Electronic supplementary information (ESI)

Supporting Information

Photoredox-catalyzed intermolecular azidosulfonylation of alkenes with DABCO$^{\cdot}(SO_2)_2$, trimethylsilyl azide and thianthrenium salts

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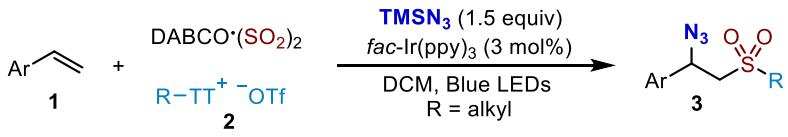
1. General Information

Unless otherwise stated, all commercial reagents were used as received. All solvents were dried and distilled according to standard procedures. Flash column chromatography was performed using silica gel (60-Å pore size, 32–63μm, standard grade). Analytical thin–layer chromatography was performed using glass plates pre-coated with 0.25 mm 230–400 mesh silica gel impregnated with a fluorescent indicator (254 nm). Thin layer chromatography plates were visualized by exposure to ultraviolet light. Organic solutions were concentrated on rotary evaporators at ~20 Torr at 25–35°C. Nuclear magnetic resonance (NMR) spectra are recorded in parts per million from internal tetramethylsilane on the δ scale. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker DRX-400 spectrometer operating at 400 MHz and 100 MHz, respectively. All chemical shift values are quoted in ppm and coupling constants quoted in Hz. High resolution mass spectrometry (HRMS) spectra were obtained on a micrOTOF II Instrument.

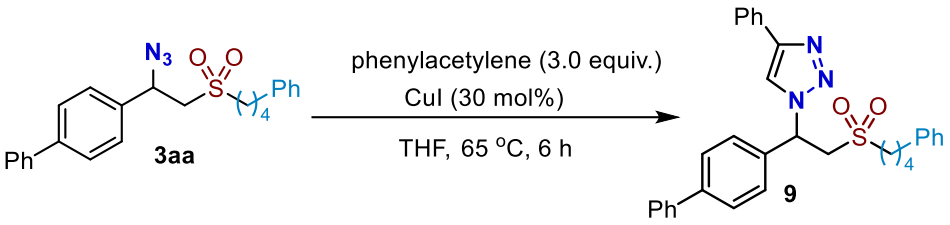
Alkyl thianthrenium salts were prepared according to literature procedures. [1]

2. General Experimental Procedure and Characterization Data.

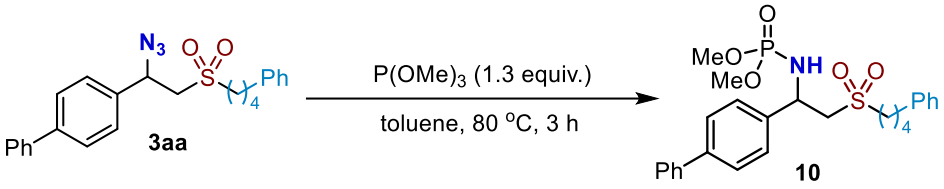


$TMSN_3$ (0.3 mmol) was added to a mixture of alkenes **1** (0.2 mmol), thianthrenium salts **2** (0.4 mmol), DABCO·$(SO_2)_2$ (0.16 mmol) and *fac*-Ir$(ppy)_3$ (3 mol%) in DCM (3 mL) under N_2 atmosphere. The mixture was placed around a 30 W blue LEDs and stirred under blue light irradiation for 12 hours at 20 °C. After completion of reaction as monitored by TLC analysis, the solvent was evaporated and the residue was purified directly by flash column chromatography on silica gel (petroleum ether /ethyl acetate = 4:1-1:1) to give the corresponding products **3**.

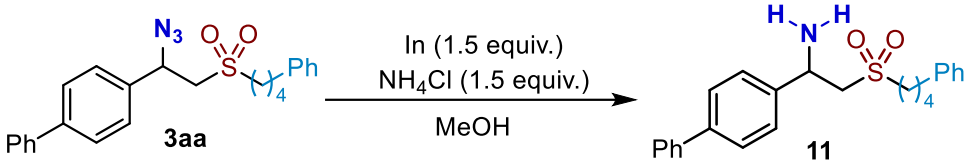
General experimental procedure for further transformation of β-azido sulfones. [2-3]



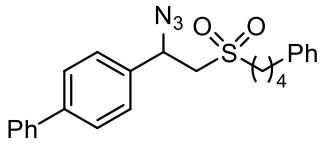
In a flame-dried flask, 4-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-1,1'-biphenyl **3aa** (0.3 mmol) and CuI (30 mol%) were added. Under the protection of N_2, phenylacetylene (3.0 equiv.) and THF (3.0 mL) were injected respectively into the tube via syringes. The reaction mixture was stirred at 65 °C for 6 h. After completition, the reaction mixture was concentrated in vacuo, the crude residue was subjected to flash column chromatography on silica gel (petroleum ether/ethyl acetate/DCM = 6:1:6 – 1:1:6) to yield the desired product **9** in 90% yield.



In a flame-dried flask, 4-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-1,1'-biphenyl **3aa** (0.3 mmol) were added. Under the protection of N_2, $P(OMe)_3$ (1.3 equiv.) and toluene (1.8 mL) were injected respectively into the tube via syringes. The reaction mixture was stirred at 80 °C for 3 h. After completition, the reaction mixture was concentrated in vacuo, the crude residue was subjected to flash column chromatography on silica gel (petroleum ether/ethyl acetate/DCM = 1:1:2 - 1:6:2) to yield the desired product **10** in 96% yield.

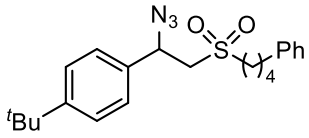


In a flame-dried flask, 4-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-1,1'-biphenyl **3aa** (0.1 mmol) were added, followed by NH_4Cl (0.15 mmol), indium powder (0.15 mmol). Under the protection of N_2, MeOH (2 mL) were injected into the tube via syringes. The reaction mixture was stirred at 65 °C for 6 h. After completition, the reaction mixture was concentrated in vacuo, the crude residue was subjected to flash column chromatography on silica gel (petroleum ether /ethyl acetate = 1:1 – 1:2) to yield the desired product **11** in 64% yield.



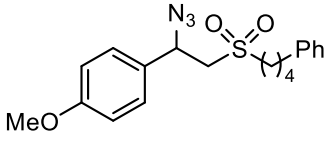
4-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-1,1'-biphenyl (**3aa**, 62.1 mg, 74%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.62 (d, *J* = 8.1 Hz, 2H), 7.56 (d, *J* = 7.3 Hz, 2H), 7.43 (t, *J* = 7.4 Hz, 2H), 7.39 – 7.33 (m, 3H), 7.27 (t, *J* = 7.3 Hz, 2H), 7.20 – 7.13 (m, 3H), 5.15 (dd, *J* = 9.8, 3.4 Hz, 1H), 3.42 (dd, *J* = 14.9, 9.9 Hz, 1H), 3.14 – 3.02 (m, 3H), 2.63 (t, *J* = 7.4 Hz, 2H), 1.91 – 1.82 (m, 2H), 1.78 – 1.69 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.5, 141.2, 140.0, 135.5, 60.5, 58.2, 54.7, 35.3, 30.2, 21.6. **HRMS (ESI)** calcd for $C_{24}H_{25}N_3NaO_2S^+$: 442.1560 (M + Na^+), found: 442.1564.



1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-(*tert*-butyl)benzene (**3ba**, 63.1 mg, 79%), yellow oil

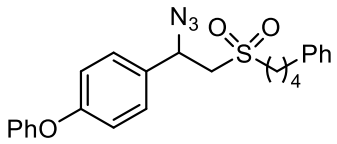
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.44 (d, *J* = 8.1 Hz, 2H), 7.29 (t, *J* = 7.5 Hz, 2H), 7.25 (d, *J* = 8.1 Hz, 2H), 7.23 – 7.15 (m, 3H), 5.09 (dd, *J* = 9.9, 3.1 Hz, 1H), 3.39 (dd, *J* = 14.9, 10.0 Hz, 1H), 3.12 – 2.95 (m, 3H), 2.66 (t, *J* = 7.4 Hz, 2H), 1.93 – 1.82 (m, 2H), 1.80 – 1.69 (m, 2H), 1.32 (s, 9H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 152.7, 141.2, 133.6, 128.5, 128.4, 126.6, 126.4, 126.1, 60.4, 58.2, 54.6, 35.3, 34.8, 31.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{22}H_{29}N_3NaO_2S^+$: 422.1873 (M + Na^+), found: 422.1883.



1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-methoxybenzene (**3ca**, 38.8 mg, 52%), yellow oil

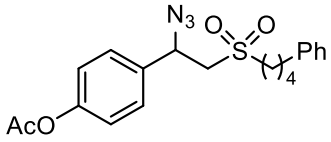
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.30 (t, *J* = 7.4 Hz, 2H), 7.27 – 7.20 (m, 3H), 7.17 (d, *J* = 7.4 Hz, 2H), 6.94 (d, *J* = 8.6 Hz, 2H), 5.07 (dd, *J* = 9.8, 3.6 Hz, 1H), 3.82 (s, 3H), 3.39 (dd, *J* = 14.9, 9.8 Hz, 1H), 3.14 – 2.89 (m, 3H), 2.65 (t, *J* = 7.5 Hz, 2H), 1.92 – 1.82 (m, 2H), 1.80 – 1.70 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 160.3, 141.3, 128.5, 128.4, 128.4, 128.3, 126.1, 114.7,

60.3, 58.2, 55.4, 54.6, 35.3, 30.2, 21.5. **HRMS (ESI)** calcd for $C_{19}H_{23}N_3NaO_3S^+$: 396.1352 (M + Na^+), found: 396.1362.



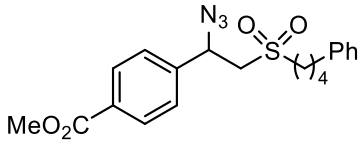
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-phenoxybenzene (**3da**, 55.7 mg, 64%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.37 (t, *J* = 7.8 Hz, 2H), 7.32 – 7.26 (m, 4H), 7.23 – 7.13 (m, 4H), 7.06 – 7.00 (m, 4H), 5.10 (dd, *J* = 9.9, 3.2 Hz, 1H), 3.39 (dd, *J* = 14.9, 10.0 Hz, 1H), 3.15 – 3.03 (m, 3H), 2.67 (t, *J* = 7.4 Hz, 2H), 1.93 – 1.83 (m, 2H), 1.81 – 1.72 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 158.5, 156.2, 141.2, 130.9, 130.0, 128.5, 128.5, 128.4, 126.1, 124.1, 119.6, 119.0, 60.2, 58.2, 54.7, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{24}H_{25}N_3NaO_3S^+$: 458.1509 (M + Na^+), found: 458.1512.



4-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)phenyl acetate (**3ea**, 43.4 mg, 54%), yellow oil

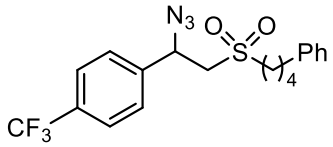
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.35 (d, *J* = 8.5 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 2H), 7.23 – 7.14 (m, 5H), 5.13 (dd, *J* = 10.1, 3.1 Hz, 1H), 3.37 (dd, *J* = 14.9, 10.2 Hz, 1H), 3.16 – 2.97 (m, 3H), 2.67 (t, *J* = 7.4 Hz, 2H), 2.32 (s, 3H), 1.92 – 1.83 (m, 2H), 1.82 – 1.72 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 169.3, 151.3, 141.2, 134.3, 128.5, 128.4, 128.0, 126.1, 122.7, 60.1, 58.2, 54.8, 35.3, 30.1, 21.5, 21.2. **HRMS (ESI)** calcd for $C_{20}H_{23}N_3NaO_4S^+$: 424.1301 (M + Na^+), found: 424.1310.



Methyl 4-(1-azido-2-((4-phenylbutyl)sulfonyl)ethyl)benzoate (**3fa**, 63.4 mg, 79%), yellow oil

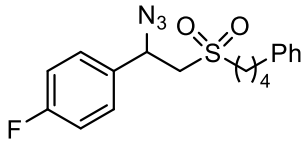
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.10 (d, *J* = 8.1 Hz, 2H), 7.42 (d, *J* = 8.1 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.24 – 7.14 (m, 3H), 5.19 (dd, *J* = 10.0, 2.8 Hz, 1H), 3.93 (s, 3H), 3.39 (dd, *J* = 14.9,

10.1 Hz, 1H), 3.20 – 3.01 (m, 3H), 2.67 (t, *J* = 7.4 Hz, 2H), 1.94 – 1.84 (m, 2H), 1.82 – 1.74 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 166.3, 141.5, 141.2, 131.2, 130.7, 128.5, 128.4, 127.0, 126.2, 60.3, 58.0, 54.8, 52.4, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{20}H_{23}N_3NaO_4S^+$: 424.1301 ($M + Na^+$), found: 424.1310.



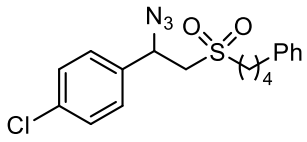
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-(trifluoromethyl)benzene (**3ga**, 53.5 mg, 65%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.70 (d, *J* = 8.0 Hz, 2H), 7.48 (d, *J* = 8.0 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 2H), 7.23 – 7.16 (m, 3H), 5.21 (dd, *J* = 10.1, 2.8 Hz, 1H), 3.38 (dd, *J* = 14.9, 10.2 Hz, 1H), 3.17 – 3.00 (m, 3H), 2.67 (t, *J* = 7.4 Hz, 2H), 1.94 – 1.85 (m, 2H), 1.83 – 1.74 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$): δ (ppm) -62.75 (s). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.0 (d, $^{1}J_{CF}$= 39.9 Hz), 131.6 (q, $^{2}J_{CF}$ = 32.8 Hz), 128.5, 128.4, 127.3, 126.5 (q,$^{3}J_{CF}$ = 3.6 Hz), 126.2, 125.0, 122.3, 60.2, 58.0, 54.9, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{19}H_{20}F_3N_3NaO_2S^+$: 434.1121 ($M + Na^+$), found: 434.1128.



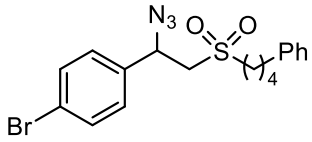
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-fluorobenzene (**3ha**, 48.4 mg, 67%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.35 – 7.27 (m, 4H), 7.23 – 7.16 (m, 3H), 7.12 (t, *J* = 8.5 Hz, 2H), 5.12 (dd, *J* = 10.0, 3.2 Hz, 1H), 3.38 (dd, *J* = 14.9, 10.1 Hz, 1H), 3.13 – 3.00 (m, 3H), 2.67 (t, *J* = 7.4 Hz, 2H), 1.93 – 1.84 (m, 2H), 1.82 – 1.72 (m, 2H). **^{19}F NMR (376 MHz, $CDCl_3$)**: δ (ppm) -111.27 – -111.17 (m). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 163.1 (d, $^{1}J_{CF}$ = 249.3 Hz), 141.2, 132.6 (d, $^{3}J_{CF}$= 3.3 Hz), 128.8, 128.8, 128.5, 128.4, 116.6 (d, $^{2}J_{CF}$= 21.8 Hz), 60.0, 58.2, 54.7, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{18}H_{20}FN_3NaO_2S^+$: 384.1152 ($M + Na^+$), found: 384.1159.



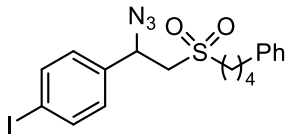
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-chlorobenzene (**3ia**, 56.7 mg, 75%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.40 (d, *J* = 8.4 Hz, 2H), 7.32 – 7.26 (m, 4H), 7.23 – 7.16 (m, 3H), 5.11 (dd, *J* = 10.0, 3.2 Hz, 1H), 3.36 (dd, *J* = 14.9, 10.0 Hz, 1H), 3.14 – 2.99 (m, 3H), 2.66 (t, *J* = 7.4 Hz, 2H), 1.92 – 1.83 (m, 2H), 1.81 – 1.72 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 164.3, 161.8, 141.2, 132.6, 132.6, 128.8, 128.8, 128.5, 128.4, 126.2, 116.7, 116.4, 60.0, 58.2, 54.7, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{18}H_{20}ClN_3NaO_2S^+$: 400.0857 ($M + Na^+$), found: 400.0865.



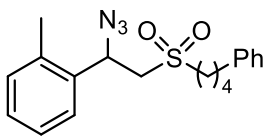
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-bromobenzene (**3ja**, 63.4 mg, 75%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.56 (d, *J* = 8.4 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.23 – 7.16 (m, 5H), 5.09 (dd, *J* = 10.0, 3.3 Hz, 1H), 3.35 (dd, *J* = 14.9, 10.0 Hz, 1H), 3.12 – 2.99 (m, 3H), 2.66 (t, *J* = 7.4 Hz, 2H), 1.93 – 1.83 (m, 2H), 1.82 – 1.72 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.2, 135.8, 132.7, 128.5, 128.4, 126.2, 123.6, 60.1, 58.0, 54.8, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{18}H_{20}BrN_3NaO_2S^+$: 444.0352 ($M + Na^+$), found: 444.0357.



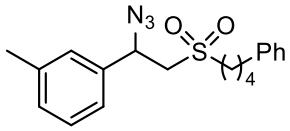
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-iodobenzene (**3ka**, 69.5 mg, 74%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.77 (d, *J* = 8.3 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 2H), 7.23 – 7.15 (m, 3H), 7.08 (d, *J* = 8.3 Hz, 2H), 5.07 (dd, *J* = 10.0, 3.3 Hz, 1H), 3.35 (dd, *J* = 14.9, 10.0 Hz, 1H), 3.12 – 2.98 (m, 3H), 2.67 (t, *J* = 7.4 Hz, 2H), 1.93 – 1.83 (m, 2H), 1.82 – 1.72 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.2, 138.6, 136.4, 128.7, 128.5, 128.4, 126.2, 95.3, 60.2, 58.0, 54.8, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{18}H_{20}IN_3NaO_2S^+$: 492.0213 ($M + Na^+$), found: 492.0220.



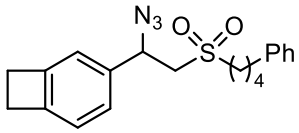
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-2-methylbenzene (**3la**, 58.6 mg, 82%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.35 – 7.26 (m, 5H), 7.25 – 7.16 (m, 4H), 5.39 (dd, *J* = 9.8, 2.9 Hz, 1H), 3.37 (dd, *J* = 15.0, 9.9 Hz, 1H), 3.13 – 2.94 (m, 3H), 2.66 (t, *J* = 7.4 Hz, 2H), 2.41 (s, 3H), 1.94 – 1.83 (m, 2H), 1.81 – 1.71 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.2, 135.5, 134.8, 131.5, 129.2, 128.5, 128.4, 127.1, 126.4, 126.1, 57.5, 57.2, 54.6, 35.3, 30.1, 21.6, 19.3. **HRMS (ESI)** calcd for $C_{19}H_{23}N_3NaO_2S^+$: 380.1403 (M + Na^+), found: 380.1412.



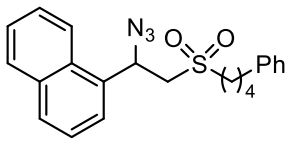
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-3-methylbenzene (**3ma**, 51.5 mg, 72%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.34 – 7.27 (m, 3H), 7.23 – 7.16 (m, 4H), 7.12 (d, *J* = 7.8 Hz, 2H), 5.07 (dd, *J* = 10.0, 3.1 Hz, 1H), 3.39 (dd, *J* = 15.0, 10.0 Hz, 1H), 3.11 – 3.02 (m, 3H), 2.66 (t, *J* = 7.5 Hz, 2H), 2.38 (s, 3H), 1.93 – 1.82 (m, 2H), 1.81 – 1.70 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.3, 139.4, 136.5, 130.3, 129.4, 128.5, 128.4, 127.6, 126.1, 123.9, 60.7, 58.2, 54.6, 35.3, 30.2, 21.5, 21.5. **HRMS (ESI)** calcd for $C_{19}H_{23}N_3NaO_2S^+$: 380.1403 (M + Na^+), found: 380.1414.



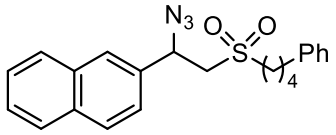
3-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)bicyclo[4.2.0]octa-1(6),2,4-triene (**3na**, 56.9 mg, 77%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.21 (t, *J* = 7.4 Hz, 2H), 7.15 – 7.04 (m, 4H), 7.00 (d, *J* = 7.5 Hz, 1H), 6.94 (s, 1H), 4.98 (dd, *J* = 9.9, 3.4 Hz, 1H), 3.31 (dd, *J* = 15.0, 10.0 Hz, 1H), 3.10 (s, 4H), 2.98 (dd, *J* = 9.9, 4.9 Hz, 3H), 2.57 (t, *J* = 7.5 Hz, 2H), 1.86 – 1.73 (m, 2H), 1.69 - 1.65 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 146.3, 146.0, 140.2, 134.1, 127.4, 127.3, 125.1, 124.8, 122.4, 120.1, 60.3, 57.3, 53.5, 34.2, 29.1, 28.5, 28.5, 20.5. **HRMS (ESI)** calcd for $C_{20}H_{23}N_3NaO_2S^+$: 392.1403 (M + Na^+), found: 392.1412.



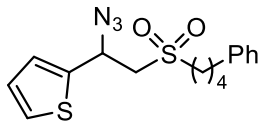
1-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)naphthalene (**3oa**, 60.6 mg, 77%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.10 (d, *J* = 8.4 Hz, 1H), 7.94 – 7.86 (m, 2H), 7.63 – 7.48 (m, 4H), 7.28 (t, *J* = 7.3 Hz, 2H), 7.22 – 7.14 (m, 3H), 5.92 (dd, *J* = 9.9, 2.4 Hz, 1H), 3.48 (dd, *J* = 15.1, 10.0 Hz, 1H), 3.23 (dd, *J* = 15.1, 2.6 Hz, 1H), 3.18 – 3.05 (m, 2H), 2.64 (t, *J* = 7.5 Hz, 2H), 1.93 – 1.84 (m, 2H), 1.79 – 1.71 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.2, 134.2, 132.3, 130.0, 129.8, 129.4, 128.5, 128.4, 127.5, 126.5, 126.1, 125.4, 124.9, 122.4, 58.1, 57.8, 54.7, 35.3, 30.1, 21.6. **HRMS (ESI)** calcd for $C_{22}H_{23}N_3NaO_2S^+$: 416.1403 (M + Na^+), found: 416.1411.



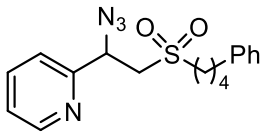
2-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)naphthalene (**3pa**, 63.7 mg, 81%), yellow solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.93 – 7.81 (m, 4H), 7.57 – 7.52 (m, 2H), 7.42 – 7.37 (m, 1H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.22 – 7.13 (m, 3H), 5.29 (dd, *J* = 9.9, 3.4 Hz, 1H), 3.48 (dd, *J* = 15.0, 9.9 Hz, 1H), 3.16 (dd, *J* = 15.0, 3.4 Hz, 1H), 3.12 – 3.04 (m, 2H), 2.63 (t, *J* = 7.5 Hz, 2H), 1.93 – 1.84 (m, 2H), 1.76 – 1.72 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.2, 133.9, 133.5, 133.2, 129.8, 128.5, 128.4, 128.2, 127.9, 127.1, 127.1, 126.7, 126.1, 123.6, 61.0, 58.2, 54.7, 35.3, 30.1, 21.6. **HRMS (ESI)** calcd for $C_{22}H_{23}N_3NaO_2S^+$: 416.1403 (M + Na^+), found: 416.1412.



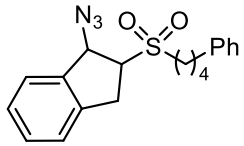
2-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)thiophene (**3qa**, 37.0 mg, 53%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.38 (d, *J* = 4.9 Hz, 1H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.23 – 7.15 (m, 3H), 7.11 (d, *J* = 3.1 Hz, 1H), 7.05 – 7.01 (m, 1H), 5.41 (dd, *J* = 9.7, 3.7 Hz, 1H), 3.45 (dd, *J* = 14.9, 9.8 Hz, 1H), 3.21 (dd, *J* = 14.9, 3.7 Hz, 1H), 3.11 – 3.02 (m, 2H), 2.66 (t, *J* = 7.4 Hz, 2H), 1.96 – 1.82 (m, 2H), 1.82 – 1.70 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.2, 139.0, 128.5, 128.4, 127.3, 127.1, 127.0, 126.2, 58.4, 56.3, 54.7, 35.3, 30.1, 21.5. **HRMS (ESI)** calcd for $C_{16}H_{19}N_3NaO_2S_2^+$: 372.0811 (M + Na^+), found: 372.0819.



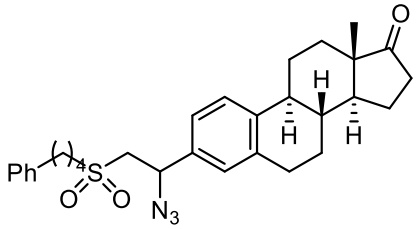
2-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)pyridine (**3ra**, 23.4 mg, 34%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.63 (d, *J* = 4.2 Hz, 1H), 7.81 – 7.76 (m, 1H), 7.40 (d, *J* = 7.8 Hz, 1H), 7.35 – 7.27 (m, 3H), 7.22 – 7.16 (m, 3H), 5.09 (dd, *J* = 7.6, 5.5 Hz, 1H), 3.61 – 3.55 (m, 2H), 3.09 – 3.03 (m, 2H), 2.66 (t, *J* = 7.5 Hz, 2H), 1.95 – 1.87 (m, 2H), 1.80 – 1.72 (m, 2H).
^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 155.4, 150.2, 141.2, 137.6, 128.5, 128.4, 126.1, 124.1, 122.5, 60.5, 56.1, 54.7, 35.3, 30.2, 21.5. **HRMS (ESI)** calcd for $C_{17}H_{20}N_4NaO_2S^+$: 367.1199 (M + Na^+), found: 367.1211.



1-Azido-2-((4-phenylbutyl)sulfonyl)-2,3-dihydro-1H-indene (**3sa**, 44.1 mg, 62%), yellow oil

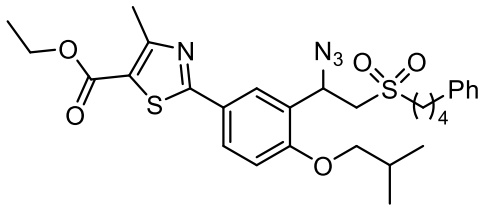
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.40 (d, *J* = 7.7 Hz, 1H), 7.38 – 7.32 (m, 2H), 7.32 – 7.26 (m, 3H), 7.19 (t, *J* = 9.3 Hz, 3H), 5.34 (d, *J* = 6.6 Hz, 1H), 3.78 (dd, *J* = 15.6, 8.3 Hz, 1H), 3.51 – 3.31 (m, 2H), 3.12 – 3.02 (m, 2H), 2.69 (t, *J* = 7.5 Hz, 2H), 2.01 – 1.90 (m, 2H), 1.87 – 1.76 (m, 2H).
^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 141.2, 138.7, 137.9, 129.8, 128.5, 128.4, 128.1, 126.2, 125.1, 124.5, 66.8, 65.7, 52.5, 35.3, 31.1, 30.2, 21.2. **HRMS (ESI)** calcd for $C_{19}H_{21}N_3NaO_2S^+$: 378.1247 (M + Na^+), found: 378.1252.



(8*R*,9*S*,13*S*,14*S*)-3-(1-Azido-2-((4-phenylbutyl)sulfonyl)ethyl)-13-methyl-6,7,8,9,11,12,13,14,15,16-decahydro-17*H*-cyclopenta[a]phenanthren-17-one (**3ta**, 48.9 mg, 47%), yellow oil

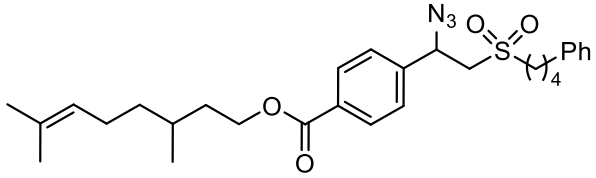
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.36 – 7.27 (m, 3H), 7.23 – 7.16 (m, 3H), 7.10 (d, *J* = 8.1 Hz, 1H), 7.05 (s, 1H), 5.05 (dd, *J* = 10.0, 3.3 Hz, 1H), 3.39 (dd, *J* = 14.9, 10.1 Hz, 1H), 3.11 – 3.03 (m, 3H), 2.96 – 2.91 (m, 2H), 2.66 (t, *J* = 7.5 Hz, 2H), 2.58 – 2.47 (m, 1H), 2.45 – 2.38 (m, 1H), 2.35 – 2.26 (m, 1H), 2.21 – 2.06 (m, 2H), 2.05 – 1.94 (m, 2H), 1.92 – 1.84 (m, 2H), 1.81 – 1.71 (m, 2H), 1.69 – 1.59 (m, 2H), 1.56 – 1.42 (m, 4H), 0.91 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: 220.7,

141.3, 141.2, 137.8, 134.0, 128.5, 128.4, 127.5, 127.4, 126.5, 126.5, 126.1, 124.2, 124.1, 60.5, 60.4, 58.2, 54.6, 50.5, 47.9, 44.4, 37.9, 35.8, 35.3, 31.5, 30.2, 29.4, 26.3, 25.7, 21.6, 21.5, 13.8. **HRMS (ESI)** calcd for $C_{30}H_{37}N_3NaO_3S^+$: 542.2448 (M + Na^+), found: 542.2453.



Ethyl 2-(3-(1-azido-2-((4-phenylbutyl)sulfonyl)ethyl)-4-isobutoxyphenyl)-4-methylthiazole-5-carboxylate (**3ua**, 85.1 mg, 77%), white solid

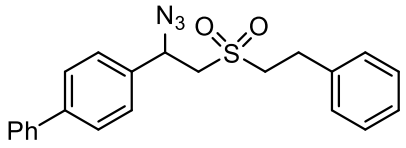
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.99 (s, 1H), 7.95 – 7.90 (m, 1H), 7.34 – 7.25 (m, 2H), 7.20 (t, *J* = 7.8 Hz, 3H), 6.98 (d, *J* = 8.6 Hz, 1H), 5.56 (d, *J* = 10.1 Hz, 1H), 4.36 (q, *J* = 7.1 Hz, 1H), 3.92 – 3.80 (m, 2H), 3.44 (dd, *J* = 14.9, 10.5 Hz, 1H), 3.23 – 3.11 (m, 3H), 2.78 (s, 3H), 2.68 (t, *J* = 7.4 Hz, 2H), 2.23 – 2.13 (m, 1H), 1.97 - 1.88 (m, 2H), 1.85 – 1.76 (m, 2H), 1.39 (t, *J* = 7.1 Hz, 3H), 1.13 - 1.05 (m, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 168.8, 162.3, 161.1, 158.0, 141.3, 129.1, 128.5, 128.4, 126.2, 126.1, 126.1, 125.7, 121.4, 112.2, 75.2, 61.3, 56.6, 56.1, 54.8, 35.4, 30.2, 28.3, 21.6, 19.3, 19.3, 17.6, 14.4. **HRMS (ESI)** calcd for $C_{29}H_{36}N_4NaO_5S_2^+$: 607.2019 (M + Na^+), found: 607.2025.



3,7-Dimethyloct-6-en-1-yl 4-(1-azido-2-((4-phenylbutyl)sulfonyl)ethyl)benzoate (**3va**, 83.1 mg, 79%), yellow oil

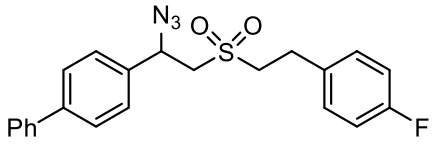
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.10 (d, *J* = 8.0 Hz, 2H), 7.42 (d, *J* = 8.1 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.24 – 7.15 (m, 3H), 5.19 (dd, *J* = 10.0, 2.5 Hz, 1H), 5.10 (t, *J* = 6.7 Hz, 1H), 4.43 – 4.32 (m, 2H), 3.39 (dd, *J* = 14.9, 10.2 Hz, 1H), 3.15 – 3.03 (m, 3H), 2.67 (t, *J* = 7.4 Hz, 2H), 2.09 – 1.96 (m, 2H), 1.94 – 1.85 (m, 2H), 1.84 – 1.74 (m, 3H), 1.71 - 1.55 (m, 8H), 1.45 – 1.36 (m, 1H), 1.30-1.19 (m, 1H), 0.97 (d, *J* = 6.3 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 165.8, 141.3, 141.2, 131.6, 131.5, 130.7, 128.5, 128.4, 126.9, 126.2, 124.5, 63.9, 60.3, 58.0, 54.8, 37.0,

35.5, 35.3, 30.1, 29.5, 25.8, 25.4, 21.5, 19.5, 17.7. **HRMS (ESI)** calcd for $C_{29}H_{39}N_3NaO_4S^+$: 548.2553 (M + Na^+), found: 548.2559.



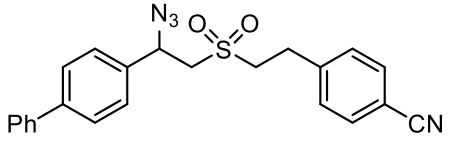
4-(1-Azido-2-(phenethylsulfonyl)ethyl)-1,1'-biphenyl (**3ab**, 50.9 mg, 65%), yellow oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.64 (d, *J* = 8.0 Hz, 2H), 7.58 (d, *J* = 7.7 Hz, 2H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.40 – 7.31 (m, 5H), 7.28 (d, *J* = 7.0 Hz, 1H), 7.22 (d, *J* = 7.3 Hz, 2H), 5.17 (dd, *J* = 9.9, 3.2 Hz, 1H), 3.47 – 3.30 (m, 3H), 3.19 – 3.07 (m, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 168.8, 162.3, 161.1, 158.0, 141.3, 129.1, 128.5, 128.4, 126.2, 126.1, 126.1, 125.7, 121.4, 112.2, 75.2, 61.3, 56.6, 56.1, 54.8, 35.4, 30.2, 28.3, 21.6, 19.3, 19.3, 17.6, 14.4. **HRMS (ESI)** calcd for $C_{22}H_{21}N_3NaO_2S^+$: 414.1247 (M + Na^+), found: 414.1254.



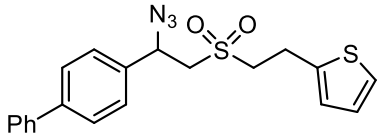
4-(1-Azido-2-((4-fluorophenethyl)sulfonyl)ethyl)-1,1'-biphenyl (**3ac**, 59.8 mg, 73%), white oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.65 (d, *J* = 8.2 Hz, 2H), 7.58 (d, *J* = 7.3 Hz, 2H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.41 – 7.36 (m, 3H), 7.21 – 7.15 (m, 2H), 7.01 (t, *J* = 8.6 Hz, 2H), 5.18 (dd, *J* = 9.9, 3.5 Hz, 1H), 3.41 – 3.28 (m, 3H), 3.17 – 3.09 (m, 3H). **^{19}F NMR (376 MHz, $CDCl_3$)**: δ (ppm) -115.38 – -115.29 (m). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 161.9 (d, $^1J_{CF}$= 245.8 Hz), 142.6, 139.9, 135.3, 133.1 (d, $^4J_{CF}$= 3.5 Hz), 130.1 (d, $^3J_{CF}$= 8.0 Hz), 129.0, 128.2, 127.9, 127.4, 127.1, 115.9 (d, $^2J_{CF}$= 21.6 Hz), 60.5, 58.7, 56.2, 27.4. **HRMS (ESI)** calcd for $C_{22}H_{20}FN_3NaO_2S^+$: 432.1152 (M + Na^+), found: 432.1159.



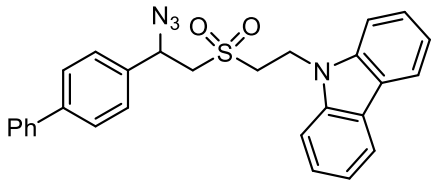
4-(2-((2-([1,1'-Biphenyl]-4-yl)-2-azidoethyl)sulfonyl)ethyl)benzonitrile (**3ad**, 56.6 mg, 68%), white oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.67 (d, *J* = 8.2 Hz, 2H), 7.64 – 7.56 (m, 4H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.42 – 7.37 (m, 3H), 7.34 (d, *J* = 8.1 Hz, 2H), 5.19 (dd, *J* = 10.0, 3.5 Hz, 1H), 3.46 – 3.33 (m, 3H), 3.26 – 3.14 (m, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 143.0, 142.7, 139.8, 135.1, 132.7, 129.4, 129.0, 128.2, 128.0, 127.4, 127.1, 118.5, 111.2, 60.6, 58.9, 55.4, 28.0. **HRMS (ESI)** calcd for $C_{23}H_{20}N_4NaO_2S^+$: 439.1199 (M + Na^+), found: 439.1208.



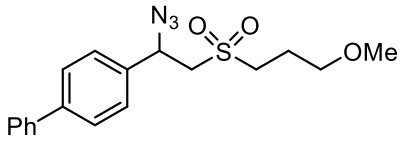
2-(2-((2-([1,1'-Biphenyl]-4-yl)-2-azidoethyl)sulfonyl)ethyl)thiophene (**3ae**, 48.5 mg, 61%), yellow solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.64 (d, *J* = 8.2 Hz, 2H), 7.58 (d, *J* = 7.4 Hz, 2H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.40 – 7.36 (m, 3H), 7.22 – 7.18 (m, 1H), 6.97 – 6.93 (m, 1H), 6.90 (d, *J* = 3.1 Hz, 1H), 5.18 (dd, *J* = 10.0, 3.4 Hz, 1H), 3.52 – 3.44 (m, 1H), 3.42 – 3.33 (m, 4H), 3.11 (dd, *J* = 15.0, 3.5 Hz, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 143.0, 142.7, 139.8, 135.1, 132.7, 129.4, 129.0, 128.2, 128.0, 127.4, 127.1, 118.5, 111.2, 60.6, 58.9, 55.4, 28.0. **HRMS (ESI)** calcd for $C_{20}H_{19}N_3NaO_2S_2^+$: 420.0811 (M + Na^+), found: 420.0820.



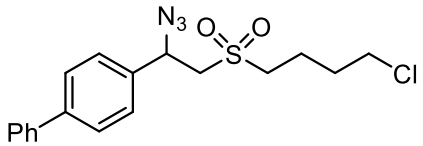
9-(2-((2-([1,1'-Biphenyl]-4-yl)-2-azidoethyl)sulfonyl)ethyl)-9*H*-carbazole (**3af**, 61.5 mg, 64%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.11 (d, *J* = 7.8 Hz, 2H), 7.52 – 7.41 (m, 10H), 7.36 (t, *J* = 7.2 Hz, 1H), 7.32 – 7.26 (m, 2H), 6.91 (d, *J* = 8.2 Hz, 2H), 4.99 – 4.89 (m, 2H), 4.82 – 4.74 (m, 1H), 3.94 – 3.80 (m, 1H), 3.53 – 3.40 (m, 1H), 2.96 (dd, *J* = 15.1, 10.4 Hz, 1H), 2.81 (dd, *J* = 15.0, 2.9 Hz, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.4, 140.0, 139.7, 134.7, 128.9, 127.0, 128.86, 127.1, 127.1, 126.3, 123.3, 120.7, 120.0, 108.8, 60.1, 59.2, 52.9, 36.8. **HRMS (ESI)** calcd for $C_{28}H_{24}N_4NaO_2S^+$: 503.1512 (M + Na^+), found: 503.1521.



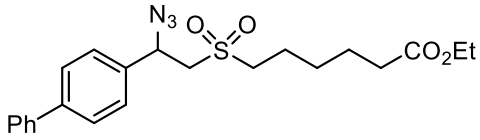
4-(1-Azido-2-((3-methoxypropyl)sulfonyl)ethyl)-1,1'-biphenyl (**3ag**, 59.6 mg, 83%), yellow solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.66 (d, *J* = 8.2 Hz, 2H), 7.59 (d, *J* = 7.3 Hz, 2H), 7.49 – 7.36 (m, 5H), 5.20 (dd, *J* = 10.1, 3.2 Hz, 1H), 3.50 (dd, *J* = 15.0, 8.9 Hz, 3H), 3.34 (s, 3H), 3.27 – 3.13 (m, 3H), 2.19 – 2.08 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.4, 140.0, 135.6, 129.0, 128.1, 127.9, 127.3, 127.2, 70.2, 60.4, 58.7, 58.5, 52.1, 22.3. **HRMS (ESI)** calcd for $C_{18}H_{21}N_3NaO_3S^+$: 382.1196 (M + Na^+), found: 382.1201.



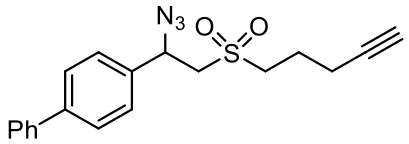
4-(1-Azido-2-((4-chlorobutyl)sulfonyl)ethyl)-1,1'-biphenyl (**3ah**, 57.4 mg, 76%), white solid

^{1}H NMR (400 MHz, DMSO-*d_6*): δ (ppm) 7.77 – 7.68 (m, 4H), 7.59 (d, *J* = 8.2 Hz, 2H), 7.48 (t, *J* = 7.5 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 1H), 5.29 (dd, *J* = 9.7, 3.7 Hz, 1H), 3.89 (dd, *J* = 14.7, 9.7 Hz, 1H), 3.70 – 3.58 (m, 3H), 3.22 (d, *J* = 6.3 Hz, 2H), 1.89 – 1.80 (m, 4H). **^{13}C NMR (100 MHz, DMSO-*d_6*)**: δ (ppm) 141.1, 139.9, 136.9, 129.5, 128.5, 128.2, 127.6, 127.2, 59.3, 56.5, 53.0, 45.1, 31.1, 19.2. **HRMS (ESI)** calcd for $C_{18}H_{20}ClN_3NaO_2S^+$: 400.0857 (M + Na^+), found: 400.0862.



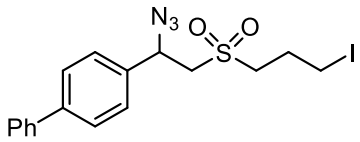
Ethyl 6-((2-([1,1'-biphenyl]-4-yl)-2-azidoethyl)sulfonyl)hexanoate (**3ai**, 34.4 mg, 40%), white oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.66 (d, *J* = 8.2 Hz, 2H), 7.61 – 7.57 (m, 2H), 7.49 – 7.41 (m, 4H), 7.38 (t, *J* = 7.3 Hz, 1H), 5.19 (dd, *J* = 10.0, 3.3 Hz, 1H), 4.16 – 4.10 (m, 2H), 3.47 (dd, *J* = 14.9, 10.1 Hz, 1H), 3.18 – 3.07 (m, 3H), 2.33 (t, *J* = 7.3 Hz, 2H), 1.94 – 1.84 (m, 2H), 1.69 (dd, *J* = 15.4, 7.4 Hz, 2H), 1.53 – 1.45 (m, 2H), 1.26 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 173.3, 142.5, 140.0, 135.5, 128.9, 128.2, 127.9, 127.3, 127.1, 60.5, 60.4, 58.3, 54.6, 33.8, 27.9, 24.3, 21.6, 14.3. **HRMS (ESI)** calcd for $C_{22}H_{27}N_3NaO_4S^+$: 452.1614 (M + Na^+), found: 452.1624.



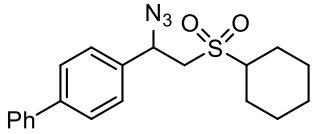
4-(1-Azido-2-(pent-4-yn-1-ylsulfonyl)ethyl)-1,1'-biphenyl (**3aj**, 41.7 mg, 59%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.66 (d, *J* = 8.2 Hz, 2H), 7.61 – 7.57 (m, 2H), 7.49 – 7.41 (m, 4H), 7.38 (t, *J* = 7.3 Hz, 1H), 5.20 (dd, *J* = 10.1, 3.3 Hz, 1H), 3.49 (dd, *J* = 15.0, 10.1 Hz, 1H), 3.31 – 3.24 (m, 2H), 3.16 (dd, *J* = 15.0, 3.3 Hz, 1H), 2.44 – 2.38 (m, 2H), 2.14 – 2.02 (m, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.5, 140.0, 135.5, 129.0, 128.2, 127.9, 127.3, 127.1, 81.8, 70.4, 60.5, 58.6, 53.6, 20.9, 17.5. **HRMS (ESI)** calcd for $C_{19}H_{19}N_3NaO_2S^+$: 376.1090 (M + Na^+), found: 376.1099.



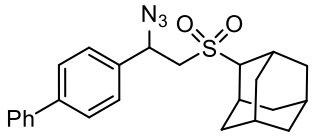
4-(1-Azido-2-((3-iodopropyl)sulfonyl)ethyl)-1,1'-biphenyl (**3ak**, 68.3 mg, 75%), white solid

^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 7.76 – 7.68 (m, 4H), 7.60 (d, *J* = 8.2 Hz, 2H), 7.48 (t, *J* = 7.6 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 1H), 5.28 (dd, *J* = 9.6, 3.2 Hz, 1H), 4.00 (dd, *J* = 14.8, 9.9 Hz, 1H), 3.65 (dd, *J* = 14.8, 3.7 Hz, 1H), 3.36 (t, *J* = 6.9 Hz, 2H), 3.28 (t, *J* = 7.6 Hz, 2H), 2.30 – 2.20 (m, 2H). **^{13}C NMR (100 MHz, DMSO-d_6)**: δ (ppm) 147.1, 141.2, 139.8, 137.3, 131.0, 129.4, 128.5, 128.3, 128.2, 127.7, 127.3, 125.6, 121.5, 120.1, 58.2, 55.4, 52.2, 18.4, 15.8. **HRMS (ESI)** calcd for $C_{17}H_{18}IN_3NaO_2S^+$: 478.0057 (M + Na^+), found: 478.0064.



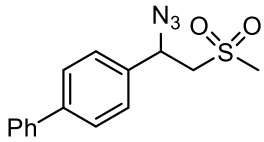
4-(1-Azido-2-(cyclohexylsulfonyl)ethyl)-1,1'-biphenyl (**3al**, 52.5 mg, 71%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.65 (d, *J* = 8.2 Hz, 2H), 7.58 (d, *J* = 7.3 Hz, 2H), 7.48 – 7.42 (m, 4H), 7.38 (t, *J* = 7.3 Hz, 1H), 5.20 (dd, *J* = 9.7, 3.6 Hz, 1H), 3.50 (dd, *J* = 14.7, 9.7 Hz, 1H), 3.08 (dd, *J* = 14.7, 3.6 Hz, 1H), 3.02 – 2.92 (m, 1H), 2.18 (t, *J* = 12.9 Hz, 2H), 1.98 – 1.89 (m, 2H), 1.75 – 1.59 (m, 2H), 1.56 – 1.50 (m, 1H), 1.34 – 1.24 (m, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.3, 140.1, 135.9, 129.0, 128.1, 127.8, 127.4, 127.1, 62.2, 60.2, 55.0, 25.7, 25.1, 23.9. **HRMS (ESI)** calcd for $C_{20}H_{23}N_3NaO_2S^+$: 392.1403 (M + Na^+), found: 392.1408.



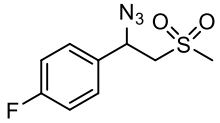
(1*R*,3*S*,5r,7r)-2-((2-([1,1'-biphenyl]-4-yl)-2-azidoethyl)sulfonyl)adamantane (**3am**, 50.6 mg, 60%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.65 (d, J = 8.2 Hz, 2H), 7.60 – 7.56 (m, 2H), 7.49 – 7.42 (m, 4H), 7.38 (t, J = 7.3 Hz, 1H), 5.19 (dd, J = 9.0, 4.0 Hz, 1H), 3.54 (dd, J = 14.8, 9.1 Hz, 1H), 3.23 – 3.11 (m, 2H), 2.63 – 2.36 (m, 4H), 2.04 – 1.81 (m, 5H), 1.77 – 1.63 (m, 5H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.4, 140.1, 136.0, 128.9, 128.1, 127.8, 127.4, 127.1, 67.3, 60.4, 57.2, 39.0, 38.9, 37.0, 31.8, 31.5, 28.4, 27.6, 27.4, 26.7. **HRMS (ESI)** calcd for $C_{24}H_{27}N_3NaO_2S^+$: 444.1716 ($M + Na^+$), found: 444.1721.



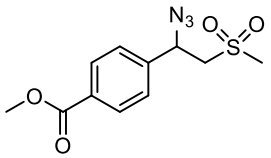
4-(1-Azido-2-(methylsulfonyl)ethyl)-1,1'-biphenyl (**3an**, 42.4 mg, 70%), yellow solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.67 (d, *J* = 8.2 Hz, 2H), 7.59 (d, *J* = 7.5 Hz, 2H), 7.49 – 7.37 (m, 5H), 5.20 (dd, *J* = 10.2, 3.3 Hz, 1H), 3.50 (dd, *J* = 14.9, 10.3 Hz, 1H), 3.20 (dd, *J* = 14.9, 2.8 Hz, 1H), 3.04 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.5, 140.0, 135.3, 129.0, 128.2, 127.9, 127.4, 127.1, 60.7, 60.3, 43.1. **HRMS (ESI)** calcd for $C_{15}H_{15}N_3NaO_2S^+$: 324.0777 ($M + Na^+$), found: 324.0781.



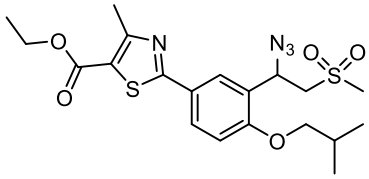
1-(1-Azido-2-(methylsulfonyl)ethyl)-4-fluorobenzene (**3hn**, 25.9 mg, 50%), white solid [4]

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.39 – 7.33 (m, 2H), 7.18 – 7.12 (m, 2H), 5.15 (dd, *J* = 10.2, 3.4 Hz, 1H), 3.44 (dd, *J* = 14.9, 10.2 Hz, 1H), 3.17 – 3.11 (m, 1H), 3.02 (s, 3H). **^{19}F NMR (376 MHz, $CDCl_3$)**: δ (ppm) -111.19 – -111.10 (m). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 163.1 (d, $^1J_{CF}$ = 249.4 Hz), 132.4 (d, $^4J_{CF}$ = 3.3 Hz), 128.8 (d, $^3J_{CF}$= 8.4 Hz), 116.6 (d, $^2J_{CF}$= 21.8 Hz), 60.2, 60.2, 43.1.



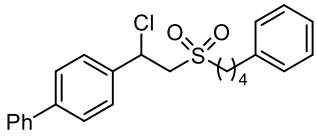
Methyl 4-(1-azido-2-(methylsulfonyl)ethyl)benzoate (**3fn**, 30.2 mg, 53%), white oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.12 (d, *J* = 8.3 Hz, 2H), 7.46 (d, *J* = 8.3 Hz, 2H), 5.22 (dd, *J* = 10.2, 3.2 Hz, 1H), 3.94 (s, 3H), 3.47 (dd, *J* = 14.9, 10.3 Hz, 1H), 3.17 (dd, *J* = 15.0, 2.5 Hz, 1H), 3.05 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 166.2, 141.3, 131.3, 130.8, 127.0, 60.5, 59.9, 52.4, 43.2. **HRMS (ESI)** calcd for $C_{11}H_{13}N_3NaO_4S^+$: 306.0519 (M + Na^+), found: 306.0532.



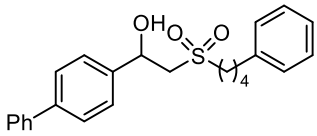
Ethyl 2-(3-(1-azido-2-(methylsulfonyl)ethyl)-4-isobutoxyphenyl)-4-methylthiazole-5-carboxylate (**3un**, 33.5 mg, 36%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.01 (d, J = 2.1 Hz, 1H), 7.95 – 7.91 (m, 1H), 6.99 (d, J = 8.7 Hz, 1H), 5.58 (dd, J = 10.5, 2.5 Hz, 1H), 4.39 – 4.33 (m, 2H), 3.91 – 3.83 (m, 2H), 3.48 (dd, J = 14.9, 10.6 Hz, 1H), 3.29 – 3.23 (m, 1H), 3.10 (s, 3H), 2.78 (s, 3H), 2.25 – 2.15 (m, 1H), 1.42 – 1.37 (m, 3H), 1.12 – 1.08 (m, 6H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 168.8, 162.3, 161.1, 158.0, 129.1, 126.2, 126.1, 125.6, 121.4, 112.2, 75.2, 61.3, 58.7, 56.1, 43.2, 28.3, 19.3, 19.3, 17.6, 14.4. **HRMS (ESI)** calcd for $C_{20}H_{26}N_4NaO_5S_2^+$: 489.1237 (M + Na^+), found: 489.1245.



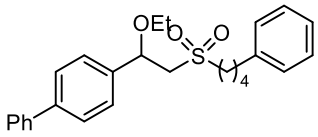
4-(2-Benzylsulfonyl)-1-chloroethyl)-1,1'-biphenyl (**4**, 30.6 mg, 37%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.64 – 7.59 (m, 2H), 7.58 – 7.54 (m, 2H), 7.51 – 7.42 (m, 4H), 7.40 – 7.36 (m, 1H), 7.29 – 7.24 (m, 2H), 7.22 – 7.16 (m, 1H), 7.11 (d, *J* = 7.1 Hz, 2H), 5.43 (t, *J* = 6.8 Hz, 1H), 3.81 (dd, *J* = 15.1, 7.4 Hz, 1H), 3.63 (dd, *J* = 15.1, 6.3 Hz, 1H), 2.88 – 2.73 (m, 2H), 2.64 – 2.52 (m, 2H), 1.89 – 1.59 (m, 4H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 142.6, 141.1, 139.9, 137.6, 129.0, 128.5, 128.4, 127.9, 127.9, 127.6, 127.1, 126.1, 61.3, 55.3, 54.3, 35.2, 30.1, 21.6. **HRMS (ESI)** calcd for $C_{24}H_{25}ClNaO_2S^+$: 435.1156 (M + Na^+), found: 435.1164.



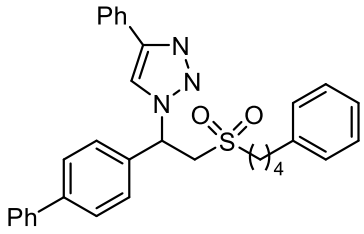
1-([1,1'-Biphenyl]-4-yl)-2-(benzylsulfonyl)ethan-1-ol (**5**, 42.1 mg, 53%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.62 – 7.55 (m, 4H), 7.47 – 7.41 (m, 4H), 7.38 – 7.34 (m, 1H), 7.31 – 7.26 (m, 2H), 7.22 – 7.15 (m, 3H), 5.38 (d, *J* = 10.2 Hz, 1H), 3.42 (dd, *J* = 14.6, 10.2 Hz, 1H), 3.20 – 3.08 (m, 4H), 2.66 (t, *J* = 7.5 Hz, 2H), 1.96 – 1.87 (m, 2H), 1.82 – 1.73 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.6, 141.2, 140.4, 140.0, 128.9, 128.5, 128.4, 127.7, 127.6, 127.1, 126.1, 68.8, 60.4, 54.6, 35.3, 30.2, 21.5. **HRMS (ESI)** calcd for $C_{24}H_{26}NaO_3S^+$: 417.1495 ($M + Na^+$), found: 417.1509.



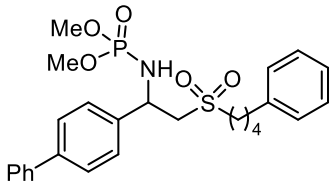
4-(1-Ethoxy-2-((4-phenylbutyl)sulfonyl)ethyl)-1,1'-biphenyl (**6**, 46.2 mg, 55%), white oil

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.63 – 7.57 (m, 4H), 7.48 – 7.43 (m, 2H), 7.40 – 7.34 (m, 3H), 7.33 – 7.27 (m, 2H), 7.23 – 7.17 (m, 3H), 4.90 (dd, *J* = 10.4, 2.2 Hz, 1H), 3.53 – 3.38 (m, 3H), 3.29 – 3.14 (m, 2H), 3.00 (dd, *J* = 15.1, 1.2 Hz, 1H), 2.69 (t, *J* = 7.6 Hz, 2H), 1.99 – 1.90 (m, 2H), 1.83 – 1.74 (m, 2H), 1.20 (t, *J* = 7.0 Hz, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.6, 141.4, 140.4, 138.1, 128.9, 128.5, 128.4, 127.7, 127.6, 127.1, 126.9, 126.1, 76.7, 64.6, 60.1, 55.1, 35.4, 30.4, 21.7, 15.2. **HRMS (ESI)** calcd for $C_{26}H_{30}NaO_3S^+$: 445.1808 ($M + Na^+$), found: 445.1816.



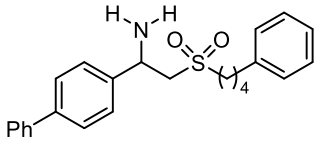
1-(1-([1,1'-Biphenyl]-4-yl)-2-((4-phenylbutyl)sulfonyl)ethyl)-4-phenyl-1H-1,2λ^2,3λ^2-triazole (**9**, 140.9 mg, 90%), white solid

^{1}H NMR (400 MHz, DMSO-*d_6*): δ (ppm) 8.93 (s, 1H), 7.85 (d, *J* = 7.3 Hz, 2H), 7.73 (d, *J* = 8.3 Hz, 2H), 7.66 (d, *J* = 7.9 Hz, 4H), 7.49 – 7.44 (m, 4H), 7.41 – 7.33 (m, 2H), 7.25 (t, *J* = 7.3 Hz, 2H), 7.19 – 7.11 (m, 3H), 6.46 (dd, *J* = 9.5, 4.4 Hz, 1H), 4.67 (dd, *J* = 14.8, 9.6 Hz, 1H), 4.25 (dd, *J* = 14.8, 4.4 Hz, 1H), 3.07 – 2.99 (m, 2H), 2.56 – 2.52 (m, 2H), 1.73 – 1.64 (m, 2H), 1.62 – 1.54 (m, 2H). **^{13}C NMR (100 MHz, DMSO-*d_6*)**: δ (ppm) 147.1, 142.0, 141.2, 139.8, 137.3, 130.9, 129.5, 128.7, 128.7, 128.6, 128.3, 128.3, 127.7, 127.2, 126.3, 125.6, 121.5, 58.5, 55.5, 53.1, 34.9, 30.0, 21.1. **HRMS (ESI)** calcd for $C_{32}H_{31}N_3NaO_2S^+$: 544.2029 ($M + Na^+$), found: 544.2036.



Dimethyl (1-([1,1'-biphenyl]-4-yl)-2-((4-phenylbutyl)sulfonyl)ethyl)phosphoramidate (**10**, 144.5 mg, 96%), white solid

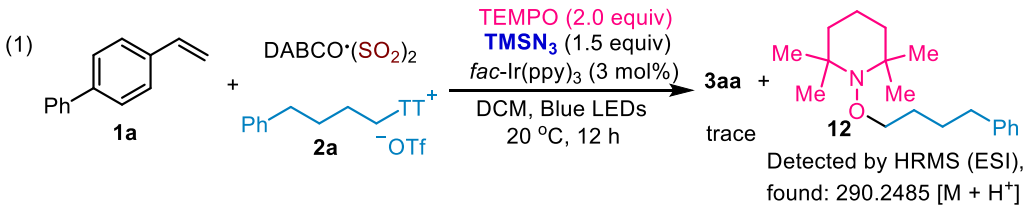
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.63 – 7.53 (m, 4H), 7.47 – 7.41 (m, 4H), 7.36 (t, *J* = 7.3 Hz, 1H), 7.23 (d, *J* = 7.5 Hz, 2H), 7.17 (t, *J* = 7.2 Hz, 1H), 7.07 (d, *J* = 7.0 Hz, 2H), 4.92 – 4.81 (m, 1H), 4.47 (t, *J* = 9.8 Hz, 1H), 3.72 (d, *J* = 11.2 Hz, 3H), 3.57 – 3.48 (m, 4H), 3.38 (dd, *J* = 14.7, 5.0 Hz, 1H), 2.64 – 2.49 (m, 4H), 1.76 – 1.69 (m, 2H), 1.60 – 1.51 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.3, 141.1, 140.0, 139.3, 128.9, 128.5, 128.3, 127.7, 127.7, 127.0, 126.9, 126.1, 59.3, 54.1, 53.6, 53.3, 51.3, 35.2, 30.0, 21.4. **HRMS (ESI)** calcd for $C_{26}H_{32}NPNaO_5S^+$: 524.1631 ($M + Na^+$), found: 524.1636.



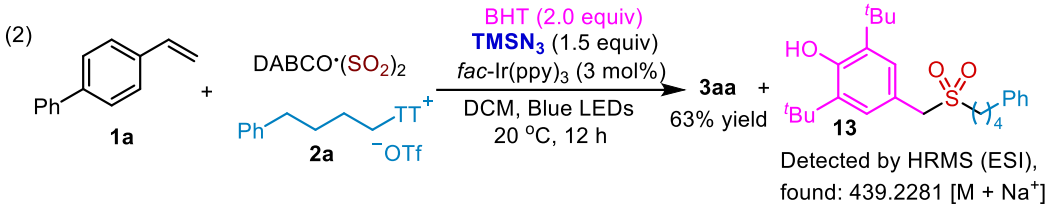
1-([1,1'-Biphenyl]-4-yl)-2-((4-phenylbutyl)sulfonyl)ethan-1-amine (**11**, 25.2 mg, 64%), white solid

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.60 – 7.55 (m, 4H), 7.46 – 7.42 (m, 4H), 7.36 (t, *J* = 7.3 Hz, 1H), 7.29 – 7.25 (m, 2H), 7.21 – 7.13 (m, 3H), 4.72 (dd, *J* = 9.5, 2.4 Hz, 1H), 3.32 (dd, *J* = 14.0, 9.7 Hz, 1H), 3.19 (dd, *J* = 14.0, 2.9 Hz, 1H), 3.01 (dd, *J* = 9.2, 6.6 Hz, 2H), 2.63 (t, *J* = 7.5 Hz, 2H), 2.10 – 2.01 (m, 2H), 1.91 – 1.82 (m, 2H), 1.77 – 1.69 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)**: δ (ppm) 141.2, 141.2, 140.4, 128.9, 128.5, 128.4, 127.7, 127.6, 127.1, 126.8, 126.1, 54.4, 35.3, 31.5, 30.2, 30.1, 21.7. **HRMS (ESI)** calcd for $C_{24}H_{27}NNaO_2S^+$: 416.1655 ($M + Na^+$), found: 416.1665.

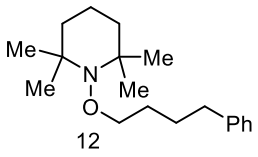
3. Radical trapping experiments



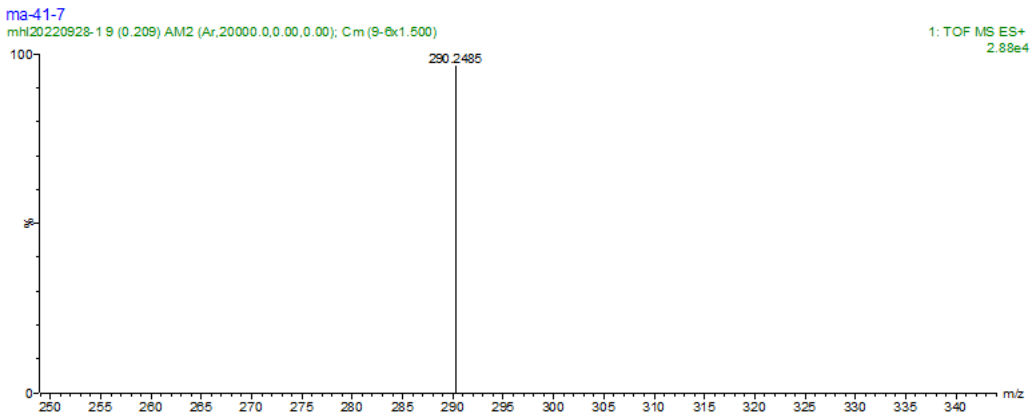
$TMSN_3$ (0.3 mmol) was added to a mixture of alkenes **1a** (0.2 mmol), thianthrenium salts **2a** (0.4 mmol), DABCO·$(SO_2)_2$ (0.16 mmol), *fac*-Ir(ppy)$_3$ (3 mol%) and TEMPO (0.4 mmol) in DCM (3 mL) under N_2 atmosphere. The mixture was placed around a 30 W blue LEDs and stirred under blue light irradiation for 12 hours at 20 °C. As a result, significant inhibition of the reactivity was observed, and the corresponding trapping product **12** was detected by HRMS.

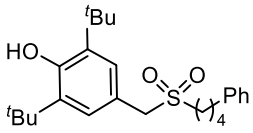


$TMSN_3$ (0.3 mmol) was added to a mixture of alkenes **1a** (0.2 mmol), thianthrenium salts **2a** (0.4 mmol), DABCO·$(SO_2)_2$ (0.16 mmol), *fac*-Ir(ppy)$_3$ (3 mol%) and BHT (0.4 mmol) in DCM (3 mL) under N_2 atmosphere. The mixture was placed around a 30 W blue LEDs and stirred under blue light irradiation for 12 hours at 20 °C. As a result, the isolated yield of **3aa** was decreased to 63% and another radical trapping adduct **13** was discovered by HRMS.



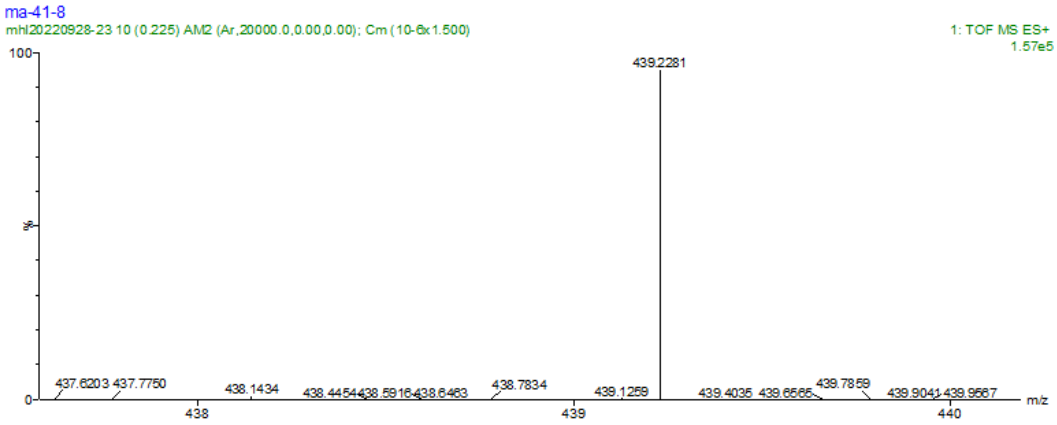
HRMS (ESI) calcd for $C_{19}H_{32}NO^+$: 290.2478 (M + H^+), found: 290.2485.





13

HRMS (ESI) calcd for $C_{25}H_{36}NaO_3S^+$: 439.2277 (M + Na^+), found: 439.2281.



4. Reference

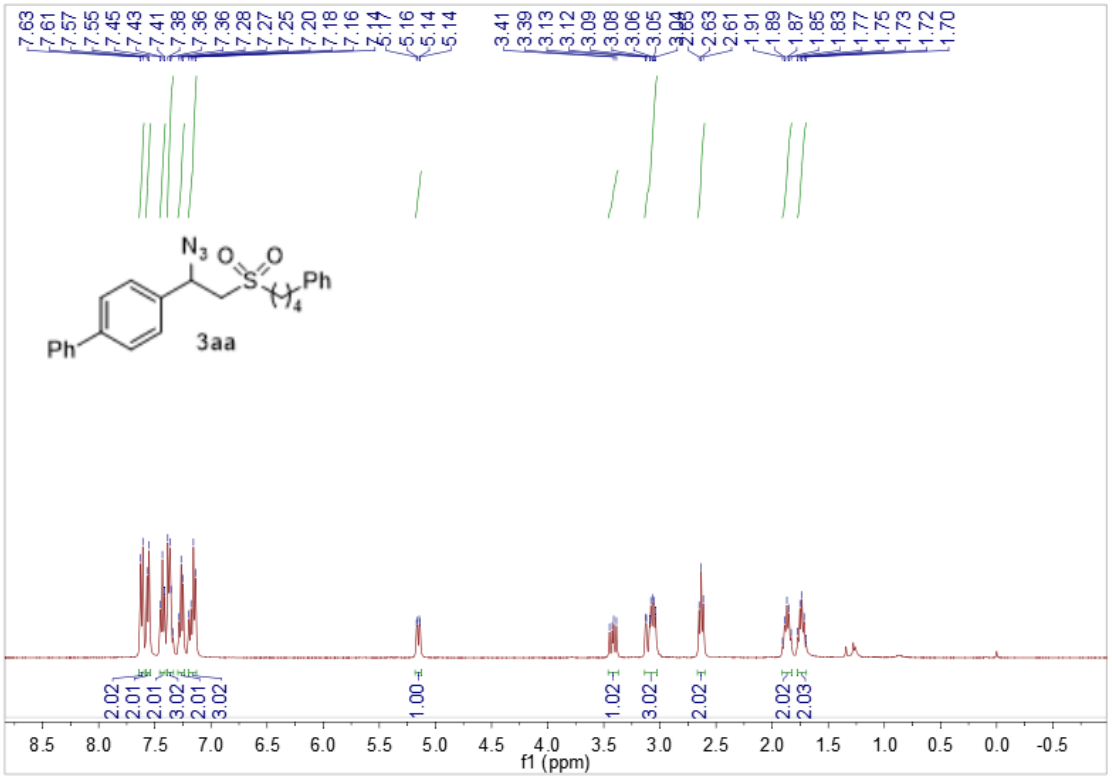
1. C. Chen, M. Wang, H. Lu, B. Zhao and Z. Shi, Enabling the Use of Alkyl Thianthrenium Salts in Cross-Coupling Reactions by Copper Catalysis, *Angew. Chem. Int. Ed.*, 2021, **60**, 21756 – 21760.

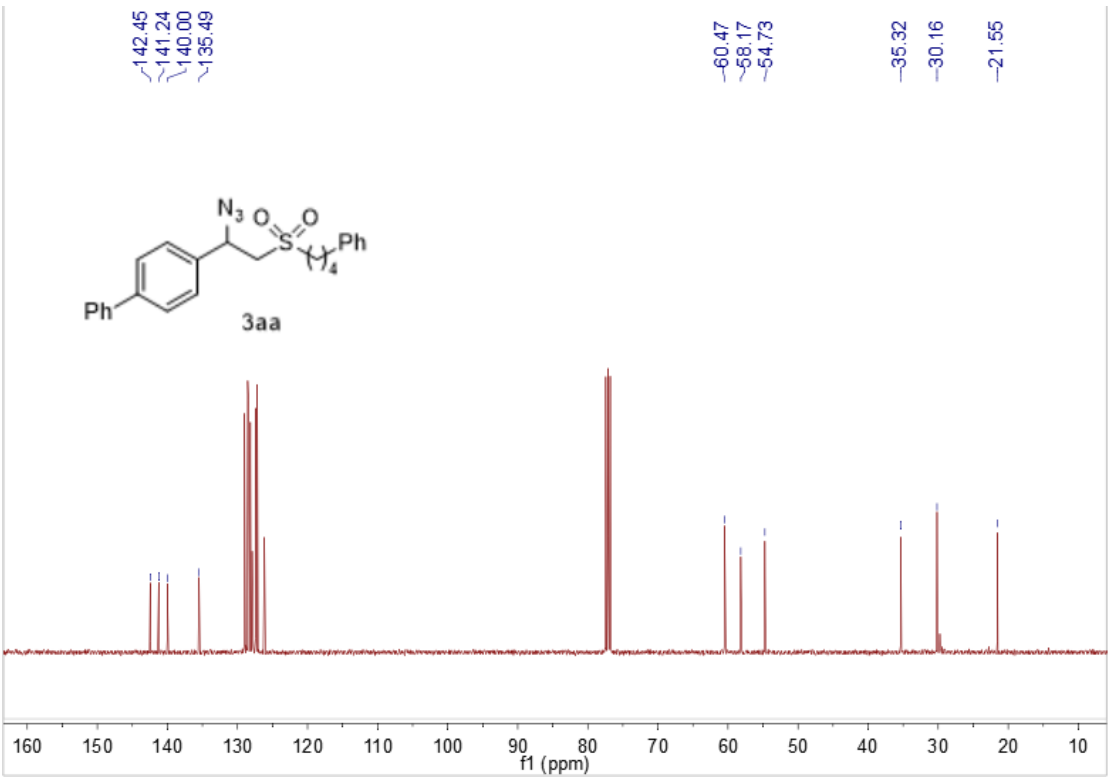
2. Y. Yu, Y.-M. Jiang, X.-B. Zhu, Y.-Y. Lin, Y. Yuan and K.-Y. Ye, Electrochemical β-Chlorosulfoxidation of Alkenes, *Org. Chem. Front.*, 2022, **9**, 5586-5591.

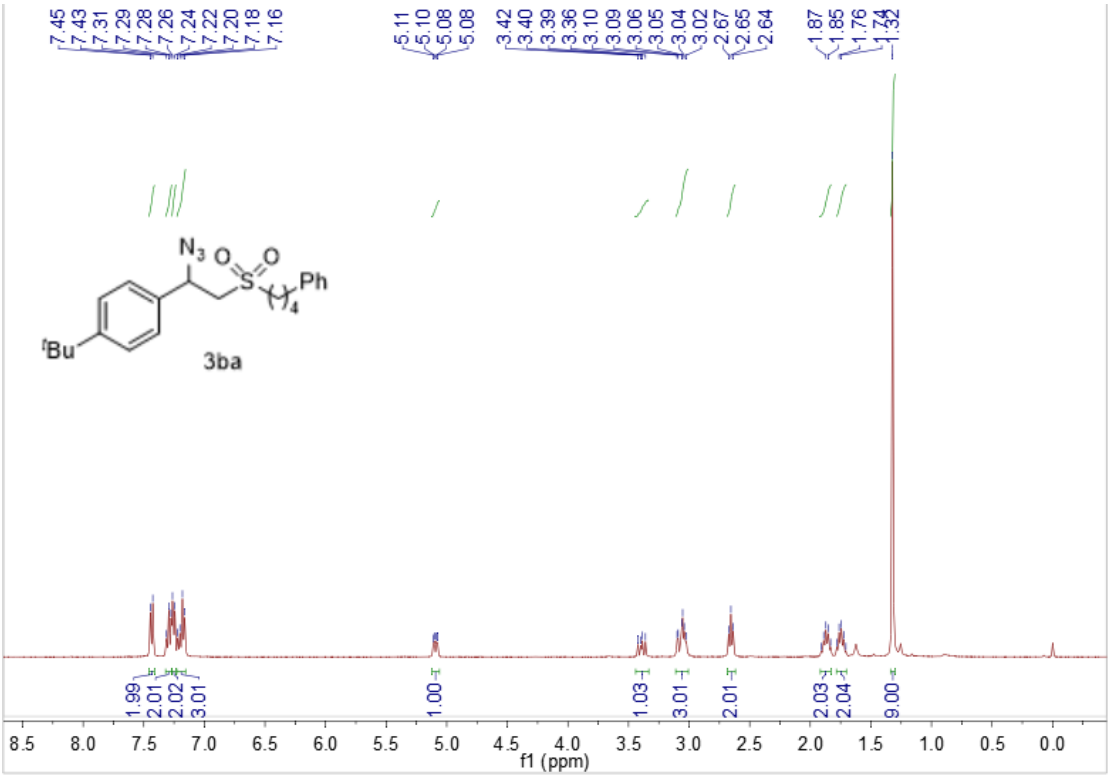
3. J. Zhang, J. Wu, X. Chang, P. Wang, J. Xia and J. Wu. An Iron-Catalyzed Multicomponent Reaction of Cycloketone Oxime Esters, Alkenes, DABCO·$(SO_2)_2$ and Trimethylsilyl Azide, *Org. Chem. Front.*, 2022, **9**, 917-922.

4. Y. Xiong, Y. Sun and G. Zhang, Copper-Catalyzed Synthesis of β-Azido Sulfonates or Fluorinated Alkanes: Divergent Reactivity of Sodium Sulfinates, *Org. Lett.,* 2018, **20**, 6250–6254.

5. ^{1}H and ^{13}C NMR spectra of compounds 3, 4, 5, 6, 9, 10, 11.



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5.08
5.08
3.42
3.40
3.39
3.36
3.10
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3.06
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3.04
3.02
2.67
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2.64
1.87
1.85
1.76
1.74
1.32
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S
Ph
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tBu
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2.02
3.01
1.00
1.03
3.01
2.01
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2.04
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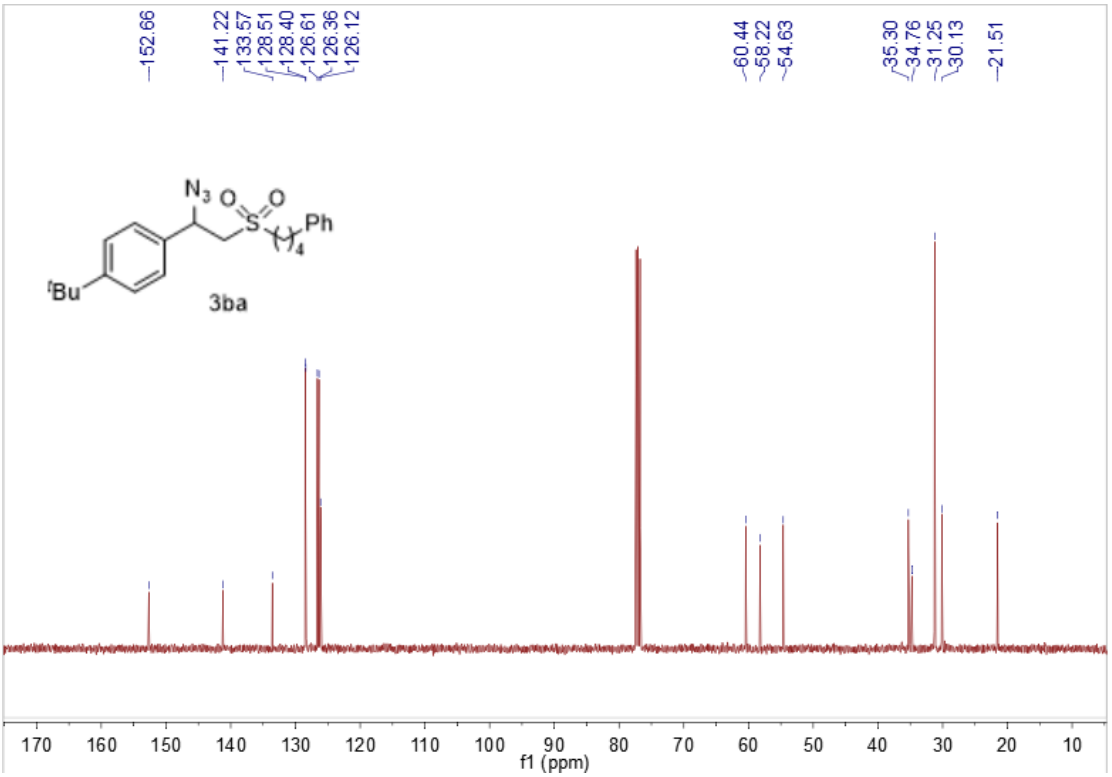
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N3
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O
S
Ph
4
tBu
3ba
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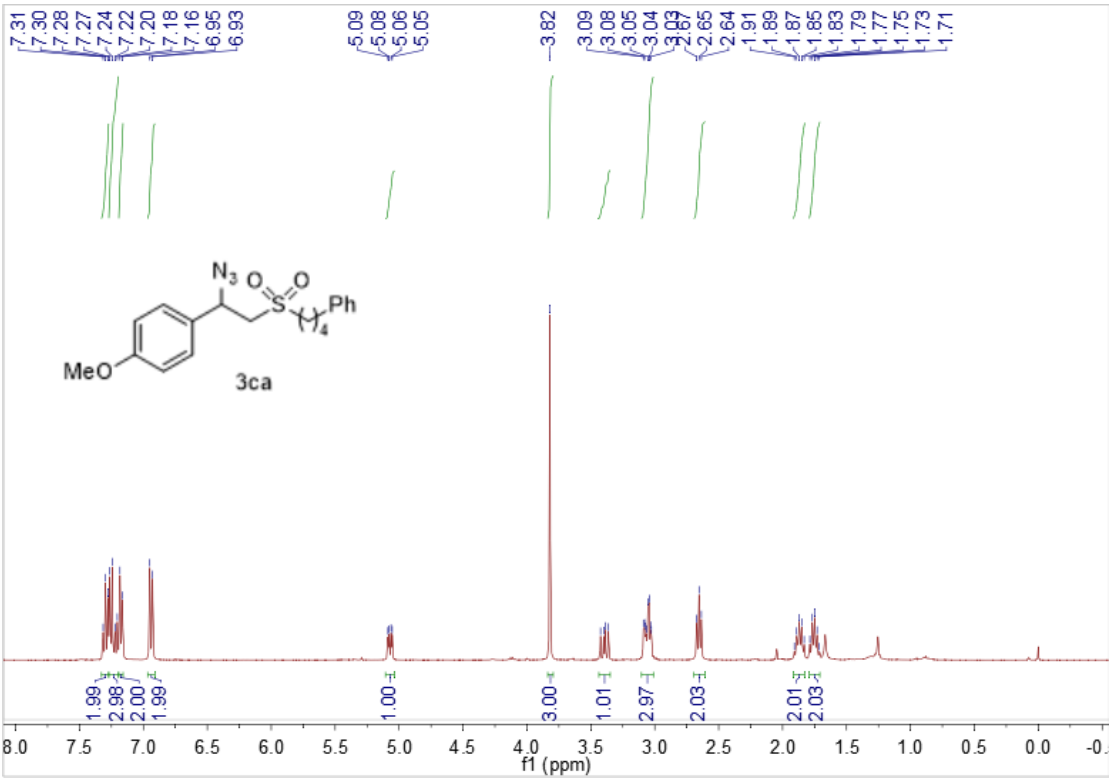
20
10
f1 (ppm)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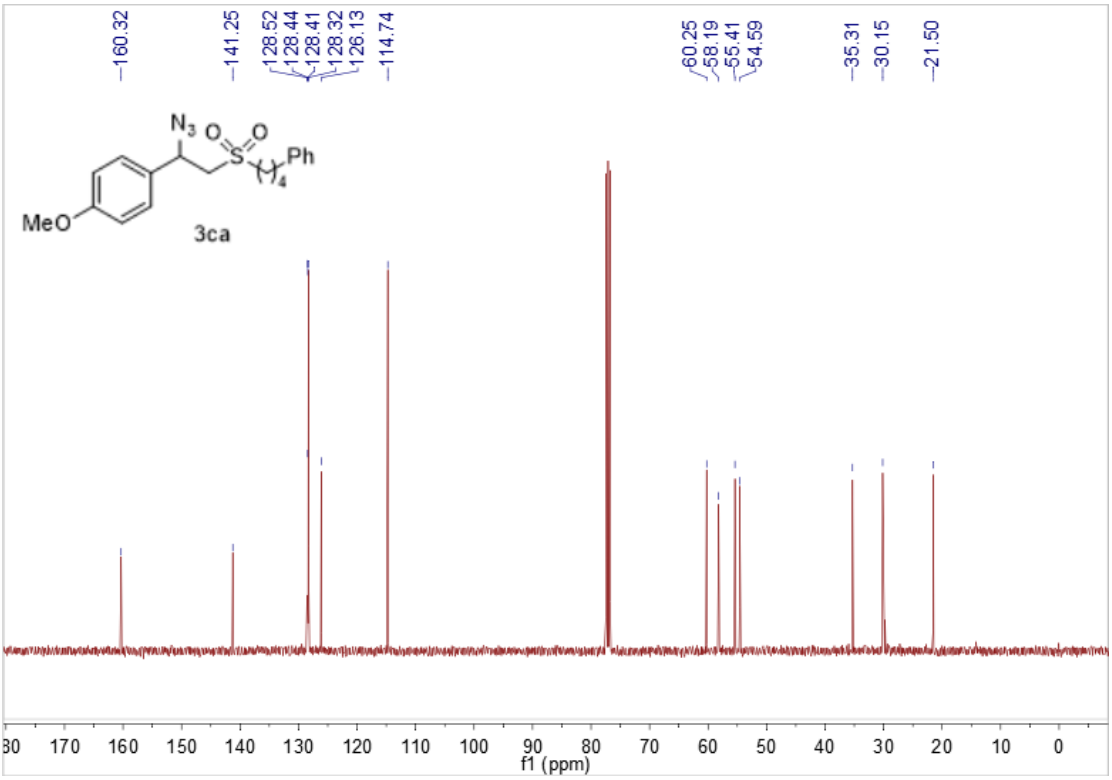
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Ph
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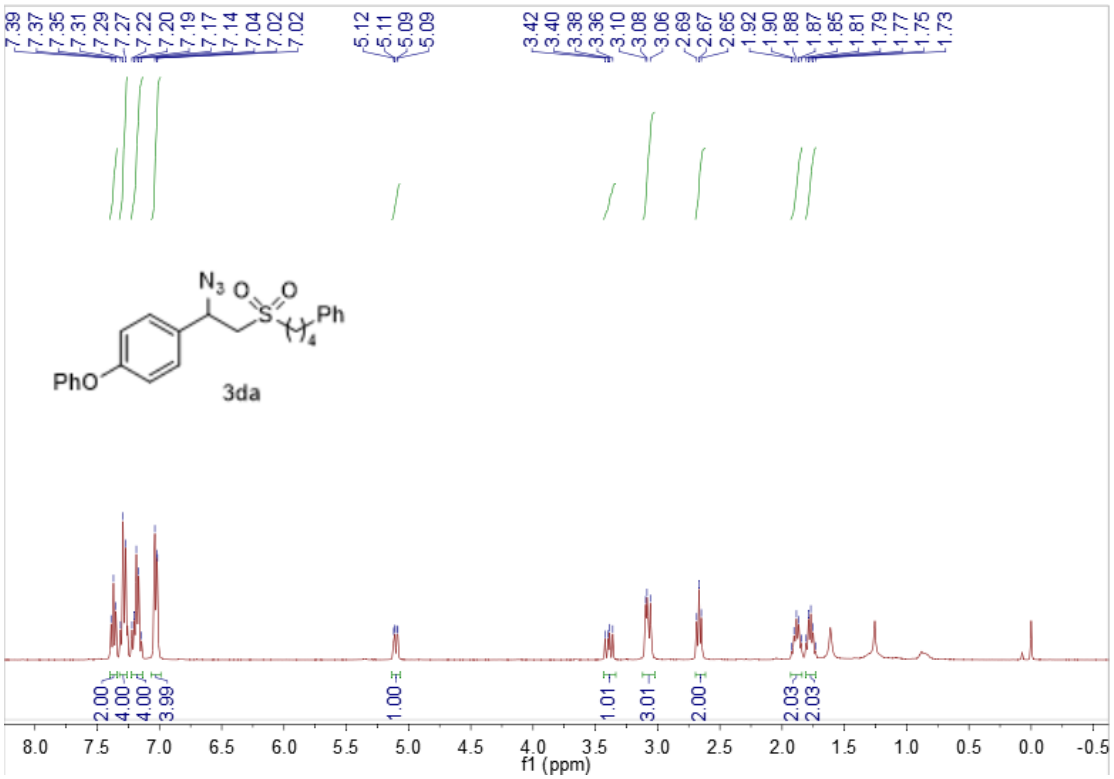
f1 (ppm)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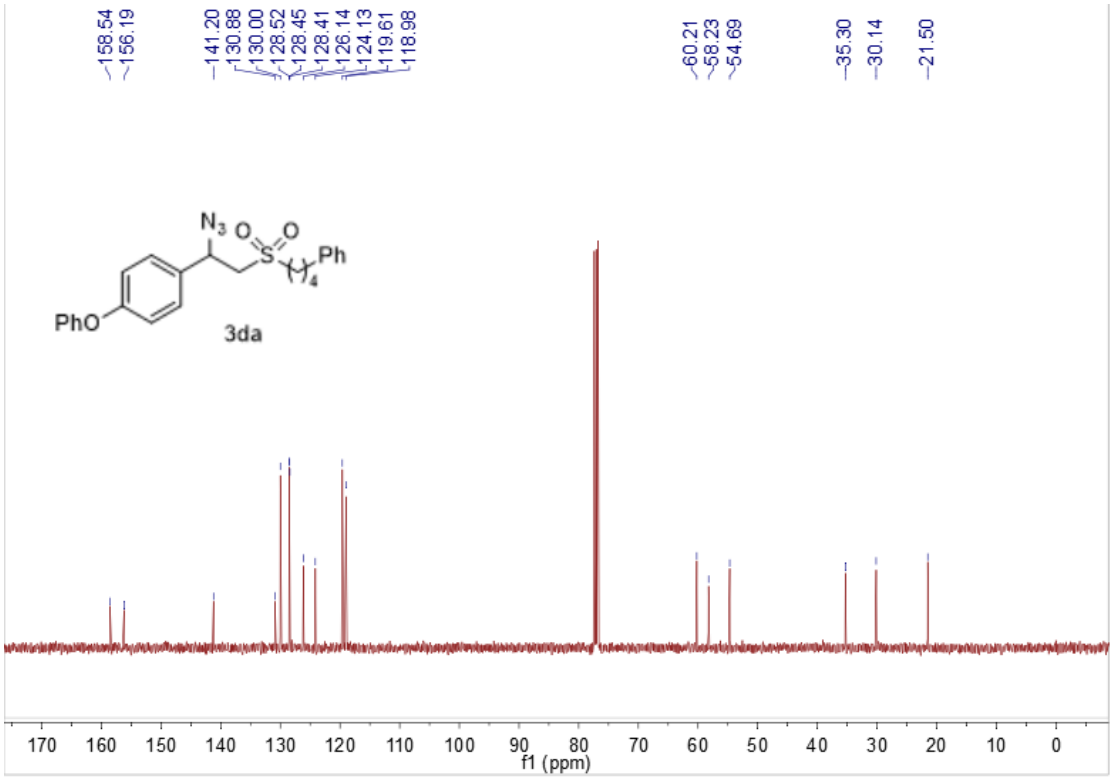
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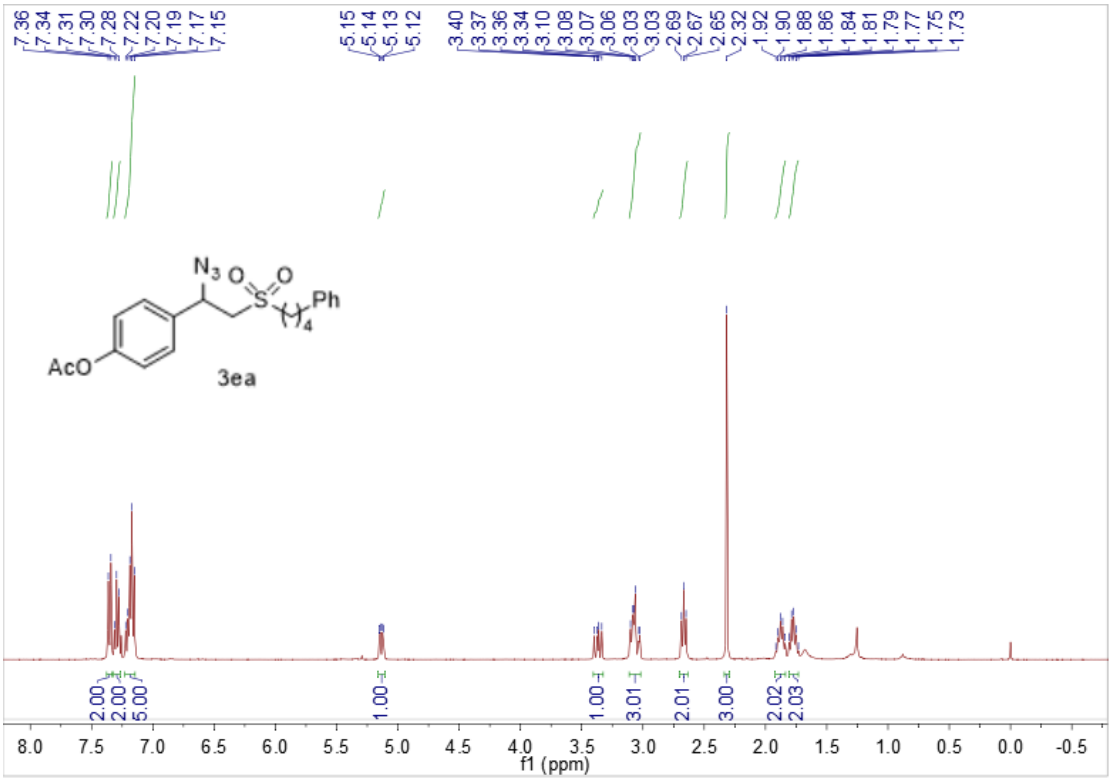
f1 (ppm)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O
Ph
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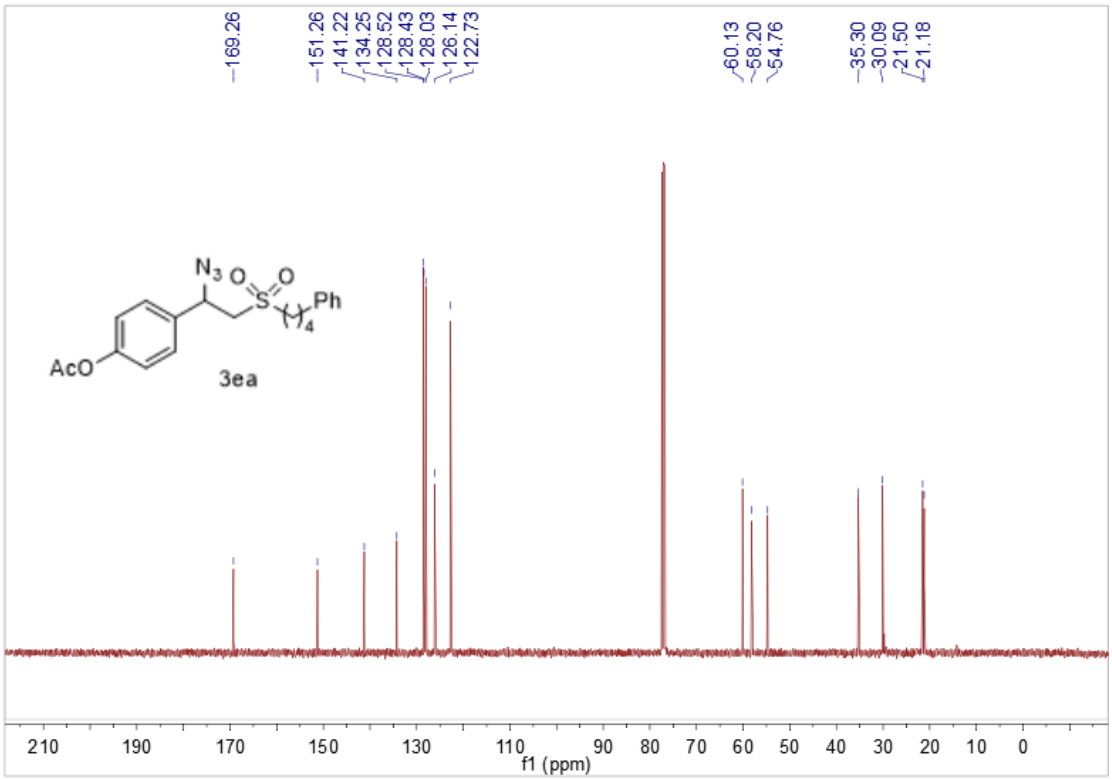
f1 (ppm)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Ph
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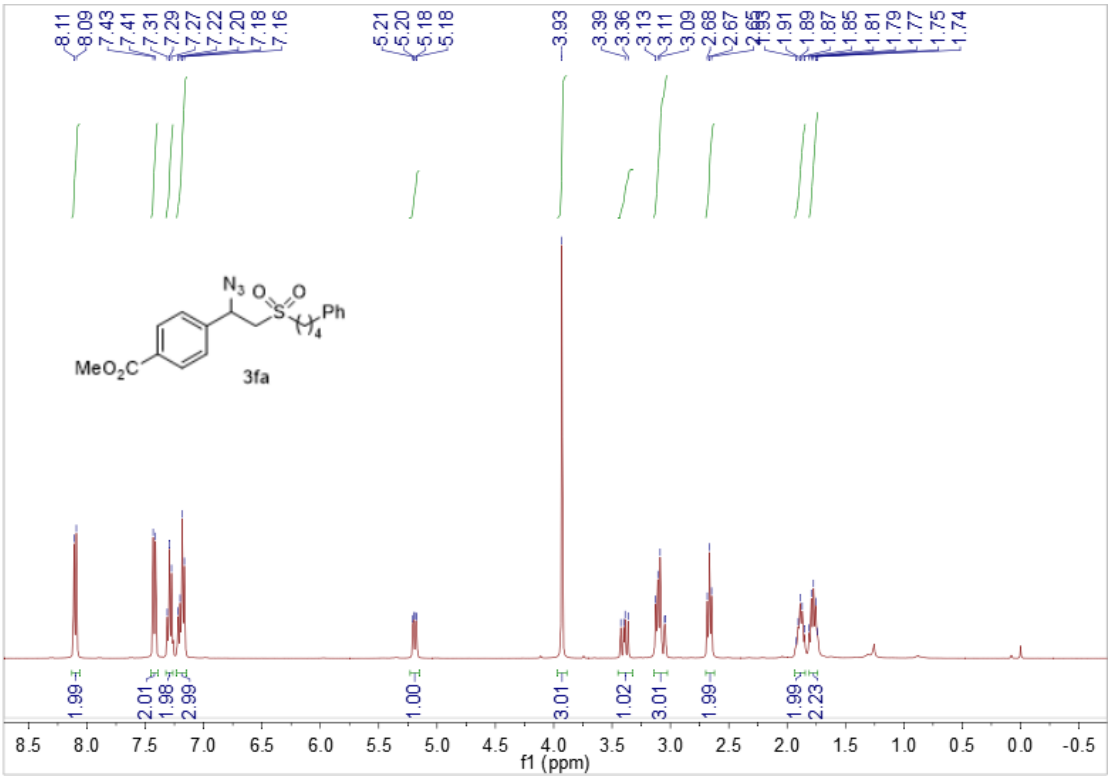
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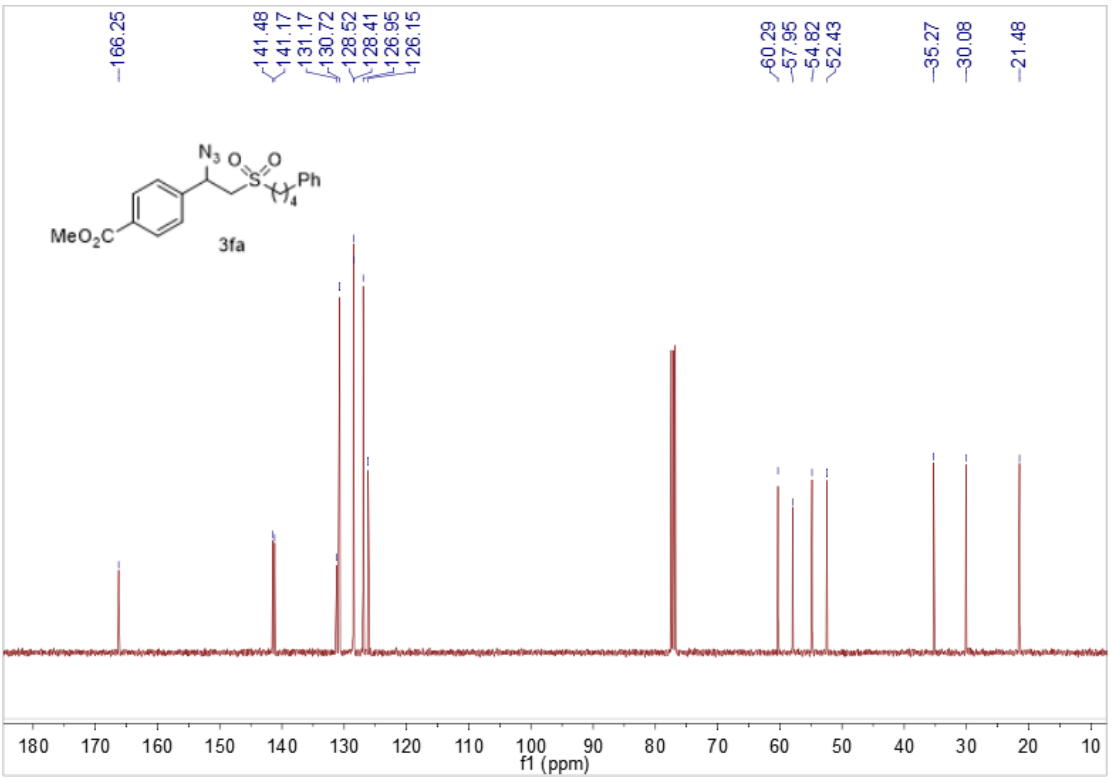
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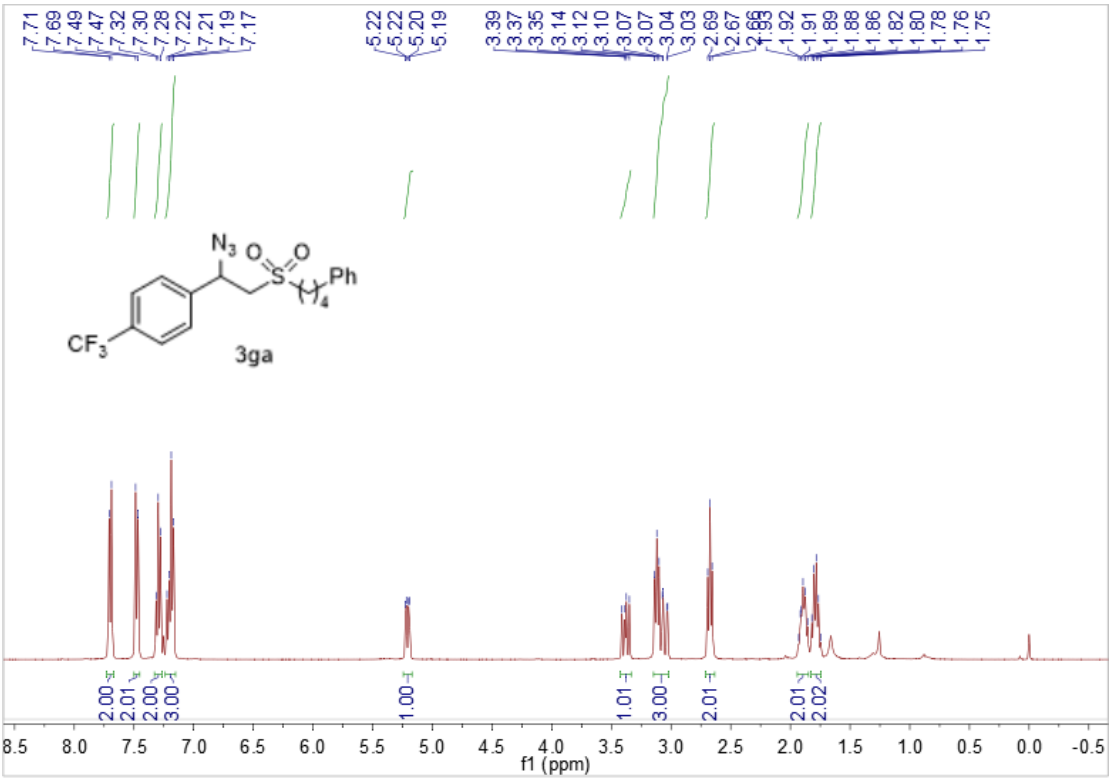
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3.00
2.01
2.01
2.02
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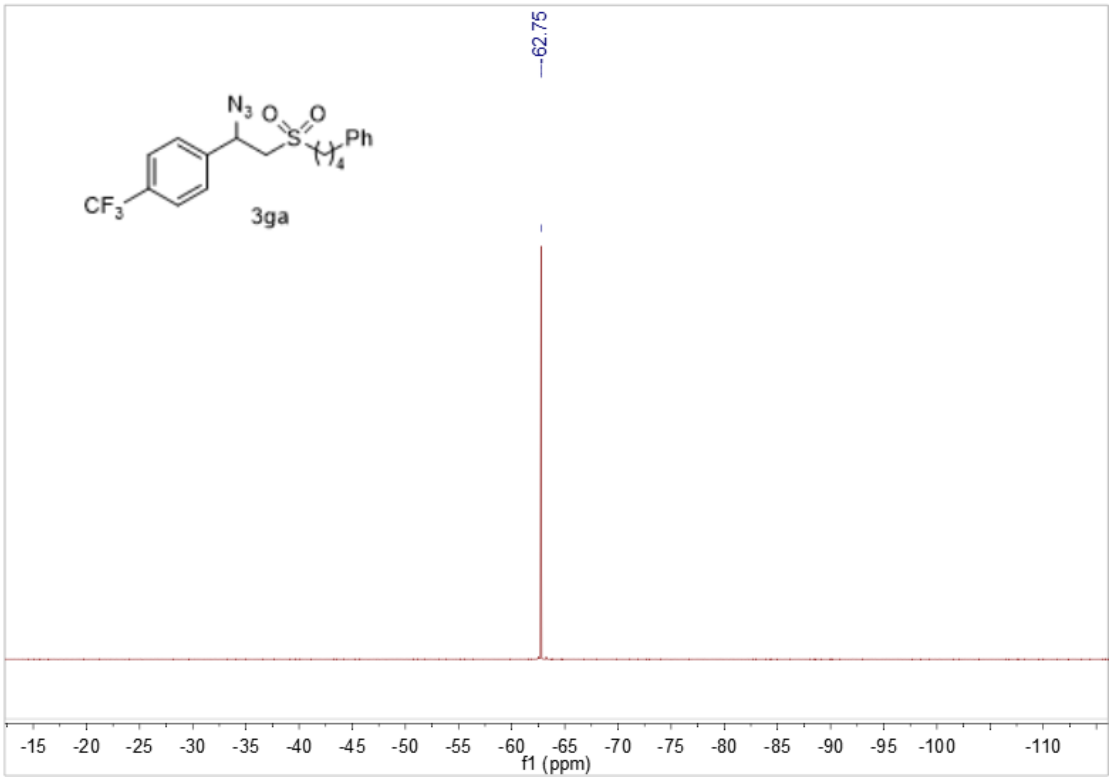
f1 (ppm)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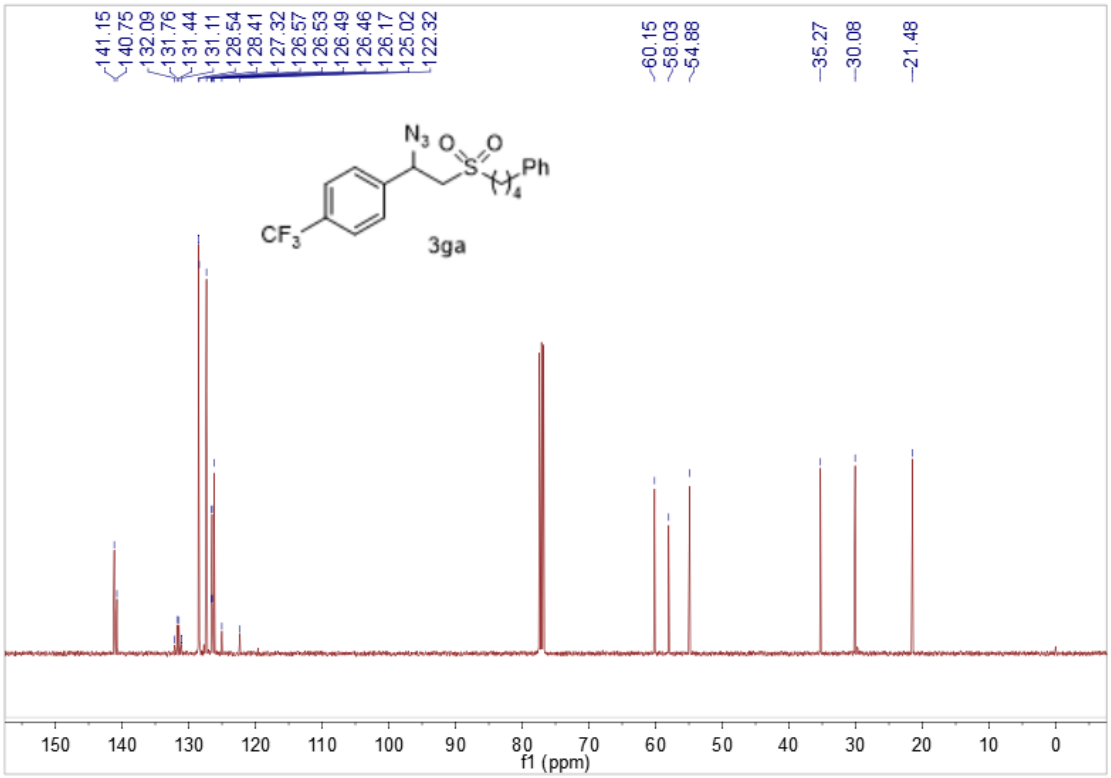
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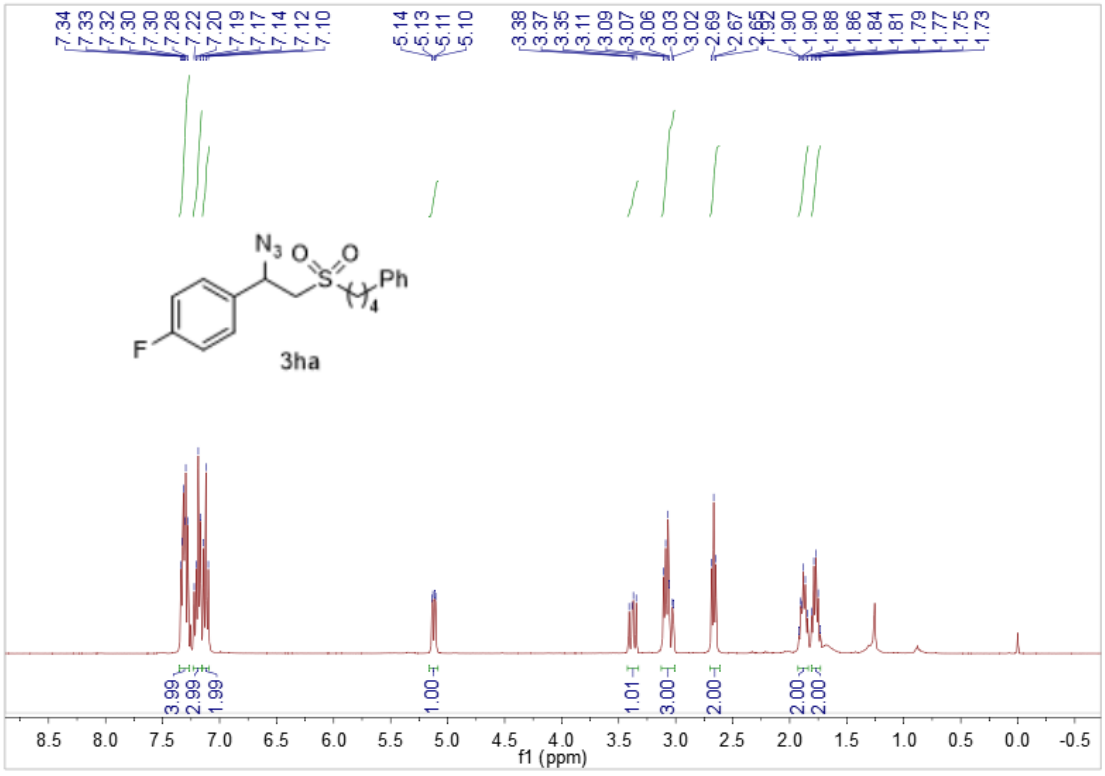
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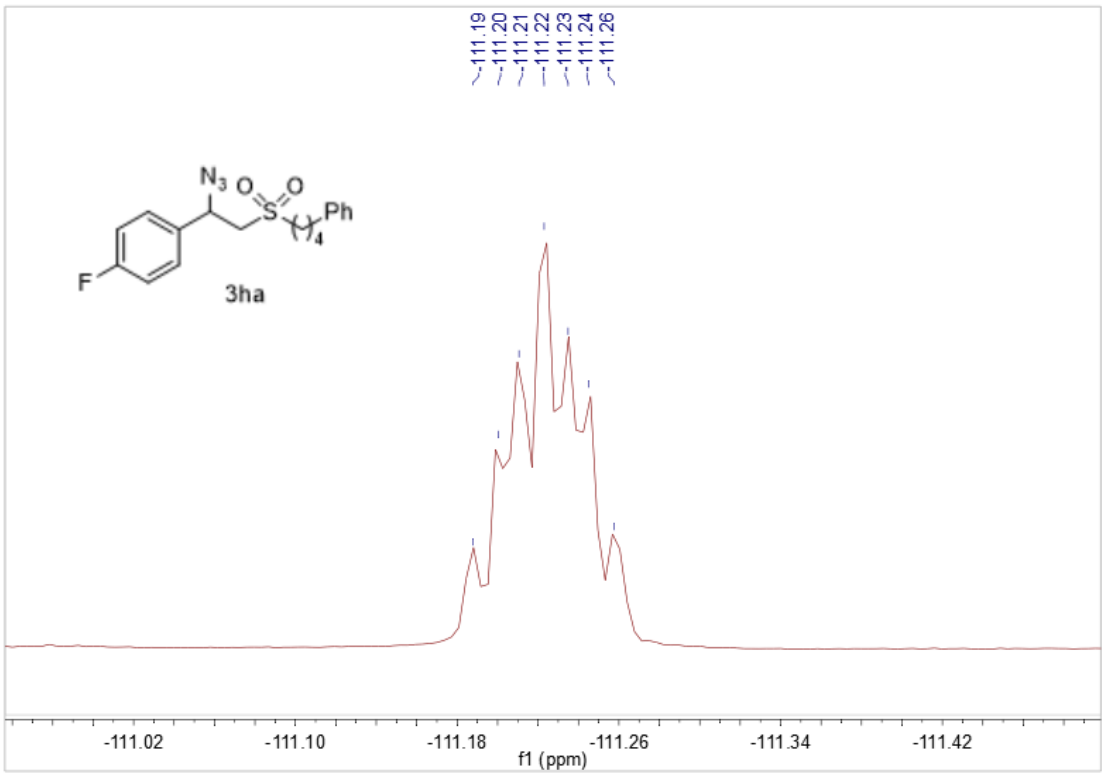
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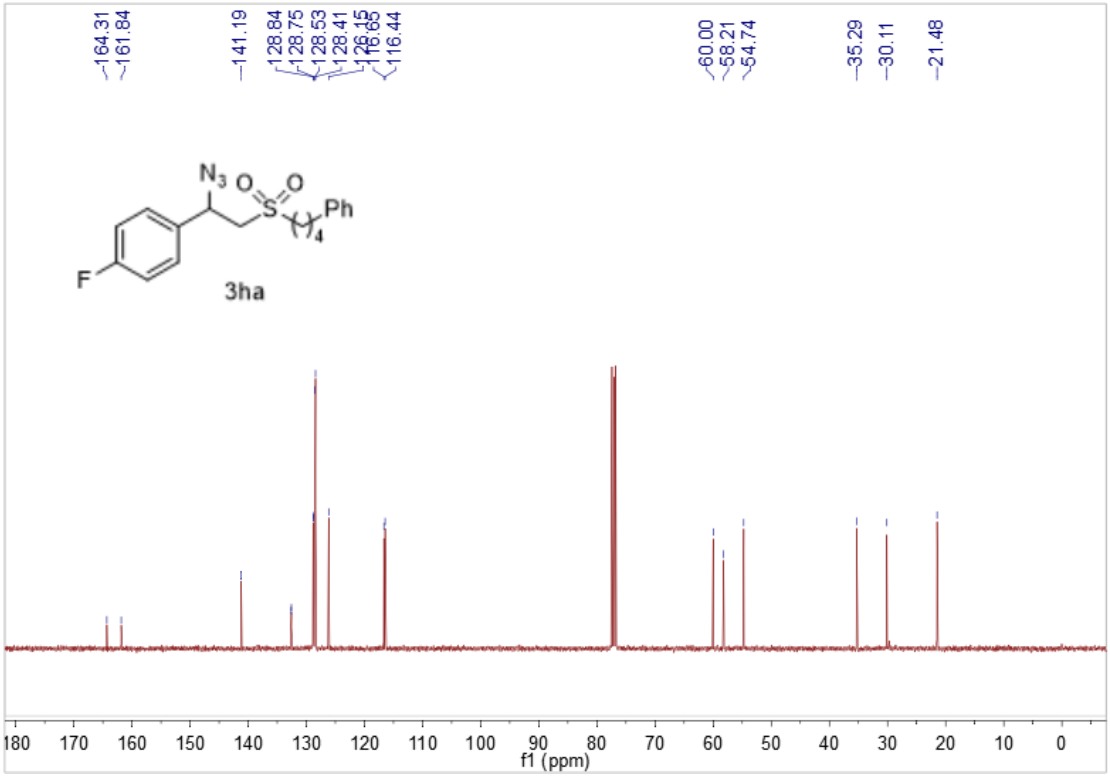
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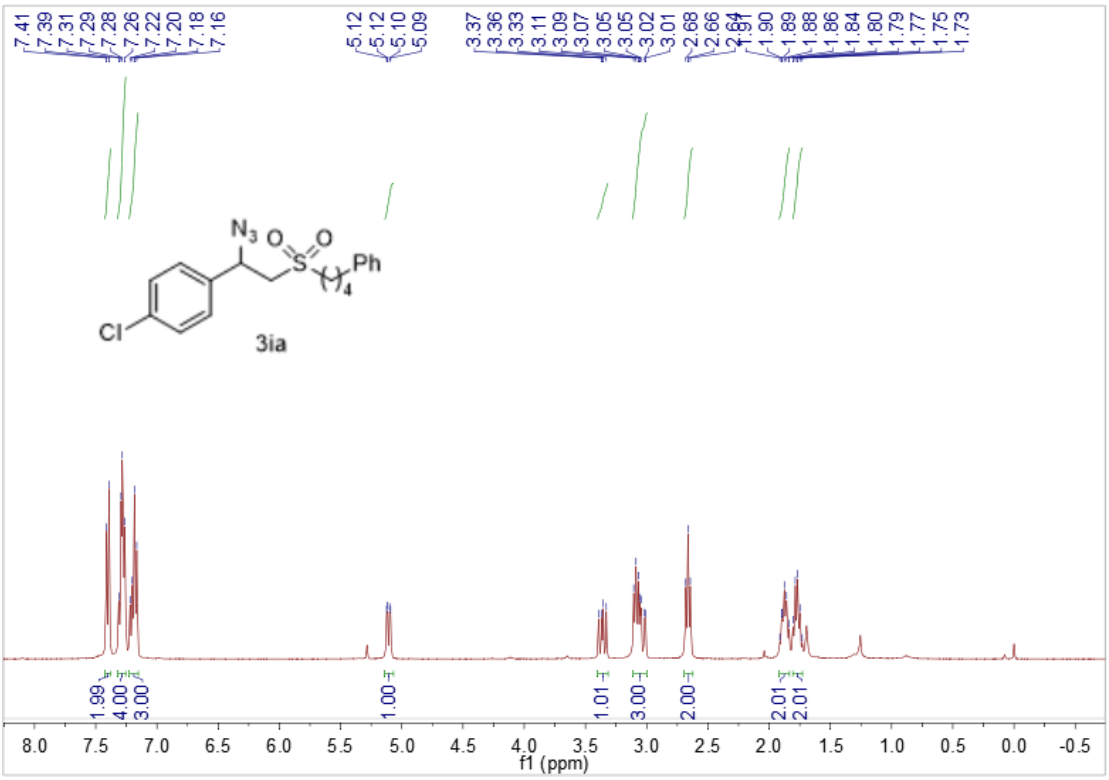
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1.75
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S
O
Ph
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Cl
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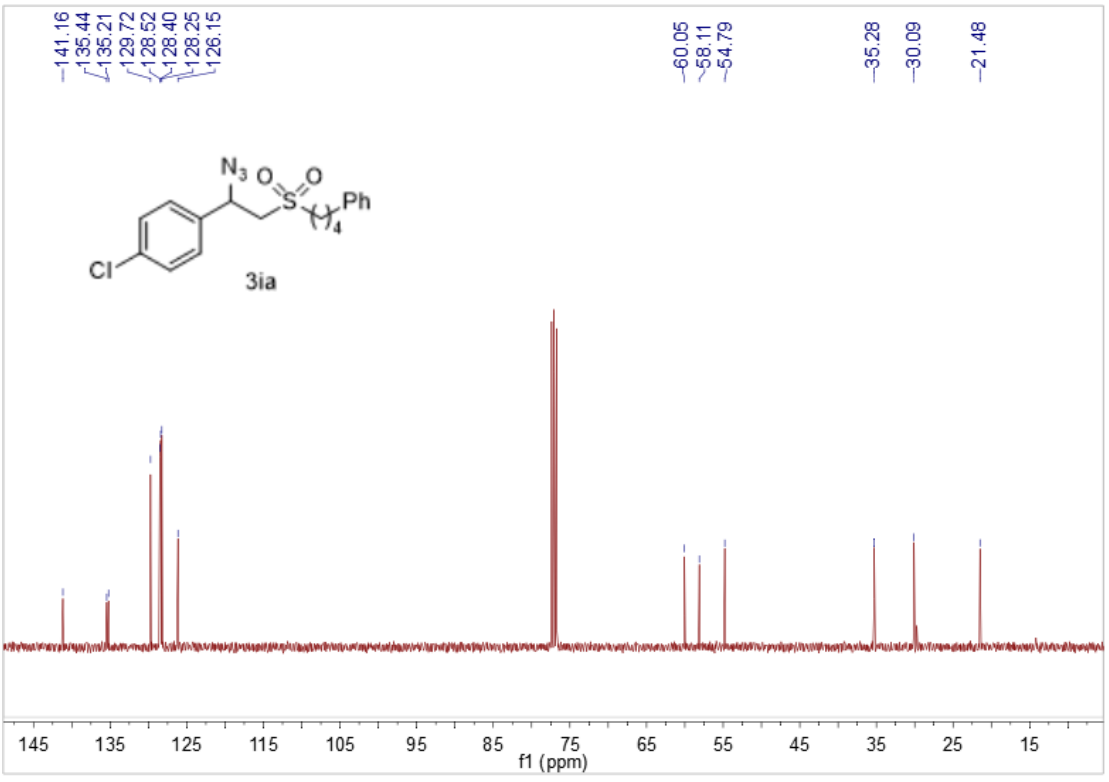
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O
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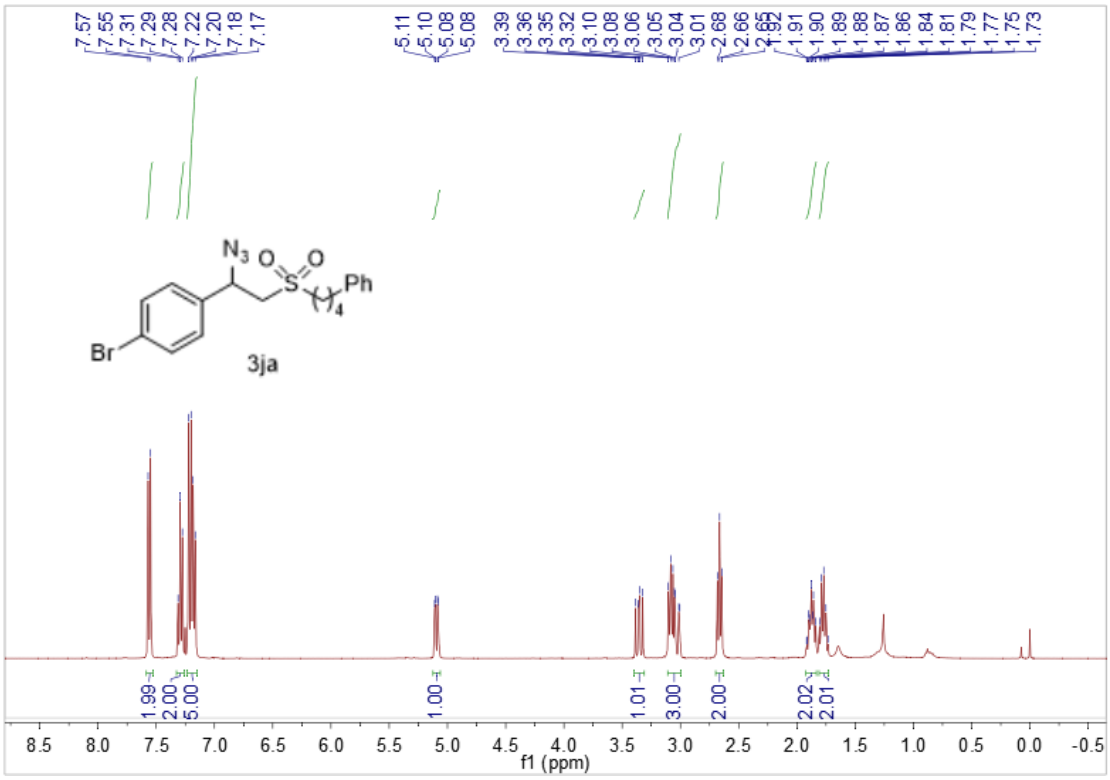
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1.73
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S
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Ph
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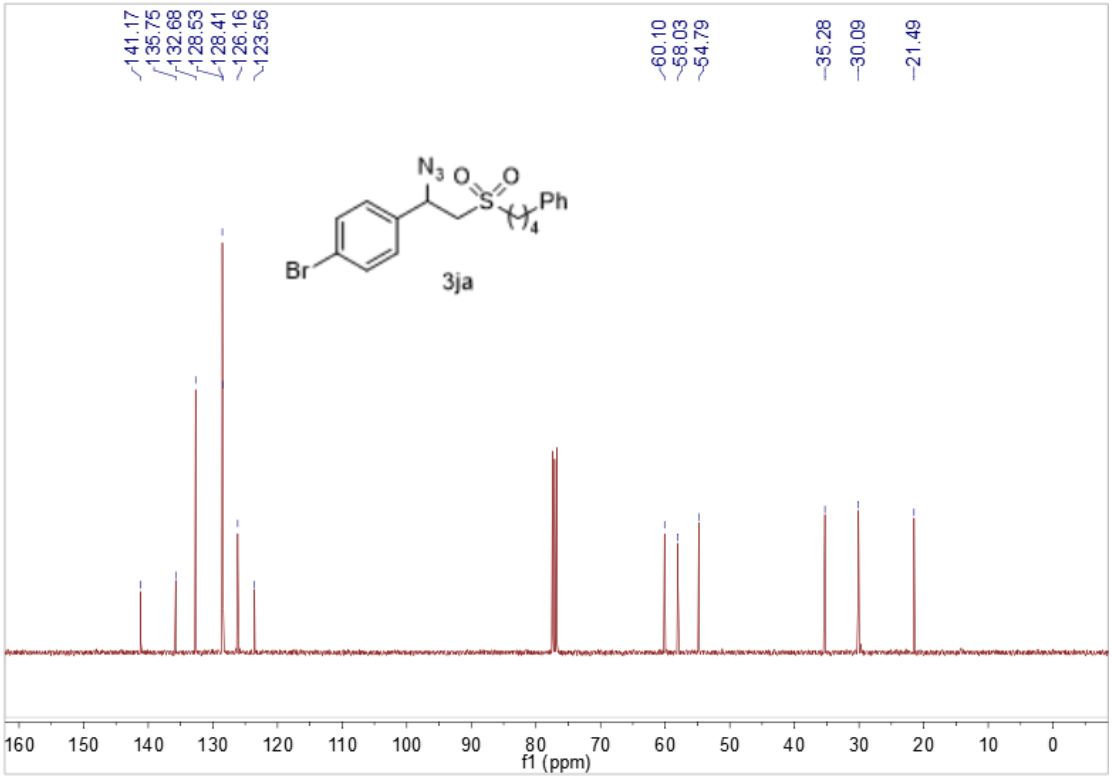
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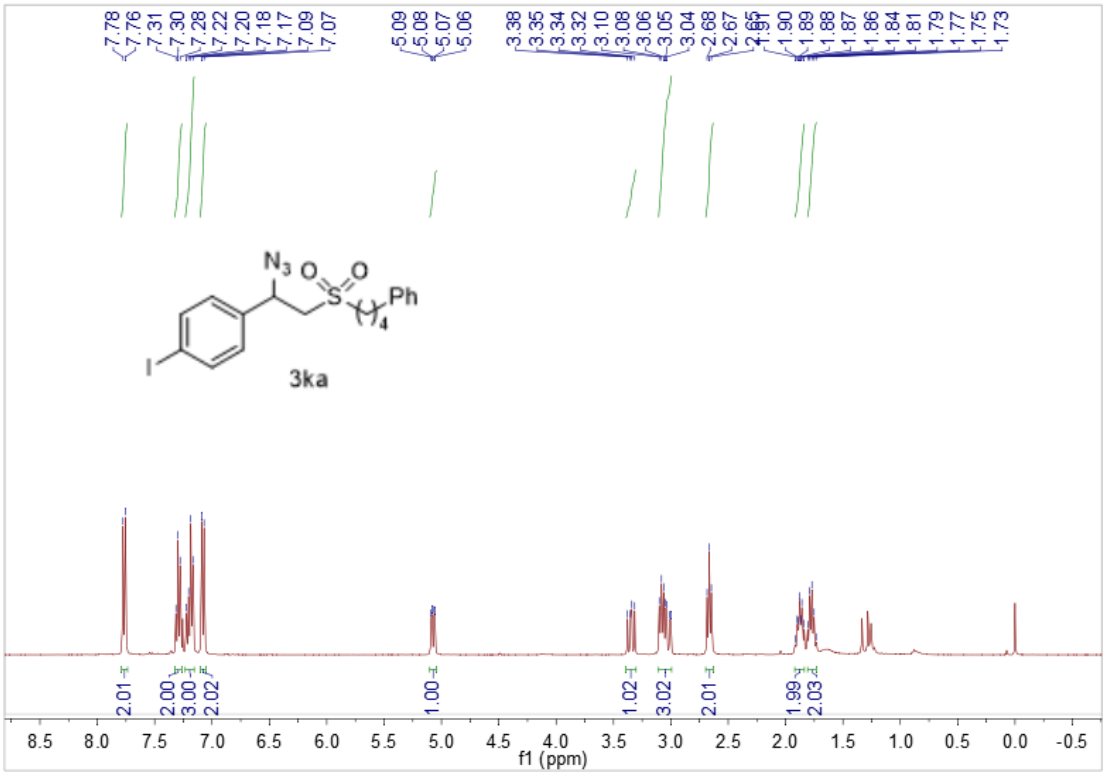
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Ph
I
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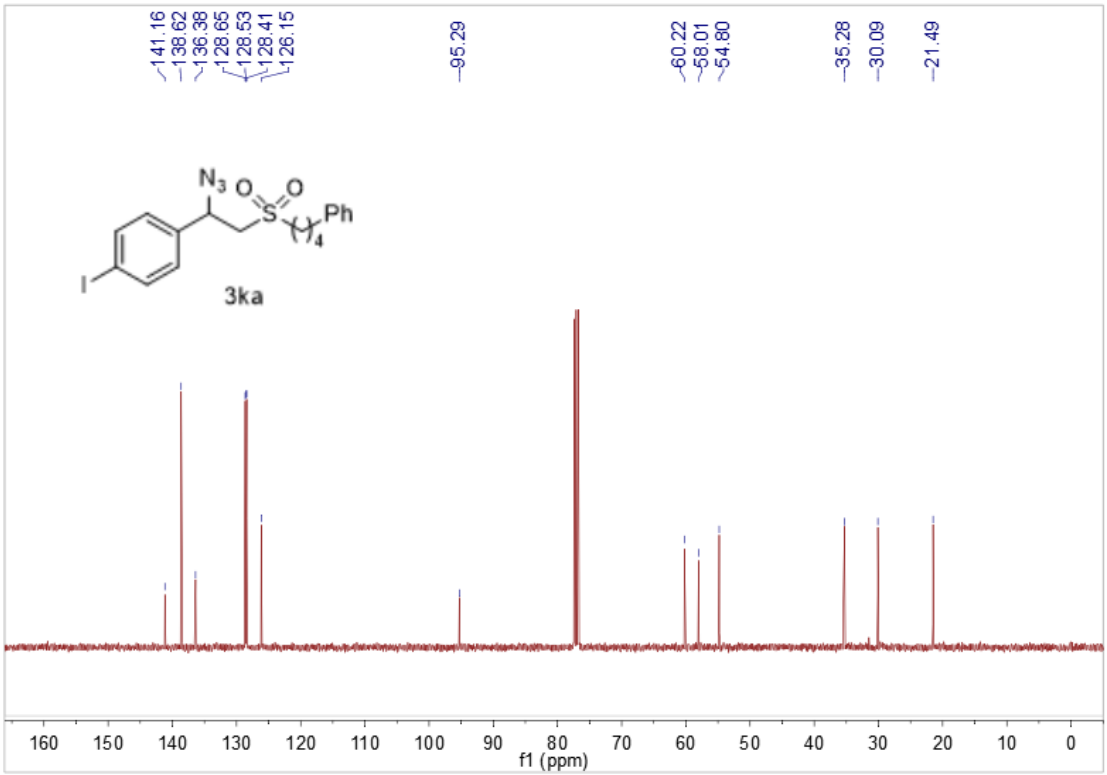
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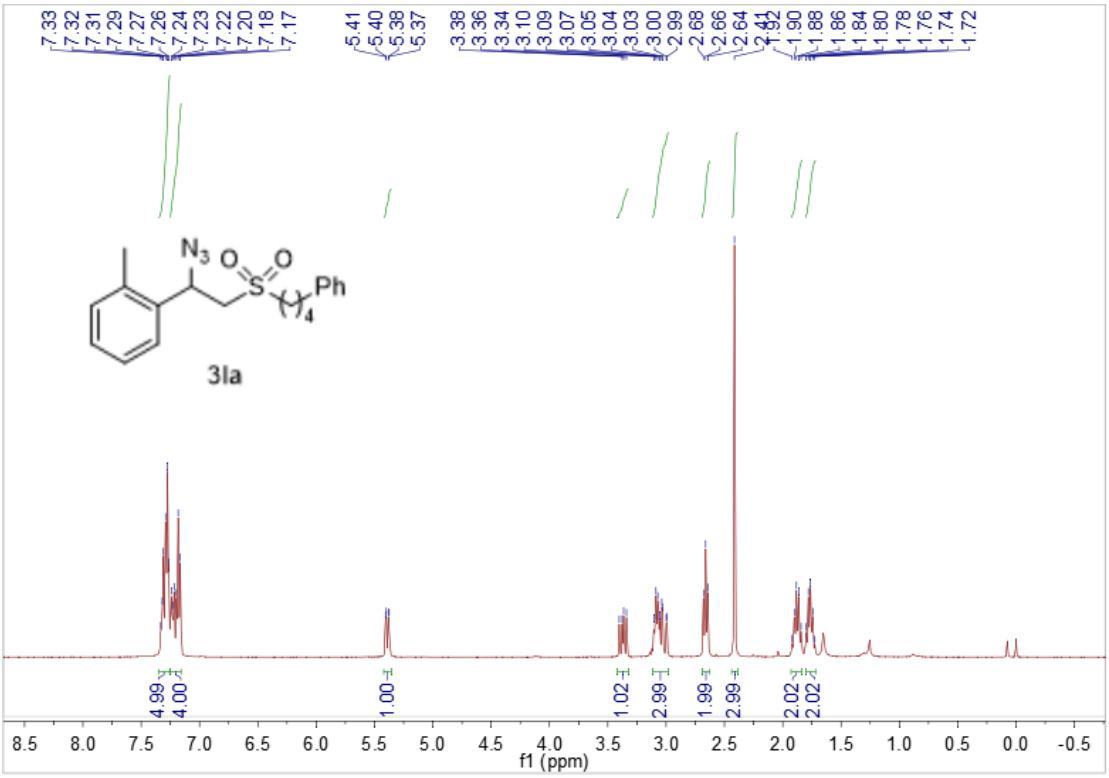
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S
O
Ph
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1.00
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2.99
1.99
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2.02
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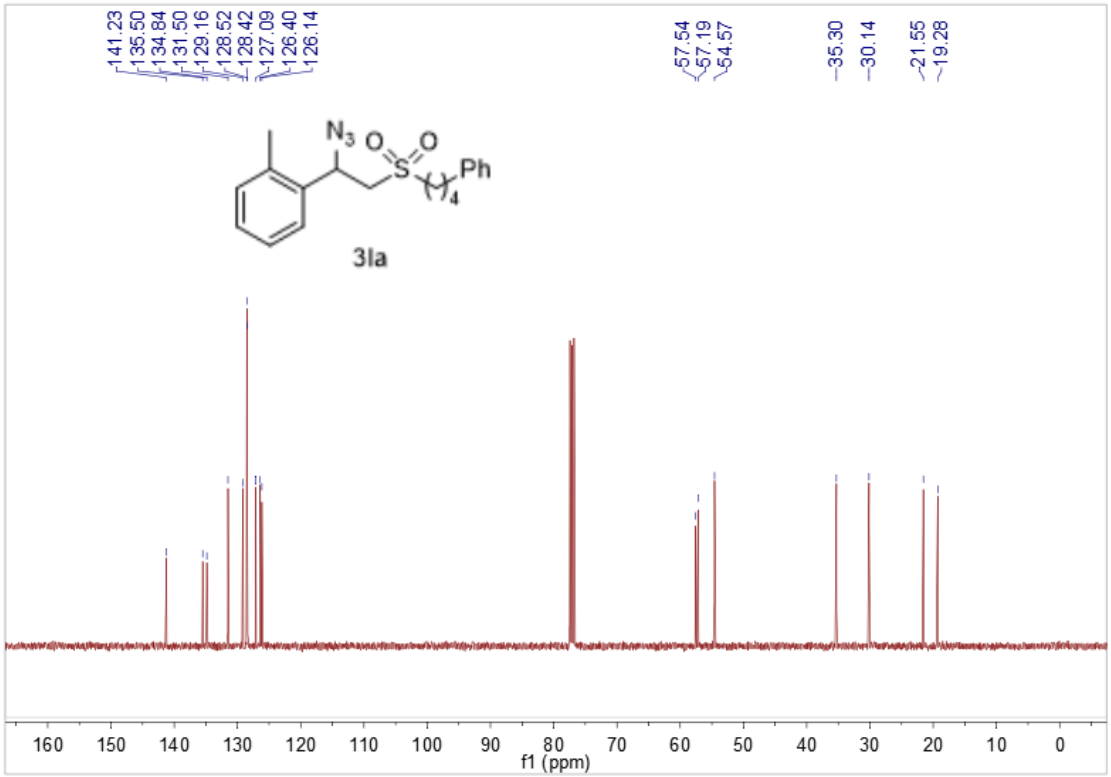
f1 (ppm)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21.55
19.28
N3
O
S
O
Ph
4
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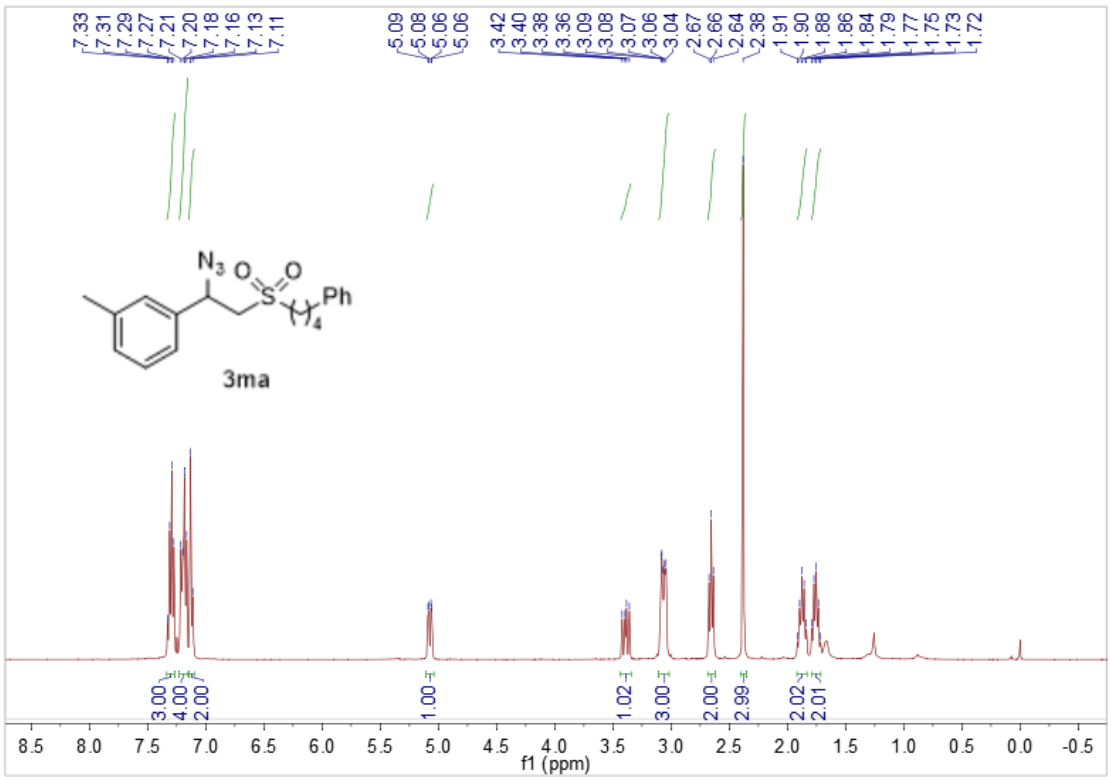
f1 (ppm)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7.20
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7.11
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5.08
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1.73
1.72
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O
S
O
Ph
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3.00
2.00
2.99
2.02
2.01
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5.0
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1.5
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0.0
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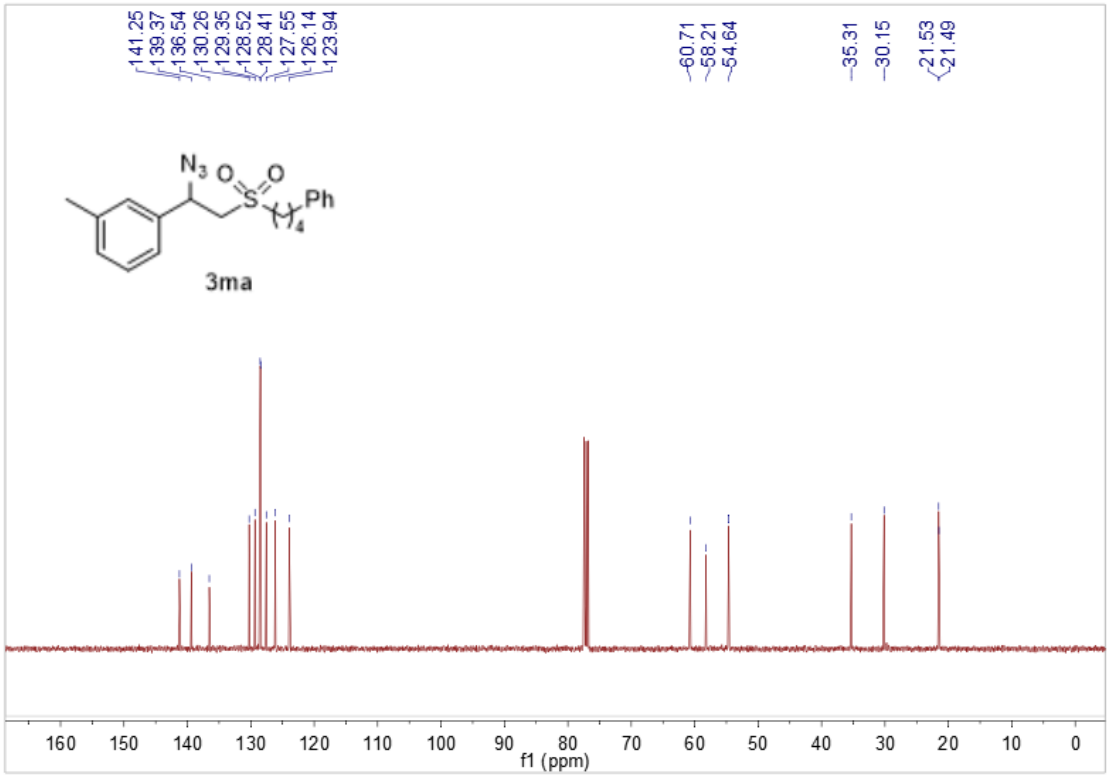
f1 (ppm)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30.15
21.53
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O
S
O
Ph
4
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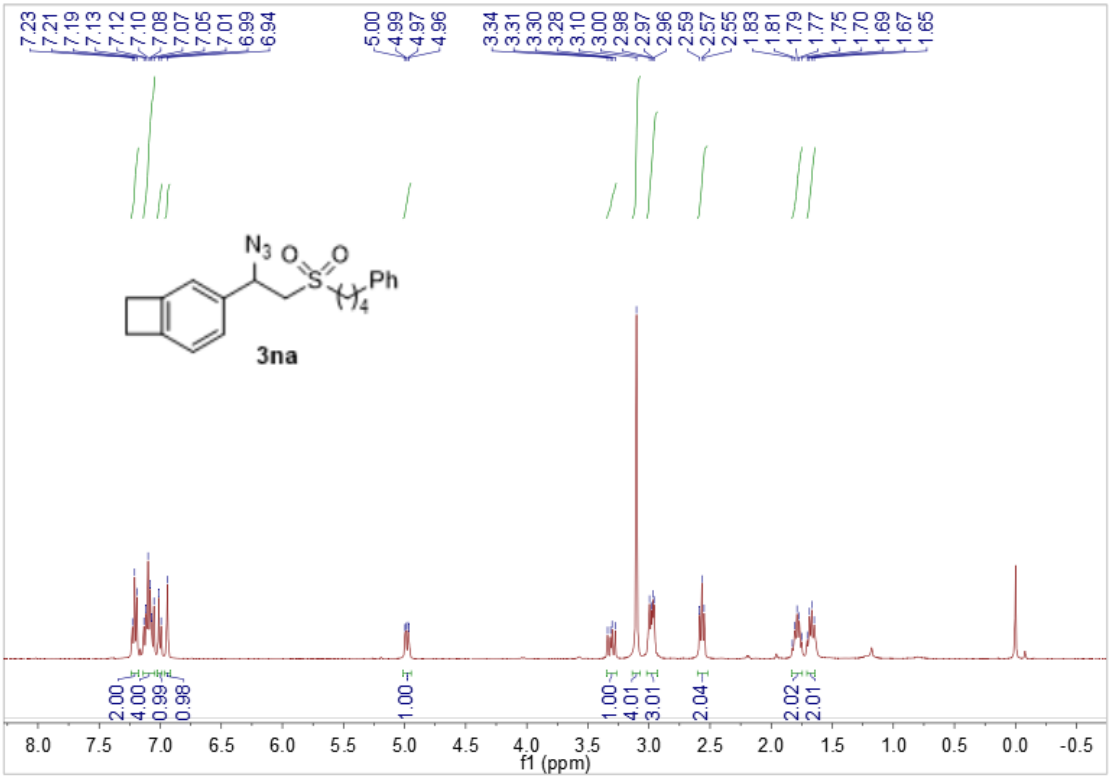
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7.01
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6.94
5.00
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4.97
4.96
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1.75
1.70
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1.67
1.65
N3
O
O
S
Ph
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1.00
4.01
3.01
2.04
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2.01
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7.0
6.5
6.0
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5.0
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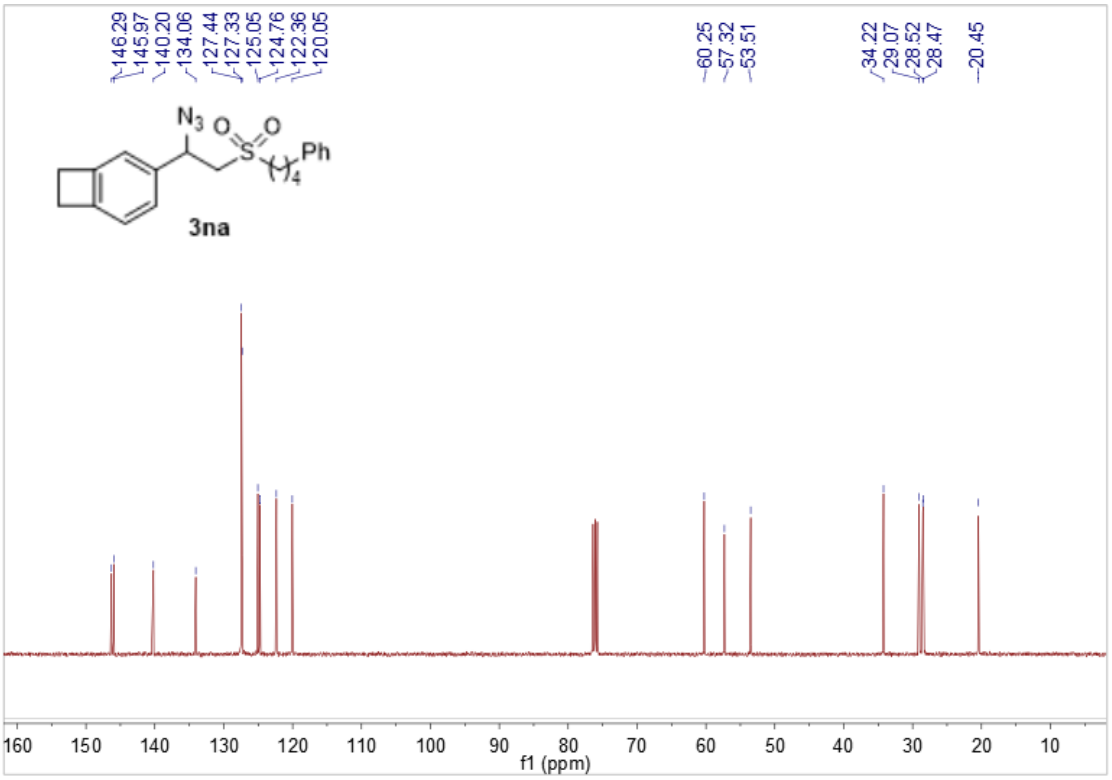
f1 (ppm)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34.22
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28.52
28.47
20.45
N3
O
O
S
Ph
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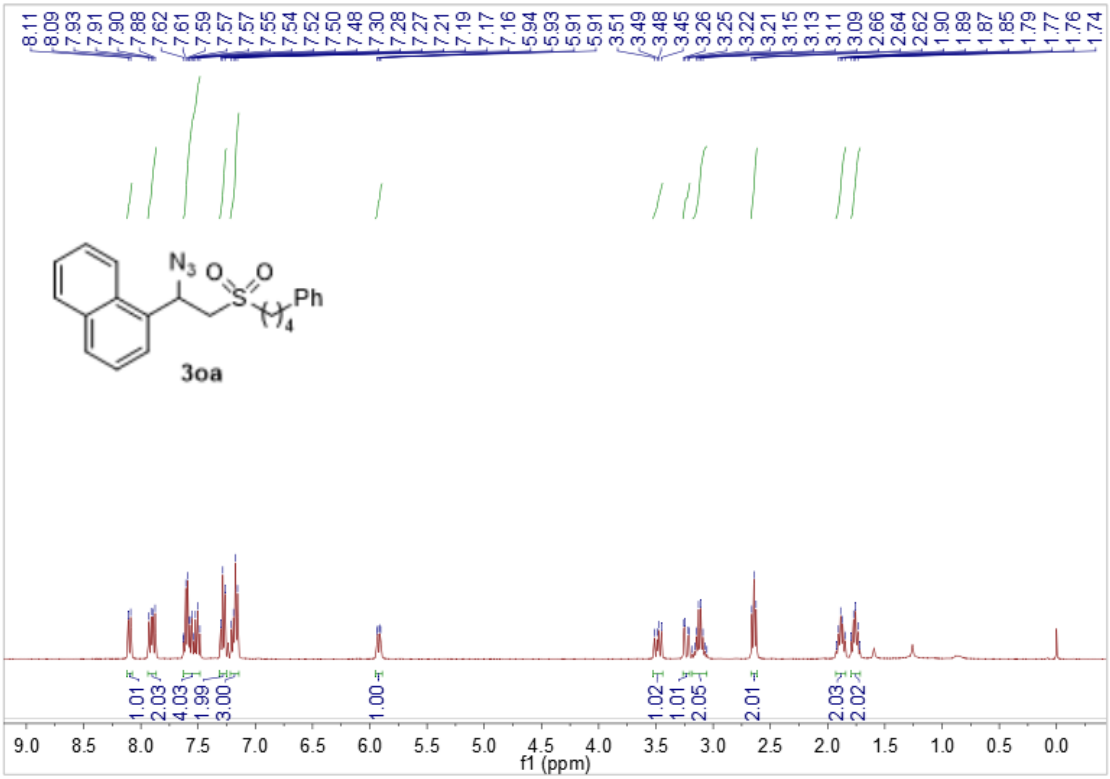
10
f1 (ppm)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S
O
Ph
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4.03
1.99
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1.02
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2.03
2.02
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2.5
2.0
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1.0
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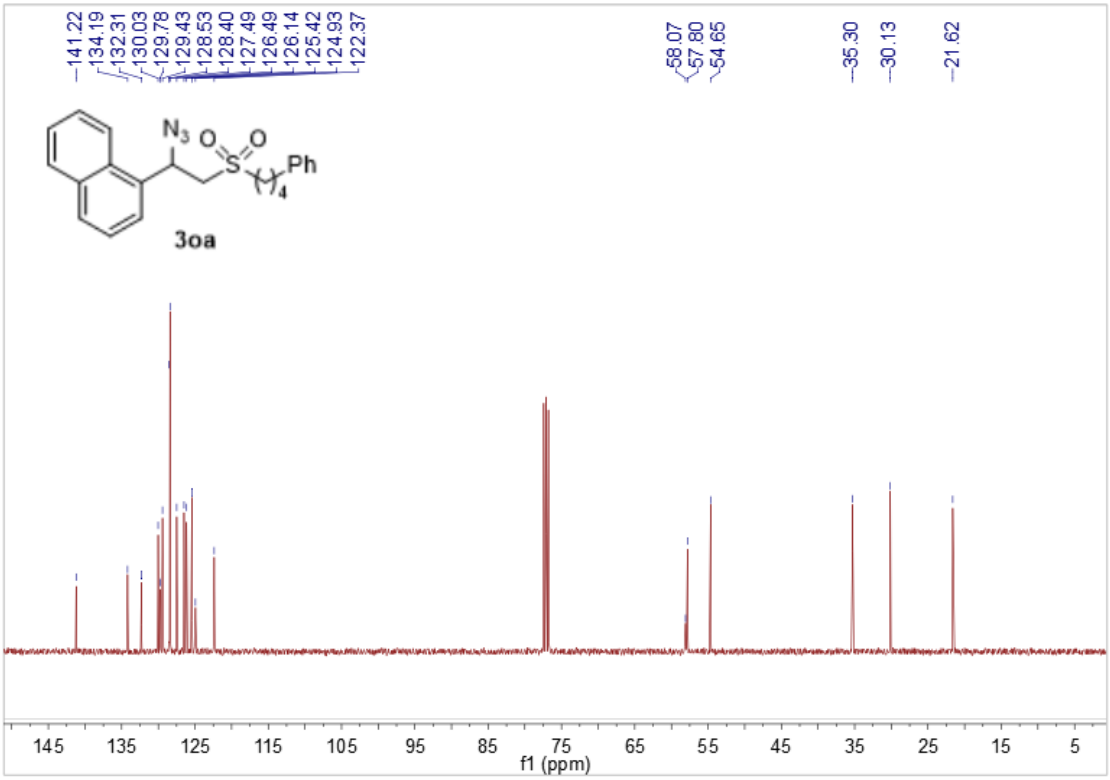
f1 (ppm)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122.37
58.07
57.80
54.65
35.30
30.13
21.62
N3
O
S
O
Ph
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3oa
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135
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115
105
95
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75
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15
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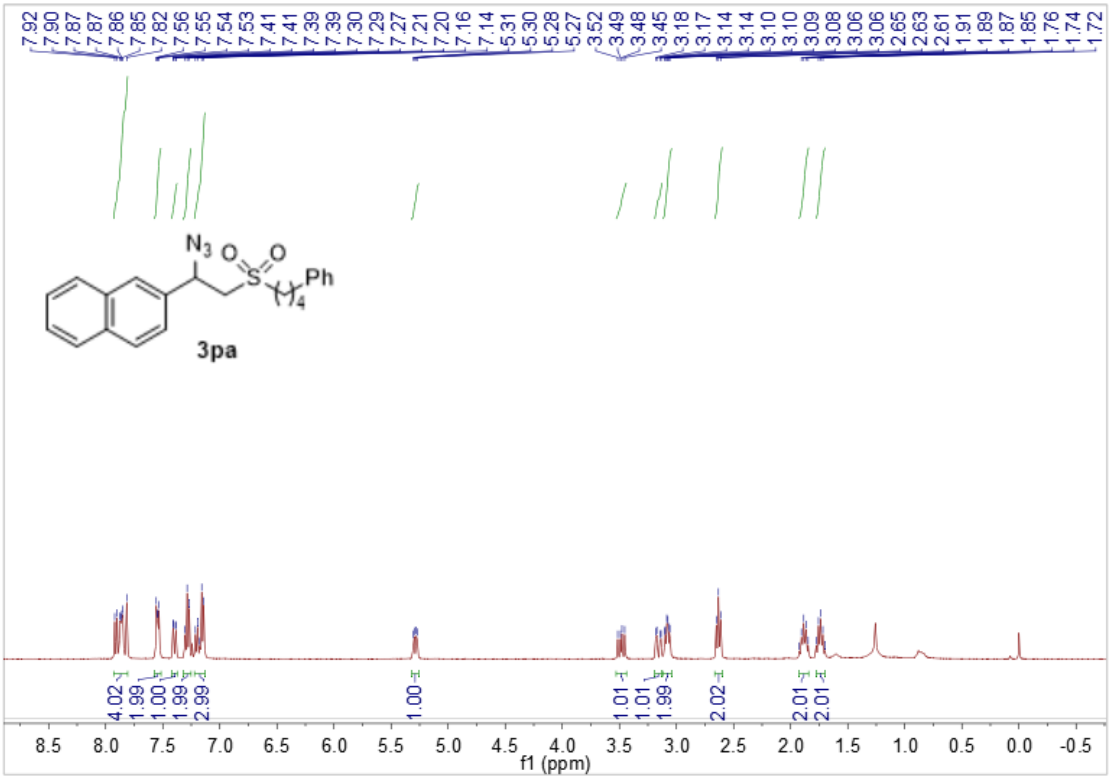
f1 (ppm)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N3 O S O Ph
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3pa
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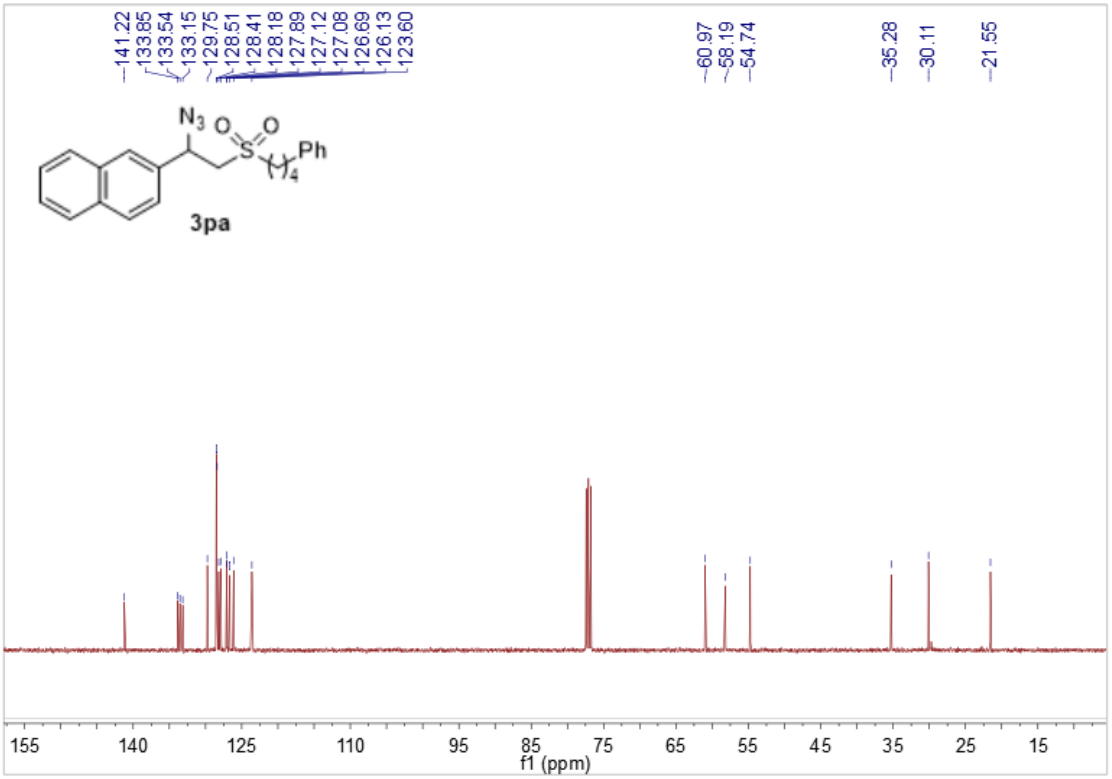
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35.28 30.11 21.55
N3 O S O Ph
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3pa
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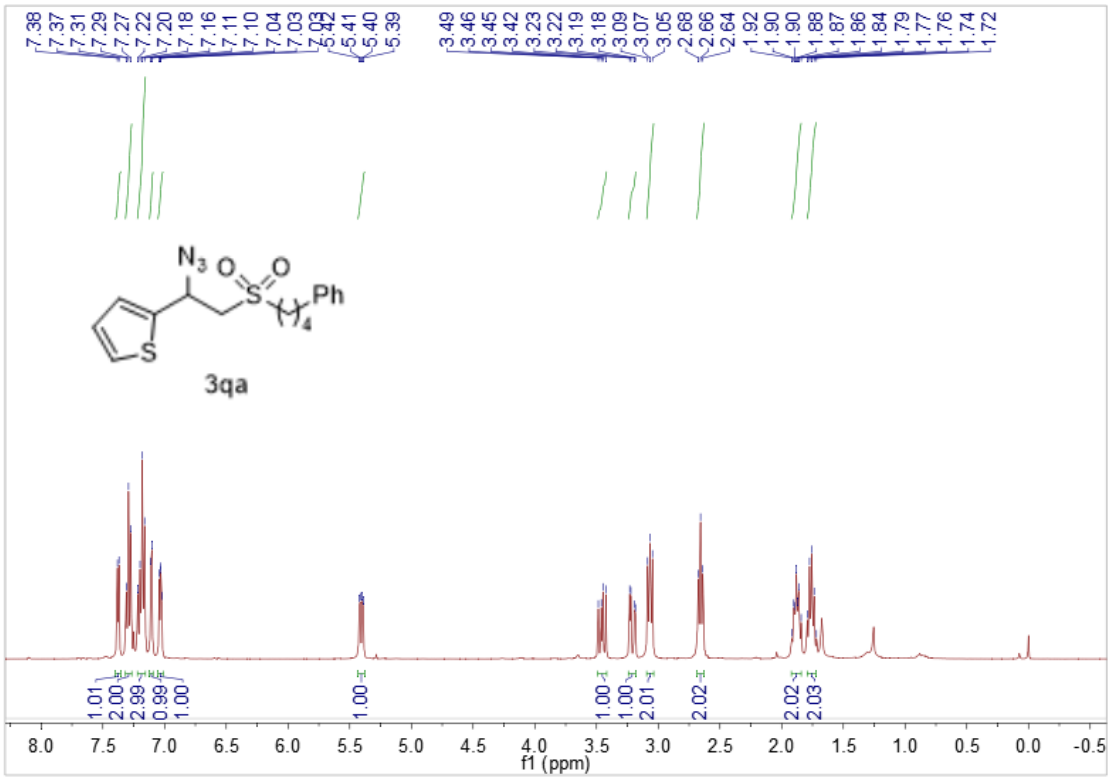
f1 (ppm)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1.92
1.90
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1.87
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1.79
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1.72
N3
O
O
S
Ph
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S
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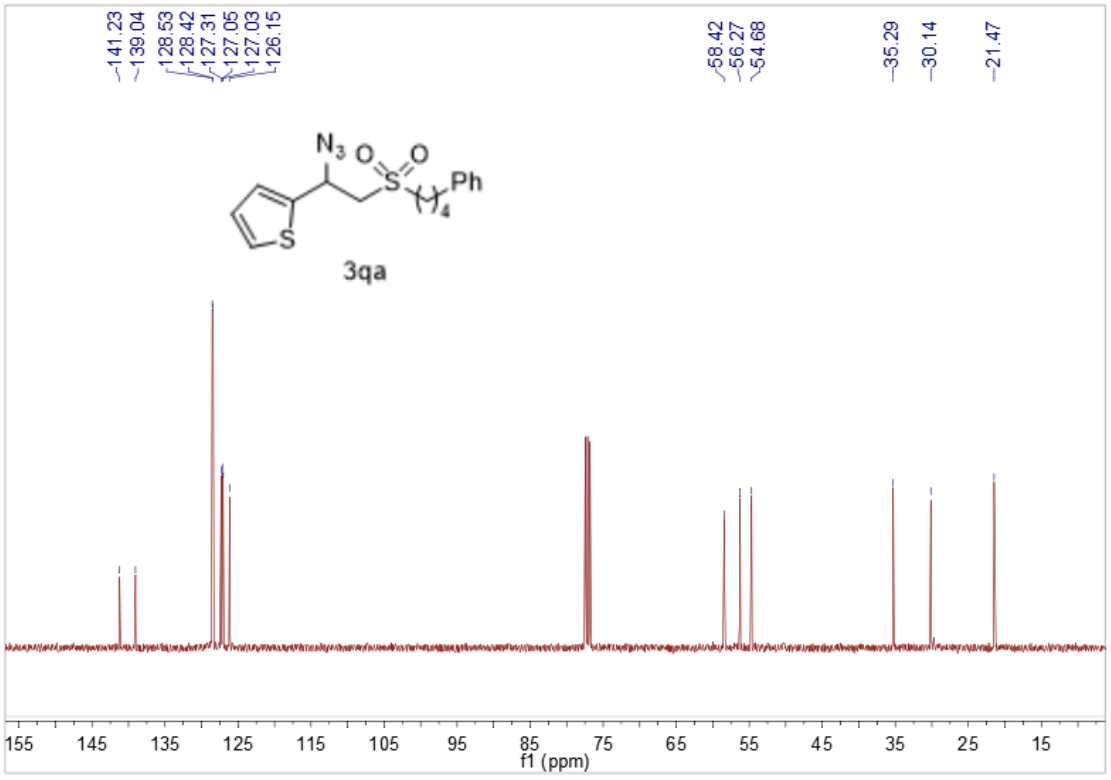
f1 (ppm)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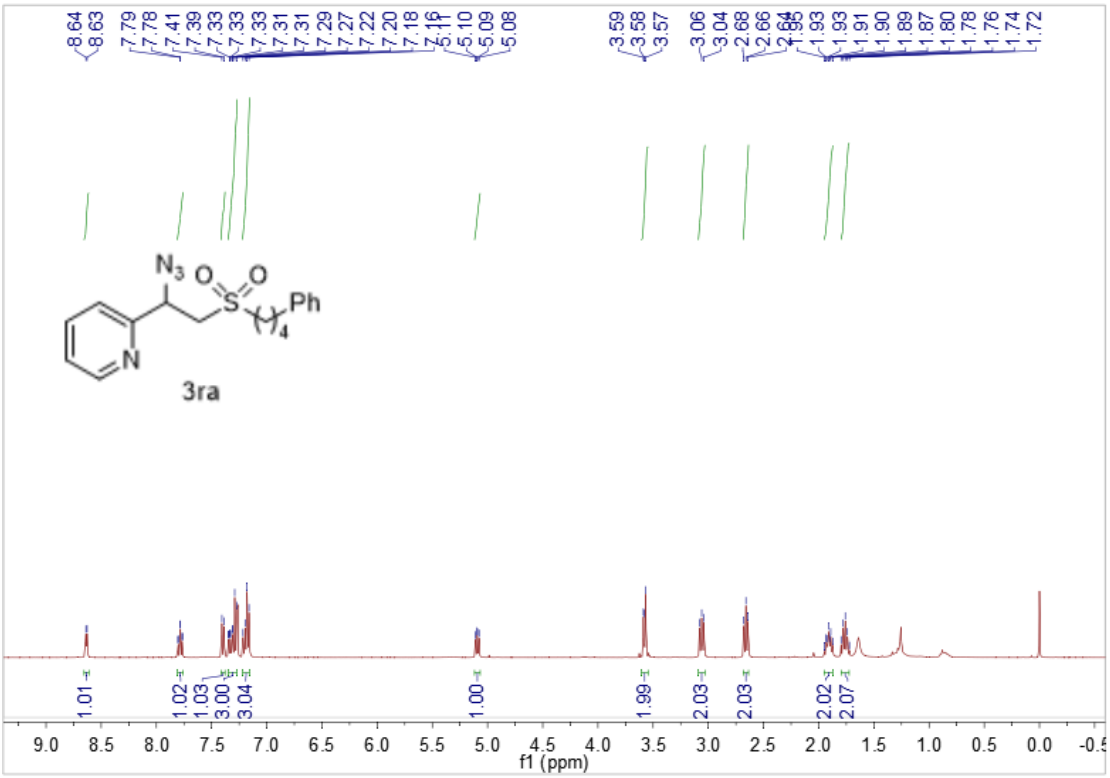
f1 (ppm)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N3
O
O
S
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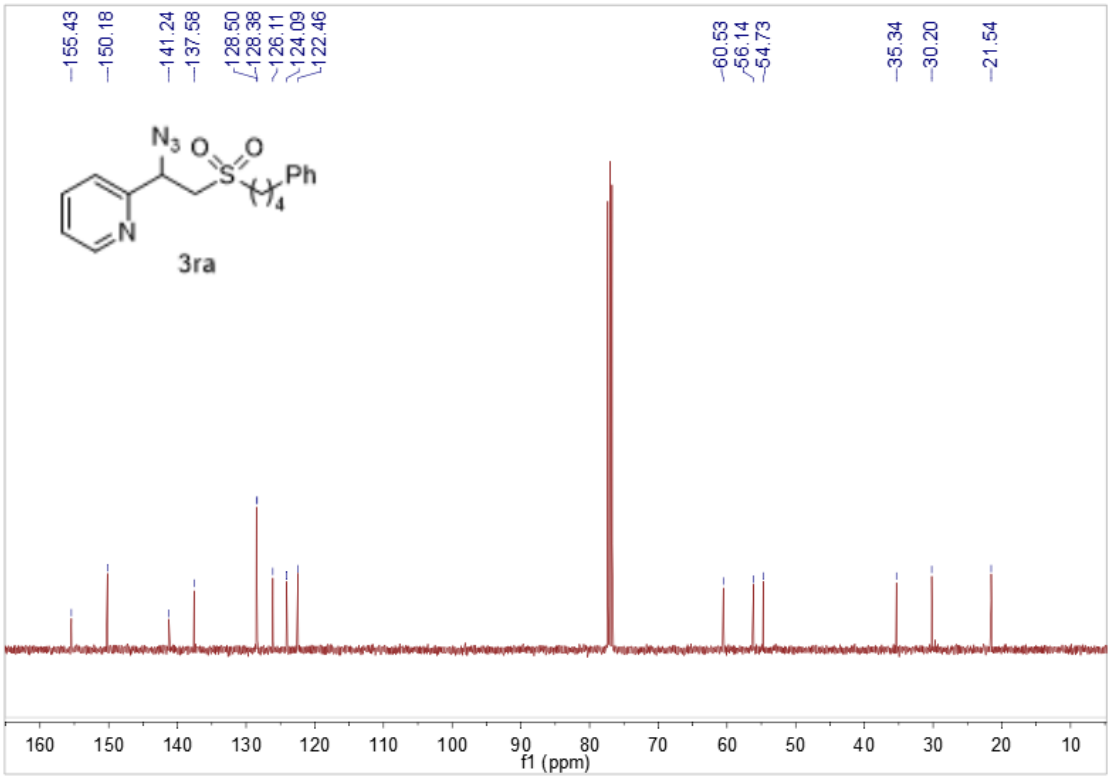
f1 (ppm)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30.20
21.54
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O
O
S
Ph
4
N
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100
90
80
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60
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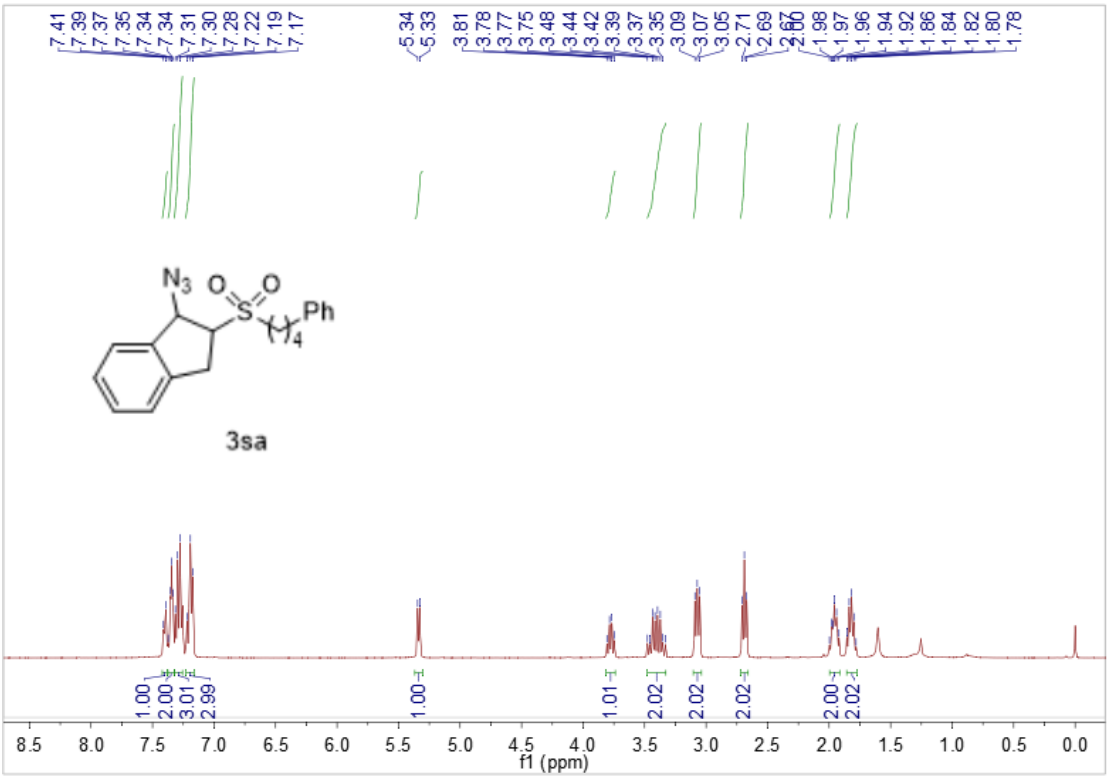
10
f1 (ppm)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S
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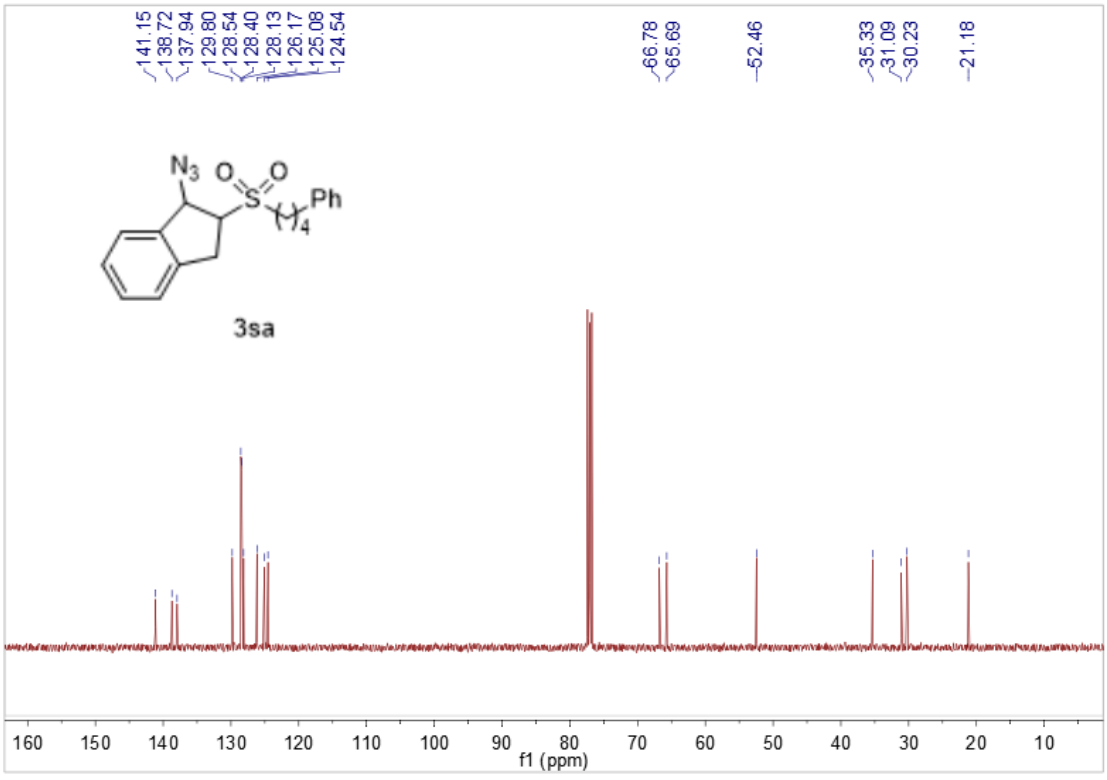
f1 (ppm)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52.46
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31.09
30.23
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N3
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S
O
Ph
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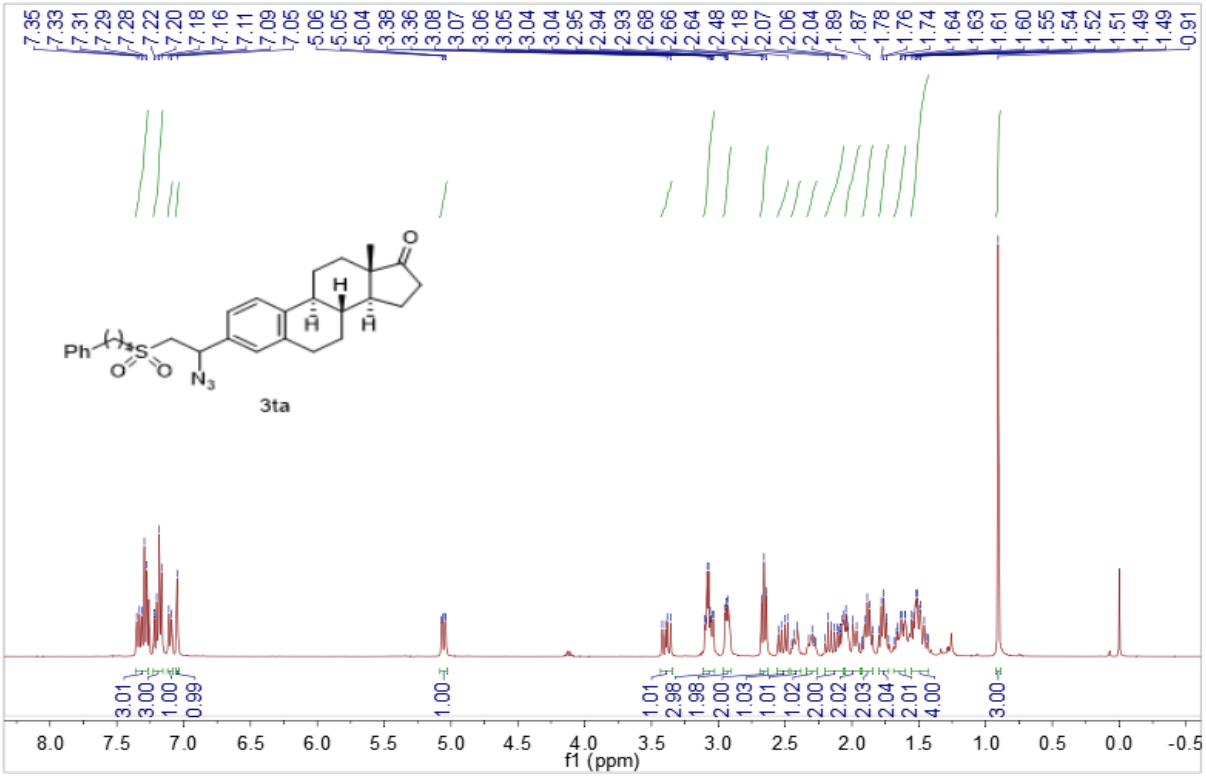
f1 (ppm)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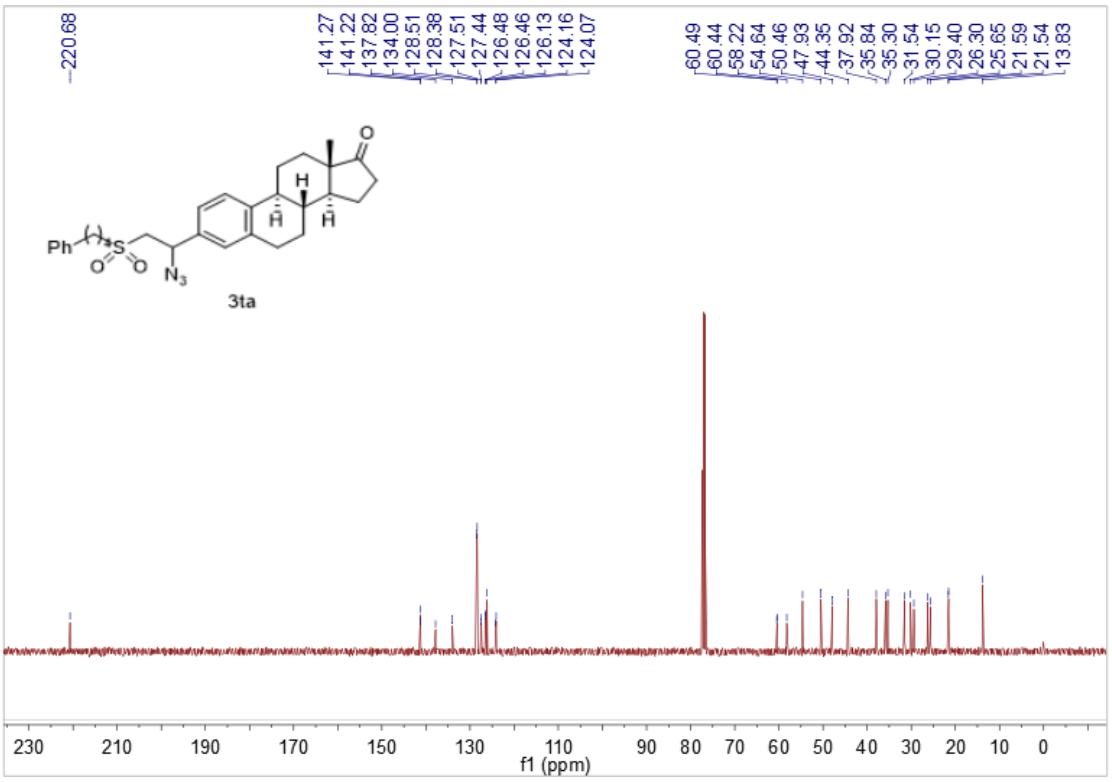
3ta
3.01 3.00 1.00 0.99 1.00 1.01 2.98 1.98 2.00 1.03 1.01 1.02 2.00 2.02 2.03 2.04 2.01 4.00 3.00
f1 (ppm)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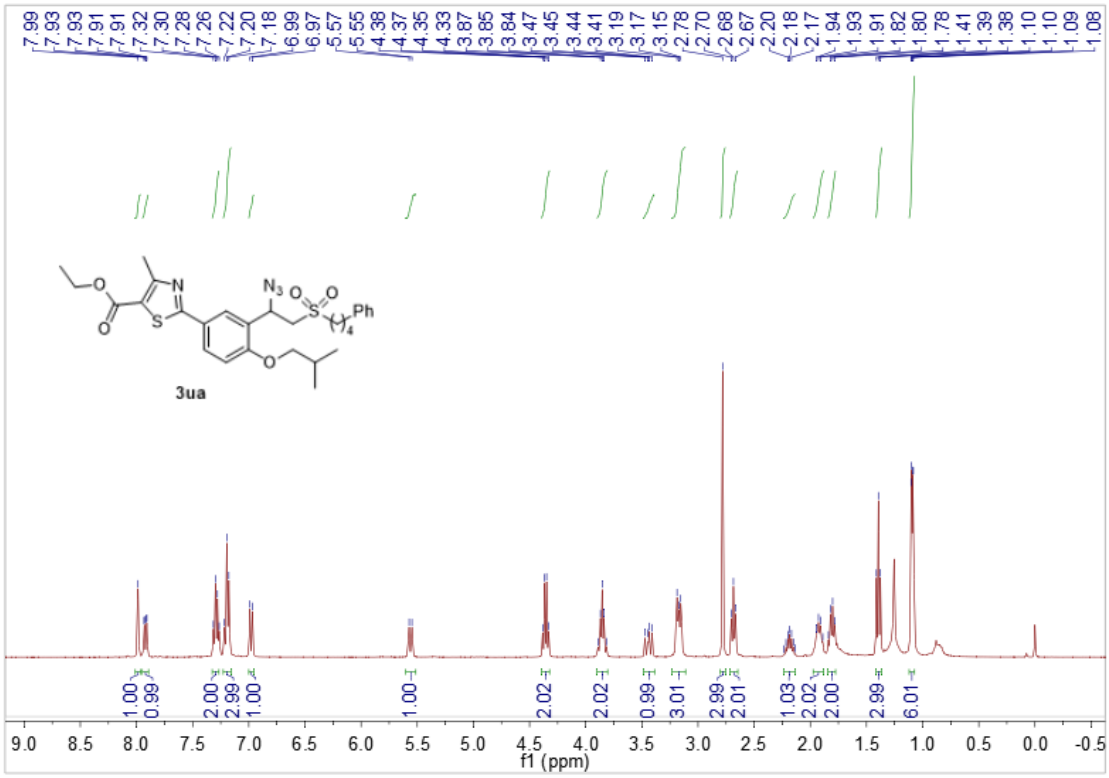
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3.84
3.47
3.45
3.44
3.41
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2.68
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2.20
2.18
2.17
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1.93
1.91
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1.41
1.39
1.38
1.10
1.10
1.09
1.08
3ua
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2.99
1.00
1.00
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2.01
1.03
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2.00
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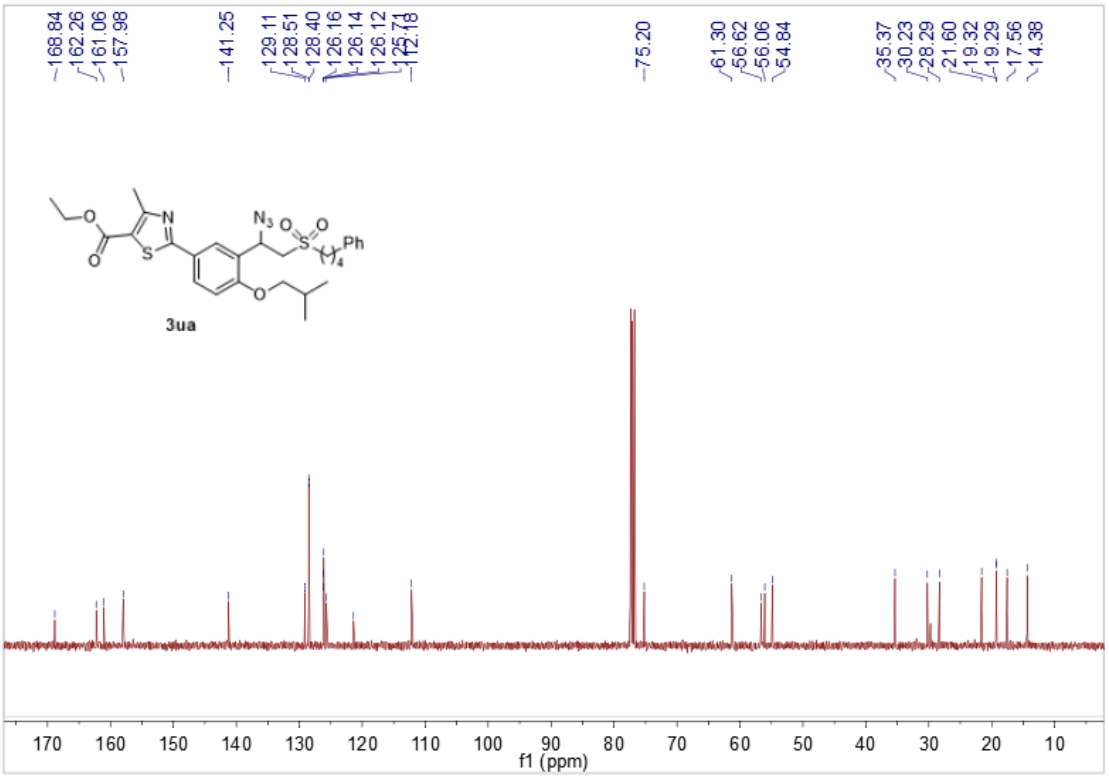
f1 (ppm)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112.18
75.20
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56.62
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19.29
17.56
14.38
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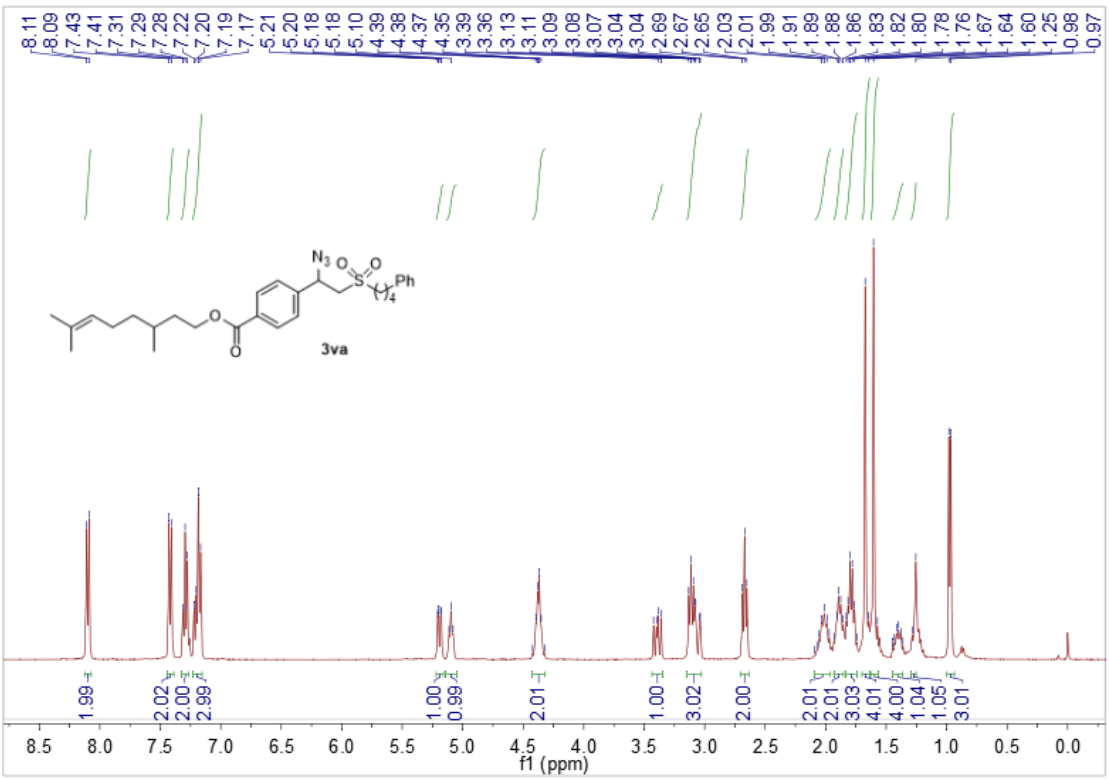
f1 (ppm)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5.20
5.18
5.18
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4.39
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4.35
3.39
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3.04
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0.97
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2.99
1.00
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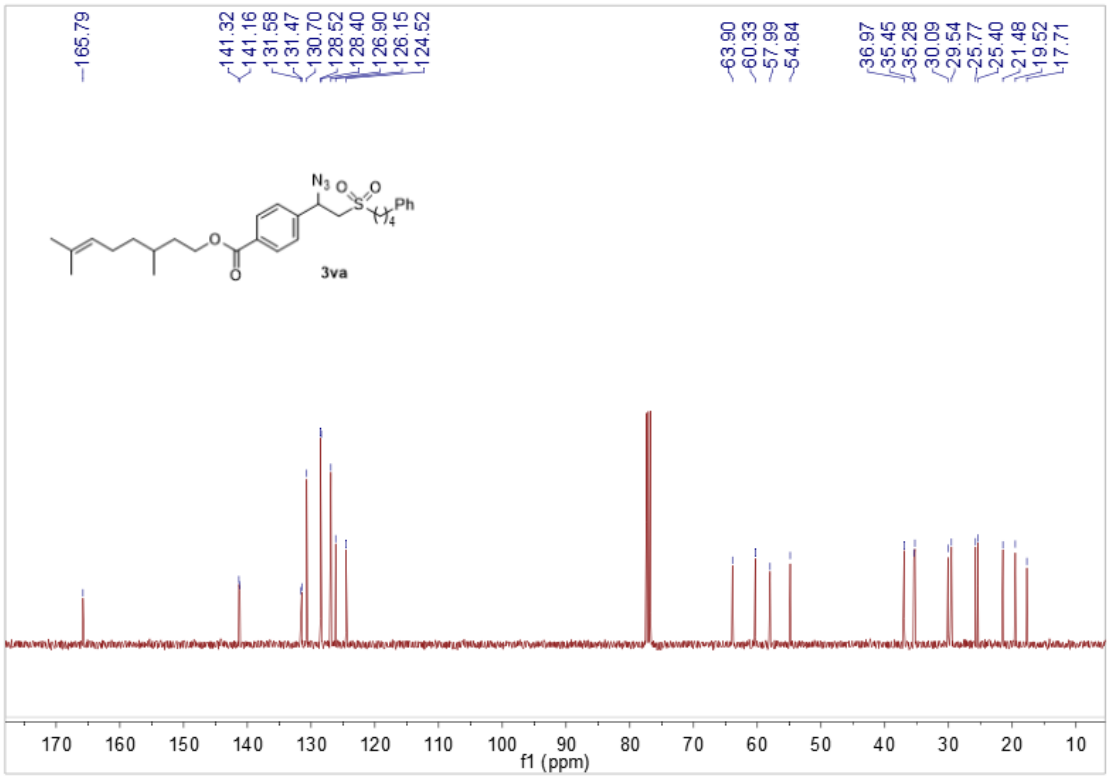
1.05
3.01
f1 (ppm)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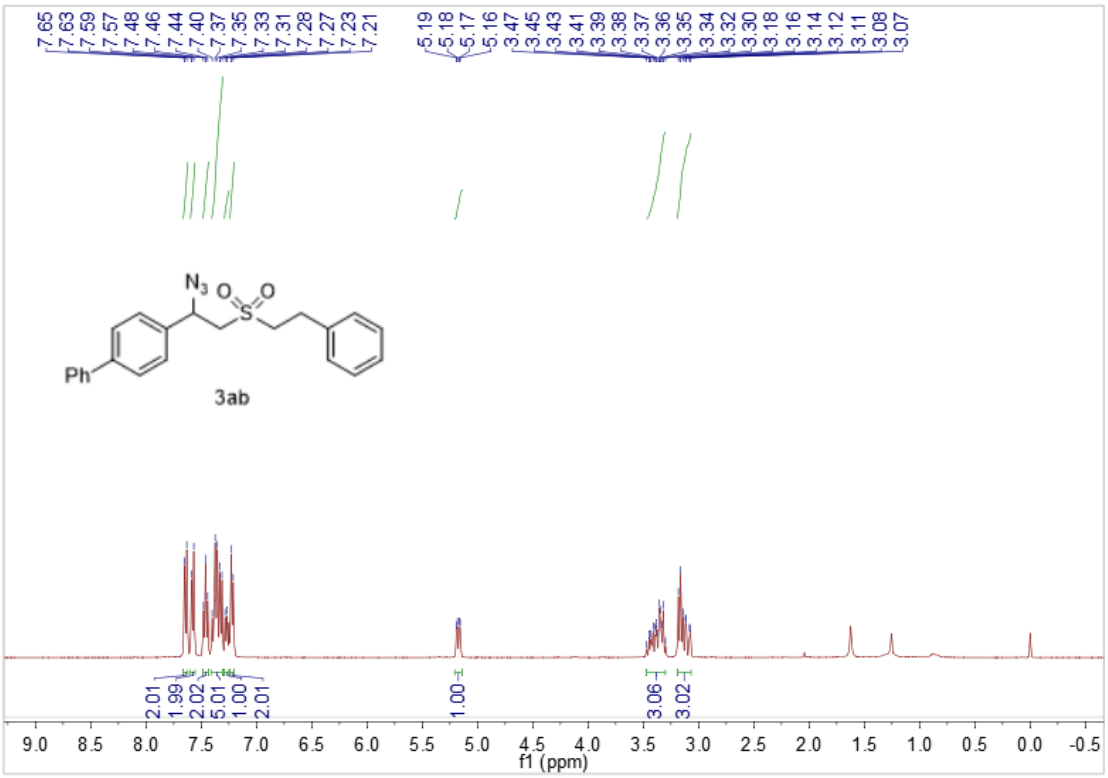
21.48
19.52
17.71
3va
f1 (ppm)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7.23
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5.18
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5.16
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3.41
3.39
3.38
3.37
3.36
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3.34
3.32
3.30
3.18
3.16
3.14
3.12
3.11
3.08
3.07
N3
O
S
O
Ph
3ab
2.01
1.99
2.02
5.01
1.00
2.01
1.00
3.06
3.02
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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5.0
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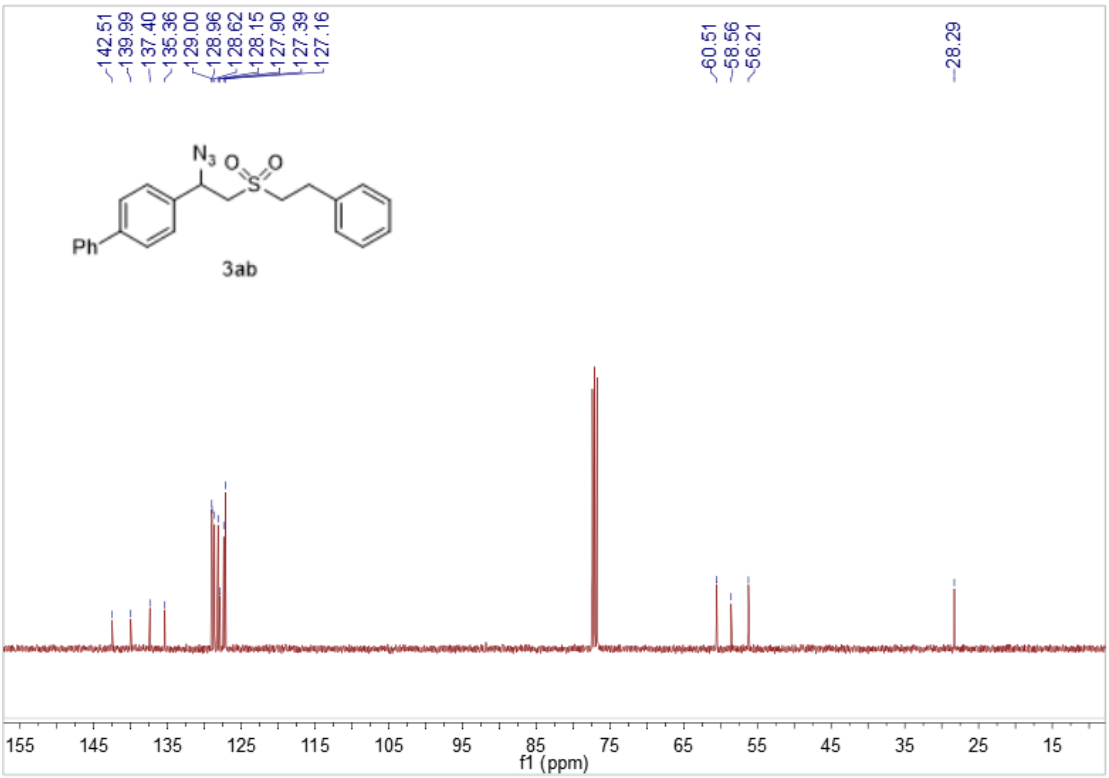
0.0
-0.5
f1 (ppm)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N3
O
S
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Ph
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135
125
115
105
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65
55
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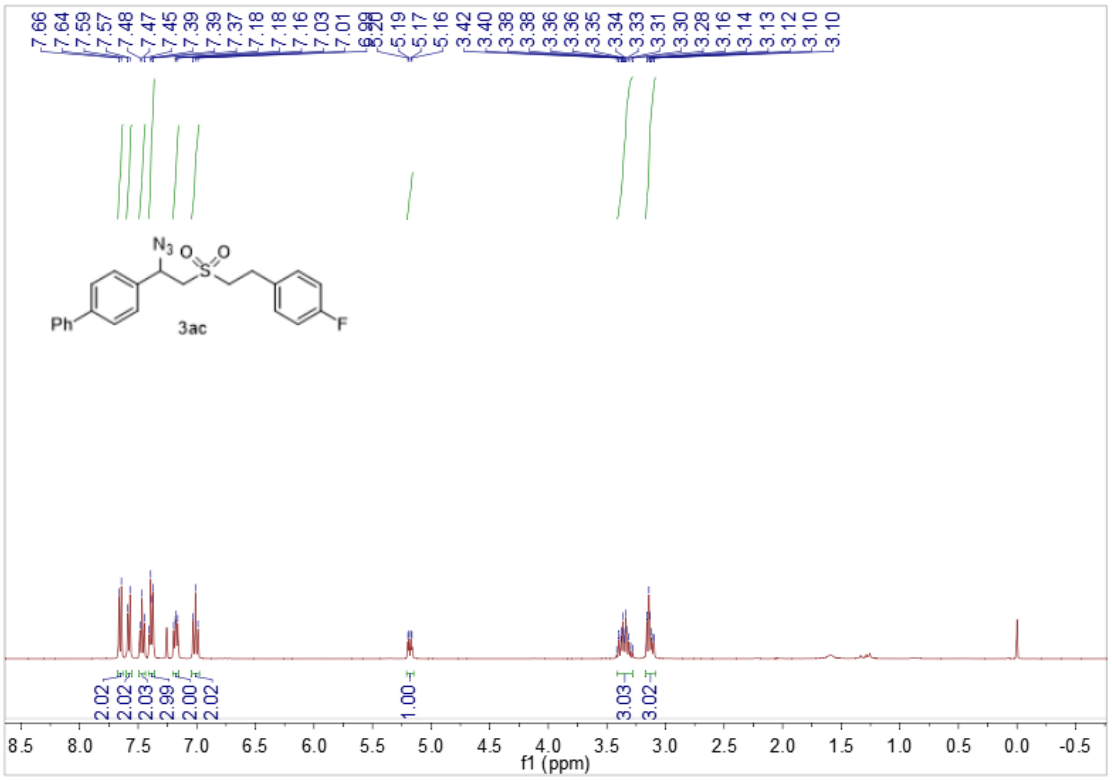
25
15
f1 (ppm)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7.01
5.19
5.17
5.16
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3.40
3.38
3.38
3.36
3.36
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3.34
3.33
3.31
3.30
3.28
3.16
3.14
3.13
3.12
3.10
3.10
N3
O
S
O
Ph
F
3ac
2.02
2.02
2.03
2.99
2.00
2.02
1.00
3.03
3.02
8.5
8.0
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7.0
6.5
6.0
5.5
5.0
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2.0
1.5
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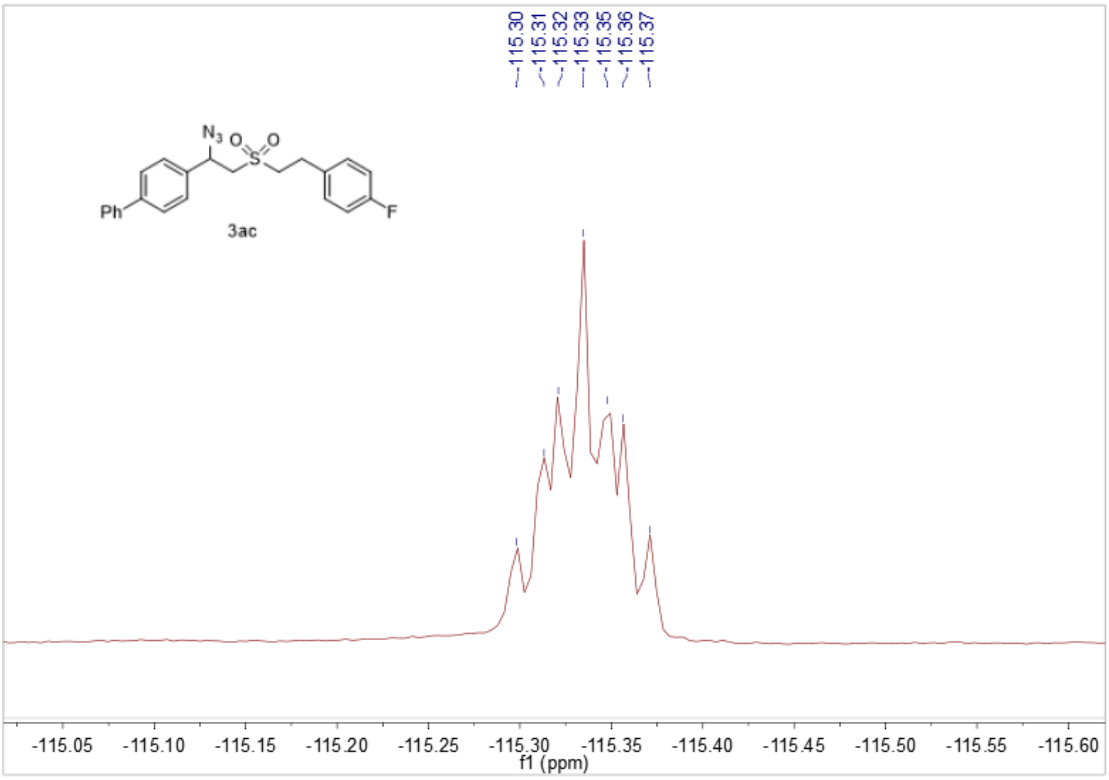
-0.5
f1 (ppm)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-115.37
N3
O
S
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Ph
F
3ac
-115.05
-115.10
-115.15
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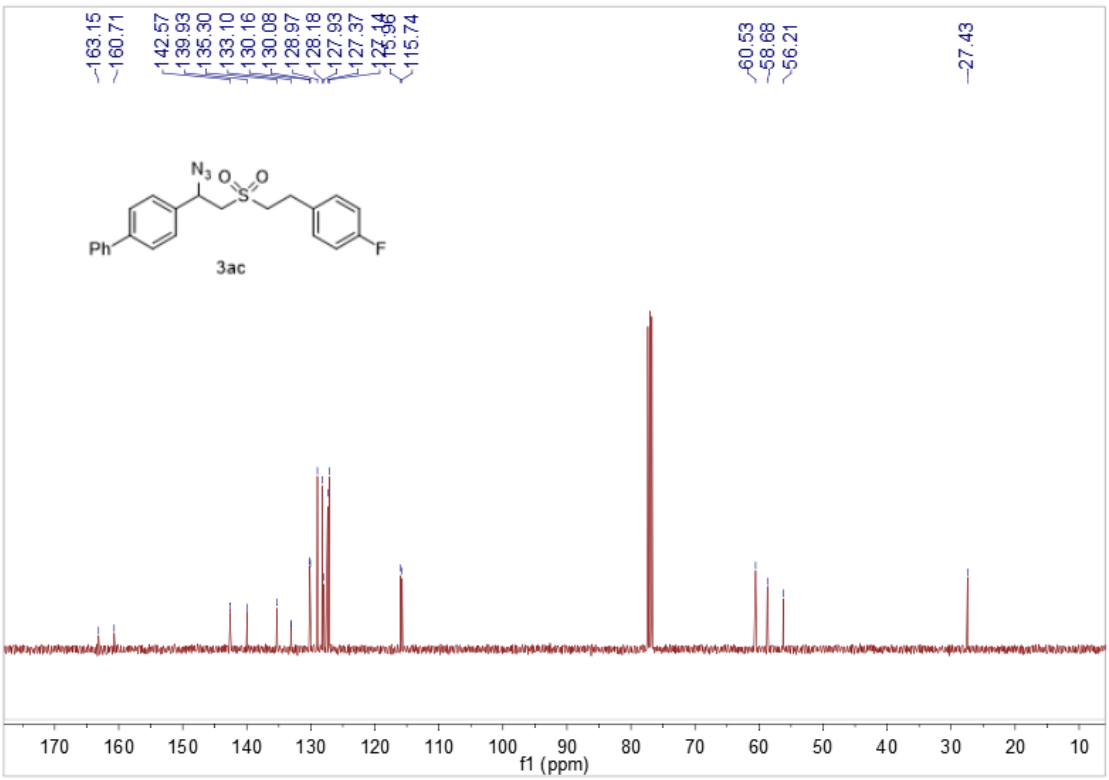
-115.35
-115.40
-115.45
-115.50
-115.55
-115.60
f1 (ppm)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115.74
60.53
58.68
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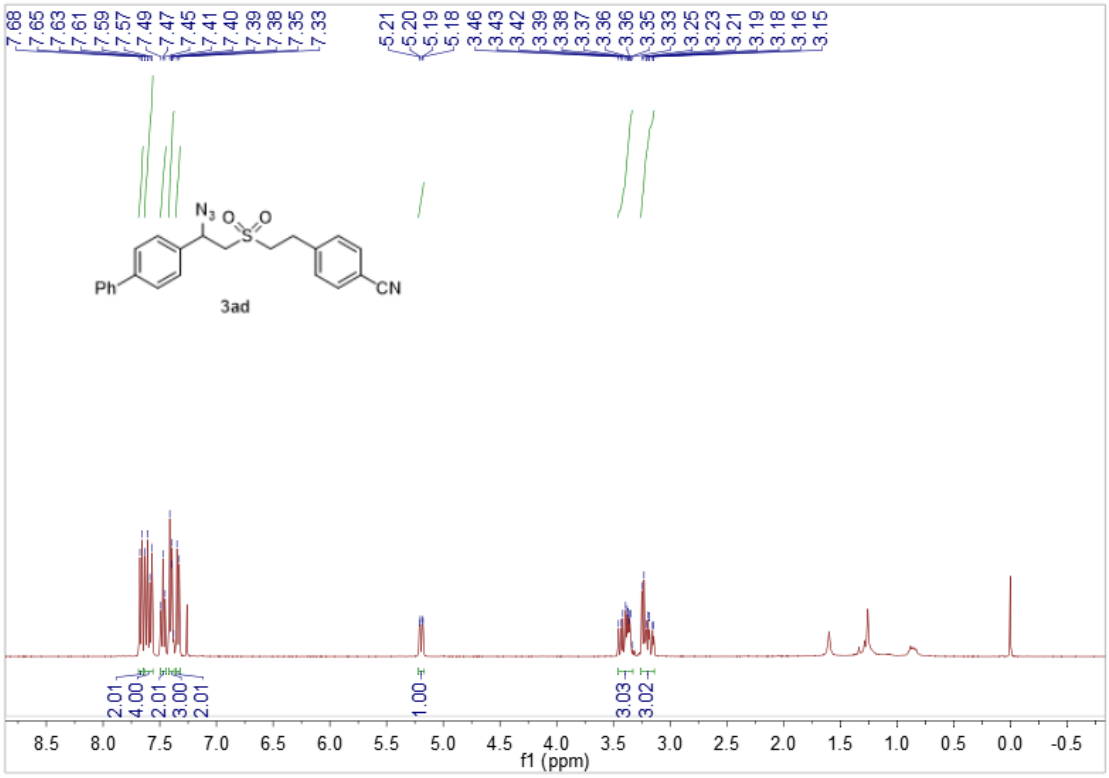
27.43
N3
O
O
S
Ph
F
3ac
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)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5.19
5.18
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3.39
3.38
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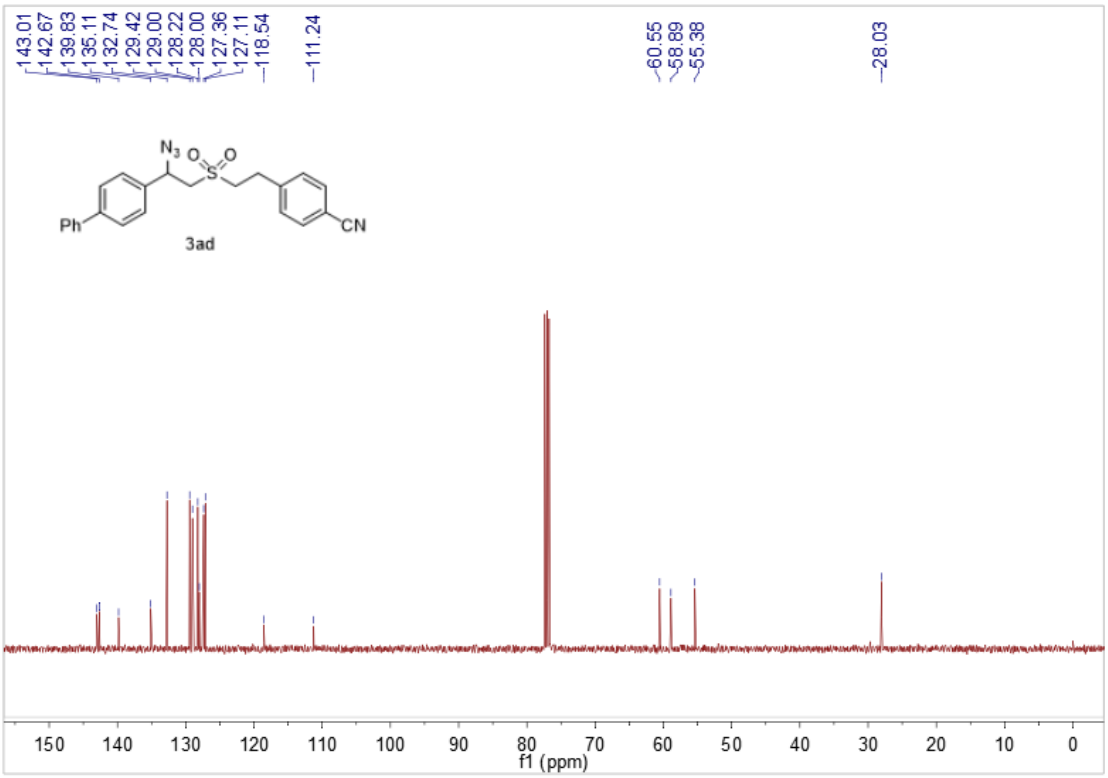
3.36
3.35
3.33
3.25
3.23
3.21
3.19
3.18
3.16
3.15
N3
O
O
S
Ph
CN
3ad
2.01
4.00
2.01
3.00
2.01
1.00
3.03
3.02
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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111.24
60.55
58.89
55.38
28.03
N3
O
S
O
Ph
CN
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130
120
110
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90
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50
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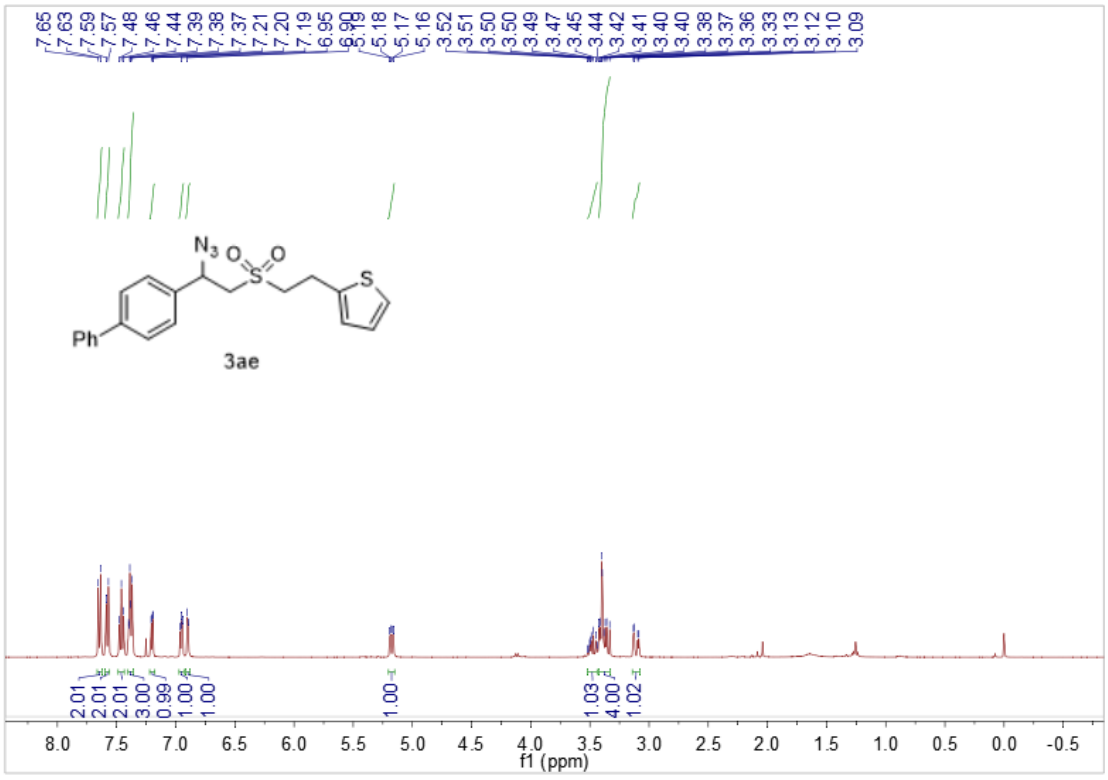
f1 (ppm)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S
O
S
Ph
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1.00
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5.0
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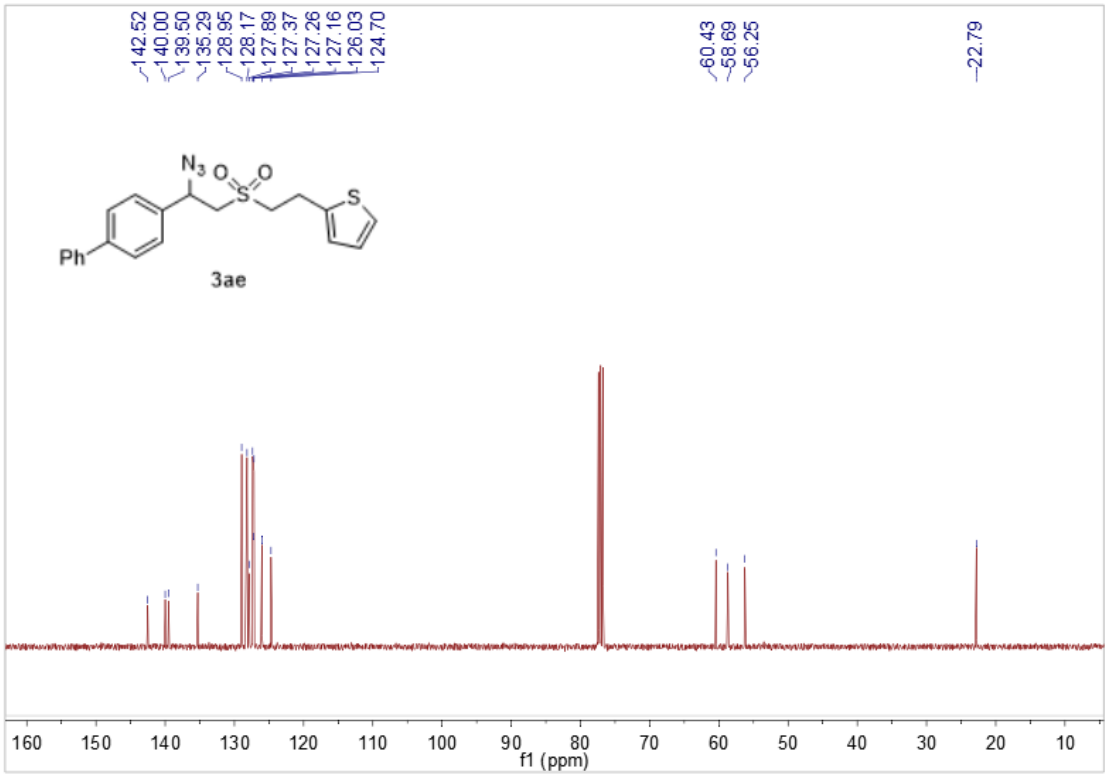
-0.5
f1 (ppm)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O
O
S
S
Ph
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80
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60
50
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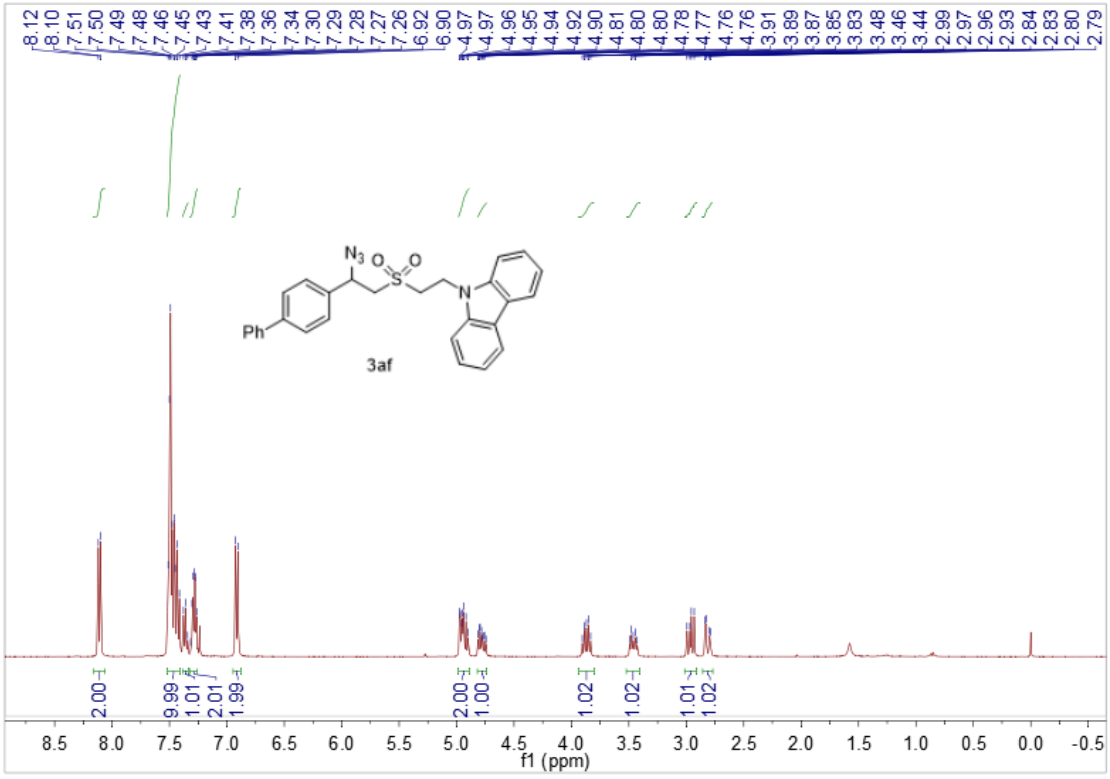
30
20
10
f1 (ppm)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7.27
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2.79
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O
S
N
Ph
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9.99
1.01
2.01
1.99
2.00
1.00
1.02
1.02
1.01
1.02
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2.0
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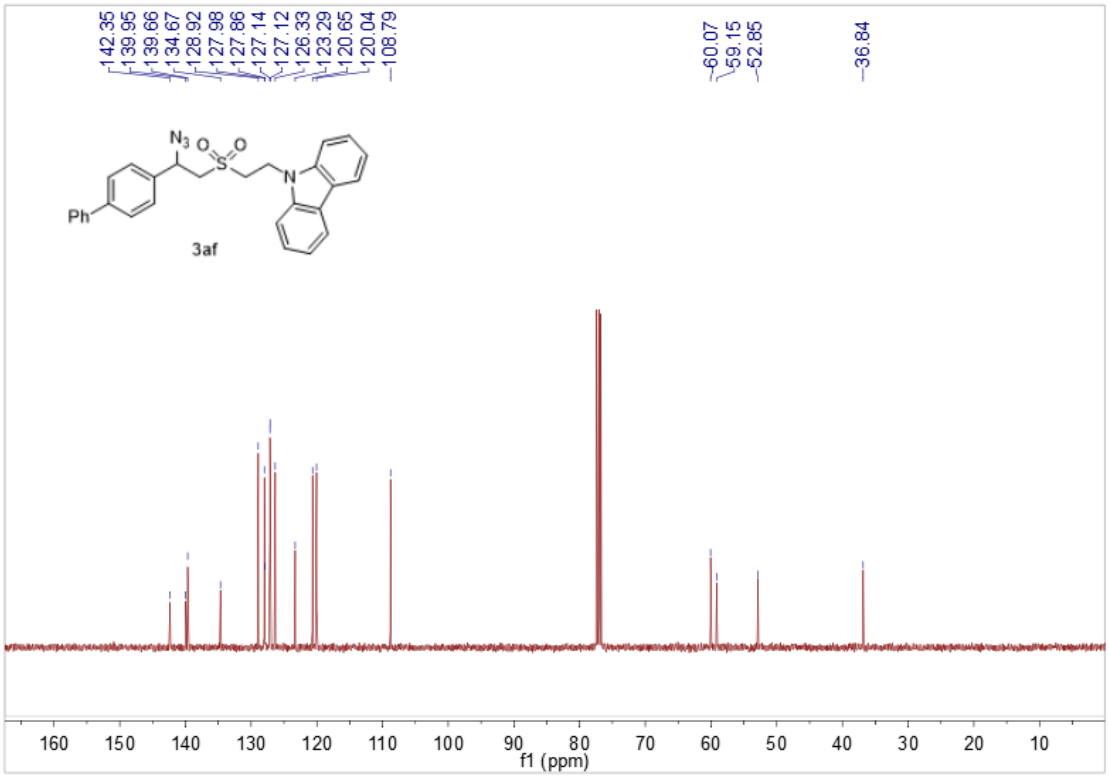
f1 (ppm)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108.79
60.07
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52.85
36.84
N3
O
S
O
N
Ph
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100
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80
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60
50
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20
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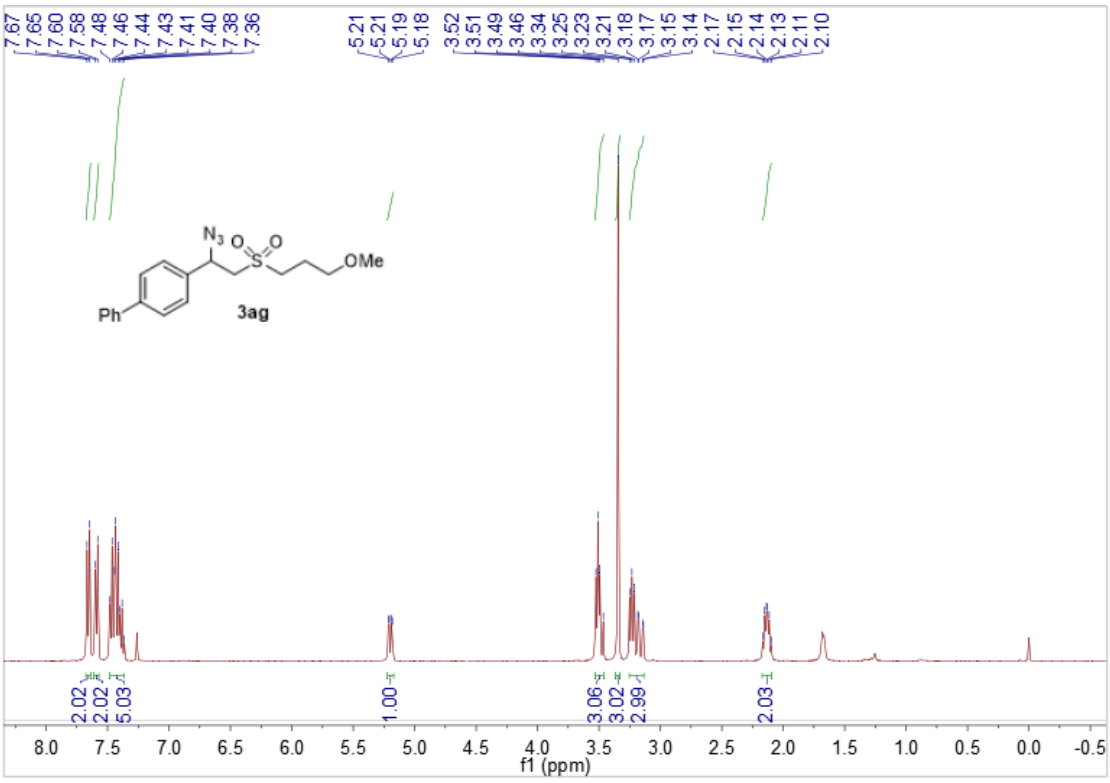
f1 (ppm)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2.10
N3
O
S
O
OMe
Ph
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2.02
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1.00
3.06
3.02
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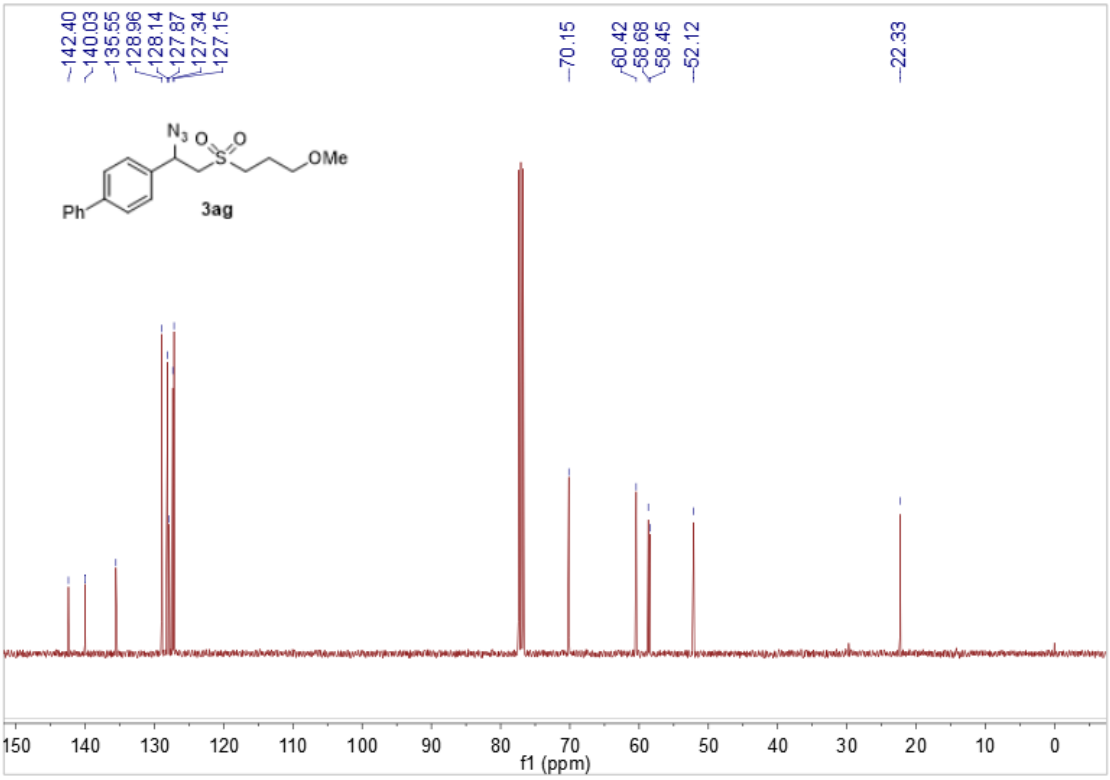
f1 (ppm)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58.45
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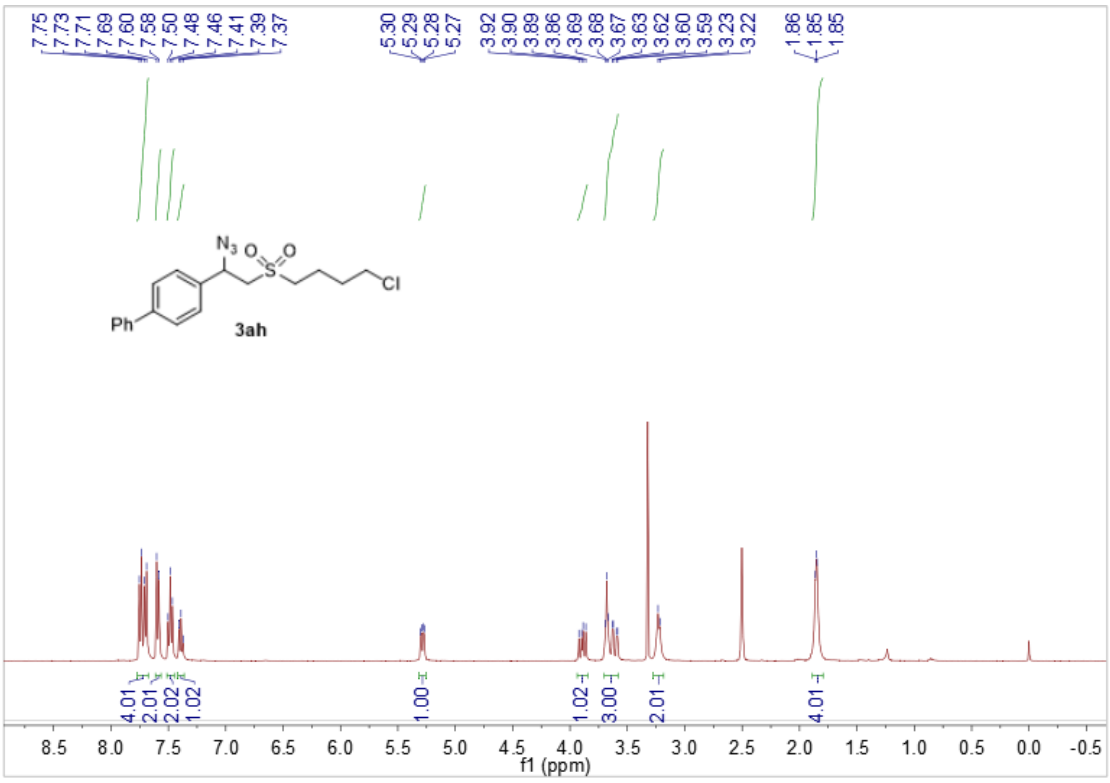
N3
O
S
O
OMe
Ph
3ag
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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1.85
1.85
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O
S
O
Cl
Ph
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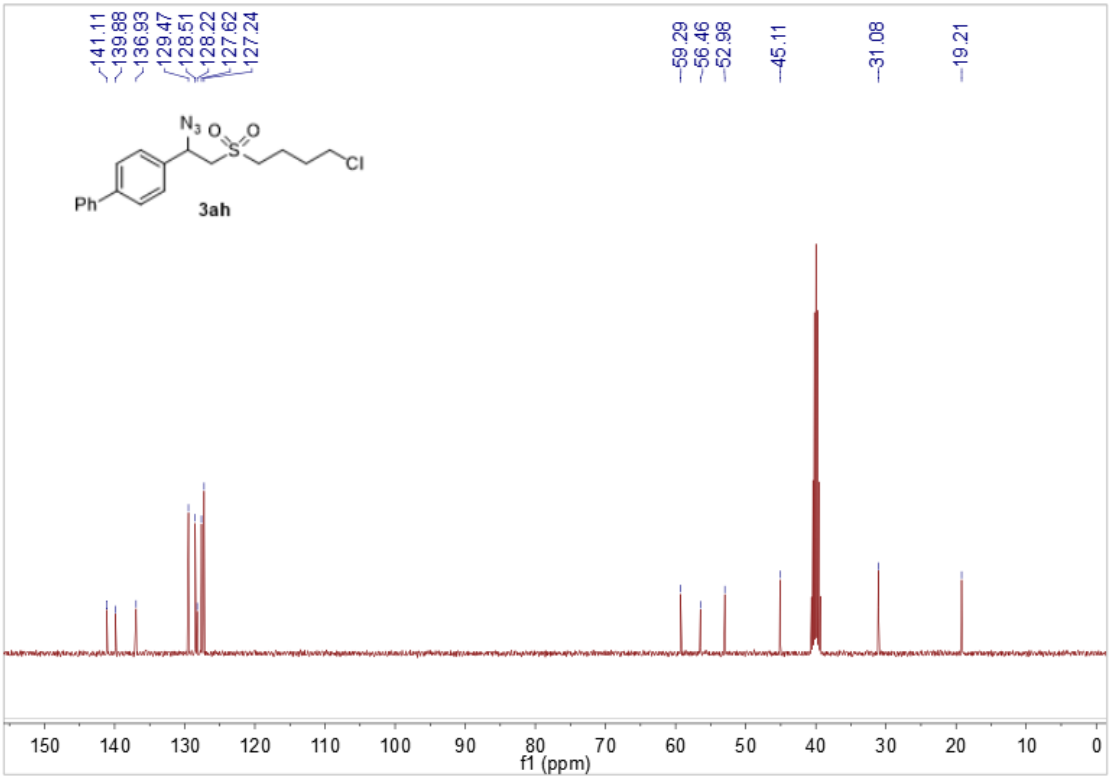
2.01
2.02
1.02
1.00
1.02
3.00
2.01
4.01
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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127.24
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45.11
31.08
19.21
N3
O
O
S
Cl
Ph
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130
120
110
100
90
80
70
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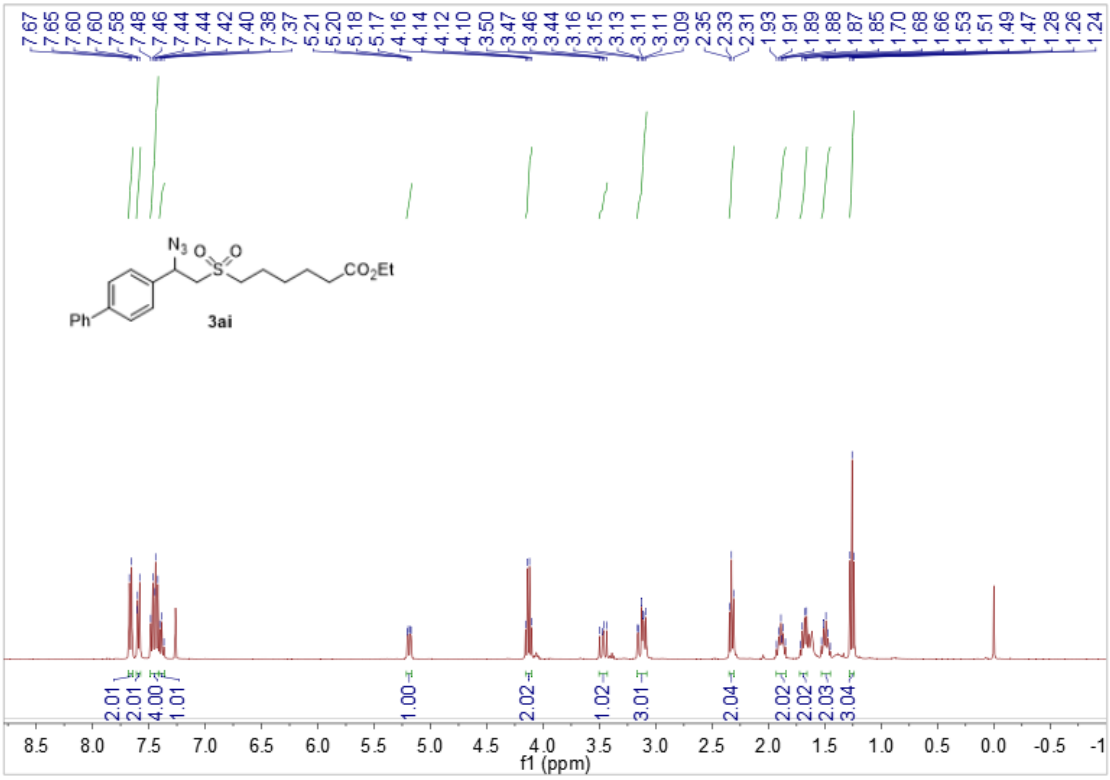
50
40
30
20
10
0
f1 (ppm)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2.02
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2.0
1.5
1.0
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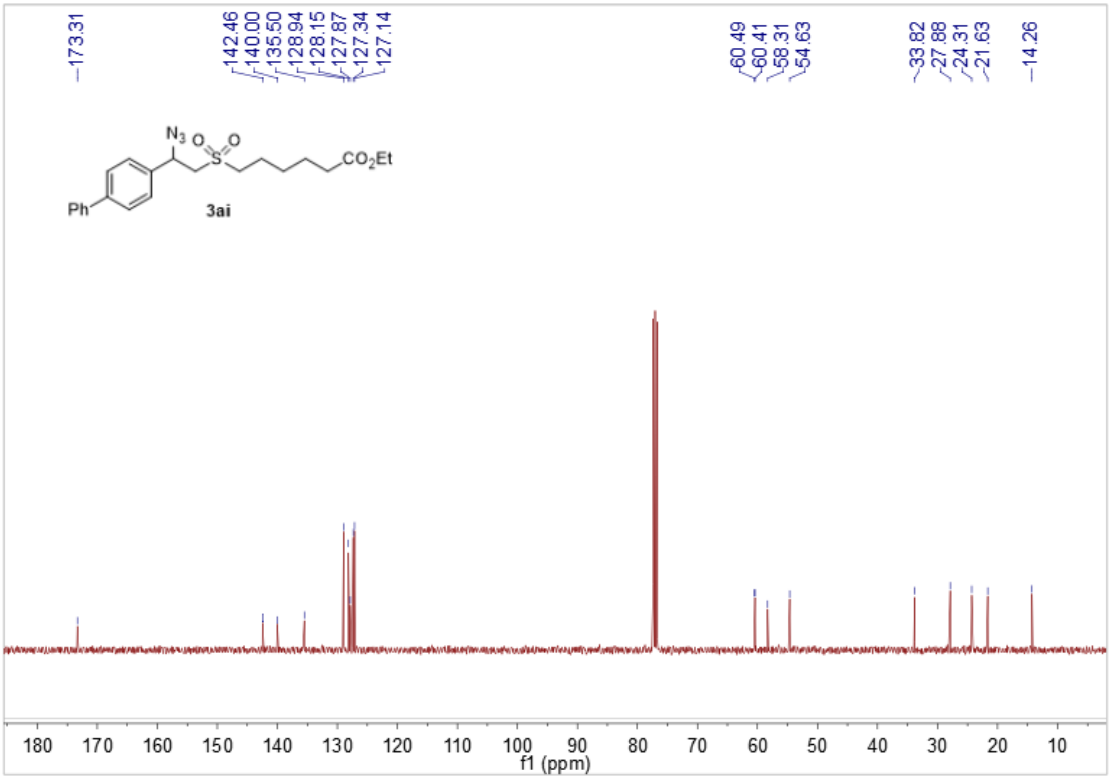
0.0
-0.5
-1
f1 (ppm)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60.41
58.31
54.63
33.82
27.88
24.31
21.63
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N3
O
S
O
CO2Et
Ph
3ai
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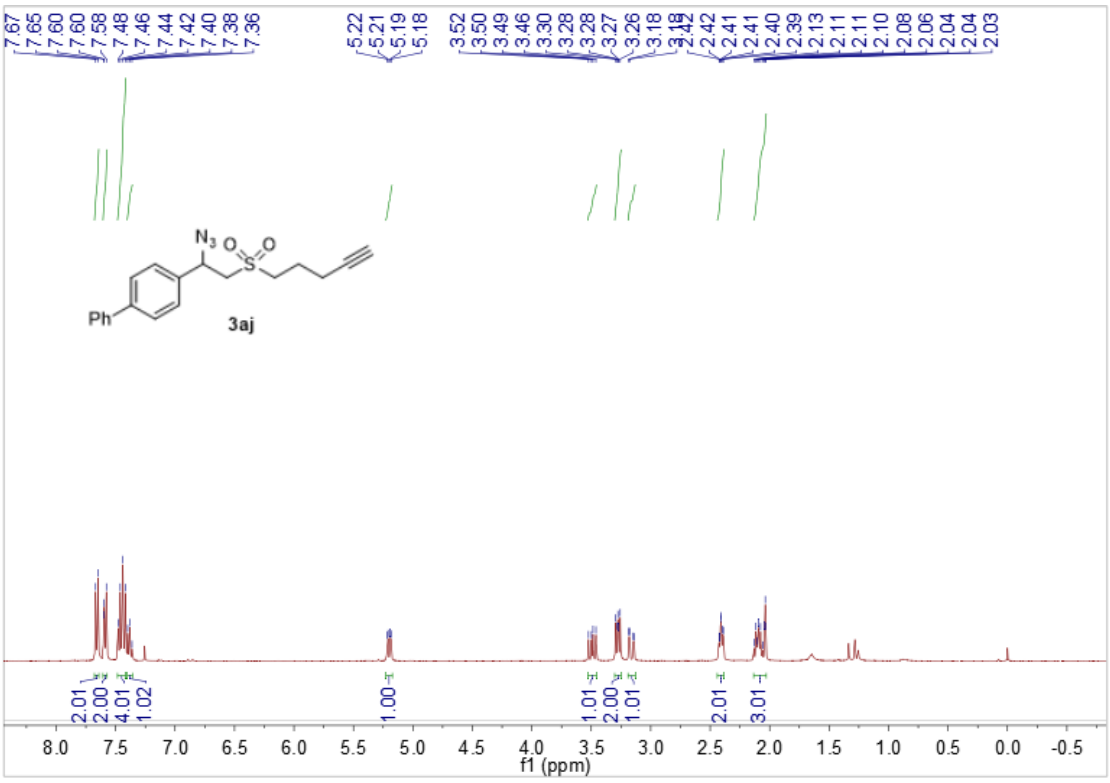
f1 (ppm)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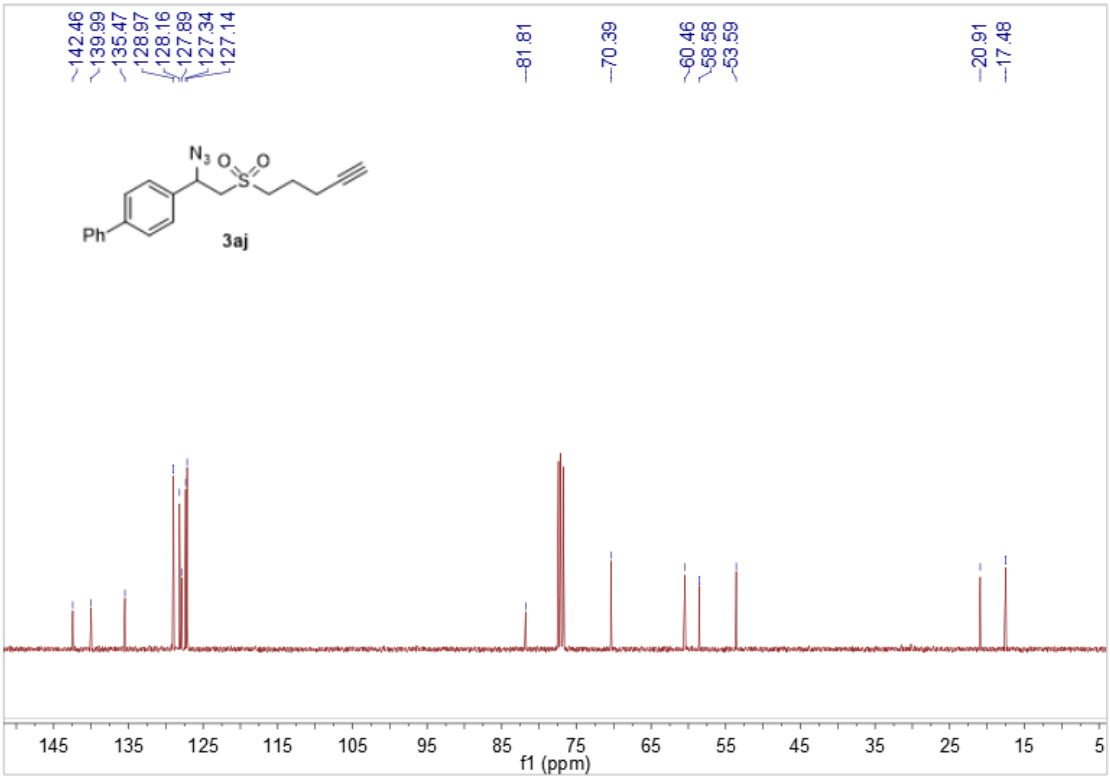
5.22
5.21
5.19
5.18
3.52
3.50
3.49
3.46
3.30
3.28
3.28
3.27
3.26
3.18
2.42
2.41
2.41
2.40
2.39
2.13
2.11
2.11
2.10
2.08
2.06
2.04
2.04
2.03
N3
O
S
O
Ph
3aj
2.01
2.00
4.01
1.02
1.00
1.01
2.00
1.01
2.01
3.01
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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20.91
17.48
N3
O
O
S
Ph
3aj
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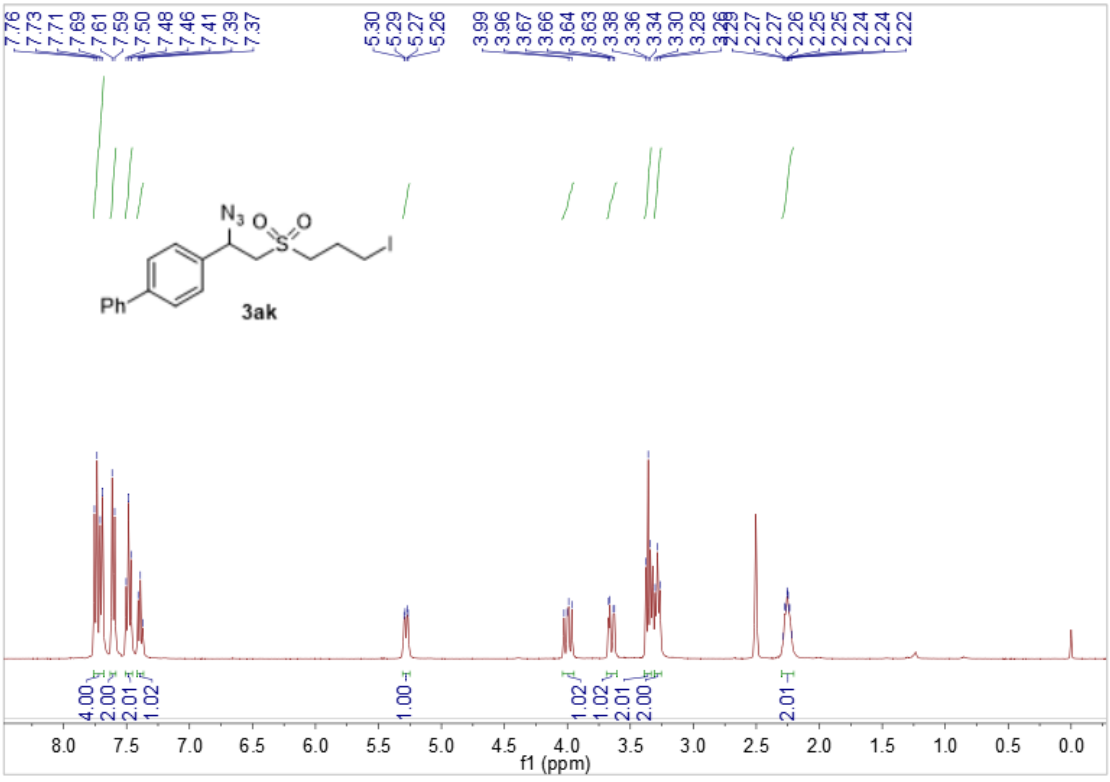
135
125
115
105
95
85
75
65
55
45
35
25
15
5
f1 (ppm)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7.71
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7.48
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7.41
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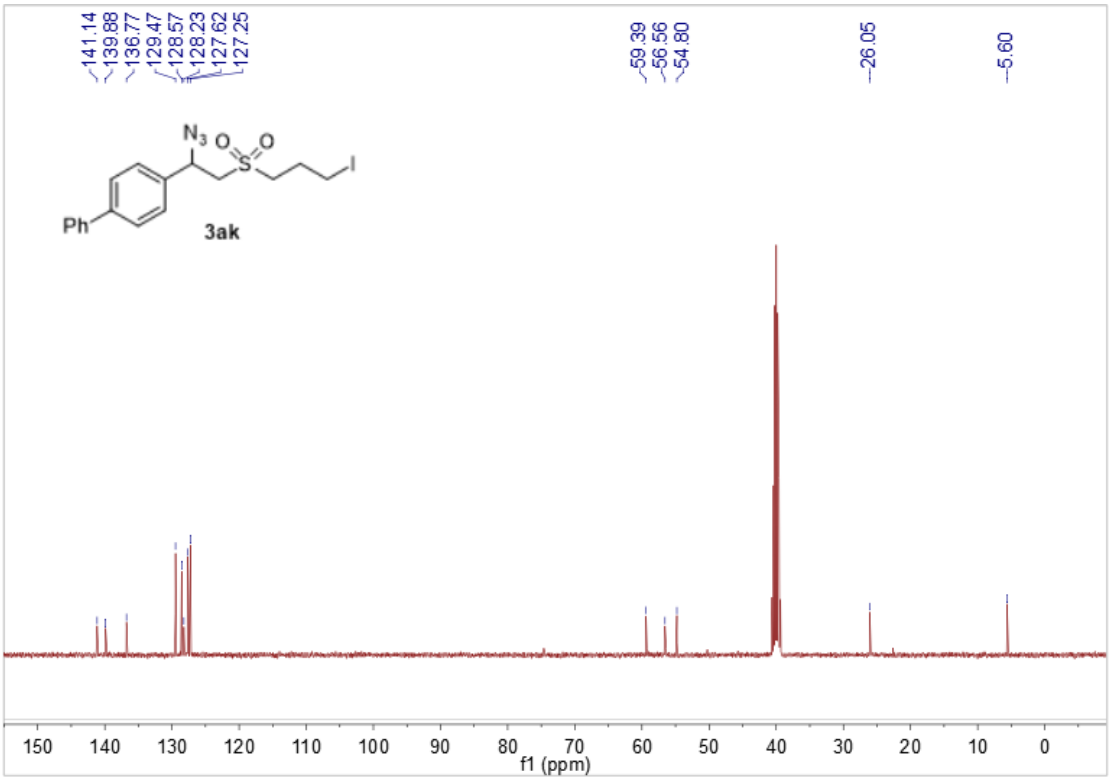
5.30
5.29
5.27
5.26
3.99
3.96
3.67
3.66
3.64
3.63
3.38
3.36
3.34
3.30
3.28
2.27
2.26
2.25
2.25
2.24
2.24
2.22
N3
O
O
S
I
Ph
3ak
4.00
2.00
2.01
1.02
1.00
1.02
1.02
2.01
2.00
2.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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56.56
54.80
26.05
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N3
O
S
O
I
Ph
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130
120
110
100
90
80
70
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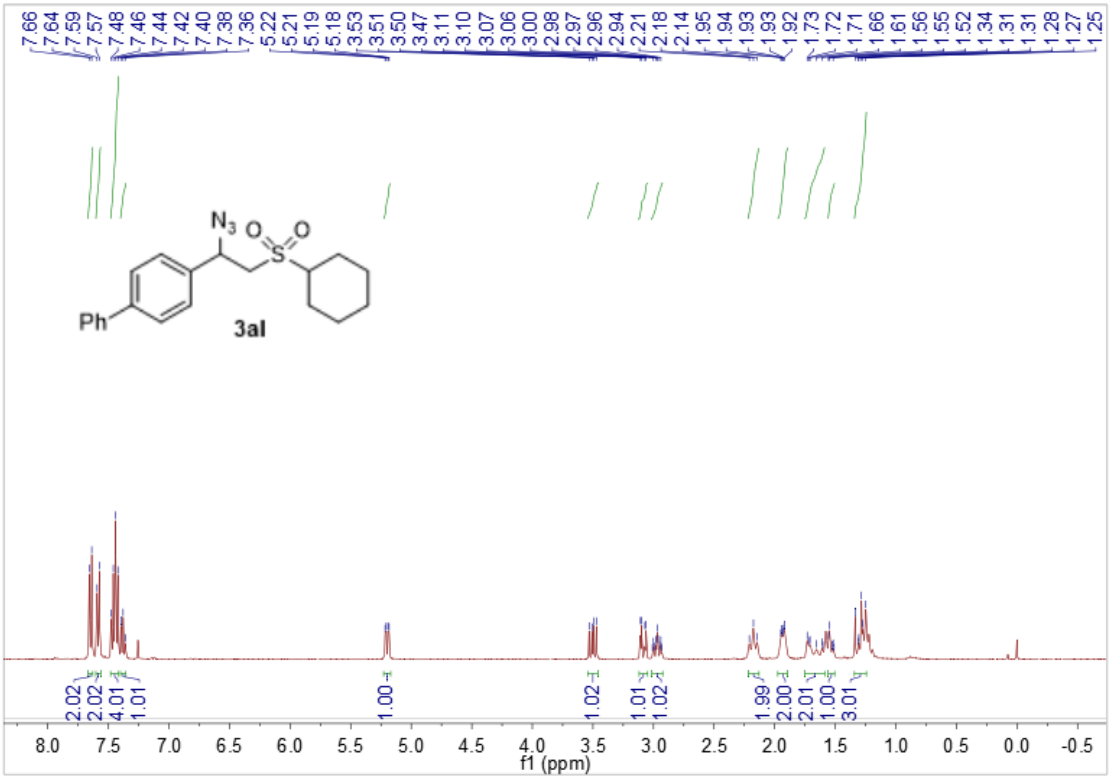
50
40
30
20
10
0
f1 (ppm)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5.21
5.19
5.18
3.53
3.51
3.50
3.47
3.11
3.10
3.07
3.06
3.00
2.98
2.97
2.96
2.94
2.21
2.18
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1.94
1.93
1.93
1.92
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1.72
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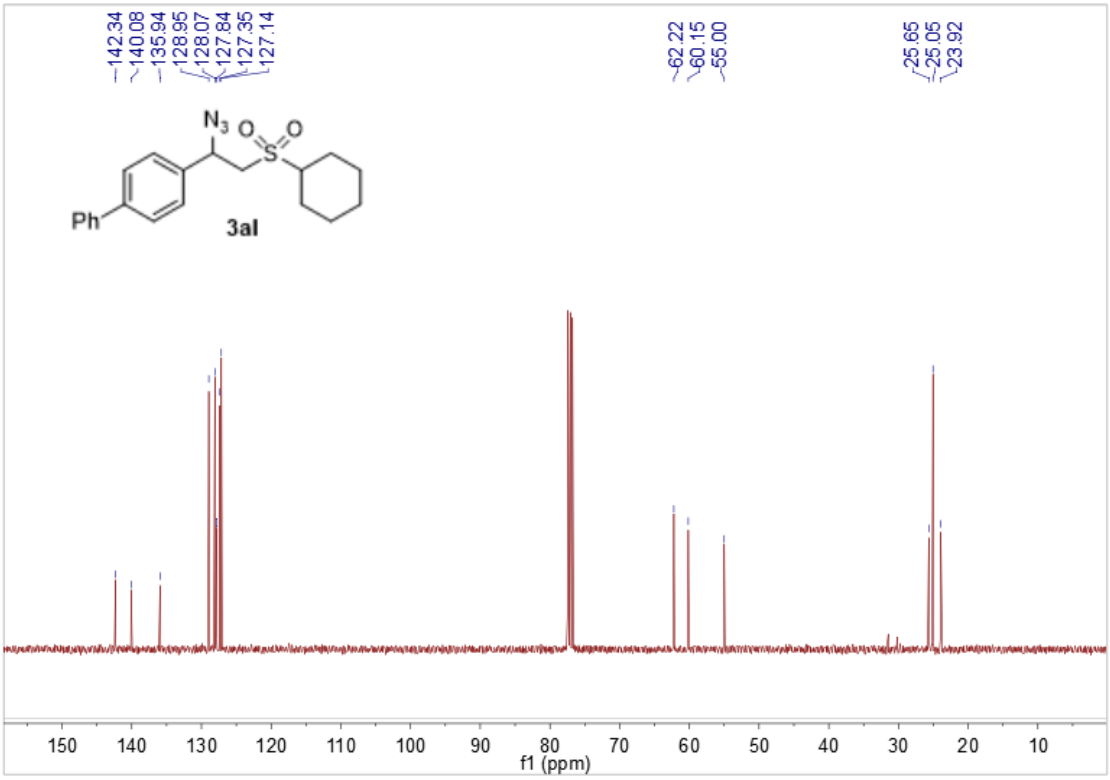
1.61
1.56
1.55
1.52
1.34
1.31
1.31
1.28
1.27
1.25
N3
O
S
O
Ph
3al
2.02
2.02
4.01
1.01
1.00
1.02
1.01
1.02
1.99
2.00
2.01
1.00
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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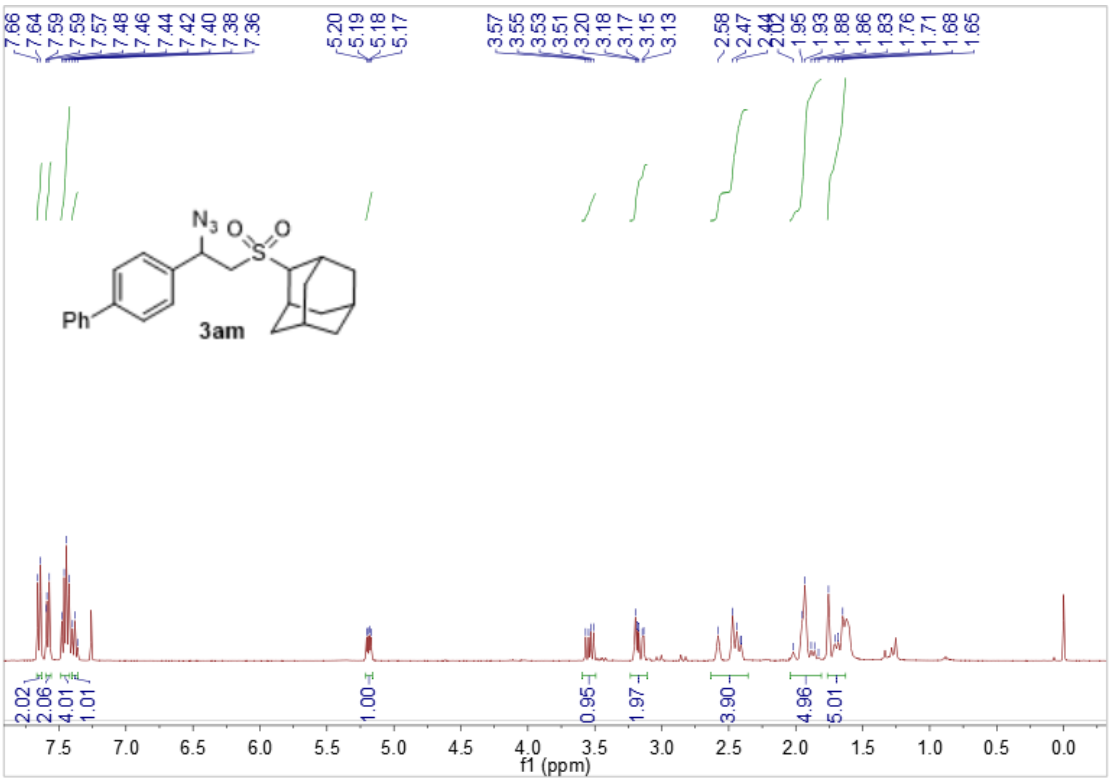
127.84
127.35
127.14
62.22
60.15
55.00
25.65
25.05
23.92
N3
O
S
O
Ph
3al
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.59
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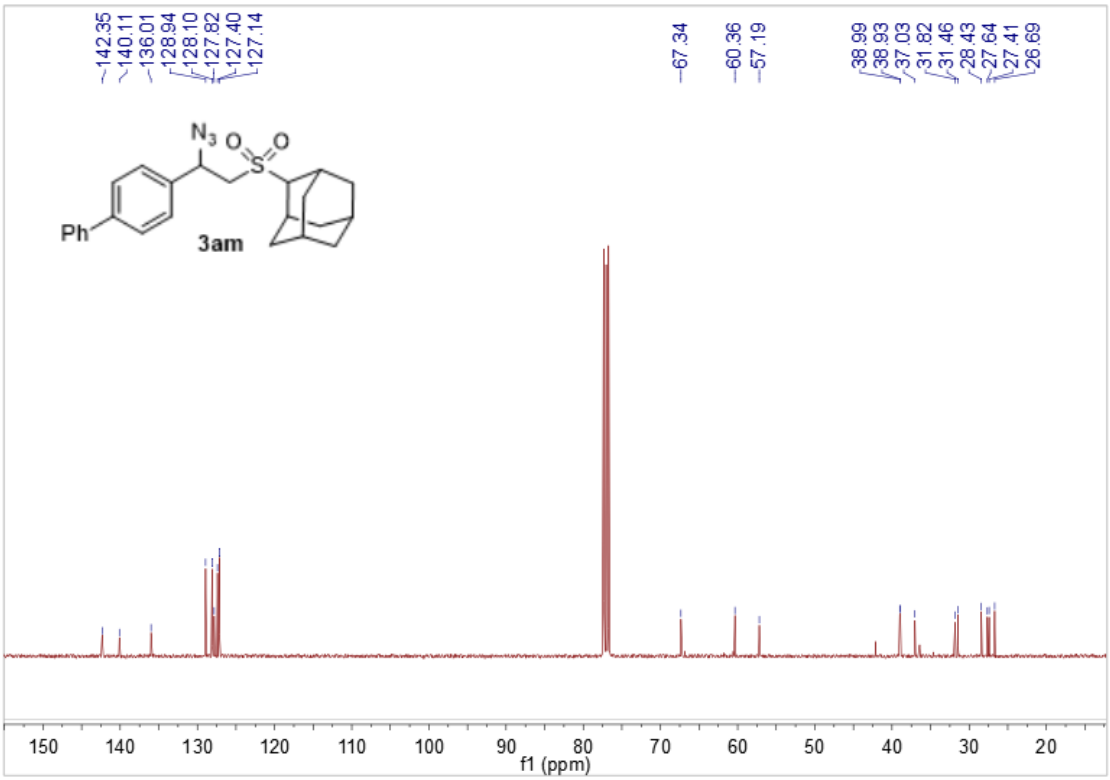
7.40
7.38
7.36
5.20
5.19
5.18
5.17
3.57
3.55
3.53
3.51
3.20
3.18
3.17
3.15
3.13
2.58
2.47
2.44
2.02
1.95
1.93
1.88
1.86
1.83
1.76
1.71
1.68
1.65
N3
O
S
O
Ph
3am
2.02
2.06
4.01
1.01
1.00
0.95
1.97
3.90
4.96
5.01
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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128.94
128.10
127.82
127.40
127.14
67.34
60.36
57.19
38.99
38.93
37.03
31.82
31.46
28.43
27.64
27.41
26.69
N3
O
S
O
Ph
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150
140
130
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70
60
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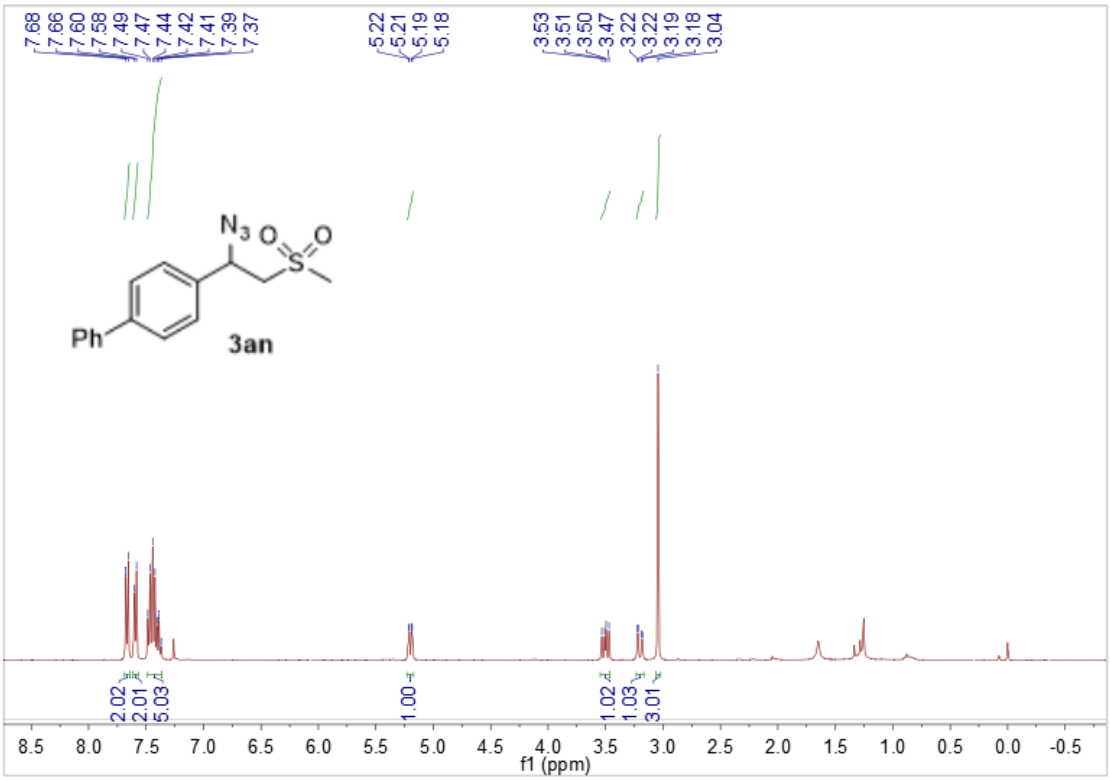
40
30
20
f1 (ppm)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7.44
7.42
7.41
7.39
7.37
5.22
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5.18
3.53
3.51
3.50
3.47
3.22
3.22
3.19
3.18
3.04
N3
O
S
O
Ph
3an
2.02
2.01
5.03
1.00
1.02
1.03
3.01
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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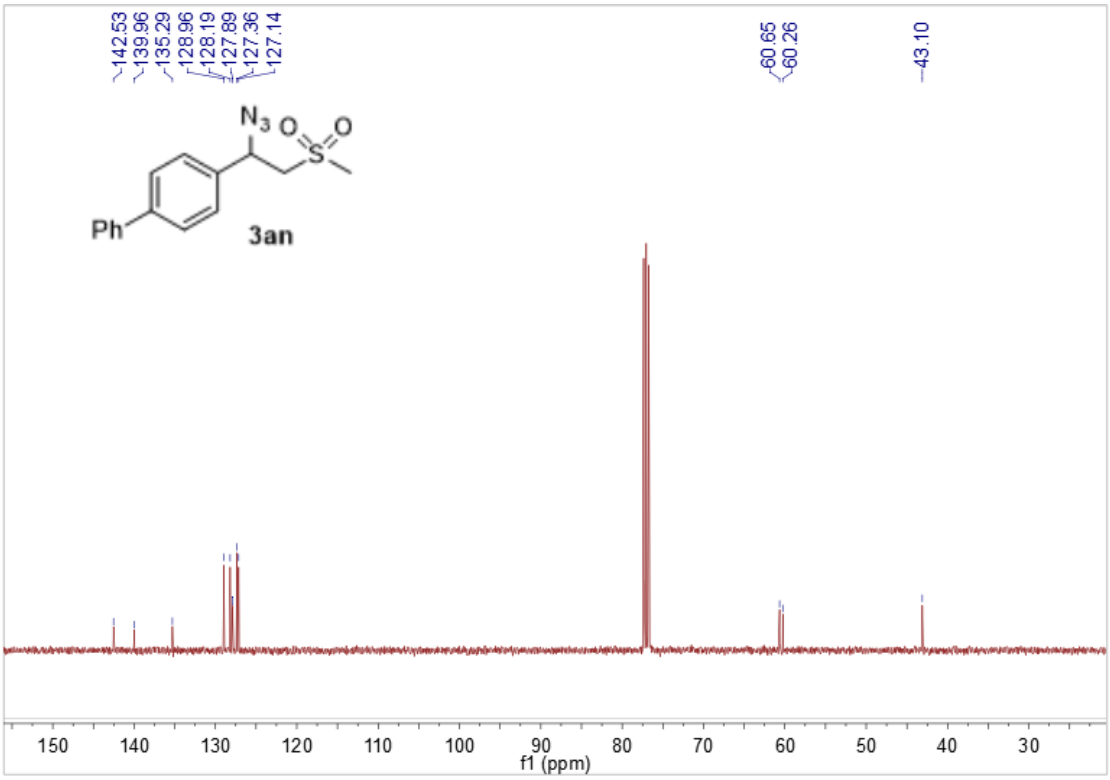
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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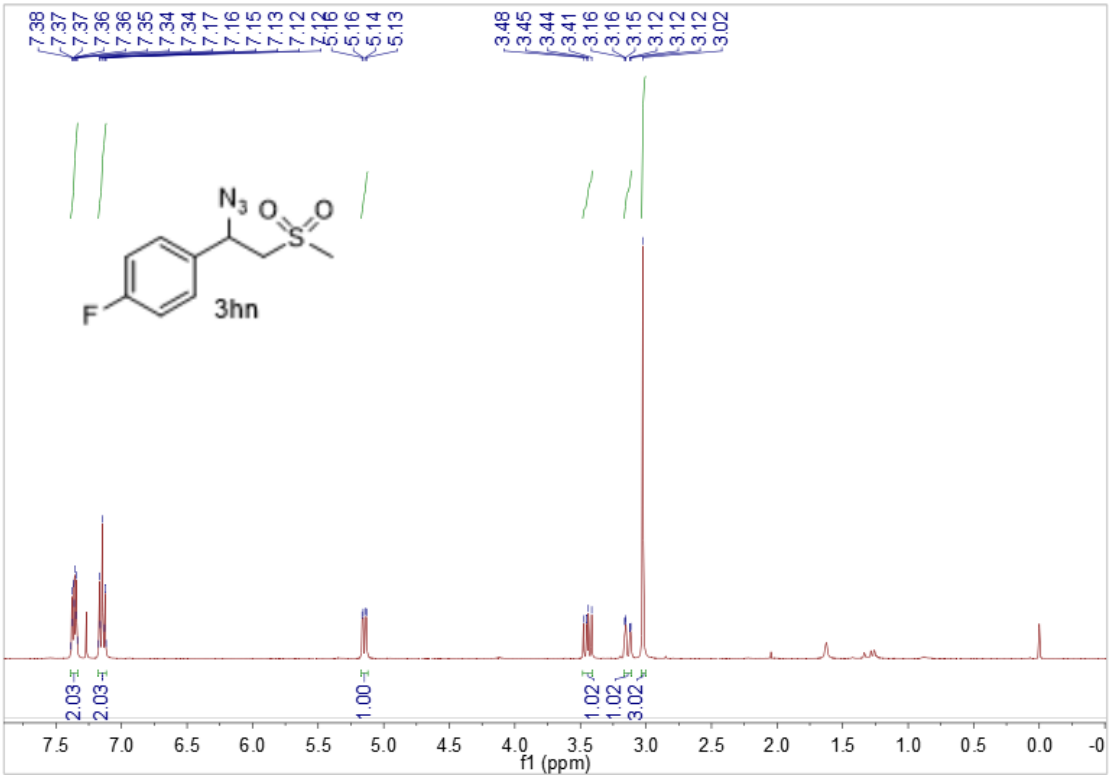
127.89
127.36
127.14
60.65
60.26
43.10
N3
O
S
O
Ph
3an
150
140
130
120
110
100
90
80
70
60
50
40
30
f1 (ppm)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7.13
7.12
5.16
5.16
5.14
5.13
3.48
3.45
3.44
3.41
3.16
3.16
3.15
3.12
3.12
3.12
3.02
N3
O
S
O
F
3hn
2.03
2.03
1.00
1.02
1.02
3.02
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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3.0
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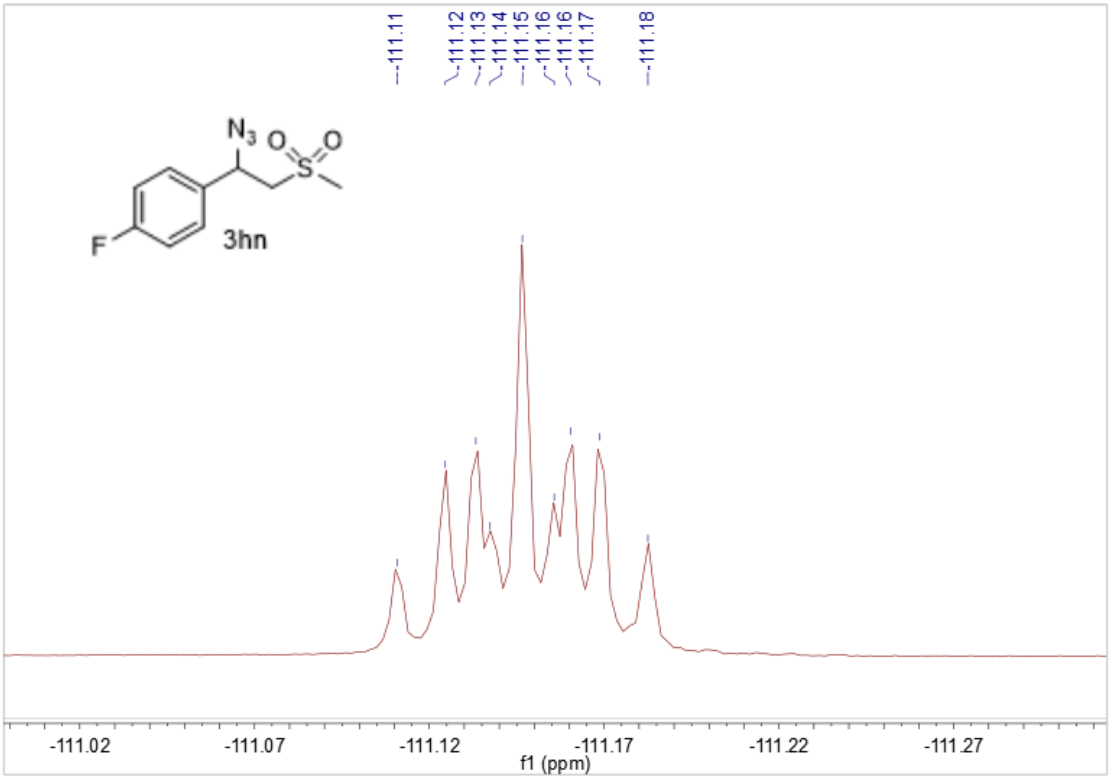
2.0
1.5
1.0
0.5
0.0
-0
f1 (ppm)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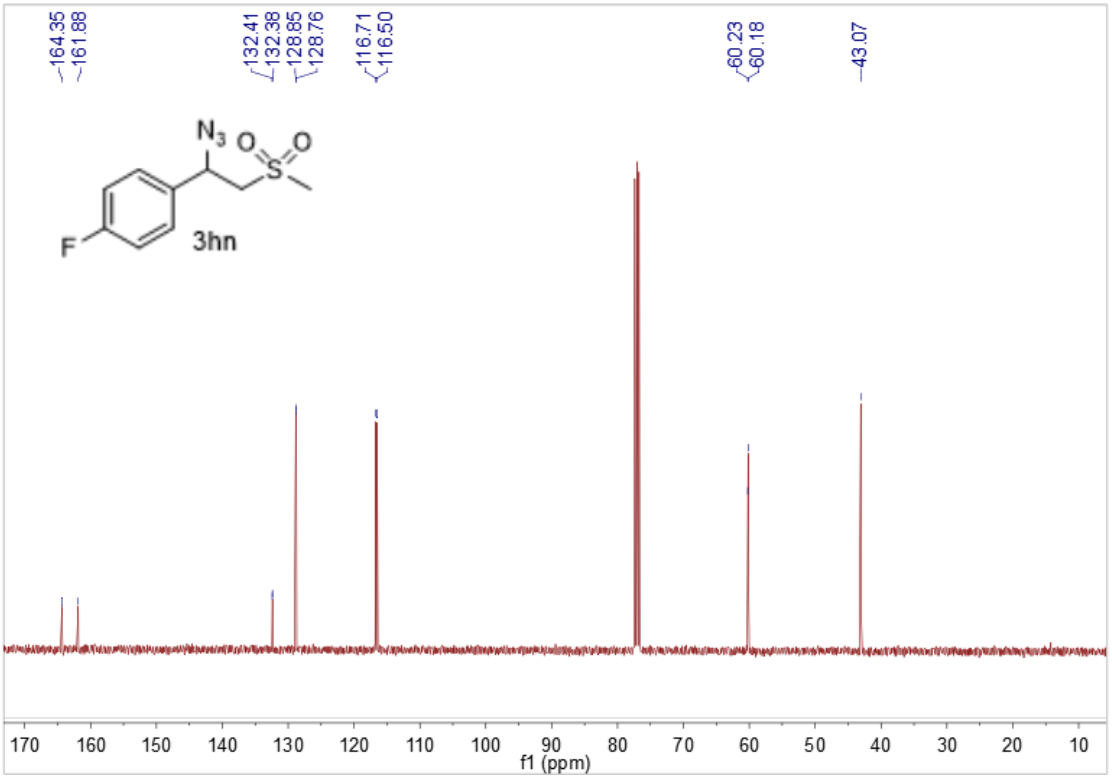
-111.12
-111.13
-111.14
-111.15
-111.16
-111.16
-111.17
-111.18
N3
O
O
S
F
3hn
-111.02
-111.07
-111.12
-111.17
-111.22
-111.27
f1 (ppm)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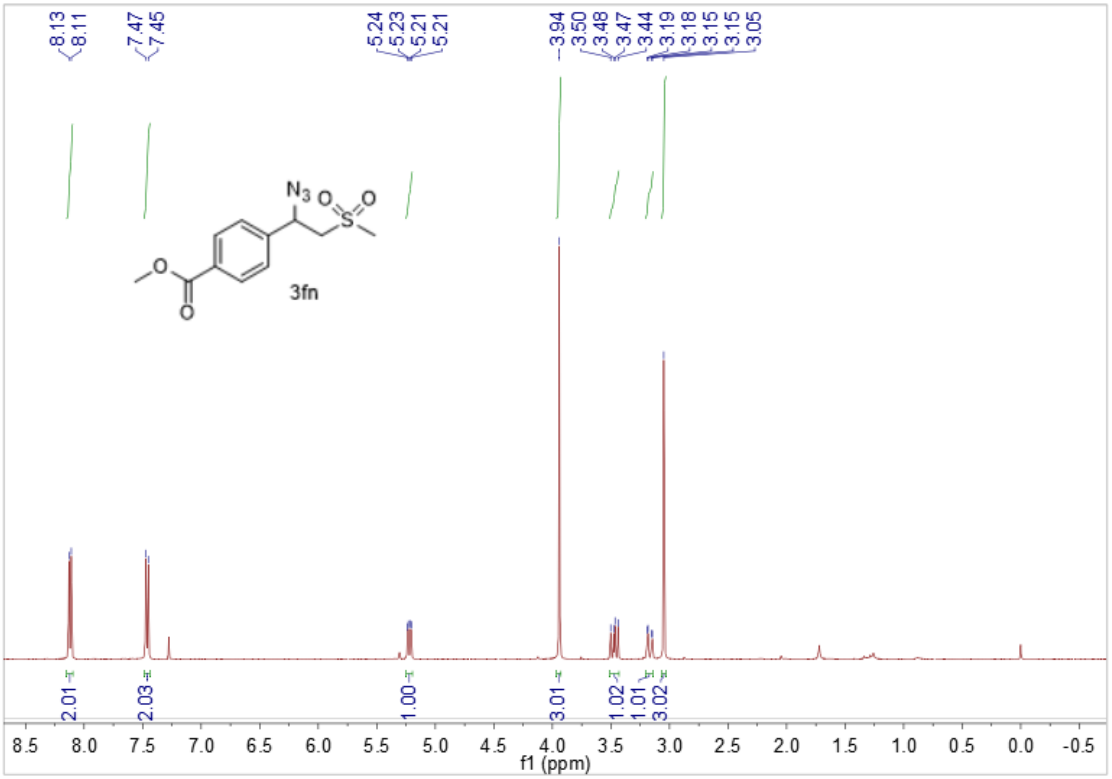
128.76
116.71
116.50
60.23
60.18
43.07
N3
O
O
S
F
3hn
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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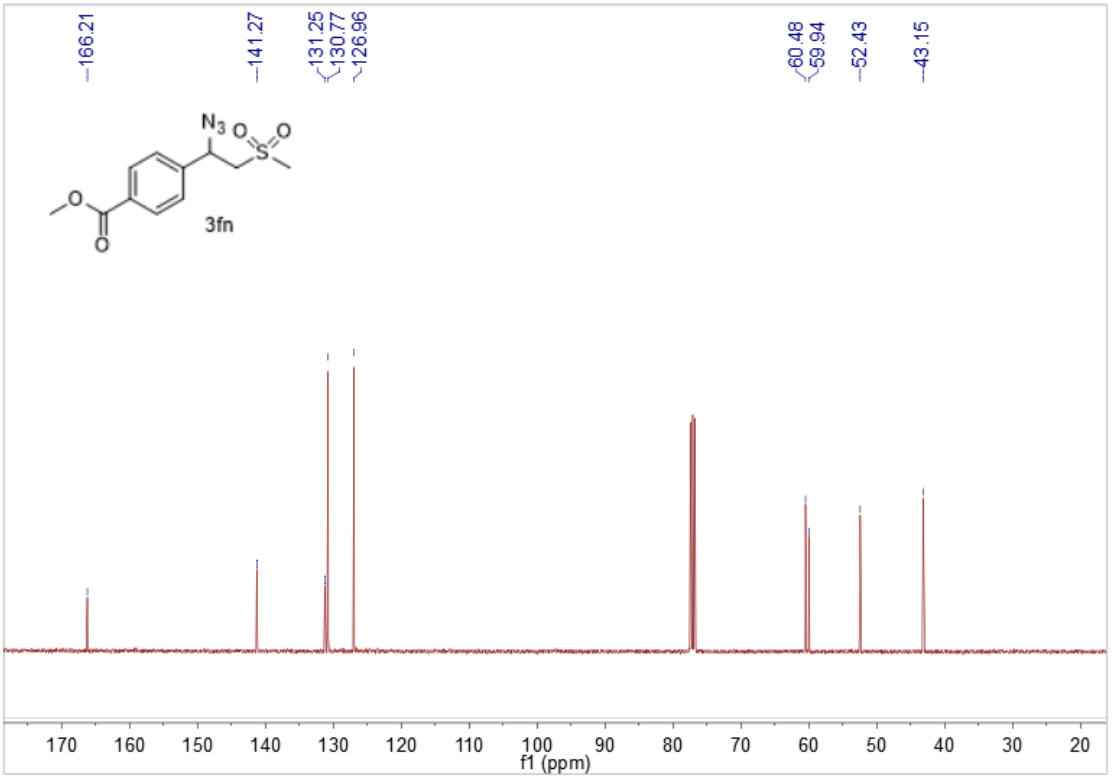
5.21
3.94
3.50
3.48
3.47
3.44
3.19
3.18
3.15
3.15
3.05
3fn
2.01
2.03
1.00
3.01
1.02
1.01
3.02
f1 (ppm)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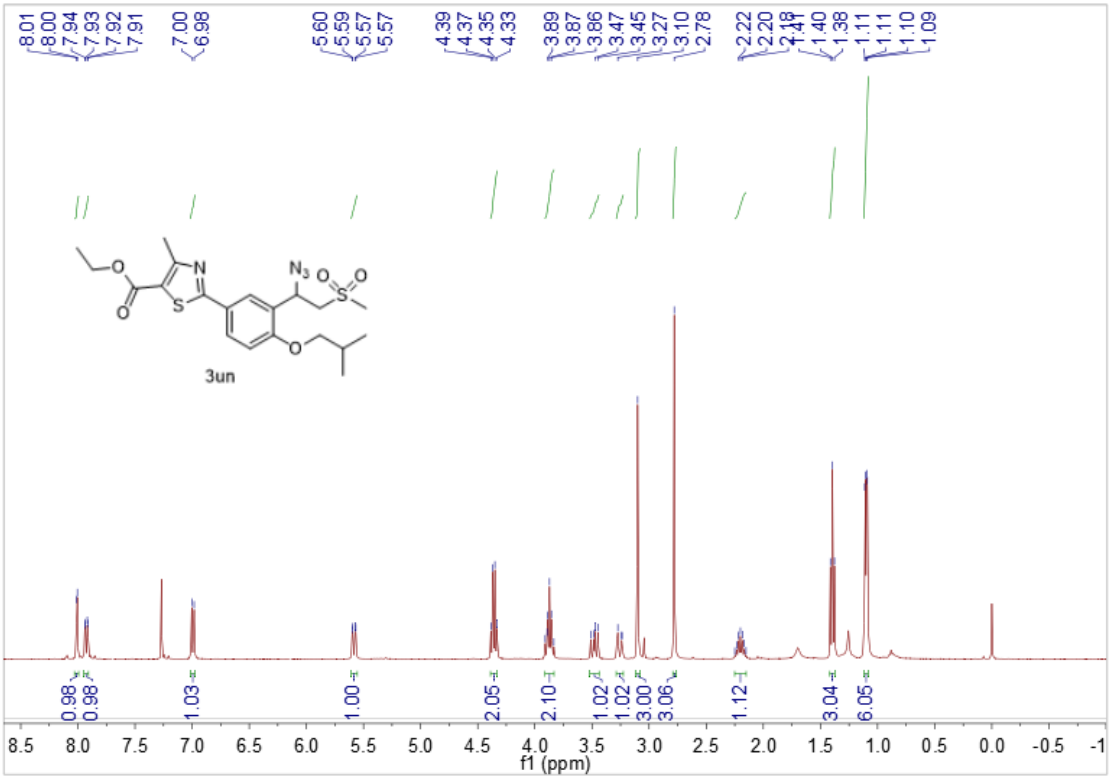
126.96
60.48
59.94
52.43
43.15
3fn
f1 (ppm)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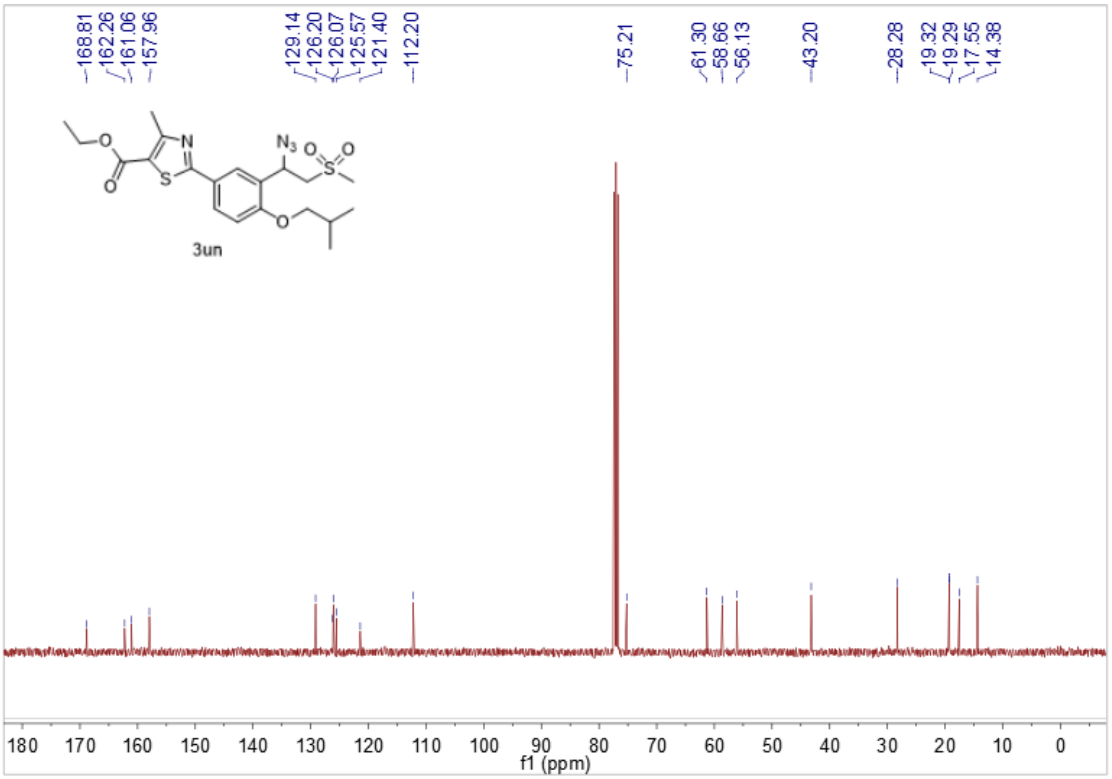
8.00
7.94
7.93
7.92
7.91
7.00
6.98
5.60
5.59
5.57
5.57
4.39
4.37
4.35
4.33
3.89
3.87
3.86
3.47
3.45
3.27
3.10
2.78
2.22
2.20
1.40
1.38
1.11
1.11
1.10
1.09
3un
0.98
0.98
1.03
1.00
2.05
2.10
1.02
1.02
3.00
3.06
1.12
3.04
6.05
f1 (ppm)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162.26
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125.57
121.40
112.20
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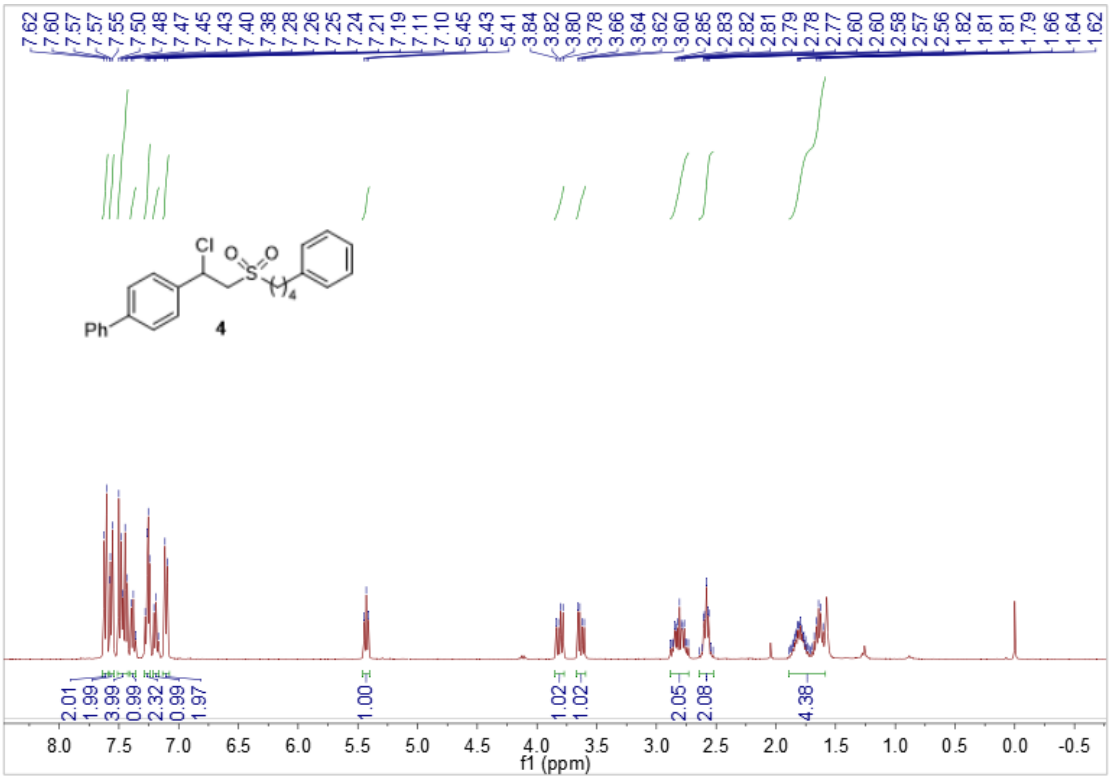
56.13
43.20
28.28
19.32
19.29
17.55
14.38
3un
f1 (ppm)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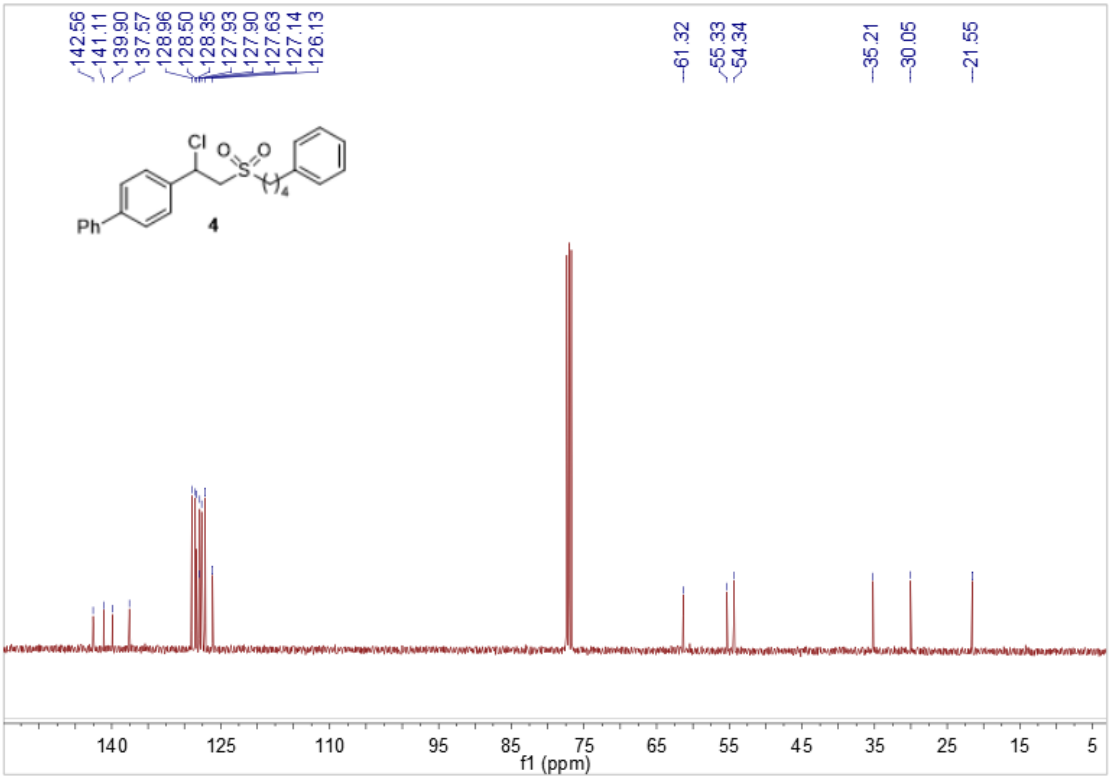
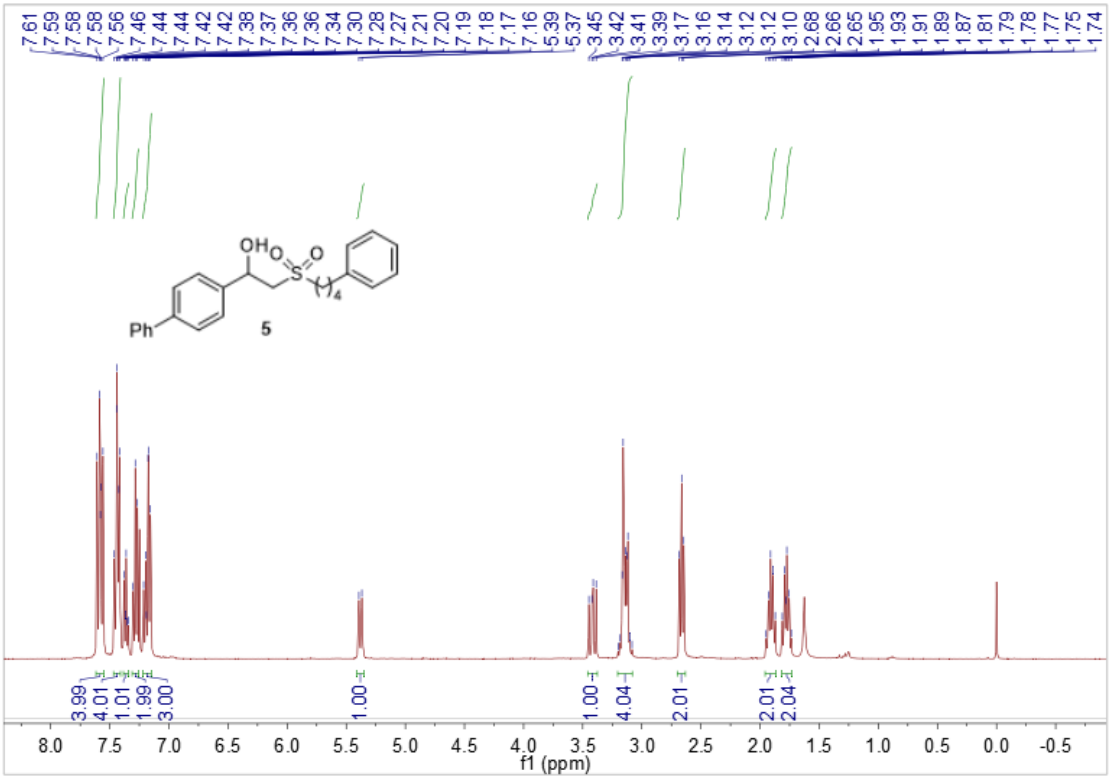
Cl
O
S
O
Ph
4
2.01 1.99 3.99 0.99 2.32 0.99 1.97 1.00 1.02 1.02 2.05 2.08 4.38
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


142.56 141.11 139.90 137.57 128.96 128.50 128.35 127.93 127.90 127.63 127.14 126.13
61.32 55.33 54.34 35.21 30.05 21.55
Cl
O
S
O
Ph
4
140 125 110 95 85 75 65 55 45 35 25 15 5
f1 (ppm)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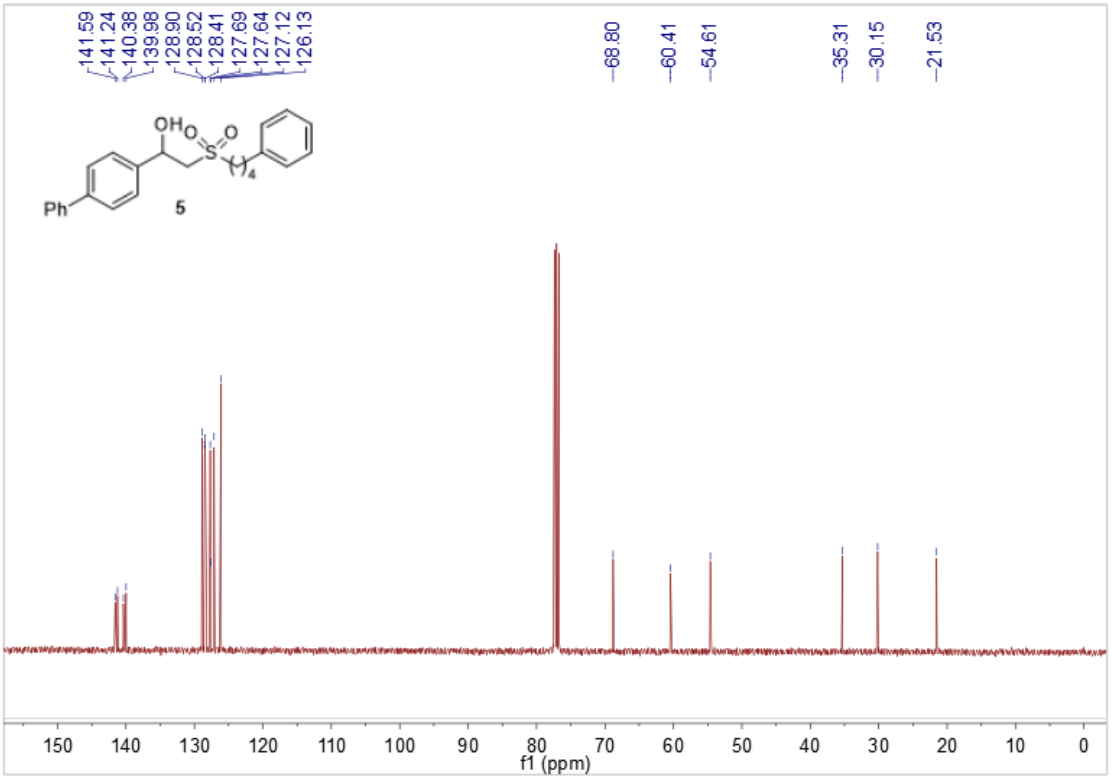
3.45 3.42 3.41 3.39 3.17 3.16 3.14 3.12 3.12 3.10 2.68 2.66 2.65 1.95 1.93 1.91 1.89 1.87 1.81 1.79 1.78 1.77 1.75 1.74
OH
O
S
O
Ph
5
3.99 4.01 1.01 1.99 3.00 1.00 1.00 4.04 2.01 2.01 2.04
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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68.80 60.41 54.61 35.31 30.15 21.53
OH
O
S
O
Ph
5
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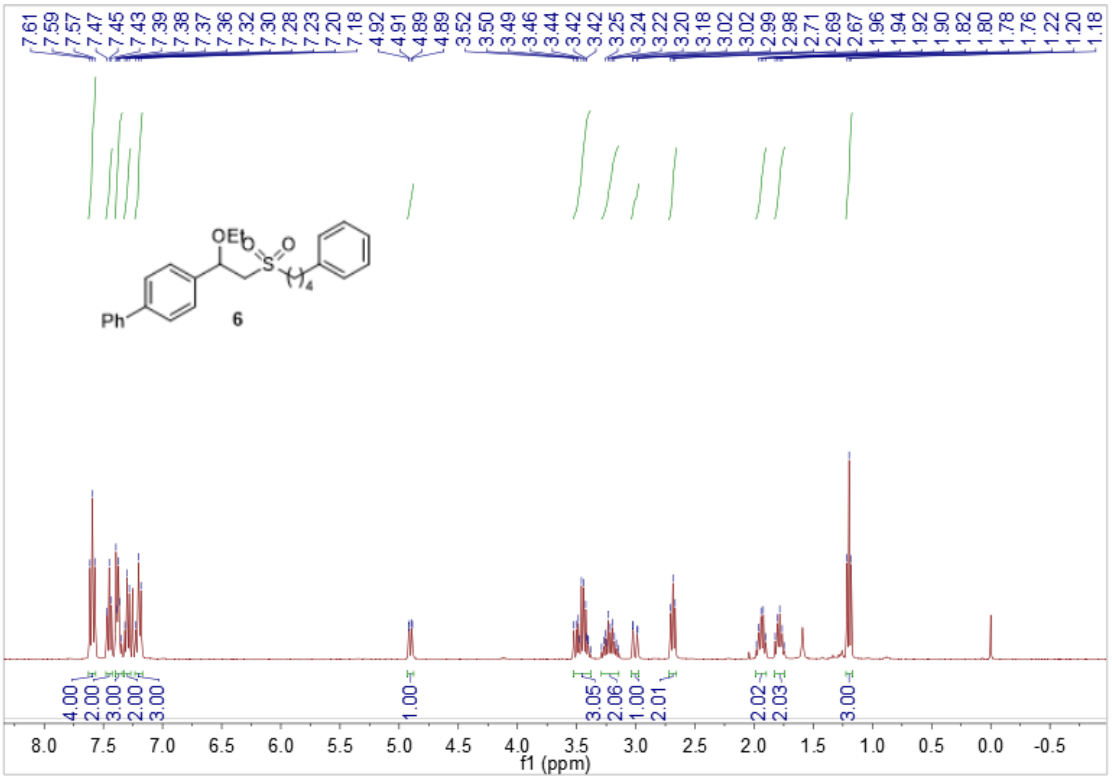
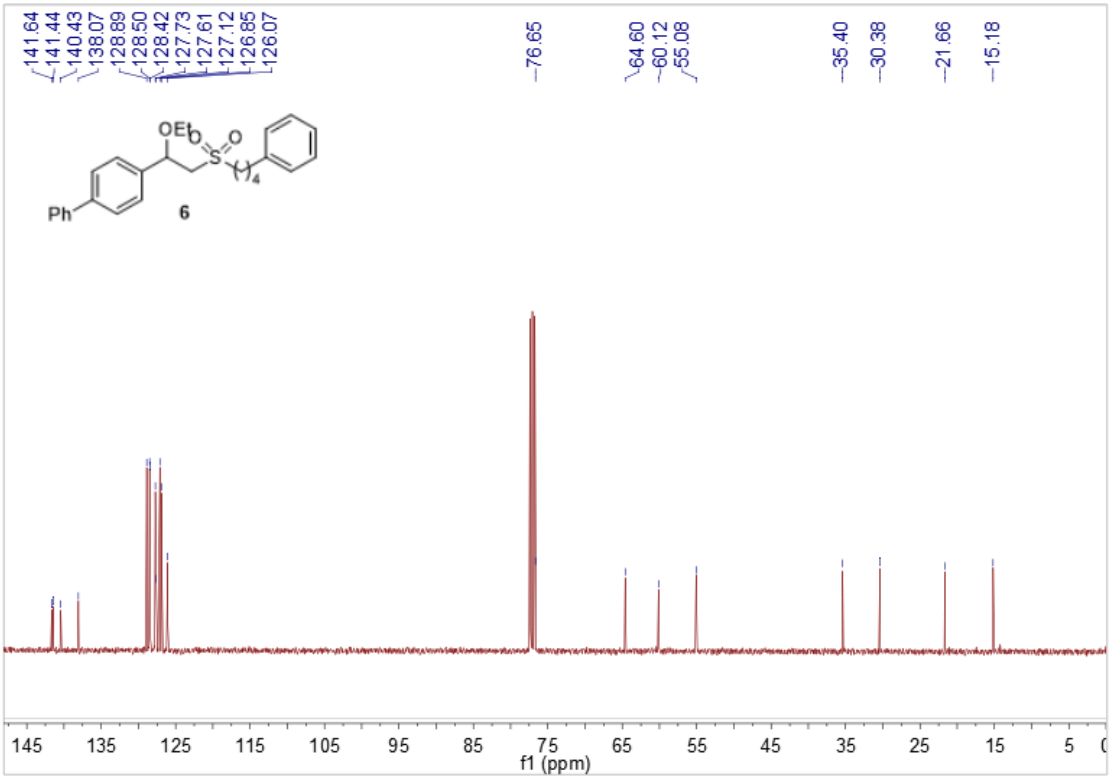
f1 (ppm)


7.61 7.59 7.57 7.47 7.45 7.43 7.39 7.38 7.37 7.36 7.32 7.30 7.28 7.23 7.20 7.18 4.92 4.91 4.89 4.89 3.52 3.50 3.49 3.46 3.44 3.42 3.42 3.25 3.24 3.22 3.20 3.18 3.02 3.02 2.99 2.98 2.71 2.69 2.67 1.96 1.94 1.92 1.90 1.82 1.80 1.78 1.76 1.22 1.20 1.18
OEt
O
S
Ph
6
4.00 2.00 3.00 2.00 3.00 1.00 3.05 2.06 1.00 2.01 2.02 2.03 3.00
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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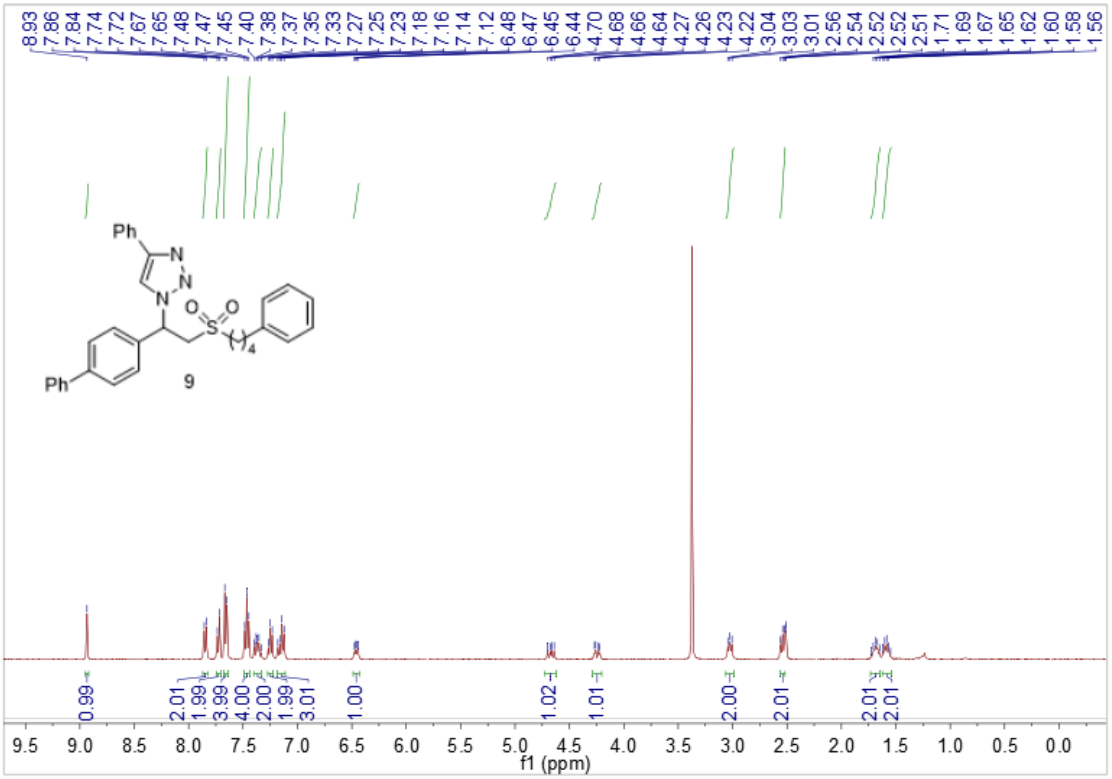
76.65
64.60 60.12 55.08
35.40 30.38 21.66 15.18
OEt
O
S
Ph
6
145 135 125 115 105 95 85 75 65 55 45 35 25 15 5
f1 (ppm)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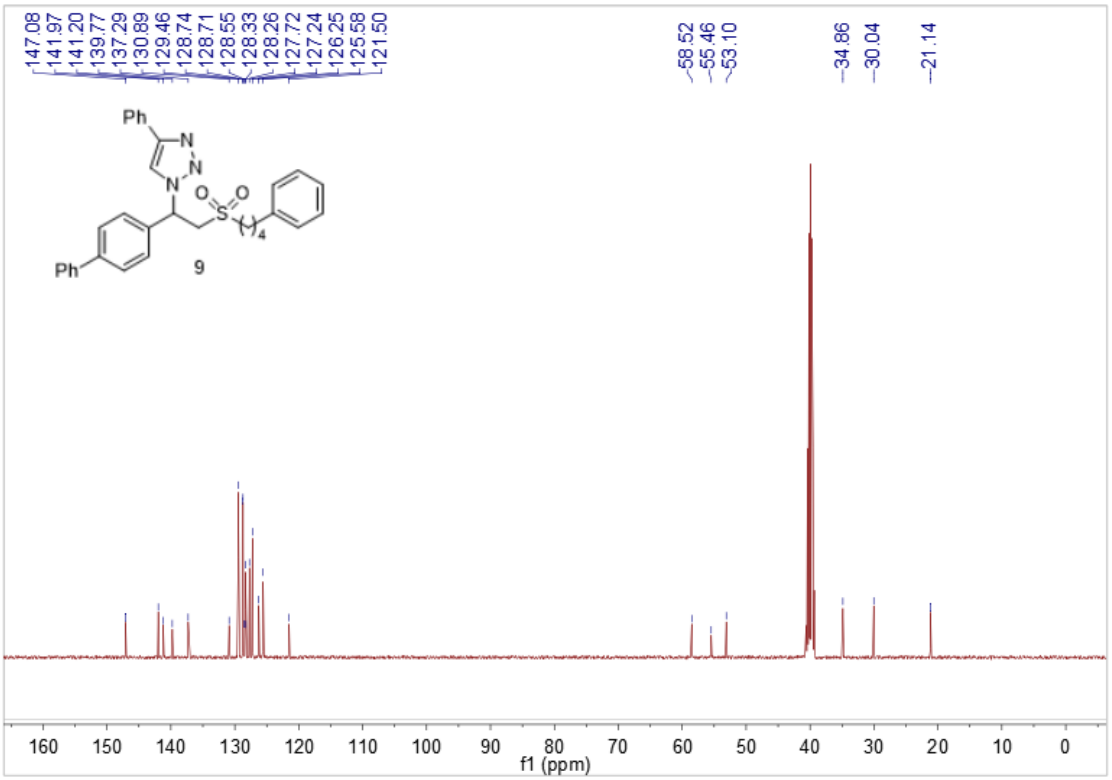
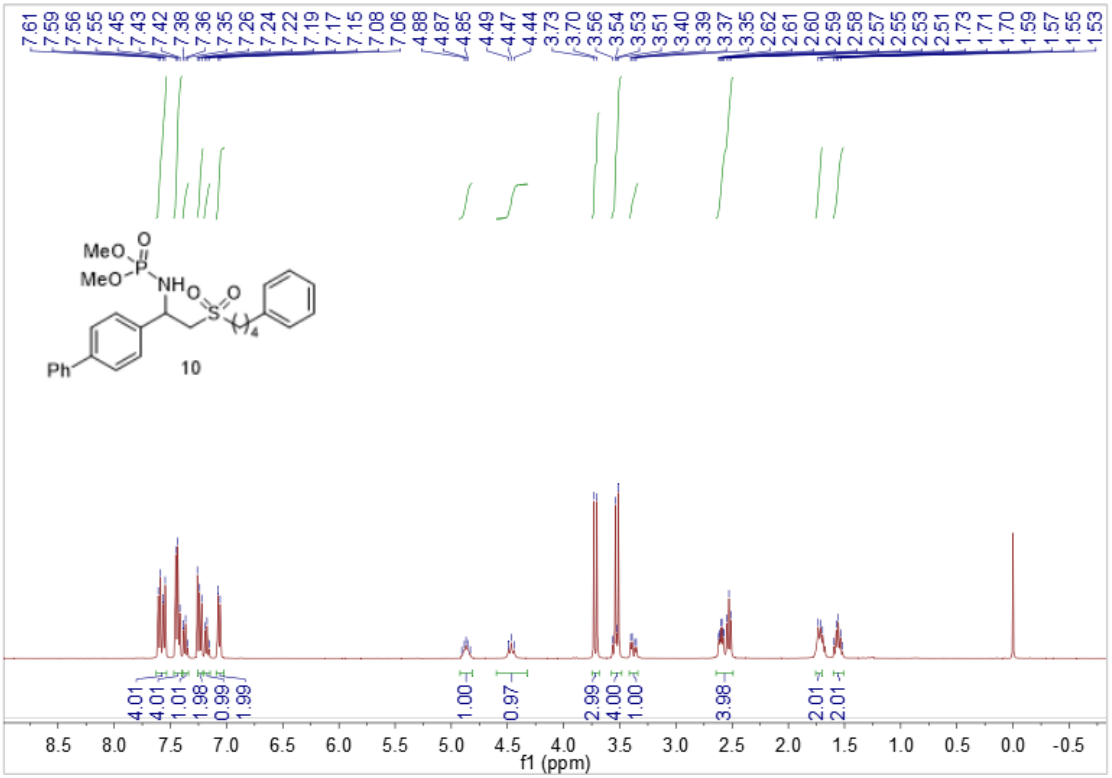
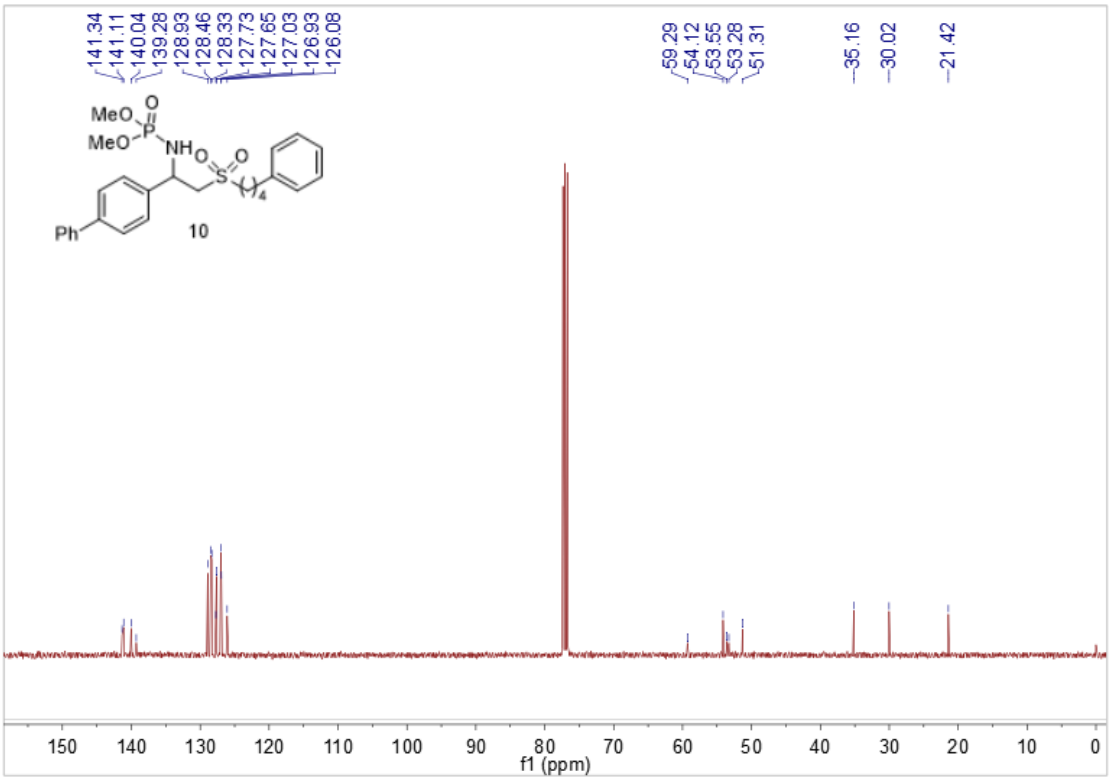
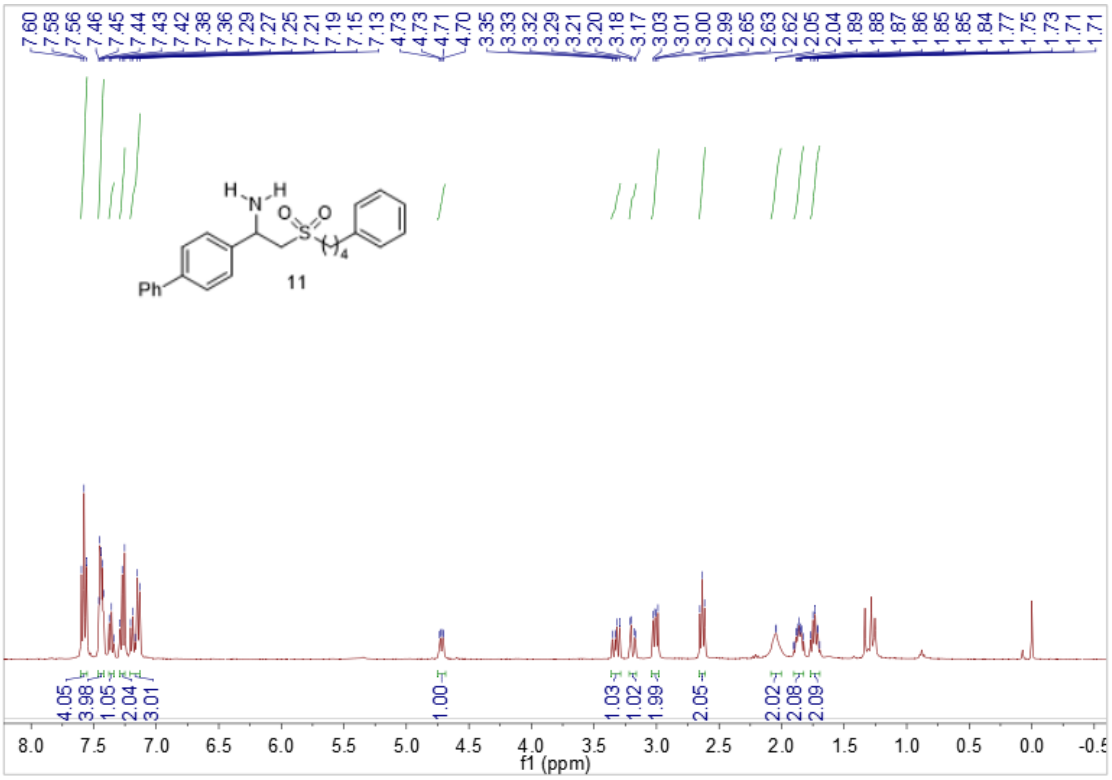
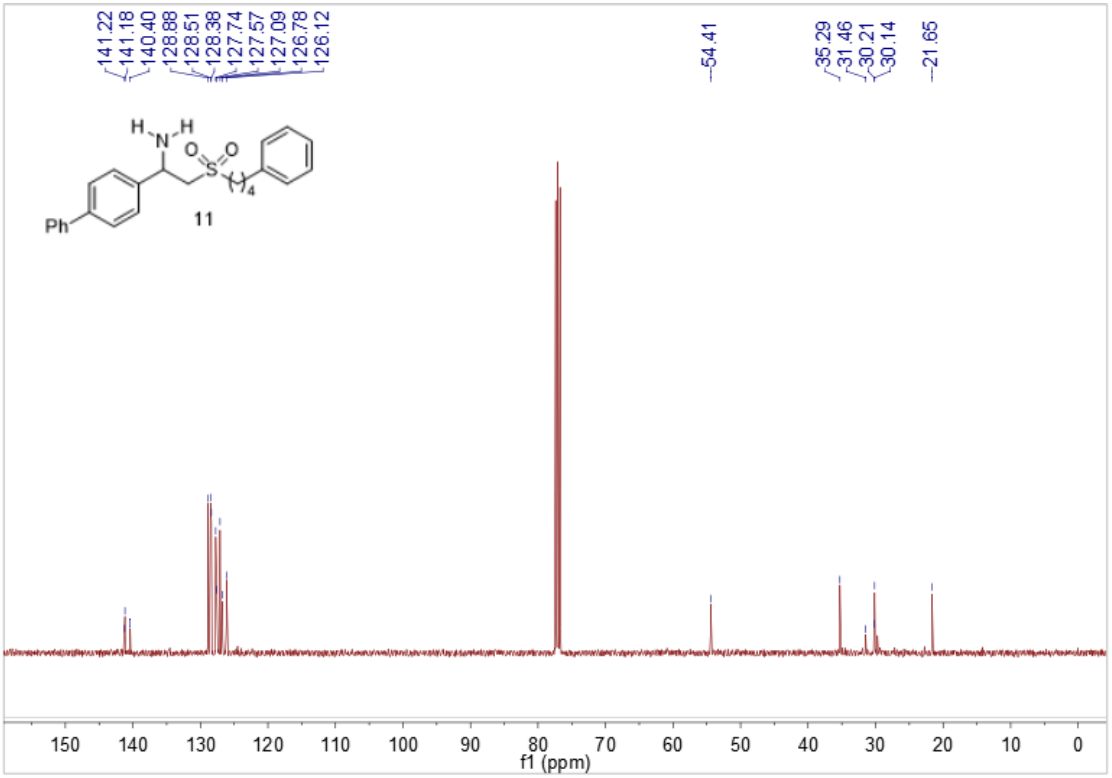
Ph
N
N
N
O
O
S
4
Ph
9
0.99 2.01 1.99 3.99 4.00 2.00 1.99 3.01 1.00 1.02 1.01 2.00 2.01 2.01 2.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


147.08 141.97 141.20 139.77 137.29 130.89 129.46 128.74 128.71 128.55 128.33 128.26 127.72 127.24 126.25 125.58 121.50
58.52 55.46 53.10
34.86 30.04 21.14
Ph
N
N
N
O
O
S
4
Ph
9
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.61 7.59 7.56 7.55 7.45 7.43 7.42 7.38 7.36 7.35 7.26 7.24 7.22 7.19 7.17 7.15 7.08 7.06 4.88 4.87 4.85 4.49 4.47 4.44 3.73 3.70 3.56 3.54 3.53 3.51 3.40 3.39 3.37 3.35 2.62 2.61 2.60 2.59 2.58 2.57 2.55 2.53 2.51 1.73 1.71 1.70 1.59 1.57 1.55 1.53
MeO
MeO
O
P
NH
O
S
O
Ph
10
4.01 4.01 1.01 1.98 0.99 1.99 1.00 0.97 2.99 4.00 1.00 3.98 2.01 2.01
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


141.34 141.11 140.04 139.28 128.93 128.46 128.33 127.73 127.65 127.03 126.93 126.08
59.29 54.12 53.55 53.28 51.31
35.16 30.02 21.42
MeO
MeO
O
P
NH
O
S
O
Ph
10
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.60 7.58 7.56 7.46 7.45 7.44 7.43 7.42 7.38 7.36 7.29 7.27 7.25 7.21 7.19 7.15 7.13 4.73 4.71 4.70 3.35 3.33 3.32 3.29 3.21 3.20 3.18 3.17 3.03 3.01 3.00 2.99 2.65 2.63 2.62 2.05 2.04 1.89 1.88 1.87 1.86 1.85 1.85 1.84 1.77 1.75 1.73 1.71 1.71
11
4.05 3.98 1.05 2.04 3.01 1.00 1.03 1.02 1.99 2.05 2.02 2.08 2.09
f1 (ppm)


141.22 141.18 140.40 128.88 128.51 128.38 127.74 127.57 127.09 126.78 126.12 54.41 35.29 31.46 30.21 30.14 21.65
11
f1 (ppm)