Electronic Supporting Information for

Eco-friendly Construction of the Spiroquinazolin-2-(thi)ones and Quinolin-(thio)ureas *via* Fe(III)-Catalyzed Multi-Component Domino Double [4+2] Annulations

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1. General information.

All starting materials and reagents were purchased from commercial sources and used as received unless otherwise noted. Reactions were monitored using thin-layer chromatography (TLC) on commercial silica gel plates. Visualization of the developed plates was performed under UV light (254 nm). NMR spectra data were obtained on Avance (III) HD 400 MHz instruments. ^{1}H NMR and ^{13}C NMR spectra were referenced to residual protic solvent peaks or TMS signal (0 ppm). ^{19}F NMR chemical shifts were externally referenced to CCl_3F (0 ppm). Data for ^{1}H NMR are recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet or unresolved, br = broad singlet, coupling constant (s) in Hz, integration). Data for ^{13}C and ^{19}F NMR are reported in terms of chemical shift (δ, ppm).

2. Experimental section

2.1 General synthesis of spiroquinazolin-2-(thi)ones 4 and (thio)urea-containing quinolines 5.

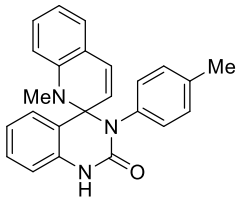
A solution of 2-aminoacetophenones **1** (1.0 mmol), 2-(methylamino)benzaldehydes **2** and iso(thio)cyanates **3** (1.05 mmol), and $FeCl_3$ (0.05 mmol) were dissolved in EtOH (5 mL) under an ambient atmosphere. The mixture was stirred at 50 ºC for 8 h. Then the reaction mixture was filtered by a Buchner funnel and the filter cake was subsequently washed with EtOH (3 x 2 mL). Drying the filter cake under vacuo afforded the pure product **4** or **5**.

2.2 Gram-scale preparation of spiroquinazolin-2-one 4b.

A solution of 1-(2-aminophenyl)ethan-1-one **1a** (1.35g, 10 mmol), 4-formyl-3-(methylamino)benzene-1-ylium **2a** (1.42g, 10.5 mmol) and 1-ethoxy-4-isocyanatobenzene **3b** (1.79g, 11 mmol), and $FeCl_3$ (80mg, 0.5 mmol) were dissolved in EtOH (50 mL) under an ambient atmosphere. The mixture was stirred at 50 ºC for 8 h. Then the reaction mixture was filtered by a Buchner funnel and the filter cake was subsequently washed with EtOH (3 x 2 mL). Drying the filter cake under vacuo afforded the pure 3-(4-ethoxyphenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one **4b** (3.57g, 90%) as white solid.

3. Characterization data of products

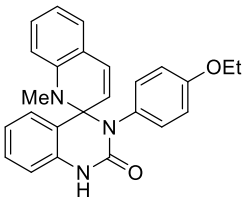
1'-Methyl-3-(*p*-tolyl)-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4a)



4a

White solid, 89% yield, 326.8 mg; m.p. 226.3-228.1 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.86 (s, 1H), 7.26 (dd, *J* = 11.2, 4.0 Hz, 1H), 7.06 (dd, *J* = 6.8, 4.4 Hz, 2H), 6.97 (d, *J* = 7.2 Hz, 1H), 6.93 (m, 5H), 6.82 – 6.77 (m, 1H), 6.51 (t, *J* = 8.0 Hz, 2H), 6.41 (d, *J* = 9.6 Hz, 1H), 5.66 (d, *J* = 9.6 Hz, 1H), 2.75 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 150.7, 142.0, 136.7, 134.5, 130.1, 129.9, 128.9, 127.3, 125.0, 124.0, 123.7, 122.2, 117.6, 116.8, 114.0, 109.4, 81.0, 32.3, 21.0; HRMS: calcd for $C_{24}H_{22}N_3O$ $[M+H]^+$: 368.1757, found: 367.1764.

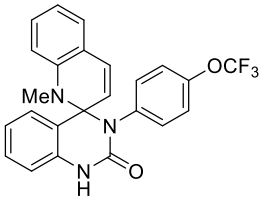
3-(4-Ethoxyphenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4b)



4b

White solid, 92% yield, 365.7 mg; m.p. 243.9-245.5 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.85 (s, 1H), 7.28 – 7.24 (m, 1H), 7.06 (d, *J* = 7.2 Hz, 2H), 6.94 (m, 4H), 6.80 (d, *J* = 7.2 Hz, 1H), 6.63 (s, 2H), 6.52 (d, *J* = 8.0 Hz, 2H), 6.41 (d, *J* = 9.6 Hz, 1H), 5.65 (d, *J* = 9.6 Hz, 1H), 4.04 – 3.83 (q, *J* = 6.4 Hz, 2H), 2.74 (s, 3H), 1.23 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, DMSO) δ 157.6, 150.8, 142.1, 134.6, 131.6, 130.1, 129.9, 128.9, 127.3, 125.1, 124.0, 123.7, 122.2, 120.6, 117.7, 116.8, 115.0, 113.9, 109.4, 81.0, 63.5, 32.3, 15.0; HRMS: calcd for $C_{25}H_{24}N_3O_2$ $[M+H]^+$: 398.1863, found: 398.1871.

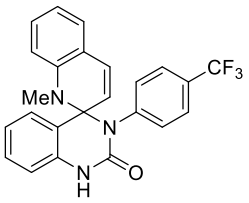
1'-Methyl-3-(4-(trifluoromethoxy)phenyl)-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4c)



4c

White solid, 85% yield, 371.8 mg; m.p. 261.5-262.9 °C; ^{1}H NMR (400 MHz, DMSO) δ 10.04 (s, 1H), 7.31 – 7.25 (m, 1H), 7.17 (s, 2H), 7.13 – 7.04 (m, 4H), 6.97 (m, 2H), 6.79 (d, *J* = 7.2 Hz, 1H), 6.53 (m, 2H), 6.45 (d, *J* = 9.6 Hz, 1H), 5.77 – 5.72 (m, 1H), 2.79 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 150.4, 147.5 142.0, 138.4, 134.9, 133.1, 130.1, 129.9, 129.0, 127.2, 125.5, 123.8, 123.6, 122.3, 120.6, 120.4 (q, *J* = 254.6 Hz), 117.8, 117.0, 114.1, 109.6, 81.1, 32.4; ^{19}F NMR (376 MHz, DMSO) δ -56.9; HRMS: calcd for $C_{24}H_{19}F_3N_3O_2$ $[M+H]^+$: 438.1424, found: 438.1433.

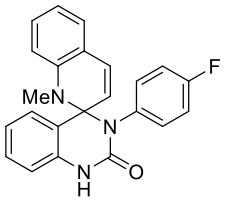
1'-Methyl-3-(4-(trifluoromethyl)phenyl)-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4d)



4d

White solid, 66% yield, 278.1 mg; m.p. 258.8-260.2 °C; ^{1}H NMR (400 MHz, DMSO) δ 10.06 (s, 1H), 7.47 (d, *J* = 7.6 Hz, 2H), 7.30 (d, *J* = 6.8 Hz, 3H), 7.08 (t, *J* = 8.8 Hz, 2H), 6.98 (m, 2H), 6.80 (d, *J* = 7.2Hz, 1H), 6.53 (m, 2H), 6.46 (d, *J* = 9.6 Hz, 1H), 5.75 (d, *J* = 9.6 Hz, 1H), 2.79 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 150.4, 143.4, 141.9, 134.5, 132.1, 130.3, 130.0, 128.9, 128.2, 127.3, 125.5, 125.2, 125.1, 124.5 (q, *J* = 270 Hz), 123.7, 122.4, 117.6, 117.1, 114.2, 109.7, 81.3, 32.4; ^{19}F NMR (376 MHz, DMSO) δ -60.9; HRMS: calcd for $C_{24}H_{19}F_3N_3O$ $[M+H]^+$: 422.1475, found: 422.1477.

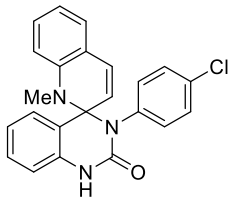
3-(4-Fluorophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4e)



4e

White solid, 75% yield, 278.6 mg; m.p. 210.6-212.5 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.96 (s, 1H), 7.28 (s, 1H), 7.08 (t, *J* = 9.2 Hz, 4H), 6.99 (d, *J* = 7.6 Hz, 1H), 6.94 (d, *J* = 8.0 Hz, 3H), 6.81 (d, *J* = 7.2 Hz, 1H), 6.54 (m, 2H), 6.44 (d, *J* = 9.6 Hz, 1H), 5.71 (d, *J* = 9.6 Hz, 1H), 2.77 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 161.3 (d, *J* = 242.2 Hz), 150.5, 142.0, 135.4 (d, *J* = 3.0 Hz), 134.7, 133.1, 130.2, 129.9, 129.0, 127.3, 125.3, 123.8 (d, *J* = 12.3 Hz), 122.3, 117.7, 117.0, 114.9 (d, *J* = 22.1 Hz), 114.1, 109.5, 81.0, 32.3; ^{19}F NMR (376 MHz, DMSO) δ -115.2; HRMS: calcd for $C_{23}H_{19}FN_3O$ $[M+H]^+$: 372.1507, found: 372.1513.

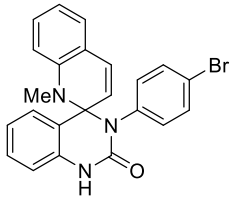
3-(4-Chlorophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4f)



4f

White solid, 81% yield, 62.8 mg; m.p. 224.7-226.9 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.36 (s, 1H), 7.35 (t, *J* = 6.4 Hz, 1H), 7.30 – 6.90 (m, 8H), 6.84 (d, *J* = 7.2 Hz, 1H), 6.57 (t, *J* = 7.6 Hz, 2H), 6.48 (d, *J* = 9.6 Hz, 1H), 5.80 (d, *J* = 9.6 Hz, 1H), 2.77 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 173.5, 141.5, 141.1, 133.0, 132.3, 130.4, 130.1, 129.1, 128.0, 127.4, 125.8, 123.9, 123.8, 123.2, 117.6, 117.5, 114.2, 109.7, 81.4, 32.6; HRMS: calcd for $C_{23}H_{19}ClN_3O$ $[M+H]^+$: 388.1211, found: 388.1215.

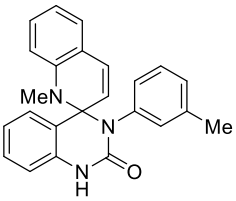
3-(4-Bromophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4g)



4g

Yellow solid, 72% yield, 311.3 mg; m.p. 281.6-283.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.99 (s, 1H), 7.28 (t, *J* = 9.6 Hz, 3H), 7.07 (d, *J* = 6.4 Hz, 2H), 6.96 (m, 4H), 6.83 (d, *J* = 7.2 Hz, 1H), 6.54 (d, *J* = 6.8 Hz, 2H), 6.45 (d, *J* = 9.6 Hz, 1H), 5.70 (d, *J* = 9.6 Hz, 1H), 2.76 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 150.4, 141.9, 138.8, 134.6, 133.3, 131.2, 130.3, 130.0, 129.0, 127.4, 125.4, 123.7, 123.6, 122.4, 120.7, 117.6, 117.1, 114.1, 109.5, 81.1, 32.3; HRMS: calcd for $C_{23}H_{19}BrN_3O$ $[M+H]^+$: 432.0706, found: 432.0715.

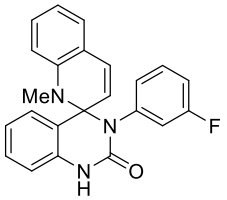
1'-Methyl-3-(*m*-tolyl)-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4h)



4h

White solid, 73% yield, 268.2 mg; m.p. 217.1-219.8 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.88 (s, 1H), 7.27 (t, *J* = 7.6 Hz, 1H), 7.11 – 7.06 (m, 2H), 6.97 (m, 3H), 6.93 – 6.86 (m, 2H), 6.79 (d, *J* = 6.8 Hz, 2H), 6.56 – 6.50 (m, 2H), 6.40 (d, *J* = 9.6 Hz, 1H), 5.64 (d, *J* = 9.6 Hz, 1H), 2.77 (s, 3H), 2.05 (s, 3H);^{13}C NMR (100 MHz, DMSO) δ 150.6, 142.2, 139.2, 137.4, 134.8, 131.5, 130.1, 129.9, 129.0, 128.1, 127.9, 127.2, 125.2, 123.9, 122.2, 117.8, 116.9, 114.0, 109.4, 80.8, 32.3, 21.0; HRMS: calcd for $C_{24}H_{22}N_3O$ $[M+H]^+$: 368.1757, found: 368.1764.

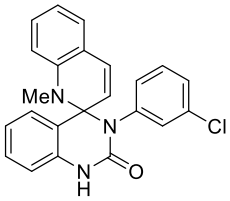
3-(3-Fluorophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4i)



4i

White solid, 59% yield, 219.0 mg; m.p. 225.1-227.8 °C;^{1}H NMR (400 MHz, DMSO) δ 10.02 (s, 1H), 7.28 (t, *J* = 7.2 Hz, 1H), 7.12 (m, 3H), 6.97 (d, *J* = 6.0 Hz, 2H), 6.92 (d, *J* = 6.4 Hz, 3H), 6.83 (d, *J* = 7.2 Hz, 1H), 6.54 (m, 2H), 6.46 (d, *J* = 9.6 Hz, 1H), 5.74 (d, *J* = 9.6 Hz, 1H), 2.78 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 161.8 (d, *J* = 242.9 Hz), 150.3, 142.0, 141.2 (d, *J* = 10.1 Hz), 134.7, 130.3 (d, *J* = 25.3 Hz), 129.4 (d, *J* = 9.2 Hz), 127.4, 127.3, 125.3, 123.8 (d, *J* = 2.4 Hz), 122.3, 117.7, 117.0, 114.5 (d, *J* = 20.6 Hz), 114.1, 109.5, 81.1, 32.3; ^{19}F NMR (376 MHz, DMSO) δ -114.2; HRMS: calcd for $C_{23}H_{19}FN_3O$ $[M+H]^+$: 372.1507, found: 372.1513.

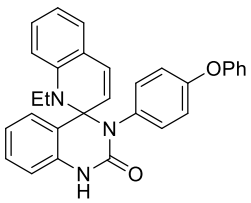
3-(3-Chlorophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4j)



4j

White solid, 62% yield. 240.5 mg; m.p. 213.3-215.6 °C; ^{1}H NMR (400 MHz, DMSO) δ 10.04 (s, 1H), 7.28 (t, *J* = 7.6 Hz, 1H), 7.18 (d, *J* = 8.0 Hz, 1H), 7.11 (m, 4H), 7.04 – 6.90 (m, 3H), 6.83 (d, *J* = 7.2 Hz, 1H), 6.55 (m, 2H), 6.46 (d, *J* = 9.6 Hz, 1H), 5.75 (d, *J* = 9.6 Hz, 1H), 2.78 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.1, 146.7, 145.7, 139.5, 137.1, 136.0, 135.0, 134.7, 134.3, 133.7, 132.4, 132.1, 130.1, 128.5, 127.0, 122.4, 121.8, 118.9, 114.3, 85.9, 37.1; HRMS: calcd for $C_{23}H_{19}ClN_3O$ $[M+H]^+$: 388.1211, found: 388.1215.

1'-Ethyl-3-(4-phenoxyphenyl)-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4k)

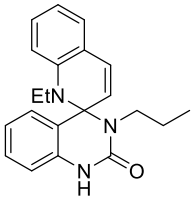


4k

White solid, 65% yield, 298.7 mg; m.p. 291.3-292.8 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.94 (s, 1H), 7.31 (d, *J* = 8.0 Hz, 3H), 7.23 (d, *J* = 7.6 Hz, 1H), 7.07 (s, 3H), 7.02 (d, *J* = 7.6 Hz, 2H), 6.94 (d, *J* = 8.0 Hz, 1H), 6.84 (d, *J* = 7.2 Hz, 1H), 6.69 (s, 2H), 6.63 (d, *J* = 8.0 Hz, 2H), 6.55 (t, *J* = 8.8 Hz, 2H), 6.47 (d, *J* = 9.6 Hz, 1H), 5.66 (d, *J* = 9.6 Hz, 1H), 3.29 (m, 2H), 0.71 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 157.8, 155.2, 150.3, 140.4, 135.0, 134.4, 133.0, 130.8, 130.3, 129.9, 127.5, 125.7, 123.7,

123.4, 123.3, 121.6, 119.0, 118.3, 117.9, 116.5, 114.1, 109.9, 80.8, 12.5; HRMS: calcd for $C_{30}H_{26}N_3O_2$ $[M+H]^+$: 460.2020, found: 460.2025.

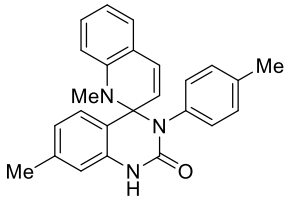
1'-Ethyl-3-propyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4l)



4l

White solid, 59% yield, 196.7 mg; m.p. 186.5-188.7 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.67 (s, 1H), 7.21 (t, *J* = 7.6 Hz, 1H), 7.18 – 7.11 (m, 2H), 7.09 (d, *J* = 7.6 Hz, 1H), 6.93 (t, *J* = 7.6 Hz, 1H), 6.83 (d, *J* = 8.0 Hz, 1H), 6.78 (d, *J* = 9.6 Hz, 1H), 6.65 (t, *J* = 7.2 Hz, 1H), 6.58 (d, *J* = 8.4 Hz, 1H), 5.52 (d, *J* = 9.6 Hz, 1H), 3.09 (m, 3H), 2.83 – 2.72 (m, 1H), 1.47 (m, 2H), 0.74 (t, *J* = 6.8 Hz, 3H), 0.62 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, DMSO) δ 150.1, 140.6, 134.6, 130.5, 130.3, 129.8, 128.3, 125.2, 123.5, 122.9, 121.6, 117.6, 116.7, 113.6, 109.8, 79.3, 45.0, 38.9, 22.8, 12.2, 12.1; HRMS: calcd for $C_{21}H_{24}N_3O$ $[M+H]^+$: 334.1914, found: 334.1923.

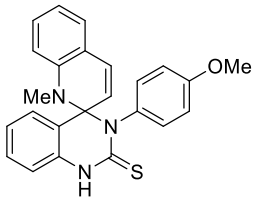
1',7-Dimethyl-3-(*p*-tolyl)-1*H*,1'*H*-spiro[quinazoline-4,2'-quinolin]-2(3*H*)-one (4m)



4m

White solid, 91% yield, 347.1 mg; m.p. 236.5-238.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.84 (s, 1H), 7.06 (s, 1H), 6.98 – 6.86 (m, 5H), 6.83 – 6.75 (m, 2H), 6.72 (s, 1H), 6.51 (t, *J* = 7.6 Hz, 2H), 6.40 (d, *J* = 9.6 Hz, 1H), 5.65 (d, *J* = 9.6 Hz, 1H), 2.76 (s, 3H), 2.27 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 150.8, 142.1, 139.4, 136.9, 136.5, 134.5, 130.0, 128.9, 127.3, 124.9, 124.1, 123.1, 121.2, 117.6, 116.7, 114.0, 109.3, 80.8, 32.3, 21.3, 21.0; HRMS: calcd for $C_{25}H_{24}N_3O$ $[M+H]^+$: 382.1914, found: 382.1916.

3-(4-Methoxyphenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinoline]-2(3*H*)-thione (4q)

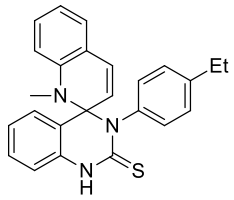


4q

White solid, 79% yield, 315.6 mg; m.p. 247.4-250.1 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.24 (s, 1H), 7.32 (m, 1H), 7.15 (d, *J* = 8.0 Hz, 1H), 7.13 – 7.04 (m, 4H), 6.83 (m, 1H), 6.73 (d, *J* = 7.6 Hz, 2H), 6.55 (m, 2H), 6.51 (s, 1H), 6.44 (d, *J* = 9.6 Hz, 1H), 5.74 (d, *J* = 9.6 Hz, 1H), 3.63 (s, 3H), 2.76

(s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 174.0, 158.4, 141.7, 134.9, 133.0, 132.8, 130.3, 130.0, 129.0, 127.4, 125.4, 123.9, 123.7, 123.4, 117.7, 117.3, 114.0, 113.2, 109.6, 81.2, 55.5, 32.5; HRMS: calcd for $C_{24}H_{22}N_3OS$ $[M+H]^+$: 400.1478, found: 400.1482.

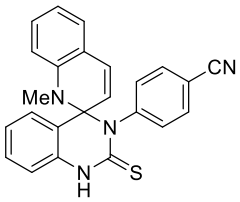
1'-Ethyl-3-(4-(trifluoromethyl)phenyl)-1*H*,1'*H*-spiro[quinazoline-4,2'-quinoline]-2(3*H*)-thione (4r)



4r

White solid, 63% yield, 55.1 mg; m.p. 257.1-259.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.24 (s, 1H), 7.37 – 7.29 (m, 1H), 7.16 (d, *J* = 7.6 Hz, 1H), 7.11 (d, *J* = 1.7 Hz, 1H), 7.08 (m, 2H), 7.00 (d, *J* = 7.6 Hz, 1H), 6.86 – 6.76 (m, 2H), 6.73 (d, *J* = 7.6 Hz, 1H), 6.54 (m, 2H), 6.43 (d, *J* = 9.6 Hz, 1H), 5.74 (d, *J* = 9.6 Hz, 1H), 2.77 (s, 3H), 2.45 (q, *J* = 7.6 Hz, 2H), 1.05 (t, *J* = 7.6 Hz, 3H). ^{13}C NMR (100 MHz, DMSO) δ 173.7, 142.9, 141.7, 139.7, 133.1, 131.6, 130.2, 130.0, 129.0, 127.3, 127.1, 125.5, 123.9, 123.7, 123.4, 117.8, 117.3, 114.1, 109.6, 81.2, 32.6, 28.1, 15.8; HRMS: calcd for $C_{25}H_{24}N_3S$ $[M+H]^+$: 398.1691, found: 398.1696.

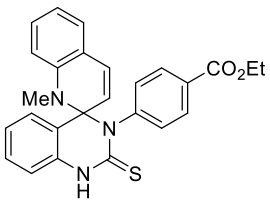
4-(1'-Methyl-2-thioxo-1,2-dihydro-1'*H*,3*H*-spiro[quinazoline-4,2'-quinolin]-3-yl)benzonitrile (4s)



4s

White solid, 61% yield, 240.4 mg; m.p. 251.2-252.9 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.45 (s, 1H), 7.56 (d, *J* = 8.4 Hz, 2H), 7.39 – 7.34 (m, 1H), 7.25 (d, *J* = 7.6 Hz, 2H), 7.18 (d, *J* = 8.0 Hz, 1H), 7.15 – 7.07 (m, 3H), 6.83 (m, 1H), 6.63 – 6.55 (m, 2H), 6.48 (d, *J* = 9.6 Hz, 1H), 5.84 (d, *J* = 9.6 Hz, 1H), 2.80 (s, 3H); ^{3}C NMR (100 MHz, DMSO) δ 173.0, 146.6, 141.4, 133.1, 132.6, 132.0, 130.5, 130.2, 129.1, 127.4, 126.1, 124.1, 123.9, 123.0, 118.9, 117.7, 117.6, 114.3, 110.4, 109.9, 81.7, 32.6; HRMS: calcd for $C_{24}H_{19}N_4S$ $[M+H]^+$: 395.1325, found: 395.1339.

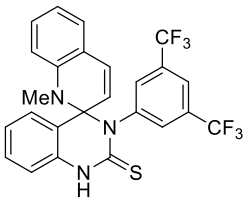
Ethyl 4-(1'-methyl-2-thioxo-1,2-dihydro-1'*H*,3*H*-spiro[quinazoline-4,2'-quinolin]-3-yl)benzoate (4t)



4t

White solid, 67% yield, 295.8 mg; m.p. 289.6-293.5 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.40 (s, 1H), 7.65 (s, 2H), 7.35 (m, 1H), 7.17 (d, *J* = 8.0 Hz, 3H), 7.13 – 7.07 (m, 3H), 6.81 (d, *J* = 7.6 Hz, 1H), 6.62 – 6.52 (m, 2H), 6.46 (d, *J* = 9.6 Hz, 1H), 5.81 (d, *J* = 9.6 Hz, 1H), 4.25 (q, *J* = 7.2 Hz, 2H), 2.80 (s, 3H), 1.28 (t, *J* = 7.2 Hz, 3H); NMR (100 MHz, DMSO) δ 173.2, 165.7, 146.7, 141.5, 133.0, 130.5, 130.1, 129.0, 128.9, 127.5, 125.8, 124.0, 123.9, 123.0, 117.6, 117.5, 114.2, 109.8, 81.6, 61.2, 32.6, 14.6; HRMS: calcd for $C_{26}H_{24}N_3O_2S$ $[M+H]^+$: 442.1584, found: 442.1585.

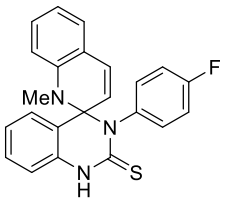
3-(3,5-Bis(trifluoromethyl)phenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinoline]-2(3*H*)-thione (4u)



4u

White solid, 58% yield, 293.2 mg; m.p. 275.4-276.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.59 (s, 1H), 7.80 (s, 1H), 7.70 (s, 2H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.20 (d, *J* = 8.4 Hz, 2H), 7.17 – 7.09 (m, 2H), 6.78 (d, *J* = 7.2 Hz, 1H), 6.62 (d, *J* = 8.4 Hz, 1H), 6.56 (t, *J* = 7.2 Hz, 1H), 6.49 (d, *J* = 9.6 Hz, 1H), 5.98 (d, *J* = 9.6 Hz, 1H), 2.83 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 173.1, 143.7, 141.2, 133.5, 132.4, 130.6, 130.2, 129.8, 129.3, 127.4, 126.5, 126.0 (q, *J* = 254 Hz), 124.1, 124.0, 122.9, 121.9, 117.9, 117.7, 114.5, 109.9, 81.8, 32.8; ^{19}F NMR (376 MHz, DMSO) δ -61.4; HRMS: calcd for $C_{25}H_{18}F_6N_3S$ $[M+H]^+$: 506.1120, found: 506.1133.

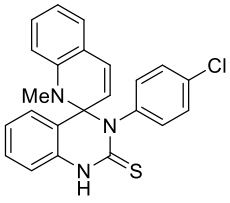
3-(4-Fluorophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinoline]-2(3*H*)-thione (4v)



4v

White solid, 65% yield, 251.9 mg; m.p. 216.8-219.5 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.33 (s, 1H), 7.38 – 7.33 (m, 1H), 7.21 (d, *J* = 16.8 Hz, 1H), 7.17 (d, *J* = 8.0 Hz, 1H), 7.14 – 7.06 (m, 3H), 7.00 (s, 1H), 6.83 (m, 3H), 6.61 – 6.53 (m, 2H), 6.47 (d, *J* = 9.6 Hz, 1H), 5.80 (d, *J* = 9.6 Hz, 1H), 2.78 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 173.7, 161.4 (d, *J* = 243.9 Hz), 141.6, 138.3 (d, *J* = 3.0 Hz), 133.1, 130.4, 130.0, 129.1, 127.4, 125.7, 123.8 (d, *J* = 4.9 Hz), 123.2, 117.7, 117.4, 114.7 (d, *J* = 22.4 Hz), 114.2, 109.7, 81.3, 32.6; ^{19}F NMR (376 MHz, DMSO) δ -113.6; HRMS: calcd for $C_{23}H_{19}FN_3S$ $[M+H]^+$: 388.1278, found: 388.1287.

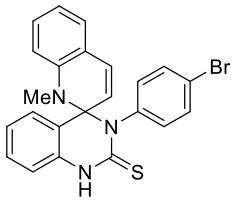
3-(4-Chlorophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinoline]-2(3*H*)-thione (4w)



4w

White solid, 70% yield, 282.8 mg; m.p. 221.6-223.8 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.36 (s, 1H), 7.35 (t, *J* = 6.4 Hz, 1H), 7.31 – 6.88 (m, 8H), 6.84 (d, *J* = 7.2 Hz, 1H), 6.57 (t, *J* = 7.6 Hz, 2H), 6.48 (d, *J* = 9.6 Hz, 1H), 5.80 (d, *J* = 9.6 Hz, 1H), 2.77 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 173.5, 141.5, 141.0, 133.0, 132.2, 130.4, 130.1, 129.1, 128.0, 127.4, 125.8, 123.9, 123.8, 123.1, 117.6, 117.5, 114.2, 109.7, 81.4, 32.6; HRMS: calcd for $C_{23}H_{19}ClN_3S$ $[M+H]^+$: 404.0983, found: 404.0991.

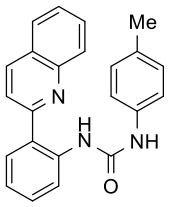
3-(4-Bromophenyl)-1'-methyl-1*H*,1'*H*-spiro[quinazoline-4,2'-quinoline]-2(3*H*)-thione (4x)



4x

Yellow solid, 68% yield, 304.9 mg; m.p. 248.2-249.8 °C; ^{1}H NMR (400 MHz, DMSO) δ 10.04 (s, 1H), 7.27 (d, *J* = 7.6 Hz, 1H), 7.18 (d, *J* = 8.0 Hz, 1H), 7.11 (m, 4H), 7.05 – 6.92 (m, 3H), 6.83 (d, *J* = 7.2 Hz, 1H), 6.55 (m, 2H), 6.46 (d, *J* = 9.6 Hz, 1H), 5.75 (d, *J* = 9.6 Hz, 1H), 2.78 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 155.1, 146.7, 145.7, 139.5, 137.1, 136.0, 135.0, 134.7, 134.3, 133.7, 132.4, 132.1, 130.1, 128.5, 127.0, 122.4, 121.8, 118.9, 114.3, 85.9, 37.1; HRMS: calcd for $C_{23}H_{19}BrN_3S$ $[M+H]^+$: 448.0478, founFd: 448.0487.

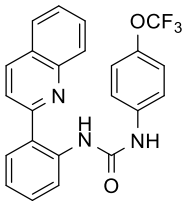
1-(2-(Quinolin-2-yl)phenyl)-3-(*p*-tolyl)urea (5a)



5a

White solid, 86% yield, 304.0 mg; m.p. 176.8-178.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.24 (s, 1H), 9.41 (s, 1H), 8.51 (d, *J* = 8.8 Hz, 1H), 8.27 (d, *J* = 8.4 Hz, 1H), 8.18 (d, *J* = 8.4 Hz, 1H), 8.03 (t, *J* = 8.0 Hz, 2H), 7.90 (d, *J* = 7.6 Hz, 1H), 7.82 (t, *J* = 7.6 Hz, 1H), 7.64 (t, *J* = 7.6 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.37 (d, *J* = 8.4 Hz, 2H), 7.18 (t, *J* = 7.6 Hz, 1H), 7.08 (d, *J* = 8.0 Hz, 2H), 2.24 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 158.0, 153.3, 146.5, 139.1, 138.2, 137.7, 131.4, 130.5, 130.4, 130.2, 129.6, 129.5, 128.1, 127.4, 126.7, 126.3, 122.6, 122.4, 121.5, 119.7, 20.8; HRMS: calcd for $C_{23}H_{20}N_3O$ $[M+H]^+$: 354.1601, found: 354.1613.

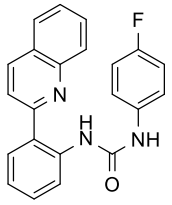
1-(2-(Quinolin-2-yl)phenyl)-3-(4-(trifluoromethoxy)phenyl)urea (5b)



5b

White solid, 77% yield, 326.0 mg; m.p. 187.1-188.9 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.35 (s, 1H), 9.74 (s, 1H), 8.53 (s, 1H), 8.35 (s, 1H), 8.16 (s, 1H), 8.05 (s, 2H), 7.94 (s, 1H), 7.85 (s, 1H), 7.66 (s, 1H), 7.59 (s, 2H), 7.47 (s, 1H), 7.30 (s, 2H), 7.21 (s, 1H); ^{13}C NMR (100 MHz, DMSO) δ 157.9, 153.1, 146.5, 143.2, 139.7, 138.8, 138.3, 130.6, 130.4, 130.3, 129.5, 128.1, 127.4, 126.8, 126.4, 122.9, 122.4, 122.1, 121.5, 120.7 (q, *J* = 9.2 Hz), 120.4; ^{19}F NMR (376 MHz, DMSO) δ -59.5; HRMS: calcd for $C_{23}H_{17}F_3N_3O_2$ $[M+H]^+$: 424.1267, found: 424.1272.

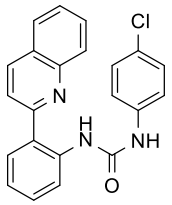
1-(4-Fluorophenyl)-3-(2-(quinolin-2-yl)phenyl)urea (5c)



5c

White solid, 78% yield, 278.8 mg; m.p. 169.4-170.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 10.69 (s, 1H), 9.19 (s, 1H), 8.52 (d, *J* = 8.8 Hz, 1H), 8.22 (d, *J* = 8.4 Hz, 1H), 8.13 (d, *J* = 8.4 Hz, 1H), 8.04 (d, *J* = 8.0 Hz, 1H), 7.97 (d, *J* = 8.8 Hz, 1H), 7.88 (s, 1H), 7.83 (d, *J* = 7.6 Hz, 2H), 7.66 (d, *J* = 7.6 Hz, 1H), 7.46 (s, 1H), 7.21 (t, *J* = 8.4 Hz, 2H), 7.13 (d, *J* = 7.6 Hz, 1H), 7.06 (d, *J* = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, DMSO) δ 158.0, 157.9 (d, *J* = 236.9 Hz), 153.3, 146.5, 139.0, 138.2, 136.6 (d, *J* = 2.4 Hz), 130.5, 130.4, 130.0, 129.5, 128.1, 127.4, 126.8, 126.3, 122.7, 122.4, 121.5, 121.1 (d, *J* = 7.7 Hz), 115.7 (d, *J* = 22.1 Hz); ^{19}F NMR (376 MHz, DMSO) δ = -121.2; HRMS: calcd for $C_{22}H_{17}FN_3O$ $[M+H]^+$: 358.1350, found: 358.1355.

1-(4-Chlorophenyl)-3-(2-(quinolin-2-yl)phenyl)urea (5d)

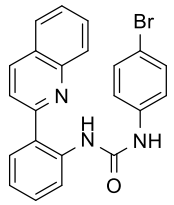


5d

Yellow solid, 82% yield, 306.5 mg; m.p. 172.6-174.1 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.32 (s, 1H), 9.67 (s, 1H), 8.53 (d, *J* = 8.8 Hz, 1H), 8.33 (t, *J* = 6.8 Hz, 1H), 8.16 (d, *J* = 8.4 Hz, 1H), 8.05 (t, *J* = 8.8 Hz, 2H), 7.93 (d, *J* = 7.6 Hz, 1H), 7.85 (t, *J* = 7.6 Hz, 1H), 7.66 (t, *J* = 7.6 Hz, 1H), 7.52 (d, *J* = 8.8 Hz, 2H), 7.46 (t, *J* = 7.4 Hz, 1H), 7.33 (d, *J* = 8.8 Hz, 2H), 7.20 (t, *J* = 7.6 Hz, 1H); ^{13}C NMR

(100 MHz, DMSO) δ 157.9, 153.1, 146.5, 139.4, 138.8, 138.3, 130.6, 130.4, 130.3, 129.5, 129.1, 128.1, 127.4, 126.8, 126.4, 126.0, 122.9, 122.4, 121.5, 120.8; HRMS: calcd for $C_{22}H_{17}ClN_3O$ $[M+H]^+$: 374.1055, found: 374.1064.

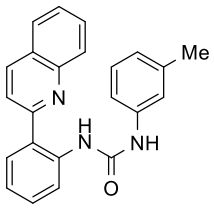
1-(4-Bromophenyl)-3-(2-(quinolin-2-yl)phenyl)urea (5e)



5e

Yellow solid, 67% yield, 280.3 mg; m.p. 201.4-203.9 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.34 (s, 1H), 9.69 (s, 1H), 8.53 (d, *J* = 8.6 Hz, 1H), 8.34 (d, *J* = 8.4 Hz, 1H), 8.16 (d, *J* = 8. Hz, 1H), 8.09 – 7.99 (m, 2H), 7.93 (d, *J* = 7.6 Hz, 1H), 7.85 (t, *J* = 7.2 Hz, 1H), 7.66 (t, *J* = 7.2 Hz, 1H), 7.46 (s, 5H), 7.20 (t, *J* = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, DMSO) δ 157.9, 153.0, 146.5, 139.8, 138.8, 138.3, 131.9, 130.6, 130.4, 130.3, 129.5, 128.1, 127.4, 126.8, 126.4, 122.9, 122.4, 121.5, 121.2, 113.9; HRMS: calcd for $C_{22}H_{17}BrN_3O$ $[M+H]^+$: 418.0550, found: 418.0552.

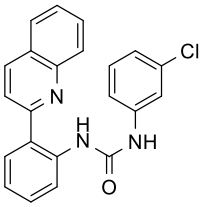
1-(2-(Quinolin-2-yl)phenyl)-3-(m-tolyl)urea (5f)



5f

White solid, 82% yield, 289.8 mg; m.p. 186.3-188.7 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.18 (s, 1H), 9.41 (s, 1H), 8.53 (d, *J* = 8.8 Hz, 1H), 8.28 (d, *J* = 8.4 Hz, 1H), 8.17 (d, *J* = 8.4 Hz, 1H), 8.04 (m, 2H), 7.91 (d, *J* = 7.6 Hz, 1H), 7.84 (t, *J* = 7.6 Hz, 1H), 7.66 (t, *J* = 7.6 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 1H), 7.29 (d, *J* = 10.8 Hz, 2H), 7.18 (m, 2H), 6.80 (d, *J* = 7.6 Hz, 1H), 2.26 (s, 3H);^{13}C NMR (100 MHz, DMSO) δ 158.0, 153.2, 146.6, 140.2, 139.0, 138.3, 138.2, 130.5, 130.4, 130.2, 129.5, 129.0, 128.1, 127.4, 126.7, 126.5, 123.3, 122.7, 122.5, 121.5, 120.0, 116.7, 21.7; HRMS: calcd for $C_{23}H_{20}N_3O$ $[M+H]^+$: 354.1601, found: 354.1613.

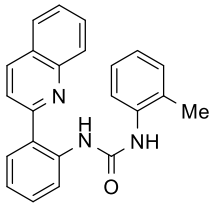
1-(3-Chlorophenyl)-3-(2-(quinolin-2-yl)phenyl)urea (5g)



5g

Yellow solid, 73% yield, 272.9 mg; m.p. 195.2-196.9 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.31 (s, 1H), 9.83 (s, 1H), 8.53 (d, *J* = 8.8 Hz, 1H), 8.37 (d, *J* = 8.4 Hz, 1H), 8.15 (d, *J* = 8.4 Hz, 1H), 8.04 (t, *J* = 8.4 Hz, 2H), 7.93 (d, *J* = 7.6 Hz, 1H), 7.85 (t, *J* = 7.6 Hz, 1H), 7.66 (t, *J* = 7.6 Hz, 1H), 7.47 (t, *J* = 11.6 Hz, 2H), 7.30 (m, 1H), 7.21 (t, *J* = 8.4 Hz, 2H), 6.78 (t, *J* = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, DMSO) δ 157.8, 152.9, 146.4, 140.6, 138.6, 138.3, 131.4, 131.0, 130.6, 130.4, 130.3, 129.5, 128.1, 127.4, 126.8, 126.4, 123.7, 123.1, 122.5, 121.4, 120.2, 119.2. HRMS: calcd for $C_{22}H_{17}ClN_3O$ $[M+H]^+$: 374.1055, found: 374.1064.

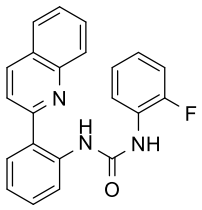
1-(2-(Quinolin-2-yl)phenyl)-3-(*o*-tolyl)urea (5h)



5h

White solid, 77% yield, 272.1 mg; m.p. 169.8-170.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.08 (s, 1H), 8.65 (s, 1H), 8.52 (s, 1H), 8.18 (s, 1H), 8.02 (s, 3H), 7.89 (s, 1H), 7.79 (s, 1H), 7.65 (s, 1H), 7.50 (s, 2H), 7.19 (s, 3H), 7.05 (s, 1H), 2.21 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 158.0, 153.8, 146.6, 139.1, 138.1, 137.5, 131.6, 130.9, 130.4, 130.2, 129.4, 128.1, 127.3, 126.8, 126.7, 124.8, 122.7, 122.5, 121.6, 18.4; HRMS: calcd for $C_{23}H_{20}N_3O$ $[M+H]^+$: 354.1601, found: 354.1613.

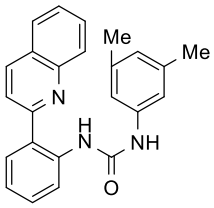
1-(2-Fluorophenyl)-3-(2-(quinolin-2-yl)phenyl)urea (5i)



5i

White solid, 70% yield, 250.2 mg; m.p. 162.6-164.5 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.75 (s, 1H), 10.25 (s, 1H), 9.56 (d, *J* = 8.8 Hz, 1H), 9.26 (d, *J* = 8.4 Hz, 1H), 9.17 (d, *J* = 8.4 Hz, 1H), 9.08 (d, *J* = 78.0 Hz, 1H), 9.01 (d, *J* = 8.8 Hz, 1H), 8.89 (m, 3H), 8.69 (t, *J* = 7.2 Hz, 1H), 8.50 (t, *J* = 7.6 Hz, 1H), 8.25 (t, *J* = 8.0 Hz, 2H), 8.18 (t, *J* = 7.6 Hz, 1H), 8.14 – 8.04 (m, 1H); ^{13}C NMR (100 MHz, DMSO) δ 158.9, 154.9 (d, *J* = 241.7 Hz), 154.3, 148.0, 139.3, 139.0, 131.6, 131.5, 131.1, 130.5, 129.2, 129.0, 128.7 (d, *J* = 11.0 Hz), 128.4, 127.9, 125.9 (d, *J* = 3.3 Hz), 125.2 (d, *J* = 7.6 Hz), 124.6, 124.2, 123.7, 122.9, 116.8 (d, *J* = 19.3 Hz); ^{19}F NMR (376 MHz, DMSO) δ -126.5; HRMS: calcd for $C_{22}H_{17}FN_3O$ $[M+H]^+$: 358.1350, found: 358.1355.

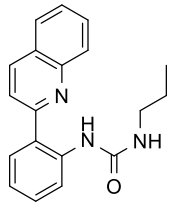
1-(3,5-Dimethylphenyl)-3-(2-(quinolin-2-yl)phenyl)urea (5j)



5j

White solid, 75% yield, 275.6 mg; m.p. 186.9-188.2 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.18 (s, 1H), 9.34 (s, 1H), 8.52 (d, *J* = 8.8 Hz, 1H), 8.26 (d, *J* = 8.4 Hz, 1H), 8.17 (d, *J* = 8.4 Hz, 1H), 8.03 (m, 2H), 7.90 (d, *J* = 7.6 Hz, 1H), 7.83 (t, *J* = 7.2 Hz, 1H), 7.65 (t, *J* = 7.6 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.18 (t, *J* = 7.6 Hz, 1H), 7.09 (d, *J* = 6.0 Hz, 2H), 6.61 (s, 1H), 2.22 (d, *J* = 8.4 Hz, 6H); ^{13}C NMR (100 MHz, DMSO) δ 158.0, 153.2, 146.5, 140.1, 139.0, 138.1, 130.5, 130.4, 130.2, 129.5, 128.1, 127.4, 126.7, 126.5, 124.2, 122.6, 122.4, 121.5, 117.3, 116.3, 21.6; HRMS: calcd for $C_{24}H_{22}N_3O$ $[M+H]^+$: 368.1757, found: 368.1764.

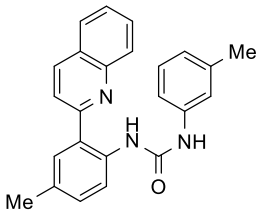
1-Propyl-3-(2-(quinolin-2-yl)phenyl)urea (5k)



5k

White solid, 62% yield, 189.3 mg; m.p. 154.5-156.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.69 (s, 1H), 8.39 (d, *J* = 7.2 Hz, 1H), 8.27 (d, *J* = 8.0 Hz, 1H), 8.03 (d, *J* = 7.2 Hz, 1H), 7.86 (d, *J* = 7.2 Hz, 2H), 7.76 (s, 2H), 7.57 (s, 1H), 7.42 (s, 1H), 7.12 (s, 1H), 4.56 (s, 1H), 3.28 (d, *J* = 4.4 Hz, 2H), 1.57 (d, *J* = 6.4 Hz, 2H), 0.95 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.6, 155.8, 146.2, 139.4, 137.4, 130.3, 130.1, 129.5, 128.3, 127.7, 126.7, 126.5, 125.2, 121.9, 121.5, 121.2, 42.7, 23.3, 11.4; HRMS: calcd for $C_{19}H_{20}N_3O$ $[M+H]^+$: 306.1601, found: 306.1607.

1-(4-Methyl-2-(quinolin-2-yl)phenyl)-3-(*m*-tolyl)urea (5l)

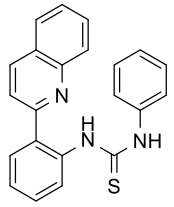


5l

White solid, 85% yield, 312.3 mg; m.p. 181.3-183.2 °C; ^{1}H NMR (400 MHz, DMSO) δ 11.48 (s, 1H), 9.42 (s, 1H), 8.48 (d, *J* = 8.8 Hz, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 8.02 (t, *J* = 10.4 Hz, 3H), 7.81 (t,

J = 9.6 Hz, 2H), 7.63 (d, *J* = 7.6 Hz, 1H), 7.38 (d, *J* = 8.0 Hz, 2H), 7.09 (d, *J* = 8.0 Hz, 2H), 6.99 (d, *J* = 7.6 Hz, 1H), 2.37 (s, 3H), 2.24 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 158.0, 153.3, 146.4, 140.0, 139.2, 138.1, 137.7, 131.4, 130.4, 130.2, 129.6, 129.3, 128.0, 127.2, 126.6, 123.4, 123.3, 122.7, 121.2, 119.7, 21.7, 20.8; HRMS: calcd for $C_{24}H_{22}N_3O$ $[M+H]^+$: 368.1757, found: 368.1764.

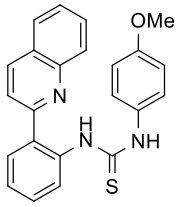
1-Phenyl-3-(2-(quinolin-2-yl)phenyl)thiourea (5m)



5m

White solid, 76% yield, 270.2 mg; m.p. 192.3-194.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.54 (s, 1H), 8.45 (d, *J* = 8.4 Hz, 1H), 8.22 (s, 1H), 8.18 (d, *J* = 8.8 Hz, 1H), 7.77 – 7.67 (m, 3H), 7.52 – 7.40 (m, 5H), 7.37 (t, *J* = 6.4 Hz, 3H), 7.29 (t, *J* = 7.6 Hz, 1H), 6.54 (d, *J* = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.0, 157.1, 146.0, 138.2, 137.5, 137.5, 130.1, 129.7, 129.5, 129.4, 129.1, 128.5, 127.3, 126.7, 126.5, 126.4, 126.3, 125.2, 124.1, 120.8; HRMS: calcd for $C_{22}H_{18}N_3S$ $[M+H]^+$: 356.1216, found: 356.1220.

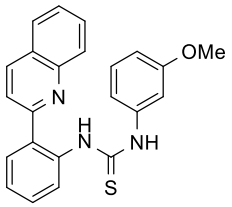
1-(4-Methoxyphenyl)-3-(2-(quinolin-2-yl)phenyl)thiourea (5n)



5n

White solid, 72% yield, 277.6 mg; m.p. 189.2-190.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.94 (s, 1H), 8.45 (d, *J* = 8.4 Hz, 1H), 8.19 (d, *J* = 8.8 Hz, 1H), 8.03 (s, 1H), 7.77 – 7.70 (m, 2H), 7.65 (m, 1H), 7.47 (m, 3H), 7.31 – 7.26 (m, 1H), 7.21 (t, *J* = 6.0 Hz, 2H), 6.95 – 6.91 (m, 2H), 6.78 (s, 1H), 3.88 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.5, 158.5, 157.4, 146.1, 138.0, 137.5, 130.0, 129.9, 129.6, 129.5, 128.9, 128.8, 127.3, 126.7, 126.6, 126.6, 126.4, 125.2, 121.0, 115.2, 55.6; HRMS: calcd for $C_{23}H_{20}N_3OS$ $[M+H]^+$: 386.1322, found: 386.1331.

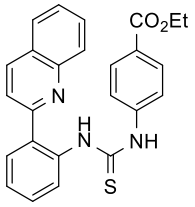
1-(3-Methoxyphenyl)-3-(2-(quinolin-2-yl)phenyl)thiourea (5o)



5o

White solid, 69% yield, 266.0 mg; m.p. 177.5-180.1 °C; ^{1}H NMR (400 MHz, DMSO) δ 12.10 (s, 1H), 10.32 (s, 1H), 8.42 (d, *J* = 8.6 Hz, 1H), 8.25 (d, *J* = 8.0 Hz, 1H), 8.00 – 7.89 (m, 2H), 7.85 (d, *J* = 7.6 Hz, 1H), 7.54 (ddd, *J* = 20.4, 15.6, 6.8 Hz, 3H), 7.34 (dt, *J* = 15.2, 7.6 Hz, 2H), 7.11 (s, 1H), 7.07 (d, *J* = 7.8 Hz, 1H), 7.02 (s, 1H), 6.87 (d, *J* = 7.8 Hz, 1H), 3.72 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 179.2, 160.5, 157.3, 146.1, 140.2, 138.7, 138.2, 130.6, 130.4, 130.2, 123.0, 129.3, 128.4, 128.1, 127.4, 127.2, 126.7, 125.3, 121.5, 116.3, 111.0, 110.0, 55.7. HRMS: calcd for $C_{23}H_{20}N_3OS$ $[M+H]^+$: 386.1322, found: 386.1331.

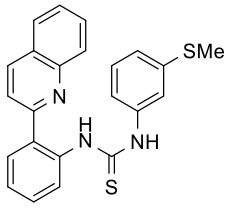
Ethyl 4-(3-(2-(quinolin-2-yl)phenyl)thioureido)benzoate (5p)



5p

White solid, 62% yield, 265.1 mg; m.p. 178.5-179.6 °C; ^{1}H NMR (400 MHz, DMSO) δ 12.05 (s, 1H), 10.58 (s, 1H), 8.50 (d, *J* = 8.8 Hz, 1H), 8.14 (d, *J* = 8.0 Hz, 1H), 7.96 (m, 5H), 7.68 – 7.57 (m, 4H), 7.52 (t, *J* = 7.6 Hz, 1H), 7.37 (t, *J* = 7.2 Hz, 2H), 4.33 (q, *J* = 7.2 Hz, 2H), 1.33 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, DMSO) δ 179.5, 165.8, 157.4, 146.4, 143.9, 138.3, 138.2, 130.7, 130.6, 130.4, 129.5, 128.4, 128.2, 127.4, 127.1, 126.8, 125.8, 125.6, 122.7, 121.7, 61.1, 14.7; HRMS: calcd for $C_{25}H_{22}N_3O_2S$ $[M+H]^+$: 428.1427, found: 428.1431.

1-(3-(Methylthio)phenyl)-3-(2-(quinolin-2-yl)phenyl)thiourea (5q)

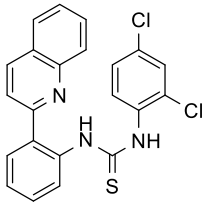


5q

Yellow solid, 75% yield, 301.2 mg; m.p. 182.7-183.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.58 (s, 1H), 8.44 (d, *J* = 8.4 Hz, 2H), 8.17 (d, *J* = 8.8 Hz, 1H), 7.74 – 7.66 (m, 3H), 7.51 – 7.42 (m, 3H), 7.35

– 7.26 (m, 2H), 7.23 – 7.16 (m, 2H), 7.13 (t, *J* = 2.0 Hz, 1H), 6.65 (d, *J* = 8.0 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.0, 157.1, 146.0, 141.2, 138.2, 138.1, 137.6, 130.1, 129.9, 129.5, 129.3, 129.1, 128.4, 127.3, 126.8, 126.4, 126.3, 125.2, 124.2, 121.2, 120.8, 120.7, 15.6; HRMS: calcd for $C_{23}H_{20}N_3S_2$ $[M+H]^+$: 402.1093, found: 402.1098.

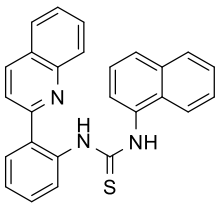
1-(2,4-Dichlorophenyl)-3-(2-(quinolin-2-yl)phenyl)thiourea (5r)



5r

White solid, 78% yield, 331.0 mg; m.p. 185.4-187.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.07 (s, 1H), 8.43 (d, *J* = 8.4 Hz, 1H), 8.27 (t, *J* = 8.8 Hz, 2H), 7.96 (M, 2H), 7.87 (M, 2H), 7.80 – 7.73 (m, 1H), 7.59 (t, *J* = 7.6 Hz, 1H), 7.50 – 7.43 (m, 1H), 7.37 (d, *J* = 2.4 Hz, 1H), 7.23 – 7.15 (m, 2H), 7.01 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.1, 151.8, 145.8, 139.1, 137.7, 134.4, 130.7, 130.5, 129.2, 128.6, 128.0, 128.0, 127.7, 127.6, 127.0, 126.5, 124.2, 122.7, 122.5, 121.4, 121.1, 120.5; HRMS: calcd for $C_{22}H_{16}Cl_2N_3S$ $[M+H]^+$: 424.0437, found: 424.0445.

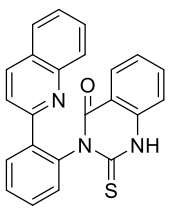
1-(Naphthalen-1-yl)-3-(2-(quinolin-2-yl)phenyl)thiourea (5s)



5s

White solid, 67% yield, 271.7 mg; m.p. 194.6-196.1 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.66 (s, 1H), 8.52 (d, *J* = 8.0 Hz, 1H), 8.19 (s, 1H), 8.08 (d, *J* = 8.4 Hz, 1H), 7.93 – 7.82 (m, 3H), 7.63 (d, *J* = 8.0 Hz, 2H), 7.59 – 7.52 (m, 2H), 7.50 – 7.41 (m, 3H), 7.35 (m, 2H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.25 (d, *J* = 7.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.7, 157.2, 145.8, 137.8, 137.4, 134.7, 132.8, 130.5, 129.6, 129.5, 129.4, 128.9, 128.4, 128.4, 128.3, 127.2, 127.1, 126.8, 126.7, 126.5, 126.2, 125.9, 125.3, 124.5, 122.3, 120.9; HRMS: calcd for $C_{26}H_{19}N_3S$ $[M+H]^+$: 406.1372, found: 406.1381.

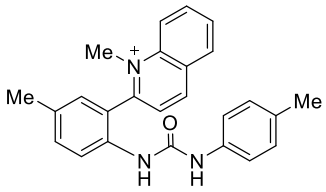
3-(2-(Quinolin-2-yl)phenyl)-2-thioxo-2,3-dihydroquinazolin-4(1*H*)-one (5t)



5t

White solid, 83% yield, 316.2 mg; m.p. 285.1-286.3 °C; ^{1}H NMR (400 MHz, DMSO) δ 12.7 (s, 1H), 8.4 (d, *J* = 8.6 Hz, 1H), 8.1 (d, *J* = 7.8 Hz, 1H), 8.03 – 7.96 (m, 1H), 7.92 – 7.87 (m, 1H), 7.9 (d, *J* = 8.8 Hz, 1H), 7.8 (t, *J* = 7.6 Hz, 1H), 7.6 (dd, *J* = 5.6, 3.2 Hz, 2H), 7.5 (dd, *J* = 6.0, 3.2 Hz, 3H), 7.4 (t, *J* = 7.6 Hz, 1H), 7.4 (d, *J* = 8.2 Hz, 1H), 7.02 – 6.92 (m, 1H). ^{13}C NMR (100 MHz, DMSO) δ 175.9, 161.1, 156.2, 147.2, 140.0, 137.8, 137.2, 136.7, 136.0, 131.4, 130.8, 130.2, 130.0, 129.4, 128.5, 128.2, 128.0, 127.0, 126.8, 124.9, 121.4, 116.8, 116.1. HRMS: calcd for $C_{23}H_{16}N_3OS$ $[M+H]^+$: 382.1009, found: 382.1014.

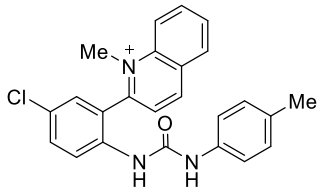
1-Methyl-2-(5-methyl-2-(3-(*p*-tolyl)ureido)phenyl)quinolin-1-ium (5')



5'

Yellow solid, 68% yield, 259.8 mg; m.p. 195.2-195.9 °C; ^{1}H NMR (400 MHz, DMSO) 9.43 (s, 1H), 9.33 (s, 1H), 9.20 (d, J = 8.6 Hz, 1H), 8.61 (d, *J* = 9.0 Hz, 1H), 8.47 (d, *J* = 8.1 Hz, 1H), 8.28 (s, 1H), 8.04 (dd, *J* = 17.6, 8.4 Hz, 2H), 7.75 (d, *J* = 8.4 Hz, 1H), 7.49 (d, *J* = 8.4 Hz, 1H), 7.43 (s, 1H), 7.05 (d, *J* = 8.0 Hz, 2H), 6.94 (d, *J* = 8.0 Hz, 2H), 4.42 (s, 3H), 2.38 (s, 3H), 2.15 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 170.9, 158.9, 153.3, 146.3, 140.1, 137.2, 135.8, 135.0, 133.3, 131.2, 130.7, 130.5, 130.0, 129.5, 128.9, 125.7, 125.4, 123.4, 120.2, 118.5, 42.7, 20.8, 20.7; HRMS: calcd for $C_{25}H_{24}N_3O^+$ $[M]^+$: 382.1914, found: 382.1926.

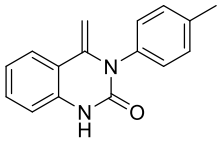
2-(5-Chloro-2-(3-(*p*-tolyl)ureido)phenyl)-1-methylquinolin-1-ium (5'')



5''

Yellow solid, 53% yield, 213.1 mg; m.p. 201.7-202.5 °C; ^{1}H NMR (400 MHz, DMSO) δ 9.26 (d, *J* = 8.4 Hz, 1H), 9.09 (d, *J* = 9.2 Hz, 2H), 8.64 (d, *J* = 9.2 Hz, 1H), 8.49 (d, *J* = 8.0 Hz, 1H), 8.32 (t, *J* = 8.0 Hz, 1H), 8.12 – 8.04 (m, 2H), 7.94 (t, *J* = 8.4 Hz, 1H), 7.79 – 7.71 (m, 2H), 7.10 – 7.01 (m, 2H), 6.96 (d, *J* = 8.0 Hz, 2H), 4.43 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 170.9, 157.0, 153.0, 146.8, 140.2, 136.7, 136.1, 132.4, 131.6, 130.8, 130.3, 123.0, 129.6, 129.2, 127.7, 126.4, 125.5, 124.8, 120.2, 118.8, 42.8, 20.7; HRMS: calcd for $C_{24}H_{21}ClN_3O^+$ $[M]^+$: 402.1368, found: 402.1370.

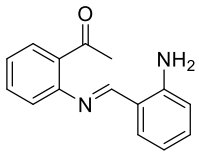
4-Methylene-3-(*p*-tolyl)-3,4-dihydroquinazolin-2(1H)-one (6a)



6a

White solid, 67% yield, 271.7 mg; m.p. 215.3-218.1 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (dd, J = 8.0, 1.2 Hz, 1H), 7.37 (d, *J* = 8.4 Hz, 1H), 7.32 (d, *J* = 8.0 Hz, 2H), 7.14 – 7.11 (m, 2H), 7.05 (d, *J* = 8.4 Hz, 2H), 7.02 – 6.97 (m, 1H), 6.94 (dd, *J* = 8.1, 0.9 Hz, 1H), 4.76 (d, *J* = 1.6 Hz, 1H), 3.43 (d, *J* = 1.7 Hz, 1H), 2.37 (s, 3H).

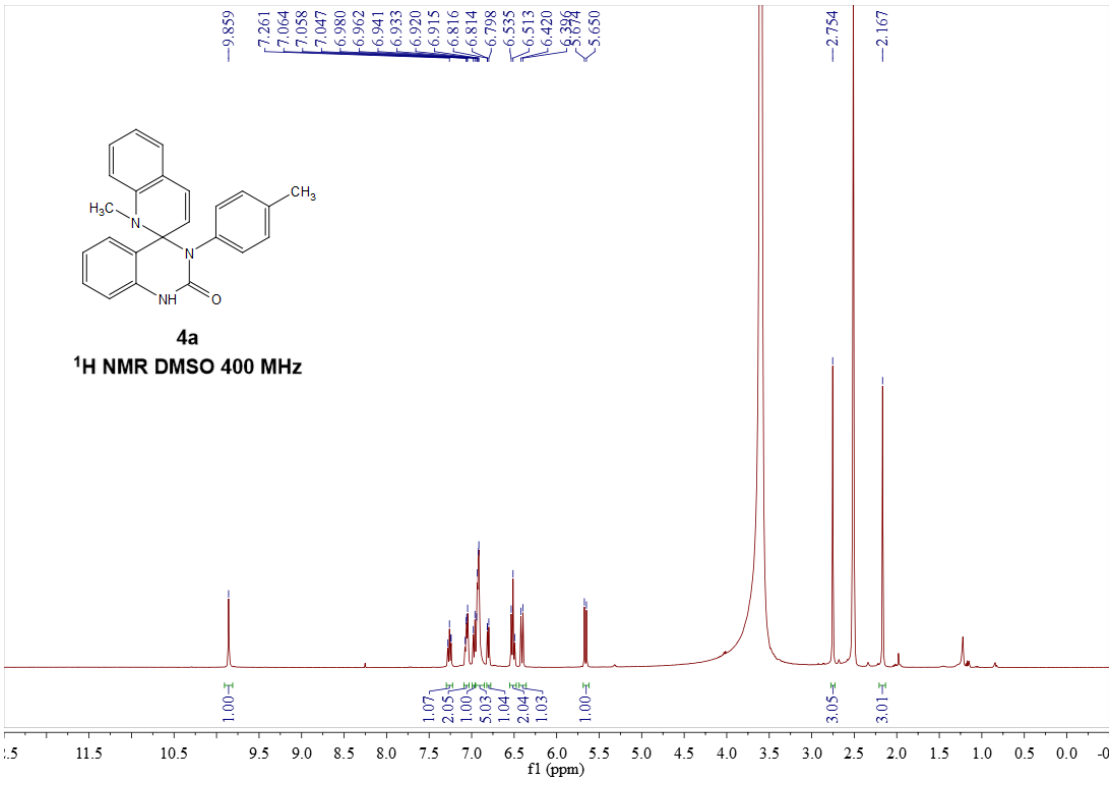
1-(2-((2-Aminobenzylidene)amino)phenyl)ethan-1-one (7ad)



7ad

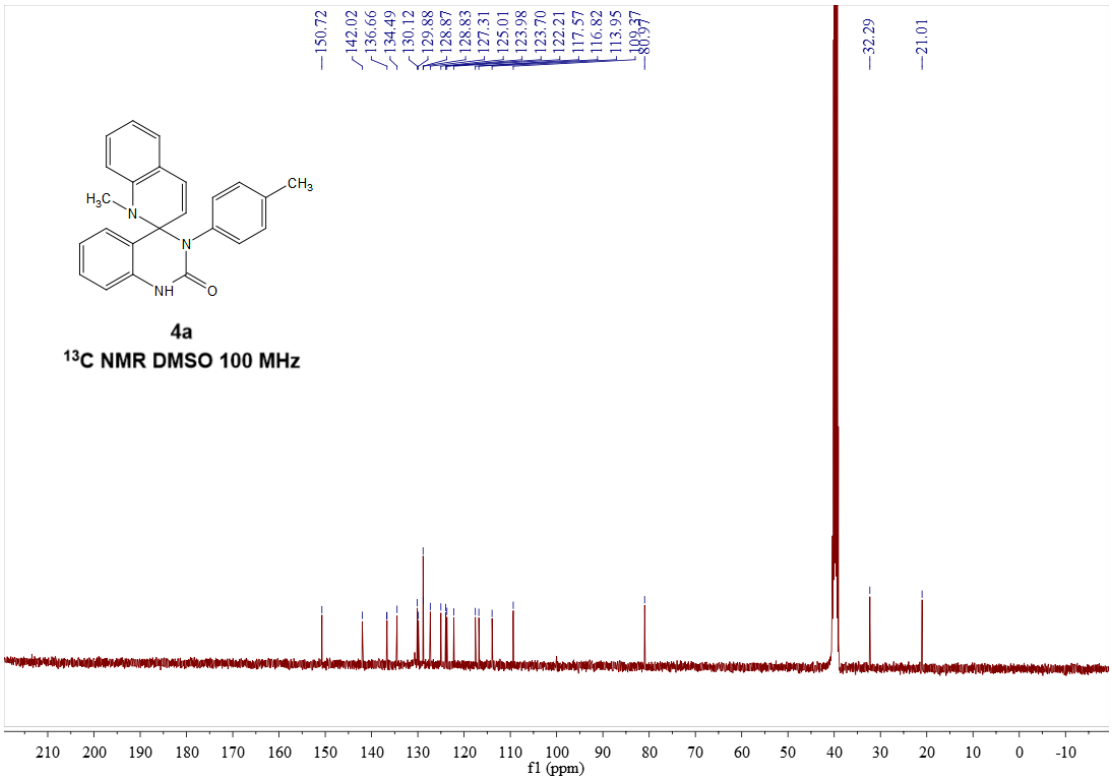
White solid, 13% yield, 31.1 mg; m.p. 124.6-127.3 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 8.4 Hz, 1H), 7.98 (d, *J* = 8.3 Hz, 1H), 7.71 – 7.67 (m, 2H), 7.66 (s, 1H), 7.53 (t, *J* = 7.6 Hz, 1H), 7.22 – 7.16 (m, 1H), 6.84 – 6.77 (m, 2H), 6.14 (s, 2H), 2.75 (s, 3H).

4. ^{1}H NMR, ^{13}C NMR and ^{19}F spectra of products



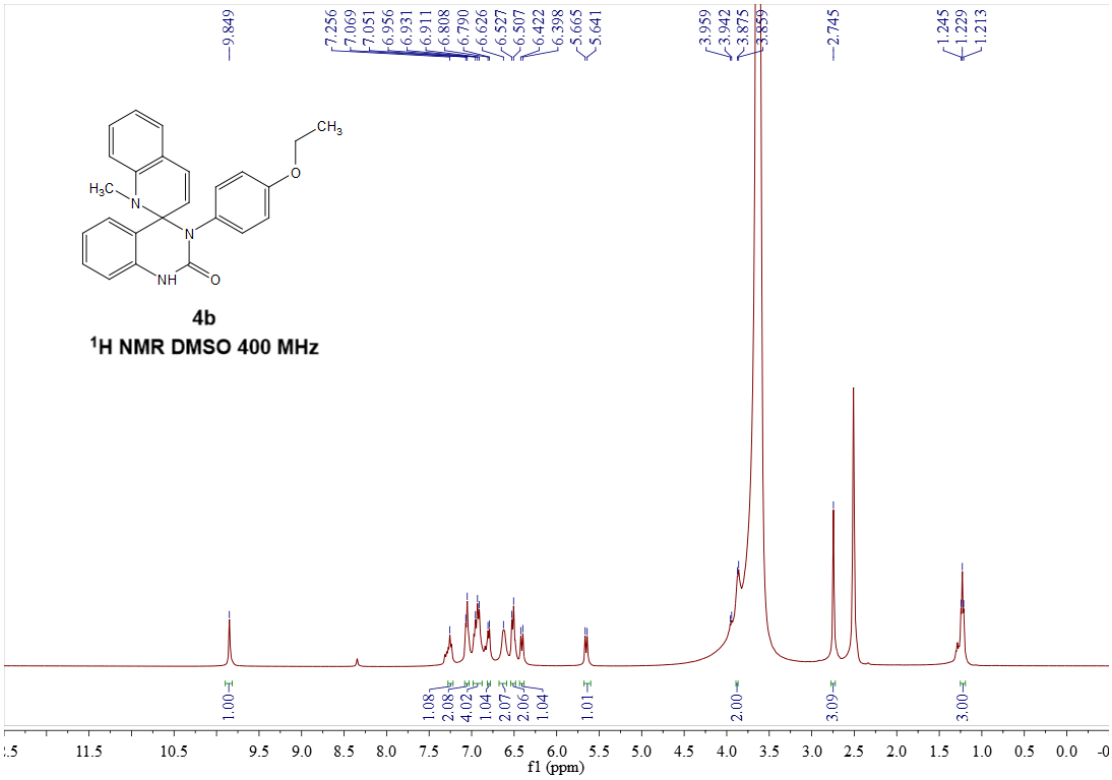
4a

^{1}H NMR DMSO 400 MHz



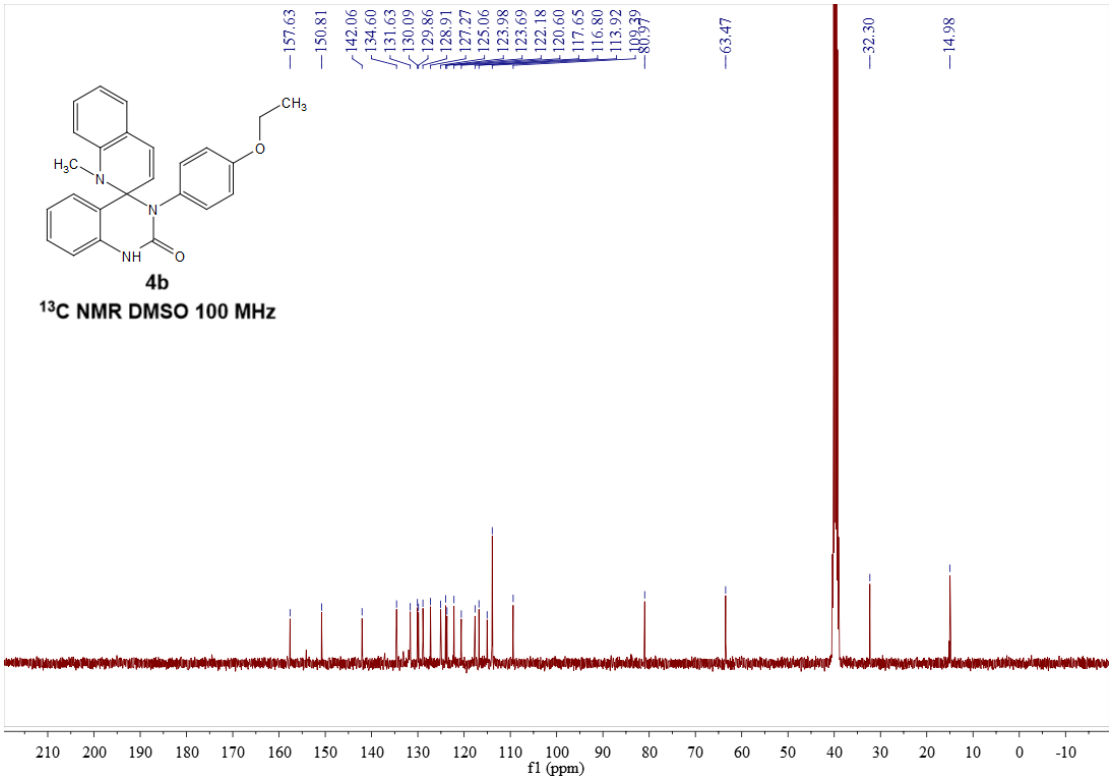
4a

^{13}C NMR DMSO 100 MHz



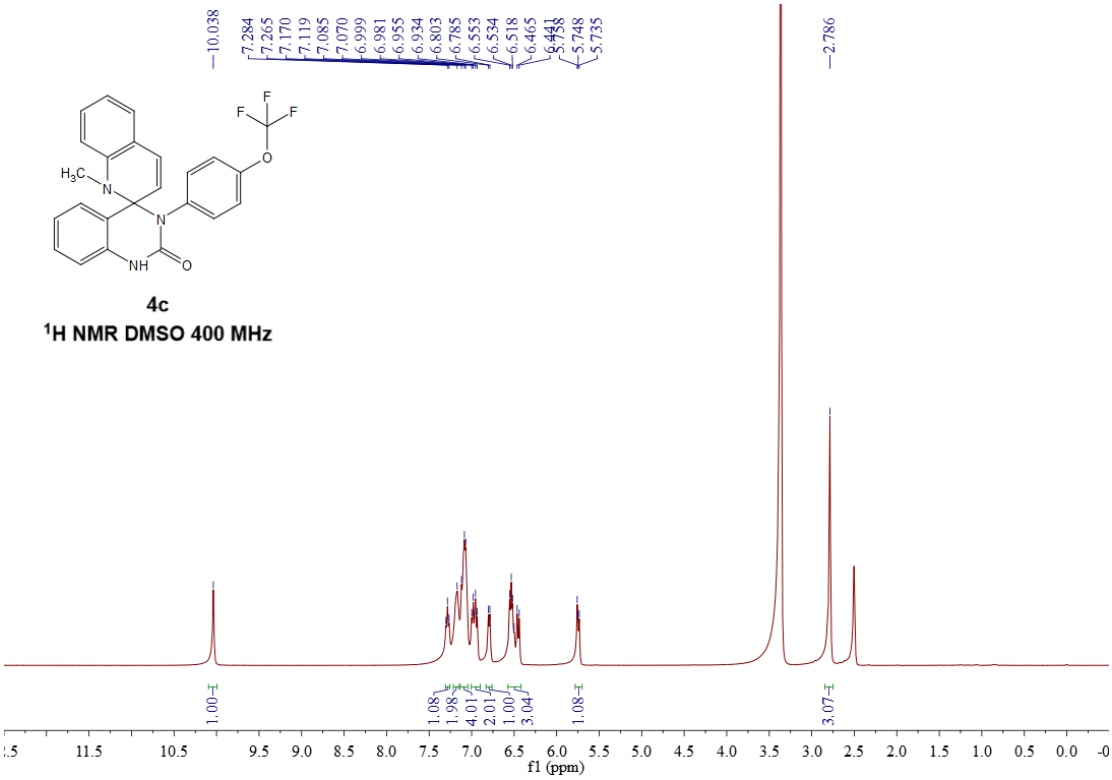
4b

^{1}H NMR DMSO 400 MHz



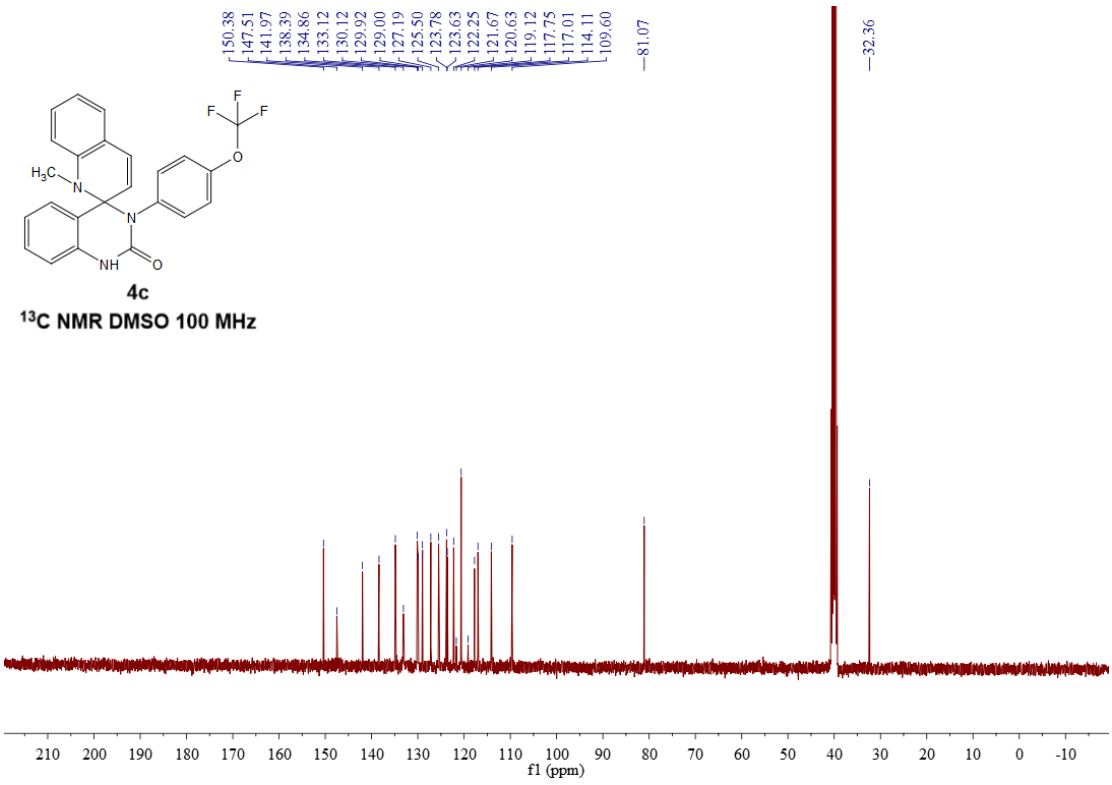
4b

^{13}C NMR DMSO 100 MHz



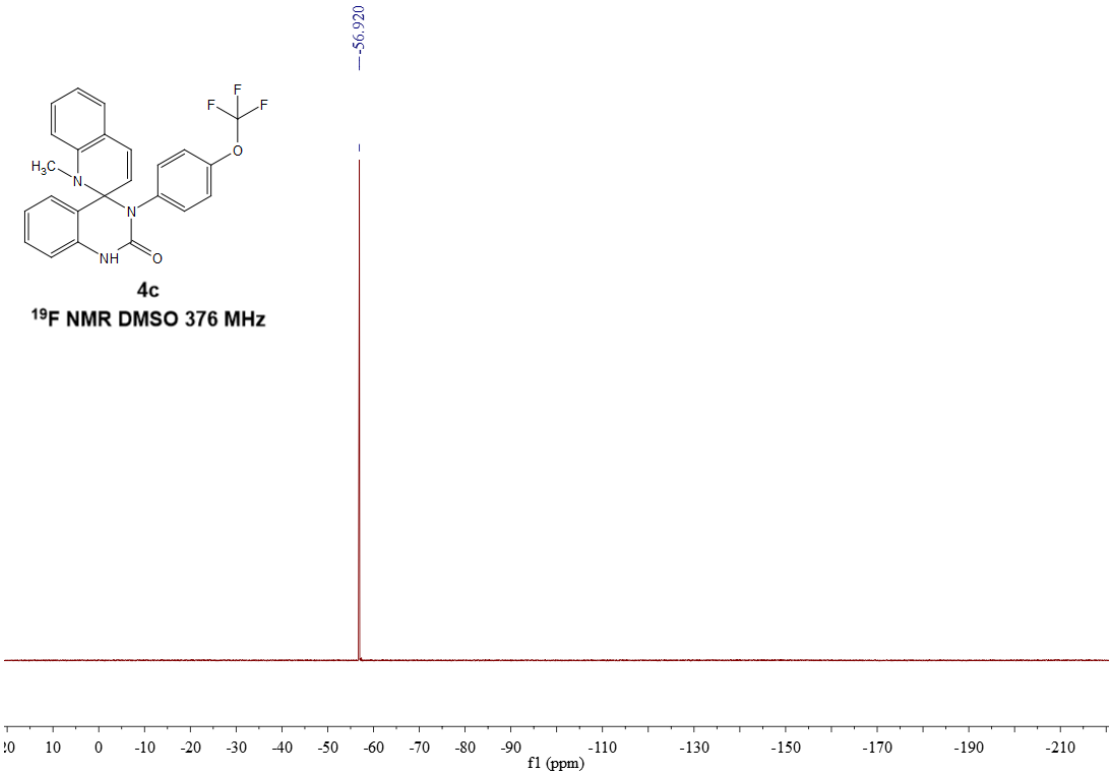
4c

^{1}H NMR DMSO 400 MHz



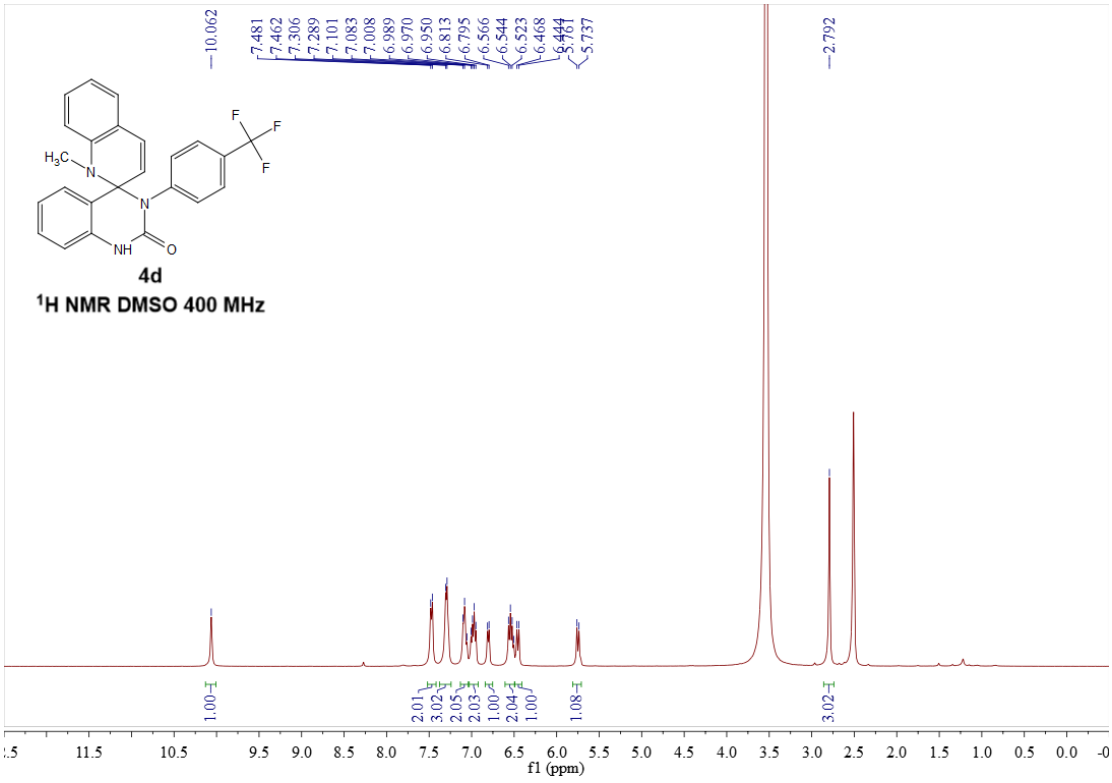
4c

^{13}C NMR DMSO 100 MHz



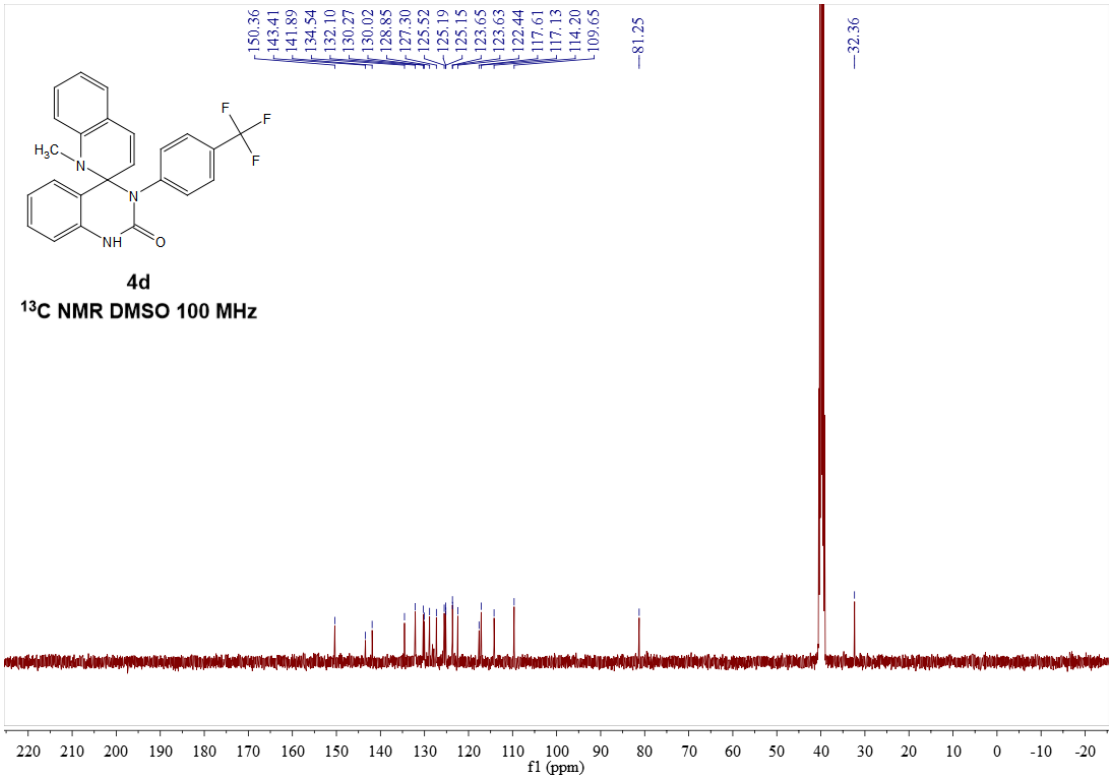
4c

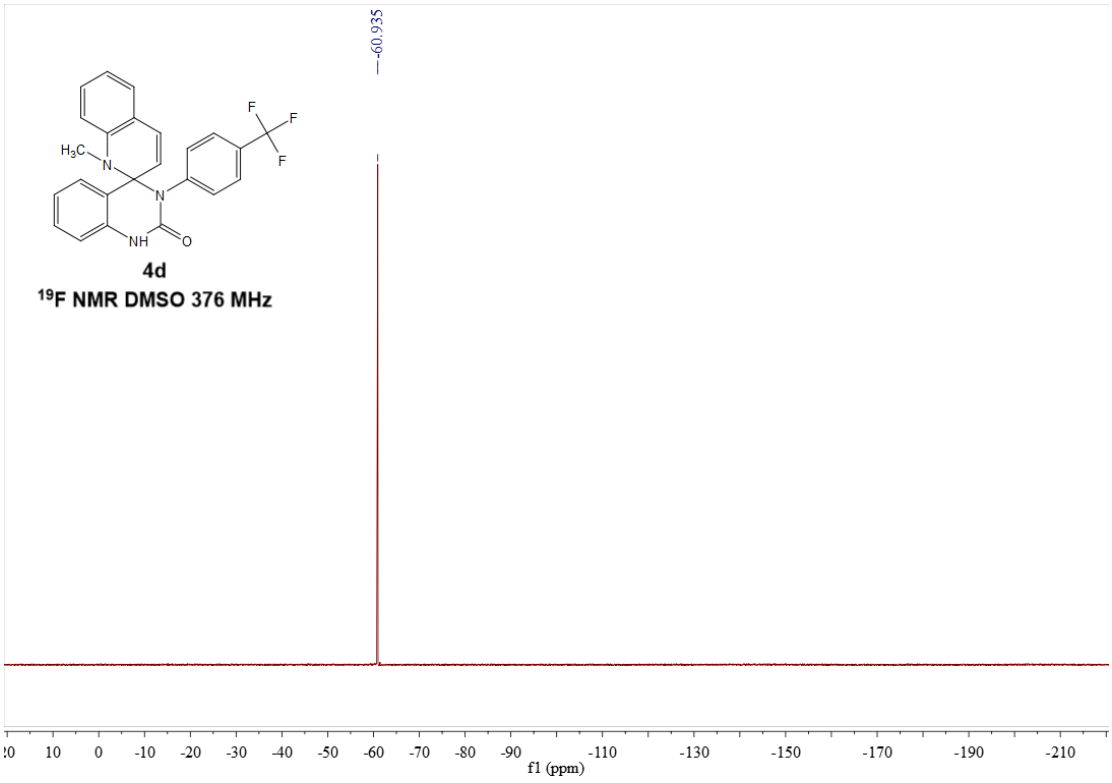
^{19}F NMR DMSO 376 MHz

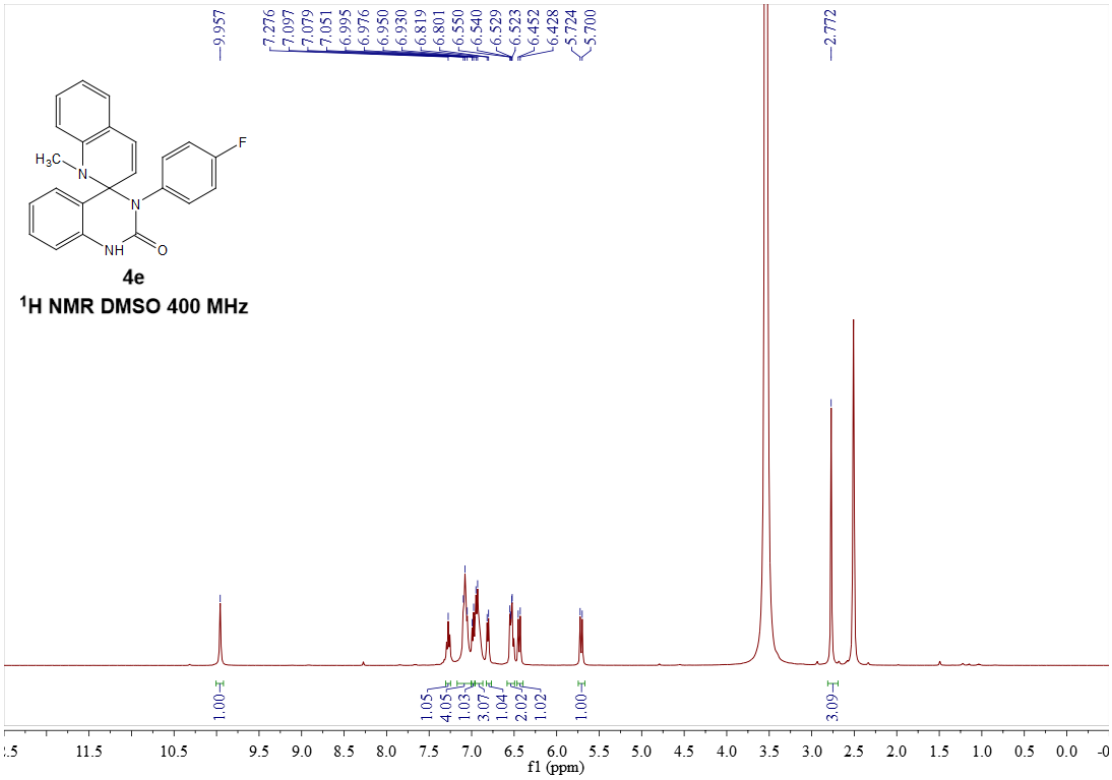


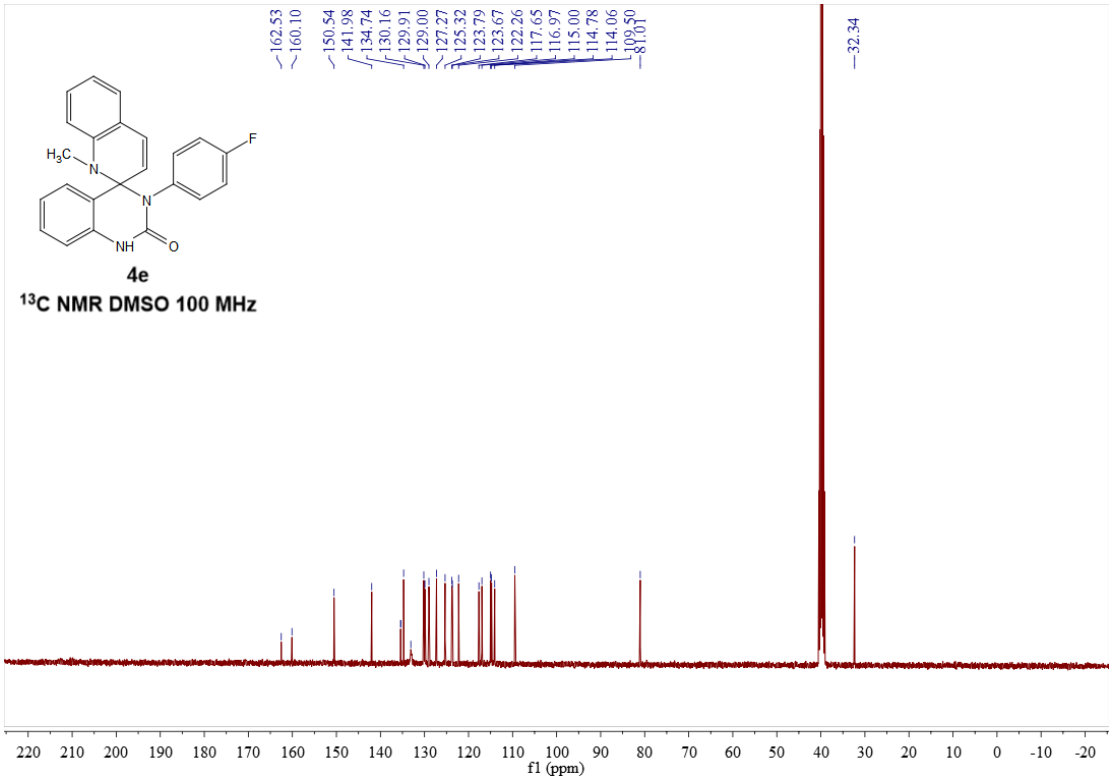
4d

^{1}H NMR DMSO 400 MHz


150.36
143.41
141.89
134.54
132.10
130.27
130.02
128.85
127.30
125.52
125.19
125.15
123.65
123.63
122.44
117.61
117.13
114.20
109.65
81.25
32.36
F
F
F
H3C
N
N
NH
O
4d
13C NMR DMSO 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)

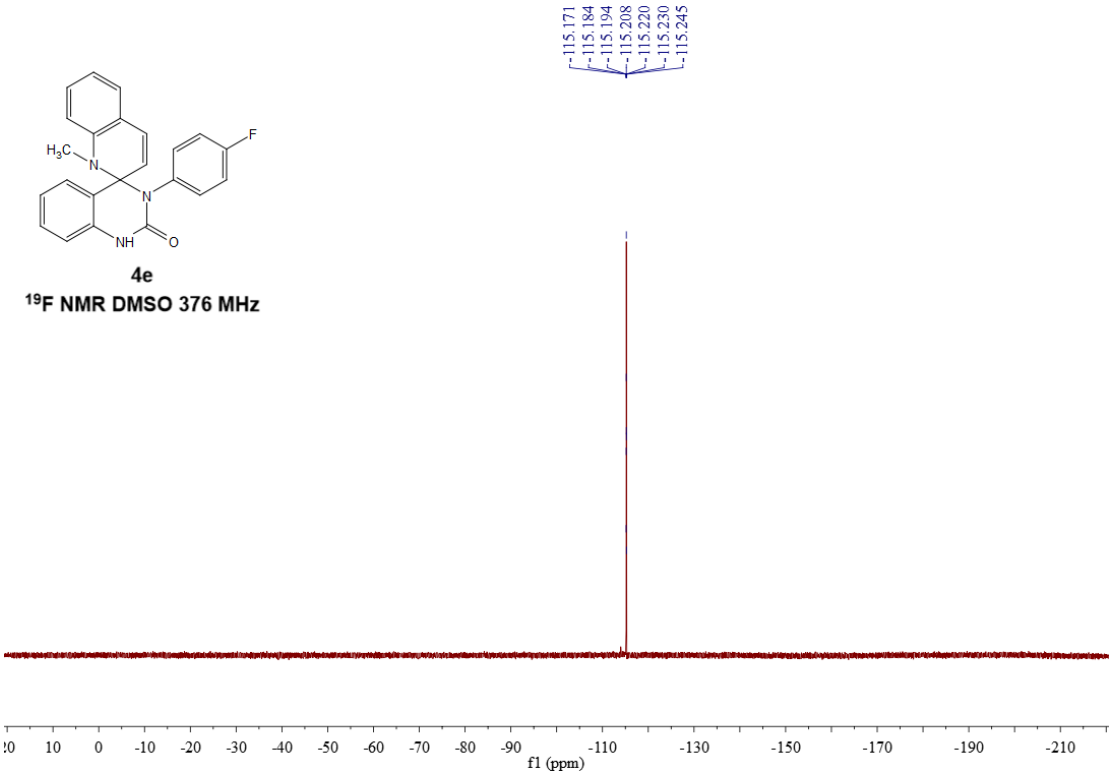

60.935
F
F
F
H3C
N
N
NH
O
4d
19F NMR DMSO 376 MHz
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210
f1 (ppm)

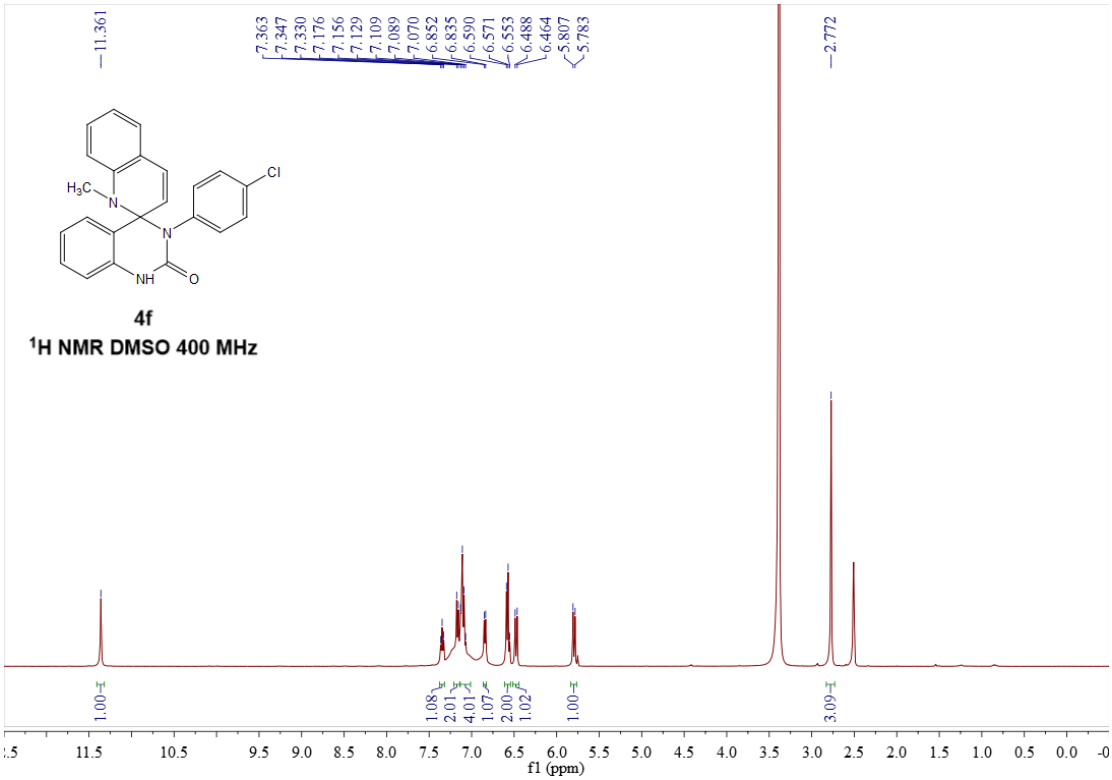

9.957
7.276
7.097
7.079
7.051
6.995
6.976
6.950
6.930
6.819
6.801
6.550
6.540
6.529
6.523
6.452
6.428
5.724
5.700
2.772
H3C
N
F
N
NH
O
4e
1H NMR DMSO 400 MHz
1.00
1.05
4.05
1.03
3.07
1.04
2.02
1.02
1.00
3.09
f1 (ppm)


162.53
160.10
150.54
141.98
134.74
130.16
129.91
129.00
127.27
125.32
123.79
123.67
122.26
117.65
116.97
115.00
114.78
114.06
109.50
81.01
32.34
H3C
N
F
N
NH
O
4e
13C NMR DMSO 100 MHz
f1 (ppm)

4e

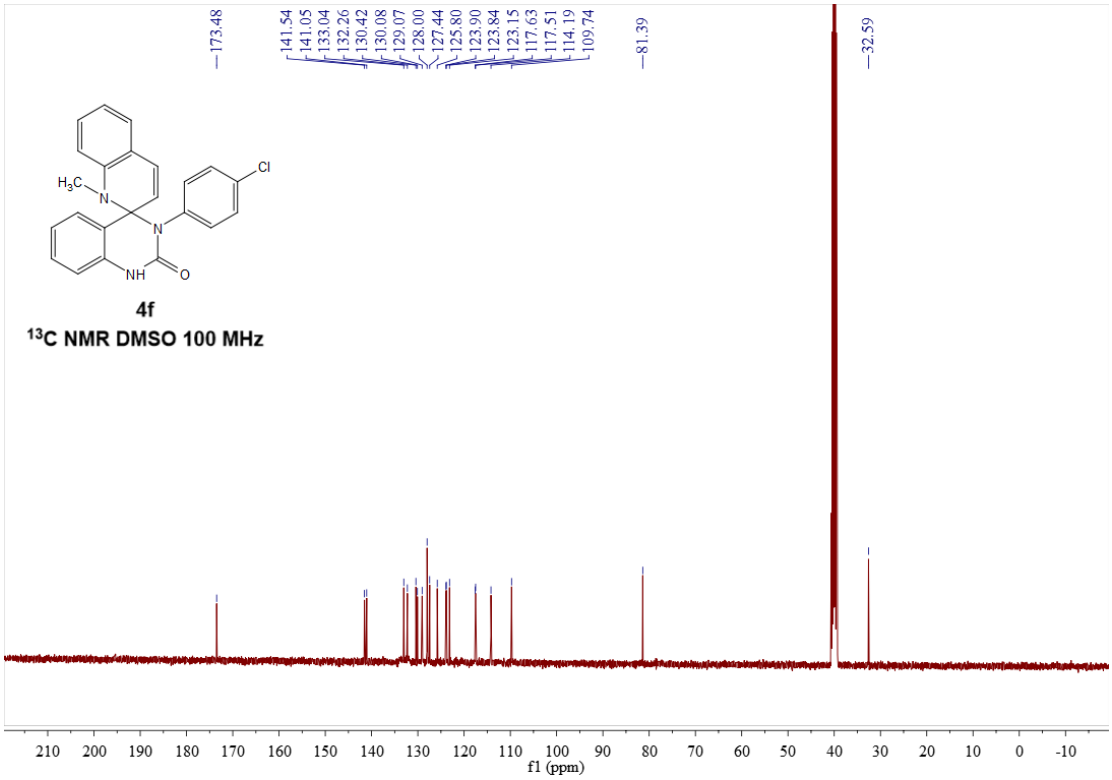
^{19}F NMR DMSO 376 MHz





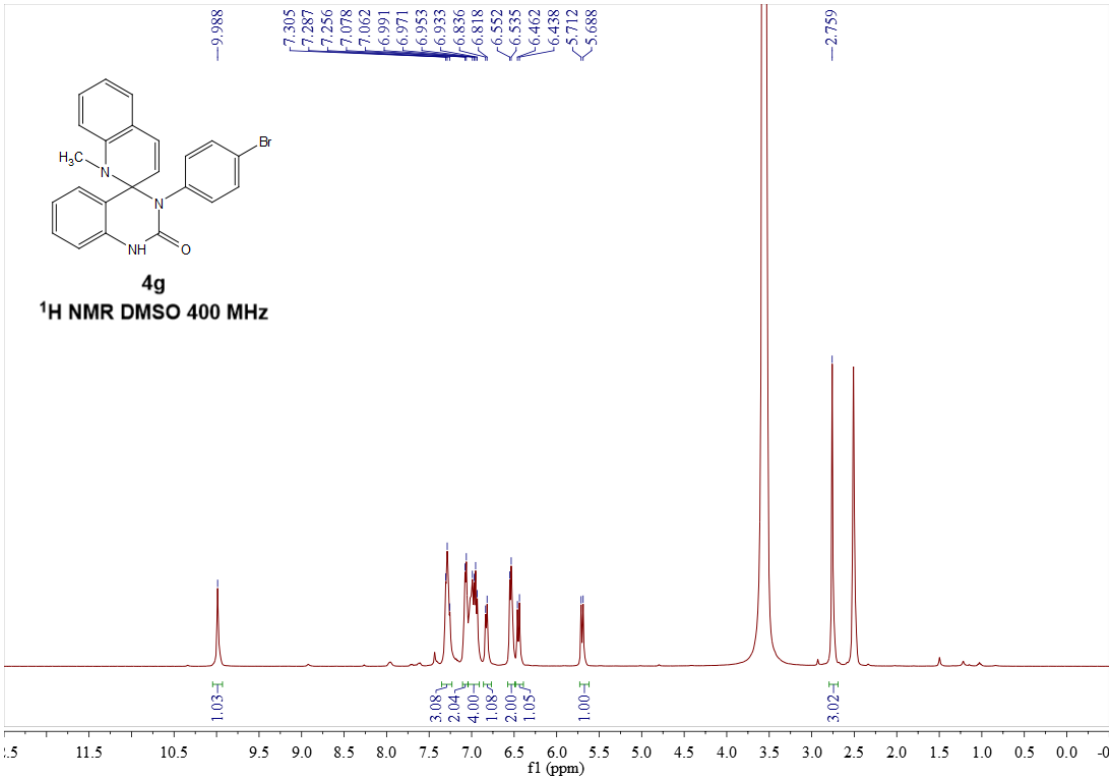
4f

^{1}H NMR DMSO 400 MHz



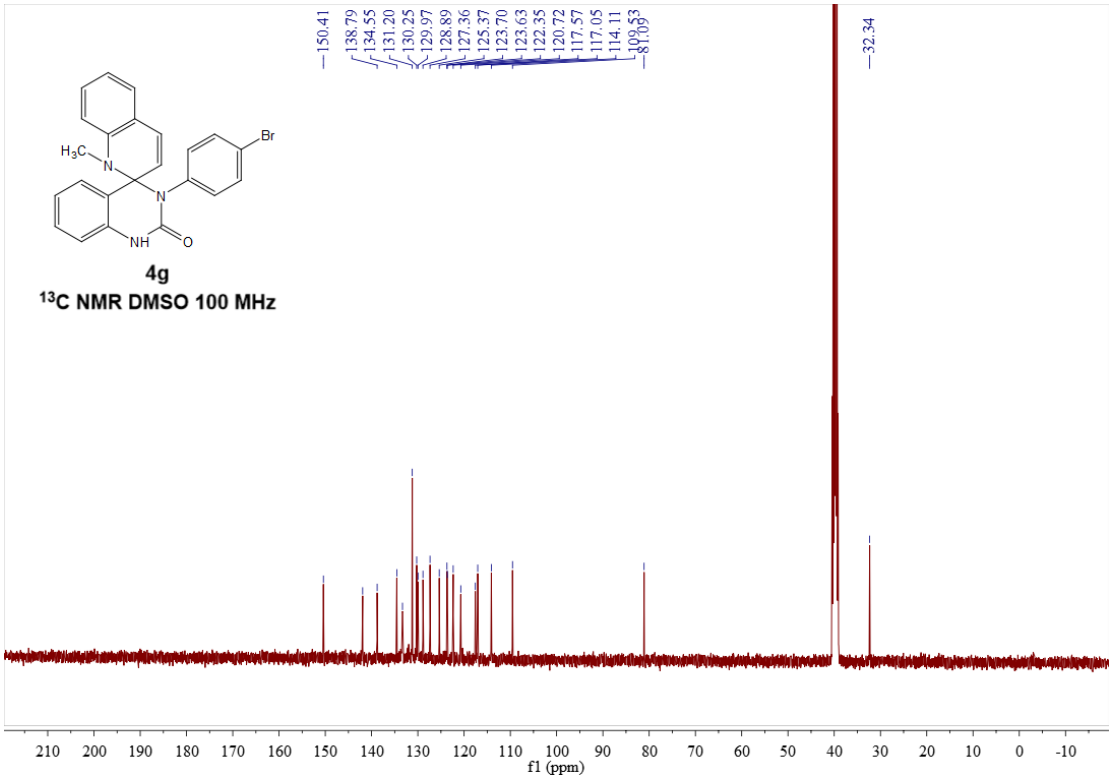
4f

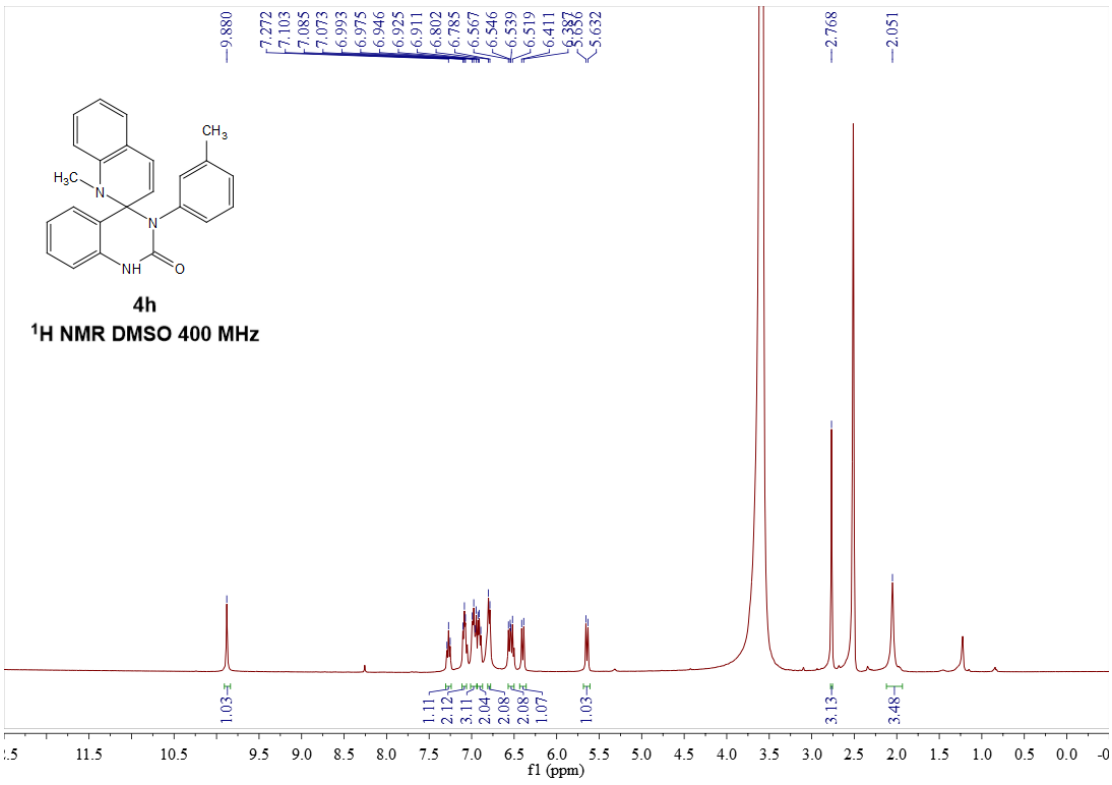
^{13}C NMR DMSO 100 MHz

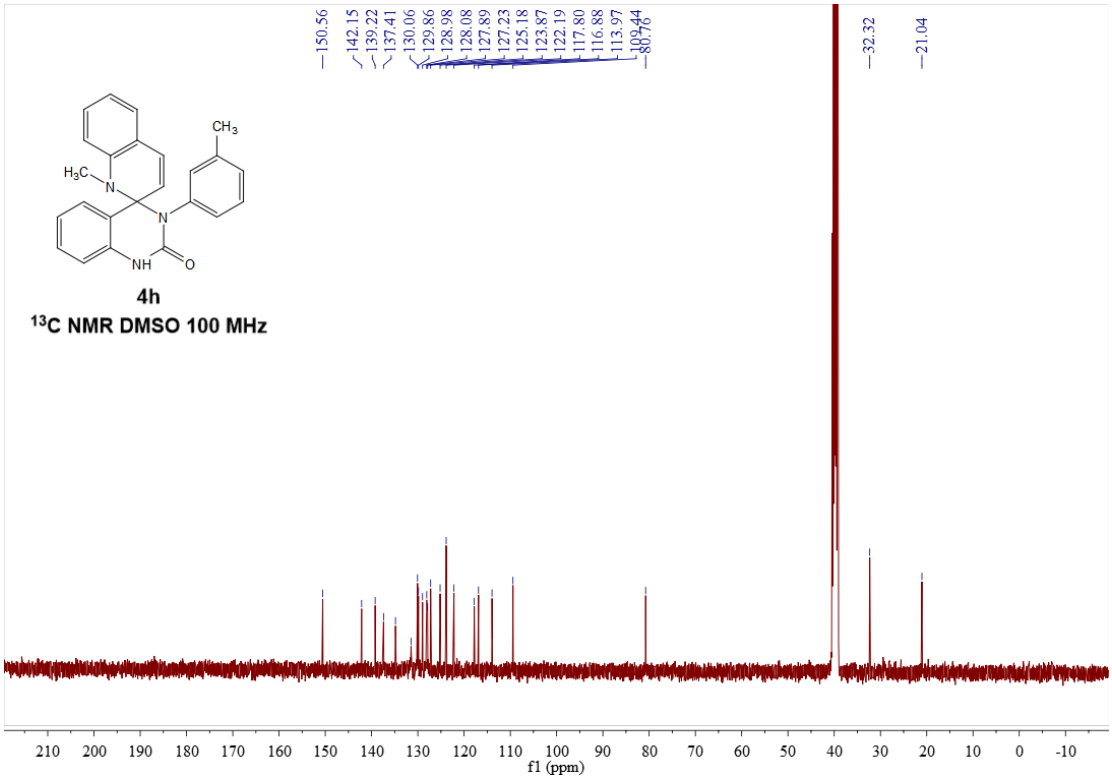


4g

^{1}H NMR DMSO 400 MHz

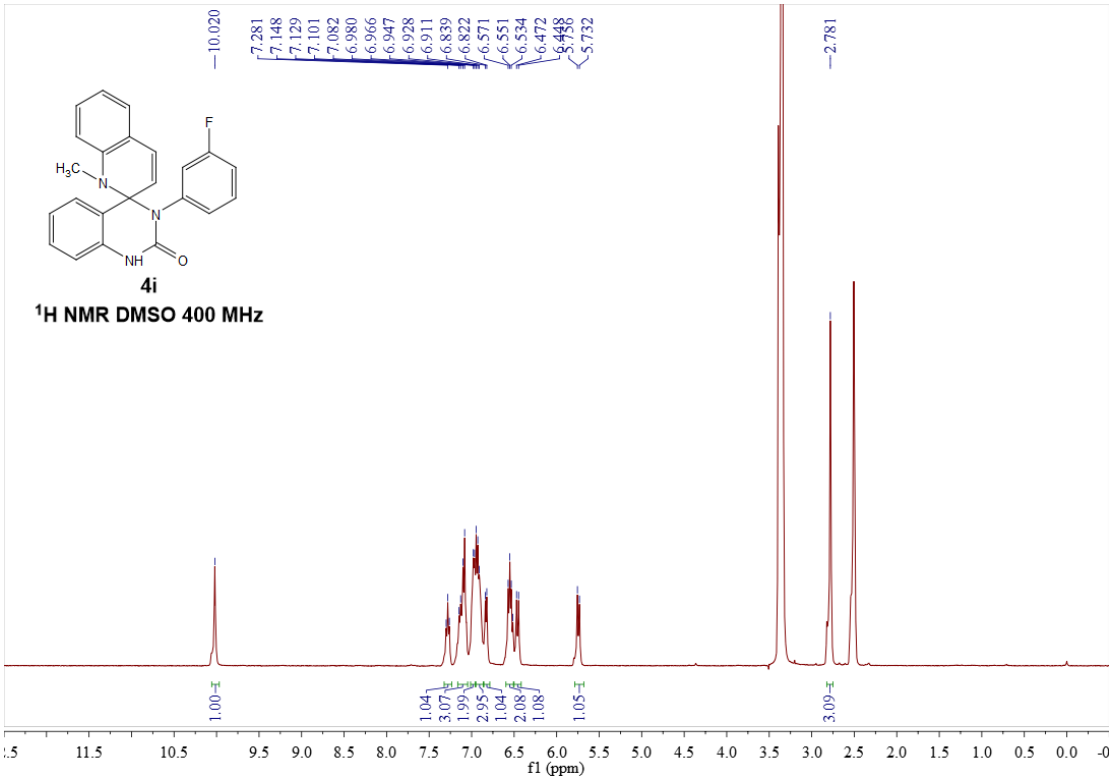

150.41
138.79
134.55
131.20
130.25
129.97
128.89
127.36
125.37
123.70
123.63
122.35
120.72
117.57
117.05
114.11
109.53
81.09
32.34
Br
H3C
N
N
NH
O
4g
13C NMR DMSO 100 MHz
f1 (ppm)


9.880
7.272
7.103
7.085
7.073
6.993
6.975
6.946
6.925
6.911
6.802
6.785
6.567
6.546
6.539
6.519
6.411
6.387
6.356
5.632
2.768
2.051
CH3
H3C
N
N
NH
O
4h
1H NMR DMSO 400 MHz
1.03
1.11
2.12
3.11
2.04
2.08
2.08
1.07
1.03
3.13
3.48
f1 (ppm)



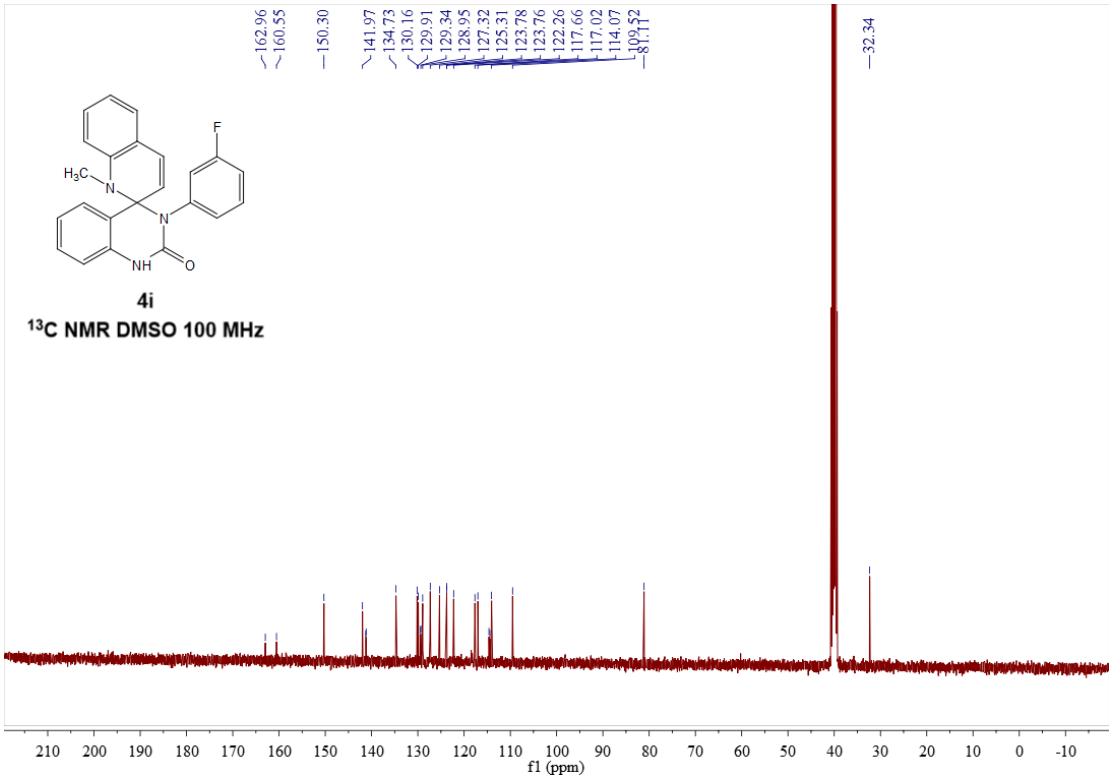
4h

^{13}C NMR DMSO 100 MHz



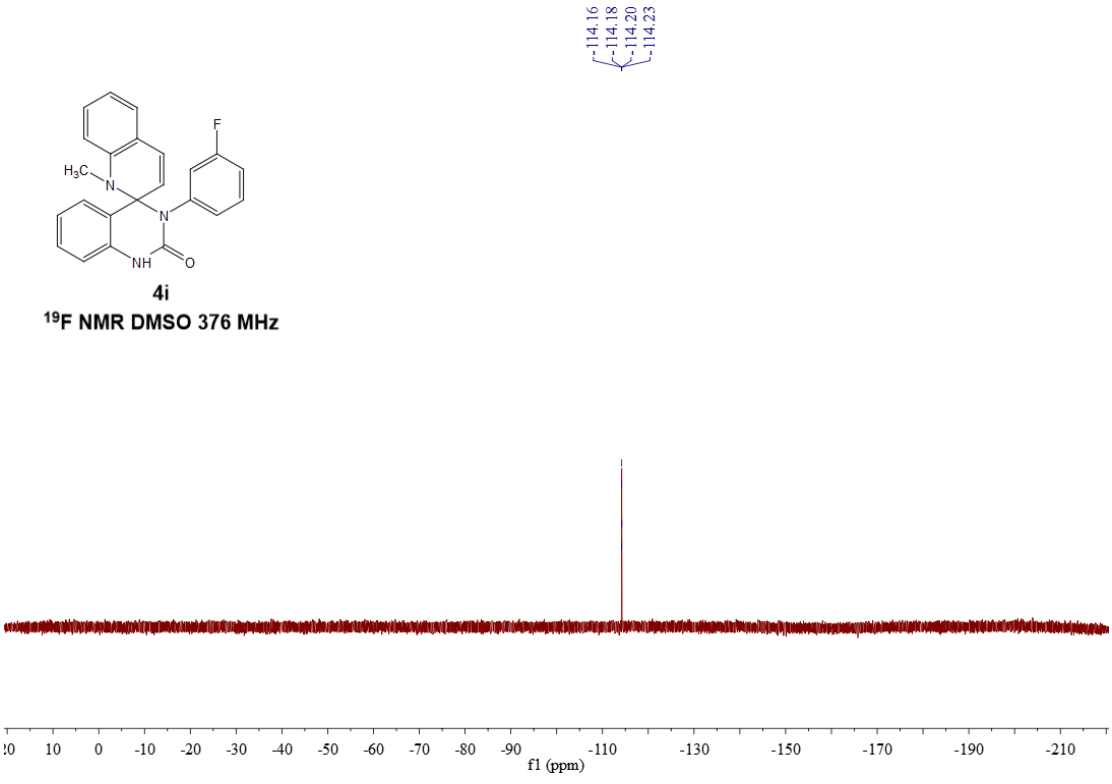
4i

^{1}H NMR DMSO 400 MHz



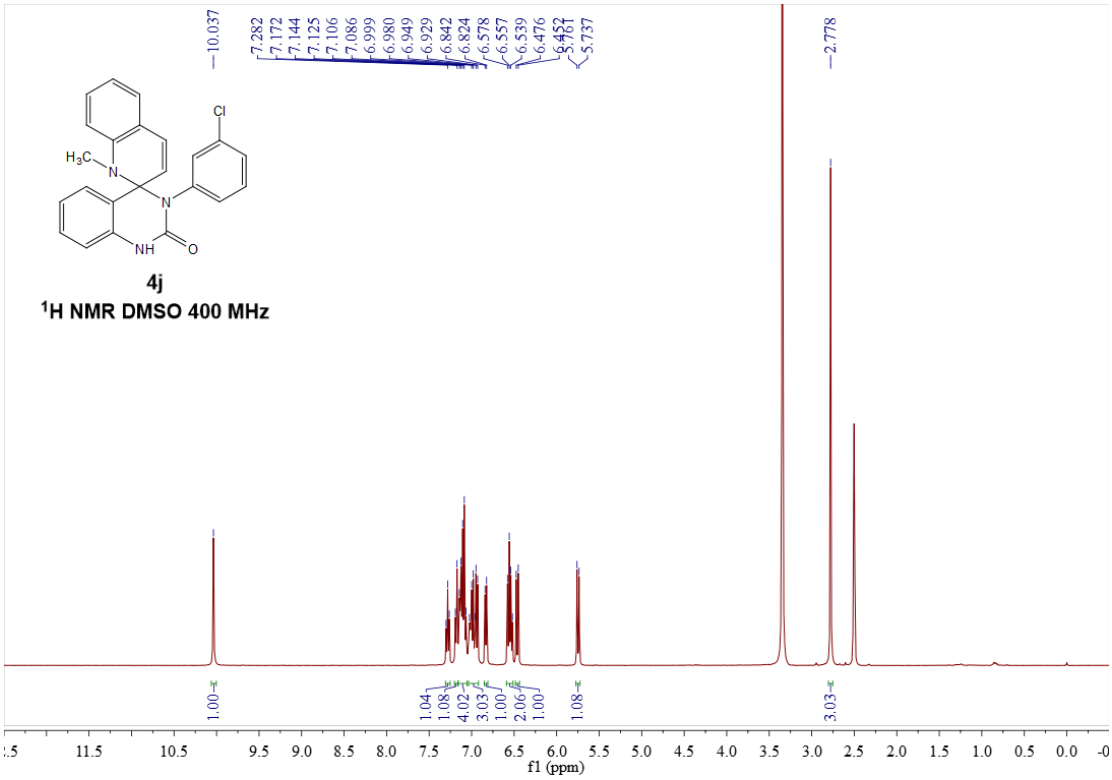
4i

^{13}C NMR DMSO 100 MHz



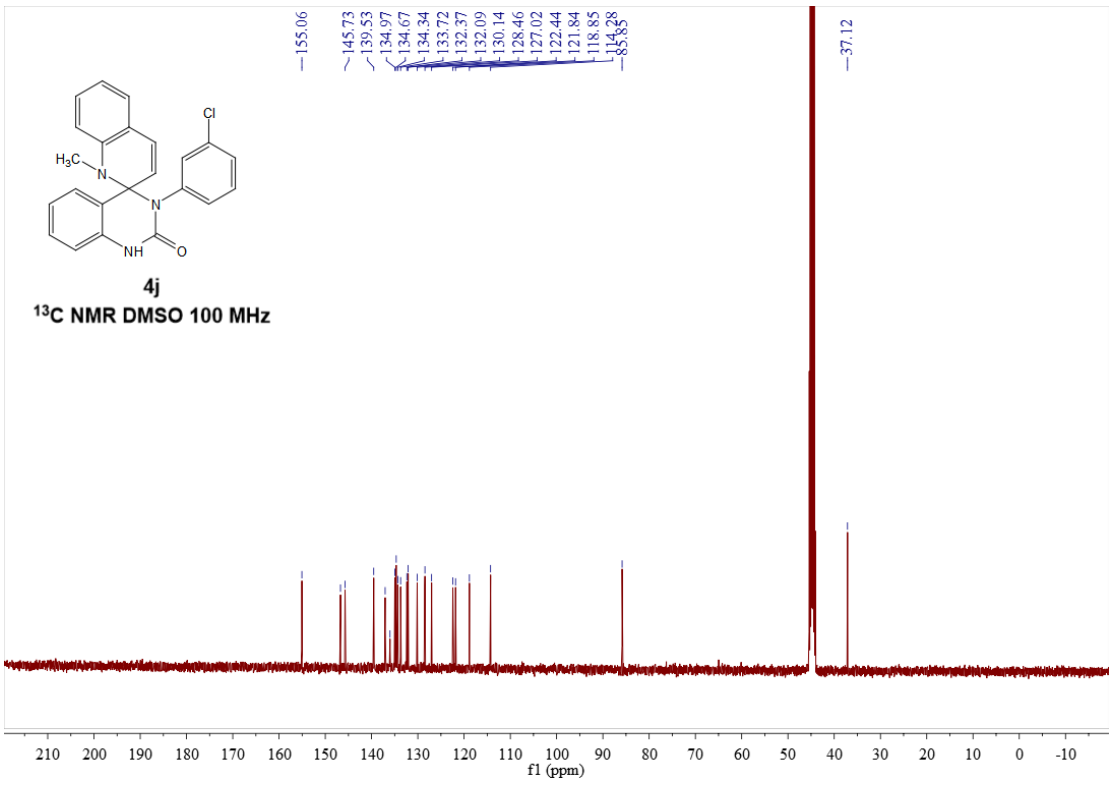
4i

^{19}F NMR DMSO 376 MHz



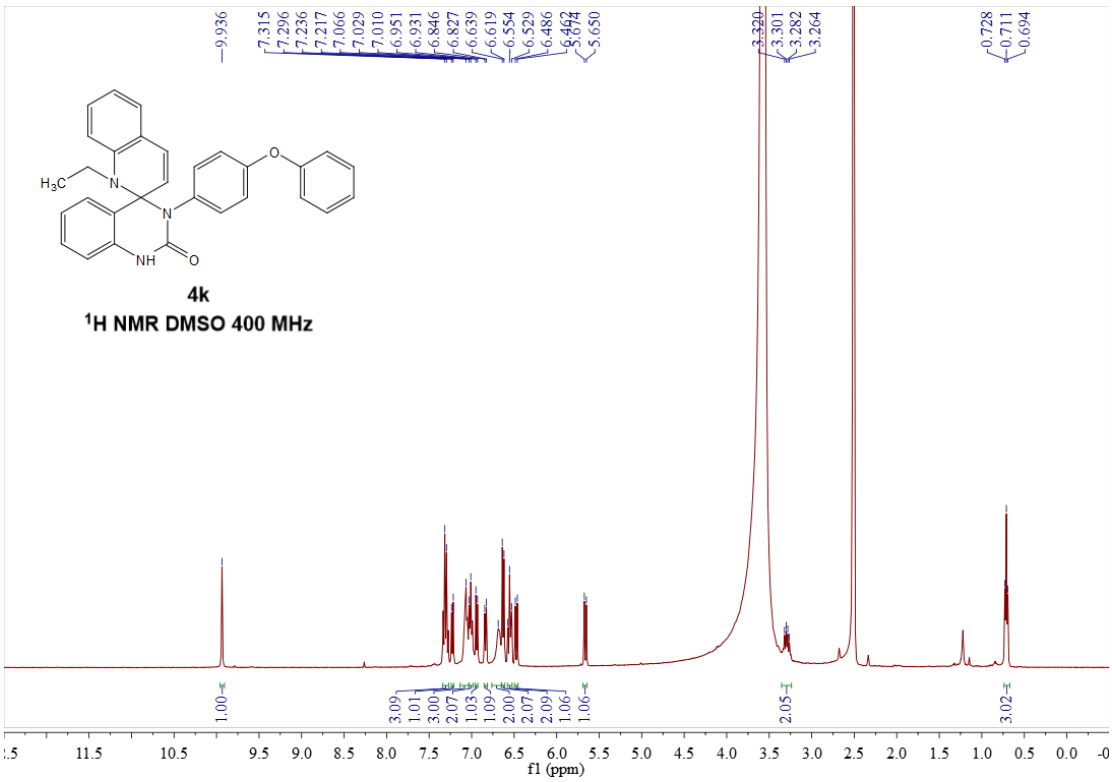
4j

^{1}H NMR DMSO 400 MHz



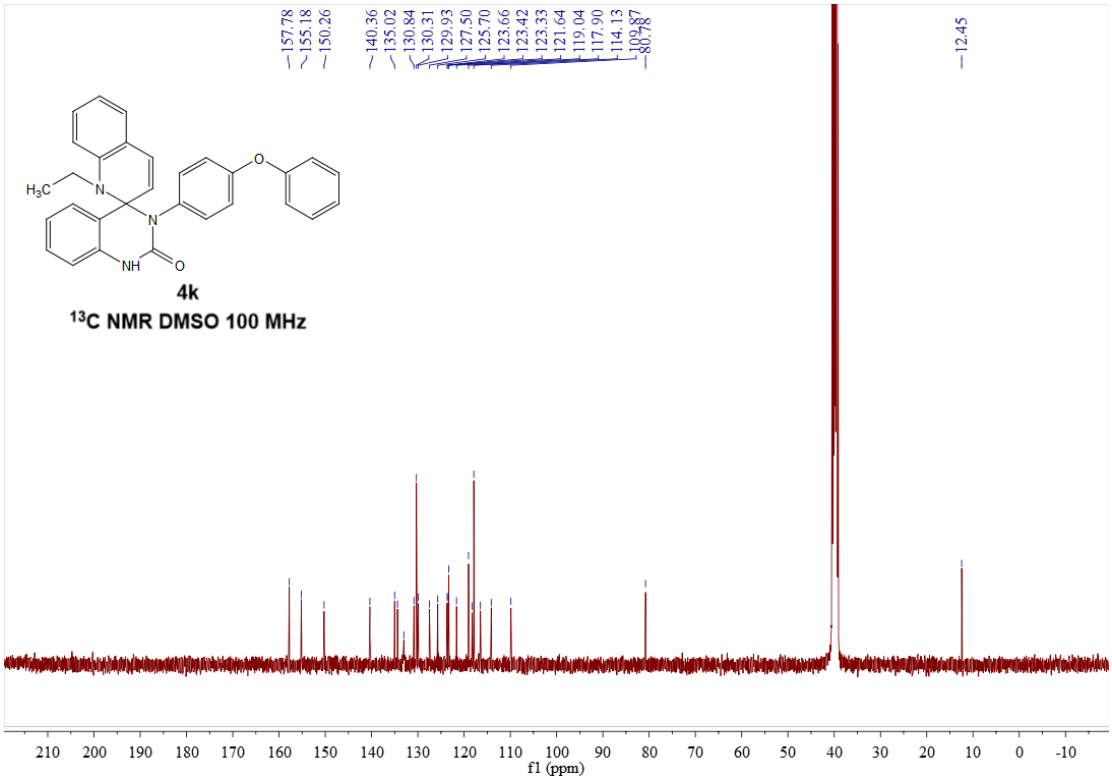
4j

^{13}C NMR DMSO 100 MHz



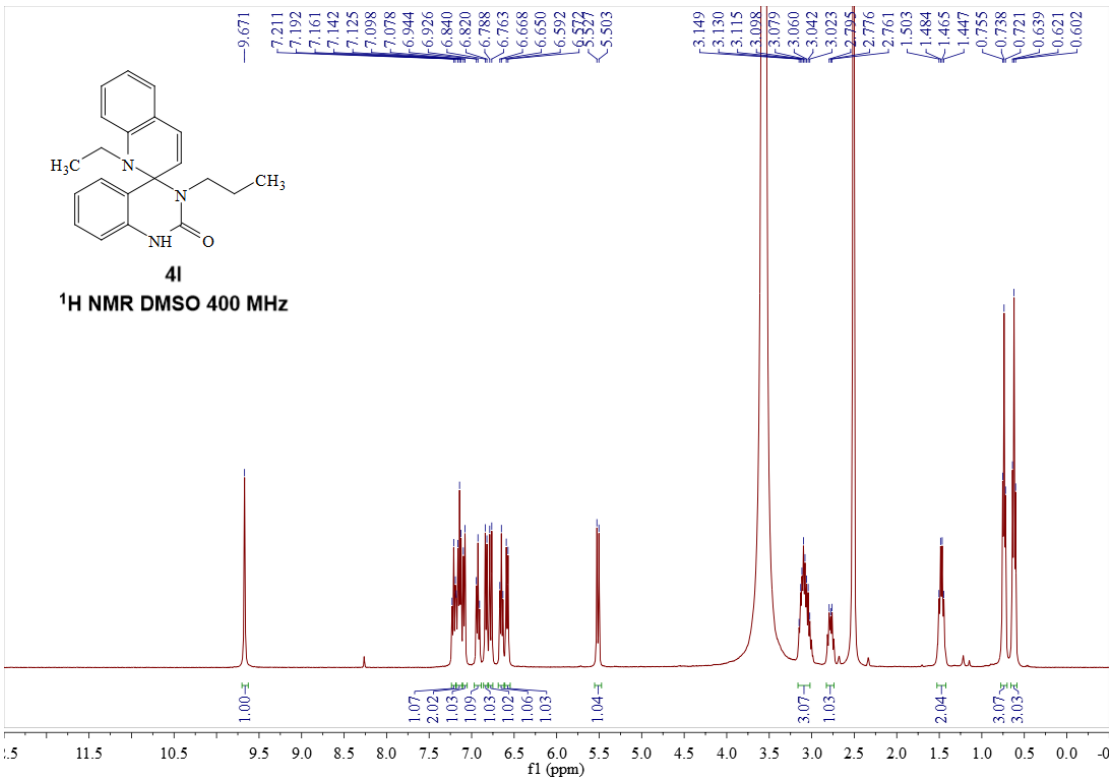
4k

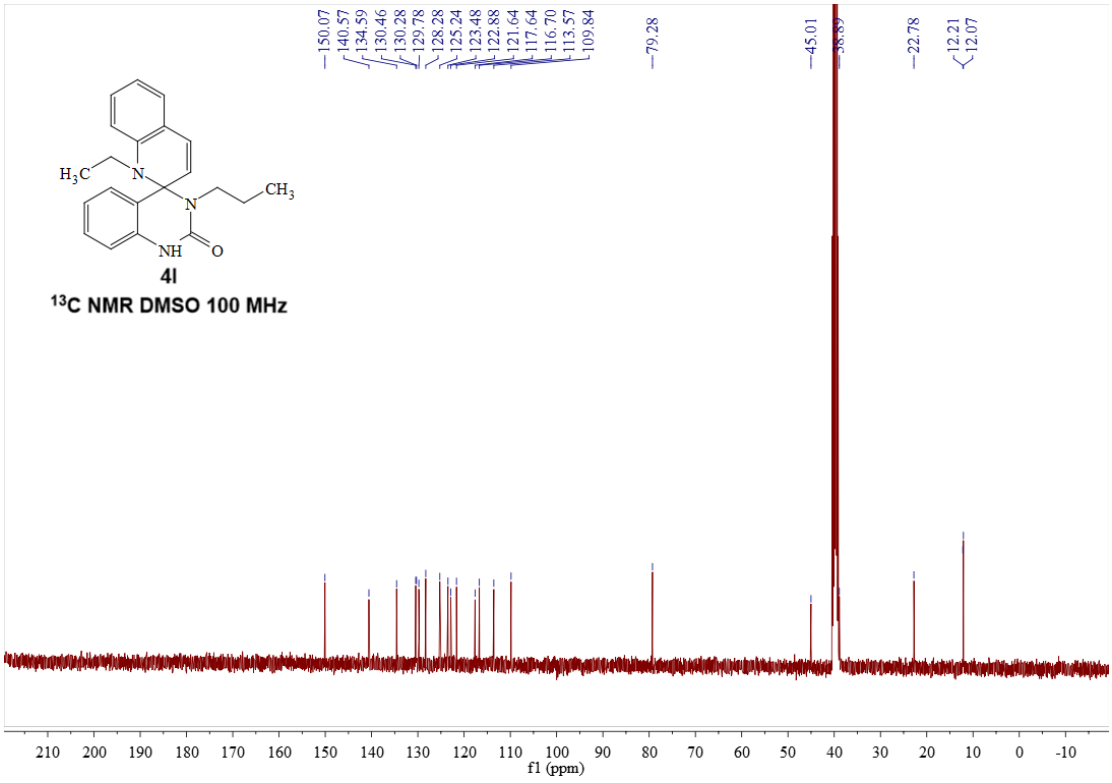
^{1}H NMR DMSO 400 MHz

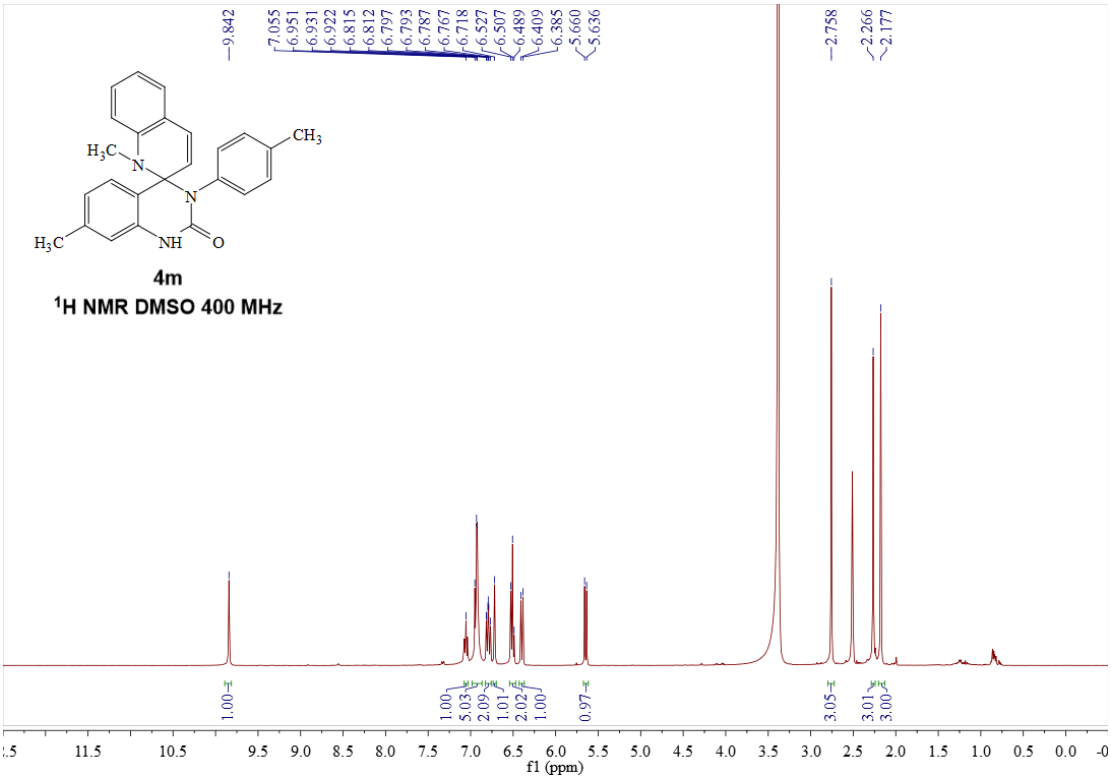


4k

^{13}C NMR DMSO 100 MHz

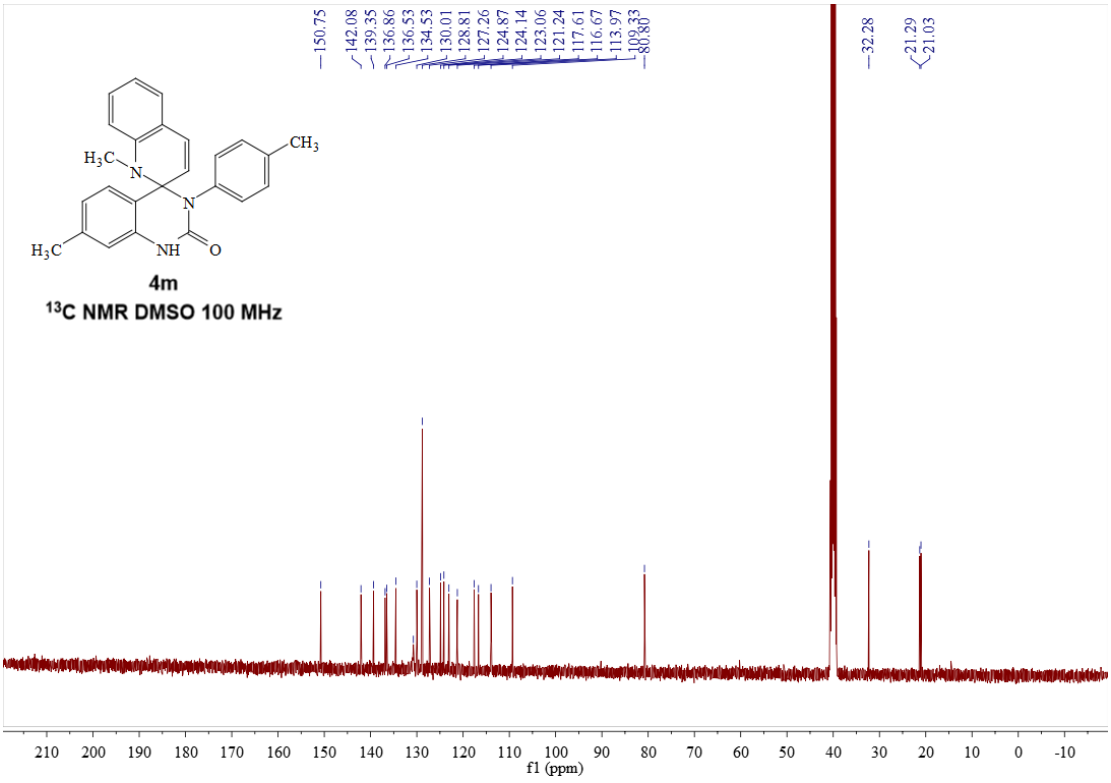

4l
1H NMR DMSO 400 MHz
f1 (ppm)


4l
13C NMR DMSO 100 MHz
f1 (ppm)



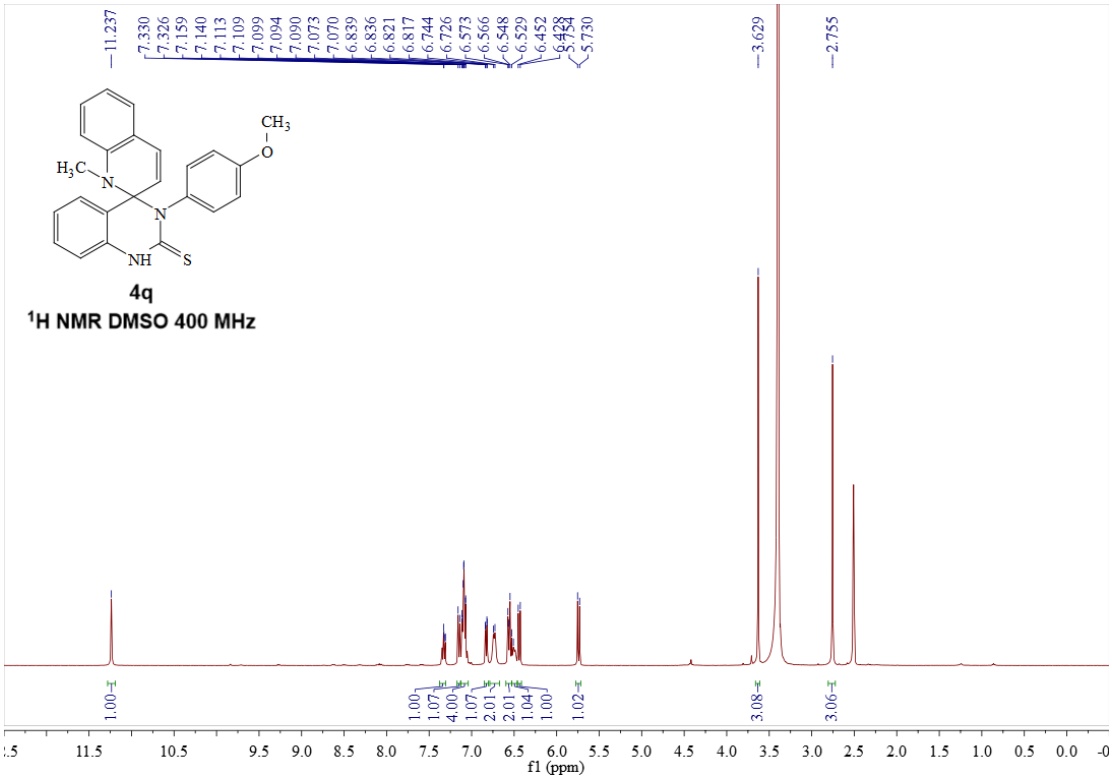
4m

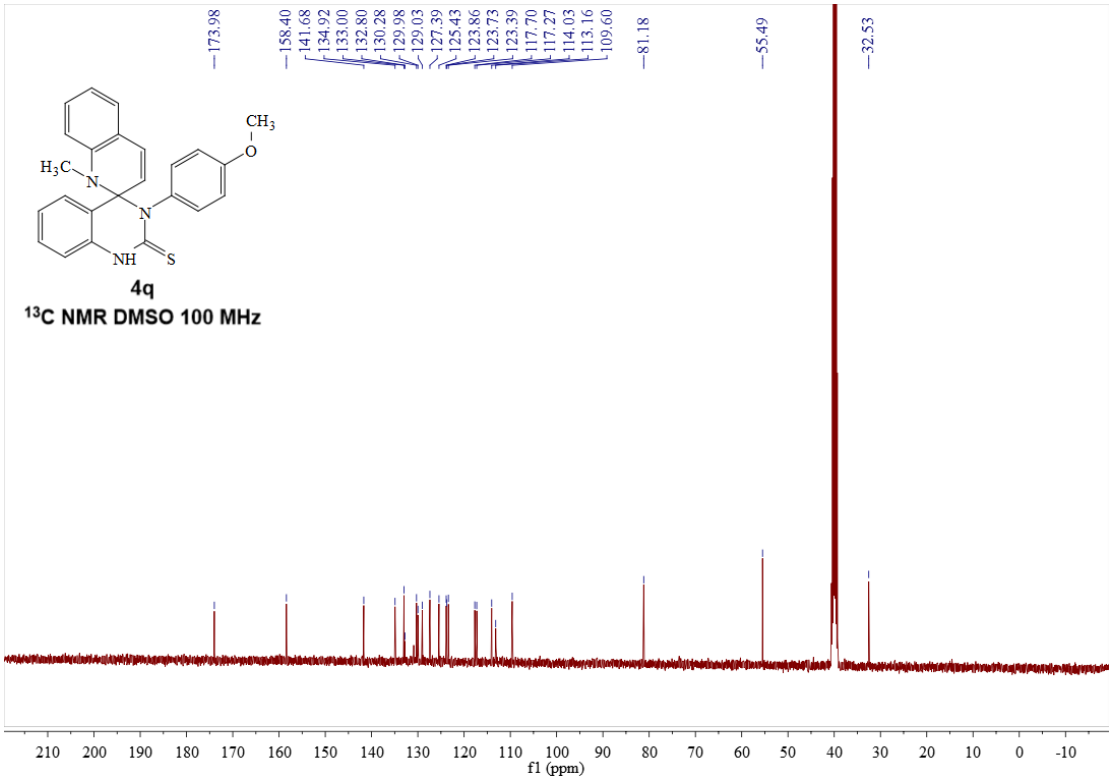
^{1}H NMR DMSO 400 MHz

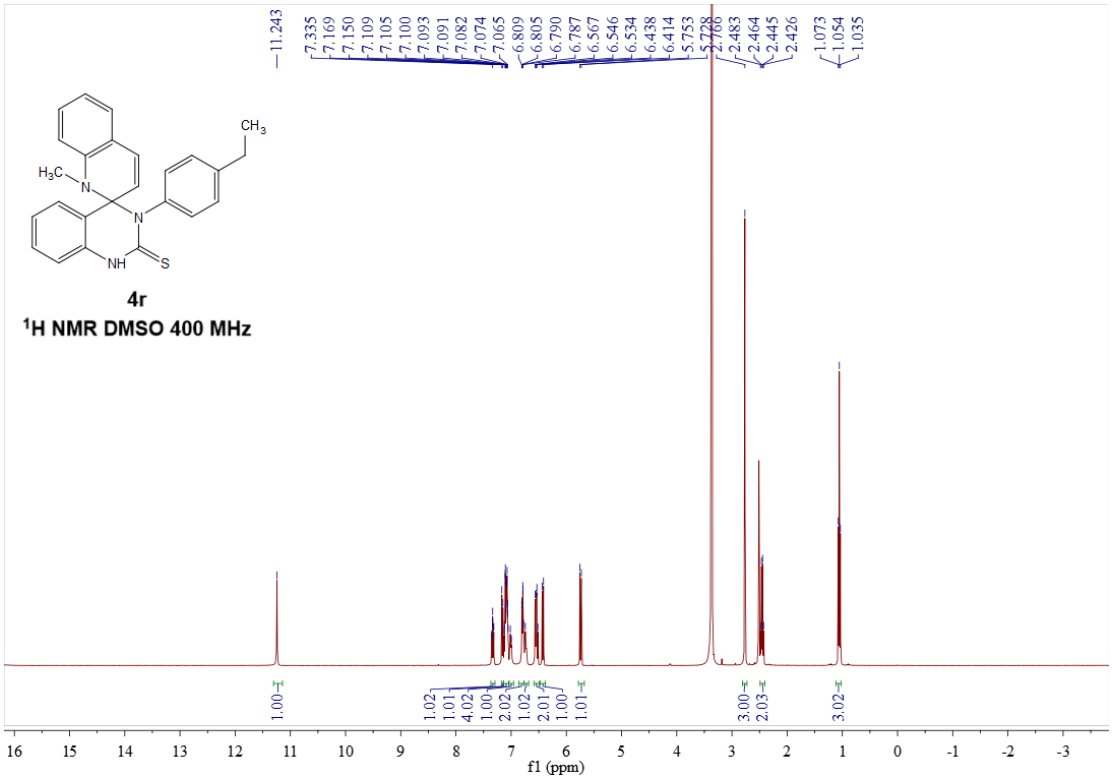


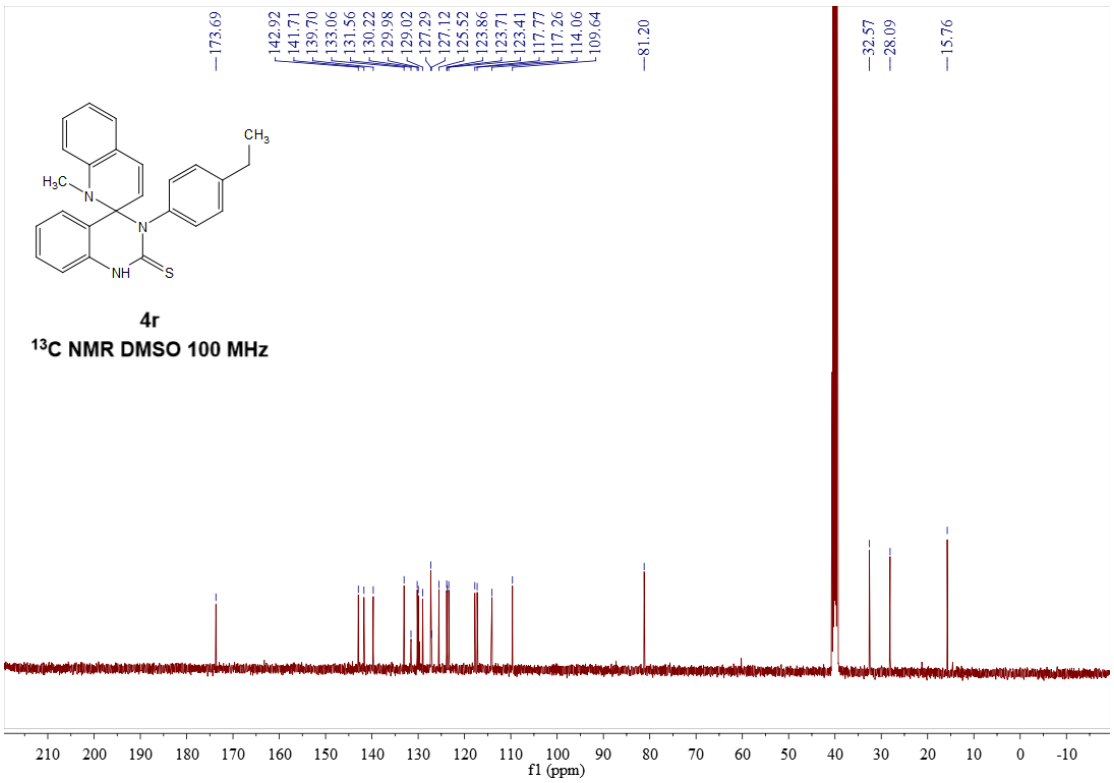
4m

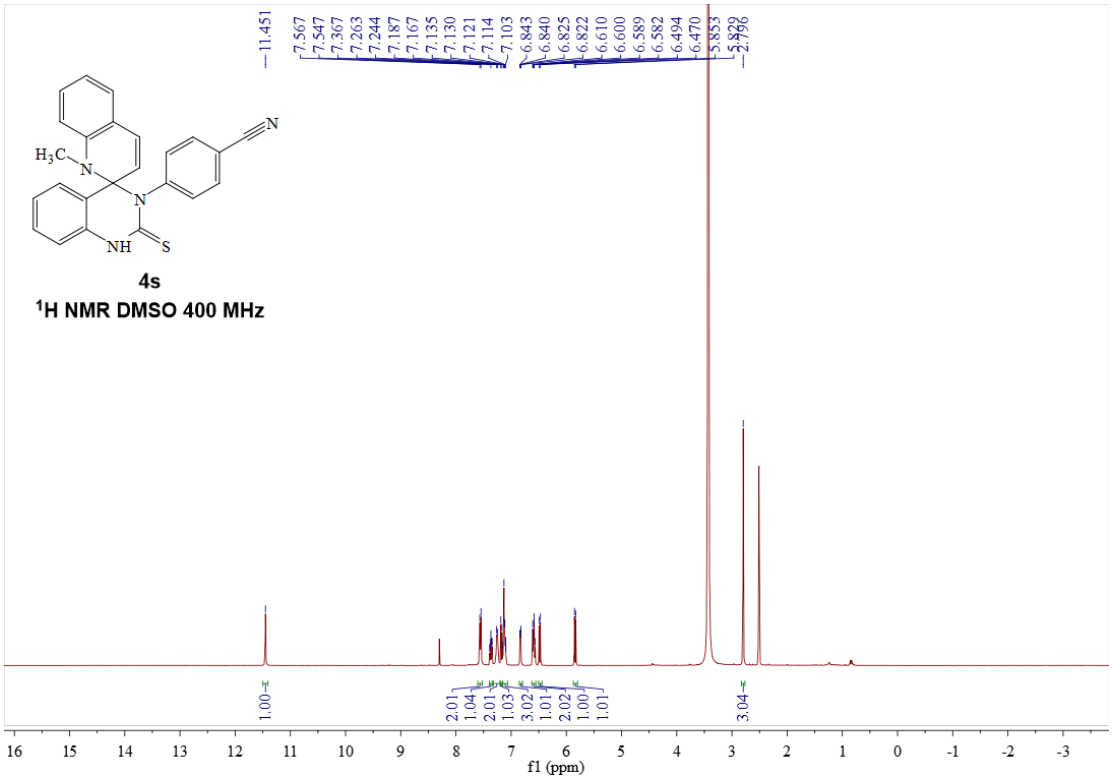
^{13}C NMR DMSO 100 MHz


11.237
7.330
7.326
7.159
7.140
7.113
7.109
7.099
7.094
7.090
7.073
7.070
6.839
6.836
6.821
6.817
6.744
6.726
6.573
6.566
6.548
6.529
6.452
6.428
5.754
5.730
3.629
2.755
CH3
O
H3C
N
N
NH
S
4q
1H NMR DMSO 400 MHz
1.00
1.00
1.07
4.00
1.07
2.01
2.01
1.04
1.00
1.02
3.08
3.06
f1 (ppm)


173.98
158.40
141.68
134.92
133.00
132.80
130.28
129.98
129.03
127.39
125.43
123.86
123.73
123.39
117.70
117.27
114.03
113.16
109.60
81.18
55.49
32.53
CH3
O
H3C
N
N
NH
S
4q
13C NMR DMSO 100 MHz
f1 (ppm)

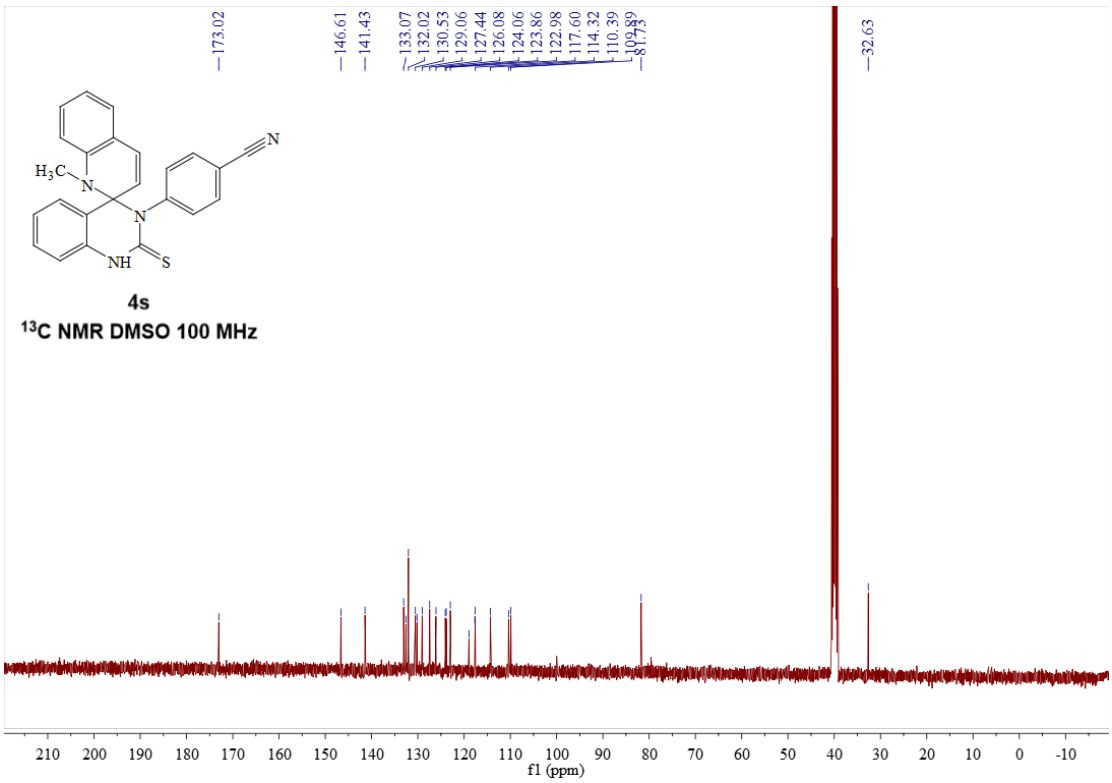

11.243
7.335
7.169
7.150
7.109
7.105
7.100
7.093
7.091
7.082
7.074
7.065
6.809
6.805
6.790
6.787
6.567
6.546
6.534
6.438
6.414
5.753
5.728
2.766
2.483
2.464
2.445
2.426
1.073
1.054
1.035
CH3
H3C
N
N
NH
S
4r
1H NMR DMSO 400 MHz
1.00
1.02
1.01
4.02
1.00
2.02
1.02
2.01
1.00
1.01
3.00
2.03
3.02
f1 (ppm)


173.69
142.92
141.71
139.70
133.06
131.56
130.22
129.98
129.02
127.29
127.12
125.52
123.86
123.71
123.41
117.77
117.26
114.06
109.64
81.20
32.57
28.09
15.76
CH3
H3C
N
N
NH
S
4r
13C NMR DMSO 100 MHz
f1 (ppm)



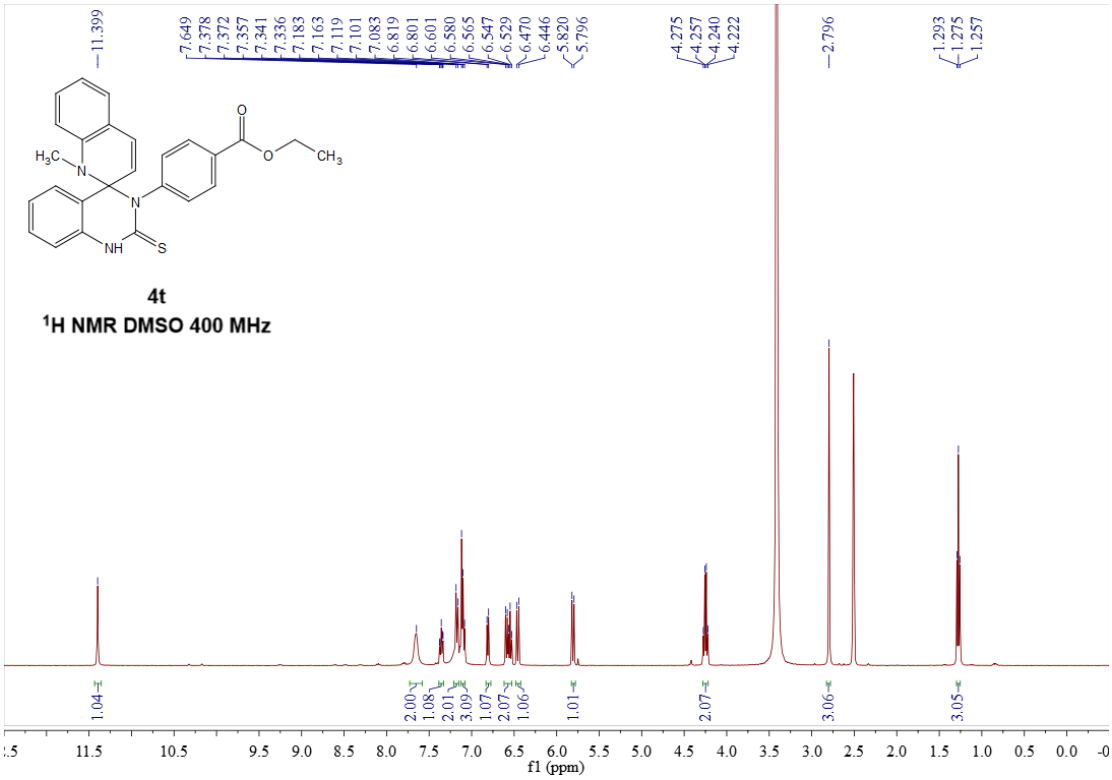
4s

^{1}H NMR DMSO 400 MHz



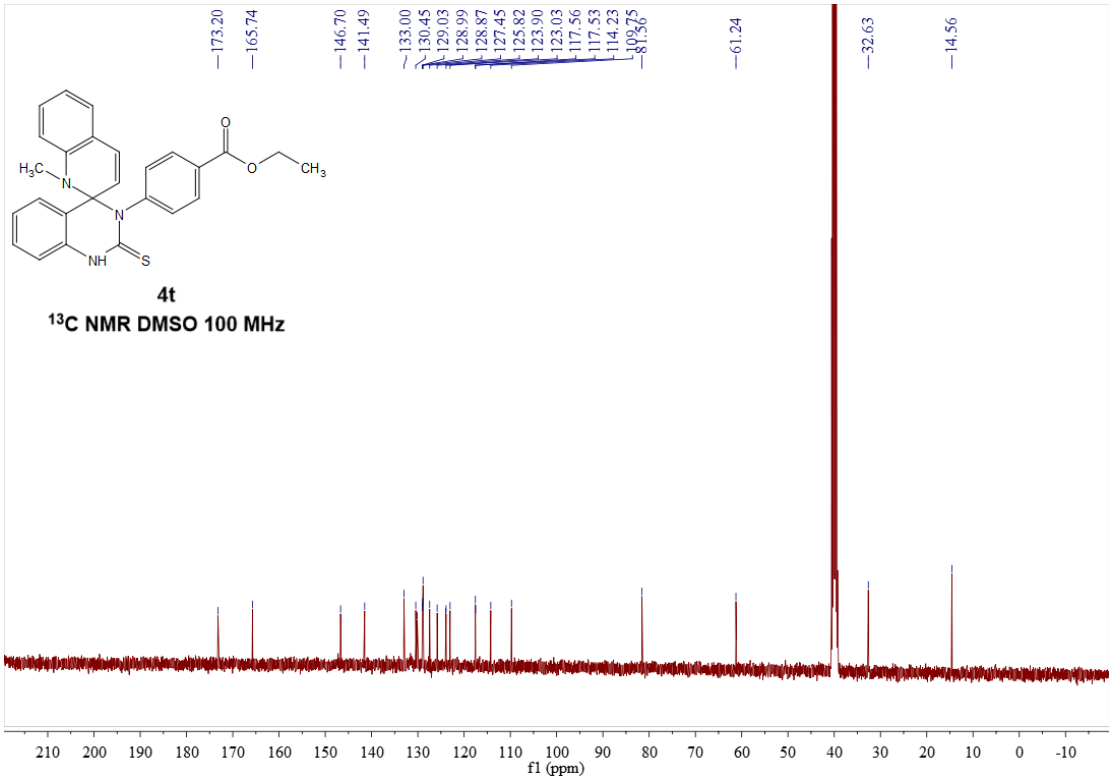
4s

^{13}C NMR DMSO 100 MHz



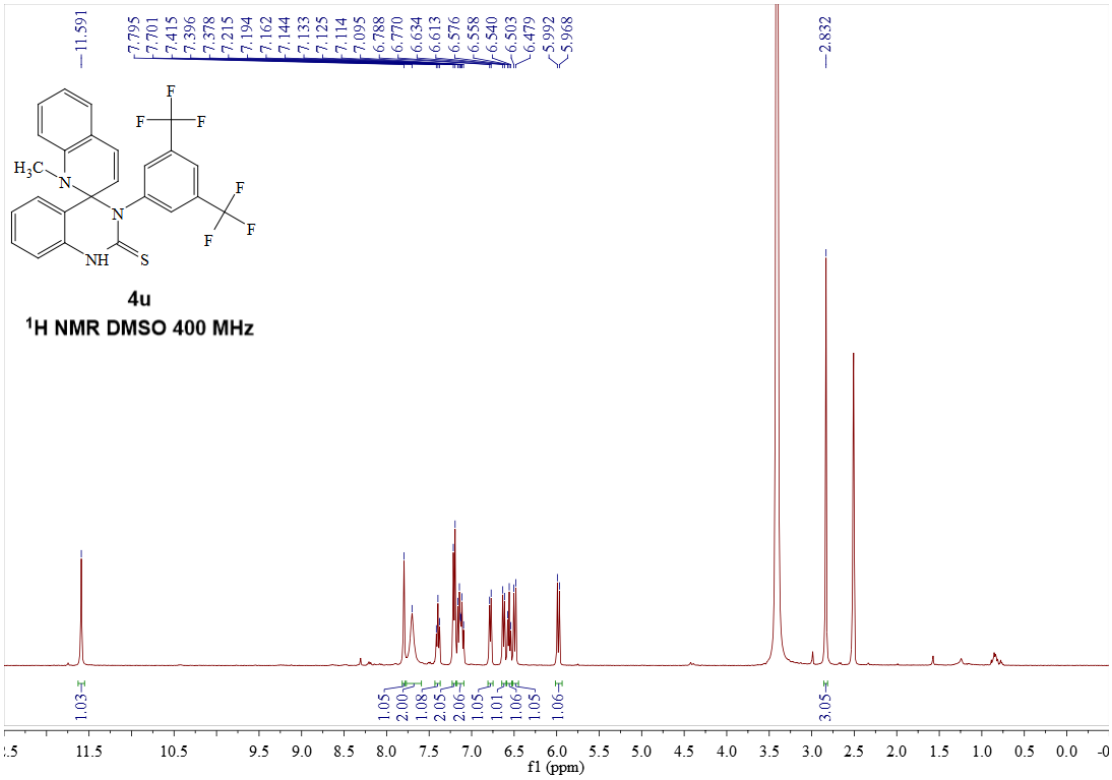
4t

^{1}H NMR DMSO 400 MHz



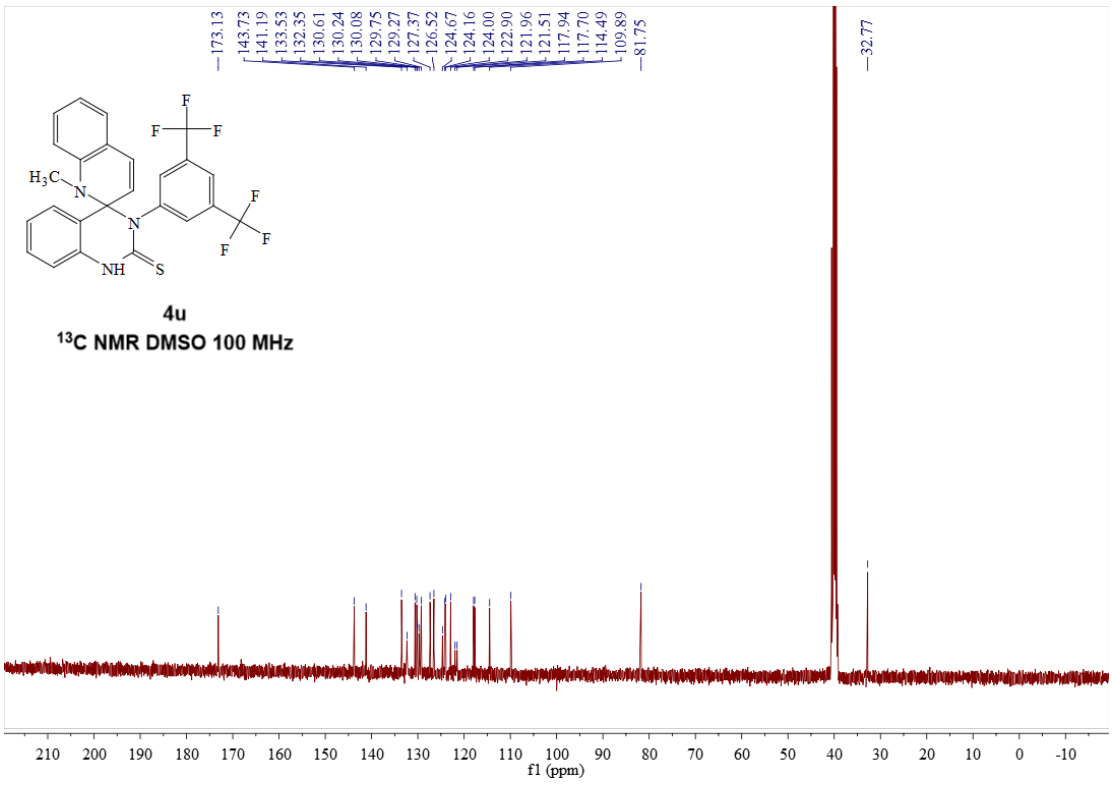
4t

^{13}C NMR DMSO 100 MHz



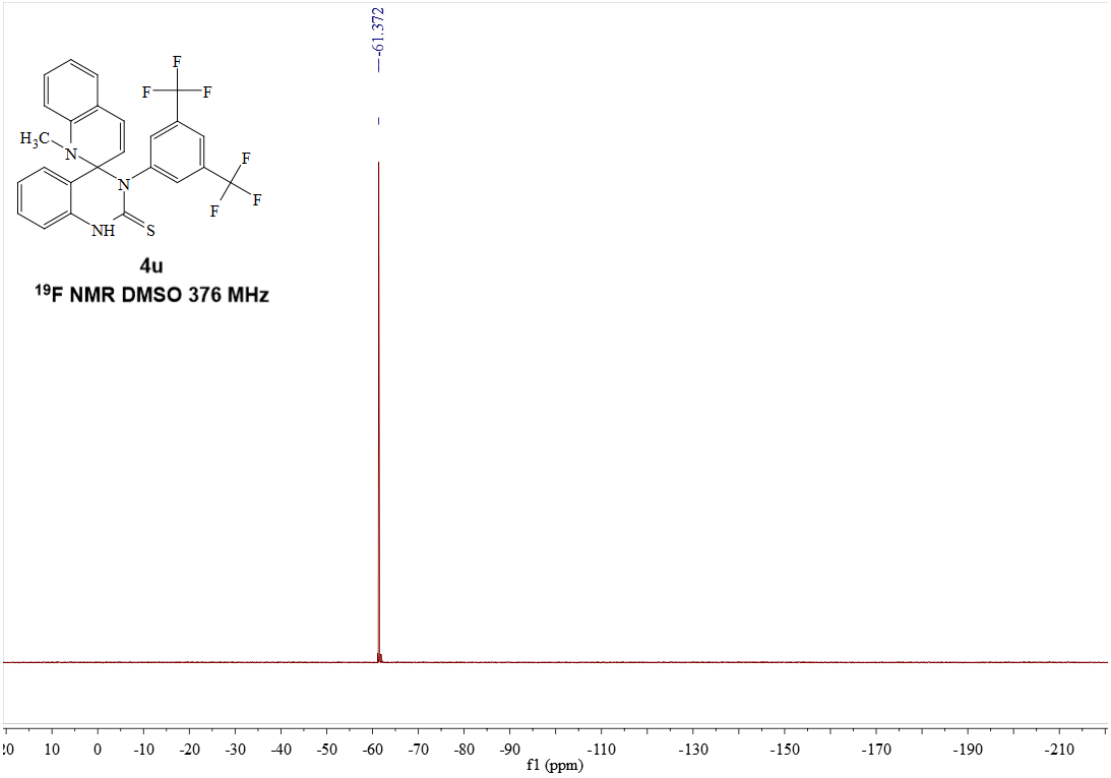
4u

^{1}H NMR DMSO 400 MHz



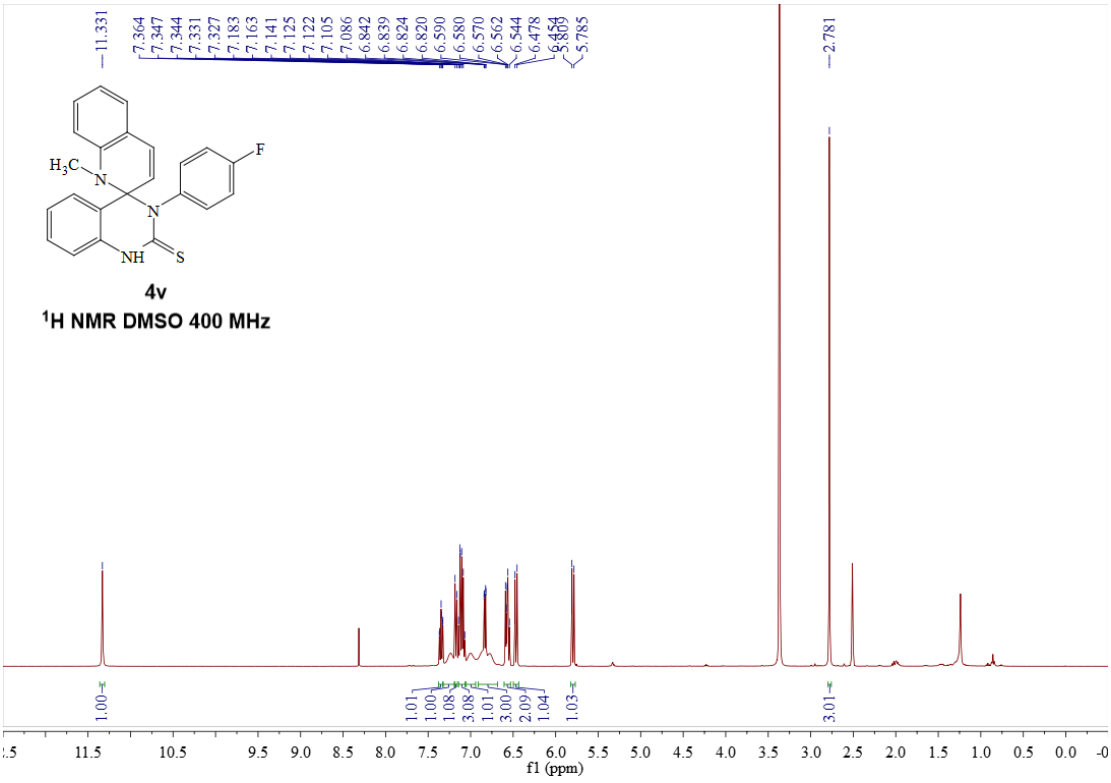
4u

^{13}C NMR DMSO 100 MHz



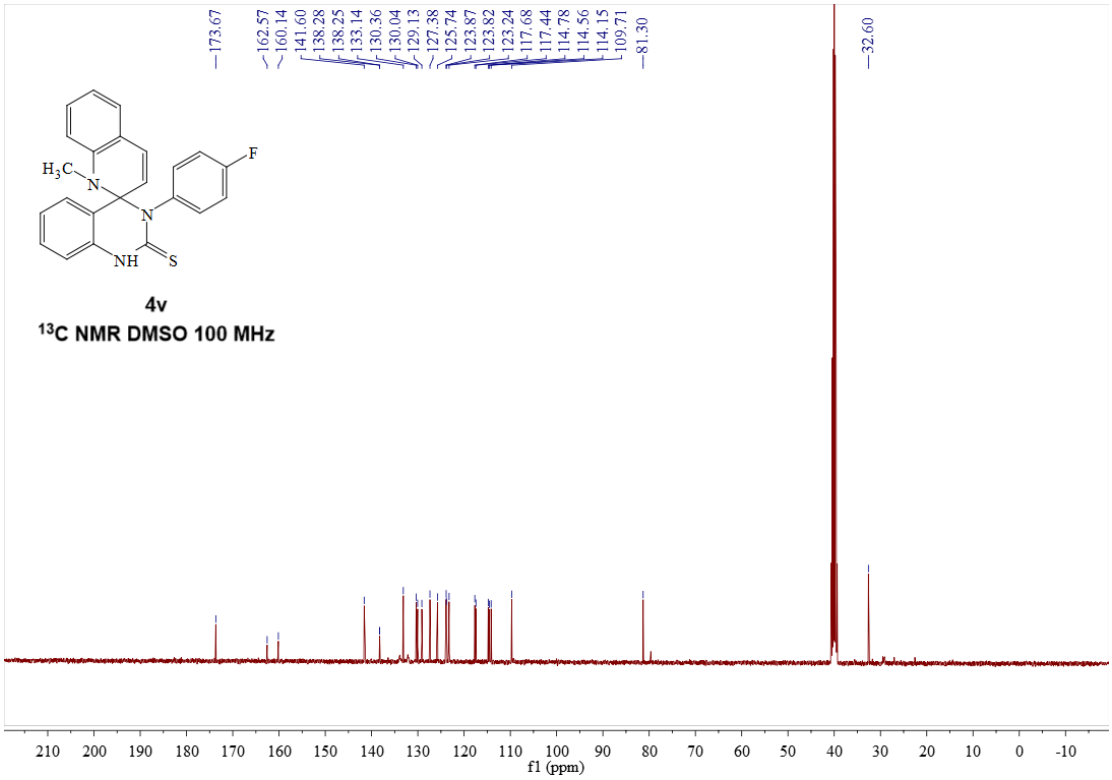
4u

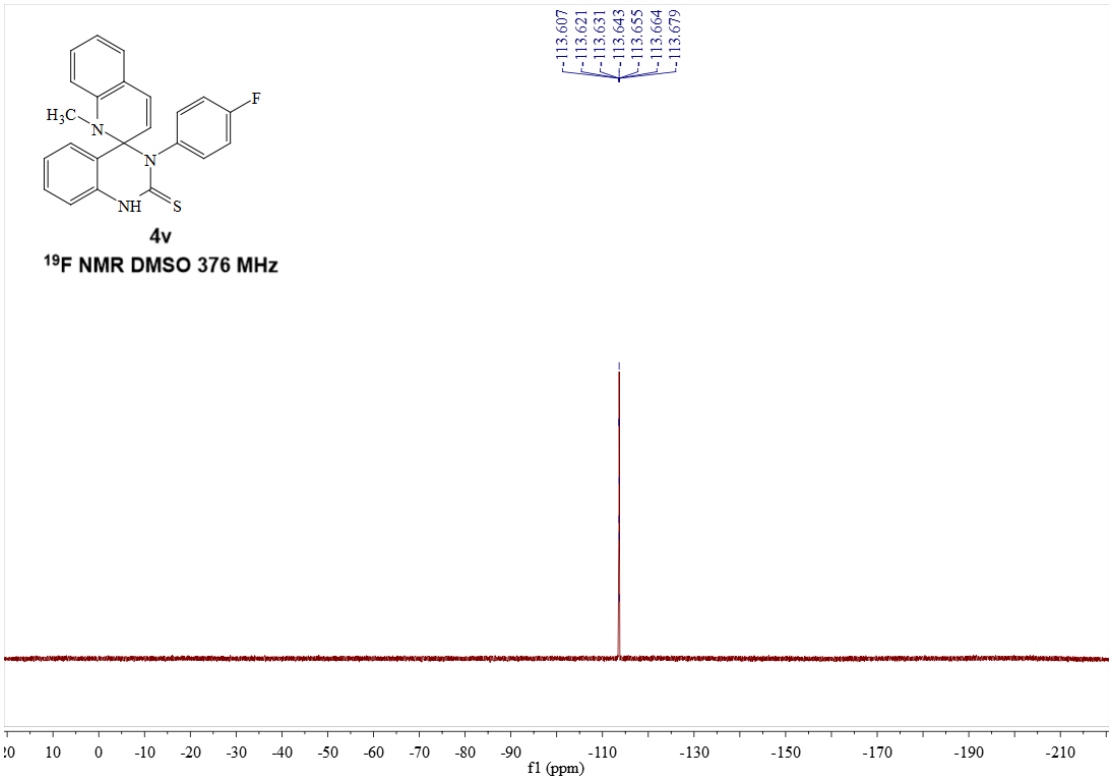
^{19}F NMR DMSO 376 MHz

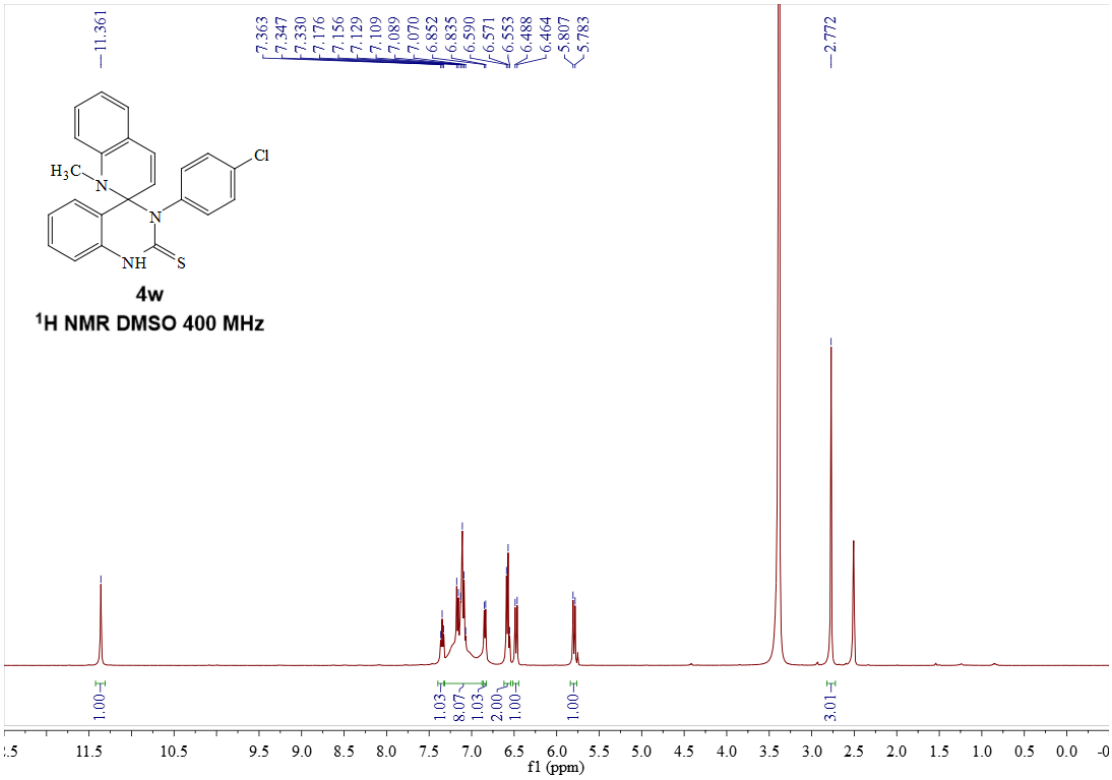


4v

^{1}H NMR DMSO 400 MHz

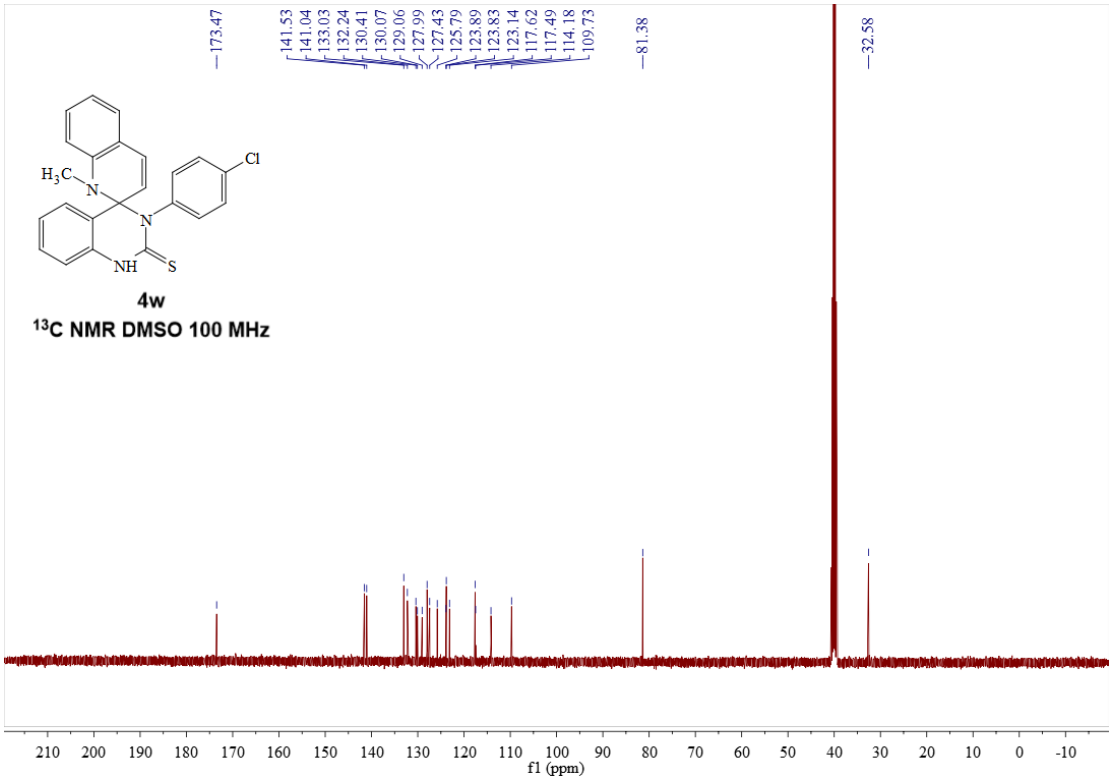

173.67
162.57
160.14
141.60
138.28
138.25
133.14
130.36
130.04
129.13
127.38
125.74
123.87
123.82
123.24
117.68
117.44
114.78
114.56
114.15
109.71
81.30
32.60
H3C
N
N
NH
S
F
4v
13C NMR DMSO 100 MHz
f1 (ppm)


113.607
113.621
113.631
113.643
113.655
113.664
113.679
H3C
N
N
NH
S
F
4v
19F NMR DMSO 376 MHz
f1 (ppm)



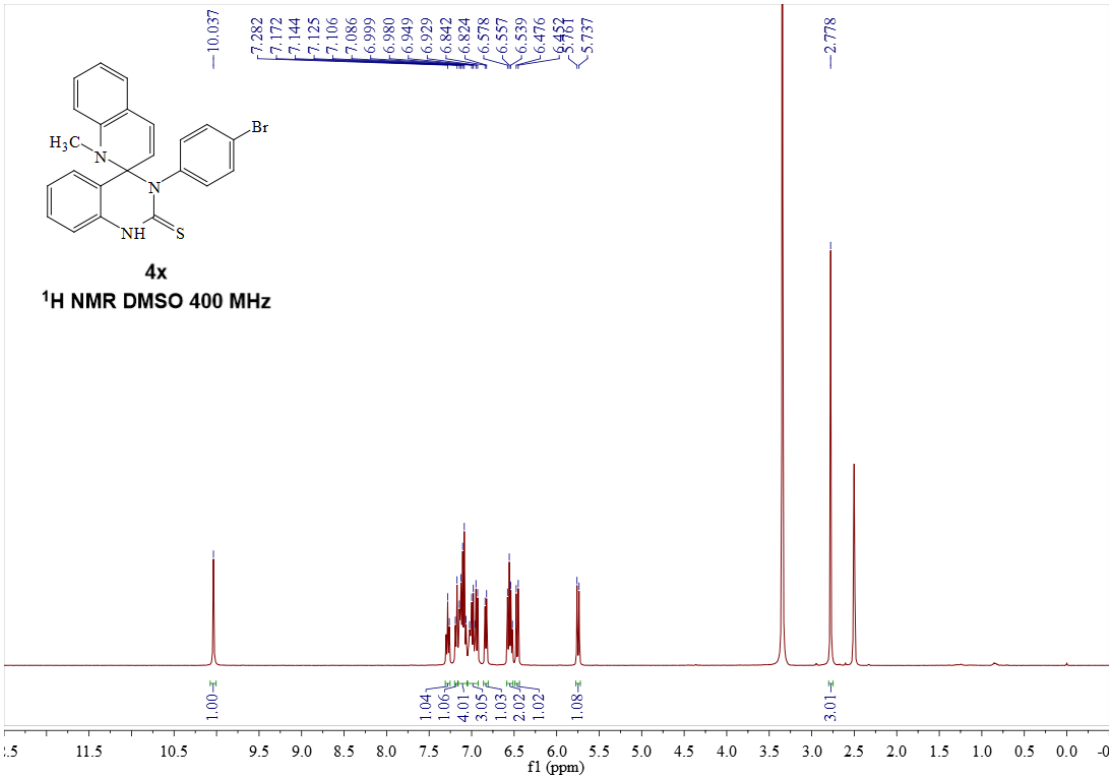
4w

^{1}H NMR DMSO 400 MHz



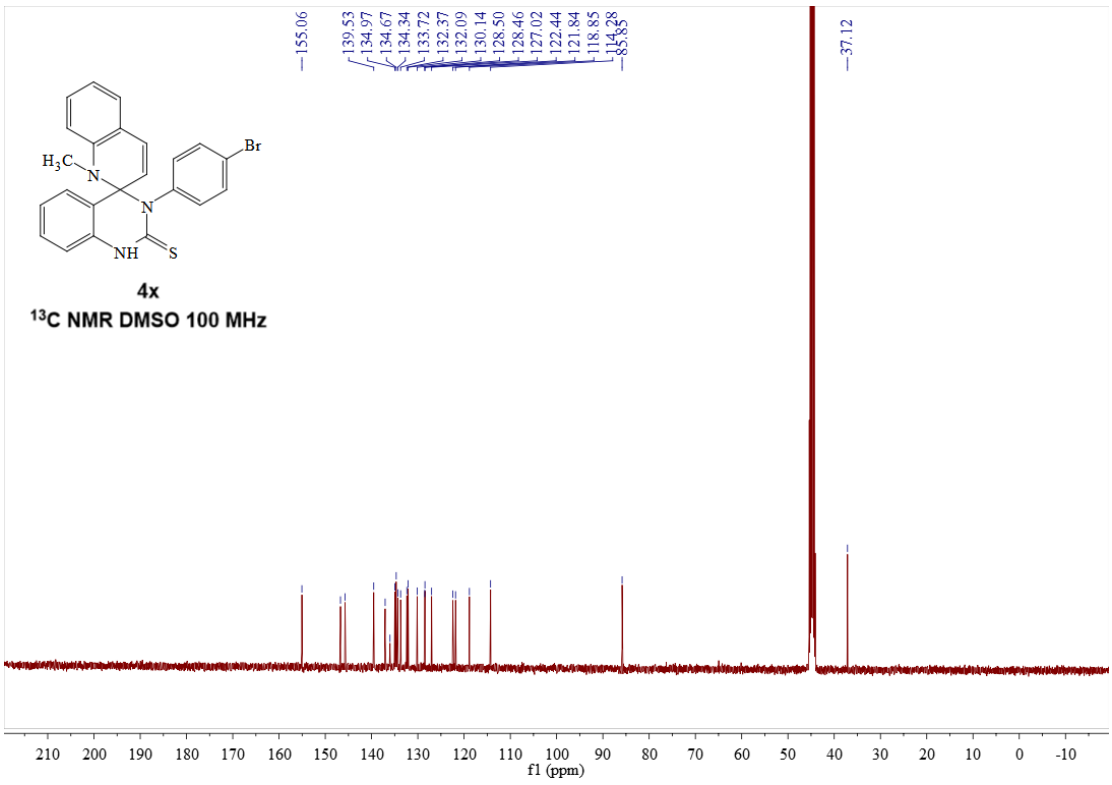
4w

^{13}C NMR DMSO 100 MHz



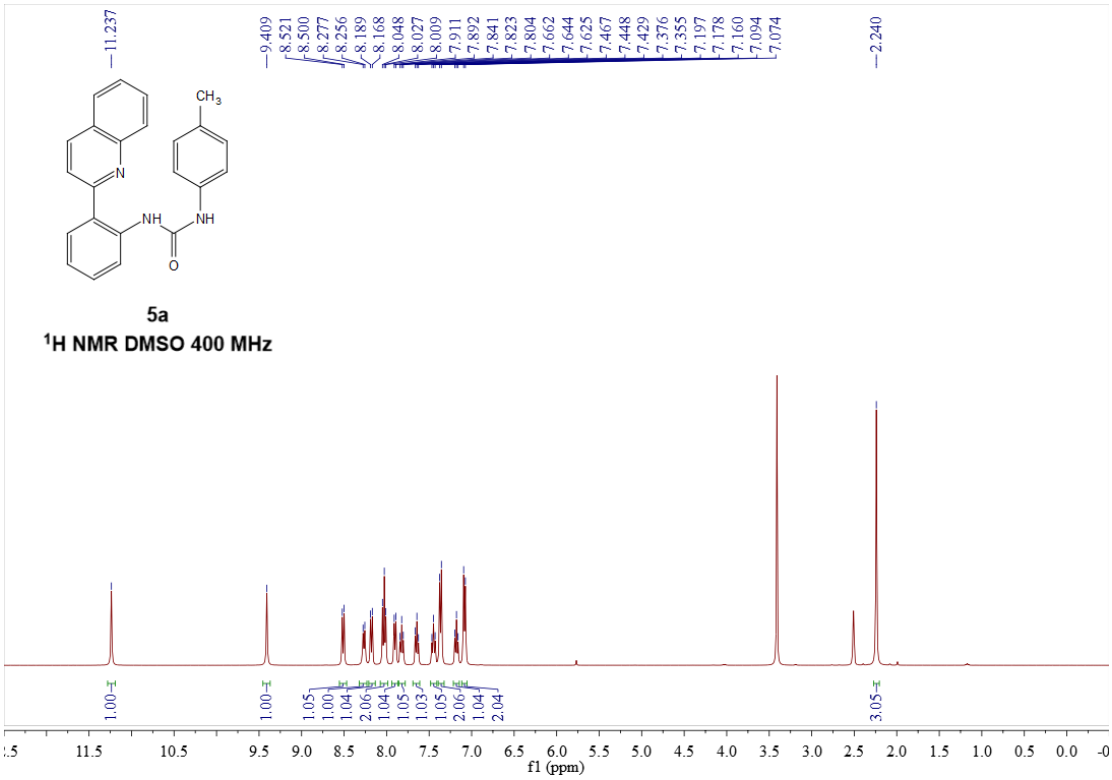
4x

^{1}H NMR DMSO 400 MHz



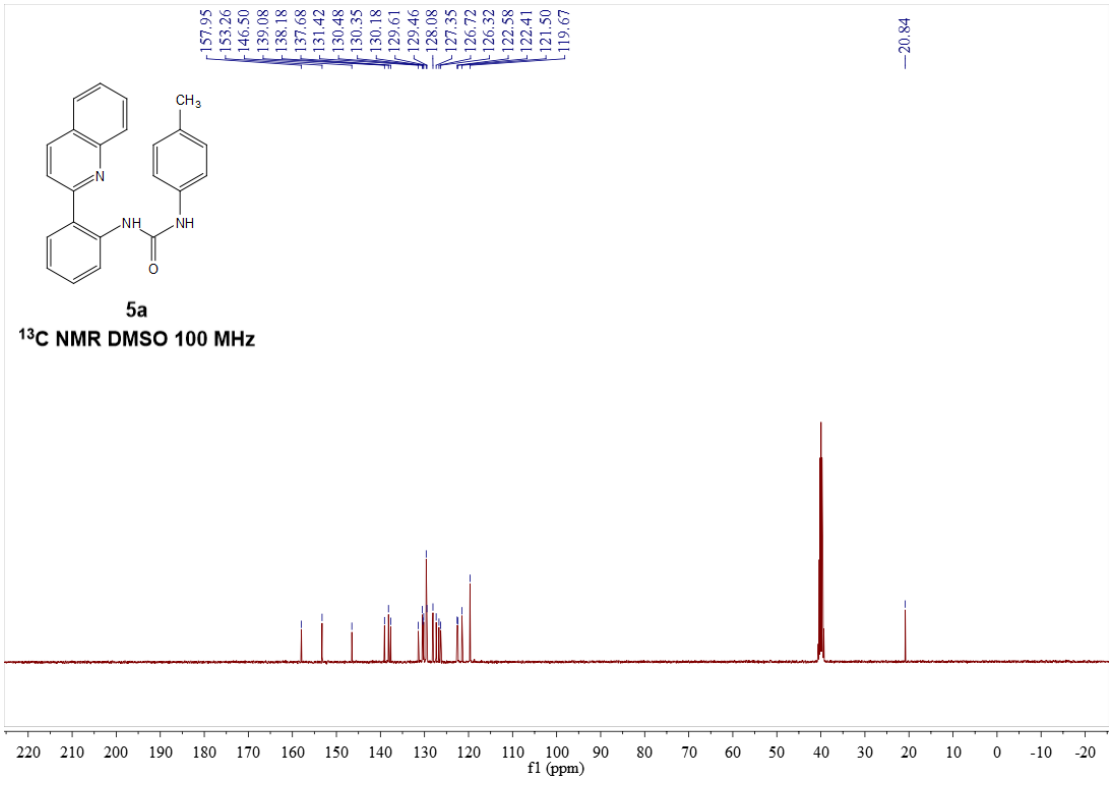
4x

^{13}C NMR DMSO 100 MHz



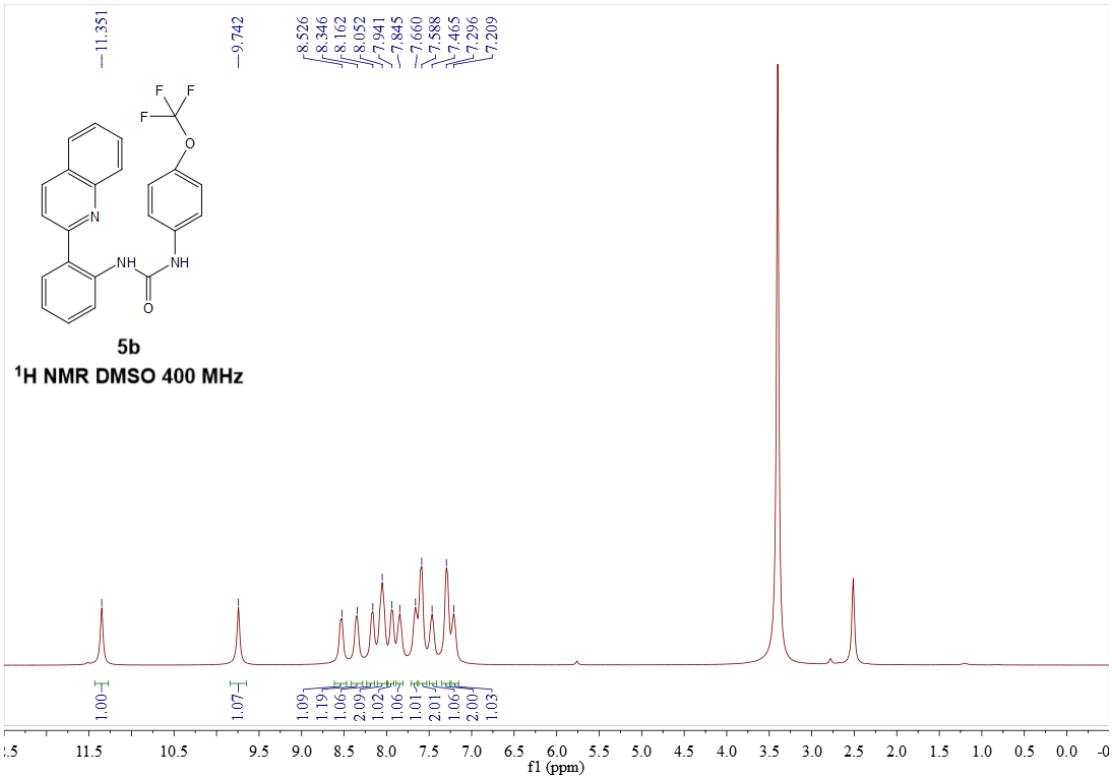
5a

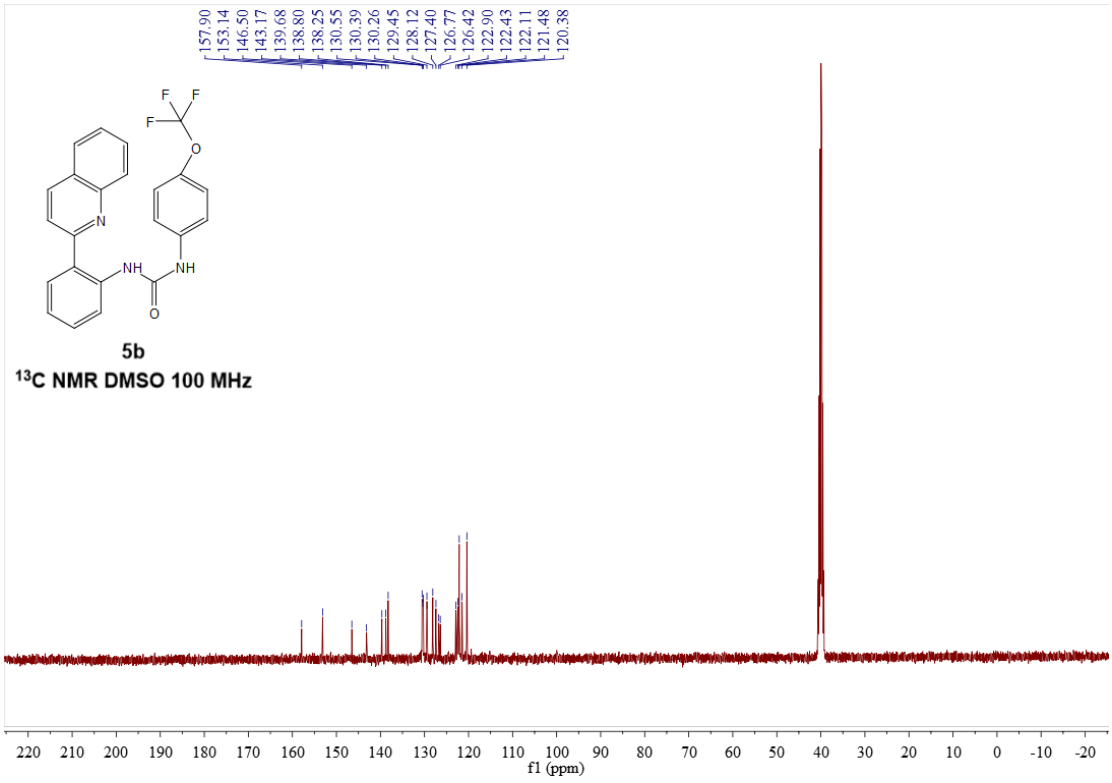
^{1}H NMR DMSO 400 MHz

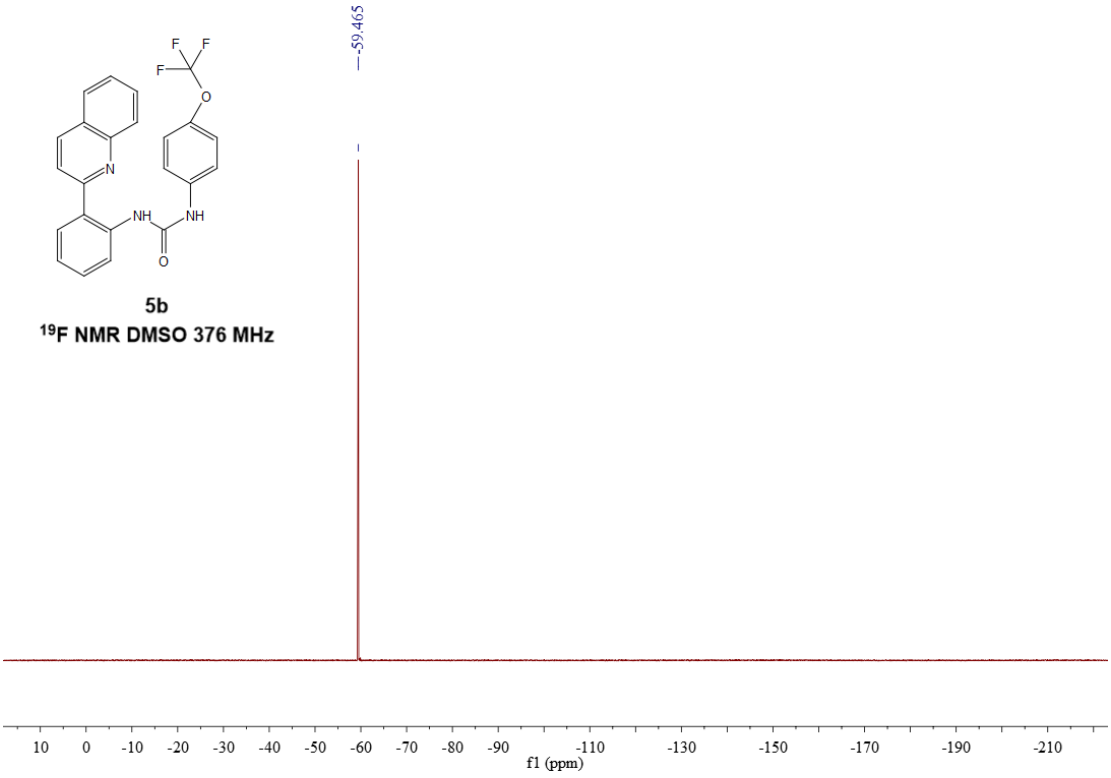


5a

^{13}C NMR DMSO 100 MHz

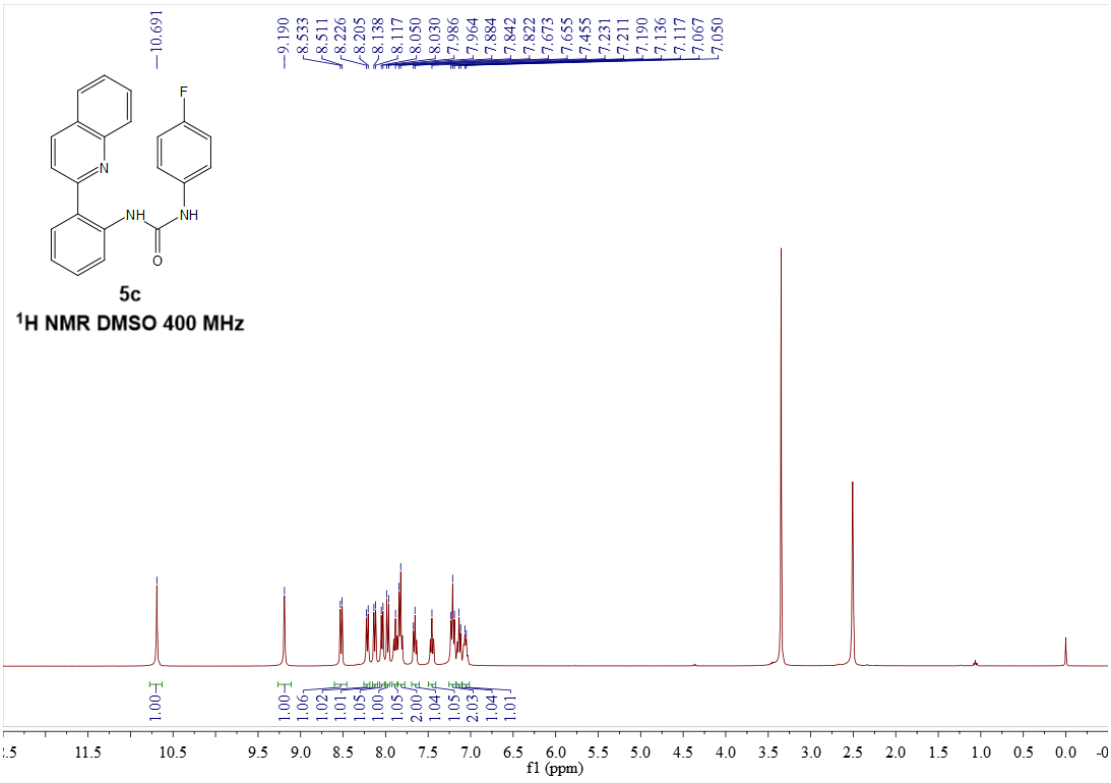

11.351
9.742
8.526
8.346
8.162
8.052
7.941
7.845
7.660
7.588
7.465
7.296
7.209
F
F
F
O
N
NH
NH
O
5b
1H NMR DMSO 400 MHz
1.00
1.07
1.09
1.19
1.06
2.09
1.02
1.06
1.01
2.01
1.06
2.00
1.03
f1 (ppm)


157.90
153.14
146.50
143.17
139.68
138.80
138.25
130.55
130.39
130.26
129.45
128.12
127.40
126.77
126.42
122.90
122.43
122.11
121.48
120.38
F
F
F
O
N
NH
NH
O
5b
13C NMR DMSO 100 MHz
f1 (ppm)



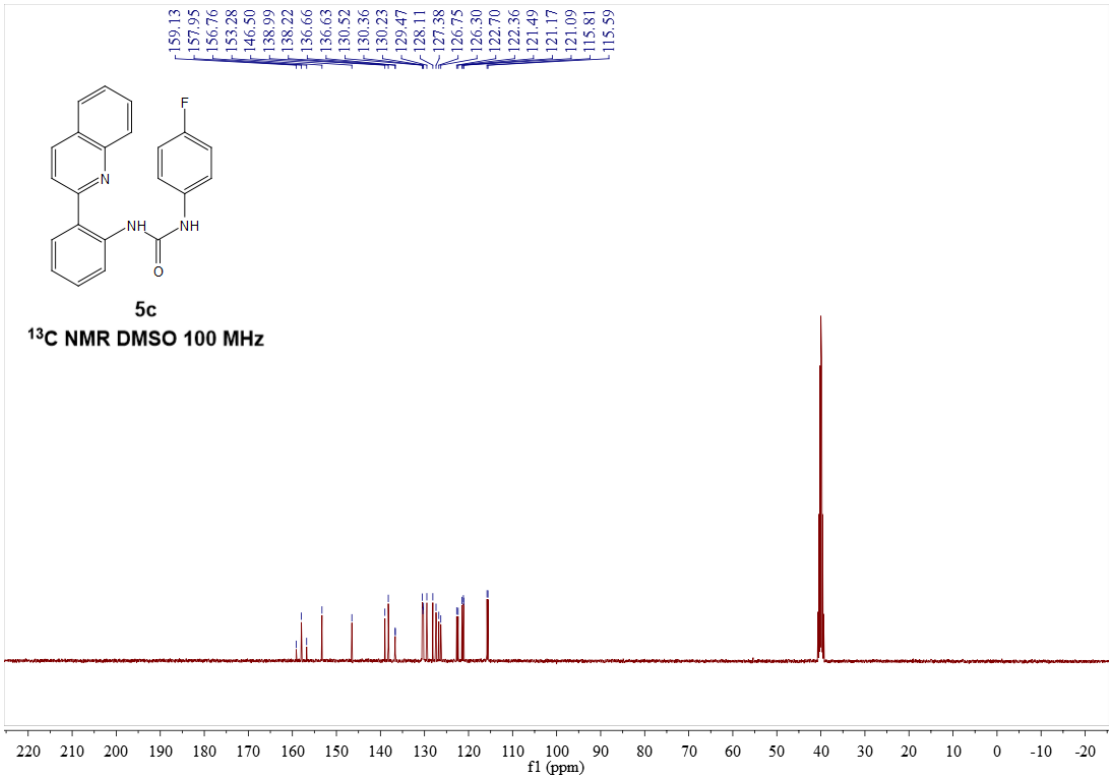
5b

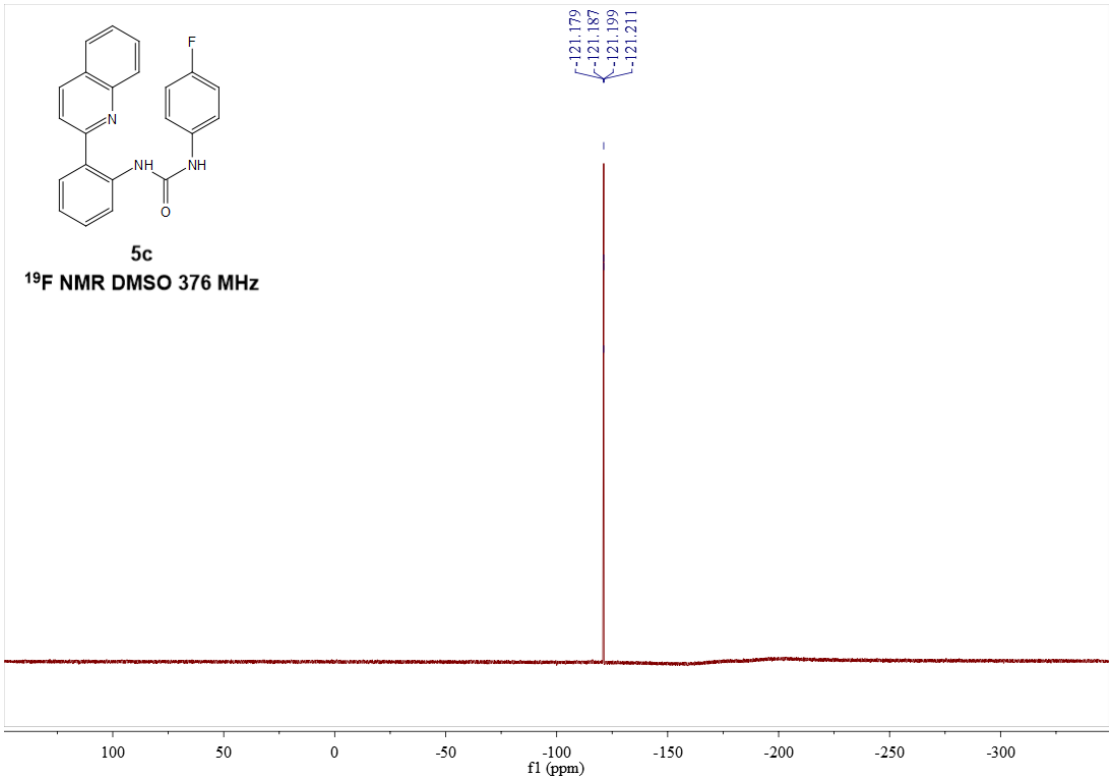
^{19}F NMR DMSO 376 MHz

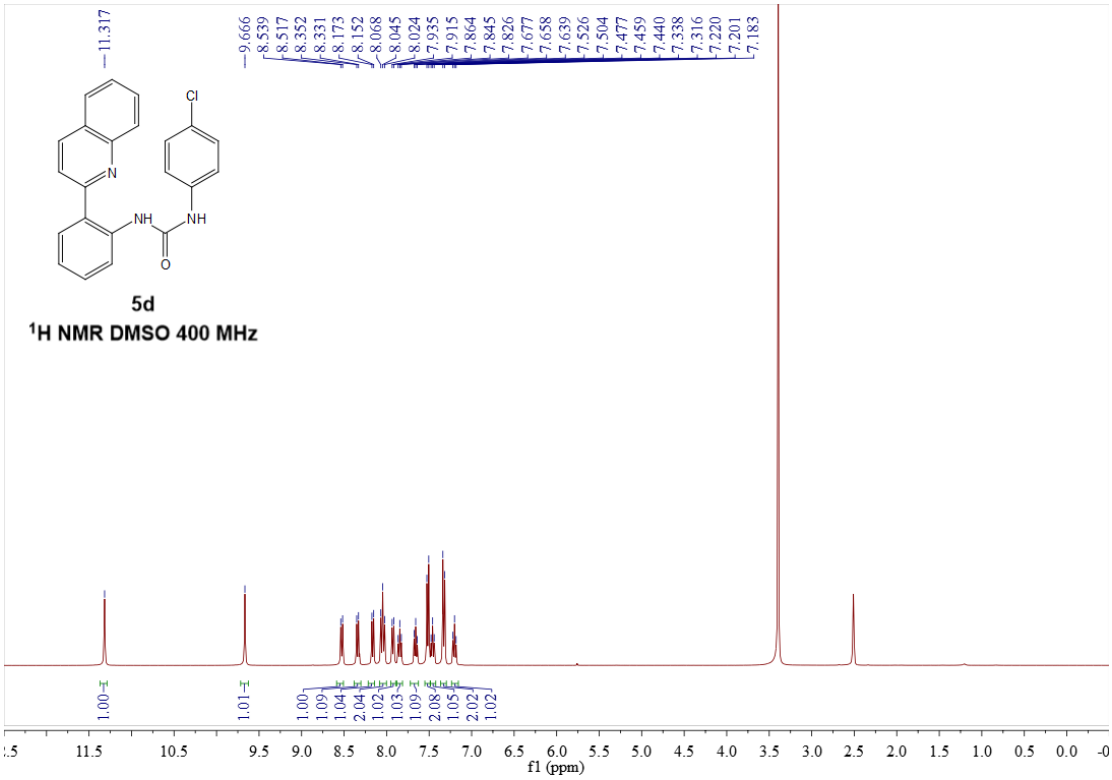


5c

^{1}H NMR DMSO 400 MHz

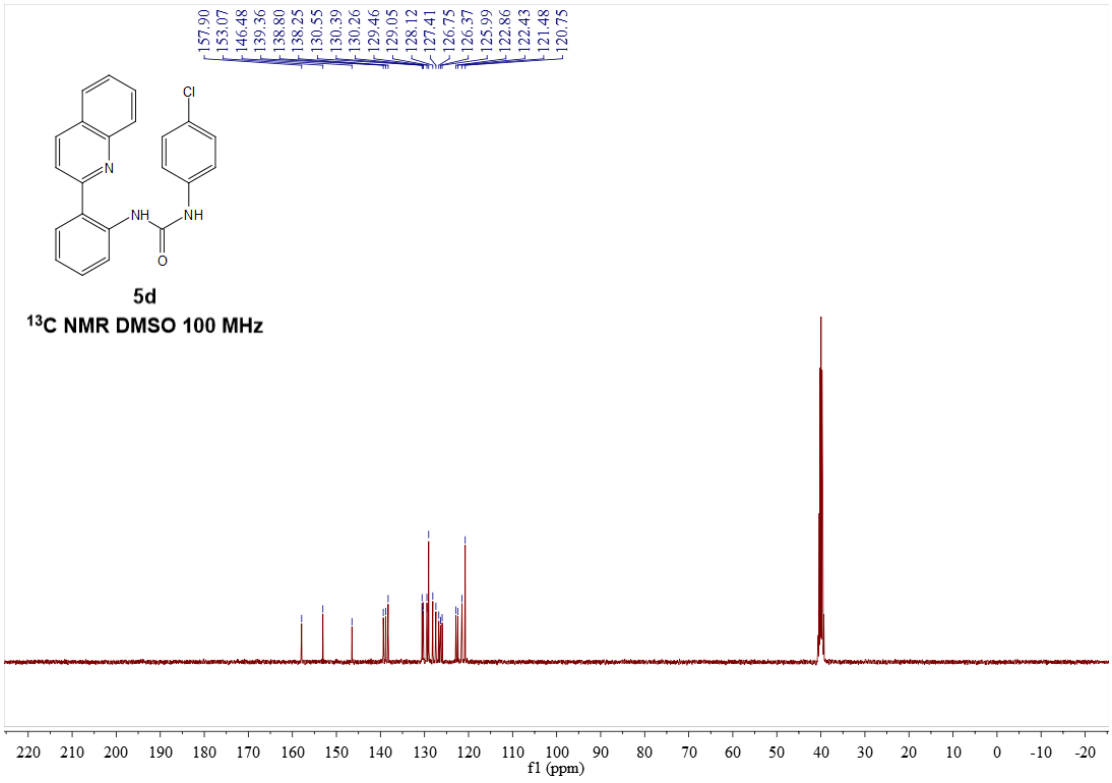

159.13
157.95
156.76
153.28
146.50
138.99
138.22
136.66
136.63
130.52
130.36
130.23
129.47
128.11
127.38
126.75
126.30
122.70
122.36
121.49
121.17
121.09
115.81
115.59
F
N
NH
NH
O
5c
13C NMR DMSO 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


-121.179
-121.187
-121.199
-121.211
F
N
NH
NH
O
5c
19F NMR DMSO 376 MHz
100 50 0 -50 -100 -150 -200 -250 -300
f1 (ppm)



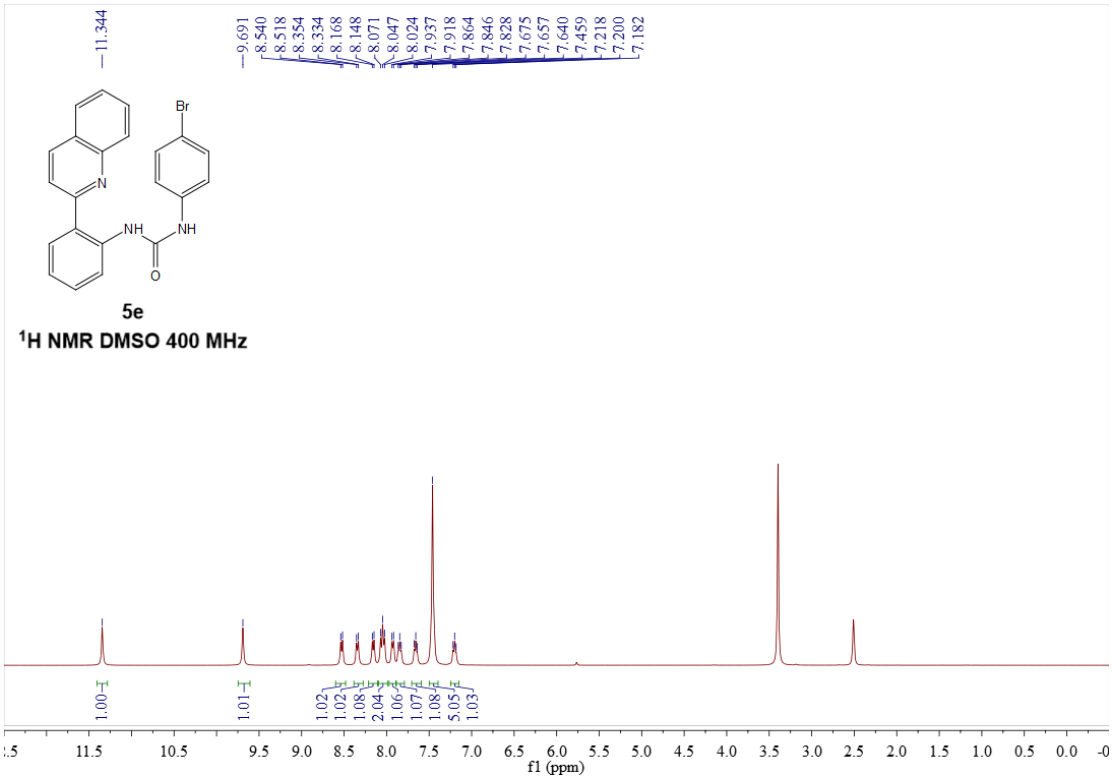
5d

^{1}H NMR DMSO 400 MHz



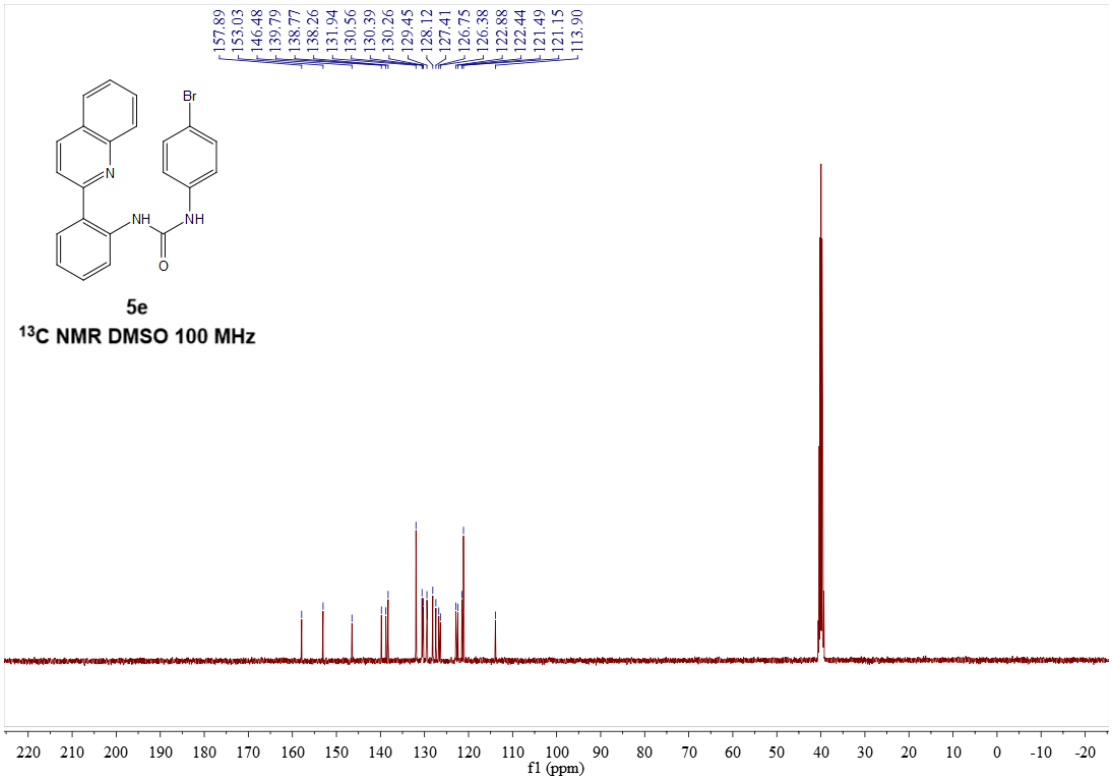
5d

^{13}C NMR DMSO 100 MHz



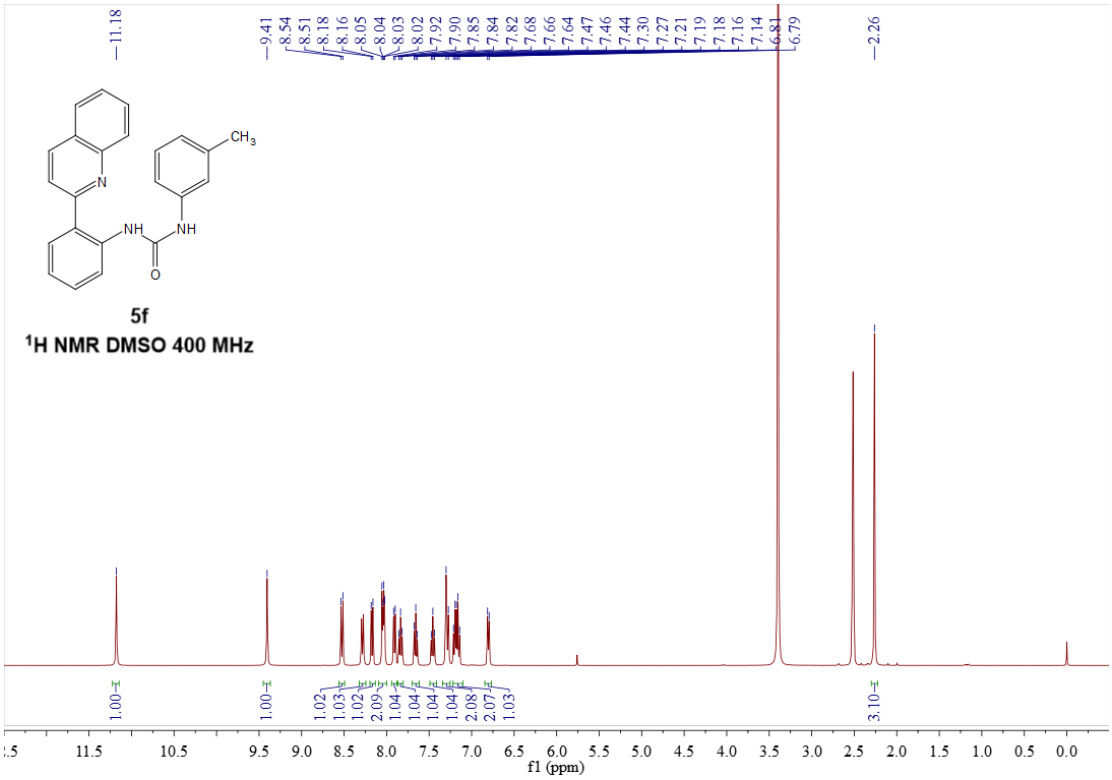
5e

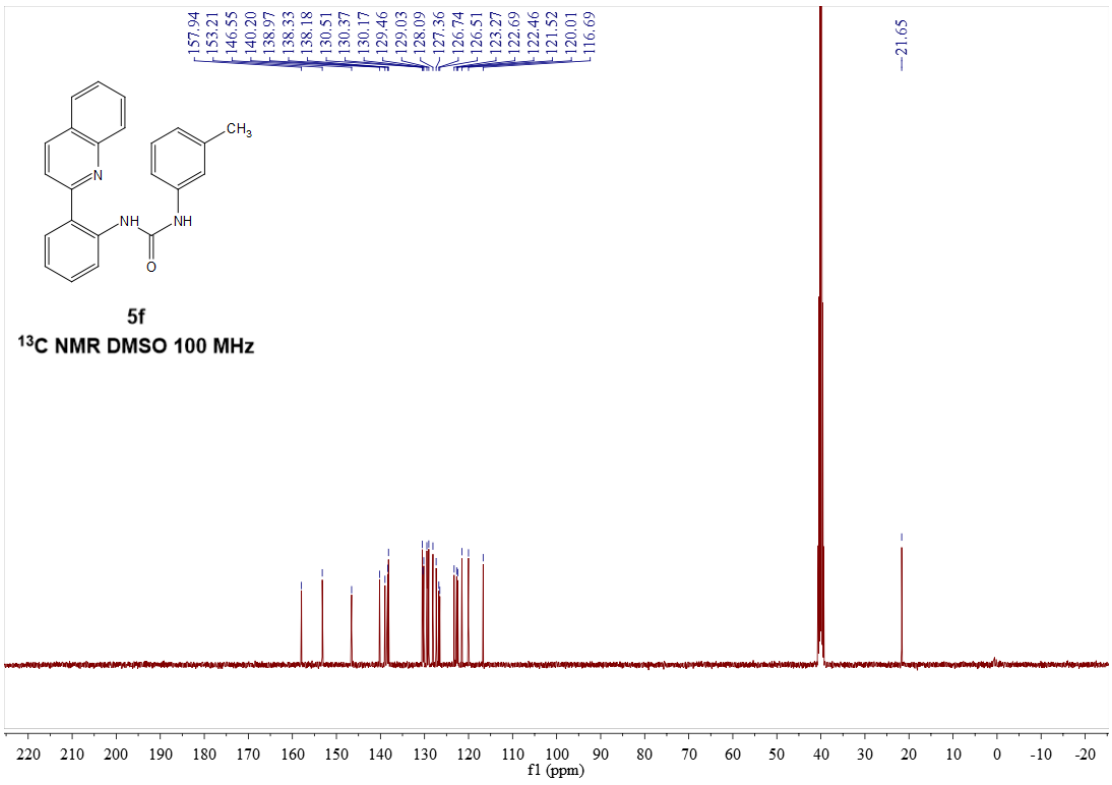
^{1}H NMR DMSO 400 MHz

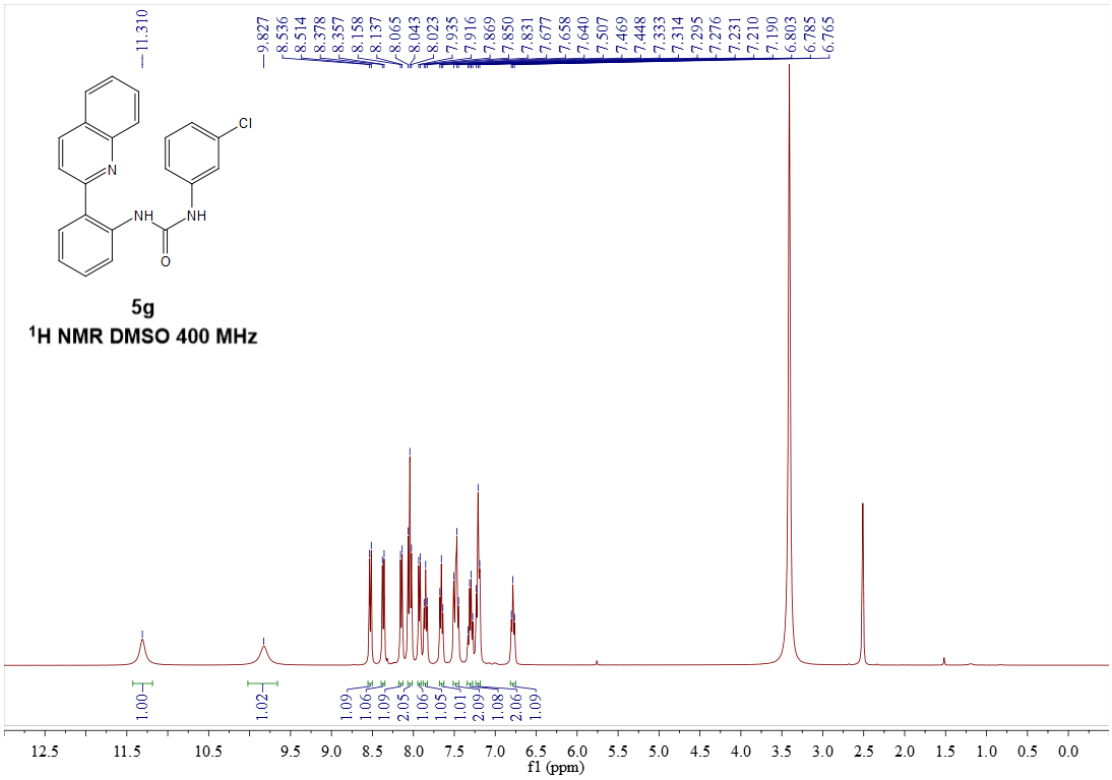


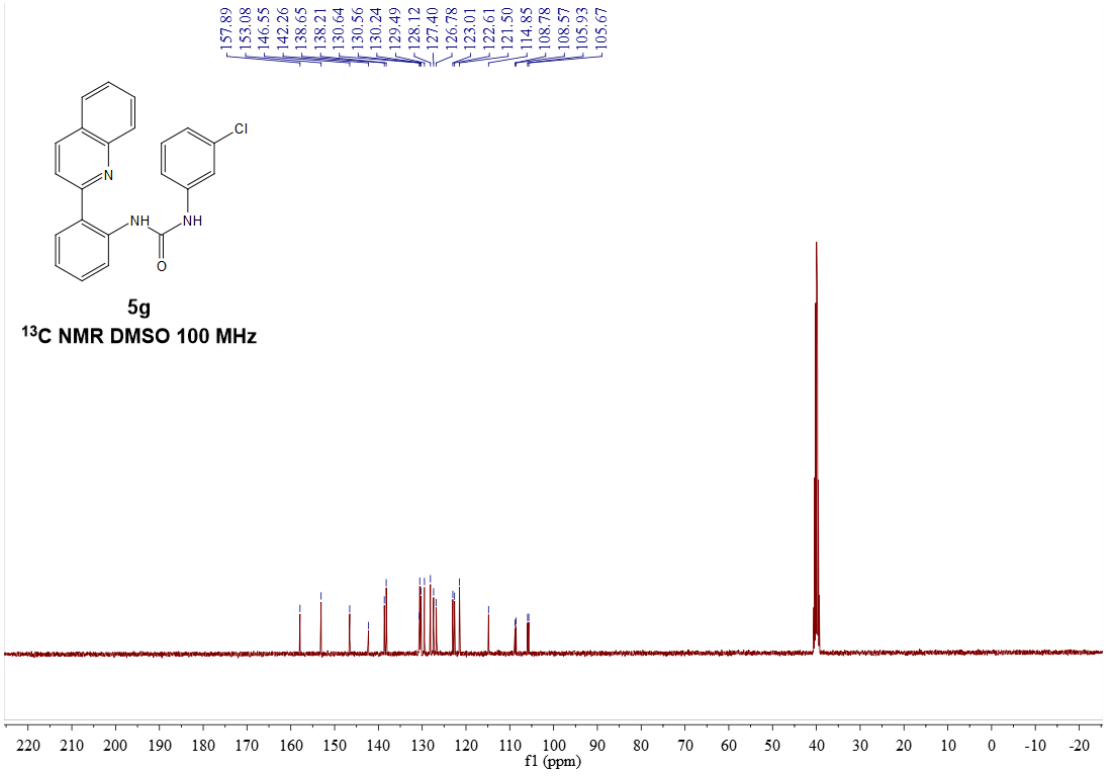
5e

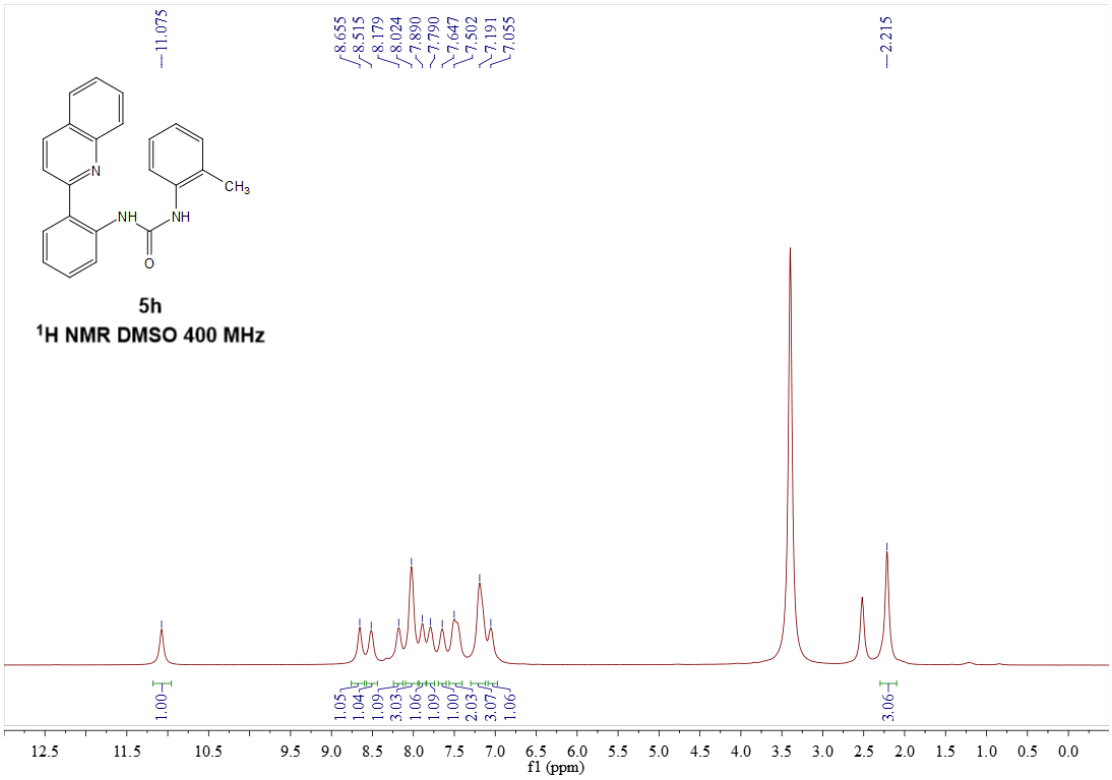
^{13}C NMR DMSO 100 MHz

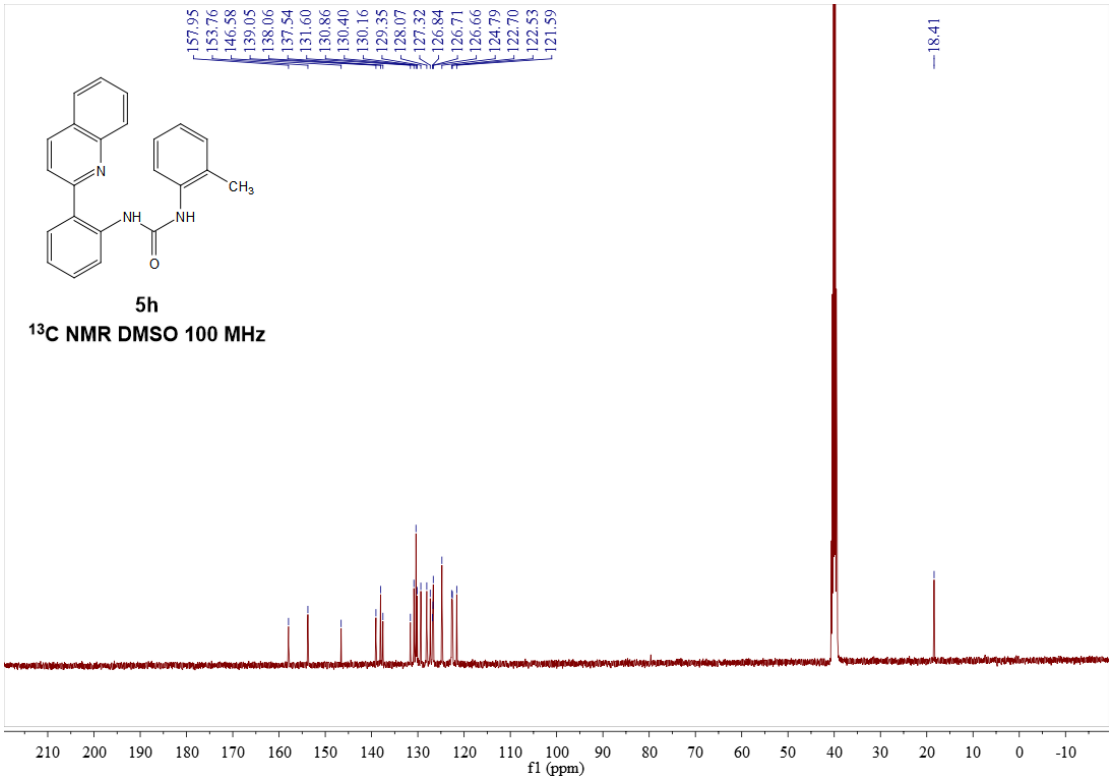

11.18
9.41
8.54
8.51
8.18
8.16
8.05
8.04
8.03
8.02
7.92
7.90
7.85
7.84
7.82
7.68
7.66
7.64
7.47
7.46
7.44
7.30
7.27
7.21
7.19
7.18
7.16
7.14
6.81
6.79
2.26
CH3
N
NH
NH
O
5f
1H NMR DMSO 400 MHz
1.00
1.00
1.02
1.03
1.02
2.09
1.04
1.04
1.04
1.04
2.08
2.07
1.03
3.10
f1 (ppm)

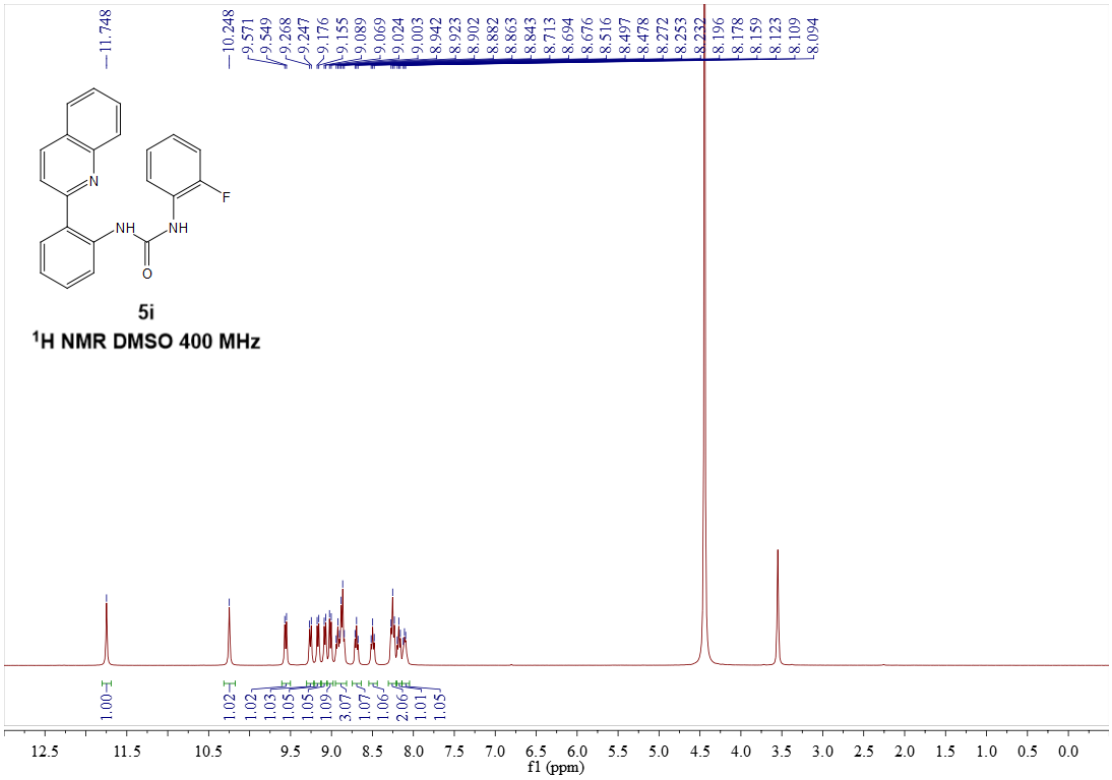

157.94
153.21
146.55
140.20
138.97
138.33
138.18
130.51
130.37
130.17
129.46
129.03
128.09
127.36
126.74
126.51
123.27
122.69
122.46
121.52
120.01
116.69
21.65
CH3
N
NH
NH
O
5f
13C NMR DMSO 100 MHz
f1 (ppm)

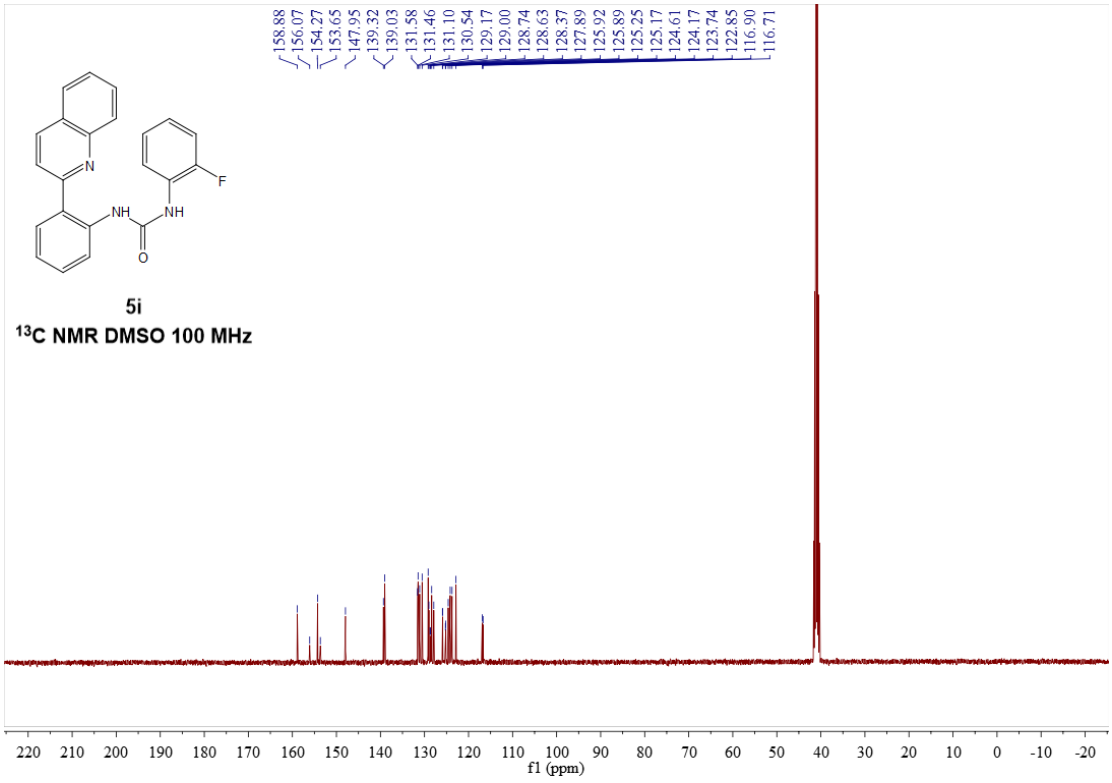

11.310
9.827
8.536
8.514
8.378
8.357
8.158
8.137
8.065
8.043
8.023
7.935
7.916
7.869
7.850
7.831
7.677
7.658
7.640
7.507
7.469
7.448
7.333
7.314
7.295
7.276
7.231
7.210
7.190
6.803
6.785
6.765
Cl
N
NH
NH
O
5g
1H NMR DMSO 400 MHz
1.00
1.02
1.09
1.06
1.09
2.05
1.06
1.05
1.01
2.09
1.08
2.06
1.09
12.5
11.5
10.5
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)

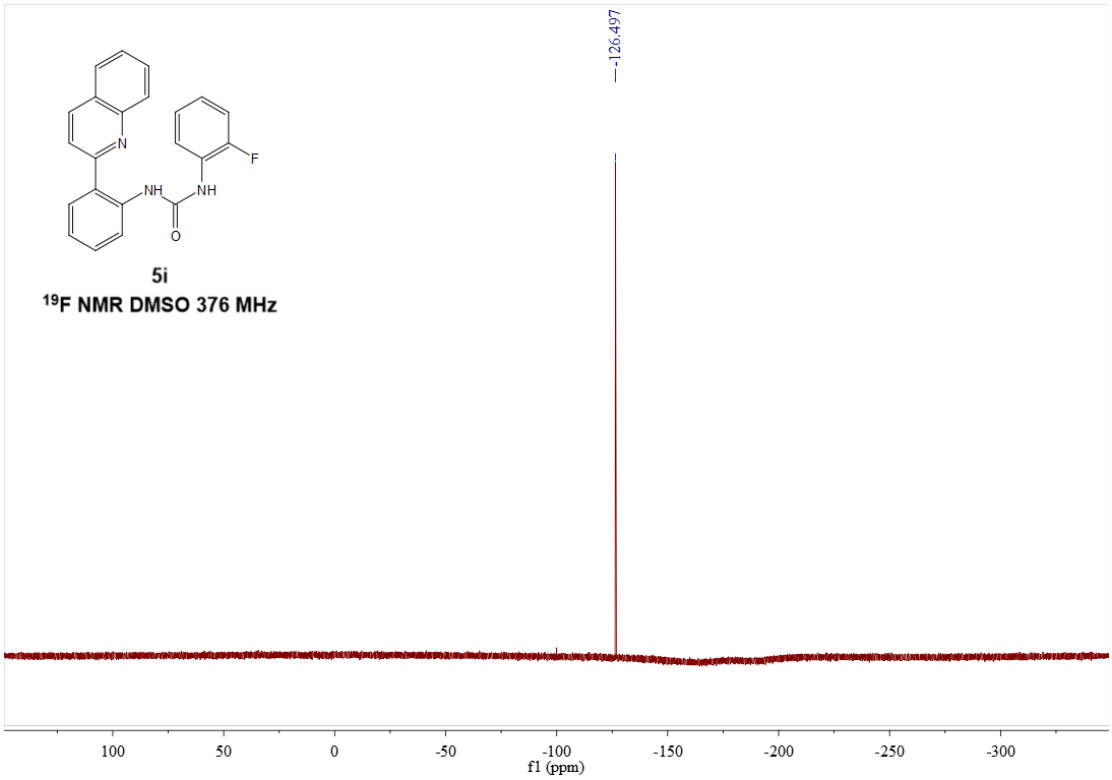

157.89
153.08
146.55
142.26
138.65
138.21
130.64
130.56
130.24
129.49
128.12
127.40
126.78
123.01
122.61
121.50
114.85
108.78
108.57
105.93
105.67
Cl
N
NH
NH
O
5g
13C NMR DMSO 100 MHz
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)


11.075
8.655
8.515
8.179
8.024
7.890
7.790
7.647
7.502
7.191
7.055
2.215
N
NH
NH
O
CH3
5h
1H NMR DMSO 400 MHz
1.00
1.05
1.04
1.09
3.03
1.06
1.09
1.00
2.03
3.07
1.06
3.06
f1 (ppm)


157.95
153.76
146.58
139.05
138.06
137.54
131.60
130.86
130.40
130.16
129.35
128.07
127.32
126.84
126.71
126.66
124.79
122.70
122.53
121.59
18.41
N
NH
NH
O
CH3
5h
13C NMR DMSO 100 MHz
f1 (ppm)

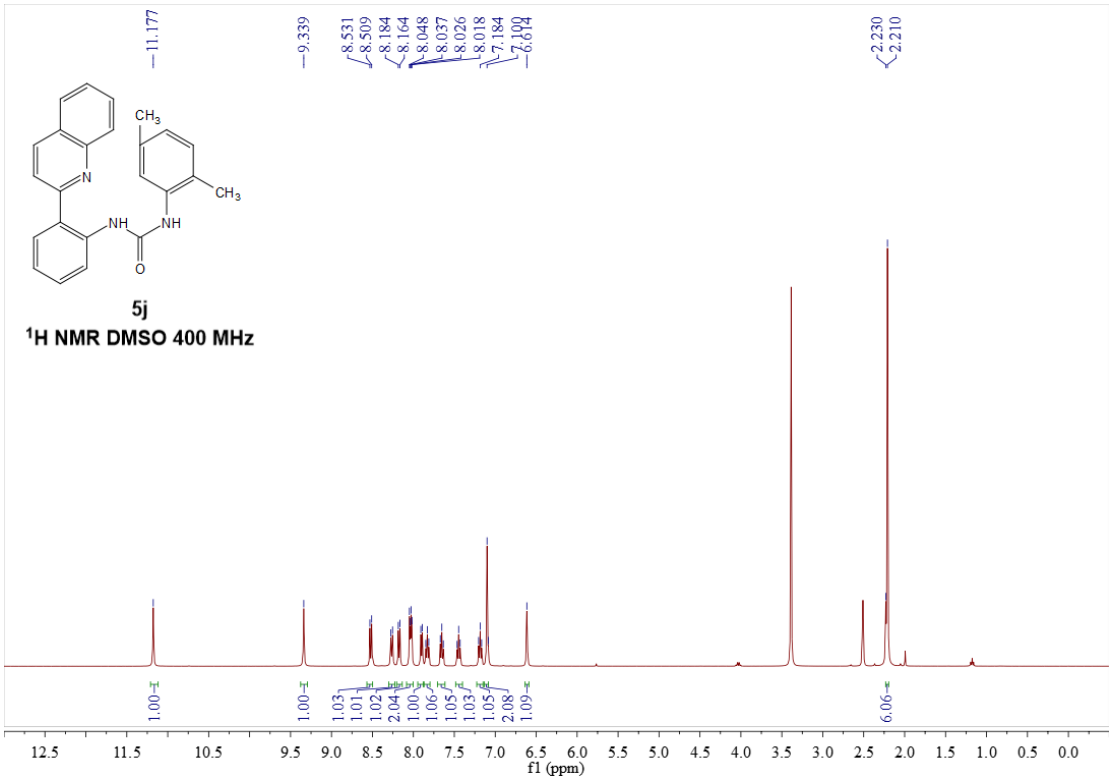

11.748
10.248
9.571
9.549
9.268
9.247
9.176
9.155
9.089
9.069
9.024
9.003
8.942
8.923
8.902
8.882
8.863
8.843
8.713
8.694
8.676
8.516
8.497
8.478
8.272
8.253
8.232
8.196
8.178
8.159
8.123
8.109
8.094
N
NH
NH
O
F
5i
1H NMR DMSO 400 MHz
1.00
1.02
1.02
1.03
1.05
1.05
1.09
3.07
1.07
1.06
2.06
1.01
1.05
12.5
11.5
10.5
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)


158.88
156.07
154.27
153.65
147.95
139.32
139.03
131.58
131.46
131.10
130.54
129.17
129.00
128.74
128.63
128.37
127.89
125.92
125.89
125.25
125.17
124.61
124.17
123.74
122.85
116.90
116.71
N
NH
NH
O
F
5i
13C NMR DMSO 100 MHz
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)



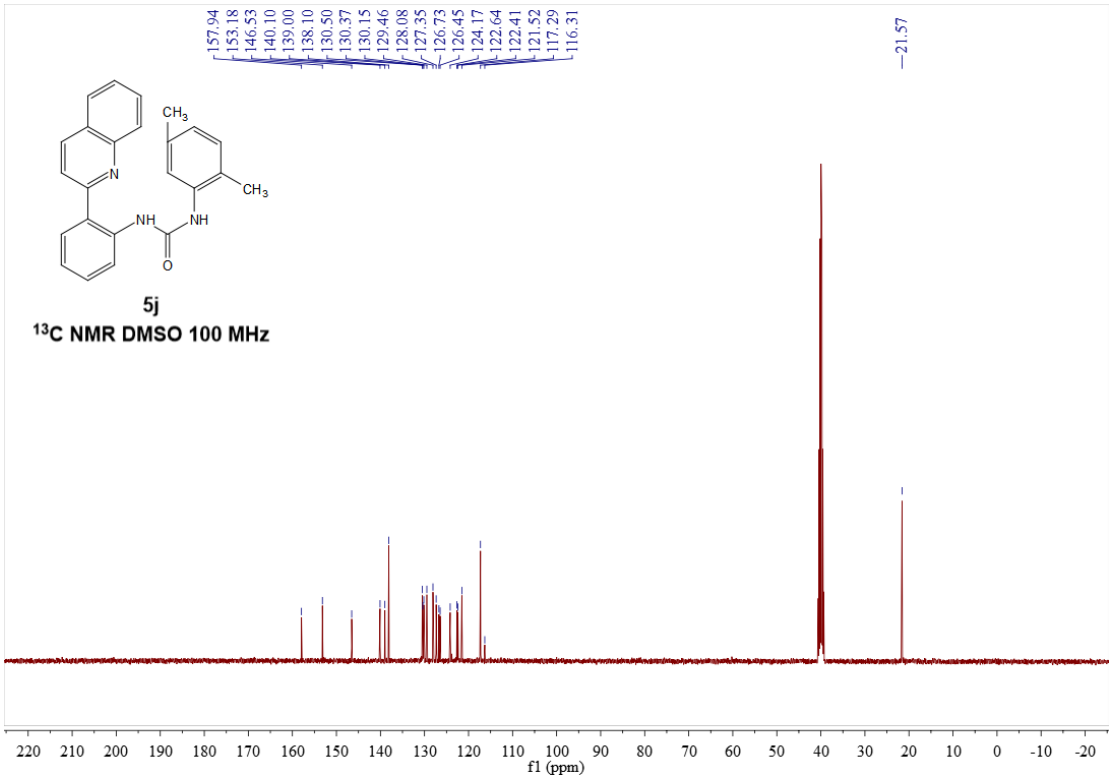
5i

^{19}F NMR DMSO 376 MHz



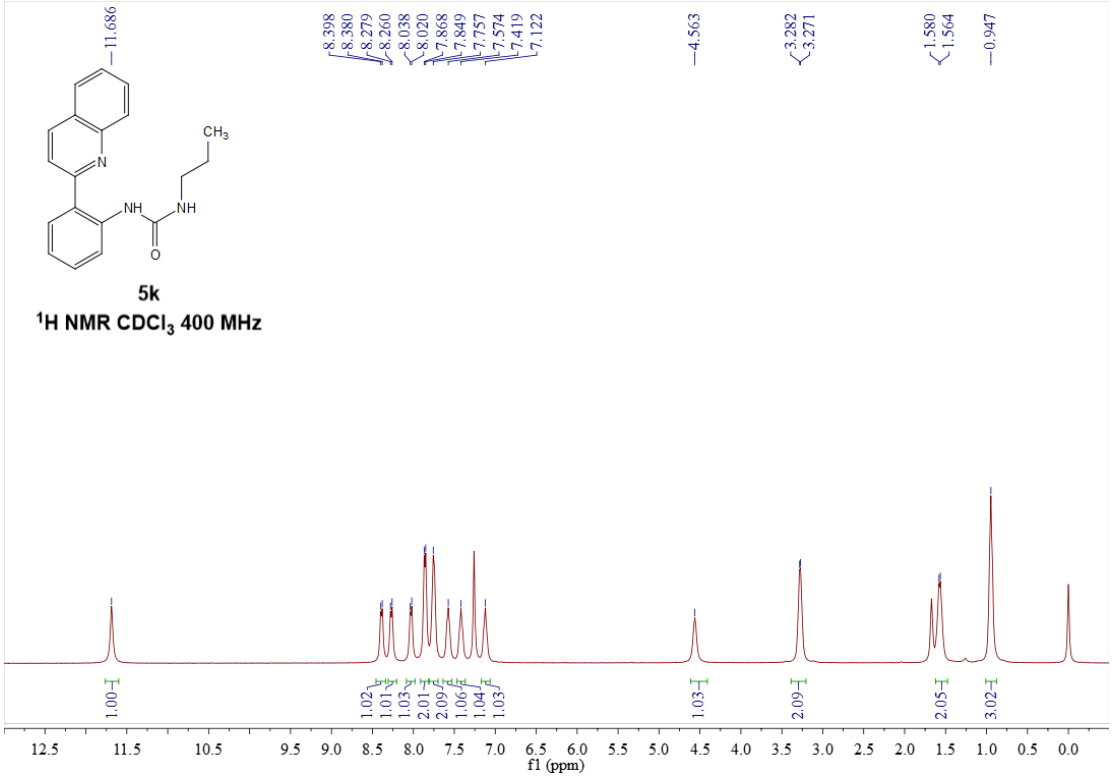
5j

^{1}H NMR DMSO 400 MHz



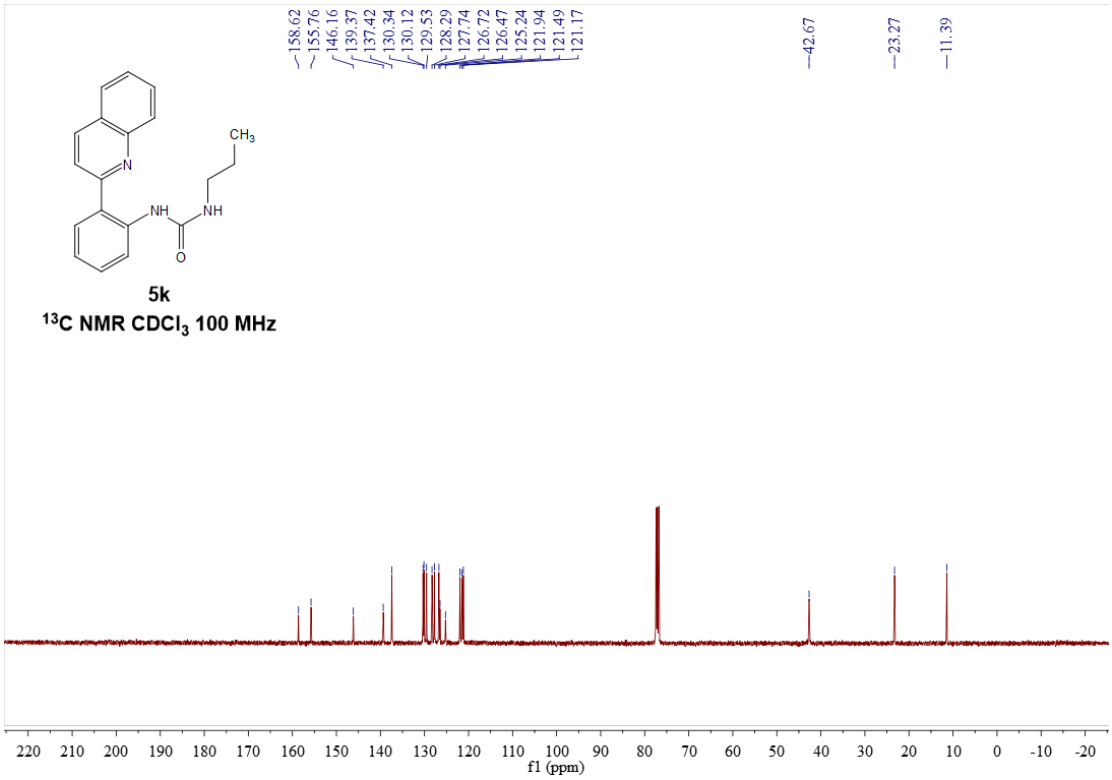
5j

^{13}C NMR DMSO 100 MHz



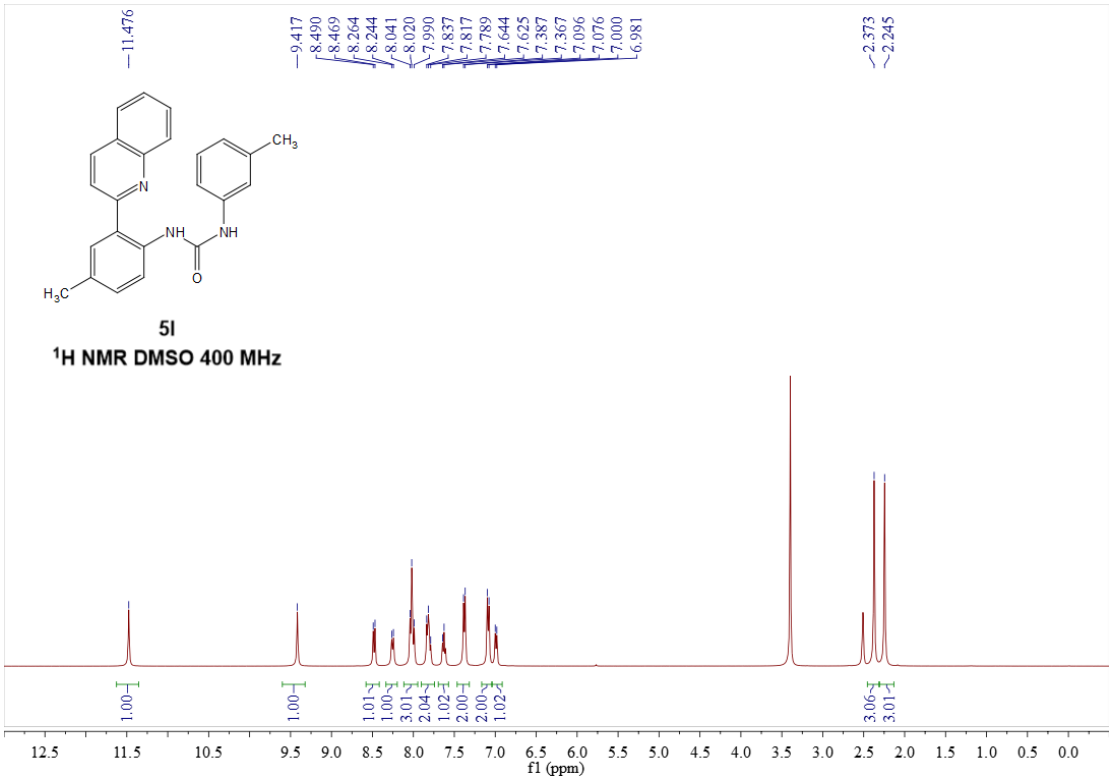
5k

^{1}H NMR $CDCl_3$ 400 MHz



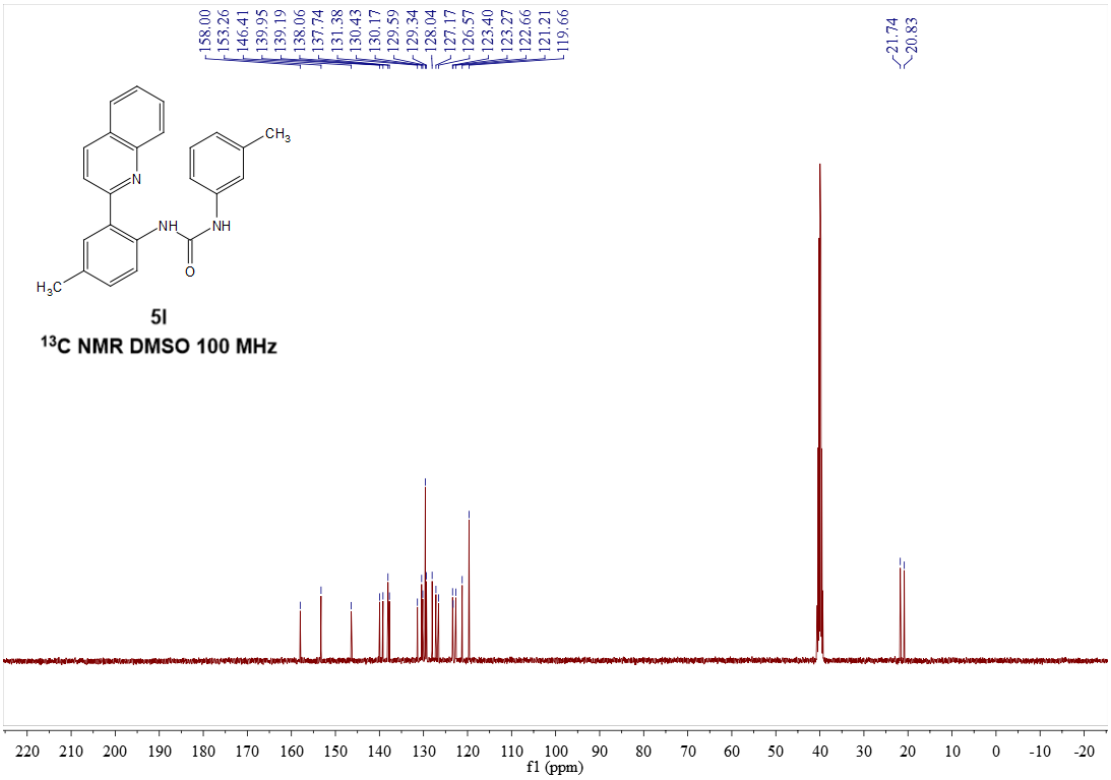
5k

^{13}C NMR $CDCl_3$ 100 MHz



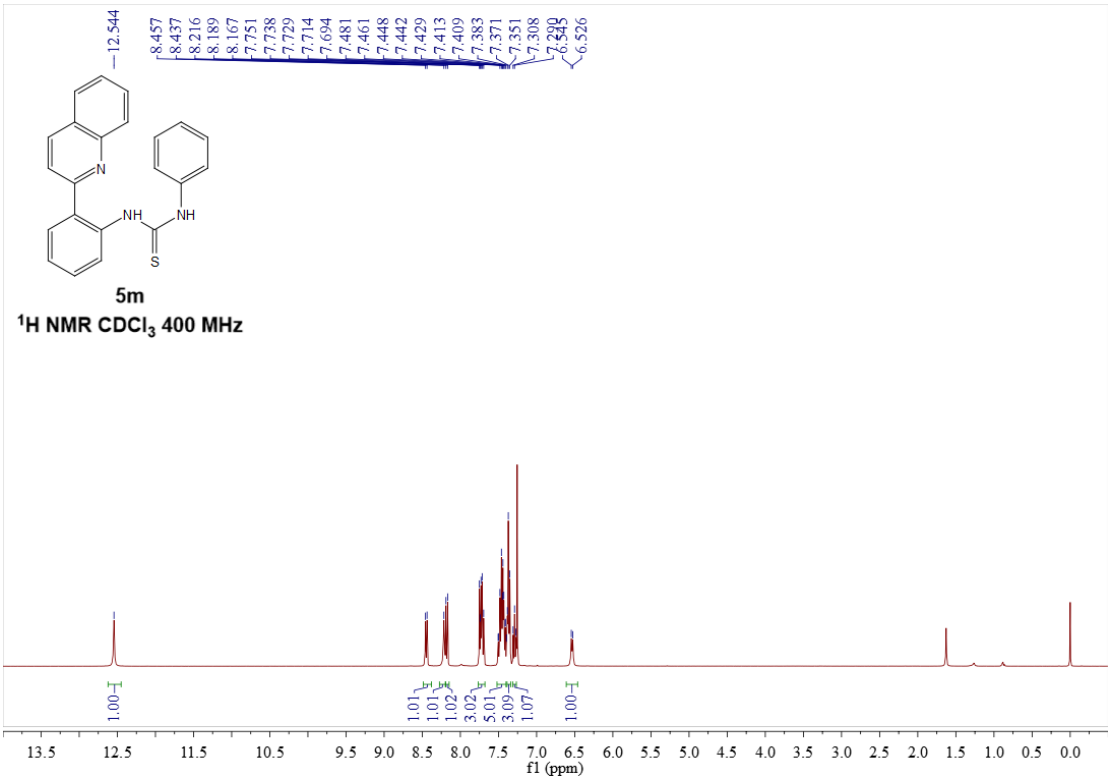
5l

^{1}H NMR DMSO 400 MHz



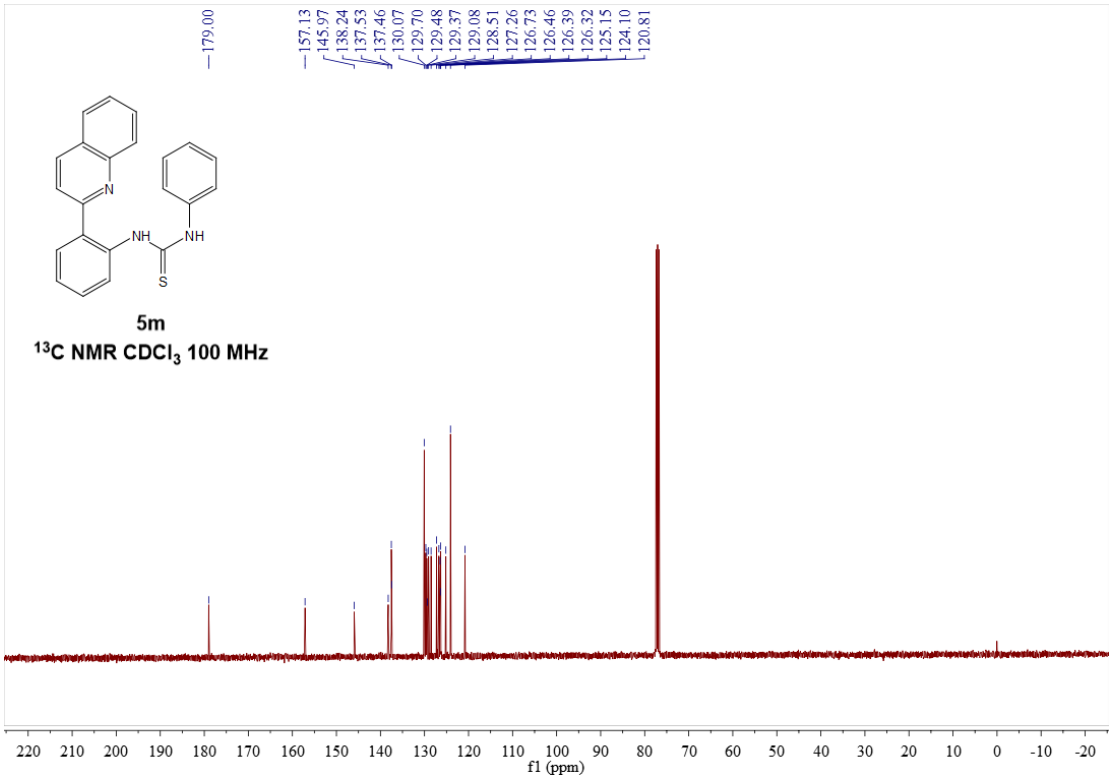
5l

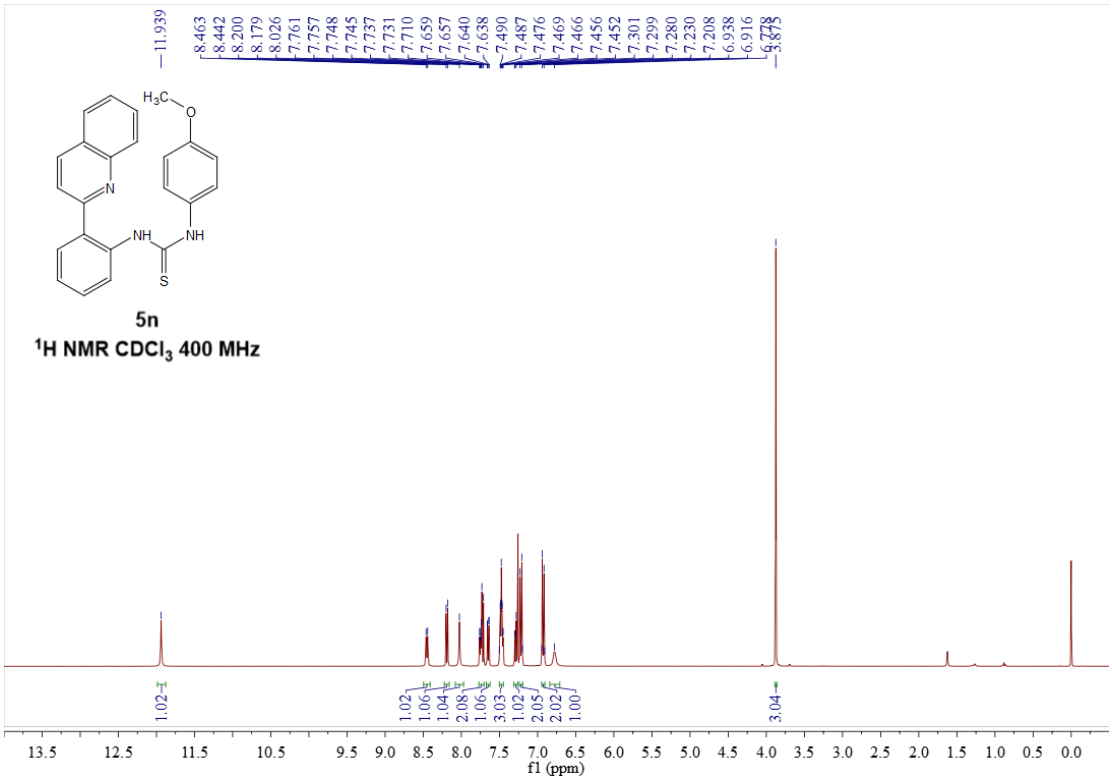
^{13}C NMR DMSO 100 MHz

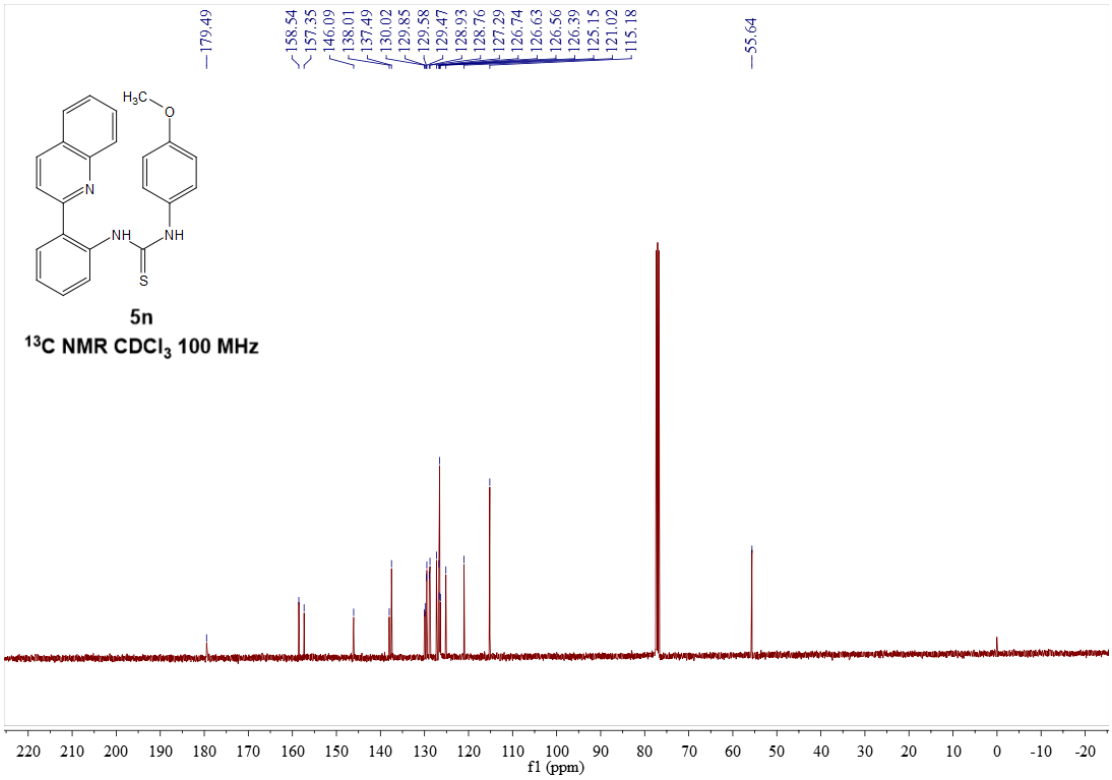


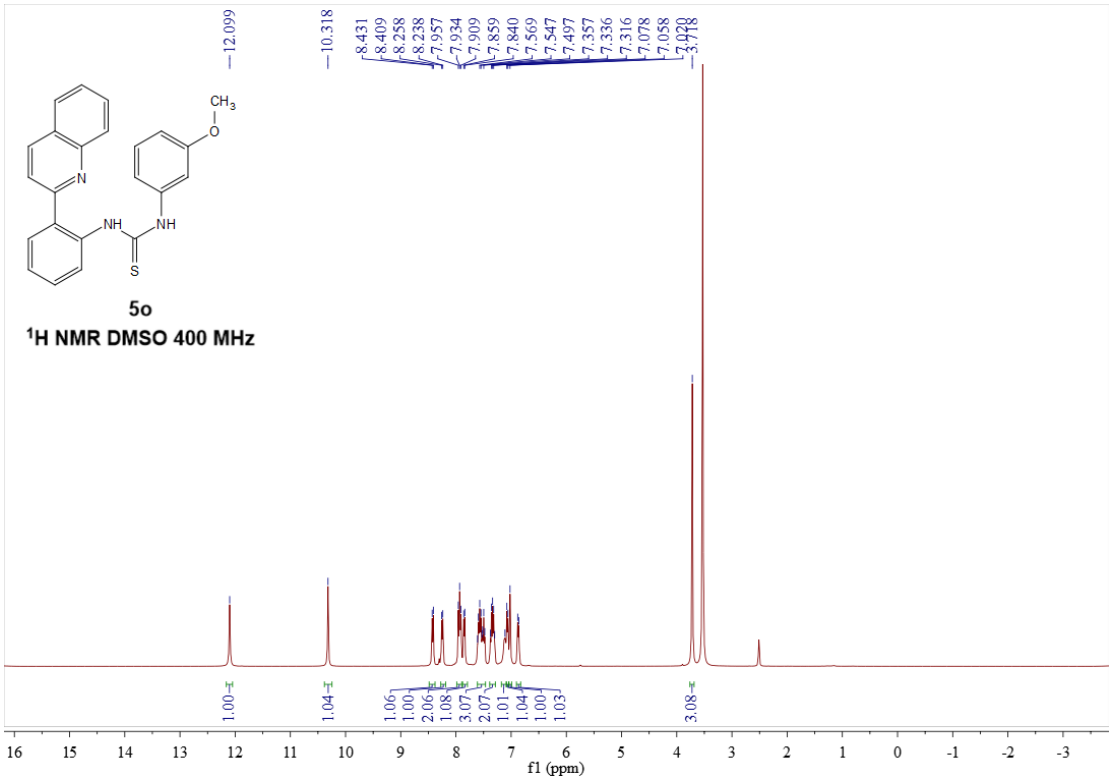
5m

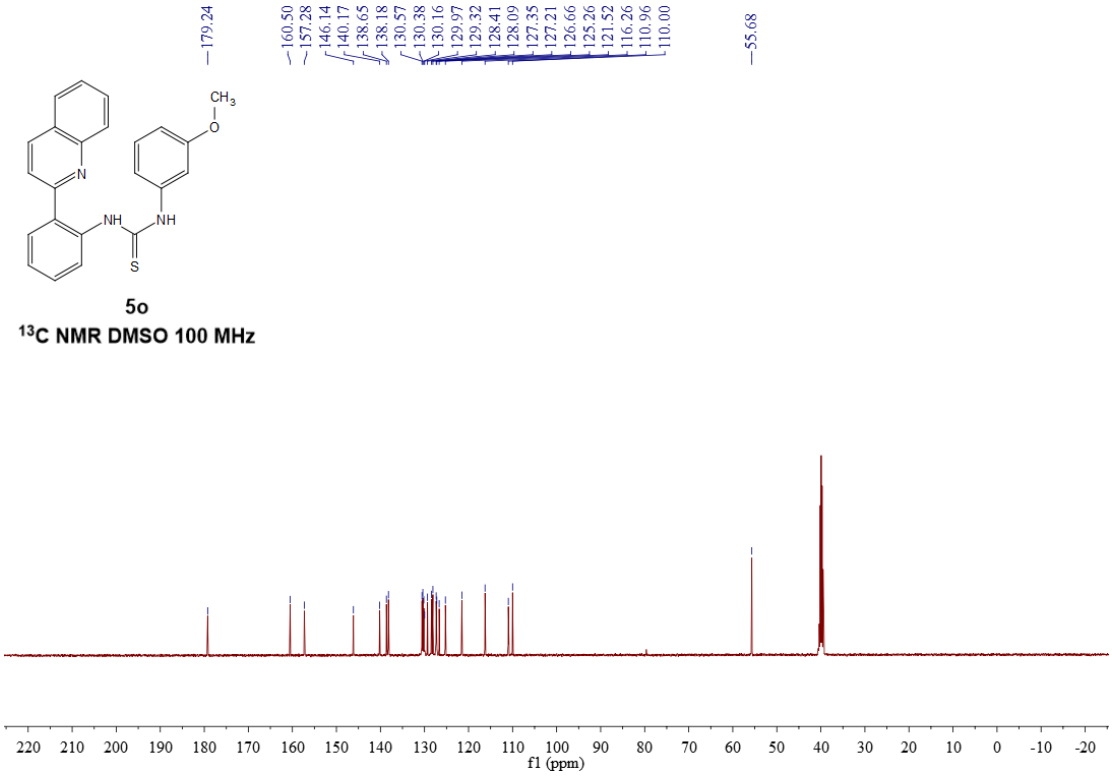
^{1}H NMR $CDCl_3$ 400 MHz


179.00
157.13
145.97
138.24
137.53
137.46
130.07
129.70
129.48
129.37
129.08
128.51
127.26
126.73
126.46
126.39
126.32
125.15
124.10
120.81
N
NH
NH
S
5m
13C NMR CDCl3 100 MHz
f1 (ppm)


11.939
8.463
8.442
8.200
8.179
8.026
7.761
7.757
7.748
7.745
7.737
7.731
7.710
7.659
7.657
7.640
7.638
7.490
7.487
7.476
7.469
7.466
7.456
7.452
7.301
7.299
7.280
7.230
7.208
6.938
6.916
3.873
H3C
O
N
NH
NH
S
5n
1H NMR CDCl3 400 MHz
1.02
1.02
1.06
1.04
2.08
1.06
3.03
1.02
2.05
2.02
1.00
3.04
f1 (ppm)

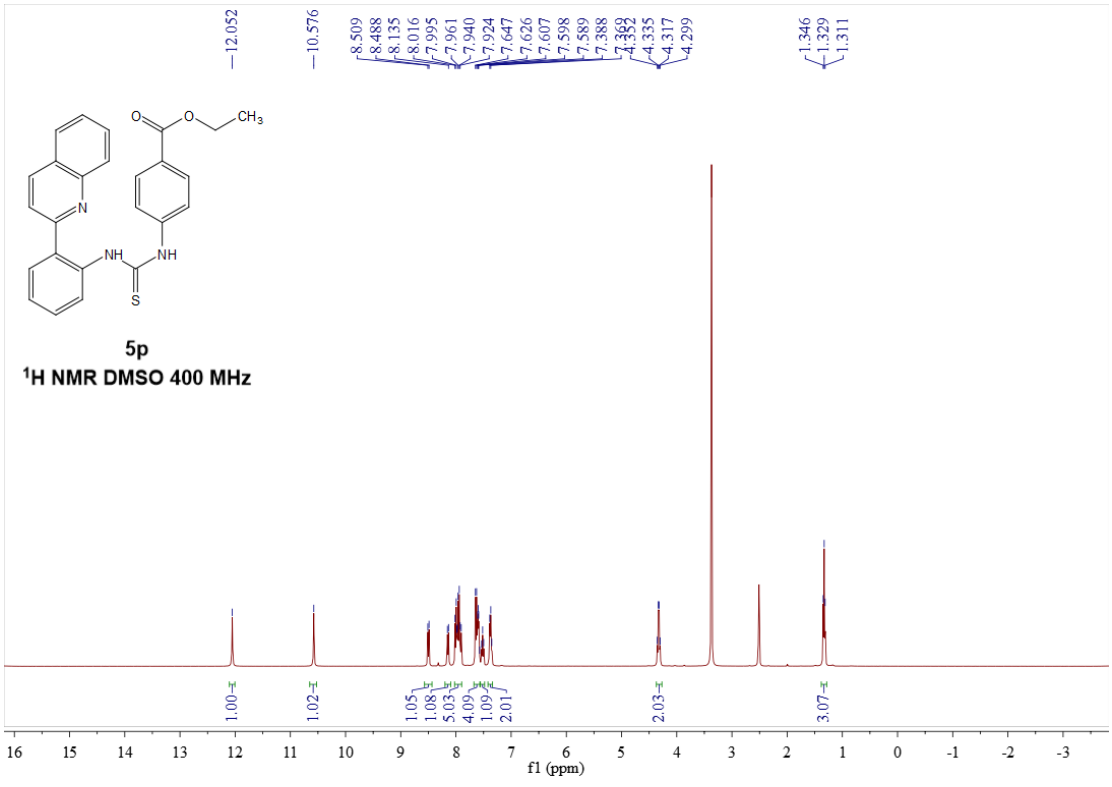

179.49
158.54
157.35
146.09
138.01
137.49
130.02
129.85
129.58
129.47
128.93
128.76
127.29
126.74
126.63
126.56
126.39
125.15
121.02
115.18
55.64
H3C
O
N
NH
NH
S
5n
13C NMR CDCl3 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


12.099
10.318
8.431
8.409
8.258
8.238
7.957
7.934
7.909
7.859
7.840
7.569
7.547
7.497
7.357
7.336
7.316
7.078
7.058
7.020
3.718
CH3
O
N
NH
NH
S
5o
1H NMR DMSO 400 MHz
1.00
1.04
1.06
1.00
2.06
1.08
3.07
2.07
1.01
1.04
1.00
1.03
3.08
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)



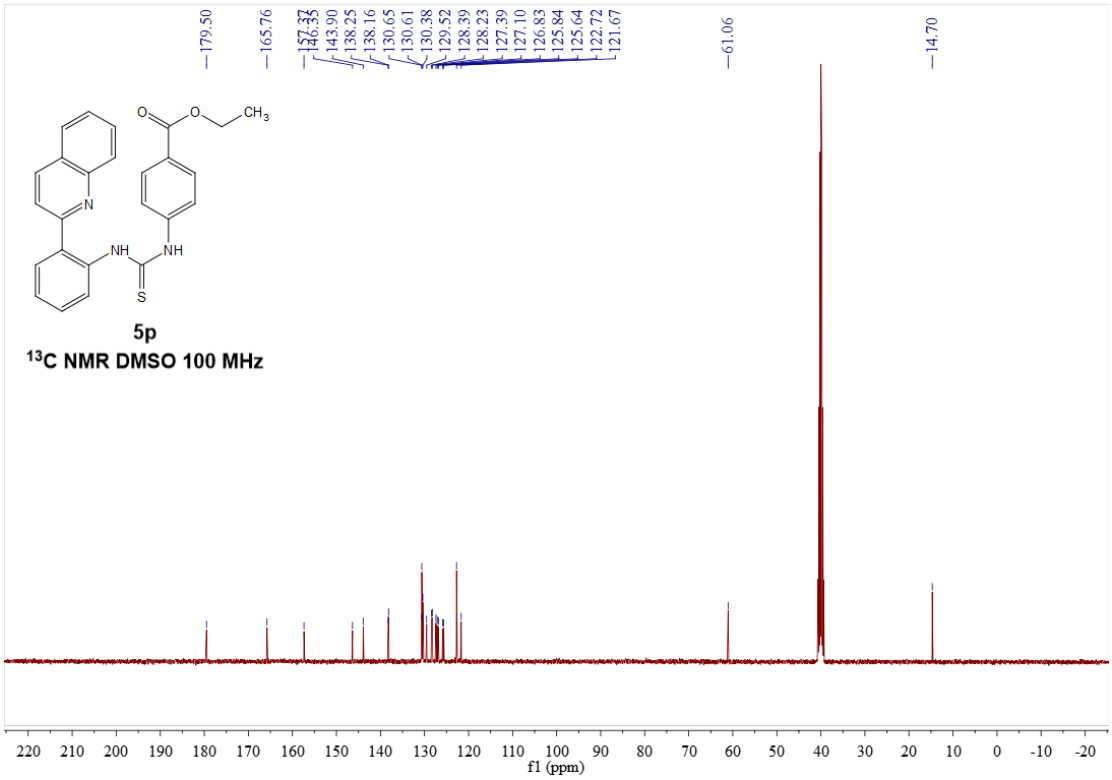
5o

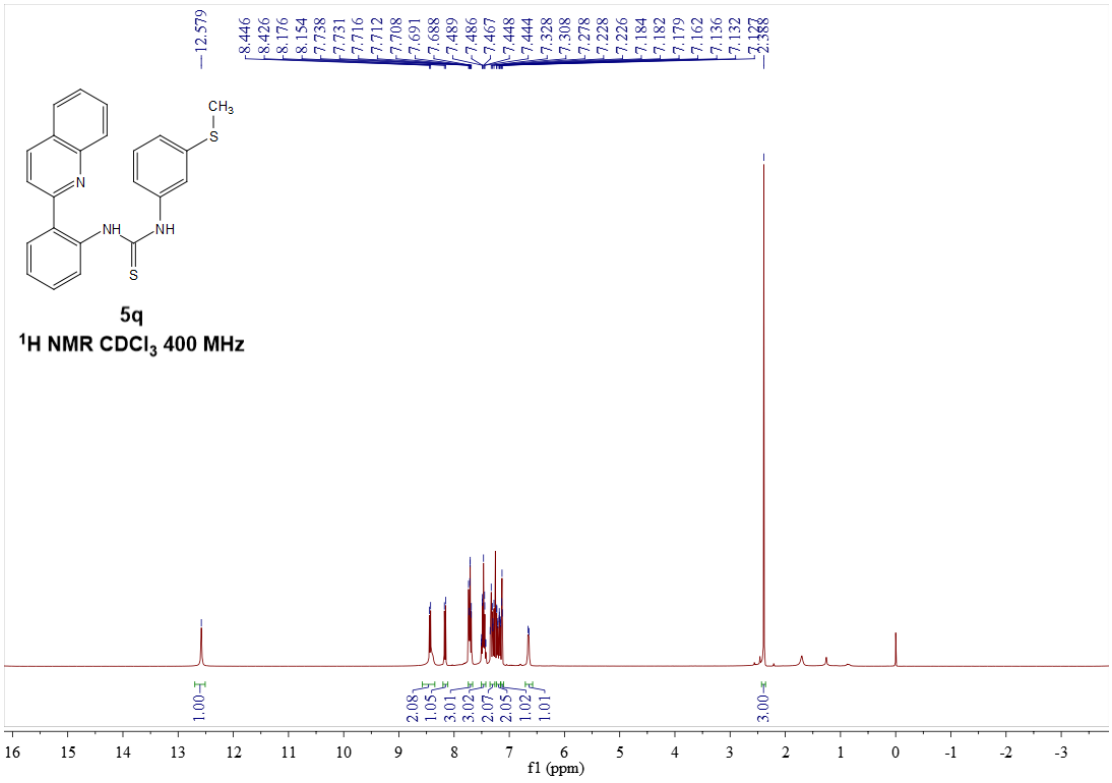
^{13}C NMR DMSO 100 MHz

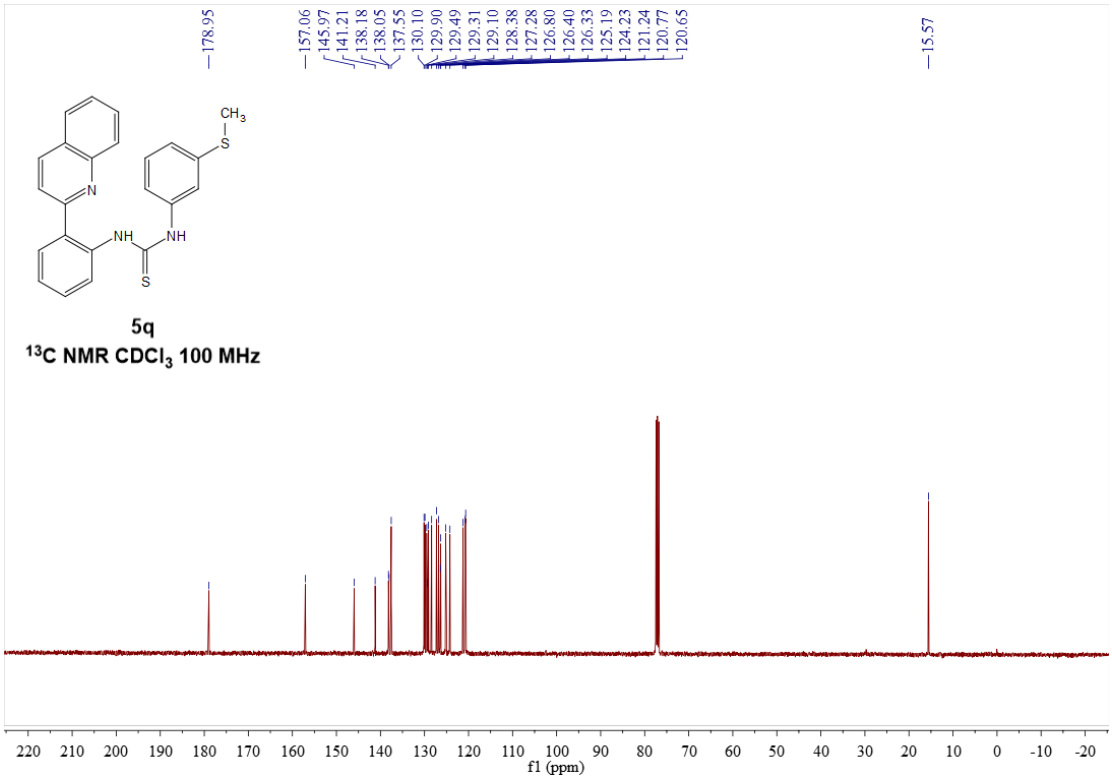


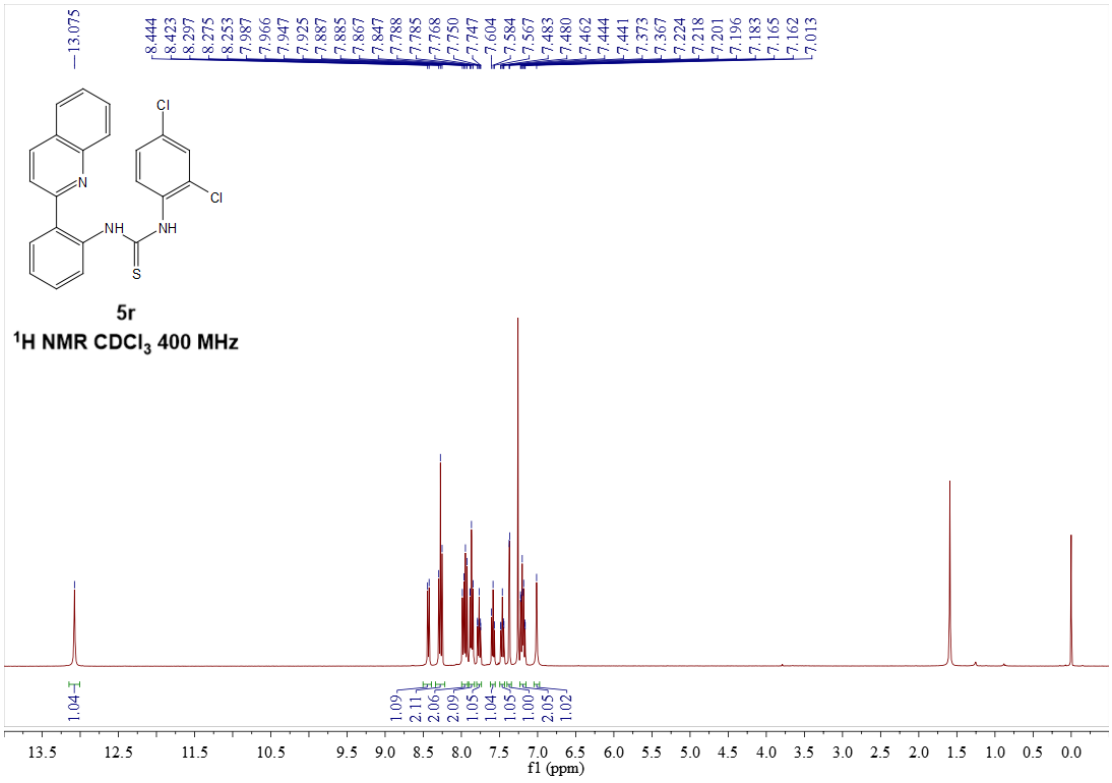
5p

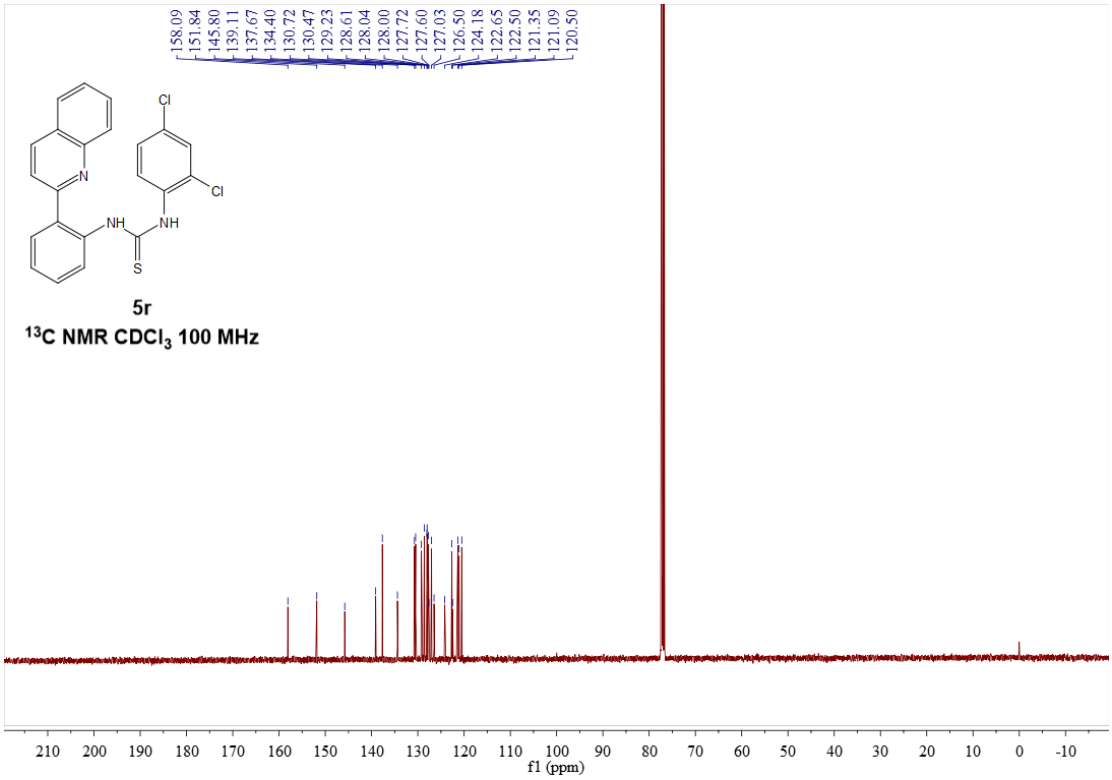
^{1}H NMR DMSO 400 MHz

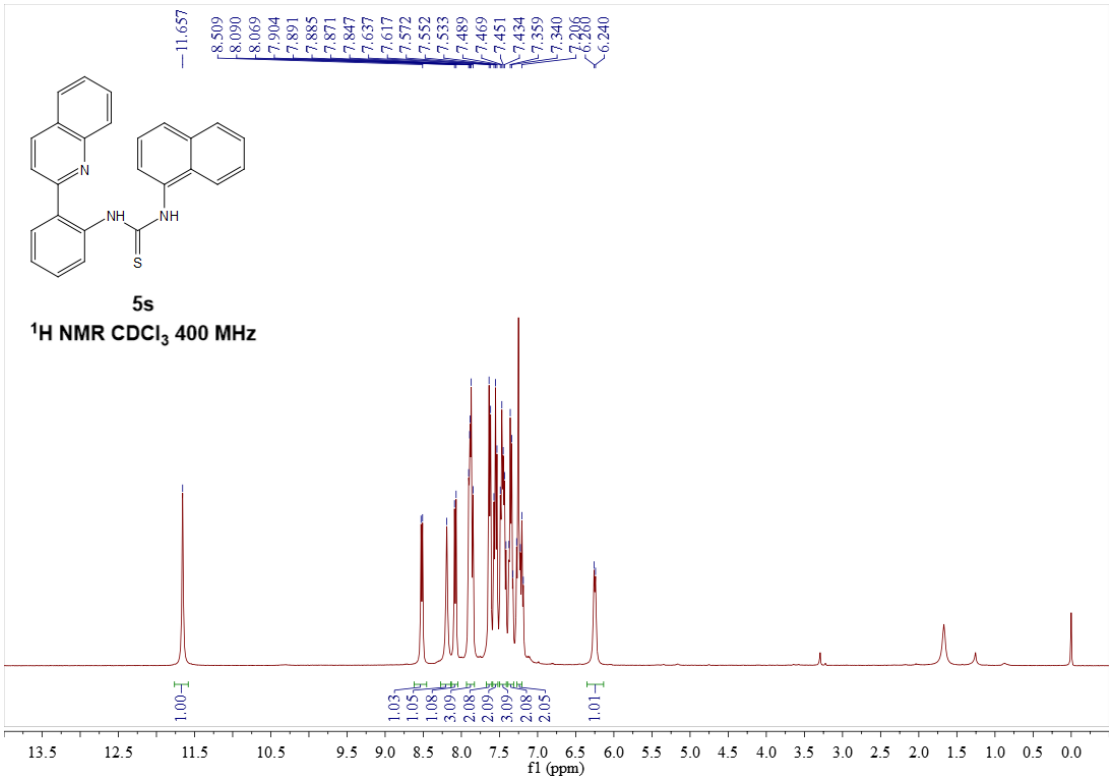

179.50
165.76
157.37
146.35
143.90
138.25
138.16
130.65
130.61
130.38
129.52
128.39
128.23
127.39
127.10
126.83
125.84
125.64
122.72
121.67
61.06
14.70
O
O
CH3
N
NH
NH
S
5p
13C NMR DMSO 100 MHz
f1 (ppm)

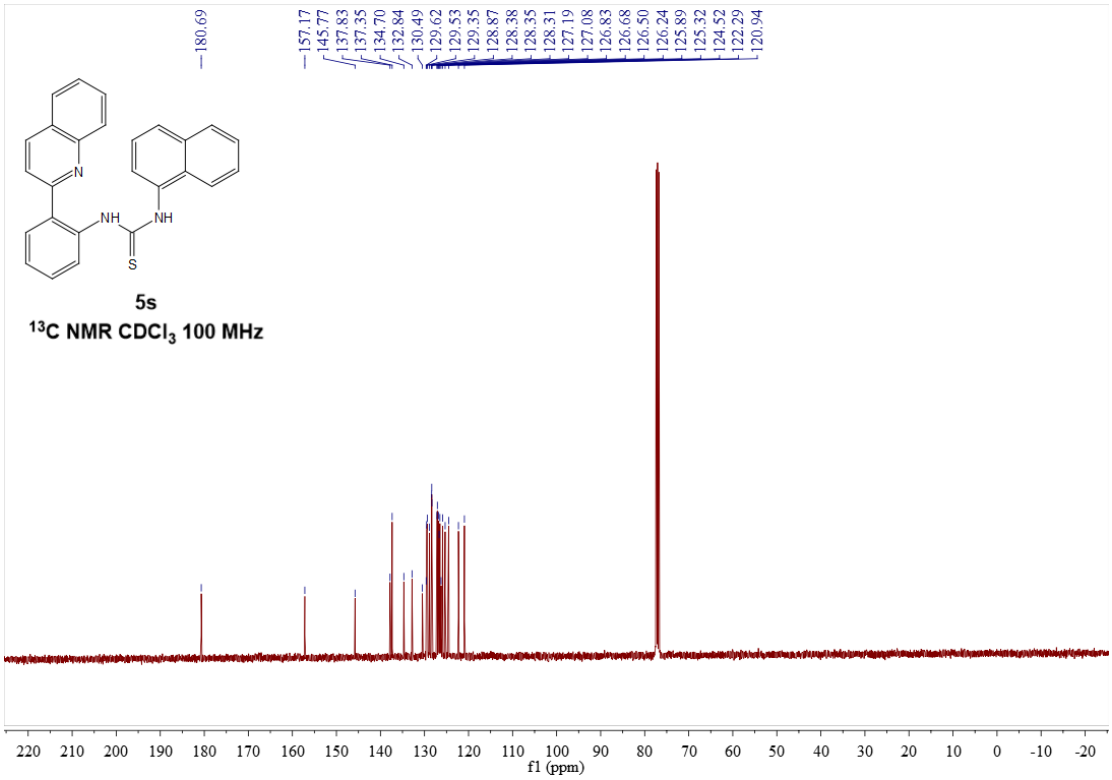

12.579
8.446
8.426
8.176
8.154
7.738
7.731
7.716
7.712
7.708
7.691
7.688
7.489
7.486
7.467
7.448
7.444
7.328
7.308
7.278
7.228
7.226
7.184
7.182
7.179
7.162
7.136
7.132
7.127
2.388
CH3
S
N
NH
NH
S
5q
1H NMR CDCl3 400 MHz
1.00
2.08
1.05
3.01
3.02
2.07
2.05
1.02
1.01
3.00
f1 (ppm)

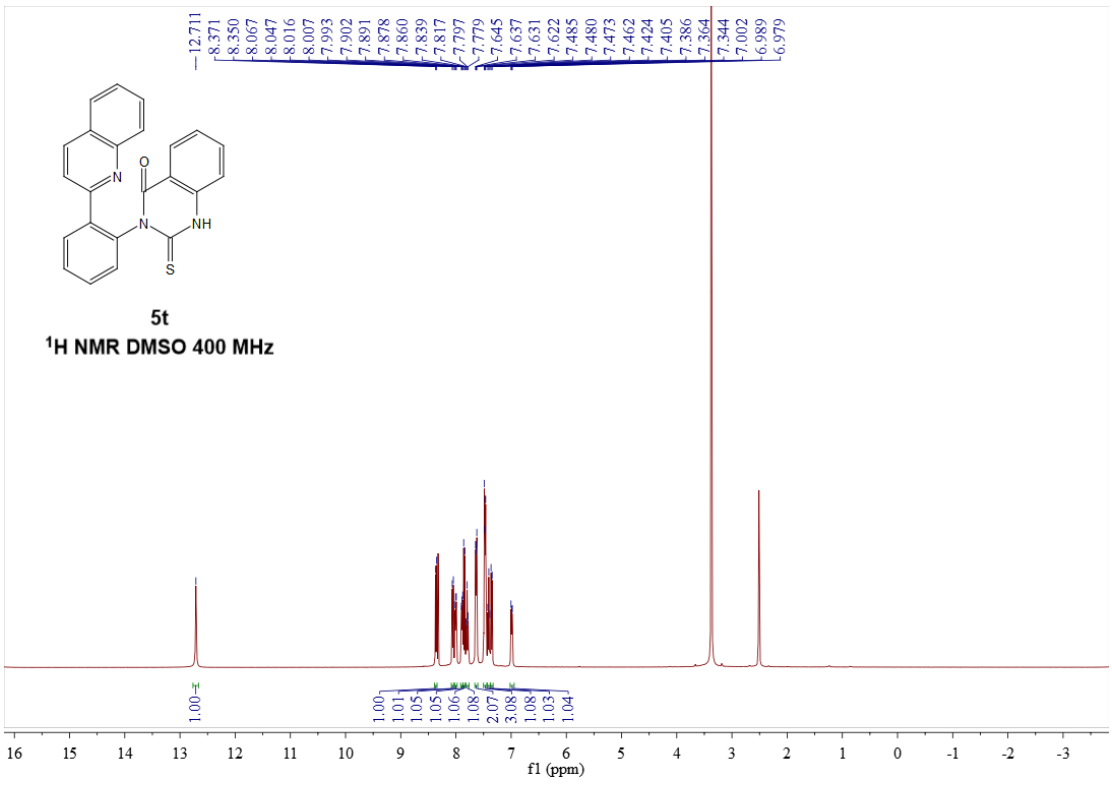

178.95
157.06
145.97
141.21
138.18
138.05
137.55
130.10
129.90
129.49
129.31
129.10
128.38
127.28
126.80
126.40
126.33
125.19
124.23
121.24
120.77
120.65
15.57
CH3
S
N
NH
NH
S
5q
13C NMR CDCl3 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


13.075
8.444
8.423
8.297
8.275
8.253
7.987
7.966
7.947
7.925
7.887
7.885
7.867
7.847
7.788
7.785
7.768
7.750
7.747
7.604
7.584
7.567
7.483
7.480
7.462
7.444
7.441
7.373
7.367
7.224
7.218
7.201
7.196
7.183
7.165
7.162
7.013
Cl
Cl
N
NH
NH
S
5r
1H NMR CDCl3 400 MHz
1.04
1.09
2.11
2.06
2.09
1.05
1.04
1.05
1.00
2.05
1.02
13.5 12.5 11.5 10.5 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)


158.09
151.84
145.80
139.11
137.67
134.40
130.72
130.47
129.23
128.61
128.04
128.00
127.72
127.60
127.03
126.50
124.18
122.65
122.50
121.35
121.09
120.50
Cl
Cl
N
NH
NH
S
5r
13C NMR CDCl3 100 MHz
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


11.657
8.509
8.090
8.069
7.904
7.891
7.885
7.871
7.847
7.637
7.617
7.572
7.552
7.533
7.489
7.469
7.451
7.434
7.359
7.340
7.206
6.268
6.240
N
NH
NH
S
5s
1H NMR CDCl3 400 MHz
1.00
1.03
1.05
1.08
3.09
2.08
2.09
3.09
2.08
2.05
1.01
13.5 12.5 11.5 10.5 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)


180.69
157.17
145.77
137.83
137.35
134.70
132.84
130.49
129.62
129.53
129.35
128.87
128.38
128.35
128.31
127.19
127.08
126.83
126.68
126.50
126.24
125.89
125.32
124.52
122.29
120.94
N
NH
NH
S
5s
13C NMR CDCl3 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


12.711
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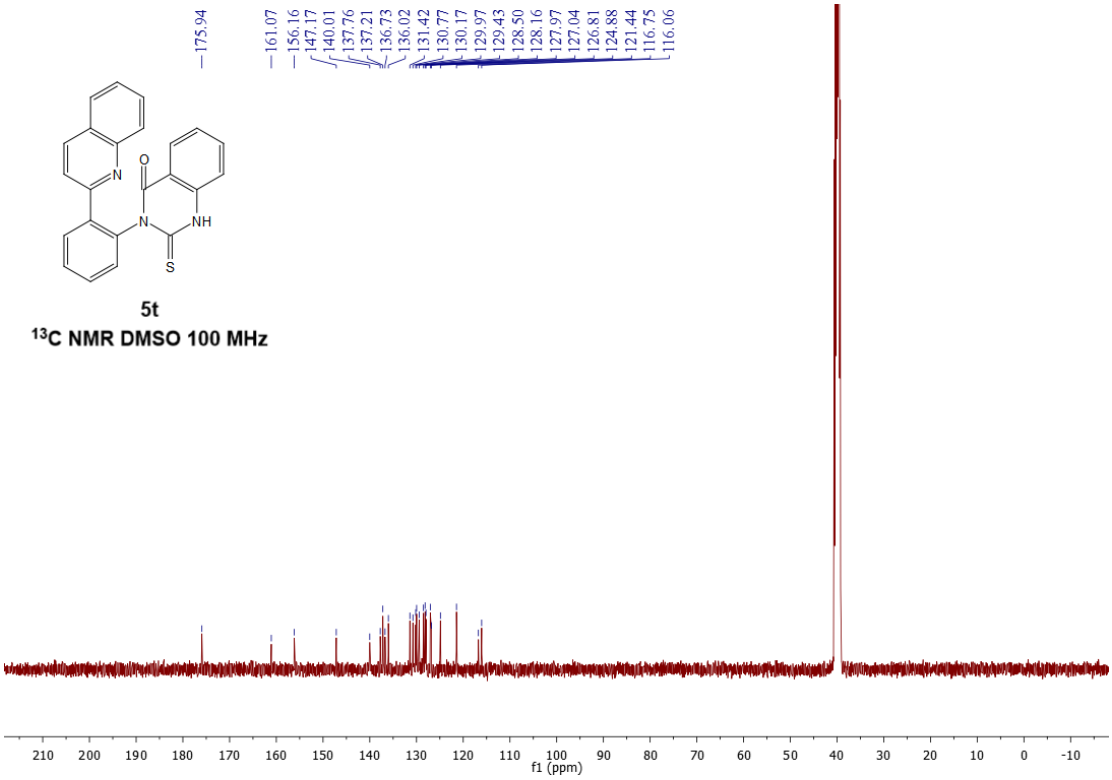
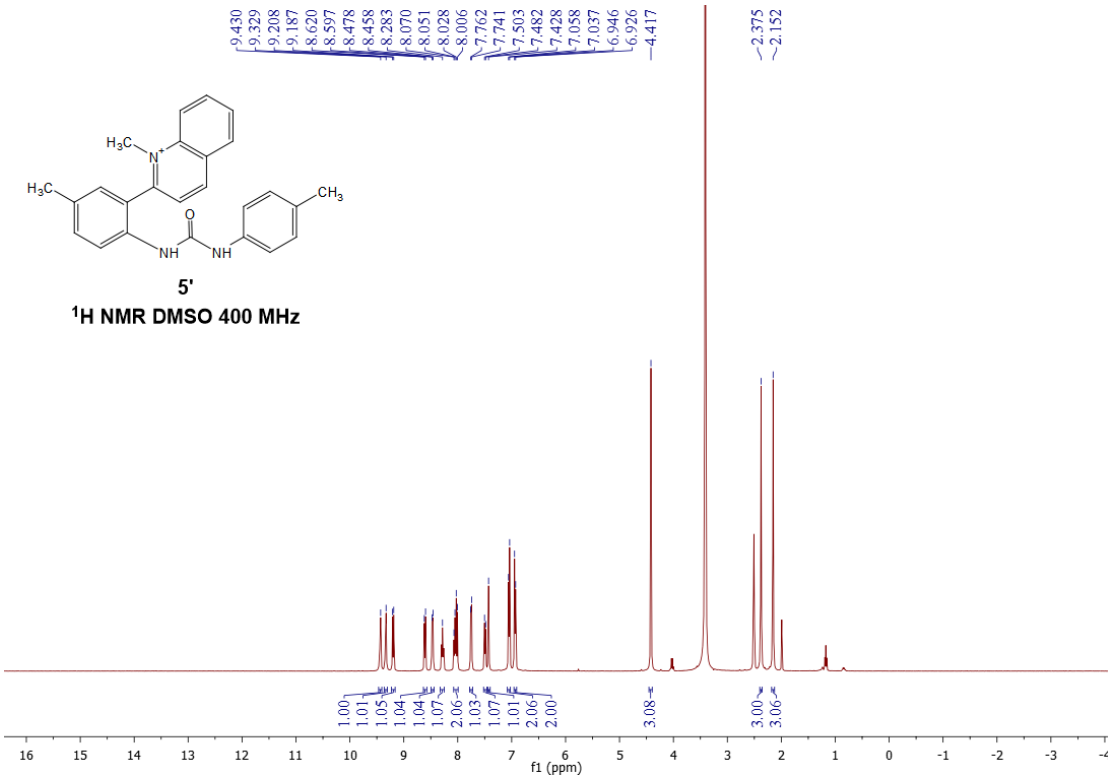
8.350
8.067
8.047
8.016
8.007
7.993
7.902
7.891
7.878
7.860
7.839
7.817
7.797
7.779
7.645
7.637
7.631
7.622
7.485
7.480
7.473
7.462
7.424
7.405
7.386
7.364
7.344
7.002
6.989
6.979
O
N
N
NH
S
5t
1H NMR DMSO 400 MHz
1.00
1.00
1.01
1.05
1.05
1.06
1.08
2.07
3.08
1.08
1.03
1.04
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)



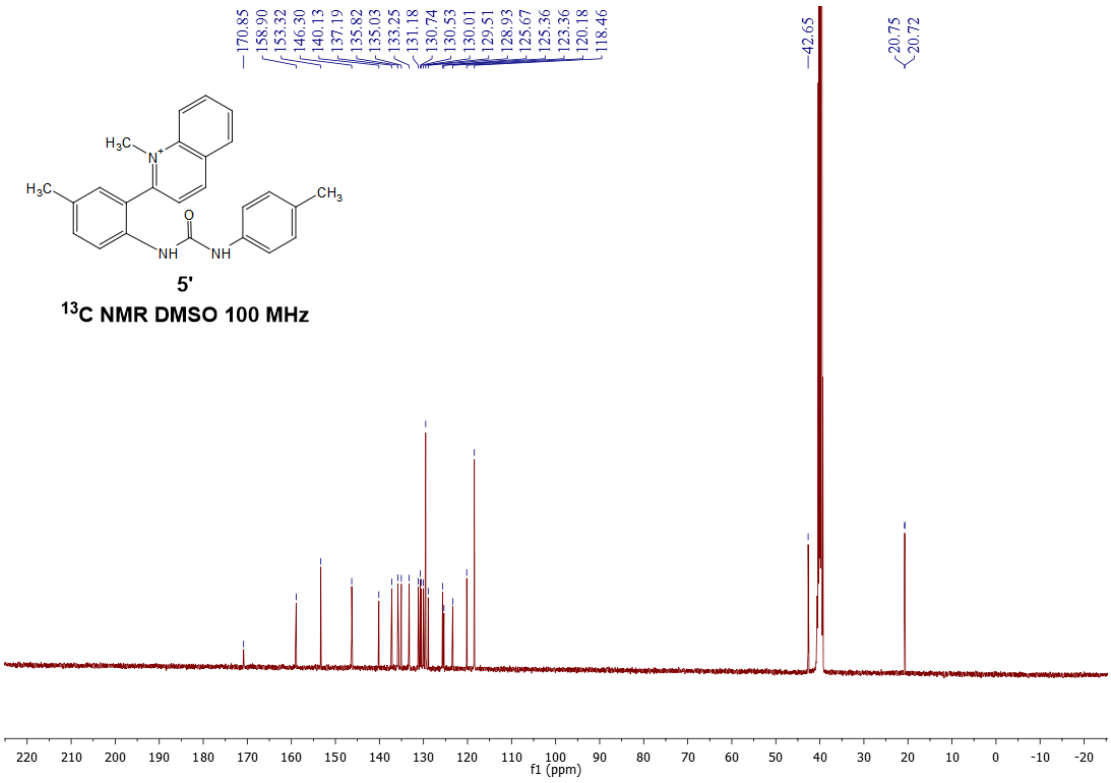
5t

^{13}C NMR DMSO 100 MHz



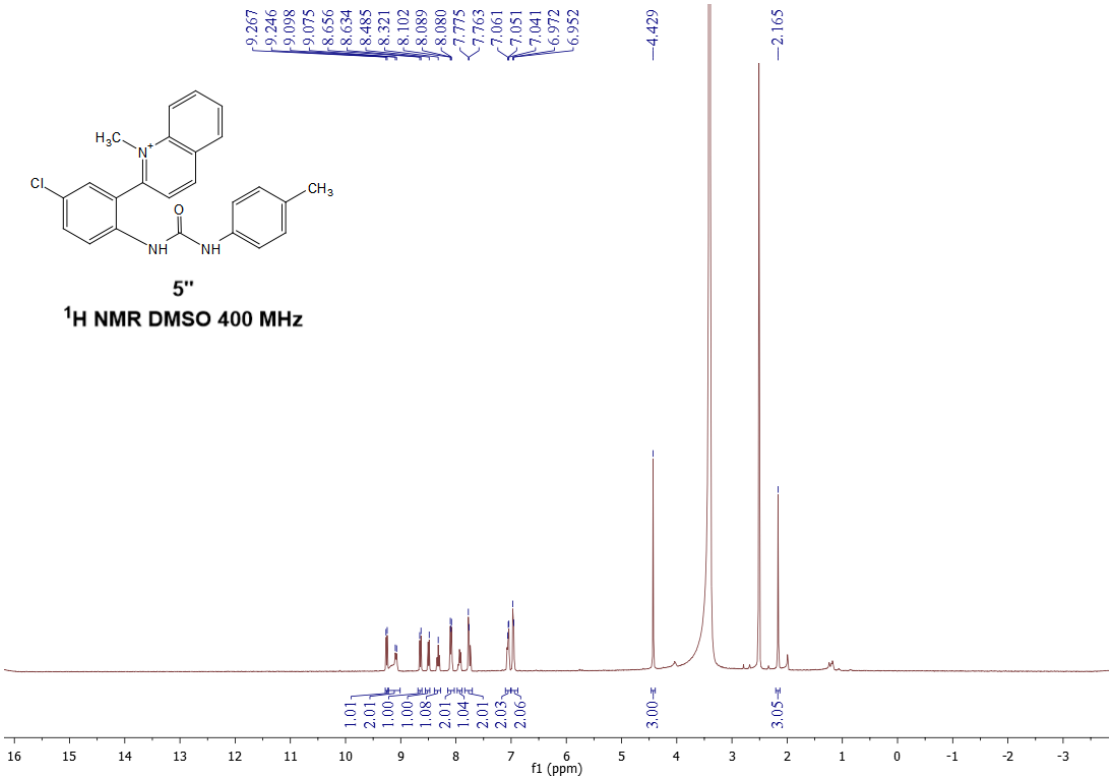
5'

^{1}H NMR DMSO 400 MHz



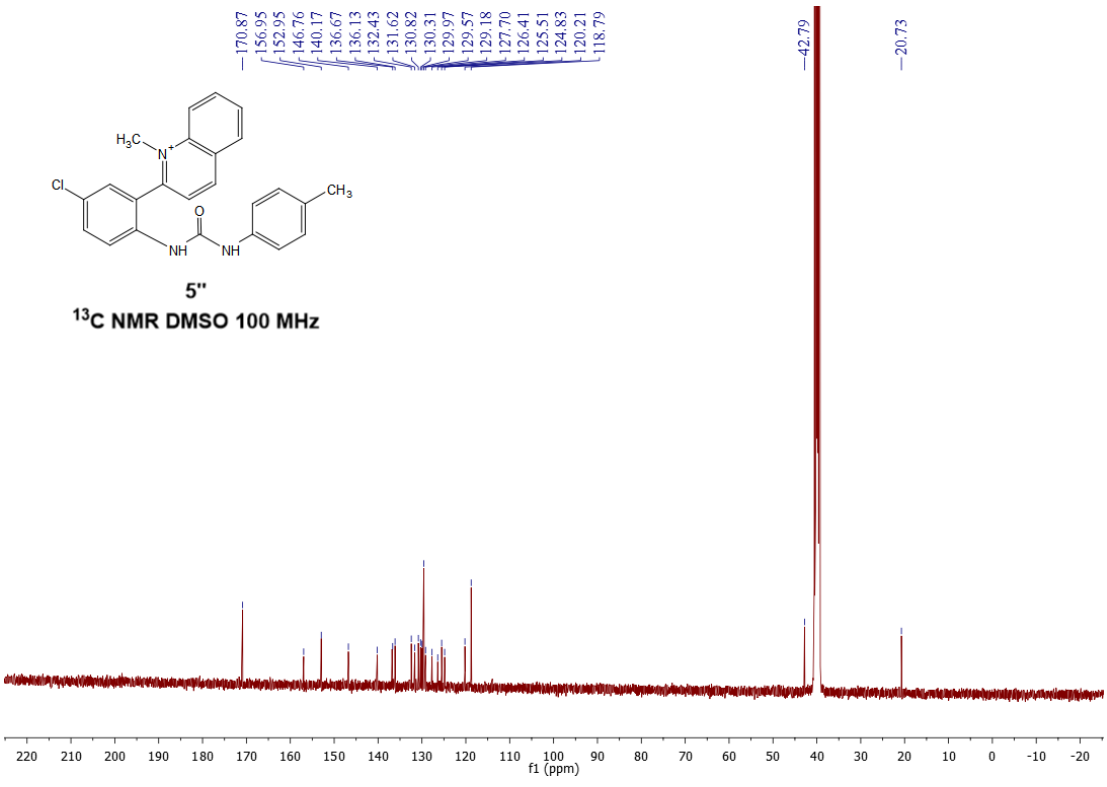
5'

^{13}C NMR DMSO 100 MHz



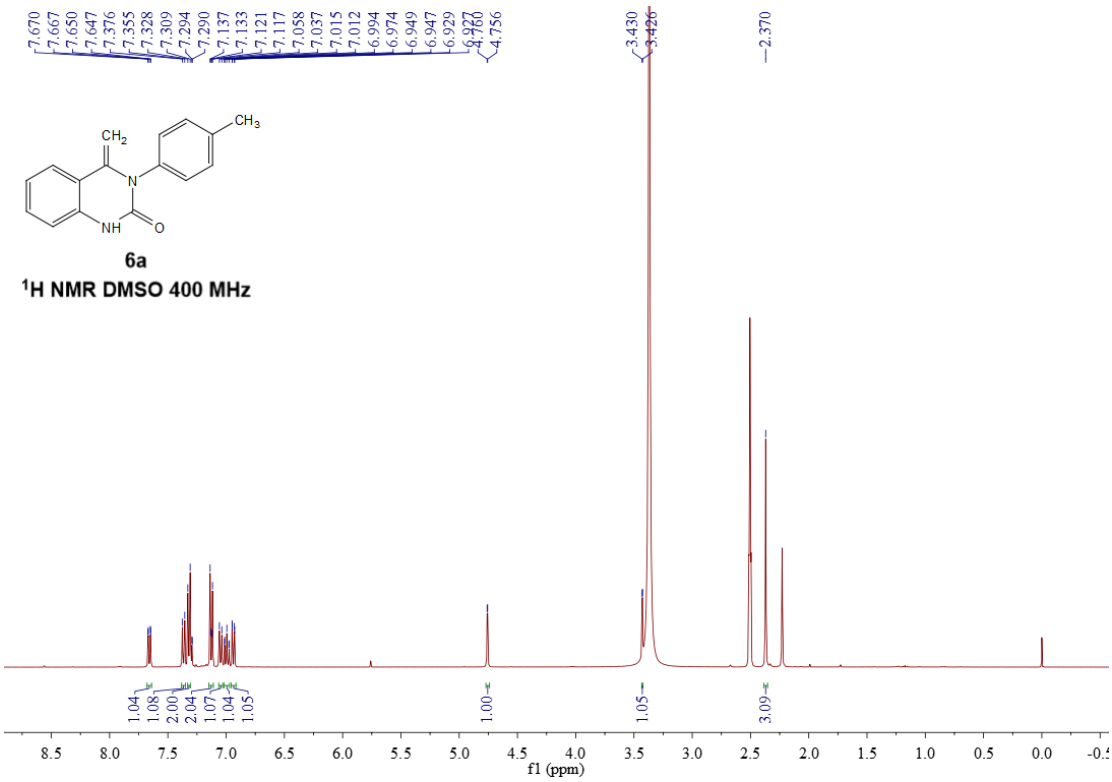
5''

^{1}H NMR DMSO 400 MHz



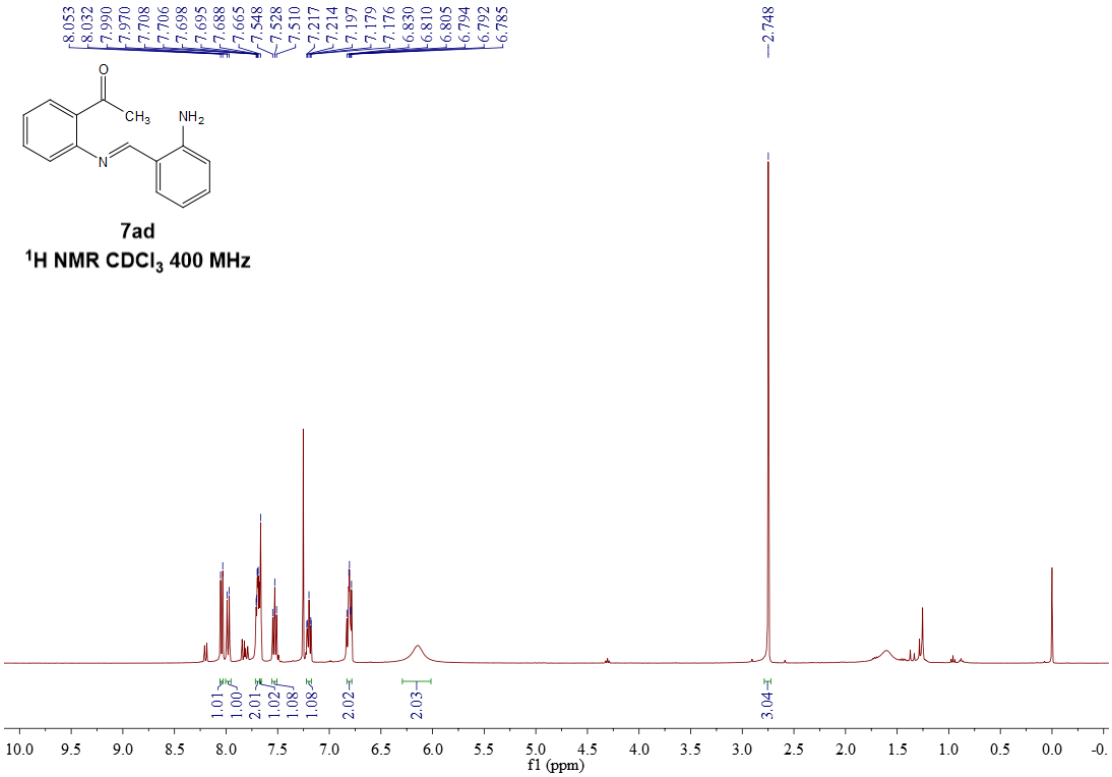
5''

^{13}C NMR DMSO 100 MHz



6a

^{1}H NMR DMSO 400 MHz



7ad

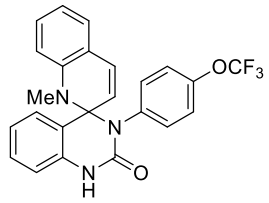
^{1}H NMR $CDCl_3$ 400 MHz

5. Crystal Data of 4c, 5n and 5v

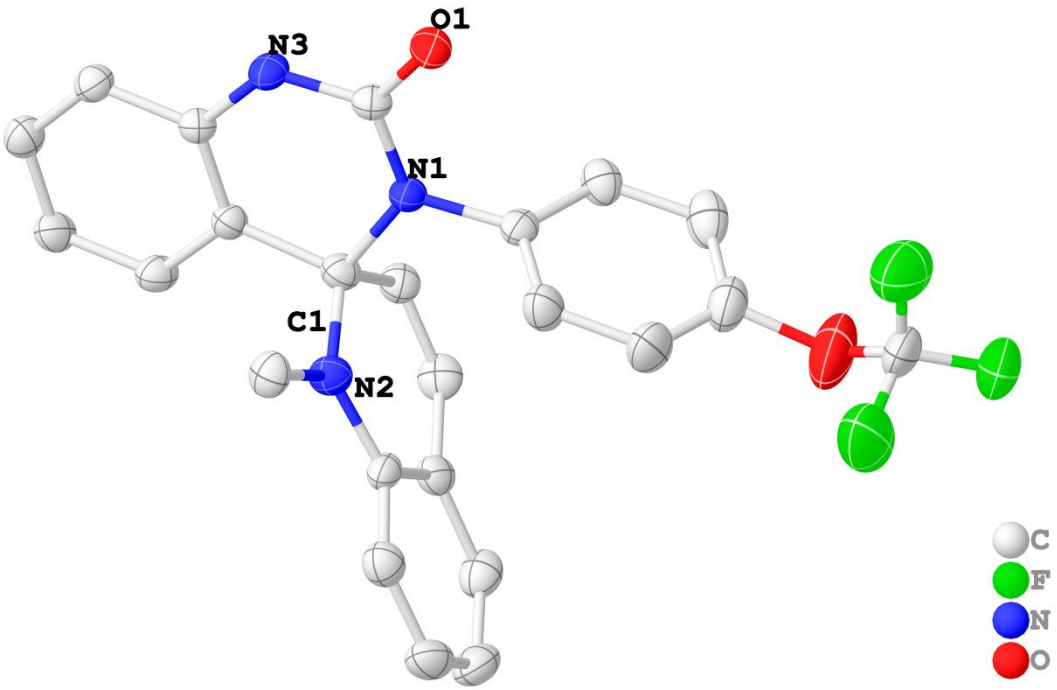
The crystals suitable for single crystal X-ray diffraction were obtained by slow evaporating the chloroform and methanol solution of **4c, 5n** and **5v** at room temperature in open air for about five days.

For X-ray structure analyses, the crystals were mounted onto the tip of glass fibers, and diffraction data were collected on a Bruker Smart Apex II CCD diffractometer with graphite-monochromated Mo Kα (λ = 0.71073 Å). An empirical (multi-scan) absorption correction was applied with the program SADABS. The structures were solved by direct method and subsequently refined on F_2 by using full-matrix least-squares techniques (SHELXT). If not noted otherwise, all non-hydrogen atoms were refined anisotropically, and hydrogen atoms were located at calculated positions. Figures of the solid-state molecular structures were generated using XP as implemented in SHELXTL program.

A summary of the crystallographic data and selected experimental information are given in Table S1-S2. Crystallographic data for the structures of compounds reported in this paper have been deposited with the Cambridge Crystallographic Data Center as supplementary publication nos. CCDC2502094 (**4c**), CCDC2502096 (**5n**) and CCDC2061255 (**5v**).



4c

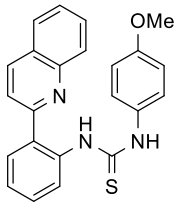


CDCC2502094

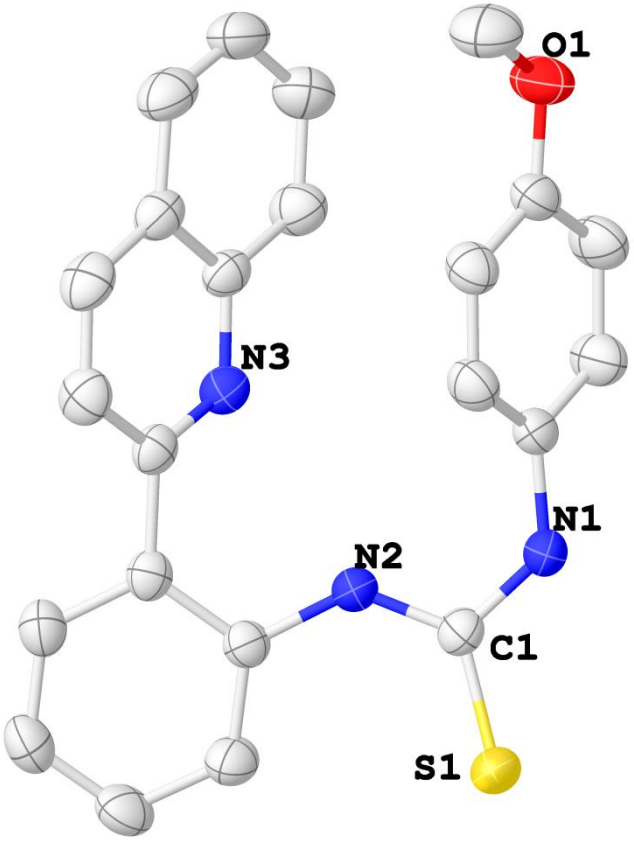
Table S1 Crystal data and structure refinement for 4c.

Identification code	4c
Empirical formula	$C_{24}H_{18}F_3N_3O_2$
Formula weight	437.41
Temperature/K	296.15
Crystal system	tetragonal
Space group	P4/n
a/Å	24.437(3)
b/Å	24.437(3)
c/Å	7.3579(8)
α/°	90
β/°	90
γ/°	90
Volume/Å^3	4394.0(10)
Z	8
ρ_{calc}g/cm^3	1.322
μ/mm^{-1}	0.103
F(000)	1808.0
Crystal size/mm^3	0.25 × 0.25 × 0.2
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	2.356 to 49.99
Index ranges	-29 ≤ h ≤ 29, -29 ≤ k ≤ 29, -8 ≤ l ≤ 8
Reflections collected	32344
Independent reflections	3874 [R_{int} = 0.1101, R_{sigma} = 0.0615]
Data/restraints/parameters	3874/316/332

Goodness-of-fit on F^2	1.109
Final R indexes [I>=2σ (I)]	R_1 = 0.0753, wR_2 = 0.2175
Final R indexes [all data]	R_1 = 0.1369, wR_2 = 0.2450
Largest diff. peak/hole / e $Å^{-3}$	0.67/-0.30



5n

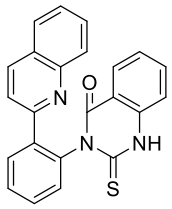


CDCC2502096

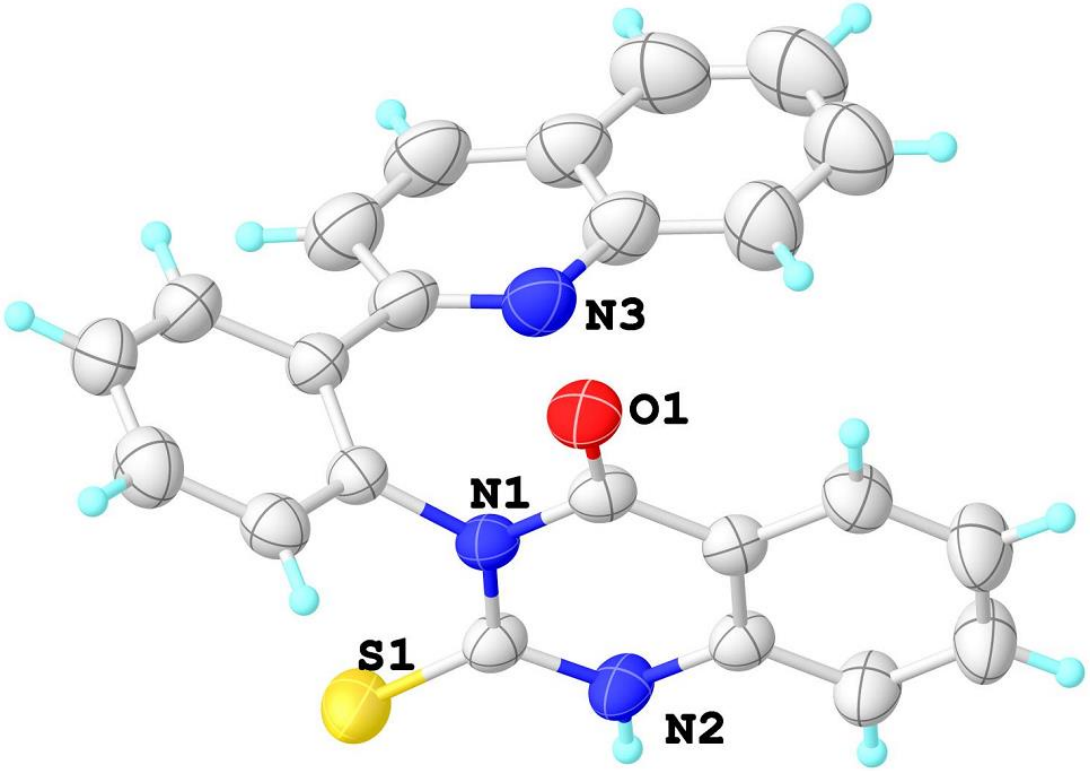
Table S2 Crystal data and structure refinement for 5n.

Identification code	5n
Empirical formula	$C_{23}H_{19}N_3OS$
Formula weight	385.47
Temperature/K	296.15

Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	8.754(5)
b/Å	18.911(10)
c/Å	11.952(5)
α/°	90
β/°	104.763(13)
γ/°	90
Volume/$Å^3$	1913.3(16)
Z	4
$\rho_{calc}g/cm^3$	1.338
μ/mm^{-1}	0.188
F(000)	808.0
Crystal size/mm^3	0.15 × 0.15 × 0.12
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	4.13 to 61.004
Index ranges	$-11 \leq h \leq 12$, $-26 \leq k \leq 26$, $-16 \leq l \leq 15$
Reflections collected	18505
Independent reflections	5181 [R_{int} = 0.0684, R_{sigma} = 0.0681]
Data/restraints/parameters	5181/0/262
Goodness-of-fit on F^2	1.025
Final R indexes [I>=2σ (I)]	R_1 = 0.0501, wR_2 = 0.1163
Final R indexes [all data]	R_1 = 0.0989, wR_2 = 0.1386
Largest diff. peak/hole / e $Å^{-3}$	0.17/-0.27



5v



CDCC2061255

Table S3 Crystal data and structure refinement for 5v.

Identification code	5v
Empirical formula	$C_{23}H_{14}N_3OS$
Formula weight	380.43
Temperature/K	296.15
Crystal system	triclinic
Space group	P-1

a/Å	13.632(18)
b/Å	13.694(18)
c/Å	22.48(3)
α/°	98.57(3)
β/°	95.81(3)
γ/°	92.80(3)
Volume/$Å^3$	4120(9)
Z	8
$\rho_{calc}g/cm^3$	1.227
μ/mm^{-1}	0.174
F(000)	1576.0
Crystal size/mm^3	0.15 × 0.15 × 0.1
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	3.28 to 61.15
Index ranges	$-18 \leq h \leq 17$, $-18 \leq k \leq 19$, $-31 \leq l \leq 27$
Reflections collected	39197
Independent reflections	21066 [R_{int} = 0.0901, R_{sigma} = 0.1918]
Data/restraints/parameters	21066/936/985
Goodness-of-fit on F^2	0.921
Final R indexes [I>=2σ (I)]	R_1 = 0.0746, wR_2 = 0.1651
Final R indexes [all data]	R_1 = 0.2273, wR_2 = 0.2275
Largest diff. peak/hole / e $Å^{-3}$	0.38/-0.32