# Substrate-dependent regiodivergence in [3+2] annulation reactions of 2-(phenacylethylidene)cyclobutanones with thioureas

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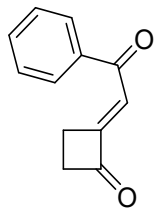
## General Methods

$^{1}H$ NMR spectra were recorded on a 600 MHz spectrometer at ambient temperature with $CDCl_3$ or DMSO-$d_6$ as solvent. Data are reported as follows: chemical shifts (δ), multiplicity, coupling constants and integration. $^{13}C$ NMR spectra were recorded on the same instrument at 151 MHz with $CDCl_3$ or DMSO-$d_6$ as solvent. $^{19}F$ NMR spectra was recorded on a 600 MHz spectrometer at 565 MHz. Routine infrared spectra were recorded on an FT-IR spectrophotometer in ATP mode; samples were neat (for liquids) or nujol mulls (for solids). High resolution mass spectrometry (HRMS) was performed using electrospray ionization (ESI) and a Q-TOF mass analyzer. Analytical thin layer chromatography was performed using 0.25 mm silica gel 60–F plates. Flash chromatography was performed using columns of 230–400 mesh silica gel 60 (0.040–0.063 mm).

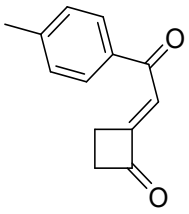
## General procedure for the preparation of 3a-l

A solution of **1** (0.1 g, 1.12 mmol) and phosphonium ylide **2** (1.12 mmol) in $CH_2Cl_2$ (5 mL) was stirred at reflux for 1 h. After the mixture was cooled to 0 °C, Dess-Martin periodinane (0.474 g, 1.12 mmol) was added and the reaction mixture was stirred at 0 °C for 2 h. The precipitate was filtered then the mixture was quenched with sat. aq. $NaHCO_3$ solution and extracted twice with $CH_2Cl_2$. The combined organic layers were dried over $Na_2SO_4$, filtered, and concentrated under reduced pressure. The crude residue was purified by flash column chromatography (eluent: petroleum ether/ether = 10:1→1:1) to give compound **3**. Yields refer to chromatographically purified materials.

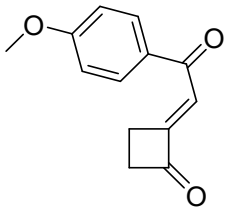



(**3a**) Yield 38% (79 mg); yellow solid; m. p. = 90 °C. IR (ATR) ν 2929, 2591, 2360, 2314, 2075, 1986, 1754, 1655, 1586, 1486, 1442, 1385, 1323, 1225, 1178, 1084, 870 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 7.97 – 7.96 (m, 2H), 7.62 – 7.59 (m, 1H), 7.52 – 7.49 (m, 2H), 7.29 – 7.28 (m, 1H), 3.23 – 3.20 (m, 2H), 3.18 – 3.13 (m, 2H). $^{13}C$ NMR

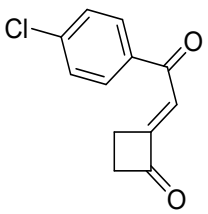
(151 MHz, $CDCl_3$) δ 200.2, 190.7, 161.5, 137.8, 133.8, 129.0, 128.5, 116.0, 46.9, 25.0. HRMS (ESI) Calcd. for $C_{12}H_{11}O_2$ ($M+H^+$) *m/z* 187.0754, found 187.0756.



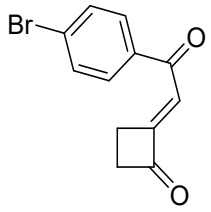
(**3b**) Yield 55% (123 mg); yellow solid; m. p. = 71–73 °C. IR (ATR) ν 2924, 2860, 2596, 2359, 2302, 2187, 1926, 1664, 1601, 1571, 1474, 1409, 1339, 1297, 1233, 1175, 1090, 1009, 913, 870 $cm^{-1}$. $^1H$ NMR (600 MHz, $CDCl_3$) δ 7.78 (d, *J* = 8.1 Hz, 2H), 7.20 (d, *J* = 8.1 Hz, 2H), 7.19 – 7.17 (m, 1H), 3.13 – 3.09 (m, 2H), 3.06 – 3.03 (m, 2H), 2.34 (s, 3H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 200.3, 190.1, 161.1, 144.8, 135.3, 129.6, 116.1, 46.7, 24.9, 21.7. HRMS (ESI) Calcd. for $C_{13}H_{13}O_2$ ($M+H^+$) *m/z* 201.0910, found 201.0913.



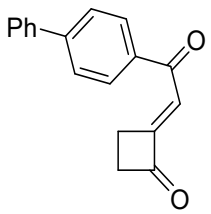
(**3c**) Yield 43% (104 mg); pale yellow solid; m. p. = 105 °C. IR (ATR) ν 2970, 1743, 1664, 1580, 1463, 1371, 1267, 1180, 1161, 1118, 1096, 1042, 999, 947 $cm^{-1}$. $^1H$ NMR (600 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.9 Hz, 2H), 7.24 (t, *J* = 2.9 Hz, 1H), 6.95 (d, *J* = 8.9 Hz, 2H), 3.87 (s, 3H), 3.19 – 3.16 (m, 2H), 3.14 – 3.10 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 200.4, 188.9, 164.1, 160.7, 131.0, 130.9, 114.2, 55.6, 46.8, 24.9. HRMS (ESI) Calcd. for $C_{13}H_{13}O_3$ ($M+H^+$) *m/z* 217.0859, found 217.0865.



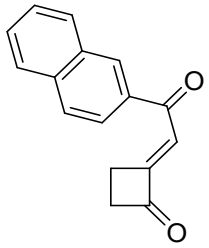
(**3d**) Yield 42% (103 mg); yellow solid; m. p. = 111–113 °C. IR (ATR) ν 2957, 1751, 1666, 1648, 1582, 1463, 1428, 1371, 1267, 1160, 1157, 1109, 1085, 1042, 999, 947, 689 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 7.91 – 7.89 (m, 2H), 7.50 – 7.46 (m, 2H), 7.23 – 7.22 (m, 1H), 3.24 – 3.20 (m, 2H), 3.16 – 3.12 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 200.0, 189.4, 162.1, 140.4, 136.1, 129.9, 115.4, 47.0, 25.1. HRMS (ESI) Calcd. for $C_{12}H_{10}ClO_2$ ($M+H^+$) *m/z* 221.0364, found 221.0360.



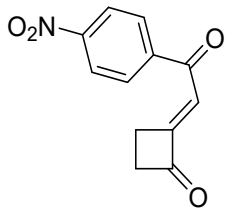

(**3e**) Yield 31% (91 mg); yellow solid; m. p. = 151 °C. IR (ATR) ν 2935, 1748, 1666, 1618, 1572, 1484, 1389, 1344, 1229, 1175, 1096, 997, 875, 825 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 7.81 (d, *J* = 8.2 Hz, 2H), 7.63 (d, *J* = 8.4 Hz, 2H), 7.21 (t, *J* = 3.0 Hz, 1H), 3.23 – 3.19 (m, 2H), 3.15 – 3.11 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 200.0, 189.5, 162.2, 136.5, 132.3, 129.9, 129.1, 115.3, 47.0, 25.1. HRMS (ESI) Calcd. for $C_{12}H_{10}BrO_2$ ($M+H^+$) *m/z* 264.9859, found 264.9862.



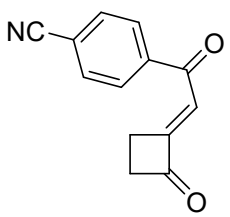

(**3f**) Yield 27% (79 mg); yellow solid; m. p. = 159–161 °C. IR (ATR) ν 2990, 1751, 1665, 1623, 1591, 1402, 1350, 1317, 1237, 1203, 1095, 1006, 914, 878 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 8.03 (d, *J* = 8.2 Hz, 2H), 7.72 (d, *J* = 8.1 Hz, 2H), 7.64 – 7.63 (m, 2H), 7.48 – 7.46 (m, 2H), 7.42 – 7.40 (m, 1H), 7.32 – 7.31 (m, 1H), 3.23 – 3.20 (m, 2H), 3.18 – 3.14 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 161.5, 146.4, 139.6, 136.5, 129.16, 129.10, 128.5, 127.5, 127.3, 116.0, 46.9, 25.0. HRMS (ESI) Calcd. for $C_{18}H_{15}O_2$ ($M+H^+$) *m/z* 263.1067, found 263.1072.



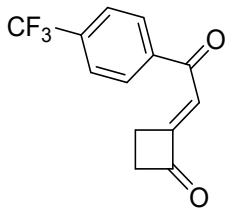
(**3g**) Yield 50% (132 mg); yellow solid; m. p. = 134–136 °C. IR (ATR) ν 2975, 1733, 1656, 1623, 1598, 1425, 1321, 1267, 1180, 1118, 1096, 999, 947 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 8.45 (s, 1H), 8.02 – 8.00 (m, 1H), 7.95 – 7.94 (m, 1H), 7.90 – 7.89 (m, 1H), 7.87 – 7.85 (m, 1H), 7.62 – 7.59 (m, 1H), 7.57 – 7.54 (m, 1H), 7.42 – 7.41 (m, 1H), 3.23 – 3.20 (m, 2H), 3.17 – 3.14 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 200.3, 190.3, 161.4, 135.8, 135.1, 132.5, 130.6, 129.8, 129.0, 128.9, 127.9, 127.1, 123.7, 116.0, 46.9, 25.0. HRMS (ESI) Calcd. for $C_{16}H_{13}O_2$ ($M+H^+$) *m/z* 237.0910, found 237.0925.



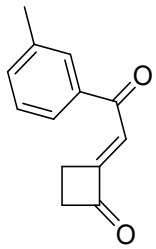
(**3h**) Yield 42% (108 mg); yellow solid; m. p. = 134–136 °C. IR (ATR) ν 2964, 1751, 1706, 1672, 1597, 1515, 1465, 1426, 1397, 1334, 1218, 1101, 1015, 957, 848 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 8.28 (d, *J* = 8.7 Hz, 2H), 8.05 (d, *J* = 8.8 Hz, 2H), 7.20 – 7.19 (m, 1H), 3.21 – 3.18 (m, 2H), 3.13 – 3.09 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 199.5, 189.1, 163.6, 150.6, 142.0, 129.5, 124.2, 114.8, 47.1, 25.4. HRMS (ESI) Calcd. for $C_{12}H_{10}NO_4$ ($M+H^+$) *m/z* 232.0604, found 232.0607.



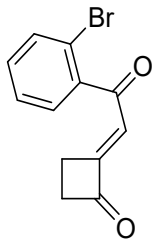
(**3i**) Yield 33% (78 mg); pale orange solid; m. p. = 128 °C. IR (ATR) ν 2969, 2233, 1753, 1724, 1675, 1626, 1565, 1531, 1463, 1398, 1349, 1231, 1093, 1048, 891 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 8.03 (d, *J* = 8.2 Hz, 2H), 7.80 (d, *J* = 8.2 Hz, 2H), 7.23 – 7.22 (m, 1H), 3.25 – 3.22 (m, 2H), 3.16 – 3.12 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 199.6, 189.2, 163.3, 140.5, 132.8, 128.8, 117.8, 116.8, 114.7, 47.0, 25.3. HRMS (ESI) Calcd. for $C_{13}H_{10}NO_2$ ($M+H^+$) *m/z* 212.0706, found 212.0692.




(**3j**) Yield 35% (99 mg); yellowish solid; m. p. = 134°C. IR (ATR) ν 2929, 1754, 1655, 1586, 1486, 1442, 1385, 1323, 1225, 1178, 1084, 1004, 870, 774 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.1 Hz, 2H), 7.76 (d, *J* = 8.0 Hz, 2H), 7.26 – 7.25 (m, 1H), 3.25 – 3.22 (m, 2H), 3.18 – 3.13 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 199.8, 189.6, 162.9, 140.3, 134.9 (q, *J* = 32.9 Hz), 128.8, 126.0 (q, *J* = 3.9 Hz), 123.5 (q, *J* = 273.1 Hz), 115.1, 47.0, 25.3. HRMS (ESI) Calcd. for $C_{13}H_{10}F_3O_2$ ($M+H^+$) *m/z* 255.0627, found 255.0624.



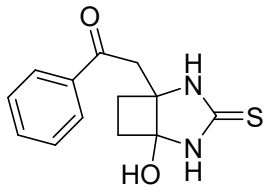

(**3k**) Yield 35% (78 mg); yellow solid; m. p. = 84–85 °C. IR (ATR) ν 2918, 1748, 1664, 1614, 1576, 1445, 1426, 1356, 1306, 1248, 1187, 1094, 1015, 933, 730 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 7.69 – 7.67 (m, 2H), 7.34 – 7.29 (m, 2H), 7.20 – 7.19 (m, 1H), 3.14 – 3.11 (m, 2H), 3.07 – 3.04 (m, 2H), 2.34 (s, 3H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 200.3, 190.7, 161.2, 138.8, 137.8, 134.5, 129.0, 128.8, 125.7, 116.2, 46.8, 24.9, 21.4. HRMS (ESI) Calcd. for $C_{13}H_{13}O_2$ ($M+H^+$) *m/z* 201.0910, found 201.0912.



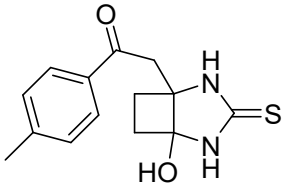

(**3l**) Yield 31% (91 mg); yellow solid; m. p. = 143 °C. IR (ATR) ν 2929, 1986, 1732, 1695, 1589, 1476, 1432, 1365, 1322, 1221, 1172, 1084, 870, 771 $cm^{-1}$.$^1$H NMR (600 MHz, $CDCl_3$) δ 7.64 – 7.63 (m, 1H), 7.45 – 7.40 (m, 2H), 7.37 – 7.34 (m, 1H), 6.91 – 6.90 (m, 1H), 3.18 – 3.15 (m, 2H), 2.92 – 2.88 (m, 2H). $^{13}$C NMR (151 MHz, $CDCl_3$) δ 199.7, 193.7, 160.9, 141.0, 133.8, 132.5, 129.4, 127.9, 119.5, 119.3, 46.8, 24.8. HRMS (ESI) Calcd. for $C_{12}H_{10}BrO_2$ ($M+H^+$) *m/z* 264.9859, found 264.9866.

**General procedure for the preparation of 5a-q and 6a-e**

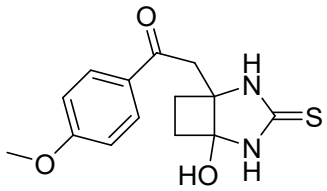
A solution of **3** (0.215 mmol) and **4** (0.215 mmol) in EtOAc (2 mL) was stirred in a sealed tube reactor at reflux for 8 h. The crude mixture, without aqueous work-up, was directly purified by flash column chromatography ($SiO_2$, petroleum ether/ether = 5:1→1:1) to give compound **5** or **6**.



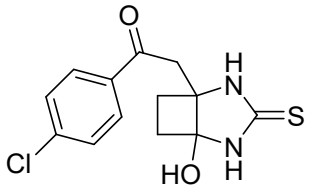

(**5a**) The reaction was conducted with 0.108 mmol of **3a** and **4a** in 1 mL of EtOAc (see Table 1, entry 2). Yield 89% (25 mg); white solid; m. p. = 110 °C. IR (ATR) ν 3679, 3436, 3204, 1740, 1706, 1690, 1668, 1644, 1548, 1531, 1498, 1465, 1385, 1262, 1198, 1036, 906 $cm^{-1}$. $^1$H NMR (600 MHz, DMSO-$d_6$) δ 8.94 (s, 1H), 8.04 (s, 1H), 7.94 (dd, *J* = 8.1, 1.3 Hz, 2H), 7.65 (t, *J* = 7.4 Hz, 1H), 7.55 (t, *J* = 7.7 Hz, 2H), 6.43 (s, 1H), 3.63 – 3.60 (m, 1H), 3.29 – 3.26 (m, 1H), 2.33 – 2.24 (m, 2H), 2.14 – 2.10 (m, 1H), 1.82 – 1.77 (m, 1H). $^{13}$C NMR (151 MHz, DMSO-$d_6$) δ 196.9, 181.6, 136.9, 133.2, 128.6, 127.8, 90.2, 66.5, 39.3, 32.8, 28.6. HRMS (ESI) Calcd. for $C_{13}H_{15}N_2O_2S$ ($M+H^+$) *m/z* 263.0849, found 263.0844.



(**5b**) Yield 91% (54 mg); white solid; m. p. = 125 °C. IR (ATR) ν 3698, 3618, 3302, 2948, 1743, 1706, 1671, 1606, 1579, 1507, 1444, 1370, 1267, 1175, 1089, 989 $cm^{-1}$. $^{1}H$ NMR (600 MHz, DMSO-$d_6$) δ 8.92 (s, 1H), 7.97 (s, 1H), 7.82 (d, $J$ = 8.3 Hz, 2H), 7.33 (d, $J$ = 7.9 Hz, 2H), 6.41 (s, 1H), 3.57 – 3.54 (m, 1H), 3.23 – 3.20 (m, 1H), 2.36 (s, 3H), 2.29 – 2.23 (m, 2H), 2.10 – 2.05 (m, 1H), 1.79 – 1.74 (m, 1H). $^{13}C$ NMR (151 MHz, DMSO-$d_6$) δ 196.5, 181.6, 143.6, 134.5, 129.2, 128.0, 90.2, 66.5, 39.2, 32.8, 28.6, 21.1. HRMS (ESI) Calcd. for $C_{14}H_{17}N_2O_2S$ ($M+H^+$) *m/z* 277.1005, found 277.1020.

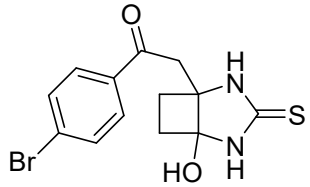


(**5c**) Yield 90% (57 mg); yellow oil. IR (ATR) ν 3680, 3457, 2958, 1777, 1643, 1594, 1486, 1411, 1371, 1313, 1257, 1161, 1019, 992, 877 $cm^{-1}$. $^{1}H$ NMR (600 MHz, DMSO-$d_6$) δ 8.94 (s, 1H), 7.95 – 7.91 (m, 3H), 7.07– 7.05 (m, 2H), 6.43 (br s, 1H), 3.84 (s, 3H), 3.56 (d, $J$ = 17.8 Hz, 1H), 3.20 (d, $J$ = 17.8 Hz, 1H), 2.32 – 2.24 (m, 2H), 2.11 – 2.06 (m, 1H), 1.80 – 1.75 (1H). $^{13}C$ NMR (151 MHz, DMSO-$d_6$) δ 195.5, 181.6, 163.2, 130.2, 129.9, 113.9, 90.2, 66.6, 55.5, 38.9, 32.8, 28.6. HRMS (ESI) Calcd. for $C_{14}H_{17}N_2O_3S$ ($M+H^+$) *m/z* 293.0954, found 293.0963.

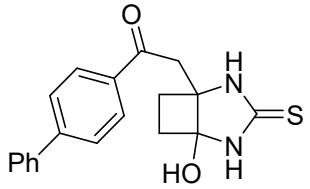


(**5d**) Yield 59% (38 mg); white solid; m. p. = 138–139 °C. IR (ATR) ν 3618, 3224, 2963, 1677, 1559, 1496, 1398, 1332, 1260, 1217, 1151, 1081, 1010, 996, 869 $cm^{-1}$. $^{1}H$

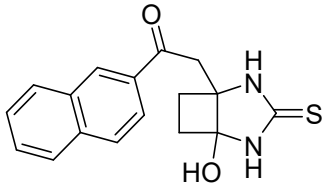
NMR (600 MHz, DMSO-$d_6$) δ 8.94 (s, 1H), 8.07 (s, 1H), 7.96 – 7.94 (m, 2H), 7.63 – 7.62 (m, 2H), 6.44 (s, 1H), 3.60 – 3.57 (m, 1H), 3.28 – 3.25 (m, 1H), 2.30 – 2.26 (m, 2H), 2.16 – 2.11 (m, 1H), 1.82 – 1.77 (m, 1H). $^{13}$C NMR (151 MHz, DMSO-$d_6$) δ 195.9, 181.6, 138.0, 135.7, 129.8, 128.8, 90.2, 66.5, 39.3, 32.8, 28.5. HRMS (ESI) Calcd. for $C_{13}H_{14}ClN_2O_2S$ ($M+H^+$) *m/z* 297.0459, found 297.0462.



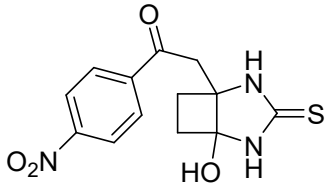

(**5e**) Yield 51% (37 mg); white solid; m. p. = 154 °C. IR (ATR) ν 3617, 3315, 2981, 1748, 1677, 1617, 1576, 1512, 1496, 1462, 1391, 1348, 1285, 1179, 1087, 923 cm$^{-1}$. $^1$H NMR (600 MHz, DMSO-$d_6$) δ 8.91 (s, 1H), 8.04 (s, 1H), 7.85 – 7.83 (m, 2H), 7.75 – 7.73 (m, 2H), 6.43 (br s, 1H), 3.57 – 3.54 (m, 1H), 3.25 – 3.22 (m, 1H), 2.29 – 2.22 (m, 2H), 2.13 – 2.08 (m, 1H), 1.79 – 1.74 (m, 1H). $^{13}$C NMR (151 MHz, DMSO-$d_6$) δ 196.2, 181.6, 136.0, 131.7, 129.9, 127.3, 90.3, 66.5, 39.3, 32.8, 28.6. HRMS (ESI) Calcd. for $C_{13}H_{14}BrN_2O_2S$ ($M+H^+$) *m/z* 340.9954, found 340.9962.



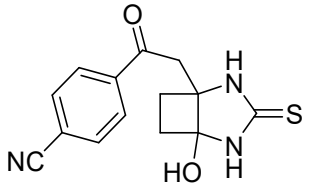

(**5f**) Yield 73% (53 mg); white solid; m. p. = 177–178 °C. IR (ATR) ν 3618, 3438, 2994, 1781, 1677, 1600, 1546, 1482, 1436, 1300, 1261, 1210, 1148, 1024, 904 cm$^{-1}$. $^1$H NMR (600 MHz, DMSO-$d_6$) δ 8.97 (s, 1H), 8.07 (s, 1H), 8.03 (d, $J$ = 8.1 Hz, 2H), 7.85 (d, $J$ = 8.2 Hz, 2H), 7.75 (d, $J$ = 7.6 Hz, 2H), 7.51 (t, $J$ = 7.6 Hz, 2H), 7.43 (t, $J$ = 7.4 Hz, 1H), 6.48 (s, 1H), 3.66 – 3.63 (m, 1H), 3.36 – 3.33 (m, 1H), 2.35 – 2.26 (m, 2H), 2.17 – 2.12 (m, 1H), 1.84 – 1.79 (m, 1H). $^{13}$C NMR (151 MHz, DMSO-$d_6$) δ 196.5, 181.6, 144.5, 138.8, 135.7, 129.1, 128.6, 128.4, 126.9, 126.8, 90.3, 66.6, 39.3, 32.8, 28.6. HRMS (ESI) Calcd. for $C_{19}H_{19}N_2O_2S$ ($M+H^+$) *m/z* 339.1162, found 339.1171.



(**5g**) Yield 73% (49 mg); white solid; m. p. = 169 °C. IR (ATR) ν 3623, 3438, 2981, 1715, 1664, 1629, 1515, 1446, 1421, 1382, 1274, 1168, 983 $cm^{-1}$. $^{1}H$ NMR (600 MHz, DMSO-$d_6$) δ 8.97 (s, 1H), 8.64 (s, 1H), 8.16 – 8.15 (m, 1H), 8.08 (s, 1H), 8.04 – 9.99 (m, 3H), 7.69 – 7.67 (m, 1H), 7.64 – 7.62 (m, 1H), 6.49 (s, 1H), 3.77 (d, $J$ = 17.8 Hz, 1H), 3.40 (d, $J$ = 17.9 Hz, 1H), 2.36 – 2.27 (m, 2H), 2.19 – 2.15 (m, 1H), 1.85 – 1.80 (m, 1H). $^{13}C$ NMR (151 MHz, DMSO-$d_6$) δ 197.0, 181.6, 135.0, 134.3, 132.1, 129.8, 129.6, 128.6, 128.2, 127.6, 126.9, 123.5, 90.3, 66.7, 32.8, 28.6 (one carbon overlaps with DMSO). HRMS (ESI) Calcd. for $C_{17}H_{17}N_2O_2S$ ($M+H^+$) *m/z* 313.1005, found 313.1018.

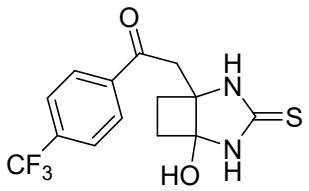


(**5h**) Yield 88% (58 mg); yellow solid; m. p. = 136 °C. IR (ATR) ν 3393, 2980, 1725, 1642, 1560, 1443, 1380, 1217, 1198, 1105, 1014, 1002, 822, 758 $cm^{-1}$. $^{1}H$ NMR (600 MHz, DMSO-$d_6$) δ 8.95 (s, 1H), 8.36 (d, $J$ = 8.4 Hz, 2H), 8.14 (d, $J$ = 8.8 Hz, 3H), 6.48 (s, 1H), 3.68 – 3.65 (m, 1H), 3.35 – 3.32 (m, 1H), 2.32 – 2.25 (m, 2H), 2.19 – 2.15 (m, 1H), 1.83 – 1.78 (m, 1H). $^{13}C$ NMR (151 MHz, DMSO-$d_6$) δ 196.1, 181.6, 149.8, 141.6, 129.3, 123.8, 90.3, 66.5, 39.9, 32.8, 28.5. HRMS (ESI) Calcd. for $C_{13}H_{14}N_3O_4S$ ($M+H^+$) *m/z* 308.0700, found 308.0710.

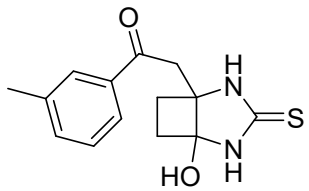


(**5i**) Yield 89% (55 mg); pale yellow solid; m. p. = 140–142 °C. IR (ATR) ν 3383, 2994, 2235, 1780, 1689, 1515, 1498, 1407, 1304, 1262, 1212, 1158, 994, 827 $cm^{-1}$. $^{1}H$

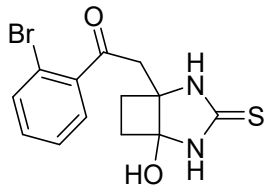
NMR (600 MHz, DMSO-$d_6$) δ 8.94 (s, 1H), 8.12 (s, 1H), 8.06 (d, $J$ = 8.0 Hz, 2H), 8.02 (d, $J$ = 8.0 Hz, 2H), 6.46 (s, 1H), 3.64 – 3.61 (m, 1H), 3.32 – 3.29 (m, 1H), 2.31 – 2.24 (m, 2H), 2.17 – 2.13 (m, 1H), 1.82 – 1.76 (m, 1H). $^{13}$C NMR (151 MHz, DMSO-$d_6$) δ 196.3, 181.6, 140.2, 132.7, 128.5, 118.1, 115.0, 90.3, 66.5, 39.7, 32.8, 28.5. HRMS (ESI) Calcd. for $C_{14}H_{14}N_3O_2S$ (M+H$^+$) *m/z* 288.0801, found 288.0810.



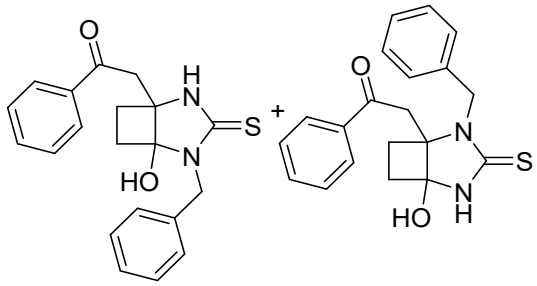

(**5j**) Yield 55% (39 mg); white solid; m. p. = 143 °C. IR (ATR) ν 3398, 1734, 1690, 1643, 1503, 1412, 1384, 1321, 1263, 1159, 1132, 1014, 997, 830 cm$^{-1}$. $^1$H NMR (600 MHz, DMSO-$d_6$) δ 8.95 (s, 1H), 8.12 – 8.11 (m, 3H), 7.93 – 7.92 (m, 2H), 6.47 (br s, 1H), 3.66 – 3.63 (m, 1H), 3.34 – 3.31 (m, 1H), 2.32 – 2.25 (m, 2H), 2.19 – 2.14 (m, 1H), 1.83 – 1.78 (m, 1H). $^{13}$C NMR (151 MHz, DMSO-$d_6$) δ 196.3, 181.6, 140.1, 132.4 (q, $J$ = 31.6 Hz), 128.7, 125.6 (q, $J$ = 3.4 Hz), 123.80 (q, $J$ = 273.0 Hz), 90.3, 66.5, 39.6, 32.8, 28.5. $^{19}$F NMR (565 MHz, DMSO-$d_6$) δ -61.52. HRMS (ESI) Calcd. for $C_{14}H_{14}F_3N_2O_2S$ (M+H$^+$) *m/z* 331.0723, found 331.0732.




(**5k**) Yield 90% (53 mg); brownish paste; IR (ATR) ν 3638, 2995, 1739, 1690, 1678, 1515, 1427, 1376, 1262, 1212, 1157, 1045, 990, 843 cm$^{-1}$. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.73 – 7.68 (m, 3H), 7.37 – 7.35 (m, 1H), 7.33 – 7.30 (m, 2H), 3.73 – 3.70 (m, 1H), 3.34 – 3.31 (m, 1H), 2.54 – 2.50 (m, 1H), 2.44 – 2.40 (m, 1H), 2.37 (s, 3H), 2.11 – 2.05 (m, 1H), 2.00 – 1.95 (m, 1H), the O*H* signal is not visible in the $^1$H NMR spectrum. $^{13}$C NMR (151 MHz, $CDCl_3$) δ 198.3, 181.6, 138.7, 136.4, 134.8, 128.8, 128.7, 125.6, 91.1, 67.6, 40.0, 33.1, 28.8, 21.4. HRMS (ESI) Calcd. for $C_{14}H_{17}N_2O_2S$ (M+H$^+$) *m/z* 277.1005, found 277.1017.

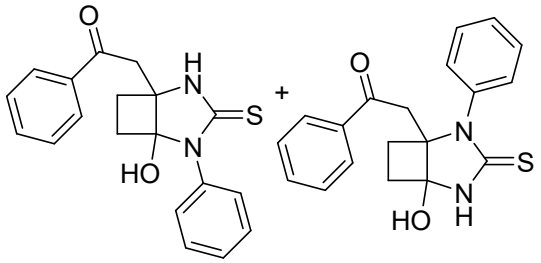


(**5l**) Yield 86% (63 mg); white solid; m. p. = 143 °C. IR (ATR) ν 3661, 3403, 2956, 1738, 1643, 1594, 1486, 1427, 1376, 1262, 1102, 1041, 1023, 976, 899 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 7.60 – 7.58 (m, 2H), 7.52 – 7.51 (m, 1H), 7.40 – 7.38 (m, 1H), 7.33 – 7.28 (m, 2H), 5.29 (br s, 1H), 3.73 – 3.70 (m, 1H), 3.37 – 3.34 (m, 1H), 2.57 – 2.53 (m, 1H), 2.46 – 2.41 (m, 1H), 2.12 – 2.09 (m, 2H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 201.9, 181.7, 140.2, 134.1, 132.6, 129.2, 127.8, 119.0, 91.2, 67.6, 44.0, 33.0, 28.7. HRMS (ESI) Calcd. for $C_{13}H_{14}BrN_2O_2S$ ($M+H^+$) *m/z* 340.9954, found 340.9967.

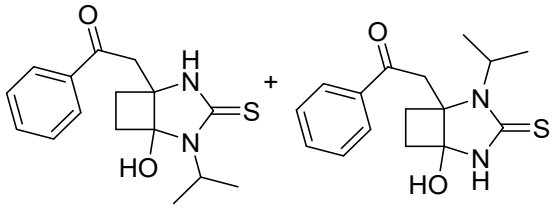


(**5m+5'm**) Overall yield 86% (65 mg). (**5m**) White solid; m. p. = 167 °C. IR (ATR) ν 3658, 3389, 2911, 1745, 1640, 1512, 1487, 1432, 1365, 1260, 1105, 1089, 1001, 934, 819 $cm^{-1}$. $^{1}H$ NMR (600 MHz, DMSO-$d_6$) δ 8.46 (s, 1H), 7.96 (d, $J$ = 7.7 Hz, 2H), 7.66 (t, $J$ = 7.4 Hz, 1H), 7.55 (t, $J$ = 7.6 Hz, 2H), 7.42 (d, $J$ = 7.5 Hz, 2H), 7.33 (t, $J$ = 7.5 Hz, 2H), 7.26 – 7.23 (m, 1H), 6.75 (s, 1H), 5.16 (d, $J$ = 15.6 Hz, 1H), 4.43 (d, $J$ = 15.6 Hz, 1H), 3.66 – 3.63 (m, 1H), 3.35 – 3.32 (m, 1H), 2.16 – 2.06 (m, 2H), 1.88 – 1.84 (m, 1H), 1.79 – 1.74 (m, 1H). $^{13}C$ NMR (151 MHz, DMSO-$d_6$) δ 196.8, 182.2, 139.2, 136.9, 133.2, 128.7, 128.1, 127.9, 127.3, 126.8, 92.5, 64.2, 44.1, 39.3, 31.0, 28.2. HRMS (ESI) Calcd. for $C_{20}H_{21}N_2O_2S$ ($M+H^+$) *m/z* 353.1318, found 353.1328. The following data are attributed to (**5'm**) in a mixture with (**5m**): $^{1}H$ NMR (600 MHz, DMSO-$d_6$) δ 9.20 (s, 1H), 7.67 – 7.64 (m, 2H), 7.56 – 7.54 (m, 1H), 7.44 – 7.41 (m, 2H), 7.26 – 7.23 (m, 2H), 7.13 – 7.10 (m, 2H), 7.05 – 7.02 (m, 1H), 6.32 (s, 1H), 4.82 – 4.75 (m, 2H), 3.53 – 3.50 (m, 1H), 3.30 – 3.27 (m, 1H), 2.33 – 2.22 (m, 2H), 2.16 – 2.06 (m, 1H), 1.70 – 1.65 (m, 1H). $^{13}C$ NMR (151 MHz, DMSO-$d_6$) δ 196.5, 182.1,

136.8, 132.9, 128.3, 127.8, 127.57, 127.55, 126.6, 87.0, 69.7, 46.5, 37.6, 32.6, 27.2. HRMS (ESI) Calcd. for $C_{20}H_{21}N_2O_2S$ ($M+H^+$) *m/z* 353.1318, found 353.1328.

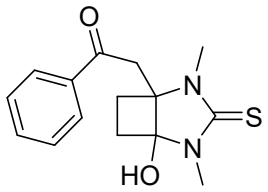


(**5n+5'n**) Overall yield 77% (56 mg). (**5n**) White solid; m. p. = 151 °C. IR (ATR) ν 3645, 3348, 2980, 1734, 1667, 1623, 1589, 1503, 1457, 1378, 1307, 1298, 1212, 1082, 984 $cm^{-1}$. $^1H$ NMR (600 MHz, DMSO-$d_6$) δ 8.69 (s, 1H), 8.00 – 7.99 (m, 2H), 7.68 – 7.66 (m, 1H), 7.58 – 7.56 (m, 2H), 7.43 – 7.39 (m, 4H), 7.34 – 7.31 (m, 1H), 7.00 (s, 1H), 3.76 – 3.73 (m, 1H), 3.46 – 3.43 (m, 1H), 2.27 – 2.18 (m, 3H), 2.02 – 1.96 (m, 1H). $^{13}C$ NMR (151 MHz, DMSO-$d_6$) δ 196.7, 181.8, 137.3, 136.9, 133.2, 129.5, 128.7, 128.2, 127.9, 127.0, 93.9, 64.6, 39.3, 30.5, 28.4. HRMS (ESI) Calcd. for $C_{19}H_{19}N_2O_2S$ ($M+H^+$) *m/z* 339.1162, found 339.1175. (**5'n**) White solid; m. p. = 160 °C. IR (ATR) ν 3640, 3323, 2941, 1712, 1660, 1615, 1568, 1499, 1410, 1388, 1300, 1267, 1222, 1073, 976 $cm^{-1}$. $^1H$ NMR (600 MHz, $CDCl_3$) δ 7.53 – 7.49 (m, 3H), 7.45 – 7.43 (m, 1H), 7.32 – 7.29 (m, 2H), 7.17 – 7.15 (m, 2H), 7.13 – 7.08 (m, 3H), 6.96 (s, 1H), 3.72 (d, *J* = 17.6 Hz, 1H), 3.24 (d, *J* = 17.6 Hz, 1H), 2.70 – 2.65 (m, 1H), 2.60 – 2.56 (m, 1H), 2.53 – 2.48 (m, 1H), 2.30 – 2.25 (m, 1H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 199.7, 181.7, 137.0, 136.3, 134.1, 130.3, 129.0, 128.6, 128.1, 127.8, 87.8, 72.8, 38.7, 32.4, 28.6. HRMS (ESI) Calcd. for $C_{19}H_{19}N_2O_2S$ ($M+H^+$) *m/z* 339.1162, found 339.1174.

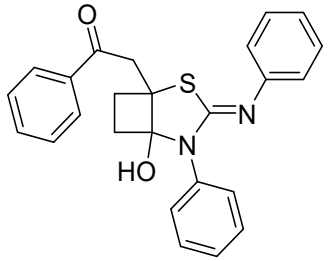


(**5o+5'o**) Overall yield 85% (55 mg). (**5o**) Yellow solid; m. p. = 140 °C. IR (ATR) ν 3621, 3331, 2945, 1710, 1689, 1635, 1542, 1484, 1413, 1345, 1274, 1262, 1123, 1073,

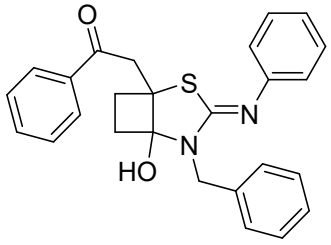
912 $cm^{-1}$. $^1H$ NMR (600 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.8 Hz, 2H), 7.60 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 6.77 (br s, 1H), 4.86 (br s, 1H), 4.63 – 4.59 (m, 1H), 3.78 (d, *J* = 17.6 Hz, 1H), 3.33 (d, *J* = 17.5 Hz, 1H), 2.65 – 2.61 (m, 1H), 2.52 – 2.47 (m, 1H), 2.08 – 1.98 (m, 2H), 1.43 – 1.41 (m, 6H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 199.3, 181.2, 136.5, 134.2, 128.9, 128.6, 94.3, 64.4, 48.7, 40.6, 33.7, 28.6, 22.8, 20.0. HRMS (ESI) Calcd. for $C_{16}H_{21}N_2O_2S$ ($M+H^+$) *m/z* 305.1318, found 305.1327. The following data are attributed to (**5'o**) in a mixture with **5o**: $^1H$ NMR (600 MHz, $CDCl_3$) δ 7.63 – 7.62 (m, 1H), 7.51 – 7.48 (m, 2H), 6.75 (br s, 1H), 4.88 – 4.83 (m, 1H), 4.47 (br s, 1H), 4.05 – 4.02 (m, 1H), 3.51 – 3.48 (m, 1H), 2.45 – 2.40 (m, 1H), 2.16 – 2.09 (m, 1H), 1.21 (d, *J* = 7.0 Hz, 3H), 0.94 (d, *J* = 7.0 Hz, 3H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 199.0, 181.8, 136.4, 134.3, 129.1, 128.3, 87.0, 69.8, 48.3, 39.7, 32.0, 29.3, 21.9, 20.1. HRMS (ESI) Calcd. for $C_{16}H_{21}N_2O_2S$ ($M+H^+$) *m/z* 305.1318, found 305.1326.



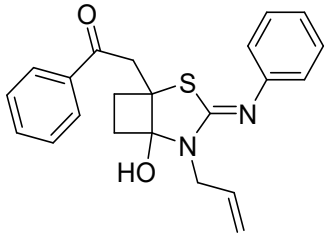

(**5p**) Yield 10% (6 mg); orange oil. IR (ATR) ν 3329, 2944, 1716, 1682, 1594, 1446, 1377, 1326, 1218, 1176, 1122, 1045, 998, 913 $cm^{-1}$. $^1H$ NMR (600 MHz, $CDCl_3$) δ 7.99 – 7.97 (m, 2H), 7.65 – 7.63 (m, 1H), 7.52 – 7.49 (m, 2H), 4.85 (br s, 1H), 3.96 – 3.93 (m, 1H), 3.38 – 3.34 (m, 1H), 3.19 (s, 3H), 2.90 (s, 3H), 2.46 – 2.36 (m, 2H), 2.04 – 1.99 (m, 1H), 1.94 – 1.88 (m, 1H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 199.1, 136.1, 134.6, 129.1, 128.6, 90.1, 68.3, 38.4, 30.0, 29.2, 28.5, 25.5. HRMS (ESI) Calcd. for $C_{15}H_{19}N_2O_2S$ ($M+H^+$) *m/z* 291.1162, found 291.1176.



(**6a**) Yield 84% (75 mg); white solid; m. p. = 210–212 °C. IR (ATR) ν 3332, 2949, 2217, 1709, 1698, 1555, 1472, 1398, 1264, 1216, 1159, 1130, 991, 833 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 7.95 – 7.93 (m, 2H), 7.62 – 7.59 (m, 1H), 7.57 – 7.56 (m, 2H), 7.49 – 7.46 (m, 2H), 7.44 – 7.41 (m, 2H), 7.30 – 7.27 (m, 1H), 7.20 – 7.17 (m, 2H), 6.97 – 6.95 (m, 1H), 6.93 – 6.91 (m, 2H), 3.90 (d, *J* = 17.6 Hz, 1H), 3.48 (d, *J* = 17.6 Hz, 1H), 2.54 – 2.50 (m, 1H), 2.36 – 2.23 (m, 3H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 198.5, 158.7, 150.9, 138.5, 136.6, 134.0, 129.2, 128.9, 128.8, 128.5, 127.6, 126.9, 123.5, 122.3, 95.3, 56.0, 43.4, 31.6, 31.5. HRMS (ESI) Calcd. for $C_{25}H_{23}N_2O_2S$ ($M+H^+$) *m/z* 415.1475, found 415.1485.

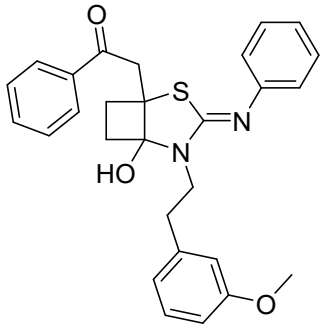



(**6b**) Yield 67% (62 mg); white solid; m. p. = 198–199 °C. IR (ATR) ν 3310, 2965, 2202, 1753, 1626, 1588, 1579, 1491, 1432, 1304, 1278, 1123, 1040, 937, 829 $cm^{-1}$. $^{1}H$ NMR (600 MHz, $CDCl_3$) δ 7.93 – 7.92 (m, 2H), 7.61 – 7.58 (m, 1H), 7.52 – 7.51 (m, 2H), 7.48 – 7.45 (m, 2H), 7.36 – 7.33 (m, 2H), 7.30 – 7.25 (m, 1H), 7.22 – 7.19 (m, 2H), 6.99 – 6.97 (m, 1H), 6.94 – 6.92 (m, 2H), 4.91 – 4.82 (m, 2H), 3.88 – 3.85 (m, 1H), 3.42 – 3.39 (m, 1H), 2.73 (br s, 1H), 2.41 – 2.37 (m, 1H), 2.35 – 2.30 (m, 1H), 2.24 – 2.16 (m, 1H). $^{13}C$ NMR (151 MHz, $CDCl_3$) δ 198.5, 157.5, 150.7, 139.1, 136.6, 134.0, 128.9, 128.8, 128.6, 128.5, 127.9, 127.2, 123.3, 122.5, 95.2, 55.8, 46.1, 43.3, 31.8, 31.5. HRMS (ESI) Calcd. for $C_{26}H_{25}N_2O_2S$ ($M+H^+$) *m/z* 429.1631, found 429.1644.

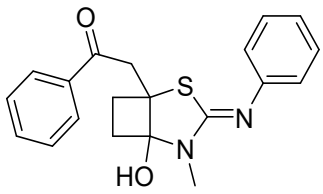



(**6c**) Yield 74% (60 mg); white solid; m. p. = 155 °C. IR (ATR) ν 3310, 2965, 2245, 2202, 1753, 1668, 1644, 1548, 1476, 1337, 1277, 1168, 973 $cm^{-1}$. $^{1}H$ NMR (600 MHz,

$CDCl_3$) δ 7.94 – 7.93 (m, 2H), 7.61 – 7.58 (m, 1H), 7.48 – 7.45 (m, 2H), 7.21 – 7.18 (m, 2H), 6.99 – 6.96 (m, 1H), 6.91 – 6.90 (m, 2H), 6.18 – 6.12 (m, 1H), 5.38 – 5.34 (m, 1H), 5.22 – 5.20 (m, 1H), 4.27 – 4.17 (m, 2H), 3.87 (d, J = 17.5 Hz, 1H), 3.43 (d, J = 17.5 Hz, 1H), 2.64 – 2.60 (m, 1H), 2.44 – 2.38 (m, 1H), 2.24 – 2.21 (m, 3H). $^{13}$C NMR (151 MHz, $CDCl_3$) δ 198.5, 156.7, 150.9, 136.7, 134.7, 128.9, 128.8, 128.5, 123.3, 122.5, 116.6, 95.1, 55.8, 45.5, 43.2, 31.9, 31.5. HRMS (ESI) Calcd. for $C_{22}H_{23}N_2O_2S$ ($M+H^+$) *m/z* 379.1475, found 379.1487.




(**6d**) Yield 70 % (71 mg); yellow semi-solid. IR(ATR) ν 3241, 3063, 2993, 2945, 2839, 1683, 1619, 1577, 1489, 1454, 1347, 1318, 1235, 1158, 1047, 999, 694 $cm^{-1}$. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.89 – 7.87 (m, 2H), 7.59 – 7.56 (m, 1H), 7.45 – 7.43 (m, 2H), 7.25 – 7.22 (m, 3H), 7.01 – 6.99 (m, 3H), 6.91 – 6.90 (m, 1H), 6.88 – 6.87 (m, 1H), 6.80 – 6.78 (m, 1H), 3.86 – 3.82 (m, 1H), 3.80 (s, 3H), 3.77 (d, *J* = 17.8 Hz, 1H), 3.70 – 3.65 (m, 1H), 3.51 (br s, 1H), 3.30 (d, *J* = 17.8 Hz, 1H), 3.26 – 3.21 (m, 1H), 3.18 – 3.14 (m, 1H), 2.30 – 2.24 (m, 1H), 2.23 – 2.18 (m, 1H), 2.11 – 2.08 (m, 2H). $^{13}$C NMR (151 MHz, $CDCl_3$) δ 198.0, 159.8, 157.5, 150.6, 141.6, 136.5, 133.9, 129.6, 128.9, 128.8, 128.4, 123.4, 122.6, 121.6, 114.8, 112.2, 95.0, 55.7, 55.3, 45.5, 43.4, 34.1, 31.9, 31.4. HRMS (ESI) Calcd. for $C_{28}H_{29}N_2O_3S$ ($M+H^+$) m/z 473.1893, found 473.1883.

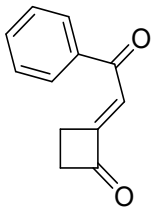



(**6e**) Yield 79% (60 mg); yellow solid; m. p. = 159–161 °C. IR (ATR) ν 3665, 3390, 2910, 1746, 1639, 1513, 1488, 1431, 1366, 1261, 1106, 1090, 1000, 935, 820 $cm^{-1}$. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.84 – 7.83 (m, 2H), 7.58 – 7.56 (m, 1H), 7.44 – 7.41 (m,

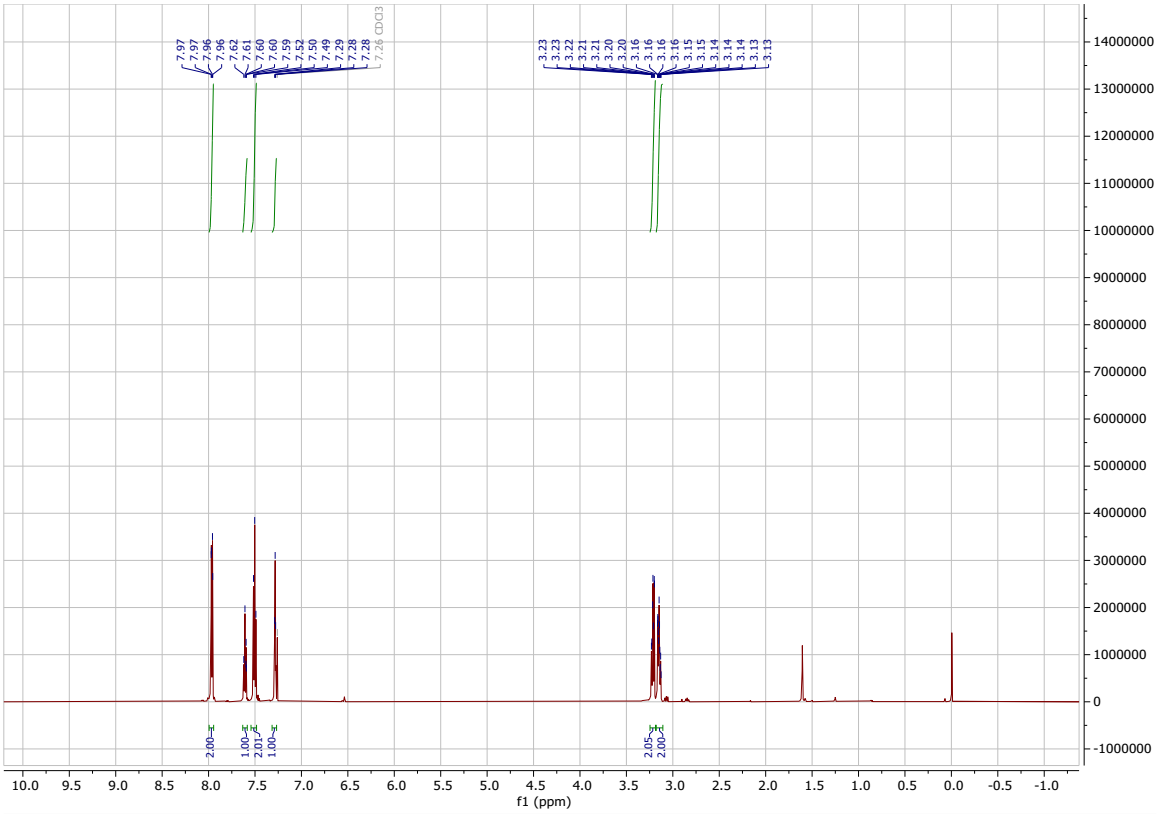
2H), 7.19 – 7.17 (m, 2H), 7.01 – 6.98 (m, 2H), 6.95 – 6.92 (m, 1H), 4.76 (br s, 1H), 3.78 (d, $J$ = 18.0 Hz, 1H), 3.29 (d, $J$ = 18.0 Hz, 1H), 3.13 (s, 3H), 2.53 – 2.48 (m, 1H), 2.37 – 2.31 (m, 1H), 2.17 – 2.14 (m, 2H). $^{13}$C NMR (151 MHz, $CDCl_3$) δ 198.0, 159.7, 136.4, 133.8, 128.8, 128.7, 128.4, 123.6, 123.0, 95.1, 55.4, 43.3, 31.4, 30.8. HRMS (ESI) Calcd. for $C_{20}H_{21}N_2O_2S$ ($M+H^+$) *m/z* 353.1318, found 353.1324.

**Large scale synthesis of 5a**

A solution of **3a** (1.3 mmol) and **4a** (1.3 mmol) in EtOAc (12 mL) was stirred in a sealed tube reactor at reflux for 8 h. The crude mixture, without aqueous work-up, was directly purified by flash column chromatography ($SiO_2$, petroleum ether/ether = 5:1→1:1) to give 265 mg of compound **5a** (78% yield).



**3a**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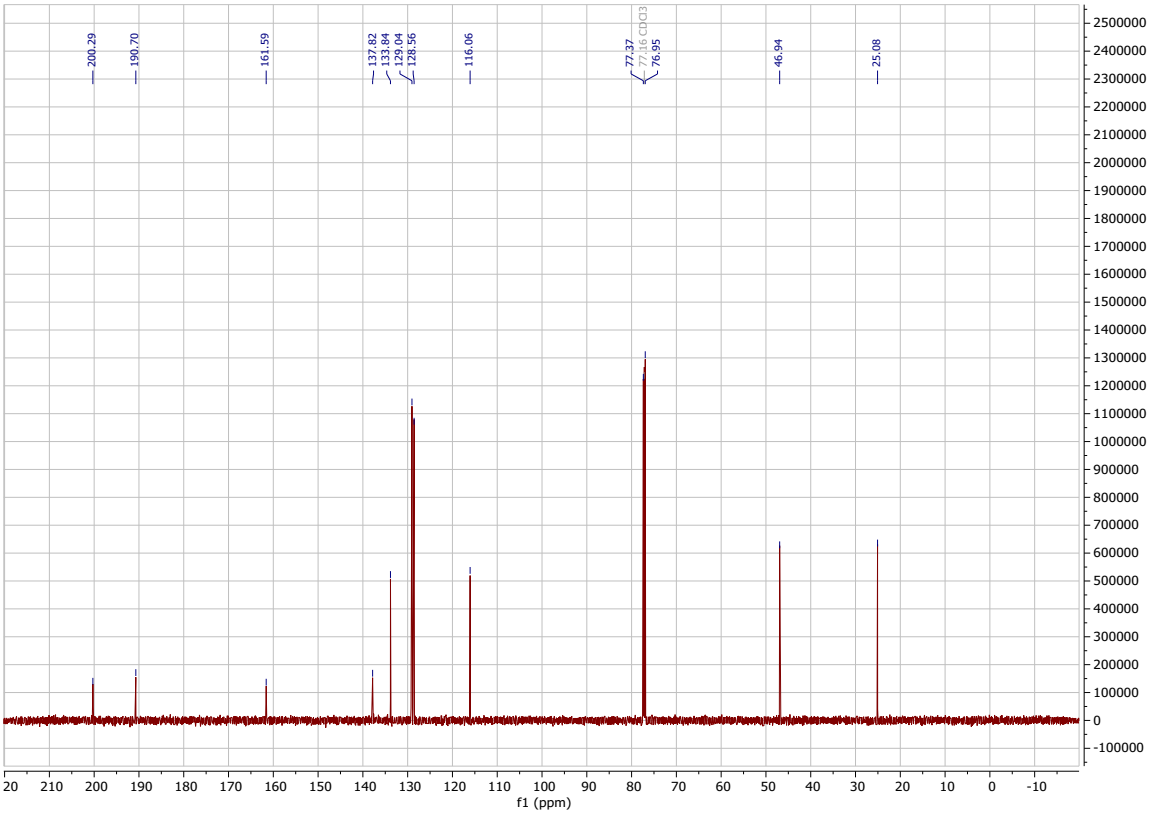
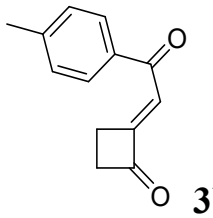
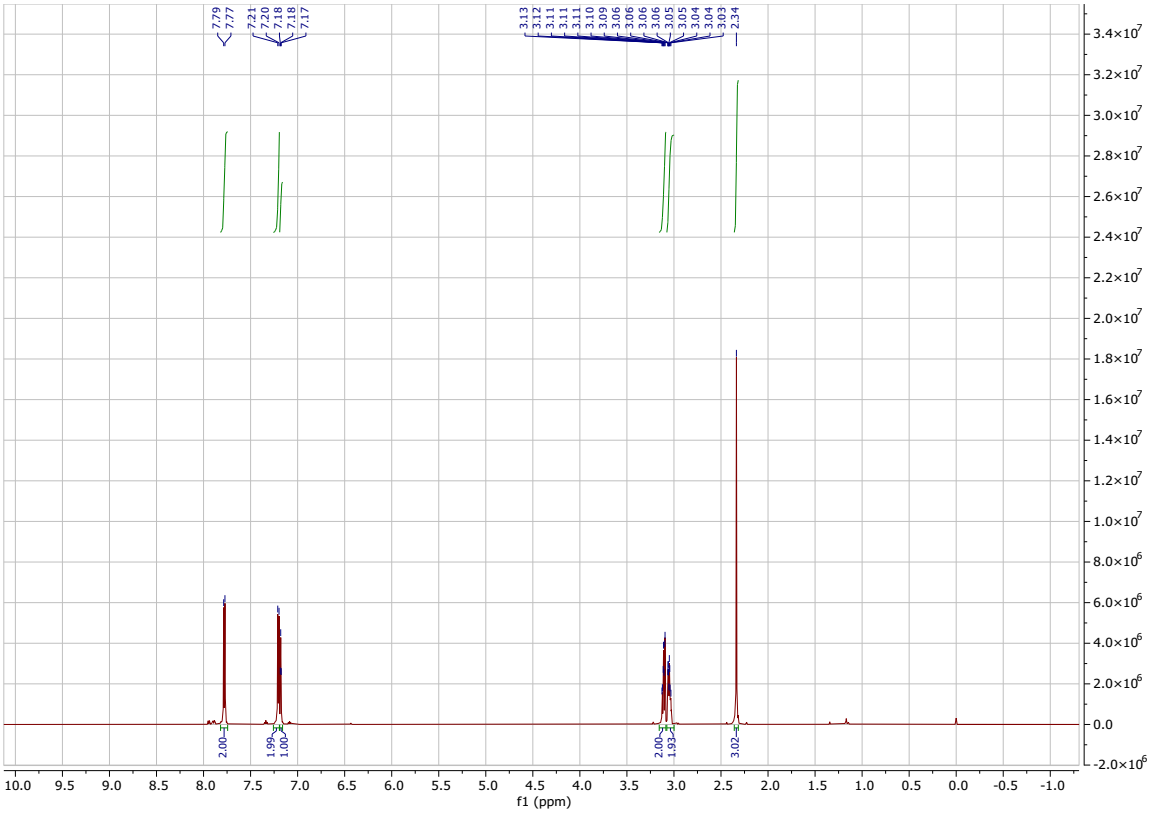
7.97
7.96
7.96
7.62
7.61
7.60
7.60
7.59
7.52
7.50
7.49
7.29
7.28
7.28
7.26 CDCl3
3.23
3.23
3.22
3.21
3.21
3.20
3.20
3.16
3.16
3.16
3.16
3.15
3.15
3.14
3.14
3.14
3.13
3.13
2.00
1.00
2.01
1.00
2.05
2.00
f1 (ppm)


200.29
190.70
161.59
137.82
133.84
129.04
128.56
116.06
77.37
77.16 CDCl3
76.95
46.94
25.08
f1 (ppm)



**3b**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7.18
7.17
3.13
3.12
3.11
3.11
3.11
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3.09
3.06
3.06
3.06
3.06
3.05
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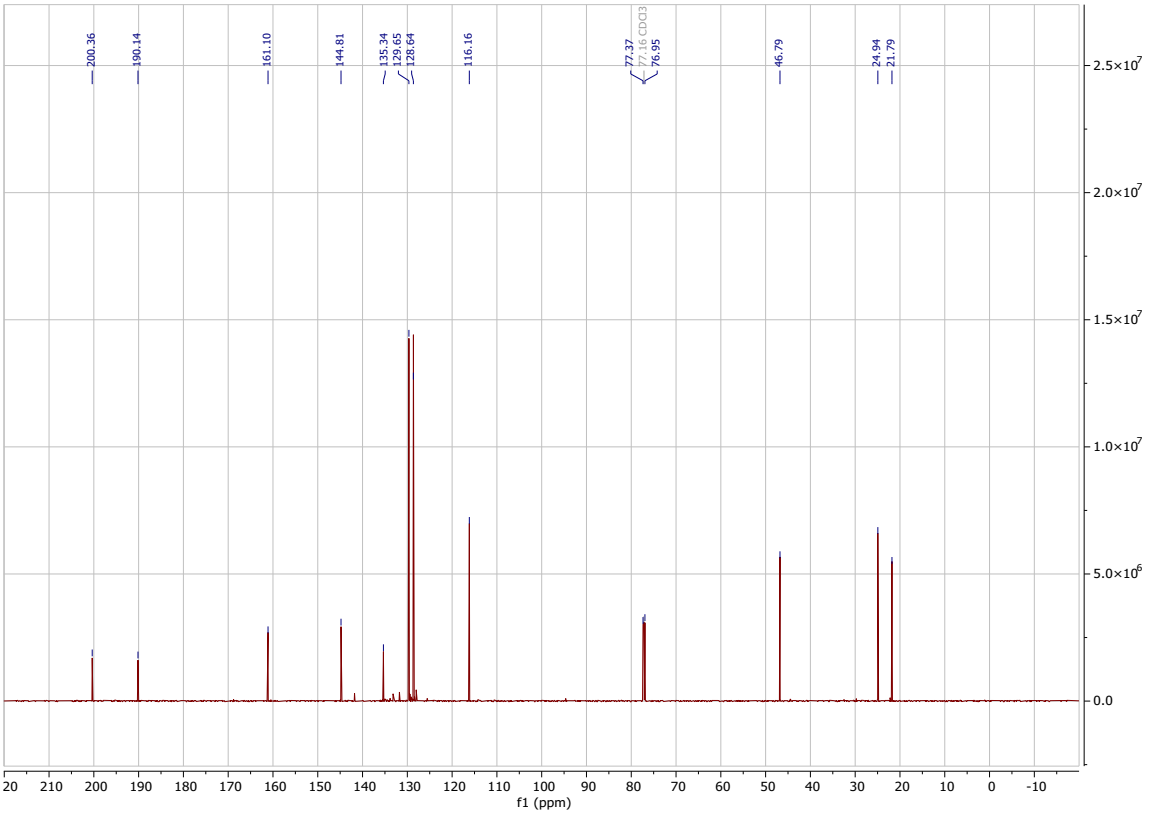
1.00
2.00
1.93
3.02
f1 (ppm)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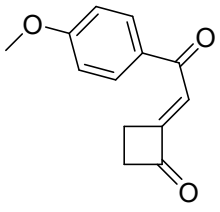
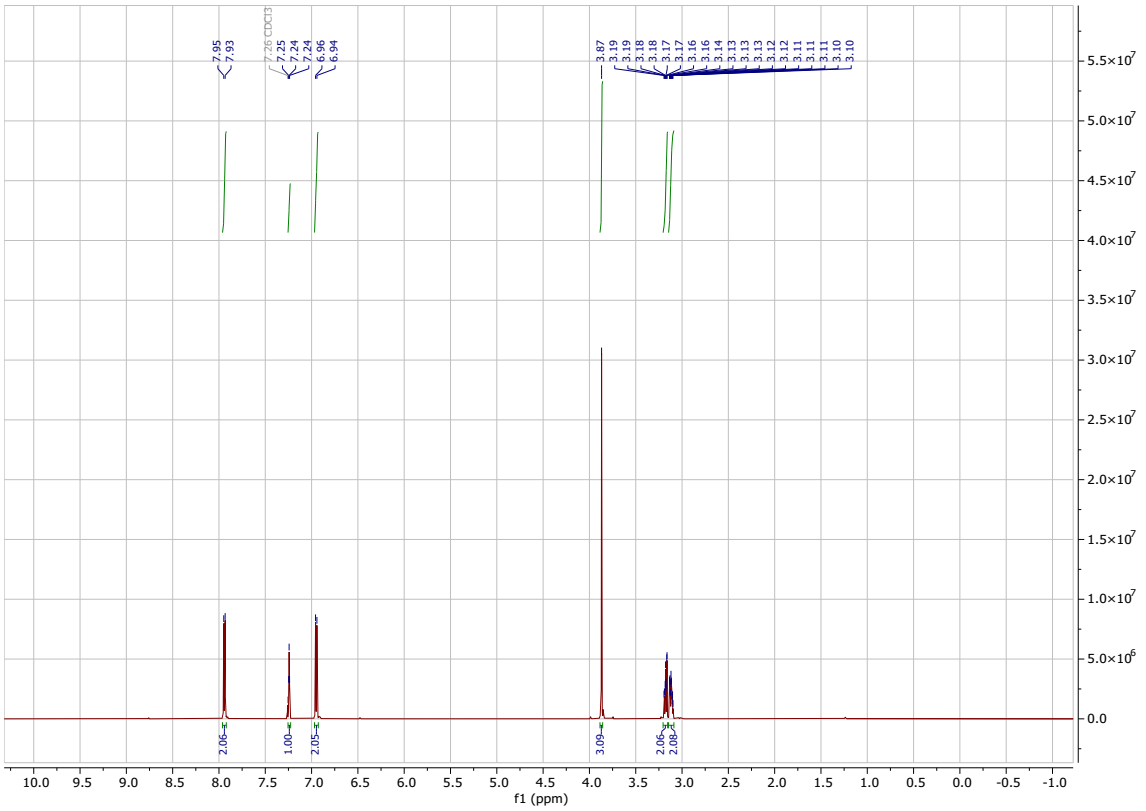
190.14
161.10
144.81
135.34
129.65
128.64
116.16
77.37
77.16 CDCl3
76.95
46.79
24.94
21.79
f1 (ppm)



**3c**


7.95
7.93
7.26 CDCl3
7.25
7.24
7.24
6.96
6.94
3.87
3.19
3.19
3.18
3.18
3.17
3.17
3.16
3.16
3.14
3.13
3.13
3.13
3.12
3.12
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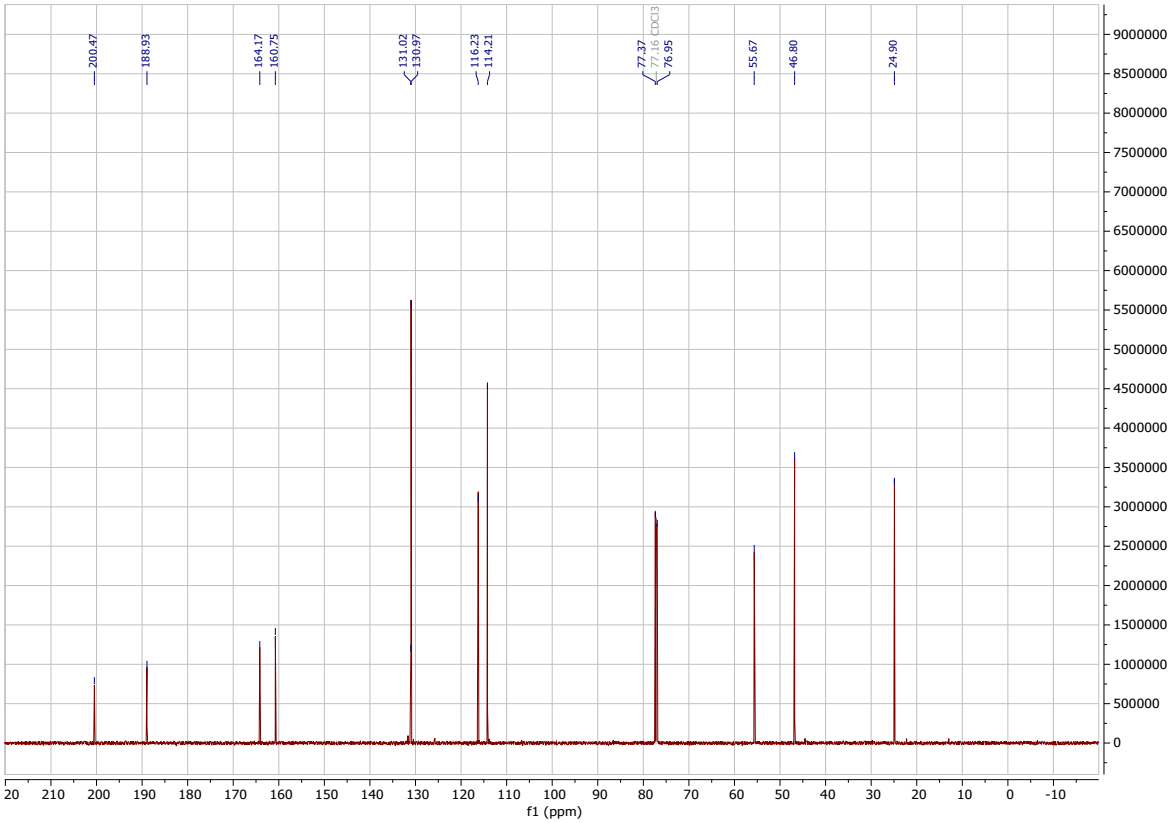
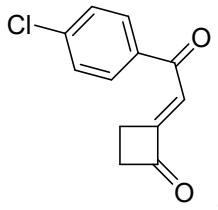
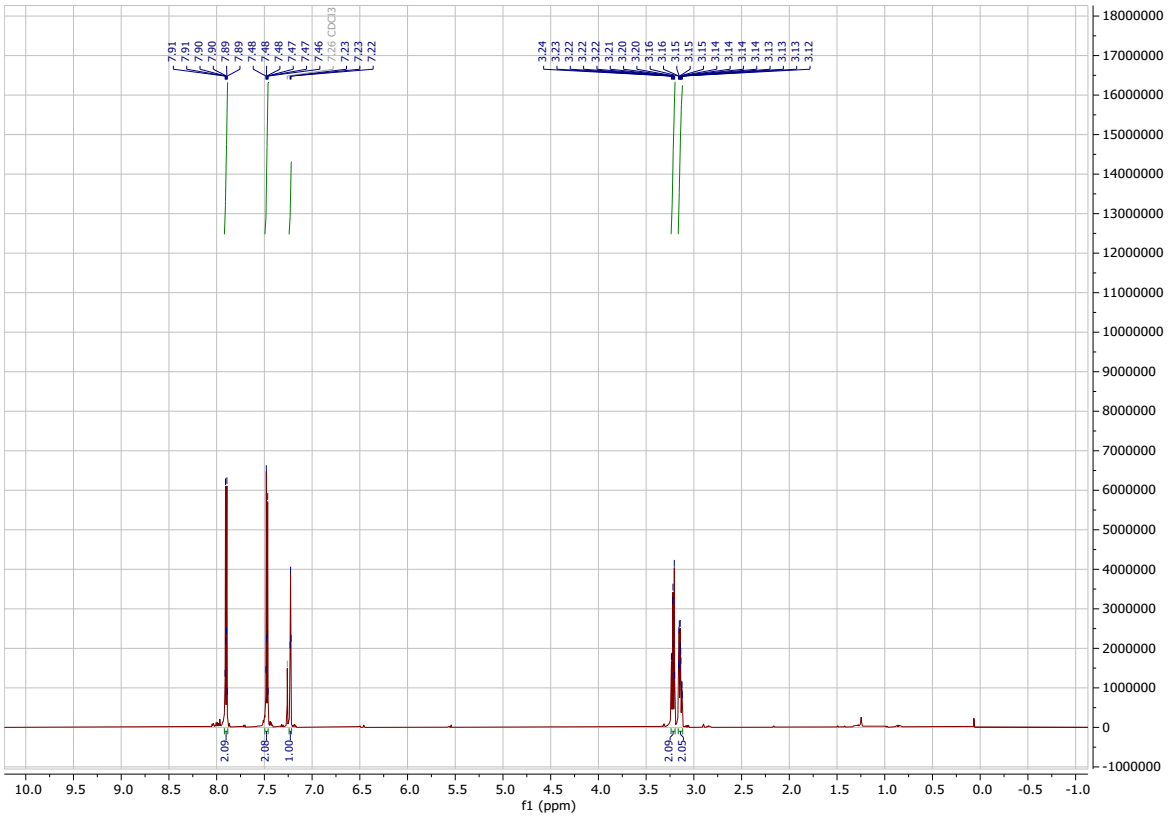
2.05
3.09
2.06
2.08
f1 (ppm)


200.47
188.93
164.17
160.75
131.02
130.97
116.23
114.21
77.37
77.16 CDCl3
76.95
55.67
46.80
24.90
f1 (ppm)


Cl
O
O

**3d**


7.91
7.91
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7.90
7.89
7.89
7.48
7.48
7.48
7.47
7.47
7.46
7.26 CDCl3
7.23
7.23
7.22
3.24
3.23
3.22
3.22
3.22
3.21
3.20
3.20
3.16
3.16
3.15
3.15
3.15
3.14
3.14
3.14
3.14
3.13
3.13
3.13
3.12
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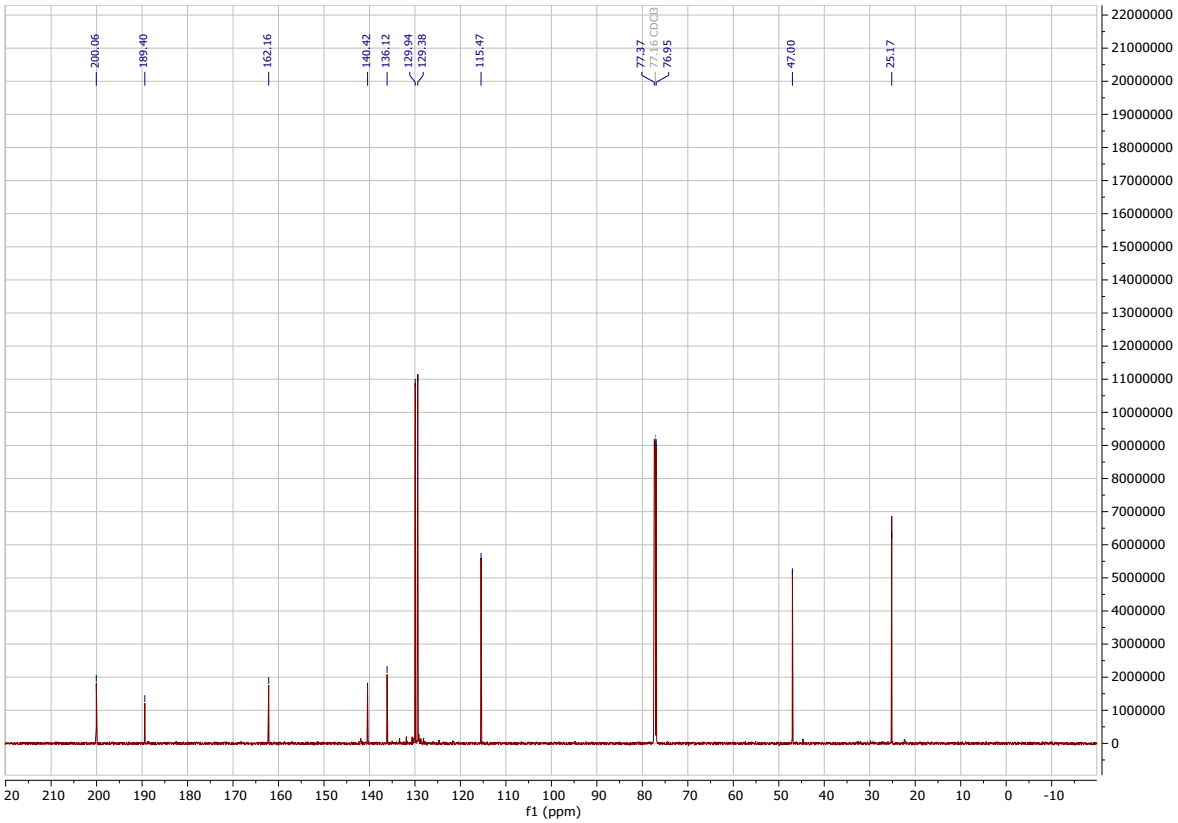
2.08
1.00
2.09
2.05
f1 (ppm)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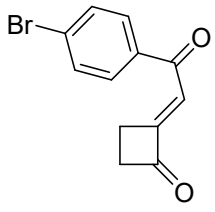
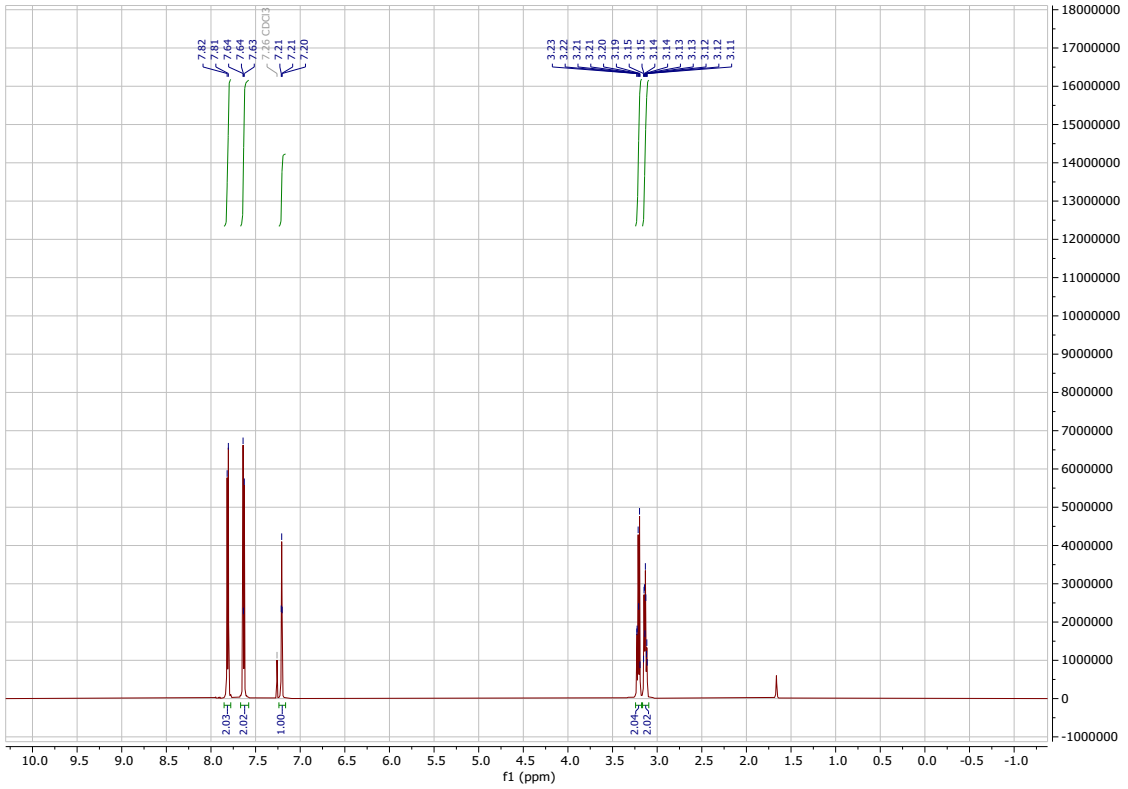
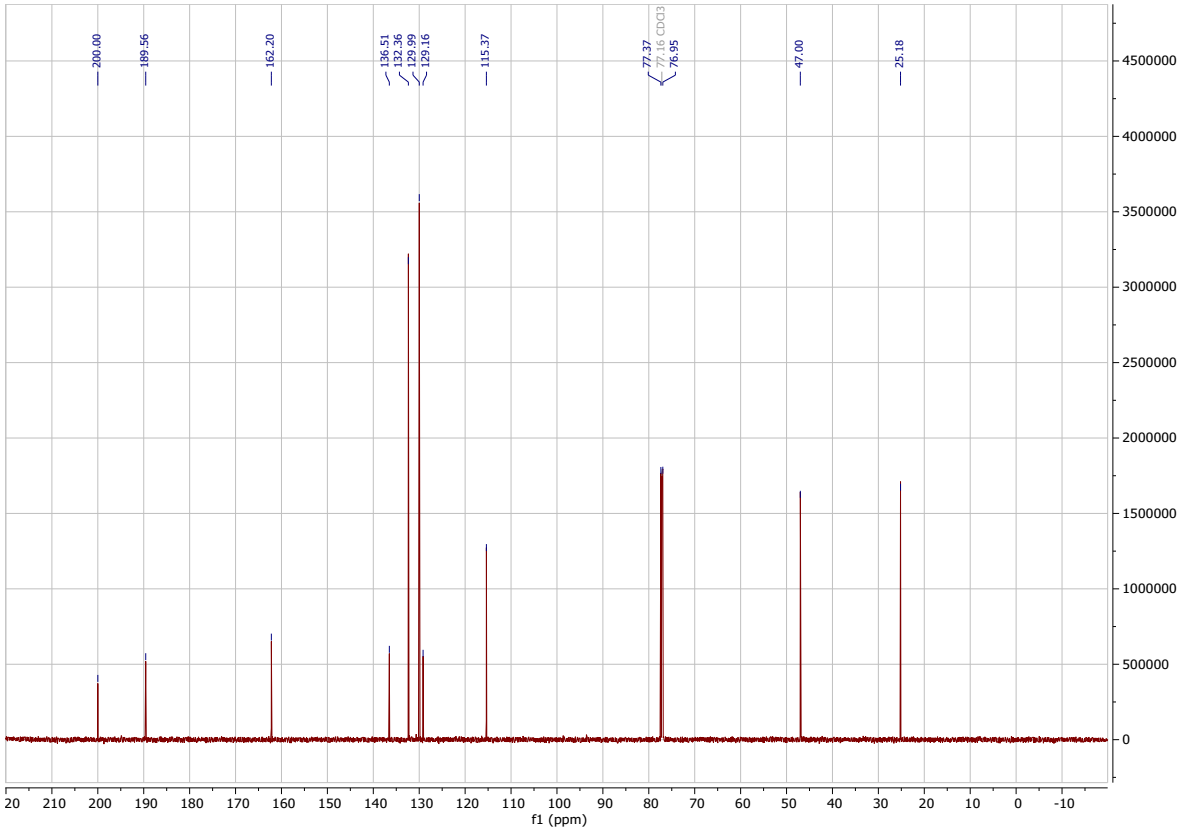
129.94
129.38
115.47
77.37
77.16 CDCl3
76.95
47.00
25.17
f1 (ppm)


Br
O
O

**3e**


7.82
7.81
7.64
7.64
7.63
7.26 CDCl3
7.21
7.21
7.20
3.23
3.22
3.21
3.21
3.20
3.19
3.15
3.15
3.14
3.14
3.13
3.13
3.12
3.12
3.11
2.03
2.02
1.00
2.04
2.02
f1 (ppm)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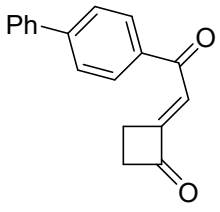
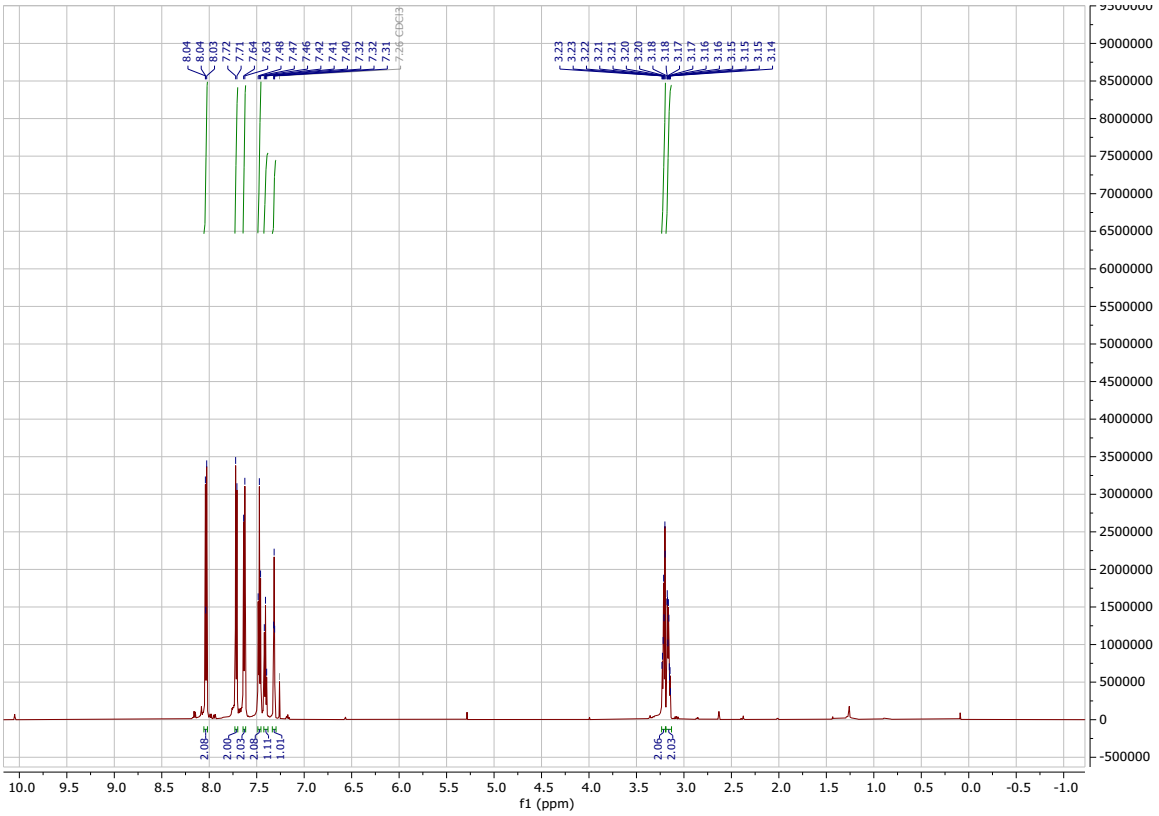
132.36
129.99
129.16
115.37
77.37
77.16 CDCl3
76.95
47.00
25.18
f1 (ppm)


Ph
O
O

**3f**


8.04
8.04
8.03
7.72
7.71
7.64
7.63
7.48
7.47
7.46
7.42
7.41
7.40
7.32
7.31
7.26 CDCl3
3.23
3.23
3.22
3.21
3.21
3.20
3.20
3.18
3.18
3.17
3.17
3.16
3.16
3.15
3.15
3.15
3.14
2.08
2.00
2.03
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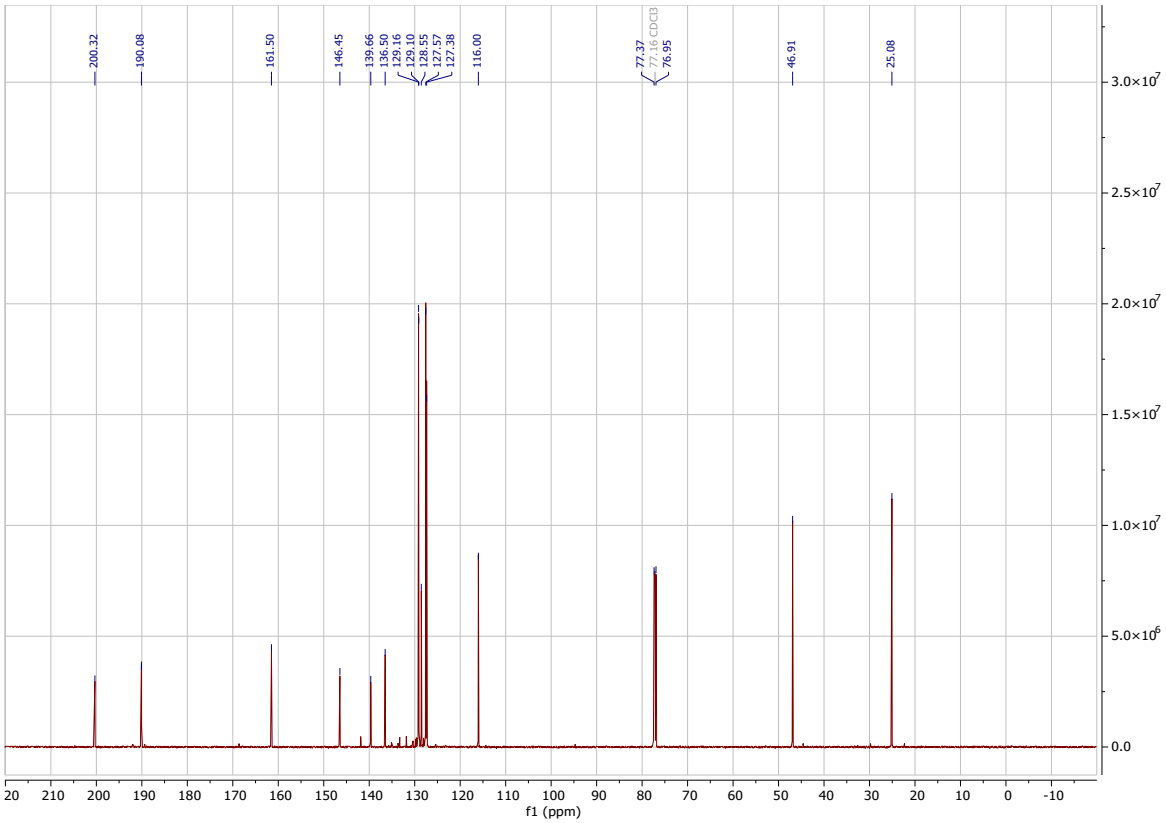
1.11
1.01
2.06
2.03
f1 (ppm)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139.66
136.50
129.16
129.10
128.55
127.57
127.38
116.00
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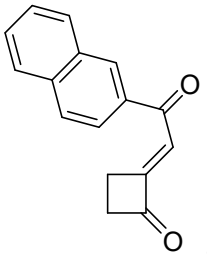
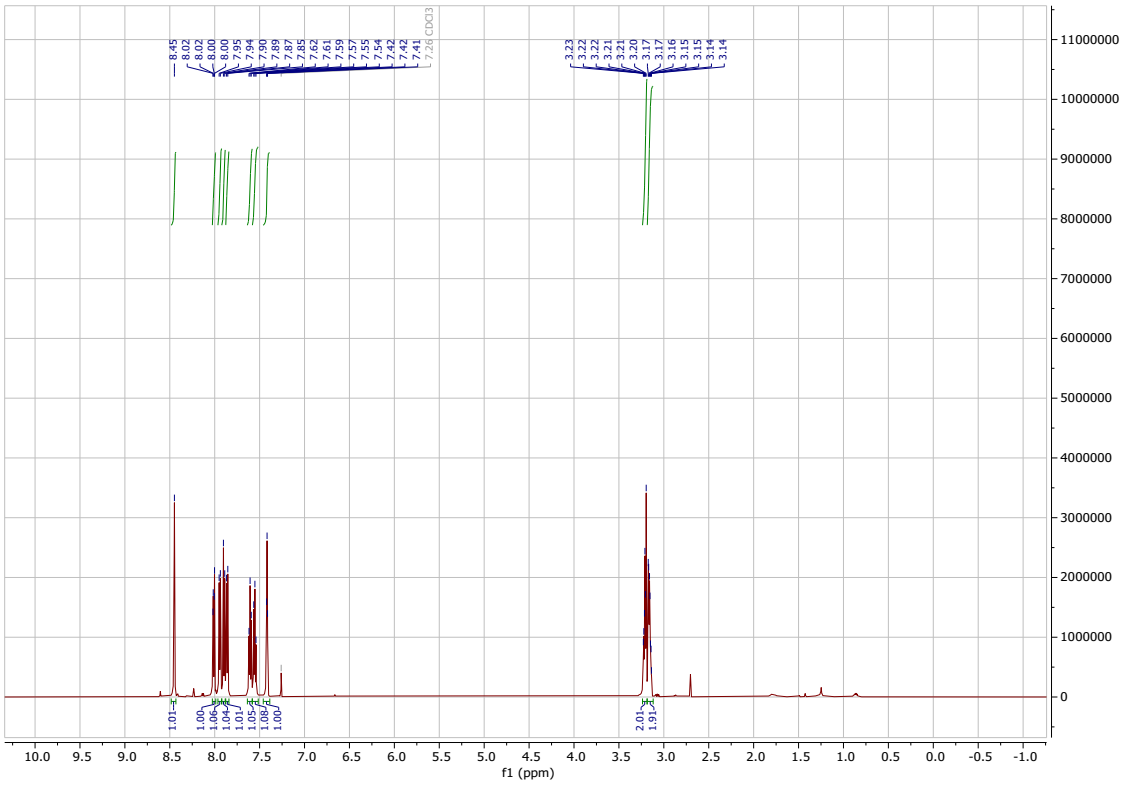
77.16 CDCl3
76.95
46.91
25.08
f1 (ppm)



**3g**


8.45
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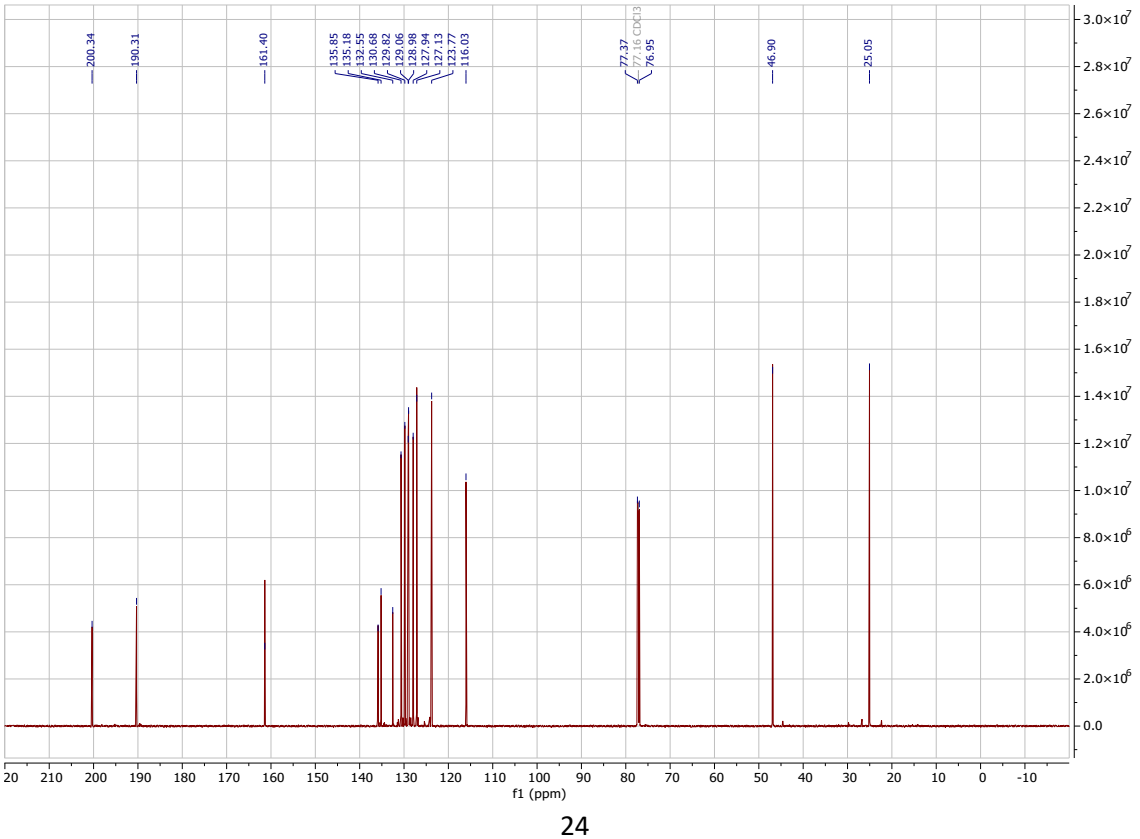
8.02
8.00
8.00
7.95
7.94
7.90
7.89
7.87
7.85
7.62
7.61
7.59
7.57
7.55
7.54
7.42
7.42
7.41
7.26 CDCl3
3.23
3.22
3.22
3.21
3.21
3.20
3.17
3.17
3.16
3.15
3.15
3.14
3.14
1.01
1.00
1.06
1.04
1.01
1.05
1.08
1.00
2.01
1.91
f1 (ppm)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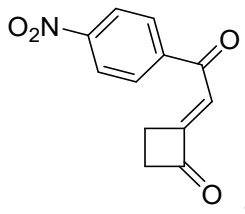
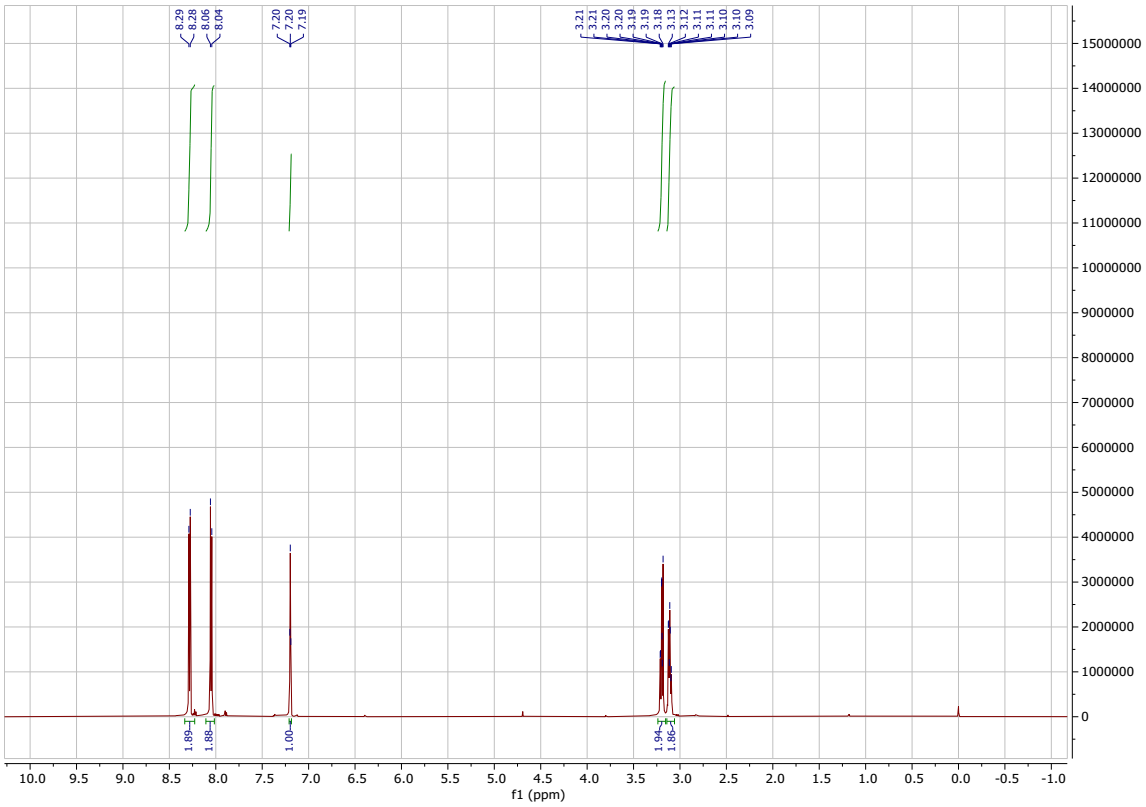
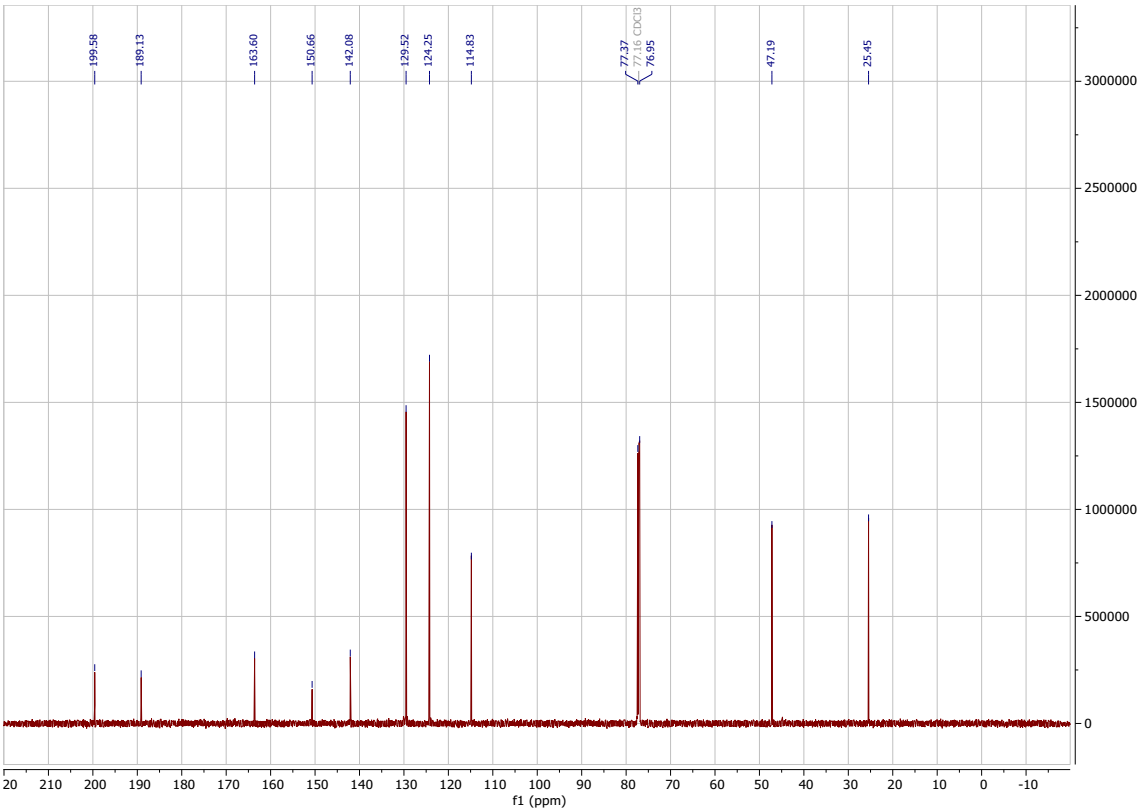
190.31
161.40
135.85
135.18
132.55
130.68
129.82
129.06
128.98
127.94
127.13
123.77
116.03
77.37
77.16 CDCl3
76.95
46.90
25.05
f1 (ppm)


O2N
O
O

**3h**


8.29
8.28
8.06
8.04
7.20
7.20
7.19
3.21
3.21
3.20
3.20
3.19
3.19
3.18
3.13
3.12
3.11
3.11
3.10
3.10
3.09
1.89
1.88
1.00
1.94
1.86
f1 (ppm)


199.58
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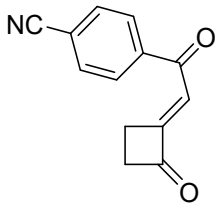
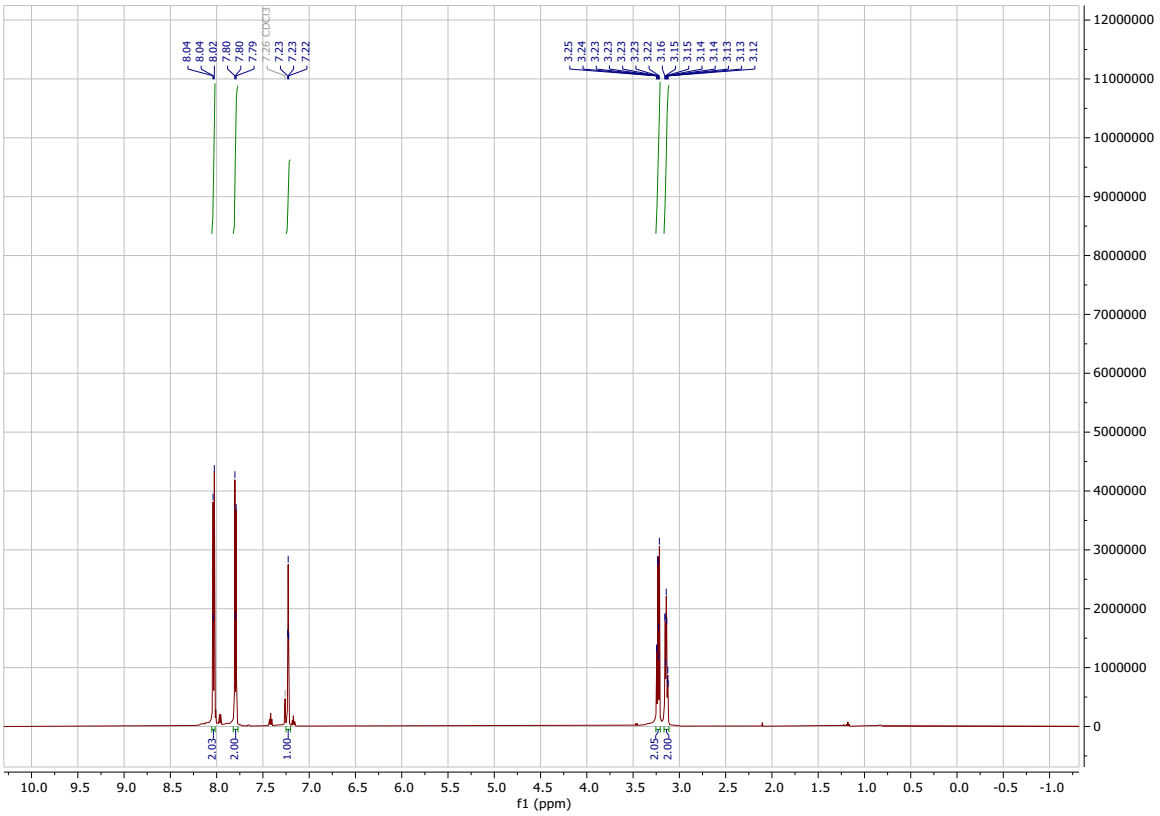
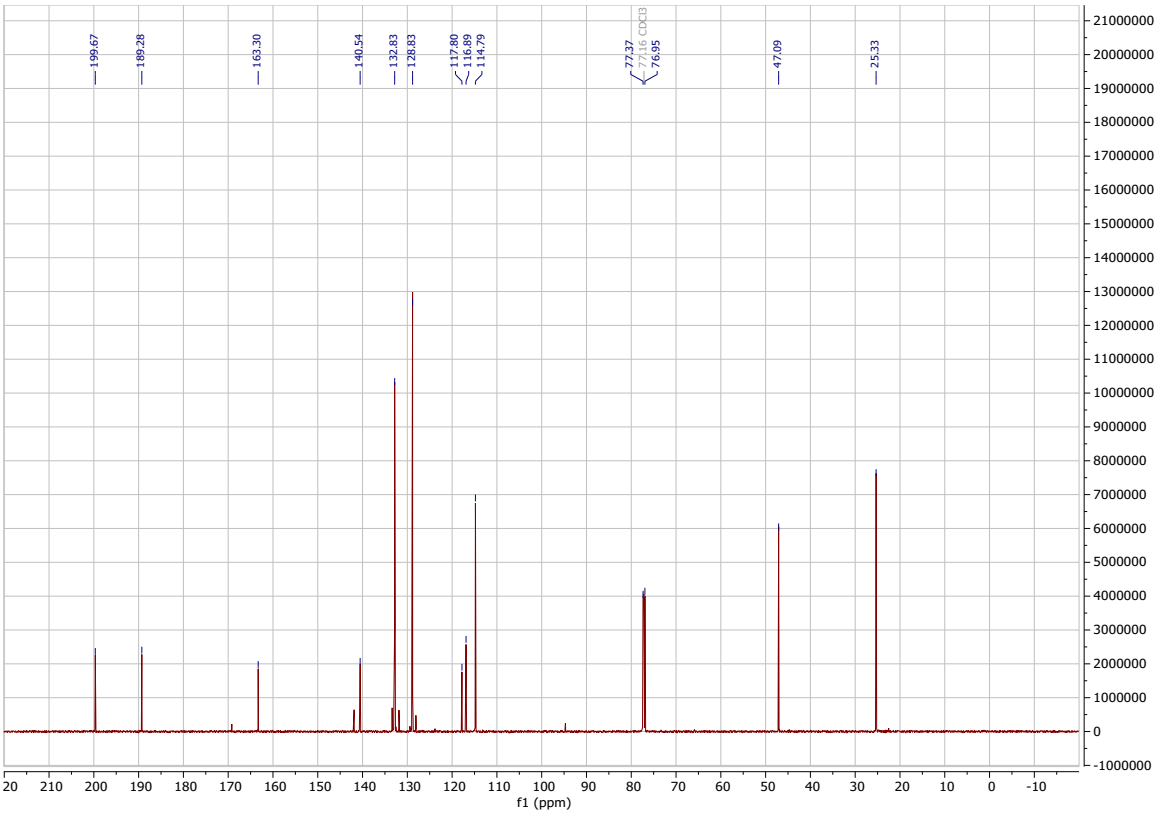
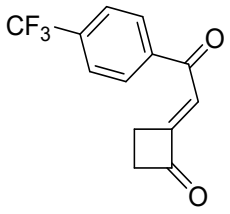
142.08
129.52
124.25
114.83
77.37
77.16 CDCl3
76.95
47.19
25.45
f1 (ppm)


NC
O
O

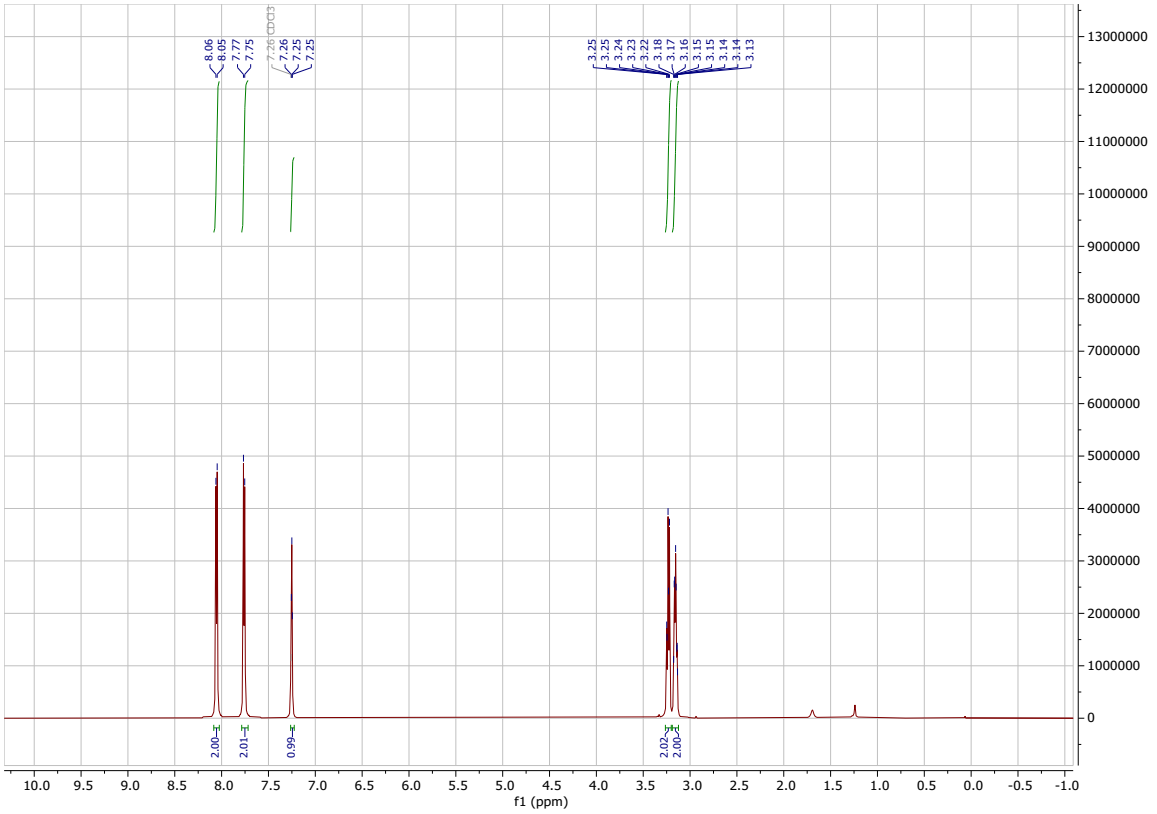
**3i**

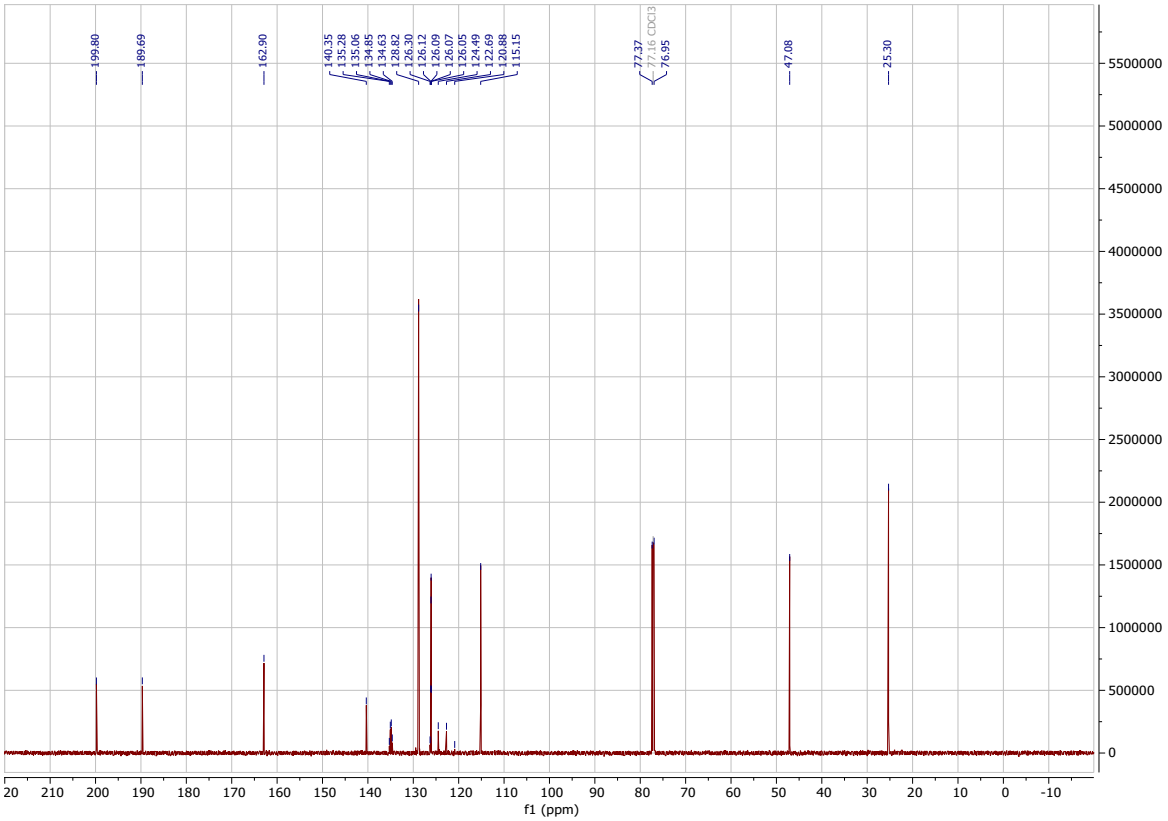

8.04
8.04
8.02
7.80
7.80
7.79
7.26 CDCl3
7.23
7.23
7.22
3.25
3.24
3.23
3.23
3.23
3.23
3.22
3.16
3.15
3.15
3.14
3.14
3.13
3.13
3.12
2.03
2.00
1.00
2.05
2.04
f1 (ppm)

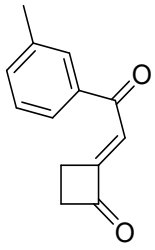

199.67
189.28
163.30
140.54
132.83
128.83
117.80
116.89
114.79
77.37
77.16 CDCl3
76.95
47.09
25.33
f1 (ppm)


CF3
O
O

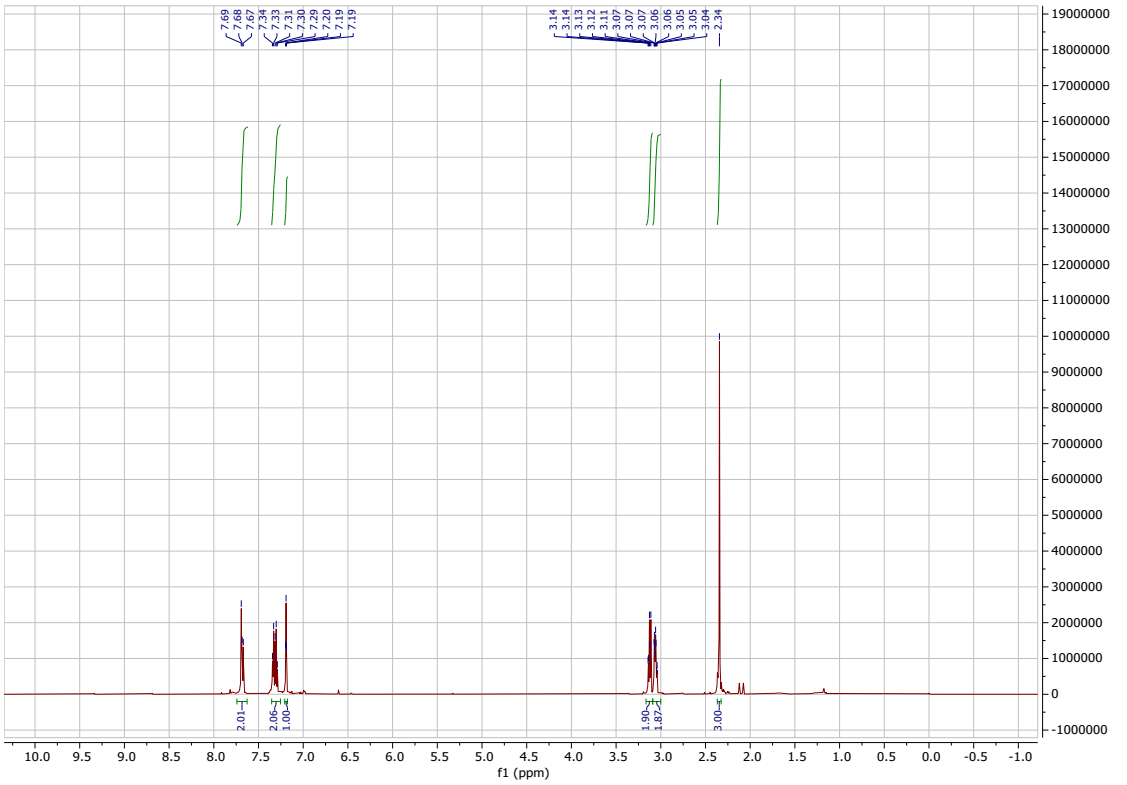
**3j**

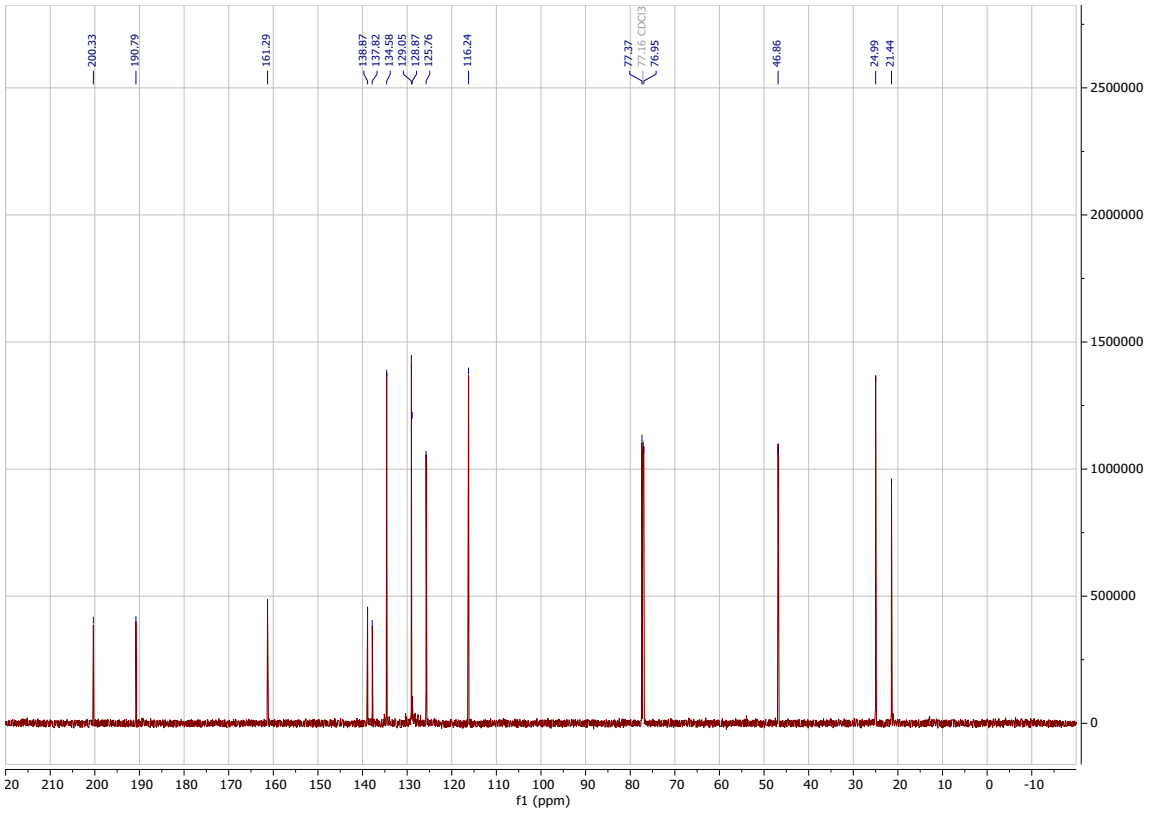

8.06
8.05
7.77
7.75
7.26 CDCl3
7.26
7.25
7.25
3.25
3.25
3.24
3.23
3.22
3.18
3.17
3.16
3.15
3.15
3.14
3.14
3.13
2.00
2.01
0.99
2.02
2.00
f1 (ppm)

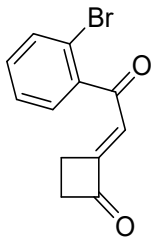

199.80
189.69
162.90
140.35
135.28
135.06
134.85
134.63
128.82
126.30
126.12
126.09
126.07
126.05
124.49
122.69
120.88
115.15
77.37
77.16 CDCl3
76.95
47.08
25.30
f1 (ppm)



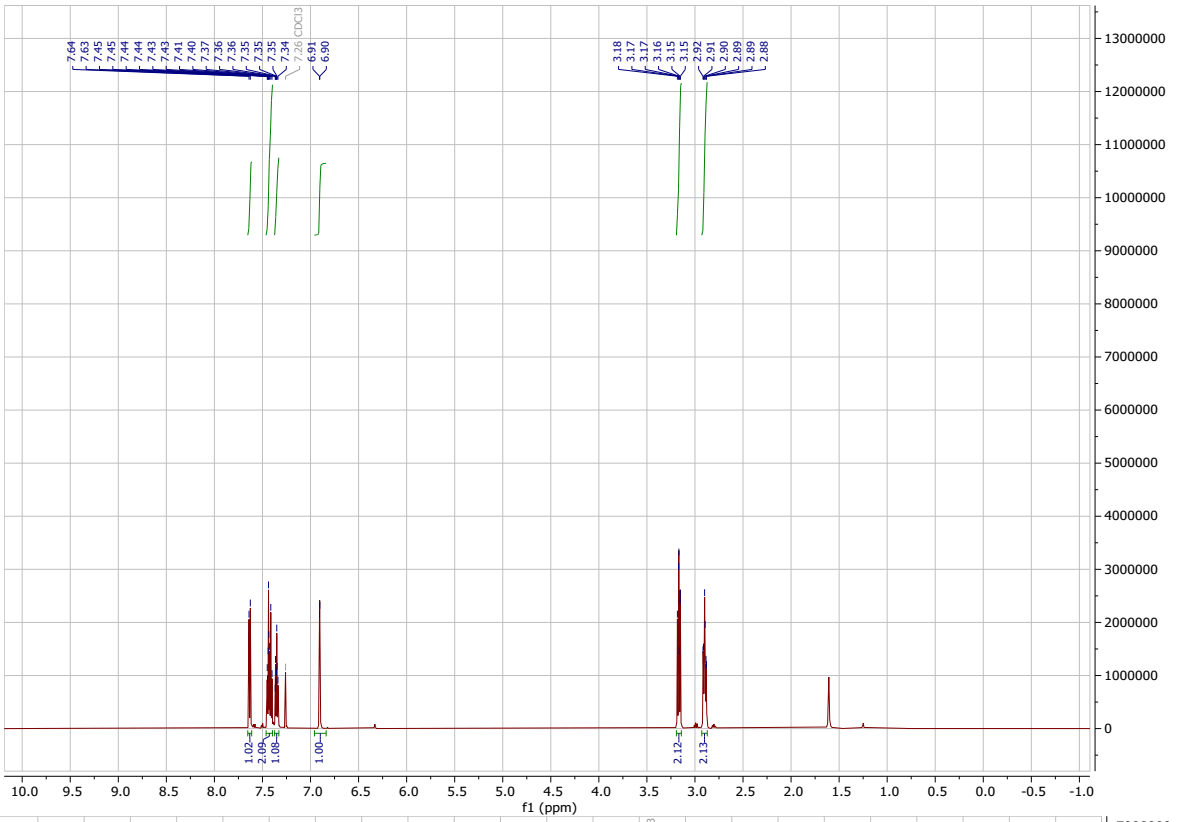
**3k**

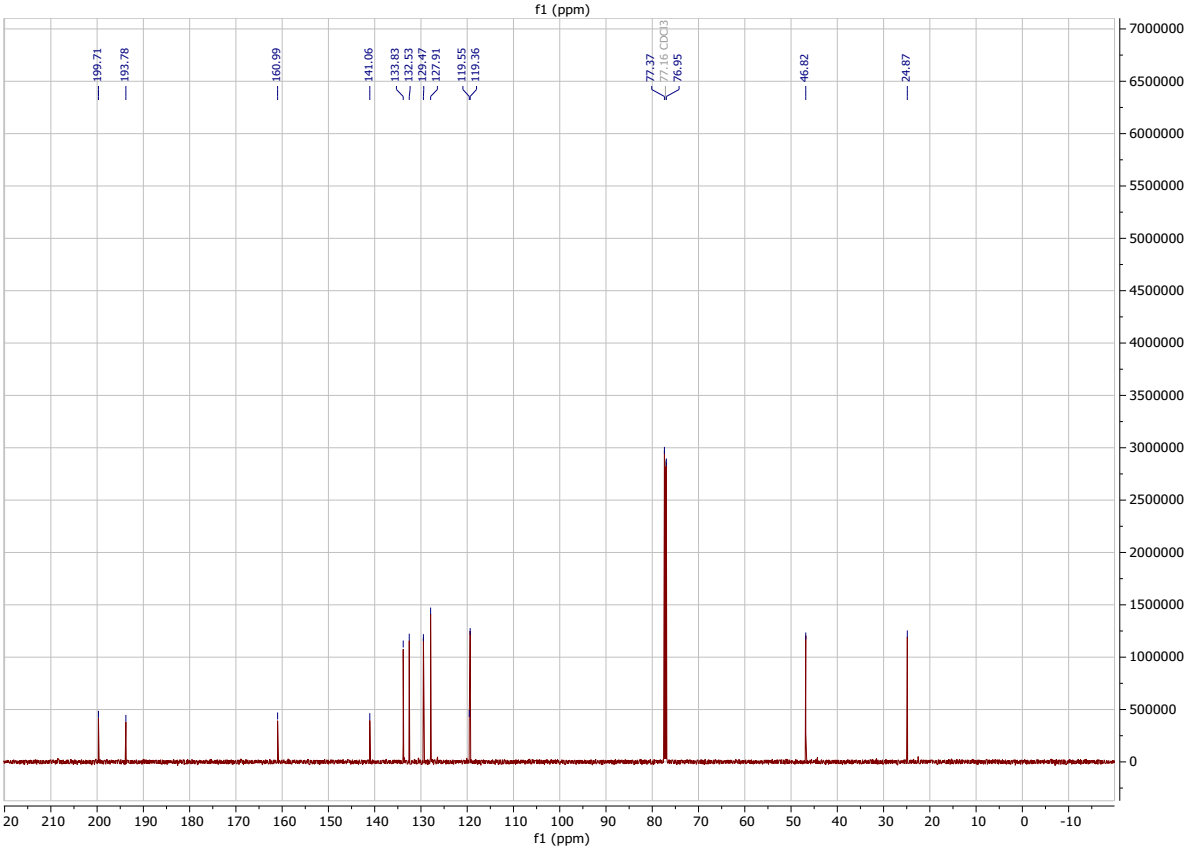

7.69
7.68
7.67
7.34
7.33
7.31
7.30
7.29
7.20
7.19
7.19
3.14
3.14
3.13
3.12
3.11
3.07
3.07
3.07
3.06
3.06
3.05
3.05
3.04
2.34
2.01
2.06
1.00
1.90
1.87
3.00
f1 (ppm)

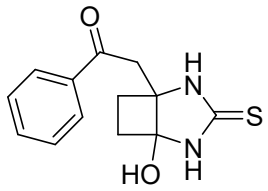

200.33
190.79
161.29
138.87
137.82
134.58
129.05
128.87
125.76
116.24
77.37
77.16 CDCl3
76.95
46.86
24.99
21.44
f1 (ppm)


Br
O
O

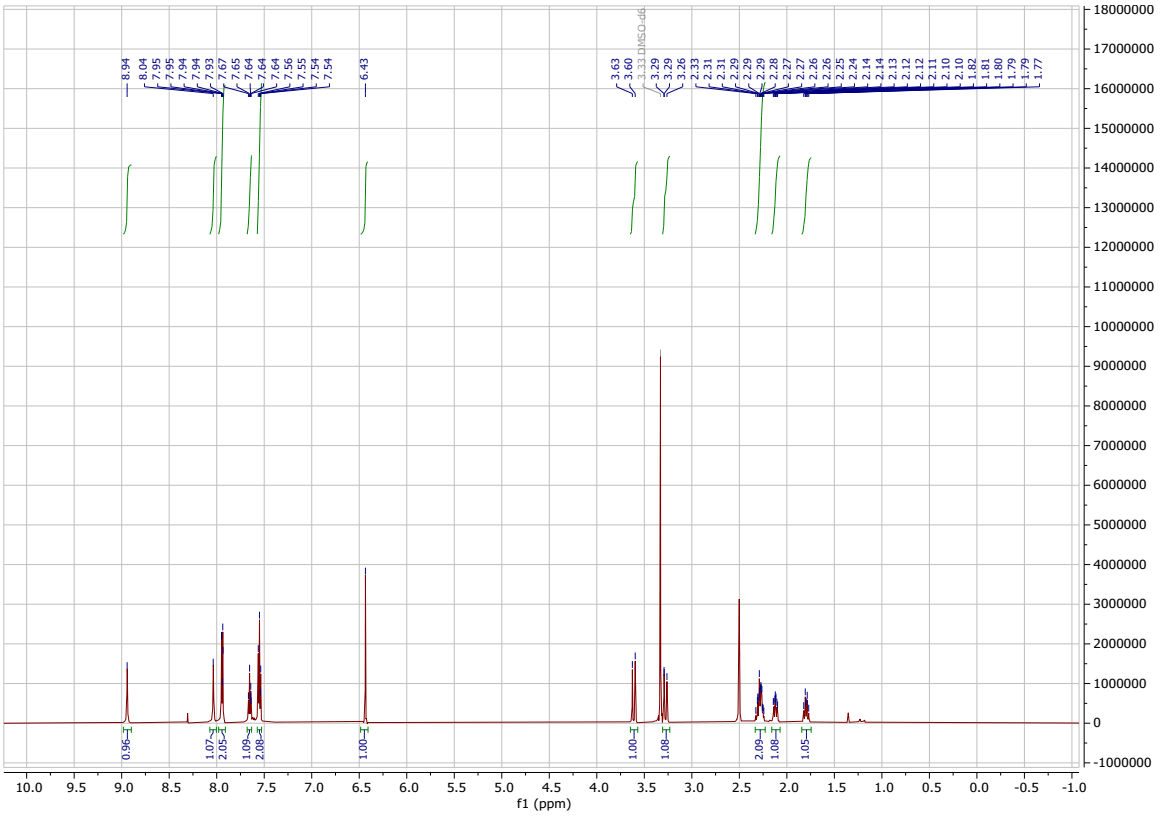
**3l**

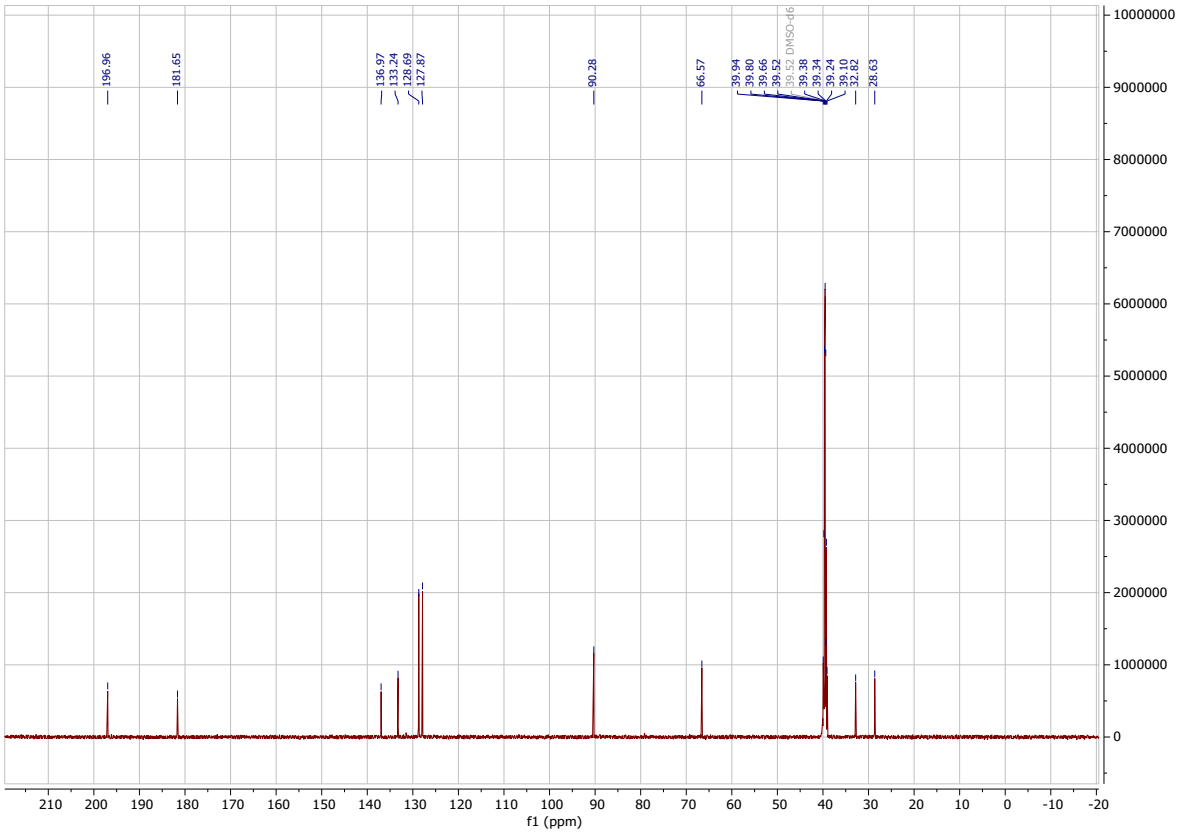

7.64
7.63
7.45
7.45
7.44
7.44
7.43
7.43
7.41
7.40
7.37
7.36
7.36
7.35
7.35
7.35
7.34
7.26 CDCl3
6.91
6.90
3.18
3.17
3.17
3.16
3.15
3.15
2.92
2.91
2.90
2.89
2.89
2.88
1.02
2.09
1.08
1.00
2.12
2.13
f1 (ppm)

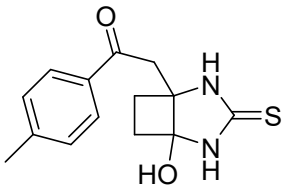

199.71
193.78
160.99
141.06
133.83
132.53
129.47
127.91
119.55
119.36
77.37
77.16 CDCl3
76.95
46.82
24.87
f1 (ppm)


O
H
N
S
N
H
HO

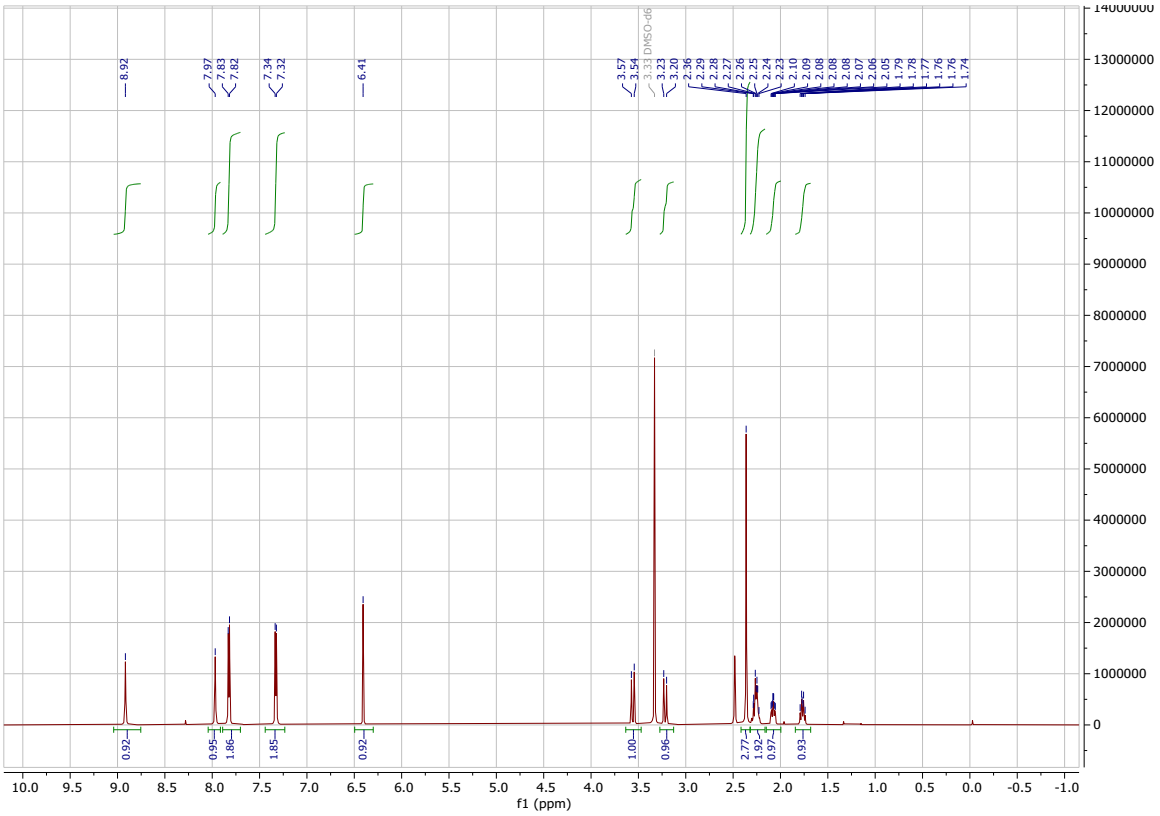
**5a**

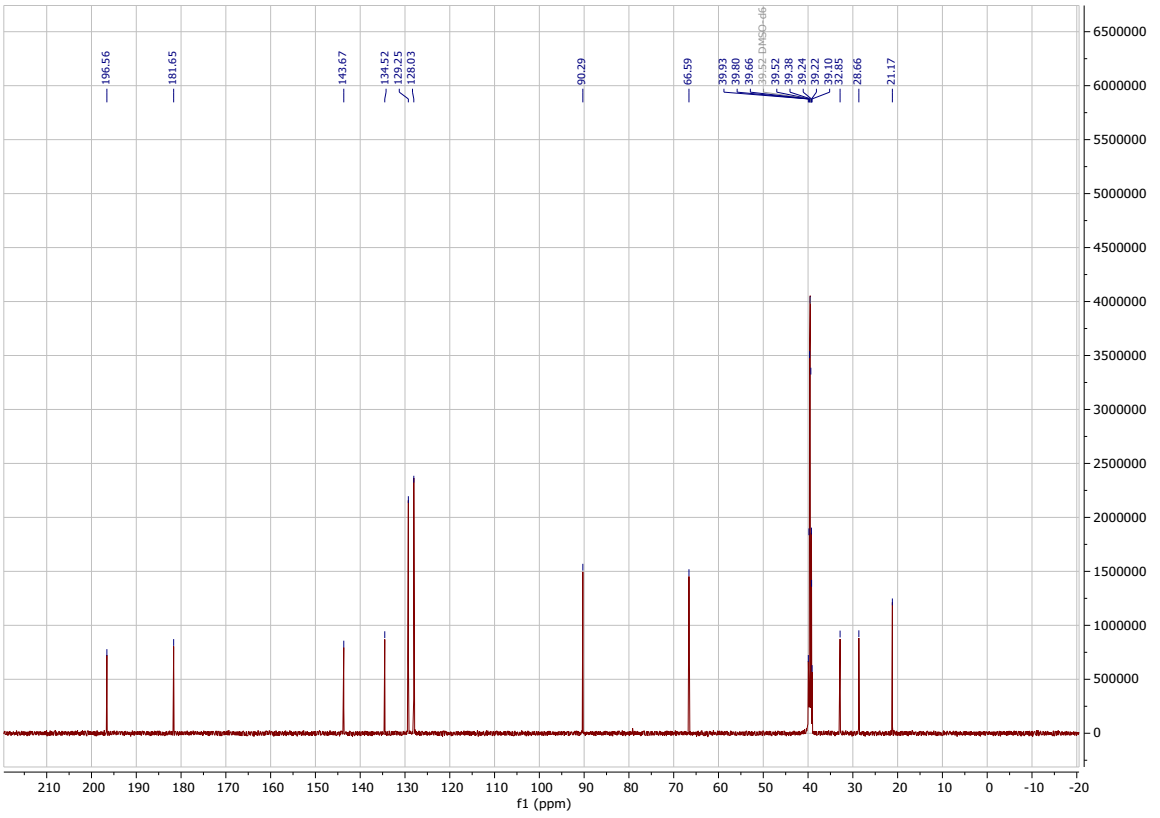

8.94
8.04
7.95
7.95
7.94
7.94
7.93
7.67
7.65
7.64
7.64
7.56
7.55
7.54
7.54
6.43
3.63
3.60
3.35 DMSO-d6
3.29
3.29
3.26
3.33
2.31
2.31
2.29
2.29
2.29
2.28
2.27
2.27
2.26
2.26
2.25
2.24
2.14
2.13
2.12
2.12
2.11
2.10
2.10
1.82
1.81
1.80
1.79
1.79
1.77
0.96
1.07
2.05
1.09
2.08
1.00
1.00
1.08
2.09
1.08
1.05
f1 (ppm)

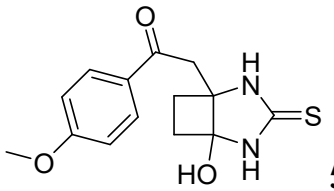

196.96
181.65
136.97
133.24
128.69
127.87
90.28
66.57
39.94
39.80
39.66
39.52
39.38
39.34
39.24
39.10
32.82
28.63
39.52 DMSO-d6
f1 (ppm)


O
H
N
S
N
H
HO

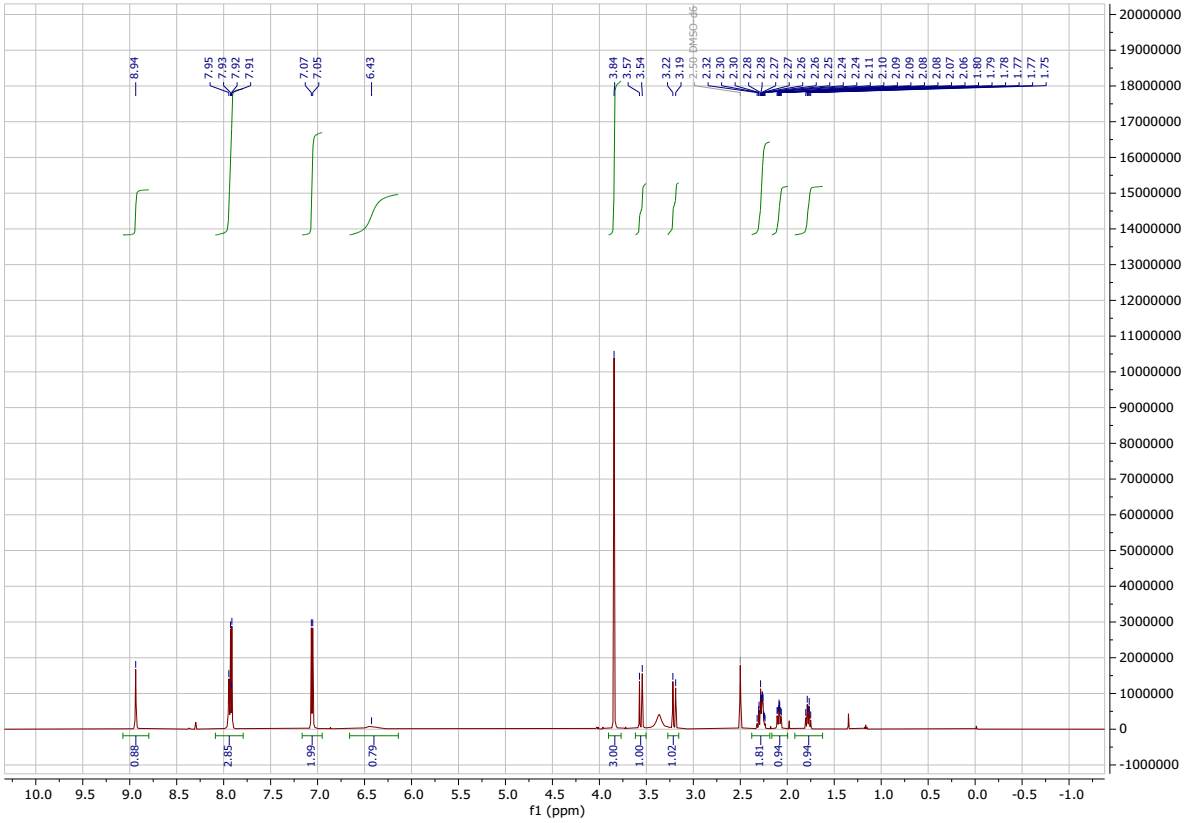
**5b**

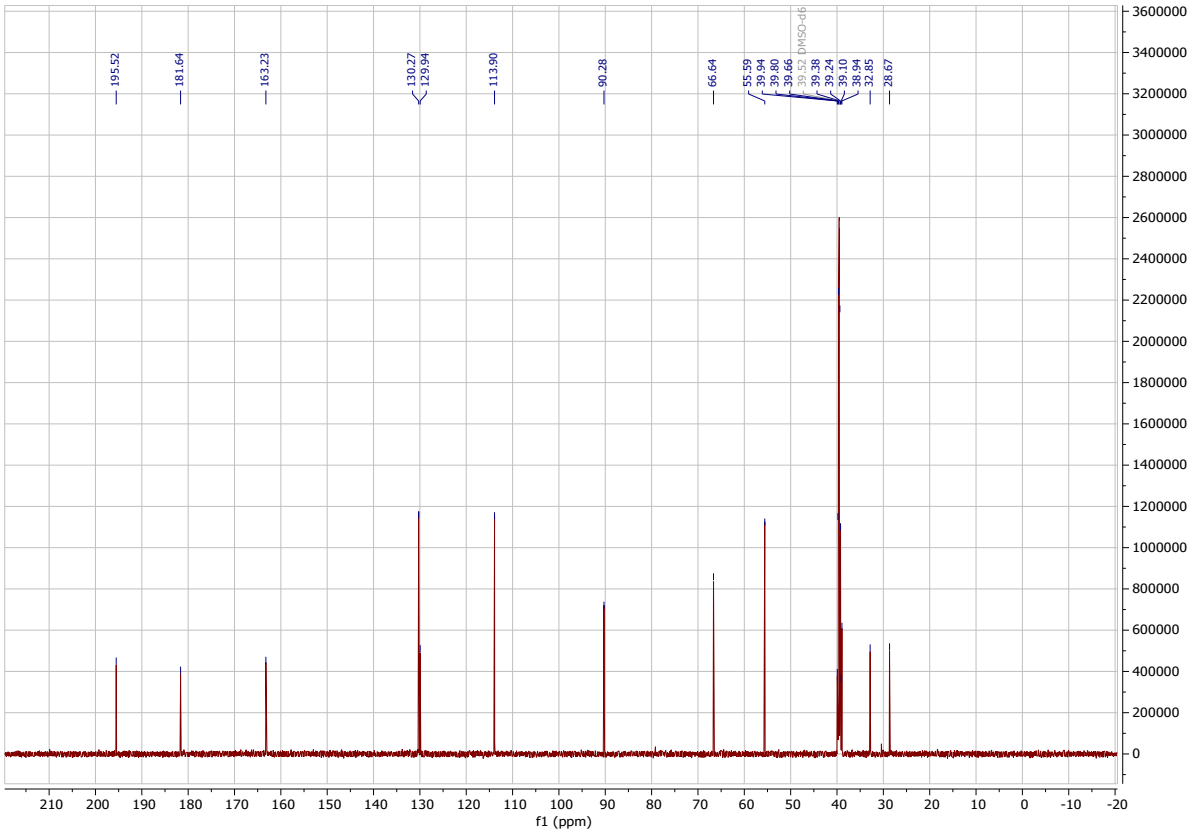

8.92
7.97
7.83
7.82
7.34
7.32
6.41
3.57
3.54
3.33 DMSO-d6
3.23
3.20
2.36
2.29
2.28
2.27
2.26
2.25
2.24
2.23
2.10
2.09
2.08
2.08
2.08
2.07
2.06
2.05
1.79
1.78
1.77
1.76
1.76
1.74
0.92
0.95
1.86
1.85
0.92
1.00
0.96
2.77
1.92
0.97
0.93
f1 (ppm)

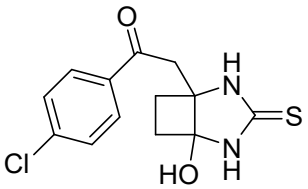

196.56
181.65
143.67
134.52
129.25
128.03
90.29
66.59
39.93
39.80
39.66
39.52 DMSO-d6
39.52
39.38
39.24
39.22
39.10
32.85
28.66
21.17
f1 (ppm)


O
H
N
S
N
H
HO
O

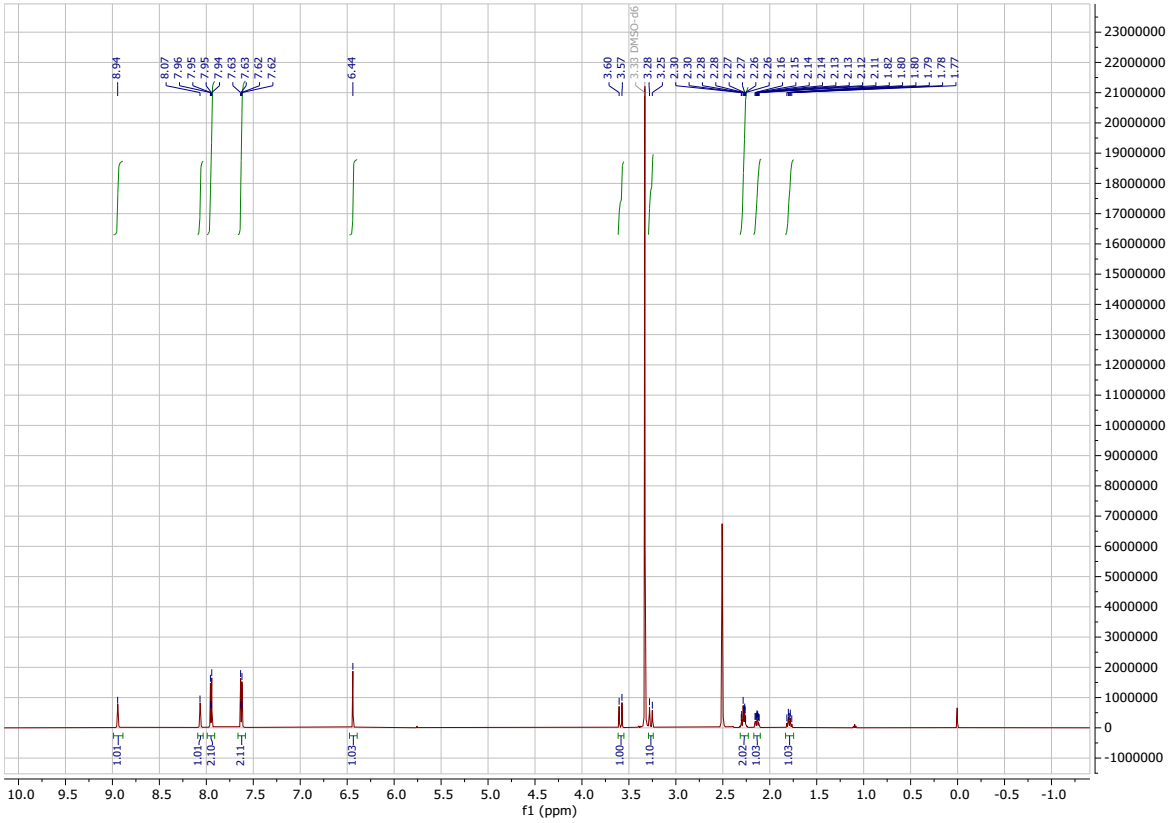
**5c**

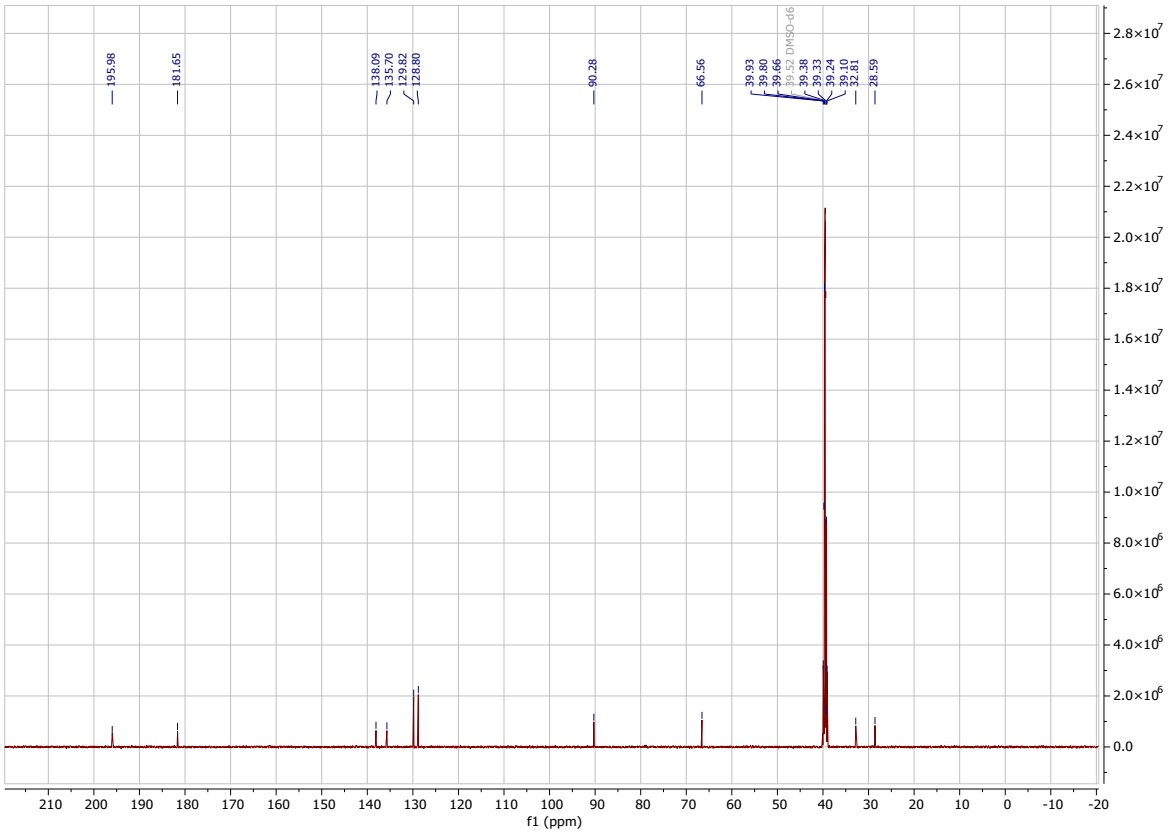

8.94
7.95
7.93
7.92
7.91
7.07
7.05
6.43
3.84
3.57
3.54
3.22
3.19
2.50 DMSO-d6
0.88
2.85
1.99
0.79
3.00
1.00
1.02
1.81
0.94
0.94
f1 (ppm)

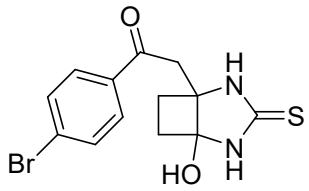

195.52
181.64
163.23
130.27
129.94
113.90
90.28
66.64
55.59
39.94
39.80
39.66
39.52 DMSO-d6
39.38
39.24
39.10
38.94
32.85
28.67
f1 (ppm)


O
H
N
S
Cl
HO
N
H

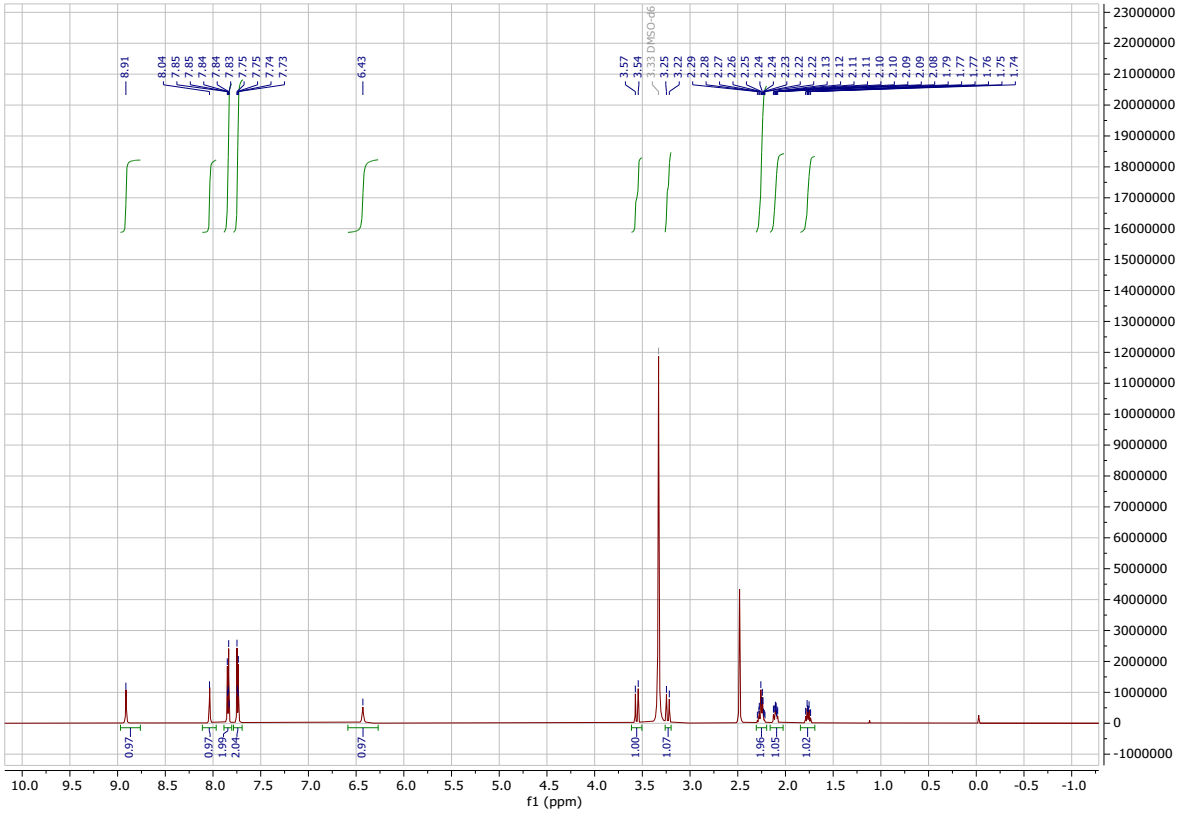
**5d**

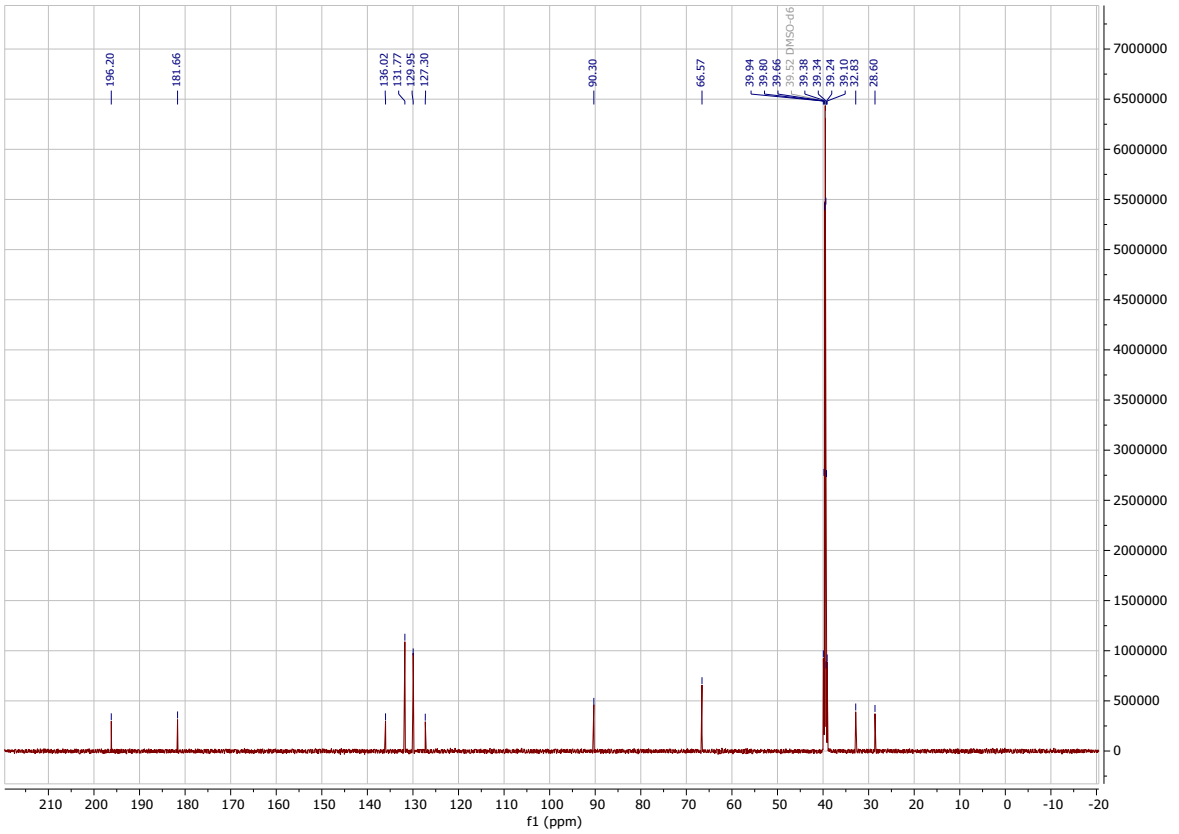

8.94
8.07
7.96
7.95
7.95
7.94
7.63
7.62
7.62
6.44
3.60
3.57
3.28
3.25
2.30
2.30
2.28
2.28
2.27
2.27
2.26
2.26
2.16
2.15
2.14
2.14
2.13
2.13
2.12
2.11
1.82
1.80
1.80
1.79
1.78
1.77
1.01
1.01
2.10
2.11
1.03
1.00
1.10
2.02
1.03
1.03
f1 (ppm)

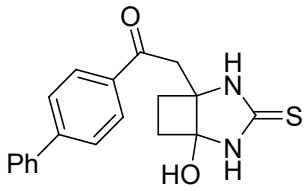

195.98
181.65
138.09
135.70
129.82
128.80
90.28
66.56
39.93
39.80
39.66
39.38
39.33
39.24
39.10
32.81
28.59
f1 (ppm)


O
H
N
S
Br
HO
N
H

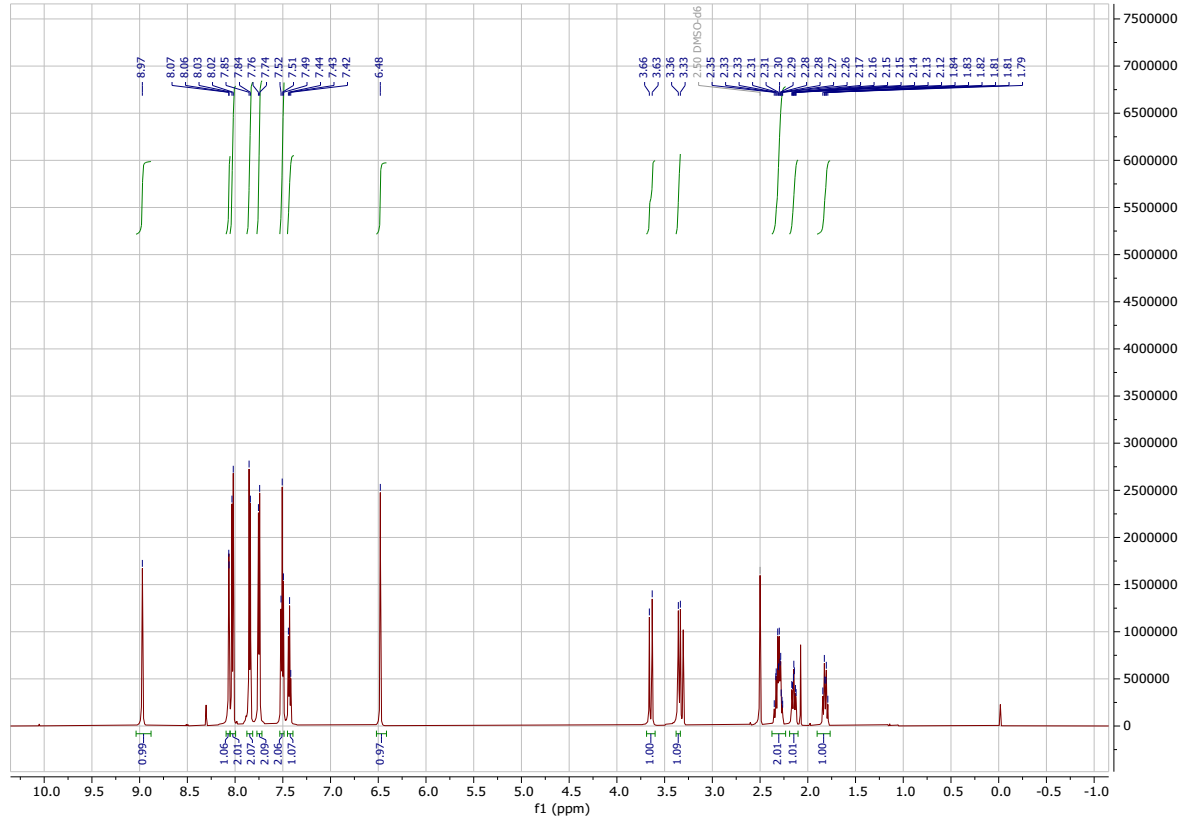
**5e**

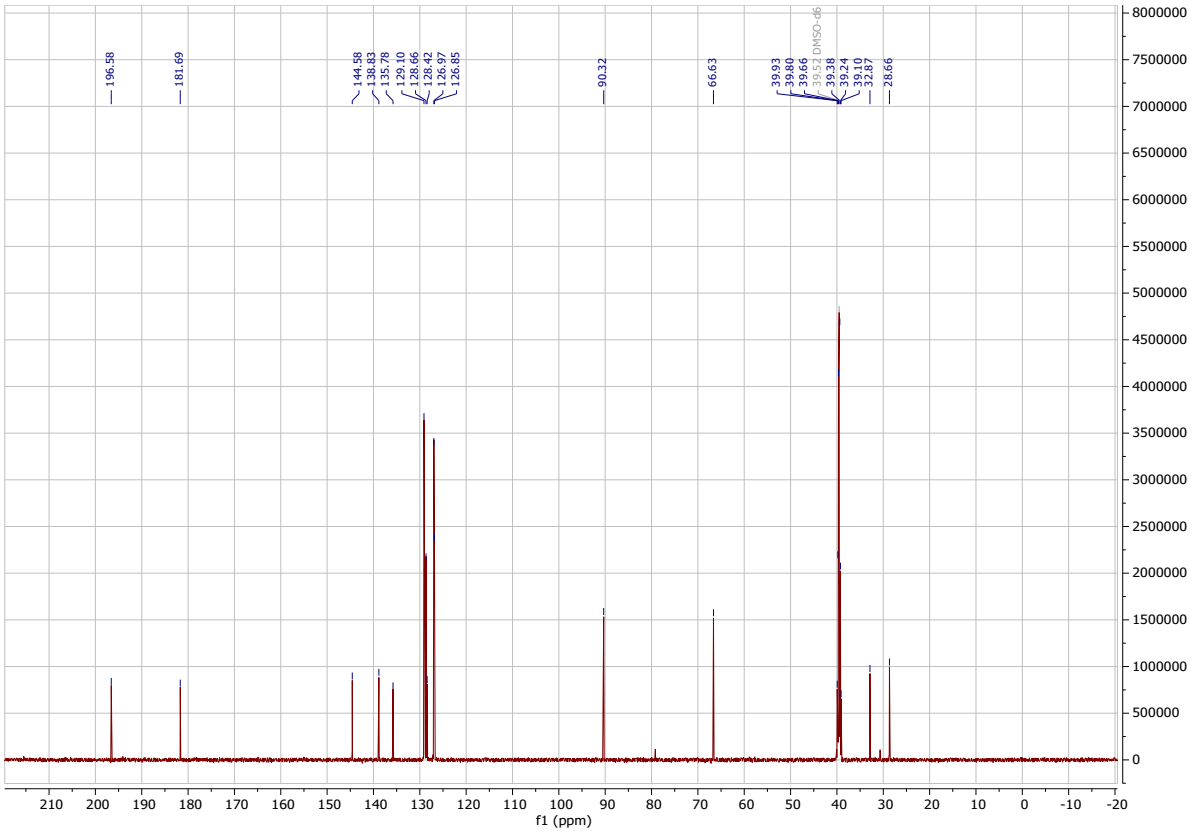

8.91
8.04
7.85
7.85
7.84
7.84
7.83
7.75
7.75
7.74
7.73
6.43
3.57
3.54
3.35
DMSO-d6
3.25
3.22
2.29
2.28
2.27
2.26
2.25
2.24
2.24
2.24
2.23
2.22
2.22
2.13
2.12
2.11
2.11
2.10
2.09
2.09
2.08
1.79
1.77
1.77
1.76
1.75
1.74
0.97
0.97
1.99
2.04
0.97
1.00
1.07
1.96
1.05
1.02
f1 (ppm)

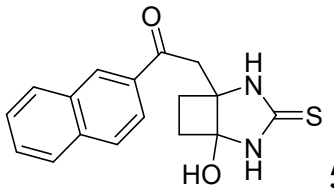

196.20
181.66
136.02
131.77
129.95
127.30
90.30
66.57
39.94
39.80
39.66
39.52
DMSO-d6
39.38
39.24
39.10
32.83
28.60
f1 (ppm)


O
H
N
S
Ph
HO
N
H

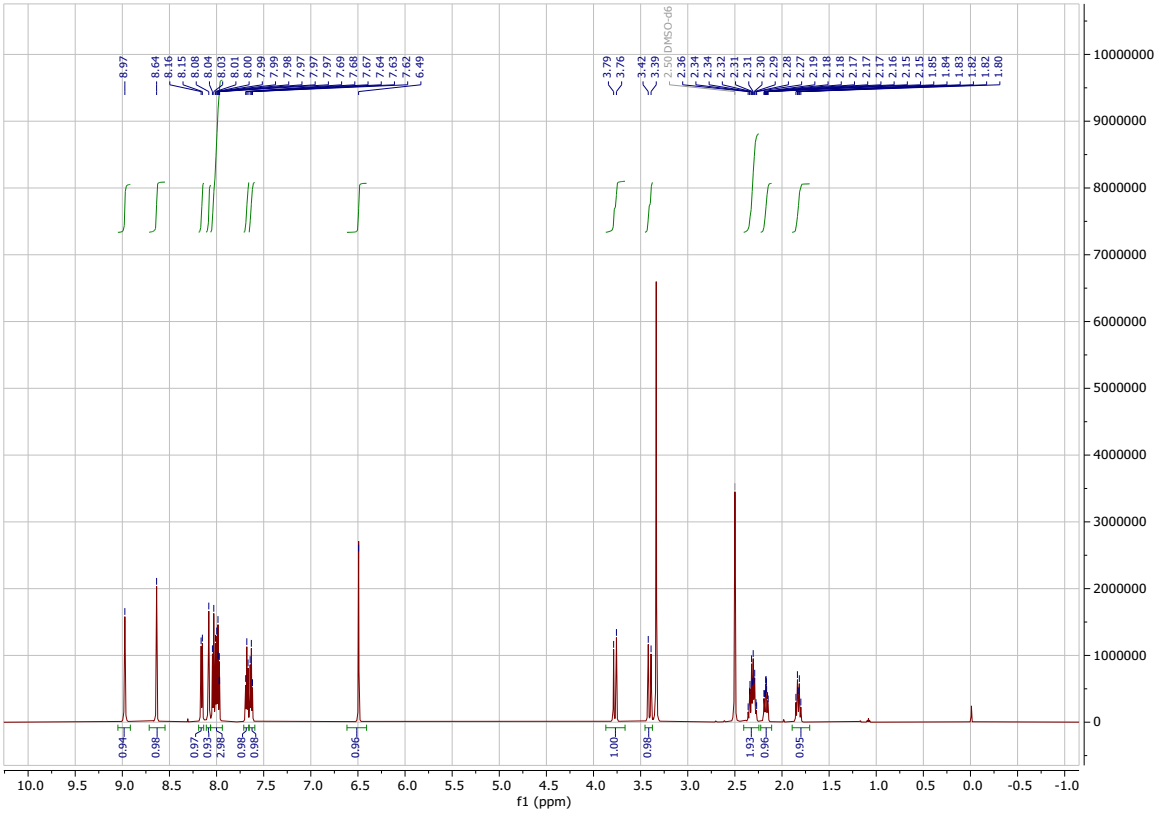
**5f**

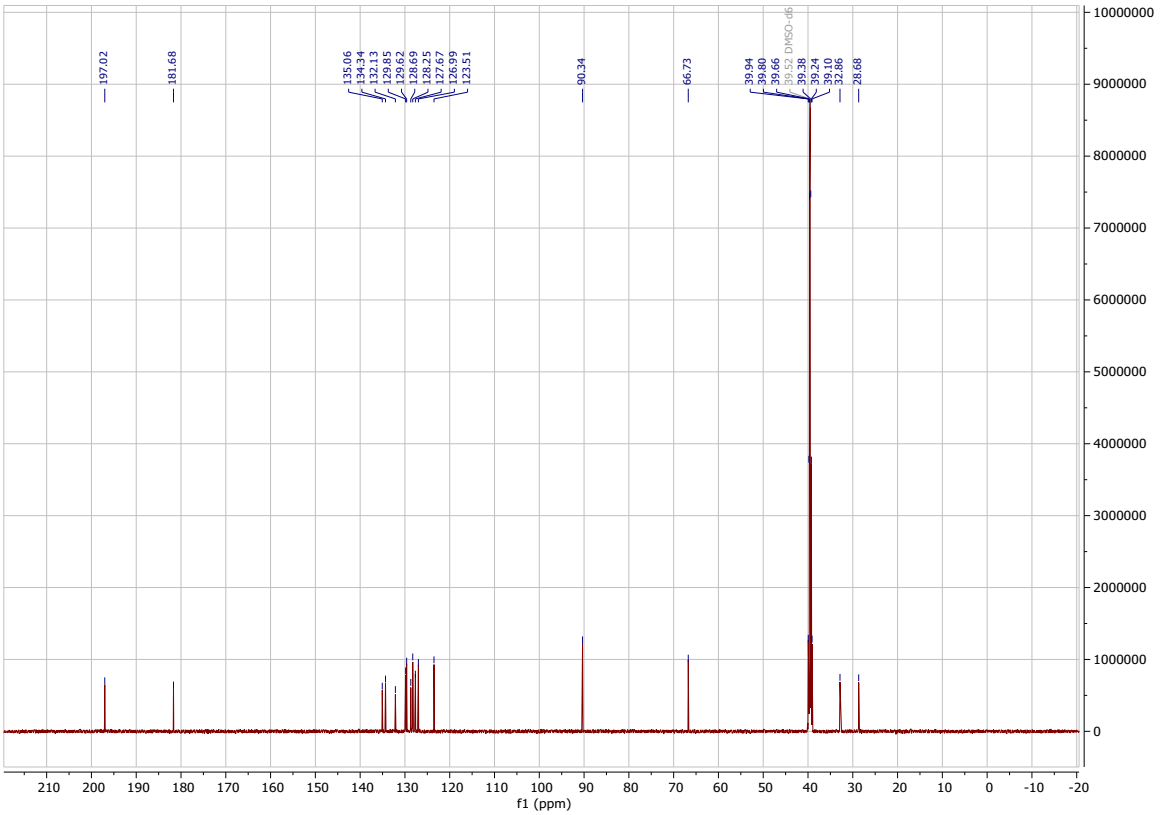

8.97
8.07
8.06
8.03
8.02
7.85
7.84
7.76
7.74
7.52
7.51
7.49
7.44
7.43
7.42
6.48
3.66
3.63
3.36
3.33
2.50 DMSO-d6
2.35
2.33
2.33
2.31
2.31
2.30
2.29
2.28
2.28
2.27
2.26
2.17
2.16
2.15
2.15
2.14
2.13
2.12
1.84
1.83
1.82
1.81
1.81
1.79
0.99
1.06
2.01
2.07
2.09
2.06
1.07
0.97
1.00
1.09
2.01
1.01
1.00
f1 (ppm)

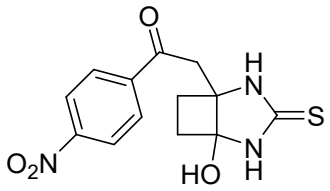

196.58
181.69
144.58
138.83
135.78
129.10
128.66
128.42
126.97
126.85
90.32
66.63
39.93
39.80
39.66
39.52 DMSO-d6
39.38
39.24
39.10
32.87
28.66
f1 (ppm)


O
H
N
S
N
H
HO

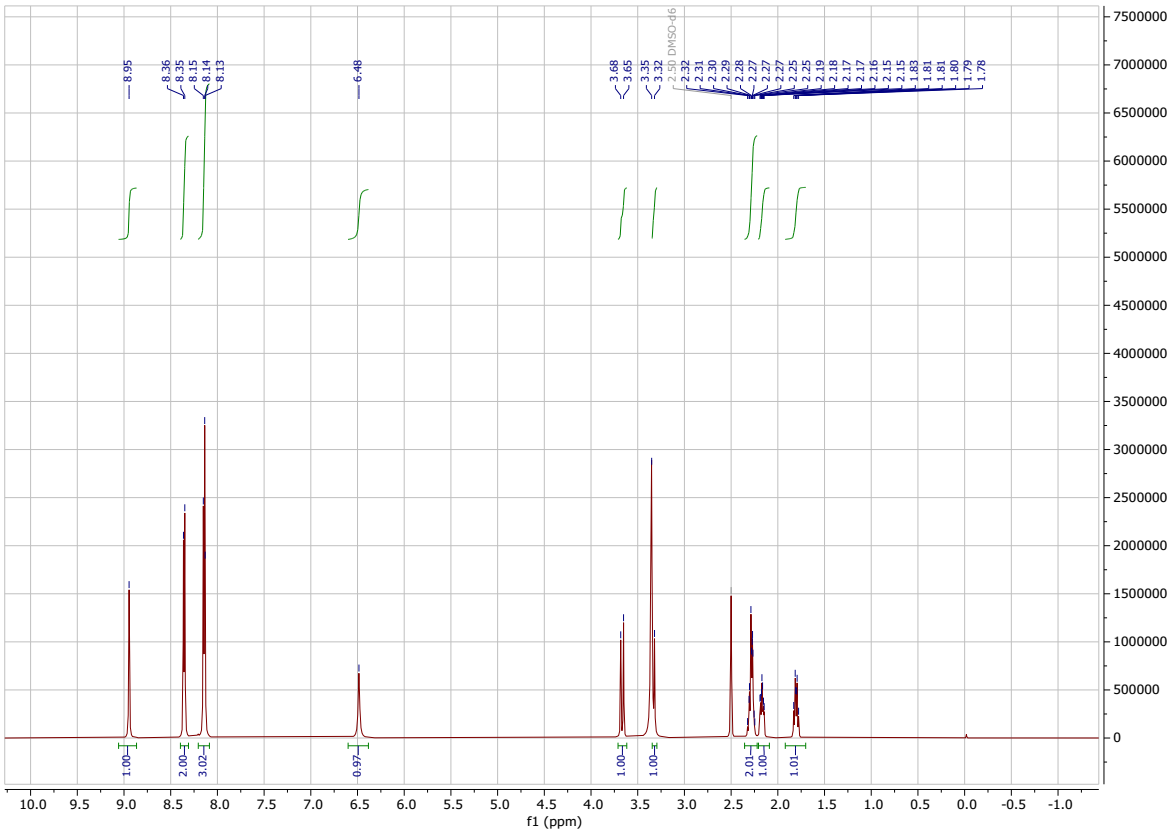
**5g**

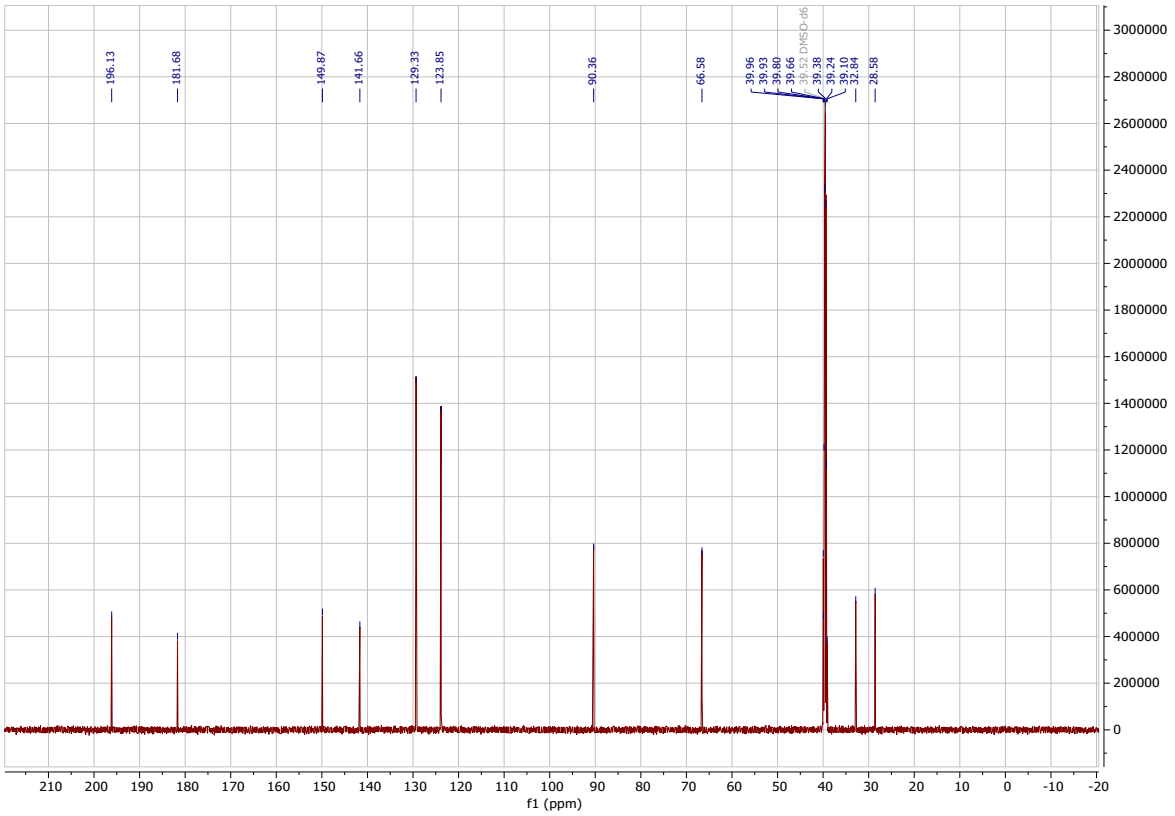

8.97
8.64
8.16
8.15
8.08
8.04
8.03
8.01
8.00
7.99
7.98
7.97
7.97
7.97
7.69
7.68
7.67
7.64
7.63
7.62
6.49
3.79
3.76
3.42
3.39
DMSO-d6
2.35
2.34
2.34
2.32
2.31
2.31
2.30
2.29
2.28
2.27
2.19
2.18
2.18
2.17
2.17
2.16
2.15
2.15
1.85
1.84
1.83
1.82
1.82
1.80
0.94
0.98
0.97
0.93
2.98
0.98
0.98
0.96
1.00
0.98
1.93
0.96
0.95
f1 (ppm)

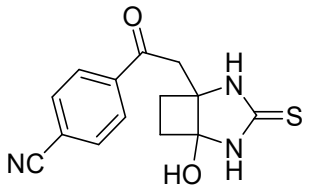

197.02
181.68
135.06
134.34
132.13
129.85
129.62
128.69
128.25
127.67
126.99
123.51
90.34
66.73
39.94
39.80
39.66
39.52
DMSO-d6
39.38
39.24
39.10
32.86
28.68
f1 (ppm)


O
H
N
S
$O_2N$
HO
N
H

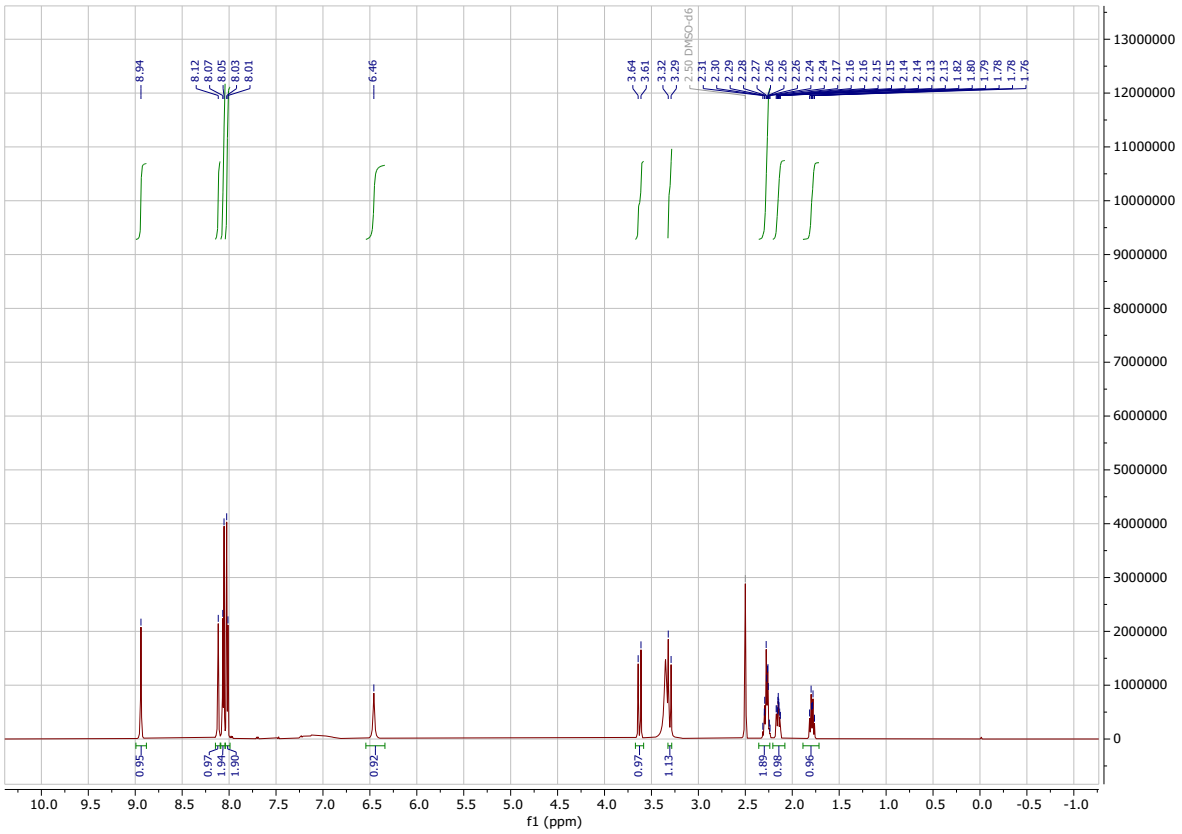
**5h**

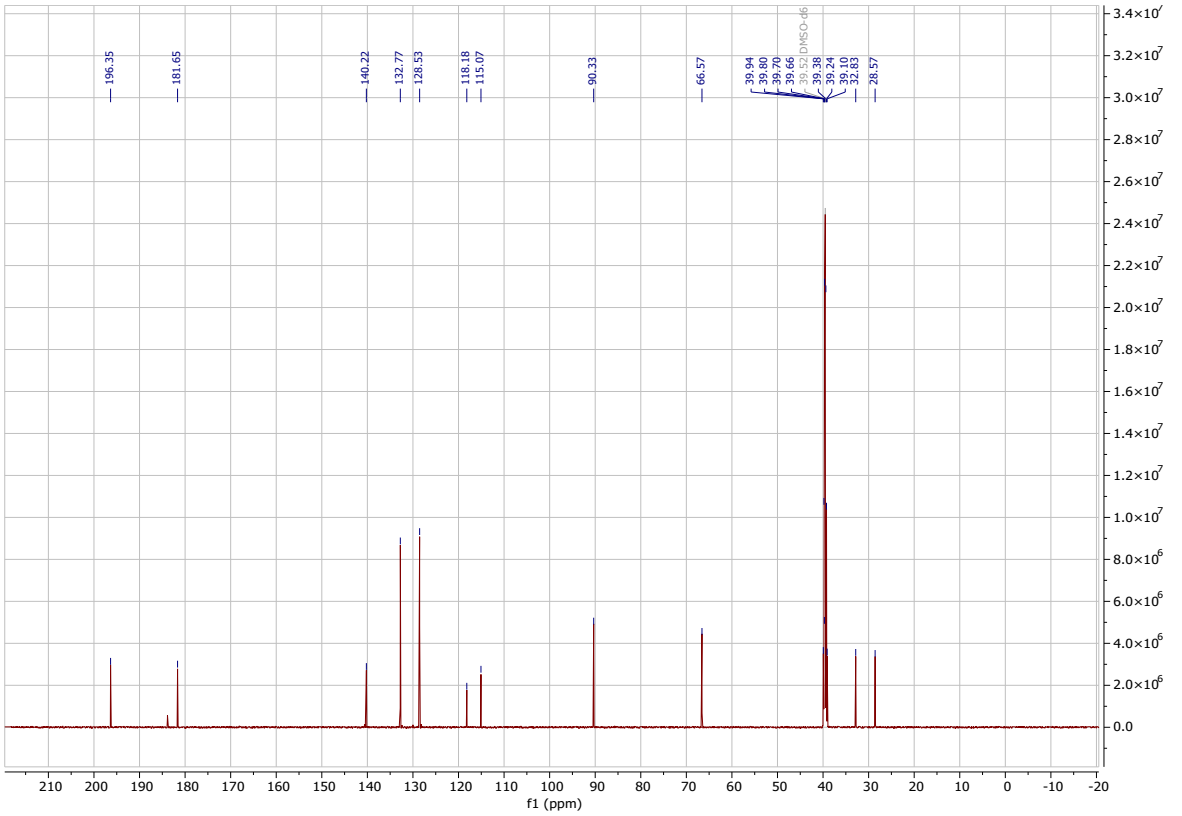

8.95
8.36
8.35
8.15
8.14
8.13
6.48
3.68
3.65
3.35
3.32
2.50 DMSO-d6
2.32
2.31
2.30
2.29
2.28
2.27
2.27
2.27
2.25
2.25
2.19
2.18
2.17
2.17
2.16
2.15
2.15
1.83
1.81
1.81
1.80
1.79
1.78
1.00
2.00
3.02
0.97
1.00
1.00
2.01
1.08
1.01
f1 (ppm)

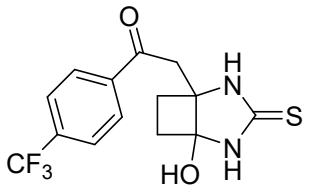

196.13
181.68
149.87
141.66
129.33
123.85
90.36
66.58
39.96
39.93
39.80
39.66
39.52 DMSO-d6
39.38
39.24
39.10
32.84
28.58
f1 (ppm)


O
H
N
S
NC
HO
N
H

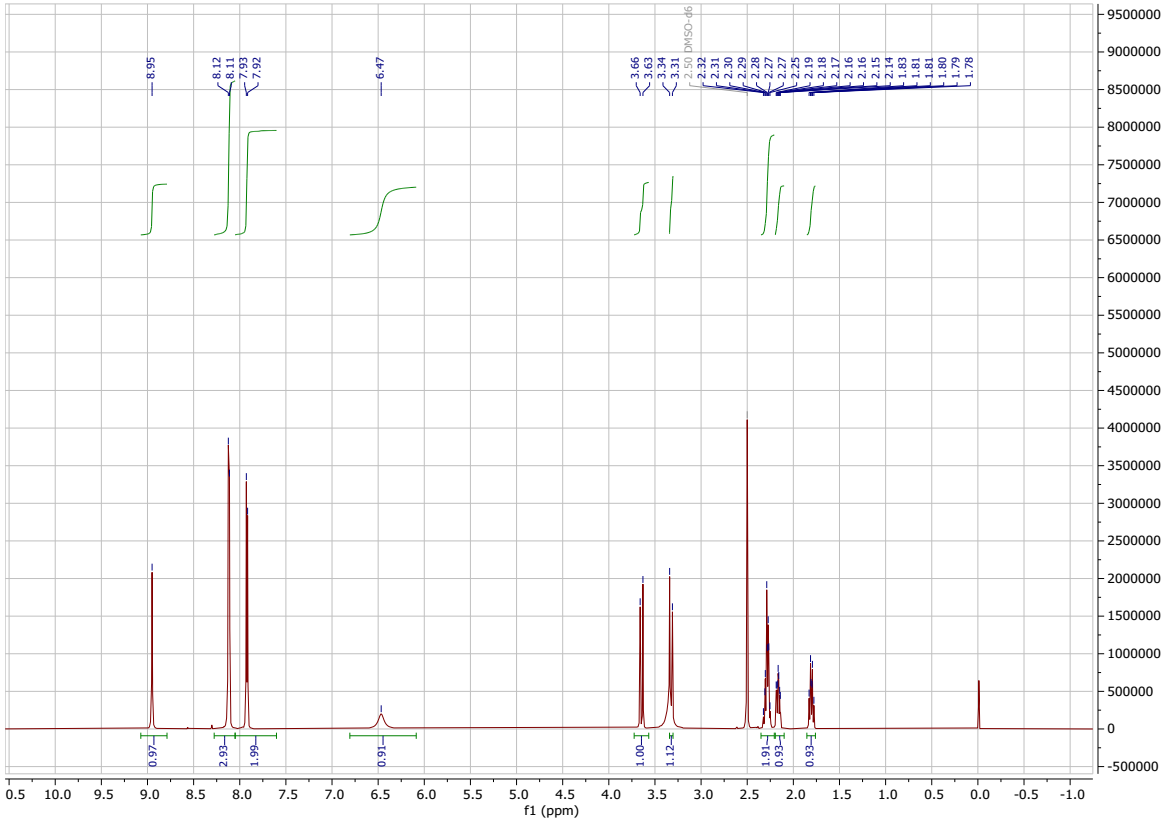
**5i**

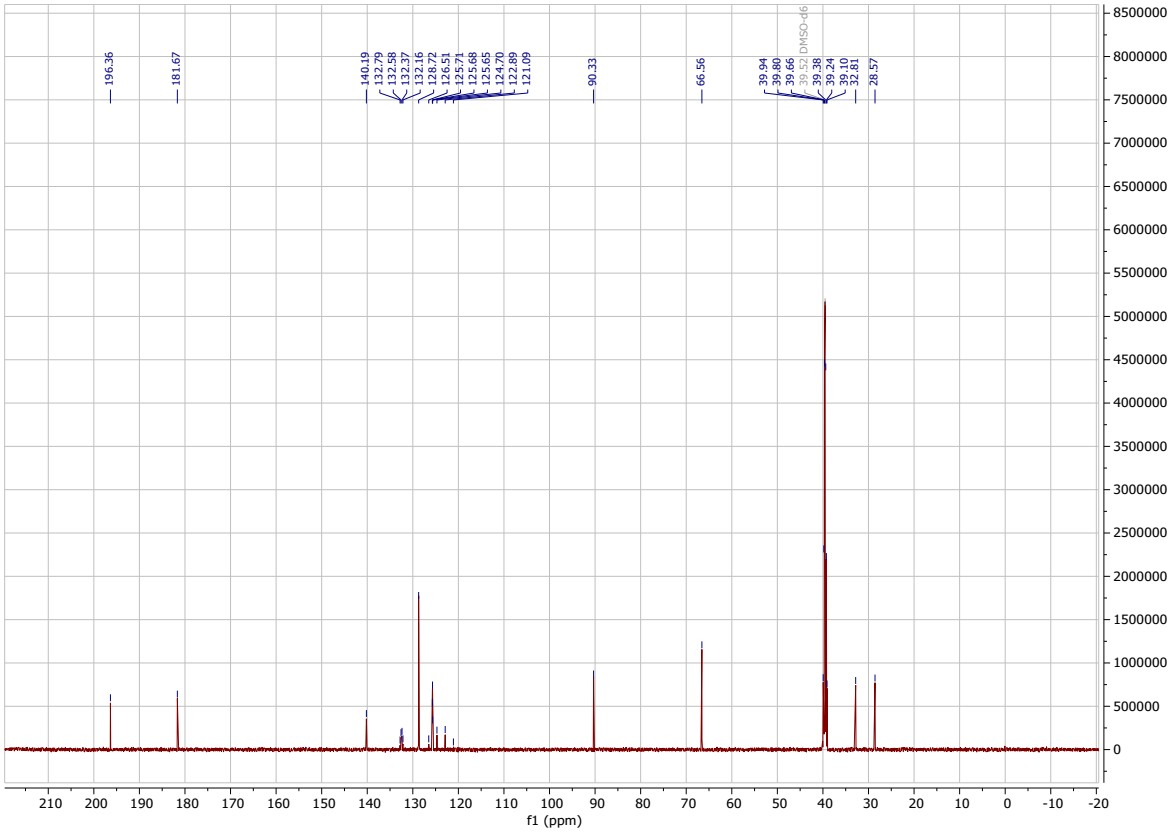

8.94
8.12
8.07
8.05
8.03
8.01
6.46
3.64
3.61
3.32
3.29
2.50 DMSO-d6
0.95
0.97
1.94
1.90
0.92
0.97
1.13
1.89
0.98
0.96
f1 (ppm)

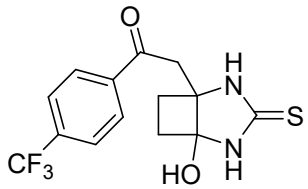

196.35
181.65
140.22
132.77
128.53
118.18
115.07
90.33
66.57
39.94
39.80
39.70
39.66
39.52 DMSO-d6
39.38
39.24
39.10
32.83
28.57
f1 (ppm)


O
H
N
S
N
H
HO
CF3

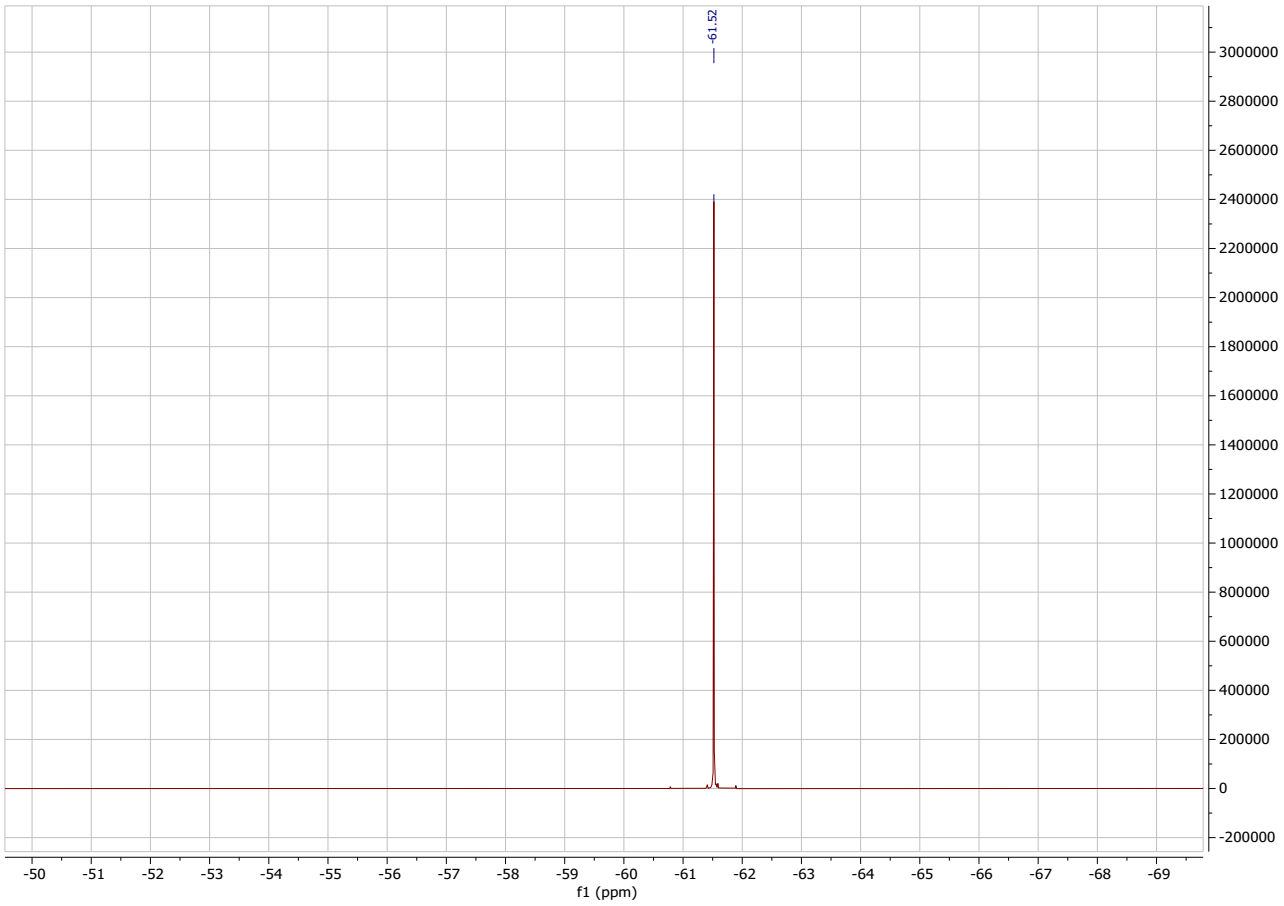
**5j**

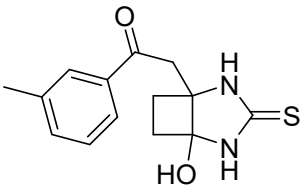

8.95
8.12
8.11
7.93
7.92
6.47
3.66
3.63
3.34
3.31
2.50 DMSO-d6
0.97
2.93
1.99
0.91
1.00
1.12
1.91
0.93
0.93
f1 (ppm)


196.36
181.67
140.19
132.79
132.58
132.37
132.16
128.72
126.51
125.71
125.68
125.65
124.70
122.89
121.09
90.33
66.56
39.94
39.80
39.66
39.52 DMSO-d6
39.38
39.24
39.10
32.81
28.57
f1 (ppm)

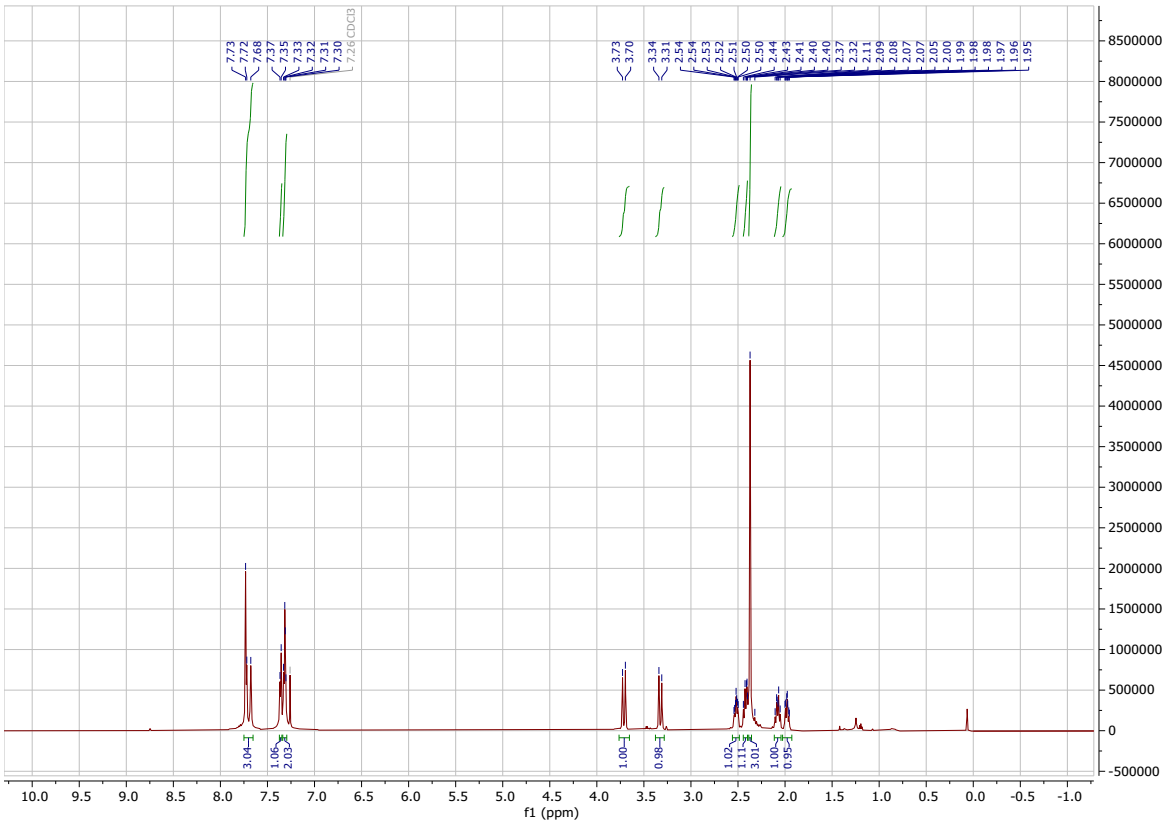

O
H
N
S
N
H
CF3
HO

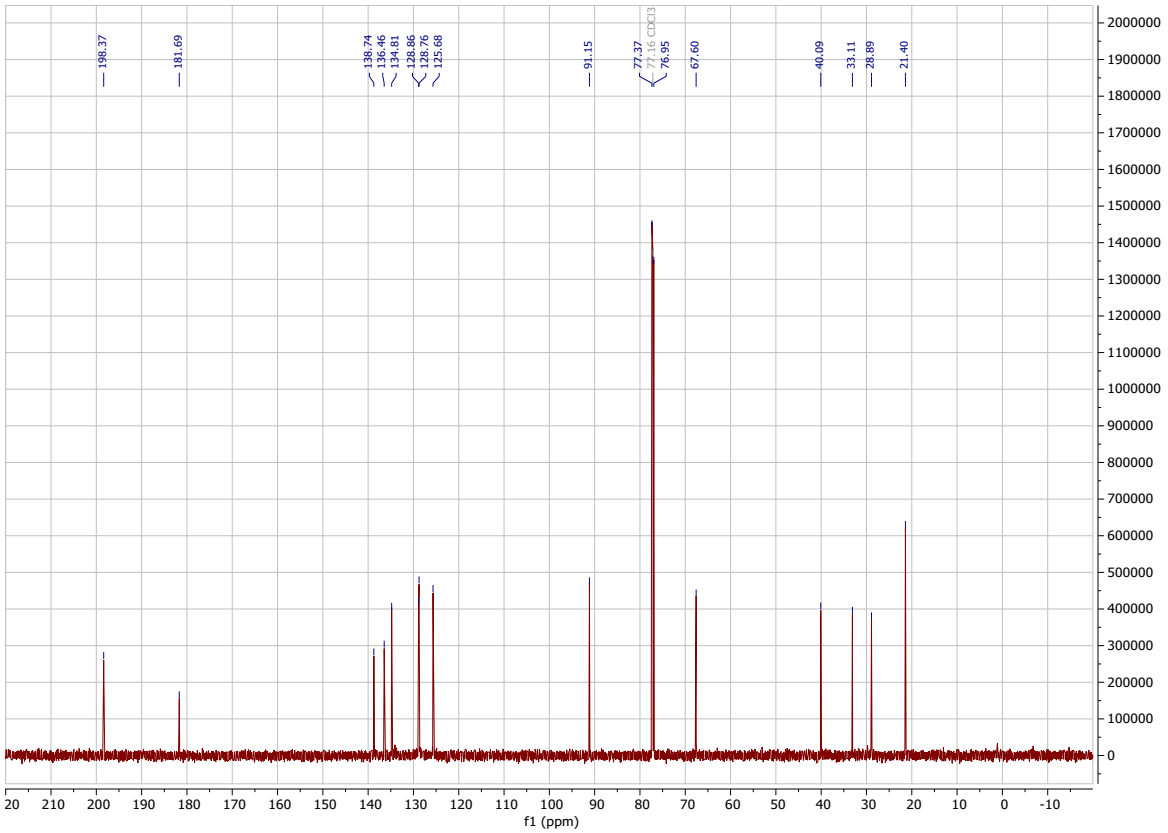
**5j** $^{19}$F NMR

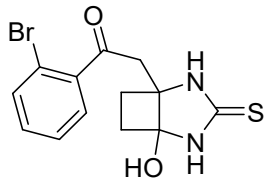

-61.52
3000000
2800000
2600000
2400000
2200000
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
-200000
-50
-51
-52
-53
-54
-55
-56
-57
-58
-59
-60
-61
-62
-63
-64
-65
-66
-67
-68
-69
f1 (ppm)


O
H
N
S
N
H
HO

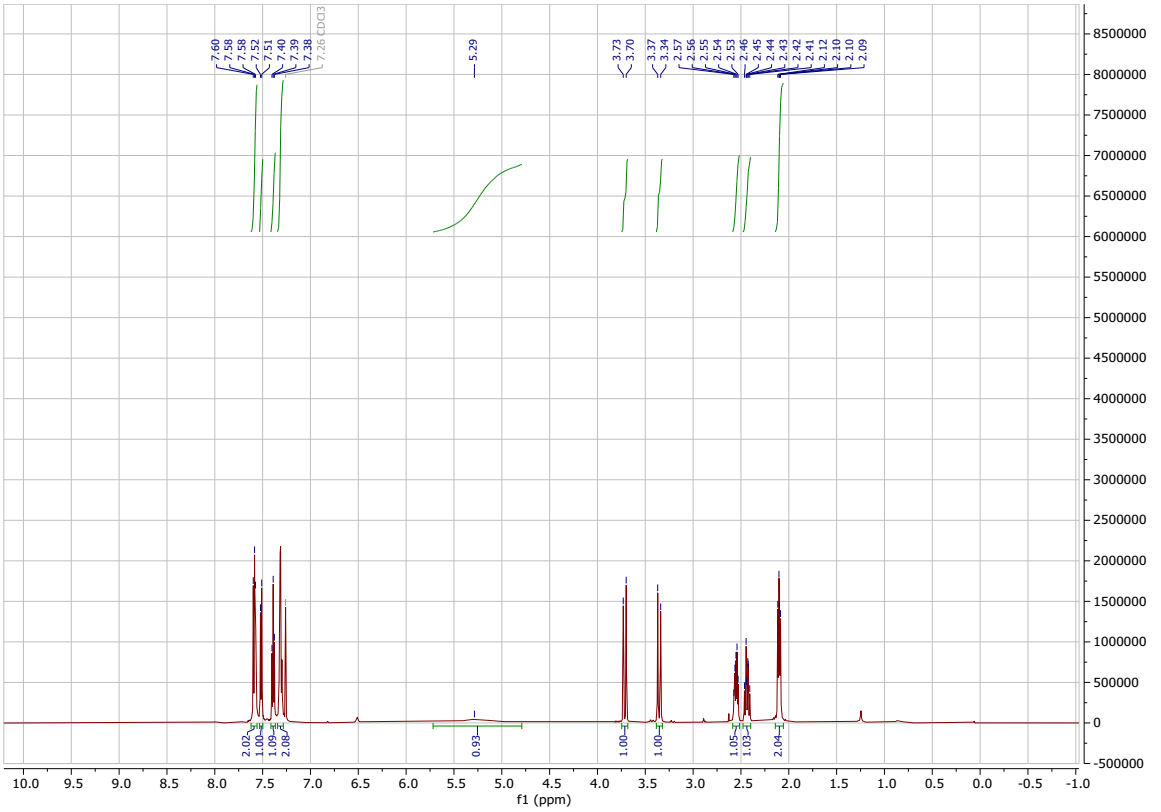
**5k**

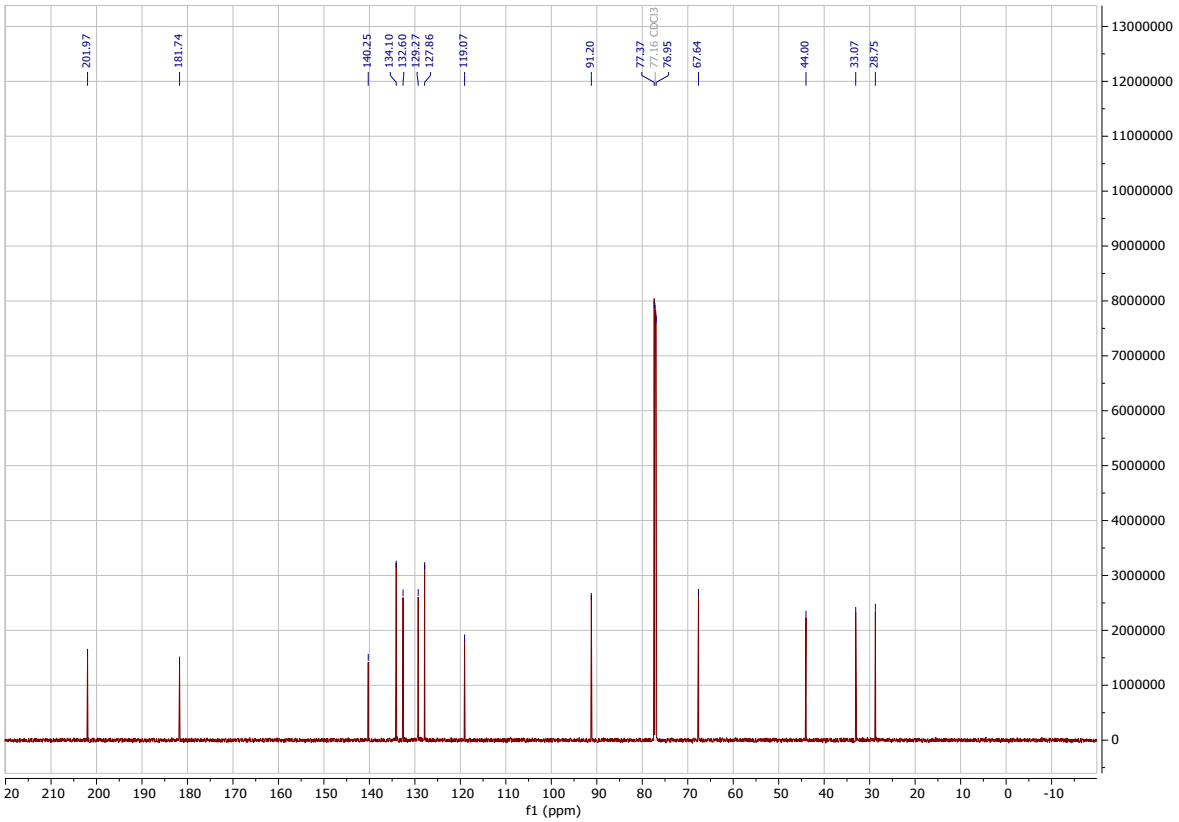

7.73
7.72
7.68
7.37
7.35
7.33
7.32
7.31
7.30
7.26 CDCl3
3.73
3.70
3.34
3.31
2.54
2.54
2.53
2.52
2.51
2.50
2.50
2.44
2.43
2.41
2.40
2.40
2.37
2.32
2.11
2.09
2.08
2.07
2.07
2.05
2.00
1.99
1.98
1.98
1.97
1.96
1.95
3.04
1.06
2.03
1.00
0.98
1.02
1.11
3.01
1.00
0.95
f1 (ppm)

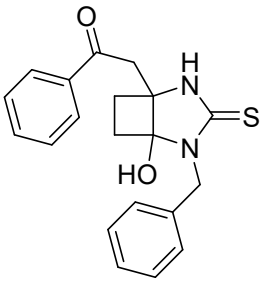

190.37
181.69
138.74
136.46
134.81
128.86
128.76
125.68
91.15
77.37
77.16 CDCl3
76.95
67.60
40.09
33.11
28.89
21.40
f1 (ppm)


Br
O
H
N
S
N
H
HO

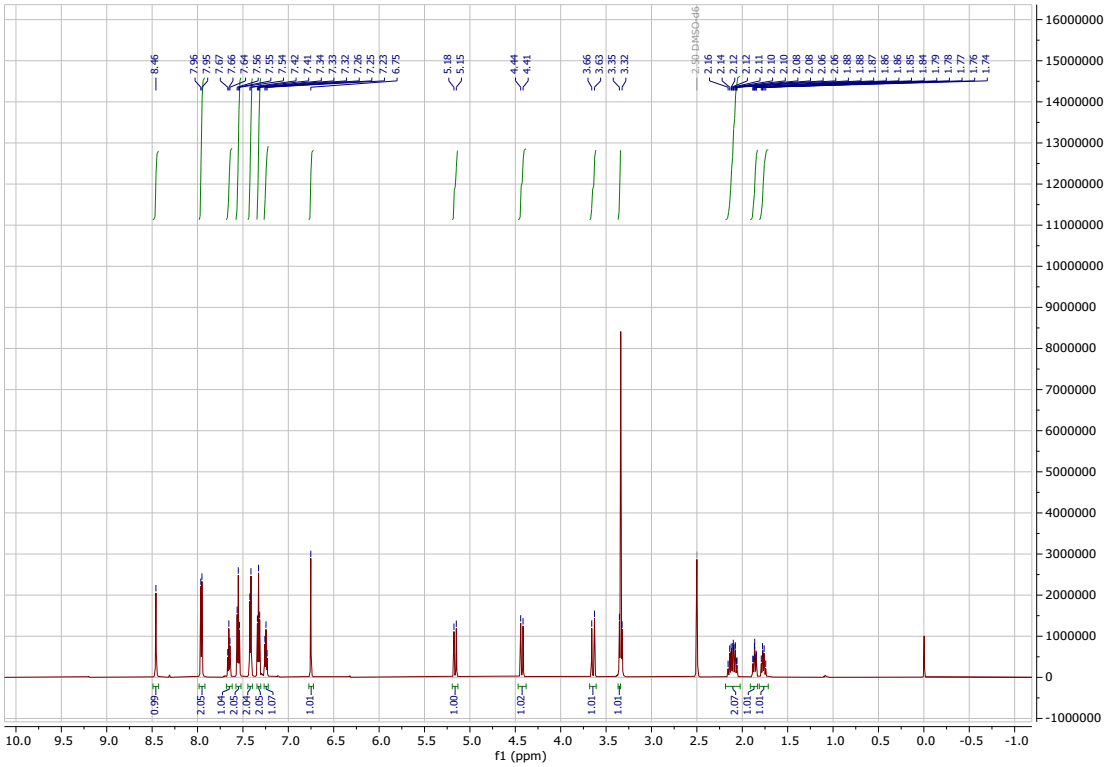
**5l**

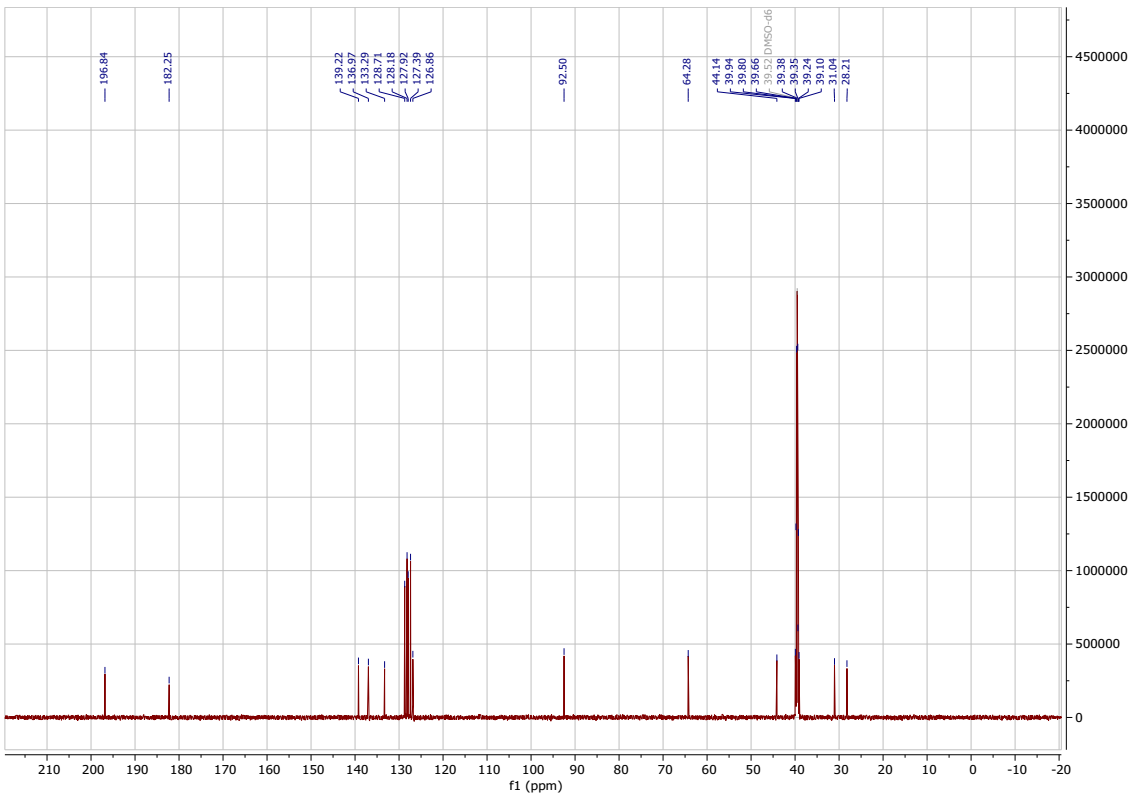

7.60
7.58
7.58
7.52
7.51
7.40
7.39
7.38
7.26 CDCl3
5.29
3.73
3.70
3.37
3.34
2.57
2.56
2.55
2.54
2.53
2.46
2.45
2.44
2.43
2.42
2.41
2.12
2.10
2.10
2.09
2.02
1.00
1.09
2.08
0.93
1.00
1.00
1.05
1.03
2.04
f1 (ppm)

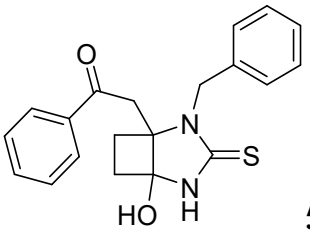

201.97
181.74
140.25
134.10
132.60
129.27
127.86
119.07
91.20
77.37
77.16 CDCl3
76.95
67.64
44.00
33.07
28.75
f1 (ppm)


O
H
N
S
N
HO

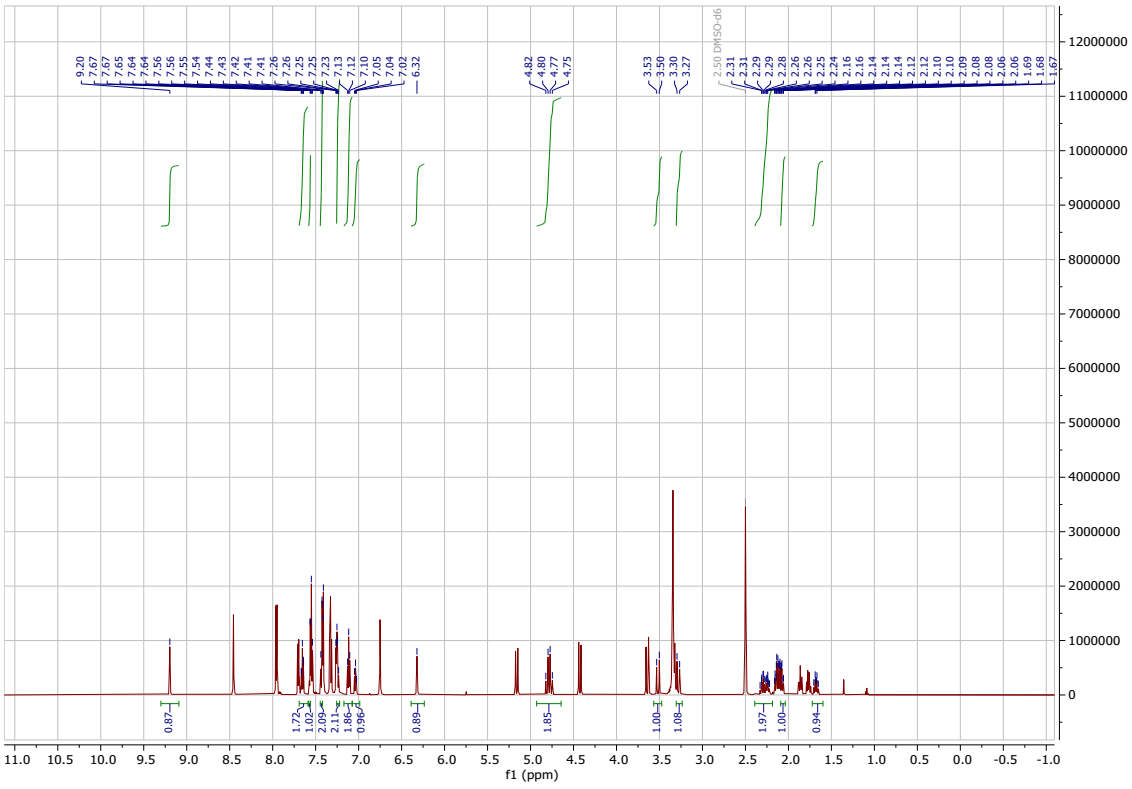
**5m**

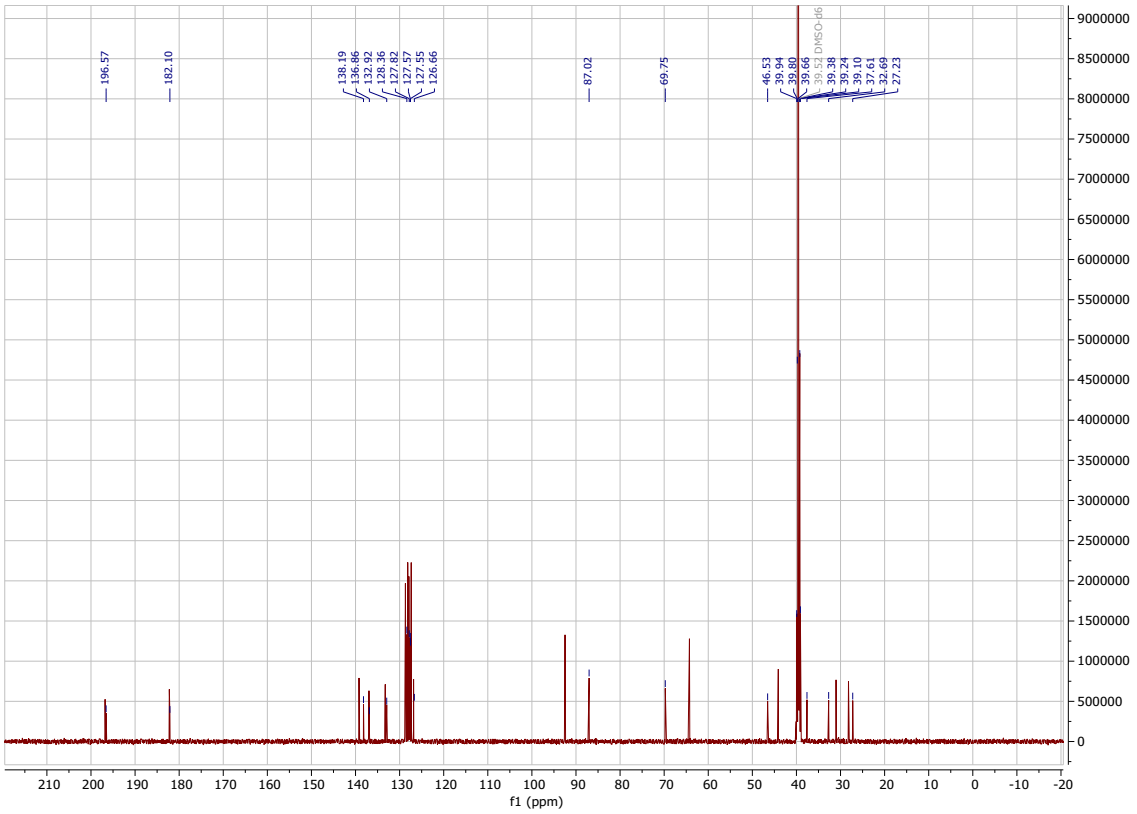

8.46
7.96
7.95
7.67
7.66
7.64
7.56
7.55
7.54
7.42
7.41
7.34
7.33
7.26
7.25
7.23
6.75
5.18
5.15
4.44
4.41
3.66
3.63
3.35
3.32
2.50 DMSO-d6
2.16
2.14
2.12
2.11
2.10
2.08
2.06
1.88
1.87
1.86
1.85
1.84
1.79
1.78
1.77
1.76
1.74
0.99
2.05
1.04
2.04
2.04
2.05
1.07
1.01
1.00
1.02
1.01
1.01
2.07
1.01
1.01
f1 (ppm)

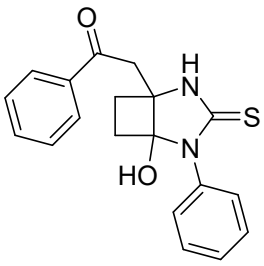

196.84
182.25
139.22
136.97
133.29
128.71
128.18
127.92
127.39
126.86
92.50
64.28
44.14
39.94
39.80
39.66
39.52 DMSO-d6
39.38
39.35
39.24
39.10
31.04
28.21
f1 (ppm)



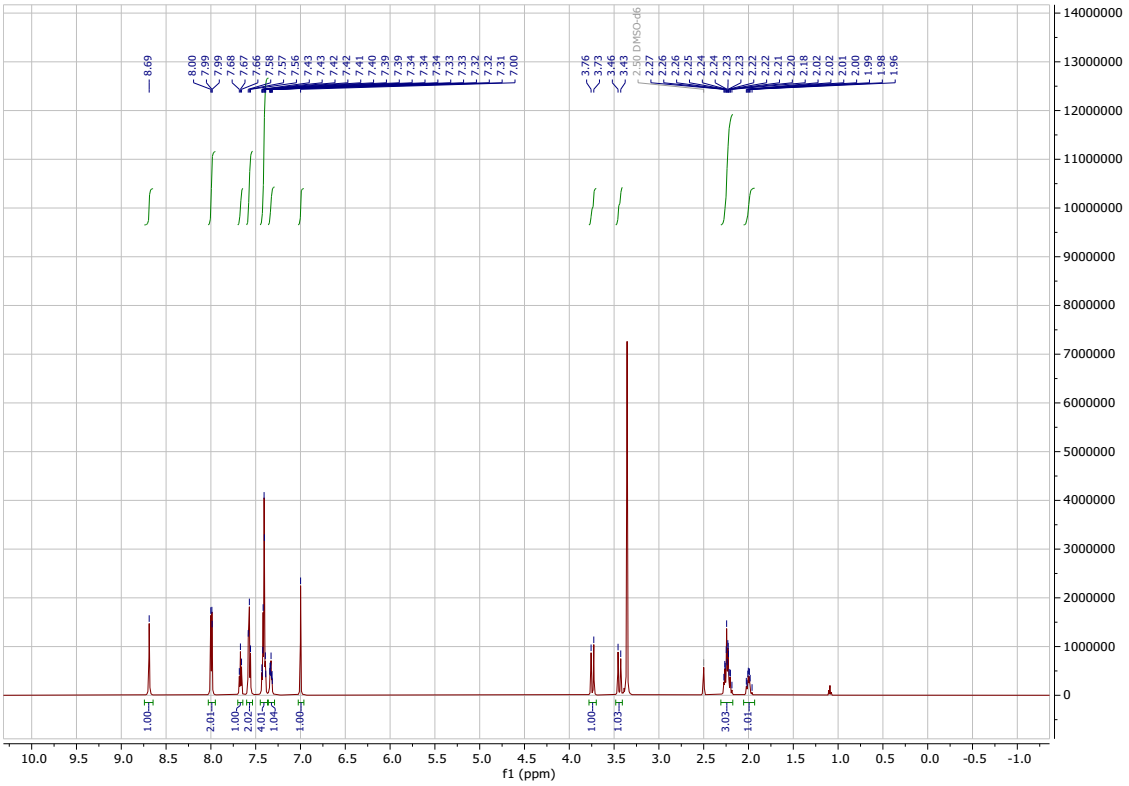

**5'm**

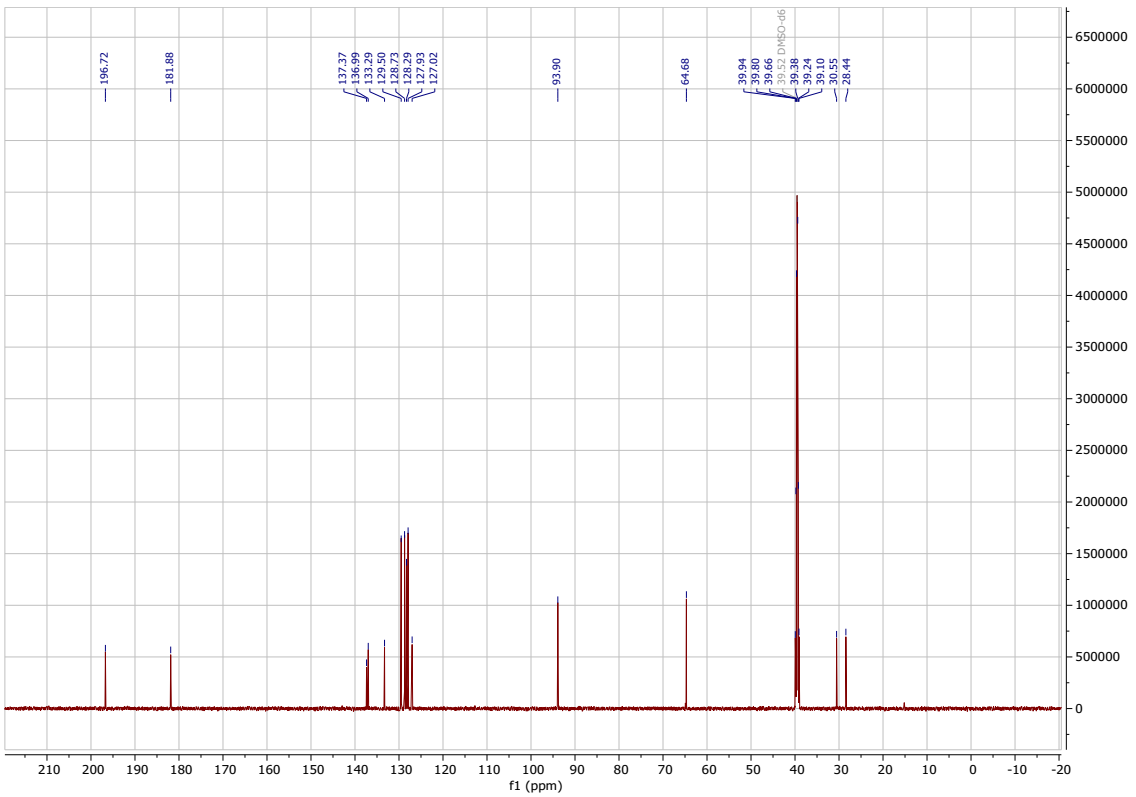


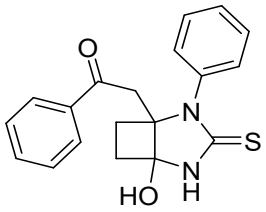




O
H
N
S
N
HO

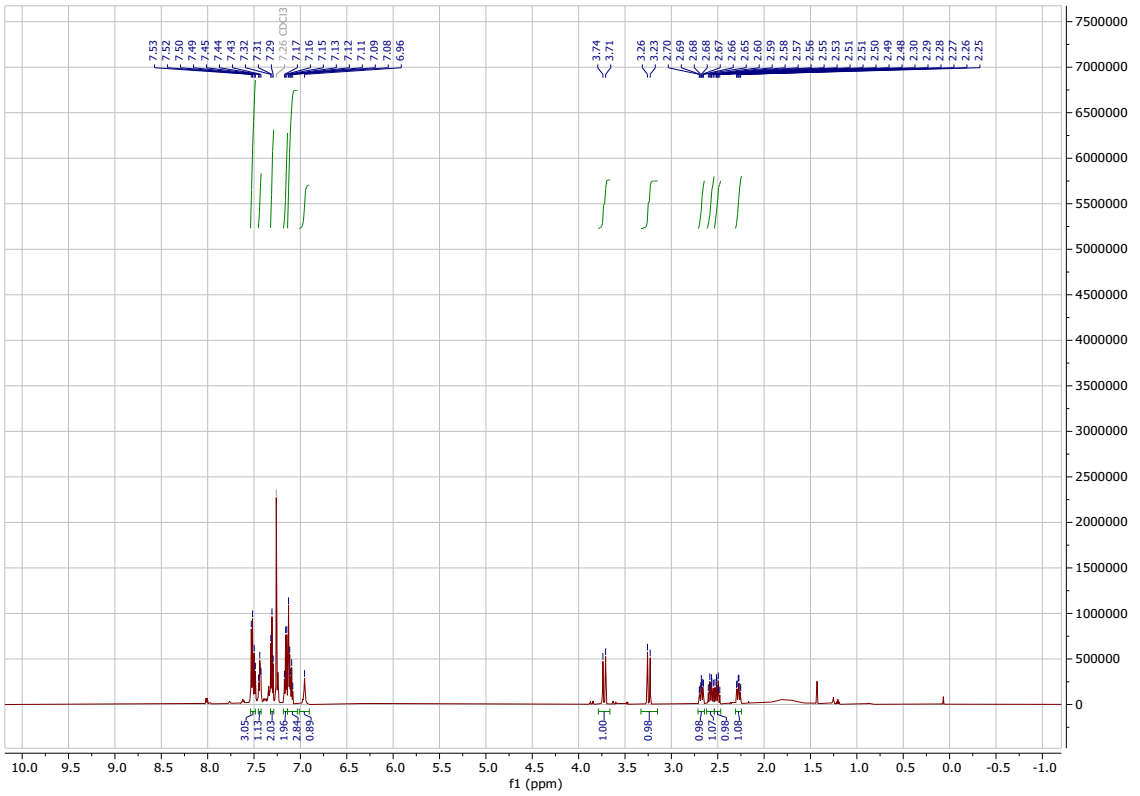
**5n**

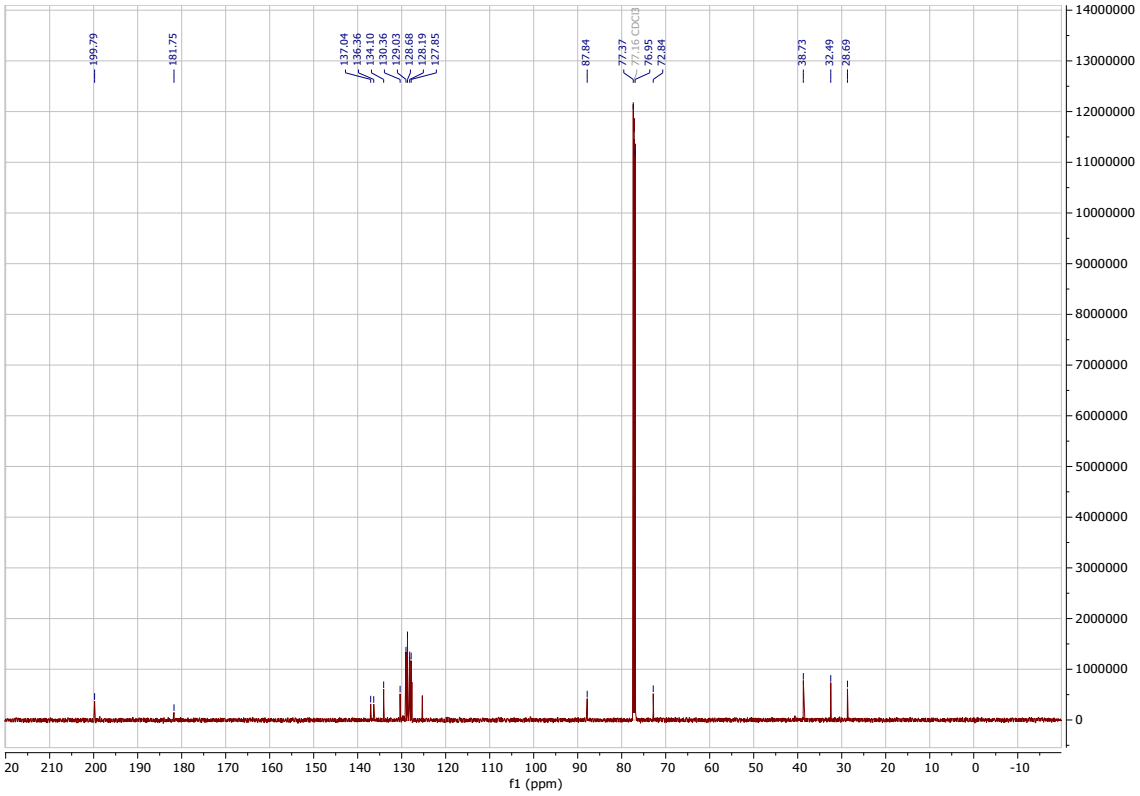

8.69
8.00
7.99
7.99
7.68
7.67
7.66
7.58
7.57
7.56
7.43
7.43
7.42
7.42
7.41
7.40
7.39
7.39
7.34
7.34
7.34
7.33
7.33
7.32
7.32
7.31
7.00
3.76
3.73
3.46
3.45
3.37 DMSO-d6
2.27
2.26
2.26
2.25
2.24
2.24
2.23
2.23
2.22
2.22
2.21
2.20
2.18
2.02
2.02
2.01
2.00
1.99
1.98
1.96
1.00
2.01
1.00
2.02
4.01
1.04
1.00
1.00
1.03
3.03
1.01
f1 (ppm)

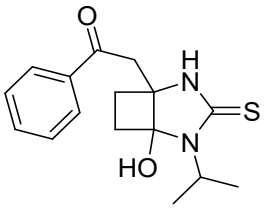

196.72
181.88
137.37
136.99
133.29
129.50
128.73
128.29
127.93
127.02
93.90
64.68
39.94
39.80
39.66
39.52 DMSO-d6
39.38
39.24
39.10
30.55
28.44
f1 (ppm)


O
N
S
N
H
HO

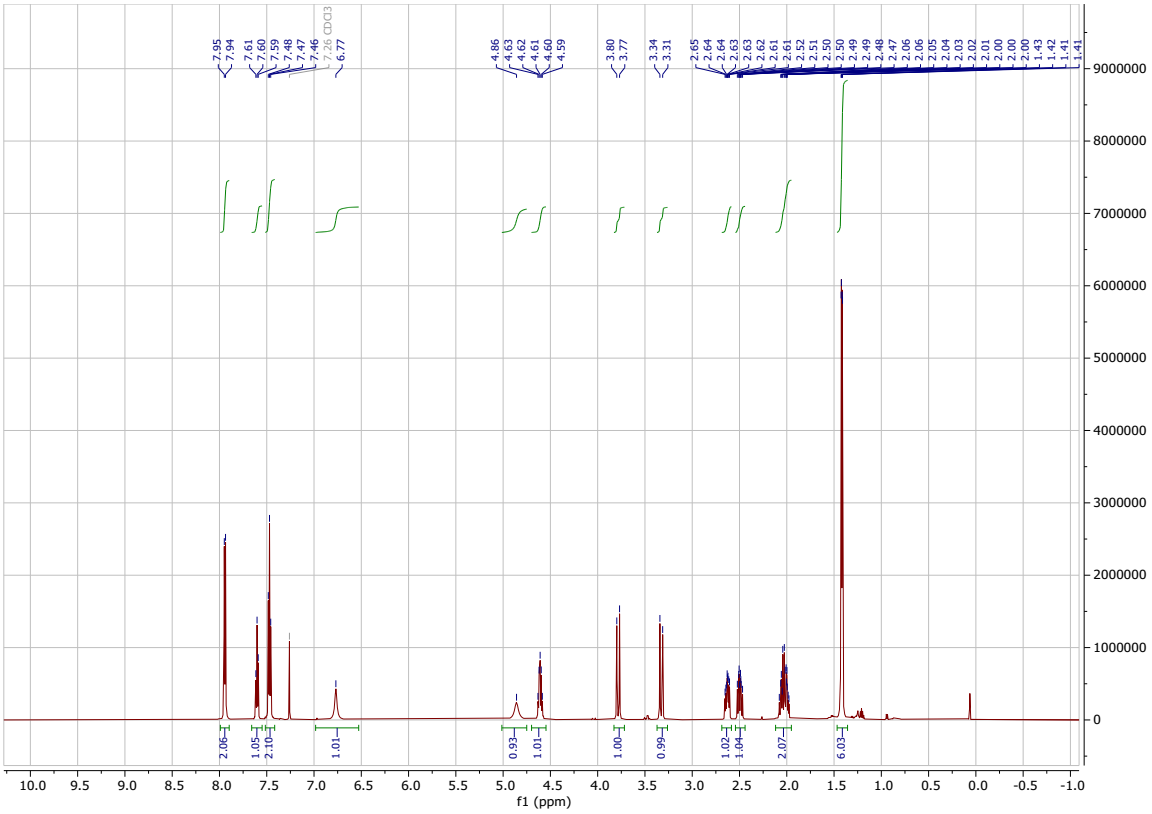
**5'n**

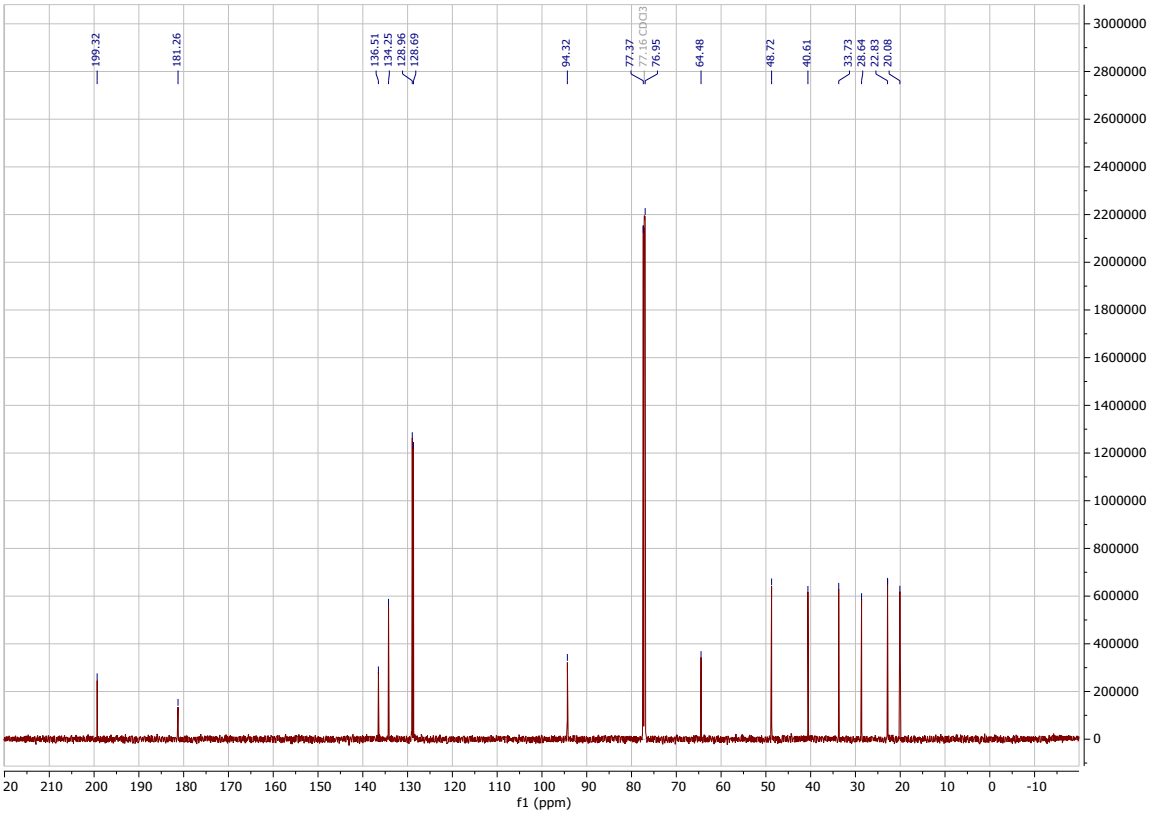

7.53
7.52
7.50
7.49
7.45
7.44
7.43
7.32
7.31
7.29
CDCl3
7.26
7.17
7.16
7.15
7.13
7.12
7.11
7.09
7.08
6.96
3.74
3.71
3.26
3.23
2.70
2.69
2.68
2.68
2.67
2.66
2.65
2.60
2.59
2.58
2.57
2.56
2.55
2.53
2.51
2.51
2.50
2.49
2.48
2.30
2.29
2.28
2.27
2.26
2.25
3.05
1.13
2.03
1.96
2.84
0.89
1.00
0.98
0.98
1.07
0.98
1.08
f1 (ppm)

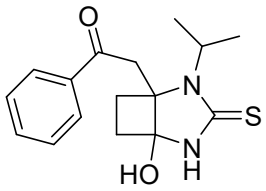

199.79
181.75
137.04
136.36
134.10
130.36
129.03
128.68
128.19
127.85
87.84
77.37
77.16
CDCl3
76.95
72.84
38.73
32.49
28.69
f1 (ppm)


O
H
N
S
N
HO

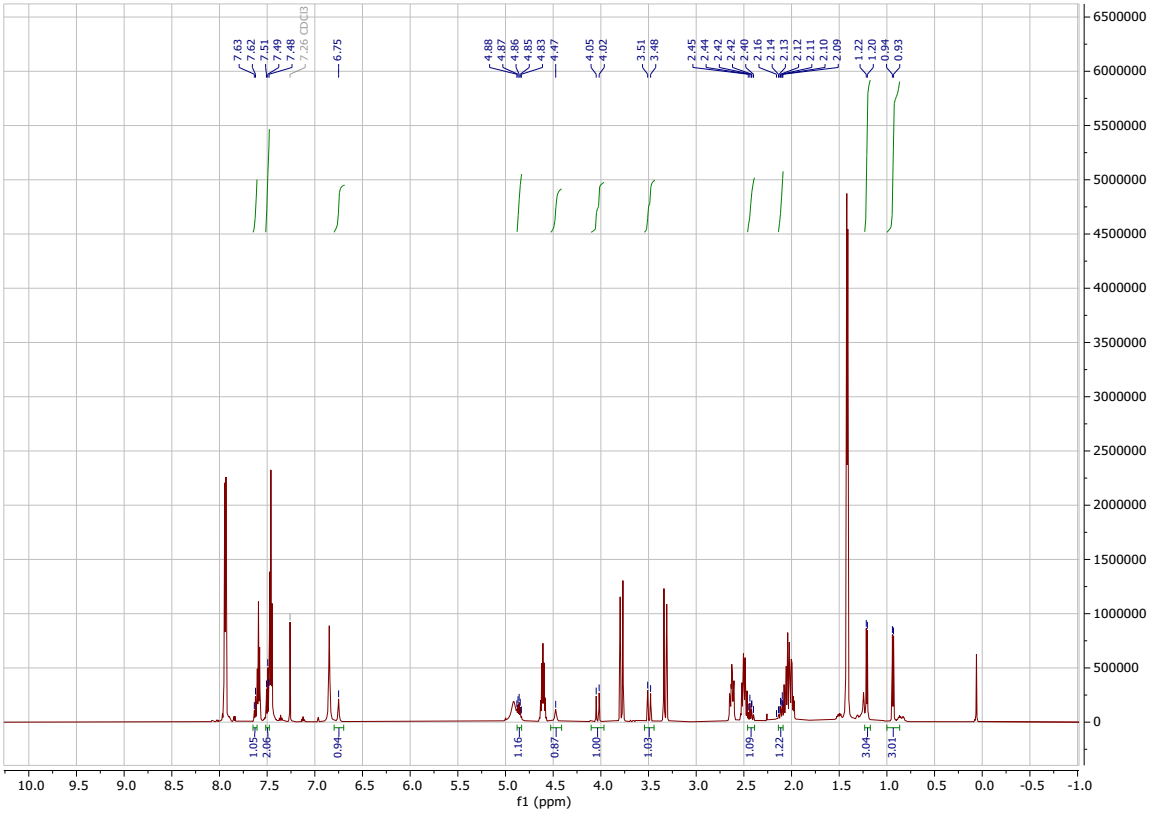
**5o**


7.95
7.94
7.61
7.60
7.59
7.48
7.47
7.46
7.26 CDCl3
6.77
4.86
4.63
4.62
4.61
4.60
4.59
3.80
3.77
3.34
3.31
2.65
2.64
2.64
2.63
2.63
2.62
2.61
2.61
2.52
2.51
2.50
2.50
2.49
2.49
2.48
2.47
2.06
2.05
2.04
2.03
2.02
2.01
2.00
2.00
2.00
1.43
1.42
1.41
1.41
2.06
1.05
2.10
1.01
0.93
1.01
1.00
0.99
1.02
1.04
2.07
6.03
f1 (ppm)


199.32
181.26
136.51
134.45
128.86
128.69
94.32
77.37
77.16 CDCl3
76.95
64.48
48.72
40.61
33.73
28.64
22.83
20.08
f1 (ppm)


O
N
S
N
H
HO

**5'o**


7.63
7.62
7.51
7.49
7.48
7.26 CDCl3
6.75
4.88
4.87
4.86
4.85
4.83
4.47
4.05
4.02
3.51
3.48
2.45
2.44
2.42
2.42
2.40
2.16
2.14
2.13
2.12
2.11
2.10
2.09
1.22
1.20
0.94
0.93
1.05
2.06
0.94
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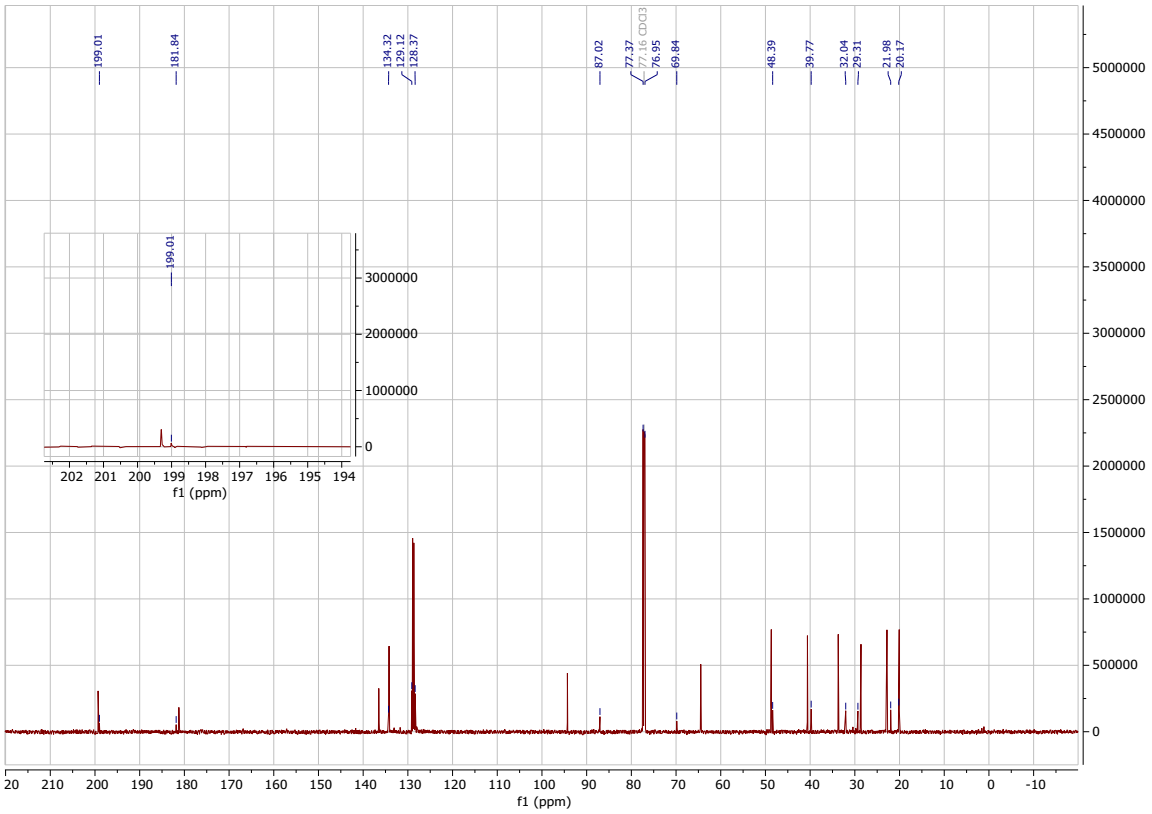
0.87
1.00
1.03
1.09
1.22
3.04
3.01
f1 (ppm)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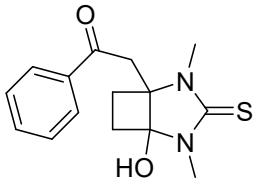
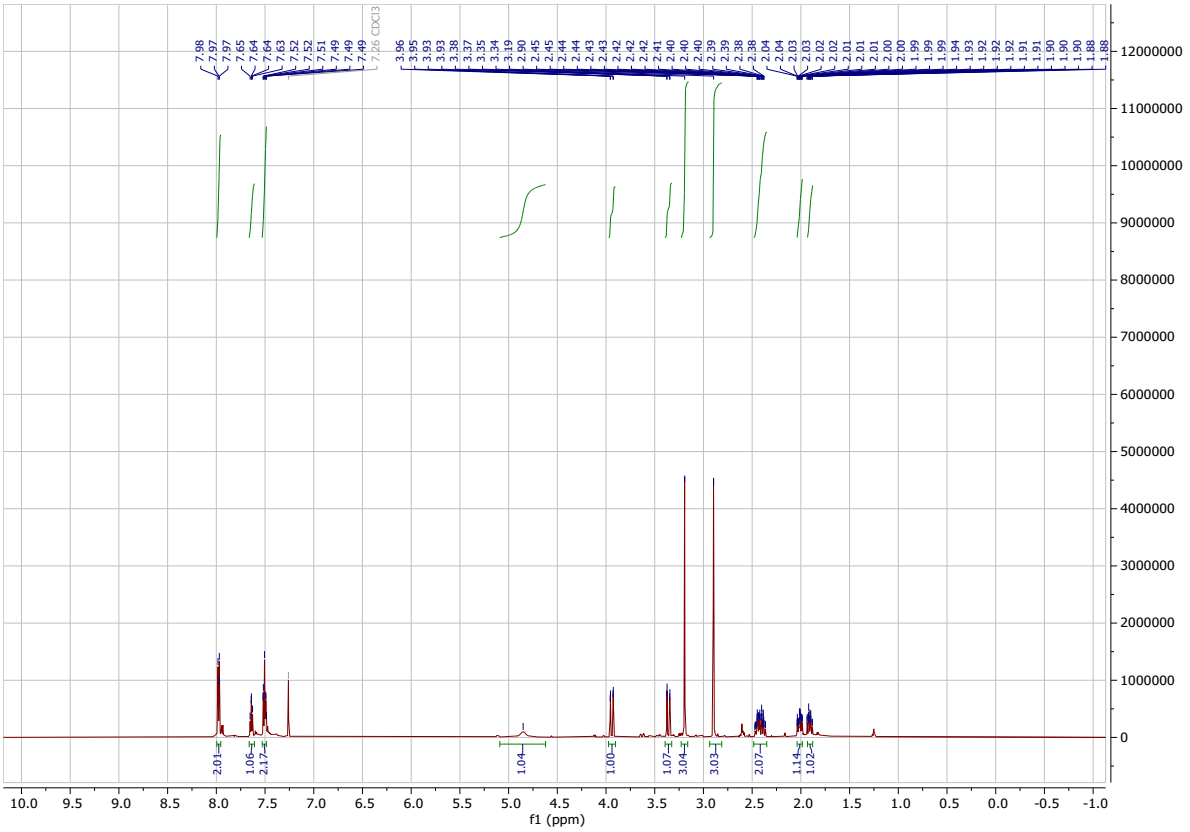
134.32
129.12
128.37
87.02
77.37
77.16 CDCl3
76.95
69.84
48.39
39.77
32.04
29.31
21.98
20.17
f1 (ppm)


O
N
S
N
HO

**5p**


7.98
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7.97
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7.64
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7.51
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7.49
7.49
7.26 CDCl3
3.96
3.95
3.93
3.93
3.38
3.37
3.35
3.34
3.19
2.90
2.45
2.45
2.44
2.44
2.43
2.43
2.42
2.42
2.42
2.41
2.40
2.40
2.40
2.39
2.39
2.38
2.38
2.04
2.04
2.03
2.03
2.02
2.02
2.01
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2.01
2.00
2.00
1.99
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1.90
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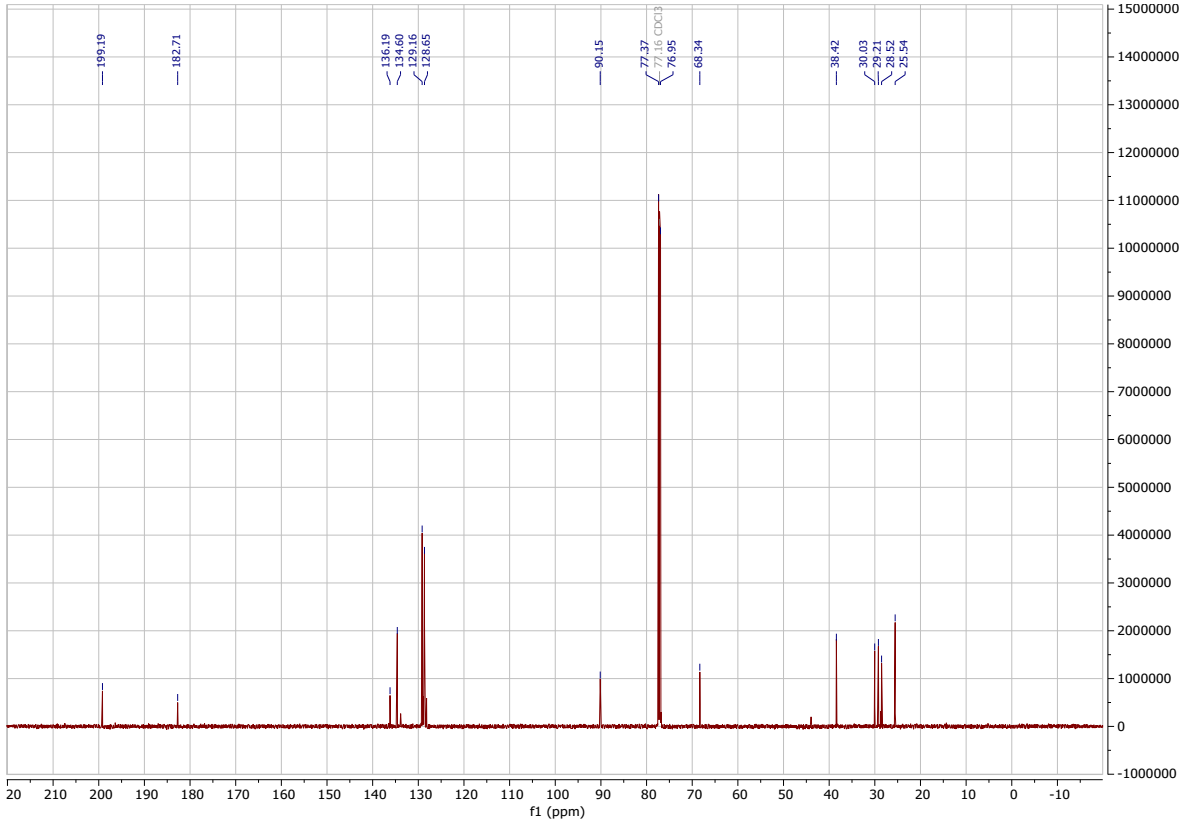
3.03
2.07
1.14
1.02
f1 (ppm)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128.65
90.15
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77.16 CDCl3
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68.34
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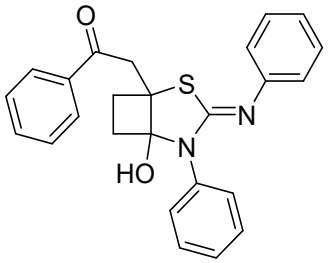
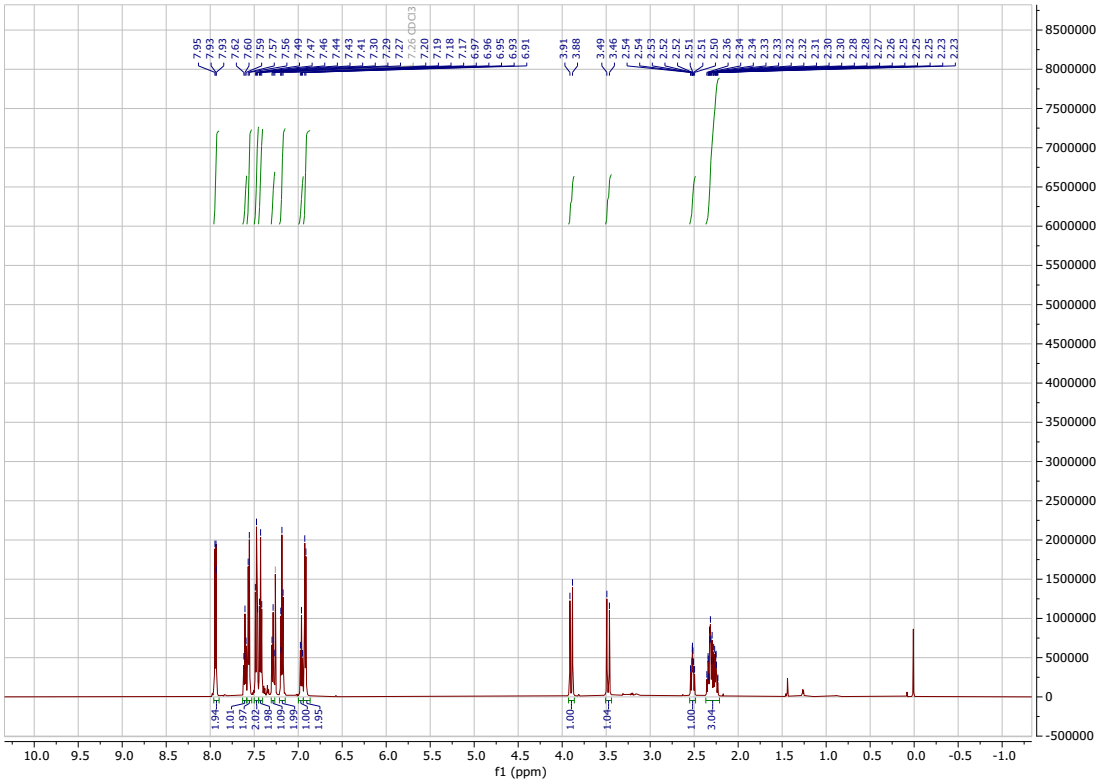
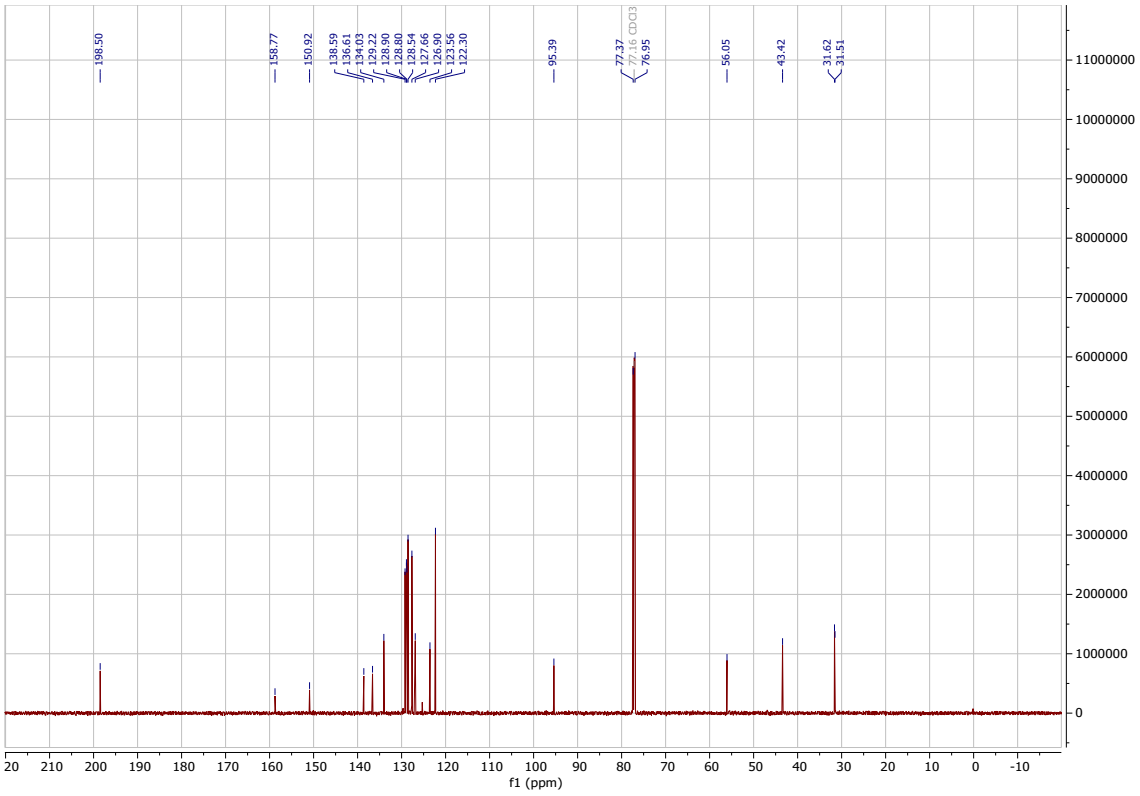
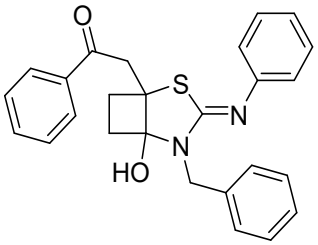
30.03
29.21
28.52
25.54
f1 (ppm)



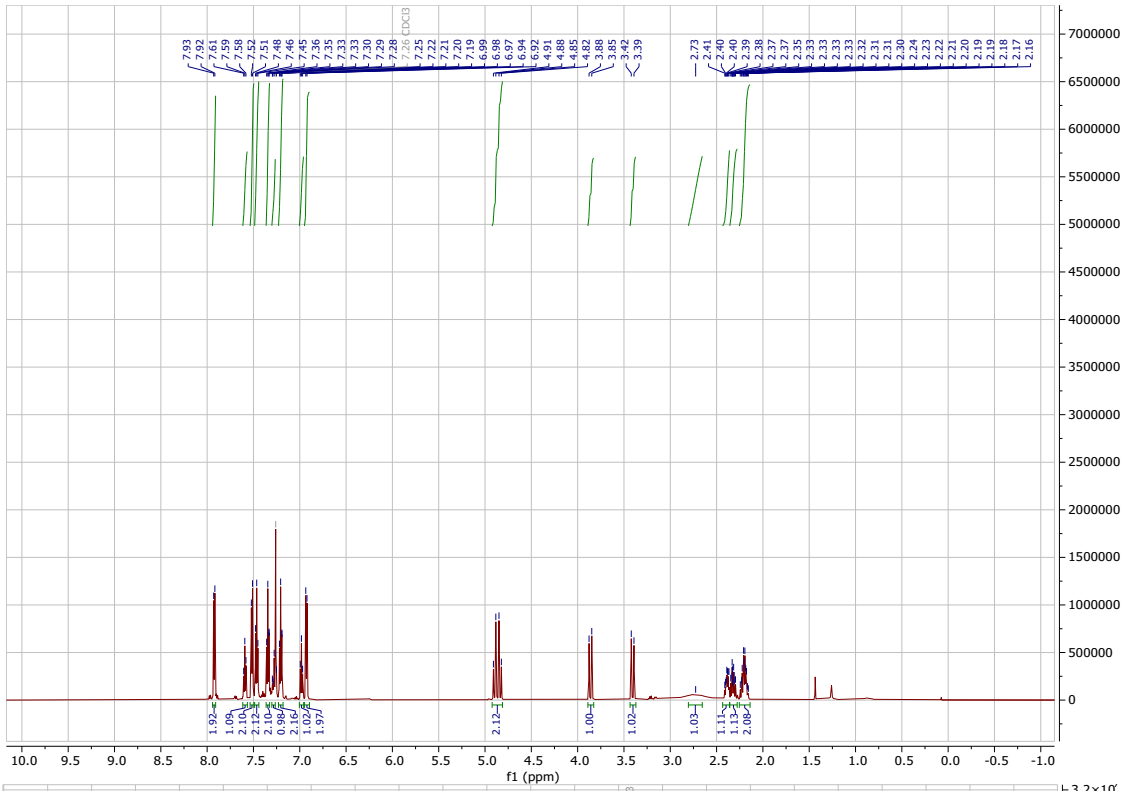

**6a**

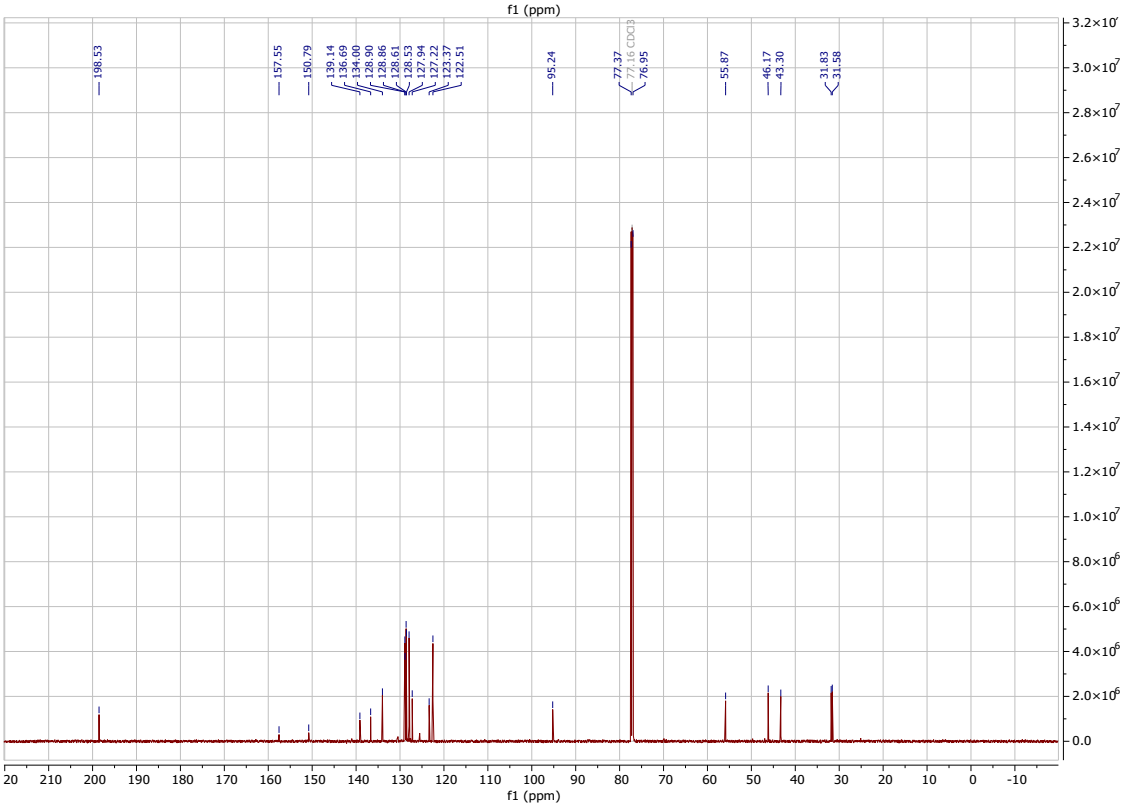


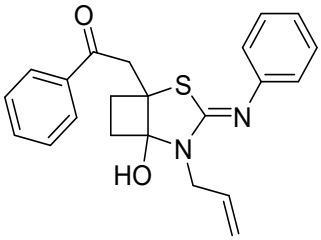





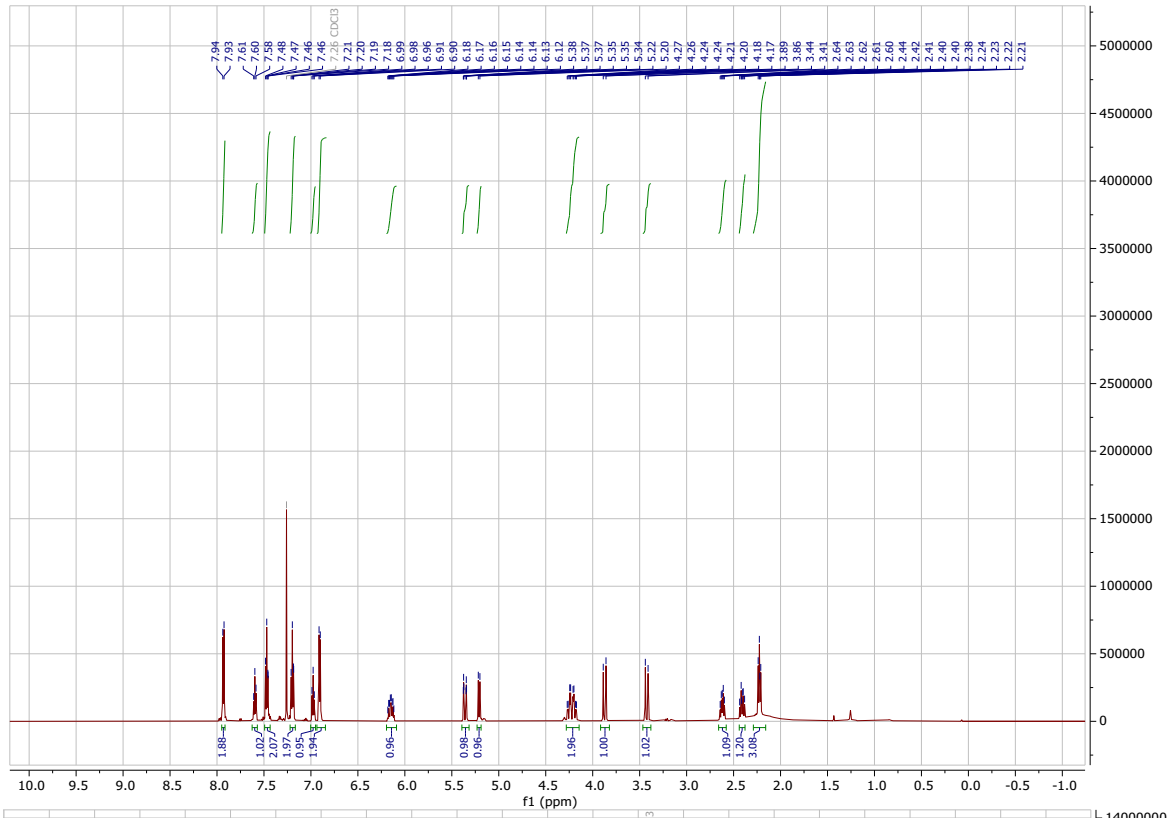

**6b**




O
S
N
N
HO

**6c**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7.19
7.18
6.99
6.98
6.96
6.91
6.90
6.18
6.17
6.16
6.15
6.14
6.14
6.13
6.12
5.38
5.37
5.37
5.35
5.35
5.34
5.22
5.20
4.27
4.26
4.24
4.24
4.21
4.20
4.19
4.17
3.89
3.86
3.44
3.41
2.64
2.63
2.62
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2.38
2.24
2.23
2.22
2.21
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1.02
2.07
1.97
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0.98
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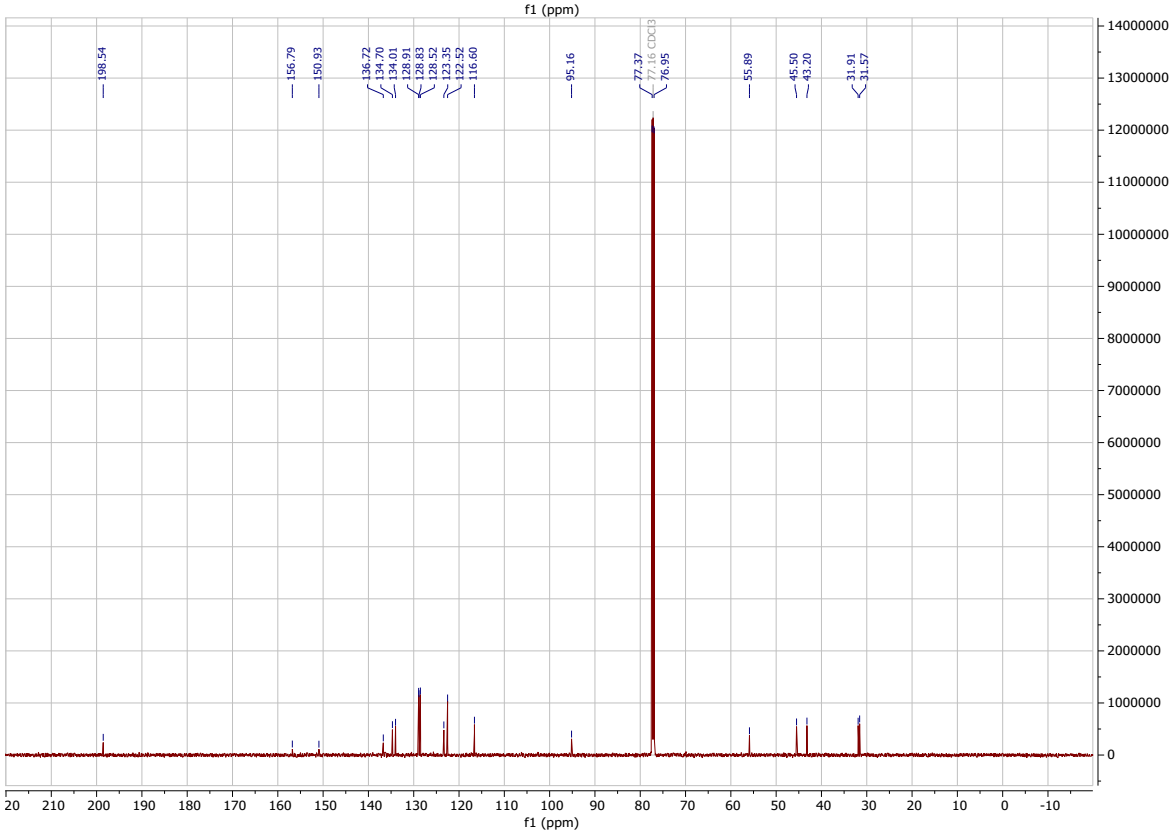
1.96
1.00
1.02
1.09
1.20
3.08
f1 (ppm)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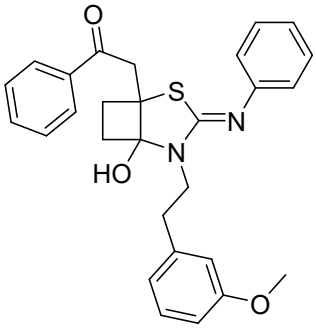
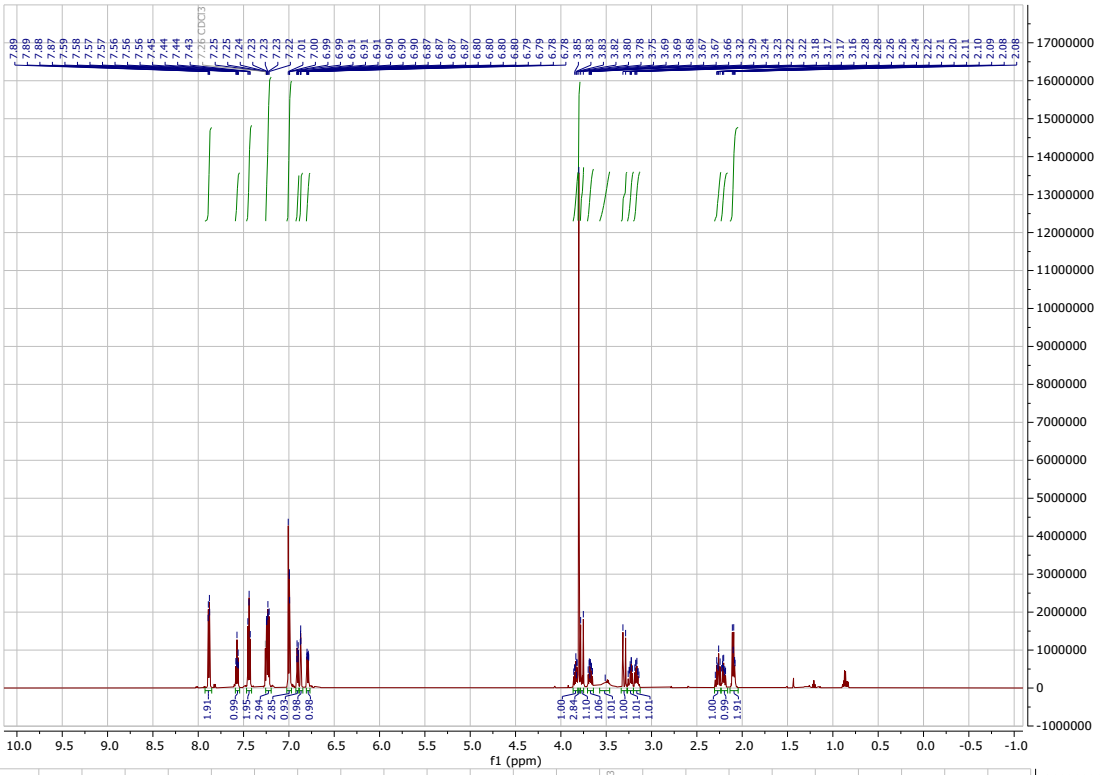
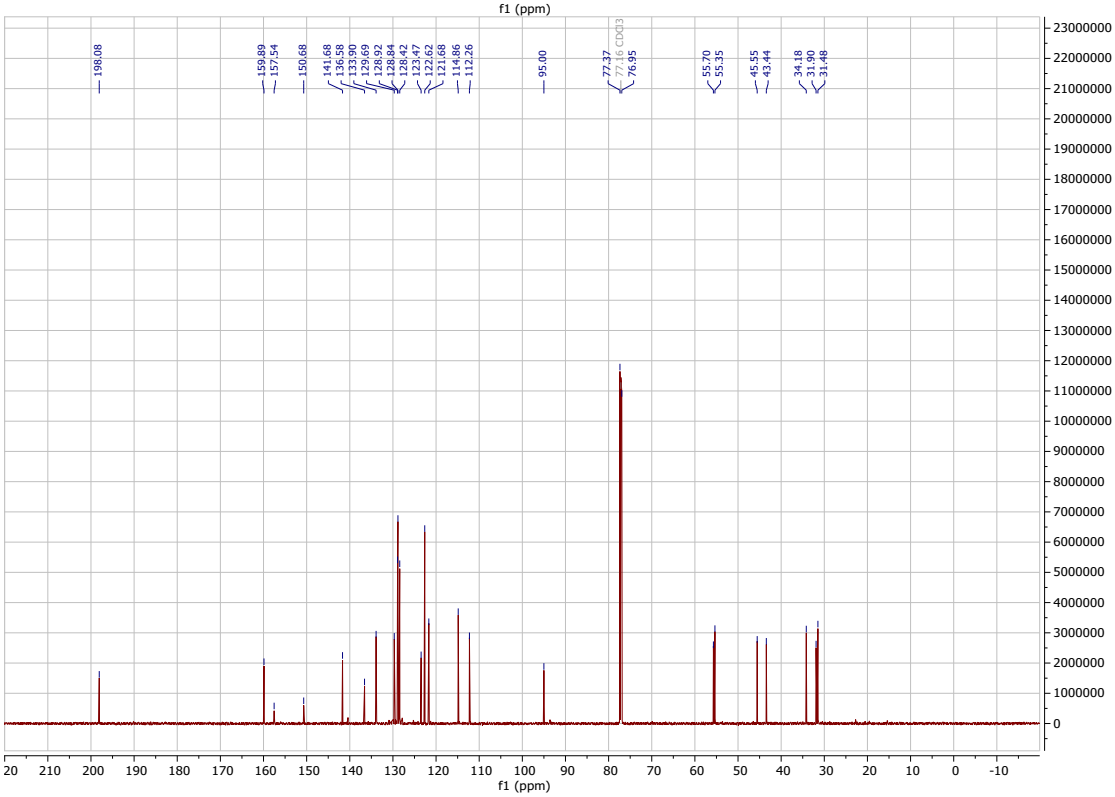
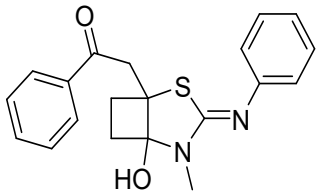
134.70
134.01
128.91
128.83
128.52
123.35
122.52
116.60
95.16
77.37
77.16 CDCl3
76.95
55.89
45.50
43.20
31.91
31.57
f1 (ppm)



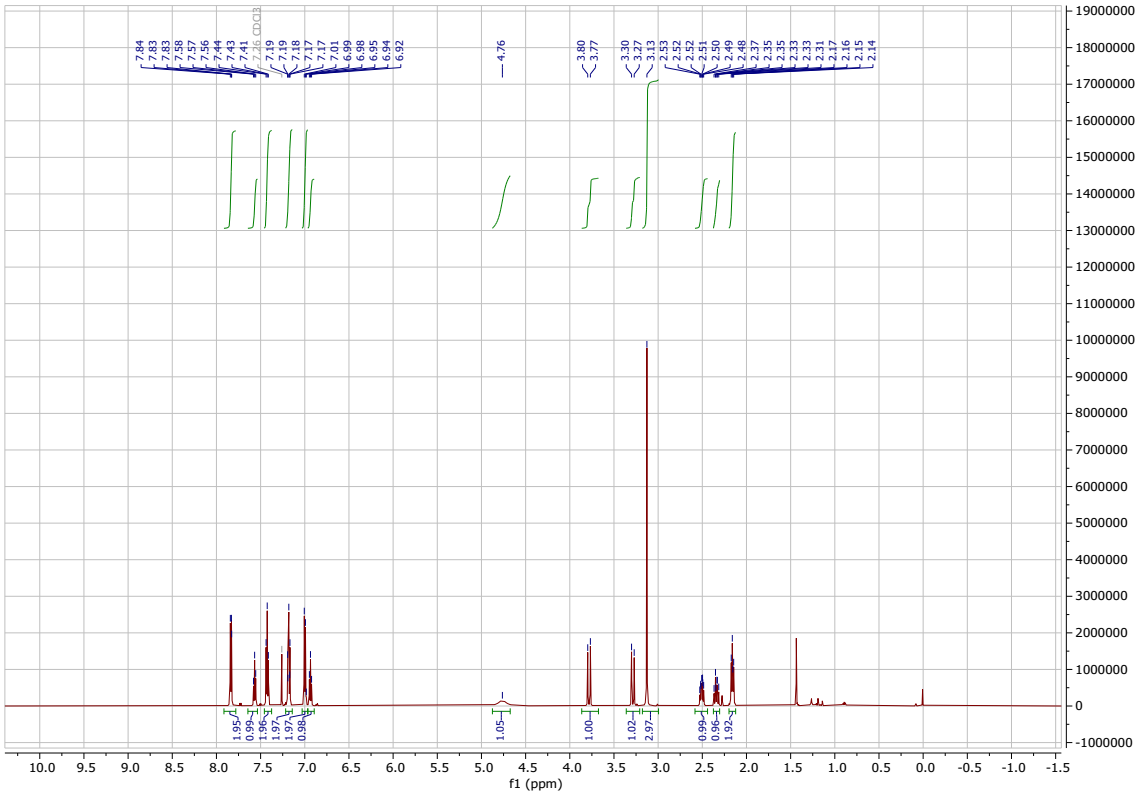

**6d**




O
S
N
N
HO

**6e**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7.43
7.41
7.26 CDCl3
7.19
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3.80
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3.30
3.27
3.13
2.53
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2.51
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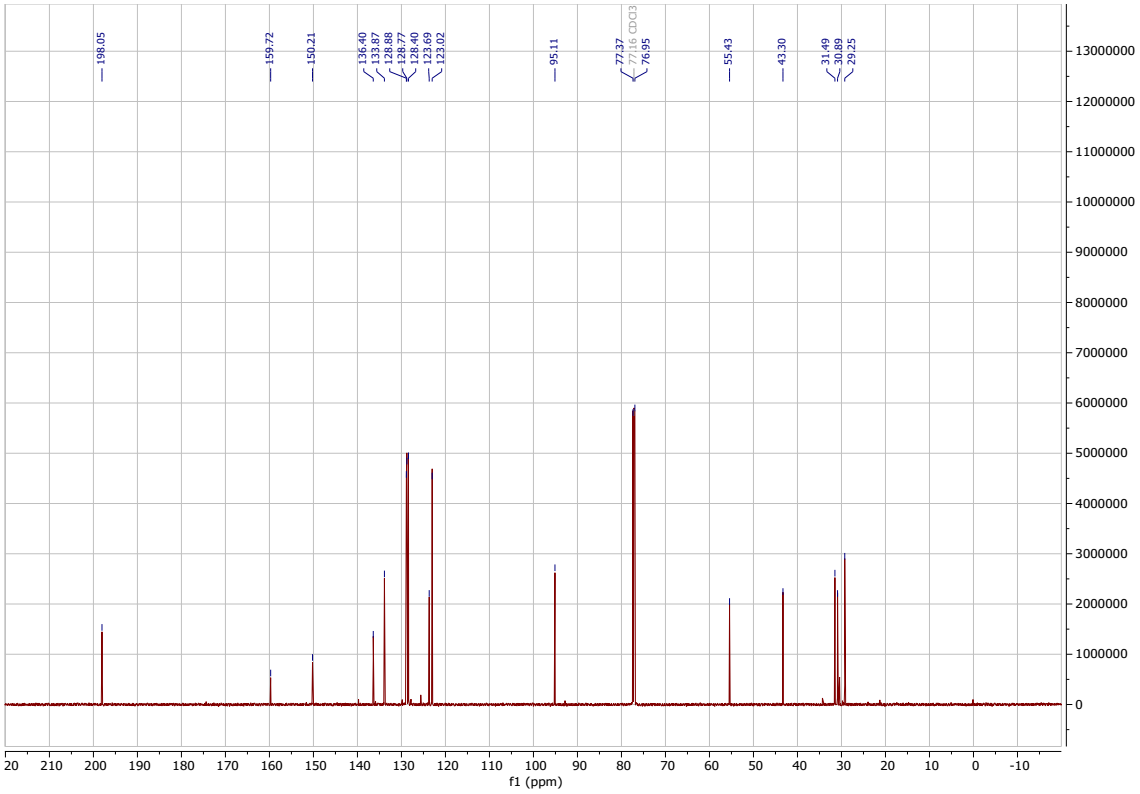
2.48
2.37
2.35
2.35
2.33
2.33
2.31
2.17
2.16
2.15
2.14
1.95
0.99
1.96
1.97
1.97
0.98
1.05
1.00
1.02
2.97
0.99
0.96
1.92
f1 (ppm)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128.40
123.69
123.02
95.11
77.37
77.16 CDCl3
76.95
55.43
43.30
31.49
30.89
29.25
f1 (ppm)

## X-Ray Crystallographic studies

X-ray diffraction data for compounds **5f** & **5o** were collected using a Bruker VENTURE PHOTON III c7 diffractometer with Micro-focus IμS source CuKα radiation (λ = 1.54178 Å). X-ray diffraction data for compounds **5n** & **6e** were collected using a Bruker VENTURE PHOTON III c7 CMOS diffractometer with Micro-focus IμS source MoKα radiation (λ = 0.71073 Å). Crystals were mounted on a CryoLoop (Hampton Research) with Paratone-N (Hampton Research) as cryoprotectant and then placed in a nitrogen gas stream at 200 K (compounds **5n**, **5o** & **6e)** or 100 K (compound **5f**). The temperature of the crystal was maintained at the selected value by means of a 700 series Cryostream cooling device with an accuracy of ±1 K. Data reduction was accomplished using SAINT V7.53a. The substantial redundancy in data allowed a semi-empirical absorption correction (SADABS V2.10) to be applied, on the basis of multiple measurements of equivalent reflections. The structures were solved by direct methods using SHELXS-97[1] and refined against $F^2$ by full-matrix least-squares techniques using SHELXL-2018[2] with anisotropic displacement parameters for all non-hydrogen atoms. All calculations were performed by using the crystallographic software package WINGX.[3]

The crystal data collection and refinement parameters are given in Table S1. The molecular structures are illustrated in Figures S1-S4.

CCDC files 2361608-2361611 contain the supplementary crystallographic data. They can be obtained free of charge from the Cambridge Crystallographic Data Centre and Fachinformationszentrum Karlsruhe via http://www.ccdc.cam.ac.uk/structures/.

[1] G. M. Sheldrick, SHELXS-97, Program for Crystal Structure Solution, University of Göttingen, Göttingen, Germany, **1997**.
[2] G. M. Sheldrick, *Acta Crystallogr., Sect. A: Found. Crystallogr.,* **2008**, *64*, 112-122.
[3] L. J. Farrugia, *J. Appl. Cryst*. **1999**, *32*, 837.

**Table S1**. Crystallographic data and structure refinement details.

| **Compound** | **5f** | **5n** | **5o** | **6e** |
|---|---|---|---|---|
| CCDC | 2361611 | 2361609 | 2361608 | 2361610 |
| Empirical Formula | $C_{19}$ $H_{18}$ $N_2$ $O_2$ S | $C_{19}$ $H_{18}$ $N_2$ $O_2$ S, C H $Cl_3$ | $C_{16}$ $H_{20}$ $N_2$ $O_2$ S | $C_{20}$ $H_{20}$ $N_2$ $O_2$ S |
| $M_r$ | 338.41 | 457.78 | 304.40 | 352.44 |
| Crystal size, $mm^3$ | 0.10 × 0.06 × 0.04 | 0.12 × 0.03 × 0.02 | 0.15 × 0.13 × 0.04 | 0.07 × 0.04 × 0.04 |
| Crystal system | monoclinic | monoclinic | orthorhombic | triclinic |
| Space group | *P* $2_1/c$ | *P* $2_1/c$ | *P b c a* | *P* –1 |
| a, Å | 14.3538(2) | 11.0280(14) | 11.5953(2) | 11.754(3) |
| b, Å | 29.2862(4) | 18.344(2) | 11.3000(2) | 11.915(3) |
| c, Å | 7.77910(10) | 11.1908(13) | 24.7099(4) | 15.389(4) |
| α, ° | 90 | 90 | 90 | 99.849(8) |
| β, ° | 94.1680(10) | 108.215(4) | 90 | 101.129(8) |
| γ, ° | 90 | 90 | 90 | 117.442(8) |
| Cell volume, $Å^3$ | 3261.44(8) | 2150.4(5) | 3237.66(10) | 1791.1(7) |
| Z ; Z’ | 8 ; 2 | 4 ; 1 | 8 ; 1 | 4 ; 2 |
| T, K | 100(1) | 200(1) | 200(1) | 200(1) |
| Radiation type ; wavelength Å | CuKα ; 1.54178 | MoKα ; 0.71073 | CuKα ; 1.54178 | MoKα ; 0.71073 |
| $F_{000}$ | 1424 | 944 | 1296 | 744 |
| μ, $mm^{-1}$ | 1.875 | 0.542 | 1.822 | 0.196 |
| range, ° | 4.319 - 65.197 | 2.214 - 31.060 | 5.231 - 65.076 | 2.014 - 31.039 |
| Reflection collected | 54 989 | 86 872 | 23 306 | 137 955 |
| Reflections unique | 5 541 | 6 870 | 2 731 | 11 402 |
| $R_{int}$ | 0.0671 | 0.0928 | 0.0389 | 0.1082 |
| GOF | 1.283 | 1.031 | 1.040 | 1.028 |
| Refl. obs. ($I$>2($I$)) | 5 283 | 4 277 | 2 453 | 7 095 |
| Parameters ; restraints | 425 ; 0 | 291 ; 0 | 197 ; 0 | 455 ; 0 |
| $wR_2$ (all data) | 0.1649 | 0.1618 | 0.0859 | 0.1402 |
| R value ($I$>2($I$)) | 0.0766 | 0.0562 | 0.0324 | 0.0495 |
| Largest diff. peak and hole ($e^-.Å^{-3}$) | 0.704 ; –0.890 | 0.661 ; –0.530 | 0.225 ; –0.198 | 0.351 ; –0.257 |

**X-ray structure drawings**

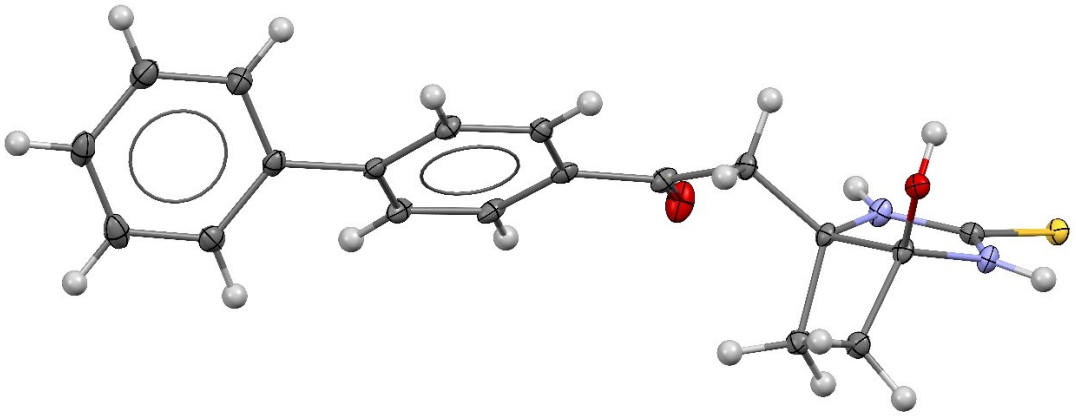

**Figure S1.** An ORTEP drawing of compound **5f**. Thermal ellipsoids are shown at the 30% level. Only one of the two similar molecules in the asymmetric unit is shown.

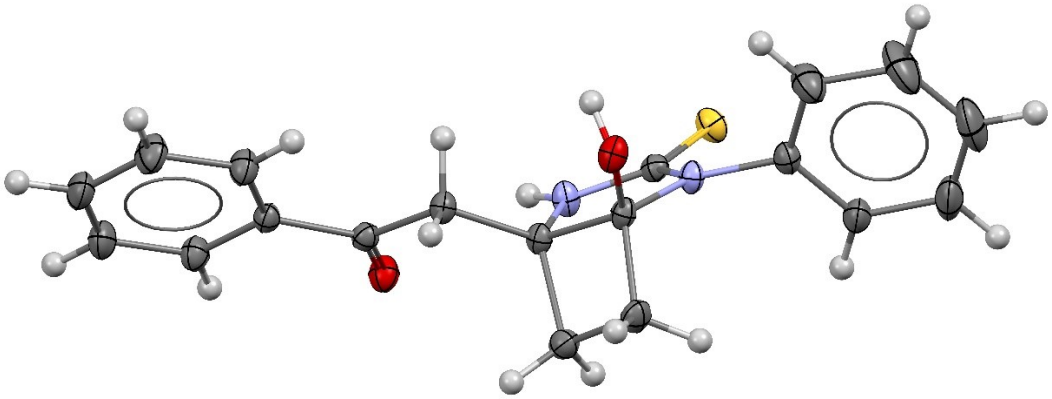

**Figure S2.** An ORTEP drawing of compound **5n**. Thermal ellipsoids are shown at the 30% level. A solvent molecule is omitted for clarity.

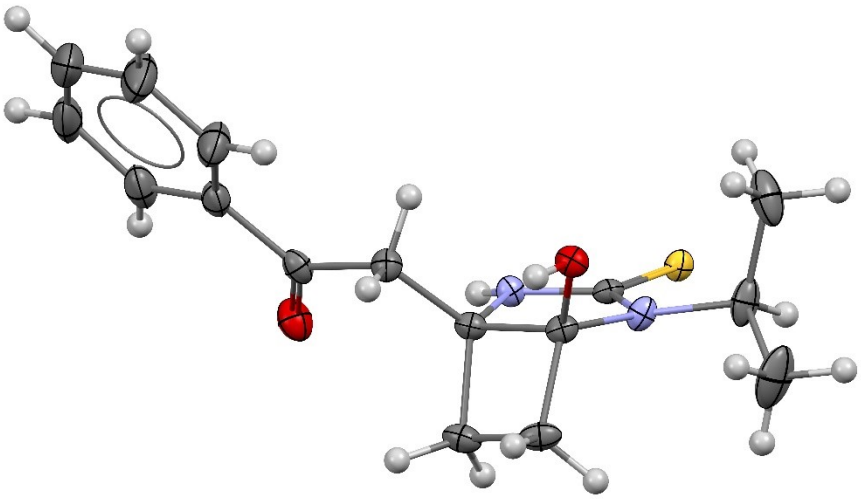

**Fig. S3.** An ORTEP drawing of compound **5o**. Thermal ellipsoids are shown at the 30% level.

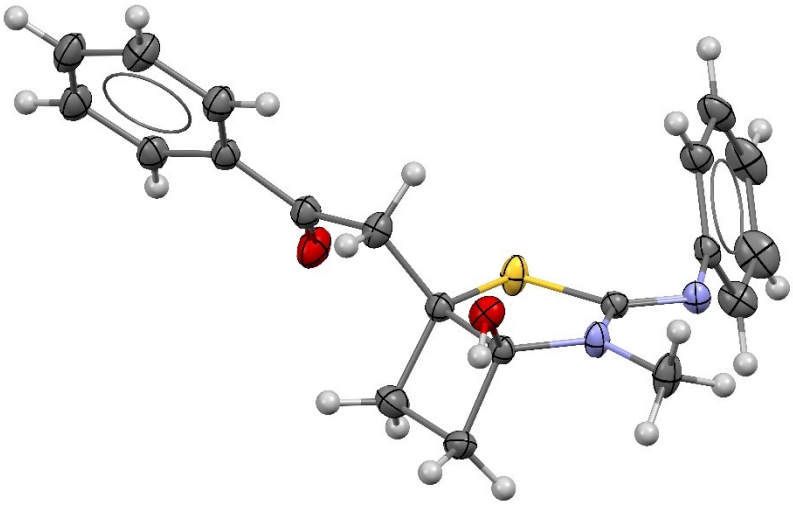

**Figure S4.** An ORTEP drawing of compound **6e**. Thermal ellipsoids are shown at the 30% level. Only one of the two similar molecules in the asymmetric unit is shown.