Supporting information *for*

Synthesis of 2-trifluoromethyl thiazoles via [3 + 2] cycloaddition of pyridinium 1,4-zwitterionic thiolates with CF_3CN

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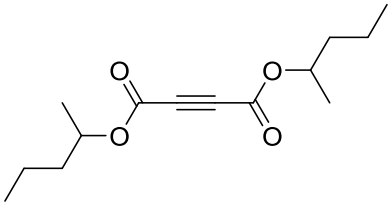
General information

^{1}H NMR, ^{19}F NMR and ^{13}C NMR spectra were recorded using Bruker AVIII 400 spectrometer. ^{1}H NMR and ^{13}C NMR chemical shifts were reported in parts per million (ppm) downfield from tetramethylsilane and ^{19}F NMR chemical shifts were determined relative to $CFCl_3$ as the external standard and low field is positive. Coupling constants (*J*) are reported in Hertz (Hz). The residual solvent peak was used as an internal reference: ^{1}H NMR ($CDCl_3$ δ 7.26 ; DMSO-d_6 δ 2.50 ppm), ^{13}C NMR ($CDCl_3$ δ 77.0; DMSO-d_6 δ 39.52 ppm,), The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. Solvents are directly purchased commercially without further purification. The infrared(IR) spectra were recorded using a Nicolet iS 50 at room temperature. HRMS were obtained on State Key Discipline Testing Center for Physical Chemistry of Fuzhou University. 2,2,2-trifluoroacetaldehyde *O*-(aryl)oximes[1] were prepared according to the published procedures. Column chromatography purifications were performed by flash chromatography using Merck silica gel 60.

Synthesis of pyridinium 1,4-zwitterionic thiolate substrates

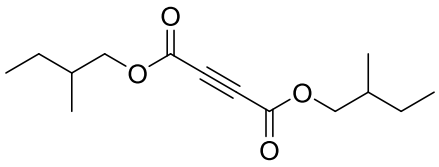
(i) Synthesis of but-2-ynedioates.

But-2-ynedioates **S-2g**, **S-2h**, **S-2i**, and **S-2j** were prepared according to the published procedures[2]



di(pentan-2-yl) but-2-ynedioate (S-2g)

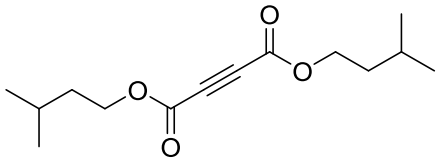
Obtained as a white liquid in 72% yield (3.40 g). R_f (petroleum ether) = 0.59. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.11 – 4.96 (m, 2H), 1.74 – 1.57 (m, 2H), 1.57 – 1.45 (m, 2H), 1.44 – 1.31 (m, 4H), 1.27 (d, J = 6.2 Hz, 6H), 0.92 (t, J = 7.3 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.7 (s), 74.8 (s), 74.5 (s), 37.7 (s), 19.7 (s), 18.5 (s), 13.8 (s). IR (ATR): ν 2962, 2936, 1715, 1457, 1251, 1117, 1056, 1031, 1017, 928, 883, 822, 748, 674 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{14}H_{27}O_4$ $[M + 3H]^+$: 257.1747; found: 257.1744.



bis(2-methylbutyl) but-2-ynedioate (S-2h)

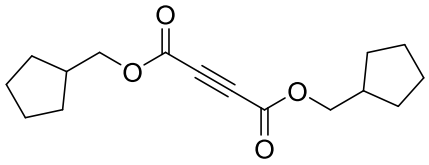
Obtained as a white liquid in 82% yield (2.48 g). R_f (petroleum ether) = 0.82. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.14 – 4.05 (m, 2H), 4.06 – 3.96 (m, 2H), 1.80 – 1.67 (m, 2H), 1.50 – 1.36 (m, 2H), 1.25 – 1.13 (m, 2H), 1.06 – 0.67 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.9 (s), 74.6 (s), 71.3 (s), 33.8 (s), 25.7 (s), 16.1 (s), 11.0 (s). IR

(ATR): ν 2964, 2878, 1718, 1463, 1389, 1230, 1029, 933, 769, 746, 675, 585 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{14}H_{23}O_4$ $[M + H]^+$: 255.1590; found: 255.1588.



diisopentyl but-2-ynedioate (S-2i)

Obtained as a yellow liquid in 61% yield (2.64 g). R_f (petroleum ether) = 0.82. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.27 (t, *J* = 6.9 Hz, 4H), 1.81 – 1.64 (m, 2H), 1.58 (q, *J* = 6.9 Hz, 4H), 0.94 (d, *J* = 7.3 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.9 (s), 74.7 (s), 65.6 (s), 36.9 (s), 33.9 (s), 24.8 (s), 22.3 (s). IR (ATR): ν 2959, 2872, 1717, 1464, 1387, 1369, 1239, 1170, 1049, 1024, 921, 823, 746, 677, 581 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{14}H_{23}O_4$ $[M + H]^+$: 255.1590; found: 255.1587.

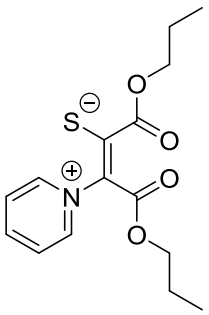


bis(cyclopentylmethyl) but-2-ynedioate (S-2j)

Obtained as a yellow liquid in 72% yield (3.40 g). R_f (petroleum ether) = 0.78. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.15 – 3.96 (m, 4H), 2.35 – 1.99 (m, 2H), 1.86 – 1.60 (m, 4H), 1.59 – 1.36 (m, 8H), 1.34 – 1.04 (m, 4H). ^{13}C NMR (101 MHz, Chloroform-*d*) δ 151.7 (s), 74.6 (s), 70.5 (s), 38.2 (s), 29.1 (s), 25.1 (s). IR (ATR): ν 2952, 2868, 1716, 1453, 1387, 1351, 1234, 1075, 1029, 950, 907, 746, 679, 560 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{16}H_{23}O_4$ $[M + H]^+$: 279.1590; found: 279.1583.

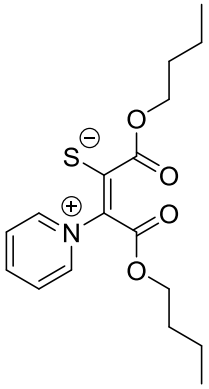
(ii) Synthesis of pyridinium 1,4-zwitterionic thiolates

pyridinium 1,4-zwitterionic thiolates **2c**, **2e**, **2f–2p**, **2r**, **2s** and **2a-2** were prepared according to the published procedures[3]



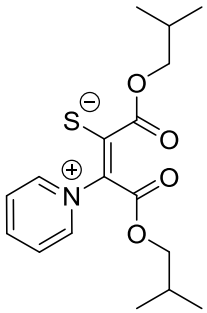
1,4-dioxo-1,4-dipropoxy-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2c)

Obtained as a yellow solid in 16% yield (0.25 g). Mp: 142.0 – 142.8 ℃. R_f (ethyl acetate) = 0.67. ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.90 (d, J = 6.0 Hz, 2H), 8.62 (t, J = 7.9 Hz, 1H), 8.14 (t, J = 7.0 Hz, 2H), 4.09 (t, J = 6.7 Hz, 2H), 3.95 (t, J = 6.4 Hz, 2H), 1.70 – 1.58 (m, 2H), 1.54 – 1.37 (m, 2H), 0.94 (t, J = 7.4 Hz, 3H), 0.78 (t, J = 7.4 Hz, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.4 (s), 168.9 (s), 160.2 (s), 149.2 (s), 146.3 (s), 128.1 (s), 125.4 (s), 66.5 (s), 66.0 (s), 22.0 (s), 21.9 (s), 10.8 (s), 10.7(s). IR (ATR): ν 3111, 3056, 1660, 1504, 1378, 1318, 1197, 1008, 957, 869, 777, 716, 679, 653, 620 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{15}H_{20}NO_4S$ $[M + H]^+$: 310.1107; found: 310.1102.



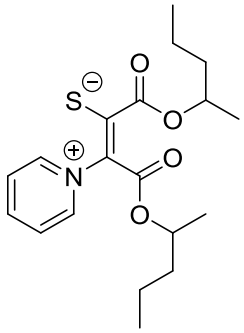
1,4-dibutoxy-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2e)

Obtained as a yellow solid in 48% yield (0.83 g). Mp: 114.3 – 144.6 ℃. R_f (ethyl acetate) = 0.70. ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.89 (d, J = 5.9 Hz, 2H), 8.62 (t, J = 7.8 Hz, 1H), 8.14 (t, J = 7.0 Hz, 2H), 4.12 (t, J = 6.7 Hz, 2H), 3.99 (t, J = 6.4 Hz, 2H), 1.67 – 1.56 (m, 2H), 1.50 – 1.30 (m, 4H), 1.28 – 1.12 (m, 2H), 0.91 (t, J = 7.4 Hz, 3H), 0.82 (t, J = 7.4 Hz, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.4 (s), 168.9 (s), 160.2 (s), 149.2 (s), 146.3 (s), 128.1 (s), 125.4 (s), 64.7 (s), 64.2 (s), 30.7 (s), 30.5 (s), 19.1 (s), 19.0 (s), 14.0 (s), 13.9 (s). IR (ATR): ν 3108, 3052, 2960, 2872, 1717, 1659, 1501, 1464, 1298, 1240, 1198, 1024, 1013, 960, 934, 765, 718, 680, 620 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{17}H_{24}NO_4S$ $[M + H]^+$: 338.1420; found: 338.1414.



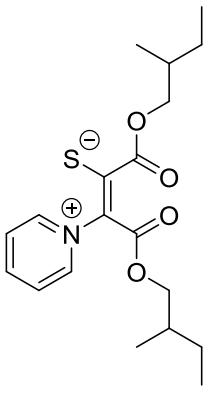
1,4-diisobutoxy-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2f)

Obtained as a yellow solid in 27% yield (0.45 g). Mp: 145.7 – 146.8 ℃. R_f (ethyl acetate) = 0.75. ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.91 (d, J = 5.9 Hz, 2H), 8.63 (t, J = 7.8 Hz, 1H), 8.15 (t, J = 6.9 Hz, 2H), 3.92 (d, J = 6.8 Hz, 2H), 3.78 (d, J = 6.4 Hz, 2H), 2.14 – 1.88 (m, 1H), 1.80 – 1.63 (m, 1H), 0.93 (d, J = 6.8 Hz, 6H), 0.76 (d, J = 6.7 Hz, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.6 (s), 168.9 (s), 160.1 (s), 149.3 (s), 146.4 (s), 128.2 (s), 125.3 (s), 70.9 (s), 70.4 (s), 27.8 (s), 19.5 (s), 19.3 (s). IR (ATR): ν 3107, 3053, 2959, 2887, 1716, 1661, 1623, 1498, 1462, 1377, 1309, 1269, 1234, 1197, 1069, 1011, 977, 903, 792, 765, 719, 683, 622 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{17}H_{24}NO_4S$ $[M + H]^+$: 338.1420; found: 338.1413.



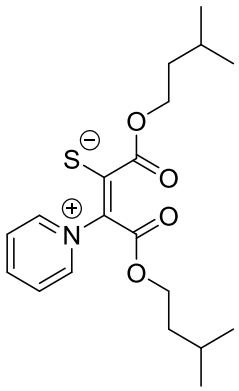
1,4-dioxo-1,4-bis(pentan-2-yloxy)-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2g)

Obtained as a yellow liquid in 25% yield (0.46 g). R_f (ethyl acetate) = 0.81. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.43 – 8.39 (m, 2H), 8.38 – 8.30 (m, 1H), 7.94 (t, *J* = 7.9, 6.5 Hz, 2H), 5.02 – 4.88 (m, 1H), 4.87 – 4.76 (m, 1H), 1.73 – 1.60 (m, 1H), 1.53 – 1.29 (m, 5H), 1.29 – 1.24 (m, 3H), 1.19 – 1.08 (m, 2H), 1.08 – 1.03 (m, 3H), 0.82 (t, *J* = 7.3 Hz, 3H), 0.73 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 178.7 (s), 168.9 (s), 159.6 (s), 148.1 (s), 145.2 (s), 127.5 (s), 125.5 (s), 72.3 (s), 71.8 (s), 37.9 (s, 2C), 19.9 (s, 2C), 19.5 (s, 2C), 18.6 (s), 18.5 (s), 14.0 (s), 13.8 (s). IR (ATR): ν 2958, 2933, 2872, 1715, 1624, 1566, 1462, 1380, 1233, 1118, 1075, 1028, 989, 940, 883, 822, 706, 676, 624 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{19}H_{28}NO_4S$ $[M + H]^+$: 366.1733; found: 366.1729.



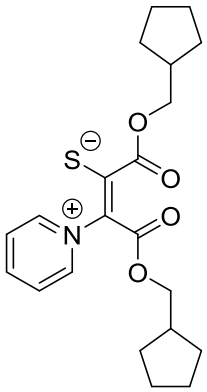
1,4-bis(2-methylbutoxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2h)

Obtained as a yellow solid in 21% yield (0.38 g). Mp: 80.1 – 80.9 ℃. R_f (ethyl acetate) = 0.75. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.40 – 8.36 (m, 2H), 8.34 – 8.29 (m, 1H), 7.92 (t, *J* = 7.1 Hz, 2H), 4.05 – 3.98 (m, 1H), 3.94 – 3.88 (m, 1H), 3.84 – 3.79 (m, 1H), 3.75 – 3.68 (m, 1H), 1.76 – 1.65 (m, 1H), 1.49 – 1.33 (m, 2H), 1.13 – 1.03 (m, 2H), 0.94 – 0.86 (m, 1H), 0.83 (d, *J* = 6.8 Hz, 3H), 0.76 (t, *J* = 7.5 Hz, 3H), 0.68 – 0.60 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 178.8 (s), 169.5 (s), 159.9 (s), 148.1 (s), 145.3 (s), 127.6 (s), 125.3 (s), 70.4 (s), 69.5 (s), 34.0 (s), 33.9 (s), 25.9 (s), 25.8 (s), 20.9 (s), 16.4 (s), 16.3 (s), 14.1 (s), 11.1 (s), 11.0 (s). IR (ATR): ν 3065, 2962, 2932, 2876, 1723, 1687, 1622, 1462, 1391, 1376, 1300, 1226, 1188, 1157, 1073, 1048, 1009, 942, 781, 755, 713, 679, 637 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{19}H_{28}NO_4S$ $[M + H]^+$: 366.1733; found: 366.1729.



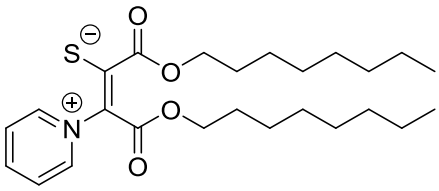
1,4-bis(isopentyloxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2i)

Obtained as a yellow solid in 21% yield (0.38 g). Mp: 76.7 – 77.9 ℃. R_f (ethyl acetate) = 0.83. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.63 (d, *J* = 6.1 Hz, 2H), 8.41 (t, *J* = 7.9 Hz, 1H), 7.97 (t, *J* = 7.0 Hz, 2H), 4.35 (t, *J* = 7.1 Hz, 2H), 4.18 (t, *J* = 7.1 Hz, 2H), 1.74 – 1.60 (m, 4H), 1.55 – 1.45 (m, 2H), 1.06 – 0.94 (m, 6H), 0.92 – 0.84 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 179.6 (s), 169.2 (s), 160.3 (s), 148.5 (s), 144.5 (s), 127.0 (s), 125.5 (s), 64.7 (s), 63.9 (s), 37.4 (s), 37.2 (s), 34.1 (s), 25.2 (s), 24.9 (s), 22.6 (s), 22.4 (s), 16.4 (s), 11.3 (s), 11.2 (s). IR (ATR): ν 3113, 3064, 2956, 2871, 1714, 1667, 1620, 1457, 1391, 1298, 1247, 1202, 1154, 1046, 1029, 990, 767, 716, 676, 616 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{19}H_{28}NO_4S$ $[M + H]^+$: 366.1733; found: 366.1729.



1,4-bis(cyclopentylmethoxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2j)

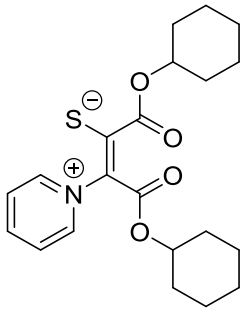
Obtained as a yellow solid in 35% yield (0.67 g). Mp: 143.4 – 144.0 ℃. R_f (ethyl acetate) = 0.63. ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.90 (d, J = 5.9 Hz, 2H), 8.62 (t, J = 7.9 Hz, 1H), 8.14 (t, J = 6.9 Hz, 2H), 4.01 (d, J = 7.1 Hz, 2H), 3.88 (d, J = 6.8 Hz, 2H), 2.29 – 2.16 (m, 1H), 2.09 – 1.90 (m, 1H), 1.76 – 1.66 (m, 2H), 1.62 – 1.47 (m, 6H), 1.46 – 1.38 (m, 4H), 1.30 – 1.24 (m, 2H), 1.14 – 1.00 (m, 2H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.6 (s), 169.0 (s), 160.2 (s), 149.3 (s), 146.4 (s), 128.1 (s), 125.3 (s), 68.8 (s), 68.0 (s), 38.6 (s), 38.4 (s), 29.4 (s), 29.1 (s), 25.3 (s), 25.2 (s). IR (ATR): ν 3108, 3012, 2953, 2863, 1702, 1623, 1499, 1465, 1384, 1288, 1250, 1163, 1072, 1015, 940, 918, 761, 706, 675, 638 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{21}H_{28}NO_4S$ $[M + H]^+$: 390.1733; found: 390.1727.



1,4-bis(octyloxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2k)

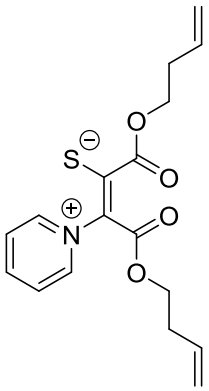
Obtained as a yellow solid in 41% yield (0.91 g). Mp: 123.4 – 124.6 ℃. R_f (ethyl acetate) = 0.81. ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.88 (d, J = 5.3 Hz, 2H), 8.62 (t, J = 7.7 Hz, 1H), 8.14 (t, J = 7.0 Hz, 2H), 4.11 (t, J = 6.7 Hz, 2H), 3.98 (t, J = 6.5 Hz, 2H),

1.64 (t, *J* = 7.1 Hz, 2H), 1.47 (t, *J* = 6.6 Hz, 2H), 1.38 – 1.13 (m, 20H), 0.93 – 0.79 (m, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.4 (s), 168.9 (s), 160.2 (s), 149.3 (s), 146.4 (s), 128.2 (s), 125.4 (s), 65.1 (s), 64.5 (s), 31.7 (s), 31.7 (s), 29.2 (s, 2C), 29.1 (s), 29.1 (s), 28.7 (s), 28.5 (s), 22.6 (s), 22.6 (s), 14.4 (s). IR (ATR): ν 3105, 2954, 2917, 2849, 1717, 1688, 1622, 1461, 1295, 1228, 1199, 1065, 1027, 987, 942, 880, 761, 712, 675, 652, 624 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{25}H_{40}NO_4S$ $[M + H]^+$: 450.2672; found: 450.2666.



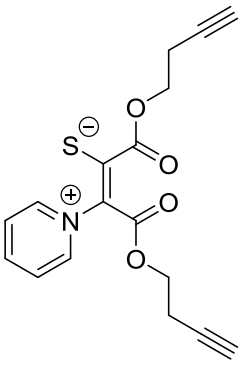
1,4-bis(cyclohexyloxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2l)

Obtained as a yellow solid in 29% yield (0.42 g). Mp: 169.7 – 170.5 ℃. R_f (ethyl acetate) = 0.74. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.63 (s, 2H), 8.41 (s, 1H), 7.97 (s, 2H), 4.90 (d, *J* = 66.0 Hz, 2H), 2.12 – 1.00 (m, 20H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 179.4 (s), 168.6 (s), 159.6 (s), 148.5 (s), 144.4 (s), 126.9 (s), 125.6 (s), 74.4 (s), 73.9 (s), 31.8 (s), 31.4 (s), 25.5 (s), 25.3 (s), 24.0 (s), 23.9 (s). IR (ATR): ν 3070, 2936, 2854, 1716, 1698, 1622, 1489, 1462, 1292, 1235, 1195, 1014, 993, 954, 760, 709, 673, 637, 562 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{21}H_{28}NO_4S$ $[M + H]^+$: 390.1733; found: 390.1727.



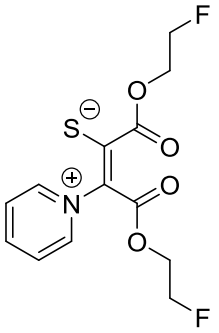
1,4-bis(but-3-en-1-yloxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2m)

Obtained as a yellow solid in 38% yield (0.64 g). Mp: 110.1 – 111.7 ℃. R_f (ethyl acetate) = 0.76. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.59 (s, 2H), 8.42 (t, *J* = 7.9 Hz, 1H), 7.99 (t, *J* = 6.9 Hz, 2H), 5.97 – 5.82 (m, 1H), 5.78 – 5.65 (m, 1H), 5.24 – 4.84 (m, 4H), 4.36 (t, *J* = 7.0 Hz, 2H), 4.17 (t, *J* = 6.8 Hz, 2H), 2.64 – 2.49 (m, 2H), 2.44 – 2.28 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 179.6 (s), 169.1 (s), 159.9 (s), 148.4 (s), 144.7 (s, 2C), 133.9 (s), 133.9 (s), 127.2 (s), 127.2 (s), 125.3 (s), 117.4 (s), 117.3 (s), 65.1 (s), 64.0 (s), 33.1 (s), 32.8 (s). IR (ATR): ν 3107, 3075, 2974, 1715, 1655, 1623, 1491, 1462, 1294, 1235, 1195, 984, 913, 761, 717, 677, 642, 609 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{17}H_{20}NO_4S$ $[M + H]^+$: 334.1107; found: 334.1102.



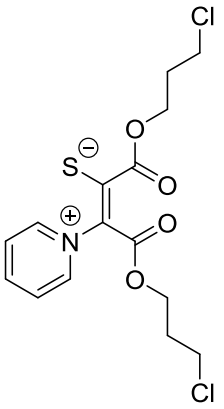
1,4-bis(but-3-yn-1-yloxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2n)

Obtained as a yellow solid in 25% yield (0.42 g). Mp: 122.8 – 123.5 ℃. R_f (ethyl acetate) = 0.79. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.52 (d, *J* = 6.0 Hz, 2H), 8.42 (t, *J* = 7.8 Hz, 1H), 7.99 (t, *J* = 7.1 Hz, 2H), 4.36 (t, *J* = 7.2 Hz, 2H), 4.14 (t, *J* = 6.6 Hz, 2H), 2.67 – 2.59 (m, 2H), 2.45 – 2.37 (m, 2H), 1.98 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 179.3 (s), 171.2 (s), 168.8 (s), 159.5 (s), 148.2 (s), 145.2 (s), 127.5 (s), 124.9 (s), 80.2 (s), 70.3 (s), 63.5 (s), 62.5 (s), 60.4 (s), 21.1 (s), 19.0 (s), 18.7 (s), 14.2 (s). IR (ATR): ν 3254, 3200, 3067, 1721, 1687, 1623, 1491, 1465, 1293, 1237, 1192, 1069, 1030, 1006, 976, 957, 919, 774, 703, 673, 546 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{17}H_{16}NO_4S$ $[M + H]^+$: 330.0794; found: 330.0790.



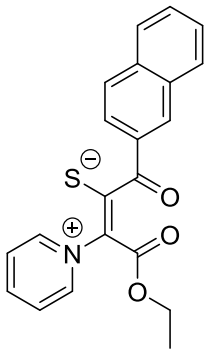
1,4-bis(2-fluoroethoxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2o)

Obtained as a yellow solid in 46% yield (0.72 g). Mp: 163.6 – 164.3 ℃. R_f (ethyl acetate) = 0.55. ^{1}H NMR (400 MHz, DMSO-d_6) δ 8.93 (d, *J* = 6.0 Hz, 2H), 8.64 (t, *J* = 7.8 Hz, 1H), 8.16 (t, *J* = 7.0 Hz, 2H), 4.75 (t, *J* = 4.0 Hz, 1H), 4.63 (t, *J* = 4.0 Hz, 1H), 4.58 (t, *J* = 4.0 Hz, 1H), 4.48 – 4.44 (m, 1H), 4.44 – 4.41 (m, 1H), 4.35 (t, *J* = 3.9 Hz, 1H), 4.30 (t, *J* = 4.0 Hz, 1H), 4.23 (t, *J* = 4.0 Hz, 1H). ^{19}F NMR (376 MHz, DMSO-d_6) δ -222.3 – 222.9 (m, 1F), -223.0 – 223.9 (m, 1F). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.8 (s), 168.6 (s), 159.9 (s), 149.2 (s), 146.6 (s), 128.3 (s), 125.1 (s), 82.9 (s), 82.8 (s), 81.3 (s), 81.1 (s), 64.7 (s), 64.5 (s), 64.0 (s), 63.8 (s). IR (ATR): ν 3111, 3037, 2964, 1725, 1689, 1621, 1479, 1461, 1365, 1294, 1228, 1192, 1039, 979, 922, 878, 758, 705, 674, 623 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{13}H_{14}F_2NO_4S$ $[M + H]^+$: 318.0606; found: 318.0603.



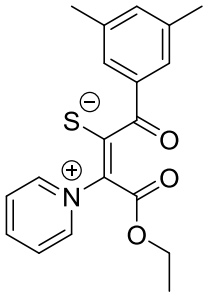
1,4-bis(3-chloropropoxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2p)

Obtained as a yellow solid in 43% yield (0.80 g). Mp: 77.4 – 78.6 ℃. R_f (ethyl acetate) = 0.69. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.48 (d, *J* = 5.2 Hz, 2H), 8.38 (t, *J* = 7.9 Hz, 1H), 7.95 (t, *J* = 7.1 Hz, 2H), 4.40 – 4.29 (m, 2H), 4.16 (t, *J* = 6.0 Hz, 2H), 3.61 (t, *J* = 6.4 Hz, 2H), 3.42 (t, *J* = 6.3 Hz, 2H), 2.16 – 2.10 (m, 2H), 1.95 – 1.89 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 178.9 (s), 169.1 (s), 159.8 (s), 148.2 (s), 145.3 (s), 127.6 (s), 125.1 (s), 62.3 (s), 61.8 (s), 41.6 (s), 41.4 (s), 31.5 (s). IR (ATR): ν 3379, 2966, 1724, 1624, 1586, 1470, 1244, 1202, 1189, 1094, 1045, 1008, 894, 729, 697, 655 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{15}H_{18}Cl_2NO_4S$ $[M + H]^+$: 378.0328; found:378.0325.



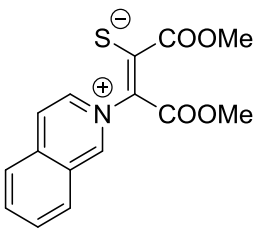
4-ethoxy-1-(naphthalen-2-yl)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2r)

Obtained as a yellow solid in 37% yield (0.67 g). Mp: 191.6 – 192.0 ℃. R_f (ethyl acetate) = 0.38. ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.16 (d, J = 6.0 Hz, 2H), 8.69 (t, J = 7.8 Hz, 1H), 8.57 (s, 1H), 8.25 (t, J = 7.0 Hz, 2H), 8.15 (d, J = 7.9 Hz, 1H), 8.05 (d, J = 8.6 Hz, 1H), 8.00 (d, J = 8.3 Hz, 2H), 7.68 – 7.56 (m, 2H), 3.95 – 3.75 (m, 2H), 0.77 (t, J = 7.0 Hz, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 191.1 (s), 185.8 (s), 160.4 (s), 149.3 (s), 146.4 (s), 135.2 (s), 133.5 (s), 132.7 (s), 131.0 (s), 129.9 (s), 128.6 (s), 128.2 (s), 128.2 (s), 128.1 (s), 127.0 (s), 126.1 (s), 125.5 (s), 60.4 (s), 14.1 (s). IR (ATR): ν 3126, 3062, 2987, 2904, 1681, 1659, 1482, 1455, 1294, 1253, 1185, 1023, 1005, 964, 939, 787, 755, 710, 678, 639, 578 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{21}H_{18}NO_3S$ $[M + H]^+$: 364.1001; found: 364.0997.



1-(3,5-dimethylphenyl)-4-ethoxy-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate (2s)

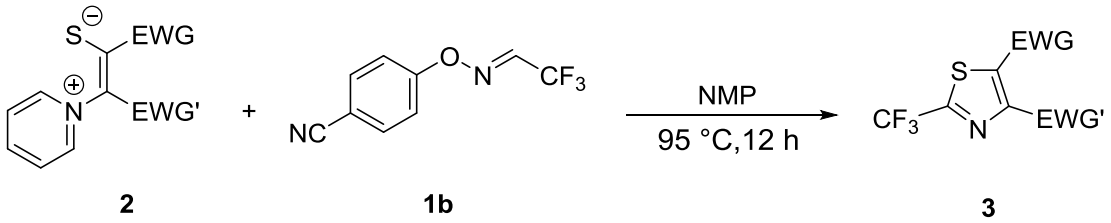
Obtained as a yellow solid in 40% yield (0.68 g). Mp: 236.3 – 237.8 ℃. R_f (ethyl acetate) = 0.72. This compound is almost insoluble in any solvent, thus no NMR spectra is available. IR (ATR): ν 3111, 3060, 2985, 1671, 1646, 1485, 1450, 1299, 1261, 1188, 1162, 1092, 1021, 955, 785, 733, 720, 682, 616 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{19}H_{20}NO_3S$ $[M + H]^+$: 342.1158; found: 342.1156.



3-(isoquinolin-2-ium-2-yl)-1,4-dimethoxy-1,4-dioxobut-2-ene-2-thiolate (2a-2)

Obtained as a yellow solid in 45% yield (0.68 g). Mp: 158.2 – 159.6 ℃. R_f (ethyl acetate) = 0.38. ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.03 (s, 1H), 8.53 (d, J = 8.5 Hz, 3H), 8.36 (d, J = 8.3 Hz, 1H), 8.27 (t, J = 7.7 Hz, 1H), 8.04 (t, J = 7.7 Hz, 1H), 3.75 (s, 3H), 3.58 (s, 3H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.7(s), 169.5(s), 160.8(s), 154.5(s), 138.9(s), 137.7(s), 137.6(s), 131.3(s), 130.9(s), 127.9(s), 127.7(s), 125.8(s), 125.2(s), 52.4(s), 52.0(s). IR (ATR): ν 3048, 2943, 1735, 1668, 1642, 1478, 1429, 1298, 1236, 1199, 1178, 1076, 1035, 920, 871, 819, 758, 739, 698, 567 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{15}H_{14}NO_4S$ $[M + H]^+$: 304.0638; found: 304.0636.

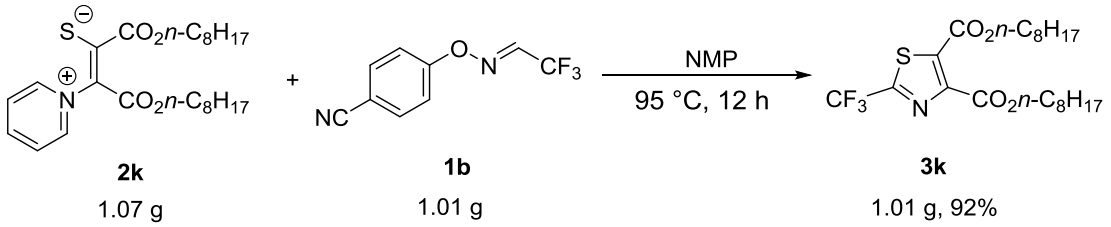
General procedure for the synthesis of 2-trifluoromethyl thiazoles (3)



2 **1b** **3**

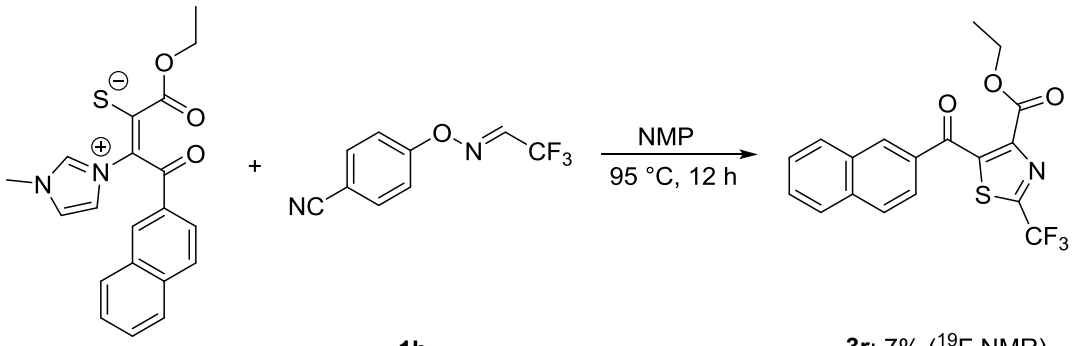
Pyridinium 1,4-zwitterionic thiolates **2** (0.30 mmol), 2,2,2-trifluoroacetaldehyde *O*-(aryl)oxime **1b** (128.5 mg, 0.60 mmol, 2.0 equiv), NMP (2 ml) were added to a reaction tube equipped with a stir bar. The reaction mixture was stirred at 95 ℃ for 12 hours under nitrogen atmosphere. After the reaction was terminated, the mixture was poured into the separatory funnel, then water and ethyl acetate was added. The organic layer was washed with water, brine, and dried over anhydrous sodium sulfate. The solution was filtered and the filtrate was vacuumed to remove the solvent. The crude product was purified by column chromatography (silica gel) with petroleum ether and ethyl acetate as eluent to obtain 2-trifluoromethyl thiazoles **3**.

Procedure for gram scale reaction for synthesis of dioctyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3k)



1,4-Bis(octyloxy)-1,4-dioxo-3-(pyridin-1-ium-1-yl) but-2-ene-2-thiolate **2k** (1.07 g, 2.37 mmol), 2,2,2-trifluoroacetaldehyde *O*-(aryl)oxime **1b** (1.01 g, 4.74 mmol, 2.0 equiv), NMP (10 ml) were added to a reaction tube equipped with a stir bar. The reaction mixture was stirred at 95 ℃ for 12 hours under nitrogen atmosphere. After the reaction was terminated, the mixture was poured into the separatory funnel, then water and ethyl acetate was added. The organic layer was washed with water, brine, and dried over anhydrous sodium sulfate. The solution was filtered and the filtrate was vacuumed to remove the solvent. The crude product was purified by column chromatography (silica gel) with petroleum ether and ethyl acetate as eluent to obtain dioctyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate **3k**.

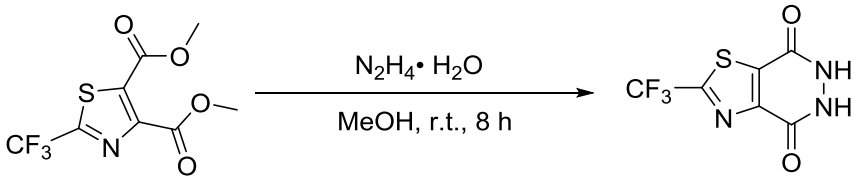
One example of reaction of with imidazolium 1,4-zwitterionic thiolate



2r-3 + **1b** → **3r**: 7% (^{19}F NMR)

Procedures for derivatization

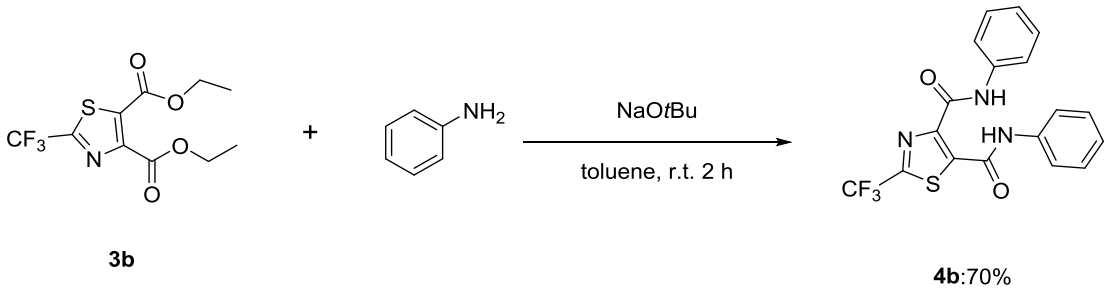
(a) Procedures for derivatization of **3a**



3a **4a**: 85%

To a solution of **3a** (113.0 mg, 0.42 mmol) in MeOH (2 mL) was added N_2H_4•H_2O (67.3 mg, 2.10 mmol, 5.0 equiv), and the mixture was stirred at room temperature for 8 h. After the reaction was terminated, the mixture was filtered and the precipitate washed with hxane (2×5 ml) to afford **4a** as yellow powder (85 mg, 85%).

(b) Procedures for derivatization of **3b**

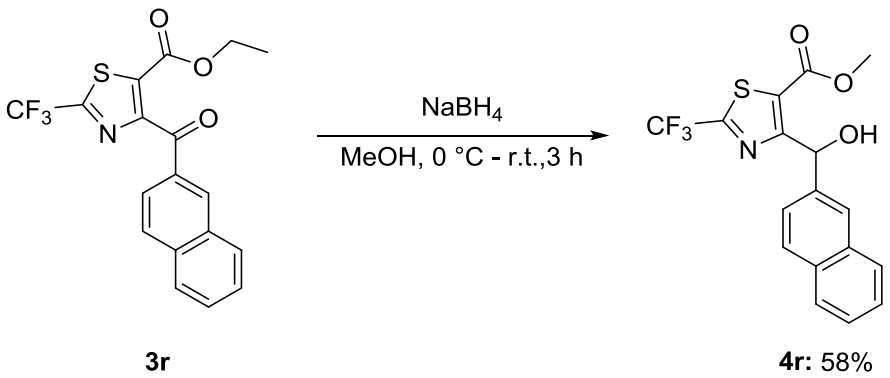


3b

4b:70%

To a 10 mL Schlenk tube was added **3b** (0.60 mmol), aniline (167.6 mg, 1.80 mmol, 3.0 equiv), NaO*t*Bu (172.9 mg, 1.80 mmol, 3.0 equiv), and 2.0 ml of toluene under nitrogen atmosphere, and then the tube was sealed and stirred at room temperature for 2 h. After the reaction was terminated, the solvent was removed under vacuum, and the residue was purified by column chromatography (silica gel) with petroleum ether and ethyl acetate as eluent to obtain **4b** (164.3 mg, 70%).

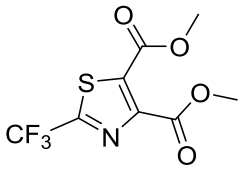
(c) Procedures for derivatization of **3r**



3r **4r:** 58%

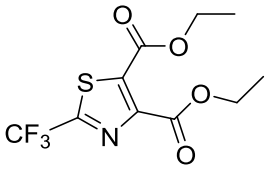
To a solution of compound **3r** (45.0 mg, 0.12 mmol) in MeOH (1 mL) at 0 ℃ was added $NaBH_4$ (4.9 mg, 0.13 mmol) in small portions. After the addition, the mixture was allowed to warm to r.t. with stirring for 3 h. The mixture was diluted with EtOAc (10 mL) and H_2O (10 mL). The organic layer was separated and washed with H_2O (2 × 5 mL). The organic layer was separated, dried (Na_2SO_4), and evaporated under vacuum. The resulting residue was purified by column chromatography on silica gel with petroleum ether/ethyl acetate (20:1 v/v) to obtain **4r** (25.3 mg, 58%).

Data for compounds



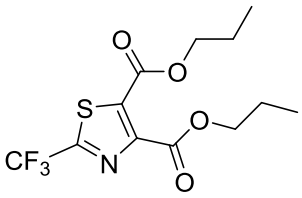
dimethyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3a)

Obtained as a yellow solid in 73% yield (58.9 mg). Mp: 60.0 – 60.9 ℃. R_f (petroleum ether/ethyl acetate = 10:1) = 0.76. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.00 (s, 3H), 3.96 (s, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.5 (s), 159.3 (s), 157.8 (q, J = 42.1 Hz), 149.5 (s), 133.2 (s), 118.7 (q, J = 273.6 Hz), 53.7 (s), 53.4 (s). IR (ATR): ν 2960, 1750, 1731, 1521, 1469, 1431, 1332, 1304, 1261, 1222, 1152, 1092, 1045, 995, 949, 893, 815, 775, 742, 688 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_8H_7F_3NO_4S$ $[M + H]^+$: 270.0042; found: 270.0036.



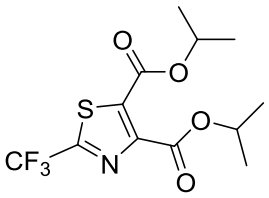
diethyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3b)

Obtained as a yellow liquid in 80% yield (71.3 mg). R_f (petroleum ether/ethyl acetate = 10:1) = 0.85. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.45 – 4.30 (m, 4H), 1.51 – 1.32 (m, 6H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.4 (s), 158.9 (s), 157.6 (q, J = 41.9 Hz), 149.9 (s), 133.9 (s), 118.8 (q, J = 273.5 Hz), 115.1 (s), 63.1 (s), 62.8 (s), 13.9 (s, 2C). IR (ATR): ν 2986, 1728, 1519, 1468, 1372, 1301, 1257, 1208, 1150, 1088, 1048, 1015, 957, 858, 838, 754, 684 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{10}H_{11}F_3NO_4S$ $[M + H]^+$: 298.0355; found: 298.0348.



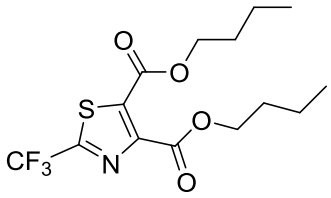
dipropyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3c)

Obtained as a yellow liquid in 62% yield (60.5 mg). R_f (petroleum ether/ethyl acetate = 30:1) = 0.60. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.65 – 1.61 (m, 8H), 1.59 – 1.57 (m, 6H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.5 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.6 (s), 158.9 (s), 157.8 (s), 156.8 (q, *J* = 41.7 Hz), 150.9 (s), 118.9 (q, *J* = 273.4 Hz), 84.8 (s), 84.2 (s), 83.4 (s), 83.1 (s), 28.0 (s), 27.9 (s). IR (ATR): ν 2981, 1727, 1516, 1458, 1369, 1305, 1257, 1229, 1147, 1092, 1048, 961, 834, 812, 769, 748, 733, 694 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{12}H_{15}F_3NO_4S$ $[M + H]^+$: 326.0668; found: 326.0661.



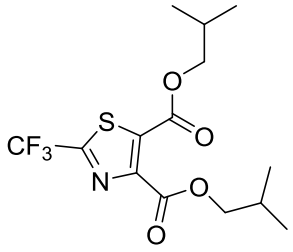
diisopropyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3d)

Obtained as a yellow liquid in 82% yield (80.0 mg). R_f (petroleum ether/ethyl acetate = 10:1) = 0.88. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.39 – 5.17 (m, 2H), 1.42 (d, *J* = 6.3 Hz, 6H), 1.38 (d, *J* = 6.3 Hz, 6H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.2 (s), 158.5 (s), 157.6 (q, *J* = 41.8 Hz), 150.5 (s), 132.8 (s), 118.9 (q, *J* = 273.5 Hz), 71.4 (s), 71.0 (s), 21.6 (s, 2C). IR (ATR): ν 2985, 1728, 1519, 1468, 1375, 1306, 1262, 1215, 1154, 1104, 1082, 1046, 967, 903, 832, 756, 680 cm^{-1}. HRMS (ESI) m/z: calcd. For $C_{12}H_{15}F_3NO_4S$ $[M + H]^+$: 326.0668; found: 326.0660.



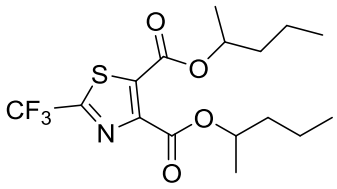
dibutyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3e)

Obtained as a yellow liquid in 55% yield (58.3 mg). R_f (petroleum ether/ethyl acetate = 30:1) = 0.44. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.44 – 4.27 (m, 4H), 1.80 – 1.68 (m, 4H), 1.51 – 1.38 (m, 4H), 1.00 – 0.92 (m, 6H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.5 (s), 159.0 (s), 157.8 (q, *J* = 42.0 Hz), 150.1 (s), 132.9 (s), 118.8 (q, *J* = 273.6 Hz), 66.9 (s), 66.7 (s), 30.4 (s), 19.0 (s), 13.7 (s), 13.6 (s). IR (ATR): ν 2961, 2875, 1731, 1520, 1466, 1305, 1256, 1203, 1153, 1089, 1047, 1017, 969, 757, 740, 685 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{14}H_{19}F_3NO_4S$ [M + H]$^+$: 354.0981; found: 354.0976.



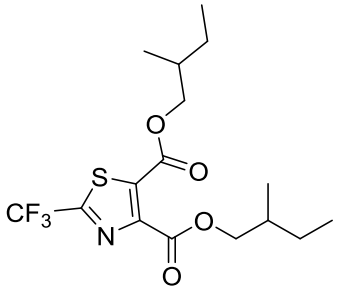
diisobutyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3f)

Obtained as a yellow liquid in 89% yield (94.3 mg). R_f (petroleum ether/ethyl acetate = 25:1) = 0.81. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.21 – 4.17 (m, 2H), 4.16 – 4.09 (m, 2H), 2.13 – 1.97 (m, 2H), 1.05 – 0.94 (m, 12H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.5 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.6 (s), 158.9 (s), 157.8 (q, *J* = 41.8 Hz), 150.1 (s), 132.7 (s), 118.8 (q, *J* = 273.6 Hz), 72.9 (s), 72.8 (s), 27.7 (s, 2C), 18.9 (s, 2C). IR (ATR): ν 2963, 2876, 1732, 1589, 1521, 1469, 1371, 1206, 1156, 1088, 1048, 991, 941, 807, 757, 686, 607 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{14}H_{19}F_3NO_4S$ [M + H]$^+$: 354.0981; found: 354.0973.



di(pentan-2-yl) 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3g)

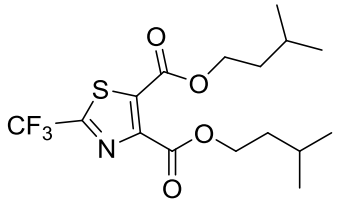
Obtained as a yellow liquid in 80% yield (91.5 mg). R_f (petroleum ether/ethyl acetate = 25:1) = 0.84. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.31 – 5.09 (m, 2H), 1.88 – 1.32 (m, 14H), 1.00 – 0.96 (m, 6H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.3 (s), 158.6 (s), 157.5 (q, *J* = 41.9 Hz), 150.6 (s), 132.7 (s), 118.9 (q, *J* = 273.5 Hz), 74.5 (s), 74.2 (s), 37.8 (s), 19.8 (s), 19.6 (s), 18.6 (s), 13.9 (s), 13.8 (s). IR (ATR): ν 2961, 2936, 2875, 1732, 1521, 1467, 1371, 1307, 1259, 1213, 1155, 1088, 1047, 993, 964, 936, 884, 827, 759, 744, 681, 607 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{16}H_{23}F_3NO_4S$ $[M + H]^+$: 382.1294; found: 382.1285.



bis(2-methylbutyl) 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3h)

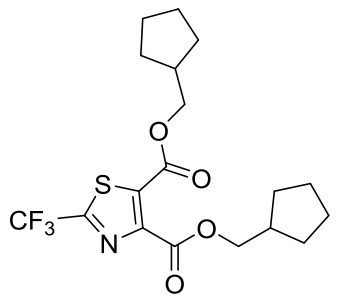
Obtained as a yellow liquid in 50% yield (57.2 mg). R_f (petroleum ether/ethyl acetate = 25:1) = 0.82. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.34 – 4.04 (m, 4H), 1.93 – 1.73 (m, 2H), 1.55 – 1.41 (m, 2H), 1.28 – 1.14 (m, 2H), 1.02 – 0.89 (m, 12H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.5 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.7 (s), 161.6 (s), 160.0 (s), 159.0 (s), 157.8 (q, *J* = 42.0 Hz), 150.2 (s), 132.7 (s), 118.8 (q, *J* = 273.6 Hz), 71.6 (s), 71.4 (s), 71.1 (s), 70.9 (s), 34.1 (s), 34.0 (s), 25.9 (s, 2C), 16.3 (s), 11.1

(s). IR (ATR): ν 2963, 2878, 1732, 1521, 1463, 1381, 1258, 1203, 1155, 1089, 1049, 982, 767, 686 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{16}H_{23}F_3NO_4S$ $[M + H]^+$: 382.1294; found: 382.1287.



diisopentyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3i)

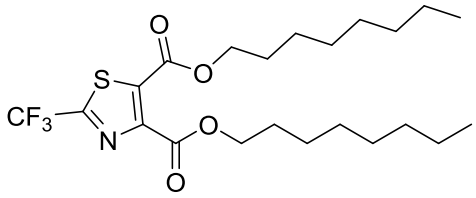
Obtained as a yellow liquid in 85% yield (97.2 mg). R_f (petroleum ether/ethyl acetate = 25:1) = 0.82. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.44 (t, J = 6.9 Hz, 2H), 4.39 (t, J = 6.8 Hz, 2H), 1.70 – 1.62 (m, 4H), 0.98 – 0.93 (m, 14H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.5 (s), 159.0 (s), 157.7 (q, J = 41.9 Hz), 150.1 (s), 132.9 (s), 118.8 (q, J = 273.6 Hz), 71.6 (s), 65.7 (s), 65.5 (s), 37.0 (s, 2C), 24.9 (s), 22.4 (s, 2C), 16.3 (s), 11.1 (s). IR (ATR): ν 2960, 2873, 1737, 1520, 1465, 1371, 1307, 1239, 1205, 1156, 1091, 1046, 973, 940, 754, 685, 634, 607 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{16}H_{23}F_3NO_4S$ $[M + H]^+$: 382.1294; found: 382.1288.



bis(cyclopentylmethyl) 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3j)

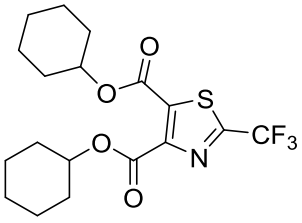
Obtained as a yellow liquid in 65% yield (79.1 mg). R_f (petroleum ether/ethyl acetate = 25:1) = 0.75. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.35 – 4.03 (m, 4H), 2.42 – 2.19 (m, 2H), 1.86 – 1.52 (m, 12H), 1.38 – 1.24 (m, 4H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.5

(s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.6 (s), 159.0 (s), 157.7 (q, *J* = 42.0 Hz), 150.2 (s), 132.8 (s), 118.8 (q, *J* = 273.6 Hz), 70.8 (s), 70.7 (s), 38.4 (s, 2C), 29.4 (s), 29.3 (s), 25.3 (s), 25.2 (s). IR (ATR): ν 2952, 2869, 1735, 1520, 1453, 1372, 1297, 1239, 1206, 1155, 1085, 1047, 977, 913, 846, 757, 687, 633, 607, 567 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{18}H_{23}F_3NO_4S$ $[M + H]^+$: 406.1294; found: 406.1288.



dioctyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3k)

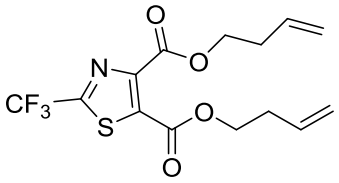
Obtained as a yellow liquid in 92% yield (128.5 mg). R_f (petroleum ether/ethyl acetate = 30:1) = 0.64. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.40 (t, *J* = 6.9 Hz, 2H), 4.35 (t, *J* = 6.7 Hz, 2H), 1.79 – 1.67 (m, 4H), 1.46 – 1.27 (m, 20H), 0.91 – 0.86 (m, 6H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.5 (s), 159.0 (s), 157.7 (q, *J* = 41.9 Hz), 150.0 (s), 132.9 (s), 118.8 (q, *J* = 273.6 Hz), 29.2 (s), 29.1 (s, 2C), 28.4 (s, 2C), 25.8 (s), 22.6 (s), 14.0 (s). IR (ATR): ν 2925, 2856, 1736, 1520, 1467, 1334, 1306, 1261, 1205, 1156, 1092, 1048, 973, 757, 741, 723 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{22}H_{35}F_3NO_4S$ $[M + H]^+$: 466.2233; found: 466.2227.



dicyclohexyl 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3l)

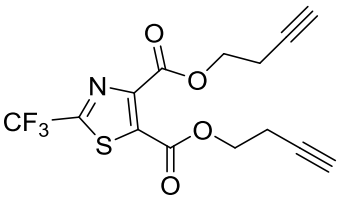
Obtained as a yellow liquid in 65% yield (79.0 mg). R_f (petroleum ether/ethyl acetate = 30:1) = 0.56. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.16 – 4.95 (m, 2H), 2.09 – 2.01 (m,

2H), 1.98 – 1.89 (m, 2H), 1.84 – 1.72 (m, 4H), 1.68 – 1.52 (m, 6H), 1.50 – 1.36 (m, 4H), 1.35 – 1.25 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.5 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.2 (s), 158.4 (s), 157.6 (q, *J* = 41.8 Hz), 150.7 (s), 132.7 (s), 118.9 (q, *J* = 273.5 Hz), 76.0 (s), 75.9 (s), 31.3 (s), 25.3 (s), 25.2 (s), 23.8 (s), 23.5 (s). IR (ATR): ν 2938, 2861, 1736, 1519, 1468, 1451, 1373, 1300, 1237, 1210, 1154, 1092, 1046, 1007, 970, 904, 830, 815, 756, 687, 634, 607 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{18}H_{23}F_3NO_4S$ $[M + H]^+$: 406.1294; found: 406.1287.



di(but-3-en-1-yl) 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3m)

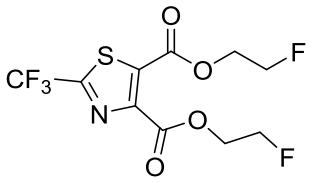
Obtained as a yellow liquid in 60% yield (62.9 mg). R_f (petroleum ether/ethyl acetate = 30:1) = 0.64. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.91 – 5.70 (m, 2H), 5.24 – 5.09 (m, 4H), 4.50 – 4.35 (m, 4H), 2.63 – 2.45 (m, 4H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.3(s), 158.8(s), 157.8 (q, *J* = 42.1 Hz), 149.9(s), 133.3(s), 133.0(s), 132.9(s), 118.8 (q, *J* = 273.6 Hz), 118.1(s), 117.8(s), 65.9 (s), 65.8 (s), 32.8 (s), 32.7 (s). IR (ATR): ν 2962, 1732, 1643, 1519, 1469, 1336, 1306, 1255, 1203, 1091, 1047, 980, 918, 755, 741, 686, 634 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{14}H_{15}F_3NO_4S$ $[M + H]^+$: 350.0668; found: 350.0663.



di(but-3-yn-1-yl) 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3n)

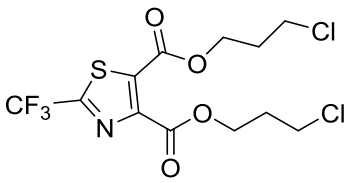
Obtained as a yellow liquid in 55% yield (56.9 mg). R_f (petroleum ether/ethyl acetate

= 25:1) = 0.53. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.53 (t, *J* = 7.0 Hz, 2H), 4.48 (t, *J* = 6.6 Hz, 2H), 2.76 – 2.62 (m, 4H), 2.10 – 2.02 (m, 2H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.5 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.9 (s), 158.6 (s), 158.1 (q, *J* = 42.1 Hz), 149.6 (s), 132.9 (s), 118.8 (q, *J* = 273.6 Hz), 79.3 (s), 79.0 (s), 70.7 (s), 70.4 (s), 64.5 (s), 64.3 (s), 18.9 (s), 18.7 (s). IR (ATR): ν 3289, 2917, 2849, 1731, 1519, 1466, 1335, 1305, 1254, 1202, 1154, 1096, 1047, 992, 754, 642, 552 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{14}H_{11}F_3NO_4S$ $[M + H]^+$: 346.0355; found: 346.0352.



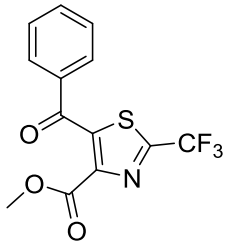
bis(2-fluoroethyl) 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3o)

Obtained as a yellow liquid in 60% yield (59.9 mg). R_f (petroleum ether/ethyl acetate = 25:1) = 0.35. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.83 – 4.79 (m, 1H), 4.79 – 4.75 (m, 1H), 4.71 – 4.67 (m, 2H), 4.66 – 4.60 (m, 3H), 4.60 – 4.56 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.6 (s, 3F), -224.22 – -224.62 (m, 1F), -224.62 – -225.06 (m, 1F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.9 (s), 158.7 (s), 158.3 (q, *J* = 42.2 Hz), 149.4 (s), 132.9 (s), 118.7 (q, *J* = 273.7 Hz), 81.5 (d, *J* = 19.6 Hz), 79.8 (d, *J* = 20.4 Hz), 65.7 (d, *J* = 20.0 Hz), 65.4 (d, *J* = 20.3 Hz). IR (ATR): ν 2961, 1731, 1519, 1468, 1408, 1378, 1334, 1261, 1206, 1153, 1095, 1046, 964, 883, 756, 742 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{10}H_9F_5NO_4S$ $[M + H]^+$: 334.0167; found: 334.0161.



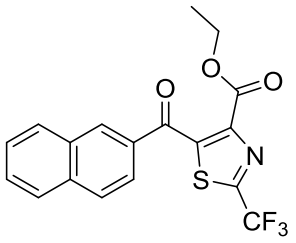
bis(3-chloropropyl) 2-(trifluoromethyl)thiazole-4,5-dicarboxylate (3p)

Obtained as a yellow liquid in 49% yield (57.6 mg). R_f (petroleum ether/ethyl acetate = 20:1) = 0.55. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.64 – 4.53 (m, 4H), 3.75 – 3.63 (m, 4H), 2.31 – 2.18 (m, 4H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.5 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.2 (s), 158.8 (s), 158.1 (q, J = 42.3 Hz), 149.7 (s), 132.8 (s), 118.7 (q, J = 273.6 Hz), 63.8 (s), 63.5 (s), 40.9 (s), 40.7 (s), 31.3 (s), 31.2 (s). IR (ATR): ν 2921, 2850, 1731, 1519, 1465, 1391, 1302, 1257, 1204, 1153, 1098, 1047, 1006, 896, 826, 756, 685, 656 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{12}H_{13}Cl_2F_3NO_4S$ $[M + H]^+$: 393.9889; found: 393.9884.



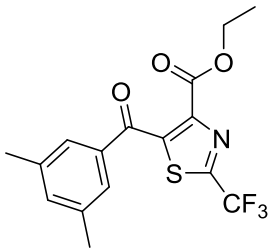
methyl 5-benzoyl-2-(trifluoromethyl)thiazole-4-carboxylate (3q)

Obtained as a yellow liquid in 34% yield (57.6 mg). R_f (petroleum ether/ethyl acetate = 20:1) = 0.36. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.81 (m, 2H), 7.78 – 7.65 (m, 1H), 7.57 – 7.46 (m, 2H), 3.72 (s, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.1 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 186.2 (s), 160.4 (s), 156.3 (q, J = 43.5, 42.9 Hz), 145.6 (s), 144.3 (s), 136.2 (s), 134.7 (s), 129.4 (s), 129.1 (s), 118.9 (q, J = 273.8 Hz), 52.9 (s). IR (ATR): ν 2957, 1744, 1671, 1597, 1509, 1450, 1334, 1302, 1259, 1234, 1191, 1151, 1040, 999, 896, 791, 752, 711, 690 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{13}H_9F_3NO_3S$ $[M + H]^+$: 316.0249; found: 316.0245.



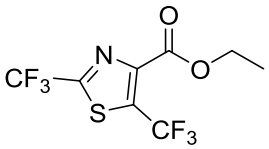
ethyl 5-(2-naphthoyl)-2-(trifluoromethyl)thiazole-4-carboxylate (3r)

Obtained as a white solid in 30% yield (34.1 mg). Mp: 112.8 – 113.4 ℃. R_f (petroleum ether/ethyl acetate = 20:1) = 0.41. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 1.7 Hz, 1H), 8.06 – 7.97 (m, 2H), 7.96 – 7.90 (m, 2H), 7.72 – 7.65 (m, 1H), 7.64 – 7.56 (m, 1H), 4.11 (q, *J* = 7.1 Hz, 2H), 0.98 (t, *J* = 7.1 Hz, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.0 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 186.2 (s), 159.9 (s), 156.2 (q, *J* = 42.3 Hz), 145.9 (s), 144.0 (s), 136.2 (s), 133.7 (s), 132.5 (s), 132.3 (s), 129.8 (s), 129.7 (s), 129.2 (s), 128.0 (s), 127.5 (s), 123.8 (s), 118.9 (q, *J* = 273.7 Hz), 62.5 (s), 13.6 (s). IR (ATR): ν 3203, 3061, 1720, 1661, 1626, 1465, 1279, 1194, 1146, 1040, 1018, 906, 838, 801, 756, 724, 606 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{18}H_{13}F_3NO_3S$ $[M + H]^+$: 380.0562; found: 380.0556.



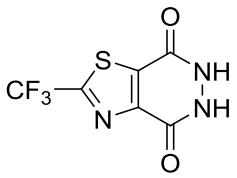
ethyl 5-(3,5-dimethylbenzoyl)-2-(trifluoromethyl)thiazole-4-carboxylate (3s)

Obtained as a white solid in 35% yield (37.5 mg). Mp: 73.5 – 74.6 ℃. R_f (petroleum ether/ethyl acetate = 20:1) = 0.50. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 (d, *J* = 1.6 Hz, 2H), 7.31 (s, 1H), 4.18 (q, *J* = 7.1 Hz, 2H), 2.38 (s, 6H), 1.08 (t, *J* = 7.1 Hz, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.0 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 186.6 (s), 159.9 (s), 156.0 (q, *J* = 42.3 Hz), 145.8 (s), 144.2 (s), 138.9 (s), 136.5 (s), 136.3 (s), 127.3 (s), 118.9 (q, *J* = 273.6 Hz), 62.5 (s), 21.2 (s), 13.6 (s). IR (ATR): ν 2979, 2917, 1715, 1656, 1605, 1506, 1481, 1447, 1333, 1294, 1220, 1184, 1147, 1042, 1022, 938, 858, 786, 769, 734, 693, 679, 617, 544 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{16}H_{15}F_3NO_3S$ $[M + H]^+$: 358.0719; found: 358.0713.



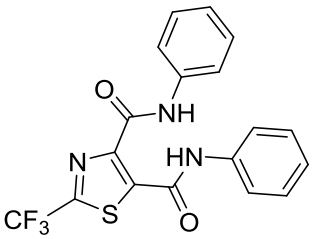
ethyl 2,5-bis(trifluoromethyl)thiazole-4-carboxylate (3t)

Obtained as a yellow liquid in 41% yield (36.0 mg). R_f (petroleum ether) = 0.64 . ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.46 (q, *J* = 7.1 Hz, 2H), 1.42 (t, *J* = 7.1 Hz, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.2 (s, 3F), -62.0 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.7 (s), 157.6 (q, *J* = 42.7 Hz), 146.6 (q, *J* = 39.8 Hz), 119.3 (s), 119.1 (q, *J* = 273.0 Hz), 118.6 (q, *J* = 273.6 Hz), 63.6 (s), 13.8 (s). IR (ATR): ν 2990, 1746, 1721, 1478, 1355, 1280, 1256, 1147, 1087, 1046, 1010, 918, 768, 737, 682 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_8H_6F_6NO_2S$ $[M + H]^+$: 294.0017; found: 294.0016.



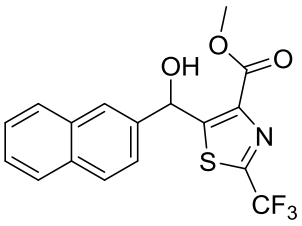
2-(trifluoromethyl)-5,6-dihydrothiazolo[4,5-d]pyridazine-4,7-dione (4a)

Obtained as a white solid in 85% yield (85.0 mg). Mp: 132.8 – 133.5 ℃. R_f (ethyl acetate) = 0.37. ^{1}H NMR (400 MHz, DMSO-d_6) δ 4.14 – 3.47 (m, 2H). ^{19}F NMR (376 MHz, DMSO-d_6) δ -60.7 (s, 3F). ^{13}C NMR (101 MHz, DMSO-d_6) δ 158.9 (s), 156.7 (s), 154.1 (q, J = 41.1 Hz), 143.8 (s), 143.2 (s), 119.5 (q, J = 273.0 Hz). IR (ATR): ν 3287, 3174, 3011, 1668, 1608, 1557, 1530, 1503, 1487, 1305, 1194, 1148, 1047, 1001, 926, 856, 807, 760, 706, 677, 656, 582 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_6H_2F_3N_3O_2S$ $[M + H]^+$: 237.9892; found: 237.9888.



***N*^{4},*N*^{5}-diphenyl-2-(trifluoromethyl)thiazole-4,5-dicarboxamide (4b)**

Obtained as a yellow solid in 70% yield (164.4 mg). Mp: 156.3 – 157.7 ℃. R_f (petroleum ether/ethyl acetate = 7:1) = 0.78. ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.37 (s, 1H), 9.60 (s, 1H), 7.79 – 7.71 (m, 4H), 7.44 (t, J = 7.9 Hz, 2H), 7.37 (t, J = 7.9 Hz, 2H), 7.26 (t, J = 7.5 Hz, 1H), 7.22 – 7.13 (m, 1H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.8 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.7 (s), 155.8 (s), 155.7 (q, J = 41.8 Hz), 149.3 (s), 142.3 (s), 137.6 (s), 136.2 (s), 129.3 (s), 129.1 (s), 125.9 (s), 125.1 (s), 120.7 (s), 120.3 (s), 118.9 (q, J = 118.9 Hz). IR (ATR): ν 3353, 2986, 1651, 1597, 1538, 1498, 1440, 1311, 1141, 1071, 1041, 896, 882, 802, 786, 749, 733, 685, 628, 591, 561 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{18}H_{13}F_3N_3O_2S$ $[M + H]^+$: 392.0675; found: 392.0674.



methyl 4-(hydroxy(naphthalen-2-yl)methyl)-2-(trifluoromethyl)

thiazole-5-carboxylate (4r)

Obtained as a yellow liquid in 58% yield (25.3 mg). R_f (petroleum ether/ethyl acetate = 10:1) = 0.68. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (s, 1H), 7.97 – 7.86 (m, 3H), 7.59 – 7.51 (m, 3H), 6.79 (s, 1H), 4.02 (s, 3H). ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.3 (s, 3F). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.6 (s), 158.1 (s), 153.9 (q, J = 42.1 Hz), 141.3 (s), 138.0 (s), 133.4 (s), 133.1 (s), 128.9 (s), 128.3 (s), 127.8 (s), 126.8 (s), 126.7 (s), 125.8 (s), 123.9 (s), 119.2 (q, J = 273.3 Hz), 69.3 (s), 53.2 (s). IR (ATR): ν 3427, 2924, 2851, 1723, 1491, 1334, 1303, 1219, 1149, 1042, 997, 891, 821, 755, 686, 606 cm^{-1}. HRMS (ESI) m/z: calcd. for $C_{17}H_{13}F_3NO_3S$ $[M + H]^+$: 368.0562; found: 368.0561.

Crystal structure analyses

The crystal samples of **3a** and **3r** were prepared by slow volatilization in ethyl acetate. The suitable crystals of **3a** (CCDC 2179670) and **3r** (CCDC 2183006) were mounted on quartz fibers and X-ray data collected on a Bruker AXS APEX diffractometer, equipped with a CCD detector at -50 ℃, using MoKα radiation (λ 0.71073 Å) and CuKα radiation (λ 1.54184 Å). The data was corrected for Lorentz and polarisation effect with the **SMART** suite of programs and for absorption effects with SADABS.[4] Structure solution and refinement were carried out with the SHELXTL suite of programs. The structure was solved by direct methods to locate the heavy atoms, followed by difference maps for the light non-hydrogen atoms.

Table S1. Crystal data and structure refinement for compounds

Compound	**3a** (CCDC 2179670)	**3r** (CCDC 2183006)
Empirical formula	$C_8H_6F_3NO_4S$	$C_{18}H_{12}F_3NO_3S$
Formula weight	269.20	379.35
Temperature/K	296.15	293
Wavelength/Å	0.71073	1.54184
Crystal system	Triclinic	Monoclinic
a/Å	7.7049(7)	4.8566(2)
b/Å	8.0698(6)	35.3036(13)
c/Å	9.0862(8)	10.3267(4)
α/°	74.601(3)	90
β/°	77.073(3)	96.951(4)
γ/°	82.099(3)	90
Volume/Å^3	529.03(8)	1757.56(12)
Z	2	4
Density (calc.)/cm^3	1.690	1.434
Absorption coefficient /mm^{-1}	0.352	2.088
F(000)	272.0	776.0
Crystal size/mm	0.10 × 0.05 × 0.01	0.10 × 0.1 × 0.01
Theta range for data collection / °	4.742~50.098	5.006~136.532
Reflections collected	15440	8045
Independent reflections	1877 [R(int) = 0.0229]	3167[R(int) = 0.0283]
Data/restraints/parameters	1877 / 0 / 157	3167 / 0 / 236
Goodness-of-fit on F^2	1.043	1.098
Final R indexes [I>=2σ (I)]	0.0263	0.0630
Final R indexes [all data]	0.0272	0.0894
Largest diff. peak and hole / e Å^{-3}	0.32/-0.31	0.55/-0.34

ORTEP diagrams

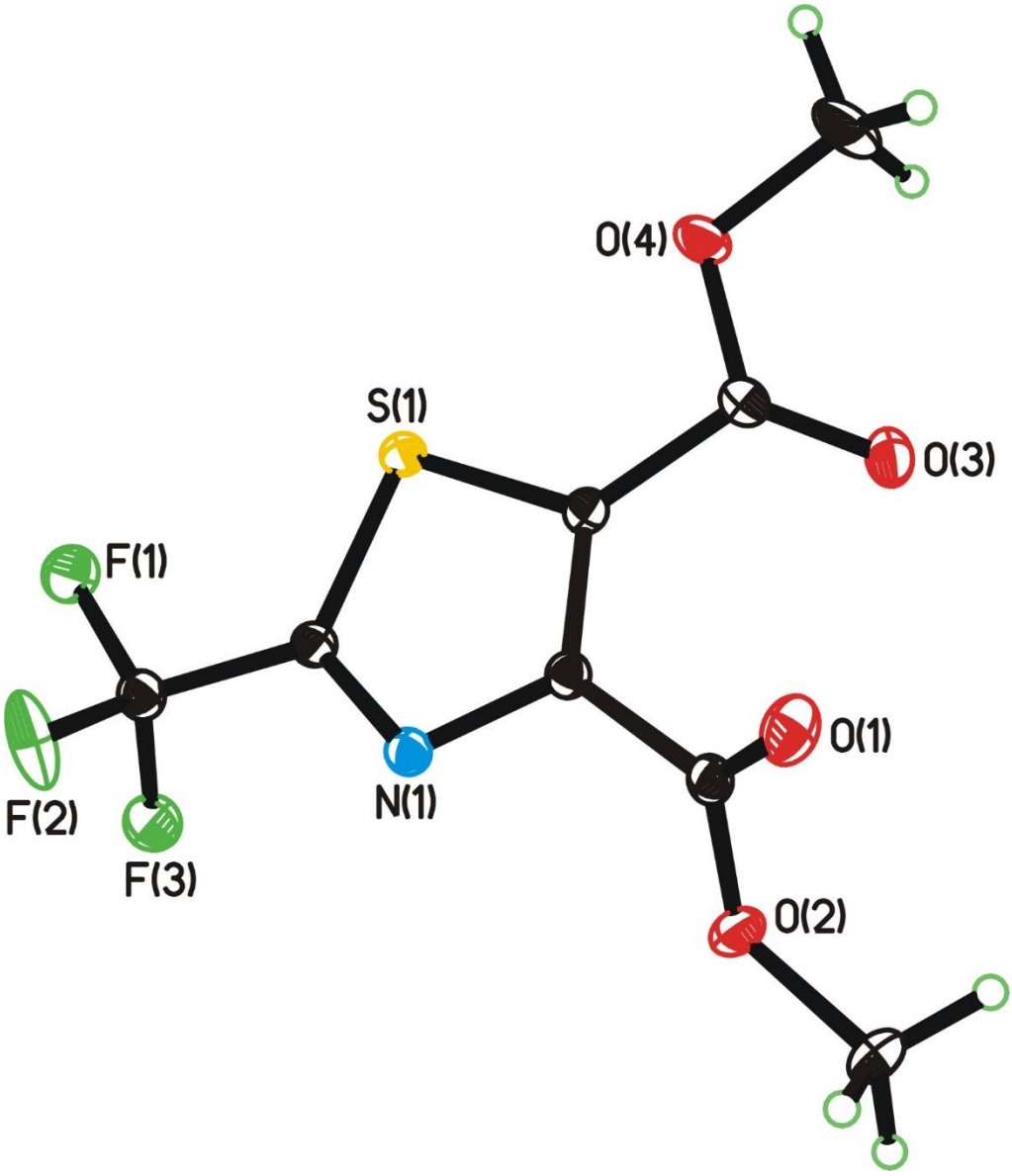


Figure S1. ORTEP diagram of 3a with thermal ellipsoids at the 40% probability level

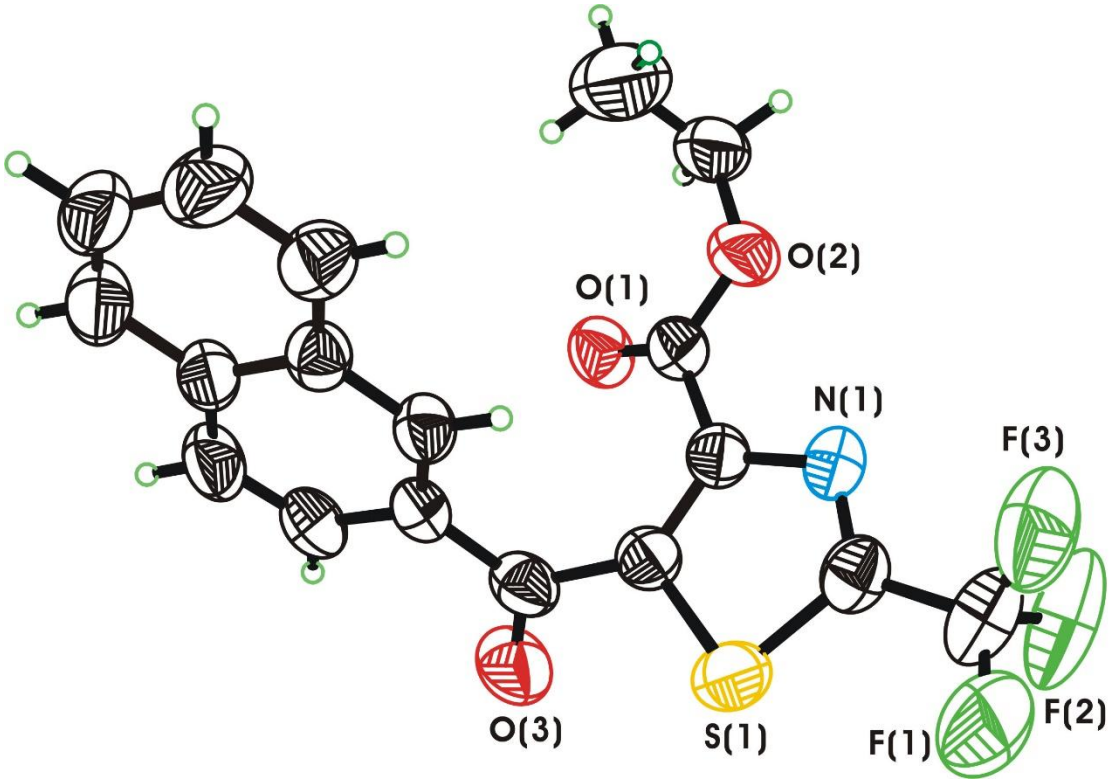


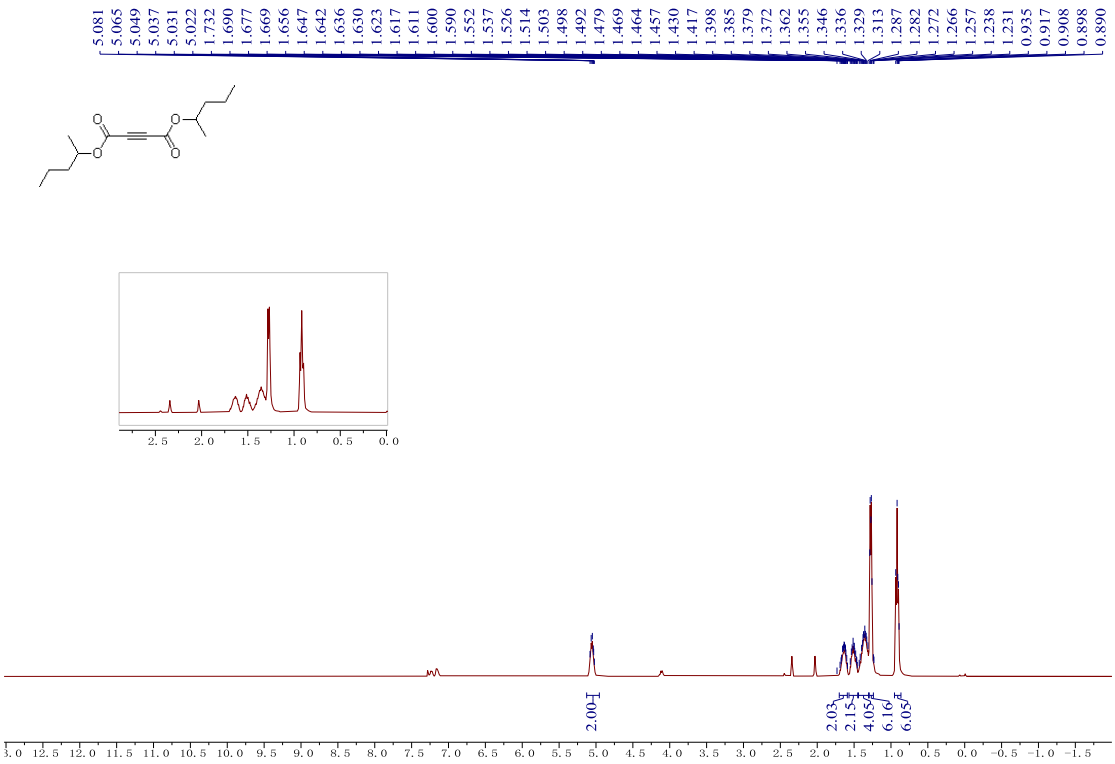
Figure S2. ORTEP diagram of 3r with thermal ellipsoids at the 40% probability level

References

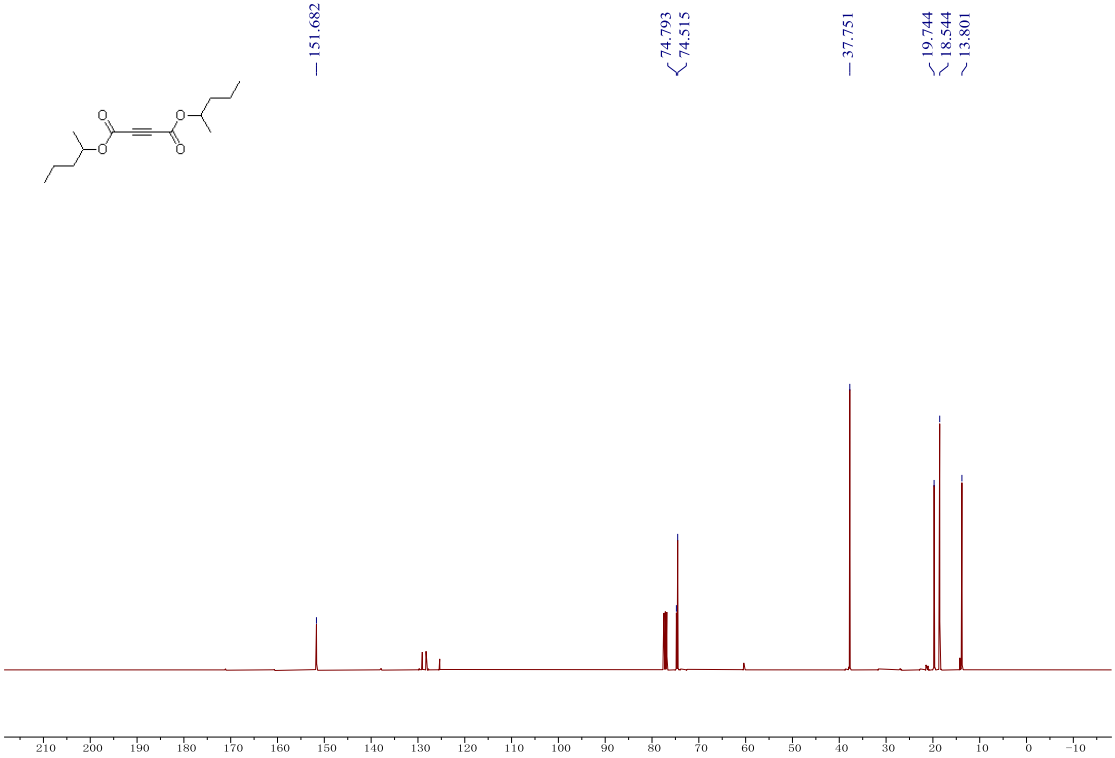
1. B. Lin, Y. Yao, Y. Huang and Z. Weng, 2,2,2-Trifluoroacetaldehyde O-(Aryl)oxime: A Precursor of Trifluoroacetonitrile, *Org. Lett.*, 2022, **24**, 2055-2058.
2. A. A. Rafaniello and M. A. Rizzacasa, Total Synthesis of (+)-Trachyspic Acid 19-n-Butyl Ester, *Org. Lett.*, 2020, **22**, 1972-1975.
3. S. Duan, C. Chen, Y. Chen, Y. Jie, H. Luo, Z.-F. Xu, B. Cheng and C.-Y. Li, Two reaction modes of 1-sulfonyl-1,2,3-triazoles and pyridinium 1,4-zwitterionic thiolates: catalyst-free synthesis of pyrido[1,2- a]pyrazine derivatives and 1,4-thiazine derivatives, *Org. Chem. Front.*, 2021, **8**, 6962-6967.
4. SHELXTL version 5.03; Bruker Analytical X-ray Systems, Madison, WI, 1997.

Copies of ^{1}H NMR, ^{19}FNMR and ^{13}C NMR spectra

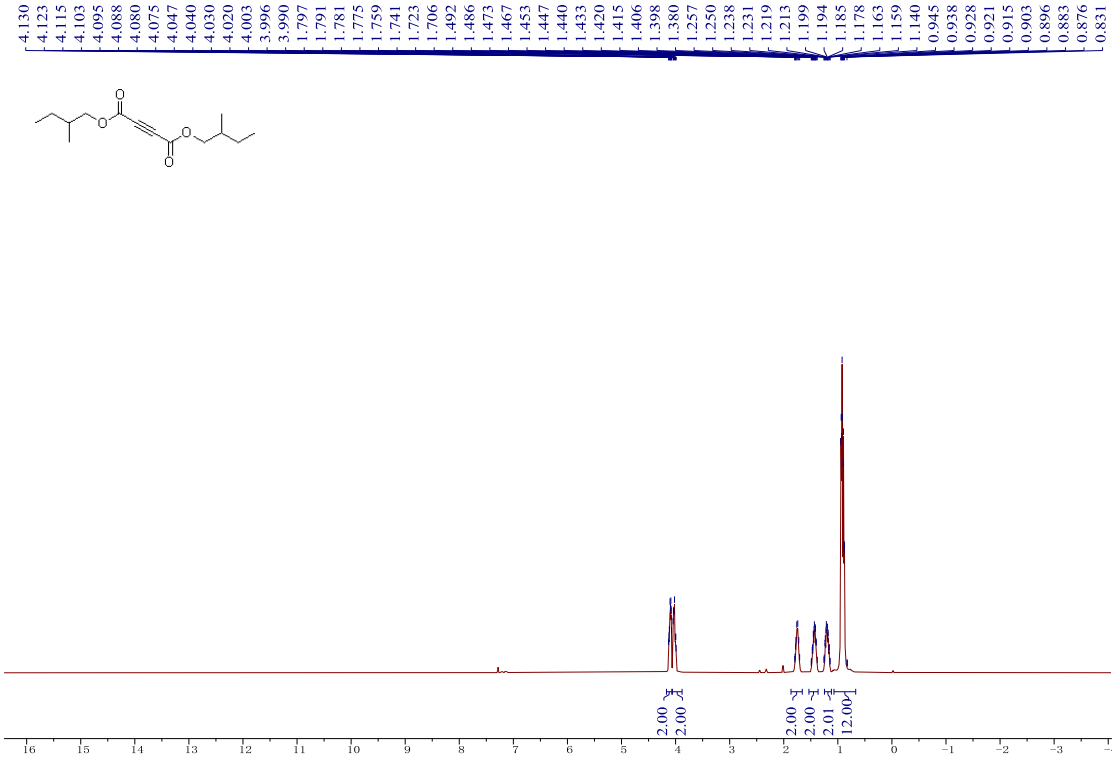
^{1}H NMR spectra of **S-2g** in $CDCl_3$



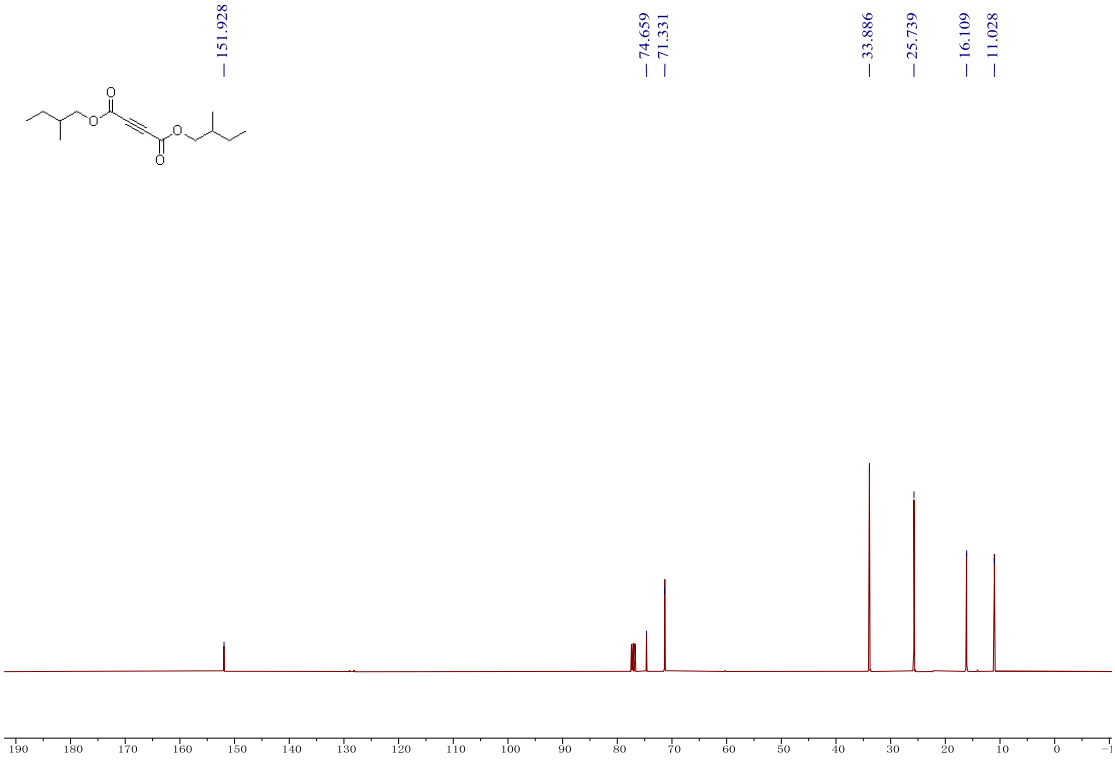
^{13}C{1H} NMR spectra of **S-2g** in $CDCl_3$



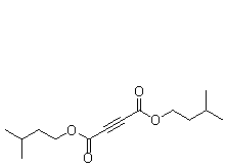
^{1}H NMR spectra of **S-2h** in $CDCl_3$

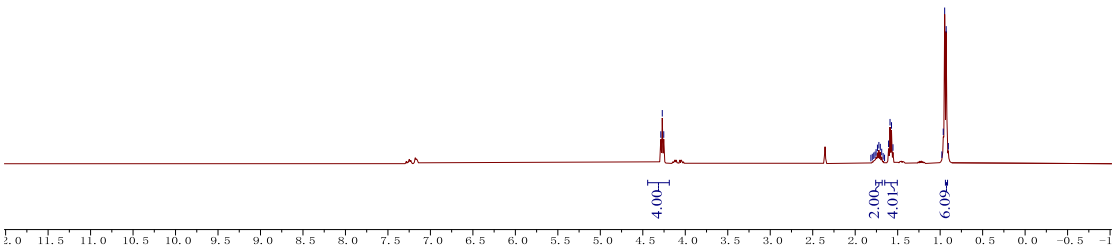


^{13}C{1H} NMR spectra of **S-2h** in $CDCl_3$



^{1}H NMR spectra of **S-2i** in $CDCl_3$





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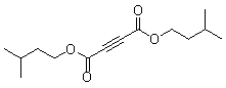
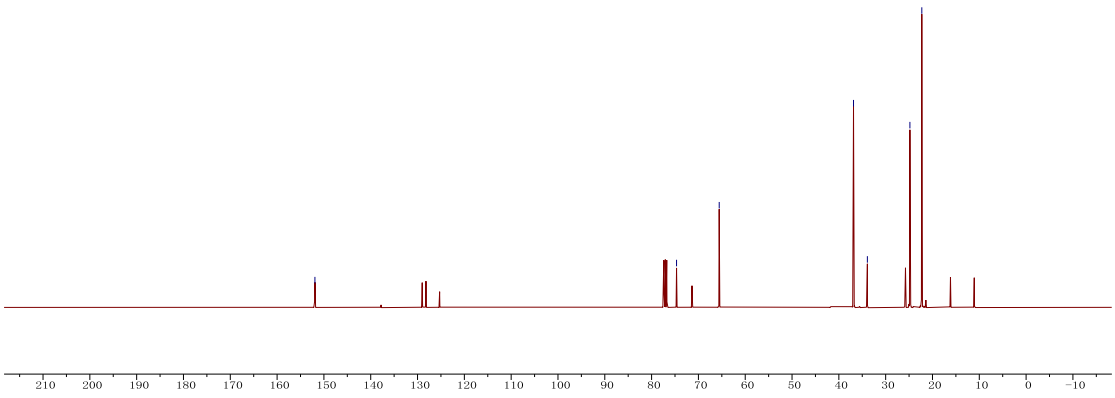
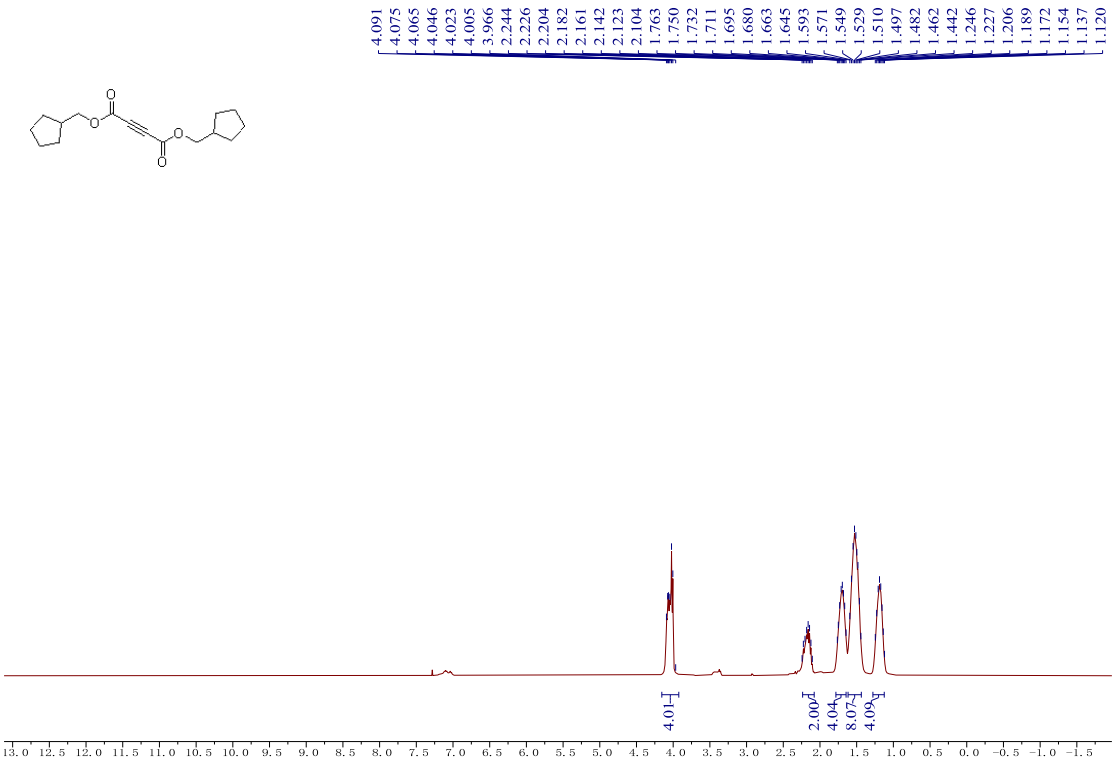




^{1}H NMR spectra of **S-2j** in $CDCl_3$



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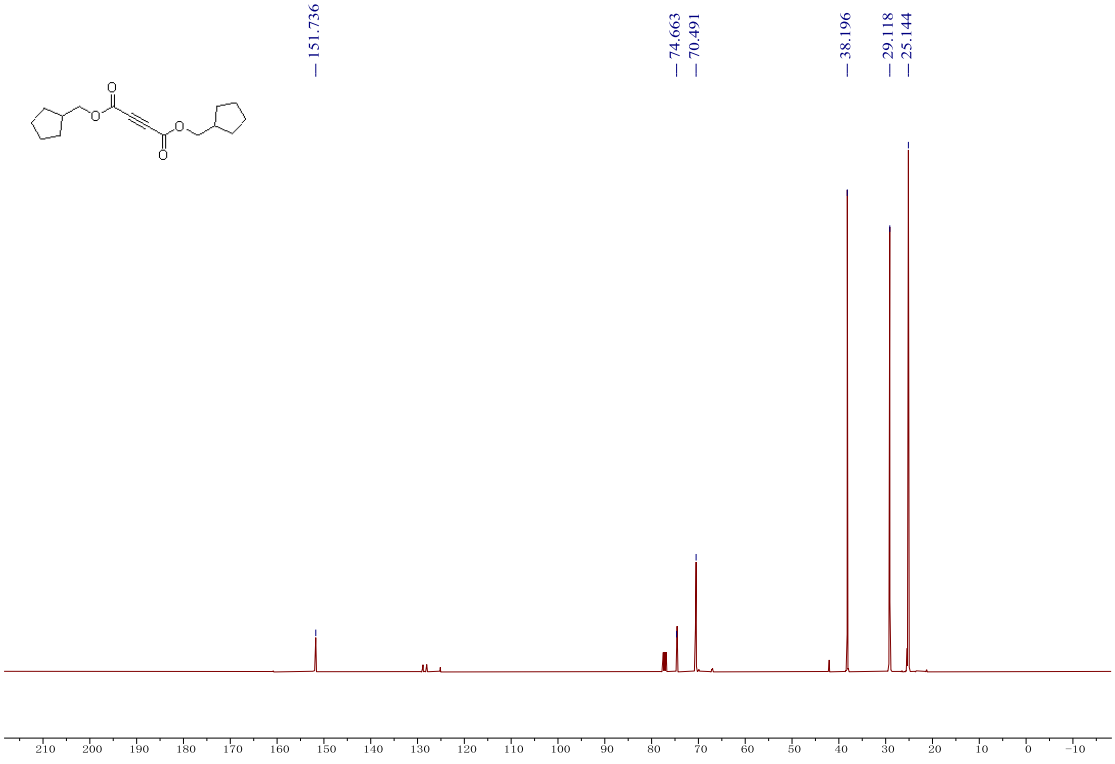
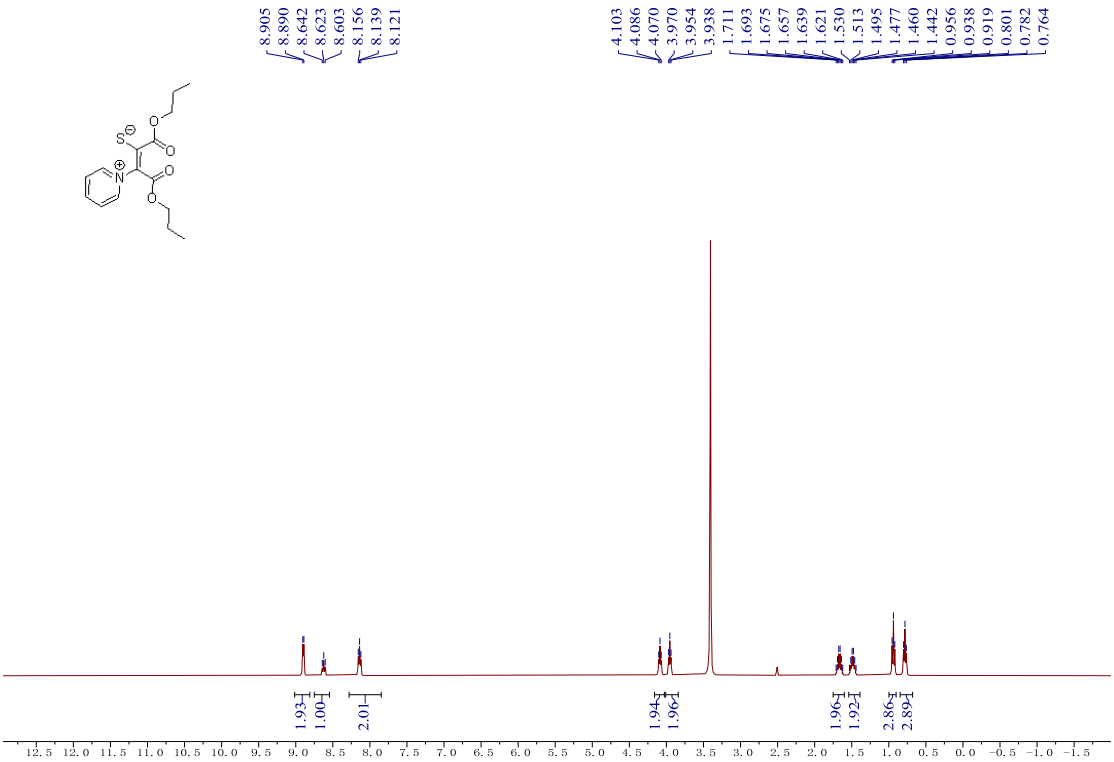
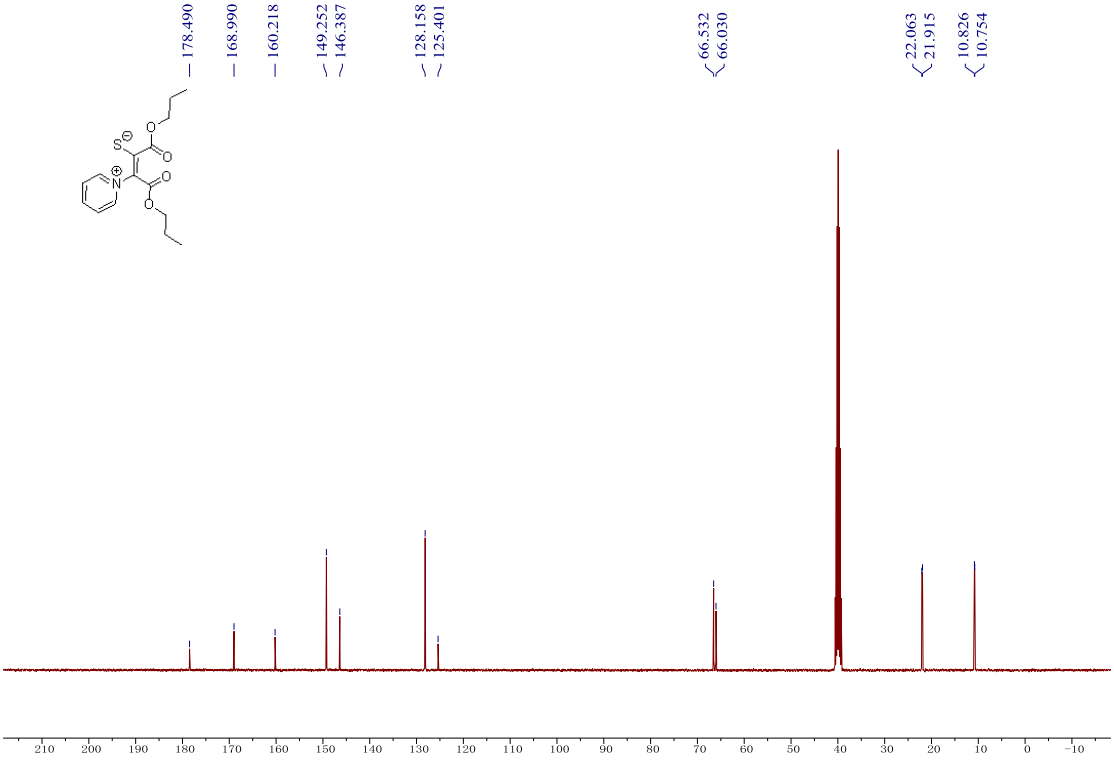


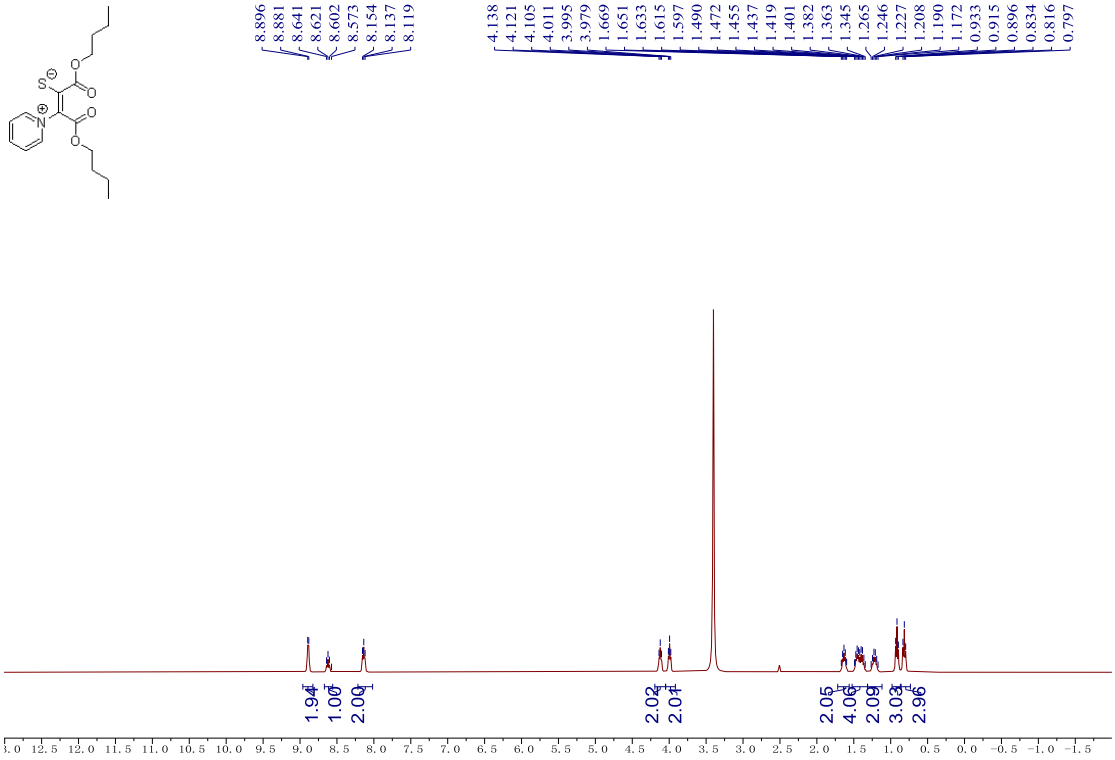
^{1}H NMR spectra of **2c** in DMSO-d_6



^{13}C{1H} NMR spectra of **2c** in DMSO-d_6



^{1}H NMR spectra of **2e** in DMSO-d_6



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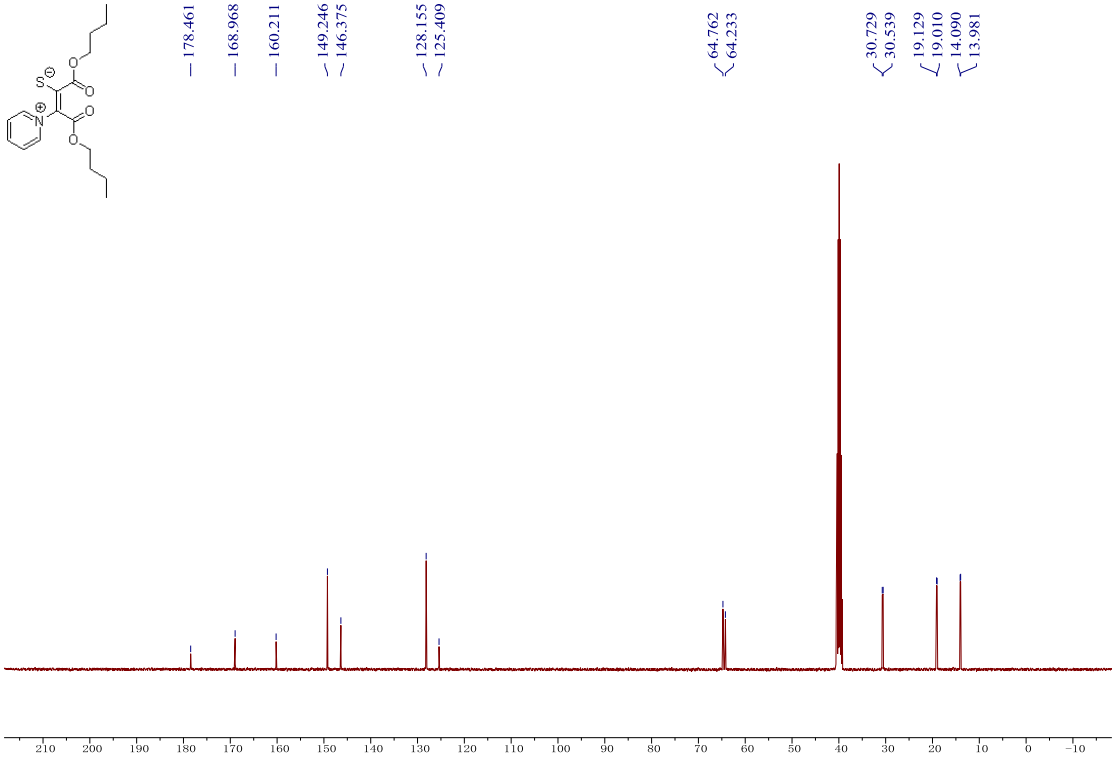

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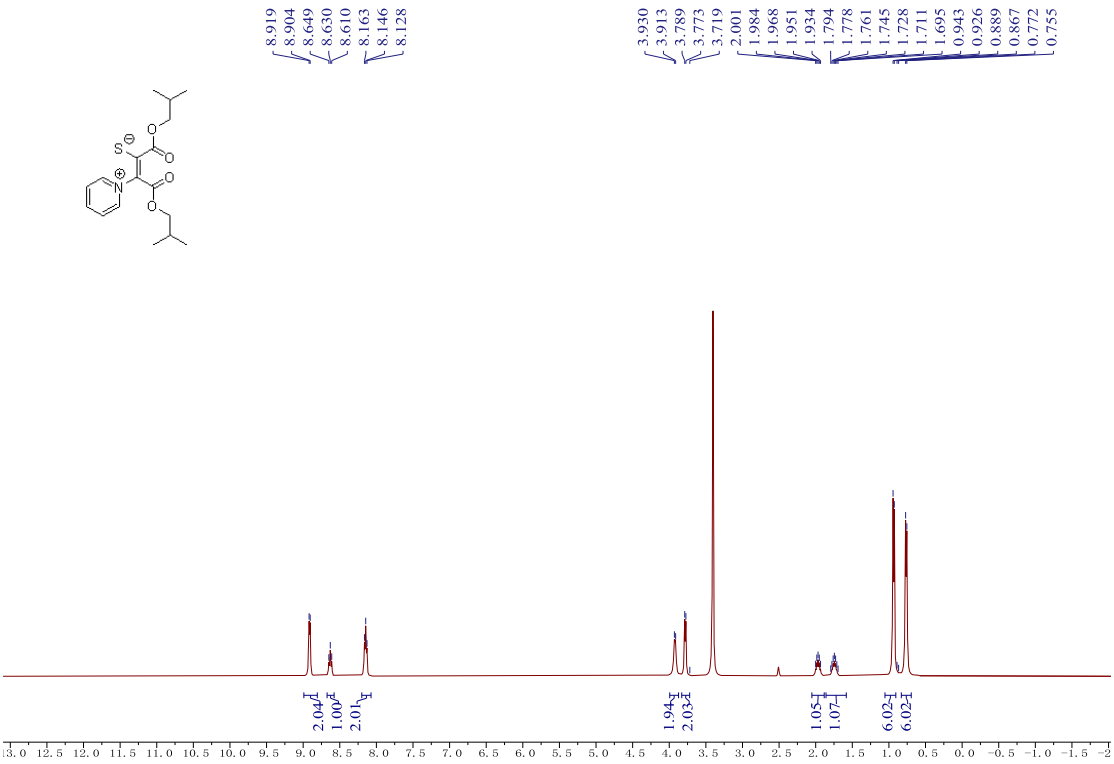

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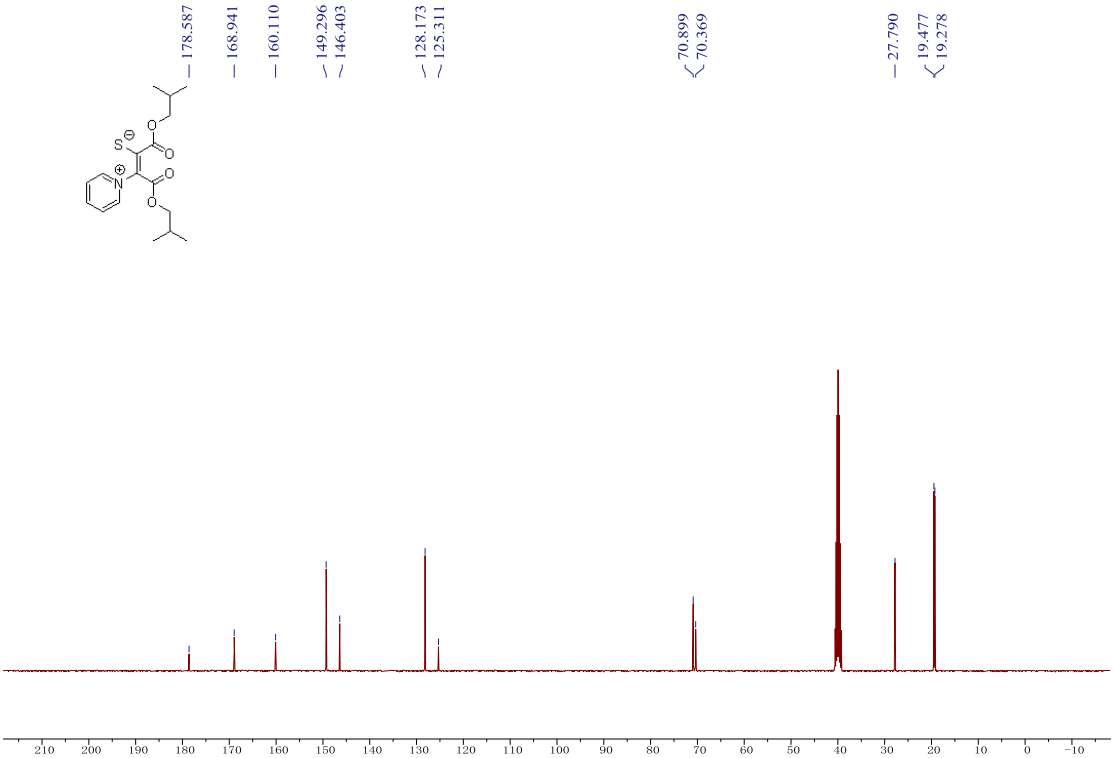
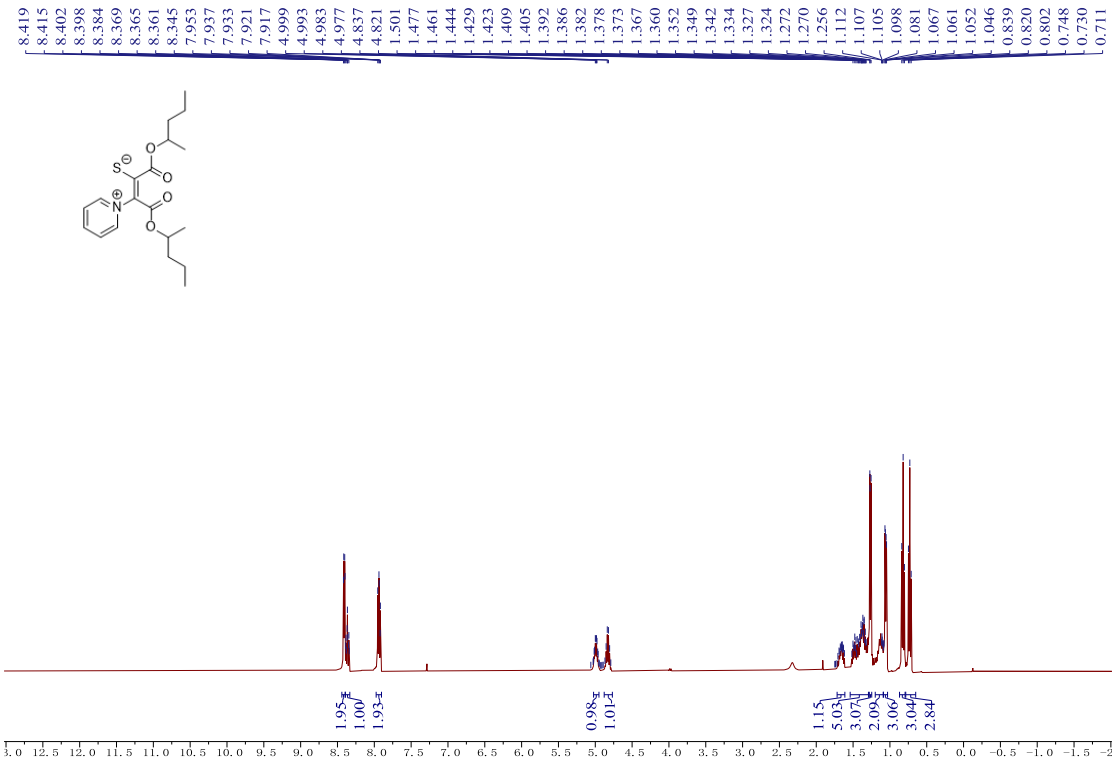


^{1}H NMR spectra of **2g** in $CDCl_3$



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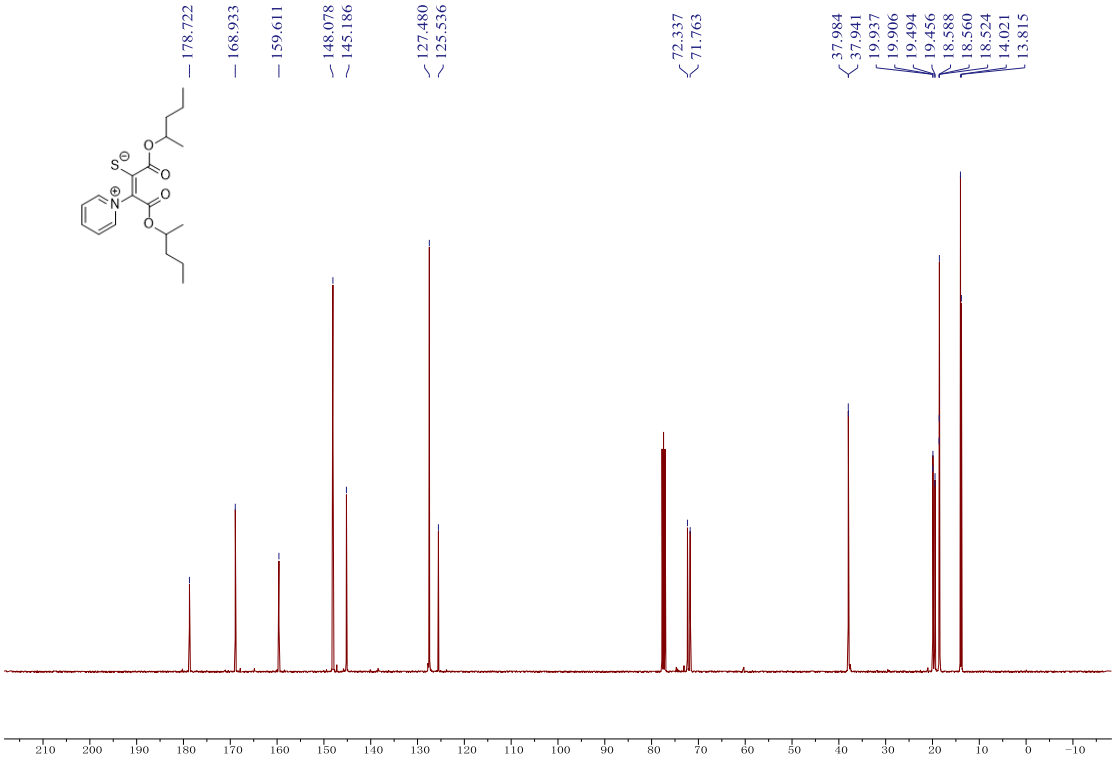

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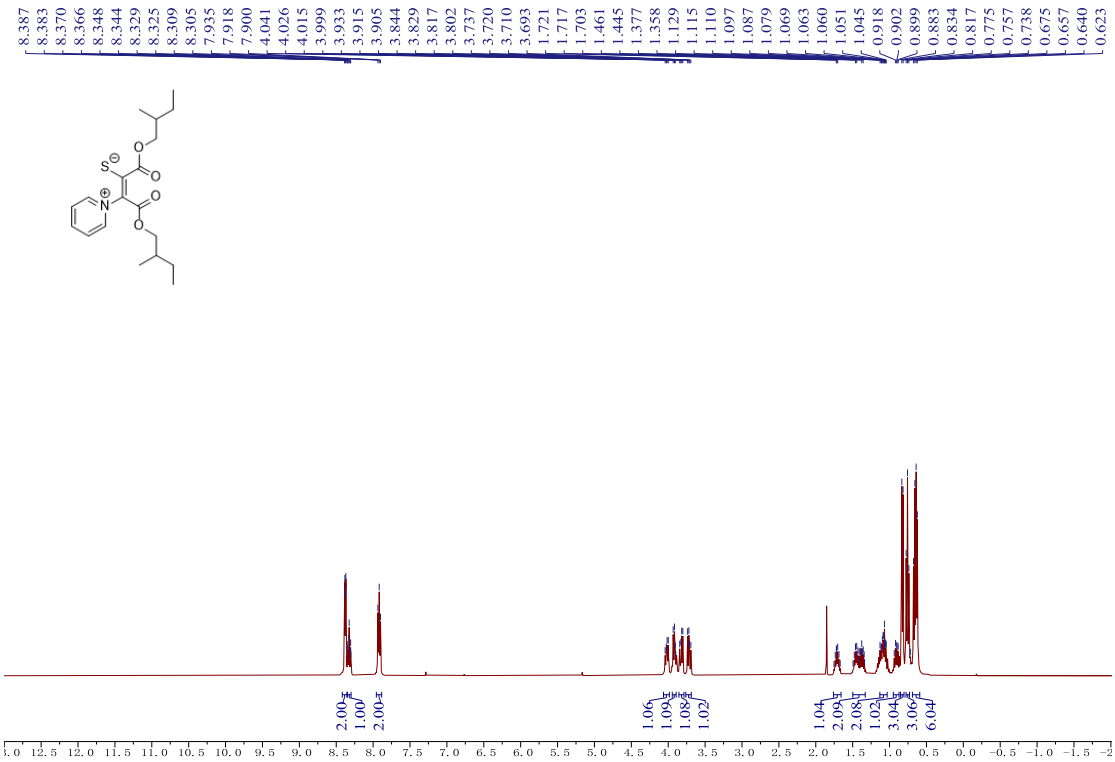

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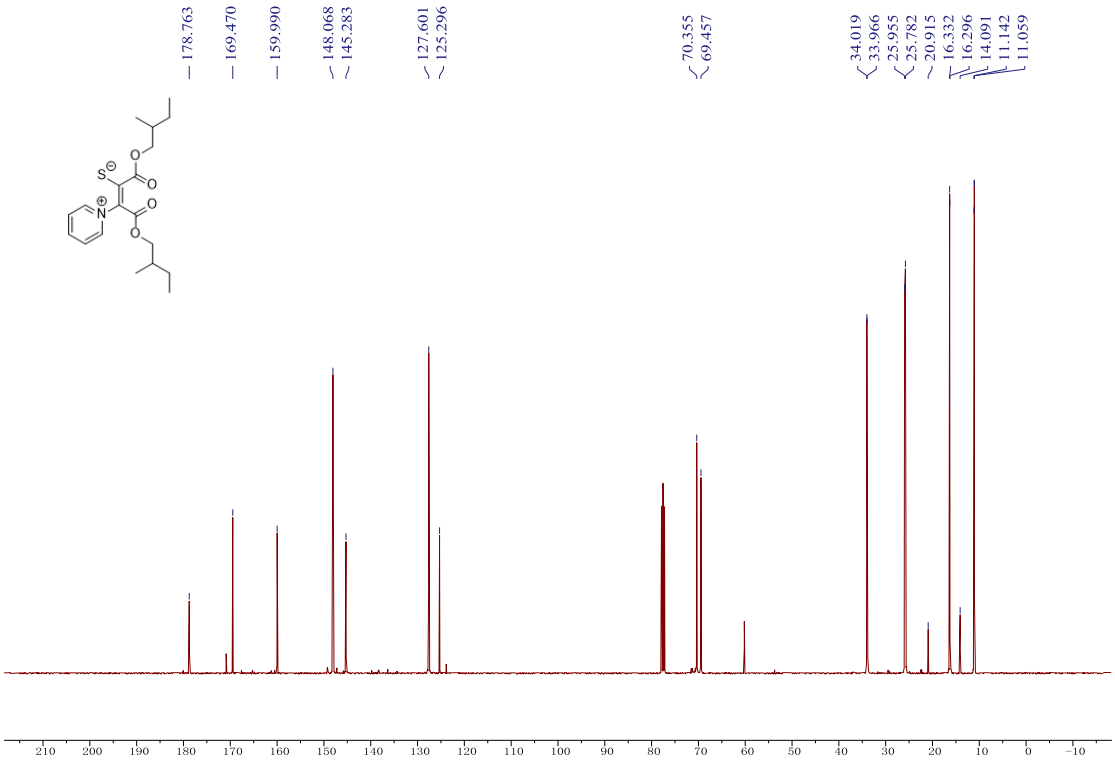

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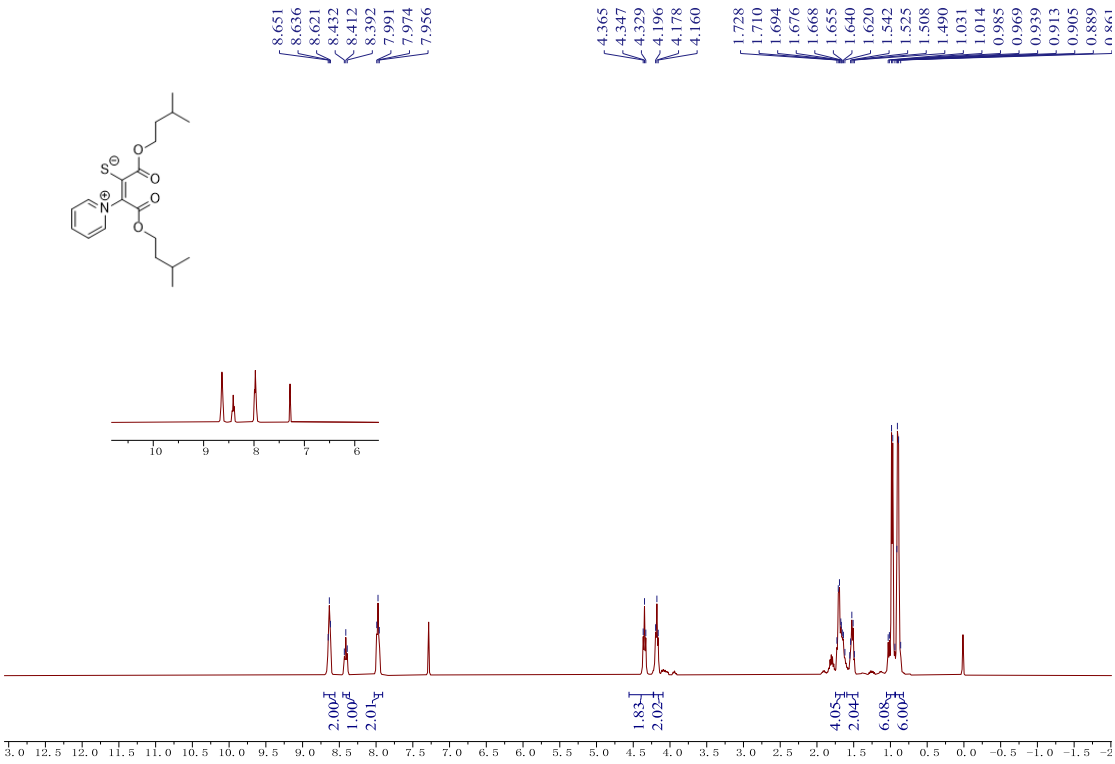

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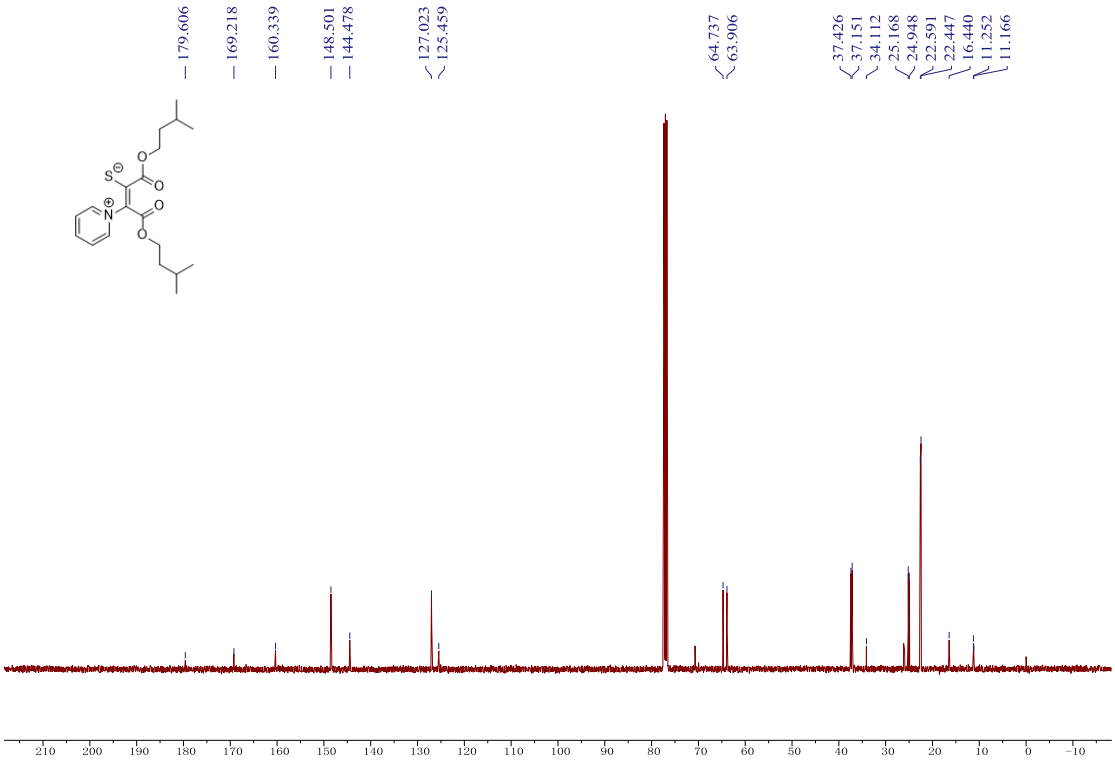
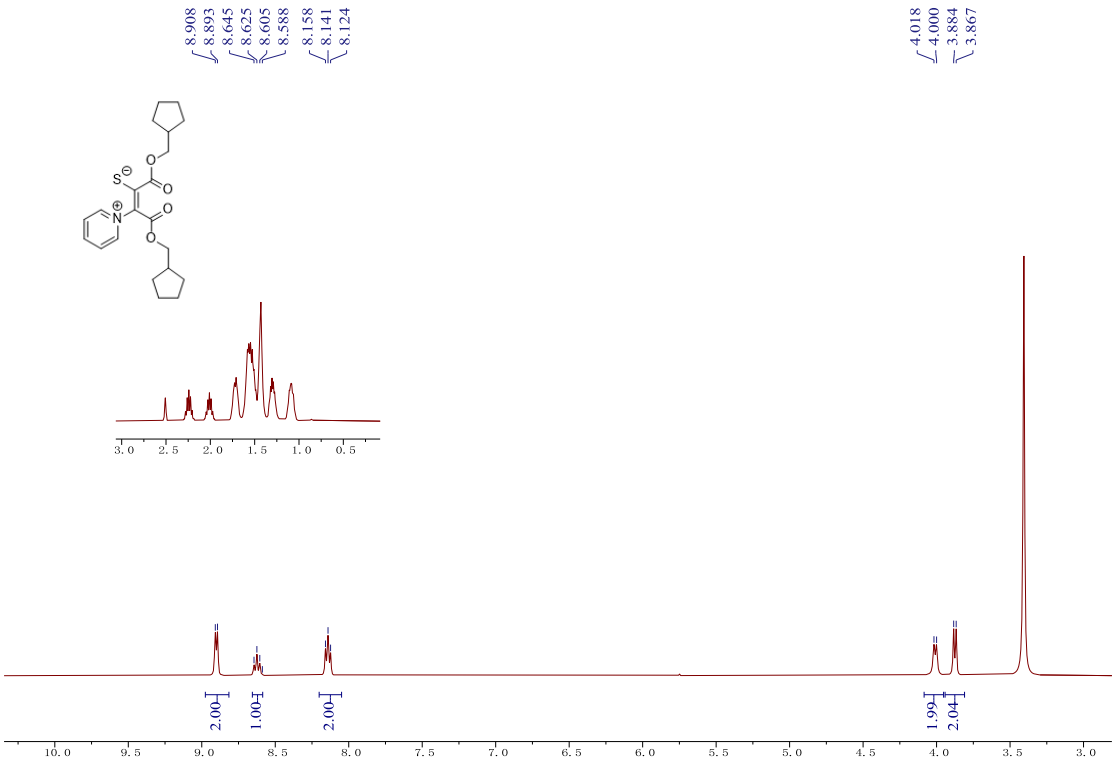


^{1}H NMR spectra of **2j** in DMSO-d_6



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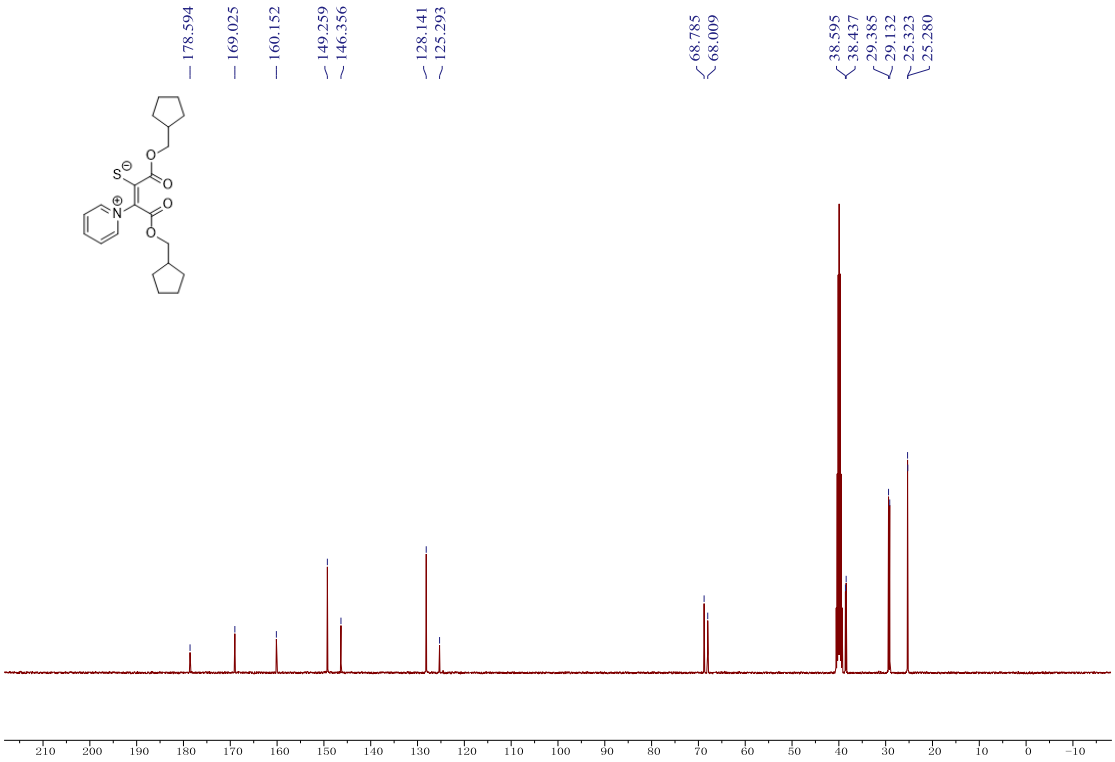

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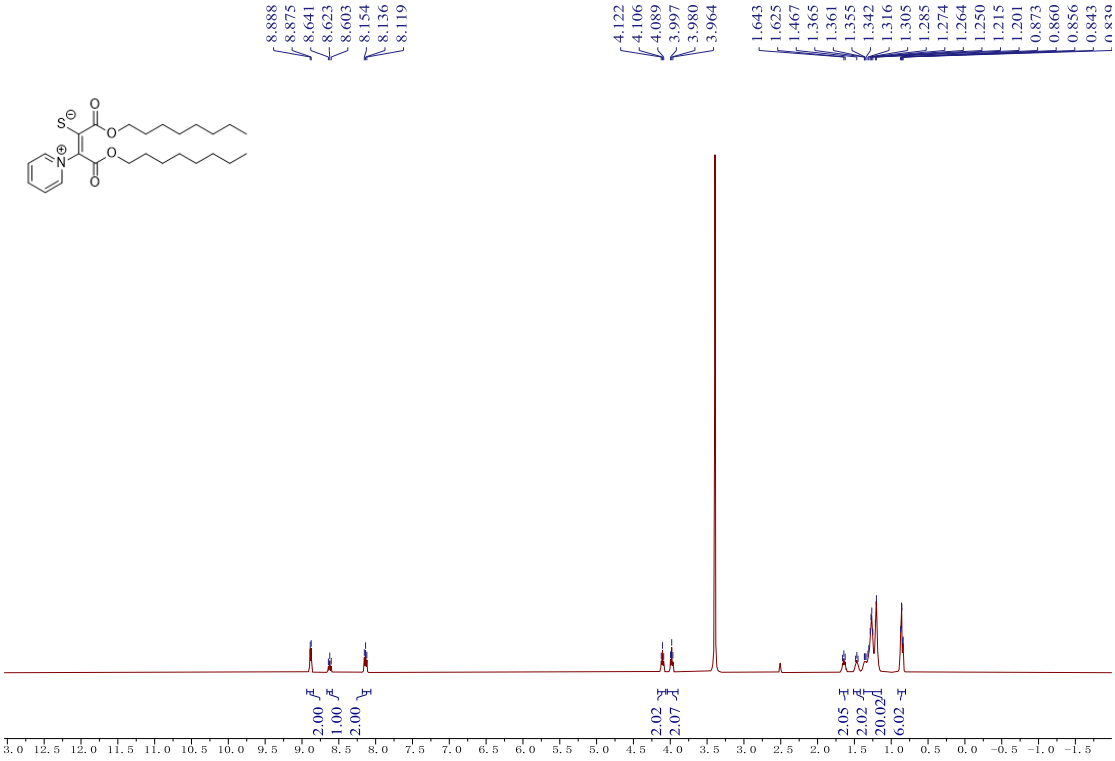

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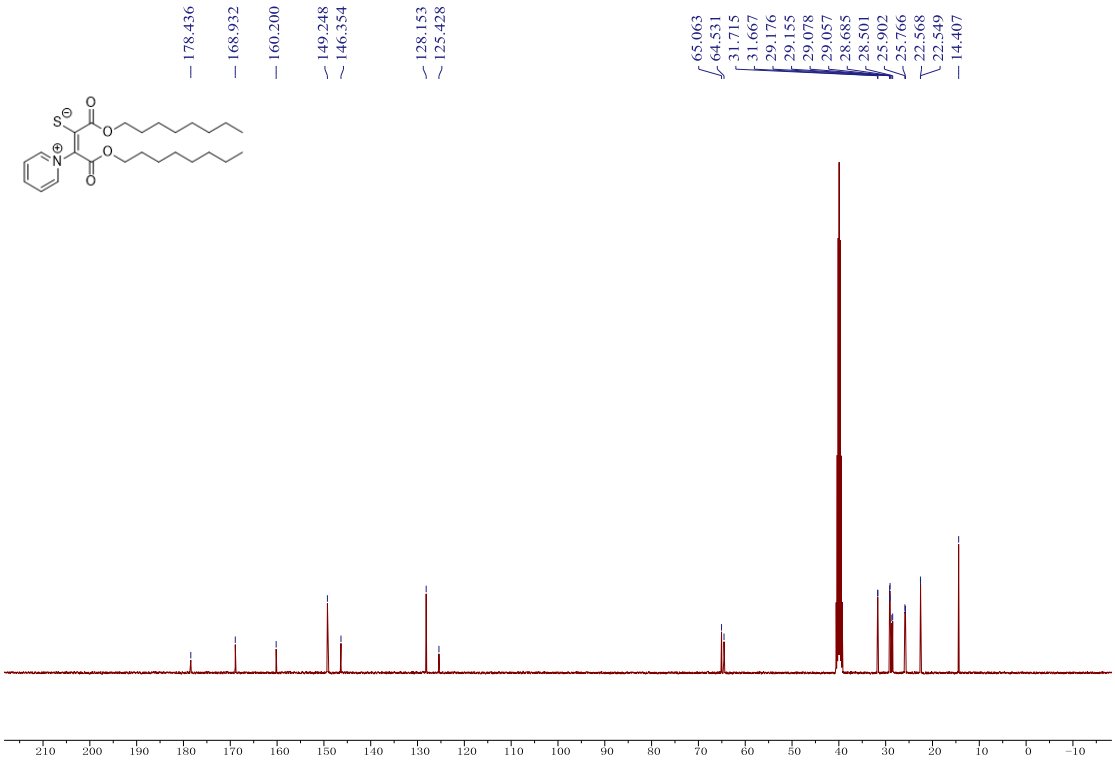
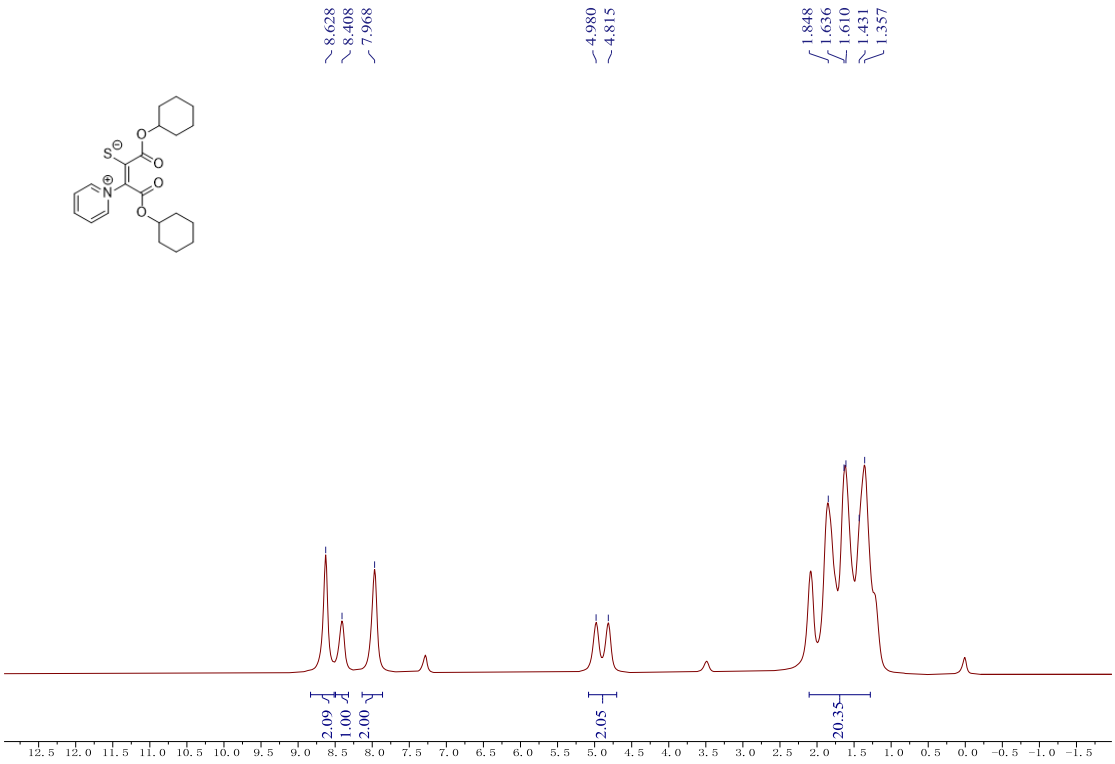


^{1}H NMR spectra of **2l** in $CDCl_3$



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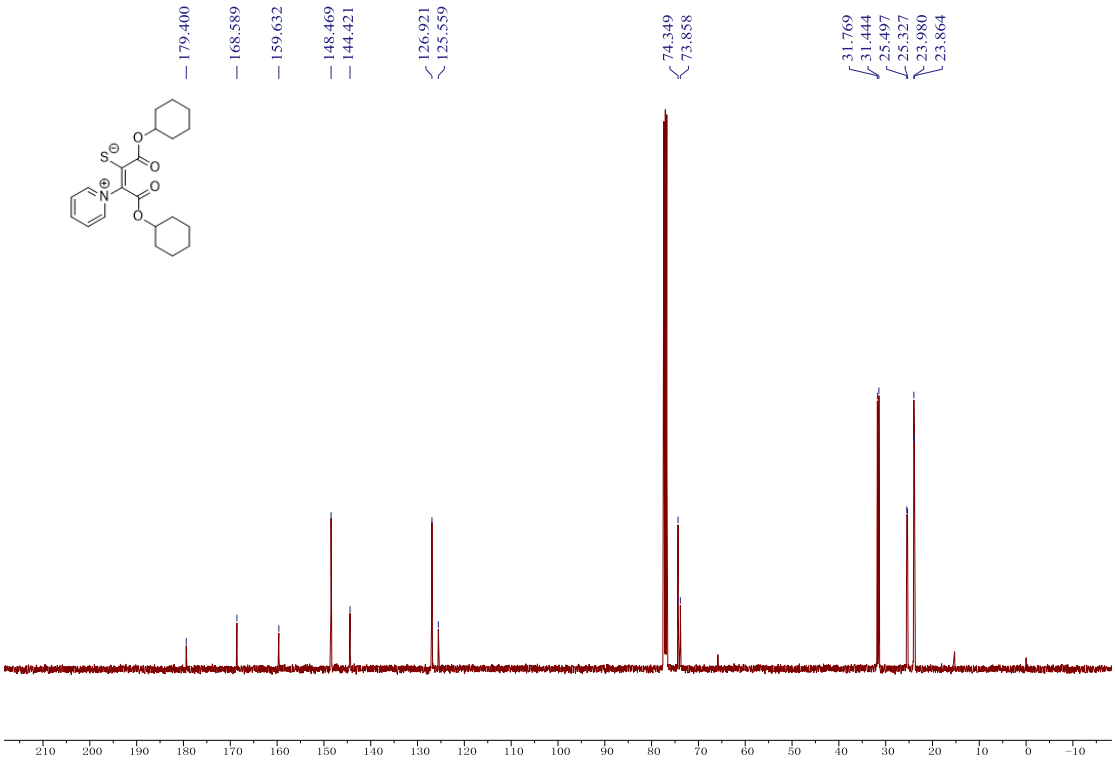
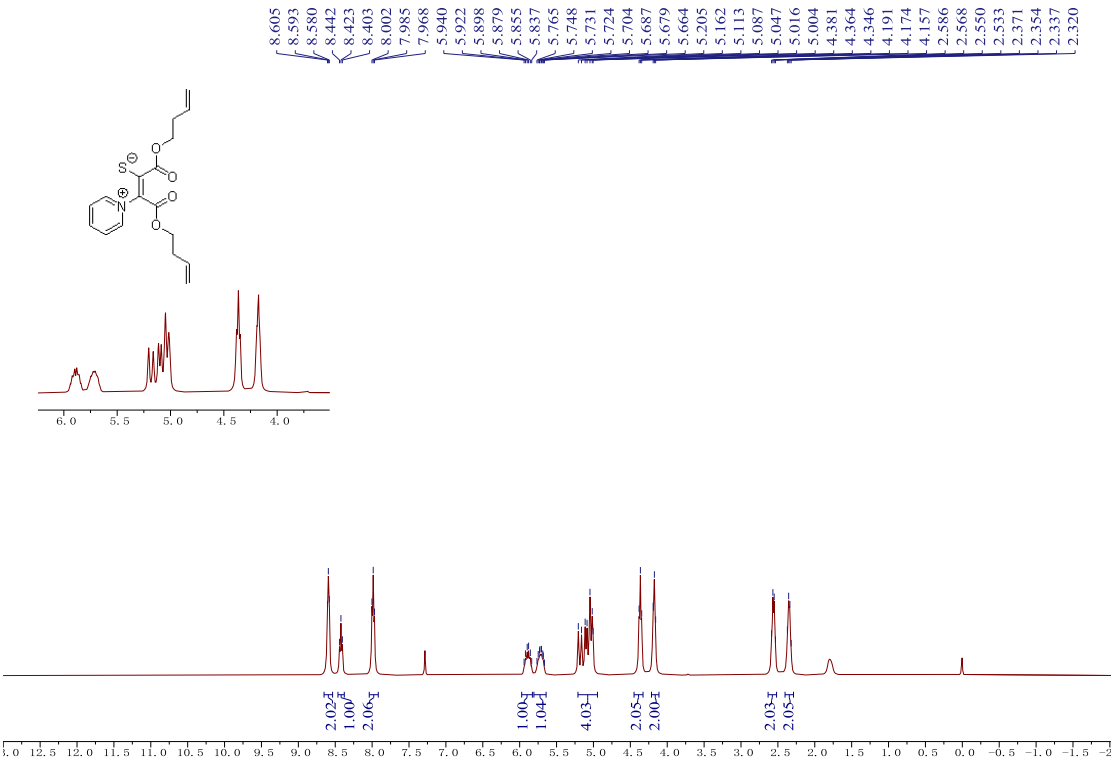
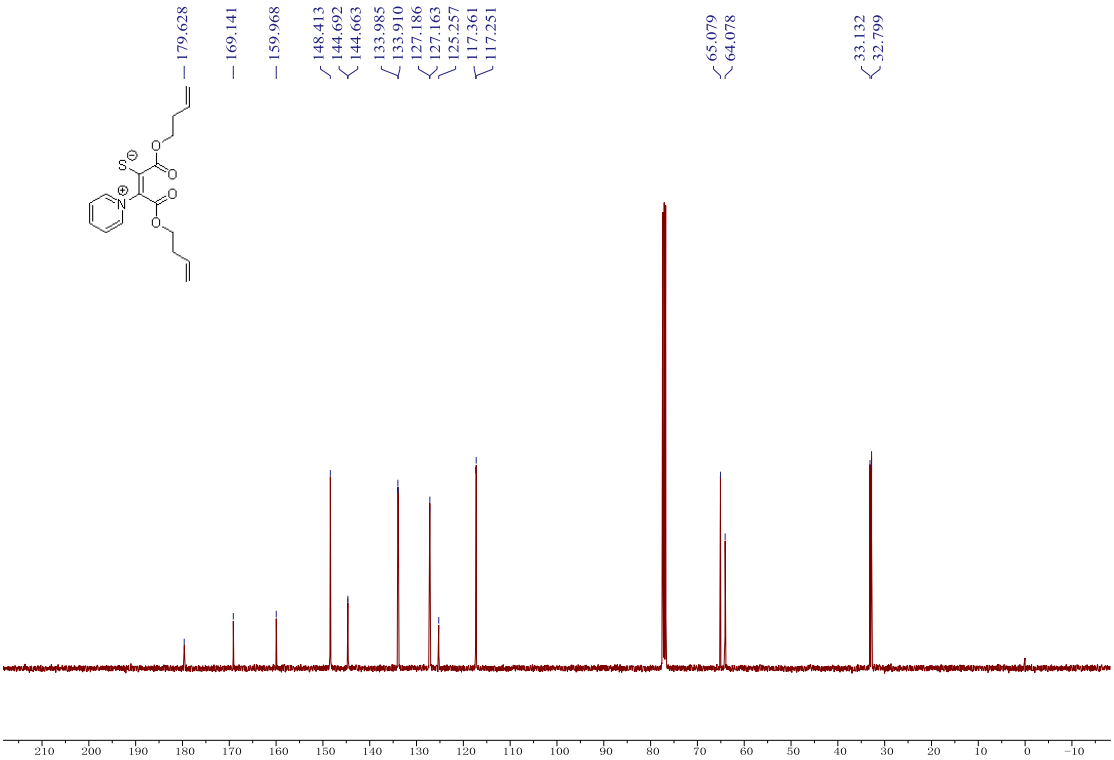


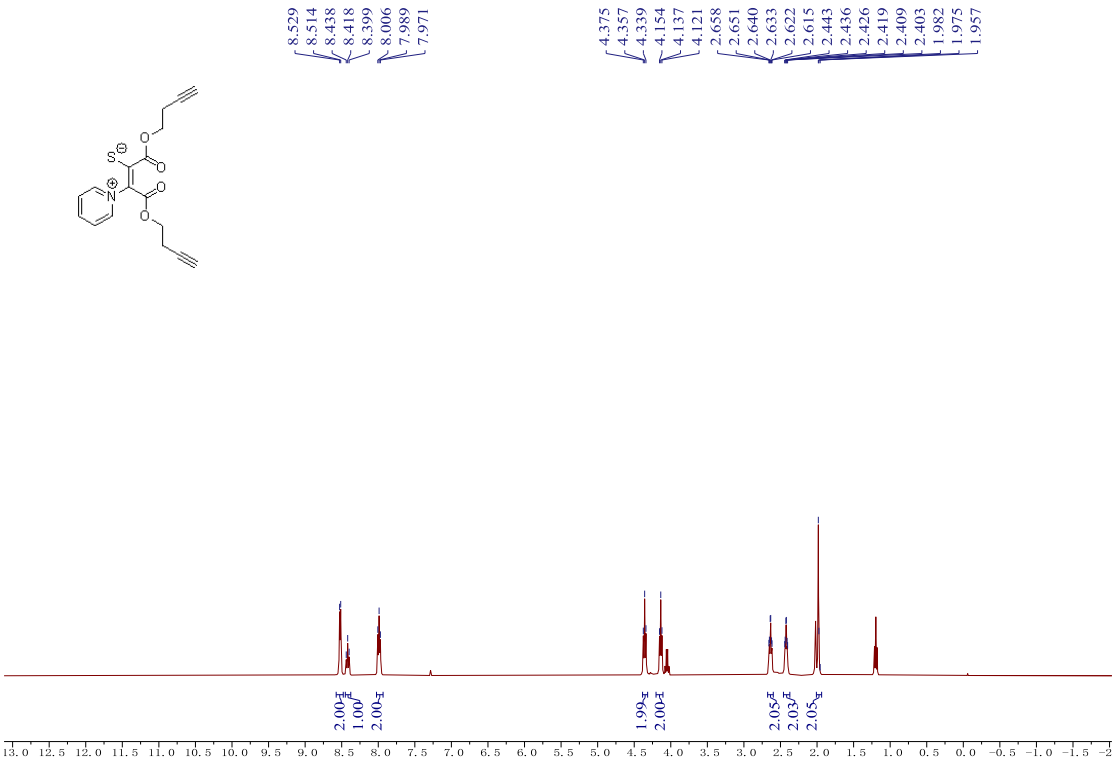
^{1}H NMR spectra of **2m** in $CDCl_3$



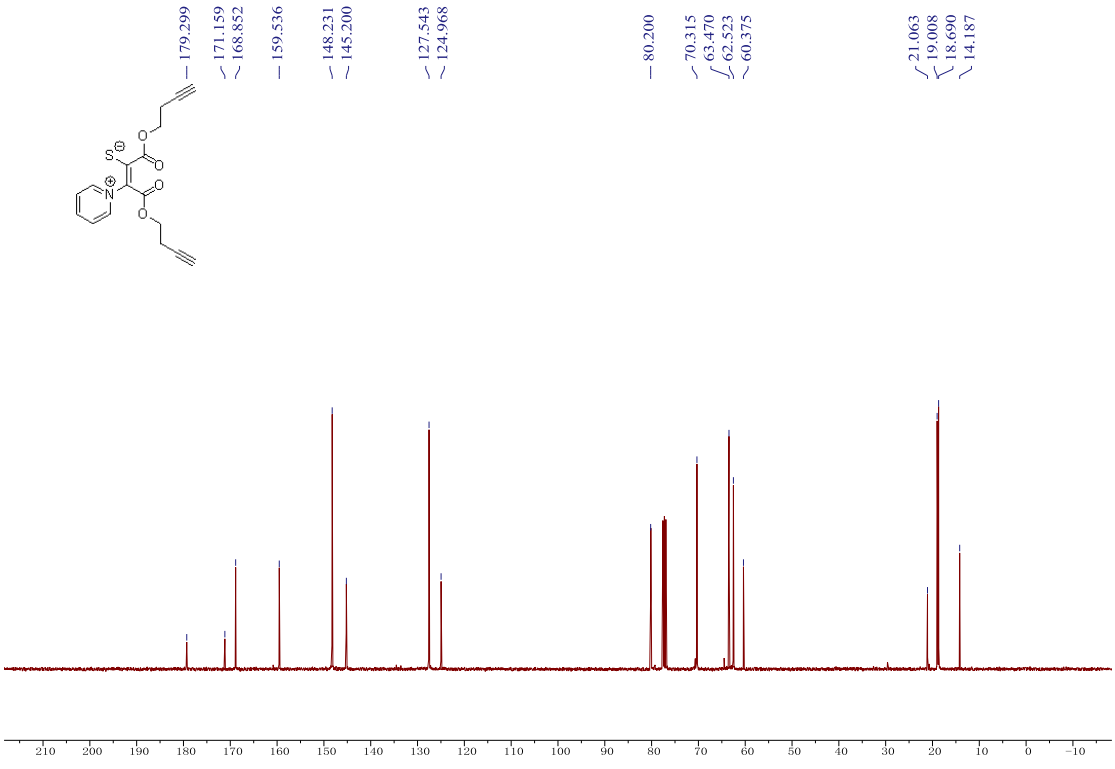
^{13}C{1H} NMR spectra of **2m** in $CDCl_3$



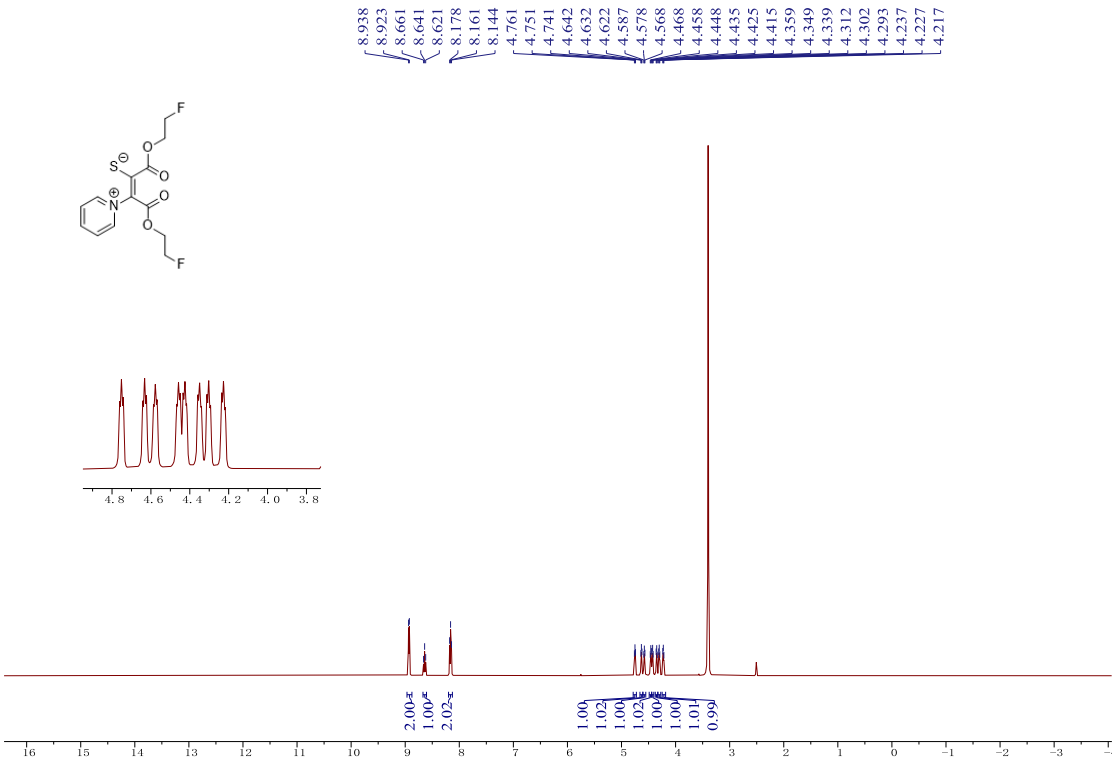
^{1}H NMR spectra of **2n** in $CDCl_3$



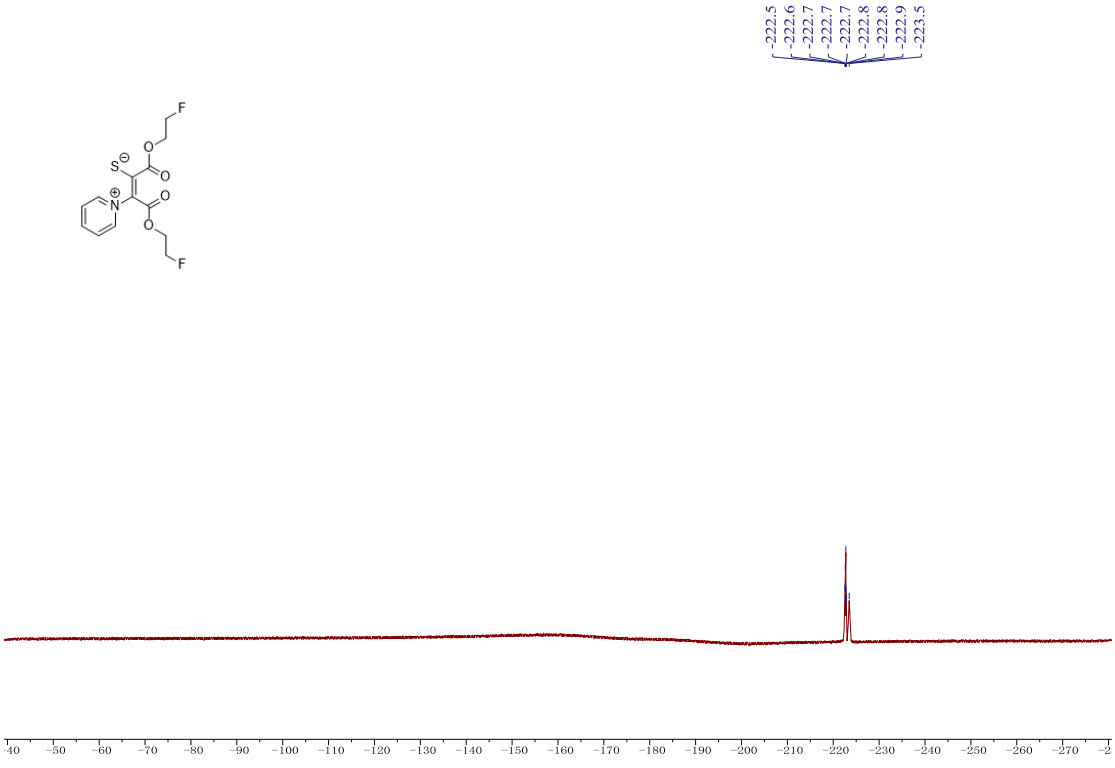
^{13}C{1H} NMR spectra of **2n** in $CDCl_3$



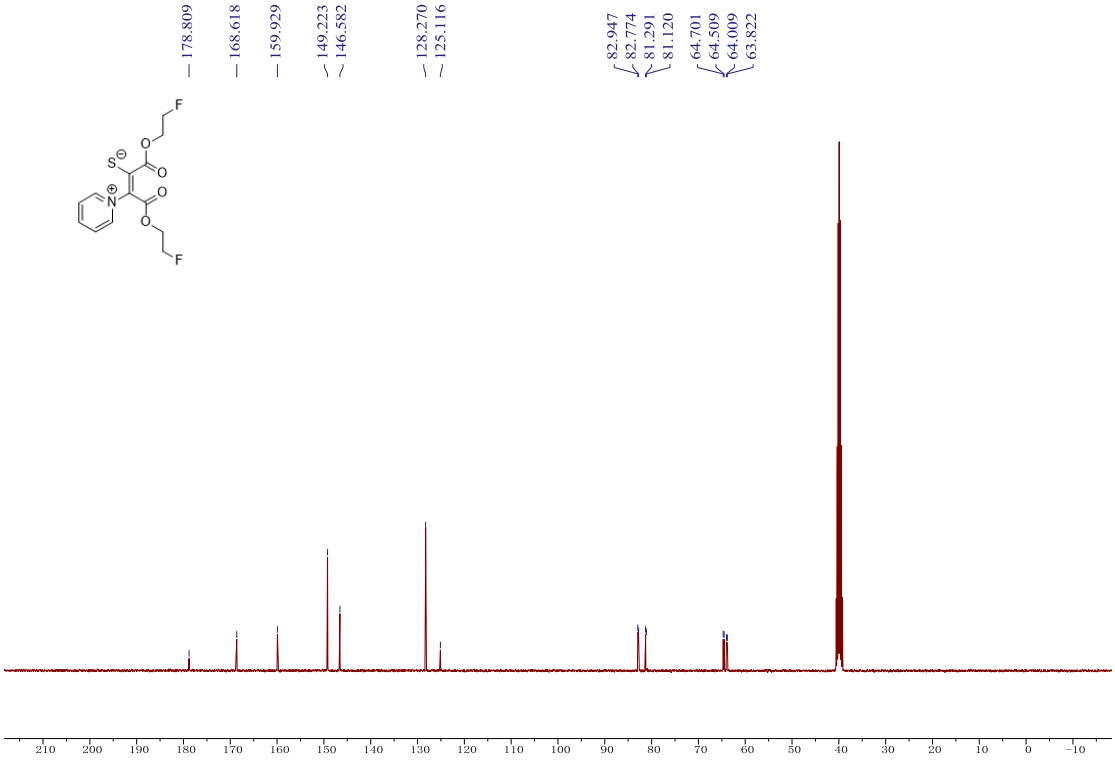
^{1}H NMR spectra of **2o** in DMSO-d_6



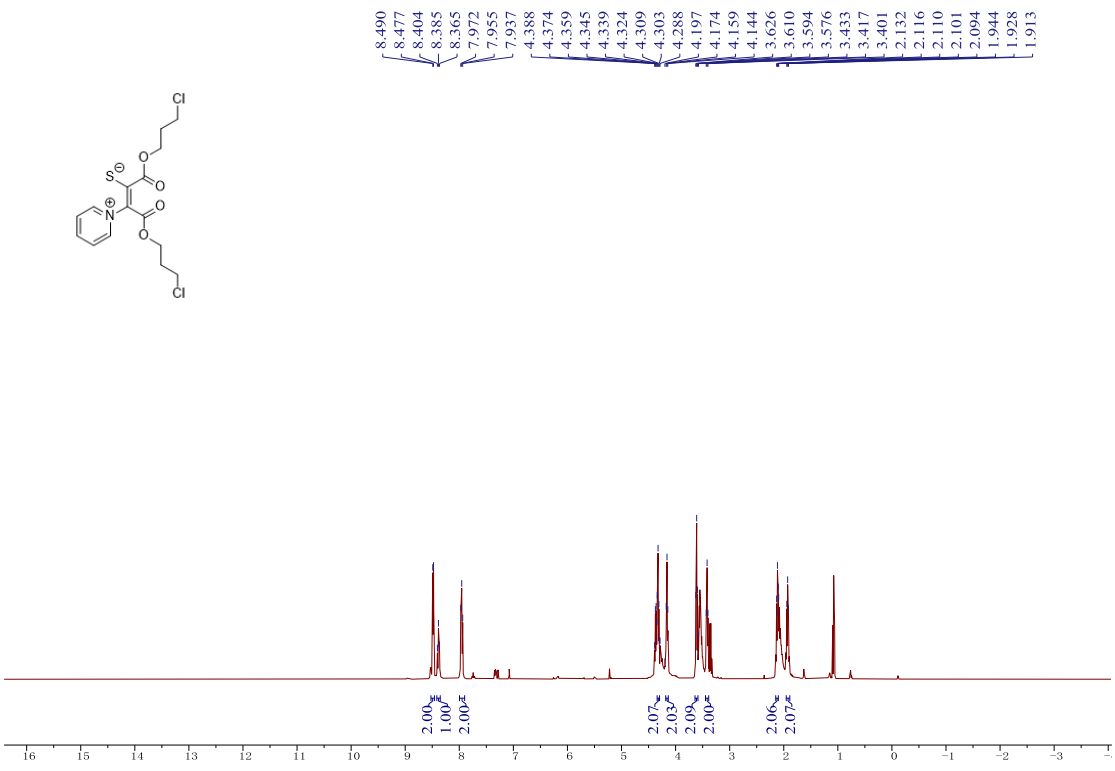
^{19}F NMR spectra of **2o** in DMSO-d_6



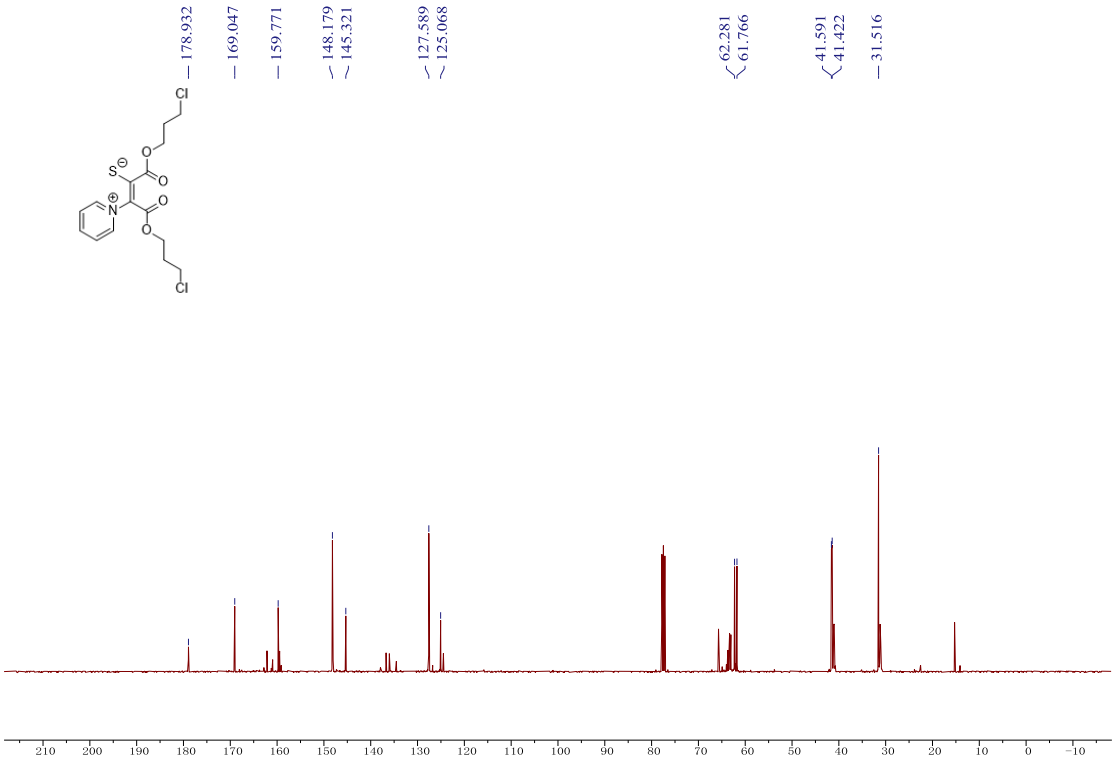
$^{13}C\{1H\}$ NMR spectra of **2o** in DMSO-d_6



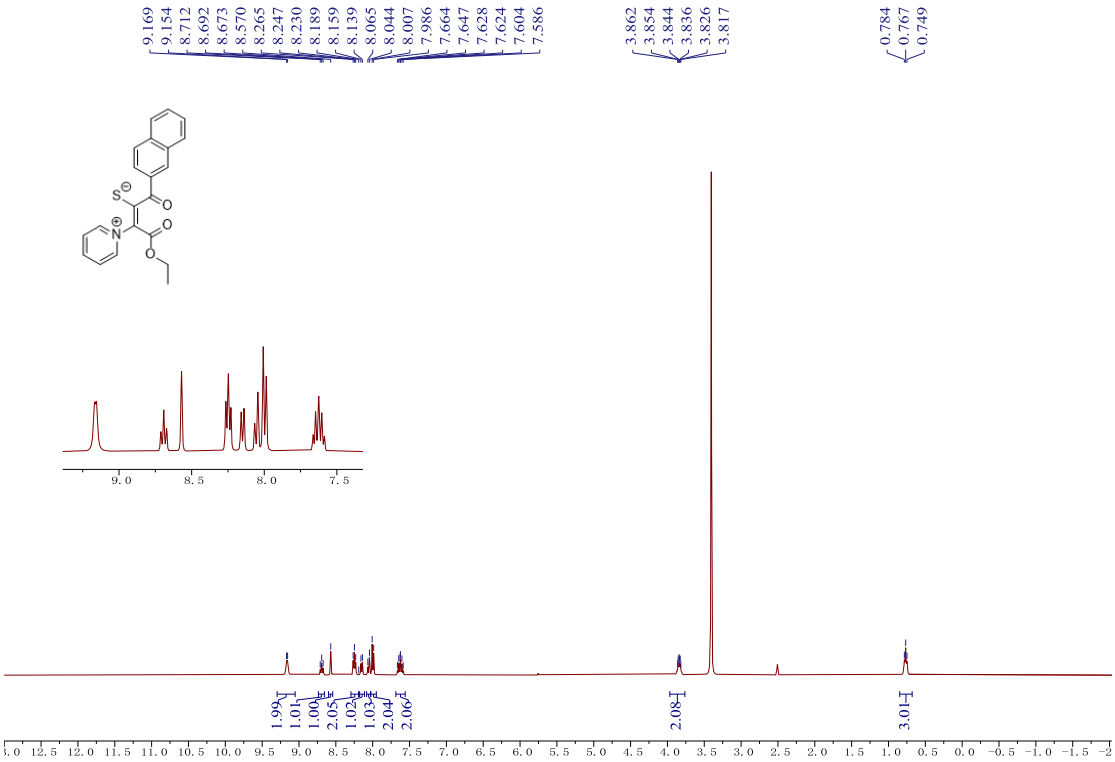
^{1}H NMR spectra of **2p** in $CDCl_3$



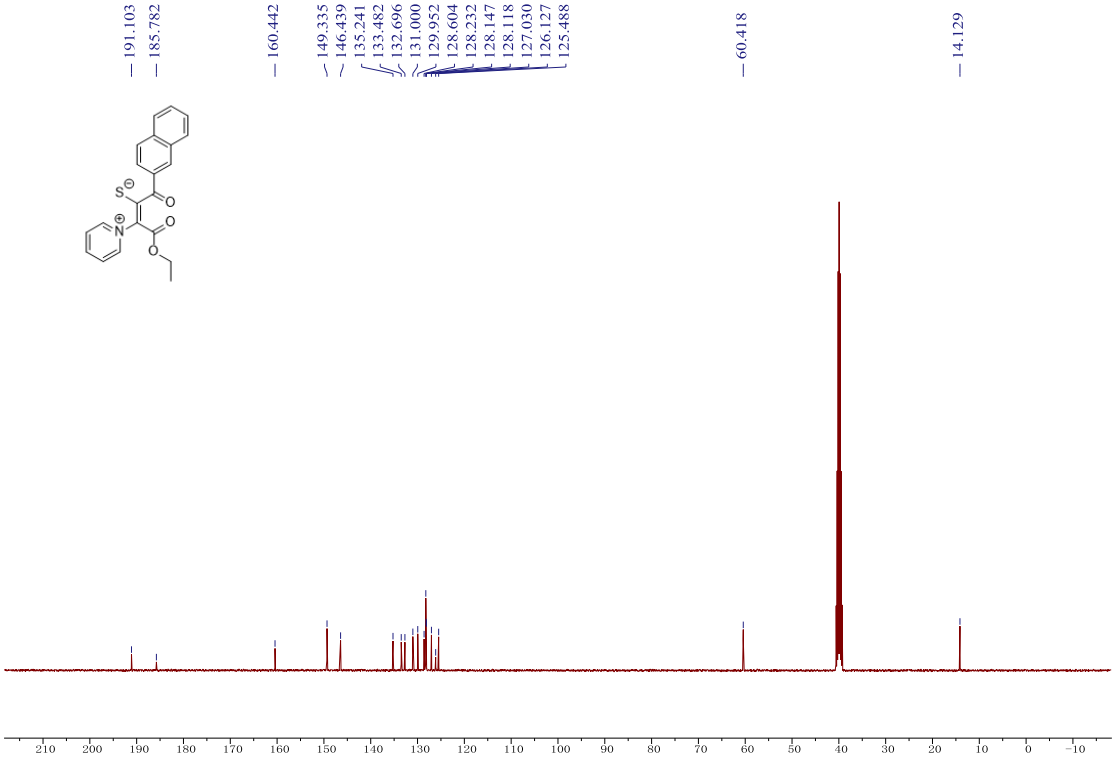
$^{13}C\{1H\}$ NMR spectra of **2p** in $CDCl_3$



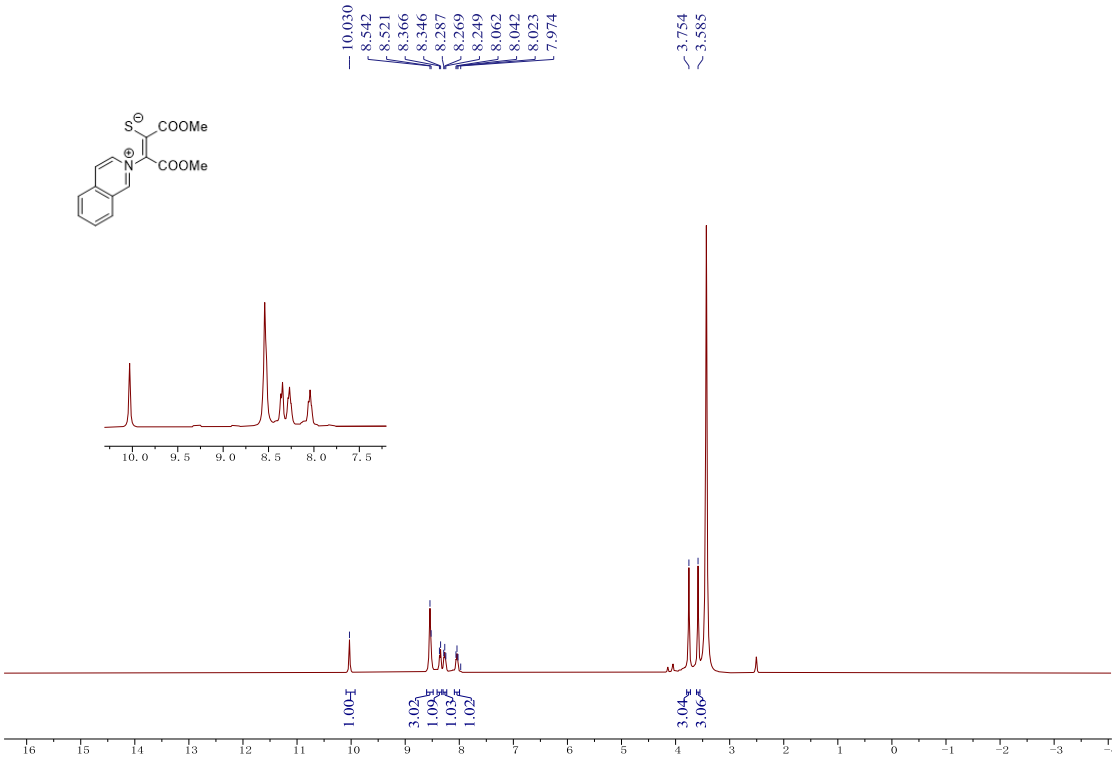
^{1}H NMR spectra of **2r** in DMSO-d_6



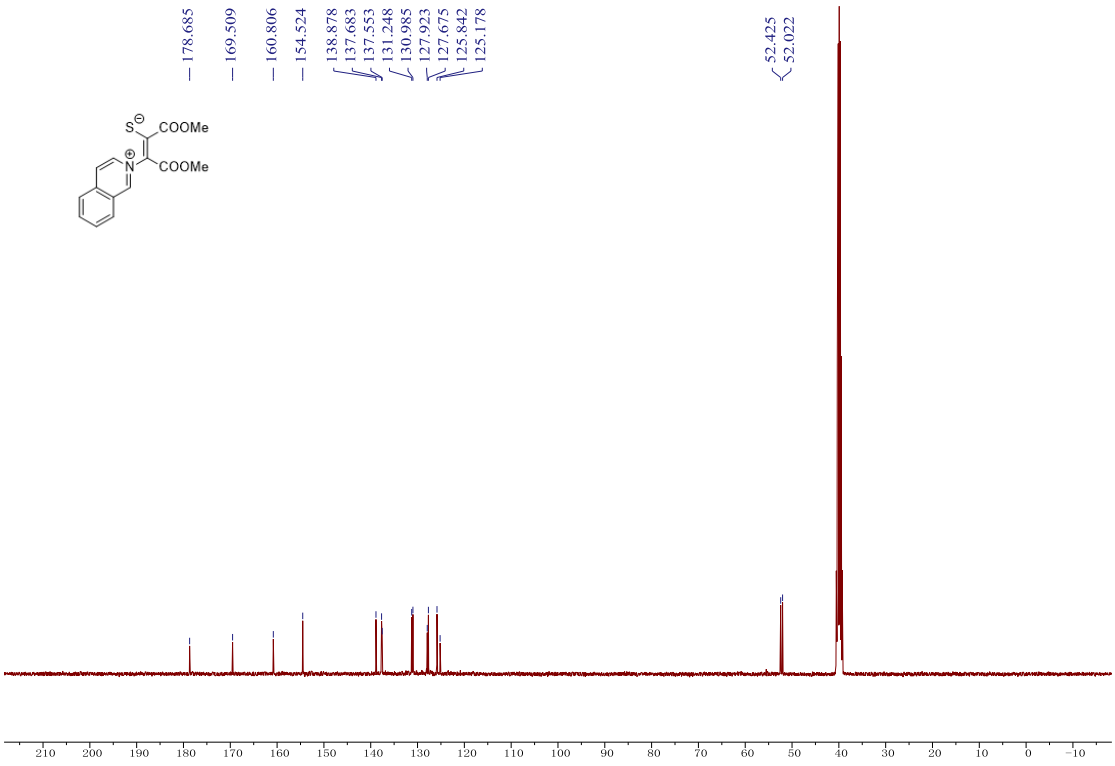
$^{13}C\{1H\}$ NMR spectra of **2r** in DMSO-d_6



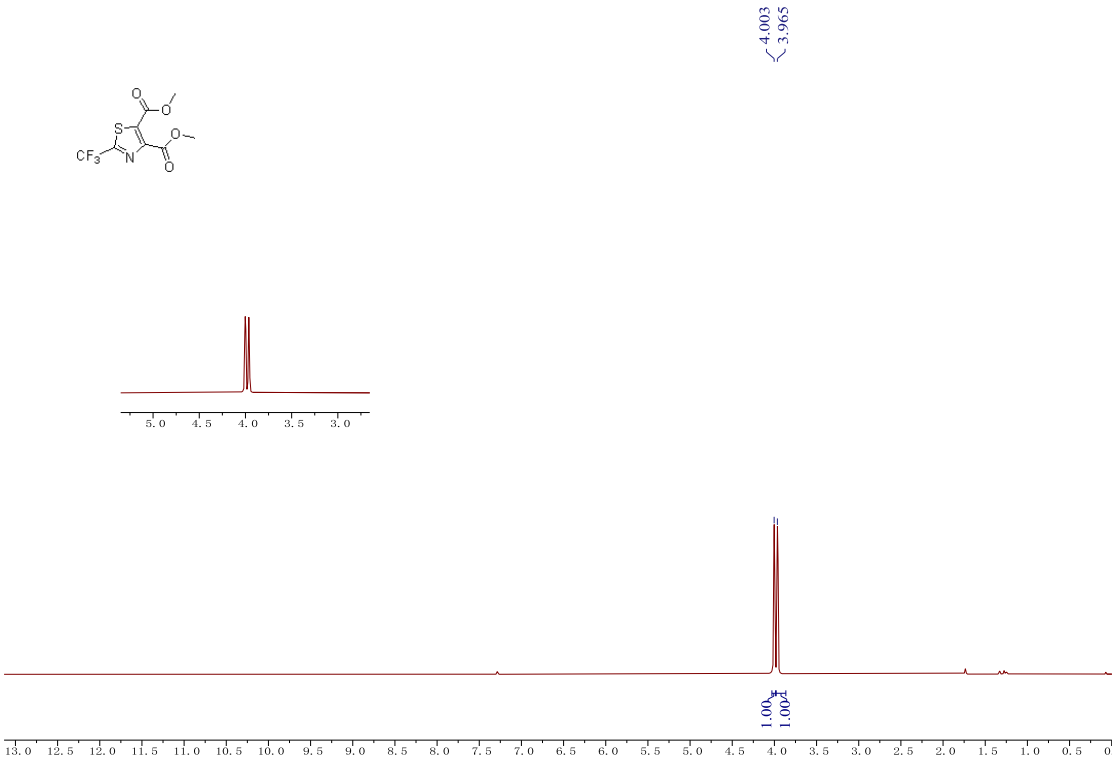
^{1}H NMR spectra of **2a-2** in DMSO-d_6



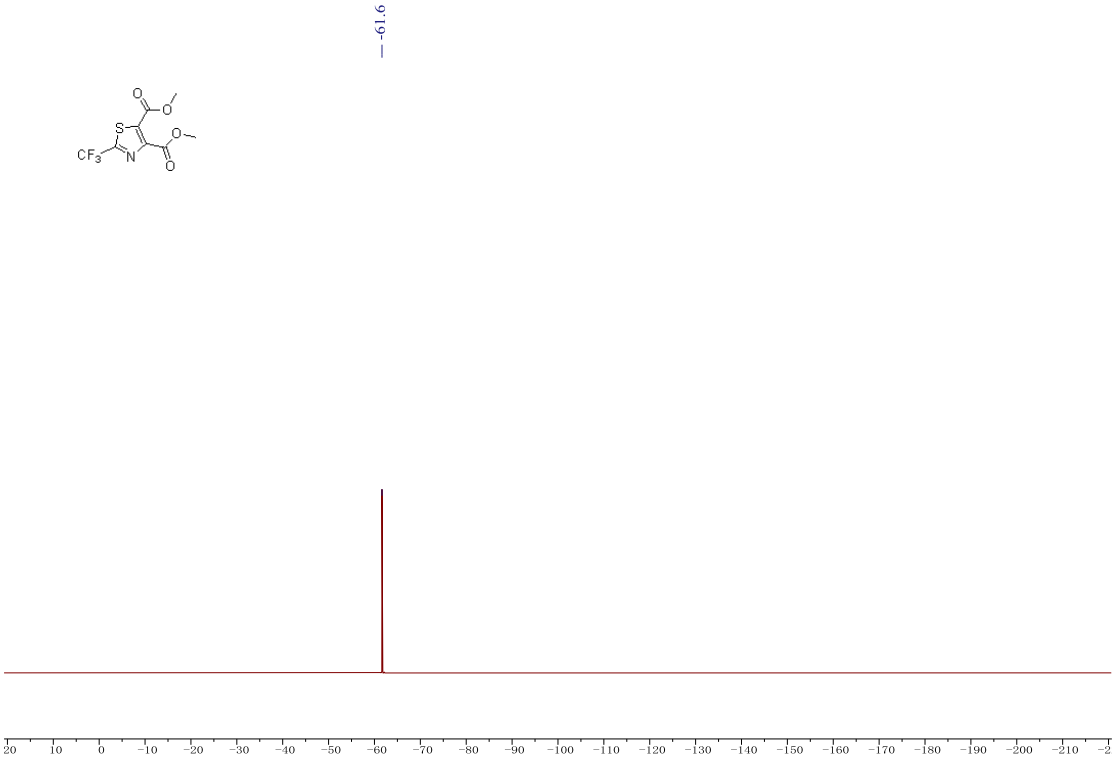
$^{13}C\{1H\}$ NMR spectra of **2a-2** in DMSO-d_6



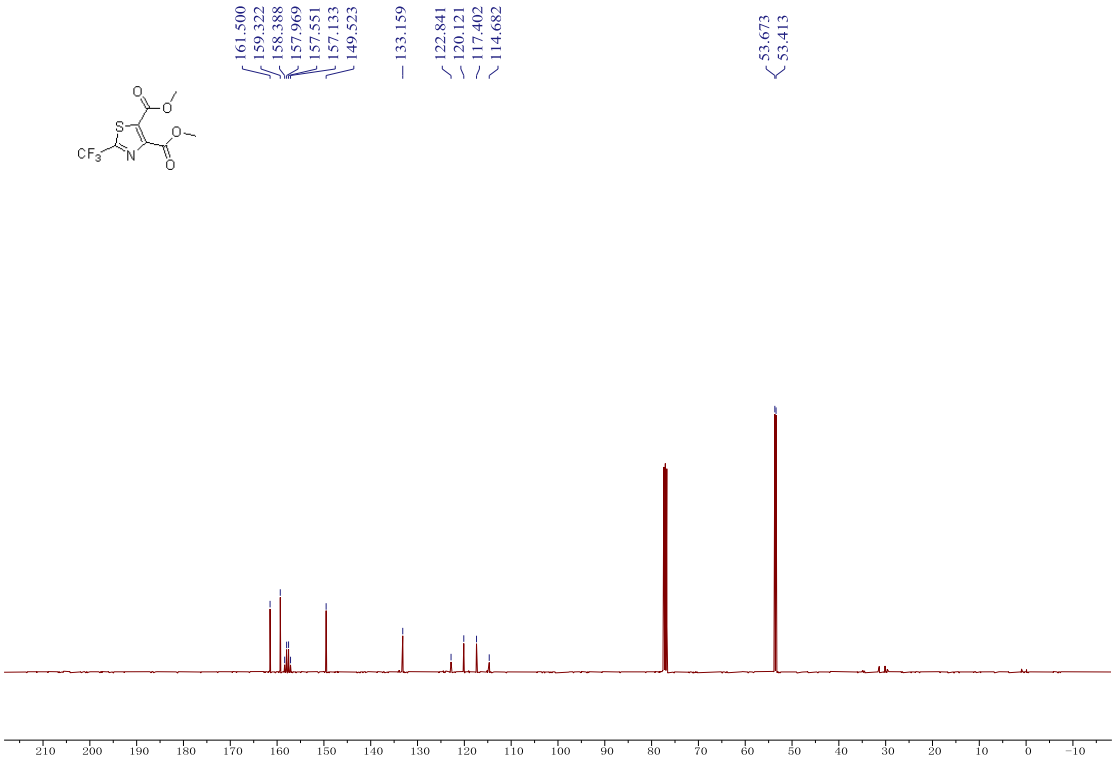
^{1}H NMR spectra of **3a** in $CDCl_3$



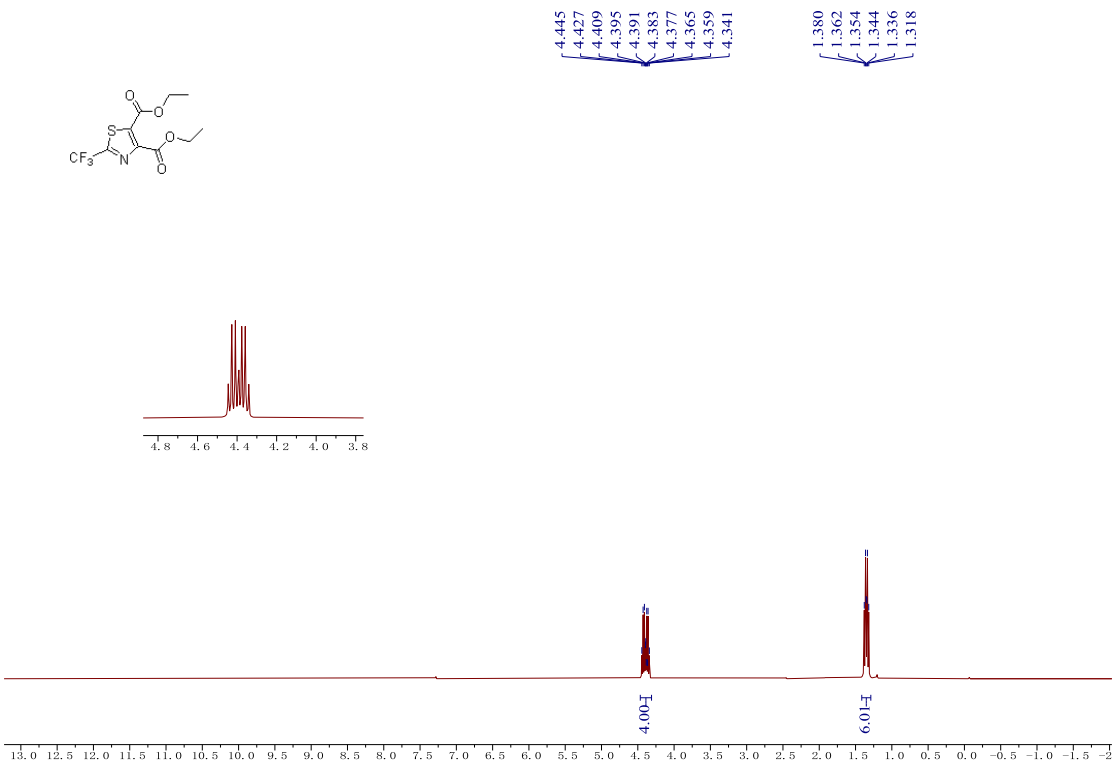
^{19}F NMR spectra of **3a** in $CDCl_3$



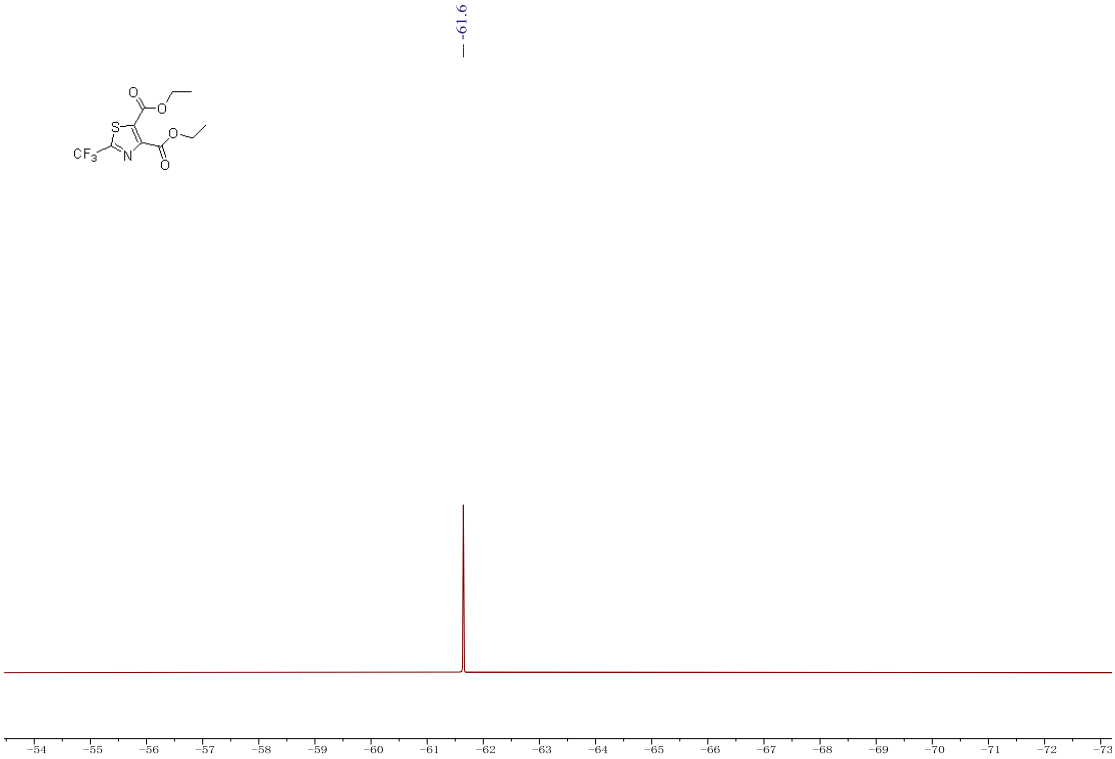
$^{13}C\{1H\}$ NMR spectra of **3a** in $CDCl_3$



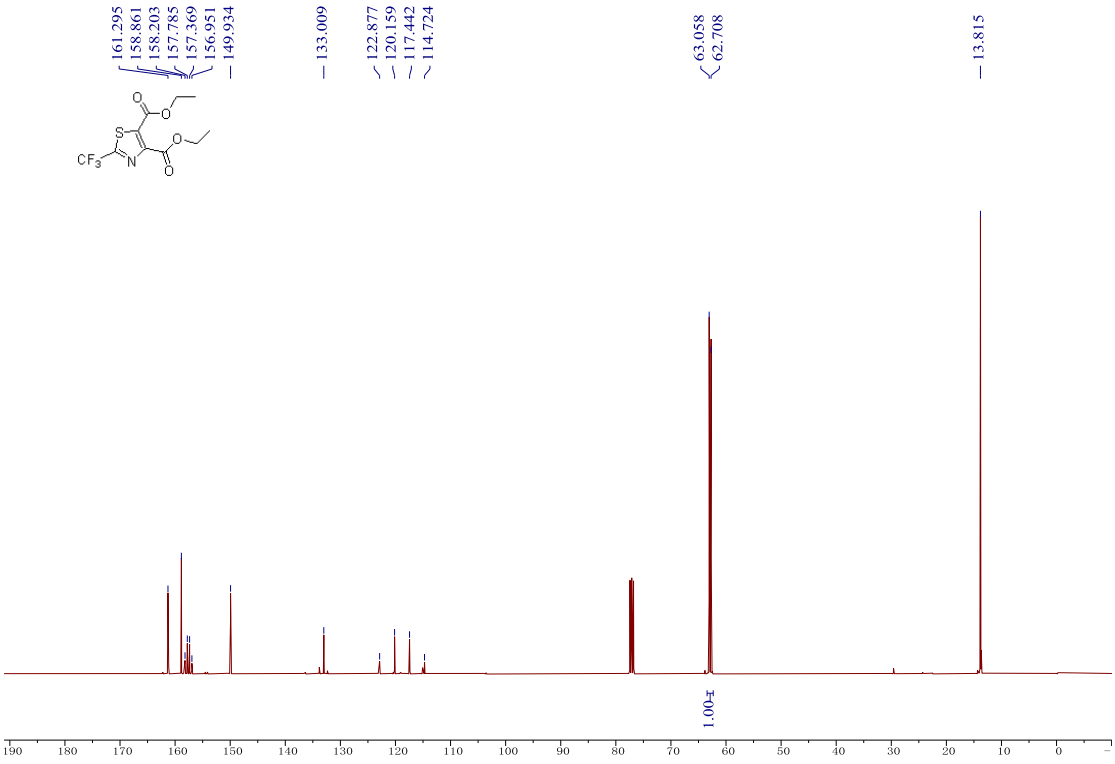
^{1}H NMR spectra of **3b** in $CDCl_3$



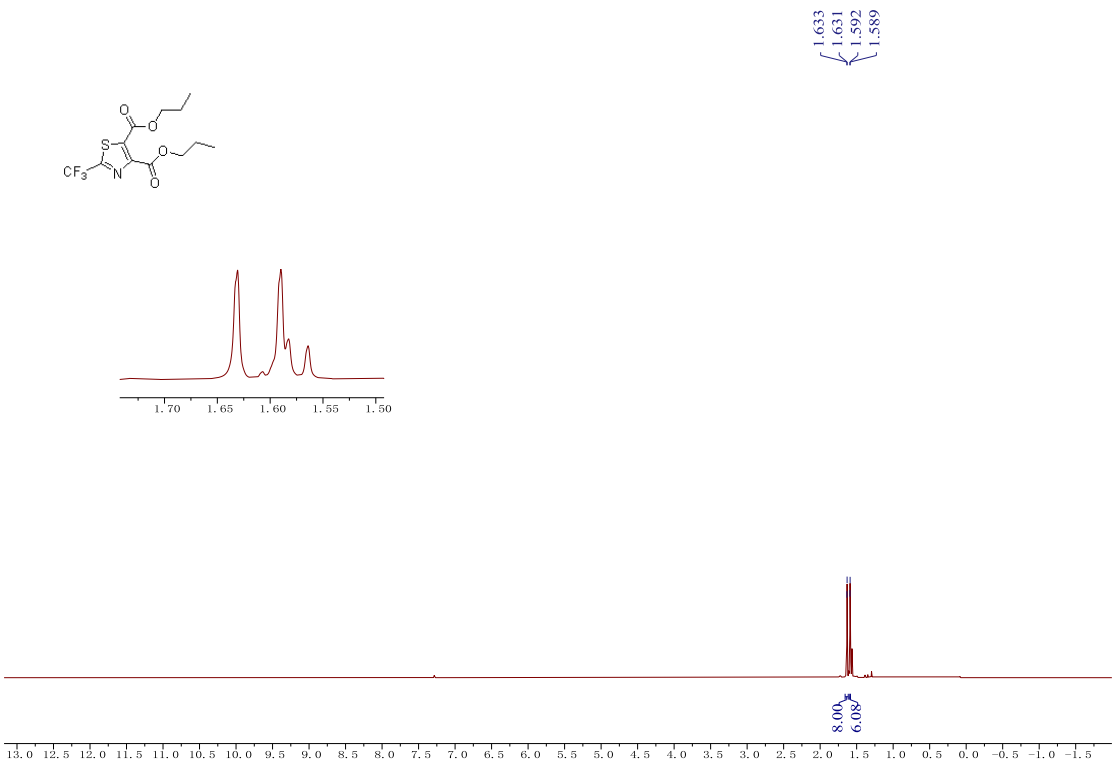
^{19}F NMR spectra of **3b** in $CDCl_3$



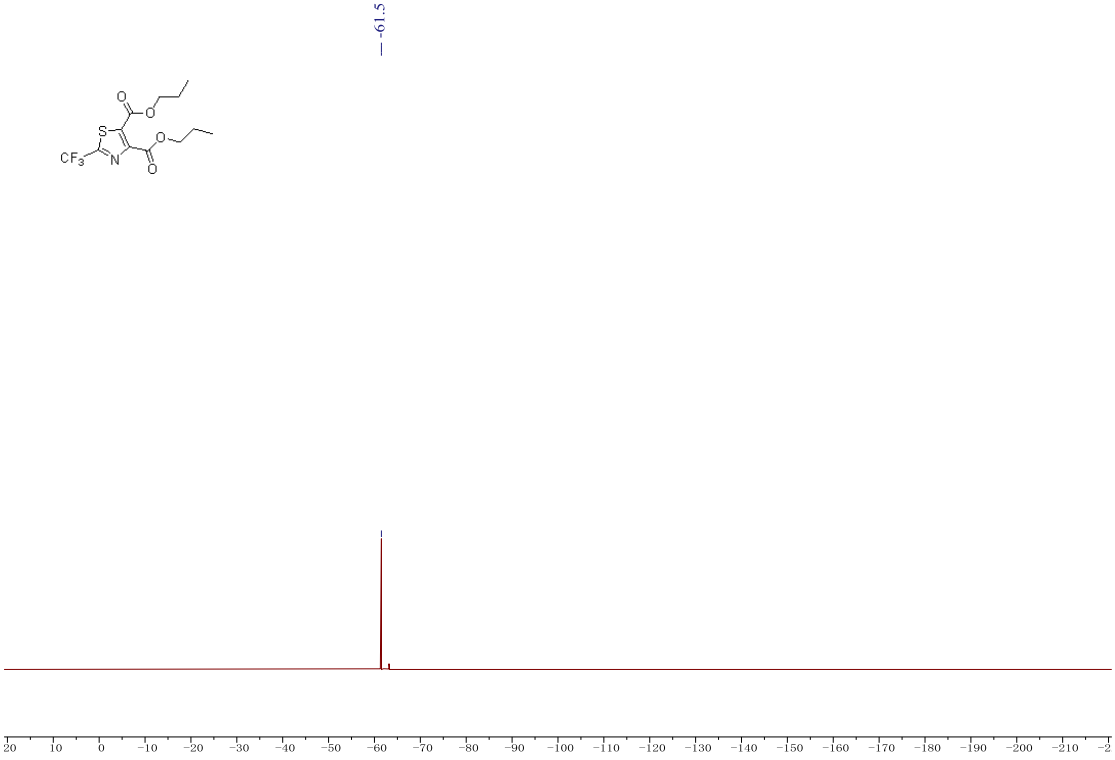
^{13}C{1H} NMR spectra of **3b** in $CDCl_3$



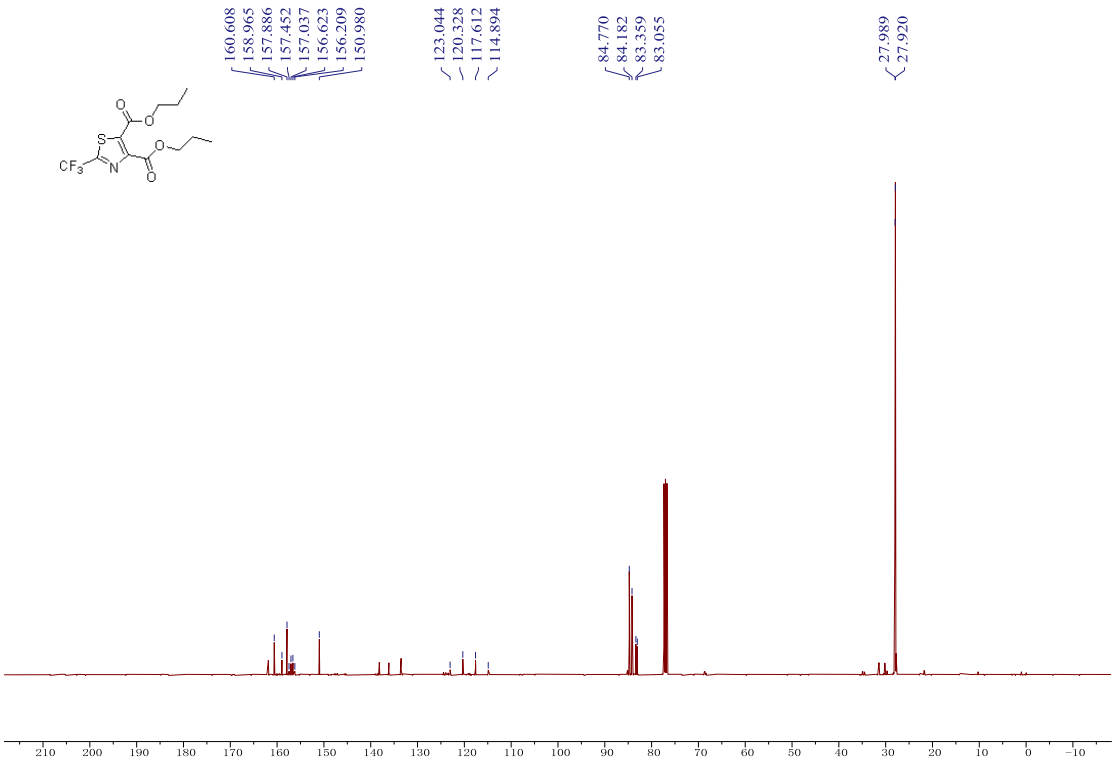
^{1}H NMR spectra of **3c** in $CDCl_3$



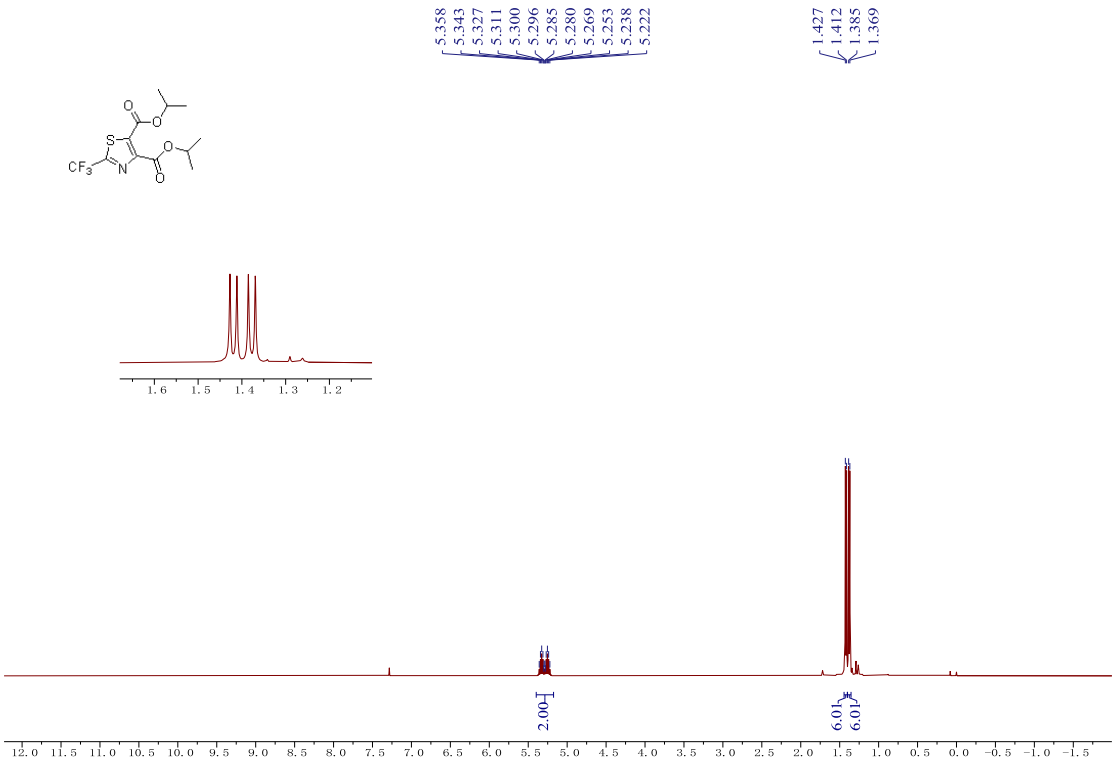
^{19}F NMR spectra of **3c** in $CDCl_3$



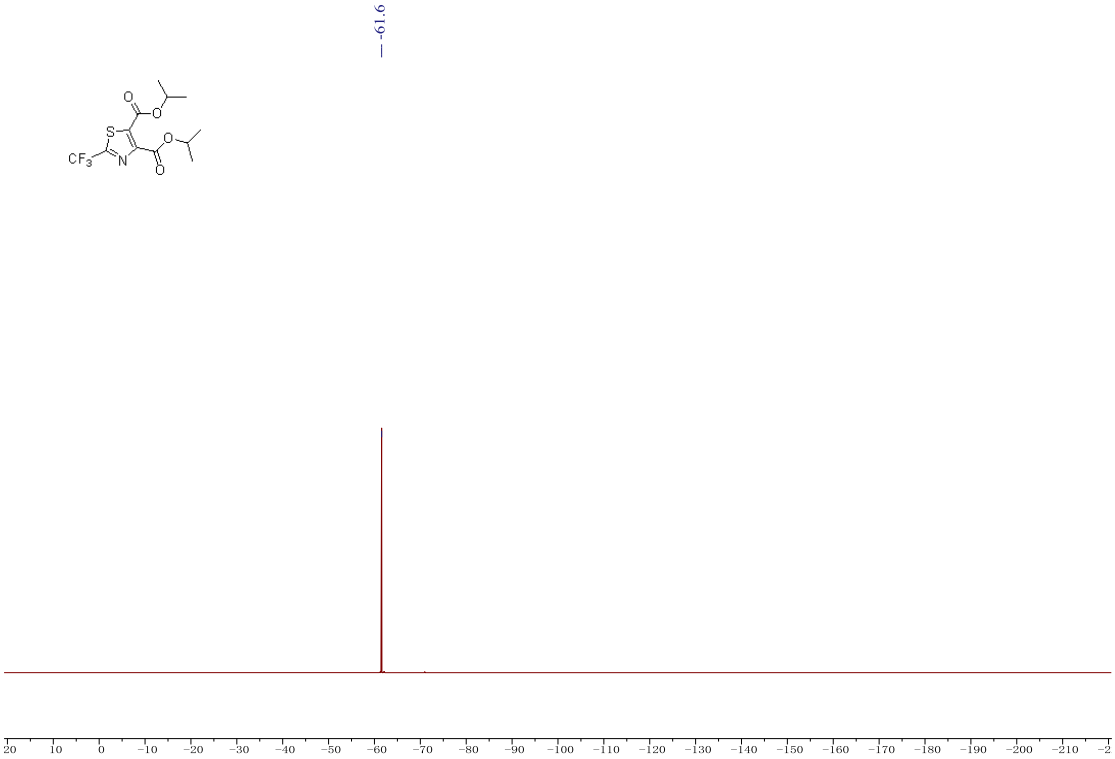
$^{13}C\{1H\}$ NMR spectra of **3c** in $CDCl_3$



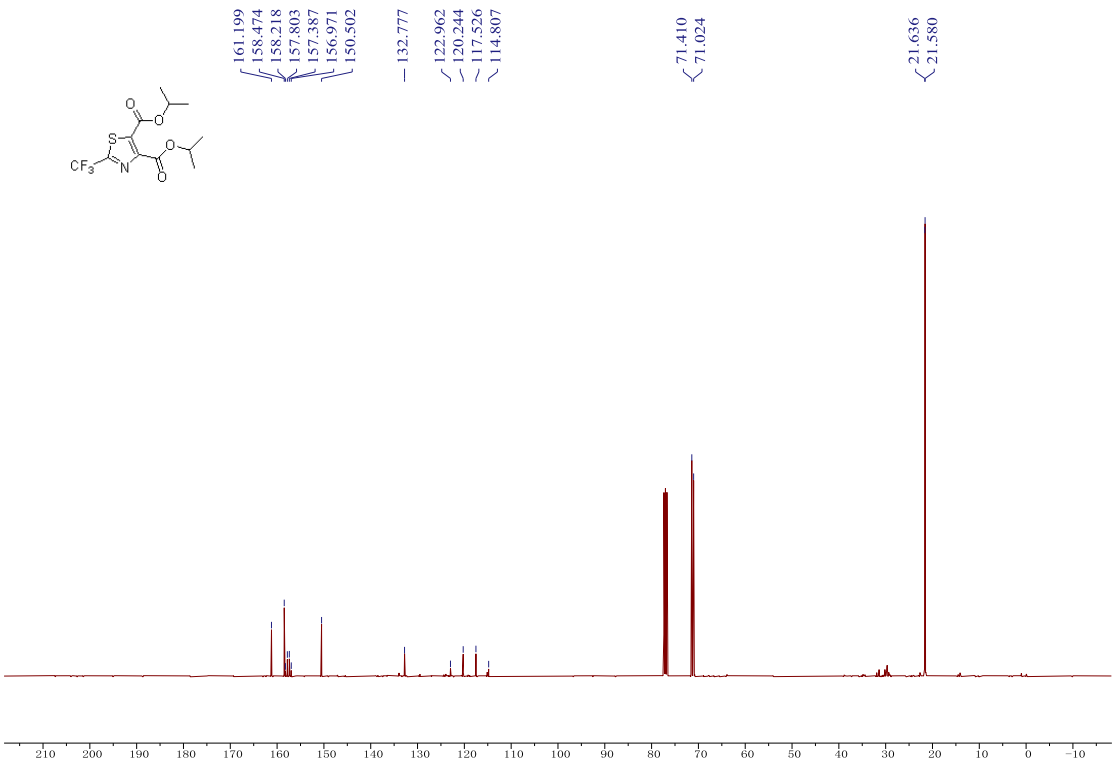
^{1}H NMR spectra of **3d** in $CDCl_3$



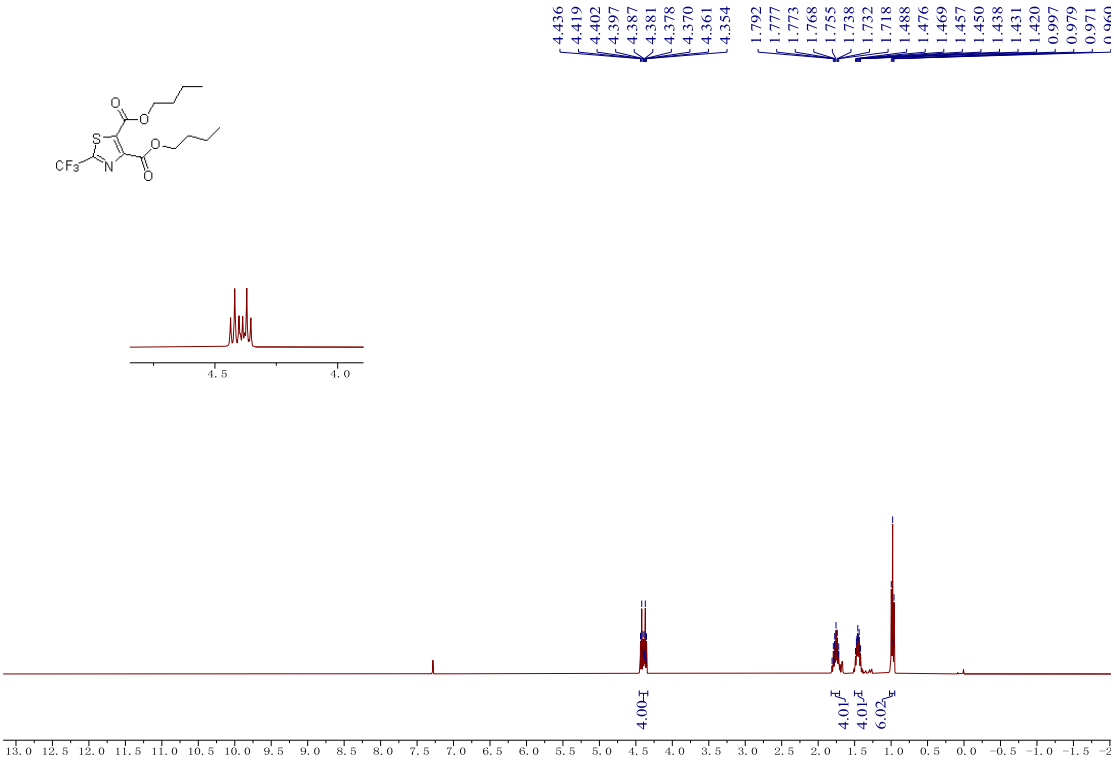
^{19}F NMR spectra of **3d** in $CDCl_3$



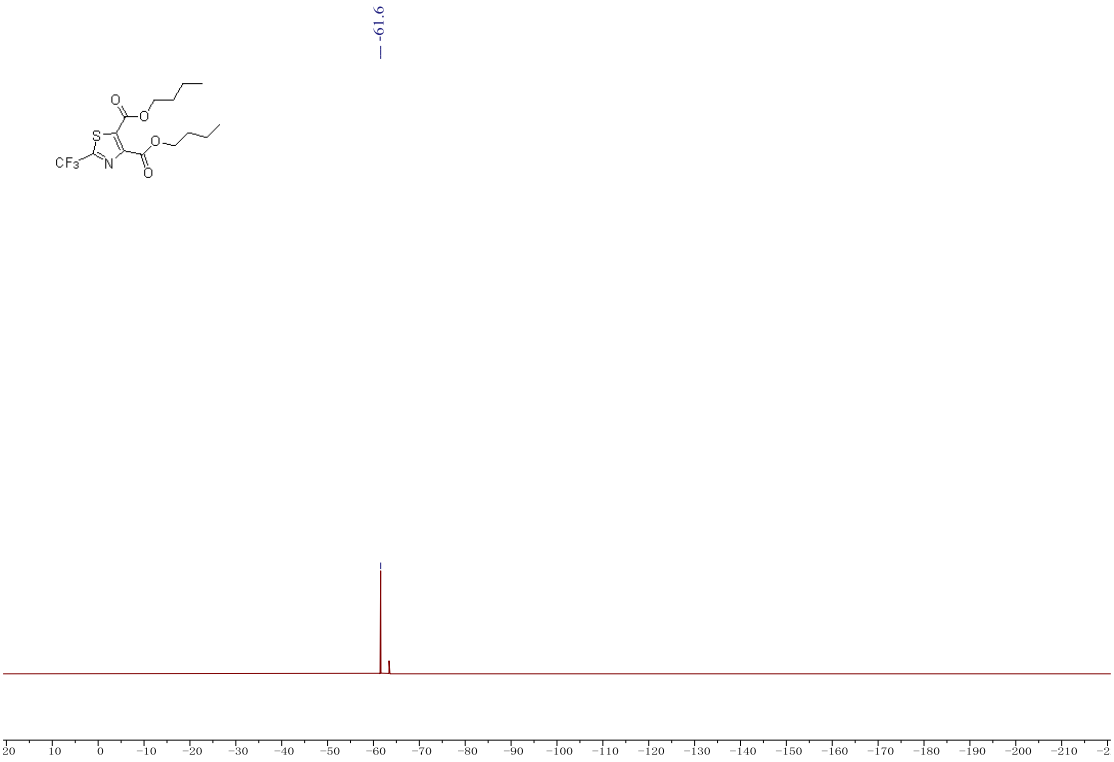
$^{13}C\{1H\}$ NMR spectra of **3d** in $CDCl_3$



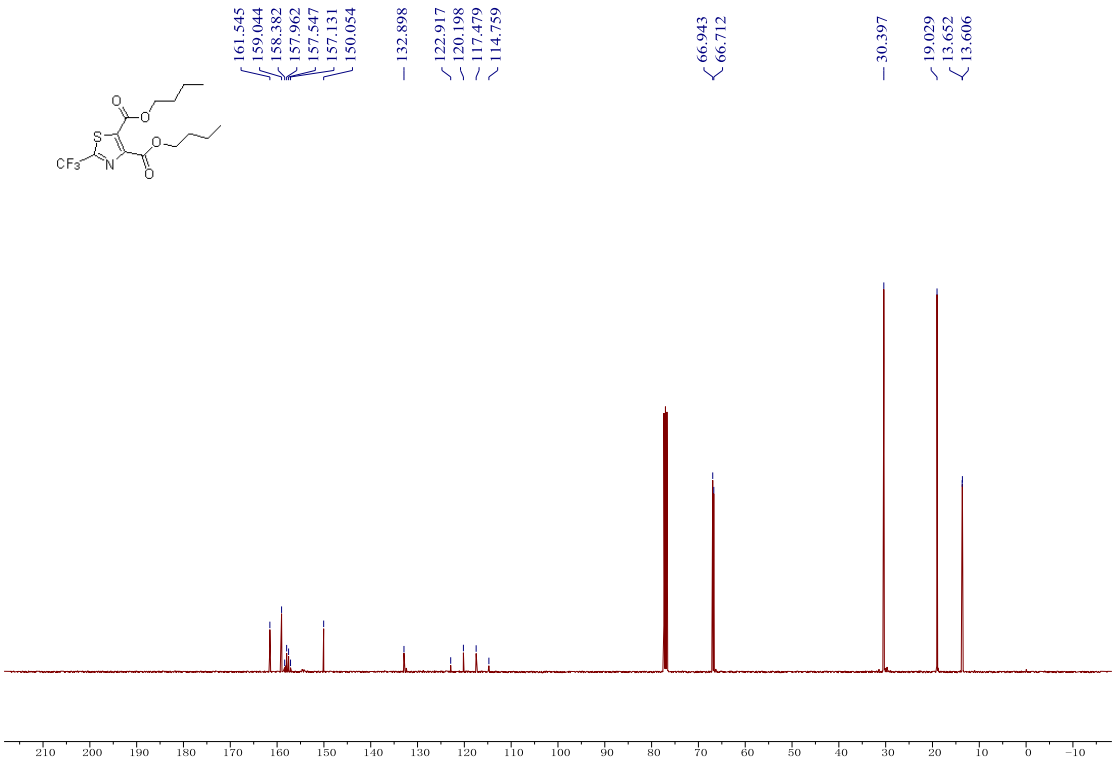
^{1}H NMR spectra of **3e** in $CDCl_3$



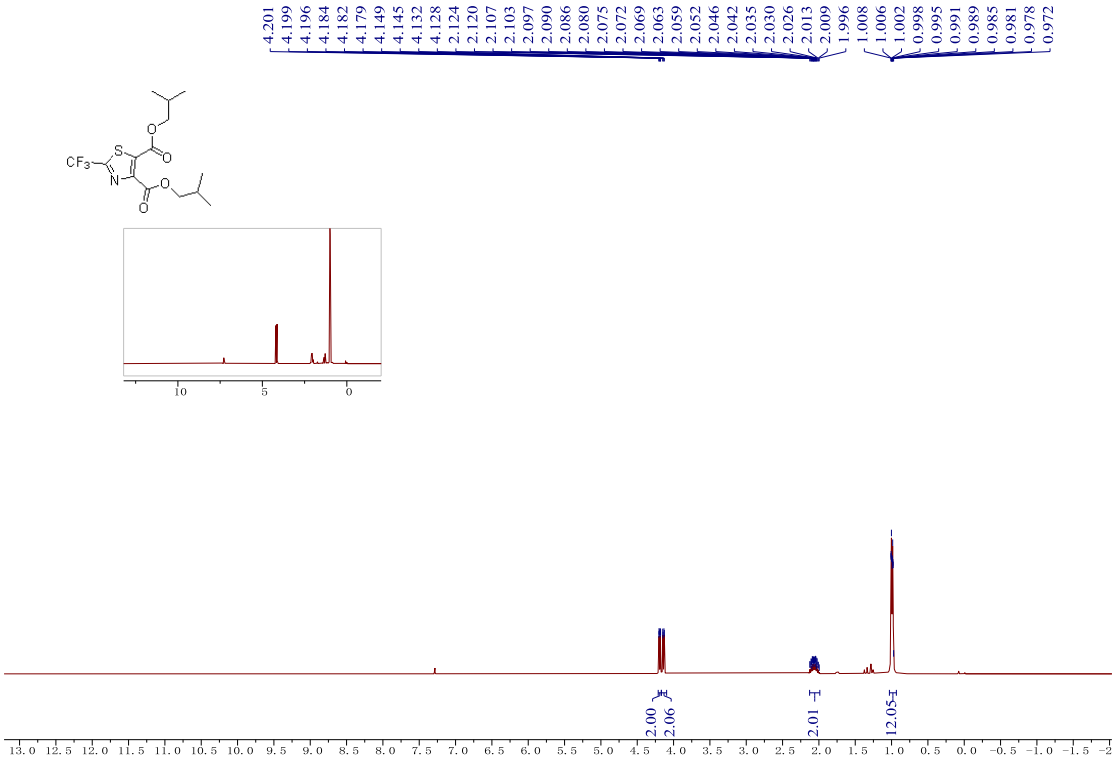
^{19}F NMR spectra of **3e** in $CDCl_3$



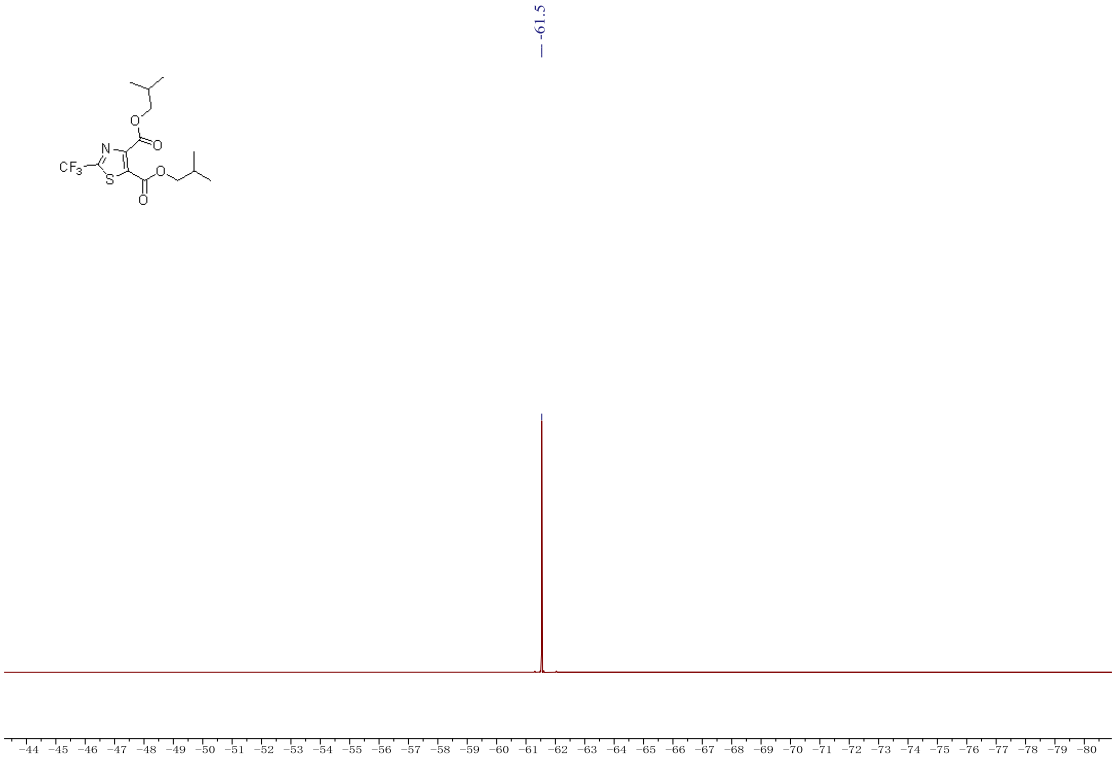
$^{13}C\{1H\}$ NMR spectra of **3e** in $CDCl_3$



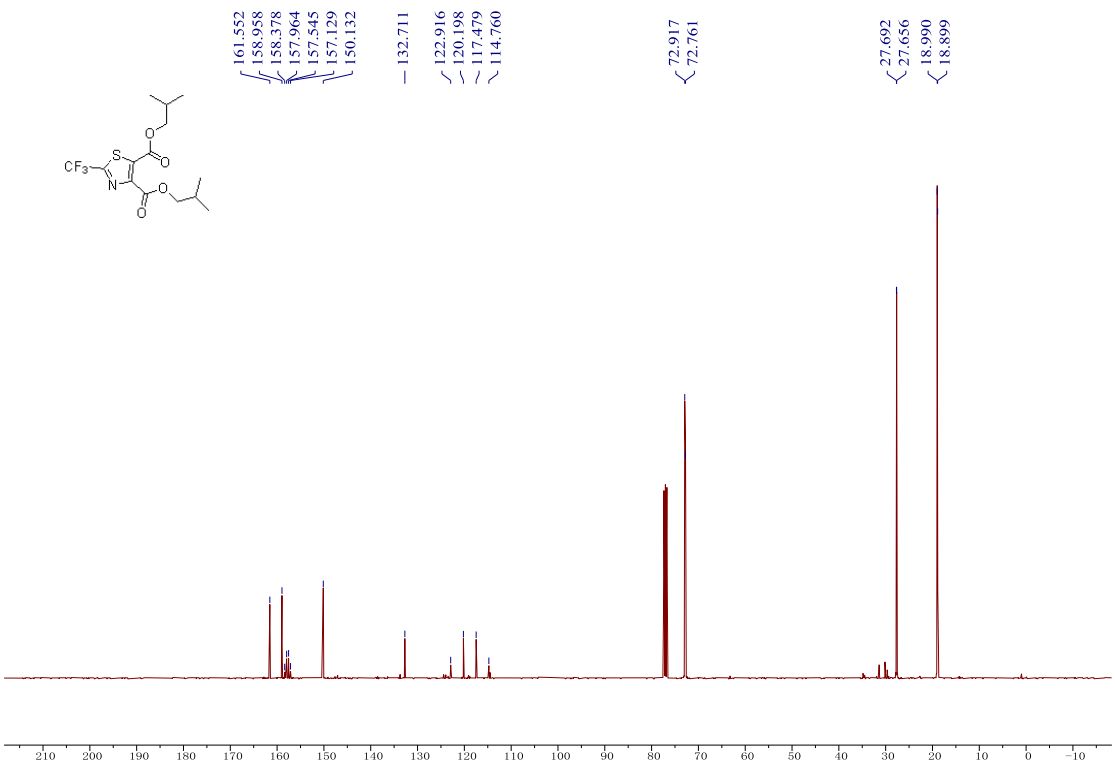
^{1}H NMR spectra of **3f** in $CDCl_3$



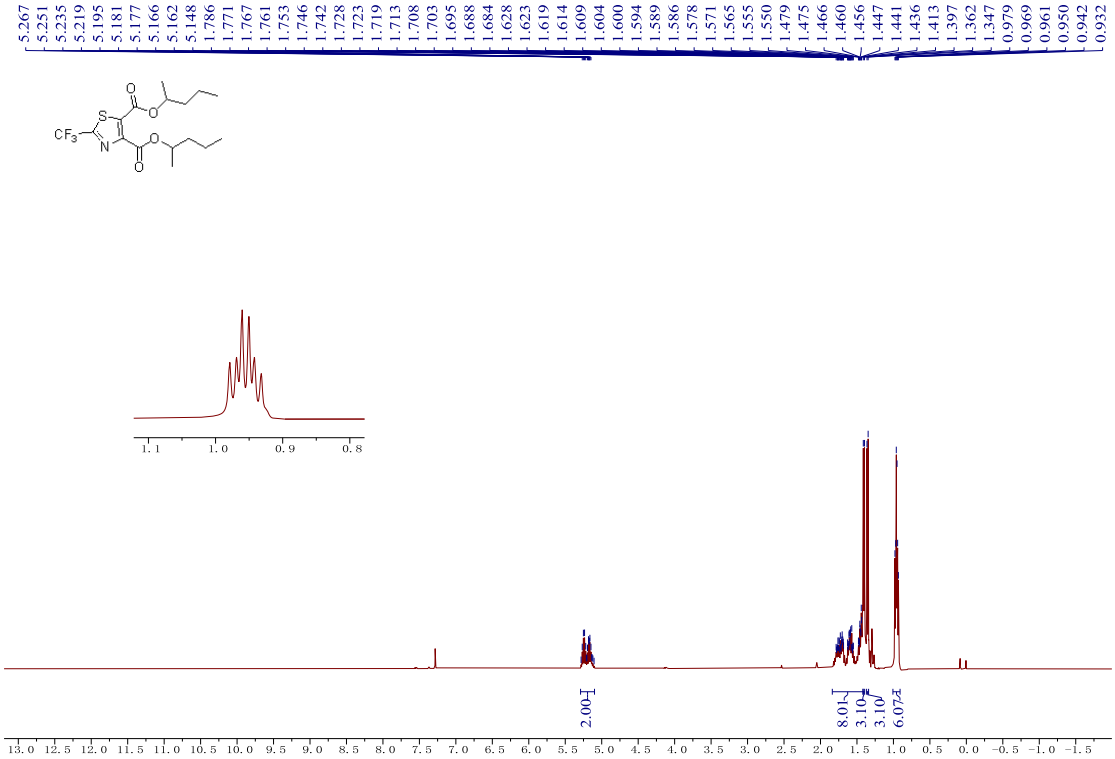
^{19}F NMR spectra of **3f** in $CDCl_3$



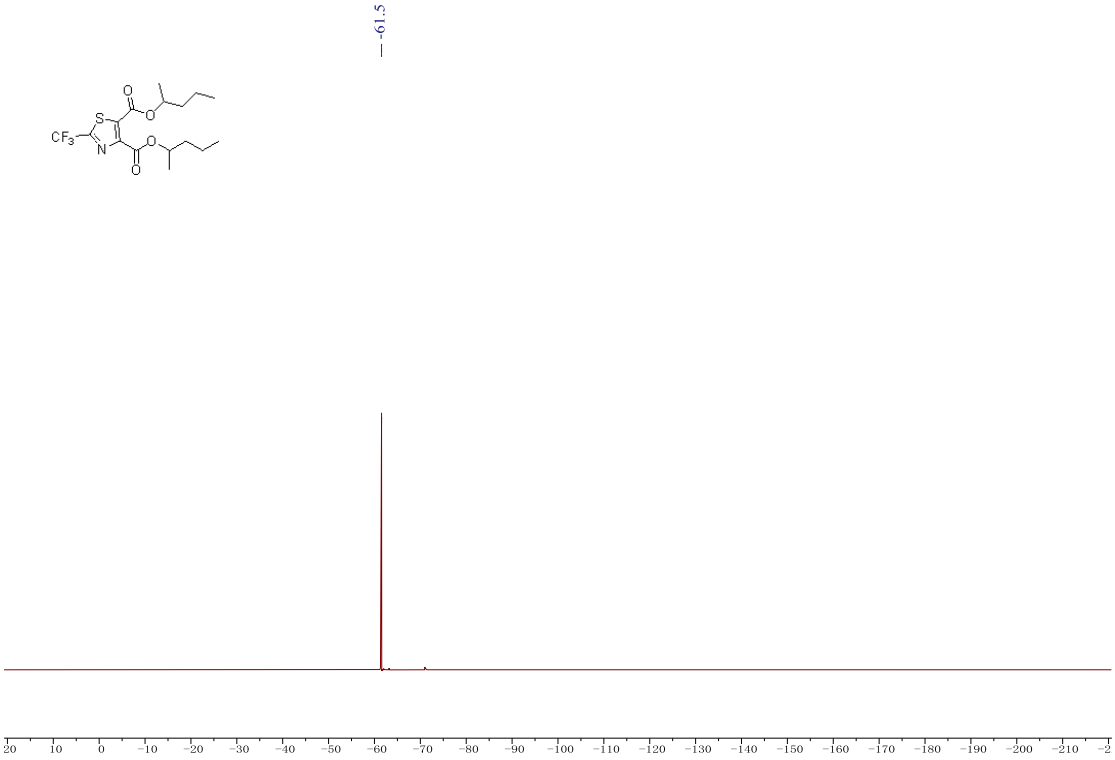
$^{13}C\{1H\}$ NMR spectra of **3f** in $CDCl_3$



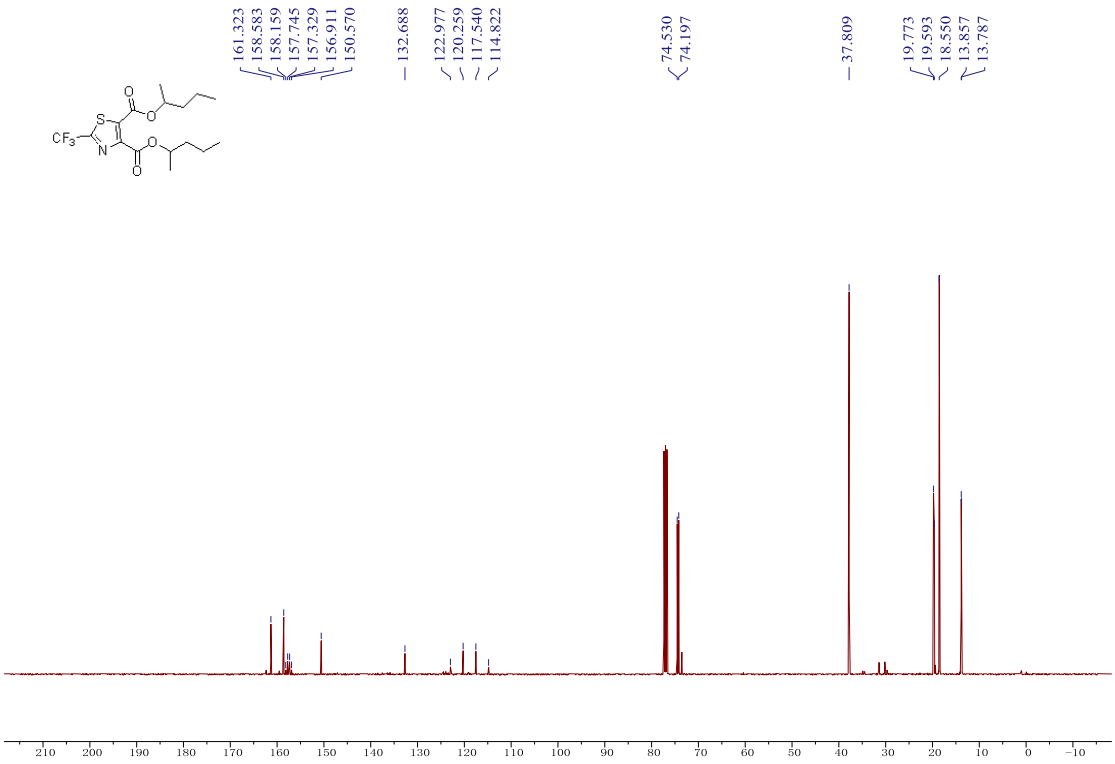
^{1}H NMR spectra of **3g** in $CDCl_3$



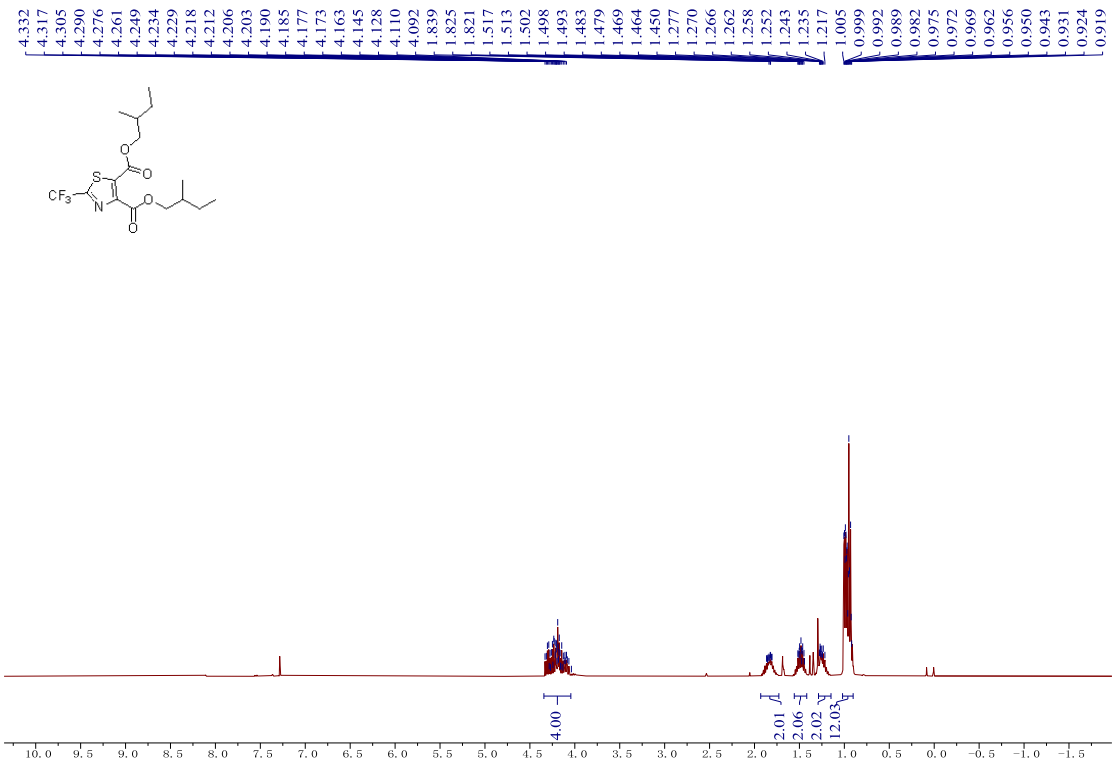
^{19}F NMR spectra of **3g** in $CDCl_3$



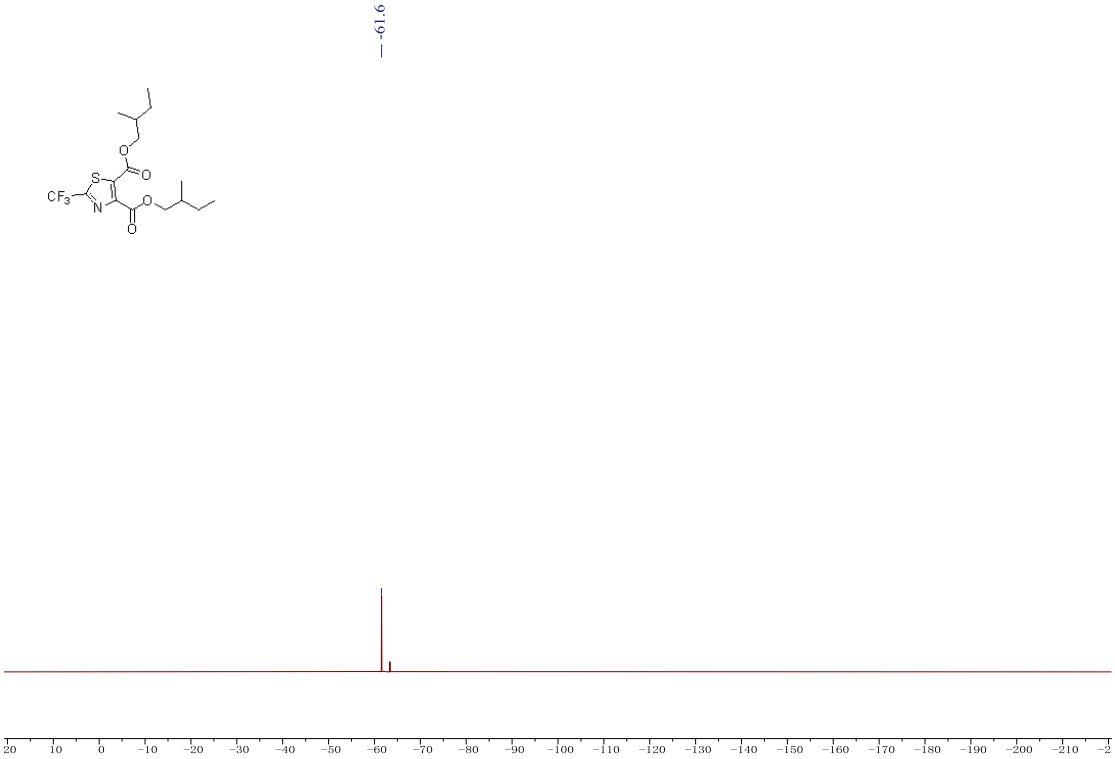
$^{13}C\{1H\}$ NMR spectra of **3g** in $CDCl_3$



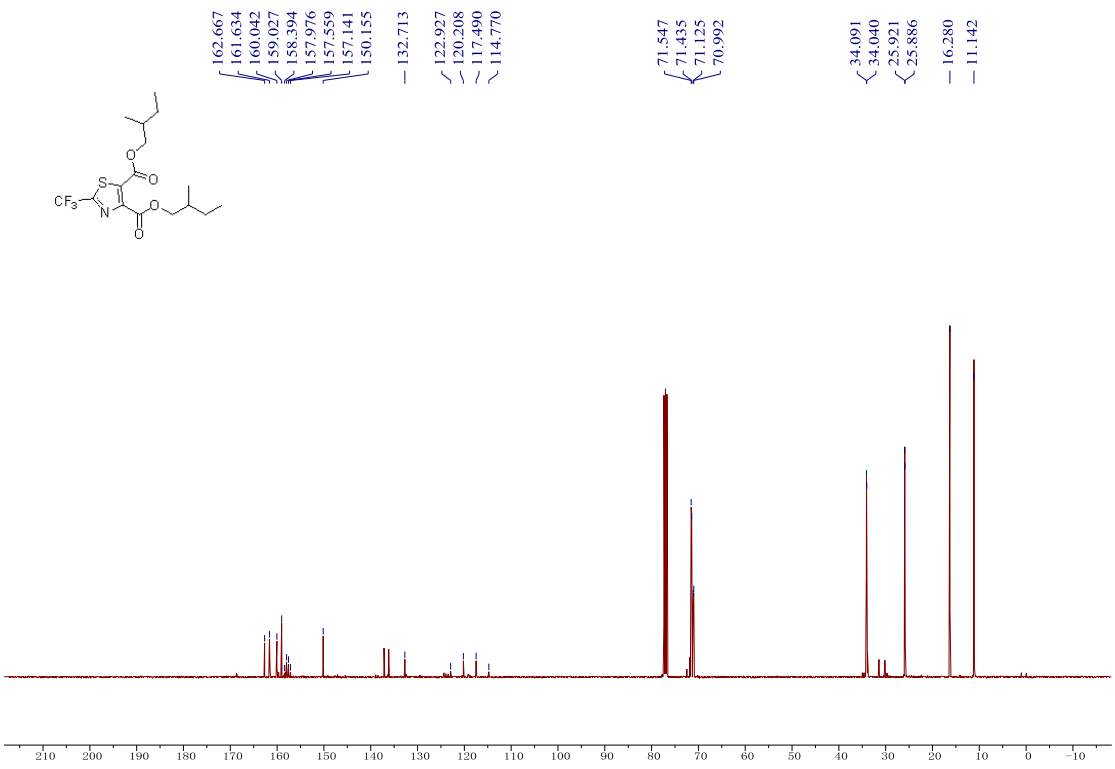
^{1}H NMR spectra of **3h** in $CDCl_3$



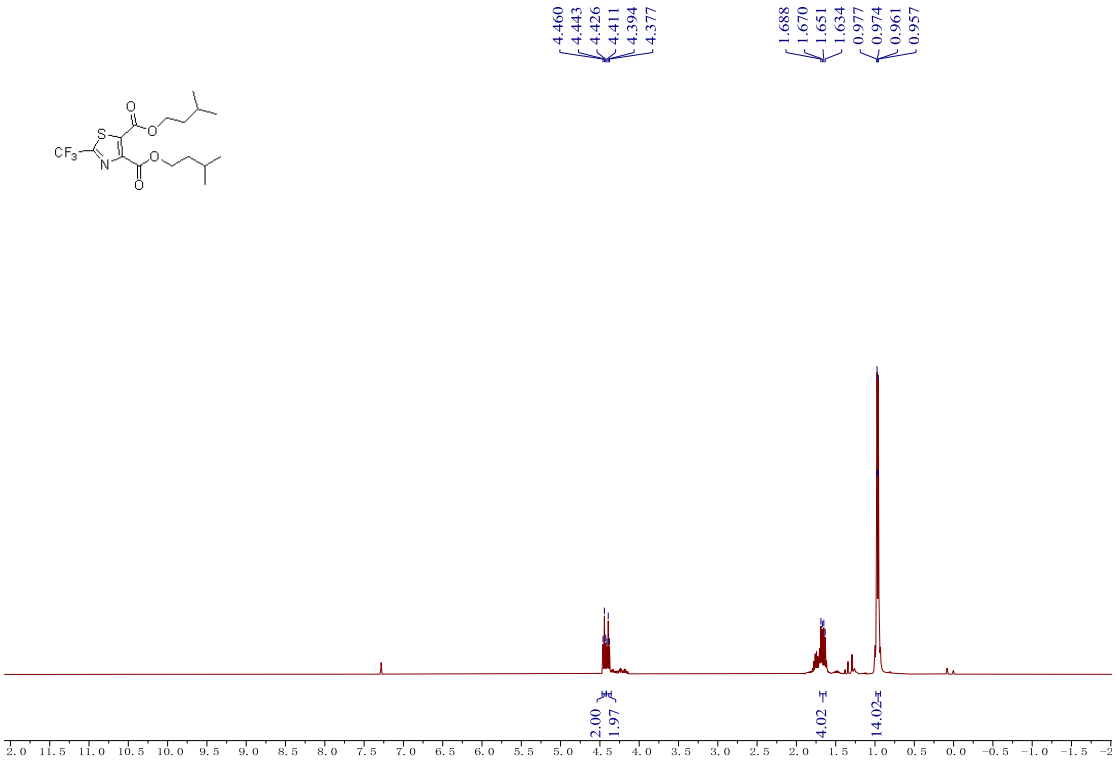
^{19}F NMR spectra of **3h** in $CDCl_3$



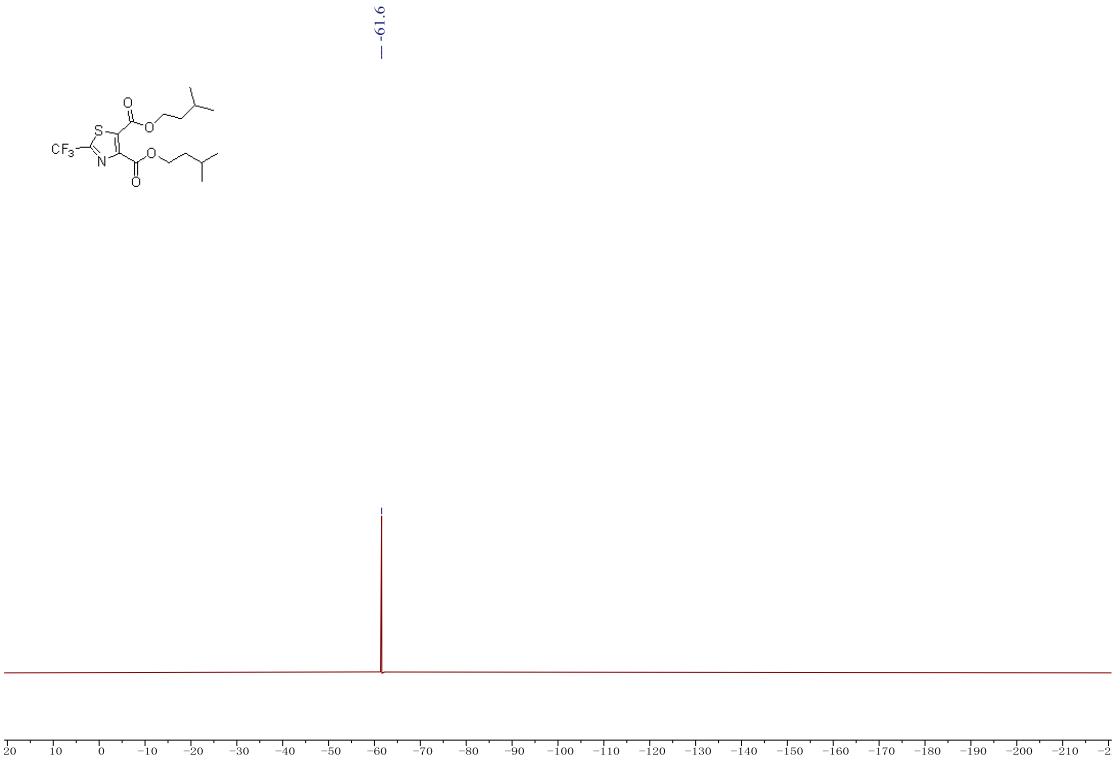
$^{13}C\{1H\}$ NMR spectra of **3h** in $CDCl_3$



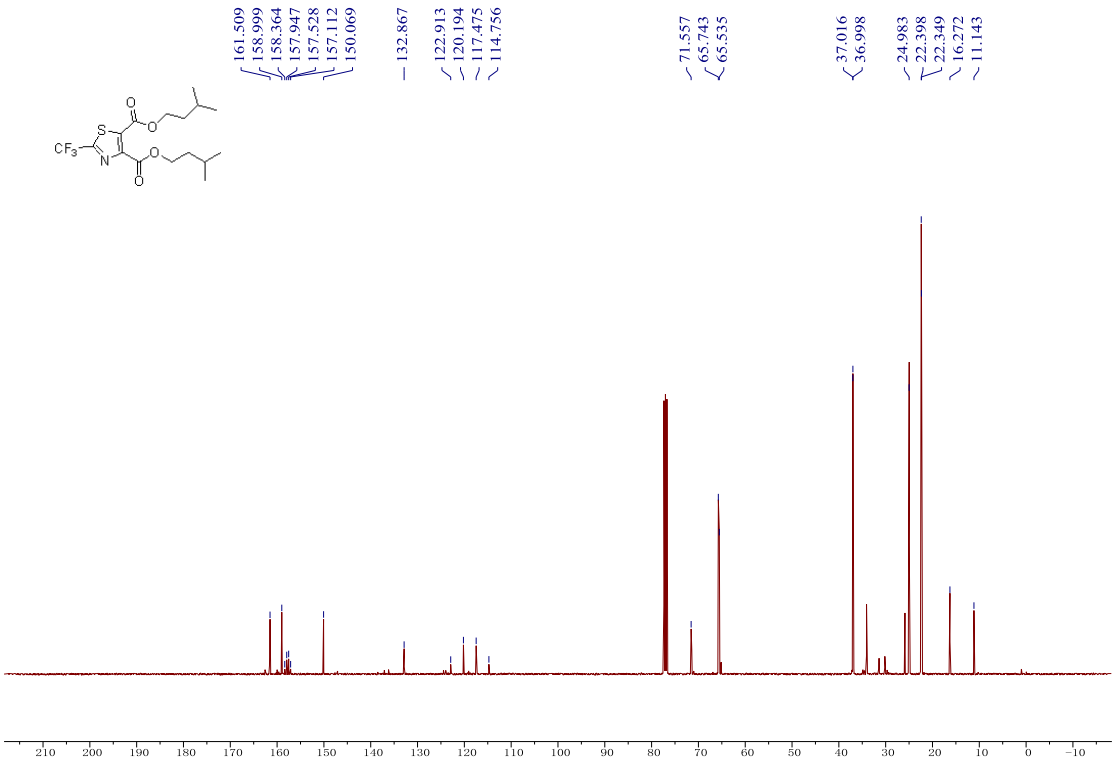
^{1}H NMR spectra of **3i** in $CDCl_3$



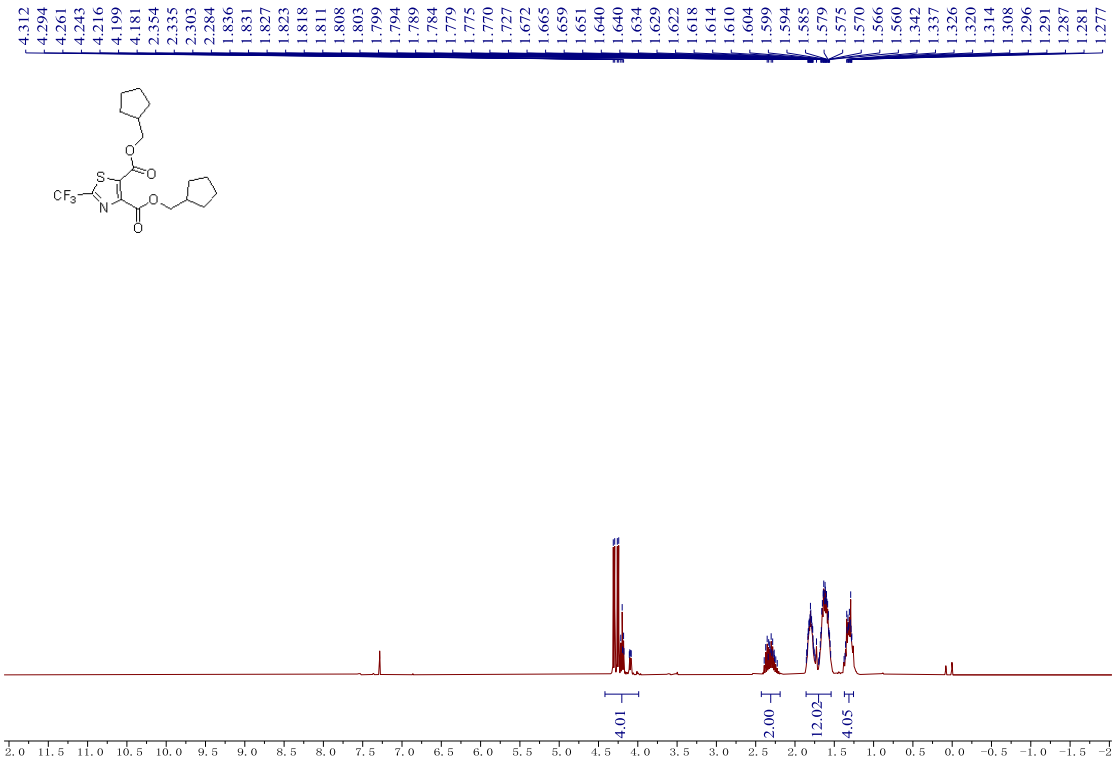
^{19}F NMR spectra of **3i** in $CDCl_3$



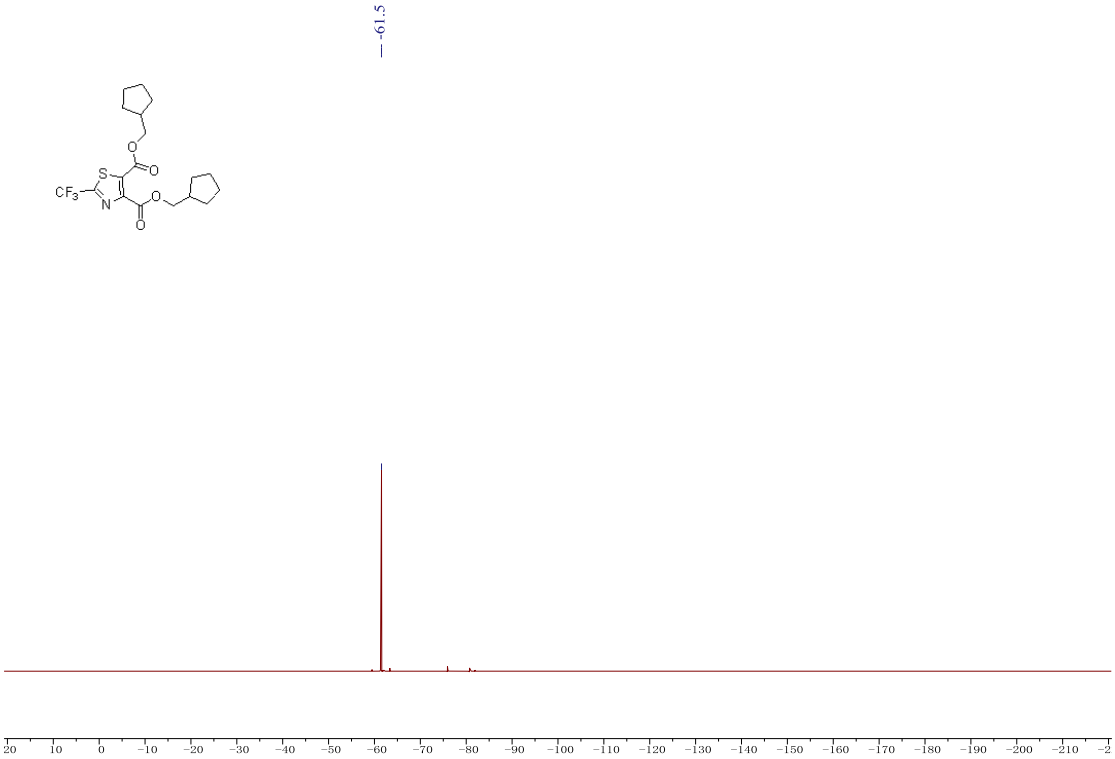
$^{13}C\{1H\}$ NMR spectra of **3i** in $CDCl_3$



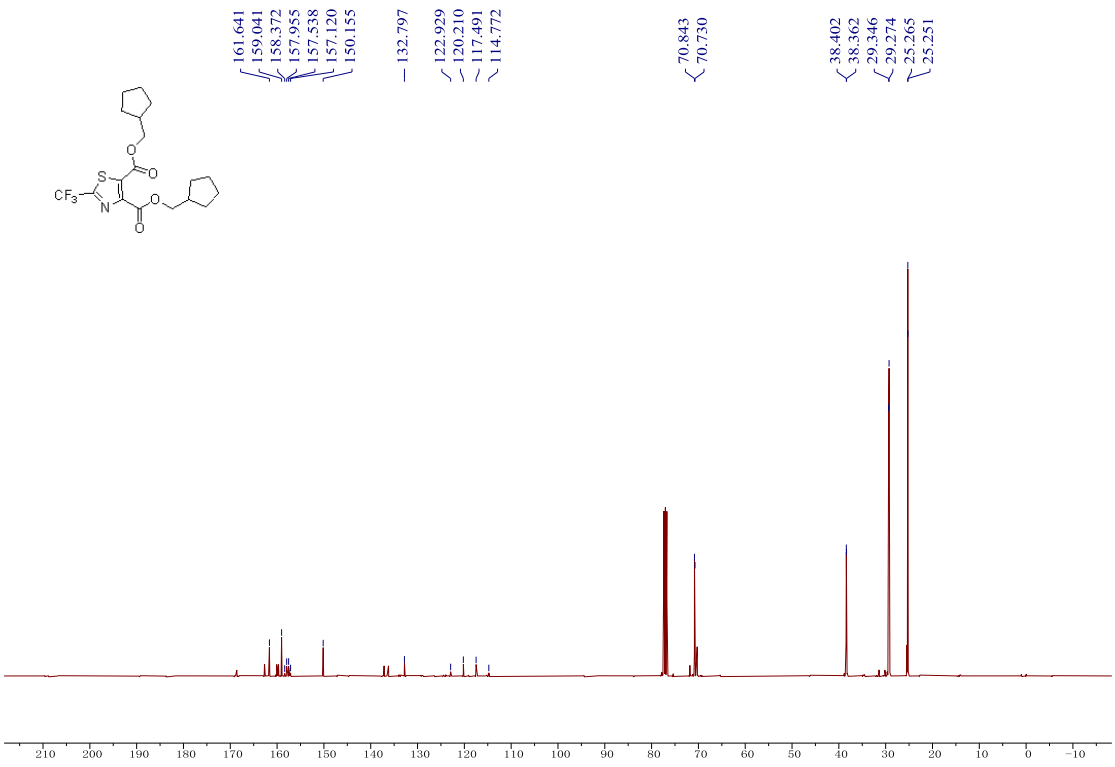
^{1}H NMR spectra of **3j** in $CDCl_3$



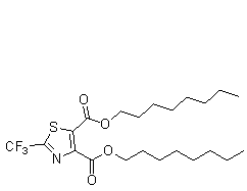
^{19}F NMR spectra of **3j** in $CDCl_3$

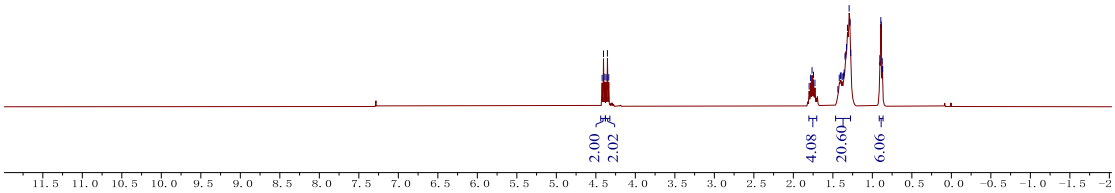


$^{13}C\{1H\}$ NMR spectra of **3j** in $CDCl_3$

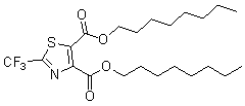


^{1}H NMR spectra of **3k** in $CDCl_3$

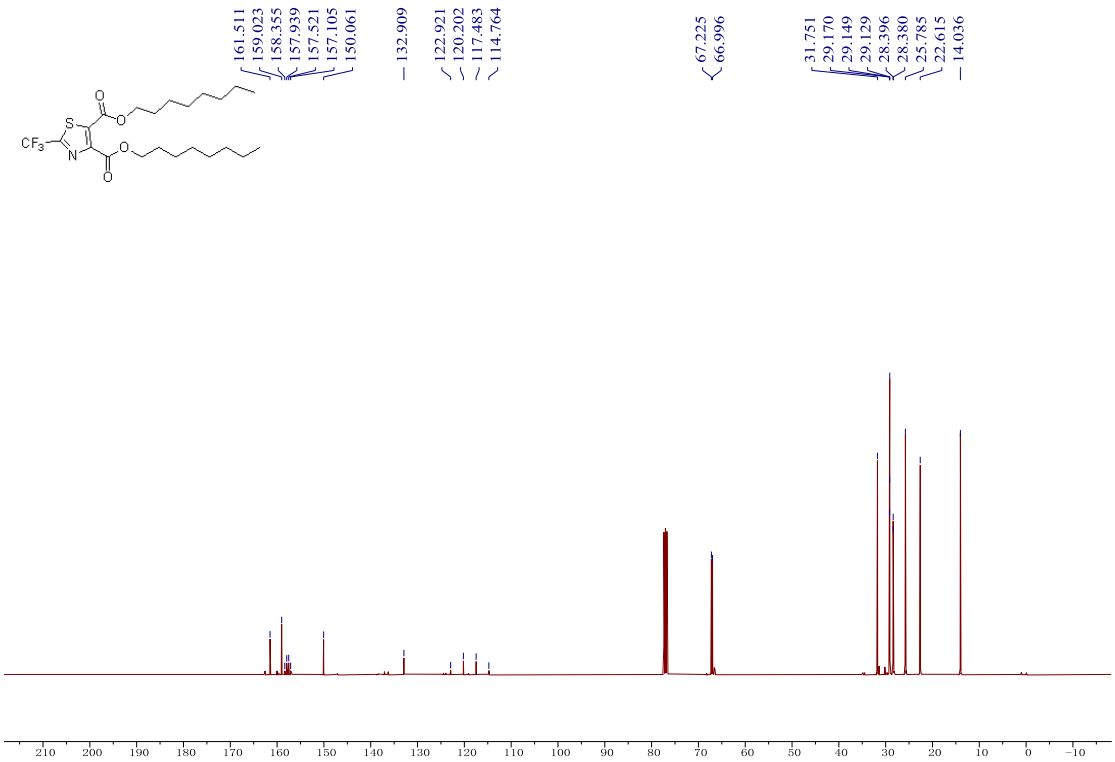




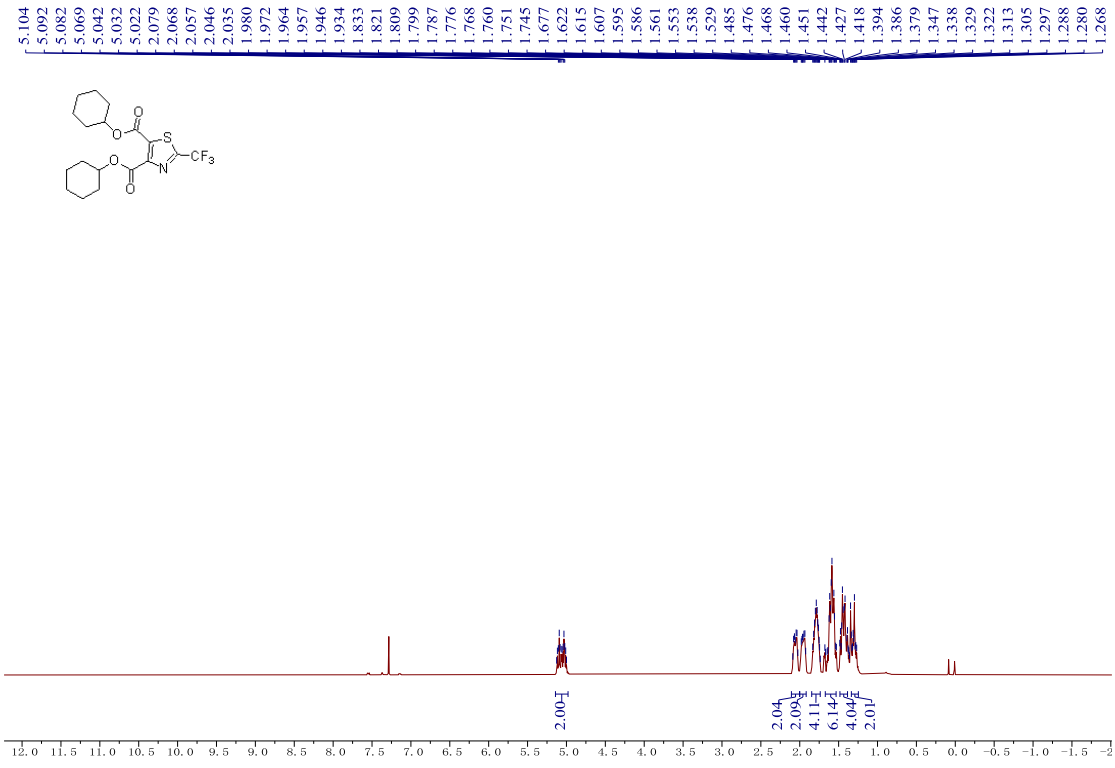
^{19}F NMR spectra of **3k** in $CDCl_3$



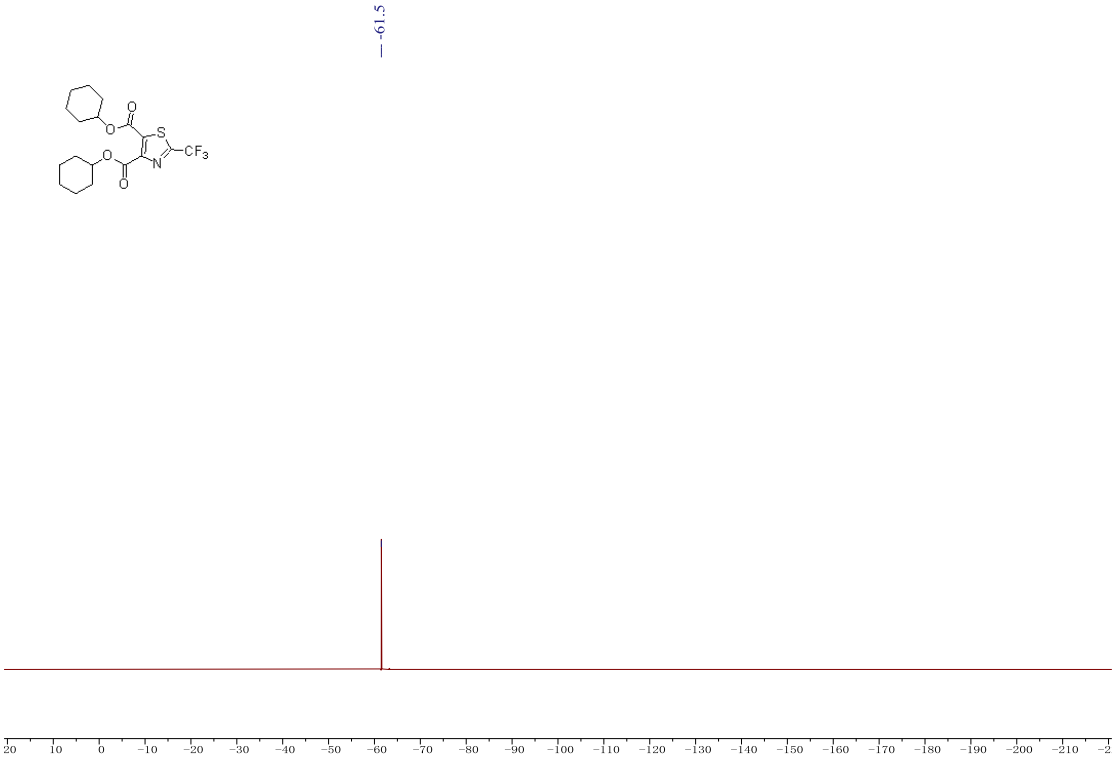
$^{13}C\{1H\}$ NMR spectra of **3k** in $CDCl_3$



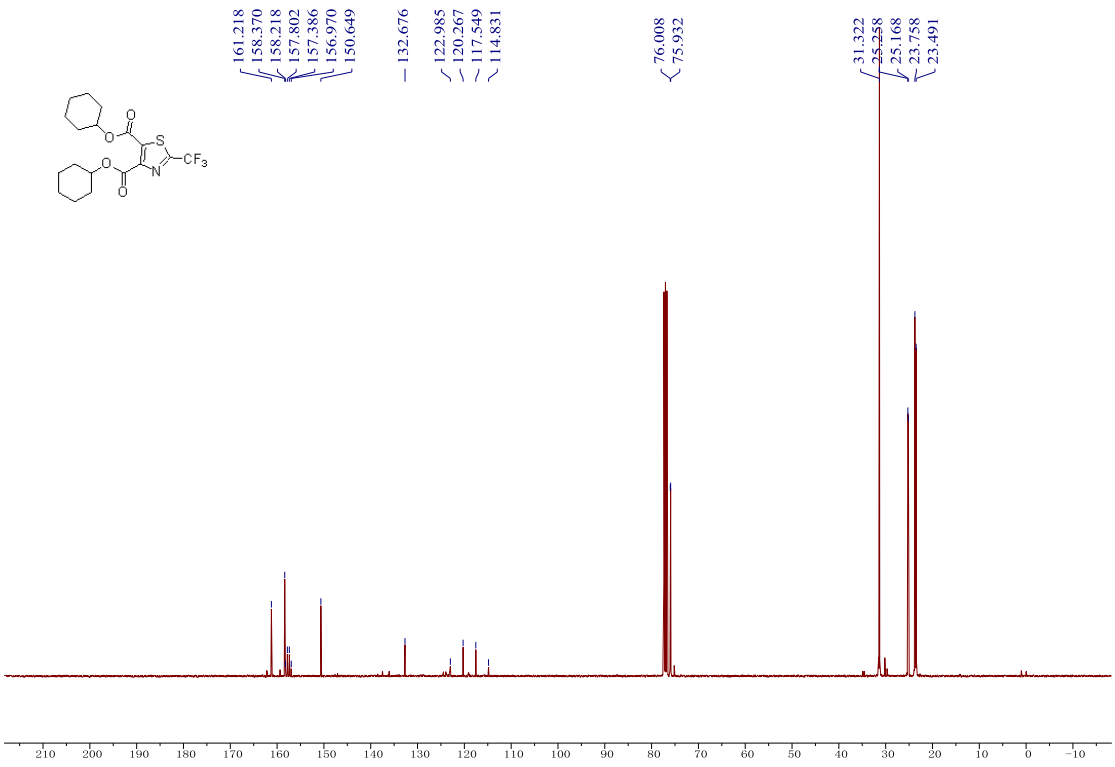
^{1}H NMR spectra of **3l** in $CDCl_3$



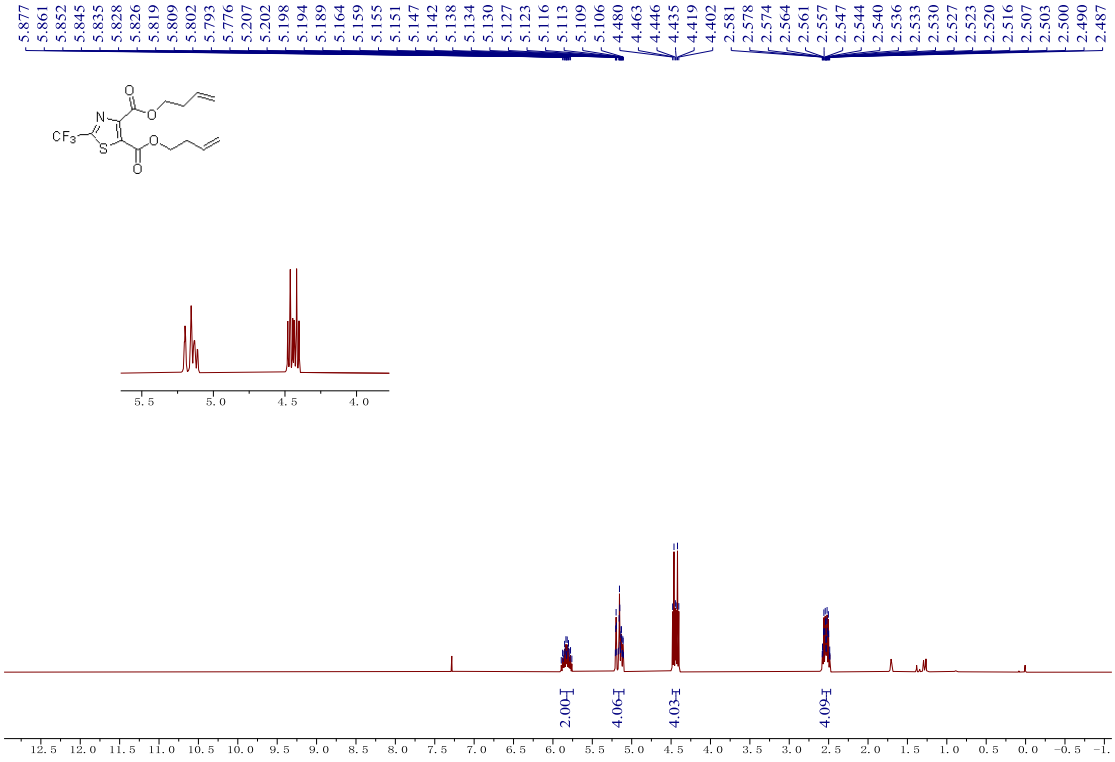
^{19}F NMR spectra of **3l** in $CDCl_3$



$^{13}C\{1H\}$ NMR spectra of **3l** in $CDCl_3$



^{1}H NMR spectra of **3m** in $CDCl_3$



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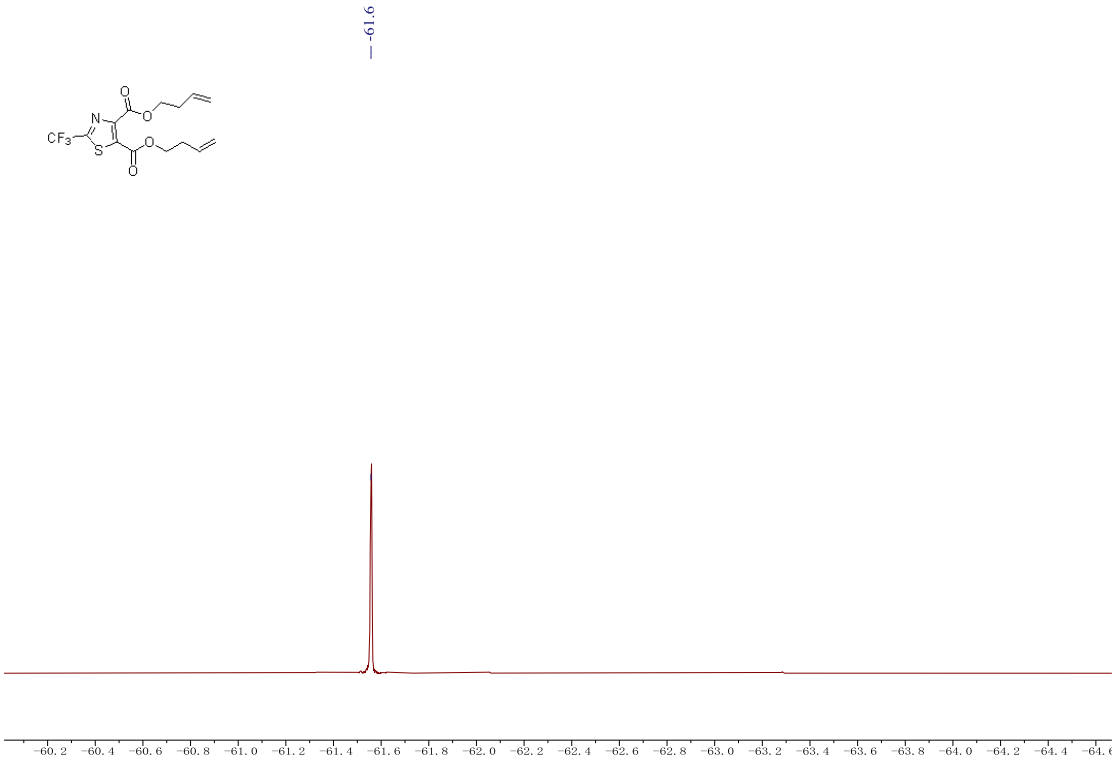
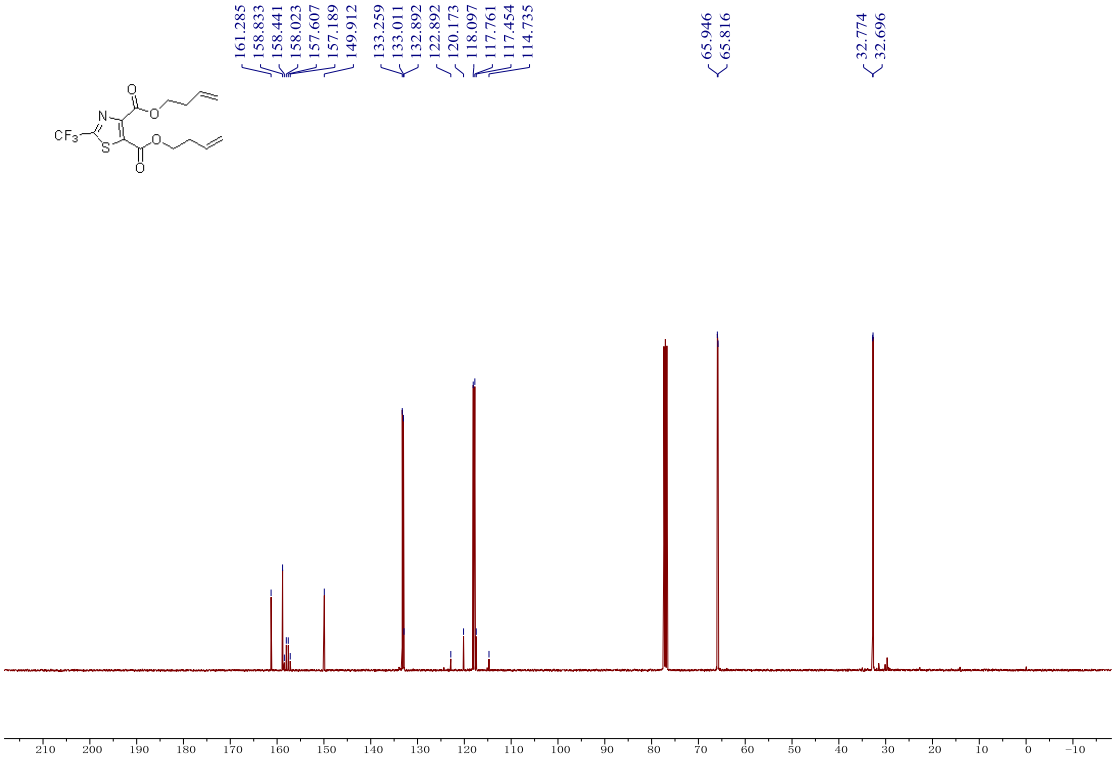
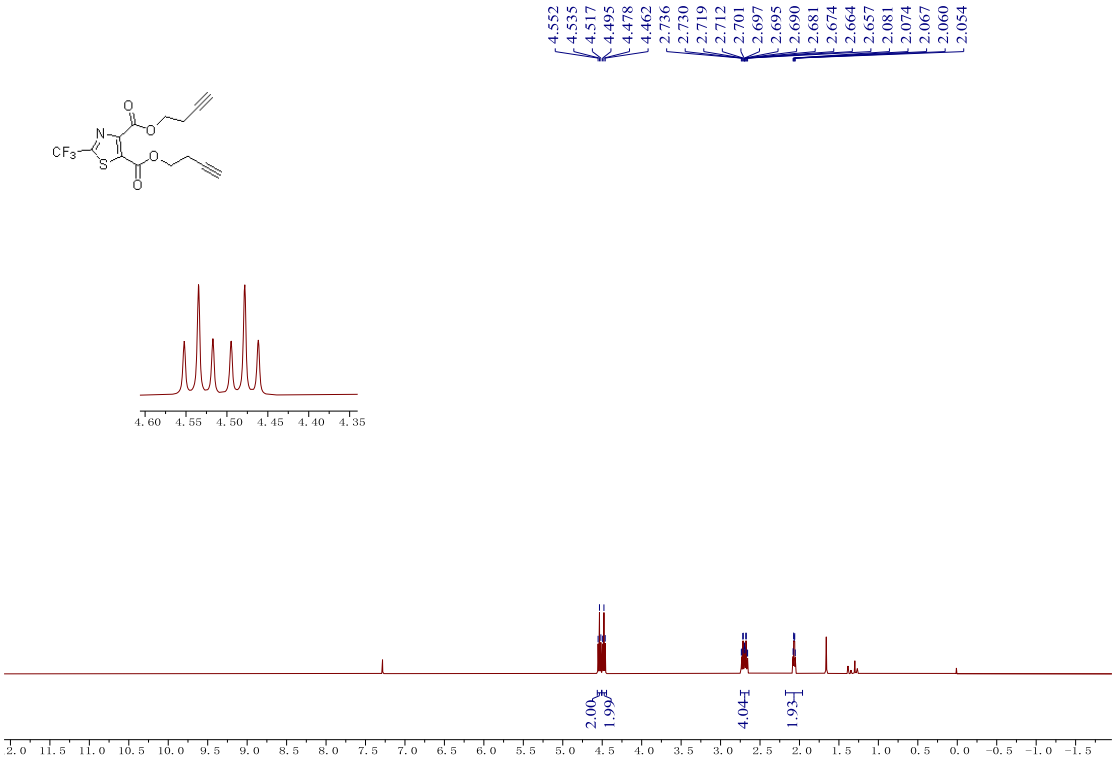


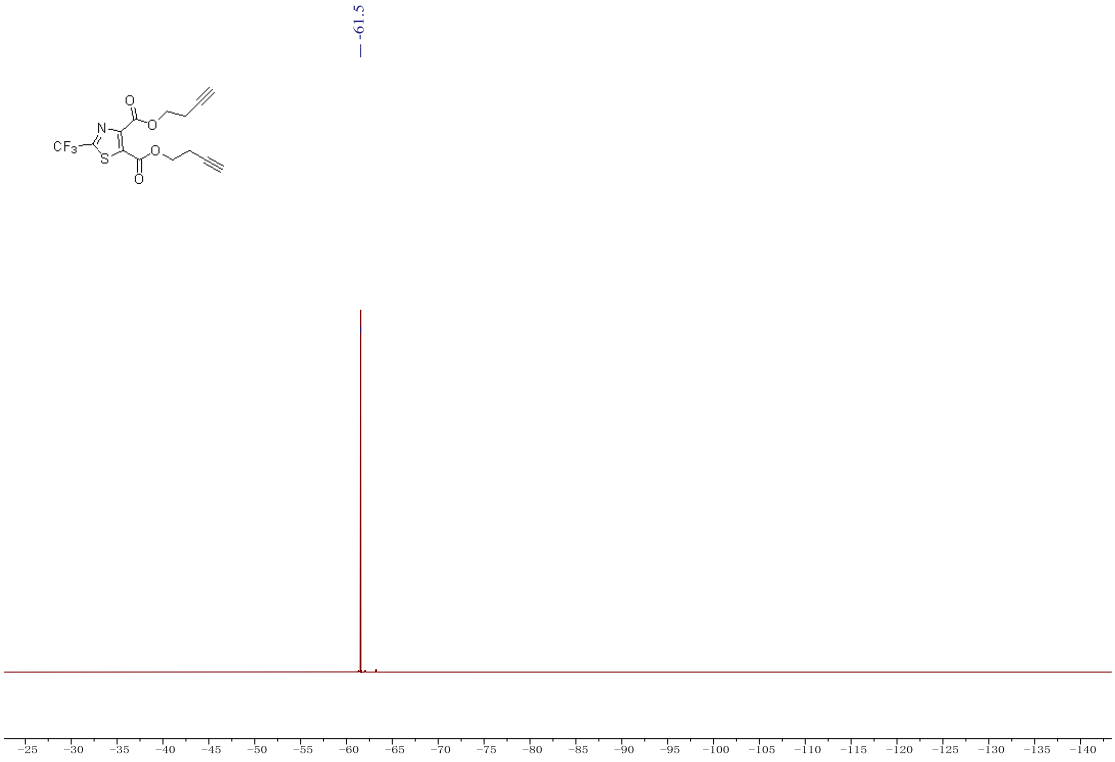
$^{13}C\{1H\}$ NMR spectra of **3m** in $CDCl_3$



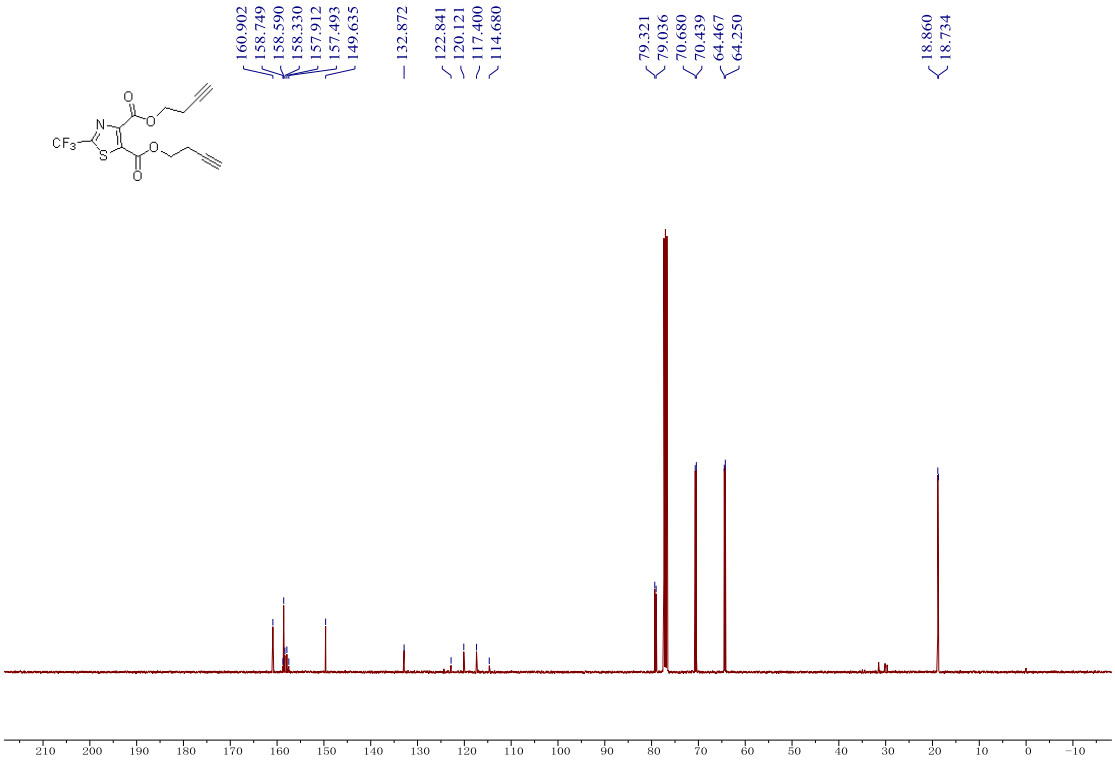
^{1}H NMR spectra of **3n** in $CDCl_3$



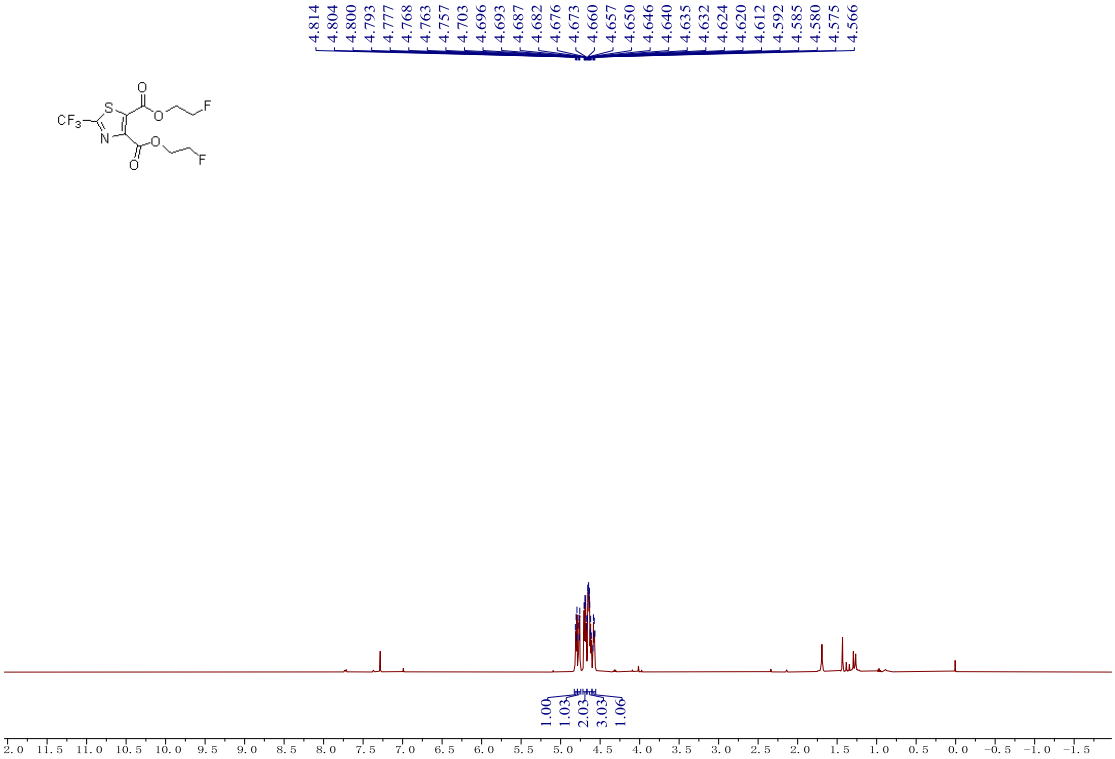
^{19}F NMR spectra of **3n** in $CDCl_3$



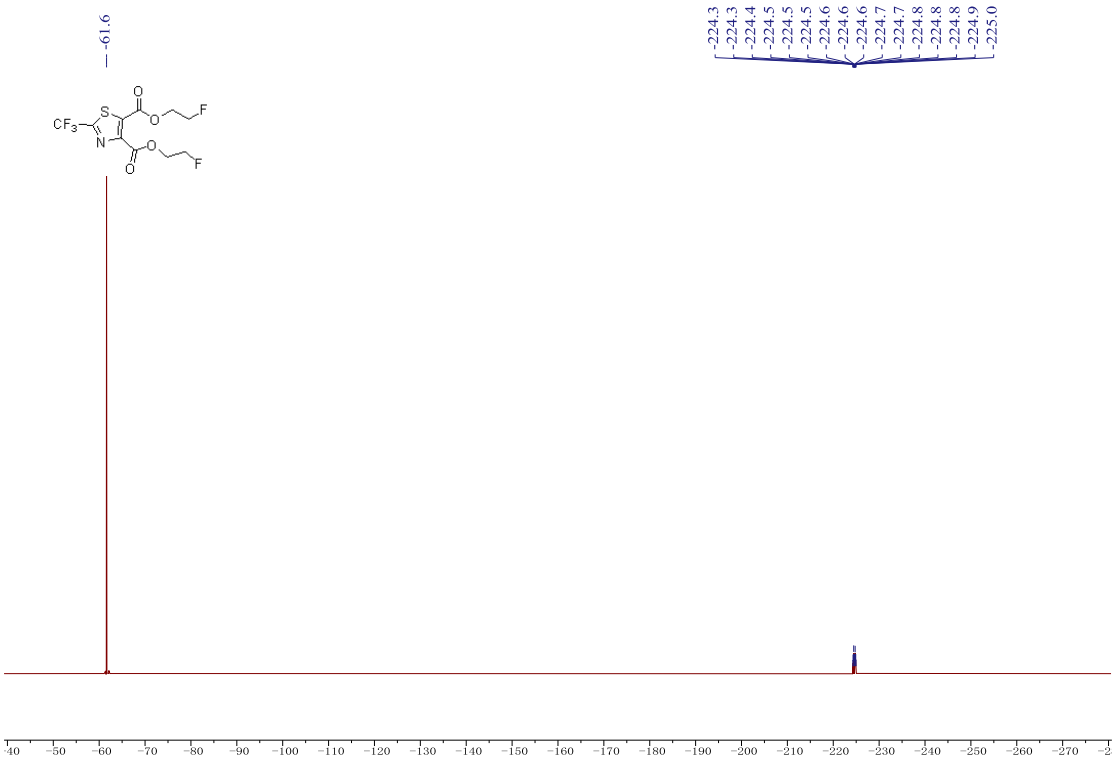
$^{13}C\{1H\}$ NMR spectra of **3n** in $CDCl_3$



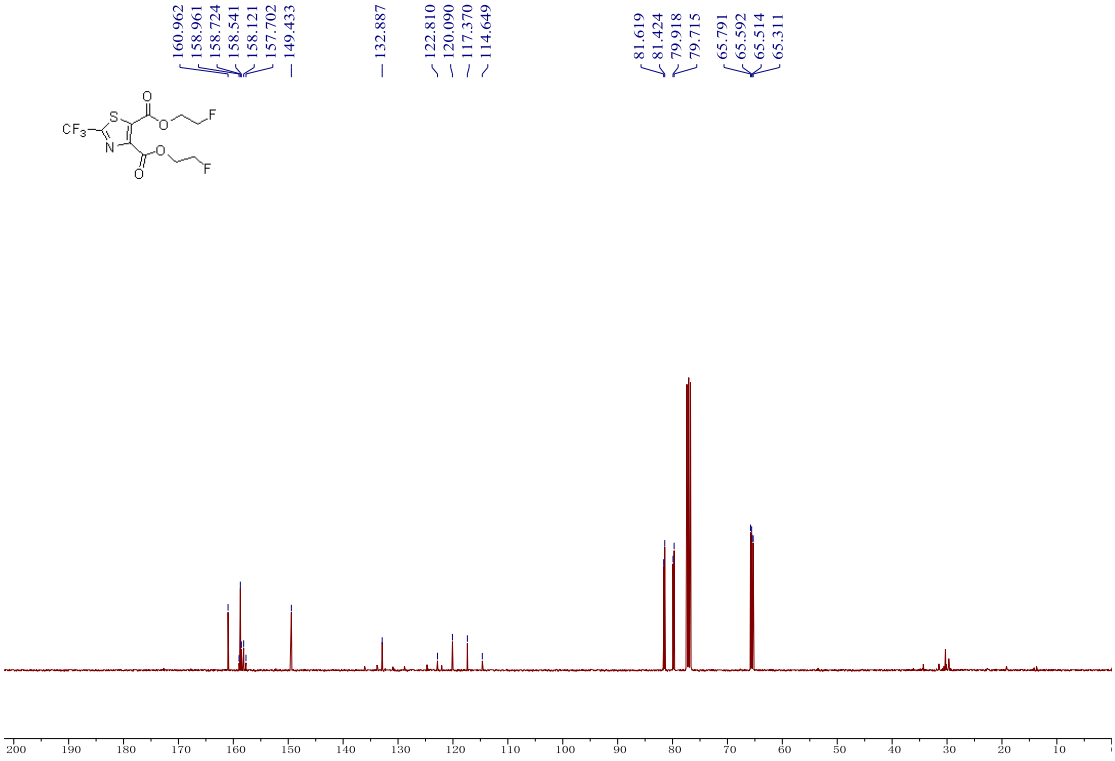
^{1}H NMR spectra of **3o** in $CDCl_3$



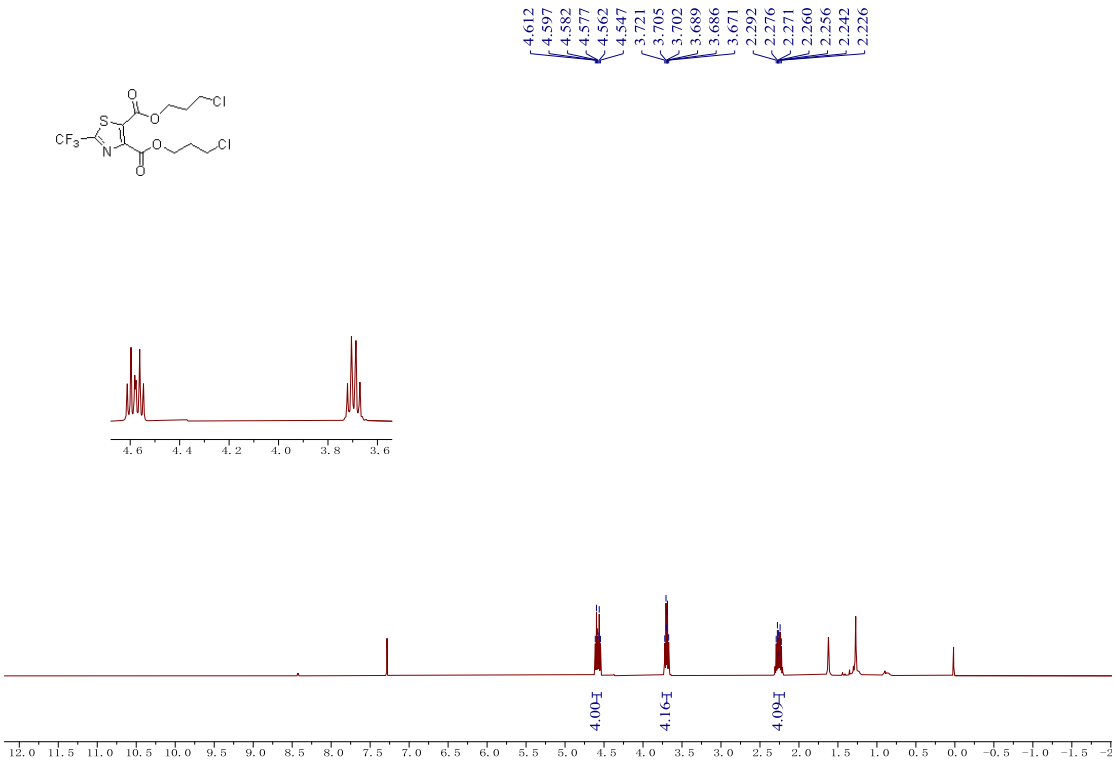
^{19}F NMR spectra of **3o** in $CDCl_3$



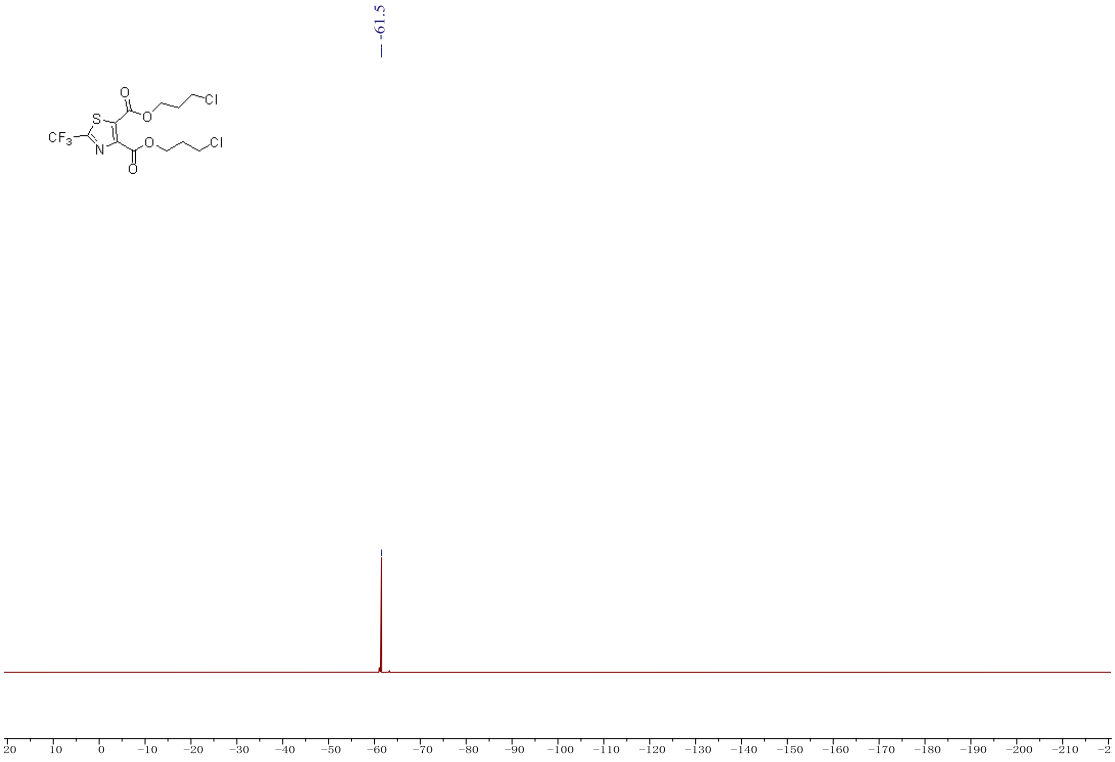
$^{13}C\{1H\}$ NMR spectra of **3o** in $CDCl_3$



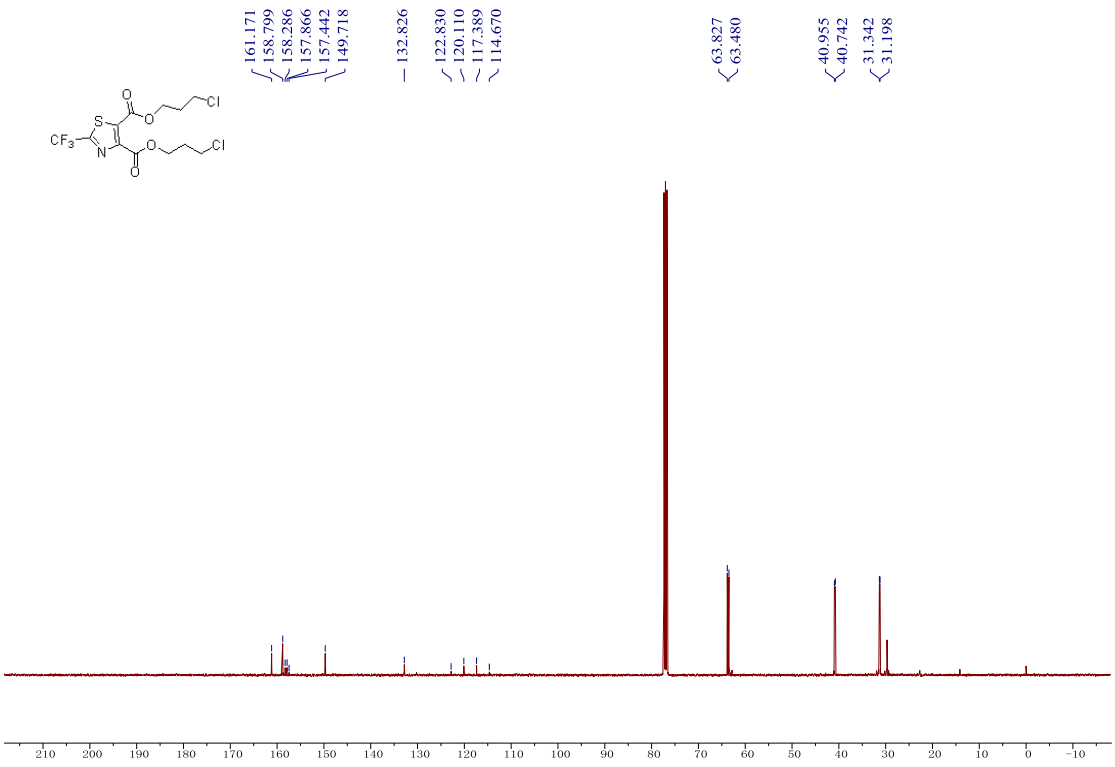
^{1}H NMR spectra of **3p** in $CDCl_3$



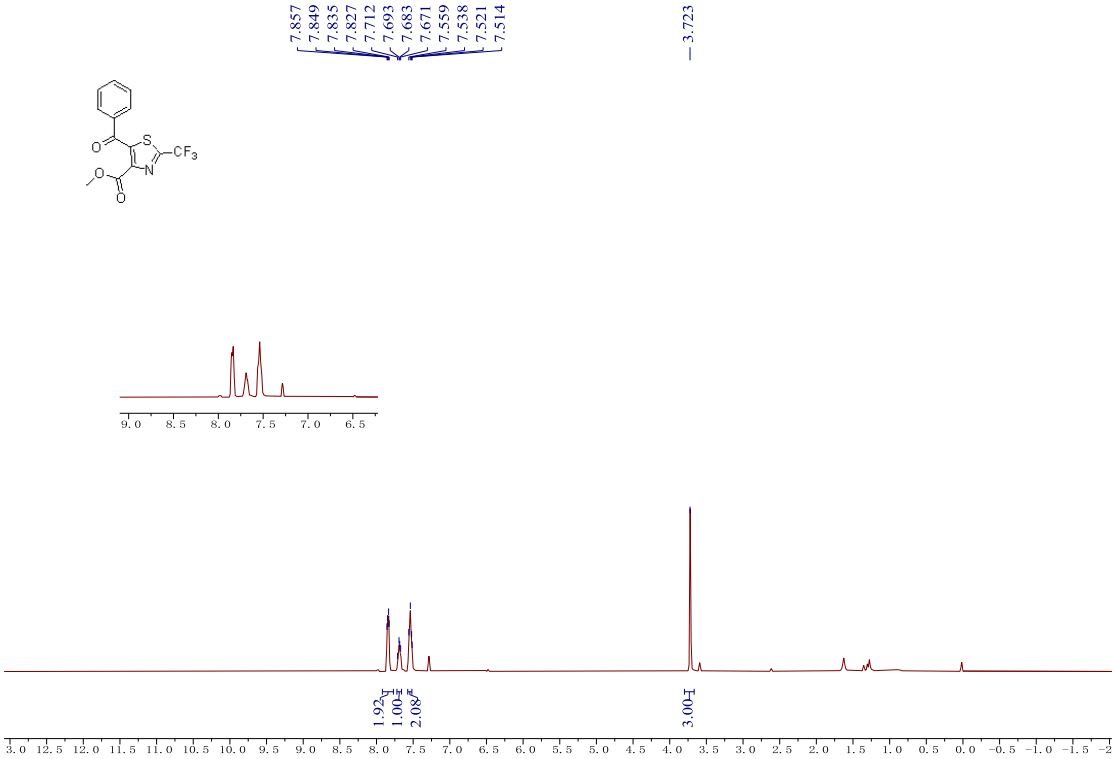
^{19}F NMR spectra of **3p** in $CDCl_3$



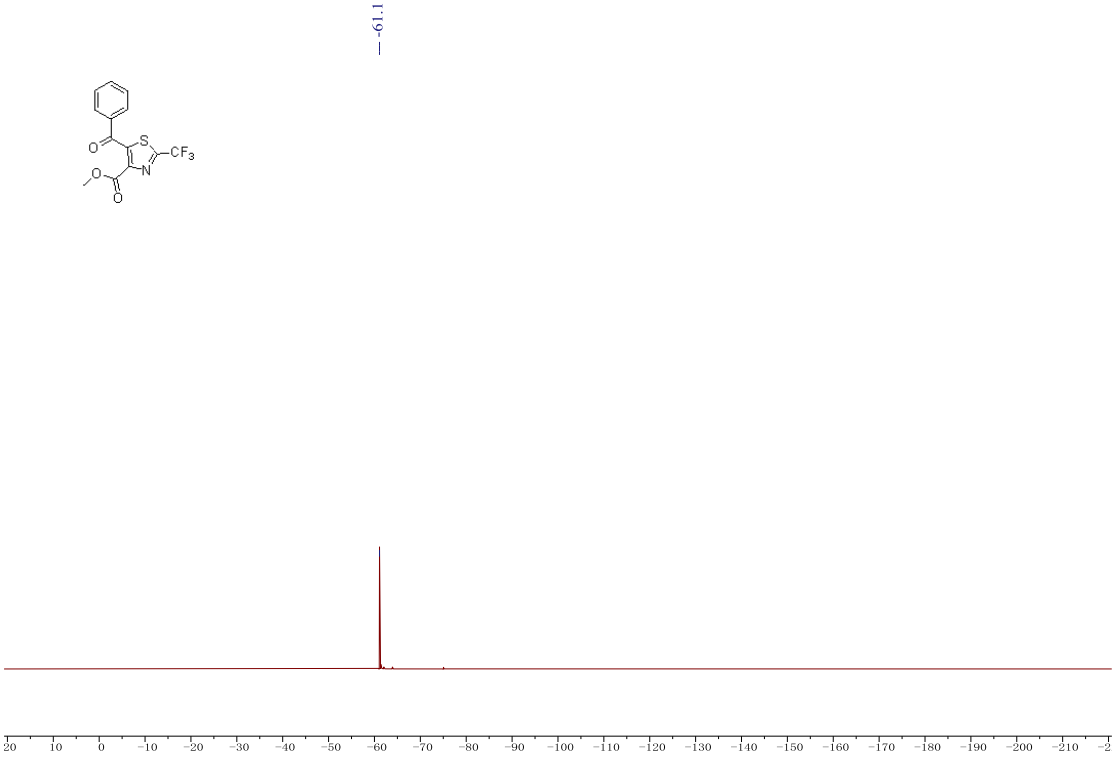
$^{13}C\{1H\}$ NMR spectra of **3p** in $CDCl_3$



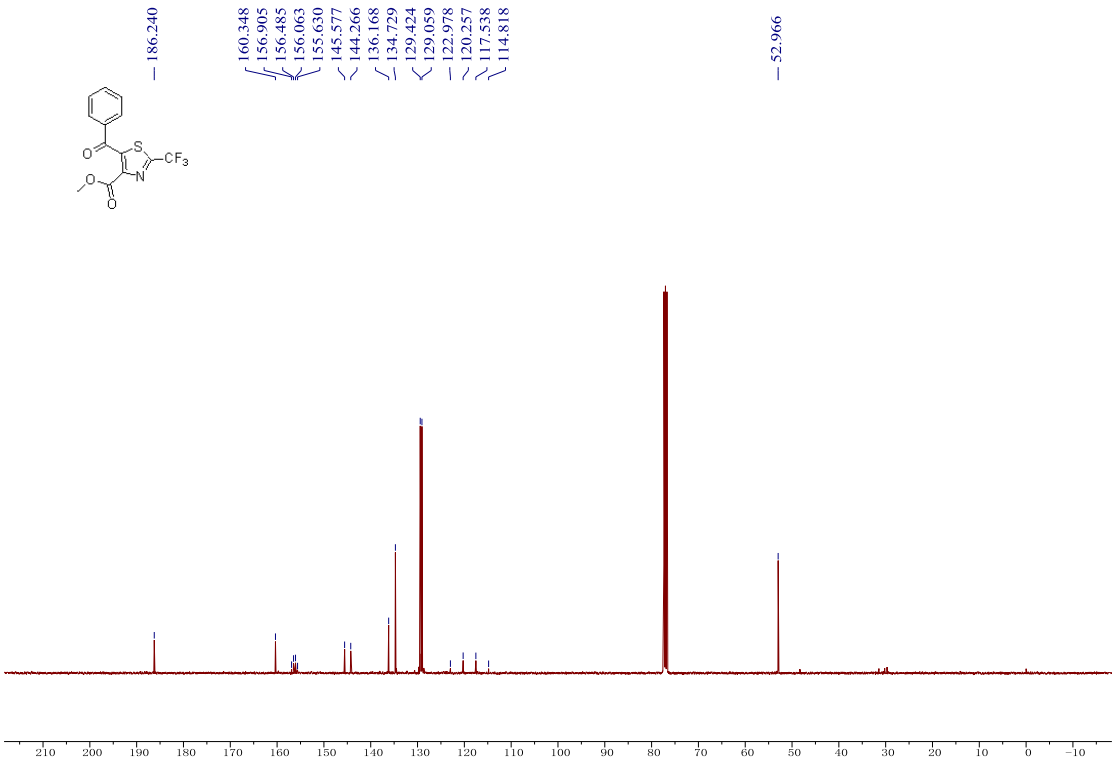
^{1}H NMR spectra of **3q** in $CDCl_3$



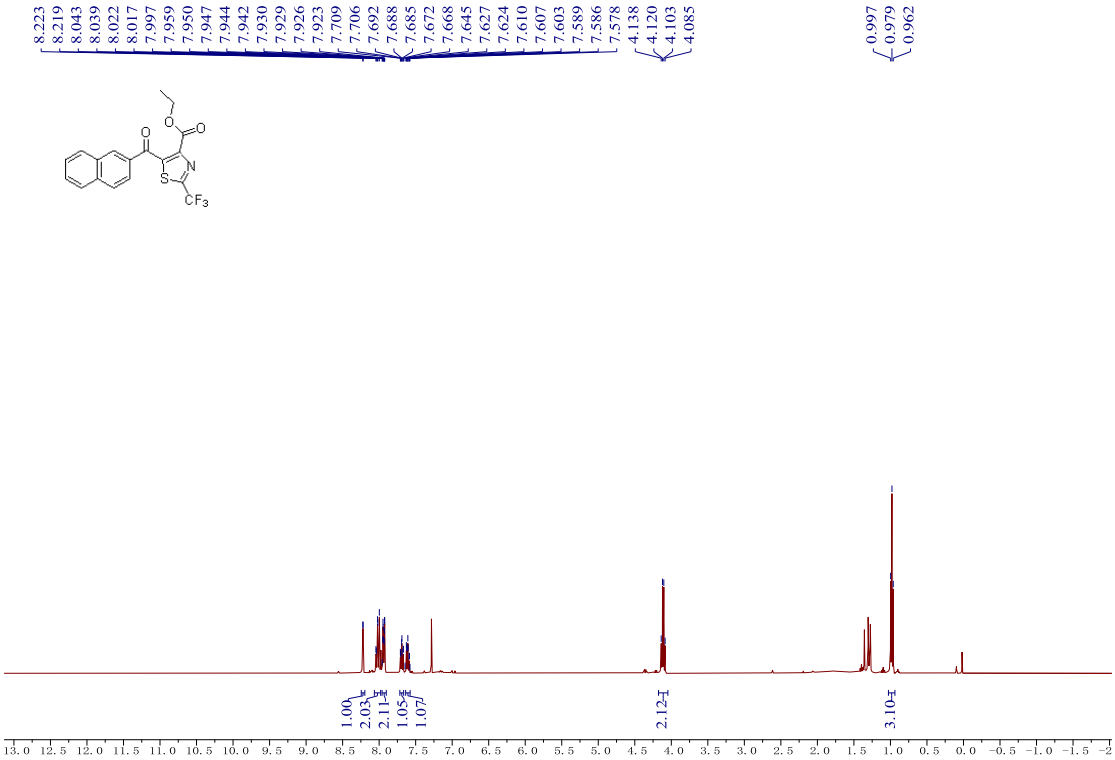
^{19}F NMR spectra of **3q** in $CDCl_3$



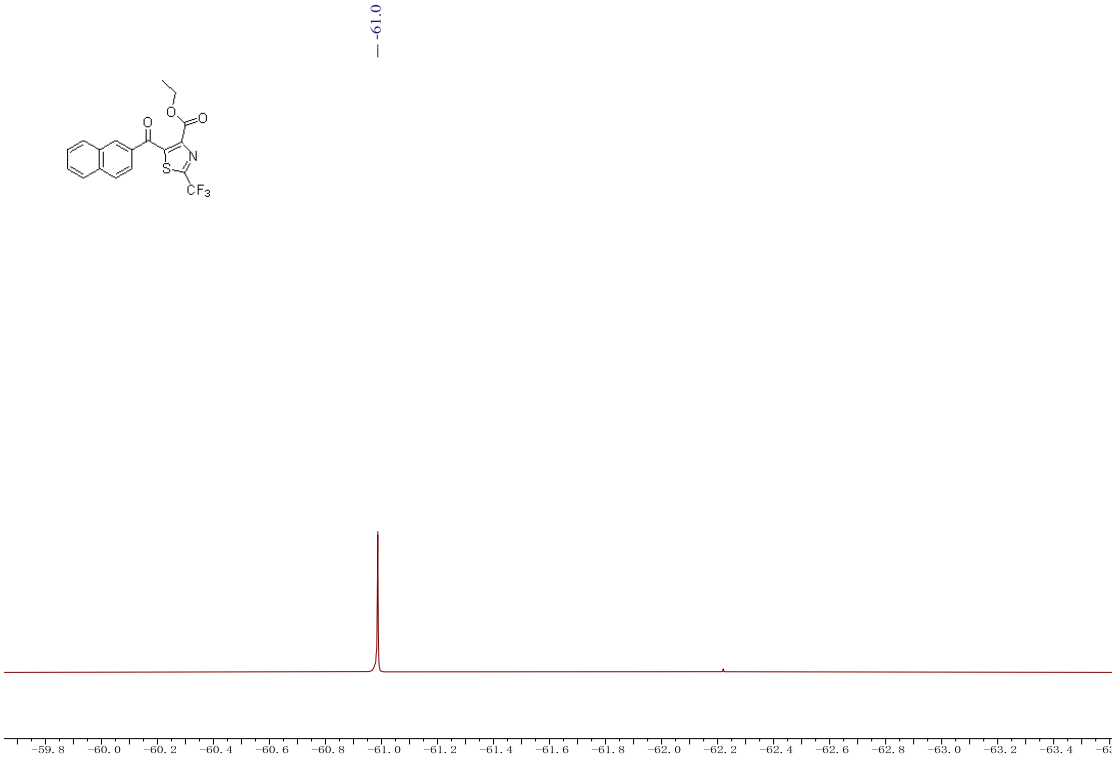
$^{13}C\{1H\}$ NMR spectra of **3q** in $CDCl_3$



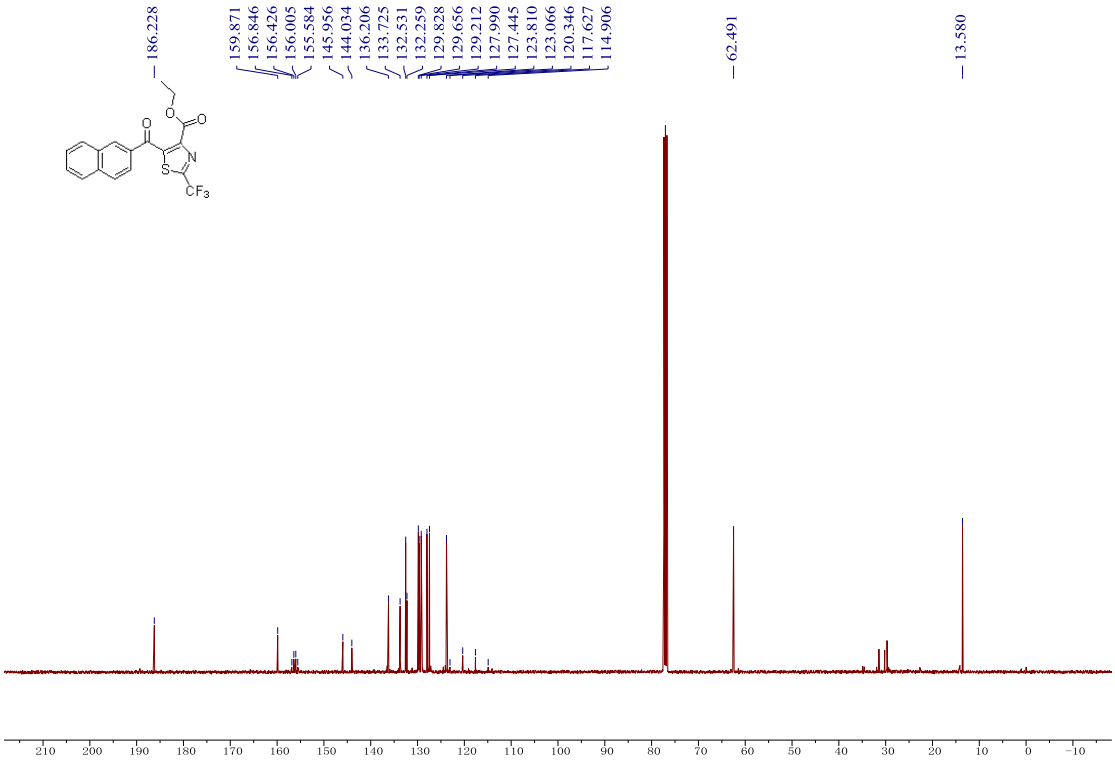
^{1}H NMR spectra of **3r** in $CDCl_3$



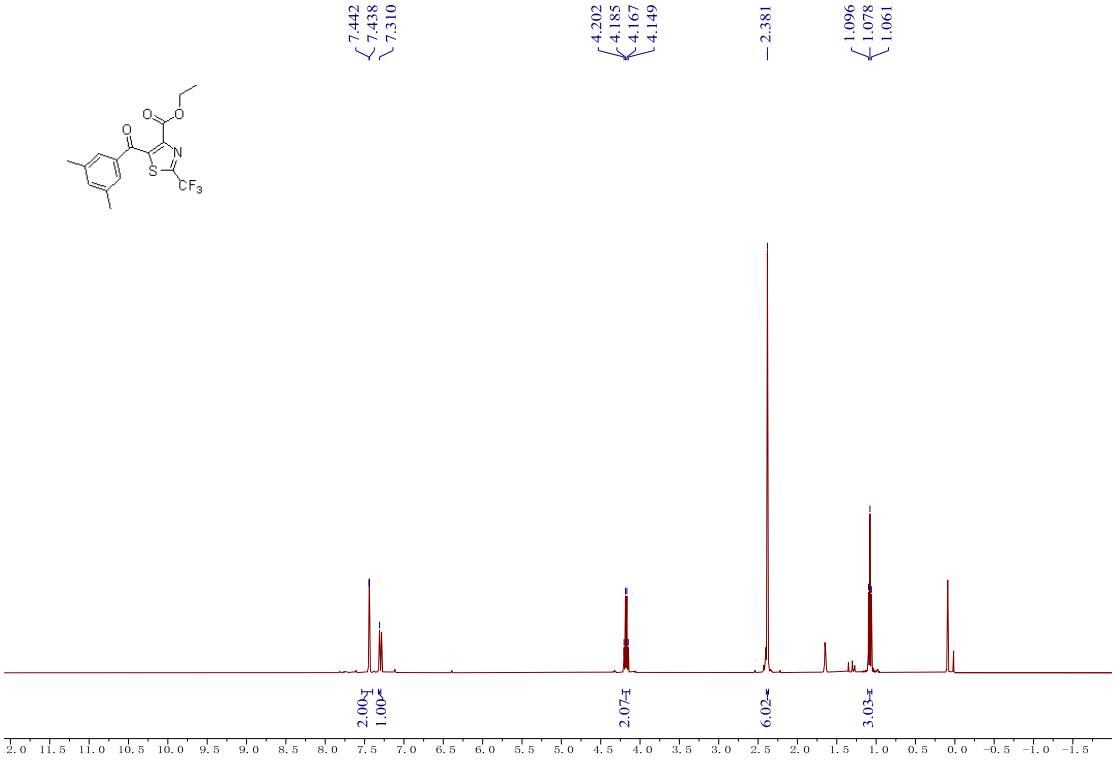
^{19}F NMR spectra of **3r** in $CDCl_3$



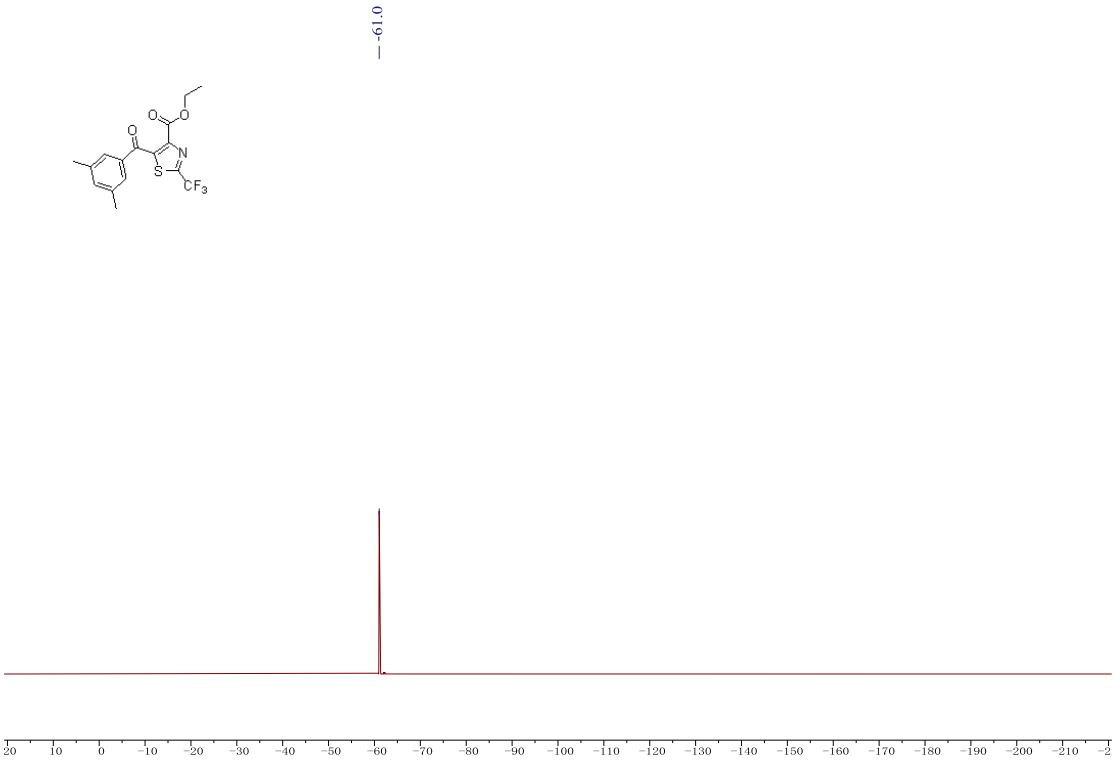
^{13}C{1H} NMR spectra of **3r** in $CDCl_3$



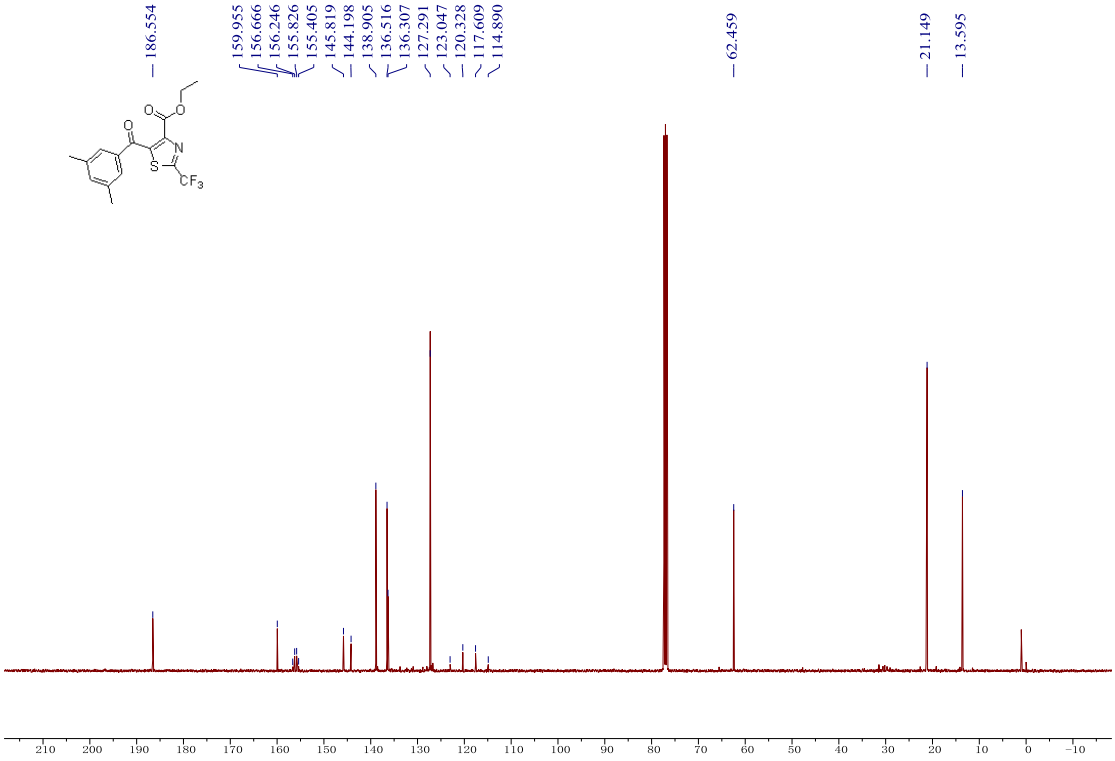
^{1}H NMR spectra of **3s** in $CDCl_3$



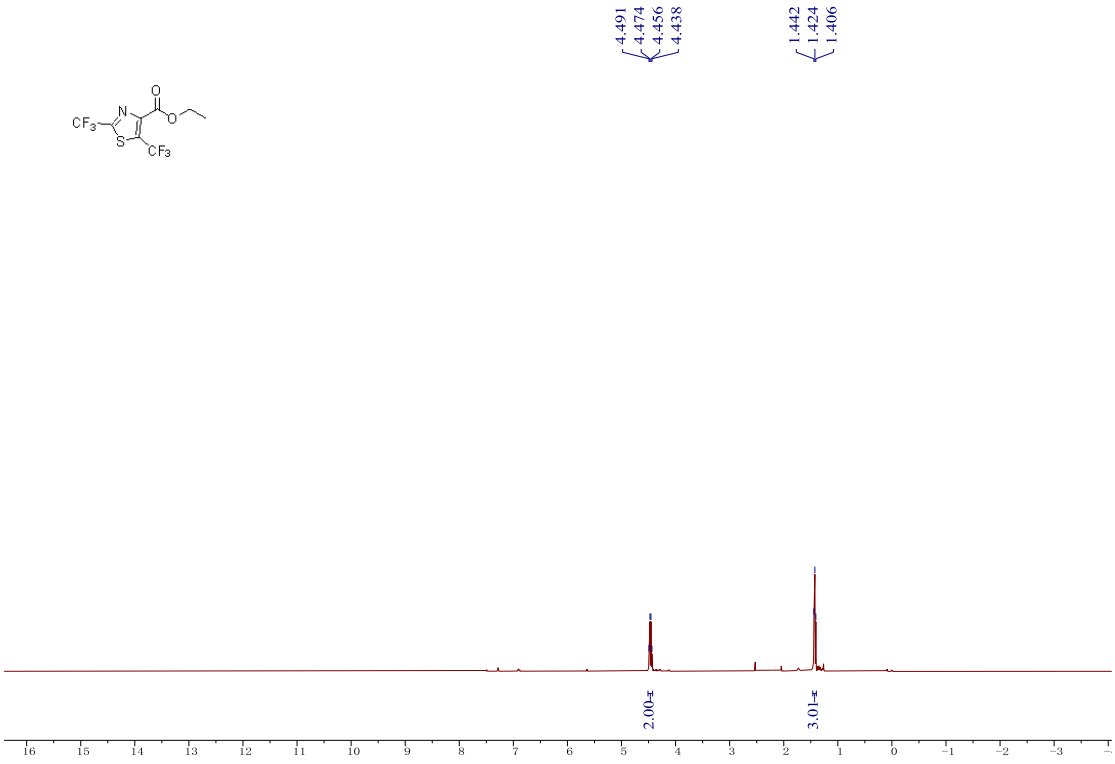
^{19}F NMR spectra of **3s** in $CDCl_3$



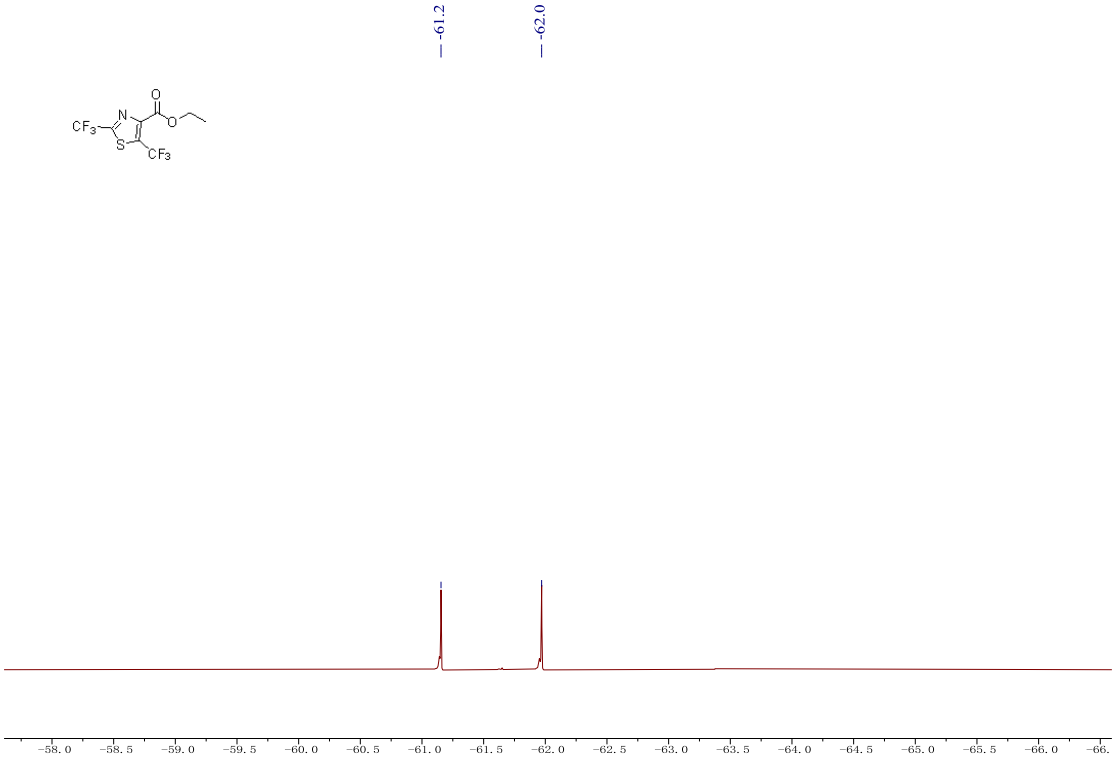
$^{13}C\{1H\}$ NMR spectra of **3s** in $CDCl_3$



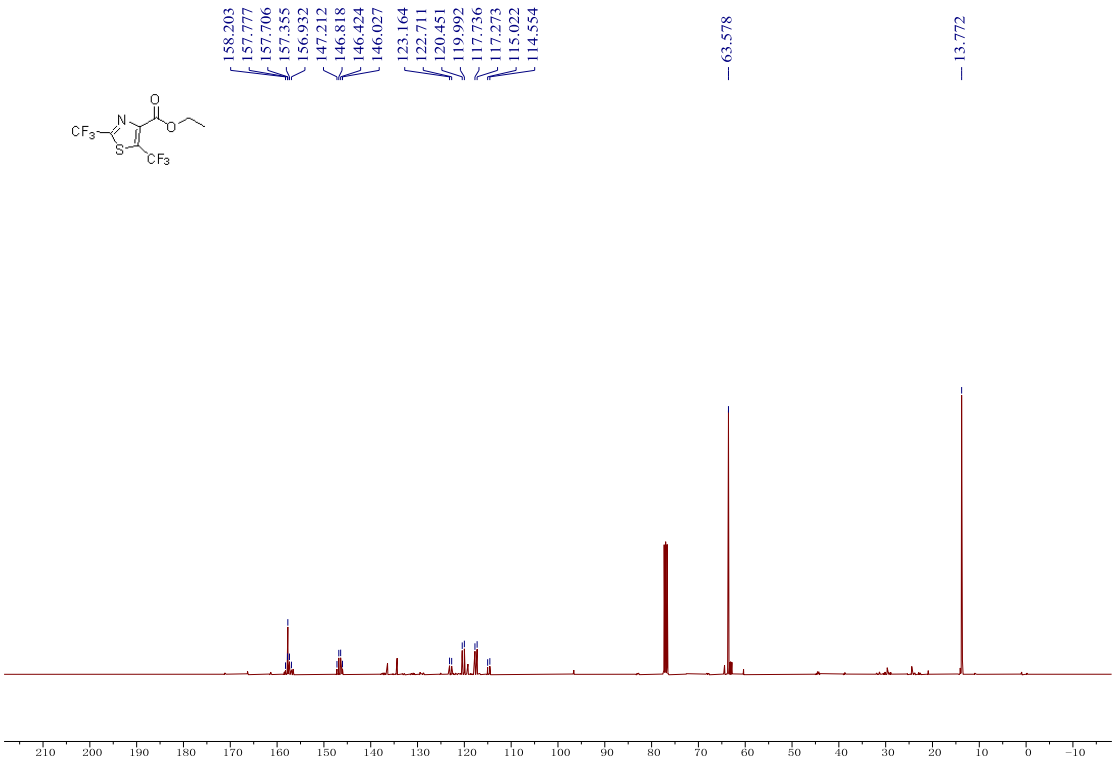
^{1}H NMR spectra of **3t** in $CDCl_3$



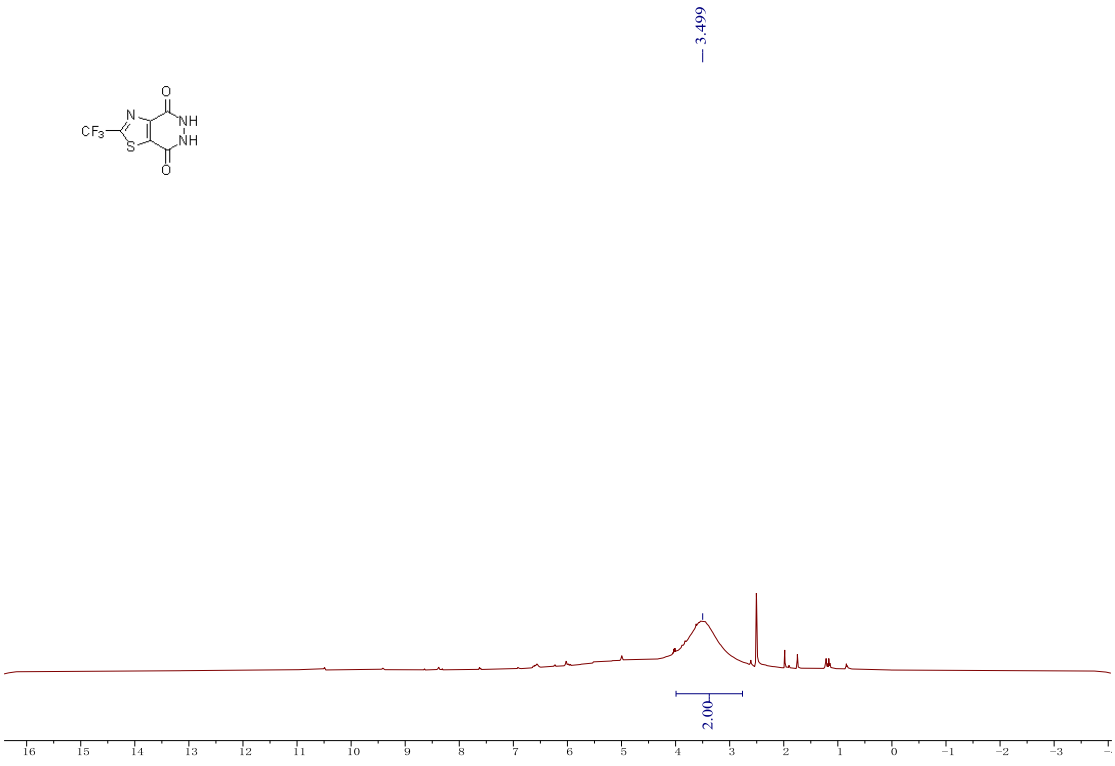
^{19}F NMR spectra of **3t** in $CDCl_3$



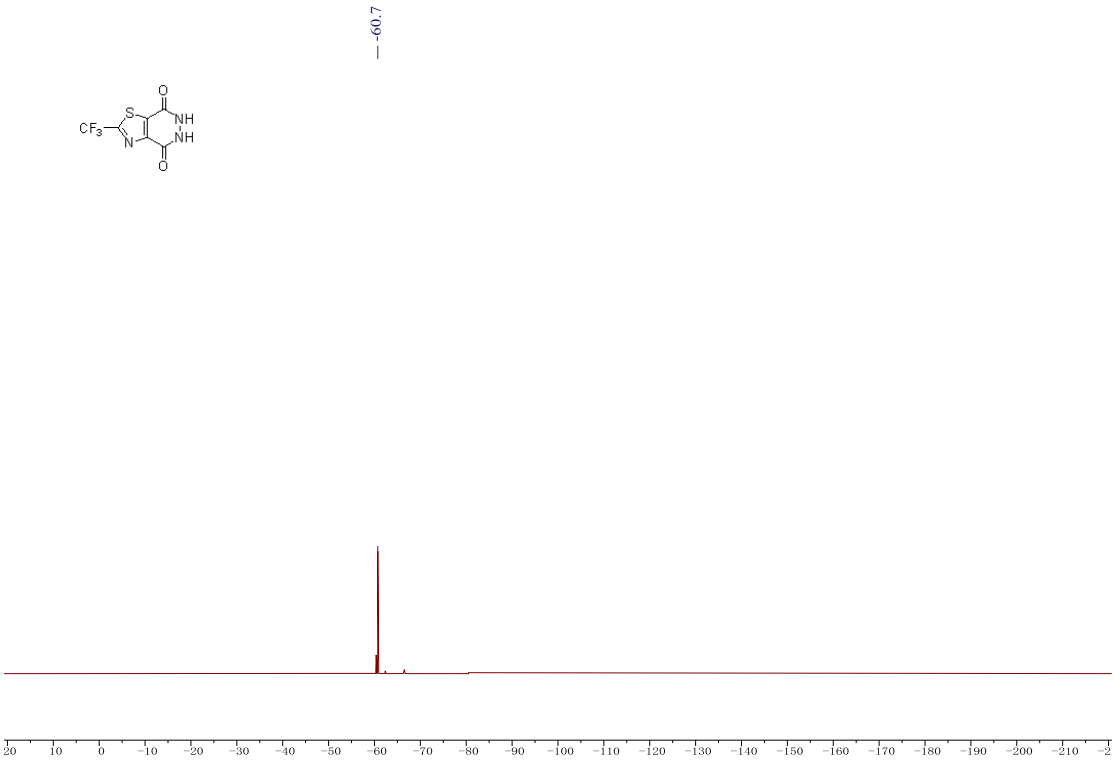
^{13}C{1H} NMR spectra of **3t** in $CDCl_3$



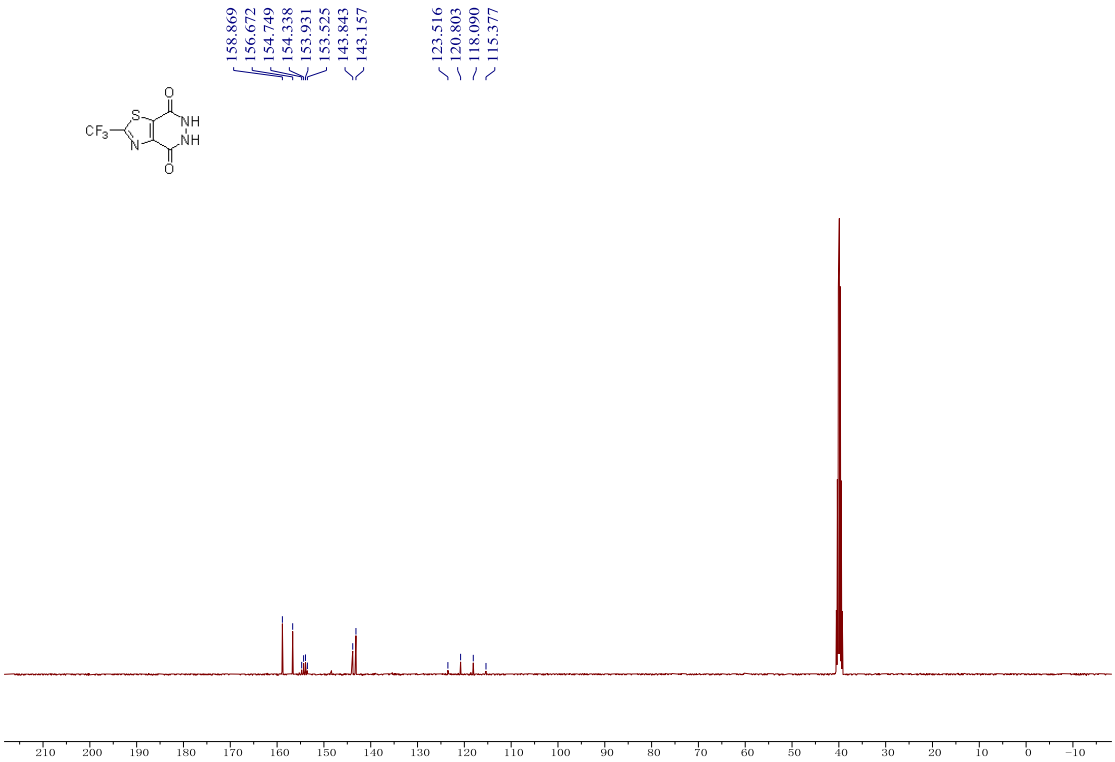
^{1}H NMR spectra of **4a** in DMSO-d_6



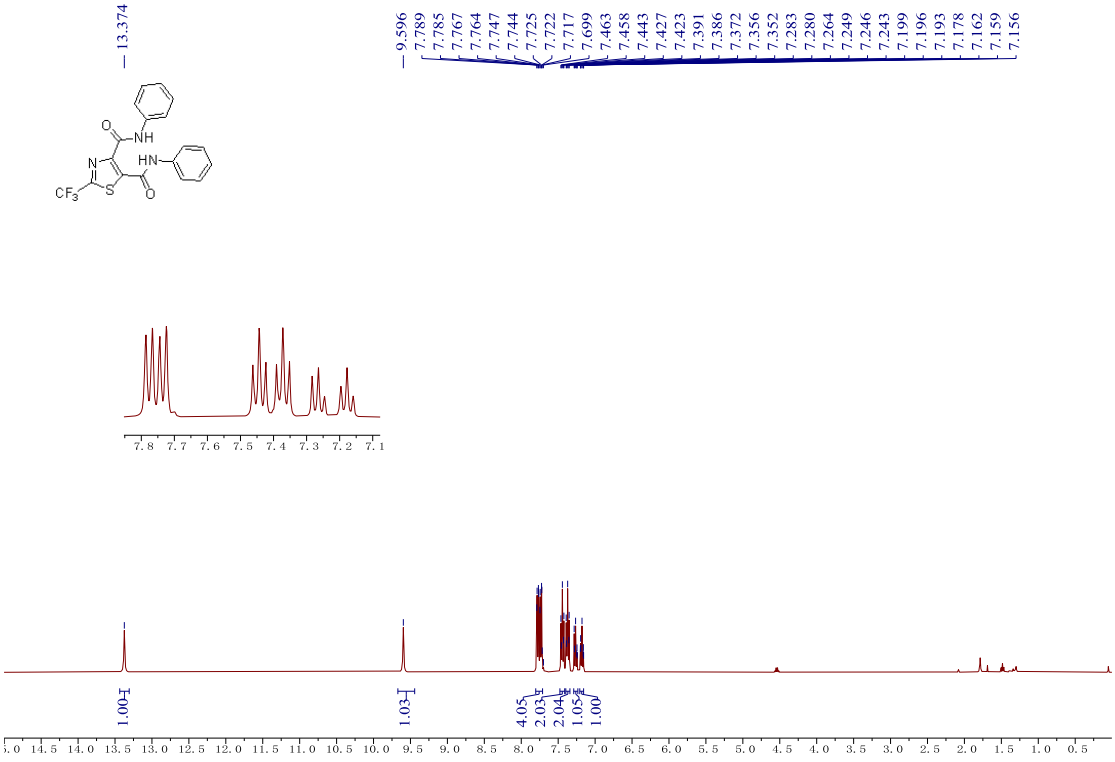
^{19}F NMR spectra of **4a** in DMSO-d_6



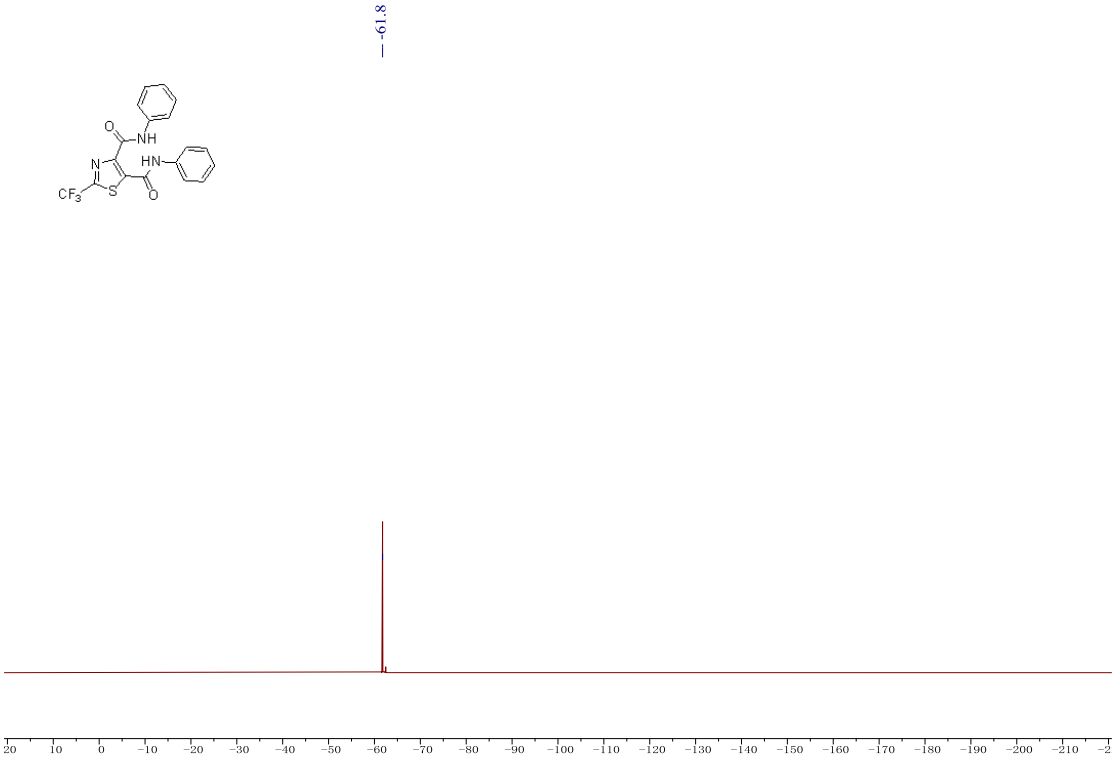
$^{13}C\{1H\}$ NMR spectra of **4a** in DMSO-d_6



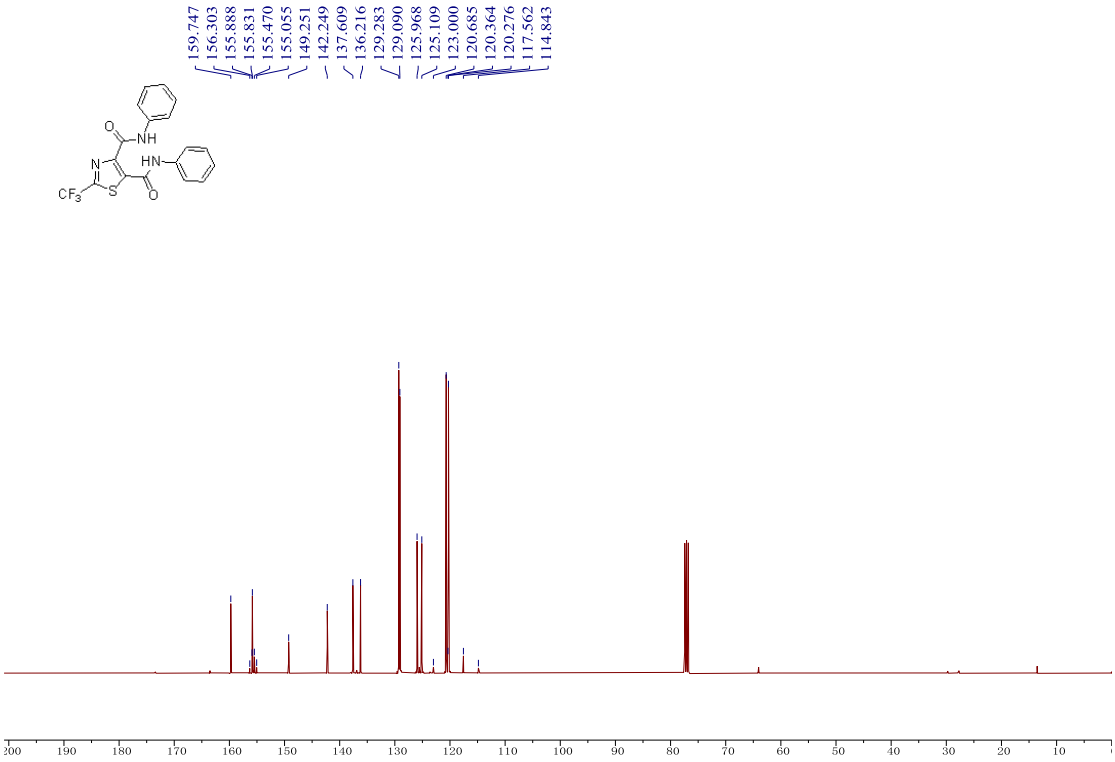
^{1}H NMR spectra of **4b** in $CDCl_3$



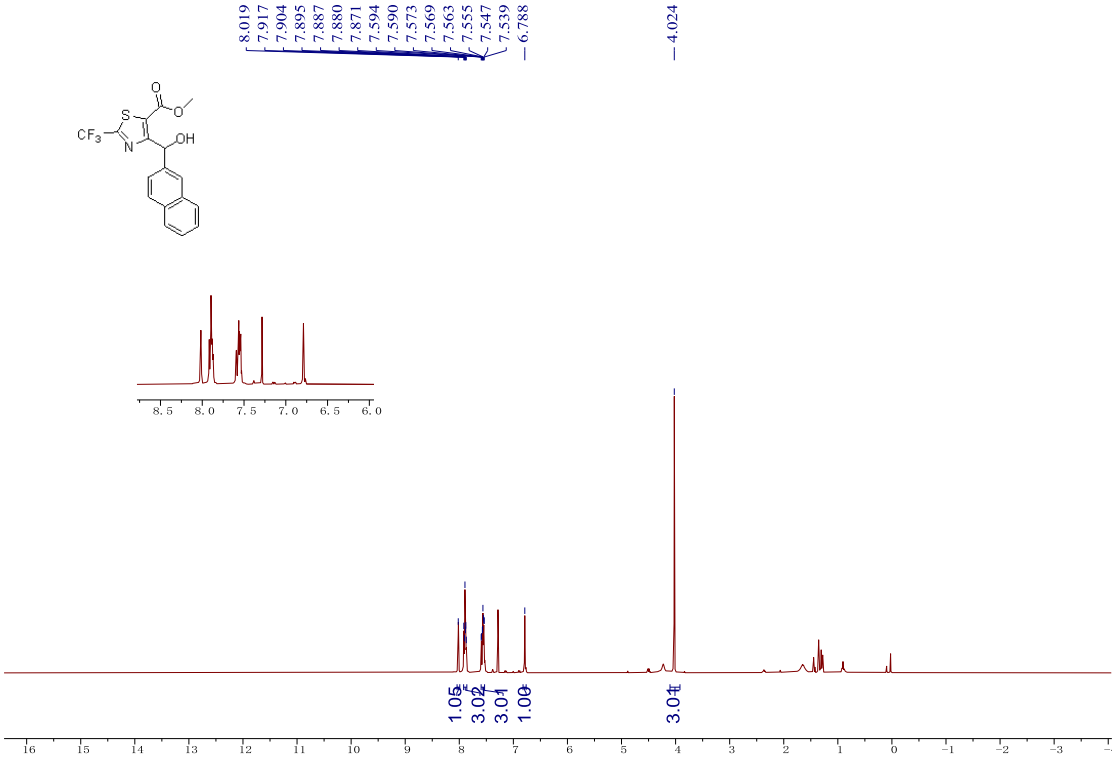
^{19}F NMR spectra of **4b** in $CDCl_3$



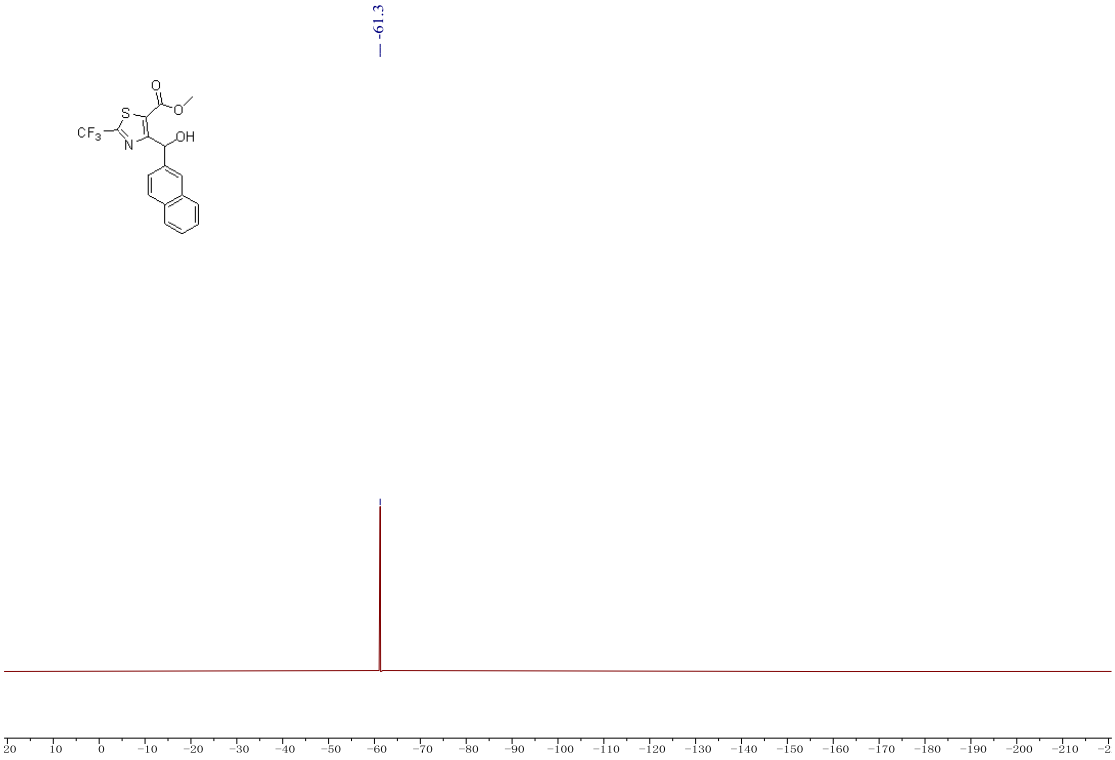
^{13}C{1H} NMR spectra of **4b** in $CDCl_3$



^{1}H NMR spectra of **4r** in $CDCl_3$



^{19}F NMR spectra of **4r** in $CDCl_3$



$^{13}C\{1H\}$ NMR spectra of **4r** in $CDCl_3$