Supporting Information

Synthesis of pyrrole disulfides via umpolung of β-ketothioamides

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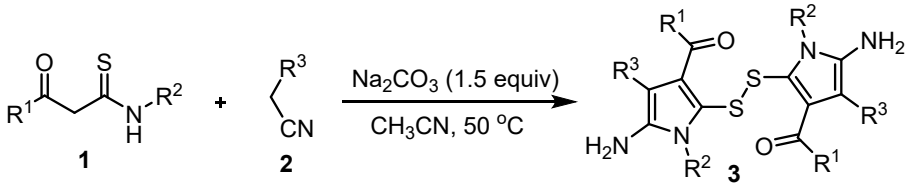
1. General information

All the reactions were carried out under an air atmosphere using glassware without being predried. Thioamide needs to be synthesized, Sodium Carbonate (Na_2CO_3), acetonitrile (MeCN), cyanoacetate acetate were obtained from commercial sources and used without further purification. The product was purified by column chromatography on silica gel (200-300 mesh) using analytical grade EtOAc, dichloromethane and petroleum ether. NMR spectra were recorded in on Avance 500 MHz spectrometers. Chemical shifts are in ppm with $CDCl_3$ as internal standard. The following abbreviations are used for multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet. The coupling constants *J* have been given in Hertz (Hz). HRMS were obtained on an Ultima Global spetrometer with an ESI source. IR spectra were recorded on Nicolet iS10. The X-ray single crystal diffraction was performed on Saturn 724^+ instrument.

2. General procedure synthesis of 3



To a stirred solution of thioamides **1** (0.3 mmol) and ethyl 2-cyanoacetate **2** (0.3 mmol) in acetonitrile (1 mL) was added Na_2CO_3 (0.45 mmol), the reaction mixture was stirred at 50 °C for 6-10 h. After completion of the reaction as monitored by TLC, the solvent was concentrated under vacuum and the residue was purified by flash column chromatography on silica gel with petroleum ether/ethyl acetate (3:1, v/v) as the eluent to give the desired product **3**.

3. Characterization data

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-phenyl-1H-pyrrole-3-carboxylate) (3a) (CCDC 1838147)

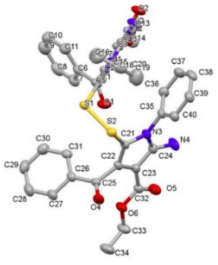
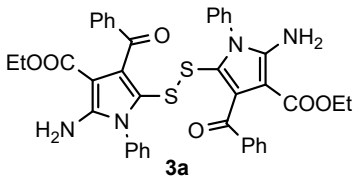


Figure S1. X-Ray crystal structure of **3a** with 50% probability displacement ellipsoids.

Table S1 Crystal data and structure refinement for 3a

Chemical formula	C40 H34 N4 O6 S2
Formula weight	730.1992
Temperature	173.1500 K
Wavelength	0.71073 Å
Crystal system	Triclinic
Space group	P -1
Unit cell dimensions	a = 8.200(3) Å
	b = 14.629(5) Å
	c = 17.002(6) Å
Volume	1981.8(11) Å3
Z	2
Density (calculated)	1.367 Mg/m3
Absorption coefficient	0.322 mm-1
F(000)	848
Crystal size	0.596 x 0.066 x 0.035 mm3
Theta range for data collection	1.427 to 27.481°.
Index ranges	-10<=h<=10, -18<=k<=18, -22<=l<=22
Reflections collected	21520
Independent reflections	8909 [R(int) = 0.0687]
Completeness to theta = 26.000°	99.0 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	1.0000 and 0.6608
Refinement method	Full-matrix least-squares on F2
Data / restraints / parameters	8909 / 0 / 533
Goodness-of-fit on F2	1.115
Final R indices [I>2sigma(I)]	R1 = 0.0772, wR2 = 0.1684
R indices (all data)	R1 = 0.0960, wR2 = 0.1797
Extinction coefficient	n/a
Largest diff. peak and hole	0.929 and -0.500 e.Å-3



3a

Isolated yield: 82% (90 mg), yellow solid, mp: 198-200 °C.

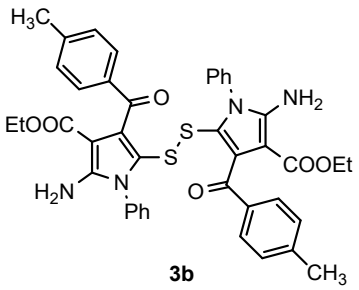
IR (KBr) *v* 3432, 3056, 2983, 1669, 1614, 1453, 1235.

^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.96 (d, J = 7.2 Hz, 2H), 7.46 (t, J = 7.0 Hz, 1H), 7.38 (s, 3H), 7.30 (t, J = 7.0 Hz, 2H), 7.16 (s, 2H), 5.15 (s, 2H), 3.93 (q, J = 6.9 Hz, 4H), 0.74 (t, J = 7.2 Hz, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ: 192.7, 164.8, 148.4, 138.4, 133.8, 132.9, 132.6, 129.7, 129.5, 129.3, 128.1, 94.8, 59.5, 13.7.

HRMS (ESI–TOF, $[M + H]^+$): calcd for $C_{40}H_{35}N_4O_6S_2$, 731.1993; found, 731.1992.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-methylbenzoyl)-1-phenyl-1H-pyrrole -3-carboxylate) (3b)



3b

Isolated yield: 80% (94 mg), yellow solid, mp: 172-174 °C.

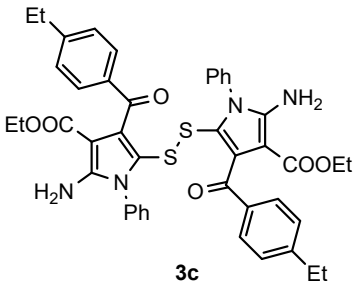
IR (KBr) *v* 3474, 3060, 2977, 1695, 1672, 1522, 1496, 1235.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.84 (d, J = 5.5 Hz, 2H), 7.37 (s, 3H), 7.14 (s, 2H), 7.08 (s, 2H), 5.13 (s, 2H), 3.96 (q, J = 6.9 Hz, 2H), 2.36 (s, 3H), 0.79 (t, J = 7.0 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.5, 164.9, 148.3, 143.3, 136.0, 129.9, 129.5, 129.2, 128.8, 94.8, 59.5, 21.9, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{38}N_4O_6NaS_2$, 781.2130; found, 781.2135.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-ethylbenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3c)



3c

Isolated yield: 51% (62 mg), yellow solid, mp: 180-182 °C.

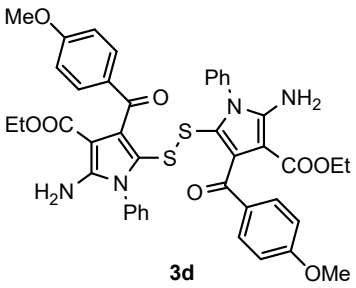
IR (KBr) *v* 3457, 3054, 2969, 1663, 1515, 1453, 1383, 1236.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 7.86 (d, *J* = 5.7 Hz, 2H), 7.38 (s, 3H), 7.11 (s, 4H), 5.15 (br s, 2H), 3.95 (d, *J* = 6.7 Hz, 2H), 2.65 (d, *J* = 6.7 Hz, 2H), 1.22 (t, *J* = 7.5 Hz, 3H), 0.76 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 192.4, 164.7, 149.4, 148.2, 136.1, 133.7, 129.8, 129.3, 129.0, 127.4, 94.6, 59.2, 28.9, 15.2, 13.5.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{44}H_{42}N_4O_6NaS_2$, 809.2443; found, 809.2440.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-methoxybenzoyl)-1-phenyl-1H-pyrrole -3-carboxylate) (3d)



3d

Isolated yield: 72% (88 mg), yellow solid, mp: 154-156 °C.

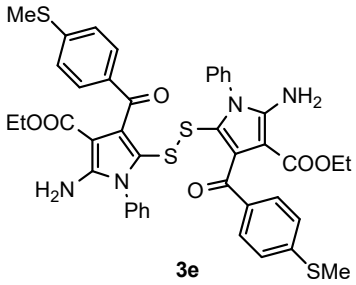
IR (KBr) *v* 3451, 3070, 2978, 1671, 1518, 1495, 1245.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 7.92 (s, 2H), 7.38 (s, 2H), 7.15 (s, 2H), 6.78 (s, 2H), 5.17 (s, 2H), 3.98 (d, *J* = 6.9 Hz, 2H), 3.81 (s, 3H), 0.82 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 191.5, 164.7, 163.2, 148.2, 133.7, 132.0, 131.6, 129.3, 129.1, 113.2, 94.6, 59.3, 55.4, 29.7, 13.7.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{38}N_4O_8NaS_2$, 813.2029; found, 813.2036.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-(methylthio)phenyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3e)



3e

Isolated yield: 65% (82 mg), yellow solid, mp: 160-162 °C.

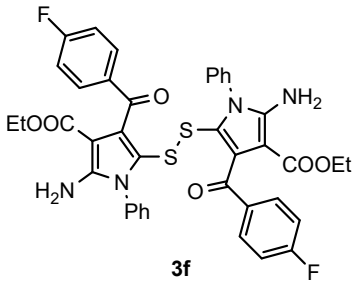
IR (KBr) *v* 3448, 3057, 2977, 1677, 1518, 1497, 1382, 1246.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.86 (s, 2H), 7.38 (s, 3H), 7.11 (s, 4H), 5.18 (s, 2H), 3.98 (d, J = 6.6 Hz, 2H), 2.48 (s, 3H), 0.82 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.0, 164.7, 148.4, 145.3, 134.9, 133.8, 130.2, 129.5, 129.3, 124.6, 59.6, 14.8, 13.9.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{38}N_4O_6NaS_4$, 845.1572; found, 845.1556.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-fluorobenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3f)



3f

Isolated yield: 89% (105 mg), yellow solid, mp: 158-160 °C.

IR (KBr) *v* 3478, 3069, 2985, 1671, 1493, 1385, 1318, 1279.

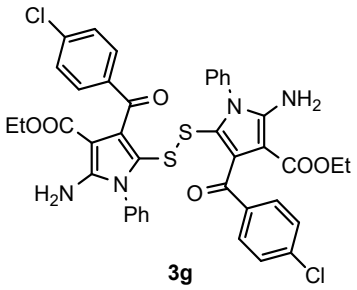
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.97 (s, 2H), 7.39 (s, 3H), 7.16 (s, 2H), 6.97 (t, J = 7.9 Hz, 2H), 5.17 (s, 2H), 3.96 (q, J = 6.9 Hz, 2H), 0.80 (t, J = 6.7 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.0, 165.5 (d, $^1J_{C\text{-}F}$ = 254.7 Hz), 164.5, 148.3, 134.8, 133.6, 132.8, 132.1 (d, $^3J_{C\text{-}F}$ = 6.1 Hz), 129.4, 129.3, 129.2, 115.1 (d, $^2J_{C\text{-}F}$ = 22.0 Hz), 94.5, 59.5, 13.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ: 105.99.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2F_2$, 789.1629; found, 789.1636.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-chlorobenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3g)



3g

Isolated yield: 72% (89 mg), yellow solid, mp: 154-156 °C.

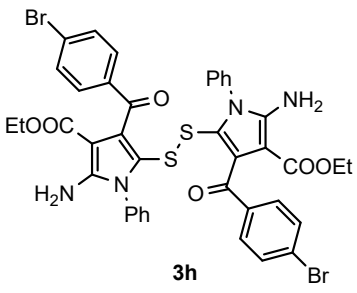
IR (KBr) *v* 3476, 3065, 2984, 1670, 1497, 1385, 1279, 1232.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.89 (d, J = 7.7 Hz, 2H), 7.40 (s, 3H), 7.28 (d, J = 8.0 Hz, 2H), 7.16 (s, 2H), 5.17 (s, 2H), 3.97 (q, J = 6.9 Hz, 2H), 0.82 (t, J = 6.5 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.4, 164.5, 148.4, 139.1, 136.9, 133.7, 131.0, 129.6, 129.5, 129.3, 128.5, 94.6, 59.7, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2Cl_2$, 821.1033; found, 821.1038.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-bromobenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3h)



3h

Isolated yield: 75% (102 mg), yellow solid, mp: 154-156 °C.

IR (KBr) *v* 3476, 3062, 1668, 1495, 1385, 1278, 1231.

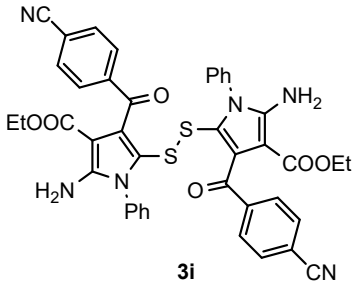
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.81 (d, J = 7.8 Hz, 2H), 7.44 (d, J = 7.5 Hz, 2H), 7.40 (s, 3H), 7.16 (s, 2H), 5.17 (s, 2H), 3.98 (q, J = 6.8 Hz, $2H_2$), 0.82 (t, J = 6.7 Hz,

3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.6, 164.5, 148.5, 137.2, 133.6, 131.5, 131.2, 129.6, 129.5, 129.2, 127.9, 94.6, 59.7, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2Br_2$, 909.0028; found, 909.0037.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-cyanobenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3i)



3i

Isolated yield: 60% (72 mg), yellow solid, mp: 234-236 °C.

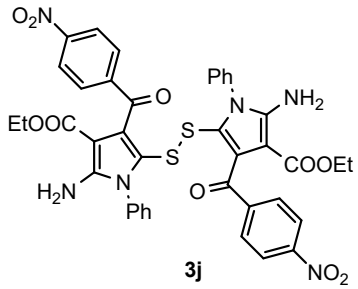
IR (KBr) *v* 3450, 3069, 2978, 1690, 1520, 1487, 1384, 1282.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 8.04 (d, J = 8.0 Hz, 2H), 7.63 (d, J = 7.9 Hz, 2H), 7.43 (s, 3H), 7.18 (s, 2H), 5.20 (s, 2H), 3.96 (q, J = 7.0 Hz, 2H), 0.79 (t, J = 6.6 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 190.8, 164.1, 148.5, 141.3, 133.4, 132.0, 131.7, 129.8, 129.7, 129.1, 118.3, 115.7, 94.3, 59.8, 13.9.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{32}N_6O_6NaS_2$, 803.1722; found, 803.1741.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-nitrobenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3j)



3j

Isolated yield: 52% (66 mg), yellow solid, mp: 230-232 °C.

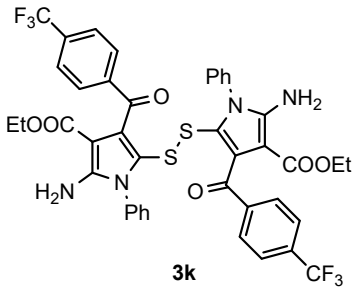
IR (KBr) *v* 3460, 3073, 2981, 1679, 1492, 1385, 1226.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 8.18 (d, J = 8.5 Hz, 2H), 8.11 (d, J = 8.5 Hz, 2H), 7.44 (s, 3H), 7.20 (br s, 2H), 5.19 (s, 2H), 3.95 (d, J = 6.9 Hz, 2H), 0.78 (t, J = 6.7 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 190.5, 164.1, 150.0, 148.6, 146.7, 133.4, 131.8, 130.4, 129.8, 129.1, 123.4, 94.3, 59.9, 13.9.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_6O_{10}NaS_2$, 843.1519; found, 843.1509.

Diethyl 5,5'-disulfanediylbis(2-amino-1-phenyl-4-(4-(trifluoromethyl)benzoyl)-1H-pyrrole-3-carboxylate) (3k)



3k

Isolated yield: 60% (80 mg), yellow solid, mp: 154-156 °C.

IR (KBr) *v* 3440, 3067, 2981, 1677, 1496, 1328, 1231.

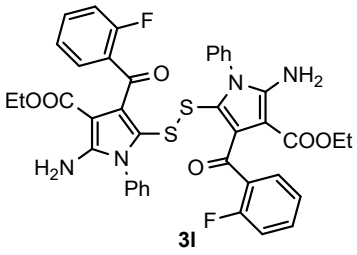
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 8.05 (d, J = 7.7 Hz, 2H), 7.57 (d, J = 7.6 Hz, 2H), 7.40 (s, 3H), 7.16 (s, 2H), 5.18 (s, 2H), 3.93 (q, J = 6.9 Hz, 2H), 0.75 (t, J = 6.7 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.5, 164.2, 148.4, 140.9, 133.9 (t, $^2J_{C\text{-}F}$ = 32.2 Hz), 133.4, 132.1, 129.7, 129.5, 129.4, 129.1, 126.4, 125.1 (d, $^3J_{C\text{-}F}$ = 3.6 Hz), 123.7 (d, $^1J_{C\text{-}F}$ = 272.9 Hz), 121.0, 114.8, 94.4, 59.5, 13.5.

^{19}F NMR (376 MHz, $CDCl_3$) δ: 62.96.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{32}N_4O_6F_6NaS_2$, 889.1565; found, 889.1568.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(2-fluorobenzoyl)-1-phenyl-1H-pyrrole -3-carboxylate) (3l)



3l

Isolated yield: 52% (62 mg), yellow solid, mp: 160-162 °C.

IR (KBr) *v* 3473, 3060, 2980, 1671, 1452, 1385, 1271, 1230.

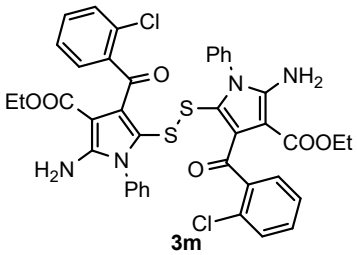
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.82 (t, J = 7.4 Hz, 1H), 7.39 (s, 4H), 7.16 (s, 2H), 7.07-6.97 (m, 2H), 5.18 (s, 2H), 3.96 (q, J = 6.9 Hz, 2H), 0.87 (t, J = 7.0 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 189.0, 164.5, 161.3 (d, $^1J_{C\text{-}F}$ = 259.6 Hz), 148.3, 133.7, 133.6, 133.3, 132.6, 129.4, 129.2, 129.1, 127.4, 127.3, 123.6, 116.3 (d, $^2J_{C\text{-}F}$ = 21.9 Hz), 94.0, 59.3, 13.7, 13.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ: 112.82.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2F_2$, 789.1629; found, 789.1633.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(2-chlorobenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3m)



3m

Isolated yield: 48% (59 mg), yellow solid, mp: 184-186 °C.

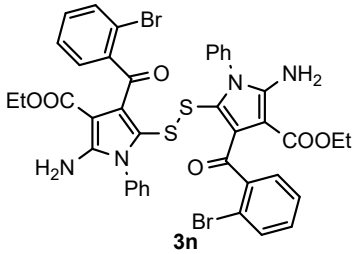
IR (KBr) *v* 3445, 3070, 2982, 1667, 1516, 1434, 1386, 1225.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.60 (d, J = 7.1 Hz, 2H), 7.41 (t, J = 3.1 Hz, 4H), 7.31 (td, J = 3.3 Hz, 1H), 7.15-7.10 (m, 3H), 5.22 (s, 2H), 4.00 (q, J = 7.1 Hz, 2H), 0.95 (t, J = 7.3 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 190.2, 164.8, 148.8, 138.0, 133.7, 133.2, 132.8, 132.5, 132.0, 131.8, 131.0, 130.8, 130.2, 130.0, 129.5, 129.3, 128.0, 126.4, 117.4, 95.4, 94.4, 59.6, 14.1.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2Cl_2$, 821.1038; found, 821.1033.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(2-bromobenzoyl)-1-phenyl-1H-pyrrole -3-carboxylate) (3n)



3n

Isolated yield: 85% (116 mg), yellow solid, mp: 178-180 °C.

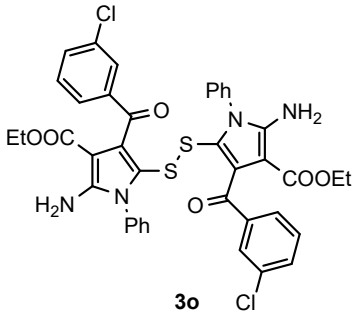
IR (KBr) *v* 3475, 3063, 2980, 1667, 1517, 1431, 1362, 1224.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.63 (d, J = 7.3 Hz, 1H), 7.57 (d, J = 6.4 Hz, 1H), 7.41 (s, 3H), 7.22 (t, J = 6.6 Hz, 1H), 7.16 (t, J = 6.6 Hz, 3H), 5.22 (s, 2H), 4.00 (d, J = 6.1 Hz, 2H), 0.95 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 190.5, 164.8, 148.9, 139.5, 134.3, 133.7, 133.0, 132.1, 132.0, 129.6, 129.4, 127.1, 121.5, 118.1, 94.5, 59.7, 14.2.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2Br_2$, 909.0028; found, 909.0030.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(3-chlorobenzoyl)-1-phenyl-1H-pyrrole -3-carboxylate) (3o)



3o

Isolated yield: 51% (62 mg), yellow solid, mp: 184-186 °C.

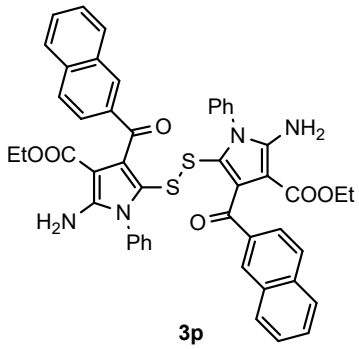
IR (KBr) *v* 3451, 3062, 2979, 1683, 1568, 1497, 1384, 1274.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.96 (s, 1H), 7.79 (d, J = 7.9 Hz, 1H), 7.45-7.41 (m, 4H), 7.21 (t, J = 7.6 Hz, 3H), 5.20 (s, 2H), 3.96 (q, J = 7.1 Hz, 2H), 0.80 (t, J = 6.9 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.2, 164.5, 148.5, 140.1, 134.4, 133.7, 132.5, 132.2, 129.6, 129.5, 129.4, 129.3, 128.9, 128.5, 115.0, 94.6, 59.6, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2Cl_2$, 821.1038; found, 821.1030.

Diethyl 5,5'-disulfanediylbis(4-(2-naphthoyl)-2-amino-1-phenyl-1H-pyrrole-3-carboxylate) (3p)



3p

Isolated yield: 78% (100 mg), yellow solid, mp: 152-154 ^oC.

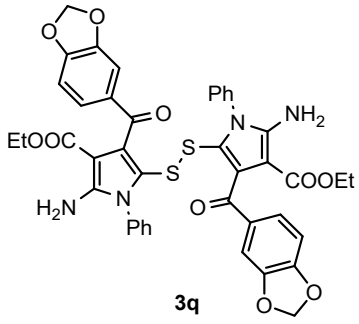
IR (KBr) *v* 3433, 3057, 2982, 1709, 1670, 1497, 1384, 1257.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 8.43 (s, 1H), 8.14 (d, J = 8.0 Hz, 1H), 7.80 (s, 3H), 7.50-7.37 (m, 5H), 7.18 (s, 2H), 5.20 (s, 2H), 3.87 (s, 2H), 0.66 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 193.0, 164.7, 148.3, 135.9, 135.5, 133.7, 132.6, 130.1, 129.4, 129.2, 128.2, 127.9, 127.7, 126.2, 125.0, 94.8, 59.5, 13.7.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{48}H_{38}N_4O_6NaS_2$, 853.2130; found, 853.2131.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(benzo[d][1,3]dioxole-5-carbonyl)-1-phenyl-1H-pyrrole-3-carboxylate) (3q)



3q

Isolated yield: 87% (110 mg), yellow solid, mp: 220-222 ^oC.

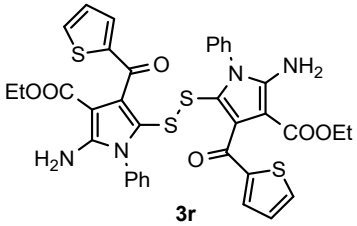
IR (KBr) *v* 3447, 3074, 2979, 1675, 1598, 1484, 1383, 1254.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.49 (s, 2H), 7.38 (s, 3H), 7.15 (s, 2H), 6.67 (s, 1H), 6.01 (s, 2H), 5.17 (s, 2H), 3.98 (s, 2H), 0.85 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.7, 164.6, 154.1, 151.3, 148.1, 147.6, 133.6, 133.3, 129.2, 126.9, 108.7, 108.2, 107.5, 101.6, 94.5, 59.3, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{34}N_4O_{10}NaS_2$, 841.1614; found, 841.1620.

Diethyl 5,5'-disulfanediylbis(2-amino-1-phenyl-4-(thiophene-2-carbonyl)-1H-pyrrole-3-carboxylate) (3r)



3r

Isolated yield: 52% (59 mg), yellow solid, mp: 225-227 °C.

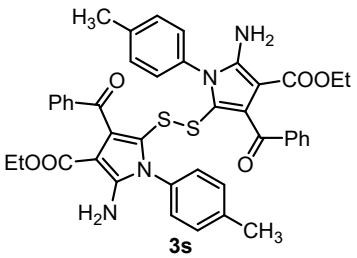
IR (KBr) *v* 3467, 3098, 2979, 1671, 1519, 1452, 1353, 1243.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.59 (s, 2H), 7.40 (s, 4H), 7.17 (s, 1H), 6.92 (s, 1H), 5.26 (s, 2H), 4.02 (s, 2H), 0.89 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 184.9, 164.7, 148.4, 146.0, 133.7, 130.3, 129.5, 128.1, 125.4, 119.8, 113.4, 94.6, 41.4, 29.8, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{36}H_{30}N_4O_6NaS_4$, 765.0946; found, 765.0943.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-(p-tolyl)-1H-pyrrole-3-carboxylate) (3s)



3s

Isolated yield: 76% (89 mg), yellow solid, mp: 210-212 °C.

IR (KBr) *v* 3447, 3062, 2979, 1670, 1522, 1448, 1384, 1278.

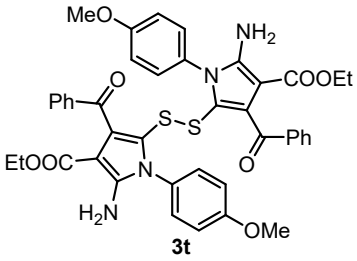
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.94 (d, J = 7.9 Hz, 2H), 7.45 (t, J = 7.3 Hz, 1H), 7.29

(t, J = 7.3 Hz, 2H), 7.17 (d, J = 6.3 Hz, 2H), 7.03 (s, 2H), 5.13 (s, 2H), 3.93 (q, J = 7.1 Hz, 2H), 2.35 (s, 3H), 0.74 (t, J = 6.7 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.7, 164.8, 148.5, 139.4, 138.4, 132.5, 131.1, 130.1, 129.7, 128.0, 128.1, 94.7, 59.4, 21.4, 13.7.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{38}N_4O_6NaS_2$, 781.2130; found, 781.2142.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-(4-methoxyphenyl)-1H-pyrrole -3-carboxylate) (3t)



3t

Isolated yield: 78% (95 mg), yellow solid, mp: 188-190 °C.

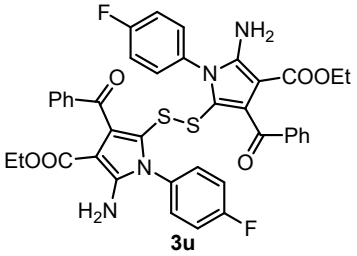
IR (KBr) v 3445, 3059, 2978, 1667, 1518, 1496, 1385, 1278.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.94 (d, J = 7.3 Hz, 2H), 7.45 (t, J = 7.3 Hz, 1H), 7.29 (t, J = 7.0 Hz, 2H), 7.09 (s, 2H), 6.87 (s, 2H), 5.12 (s, 2H), 3.92 (q, J = 6.5 Hz, 2H), 3.80 (s, 3H), 0.74 (t, J = 6.5 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.7, 164.8, 160.1, 148.7, 138.4, 132.5, 130.5, 129.7, 128.1, 126.2, 114.6, 94.6, 59.4, 55.6, 13.7.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{38}N_4O_8NaS_2$, 813.2029; found, 813.2025.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-(4-fluorophenyl)-1H-pyrrole -3-carboxylate) (3u)



3u

Isolated yield: 71% (84 mg), yellow solid, mp: 179-181 °C.

IR (KBr) *v* 3453, 3064, 2980, 1667, 1598, 1235, 1219.

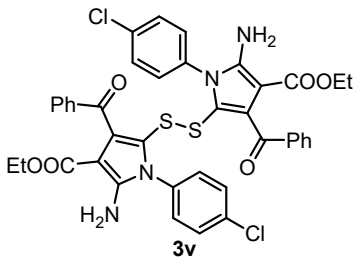
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.93 (d, J = 6.7 Hz, 2H), 7.47 (t, J = 6.7 Hz, 1H), 7.30 (s, 2H), 7.19 (s, 2H), 7.08 (s, 2H), 5.12 (s, 2H), 3.92 (d, J = 6.2 Hz, 2H), 0.72 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.3, 164.4, 162.7 (d, $^1J_{C\text{-}F}$ = 250.2 Hz), 148.4, 138.1, 133.1, 132.5, 131.1, 129.4, 128.0, 116.4 (d, $^2J_{C\text{-}F}$ = 21.9 Hz), 94.7, 59.5, 13.4.

^{19}F NMR (376 MHz, $CDCl_3$) δ: 110.99.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6F_2NaS_2$, 789.1629; found, 789.1637.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-(4-chlorophenyl)-1H-pyrrole -3-carboxylate) (3v)



3v

Isolated yield: 67% (83 mg), yellow solid, mp: 182-184 ^{o}C.

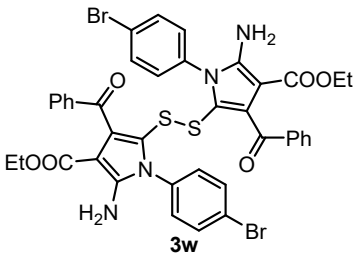
IR (KBr) *v* 3446, 3061, 2980, 1667, 1581, 1497, 1384, 1233.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.92 (d, J = 7.5 Hz, 2H), 7.47 (t, J = 7.4 Hz, 1H), 7.37 (d, J = 7.4 Hz, 2H), 7.30 (t, J = 7.0 Hz, 2H), 7.15 (s, 2H), 5.14 (s, 2H), 3.92 (d, J = 6.4 Hz, 2H), 0.73 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.5, 164.6, 148.4, 138.2, 135.5, 132.8, 132.2, 130.6, 129.8, 129.6, , 128.2, 94.9, 59.6, 29.9, 13.6.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaCl_2S_2$, 821.1038; found, 821.1047.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-(4-bromophenyl)-1H-pyrrole -3-carboxylate) (3w)



3w

Isolated yield: 75% (102 mg), yellow solid, mp: 238-240 °C.

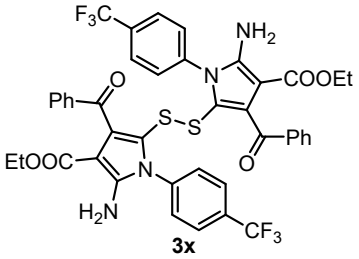
IR (KBr) *v* 3428, 3062, 2980, 1667, 1522, 1495, 1235.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 7.91 (d, *J* = 7.3 Hz, 2H), 7.53 (d, *J* = 6.1 Hz, 2H), 7.47 (t, *J* = 7.3 Hz, 1H), 7.30 (s, 2H), 7.08 (s, 2H), 5.16 (s, 2H), 3.92 (d, *J* = 6.1 Hz, 2H), 0.73 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 192.4, 164.6, 148.4, 138.2, 133.5, 132.8, 132.7, 130.9, 129.6, 128.2, 123.6, 94.9, 59.5, 13.5.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaBr_2S_2$, 909.0028; found, 909.0042.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-(4-(trifluoromethyl)phenyl) -1H-pyrrole-3-carboxylate) (3x)



3x

Isolated yield: 60% (80 mg), yellow solid, mp: 142-144 °C.

IR (KBr) *v* 3446, 3063, 2981, 1674, 1526, 1493, 1386, 1282.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 7.92 (d, *J* = 5.7 Hz, 2H), 7.67 (s, 2H), 7.48 (s, 2H), 7.31 (s, 3H), 5.19 (s, 2H), 3.93 (s, 2H), 0.72 (s, 3H).

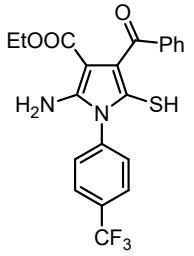
^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 192.1, 164.4, 148.1, 137.9, 136.8, 133.6, 132.7, 131.2 (d, $^2J_{C\text{-}F}$ = 32.9 Hz), 129.4, 128.1, 126.5, 123.5 (d, $^1J_{C\text{-}F}$ = 273.2 Hz), 95.0, 59.5, 13.4.

^{19}F NMR (376 MHz, $CDCl_3$) *δ*: 62.70.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{32}N_4O_6NaS_2F_6$, 889.1565; found,

889.1558.

Ethyl 2-amino-4-benzoyl-5-mercapto-1-(4-(trifluoromethyl)phenyl)-1H-pyrrole -3-carboxylate (3x')



3x'

Isolated yield: 12% (8 mg) yellow solid, mp: 142-144 °C.

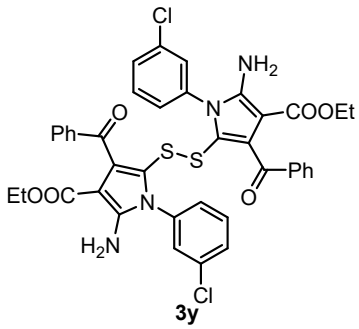
IR (KBr) *v* 3423, 3065, 2979, 1667, 1540, 1498, 1376, 1279.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 7.96 (d, *J* = 8.0 Hz, 2H), 7.70 (d, *J* =7.3 Hz, 2H), 7.60 (d, *J* = 7.9 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 1H), 7.33 (t, *J* = 7.3 Hz, 2H), 6.03 (s, 1H), 5.58 (s, 2H), 4.29 (q, *J* = 6.9 Hz, 2H), 1.35 (t, *J* = 7.0 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 184.5, 164.7, 160.5, 149.4, 138.8, 137.3, 133.1 (d, $^2J_{C\text{-}F}$ = 32.6 Hz), 130.9, 129.2, 128.4, 128.2, 126.9, 123.2 (d, $^1J_{C\text{-}F}$ = 272.3 Hz), 90.0, 81.5, 60.3, 14.5.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{21}H_{17}N_2O_3NaSF_3$, 457.0810; found, 457.0809.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-(3-chlorophenyl)-1H-pyrrole -3-carboxylate) (3y)



3y

Isolated yield: 48% (59 mg), yellow solid, mp: 170-172 °C.

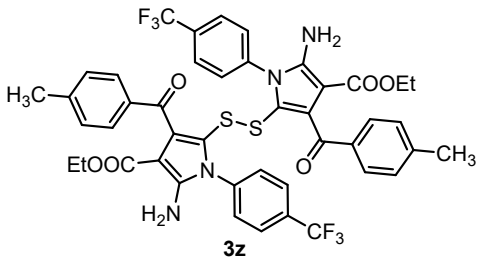
IR (KBr) *v* 3445, 3064, 2978, 1671, 1494, 1383, 1283.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 7.93 (s, 2H), 7.46 (s, 1H), 7.38 (s, 2H), 7.28 (s, 2H), 7.11 (s, 2H), 5.23 (s, 2H), 3.94 (s, 2H), 0.74 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.3, 164.4, 148.1, 138.0, 135.0, 134.8, 132.5, 130.3, 129.4, 128.0, 127.4, 94.9, 59.4, 13.5.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{32}N_4O_6NaS_2Cl_2$, 821.1038; found, 821.1041.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-methylbenzoyl)-1-(4-(trifluoromethyl) phenyl)-1H-pyrrole-3-carboxylate) (3z)



3z

Isolated yield: 75% (103 mg), yellow solid, mp: 150-152 ^oC.

IR (KBr) *v* 3442, 2982, 1673, 1526, 1489, 1385, 1238.

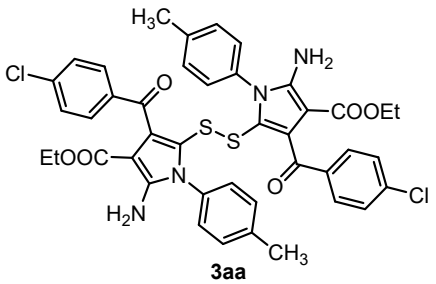
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.82 (s, 2H), 7.66 (s, 2H), 7.32 (s, 2H), 7.11 (s, 2H), 5.21 (s, 2H), 3.96 (s, 2H), 2.37 (s, 3H), 0.76 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.8, 164.5, 148.1, 143.6,136.9, 135.6, 133.8, 129.6, 128.8, 126.5, 123.5 (d, $^1J_{C\text{-}F}$ = 271.3 Hz), 94.9, 59.7, 21.9, 13.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ: 62.70 (d, J = 8.7 Hz).

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{44}H_{36}N_4O_6NaS_2F_6$, 917.1878; found, 917.1870.

Diethyl 5,5'-disulfanediylbis(2-amino-4-(4-chlorobenzoyl)-1-(p-tolyl)-1H-pyrrole -3-carboxylate) (3aa)



3aa

Isolated yield: 63% (80 mg), yellow solid, mp: 134-136 ^oC.

IR (KBr) *v* 3462, 2979, 1672, 1520, 1481, 1384, 1279.

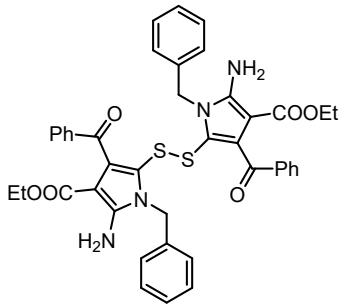
^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.88 (d, J = 8.5 Hz, 2H), 7.27 (d, J = 8.5 Hz, 2H),

7.18 (s, 2H), 7.02 (s, 2H), 5.16 (s, 2H), 3.96 (d, J = 6.7 Hz, 2H), 2.37 (s, 3H), 0.80 (s, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.3, 164.5, 148.5, 139.6, 138.9, 136.8, 132.2, 131.6, 131.0, 130.9, 130.2, 128.9, 128.4, 94.4, 59.6, 21.4, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{36}N_4O_6Cl_2NaS_2$, 849.1351; found, 849.1345.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-benzyl-1H-pyrrole-3-carboxylate) (3ab)



3ab

Isolated yield: 65% (76 mg), yellow solid, mp: 202-204 °C.

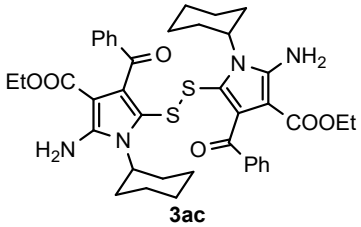
IR (KBr) v 3428, 3027, 2985, 1673, 1582, 1456, 1355, 1226.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.80 (d, J = 7.6 Hz, 2H), 7.45 (t, J = 7.0 Hz, 1H), 7.30-7.26 (m, 5H), 7.12 (d, J = 7.3 Hz, 2H), 5.05 (s, 4H), 3.87 (q, J = 6.7 Hz, 2H), 0.70 (t, J = 6.7 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.4, 164.7, 148.5, 138.3, 135.3, 132.7, 129.5, 129.3, 128.2, 126.8, 96.2, 59.5, 46.2, 13.6.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{42}H_{38}N_4O_6NaS_2$, 781.2130; found, 781.2132.

Diethyl 5,5'-disulfanediylbis(2-amino-4-benzoyl-1-cyclohexyl-1H-pyrrole-3-carboxylate) (3ac)



3ac

Isolated yield: 41% (47 mg), yellow solid, mp: 196-198 °C.

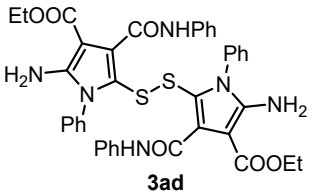
IR (KBr) *v* 3435, 3063, 2979, 1667, 1545, 1482, 1384, 1257.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.92 (d, J = 8.1 Hz, 1H), 7.84 (d, J = 7.6 Hz, 1H), 7.48 (q, J = 7.1 Hz, 1H), 7.38 (t, J = 7.6 Hz, 1H), 6.72 (s, 1H), 5.14 (s, 2H), 3.85 (q, J = 7.2 Hz, 2H), 3.74-3.68 (m, 1H), 2.05 (d, J = 12.2 Hz, 2H), 1.92 (d, J = 14.0 Hz, 2H), 1.76 (d, J = 13.3 Hz, 1H), 1.61-1.53 (m, 2H), 1.46-1.36 (m, 2H), 1.26-1.17 (m, 1H), 0.75 (t, J = 7.3 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 192.2, 166.2, 145.5, 139.9, 138.0, 132.6, 131.7, 129.4, 127.8, 121.8, 117.1, 94.1, 59.1, 54.4, 33.1, 30.0, 25.7, 25.3, 13.7.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{46}N_4O_6NaS_2$, 765.2756; found, 765.2758.

Diethyl 5,5'-disulfanediylbis(2-amino-1-phenyl-4-(phenylcarbamoyl)-1H-pyrrole -3-carboxylate) (3ad)



3ad

Isolated yield: 75% (88 mg), yellow solid, mp: 150-152 °C.

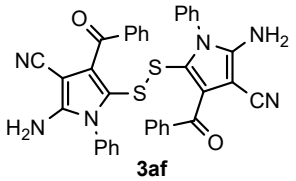
IR (KBr) *v* 3470, 3059, 2979, 1671, 1522, 1498, 1384, 1254.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 9.30 (s, 1H), 7.65 (d, J = 7.6 Hz, 2H), 7.40 (s, 3H), 7.32 (t, J = 7.9 Hz, 2H), 7.07 (t, J = 7.1 Hz, 3H), 4.97 (s, 2H), 4.12 (s, 2H), 1.17 (t, J = 7.1 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 164.8, 163.0, 148.6, 139.2, 133.9, 130.1, 129.8, 129.6, 129.3, 128.9, 123.8, 119.8, 93.8, 60.1, 14.4.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{40}H_{36}N_6O_6NaS_2$, 783.2035; found, 783.2034.

5,5'-Disulfanediylbis(2-amino-4-benzoyl-1-phenyl-1H-pyrrole-3-carbonitrile)(3af)



3af

Isolated yield: 76% (75 mg), yellow solid, mp: 190-192 °C.

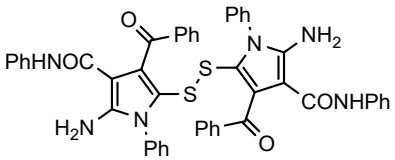
IR (KBr) *v* 3469, 3062, 2188, 1634, 1556, 1473, 1335, 1227.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 7.72-7.69 (m, 4H), 7.43 (d, *J* = 1.8 Hz, 1H), 7.42 (d, *J* =1.2 Hz, 1H) , 7.39 (d, *J* = 6.9 Hz, 1H), 7.34 (t, *J* = 7.4 Hz, 2H), 6.13 (s, 1H), 4.65 (s, 2H).

^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 184.9, 161.1, 151.2, 138.4, 134.1, 131.6, 131.3, 128.4, 127.2, 115.1, 91.5, 61.7.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{36}H_{24}N_6O_2NaS_2$, 659.1300; found, 659.1310.

5,5'-Disulfanediylbis(2-amino-4-benzoyl-N,1-diphenyl-1H-pyrrole-3-carboxamide) (3ag)



3ag

Isolated yield: 77% (98 mg), yellow solid, mp: 230-232 °C.

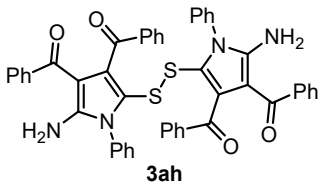
IR (KBr) *v* 3429, 3058, 1649, 1557, 1481, 1386, 1295, 1225.

^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 11.59 (s, 1H). 7.83 (d, *J* =7.3 Hz, 2H), 7.53 (d, *J* = 7.4 Hz, 3H), 7.42 (t, *J* = 7.6 Hz, 1H), 7.36 (t, *J* = 7.6 Hz, 3H), 7.29 (t, *J* = 7.6 Hz, 2H), 7.19 (d, *J* = 5.5 Hz, 1H), 7.14-7.06 (m, 2H), 6.03 (d, *J* = 6.1 Hz, 1H), 5.96 (s, 2H).

^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 193.1, 164.6, 150.6, 141.7, 139.4, 133.6, 132.8, 132.5, 130.1, 129.8, 129.4, 128.9, 128.5, 128.1, 123.3, 121.8, 120.5, 99.3.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{48}H_{36}N_6O_4NaS_2$, 847.2132; found, 847.2137.

Disulfanediylbis(5-amino-1-phenyl-1H-pyrrole-2,3,4-triyl))tetrakis(phenylmethanone (3ah)



3ah

Isolated yield: 35% (43 mg), yellow solid, mp: 156-158 °C.

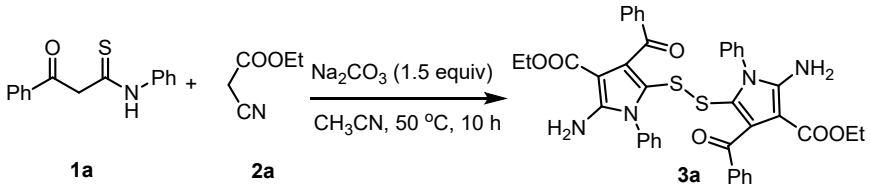
IR (KBr) *v* 3458, 3057, 1653, 1498, 1393, 1276, 1234.

^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.47–7.39 (m, 5H), 7.36 (t, J = 7.4 Hz, 1H), 7.23 (d, J = 7.8 Hz, 2H), 7.20 (s, 1H), 7.17 (dd, J = 13.5, 5.6 Hz, 4H), 7.03 (t, J = 7.6 Hz, 2H), 5.85 (s, 2H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.5, 191.2, 150.1, 141.3, 138.7, 133.4, 132.7, 132.3, 130.5, 129.7, 129.6, 129.2, 128.0, 127.9, 127.7, 105.1.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{48}H_{34}N_4O_4NaS_2$, 817.1919; found, 817.1918.

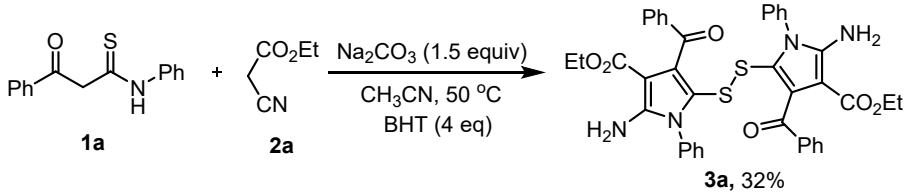
4. Gram-scale reaction



1a 1.28 g (5 mmol) **2a** 0.57 g (5 mmol) **3a** 1.27 g, 70%

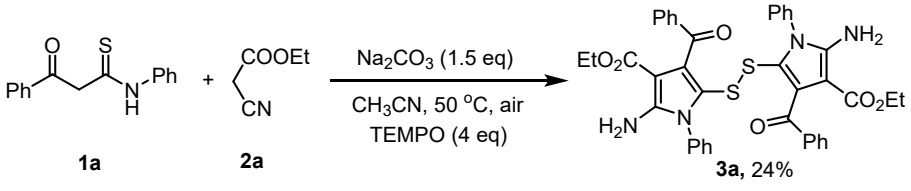
A gram-scale reaction was carried out by using β-benzoylthioamide **1a** (5 mmol) and ethyl cyanacetate **2a** (5 mmol) under the optimized conditions, the corresponding product **3a** was produced in 70% yield.

5. Mechanism study



1a **2a** **3a,** 32%

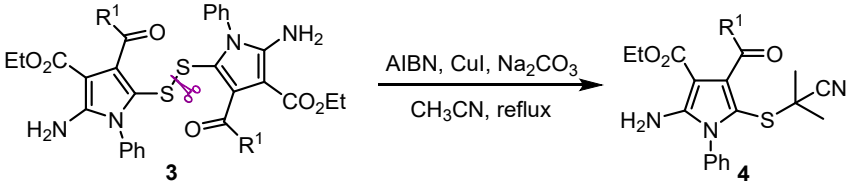
To a stirred solution of thioamides **1a** (0.3 mmol, 1.0 equiv) and ethyl 2-cyanoacetate **2a** (0.3 mmol, 1.0 equiv) in acetonitrile (1 mL) was added Na_2CO_3 (0.45 mmol, 1.5 equiv) and BHT (1.2 mmol, 4.0 equiv), the mixture was stirred at 50 °C for 6 h. After completion of the reaction as monitored by TLC the solvent was concentrated under vacuum and the residue was purified by flash column chromatography on silica gel with petroleum ether/ethyl acetate (3:1, v/v) to produce **3a** in 32% yield.



1a **2a** **3a,** 24%

To a stirred solution of thioamides **1a** (0.3 mmol, 1.0 equiv) and ethyl 2-cyanoacetate **2a** (0.3 mmol, 1.0 equiv) in acetonitrile (1 mL) was added Na_2CO_3 (0.45 mmol, 1.5 equiv) and TEMPO (1.2 mmol, 4.0 equiv), the mixture was stirred at 50 °C for 3 h. After completion of the reaction as monitored by TLC the solvent was concentrated under vacuum and the residue was purified by flash column chromatography on silica gel with petroleum ether/ethyl acetate (3:1, v/v) to produce **3a** in 24% yield.

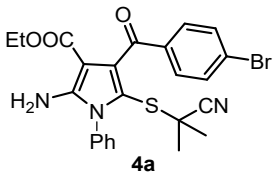
6. Follow-up transformations



3 **4**

The mixture of disulfides **3** (0.15 mmol), AIBN (0.3 mmol), CuI (0.04 mmol), Na_2CO_3 (0.3 mmol) and CH_3CN (1 mL) was stirred at 100 °C for 3 h. After the completion of the reaction (monitored by TLC), the solvent was concentrated under vacuum and the residue was purified by flash column chromatography on silica gel with petroleum ether/ethyl acetate (3:1, v/v) as the eluent to give the product **4**.

Ethyl 2-amino-4-(4-bromobenzoyl)-5-((2-cyanopropan-2-yl)thio)-1-phenyl-1H-pyrrole-3-carboxylate (4a)



4a

Isolated yield: 75% (115 mg) white solid, mp: 118-120 °C.

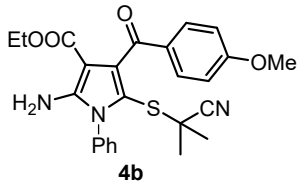
IR (KBr) *v* 3447, 3063, 2978, 2231, 1674, 1521, 1496, 1385, 1278.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.83 (d, J = 8.2 Hz, 2H), 7.61-7.56 (m, 4H), 7.53 (t, J = 7.3 Hz, 1H), 7.43 (d, J = 7.1 Hz, 2H), 5.36 (s, 2H), 3.94 (q, J = 7.1 Hz, 2H), 1.28 (s, 6H), 0.81 (t, J = 7.0 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.8, 164.4, 148.2, 137.5, 133.8, 133.6, 131.7, 131.2, 130.0, 129.9, 129.4, 128.2, 122.0, 111.6, 94.4, 59.8, 41.4, 28.1, 13.8.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{24}H_{22}N_3O_3NaSBr$, 534.0463; found, 534.0464.

Ethyl 2-Amino-5-((2-cyanopropan-2-yl)thio)-4-(4-methoxybenzoyl)-1-phenyl-1H-pyrrole-3-carboxylate (4b)



4b

Isolated yield: 72% (100 mg), yellow solid, mp: 78-80 °C.

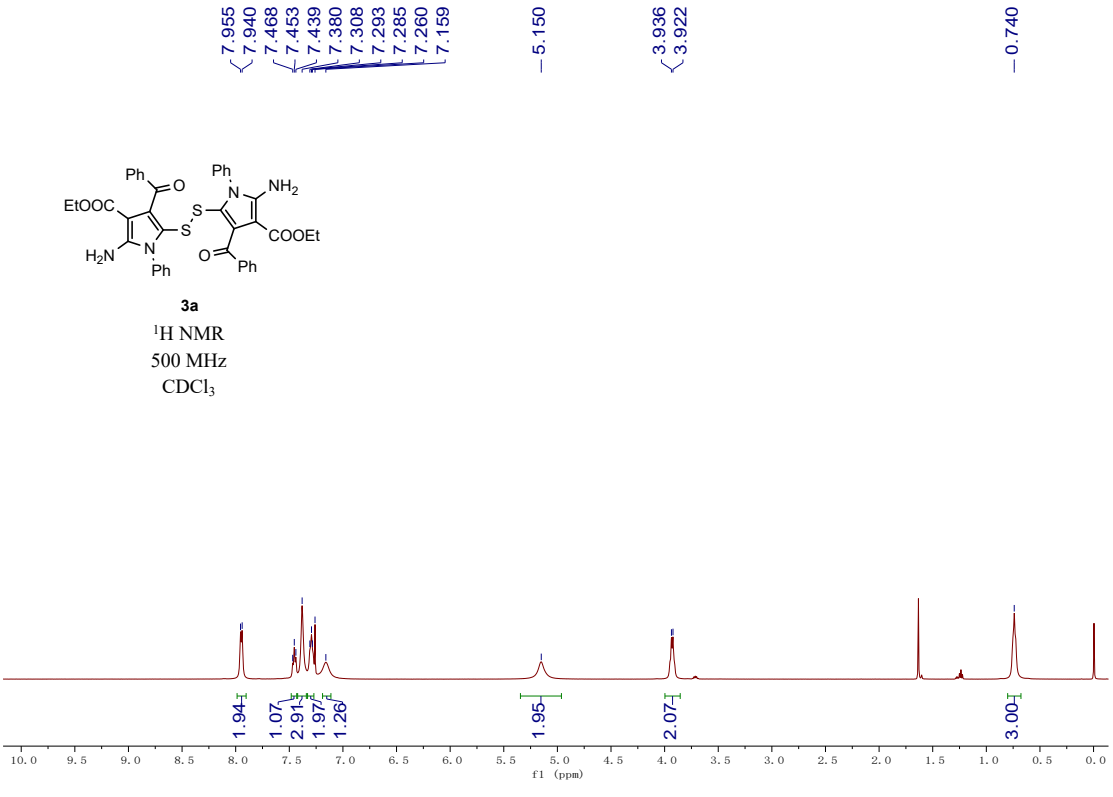
IR (KBr) *v* 3446, 3063, 2976, 2230, 1671, 1521, 1454, 1384, 1279.

^{1}H NMR ($CDCl_3$, 500 MHz) δ: 7.94 (d, J = 7.8 Hz, 2H), 7.58 (t, J = 7.5 Hz, 2H), 7.52 (t, J = 7.2 Hz, 1H), 7.44 (s, 2H), 6.92 (d, J = 8.2 Hz, 2H), 5.35 (s, 2H), 3.95 (d, J = 6.9 Hz, 2H), 3.87 (s, 3H), 1.28 (s, 6H), 0.82 (t, J = 7.0 Hz, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz) δ: 191.5, 164.5, 163.4, 148.0, 134.6, 133.6, 131.8, 131.7, 129.7, 129.5, 129.3, 122.0, 113.4, 110.6, 94.4, 59.5, 55.4, 41.1, 27.9, 13.6.

HRMS (ESI-TOF, $[M + Na]^+$): calcd for $C_{45}H_{25}N_3O_4SNa$, 486.1463; found, 486.1469.

7. NMR spectra

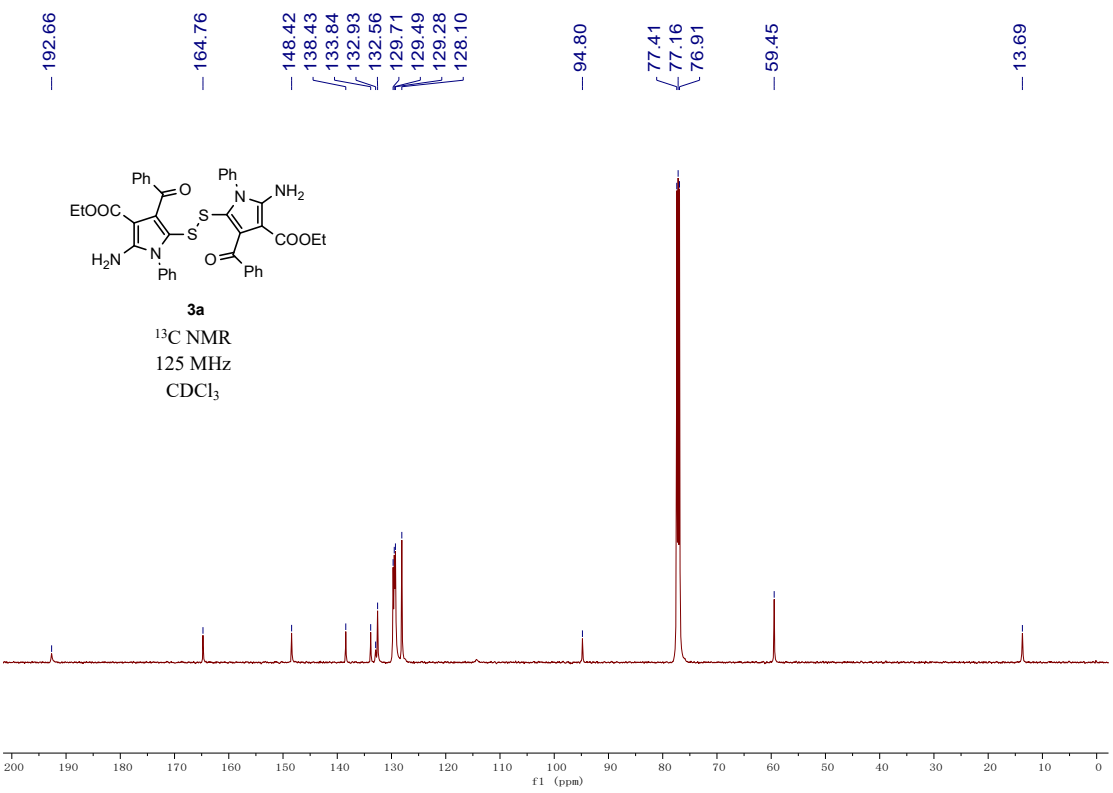


3a

^{1}H NMR

500 MHz

$CDCl_3$

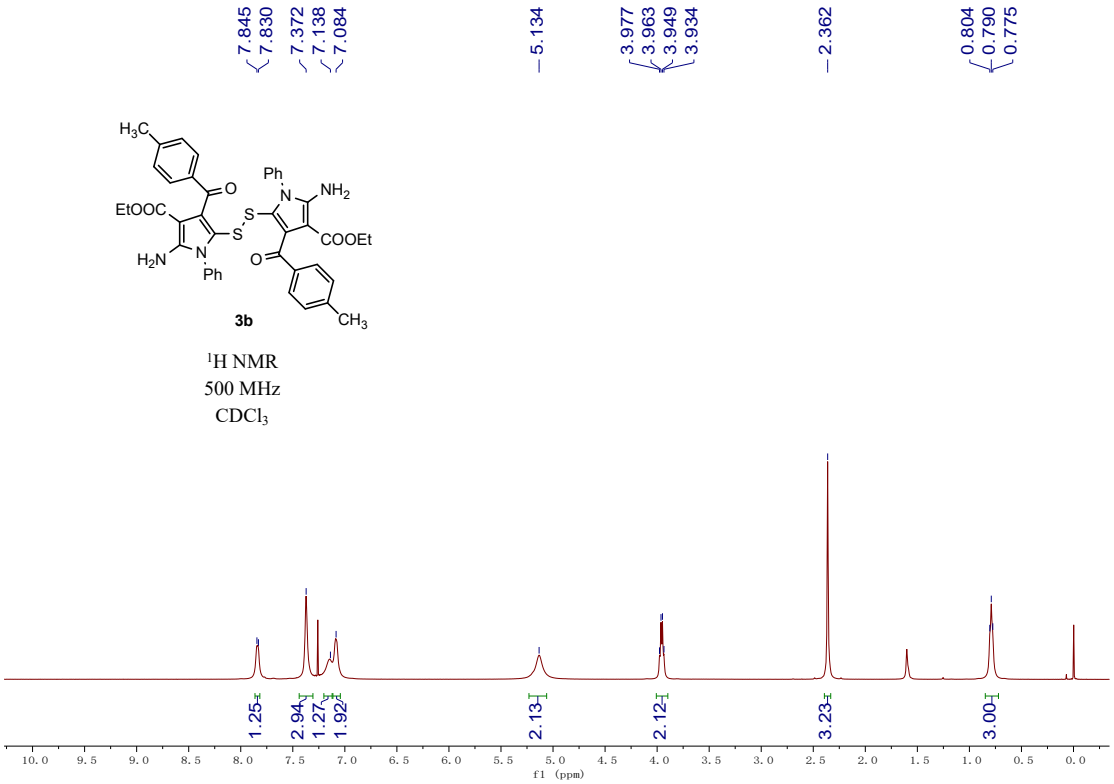


3a

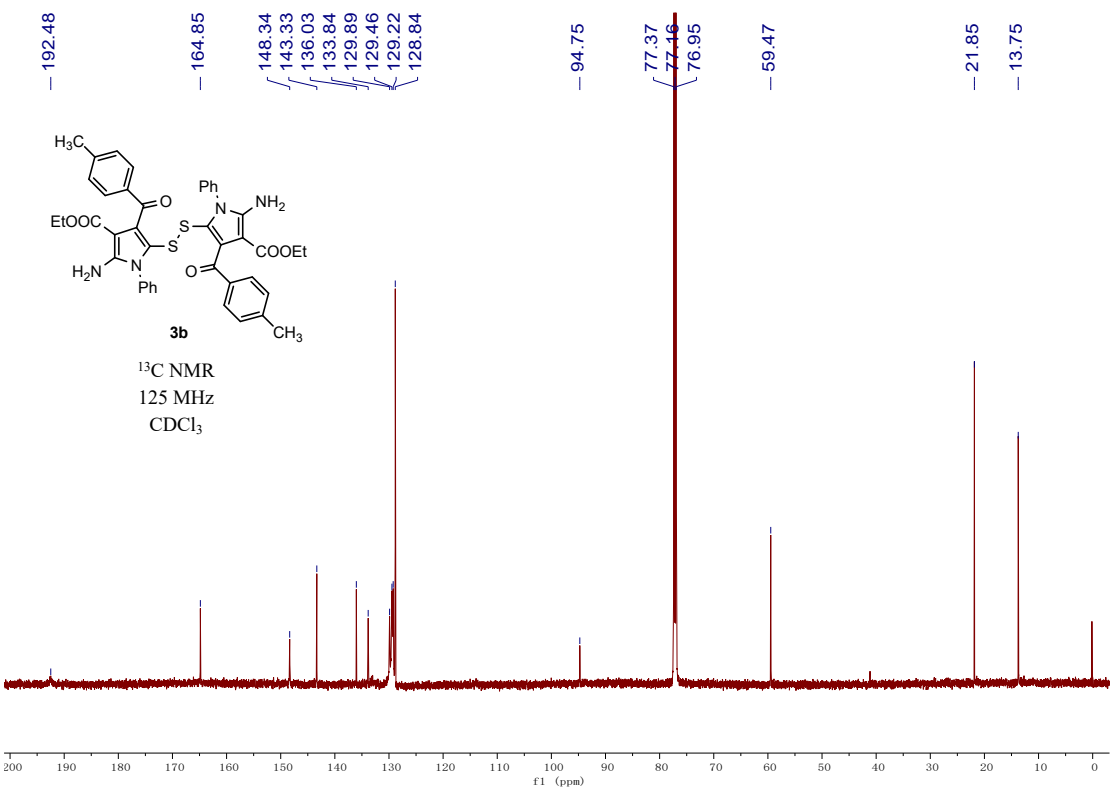
^{13}C NMR

125 MHz

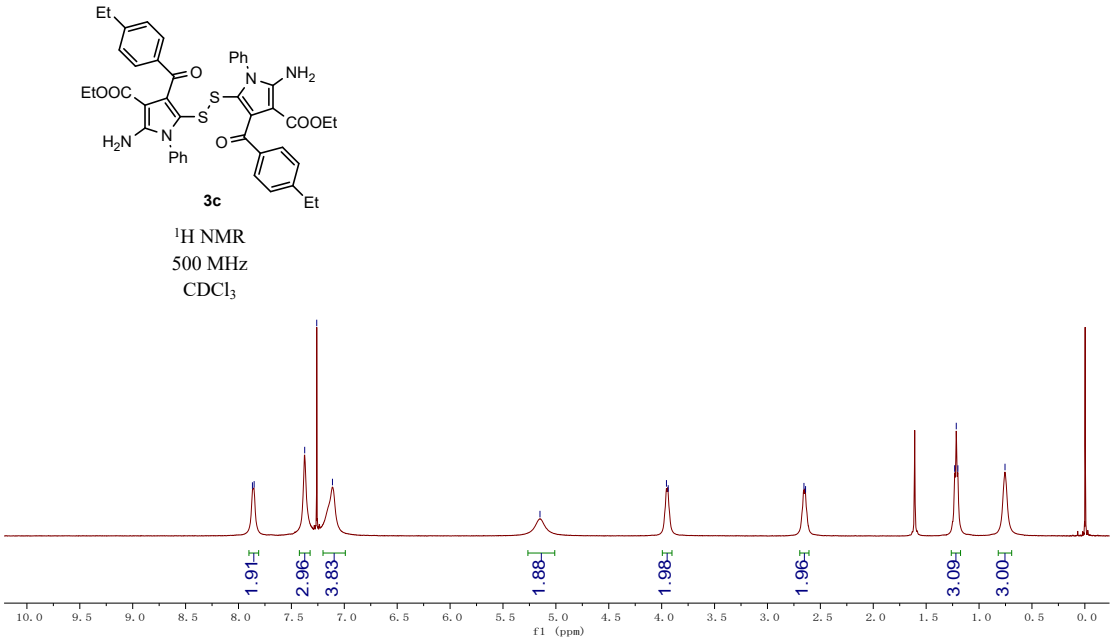
$CDCl_3$



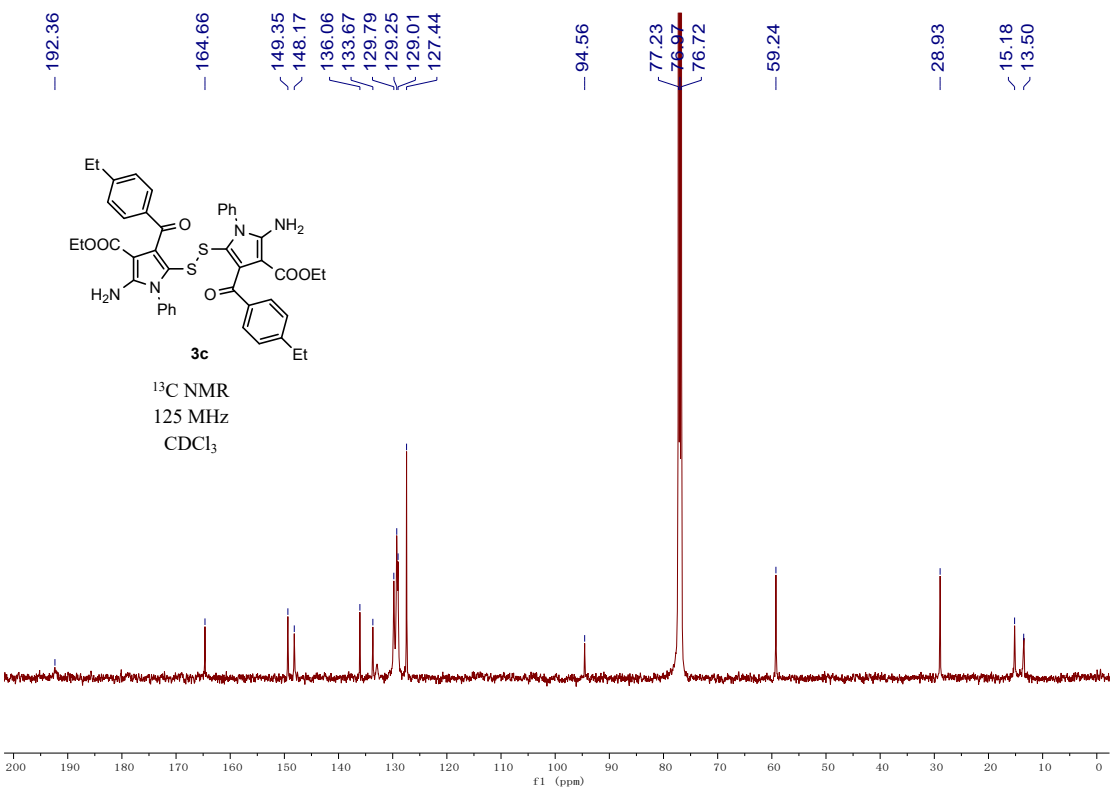
^{1}H NMR
500 MHz
$CDCl_3$



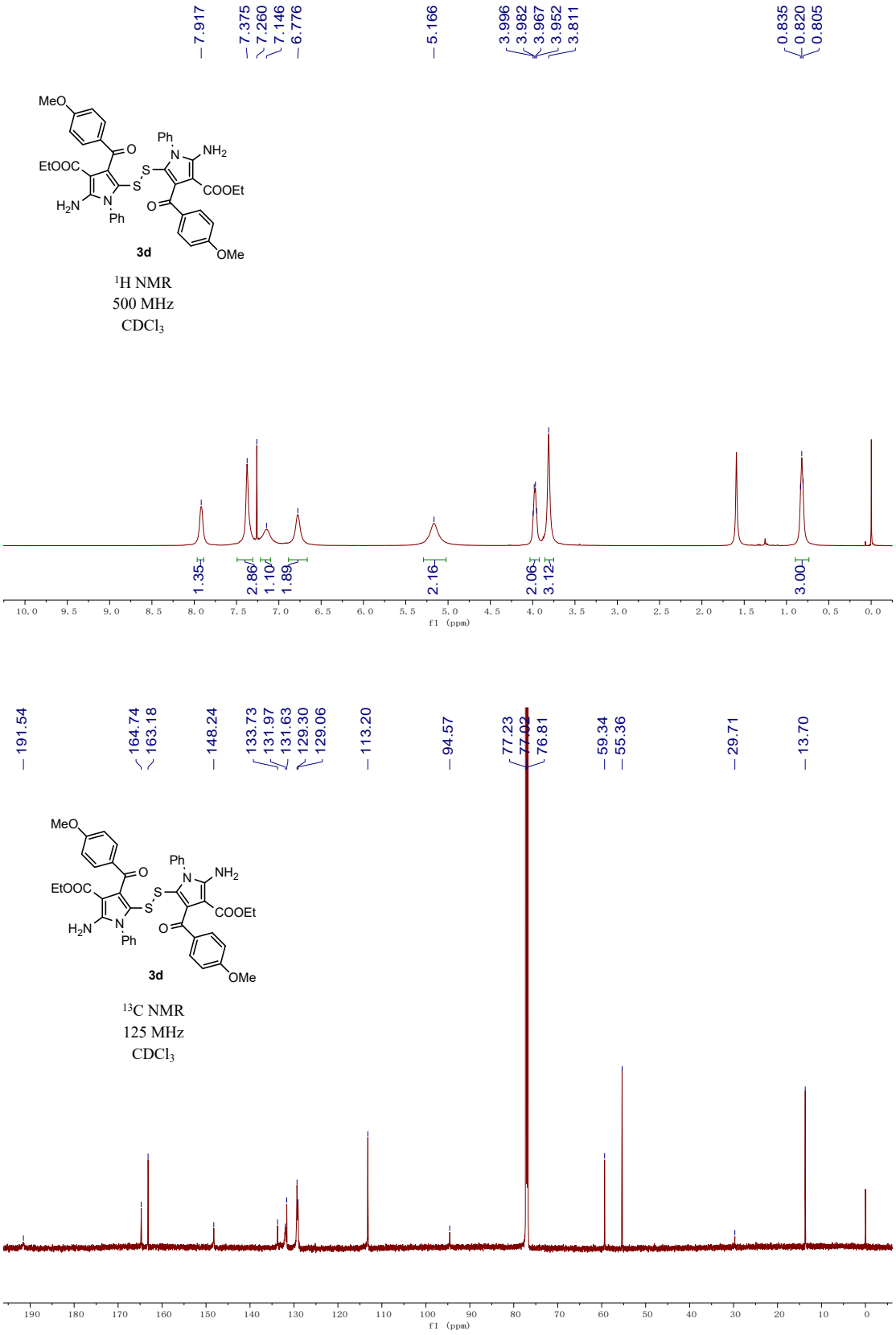
^{13}C NMR
125 MHz
$CDCl_3$



^{1}H NMR
500 MHz
$CDCl_3$

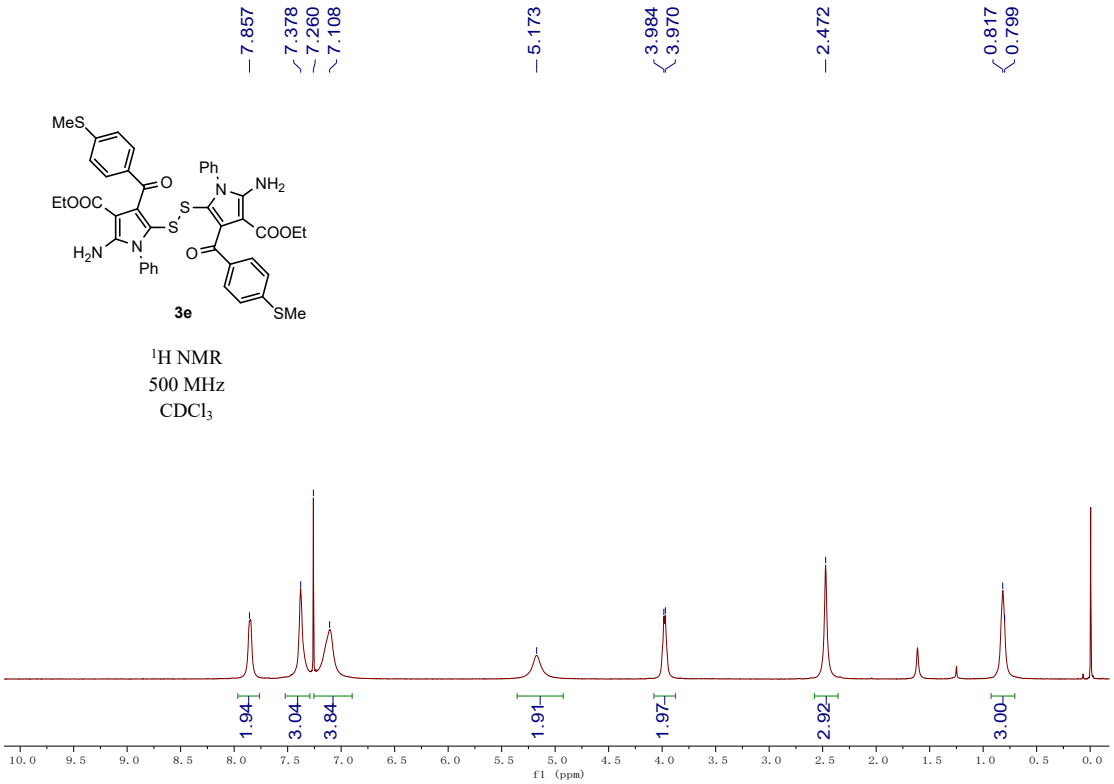


^{13}C NMR
125 MHz
$CDCl_3$

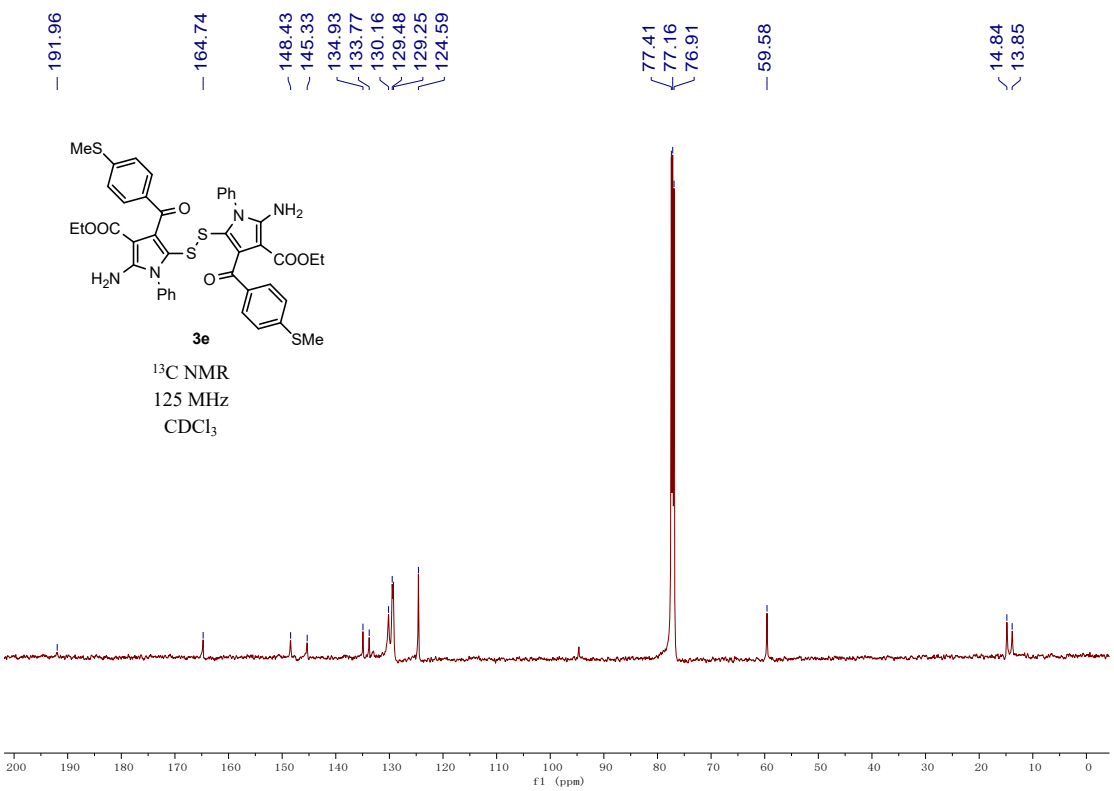


^{1}H NMR
500 MHz
$CDCl_3$

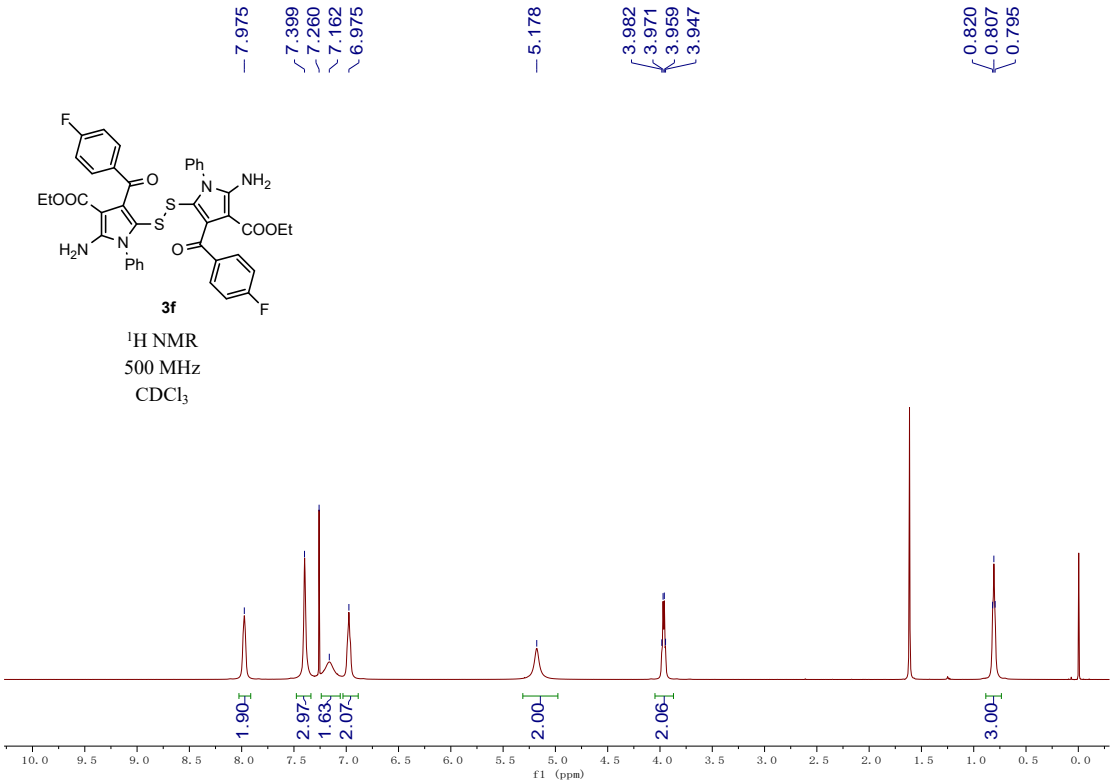
^{13}C NMR
125 MHz
$CDCl_3$



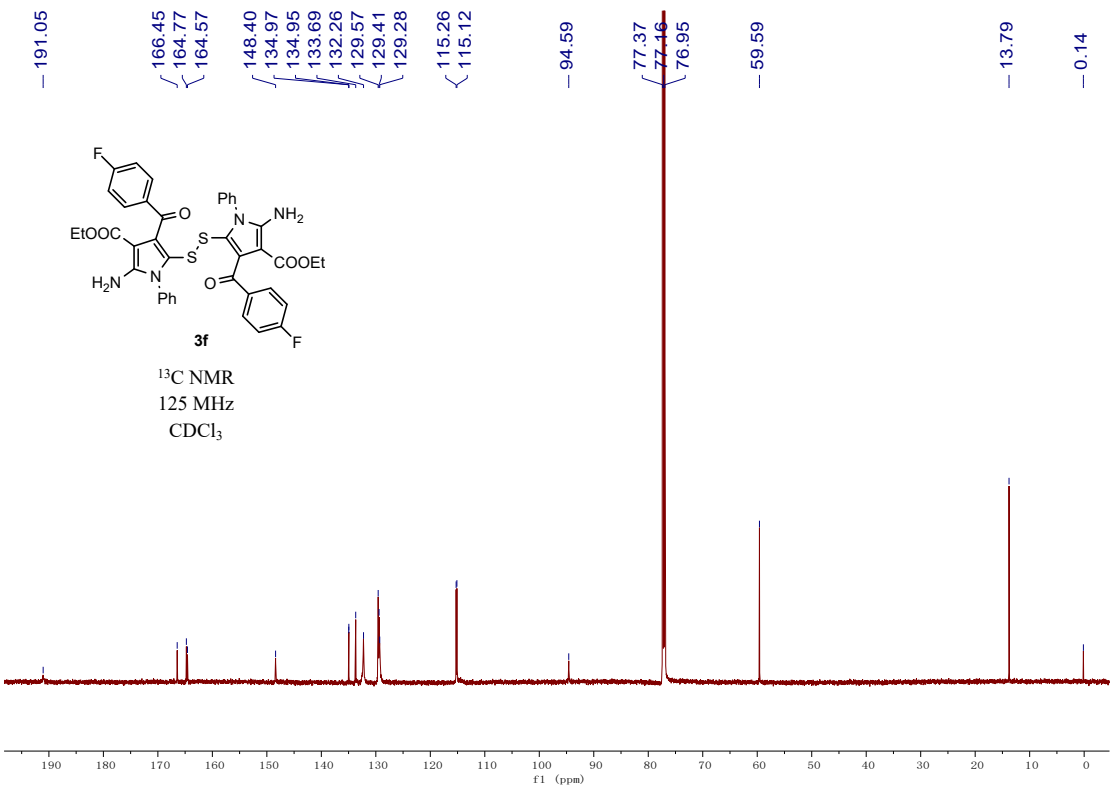
^{1}H NMR
500 MHz
$CDCl_3$



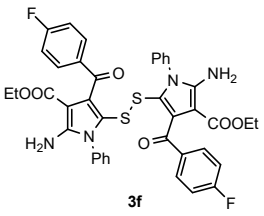
^{13}C NMR
125 MHz
$CDCl_3$



^{1}H NMR
500 MHz
$CDCl_3$

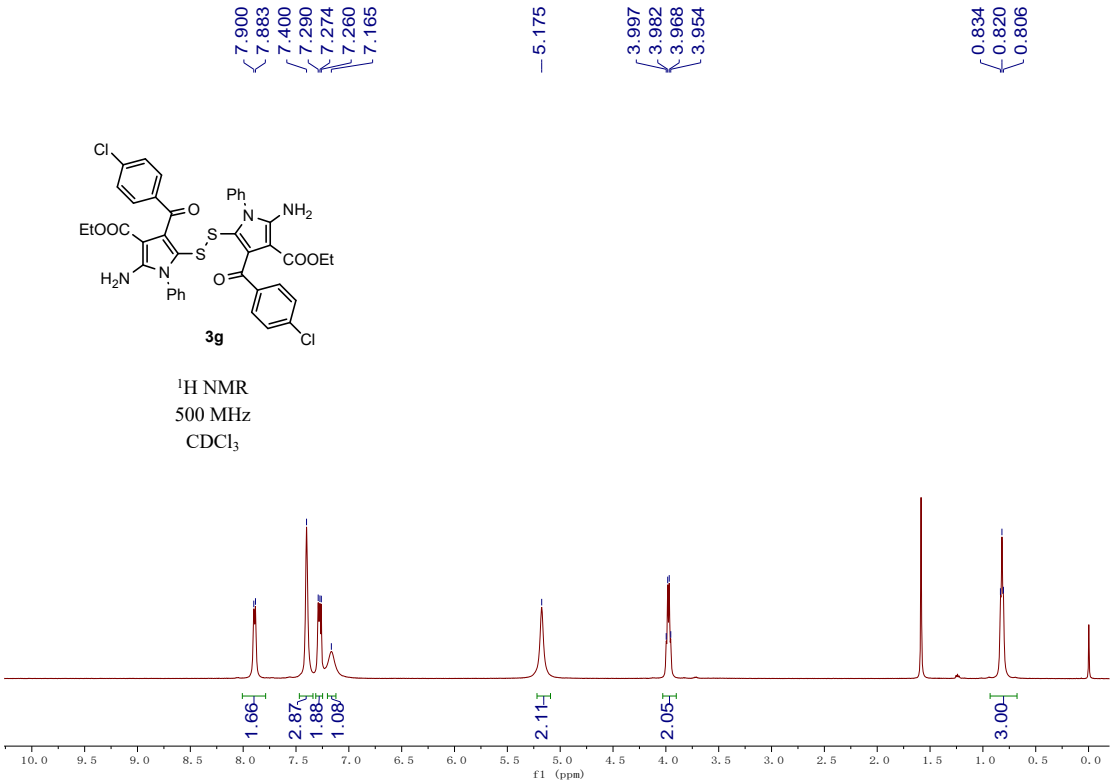


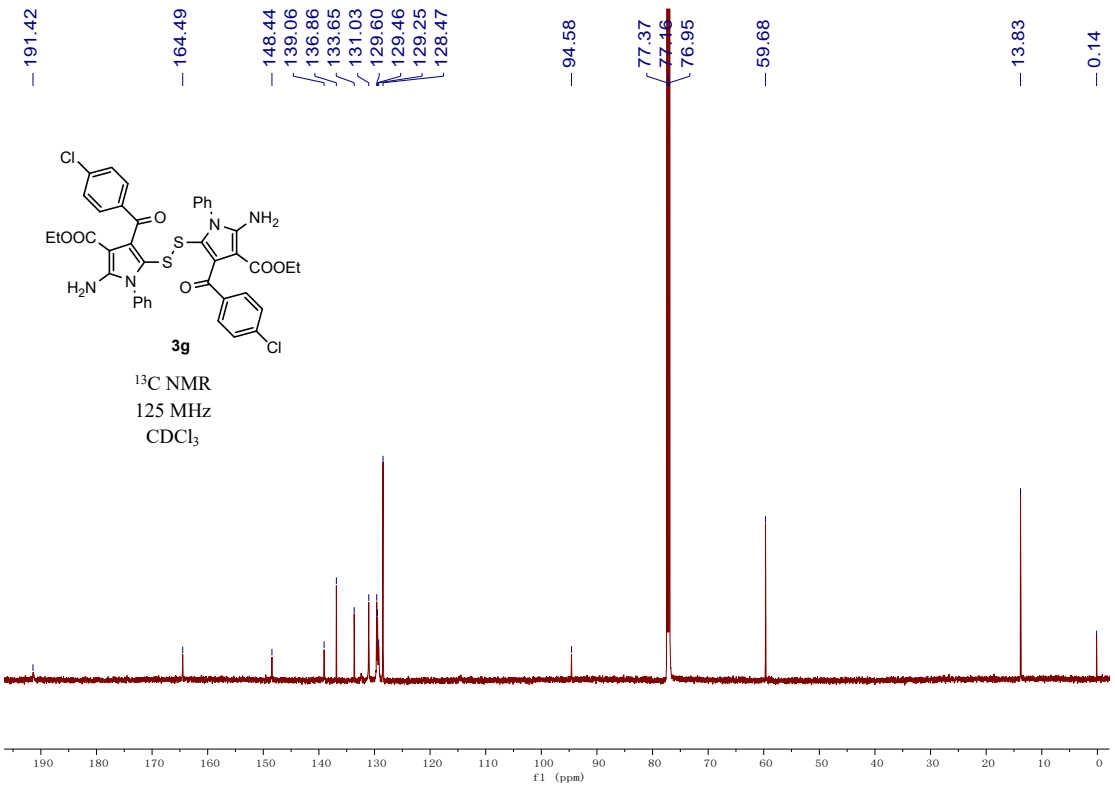
^{13}C NMR
125 MHz
$CDCl_3$

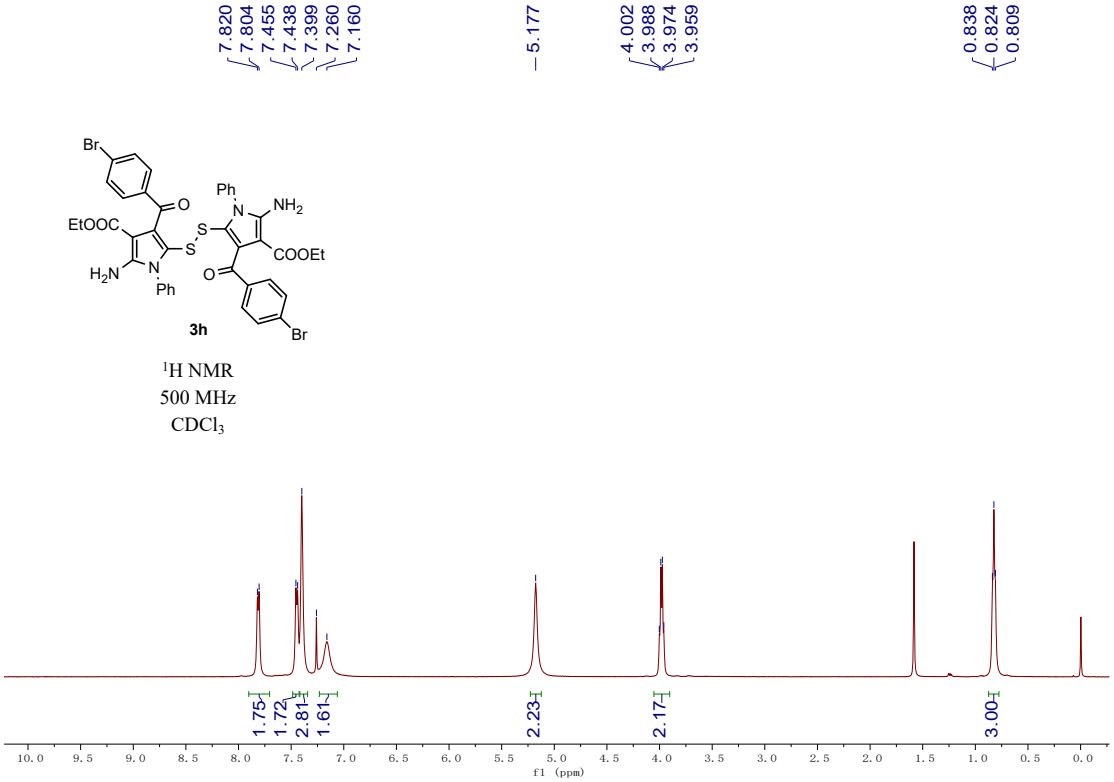


3f

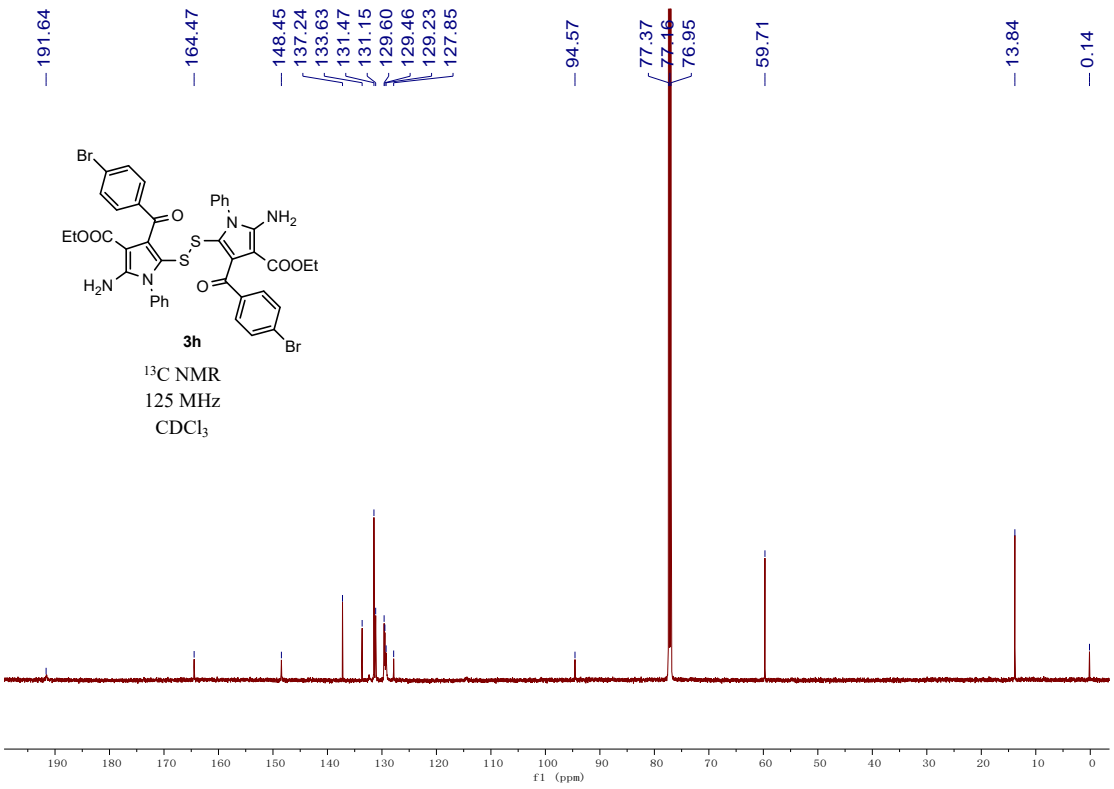
^{19}F NMR
376 MHz
$CDCl_3$


7.900
7.883
7.400
7.290
7.274
7.260
7.165
5.175
3.997
3.982
3.968
3.954
0.834
0.820
0.806
Cl
EtOOC
O
Ph
N
NH2
S
S
COOEt
H2N
N
Ph
O
Cl
3g
1H NMR
500 MHz
CDCl3
1.66
2.87
1.88
1.08
2.11
2.05
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

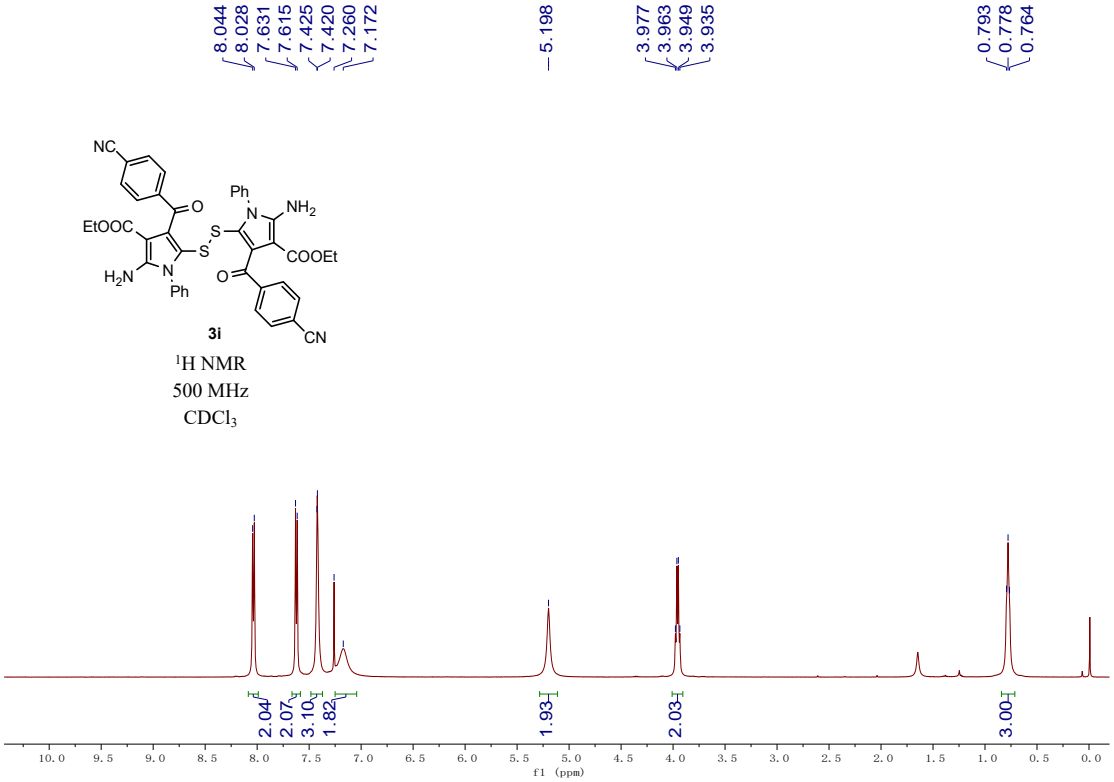

191.42
164.49
148.44
139.06
136.86
133.65
131.03
129.60
129.46
129.25
128.47
94.58
77.37
77.16
76.95
59.68
13.83
0.14
Cl
EtOOC
O
Ph
N
NH2
S
S
COOEt
H2N
N
Ph
O
Cl
3g
13C NMR
125 MHz
CDCl3
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

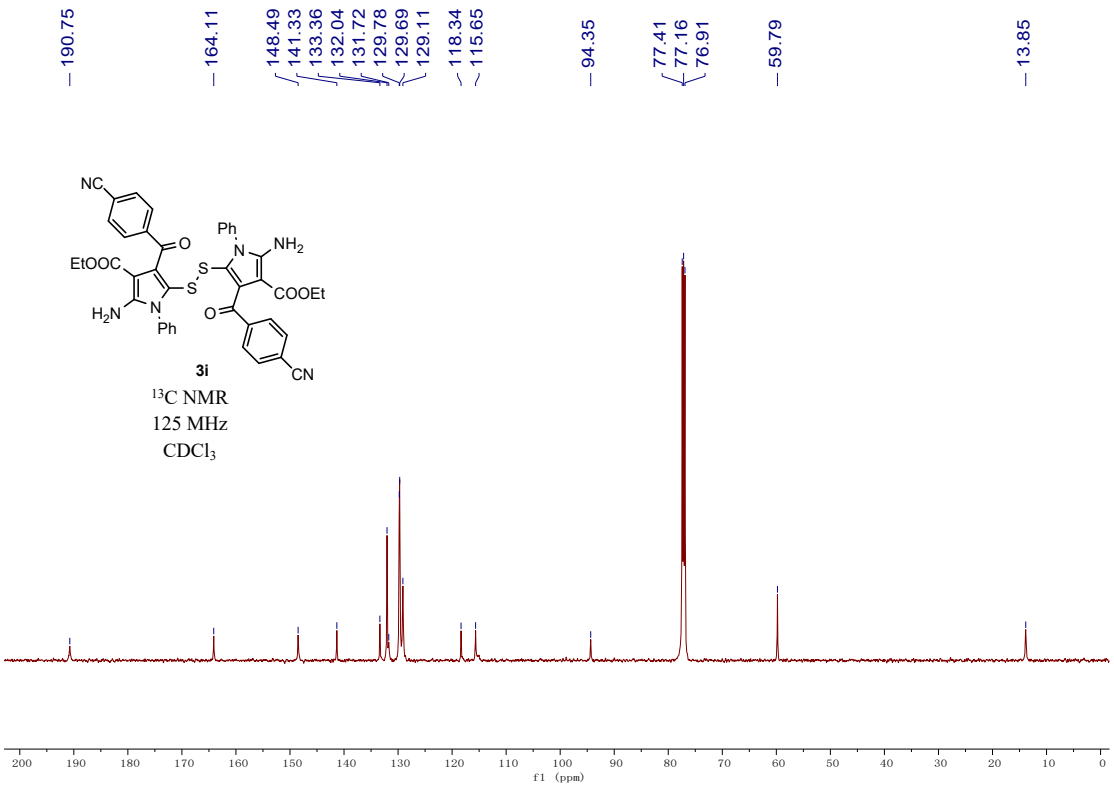


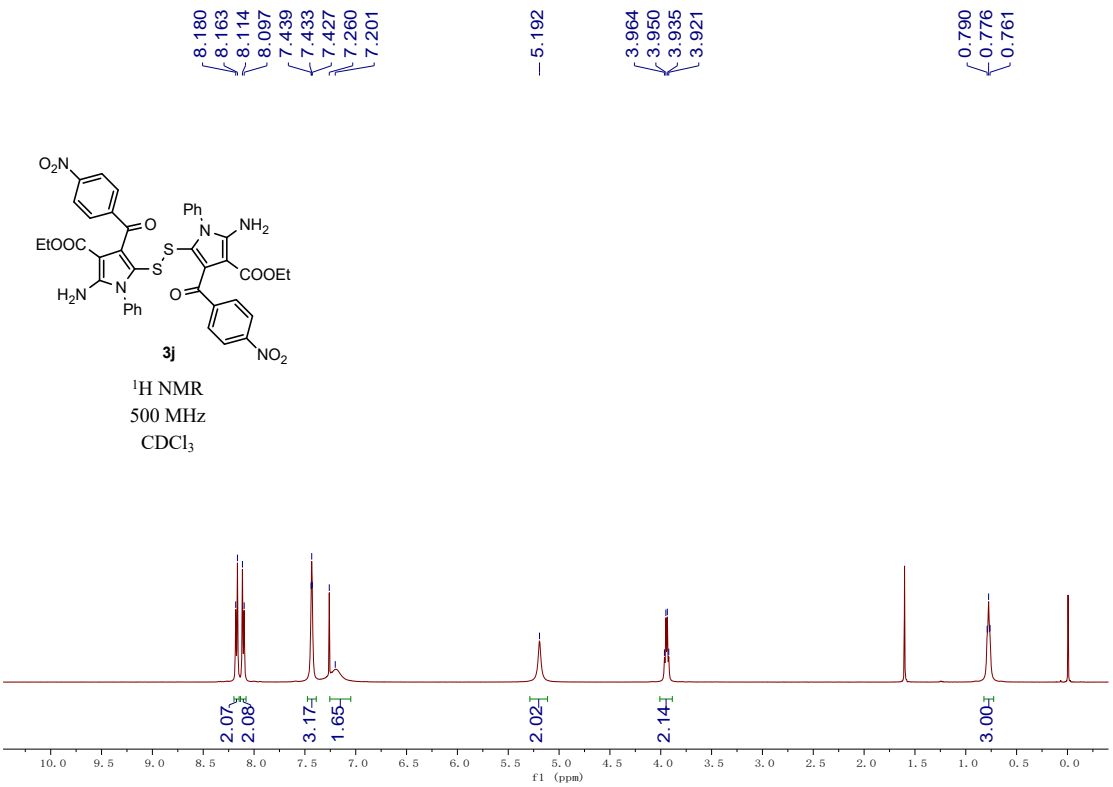
^{1}H NMR
500 MHz
$CDCl_3$



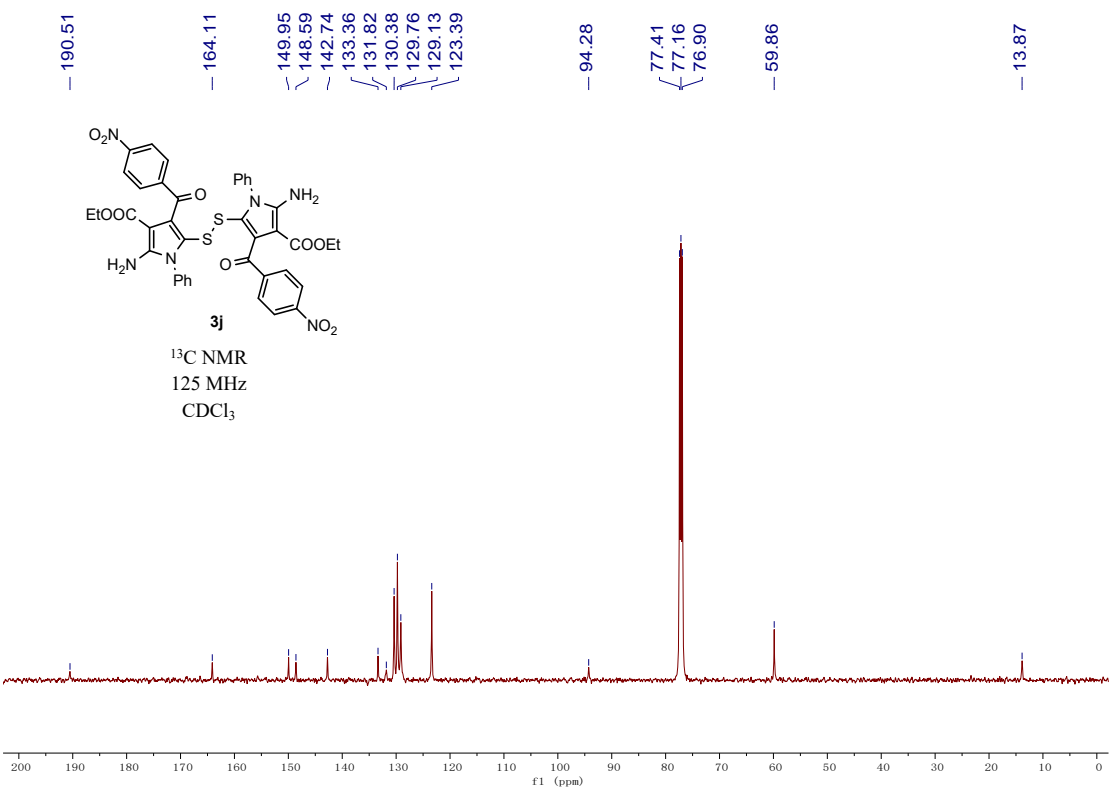
^{13}C NMR
125 MHz
$CDCl_3$


8.044
8.028
7.631
7.615
7.425
7.420
7.260
7.172
5.198
3.977
3.963
3.949
3.935
0.793
0.778
0.764
NC
EtOOC
O
S
S
Ph
N
NH2
COOEt
H2N
N
Ph
O
CN
3i
1H NMR
500 MHz
CDCl3
2.04
2.07
3.10
1.82
1.93
2.03
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

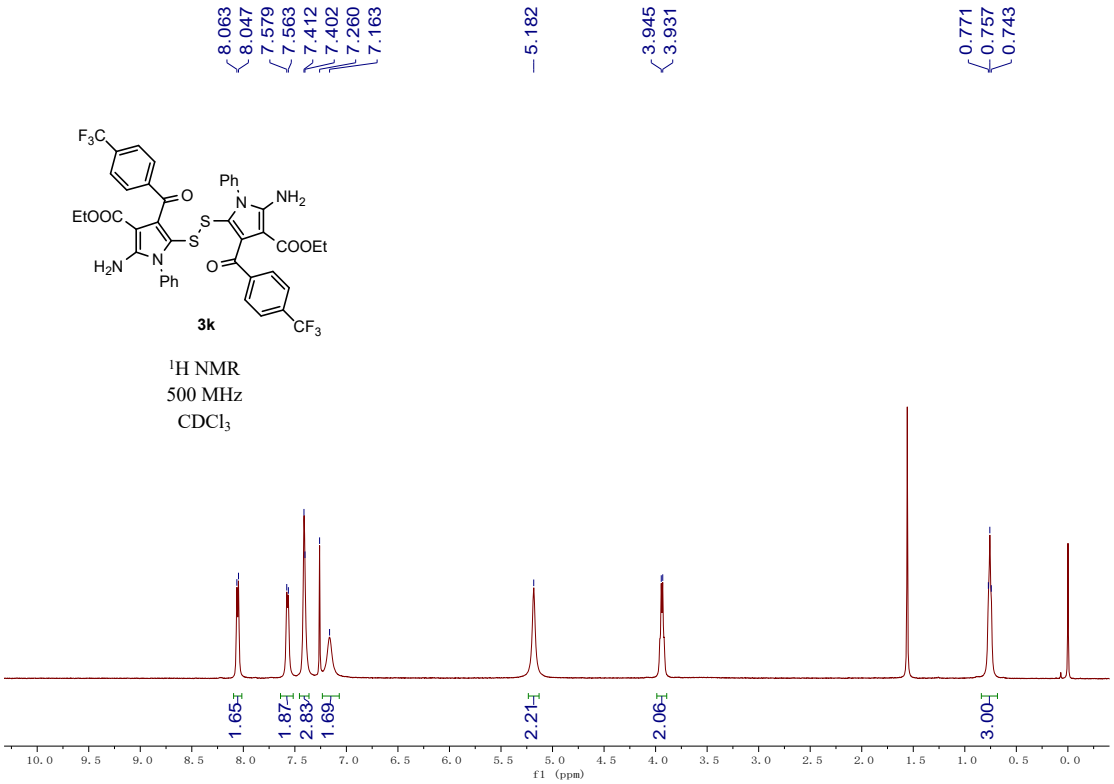

190.75
164.11
148.49
141.33
133.36
132.04
131.72
129.78
129.69
129.11
118.34
115.65
94.35
77.41
77.16
76.91
59.79
13.85
NC
EtOOC
O
S
S
Ph
N
NH2
COOEt
H2N
N
Ph
O
CN
3i
13C NMR
125 MHz
CDCl3
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



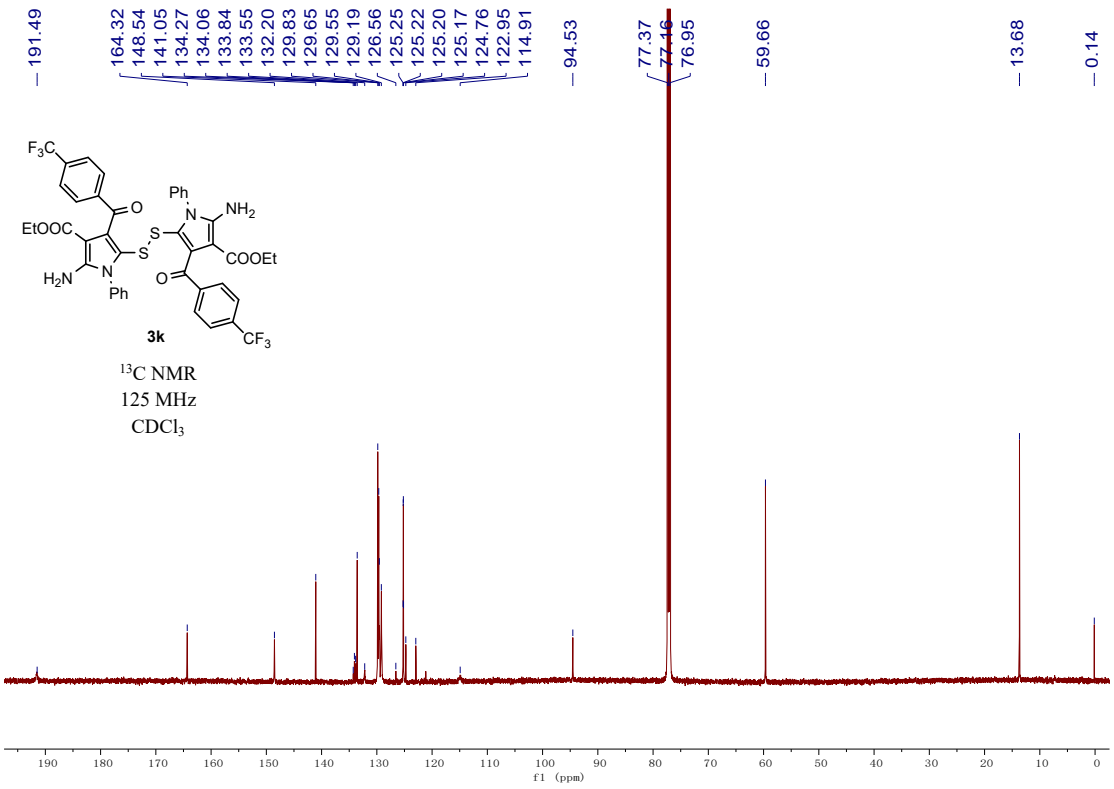
^{1}H NMR
500 MHz
$CDCl_3$



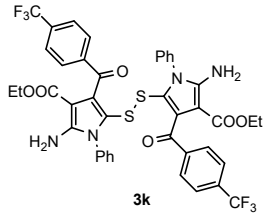
^{13}C NMR
125 MHz
$CDCl_3$



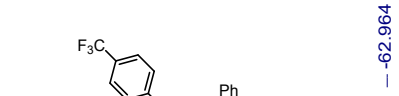
^{1}H NMR
500 MHz
$CDCl_3$



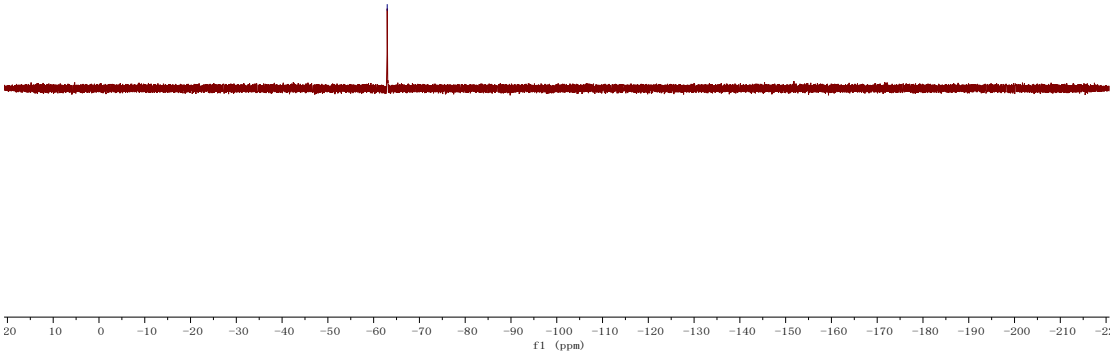
^{13}C NMR
125 MHz
$CDCl_3$

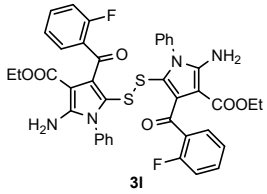


3k



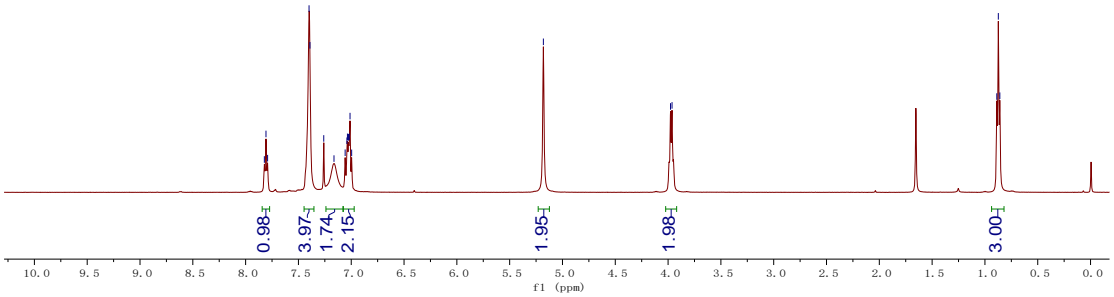
^{19}F NMR
376 MHz
$CDCl_3$

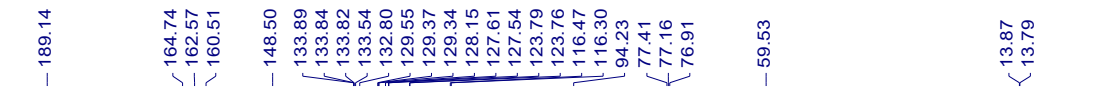


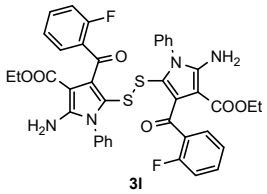


3l

^{1}H NMR
500 MHz
$CDCl_3$

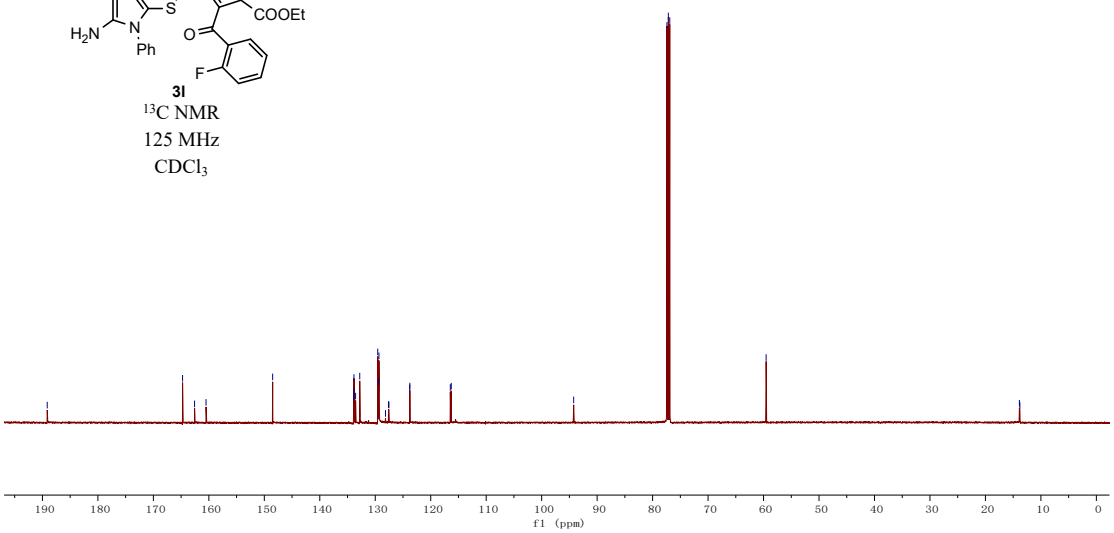


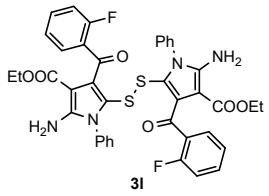




3l

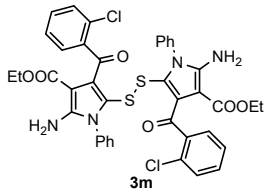
^{13}C NMR
125 MHz
$CDCl_3$



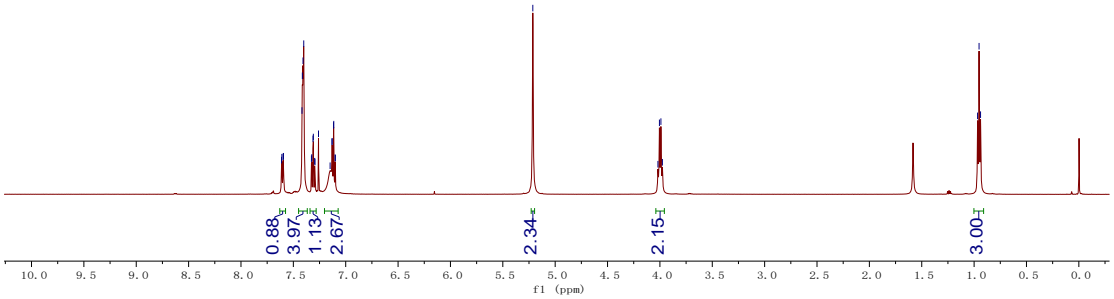


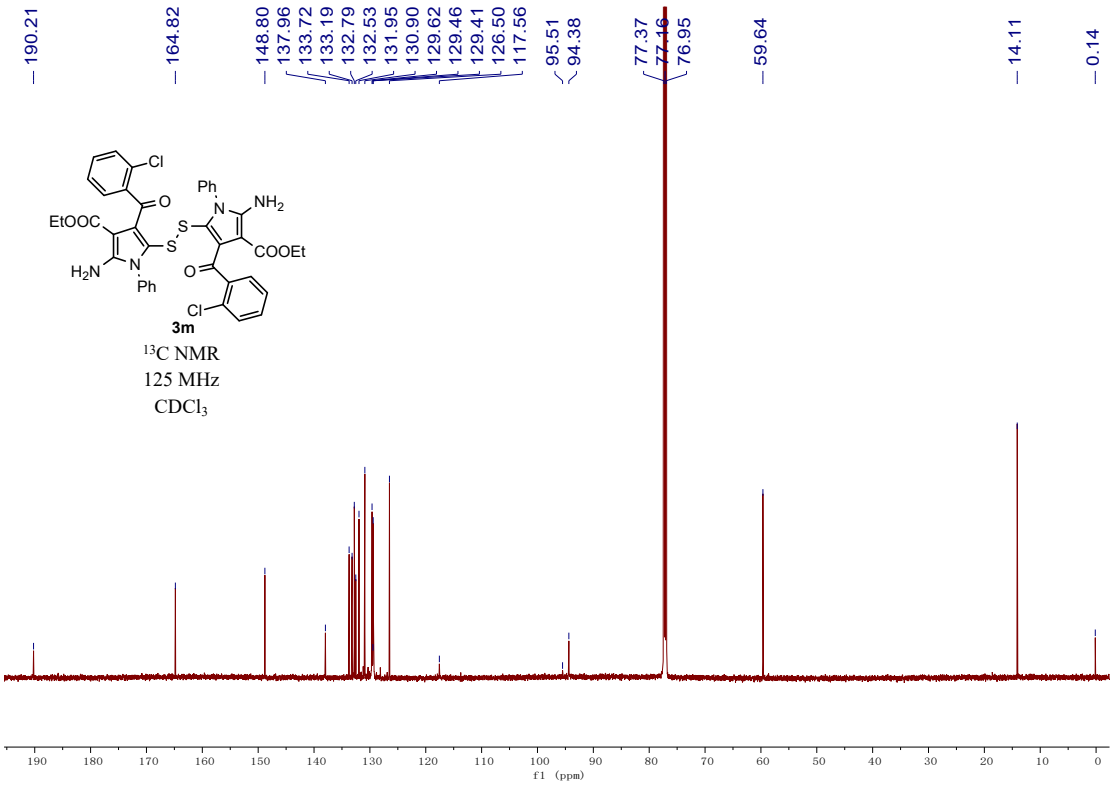
3l

^{19}F NMR
376 MHz
$CDCl_3$

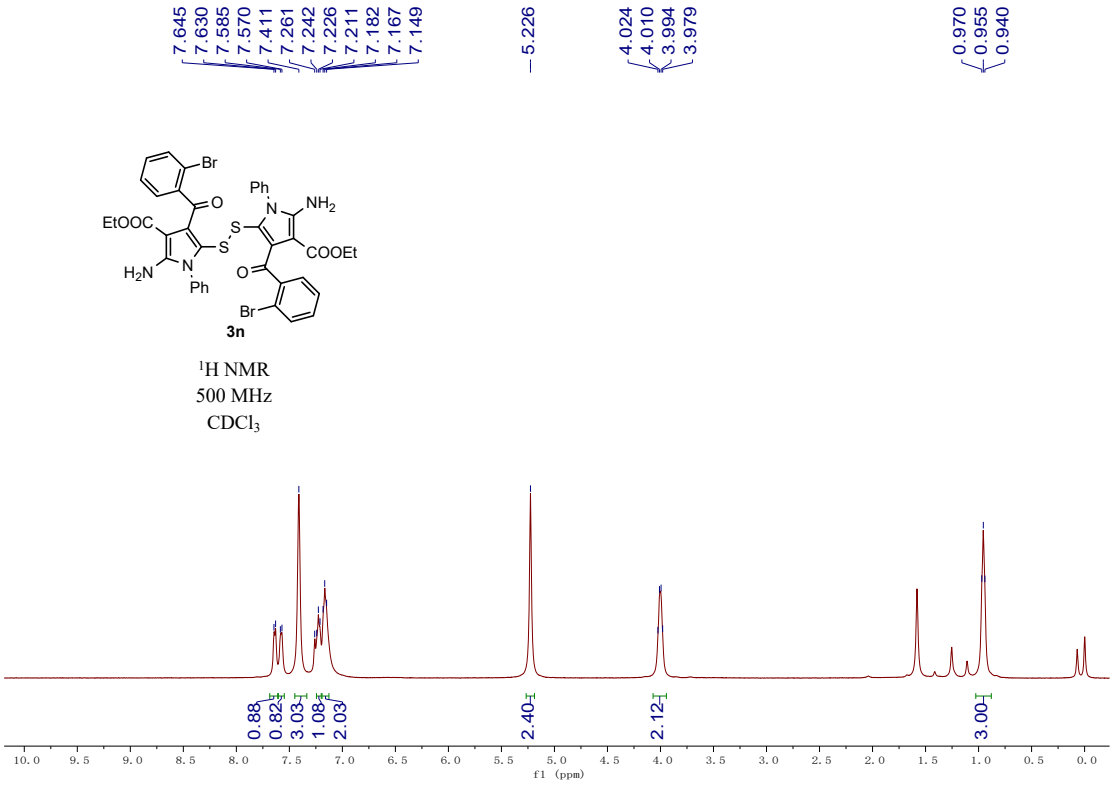


^{1}H NMR
500 MHz
$CDCl_3$

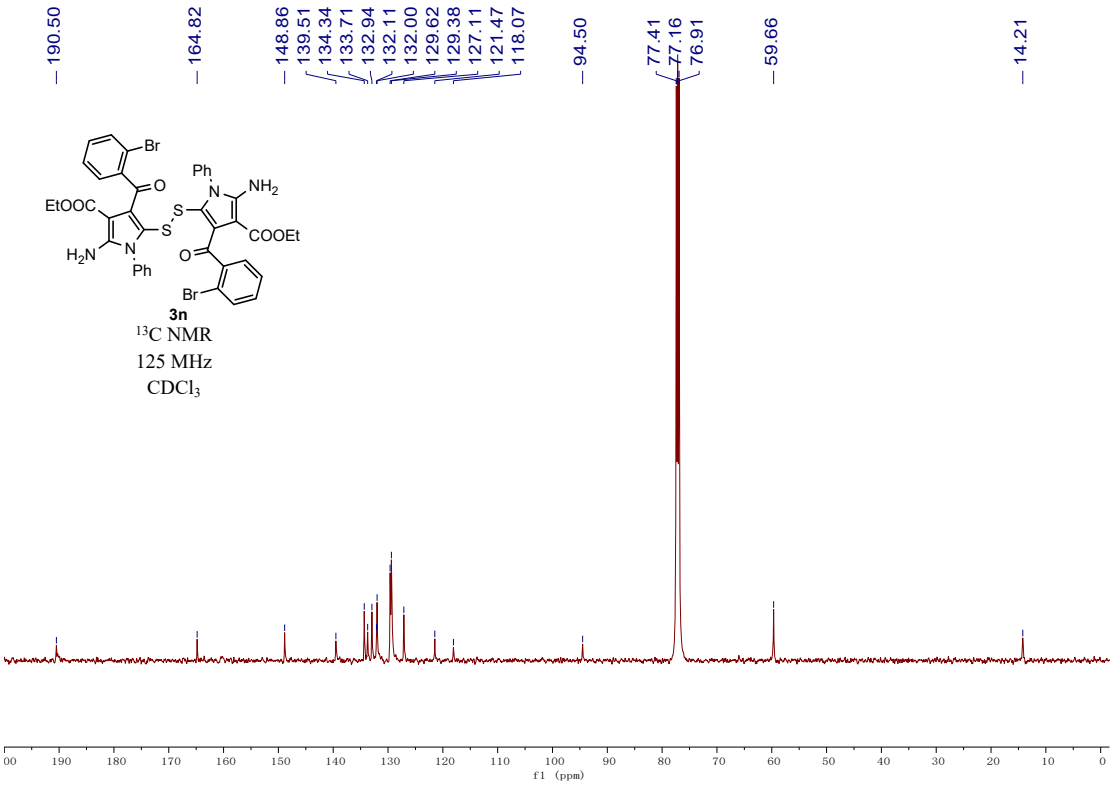




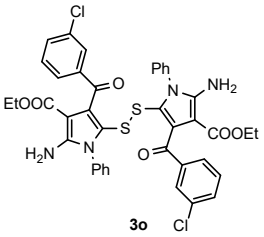
^{13}C NMR
125 MHz
$CDCl_3$



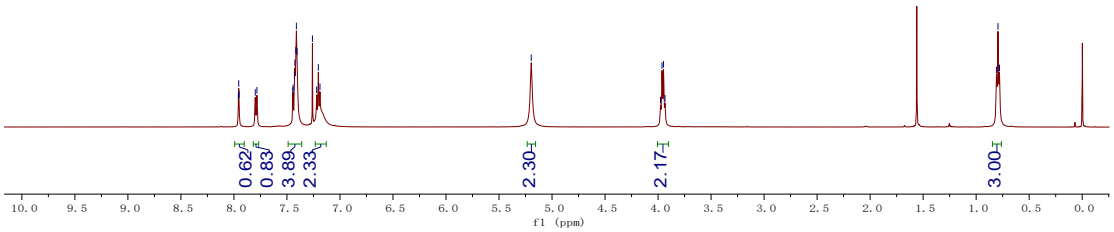
^{1}H NMR
500 MHz
$CDCl_3$

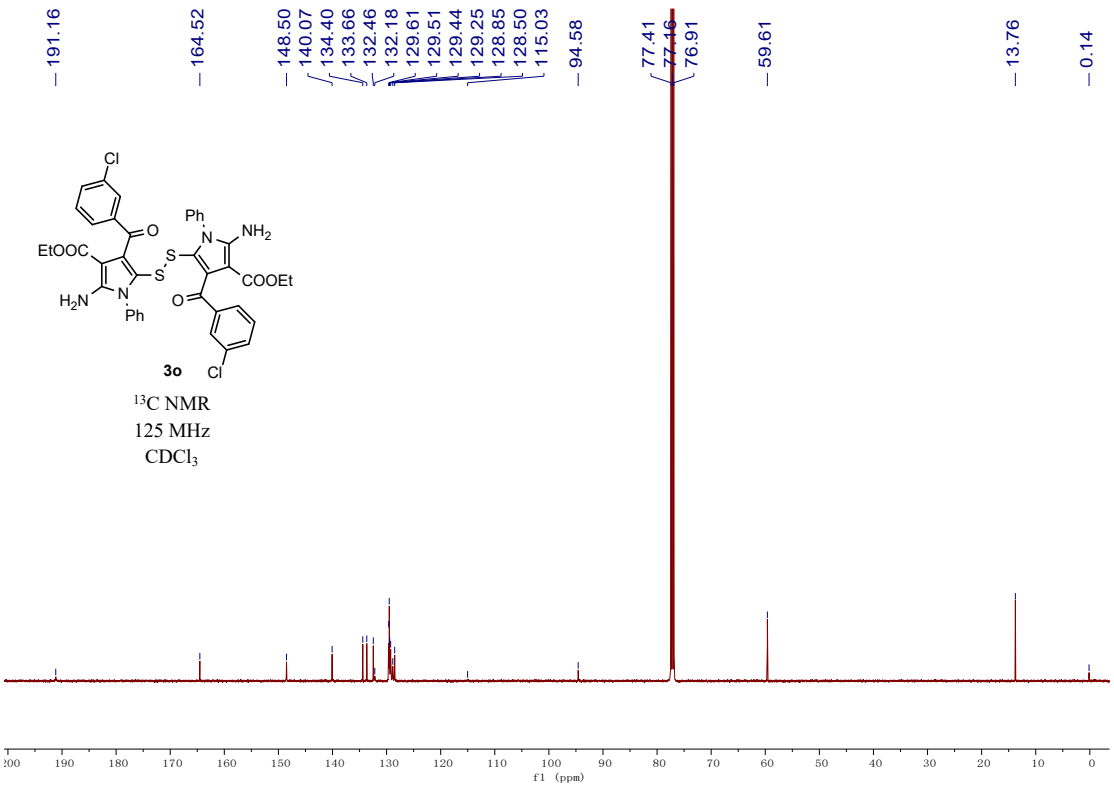


^{13}C NMR
125 MHz
$CDCl_3$

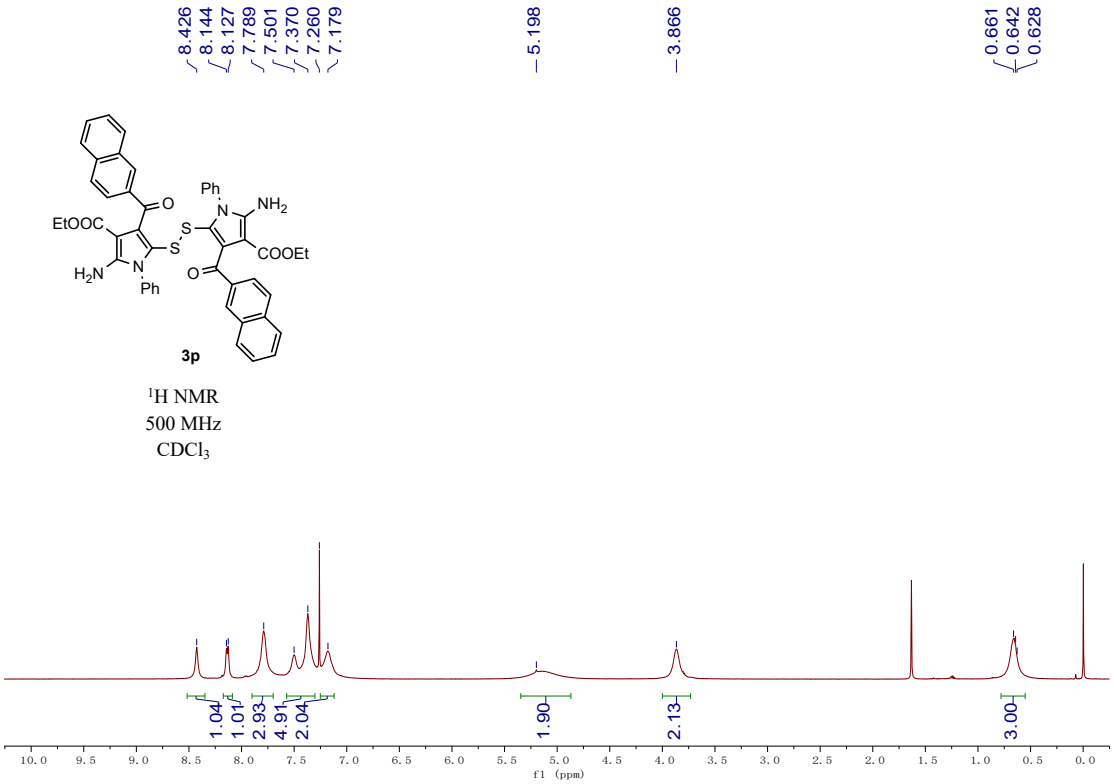


^{1}H NMR
500 MHz
$CDCl_3$



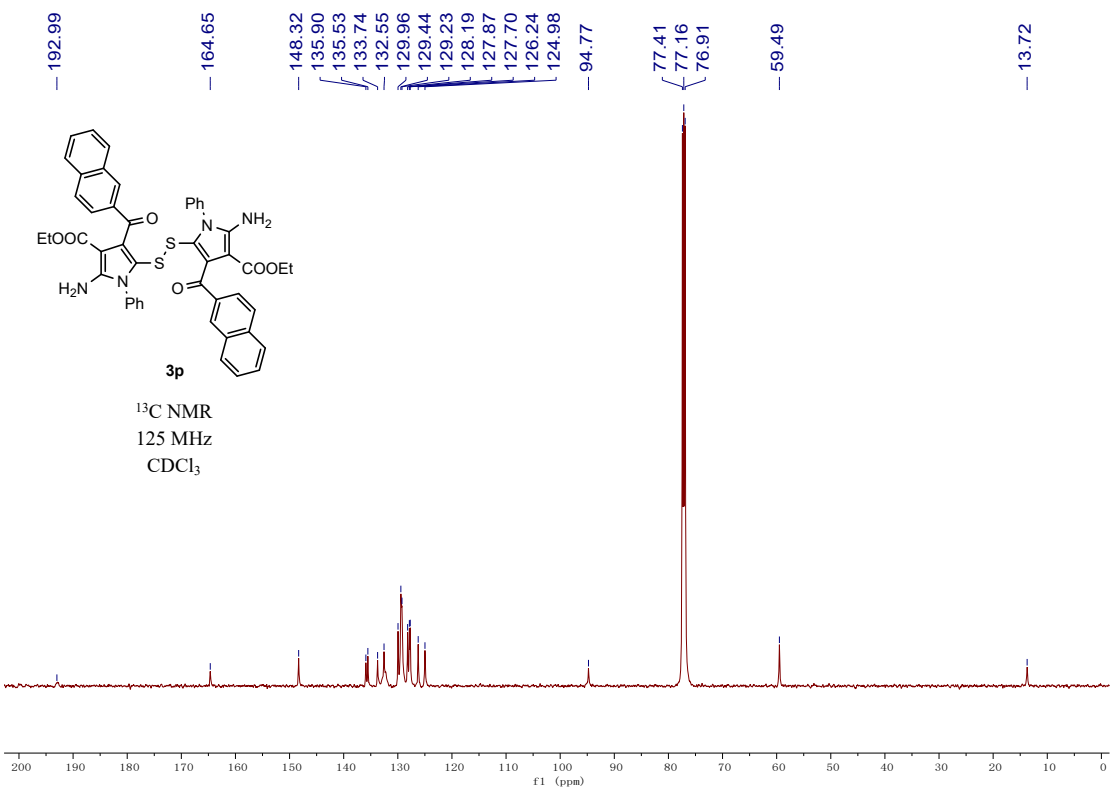


^{13}C NMR
125 MHz
$CDCl_3$



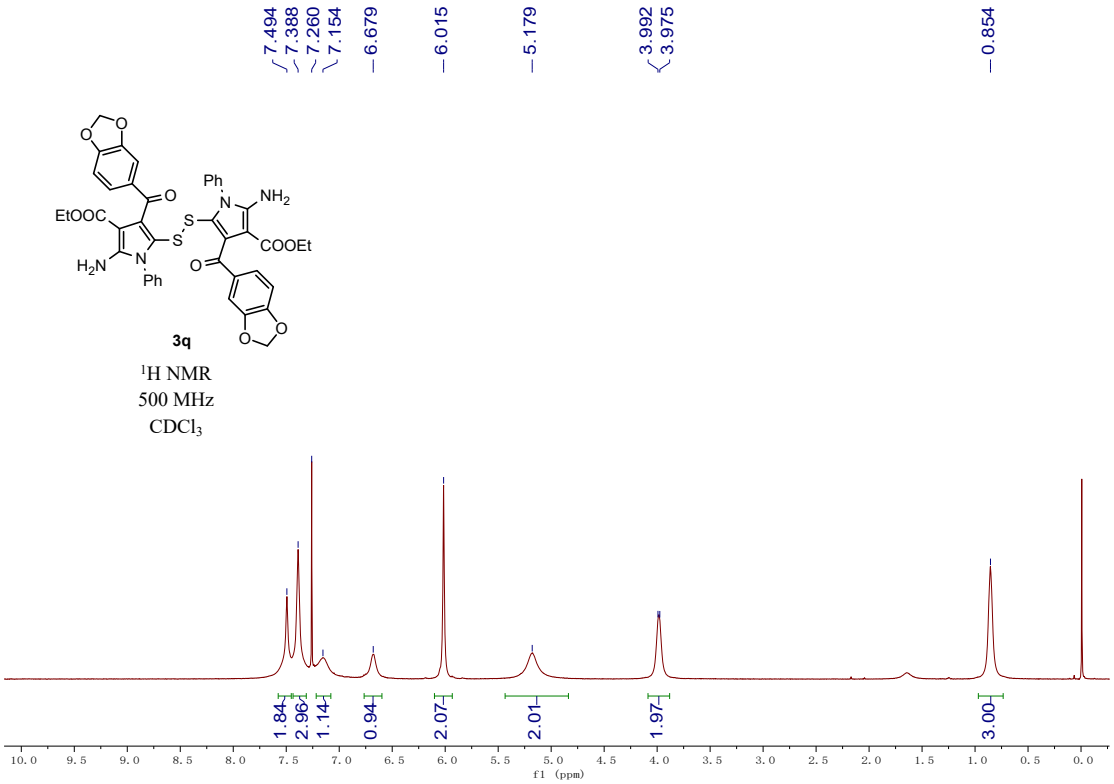
3p

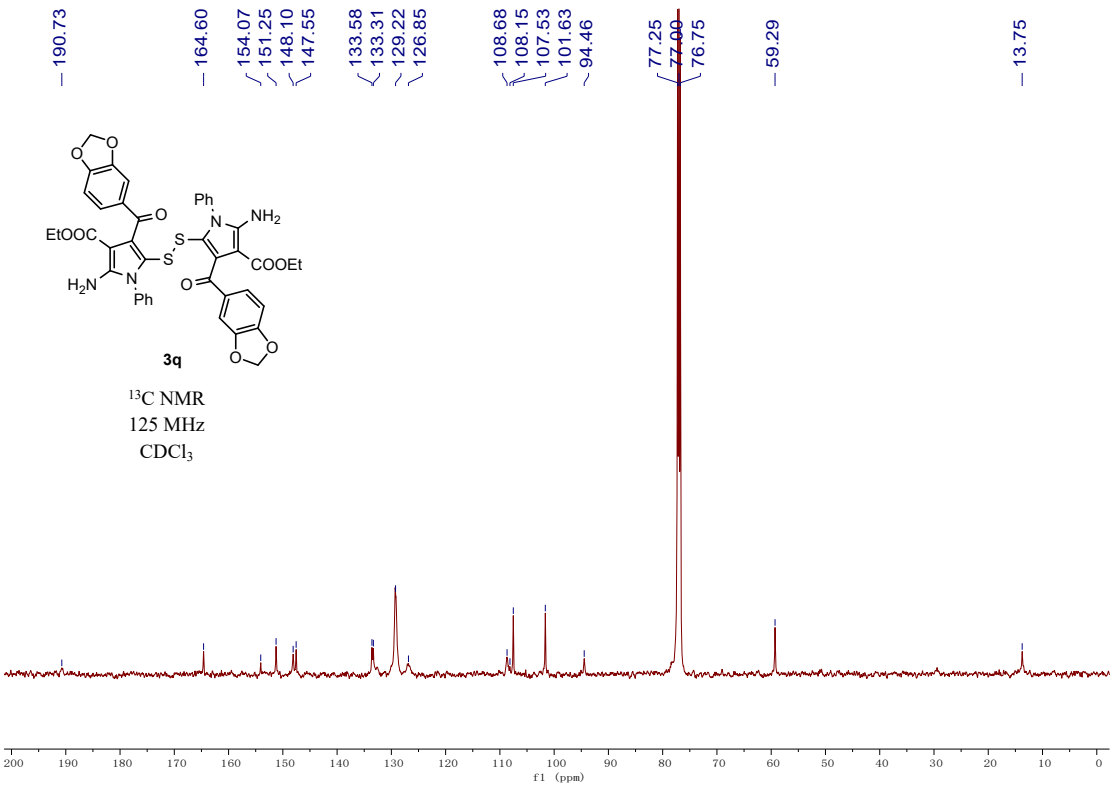
^{1}H NMR
500 MHz
$CDCl_3$

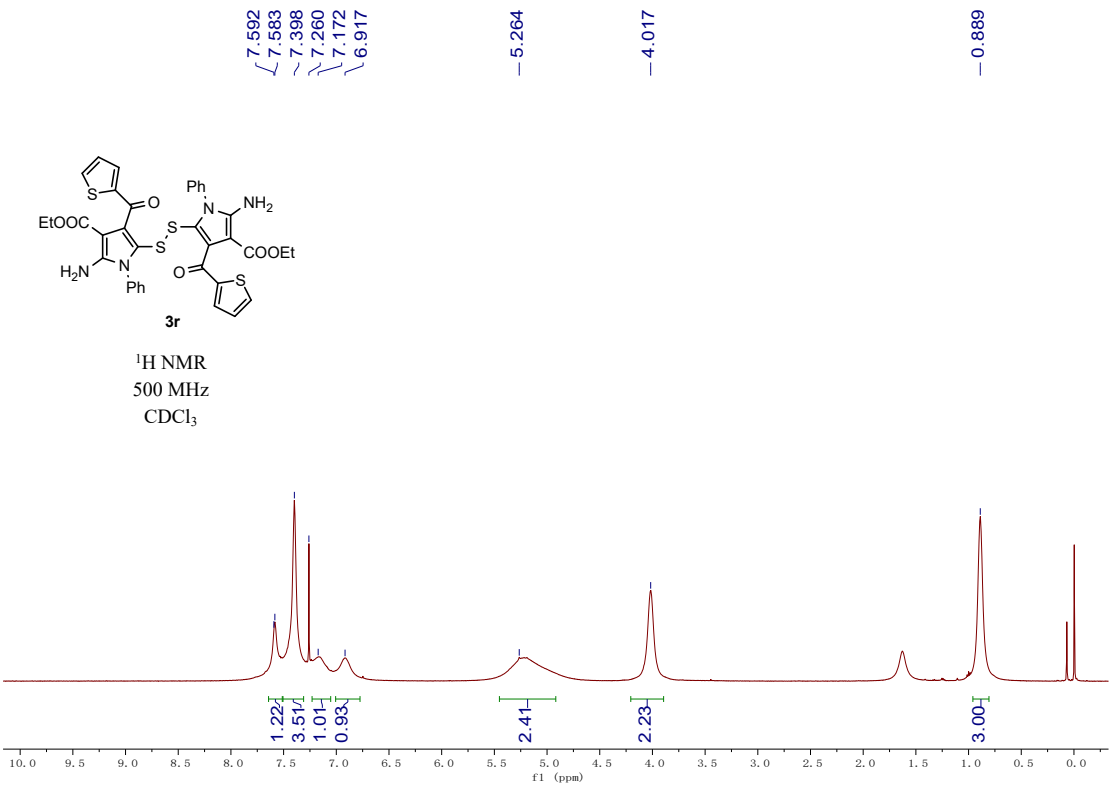


3p

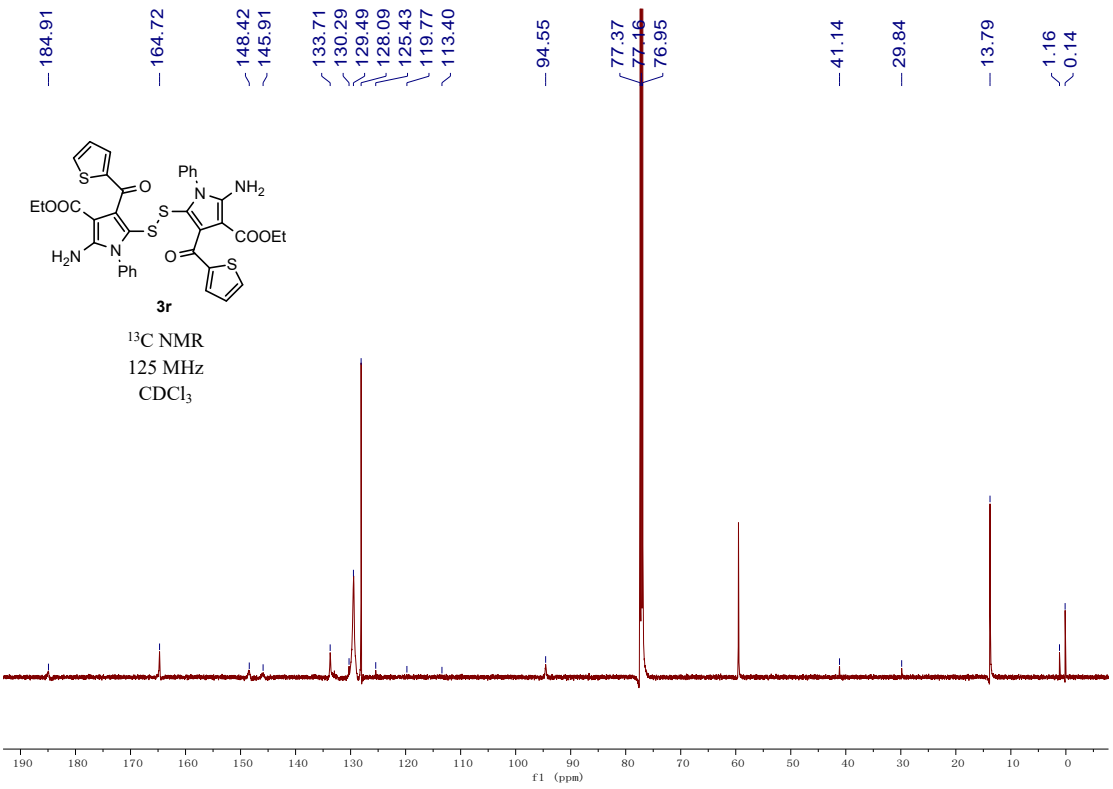
^{13}C NMR
125 MHz
$CDCl_3$


7.494
7.388
7.260
7.154
6.679
6.015
5.179
3.992
3.975
0.854
Ph
NH2
EtOOC
S
S
COOEt
H2N
N
Ph
O
O
O
O
O
3q
1H NMR
500 MHz
CDCl3
1.84
2.96
1.14
0.94
2.07
2.01
1.97
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

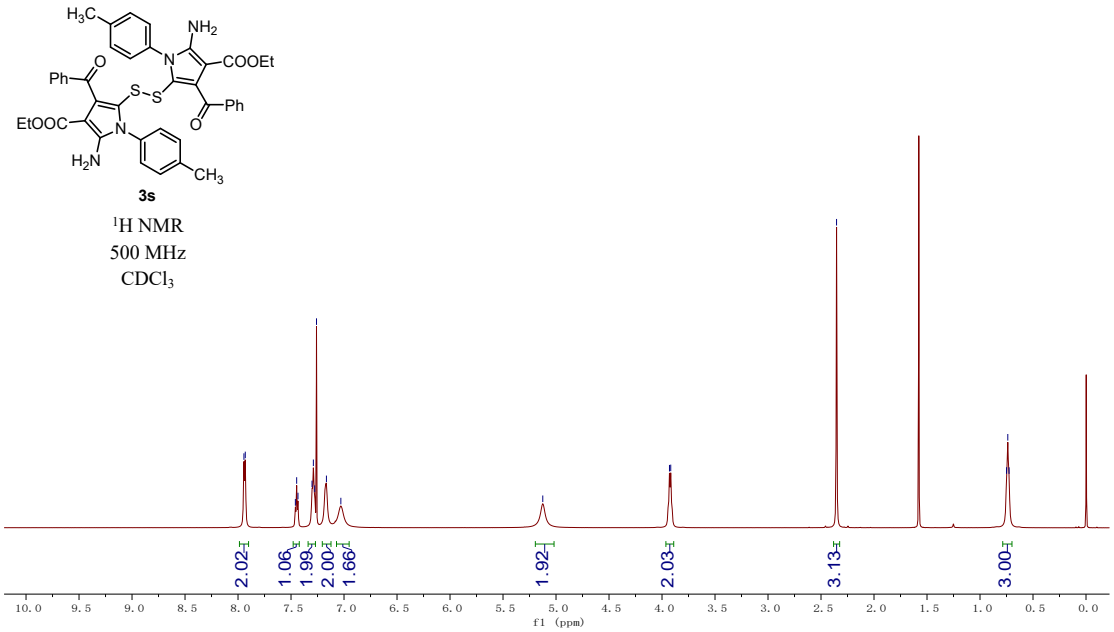

190.73
164.60
154.07
151.25
148.10
147.55
133.58
133.31
129.22
126.85
108.68
108.15
107.53
101.63
94.46
77.25
77.00
76.75
59.29
13.75
Ph
NH2
EtOOC
S
S
COOEt
H2N
N
Ph
O
O
O
O
O
3q
13C NMR
125 MHz
CDCl3
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



^{1}H NMR
500 MHz
$CDCl_3$

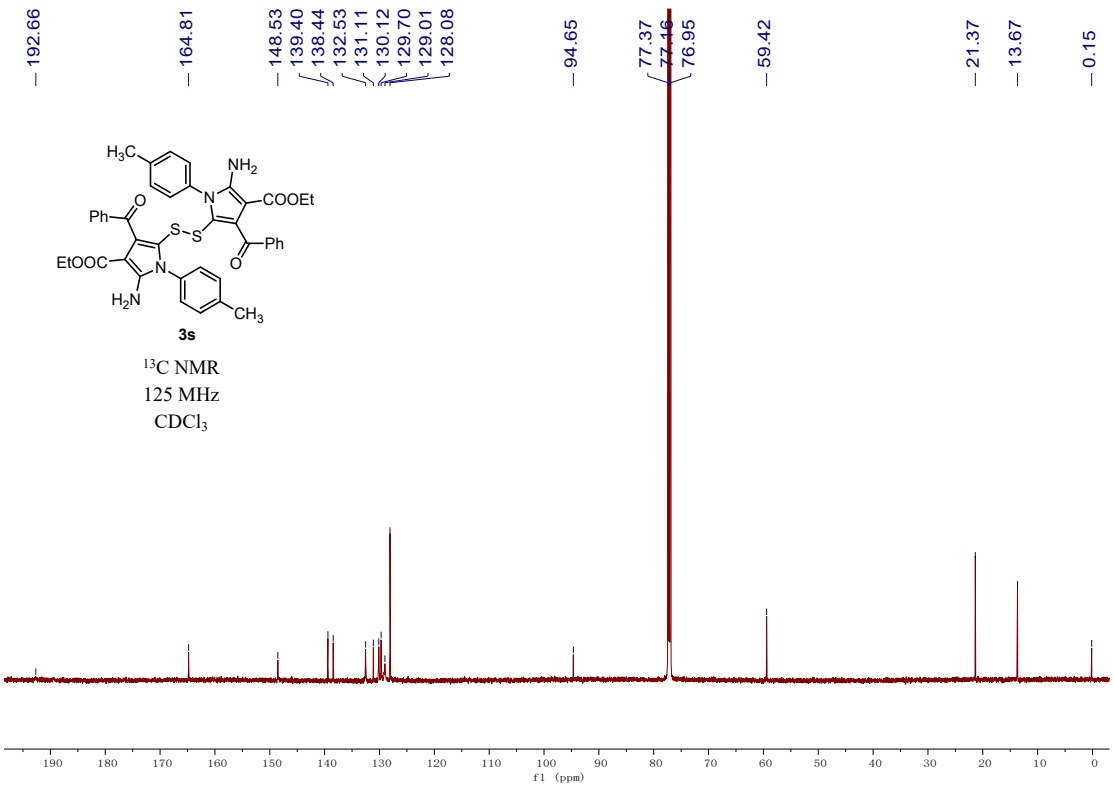


^{13}C NMR
125 MHz
$CDCl_3$



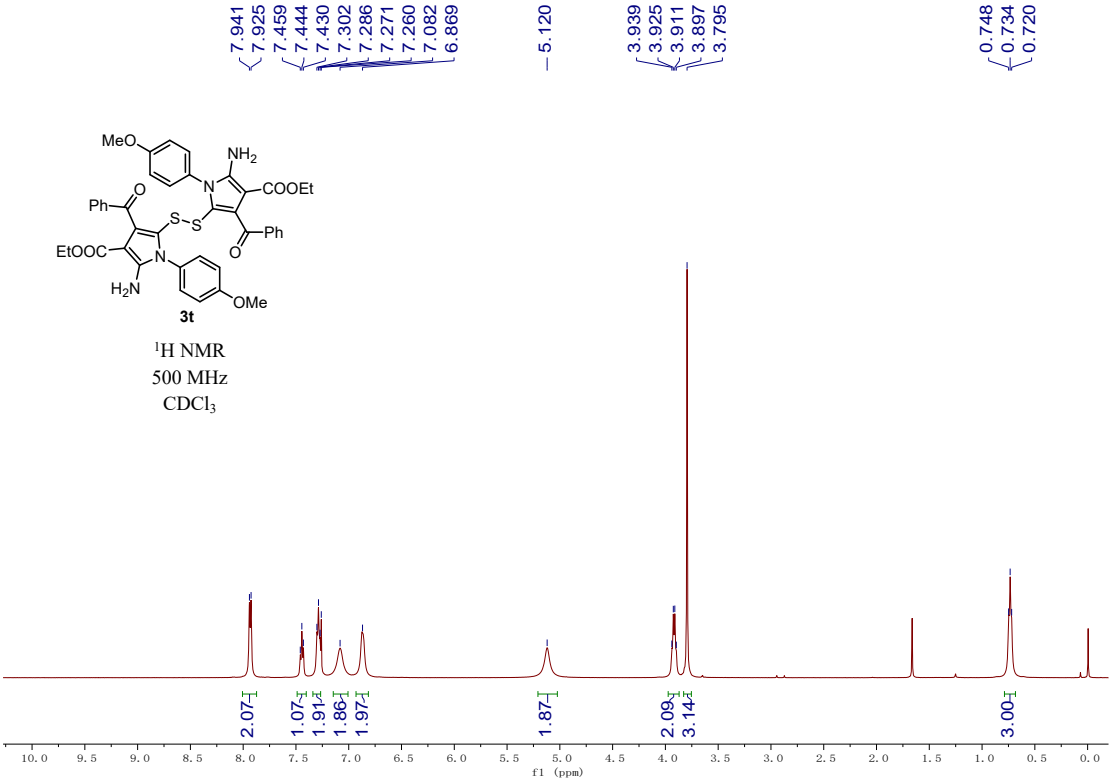
3s

^{1}H NMR
500 MHz
$CDCl_3$

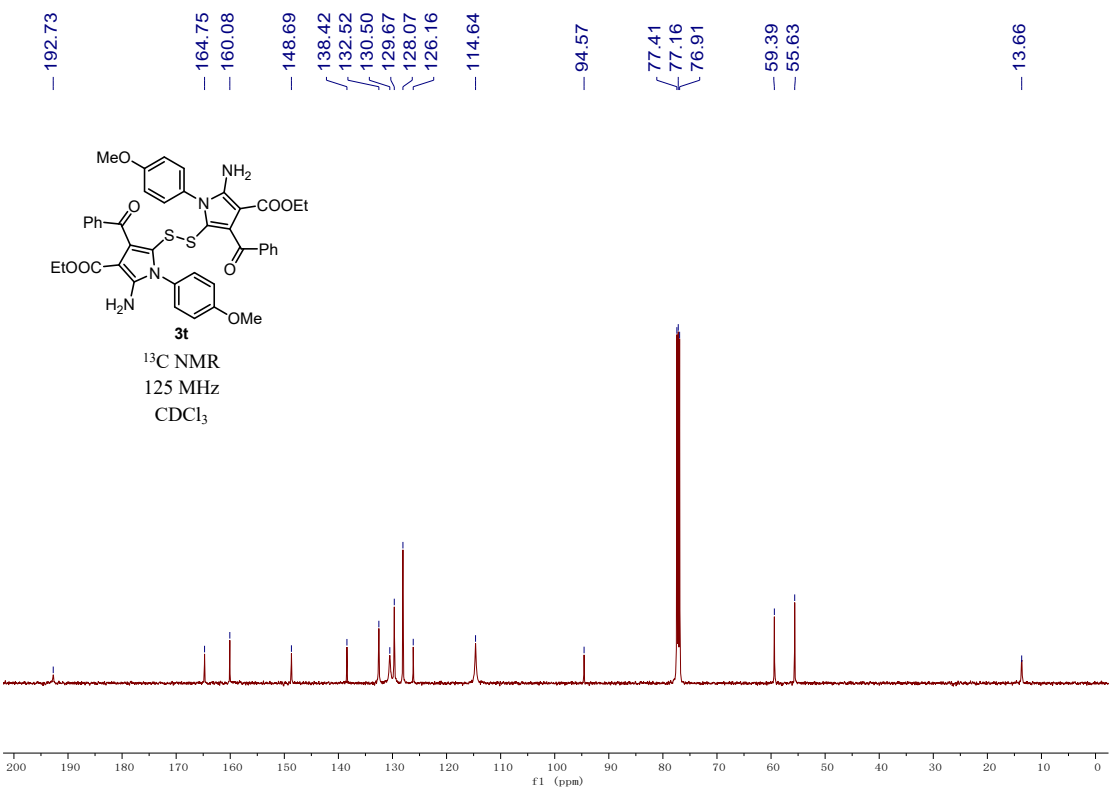


3s

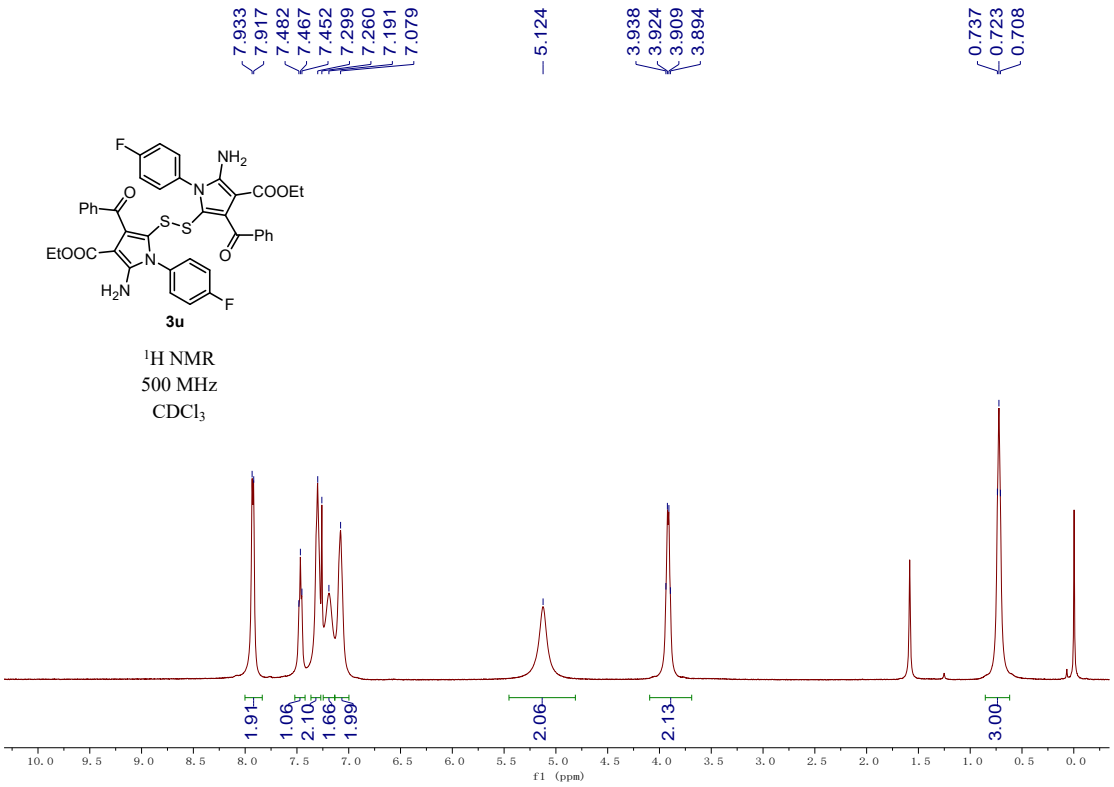
^{13}C NMR
125 MHz
$CDCl_3$

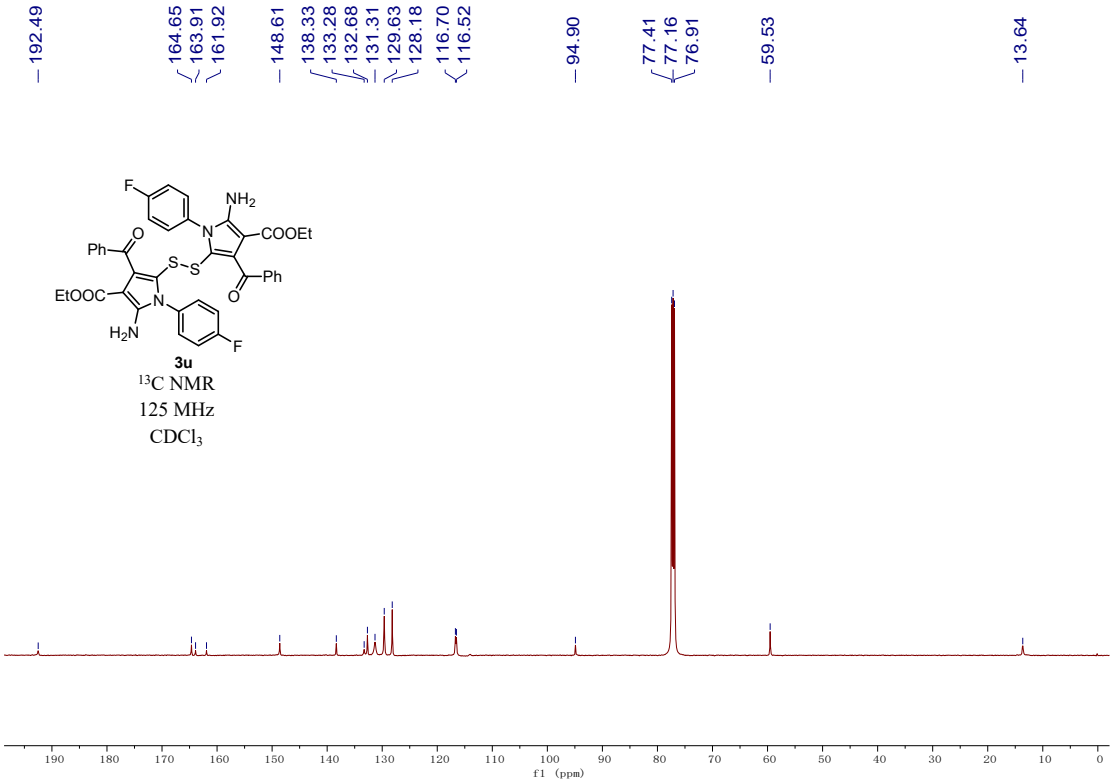


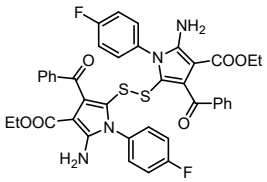
^{1}H NMR
500 MHz
$CDCl_3$



^{13}C NMR
125 MHz
$CDCl_3$


7.933
7.917
7.482
7.467
7.452
7.299
7.260
7.191
7.079
5.124
3.938
3.924
3.909
3.894
0.737
0.723
0.708
F
NH2
COOEt
Ph
O
N
S
S
Ph
O
EtOOC
N
H2N
F
3u
1H NMR
500 MHz
CDCl3
1.91
1.06
2.10
1.66
1.99
2.06
2.13
3.00
f1 (ppm)


192.49
164.65
163.91
161.92
148.61
138.33
133.28
132.68
131.31
129.63
128.18
116.70
116.52
94.90
77.41
77.16
76.91
59.53
13.64
F
NH2
COOEt
Ph
O
N
S
S
Ph
O
EtOOC
N
H2N
F
3u
13C NMR
125 MHz
CDCl3
f1 (ppm)

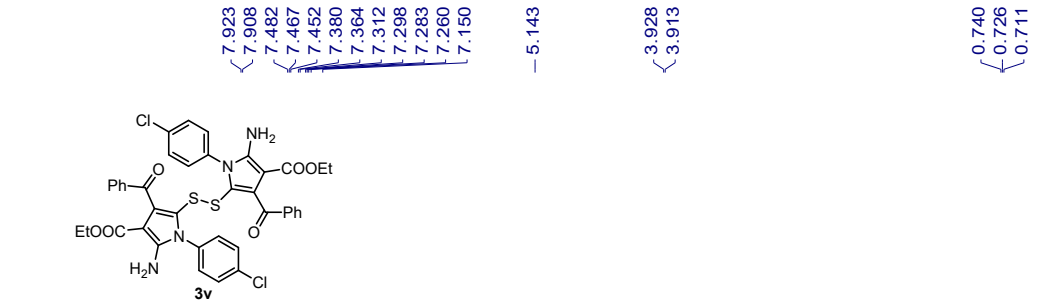


3u

^{19}F NMR

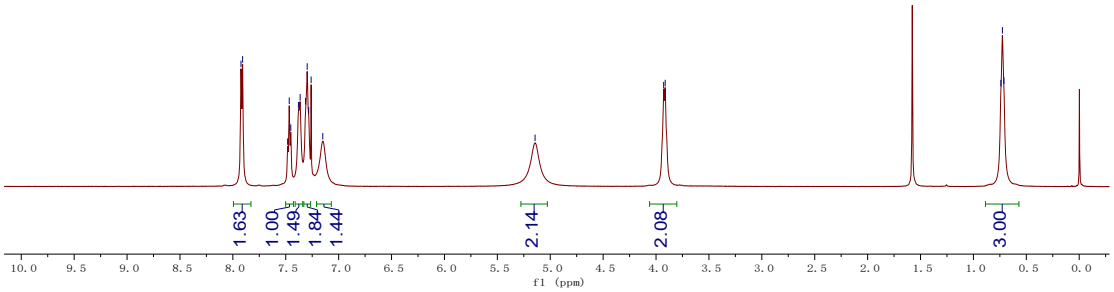
376 MHz

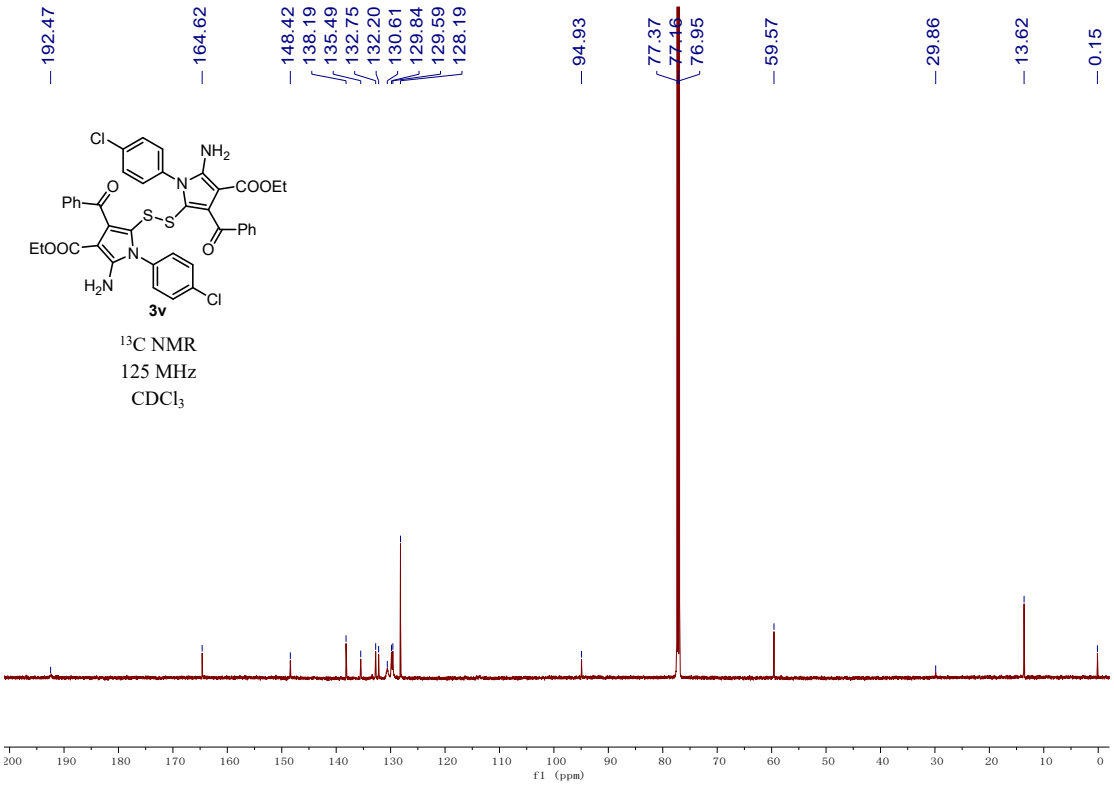
$CDCl_3$



3v

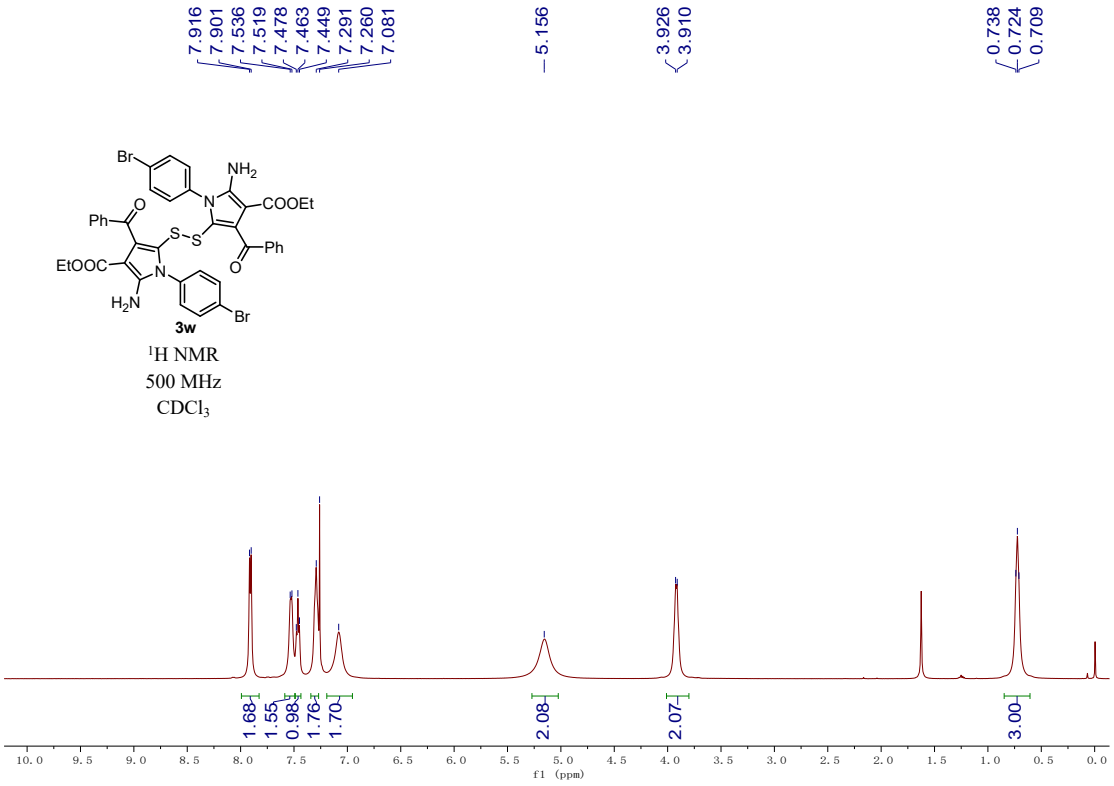
^{1}H NMR
500 MHz
$CDCl_3$



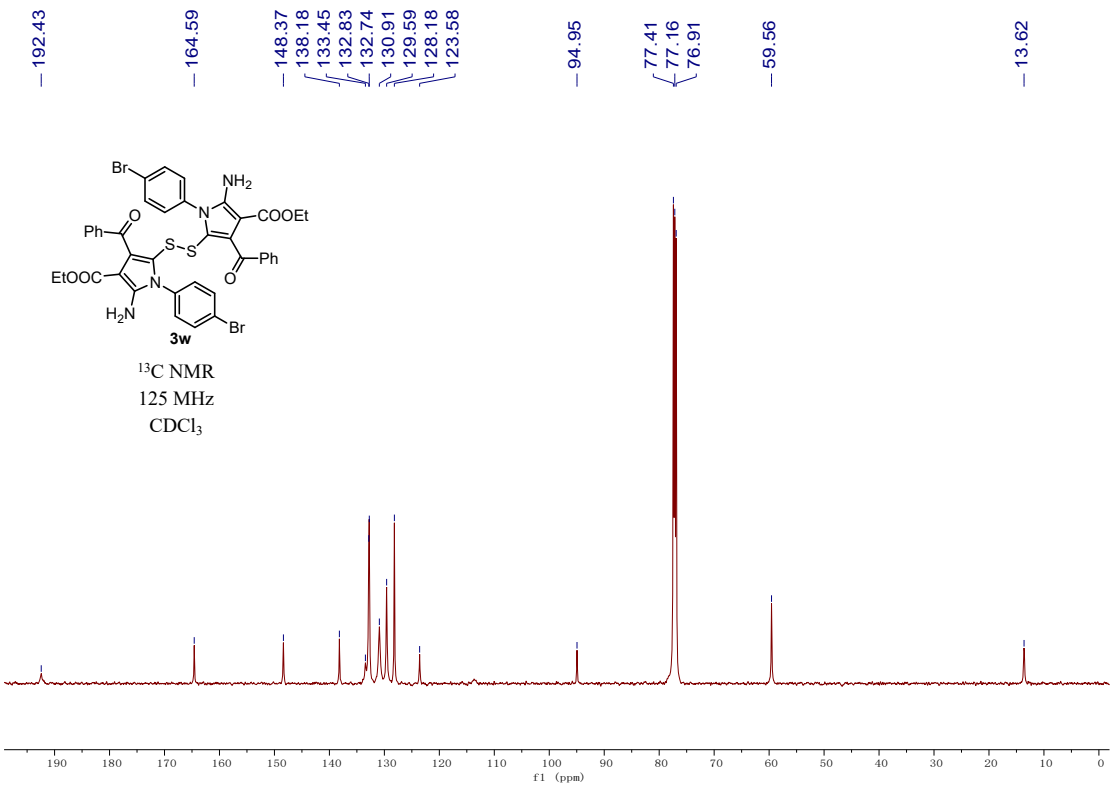


3v

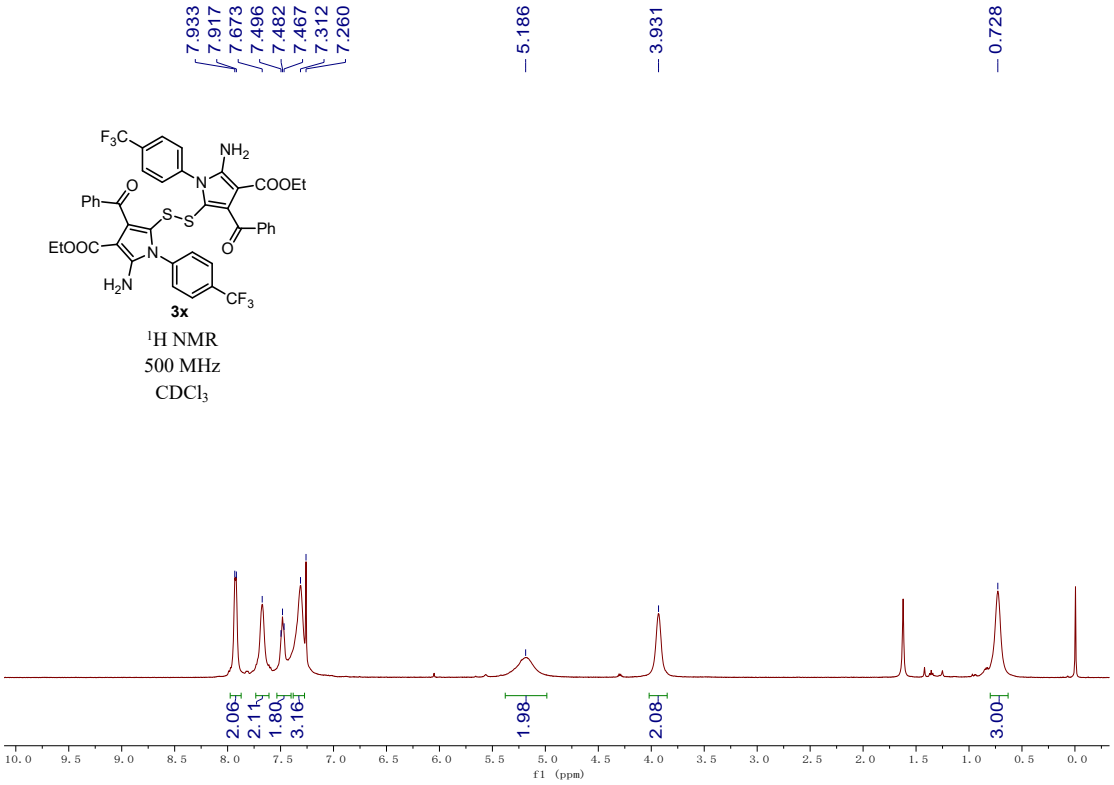
^{13}C NMR
125 MHz
$CDCl_3$



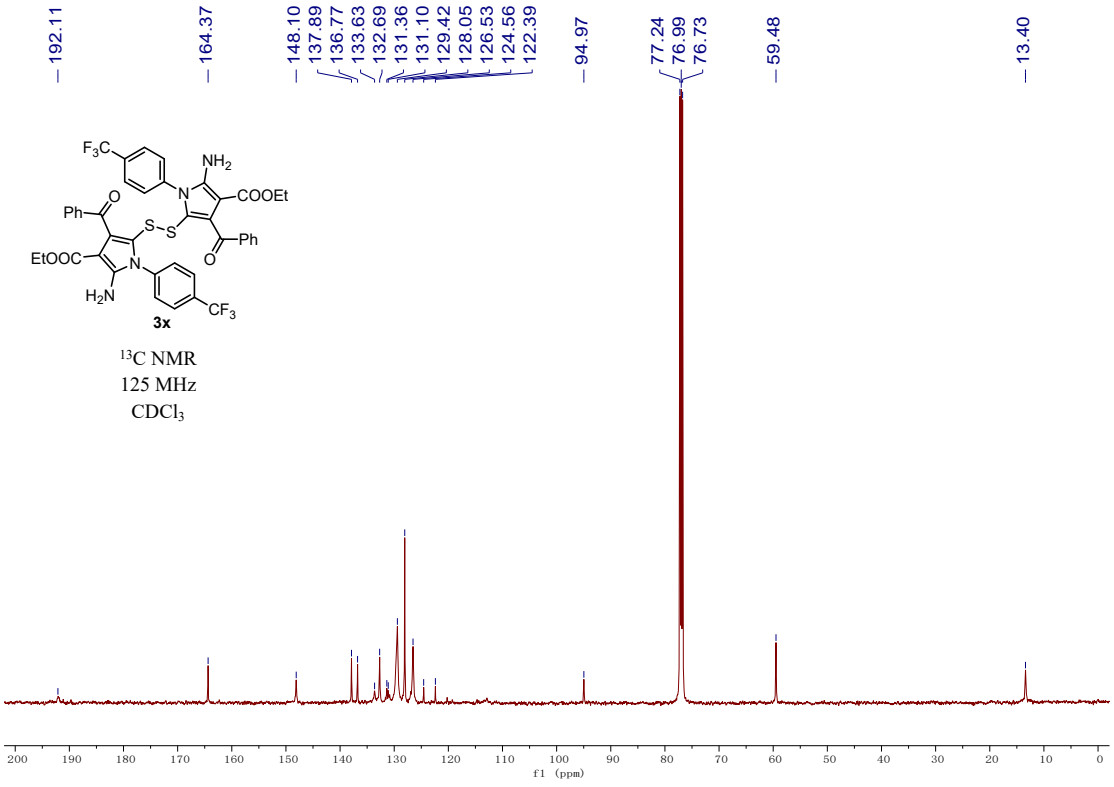
^{1}H NMR
500 MHz
$CDCl_3$



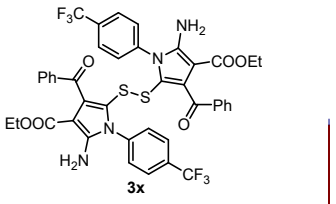
^{13}C NMR
125 MHz
$CDCl_3$



^{1}H NMR
500 MHz
$CDCl_3$

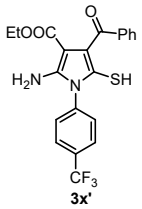


^{13}C NMR
125 MHz
$CDCl_3$



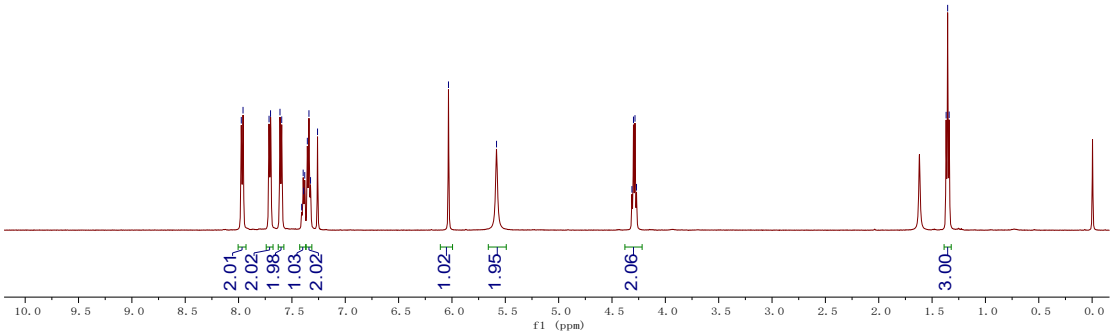
3x

^{19}F NMR
376 MHz
$CDCl_3$

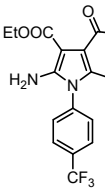


3x'

^{1}H NMR
500 MHz
$CDCl_3$

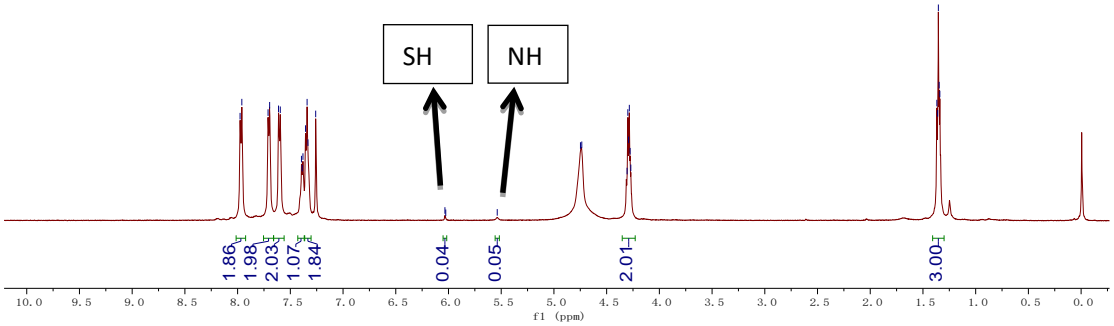


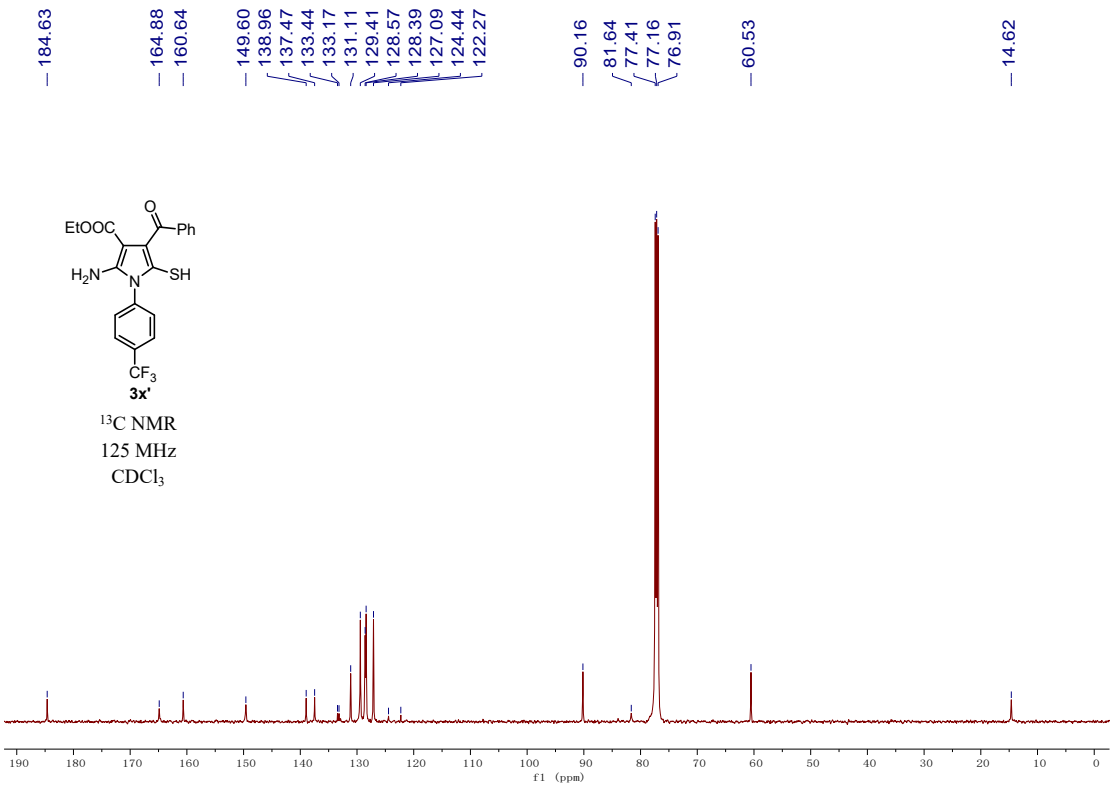
3x' (exchanged with D_2O)

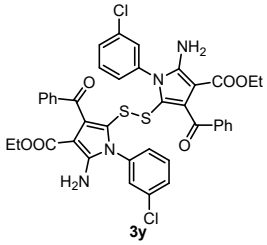


3x'

^{1}H NMR
500 MHz
$CDCl_3$

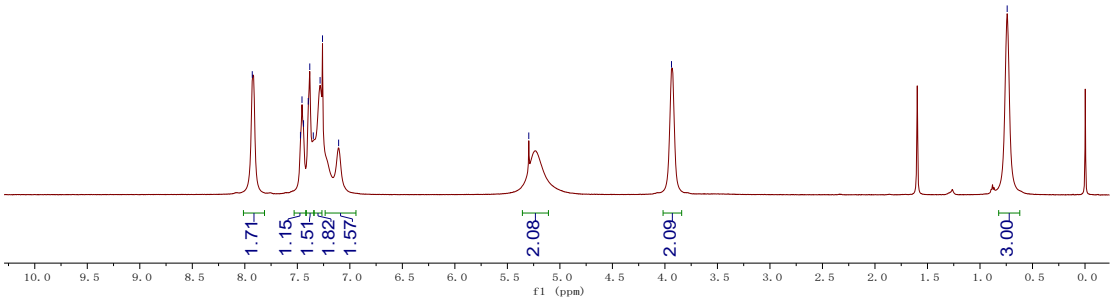


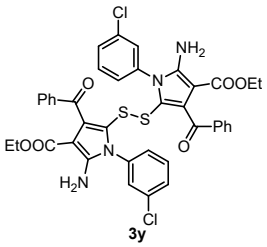

184.63
164.88
160.64
149.60
138.96
137.47
133.44
133.17
131.11
129.41
128.57
128.39
127.09
124.44
122.27
90.16
81.64
77.41
77.16
76.91
60.53
14.62
EtOOC
O
Ph
H2N
N
SH
CF3
3x'
13C NMR
125 MHz
CDCl3
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



3y

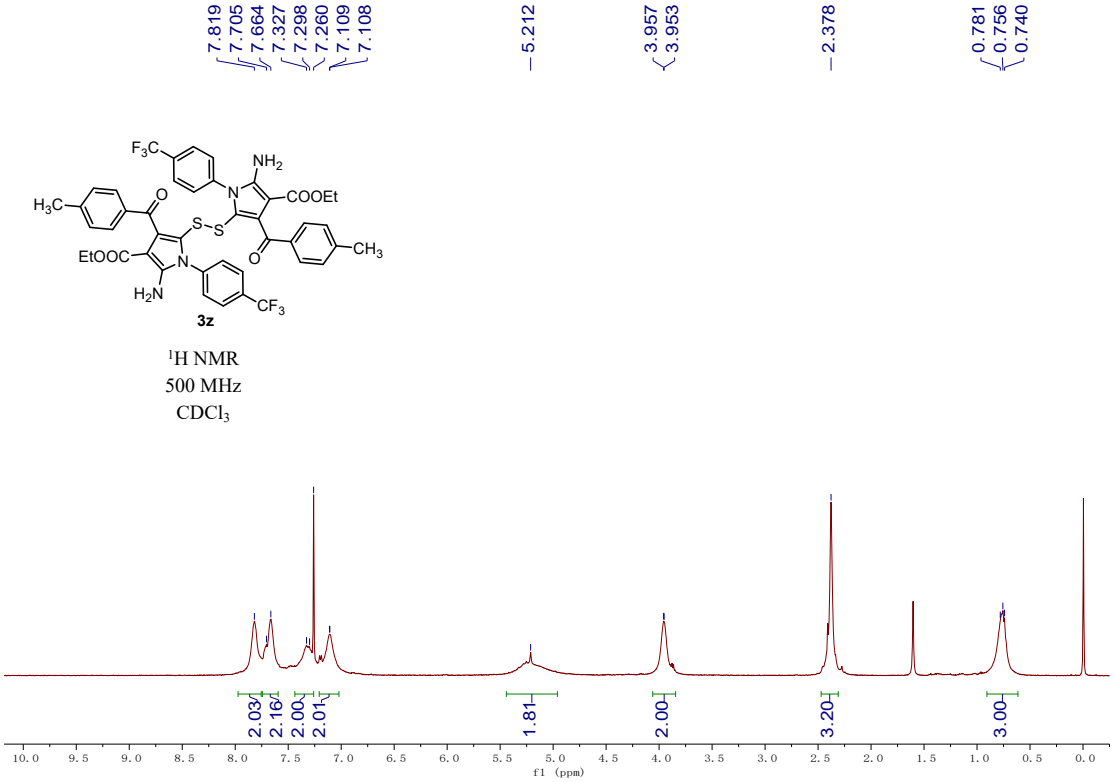
^{1}H NMR
500 MHz
$CDCl_3$



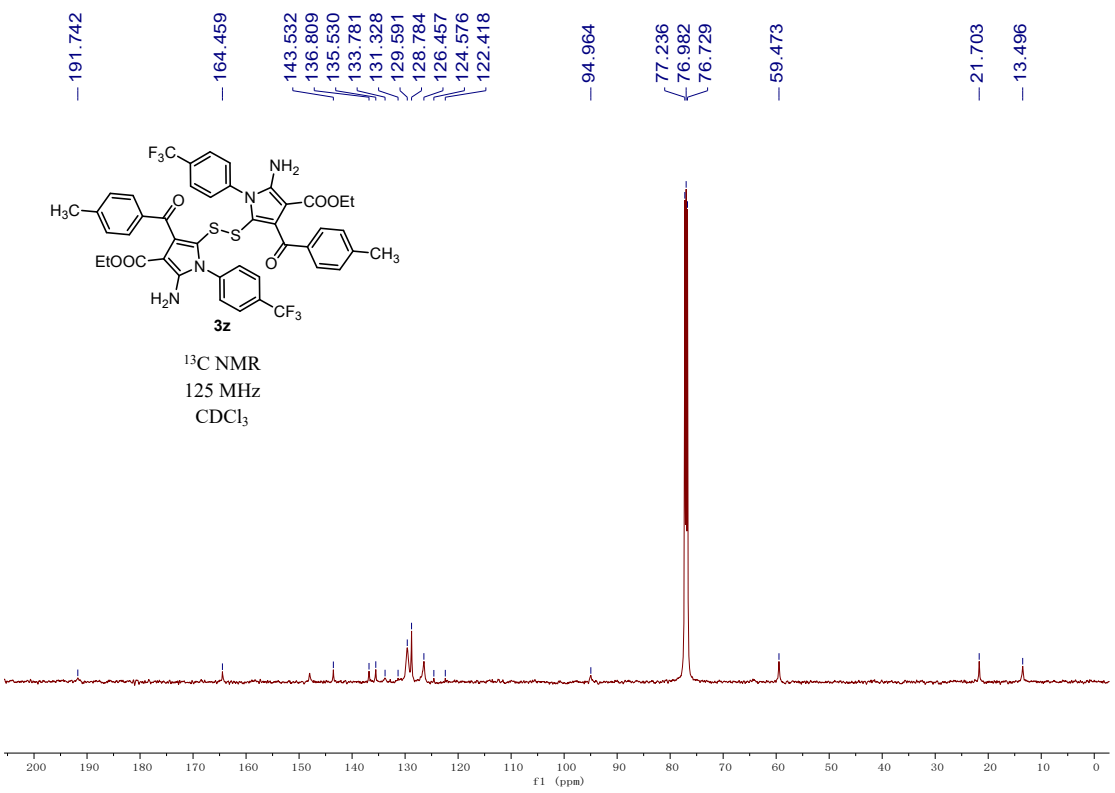


3y

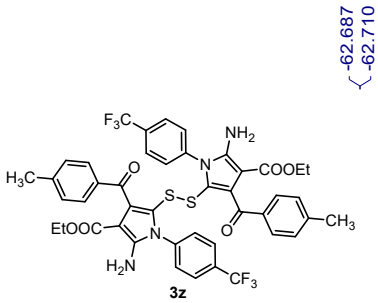
^{13}C NMR
125 MHz
$CDCl_3$



^{1}H NMR
500 MHz
$CDCl_3$

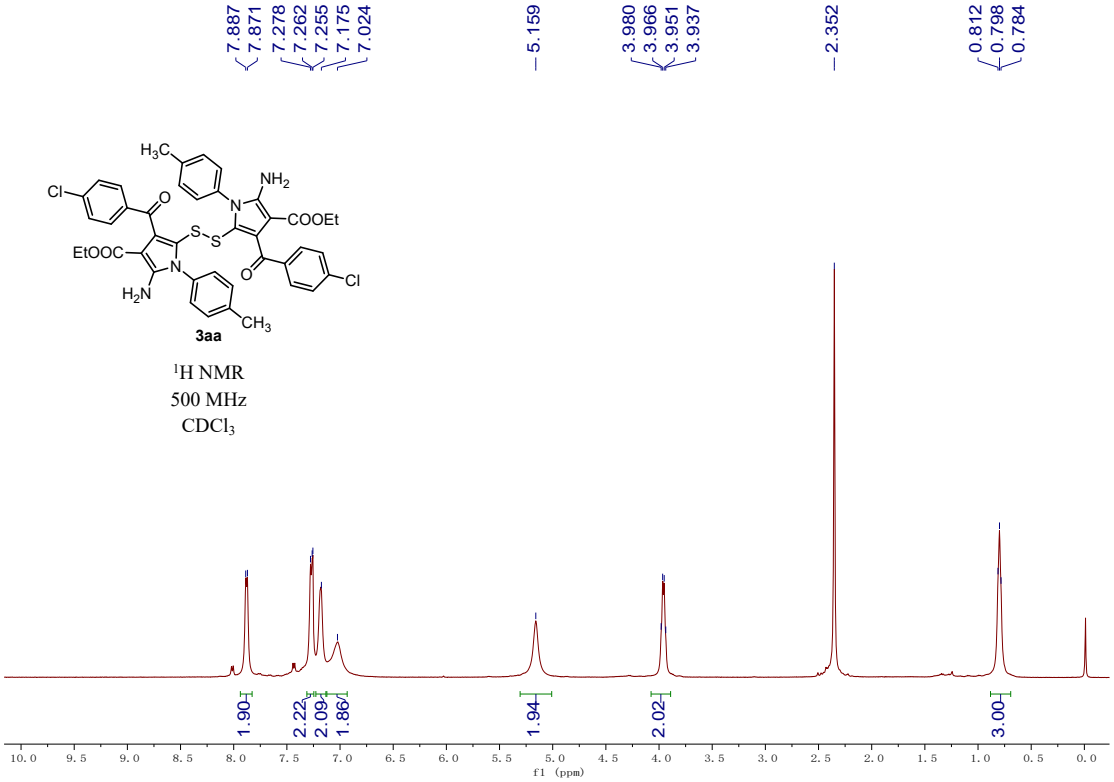


^{13}C NMR
125 MHz
$CDCl_3$

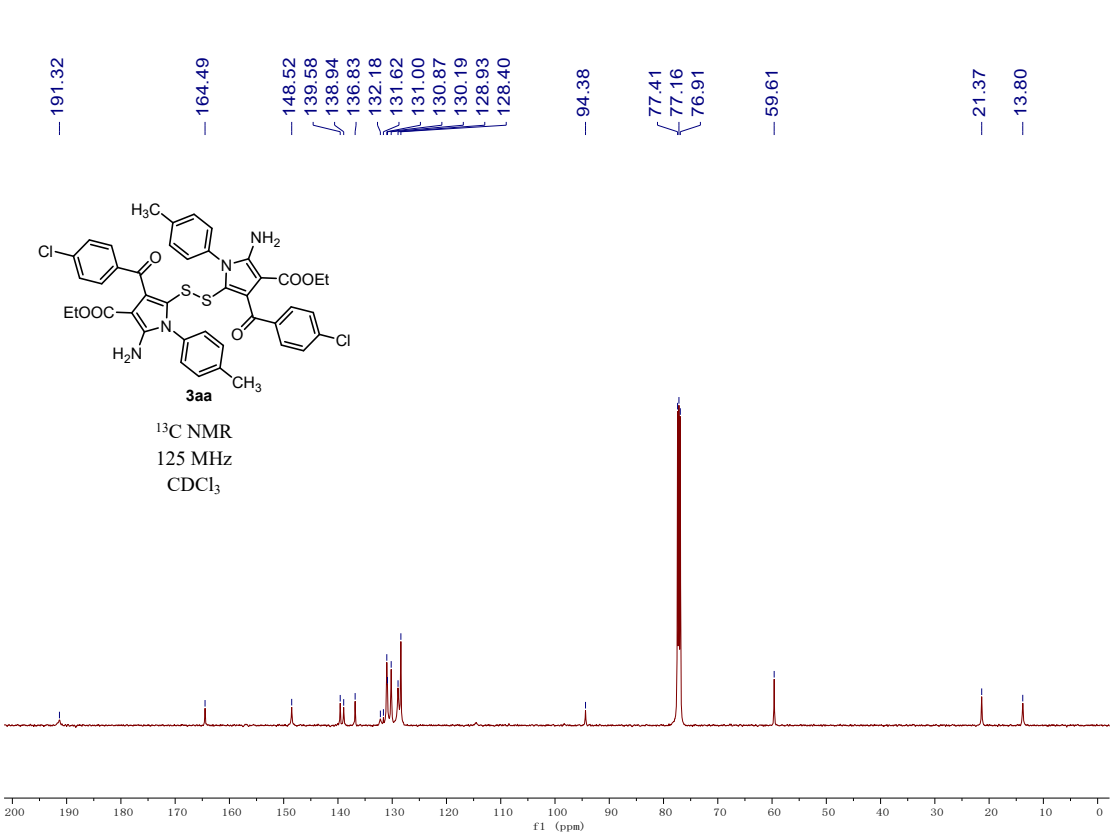


3z

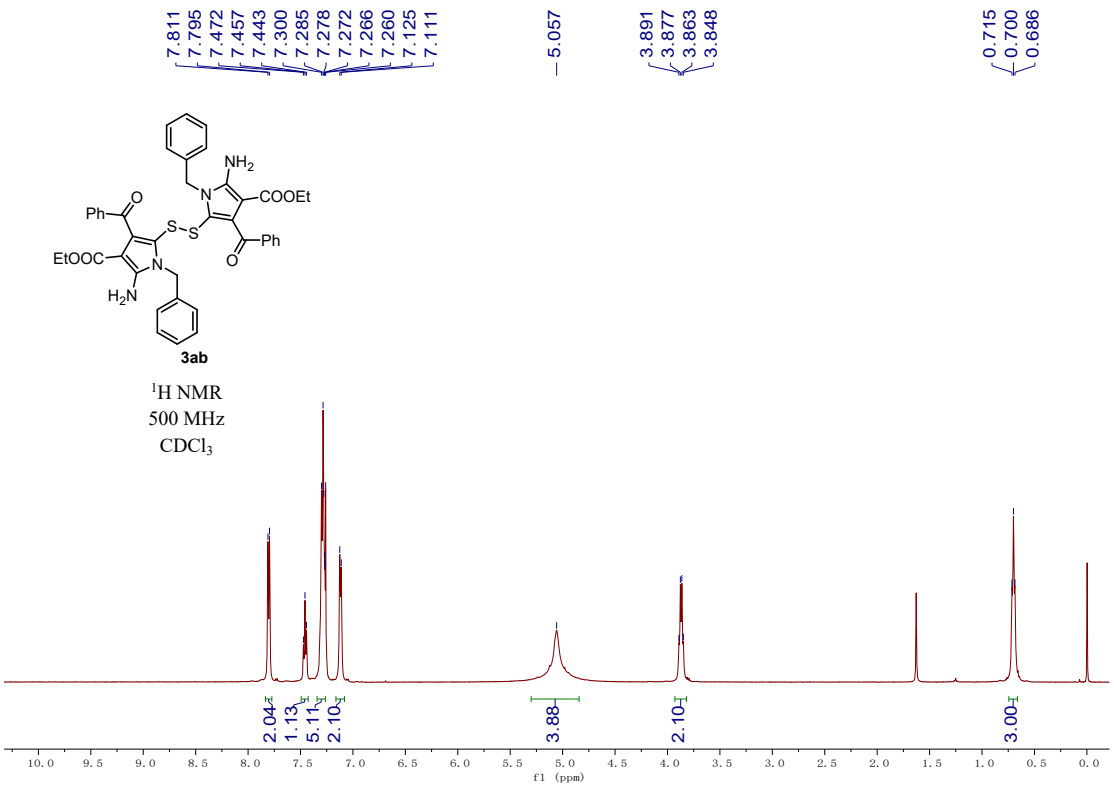
^{19}F NMR
376 MHz
$CDCl_3$

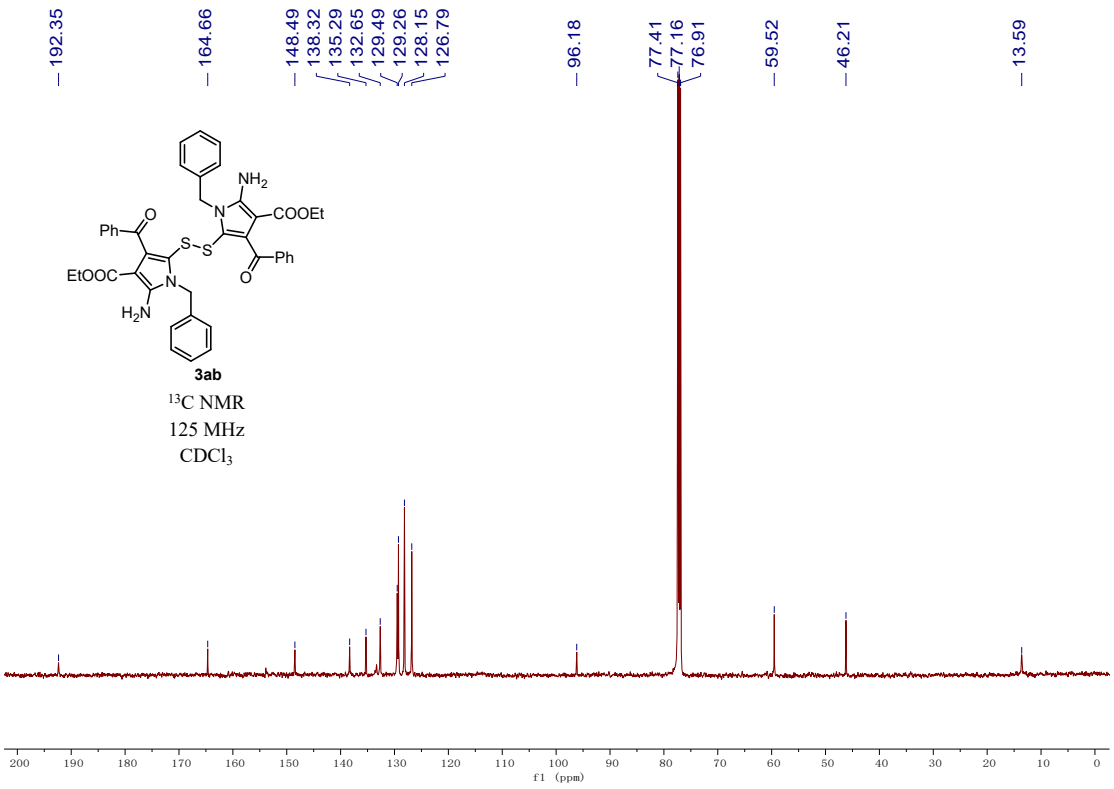


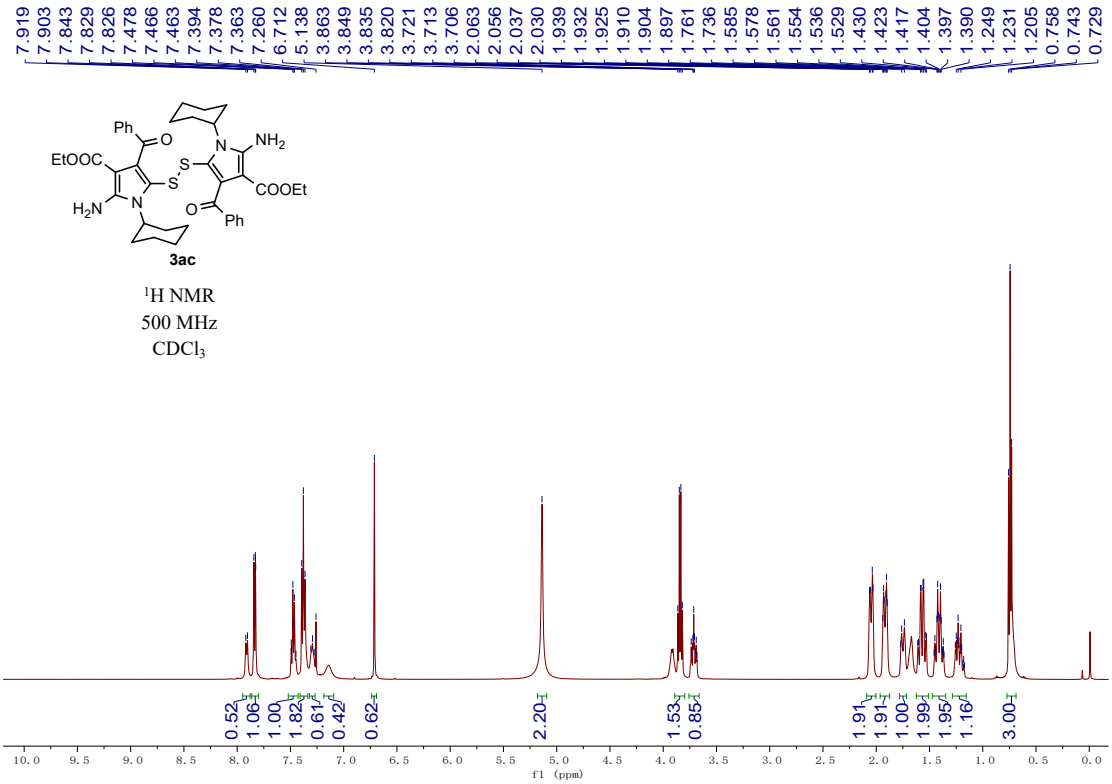
^{1}H NMR
500 MHz
$CDCl_3$



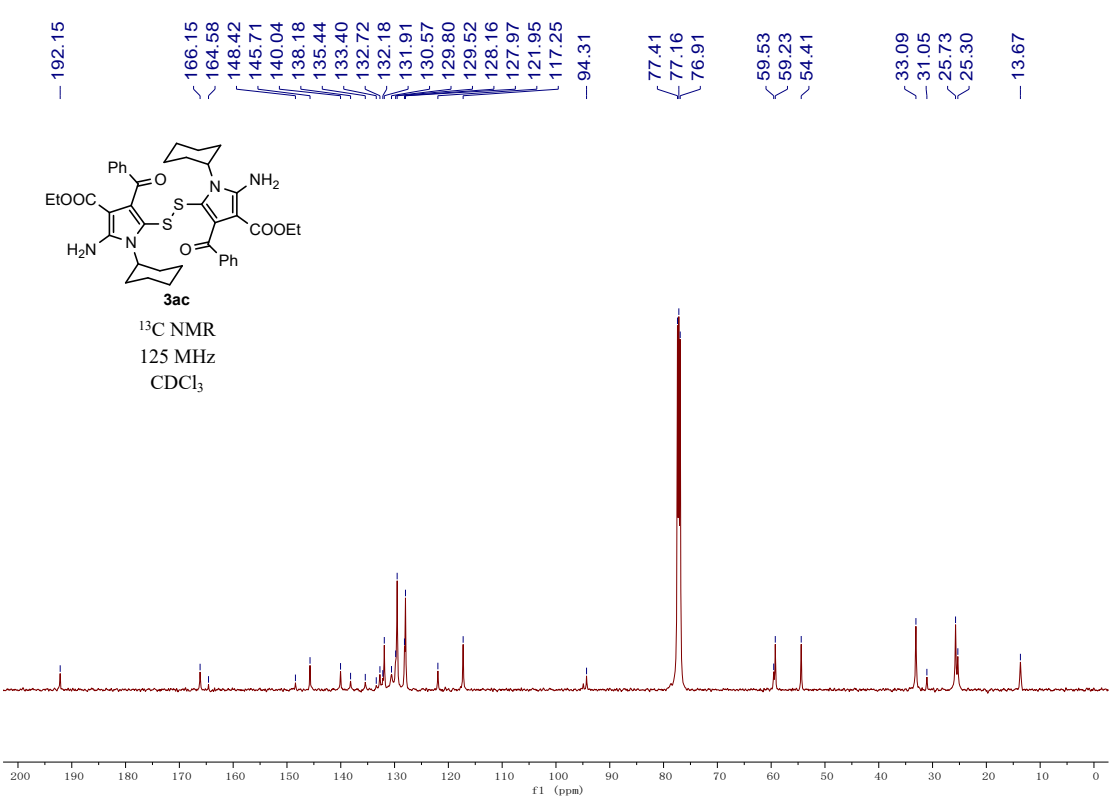
^{13}C NMR
125 MHz
$CDCl_3$


7.811
7.795
7.472
7.457
7.443
7.300
7.285
7.278
7.272
7.266
7.260
7.125
7.111
5.057
3.891
3.877
3.863
3.848
0.715
0.700
0.686
NH2
COOEt
Ph
O
S
S
Ph
O
EtOOC
N
H2N
3ab
1H NMR
500 MHz
CDCl3
2.04
1.13
5.11
2.10
3.88
2.10
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

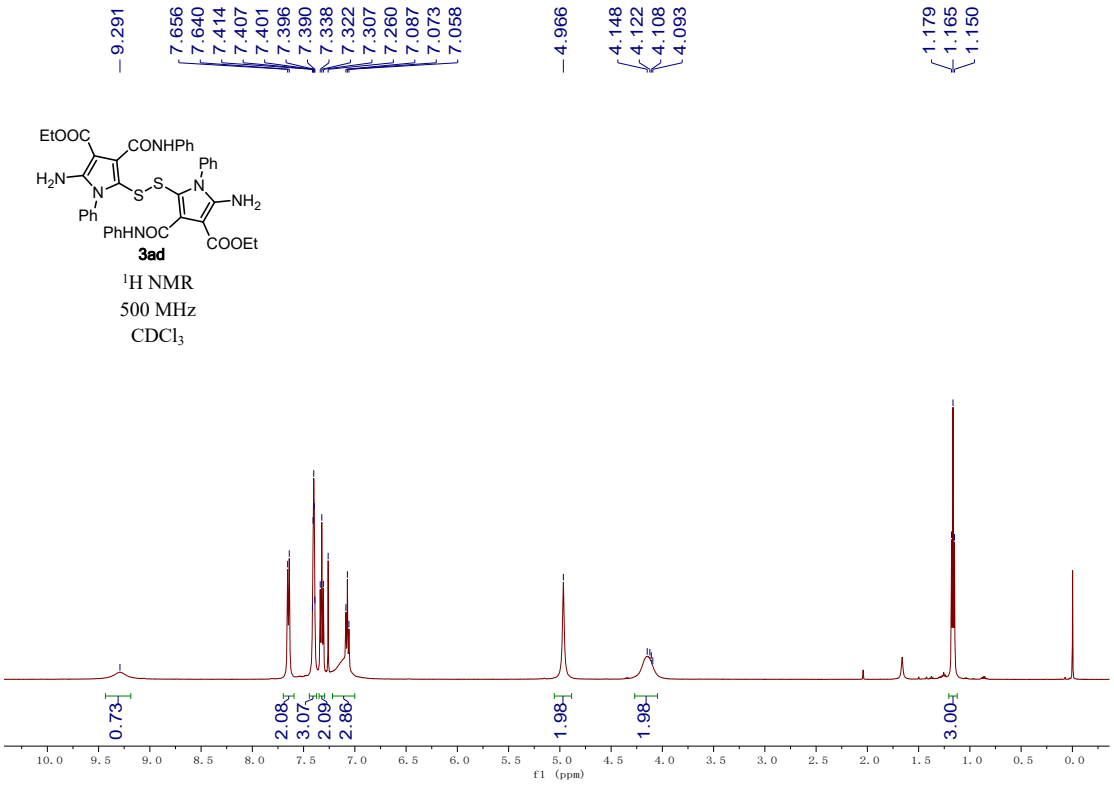

192.35
164.66
148.49
138.32
135.29
132.65
129.49
129.26
128.15
126.79
96.18
77.41
77.16
76.91
59.52
46.21
13.59
NH2
COOEt
Ph
O
S
S
Ph
O
EtOOC
N
H2N
3ab
13C NMR
125 MHz
CDCl3
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



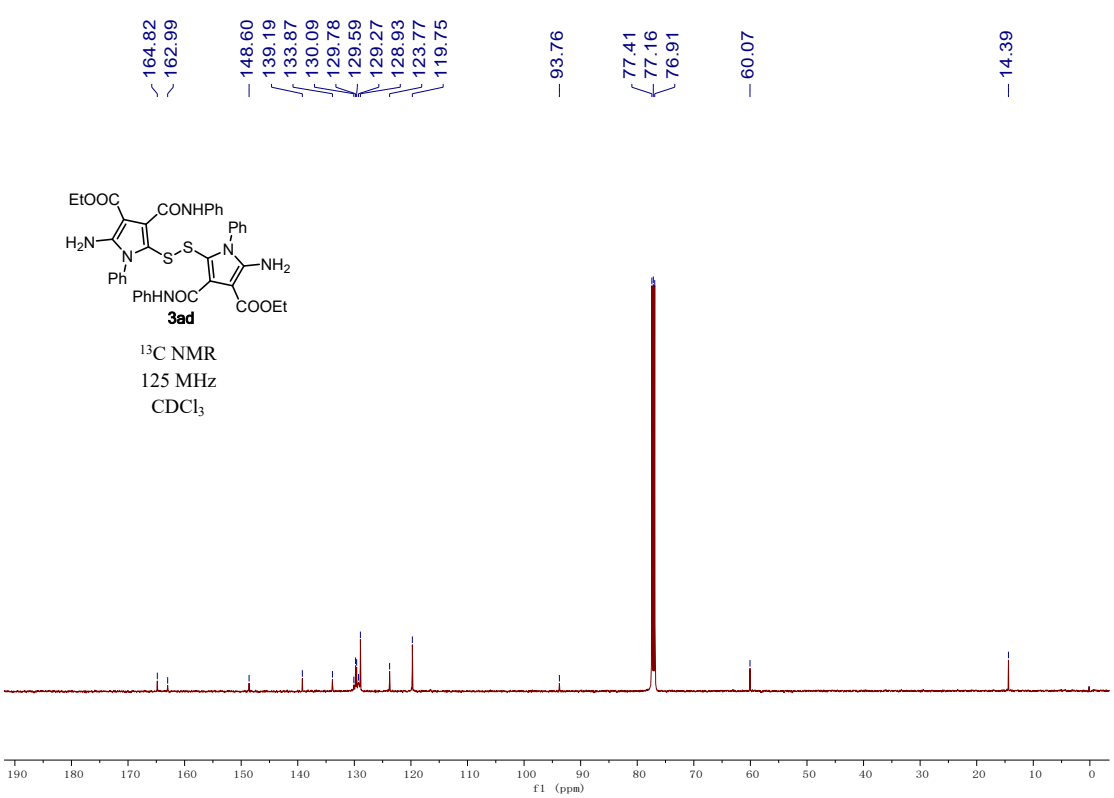
^{1}H NMR
500 MHz
$CDCl_3$



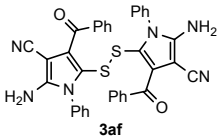
^{13}C NMR
125 MHz
$CDCl_3$



^{1}H NMR
500 MHz
$CDCl_3$

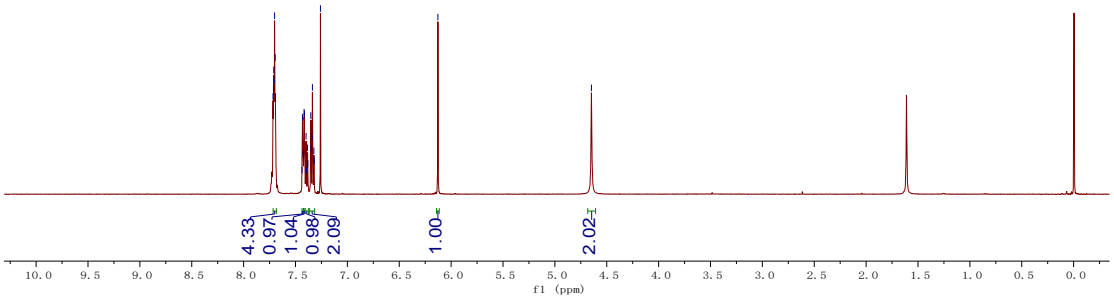


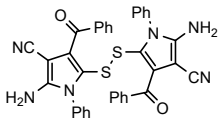
^{13}C NMR
125 MHz
$CDCl_3$



3af

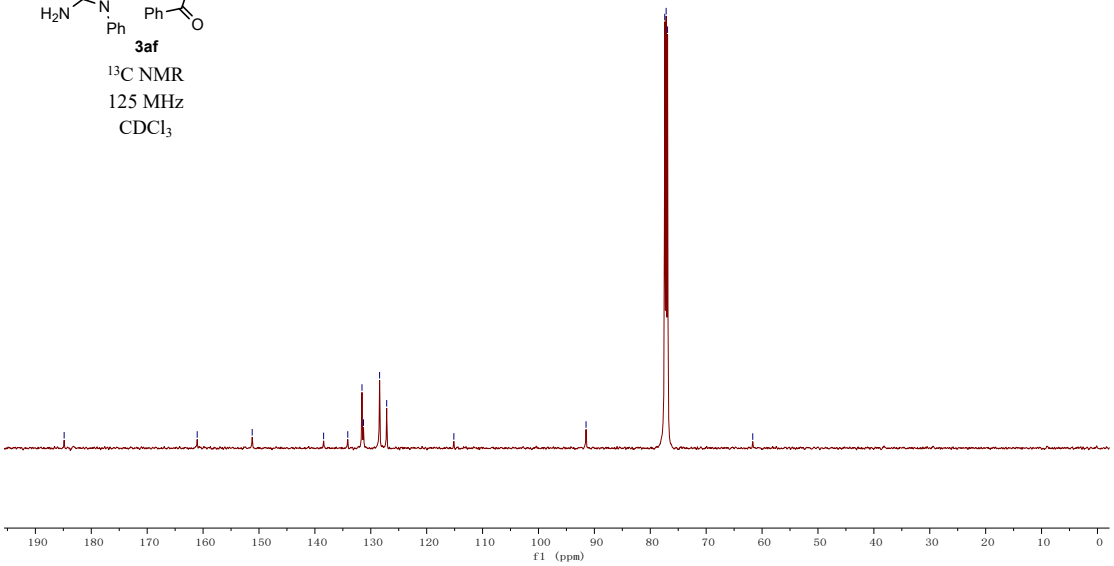
^{1}H NMR
500 MHz
$CDCl_3$

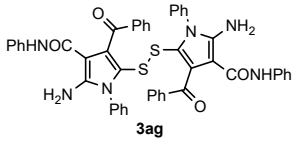




3af

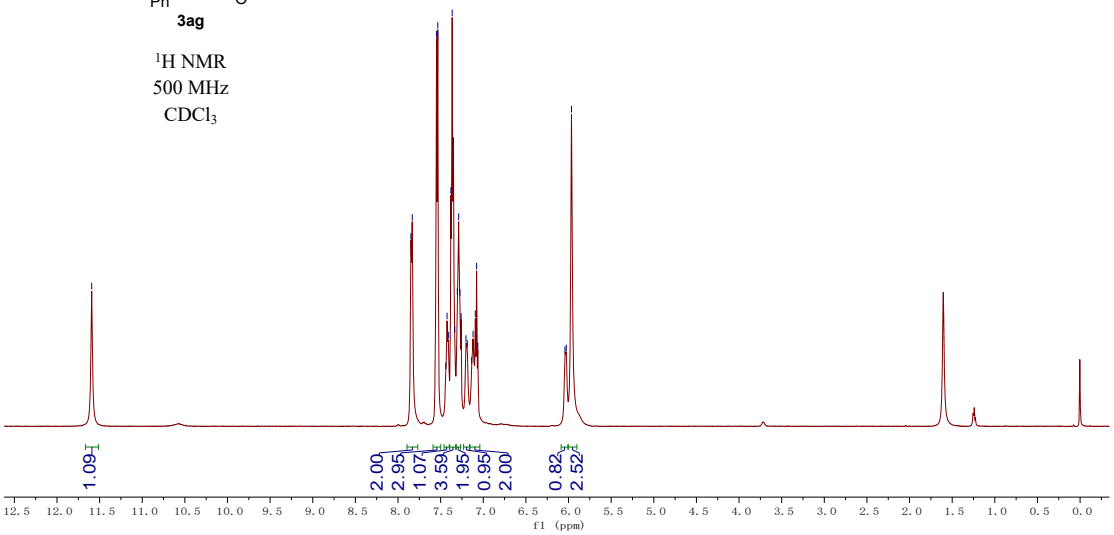
^{13}C NMR
125 MHz
$CDCl_3$

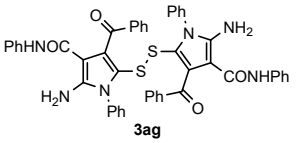




3ag

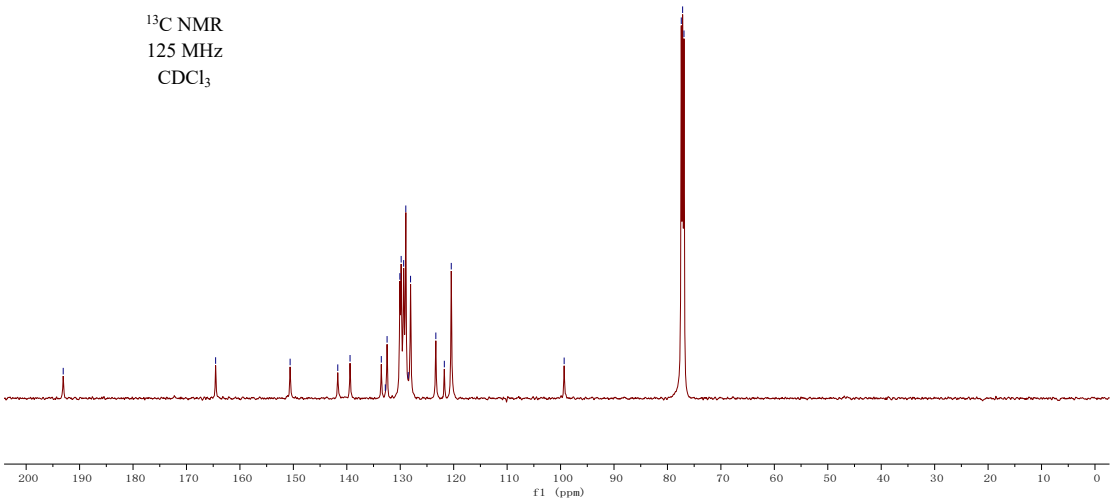
^{1}H NMR
500 MHz
$CDCl_3$

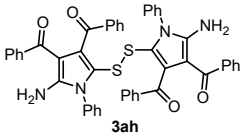




3ag

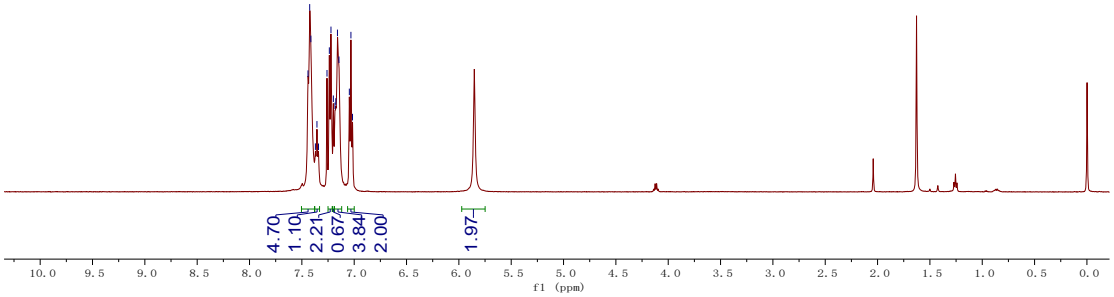
^{13}C NMR
125 MHz
$CDCl_3$

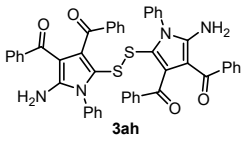




3ah

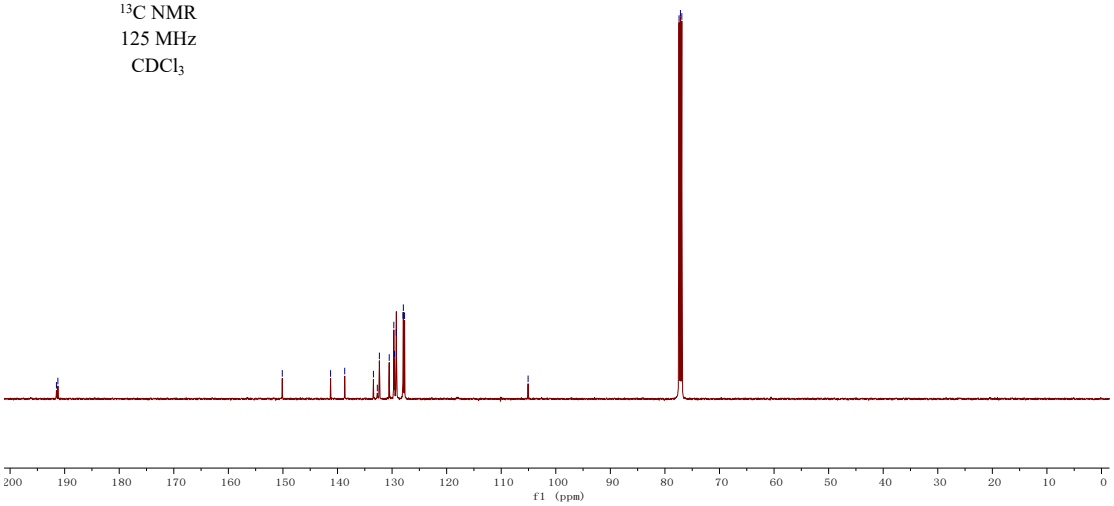
^{1}H NMR
500 MHz
$CDCl_3$

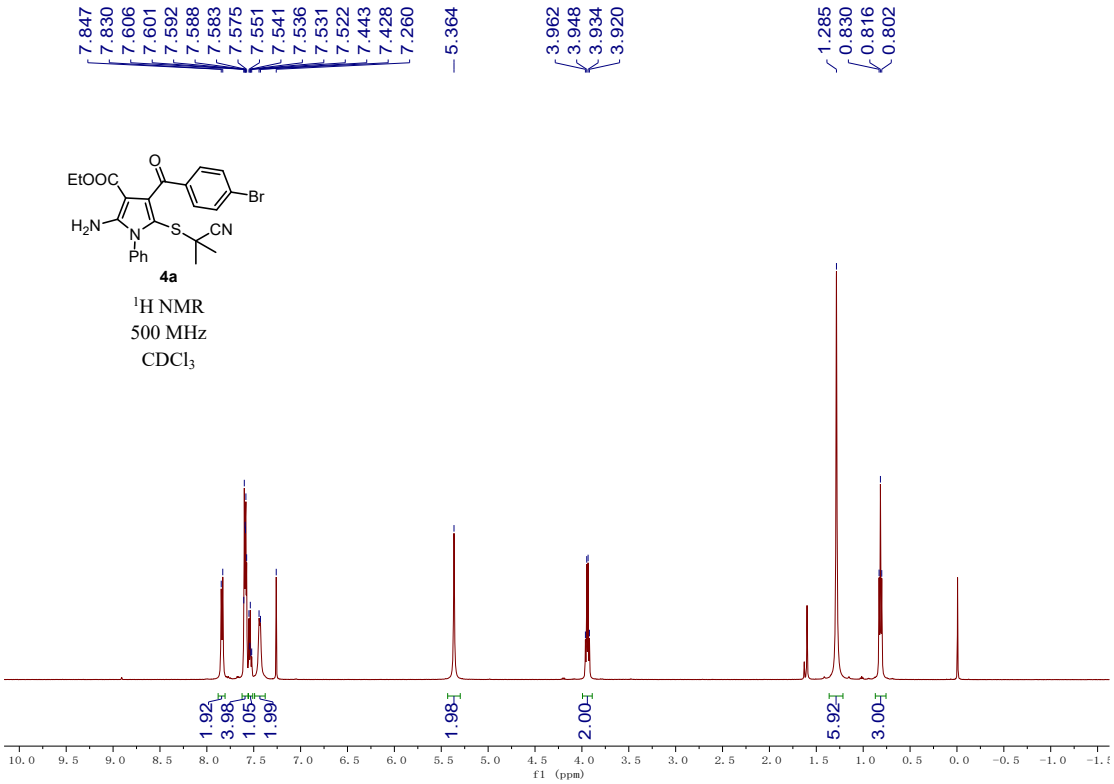




3ah

^{13}C NMR
125 MHz
$CDCl_3$

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7.606
7.601
7.592
7.588
7.583
7.575
7.551
7.541
7.536
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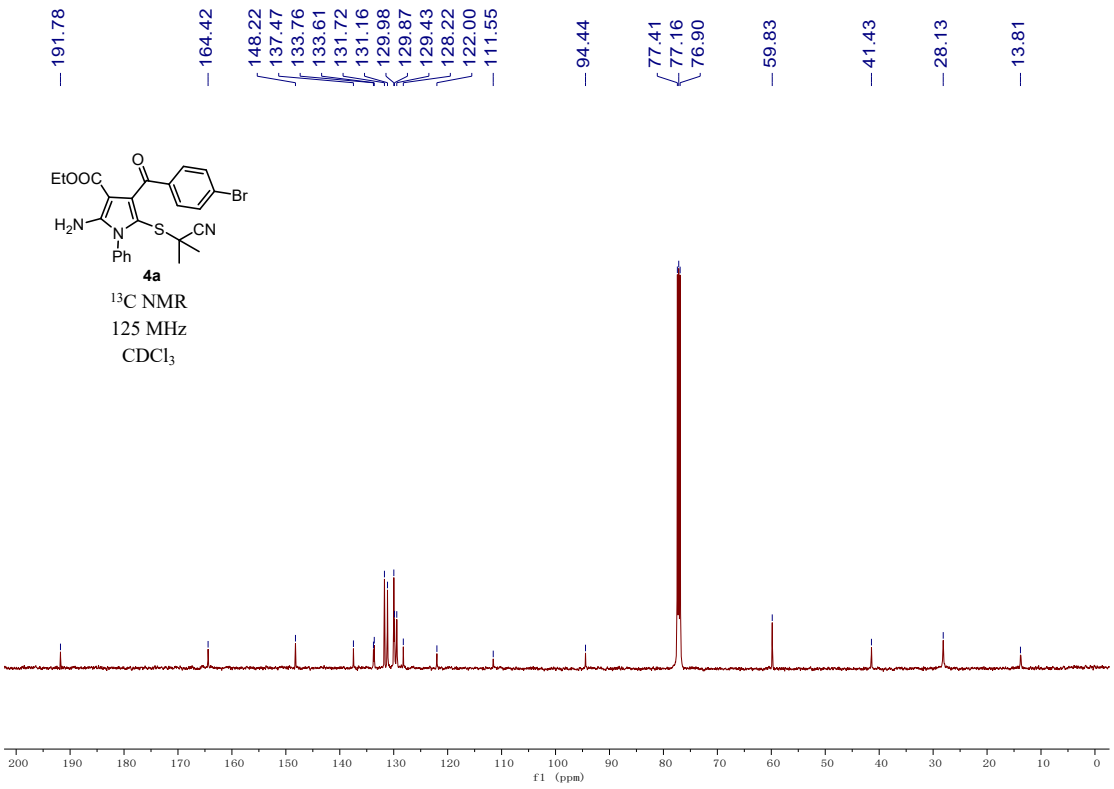
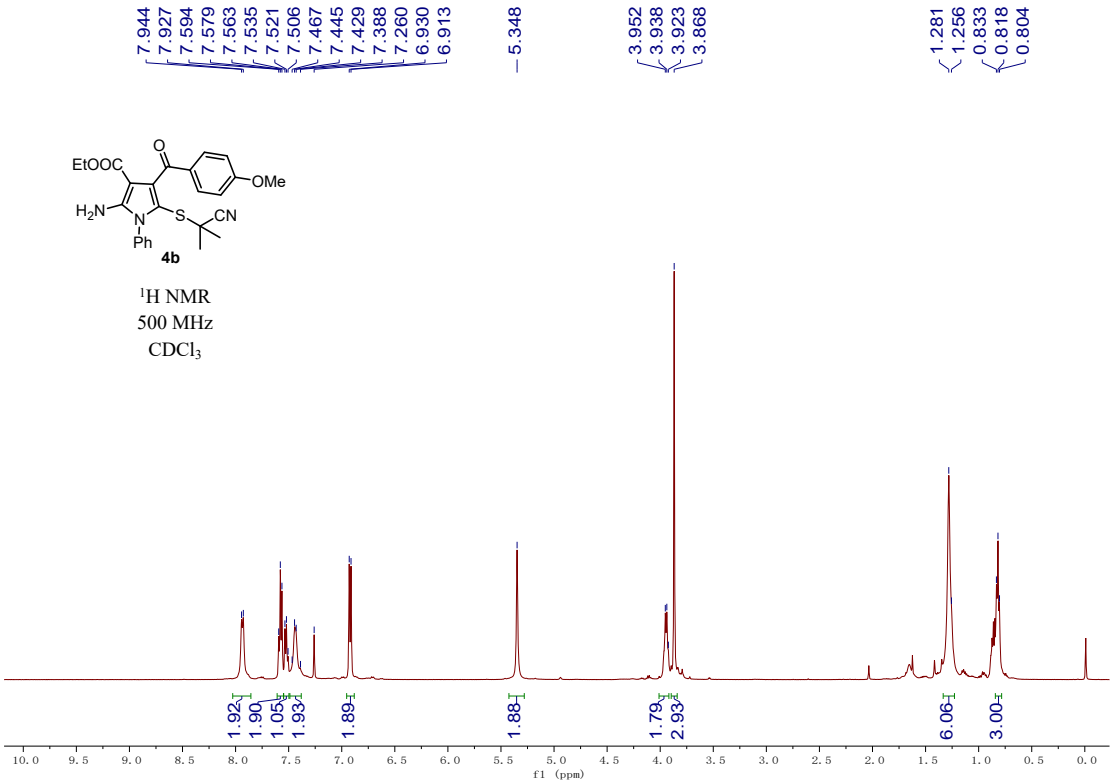
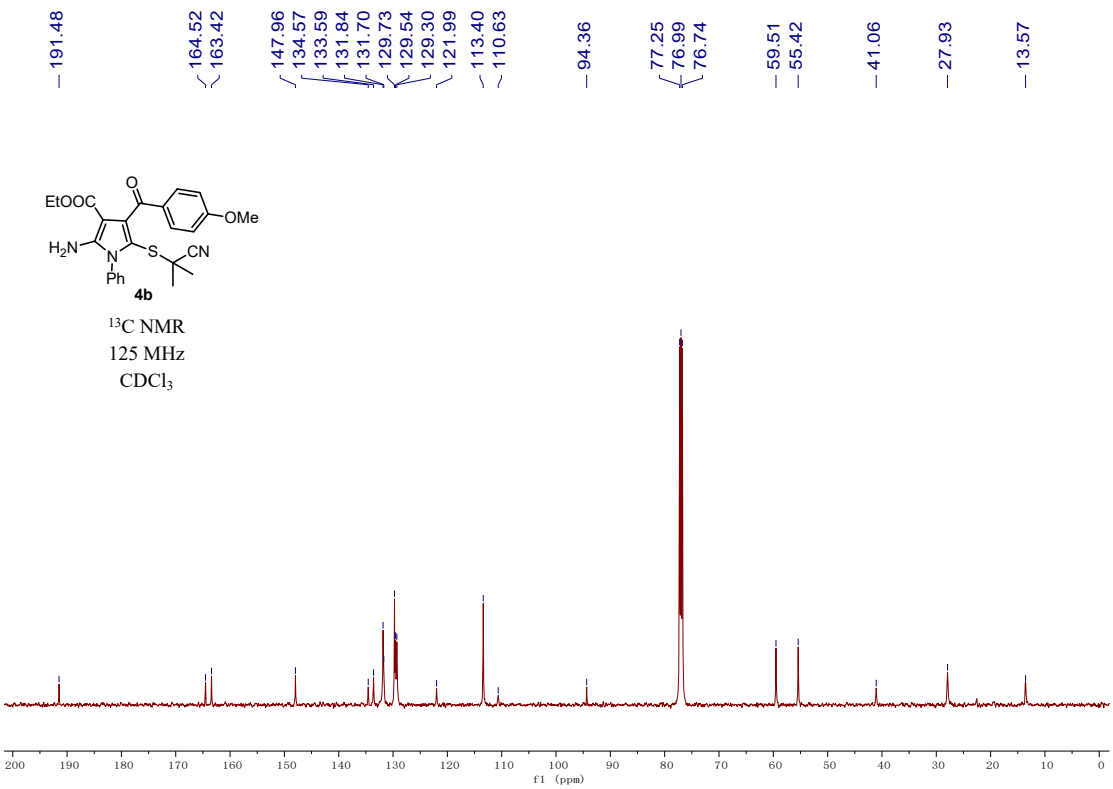
7.522
7.443
7.428
7.260
5.364
3.962
3.948
3.934
3.920
1.285
0.830
0.816
0.802
EtOOC
O
Br
H2N
N
Ph
S
CN
4a
1H NMR
500 MHz
CDCl3
1.92
3.98
1.05
1.99
1.98
2.00
5.92
3.00
f1 (ppm)


191.78
164.42
148.22
137.47
133.76
133.61
131.72
131.16
129.98
129.87
129.43
128.22
122.00
111.55
94.44
77.41
77.16
76.90
59.83
41.43
28.13
13.81
EtOOC
O
Br
H2N
N
Ph
S
CN
4a
13C NMR
125 MHz
CDCl3
f1 (ppm)


7.944
7.927
7.594
7.579
7.563
7.535
7.521
7.506
7.467
7.445
7.429
7.388
7.260
6.930
6.913
5.348
3.952
3.938
3.923
3.868
1.281
1.256
0.833
0.818
0.804
EtOOC
O
OMe
H2N
N
Ph
S
CN
4b
1H NMR
500 MHz
CDCl3
1.92
1.90
1.05
1.93
1.89
1.88
1.79
2.93
6.06
3.00
f1 (ppm)


191.48
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163.42
147.96
134.57
133.59
131.84
131.70
129.73
129.54
129.30
121.99
113.40
110.63
94.36
77.25
76.99
76.74
59.51
55.42
41.06
27.93
13.57
EtOOC
O
OMe
H2N
N
Ph
S
CN
4b
13C NMR
125 MHz
CDCl3
f1 (ppm)