Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry.

Supporting Information

Metal-free oxysulfenylation of alkenes with 1-(aryltion)pyrrolidine-2,5-diones and alcohols

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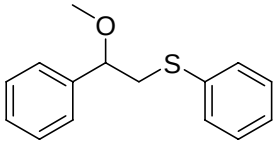
General experimental procedures

All reactions were carried out under nitrogen atmosphere. Proton and carbon magnetic resonance spectra (^{1}H NMR and ^{13}C NMR) were recorded using tetramethylsilane (TMS) in the solvent of $CDCl_3$ as the internal standard (^{1}H NMR: TMS at 0.00 ppm, $CDCl_3$ at 7.26 ppm; ^{13}C NMR: $CDCl_3$ at 77.26 ppm).

General procedure for synthesis of compounds 4a-ai

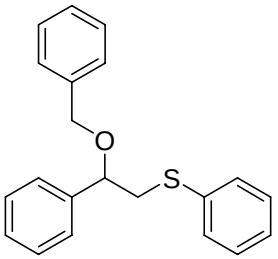
A 25 mL Schlenk tube was charged with a magnetic stirrer, alkene (**1**) (0.2 mmol), 1-(arylthio)pyrrolidine-2,5-dione (**2**) (0.3 mmol for entries 1-13, 18-26 and 28-31; 0.5 mmol for entries 14-17; 0.6 mmol for entry 27 in Table 2 of Text), alcohol (**3**) (4.0 mmol for entry 27; 2.0 mmol for the others in Table 2 of Text) and $CHCl_3$ (1.0 mL) were added to the tube. The tube was sealed, and the mixture was stirred at 80-140 ^{o}C till the reaction completed (TLC determination). The resulting mixture was cooled to room temperature, the solvent was removed by a rotary evaporator, and the residue was purified by column chromatography on silica gel using petroleum ether/ ethyl acetate as eluent to give the desired target product (**4**).

Characterization data of compounds 4a-ai



4a

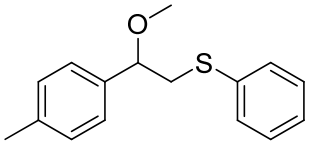
(2-Methoxy-2-phenylethyl)(phenyl)sulfane (4a). Eluent: petroleum ether/ethyl acetate (25:1). Yield 43 mg (88%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.32 (m, 6H), 7.30-7.27 (m, 2H), 7.20-7.17 (m, 1H), 4.33-4.30 (m, 1H), 3.33 (dd, J = 13.2 Hz, J = 8.2 Hz, 1H), 3.27 (s, 3H), 3.14 (dd, J = 13.3 Hz, J = 4.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.6, 136.8, 129.5, 129.0, 128.7, 128.3, 126.9, 126.1, 82.6, 57.2, 41.7. EI-MS: $[M]^+$ m/z 244.3.



4b

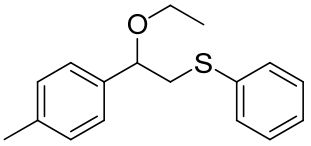
(2-(Benzyloxy)-2-phenylethyl)(phenyl)sulfane (4b). Eluent: petroleum ether/ethyl acetate (25:1). Yield 45 mg (70%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ

7.44-7.43 (m, 5H), 7.38-7.36 (m, 7H), 7.32-7.19 (m, 3H), 4.63-4.55 (m, 2H), 4.37 (d, J = 11.8 Hz, 1H), 3.48 (dd, J = 13.3 Hz, J = 8.0 Hz, 1H), 3.12 (dd, J = 13.3 Hz, J = 5.1 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.8, 138.2, 136.9, 129.4, 129.0, 128.8, 128.5, 128.4, 128.0, 127.8, 127.1, 126.1, 80.2, 71.0, 41.8. EI-MS: $[M]^+$ m/z 320.1.



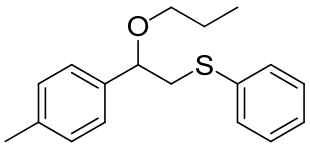
4c

(2-Methoxy-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4c). Eluent: petroleum ether/ethyl acetate (25:1). Yield 48 mg (93%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.17 (m, 9H), 4.28 (dd, J = 8.0 Hz, J = 5.1 Hz, 1H), 3.34 (dd, J = 13.2 Hz, J = 8.0 Hz, 1H), 3.25 (s, 3H), 3.34 (dd, J = 13.2 Hz, J = 5.1 Hz, 1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.0, 137.6, 136.8, 129.4, 128.9, 126.8, 126.1, 82.4, 57.0, 41.6, 21.3. EI-MS: $[M]^+$ m/z 258.3.



4d

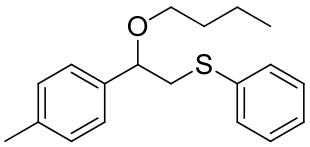
(2-Ethoxy-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4d). Eluent: petroleum ether/ethyl acetate (25:1). Yield 46 mg (86%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.33 (m, 2H), 7.29-7.24 (m, 3H), 7.22-7.15 (m, 4H), 4.38 (dd, J = 8.0 Hz, J = 5.3 Hz, 1H), 3.44-3.30 (m, 3H), 3.11 (dd, J = 13.2 Hz, J = 5.3 Hz, 1H), 2.36 (s, 3H), 1.18 (t, J = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.3, 137.8, 136.9, 129.3, 128.9, 126.7, 125.9, 80.6, 64.6, 41.7, 21.3, 15.3. EI-MS: $[M]^+$ m/z 272.2.



4e

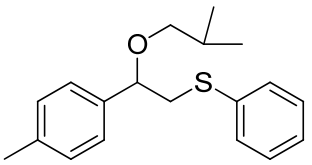
Phenyl(2-propoxy-2-(*p*-tolyl)ethyl)sulfane (4e). Eluent: petroleum ether/ethyl acetate (25:1). Yield 56 mg (99%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.35 (m, 2H), 7.30-7.27 (m, 1H), 7.25-7.23 (m, 3H), 7.19-7.17 (m, 3H), 4.39 (dd, J = 8.1 Hz, J = 5.2 Hz, 1H), 3.40-3.22 (m, 3H), 3.12 (dd, J = 13.1 Hz, J = 5.1 Hz, 1H), 2.37 (s, 3H), 1.65-1.53 (m, 2H), 0.92 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.4, 137.8, 137.1, 129.3, 129.2, 128.9, 126.7, 125.9, 80.8, 71.0, 41.8, 23.1, 21.3,

10.8. EI-MS: $[M]^+$ m/z 286.1.



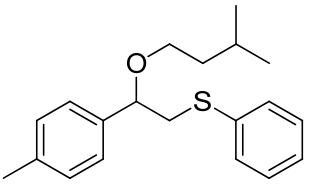
4f

(2-Butoxy-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4f). Eluent: petroleum ether/ethyl acetate (25:1). Yield 55 mg (91%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 8.2 Hz, 2H), 7.28-7.24 (m, 7H), 4.37 (dd, *J* = 7.9 Hz, *J* = 5.2 Hz, 1H), 3.38-3.25 (m, 3H), 3.11 (dd, *J* = 12.8 Hz, *J* = 5.0 Hz, 1H), 2.35 (s, 3H), 1.57-1.50 (m, 2H), 1.41-1.33 (m, 2H), 0.88 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.4, 137.8, 137.1, 129.3, 129.2, 128.9, 126.7, 125.9, 80.8, 69.1, 41.8, 31.9, 21.3, 19.4, 14.0. EI-MS: $[M]^+$ m/z 300.3.



4g

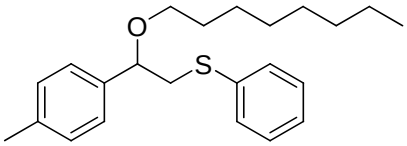
(2-Isobutoxy-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4g). Eluent: petroleum ether/ethyl acetate (25:1). Yield 73 mg (99%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.35 (d, *J* = 7.1 Hz, 2H), 7.29-7.17 (m, 7H) , 4.37 (dd, *J* = 8.2 Hz, *J* = 5.1 Hz, 1H), 3.36 (dd, *J* = 13.2 Hz, *J* = 8.2 Hz, 1H), 3.14-3.04 (m, 3H), 2.37 (s, 3H), 1.90-1.83 (m, 1H), 0.91-0.89 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.4, 137.8, 137.3, 129.3, 129.2, 128.9, 126.8, 125.8, 81.1, 76.2, 41.9, 28.7, 21.3, 19.6, 19.5. EI-MS: $[M]^+$ m/z 300.1.



4h

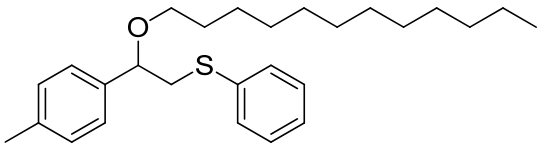
(2-(Isopentyloxy)-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4h). Eluent: petroleum ether/ethyl acetate (25:1). Yield 61 mg (98%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.35 (m, 2H), 7.29-7.25 (m, 2H), 7.22-7.16 (m, 5H), 4.38 (dd, *J* = 8.1 Hz, *J* = 5.2 Hz, 1H), 3.40-3.29 (m, 3H), 3.11 (dd, *J* = 13.1 Hz, *J* = 5.1 Hz, 1H), 2.37 (s, 3H), 1.77-1.69 (m, 1H), 1.49-1.42 (m, 2H), 0.89 (d, *J* = 6.6 Hz, 3H), 0.85 (d, *J* = 6.6

Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.4, 137.8, 137.1, 129.3, 129.2, 128.9, 126.7, 125.9, 80.9, 67.7, 41.8, 38.7, 25.0, 22.8, 22.6, 21.3. EI-MS: $[M]^+$ m/z 314.3.



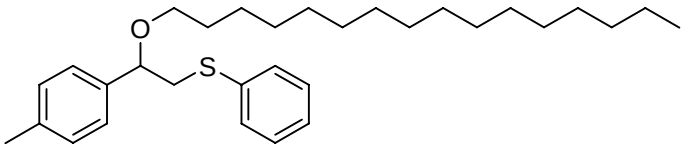
4i

(2-(Octyloxy)-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4i). Eluent: petroleum ether/ethyl acetate (25:1). Yield 67 mg (95%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36-7.34 (m, 2H), 7.28-7.21 (m, 4H), 7.18-7.15 (m, 3H), 4.37 (dd, *J* = 8.0 Hz, *J* = 5.3 Hz, 1H), 3.37-3.24 (m, 3H), 3.11 (dd, *J* = 13.1 Hz, *J* = 5.1 Hz, 1H), 2.36 (s, 3H), 1.57-1.51 (m, 2H), 1.30-1.26 (m, 10H), 0.89 (t, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.4, 137.8, 137.1, 129.3, 129.2, 128.9, 126.7, 125.9, 80.8, 69.4, 41.7, 32.0, 29.9, 29.5, 29.4, 26.2, 22.8, 21.3, 14.2. EI-MS: $[M]^+$ m/z 356.2.



4j

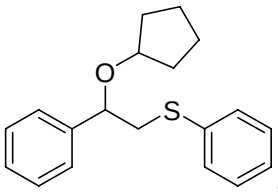
(2-(Dodecyloxy)-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4j). Eluent: petroleum ether/ethyl acetate (25:1). Yield 65 mg (79%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.35 (m, 2H), 7.30-7.16 (m, 7H), 4.58 (dd, *J* = 8.3 Hz, *J* = 4.9 Hz, 1H), 3.35-3.18 (m, 2H), 3.11 (dd, *J* = 13.1 Hz, *J* = 4.8 Hz, 1H), 2.37 (s, 3H), 1.92-1.88 (m, 1H), 1.73-1.63 (m, 3H), 1.50-1.29 (m, 3H), 1.25-1.23 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.4, 137.8, 137.1, 129.3, 129.2, 128.9, 126.7, 125.9, 80.8, 69.4, 41.7, 32.0, 29.9, 29.8, 29.7, 29.6, 29.5, 29.4, 26.2, 22.8, 21.3, 14.2. EI-MS: $[M]^+$ m/z 412.2.



4k

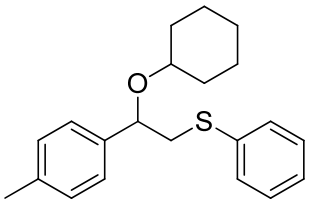
(2-(Hexadecyloxy)-2-*p*-tolylethyl)(phenyl)sulfane (4k). Eluent: petroleum ether/ethyl acetate (25:1). Yield 69 mg (85%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.35 (m, 2H), 7.30-7.15 (m, 7H), 4.38 (dd, *J* = 8.0 Hz, *J* = 5.3 Hz, 1H), 3.39-3.25 (m, 3H), 3.12 (dd, *J* = 13.1 Hz, *J* = 5.1 Hz, 1H), 2.37 (s, 3H), 1.59-1.54 (m, 2H), 1.34-1.24 (m, 26H), 0.91 (t, *J* = 6.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.4, 137.8, 137.2, 129.3, 129.2, 128.9, 126.7, 125.9, 80.8, 69.4, 41.7, 32.1, 29.8,

29.7, 29.6, 29.5, 26.3, 22.8, 21.3, 14.3. EI-MS: $[M]^+$ m/z 468.3.



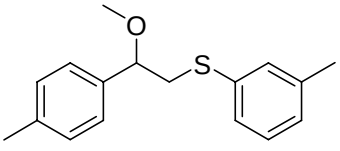
4l

(2-(Cyclopentyloxy)-2-*p*-tolylethyl)(phenyl)sulfane (4l). Eluent: petroleum ether/ethyl acetate (25:1). Yield 46 mg (73%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36-7.34 (m, 2H), 7.28-7.23 (m, 4H), 7.18-7.16 (m, 3H), 4.44 (dd, *J* = 8.0 Hz, *J* = 4.7 Hz, 1H), 3.83-3.81 (m, 1H), 3.27 (dd, *J* = 13.2 Hz, *J* = 8.6 Hz, 1H), 3.18 (dd, *J* = 13.0 Hz, *J* = 4.7 Hz, 1H), 2.36 (s, 3H), 1.63-1.59 (m, 2H), 1.57-1.45 (m, 2H), 1.44-1.39 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.9, 137.6, 137.3, 129.2, 129.0, 128.9, 126.8, 125.8, 79.4, 76.8, 42.0, 33.2, 31.7, 23.6, 23.5, 21.3. EI-MS: $[M]^+$ m/z 298.1.



4m

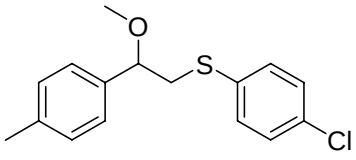
(2-(Cyclohexyloxy)-2-(*p*-tolyl)ethyl)(phenyl)sulfane (4m). Eluent: petroleum ether/ethyl acetate (25:1). Yield 41 mg (64%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 7.5 Hz, 2H), 7.28-7.14 (m, 7H), 4.37 (dd, *J* = 8.0 Hz, *J* = 5.3 Hz, 1H), 3.37-3.25 (m, 3H), 3.11 (dd, *J* = 13.1 Hz, *J* = 5.2 Hz, 1H), 2.36 (s, 3H), 1.59-1.52 (m, 2H), 1.32-1.26 (m, 18H), 0.90 (t, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.3, 137.6, 137.4, 129.2, 128.9, 128.8, 126.7, 125.8, 77.6, 75.6, 42.2, 33.6, 31.4, 25.9, 24.2, 24.0, 21.3. EI-MS: $[M]^+$ m/z 326.4.



4n

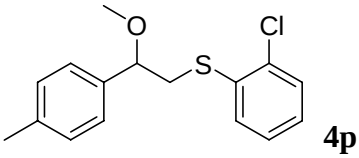
(2-Methoxy-2-*p*-tolylethyl)(*m*-tolyl)sulfane (4n). Eluent: petroleum ether/ethyl acetate (25:1). Yield 36 mg (67%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.17 (m, 7H), 7.04-6.99 (m, 1H), 4.30 (dd, *J* = 8.0 Hz, *J* = 5.1 Hz, 1H), 3.39-3.30 (m, 1H), 3.28-3.22 (m, 3H), 3.15 (dd, *J* = 13.1 Hz, *J* = 5.2 Hz, 1H), 2.39 (s, 3H), 2.34

(s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.7, 138.0, 137.7, 136.5, 130.0, 129.4, 128.8, 126.9, 126.8, 126.4, 82.5, 57.2, 41.6, 21.5, 21.3. EI-MS: $[M]^+$ m/z 272.3.



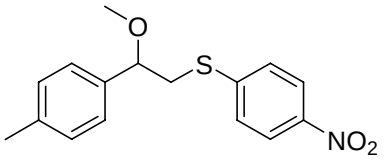
4o

(4-Chlorophenyl)(2-methoxy-2-*p*-tolylethyl)sulfane (4o). Eluent: petroleum ether/ethyl acetate (25:1). Yield 39 mg (66%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26-7.20 (m, 4H), 7.19-7.15 (m, 4H), 4.24 (dd, *J* = 8.0 Hz, *J* = 5.0 Hz, 1H), 3.28 (dd, *J* = 13.3 Hz, *J* = 8.1 Hz, 1H), 3.22 (s, 3H), 3.08 (dd, *J* = 13.3 Hz, *J* = 5.1Hz, 1H), 2.35 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.1, 137.3, 135.3, 132.0, 130.7, 129.4, 129.1, 126.8, 82.3, 57.0, 41.9, 21.3. EI-MS: $[M]^+$ m/z 292.3, 294.3.



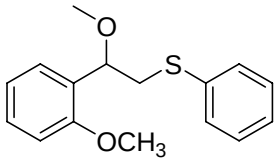
4p

(2-Chlorophenyl)(2-methoxy-2-*p*-tolylethyl)sulfane (4p). Eluent: petroleum ether/ethyl acetate (25:1). Yield 43 mg (73%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.29 (m, 2H), 7.25-7.17 (m, 5H), 7.13-7.08 (m, 1H), 4.33 (dd, *J* = 8.3 Hz, *J* = 4.7 Hz, 1H), 3.33 (dd, *J* = 13.0 Hz, *J* = 8.4 Hz, 1H), 3.26 (s, 3H), 3.12 (dd, *J* = 12.9 Hz, *J* = 4.7 Hz, 1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.1, 137.4, 136.2, 133.9, 129.8, 129.4, 129.1, 127.1, 126.8, 126.7, 82.3, 57.1, 40.6, 21.3. EI-MS: $[M]^+$ m/z 292.1, 294.1.



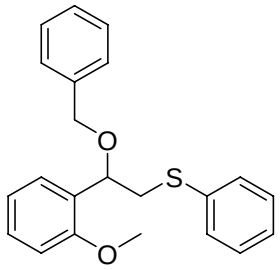
4q

(2-Methoxy-2-*p*-tolylethyl)(4-nitrophenyl)sulfane (4q). Eluent: petroleum ether/ethyl acetate (25:1). Yield 40 mg (65%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.7 Hz, 2H), 7.31 (d, *J* = 8.9 Hz, 2H), 7.24-7.17 (m, 4H), 4.35 (dd, *J* = 8.1 Hz, *J* = 4.8 Hz, 1H), 3.38 (dd, *J* = 13.1 Hz, *J* = 8.1 Hz, 1H), 3.24-3.19 (m, 4H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.8, 145.1, 138.5, 136.8, 129.6, 126.7, 126.5, 123.9, 82.1, 57.1, 40.0, 21.3. EI-MS: $[M]^+$ m/z 303.1.



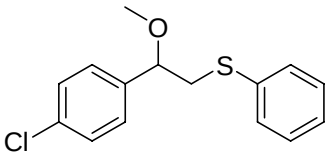
4r

(2-Methoxy-2-(2-methoxyphenyl)ethyl)(phenyl)sulfane (4r). Eluent: petroleum ether/ethyl acetate (25:1). Yield 43 mg (79%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ7.44-7.40 (m, 3H), 7.27 (t, *J* = 7.6 Hz, 3H), 7.16 (t, *J* = 7.4 Hz, 1H), 7.00 (t, *J* = 7.4 Hz, 1H), 6.87 (d, *J* = 8.2 Hz, 1H), 4.80 (dd, *J* = 9.0 Hz, *J* =3.3 Hz, 1H), 3.81 (s, 3H), 3.32 (s, 3H), 3.29-3.28 (m, 1H), 3.11 (dd, *J* = 13.4 Hz, *J* = 9.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.3, 129.0, 128.9, 128.8, 128.7, 126.5, 125.7, 120.9, 110.4, 76.7, 57.6, 55.3, 40.4. EI-MS: $[M]^+$ m/z 274.1.



4s

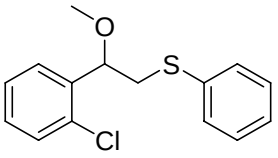
(2-(Benzyloxy)-2-(2-methoxyphenyl)ethyl)(phenyl)sulfane (4s). Eluent: petroleum ether/ethyl acetate (25:1). Yield 46 mg (66%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (dd, *J* = 17.6 Hz, *J* = 1.6 Hz, 1H), 7.45-7.26 (m, 10H), 7.20-7.15 (m, 1H), 7.05 (t, *J* = 7.4 Hz, 1H), 6.91 (d, *J* = 8.2 Hz, 1H), 5.08 (dd, *J* = 8.7 Hz, *J* = 3.5 Hz, 1H), 4.57 (d, *J* = 11.6 Hz, 1H), 4.42 (d, *J* = 11.6 Hz, 1H), 3.82 (s, 3H), 3.35 (dd, *J* = 13.6 Hz, *J* = 3.6 Hz, 1H), 3.23 (dd, *J* = 13.7 Hz, *J* = 8.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.0, 138.5, 137.5, 129.1, 129.0, 128.9, 128.8, 128.4, 127.9, 127.6, 126.8, 125.7, 121.0, 74.8, 71.6, 40.4. EI-MS: $[M]^+$ m/z 350.2.



4t

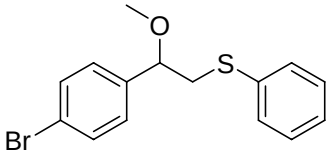
(2-(4-Chlorophenyl)-2-methoxyethyl)(phenyl)sulfane (4t). Eluent: petroleum ether/ethyl acetate (25:1). Yield 44 mg (80%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34-7.31 (m, 4H), 7.28-7.23 (m, 4H), 7.20-7.16 (m, 1H), 4.26 (dd, *J* = 7.6 Hz, *J* = 5.5 Hz, 1H), 3.30 (dd, *J* = 13.3 Hz, *J* = 7.5 Hz, 1H), 3.23 (s, 3H), 3.08 (dd, *J* =

13.3 Hz, J = 5.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.1, 136.3, 134.0, 129.6, 129.0, 128.8, 128.3, 126.3, 82.0, 57.2, 41.5. EI-MS: $[M]^+$ m/z 278.3, 280.1.



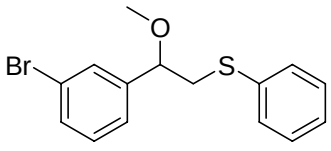
4u

(2-(2-Chlorophenyl)-2-methoxyethyl)(phenyl)sulfane (4u). Eluent: petroleum ether/ethyl acetate (25:1). Yield 30 mg (55%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ7.52-7.51 (m, 1H), 7.42-7.40 (m, 2H), 7.34-7.16 (m, 6H), 4.82 (dd, J = 8.6 Hz, J = 3.5 Hz, 1H), 3.29 (s, 3H), 3.26-3.25 (m, 1H), 3.14 (dd, J = 13.5 Hz, J = 8.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.1, 136.4, 133.2, 130.0, 129.7, 129.2, 128.9, 127.6, 127.4, 126.3, 78.7, 57.6, 40.5. EI-MS: $[M]^+$ m/z 278.3.



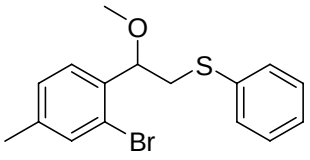
4v

(2-(4-Bromophenyl)-2-methoxyethyl)(phenyl)sulfane (4v). Eluent: petroleum ether/ethyl acetate (25:1). Yield 41 mg (64%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, J = 7.8 Hz, 2H), 7.32 (d, J = 8.1 Hz, 2H), 7.28-7.25 (m, 2H), 7.19-7.17 (m, 3H), 4.26-4.22 (m, 1H), 3.29 (dd, J = 13.3 Hz, J =7.5 Hz, 1H), 3.23 (s, 3H), 3.08 (dd, J = 13.5 Hz, J = 5.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.6, 136.3, 131.8, 129.6, 129.0, 128.6, 126.3, 122.1, 82.0, 57.2, 41.4. EI-MS: $[M]^+$ m/z 322.3, 324.3.



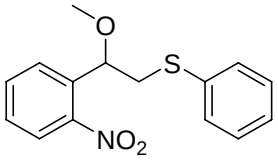
4w

(2-(3-Bromophenyl)-2-methoxyethyl)(phenyl)sulfane (4w). Eluent: petroleum ether/ethyl acetate (25:1). Yield 40 mg (60%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ7.45-7.41 (m, 2H), 7.34-7.33 (m, 2H), 7.29-7.25 (m, 2H), 7.22-7.18 (m, 3H), 4.25-4.22 (d, J = 7.8 Hz, J = 5.3 Hz, 1H), 3.28 (dd, J = 13.4 Hz, J =7.8 Hz, 1H), 3.25 (s, 3H), 3.18 (dd, J = 13.4 Hz, J = 5.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.1, 136.2, 131.3, 130.3, 129.9, 129.7, 129.1, 126.4, 125.5, 122.9, 82.0, 57.4, 41.5. EI-MS: $[M]^+$ m/z 322.0, 324.0.



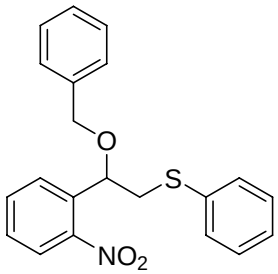
4x

(2-(3-Bromophenyl)-2-methoxyethyl)(phenyl)sulfane (4x). Eluent: petroleum ether/ethyl acetate (25:1). Yield 39 mg (59%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43-7.36 (m, 4H), 7.30-7.25 (m, 2H), 7.21-7.14 (m, 2H), 4.73 (dd, *J* = 8.6 Hz, *J* = 5.8 Hz, 1H), 3.28 (s, 3H), 3.26-3.22 (m, 1H), 3.11 (dd, *J* = 13.5 Hz, *J* = 8.8 Hz, 1H), 2.32 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.7, 136.5, 136.4, 133.3, 130.1, 128.9, 128.8, 127.5, 126.3, 123.1, 80.8, 57.4, 40.7, 20.9. EI-MS: $[M]^+$ m/z 336.2, 338.2.



4y

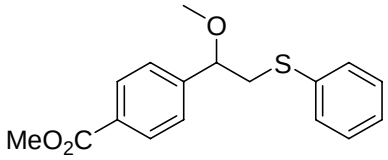
(2-Methoxy-2-(2-nitrophenyl)ethyl)(phenyl)sulfane (4y). Eluent: petroleum ether/ethyl acetate (25:1). Yield 23 mg (40%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 8.2 Hz, *J* = 1.1 Hz, 1H), 7.79 (dd, *J* = 7.8 Hz, *J* = 1.3 Hz, 1H), 7.65(dt, *J* = 7.6 Hz, *J* = 1.1 Hz, 1H), 7.46-7.38 (m, 3H), 7.29-7.24 (m, 2H), 7.20-7.15 (m, 1H), 4.98 (dd, *J* = 8.0 Hz, *J* = 3.9 Hz, 1H), 3.40 (dd, *J* = 13.5 Hz, *J* = 3.8 Hz, 1H), 3.28-3.21 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9, 136.5, 136.0, 133.7, 130.2, 129.0, 128.8, 128.5, 126.5, 124.6, 78.0, 57.8, 41.5. EI-MS: $[M]^+$ m/z 289.3.



4z

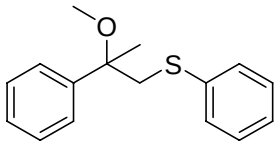
(2-(Benzyloxy)-2-(2-nitrophenyl)ethyl)(phenyl)sulfane (4z). Eluent: petroleum ether/ethyl acetate (25:1). Yield 27 mg (37%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 8.2 Hz, *J* = 1.2 Hz, 1H), 7.87 (dd, *J* = 7.8 Hz, *J* = 1.0 Hz, 1H), 7.65 (t, *J* = 7.6 Hz, 1H), 7.47-7.42 (m, 1H), 7.39-7.35 (m, 2H), 6.22 (dd, *J* = 7.7 Hz, *J* = 4.1 Hz, 1H), 6.41 (dd, *J* = 21.4 Hz, *J* = 11.5 Hz, 1H), 3.42 (dd, *J* = 13.7 Hz, *J* = 4.2

Hz, 1H), 3.33 (dd, J = 13.6 Hz, J = 7.7 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9, 137.4, 136.7, 136.2, 133.7, 130.1, 128.9, 128.8, 128.5, 127.9, 126.4, 124.6, 75.8, 72.0, 41.6. EI-MS: $[M]^+$ m/z 365.2.



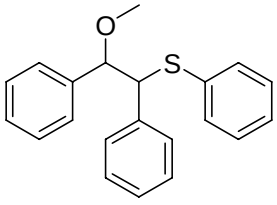
4aa

Methyl 4-(1-methoxy-2-(phenylthio)ethyl)benzoate (4aa). Eluent: petroleum ether/ethyl acetate (5:1). Yield 32 mg (53%). Colorless film. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.03 (d, J = 8.3 Hz, 2H), 7.39-7.33 (m, 4H), 7.29-7.24 (m, 2H), 7.21-7.17 (m, 1H), 4.33 (dd, J = 7.7 Hz, J = 5.3 Hz, 1H), 3.92 (s, 3H), 3.31 (dd, J = 13.3 Hz, J = 7.7 Hz, 1H), 3.25 (s, 3H), 3.11 (dd, J = 13.3 Hz, J = 5.3 Hz, 1H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 166.9, 145.8, 136.2, 130.1, 129.9, 129.7, 129.1, 126.9, 126.4, 82.2, 57.4, 52.2, 41.4. EI-MS: $[M]^+$ m/z 302.2.



4ab

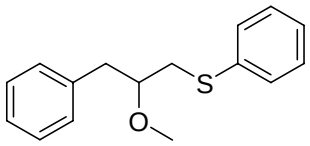
(2-Methoxy-2-phenylpropyl)(phenyl)sulfane (4ab). Eluent: petroleum ether/ethyl acetate (25:1). Yield 35 mg (70%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (d, J = 7.5 Hz, 2H), 7.37-7.33 (m, 2H), 7.28-7.27 (m, 3H), 7.23-7.19 (m, 2H), 7.12 (d, J = 7.2 Hz, 1H), 3.40 (d, J = 12.5 Hz, 1H), 3.28 (d, J = 12.5 Hz, 1H), 1.71 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.6, 137.6, 129.4, 128.8, 128.4, 127.6, 126.4, 125.9, 79.1, 76.8, 51.0, 47.6, 22.5. EI-MS: $[M]^+$ m/z 258.3.



4ac

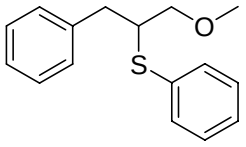
(2-Methoxy-1,2-diphenylethyl)(phenyl)sulfane (4ac). Eluenrt: petroleum ether/ethyl acetate (25:1). Yield 28 mg (44%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25-7.23 (m, 3H), 7.20-7.19 (m, 7H), 7.14-7.12 (m, 3H), 7.10-7.09 (m, 2H), 4.62 (d, J = 5.7 Hz, 1H), 4.37 (d, J = 5.9 Hz, 1H), 3.23 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ

139.0, 138.8, 131.9, 129.4, 128.7, 128.1, 128.0, 127.8, 127.6, 127.2, 126.9, 86.2, 60.3, 57.5. EI-MS: $[M]^+$ m/z 320.4.



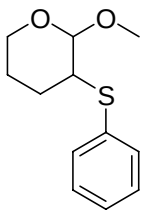
4ad

(2-Methoxy-3-phenylpropyl)(phenyl)sulfane (4ad). Eluenrt: petroleum ether/ethyl acetate (25:1). Yield 20 mg (40%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.17 (m, 10H), 3.61-3.54 (m, 1H), 3.25 (s, 3H), 3.02 (dd, *J* = 5.6 Hz, *J* = 4.0 Hz, 2H), 2.94 (d, *J* = 6.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.2, 136.7, 129.6, 129.3, 129.0, 128.5, 126.5, 126.1, 81.3, 57.6, 39.6, 37.2. EI-MS: $[M]^+$ m/z 258.1.



4ad'

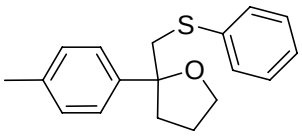
(3-Methoxy-1-phenylpropan-2-yl)(phenyl)sulfane (4ad'). Eluenrt: petroleum ether/ethyl acetate (25:1). Yield 13 mg (25%). Colorless film. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39-7.37 (m, 2H), 7.31-7.20 (m, 8H), 3.48-3.40 (m, 3H), 3.34 (s, 3H), 3.07 (dd, *J* = 13.8 Hz, *J* = 6.7 Hz, 1H), 2.87 (dd, *J* = 13.9 Hz, *J* = 6.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.9, 134.9, 132.1, 129.5, 129.0, 128.4, 127.1, 126.5, 73.5, 59.0, 49.9, 37.9. EI-MS: $[M]^+$ m/z 258.3.



4ae

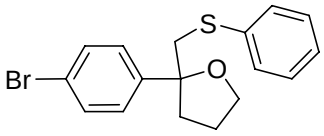
Tetrahydro-2-methoxy-3-(phenylthio)-2*H*-pyran (4ae). Eluent: petroleum ether/ethyl acetate (25:1). Yield 18 mg (41%). Colorless film. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.47-7.41 (m, 3.2H) (a pair of diastereoisomers was obsvered, ratio = 1.7: 1), 7.30-7.28 (m, 2H), 7.24-7.20 (m, 2.8H), 4.70 (d, *J* = 3.1 Hz, 0.6H), 4.43 (d, *J* = 4.4 Hz, 1H), 3.92-3.84 (m, 1H), 3.81-3.73 (m, 0.7H), 3.58-3.51 (m, 1.7H), 3.42 (s, 1.8H), 3.41 (s, 3H), 3.31-3.25 (m, 0.6H), 3.23-3.18 (m, 1H), 2.23-2.13 (m, 1H), 1.99-1.83 (m, 2.3H), 1.73-1.64 (m, 2.3H), 1.54-1.49 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 134.9,

134.8, 131.9, 131.8, 129.0, 128.9, 127.0, 102.3, 99.2, 62.4, 59.1, 55.6, 55.3, 48.9, 47.7, 26.4, 26.1, 25.9, 23.1. EI-MS: $[M]^+$ m/z 224.3.



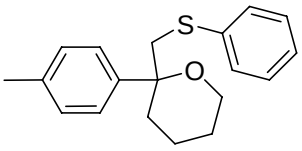
4af

Tetrahydro-2-((phenylthio)methyl)-2-p-tolylfuran (4af). Eluenrt: petroleum ether/ethyl acetate (25:1). Yield 43 mg (80%). Colorless film. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.32 (d, *J* = 8.1 Hz, 2H), 7.28 (dd, *J* = 8.3 Hz, *J* = 0.9 Hz, 2H), 7.20 (t, *J* = 7.8 Hz, 2H), 7.14-7.10 (m, 3H), 4.04-4.01 (m, 1H), 3.92-3.88 (m, 1H), 3.43 (d, *J* = 12.8 Hz, 1H), 3.32 (d, *J* = 12.8 Hz, 1H), 2.39-2.34 (m, 1H), 2.33 (s, 3H), 2.24-2.20 (m, 1H), 2.04-1.98 (m, 1H), 1.85-1.78 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 142.7, 137.8, 136.7, 129.1, 129.0, 128.8, 125.7, 125.4, 86.1, 68.3, 46.7, 37.0, 26.0, 12.1. EI-MS: $[M]^+$ m/z 284.3.



4ag

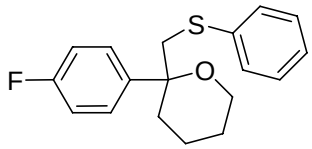
2-(4-Bromophenyl)-tetrahydro-2-((phenylthio)methyl)furan (4ag). Eluenrt: petroleum ether/ethyl acetate (25:1). Yield 51 mg (74%). Colorless film. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42 (d, *J* = 8.5 Hz, 2H), 7.31-7.11 (m, 7H), 4.07-4.00 (m, 1H), 3.93-3.86 (m, 1H), 3.39 (d, *J* = 12.9 Hz, 1H), 3.30 (d, *J* = 12.9 Hz, 1H), 2.41-2.34 (m, 1H), 2.23-2.14 (m, 1H), 2.10-1.98 (m, 1H), 1.88-1.76 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.7, 137.4, 131.3, 129.5, 128.8, 127.4, 125.9, 121.1, 86.0, 68.4, 46.6, 37.2, 26.0. EI-MS: $[M]^+$ m/z 348.3.



4ah

Tetrahydro-2-((phenylthio)methyl)-2-p-tolyl-2H-pyran (4ah). Eluenrt: petroleum ether/ethyl acetate (25:1). Yield 49 mg (83%). Colorless film. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.34 (d, *J* = 8.2 Hz, 2H), 7.23-7.06 (m, 7H), 3.79-3.74 (m, 1H), 3.52 (dt, *J* = 11.3 Hz, *J* = 2.6 Hz, 1H), 3.25 (d, *J* = 12.5 Hz, 1H), 3.17 (d, *J* = 12.5 Hz, 1H), 2.35 (s, 3H), 2.00 (dt, *J* = 12.4 Hz, *J* = 2.7 Hz, 1H), 1.73-1.37 (m, 5H). ^{13}C NMR (75 MHz,

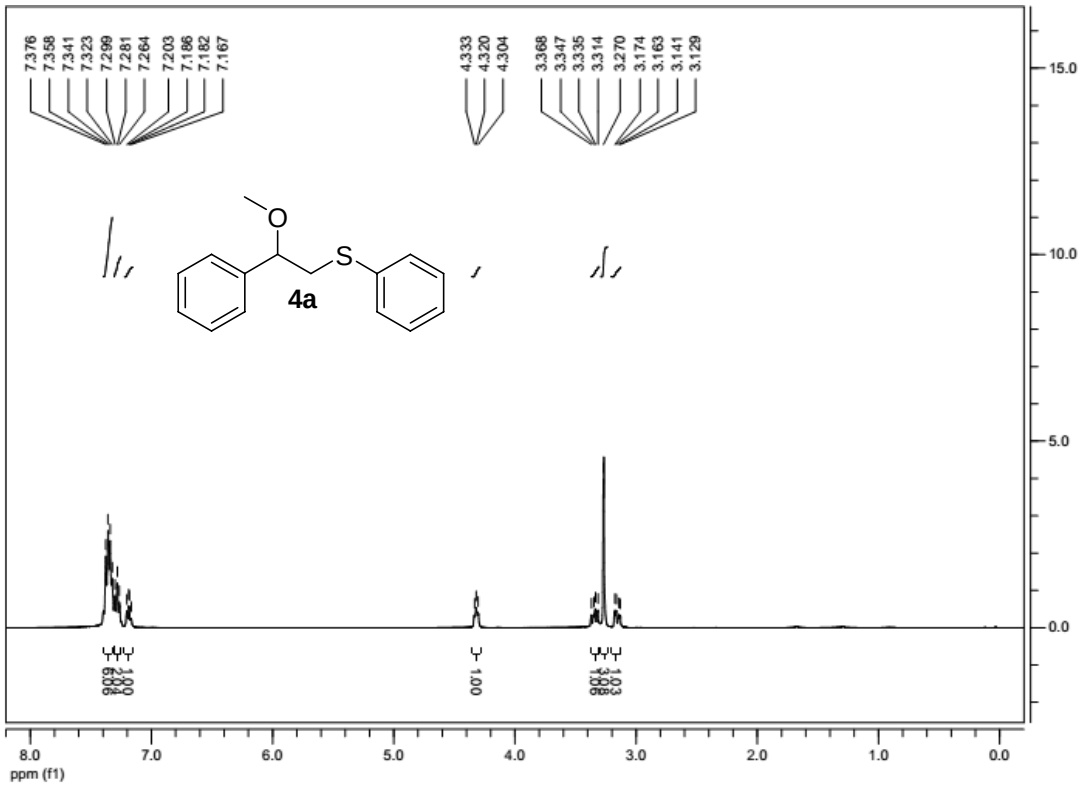
$CDCl_3$) δ 138.9, 137.8, 136.9, 129.3, 129.1, 128.7, 126.9, 125.6, 78.2, 63.0, 49.1, 31.7, 25.9, 21.1, 19.9. EI-MS: $[M]^+$ m/z 298.2.

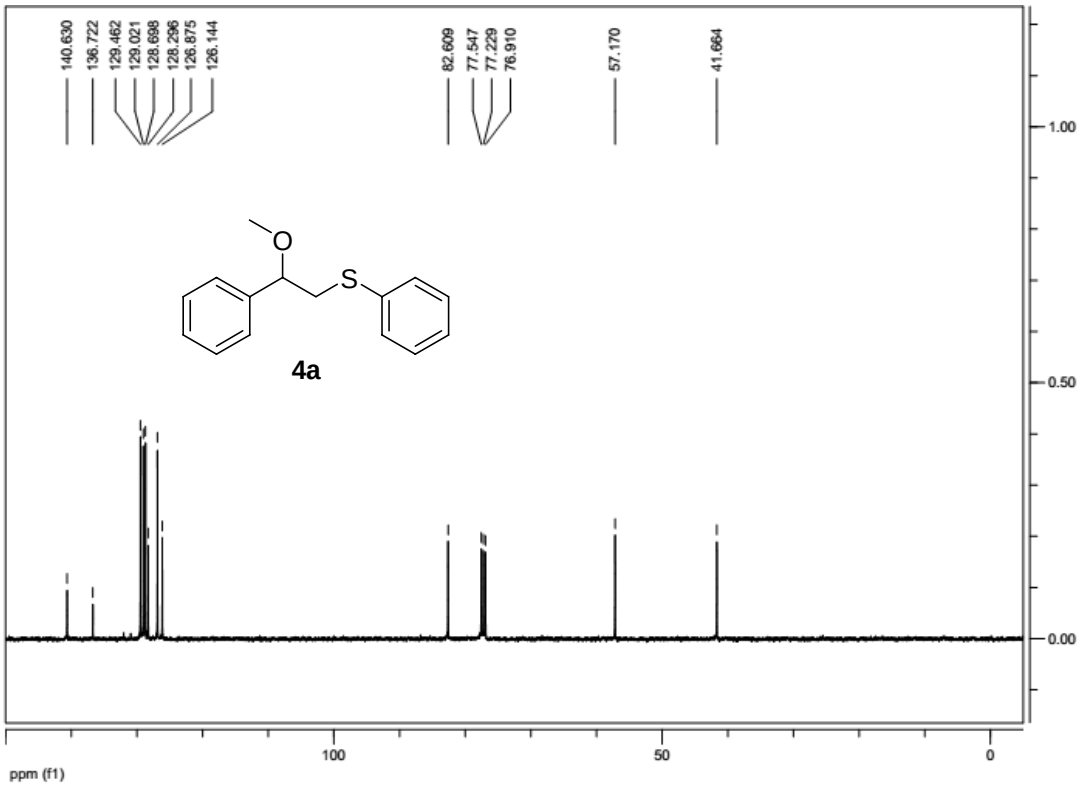


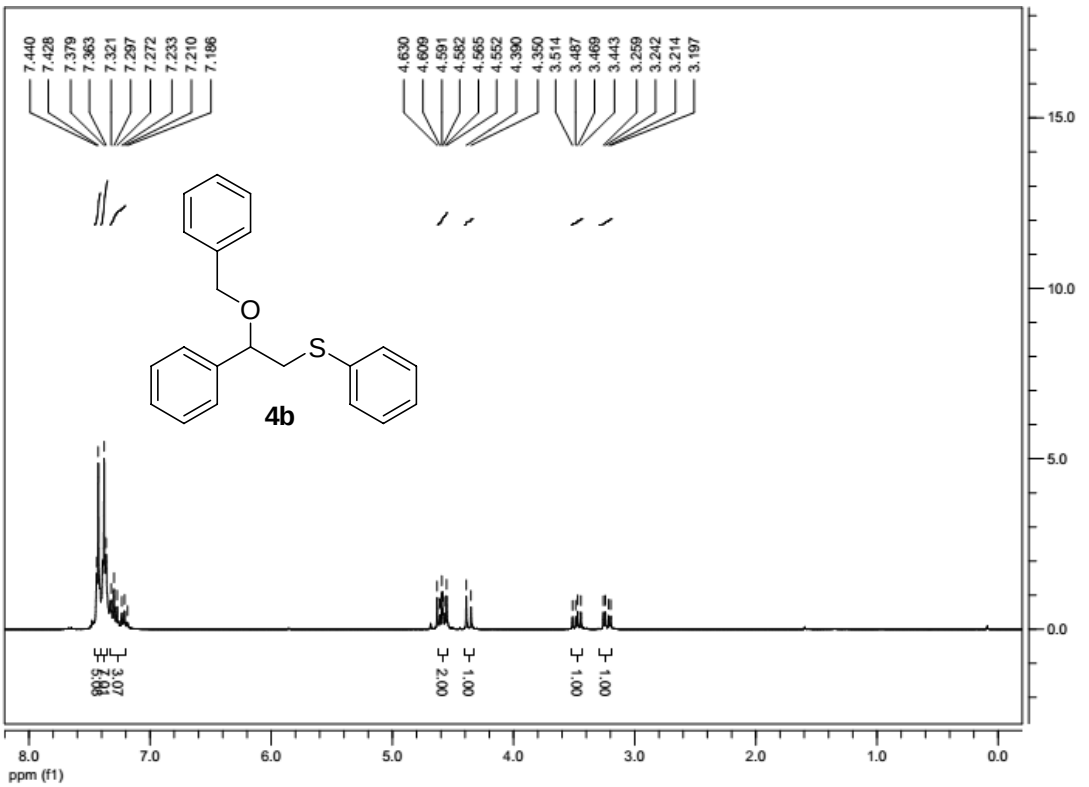
4ai

2-(4-Fluorophenyl)-tetrahydro-2-((phenylthio)methyl)-2H-pyran (4ai). Eluenrt: petroleum ether/ethyl acetate (25:1). Yield 40 mg (66%). Colorless film. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.43-7.38 (m, 2H), 7.19-6.99 (m, 7H), 3.79-3.74 (m, 1H), 3.48 (dt, *J* = 11.4 Hz, *J* = 2.7 Hz, 1H), 3.24 (d, *J* = 12.7 Hz, 1H), 3.19 (d, *J* = 12.7 Hz, 1H), 2.36 (dt, *J* = 13.8 Hz, *J* = 3.2 Hz, 1H), 1.97 (dt, *J* = 12.9 Hz, *J* = 3.7 Hz, 1H), 1.74-1.59 (m, 2H), 1.53-1.40 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 162.1 (d, *J* = 245.7 Hz), 137.5 (d, *J* = 3.1 Hz), 137.4, 129.3, 128.8 (d, *J* = 8.0 Hz), 128.7, 125.8, 115.3 (d, *J* = 21.1 Hz), 77.9, 63.0, 48.9, 32.0, 25.8, 19.8. EI-MS: $[M]^+$ m/z 302.2.

^{1}H and ^{13}C NMR spectra of compounds **4a-4ai**



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4.565
4.552
4.390
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3.514
3.487
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3.443
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S
4b
3.07
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1.00
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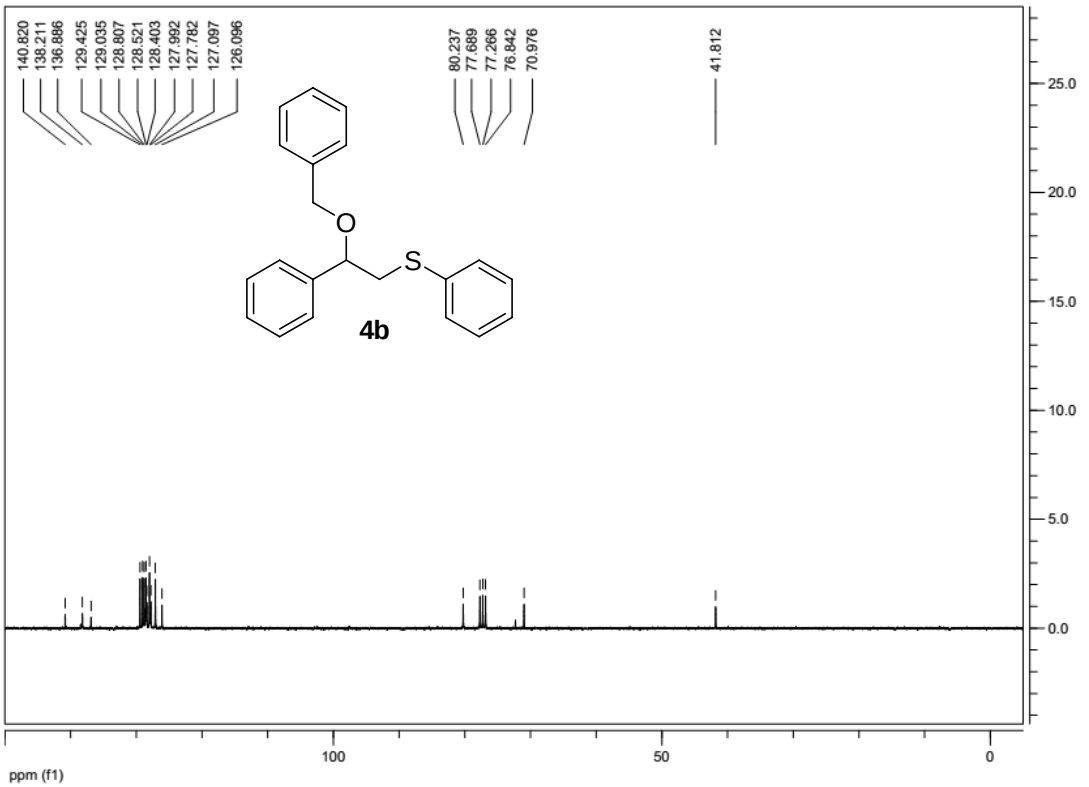
1.00
ppm (f1)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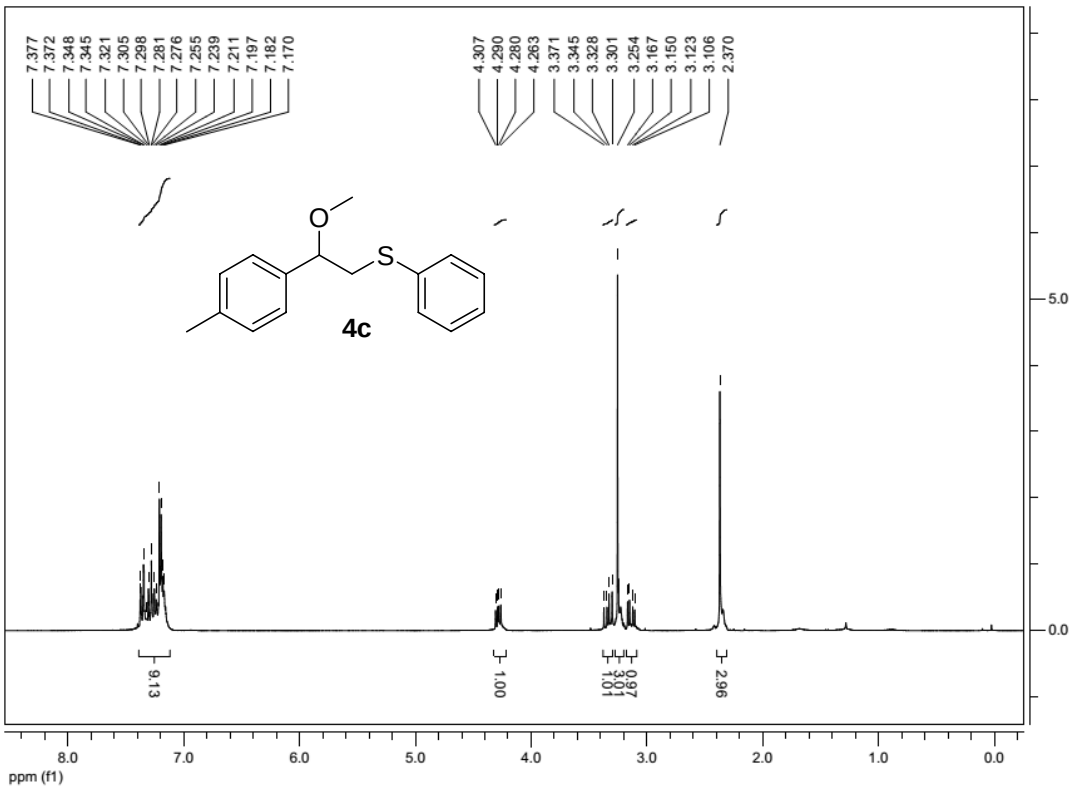
S
4b
ppm (f1)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7.170
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4.290
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3.371
3.345
3.328
3.301
3.254
3.167
3.150
3.123
3.106
2.370
O
S
4c
6.13
1.00
3.01
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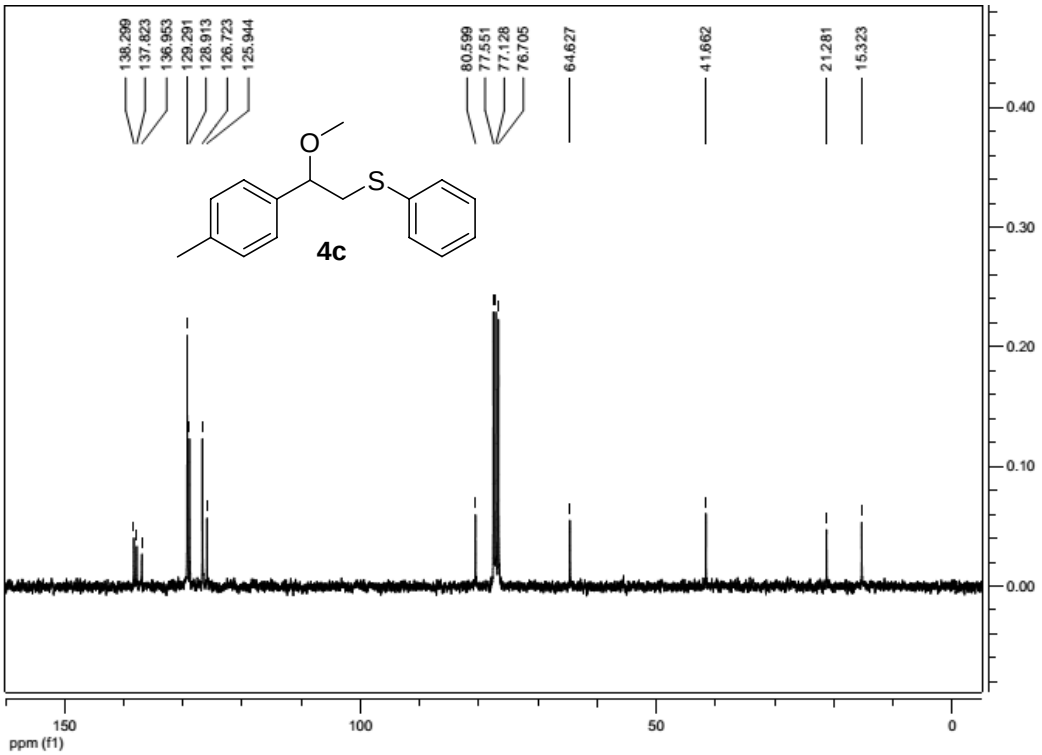
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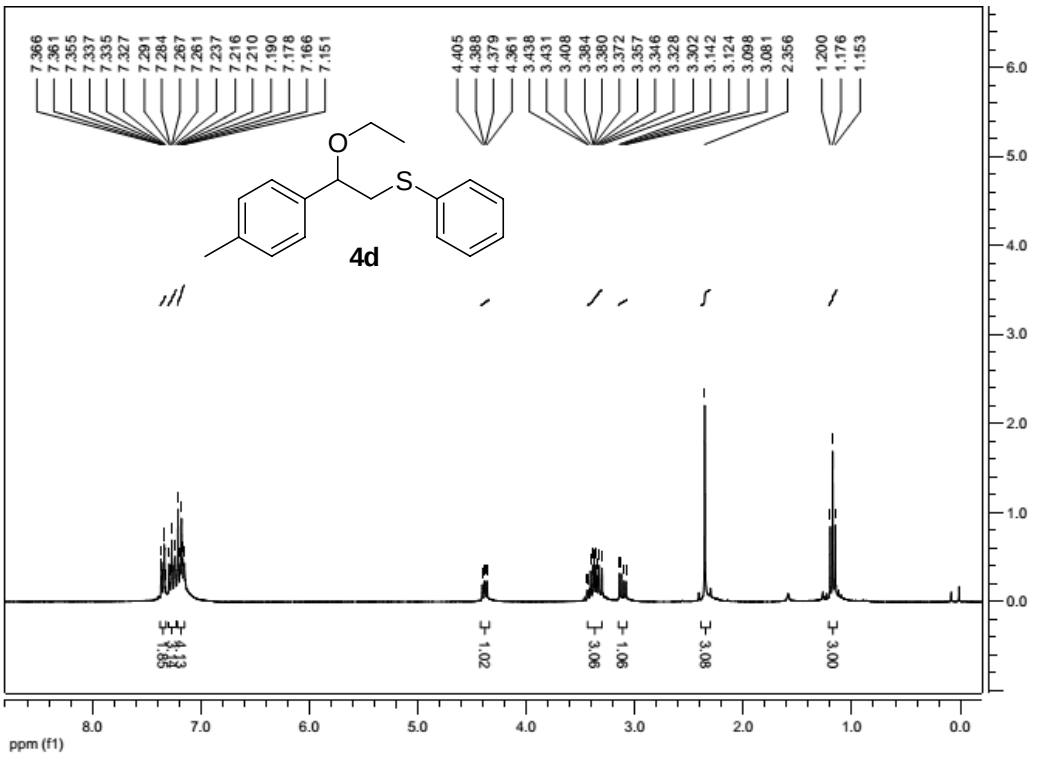
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7.210
7.190
7.178
7.166
7.151
4.405
4.388
4.379
4.361
3.438
3.431
3.408
3.384
3.380
3.372
3.357
3.346
3.328
3.302
3.142
3.124
3.098
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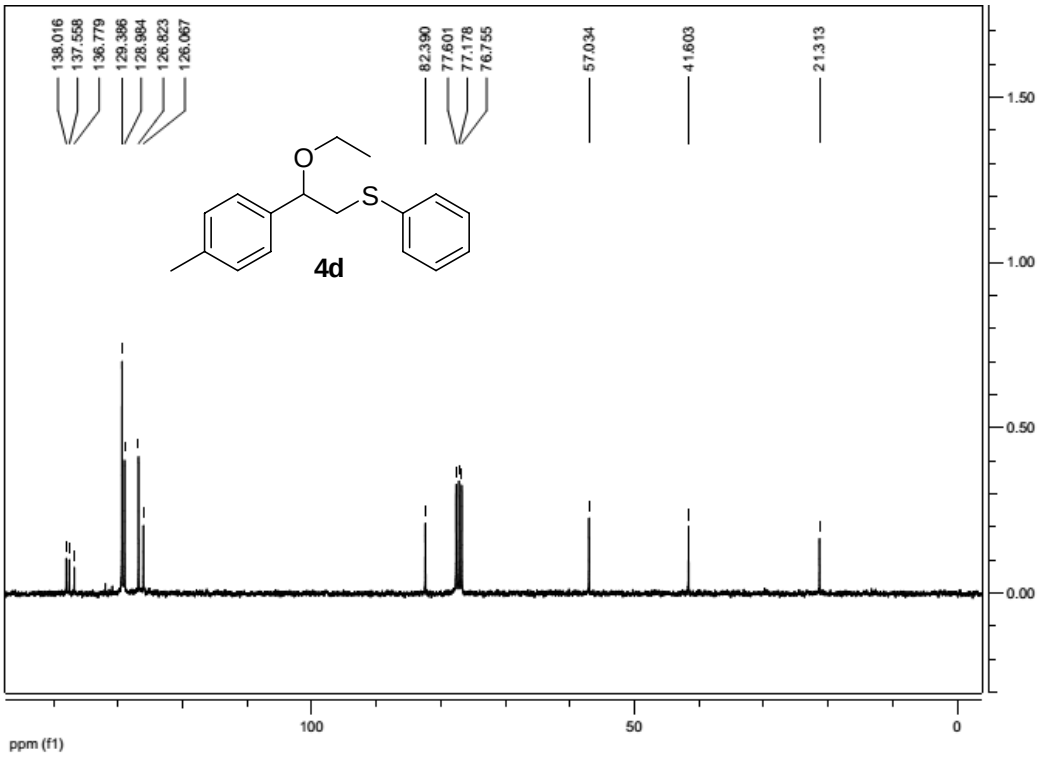
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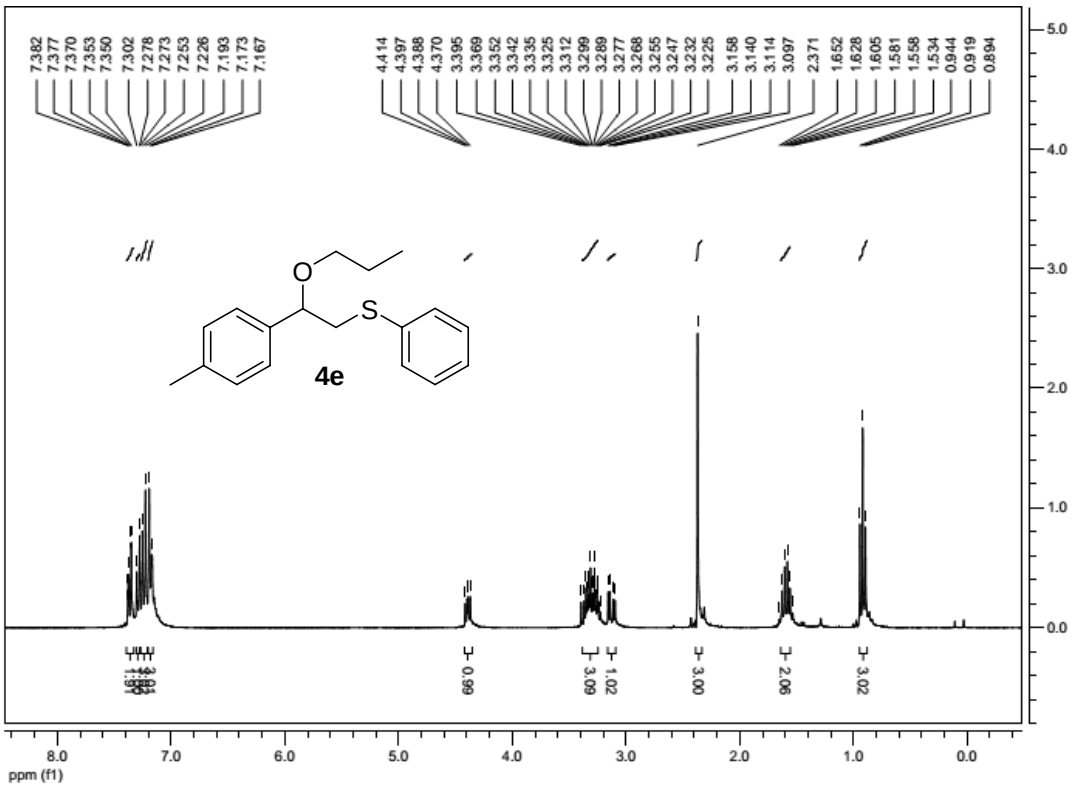
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7.167
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4.397
4.388
4.370
3.395
3.369
3.352
3.342
3.335
3.325
3.312
3.299
3.289
3.277
3.268
3.255
3.247
3.232
3.225
3.158
3.140
3.114
3.097
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1.652
1.628
1.605
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1.558
1.534
0.944
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S
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3.00
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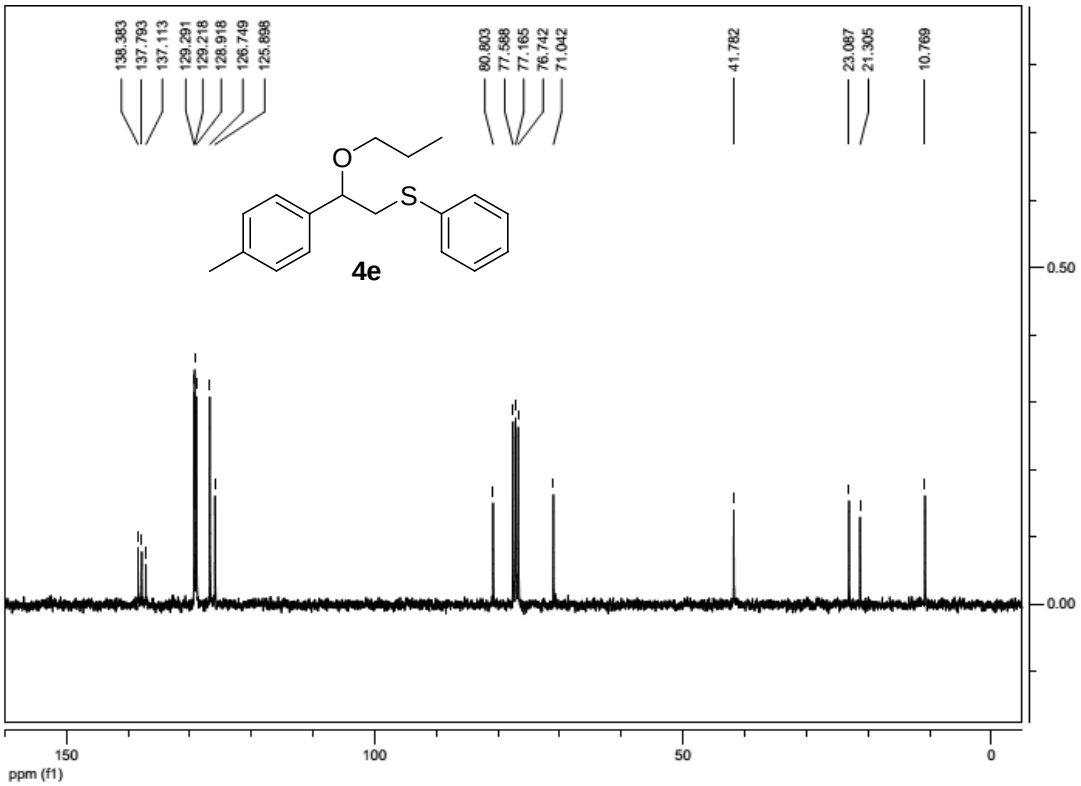
ppm (f1)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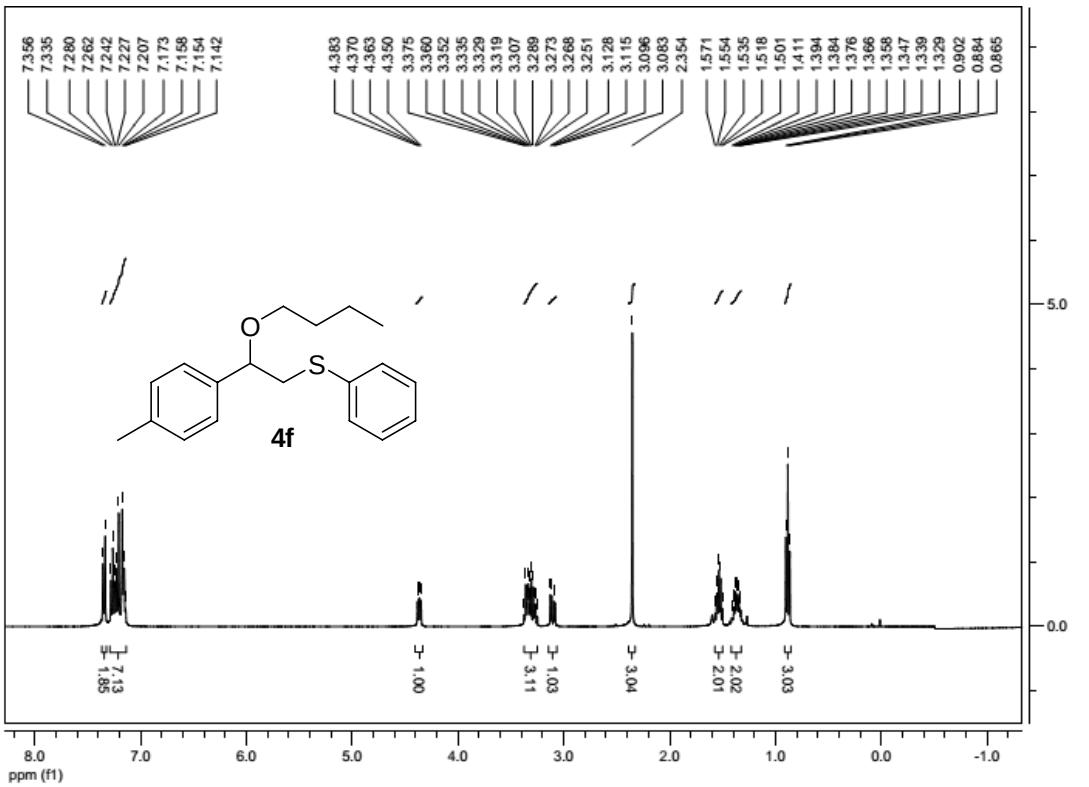
O
S
4e
ppm (f1)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2.01
2.02
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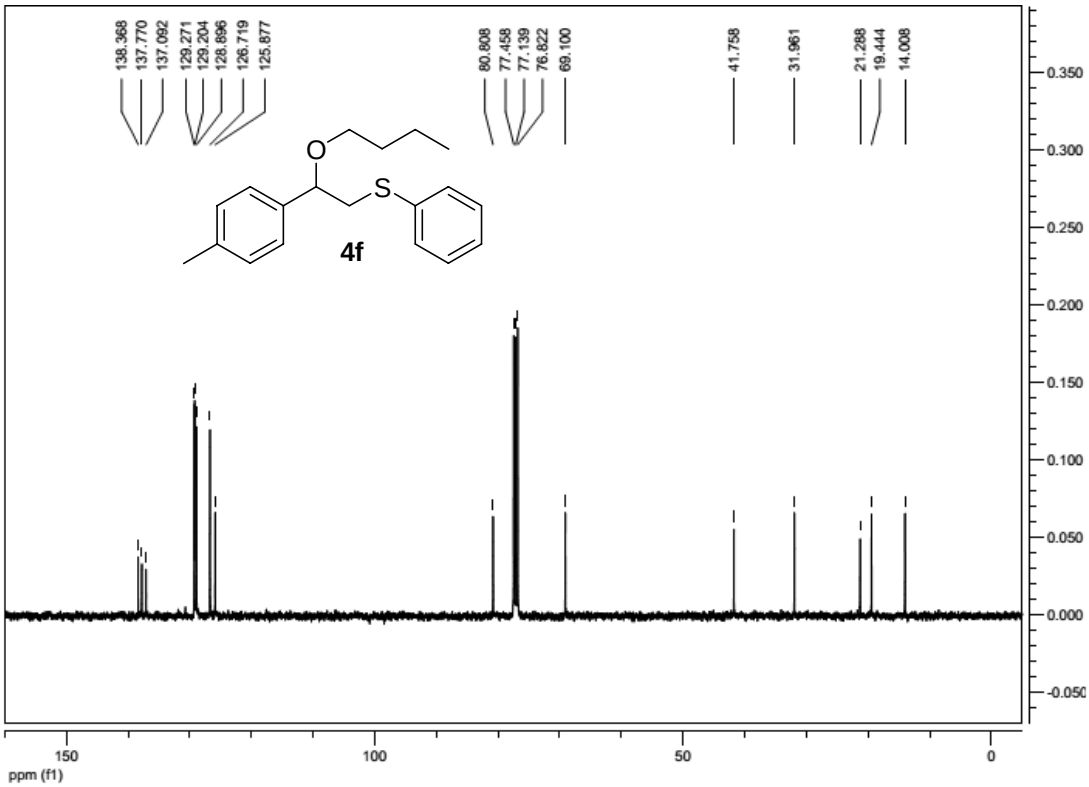
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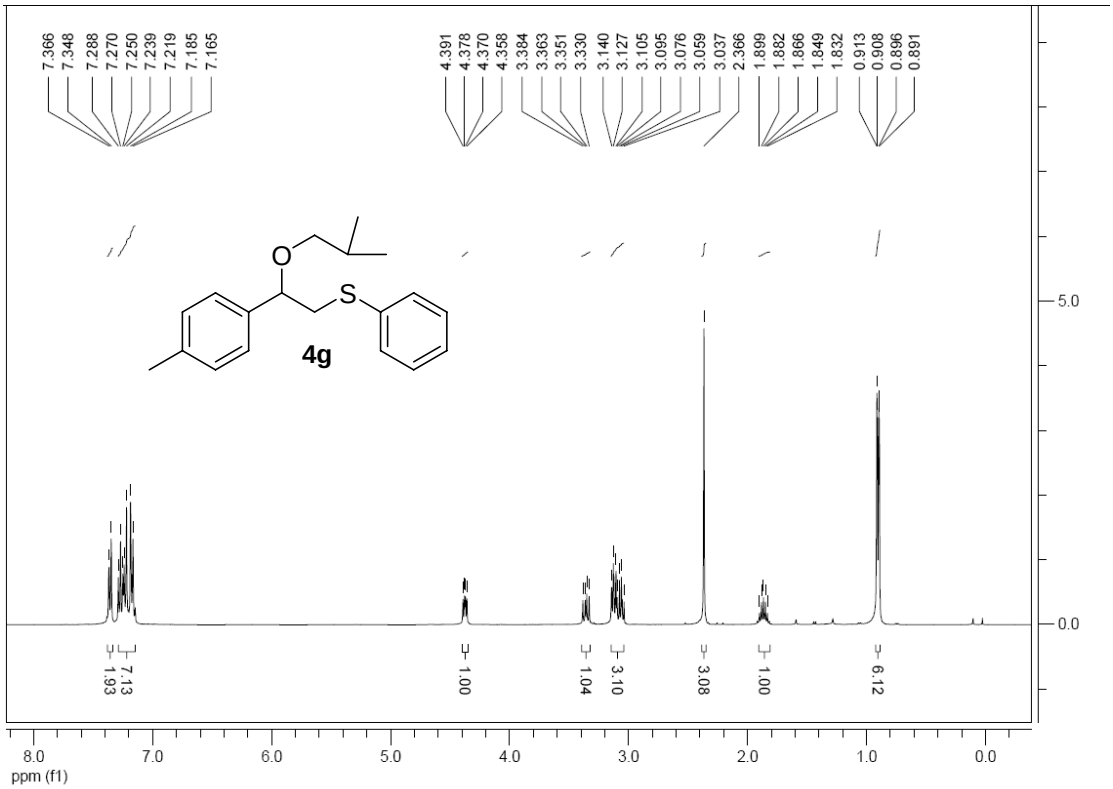
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3.08
1.00
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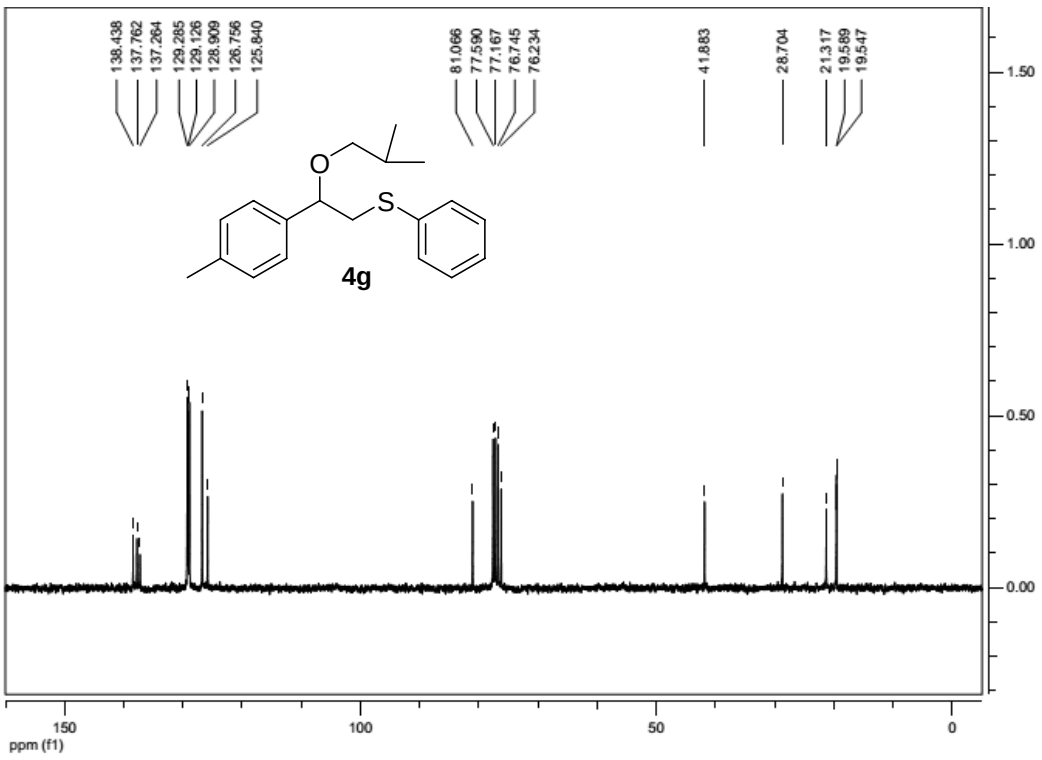
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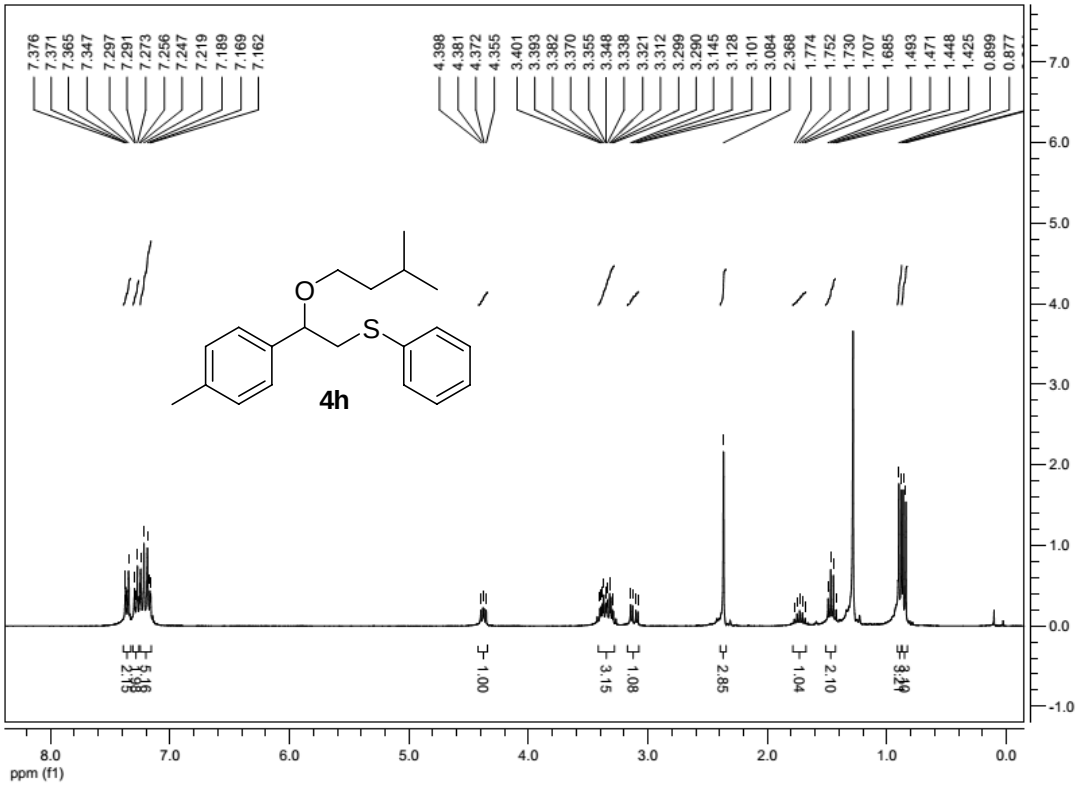
ppm (f1)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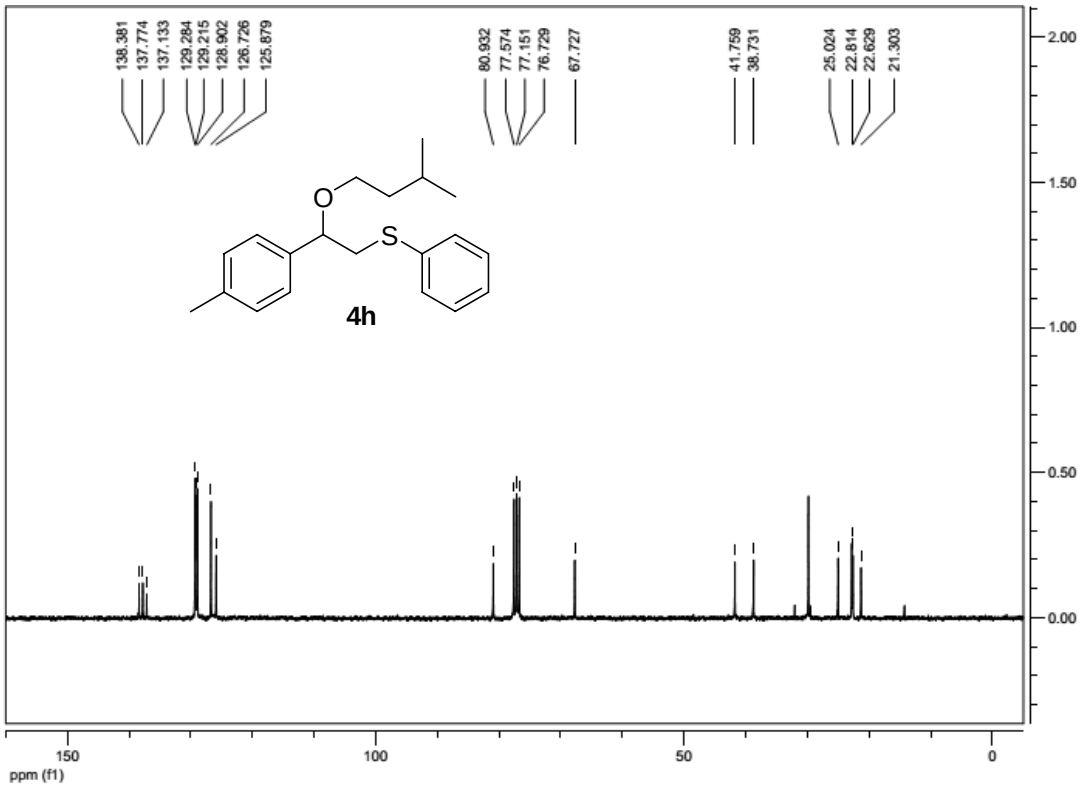
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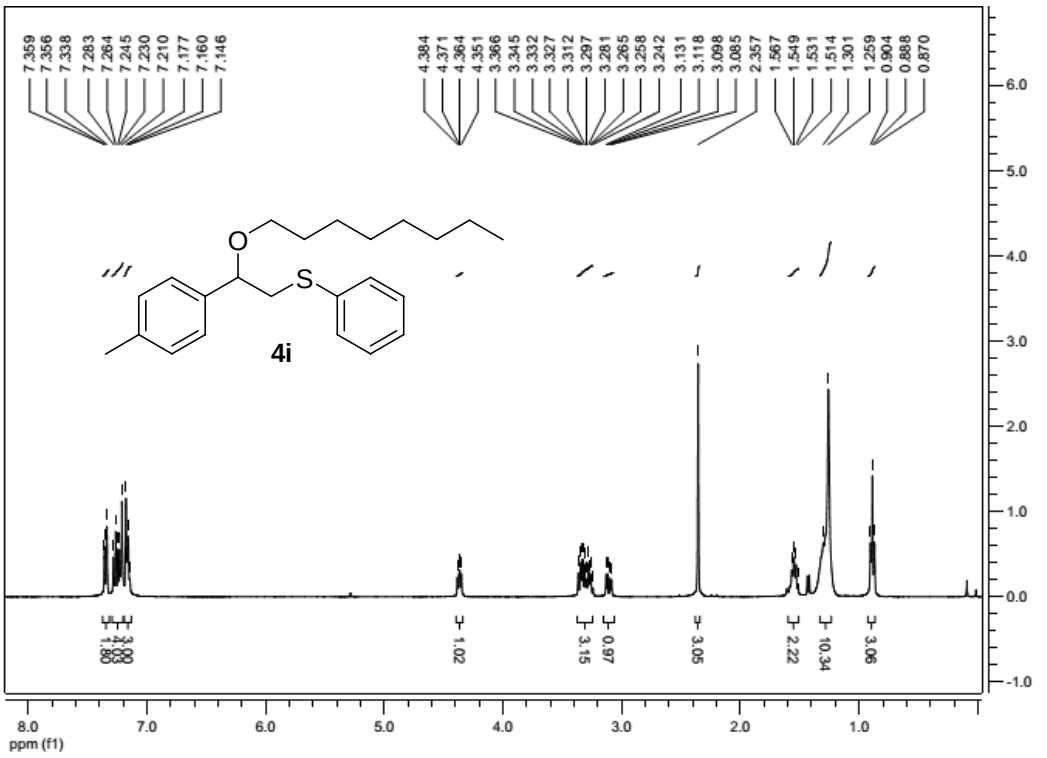
4h
ppm (f1)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3.131
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1.514
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0.870
O
S
4i
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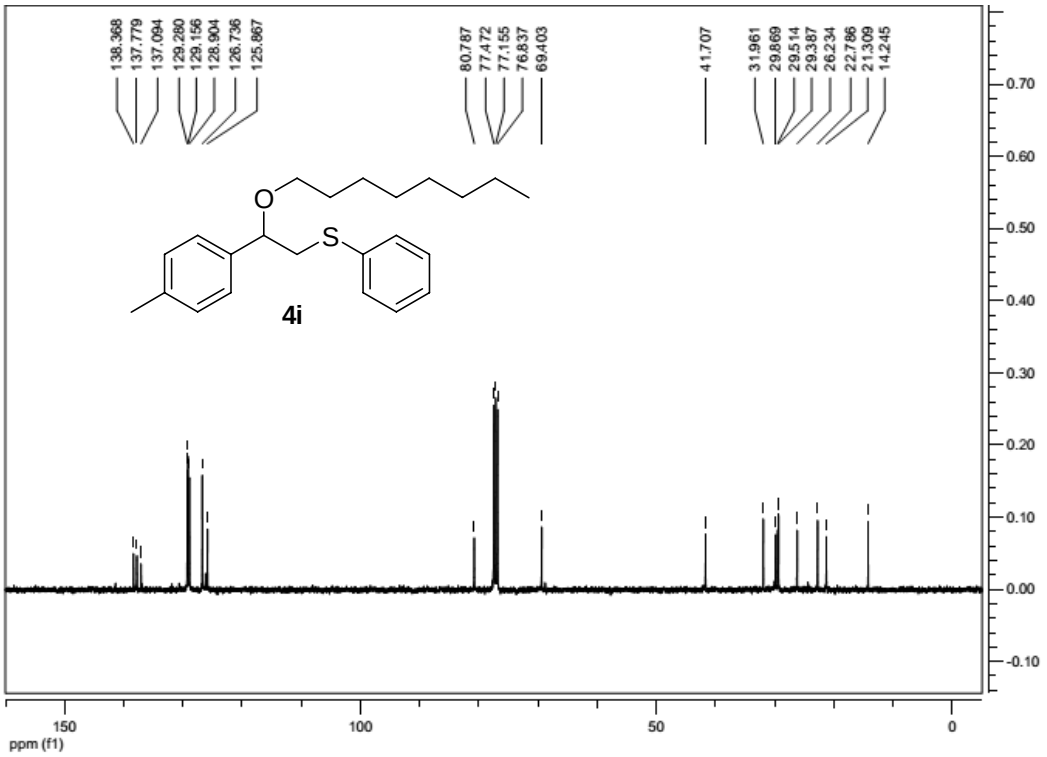
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41.707
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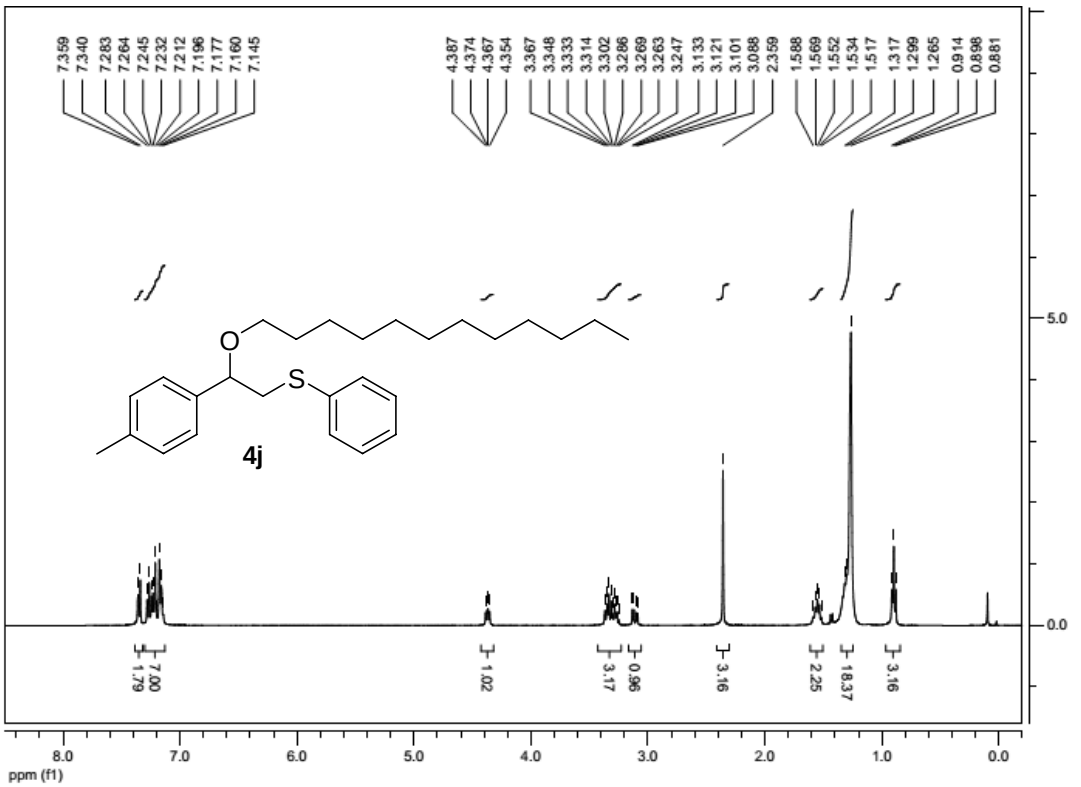
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1.299
1.265
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0.881
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S
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18.37
3.16
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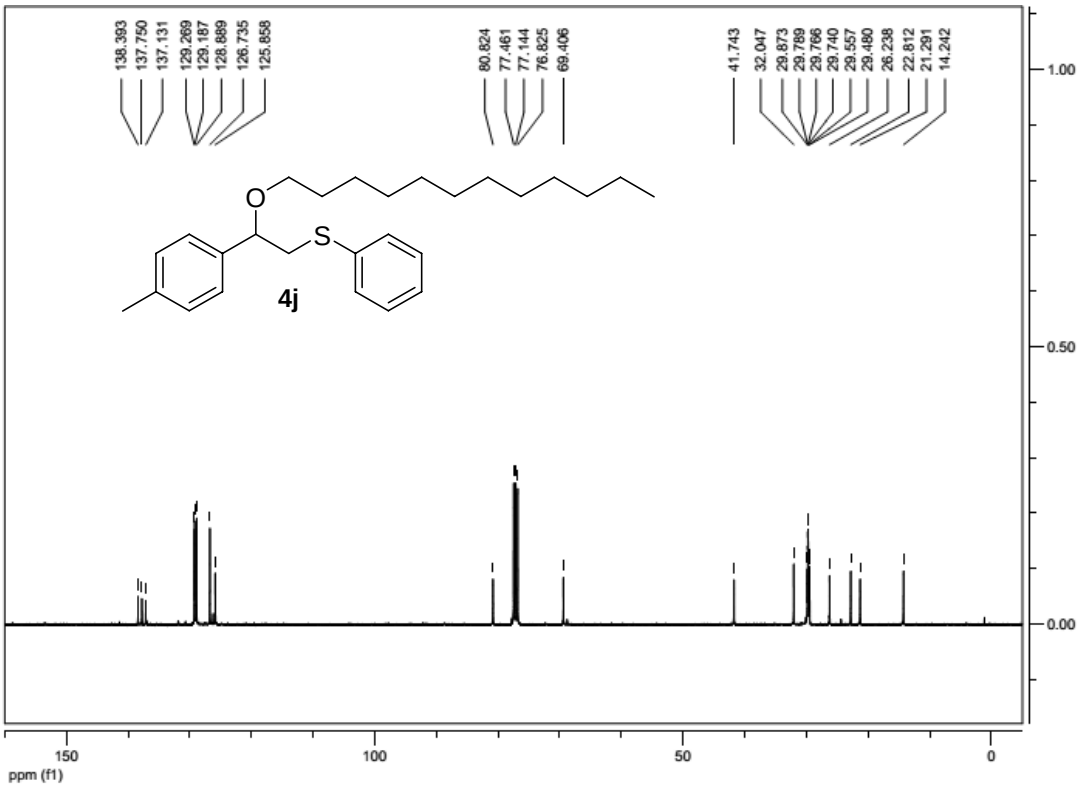
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0
ppm (f1)
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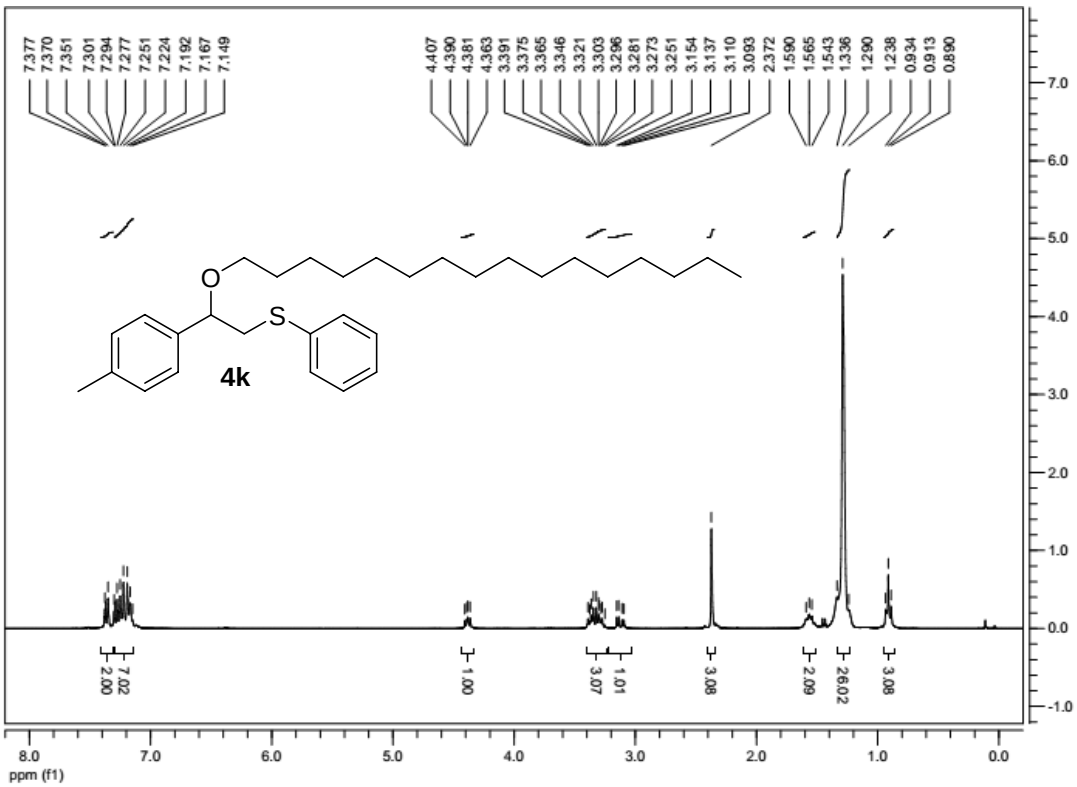
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1.543
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1.290
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0.934
0.913
0.890
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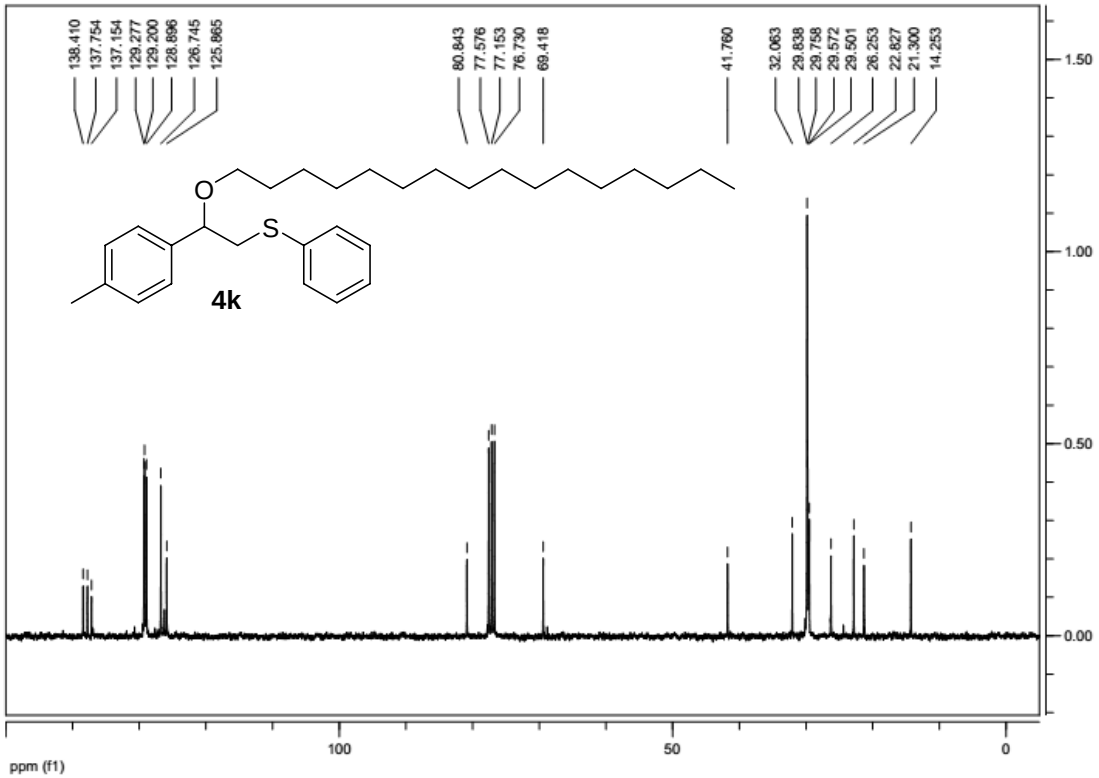
3.08
ppm (f1)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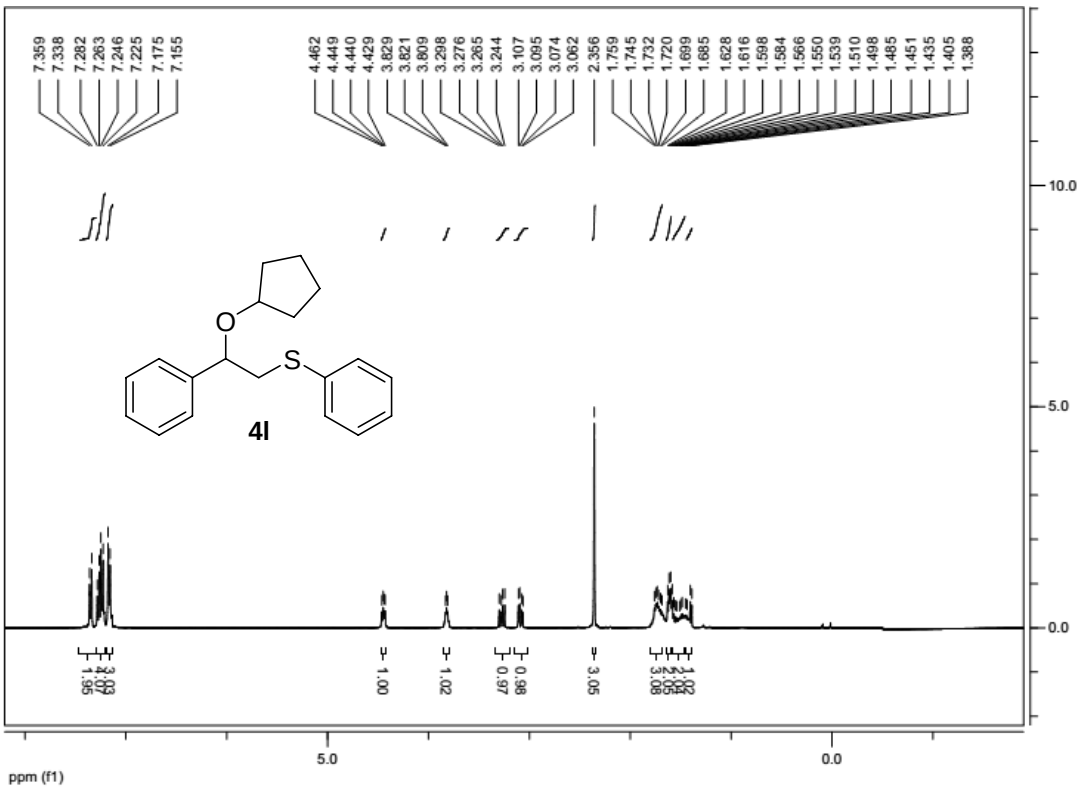
4k
ppm (f1)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1.566
1.550
1.539
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1.498
1.485
1.451
1.435
1.405
1.388
O
S
4l
10.0
5.0
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3.08
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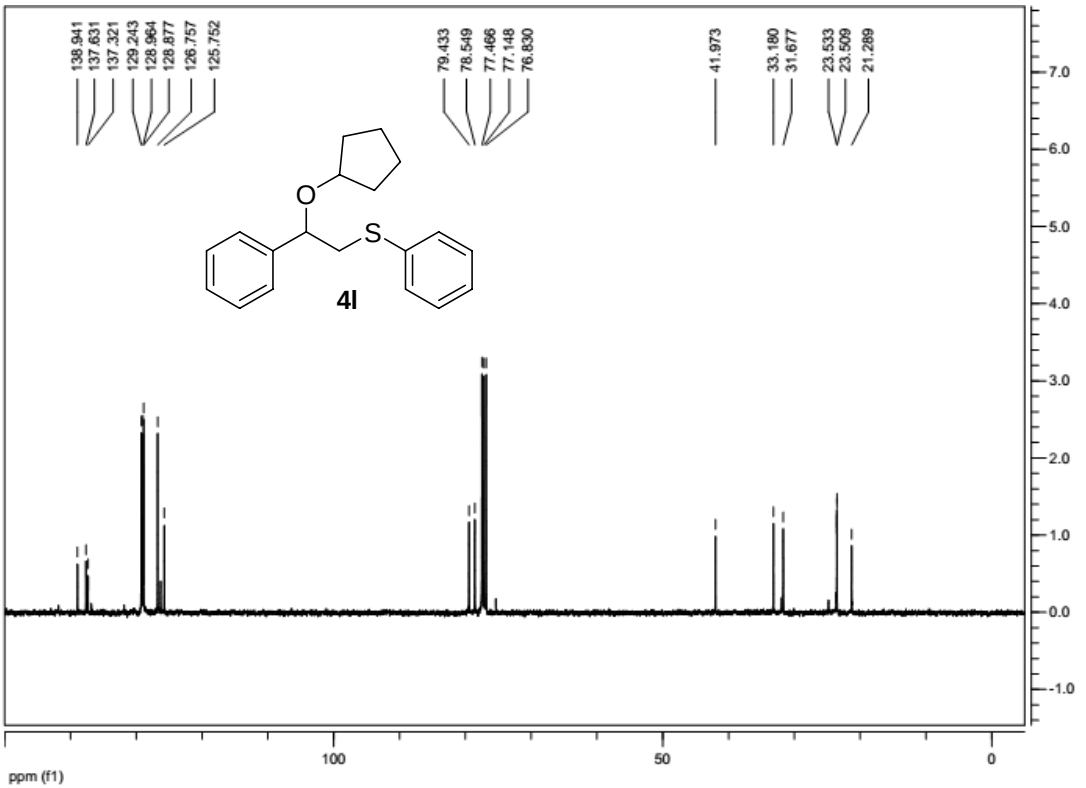
ppm (f1)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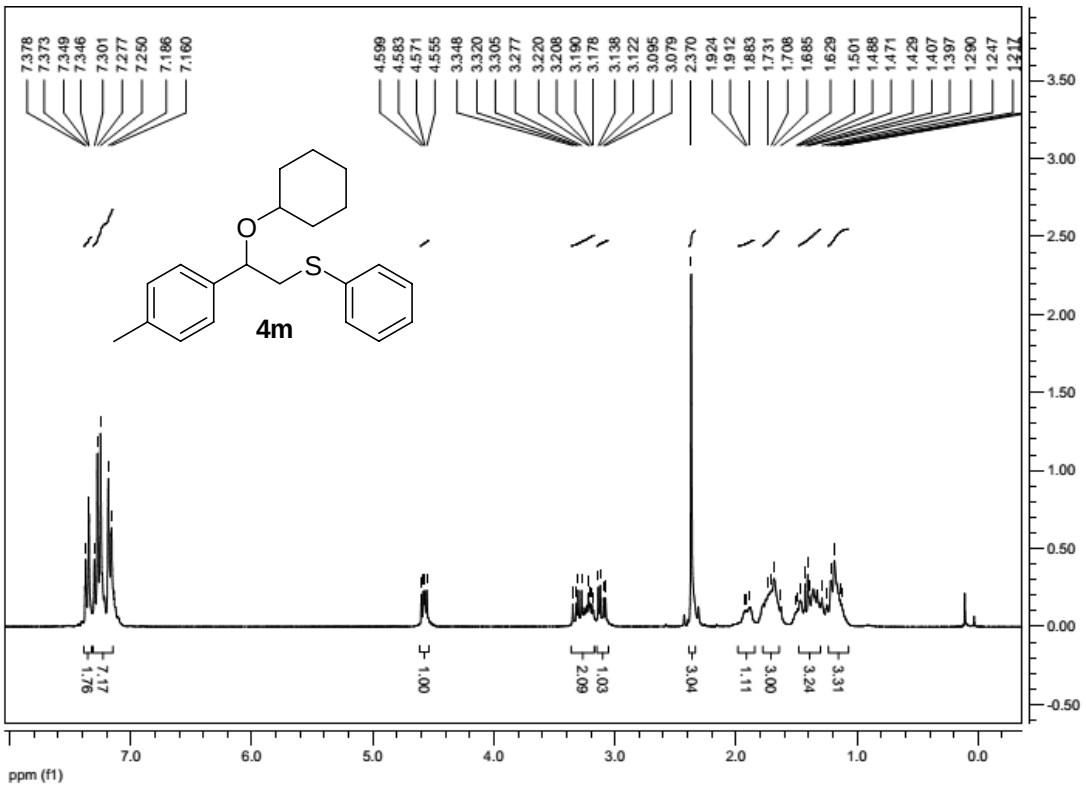
77.466
77.148
76.830
41.973
33.180
31.677
23.533
23.509
21.289
O
S
4l
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
100
50
0
ppm (f1)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7.250
7.186
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4.599
4.583
4.571
4.555
3.348
3.320
3.305
3.277
3.220
3.208
3.190
3.178
3.138
3.122
3.095
3.079
2.370
1.924
1.912
1.883
1.731
1.708
1.685
1.629
1.501
1.488
1.471
1.429
1.407
1.397
1.290
1.247
1.217
O
S
4m
1.76
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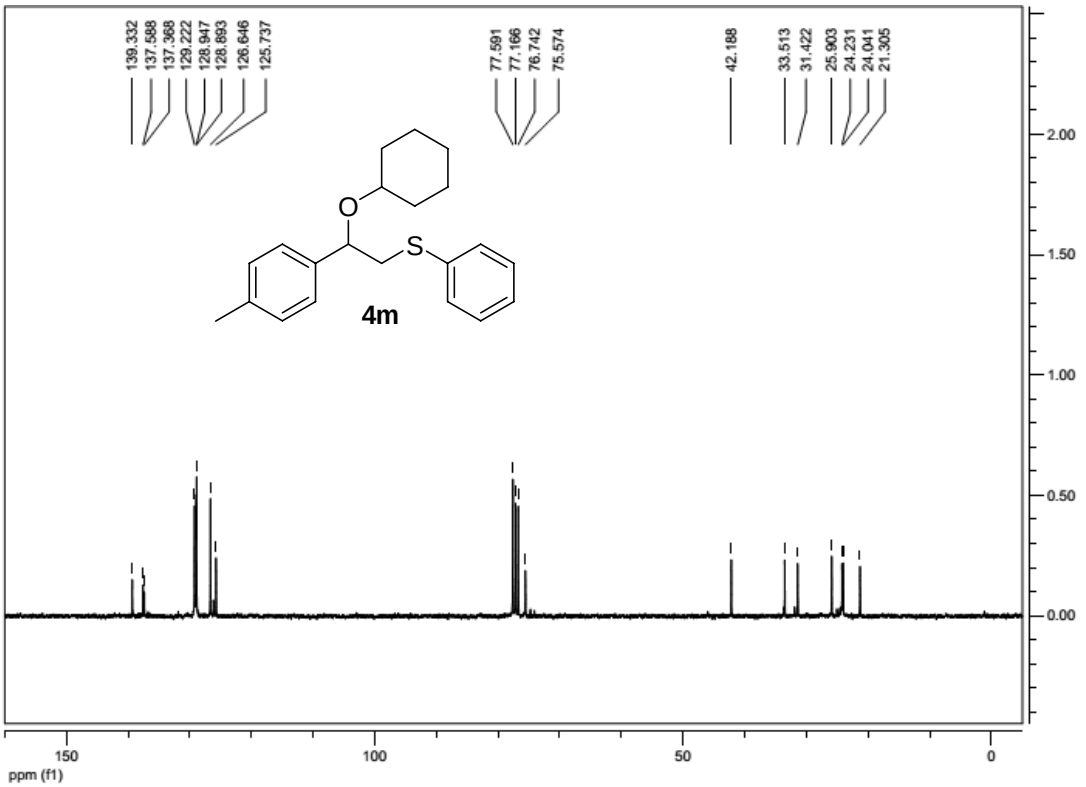
1.00
2.09
1.03
3.04
1.11
3.00
3.24
3.31
ppm (f1)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77.166
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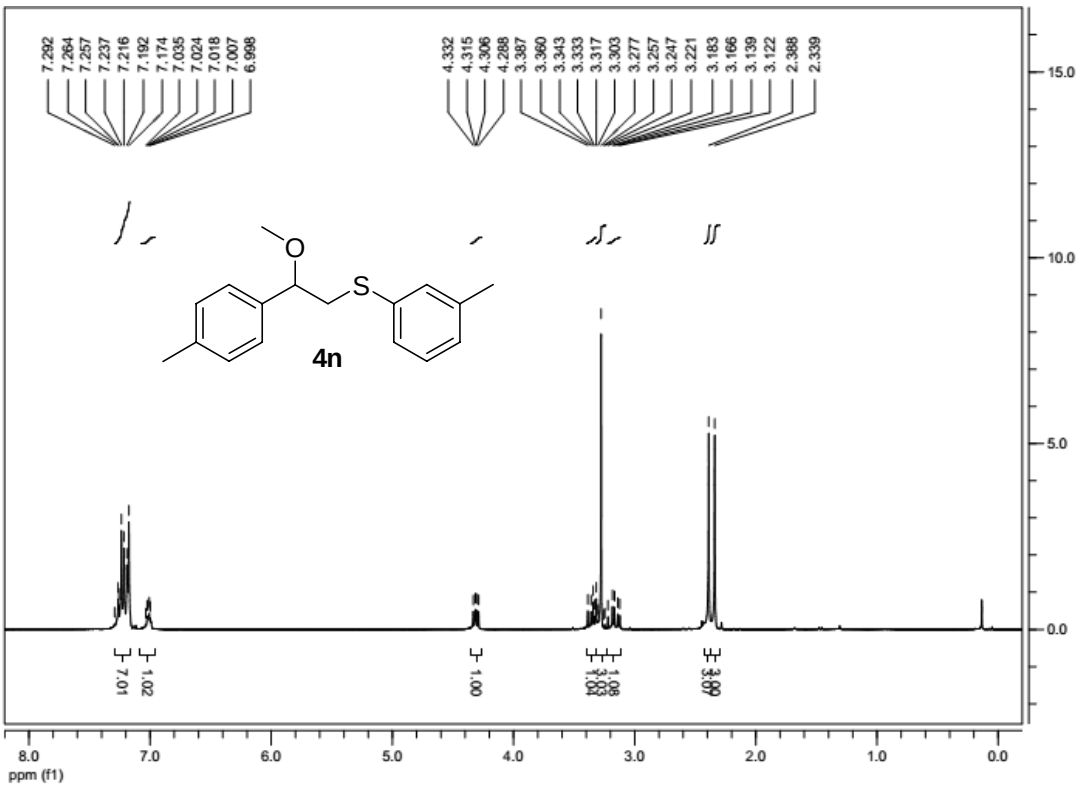
42.188
33.513
31.422
25.903
24.231
24.041
21.305
O
S
4m
ppm (f1)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7.216
7.192
7.174
7.035
7.024
7.018
7.007
6.998
4.332
4.315
4.306
4.288
3.387
3.360
3.343
3.333
3.317
3.303
3.277
3.257
3.247
3.221
3.183
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2.339
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4n
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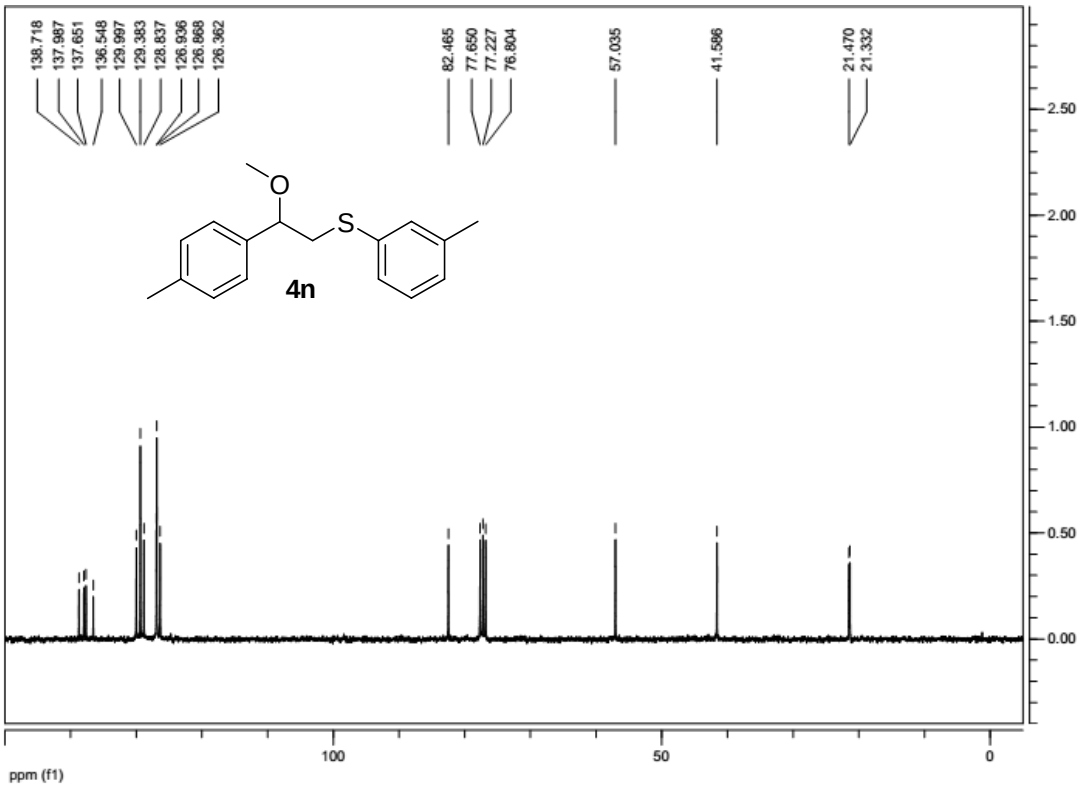
1.02
1.00
3.09
ppm (f1)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126.936
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77.227
76.804
57.035
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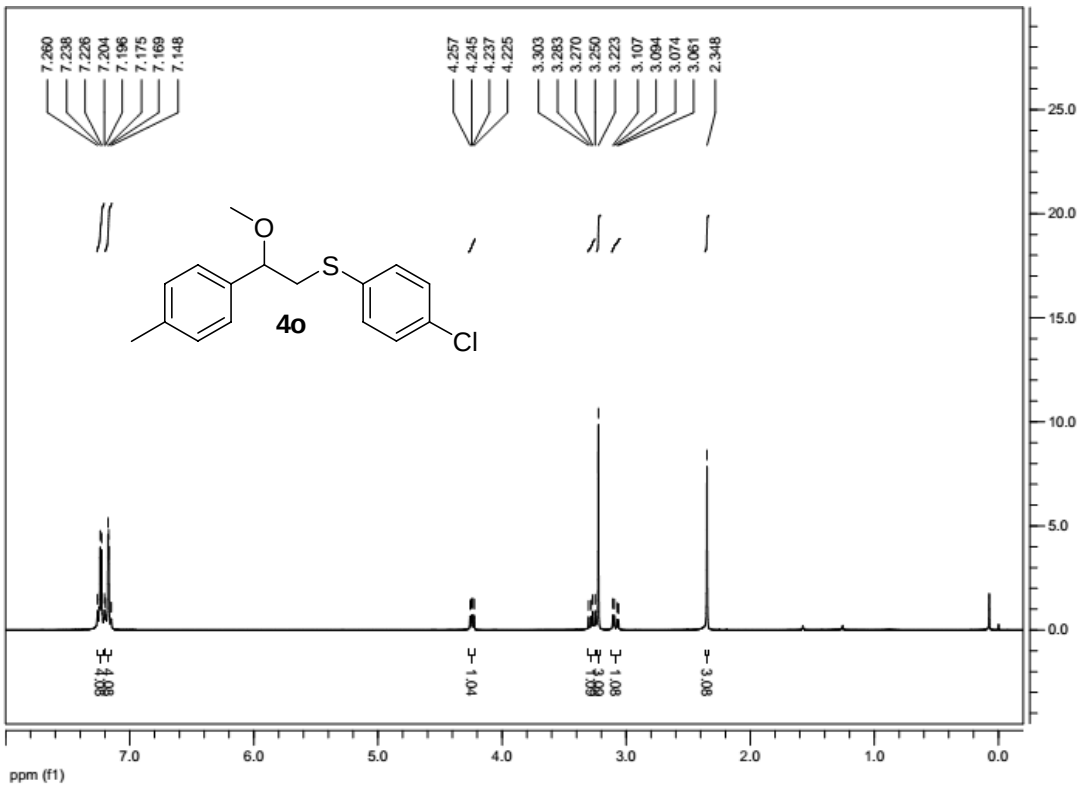
21.332
O
S
4n
ppm (f1)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7.238
7.226
7.204
7.196
7.175
7.169
7.148
4.257
4.245
4.237
4.225
3.303
3.283
3.270
3.250
3.223
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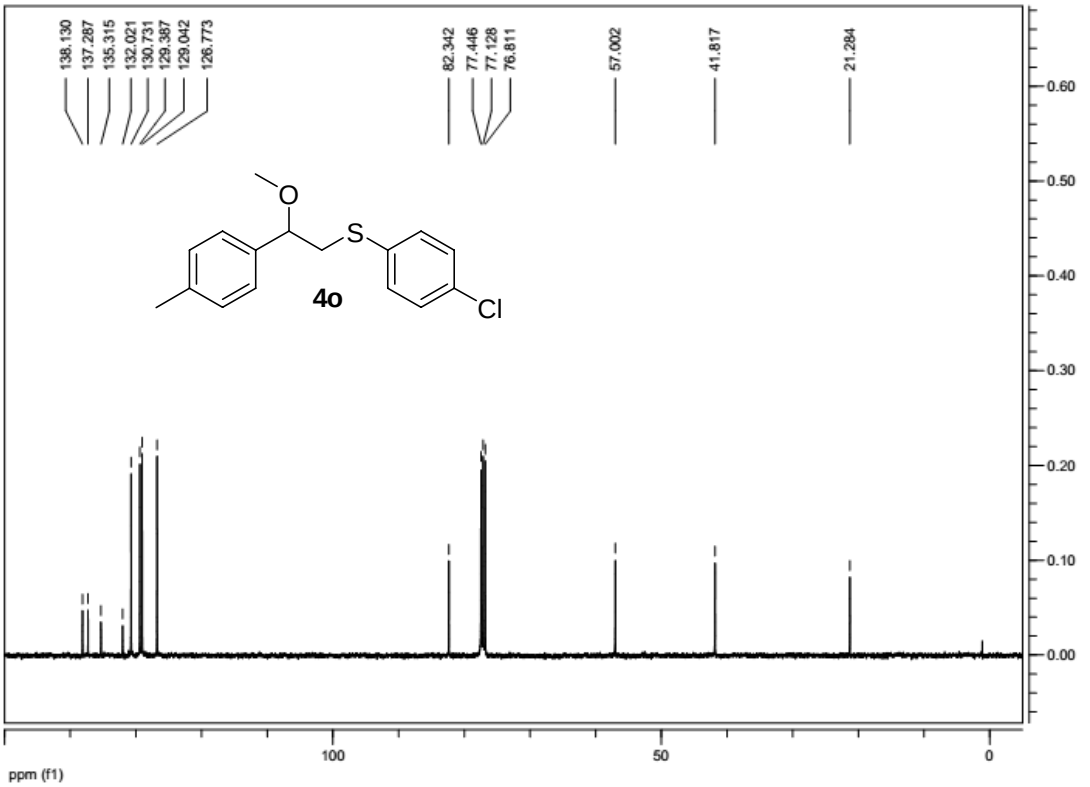
3.094
3.074
3.061
2.348
O
S
Cl
4o
4.08
1.04
3.08
ppm (f1)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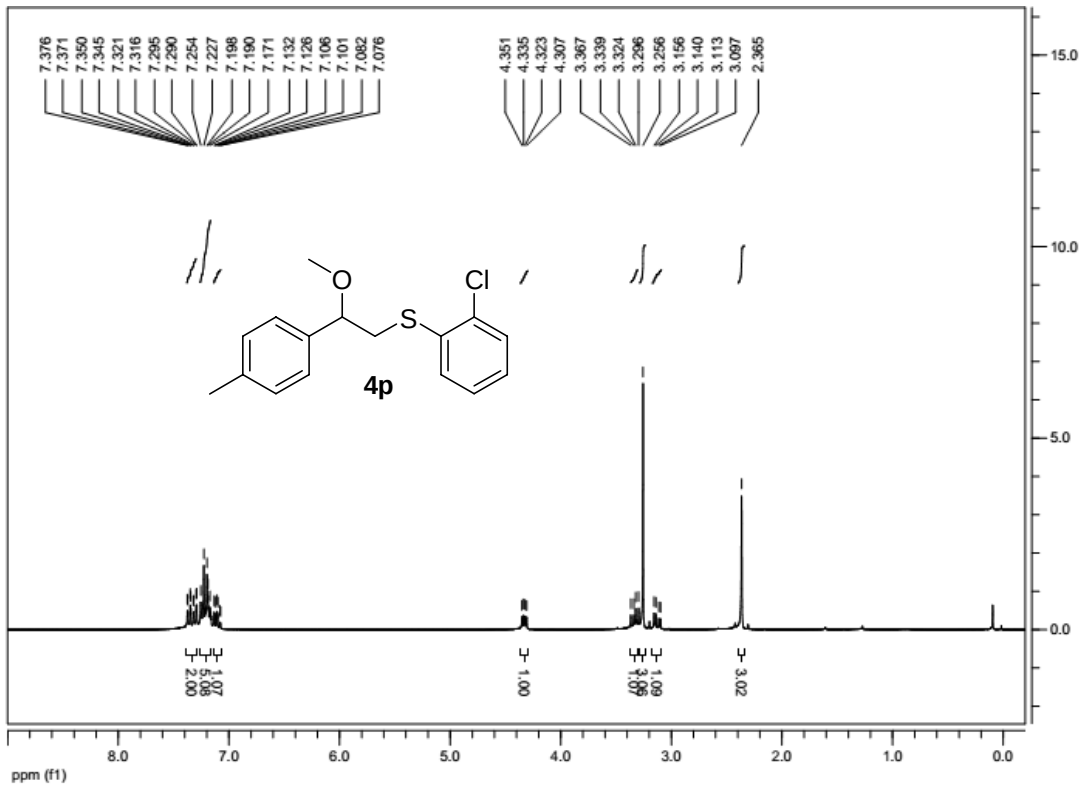
S
Cl
4o
ppm (f1)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7.227
7.198
7.190
7.171
7.132
7.126
7.106
7.101
7.082
7.076
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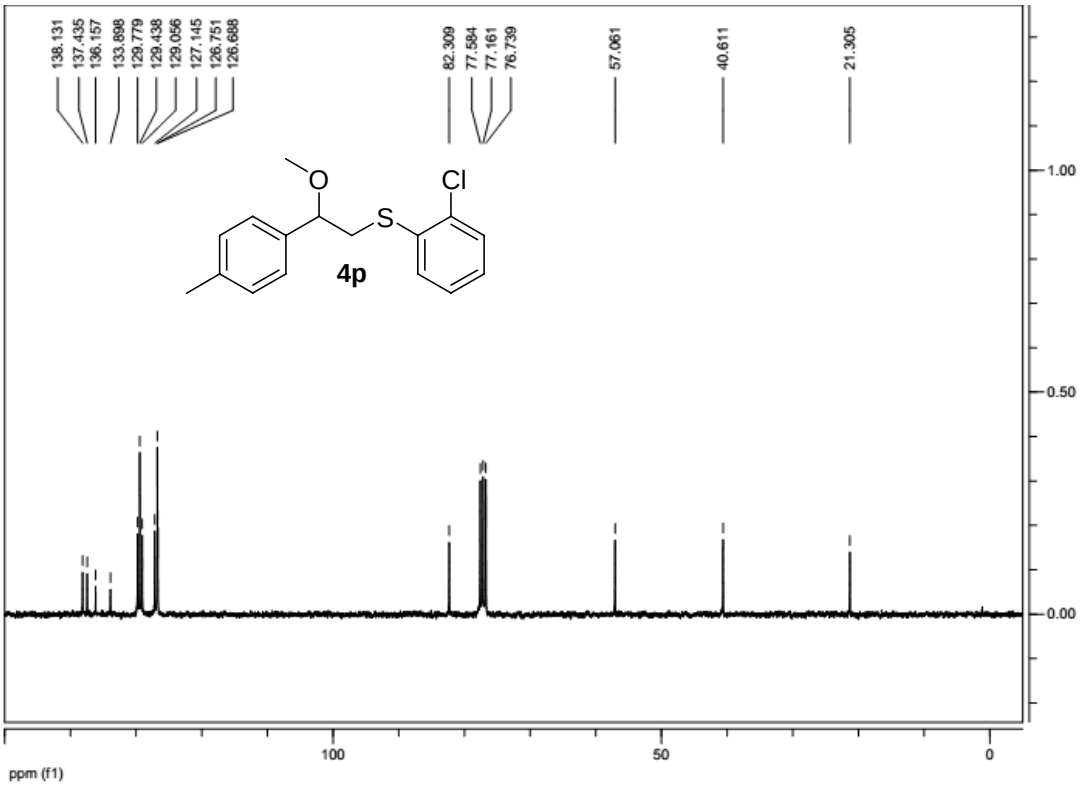
4.335
4.323
4.307
3.367
3.339
3.324
3.296
3.256
3.156
3.140
3.113
3.097
2.365
O
Cl
S
4p
15.0
10.0
5.0
0.0
1.07
5.08
2.00
1.00
1.09
3.18
1.00
3.02
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)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136.157
133.898
129.779
129.438
129.056
127.145
126.751
126.688
82.309
77.584
77.161
76.739
57.061
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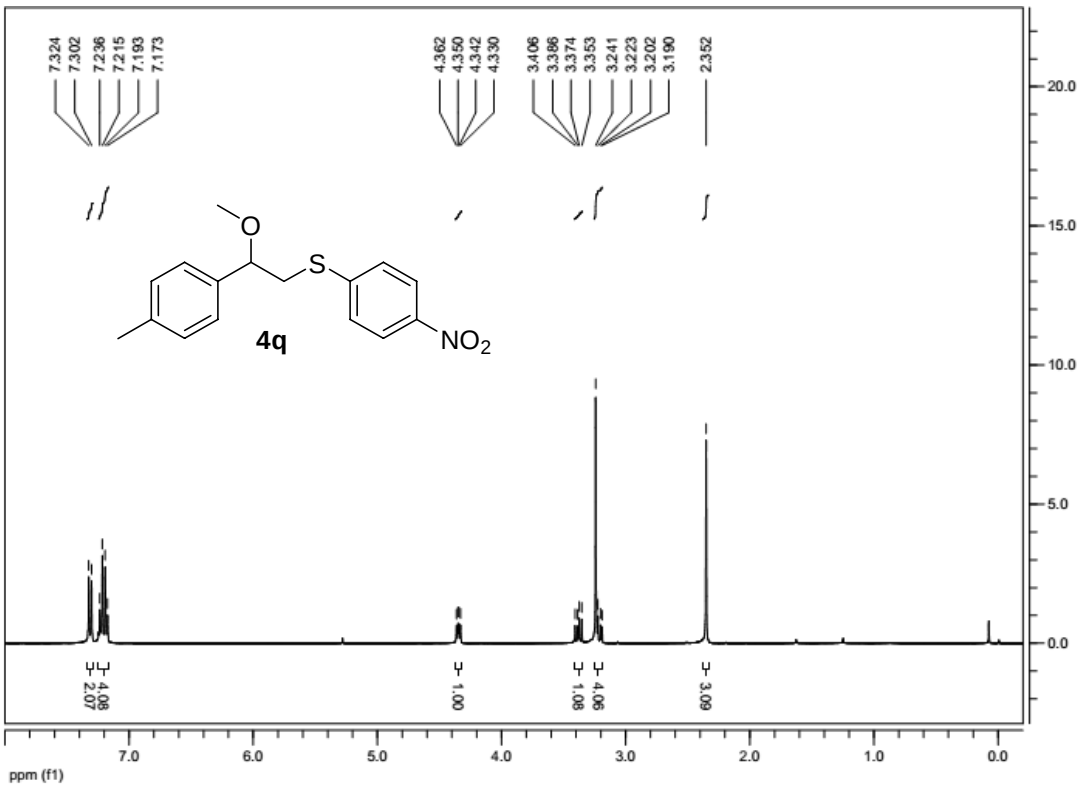
21.305
O
Cl
S
4p
1.00
0.50
0.00
100
50
0
ppm (f1)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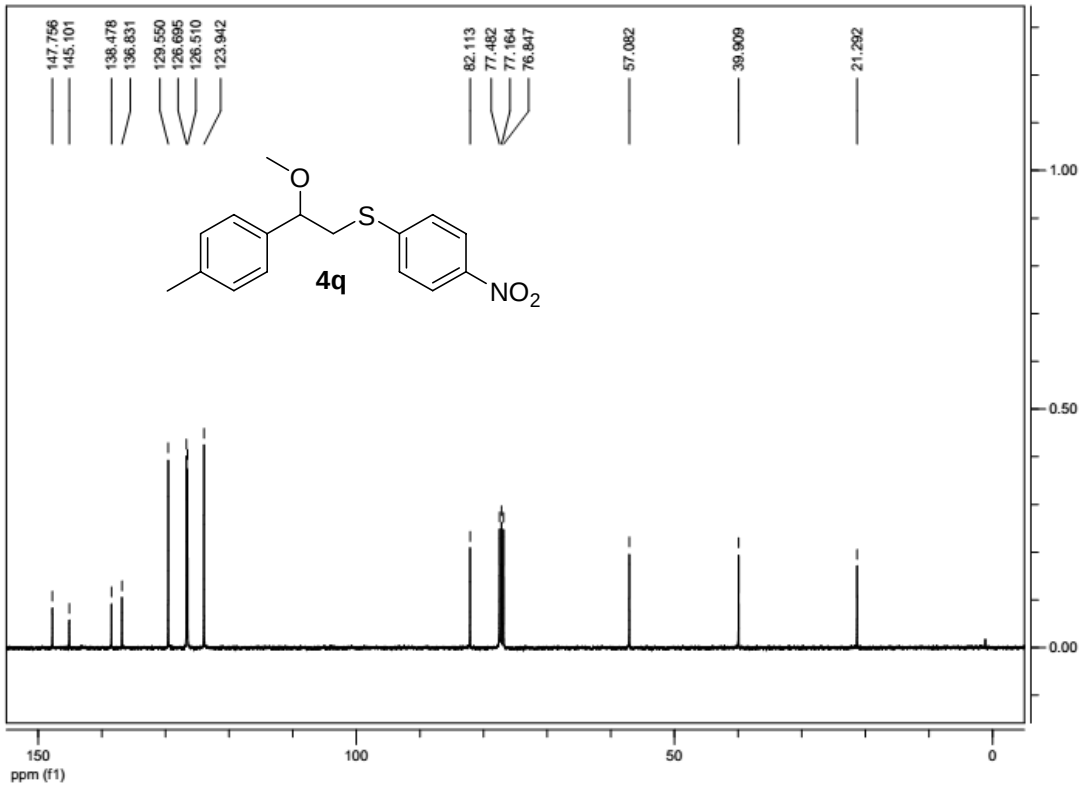
7.302
7.236
7.215
7.193
7.173
4.362
4.350
4.342
4.330
3.406
3.386
3.374
3.353
3.241
3.223
3.202
3.190
2.352
O
S
NO2
4q
2.07
4.08
1.00
1.08
4.06
3.09
ppm (f1)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126.510
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77.164
76.847
57.082
39.909
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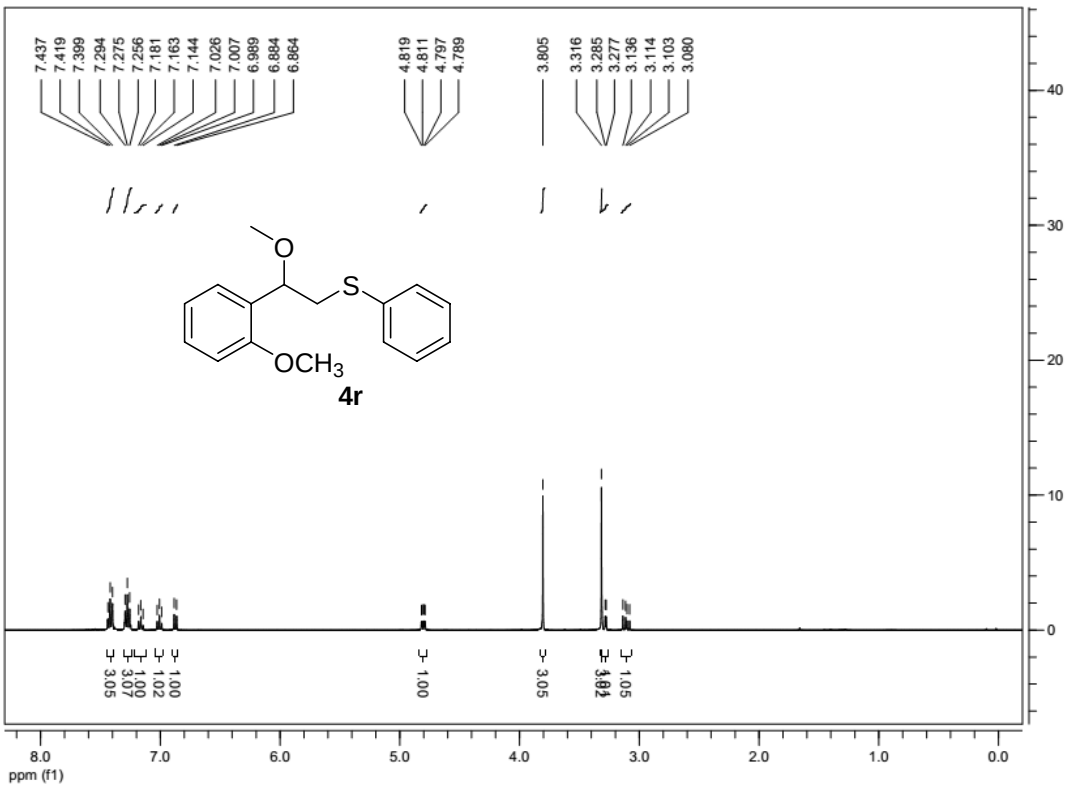
O
S
NO2
4q
ppm (f1)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7.399
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7.275
7.256
7.181
7.163
7.144
7.026
7.007
6.989
6.884
6.864
4.819
4.811
4.797
4.789
3.805
3.316
3.285
3.277
3.136
3.114
3.103
3.080
O
S
OCH3
4r
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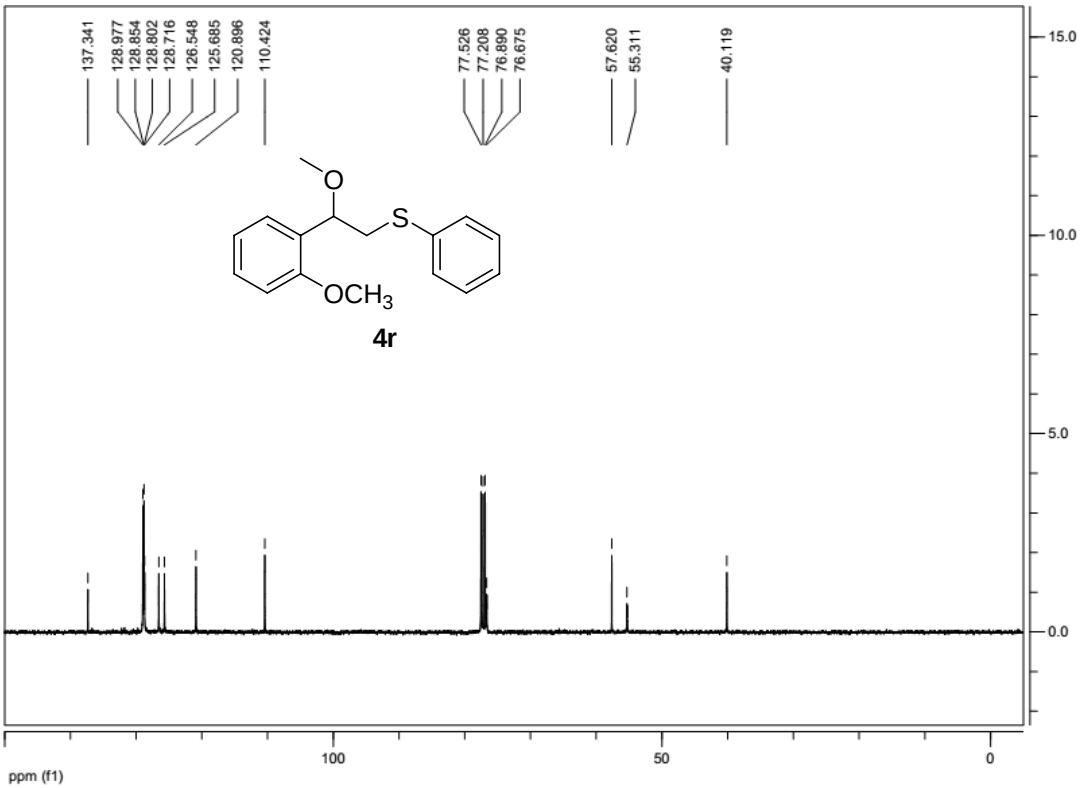
1.00
1.07
1.02
1.00
1.00
3.05
1.05
ppm (f1)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125.685
120.896
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76.890
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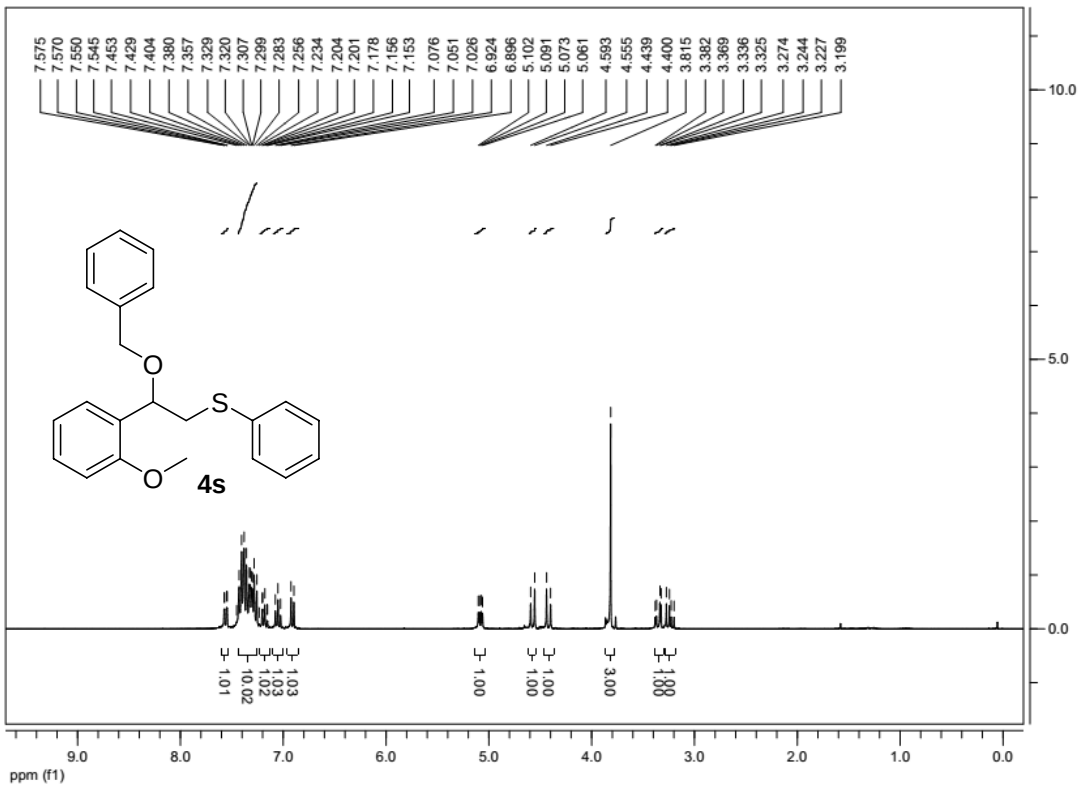
57.620
55.311
40.119
O
S
OCH3
4r
ppm (f1)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7.453
7.429
7.404
7.380
7.357
7.329
7.320
7.307
7.299
7.283
7.256
7.234
7.204
7.201
7.178
7.156
7.153
7.076
7.051
7.026
6.924
6.896
5.102
5.091
5.073
5.061
4.593
4.555
4.439
4.400
3.815
3.382
3.369
3.336
3.325
3.274
3.244
3.227
3.199
O
S
O
4s
1.01
10.02
1.22
1.03
1.03
1.00
1.00
3.00
1.00
1.00
10.0
5.0
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7.0
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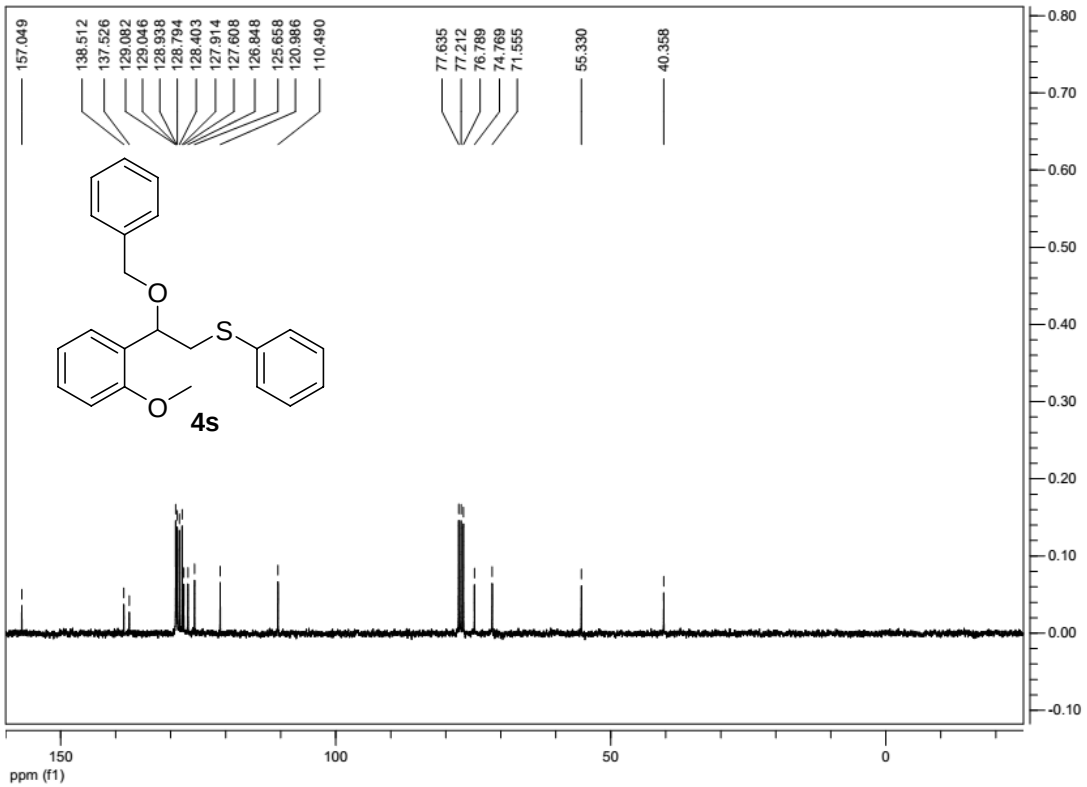
3.0
2.0
1.0
0.0
ppm (f1)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128.403
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127.608
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125.658
120.986
110.490
77.635
77.212
76.789
74.769
71.555
55.330
40.358
O
S
O
4s
0.80
0.70
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0.00
-0.10
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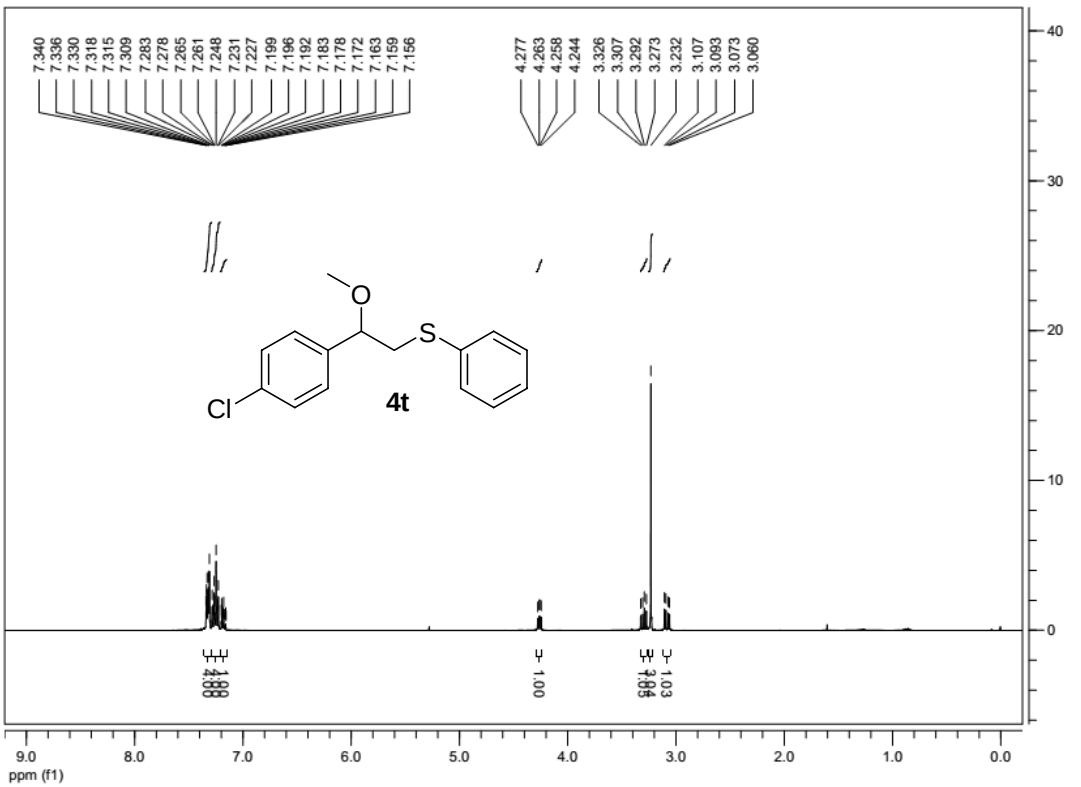
100
50
0
ppm (f1)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7.315
7.309
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7.278
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7.261
7.248
7.231
7.227
7.199
7.196
7.192
7.183
7.178
7.172
7.163
7.159
7.156
4.277
4.263
4.258
4.244
3.326
3.307
3.292
3.273
3.232
3.107
3.093
3.073
3.060
O
S
Cl
4t
1.00
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7.0
6.0
5.0
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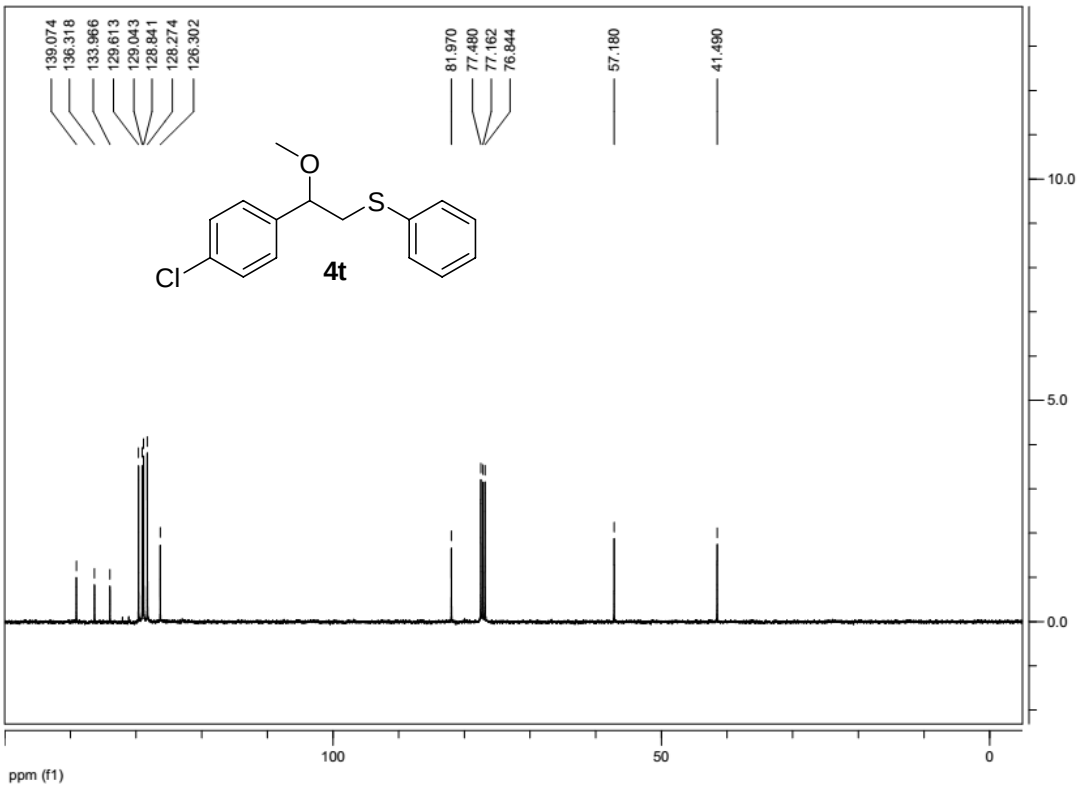
2.0
1.0
0.0
ppm (f1)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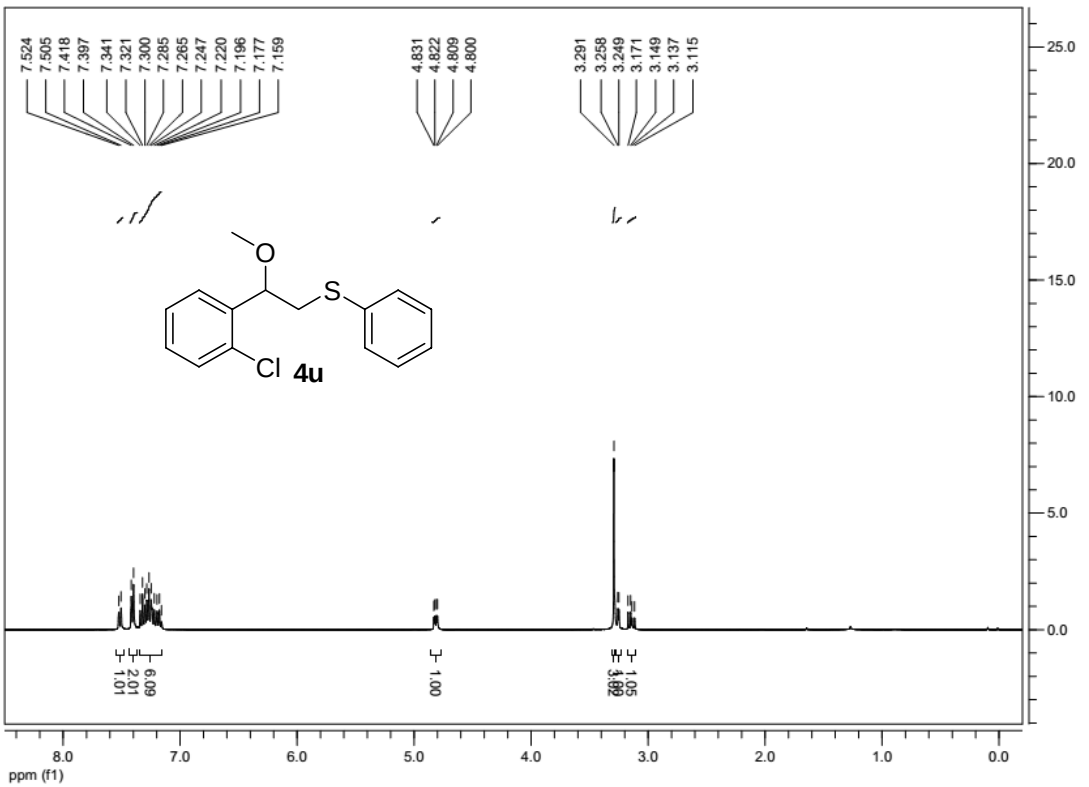
76.844
57.180
41.490
O
S
Cl
4t
100
50
0
ppm (f1)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7.285
7.265
7.247
7.220
7.196
7.177
7.159
4.831
4.822
4.809
4.800
3.291
3.258
3.249
3.171
3.149
3.137
3.115
O
S
Cl
4u
6.09
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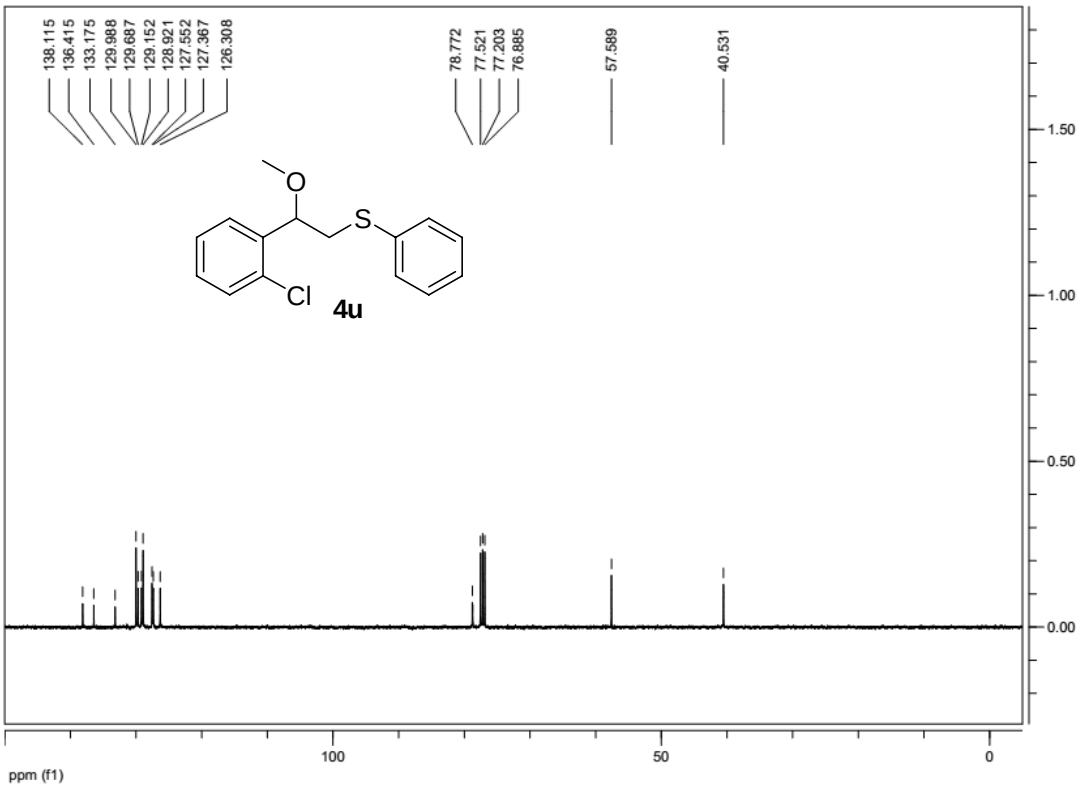
1.01
1.00
3.02
3.00
1.05
ppm (f1)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129.152
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127.552
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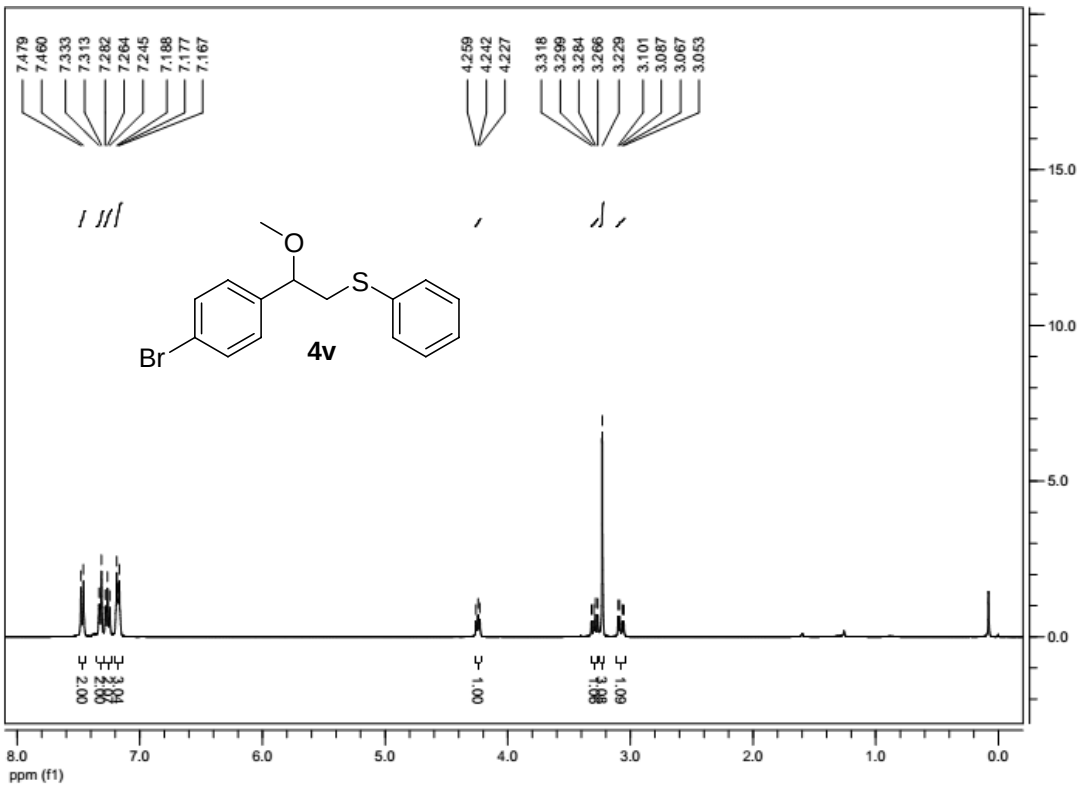
126.308
78.772
77.521
77.203
76.885
57.589
40.531
O
S
Cl
4u
ppm (f1)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7.188
7.177
7.167
4.259
4.242
4.227
3.318
3.299
3.284
3.266
3.229
3.101
3.087
3.067
3.053
O
S
Br
4v
15.0
10.0
5.0
0.0
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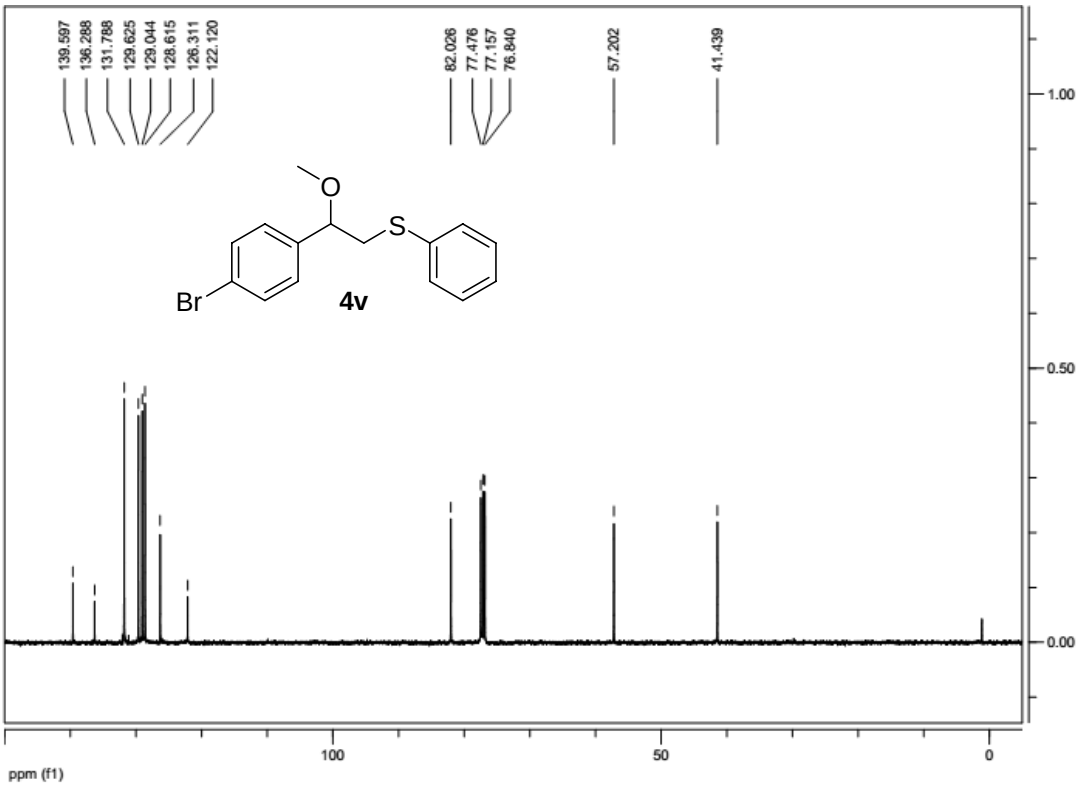
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)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128.615
126.311
122.120
82.026
77.476
77.157
76.840
57.202
41.439
O
S
Br
4v
1.00
0.50
0.00
100
50
0
ppm (f1)


7.454
7.433
7.428
7.422
7.417
7.411
7.344
7.326
7.289
7.270
7.251
7.246
7.223
7.207
7.197
7.179
4.252
4.239
4.232
4.219
3.312
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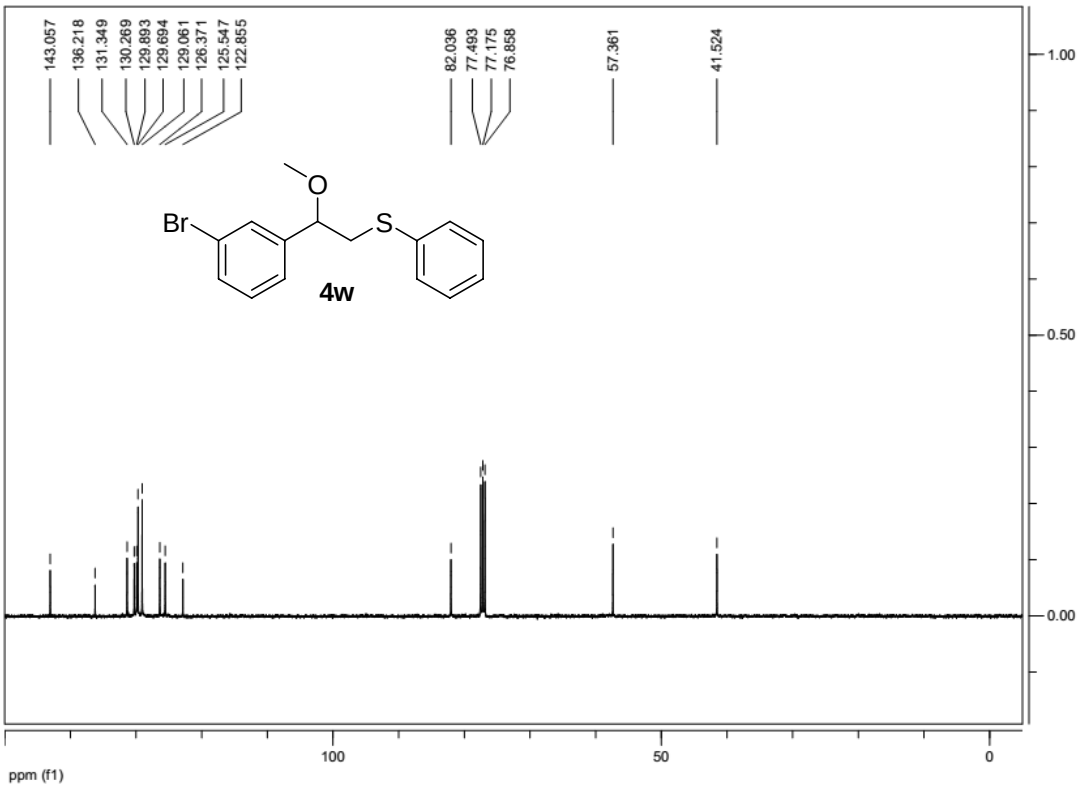
Br
O
S
4w
ppm (f1)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126.371
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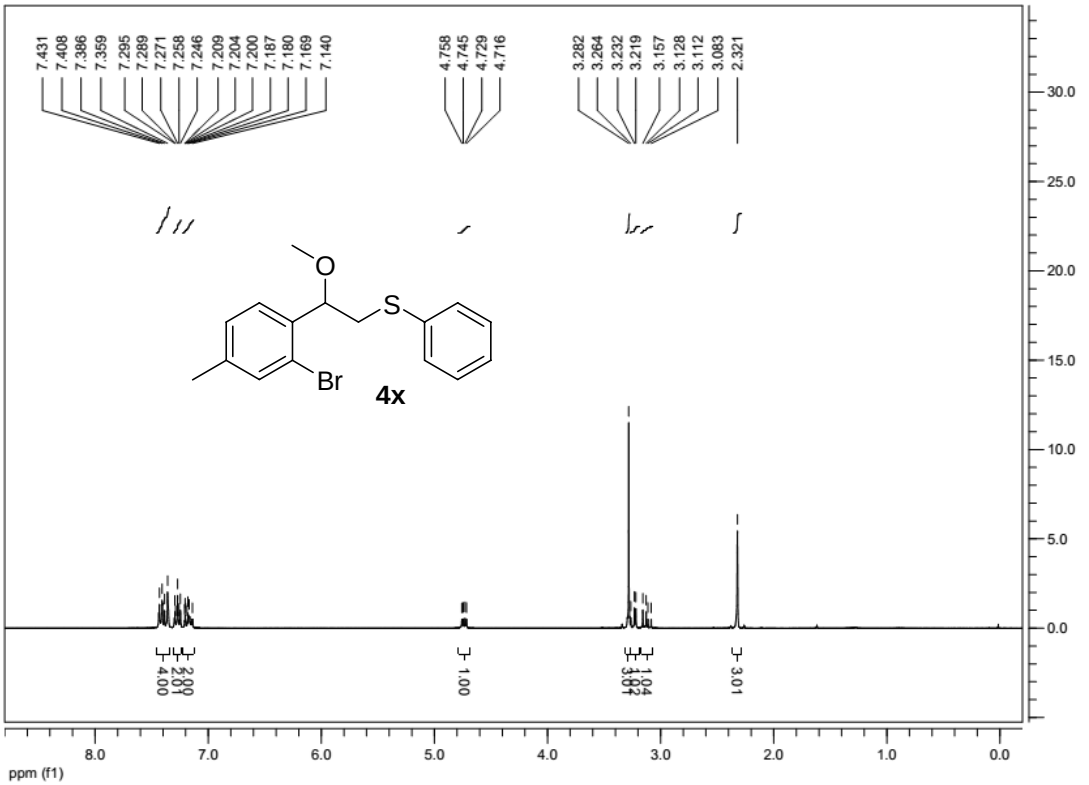
77.175
76.858
57.361
41.524
Br
O
S
4w
ppm (f1)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7.295
7.289
7.271
7.258
7.246
7.209
7.204
7.200
7.187
7.180
7.169
7.140
4.758
4.745
4.729
4.716
3.282
3.264
3.232
3.219
3.157
3.128
3.112
3.083
2.321
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S
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2.00
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1.14
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3.01
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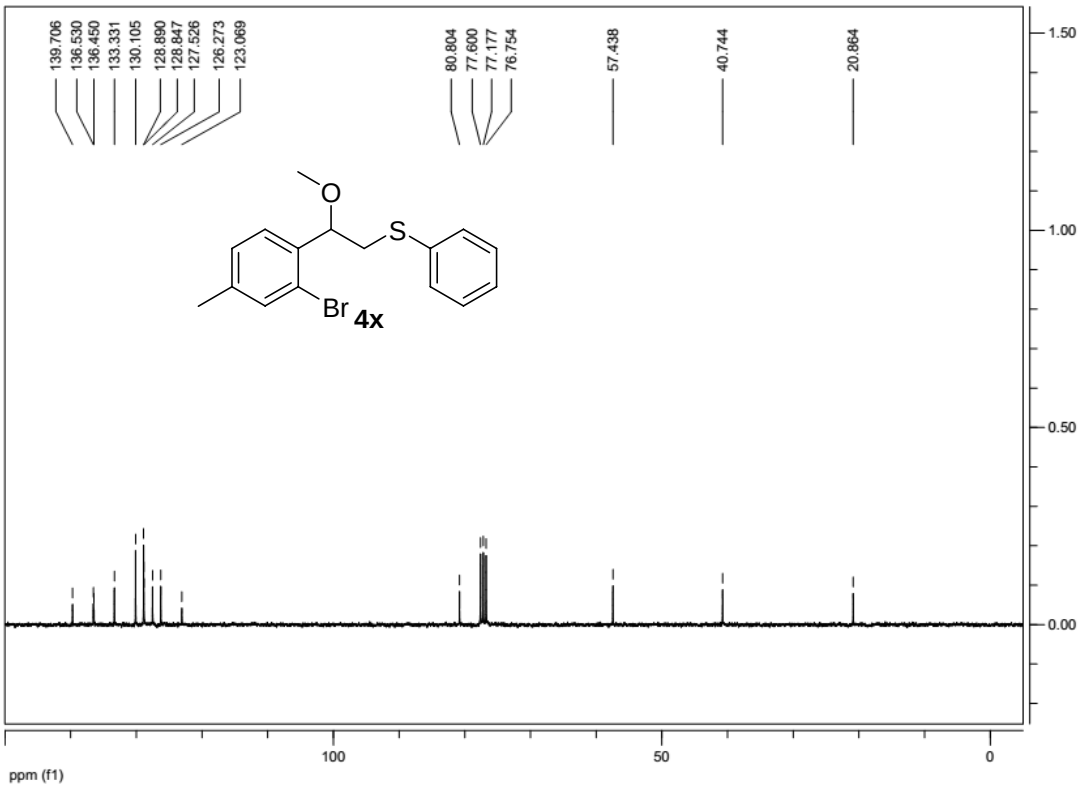
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130.105
128.890
128.847
127.526
126.273
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77.177
76.754
57.438
40.744
20.864
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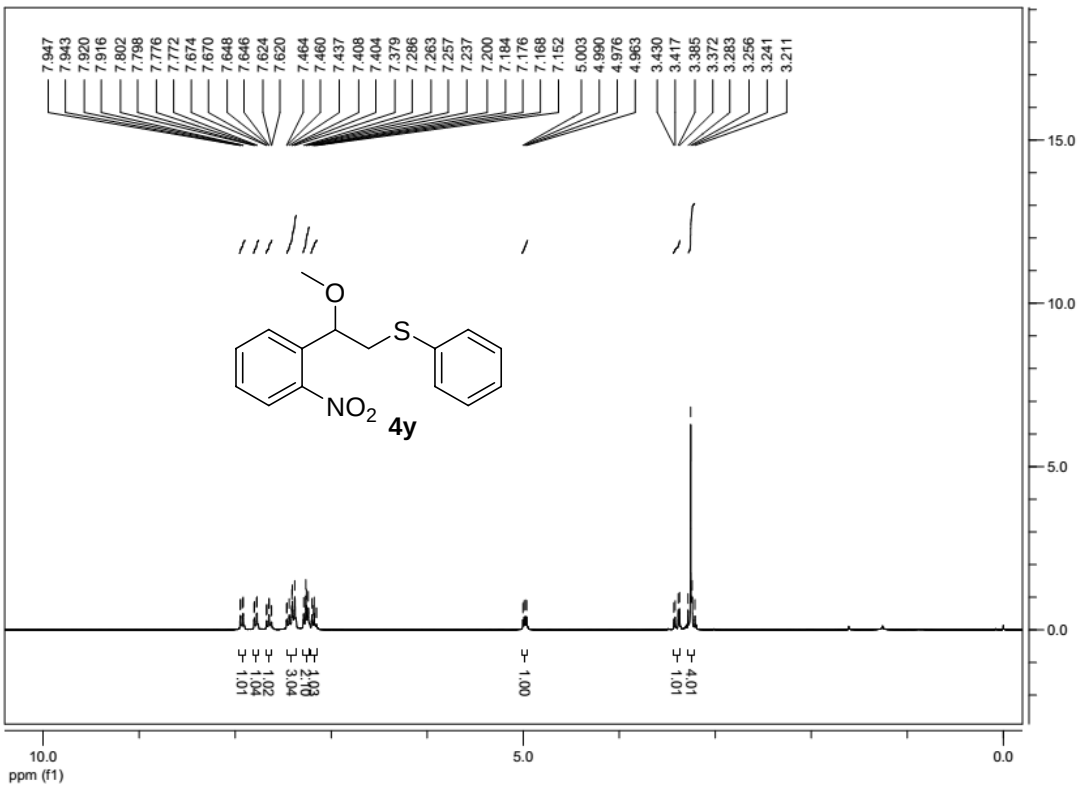
S
Br
4x
ppm (f1)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7.620
7.464
7.460
7.437
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7.404
7.379
7.286
7.263
7.257
7.237
7.200
7.184
7.176
7.168
7.152
5.003
4.990
4.976
4.963
3.430
3.417
3.385
3.372
3.283
3.256
3.241
3.211
O
S
NO2
4y
1.01
1.02
1.04
3.04
2.13
1.03
1.00
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10.0
5.0
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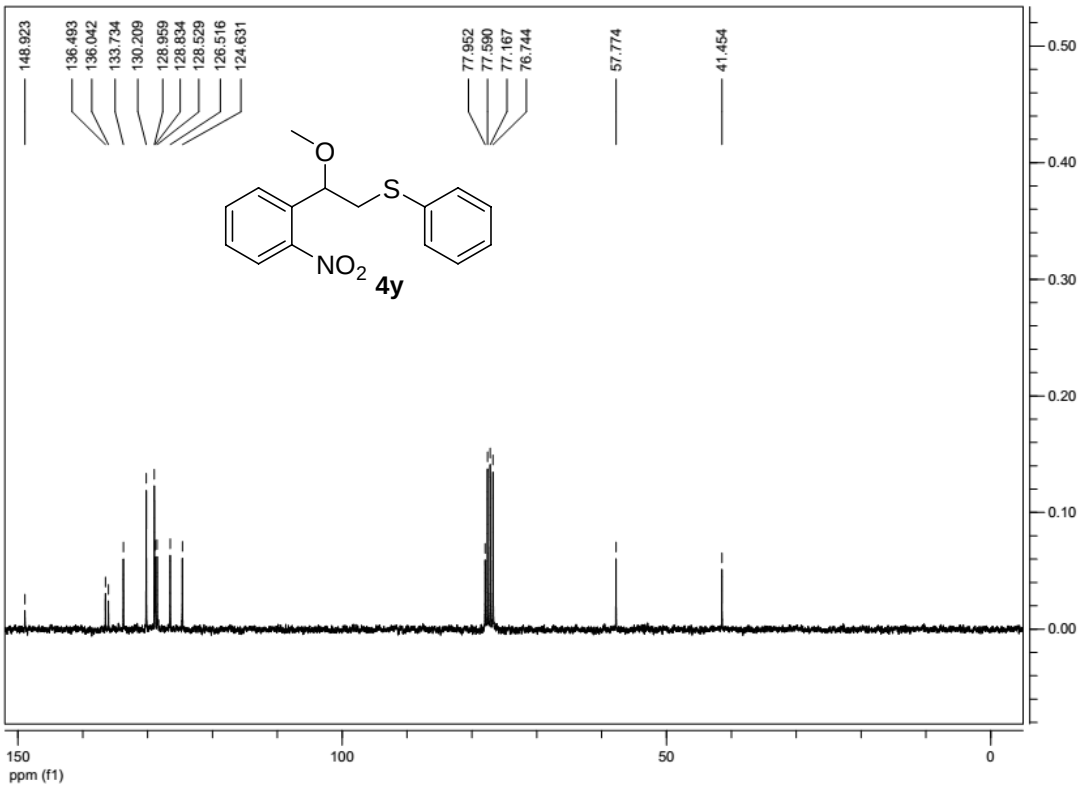
10.0
5.0
0.0
ppm (f1)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128.834
128.529
126.516
124.631
77.952
77.590
77.167
76.744
57.774
41.454
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S
NO2
4y
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0.00
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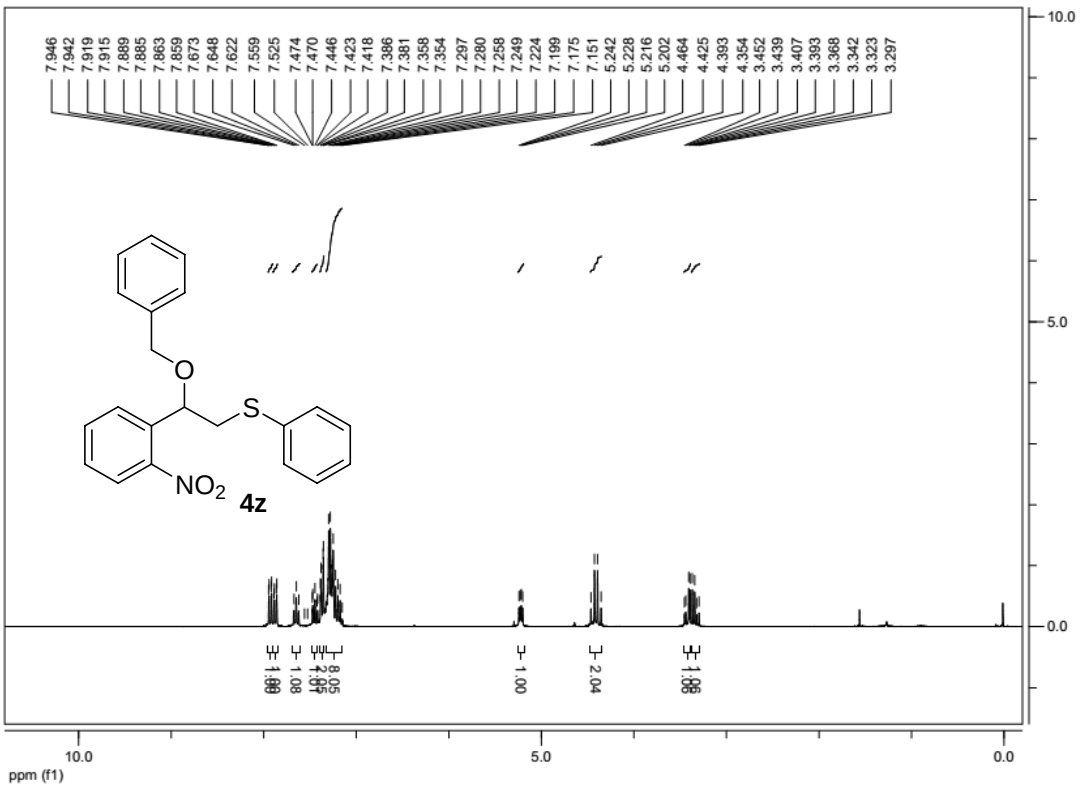
100
50
0
ppm (f1)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7.525
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7.280
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7.249
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7.175
7.151
5.242
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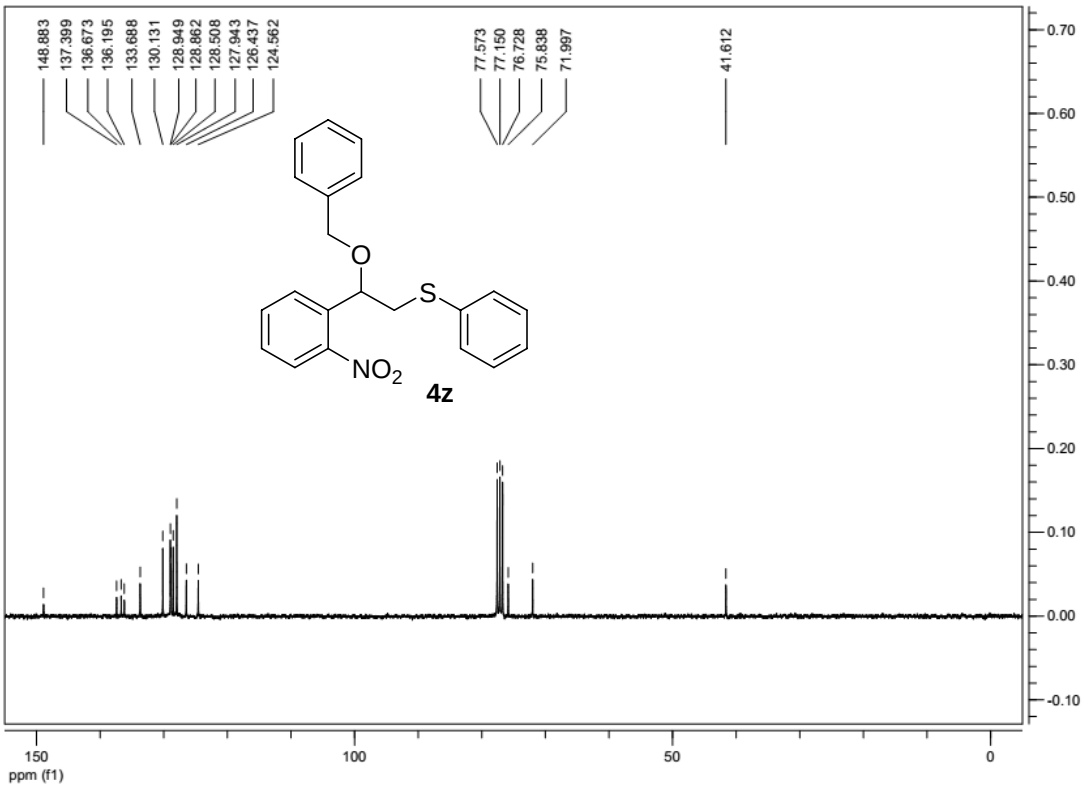
5.216
5.202
4.464
4.425
4.393
4.354
3.452
3.439
3.407
3.393
3.368
3.342
3.323
3.297
O
S
NO2
4z
1.00
2.04
10.0
5.0
0.0
ppm (f1)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136.673
136.195
133.688
130.131
128.949
128.862
128.508
127.943
126.437
124.562
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77.150
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75.838
71.997
41.612
O
S
NO2
4z
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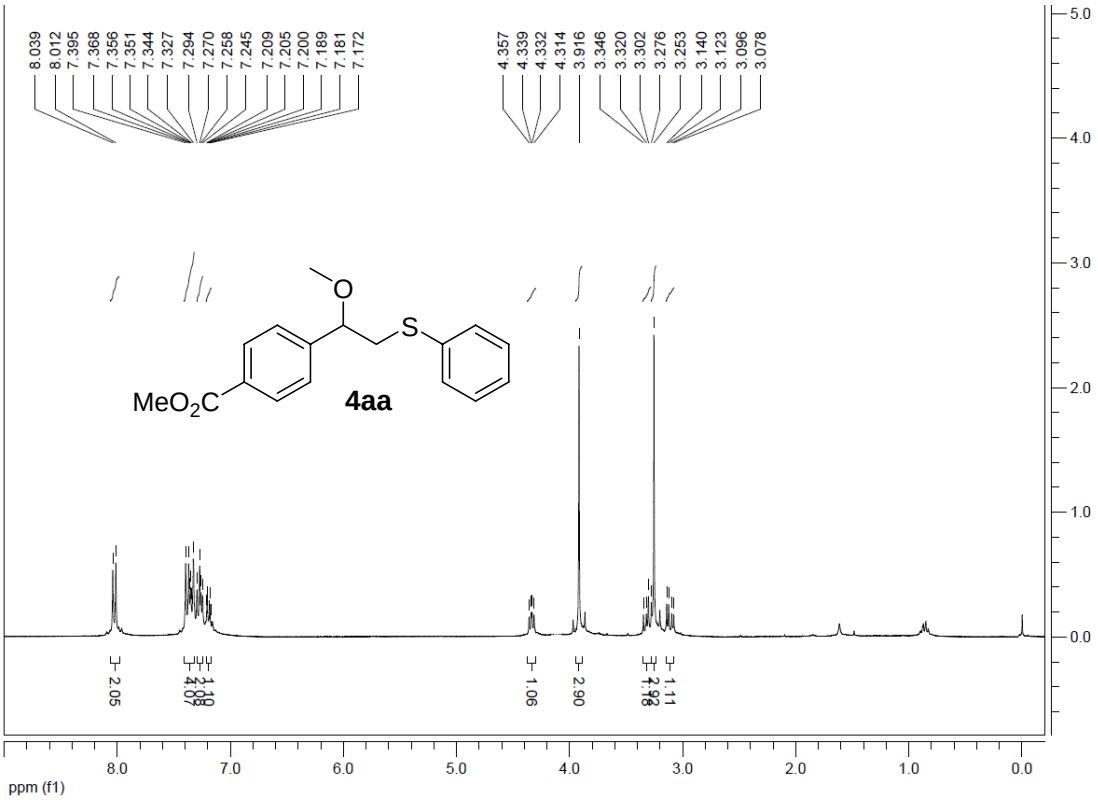
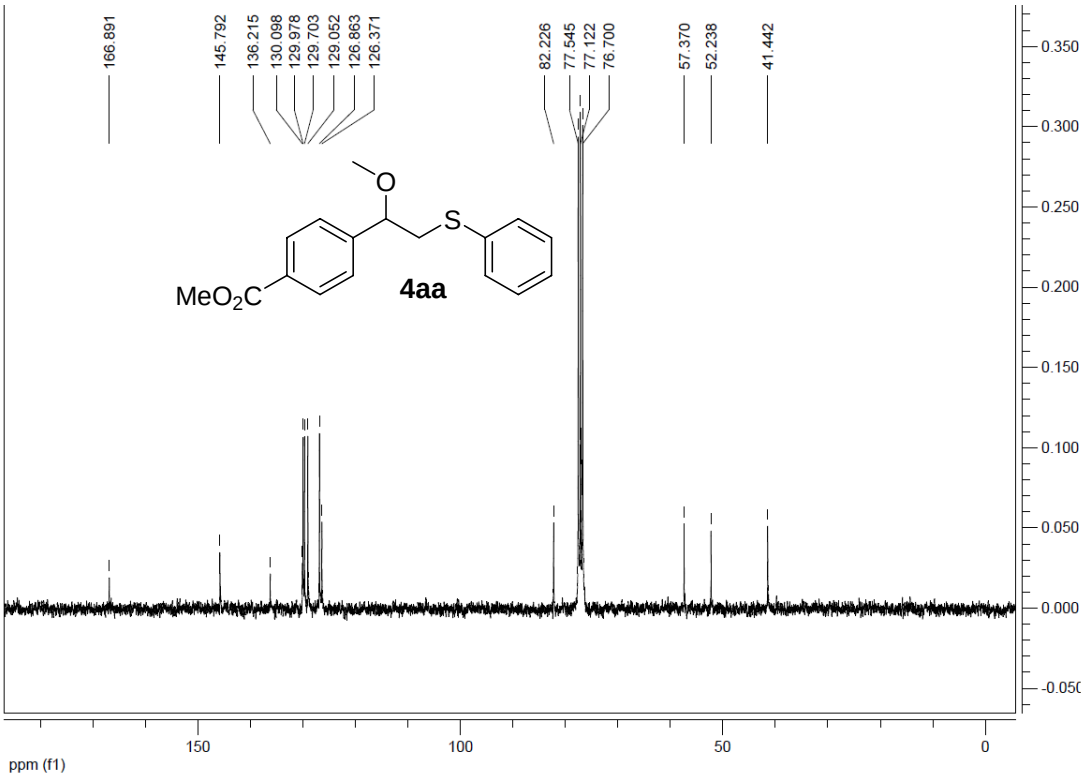
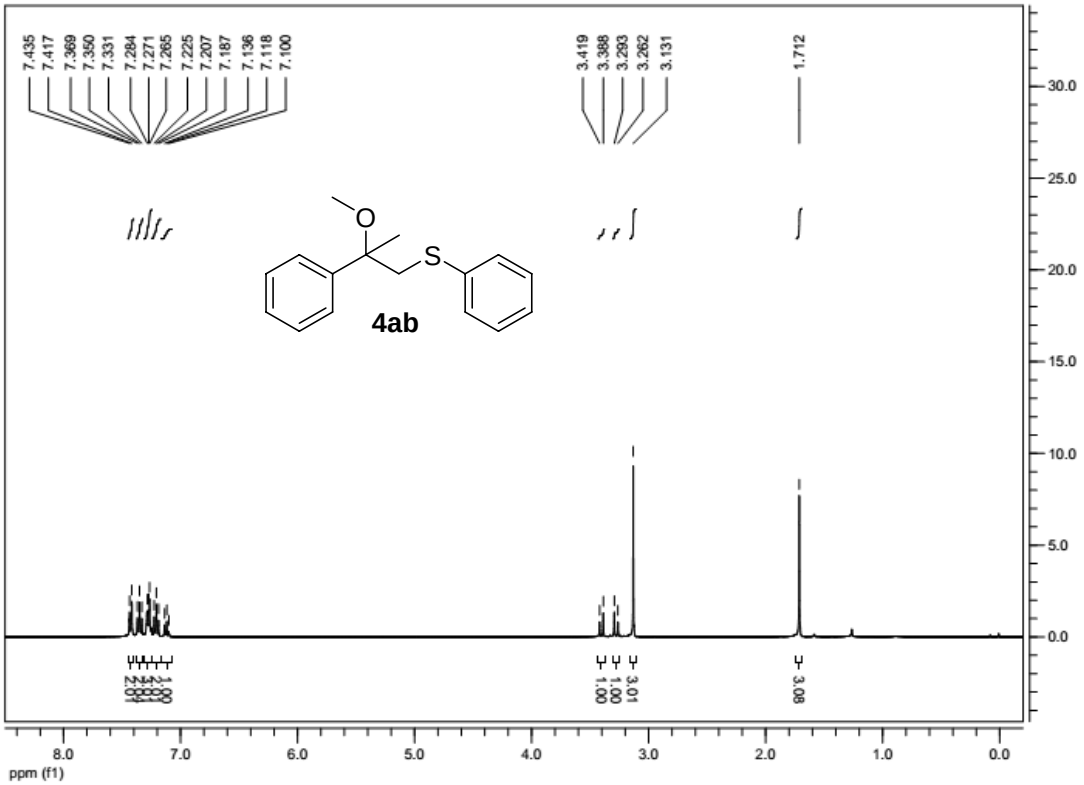
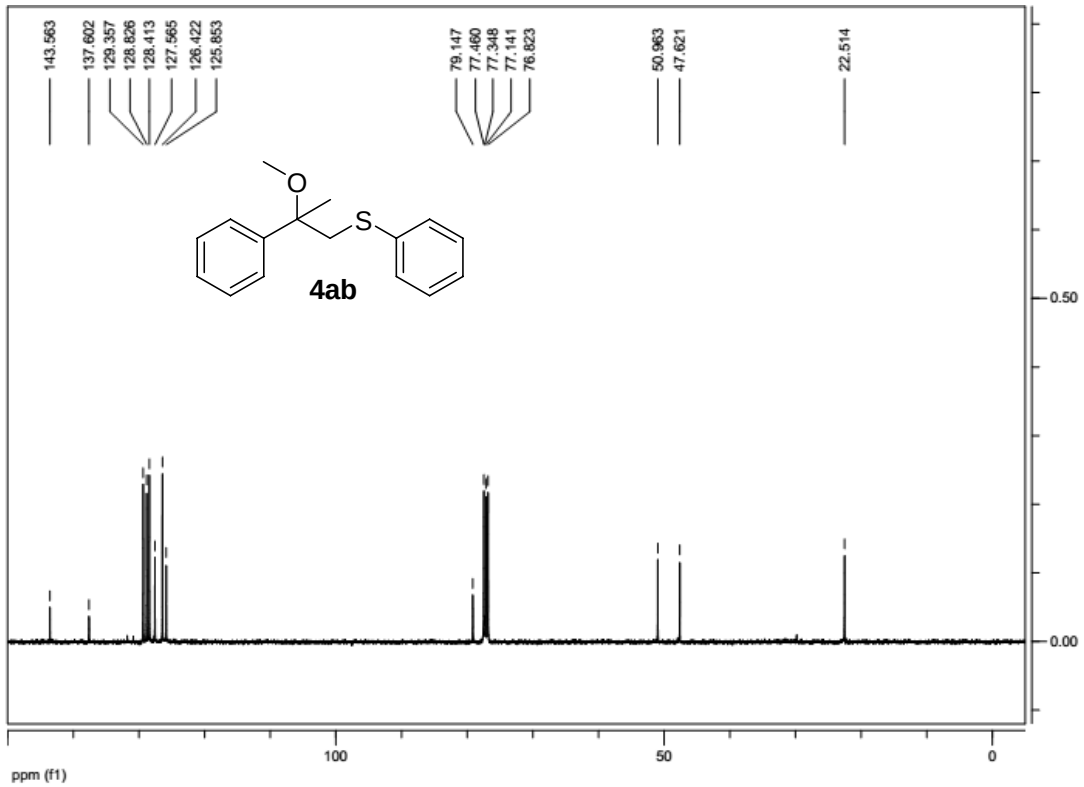
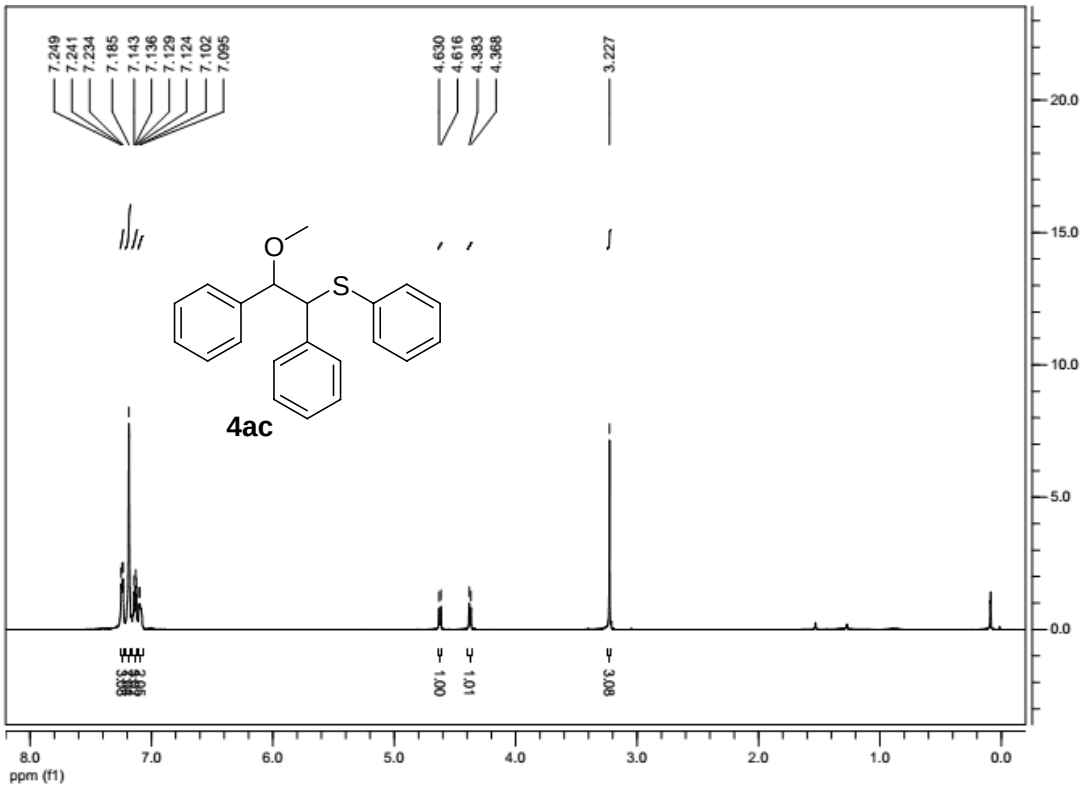
100
50
0
ppm (f1)

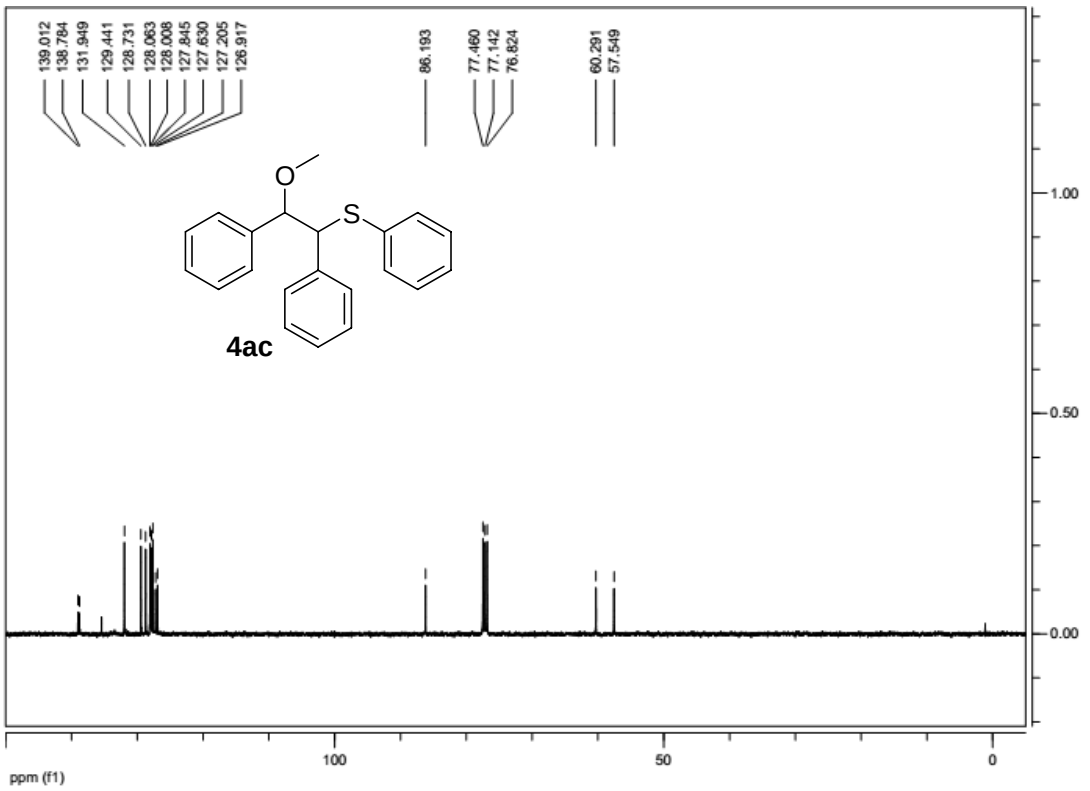

8.039
8.012
7.395
7.368
7.356
7.351
7.344
7.327
7.294
7.270
7.258
7.245
7.209
7.205
7.200
7.189
7.181
7.172
4.357
4.339
4.332
4.314
3.916
3.346
3.320
3.302
3.276
3.253
3.140
3.123
3.096
3.078
O
S
MeO2C
4aa
2.05
1.06
2.90
1.11
ppm (f1)

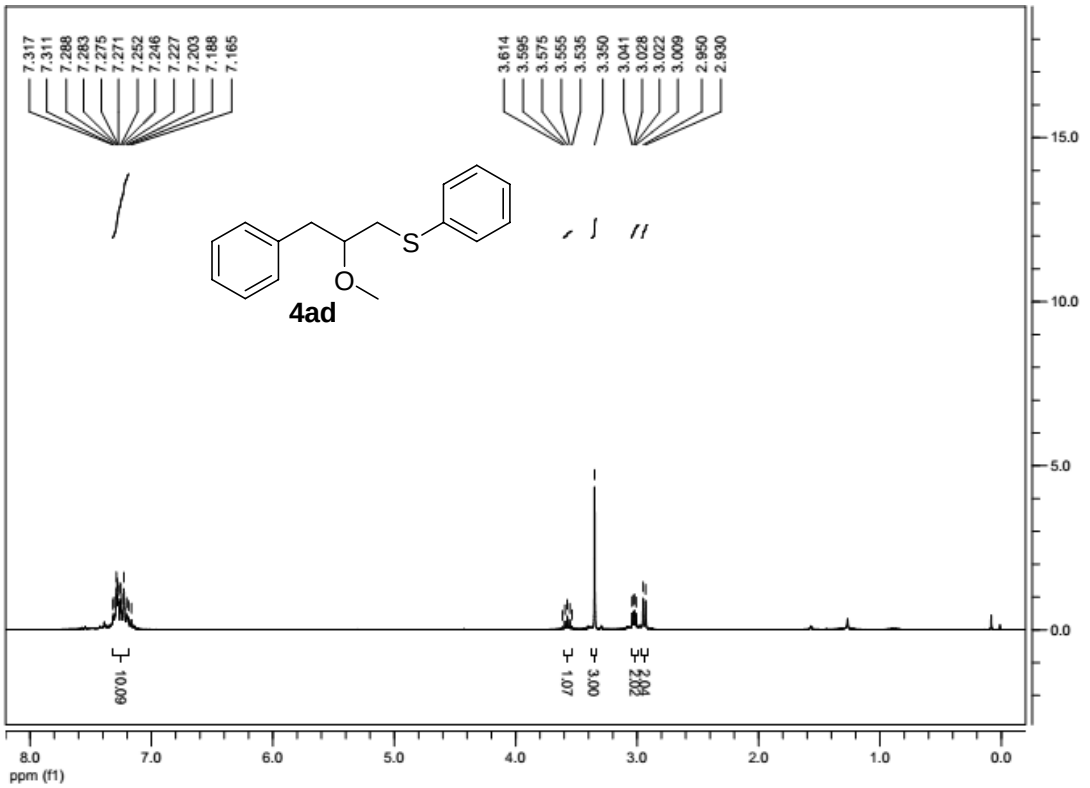

166.891
145.792
136.215
130.098
129.978
129.703
129.052
126.863
126.371
82.226
77.545
77.122
76.700
57.370
52.238
41.442
O
S
MeO2C
4aa
ppm (f1)


7.435
7.417
7.369
7.350
7.331
7.284
7.271
7.265
7.225
7.207
7.187
7.136
7.118
7.100
3.419
3.388
3.293
3.262
3.131
1.712
O
S
4ab
30.0
25.0
20.0
15.0
10.0
5.0
0.0
3.01
1.00
1.00
3.08
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)


143.563
137.602
129.357
128.826
128.413
127.565
126.422
125.853
79.147
77.460
77.348
77.141
76.823
50.963
47.621
22.514
O
S
4ab
0.50
0.00
100
50
0
ppm (f1)


7.249
7.241
7.234
7.185
7.143
7.136
7.129
7.124
7.102
7.095
4.630
4.616
4.383
4.368
3.227
O
S
4ac
1.00
1.01
3.08
20.0
15.0
10.0
5.0
0.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)


139.012
138.784
131.949
129.441
128.731
128.063
128.008
127.845
127.630
127.205
126.917
86.193
77.460
77.142
76.824
60.291
57.549
O
S
4ac
1.00
0.50
0.00
100
50
0
ppm (f1)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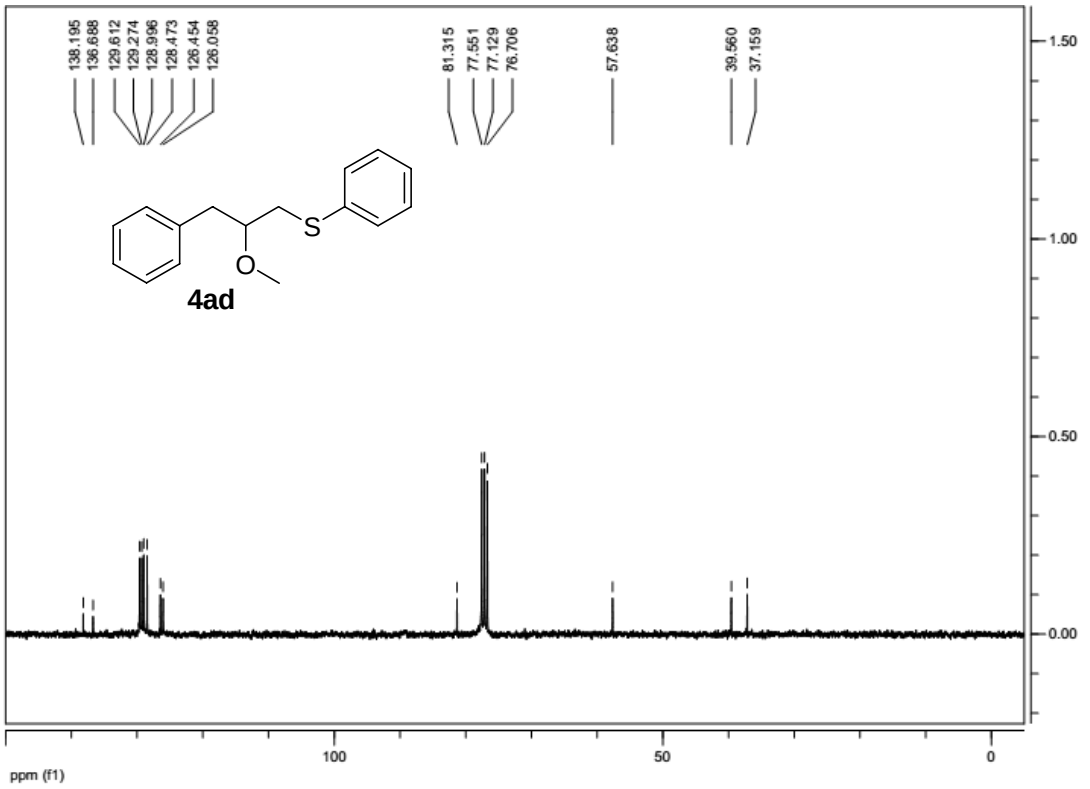
7.311
7.288
7.283
7.275
7.271
7.252
7.246
7.227
7.203
7.188
7.165
3.614
3.595
3.575
3.555
3.535
3.350
3.041
3.028
3.022
3.009
2.950
2.930
S
O
4ad
10.09
1.07
3.00
2.02
2.04
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)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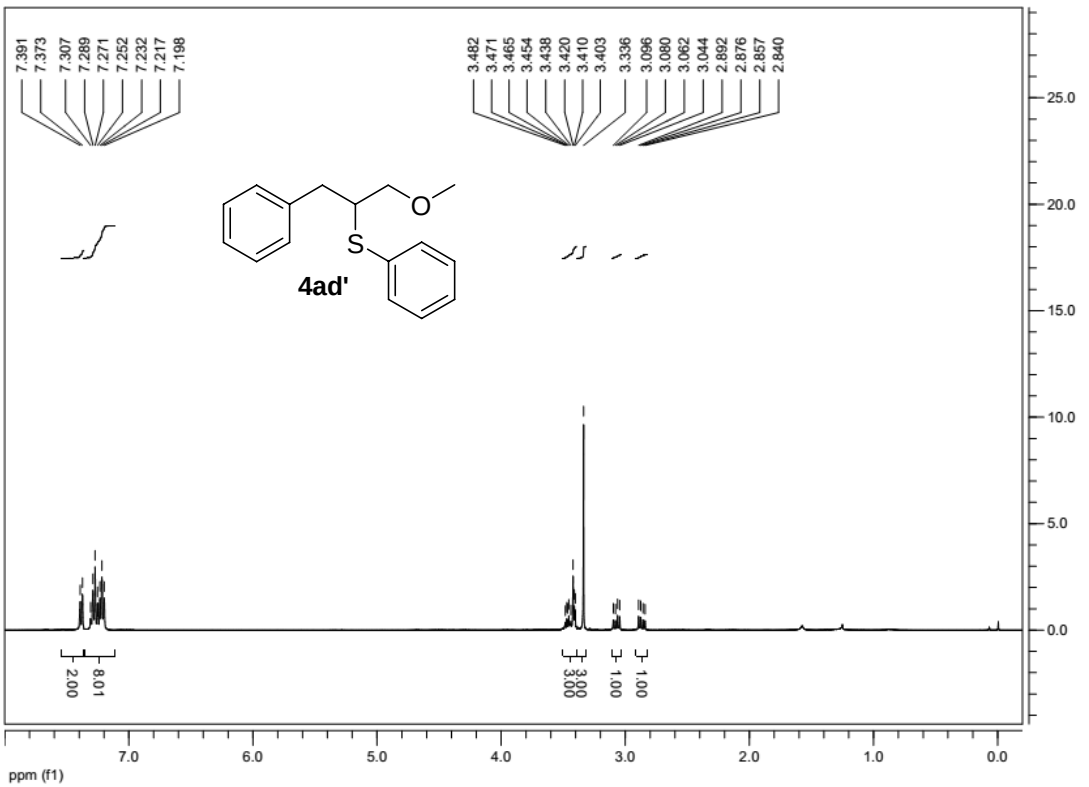
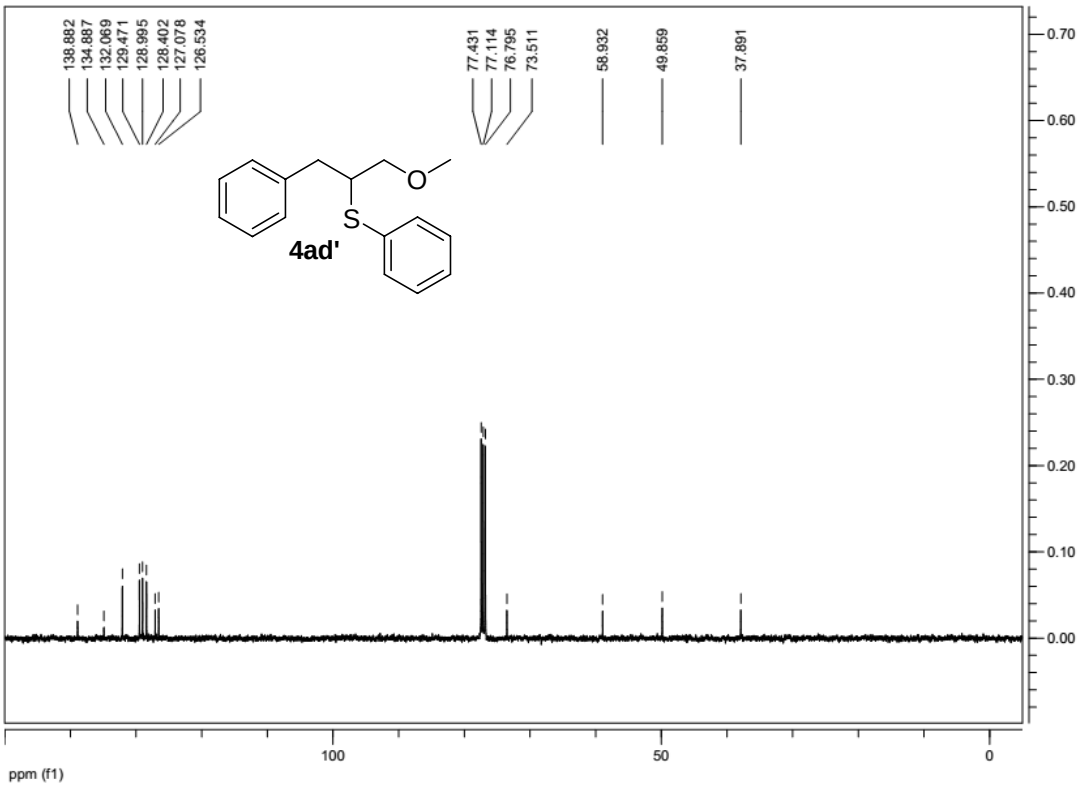
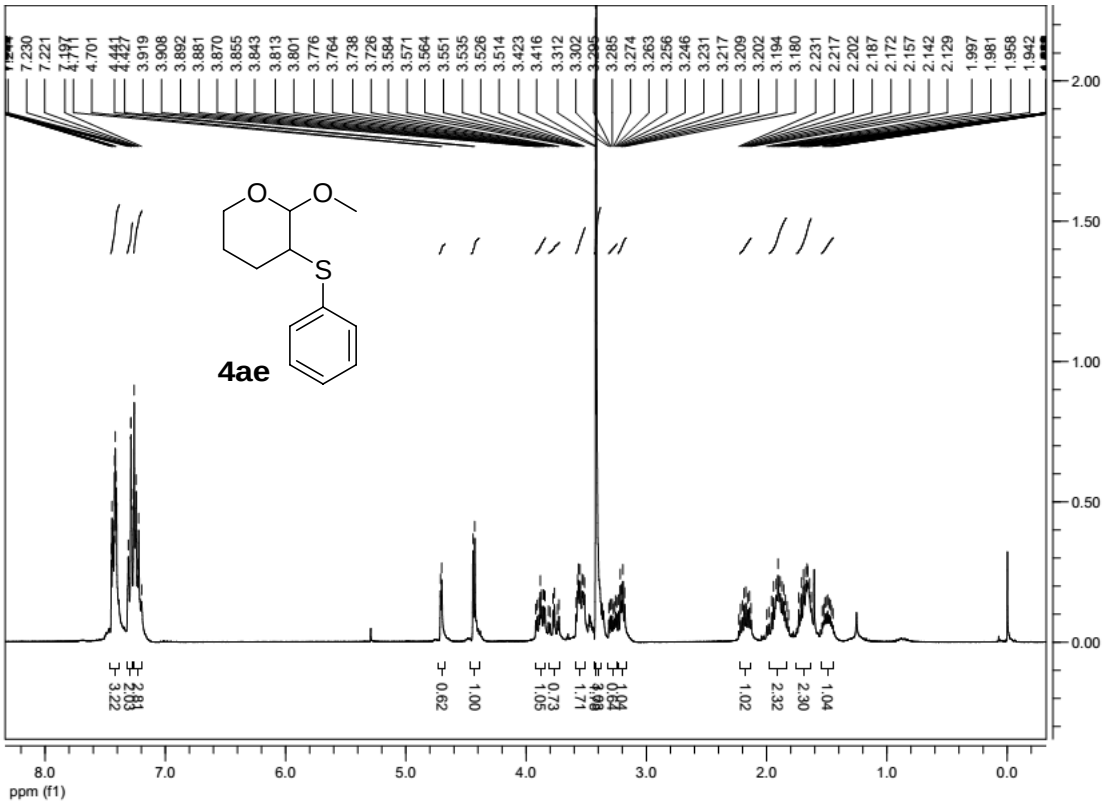
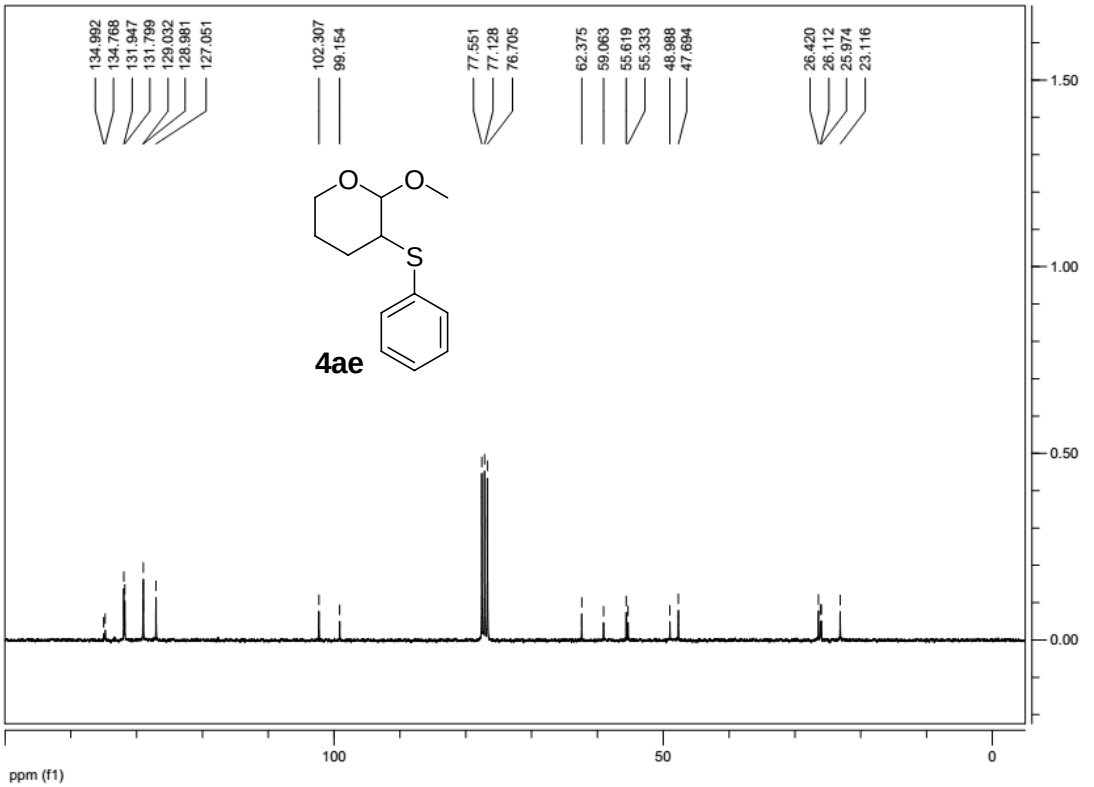
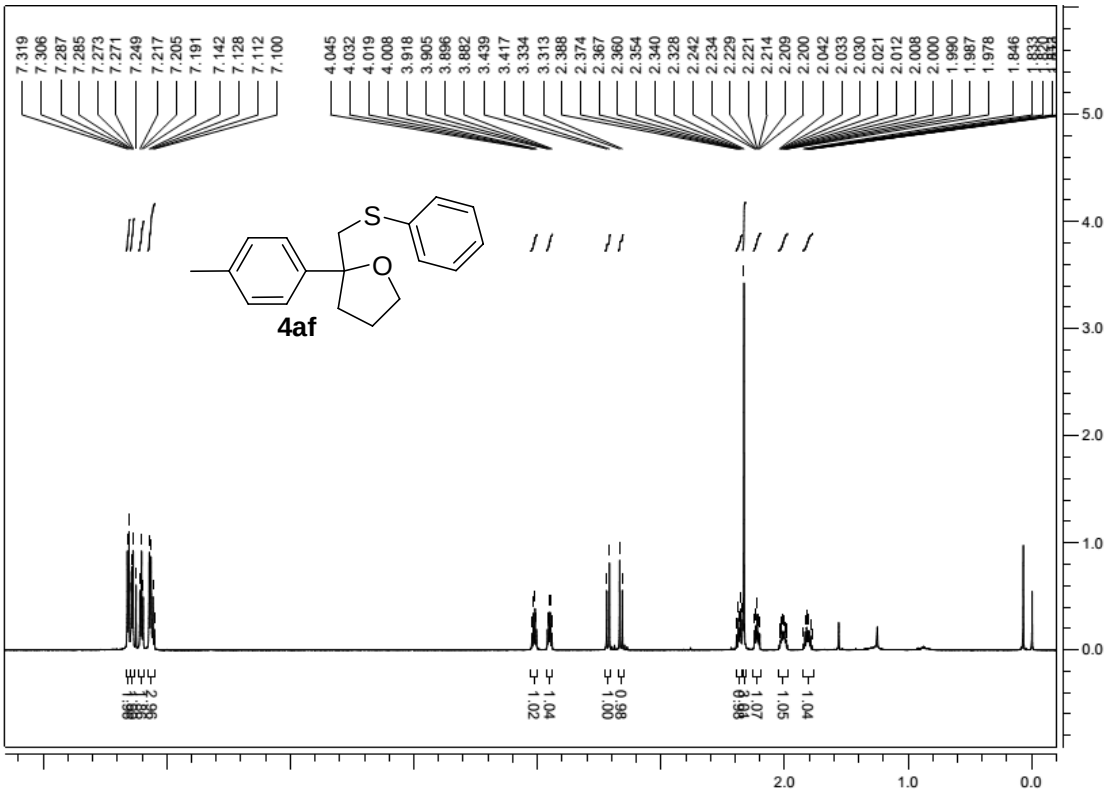
136.688
129.612
129.274
128.996
128.473
126.454
126.058
81.315
77.551
77.129
76.706
57.638
39.560
37.159
S
O
4ad
100
50
0
ppm (f1)


7.391
7.373
7.307
7.289
7.271
7.252
7.232
7.217
7.198
3.482
3.471
3.465
3.454
3.438
3.420
3.410
3.403
3.336
3.096
3.080
3.062
3.044
2.892
2.876
2.857
2.840
O
S
4ad'
2.00
8.01
3.00
1.00
1.00
ppm (f1)


138.882
134.887
132.069
129.471
128.995
128.402
127.078
126.534
77.431
77.114
76.795
73.511
58.932
49.859
37.891
O
S
4ad'
ppm (f1)


4ae
ppm (f1)


4ae
ppm (f1)


7.319
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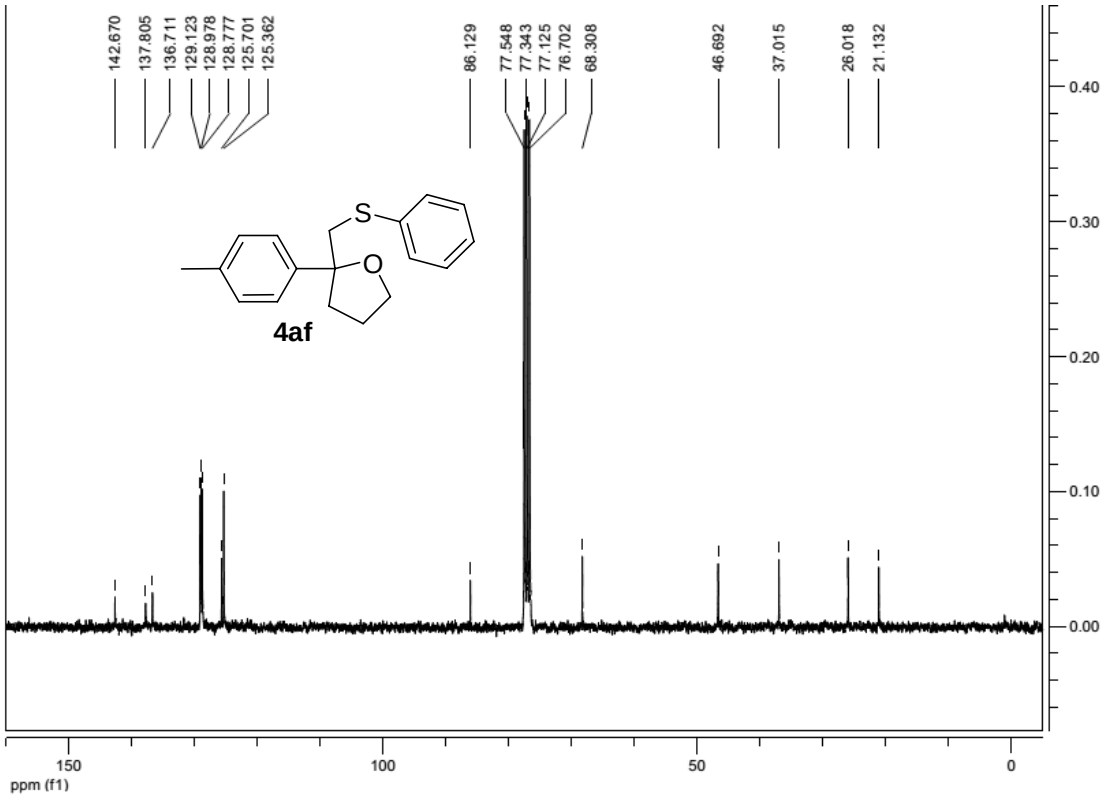
7.287
7.285
7.273
7.271
7.249
7.217
7.205
7.191
7.142
7.128
7.112
7.100
4.045
4.032
4.019
4.008
3.918
3.905
3.896
3.882
3.439
3.417
3.334
3.313
2.388
2.374
2.367
2.360
2.354
2.340
2.328
2.242
2.234
2.229
2.221
2.214
2.209
2.200
2.042
2.033
2.030
2.021
2.012
2.008
2.000
1.990
1.987
1.978
1.846
S
O
4af
5.0
4.0
3.0
2.0
1.0
0.0
2.0
1.0
0.0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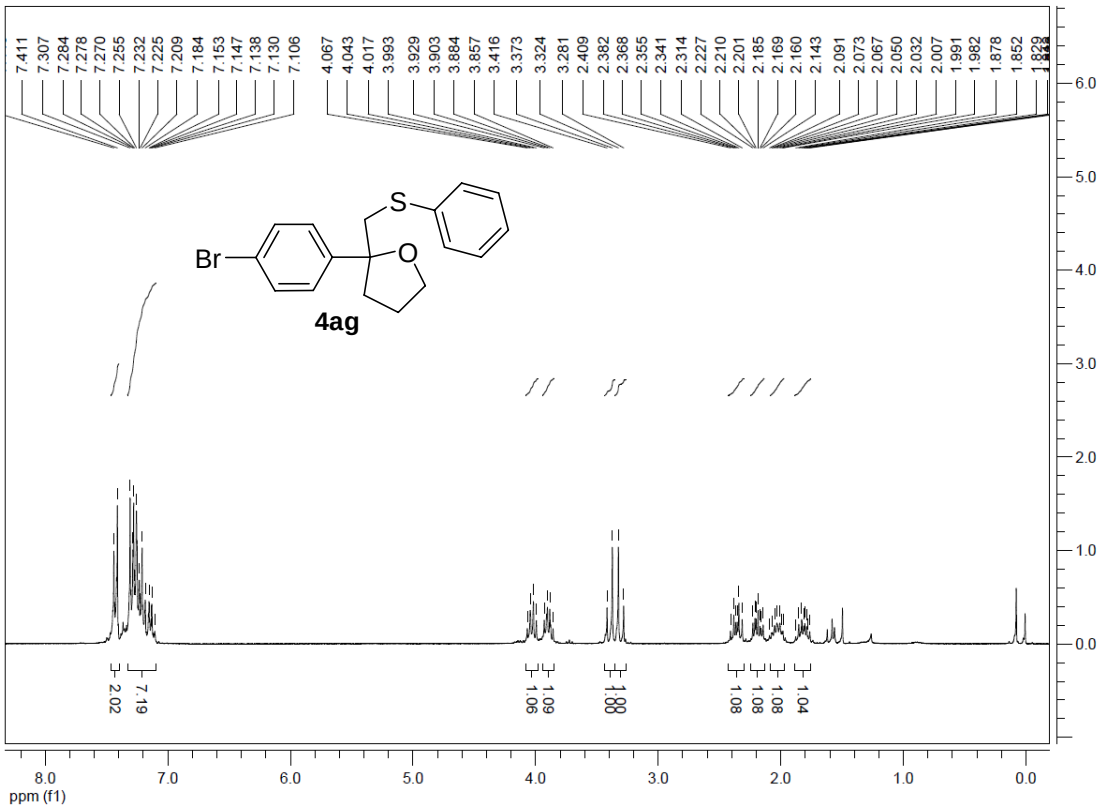
128.978
128.777
125.701
125.362
86.129
77.548
77.343
77.125
76.702
68.308
46.692
37.015
26.018
21.132
S
O
4af
0.40
0.30
0.20
0.10
0.00
150
100
50
0
ppm (f1)


7.411
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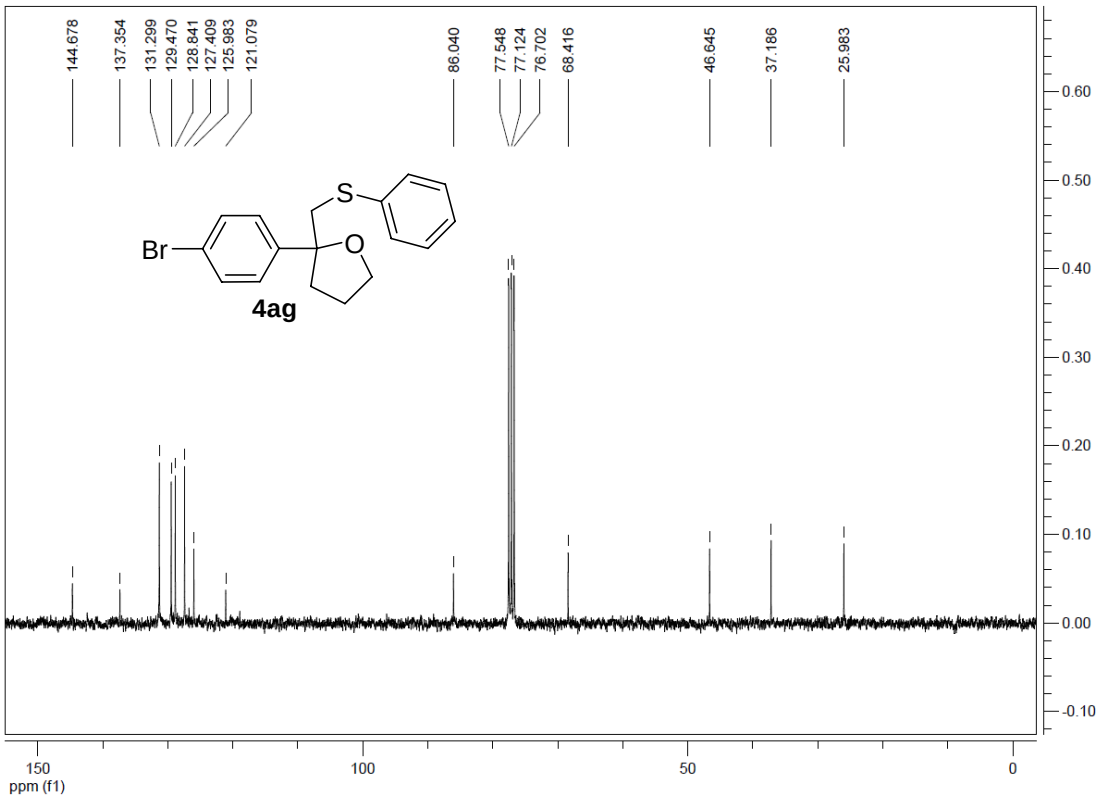
7.270
7.255
7.232
7.225
7.209
7.184
7.153
7.147
7.138
7.130
7.106
4.067
4.043
4.017
3.993
3.929
3.903
3.884
3.857
3.416
3.373
3.324
3.281
2.409
2.382
2.368
2.355
2.341
2.314
2.227
2.210
2.201
2.185
2.169
2.160
2.143
2.091
2.073
2.067
2.050
2.032
2.007
1.991
1.982
1.878
1.852
Br
O
S
4ag
2.02
2.19
1.06
1.06
1.00
1.01
1.08
1.08
1.04
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)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127.409
125.983
121.079
86.040
77.548
77.124
76.702
68.416
46.645
37.186
25.983
Br
O
S
4ag
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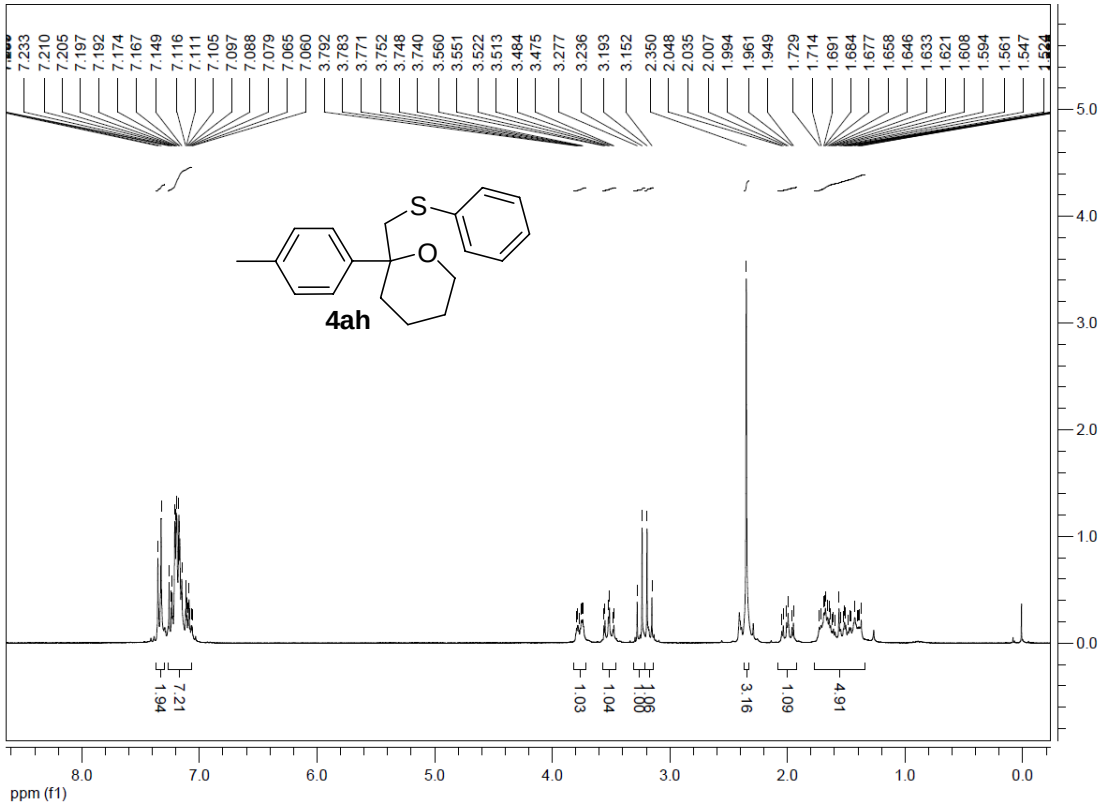
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
150
100
50
0
ppm (f1)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7.149
7.116
7.111
7.105
7.097
7.088
7.079
7.065
7.060
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3.783
3.771
3.752
3.748
3.740
3.560
3.551
3.522
3.513
3.484
3.475
3.277
3.236
3.193
3.152
2.350
2.048
2.035
2.007
1.994
1.961
1.949
1.729
1.714
1.691
1.684
1.677
1.658
1.646
1.633
1.621
1.608
1.594
1.561
1.547
S
O
4ah
1.94
7.21
1.03
1.04
1.06
3.16
1.09
4.91
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7.0
6.0
5.0
4.0
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2.0
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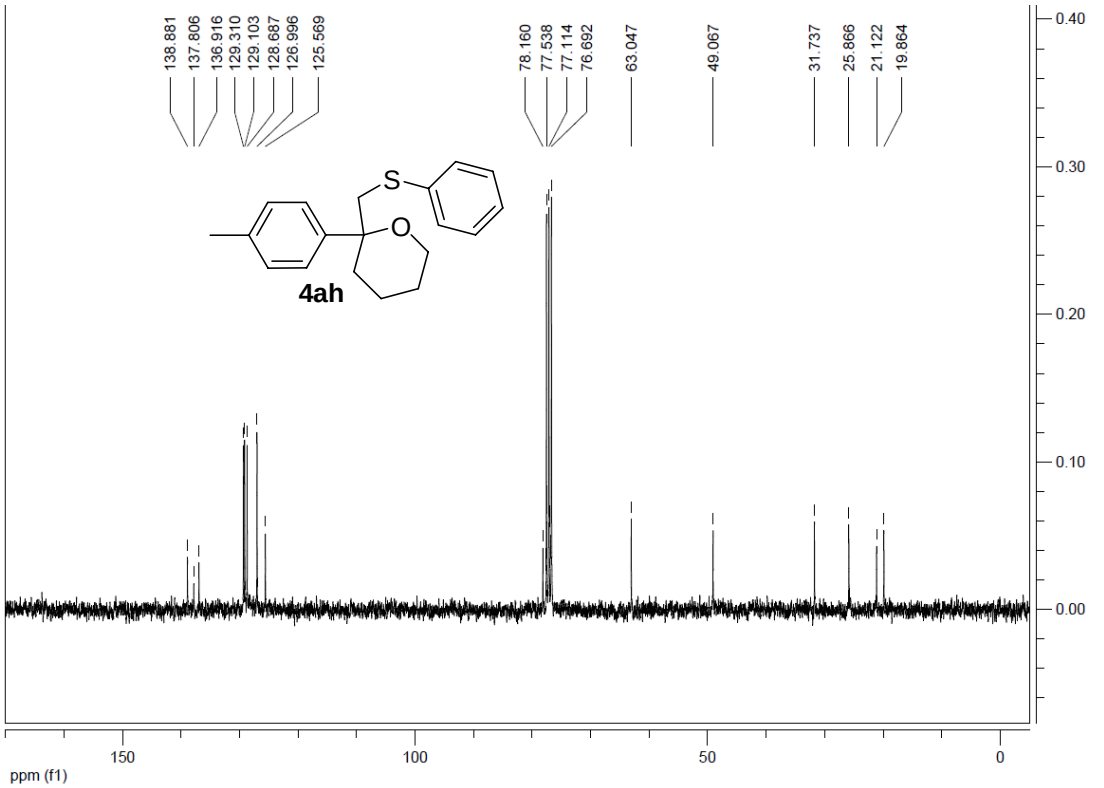
0.0
ppm (f1)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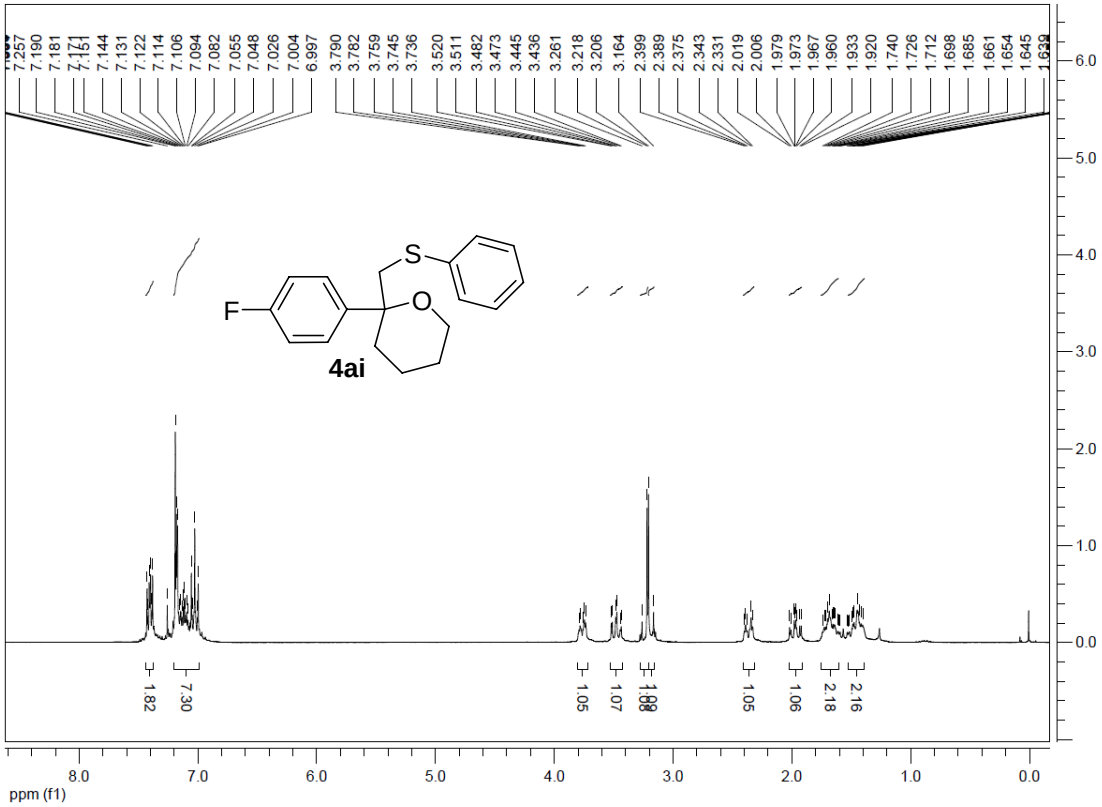
129.103
128.687
126.996
125.569
78.160
77.538
77.114
76.692
63.047
49.067
31.737
25.866
21.122
19.864
S
O
4ah
0.40
0.30
0.20
0.10
0.00
150
100
50
0
ppm (f1)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7.131
7.122
7.114
7.106
7.094
7.082
7.055
7.048
7.026
7.004
6.997
3.790
3.782
3.759
3.745
3.736
3.520
3.511
3.482
3.473
3.445
3.436
3.261
3.218
3.206
3.164
2.399
2.389
2.375
2.343
2.331
2.019
2.006
1.979
1.973
1.967
1.960
1.933
1.920
1.740
1.726
1.712
1.698
1.685
1.661
1.654
1.645
S
F
O
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7.30
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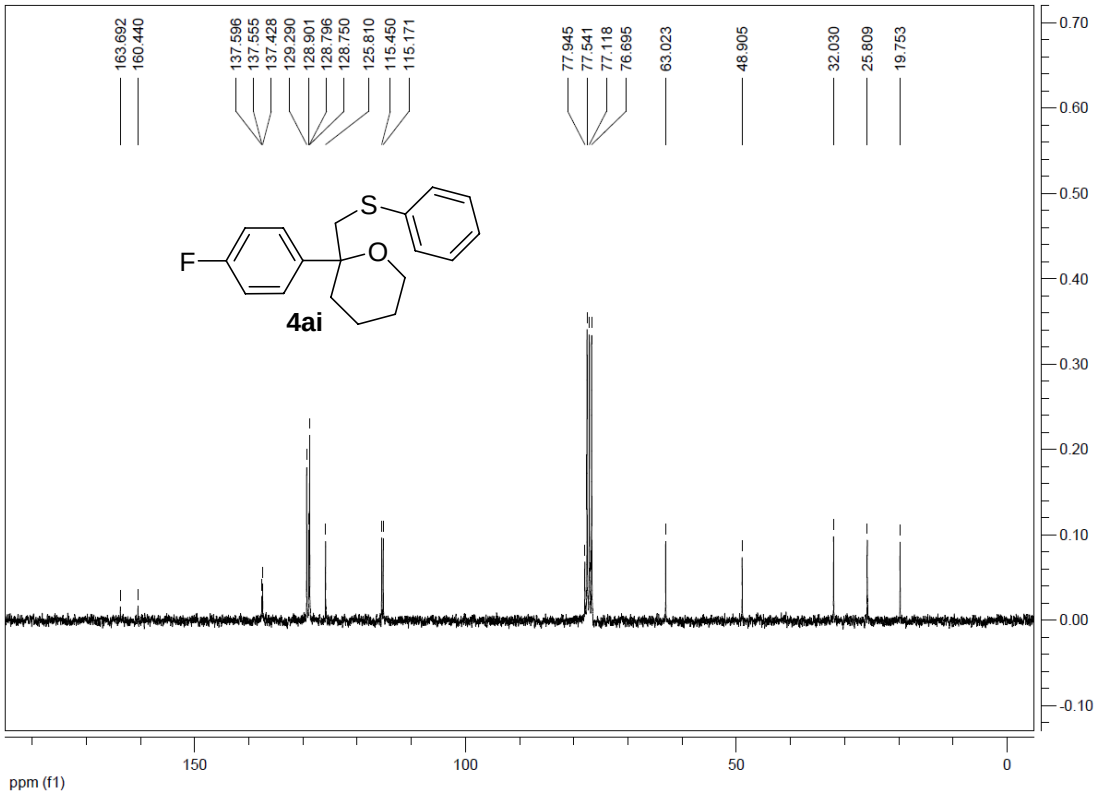
1.07
1.05
1.06
2.18
2.16
ppm (f1)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137.555
137.428
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128.796
128.750
125.810
115.450
115.171
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77.541
77.118
76.695
63.023
48.905
32.030
25.809
19.753
S
F
O
4ai
ppm (f1)