Aerobic Thiyl Radical Addition/Cyclization of N-Methacryloyl Benzamides for the Synthesis of Isoquinoline-1,3(*2H*,*4H*)-dione Derivatives

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Contents

(A) General information:

All reagents were purchased from commercial suppliers and used without further purification. All of the thiols were supplied from Zhejiang Yangfan New Materials Co., Ltd. (www.shoufu.com) and the purity of all the thiols is more than 99%. All experiments were carried out under room temperature. Flash chromatography was carried out with Merck silica gel 60 (63-200 mesh). Analytical TLC was performed with Merck silica gel 60 F_{254} plates. ^{1}H NMR and ^{13}C NMR (300 MHz and 75 MHz, respectively) spectra were recorded in $CDCl_3$. Chemical shifts (δ) are reported in ppm using TMS as internal standard, and spin-spin coupling constants (*J*) are given in Hz.

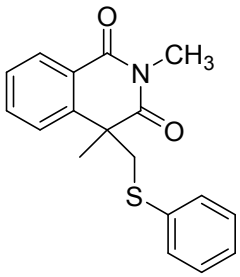
(B) Experimental section

General procedure for synthesis of N-methyl benzamide: A 100-mL round bottom flask was charged with methylamine hydrochloride (15 mmol), K_2CO_3 (20 mmol) in Ethyl acetate (20 mL) and H_2O (10 mL) and benzoyl chloride (10mmol) was added slowly to the reaction mixture at 0 ^{0}C. After that, the residue was stirred at room temperature for 4-6 h. The reaction was completed by TLC monitoring, the organic phase was separated, dried over $MgSO_4$, and concentrated under vacuum. The resulting residue was purified by flash silica gel column chromatography (eluent: hexane/EtOAc, v/v = 1/1) to afford the desired products with **95**% yield.

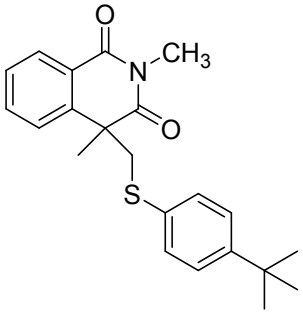
General procedure for synthesis of N-methacryloyl-N-methylbenzamide: A 100-mL round bottom flask was charged with N-methyl benzamide (10 mmol), DMAP (1 mmol), triethylamine (20 mmol) in dichloromethane (20 mL) and methacryloyl chloride (15 mmol) was added slowly to the reaction mixture at 0 ^{0}C. After that, the residue was stirred at room temperature for 4-6 h. The reaction was completed by TLC monitoring, the organic phase was separated, dried over $MgSO_4$, and concentrated under vacuum. The resulting residue was purified by flash silica gel column chromatography (eluent: hexane/EtOAc, v/v = 10/1) to afford the desired products with **75**% yield.

Typical procedure for synthesis of Sulfide-Containing 4,4-Disubstituted isoquinoline-1,3-diones: A 15-mL Schlenk tube was charged with N-methacryloyl-N-methylbenzamide (0.5mmol), thiol (0.6 mmol), $TsOH\cdot H_2O$ (20 mol %) in Dichloroethane (2 mL). The resultant mixture was stirred at 60 °C for 12 h under oxygen balloon. After the reaction was completed by TLC monitoring, the reaction mixture was cooled to room temperature, received in H_2O (20 mL) and washed with ethyl acetate (3 x 20 mL). The organic phase was separated, dried over $MgSO_4$, and concentrated under vacuum. The resulting residue was purified by flash silica gel column chromatography (eluent: hexane/EtOAc, v/v = 10/1) to afford the desired products.

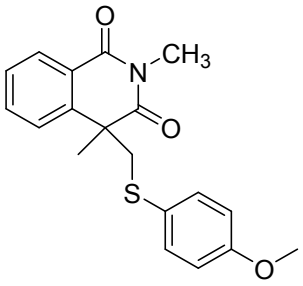
(C) Spectra Analytical data for products：



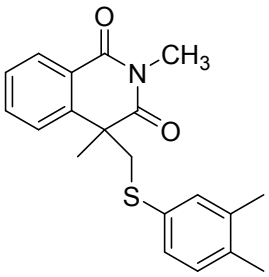
2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3aa): Isolated yield = 89% (138.4 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.25-8.22 (m, 1H), 7.42-7.37 (m, 1H), 7.30-7.26 (m, 1H), 7.33-7.22 (m, 1H), 7.12 (br, 5H), 3.85 (d, J = 13.0 Hz, 1H), 3.40 (d, J = 13.0 Hz, 1H), 3.22 (s, 3H), 1.69 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.2, 164.3, 141.5, 134.8, 133.8, 131.0, 128.7, 127.8, 126.9, 125.5, 48.7, 47.6, 28.4, 27.1. LRMS (EI) m/z: 310.95, 122.95 (100), 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{18}NO_2S$ $(M+H)^+$: 312.1058, found 312.1054.



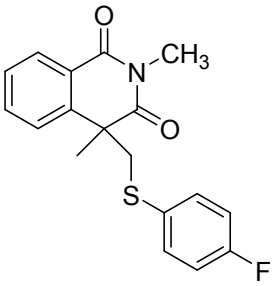
4-(((4-(tert-butyl)phenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ab): Isolated yield = 82% (150.7 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.22 (d, J = 8.2 Hz, 1H), 7.51-7.32 (m, 2H), 7.25 (d, J = 5.1 Hz, 1H), 7.14 (d, J = 8.2 Hz, 2H), 7.02 (d, J = 8.2 Hz, 2H), 3.81 (d, J = 13.2 Hz, 1H), 3.37 (d, J = 13.1 Hz, 1H), 3.21 (s, 3H), 1.68 (s, 3H), 1.26 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.2, 164.3, 150.2, 141.6, 133.6, 131.3, 131.0, 128.7, 127.7, 125.8, 125.6, 125.5, 48.8, 47.9, 34.5, 31.2, 28.5, 27.1. LRMS (EI) m/z: 367.10, 179.10 (100), 123.05, 91.05, 57.10, 41.05. HRMS (ESI+) *m/z* calculated for $C_{22}H_{26}NO_2S$ $(M+H)^+$: 368.1684, found 368.1680.



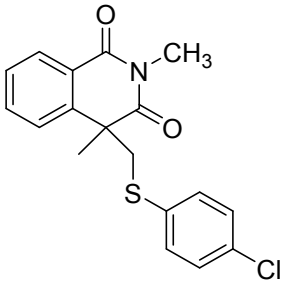
4-(((4-methoxyphenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ac): Isolated yield = 80% (136.6 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, J = 7.6 Hz,, 1H), 7.52-7.47 (m, 1H), 7.39 (t, J = 7.4 Hz, 1H), 7.25 (d, J = 7.5 Hz, 1H), 7.01 (d, J = 8.7 Hz, 2H), 6.66 (d, J = 8.6 Hz, 2H), 3.78 (d, J = 13.3 Hz, 1H), 3.73 (s, 3H), 3.32 (d, J = 13.2 Hz, 1H), 3.24 (s, 3H), 1.64 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.2, 164.3, 159.2, 141.8, 134.0, 133.7, 128.7, 127.7, 125.6, 125.2, 114.4, 55.3, 48.9, 28.8, 27.1. LRMS (EI) m/z: 341.00, 153.00 (100), 138.00, 109.10, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{20}NO_3S$ $(M+H)^+$: 342.1164, found 342.1160.



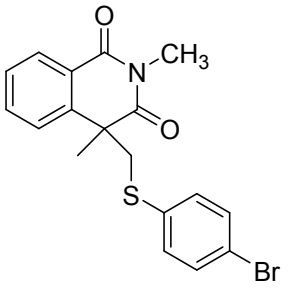
4-(((3,4-dimethylphenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ad): Isolated yield = 80% (135.8 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, J = 7.8 Hz, 1H), 7.50-7.45 (m, 1H), 7.39 (t, J = 7.3 Hz, 1H), 7.27 (d, J = 8.4 Hz, 1H), 6.91-6.85 (m, 2H), 6.79 (s, 1H), 3.80 (d, J = 13.1 Hz, 1H), 3.35 (d, J = 13.0 Hz, 1H), 3.23 (s, 3H), 2.14 (s, 3H), 2.12 (s, 3H), 1.67 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.2, 164.3, 141.7, 137.0, 135.8, 133.6, 132.9, 131.2, 130.1, 129.2, 128.6, 127.6, 125.6, 48.8, 48.2, 28.6, 27.1, 19.6, 19.3. LRMS (EI) m/z: 339.00, 150.95 (100), 107.05, 91.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{20}H_{22}NO_2S$ $(M+H)^+$: 340.1371 found 340.1367.



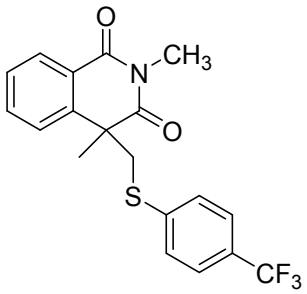
4-(((4-fluorophenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ae): Isolated yield = 86% (141.6 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, J = 8.2 Hz, 1H), 7.49-7.40 (m, 2H), 7.25-7.22 (m, 1H), 7.08-7.03 (m, 2H), 6.82-6.72 (m, 2H), 3.79 (d, J = 13.2Hz, 1H), 3.37 (d, J = 13.6 Hz, 1H), 3.25 (s, 3H), 1.67 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.1, 164.2, 163.7, 160.4, 141.53, 133.8, 133.7, 129.9, 128.8, 127.8, 125.5, 115.9 (d, J = 87.3 Hz), 48.96, 48.46, 28.68, 27.19. LRMS (EI) m/z: 329.00, 140.85 (100), 115.05, 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}FNO_2S$ $(M+H)^+$: 330.0964 found 330.0960.



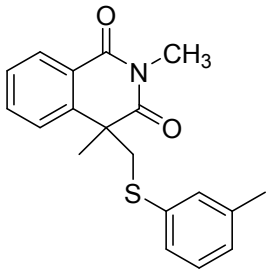
4-(((4-chlorophenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3af): Isolated yield = 80% (138.3 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, J = 7.8 Hz, 1H) 7.52 (t, J = 7.5 Hz, 1H), 7.40 (t, J = 7.5 Hz, 1H), 7.25 (d, J = 7.6 Hz, 1H), 7.09 (d, J = 8.5 Hz, 2H), 7.01 (d, J = 8.5 Hz, 2H), 3.82 (d, J = 13.2 Hz, 1H), 3.39 (d, J = 13.2 Hz, 1H), 3.26 (s, 3H), 1.68 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.1, 164.2, 141.4, 133.8, 133.4, 133.0, 132.4, 128.9, 128.8, 127.8, 125.5, 48.8, 47.7, 28.6, 27.2. LRMS (EI) m/z: 347.00, 345.00, 157.00 (100), 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}ClNO_2S$ $(M+H)^+$: 346.0669 found 346.0665.



4-(((4-bromophenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ag): Isolated yield = 85% (144.2 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, J = 7.5 Hz, 1H), 7.50-7.48 (m, 1H), 7.41-7.38 (m, 1H), 7.25-7.22 (m, 3H), 6.97-6.93 (m, 2H), 3.80 (d, J = 13.2 Hz, 1H), 3.39 (d, J = 13.1 Hz, 1H), 3.25 (s, 3H), 1.69 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.1, 164.2, 141.3, 134.0, 133.8, 132.6, 131.8, 128.8, 127.8, 125.5, 125.4, 121.0, 48.8, 47.5, 28.6, 27.2. LRMS (EI) m/z: 391.90, 389.90, 247.85, 245.85, 202.80, 200.80, 121.95 (100), 75.00, 43.05. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}BrNO_2S$ $(M+H)^+$: 390.0163 found 390.0159.



2,4-dimethyl-4-(((4-(trifluoromethyl)phenyl)thio)methyl)isoquinoline-1,3(2H,4H)-dione (3ah): Isolated yield = 90% (170.7 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.21 (d, J = 7.7 Hz, 1H), 7.46-7.23 (m, 7H), 3.86 (d, J = 13.1 Hz, 1H), 3.47 (d, J = 13.1 Hz, 1H), 3.29 (s, 3H), 1.70 (s, 3H).^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.1, 164.1, 141.1, 136.5, 133.9, 131.2, 129.1, 128.8, 127.9, 127.3, 125.4, 123.5, 121.8, 118.2, 48.8, 47.2, 28.5, 27.1. LRMS (EI) m/z: 378.95, 190.95 (100), 170.95, 115.05, 91.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{17}F_3NO_2S$ $(M+H)^+$: 380.0932 found 380.0928.



2,4-dimethyl-4-((m-tolylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3ai): Isolated yield = 80% (130.1 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, J = 7.8 Hz, 1H), 7.50 - 7.35 (m, 2H), 7.27 (d, J = 7.8 Hz, 1H), 7.05-6.89 (m, 3H), 6.84 (s, 1H), 3.84 (d, J = 13.1 Hz, 1H), 3.38 (d, J = 13.1 Hz, 1H), 3.24 (s, 3H), 2.21 (s, 3H), 1.69 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.2, 164.3, 141.6, 138.5, 134.4, 133.6, 131.8, 128.6, 128.1, 127.7, 125.5, 48.8, 47.7, 28.4, 27.1, 21.1. LRMS (EI) m/z: 325.10, 174.10, 216.00, 173.00, 137.05 (100), 45.05. HRMS (ESI+) *m/z* calculated for $C_{19}H_{20}NO_2S$ $(M+H)^+$: 326.1215 found 326.1211.

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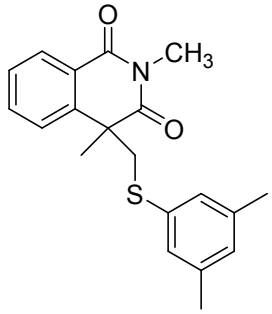
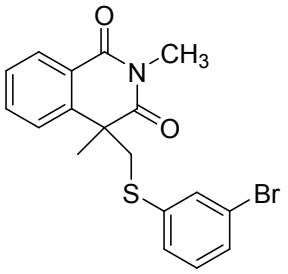
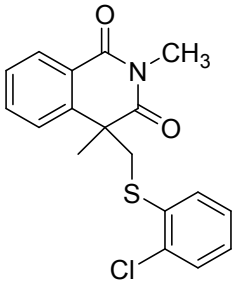


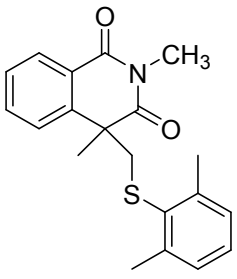
4-(((3,5-dimethylphenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3aj) : Isolated yield = 76% (128.9 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.24 (d, J = 7.8 Hz, 1H), 7.40 (t, J = 7.5 Hz, 1H), 7.38 (t, J = 7.4 Hz, 1H), 7.27 (d, J = 7.9 Hz, 1H), 6.73 (s, 1H), 6.68 (s, 2H), 3.82 (d, J = 13.0 Hz, 1H), 3.37 (d, J = 13.0 Hz, 1H), 3.26 (s, 3H), 2.18 (s, 6H), 1.69 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.3, 164.4, 141.6, 138.3, 134.1, 133.6, 128.9, 128.8, 128.5, 127.6, 125.6, 113.1, 48.8, 47.7, 28.4, 27.1, 21.1. LRMS (EI) m/z: 339.05, 151.00 (100), 107.10, 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{20}H_{22}NO_2S$ $(M+H)^+$: 340.1371 found 340.1367.



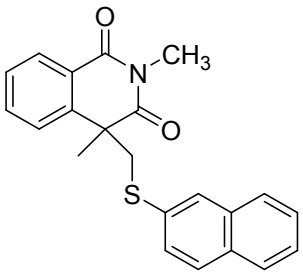
4-(((3-bromophenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ak): Isolated yield = 78% (152.2 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.22 (d, J = 7.5 Hz, 1H), 7.46 - 7.36 (m, *2*H), 7.26-7.20 (m, 2H), 7.15 (s, 1H), 7.07-6.94 (m, 2H), 3.82 (d, J = 13.1 Hz, 1H), 3.41 (d, J = 13.1 Hz, 1H), 3.30 (s, 3H), 1.70 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.1 164.2, 141.2, 137.2 133.7, 133.3, 130.0, 129.9, 129.4, 128.8, 128.0, 125.5, 125.4, 122.4, 48.8, 47.4, 28.5, 27.2. LRMS (EI) m/z: 390.85, 388.85, 202.85, 200.90, 122.00 (100), 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}BrNO_2S$ $(M+H)^+$: 390.0163 found 390.0159.



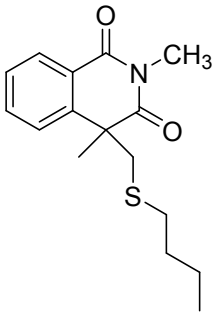
4-(((2-chlorophenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3al): Isolated yield = 70% (121.0 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.221 (d, J = 7.4 Hz, 1H), 7.45-7.22 (m, 4H), 7.09-7.00 (m, 3H), 3.81 (d, J = 13.2 Hz, 1H), 3.52 (d, J = 13.1 Hz, 1H), 3.30 (s, 3H), 1.68 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.0, 164.2, 141.4, 136.1, 133.7, 133.5, 132.8, 129.7, 128.8, 128.2, 127.8, 126.9, 125.4, 125.3, 48.8, 45.7, 29.2, 27.2. LRMS (EI) m/z: 345.00, 156.95 (100), 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}ClNO_2S$ $(M+H)^+$: 346.0669 found 346.0665.



4-(((2,6-dimethylphenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3am): Isolated yield = 65% (110.3 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.27 (d, J = 7.8 Hz, 1H), 7.56 (t, J = 7.6 Hz, 1H), 7.44 (t, J = 7.5 Hz, 1H), 7.33 (d, J = 7.8 Hz, 1H), 7.03-6.95 (m, 3H), 3.61 (d, J = 12.2 Hz, 1H), 3.34 (s, 3H), 3.23 (d, J = 12.2 Hz, 1H), 2.24 (s, 6H), 1.61 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.2, 164.3, 142.5, 142.0, 133.9, 132.8, 128.9, 128.3, 128.0, 127.8, 125.3, 125.2, 48.6, 46.2, 29.9, 27.2, 21.6. LRMS (EI) m/z: 339.00, 151.00 (100), 105.05, 91.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{20}H_{22}NO_2S$ $(M+H)^+$: 340.1370 found 340.1366.

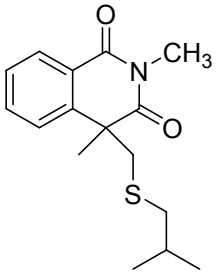


2,4-dimethyl-4-((naphthalen-2-ylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3an): Isolated yield = 52% (93.9 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.24 (d, J = 7.7 Hz, 1H), 7.71 (br, 1H), 7.63 (d, J = 8.0 Hz, 2H), 7.52-7.34 (m, 4H), 7.27 (dt, J = 11.6, 8.4 Hz, 3H), 3.95 (d, J = 13.1 Hz, 1H), 3.47 (d, J = 13.1 Hz, 1H), 3.18 (s, 3H), 1.71 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.2, 164.3, 141.5, 133.7, 133.4, 132.1, 129.8, 128.7, 128.5, 128.4, 127.7, 127.6, 127.3, 126.5, 126.1, 125.5, 48.8, 47.3, 28.5, 27.1. LRMS (EI) m/z: 360.90, 215.95, 172.90 (100), 160.00, 129.05, 114.95, 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{22}H_{20}NO_2S$ $(M+H)^+$: 362.1215 found 362.1211.

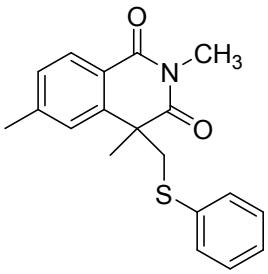


4-((butylthio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ao): Isolated yield = 78% (113.6 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ : 8.26 (d, J = 7.6 Hz, 1H), 7.63 (t, J = 7.5 Hz, 1H), 7.48-7.40 (m, 2H), 3.40 (s, 3H), 3.32 (2, J = 13.6 Hz, 1H), 3.08 (d, J = 13.5 Hz, 1H), 2.11 (t, J =

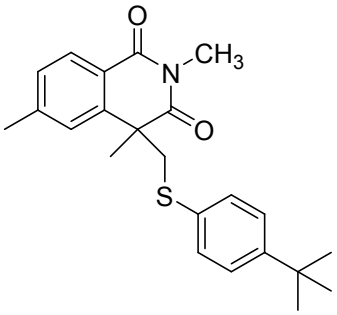
7.2 Hz, 2H), 1.68 (s, 3H), 1.37-1.15 (m, 4H), 0.79 (t, J = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.7, 164.4, 142.2, 133.8, 128.8, 127.7, 125.5, 125.4, 49.1, 45.0, 33.2, 31.6, 28.2, 27.2, 21.7, 13.6. LRMS (EI) m/z: 291.05, 103.05 (100), 61.05. HRMS (ESI+) *m/z* calculated for $C_{16}H_{22}NO_2S$ $(M+H)^+$: 292.1371 found 292.1367.



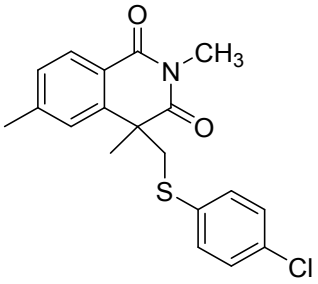
4-((isobutylthio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3ap): Isolated yield = 75% (109.2 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.26 (d, J = 7.5 Hz, 1H), 7.63 (t, J = 7.6 Hz, 1H), 7.48-7.40 (m, 2H), 3.40 (s, 3H), 3.30 (2, J = 13.2 Hz, 1H), 3.04 (d, J = 13.3 Hz, 1H),, 2.06-1.94 (m, 2H), 1.67 (s, 3H), 1.59-1.48 (m, 1H), 0.79 (dd, J = 6.5, 4.5 Hz, 6H).^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.6, 164.4, 142.2, 133.8, 128.8, 127.7, 125.6, 125.4, 49.1, 45.6, 42.7, 28.5, 28.1, 27.2, 21.7. LRMS (EI) m/z: 291.05, 103.05 (100), 91.05, 57.10, 41.05. HRMS (ESI+) *m/z* calculated for $C_{16}H_{22}NO_2S$ $(M+H)^+$: 292.1371 found 292.1367.



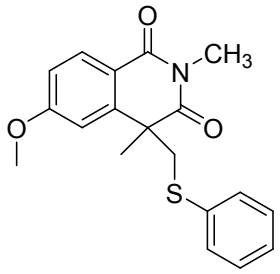
2,4,6-trimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3ba): Isolated yield = 82% (133.4 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.10 (d, J = 7.8 Hz, 1H), 7.18-7.01(m, 7H), 3.84 (d, J = 13.2 Hz, 1H), 3. 40 (d, J = 13.2 Hz, 1 H), 3.22 (s, 3H), 2.30 (s, 3H), 1.67 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.4, 164.3, 144.6, 141.4, 135.0, 131.1, 131.0, 128.8, 128.7, 126.8, 126.0, 123.0, 48.9, 47.5, 28.5, 27.1, 21.8. LRMS (EI) m/z: 324.95, 122.95 (100), 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{20}NO_2S$ $(M+H)^+$: 326.1215 found 326.1211.



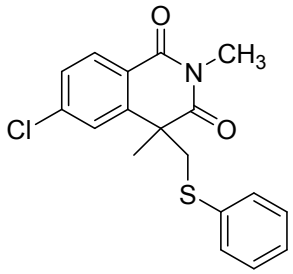
4-(((4-(tert-butyl)phenyl)thio)methyl)-2,4,6-trimethylisoquinoline-1,3(2H,4H)-dione (3bb): Isolated yield = 78% (148.7 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.10 (d, J = 8.6 Hz, 1H), 7.14 (d, J = 8.3 Hz, 3H), 7.02-6.95 (m, 3H), 3.81 (d, J = 13.2 Hz, 1H), 3.37 (d, J = 13.2 Hz, 1H), 3.22 (s, 3H), 2.29 (s, 3H), 1.65 (s, 3H), 1.25 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.4, 164.4, 150.0, 144.5, 141.6, 131.3, 131.2, 128.7, 126.1, 125.7, 123.0, 114.8, 48.9, 47.8, 34.4, 31.2, 28.5, 27.0, 21.9. LRMS (EI) m/z: 381.10, 179.10, 123.05, 57.10 (100). HRMS (ESI+) *m/z* calculated for $C_{23}H_{28}NO_2S$ $(M+H)^+$: 382.1841 found 382.1837.



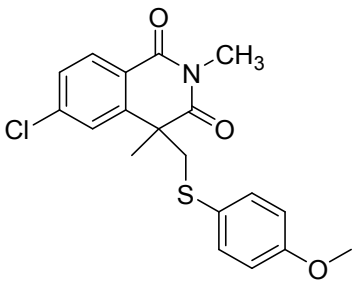
4-(((4-chlorophenyl)thio)methyl)-2,4,6-trimethylisoquinoline-1,3(2H,4H)-dione (3bc): Isolated yield = 76% (136.7 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.09 (d, J = 7.9 Hz, 1H), 7.25-7.15 (m, 1H), 7.06 (d, J = 8.5 Hz, 2H), 7.02-6.84 (m, 3H), 3.80 (d, J = 13.2 Hz, 1H), 3.38 (d, J = 13.3 Hz, 1H), 3.27 (s, 3H), 2.28 (s, 3H), 1.64 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.3, 164.2, 144.6, 141.2, 133.6, 133.0, 132.6, 132.4, 128.8, 128.7, 126.0, 122.9, 49.0, 47.7, 28.7, 27.1, 21.7. LRMS (EI) m/z: 358.95, 157.00 (100), 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{19}ClNO_2S$ $(M+H)^+$: 360.0825 found 360.0821.



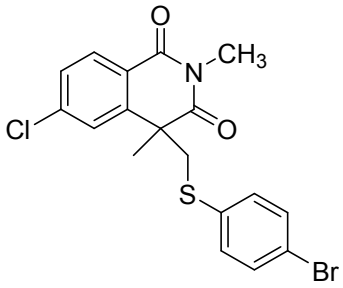
6-methoxy-2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3bd): Isolated yield = 82% (139.9 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.17 (d, J = 8.8 Hz, 1H), 7.12 (br, 5H), 6.87 (dd, J = 2.1 Hz, J = 8.8 Hz, 1H), 6.66 (d, J = 2.1 Hz, 1H), 3.86 (d, J = 13.2 Hz, 1H), 3.76 (s, 3H), 3.37 (d, J = 13.2 Hz, 1H), 3.22 (s, 3H), 1.66 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.3, 163.9, 143.7, 135.0, 131.2, 131.0, 128.7, 126.8, 118.5, 113.6, 110.7, 55.4, 49.1, 47.6, 28.6, 27.0. LRMS (EI) m/z: 341.05, 123.05 (100), 103.00, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{20}NO_3S$ $(M+H)^+$: 342.1164 found 342.1160.



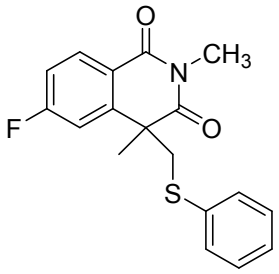
6-chloro-2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3be): Isolated yield = 76% (131.4 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.14 (d, J = 8.4 Hz, 1H), 7.38-7.28 (m, 1H), 7.20 (d, J = 1.4 Hz, 1H), 7.17-7.03 (m, 4H), 3.83 (d, J = 13.4 Hz, 1H), 3.36 (d, J = 13.4 Hz, 1H), 3.22 (s, 3H), 1.67 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.6, 163.5, 143.1, 140.3, 134.3, 131.1, 130.2, 128.8, 128.4, 127.2, 126.0, 124.0, 49.1, 47.5, 28.2, 27.2. LRMS (EI) m/z: 344.95, 123.95 (100), 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}ClNO_2S$ $(M+H)^+$: 346.0669 found 346.0665.



6-chloro-4-(((4-methoxyphenyl)thio)methyl)-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3bf): Isolated yield = 72% (135.2 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.15 (d, J = 8.4 Hz, 1H), 7.32 (dd, J = 1.8 Hz, J = 8.4 Hz, 1H), 7.14 (d, J = 1.6 Hz, 1H), 6.99 (d, J = 8.7 Hz, 2H), 6.65 (d, J = 8.7 Hz, 2H), 3.80 (d, J = 13.1 Hz, 1H), 3.75 (s, 3H), 3.30 (d, J = 13.1 Hz, 1H), 3.26 (s, 3H), 1.63 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.7, 163.5, 159.2, 143.3, 140.3, 134.0, 130.2, 128.3, 126.1, 124.8, 124.0, 114.5, 55.3, 49.3, 48.6, 28.7, 28.7, 27.2. LRMS (EI) m/z: 374.95, 153.05 (100), 137.95, 109.05, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{19}ClNO_3S$ $(M+H)^+$: 376.0774 found 376.0770.

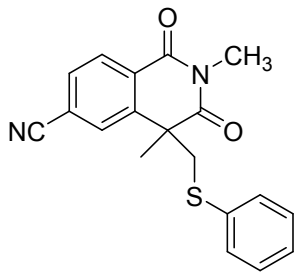


4-(((4-bromophenyl)thio)methyl)-6-chloro-2,4-dimethylisoquinoline-1,3(2H,4H)-dione (3bg): Isolated yield = 79% (167.7 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.13 (d, J = 8.4 Hz, 1H), 7.34 (dd, J = 1.5 Hz, J = 8.4 Hz, 1H), 7.24 (d, J = 8.4 Hz, 2H), 7.16 (d, J = 1.6 Hz, 1H), 6.93 (d, J = 8.4 Hz, 2H), 3.80 (d, J = 13.2 Hz, 1H), 3.36 (d, J = 13.2 Hz, 1H), 3.26 (s, 3H), 1.67 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.5, 163.4, 142.9, 140.4, 133.6, 132.7, 131.9, 130.3, 128.9, 126.0, 124.0, 121.4, 49.18, 47.51, 28.40, 27.27. LRMS (EI) m/z: 424.85, 422.85, 202.85, 200.85, 122.05 (100), 108.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{16}BrClNO_2S$ $(M+H)^+$: 423.9774 found 423.9770.

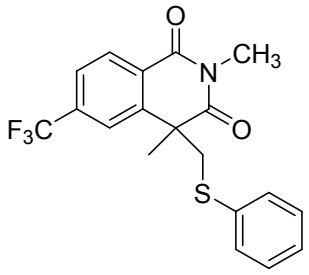


6-fluoro-2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3bh): Isolated yield = 75% (123.5 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (dd, J = 2.1 Hz, J = 6.1 Hz, 1H),

7.13-7.03 (m, 6H), 6.92 (dd, J = 2.1 Hz, J = 9.0 Hz, 1H), 3.84 (d, J = 12.9 Hz, 1H), 3.34 (d, J = 12.9 Hz, 1H), 3.22 (s, 3H), 1.68 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.7, 167.8, 164.4, 163.4, 144.6, 134.4, 131.8, 131.1, 128.8, 127.1, 115.7, 112.6, 49.2, 47.6, 28.3, 27.1. LRMS (EI) m/z: 329.05, 123.05 (100), 109.00, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}FNO_2S$ $(M+H)^+$: 330.0964 found 330.0960.



2,4-dimethyl-1,3-dioxo-4-((phenylthio)methyl)-1,2,3,4-tetrahydroisoquinoline-6-carbonitrile (3bi): Isolated yield = 72% (121.1 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.30 (d, J = 8.1 Hz, 1H), 7.56 (dd, J = 0.9 Hz, J = 9.0 Hz, 1H), 7.47 (s, 1H), 7.14-7.12 (m, 3H), 7.04-7.02 (m, 2H), 3.87 (d, J = 13.5 Hz, 1H), 3.38 (d, J = 13.4 Hz, 1H), 3.26 (s, 3H), 1.70 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.1, 162.8, 162.87, 142.3, 134.1, 131.2, 130.8, 130.1, 129.4, 129.0, 128.8, 127.5, 117.4, 117.0, 49.2, 47.6, 28.1, 27.5, 27.4. LRMS (EI) m/z: 336.05, 123.00 (100), 109.00, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{17}N_2O_2S$ $(M+H)^+$: 337.1011 found 337.1007.



2,4-dimethyl-4-((phenylthio)methyl)-6-(trifluoromethyl)isoquinoline-1,3(2H,4H)-dione (3bj): Isolated yield = 70% (132.7 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.33 (d, J = 8.1 Hz, 1H), 7.58 (d, J = 8.1 Hz, 1H), 7.44 (s, 1H), 7.10-7.02 (m, 5H), 3.87 (d, J = 13.8 Hz, 1H), 3.40 (d, J = 13.8 Hz, 1H), 3.27 (s, 3H), 1.72 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.5, 163.2, 142.2, 135.16, 134.2, 131.1, 129.5, 128.9, 128.4, 127.2, 124.6, 122.8, 121.44, 49.3, 47.8, 28.0, 27.3. LRMS (EI) m/z:

378.95, 122.95 (100), 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{17}F_3NO_2S$ $(M+H)^+$: 380.0932 found 380.0928.

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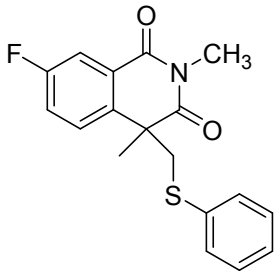
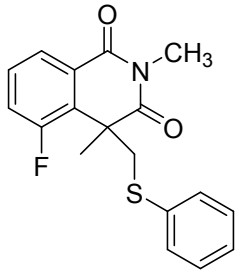
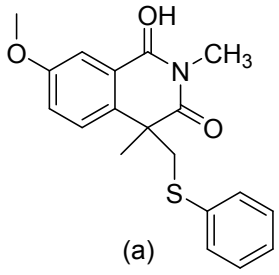


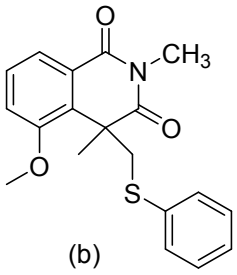
7-fluoro-2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3bk): Isolated yield = 38% (62.5mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.87 (dd, J = 2.4 Hz, J = 9.0 Hz, 1H), 7.29-7.19 (m, 1H), 7.21-6.99 (m, 6H), 3.84 (d, J = 13.3 Hz, 1H), 3.36 (d, J = 13.3 Hz, 1H), 3.22 (s, 3H), 1.68 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.9, 163.4, 160.2, 137.3, 134.6, 131.1, 128.8, 127.8, 127.6 127.0, 121.3, 114.7, 48.6, 47.9, 28.3, 27.3. LRMS (EI) m/z: 329.00, 123.00 (100), 109.00, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}FNO_2S$ $(M+H)^+$: 330.0964 found 330.0960.



5-fluoro-2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3bk´): Isolated yield = 35% (57.6mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.08 (d, J = 8.1 Hz, 1H), 7.37-7.29 (m, 1H), 7.08-7.00 (m, 6H), 3.82 (dd, J = 13.5 Hz, 2H), 3.22 (s, 3H), 1.74 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 175.0, 163.4, 161.4, 158.1, 134.0, 131.7, 129.4, 128.7, 127.0, 124.9, 121.1, 120.8, 48.2, 44.1, 27.3, 26.4. LRMS (EI) m/z: 329.00, 123.00 (100), 108.95, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{17}FNO_2S$ $(M+H)^+$: 330.0964 found 330.0960.

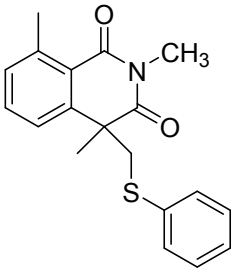


(a) and

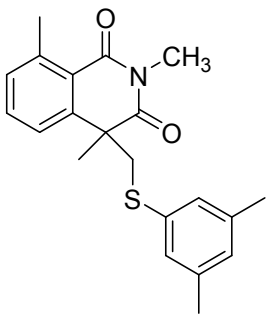


(b) (mixture a:b = 1:1)

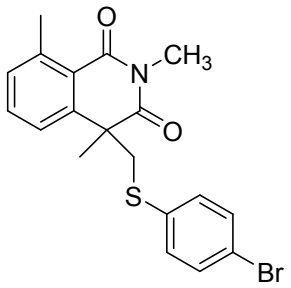
7-methoxy-2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione & 5-methoxy-2,4-dimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione: (Table 3, 3bl+3bl´) Isolated yield = 72% (122.9 mg): ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.96-7.86 (m, 1H), 7.67 (s, 1H), 7.35-7.22 (m, 2H), 7.06 (ddd, *J* = 17.1, 11.7, 6.6 Hz, 11H), 6.86-6.77 (m, 1H), 4.12 (s, 1H), 3.90-3.73 (m, 5H), 3.68 (s, 3H), 3.39 (s, 1H), 3.27-3.14 (m, 6H), 1.72 (s, 3H), 1.66 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 176.41, 175.37, 164.32, 164.25, 158.89, 156.56, 134.91, 134.81, 133.71, 131.94, 130.93, 128.72, 128.39, 126.90, 126.76, 126.73, 126.49, 121.89, 120.96, 115.54, 110.83, 55.58, 55.29, 49.38, 48.24, 47.77, 43.07, 28.31, 27.19, 25.49. LRMS (EI) m/z: 341.05, 240.00, 190.05, 122.95(100), 77.00, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{20}NO_3S$ $(M+H)^+$: 342.1164 found 342.1160.



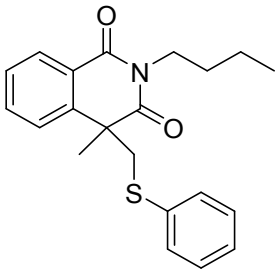
2,4,8-trimethyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3bm): Isolated yield = 63% (102.5 mg), ^{1}H NMR (300 MHz, $CDCl_3$) *δ*: 7.36 (t, *J* = 7.5 Hz, 1H), 7.22-7.13 (m, 7H), 3.82 (d, *J* = 12.9 Hz, 1H), 3.40 (d, *J* = 12.9 Hz, 1H), 3.20 (s, 3H), 2.78 (s, 3H), 1.70 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) *δ*: 174.8, 164.8, 142.8, 142.3, 135.0, 132.6, 131.8, 130.7, 128.7, 126.7, 124.0, 123.7, 48.6, 47.9, 28.7, 27.1, 24.0. LRMS (EI) m/z: 325.00, 174.00, 122.95 (100), 115.05, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{19}H_{20}NO_2S$ $(M+H)^+$: 326.1215 found 326.1211.



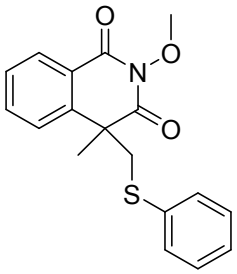
4-(((3,5-dimethylphenyl)thio)methyl)-2,4,8-trimethylisoquinoline-1,3(2H,4H)-dione (3bn): Isolated yield = 66% (116.6 mg), ^{1}H NMR (300 MHz, $CDCl_3$) ： δ 7.38-7.27 (m, 1H), 7.19-7.15 (m, 2H), 6.70-6.68 (m, 3H), 3.77 (d, J = 12.9 Hz, 1H), 3.37 (d, J = 12.9 Hz, 1H), 3.24 (s, 3H), 2.78 (s, 3H), 2.19 (s, 6H), 1.70 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ*:* 174.9, 164.9, 142.8, 142.2, 138.2, 134.2, 132.4, 131.7, 128.6, 123.9, 123.8, 48.7, 48.0, 28.6, 27.1, 24.0, 21.1. LRMS (EI) m/z: 353.10, 151.05(100), 107.10, 45.00. HRMS (ESI+) *m/z* calculated for $C_{21}H_{24}NO_2S$ $(M+H)^+$: 354.1528 found 354.1524.



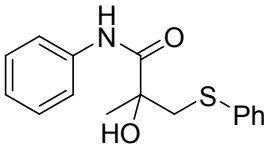
4-(((4-bromophenyl)thio)methyl)-2,4,8-trimethylisoquinoline-1,3(2H,4H)-dione (3bo): Isolated yield = 60% (121.2 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.38-7.33 (m, 1H), 7.23-7.05 (m, 4H), 6.97 (d, J = 8.3 Hz, 2H), 3.79 (d, J = 12.9 Hz, 1H), 3.40 (d, J = 12.9 Hz, 1H), 3.23 (s, 3H), 2.77 (s, 3H), 1.69 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.7, 164.7, 142.6, 142.4, 134.2, 132.7, 132.3, 131.7, 128.8, 123.9, 123.7, 120.8, 48.7, 47.8, 28.8, 27.1, 23.9. LRMS (EI) m/z: 404.90, 402.95, 202.90 (100), 200.95, 122.05, 91.05, 45.05. HRMS (ESI+) *m/z* calculated for $C_{19}H_{19}BrNO_2S$ $(M+H)^+$: 404.0320 found 404.0316.



2-butyl-4-methyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3bp): Isolated yield = 82% (144.9 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.23 (d, J = 7.5 Hz, 1H), 7.53-7.42 (m, 1H), 7.43-7.34 (m, 1H), 7.30-7.25 (m, 1H), 7.11 (s, 5H), 3.99-3.88 (m, 2H), 3.83 (d, J = 12.9 Hz, 1H), 3.45 (d, J = 12.9 Hz, 1H), 1.68 (s, 3H), 1.61-1.53 (m, 2H), 1.39-1.29 (m, 2H), 0.91 (t, J = 7.4 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 174.9, 164.0, 141.6, 135.3, 133.7, 130.8, 128.8, 128.7, 127.8, 127.7, 126.7, 125.5, 48.7, 47.4, 40.5, 30.0, 28.7, 20.3, 13.8. LRMS (EI) m/z: 353.05, 122.95 (100), 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{21}H_{24}NO_2S$ $(M+H)^+$: 354.1528 found 354.1524.

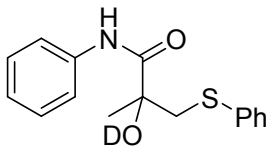


2-methoxy-4-methyl-4-((phenylthio)methyl)isoquinoline-1,3(2H,4H)-dione (3bq): Isolated yield = 78% (127.6 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.22 (d, J = 7.5 Hz, 1H), 7.53-7.44 (m, 1H), 7.44-7.36 (m, 1H), 7.29-7.22 (m, 1H), 7.10 (s, 5H), 3.96 (s, 3H), 3.85 (d, J = 12.9 Hz, 1H), 3.50 (d, J = 12.9 Hz, 1H), 1.73 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 170.9, 160.5, 140.9, 134.9, 134.2, 134.1, 131.0, 128.9, 128.8, 127.0, 125.9, 125.2, 64.12, 64.0, 50.9, 47.5, 28.4. LRMS (EI) m/z: 326.95, 151.00, 123.00 (100), 115.00, 77.05, 45.00. HRMS (ESI+) *m/z* calculated for $C_{18}H_{18}NO_3S$ $(M+H)^+$: 328.1007 found 328.1003.

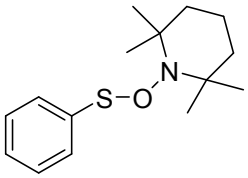


2-hydroxy-2-methyl-N-phenyl-3-(phenylthio)propanamide (3br): Isolated yield = 95% (136.5 mg), ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.66 (s, 1H), 7.43 (t, J = 8.1 Hz, 4H), 7.29-7.08 (m, 6H), 3.74

(d, J = 13.9 Hz, 1H), 3.51 (br, 1H), 3.23 (d, J = 13.9 Hz, 1H), 1.54 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 172.2, 137.2, 134.6, 130.6, 129.1, 128.9, 127.1, 124.5, 119.7, 75.5, 45.0, 26.1. LRMS (EI) m/z: 289.05, 269.00(100), 177.00, 124.05, 94.05, 43.05. HRMS (ESI+) *m/z* calculated for $C_{16}H_{18}NOS$ $(M+H)^+$: 288.1058 found 288.1054.



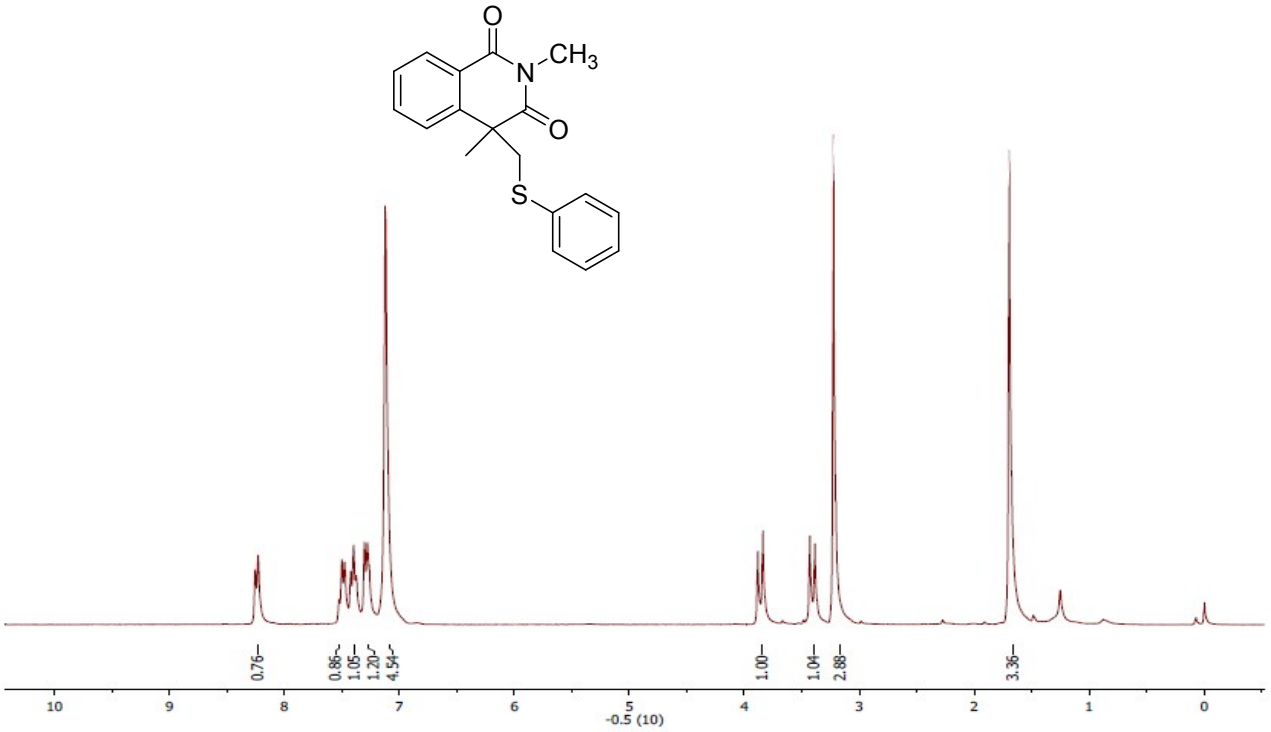
2-(hydroxy-d)-2-methyl-N-phenyl-3-(phenylthio)propanamide (3br): ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.74-8.56 (m, 1H), 7.42 (d, J = 8.1 Hz, 4H), 7.26 (d, J = 19.6 Hz, 6H), 3.83-3.66 (m, 1H), 3.30-3.13 (m, 1H), 1.54 (s, 3H).

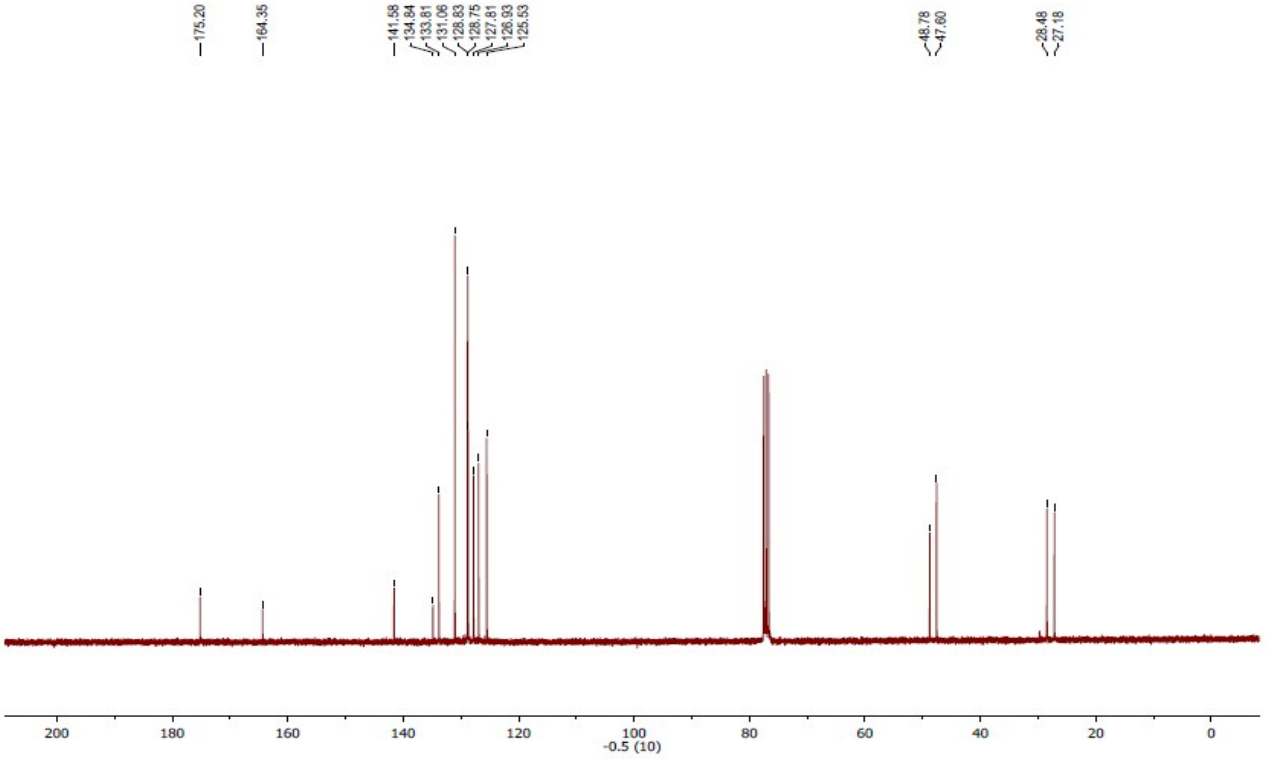


2,2,6,6-tetramethyl-1-((phenylthio)oxy)piperidine: (4) Isolated yield = 45%: ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.67 (d, J = 7.6 Hz, 2H), 7.43 (d, J = 7.6 Hz, 3H), 1.75-1.39 (m, 15H), 0.89 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ: 150.28, 150.24, 129.36, 129.34, 128.57, 128.55, 126.03, 61.32, 58.91, 43.53, 41.43, 35.39, 32.64, 28.82, 28.01, 17.33.

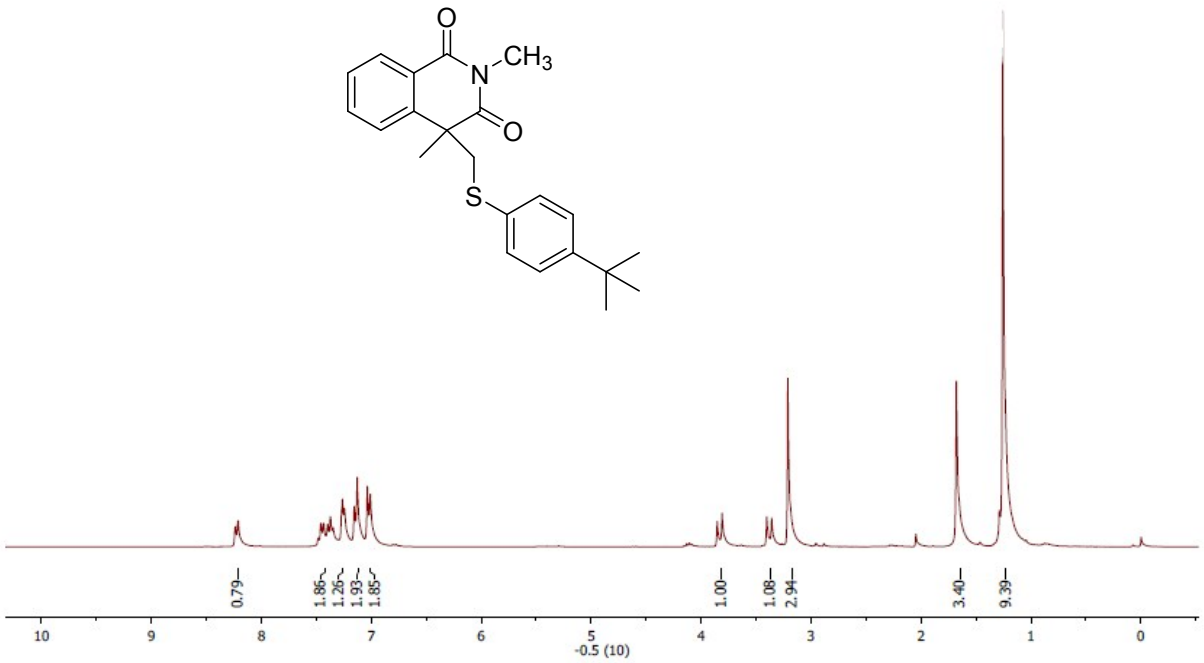
(D) Copies of ^{1}H,^{13}C, spectra for products

(Table 2, 3aa)





(Table 2, 3ab)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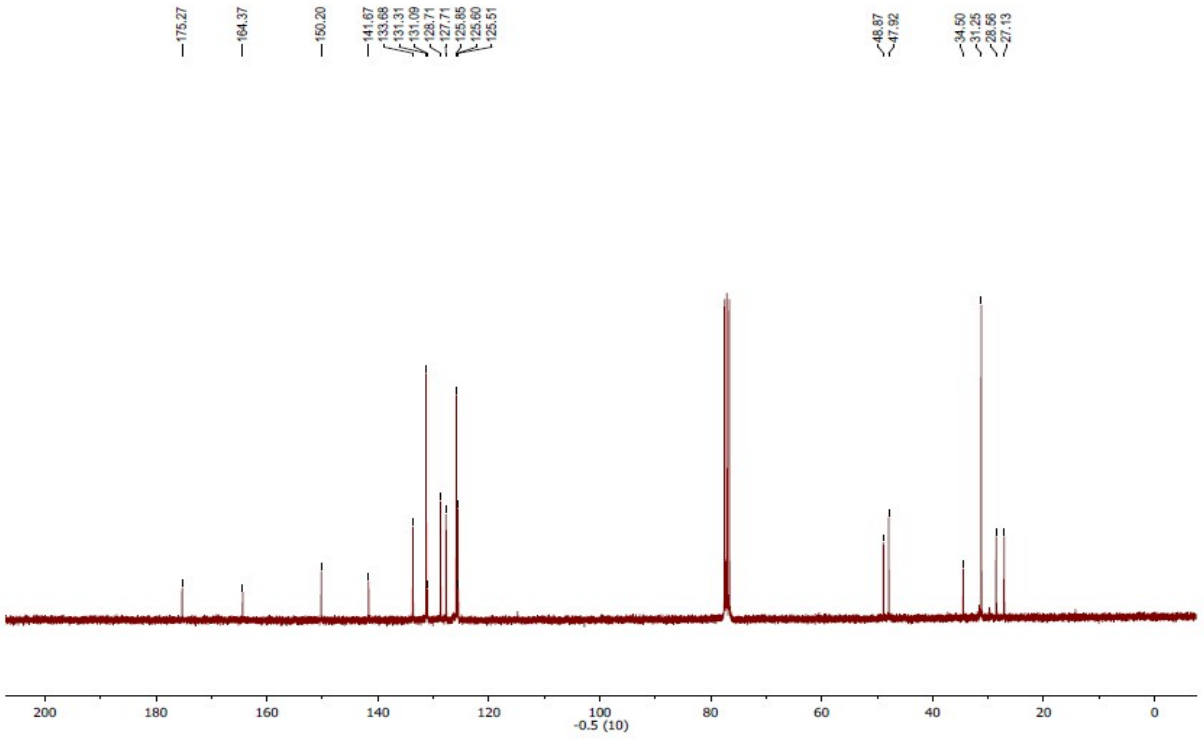
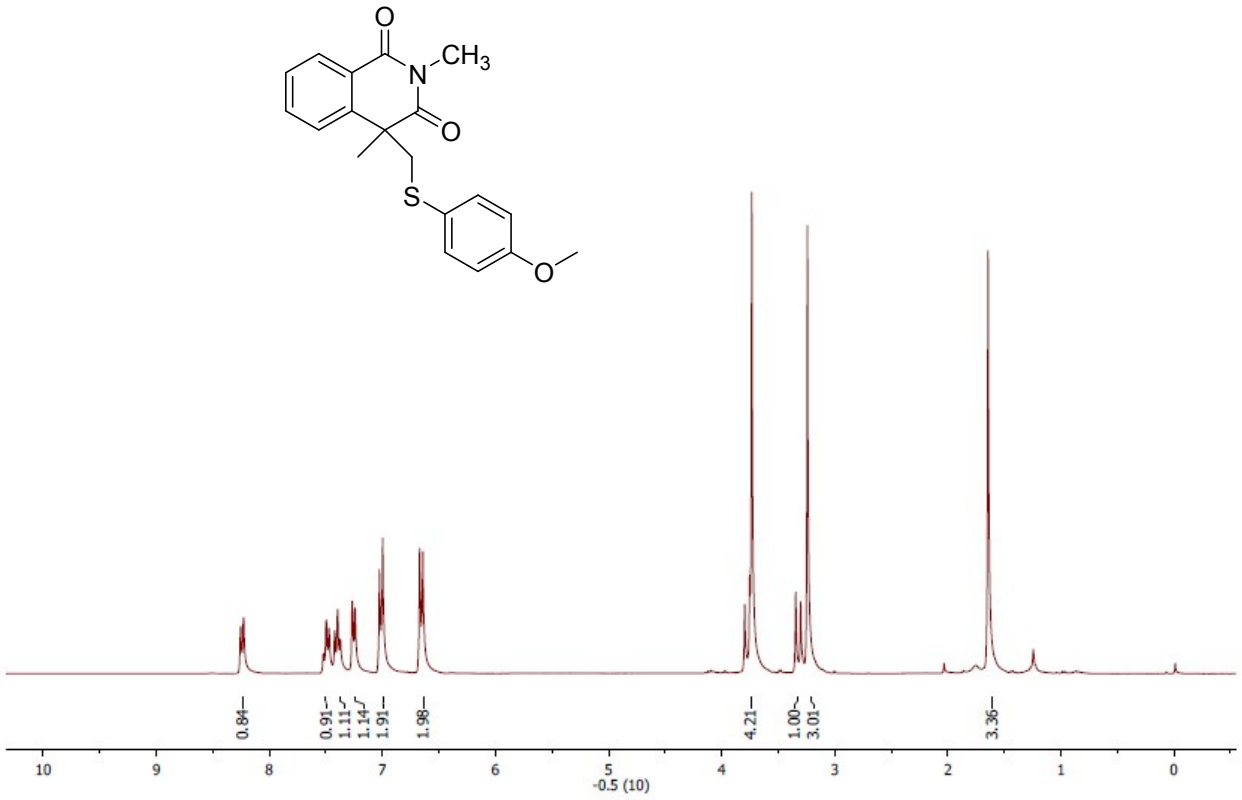
N
CH3
O
S
0.79
1.86
1.26
1.93
1.85
1.00
1.08
2.94
3.40
9.39
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0


175.27
164.37
150.20
141.67
133.68
131.31
131.09
128.71
127.71
125.85
125.60
125.51
48.87
47.92
34.50
31.25
28.56
27.13
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

(Table 2, 3ac)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CH3
O
S
O
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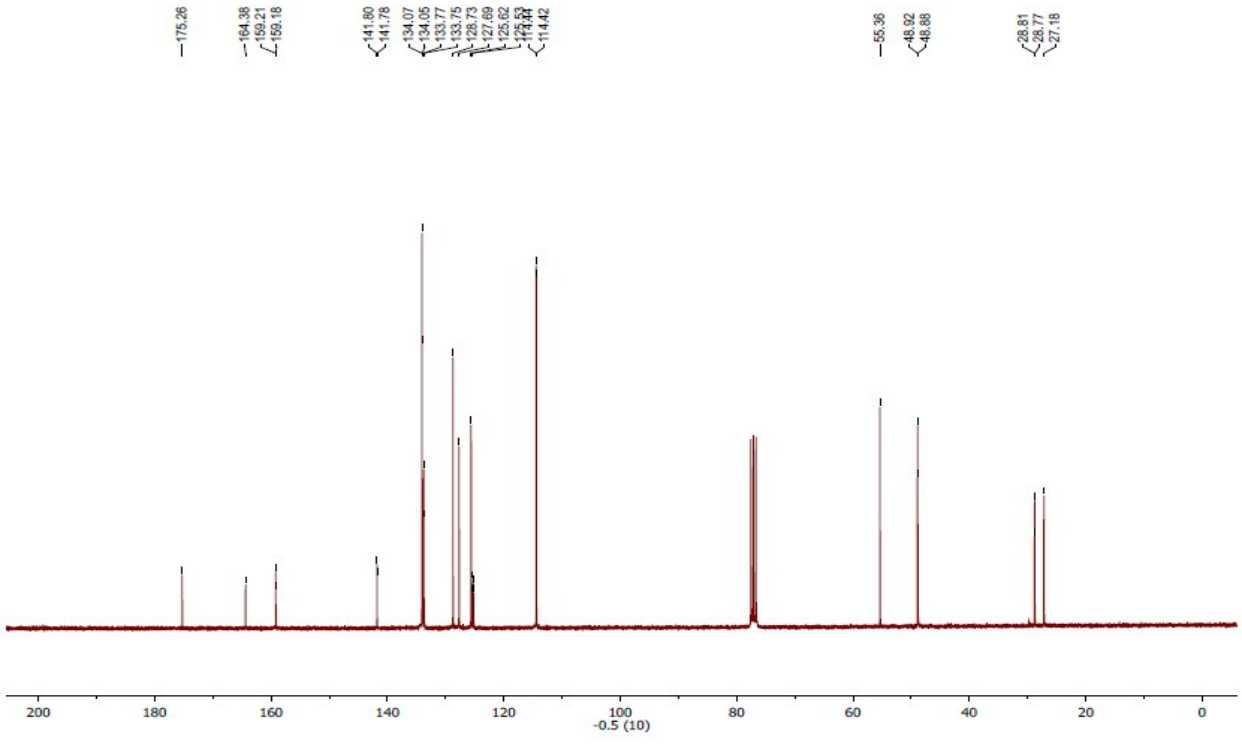
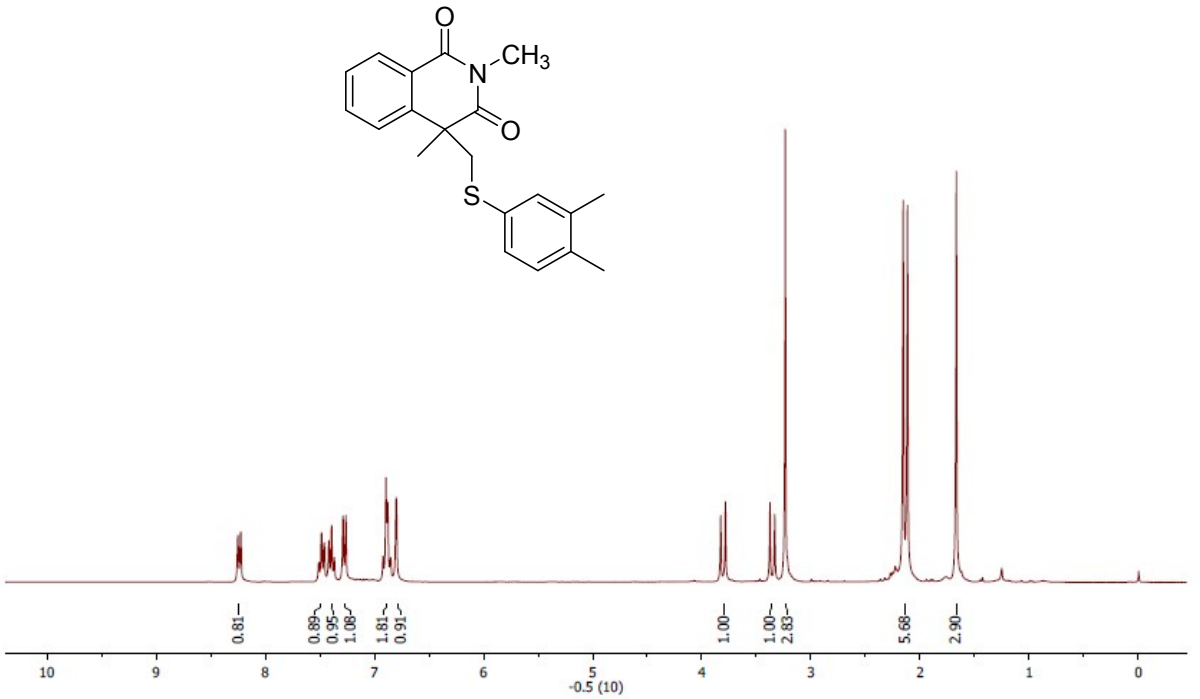
0.91
1.11
1.14
1.91
1.98
4.21
1.00
3.01
3.36
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)


175.26
164.38
150.21
150.18
141.80
141.78
134.07
134.05
133.77
133.75
128.73
127.69
125.62
114.42
55.36
48.92
48.88
28.81
28.77
27.18
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)

(Table 2, 3ad)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CH3
O
S
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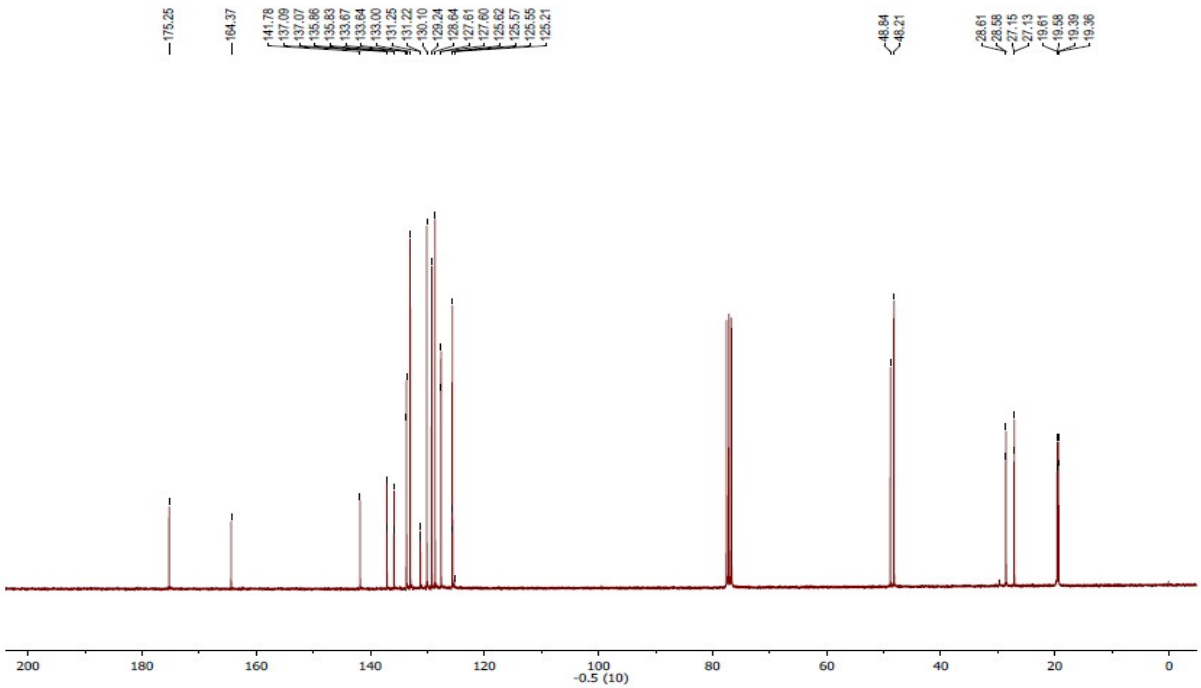
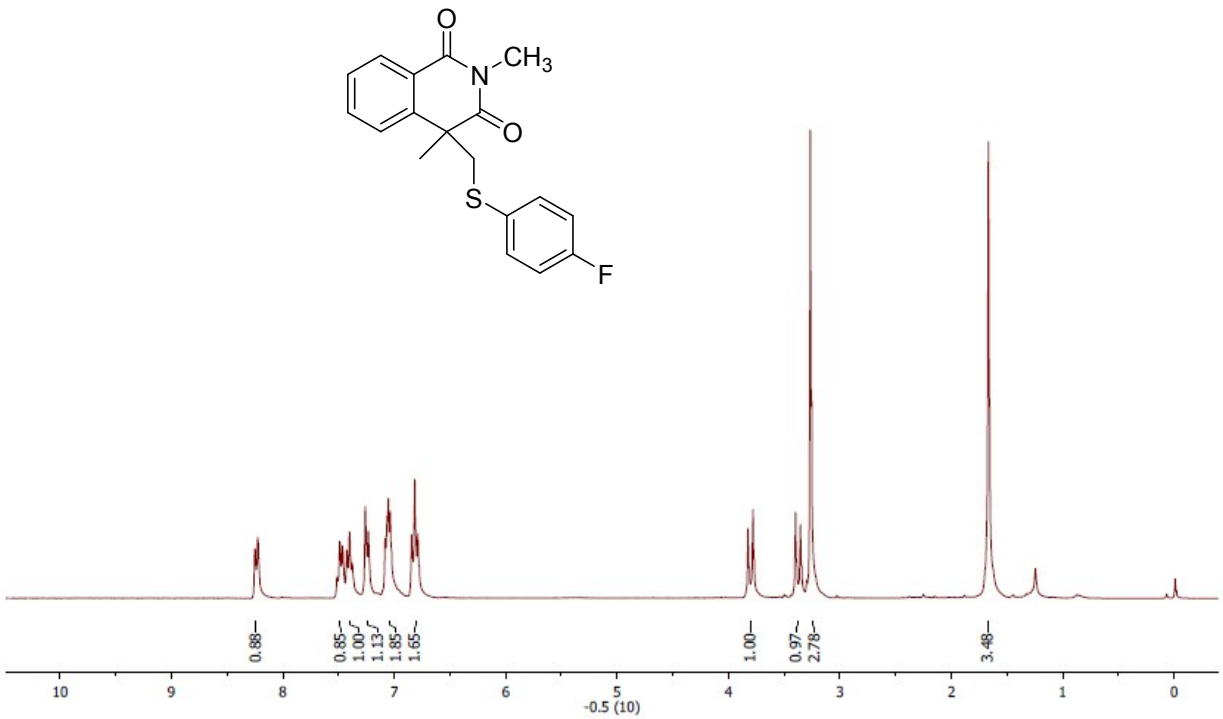
0.89
0.95
1.08
1.81
0.91
1.00
1.00
2.83
5.68
2.90
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)


175.25
164.37
141.78
137.09
137.07
135.86
135.83
133.67
133.64
133.00
131.25
131.22
130.10
129.24
128.64
127.61
127.60
125.62
125.57
125.55
125.21
48.84
48.21
28.61
28.58
27.15
27.13
19.61
19.58
19.39
19.36
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)

(Table 2, 3ae)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N
CH3
O
S
F
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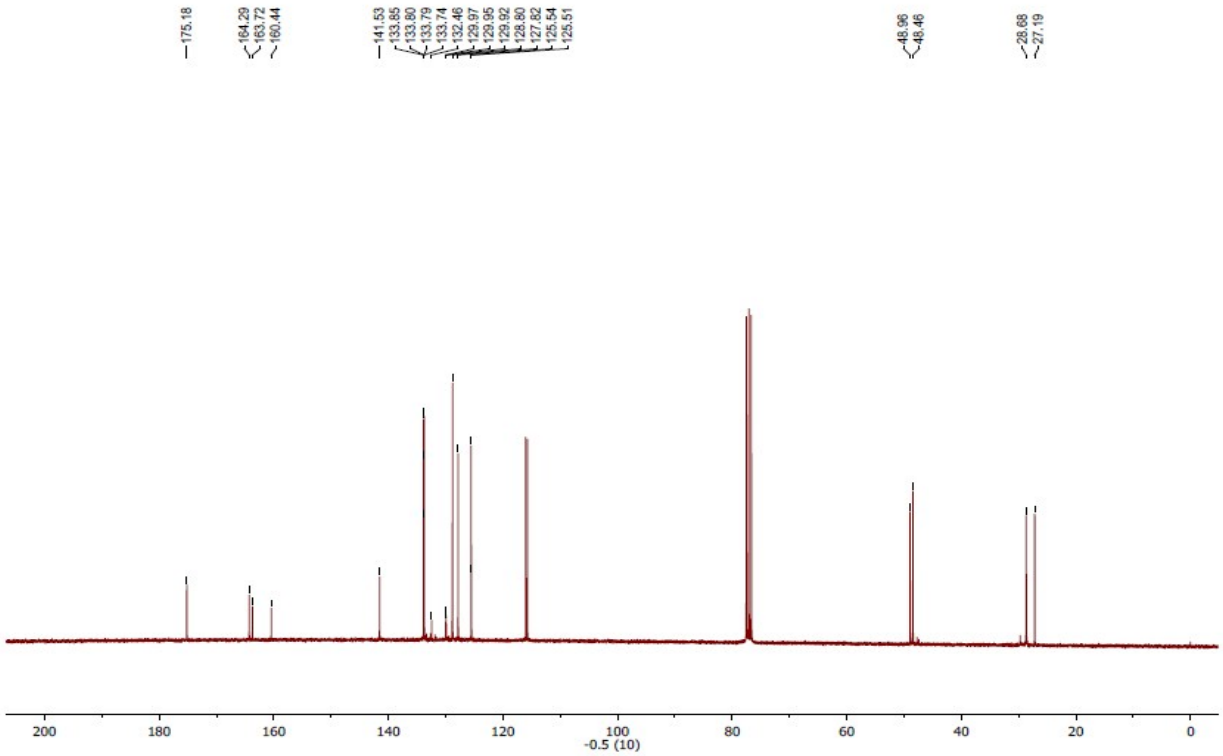
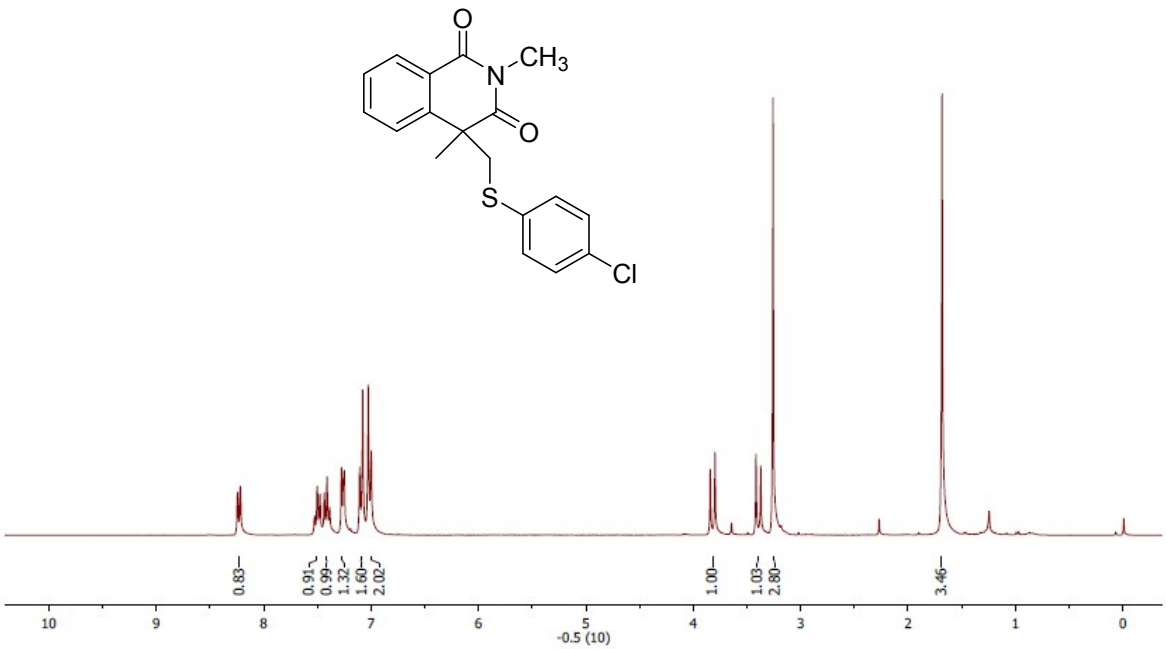
0.85
1.00
1.13
1.85
1.65
1.00
0.97
2.78
3.48
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)


175.18
164.29
163.72
160.44
141.53
133.85
133.80
133.79
133.74
132.46
129.97
129.95
129.92
128.80
127.82
125.54
125.51
48.96
48.46
28.68
27.19
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)

(Table 2, 3af)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CH3
O
S
Cl
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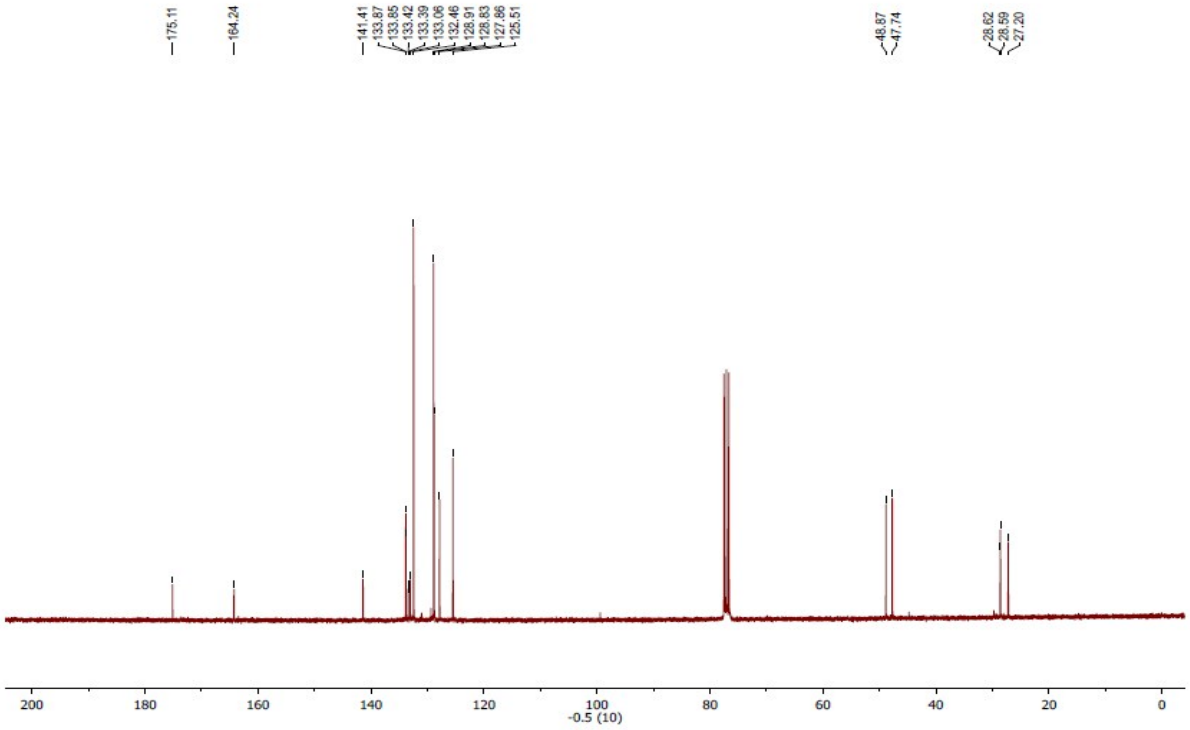
0.91
0.99
1.32
1.60
2.02
1.00
1.03
2.80
3.46
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0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141.41
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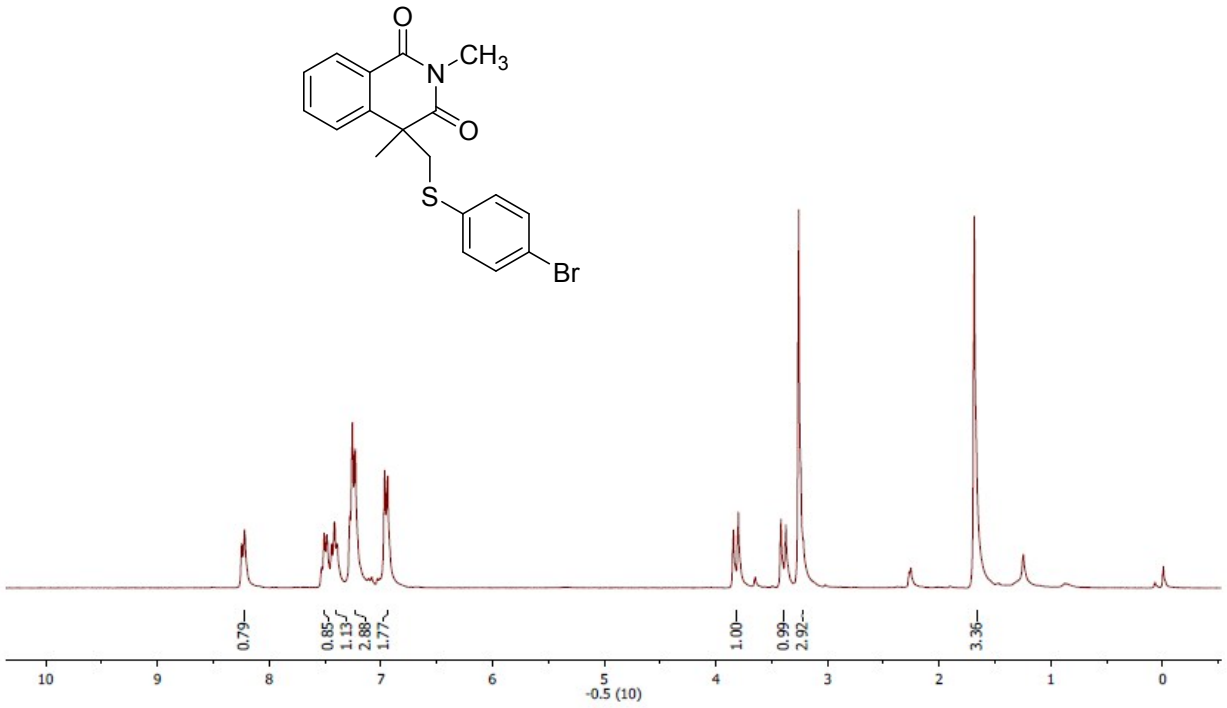
133.42
133.39
133.06
132.46
128.91
128.83
127.86
125.51
48.87
47.74
28.62
28.59
27.20
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

(Table 2, 3ag)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N
CH3
O
S
Br
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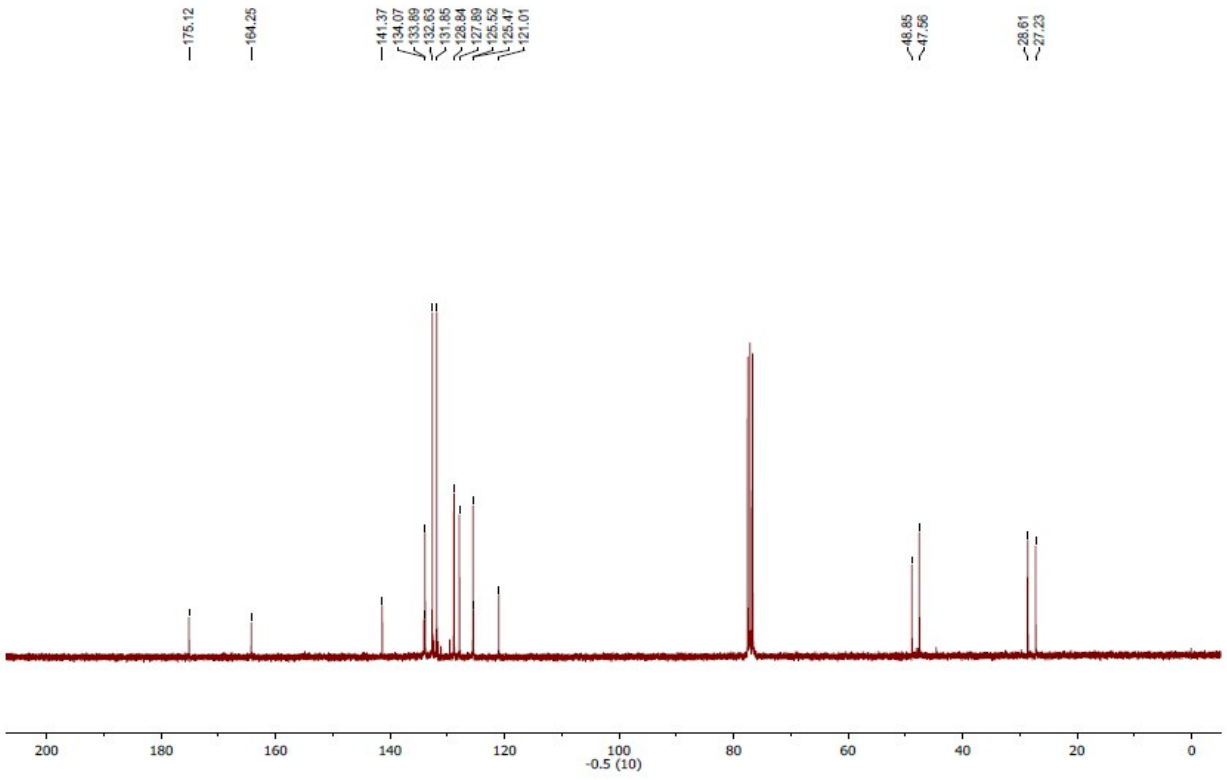
0.85
1.13
2.88
1.77
1.00
0.99
2.92
3.36
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0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164.25
141.37
134.07
133.89
132.63
131.85
128.84
127.89
125.52
125.47
121.01
48.85
47.56
28.61
27.23
200
180
160
140
120
100
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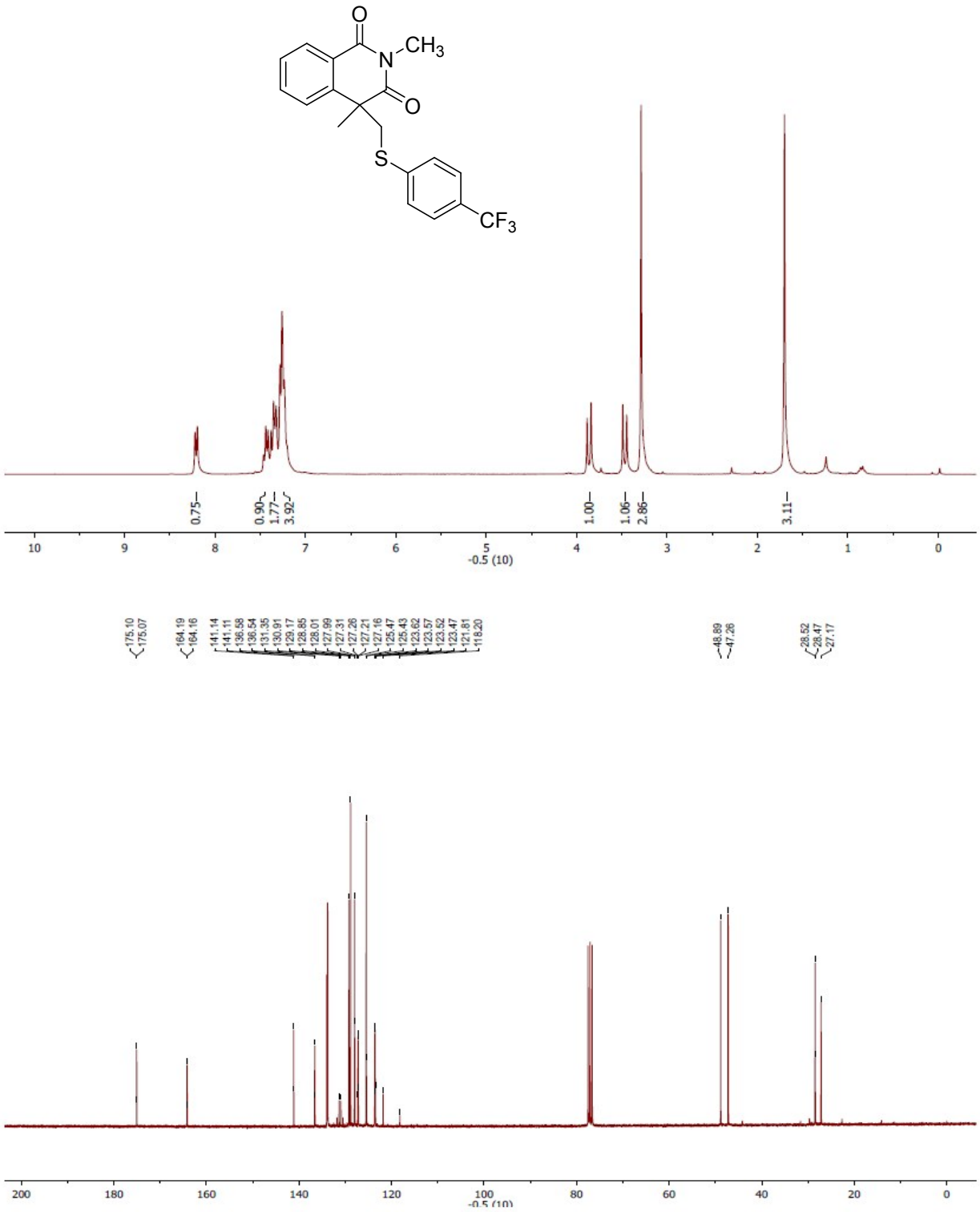
80
60
40
20
0

(Table 2, 3ag)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S
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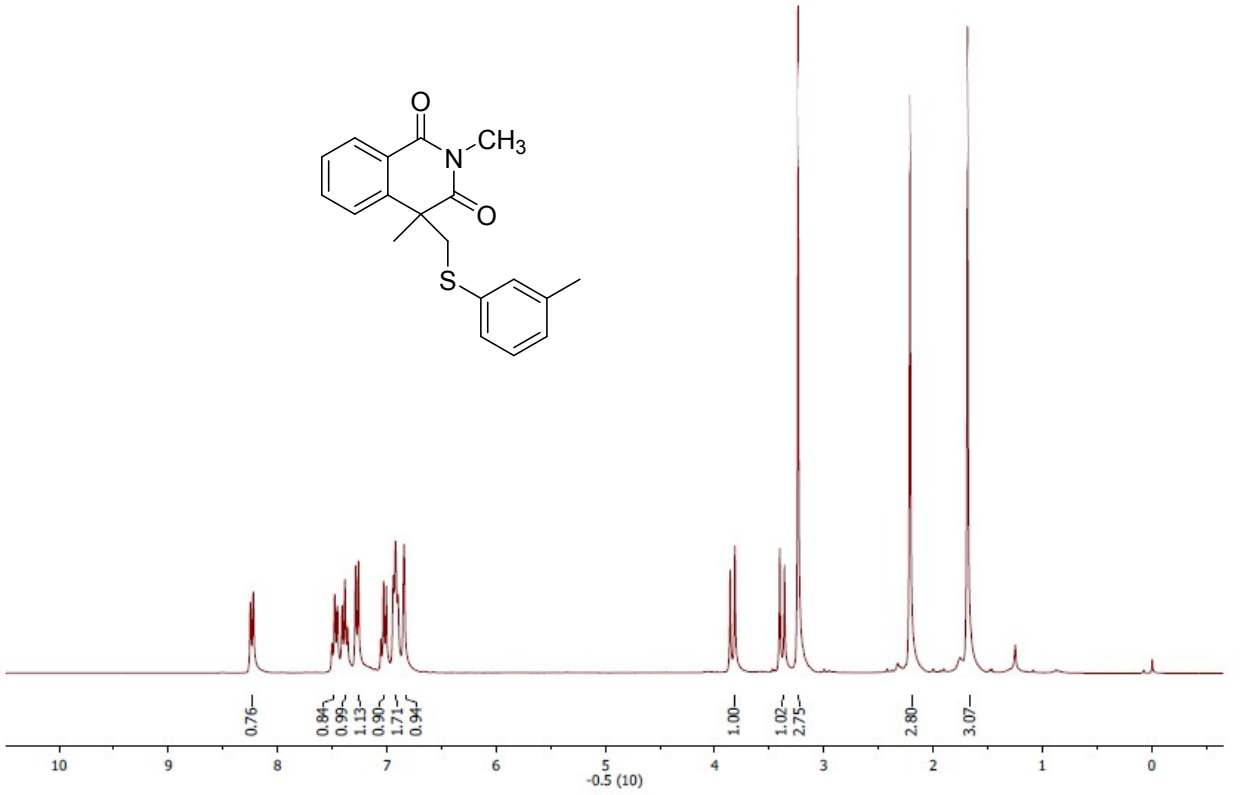
1.77
3.92
1.00
1.06
2.86
3.11
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0
175.10
175.07
164.19
164.16
141.14
141.11
136.58
136.54
131.35
130.91
129.17
128.85
128.01
127.99
127.31
127.26
127.21
127.16
125.47
125.43
123.62
123.57
123.52
123.47
121.81
118.20
48.89
47.26
28.52
28.47
27.17
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

(Table 2, 3ai)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CH3
O
S
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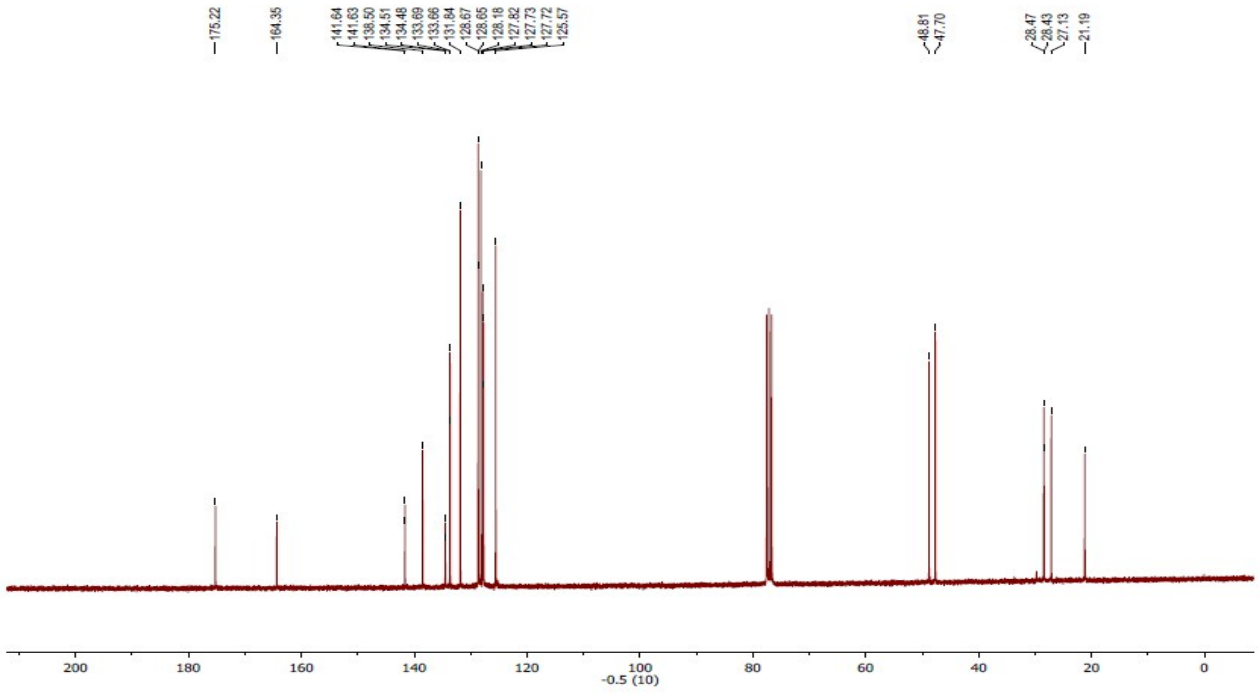
0.84
0.99
1.13
0.90
1.71
0.94
1.00
1.02
2.75
2.80
3.07
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0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134.51
134.48
133.69
133.66
131.84
128.67
128.65
128.18
127.82
127.73
127.72
125.57
48.81
47.70
28.47
28.43
27.13
21.19
200
180
160
140
120
100
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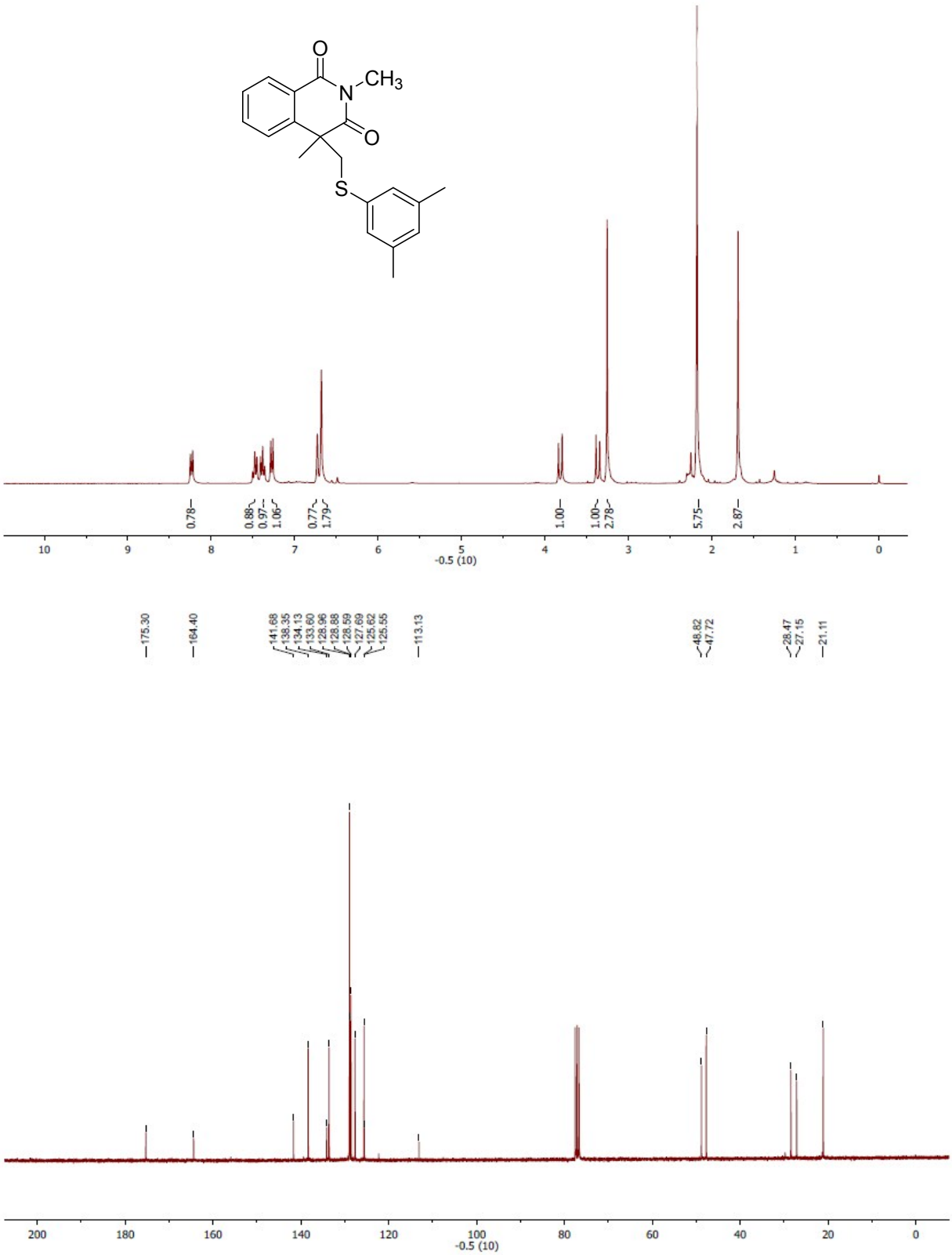
80
60
40
20
0

(Table 2, 3aj)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CH3
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S
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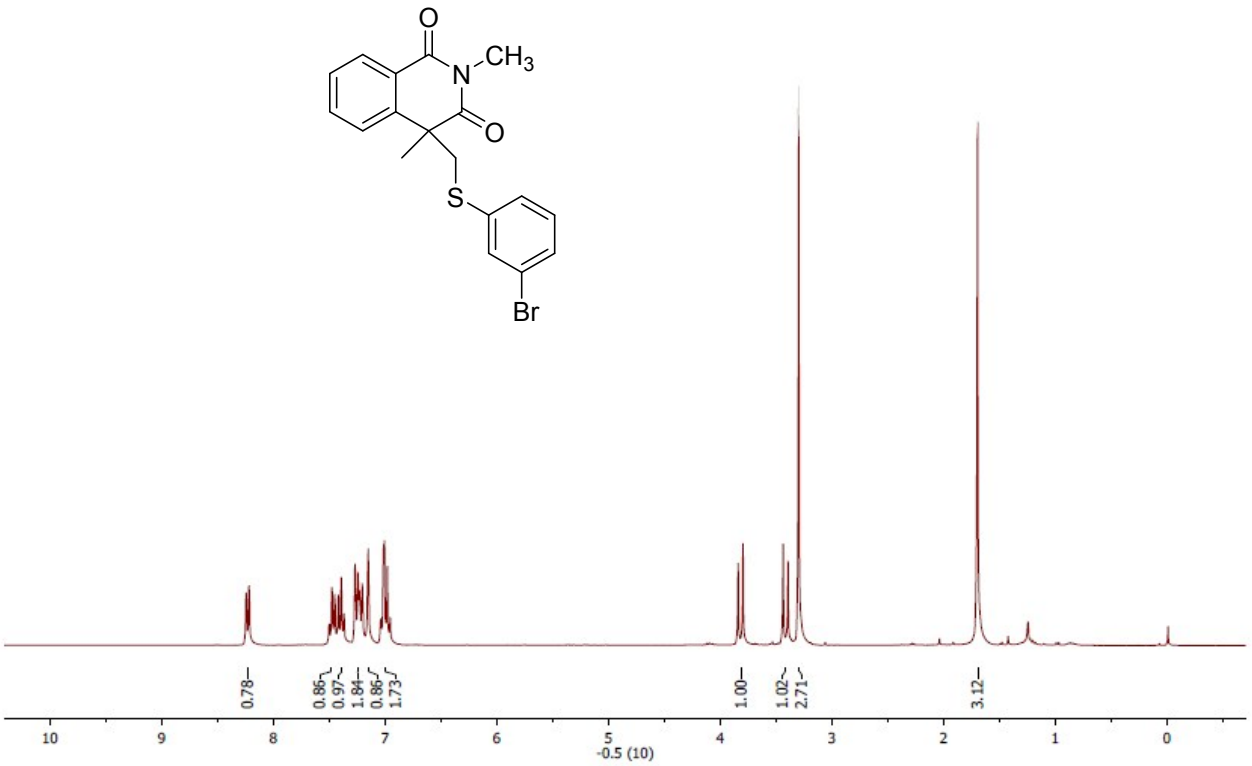
0.97
1.06
0.77
1.79
1.00
1.00
2.78
5.75
2.87
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0
175.30
164.40
141.68
138.35
134.13
133.60
128.96
128.88
128.59
127.69
125.62
125.55
113.13
48.82
47.72
28.47
27.15
21.11
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

(Table 2, 3ak)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CH3
O
S
Br
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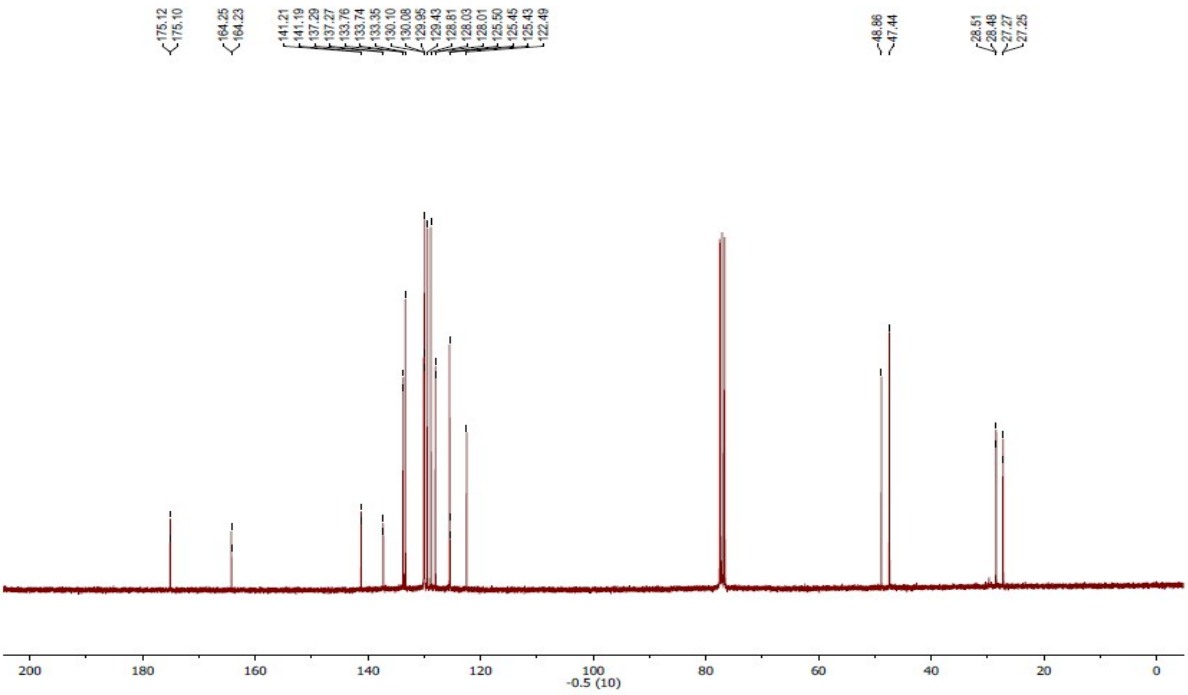
0.86
0.97
1.84
0.86
1.73
1.00
1.02
2.71
3.12
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0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175.10
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164.23
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141.19
137.29
137.27
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133.74
133.35
130.10
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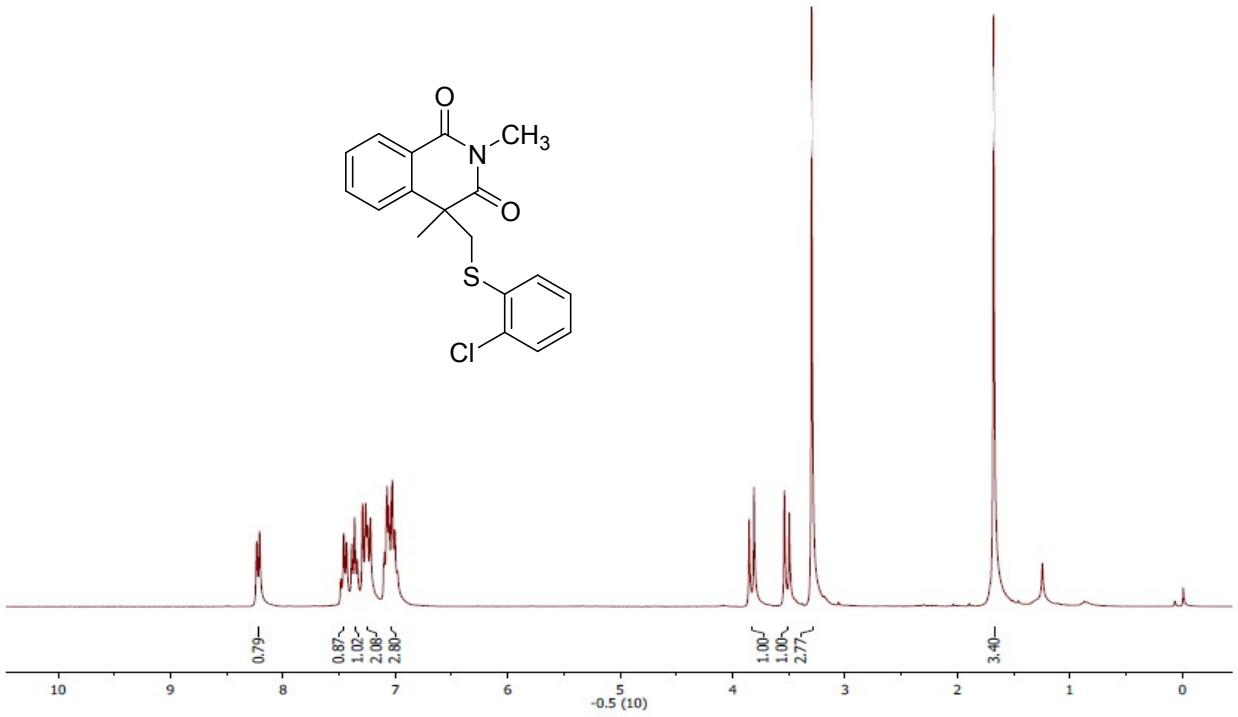
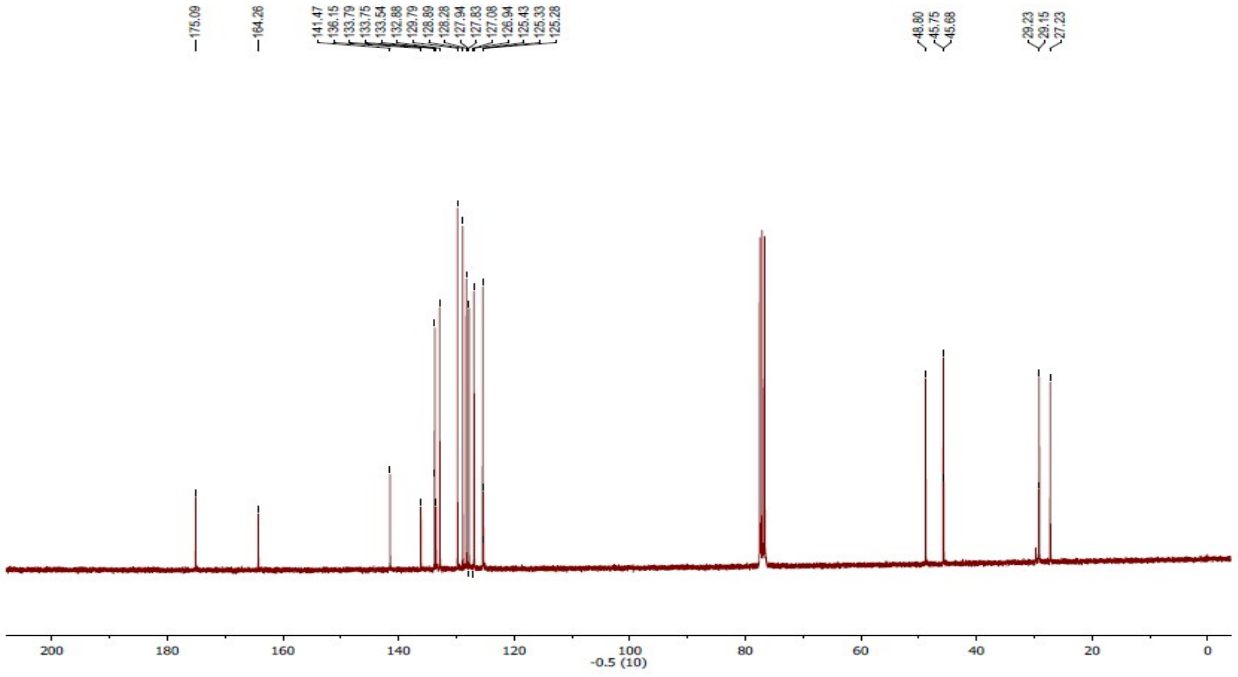
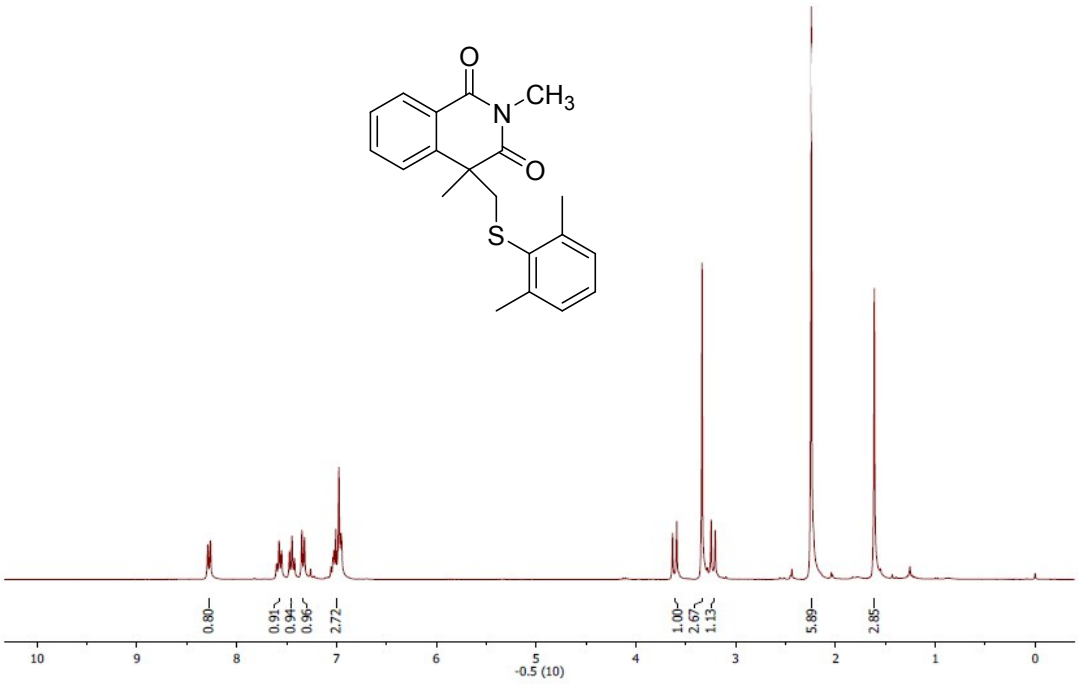
129.95
129.43
128.81
128.03
128.01
125.50
125.45
125.43
122.49
48.86
47.44
28.51
28.48
27.27
27.25
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

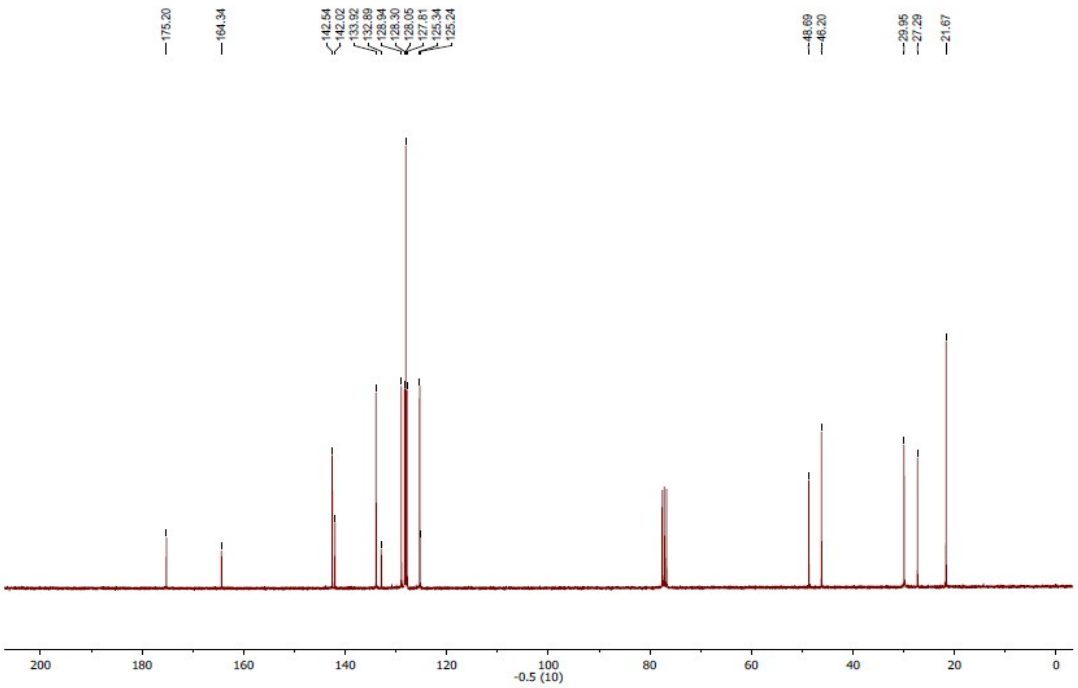
(Table 2, 3al)


O
N
CH3
O
S
Cl
0.79
0.87
1.02
2.08
2.80
1.00
1.00
2.77
3.40
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

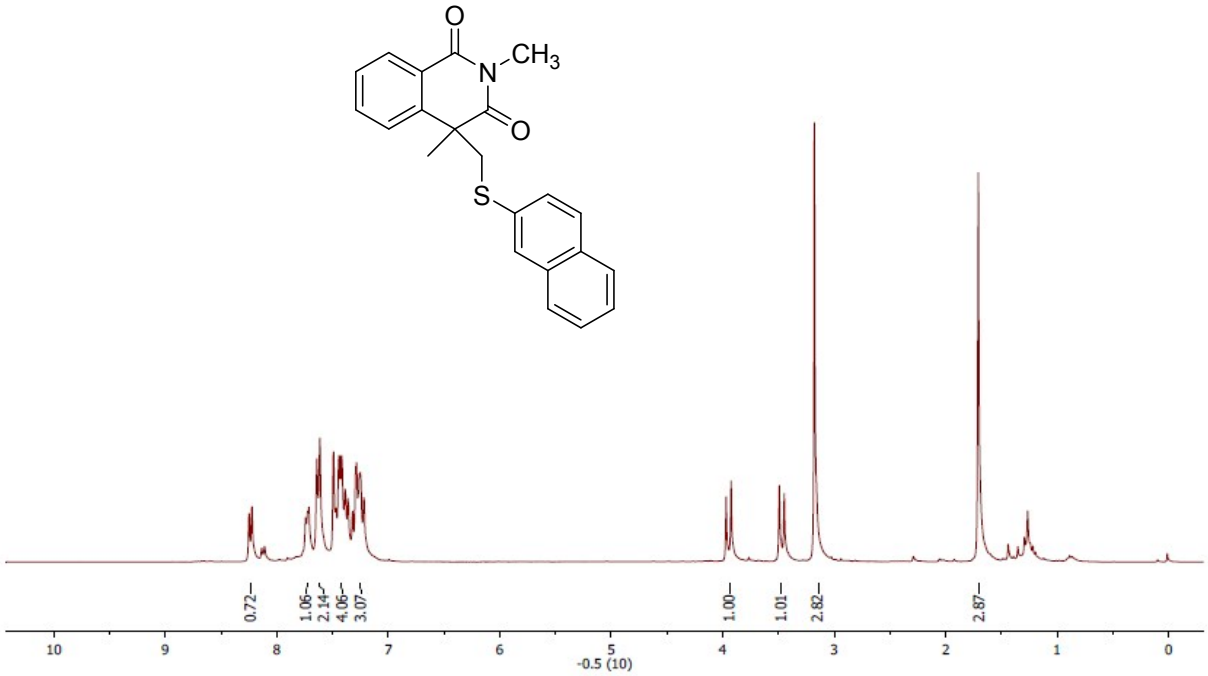

175.09
164.26
141.47
136.15
133.79
133.75
133.54
132.88
129.79
128.89
128.28
127.94
127.83
127.08
126.94
125.43
125.33
125.28
48.80
45.75
45.68
29.23
29.15
27.23
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

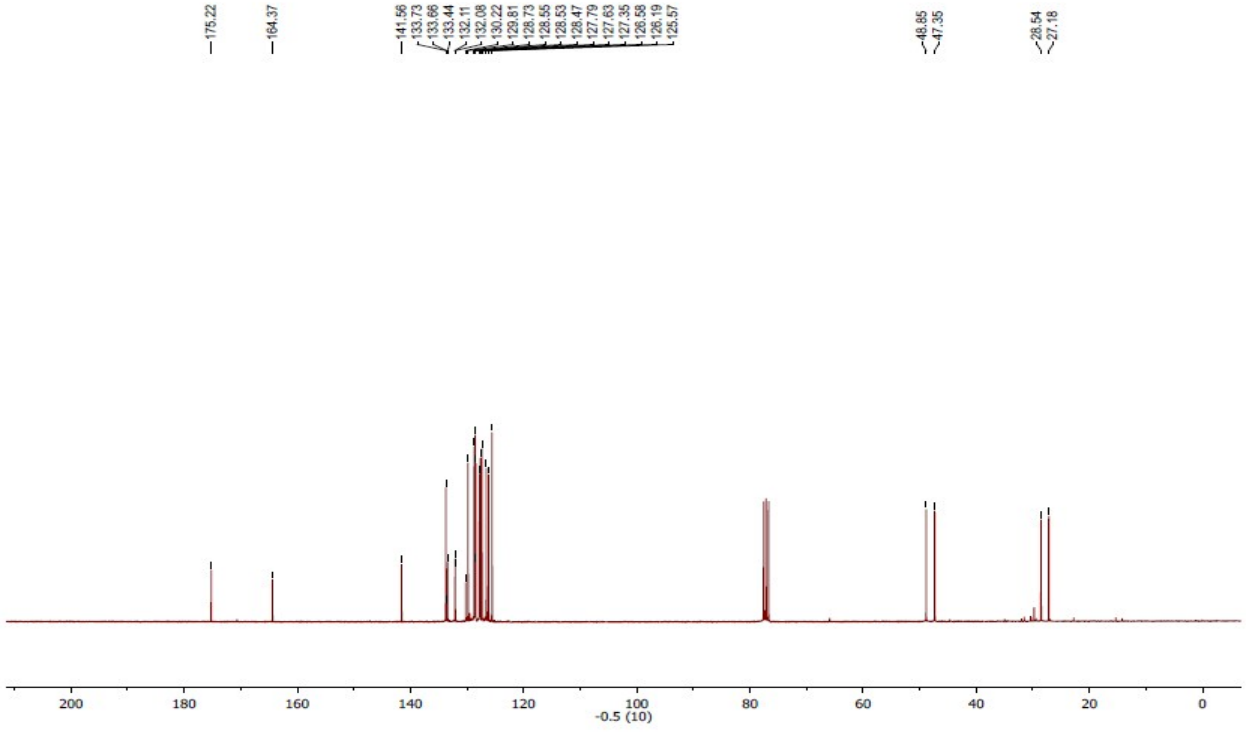
(Table 2, 3am)


O
N
CH3
O
S
0.80
0.91
0.94
0.96
2.72
1.00
2.67
1.13
5.89
2.85
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

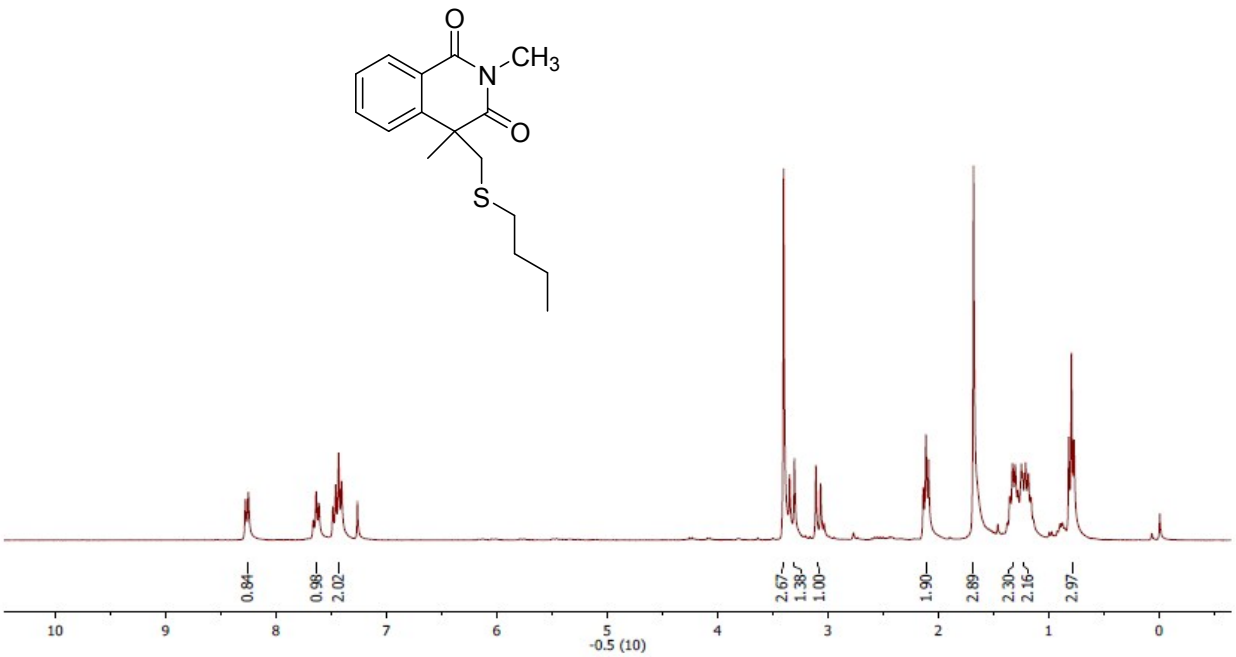

175.20
164.34
142.54
142.02
133.92
132.89
128.94
128.30
128.05
127.81
125.34
125.24
48.69
46.20
29.95
27.29
21.67
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

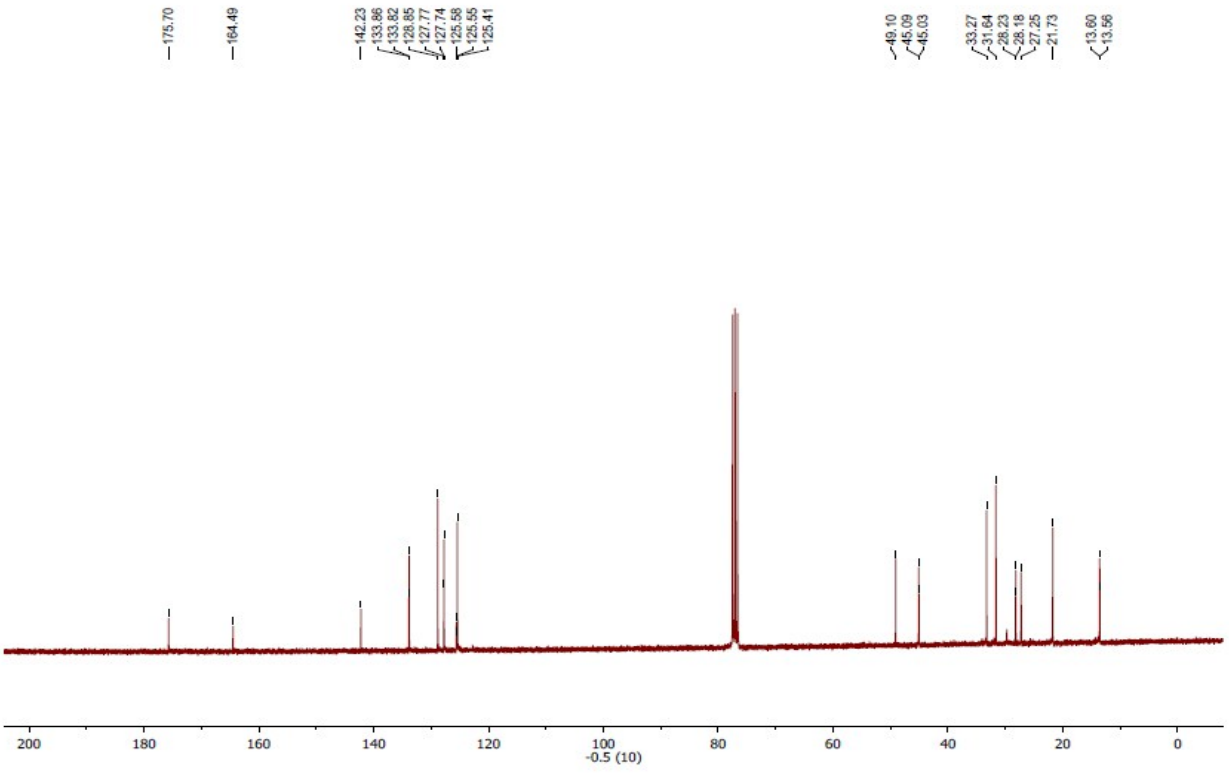
(Table 2, 3an)


O
N
CH3
O
S
0.72
1.06
2.14
4.06
3.07
1.00
1.01
2.82
2.87
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

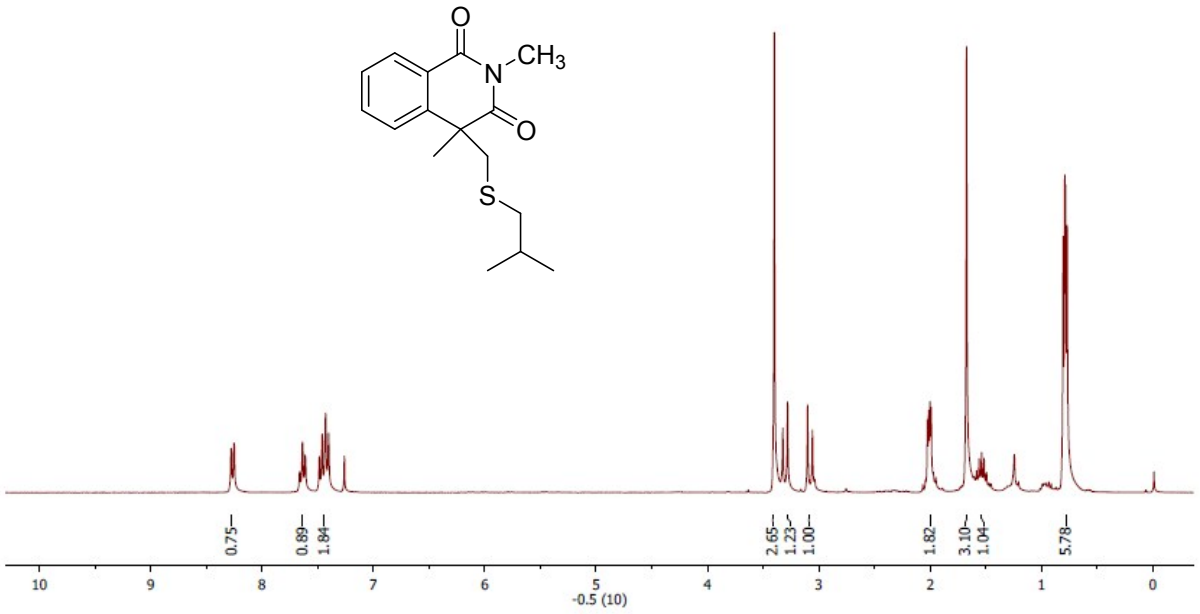

175.22
164.37
141.56
133.73
133.66
133.44
132.11
132.08
130.22
129.81
128.73
128.55
128.53
128.47
127.79
127.63
127.35
126.58
126.19
125.57
48.85
47.35
28.54
27.18
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

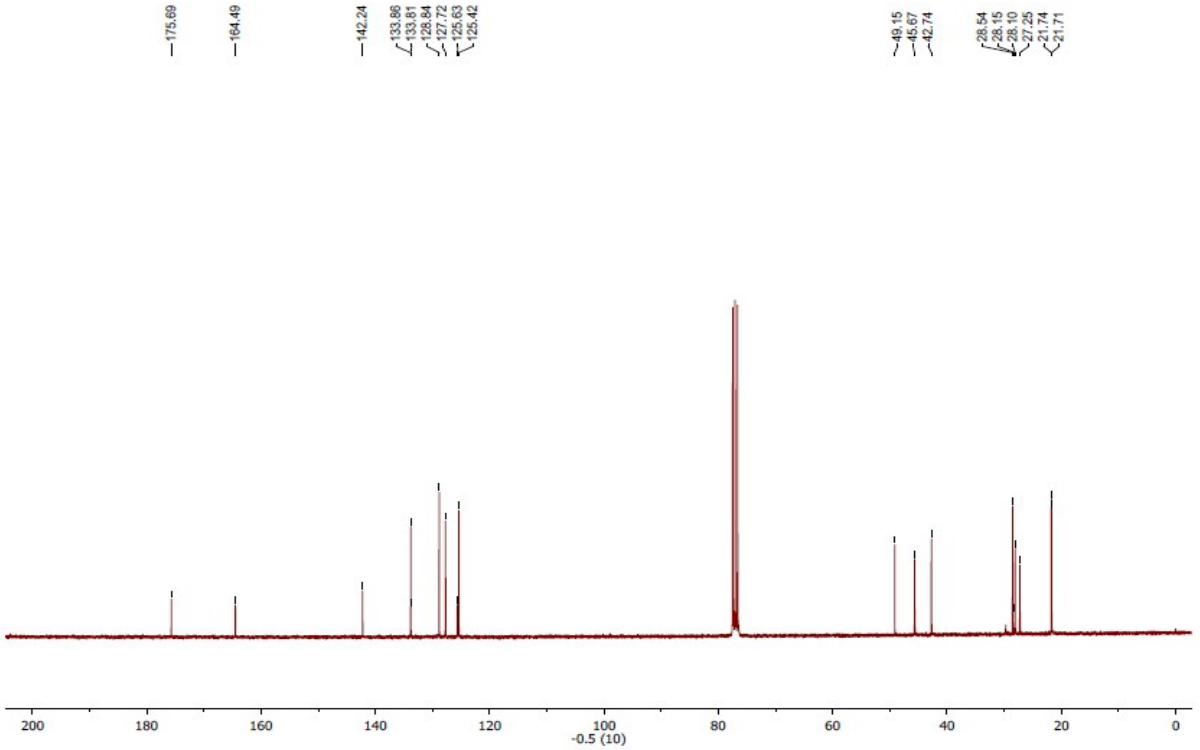
(Table 2, 3ao)


O
N
CH3
O
S
0.84
0.98
2.02
2.67
1.38
1.00
1.90
2.89
2.30
2.16
2.97
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

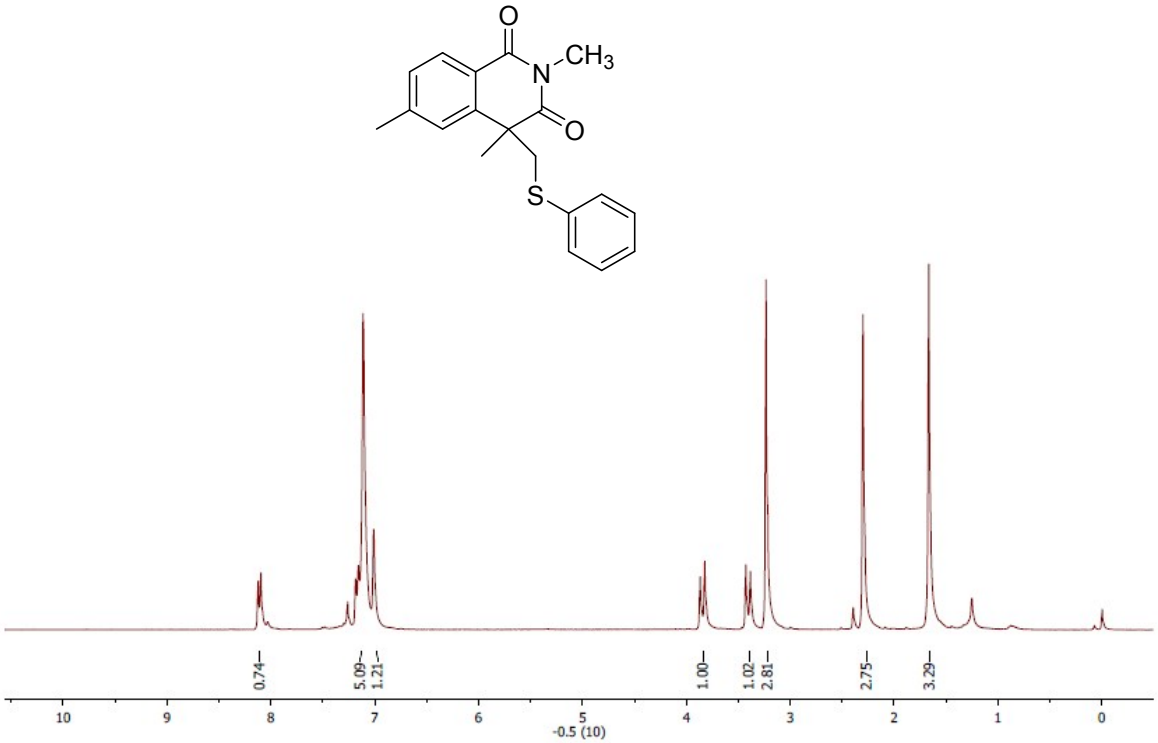

175.70
164.49
142.23
133.86
133.82
128.85
127.77
127.74
125.58
125.55
125.41
49.10
45.09
45.03
33.27
31.64
28.23
28.18
27.25
21.73
13.60
13.56
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

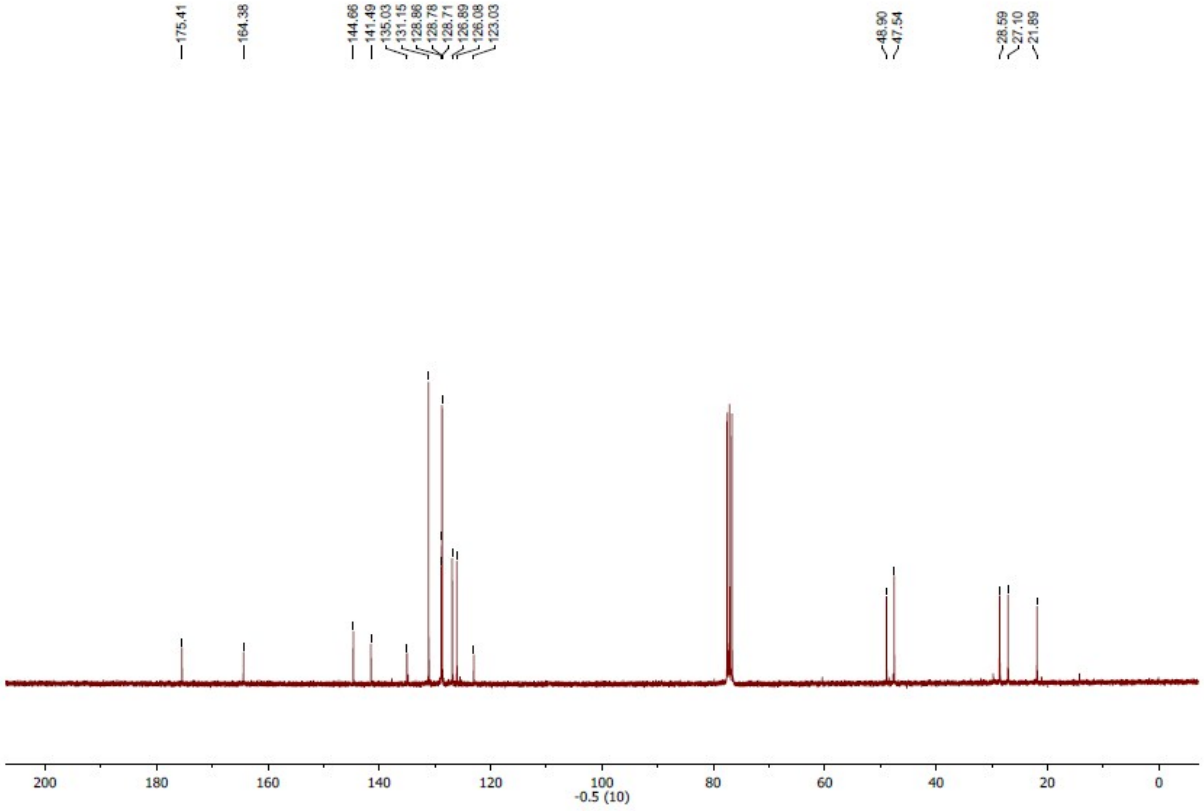
(Table 2, 3ap)


O
N
CH3
O
S
0.75
0.89
1.84
2.65
1.23
1.00
1.82
3.10
1.04
5.78
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

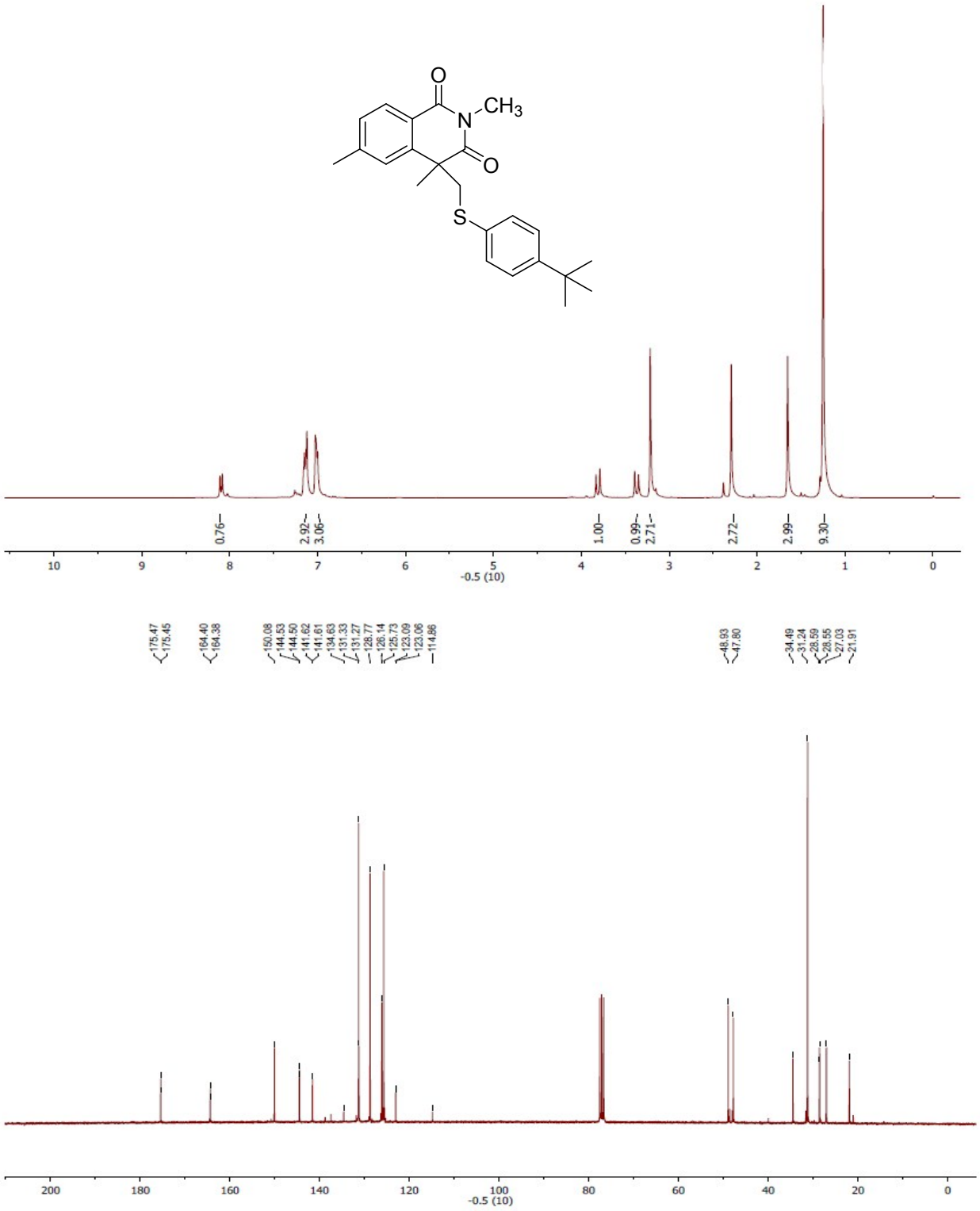

175.69
164.49
142.24
133.86
133.81
128.84
127.72
125.63
125.42
49.15
45.67
42.74
28.54
28.15
28.10
27.25
21.74
21.71
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

(Table 3, 3ba)

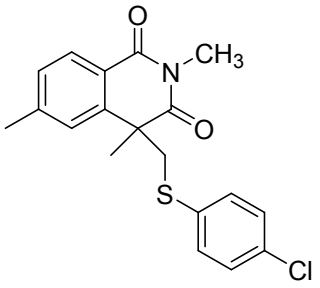

O
N
CH3
O
S
0.74
5.09
1.21
1.00
1.02
2.81
2.75
3.29
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

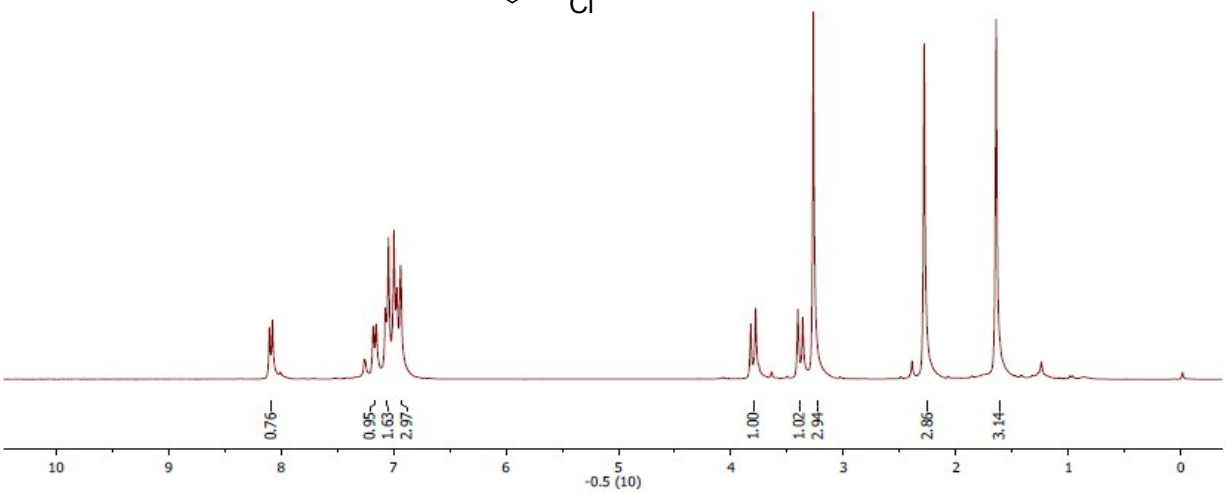

175.41
164.38
144.66
141.49
135.03
131.15
128.86
128.78
128.71
126.89
126.08
123.03
48.90
47.54
28.59
27.10
21.89
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

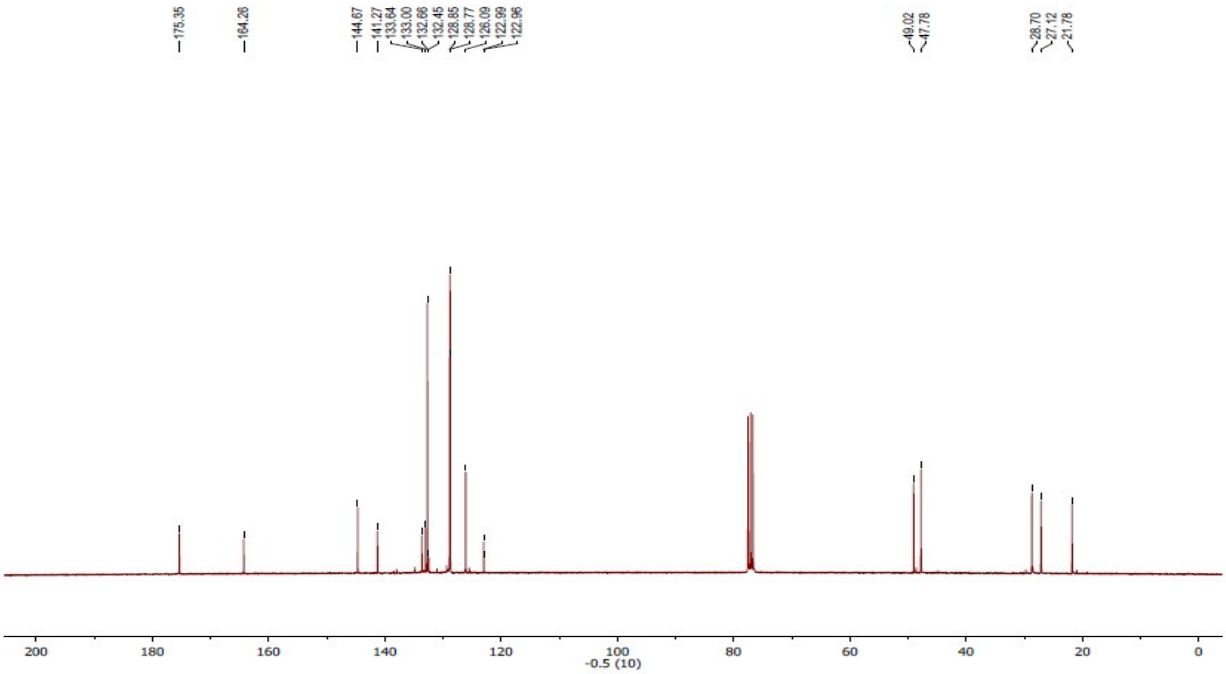
(Table 3, 3bb)


O
N
CH3
O
S
0.76
2.92
3.06
1.00
0.99
2.71
2.72
2.99
9.30
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0
175.47
175.45
164.40
164.38
150.08
144.53
144.50
141.62
141.61
134.63
131.33
131.27
128.77
126.14
125.73
123.09
123.06
114.86
48.93
47.80
34.49
31.24
28.59
28.55
27.03
21.91
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

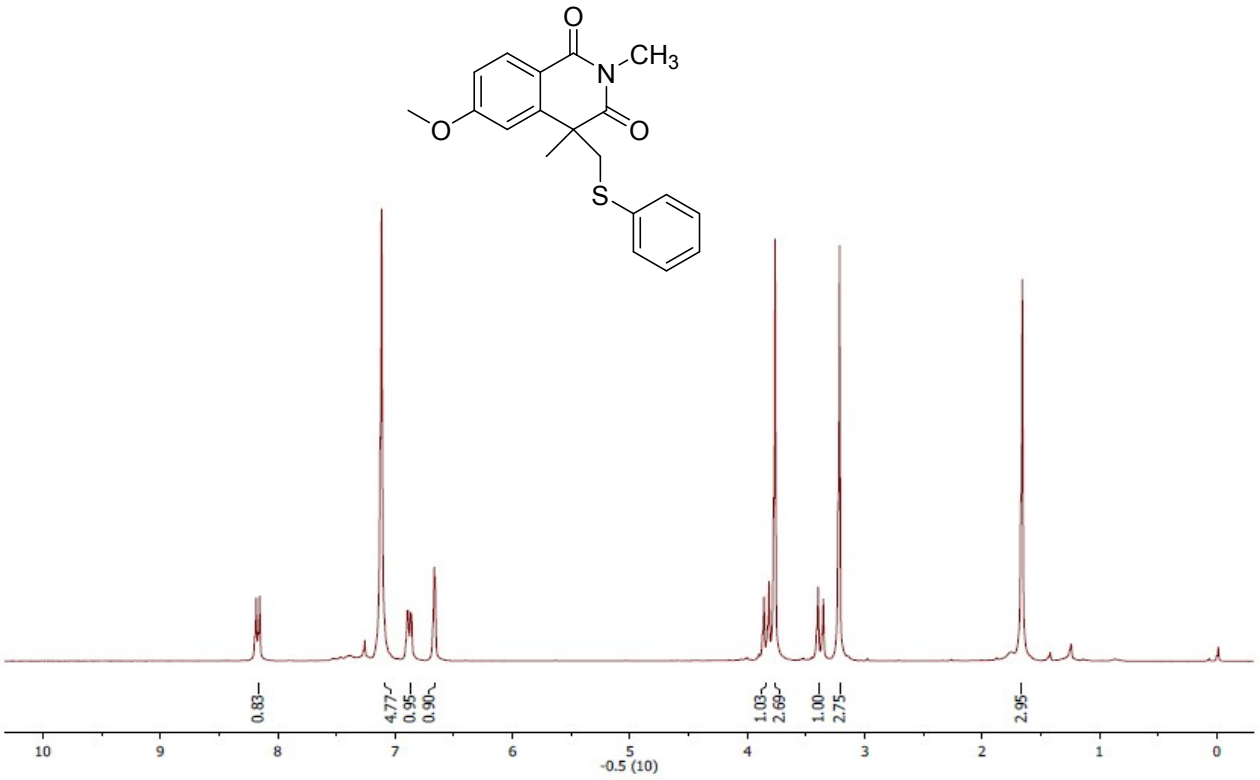
(Table 3, 3bc)

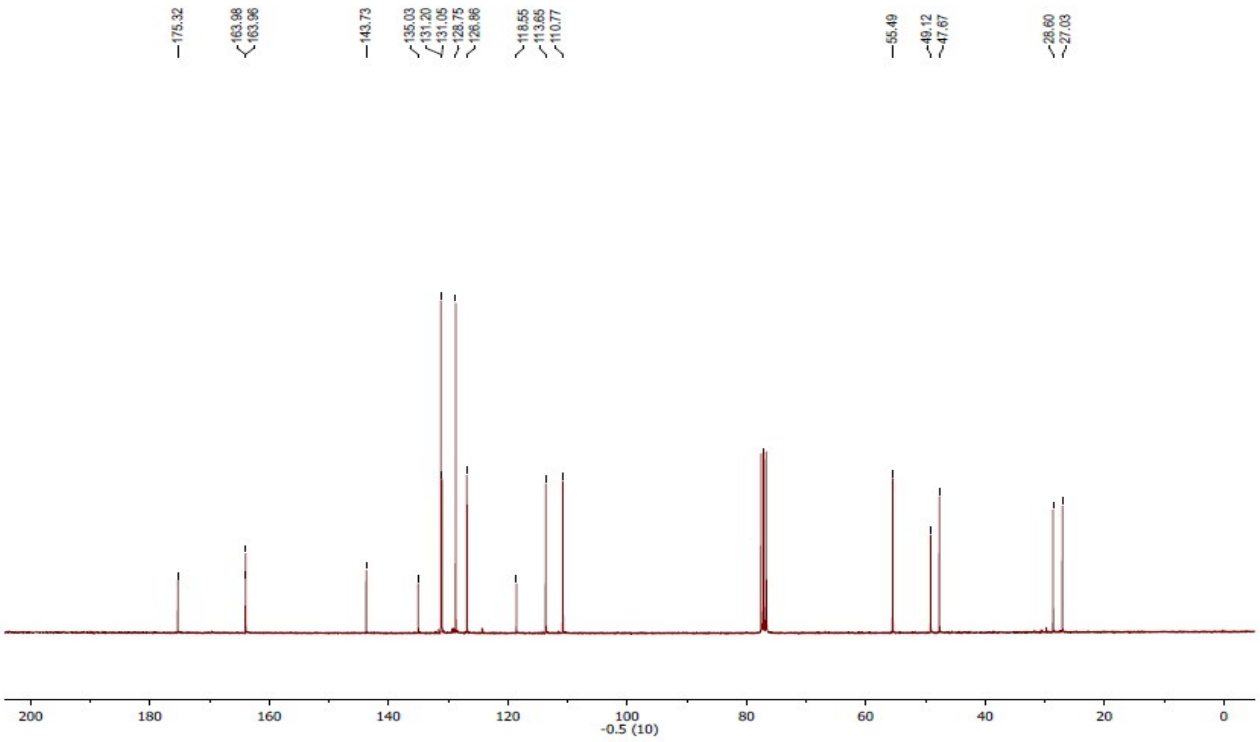

O
N
CH3
O
S
Cl


0.76
0.95
1.63
2.97
1.00
1.02
2.94
2.86
3.14
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

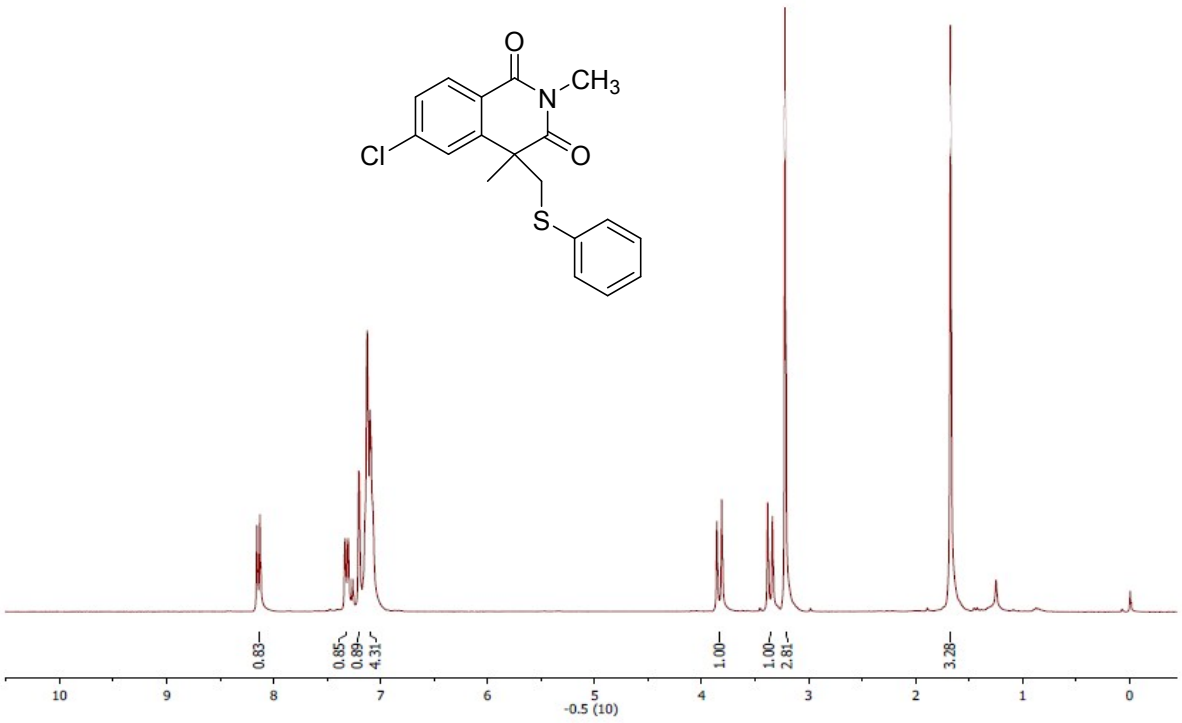

175.35
164.26
144.67
141.27
133.84
133.00
132.66
132.45
128.85
128.77
126.09
122.99
122.96
49.02
47.78
28.70
27.12
21.78
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

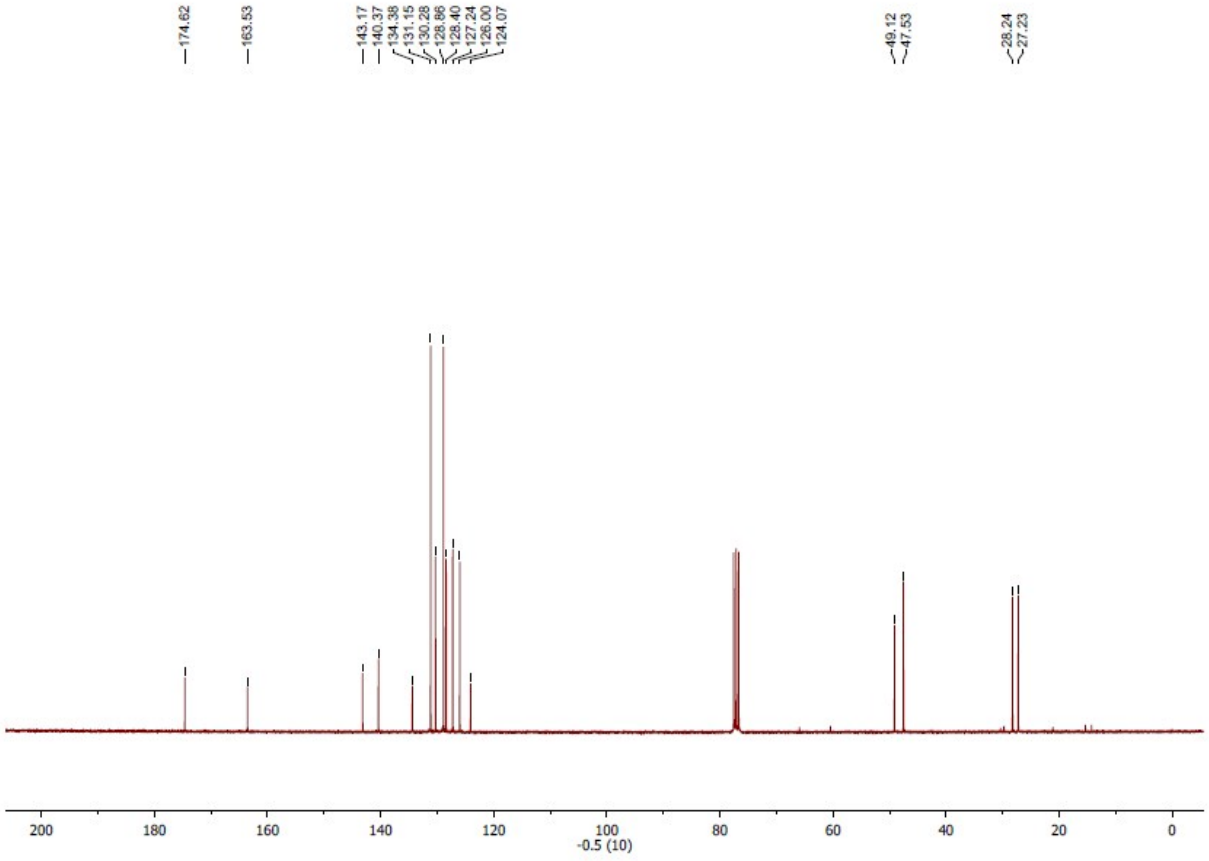
(Table 3, 3bd)


O
N
CH3
O
O
S
0.83
4.77
0.95
0.90
1.03
2.69
1.00
2.75
2.95
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)

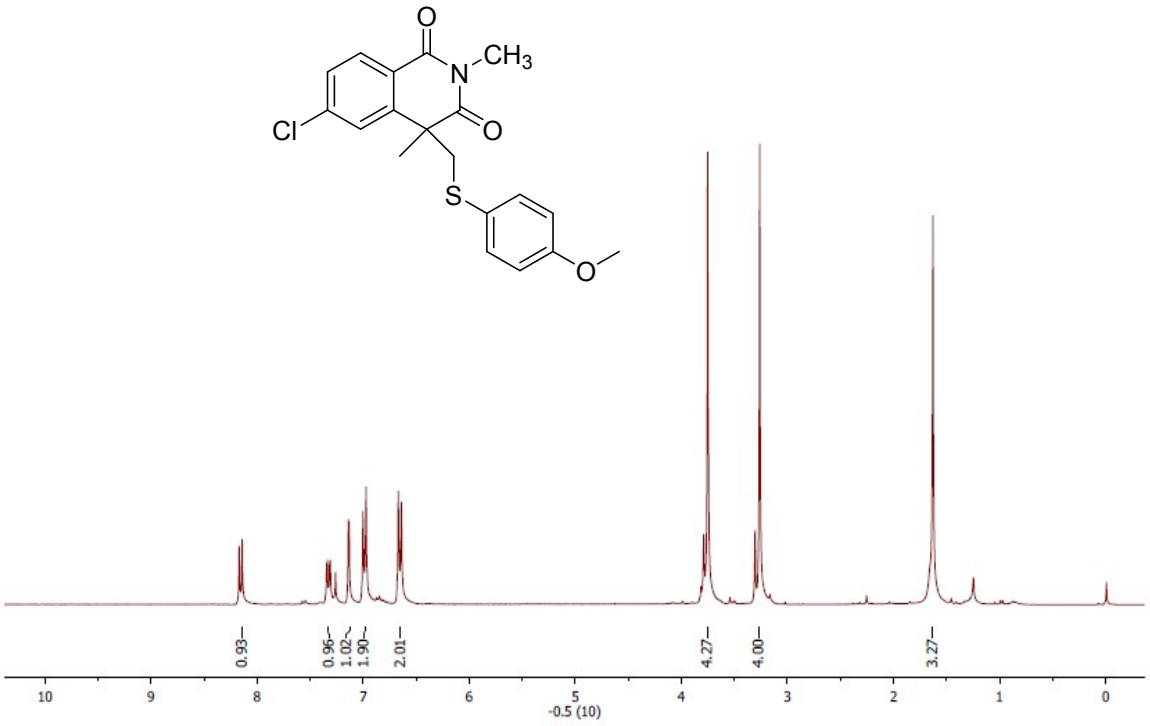

175.32
163.98
163.96
143.73
135.03
131.20
131.05
128.75
126.86
118.55
113.65
110.77
55.49
49.12
47.67
28.60
27.03
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)

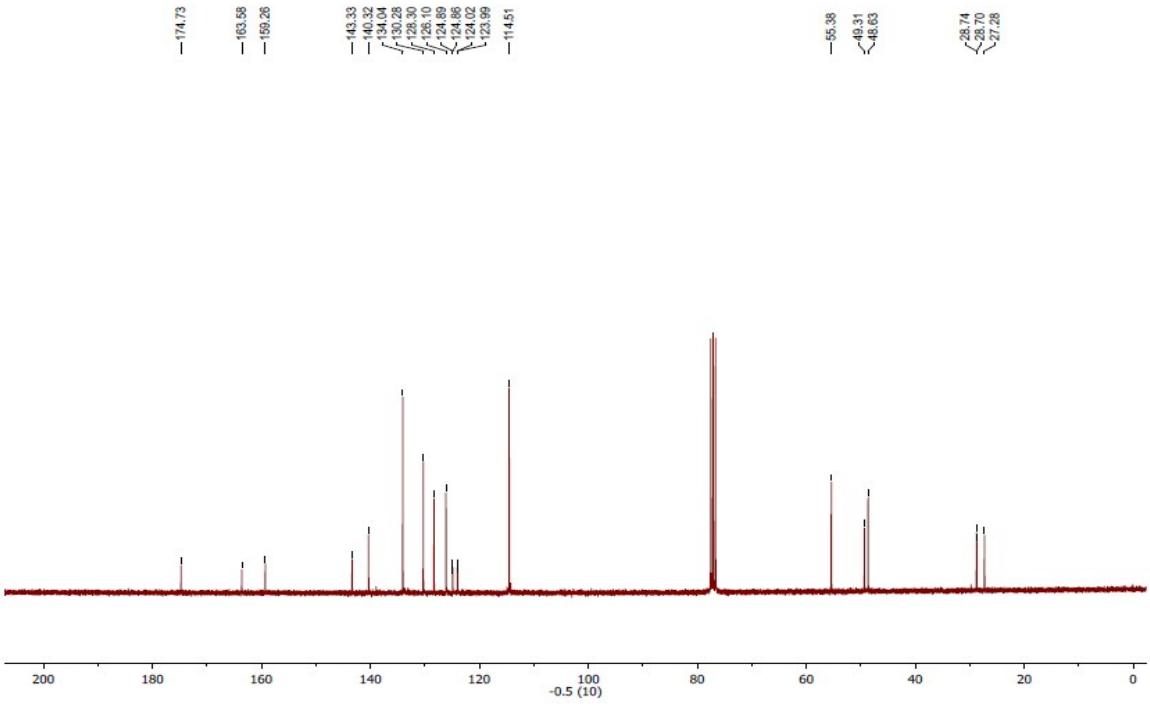
(Table 3, 3be)


O
N
CH3
O
Cl
S
0.83
0.85
0.89
4.31
1.00
1.00
2.81
3.28
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)

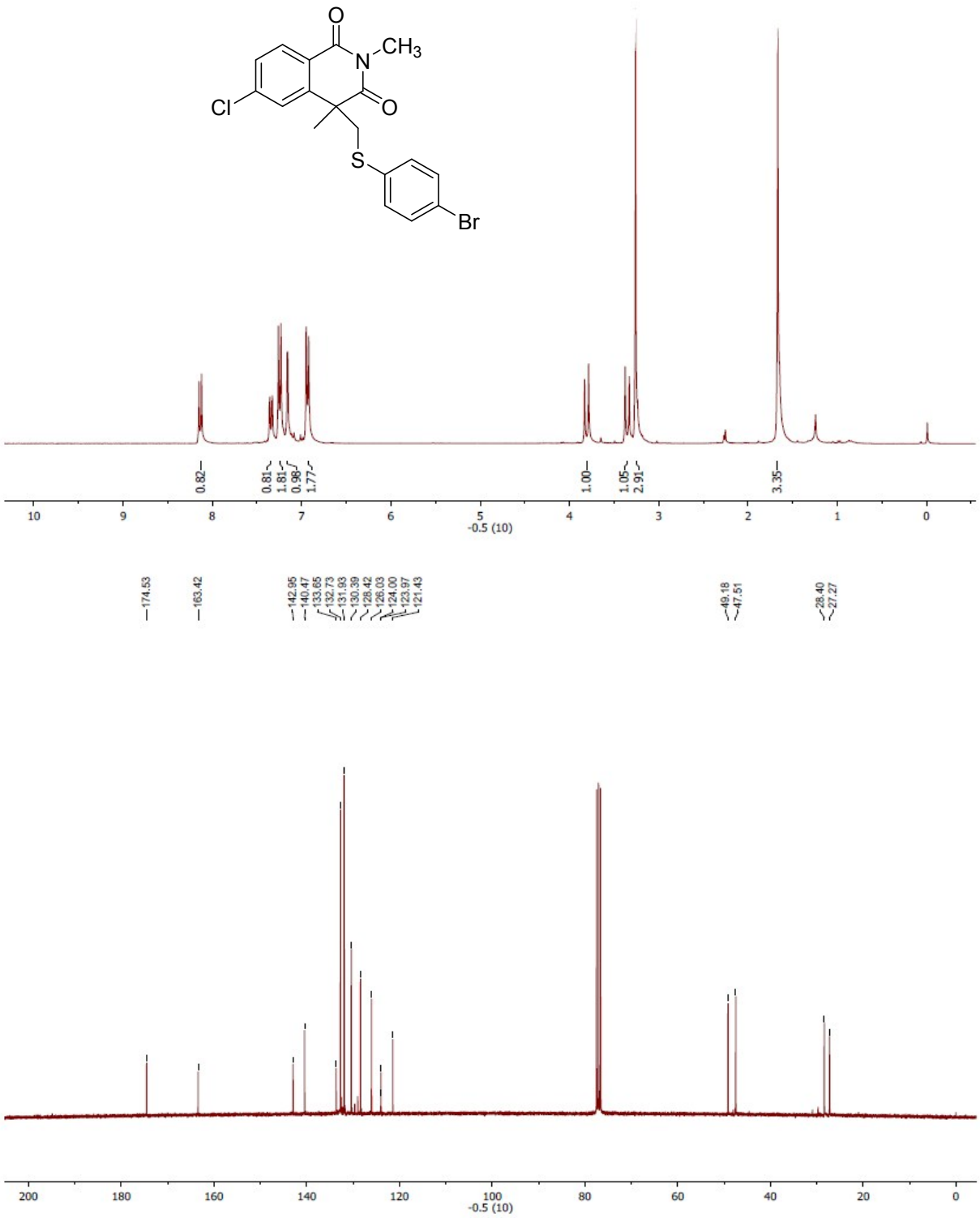

174.62
163.53
143.17
140.37
134.38
131.15
130.28
128.86
128.40
127.24
126.00
124.07
49.12
47.53
28.24
27.23
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)

(Table 3, 3bf)

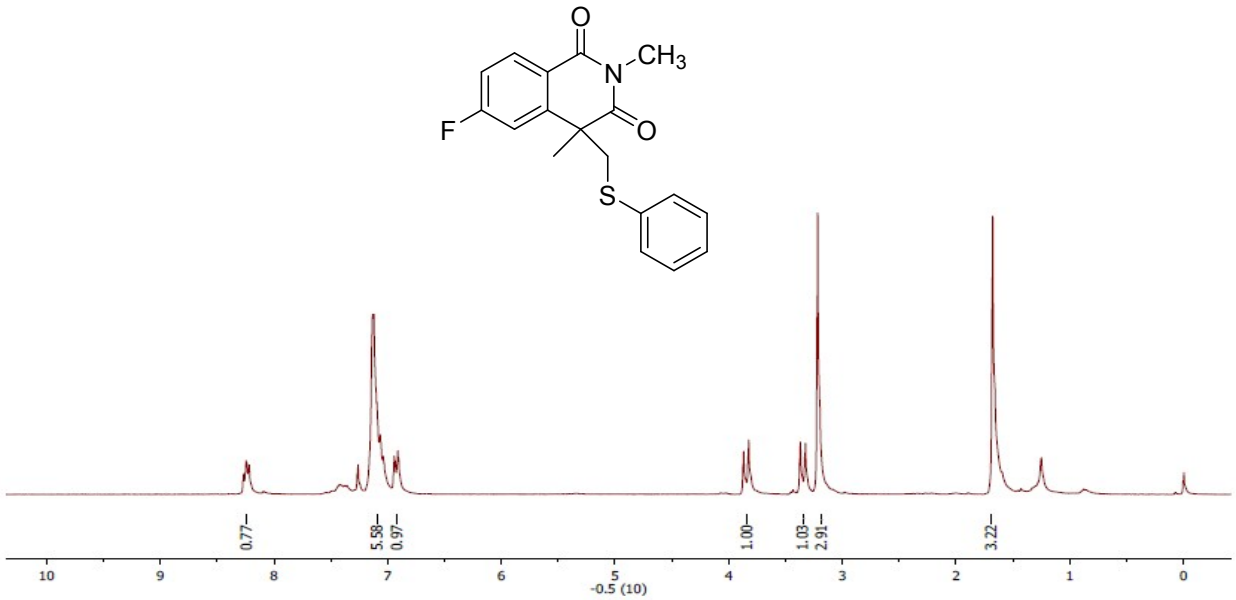

O
N
CH3
O
Cl
S
O
0.93
0.96
1.02
1.90
2.01
4.27
4.00
3.27
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)

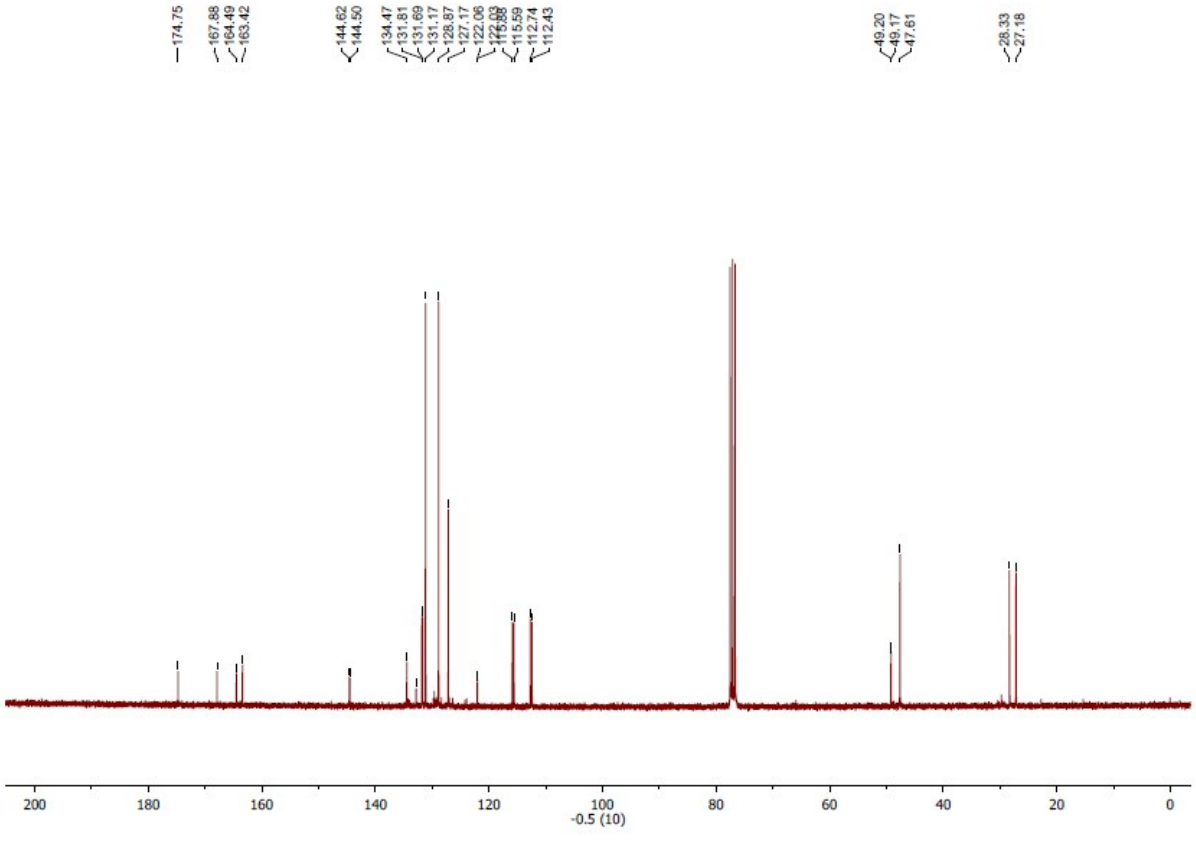

174.73
163.58
159.26
143.33
140.32
134.04
130.28
128.30
126.10
124.89
124.86
124.02
123.99
114.51
55.38
49.31
48.63
28.74
28.70
27.28
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)

(Table 3, 3bg)

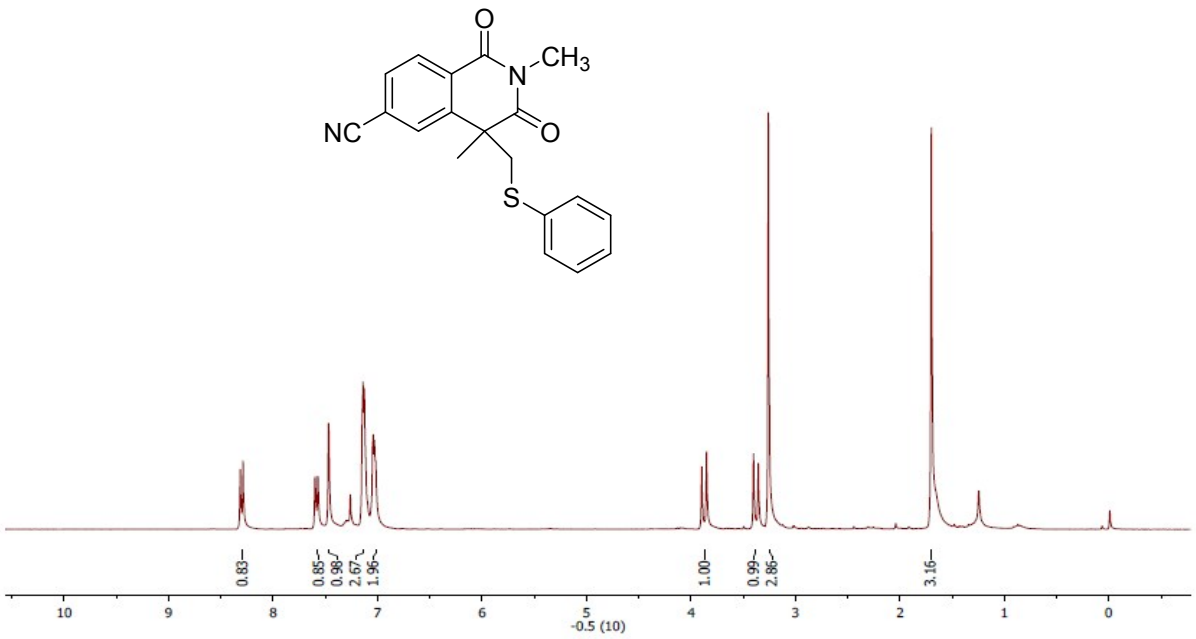

O
N
CH3
O
Cl
S
Br
0.82
0.81
1.81
0.98
1.77
1.00
1.05
2.91
3.35
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0
174.53
163.42
142.95
140.47
133.65
132.73
131.93
130.39
128.42
126.03
124.00
123.97
121.43
49.18
47.51
28.40
27.27
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

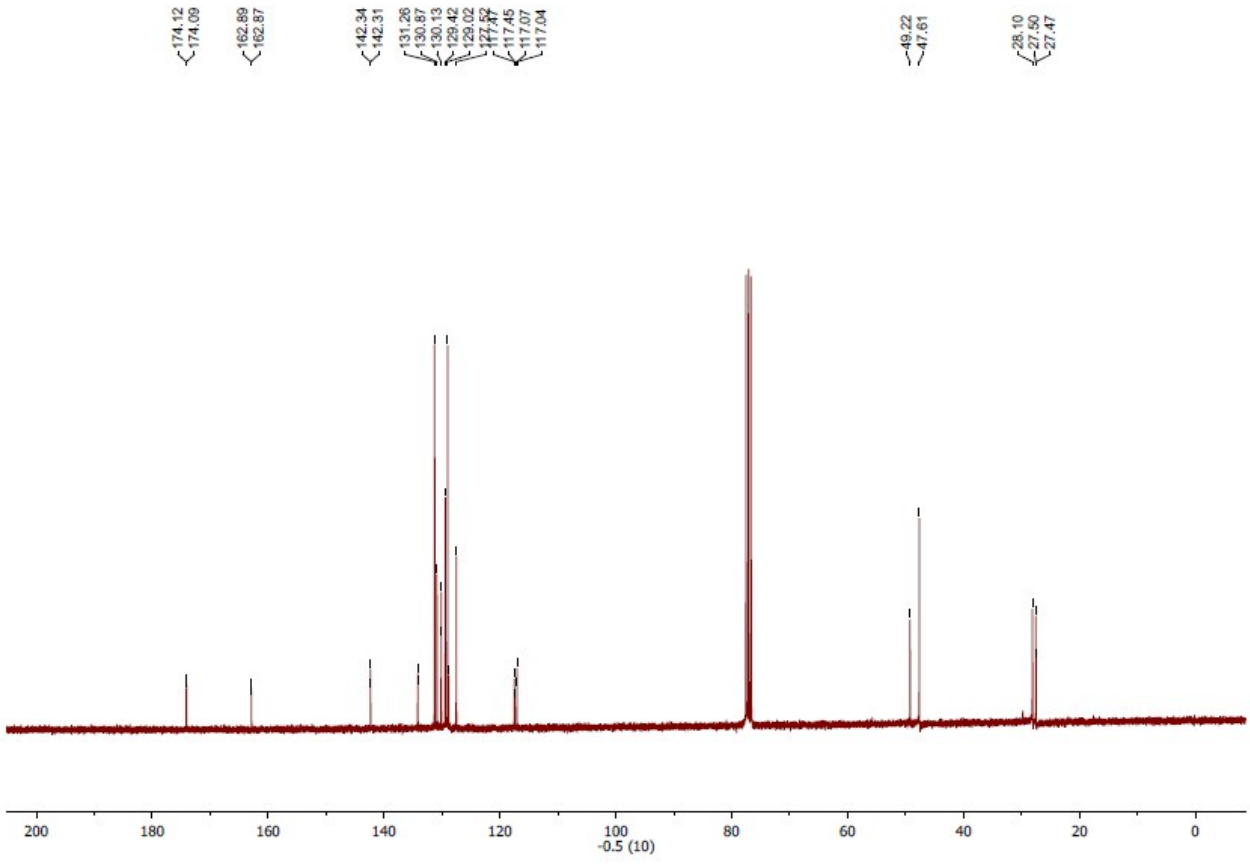
(Table 3, 3bh)


O
N
CH3
O
F
S
0.77
5.58
0.97
1.00
1.03
2.91
3.22
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

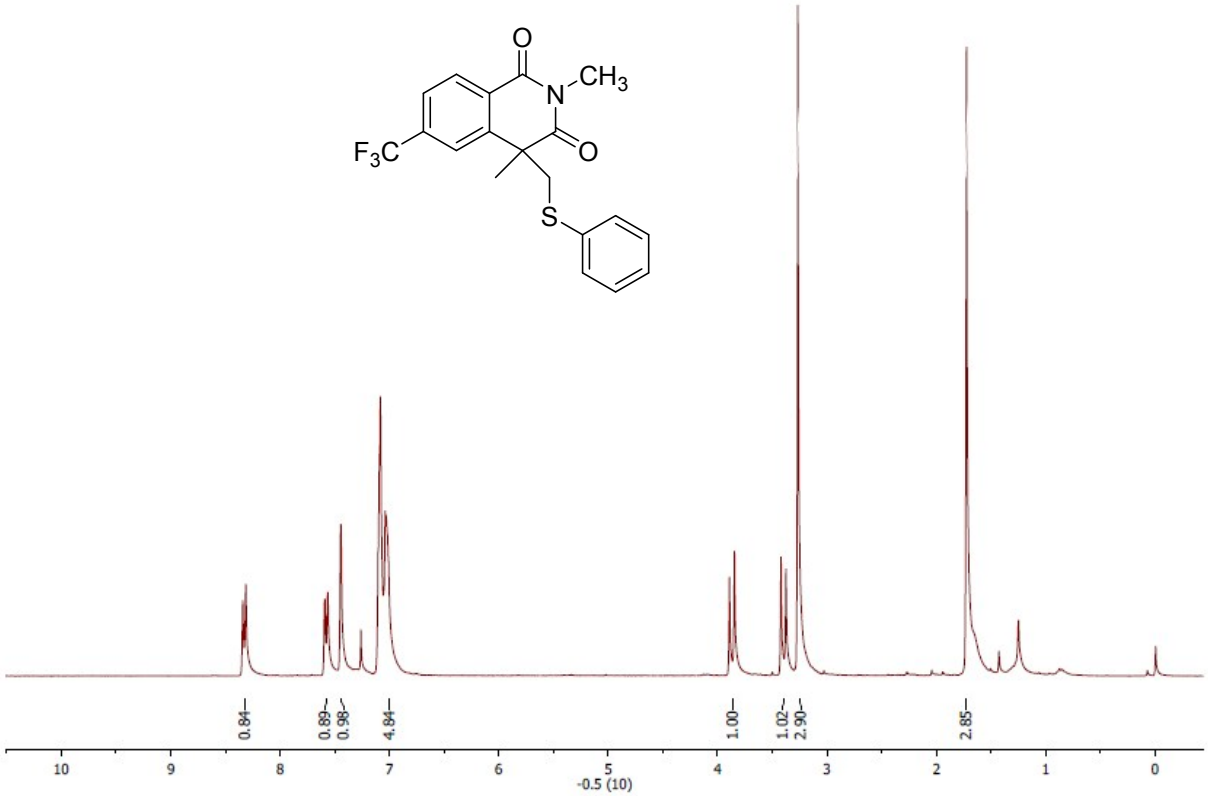

174.75
167.88
164.49
163.42
144.62
144.50
134.47
131.81
131.69
131.17
128.87
127.17
122.06
115.88
115.59
112.74
112.43
49.20
49.17
47.61
28.33
27.18
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

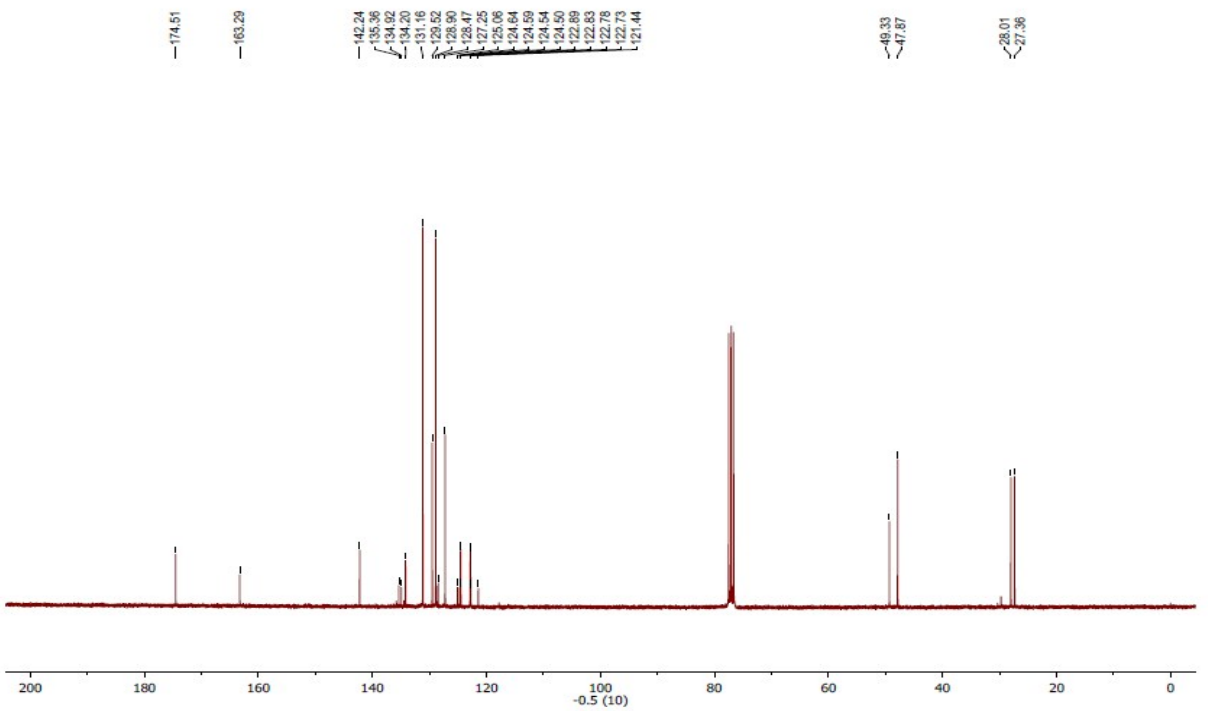
(Table 3, 3bi)


O
N
CH3
O
NC
S
0.83
0.85
0.98
2.67
1.96
1.00
0.99
2.86
3.16
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

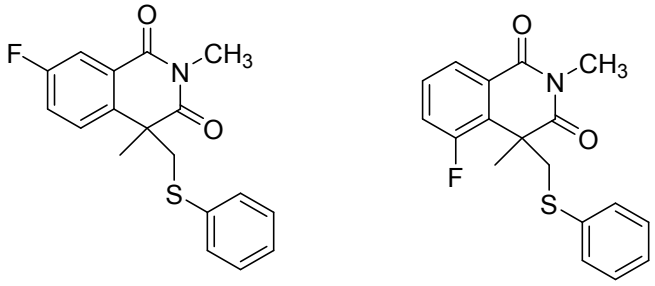

174.12
174.09
162.89
162.87
142.34
142.31
131.26
130.87
130.13
129.42
129.02
127.52
127.47
117.45
117.07
117.04
49.22
47.61
28.10
27.50
27.47
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

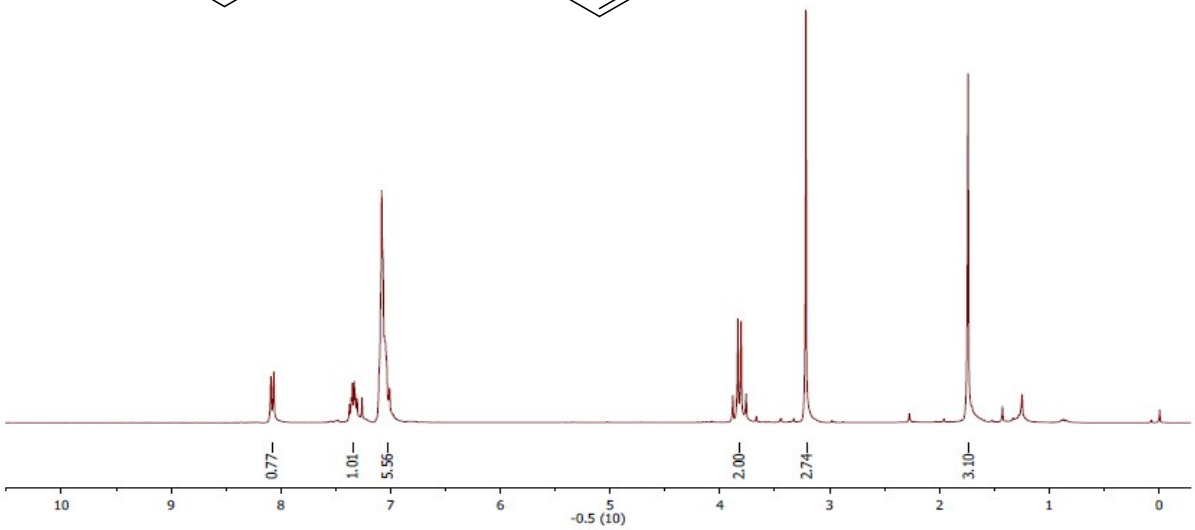
(Table 3, 3bj)

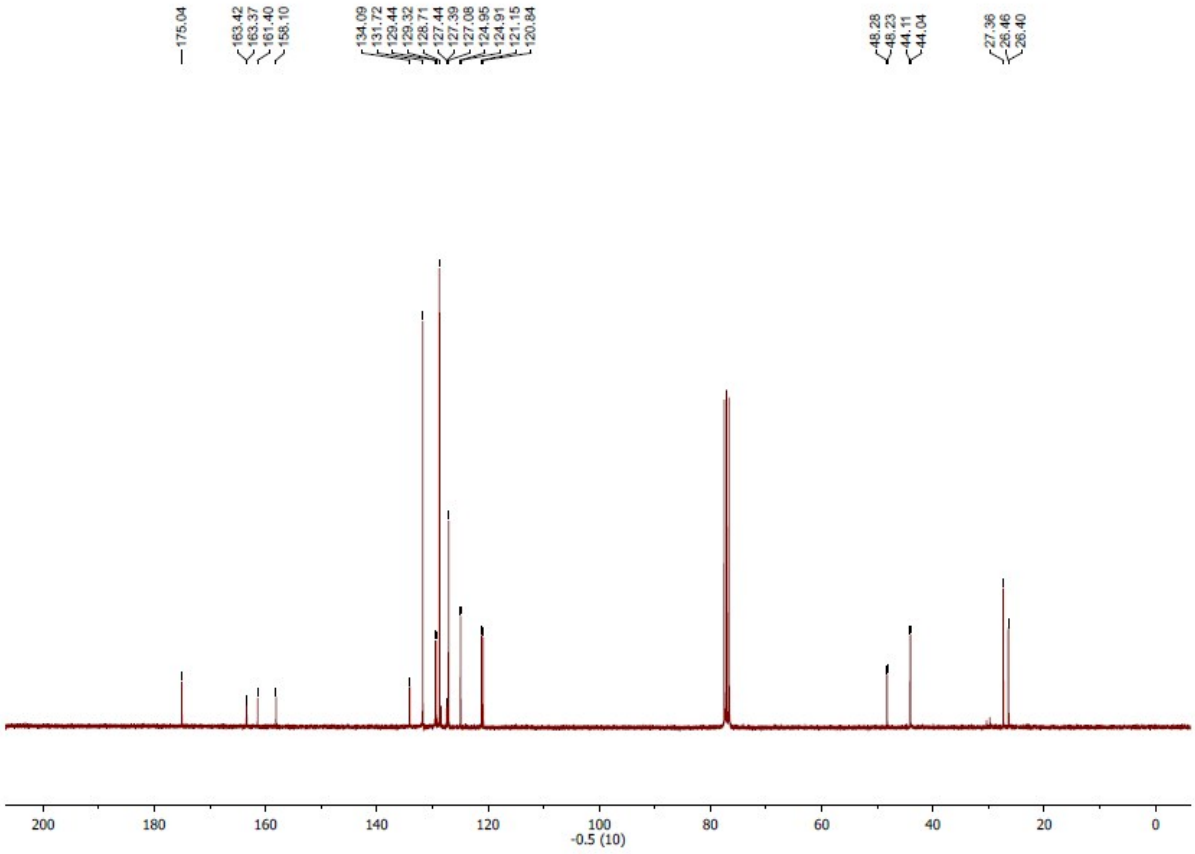

O
N
CH3
O
F3C
S
0.84
0.89
0.98
4.84
1.00
1.02
2.90
2.85
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)


174.51
163.29
142.24
135.36
134.92
134.20
131.16
129.52
128.90
128.47
127.25
125.06
124.64
124.59
124.54
124.50
122.89
122.83
122.78
122.73
121.44
49.33
47.87
28.01
27.36
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)

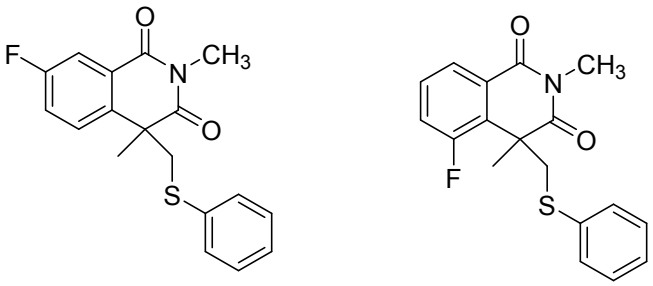
(Table 3, 3bk)


O
F
N
CH3
O
S
O
N
CH3
O
F
S

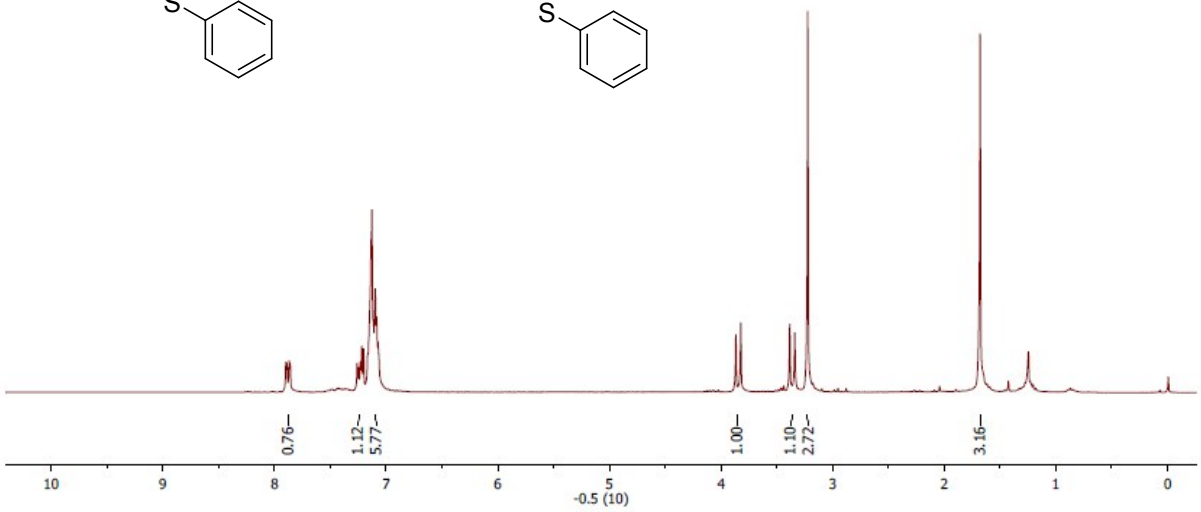

0.77
1.01
5.56
2.00
2.74
3.10
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

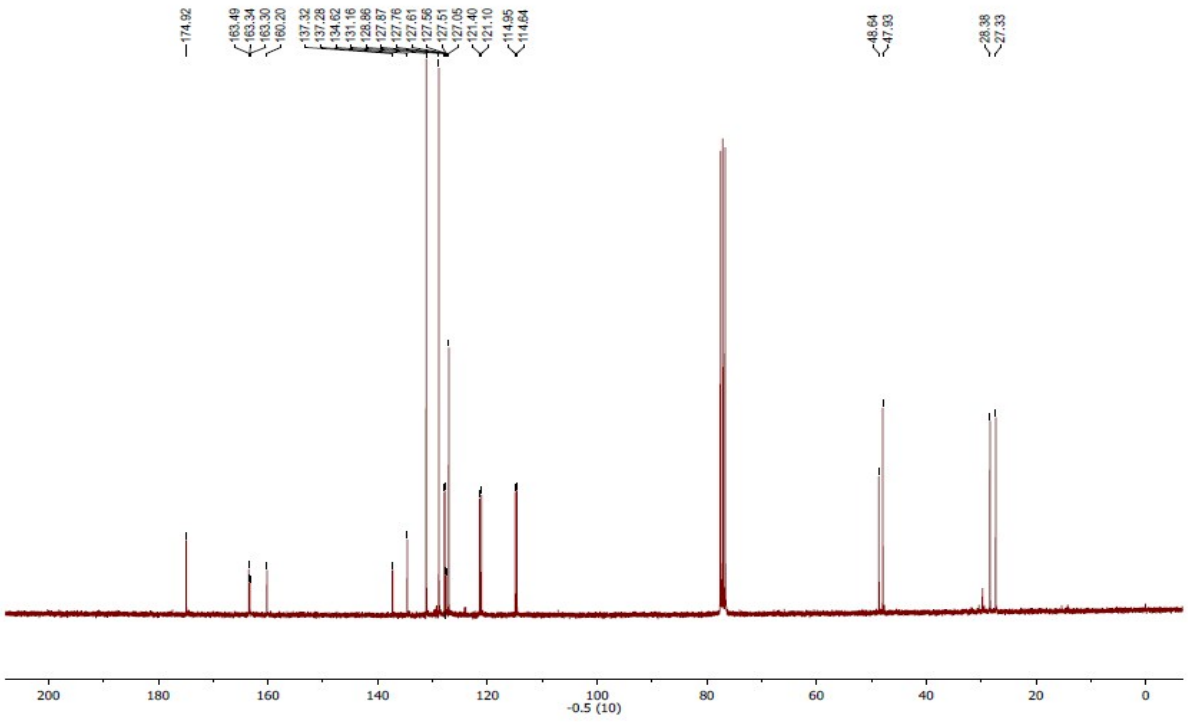

175.04
163.42
163.37
161.40
158.10
134.09
131.72
129.44
129.32
128.71
127.44
127.39
127.08
124.95
124.91
121.15
120.84
48.28
48.23
44.11
44.04
27.36
26.46
26.40
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

(Table 3, 3bk)

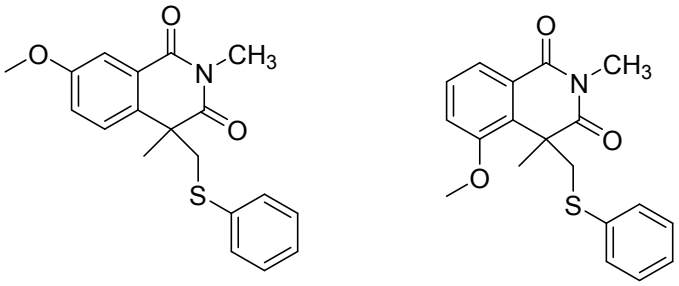

O
F
N
CH3
O
S

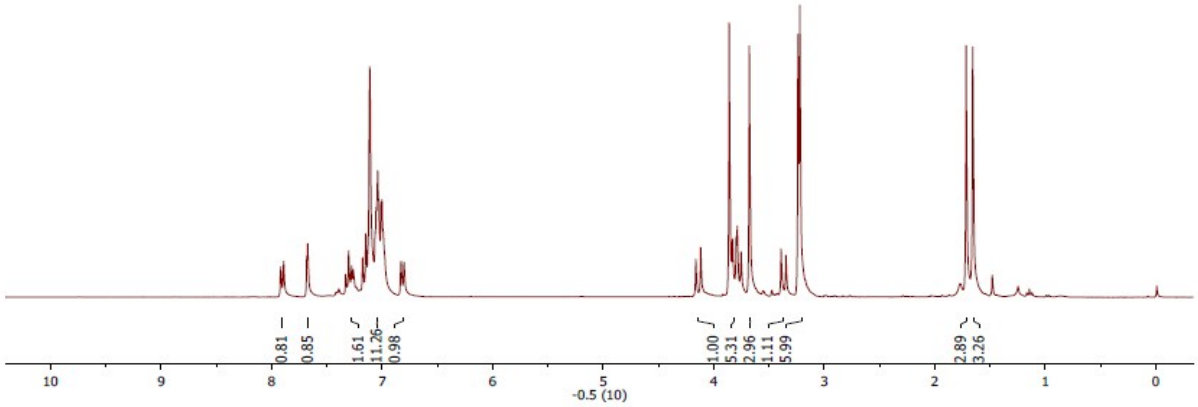
O
N
CH3
O
F
S

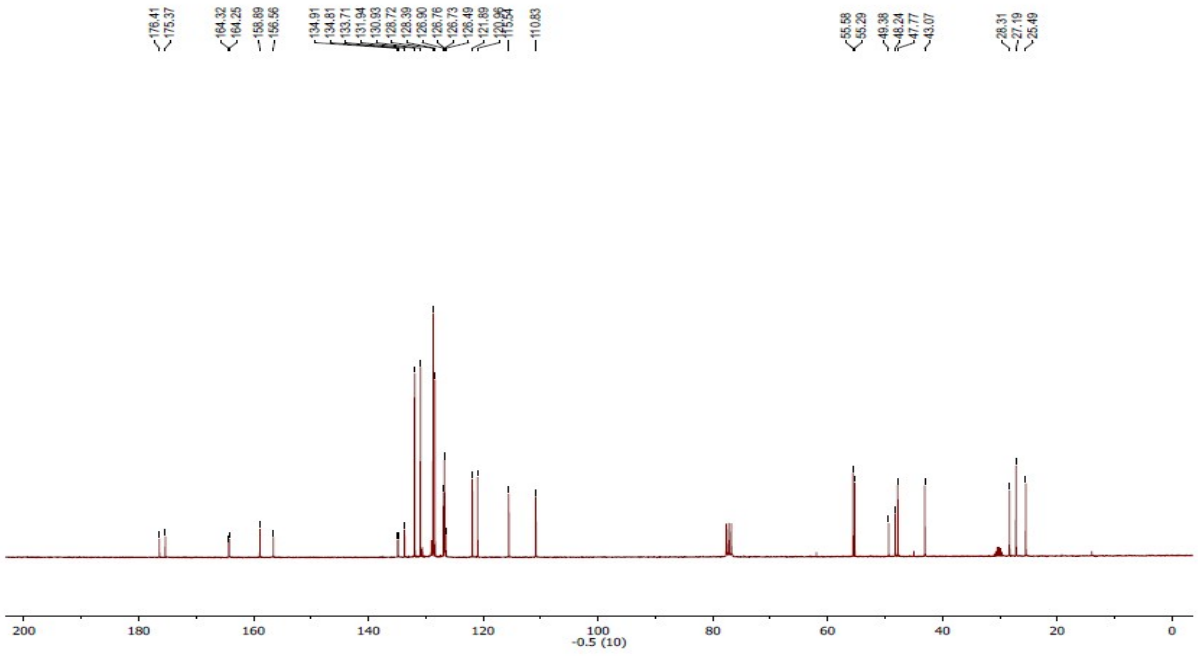

0.76
1.12
5.77
1.00
1.10
2.72
3.16
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0


174.92
163.49
163.34
163.30
160.20
137.32
137.28
134.62
131.16
128.86
127.87
127.76
127.61
127.56
127.51
127.05
121.40
121.10
114.95
114.64
48.64
47.93
28.38
27.33
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

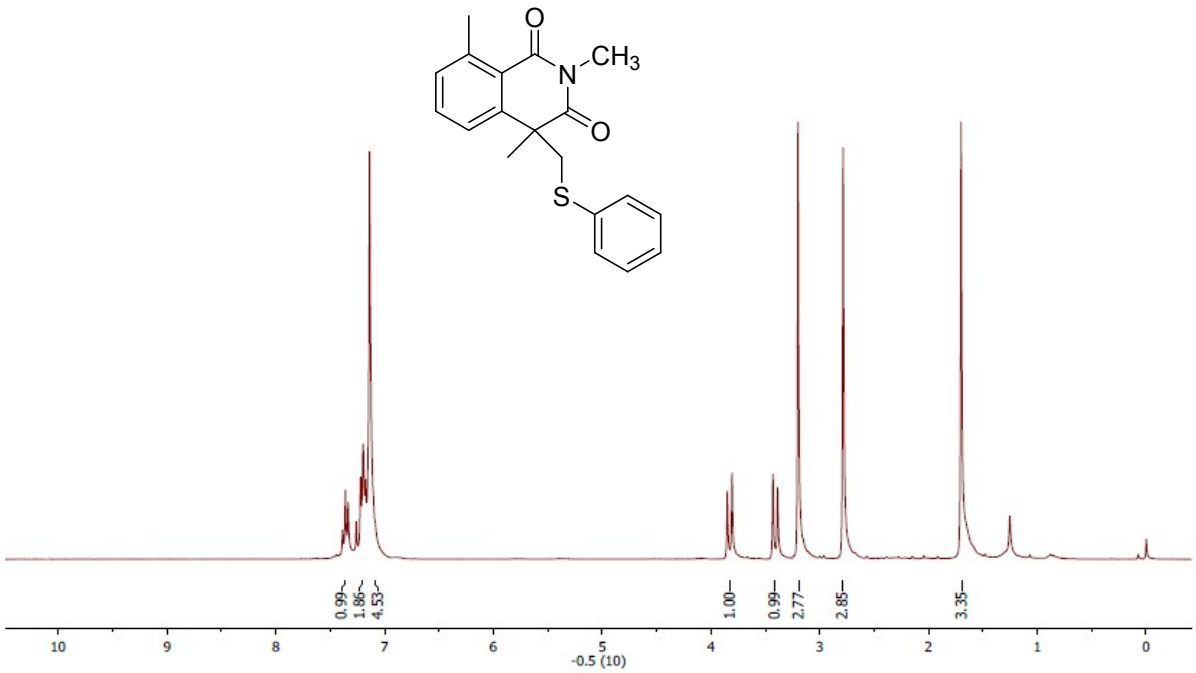
(Table 3, 3bl+3bl′)

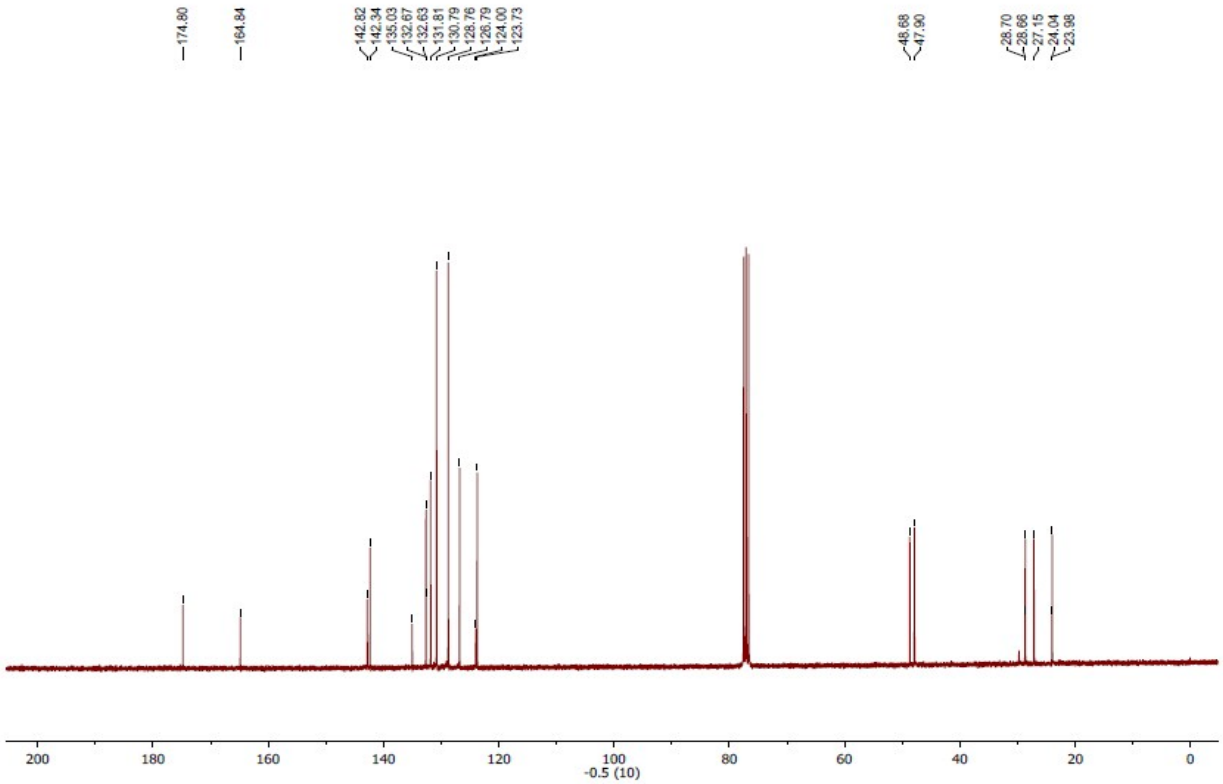




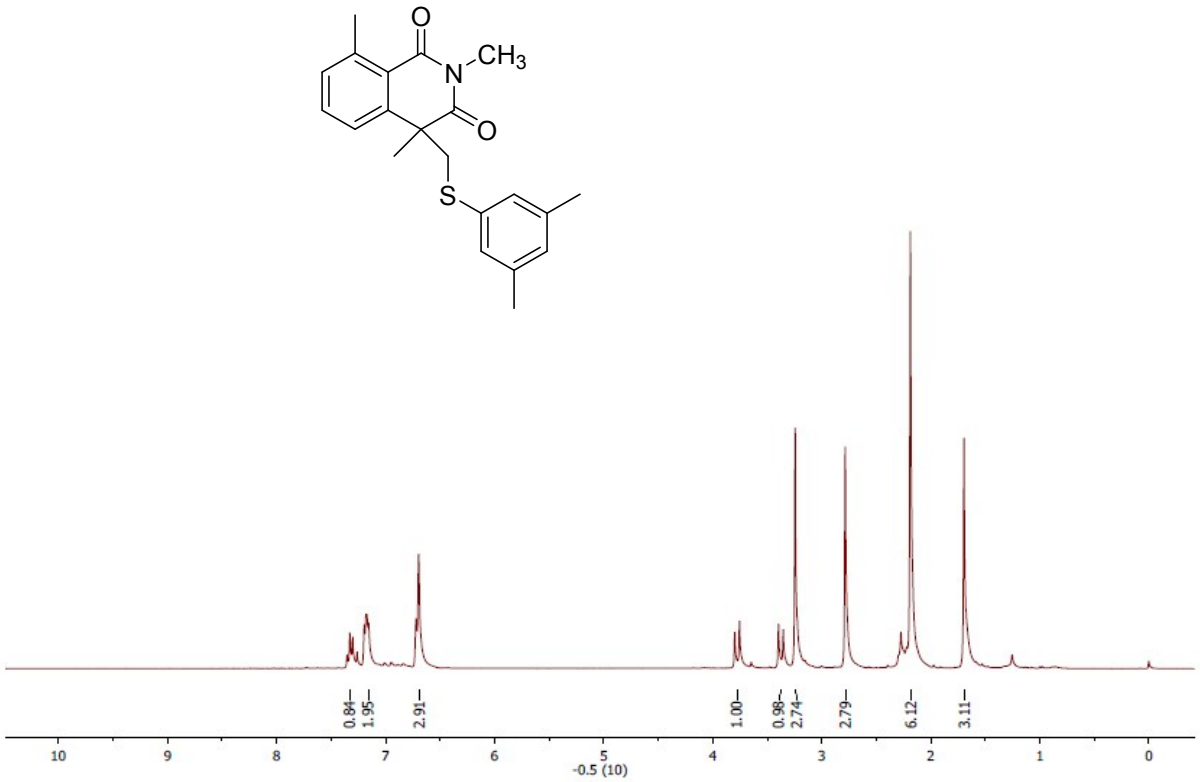


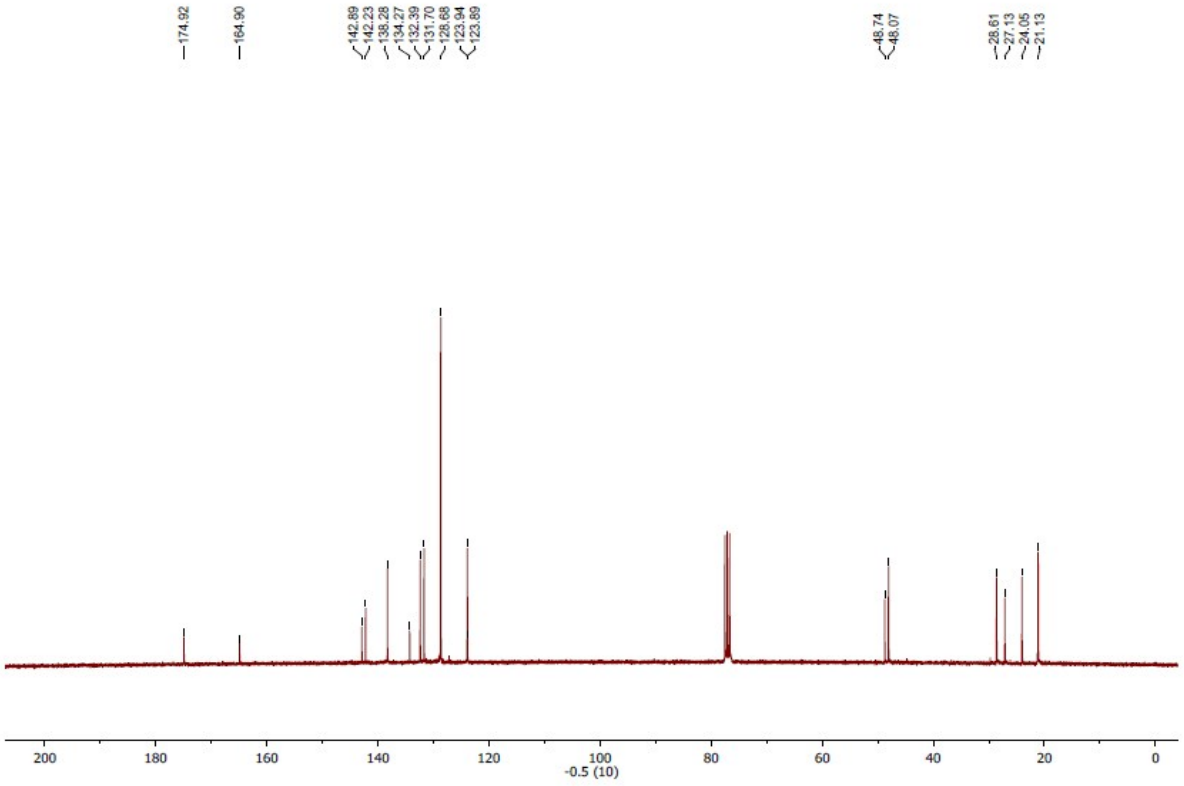
(Table 3, 3bm)


O
N
CH3
O
S
0.99
1.86
4.53
1.00
0.99
2.77
2.85
3.35
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

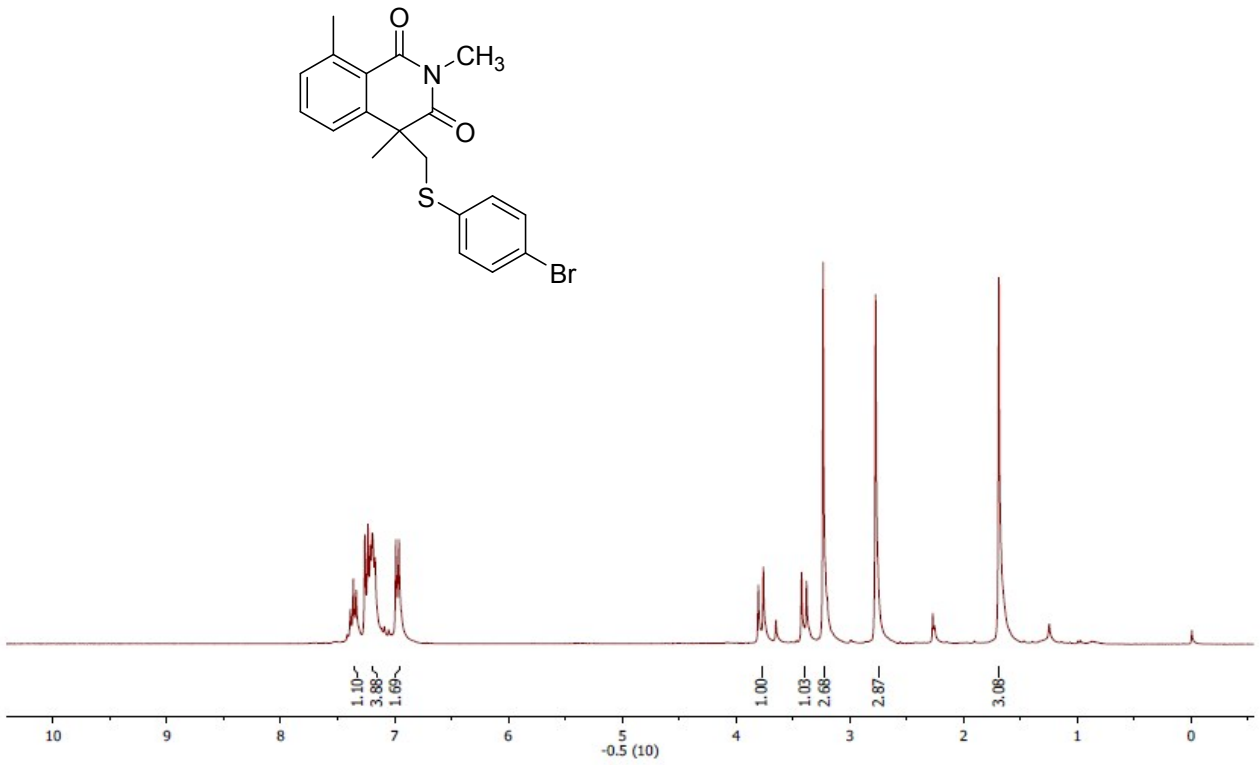

174.80
164.84
142.82
142.34
135.03
132.67
132.63
131.81
130.79
128.76
126.79
124.00
123.73
48.68
47.90
28.70
28.66
27.15
24.04
23.98
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

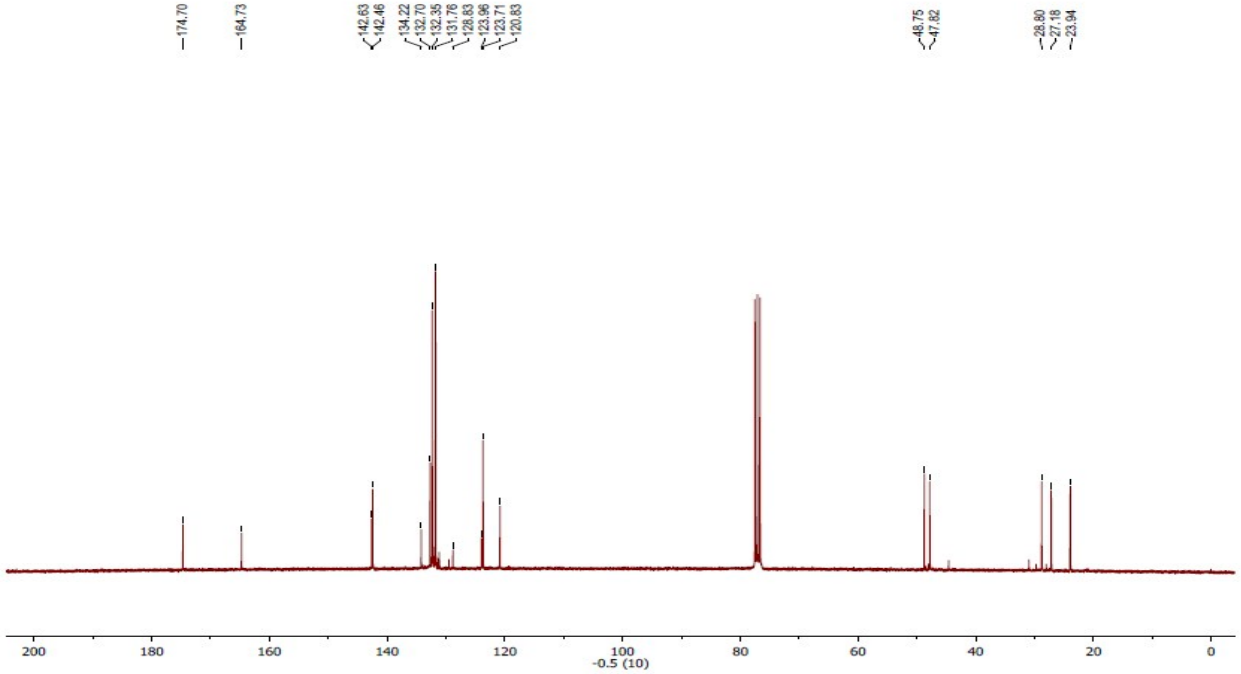
(Table 3, 3bn)


O
N
CH3
O
S
0.84
1.95
2.91
1.00
0.98
2.74
2.79
6.12
3.11
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

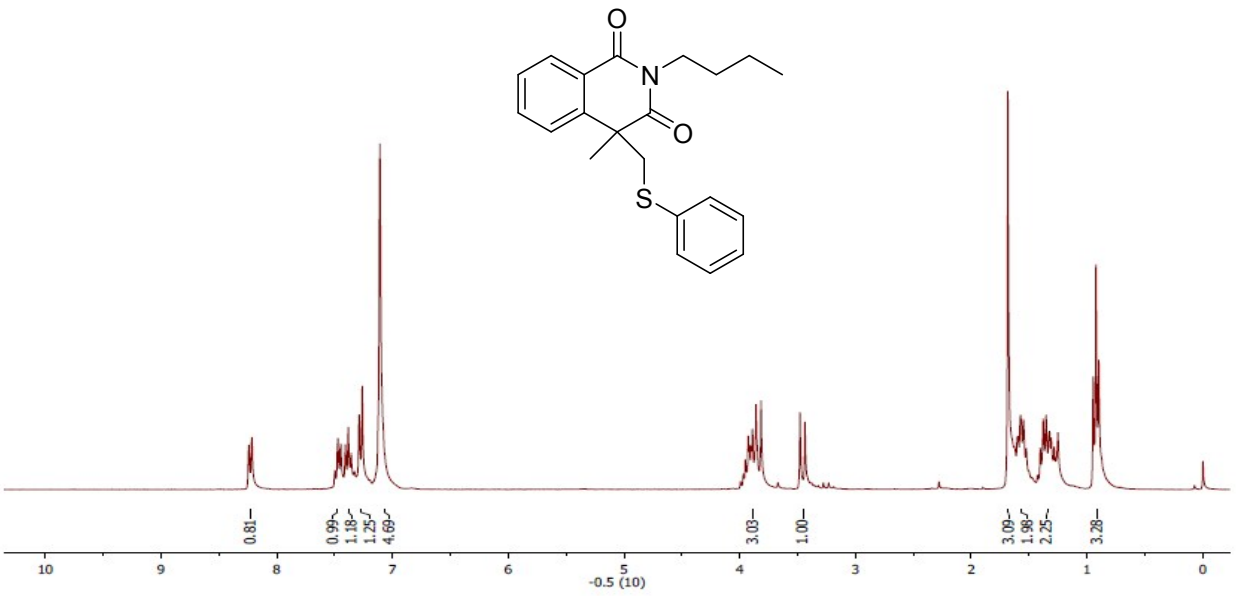

174.92
164.90
142.89
142.23
138.28
134.27
132.39
131.70
128.68
123.94
123.89
48.74
48.07
28.61
27.13
24.05
21.13
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

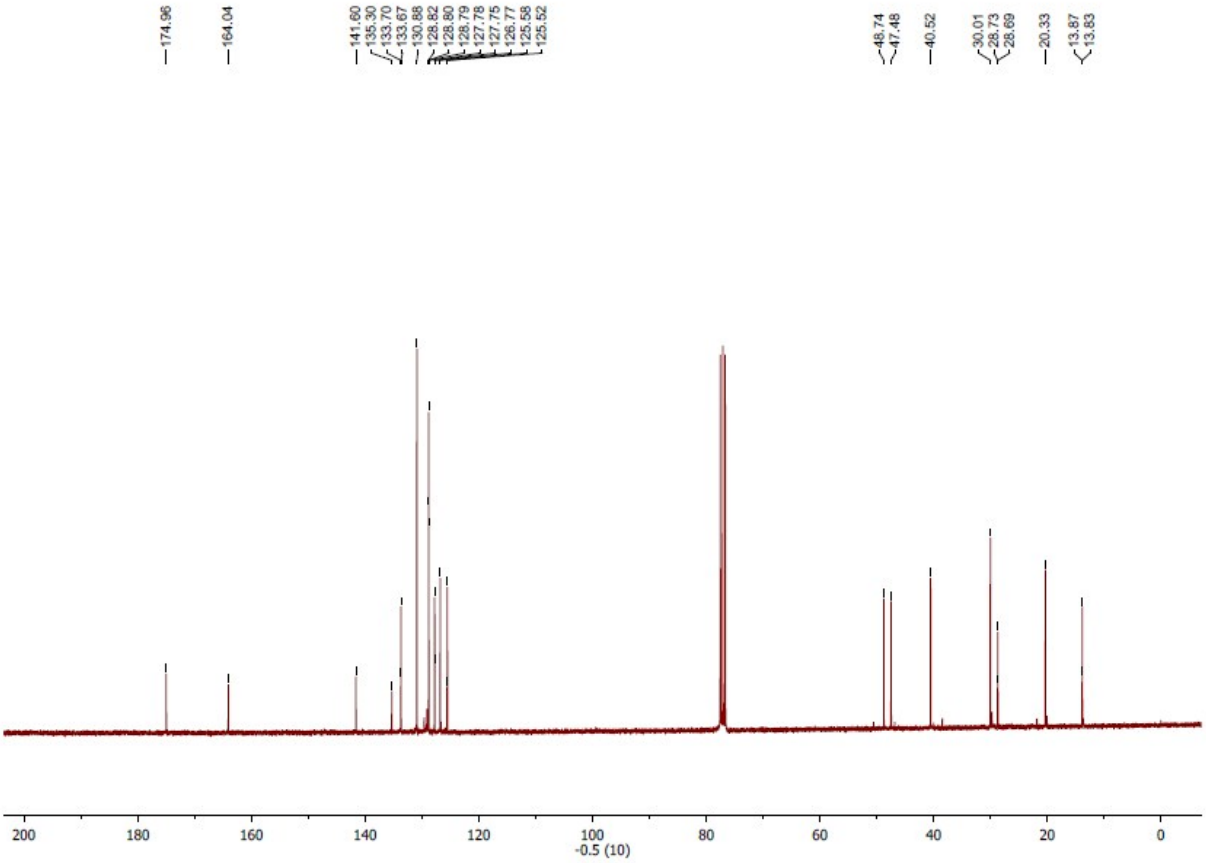
(Table 3, 3bo)


O
N
CH3
O
S
Br
1.10
3.88
1.69
1.00
1.03
2.68
2.87
3.08
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0

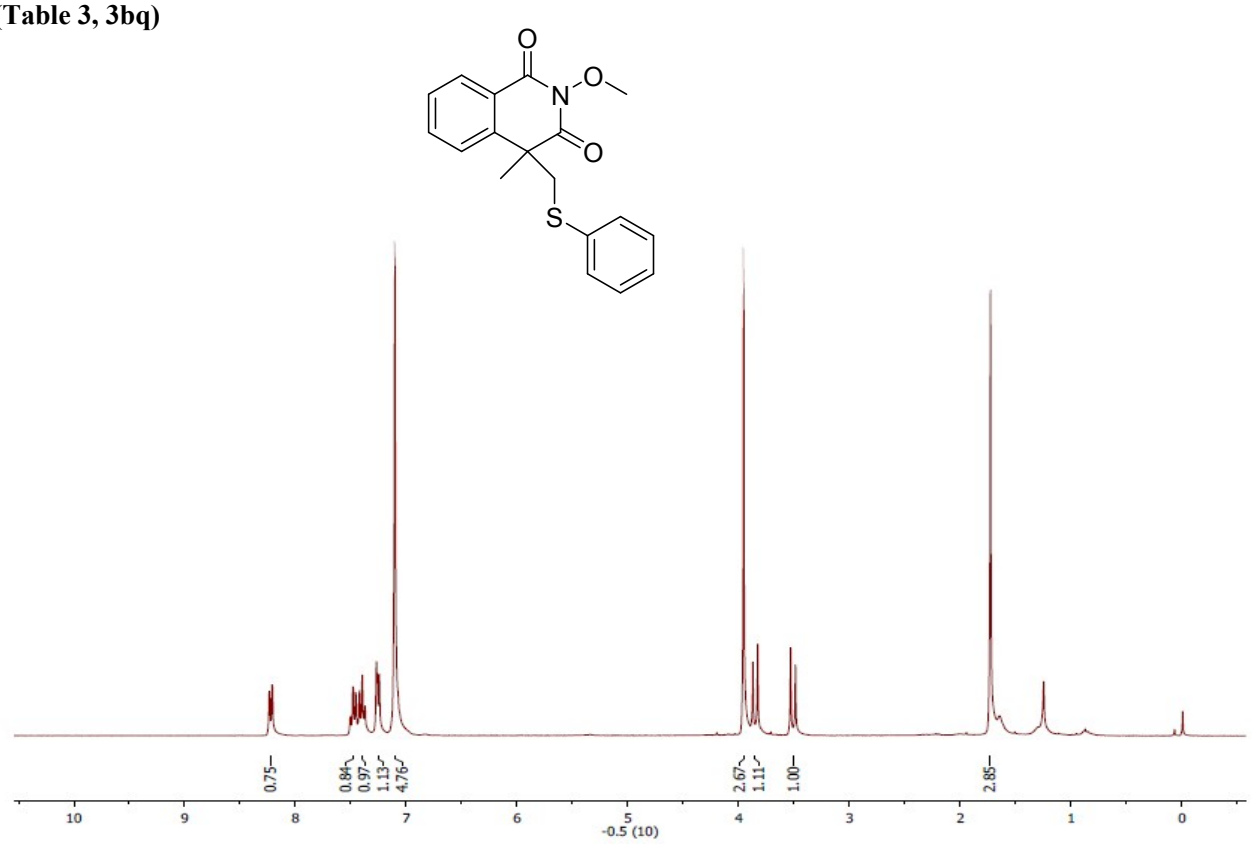

174.70
164.73
142.63
142.46
134.22
132.70
132.35
131.76
128.83
123.96
123.71
120.83
48.75
47.82
28.80
27.18
23.94
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

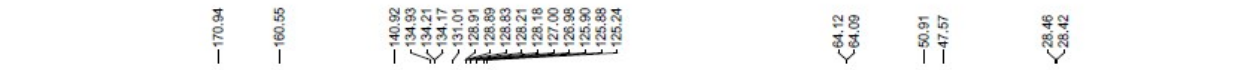
(Table 3, 3bp)

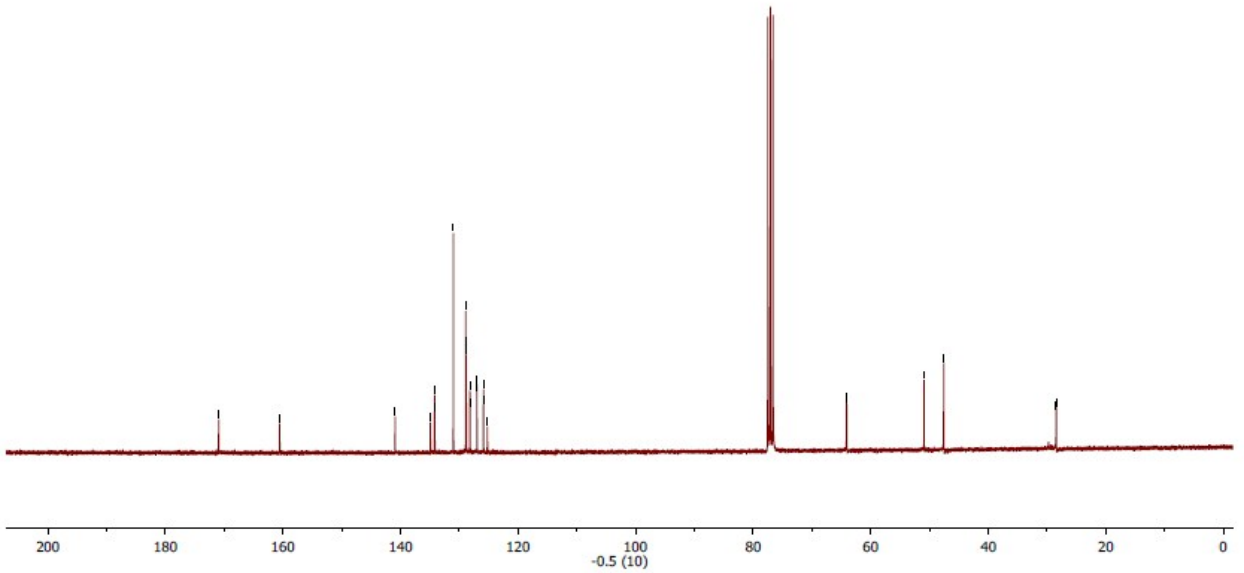

O
N
O
S
0.81
0.99
1.18
1.25
4.69
3.03
1.00
3.09
1.98
2.25
3.28
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0


174.96
164.04
141.60
135.30
133.70
133.67
130.88
128.82
128.80
128.79
127.78
127.75
126.77
125.58
125.52
46.74
47.48
40.52
30.01
28.73
28.69
20.33
13.87
13.83
200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

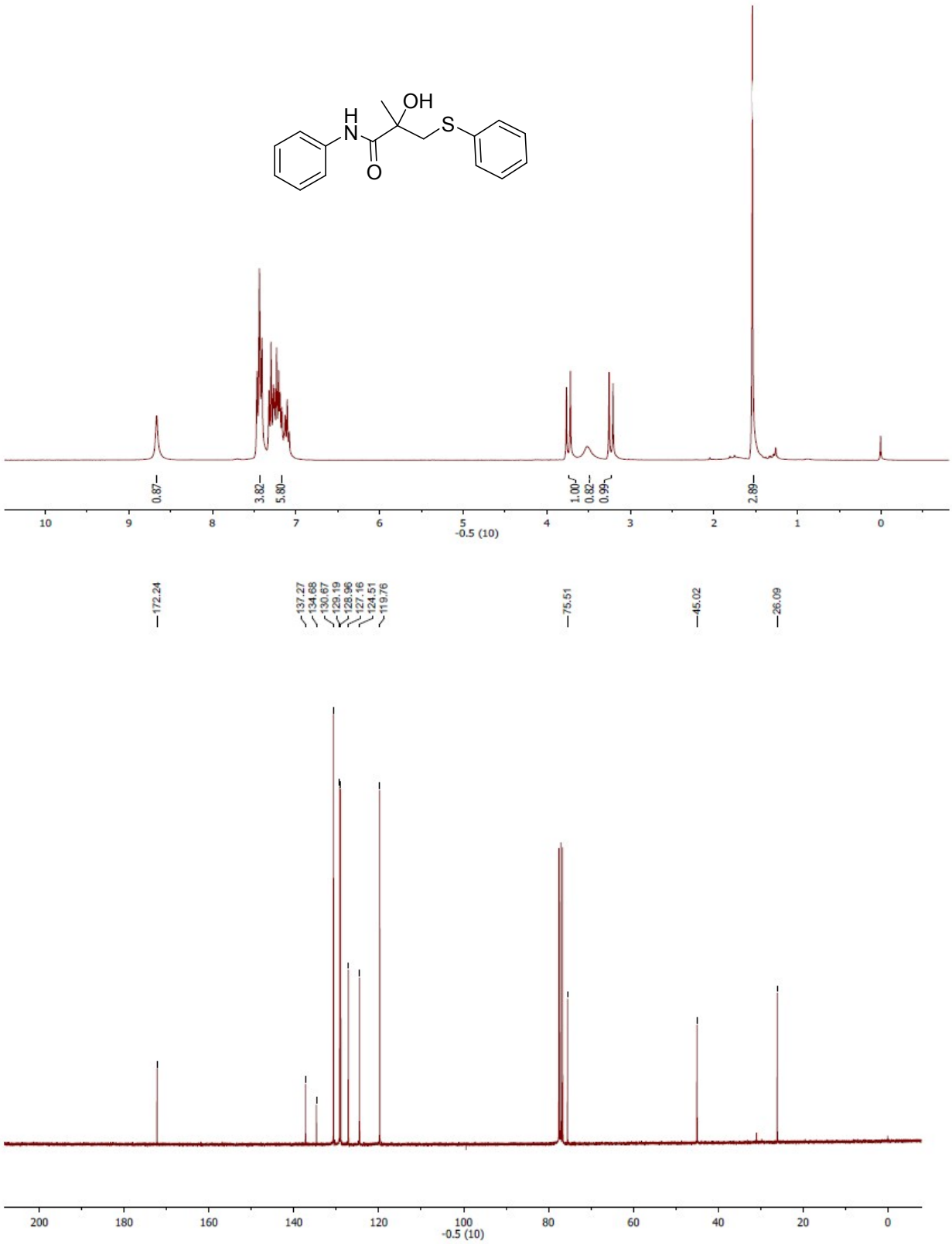
(Table 3, 3bq)

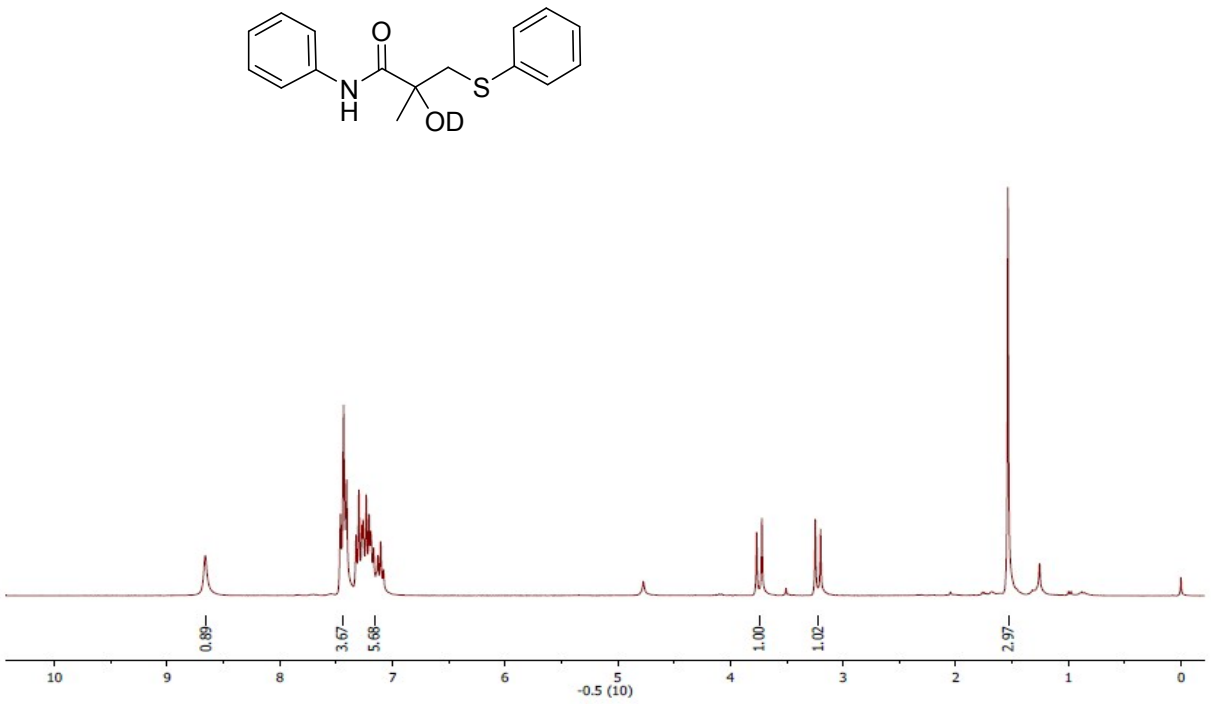

0.75
0.84
0.97
1.13
4.76
2.67
1.11
1.00
2.85
10
9
8
7
6
5
-0.5 (10)
4
3
2
1
0


170.94
160.55
140.92
134.93
134.21
134.17
131.01
128.91
128.89
128.83
128.21
128.18
127.00
126.98
125.90
125.88
125.24
64.12
64.09
50.91
47.57
28.46
28.42

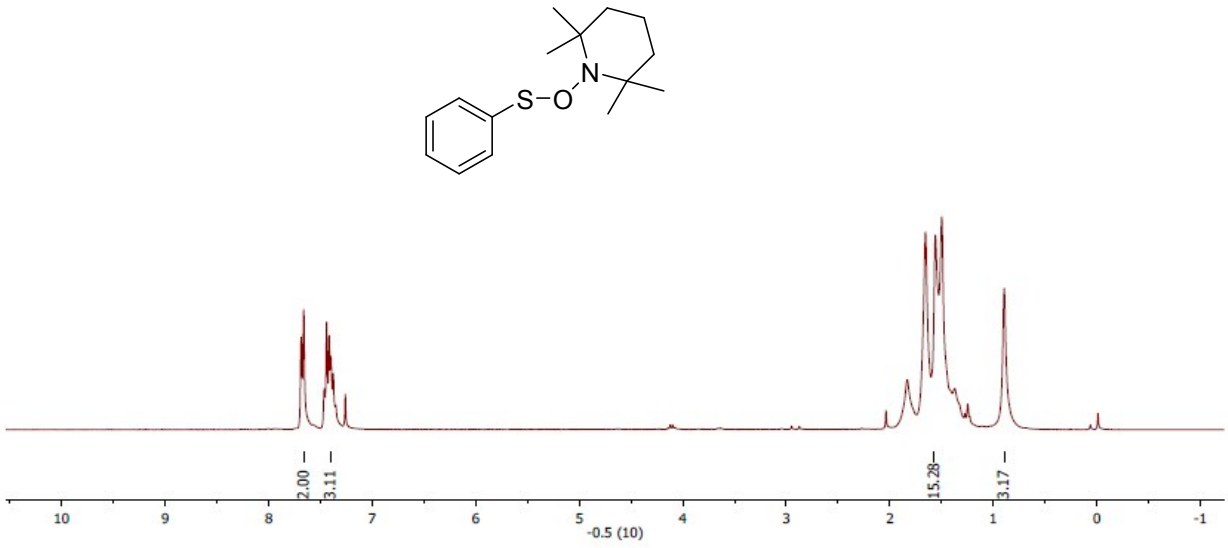

200
180
160
140
120
100
-0.5 (10)
80
60
40
20
0

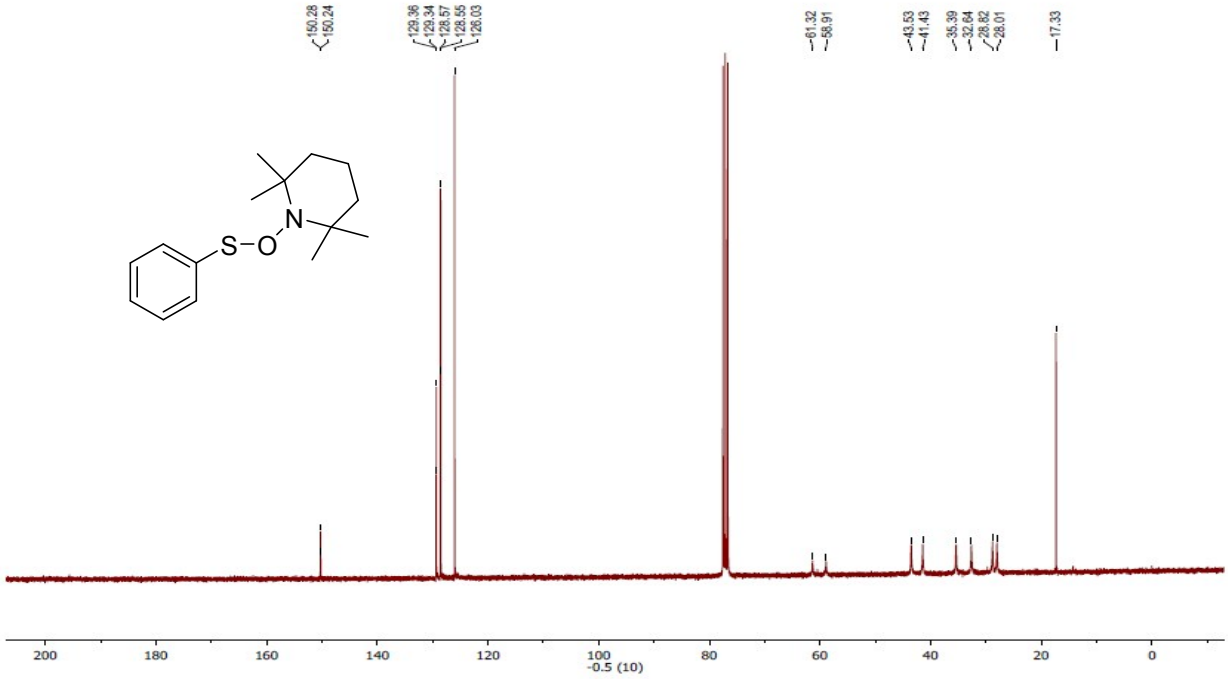
(Table 3, 3br)


OH
H
N
O
S
0.87
3.82
5.80
1.00
0.82
0.99
2.89
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)
172.24
137.27
134.68
130.67
129.19
128.96
127.16
124.51
119.76
75.51
45.02
26.09
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)


O
N
H
S
OD
0.89
3.67
5.68
1.00
1.02
2.97
10
9
8
7
6
5
4
3
2
1
0
-0.5 (10)

(Scheme 2, 4)


S–O
N
2.00
3.11
15.28
3.17
10
9
8
7
6
5
4
3
2
1
0
-1
-0.5 (10)


150.28
150.24
129.36
129.34
128.67
128.55
126.03
61.32
58.91
43.53
41.43
35.39
32.64
28.82
28.01
17.33
S
O
N
200
180
160
140
120
100
80
60
40
20
0
-0.5 (10)