Catalyst-free Three-component Sequencing Approach for Efficient Assembly of [1, 3] Oxazine *N*-Fused Imidazole-2-thiones

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Supporting Information

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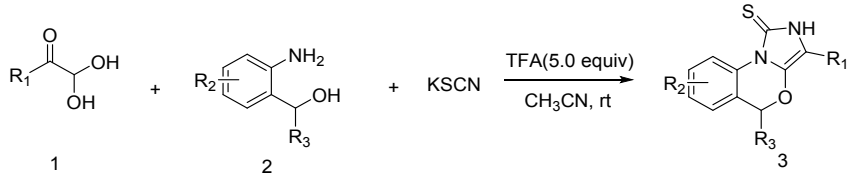
General Information

All solvents were purified according to standard methods prior to use. Melting points were recorded on a BÜCHI B-540 melting point apparatus. NMR spectra were recorded for ^{1}H NMR at 500 MHz and for ^{13}C NMR at 125 MHz. For ^{1}H NMR, tetramethylsilane (TMS) (δ=0) or DMSO (δ=2.50) served as internal standard and data are reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), and coupling constant(s) in Hz. For ^{13}C NMR, TMS (δ=0) or DMSO (δ=39.52) was used as internal standard and spectra were obtained with complete proton decoupling. HPLC analysis and the HRMS of all final products were confirmed on a Agilent 1290 HPLC-6224 Time of Fight Mass Spectrometer using PhenomenexLuna 5μ C18, 100 Å, 150 X 4.60 mm 5 micron column at a flow rate of 0.5 mL/min using liner gradients buffer B in A (B: CH_3OH containing 0.1 % formic acid, A: H_2O containing 0.1% formic acid). Mobile phase B was increased linearly from 5% to 95% over 7 min and 95% over the next 2 min, after which the column was equilibrated to 5% for 1 min. The benzyl alcohol derivatives **2** were readily prepared from the corresponding substituted benzoic acid derivatives [1]. Glyoxal Monohydrates **1** were synthesized by the method of acetophenone oxidation by DMSO-HBr system or using selenium dioxide in 1, 4-dioxane-water mixture [2].

Reference:

1. Zhan, G.; Shi, M.-L.; He Q.; Du W.; Chen Y.-C. *Org. Lett.* **2015**, 17, 4750.
2. (a) Karpova, S. V.; Kayukova, Y. S.; Grigor'eva, A. A.; Tafeenko, V. A. *Tetrahedron Lett.* **2015**, 56, 1732. (b) Antoinea M.; Gerlachb M.; Güntherb, E.; Schusterb, T.; Czechb, M.; Seipeltb, I.; Marchand, P. *Synthesis* **2012**, 1, 69.

General Procedure for the Synthesis of 3:

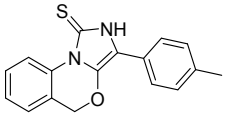


1 2 3

TFA (5 mmol, 370 μL) was added to a mixture of aminoaryl alcohol **2** (1.0 mmol), glyoxal hydrates **1** (1.2 mmol, 1.2 equiv) and KSCN (2.0 mmol) in CH_3CN (2 mL) and stirred at room temperature. After the reaction was completed (monitored by TLC), the reaction mixture was filtered, and the precipitation was washed with CH_3CN to afford **3**.

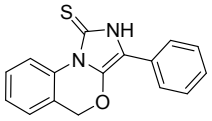
Characterization data of compound 3

3-(*p*-tolyl)-5*H*-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2*H*)-thione (**3a**)



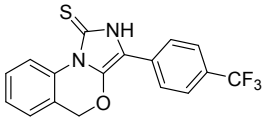
White solid, m.p. 249.6-251.8 ^{o}C, ^{1}H NMR (500 MHz, DMSO) δ 12.68 (s, 1H, NH), 9.56 (d, J = 8.5 Hz, 1H, H_{Ar}), 7.63 (d, J = 8.0 Hz, 2H, H_{Ar}), 7.52-7.49 (m, 1H, H_{Ar}), 7.43 (d, J = 7.0 Hz, 1H, H_{Ar}), 7.35-7.32 (m, 1H, H_{Ar}), 7.23 (d, J = 8.0 Hz, 2H, H_{Ar}), 5.34 (s, 2H, CH_2), 2.30 (s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 155.5 (C=S), 135.9 (C=C), 132.2 (C_{Ar}), 129.3(C_{Ar}), 128.4(C_{Ar}), 126.0(C_{Ar}), 125.6(C_{Ar}), 124.4(C_{Ar}), 124.2(C_{Ar}), 124.0(C_{Ar}), 117.6(C_{Ar}), 106.9(C=C), 69.2(CH_2), 20.8(CH_3). HRMS (ESI): m/z calcd for $(C_{17}H_{12}N_2OS+H)^+$: 295.0900; found: 295.0901.

3-phenyl-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3b**)



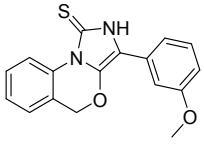
White solid, m.p. 237.0-237.9 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.81 (s, 1H, NH), 9.54 (d, *J* = 7.8 Hz, 1H, H_{Ar}), 7.74 (d, *J* = 7.8 Hz, 2H, H_{Ar}), 7.51 (t, *J* = 7.6 Hz, 1H, H_{Ar}), 7.43 (m, 3H, H_{Ar}), 7.35 (t, *J* = 7.4 Hz, 1H, H_{Ar}), 7.25 (t, *J* = 7.3 Hz, 1H, H_{Ar}), 5.38 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 156.2 (C=S), 137.0 (C=C), 132.6 (C_{Ar}), 130.0(C_{Ar}), 129.3(C_{Ar}), 128.9(C_{Ar}), 127.7(C_{Ar}), 127.1(C_{Ar}), 126.6(C_{Ar}), 126.2(C_{Ar}), 124.7(C_{Ar}), 124.4(C_{Ar}), 118.1(C_{Ar}), 107.3(C=C), 69.8(CH_2). HRMS (ESI): m/z calcd for $(C_{16}H_{12}N_2OS+H)^+$: 281.0743; found: 281.0746.

3-(4-(trifluoromethyl) phenyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3c**)



White solid, m.p. 248.3-248.6 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.99 (s, 1H, NH), 9.54 (d, *J* = 8.5 Hz, 1H, H_{Ar}), 7.92 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.78 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.54-7.51 (m, 1H, H_{Ar}), 7.46 (d, *J* = 7.4 Hz, 1H, H_{Ar}), 7.38-7.35 (m, 1H, H_{Ar}), 5.43 (s, 2H, CH_2). ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.4 (C=S), 138.2 (C=C), 132.0 (C_{Ar}), 131.2(C_{Ar}), 128.5(C_{Ar}), 126.3(C_{Ar}), 126.0 (d, *J* = 33.75 Hz, C_{Ar}), 125.8 (q, *J* = 3.75Hz, C_{Ar}), 125.7(C_{Ar}), 124.3(C_{Ar}), 124.2 (d, *J* = 270Hz, CF_3), 123.8(C_{Ar}), 117.6(C_{Ar}), 105.7(C=C), 69.4(CH_2). HRMS (ESI): m/z calcd for $(C_{17}H_{11}F_3N_2OS+H)^+$: 349.0617; found: 349.0616.

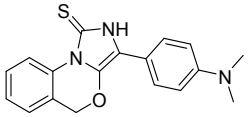
3-(3-methoxyphenyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3d**)



White solid, m.p. 169.1-171.9 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.83 (s, 1H, NH), 9.54 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 7.51 (t, *J* = 8.0 Hz, 1H, H_{Ar}), 7.44 (d, *J* = 7.5 Hz, 1H, H_{Ar}), 7.36-7.33 (m, 4H, H_{Ar}), 6.83-6.81 (m, 1H, H_{Ar}), 5.38(s, 2H, CH_2), 3.79(s, 3H, OCH_3).^{13}C NMR (125 MHz, DMSO) δ 159.6 (C=S), 155.7(C=C), 136.8(C_{Ar}), 132.1(C_{Ar}), 130.0(C_{Ar}), 128.5(C_{Ar}), 128.4(C_{Ar}), 126.2(C_{Ar}), 125.7(C_{Ar}), 124.0(C_{Ar}),

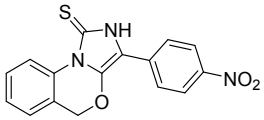
117.7(C_{Ar}), 116.7(C_{Ar}), 112.5(C_{Ar}), 109.3(C_{Ar}), 106.8(C=C), 69.3(CH_2), 55.2(OCH_3). HRMS (ESI): m/z calcd for $(C_{17}H_{14}N_2O_2S+H)^+$: 311.0849; found: 311.0849.

3-(4-(dimethylamino) phenyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3e**)



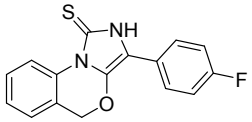
Gray solid, m.p. 220.2-220.7 °C , ^{1}H NMR (500 MHz, DMSO) δ 12.82 (s, 1H, NH), 9.53 (d, *J* = 8.5 Hz, 1H, H_{Ar}), 7.77 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 7.53-7.50 (m, 1H, H_{Ar}), 7.45 (d, *J* = 6.8 Hz, 1H, H_{Ar}), 7.43-7.37 (m, 2H, H_{Ar}), 7.36-7.34 (m, 1H, H_{Ar}), 5.37 (s, 2H, CH_2), 3.11 (s, 6H, $N(CH_3)_2$). ^{13}C NMR (125 MHz, DMSO) δ 156.1(C=S), 132.6(C=C), 130.3(C_{Ar}), 128.9(C_{Ar}), 126.6(C_{Ar}), 126.2(C_{Ar}), 125.8(C_{Ar}), 124.4(C_{Ar}), 118.1(C_{Ar}), 106.7(C=C), 69.8(CH_2), 44.2($N(CH_3)_2$). HRMS (ESI): m/z calcd for $(C_{18}H_{17}N_3OS+H)^+$: 324.1165; found: 324.1161.

3-(4-nitrophenyl)-5*H*-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3f**)



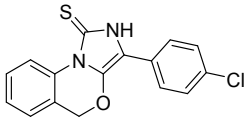
White solid, m.p. >250 °C, ^{1}H NMR (500 MHz, DMSO) δ 13.07 (s, 1H, NH), 9.53 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 8.27 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.94 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 7.53 (t, *J* = 7.5 Hz, 1H, H_{Ar}), 7.46 (d, *J* = 7.0 Hz, 1H, H_{Ar}), 7.38 (t, *J* = 7.0 Hz, 1H, H_{Ar}), 5.47 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 157.0(C=S), 144.6(C=C), 139.5(C_{Ar}), 133.6(C_{Ar}), 131. 8(C_{Ar}), 128.6(C_{Ar}), 126.5(C_{Ar}), 125.8(C_{Ar}), 124.4(C_{Ar}), 124.2(C_{Ar}), 123.6(C_{Ar}), 117.6(C_{Ar}), 105.6(C=C), 69.5(CH_2). HRMS (ESI): m/z calcd for $(C_{16}H_{11}N_3O_3S+H)^+$: 326.0594; found: 326.0593.

3-(4-fluorophenyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3g**)



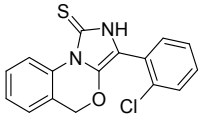
Light yellow solid, m.p. 241.6-242.0 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.84 (s, 1H, NH), 9.54 (d, *J* = 8.5 Hz, 1H, H_{Ar}), 7.76 (dd, *J* = 8.5, 5.5 Hz, 2H, H_{Ar}), 7.53-7.50 (m, 1H, H_{Ar}), 7.44 (d, *J* = 7.0 Hz, 1H, H_{Ar}), 7.36-7.33 (m, 1H, H_{Ar}), 7.28 (t, *J* = 9 Hz, 2H, H_{Ar}), 5.37 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 160.7 (d, *J* = 242.5 Hz, C-F), 155.7(C=S), 136.3(C=C), 132.2(C_{Ar}), 128.5(C_{Ar}), 126.3 (d, *J* = 7.5 Hz, C_{Ar}), 126.2(C_{Ar}), 125.7(C_{Ar}), 124.0(C_{Ar}), 123.8 (d, *J* = 2.5 Hz, C_{Ar}), 117.7(C_{Ar}), 115.9 (d, *J* = 21.3 Hz, C_{Ar}), 106.1(C=C), 69.4(CH_2). HRMS (ESI): m/z calcd for $(C_{16}H_{11}FN_2OS+H)^+$: 299.0649; found: 299.0648.

3-(4-chlorophenyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3h**)



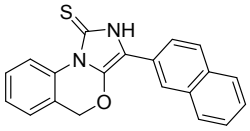
White solid, m.p. >250 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.87 (s, 1H, NH), 9.53 (d, *J* = 8.5 Hz, 1H, H_{Ar}), 7.74 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 7.52 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 7.49 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 7.44 (d, *J* = 7.5 Hz, 1H, H_{Ar}), 7.35 (t, *J* = 7.5 Hz, 1H, H_{Ar}), 5.39 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 155.9(C=S), 136.9(C=C), 132.1(C_{Ar}), 130.8(C_{Ar}), 128.9(C_{Ar}), 128.5(C_{Ar}), 126.2(C_{Ar}), 126.2(C_{Ar}), 125.8(C_{Ar}), 125.7(C_{Ar}), 123.9(C_{Ar}), 117.7(C_{Ar}), 105.9(C=C), 69.4(CH_2). HRMS (ESI): m/z calcd for $(C_{16}H_{11}ClN_2OS+H)^+$: 315.0354; found: 315.0352.

3-(2-chlorophenyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3i**)



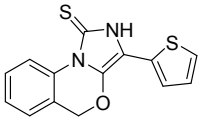
White solid, m.p. 209.7-210.6 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.71 (s, 1H, NH), 9.55 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 7.60-7.57 (m, 1H, H_{Ar}), 7.54-7.50 (m, 2H, H_{Ar}), 7.45-7.42 (m, 3H, H_{Ar}), 7.37-7.33 (m, 1H, H_{Ar}), 5.30 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 155.5(C=S), 136.5(C=C), 132.4(C_{Ar}), 132.3(C_{Ar}), 131.8(C_{Ar}), 130.3(C_{Ar}), 129.9(C_{Ar}), 128.5(C_{Ar}), 127.3(C_{Ar}), 126.2(C_{Ar}), 125.8(C_{Ar}), 125.7(C_{Ar}), 124.0(C_{Ar}), 117.6(C_{Ar}), 104.4(C=C), 68.9(CH_2). HRMS (ESI): m/z calcd for $(C_{16}H_{11}ClN_2OS+H)^+$: 315.0354; found: 315.0351.

3-(naphthalen-2-yl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3j**)



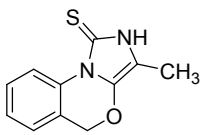
White solid, m.p. 244.8-245.3 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.83 (s, 1H, NH), 9.63 (d, *J* = 8.2 Hz, 1H, H_{Ar}), 8.01-7.96 (m, 3H, H_{Ar}), 7.62-7.57 (m, 4H, H_{Ar}), 7.54-7.52 (m, 1H, H_{Ar}), 7.42 (d, *J* = 6.7 Hz, 1H, H_{Ar}), 7.37-7.34 (m, 1H, H_{Ar}), 5.32 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 155.7(C=S), 136.4(C=C), 133.4(C_{Ar}), 132.6(C_{Ar}), 130.4(C_{Ar}), 128.8(C_{Ar}), 128.5(C_{Ar}), 128.4(C_{Ar}), 128.0(C_{Ar}), 126.6(C_{Ar}), 126.3(C_{Ar}), 126.1(C_{Ar}), 125.7(C_{Ar}), 125.6(C_{Ar}), 125.5(C_{Ar}), 124.3(C_{Ar}), 124.2(C_{Ar}), 117.7(C_{Ar}), 105.4(C=C), 69.0(CH_2). HRMS (ESI): m/z calcd for ($C_{20}H_{14}N_2OS$+H) $^{+}$: 331.0900; found: 331.0903.

3-(thiophen-2-yl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3k**)



Purple solid, m.p. 235.3-235.7 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.95 (s, 1H, NH), 9.52 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 7.53-7.49 (m, 2H, H_{Ar}), 7.46-7.41 (m, 2H, H_{Ar}), 7.35 (td, *J* = 7.4, 0.9 Hz, 1H, H_{Ar}), 7.09 (dd, *J* = 5.0, 3.7 Hz, 1H, H_{Ar}), 5.39 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 155.5(C=S), 135.2(C=C), 132.2(C_{Ar}), 128.5(C_{Ar}), 128.2(C_{Ar}), 127.4(C_{Ar}), 126.2(C_{Ar}), 125.8(C_{Ar}), 125.0(C_{Ar}), 123.8(C_{Ar}), 122.7(C_{Ar}), 117.5(C_{Ar}), 103.4(C=C), 69.5(CH_2). HRMS (ESI): m/z calcd for ($C_{14}H_{10}N_2OS_2$+H) $^{+}$: 287.0308; found: 287.0306.

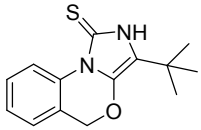
3-Methyl-5H-benzo[d]imidazo[5,1-b][1,3]oxazine-1(2H)-thione (**3l**)



White solid, m.p.>250 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.16(s, 1H, NH), 9.47(d, *J* = 8.5 Hz, 1H, H_{Ar}), 7.46(t, *J* = 7.5 Hz, 1H, H_{Ar}), 7.37(d, *J* = 7.0 Hz, 1H, H_{Ar}), 7.28(t, *J*

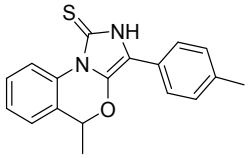
= 7.5 Hz, 1H, H_{Ar}), 5.17(s, 2H, CH_2), 1.97(s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 154.0(C=S), 135.5(C=C), 132.6(C_{Ar}), 128.3(C_{Ar}), 125.6(C_{Ar}), 124.1(C_{Ar}), 117.4(C_{Ar}), 102.1(C=C), 69.1(CH_2), 7.3(CH_3). HRMS (ESI): m/z calcd for $(C_{11}H_{10}N_2OS+H)^+$:219.0587; found: 219.0587.

3-(*tert*-butyl)-5*H*-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3m**)



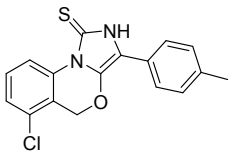
White solid, m.p. >250 °C, ^1H NMR (500 MHz, DMSO) δ 12.12 (s, 1H, NH), 9.46 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 7.47-7.44 (m, 1H, H_{Ar}), 7.37 (d, *J* = 7.0 Hz, 1H, H_{Ar}), 7.30-7.26 (m, 1H, H_{Ar}), 5.14 (s, 2H, CH_2), 1.27 (s, 9H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 154.3(C=S), 134.1(C=C), 132.6(C_{Ar}), 128.2(C_{Ar}), 125.6(C_{Ar}), 125.5(C_{Ar}), 124.5(C_{Ar}), 117.8(C_{Ar}), 114.8(C=C), 69.1(CH_2), 30.3($C(CH_3)_3$), 29.1(CH_3). HRMS (ESI): m/z calcd for $(C_{14}H_{16}N_2OS+H)^+$:261.1056; found: 261.1066.

5-methyl-3-(p-tolyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3n**)



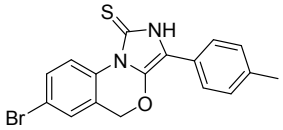
White solid, m.p. 231.2-232.4 °C, ^1H NMR (500 MHz, DMSO) δ 12.76 (s, 1H, NH), 9.57 (d, *J* = 8.5 Hz, 1H, H_{Ar}), 7.65 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.51 (t, *J* = 7.5 Hz, 1H, H_{Ar}), 7.44 (d, *J* = 7.5 Hz, 1H, H_{Ar}), 7.36 (t, *J* = 7.5 Hz, 1H, H_{Ar}), 7.23 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.56 (q, *J* = 6.5 Hz, 1H, $CH(CH_3)$), 2.30 (s, 3H, CH_3), 1.65 (d, *J* = 6.5 Hz, 3H, $CH(CH_3)$). ^{13}C NMR (125 MHz, DMSO) δ 155.4(C=S), 136.0(C=C), 134.7(C_{Ar}), 131.5(C_{Ar}), 129.4(C_{Ar}), 128.3(C_{Ar}), 128.1(C_{Ar}), 126.2(C_{Ar}), 124.9(C_{Ar}), 124.5(C_{Ar}), 124.1(C_{Ar}), 117.8(C_{Ar}), 107.7(C=C), 75.6($CH(CH_3)$), 20.8(CH_3), 19.2($CH(CH_3)$). HRMS (ESI): m/z calcd for $(C_{18}H_{16}N_2OS+H)^+$:309.1056; found: 309.1059.

6-chloro-3-(p-tolyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3o**)



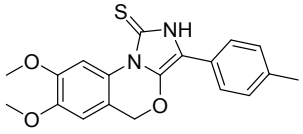
White solid, m.p. 239.7-234.3 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.85 (s, 1H, NH), 9.59 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 7.62 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.55 (t, *J* = 8.0 Hz, 1H, H_{Ar}), 7.47-7.45 (m, 1H, H_{Ar}), 7.24 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.45 (s, 2H, CH_2), 2.30 (s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 155.9(C=S), 136.2(C=C), 135.4(C_{Ar}), 133.6(C_{Ar}), 129.7(C_{Ar}), 129.5(C_{Ar}), 129.4(C_{Ar}), 126.6(C_{Ar}), 124.3(C_{Ar}), 124.2(C_{Ar}), 122.1(C_{Ar}), 116.7(C_{Ar}), 107.1(C=C), 66.8(CH_2), 20.8(CH_3). HRMS (ESI): m/z calcd for $(C_{17}H_{13}ClN_2OS+H)^+$:329.0510; found: 329.0512.

7-bromo-3-(p-tolyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3p**)



Light yellow solid, m.p. 245.8-246.0 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.81 (s, 1H, NH), 9.52 (d, *J* = 9.0 Hz, 1H, H_{Ar}), 7.72 (d, *J* = 8.5 Hz, 1H, H_{Ar}), 7.69 (s, 1H, H_{Ar}), 7.61 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 7.22 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.35 (s, 2H, CH_2), 2.29 (s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 155.6(C=S), 136.1(C=C), 135.6(C_{Ar}), 131.5(C_{Ar}), 131.2(C_{Ar}), 129.4(C_{Ar}), 128.4(C_{Ar}), 126.5(C_{Ar}), 124.3(C_{Ar}), 119.6(C_{Ar}), 118.1(C_{Ar}), 107.2(C=C), 68.6(CH_2), 20.8(CH_3). HRMS (ESI): m/z calcd for $(C_{17}H_{13}BrN_2OS+H)^+$:373.0005; found: 373.0003.

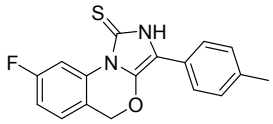
7, 8-dimethoxy-3-(p-tolyl)-5*H*-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2*H*)-thione (**3q**)



Yellow solid, m.p.234.2-234.5 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.68 (s, 1H, NH), 9.40 (s, 1H, H_{Ar}), 7.62 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.22 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.07 (s, 1H, H_{Ar}), 5.28 (s, 2H, CH_2), 3.80 (s, 3H, OCH_3), 3.79 (s, 3H, OCH_3), 2.30 (s, 3H,

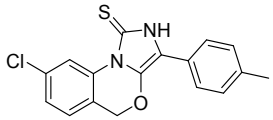
CH_3). ^{13}C NMR (125 MHz, DMSO) δ 154.5(C=S), 147.8(C=C), 146.4(C_{Ar}), 135.9(C_{Ar}), 135.8(C_{Ar}), 129.3(C_{Ar}), 125.4(C_{Ar}), 124.5(C_{Ar}), 124.1(C_{Ar}), 115.8(C_{Ar}), 108.9(C_{Ar}), 106.8(C_{Ar}), 102.7(C=C), 69.0(CH_2), 55.8(OCH_3), 20.8(CH_3). HRMS (ESI): m/z calcd for $(C_{19}H_{18}N_2O_3S+H)^+$:355.1111; found: 355.1112.

8-fluoro-3-(p-tolyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3r**)



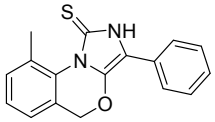
White solid, m.p.249.4-250.0 °C, ^1H NMR (500 MHz, DMSO) δ 12.86 (s, 1H, NH), 9.51 (dd, *J* = 11.5, 2.5 Hz, 1H, H_{Ar}), 7.62 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 7.50 (dd, *J* = 8.2, 6.0 Hz, 1H, H_{Ar}), 7.23 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.22-7.20 (m, 1H, H_{Ar}), 5.35 (s, 2H, CH_2), 2.30 (s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 161.0 (d, *J* = 241 Hz, C-F), 155.8(C=S), 136.1(C=C), 135.5(C_{Ar}), 133.2 (d, *J* = 12.5 Hz, C_{Ar}), 129.3(C_{Ar}), 127.5 (d, *J* = 8.8 Hz, C_{Ar}), 124.3(C_{Ar}), 124.2(C_{Ar}), 120.1(d, *J* = 2.5 Hz, C_{Ar}), 112.7 (d, *J* = 21.2 Hz, C_{Ar}), 107.0(C=C), 105.1 (d, *J* = 30 Hz, C_{Ar}), 68.7(CH_2), 20.8(CH_3). HRMS (ESI): m/z calcd for $(C_{17}H_{13}FN_2OS+H)^+$: 313.0806; found: 313.0806.

8-chloro-3-(p-tolyl)-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3s**)



White solid, m.p. 246.7-247.1 °C, ^1H NMR (500 MHz, DMSO) δ 12.86 (s, 1H, NH), 9.73 (d, *J* = 2.0 Hz, 1H, H_{Ar}), 7.61 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.48 (d, *J* = 8.0 Hz, 1H, H_{Ar}), 7.44-7.41 (m, 1H, H_{Ar}), 7.23 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.36 (s, 2H, CH_2), 2.30 (s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 155.7(C=S), 136.2(C=C), 135.6(C_{Ar}), 133.2(C_{Ar}), 132.4(C_{Ar}), 129.4(C_{Ar}), 127.4(C_{Ar}), 125.9(C_{Ar}), 124.3(C_{Ar}), 124.2(C_{Ar}), 122.9(C_{Ar}), 117.3(C_{Ar}), 107.1(C=C), 68.8(CH_2), 20.8(CH_3). HRMS (ESI): m/z calcd for $(C_{17}H_{13}ClN_2OS+H)^+$:329.0510; found: 329.0511.

9-methyl-3-phenyl-5H-benzo[d]imidazo [5, 1-b] [1, 3] oxazine-1(2H)-thione (**3t**)



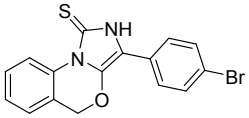
White solid, m.p. 181.9-182.3 °C, ^{1}NMR (500 MHz, DMSO) δ 12.78 (s, 1H, NH), 7.75 (d, *J* = 7.5 Hz, 2H, H_{Ar}), 7.43 (t, *J* = 8.0 Hz, 2H, H_{Ar}), 7.39 (d, *J* = 6.5 Hz, 1H, H_{Ar}), 7.36-7.33 (m, 2H, H_{Ar}), 7.26 (t, *J* = 7.0 Hz, 1H, H_{Ar}), 5.38 (s, 1H, CH_2), 5.11 (s, 1H, CH_2), 2.61 (s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 157.0(C=S), 138.6(C=C), 132.6(C_{Ar}), 131.2(C_{Ar}), 129.8(C_{Ar}), 129.6(C_{Ar}), 128.9(C_{Ar}), 127.3(C_{Ar}), 126.7(C_{Ar}), 126.6(C_{Ar}), 124.4(C_{Ar}), 123.3(C_{Ar}), 108.3(C=C), 72.4(CH_2), 22.6(CH_3). HRMS (ESI): m/z calcd for $(C_{17}H_{14}N_2OS+H)^+$:295.0900; found: 295.0904.

General Procedure for the Gram Large-scale Synthesis of 3u:

1u 2a 3u

TFA (25 mmol) was added to a mixture of (2-aminophenyl) methanol **2a** (5.0 mmol), 1-(4-bromophenyl)-2,2-dihydroxyethan-1-one **1u** (6.0 mmol, 1.2 equiv) and KSCN (10.0 mmol) in CH_3CN (15 mL) and stirred at room temperature. After the reaction was completed (monitored by TLC), the reaction mixture was filtered, and the precipitation was washed with CH_3CN to afford **3u**.

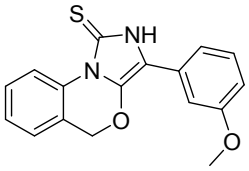
3-(4-bromophenyl)-5H-benzo[d]imidazo[5,1-b][1,3]oxazine-1(2H)-thione (**3u**)



White solid, m.p. 228.8-229.0 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.84 (s, 1H, NH), 9.54 (d, *J* = 7.5 Hz, 1H, H_{Ar}), 7.69-7.66 (m, 2H, H_{Ar}), 7.64-7.61 (m, 2H, H_{Ar}), 7.52 (m, 1H, H_{Ar}), 7.45 (d, *J* = 7.5 Hz, 1H, H_{Ar}), 7.35 (m, 1H, H_{Ar}), 5.39 (s, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 156.0(C=S), 137.0(C=C), 132.1(C_{Ar}), 131.7(C_{Ar}), 128.5(C_{Ar}), 126.5(C_{Ar}), 126.2(C_{Ar}), 126.0(C_{Ar}), 125.7(C_{Ar}), 123.8(C_{Ar}), 119.3(C_{Ar}), 117.6(C_{Ar}), 105.9(C=C), 69.3(CH_2). HRMS (ESI): m/z calcd for $(C_{16}H_{11}BrN_2OS+H)^+$:358.9848; found: 358.9848.

X-ray Crystallography Data of 3d (CCDC No. 1571499)

Single crystals of compound **3d** were measured on a Rigaku RAXIS-RAPID single-crystal diffractometer. The recrystallization solvent of **3d** was acetone.



3d

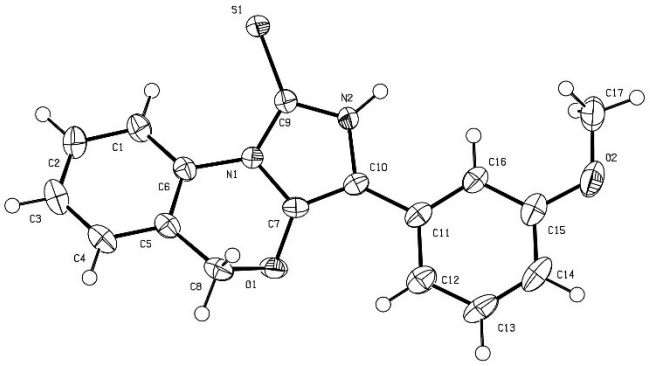


Figure S1 X-ray crystallography of **3d**

Table S1 X-ray crystallography data of **3d**

Formula moiety	$C_{17}H_{14}N_2O_2S$
Formula sum	$C_{17}H_{14}N_2O_2S$
Formula weight	310.08
Temperature	170 K
Crystal system	monoclinic
Space group	P -1

Unit cell dimensions	a= 8.4181(10) Å
	b= 9.1433(7) Å
	c= 10.4688(9) Å
	alpha=74.013 deg.
	beta = 76.640(9) deg.
	gamma = 69.444 deg.
Volume	706.85 (9) $Å^3$
Z	2
Calculated density	1.458 g/cm^3
Absorption coefficient	0.238mm^{-1}
F(000)	324.0
Crystal size	0.4 x 0.38 x 0.26 mm
Theta range for data collection	3.010 to 25.349 deg
Reflections collected / unique	2059 / 2579 [R(int) = 0.0480]
Data / restraints / parameters	2579 / 0 / 200
Goodness-of-fit on F2	1.063
Final R indices [I>2sigma(I)]	R1 = 0.0480, wR2 = 0.1078
R indices (all data)	R1 = 0.0622, wR2 = 0.11218

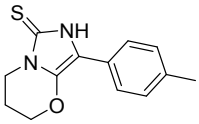
General Procedure for the Synthesis of 5:

1 4 5

TFA (5 mmol, 370 μL) was added to a mixture of amino alcohol **4** (1.0 mmol), glyoxal hydrates **1** (1.2 mmol, 1.2 equiv) and KSCN (2.0 mmol) in CH_3CN (2 mL) and stirred at room temperature. After the reaction was completed (monitored by TLC), the reaction mixture was filtered, and the precipitation was washed with CH_3CN to afford **5**.

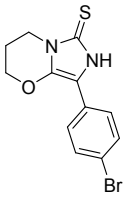
Characterization Data of Compound 5

8-(*p*-tolyl)-3, 4-dihydro-2H-imidazo [5, 1-b] [1, 3] oxazine-6(7H)-thione (**5a**)



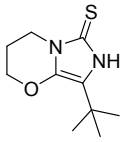
White solid, m.p. >250 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.32 (s, 1H, NH), 7.50 (d, J = 8.5 Hz, 2H, H_{Ar}), 7.14 (d, J = 8.0 Hz, 2H, H_{Ar}), 4.35 (t, J = 5.0 Hz, 2H, OCH_2), 3.82 (t, J = 6.5 Hz, 2H, NCH_2), 2.26 (s, 3H, CH_3), 2.15 (m, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 155.4(C=S), 137.6(C=C), 134.3(C_{Ar}), 129.2(C_{Ar}), 125.7(C_{Ar}), 122.9(C_{Ar}), 104.6(C=C), 65.9(OCH_2), 40.4(NCH_2), 20.8(CH_3), 20.7(CH_2). HRMS (ESI): m/z calcd for $(C_{13}H_{14}N_2OS+H)^+$:247.0900; found: 247.0900.

8-(4-bromophenyl)-3, 4-dihydro-2H-imidazo [5, 1-b] [1, 3] oxazine-6(7H)-thione (**5b**)



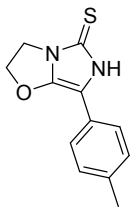
White solid, m.p. >250 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.44 (s, 1H, NH), 7.57-7.50 (m, 4H, H_{Ar}), 4.39 (t, *J* = 5.0 Hz, 2H, OCH_2), 3.82 (t, *J* = 6.0 Hz, 2H, NCH_2), 2.19-2.14 (m, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 156.0(C=S), 138.7(C=C), 131.5(C_{Ar}), 127.7(C_{Ar}), 124.6(C_{Ar}), 117.5(C_{Ar}), 103.6(C=C), 66.5(OCH_2), 40.4(NCH_2), 20.7(CH_2). HRMS (ESI): m/z calcd for $(C_{12}H_{11}BrN_2OS+H)^+$:310.9848; found: 310.9850.

8-(*tert*-butyl)-3, 4-dihydro-2H-imidazo [5, 1-b] [1, 3] oxazine-6(7H)-thione (**5c**)



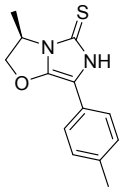
White solid, m.p.180.3-180.5 °C, ^{1}H NMR (500 MHz, $CDCl_3$) δ 10.54 (s, 1H, NH), 4.14 (t, *J* = 5.5 Hz, 2H, OCH_2), 3.92 (t, *J* = 6.5 Hz, 2H, NCH_2), 2.13 (m, 2H, CH_2), 1.25 (s, 9H, CH_3). ^{13}C NMR (125 MHz, $CDCl_3$) δ 152.4(C=S), 135.5(C=C), 114.0 (C=C), 65.3(OCH_2), 41.0(NCH_2), 30.8(CH_2), 29.7($C(CH_3)_3$), 21.6(CH_3). HRMS (ESI): m/z calcd for $(C_{10}H_{16}N_2OS+H)^+$:213.1056; found: 213.1057.

7-(*p*-tolyl)-2, 3-dihydroimidazo [5, 1-b] oxazole-5(6H)-thione (**5d**)



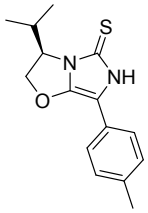
White solid, m.p. >250 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.06 (s, 1H, NH), 7.35 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.15 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.12 (t, *J* = 7.5 Hz, 2H, OCH_2), 4.04 (t, *J* = 7.5 Hz, 2H, NCH_2), 2.25 (s, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 152.7(C=S), 144.2(C=C), 134.4(C_{Ar}), 129.4(C_{Ar}), 125.3(C_{Ar}), 122.3(C_{Ar}), 100.5(C=C), 77.8(OCH_2), 41.8(OCH_2), 20.7(CH_3). HRMS (ESI): m/z calcd for $(C_{12}H_{12}N_2OS+H)^+$:233.0743; found: 233.0743.

(*R*)-3-methyl-7-(*p*-tolyl)-2, 3-dihydroimidazo [5, 1-b] oxazole-5(6H)-thione (**5e**)



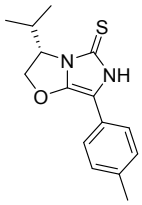
White solid, m.p. >250 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.08 (s, 1H, NH), 7.35 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.15 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.18 (t, *J* = 8.0 Hz, 1H, OCH_2), 4.73 (dd, *J* = 8.5, 4.5 Hz, 1H, OCH_2), 4.59-4.53 (m, 1H, NCH), 2.25 (s, 3H, Ar-CH_3), 1.53 (d, *J* = 6.0 Hz, 3H, $CHCH_3$). ^{13}C NMR (125 MHz, DMSO) δ 152.3(C=S), 143.9(C=C), 134.4(C_{Ar}), 129.4(C_{Ar}), 125.3(C_{Ar}), 122.4(C_{Ar}), 100.3(C=C), 83.7(OCH_2), 50.9(NCH), 20.7(Ar-CH_3), 16.9($CHCH_3$). HRMS (ESI): m/z calcd for $(C_{13}H_{14}N_2OS+H)^+$:247.0900; found: 247.0901.

(*R*)-3-isopropyl-7-(*p*-tolyl)-2, 3-dihydroimidazo [5, 1-b] oxazole-5(6H)-thione (**5f**)



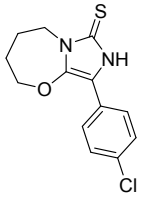
White solid, m.p. 240.8-243 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.11 (s, 1H, NH), 7.35 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 7.15 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.06-5.03 (m, 2H, OCH_2), 4.50-4.47 (m, 1H, NCH), 2.87-2.80 (m, 1H, $CH(CH_3)_2$), 2.25 (s, 3H, Ar-CH_3), 0.94 (d, *J* = 7.0 Hz, 3H, CH_3), 0.75 (d, *J* = 7.0 Hz, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 152.4(C=S), 144.5(C=C), 134.4(C_{Ar}), 129.4(C_{Ar}), 125.2(C_{Ar}), 122.3(C_{Ar}), 100.1(C=C), 77.51(OCH_2), 58.95(NCH), 26.72($CH(CH_3)_2$), 20.69(Ar-CH_3), 17.82(CH_3), 14.28(CH_3). HRMS (ESI): m/z calcd for $(C_{15}H_{18}N_2OS+H)^+$:275.1213; found: 275.1213.

(*S*)-3-isopropyl-7-(*p*-tolyl)-2, 3-dihydroimidazo [5, 1-b] oxazole-5(6H)-thione (**5g**)



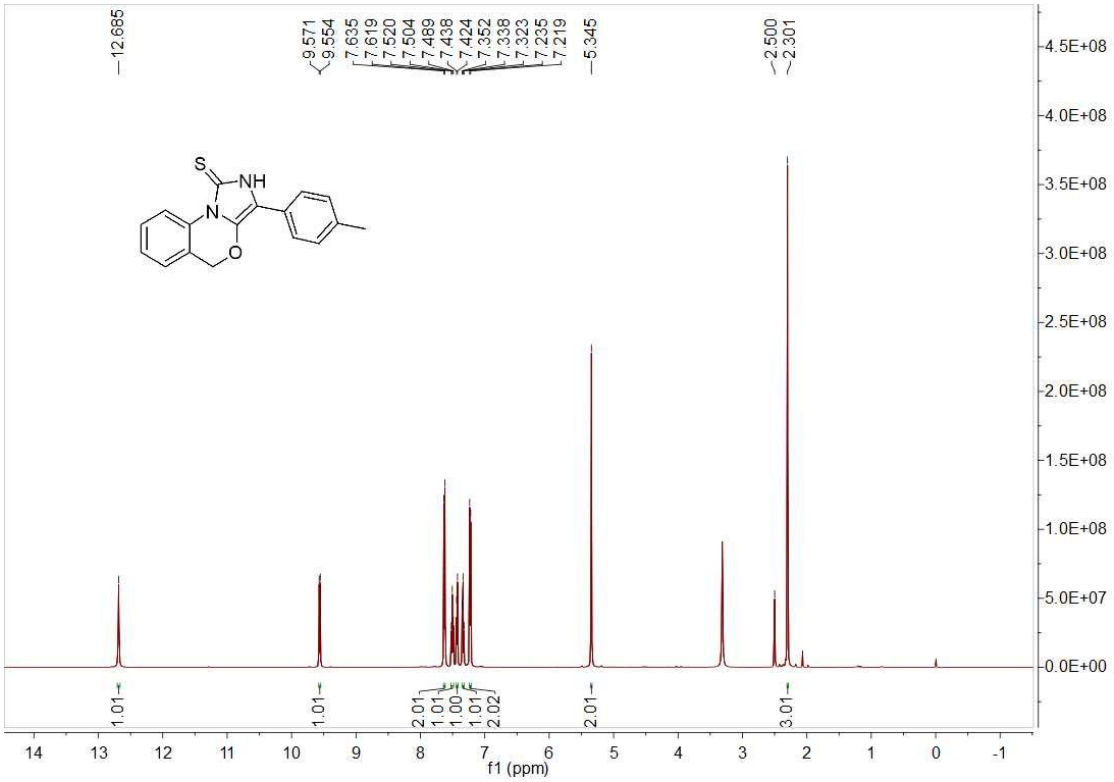
Yellow solid, m.p. 241.2-244.0 °C, ^{1}H NMR (500 MHz, DMSO) δ 12.11 (s, 1H, NH), 7.35 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 7.15 (d, *J* = 8.0 Hz, 2H, H_{Ar}), 5.07-5.00 (m, 2H, OCH_2), 4.50-4.47 (m, 1H, NCH), 2.87-2.80 (m, 1H, $CH(CH_3)_2$), 2.25 (s, 3H, Ar-CH_3), 0.94 (d, *J* = 7.5 Hz, 3H, CH_3), 0.75 (d, *J* = 7.0 Hz, 3H, CH_3). ^{13}C NMR (125 MHz, DMSO) δ 152.4(C=S), 144.5(C=C), 134.4(C_{Ar}), 129.4(C_{Ar}), 125.2(C_{Ar}), 122.3(C_{Ar}), 100.1(C=C), 77.5(OCH_2), 59.0(NCH), 26.7($CH(CH_3)_2$), 20.7(Ar-CH_3), 17.8(CH_3), 14.3(CH_3). HRMS (ESI): m/z calcd for $(C_{15}H_{18}N_2OS+H)^+$:275.1213; found: 275.1213.

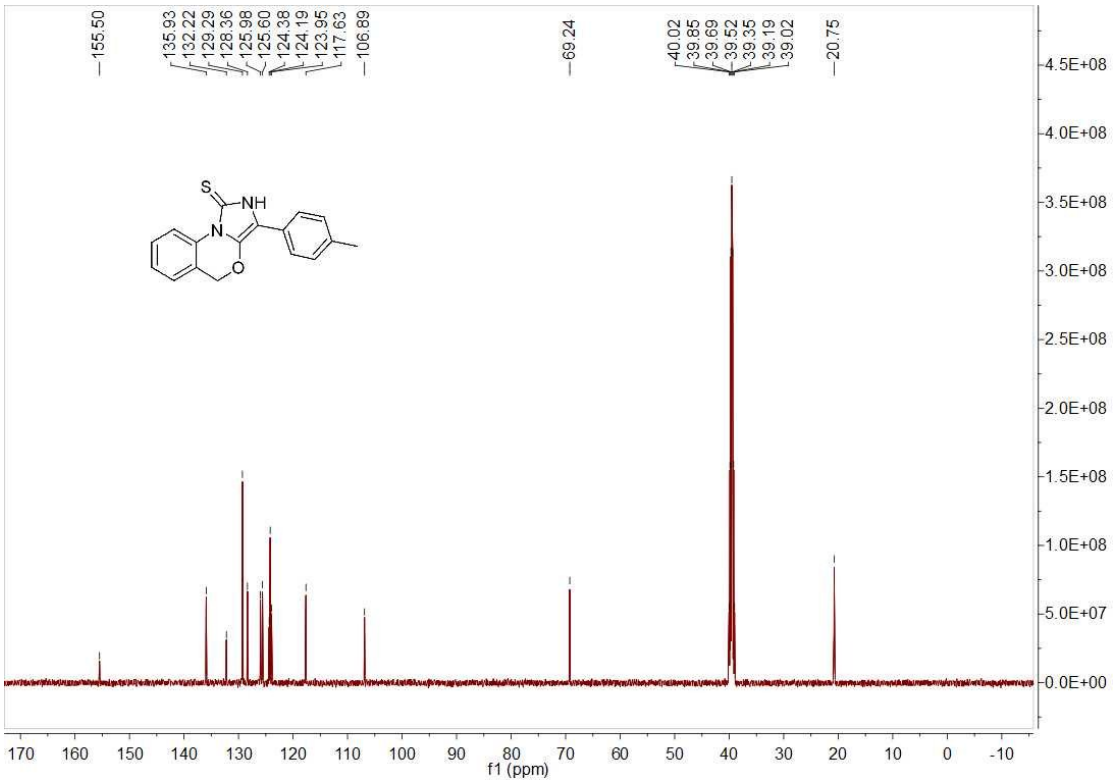
9-(4-chlorophenyl)-2,3,4,5-tetrahydroimidazo[5,1-b][1,3]oxazepine-7(8H)-thione (**5h**)



White Soild. m.p. 208.8-209.8 °C. ^{1}H NMR (500 MHz, DMSO) δ 12.49 (s, 1H, NH), 7.69 (d, *J* = 9.0 Hz, 2H, H_{Ar}), 7.45 (d, *J* = 8.5 Hz, 2H, H_{Ar}), 4.17 (m, 4H, OCH_2 and NCH_2), 1.99 (m, 2H, CH_2), 1.75 (m, 2H, CH_2). ^{13}C NMR (125 MHz, DMSO) δ 155.2(C=S), 140.9(C=C), 129.1(C_{Ar}), 127.1(C_{Ar}), 125.1(C_{Ar}), 123.8(C_{Ar}), 107.3(C=C), 74.3(OCH_2), 43.2(NCH_2), 29.3(CH_2), 24.3(CH_2). HRMS (ESI): m/z calcd for $(C_{13}H_{13}ClN_2OS+H)^+$: 281.0510; found: 281.0511.

NMR spectrum of intermediates and final products

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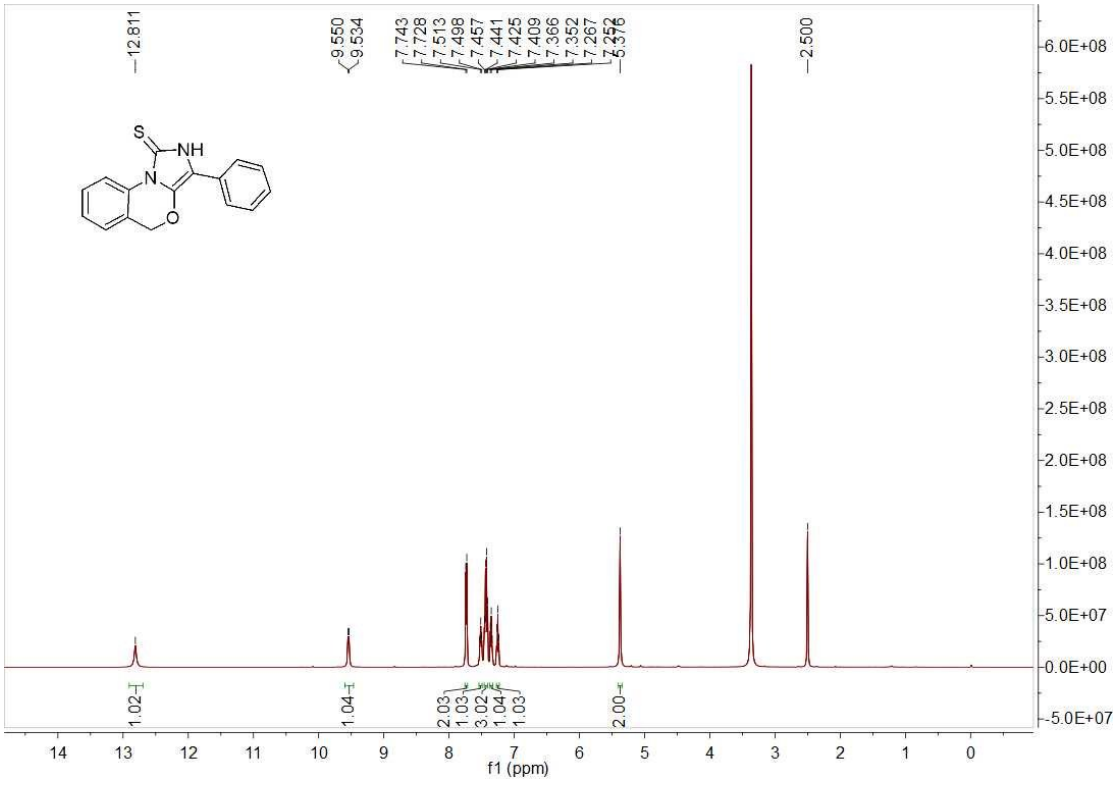
135.93
132.22
129.29
128.36
125.98
125.60
124.38
124.19
123.95
117.63
106.89
69.24
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.75
S
NH
N
O
f1 (ppm)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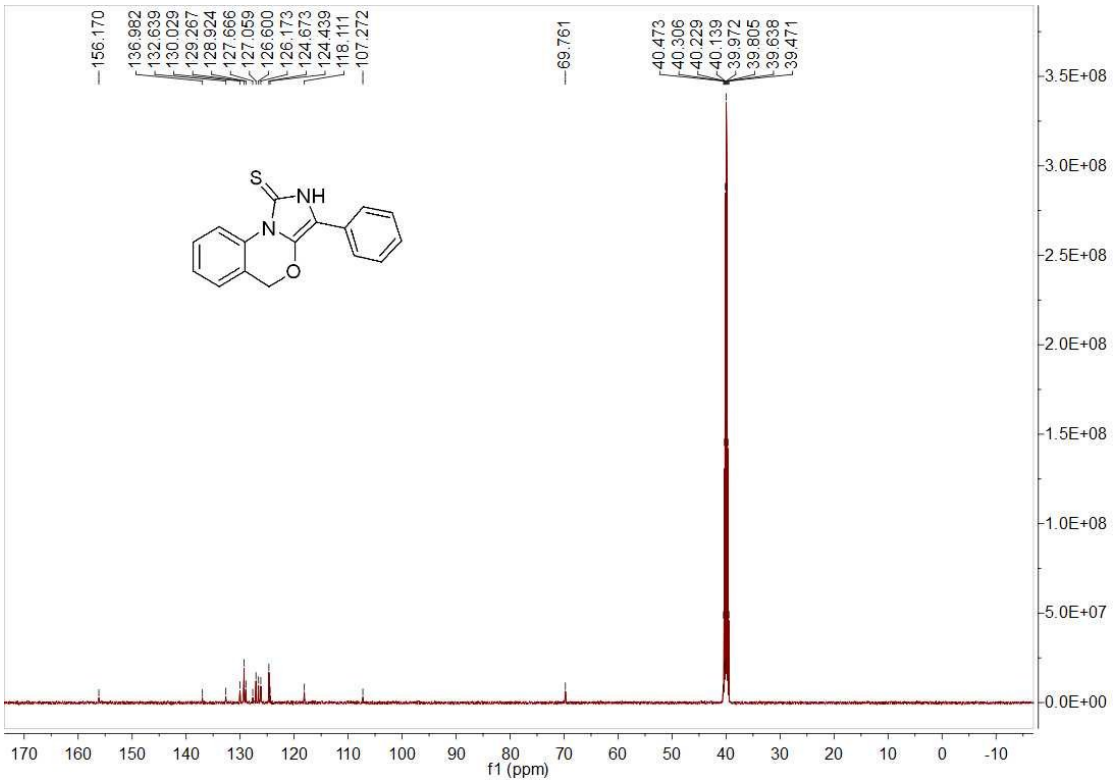
9.550
9.534
7.743
7.728
7.513
7.498
7.457
7.441
7.425
7.409
7.366
7.352
7.267
2.500
S
NH
N
O
1.02
1.04
2.03
1.03
3.02
1.04
1.03
2.00
f1 (ppm)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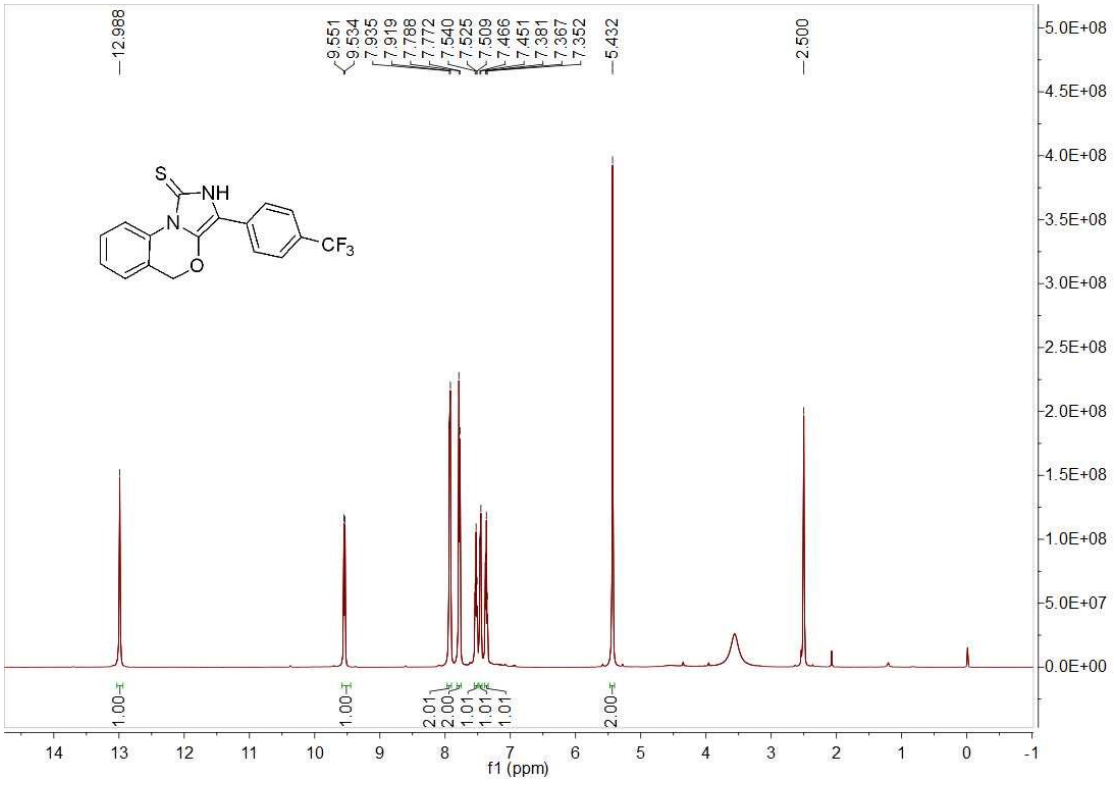
136.982
132.639
130.029
129.267
128.924
127.666
127.059
126.600
126.173
124.673
124.439
118.111
107.272
69.761
40.473
40.306
40.229
40.139
39.972
39.805
39.638
39.471
S
NH
N
O
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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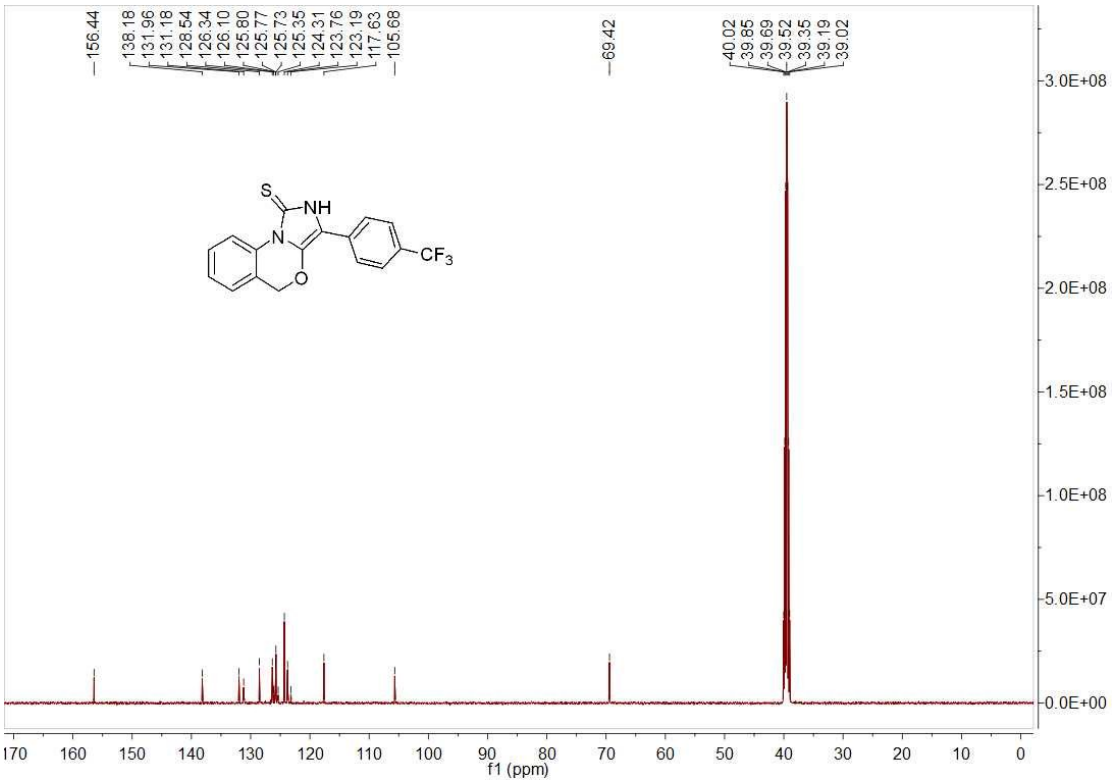
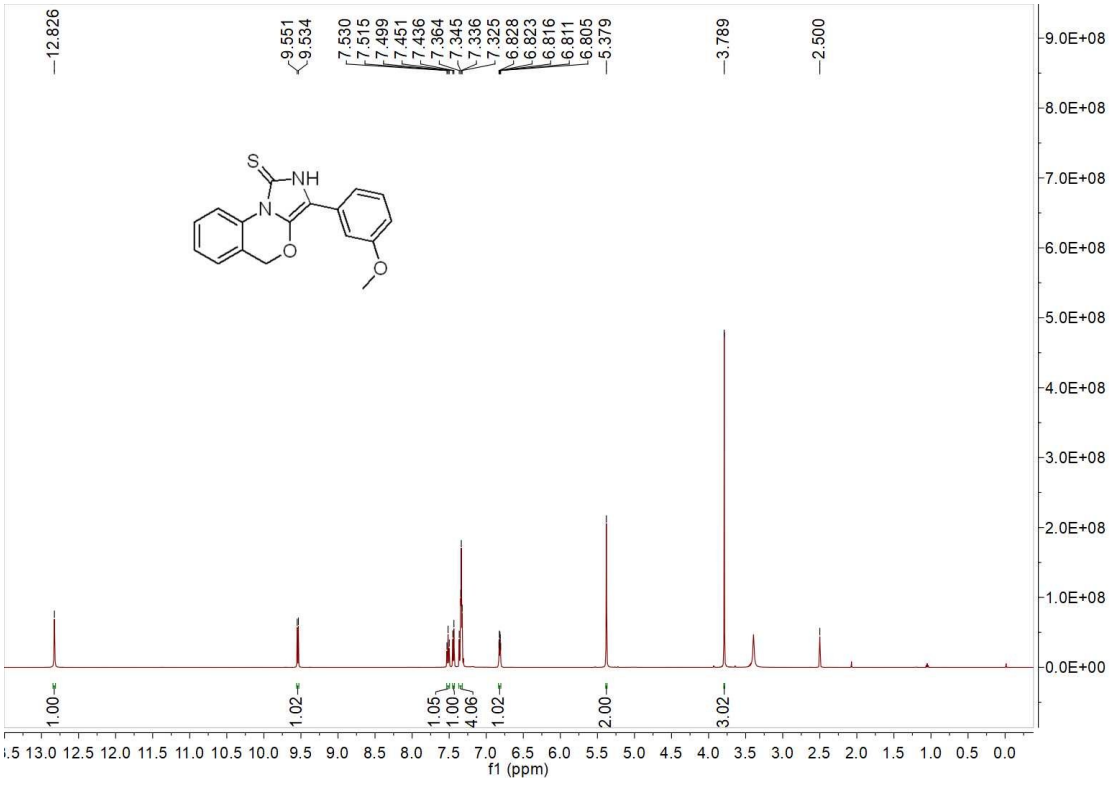
7.935
7.919
7.788
7.772
7.540
7.525
7.509
7.466
7.451
7.381
7.367
7.352
5.432
2.500
S
NH
N
O
CF3
5.0E+08
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
1.00
1.00
2.01
2.00
1.01
1.01
2.00
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


156.44
138.18
131.96
131.18
128.54
126.34
126.10
125.80
125.77
125.73
125.35
124.31
123.76
123.19
117.63
105.68
69.42
40.02
39.85
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
CF3
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
f1 (ppm)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7.530
7.515
7.499
7.451
7.436
7.364
7.345
7.336
7.325
6.828
6.823
6.816
6.811
6.805
5.379
3.789
2.500
S
NH
N
O
O
9.0E+08
8.0E+08
7.0E+08
6.0E+08
5.0E+08
4.0E+08
3.0E+08
2.0E+08
1.0E+08
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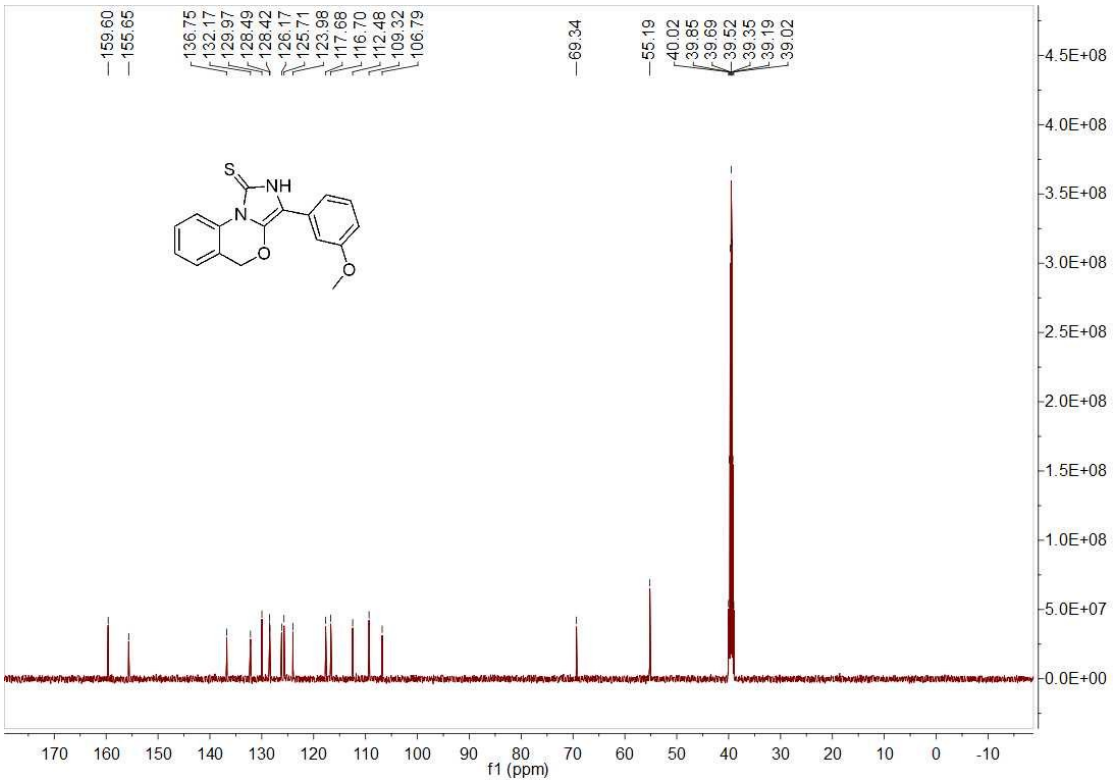
1.00
1.02
1.05
1.00
4.06
1.02
2.00
3.02
f1 (ppm)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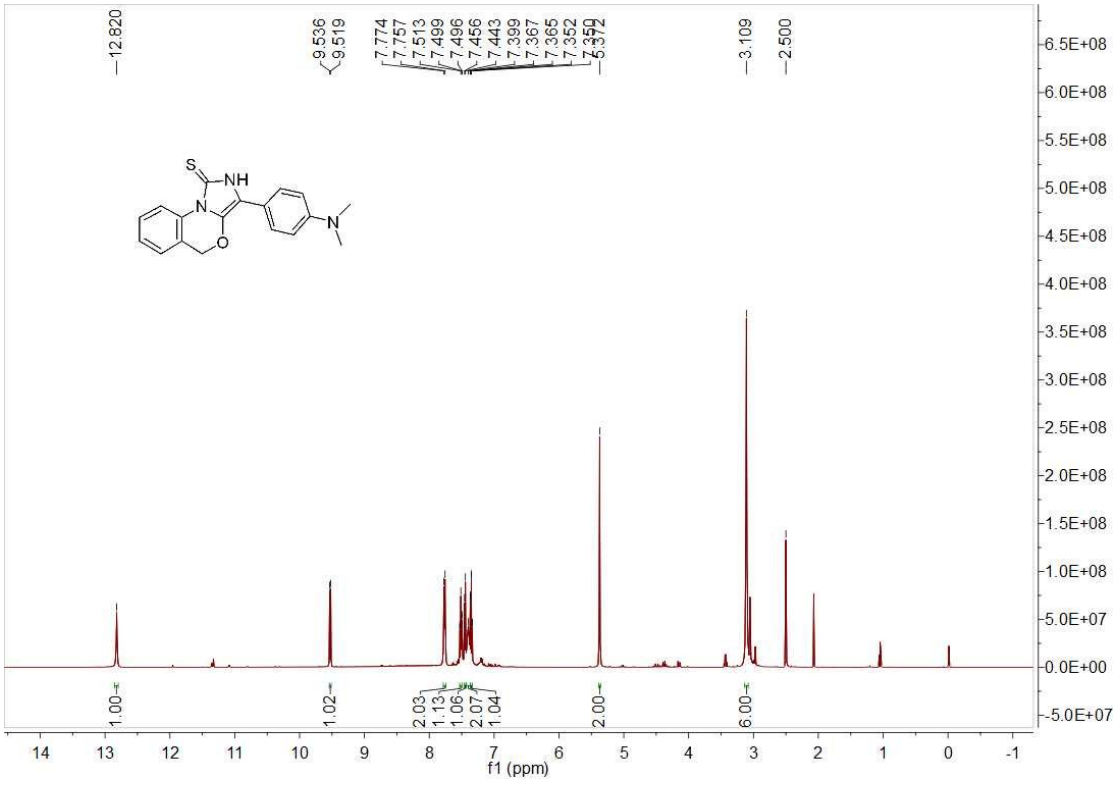
155.65
136.75
132.17
129.97
128.49
128.42
126.17
125.71
123.98
117.68
116.70
112.48
109.32
106.79
69.34
55.19
40.02
39.85
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
O
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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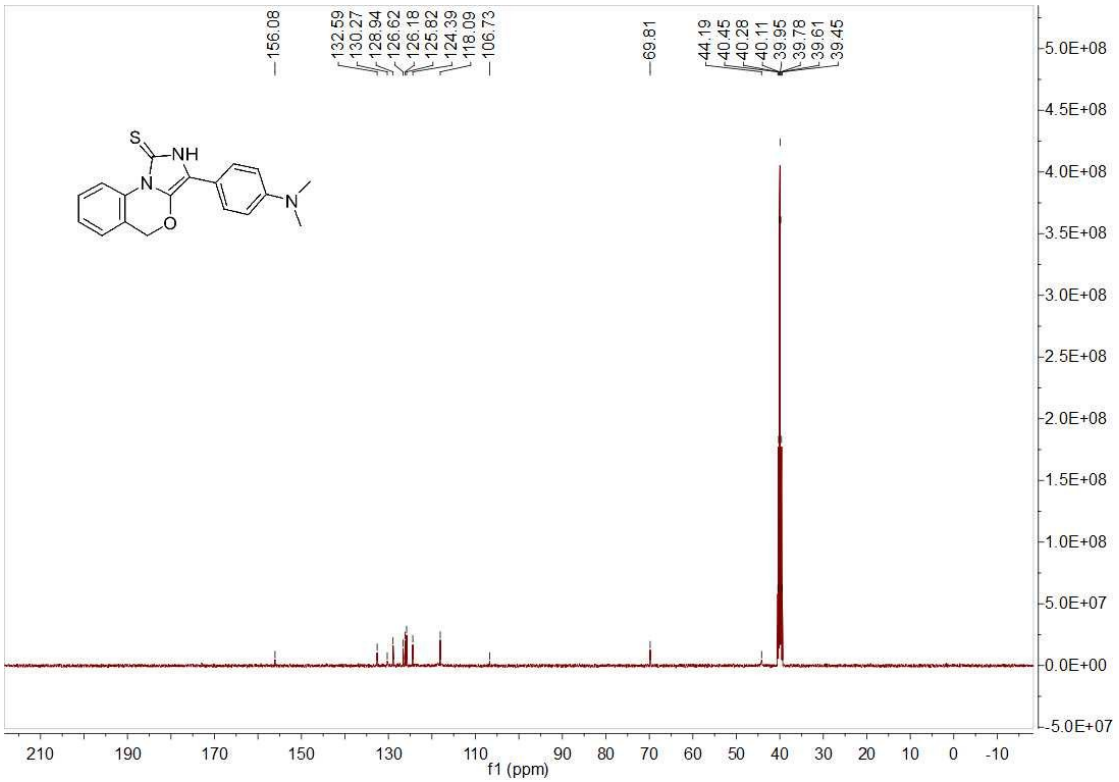
9.519
7.774
7.757
7.513
7.499
7.496
7.456
7.443
7.399
7.367
7.365
7.352
7.350
7.332
3.109
2.500
S
NH
N
O
N
6.5E+08
6.0E+08
5.5E+08
5.0E+08
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
-5.0E+07
1.00
1.02
2.03
1.13
1.06
2.07
1.04
2.00
6.00
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)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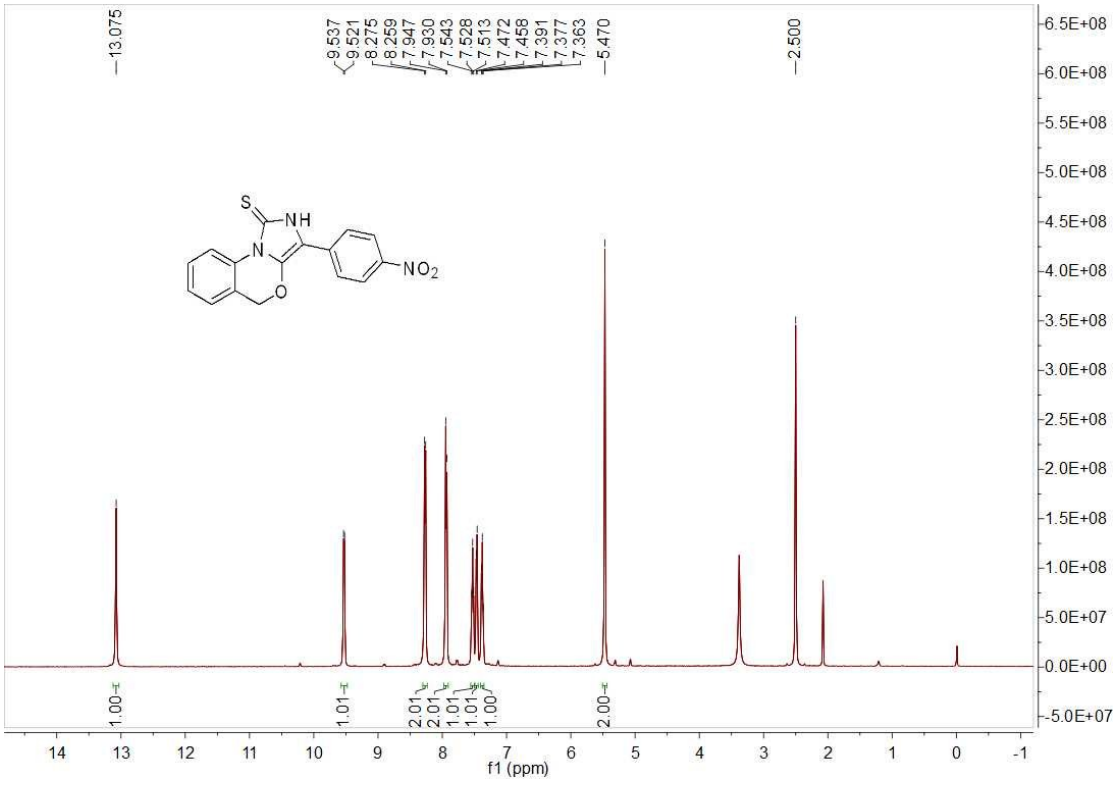
130.27
128.94
126.62
126.18
125.82
124.39
118.09
106.73
69.81
44.19
40.45
40.28
40.11
39.95
39.78
39.61
39.45
S
NH
N
O
N
5.0E+08
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
-5.0E+07
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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9.521
8.275
8.259
7.947
7.930
7.543
7.528
7.513
7.472
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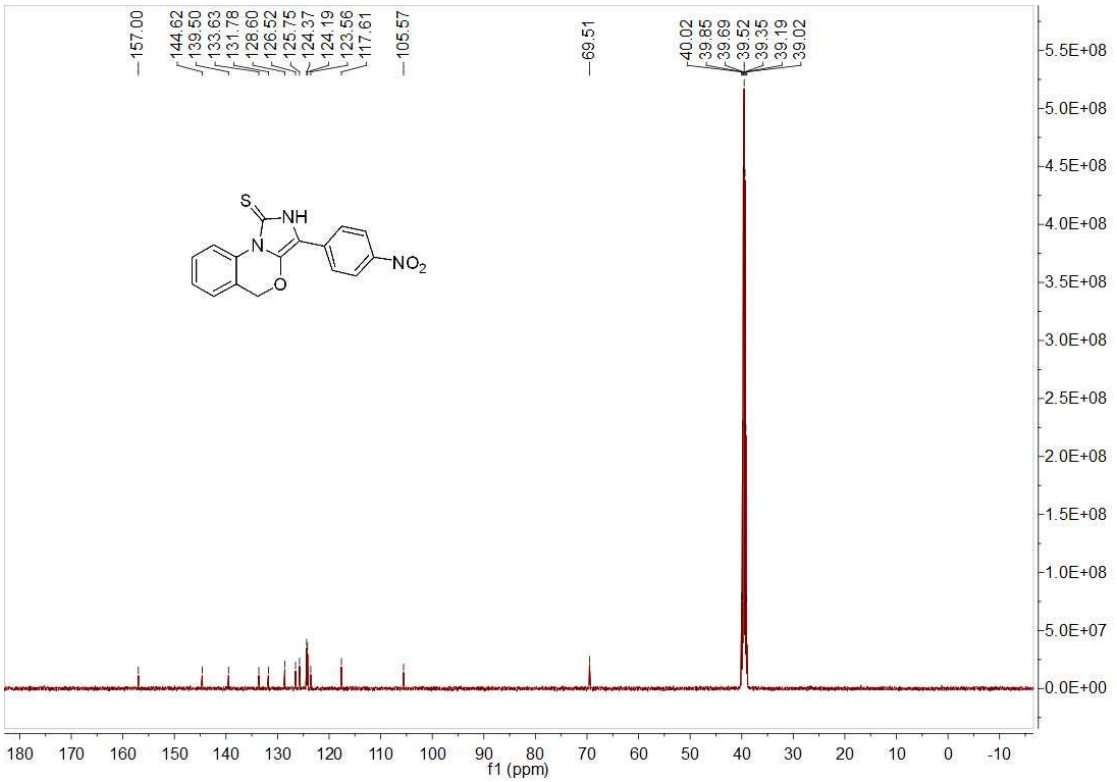
7.391
7.377
7.363
5.470
2.500
S
NH
N
O
NO2
6.5E+08
6.0E+08
5.5E+08
5.0E+08
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
-5.0E+07
1.00
1.01
2.01
2.01
1.01
1.01
1.00
2.00
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)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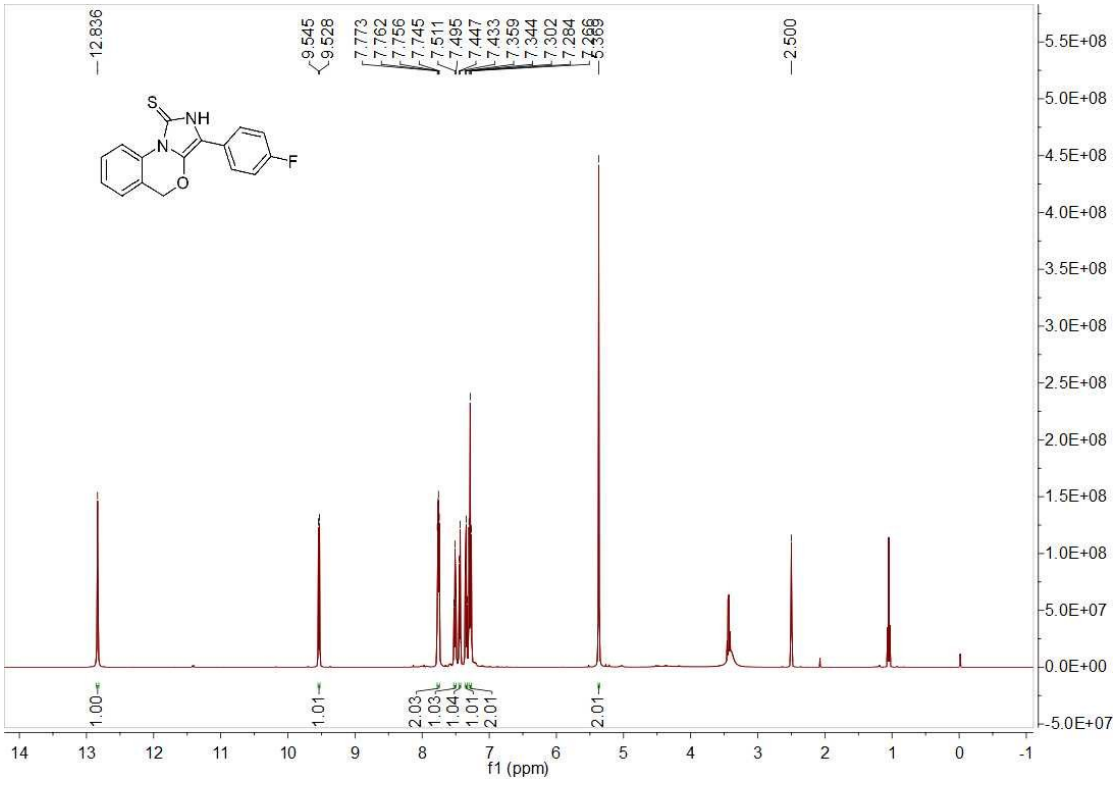
139.50
133.63
131.78
128.60
126.52
125.75
124.37
124.19
123.56
117.61
105.57
69.51
40.02
39.85
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
NO2
f1 (ppm)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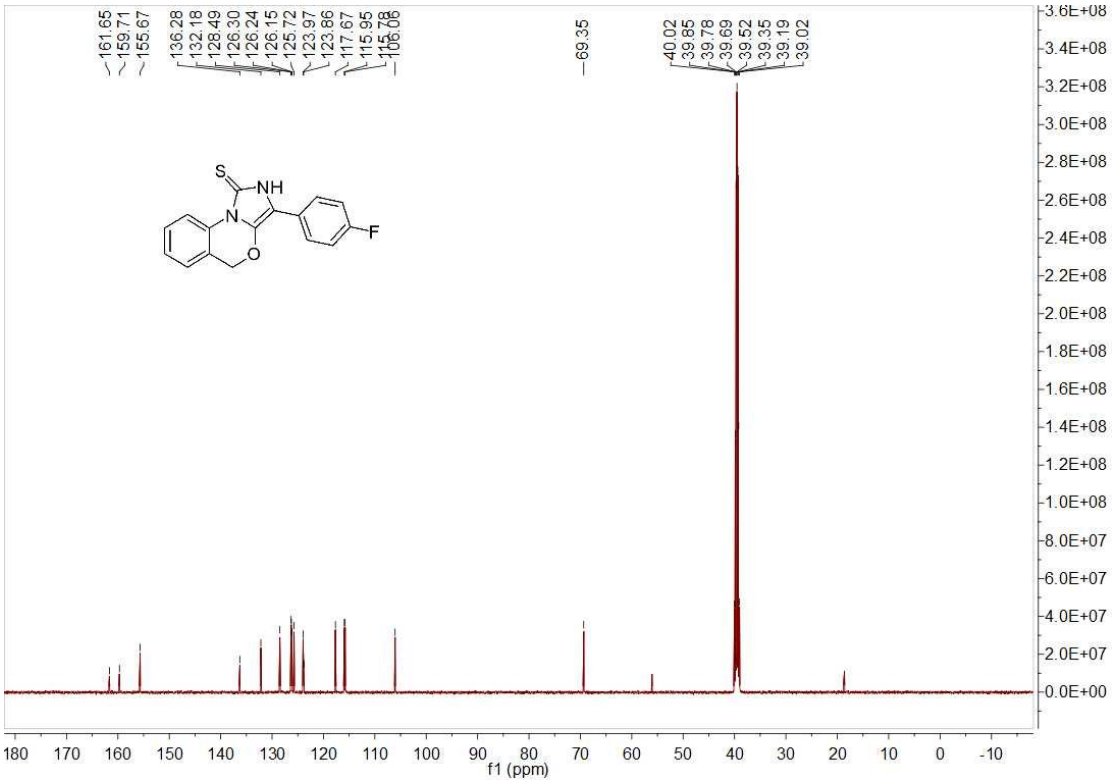
7.359
7.344
7.302
7.284
2.500
S
NH
N
O
F
1.00
1.01
2.03
1.03
1.04
1.01
2.01
2.01
f1 (ppm)


161.65
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132.18
128.49
126.30
126.24
126.15
125.72
123.97
123.86
117.67
115.95
115.78
106.06
69.35
40.02
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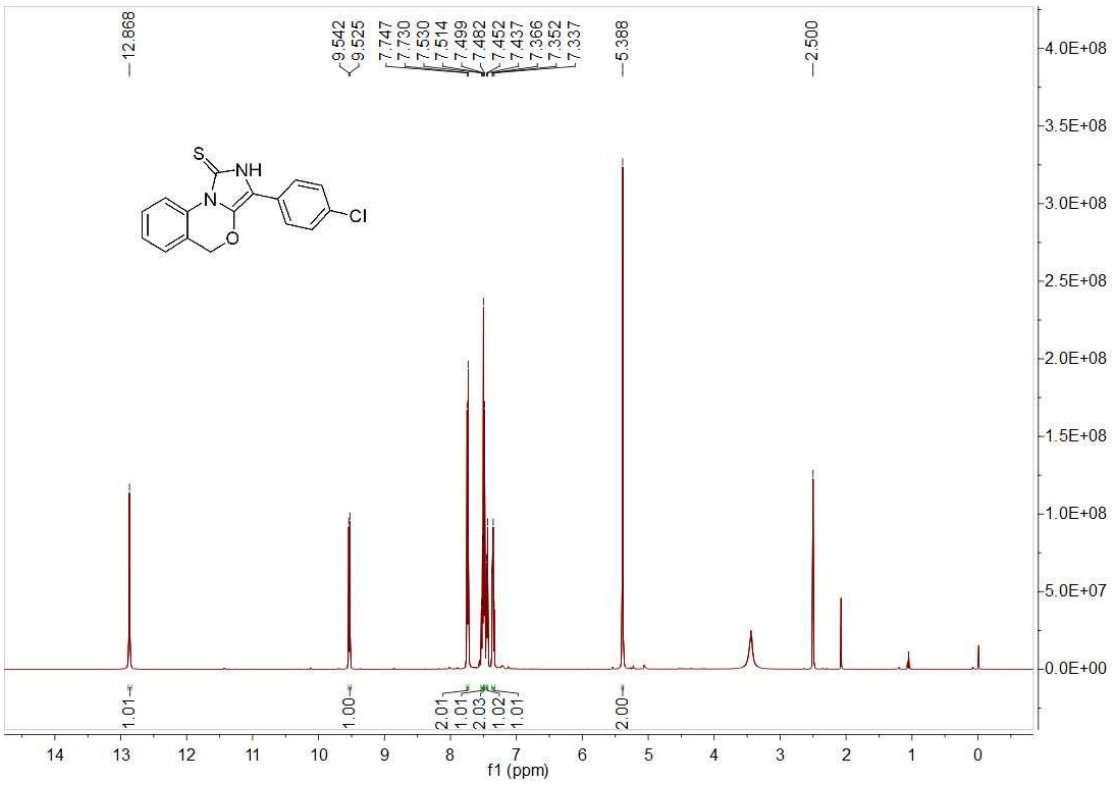
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
F
f1 (ppm)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7.452
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7.352
7.337
5.388
2.500
S
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N
O
Cl
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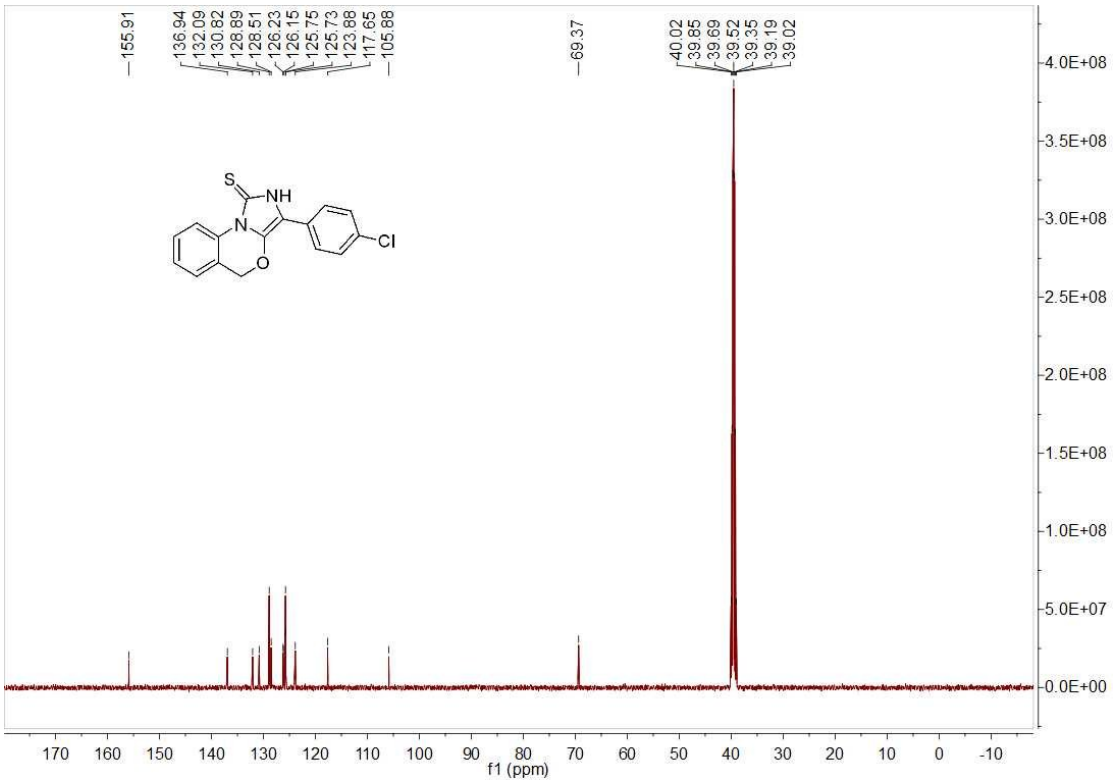
1.00
2.01
1.01
2.03
1.02
1.01
2.00
f1 (ppm)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128.89
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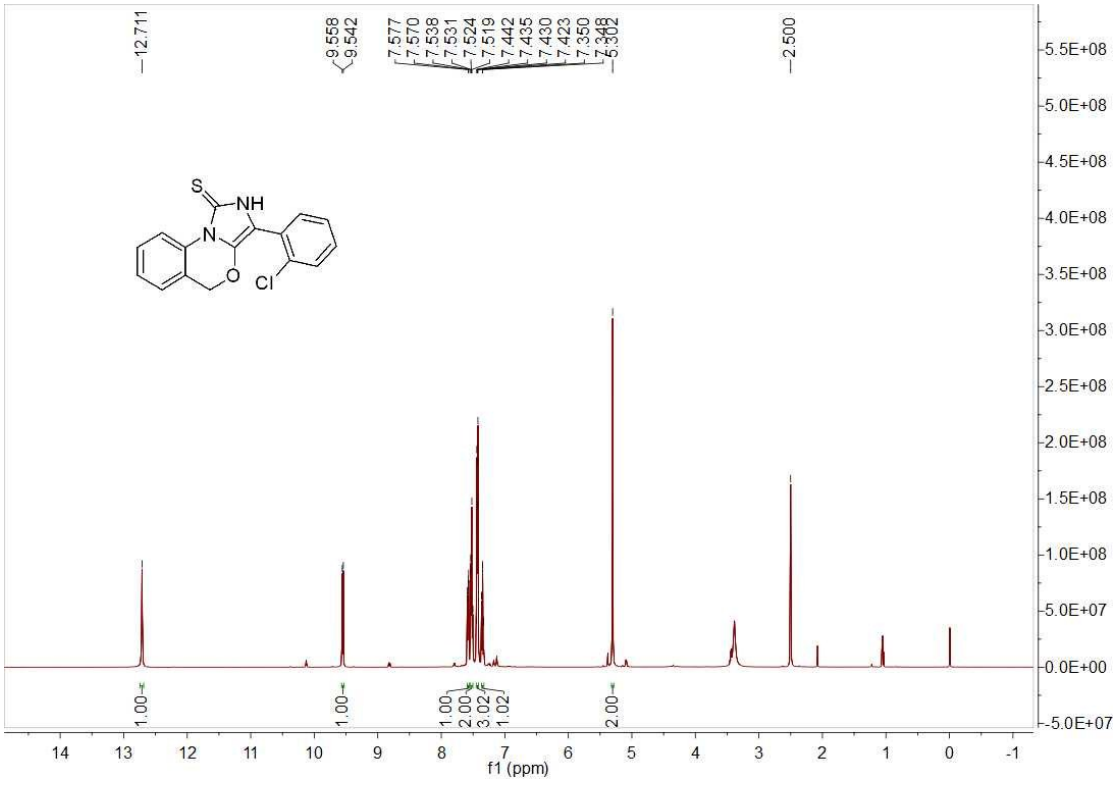
126.23
126.15
125.75
125.73
123.88
117.65
105.88
69.37
40.02
39.85
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
Cl
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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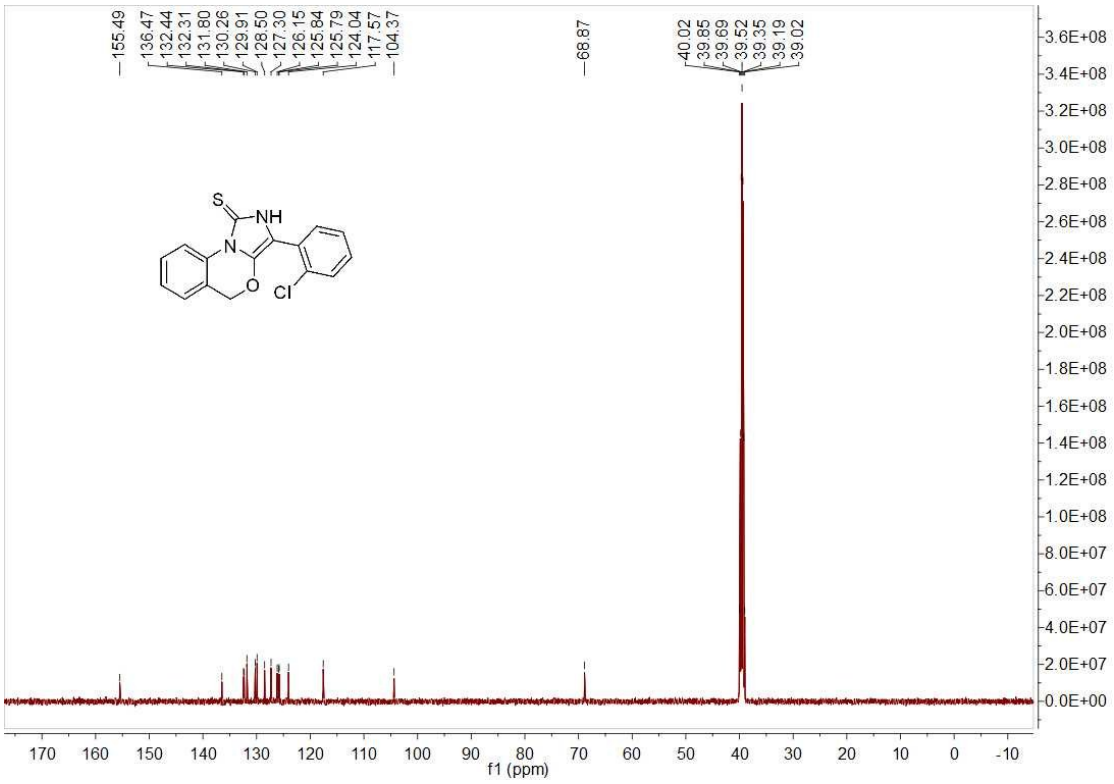
7.538
7.531
7.524
7.519
7.442
7.435
7.430
7.423
7.350
7.348
7.302
2.500
S
NH
N
O
Cl
5.5E+08
5.0E+08
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
-5.0E+07
1.00
1.00
1.00
2.00
3.02
1.02
2.00
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)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132.31
131.80
130.26
129.91
128.50
127.30
126.15
125.84
125.79
124.04
117.57
104.37
68.87
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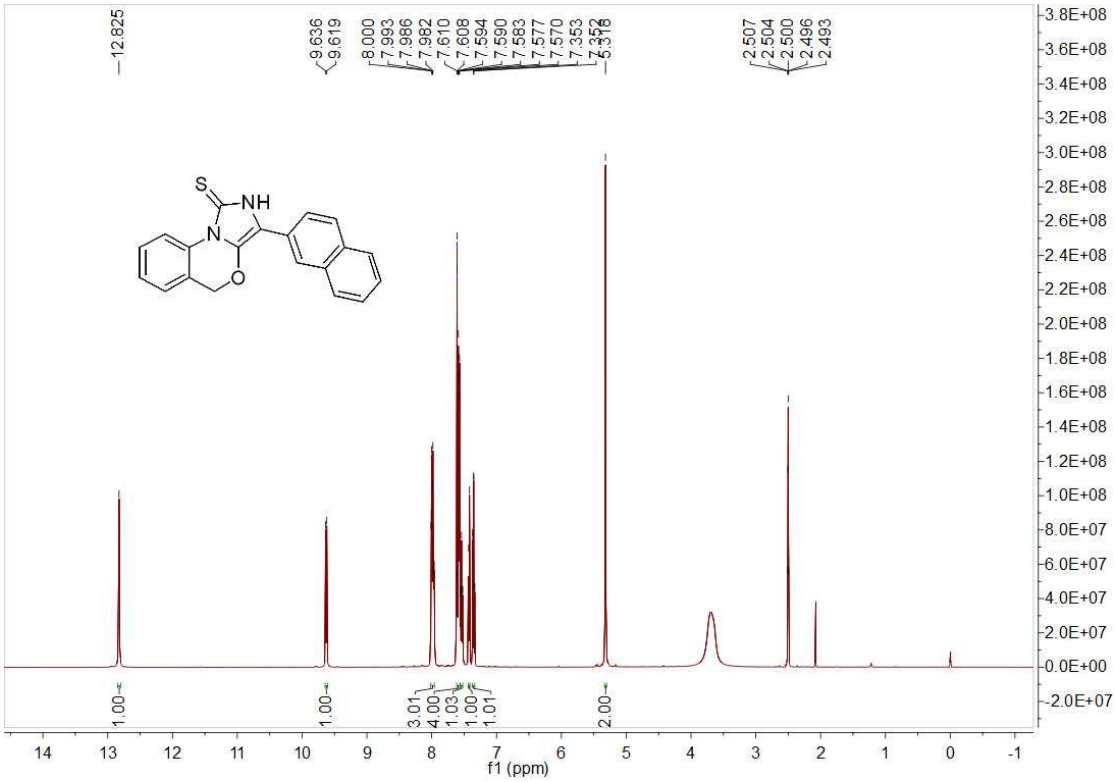
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
Cl
f1 (ppm)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7.608
7.594
7.590
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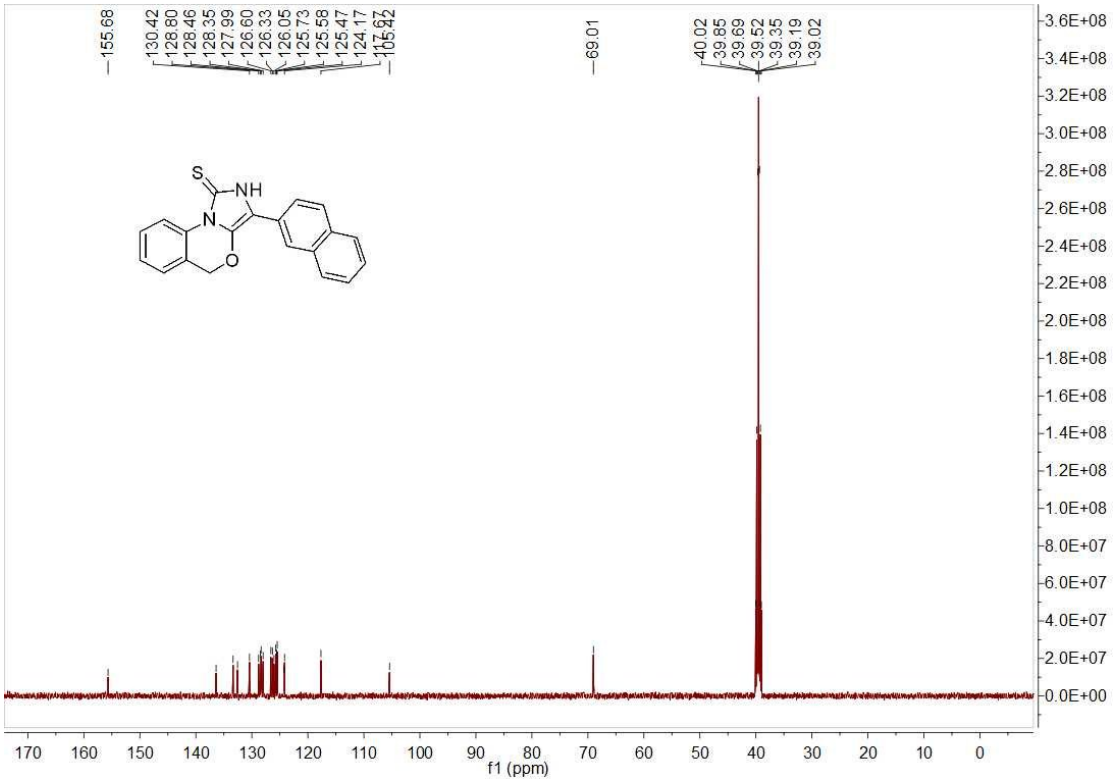
7.577
7.570
7.353
2.507
2.504
2.500
2.496
2.493
1.00
1.00
3.01
4.00
1.03
1.00
1.01
2.00
S
NH
N
O
f1 (ppm)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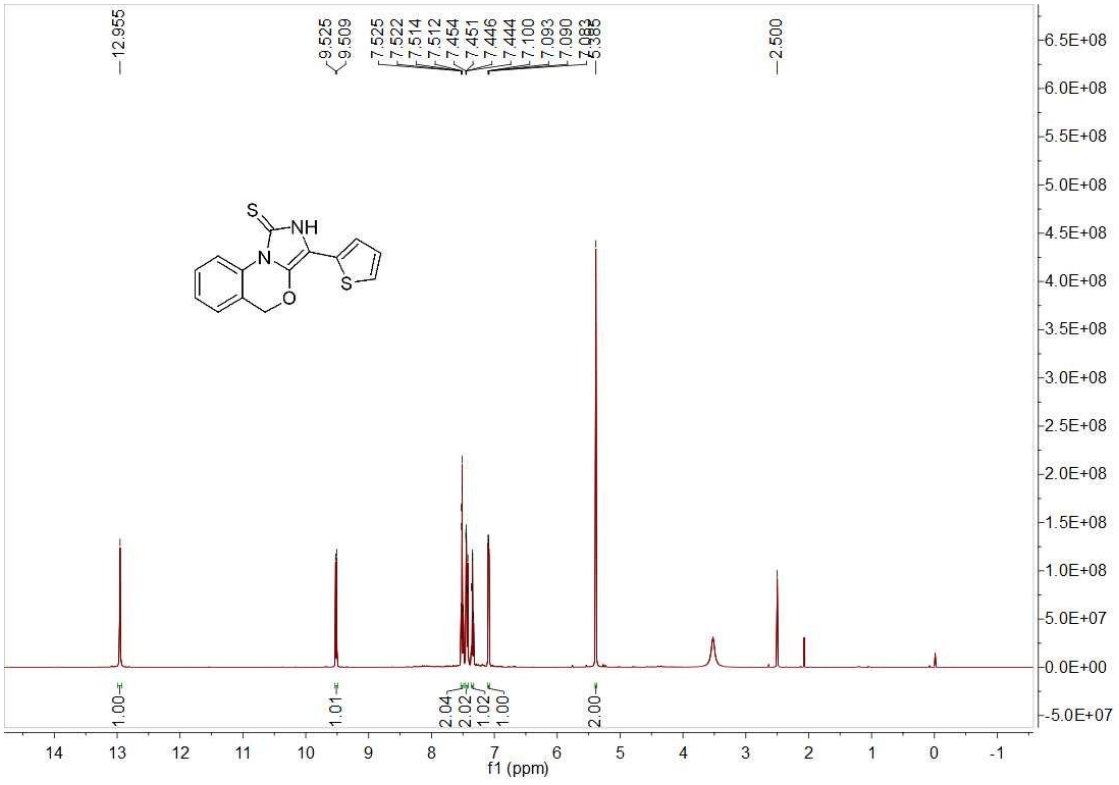
128.35
127.99
126.60
126.33
126.05
125.73
125.58
125.47
124.17
117.67
105.42
69.01
40.02
39.85
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
f1 (ppm)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7.090
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N
O
S
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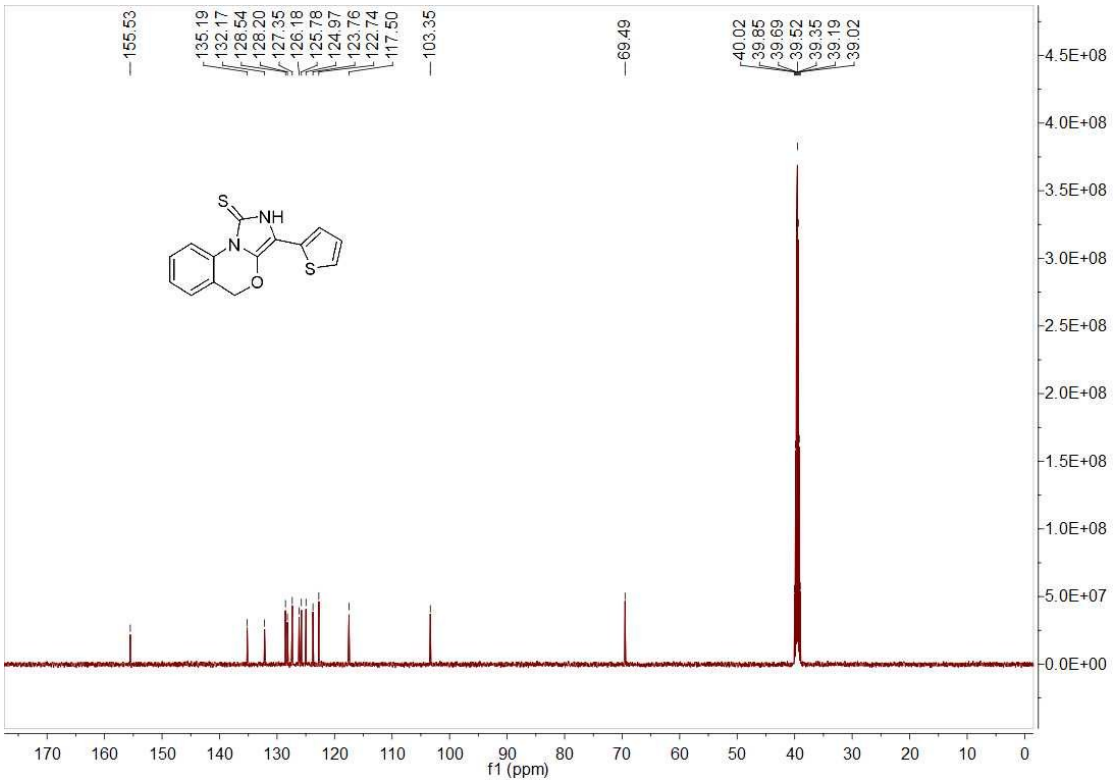
1.01
2.04
2.02
1.02
1.00
2.00
f1 (ppm)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123.76
122.74
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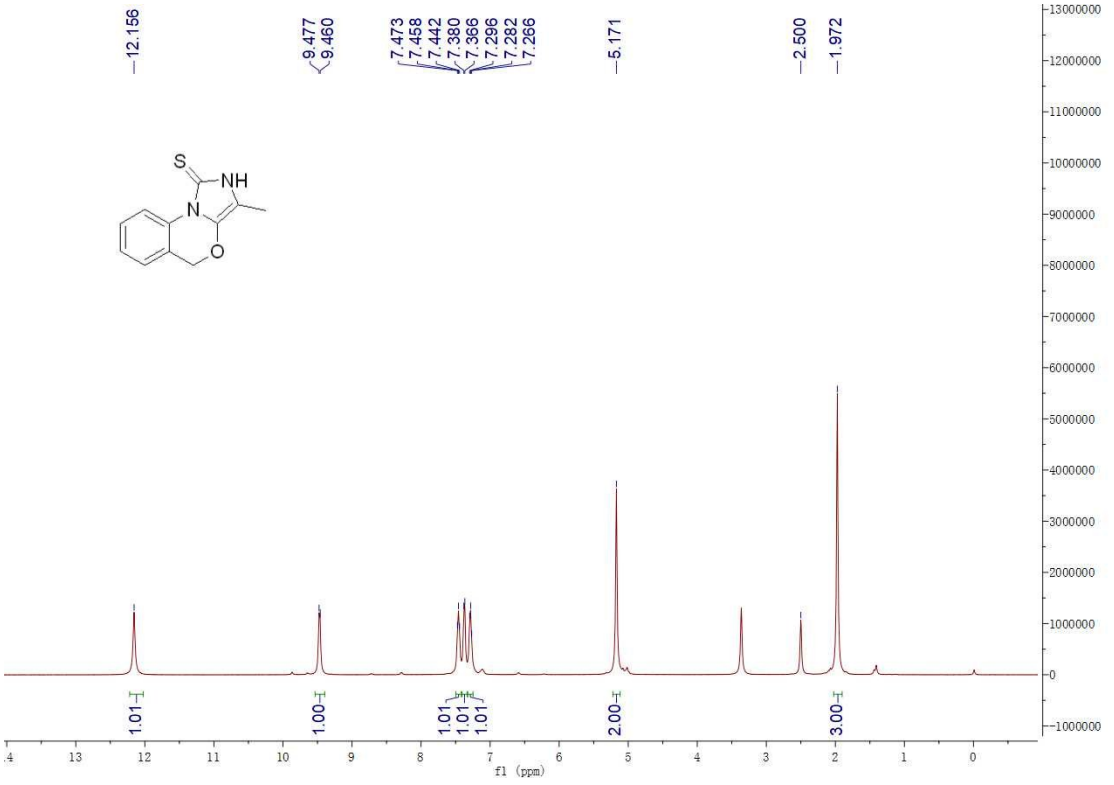
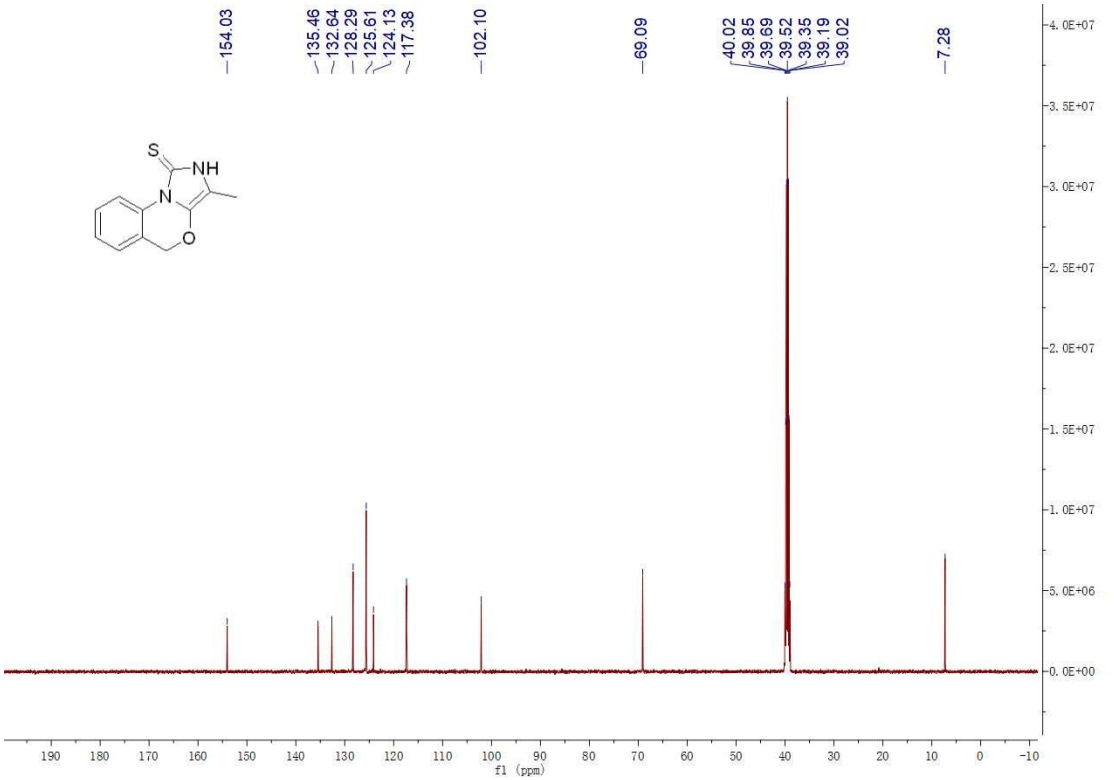
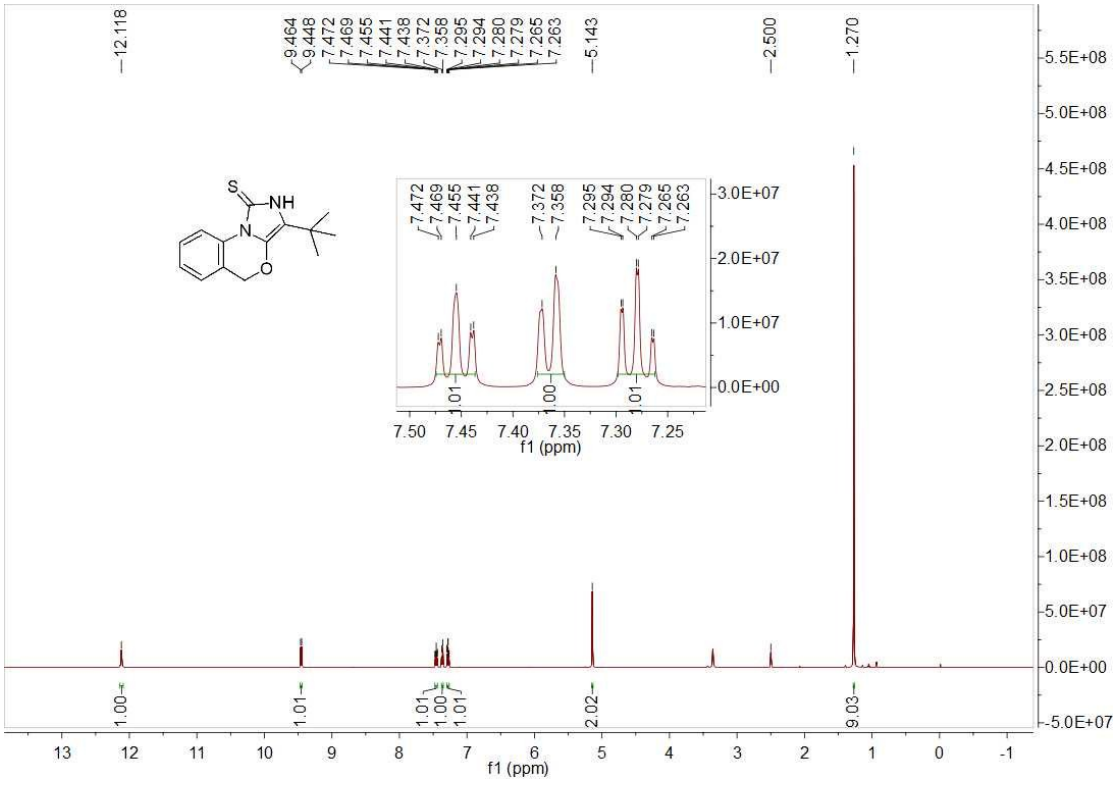
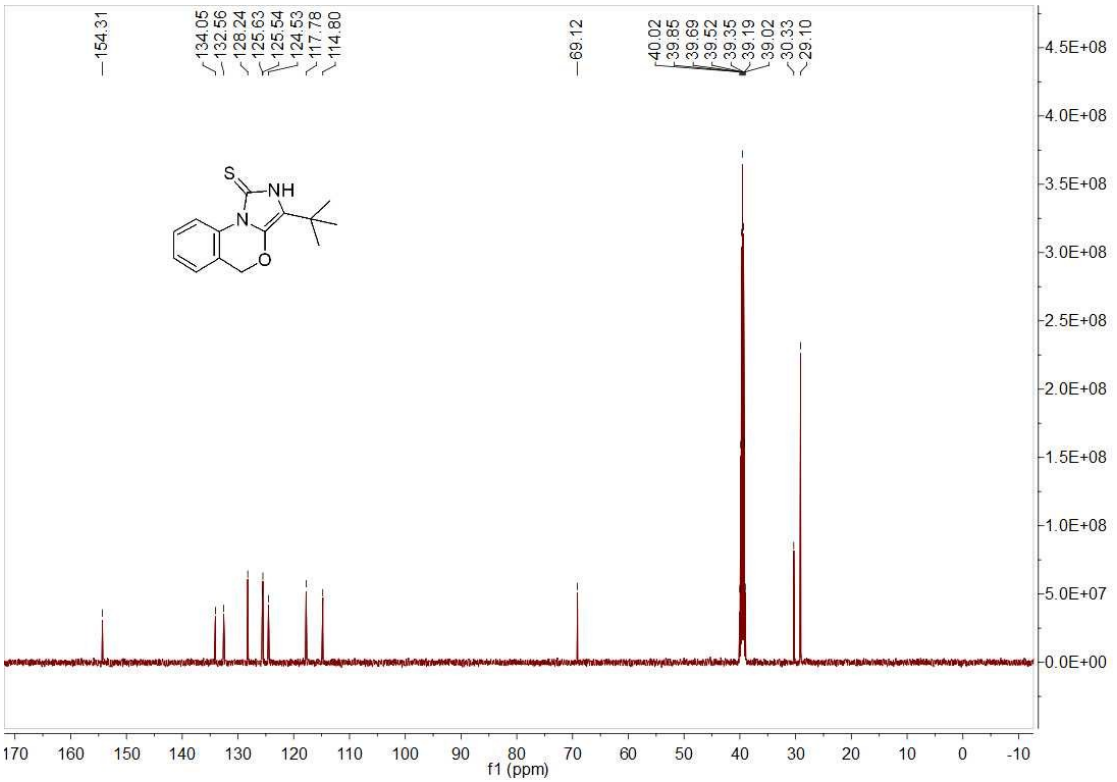
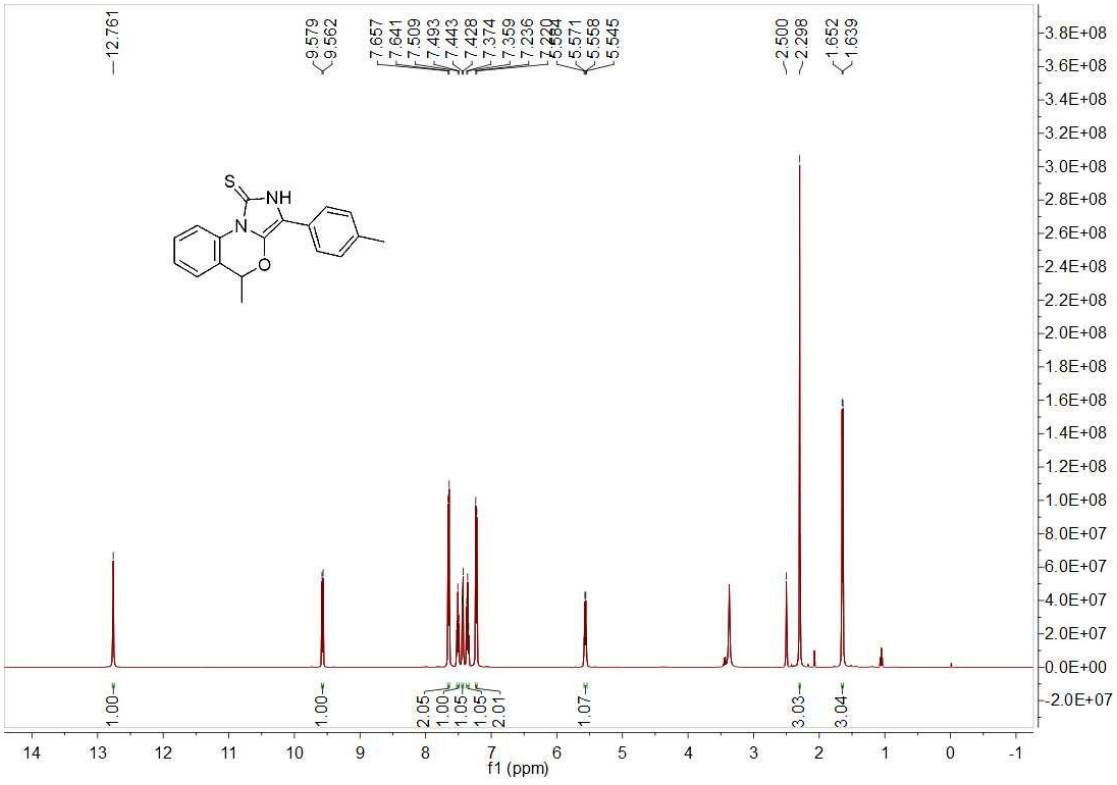
103.35
69.49
40.02
39.85
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
S
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

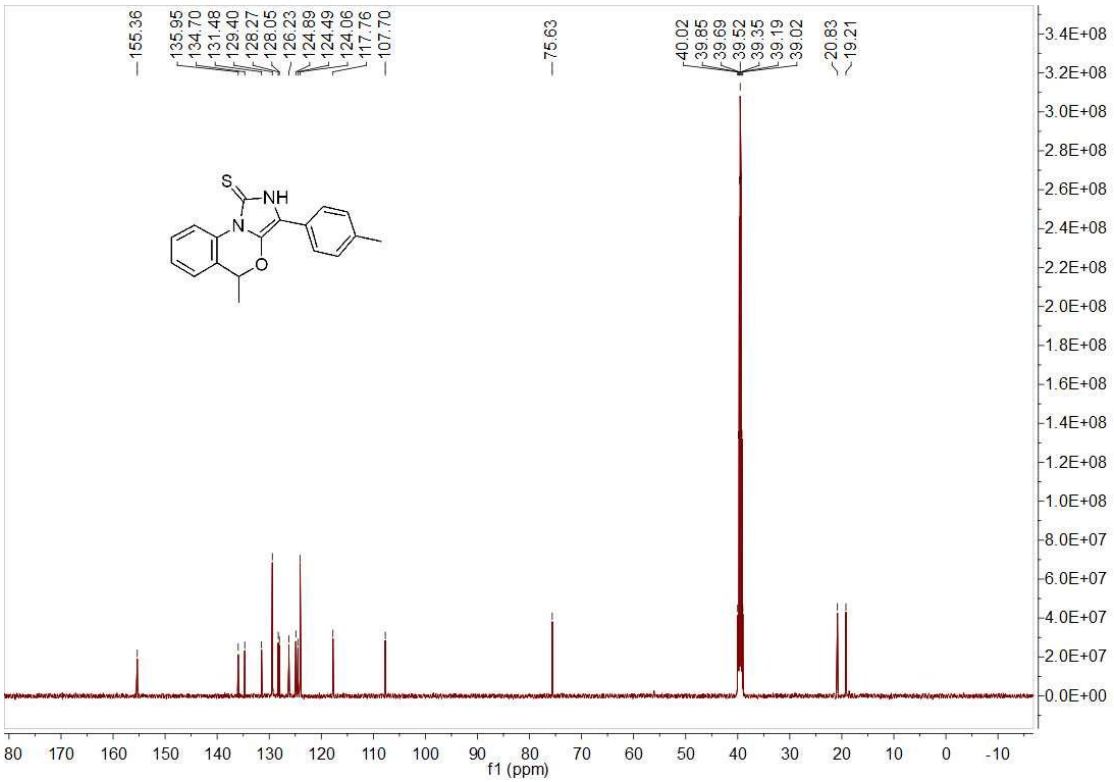

12.156
9.477
9.460
7.473
7.458
7.442
7.380
7.366
7.296
7.282
7.266
5.171
2.500
1.972
S
NH
N
O
13000000
12000000
11000000
10000000
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
-1000000
1.01
1.00
1.01
1.01
1.01
2.00
3.00
13 12 11 10 9 8 7 6 5 4 3 2 1 0
f1 (ppm)

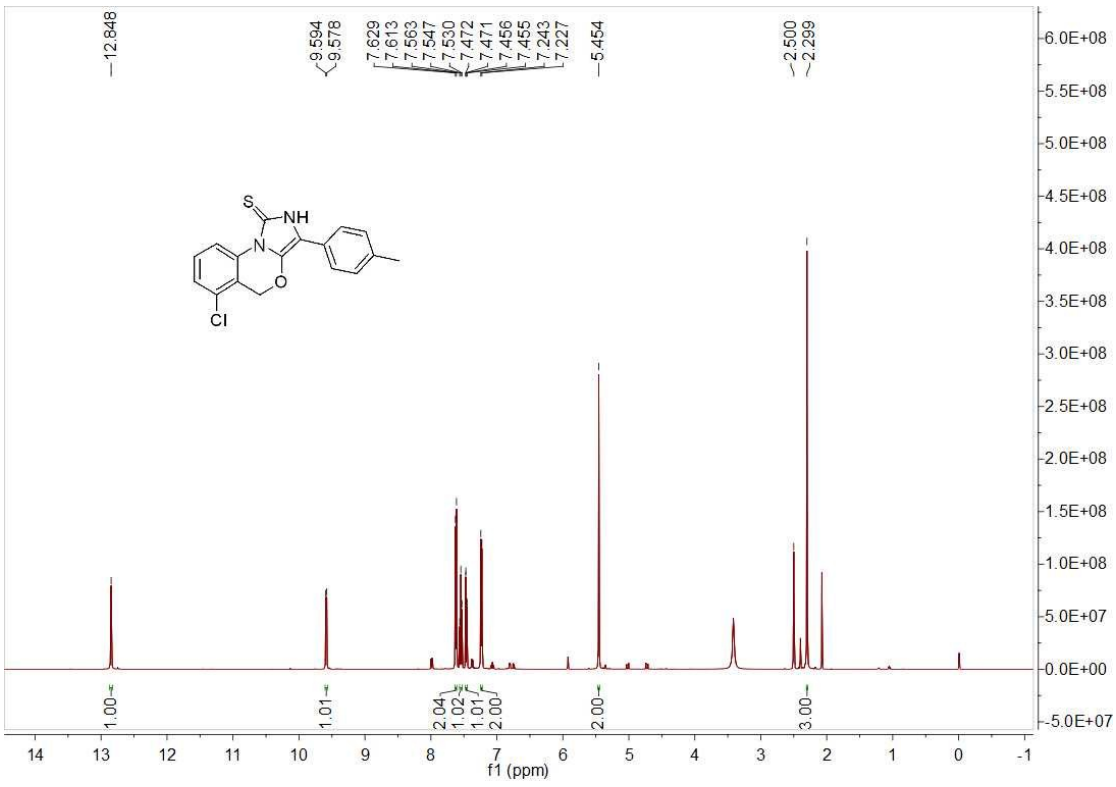

154.03
135.46
132.64
128.29
125.61
124.13
117.38
102.10
69.09
40.02
39.85
39.69
39.52
39.35
39.19
39.02
7.28
S
NH
N
O
f1 (ppm)

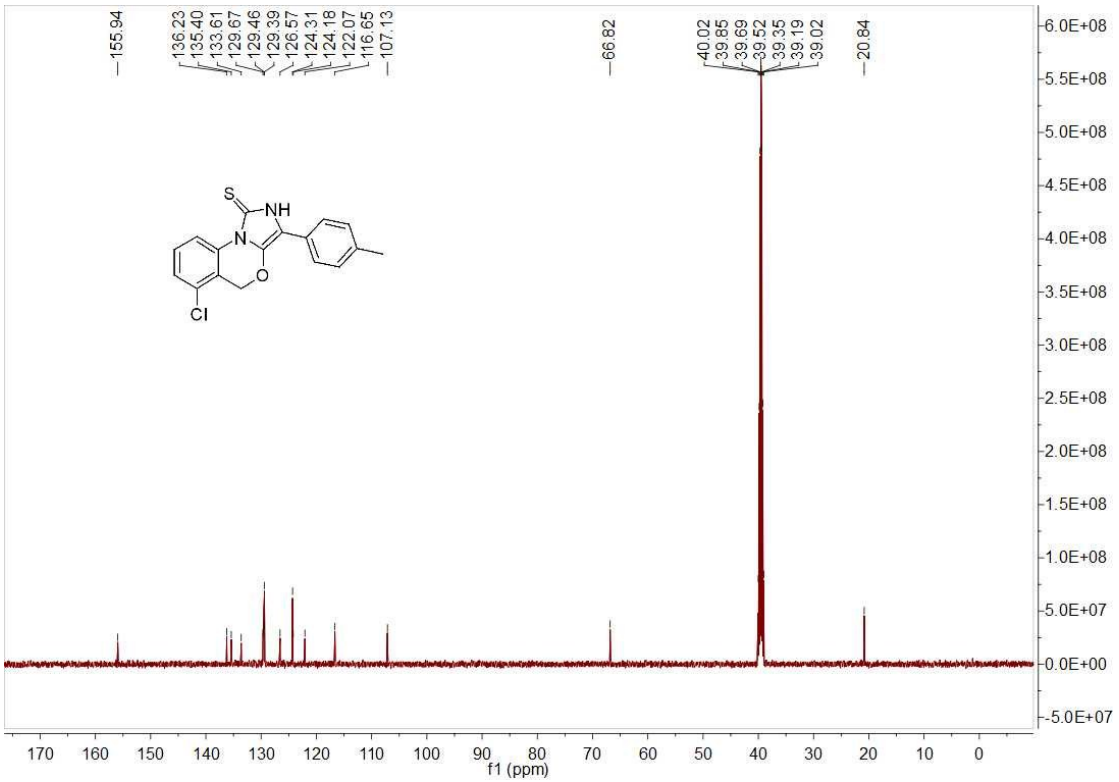

12.118
9.464
9.448
7.472
7.469
7.455
7.441
7.438
7.372
7.358
7.295
7.294
7.280
7.279
7.265
7.263
5.143
2.500
1.270
S
NH
N
O
1.00
1.01
1.01
1.00
1.01
2.02
9.03
f1 (ppm)


154.31
134.05
132.56
128.24
125.63
125.54
124.53
117.78
114.80
69.12
40.02
39.85
39.69
39.52
39.35
39.19
39.02
30.33
29.10
S
NH
N
O
f1 (ppm)


12.761
9.579
9.562
7.657
7.641
7.509
7.493
7.443
7.428
7.374
7.359
7.236
5.571
5.558
5.545
2.500
2.298
1.652
1.639
1.00
1.00
2.05
1.00
1.05
1.05
2.01
1.07
3.03
3.04
S
NH
N
O
f1 (ppm)


155.36
135.95
134.70
131.48
129.40
128.27
128.05
126.23
124.89
124.49
124.06
117.76
107.70
75.63
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.83
19.21
S
NH
N
O
f1 (ppm)


12.848
9.594
9.578
7.629
7.613
7.563
7.547
7.530
7.472
7.471
7.456
7.455
7.243
7.227
5.454
2.500
2.299
S
NH
N
O
Cl
1.00
1.01
2.04
1.02
1.01
2.00
2.00
3.00
f1 (ppm)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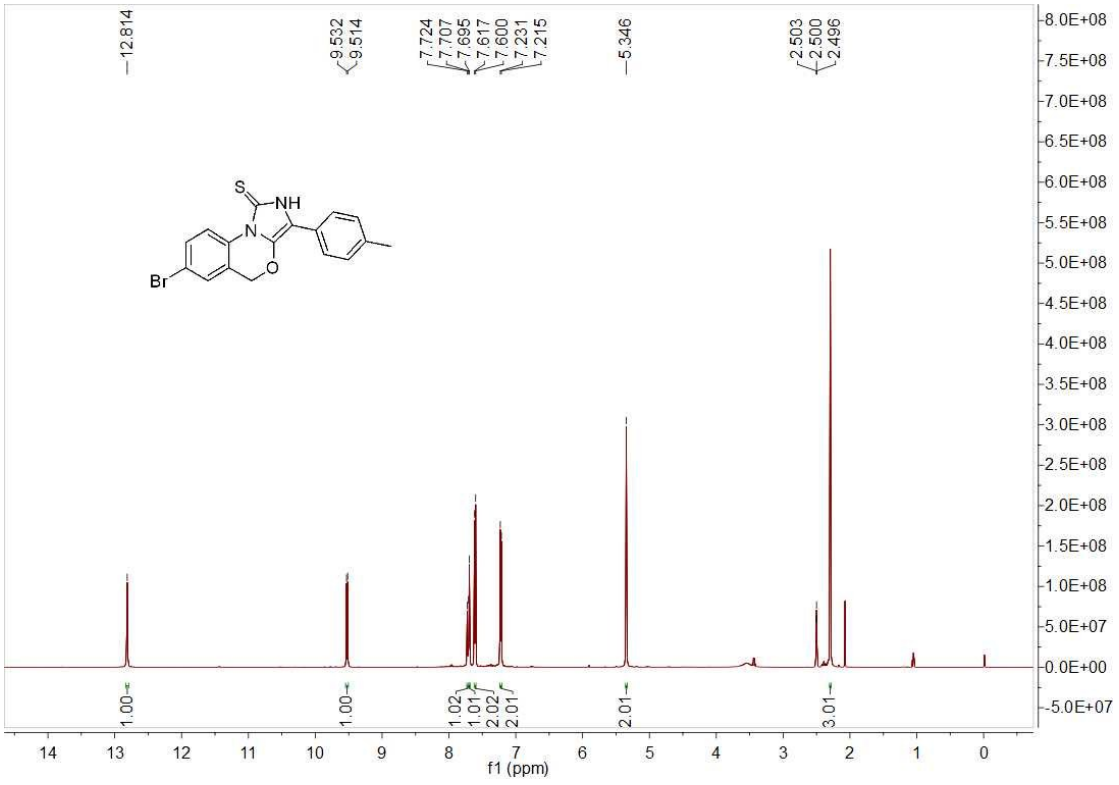
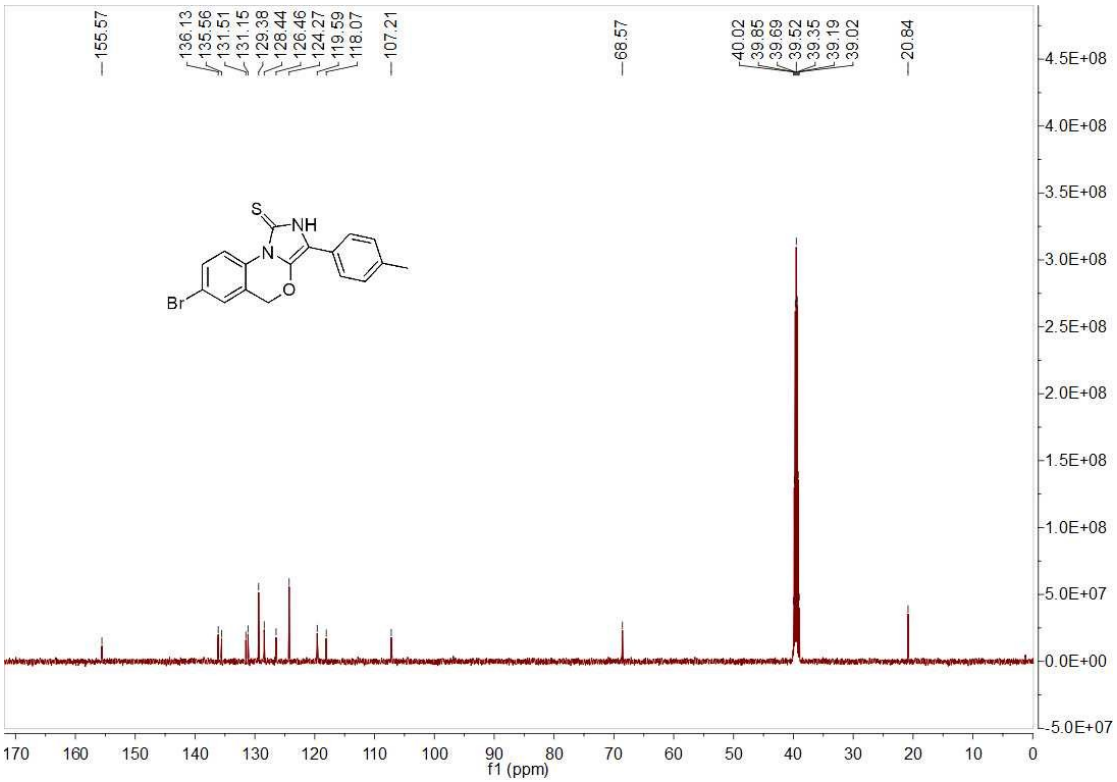
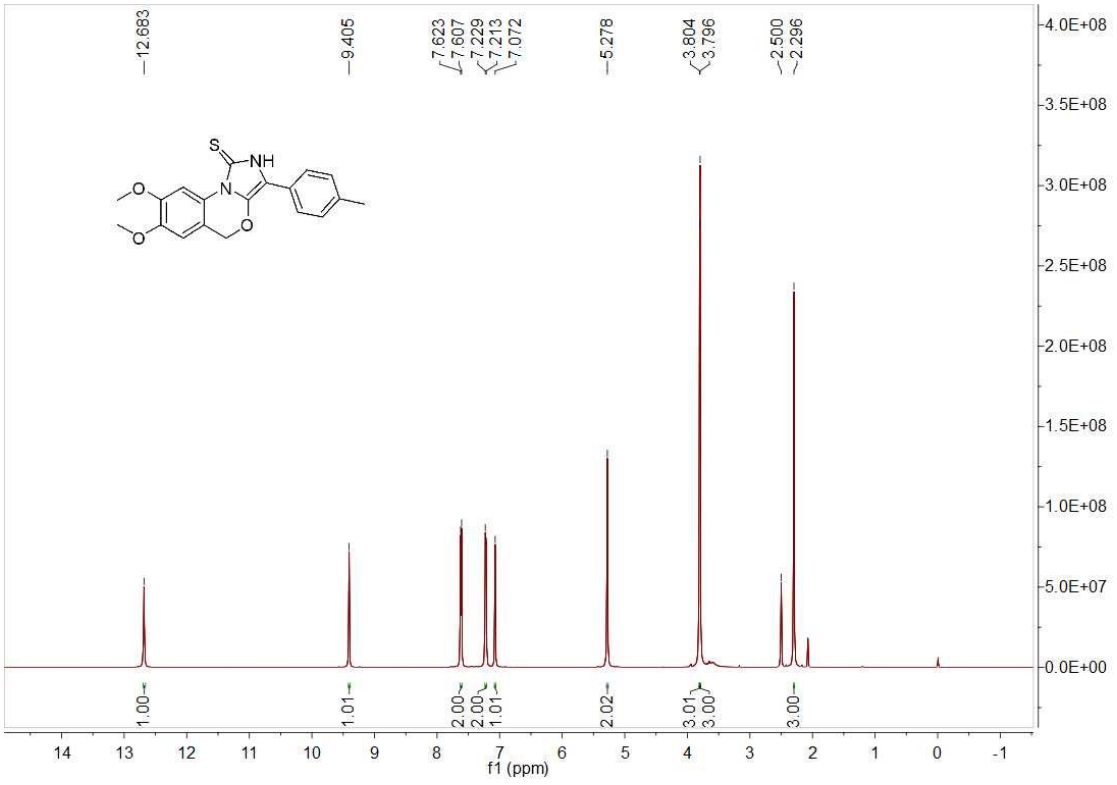
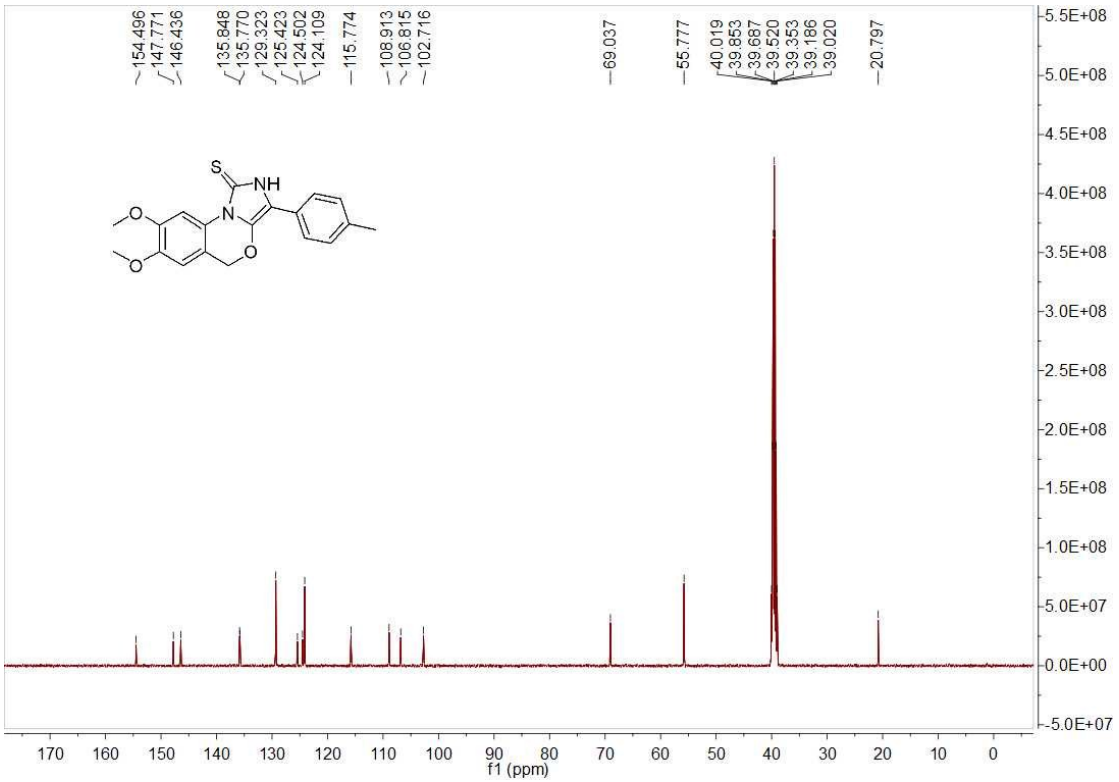
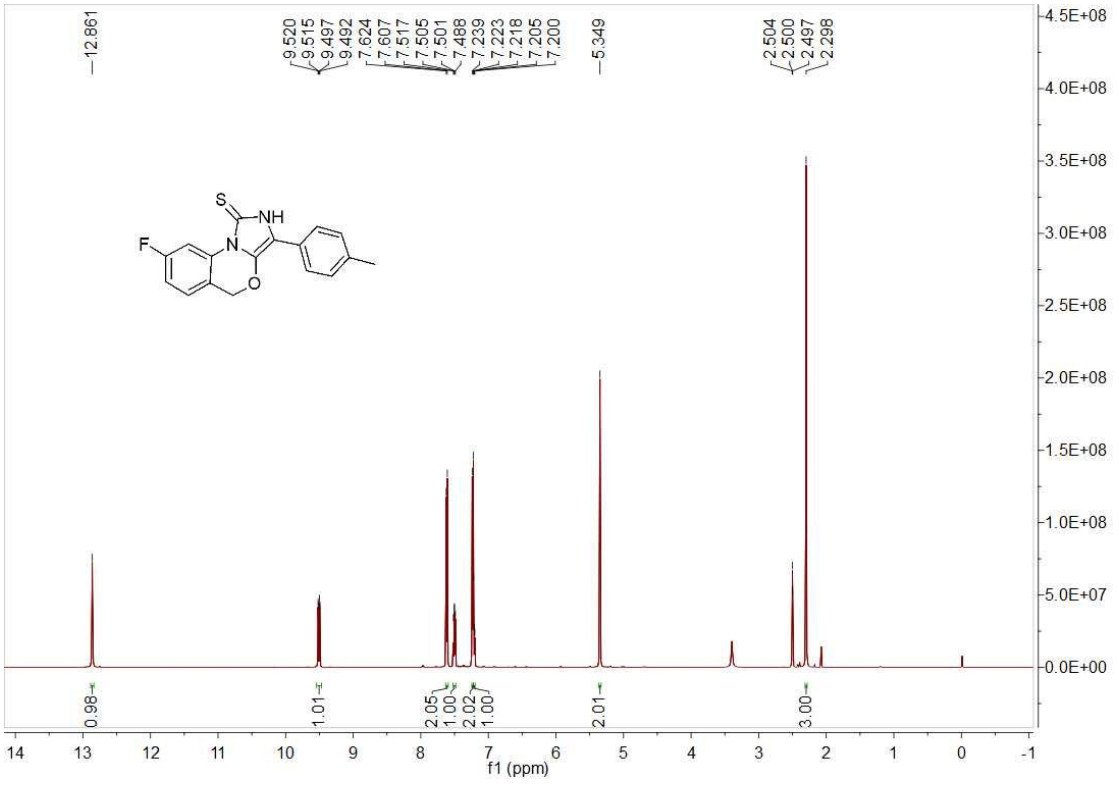
136.23
135.40
133.61
129.67
129.46
129.39
126.57
124.31
124.18
122.07
116.65
107.13
66.82
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.84
S
NH
N
O
Cl
f1 (ppm)

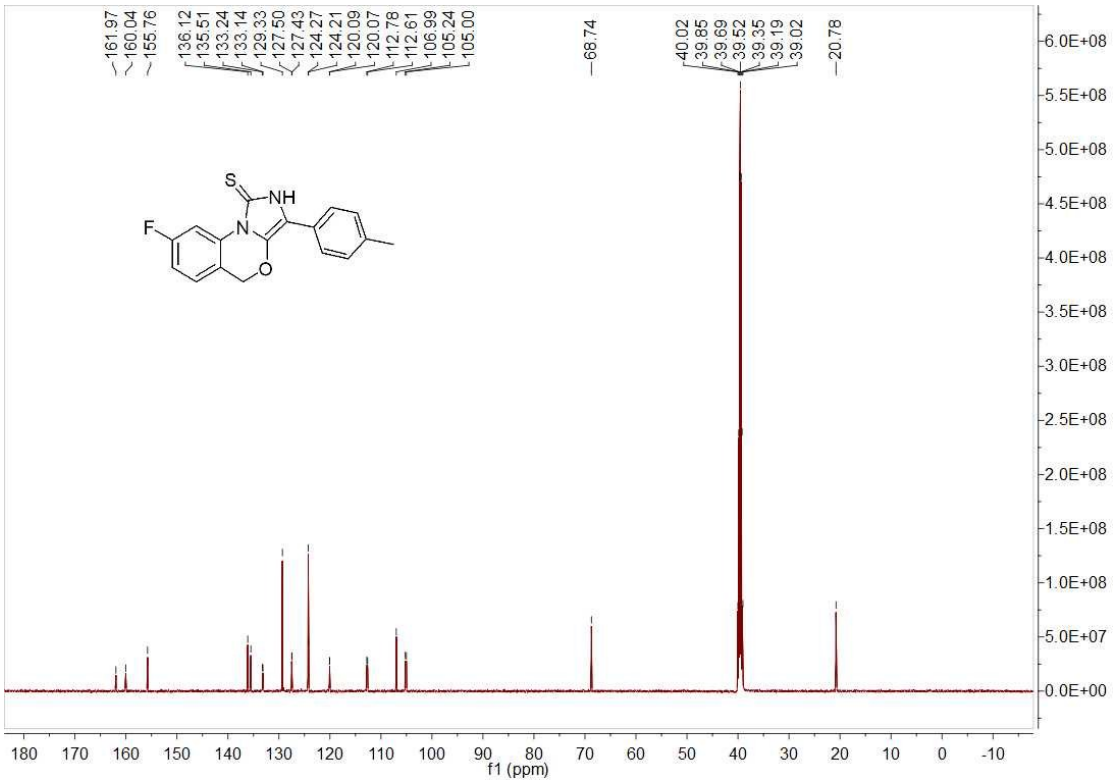

12.814
9.532
9.514
7.724
7.707
7.695
7.617
7.600
7.231
7.215
5.346
2.503
2.500
2.496
S
NH
N
O
Br
1.00
1.00
1.02
1.01
2.02
2.01
2.01
3.01
f1 (ppm)

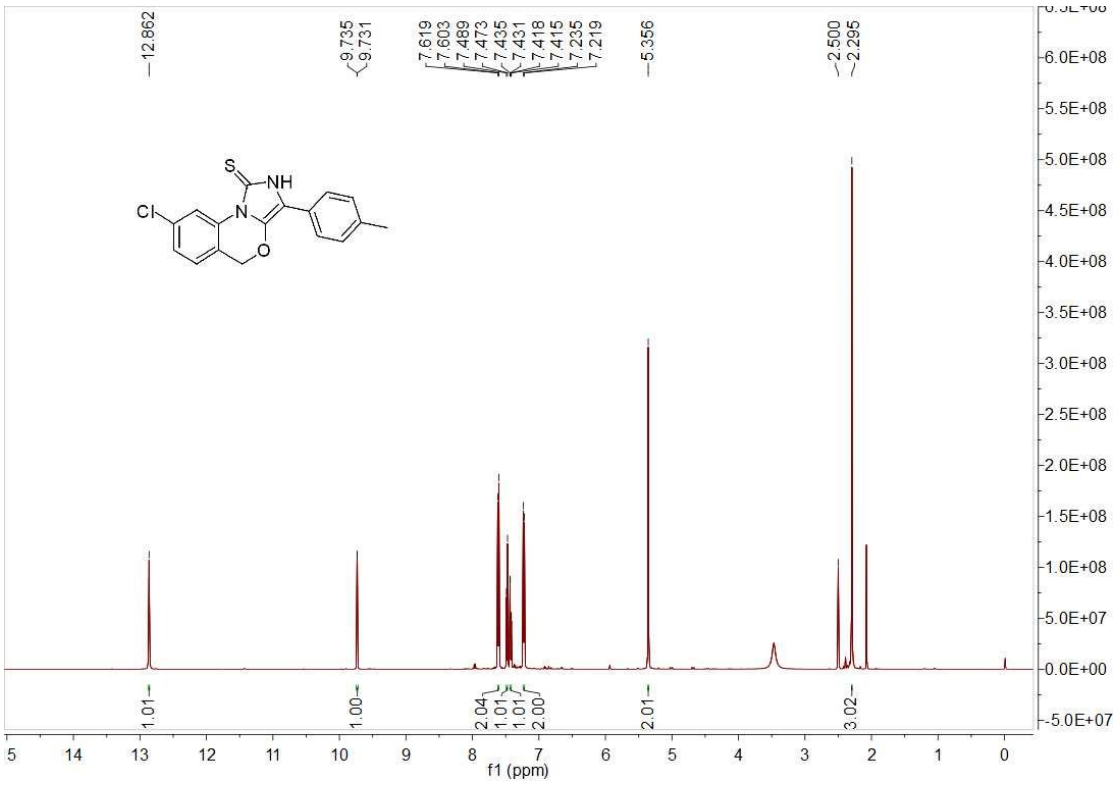

155.57
136.13
135.56
131.51
131.15
129.38
128.44
126.46
124.27
119.59
118.07
107.21
68.57
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.84
S
NH
N
O
Br
4.5E+08
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
-5.0E+07
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


12.683
9.405
7.623
7.607
7.229
7.213
7.072
5.278
3.804
3.796
2.500
2.296
S
NH
N
O
O
O
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
1.00
1.01
2.00
2.00
1.01
2.02
3.01
3.00
3.00
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


154.496
147.771
146.436
135.848
135.770
129.323
125.423
124.502
124.109
115.774
108.913
106.815
102.716
69.037
55.777
40.019
39.853
39.687
39.520
39.353
39.186
39.020
20.797
S
NH
N
O
O
O
f1 (ppm)


12.861
9.520
9.515
9.497
9.492
7.624
7.607
7.517
7.505
7.501
7.488
7.239
7.223
7.218
7.205
7.200
5.349
2.504
2.500
2.497
2.298
0.98
1.01
2.05
1.00
2.02
1.00
2.01
3.00
S
NH
F
N
O
f1 (ppm)


161.97
160.04
155.76
136.12
135.51
133.24
133.14
129.33
127.50
127.43
124.27
124.21
120.09
120.07
112.78
112.61
106.99
105.24
105.00
68.74
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.78
S
NH
F
N
O
f1 (ppm)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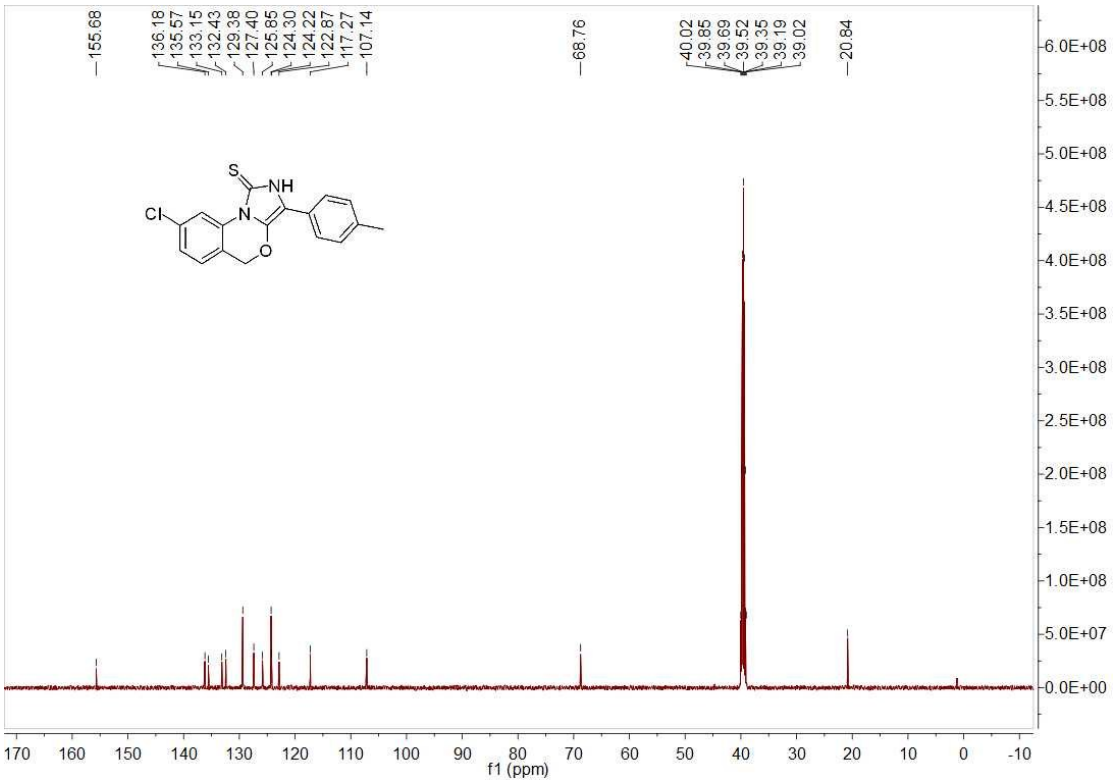
9.731
7.619
7.603
7.489
7.473
7.435
7.431
7.418
7.415
7.235
7.219
5.356
2.500
2.295
S
NH
Cl
N
O
1.01
1.00
2.04
1.01
1.01
2.00
2.01
3.02
f1 (ppm)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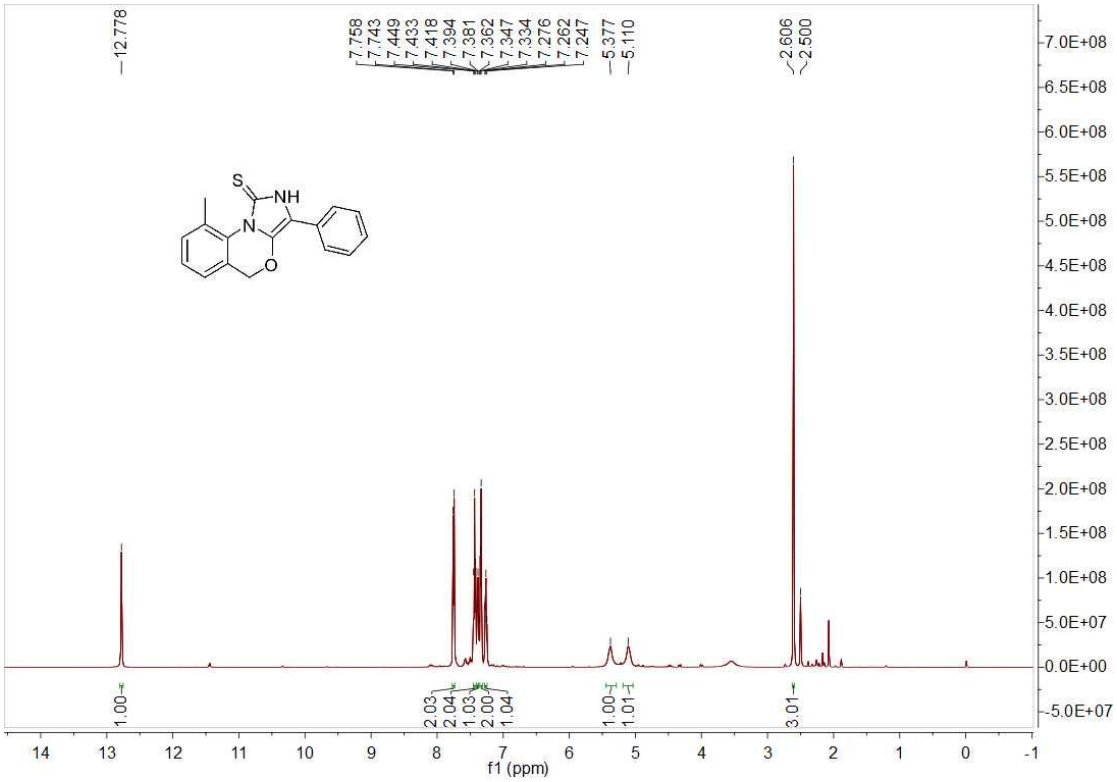
136.18
135.57
133.15
132.43
129.38
127.40
125.85
124.30
124.22
122.87
117.27
107.14
68.76
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.84
S
NH
N
O
Cl
f1 (ppm)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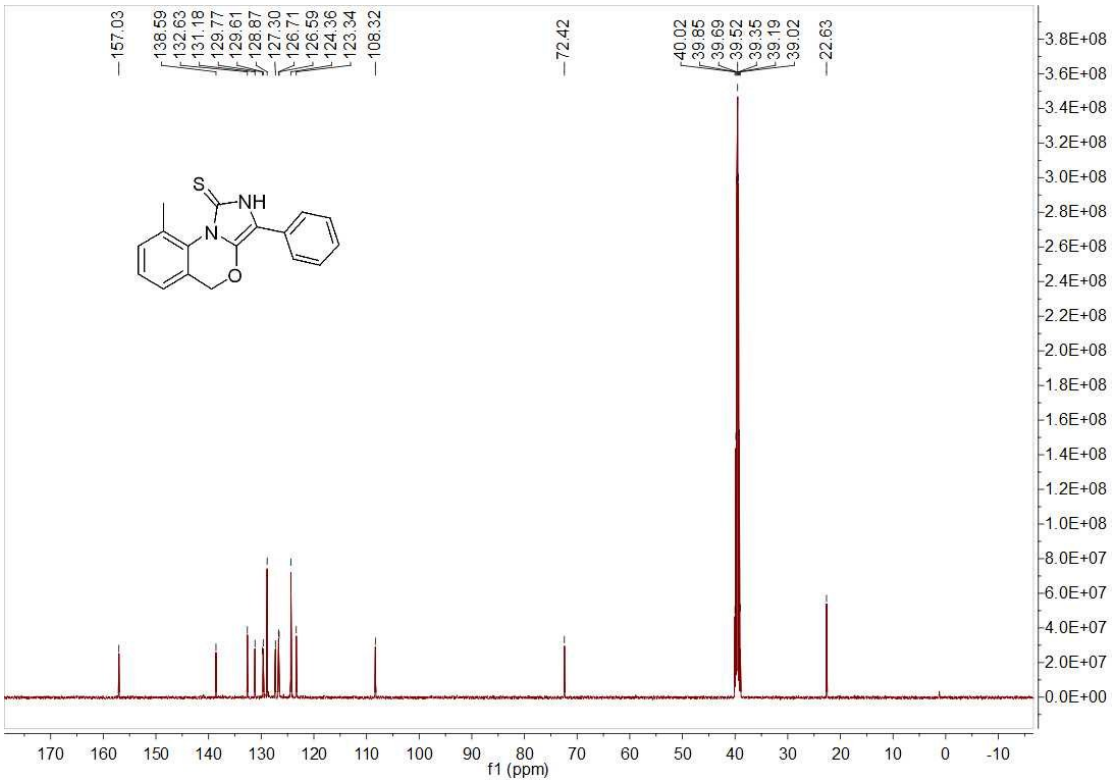
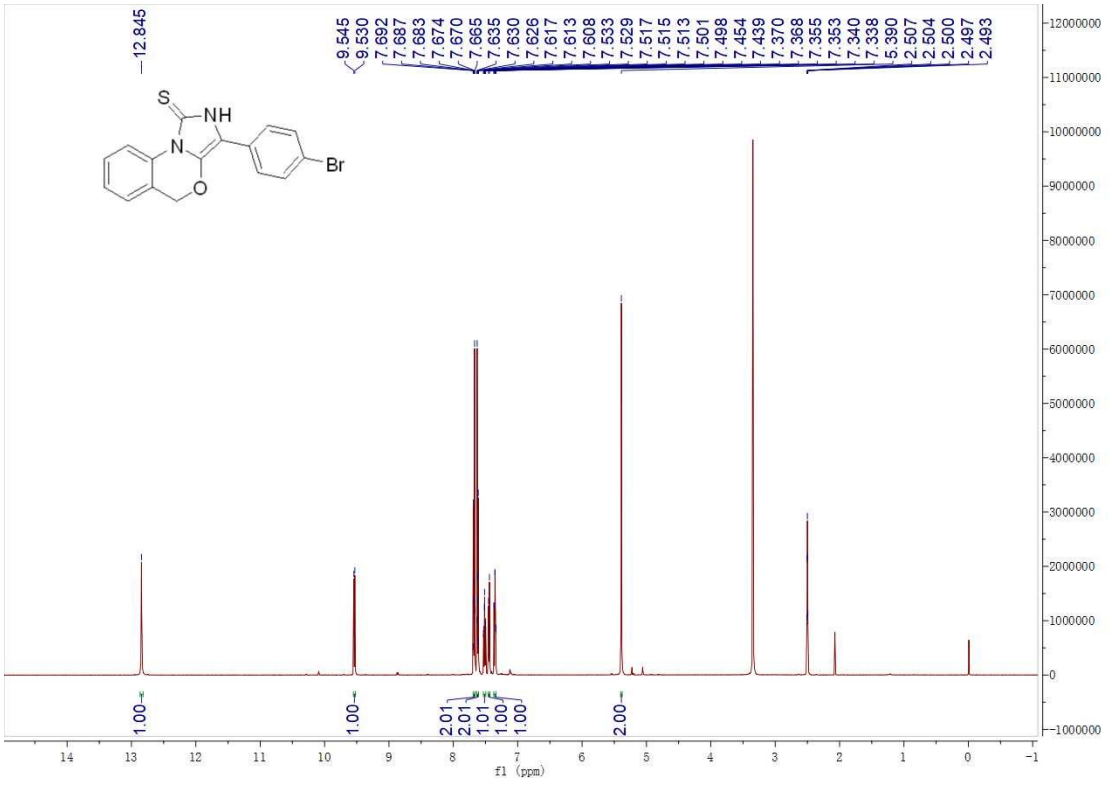
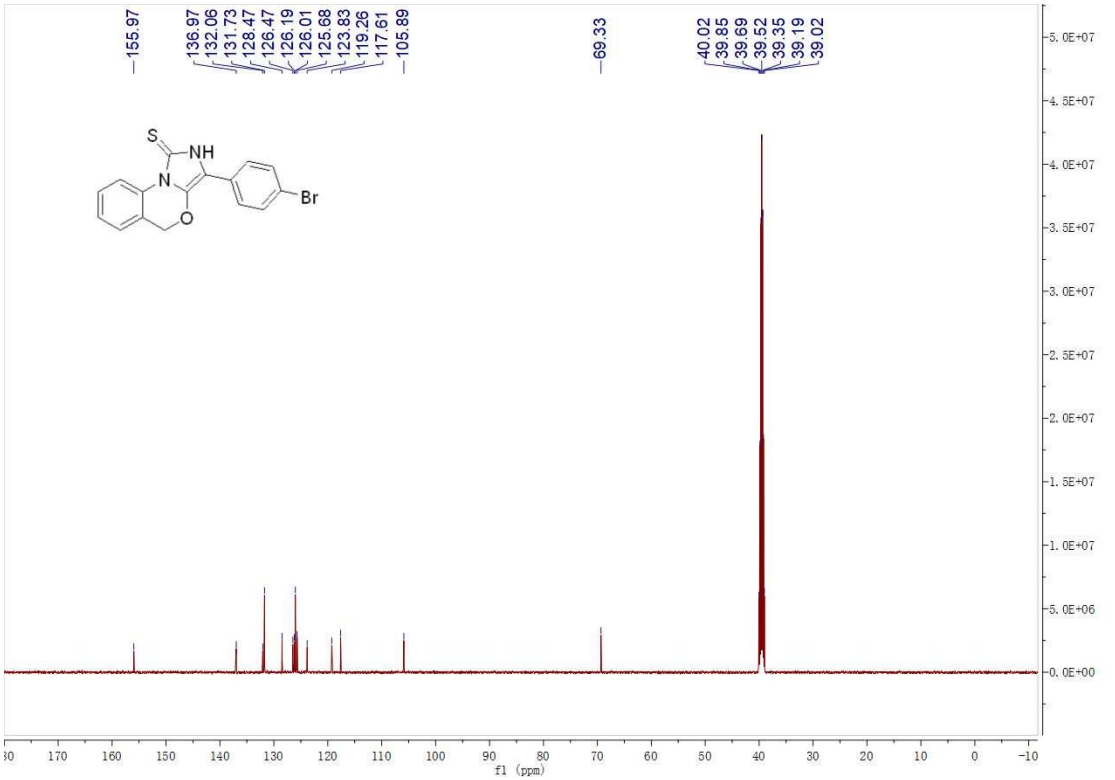
7.743
7.449
7.433
7.418
7.394
7.381
7.362
7.347
7.334
7.276
7.262
7.247
5.377
5.110
2.606
2.500
S
NH
N
O
1.00
2.03
2.04
1.03
2.00
1.04
1.00
1.01
3.01
f1 (ppm)


157.03
138.59
132.63
131.18
129.77
129.61
128.87
127.30
126.71
126.59
124.36
123.34
108.32
72.42
40.02
39.85
39.69
39.52
39.35
39.19
39.02
22.63
S
NH
N
O
f1 (ppm)


12.845
9.545
9.530
7.692
7.687
7.683
7.674
7.670
7.665
7.635
7.630
7.626
7.617
7.613
7.608
7.533
7.529
7.517
7.515
7.513
7.501
7.498
7.454
7.439
7.370
7.368
7.355
7.353
7.340
7.338
5.390
2.507
2.504
2.500
2.497
2.493
S
NH
N
O
Br
1.00
1.00
2.01
2.01
1.01
1.00
1.00
2.00
f1 (ppm)


155.97
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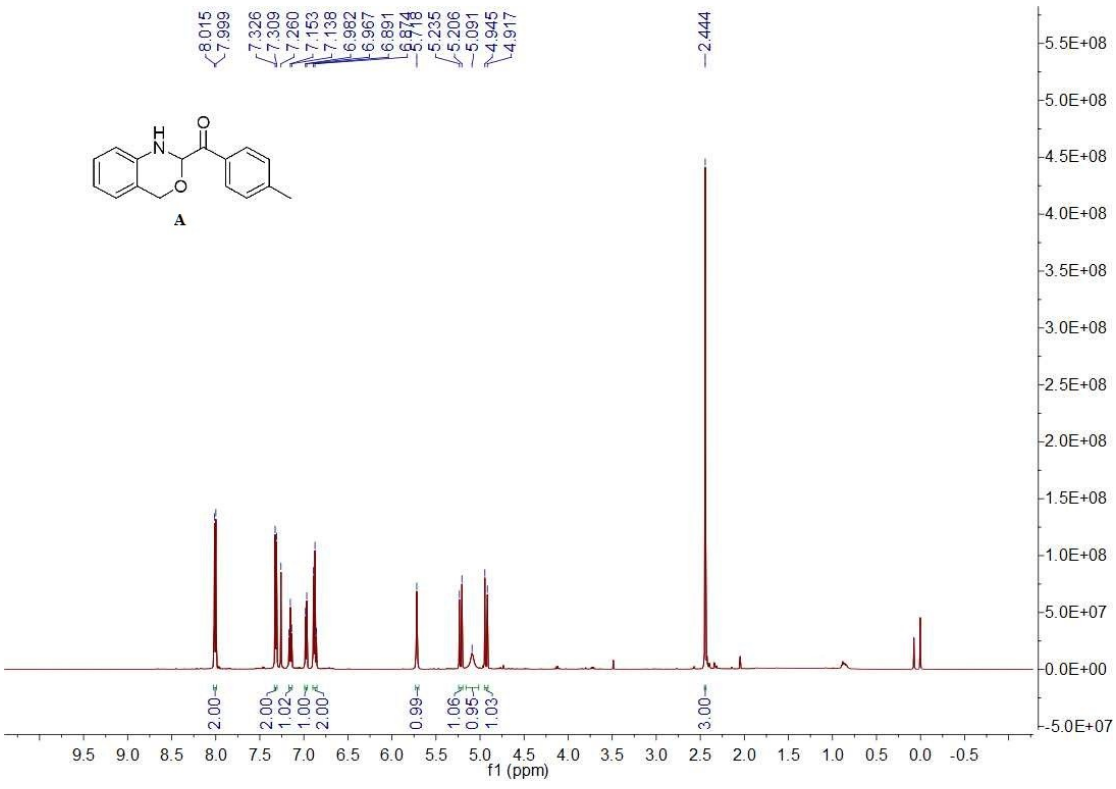
132.06
131.73
128.47
126.47
126.19
126.01
125.68
123.83
119.26
117.61
105.89
69.33
40.02
39.85
39.69
39.52
39.35
39.19
39.02
S
NH
N
O
Br
f1 (ppm)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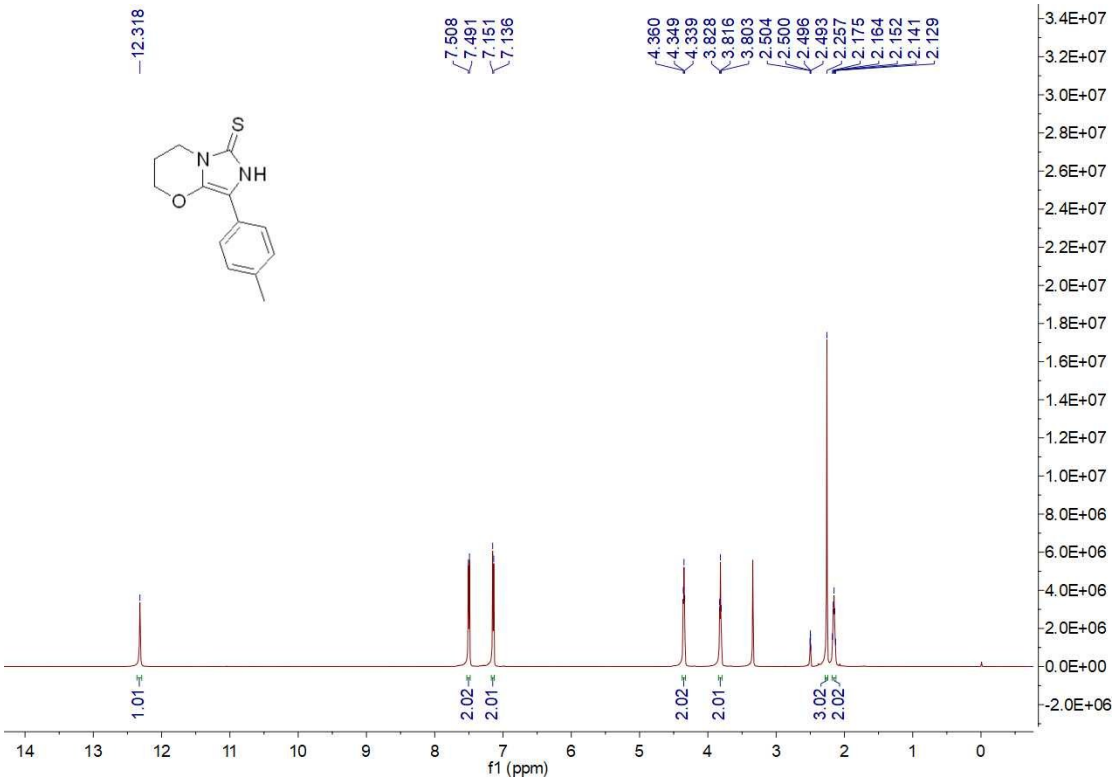
7.999
7.326
7.309
7.260
7.153
7.138
6.982
6.967
6.891
6.874
6.718
5.235
5.206
5.091
4.945
4.917
2.444
H
N
O
O
A
2.00
2.00
1.02
1.00
2.00
0.99
1.06
0.95
1.03
3.00
f1 (ppm)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7.151
7.136
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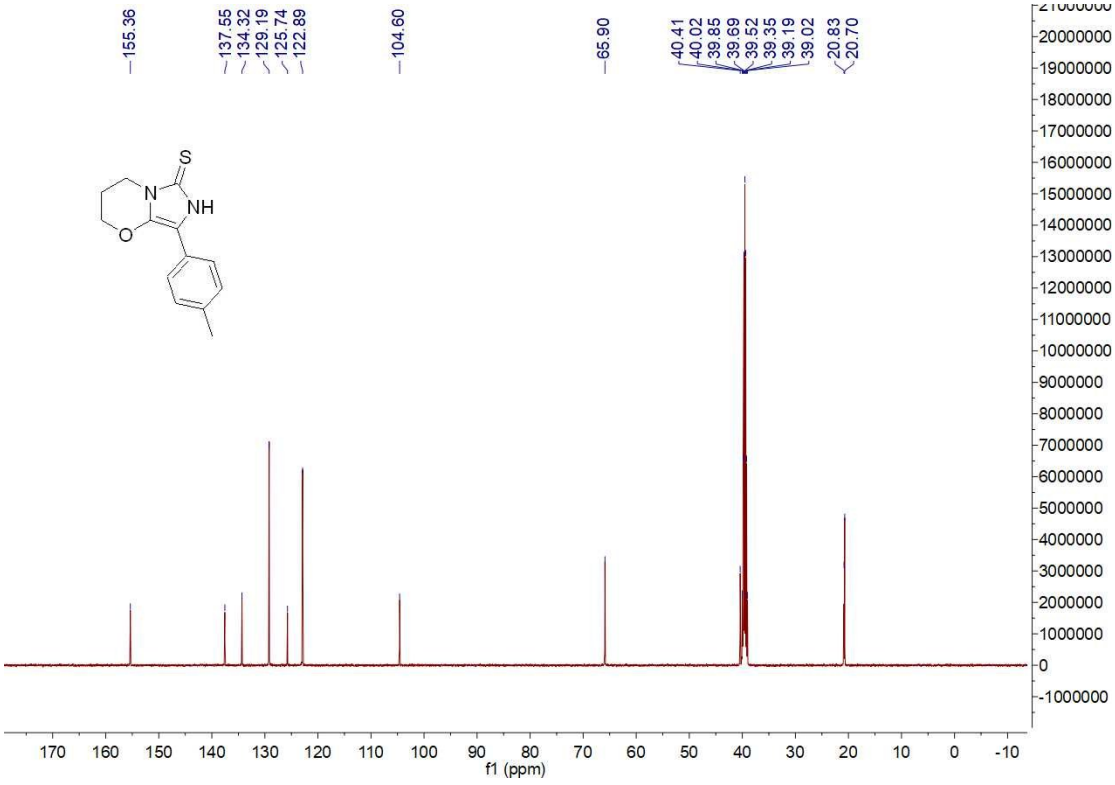
4.349
4.339
3.828
3.816
3.803
2.504
2.500
2.496
2.493
2.257
2.175
2.164
2.152
2.141
2.129
S
N
NH
O
1.01
2.02
2.01
2.02
2.01
3.02
2.02
f1 (ppm)


155.36
137.55
134.32
129.19
125.74
122.89
104.60
65.90
40.41
40.02
39.85
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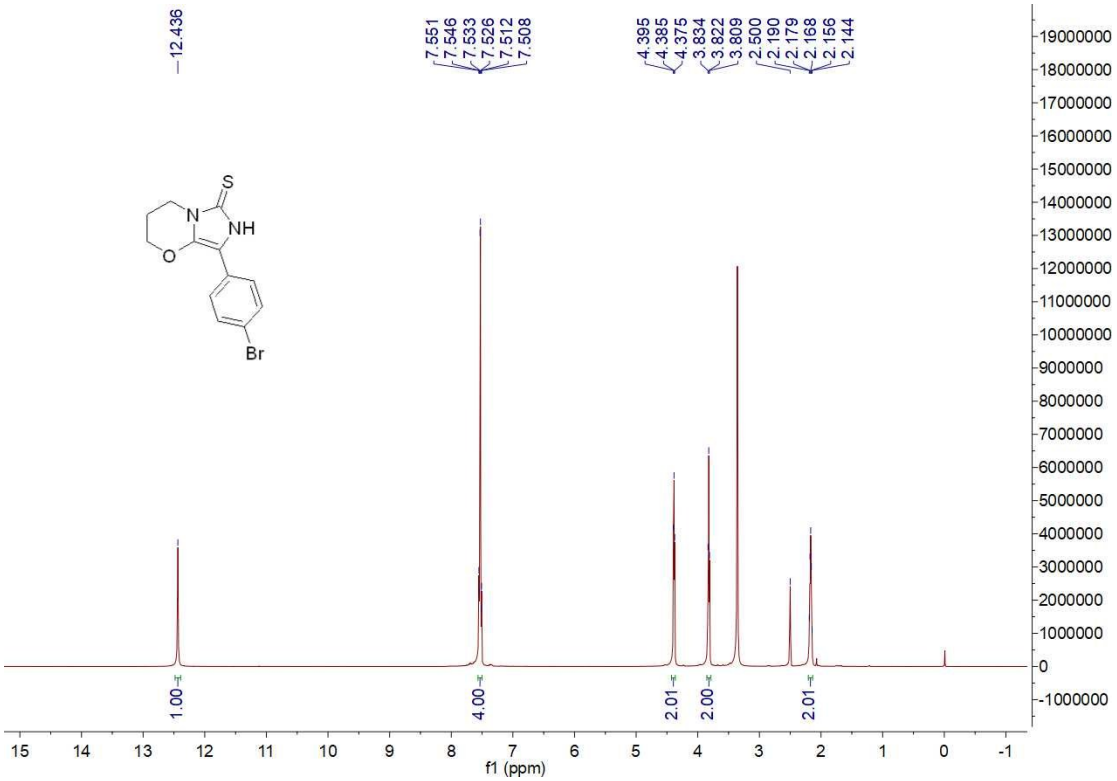
39.52
39.35
39.19
39.02
20.83
20.70
S
N
NH
O
f1 (ppm)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7.546
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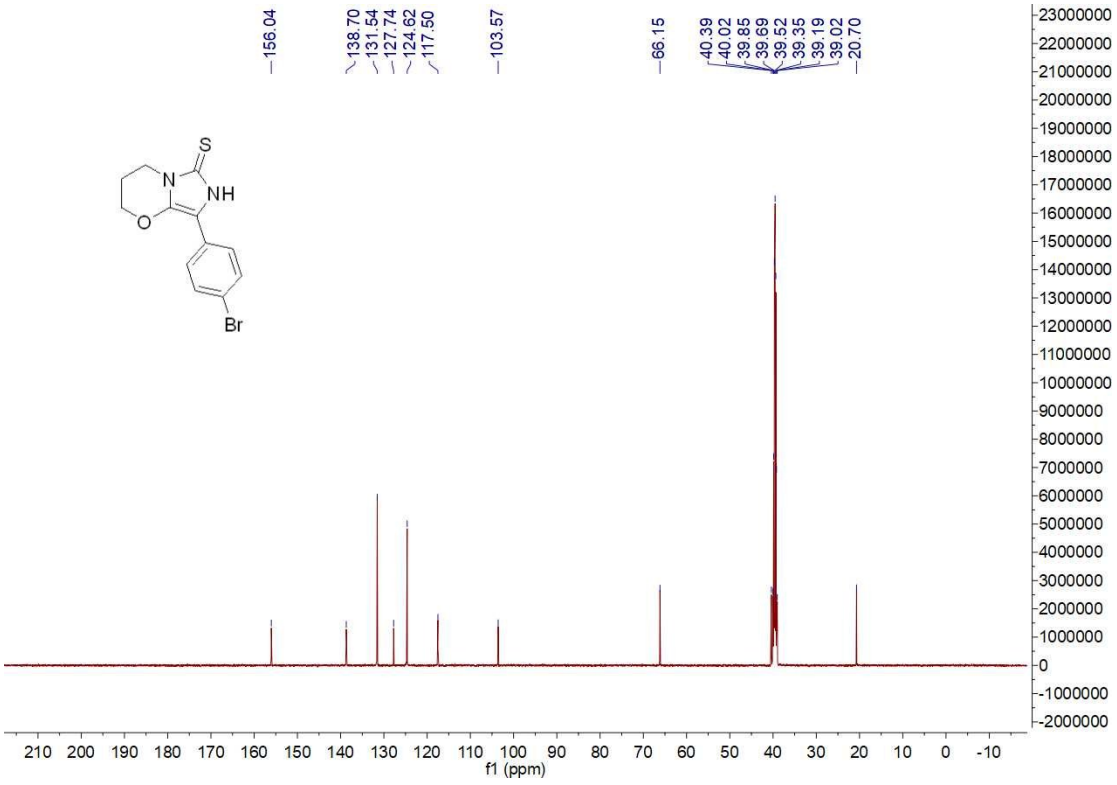
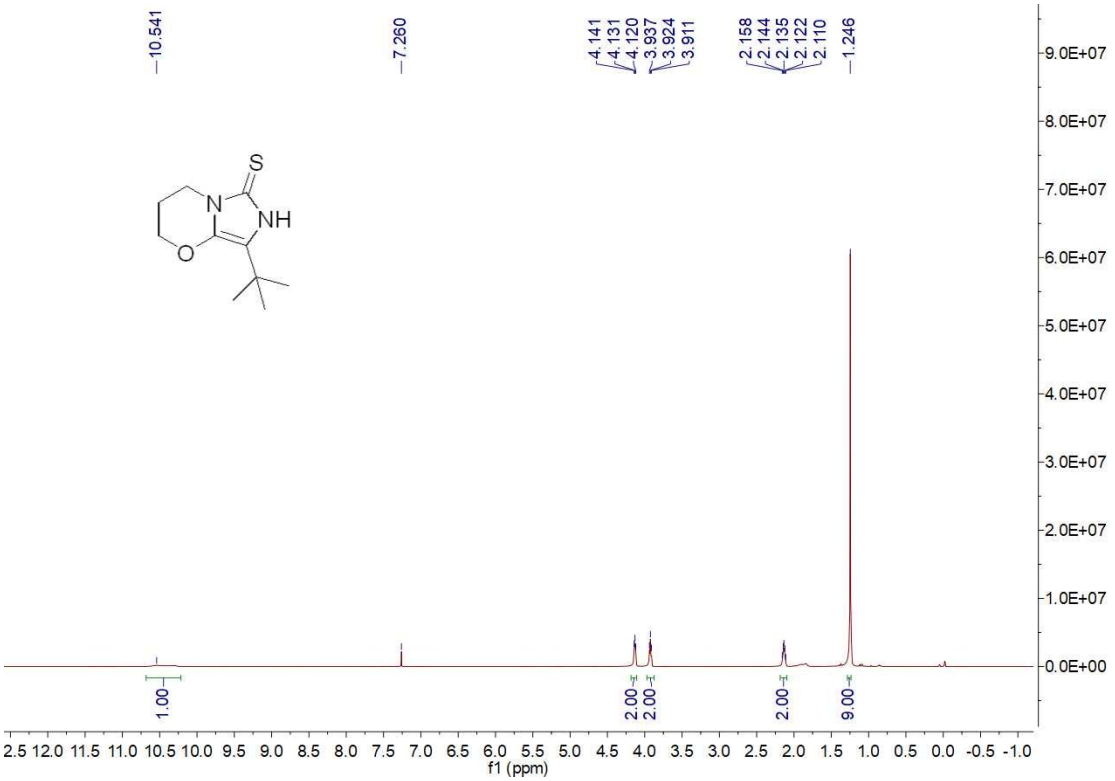
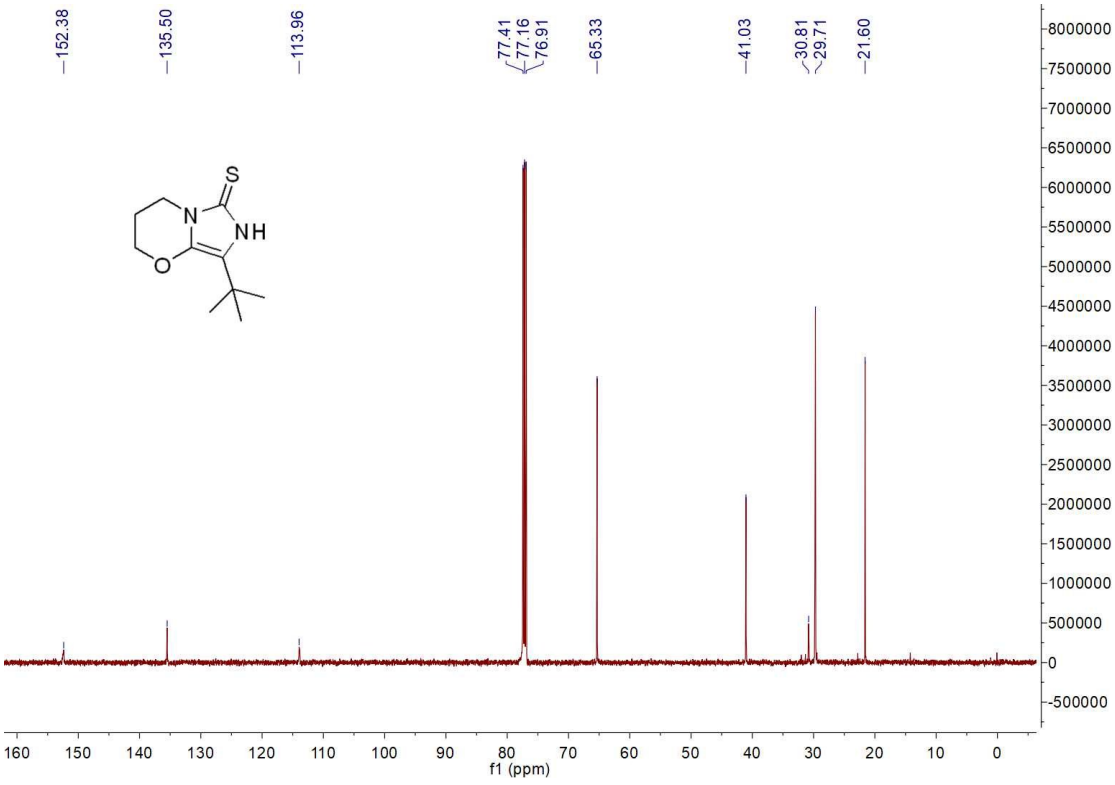
7.526
7.512
7.508
4.395
4.385
4.375
3.834
3.822
3.809
2.500
2.190
2.179
2.168
2.156
2.144
S
N
NH
O
Br
1.00
4.00
2.01
2.00
2.01
f1 (ppm)


156.04
138.70
131.54
127.74
124.62
117.50
103.57
66.15
40.39
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.70
S
N
NH
O
Br
f1 (ppm)


10.541
7.260
4.141
4.131
4.120
3.937
3.924
3.911
2.158
2.144
2.135
2.122
2.110
1.246
S
N
NH
O
1.00
2.00
2.00
2.00
9.00
f1 (ppm)


152.38
135.50
113.96
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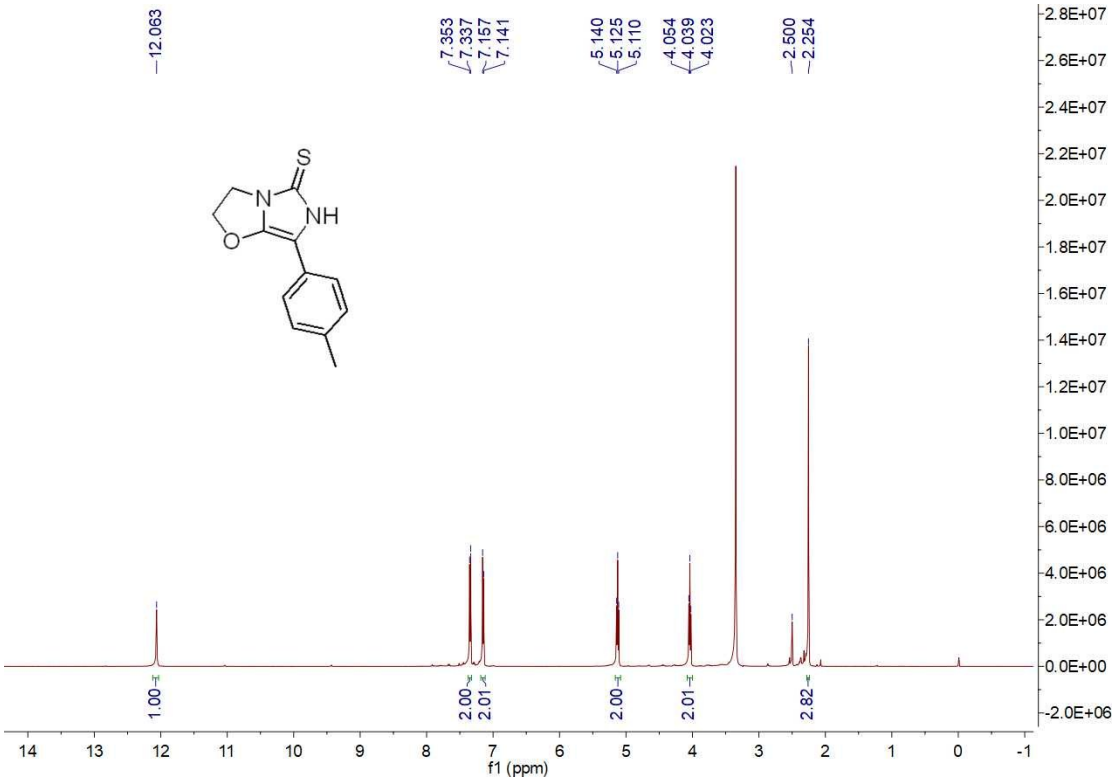
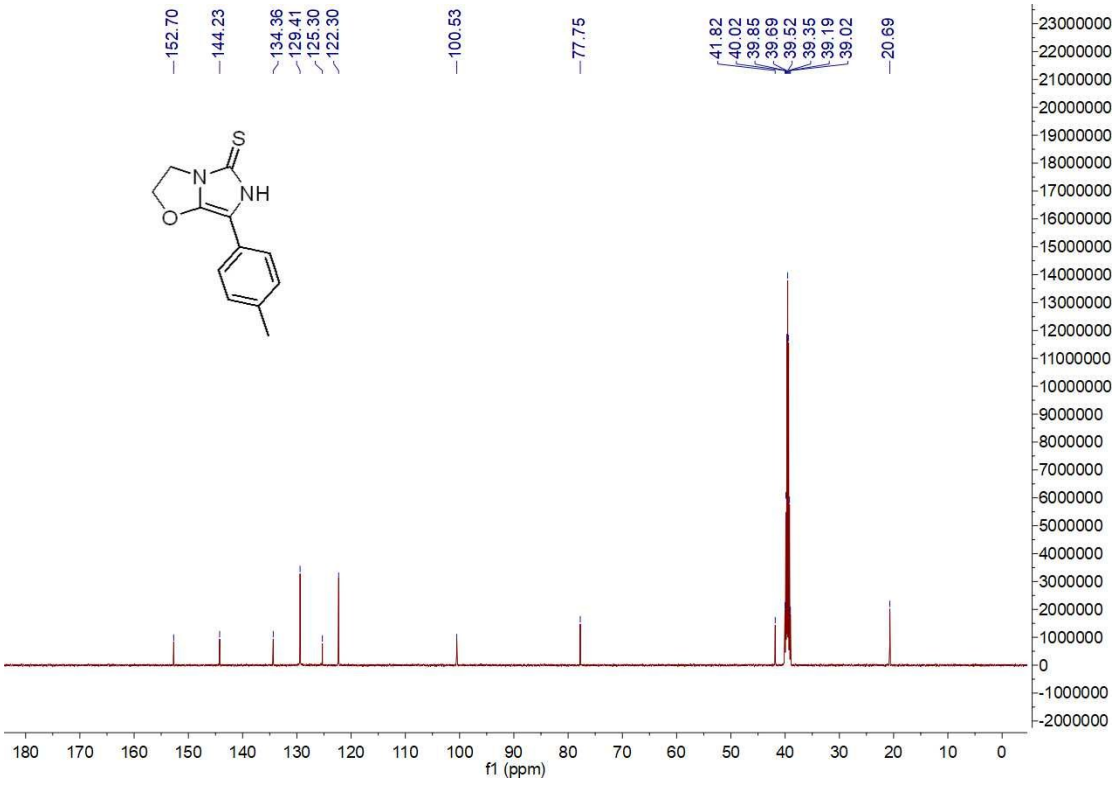
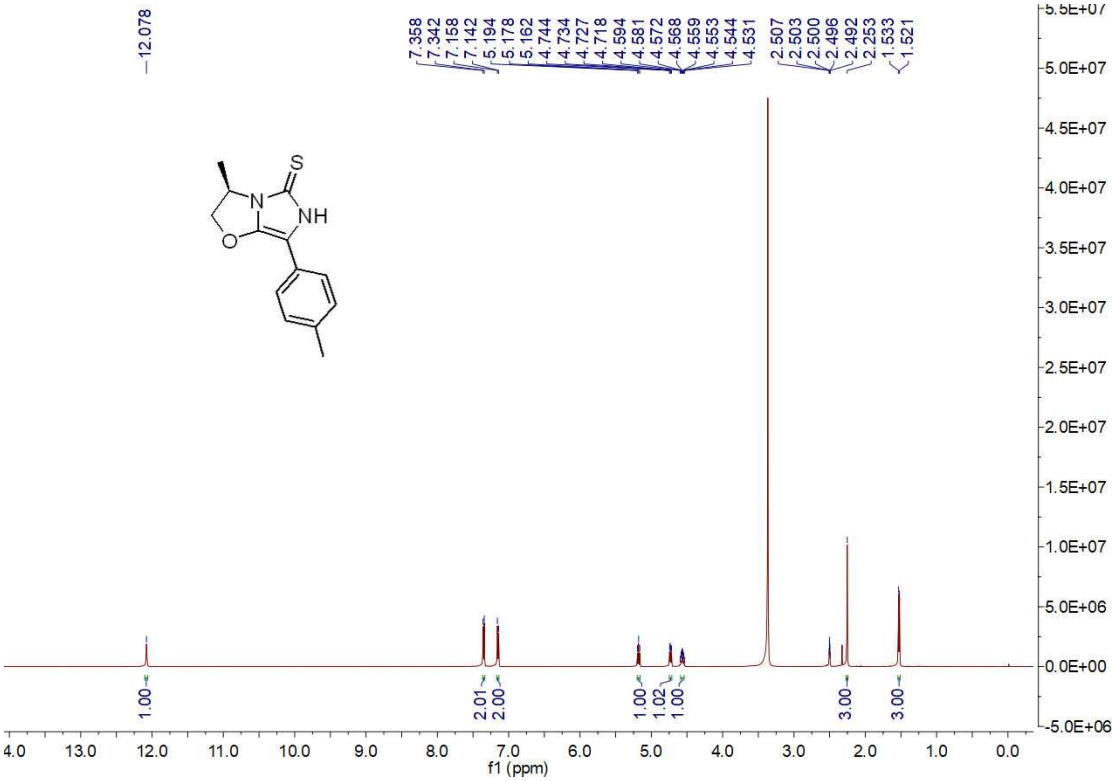
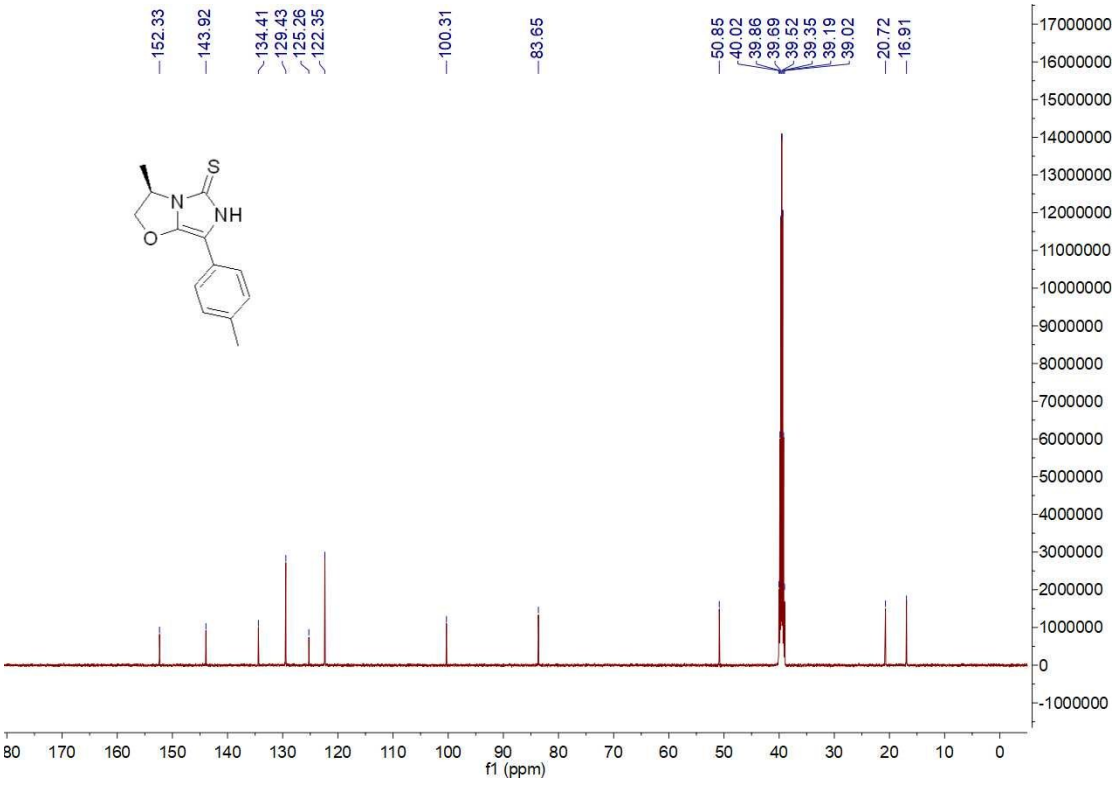
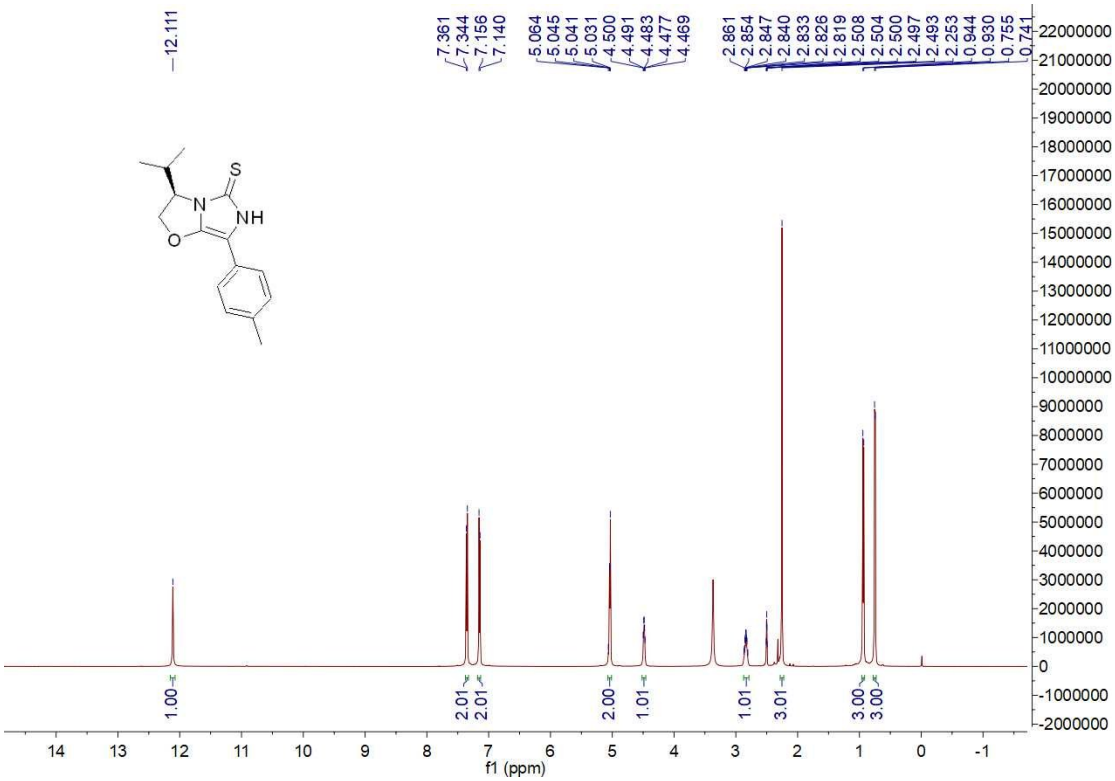
77.16
76.91
65.33
41.03
30.81
29.71
21.60
S
N
NH
O
f1 (ppm)

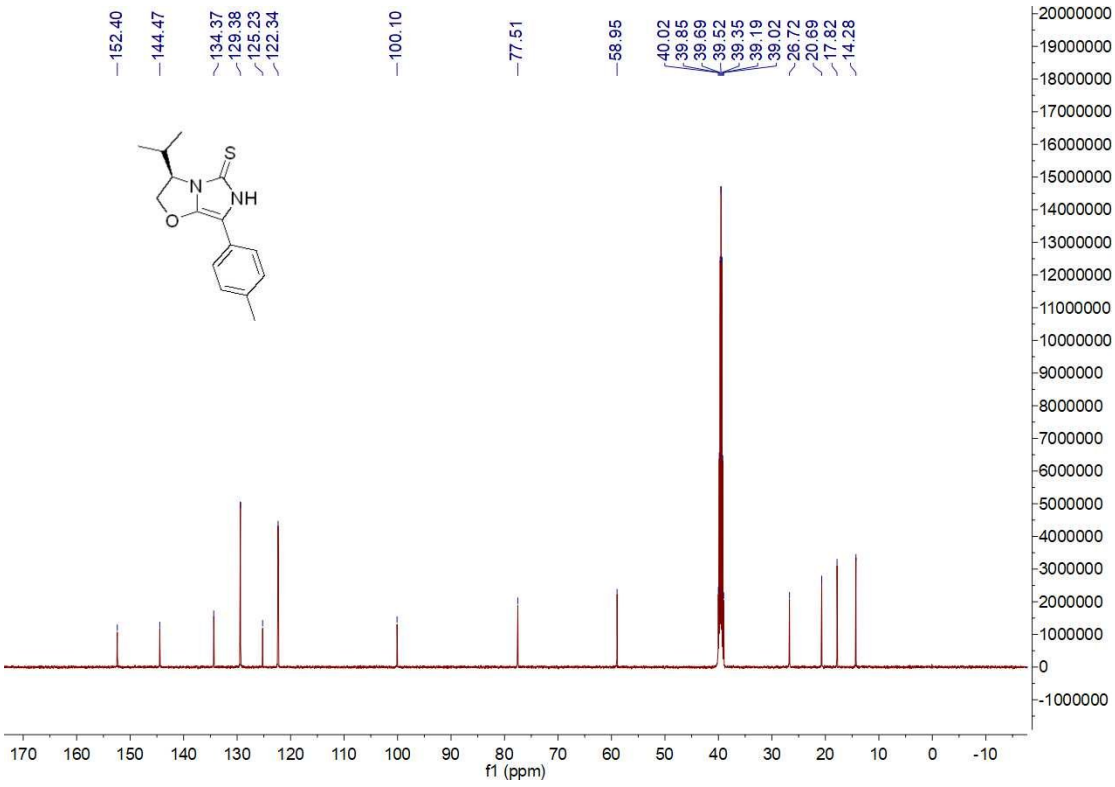

12.063
7.353
7.337
7.157
7.141
5.140
5.125
5.110
4.054
4.039
4.023
2.500
2.254
S
N
NH
O
1.00
2.00
2.01
2.00
2.01
2.82
f1 (ppm)

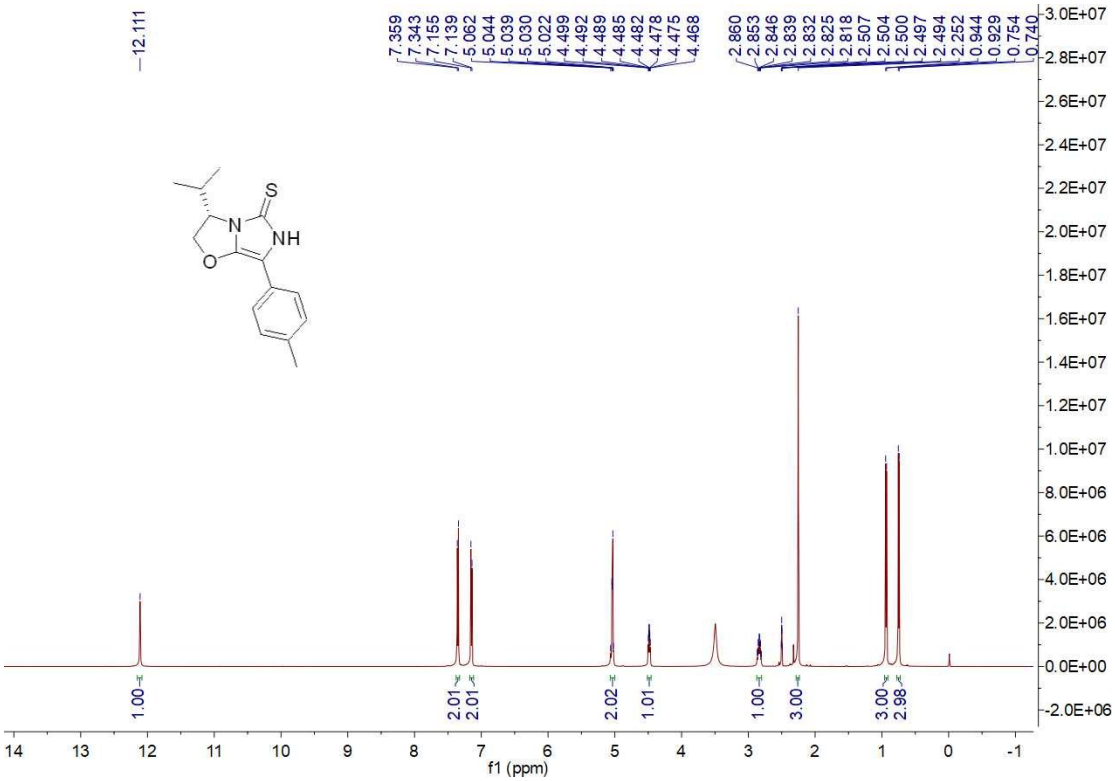

152.70
144.23
134.36
129.41
125.30
122.30
100.53
77.75
41.82
40.02
39.85
39.69
39.52
39.35
39.19
39.02
20.69
S
N
NH
O
f1 (ppm)


12.078
7.358
7.342
7.158
7.142
5.194
5.178
5.162
4.744
4.734
4.727
4.718
4.594
4.581
4.572
4.568
4.559
4.553
4.544
4.531
2.507
2.503
2.500
2.496
2.492
2.253
1.533
1.521
S
N
NH
O
1.00
2.01
2.00
1.00
1.02
1.00
3.00
3.00
f1 (ppm)


152.33
143.92
134.41
129.43
125.26
122.35
100.31
83.65
50.85
40.02
39.86
39.69
39.52
39.35
39.19
39.02
20.72
16.91
S
N
NH
O
f1 (ppm)


12.111
7.361
7.344
7.156
7.140
5.064
5.045
5.041
5.031
4.500
4.491
4.483
4.477
4.469
2.861
2.854
2.847
2.840
2.833
2.826
2.819
2.508
2.504
2.500
2.497
2.493
2.253
0.944
0.930
0.755
0.741
S
N
NH
O
1.00
2.01
2.01
2.00
1.01
1.01
3.01
3.00
3.00
f1 (ppm)


152.40
144.47
134.37
129.38
125.23
122.34
100.10
77.51
58.95
40.02
39.85
39.69
39.52
39.35
39.19
39.02
26.72
20.69
17.82
14.28
S
N
NH
O
f1 (ppm)


12.111
7.359
7.343
7.155
7.139
5.062
5.044
5.039
5.030
5.022
4.499
4.492
4.489
4.485
4.482
4.478
4.475
4.468
2.860
2.853
2.846
2.839
2.832
2.825
2.818
2.507
2.504
2.500
2.497
2.494
2.252
0.944
0.929
0.754
0.740
S
N
NH
O
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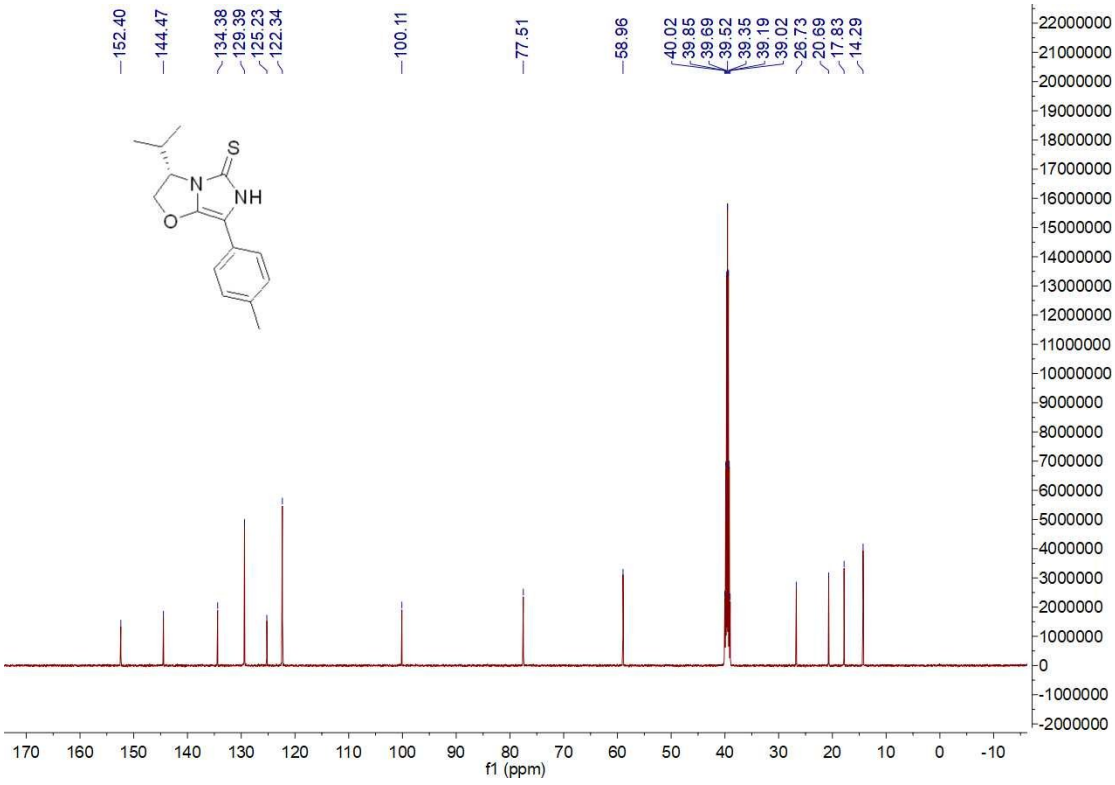
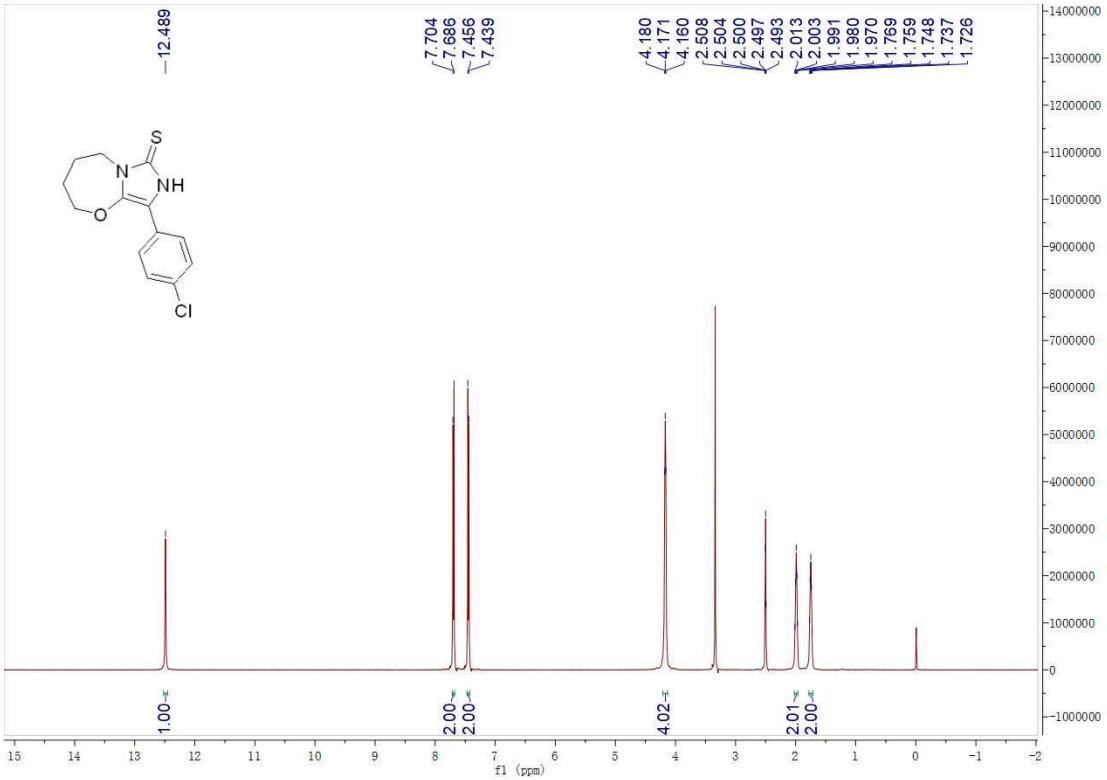
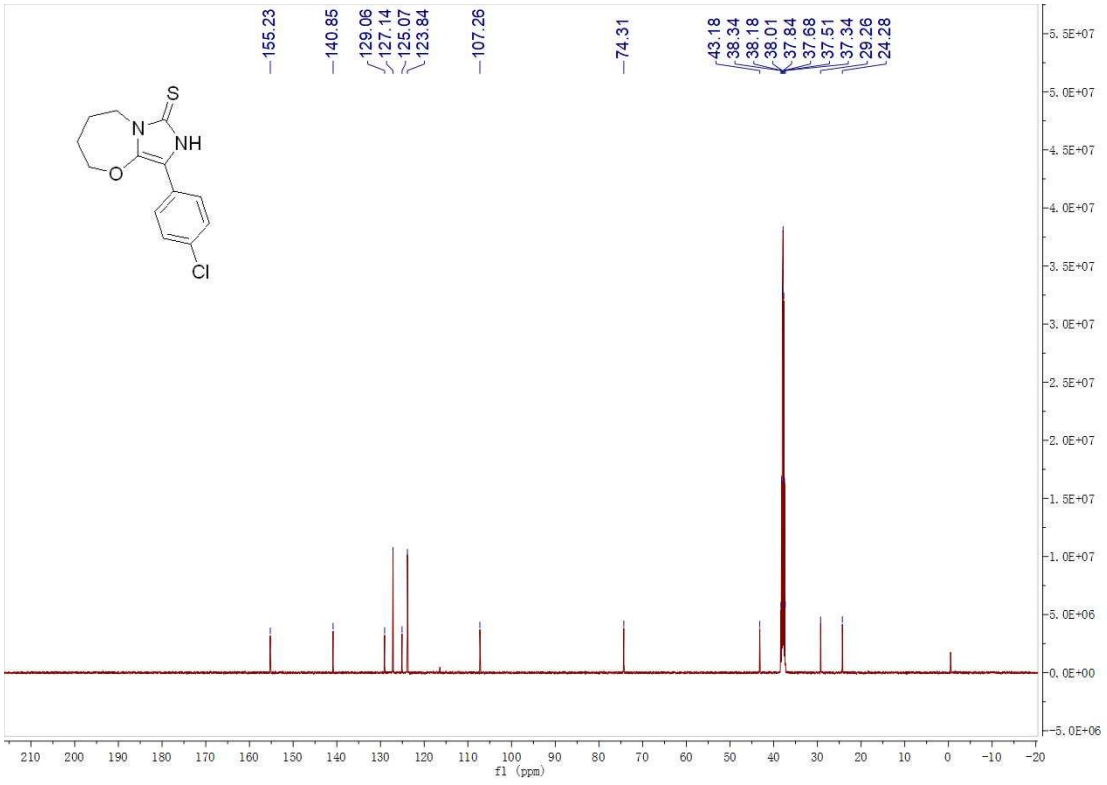
2.01
2.01
2.02
1.01
1.00
3.00
3.00
2.98
f1 (ppm)


152.40
144.47
134.38
129.39
125.23
122.34
100.11
77.51
58.96
40.02
39.85
39.69
39.52
39.35
39.19
39.02
26.73
20.69
17.83
14.29
S
N
NH
O
f1 (ppm)


12.489
7.704
7.686
7.456
7.439
4.180
4.171
4.160
2.508
2.504
2.500
2.497
2.493
2.013
2.003
1.991
1.980
1.970
1.769
1.759
1.748
1.737
1.726
S
N
NH
O
Cl
1.00
2.00
2.00
4.02
2.01
2.00
f1 (ppm)


155.23
140.85
129.06
127.14
125.07
123.84
107.26
74.31
43.18
38.34
38.18
38.01
37.84
37.68
37.51
37.34
29.26
24.28
S
N
NH
O
Cl
f1 (ppm)