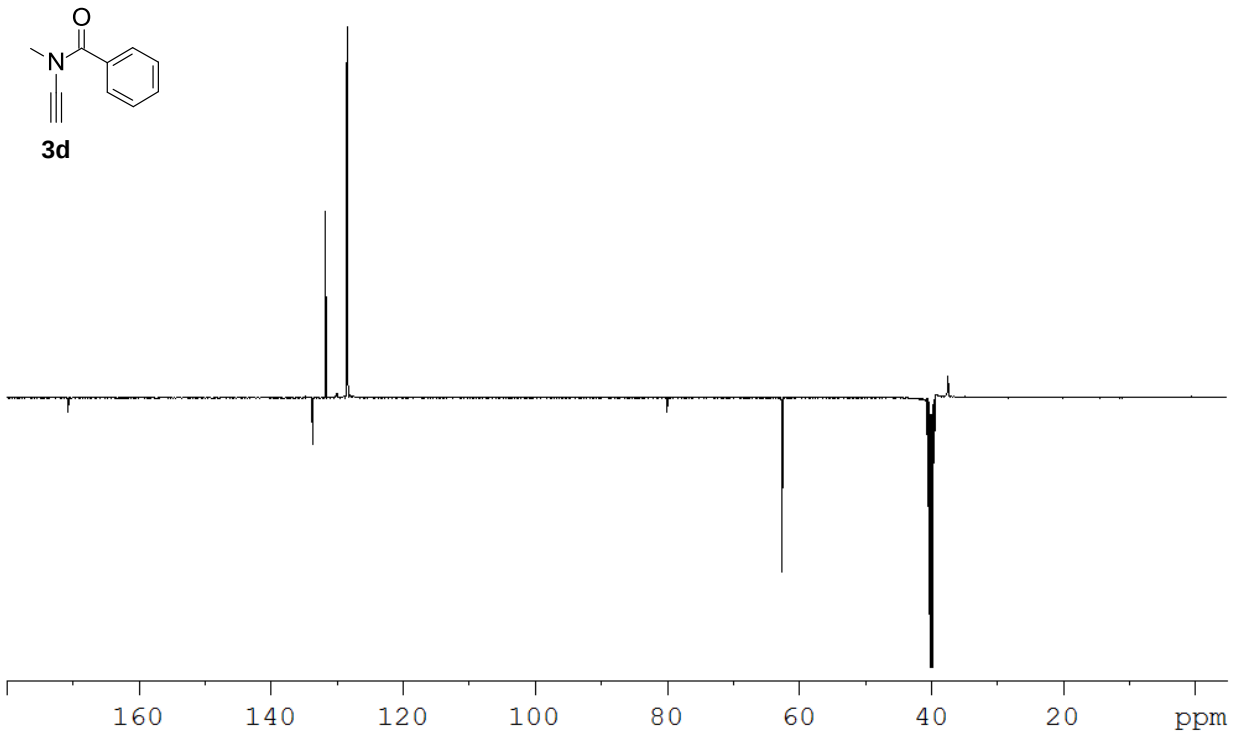

3.85
3.24

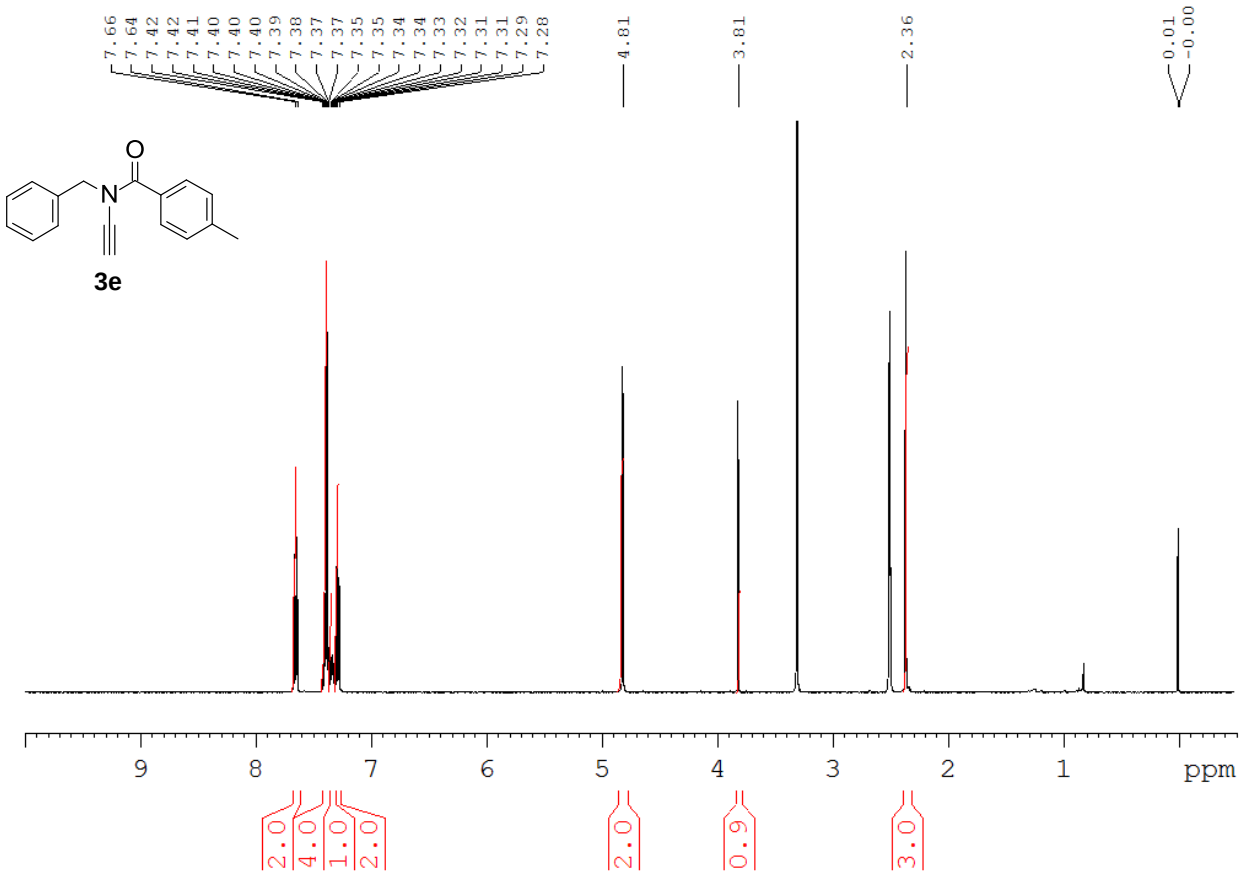

0.00

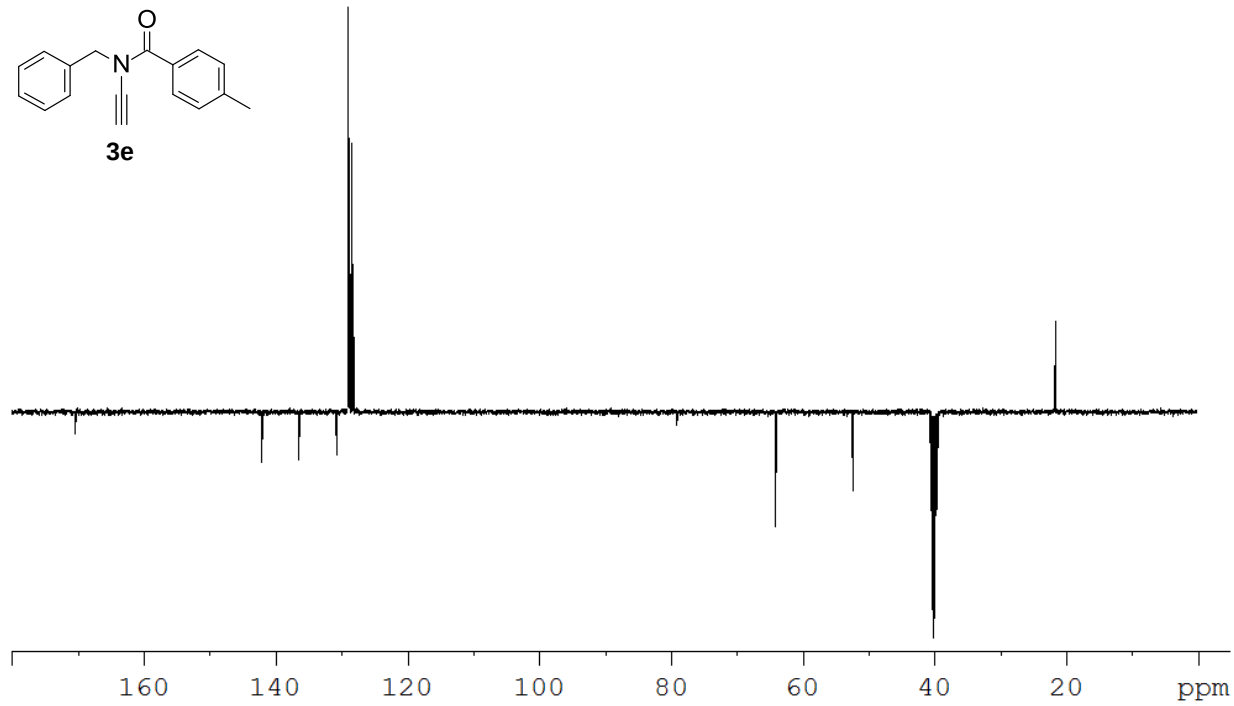


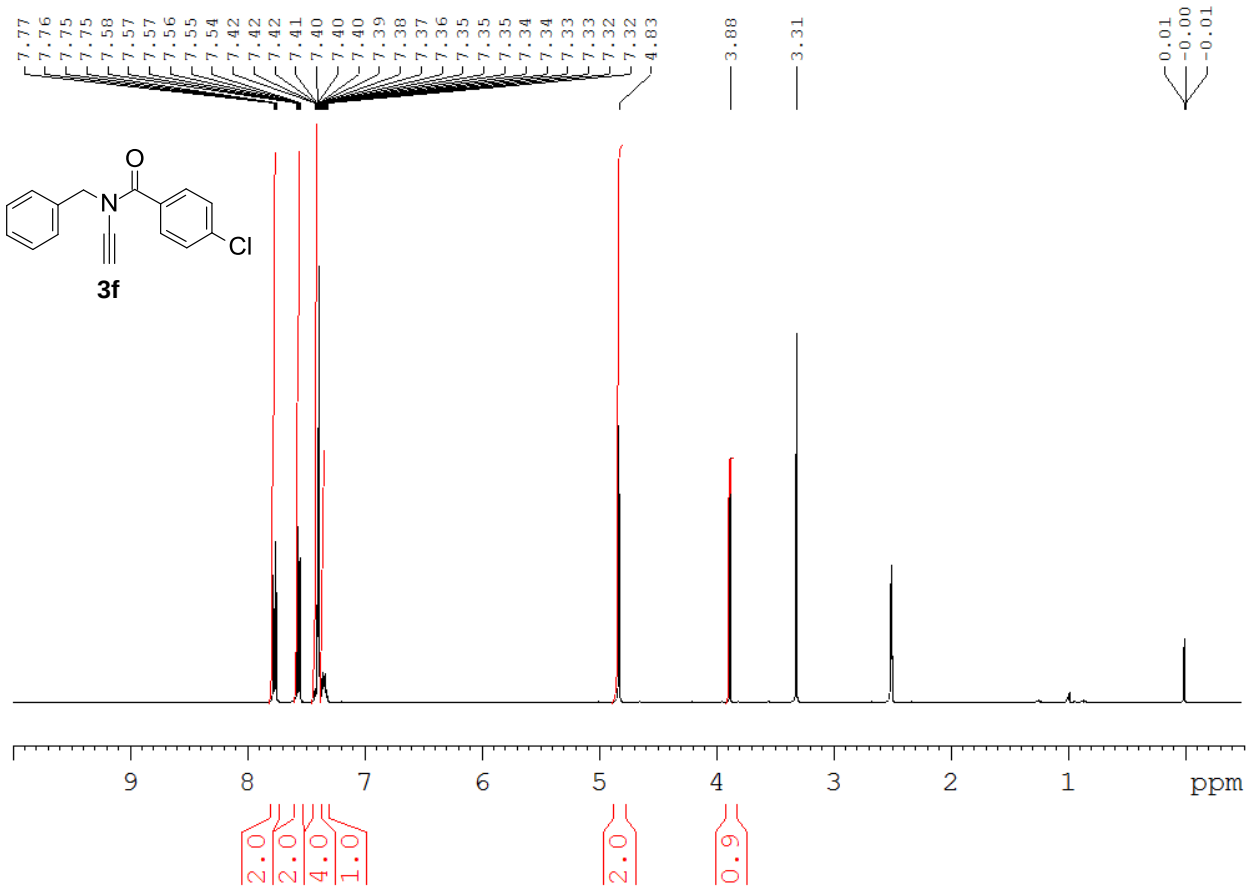
3d

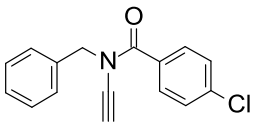

9
8
7
6
5
4
3
2
1
ppm
2.0
1.1
2.2
0.8
3.1


O
N
3d
160
140
120
100
80
60
40
20
ppm

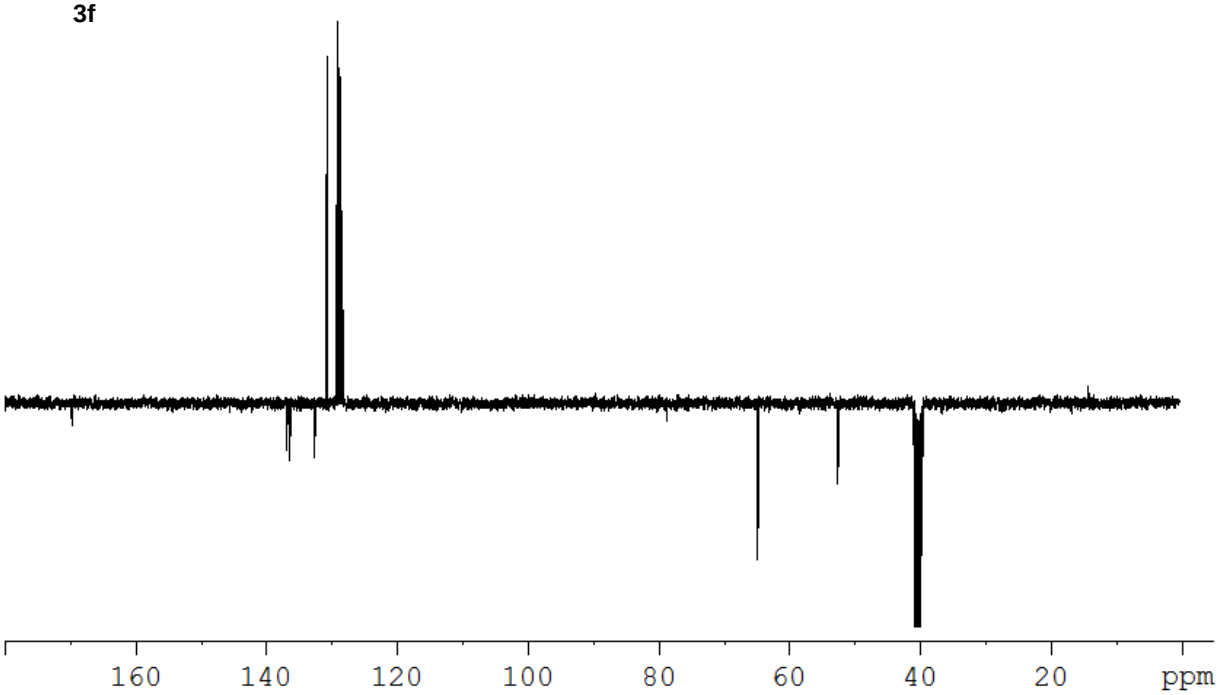

7.66
7.64
7.42
7.42
7.41
7.40
7.40
7.40
7.39
7.38
7.37
7.37
7.35
7.35
7.34
7.34
7.33
7.32
7.31
7.31
7.29
7.28
4.81
3.81
2.36
0.01
-0.00
O
N
3e
9
8
7
6
5
4
3
2
1
ppm
2.0
4.0
1.0
2.0
2.0
0.9
3.0

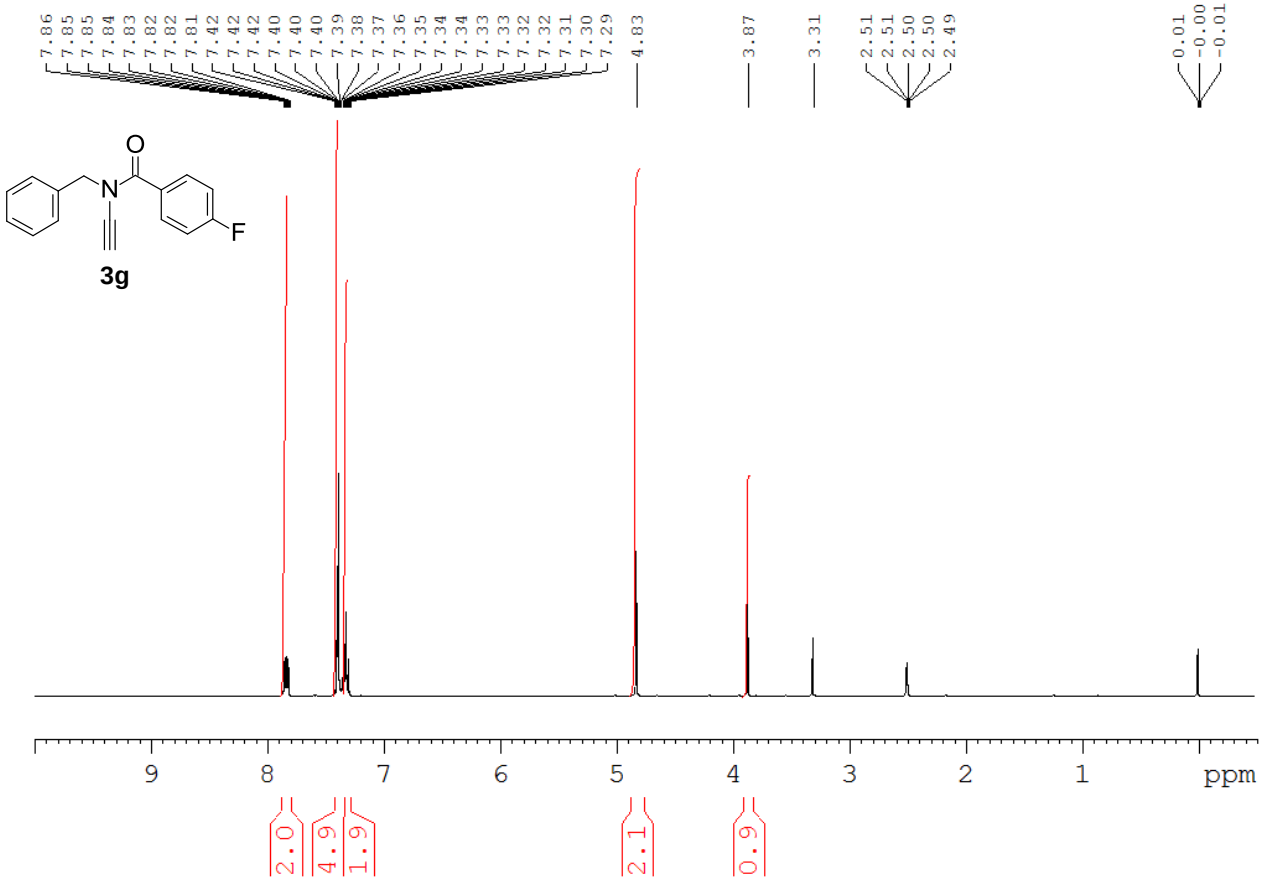

O
N
3e
160
140
120
100
80
60
40
20
ppm


7.77
7.76
7.75
7.75
7.58
7.57
7.57
7.56
7.55
7.54
7.42
7.42
7.41
7.40
7.40
7.40
7.39
7.38
7.37
7.36
7.35
7.35
7.35
7.34
7.34
7.33
7.33
7.32
7.32
4.83
3.88
3.31
0.01
0.00
0.01
O
N
Cl
3f
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
1.0
2.0
0.9

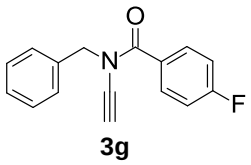

O
N
Cl

3f


160
140
120
100
80
60
40
20
ppm

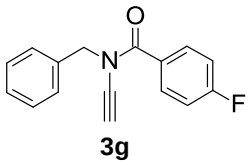

7.86
7.85
7.85
7.84
7.83
7.82
7.82
7.81
7.42
7.42
7.42
7.40
7.40
7.40
7.39
7.38
7.37
7.36
7.35
7.34
7.34
7.33
7.33
7.32
7.32
7.31
7.30
7.29
4.83
3.87
3.31
2.51
2.51
2.50
2.50
2.49
0.01
-0.00
-0.01
O
N
F
9
8
7
6
5
4
3
2
1
ppm
2.0
4.9
1.9
2.1
0.9

3g


O
N
F

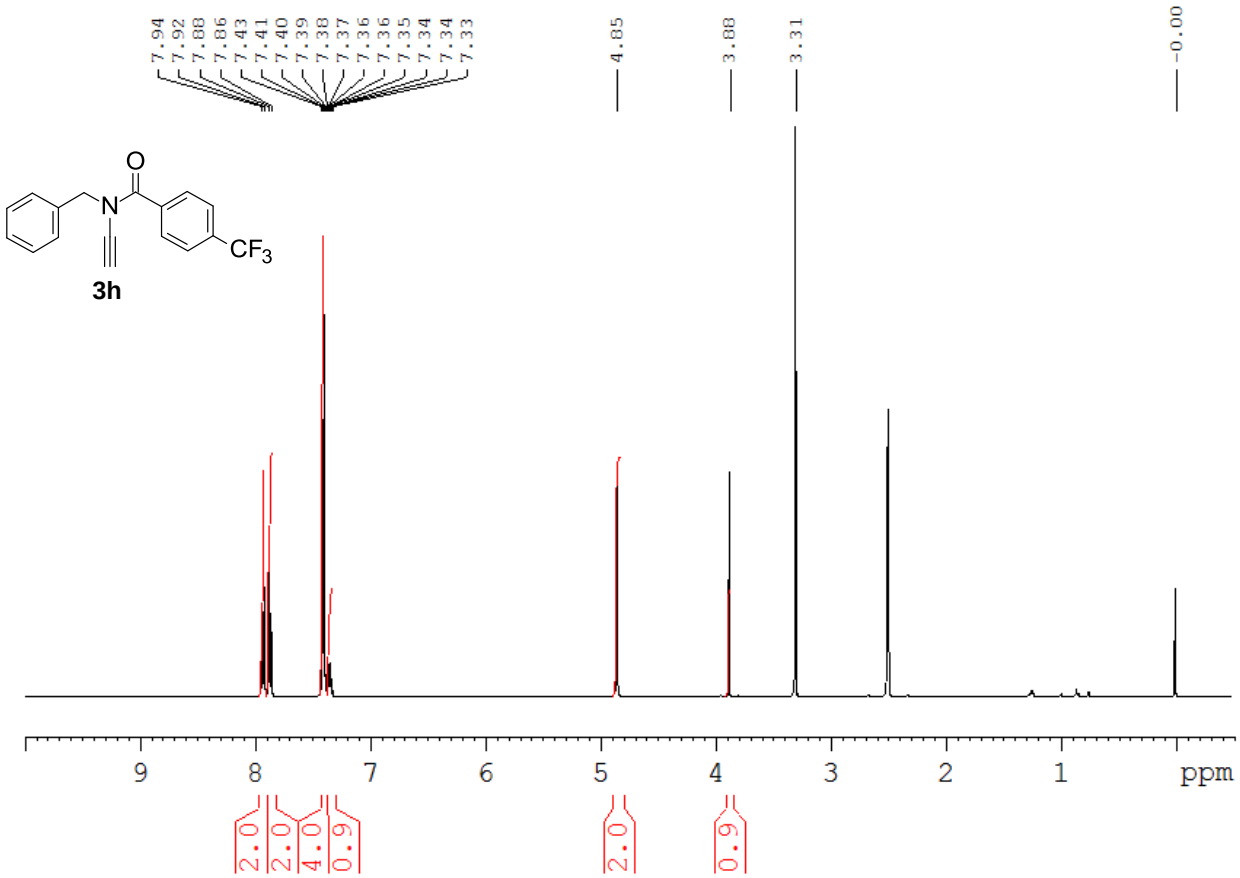
3g

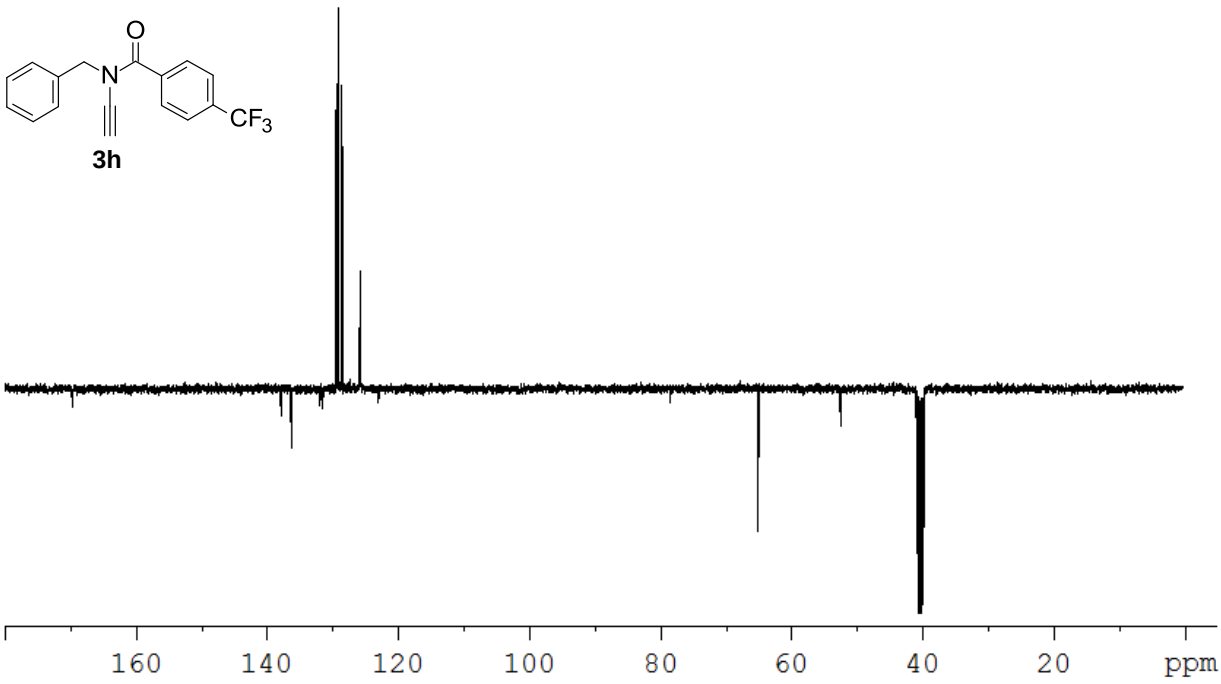
160
140
120
100
80
60
40
20
ppm

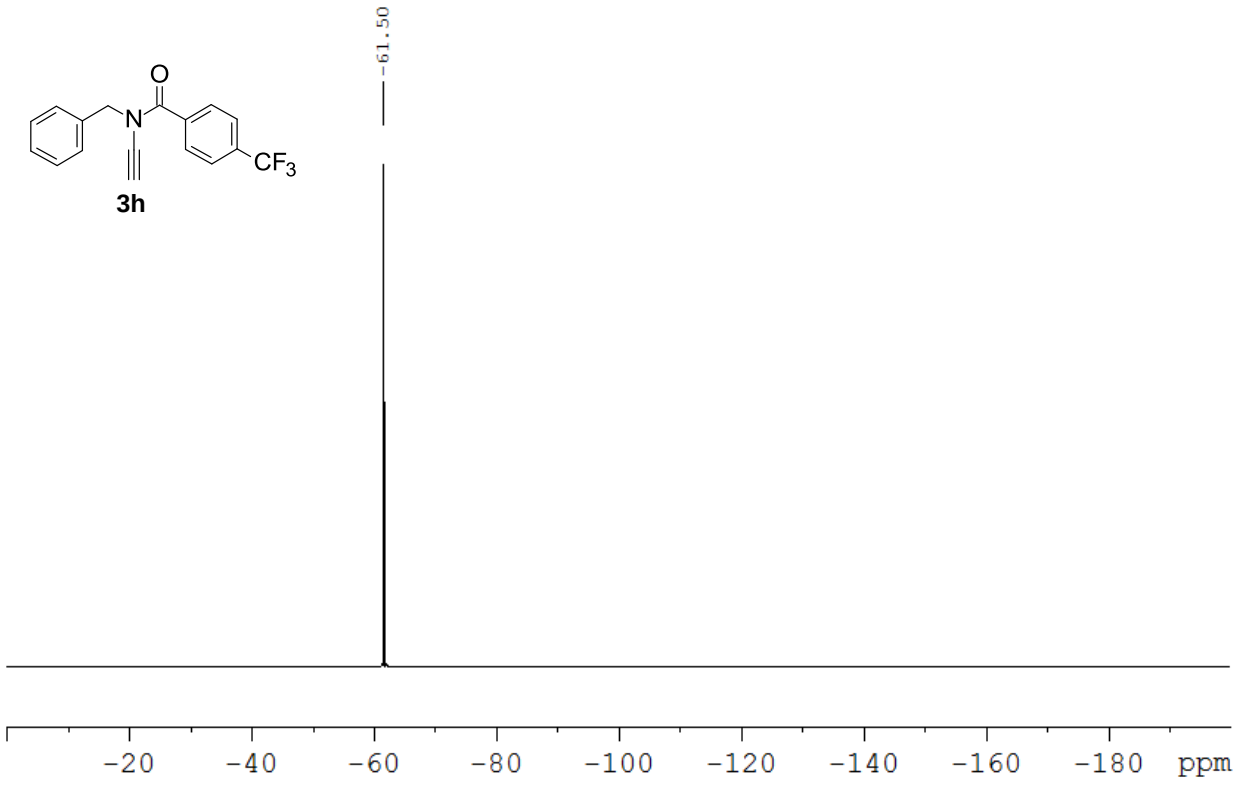

O
N
F

3g

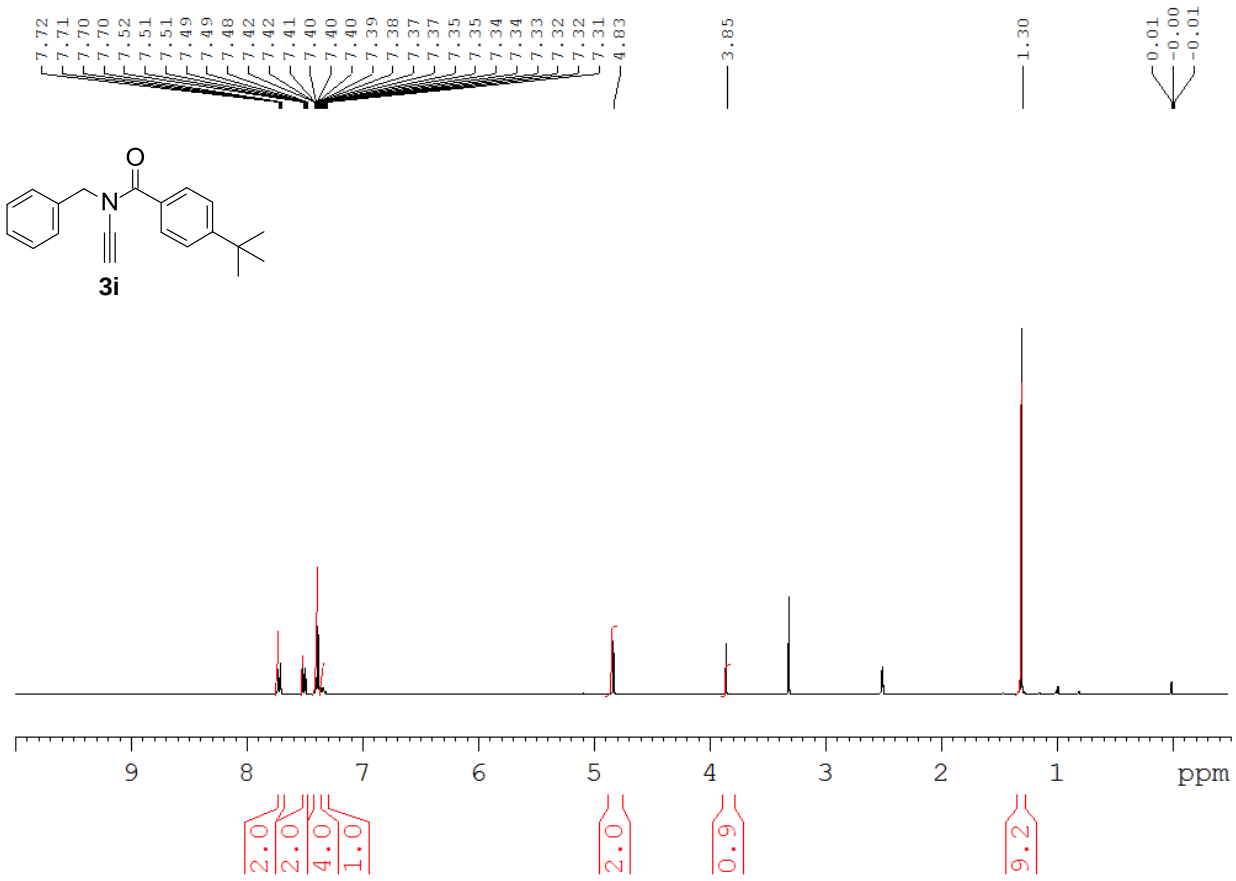
-107.93
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.94
7.92
7.88
7.86
7.43
7.41
7.40
7.39
7.38
7.37
7.36
7.36
7.35
7.34
7.34
7.33
4.85
3.88
3.31
0.00
O
N
CF3
3h
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
0.9
2.0
0.9

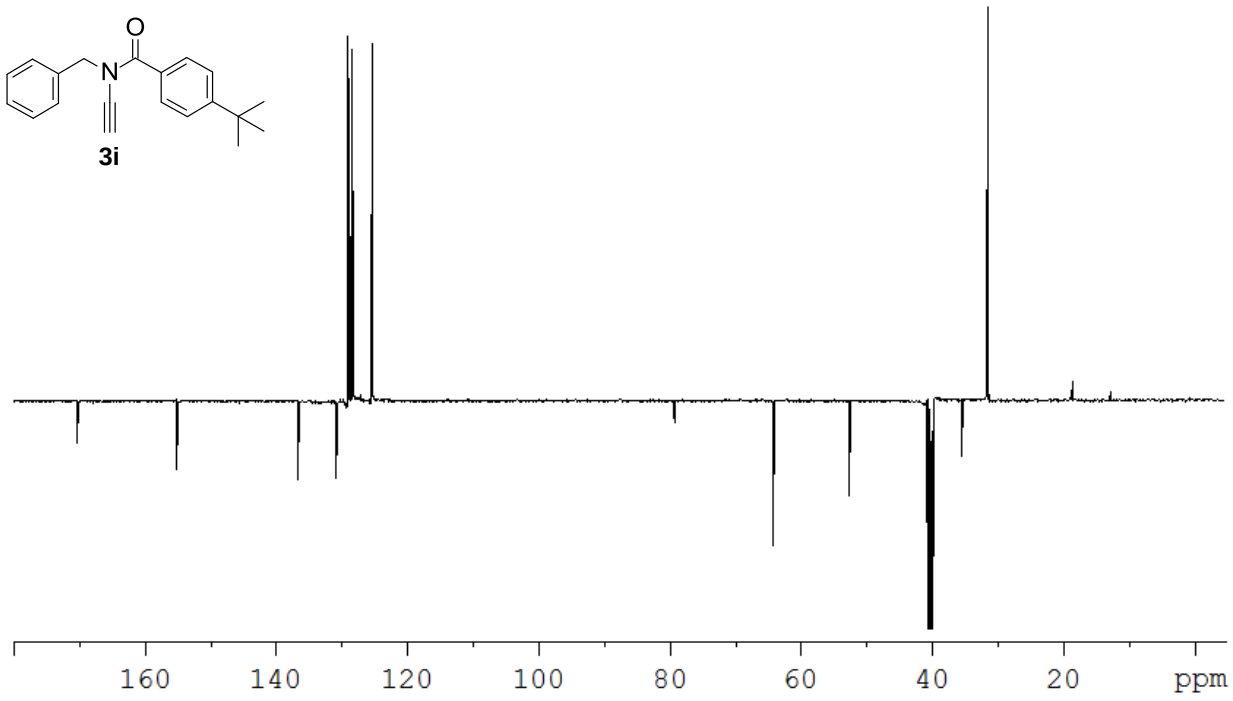

O
N
CF3
3h
160
140
120
100
80
60
40
20
ppm

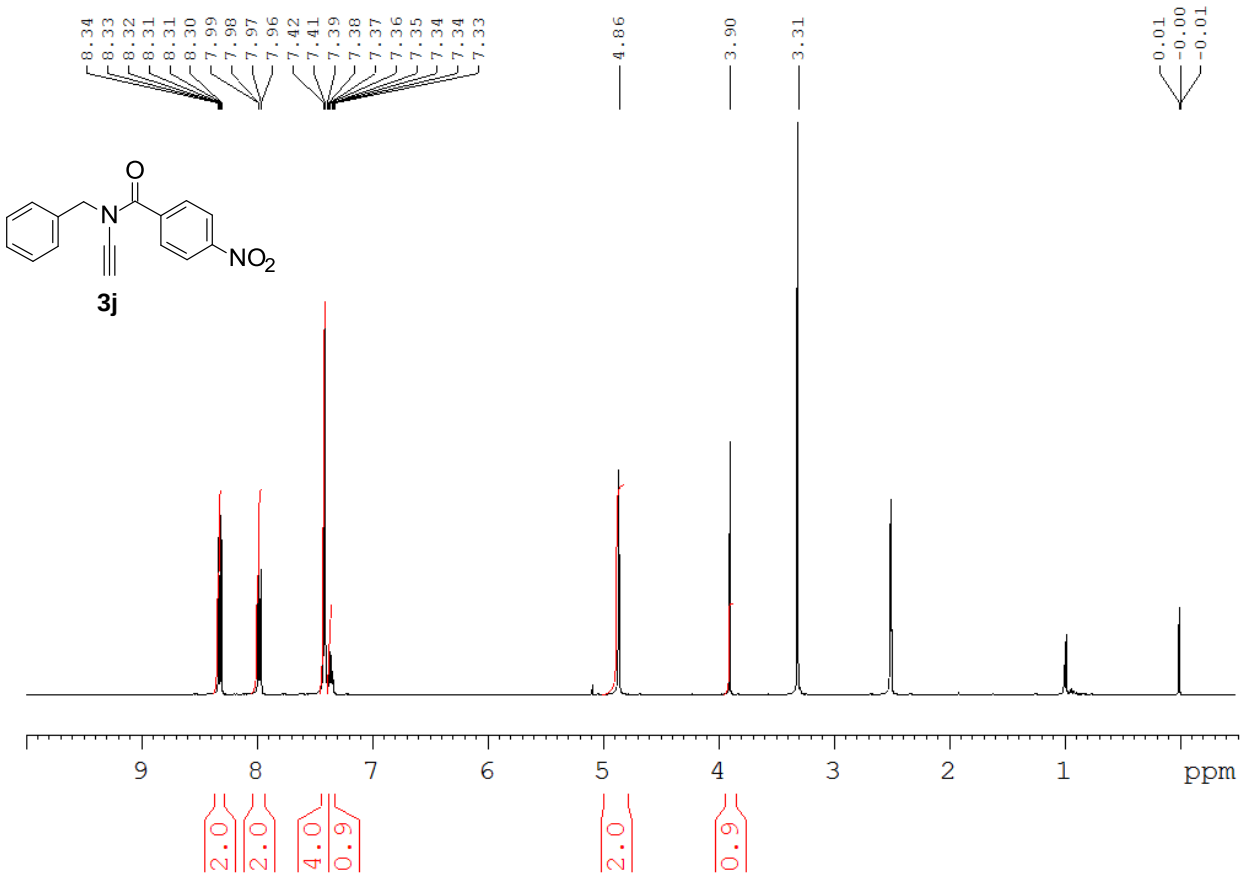

O
N
CF3
-61.50
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

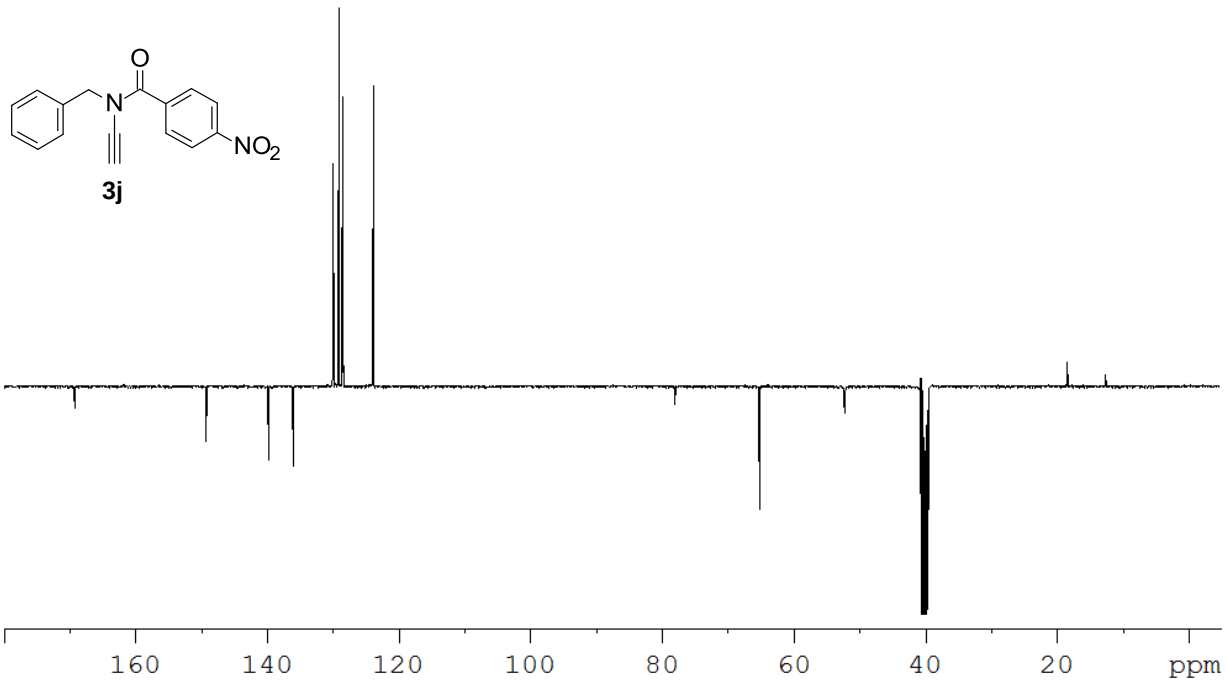
3h

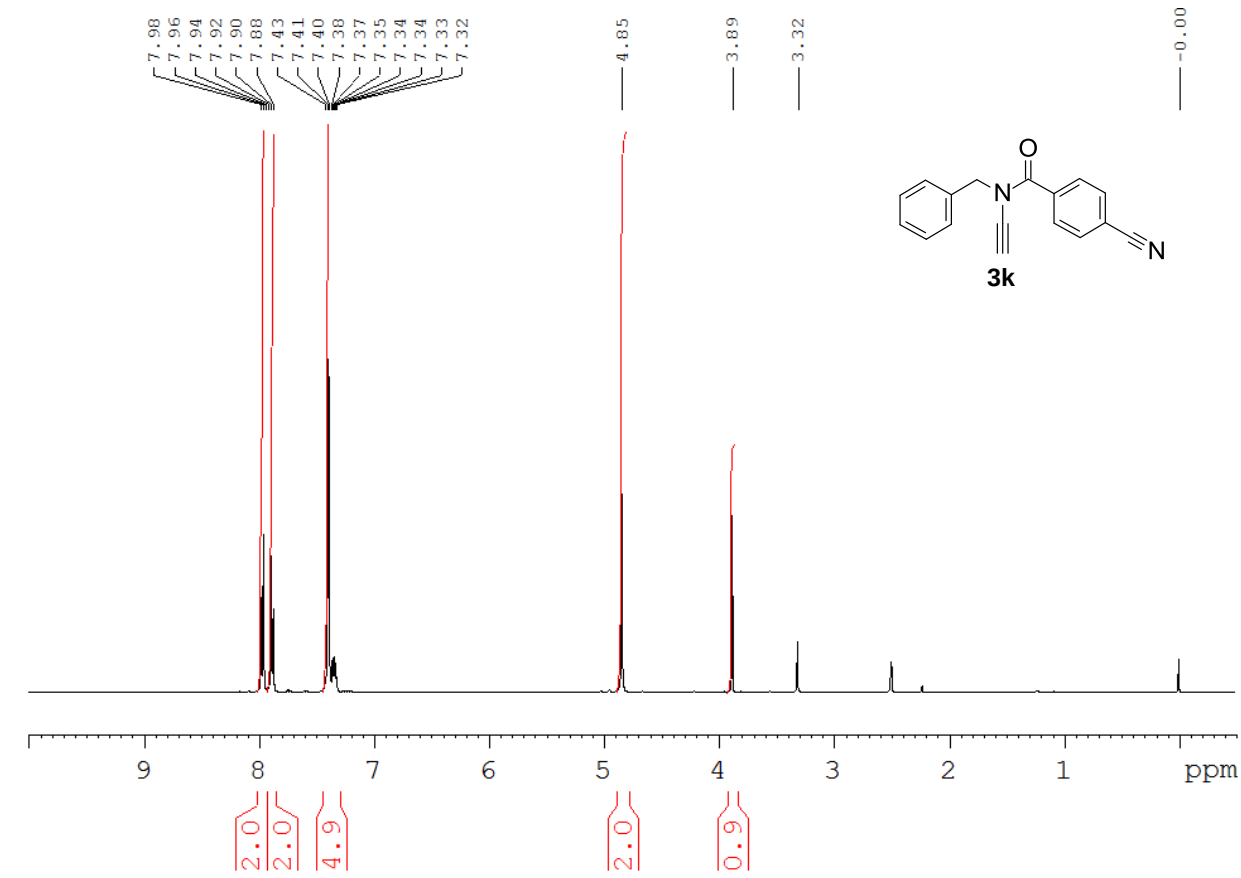

7.72
7.71
7.70
7.70
7.52
7.51
7.51
7.49
7.49
7.48
7.42
7.42
7.41
7.40
7.40
7.40
7.39
7.38
7.37
7.37
7.35
7.35
7.34
7.34
7.33
7.32
7.32
7.31
4.83
3.85
1.30
0.01
-0.00
-0.01
O
N
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
1.0
2.0
0.9
9.2

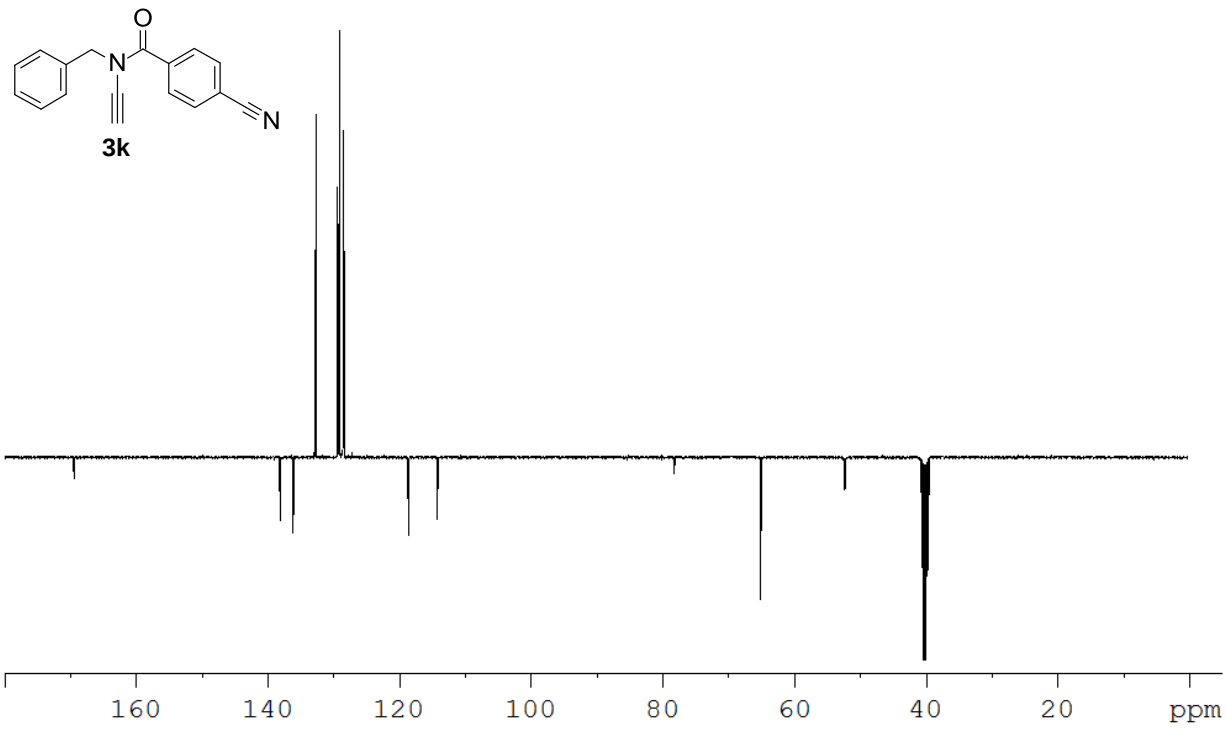
3i

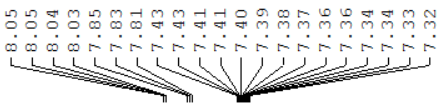

O
N
3i
160
140
120
100
80
60
40
20
ppm

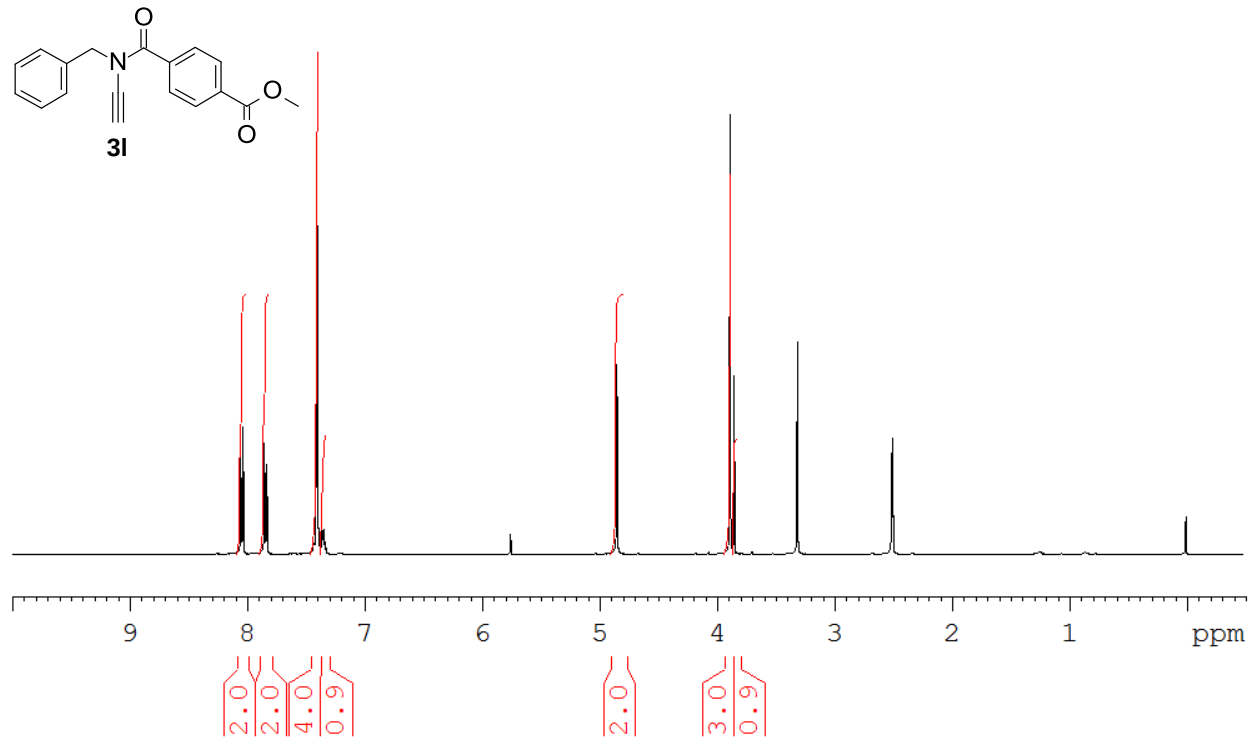

8.34
8.33
8.32
8.31
8.31
8.30
7.99
7.98
7.97
7.96
7.42
7.41
7.39
7.38
7.37
7.36
7.35
7.34
7.34
7.33
4.86
3.90
3.31
0.01
-0.00
-0.01
O
N
NO2
3j
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
0.9
2.0
0.9

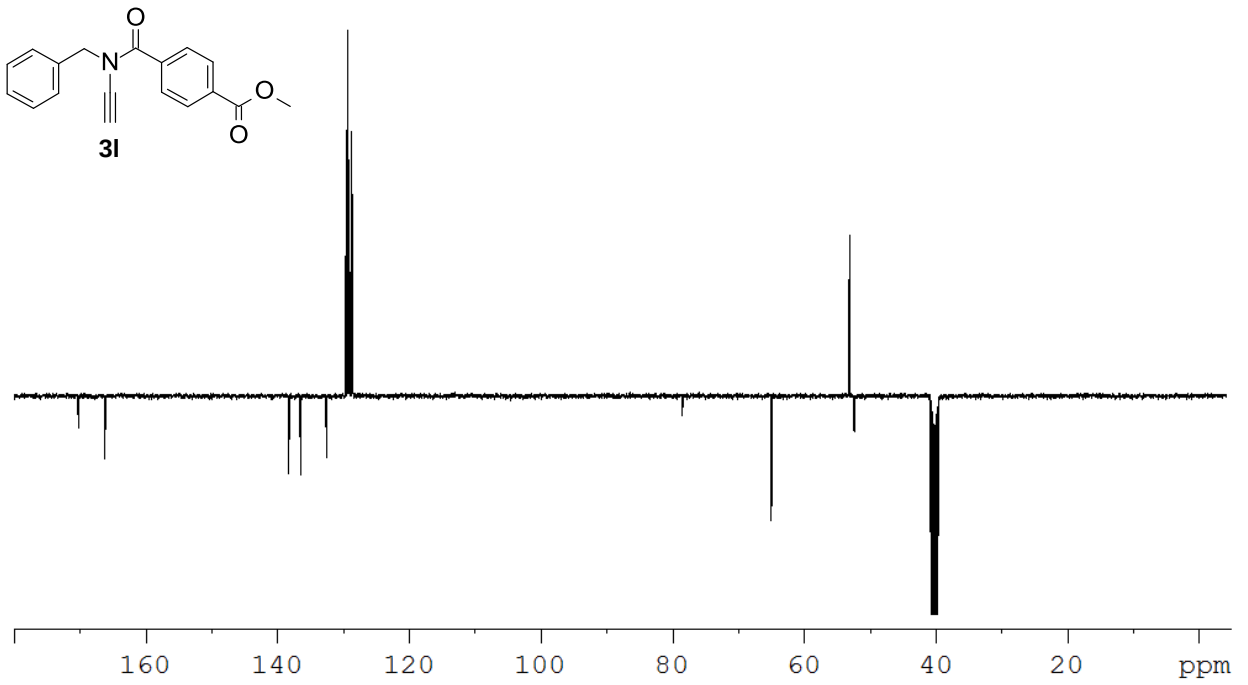

O
N
NO2
3j
160
140
120
100
80
60
40
20
ppm

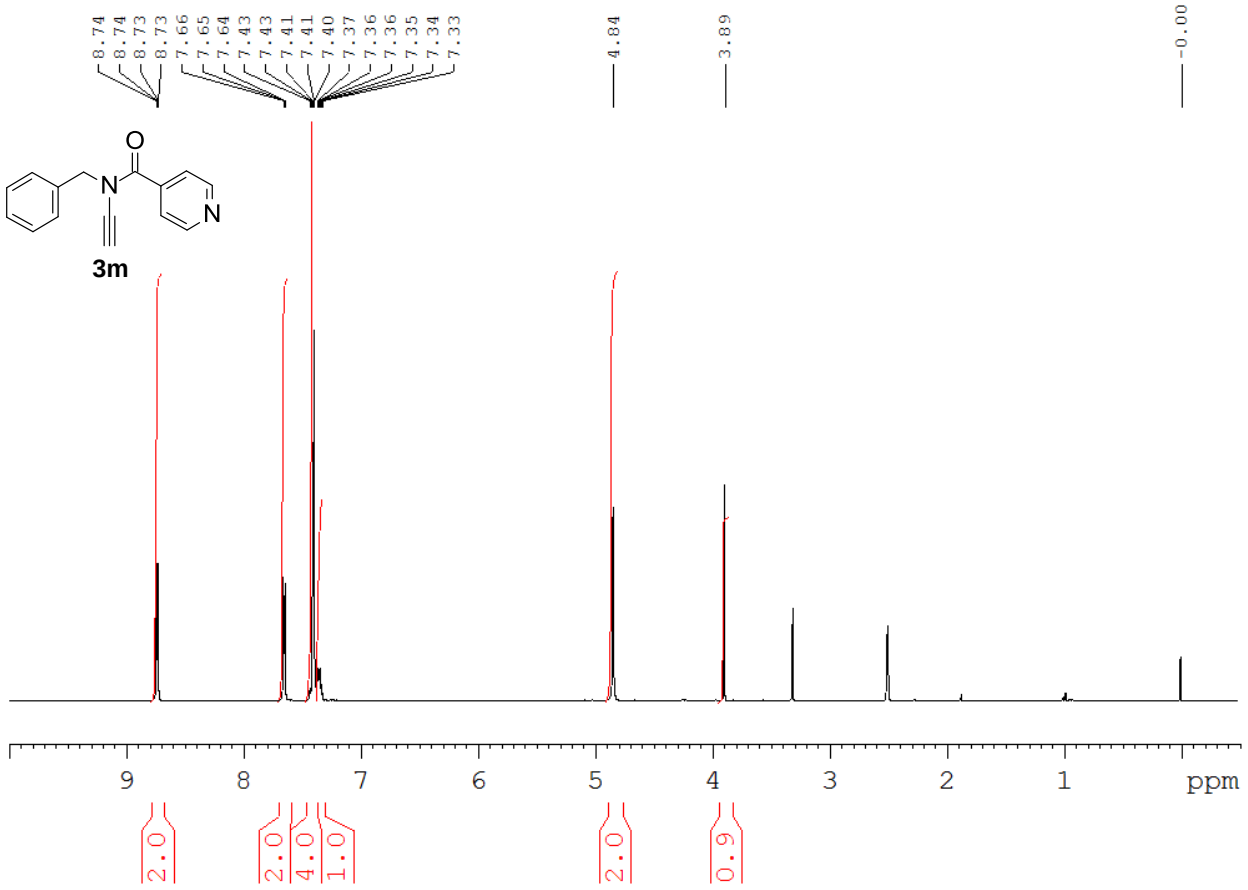

7.98
7.96
7.94
7.92
7.90
7.88
7.43
7.41
7.40
7.38
7.37
7.35
7.34
7.34
7.33
7.32
4.85
3.89
3.32
-0.00
O
N
N
3k
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.9
2.0
0.9

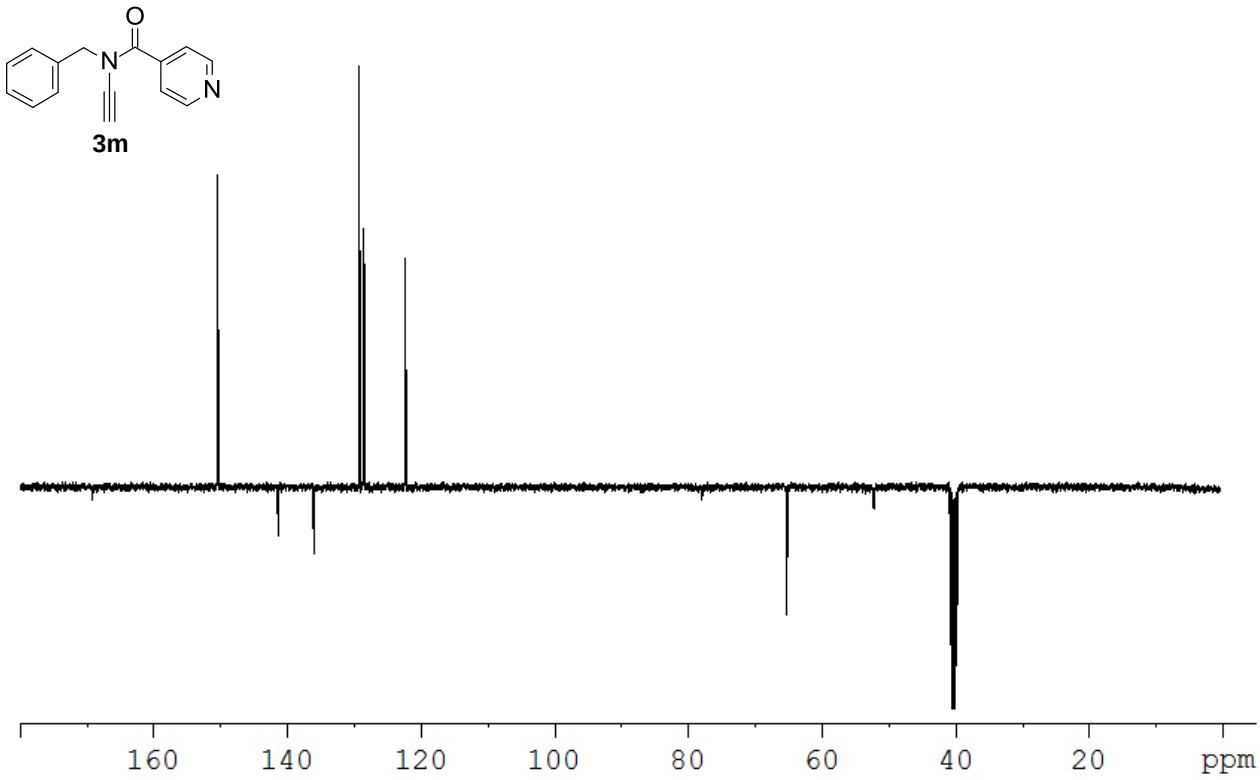

O
N
N
3k
160
140
120
100
80
60
40
20
ppm

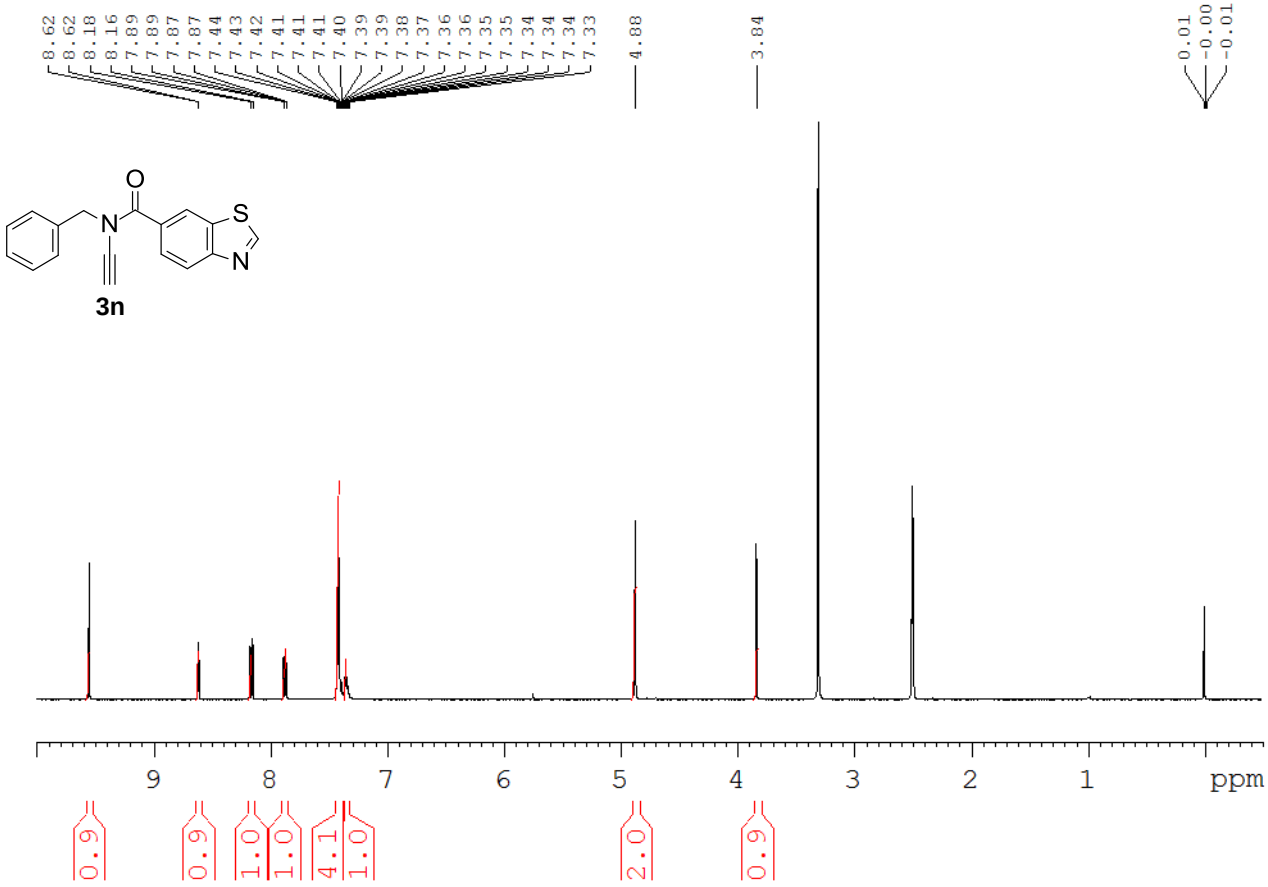

8.05
8.05
8.04
8.03
7.85
7.83
7.81
7.43
7.41
7.41
7.40
7.39
7.38
7.37
7.36
7.36
7.34
7.34
7.33
7.32
4.85
3.88
3.85
3.31
2.51
2.51
2.50
2.50
2.49
0.01
-0.00
-0.01

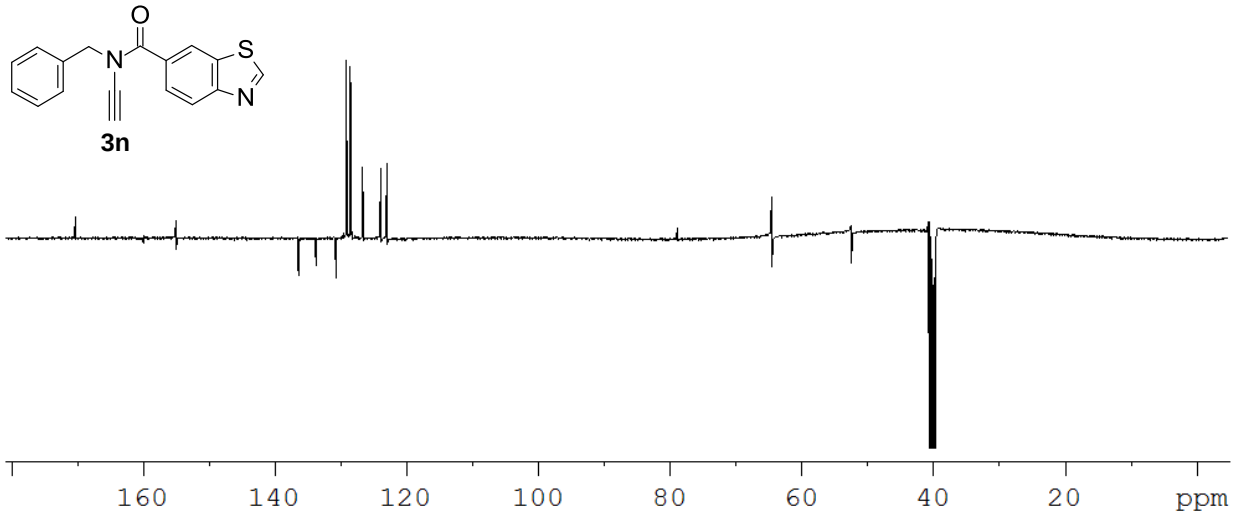

O
N
O
O
3l
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
0.9
2.0
3.0
0.9

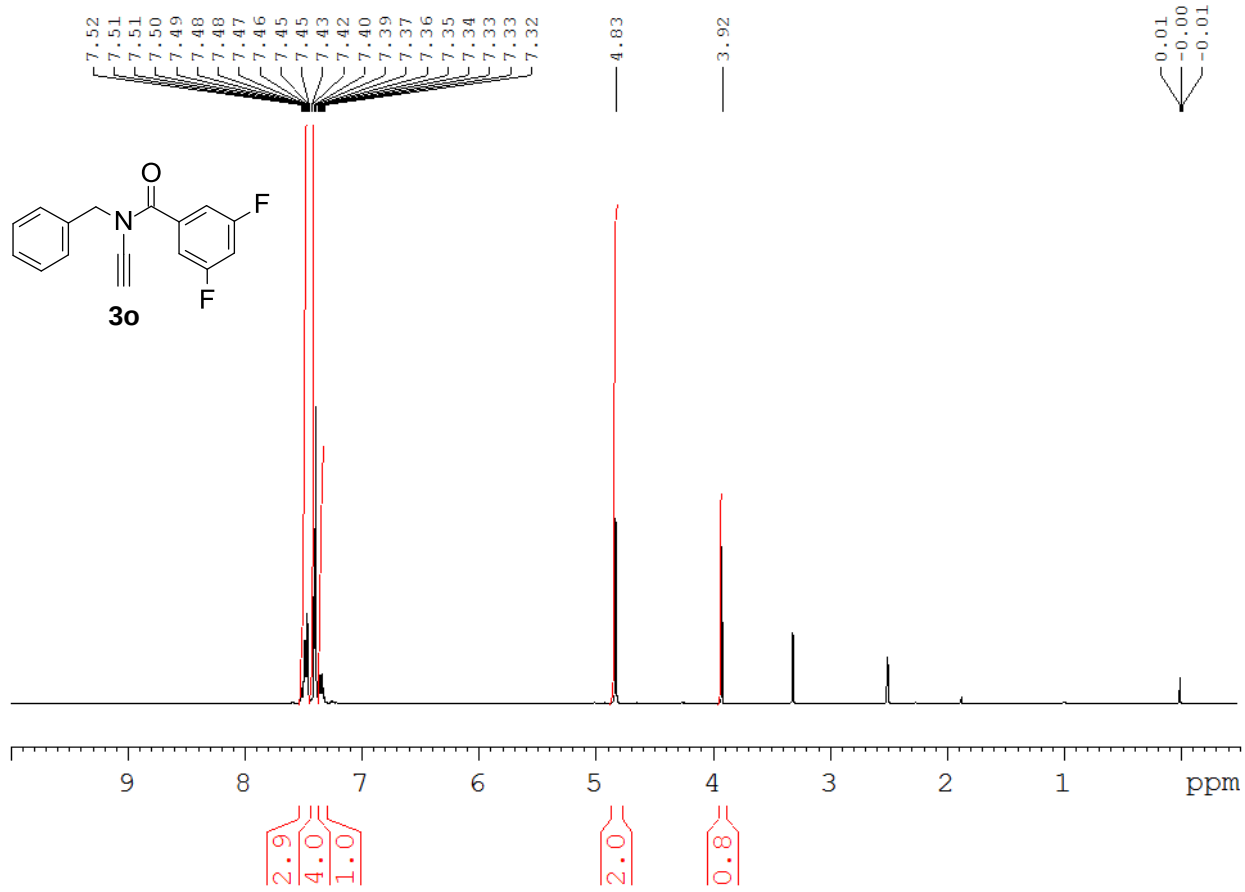

3l
160
140
120
100
80
60
40
20
ppm

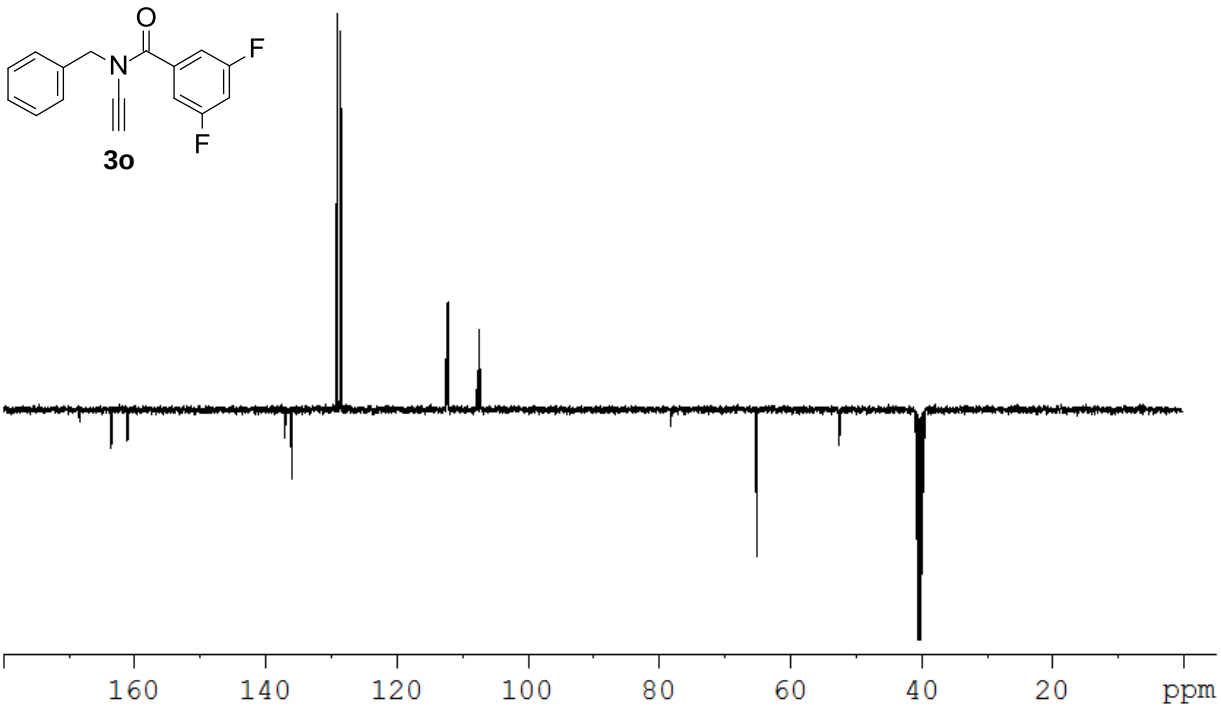

8.74
8.74
8.73
8.73
7.66
7.65
7.64
7.43
7.43
7.41
7.41
7.40
7.37
7.36
7.36
7.35
7.34
7.33
4.84
3.89
-0.00
3m
9
8
7
6
5
4
3
2
1
ppm
2.0
2.0
4.0
1.0
2.0
0.9

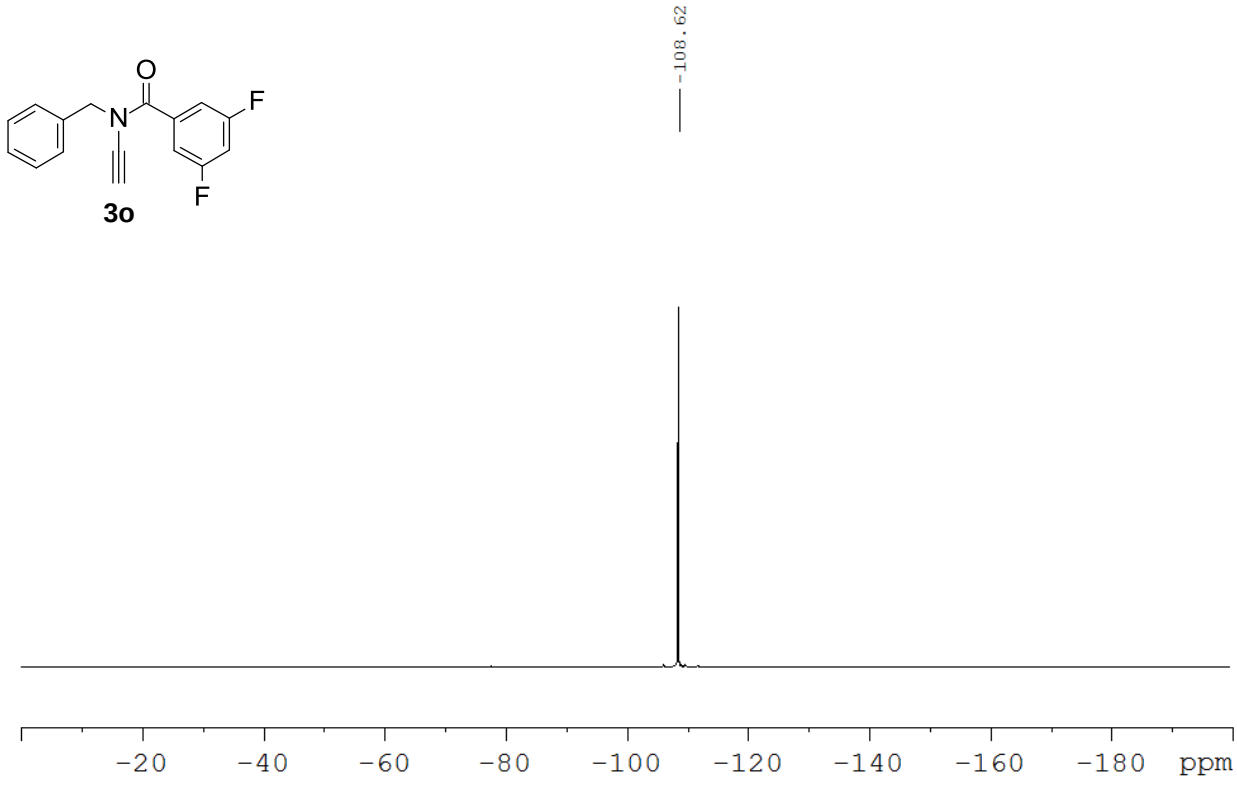

O
N
N
3m
160
140
120
100
80
60
40
20
ppm

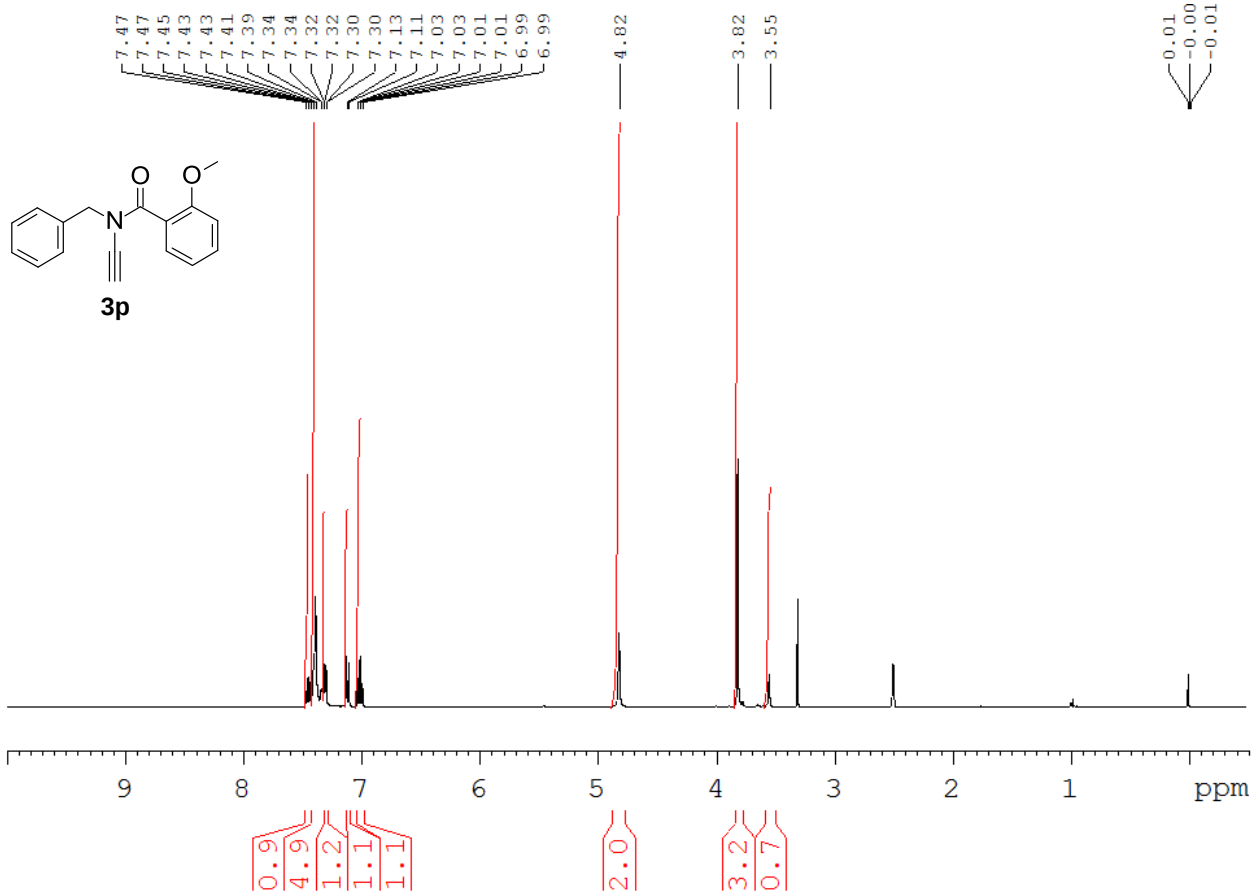

8.62
8.62
8.18
8.16
7.89
7.89
7.87
7.87
7.44
7.43
7.42
7.41
7.41
7.41
7.40
7.39
7.39
7.38
7.37
7.36
7.36
7.35
7.35
7.34
7.34
7.34
7.33
4.88
3.84
0.01
-0.00
-0.01
O
N
S
N
3n
9
8
7
6
5
4
3
2
1
ppm
0.9
0.9
1.0
1.0
4.1
1.0
2.0
0.9

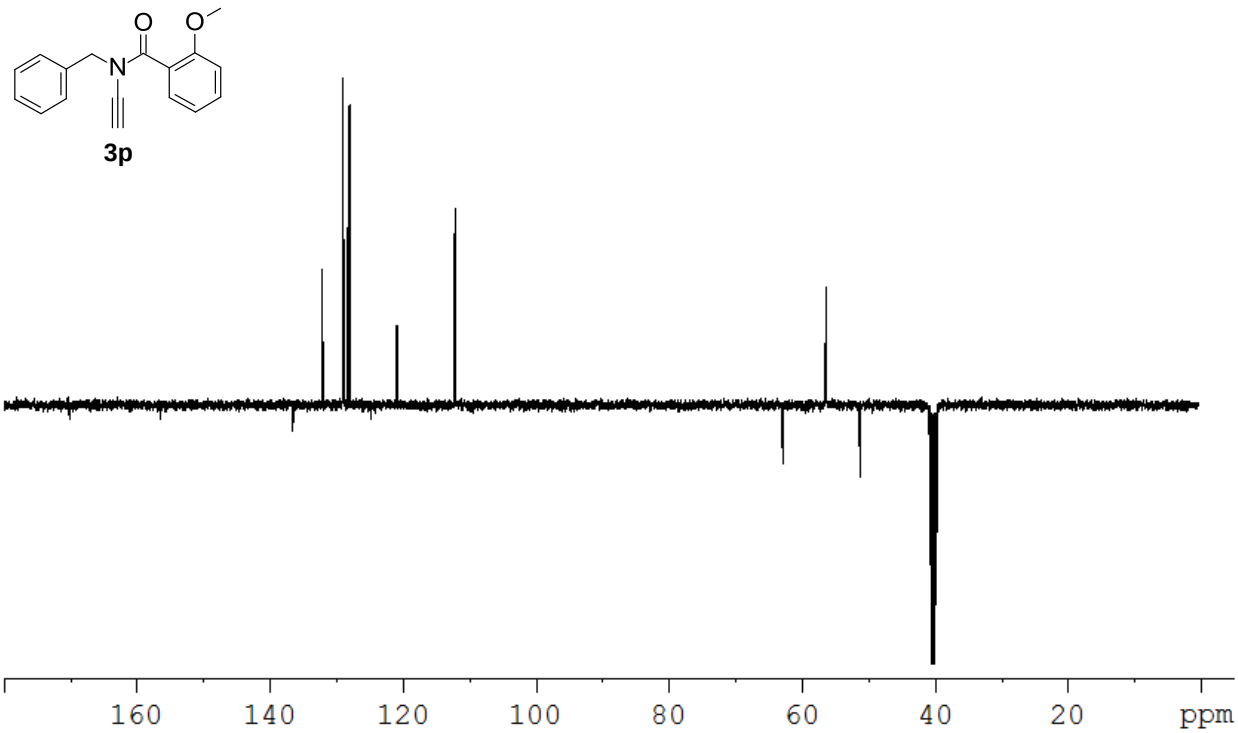

O
N
S
N
3n
160
140
120
100
80
60
40
20
ppm

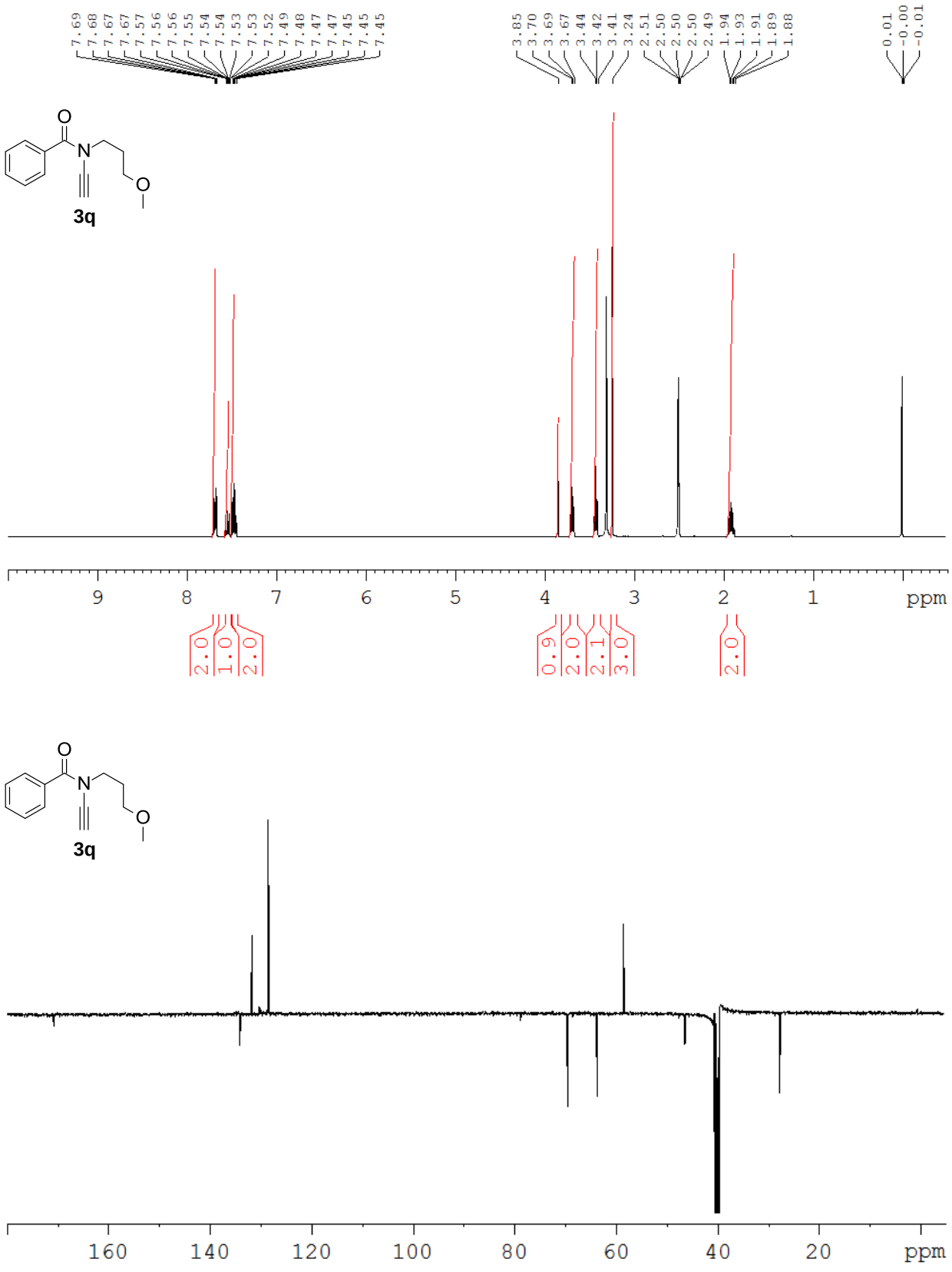

7.52
7.51
7.51
7.50
7.49
7.48
7.48
7.47
7.46
7.45
7.45
7.43
7.42
7.40
7.39
7.37
7.36
7.35
7.34
7.33
7.32
4.83
3.92
0.01
0.00
-0.01
O
N
F
F
3o
9
8
7
6
5
4
3
2
1
ppm
2.9
4.0
1.0
2.0
0.8

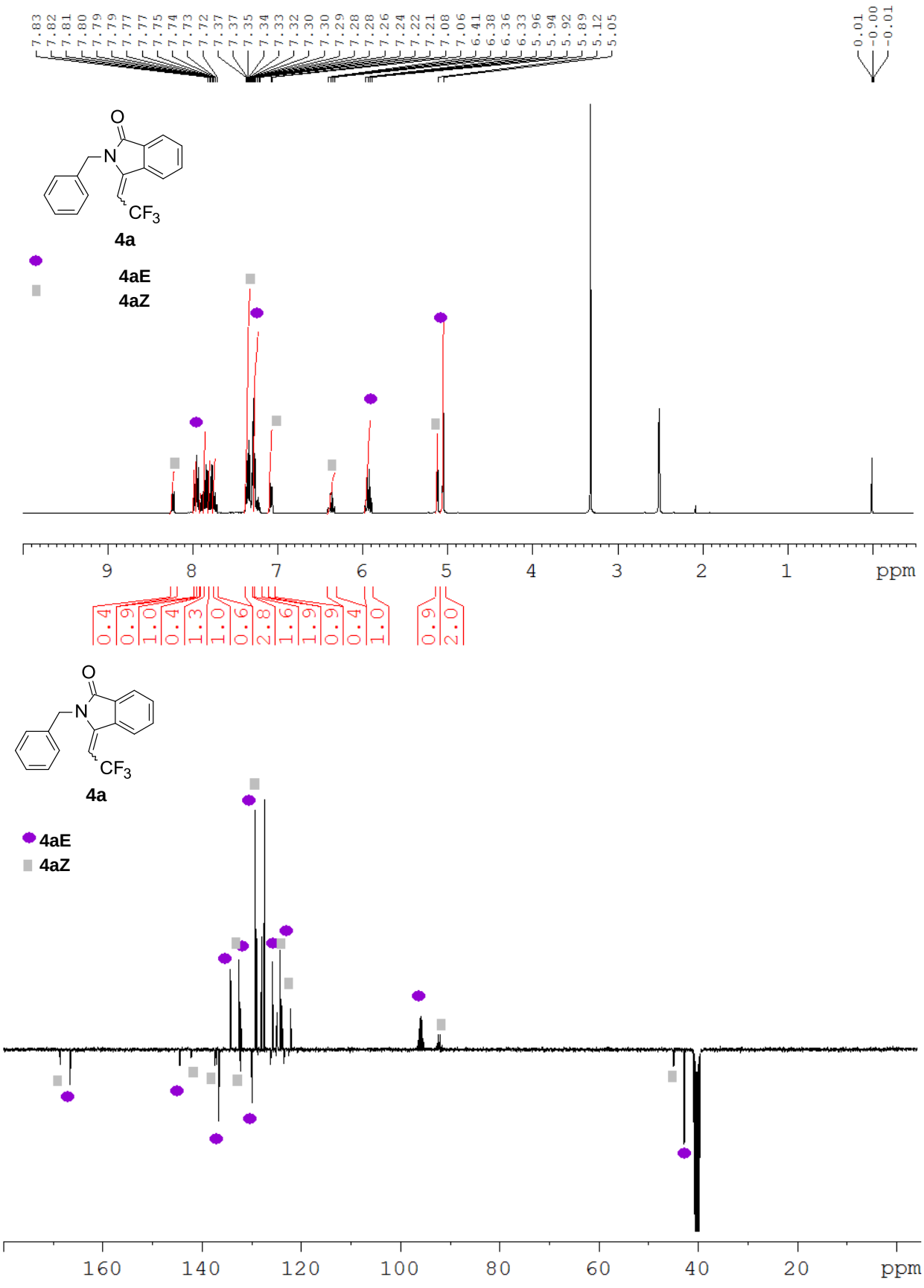

O
N
F
F
3o
160
140
120
100
80
60
40
20
ppm

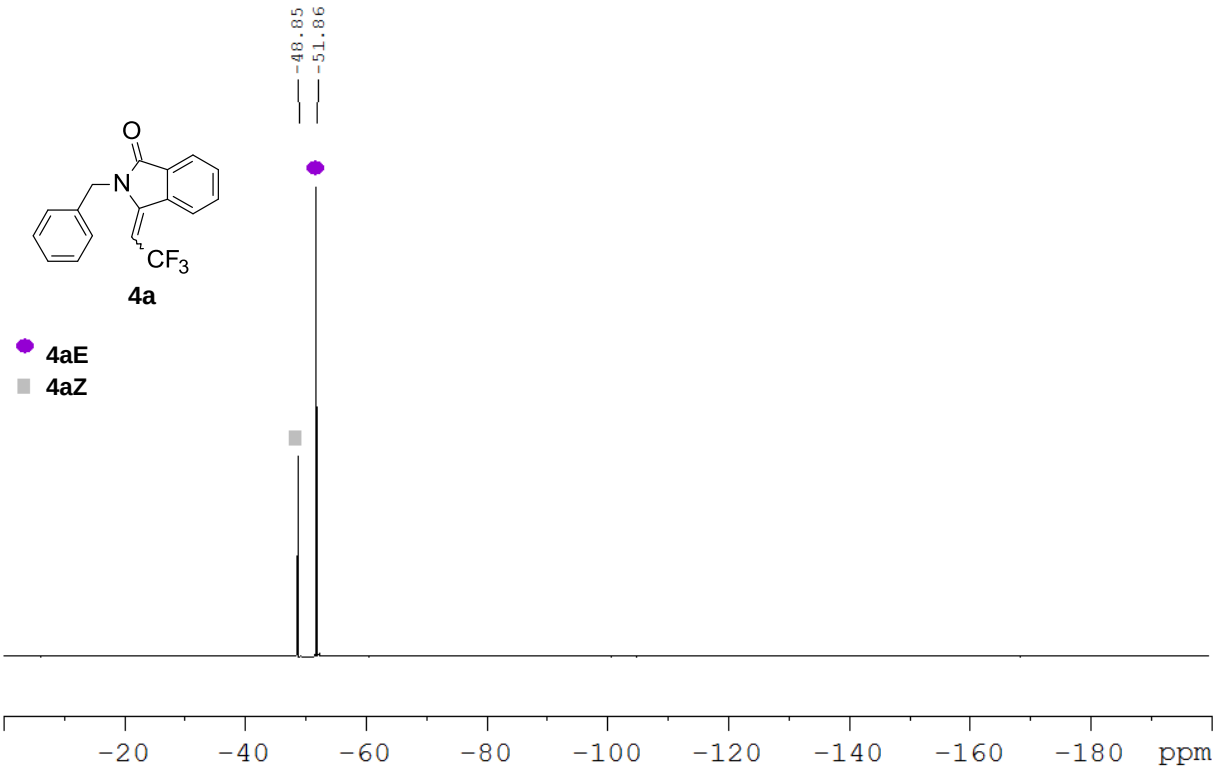

-108.62
O
N
F
F
3o
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

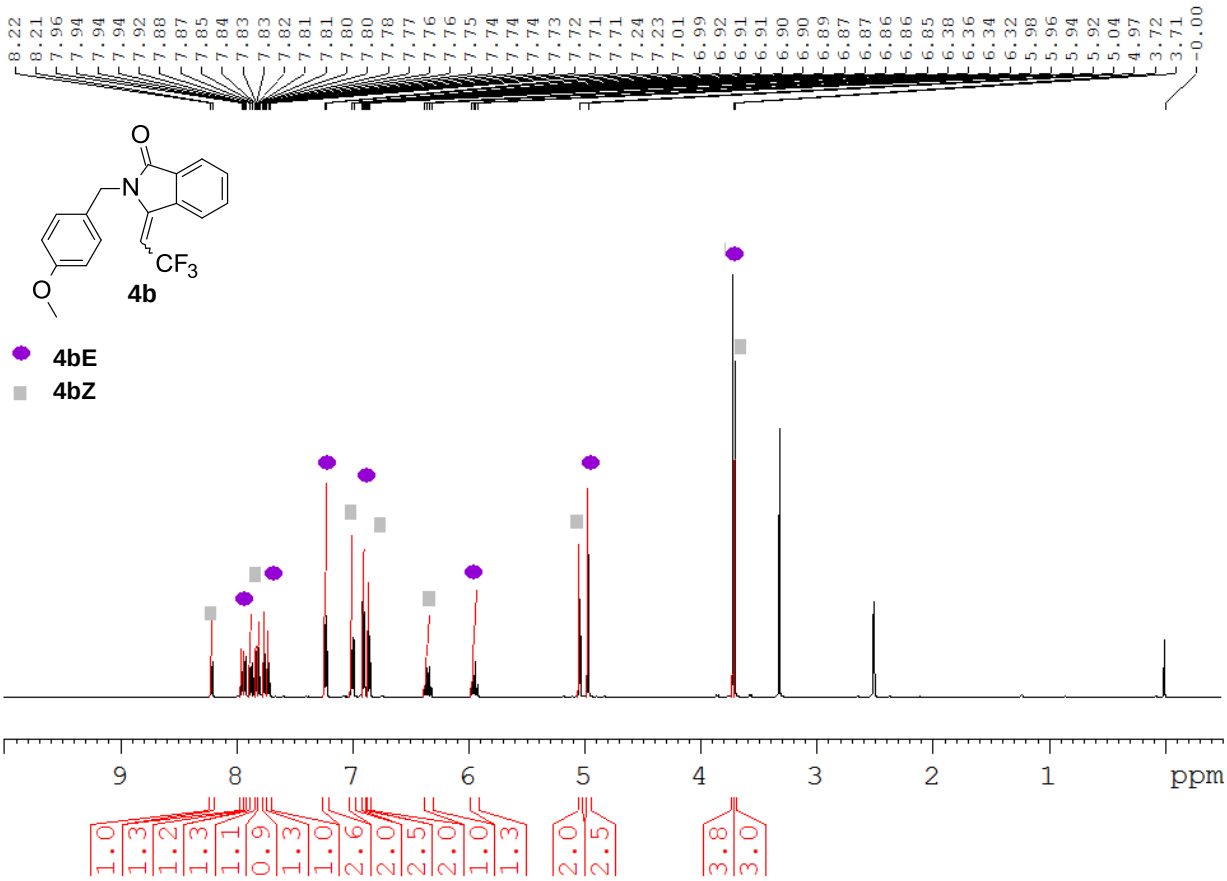

7.47
7.47
7.45
7.43
7.43
7.41
7.39
7.34
7.34
7.32
7.32
7.30
7.30
7.13
7.11
7.03
7.03
7.01
7.01
6.99
6.99
4.82
3.82
3.55
0.01
-0.00
-0.01
O
O
N
3p
9
8
7
6
5
4
3
2
1
ppm
0.9
4.9
1.2
1.1
1.1
2.0
3.2
0.7

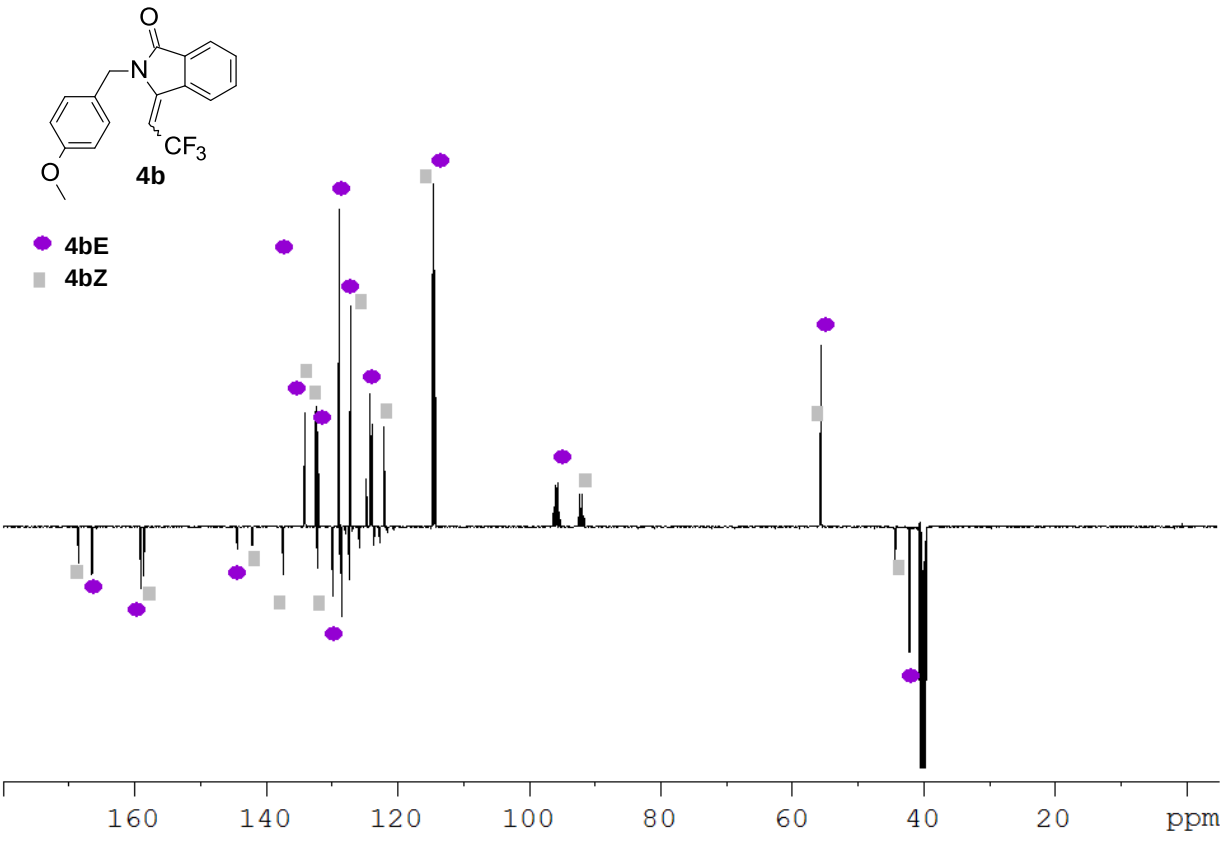

O
O
N
3p
160
140
120
100
80
60
40
20
ppm

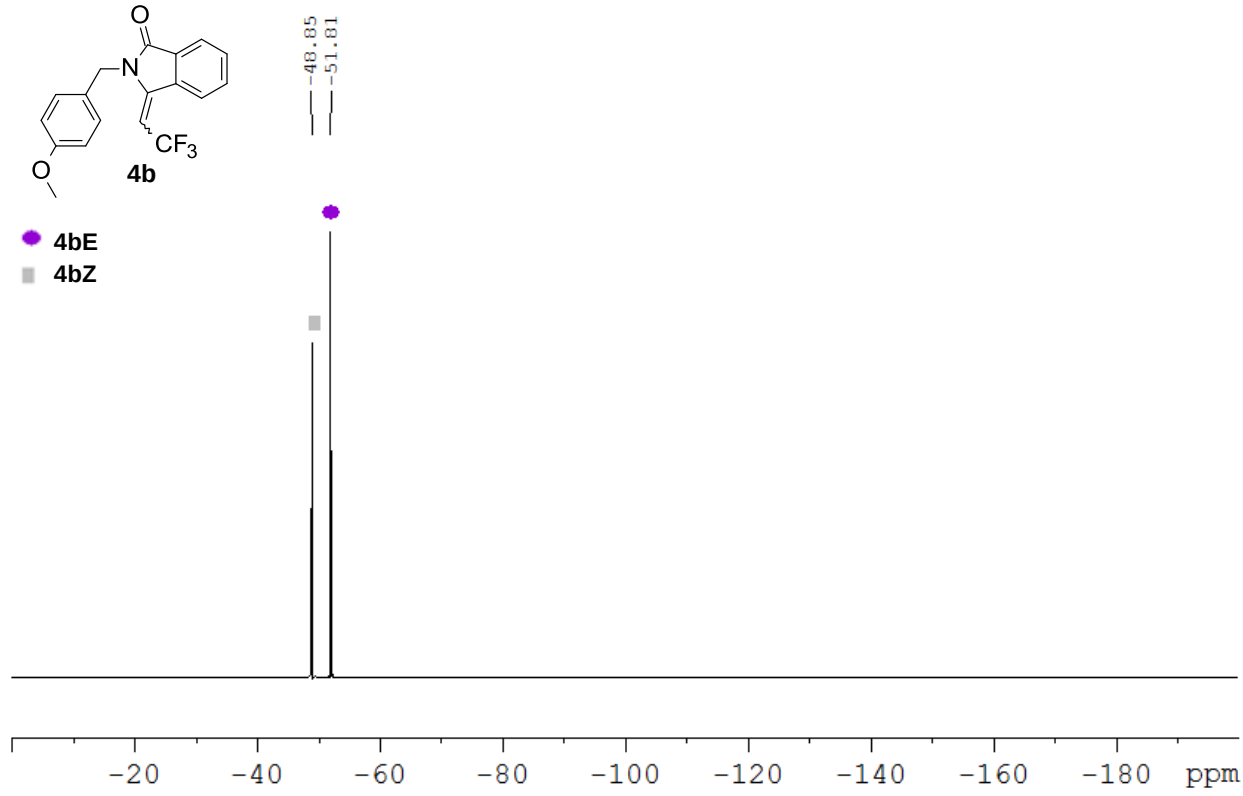

7.69
7.68
7.67
7.67
7.57
7.56
7.56
7.55
7.54
7.54
7.53
7.53
7.52
7.49
7.48
7.47
7.47
7.45
7.45
7.45
3.85
3.70
3.69
3.67
3.44
3.42
3.41
3.24
2.51
2.50
2.50
2.50
2.49
1.94
1.93
1.91
1.89
1.88
0.01
-0.00
-0.01
O
N
O
3q
9
8
7
6
5
4
3
2
1
ppm
2.0
1.0
2.0
0.9
2.0
2.1
3.0
2.0
O
N
O
3q
160
140
120
100
80
60
40
20
ppm

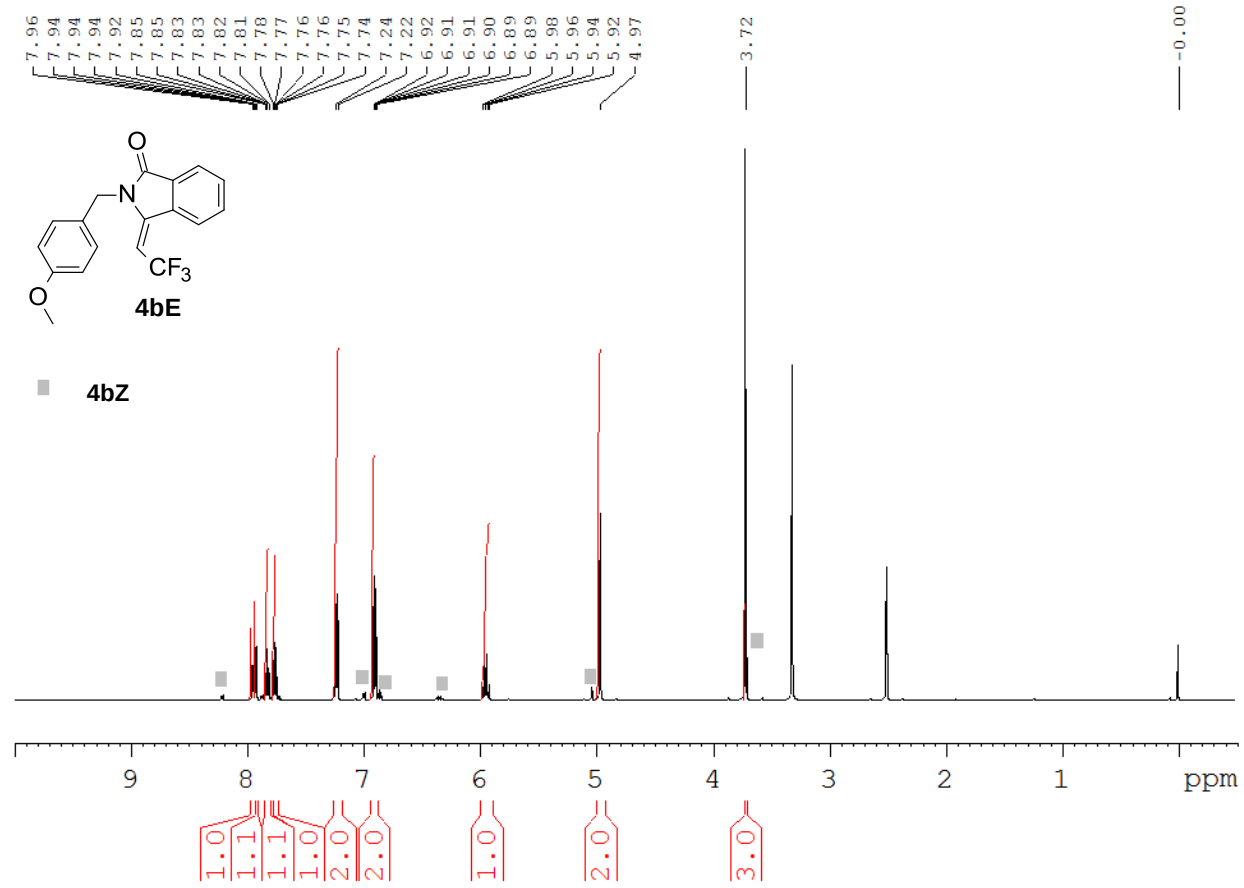

7.83 7.82 7.81 7.80 7.79 7.79 7.77 7.77 7.75 7.74 7.73 7.72 7.37 7.35 7.34 7.33 7.32 7.30 7.29 7.28 7.28 7.26 7.24 7.22 7.21 7.08 7.06 6.41 6.38 6.36 6.33 5.96 5.94 5.92 5.89 5.12 5.05
0.01 -0.00 -0.01
O
N
CF3
4a
4aE
4aZ
9 8 7 6 5 4 3 2 1 ppm
0.4 0.9 1.0 0.4 1.3 1.0 0.6 2.8 1.6 1.9 0.9 0.4 1.0 0.9 2.0
O
N
CF3
4a
4aE
4aZ
160 140 120 100 80 60 40 20 ppm

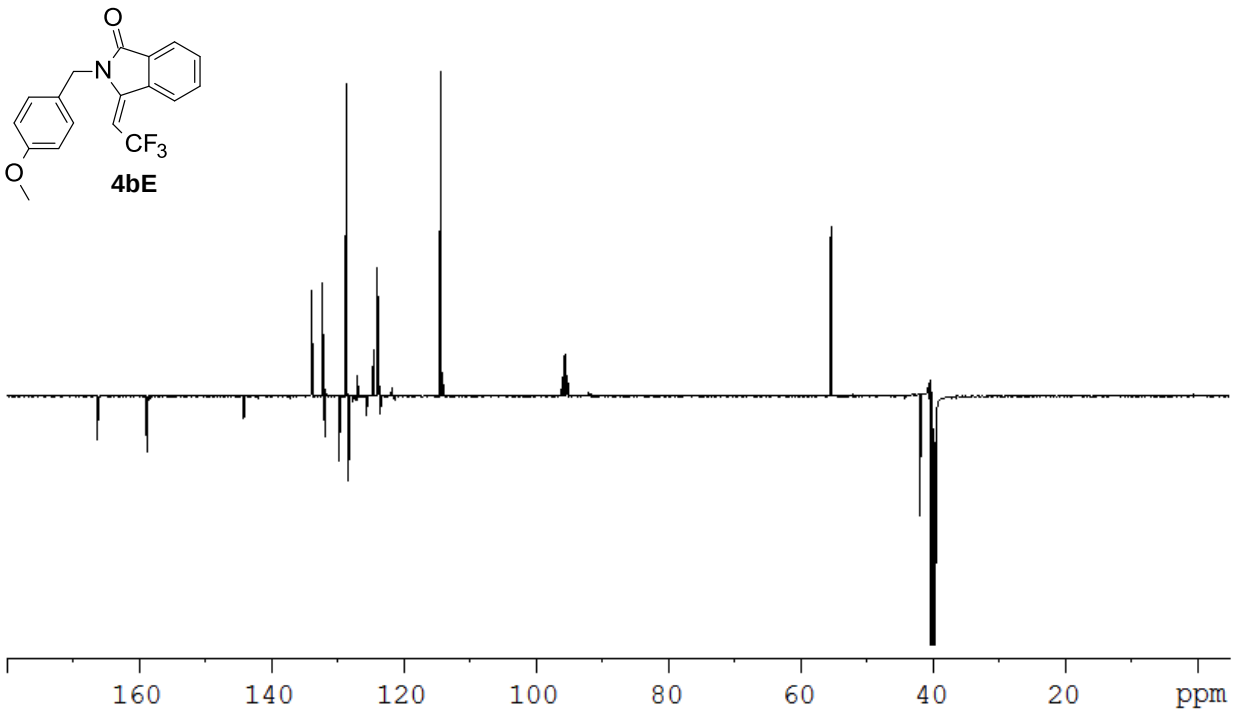

-48.85
-51.86
O
N
CF3
4a
4aE
4aZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

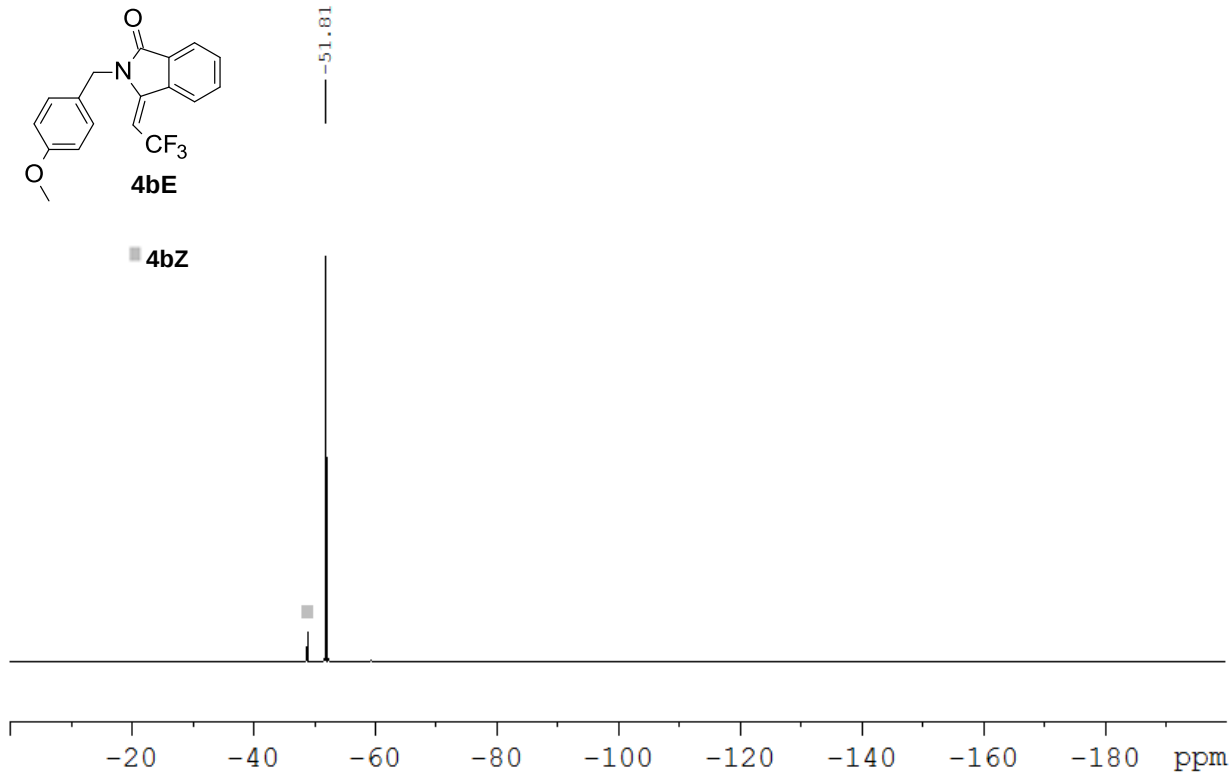

8.22
8.21
7.96
7.94
7.94
7.94
7.92
7.88
7.87
7.85
7.84
7.83
7.83
7.82
7.81
7.81
7.80
7.80
7.78
7.77
7.76
7.76
7.75
7.74
7.74
7.74
7.73
7.72
7.71
7.71
7.24
7.23
7.01
6.99
6.92
6.91
6.91
6.90
6.90
6.89
6.87
6.87
6.86
6.86
6.85
6.38
6.36
6.34
6.32
5.98
5.96
5.94
5.92
5.04
4.97
3.72
3.71
-0.00
O
N
CF3
O
4b
4bE
4bZ
9
8
7
6
5
4
3
2
1
ppm
1.0
1.3
1.2
1.3
1.1
0.9
1.3
1.0
2.6
2.0
2.5
2.0
1.0
1.3
2.0
2.5
3.8
3.0

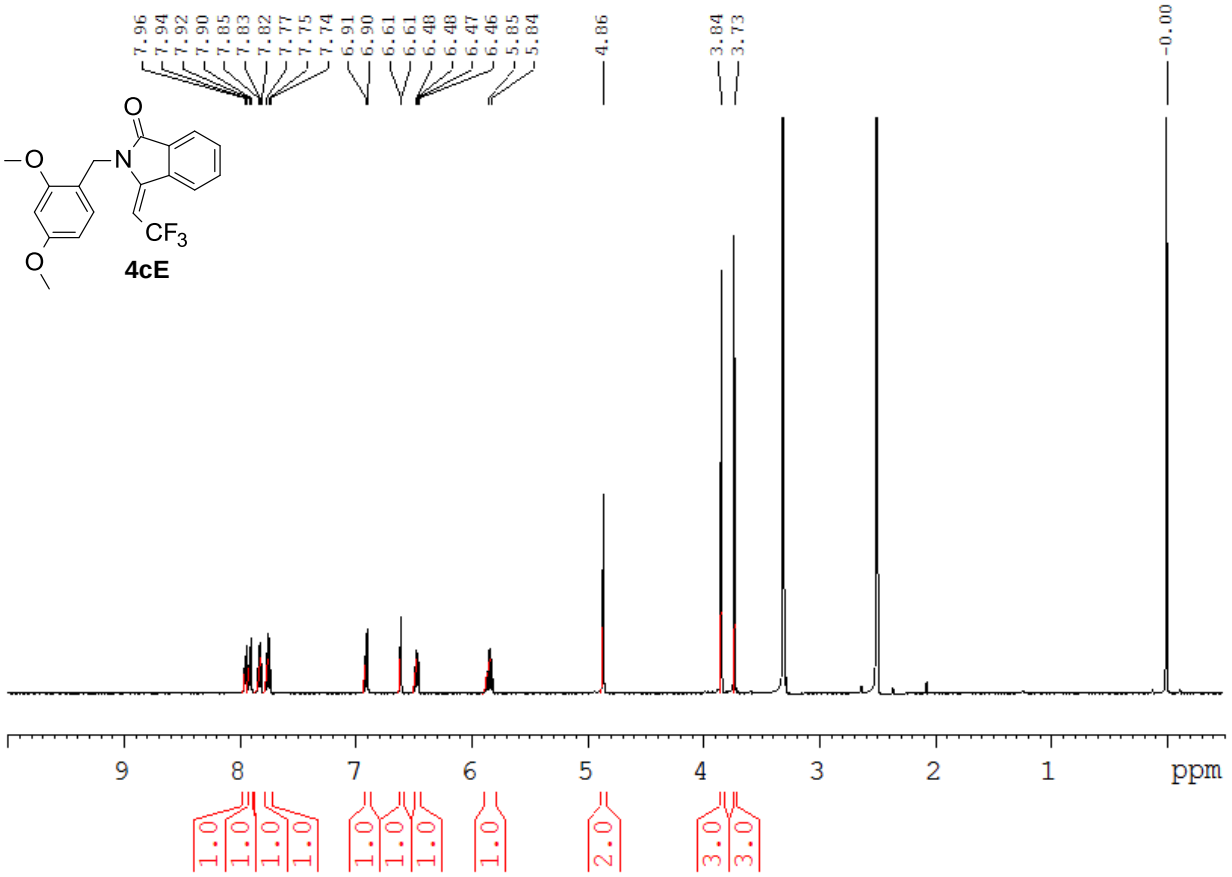

O
N
CF3
O
4b
4bE
4bZ
160
140
120
100
80
60
40
20
ppm

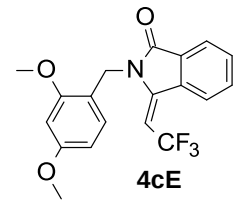

O
N
CF3
O
4b
-48.85
-51.81
4bE
4bZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.96
7.94
7.94
7.94
7.92
7.85
7.85
7.83
7.83
7.82
7.81
7.78
7.77
7.76
7.76
7.75
7.74
7.24
7.22
6.92
6.91
6.91
6.90
6.89
6.89
5.98
5.96
5.94
5.92
4.97
3.72
-0.00
O
N
CF3
O
4bE
4bZ
9
8
7
6
5
4
3
2
1
ppm
1.0
1.1
1.1
1.0
2.0
2.0
1.0
2.0
3.0


O
N
CF3
O
4bE
160
140
120
100
80
60
40
20
ppm

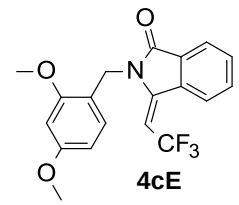

-51.81
4bE
4bZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.96
7.94
7.92
7.90
7.85
7.83
7.82
7.77
7.75
7.74
6.91
6.90
6.61
6.61
6.48
6.48
6.47
6.46
5.85
5.84
4.86
3.84
3.73
-0.00
4cE
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
1.0
1.0
1.0
1.0
1.0
2.0
3.0
3.0

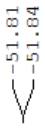

O
N
CF3
O

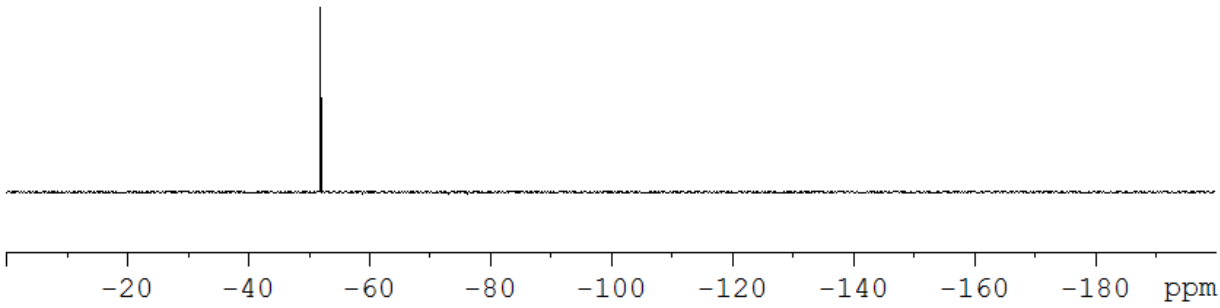
4cE

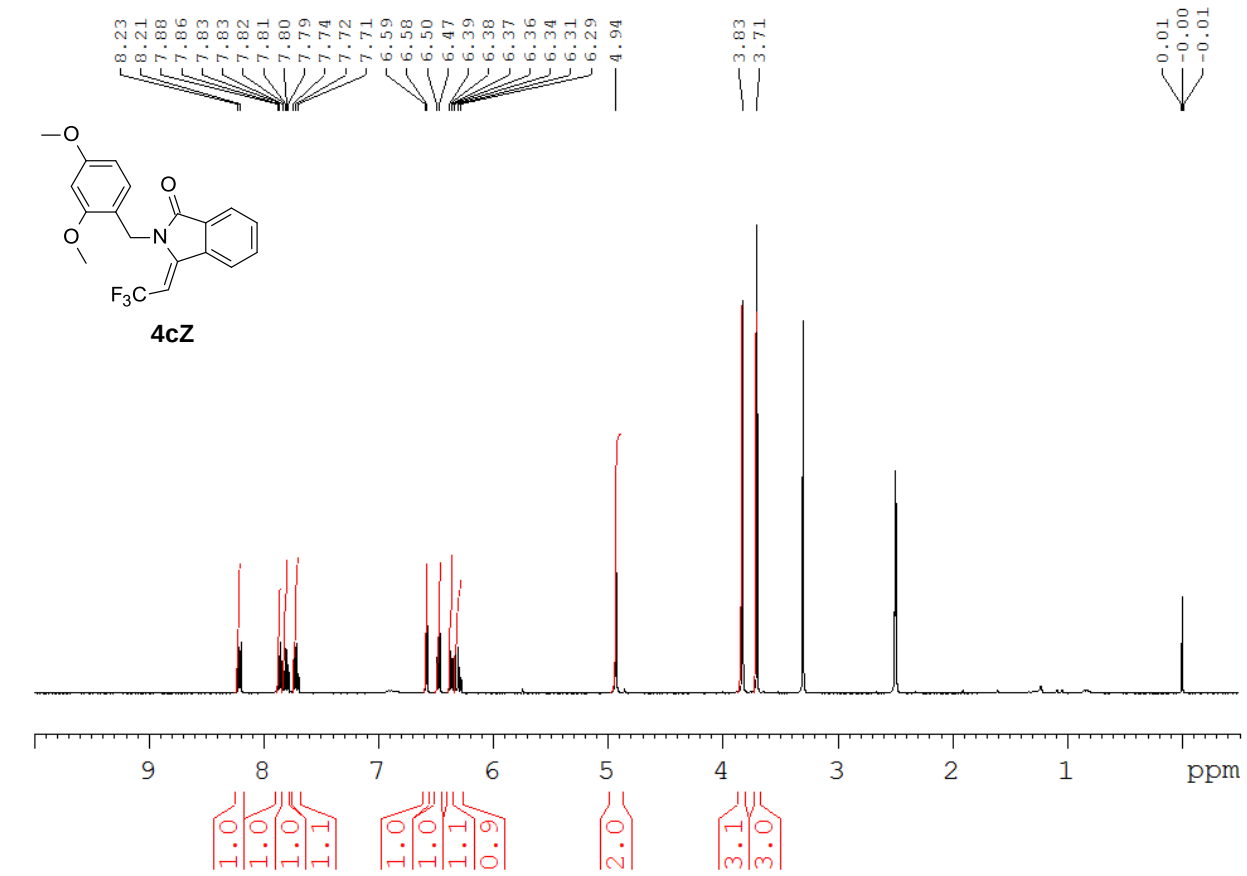
160
140
120
100
80
60
40
20
ppm

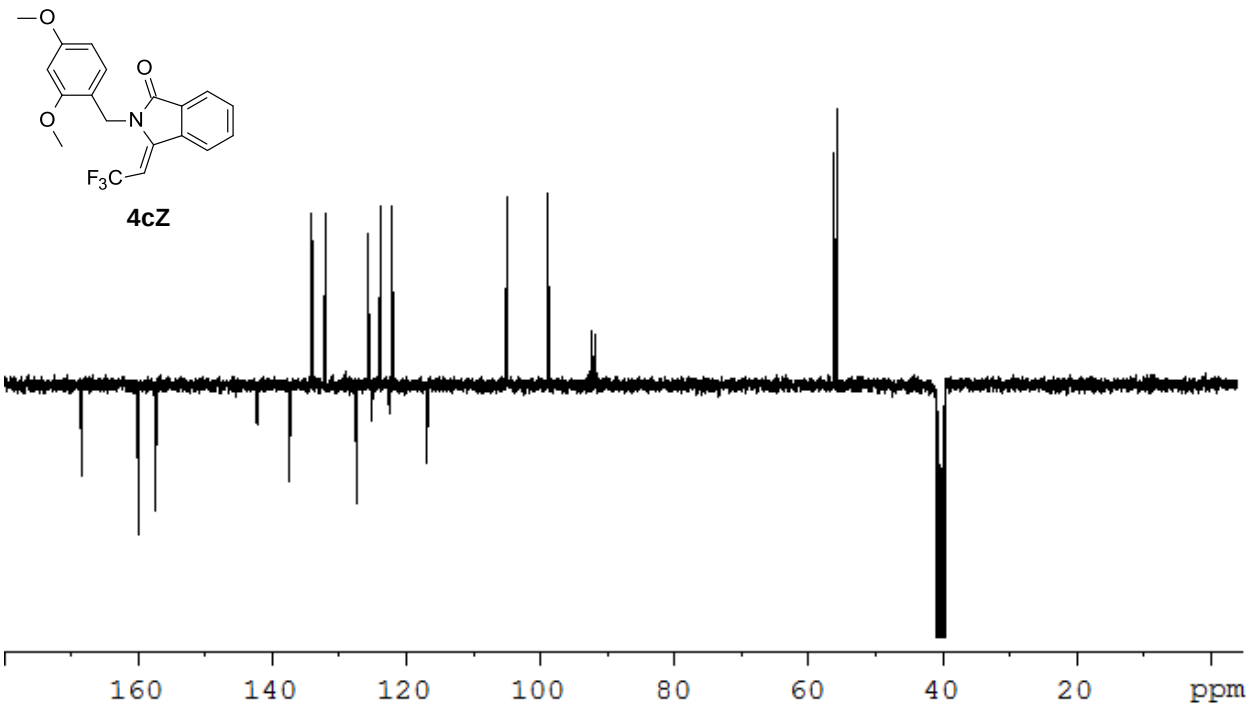

O
N
CF3
O

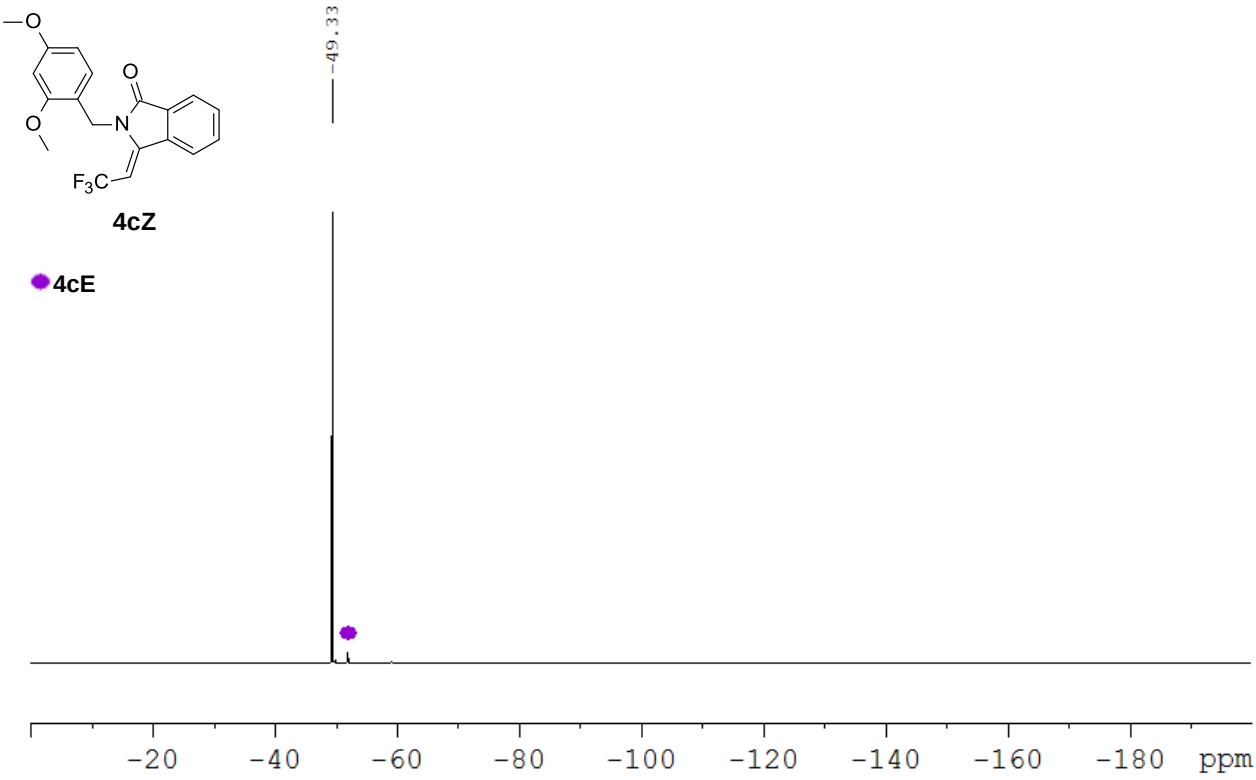
4cE

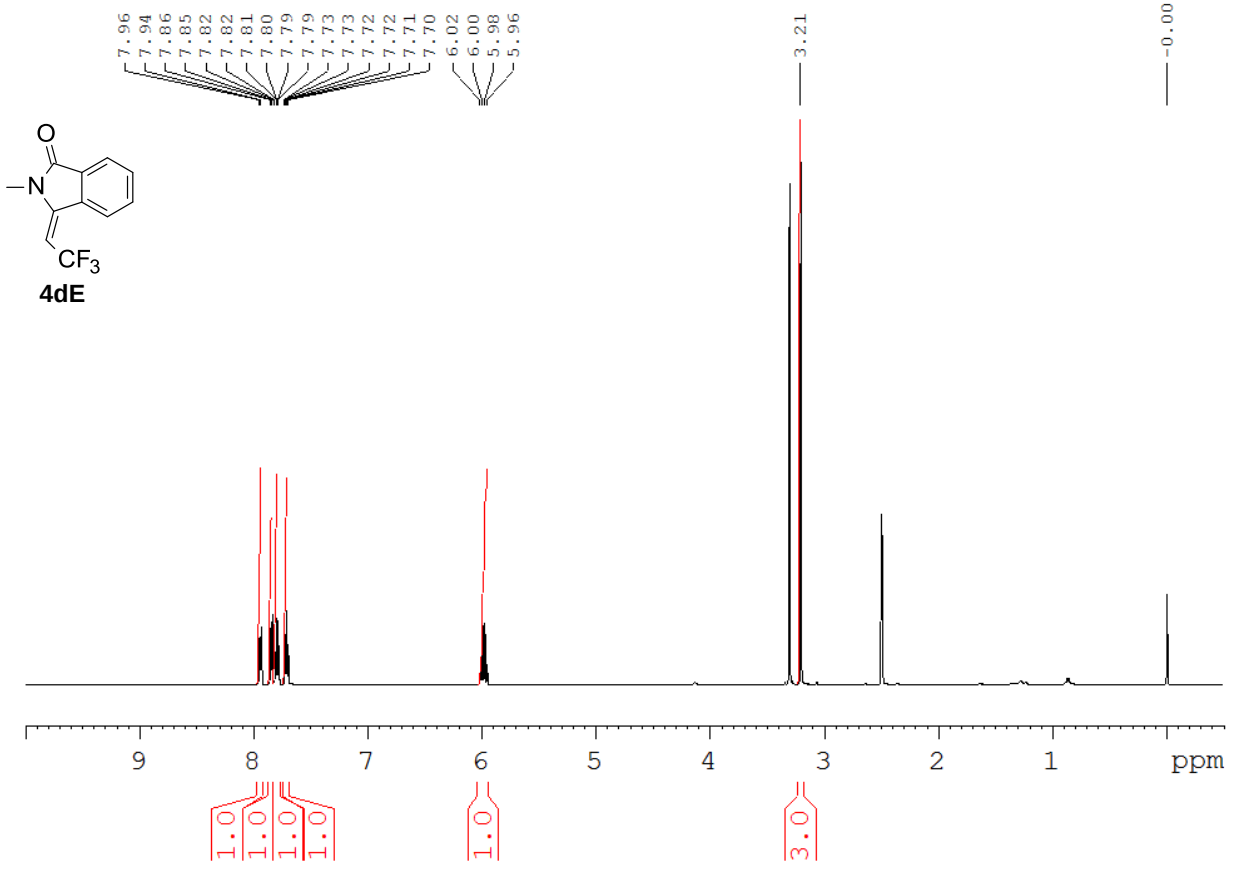

-51.81
-51.84

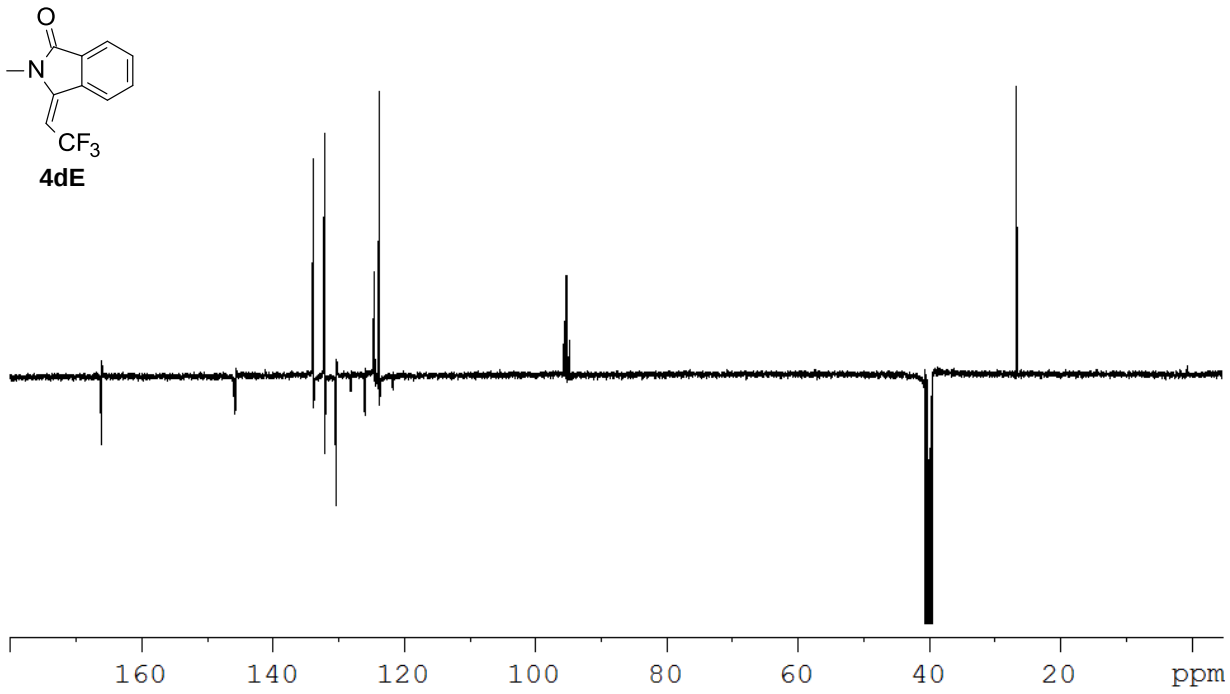

-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

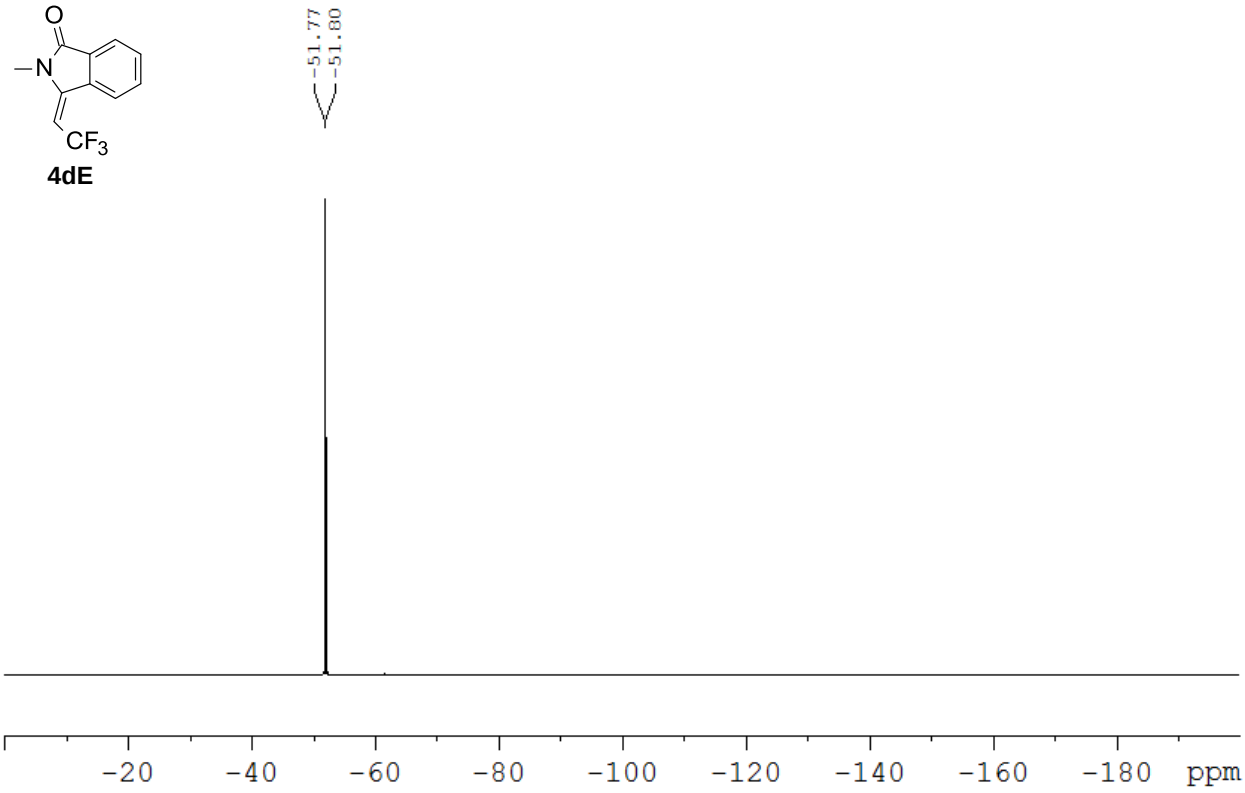

8.23
8.21
7.88
7.86
7.83
7.83
7.82
7.81
7.80
7.79
7.74
7.72
7.71
6.59
6.58
6.50
6.47
6.39
6.38
6.37
6.36
6.34
6.31
6.29
4.94
3.83
3.71
0.01
-0.00
-0.01
4cZ
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
1.1
1.0
1.0
1.1
0.9
2.0
3.1
3.0

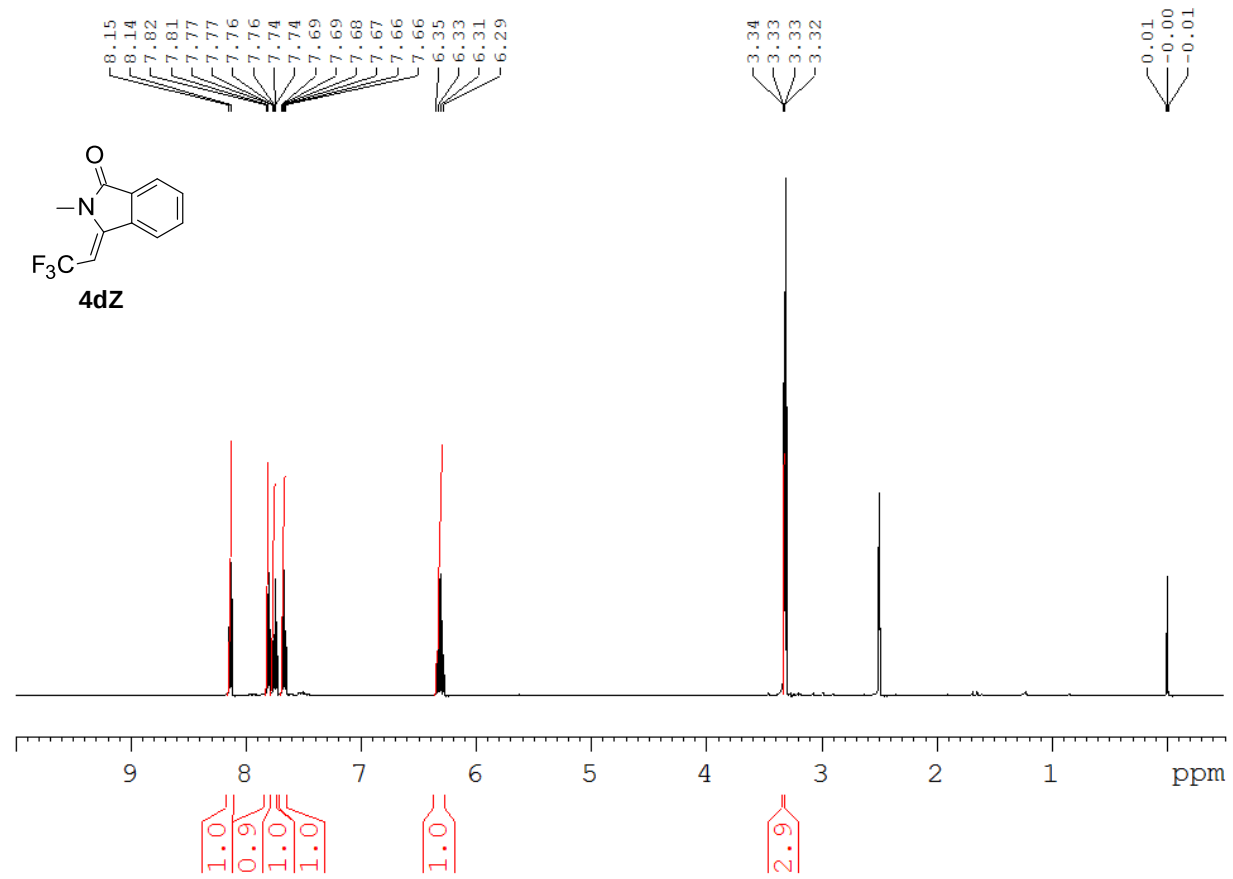

4cZ
160
140
120
100
80
60
40
20
ppm

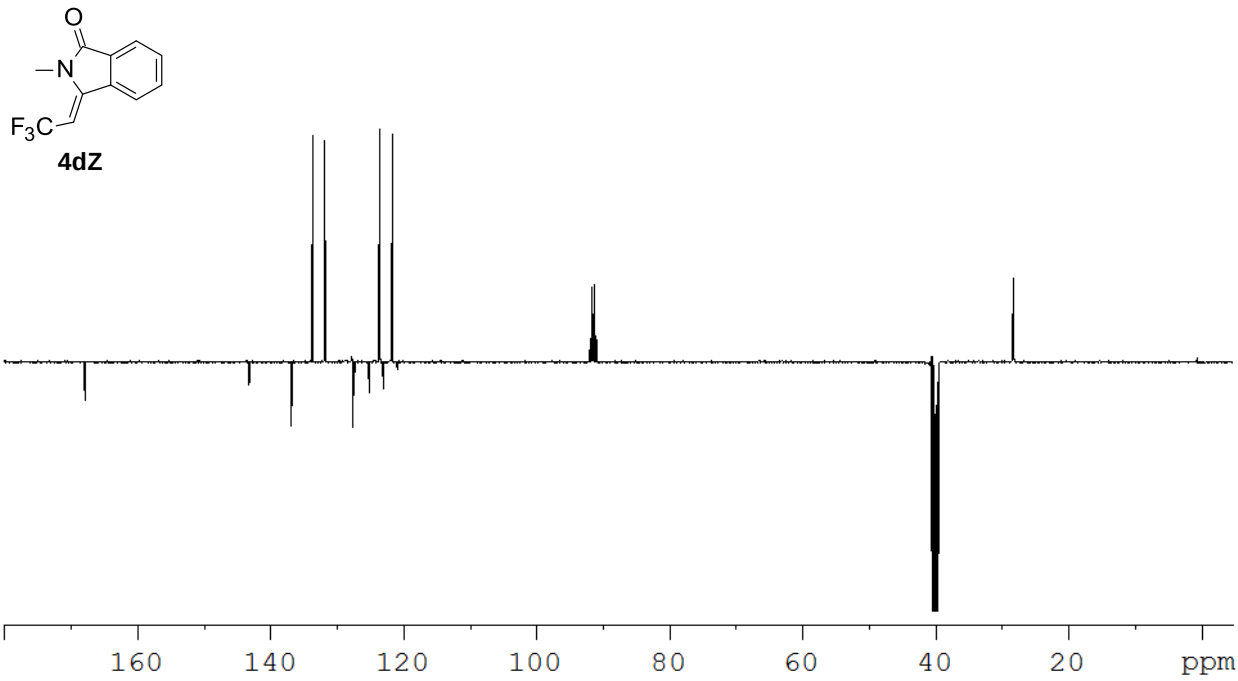

4cZ
4cE
-49.33
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

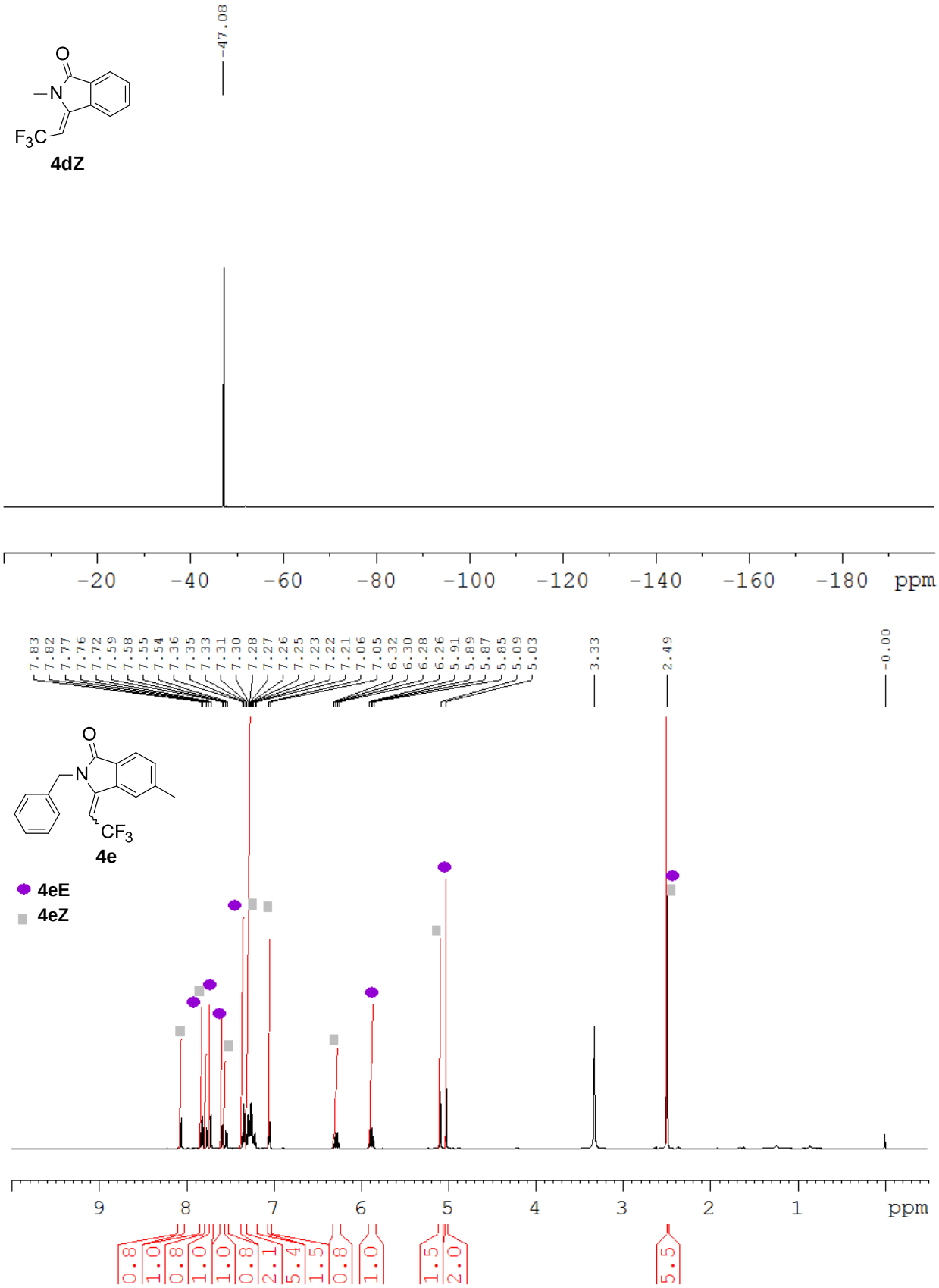

4dE
7.96
7.94
7.86
7.85
7.82
7.82
7.81
7.80
7.79
7.79
7.73
7.73
7.72
7.72
7.71
7.70
6.02
6.00
5.98
5.96
3.21
-0.00
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
1.0
1.0
3.0

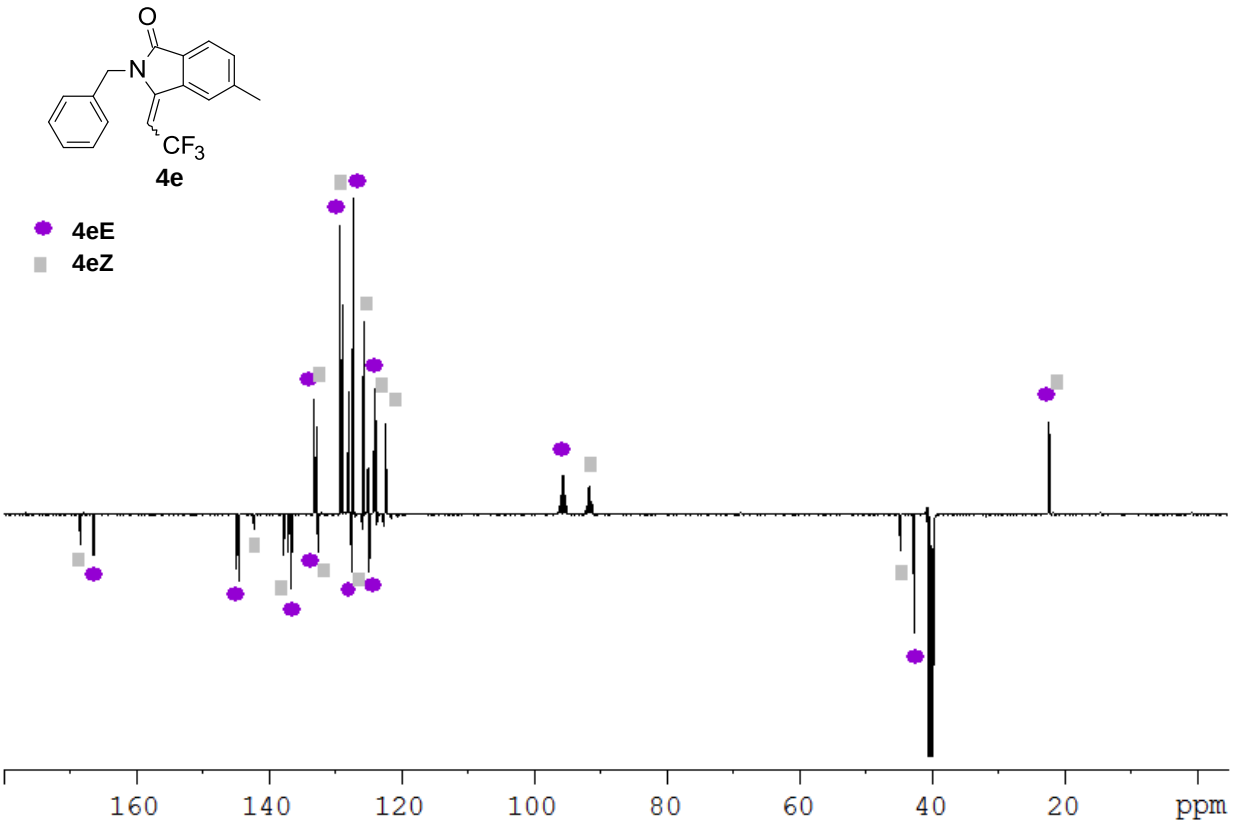

O
N
CF3
4dE
160
140
120
100
80
60
40
20
ppm

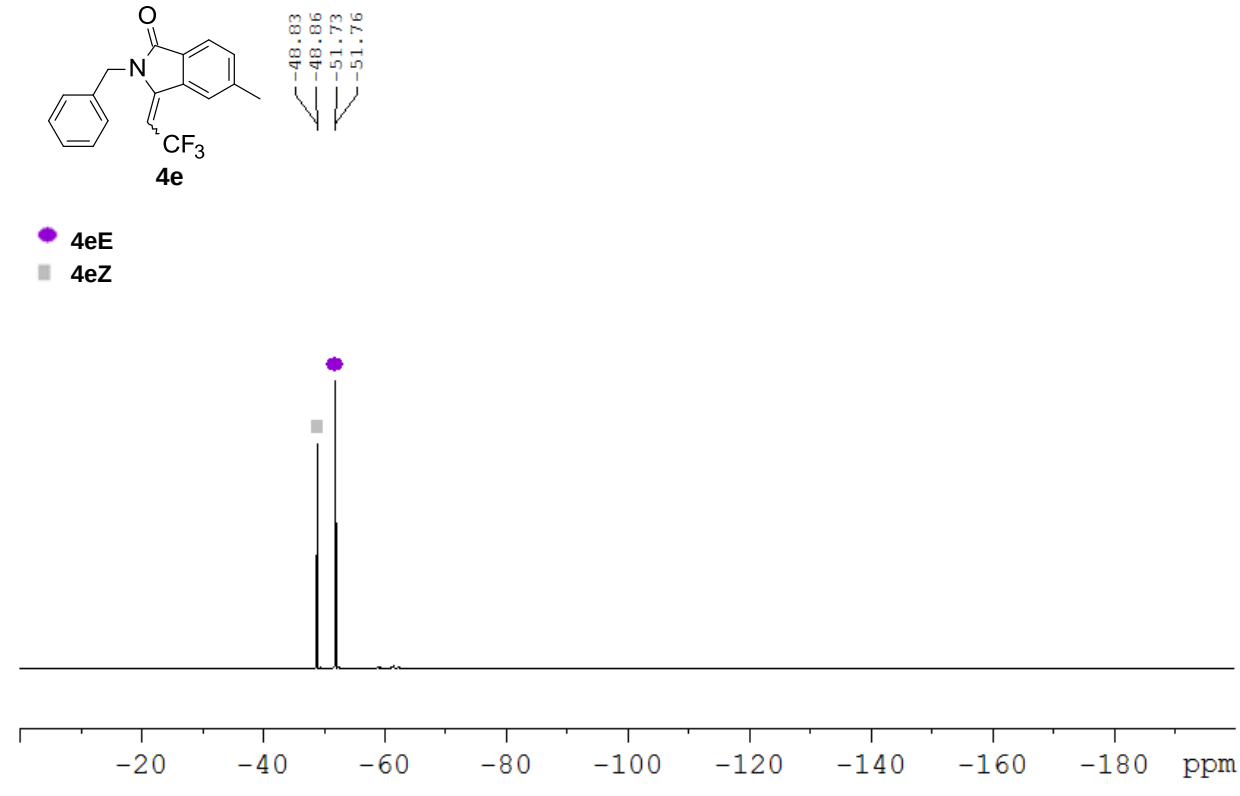

O
N
CF3
4dE
-51.77
-51.80
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

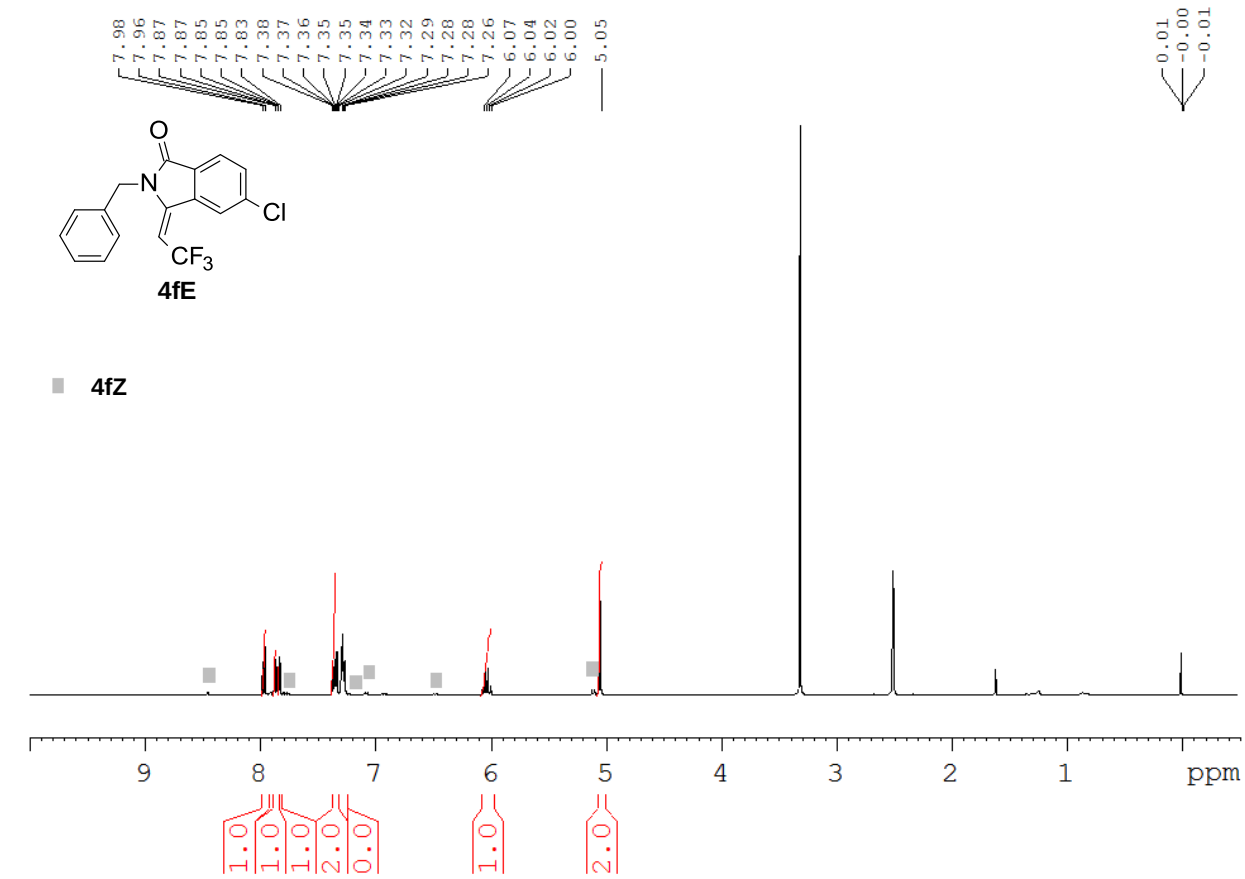

8.15
8.14
7.82
7.81
7.77
7.77
7.76
7.76
7.74
7.74
7.69
7.69
7.68
7.67
7.66
7.66
6.35
6.33
6.31
6.29
3.34
3.33
3.33
3.32
0.01
0.00
0.01
O
N
F3C
4dZ
9
8
7
6
5
4
3
2
1
ppm
1.0
0.9
1.0
1.0
1.0
2.9

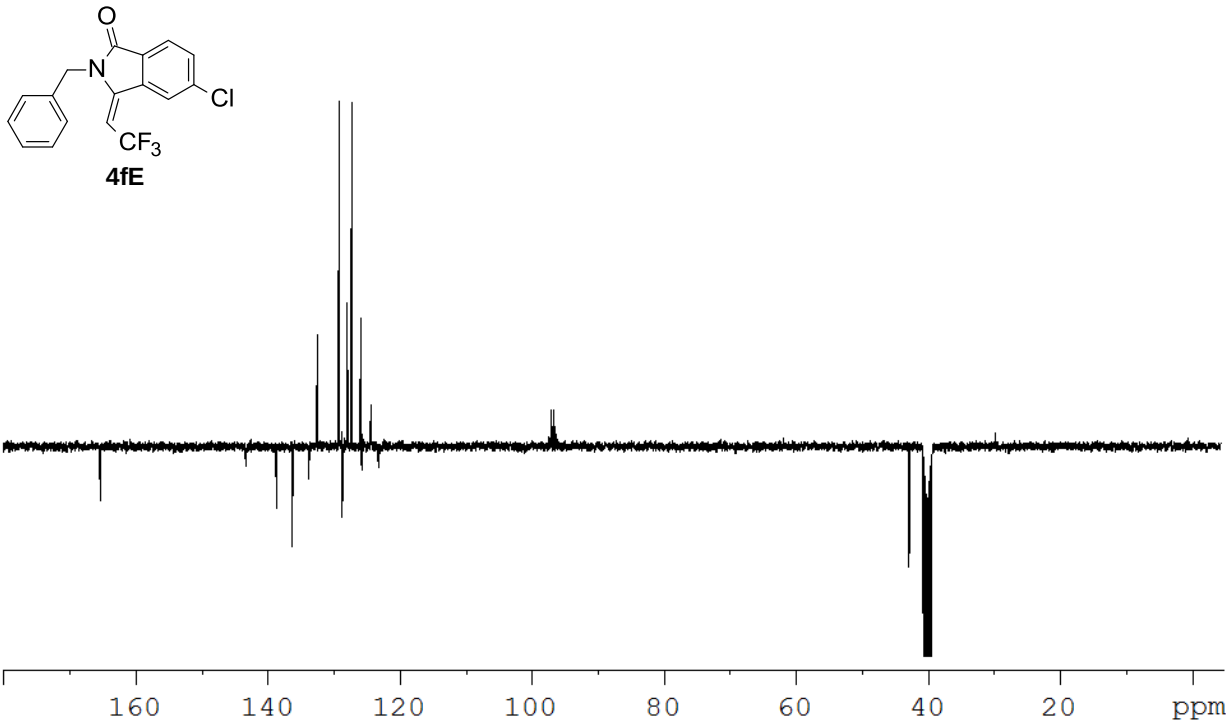

O
N
F3C
4dZ
160
140
120
100
80
60
40
20
ppm

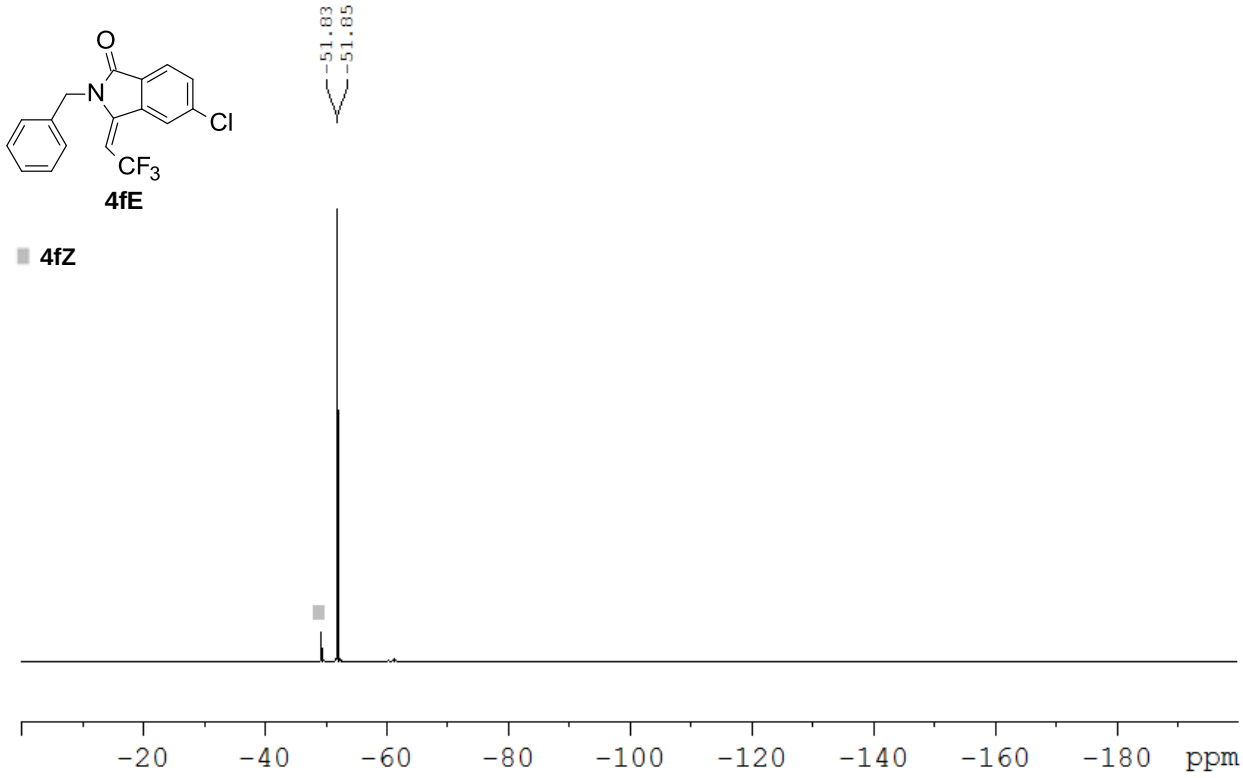

-47.08
4dZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm
7.83
7.82
7.77
7.76
7.72
7.59
7.58
7.55
7.54
7.36
7.35
7.33
7.31
7.30
7.28
7.27
7.26
7.25
7.23
7.22
7.21
7.06
7.05
6.32
6.30
6.28
6.26
5.91
5.89
5.87
5.85
5.09
5.03
3.33
2.49
-0.00
4e
4eE
4eZ
9
8
7
6
5
4
3
2
1
ppm
0.8
1.0
0.8
1.0
1.0
0.8
2.1
5.4
1.5
0.8
1.0
1.5
2.0
5.5

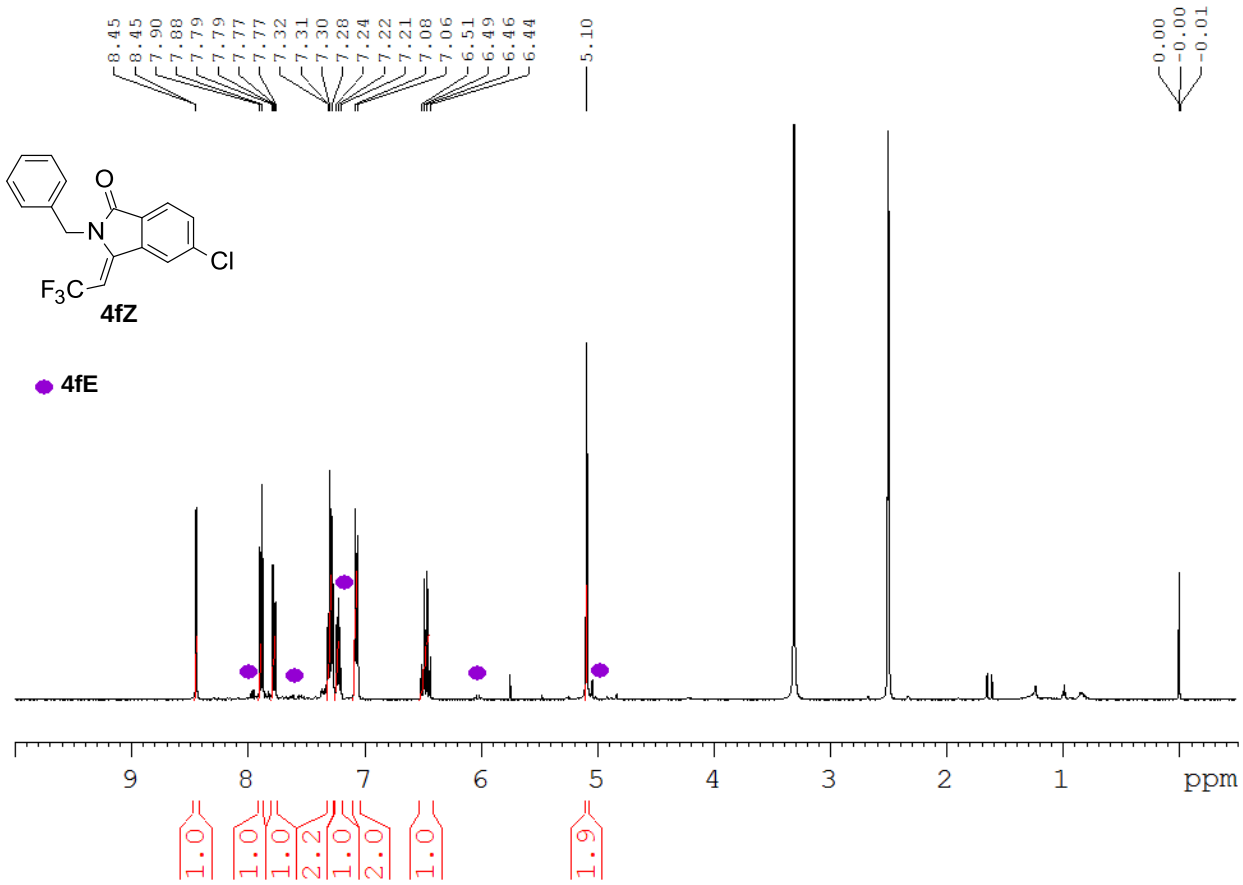

O
N
CF3
4e
4eE
4eZ
160
140
120
100
80
60
40
20
ppm

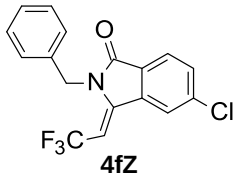

O
N
CF3
4e
-48.83
-48.86
-51.73
-51.76
4eE
4eZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.98
7.96
7.87
7.87
7.85
7.85
7.83
7.38
7.37
7.36
7.35
7.35
7.34
7.33
7.32
7.29
7.28
7.28
7.26
6.07
6.04
6.02
6.00
5.05
0.01
-0.00
-0.01
O
N
Cl
CF3
4fE
4fZ
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
2.0
0.0
1.0
2.0


O
N
Cl
CF3
4fE
160
140
120
100
80
60
40
20
ppm

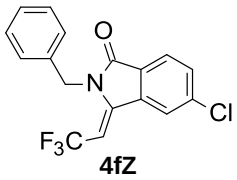

-51.83
-51.85
4fE
4fZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


8.45
8.45
7.90
7.88
7.79
7.79
7.77
7.77
7.32
7.31
7.30
7.28
7.24
7.22
7.21
7.08
7.06
6.51
6.49
6.46
6.44
5.10
0.00
-0.00
-0.01
4fZ
4fE
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
2.2
1.0
2.0
1.0
1.9

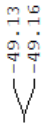

O
N
Cl
F3C

4fZ

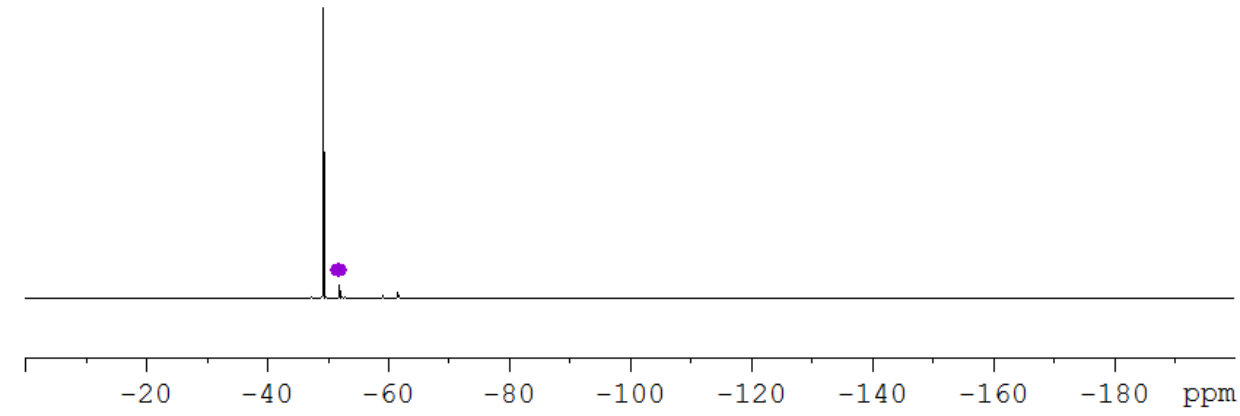
160
140
120
100
80
60
40
20
ppm

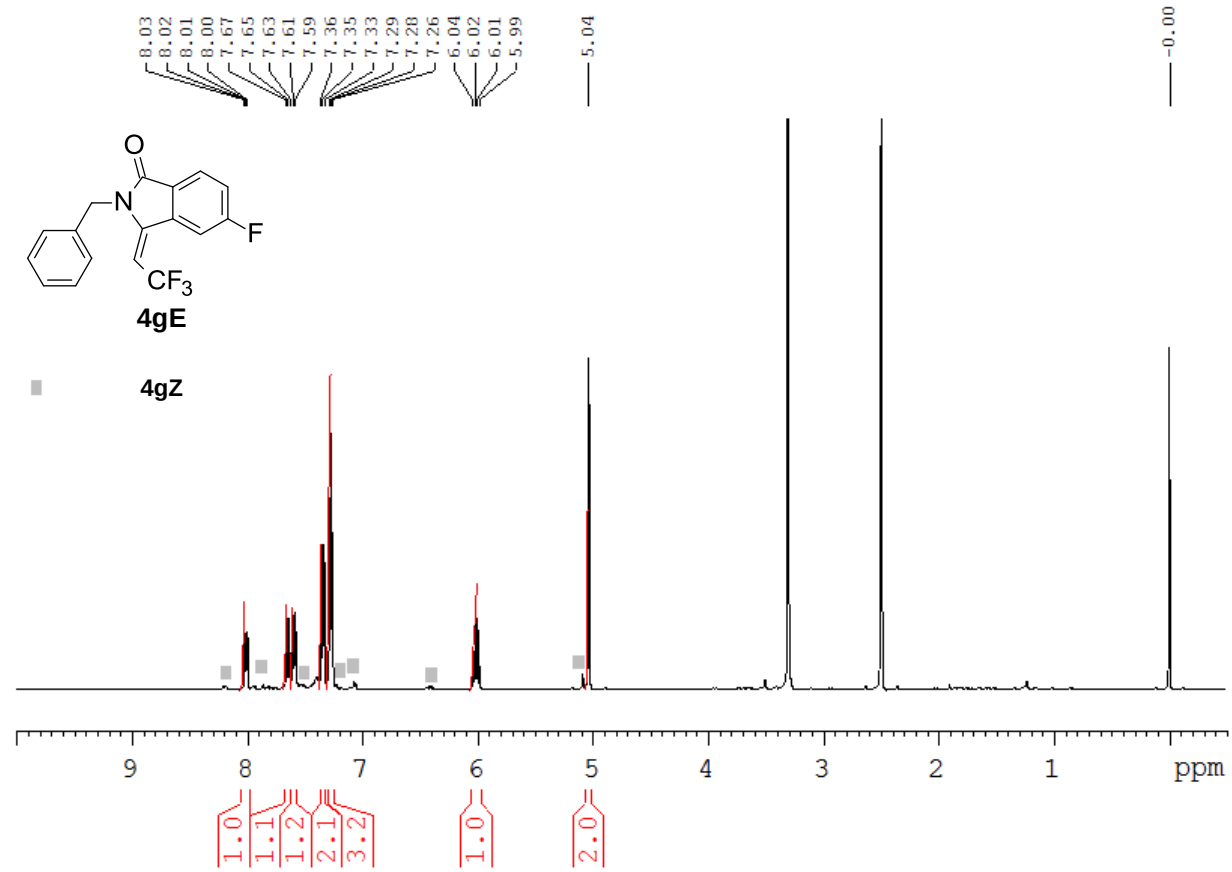

O
N
Cl
F3C

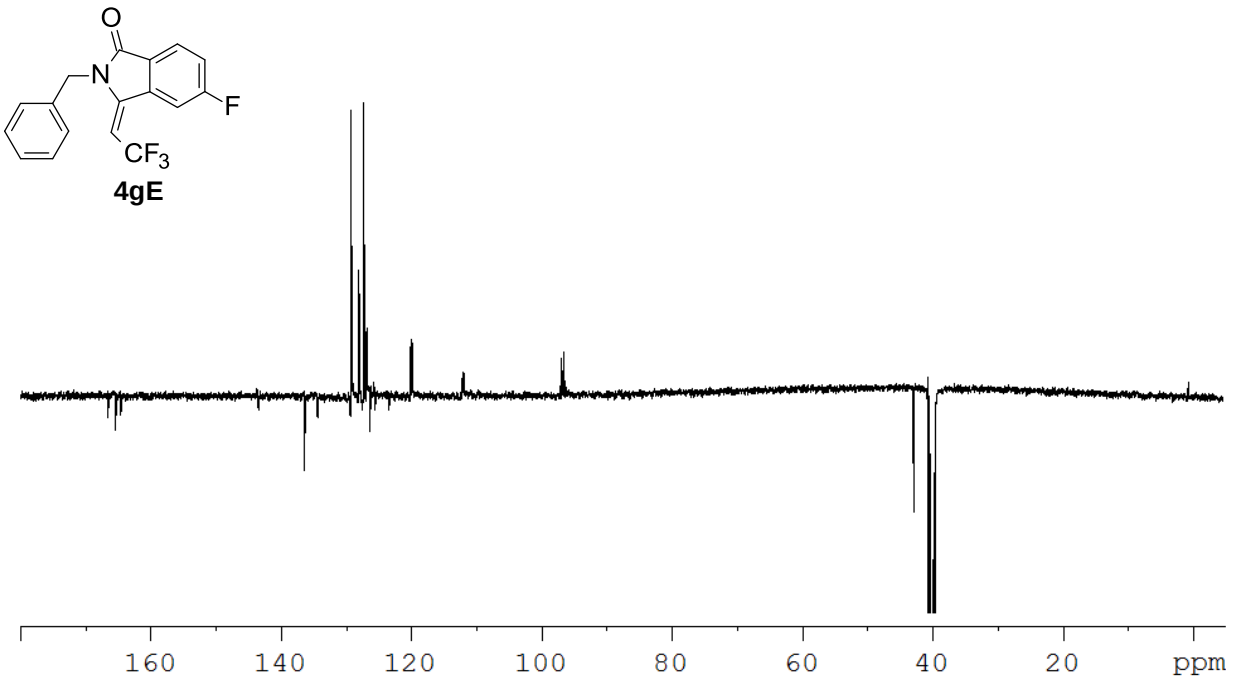
4fZ

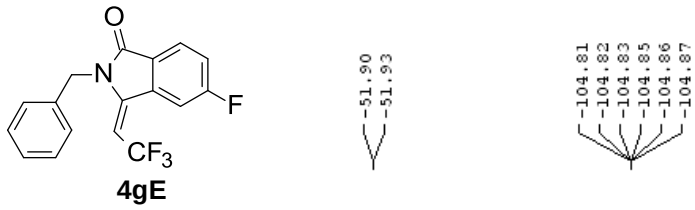

-49.13
-49.16

4fE


-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

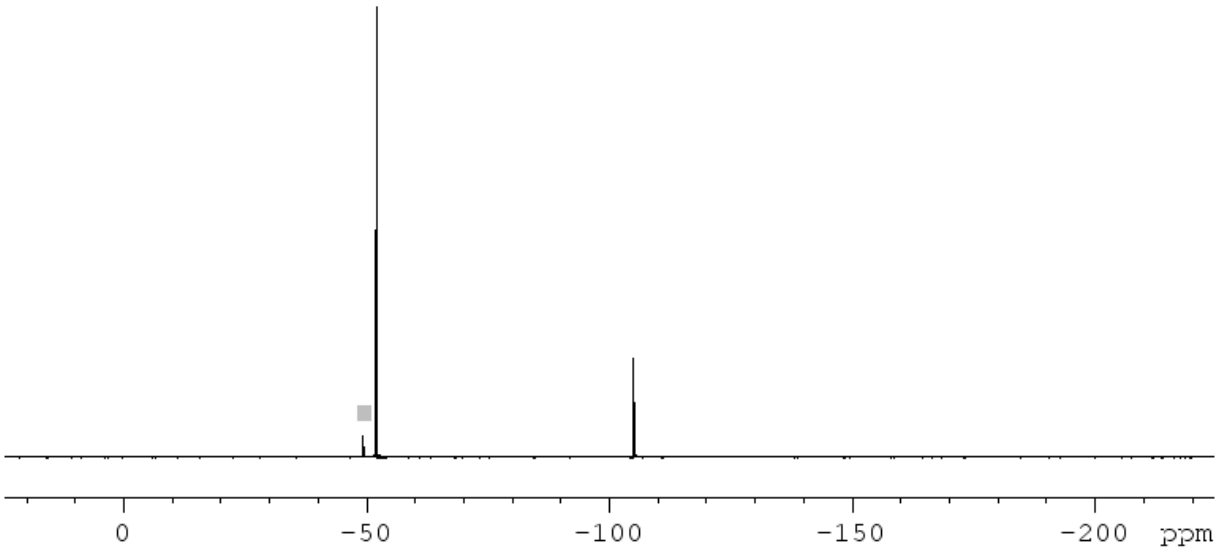

8.03
8.02
8.01
8.00
7.67
7.65
7.63
7.61
7.59
7.36
7.35
7.33
7.29
7.28
7.26
6.04
6.02
6.01
5.99
5.04
-0.00
O
N
F
CF3
4gE
4gZ
9
8
7
6
5
4
3
2
1
ppm
1.0
1.1
1.2
2.1
3.2
1.0
2.0

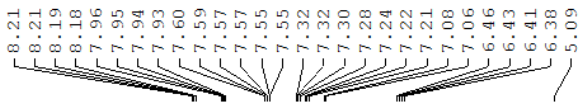

O
N
F
CF3
4gE
160
140
120
100
80
60
40
20
ppm

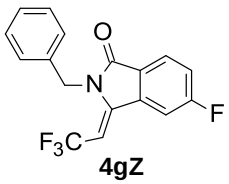


4gE

4gZ

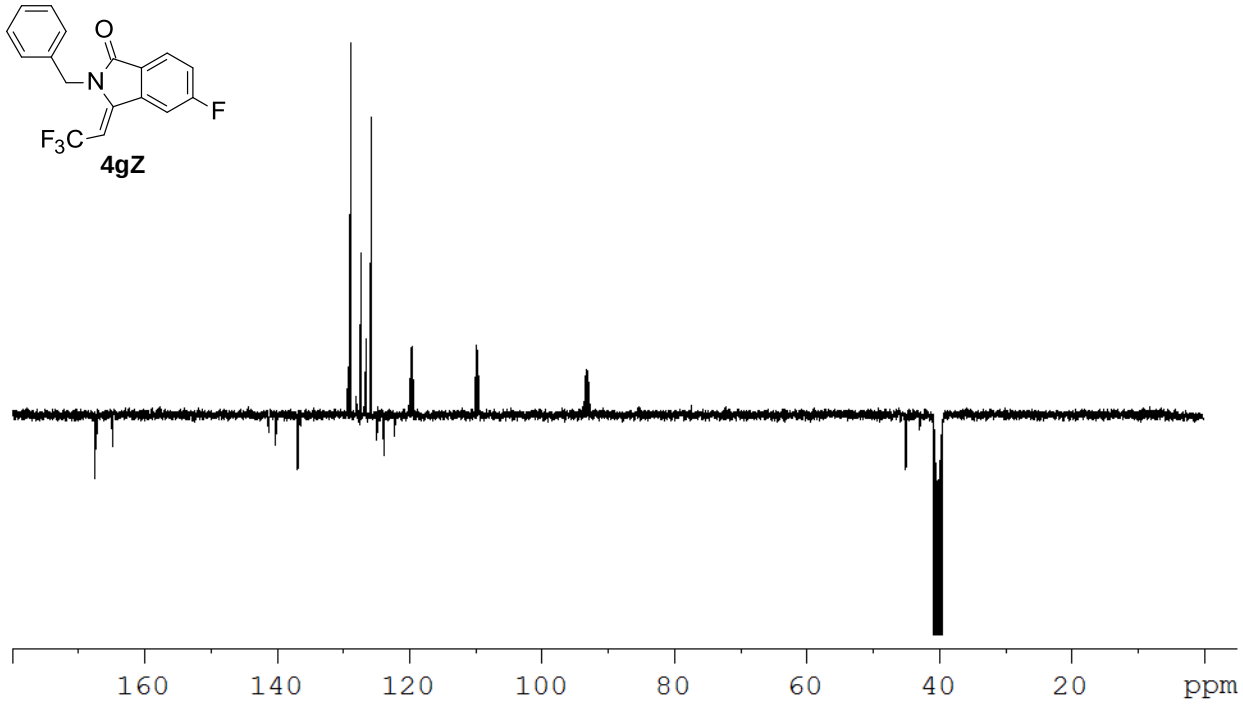


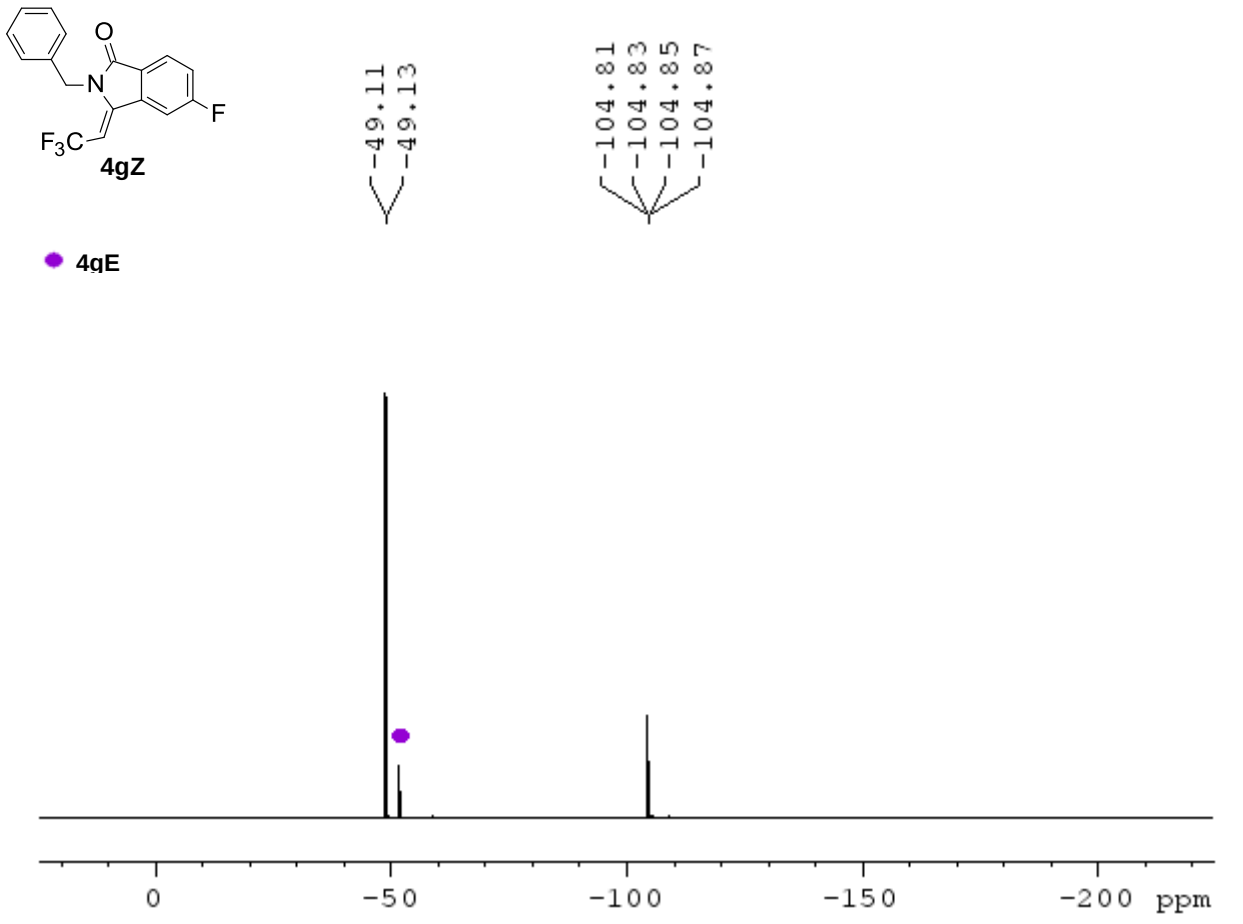


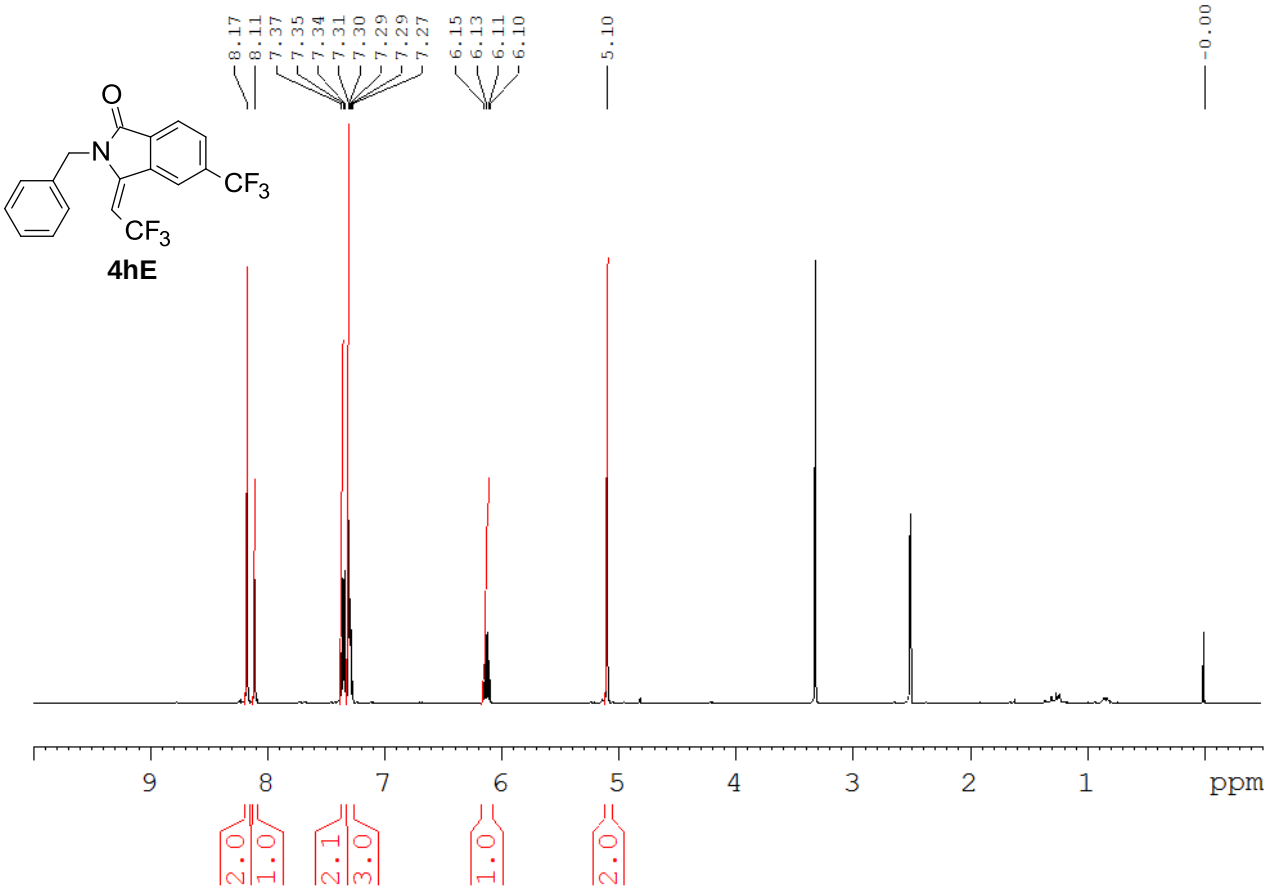


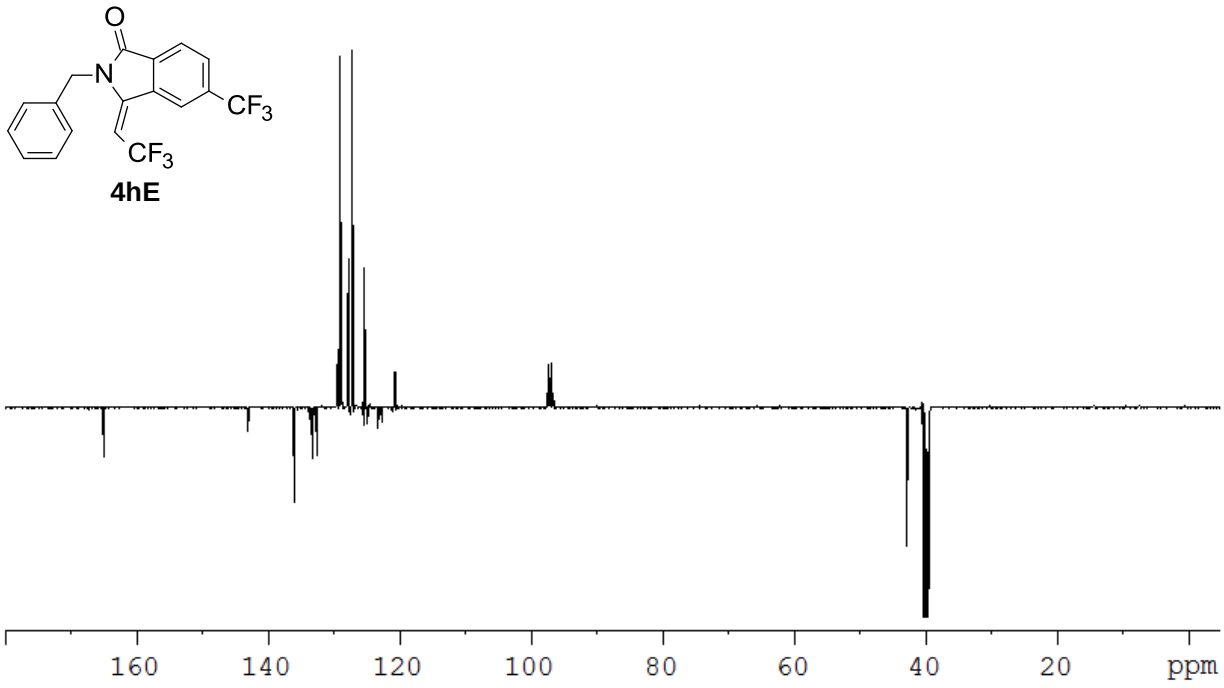
4gZ

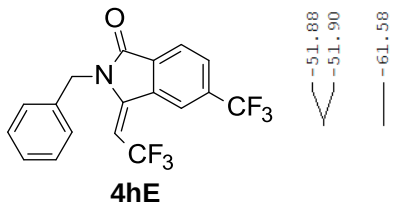
4gE


O
N
F
F3C
4gZ
160
140
120
100
80
60
40
20
ppm


O
N
F
F3C
4gZ
-49.11
-49.13
-104.81
-104.83
-104.85
-104.87
4gE
0
-50
-100
-150
-200
ppm

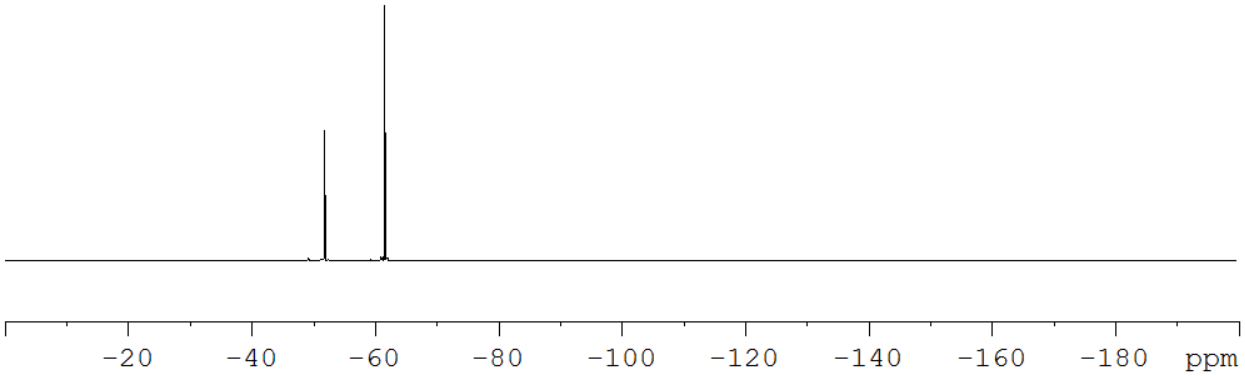

8.17
8.11
7.37
7.35
7.34
7.31
7.30
7.29
7.29
7.27
6.15
6.13
6.11
6.10
5.10
-0.00
O
N
CF3
CF3
4hE
9
8
7
6
5
4
3
2
1
ppm
2.0
1.0
2.1
3.0
1.0
2.0

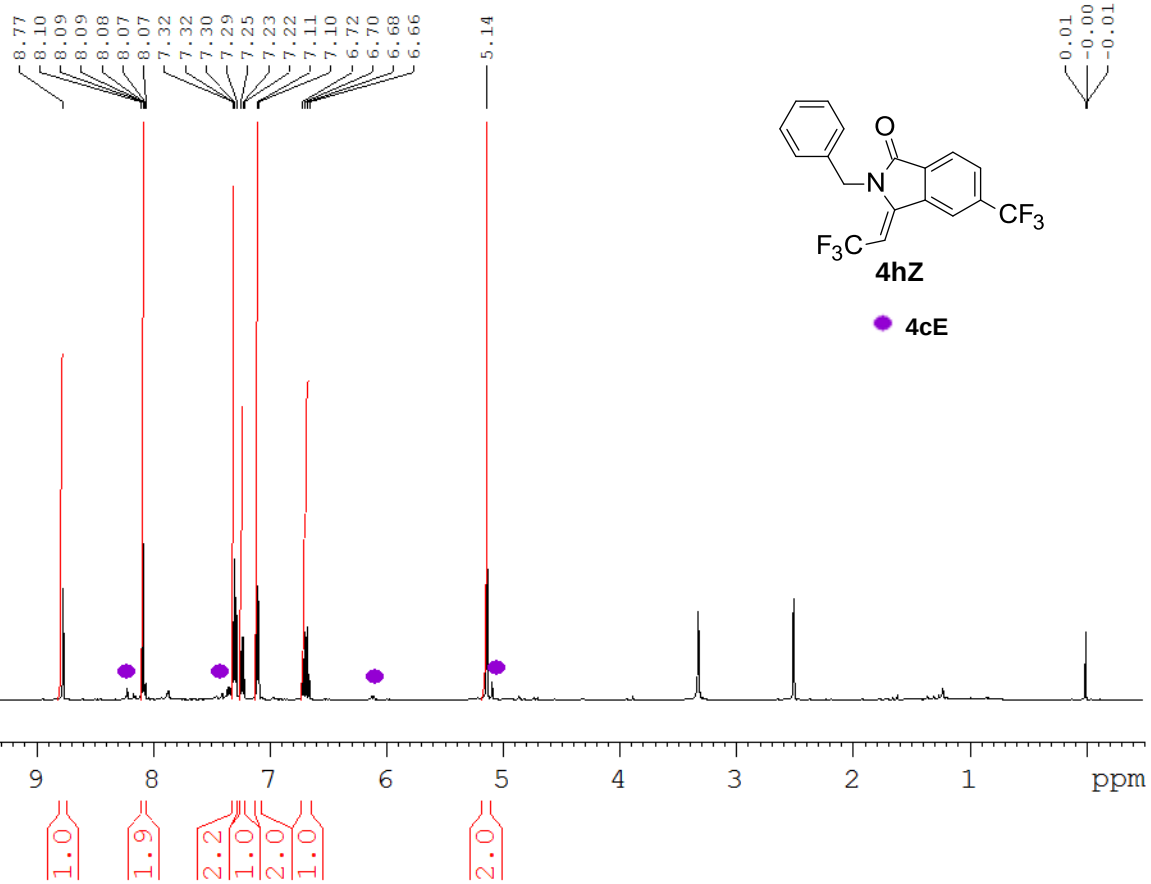

O
N
CF3
CF3
4hE
160
140
120
100
80
60
40
20
ppm

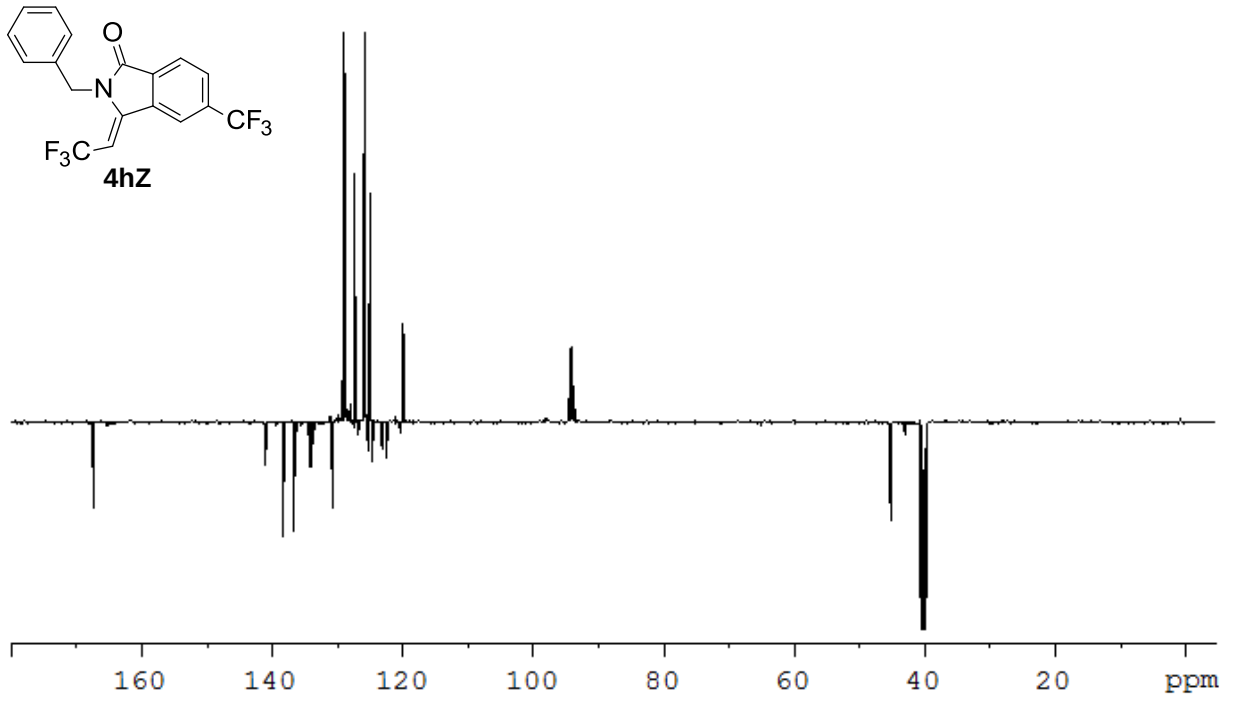

O
N
CF3
CF3

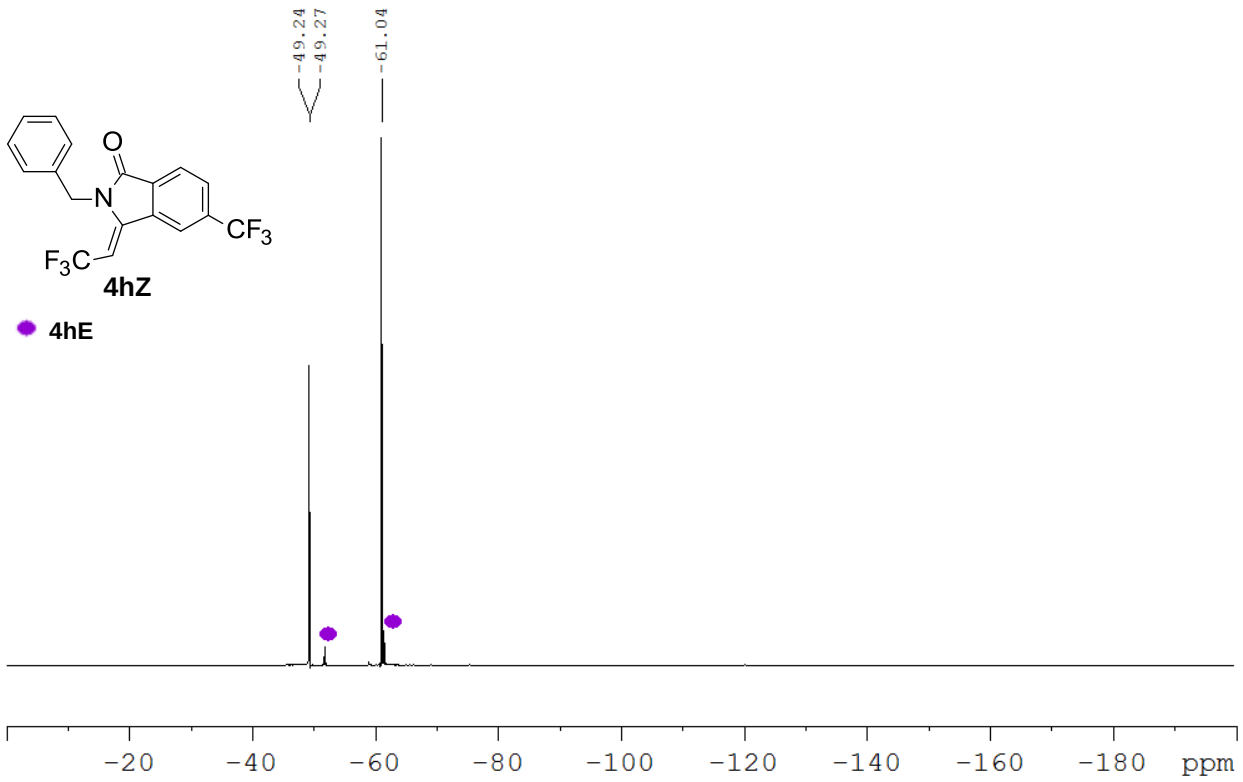
4hE

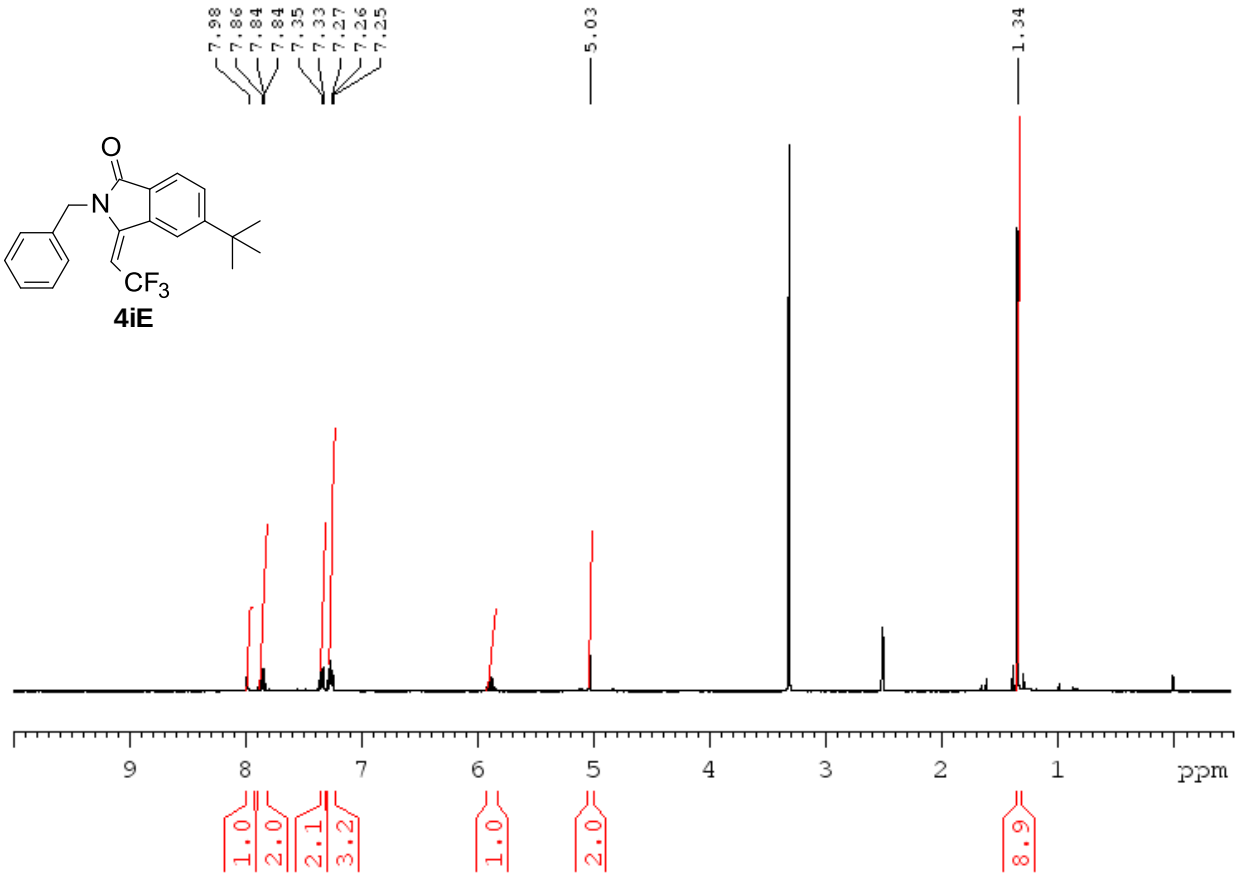
-51.88
-51.90
-61.58

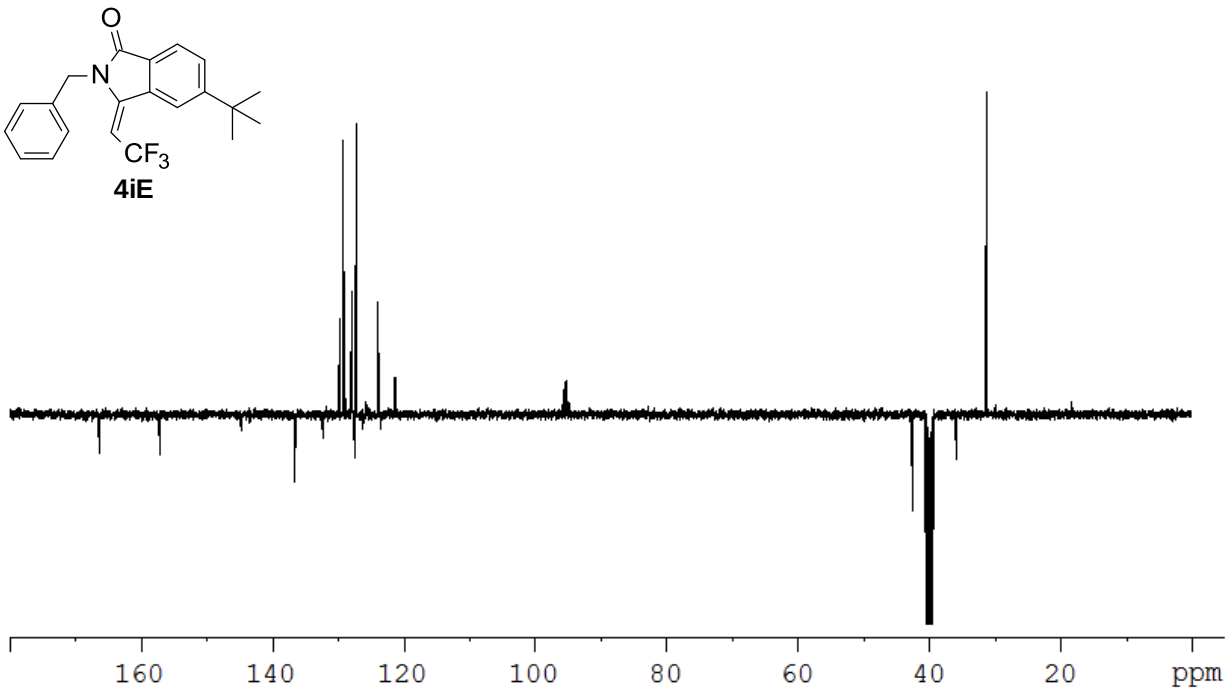

-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

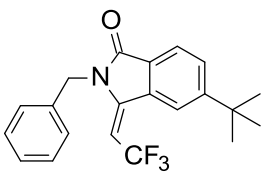

8.77
8.10
8.09
8.09
8.08
8.07
8.07
7.32
7.32
7.30
7.29
7.25
7.23
7.22
7.11
7.10
6.72
6.70
6.68
6.66
5.14
0.01
-0.00
-0.01
O
N
CF3
F3C
4hZ
4cE
9
8
7
6
5
4
3
2
1
ppm
1.0
1.9
2.2
1.0
2.0
1.0
2.0


O
N
CF3
F3C
4hZ
160
140
120
100
80
60
40
20
ppm


-49.24
-49.27
-61.04
O
N
CF3
F3C
4hZ
4hE
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.98
7.86
7.84
7.84
7.35
7.33
7.27
7.26
7.25
5.03
1.34
O
N
CF3
4iE
9
8
7
6
5
4
3
2
1
ppm
1.0
2.0
2.1
3.2
1.0
2.0
8.9

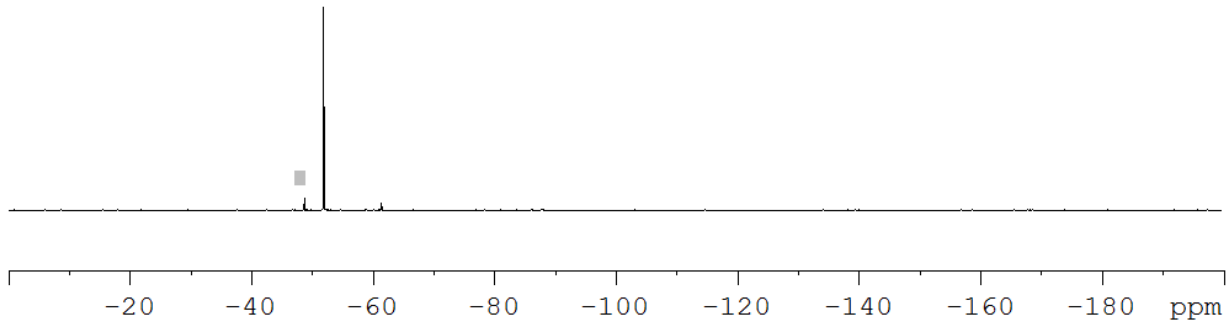

O
N
CF3
4iE
160
140
120
100
80
60
40
20
ppm

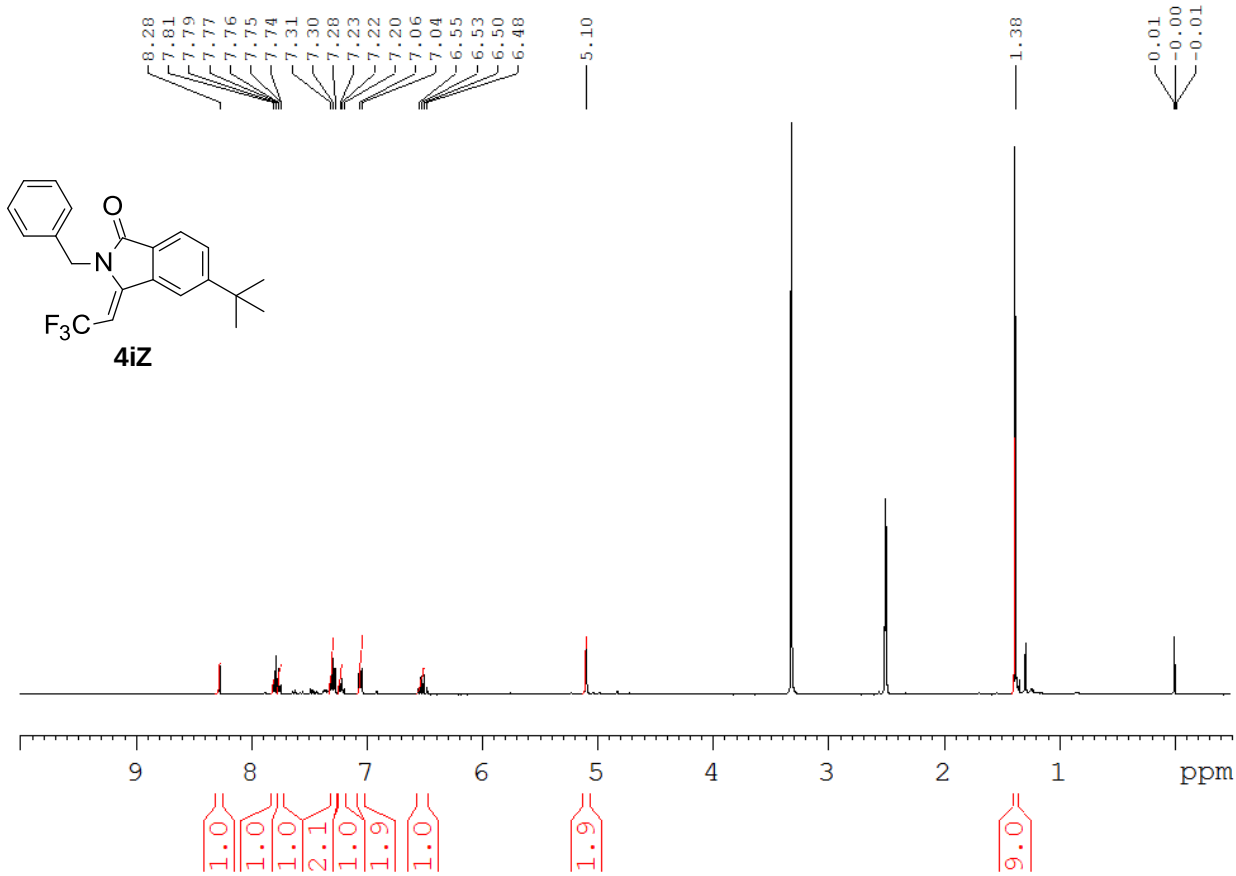


4iE

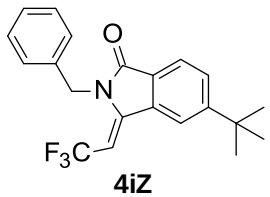
-51.85
-51.88

4cZ

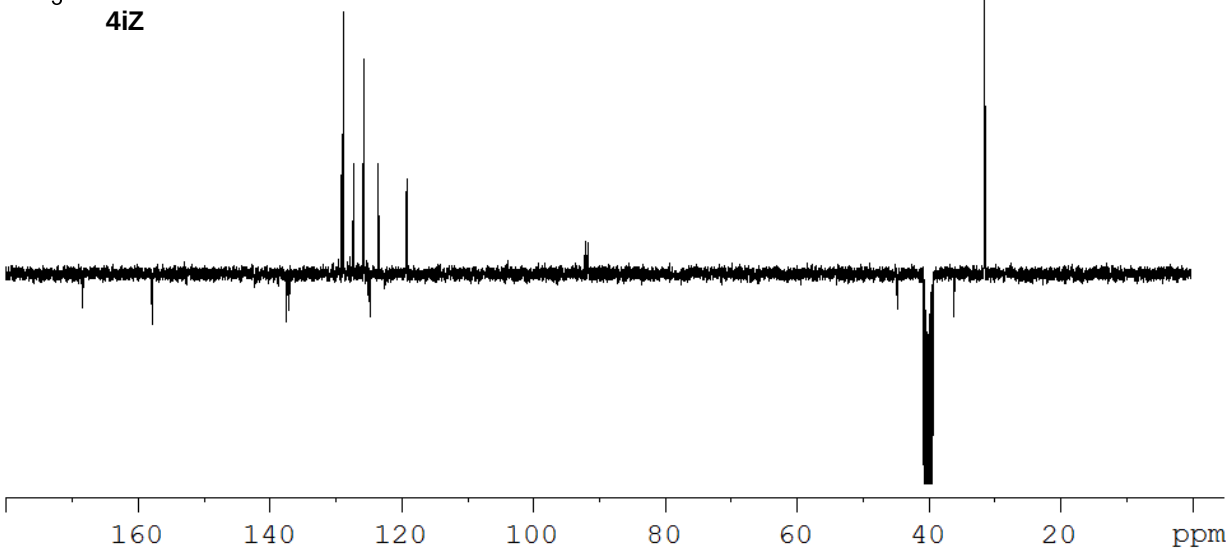


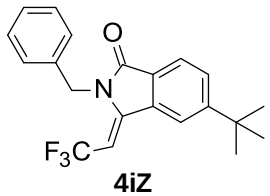


4iZ

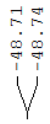

O
N
F3C

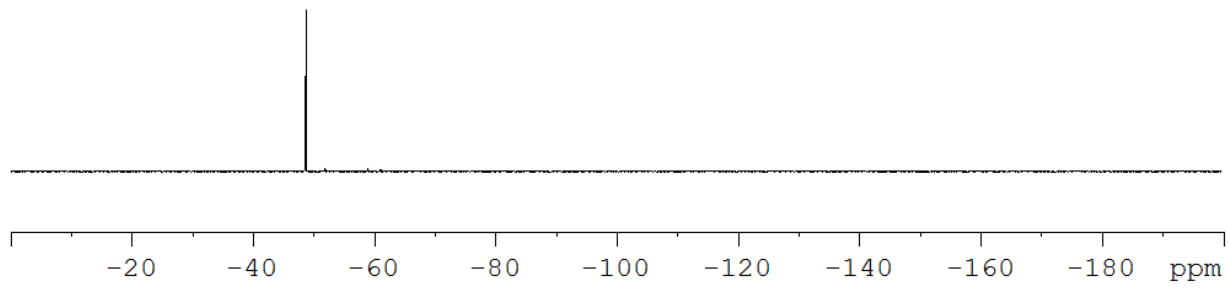
4iZ

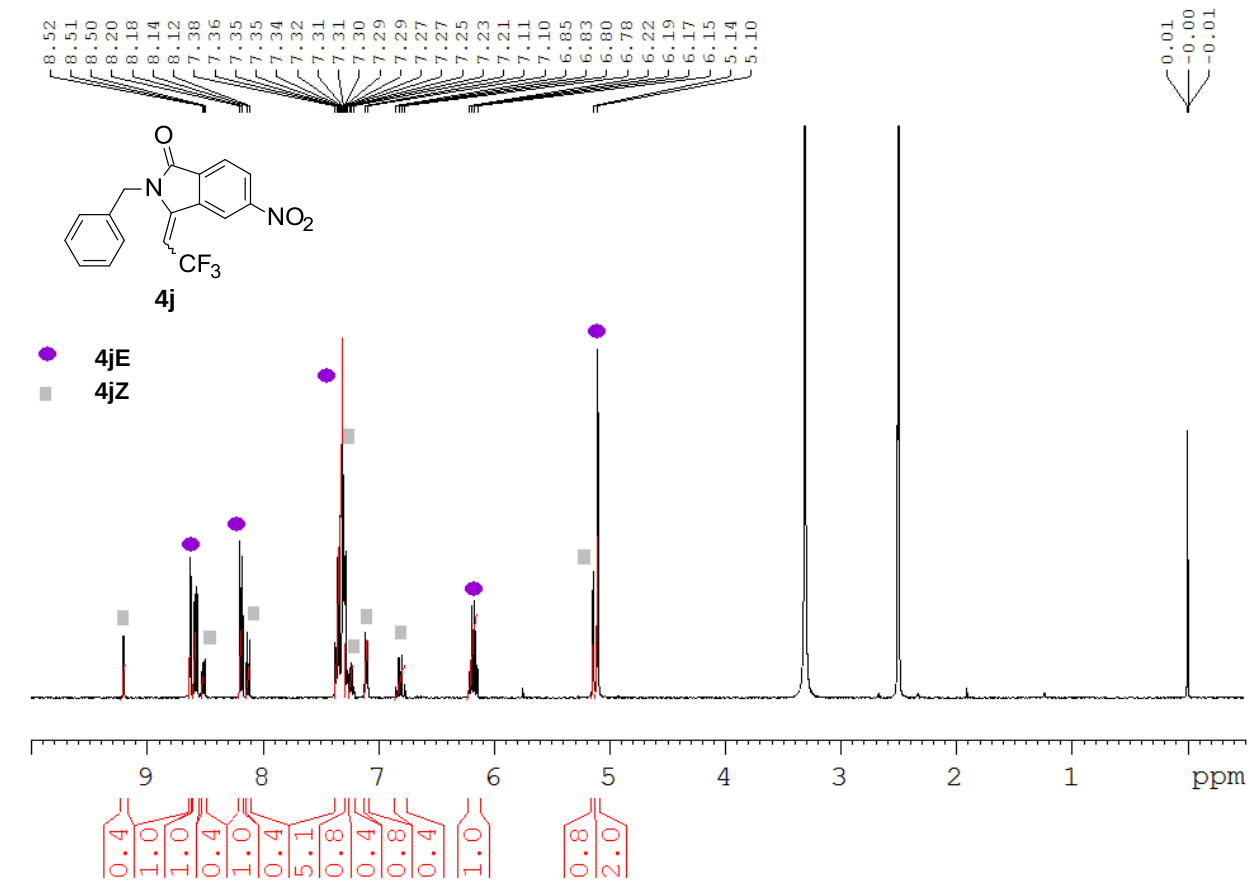

160
140
120
100
80
60
40
20
ppm

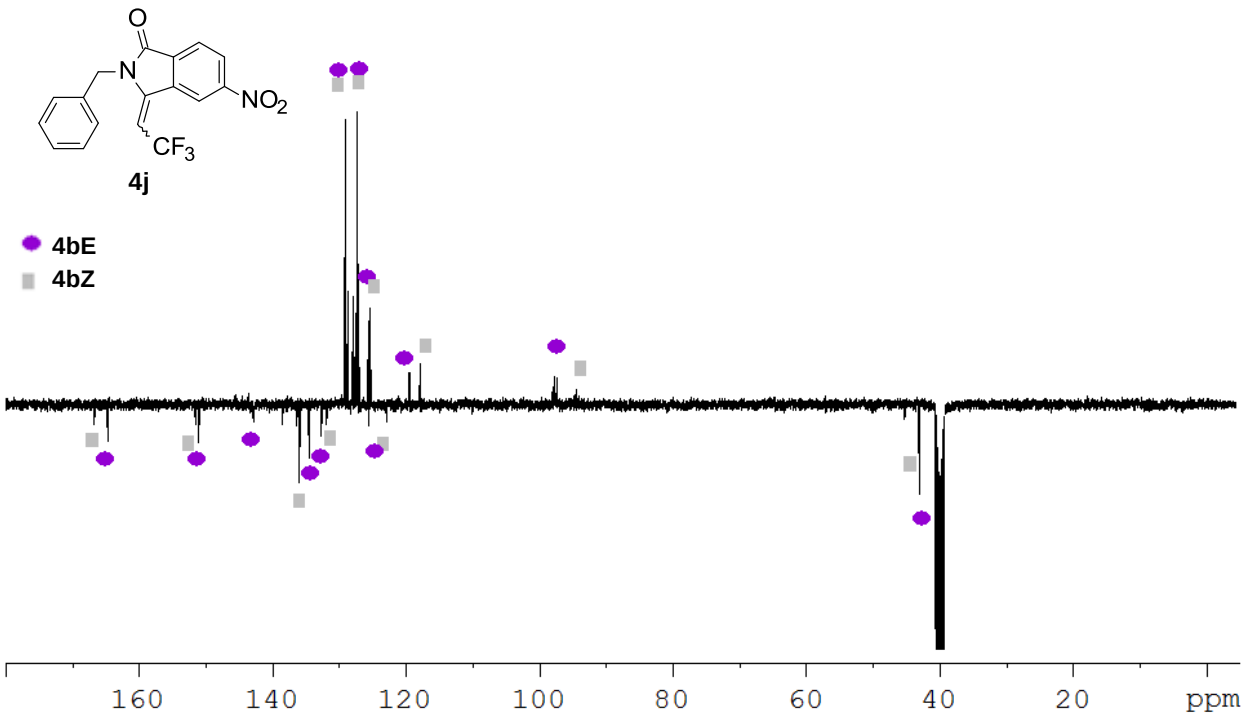

O
N
F3C

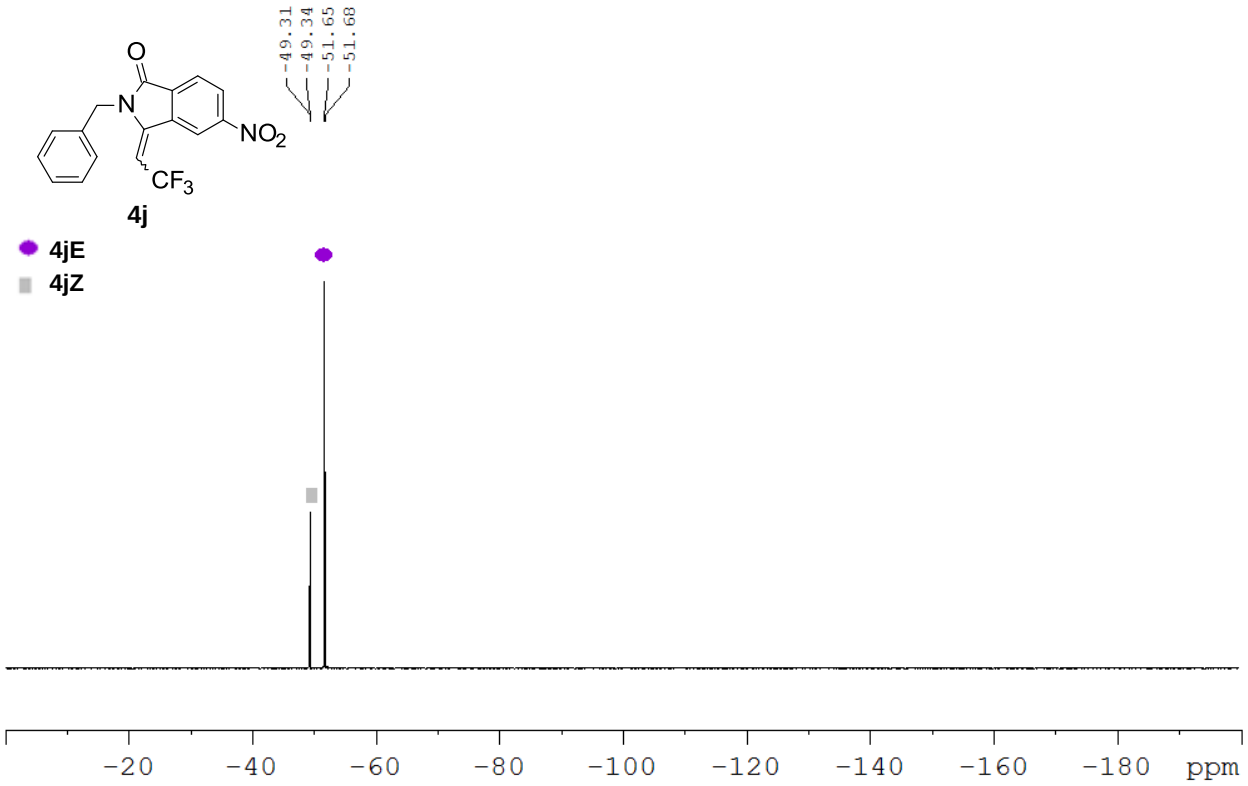
4iZ

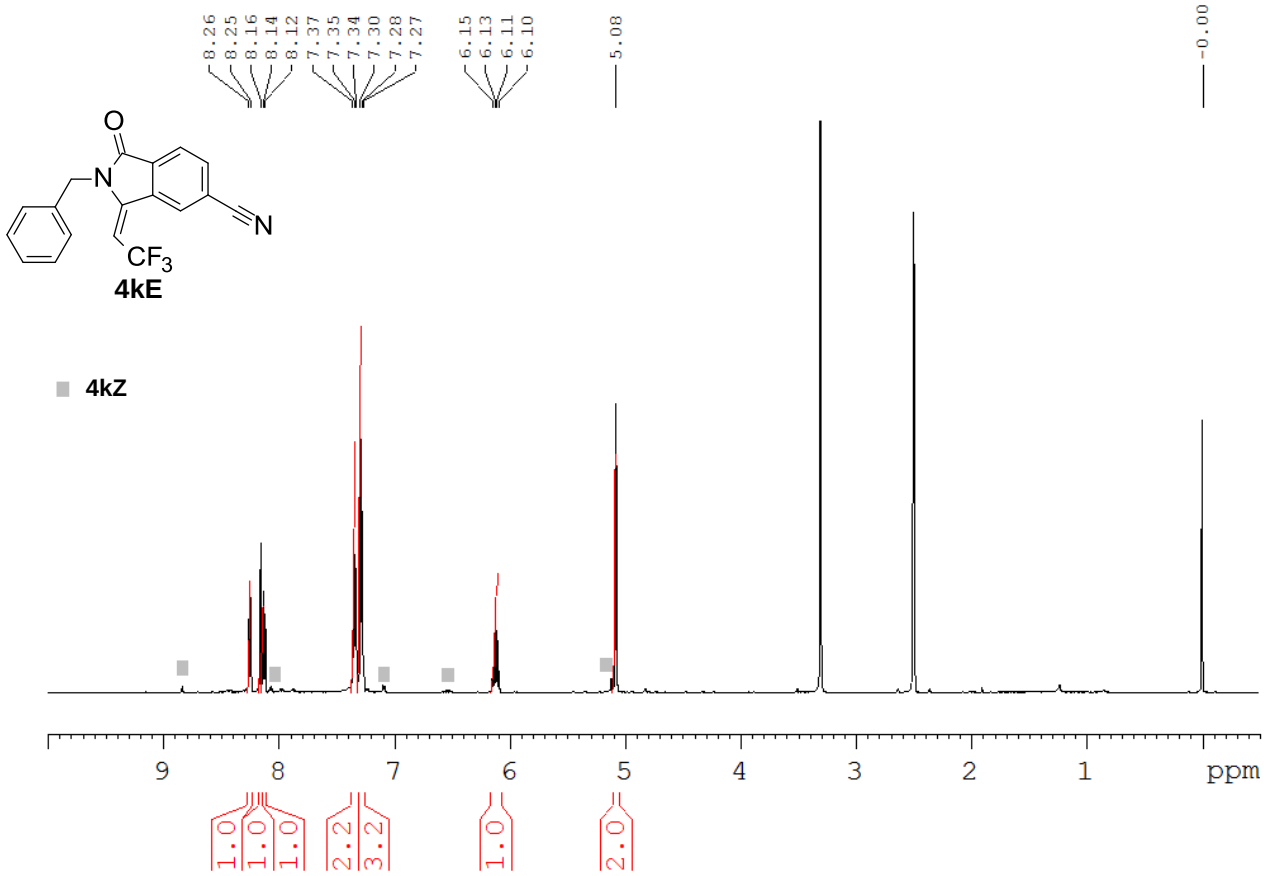

-48.71
-48.74

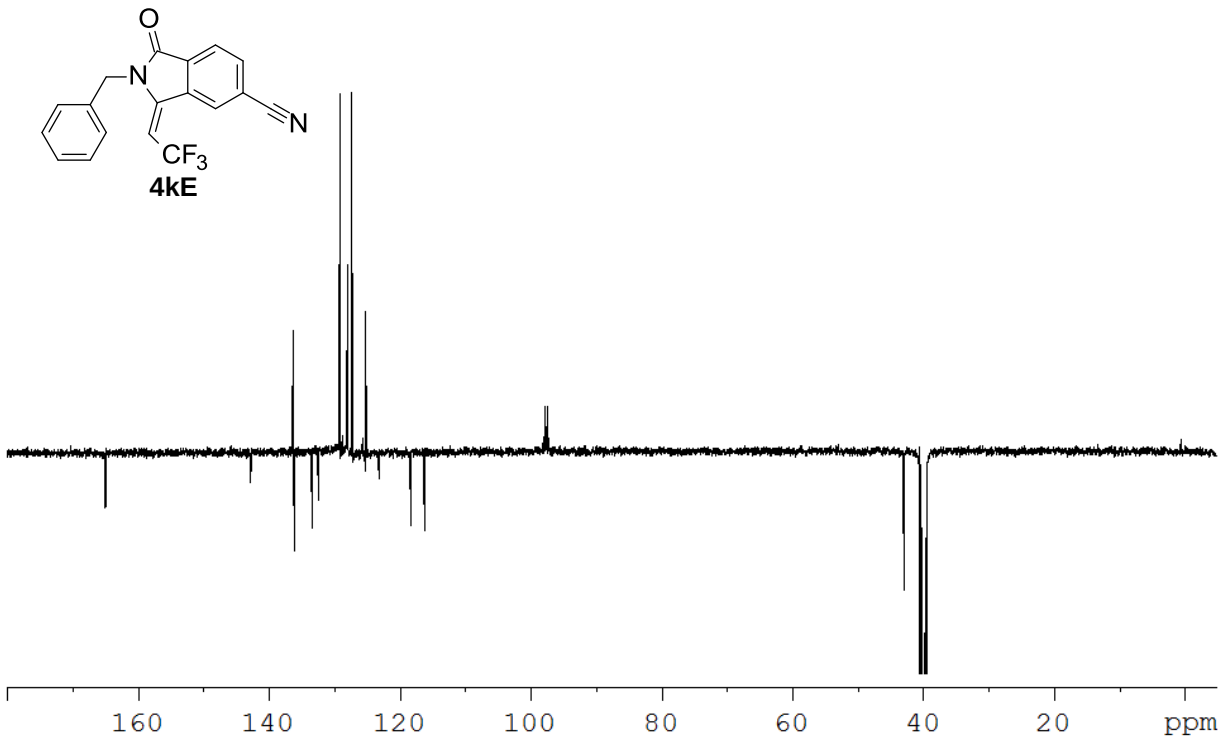

-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


8.52
8.51
8.50
8.20
8.18
8.14
8.12
7.38
7.36
7.35
7.35
7.34
7.32
7.31
7.31
7.30
7.29
7.29
7.27
7.27
7.25
7.23
7.21
7.11
7.10
6.85
6.83
6.80
6.78
6.22
6.19
6.17
6.15
5.14
5.10
0.01
0.00
-0.01
O
N
NO2
CF3
4j
4jE
4jZ
9
8
7
6
5
4
3
2
1
ppm
0.4
1.0
1.0
0.4
1.0
0.4
5.1
0.8
0.4
0.8
0.4
1.0
0.8
2.0

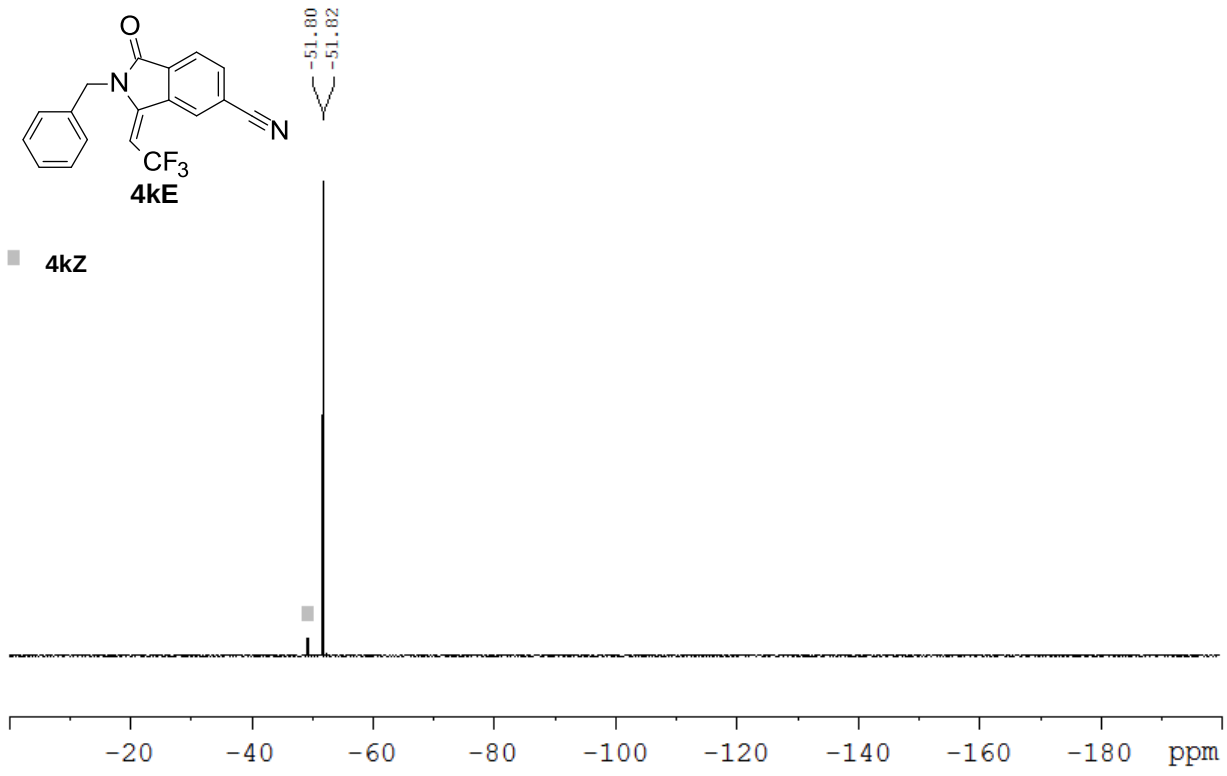

O
N
NO2
CF3
4j
4bE
4bZ
160
140
120
100
80
60
40
20
ppm


-49.31
-49.34
-51.65
-51.68
O
N
NO2
CF3
4j
4jE
4jZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


8.26
8.25
8.16
8.14
8.12
7.37
7.35
7.34
7.30
7.28
7.27
6.15
6.13
6.11
6.10
5.08
-0.00
O
N
N
CF3
4kE
4kZ
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
2.2
3.2
1.0
2.0

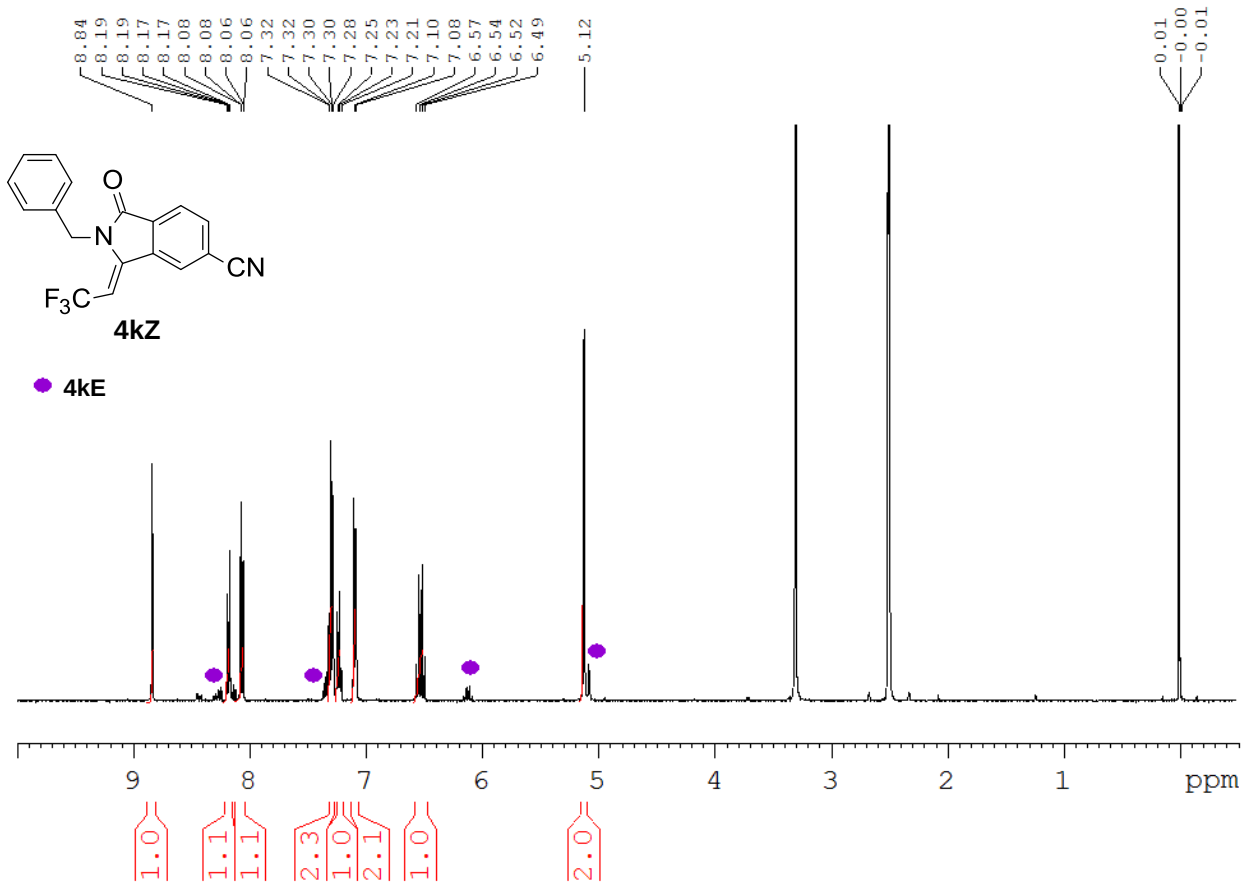

O
N
N
CF3
160
140
120
100
80
60
40
20
ppm

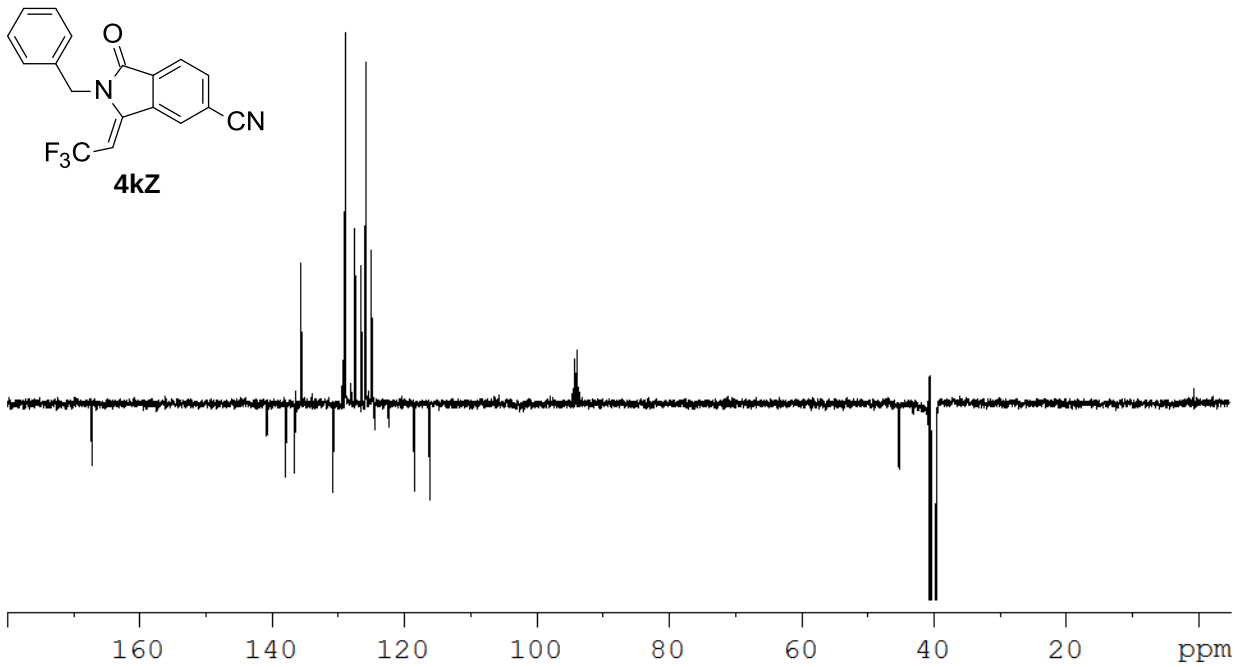
4kE

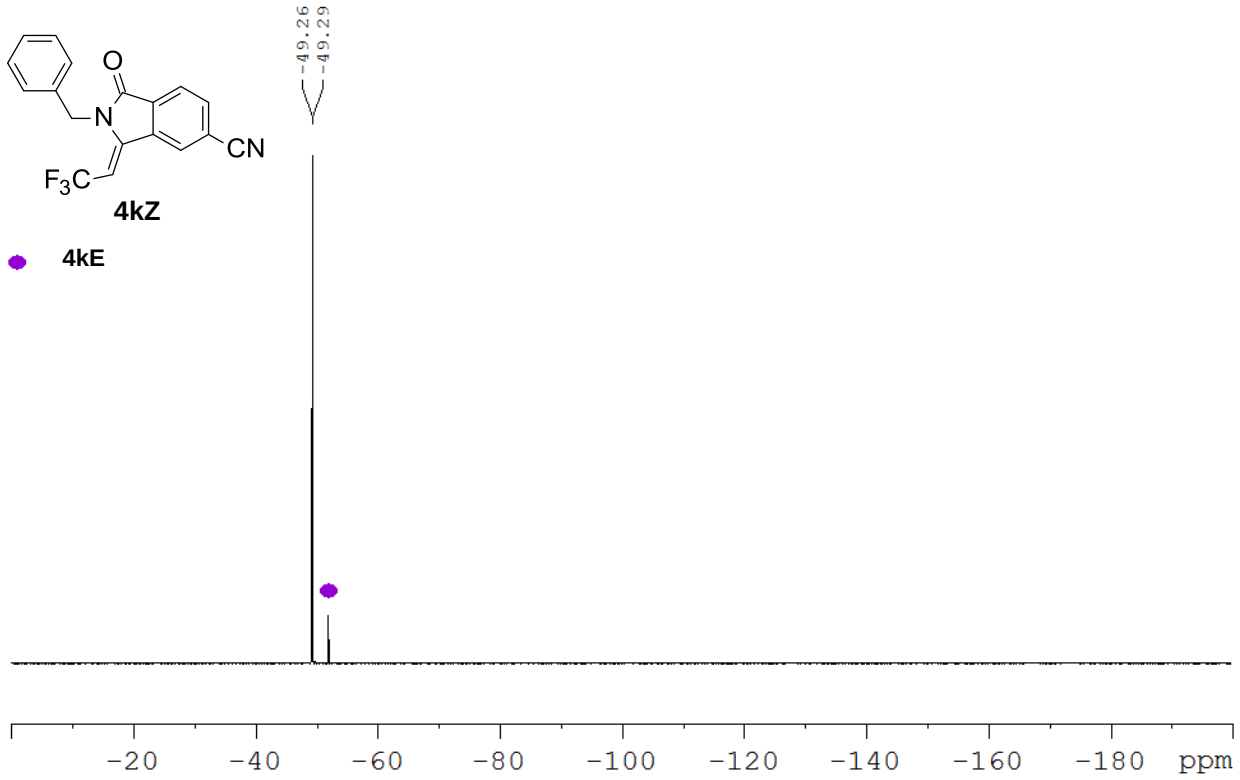

O
N
N
CF3
-51.80
-51.82
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

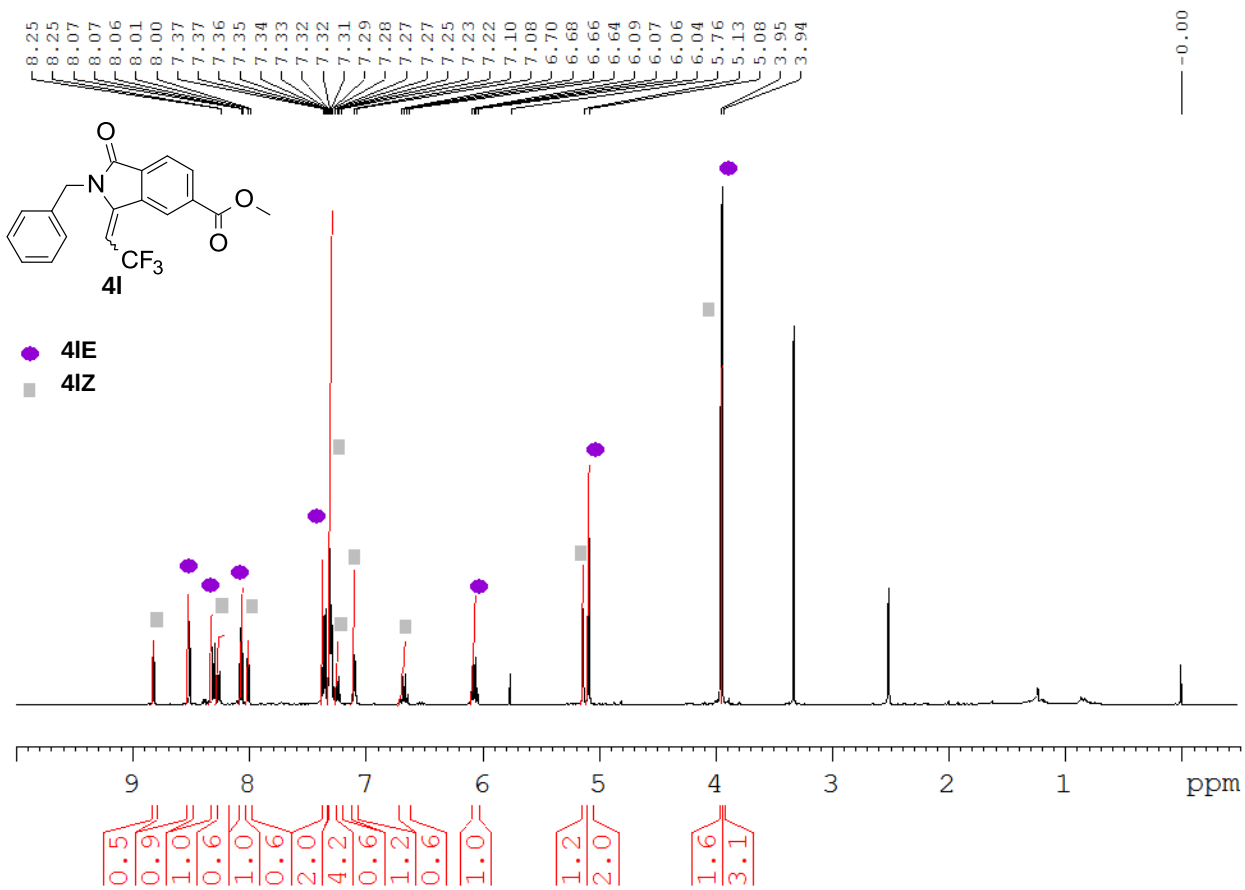
4kE

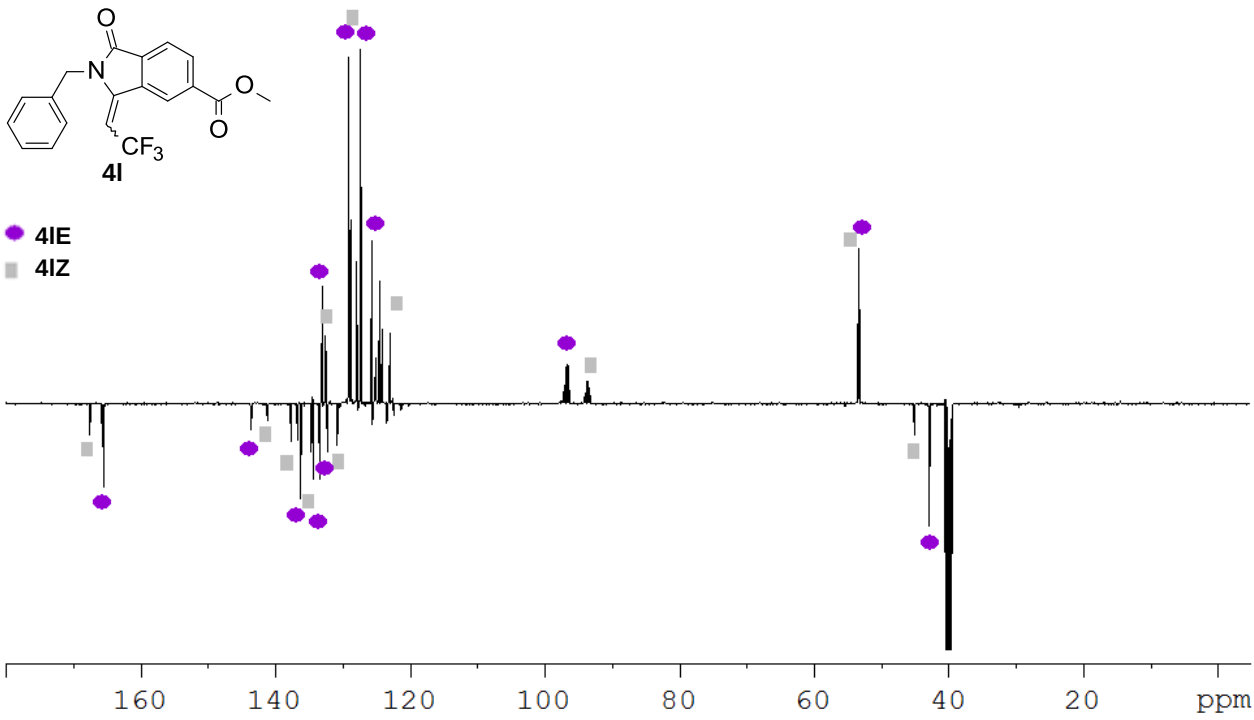
4kZ

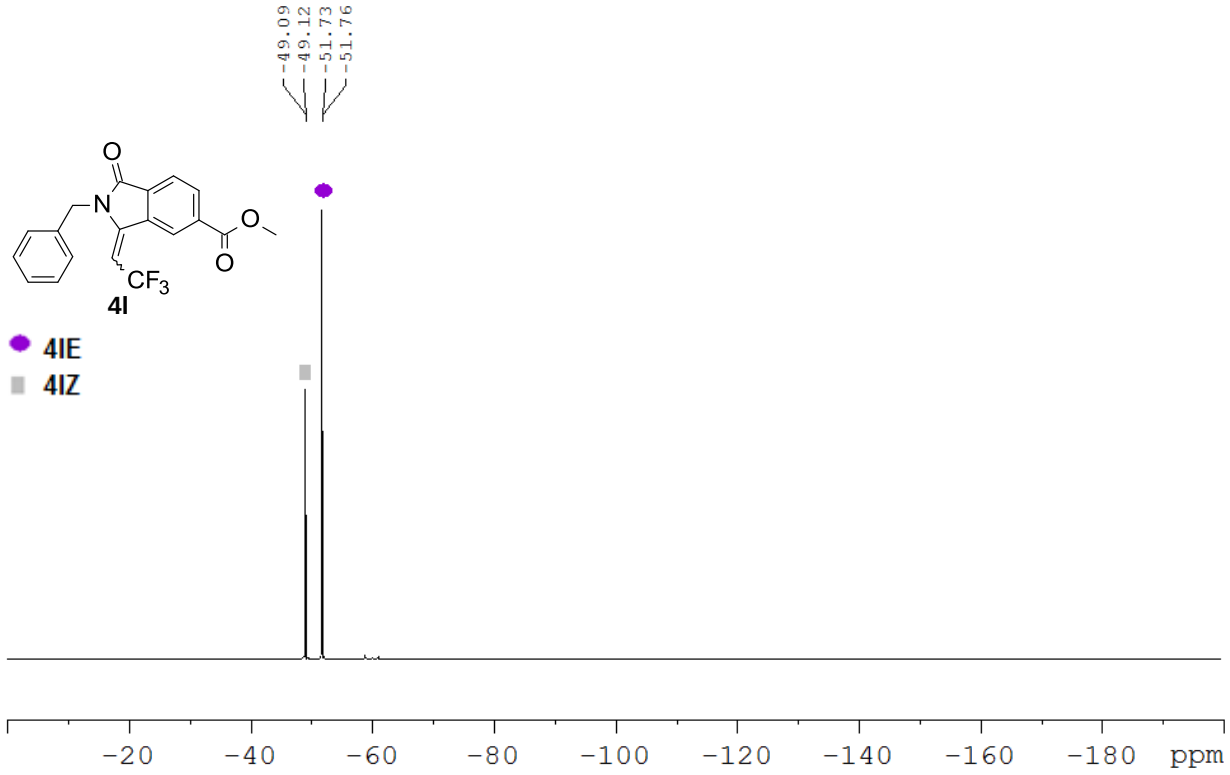

8.84
8.19
8.19
8.17
8.17
8.08
8.08
8.06
8.06
7.32
7.32
7.30
7.30
7.28
7.25
7.23
7.21
7.10
7.08
6.57
6.54
6.52
6.49
5.12
0.01
0.00
-0.01
O
N
CN
F3C
4kZ
4kE
9
8
7
6
5
4
3
2
1
ppm
1.0
1.1
1.1
2.3
1.0
2.1
1.0
2.0

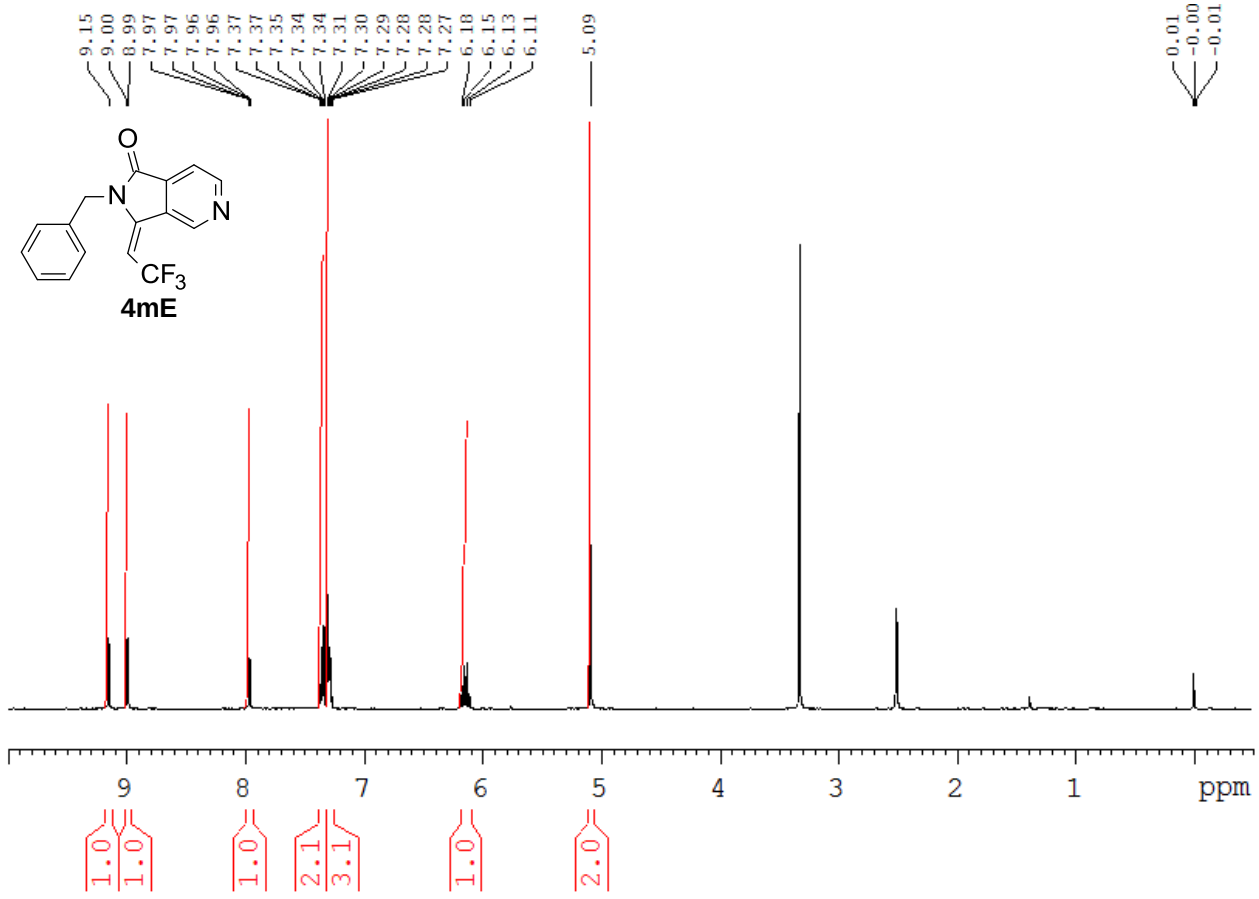

O
N
CN
F3C
4kZ
160
140
120
100
80
60
40
20
ppm

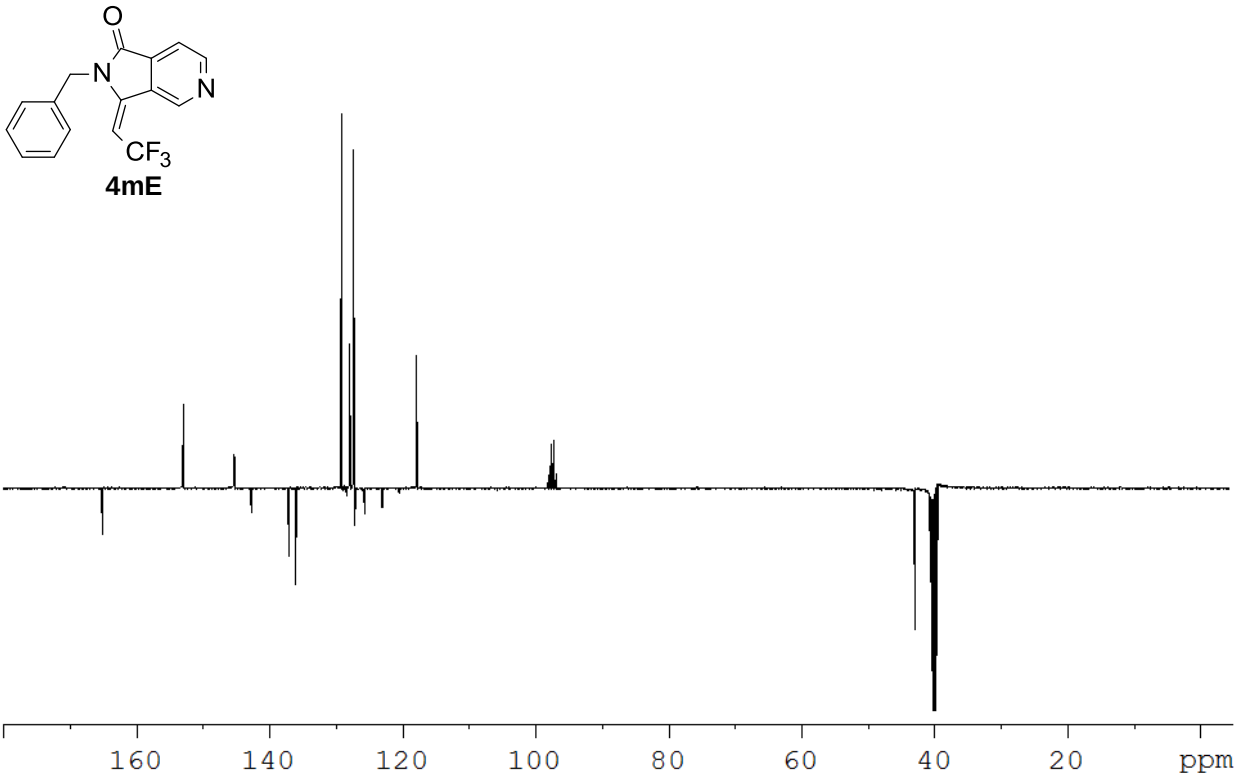

-49.26
-49.29
O
N
CN
F3C
4kZ
4kE
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

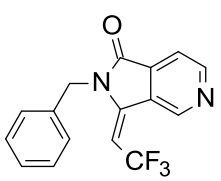

8.25
8.25
8.07
8.07
8.06
8.01
8.00
7.37
7.37
7.36
7.35
7.34
7.33
7.32
7.32
7.31
7.29
7.28
7.27
7.27
7.25
7.23
7.22
7.10
7.08
6.70
6.68
6.66
6.64
6.09
6.07
6.06
6.04
5.76
5.13
5.08
3.95
3.94
-0.00
O
N
O
O
CF3
4l
4lE
4lZ
9
8
7
6
5
4
3
2
1
ppm
0.5
0.9
1.0
0.6
1.0
0.6
2.0
4.2
0.6
1.2
0.6
1.0
1.2
2.0
1.6
3.1


O
N
O
O
CF3
4I
4IE
4IZ
160
140
120
100
80
60
40
20
ppm

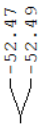

-49.09
-49.12
-51.73
-51.76
O
N
O
O
CF3
4I
4IE
4IZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

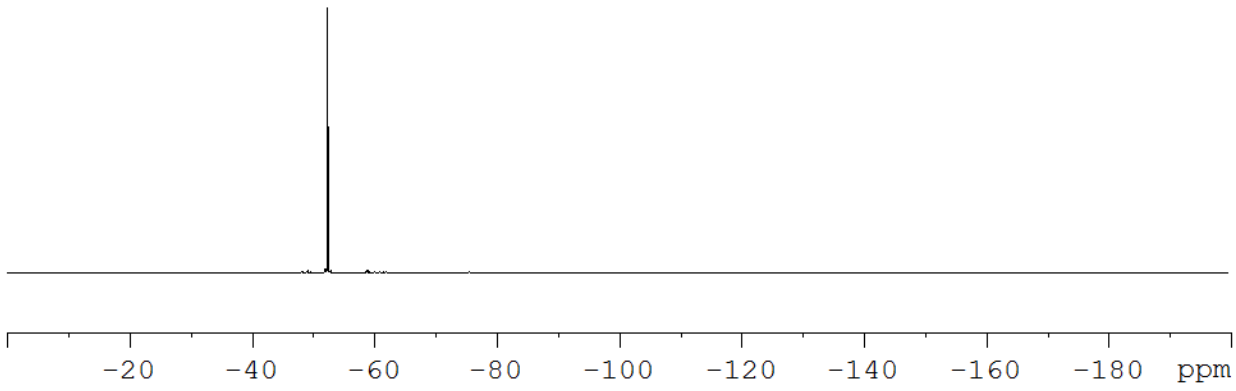

9.15
9.00
8.99
7.97
7.97
7.96
7.96
7.37
7.37
7.35
7.34
7.34
7.31
7.30
7.29
7.28
7.28
7.27
6.18
6.15
6.13
6.11
5.09
0.01
-0.00
-0.01
O
N
N
CF3
4mE
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
2.1
3.1
1.0
2.0

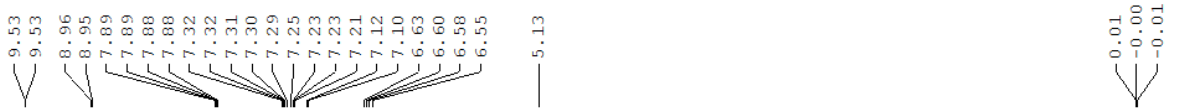

O
N
N
CF3
4mE
160
140
120
100
80
60
40
20
ppm

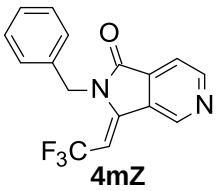

O
N
N
CF3

4mE

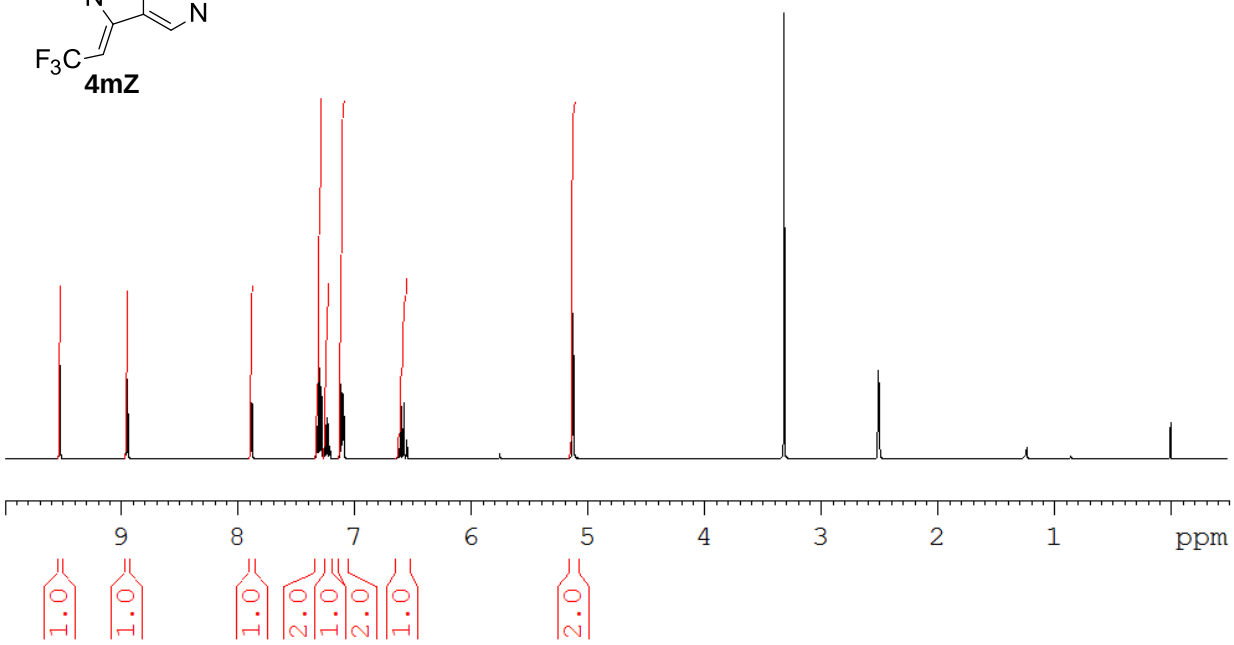

-52.47
-52.49

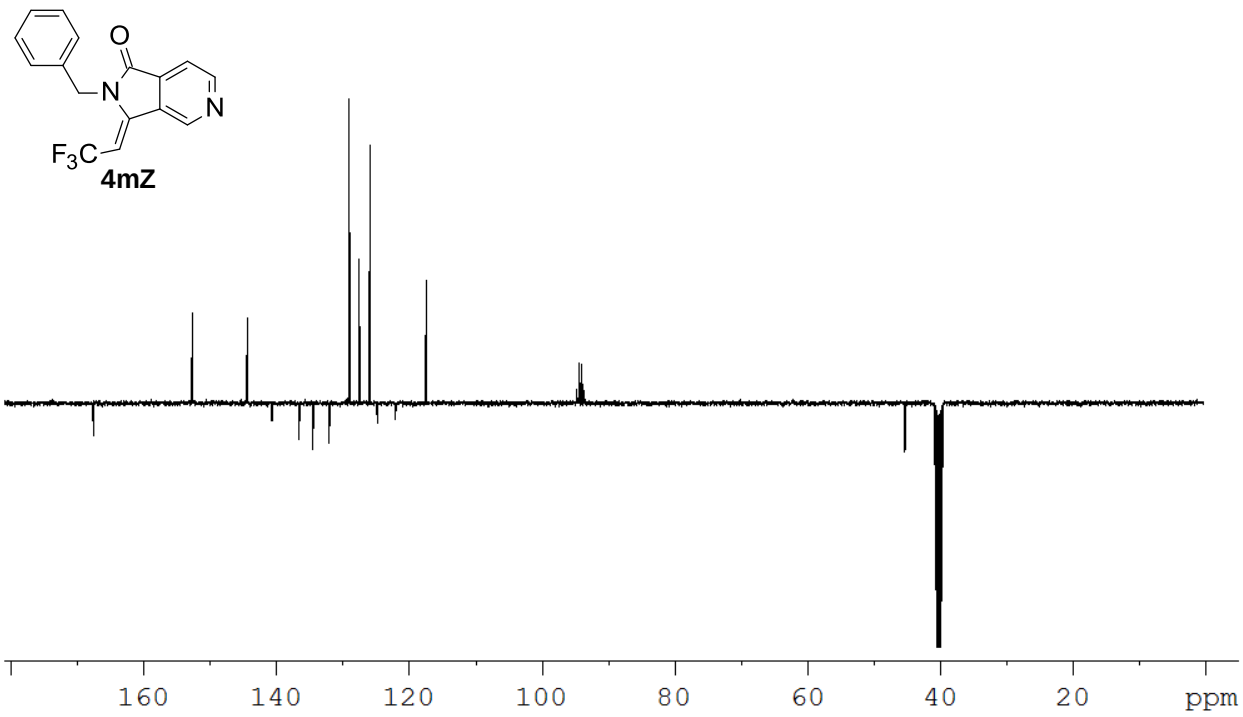

-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

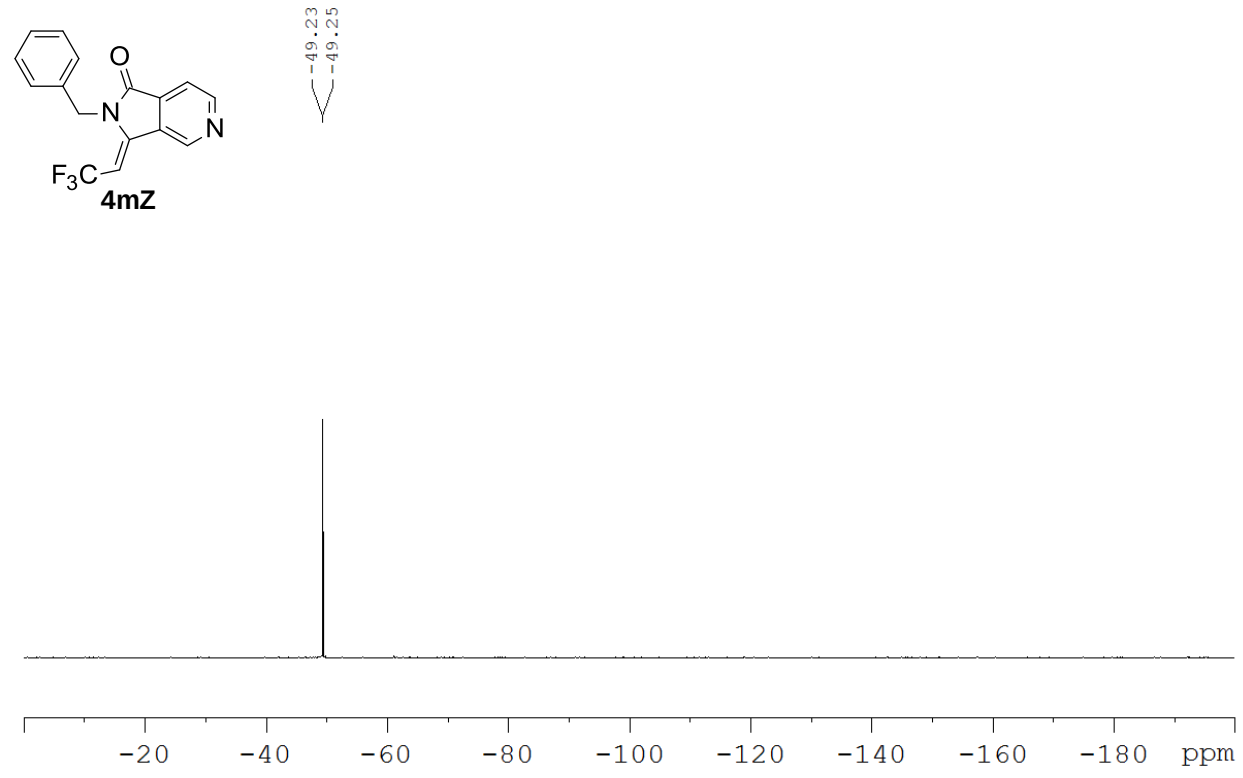

9.53
9.53
8.96
8.95
7.89
7.89
7.88
7.88
7.32
7.31
7.30
7.29
7.25
7.23
7.23
7.21
7.12
7.10
6.63
6.60
6.58
6.55
5.13
0.01
0.00
-0.01

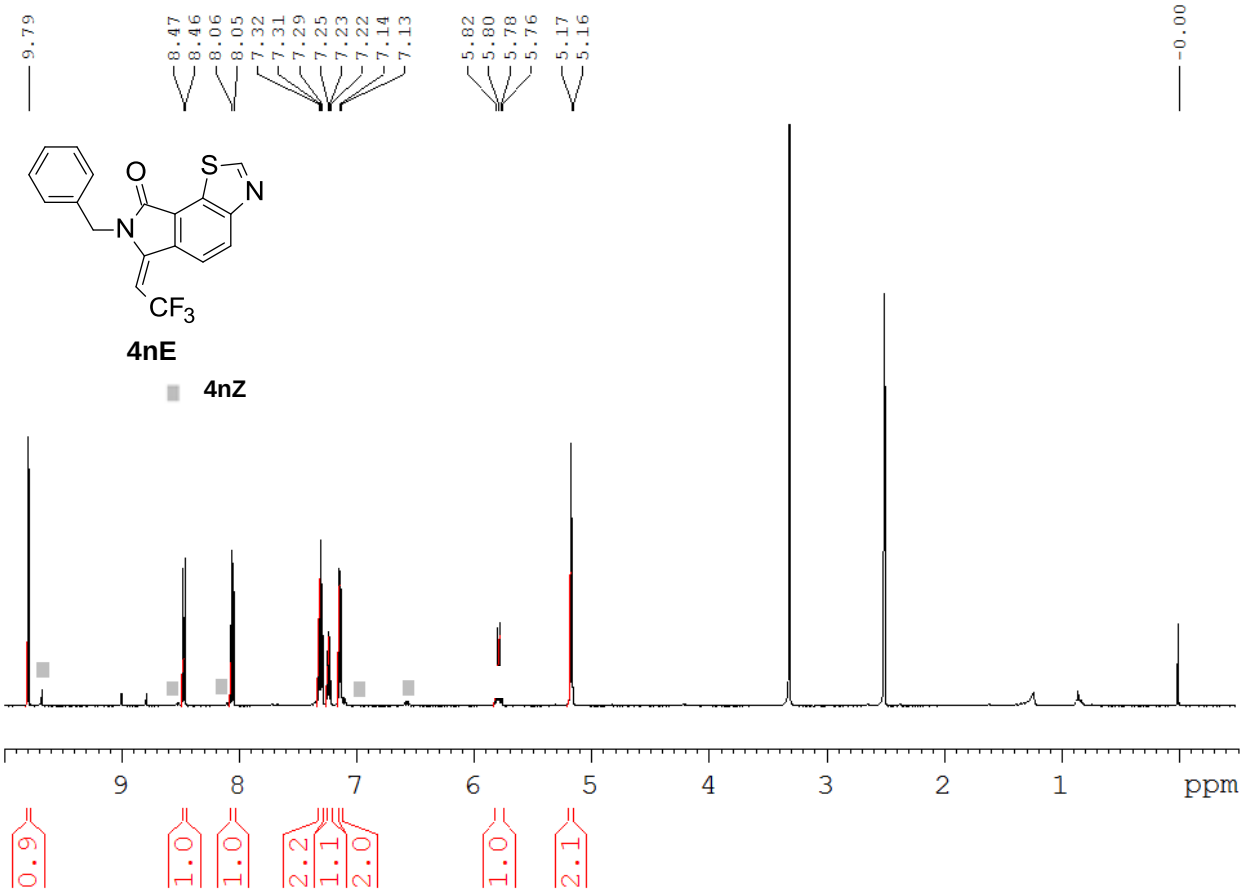

O
N
N
F3C

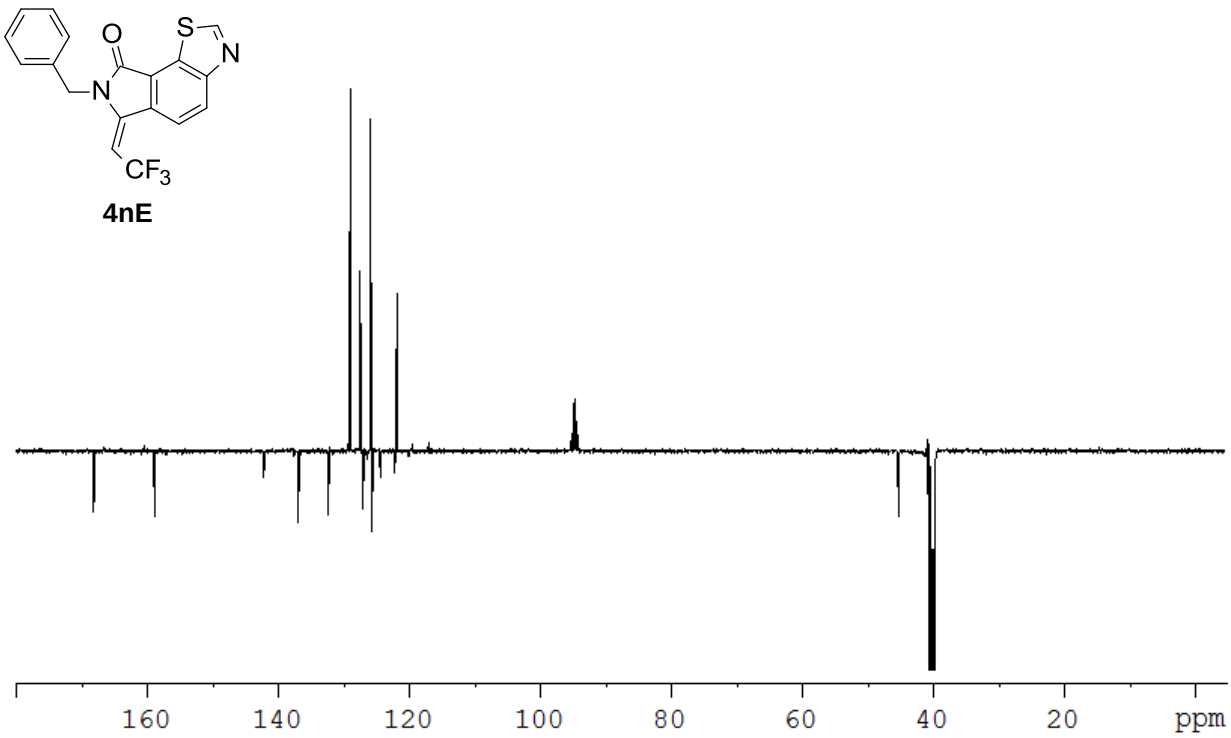
4mZ

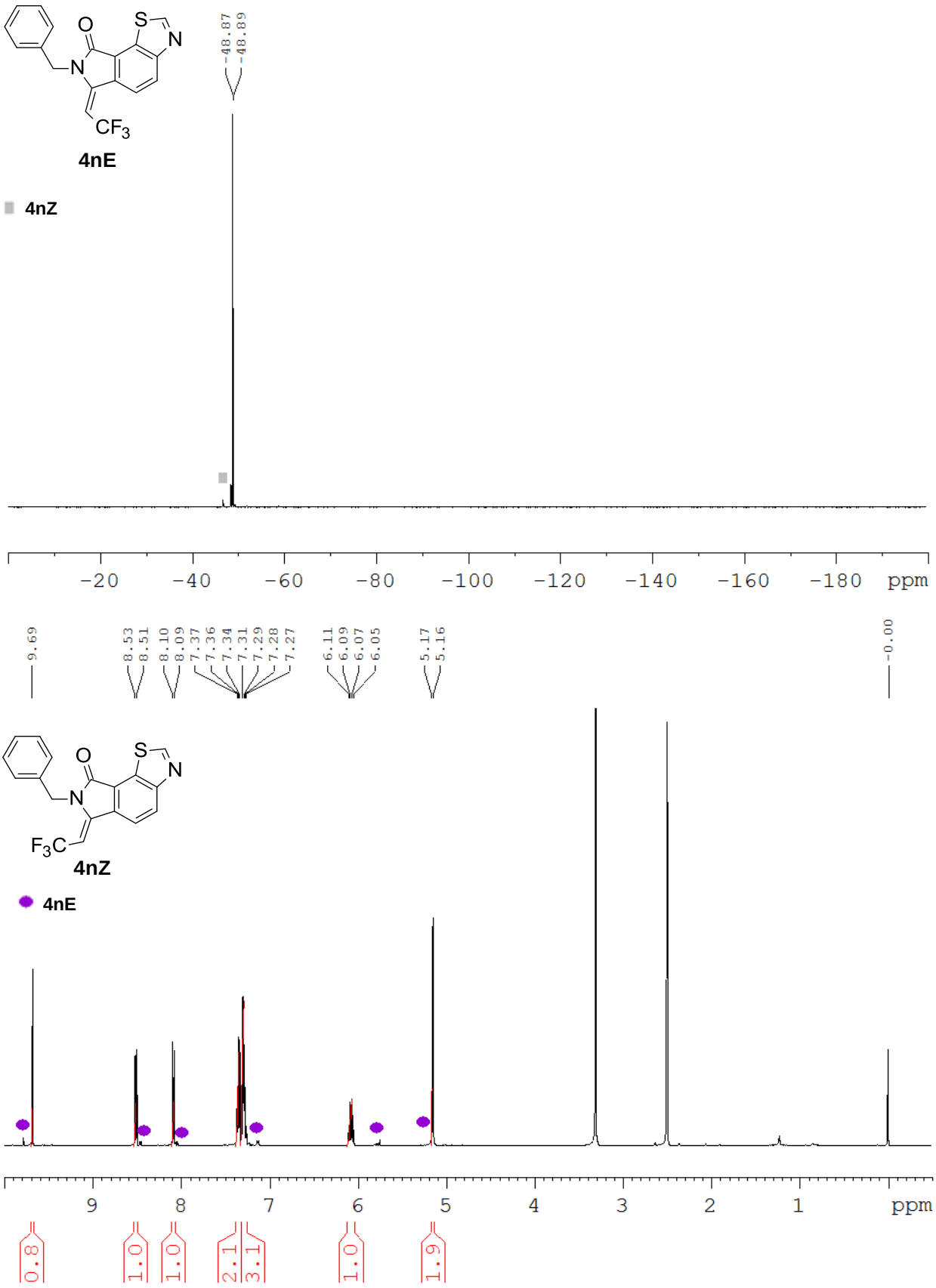

9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
2.0
1.0
2.0
1.0
2.0

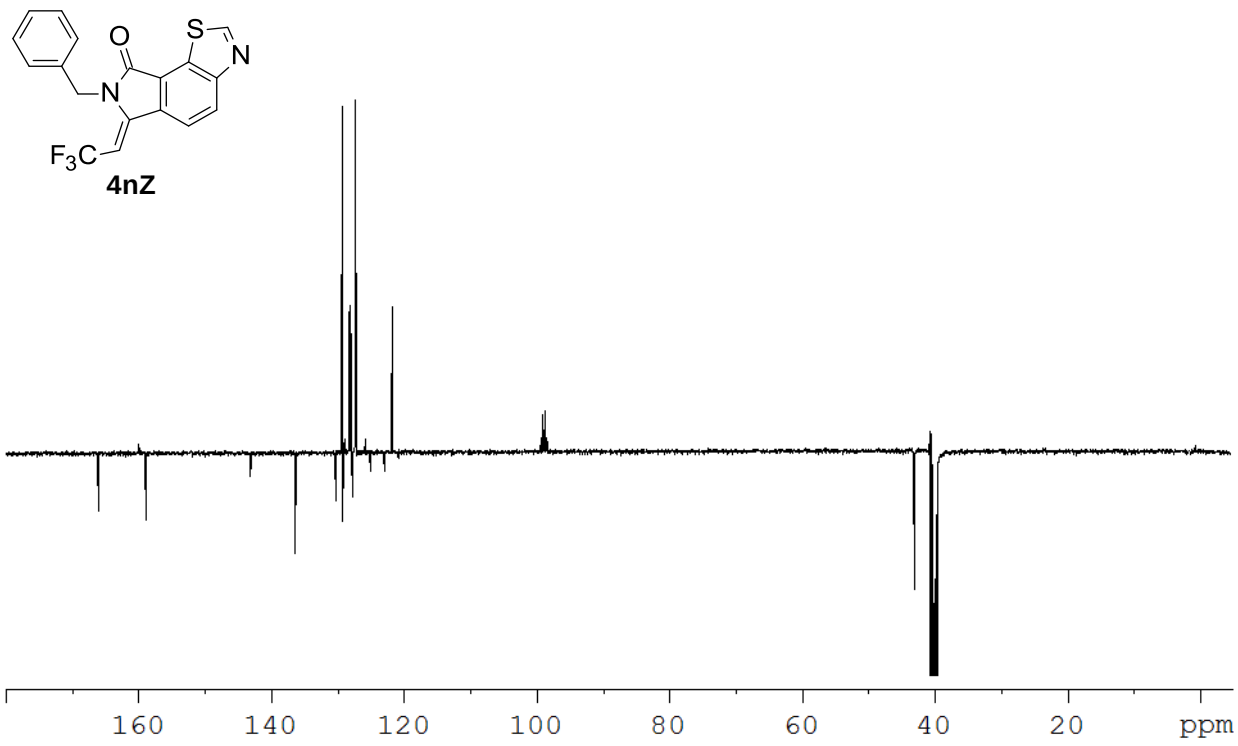

O
N
N
F3C
4mZ
160
140
120
100
80
60
40
20
ppm

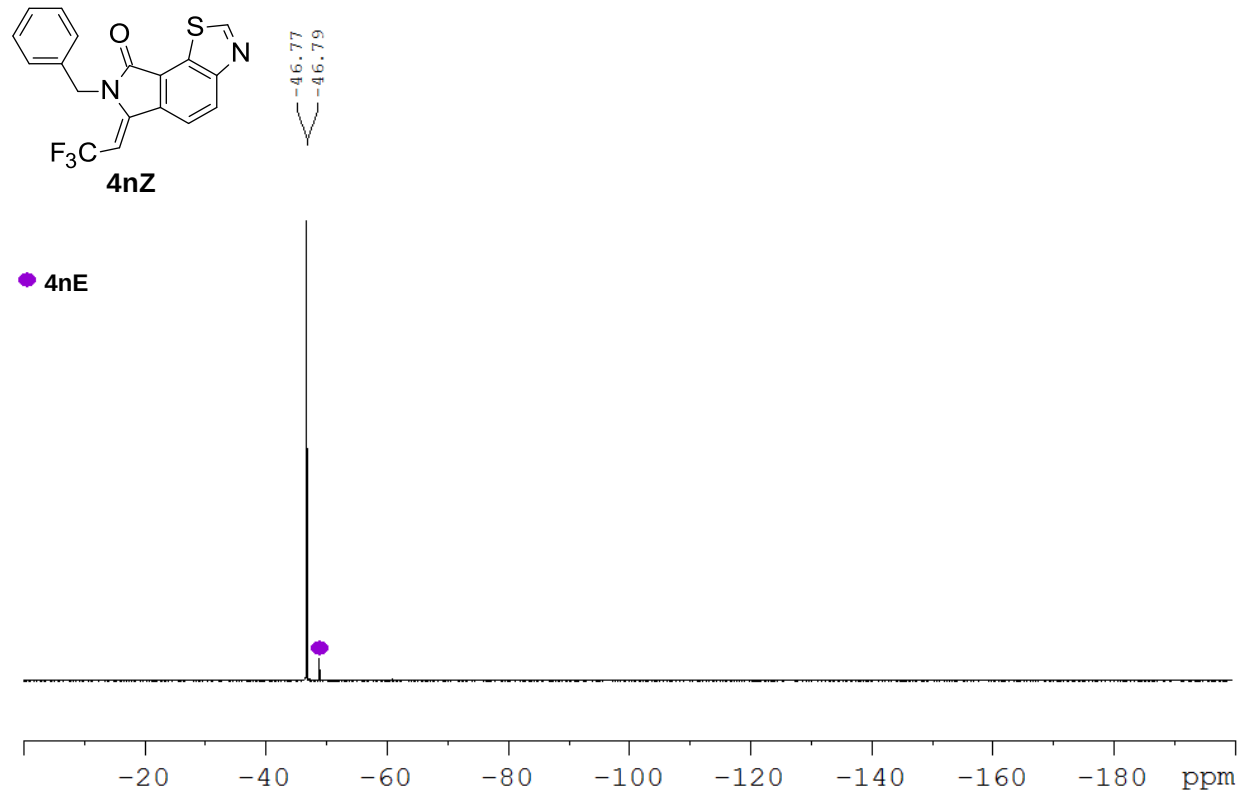

O
N
N
F3C
4mZ
-49.23
-49.25
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

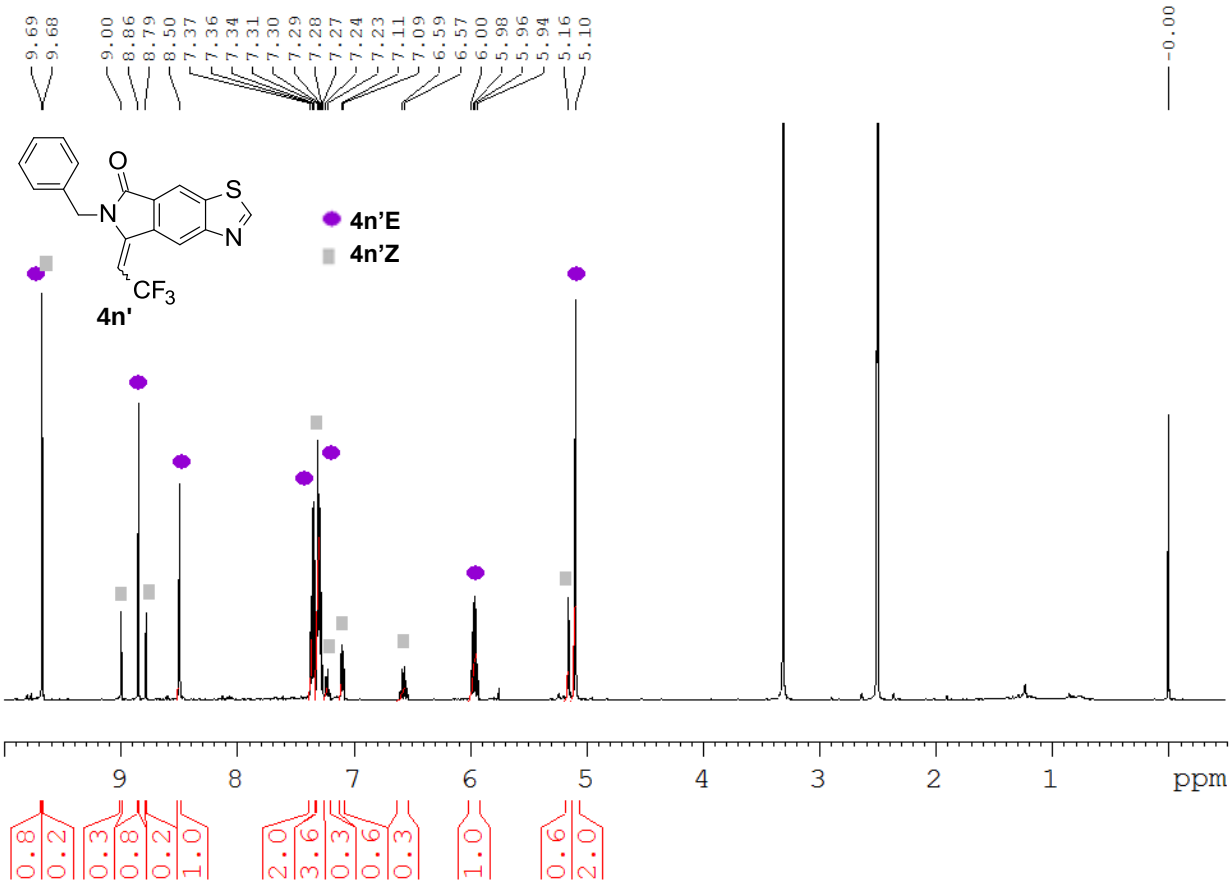

9.79
8.47
8.46
8.06
8.05
7.32
7.31
7.29
7.25
7.23
7.22
7.14
7.13
5.82
5.80
5.78
5.76
5.17
5.16
0.00
O
S
N
N
CF3
4nE
4nZ
9
8
7
6
5
4
3
2
1
ppm
0.9
1.0
1.0
2.2
1.1
2.0
1.0
2.1

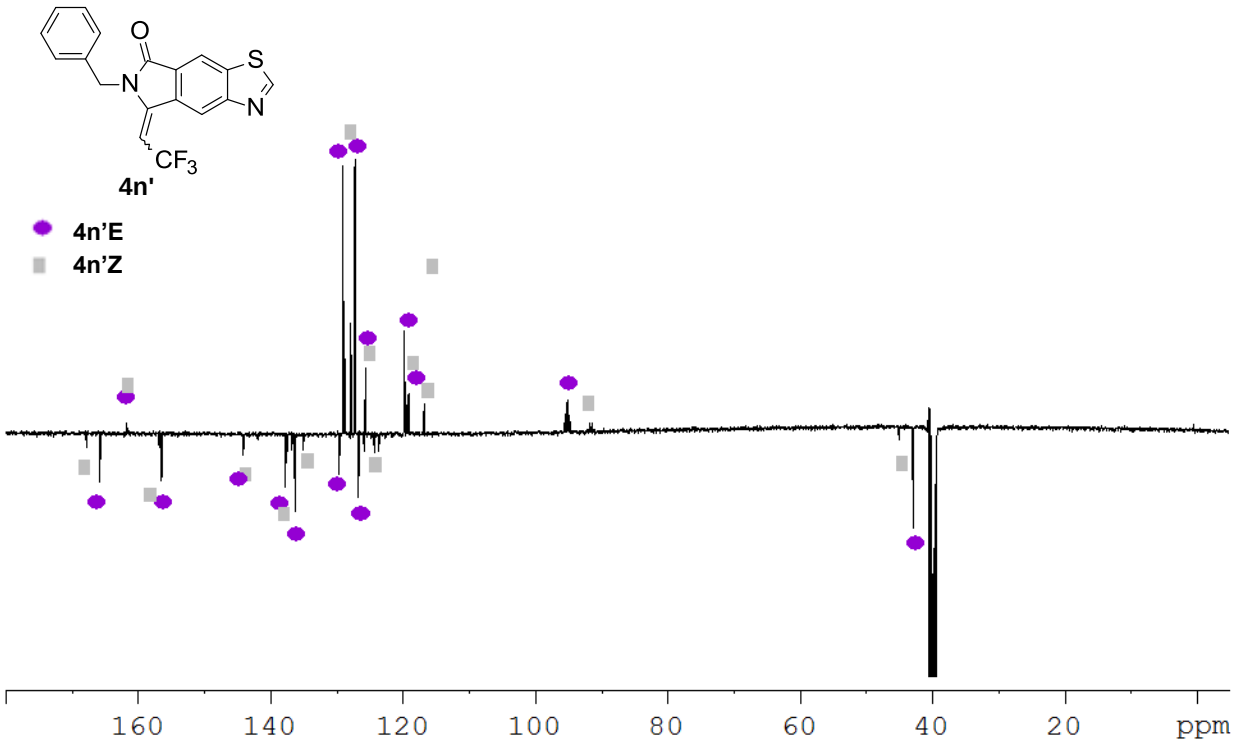

O
S
N
N
CF3
4nE
160
140
120
100
80
60
40
20
ppm

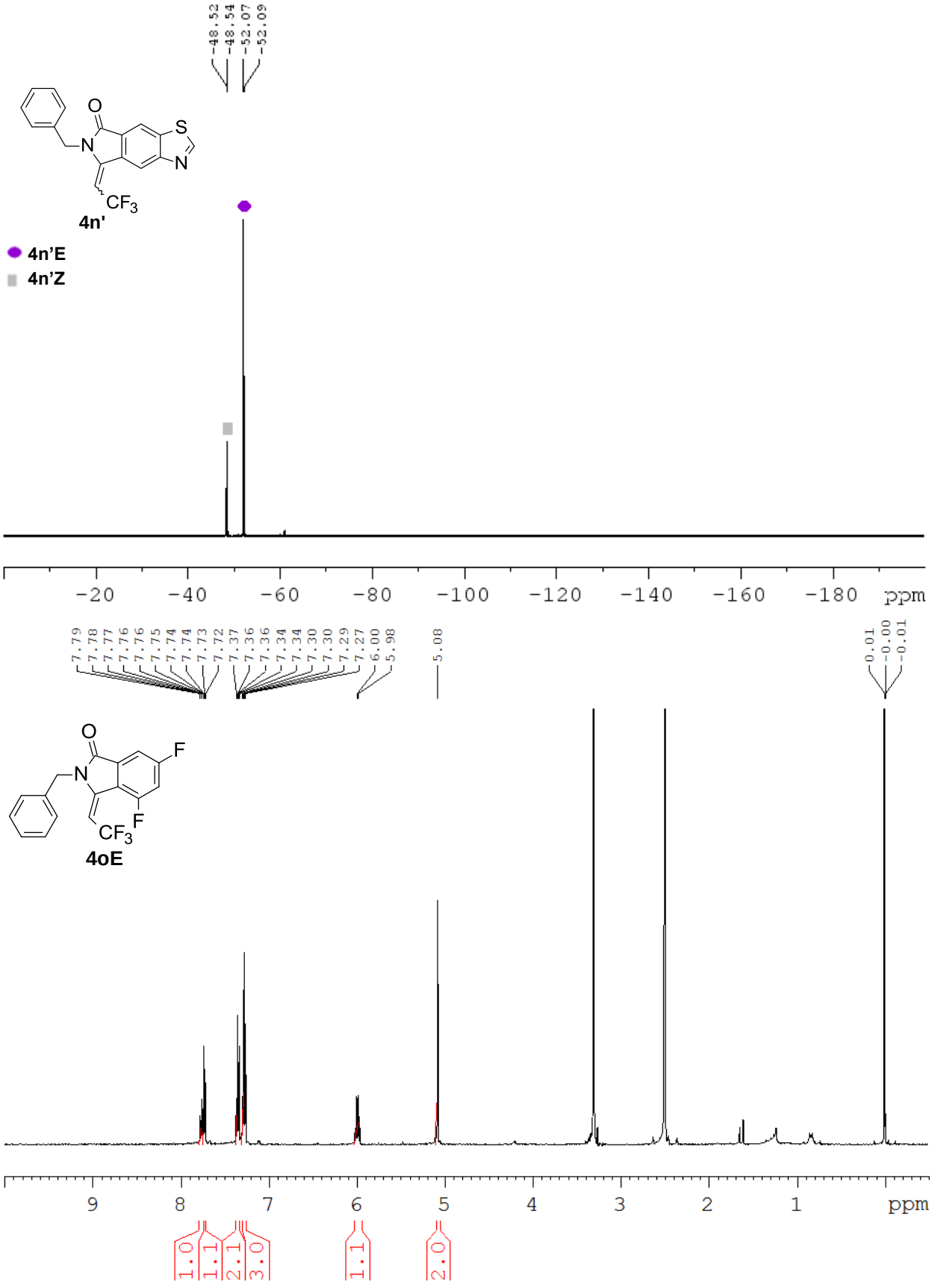

4nE
4nZ
-48.87
-48.89
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm
9.69
8.53
8.51
8.10
8.09
7.37
7.36
7.34
7.31
7.29
7.28
7.27
6.11
6.09
6.07
6.05
5.17
5.16
-0.00
4nZ
4nE
9
8
7
6
5
4
3
2
1
ppm
0.8
1.0
1.0
2.1
3.1
1.0
1.9

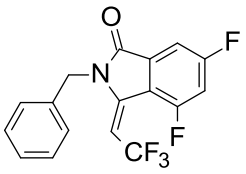

O
S
N
N
F3C
4nZ
160
140
120
100
80
60
40
20
ppm


O
S
N
N
F3C
4nZ
-46.77
-46.79
4nE
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

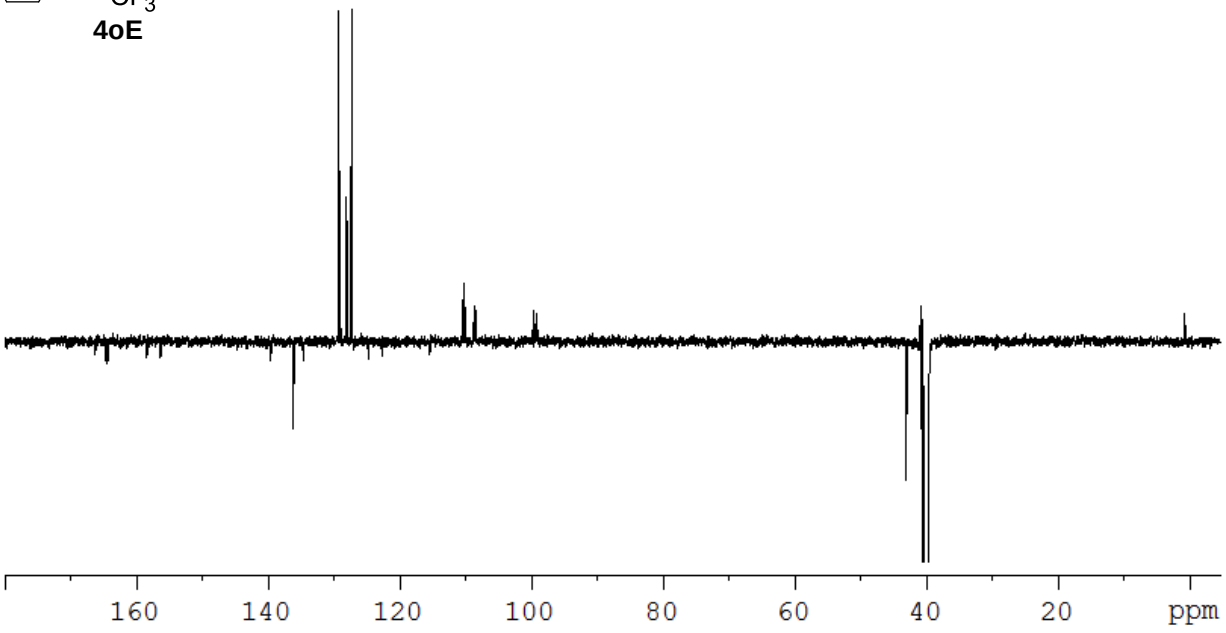

9.69
9.68
9.00
8.86
8.79
8.50
7.37
7.36
7.34
7.31
7.30
7.29
7.28
7.27
7.24
7.23
7.11
7.09
6.59
6.57
6.00
5.98
5.96
5.94
5.16
5.10
-0.00
O
S
N
N
CF3
4n'
4n'E
4n'Z
9
8
7
6
5
4
3
2
1
ppm
0.8
0.2
0.3
0.8
0.2
1.0
2.0
3.6
0.3
0.6
0.3
1.0
0.6
2.0

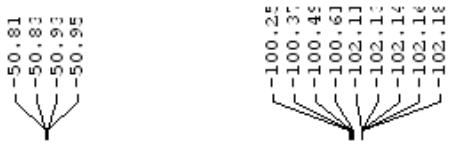

O
S
N
N
CF3
4n'
4n'E
4n'Z
160
140
120
100
80
60
40
20
ppm

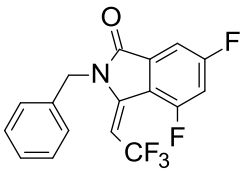

-48.52
-48.54
-52.07
-52.09
4n'
4n'E
4n'Z
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm
7.79
7.78
7.77
7.76
7.76
7.75
7.74
7.74
7.73
7.72
7.37
7.36
7.36
7.34
7.34
7.30
7.30
7.29
7.27
6.00
5.98
5.08
0.01
0.00
-0.01
4oE
9
8
7
6
5
4
3
2
1
ppm
1.0
1.1
2.1
3.0
1.1
2.0


O
F
N
F
CF3

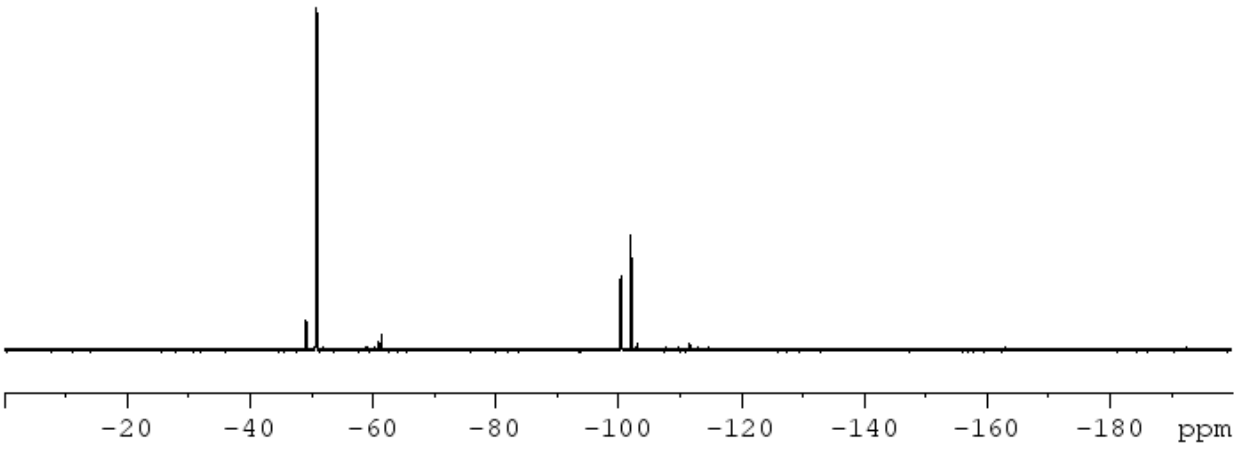
4oE

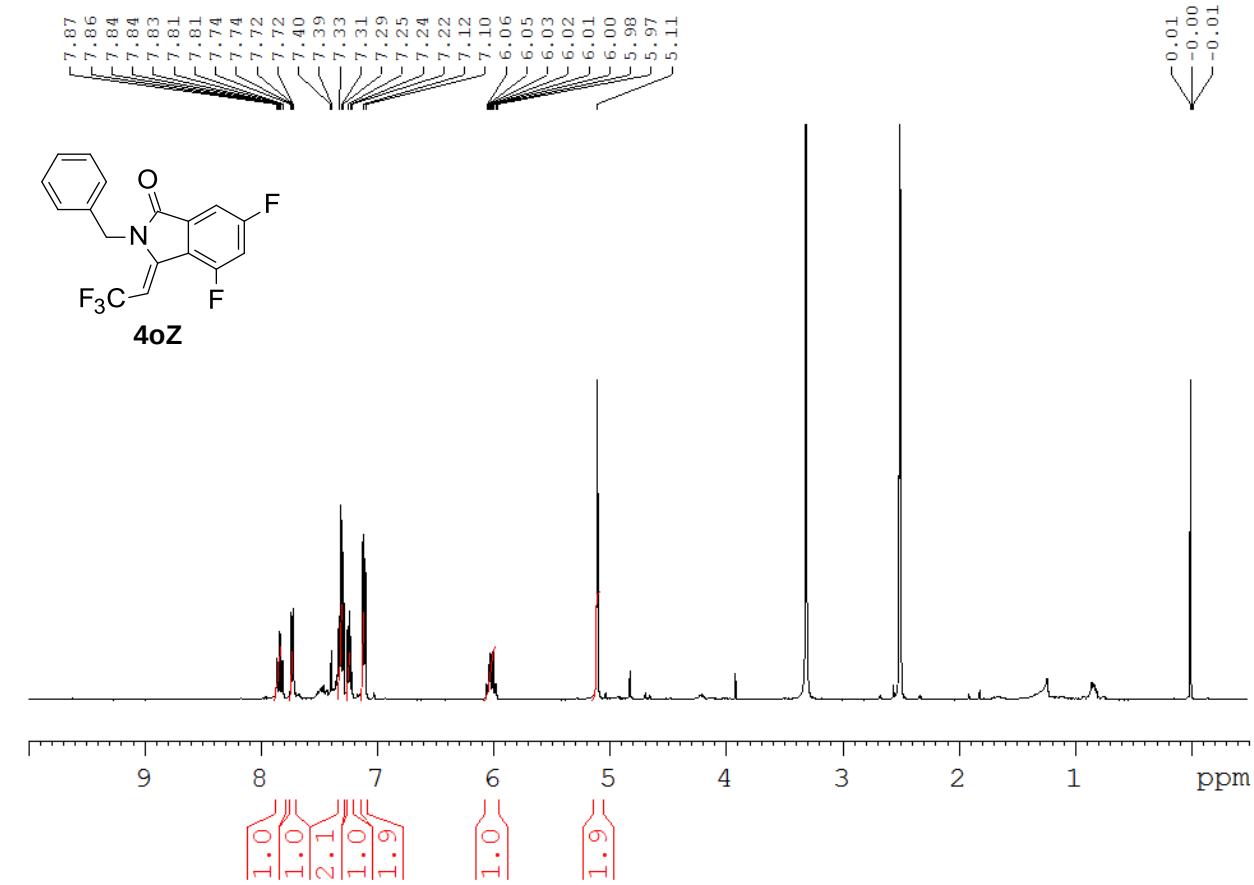

160
140
120
100
80
60
40
20
ppm

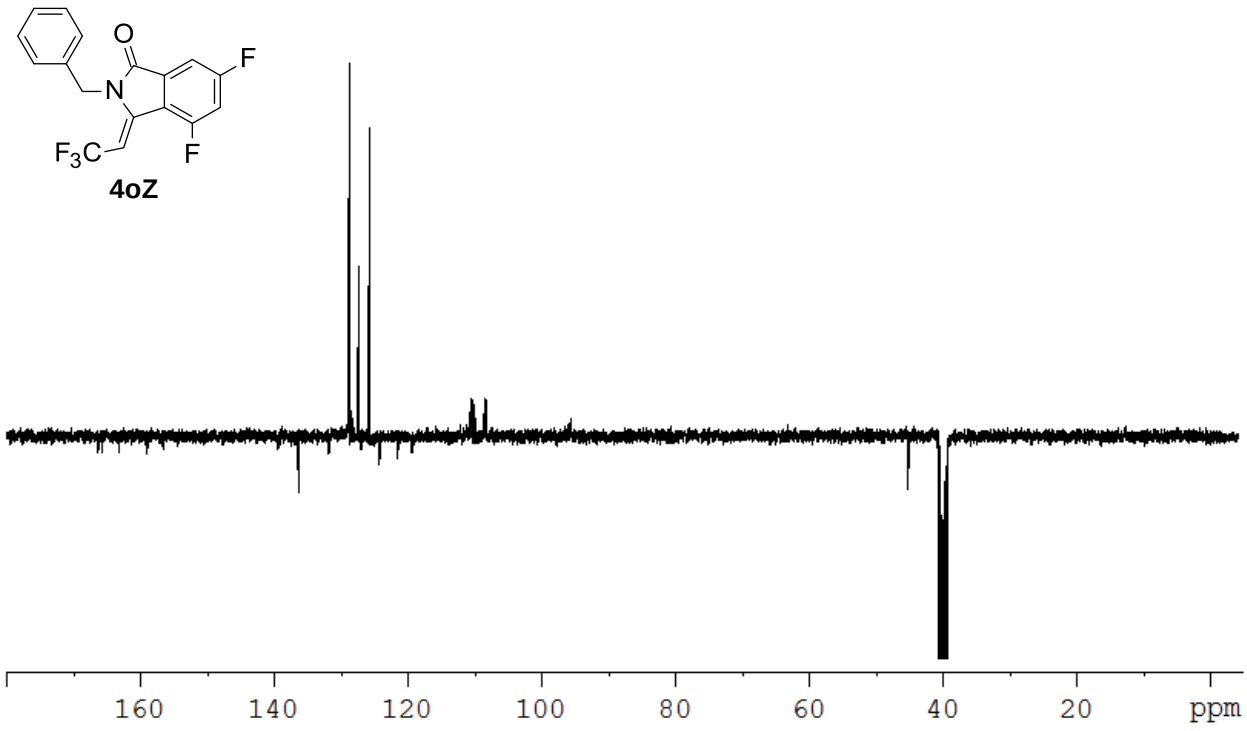

-50.81
-50.83
-50.93
-50.95
-100.25
-100.61
-102.11

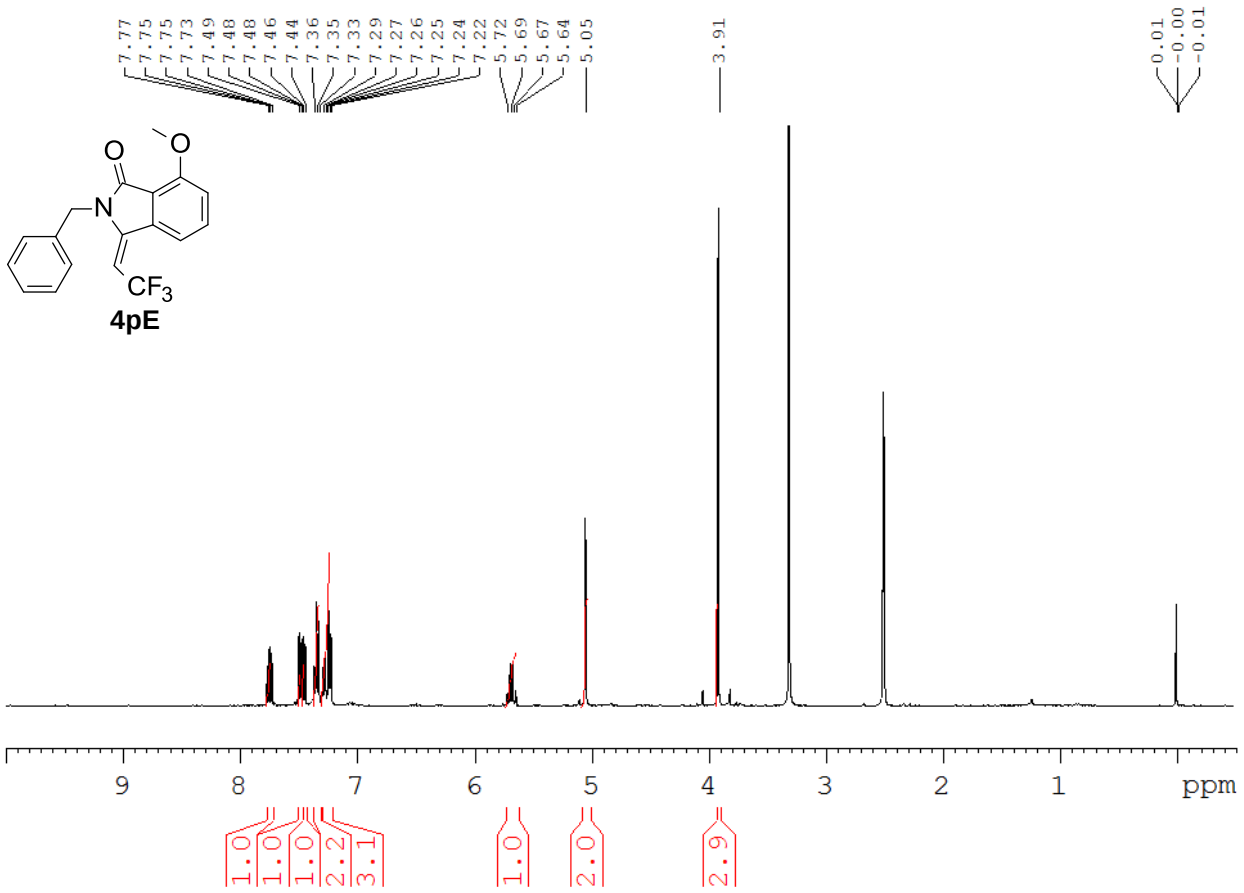

O
F
N
F
CF3

4oE

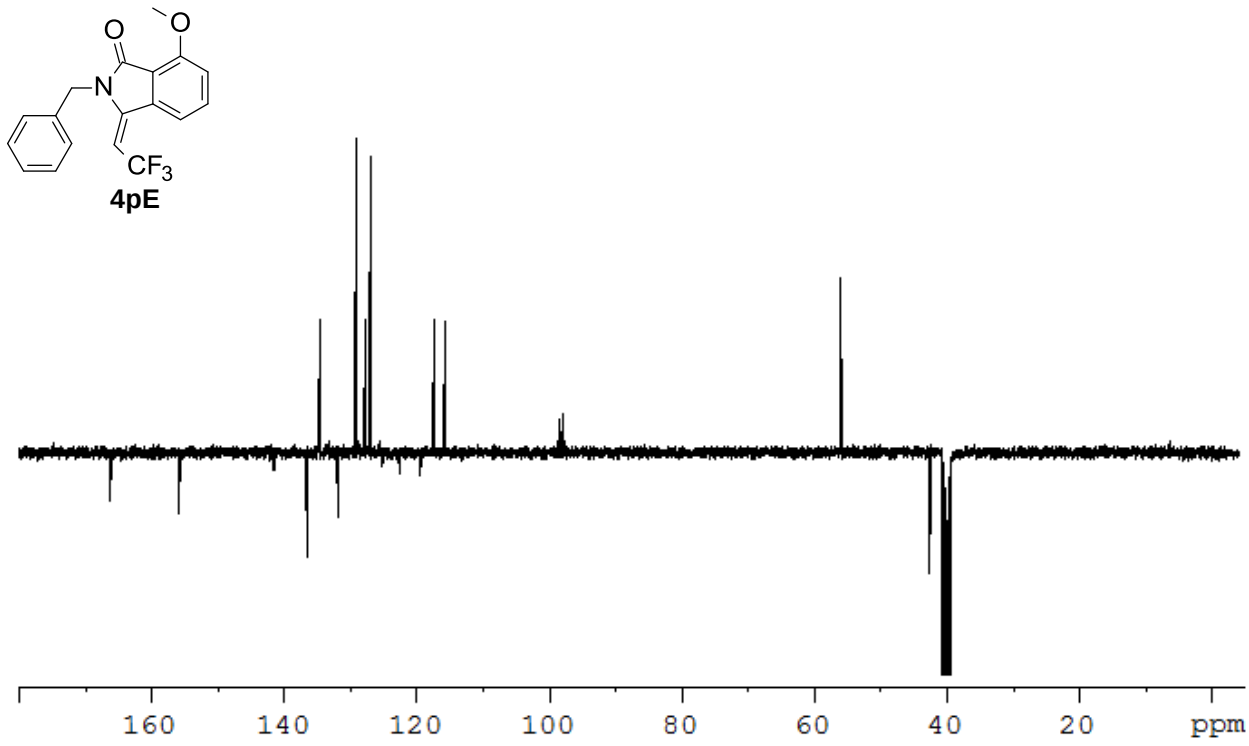

-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


7.87
7.86
7.84
7.84
7.83
7.81
7.81
7.74
7.74
7.72
7.72
7.40
7.39
7.33
7.31
7.29
7.25
7.24
7.22
7.12
7.10
6.06
6.05
6.03
6.02
6.01
6.00
5.98
5.97
5.11
0.01
-0.00
-0.01
O
N
F
F3C
F
4oZ
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
2.1
1.0
1.9
1.0
1.9

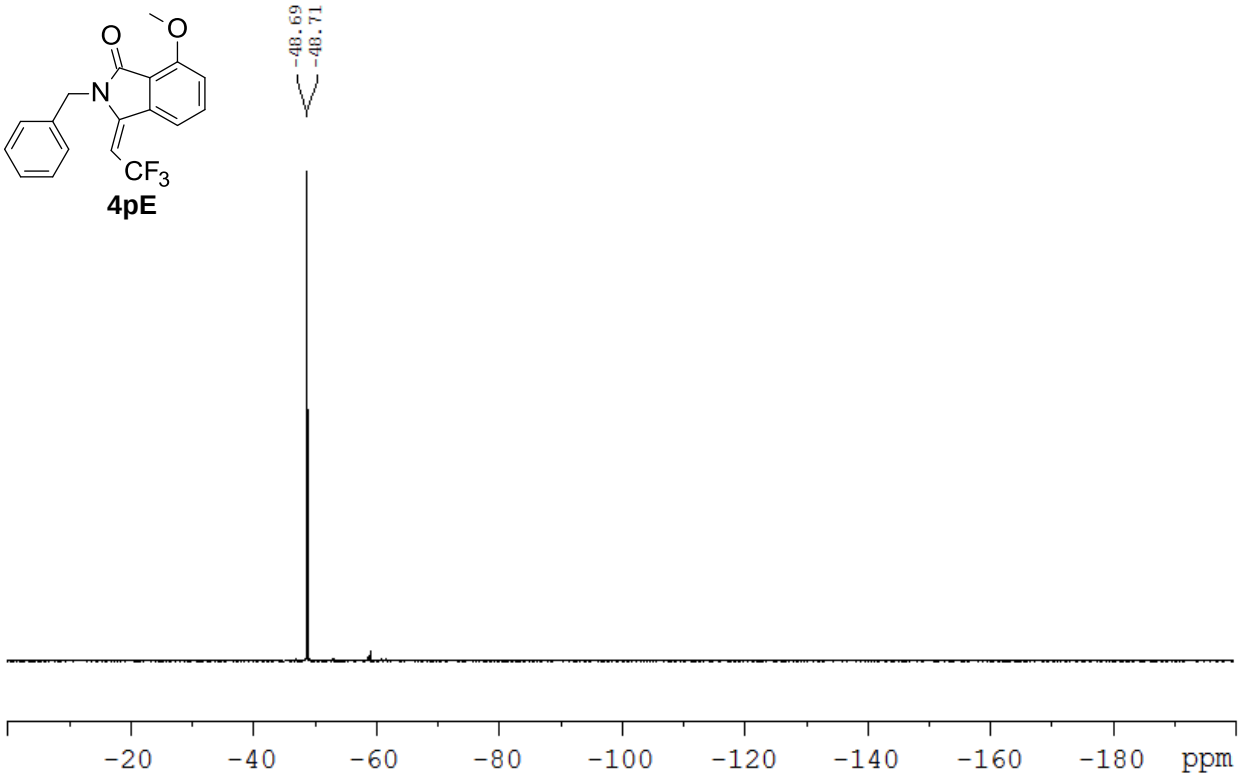

O
N
F
F3C
F
4oZ
160
140
120
100
80
60
40
20
ppm

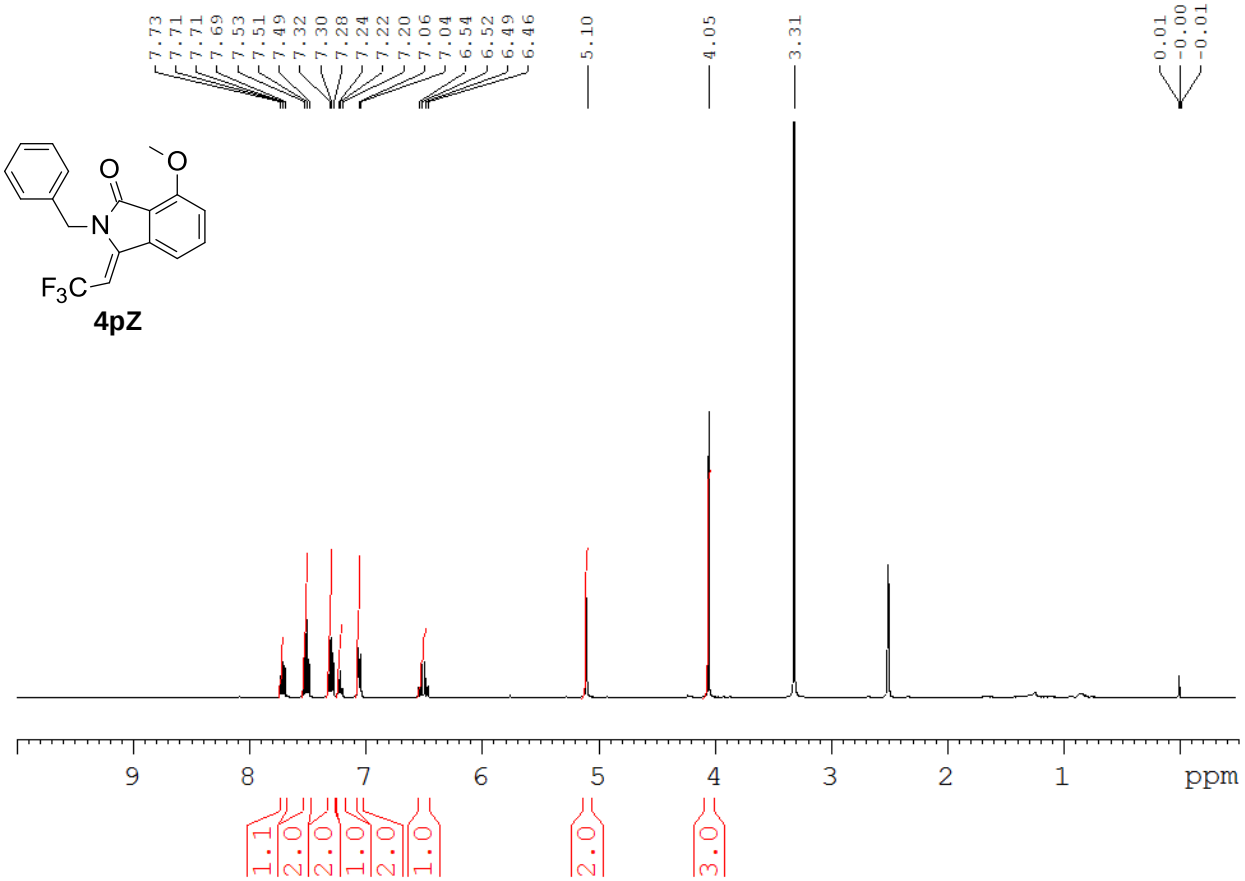

7.77
7.75
7.75
7.73
7.49
7.48
7.48
7.46
7.44
7.36
7.35
7.33
7.29
7.27
7.26
7.25
7.24
7.22
5.72
5.69
5.67
5.64
5.05
3.91
0.01
0.00
-0.01
O
O
N
CF3
9
8
7
6
5
4
3
2
1
ppm
1.0
1.0
1.0
2.2
3.1
1.0
2.0
2.9

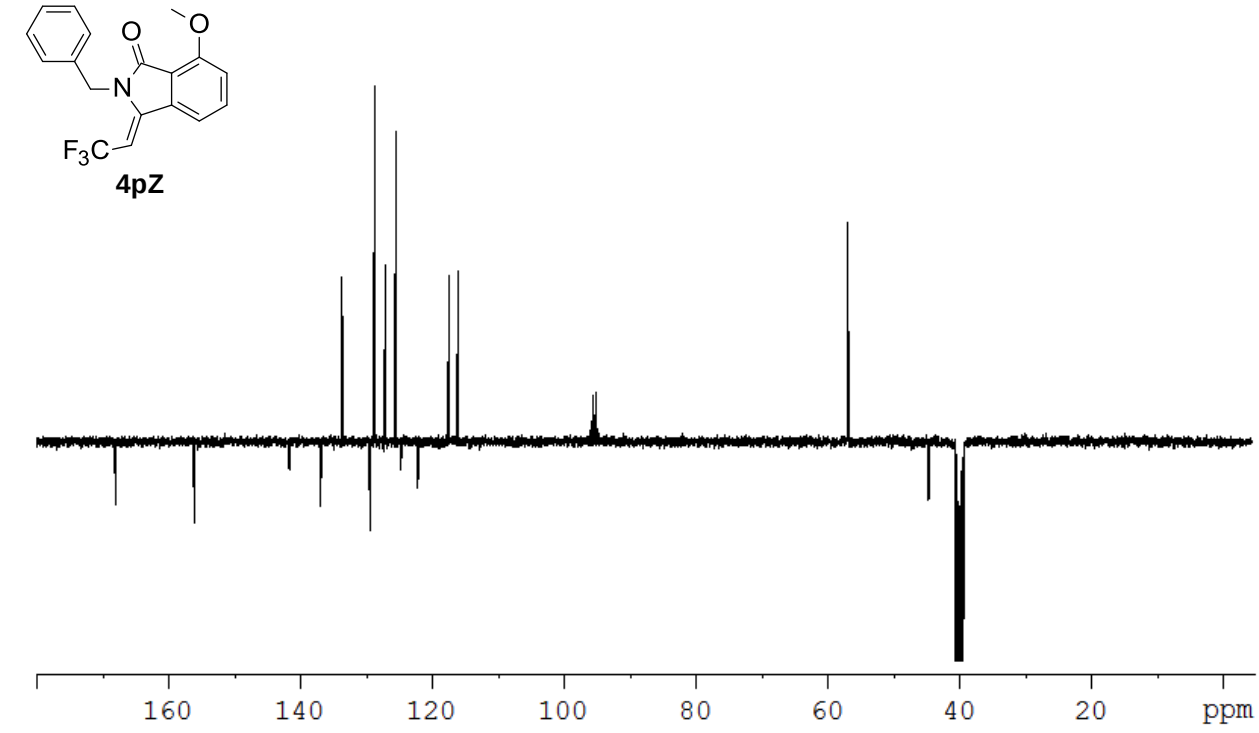
4pE


O
O
N
CF3
160
140
120
100
80
60
40
20
ppm

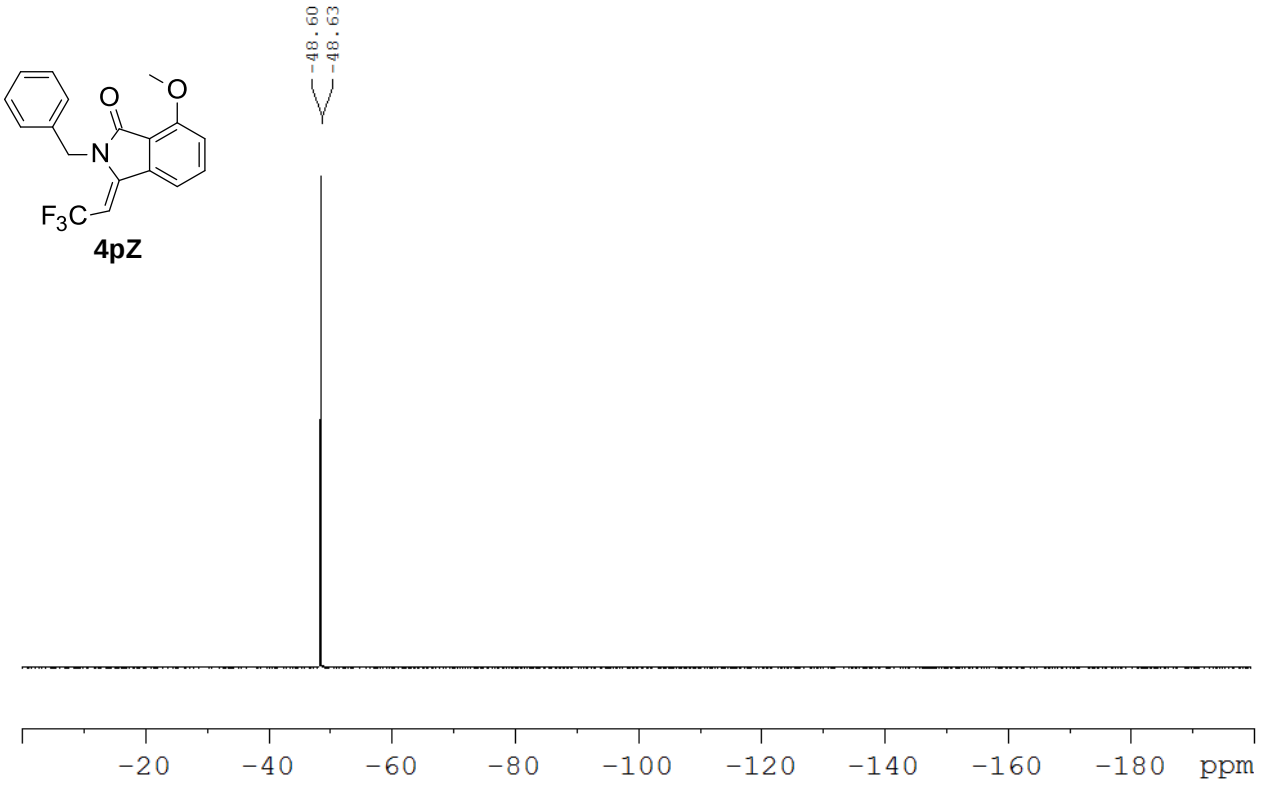
4pE


-48.69
-48.71
4pE
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

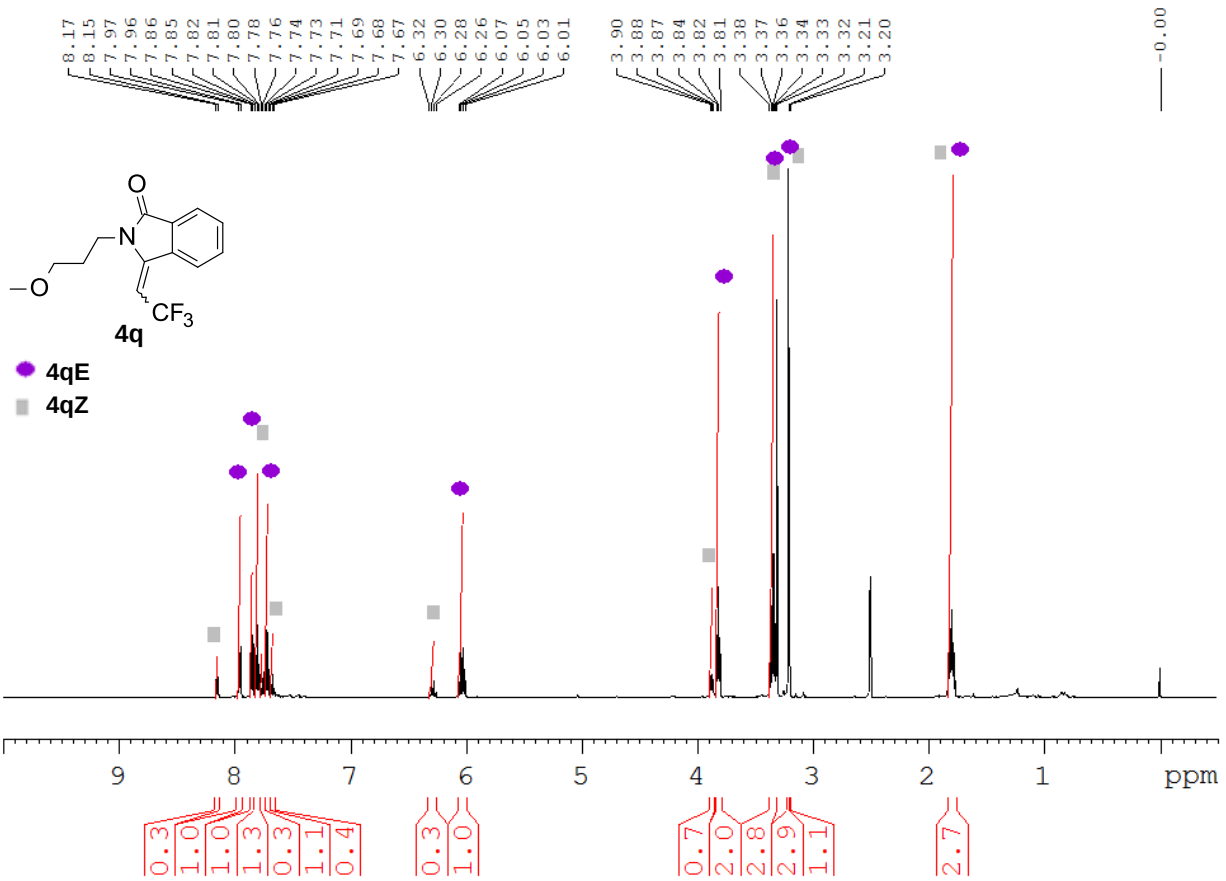

7.73
7.71
7.71
7.69
7.53
7.51
7.49
7.32
7.30
7.28
7.24
7.22
7.20
7.06
7.04
6.54
6.52
6.49
6.46
5.10
4.05
3.31
0.01
-0.00
-0.01
4pZ
9
8
7
6
5
4
3
2
1
ppm
1.1
2.0
2.0
1.0
2.0
1.0
2.0
3.0

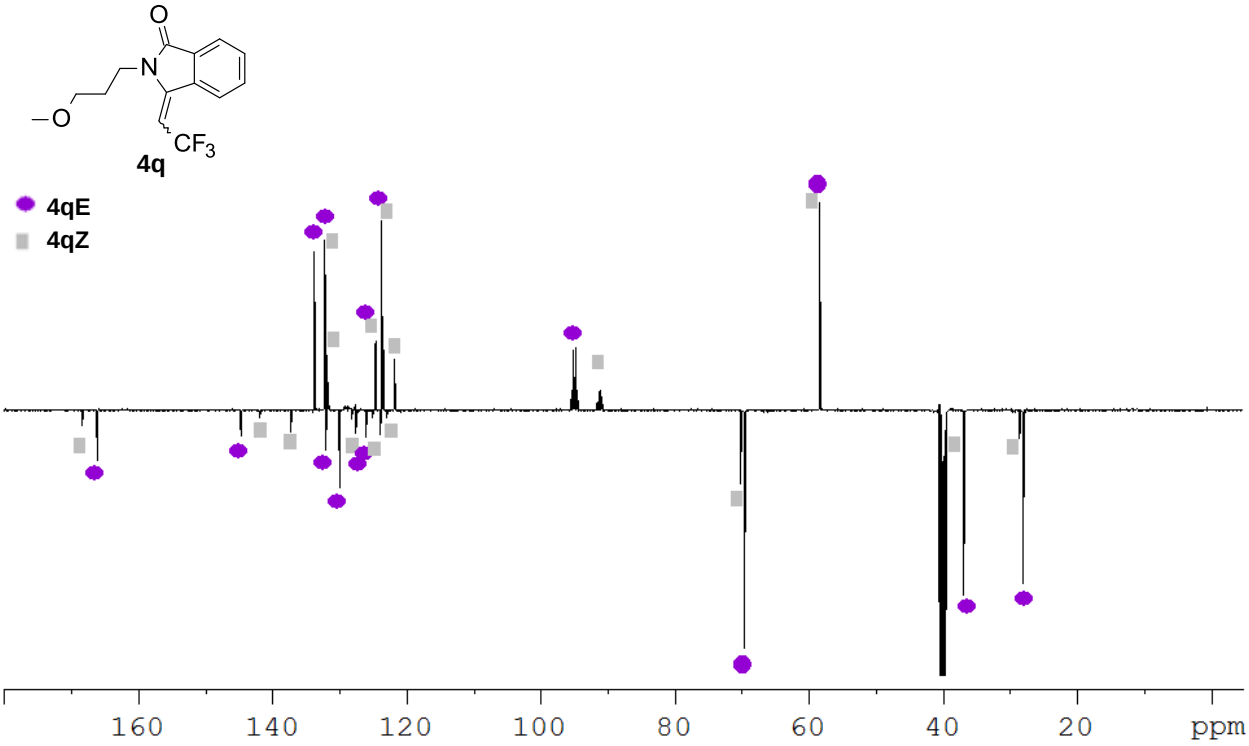

O
O
N
F3C
160
140
120
100
80
60
40
20
ppm

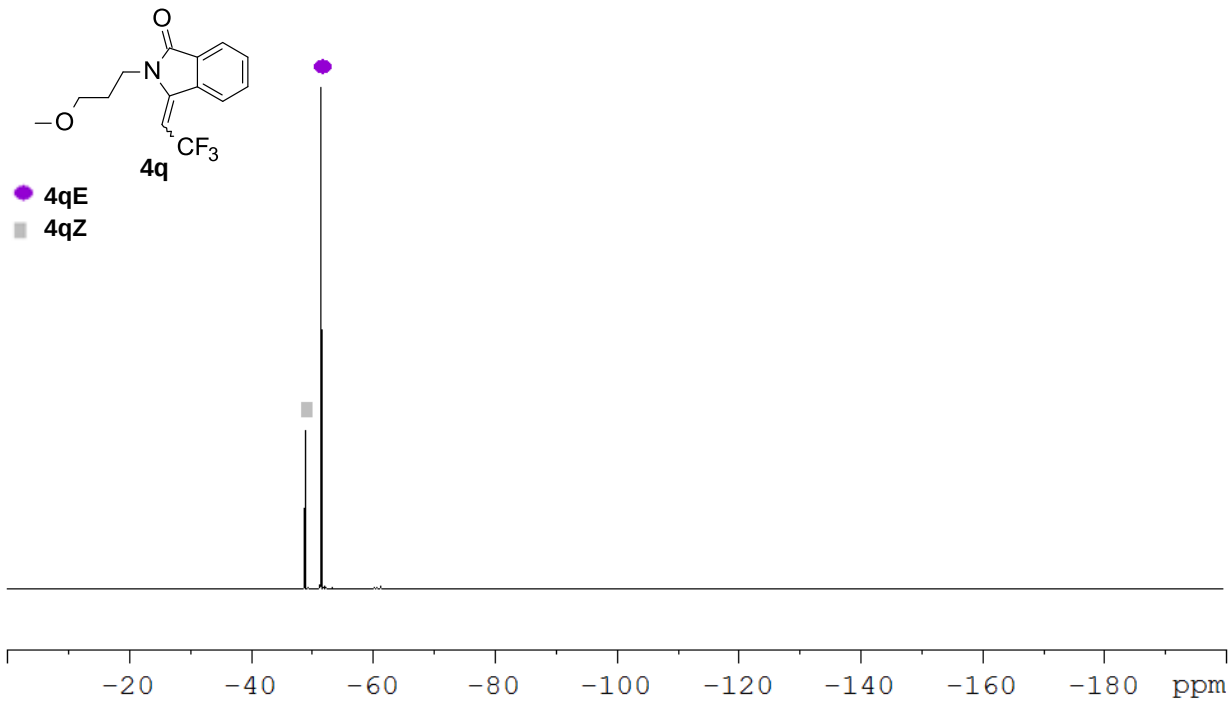
4pZ


-48.60
-48.63
O
O
N
F3C
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

4pZ


8.17
8.15
7.97
7.96
7.86
7.85
7.82
7.81
7.80
7.78
7.76
7.74
7.73
7.71
7.69
7.68
7.67
6.32
6.30
6.28
6.26
6.07
6.05
6.03
6.01
3.90
3.88
3.87
3.84
3.82
3.81
3.38
3.37
3.36
3.34
3.33
3.32
3.21
3.20
-0.00
O
N
O
CF3
4q
4qE
4qZ
9
8
7
6
5
4
3
2
1
ppm
0.3
1.0
1.0
1.3
0.3
1.1
0.4
0.3
1.0
0.7
2.0
2.8
2.9
1.1
2.7


O
N
O
CF3
4q
4qE
4qZ
160
140
120
100
80
60
40
20
ppm


O
N
O
CF3
4q
4qE
4qZ
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm