Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

Palladium-Catalyzed Cascade Cyclization/Intramolecular Redox-Relay Heck Arylation of Alkenols: Access to Tetrahydro-*β*-carbolines from 2-(Hydroxyalkenynyl)sulfonanilides

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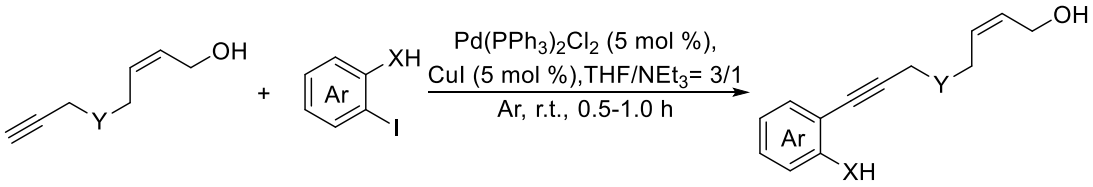
1. General Information.

NMR spectra were recorded on a Bruker AV 400 MHz or Bruker AM 600 MHz spectrometer and calibrated using residual undeuterated solvent as an internal reference ($CDCl_3$ (^1H): δ = 7.26 ppm; $CDCl_3$ ($^{13}C\{^1H\}$): δ = 77.16 ppm. High-resolution mass analysis was performed using a Thermo Scientific™ Q Exactive™ Hybrid Quadrupole-Orbitrap Mass Spectrometer. Melting points were determined on a Stanford Research Systems OptiMelt apparatus. The infrared (IR) spectra were acquired as thin films using a universal ATR sampling accessory on a Bruker Vertex 80 FT-IR spectrometer and the absorption frequencies are reported in cm^{-1}. Flash chromatography separations were carried out using silica gel columns. All new compounds were characterized by ^1H NMR, $^{13}C\{^1H\}$ NMR, HRMS, and IR. The structure of known compounds was confirmed by comparing their ^1H NMR data with those of literature. All reagents and solvents were used as received from commercial sources without further purification.

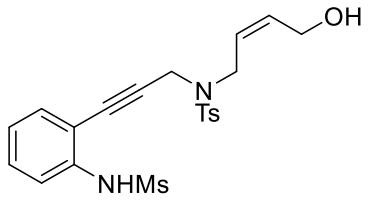
2. General Procedure A for the preparation of starting materials.



X= -O, -NAc, -NMe, -NMs, -NTs, $-C(CO_2Et)_2$.
Y= -NTs-, -O-, $-CH_2O-$, $-C(CO_2Et)_2-$.

To a solution of *N*-mesyl-2-iodoaniline (1.0 mmol, 1.0 equiv.) and $PdCl_2(PPh_3)_2$ (0.05 mmol, 0.05 equiv.) in Et_3N/THF (1:3 v/v, 4.0 mL) were added alkenynylol (1.0 mmol, 1.0 equiv.) and CuI (0.05 mmol, 0.05 equiv.). The reaction mixture was stirred at room temperature under argon for 0.5-1.0 h (unless other noted). The progress of the reaction was monitored by TLC analysis to establish its completion. The completed reaction was diluted with ethyl acetate (50 mL), washed with water (10 mL) and brine (10 mL), dried ($MgSO_4$) and concentrated. The residue was purified by column chromatography (Silica Gel, petroleum ether/ethyl acetate).

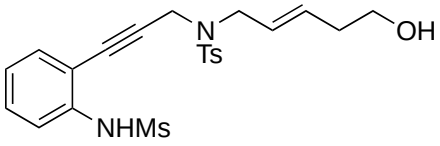
(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(3-(2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)benzenesulfonamide (1a)



1a

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide[1] (0.594 g, 2.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfon amide[2] (0.559 g, 2.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1a** was obtained as an amorphous yellow solid (0.681 g, 76%): R_f = 0.42 (PE/EtOAc = 1:1); m.p. 107-109 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz) : 7.76 (d, *J* = 7.0 Hz, 2H), 7.51 (d, *J* = 8.3 Hz, 1H), 7.35 – 7.19 (m, 4H), 7.12 (d, *J* = 7.7 Hz, 1H), 7.05 (t, *J* = 7.5 Hz, 1H), 5.94 – 5.85 (m, 1H), 5.59 – 5.50 (m, 1H), 4.33 (s, 2H), 4.22 (d, *J* = 6.2 Hz, 2H), 4.00 (d, *J* = 7.4 Hz, 2H), 2.95 (s, 3H), 2.34 (s, 3H), 2.04 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 144.2, 138.5, 136.1, 134.1, 133.1, 130.5, 130.0, 128.0, 126.5, 124.5, 119.7, 113.4, 90.1, 80.5, 58.1, 43.7, 40.1, 36.9, 21.7; IR (neat): 3414, 1590, 1492, 1102, 969 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{25}N_2O_5S_2^+$ 449.1199; found 449.1202.

(*E*)-*N*-(5-hydroxypent-2-en-1-yl)-4-methyl-*N*-(3-(2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)benzenesulfonamide (1b)



1b

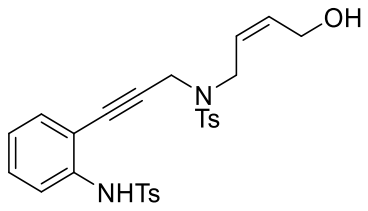
To a solution of (*E*)-5-((*tert*-butyldiphenylsilyl)oxy)pent-2-en-1-ol[3] (1.36 g, 4.0 mmol, 1.0 equiv.), 4-methyl-*N*-(prop-2-yn-1-yl)benz-enesulfonamide (0.84 g, 4.0 mmol, 1.0 equiv.) and PPh_3(1.36 g, 5.2 mmol, 1.3 equiv.) in CH_2Cl_2 (0.2 M), DEAD (0.90 g, 5.2 mmol, 1.3 equiv.) was added dropwise at 0 ºC under argon. The reaction mixture was further stirred at 0 ℃ for 2h. The completed reaction was concentrated and the residue was purified by column chromatography (Silica Gel, PE/EtOAc = 20:1) to afford (*E*)-*N*-(5-((*tert*-butyldiphenylsilyl)oxy)pent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide

(2.22 g, 99%) as a yellow oil.

To a solution of (*E*)-*N*-(5-((*tert*-butyldiphenylsilyl)oxy)pent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (2.22 g, 4.0 mmol, 1.0 equiv.) in THF (0.25 M) at RT was added tetrabutylammonium fluoride (1.0 M in THF, 4.8 mL, 4.8 mmol, 1.2 equiv.,). The resulting mixture was further stirred for 2.0 h. The progress of the reaction was monitored by TLC analysis to establish its completion. The completed reaction was concentrated and the residue was purified by column chromatography (Silica Gel, PE/EtOAc = 2:1) to afford (*E*)-*N*-(5-hydroxypent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (1.02 g, 88%).

Following general procedure **A** using *N*-(2-iodophenyl)methanesulfonamide (0.297 g, 1.0 mmol) and (*E*)-*N*-(5-hydroxypent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfon amide (0.293 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1b** was obtained as a yellow oil (0.208 g, 45%): R_f = 0.34 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.74 (d, *J* = 8.0 Hz, 2H), 7.52 (d, *J* = 8.2 Hz, 1H), 7.37 (t, *J* = 7.7 Hz, 1H), 7.27 (d, *J* = 8.0 Hz, 2H), 7.11 (d, *J* = 7.6 Hz, 1H), 7.04 (t, *J* = 7.5 Hz, 1H), 6.86 (s, 1H), 5.81 – 5.70 (m, 1H), 5.55 – 5.45 (m, 1H), 4.29 (s, 2H), 3.84 (d, *J* = 6.6 Hz, 2H), 3.65 (t, *J* = 6.1 Hz, 2H), 2.96 (s, 3H), 2.34 (s, 3H), 2.30 (q, *J* = 6.4 Hz, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 144.2, 138.4, 136.1, 133.7, 132.8, 130.4, 130.0, 128.0, 126.4, 124.6, 119.6, 113.4, 90.4, 80.5, 62.0, 49.4, 40.1, 36.8, 35.6, 21.7; IR (neat): 1631, 1492, 1334, 1156, 972 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{27}N_2O_5S_2^+$ 463.1356; found 463.1353.

(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(3-(2-((4-methylphenyl)sulfonamido)phenyl) prop-2-yn-1-yl)benzenesulfonamide (1c)

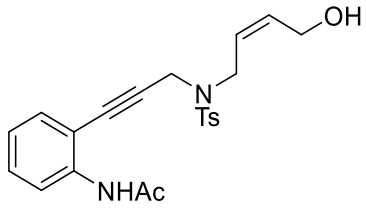


1c

Following general procedure **A** by using *N*-(2-iodophenyl)-4-methylbenzenesulfonamide[1] (0.373 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1c** was obtained as an amorphous yellow solid (0.316 g, 60 %): R_f =0.58 (PE/EtOAc = 1:1); m.p. 143-

144 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.72 (d, *J* = 7.9 Hz, 2H), 7.64 (d, *J* = 7.8 Hz, 2H), 7.45 (d, *J* = 8.2 Hz, 1H), 7.33 (s, 1H), 7.26 – 7.17 (m, 5H), 6.97 – 6.91 (m, 2H), 5.96 – 5.87 (m, 1H), 5.58 – 5.49 (m, 1H), 4.26 (s, 2H), 4.24 (d, *J* = 6.4 Hz, 2H), 3.98 (d, *J* = 7.4 Hz, 2H), 2.36 (s, 3H), 2.32 (s, 3H), 2.10 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) : 144.3, 144.1, 138.3, 136.6, 136.2, 134.2, 132.7, 130.1, 130.0, 129.9, 127.9, 127.5, 126.4, 124.3, 120.1, 113.5, 89.5, 80.5, 58.1, 43.7, 36.9, 21.7, 21.6; IR (neat): 3131, 1601, 1491, 1338, 1159, 1095 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{27}H_{29}N_2O_5S_2^+$ 525.1512; found 525.1516.

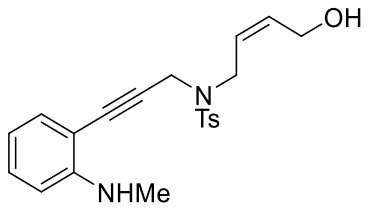
(*Z*)-*N*-(2-(3-((*N*-(4-hydroxybut-2-en-1-yl)-4-methylphenyl)sulfonamido)prop-1-yn-1-yl)phenyl)acetamide (1d)



1d

Following general procedure **A** by using *N*-(2-iodophenyl)acetamide (0.261 g, 1.0 mmol)[4] and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1d** was obtained as an amorphous yellow solid (0.344 g, 83%): R_f = 0.20 (PE/EtOAc = 1:1); m.p. 110-111 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 8.35 – 8.22 (m, 1H), 7.96 (s, 1H), 7.75 (d, *J* = 7.9 Hz, 2H), 7.34 – 7.24 (m, 3H), 7.12 (d, *J* = 7.6 Hz, 1H), 7.02 – 6.93 (m, 1H), 5.92 – 5.83 (m, 1H), 5.56 – 5.46 (m, 1H), 4.25 (s, 2H), 4.20 (d, *J* = 6.1 Hz, 2H), 3.97 (d, *J* = 7.2 Hz, 2H), 2.36 (s, 3H), 2.19 (s, 3H), 2.02 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 169.2, 144.4, 139.8, 135.7, 134.6, 132.0, 130.03, 129.95, 127.9, 125.7, 123.5, 120.4, 111.5, 89.8, 81.3, 58.2, 43.9, 37.2, 24.8, 21.6; IR (neat): 1674, 1585, 1523, 1334, 1157, 897 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{25}N_2O_4S^+$ 413.1530; found 413.1528.

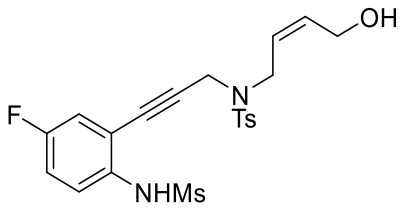
(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(3-(2-(methylamino)phenyl)prop-2-yn-1-yl)-benzenesulfonamide (1e)



1e

Following general procedure **A** by using 2-iodo-*N*-methylaniline[5] (0.233 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1e** was obtained as an amorphous yellow solid (0.273 g, 71%): R_f = 0.56 (PE/EtOAc = 1:1); m.p. 74-75 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.75 (d, *J* = 7.8 Hz, 2H), 7.26 (d, *J* = 8.0 Hz, 2H), 7.17 (t, *J* = 7.8 Hz, 1H), 6.89 (d, *J* = 7.5 Hz, 1H), 6.57 – 6.49 (m, 2H), 5.90 – 5.81 (m, 1H), 5.57 – 5.48 (m, 1H), 4.39 – 4.28 (m, 3H), 4.19 (d, *J* = 6.4 Hz, 2H), 3.95 (d, *J* = 7.3 Hz, 2H), 2.80 (s, 3H), 2.35 (s, 3H), 1.76 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 150.3, 144.0, 136.1, 134.5, 132.4, 130.5, 129.9, 128.0, 125.9, 116.4, 109.4, 106.5, 87.7, 83.0, 58.3, 43.5, 37.4, 30.4, 21.7; IR (neat): 2867, 2817, 1603, 1513, 1337, 1159 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{25}N_2O_3S^+$ 385.1580; found 385.1581.

(*Z*)-*N*-(3-(5-fluoro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydr-oxybut-2-en-1-yl)-4-methylbenzenesulfonamide (1f)

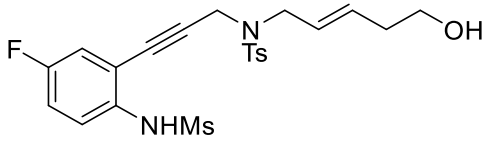


1f

Following general procedure **A** by using *N*-(4-fluoro-2-iodophenyl)methanesulfonamide[1] (0.204 g, 0.65 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.181 g, 0.65 mmol), after flash chromatography (PE/EtOAc = 2:1), **1f** was obtained as an amorphous yellow solid (0.215 g, 71 %). R_f = 0.45 (PE/EtOAc = 1:1); m.p. 128-130 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.75 (d, *J* = 7.6 Hz, 2H), 7.47 (dd, *J* = 8.8, 5.1 Hz, 1H), 7.33 – 7.26 (m, 3H), 7.02 (t, *J* = 8.4 Hz, 1H), 6.73 (dd, *J* = 8.5, 2.7 Hz, 1H), 5.94 –

5.85 (m, 1H), 5.58 – 5.49 (m, 1H), 4.32 (s, 2H), 4.20 (d, *J* = 6.4 Hz, 2H), 4.00 (d, *J* = 7.4 Hz, 2H), 2.91 (s, 3H), 2.39 (s, 3H), 2.13 (s, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 159.5 (d, *J* = 246.4 Hz), 144.4, 136.2, 134.7 (d, *J* = 2.0 Hz), 134.1, 130.1, 128.0, 126.5, 123.4 (d, *J* = 9.1 Hz), 119.4 (d, *J* = 24.2 Hz), 117.6 (d, *J* = 22.2 Hz), 116.1 (d, *J* = 10.1 Hz), 90.7, 79.8, 58.0, 43.7, 40.1, 36.8, 21.6; ^{19}F NMR ($CDCl_3$, 376 MHz): -116.9; IR (neat): 3478, 1624, 1494, 1335, 1158 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{24}FN_2O_5S_2^+$ 467.1105; found 467.1106.

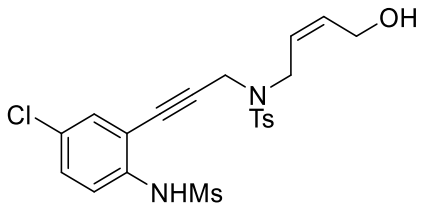
(*E*)-*N*-(3-(5-fluoro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(5-hydroxypent-2-en-1-yl)-4-methylbenzenesulfonamide (1g)



1g

Following general procedure **A** by using *N*-(4-fluoro-2-iodophenyl)methanesulfonamide (0.315 g, 1.0 mmol) and (*E*)-*N*-(5-hydroxypent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.293 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1g** was obtained as an amorphous yellow solid (0.309 g, 64 %): R_f = 0.16 (PE/EtOAc = 1:1); m.p. 89-90 ℃; ^{1}H NMR ($CDCl_3$, 600 MHz): 7.75 (d, *J* = 8.2 Hz, 2H), 7.49 (dd, *J* = 9.1, 5.0 Hz, 1H), 7.31 (d, *J* = 8.1 Hz, 2H), 7.03 (td, *J* = 8.8, 2.9 Hz, 1H), 6.94 (s, 1H), 6.70 (dd, *J* = 8.4, 2.9 Hz, 1H), 5.75 (dt, *J* = 14.3, 6.9 Hz, 1H), 5.49 (dt, *J* = 14.9, 6.7 Hz, 1H), 4.30 (s, 2H), 3.83 (d, *J* = 6.7 Hz, 2H), 3.67 (t, *J* = 6.1 Hz, 2H), 2.95 (s, 3H), 2.40 (s, 3H), 2.31 (q, *J* = 6.2 Hz, 2H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz): 159.3 (d, *J* = 246.1 Hz), 144.3, 135.7, 134.3 (d, *J* = 3.0 Hz), 133.9, 129.9, 127.9, 126.0, 123.2 (d, *J* = 9.1 Hz), 119.1 (d, *J* = 24.2 Hz), 117.5 (d, *J* = 22.7 Hz), 115.9 (d, *J* = 10.6 Hz), 90.9, 79.6, 61.8, 49.4, 39.9, 36.5, 35.4, 21.5; ^{19}F NMR ($CDCl_3$, 376 MHz): -116.8. IR (neat): 3414, 2922, 1625, 1492, 1332, 1156 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{26}FN_2O_5S_2^+$ 481.1262; found 481.1261.

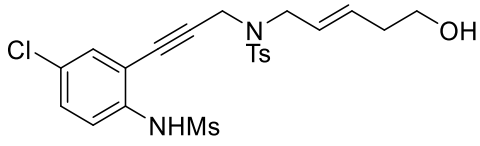
(*Z*)-*N*-(3-(5-chloro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydro-xybut-2-en-1-yl)-4-methylbenzenesulfonamide (1h)



1h

Following general procedure **A** by using *N*-(4-chloro-2-iodophenyl)methanesulfonamide[1] (0.332 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1h** was obtained as an amorphous yellow solid (0.234 g, 48 %): R_f = 0.45 (PE/EtOAc = 1:1); m.p. 125-126 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.75 (d, *J* = 7.3 Hz, 2H), 7.45 (d, *J* = 8.8 Hz, 1H), 7.40 (s, 1H), 7.31 (d, *J* = 7.7 Hz, 2H), 7.25 (d, *J* = 9.9 Hz, 1H), 7.00 – 6.98 (m, 1H), 5.94 – 5.85 (m, 1H), 5.58 – 5.49 (m, 1H), 4.32 (s, 2H), 4.21 – 4.15 (m, 2H), 3.99 (d, *J* = 7.4 Hz, 2H), 2.94 (s, 3H), 2.40 (s, 3H), 2.15 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 144.4, 137.2, 136.1, 134.1, 132.6, 130.5, 130.1, 129.9, 128.0, 126.5, 121.5, 115.2, 91.0, 79.4, 57.9, 43.7, 40.2, 36.8, 21.7; IR (neat): 3131, 1605, 1485, 1333, 1122 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{24}ClN_2O_5S_2^+$ 483.0810; found 483.0810.

(*E*)-*N*-(3-(5-chloro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(5-hydro-xypent-2-en-1-yl)-4-methylbenzenesulfonamide (1i)

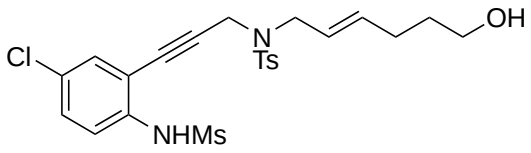


1i

Following general procedure **A** by using *N*-(4-chloro-2-iodophenyl)methanesulfonamide (0.179 g, 0.54 mmol) and (*E*)-*N*-(5-hydroxypent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.158 g, 0.54 mmol), after flash column chromatography (PE/EtOAc = 2:1), **1i** was obtained as a yellow oil (0.132 g, 49 %): R_f = 0.29 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.76 (d, *J* = 8.1 Hz, 2H), 7.48 (d, *J* = 8.8 Hz, 1H), 7.32 (d, *J* = 8.1 Hz, 2H), 7.30 – 7.25 (m, 1H), 7.01 – 6.95 (m, 2H), 5.76 (dt, *J* = 14.6, 6.9 Hz, 1H), 5.51 (dt, *J* = 14.9, 6.7 Hz, 1H), 4.30 (s, 2H), 3.84 (d, *J* = 6.7 Hz, 2H), 3.67 (t, *J* = 6.1 Hz, 2H), 2.99 (s, 3H), 2.42 (s,

3H), 2.36 – 2.27 (m, 2H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 144.3, 136.9, 135.8, 133.9, 132.2, 130.3, 129.92, 129.85, 128.0, 126.1, 121.2, 115.0, 91.3, 79.3, 61.8, 49.0, 40.2, 36.6, 35.5, 21.7; IR (neat): 3132, 1635, 1484, 1334, 1157 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{26}ClN_2O_5S_2^+$ 497.0966; found 497.0967.

(*E*)-*N*-(3-(5-chloro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(6-hydroxyhex-2-en-1-yl)-4-methylbenzenesulfonamide (1j)



1j

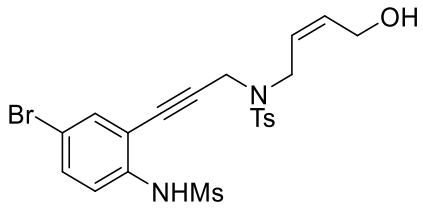
To a solution of (*E*)-6-((*tert*-butyldimethylsilyl)oxy)hex-2-en-1-ol[6] (0.460 g, 2.0 mmol), 4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.418 g, 2.0 mmol, 1.0 equiv.) and PPh_3(0.681 g, 2.6 mmol, 1.3 equiv.) in CH_2Cl_2 (0.2 M) was added DEAD (0.452 g, 2.6 mmol, 1.3 equiv.) dropwise at 0 ºC under argon. The reaction mixture was further stirred at 0 ℃ for 2 h. The progress of the reaction was monitored by TLC analysis to establish its completion. The completed reaction was concentrated and the residue was purified by column chromatography (Silica Gel, PE/EtOAc = 20:1) to afford (*E*)-*N*-(3-(*tert*-butyldimethylsilyl)prop-2-yn-1-yl)-*N*-(6-hydroxyhex-2-en-1-yl)-4-methylbenzenesulfonamide as a colorless oil (0.606 g, 72%).

Following the desilylation procedure described in **1b,** (*E*)-*N*-(6-hydroxyhex-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide was obtained as a colorless oil (0.276 g, 63%).

Following general procedure **A** by using *N*-(4-chloro-2-iodophenyl)methanesulfonamide (0.298 g, 0.9 mmol) and (*E*)-*N*-(6-hydroxyhex-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.276 g, 0.9 mmol), after flash chromatography (PE/EtOAc = 2:1), **1j** was obtained as a yellow oil (0.221 g, 48%): R_f = 0.30 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz): 7.73 (d, *J* = 8.2 Hz, 2H), 7.48 – 7.44 (m, 1H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.27 – 7.24 (m,1H), 7.06 (s, 1H), 6.96 – 6.93 (m, 1H), 5.73 (dt, *J* = 14.9, 6.7 Hz, 1H), 5.44 – 5.35 (m, 1H), 4.27 (s, 2H), 3.79 (d, *J* = 6.5 Hz, 2H), 3.63 – 3.58 (m, 2H), 2.98 (s, 3H), 2.38 (s, 3H), 2.17 – 2.09 (m, 2H), 1.90 (s, 1H), 1.65 – 1.55 (m, 2H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz): 144.2, 136.81, 136.76, 135.5, 132.1, 130.2, 129.8, 129.7, 127.9, 123.8, 121.1, 114.9, 91.1, 79.2, 62.2,

49.2, 40.1, 36.4, 31.8, 28.7, 21.6; IR (neat): 3129, 2925, 1633, 1485, 13351, 1158 cm^{-1}; HRMS(ESI) m/z : $[M+H]^+$ calculated for $C_{23}H_{28}ClN_2O_5S_2^+$ 511.1123; found 511.1123.

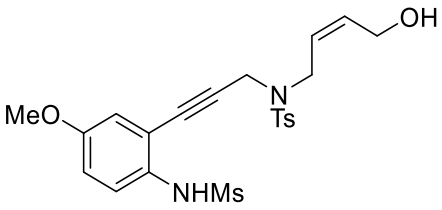
(*Z*)-*N*-(3-(5-bromo-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydroxybut-2-en-1-yl)-4-methylbenzenesulfonamide (1k)



1k

Following general procedure **A** by using *N*-(4-bromo-2-iodophenyl)methanesulfonamide[1] (0.376 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1k** was obtained as an amorphous yellow solid (0.258 g, 49 %): R_f = 0.45 (PE/EtOAc = 1:1); m.p. 113-114 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.75 (d, *J* = 8.0 Hz, 2H), 7.43 – 7.37 (m, 3H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.15 (d, *J* = 1.1 Hz, 1H), 5.94 – 5.85 (m, 1H), 5.59 –5.50 (m, 1H), 4.32 (s, 2H), 4.19 (t, *J* = 5.7 Hz, 2H), 3.99 (d, *J* = 7.5 Hz, 2H), 2.94 (s, 3H), 2.41 (s, 3H), 2.13 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) : 144.4, 137.7, 136.1, 135.5, 134.1, 133.4, 130.0, 128.0, 126.5, 121.5, 117.2, 115.4, 91.2, 79.3, 57.9, 43.7, 40.3, 36.8, 21.8; IR (neat): 3128, 1634, 1484, 1334, 1157 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{24}BrN_2O_5S_2^+$ 527.0305; found 527.0307.

(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-*N*-(3-(5-methoxy-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-4-methylbenzenesulfonamide (1l)

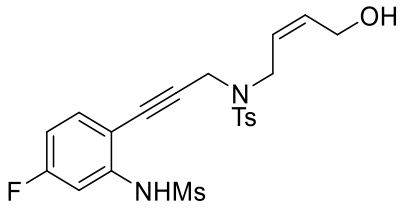


1l

Following general procedure **A** by using *N*-(2-iodo-4-methoxyphenyl)methane sulfonamide[1] (0.327 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1l** was obtained as an amorphous yellow solid (0.401 g, 84%): R_f = 0.26 (PE/EtOAc = 1:1); m.p.

86-87 °C; ^{1}H NMR ($CDCl_3$, 600 MHz): 7.77 (d, *J* = 8.3 Hz, 2H), 7.40 (d, *J* = 9.0 Hz, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.16 (s, 1H), 6.87 (dd, *J* = 9.0, 3.0 Hz, 1H), 6.63 (d, *J* = 3.0 Hz, 1H), 5.93 – 5.87 (m, 1H), 5.55 – 5.49 (m, 1H), 4.34 (s, 2H), 4.20 (d, *J* = 6.7 Hz, 2H), 4.00 (d, *J* = 7.4 Hz, 2H), 3.78 (s, 3H), 2.86 (s, 3H), 2.38 (s, 3H), 2.35 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 157.1, 144.2, 136.0, 134.1, 131.0, 129.9, 127.9, 126.2, 124.4, 118.1, 116.5, 115.9, 89.1, 80.8, 57.8, 55.8, 43.5, 39.5, 36.7, 21.6; IR (neat): 3415, 1611, 1496, 1330, 1209, 1155 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{27}N_2O_6S_2^+$ 479.1305; found 479.1305.

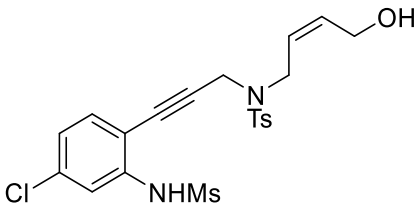
(*Z*)-*N*-(3-(4-fluoro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydroxybut-2-en-1-yl)-4-methylbenzenesulfonamide (1m)



1m

Following general procedure **A** by using *N*-(5-fluoro-2-iodophenyl)methanesulfonamide[7] (0.252 g, 0.8 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.223 g, 0.8 mmol), after flash chromatography (PE/EtOAc = 2:1), **1m** was obtained as a yellow oil (0.163 g, 44 %): R_f = 0.46 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz): 7.76 (d, *J* = 8.2 Hz, 2H), 7.54 (s, 1H), 7.32 – 7.27 (m, 3H), 7.08 (dd, *J* = 8.6, 6.1 Hz, 1H), 6.75 (td, *J* = 8.2, 2.5 Hz, 1H), 5.93 – 5.88 (m, 1H), 5.56 – 5.50 (m, 1H), 4.31 (s, 2H), 4.21 (d, *J* = 6.8 Hz, 2H), 3.99 (d, *J* = 7.5 Hz, 2H), 3.00 (s, 3H), 2.37 (s, 3H), 2.31 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 163.3 (d, *J* = 252.2 Hz), 144.1, 140.2 (d, *J* = 12.1 Hz), 135.8, 134.4 (d, *J* = 9.1 Hz), 134.0, 129.9, 127.9, 126.3, 111.5 (d, *J* = 21.1 Hz), 108.7 (d, *J* = 3.0 Hz), 106.7 (d, *J* = 27.2 Hz), 89.7, 79.5, 57.8, 43.5, 40.2, 36.7, 21.6; ^{19}F NMR ($CDCl_3$, 376 MHz): -106.0; IR (neat): 3130, 1612, 1501, 1335, 1157, 1097 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{24}FN_2O_5S_2^+$ 467.1105; found 467.1106.

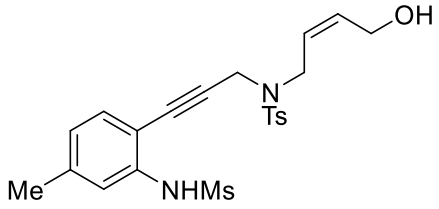
(*Z*)-*N*-(3-(4-chloro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydroxybut-2-en-1-yl)-4-methylbenzenesulfonamide (1n)



1n

Following general procedure **A** by using *N*-(5-chloro-2-iodophenyl)methanesulfonamide[7] (0.238 g, 0.717 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl) benzenesulfonamide (0.200 g, 0.717 mmol), after flash chromatography (PE/EtOAc = 2:1), **1n** was obtained as a yellow oil (0.155 g, 45 %): R_f = 0.33 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz): 7.75 (d, *J* = 8.1 Hz, 2H), 7.55 – 7.51 (m, 2H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.04 – 6.98 (m, 2H), 5.92 – 5.86 (m, 1H), 5.55 – 5.47 (m, 1H), 4.31 (s, 2H), 4.19 (d, *J* = 6.8 Hz, 2H), 3.98 (d, *J* = 7.5 Hz, 2H), 3.00 (s, 3H), 2.39 (s, 1H), 2.37 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) : 144.1, 139.5, 136.2, 135.8, 134.1, 133.7, 129.9, 127.9, 126.1, 124.5, 119.5, 111.5, 90.8, 79.5, 57.8, 43.5, 40.2, 36.7, 21.6; IR (neat): 3128, 2925, 1600, 1489, 1337, 1260 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{24}ClN_2O_5S_2^+$ 483.0810; found 483.0809.

(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(3-(4-methyl-2-(methylsulfonamido)phenyl) prop-2-yn-1-yl)benzenesulfonamide (1o)

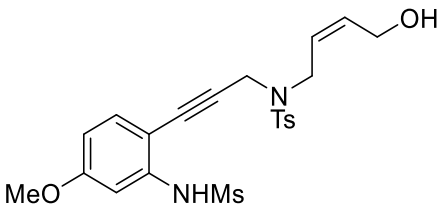


1o

Following general procedure **A** by using *N*-(2-iodo-5-methylphenyl)methanesulfonamide[7] (0.311 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.279 g, 1.0 mmol), after flash column chromatography (PE/EtOAc = 2:1), **1o** was obtained as a yellow oil (0.342 g, 74%): R_f = 0.36 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz): 7.75 (d, *J* = 8.1 Hz, 2H), 7.31 (s, 1H), 7.30 – 7.27 (m, 3H), 6.96 (dd, *J* = 7.7, 4.3 Hz, 1H), 6.86 (d, *J* = 7.8 Hz, 1H), 5.92 – 5.85 (m, 1H), 5.55 – 5.47 (m, 1H), 4.32 (s, 2H), 4.19 (d, *J* = 6.2 Hz, 2H), 3.98 (d, *J* = 7.2 Hz, 2H), 2.94 (s, 3H), 2.54 – 2.38 (m, 1H), 2.35 (s, 3H),

2.33 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz): 144.0, 141.0, 138.1, 135.9, 134.1, 132.7, 129.8, 127.8, 126.0, 125.5, 120.6, 110.6, 88.9, 80.6, 57.8, 43.5, 39.8, 36.8, 21.8, 21.5; IR (neat): 3130, 1624, 1505, 1333, 1157 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{27}N_2O_5S_2^+$ 463.1356; found 463.1355.

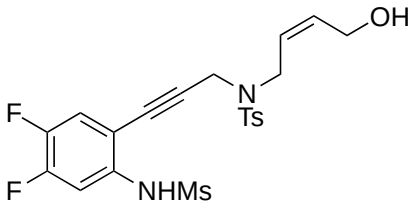
(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-*N*-(3-(4-methoxy-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-4-methylbenzenesulfonamide (1p)



1p

Following general procedure **A** by using *N*-(2-iodo-5-methoxyphenyl)methanesulfonamide[8] (0.327 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.279 g, 1.0 mmol), after flash chromatography (DCM/EtOAc = 10:1), **1p** was obtained as a yellow oil (0.342 g, 71%): R_f = 0.29 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz): 7.75 (d, *J* = 8.1 Hz, 2H), 7.30 (s, 1H), 7.29 (d, *J* = 8.1 Hz, 2H), 7.08 (d, *J* = 2.2 Hz, 1H), 7.01 (d, *J* = 8.6 Hz, 1H), 6.59 (dd, *J* = 8.6, 2.3 Hz, 1H), 5.93 – 5.87 (m, 1H), 5.56 – 5.50 (m, 1H), 4.32 (s, 2H), 4.21 (d, *J* = 6.7 Hz, 2H), 3.98 (d, *J* = 7.4 Hz, 2H), 3.80 (s, 3H), 2.95 (s, 3H), 2.37 (s, 3H), 2.31 (s, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz): 161.1, 144.0, 139.7, 135.9, 134.0, 133.9, 129.9, 127.8, 126.2, 110.7, 105.29, 105.25, 88.4, 80.4, 57.8, 55.7, 43.4, 39.8, 36.9, 21.6; IR (neat): 3129, 1620, 1505, 1333, 1157 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{27}N_2O_6S_2^+$ 479.1305; found 479.1305.

(*Z*)-*N*-(3-(4,5-difluoro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydroxybut-2-en-1-yl)-4-methylbenzenesulfonamide (1q)

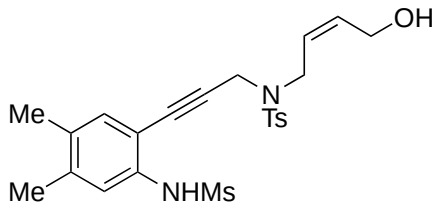


1q

Following general procedure **A** by using *N*-(4,5-difluoro-2-iodophenyl)methanesulfonamide (0.333 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene

sulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1q** was obtained as an amorphous yellow solid (0.249 g, 51%): R_f = 0.45 (PE/EtOAc = 1:1); m.p. 122-123 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.75 (d, *J* = 8.2 Hz, 2H), 7.49 (s, 1H), 7.40 (dd, *J* = 11.6, 7.3 Hz, 1H), 7.31 (d, *J* = 8.1 Hz, 2H), 6.88 – 6.80 (m, 1H), 5.94 – 5.84 (m, 1H), 5.57 – 5.48 (m, 1H), 4.29 (s, 2H), 4.19 (d, *J* = 6.8 Hz, 2H), 3.99 (d, *J* = 7.5 Hz, 2H), 2.95 (s, 3H), 2.40 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 151.1 (dd, *J* = 254.5, 13.1 Hz), 147.1 (dd, *J* = 248.5, 13.1 Hz), 144.4, 136.1, 135.6 (dd, *J* = 8.9, 2.4 Hz), 134.1, 130.1, 128.1, 126.5, 121.1 (d, *J* =20.2 Hz), 110.5 (d, *J* = 22.2 Hz), 110.0 (dd, *J* = 7.1, 4.0 Hz), 90.5, 78.8, 57.9, 43.7, 40.3, 36.7, 21.6; ^{19}F NMR ($CDCl_3$, 376 MHz): -130.2, -141.2; IR (neat): 3132, 1604, 1512, 1333, 1155 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{23}F_2N_2O_5S_2^+$ 485.1011; found 485.1010.

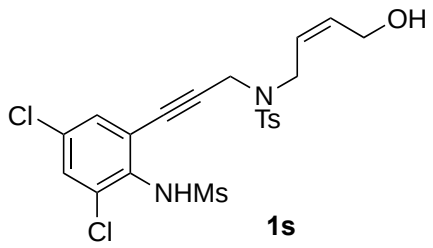
(*Z*)-*N*-(3-(4,5-dimethyl-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydroxybut-2-en-1-yl)-4-methylbenzenesulfonamide (1r)



1r

Following general procedure **A** by using *N*-(2-iodo-4,5-dimethylphenyl)methane sulfonamide (0.260 g, 0.8 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.223 g, 0.8 mmol), after flash chromatography (PE/EtOAc = 2:1), **1r** was obtained as an amorphous yellow solid (0.223 g, 58%): R_f = 0.42 (PE/EtOAc = 1:1); m.p. 98-100 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.75 (d, *J* = 8.1 Hz, 2H), 7.30 – 7.26 (m, 3H), 7.00 (s, 1H), 6.88 (s, 1H), 5.92 – 5.84 (m, 1H), 5.57 – 5.48 (m, 1H), 4.32 (s, 2H), 4.20 (t, *J* = 5.3 Hz, 2H), 3.99 (d, *J* = 7.4 Hz, 2H), 2.89 (s, 3H), 2.36 (s, 3H), 2.24 (s, 3H), 2.18 (s, 3H), 2.08 (t, *J* = 4.9 Hz, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 144.0, 139.9, 136.3, 136.1, 134.1, 133.6, 130.0, 128.0, 126.5, 122.0, 111.4, 88.9, 80.9, 58.1, 43.7, 39.8, 37.0, 21.7, 20.3, 19.2(one carbon missing due to overlap); IR (neat): 3684, 2835, 1621, 1368, 1326, 1161 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{23}H_{29}N_2O_5S_2^+$ 477.1512; found 477.1514.

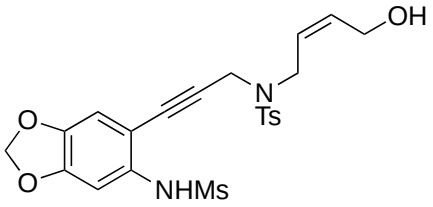
(*Z*)-*N*-(3-(3,5-dichloro-2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)-*N*-(4-hydroxybut-2-en-1-yl)-4-methylbenzenesulfonamide (1s)



1s

Following general procedure **A** by using *N*-(2,4-dichloro-6-iodophenyl)methanesulfonamide (0.176 g, 0.48 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.161 g, 0.577 mmol), after flash chromatography (PE/EtOAc = 2:1), **1s** was obtained as an amorphous yellow solid (0.157 g, 63 %): R_f = 0.29 (PE/EtOAc = 1:1); m.p. 83-84 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.76 (d, *J* = 8.0 Hz, 2H), 7.40 (s, 1H), 7.31 (d, *J* = 7.9 Hz, 2H), 6.91 (s, 1H), 6.66 (s, 1H), 5.94 – 5.83 (m, 1H), 5.57 – 5.46 (m, 1H), 4.33 (s, 2H), 4.18 (d, *J* = 6.2 Hz, 2H), 4.00 (d, *J* = 7.2 Hz, 2H), 3.15 (s, 3H), 2.42 (s, 3H), 2.12 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 144.2, 136.3, 134.4, 134.3, 133.7, 131.7, 130.8, 130.0, 128.2, 126.2, 125.4, 90.6, 80.8, 58.1, 43.7, 43.3, 36.9, 21.7 (one carbon missing due to overlap); IR (neat): 3131, 2925, 2854, 1629, 1335, 1265 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{23}Cl_2N_2O_5S_2^+$ 517.0420; found 517.0422.

(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(3-(6-(methylsulfonamido)benzo[*d*][1,3]dioxol-5-yl)prop-2-yn-1-yl)benzenesulfonamide (1t)

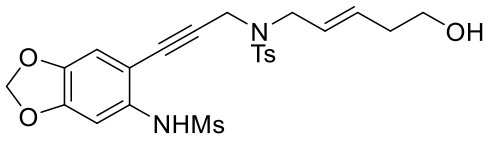


1t

Following general procedure **A** by using *N*-(6-iodobenzo[*d*][1,3]dioxol-5-yl)methane sulfonamide (0.341 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1t** was obtained as an amorphous yellow solid (0.308 g, 62%): R_f = 0.20 (PE/EtOAc = 1:1); m.p. 138-140 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.74 (d, *J* = 7.3 Hz, 2H), 7.30 (d, *J* = 7.7 Hz, 2H), 7.13 (s, 1H), 7.02 (s, 1H), 6.44 (s, 1H), 5.96 (s, 2H), 5.92 – 5.83 (m, 1H), 5.57 – 5.47 (m, 1H), 4.30 (s, 2H), 4.19 (t, *J* = 5.5 Hz, 2H), 3.99 (d, *J* = 7.4 Hz, 2H), 2.87 (s, 3H), 2.39 (s, 3H),

2.11 (t, J = 5.4 Hz, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz) : 149.5, 145.2, 144.2, 136.3, 134.0, 133.8, 130.0, 128.0, 126.5, 111.3, 107.4, 104.1, 102.3, 88.4, 80.9, 58.0, 43.7, 39.8, 36.9, 21.7; IR (neat): 3129, 1630, 1486, 1333, 1252 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{25}N_2O_7S_2^+$ 493.1098; found 493.1099.

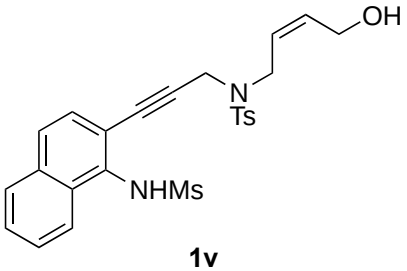
(*E*)-*N*-(5-hydroxypent-2-en-1-yl)-4-methyl-*N*-(3-(6-(methylsulfonamido)benzo[*d*][1,3] dioxol-5-yl)prop-2-yn-1-yl)benzenesulfonamide (1u)



1u

Following general procedure **A** by using *N*-(6-iodobenzo[*d*][1,3]dioxol-5-yl)methane sulfonamide (0.341 g, 1.0 mmol) and (*E*)-*N*-(5-hydroxypent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.293 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1u** was obtained as a yellow oil (0.266 g, 53 %): R_f = 0.23 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz): 7.74 (d, J = 8.0 Hz, 2H), 7.31 (d, J = 7.8 Hz, 2H), 7.06 – 7.02 (m, 1H), 6.78 (s, 1H), 6.44 – 6.40 (m, 1H), 5.98 (s, 2H), 5.75 (dt, J = 14.2, 6.9 Hz, 1H), 5.49 (dt, J = 13.9, 6.3 Hz, 1H), 4.28 (s, 2H), 3.83 (d, J = 6.5 Hz, 2H), 3.68 – 3.64 (m, 2H), 2.91 (s, 3H), 2.40 (s, 3H), 2.33 – 2.28 (m, 2H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz): 149.3, 145.1, 144.1, 135.8, 133.7, 133.4, 129.9, 127.9, 126.1, 111.0, 107.3, 103.8, 102.2, 88.5, 80.7, 61.8, 49.2, 39.6, 36.6, 35.4, 21.6; IR (neat): 3129, 2922, 1627, 1487, 1334, 1255 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{23}H_{27}N_2O_7S_2^+$ 507.1254; found 507.1254.

(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(3-(1-(methylsulfonamido)naphthalen-2-yl)-prop-2-yn-1-yl)benzenesulfonamide (1v)

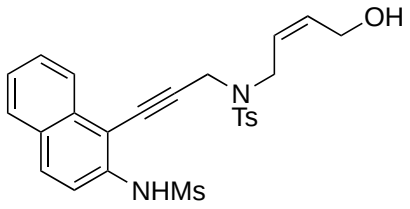


1v

Following general procedure **A** by using *N*-(2-iodonaphthalen-1-yl)methanesulfonamide (0.309 g, 0.89 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.298 g, 1.07 mmol), after flash chromatography (PE/EtOAc = 2:1),

1v was obtained as an amorphous pale solid (0.187 g, 42 %): R_f = 0.34 (PE/EtOAc = 1:1); m.p. 178-179 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 8.39 (d, *J* = 8.3 Hz, 1H), 7.83 – 7.77 (m, 3H), 7.72 (d, *J* = 8.5 Hz, 1H), 7.61 – 7.51 (m, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.19 – 7.13 (m, 2H), 5.96 – 5.88 (m, 1H), 5.62 – 5.52 (m, 1H), 4.42 (s, 2H), 4.24 (d, *J* = 6.8 Hz, 2H), 4.07 (d, *J* = 7.2 Hz, 2H), 2.97 (s, 3H), 2.38 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 144.2, 136.4, 134.7, 134.1, 131.6, 130.0, 128.4, 128.3, 128.1, 128.0, 127.5, 126.6, 125.7, 117.8, 89.8, 83.0, 58.2, 43.8, 40.9, 37.1, 21.7 (two carbon missing due to overlap); IR (neat): 3460, 3130, 1632, 1334, 1155 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{25}H_{27}N_2O_5S_2^+$ 499.1356; found 499.1355.

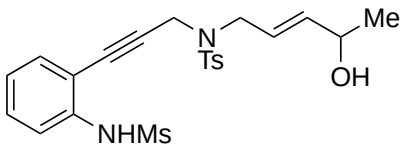
(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(3-(2-(methylsulfonamido)naphthalen-1-yl)-prop-2-yn-1-yl)benzenesulfonamide (1w)



1w

Following general procedure **A** by using *N*-(1-iodonaphthalen-2-yl)methanesulfonamide (0.347 g, 1.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzene sulfonamide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1w** was obtained as an amorphous yellow solid (0.104 g, 21 %): R_f = 0.41 (PE/EtOAc = 1:1); m.p. 144-145 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.88 (d, *J* = 8.2 Hz, 1H), 7.83 – 7.71 (m, 5H), 7.52 (t, *J* = 7.5 Hz, 1H), 7.47 (d, *J* = 7.8 Hz, 1H), 7.44 (s, 1H), 7.15 (d, *J* = 8.0 Hz, 2H), 5.95 – 5.86 (m, 1H), 5.62 – 5.53 (m, 1H), 4.50 (s, 2H), 4.25 (d, *J* = 6.1 Hz, 2H), 4.10 (d, *J* = 7.3 Hz, 2H), 2.99 (s, 3H), 2.18 (s, 3H), 2.07 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) : 144.2, 137.8, 136.3, 134.1, 133.6, 130.7, 130.6, 130.0, 128.5, 128.1, 127.8, 126.5, 126.2, 125.8, 120.0, 109.0, 95.7, 78.9, 58.3, 44.1, 40.5, 37.3, 21.6; IR (neat): 3130, 1629, 1330, 1156, 981 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{25}H_{27}N_2O_5S_2^+$ 499.1356; found 499.1355.

(*E*)-*N*-(4-Hydroxypent-2-en-1-yl)-4-methyl-*N*-(3-(2-(methylsulfonamido)phenyl)prop-2-yn-1-yl)benzenesulfonamide (1x)

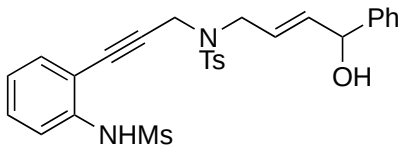


1x

To a stirred solution of (*E*)-4-methyl-*N*-(4-oxobut-2-en-1-yl)-*N*-(prop-2-yn-1-yl)benzene sulfonamide[9] (0.720 g, 2.6 mmol, 1.0 eqiv.) in THF (13 mL) at 0 ℃, methylmagnesium bromide solution (3.0 M in THF, 1.3 mL, 3.9 mmol, 1.5 equiv.) was added over 1.5 h. The reaction mixture was slowly warmed up to room temperature and was stirred for 6.0 h. The completed reaction was quenched with saturated NH_4Cl (15 mL) and extracted with ethyl acetate (3 x 20 mL). The combined organic layers were dried (Na_2SO_4), and concentrated. The residue was purified by column chromatography (Silica Gel, PE/EtOAc = 5:1) to afford (*E*)-*N*-(4-hydroxypent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide as a colorless oil (0.378 g, 50%).

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.297 g, 1.0 mmol) and (*E*)-*N*-(4-hydroxypent-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfon amide (0.293 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1x** was obtained as a yellow oil (0.290 g, 63 %): R_f = 0.38 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.74 (d, *J* = 7.8 Hz, 2H), 7.52 (d, *J* = 8.3 Hz, 1H), 7.31 (t, *J* = 7.8 Hz, 1H), 7.27 (d, *J* = 7.9 Hz, 2H), 7.14 (d, *J* = 7.6 Hz, 1H), 7.05 (t, *J* = 7.6 Hz, 1H), 6.84 (s, 1H), 5.81 (dd, *J* = 15.5, 5.6 Hz, 1H), 5.65 – 5.55 (m, 1H), 4.34 – 4.26 (m, 3H), 3.93 – 3.80 (m, 2H), 2.98 (s, 3H), 2.34 (s, 3H), 1.24 (d, *J* = 6.2 Hz, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 144.3, 140.3, 138.4, 136.0, 132.8, 130.5, 130.0, 128.0, 124.5, 123.4, 119.5, 113.3, 90.4, 80.6, 68.0, 49.0, 40.2, 37.0, 23.5, 21.7; IR (neat): 3131, 2976, 1630, 1492, 1334, 1098 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{27}N_2O_5S_2^+$ 463.1356; found 463.1356.

(*E*)-*N*-(4-Hydroxy-4-phenylbut-2-en-1-yl)-4-methyl-*N*-(3-(2-(methylsulfonamido)phenyl) prop-2-yn-1-yl)benzenesulfonamide (1y)

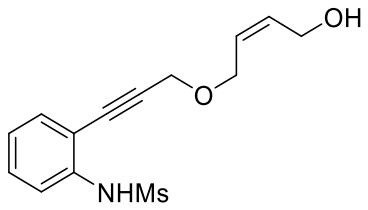


1y

To a stirring solution of (*E*)-4-methyl-*N*-(4-oxobut-2-en-1-yl)-*N*-(prop-2-yn-1-yl)benzene sulfonamide[9] (0.344 g, 1.24 mmol, 1.0 equiv.) in diethyl ether (6.5 mL) at -78 ℃, phenyl lithium solution (1.5 M in diethyl ether, 2.07 mL, 3.1 mmol, 2.5 equiv.) was added over 1.5 h. The reaction mixture was slowly warmed up to room temperature and was stirred for 0.5 h. The completed reaction was quenched with saturated NH_4Cl (15 mL) and extracted with ethyl acetate (3 × 20 mL). The combined organic layers were dried (Na_2SO_4), and concentrated. The residue was purified by column chromatography (Silica Gel, PE/EtOAc = 5:1) to afford (*E*)-*N*-(4-hydroxy-4-phenylbut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide as a colorless oil (0.230 g, 52%).

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.191 g, 0.644 mmol) and (*E*)-*N*-(4-hydroxy-4-phenylbut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.229 g, 0.644 mmol), after flash chromatography (PE/EtOAc = 2:1), **1y** was obtained as a yellow oil (0.221 g, 65%): R_f = 0.58 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz) : 7.73 (d, *J* = 8.0 Hz, 2H), 7.52 (d, *J* = 8.3 Hz, 1H), 7.35 – 7.29 (m, 5H), 7.29 – 7.24 (m, 3H), 7.11 – 7.07 (m, 1H), 7.05 (t, *J* = 7.5 Hz, 1H), 6.89 (d, *J* = 4.7 Hz, 1H), 5.96 (dd, *J* = 15.4, 6.0 Hz, 1H), 5.76 – 5.69 (m, 1H), 5.21 (d, *J* = 5.2 Hz, 1H), 4.29 (s, 2H), 3.93 (dd, *J* = 14.4, 6.2 Hz, 1H), 3.86 (dd, *J* = 14.5, 6.6 Hz, 1H), 2.94 (s, 3H), 2.51 – 2.36 (m, 1H), 2.34 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 144.2, 142.4, 138.2, 135.6, 132.7, 130.3, 129.9, 128.8, 128.0, 127.8, 126.3, 124.54, 124.48, 119.6, 113.3, 90.0, 80.5, 74.2, 48.8, 40.0, 37.0, 21.6 (one carbon missing due to overlap); IR (neat): 3131, 1626, 1502, 1331, 1156 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{27}H_{29}N_2O_5S_2^+$ 525.1512; found 525.1514.

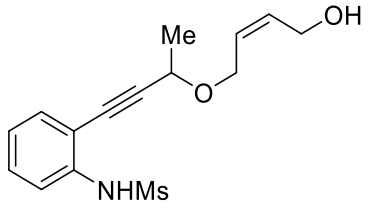
(*Z*)-*N*-(2-(3-((4-hydroxybut-2-en-1-yl)oxy)prop-1-yn-1-yl)phenyl)methanesulfonamide (1z)



1z

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.594 g, 2.0 mmol) and (*Z*)-4-(prop-2-yn-1-yloxy)but-2-en-1-ol[9] (0.302 g, 2.4 mmol), after flash chromatography (PE/EtOAc = 1:1), **1z** was obtained as a yellow oil (0.295 g, 50 %): R_f = 0.32 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.57 (d, *J* = 8.3 Hz, 1H), 7.44 (d, *J* = 7.7 Hz, 1H), 7.34 (t, *J* = 7.8 Hz, 1H), 7.21 (s, 1H), 7.10 (t, *J* = 7.6 Hz, 1H), 5.92 – 5.82 (m, 1H), 5.75 – 5.65 (m, 1H), 4.41 (s, 2H), 4.27 – 4.21 (m, 4H), 3.01 (s, 3H), 2.02 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 138.4, 133.6, 133.0, 130.5, 127.6, 124.9, 119.9, 113.8, 92.8, 81.5, 65.6, 59.0, 58.0, 40.0; IR (neat): 3130, 1636, 1492, 1330, 1154, 1075 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{14}H_{18}NO_4S^+$ 296.0951; found 296.0951.

(*Z*)-*N*-(2-(3-((4-hydroxybut-2-en-1-yl)oxy)but-1-yn-1-yl)phenyl)methanesulfonamide (1aa)

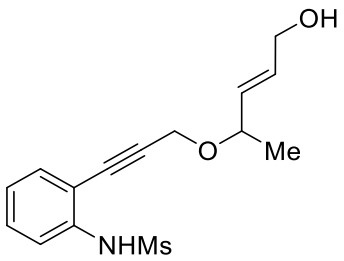


1aa

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.297 g, 1.0 mmol) and (*Z*)-4-(but-3-yn-2-yloxy)but-2-en-1-ol[2] (0.140 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1aa** was obtained as an amorphous yellow solid (0.228 g, 74 %): R_f = 0.38 (PE/EtOAc = 1:1); m.p. 65-66 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.56 (d, *J* = 8.2 Hz, 1H), 7.44 (d, *J* = 7.7 Hz, 1H), 7.33 (t, *J* = 7.8 Hz, 1H), 7.22 (s, 1H), 7.10 (t, *J* = 7.6 Hz, 1H), 5.89 – 5.80 (m, 1H), 5.75 – 5.66 (m, 1H), 4.46 (q, *J* = 6.4 Hz, 1H), 4.37 – 4.15 (m, 4H), 3.00 (s, 3H), 2.15 (s, 1H), 1.54 (d, *J* = 6.5 Hz, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) : 138.2, 133.2, 132.9, 130.3, 127.9, 124.9, 120.1, 114.0, 96.7, 80.3, 65.4, 64.8, 59.0, 40.1, 22.4; IR (neat):

3131, 2993, 1633, 1492, 1329, 1098 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{15}H_{20}NO_4S^+$ 310.1108; found 310.1105.

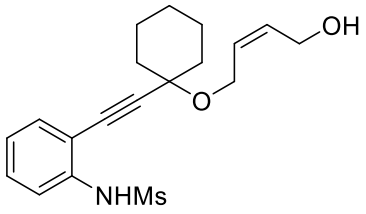
(*E*)-*N*-(2-(3-((5-hydroxypent-3-en-2-yl)oxy)prop-1-yn-1-yl)phenyl)methanesulfonamide (1ab)



1ab

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.267 g, 0.9 mmol) and (*E*)-4-(prop-2-yn-1-yloxy)pent-2-en-1-ol[2] (0.126 g, 0.9 mmol), after flash chromatography (PE/EtOAc = 2:1), **1ab** was obtained as a yellow oil (0.156 g, 56 %): R_f = 0.31 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.57 (d, *J* = 8.2 Hz, 1H), 7.47 – 7.43 (m, 1H), 7.38 – 7.32 (m, 1H), 7.15 (s, 1H), 7.12 (t, *J* = 7.6 Hz, 1H), 5.90 (dt, *J* = 15.5, 5.2 Hz, 1H), 5.64 (dd, *J* = 15.6, 7.8 Hz, 1H), 4.41 (d, *J* = 15.9 Hz, 1H), 4.32 (d, *J* = 15.9 Hz, 1H), 4.19 (d, *J* = 3.9 Hz, 2H), 4.16 – 4.08 (m, 1H), 3.02 (s, 3H), 1.91 (s, 1H), 1.31 (d, *J* = 6.3 Hz, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 138.1, 132.9, 132.6, 131.9, 130.3, 124.8, 119.7, 113.8, 93.4, 80.6, 75.8, 62.8, 56.1, 39.8, 21.5; IR (neat): 3131, 1627, 1330, 1154, 1068 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{15}H_{20}NO_4S^+$ 310.1108; found 310.1124.

(*Z*)-*N*-(2-((1-((4-hydroxybut-2-en-1-yl)oxy)cyclohexyl)ethynyl)phenyl)methanesulfonamide (1ac)

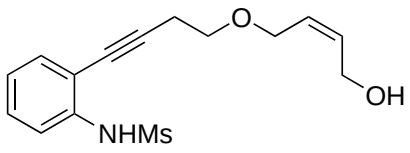


1ac

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.297 g, 1.0 mmol) and (*Z*)-4-((1-ethynylcyclohexyl)oxy)but-2-en-1-ol[10] (0.194 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1ac** was obtained as a yellow oil (0.324 g, 89%): R_f = 0.58 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.58 (t, *J* = 7.2 Hz, 1H), 7.46 (t, *J* = 6.9 Hz,

1H), 7.39 – 7.32 (m, 1H), 7.19 (s, 1H), 7.16 – 7.09 (m, 1H), 5.87 – 5.71 (m, 2H), 4.32 – 4.23 (m, 4H), 3.07 – 2.94 (m, 3H), 2.20 (s, 1H), 2.07 – 1.97 (m, 2H), 1.83 – 1.70 (m, 4H), 1.64 – 1.50 (m, 3H), 1.44 – 1.31 (m, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 138.1, 132.8, 132.3, 130.2, 128.8, 124.9, 120.0, 114.2, 98.4, 81.3, 74.8, 59.9, 59.3, 40.1, 37.5, 25.5, 23.1; IR (neat): 3131, 2935, 2858, 1636, 1491, 1333 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{19}H_{26}NO_4S^+$ 364.1577; found 364.1576.

(*Z*)-*N*-(2-(4-((4-hydroxybut-2-en-1-yl)oxy)but-1-yn-1-yl)phenyl)methanesulfonamide (1ad)



1ad

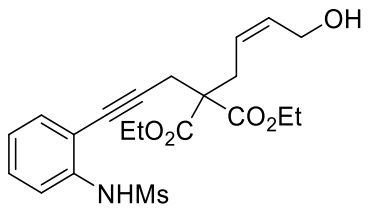
To a solution of but-3-yn-1-ol (0.140 g, 2.0 mmol, 1.0 equiv.) in DMF (0.25 M) at 0 °C under argon, was added NaH (60 wt % in mineral oil, 0.096 g, 2.4 mmol, 1.2 equiv.) and the resulting mixture was stirred for 0.5 h. Then (*Z*)-((4-bromobut-2-en-1-yl)oxy)(*tert*-butyl)dimethylsilane[11] (0.636 g, 2.4 mmol, 1.2 equiv.) was added. The reaction was warmed up to room temperature and stirred for 2.0 h. The completed reaction was quenched with water (10 mL), extracted with ethyl acetate (50 mL). The organic phase was washed with water (10 mL) and brine (10 mL), dried ($MgSO_4$), and concentrated. The residue was purified by column chromatography (Silica Gel, PE/EtOAc = 40:1) to afford (*Z*)-((4-(but-3-yn-1-yloxy)but-2-en-1-yl)oxy)(*tert*-butyl)dimethylsilane as a colorless oil (0.365 g, 72%).

Following procedure described in **1b**, (*Z*)-4-(but-3-yn-1-yloxy)but-2-en-1-ol was obtained as a colorless oil (0.192 g, 96 %).

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.297 g, 1.0 mmol) and (*Z*)-4-(but-3-yn-1-yloxy)but-2-en-1-ol (0.140 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1ad** was obtained as a yellow oil (0.177 g, 57%): R_f = 0.24 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.58 – 7.53 (m, 2H), 7.42 – 7.37 (m, 1H), 7.34 – 7.28 (m, 1H), 7.13 – 7.07 (m, 1H), 5.91 – 5.83 (m, 1H), 5.78 – 5.70 (m, 1H), 4.22 (d, *J* = 6.3 Hz, 2H), 4.17 (d, *J* = 6.2 Hz, 2H), 3.68 (t, *J* = 6.1 Hz, 2H), 2.99 (s, 3H), 2.77 (t, *J* = 6.1 Hz, 2H), 2.53 (s, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 138.2, 132.9, 132.3, 129.5, 127.8, 124.9, 120.7,

115.3, 94.7, 68.3, 66.9, 58.8, 39.7, 21.2 (one carbon missing due to overlap); IR (neat): 3130, 2865, 1635, 1491, 1331, 1099 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{15}H_{20}NO_4S^+$ 310.1108; found 310.1107.

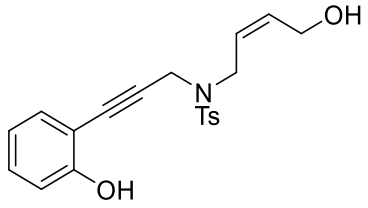
Diethyl (*Z*)-2-(4-hydroxybut-2-en-1-yl)-2-(3-(2-(methylsulfonamido)phenyl)-prop-2-yn-1-yl)malonate (1ae)



1ae

Following general procedure **A** by using *N*-(2-iodophenyl)methanesulfonamide (0.297 g, 1.0 mmol) and diethyl (*Z*)-2-(4-hydroxybut-2-en-1-yl)-2-(prop-2-yn-1-yl)malonate[2] (0.268 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1ae** was obtained as a yellow oil (0.279 g, 64%): R_f = 0.35 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.58 (d, *J* = 8.3 Hz, 1H), 7.38 – 7.32 (m, 2H), 7.29 (t, *J* = 7.9 Hz, 1H), 7.05 (t, *J* = 7.6 Hz, 1H), 5.85 – 5.76 (m, 1H), 5.42 – 5.32 (m, 1H), 4.28 – 4.17 (m, 6H), 3.03 (s, 2H), 3.00 (s, 3H), 2.88 (d, *J* = 7.9 Hz, 2H), 1.82 (s, 1H), 1.25 (t, *J* = 7.1 Hz, 6H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) : 170.1, 138.7, 133.7, 132.7, 129.9, 125.3, 124.6, 119.7, 114.1, 92.3, 78.9, 62.3, 58.4, 57.1, 39.9, 30.8, 24.3, 14.2; IR (neat): 3130, 2988, 1730, 1632, 1491, 1332 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{28}NO_7S^+$ 438.1581; found 438.1581.

(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-*N*-(3-(2-hydroxyphenyl)prop-2-yn-1-yl)-4-methylbenzenesulfonamide (1af)

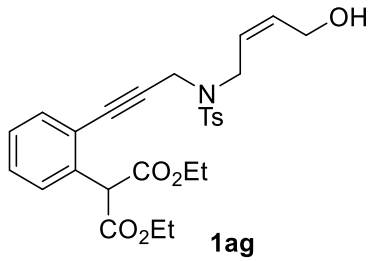


1af

Following general procedure **A** by using 2-iodophenol (0.440 g, 2.0 mmol) and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide (0.558 g, 2.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1af** was obtained as an amorphous yellow solid

(0.480 g, 65%): R_f = 0.41 (PE/EtOAc = 1:1); m.p. 101-103 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.71 (d, *J* = 7.7 Hz, 2H), 7.21 (d, *J* = 7.4 Hz, 2H), 7.14 (t, *J* = 7.3 Hz, 1H), 6.94 (d, *J* = 6.9 Hz, 1H), 6.79 (d, *J* = 8.0 Hz, 1H), 6.73 (t, *J* = 7.2 Hz, 1H), 6.18 (s, 1H), 5.90 – 5.79 (m, 1H), 5.55 – 5.46 (m, 1H), 4.27 (s, 2H), 4.17 (d, *J* = 6.0 Hz, 2H), 3.94 (d, *J* = 6.9 Hz, 2H), 2.30 (s, 3H), 1.92 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) : 157.4, 144.3, 135.8, 134.1, 132.4, 130.9, 130.0, 127.9, 126.5, 120.3, 115.6, 108.8, 88.6, 80.8, 58.1, 43.5, 37.1, 21.7; IR (neat): 3130, 1632, 1340, 1156, 1099 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{20}H_{22}NO_4S^+$ 372.1264; found 372.1264.

Diethyl (*Z*)-2-(2-(3-((*N*-(4-hydroxybut-2-en-1-yl)-4-methylphenyl)sulfonamido)prop-1-yn-1-yl)phenyl)malonate (1ag)

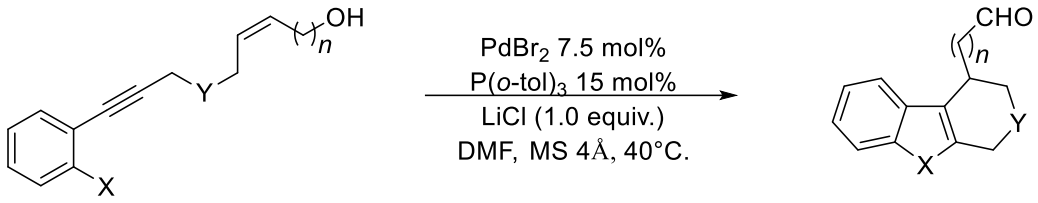


1ag

Following general procedure **A** by using diethyl 2-(2-iodophenyl)malonate (0.362 g, 1.0 mmol)[12] and (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfon amide (0.279 g, 1.0 mmol), after flash chromatography (PE/EtOAc = 2:1), **1ag** was obtained as an amorphous yellow oil (0.250 g, 49%): R_f = 0.57 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 600 MHz): 7.75 (d, *J* = 8.2 Hz, 2H), 7.43 (d, *J* = 7.9 Hz, 1H), 7.32 (t, *J* = 7.7 Hz, 1H), 7.24 (d, *J* = 8.2 Hz, 2H), 7.21 (t, *J* = 7.6 Hz, 1H), 6.99 (d, *J* = 7.7 Hz, 1H), 5.91 – 5.86 (m, 1H), 5.56 – 5.50 (m, 1H), 5.03 (s, 1H), 4.34 (s, 2H), 4.26 – 4.17 (m, 6H), 3.97 (d, *J* = 7.3 Hz, 2H), 2.31 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 6H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 168.0, 143.9, 135.9, 134.7, 134.6, 132.5, 129.8, 129.0, 128.9, 127.9, 127.8, 125.4, 122.7, 87.2, 83.3, 62.2, 58.1, 55.8, 43.4, 37.0, 21.5, 14.1; IR (neat): 3685, 1732, 1619, 1524, 1320, 1162 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{27}H_{32}NO_7S^+$ 514.1894; found 514.1895.

3 Synthesis of Polycyclic Indoles.

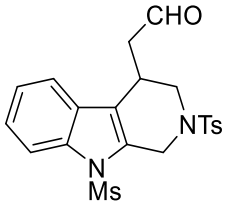
3.1 General Procedure B for the Synthesis of Tetrahydro-*β*-carbolines.



1 **2**

A suspension of LiCl (0.20 mmol, 1.0 equiv.), $PdBr_2$ (0.015 mmol, 0.075 equiv.), P(*o*-tol)$_3$ (0.03 mmol, 0.15 equiv.) in DMF (4.0 mL) was stirred at room temperature under air (balloon) for 0.5 h. Then 2-(Hydroxyalkenynyl)sulfonanilides **1** (0.2 mmol) and MS 4Å (0.150 g) were added and the reaction mixture was heated at 40 °C in a heating block under air (balloon). The progress of the reaction was monitored by TLC analysis to establish its completion. The completed reaction was diluted with ethyl acetate (50 mL), washed with water (2 x 15 mL) and brine (15 mL), dried ($MgSO_4$), filtered and concentrated. The residue was purified by column chromatography (Silica Gel, petroleum ether/ethyl acetate).

2-(9-(Methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2a)

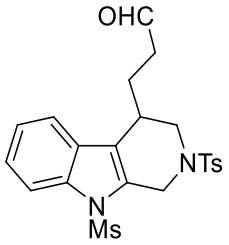


2a

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2a** was obtained as an amorphous colorless solid (0.076 g, 85%): R_f = 0.44 (PE/EtOAc = 2:1); m.p. 131-133 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.88 (s, 1H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.71 (d, *J* = 7.4 Hz, 2H), 7.40 (d, *J* = 7.6 Hz, 1H), 7.36 – 7.26 (m, 4H), 4.97 (d, *J* = 16.6 Hz, 1H), 3.97 – 3.86 (m, 2H), 3.62 (d, *J* = 9.4 Hz, 1H), 3.14 (dd, *J* = 18.9, 9.7 Hz, 1H), 3.06 (s, 3H), 2.90 – 2.78 (m, 2H), 2.41 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.6, 144.2, 136.2, 134.0, 130.6, 130.2, 128.1, 127.7, 125.4, 124.2, 119.2, 118.8, 114.0, 47.6, 46.4, 44.9, 40.9, 26.9, 21.7; IR

(neat): 1718, 1594, 1450, 1357, 1166 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{23}N_2O_5S_2^+$ 447.1043; found 447.1042.

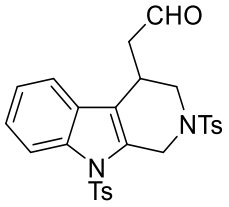
3-(9-(Methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)propanal (2b)



2b

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2b** was obtained as a yellow oil (0.056 g, 61%): R_f = 0.33 (PE/EtOAc = 2:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 9.83 (s, 1H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.74 (d, *J* = 8.0 Hz, 2H), 7.61 (d, *J* = 7.9 Hz, 1H), 7.37 – 7.27 (m, 4H), 4.91 (d, *J* = 16.6 Hz, 1H), 3.95 (d, *J* = 16.6 Hz, 1H), 3.87 (d, *J* = 12.2 Hz, 1H), 3.08 – 3.01 (m, 4H), 2.77 (dd, *J* = 12.2, 2.6 Hz, 1H), 2.74 – 2.67 (m, 2H), 2.42 (s, 3H), 2.30 – 2.19 (m, 1H), 2.10 – 1.98 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 201.8, 144.2, 136.3, 133.9, 130.2, 130.1, 128.7, 127.8, 125.3, 124.3, 120.3, 119.4, 114.0, 46.6, 44.9, 41.5, 40.9, 32.1, 24.9, 21.7; IR (neat): 3054, 1724, 1445, 1368, 1166 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{25}N_2O_5S_2^+$ 461.1199; found 461.1201.

2-(2,9-Ditosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2c)

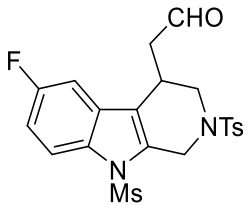


2c

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2c** was obtained as an amorphous yellow solid (0.086 g, 83%): R_f = 0.53 (PE/EtOAc = 2:1); m.p. 205-206 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.85 (s, 1H), 8.10 (d, *J* = 8.2 Hz, 1H), 7.78 (d, *J* = 7.9 Hz, 2H), 7.70 (d, *J* = 8.1 Hz, 2H), 7.39 (d, *J* = 7.9 Hz, 2H), 7.36 – 7.21 (m, 5H), 5.15 (d, *J* = 16.5 Hz, 1H), 4.10 (d, *J* = 16.5 Hz, 1H), 3.89 (d, *J* = 12.4 Hz, 1H), 3.59 (d, *J* = 9.1 Hz, 1H),

3.07 (dd, J = 18.8, 9.7 Hz, 1H), 2.88 – 2.75 (m, 2H), 2.47 (s, 3H), 2.37 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.6, 145.5, 144.2, 136.4, 135.5, 134.3, 130.6, 130.3, 130.2, 128.2, 127.7, 126.7, 125.2, 124.0, 119.4, 118.5, 114.7, 47.6, 46.5, 45.2, 26.9, 21.8, 21.7; IR (neat): 3133, 2921, 1720, 1590, 1452 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{27}H_{27}N_2O_5S_2^+$ 523.1356; found 523.1359.

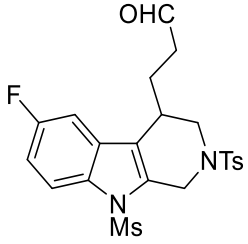
2-(6-Fluoro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2f)



2f

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2f** was obtained as an amorphous orange solid (0.063 g, 67%): R_f = 0.48 (PE/EtOAc = 2:1); m.p. 193-195 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) : 9.90 (s, 1H), 7.88 (dd, J = 9.0, 4.3 Hz, 1H), 7.72 (d, J = 8.2 Hz, 2H), 7.36 (d, J = 8.2 Hz, 2H), 7.10 – 7.03 (m, 2H), 4.97 (d, J = 16.6 Hz, 1H), 3.94 – 3.86 (m, 2H), 3.59 (d, J = 9.8 Hz, 1H), 3.17 (dd, J = 19.1, 9.8 Hz, 1H), 3.09 (s, 3H), 2.88 – 2.77 (m, 2H), 2.44 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz): 200.38, 160.1 (d, J = 243.1 Hz), 144.3, 133.7, 132.3, 130.2, 129.0 (d, J = 9.1 Hz), 127.6, 118.98, 118.95, 115.1 (d, J = 9.1 Hz), 113.1 (d, J = 25.7 Hz), 104.7 (d, J = 24.2 Hz), 47.5, 46.1, 44.8, 41.0, 26.7, 21.7; ^{19}F NMR ($CDCl_3$, 376 MHz): -118.1. IR (neat): 3129, 2922, 1720, 1594, 1463, 1397, 1166 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{22}FN_2O_5S_2^+$ 465.0949; found 465.0949.

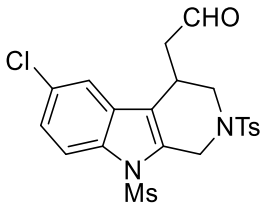
3-(6-Fluoro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)propanal (2g)



2g

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2g** was obtained as an amorphous yellow solid (0.048 g, 50%): R_f = 0.44 (PE/EtOAc = 2:1); m.p. 204-205 °C; ^{1}H NMR ($CDCl_3$, 600 MHz): 9.86 (s, 1H), 7.88 (dd, *J* = 9.1, 4.3 Hz, 1H), 7.74 (d, *J* = 8.2 Hz, 2H), 7.36 (d, *J* = 8.1 Hz, 2H), 7.34 (dd, *J* = 8.5, 2.4 Hz, 1H), 7.05 (td, *J* = 9.0, 2.5 Hz, 1H), 4.91 (d, *J* = 16.6 Hz, 1H), 3.92 (d, *J* = 16.6 Hz, 1H), 3.88 (d, *J* = 12.2 Hz, 1H), 3.08 (s, 3H), 3.00 (d, *J* = 9.6 Hz, 1H), 2.78 – 2.69 (m, 3H), 2.44 (s, 3H), 2.26– 2.18 (m, 1H), 2.05 – 1.97 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 201.7, 160.1 (d, *J* = 243.1 Hz), 144.3, 133.6, 132.3, 131.6, 130.2, 129.6 (d, *J* = 10.6 Hz), 127.6, 120.1 (d, *J* = 3.0 Hz), 115.0 (d, *J* = 9.1 Hz), 113.0 (d, *J* = 24.2 Hz), 105.3 (d, *J* = 24.2 Hz), 46.2, 44.8, 41.3, 40.9, 31.8, 24.5, 21.7; ^{19}F NMR ($CDCl_3$, 376 MHz): -118.1; IR (neat): 3134, 1716, 1576, 1402, 1165 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{24}FN_2O_5S_2^+$ 479.1105; found 479.1107.

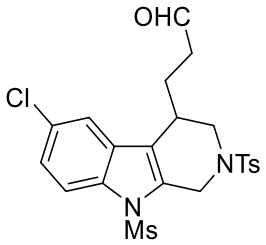
2-(6-Chloro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2h)



2h

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2h** was obtained as an amorphous orange solid (0.074 g, 77%): R_f = 0.56 (PE/EtOAc = 2:1); m.p. 214-216 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.88 (s, 1H), 7.84 (d, *J* = 8.8 Hz, 1H), 7.70 (d, *J* = 8.0 Hz, 2H), 7.37 (s, 1H), 7.34 (d, *J* = 7.9 Hz, 2H), 7.27 (d, *J* = 8.9 Hz, 1H), 4.95 (d, *J* = 16.8 Hz, 1H), 3.96 – 3.85 (m, 2H), 3.57 (d, *J* = 9.2 Hz, 1H), 3.13 (dd, *J* = 19.0, 9.8 Hz, 1H), 3.07 (s, 3H), 2.87 – 2.77 (m, 2H), 2.42 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.2, 144.4, 134.6, 134.1, 132.2, 130.3, 130.2, 129.3, 127.7, 125.6, 118.7, 118.6, 115.1, 47.6, 46.3, 44.8, 41.2, 26.9, 21.7; IR (neat): 3134, 2921, 1719, 1589, 1450, 1365, 1164 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{22}ClN_2O_5S_2^+$ 481.0653; found 481.0653.

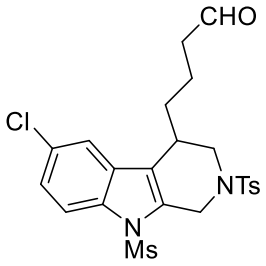
3-(6-Chloro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)propanal (2i)



2i

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2i** was obtained as an amorphous yellow solid (0.052 g, 52%): R_f = 0.41 (PE/EtOAc = 2:1); m.p. 229-231 °C; ^{1}H NMR ($CDCl_3$, 600 MHz): 9.86 (s, 1H), 7.86 (d, *J* = 8.9 Hz, 1H), 7.74 (d, *J* = 8.1 Hz, 2H), 7.64 – 7.61 (m, 1H), 7.36 (d, *J* = 8.1 Hz, 2H), 7.29 (dd, *J* = 8.9, 1.6 Hz, 1H), 4.91 (d, *J* = 16.6 Hz, 1H), 3.92 (d, *J* = 16.6 Hz, 1H), 3.89 (d, *J* = 12.2 Hz, 1H), 3.09 (s, 3H), 3.01 (d, *J* = 9.6 Hz, 1H), 2.77 – 2.71 (m, 3H), 2.44 (s, 3H), 2.26 – 2.18 (m, 1H), 2.06 – 1.97 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 201.7, 144.3, 134.4, 133.5, 131.3, 130.2, 130.1, 129.8, 127.6, 125.4, 119.6, 119.1, 114.9, 46.2, 44.8, 41.3, 41.1, 31.8, 24.6, 21.7; IR (neat): 3130, 1717, 1574, 1402, 1164 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{24}ClN_2O_5S_2^+$ 495.0810; found 495.0808.

4-(6-Chloro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)butanal (2j)

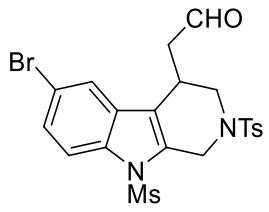


2j

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2j** was obtained as a yellow oil (0.048 g, 48%): R_f = 0.45 (PE/EtOAc = 2:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 9.82 (s, 1H), 7.86 (d, *J* = 8.9 Hz, 1H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.44 (s, 1H), 7.36 (d, *J* = 8.0 Hz, 2H), 7.29 (d, *J* = 9.1 Hz, 1H), 4.86 (d, *J* = 16.8 Hz, 1H), 3.99 (d, *J* = 16.7 Hz, 1H), 3.89 (d, *J* = 12.3 Hz, 1H), 3.08 (s, 3H), 2.97 – 2.91 (m, 1H), 2.82 (dd, *J* = 12.2, 3.2 Hz,

1H), 2.57 – 2.51 (m, 2H), 2.44 (s, 3H), 1.97 – 1.75 (m, 4H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 202.0, 144.2, 134.5, 133.9, 131.4, 130.1, 130.0, 129.9, 127.7, 125.3, 120.0, 118.8, 115.0, 46.5, 44.8, 44.0, 41.0, 33.1, 32.1, 21.7, 20.1; IR (neat): 3052, 1716, 1514, 1463, 1363 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{23}H_{26}ClN_2O_5S_2^+$ 509.0966; found 509.0968.

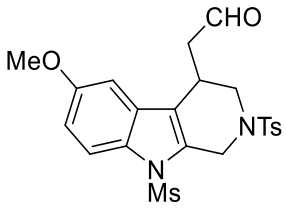
2-(6-Bromo-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2k)



2k

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2k** was obtained as an amorphous orange solid (0.075 g, 72%). R_f = 0.49 (PE/EtOAc = 2:1); m.p. 214-216 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.87 (s, 1H), 7.79 (d, *J* = 8.8 Hz, 1H), 7.70 (d, *J* = 8.1 Hz, 2H), 7.52 (s, 1H), 7.40 (d, *J* = 8.8 Hz, 1H), 7.33 (d, *J* = 8.0 Hz, 2H), 4.95 (d, *J* = 16.8 Hz, 1H), 3.92 (d, *J* = 16.9 Hz, 1H), 3.87 (d, *J* = 12.6 Hz, 1H), 3.57 (d, *J* = 9.5 Hz, 1H), 3.12 (dd, *J* = 19.0, 9.8 Hz, 1H), 3.07 (s, 3H), 2.86– 2.78 (m, 2H), 2.41 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.3, 144.3, 134.9, 134.0, 132.0, 130.2, 129.8, 128.3, 127.7, 121.6, 118.5, 117.8, 115.5, 47.6, 46.2, 44.8, 41.2, 26.8, 21.7; IR (neat): 2921, 2853, 1718, 1449, 1365, 1166 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{22}BrN_2O_5S_2^+$ 525.0148; found 525.0150.

2-(6-Methoxy-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2l)

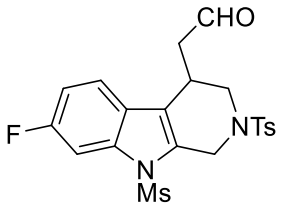


2l

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2l** was obtained as an amorphous orange solid (0.062 g, 65%): R_f = 0.37 (PE/EtOAc = 2:1); m.p. 185-186 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.90 (s, 1H), 7.81 (d, *J* = 9.1 Hz, 1H), 7.71 (d, *J* =

7.9 Hz, 2H), 7.34 (d, *J* = 7.9 Hz, 2H), 6.92 (d, *J* = 9.1 Hz, 1H), 6.82 (s, 1H), 4.95 (d, *J* = 16.6 Hz, 1H), 3.93 – 3.90 (m, 1H), 3.89 – 3.86 (m, 1H), 3.82 (s, 3H), 3.58 (d, *J* = 8.9 Hz, 1H), 3.14 (dd, *J* = 18.9, 9.6 Hz, 1H), 3.01 (s, 3H), 2.89 – 2.77 (m, 2H), 2.42 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.7, 157.3, 144.3, 134.1, 131.4, 130.8, 130.2, 129.2, 127.7, 119.4, 115.0, 113.8, 101.9, 56.1, 47.7, 46.4, 45.0, 40.6, 27.0, 21.7; IR (neat): 3008, 1716, 1627, 1552, 1164 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{25}N_2O_6S_2^+$ 477.1149; found 477.1154.

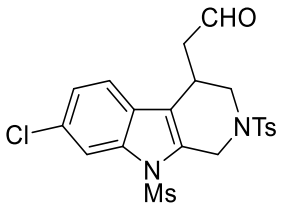
2-(7-Fluoro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2m)



2m

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2m** was obtained as an amorphous orange solid (0.069 g, 75%): R_f = 0.41 (PE/EtOAc = 2:1); m.p. 160-162 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.88 (s, 1H), 7.71 (d, *J* = 7.8 Hz, 2H), 7.67 (d, *J* = 9.8 Hz, 1H), 7.36 – 7.31 (m, 3H), 7.03 (t, *J* = 8.8 Hz, 1H), 4.94 (d, *J* = 16.6 Hz, 1H), 3.96 – 3.85 (m, 2H), 3.60 (d, *J* = 9.0 Hz, 1H), 3.14 (dd, *J* = 18.9, 9.5 Hz, 1H), 3.08 (s, 3H), 2.87 – 2.78 (m, 2H), 2.42 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.4, 161.3 (d, *J* = 243.4 Hz), 144.3, 136.4 (d, *J* = 12.1 Hz), 134.1, 130.9 (d, *J* = 4.0 Hz), 130.2, 127.7, 124.4, 119.6 (d, *J* = 10.1 Hz), 119.0, 112.5 (d, *J* = 24.2 Hz), 101.9 (d, *J* = 28.3 Hz), 47.7, 46.5, 44.8, 41.1, 26.9, 21.7; ^{19}F NMR ($CDCl_3$, 376 MHz): -115.0; IR (neat): 2925, 1721, 1620, 1486, 1259, 1167 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{22}FN_2O_5S_2^+$ 465.0949; found 465.0951.

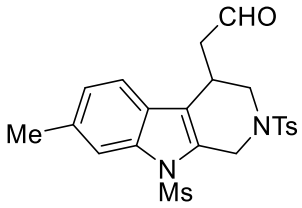
2-(7-Chloro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2n)



2n

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2n** was obtained as an amorphous orange solid (0.080 g, 83%): R_f = 0.42 (PE/EtOAc = 2:1); m.p. 188-189 °C; ^{1}H NMR ($CDCl_3$, 600 MHz): 9.90 (s, 1H), 7.97 (s, 1H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.36 (d, *J* = 8.2 Hz, 2H), 7.34 (d, *J* = 8.4 Hz, 1H), 7.28 (dd, *J* = 8.4, 1.7 Hz, 1H), 4.96 (d, *J* = 16.6 Hz, 1H), 3.93 – 3.88 (m, 2H), 3.62 (d, *J* = 9.6 Hz, 1H), 3.18 (dd, *J* = 19.1, 9.7 Hz, 1H), 3.13 (s, 3H), 2.87 – 2.82 (m, 1H), 2.80 (dd, *J* = 12.4, 3.3 Hz, 1H), 2.44 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 200.4, 144.3, 136.4, 133.7, 131.4, 131.1, 130.2, 127.6, 126.4, 124.8, 119.5, 118.8, 114.3, 47.5, 46.4, 44.7, 41.3, 26.6, 21.7; IR (neat): 2923, 2853, 1718, 1556, 1166 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{22}ClN_2O_5S_2^+$ 481.0653; found 481.0654.

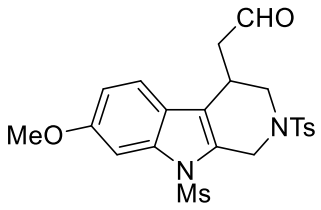
2-(7-Methyl-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2o)



2o

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2o** was obtained as an amorphous orange solid (0.061 g, 66%): R_f = 0.52 (PE/EtOAc = 2:1); m.p. 76-77 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.88 (s, 1H), 7.75 – 7.68 (m, 3H), 7.33 (d, *J* = 7.8 Hz, 2H), 7.26 (d, *J* = 8.0 Hz, 1H), 7.10 (d, *J* = 8.0 Hz, 1H), 4.94 (d, *J* = 16.5 Hz, 1H), 3.94 (d, *J* = 17.3 Hz, 1H), 3.86 (d, *J* = 12.9 Hz, 1H), 3.59 (d, *J* = 9.2 Hz, 1H), 3.12 (dd, *J* = 18.9, 9.7 Hz, 1H), 3.05 (s, 3H), 2.88 – 2.77 (m, 2H), 2.45 (s, 3H), 2.41 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.7, 144.2, 136.6, 135.8, 134.1, 130.2, 129.9, 127.7, 125.8, 125.6, 119.2, 118.4, 114.2, 47.7, 46.4, 44.9, 40.8, 27.0, 22.1, 21.7; IR (neat): 3010, 1720, 1550, 1535, 1267 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{25}N_2O_5S_2^+$ 461.1199; found 461.1195.

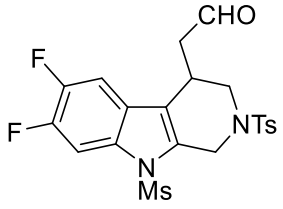
2-(7-Methoxy-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2p)



2p

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2p** was obtained as an amorphous orange solid (0.067 g, 70%): R_f = 0.32 (PE/EtOAc = 2:1); m.p. 163-164 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.88 (s, 1H), 7.71 (d, *J* = 8.1 Hz, 2H), 7.48 (d, *J* = 1.8 Hz, 1H), 7.33 (d, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 8.7 Hz, 1H), 6.89 (dd, *J* = 8.6, 1.9 Hz, 1H), 4.92 (d, *J* = 16.4 Hz, 1H), 3.91 (d, *J* = 16.4 Hz, 1H), 3.88 – 3.82 (m, 4H), 3.57 (d, *J* = 9.4 Hz, 1H), 3.12 (dd, *J* = 18.8, 9.6 Hz, 1H), 3.03 (s, 3H), 2.87 – 2.78 (m, 2H), 2.41 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.6, 158.7, 144.2, 137.4, 134.2, 130.2, 129.1, 127.7, 121.9, 119.3, 112.9, 99.0, 56.1, 47.7, 46.5, 44.9, 40.6, 27.0, 21.7 (one carbon missing due to overlap); IR (neat): 1721, 1621, 1492, 1266, 1164 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{25}N_2O_6S_2^+$ 477.1149; found 477.1150.

2-(6,7-Difluoro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2q)

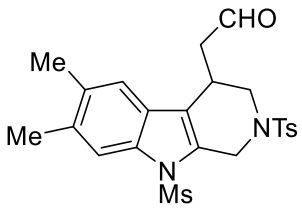


2q

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2q** was obtained as an amorphous orange solid (0.073 g, 76%): R_f = 0.38 (PE/EtOAc = 2:1); m.p. 93-95 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.87 (s, 1H), 7.79 (dd, *J* = 10.5, 6.9 Hz, 1H), 7.70 (d, *J* = 8.0 Hz, 2H), 7.34 (d, *J* = 7.8 Hz, 2H), 7.22 – 7.15 (m, 1H), 4.93 (d, *J* = 16.7 Hz, 1H), 3.94 – 3.84 (m, 2H), 3.55 (d, *J* = 8.3 Hz, 1H), 3.13 (dd, *J* = 19.2, 9.5 Hz, 1H), 3.08 (s, 3H), 2.85 – 2.76 (m, 2H), 2.42 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 204.0, 153.0 (dd, *J* = 247.5, 15.2 Hz), 152.6 (dd, *J* = 246.8, 14.1 Hz), 148.3, 137.8, 135.8 (d, *J* = 4.0 Hz), 135.1 (d, *J* = 10.1 Hz), 134.1,

131.5, 127.6 (d, J = 6.1 Hz), 122.8, 110.2 (d, J = 20.2 Hz), 107.5 (d, J = 24.2 Hz), 51.6, 50.3, 48.7, 45.1, 30.7, 25.6; ^{19}F NMR ($CDCl_3$, 376 MHz): -137.9, -140.7; IR (neat): 1720, 1629, 1473, 1166, 963 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{21}F_2N_2O_5S_2^+$ 483.0855; found 483.0855.

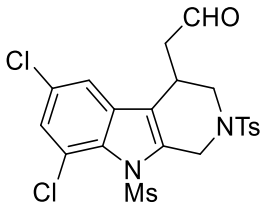
2-(6,7-Dimethyl-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2r)



2r

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2r** was obtained as an amorphous orange solid (0.067 g, 71%): R_f = 0.54 (PE/EtOAc = 2:1); m.p. 201-202 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.89 (s, 1H), 7.73 – 7.68 (m, 3H), 7.33 (d, J = 7.9 Hz, 2H), 7.12 (s, 1H), 4.93 (d, J = 16.5 Hz, 1H), 3.94 – 3.83 (m, 2H), 3.57 (d, J = 9.4 Hz, 1H), 3.12 (dd, J = 18.8, 9.8 Hz, 1H), 3.01 (s, 3H), 2.88 – 2.77 (m, 2H), 2.41 (s, 3H), 2.35 (s, 3H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.8, 144.2, 135.1, 134.7, 134.1, 133.2, 130.2, 129.7, 127.7, 126.3, 119.0, 114.6, 47.7, 46.4, 44.9, 40.5, 27.1, 21.7, 20.8, 20.1 (one carbon missing due to overlap); IR (neat): 2925, 2854, 1721, 1556, 1265 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{23}H_{27}N_2O_5S_2^+$ 475.1356; found 475.1357.

2-(6,8-Dichloro-9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acetaldehyde (2s)

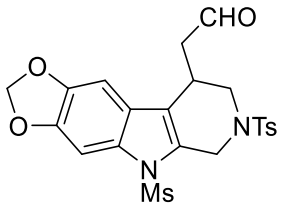


2s

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2s** was obtained as an amorphous orange solid (0.073 g, 71%): R_f = 0.64 (PE/EtOAc = 2:1); m.p. 190-192 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.87 (s, 1H), 7.71 (d, J = 8.0 Hz, 2H), 7.38 – 7.31 (m,

3H), 7.25 – 7.22 (m, 1H), 4.87 (d, J = 16.5 Hz, 1H), 4.04 (d, J = 16.5 Hz, 1H), 3.82 (d, J = 12.4 Hz, 1H), 3.69 (s, 3H), 3.60 – 3.53 (m, 1H), 3.10 (dd, J = 19.1, 10.1 Hz, 1H), 2.89 – 2.82 (m, 1H), 2.75 (d, J = 19.1 Hz, 1H), 2.43 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.1, 144.4, 135.7, 133.8, 132.3, 132.2, 130.22, 130.18, 127.7, 127.6, 120.3, 118.1, 117.1, 47.7, 45.9, 45.8, 45.1, 26.8, 21.7; IR (neat): 2925, 2854, 1722, 1595, 1558, 1373, 1263 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{21}Cl_2N_2O_5S_2^+$ 515.0264; found 515.0263.

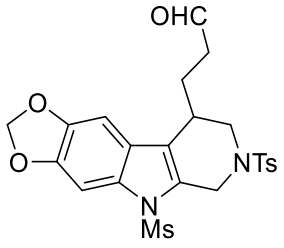
2-(5-(Methylsulfonyl)-7-tosyl-6,7,8,9-tetrahydro-5*H*-[1,3]dioxolo[4,5-*f*]pyrido[3,4-*b*]indol-9-yl)acetaldehyde (2t)



2t

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2t** was obtained as an amorphous orange solid (0.081 g, 83%): R_f = 0.41 (PE/EtOAc = 2:1); m.p. 222-223 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.88 (s, 1H), 7.71 (d, J = 7.9 Hz, 2H), 7.45 (s, 1H), 7.34 (d, J = 8.0 Hz, 2H), 6.77 (s, 1H), 5.98 (s, 2H), 4.92 (d, J = 16.4 Hz, 1H), 3.93 – 3.83 (m, 2H), 3.57 – 3.48 (m, 1H), 3.12 (dd, J = 18.8, 9.6 Hz, 1H), 3.03 (s, 3H), 2.86 – 2.76 (m, 2H), 2.43 (s, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.6, 147.1, 145.8, 144.2, 134.1, 130.9, 130.2, 129.1, 127.7, 122.3, 119.5, 101.8, 97.8, 96.1, 47.7, 46.4, 44.9, 40.6, 27.0, 21.7; IR (neat): 2921, 1718, 1463, 1353, 1164 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{23}N_2O_7S_2^+$ 491.0941; found 491.0941.

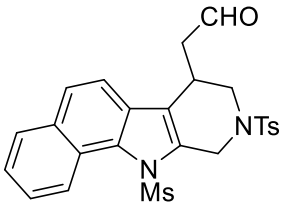
3-(5-(Methylsulfonyl)-7-tosyl-6,7,8,9-tetrahydro-5*H*-[1,3]dioxolo[4,5-*f*]pyrido[3,4-*b*]indol-9-yl)propanal (2u)



2u

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2u** was obtained as an amorphous orange solid (0.052 g, 52%): R_f = 0.25 (PE/EtOAc = 2:1); m.p. 200-202 °C; ^{1}H NMR ($CDCl_3$, 600 MHz): 9.84 (s, 1H), 7.74 (d, *J* = 8.2 Hz, 2H), 7.45 (s, 1H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.03 (s, 1H), 6.00 (s, 2H), 4.86 (d, *J* = 16.2 Hz, 1H), 3.90 – 3.84 (m, 2H), 3.03 (s, 3H), 2.94 (d, *J* = 9.5 Hz, 1H), 2.75 – 2.70 (m, 3H), 2.43 (s, 3H), 2.23 – 2.16 (m, 1H), 2.05 – 1.96 (m, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 201.8, 146.9, 145.7, 144.1, 133.6, 130.8, 130.1, 128.4, 127.6, 122.8, 120.5, 101.7, 98.4, 95.9, 46.3, 44.9, 41.3, 40.5, 31.9, 24.5, 21.7; IR (neat): 2922, 2853, 1721, 1591, 1460, 1167 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{23}H_{25}N_2O_7S_2^+$ 505.1098; found 505.1100.

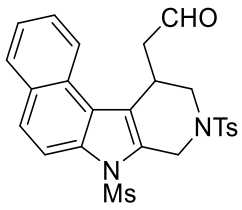
2-(11-(Methylsulfonyl)-9-tosyl-8,9,10,11-tetrahydro-7*H*-benzo[*g*]pyrido[3,4-*b*]indol-7-yl)acetaldehyde (2v)



2v

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **1v** (0.060 g, 60%) was recovered and **2v** obtained as an amorphous orange solid (0.035 g, 35%): R_f = 0.38 (PE/EtOAc = 2:1); m.p. 134-135 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.90 (s, 1H), 8.93 (d, *J* = 8.8 Hz, 1H), 7.92 (d, *J* = 8.1 Hz, 1H), 7.78 – 7.71 (m, 3H), 7.59 (t, *J* = 7.8 Hz, 1H), 7.49 (t, *J* = 7.5 Hz, 1H), 7.43 (d, *J* = 8.5 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 2H), 5.10 (d, *J* = 16.4 Hz, 1H), 4.04 (d, *J* = 16.4 Hz, 1H), 3.93 (d, *J* = 12.4 Hz, 1H), 3.70 (d, *J* = 9.7 Hz, 1H), 3.20 (dd, *J* = 19.0, 9.9 Hz, 1H), 3.00 (s, 3H), 2.93 – 2.80 (m, 2H), 2.41 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.5, 144.2, 134.3, 133.2, 133.1, 132.7, 130.2, 129.6, 127.8, 127.30, 127.28, 127.2, 125.4, 124.2, 123.9, 121.9, 116.9, 47.7, 46.5, 46.2, 40.4, 27.1, 21.7; IR (neat): 3052, 2922, 1719, 1455, 1363, 1167 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{25}H_{25}N_2O_5S_2^+$ 497.1199; found 497.1200.

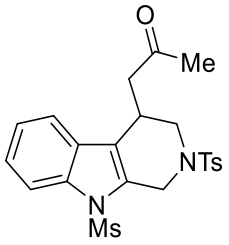
2-(7-(Methylsulfonyl)-9-tosyl-8,9,10,11-tetrahydro-7*H*-benzo[*e*]pyrido[3,4-*b*]indol-11-yl)acetaldehyde (2w)



2w

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2w** was obtained as an amorphous orange solid (0.064 g, 65%): R_f = 0.24 (PE/EtOAc = 2:1); m.p. 201-203 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.97 (s, 1H), 8.12 (d, *J* = 9.0 Hz, 1H), 7.99 (d, *J* = 8.3 Hz, 1H), 7.93 (d, *J* = 8.1 Hz, 1H), 7.78 – 7.72 (m, 3H), 7.55 (t, *J* = 7.6 Hz, 1H), 7.49 (t, *J* = 7.3 Hz, 1H), 7.36 (d, *J* = 7.8 Hz, 2H), 5.12 (d, *J* = 16.3 Hz, 1H), 4.18 (d, *J* = 10.3 Hz, 1H), 4.02– 3.94 (m, 2H), 3.38 (dd, *J* = 19.6, 10.5 Hz, 1H), 3.13 (s, 3H), 2.97 (d, *J* = 19.5 Hz, 1H), 2.83 (d, *J* = 11.8 Hz, 1H), 2.43 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.9, 144.3, 133.9, 133.4, 131.3, 130.3, 129.5, 129.2, 127.8, 127.6, 127.5, 126.5, 125.3, 122.9, 122.1, 120.6, 113.5, 47.5, 46.3, 45.1, 41.8, 28.6, 21.8; IR (neat): 3031, 1718, 1592, 1518, 1168 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{25}H_{25}N_2O_5S_2^+$ 497.1199; found 497.1197.

1-(9-(Methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)propan-2-one (2x)

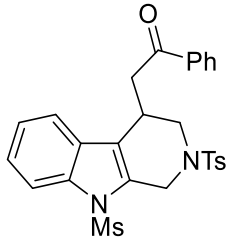


2x

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2x** was obtained as an amorphous orange solid (0.050 g, 54%): R_f = 0.52 (PE/EtOAc = 2:1); m.p. 137-138 °C; ^{1}H NMR ($CDCl_3$, 600 MHz): 7.93 (d, *J* = 8.3 Hz, 1H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.43 (d, *J* = 7.6 Hz, 1H), 7.37 – 7.32 (m, 3H), 7.29 (t, *J* = 7.5 Hz, 1H), 5.02 (d, *J* = 16.4 Hz, 1H), 3.93 – 3.84 (m, 2H), 3.60 (d, *J* = 10.5 Hz, 1H), 3.15 (dd, *J* = 18.5, 10.4 Hz, 1H), 3.07 (s, 3H), 2.78 (d, *J* = 18.3 Hz, 1H), 2.75 – 2.71 (m, 1H), 2.44 (s, 3H), 2.25 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$,

151 MHz): 207.6, 144.1, 136.1, 134.0, 130.3, 130.1, 128.1, 127.5, 125.3, 124.1, 119.6, 118.7, 113.9, 47.4, 45.4, 44.8, 40.8, 30.8, 27.9, 21.7; IR (neat) : 3131, 2922, 1711, 1400, 1163 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{25}N_2O_5S_2^+$ 461.1199; found 461.1197.

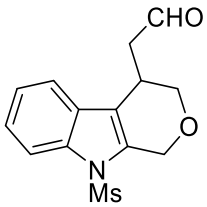
2-(9-(Methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)-1-phenylethan-1-one (2y)



2y

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2y** was obtained as a yellow solid (0.064 g, 61%): R_f = 0.57 (PE/EtOAc = 2:1); m.p. 167-168 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.99 (d, *J* = 7.9 Hz, 2H), 7.96 (d, *J* = 8.3 Hz, 1H), 7.75 – 7.69 (m, 2H), 7.61 – 7.54 (m, 1H), 7.50 – 7.42 (m, 3H), 7.37 – 7.27 (m, 4H), 5.06 (d, *J* = 16.5 Hz, 1H), 4.04 – 3.93 (m, 2H), 3.84 (d, *J* = 9.8 Hz, 1H), 3.67 (dd, *J* = 18.4, 10.0 Hz, 1H), 3.27 (d, *J* = 18.4 Hz, 1H), 3.09 (s, 3H), 2.92 – 2.83 (m, 1H), 2.40 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 198.6, 144.1, 137.0, 136.2, 134.0, 133.5, 130.6, 130.1, 128.8, 128.3, 128.2, 127.7, 125.3, 124.1, 119.9, 118.9, 114.0, 47.8, 44.9, 40.9, 40.8, 28.1, 21.7; IR (neat): 3010, 1704, 1626, 1263, 1163 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{27}H_{27}N_2O_5S_2^+$ 523.1356; found 523.1356.

2-(9-(Methylsulfonyl)-1,3,4,9-tetrahydropyrano[3,4-*b*]indol-4-yl)acetaldehyde (2z)

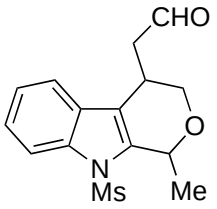


2z

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2z** was obtained as an amorphous orange solid (0.047 g, 81%): R_f = 0.39 (PE/EtOAc = 2:1); m.p. 134-135 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.92 (s, 1H), 8.00 (d, *J* = 7.8 Hz, 1H), 7.50 (d, *J* = 7.5 Hz, 1H), 7.42 – 7.32 (m, 2H), 5.07 (d, *J* = 16.6 Hz, 1H), 4.86 (d, *J* = 16.6 Hz, 1H), 4.03 (d,

J = 11.6 Hz, 1H), 3.87 (dd, *J* = 11.6, 2.6 Hz, 1H), 3.57 – 3.49 (m, 1H), 3.08 (s, 3H), 3.03 (dd, *J* = 18.6, 9.1 Hz, 1H), 2.94 (dd, *J* = 18.1, 3.6 Hz, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 201.0, 136.1, 133.4, 128.7, 125.1, 124.2, 118.8, 118.1, 113.9, 68.8, 64.9, 46.6, 40.6, 27.7; IR (neat): 2928, 1718, 1624, 1235, 1166 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{14}H_{16}NO_4S^+$ 294.0795; found 294.0794.

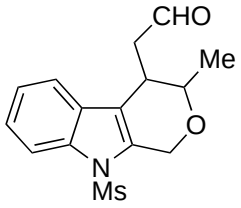
2-(1-Methyl-9-(methylsulfonyl)-1,3,4,9-tetrahydropyrano[3,4-*b*]indol-4-yl)acetaldehyde (2aa)



2aa (d.r.> 20:1)

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2aa** was obtained as an amorphous orange solid (0.046 g, 75%): R_f = 0.41 (PE/EtOAc = 2:1); m.p. 136-137 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.89 (s, 1H), 7.98 (d, *J* = 7.5 Hz, 1H), 7.49 – 7.44 (m, 1H), 7.39 – 7.30 (m, 2H), 5.14 – 5.07 (m, 1H), 3.97 (dd, *J* = 11.5, 2.3 Hz, 1H), 3.88 (dd, *J* = 11.6, 3.1 Hz, 1H), 3.54 – 3.46 (m, 1H), 3.04 – 2.87 (m, 2H), 2.84 (s, 3H), 1.66 (d, *J* = 6.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.8, 139.3, 137.5, 129.2, 125.4, 124.6, 120.8, 119.0, 115.1, 70.3, 66.9, 45.9, 39.0, 28.4, 22.9; IR (neat): 2928, 2863, 1720, 1672, 1632, 1450 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{15}H_{18}NO_4S^+$ 308.0951; found 308.0953.

2-(3-Methyl-9-(methylsulfonyl)-1,3,4,9-tetrahydropyrano[3,4-*b*]indol-4-yl)acetaldehyde (2ab)

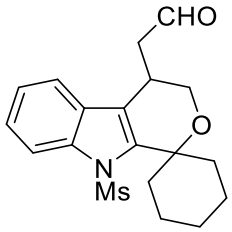


2ab (d.r.= 2.2:1)

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2ab** was obtained as a yellow oil (0.041 g, 67%): R_f = 0.50 (PE/EtOAc = 2:1); major isomer: ^{1}H NMR ($CDCl_3$, 400 MHz): 9.88 (s, 1H), 7.99 – 7.93 (m, 1H), 7.48 – 7.42 (m, 1H), 7.38 – 7.28 (m, 2H),

5.06 (d, J = 16.8 Hz, 1H), 4.93 – 4.84 (m, 1H) 3.97 – 3.89 (m, 1H), 3.48 – 3.48 (m, 1H), 3.06 – 3.00 (m, 3H), 2.94 (dd, J = 16.9, 7.0 Hz, 2H), 1.30 (d, J = 6.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 201.4, 136.2, 133.2, 128.6, 125.1, 124.1, 119.9, 118.6, 113.9, 73.1, 65.2, 43.5, 40.5, 32.0, 18.5; minor isomer: ^{1}H NMR ($CDCl_3$, 400 MHz): 9.86 (s, 1H), 7.99 – 7.93 (m, 1H), 7.48 – 7.42 (m, 1H), 7.38 – 7.28 (m, 2H), 4.93 – 4.84 (m, 2H) 4.05 – 3.97 (m, 1H), 3.34 – 3.28 (m, 1H), 3.06 – 3.00 (m, 3H), 2.72 – 2.64 (m, 2H), 1.33 (d, J = 6.4 Hz, 3H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 200.9, 136.2, 132.7, 129.1, 125.0, 124.0, 118.8, 116.8, 113.9, 72.9, 60.0, 47.1, 33.0, 17.3 (one carbon missing due to overlap); IR (neat): 3130, 1717, 1628, 1234, 1166 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{15}H_{18}NO_4S^+$ 308.0951; found 308.0950.

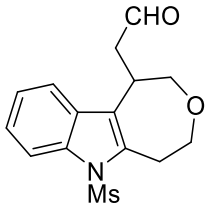
2-(9'-(Methylsulfonyl)-4',9'-dihydro-3'*H*-spiro[cyclohexane-1,1'-pyrano[3,4-*b*]indol]-4'-yl)acetaldehyde (2ac)



2ac

Following general procedure B, after flash column chromatography (PE/EtOAc = 2:1), **2ac** was obtained as an amorphous orange solid (0.050 g, 70%): R_f = 0.68 (PE/EtOAc = 2:1); m.p. 130-131 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.86 (s, 1H), 8.09 (d, J = 8.1 Hz, 1H), 7.41 (d, J = 7.4 Hz, 1H), 7.36 – 7.26 (m, 2H), 3.97 (d, J = 11.8 Hz, 1H), 3.79 (d, J = 11.8 Hz, 1H), 3.44 (d, J = 9.0 Hz, 1H), 3.00 (dd, J = 18.0, 9.3 Hz, 1H), 2.91 (s, 3H), 2.86 – 2.71 (m, 2H), 2.54 – 2.42 (m, 1H), 1.95 (d, J = 13.9 Hz, 1H), 1.84 – 1.48 (m, 6H), 1.45 – 1.30 (m, 1H); $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz): 201.2, 142.6, 137.8, 128.7, 125.7, 124.4, 121.2, 118.7, 115.9, 76.8, 61.6, 46.6, 39.9, 35.3, 29.9, 29.0, 24.6, 21.82, 21.76; IR (neat): 2929, 2858, 1721, 1448, 1402, 1172 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{19}H_{24}NO_4S^+$ 362.1421; found 362.1418.

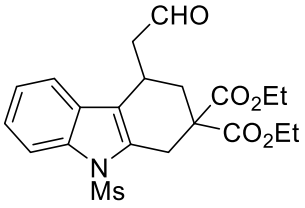
2-(6-(Methylsulfonyl)-1,4,5,6-tetrahydro-2*H*-oxepino[4,5-*b*]indol-1-yl)acetaldehyde (2ad)



2ad

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2ad** was obtained as an amorphous orange solid (0.043 g, 69%): R_f = 0.40 (PE/EtOAc = 2:1); m.p. 137-138 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.81 (s, 1H), 8.07 – 7.99 (m, 1H), 7.50 – 7.43 (m, 1H), 7.35 – 7.29 (m, 2H), 4.34 – 4.26 (m, 1H), 4.26 – 4.19 (m, 1H), 3.78 – 3.66 (m, 3H), 3.58 (t, *J* = 12.1 Hz, 1H), 3.26 – 3.07 (m, 2H), 2.98 (s, 3H), 2.69 (dd, *J* = 17.3, 4.9 Hz, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.9, 137.2, 136.3, 129.6, 125.0, 124.5, 124.2, 118.3, 115.1, 73.9, 71.0, 45.7, 40.9, 32.3, 30.4; IR (neat): 2931, 1717, 1628, 1448, 1154 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{15}H_{18}NO_4S^+$ 308.0951; found 308.0950.

Diethyl 9-(methylsulfonyl)-4-(2-oxoethyl)-1,3,4,9-tetrahydro-2*H*-carbazole-2,2-dicarboxylate (2ae)

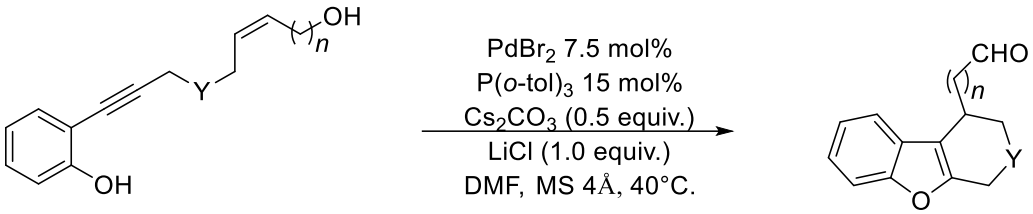


2ae

Following general procedure B, after flash chromatography (PE/EtOAc = 2:1), **2ae** was obtained as an amorphous orange solid (0.053 g, 61%): R_f = 0.57 (PE/EtOAc = 2:1); m.p. 137-139 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.84 (s, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.39 (d, *J* = 7.5 Hz, 1H), 7.32 – 7.21 (m, 2H), 4.22 (q, *J* = 7.1 Hz, 2H), 4.18 – 4.07 (m, 2H), 3.69 (d, *J* = 17.6 Hz, 1H), 3.60 (d, *J* = 6.9 Hz, 1H), 3.26 (dd, *J* = 17.6, 2.0 Hz, 1H), 3.19 – 3.08 (m, 4H), 2.82 (dd, *J* = 13.8, 6.4 Hz, 1H), 2.65 (dd, *J* = 17.8, 9.5 Hz, 1H), 2.06 (dd, *J* = 13.8, 8.8 Hz, 1H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.20 (t, *J* = 7.2 Hz, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 200.6, 171.1, 170.4, 136.9, 133.8, 128.4, 124.7, 123.8, 119.2, 118.0, 114.6, 62.3, 62.1, 54.3, 48.4, 41.1, 34.5, 30.4,

25.9, 14.2 (one carbon missing due to overlap); IR (neat): 2966, 1729, 1628, 1225, 1169 cm^{-1}; HRMS(ESI) m/z : $[M+H]^+$ calculated for $C_{21}H_{26}NO_7S^+$ 436.1425; found 436.1424.

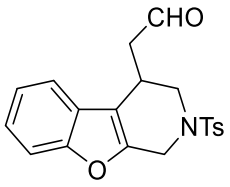
3.2 General Procedure C for the Synthesis of Tetrahydro-*β*-carbolines.



1 **2**

A suspension of LiCl (0.20 mmol, 1.0 equiv.), $PdBr_2$ (0.015 mmol, 0.075 equiv.), P(*o*-tol)$_3$ (0.03 mmol, 0.15 equiv.), Cs_2CO_3 (0.1 mmol, 0.5 equiv.) in DMF (4.0 mL) was stirred at room temperature under air (balloon) for 0.5 h. Then 2-(Hydroxyalkenynyl)phenol **1** (0.2 mmol) and MS 4Å (0.150 g) was added and the resulting mixture was heated at 40 °C in a heating block under air (balloon). The progress of the reaction was monitored by TLC analysis to establish its completion. The completed reaction was diluted with ethyl acetate (30 mL) and washed with water (2 x 10 mL) and brine (10 mL). The organic layer was dried ($MgSO_4$), filtered and concentrated. The residue was purified by column chromatography (Silica Gel, petroleum ether/ethyl acetate).

2-(2-Tosyl-1,2,3,4-tetrahydrobenzofuro[2,3-*c*]pyridin-4-yl)acetaldehyde (2af)



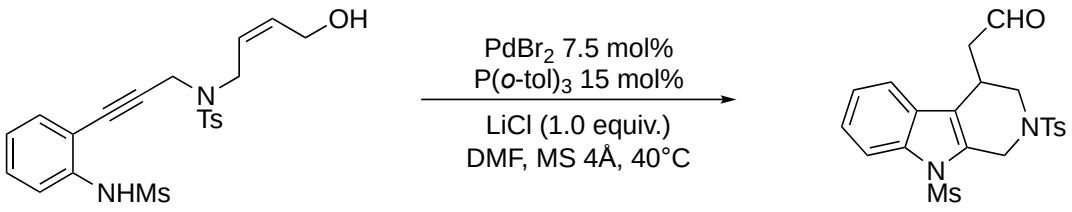
2af

Following general procedure C, after flash column chromatography (PE/EtOAc = 2:1), **2af** was obtained as an amorphous orange solid (0.028 g, 38%): R_f = 0.61 (PE/EtOAc = 2:1); m.p. 121-122 °C; ^1H NMR ($CDCl_3$, 400 MHz): 9.86 (s, 1H), 7.71 (d, *J* = 7.8 Hz, 2H), 7.42 – 7.37 (m, 2H), 7.33 (d, *J* = 7.8 Hz, 2H), 7.26 – 7.17 (m, 2H), 4.66 (d, *J* = 15.2 Hz, 1H), 3.90 (d, *J* = 15.2 Hz, 1H), 3.78 (d, *J* = 12.4 Hz, 1H), 3.58 (d, *J* = 4.1 Hz, 1H), 3.05 – 2.84 (m, 3H), 2.42 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 101 MHz): 200.8, 155.2, 148.7, 144.3, 133.9, 130.1, 127.8, 126.4, 124.5, 123.2, 119.1, 114.6, 111.7, 48.5, 46.5, 44.0, 26.8, 21.7; IR (neat): 1720, 1629, 1449,

1346, 1164 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{20}H_{20}NO_4S^+$ 370.1108; found 370.1108.

4. Scale-up Reactions and Synthetic Transformations

4.1. Scale-up of Tetrahydro-*β*-carbolines 2a

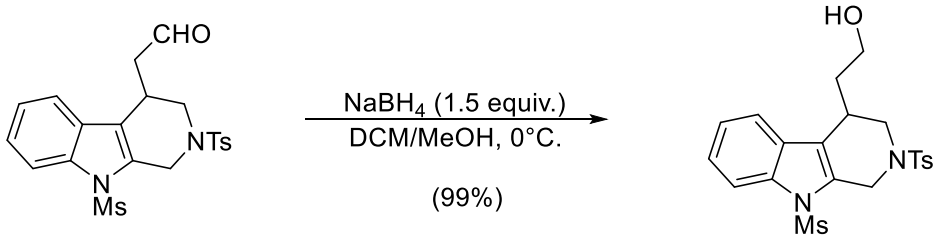


1a (1 mmol) **2a**

To a 50 mL round-bottom flask was added LiCl (0.042 g, 1.0 mmol, 1.0 equiv.), $PdBr_2$ (0.020 g, 0.075 mmol, 0.075 equiv.), P(*o*-tol)$_3$ (0.046 g, 0.15 mmol, 0.15 equiv.) and DMF (20.0 mL) and the suspension was stirred at room temperature for 0.5 h under air. Then 2-(Hydroxyalkenynyl)sulfonanilides **1a** (0.449 g, 1.0 mmol) and MS 4Å (0.750 g) were added and the reaction mixture was heated at 40 °C in an oil bath under air (balloon) for 48 h. The completed reaction was diluted with ethyl acetate (100 mL), washed with water (2 x 15 mL) and brine (15 mL), dried ($MgSO_4$), filtered and concentrated. The residue was purified by column chromatography (Silica Gel, PE/EtOAc = 2/1) to afford **2a** (0.358 g, 80%).

4.2 Synthetic Transformation of 2a.

2-(9-(Methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)ethan-1-ol (3)

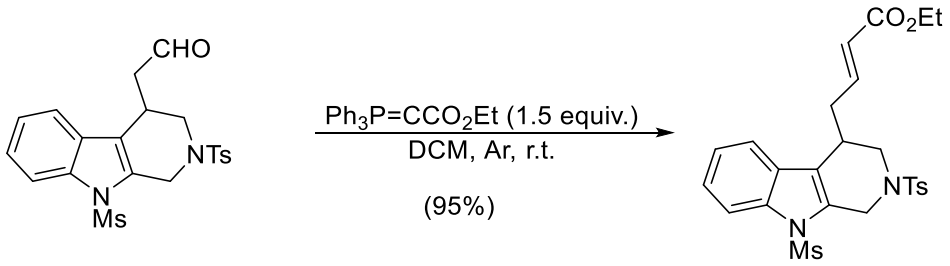


2a **3**

2a (0.045 g, 0.1 mmol) was dissolved in MeOH/CH_2Cl_2 (1:1 v/v, 0.025 M) and the solution was cooled to 0 ℃. Sodium borohydride (0.0057 g, 0.15 mmol, 1.5 equiv.) was added, and the resulting mixture was stirred for 30 min. Solvent was removed under reduced pressure. The

residue was diluted with diethyl ether (45 mL), washed with water (10 mL), dried (Na_2SO_4), and concentrated. After column chromatography (Silica Gel, PE/EtOAc=2/1), **3** was obtained as an amorphous colorless solid (0.045 g, 99%): R_f = 0.34 (PE/EtOAc = 1:1); m.p. 182-183 ℃; ^{1}H NMR ($CDCl_3$, 600 MHz): 7.93 (d, *J* = 8.2 Hz, 1H), 7.76 (d, *J* = 8.2 Hz, 2H), 7.58 (d, *J* = 7.5 Hz, 1H), 7.36 (d, *J* = 8.2 Hz, 2H), 7.33 (t, *J* = 7.6 Hz, 1H), 7.29 (t, *J* = 7.5 Hz, 1H), 4.94 (d, *J* = 16.4 Hz, 1H), 4.04 (d, *J* = 12.0 Hz, 1H), 3.97 – 3.90 (m, 2H), 3.89 – 3.84 (m, 1H), 3.29 – 3.24 (m, 1H), 3.07 (s, 3H), 2.78 (dd, *J* = 12.0, 3.5 Hz, 1H), 2.43 (s, 3H), 2.14 – 2.02 (m, 2H), 1.73 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 144.1, 136.1, 133.7, 130.1, 129.7, 128.7, 127.7, 125.1, 124.0, 120.7, 119.2, 113.8, 60.8, 47.1, 44.9, 40.7, 35.4, 29.9, 21.7; IR (neat): 3475, 3130, 3014, 1625, 1165 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{25}N_2O_5S_2^+$ 449.1199; found 449.1199.

Ethyl (*E*)-4-(9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)but-2-enoate (4)

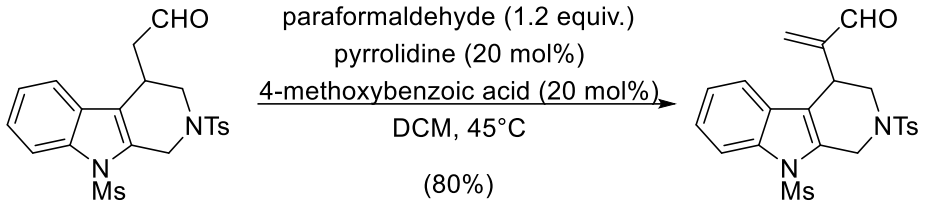


2a **4**

To a solution of **2a** (0.045 g, 0.1 mmol) in CH_2Cl_2 (4.0 mL) was added ethyl (triphenylphosphoranylidene)acetate (0.052 g, 0.15 mmol, 1.5 equiv.). The reaction mixture was stirred at room temperature under argon for 6 h. The completed reaction was concentrated. The residue was purified by column chromatography (Silica Gel, PE/EtOAc = 2/1) to afford *α*, *β*-unsaturated ester **4** as a colorless solid (0.049 g, 95%): R_f = 0.57 (PE/EtOAc = 2:1); m.p. 155-156 ℃; ^{1}H NMR ($CDCl_3$, 600 MHz): 7.94 (d, *J* = 8.2 Hz, 1H), 7.75 (d, *J* = 8.2 Hz, 2H), 7.46 (d, *J* = 7.6 Hz, 1H), 7.37 – 7.32 (m, 3H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.04 (dt, *J* = 15.3, 7.5 Hz, 1H), 6.00 (d, *J* = 15.6 Hz, 1H), 4.92 (d, *J* = 16.5 Hz, 1H), 4.26 – 4.17 (m, 2H), 3.97 (d, *J* = 16.5 Hz, 1H), 3.86 (dd, *J* = 12.1, 1.7 Hz, 1H), 3.13 – 3.07 (m, 4H), 2.79 (dd, *J* = 12.1, 3.7 Hz, 1H), 2.73 – 2.68 (m, 2H), 2.43 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz): 166.5, 145.5, 144.2, 136.1, 133.6, 130.3, 130.1, 128.3, 127.7, 125.3, 124.5, 124.1, 119.2, 119.0,

113.9, 60.5, 46.6, 44.8, 40.8, 35.3, 32.6, 21.7, 14.4; IR (neat): 1713, 1651, 1449, 1369, 1164 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{25}H_{29}N_2O_6S_2^+$ 517.1462; found 517.1462.

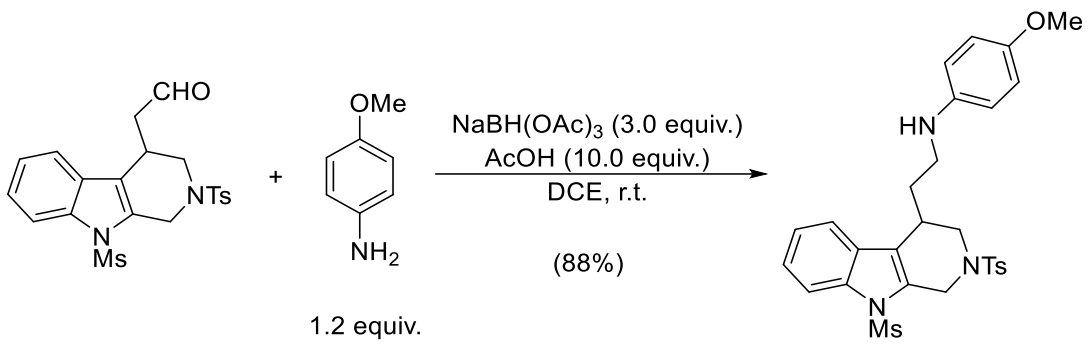
2-(9-(Methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)acrylaldehyde (5)



2a **5**

This compound was prepared by a modified reaction conditions of previous literature[13]. To a solution of 4-methoxybenzoic acid (0.003 g, 0.020 mmol, 0.2 equiv.) and pyrrolidine (0.0014 g, 0.02 mmol, 0.2 equiv.) in DCM (2 mL) were added paraformaldehyde (0.0036 g, 0.12 mmol, 1.2 equiv.) and **2a** (0.045 g, 0.1 mmol, 1.0 equiv.). The resulting mixture was heated at 45 ℃ in an oil bath for 6 h. The reaction mixture was quenched with 2N HCl (2 mL) and extracted with ethyl acetate (2 x 20 mL). The combined organic layers were dried (Na_2SO_4) and concentrated. The residue was purified by column chromatography (Silica Gel, PE/EtOAc = 2/1) to afford **5** as an amorphous colorless solid (0.037 g, 80%): R_f = 0.48 (PE/EtOAc = 2:1); m.p. 73-75 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 9.71 (s, 1H), 7.95 (d, *J* = 8.3 Hz, 1H), 7.71 (d, *J* = 8.2 Hz, 2H), 7.37 – 7.31 (m, 3H), 7.25 – 7.18 (m, 2H), 6.22 (s, 1H), 6.05 (s, 1H), 4.97 (d, *J* = 16.7 Hz, 1H), 4.28 – 4.24 (m, 1H), 4.08 – 4.01 (m, 1H), 3.80 (dd, *J* = 12.4, 1.7 Hz, 1H), 3.10 (s, 3H), 3.03 (dd, *J* = 12.4, 4.4 Hz, 1H), 2.43 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 193.6, 147.8, 144.1, 138.2, 136.2, 134.1, 131.8, 130.1, 128.0, 127.6, 125.5, 124.2, 119.3, 117.1, 113.9, 47.6, 44.7, 40.8, 31.3, 21.7; IR (neat): 2919, 2850, 1687, 1597, 1452, 1363, 1235 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{22}H_{23}N_2O_5S_2^+$ 459.1043; found 459.1043.

4-Methoxy-*N*-(2-(9-(methylsulfonyl)-2-tosyl-2,3,4,9-tetrahydro-1*H*-pyrido[3,4-*b*]indol-4-yl)ethyl)aniline (6)

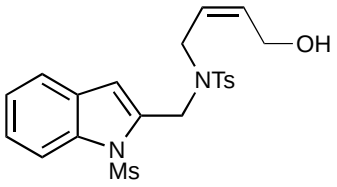


2a **6**

To a solution of **2a** (0.045 g, 0.1 mmol) in 1,2-dichloroethane (10 mL) 0 ℃, were sequential added 4-methoxyaniline (0.015 g, 0.12 mmol, 1.2 equiv.), acetic acid (0.060 g, 1.0 mmol, 10 equiv.) and sodium triacetoxyborohydride (0.064 g, 0.3 mmol, 3.0 equiv.). The resulting mixture was stirred at 0 ℃ for 10 minutes before warming up to room temperature. The reaction was stirred at room temperature overnight. The completed reaction was diluted with ethyl acetate (50 mL), washed with saturated $NaHCO_3$ (10 mL), dried ($MgSO_4$) and concentrated. The residue was purified by column chromatography (PE/EtOAc = 2:1) to afford **6** as an amorphous yellow solid (0.049 g, 88%): R_f = 0.32 (PE/EtOAc = 2:1); m.p. 192-193 ℃; ^{1}H NMR ($CDCl_3$, 400 MHz): 7.93 (d, *J* = 8.3 Hz, 1H), 7.76 (d, *J* = 8.1 Hz, 2H), 7.42 (d, *J* = 7.6 Hz, 1H), 7.36 (d, *J* = 8.1 Hz, 2H), 7.34 – 7.29 (m, 1H), 7.28 – 7.23 (m, 2H), 6.81 (d, *J* = 8.8 Hz, 2H), 6.67 (d, *J* = 8.8 Hz, 2H), 4.94 (d, *J* = 16.5 Hz, 1H), 4.10 – 4.02 (m, 1H), 3.94 (d, *J* = 16.4 Hz, 1H), 3.76 (s, 3H), 3.37 – 3.26 (m, 2H), 3.22 – 3.13 (m, 1H), 3.07 (s, 3H), 2.77 (dd, *J* = 12.0, 3.2 Hz, 1H), 2.43 (s, 3H), 2.24 – 2.04 (m, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 152.5, 144.2, 142.3, 136.0, 133.4, 130.1, 129.7, 128.5, 127.7, 125.1, 124.0, 120.4, 119.0, 115.1, 114.6, 113.8, 56.0, 47.1, 44.9, 43.2, 40.8, 32.3, 31.2, 21.7; IR (neat): 2927, 2840, 1625, 1513, 1450, 1238, 1167 cm^{-1}; HRMS(ESI) m/z : $[M+H]^+$ calculated for $C_{28}H_{32}N_3O_5S_2^+$ 554.1778; found 554.1777.

5. Synthesis of 7

(*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-((1-(methylsulfonyl)-1*H*-indol-2-yl)methyl)benzenesulfonamide (7)



7

To a solution of *N*-(2-iodophenyl)methanesulfonamide[1] (0.118 g, 0.4 mmol, 1.0 equiv.) and $PdCl_2(PPh_3)_2$ (0.014 g, 0.02 mmol, 0.05 equiv.) in Et_3N/THF (1:3 v/v, 1.6 mL) was added (*Z*)-*N*-(4-hydroxybut-2-en-1-yl)-4-methyl-*N*-(prop-2-yn-1-yl)benzenesulfonamide[2] (0.110 g, 0.4 mmol, 1.0 equiv) and CuI (0.004 g, 0.02 mmol, 0.05 equiv.). The reaction mixture was stirred at 50 ℃ in an oil bath for 1.5 h. The completed reaction was diluted with ethyl acetate (20 mL), washed with water (4 mL) and brine (4 mL), dried ($MgSO_4$) and concentrated. After flash column chromatography (PE/EtOAc = 2:1), **7** was obtained as a yellow oil (0.105 g, 59%): R_f = 0.49 (PE/EtOAc = 1:1); ^{1}H NMR ($CDCl_3$, 400 MHz): 7.94 (d, *J* = 7.8 Hz, 1H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.56 – 7.51 (m, 1H), 7.35 – 7.28 (m, 4H), 6.81 (s, 1H), 5.70 (dt, *J* = 13.0, 6.7 Hz, 1H), 5.35 (dt, *J* = 11.1, 7.3 Hz, 1H), 4.70 (s, 2H), 4.07 – 4.00 (m, 4H), 3.04 (s, 3H), 2.44 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz): 143.9, 137.4, 137.1, 136.8, 133.4, 130.0, 129.6, 127.4, 126.1, 125.0, 124.2, 121.3, 114.1, 111.6, 58.0, 45.9, 45.4, 40.6, 21.7; IR (neat): 3026, 2927, 1596, 1452, 1364, 1340 cm^{-1}; HRMS(ESI) m/z: $[M+H]^+$ calculated for $C_{21}H_{25}N_2O_5S_2^+$ 449.1199; found 449.1200.

6. References.

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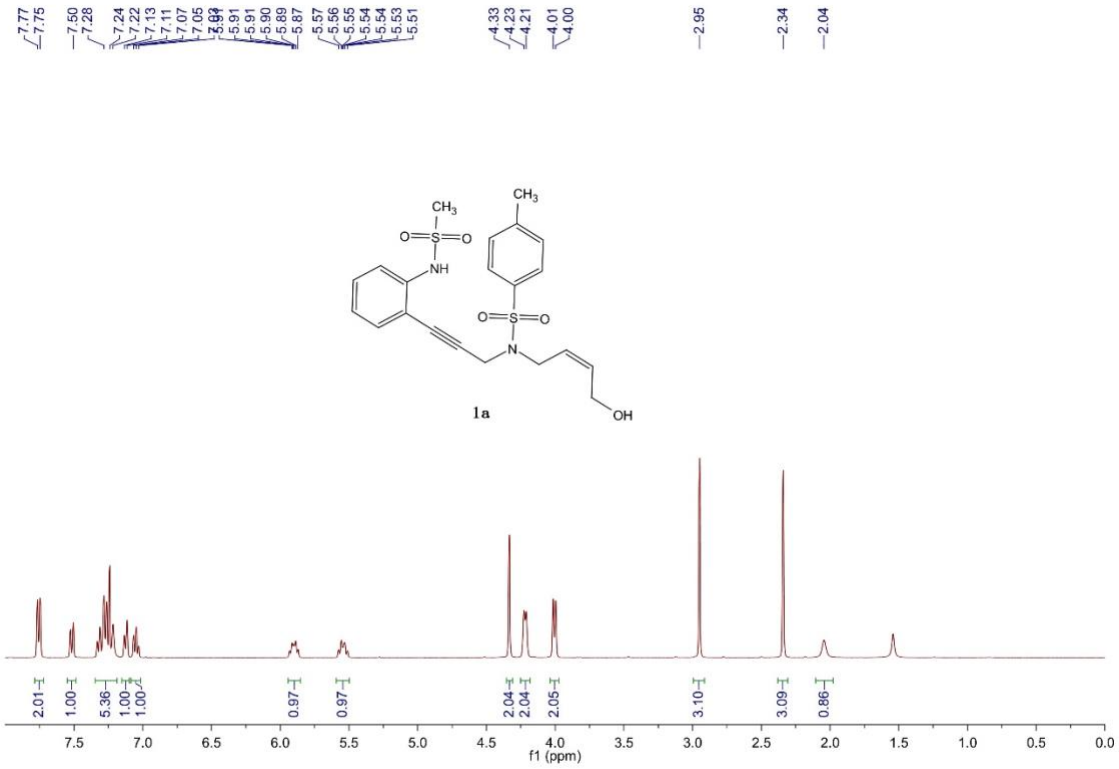
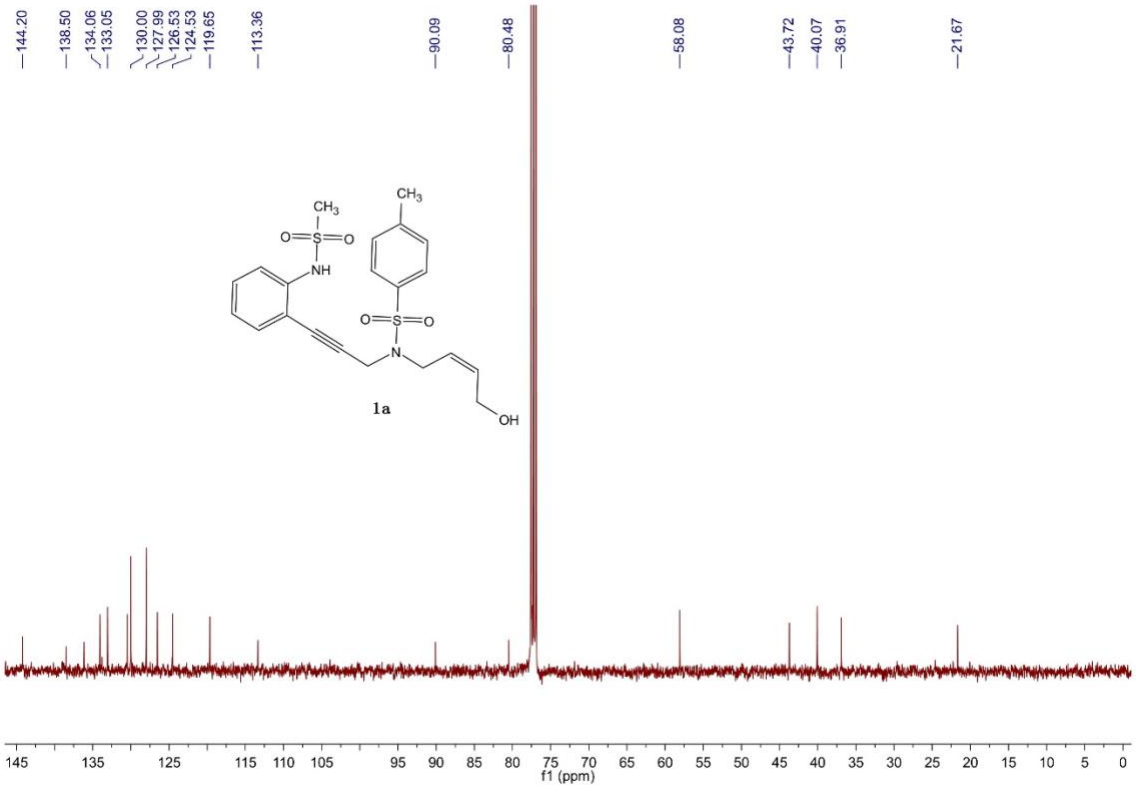
7. ^{1}H NMR, ^{13}C{^{1}H} NMR and ^{19}F NMR Spectral Copies.

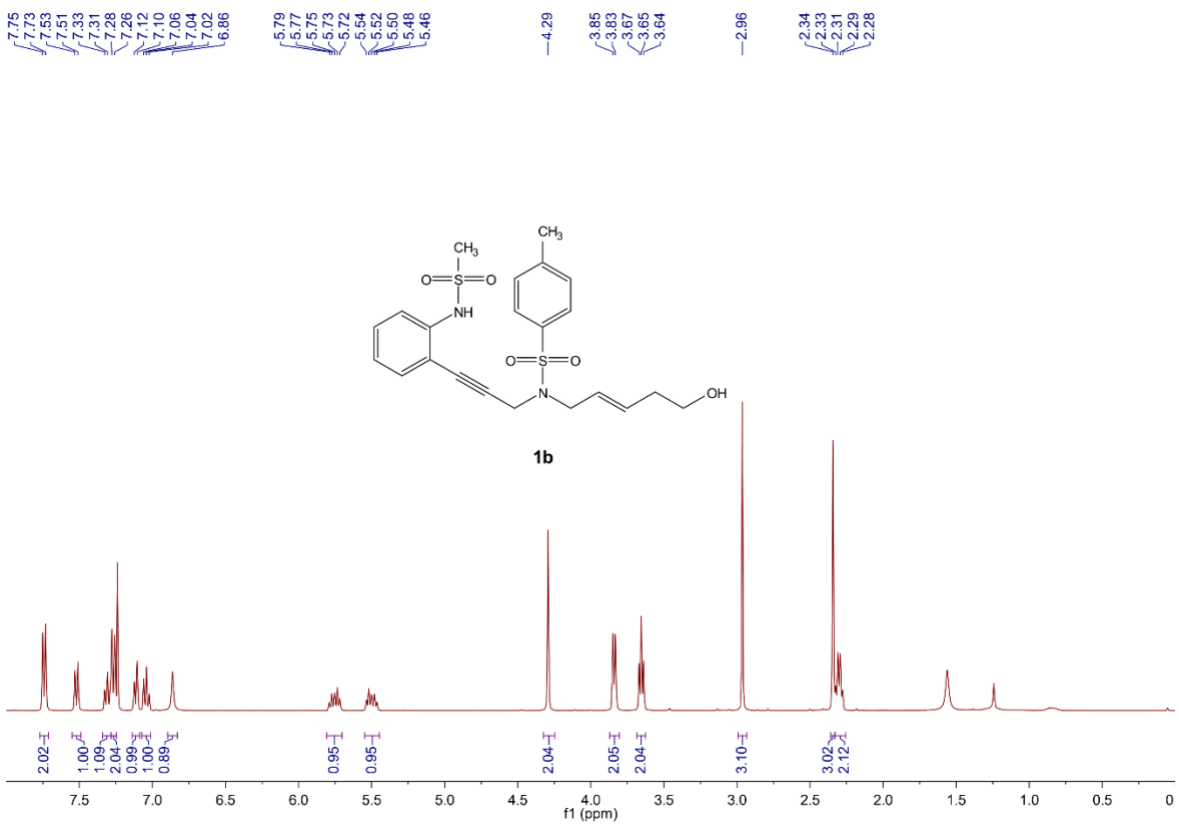
^{1}H NMR ($CDCl_3$, 400MHz) for **1a.**



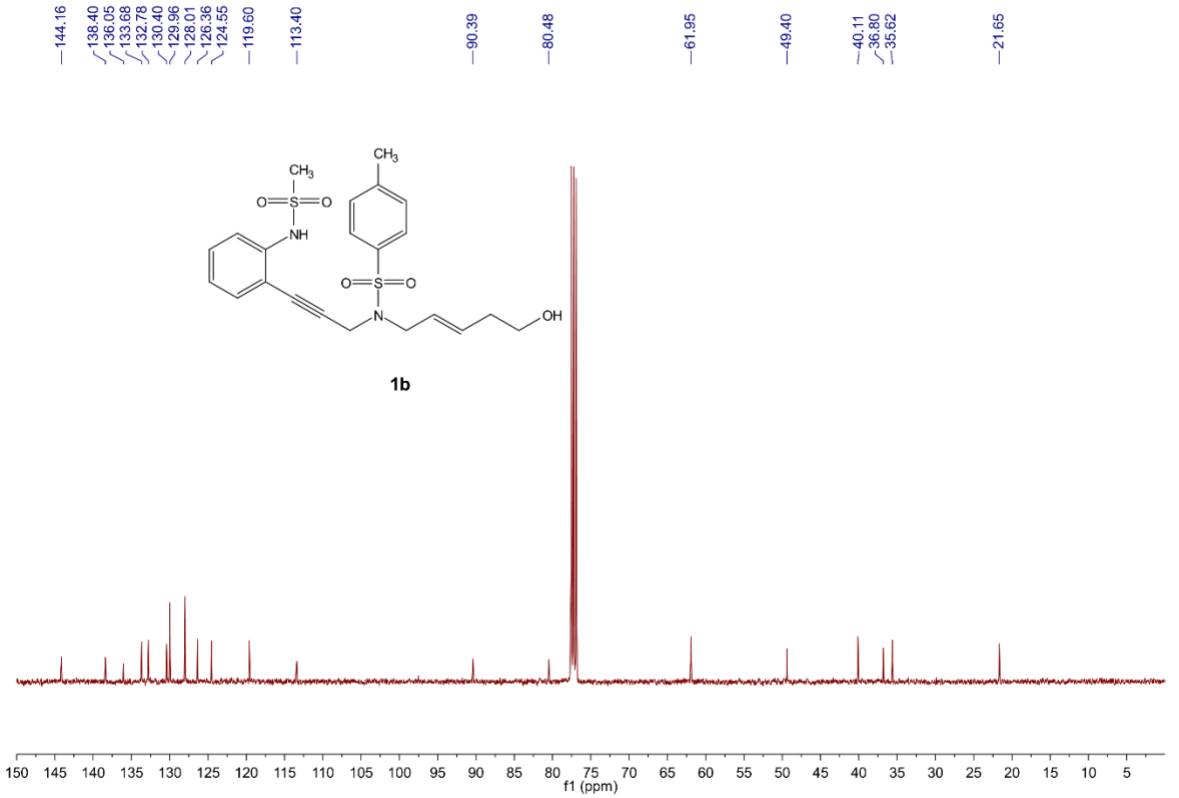
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1a**.



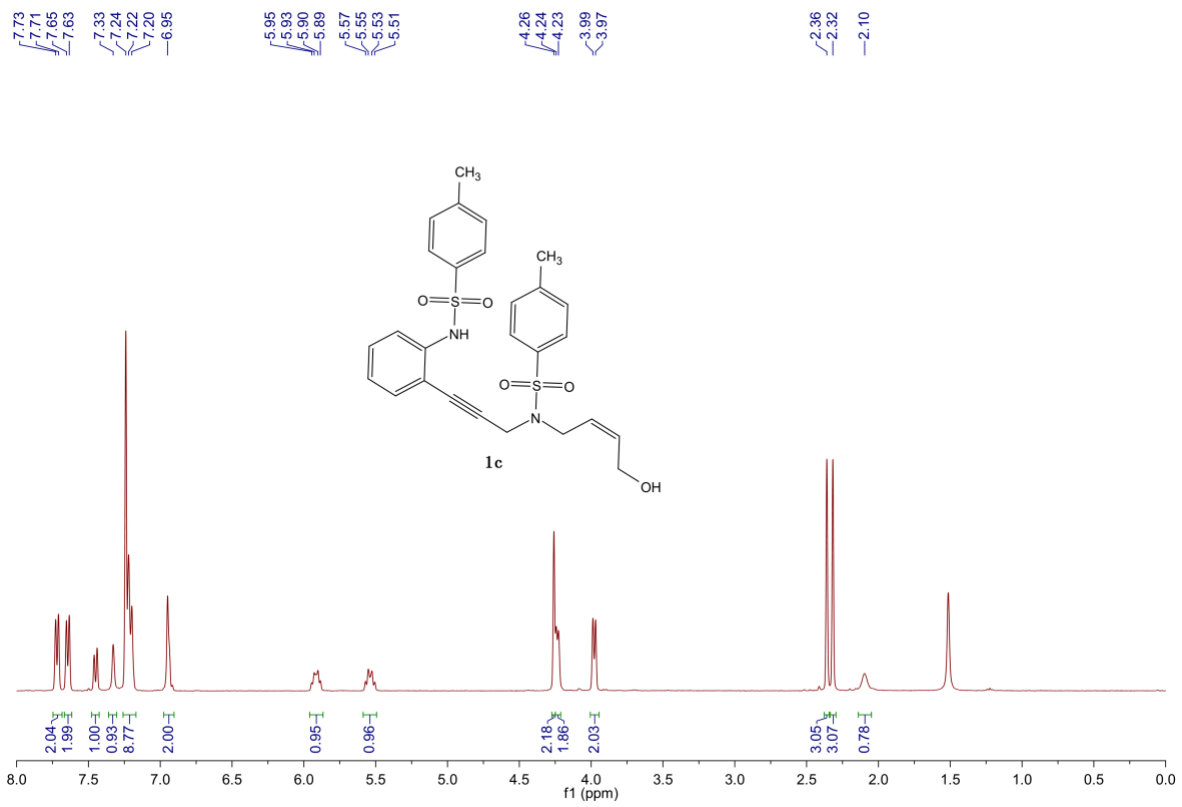
^{1}H NMR ($CDCl_3$, 400MHz) for **1b.**



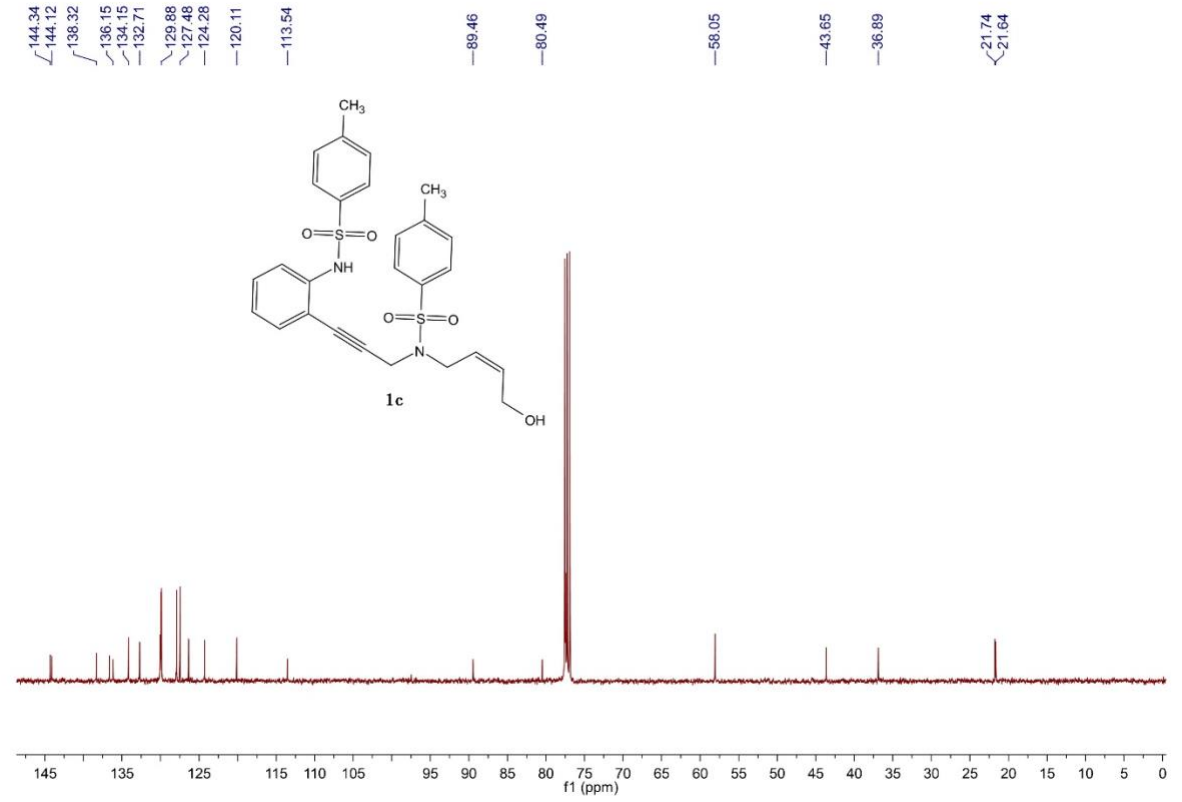
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1b**.



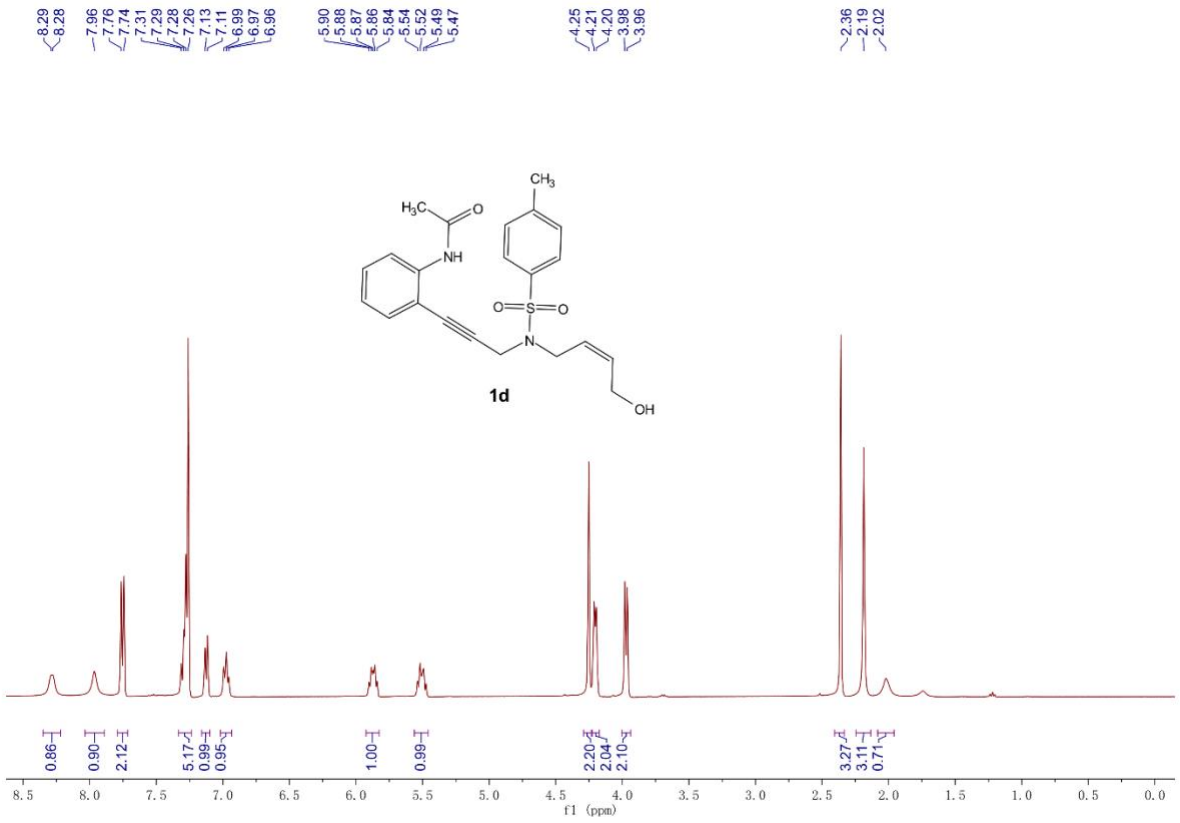
^{1}H NMR ($CDCl_3$, 400MHz) for **1c.**



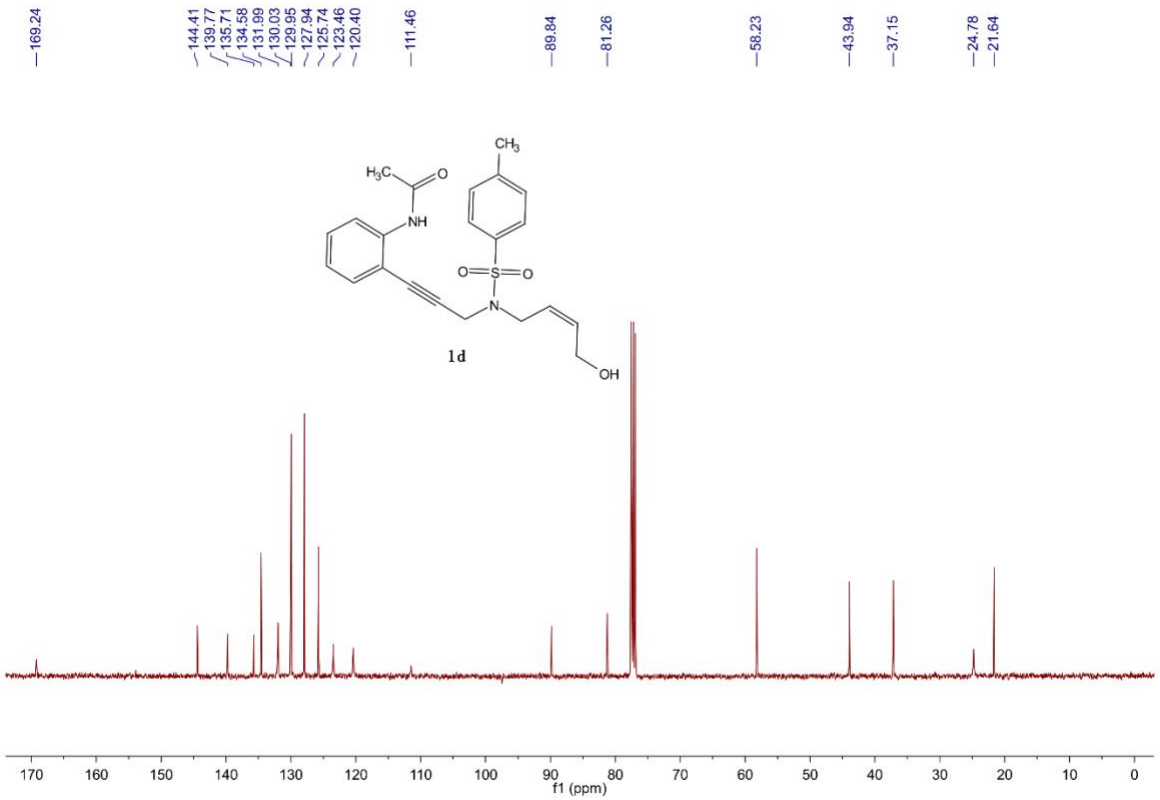
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1c**.



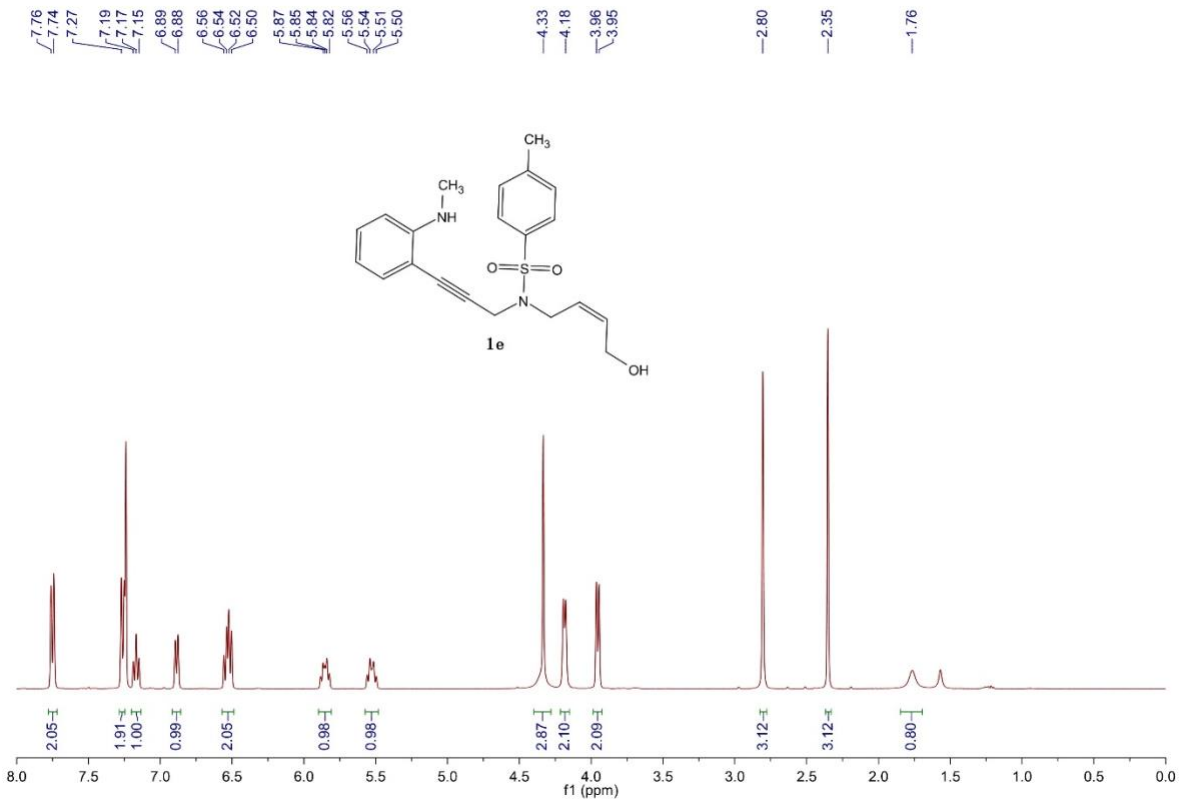
^{1}H NMR ($CDCl_3$, 400MHz) for **1d.**



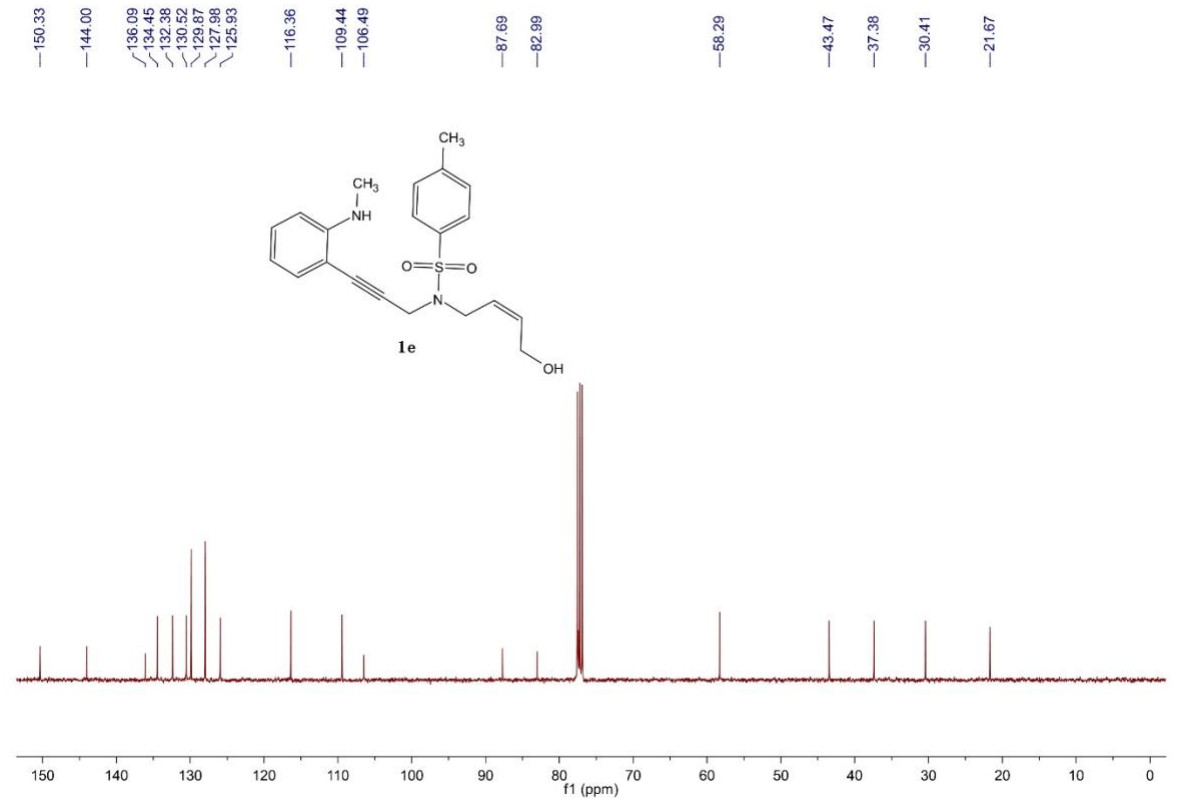
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1d**.



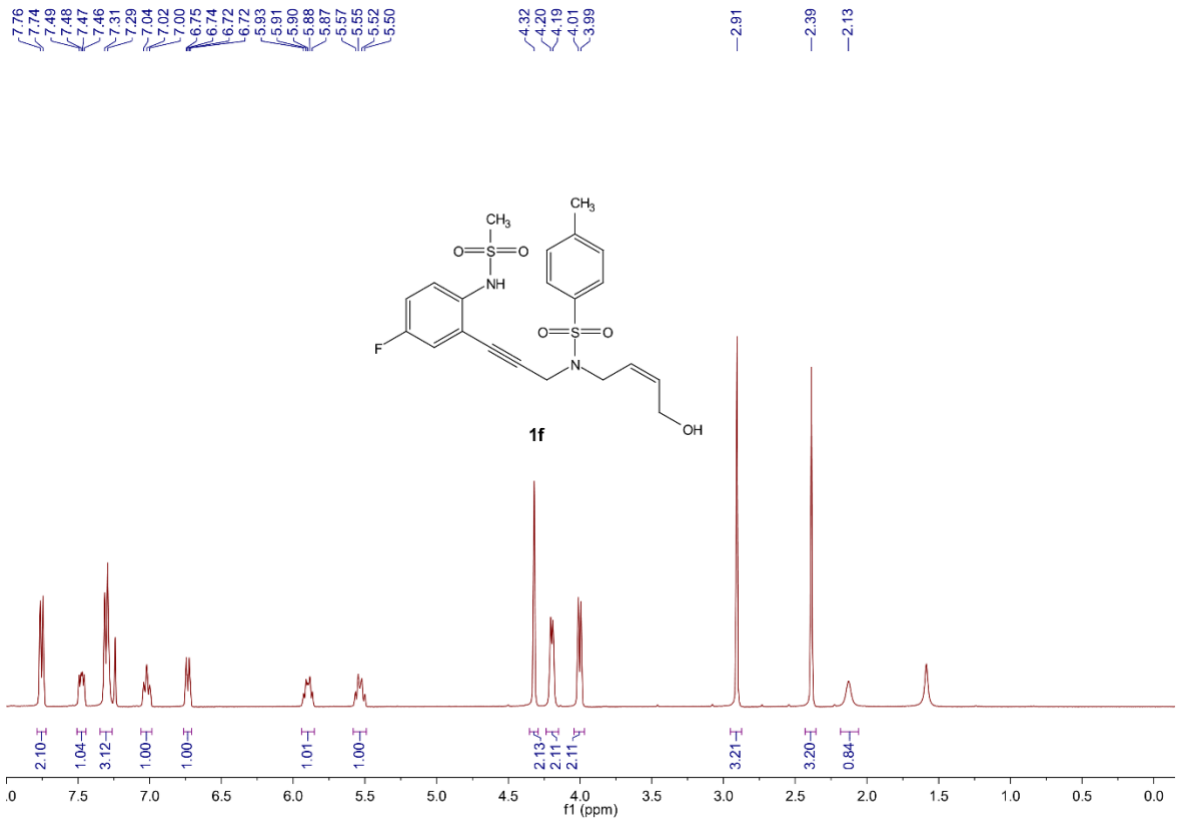
^{1}H NMR ($CDCl_3$, 400MHz) for **1e.**



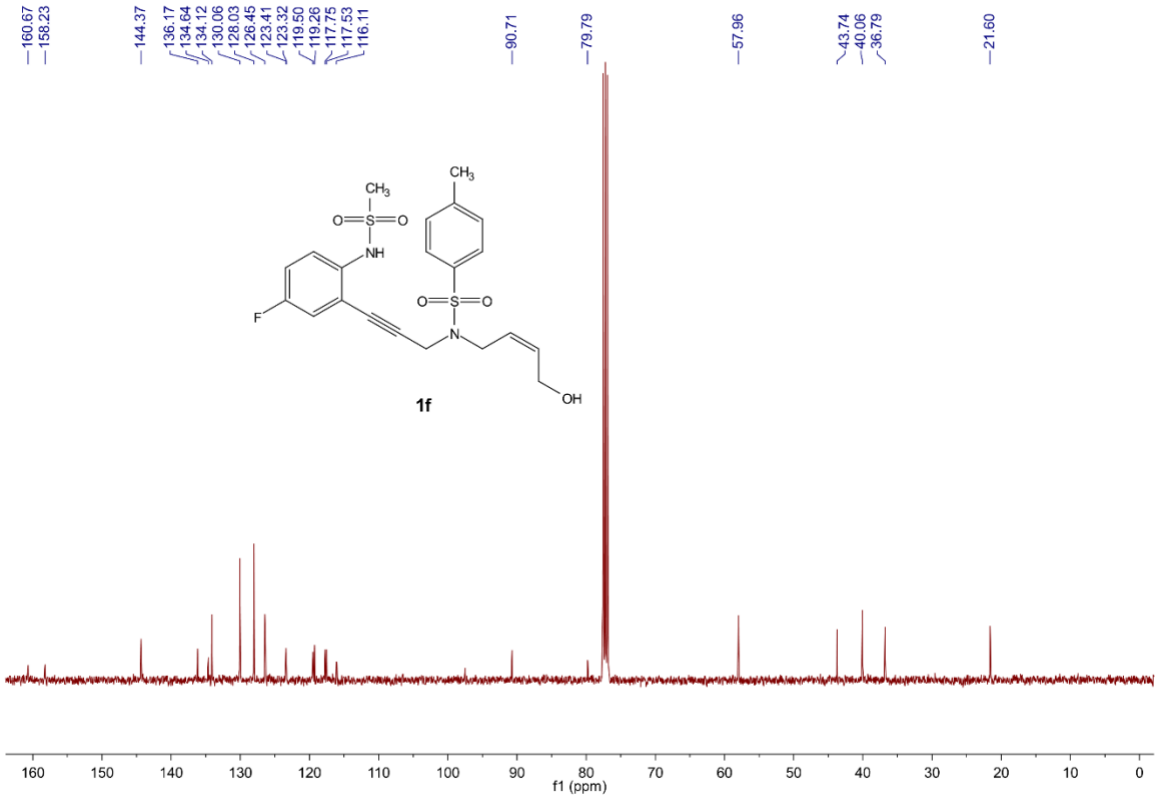
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1e**.



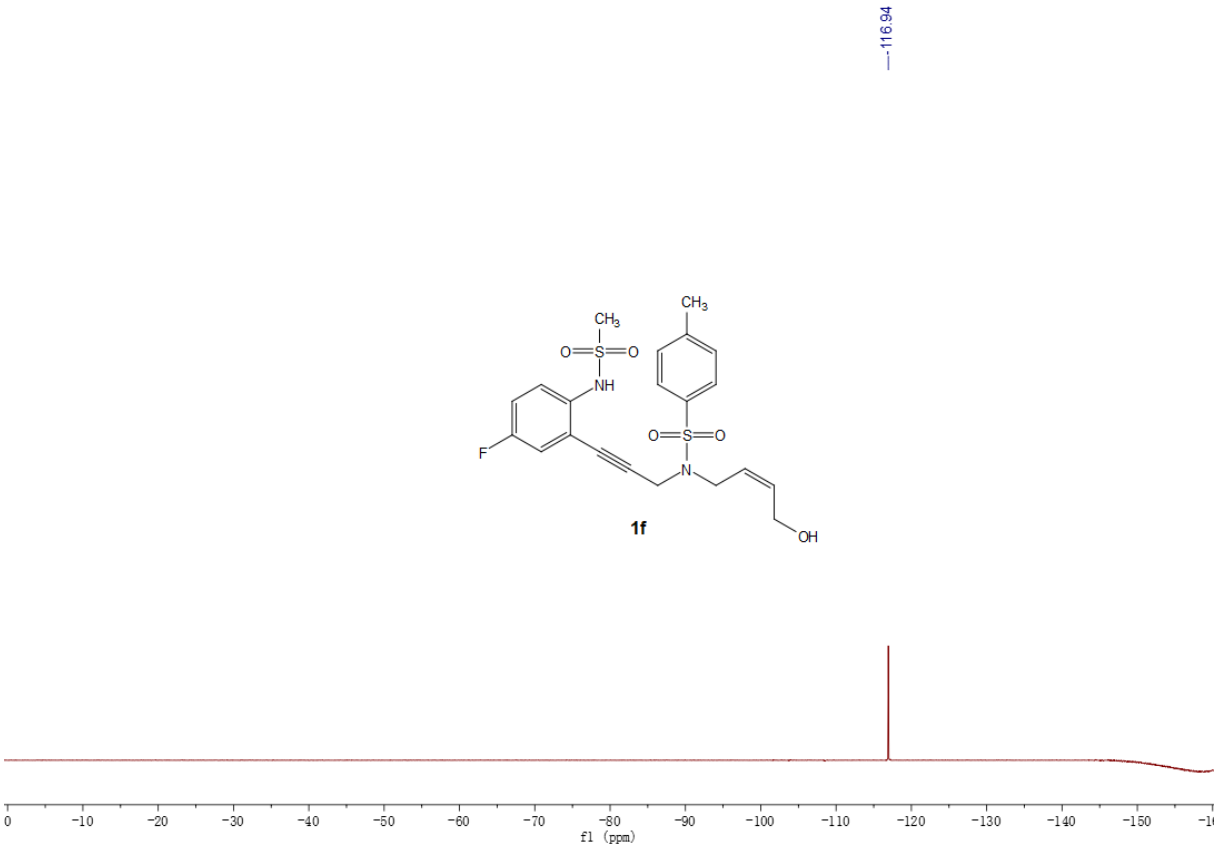
^{1}H NMR ($CDCl_3$, 400MHz) for **1f.**



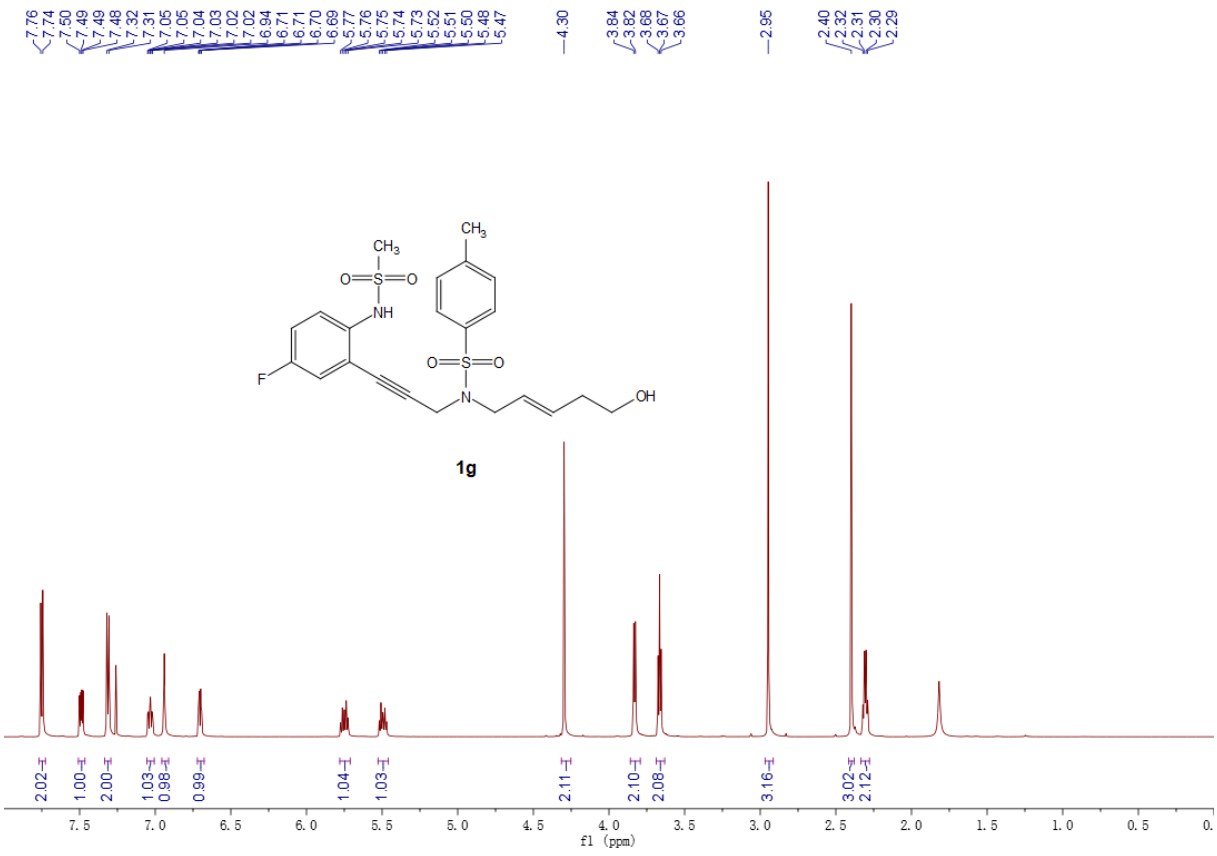
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1f**.



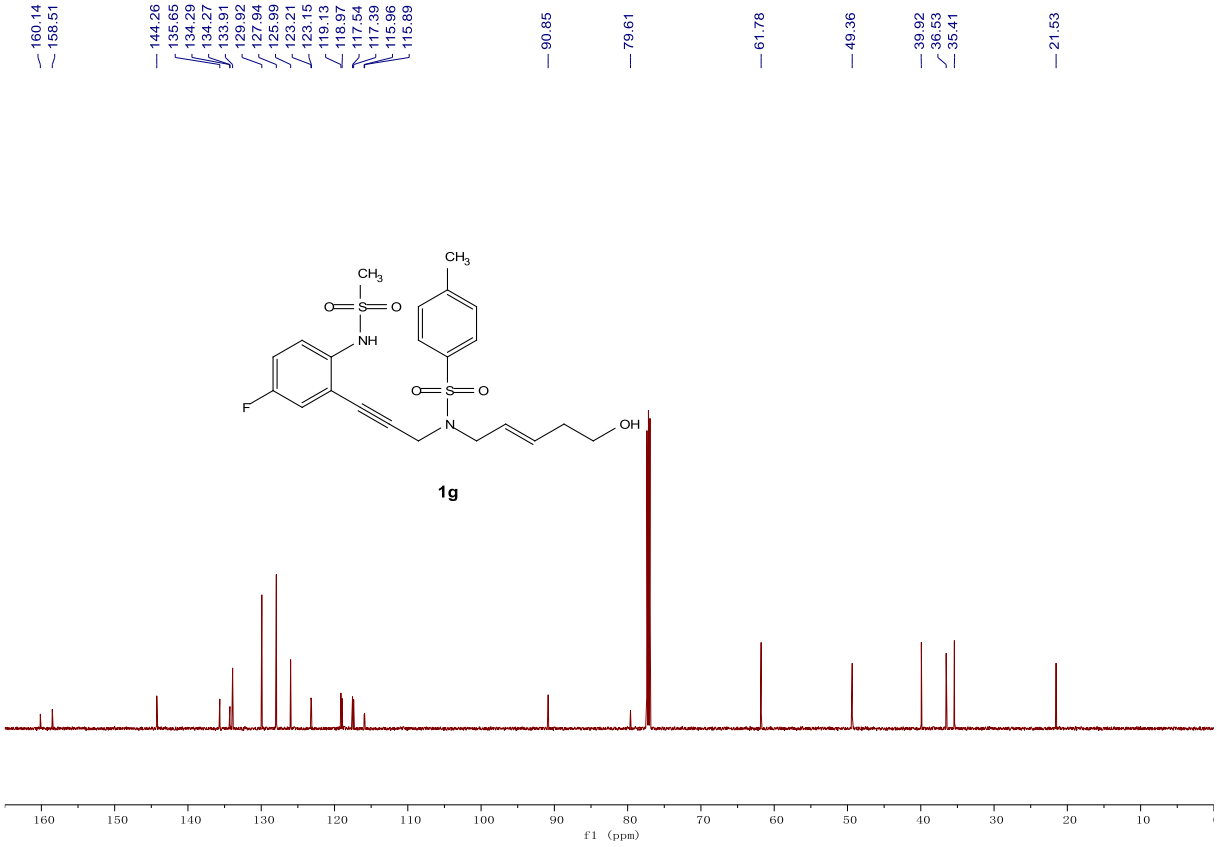
^{19}F NMR ($CDCl_3$, 376 MHz) for **1f**.



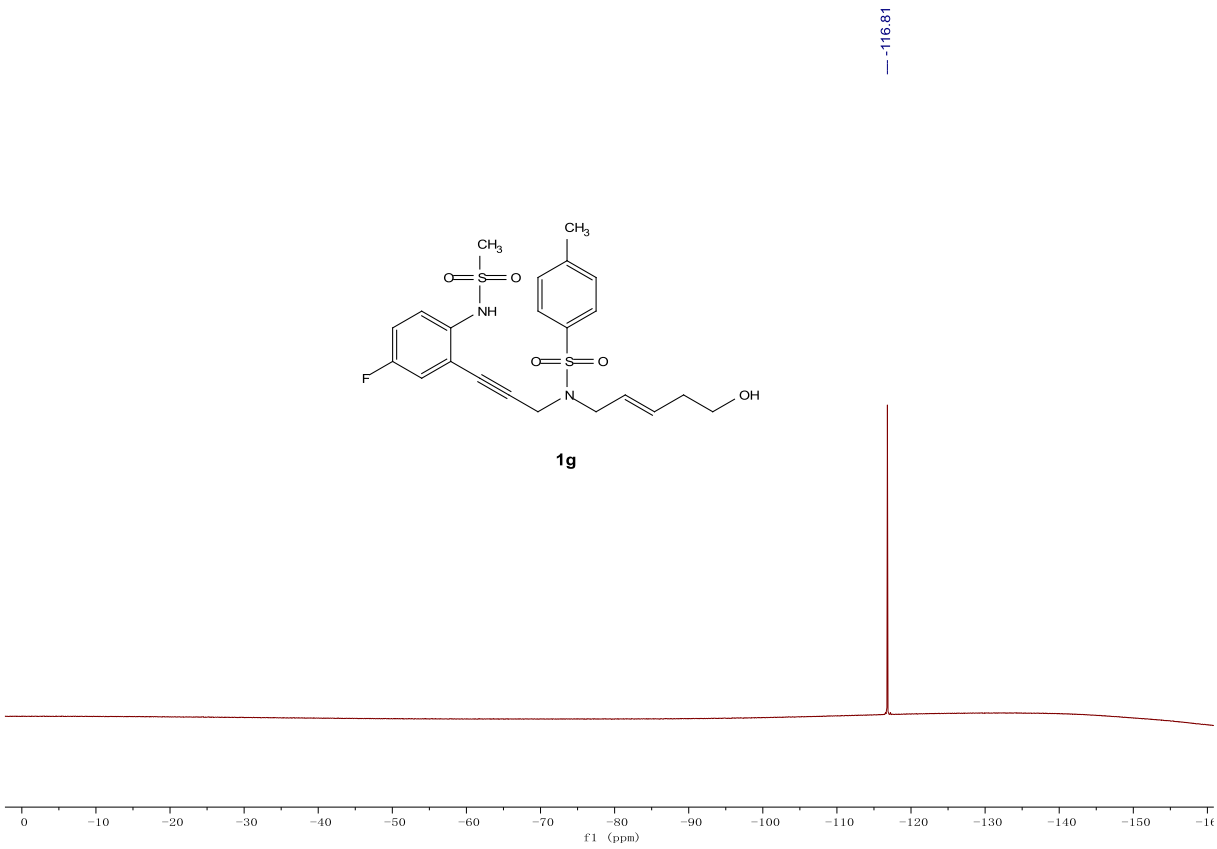
^{1}H NMR ($CDCl_3$, 600MHz) for **1g.**



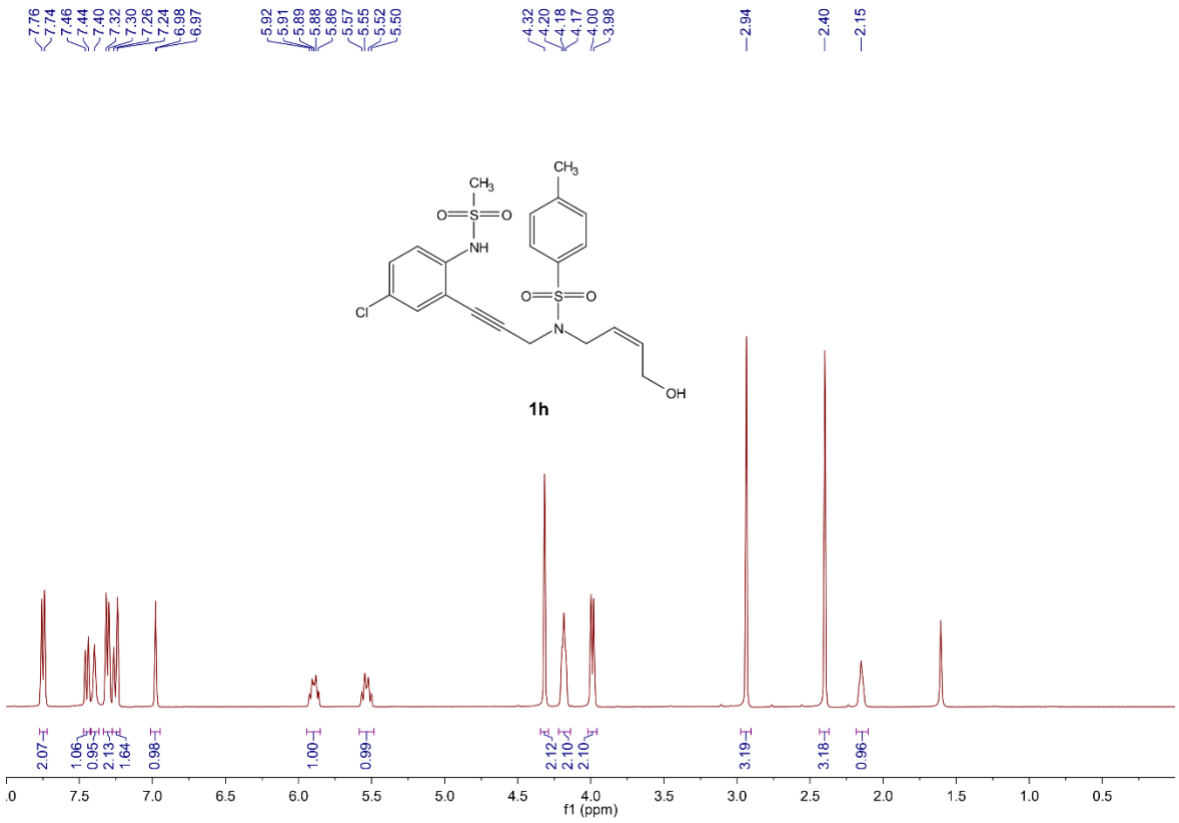
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz) for **1g**.



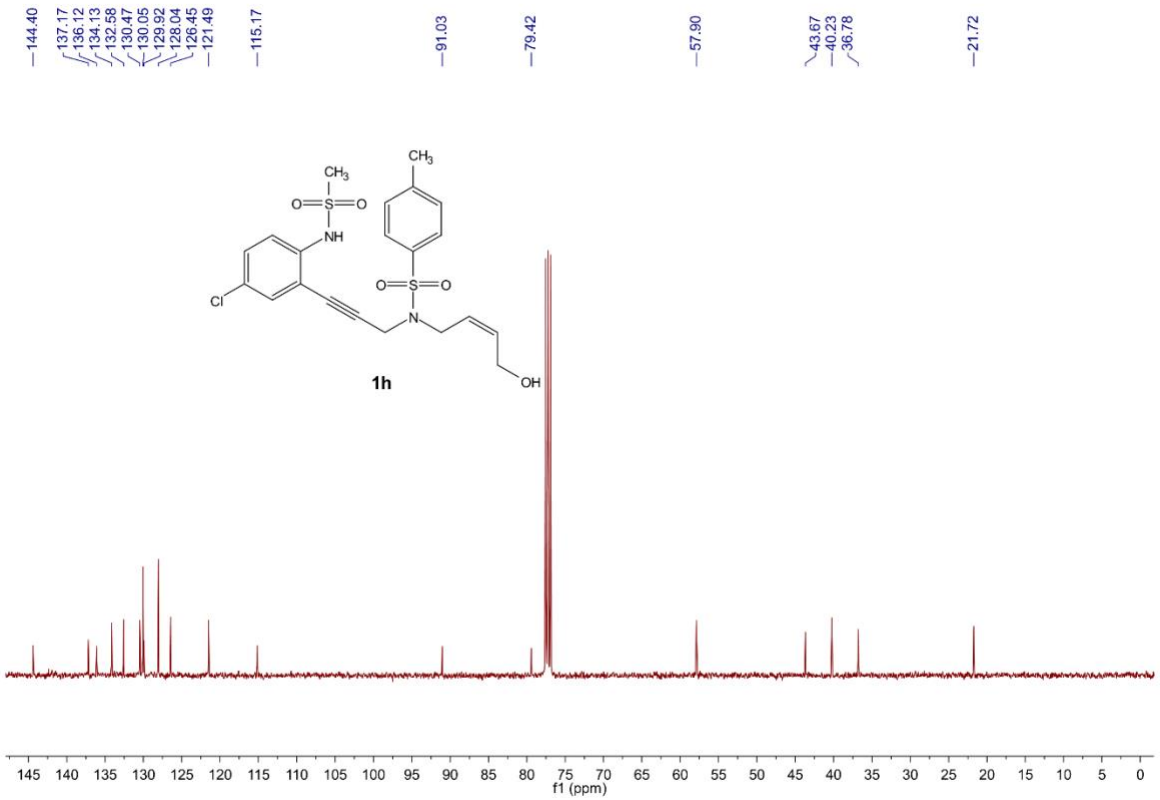
^{19}F NMR ($CDCl_3$, 376 MHz) for **1g**.



^{1}H NMR ($CDCl_3$, 400MHz) for **1h.**

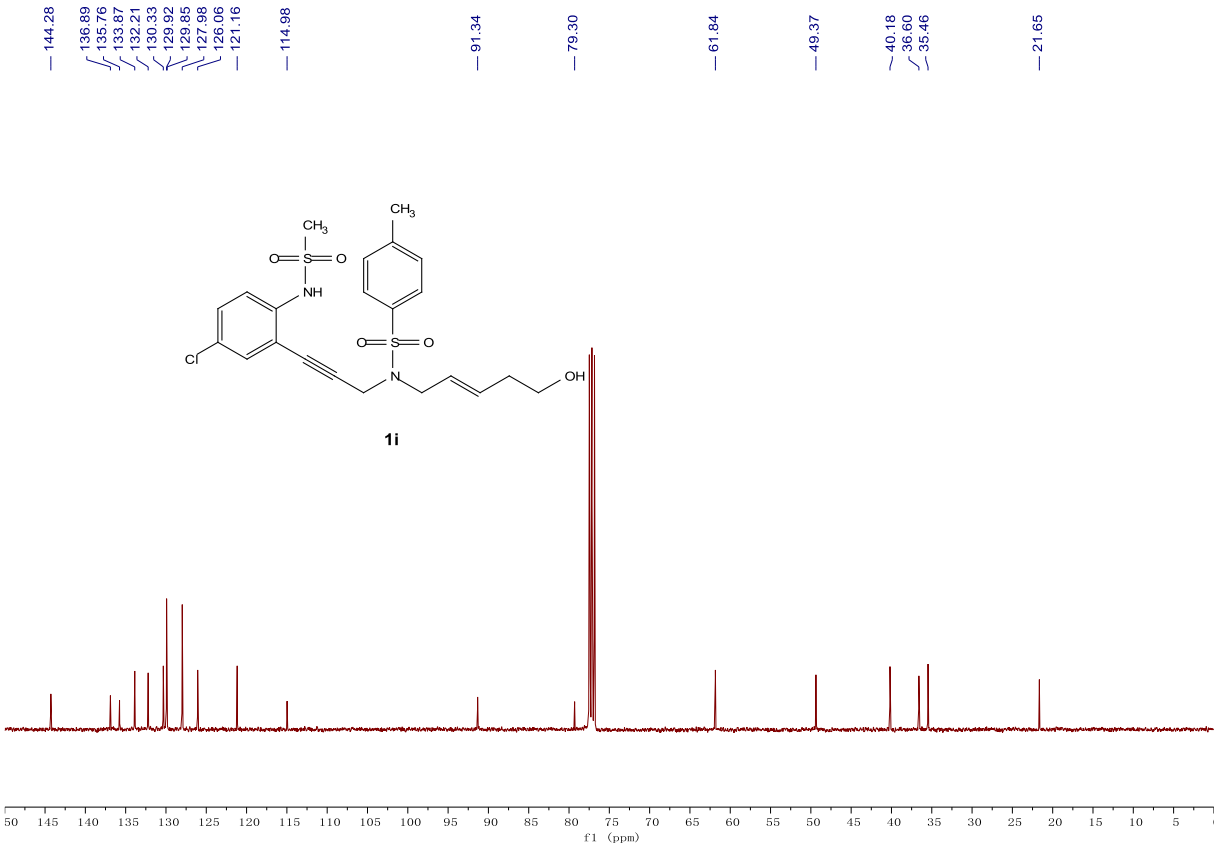


^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1h**.

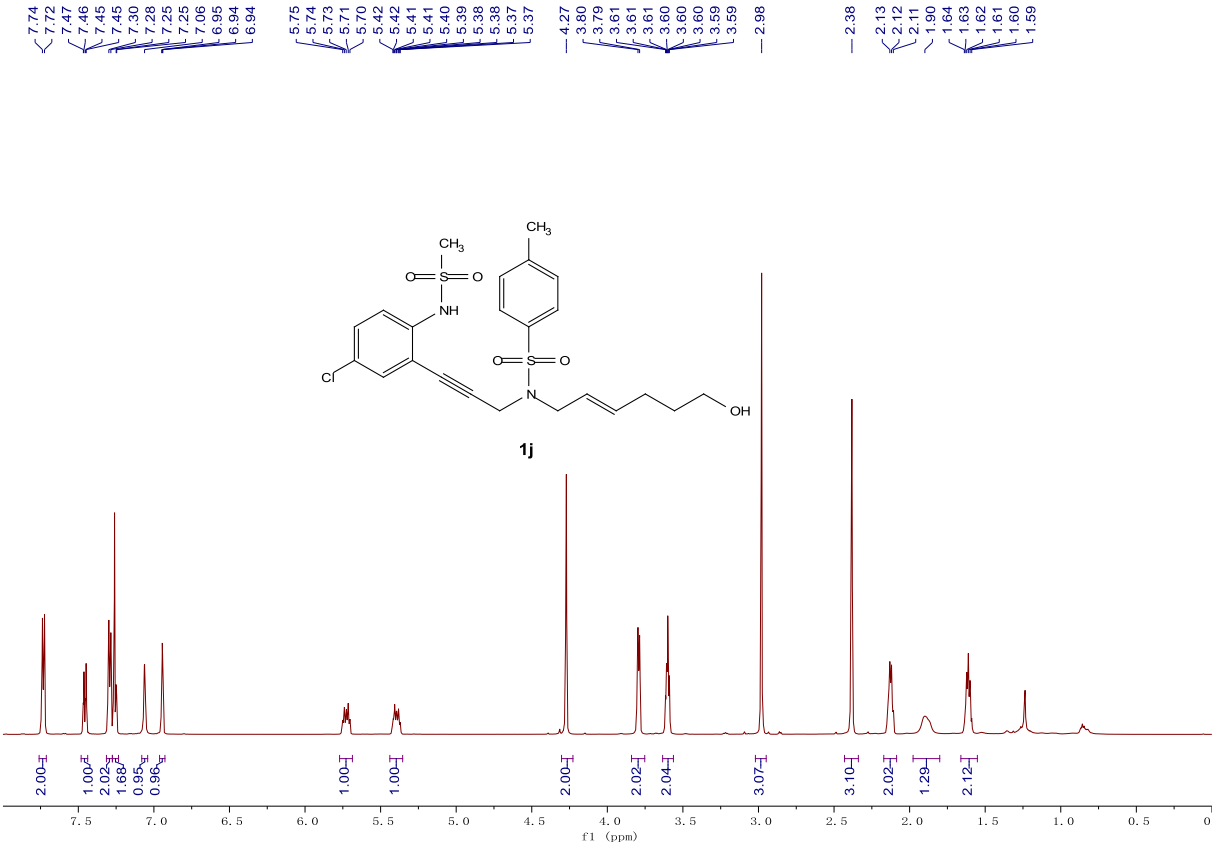


^{1}H NMR ($CDCl_3$, 400MHz) for **1i.**

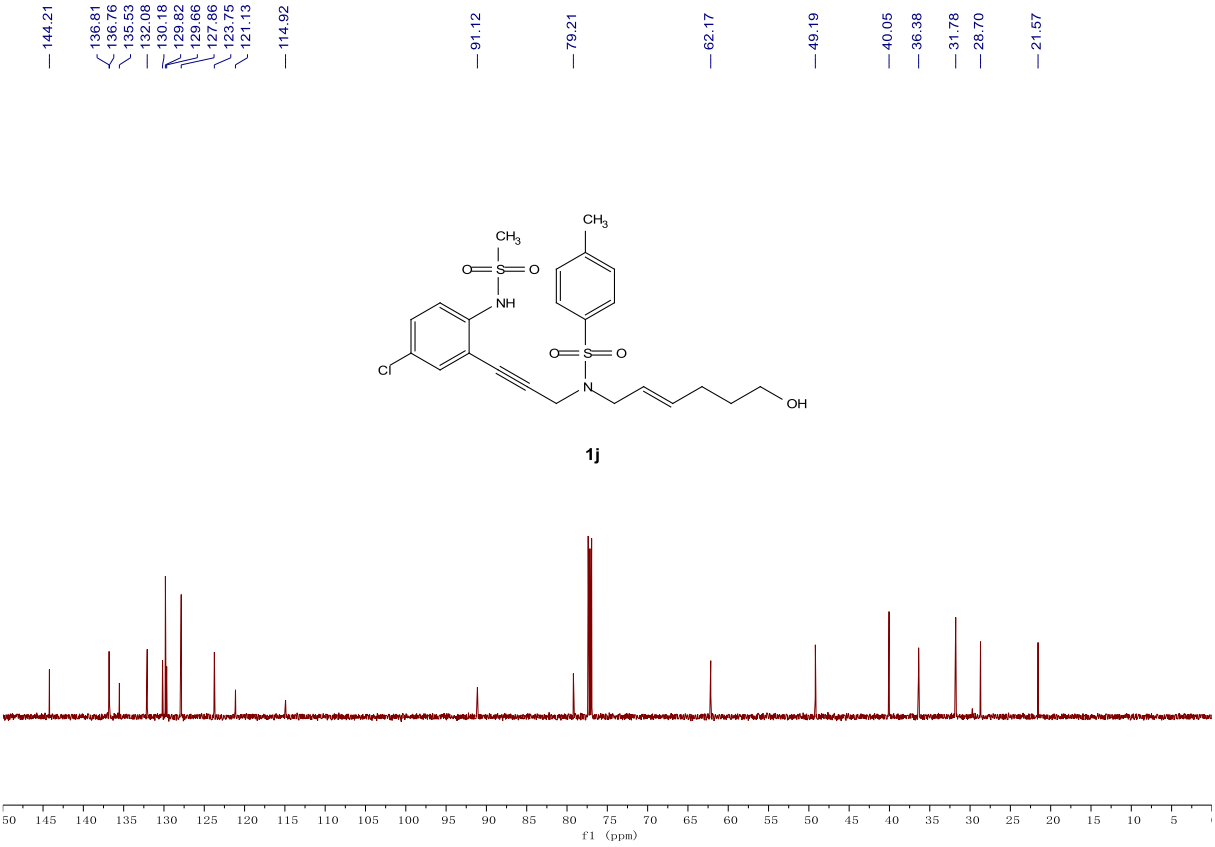
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1i**.



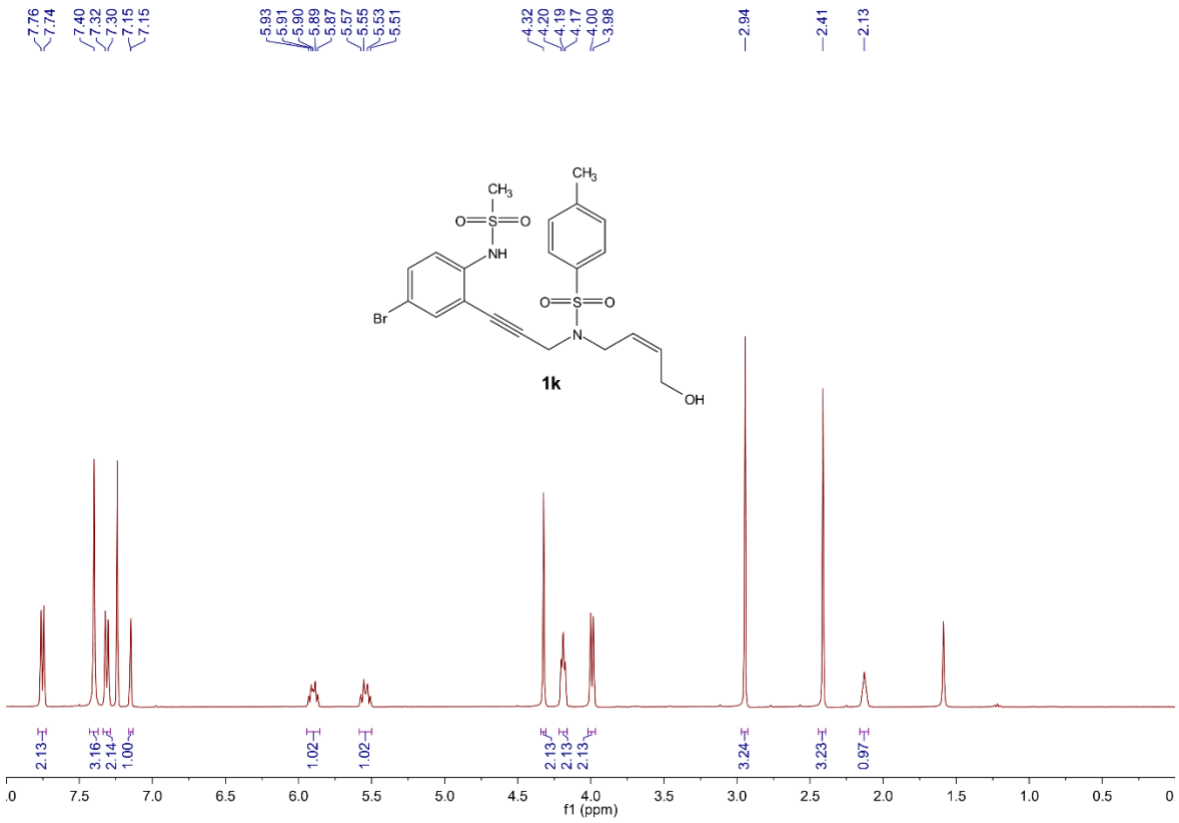
^{1}H NMR ($CDCl_3$, 600MHz) for **1j.**



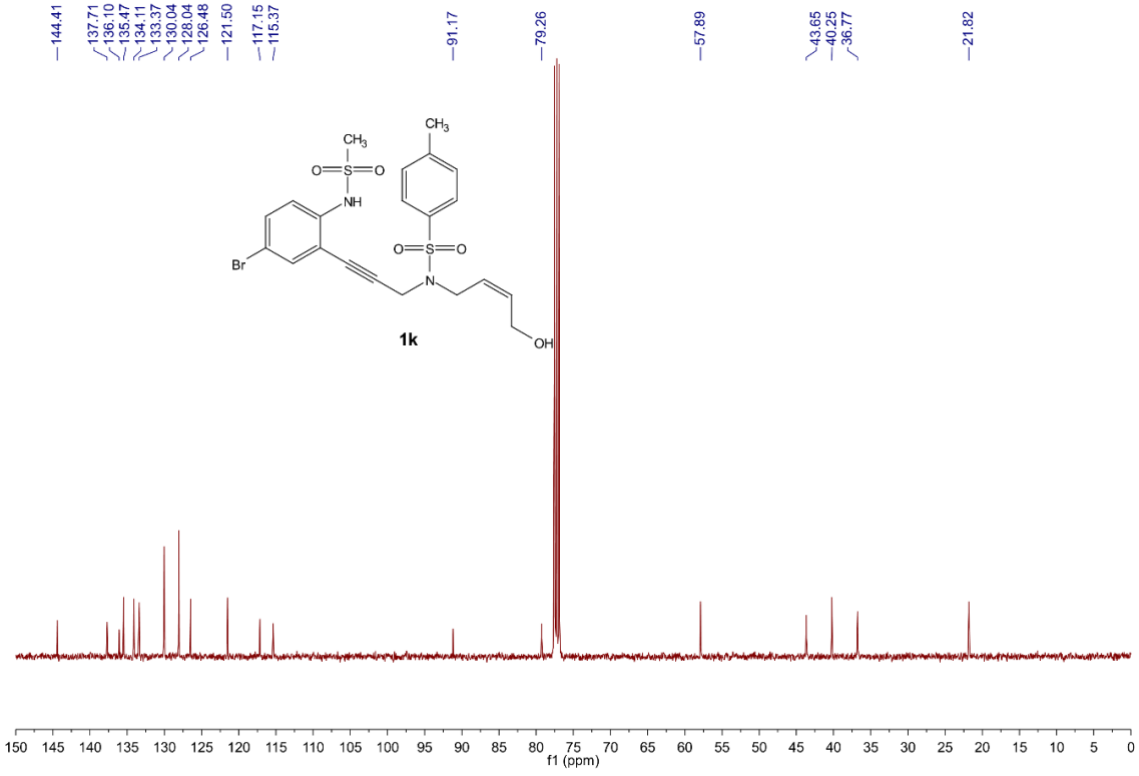
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **1j**.



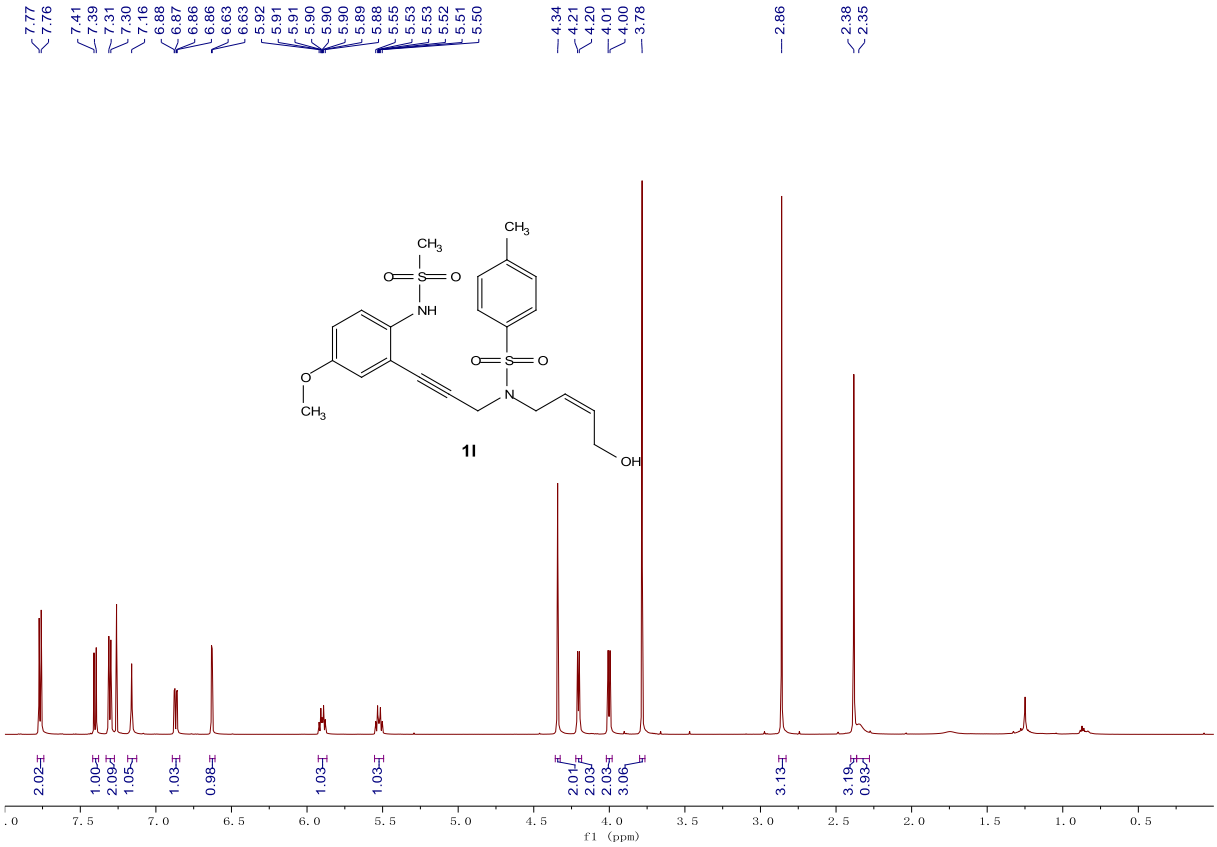
^{1}H NMR ($CDCl_3$, 400MHz) for **1k.**



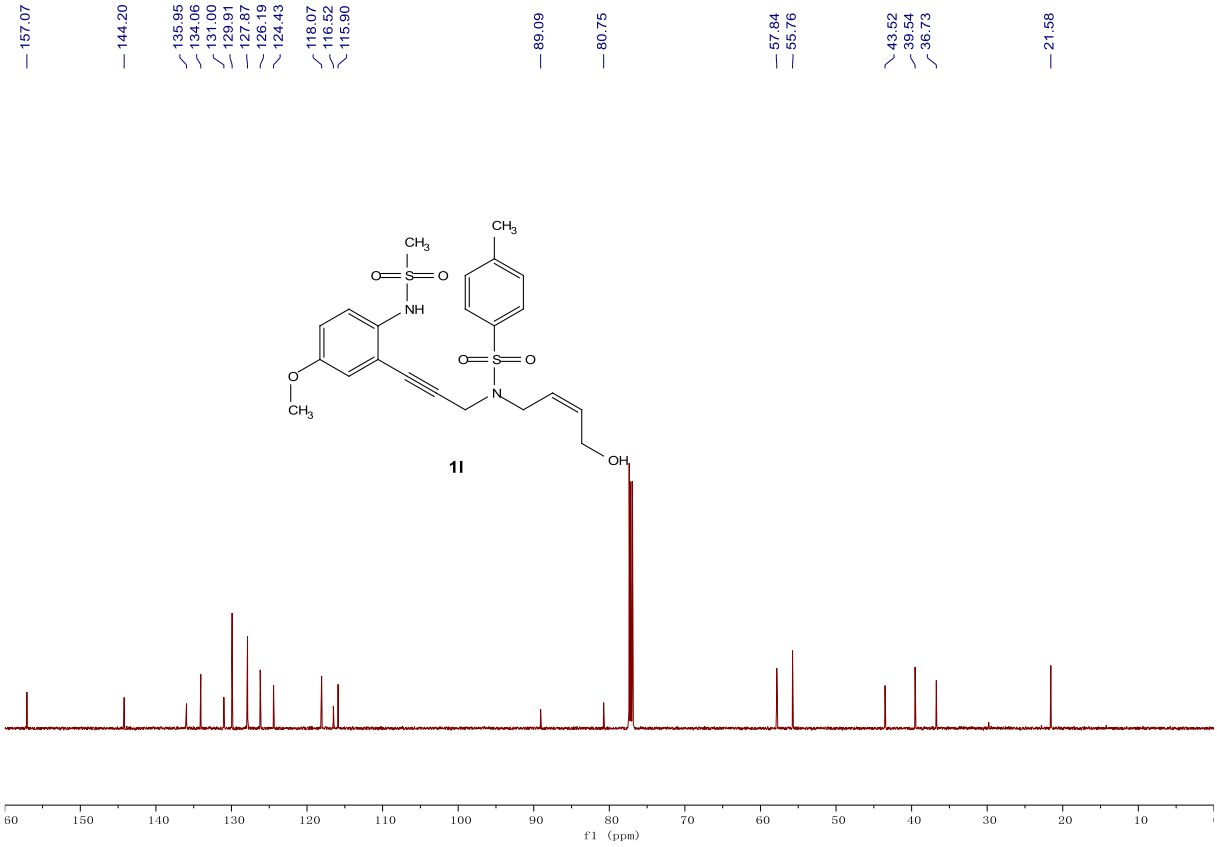
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1k**.



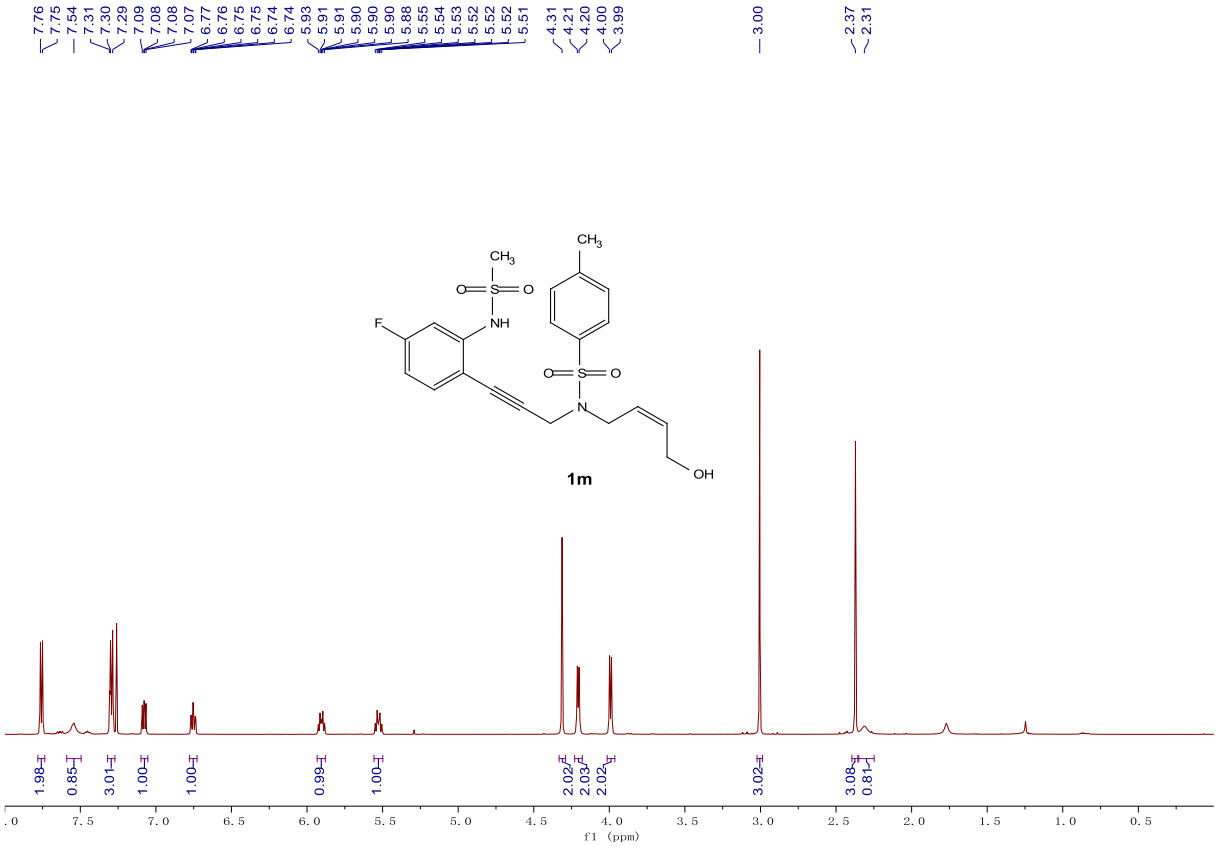
^{1}H NMR ($CDCl_3$, 600MHz) for **1l.**



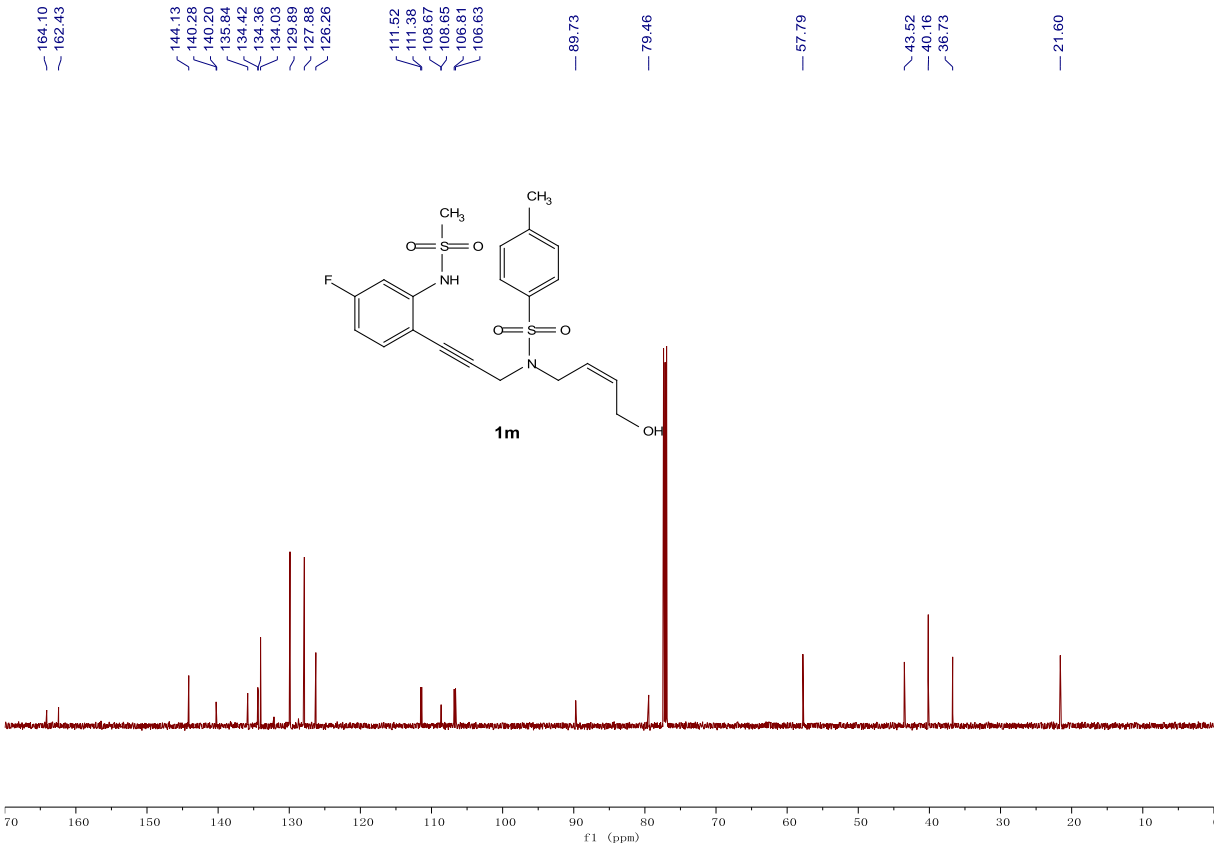
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **1l**.



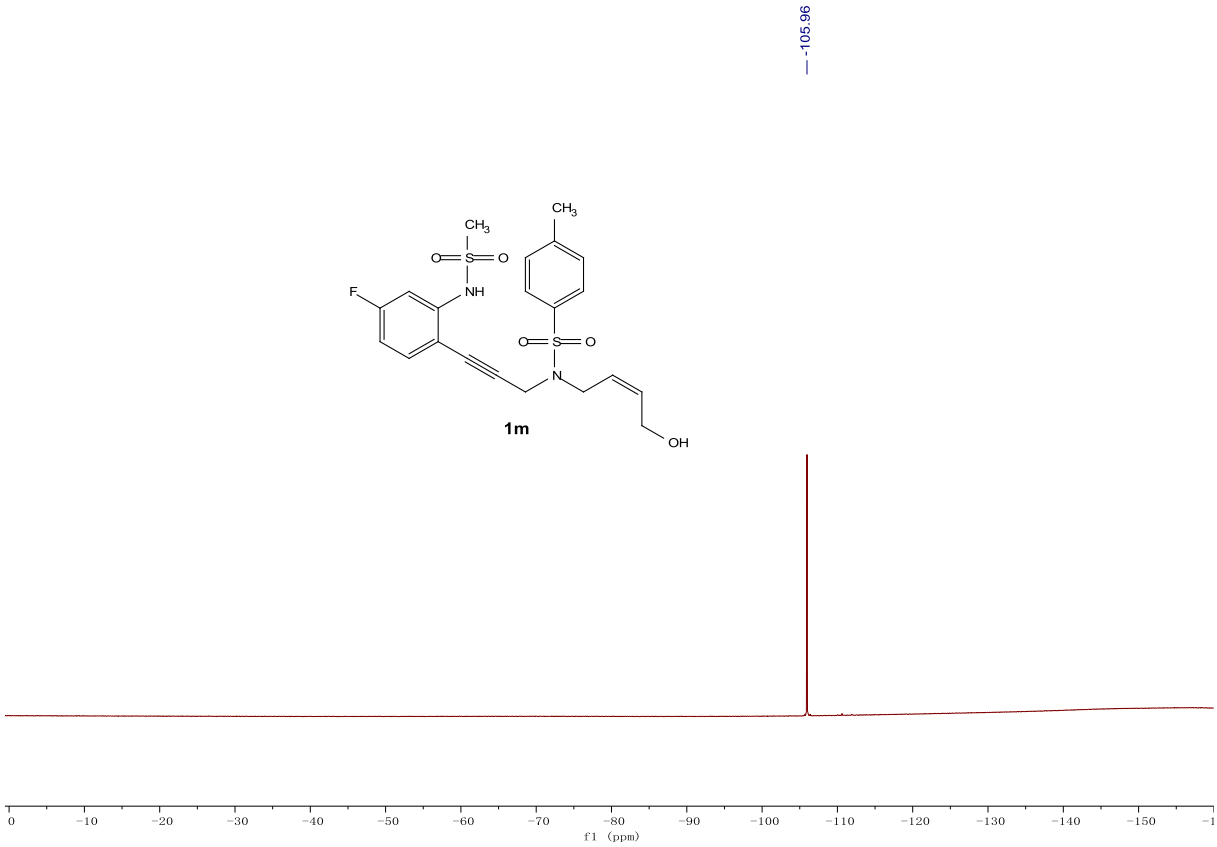
^{1}H NMR ($CDCl_3$, 600MHz) for **1m.**



^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **1m**.

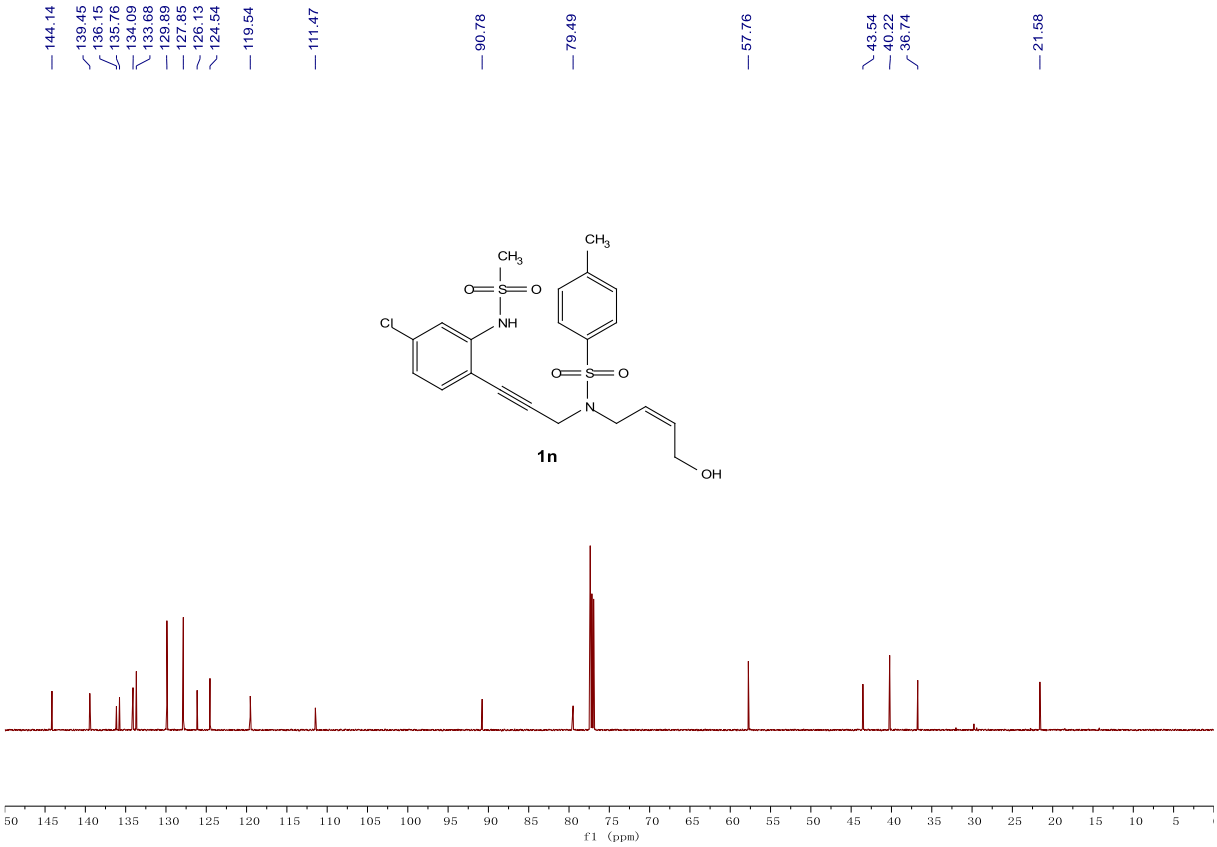


^{19}F NMR ($CDCl_3$, 376 MHz) for **1m**.

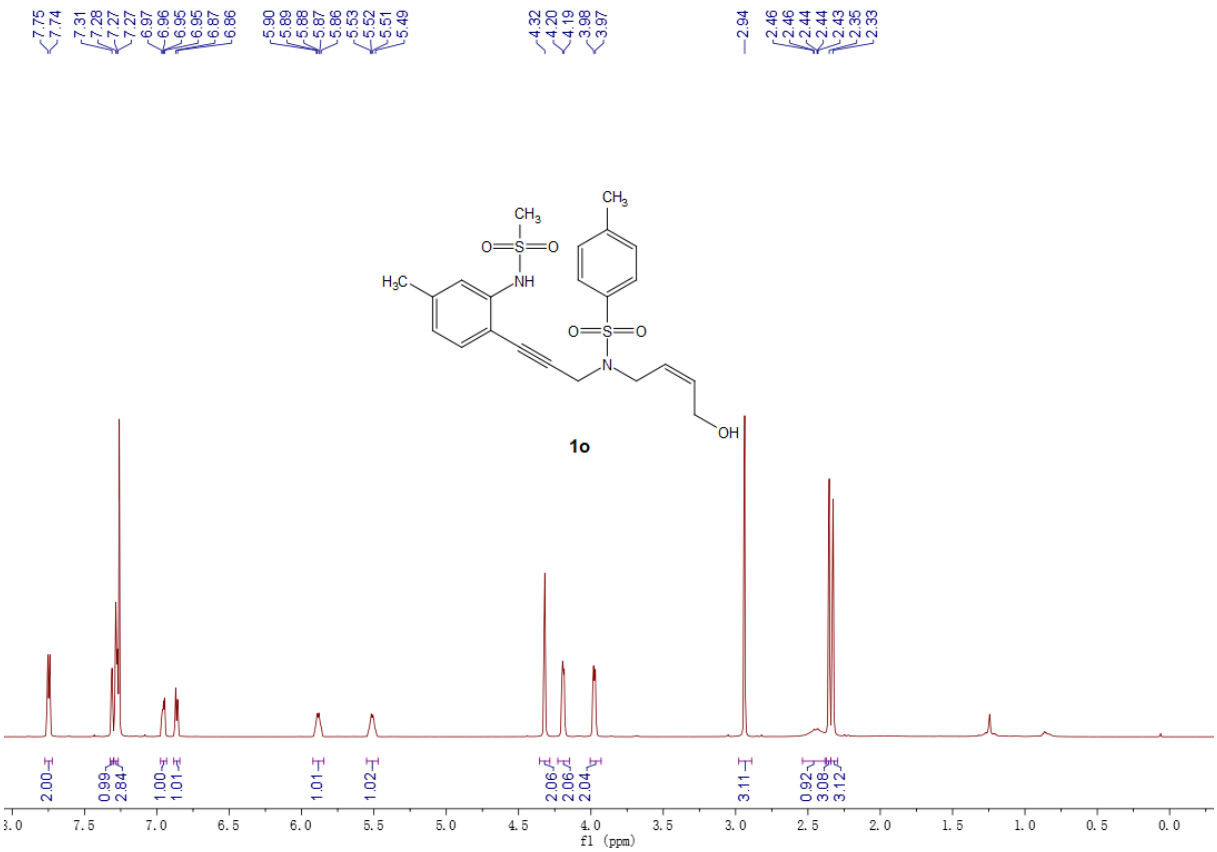


^{1}H NMR ($CDCl_3$, 600MHz) for **1n.**

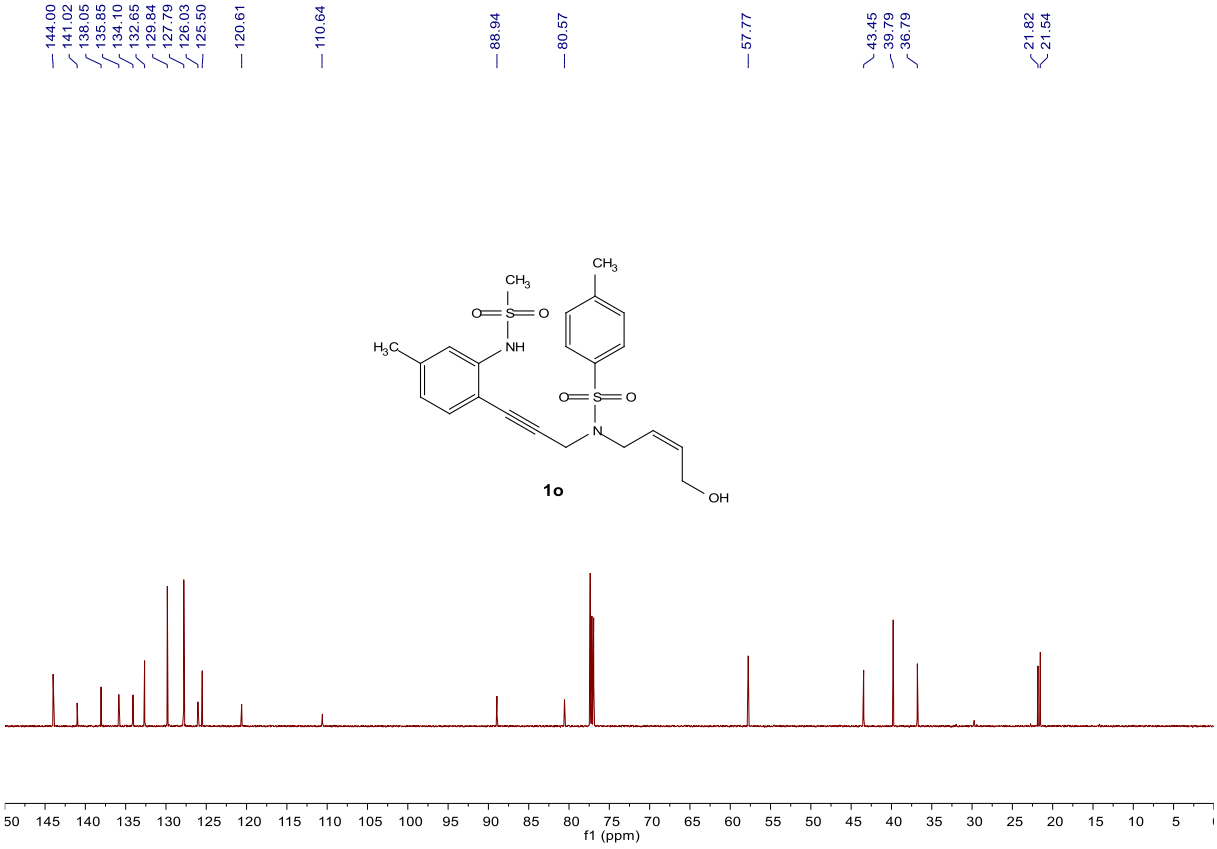
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz) for **1n**.



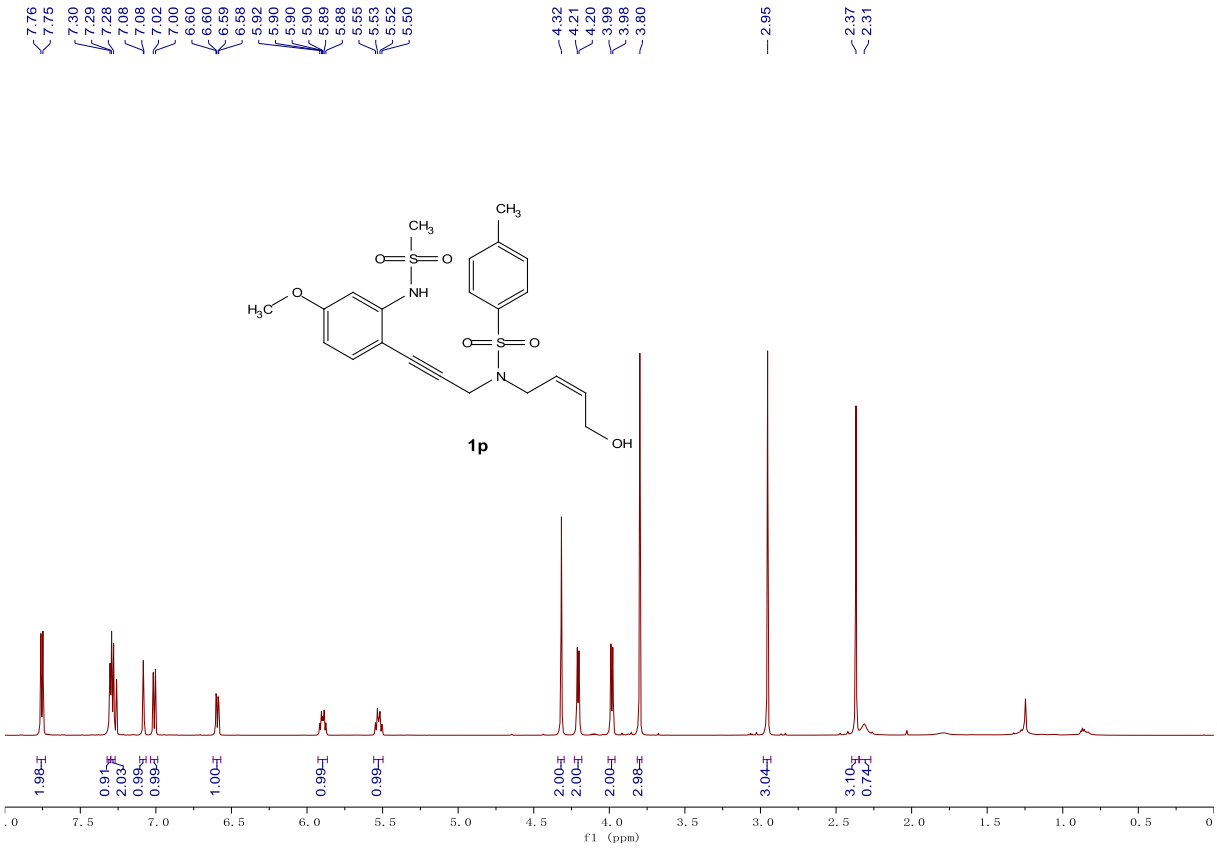
^{1}H NMR ($CDCl_3$, 600MHz) for **1o.**



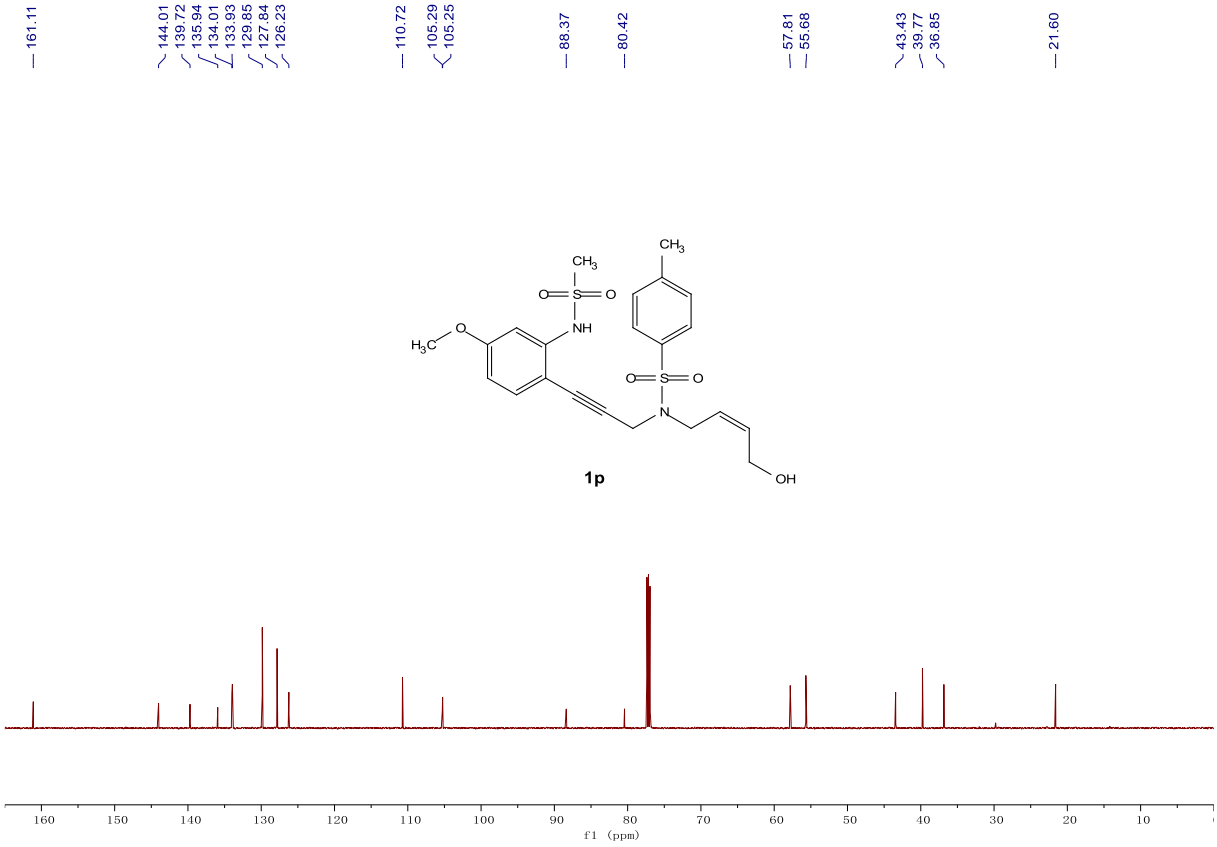
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz) for **1o**.



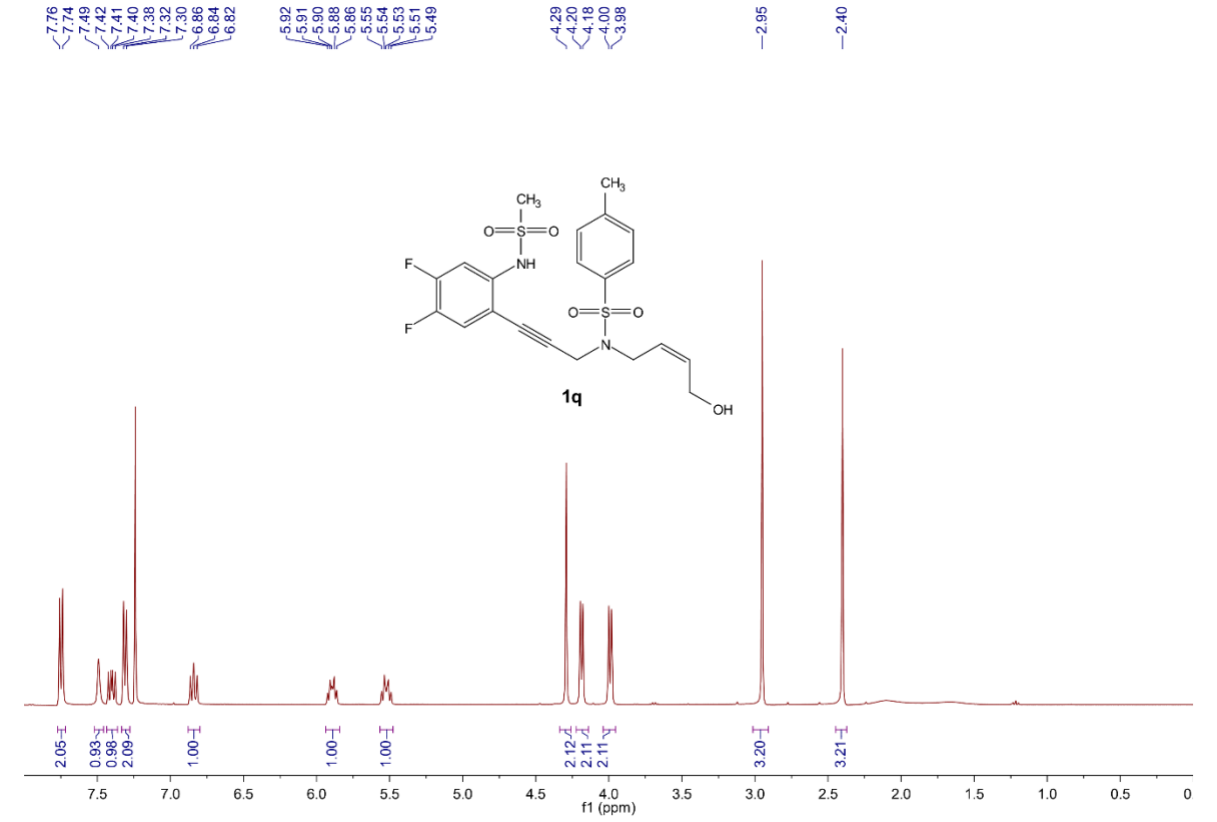
^{1}H NMR ($CDCl_3$, 600MHz) for **1p.**



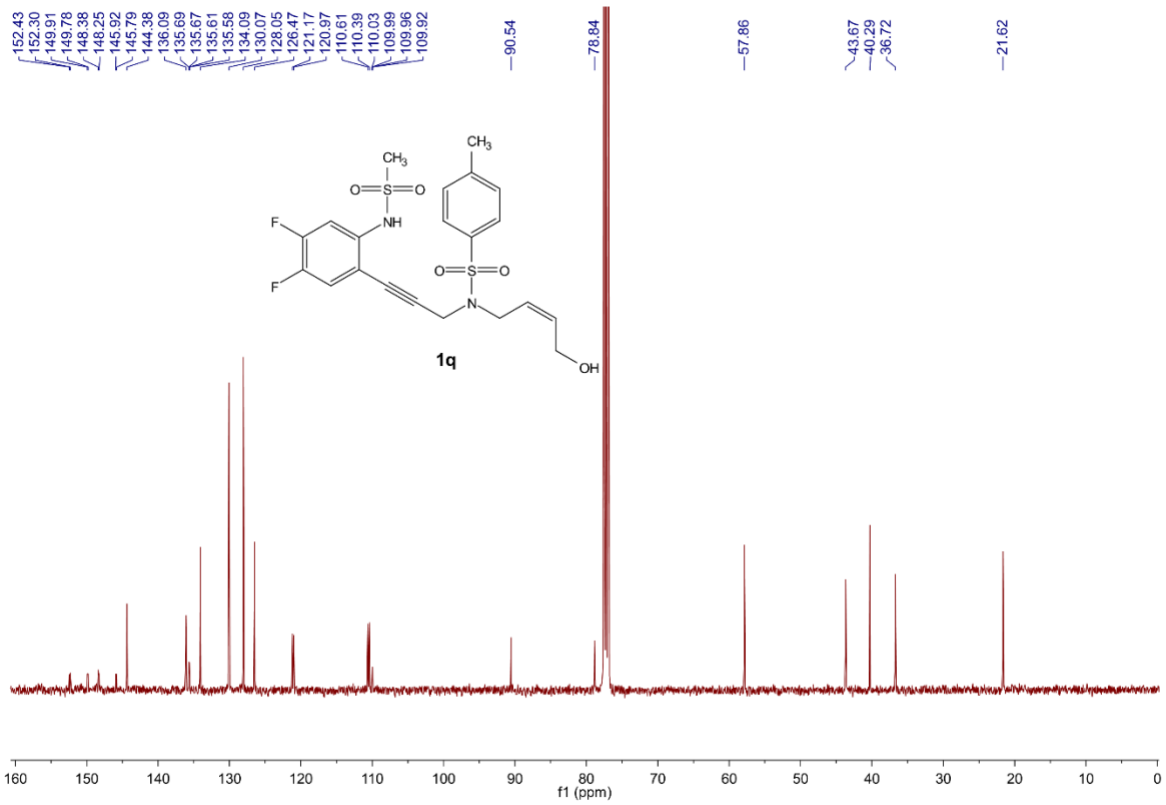
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz) for **1p**.



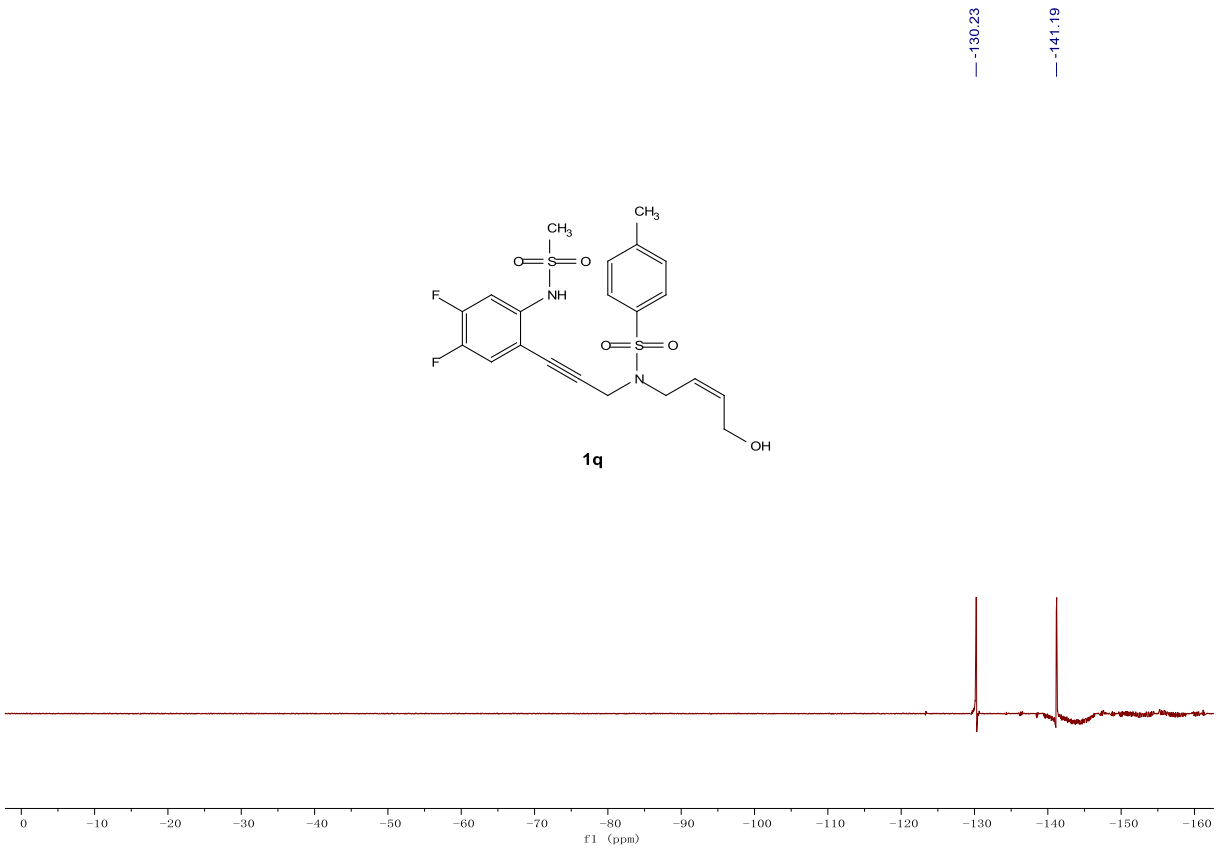
^{1}H NMR ($CDCl_3$, 400MHz) for **1q.**



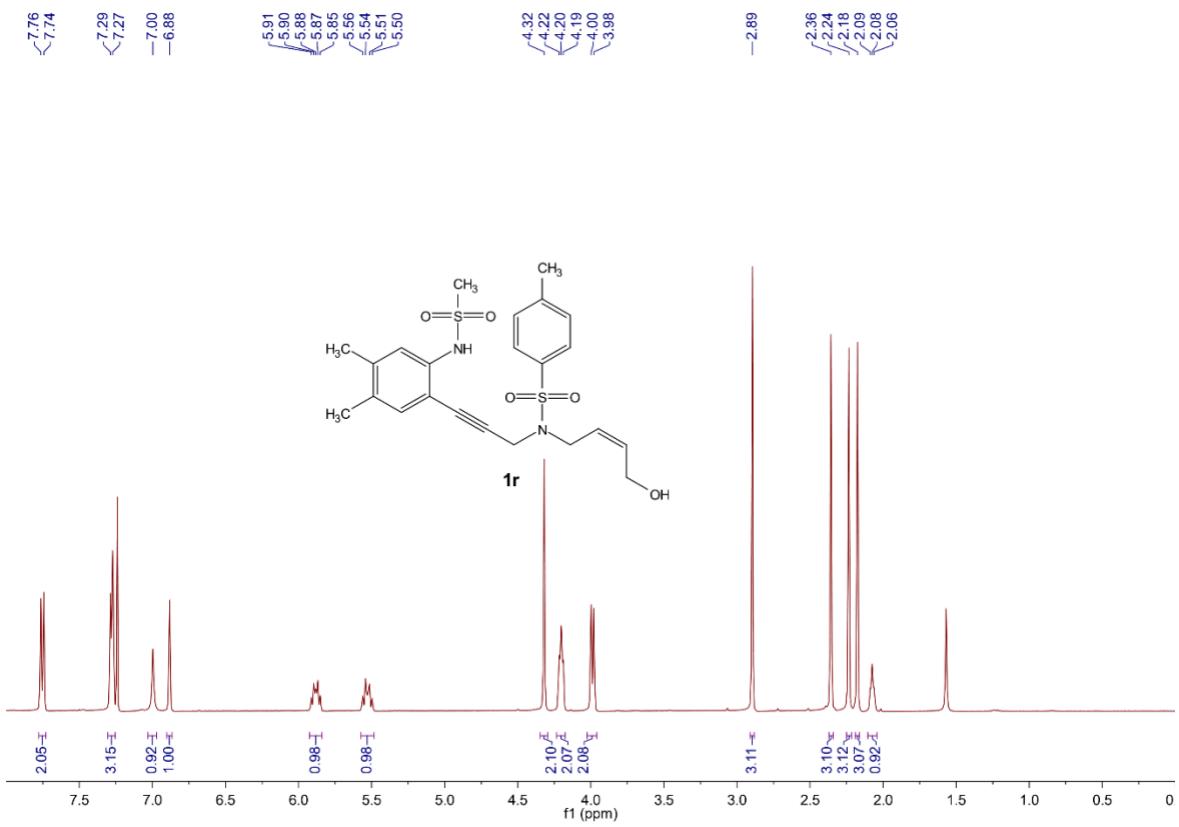
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz) for **1q**.



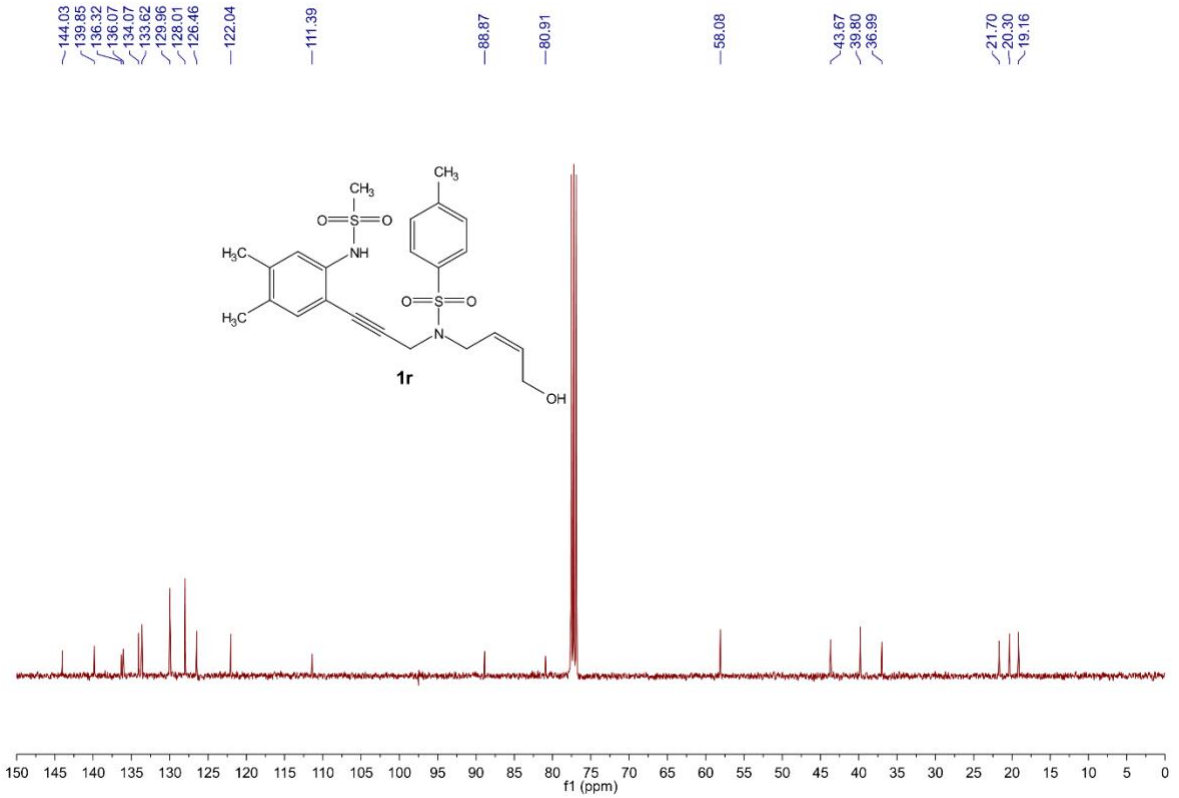
^{19}F NMR ($CDCl_3$, 376 MHz) for **1q**.



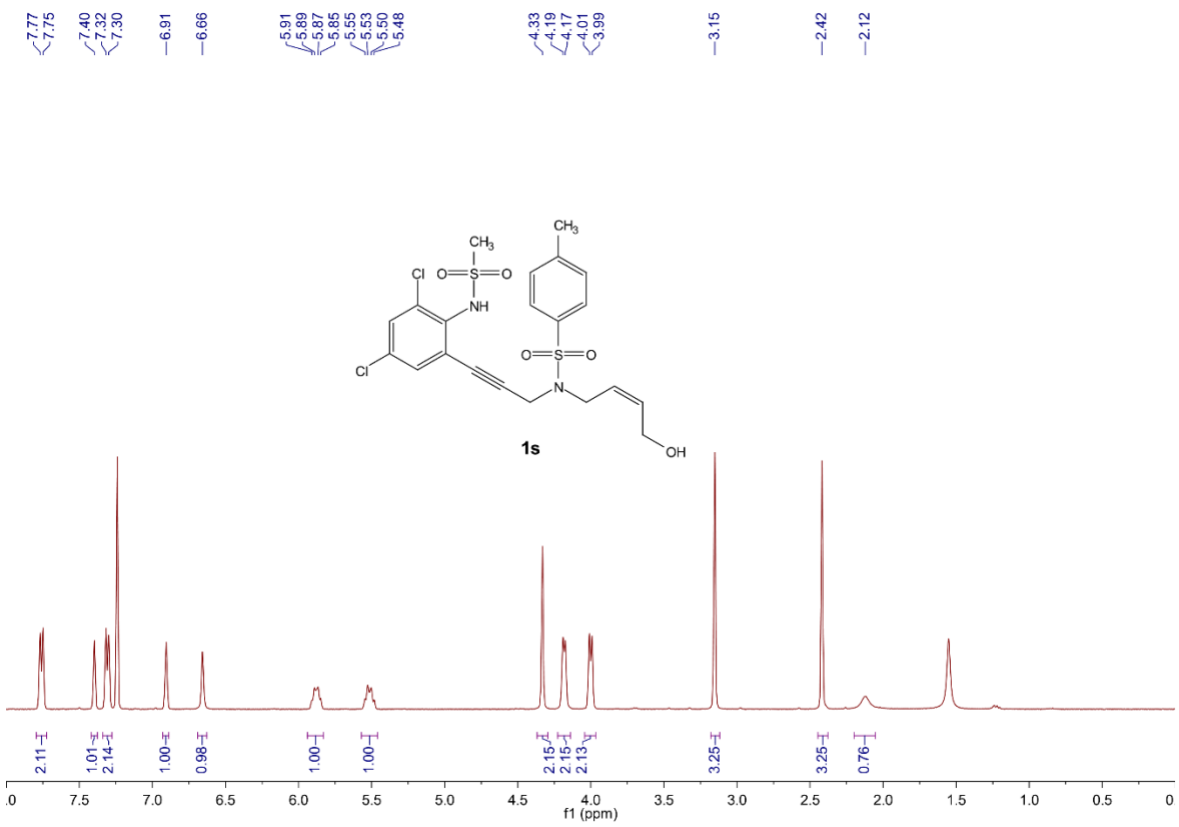
^{1}H NMR ($CDCl_3$, 400MHz) for **1r.**



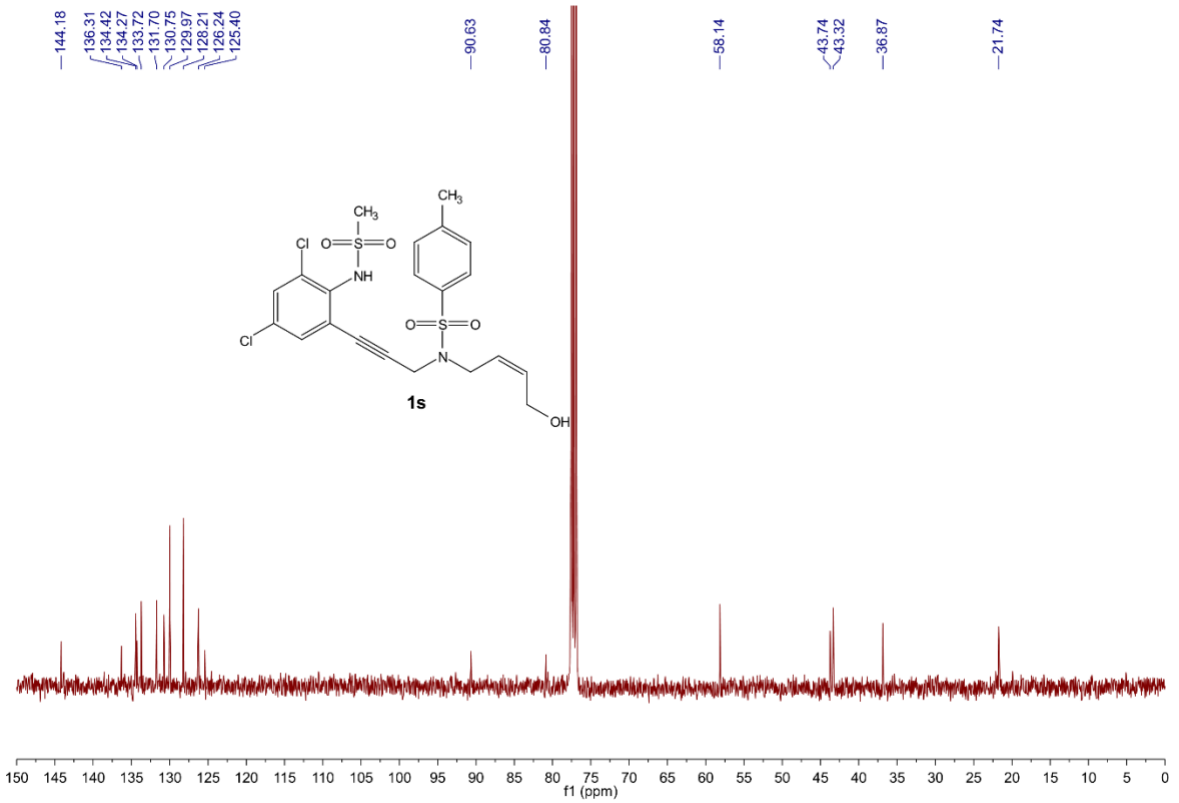
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1r**.



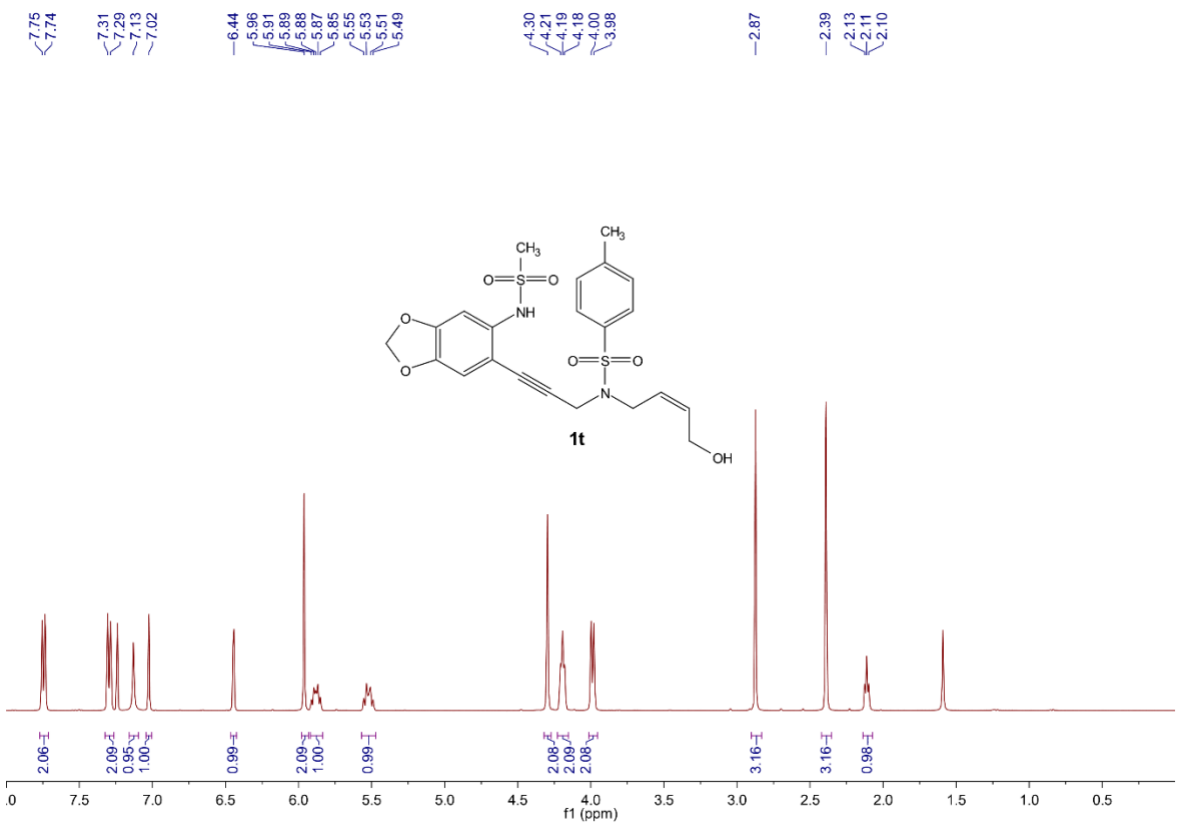
^{1}H NMR ($CDCl_3$, 400MHz) for **1s.**



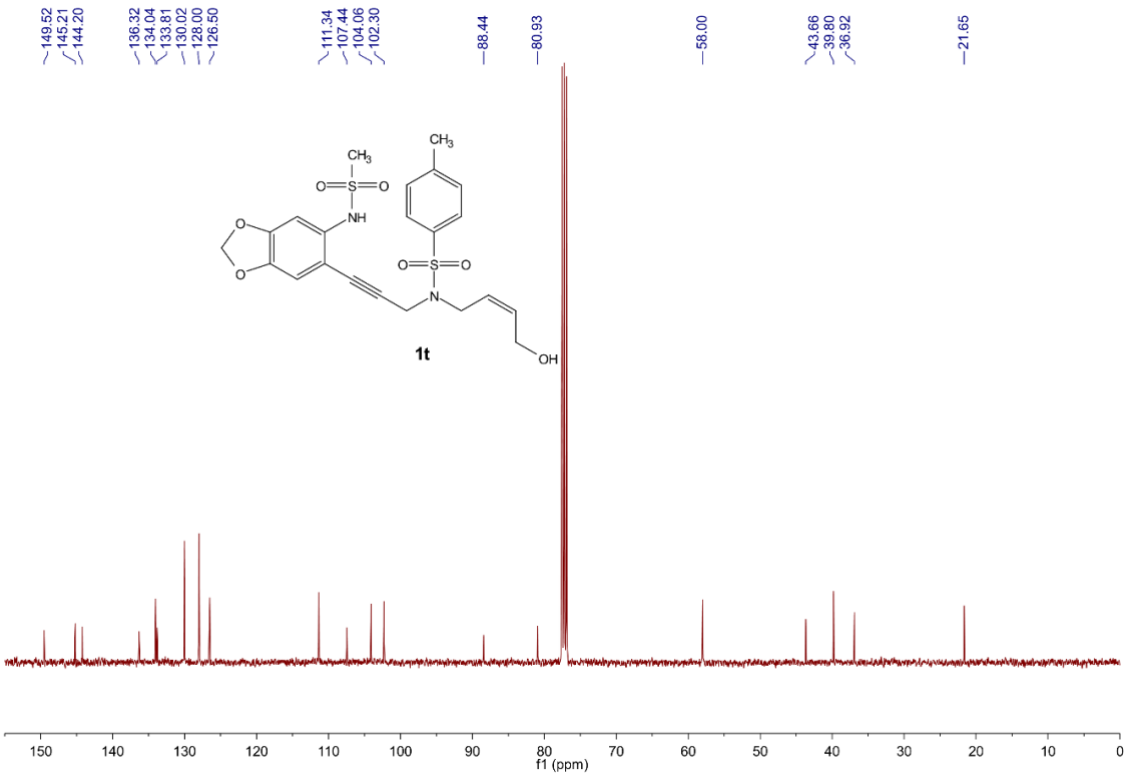
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1s**.



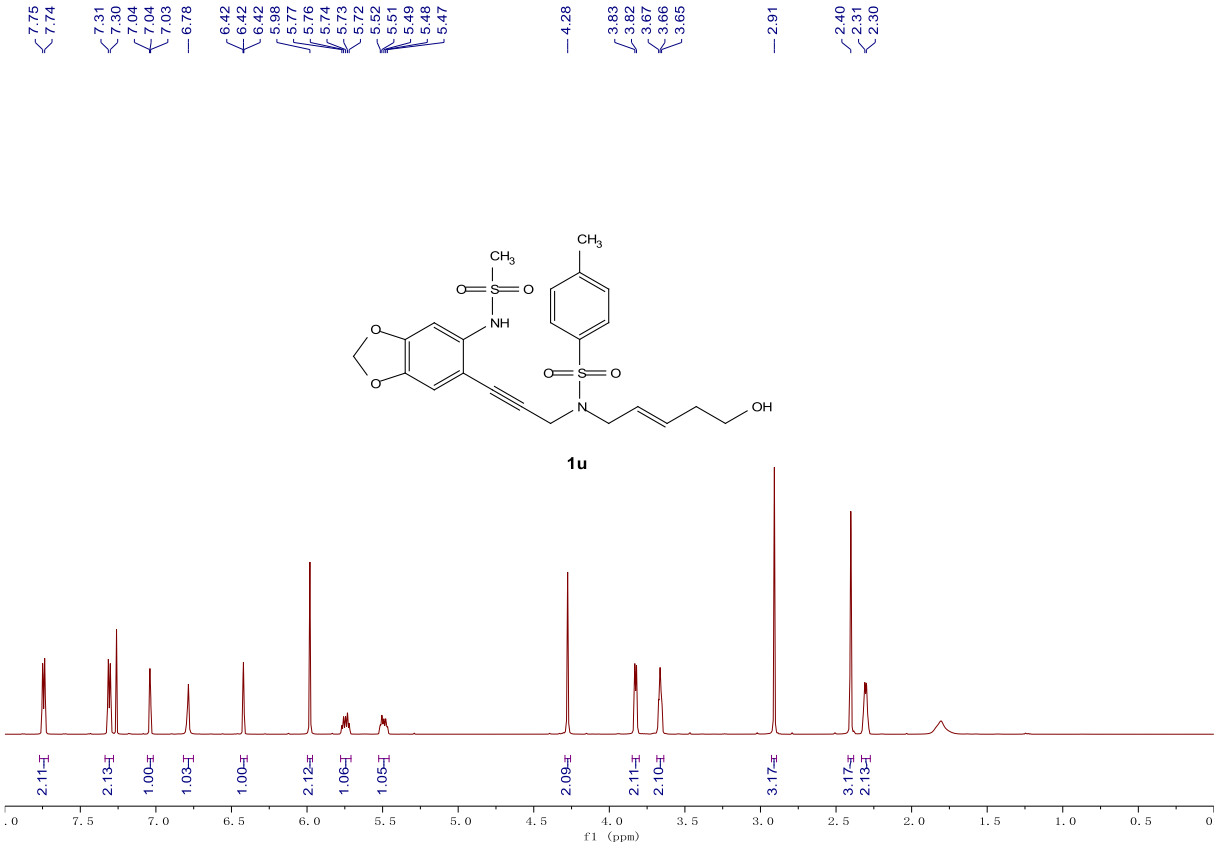
^{1}H NMR ($CDCl_3$, 400MHz) for **1t.**



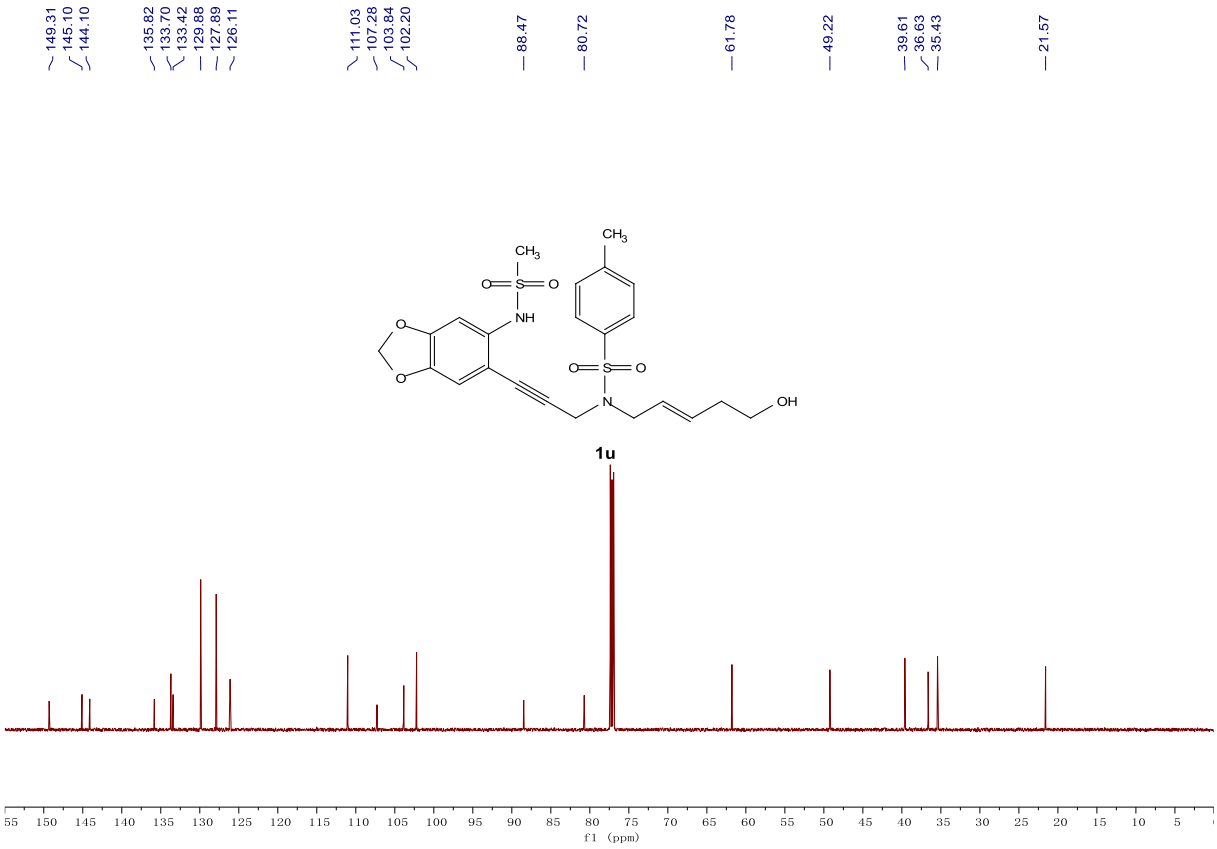
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1t**.



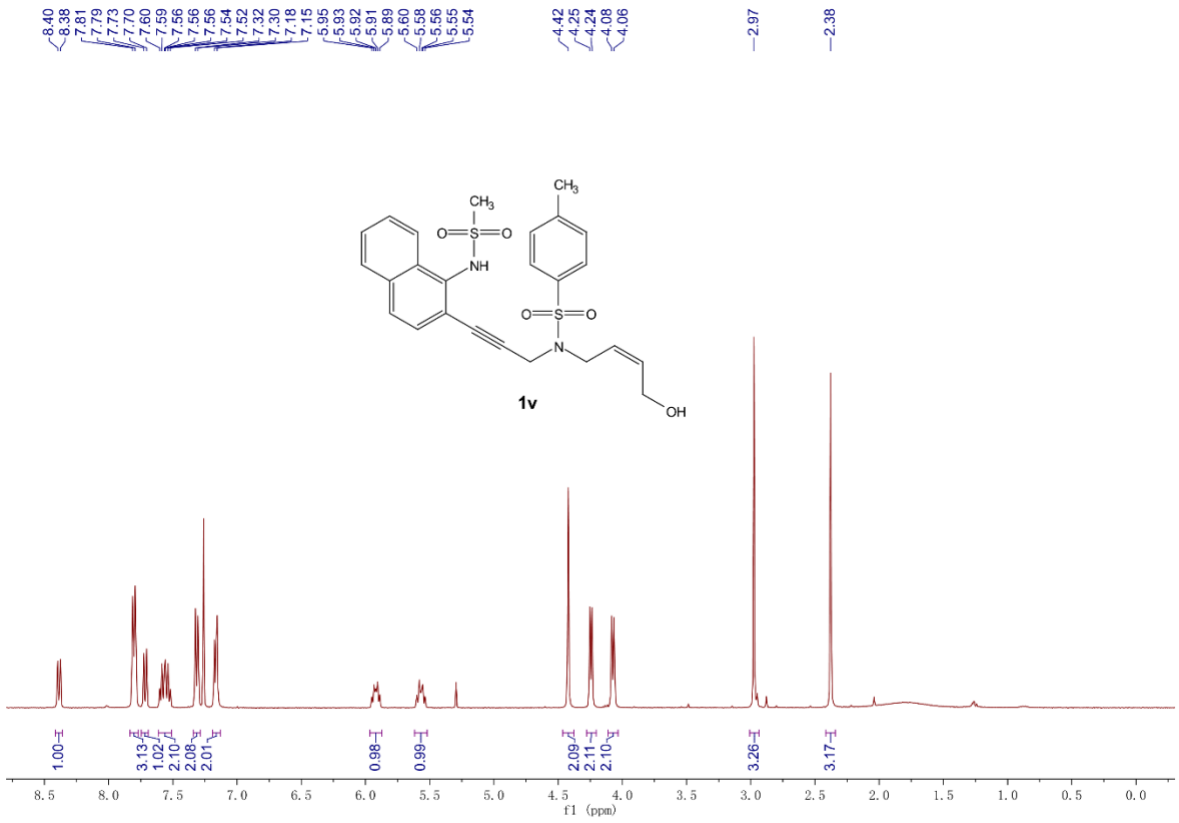
^{1}H NMR ($CDCl_3$, 600MHz) for **1u.**



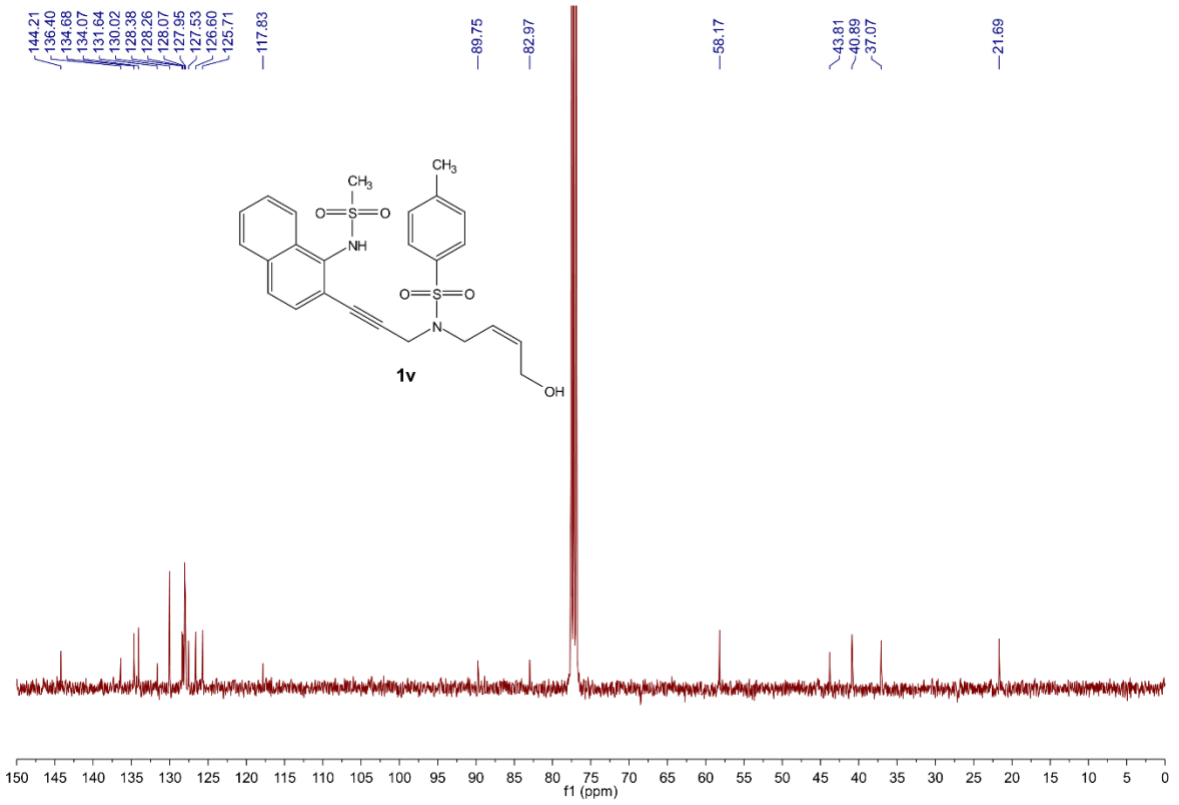
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **1u**.



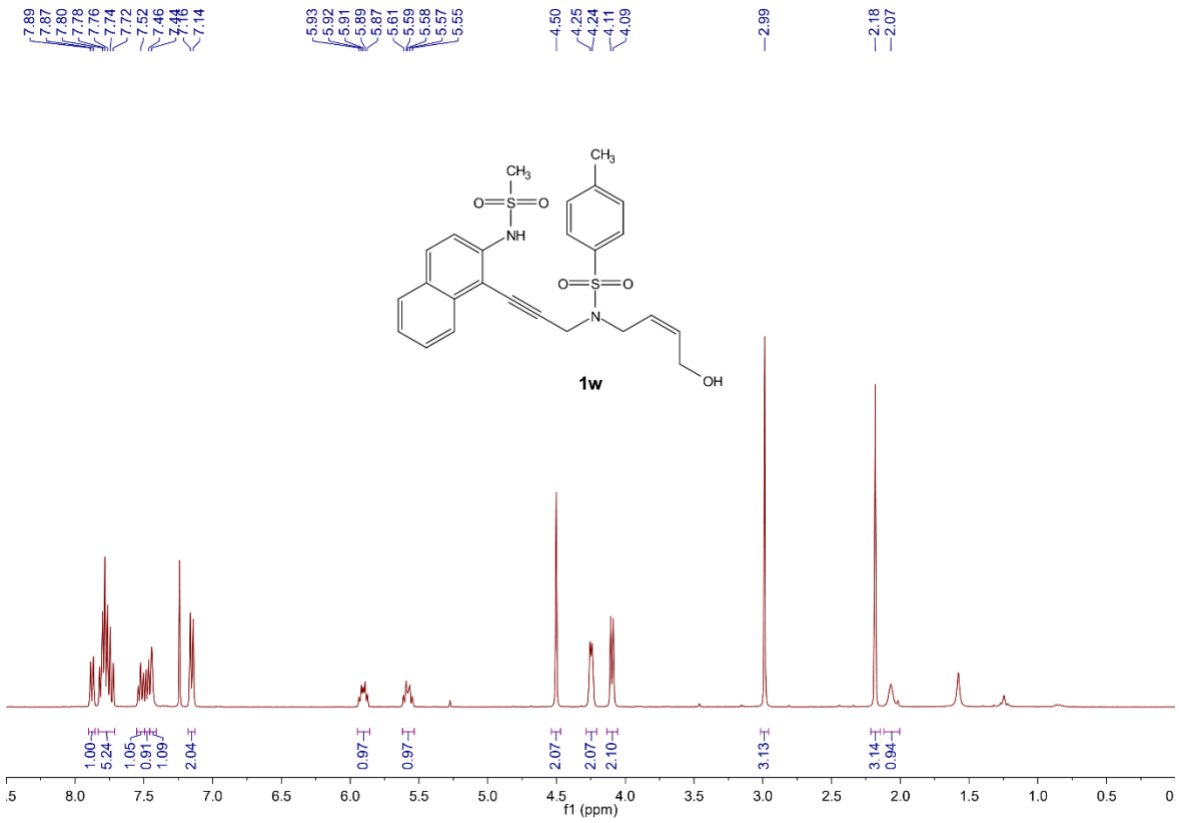
^{1}H NMR ($CDCl_3$, 400MHz) for **1v.**



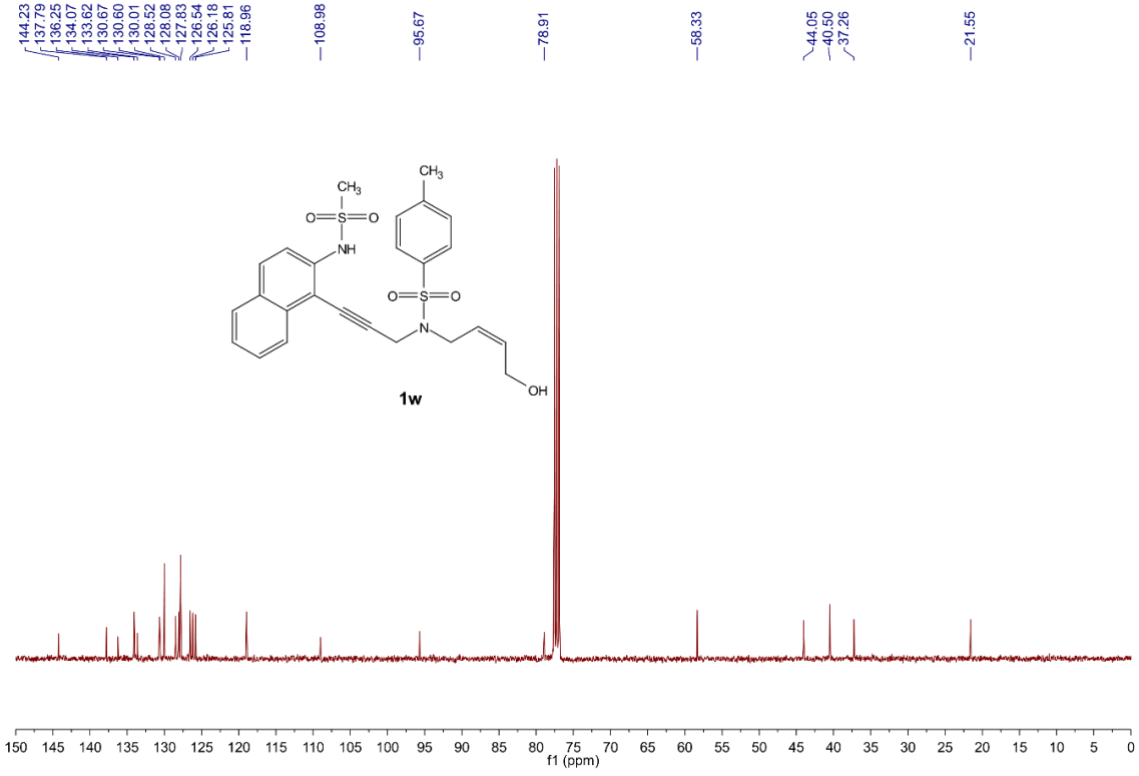
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1v**.



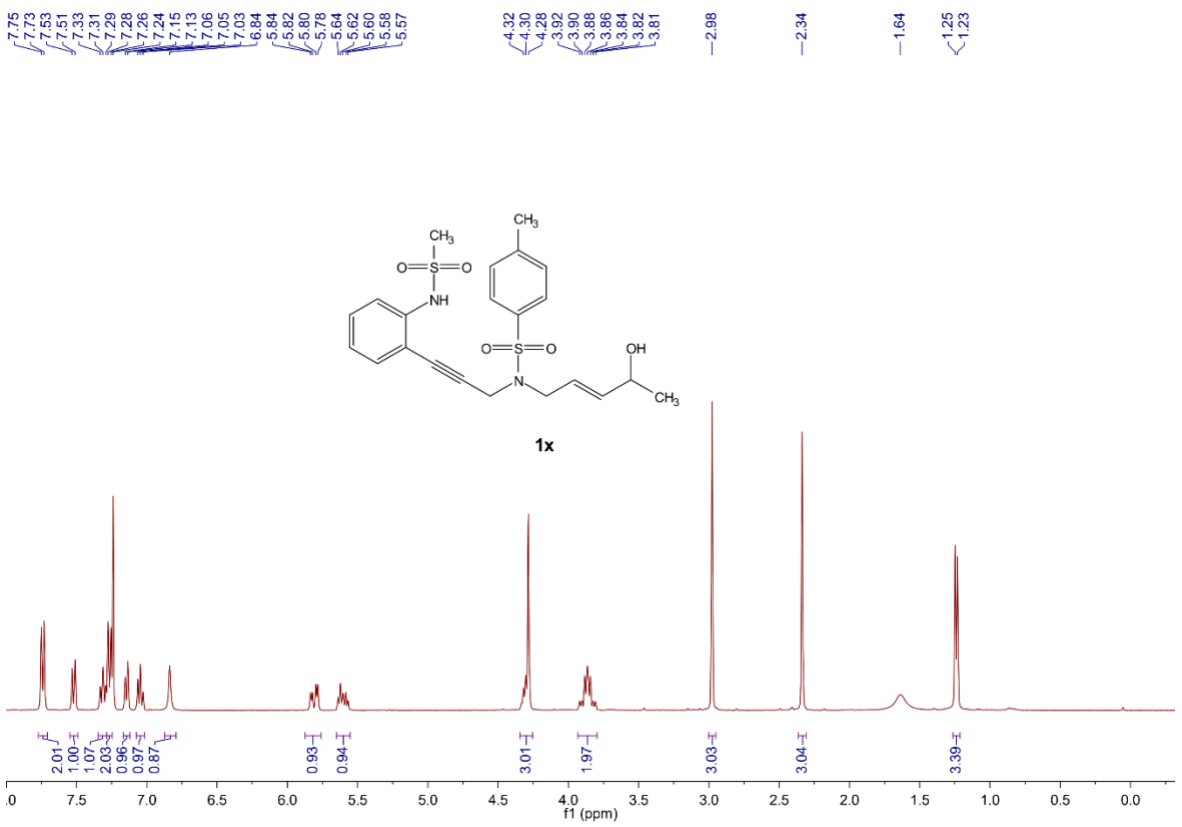
^{1}H NMR ($CDCl_3$, 400MHz) for **1w.**



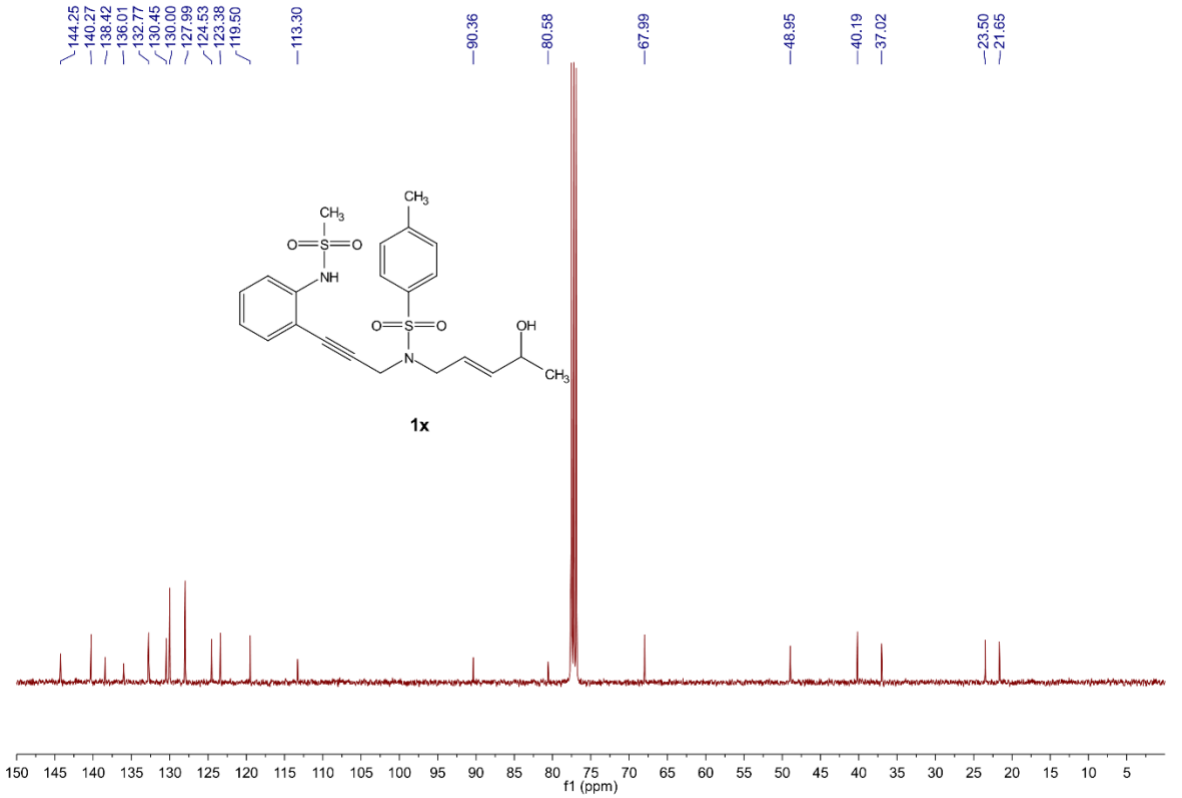
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1w**.



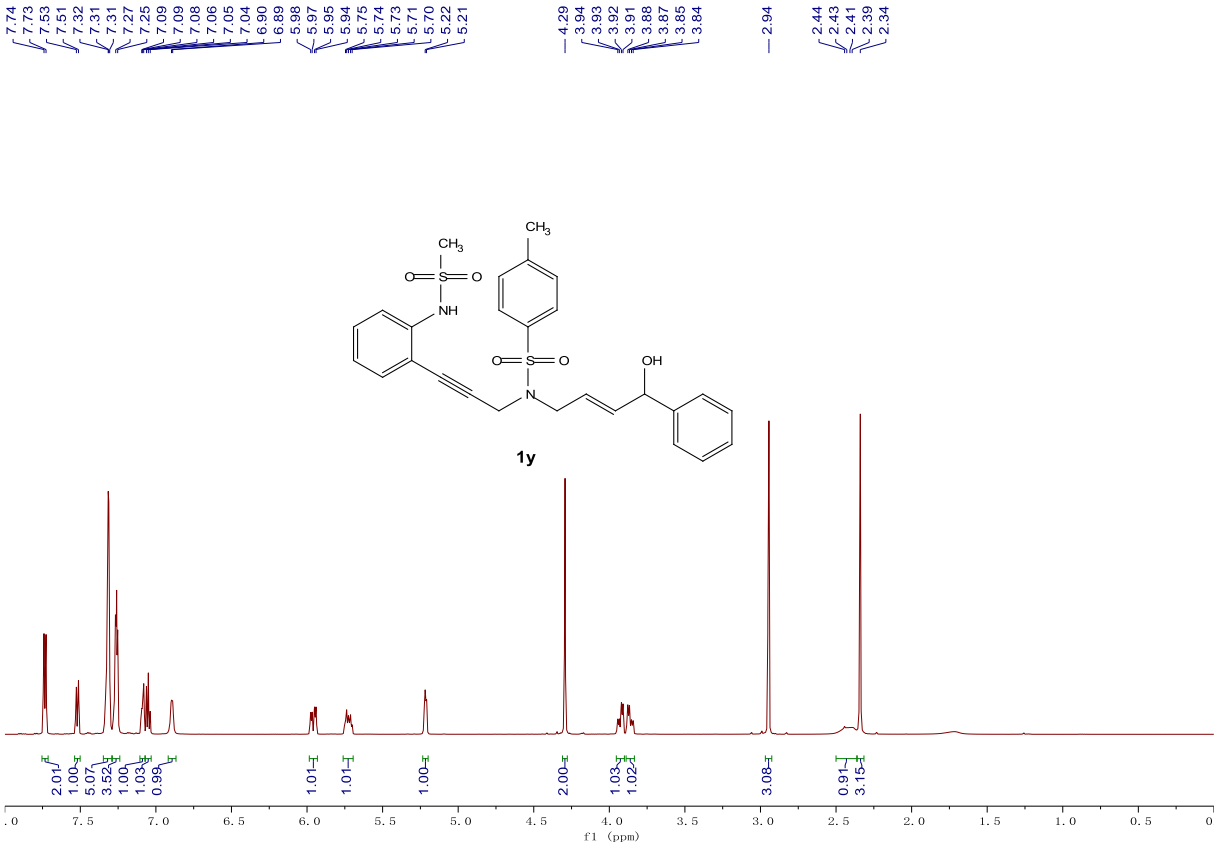
^{1}H NMR ($CDCl_3$, 400MHz) for **1x.**



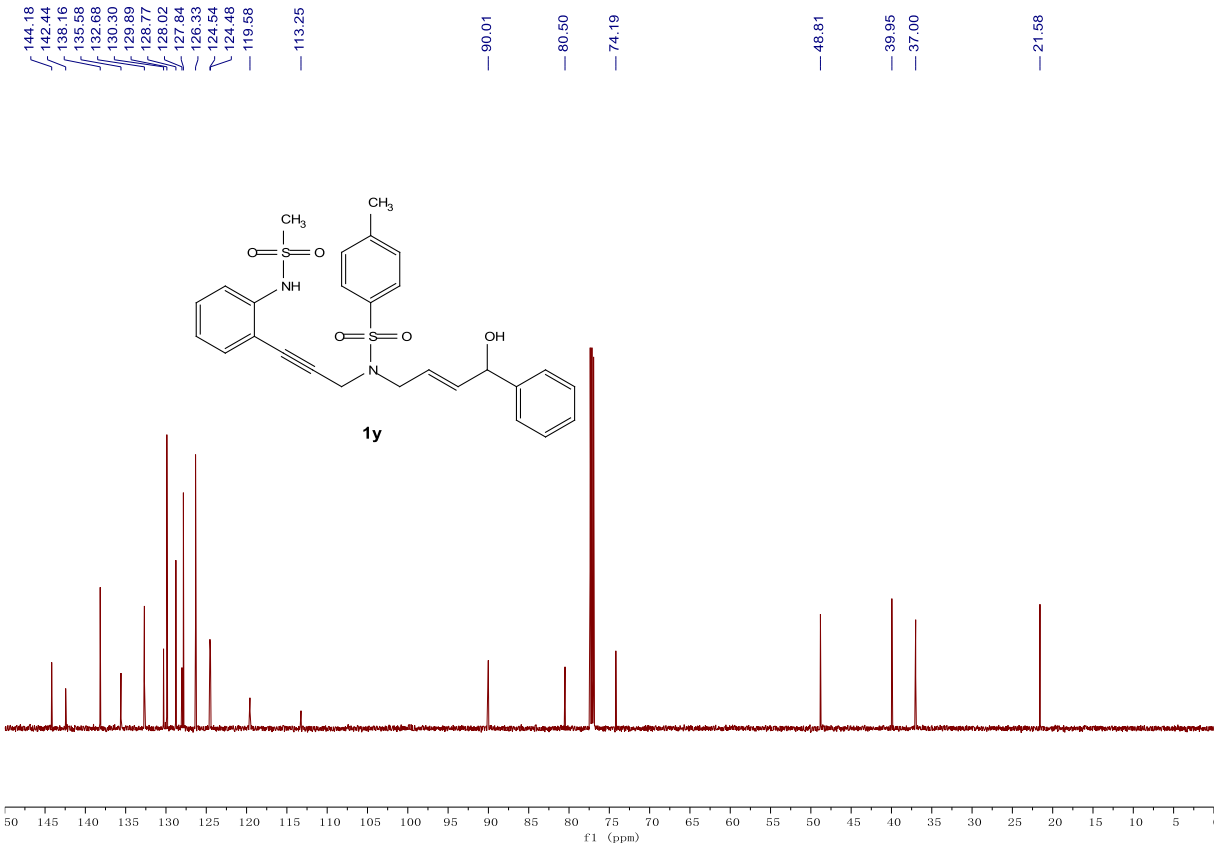
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1x**.



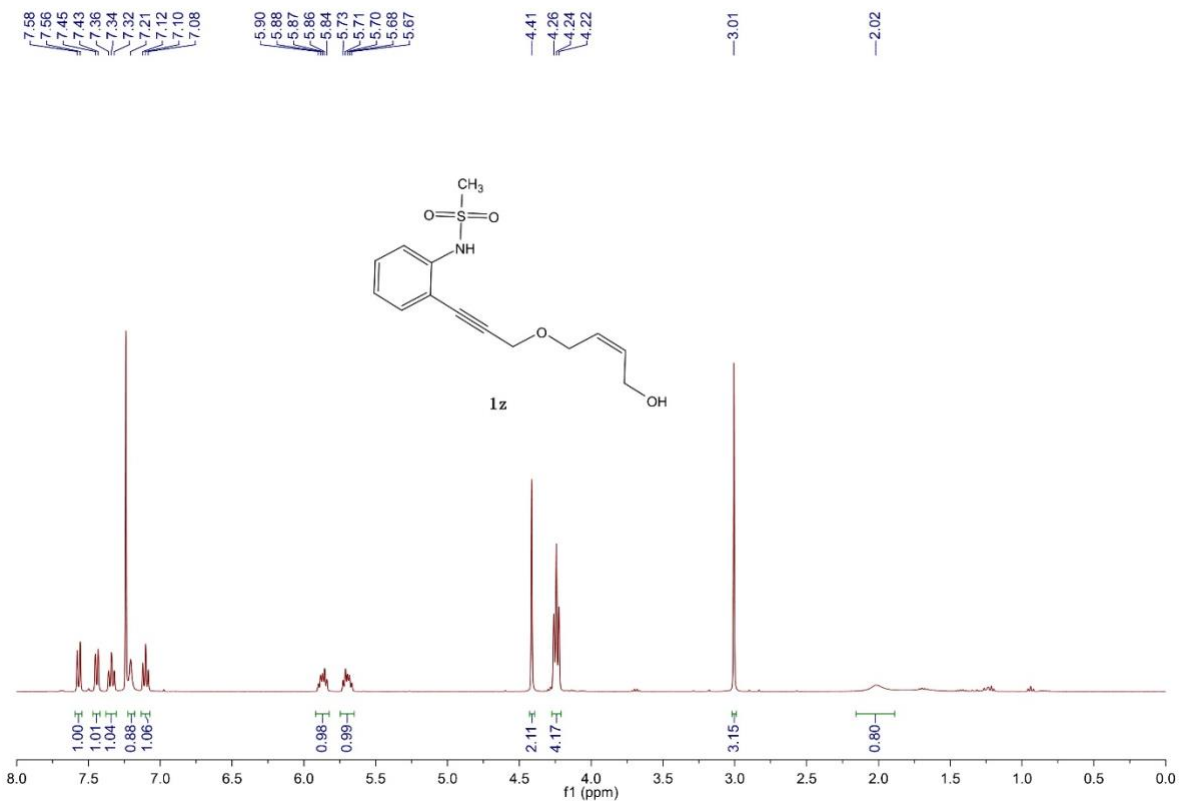
^{1}H NMR ($CDCl_3$, 600MHz) for **1y.**



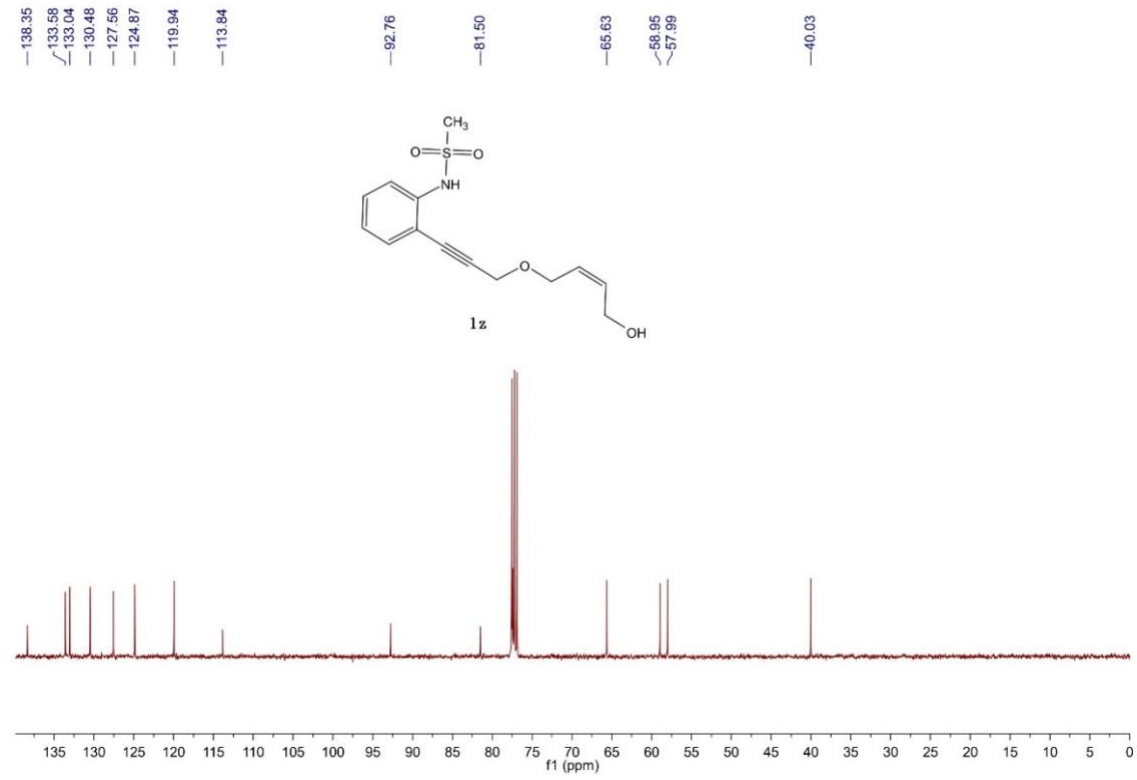
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **1y**.



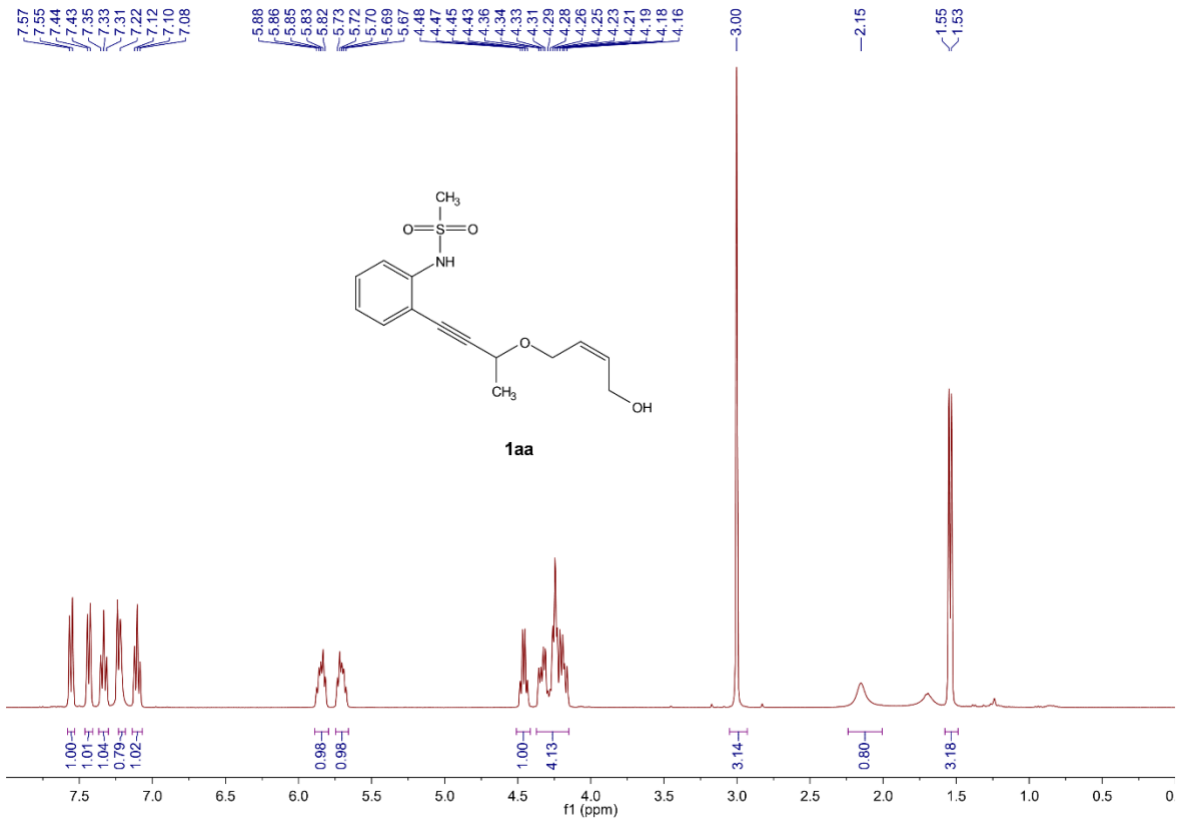
^{1}H NMR ($CDCl_3$, 400MHz) for **1z.**



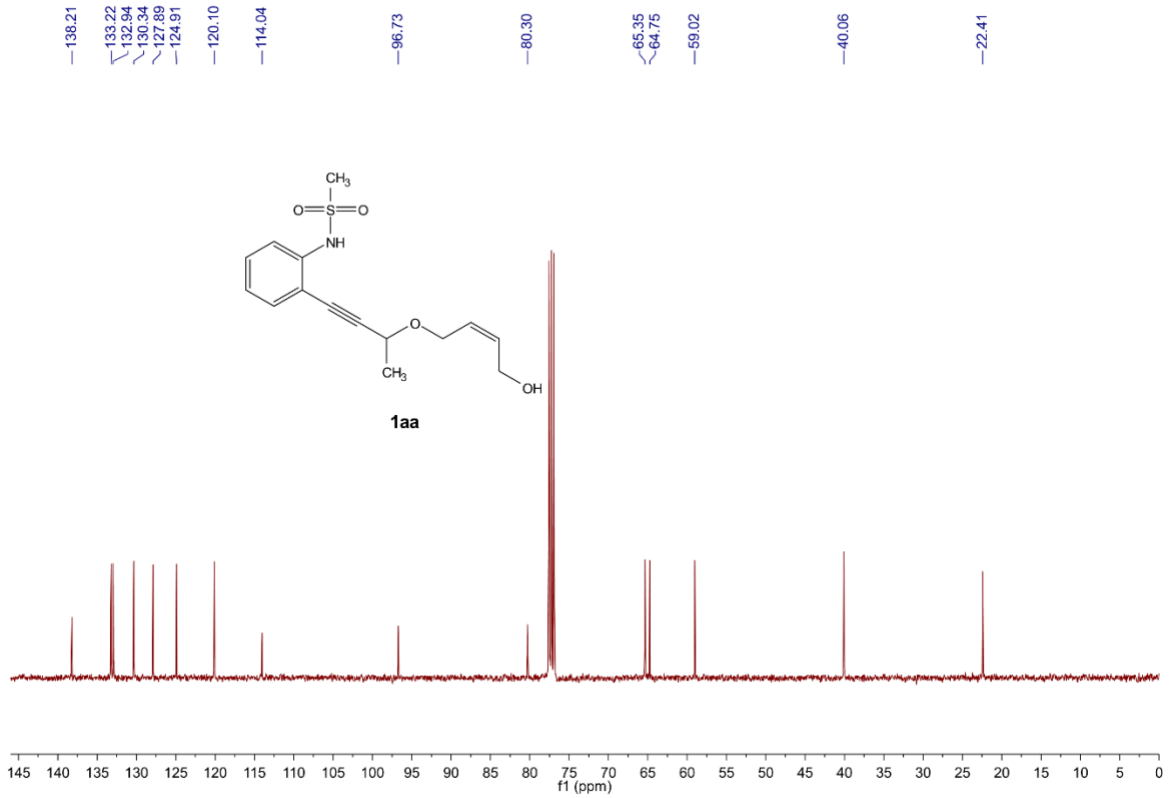
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1z**.



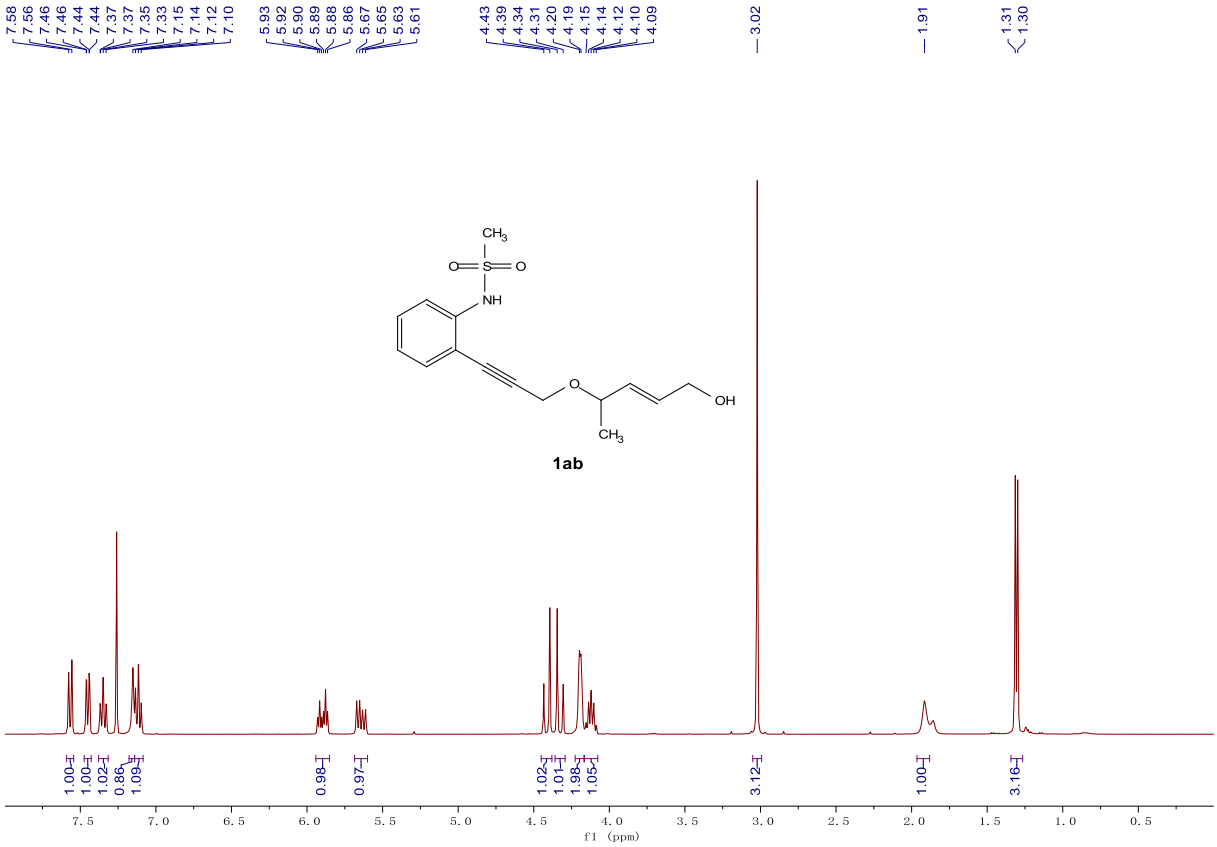
^{1}H NMR ($CDCl_3$, 400MHz) for **1aa.**



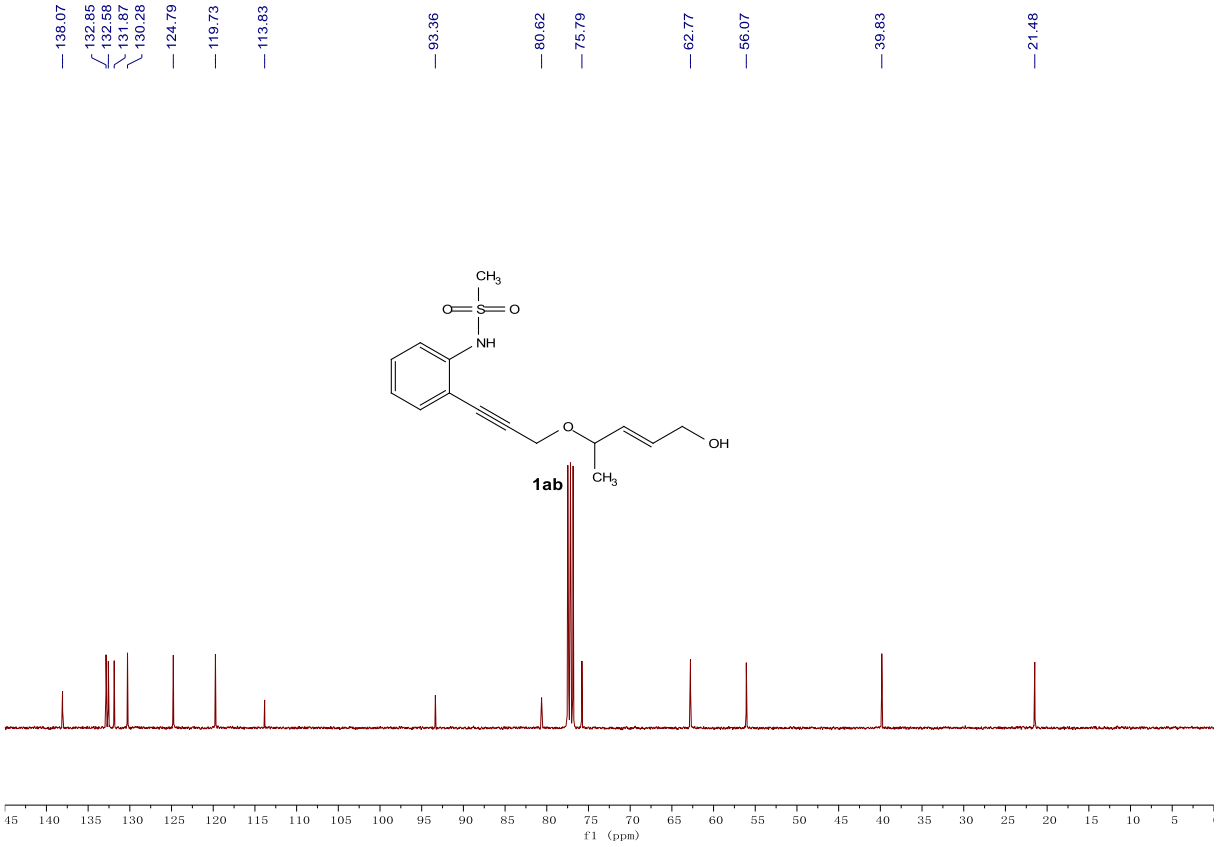
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1aa**.



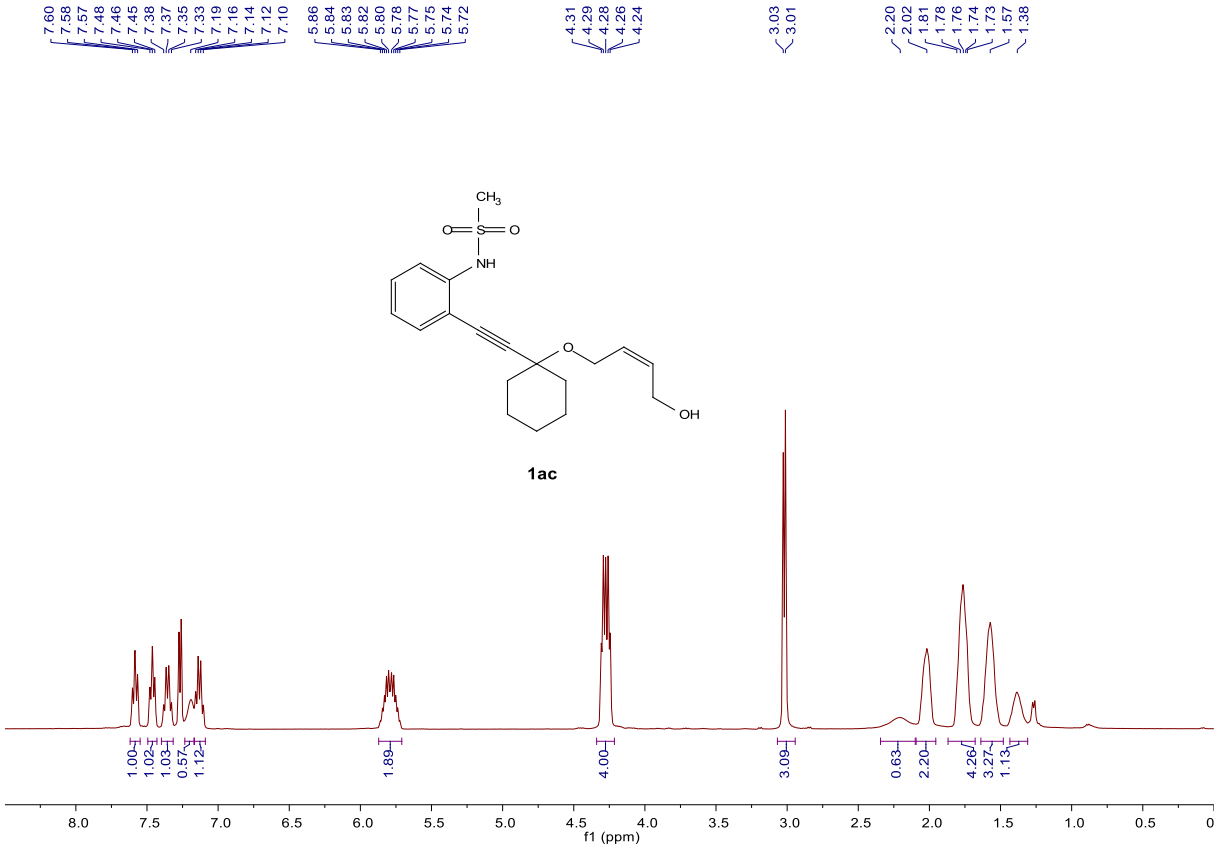
^{1}H NMR ($CDCl_3$, 400MHz) for **1ab.**



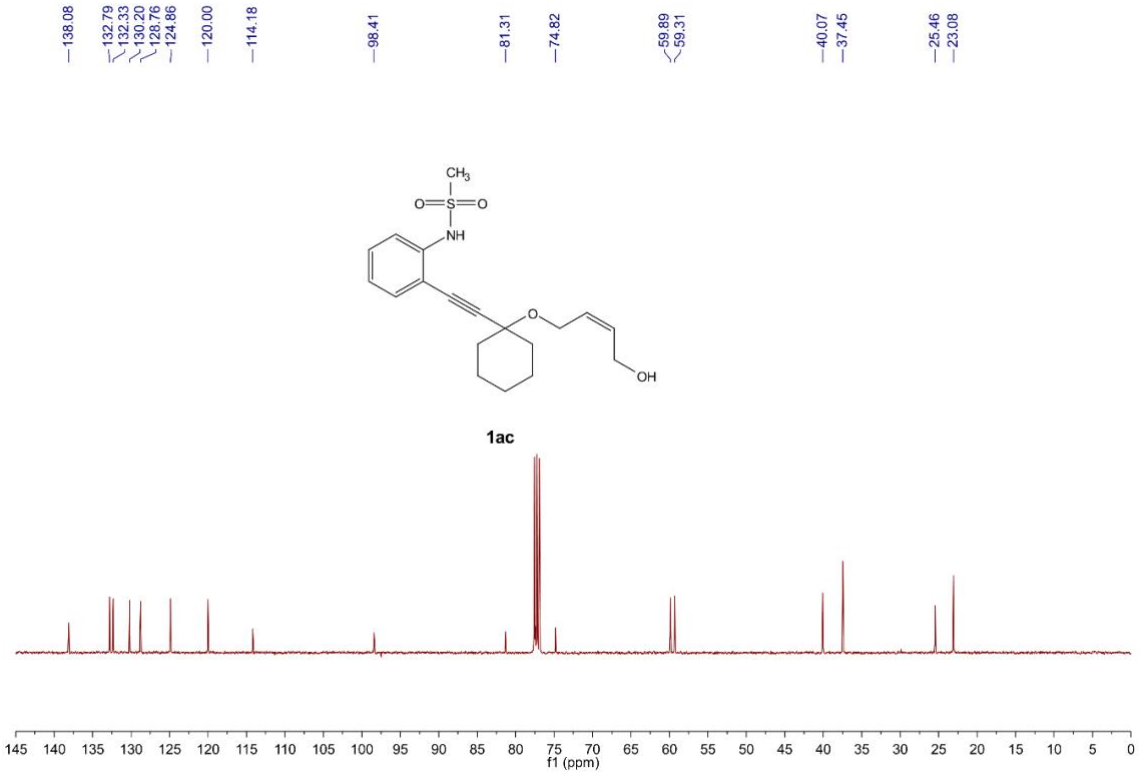
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1ab**.



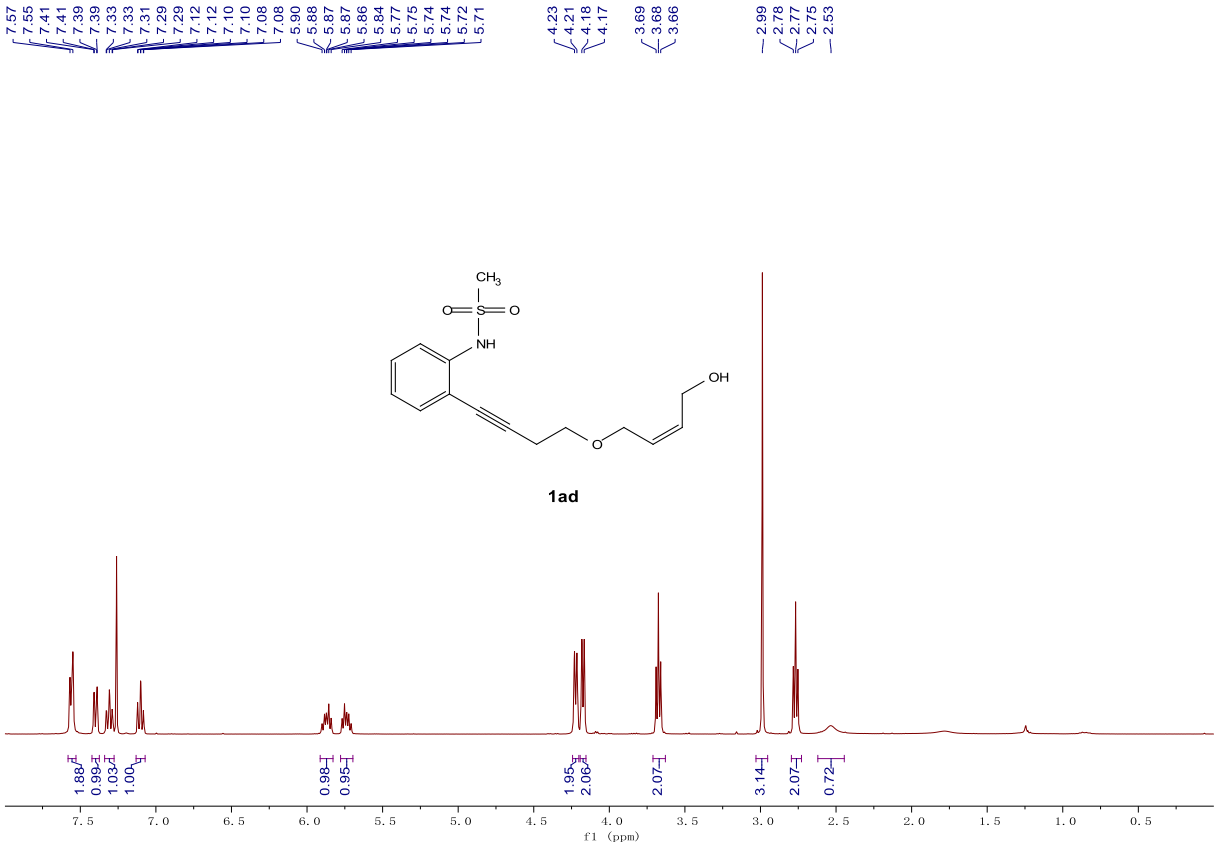
^{1}H NMR ($CDCl_3$, 400MHz) for **1ac.**



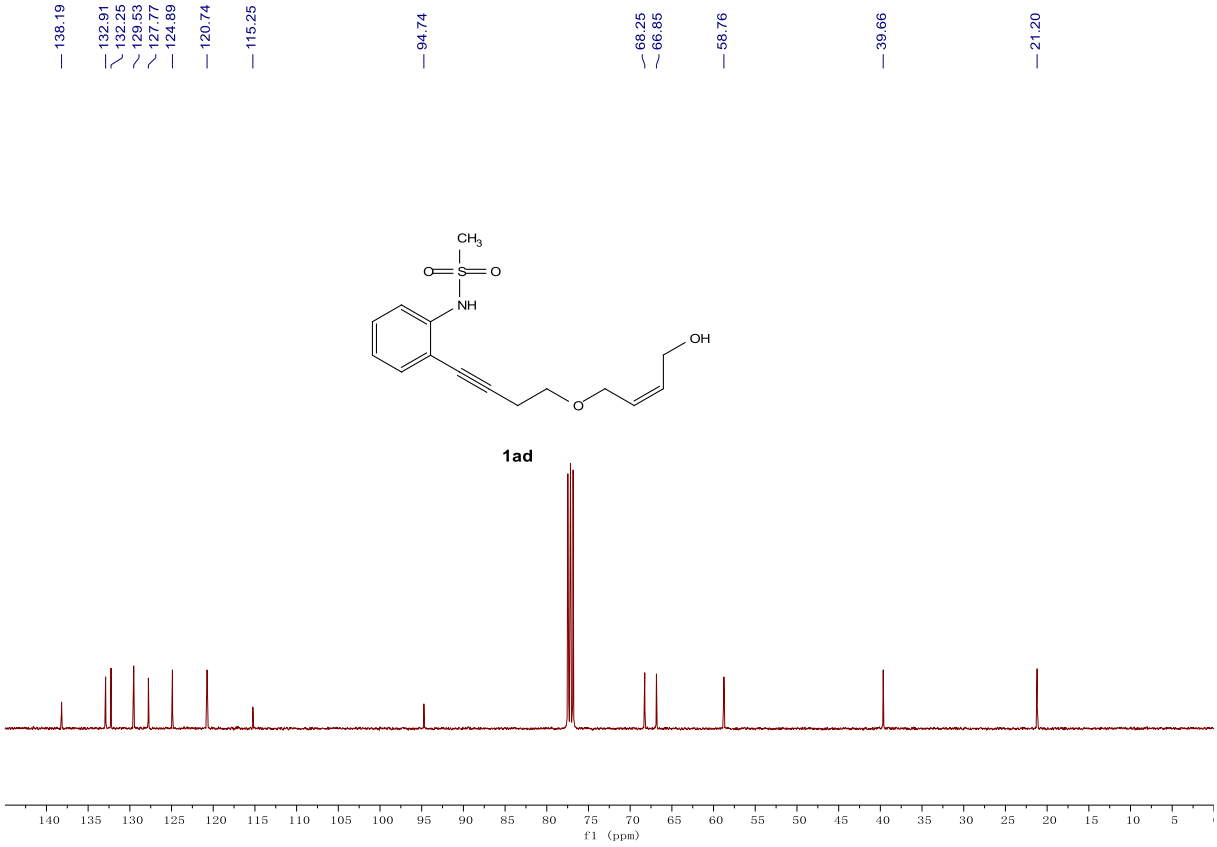
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1ac**.



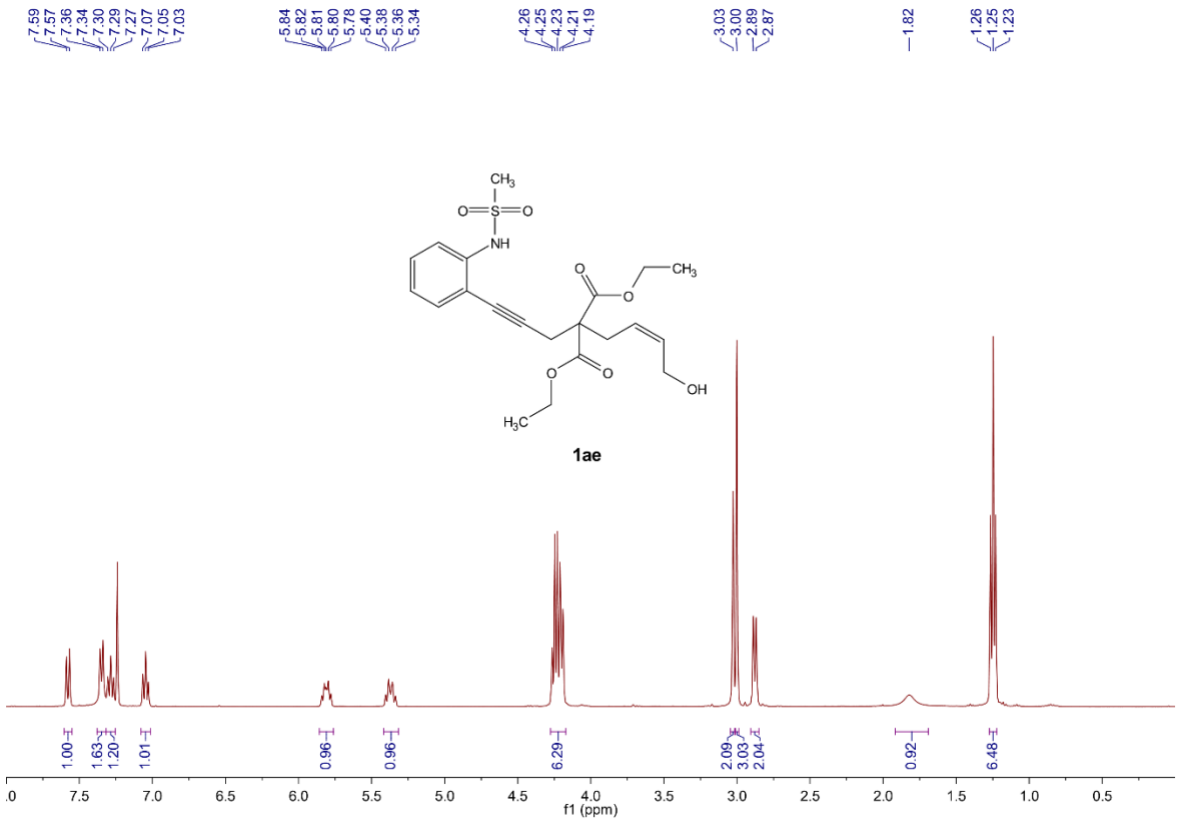
^{1}H NMR ($CDCl_3$, 400MHz) for **1ad.**



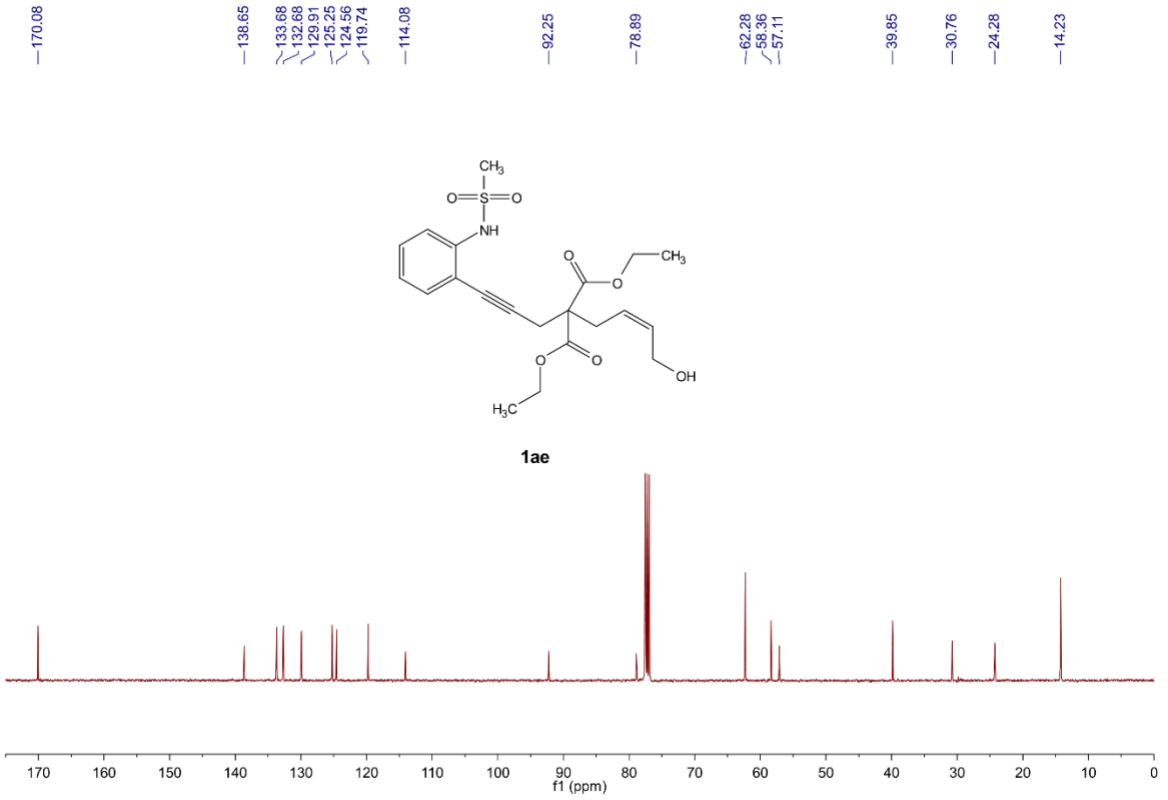
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1ad**.



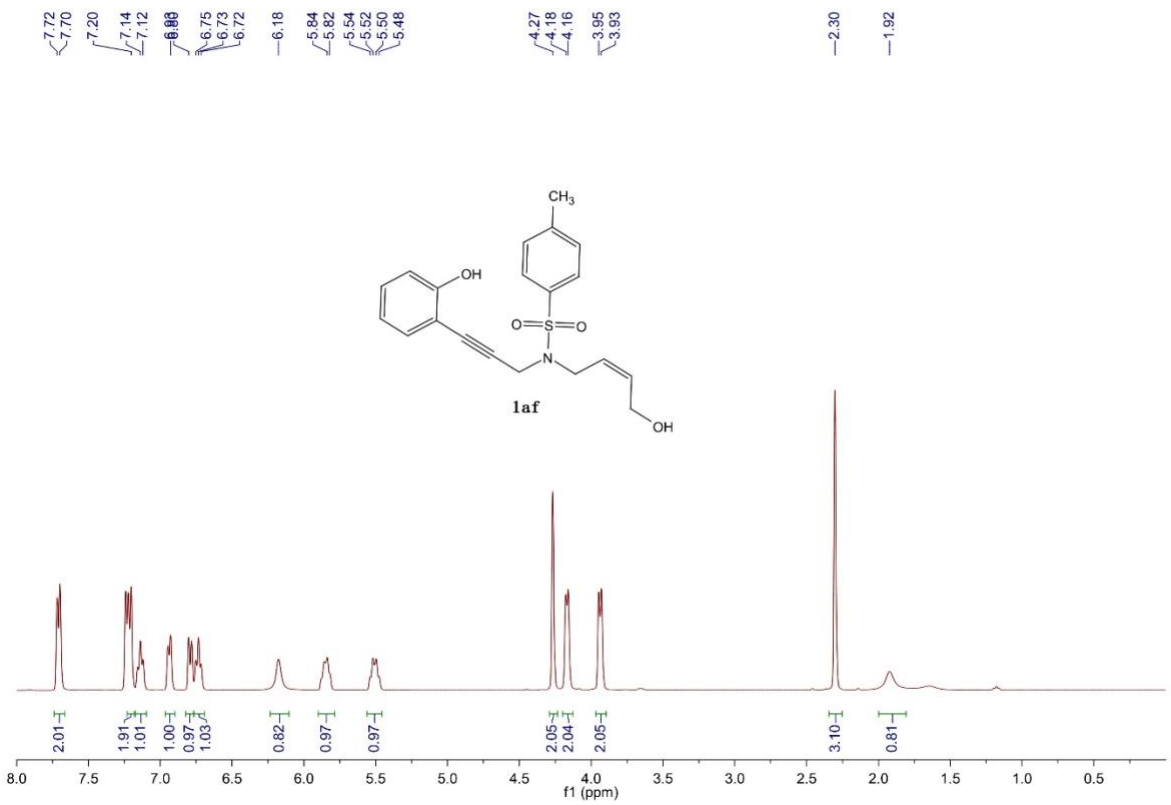
^{1}H NMR ($CDCl_3$, 400MHz) for **1ae.**



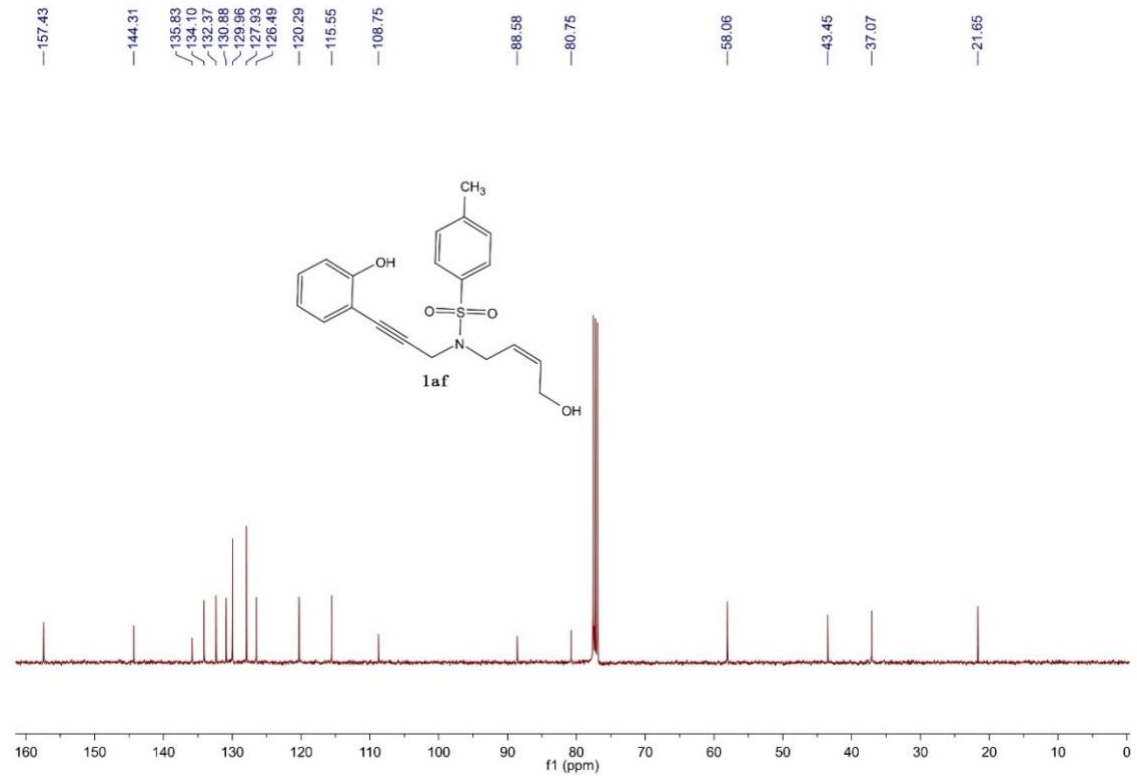
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1ae**.



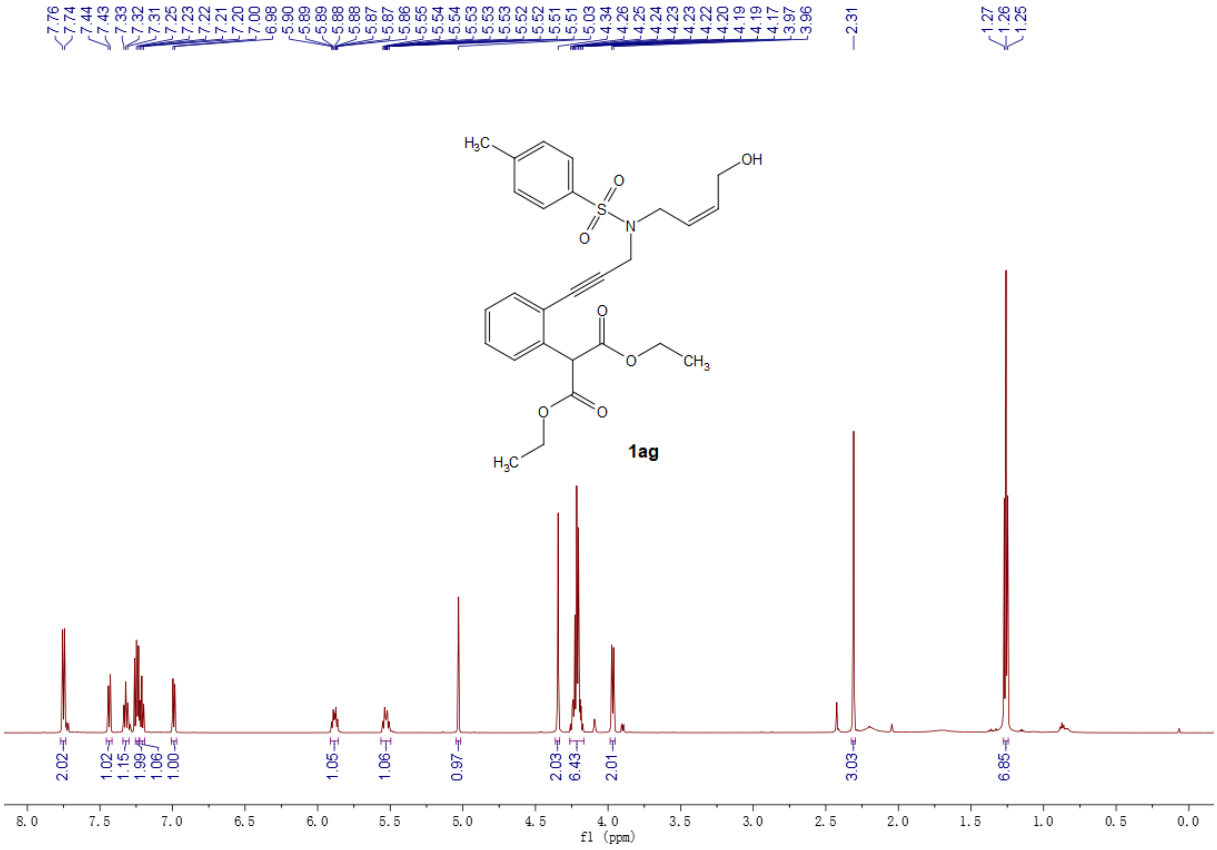
^{1}H NMR ($CDCl_3$, 400MHz) for **1af.**



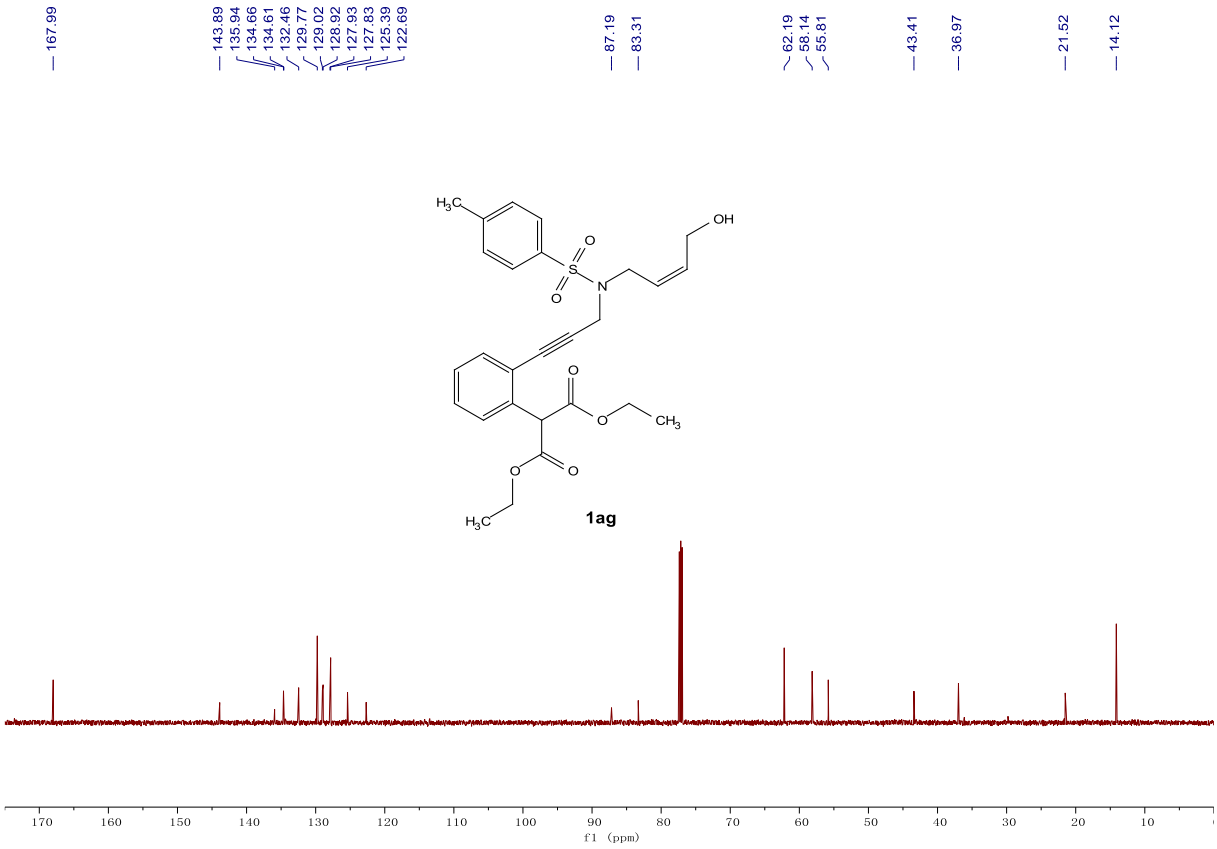
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **1af**.



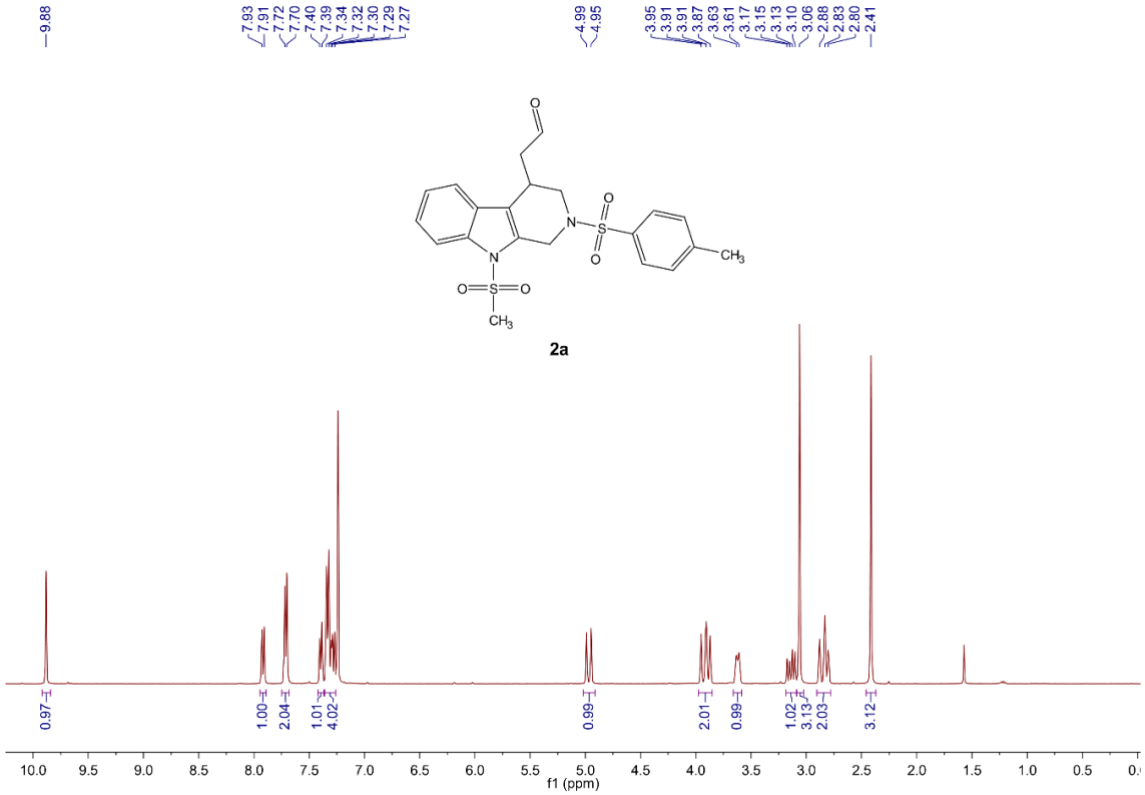
^{1}H NMR ($CDCl_3$, 600MHz) for **1ag.**



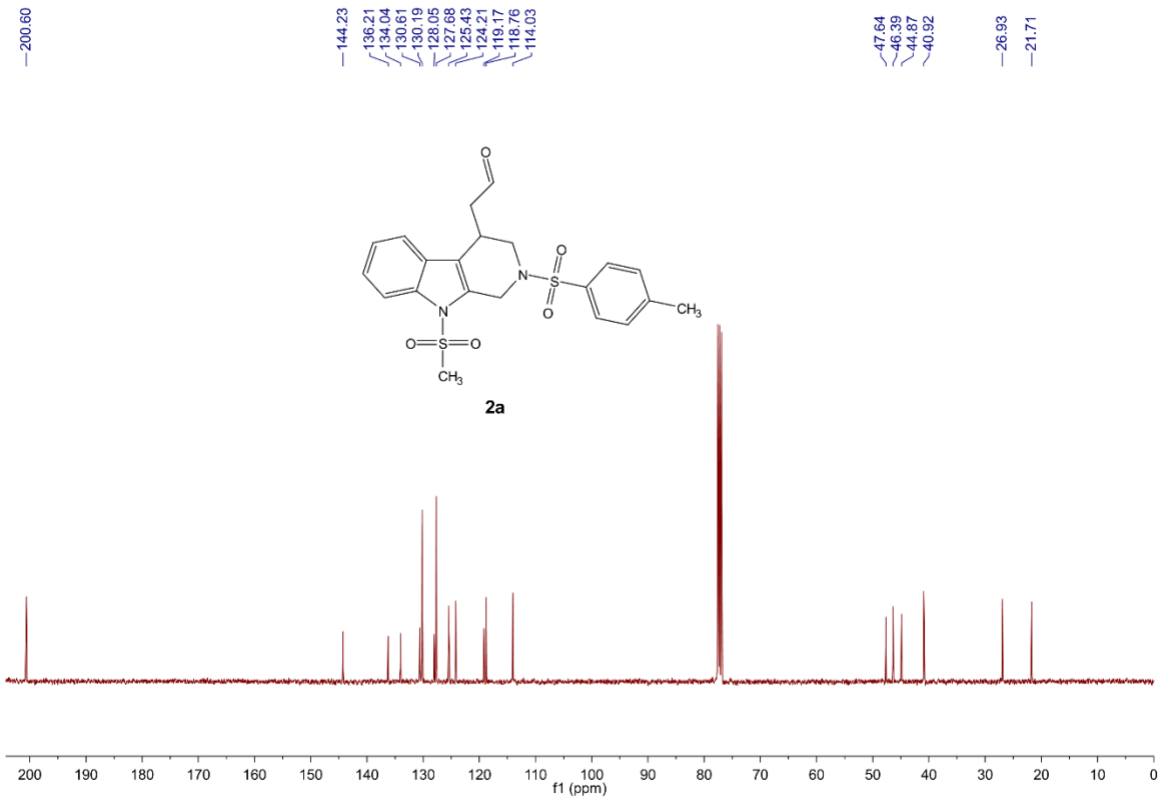
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **1ag**.



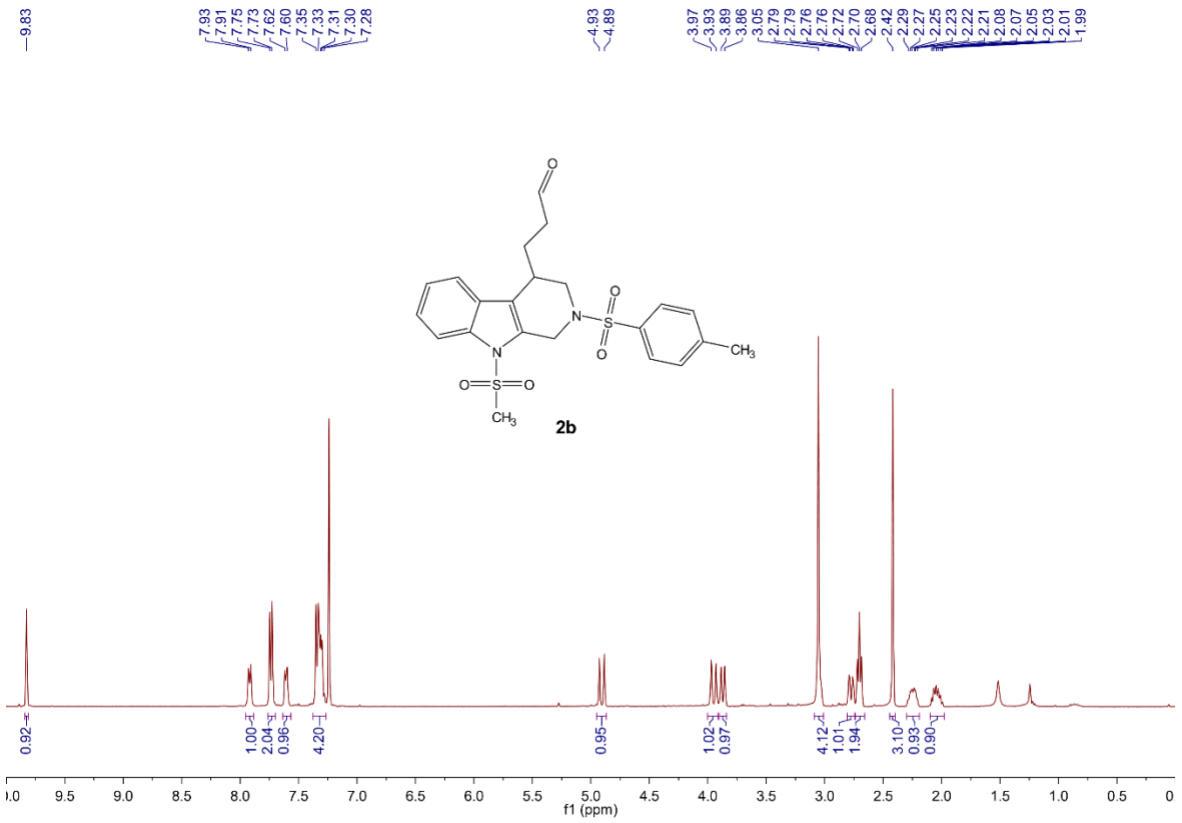
^{1}H NMR ($CDCl_3$, 400MHz) for **2a.**



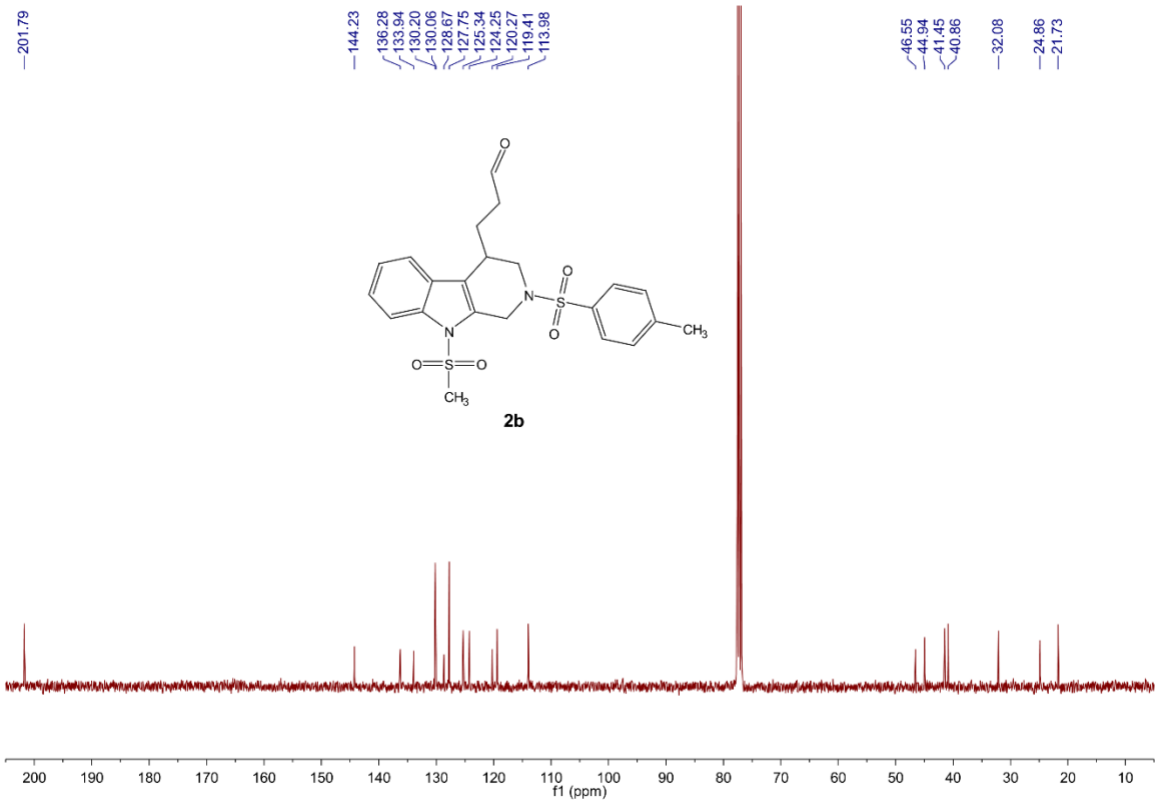
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2a**.



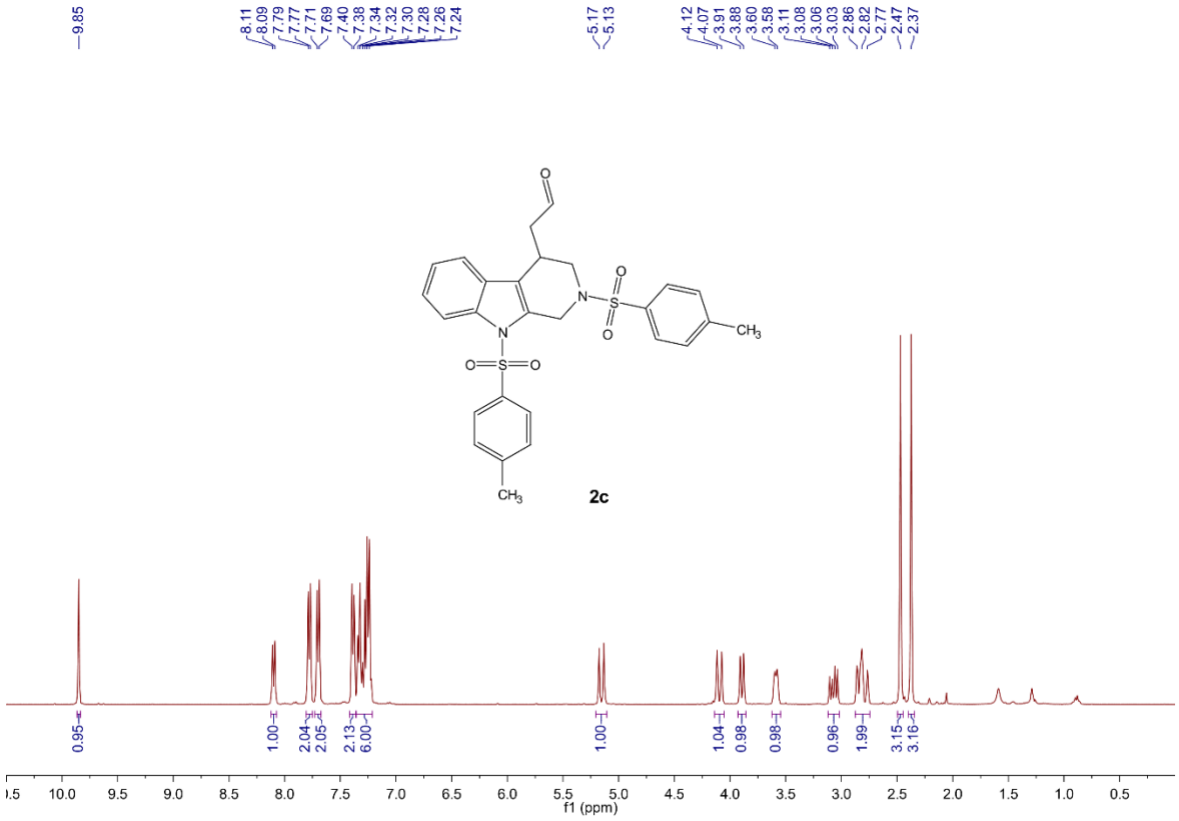
^{1}H NMR ($CDCl_3$, 400MHz) for **2b.**



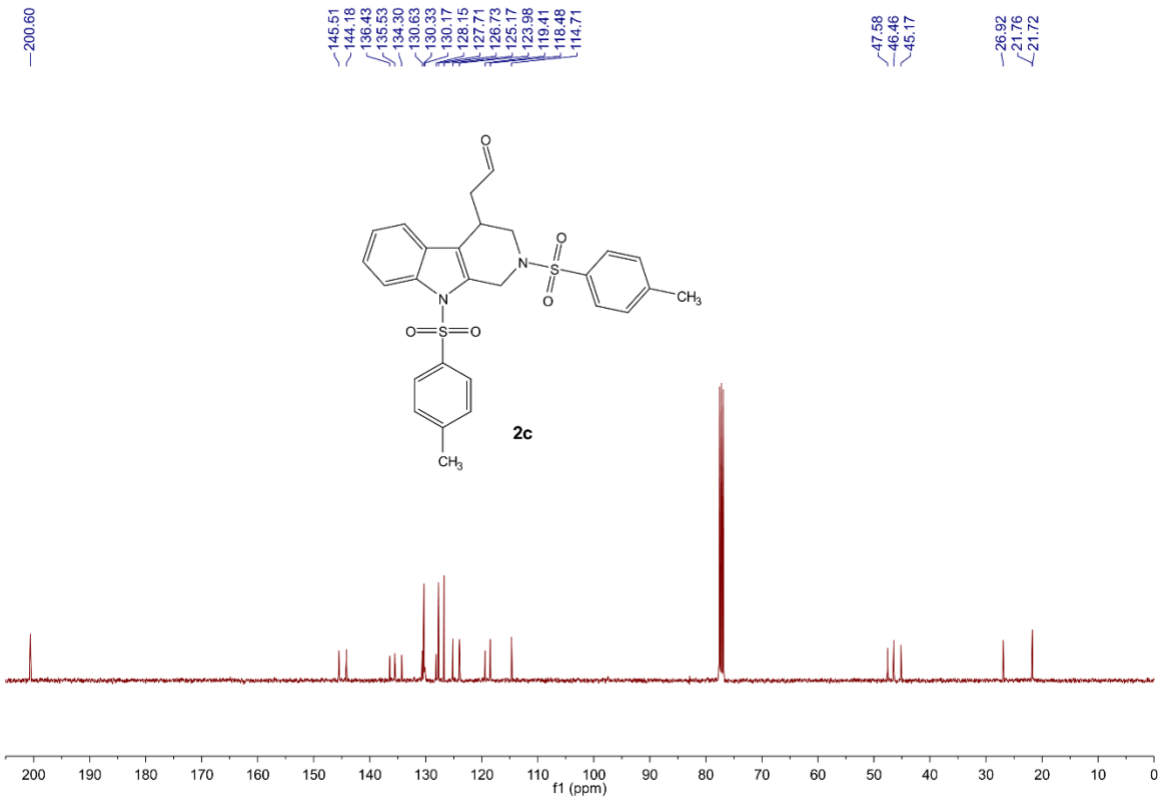
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2b**.



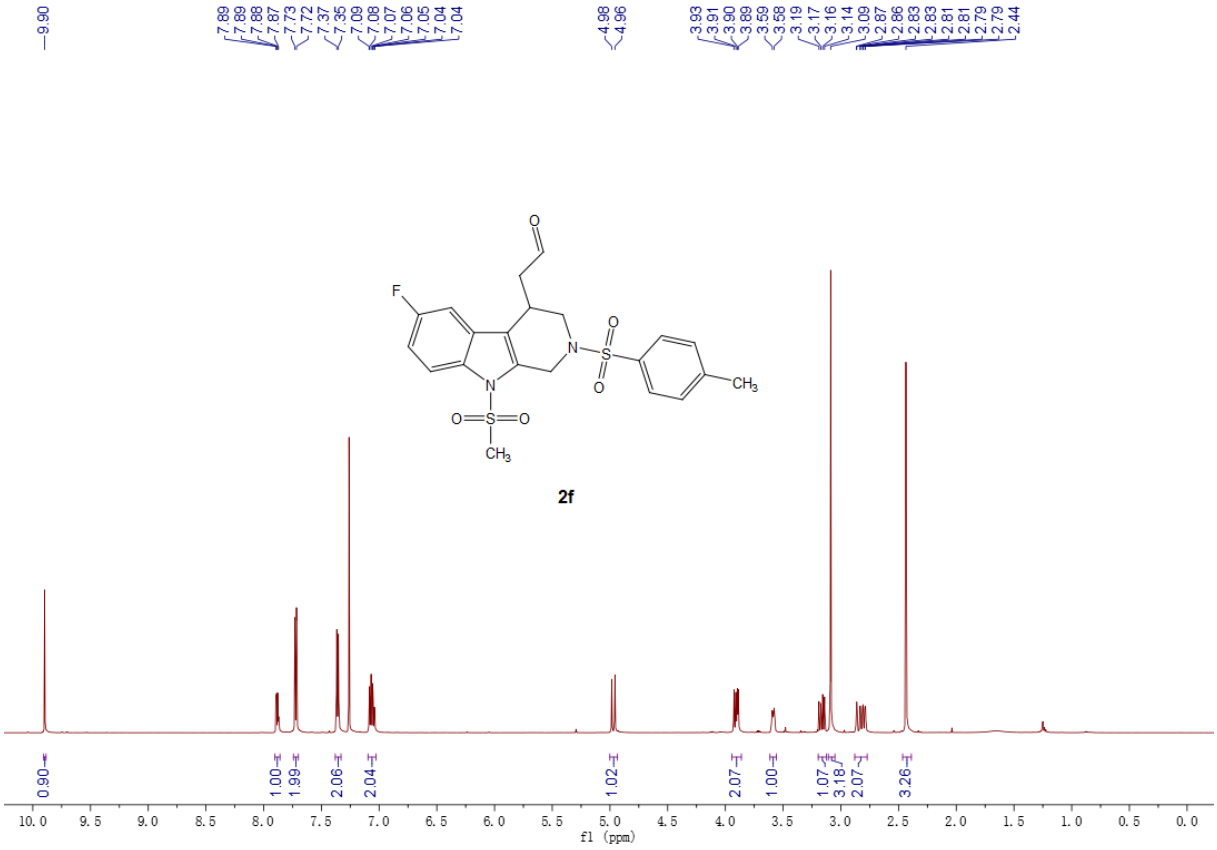
^{1}H NMR ($CDCl_3$, 400MHz) for **2c.**



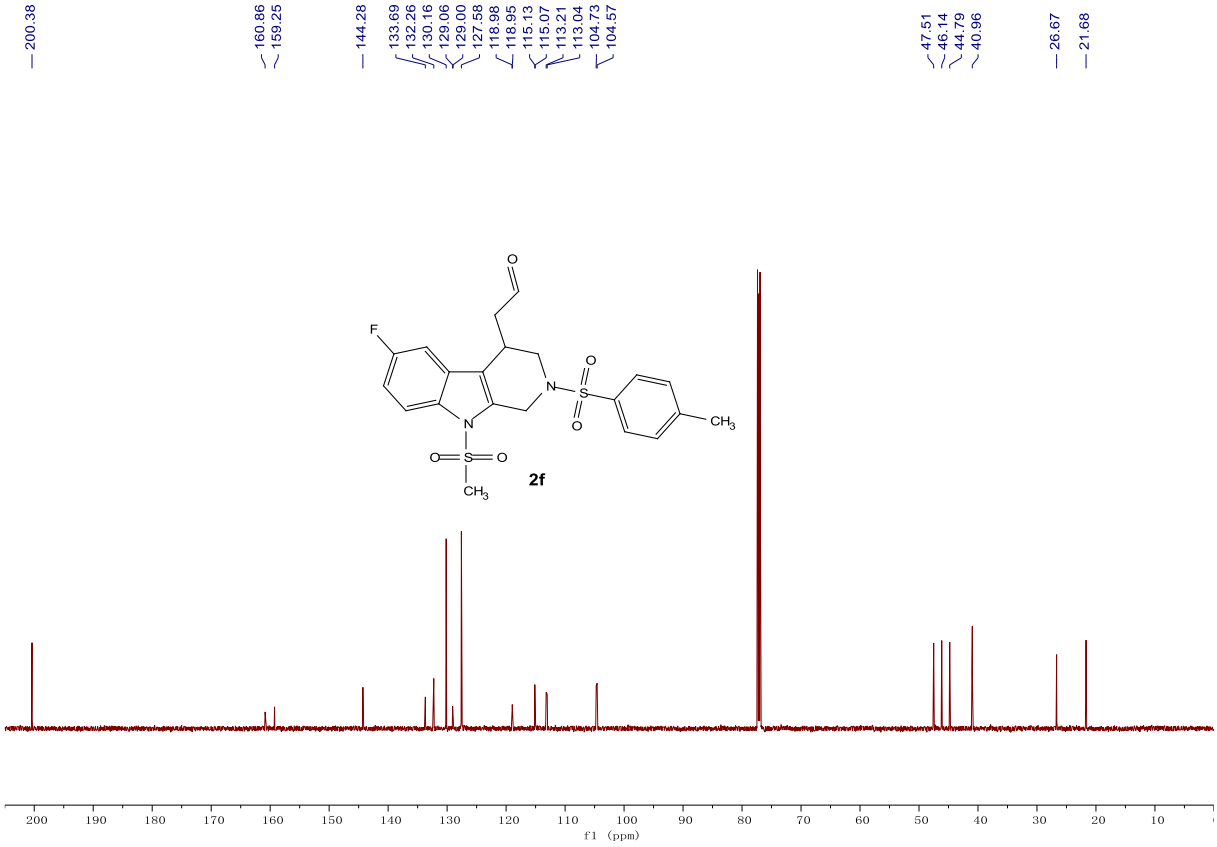
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2c**.



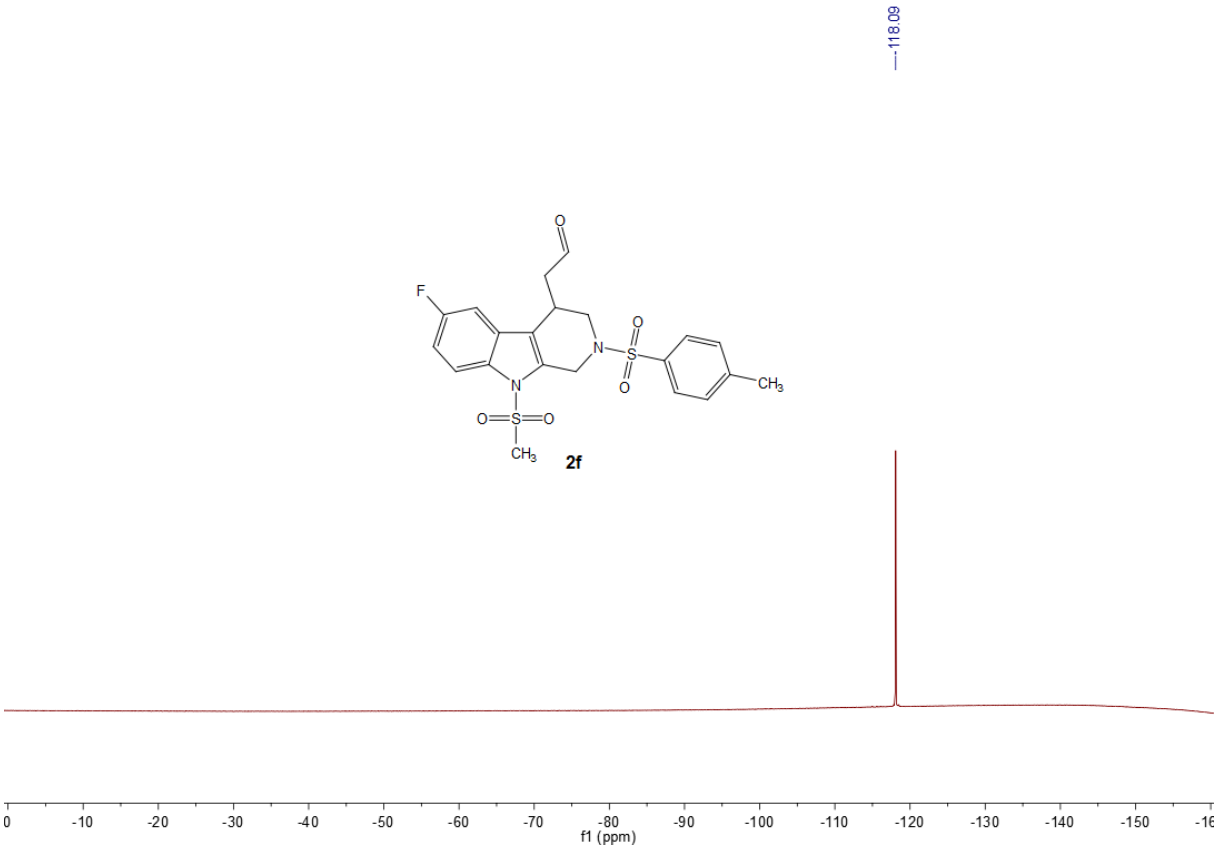
^{1}H NMR ($CDCl_3$, 600MHz) for **2f.**



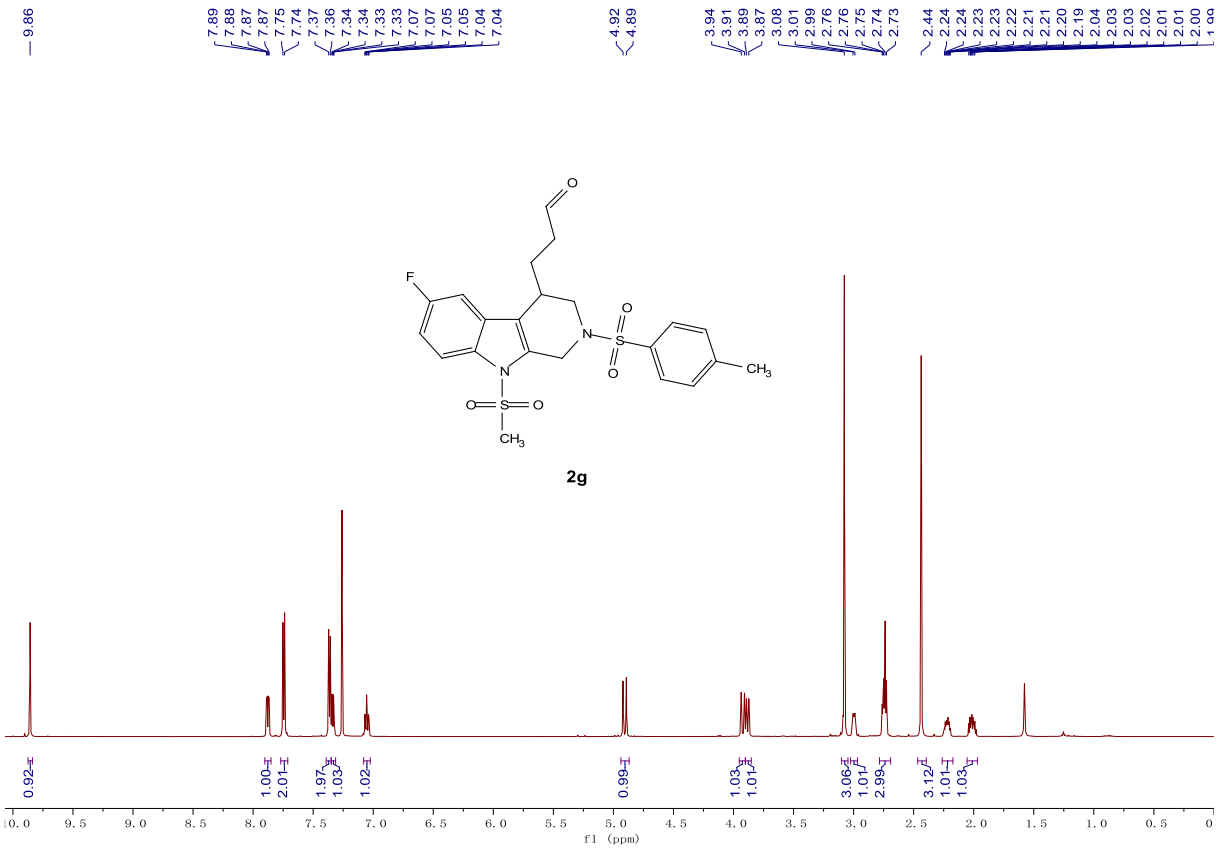
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **2f**.



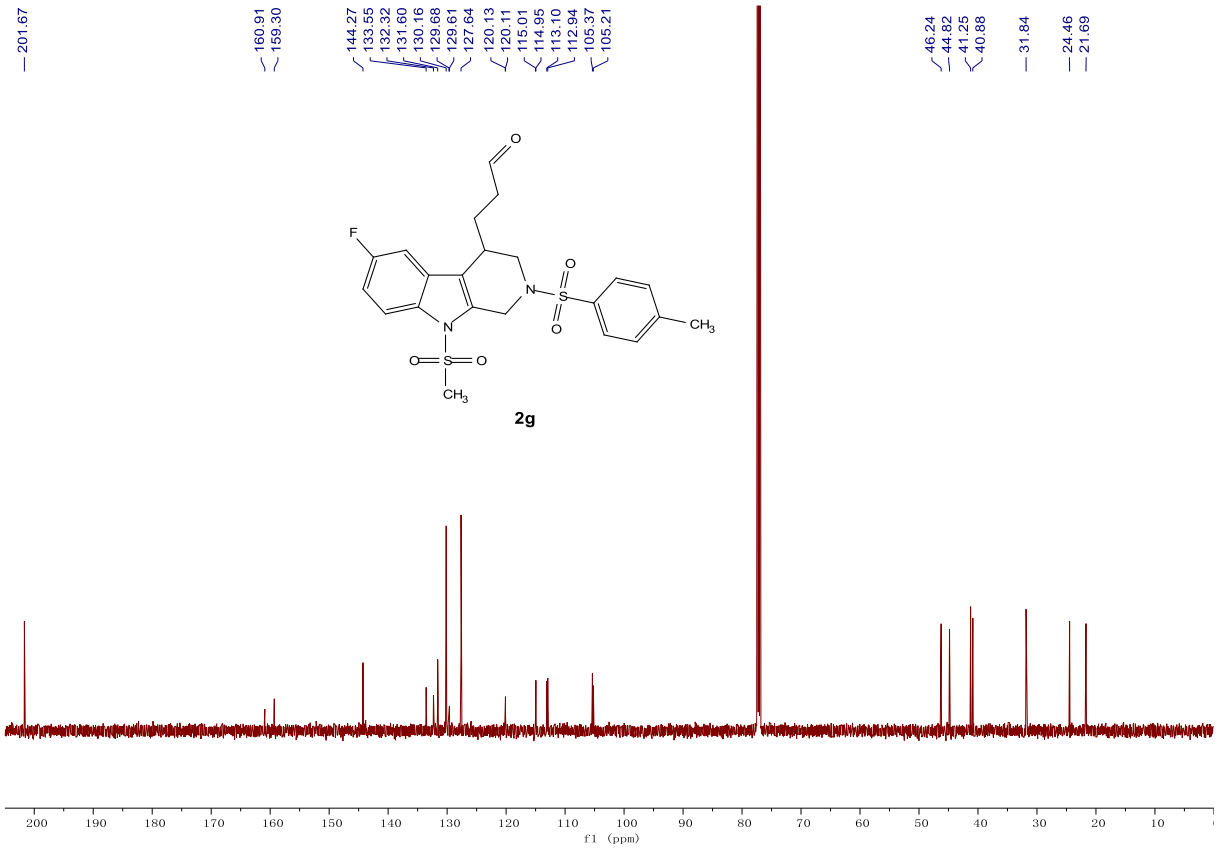
^{19}F NMR ($CDCl_3$, 376 MHz) for **2f**.



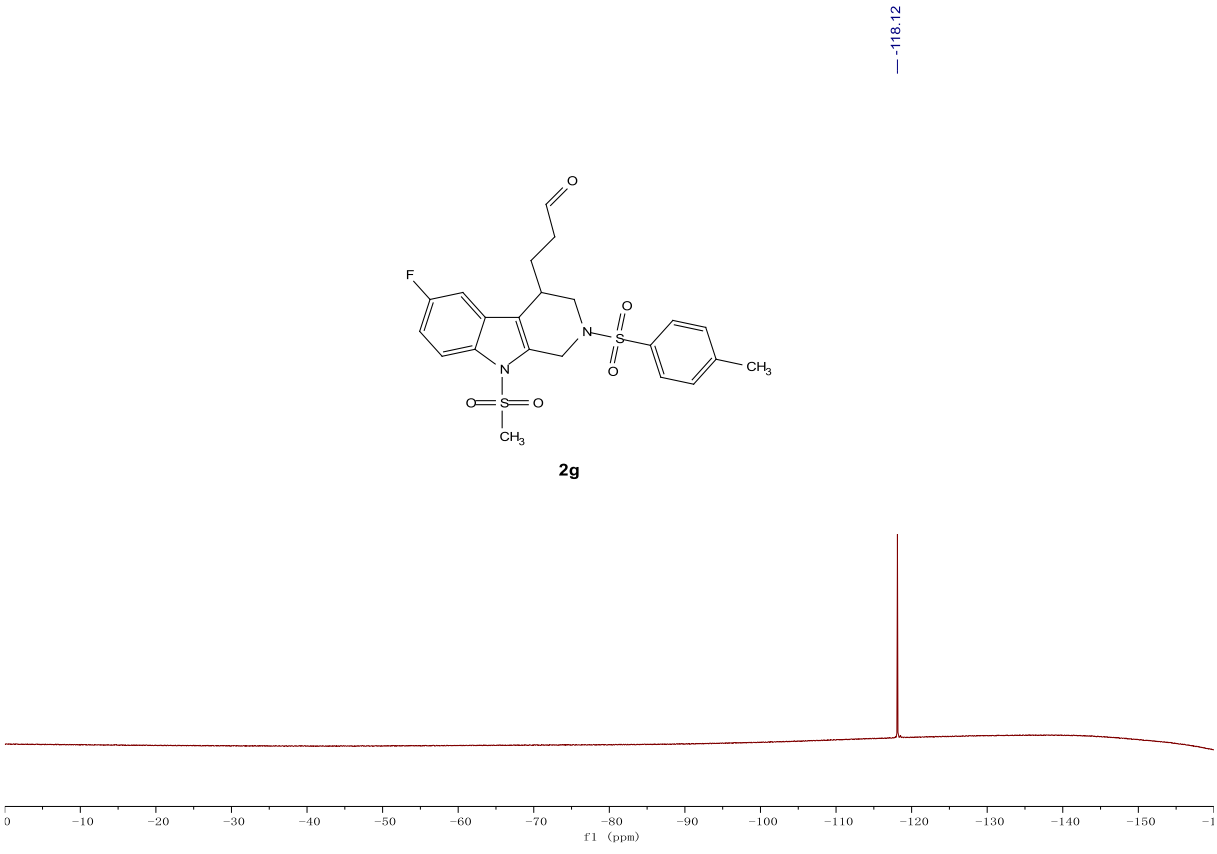
^{1}H NMR ($CDCl_3$, 600MHz) for **2g.**



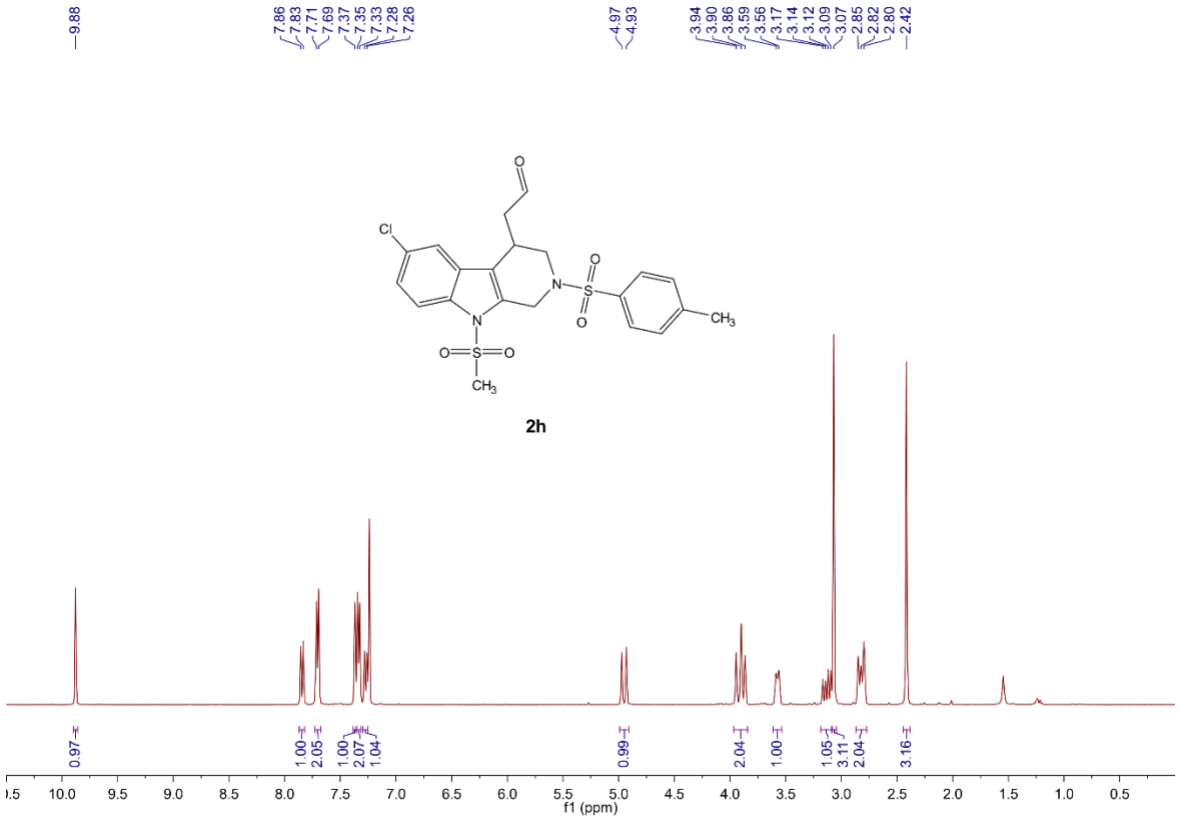
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz) for **2g**.



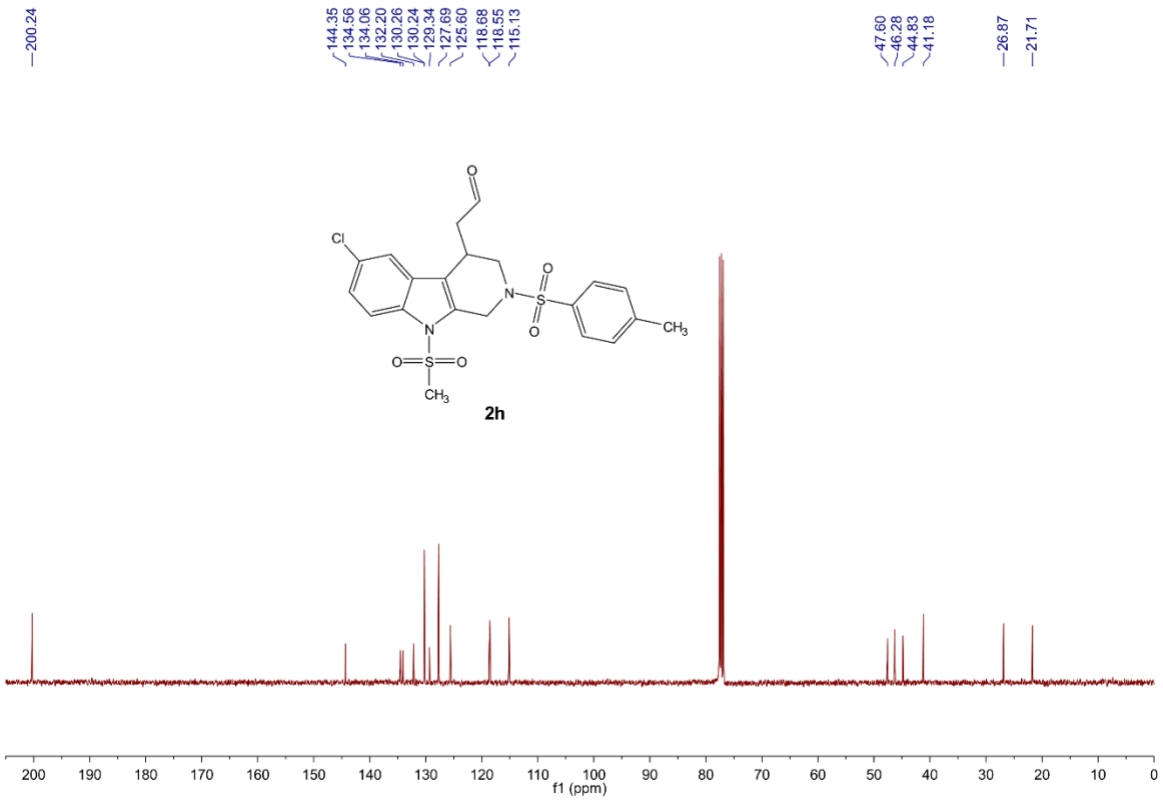
^{19}F NMR ($CDCl_3$, 376 MHz) for **2g**.



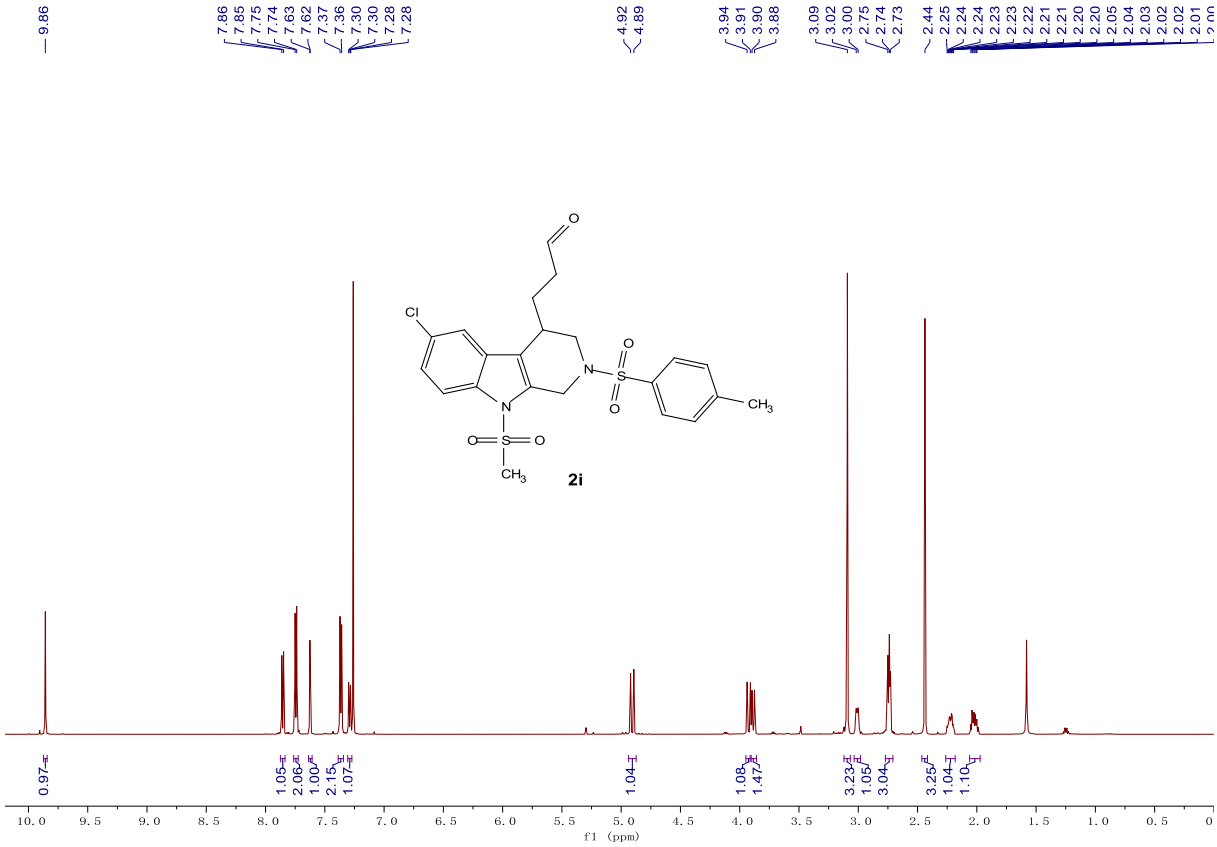
^{1}H NMR ($CDCl_3$, 400MHz) for **2h.**



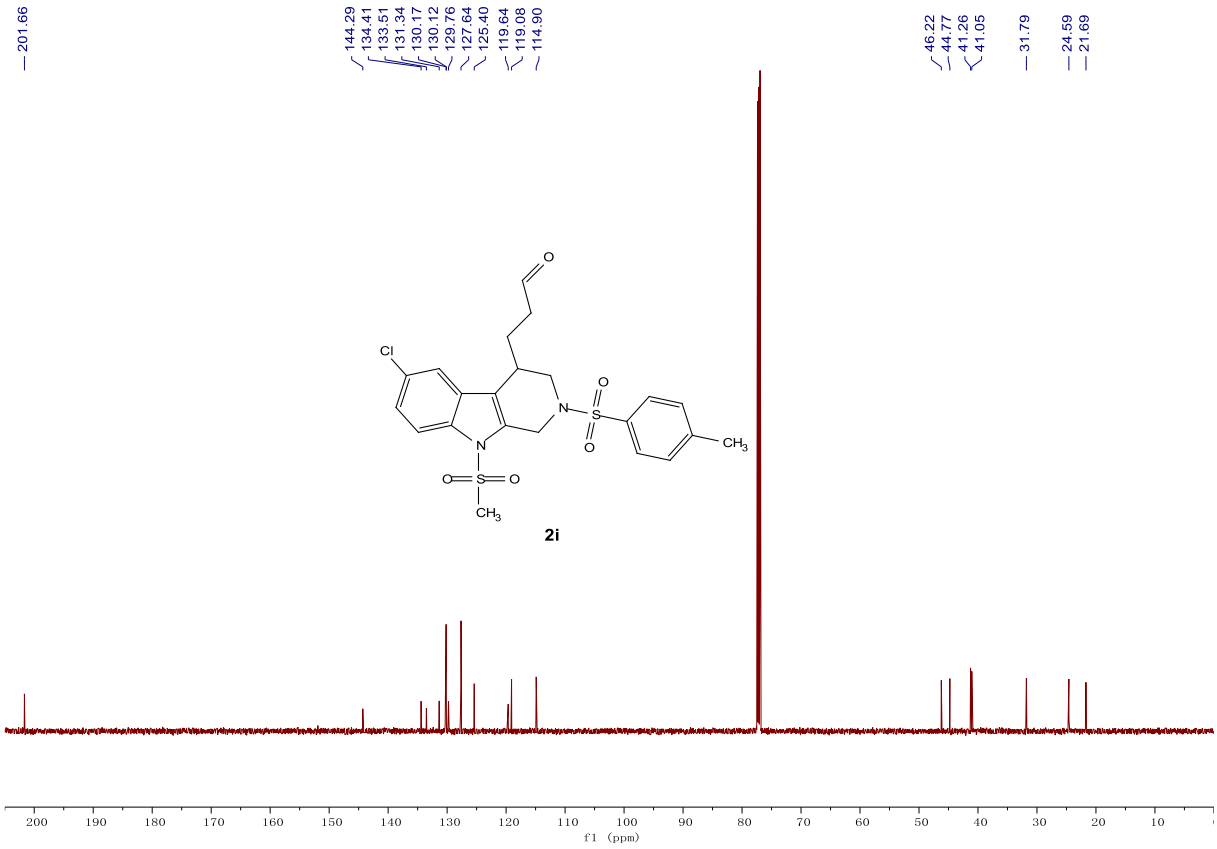
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2h**.



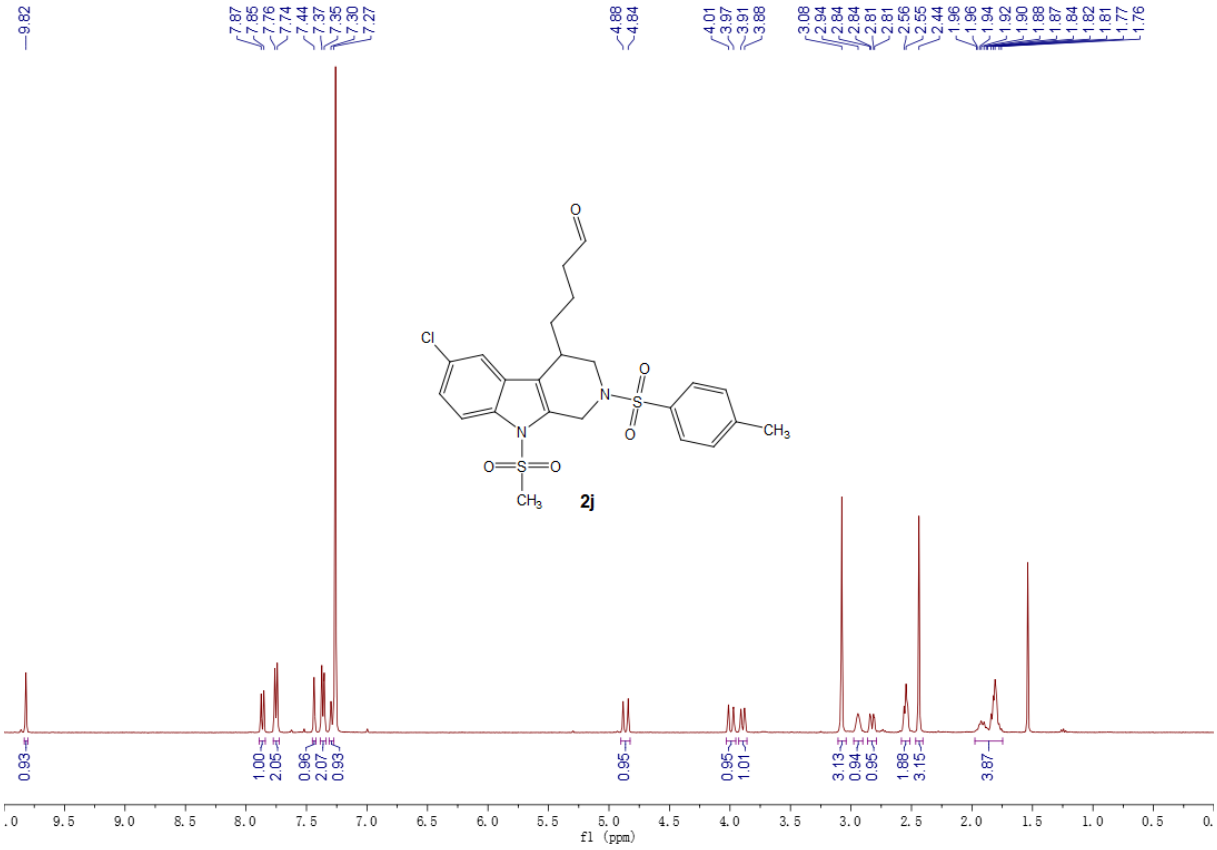
^{1}H NMR ($CDCl_3$, 600MHz) for **2i.**



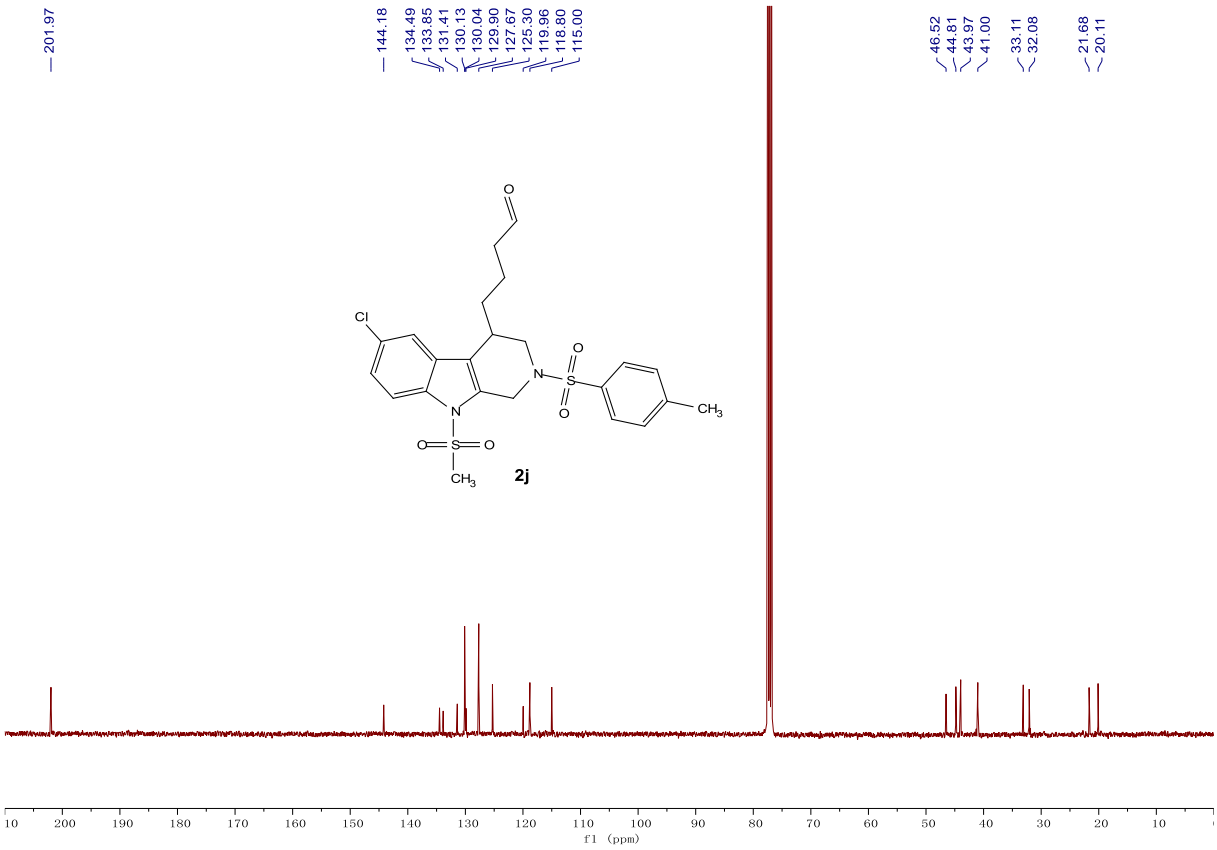
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **2i**.



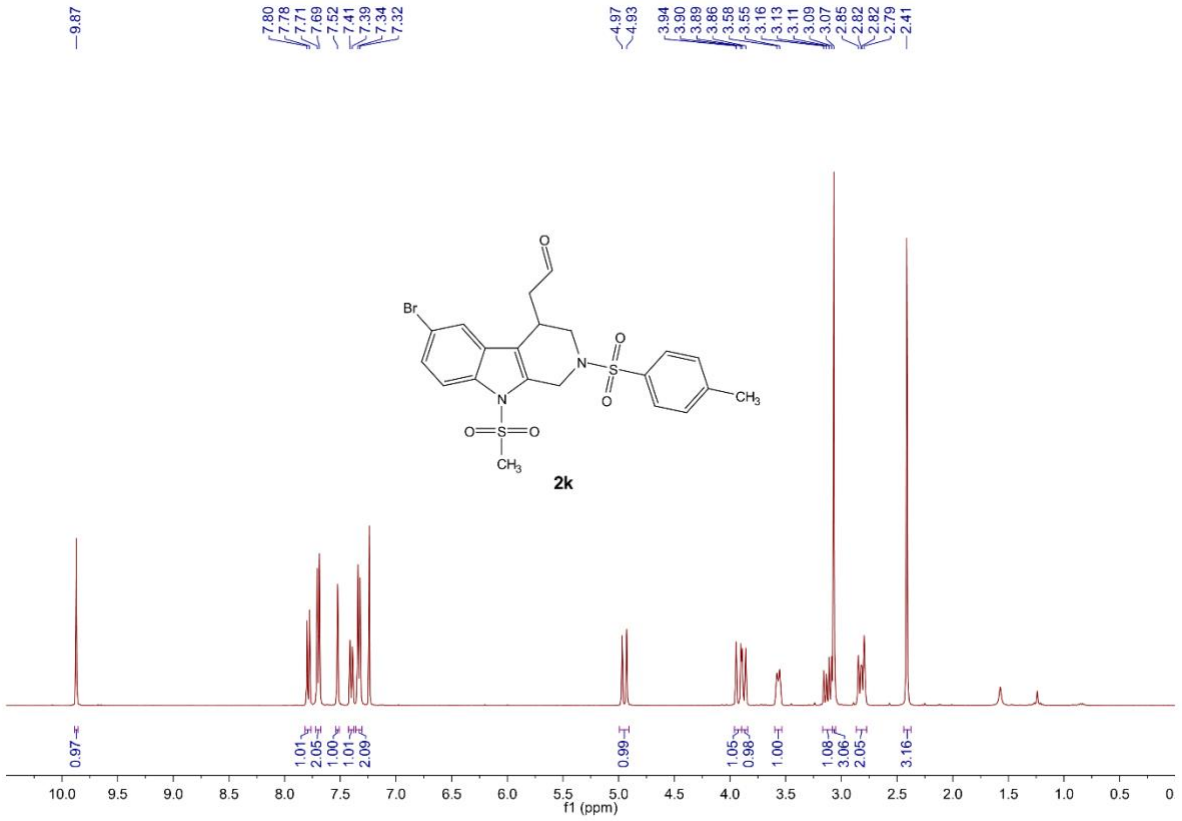
^{1}H NMR ($CDCl_3$, 400MHz) for **2j.**



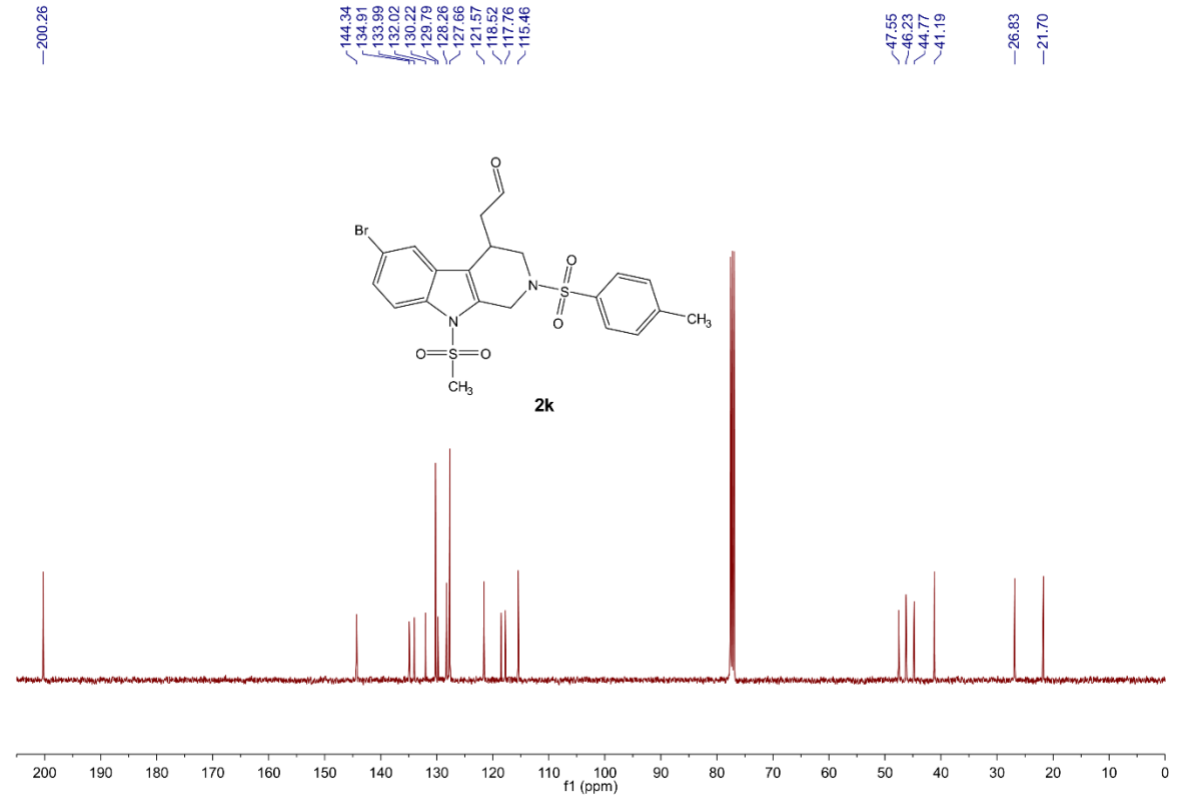
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2j**.



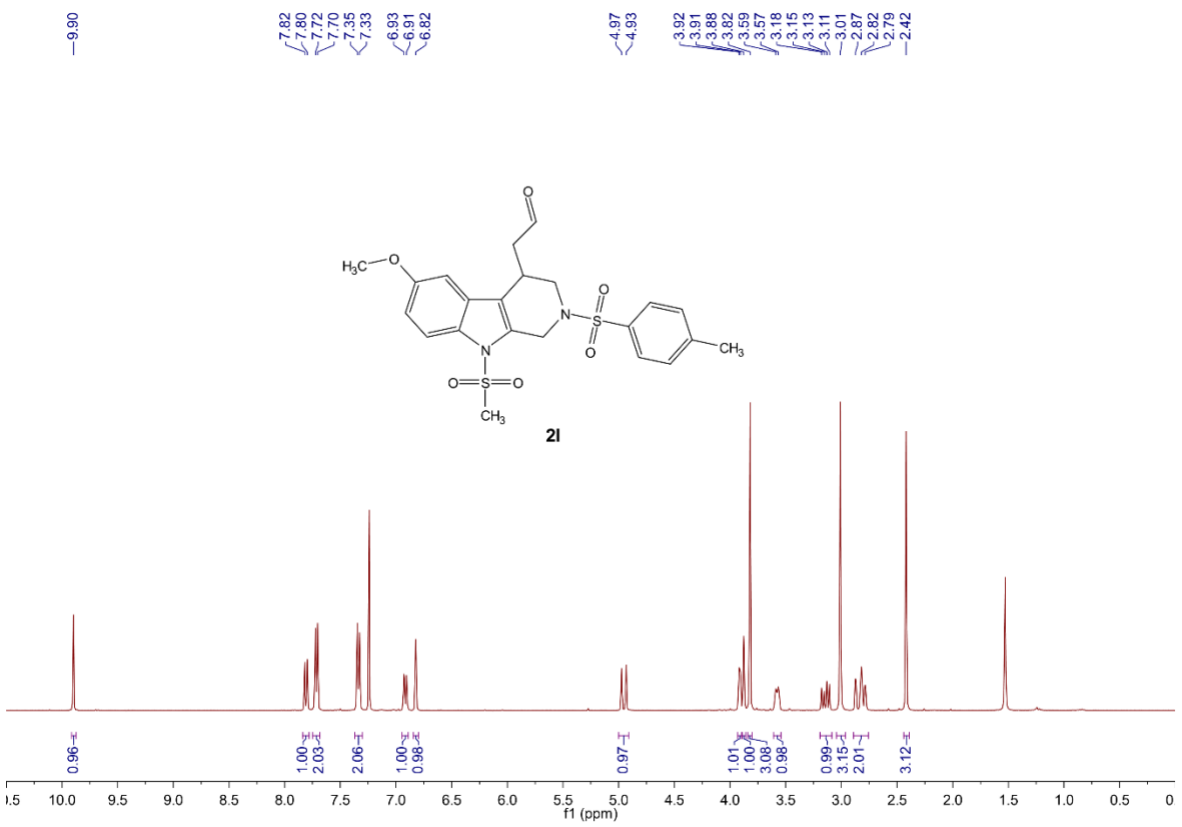
^{1}H NMR ($CDCl_3$, 400MHz) for **2k.**



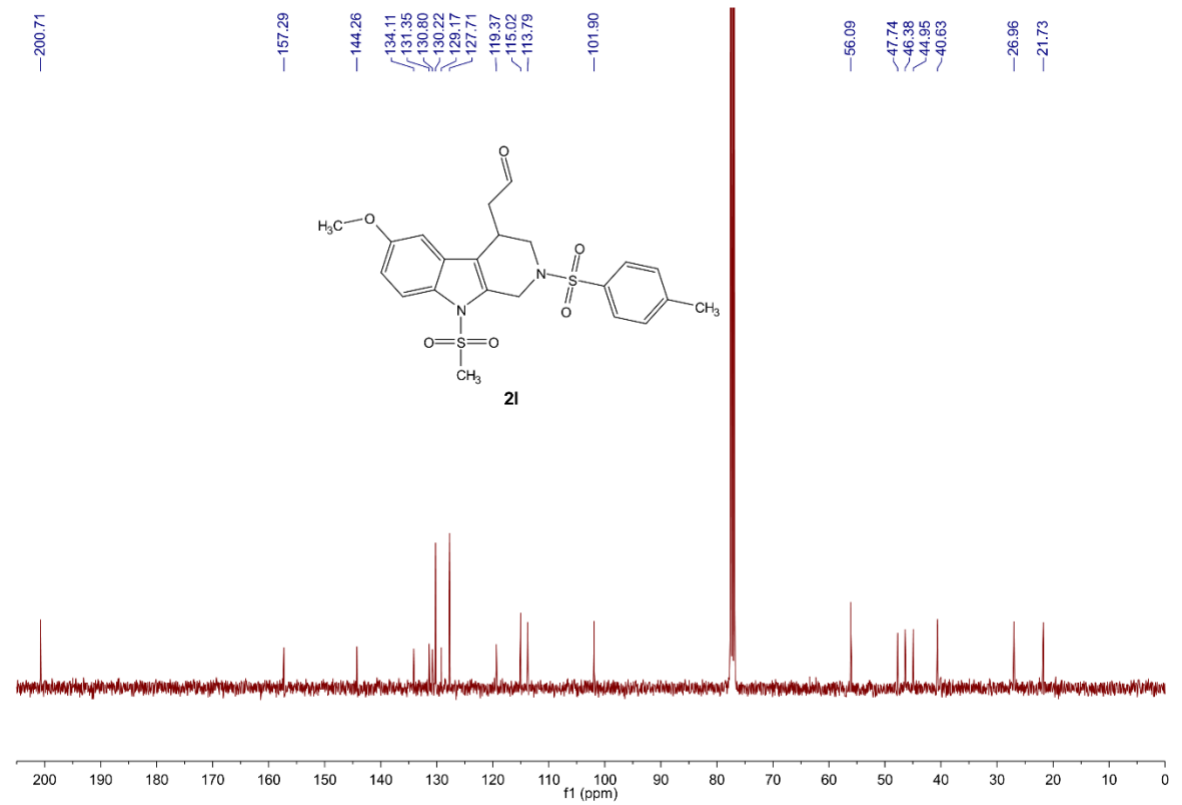
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2k**.



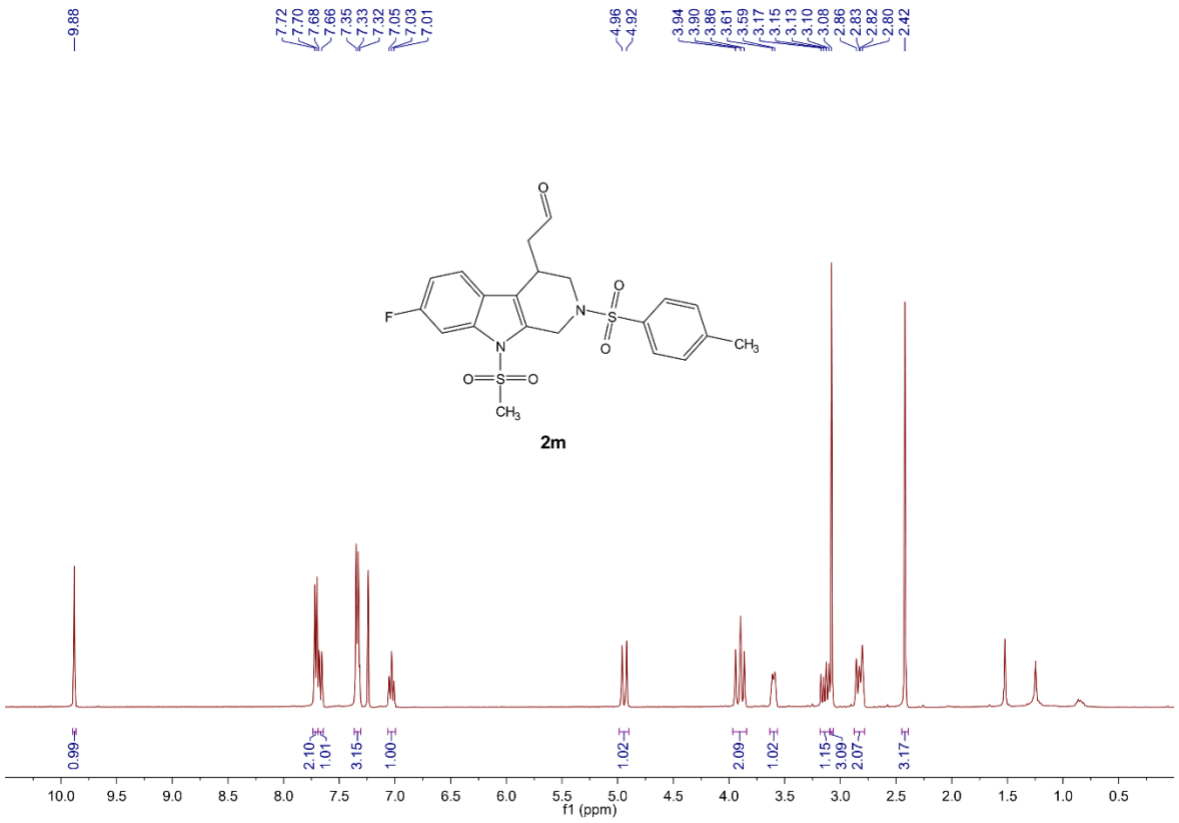
^{1}H NMR ($CDCl_3$, 400MHz) for **2l.**



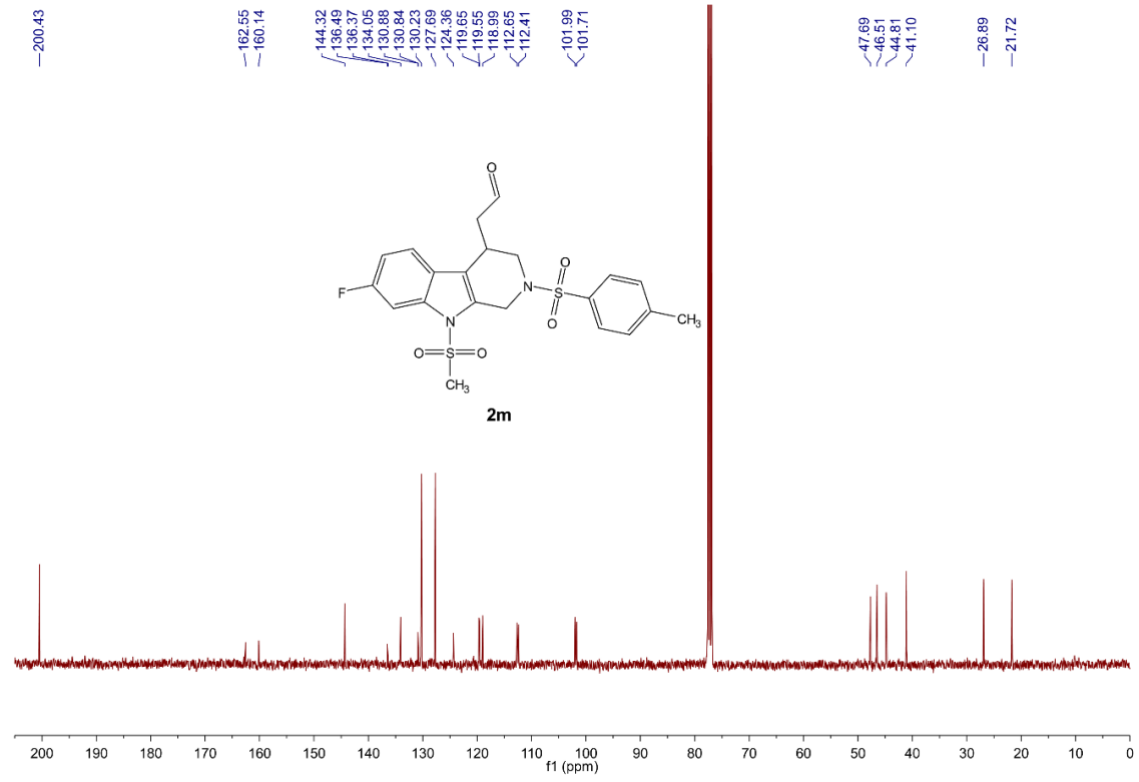
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2l**.



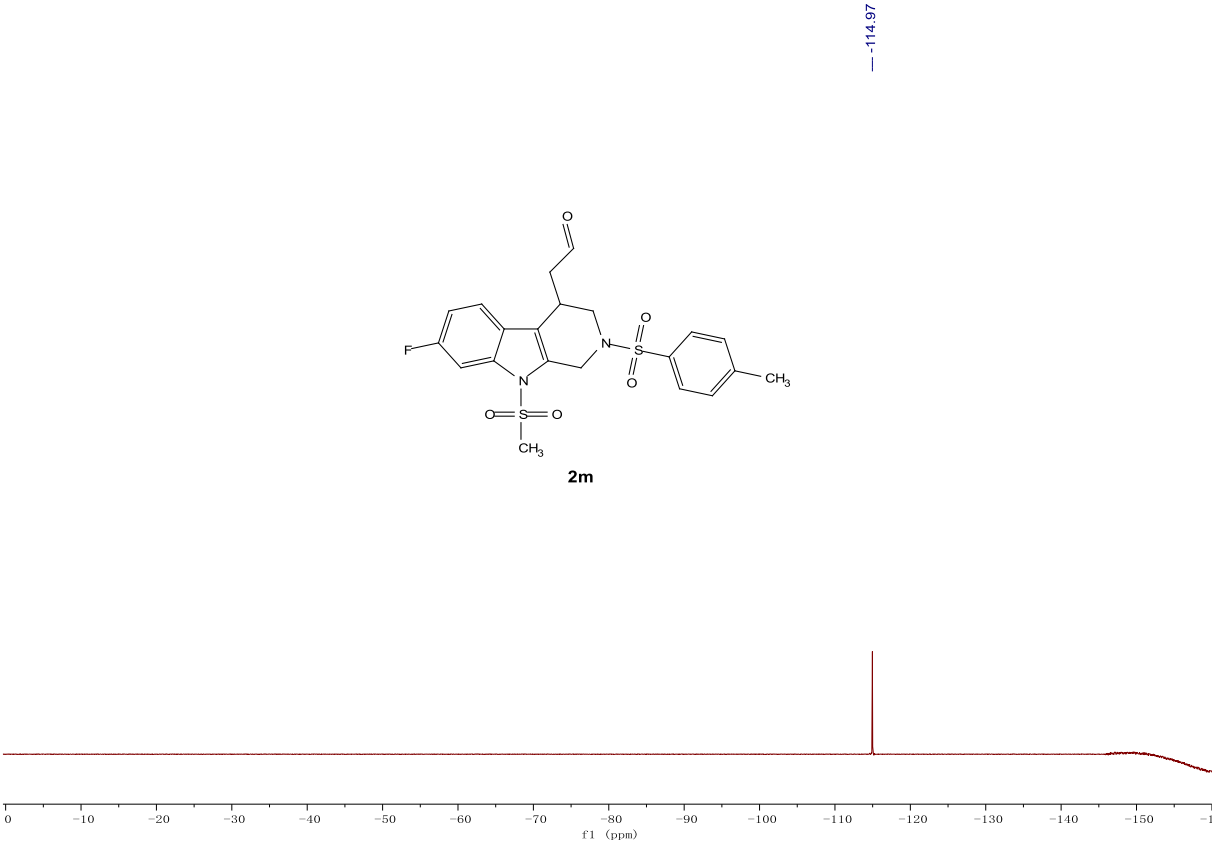
^{1}H NMR ($CDCl_3$, 400MHz) for **2m.**



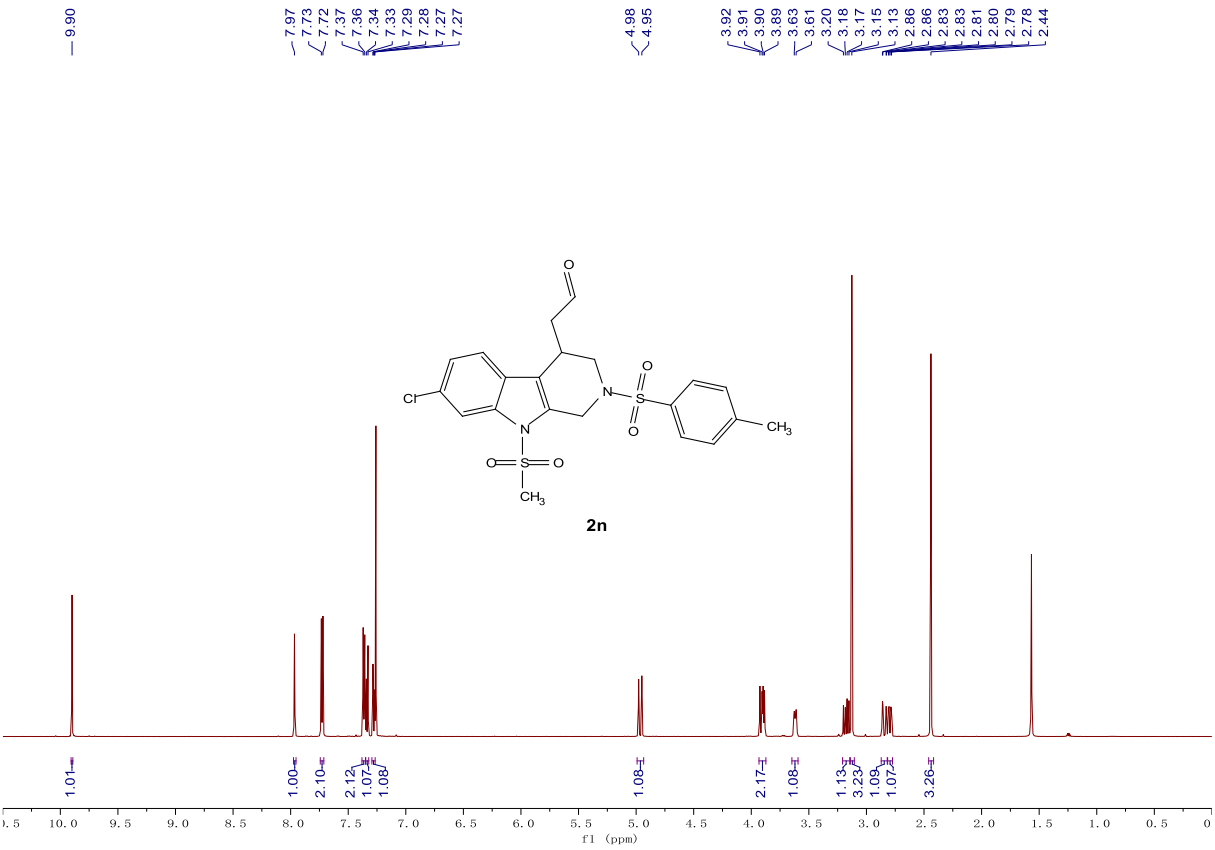
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2m**.



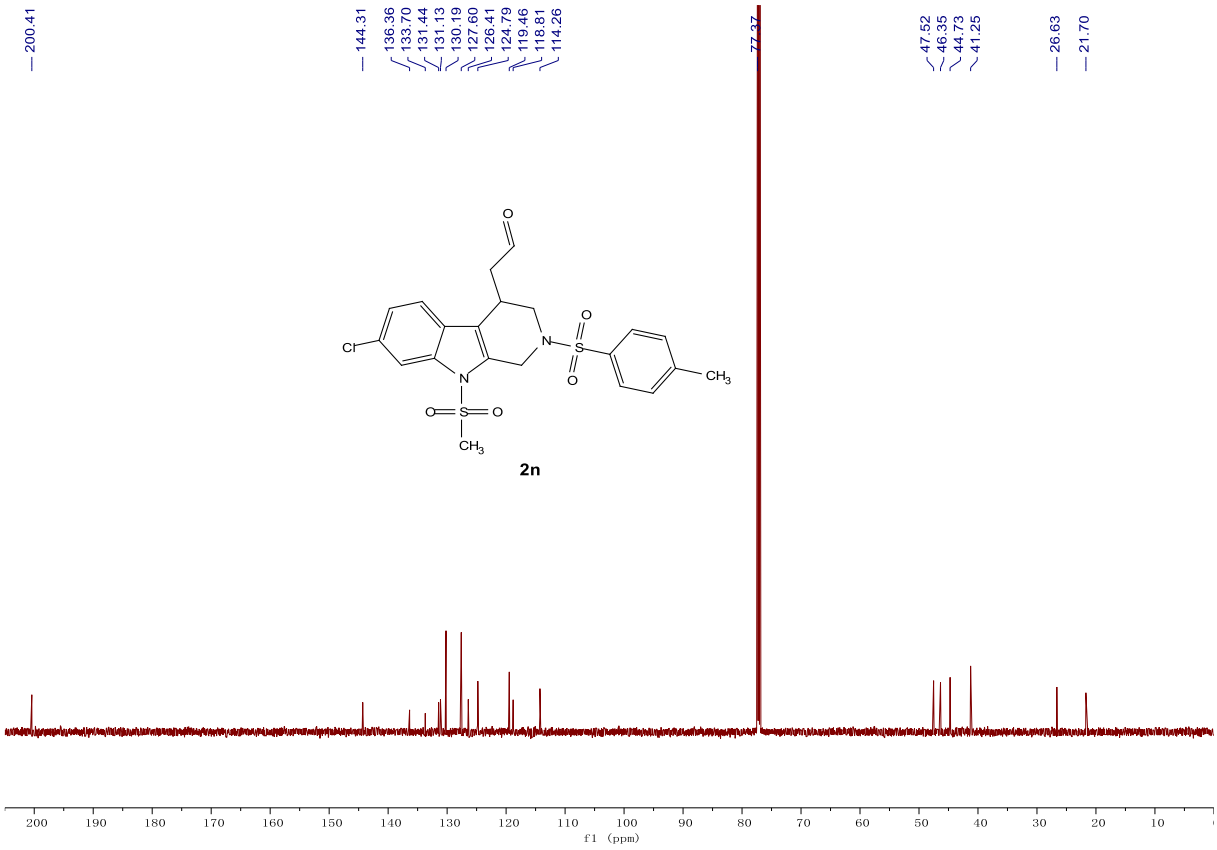
^{19}F NMR ($CDCl_3$, 376 MHz) for **2m**.



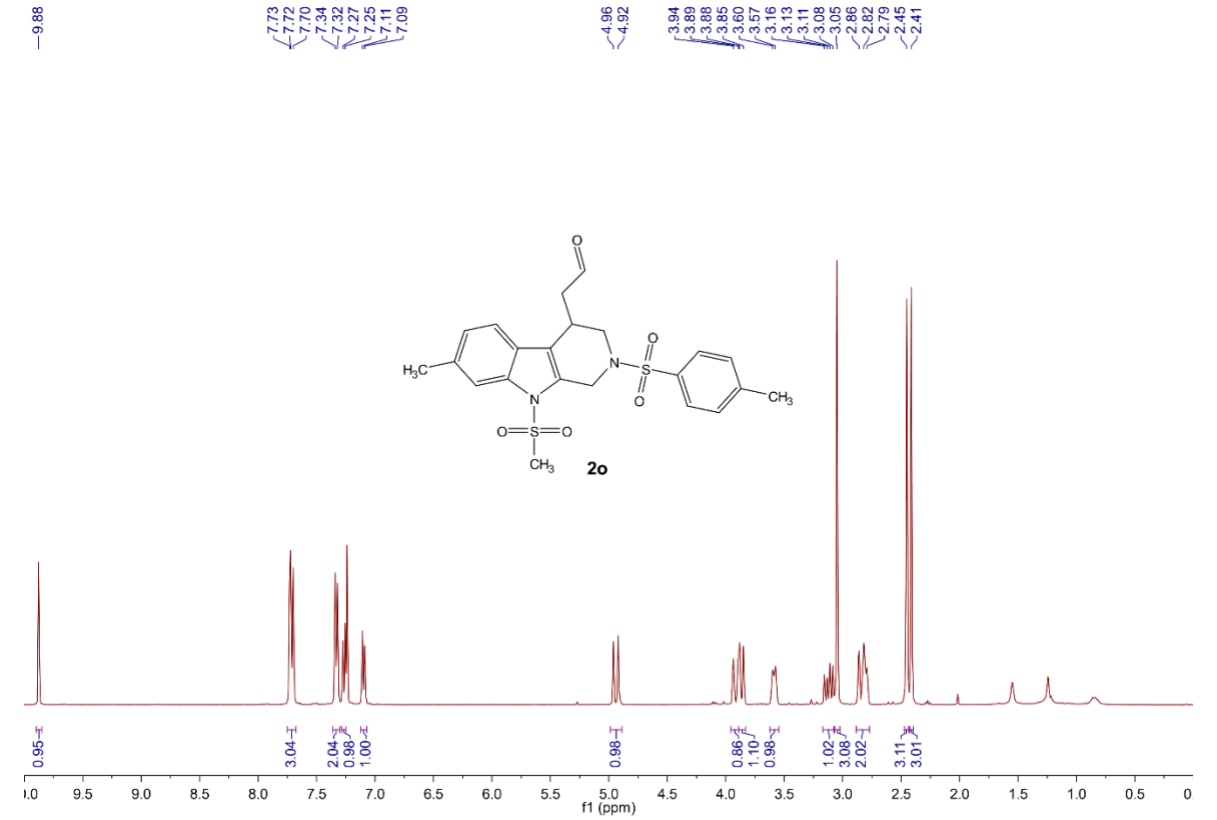
^{1}H NMR ($CDCl_3$, 600MHz) for **2n.**



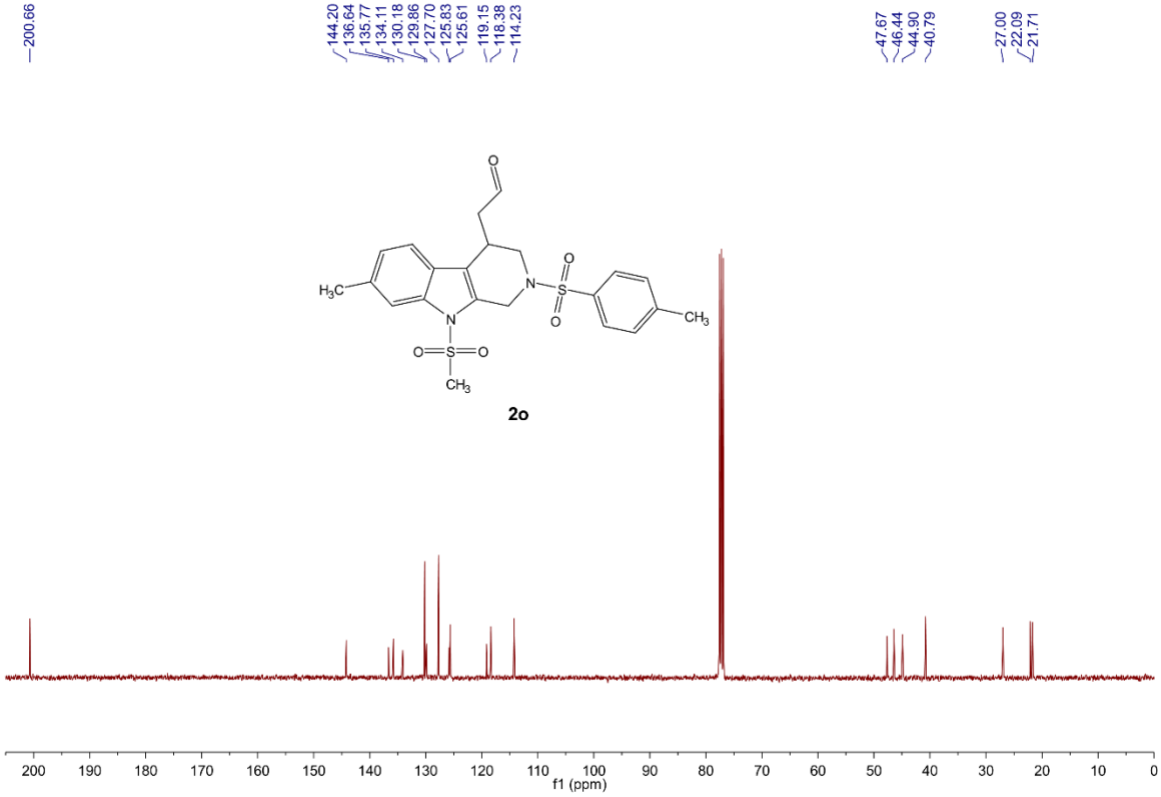
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz) for **2n**.



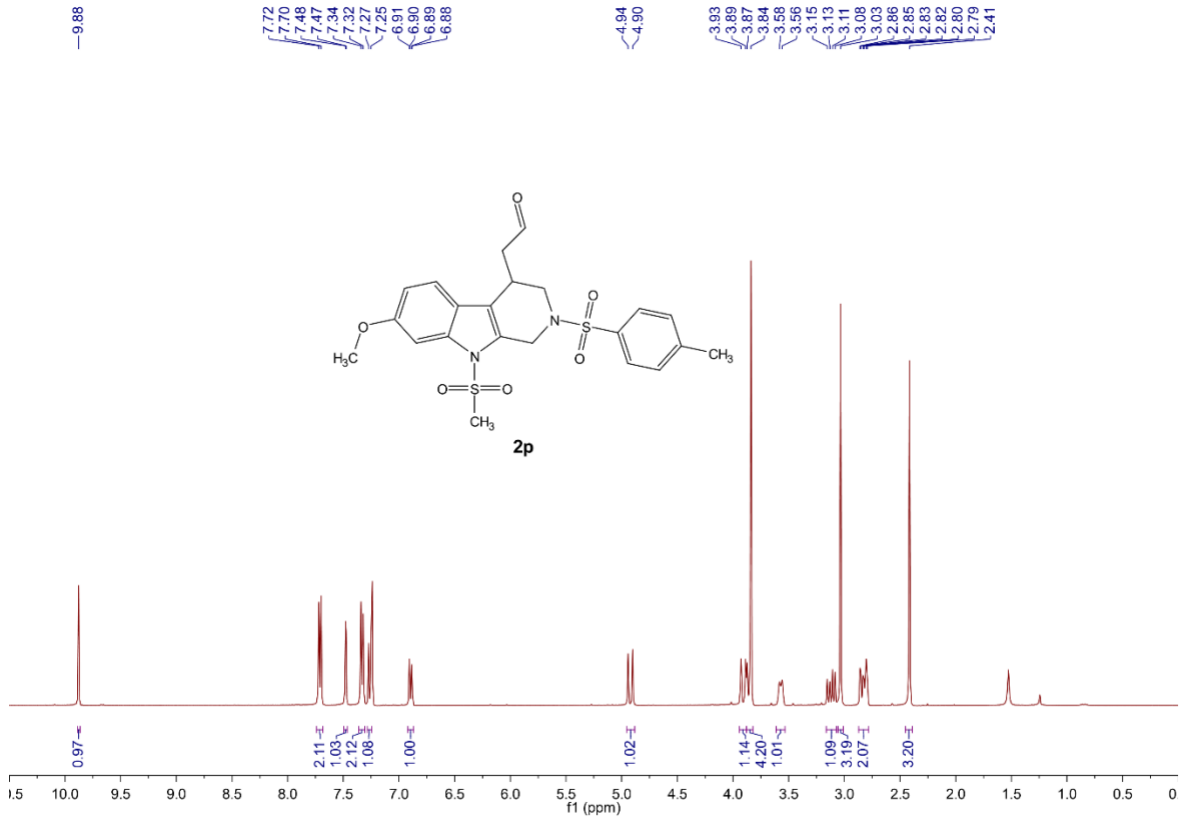
^{1}H NMR ($CDCl_3$, 400MHz) for **2o.**



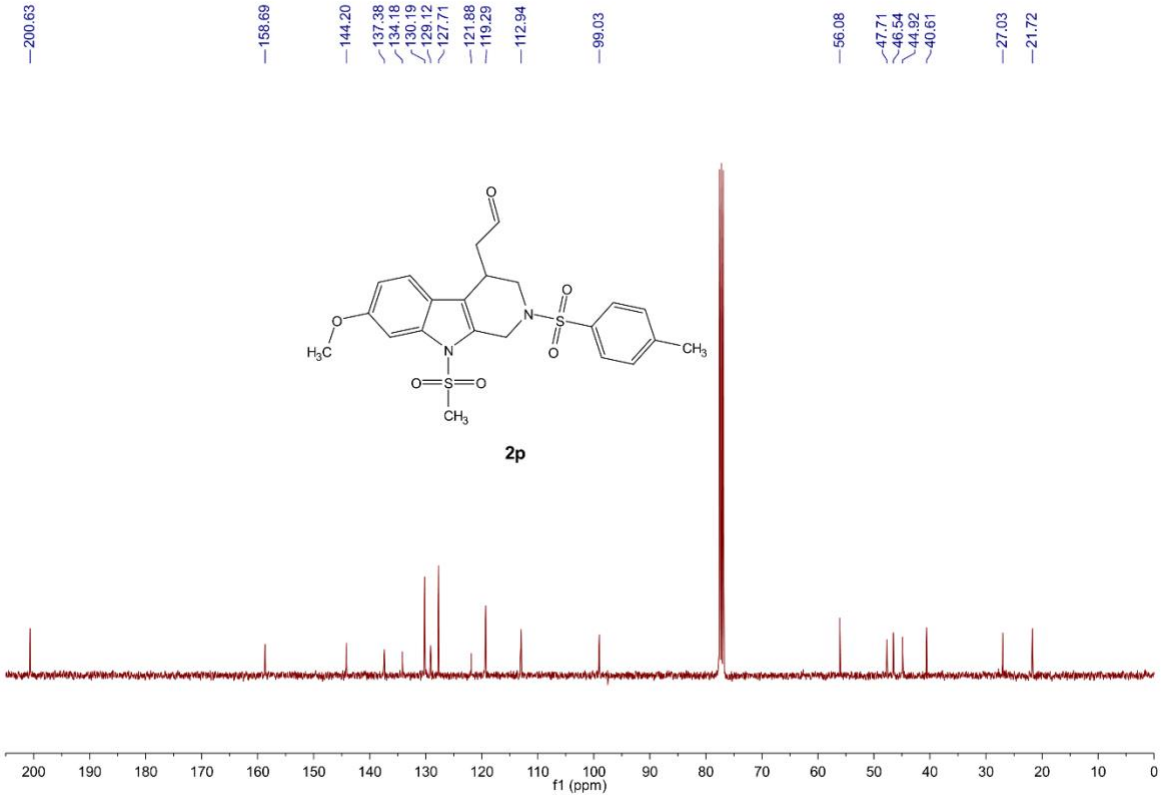
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz) for **2o**.



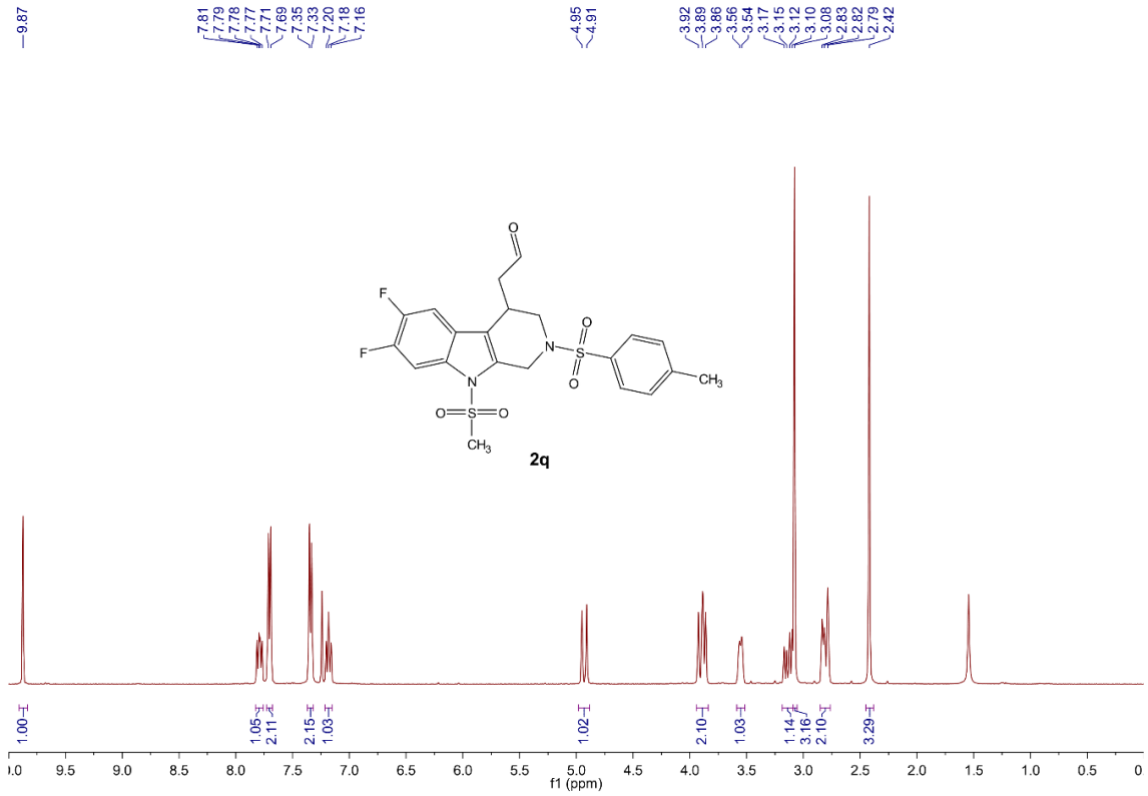
^{1}H NMR ($CDCl_3$, 400MHz) for **2p.**



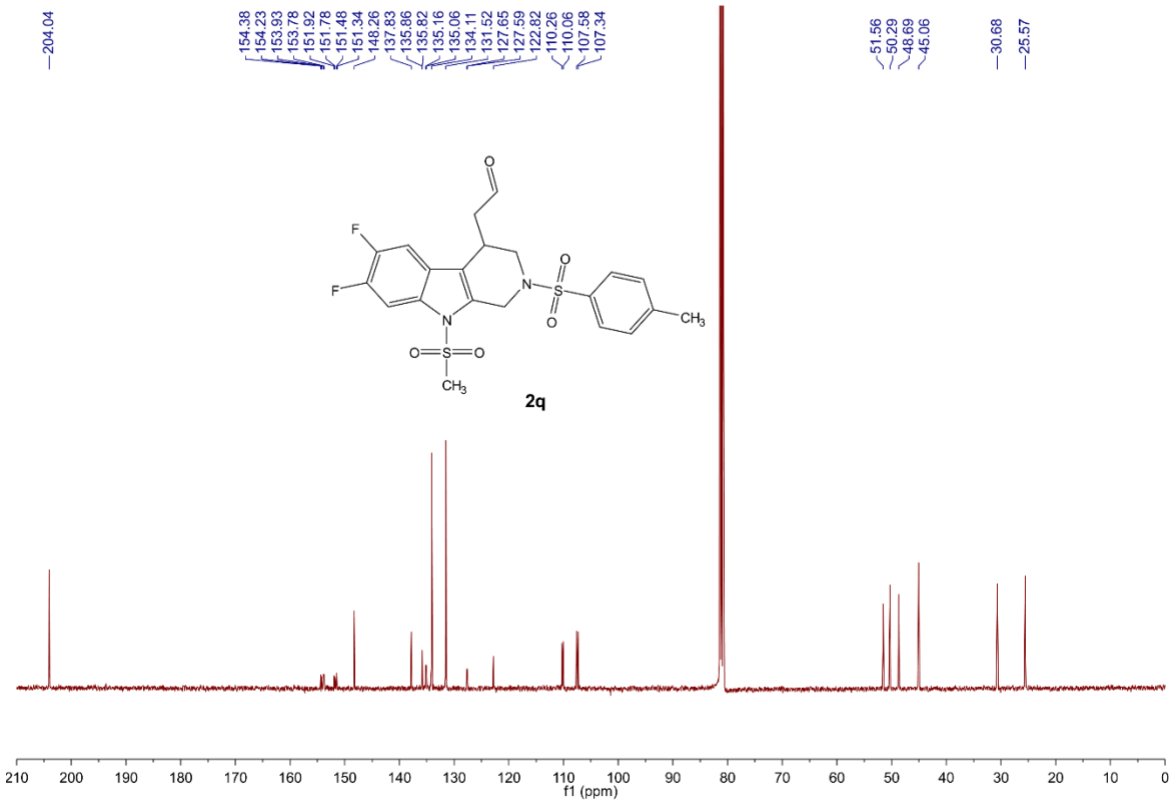
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz) for **2p**.



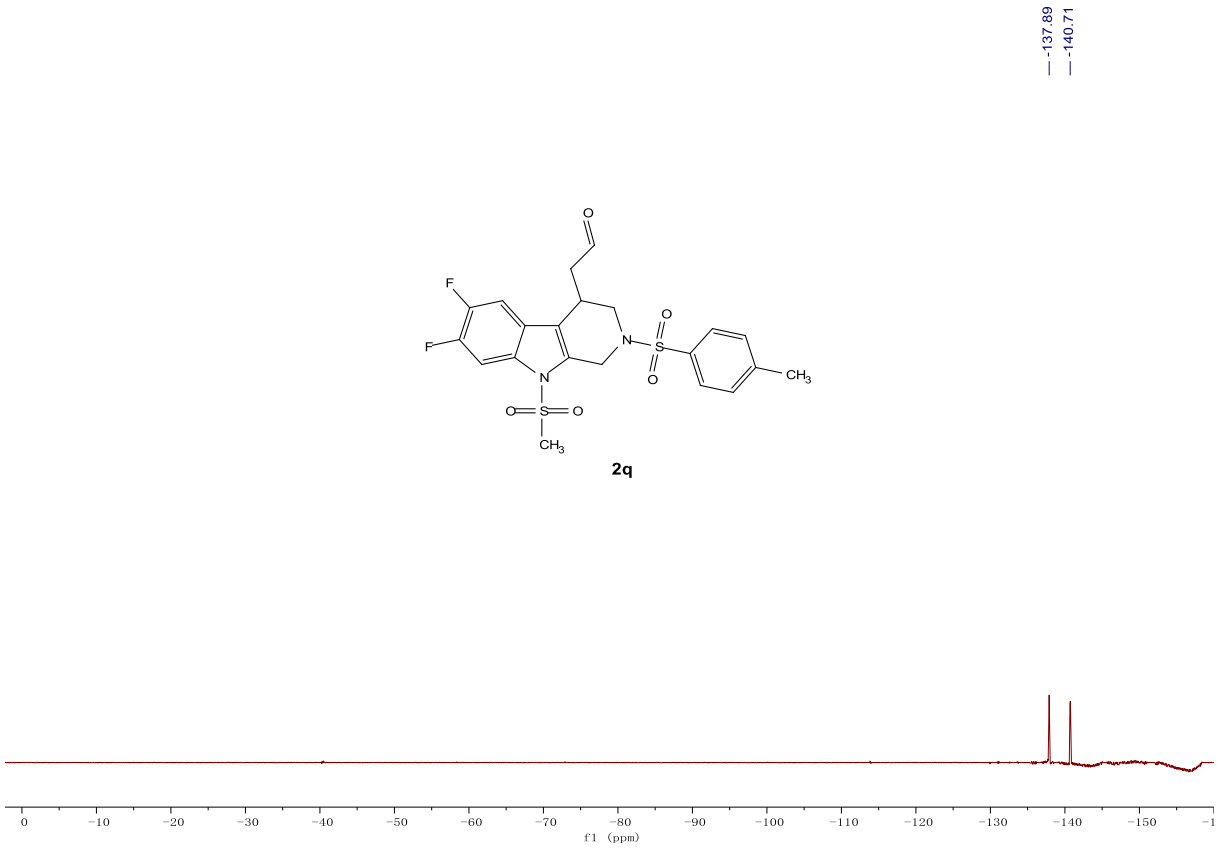
^{1}H NMR ($CDCl_3$, 400MHz) for **2q.**



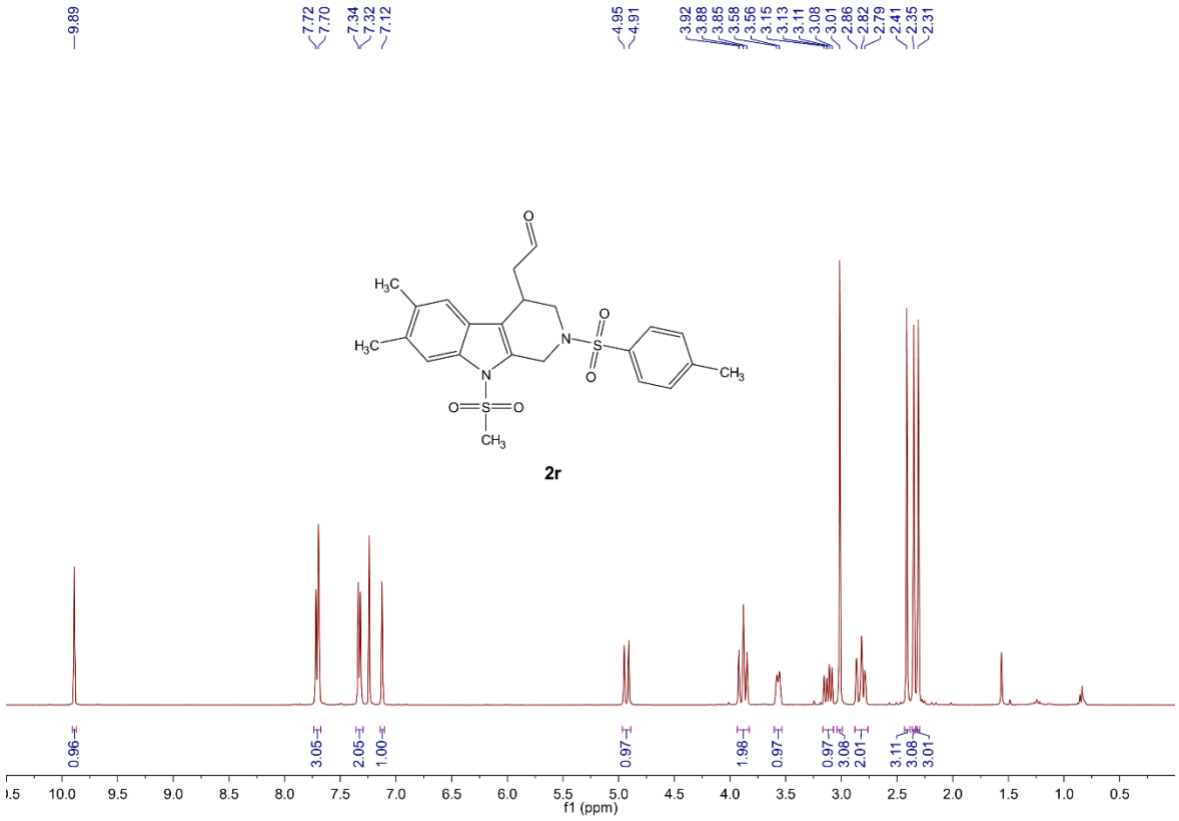
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz) for **2q**.



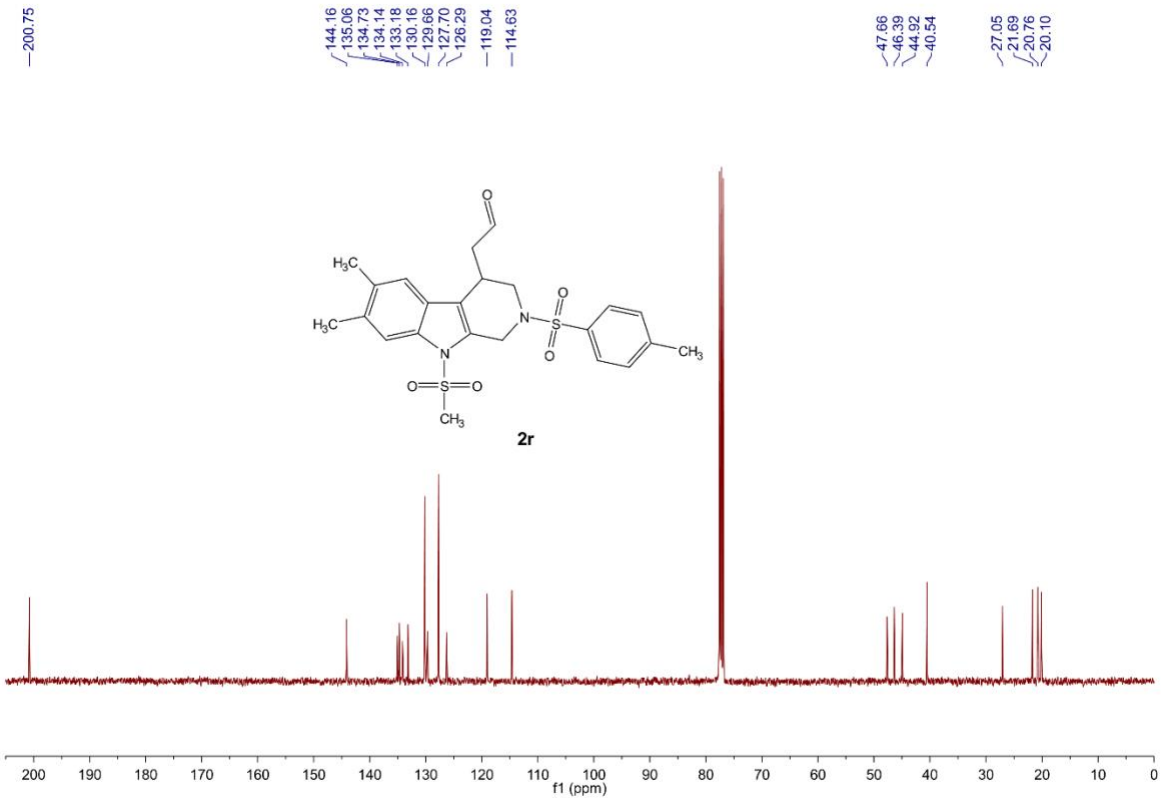
^{19}F NMR ($CDCl_3$, 376 MHz) for **2q**.



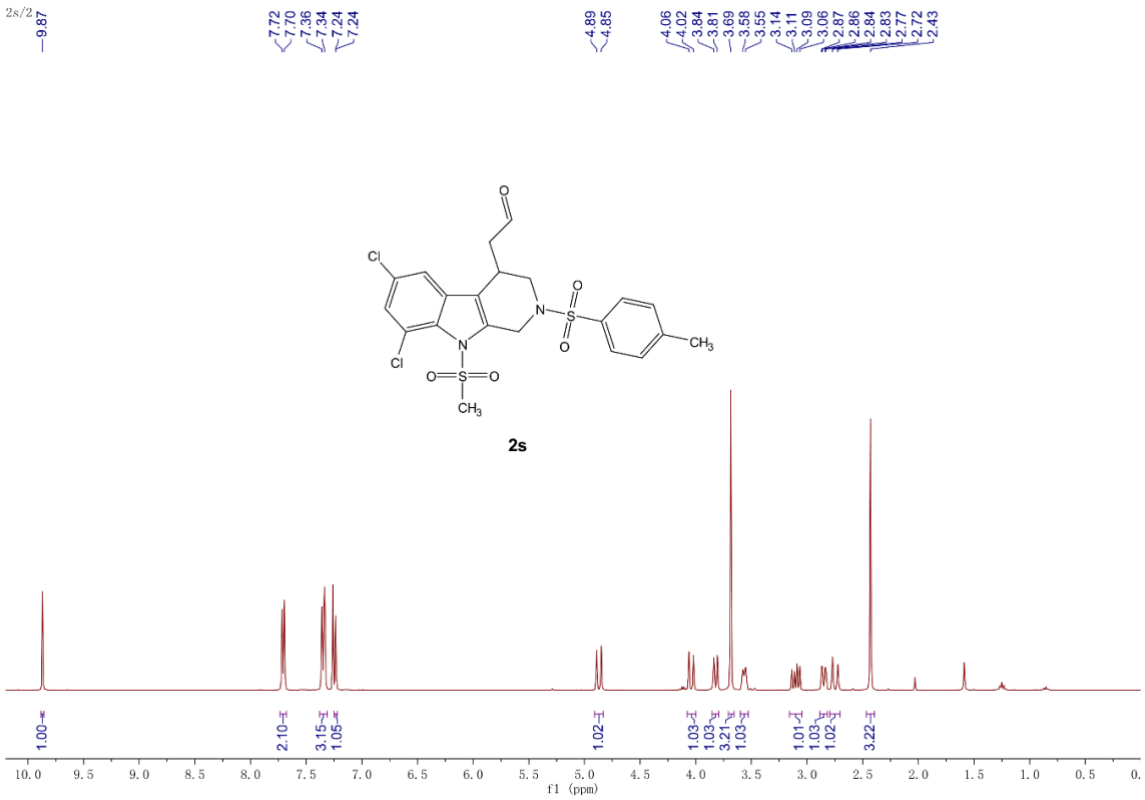
^{1}H NMR ($CDCl_3$, 400MHz) for **2r.**



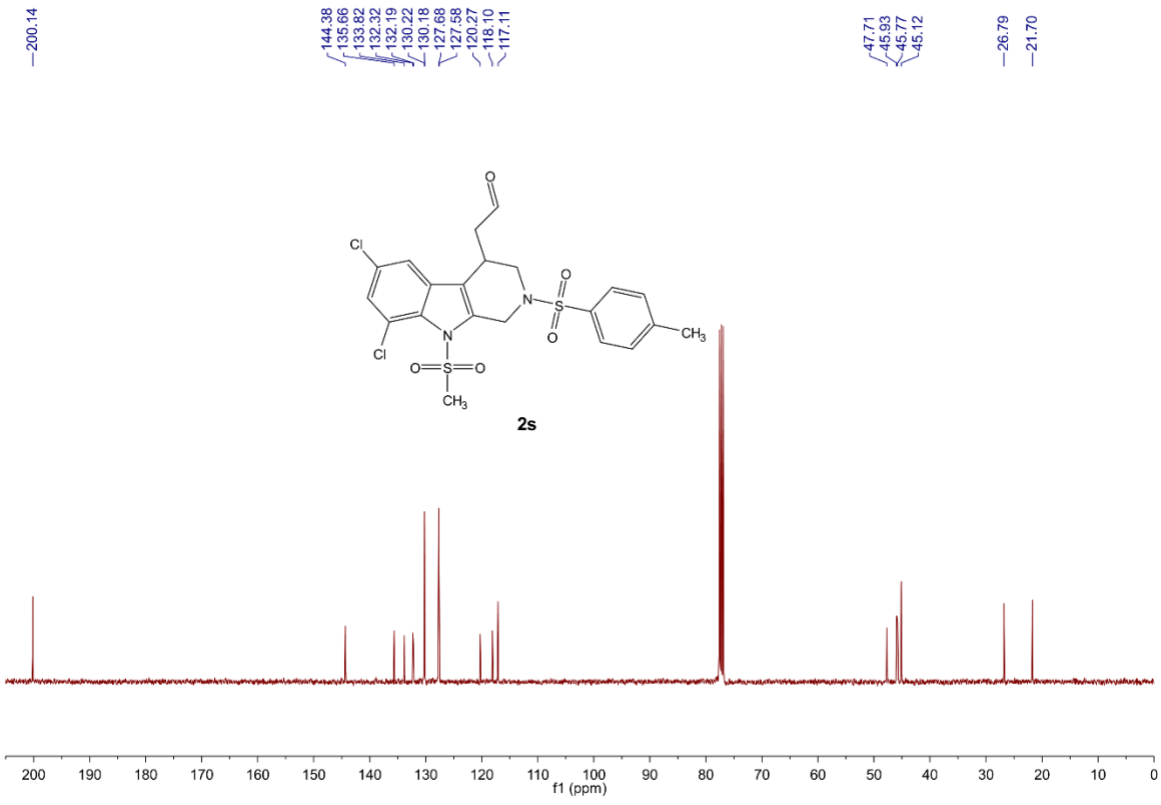
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2r**.



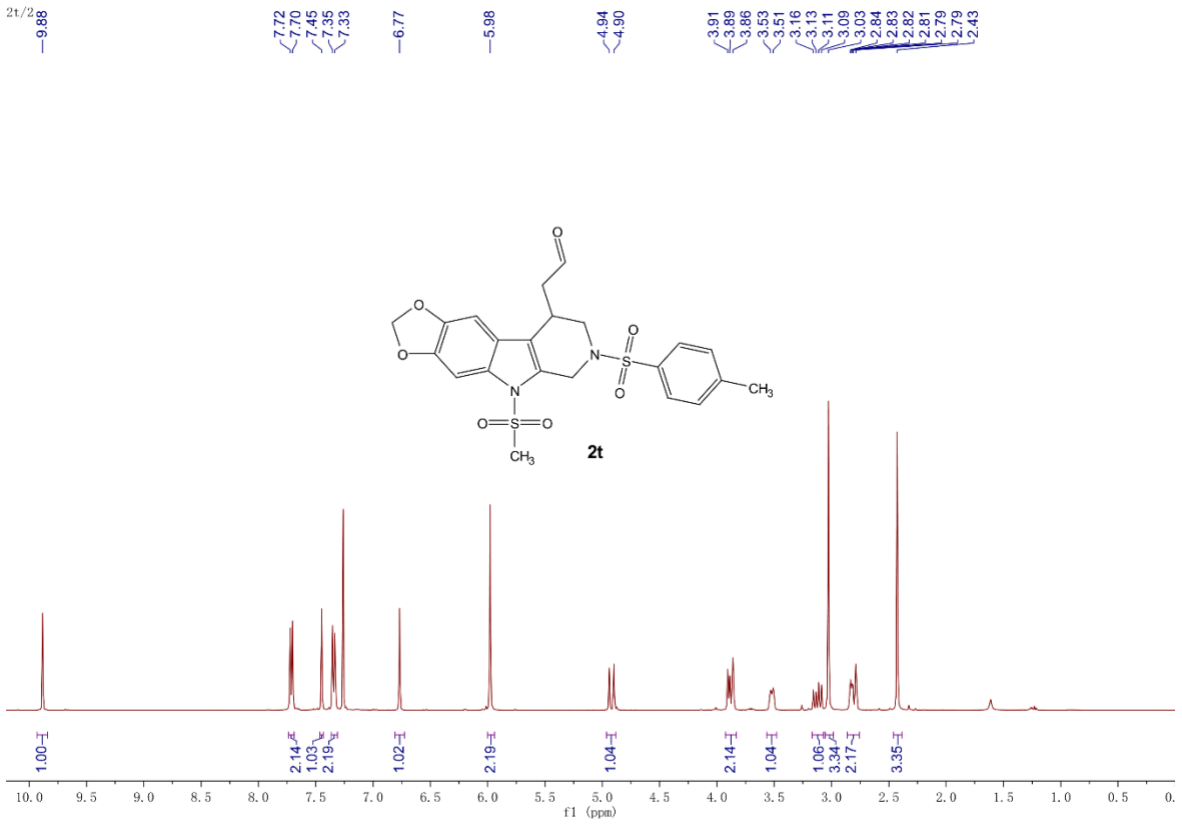
^{1}H NMR ($CDCl_3$, 400MHz) for **2s.**



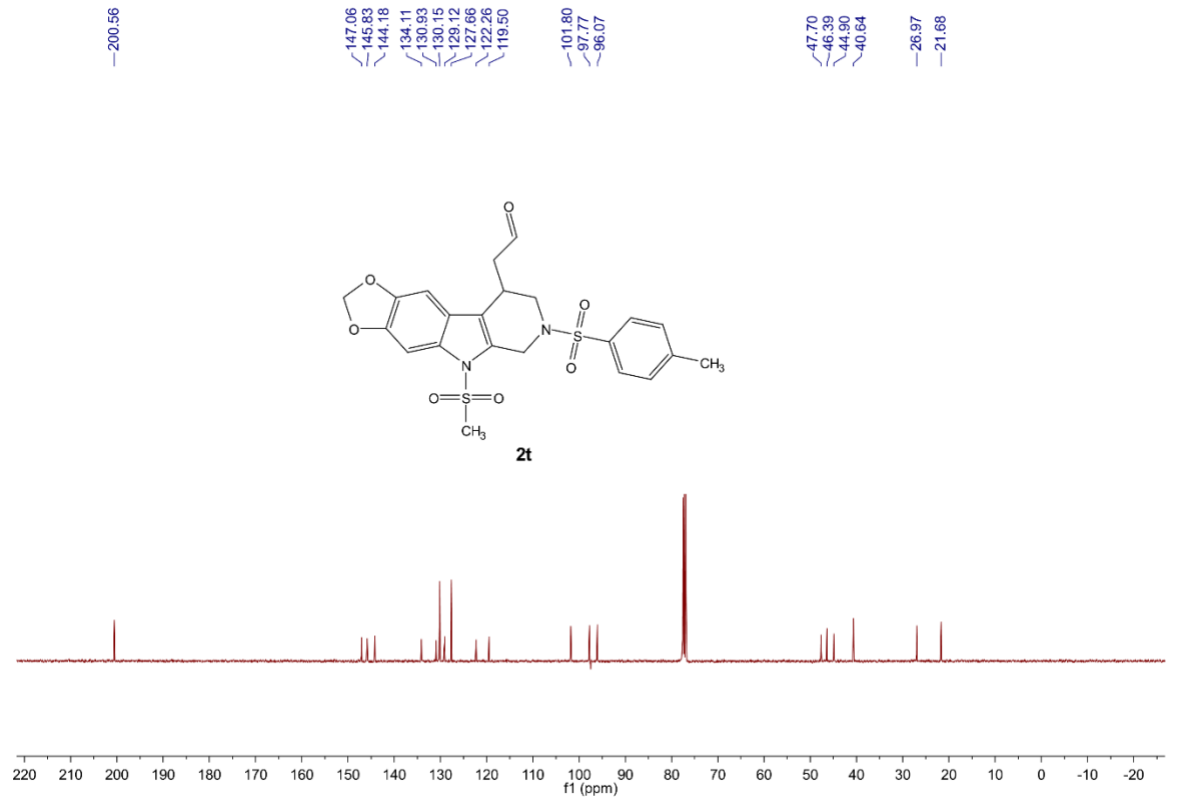
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2s**.



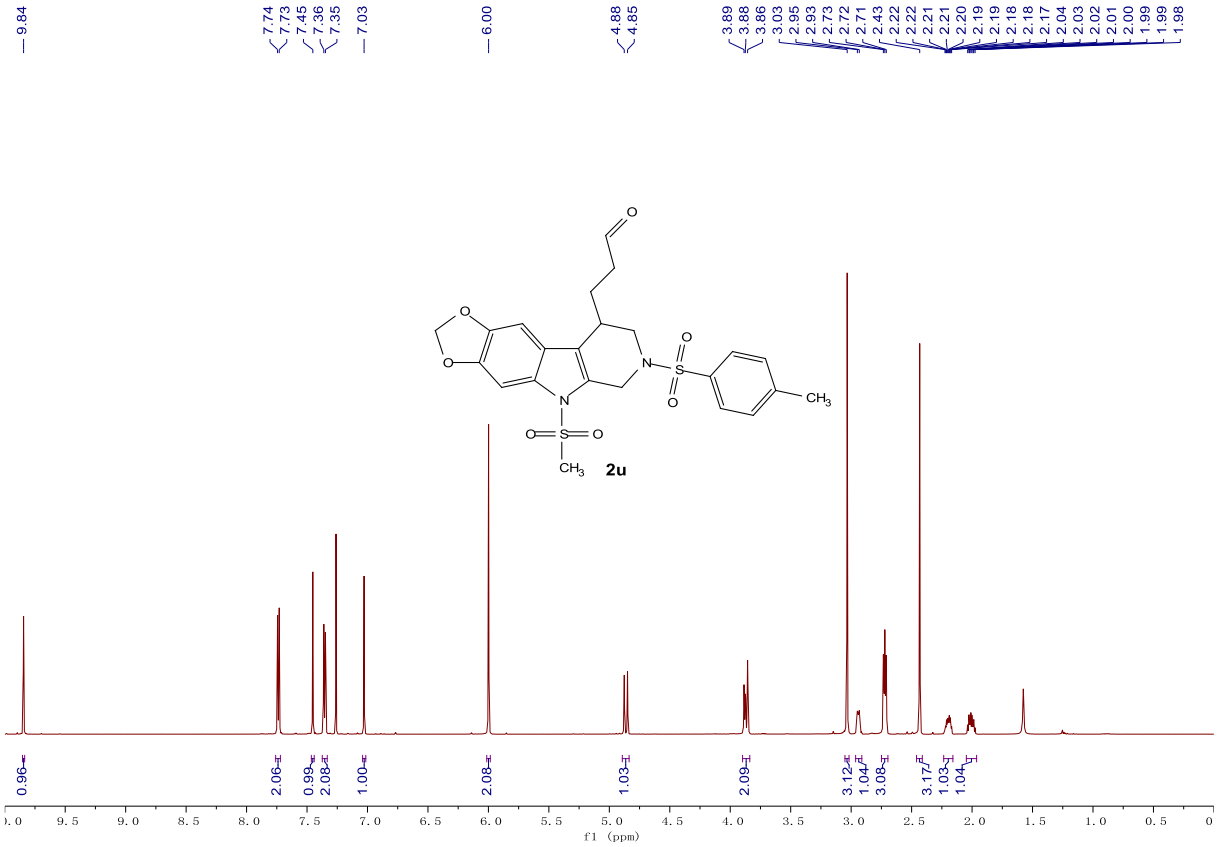
^{1}H NMR ($CDCl_3$, 400MHz) for **2t.**



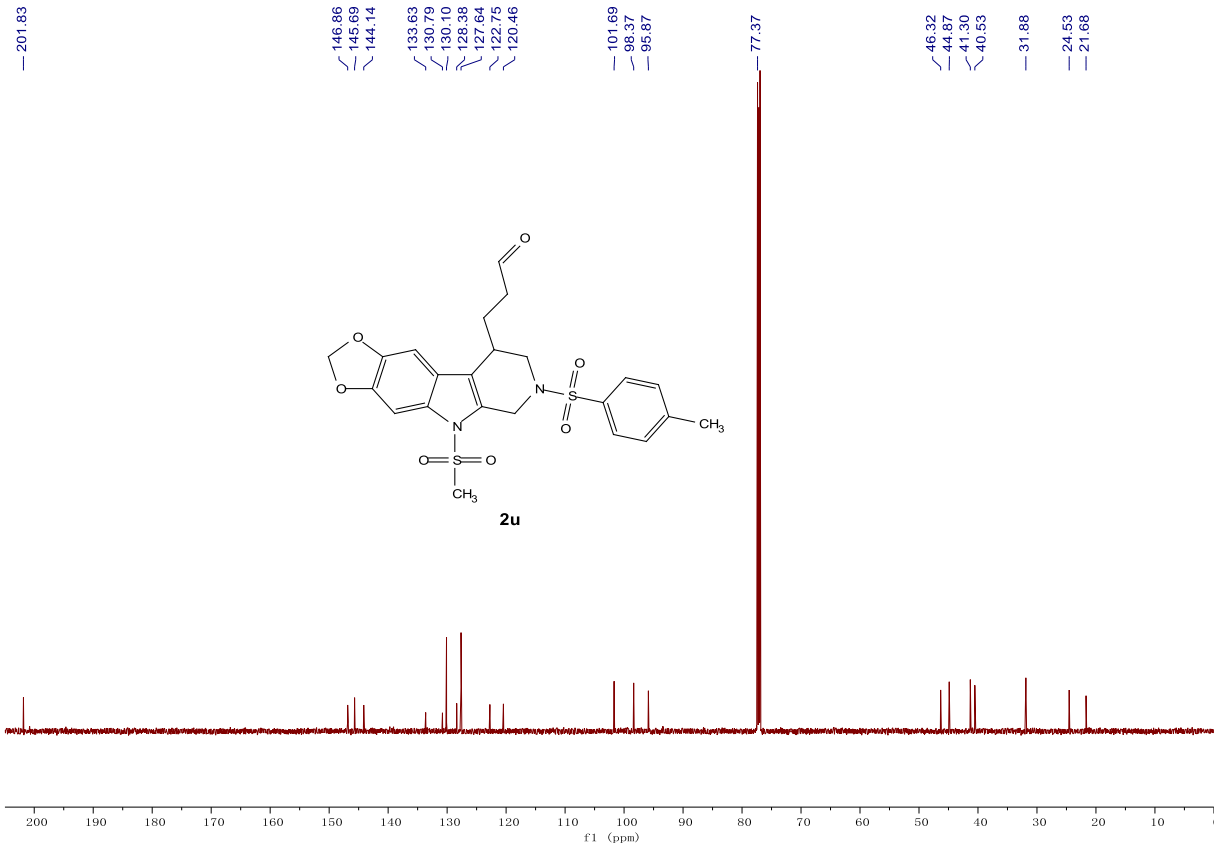
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2t**.



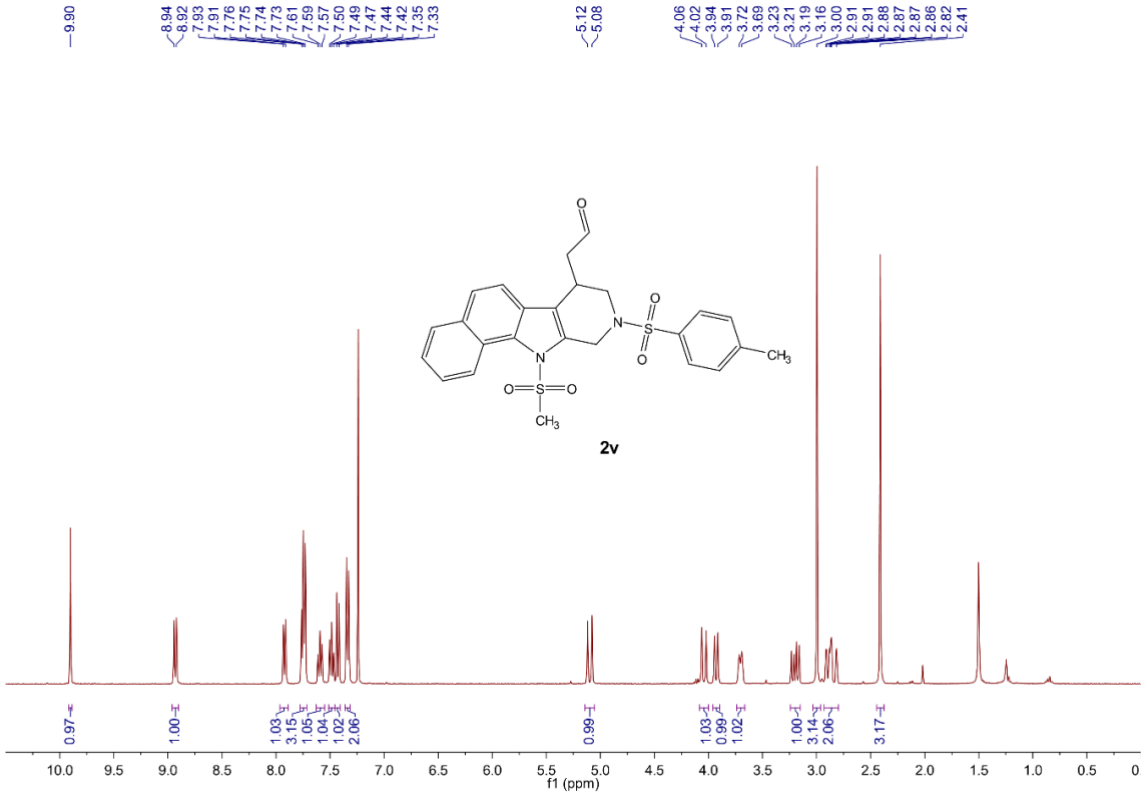
^{1}H NMR ($CDCl_3$, 600MHz) for **2u.**



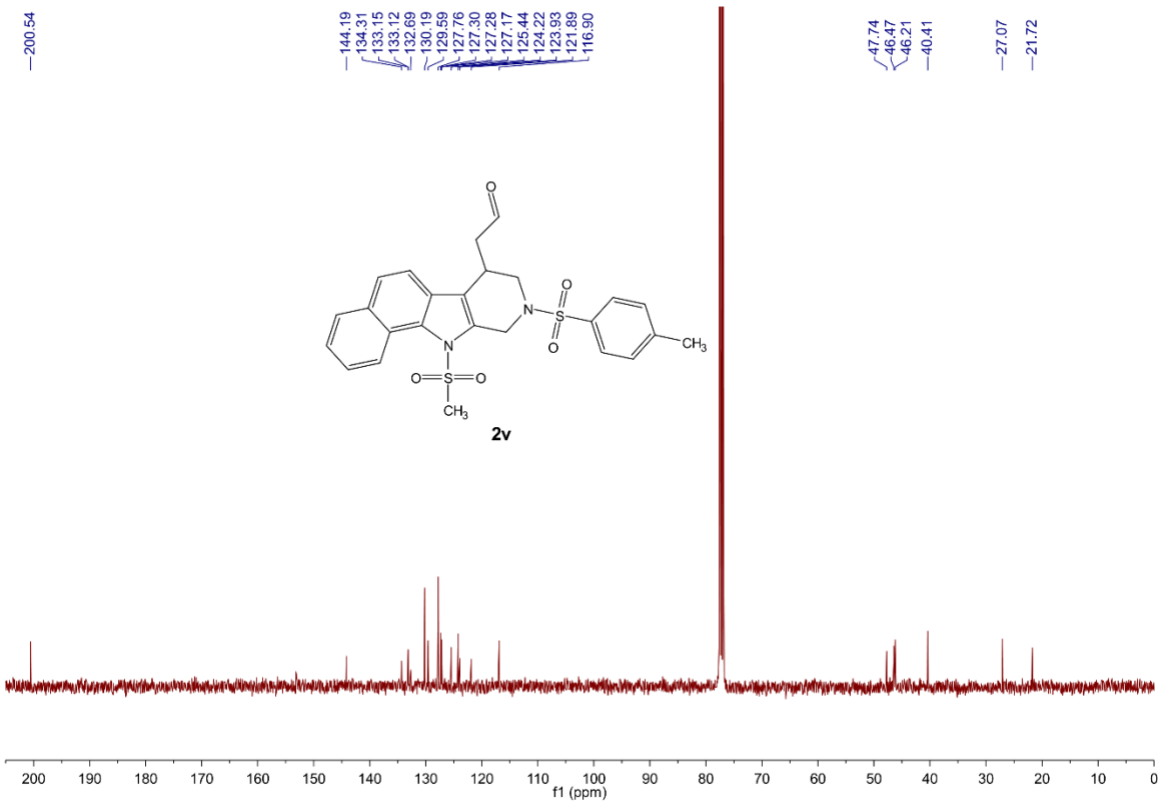
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **2u**.



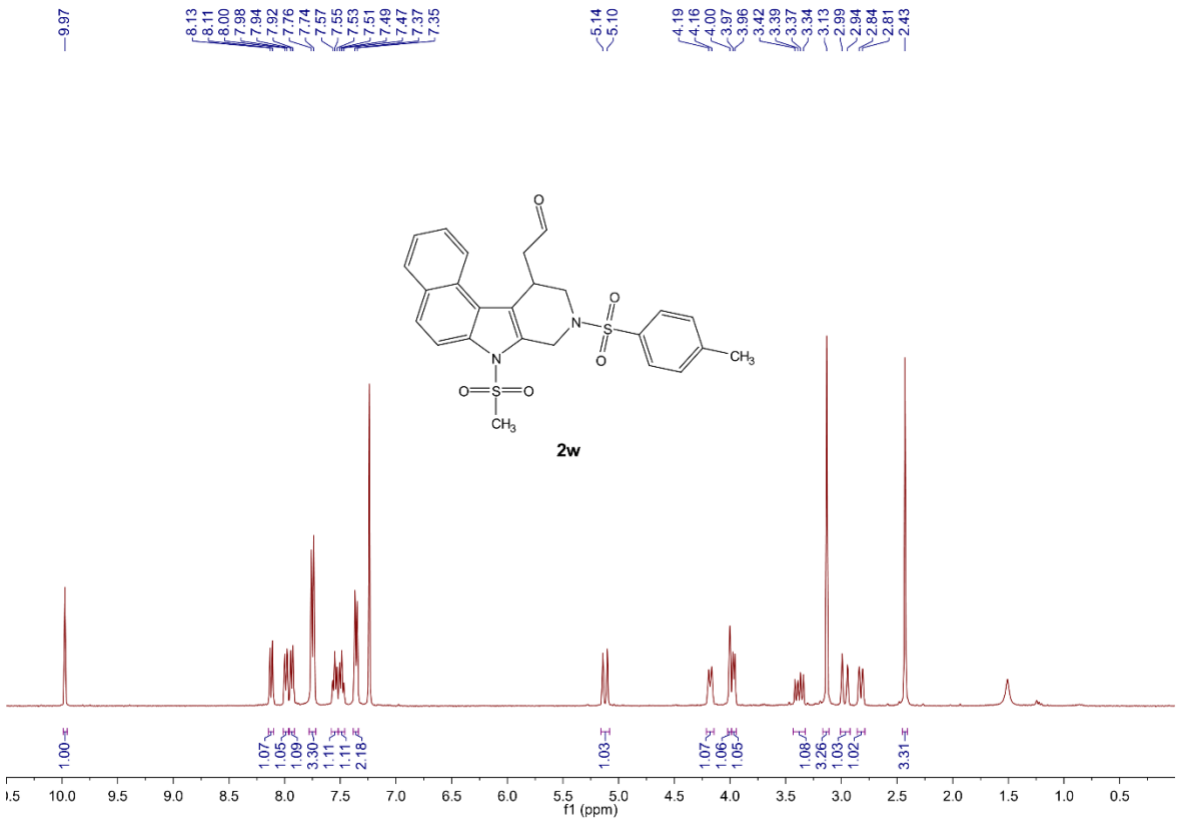
^{1}H NMR ($CDCl_3$, 400MHz) for **2v.**



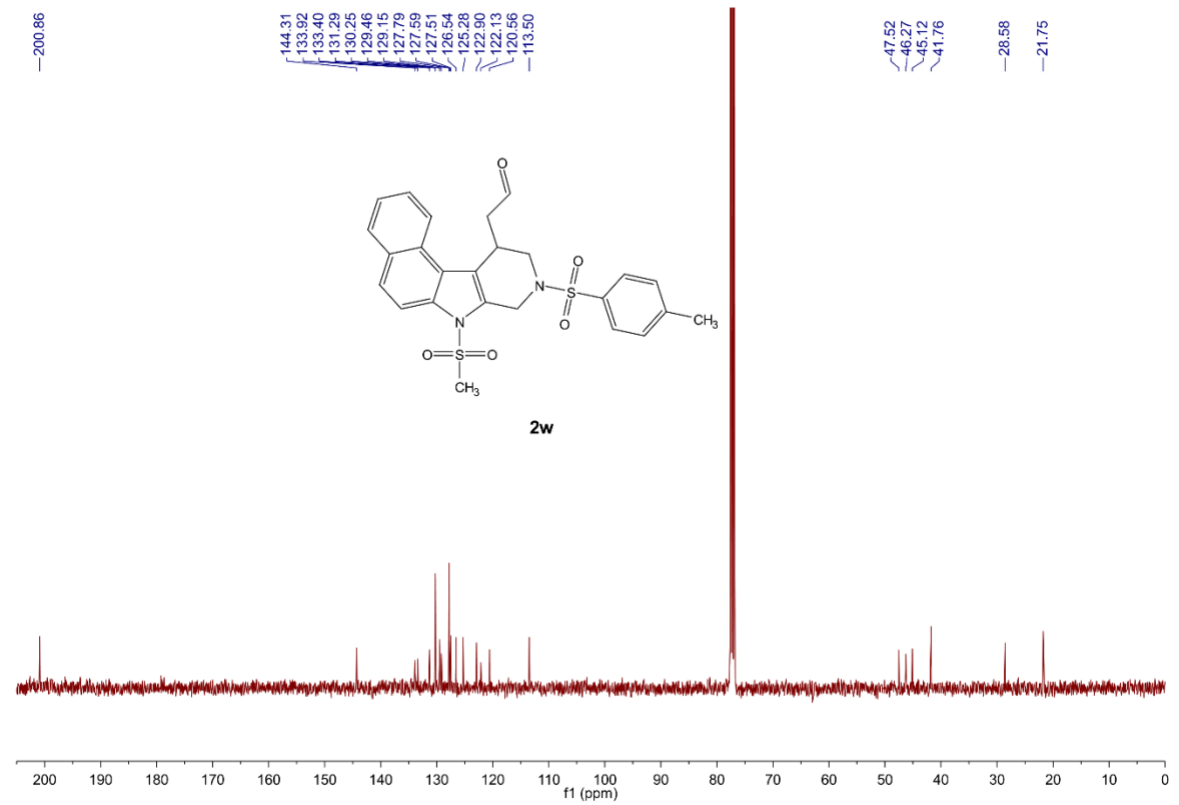
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2v**.



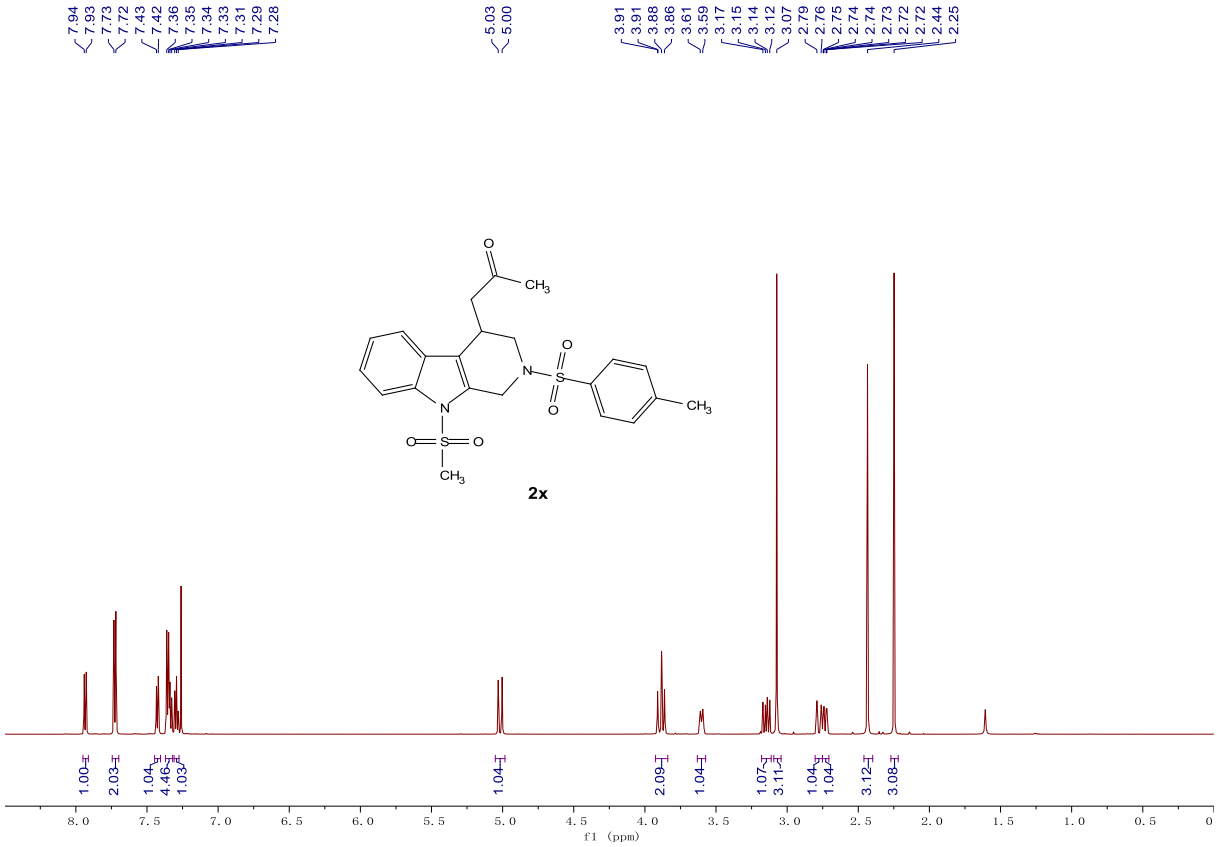
^{1}H NMR ($CDCl_3$, 400MHz) for **2w.**



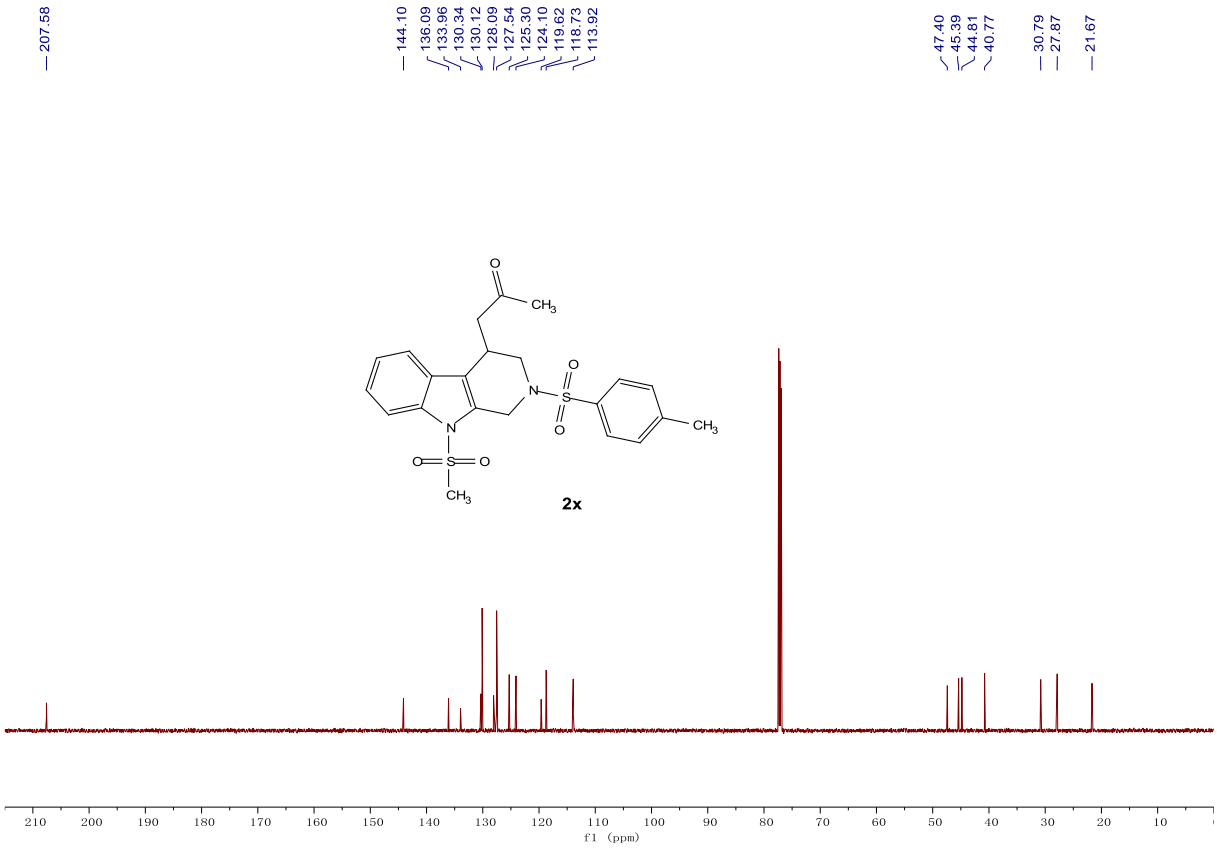
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2w**.



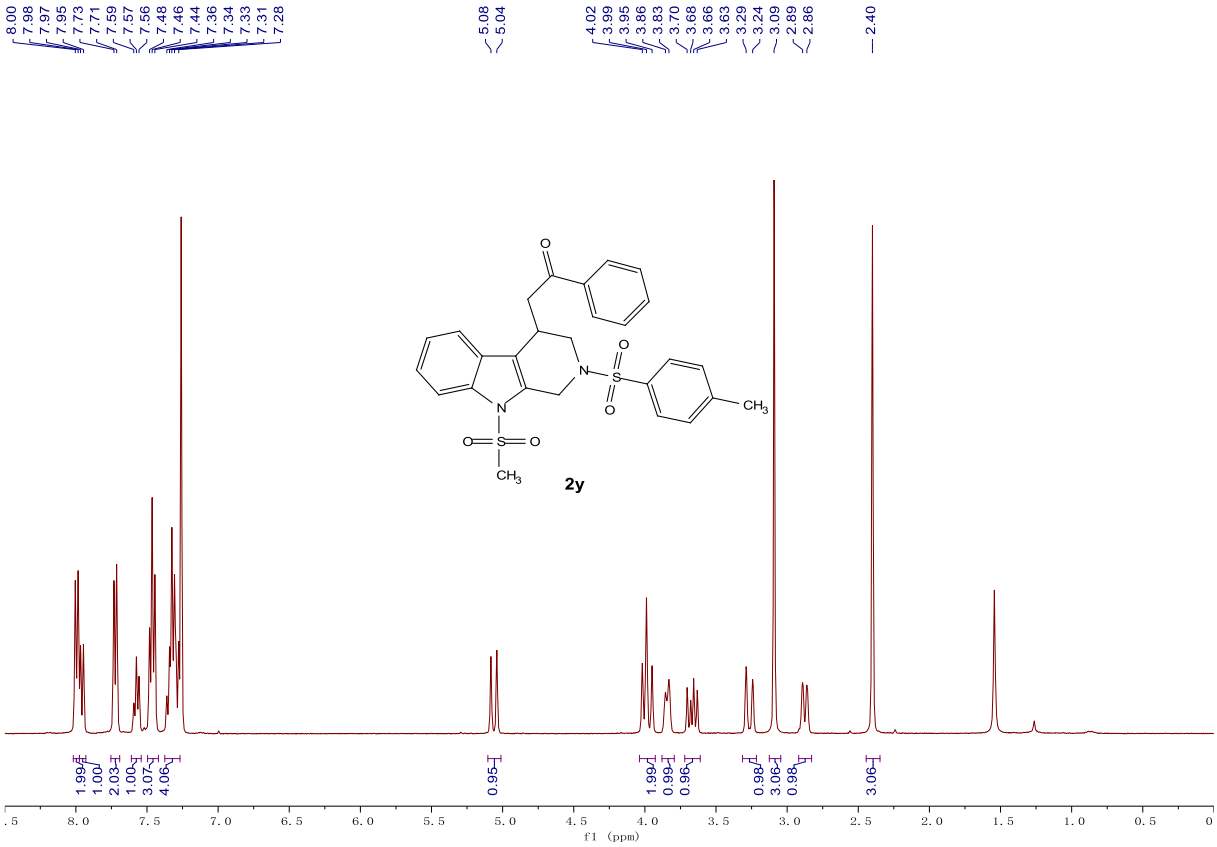
^{1}H NMR ($CDCl_3$, 600MHz) for **2x.**



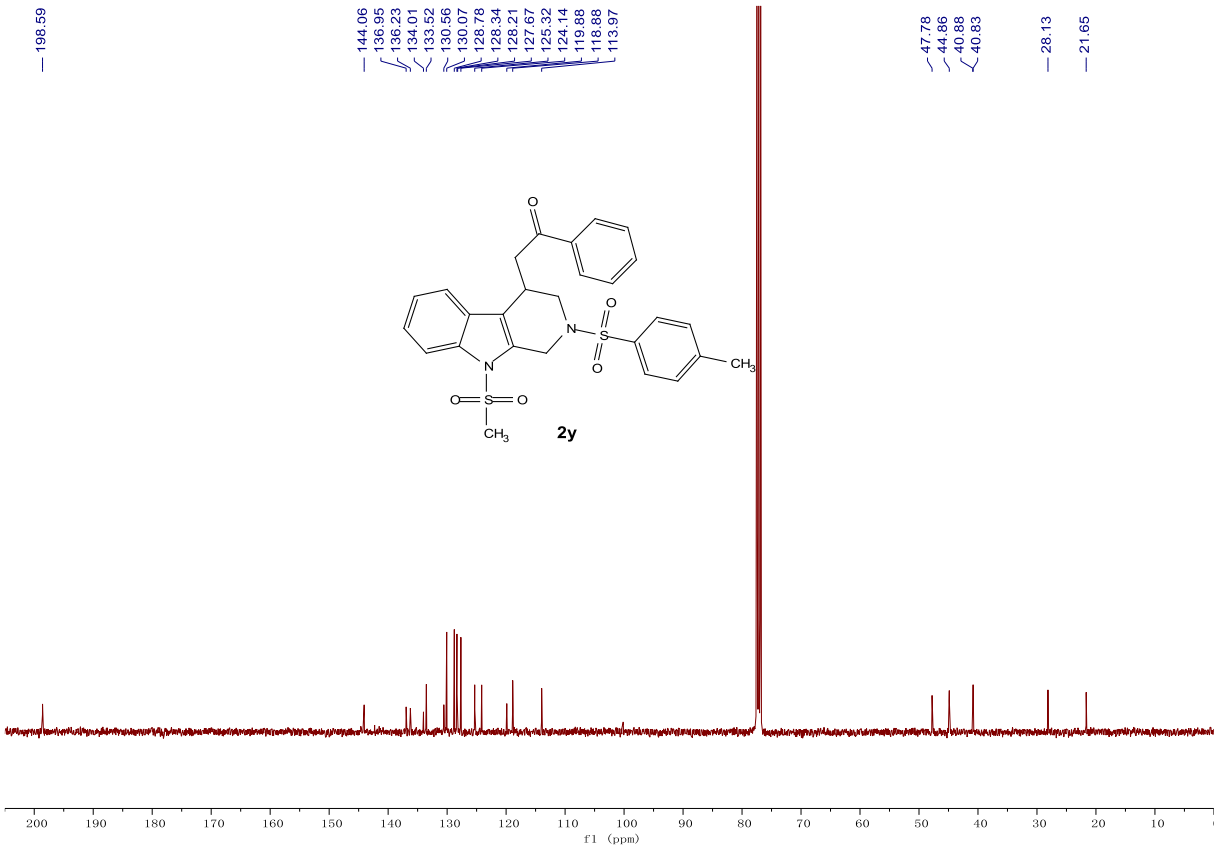
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **2x**.



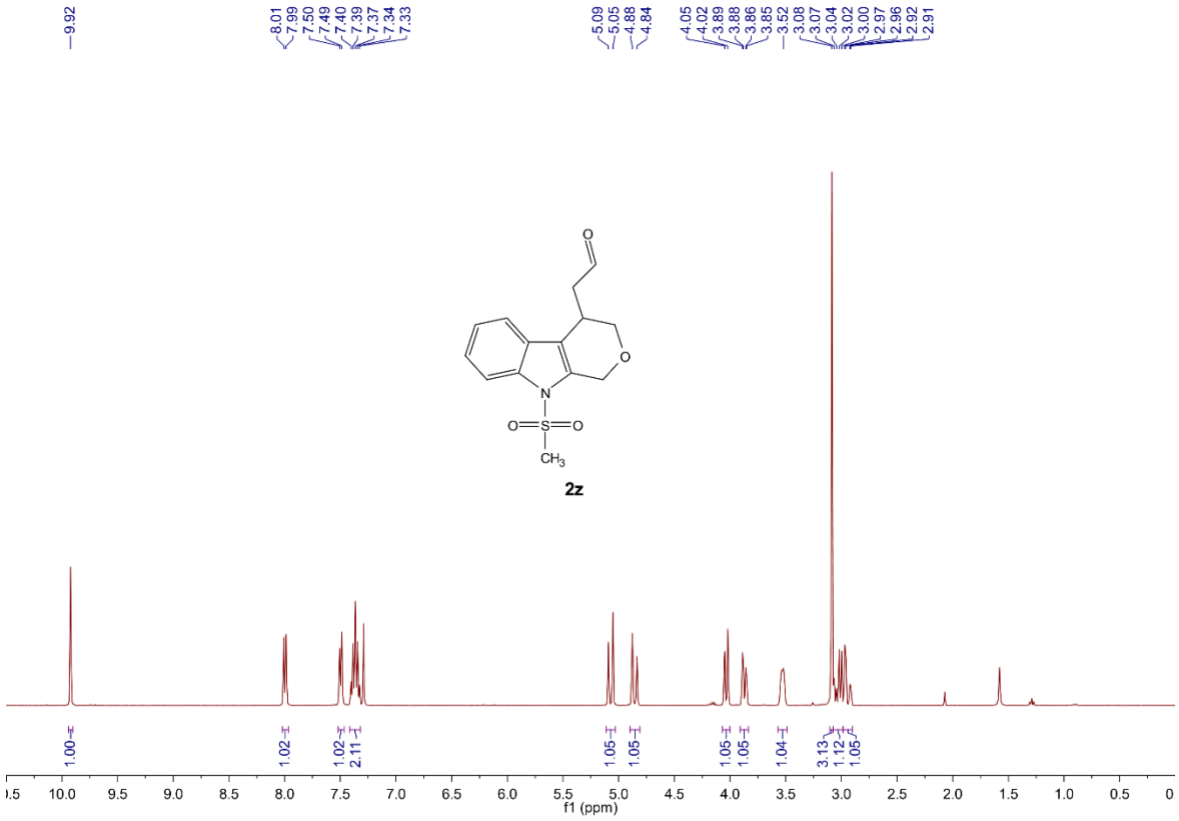
^{1}H NMR ($CDCl_3$, 400MHz) for **2y.**



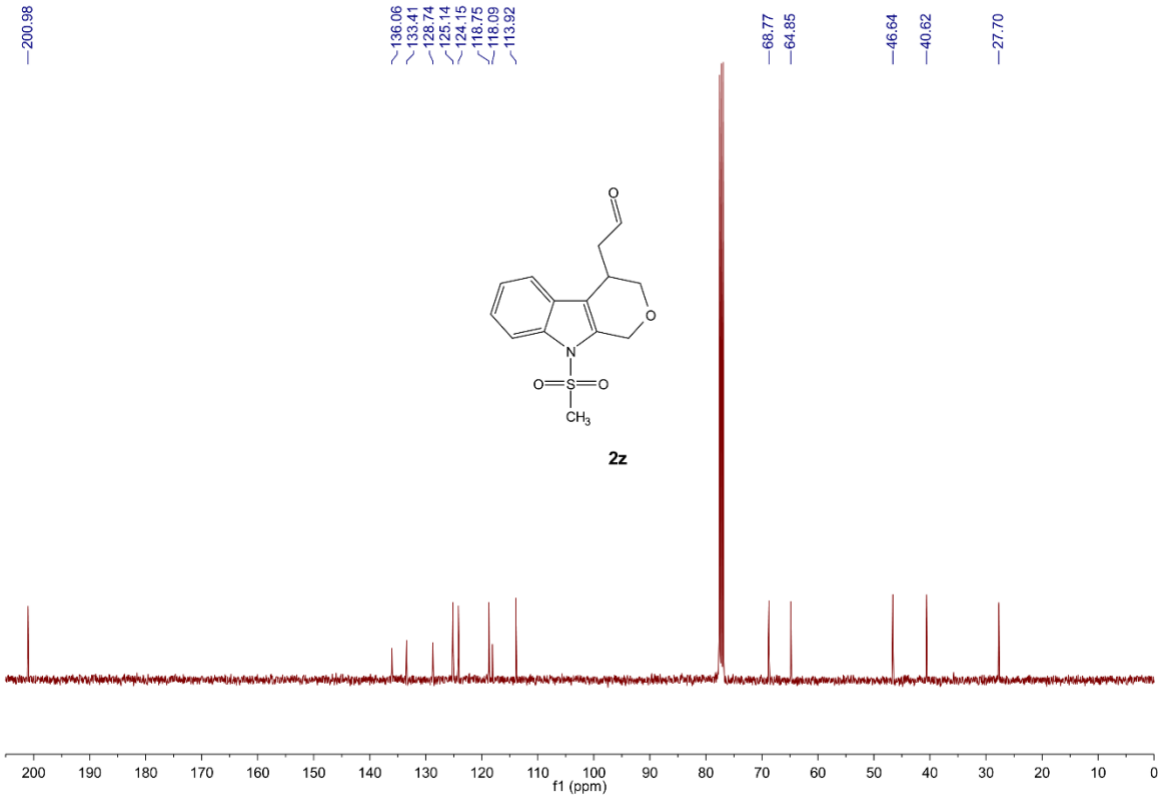
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2y**.



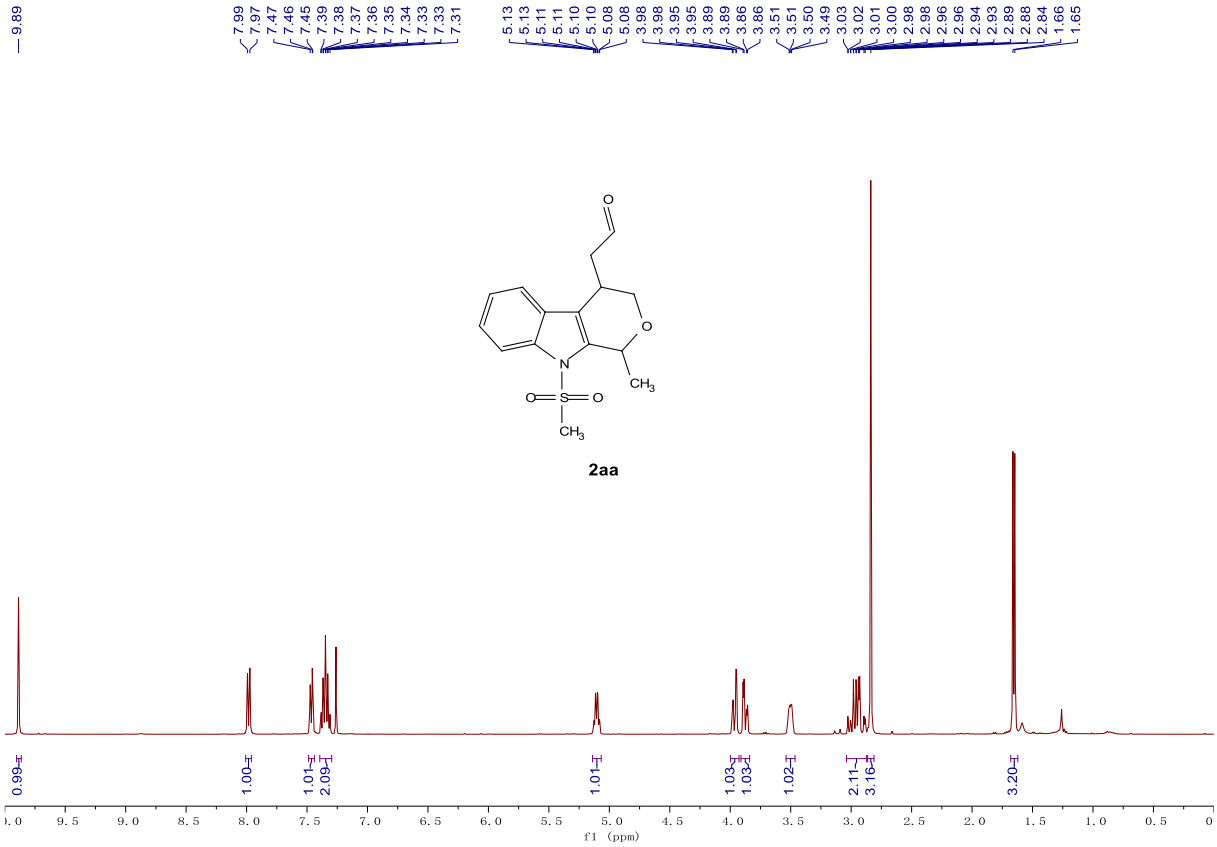
^{1}H NMR ($CDCl_3$, 400MHz) for **2z.**



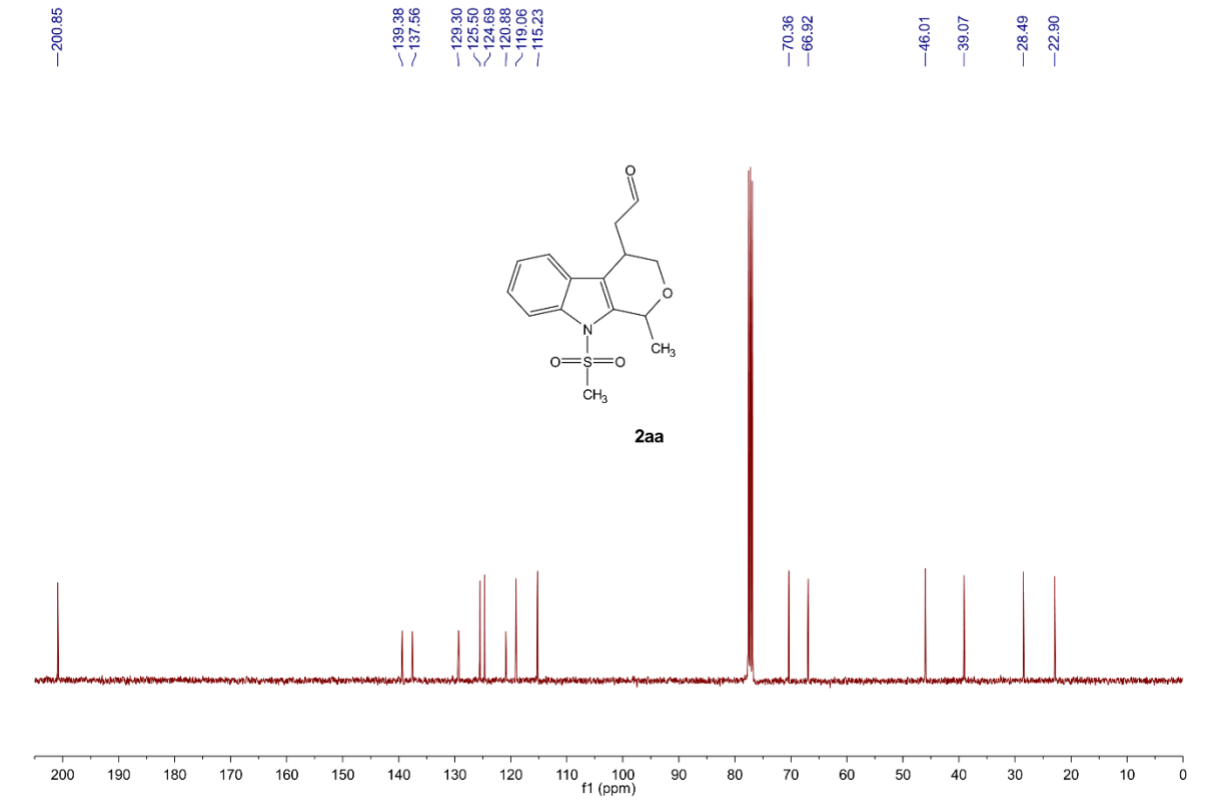
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2z**.



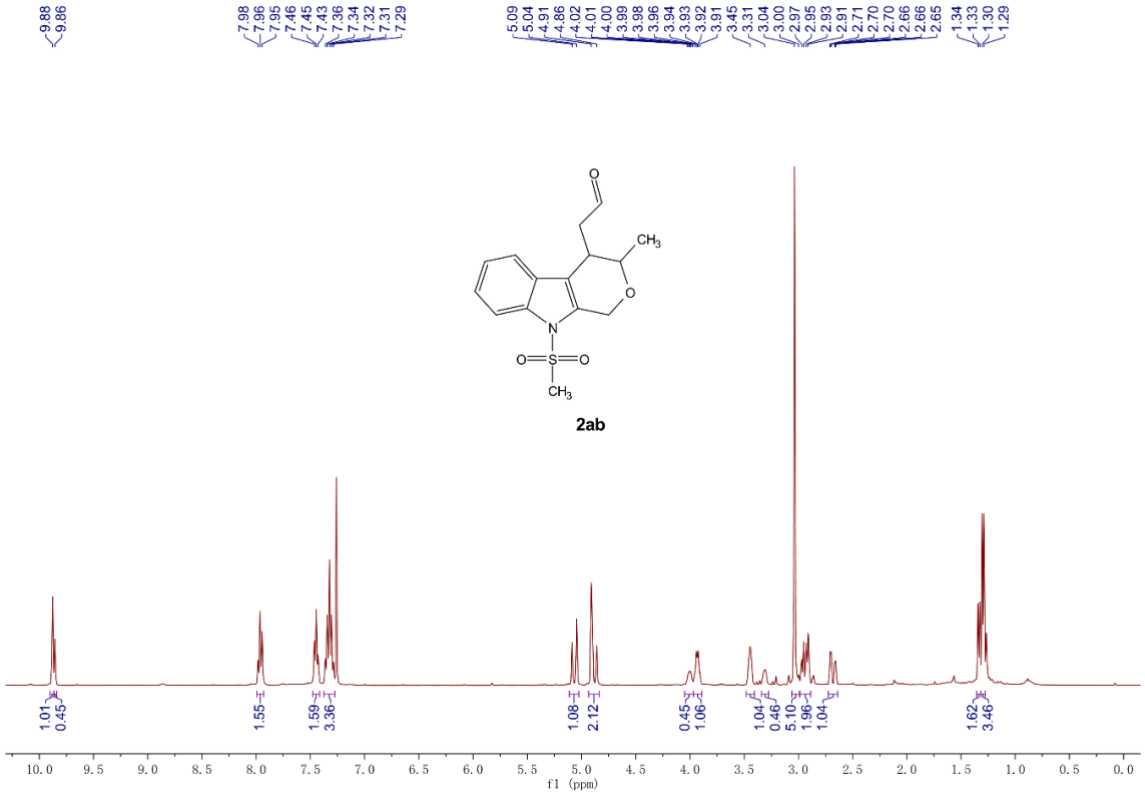
^{1}H NMR ($CDCl_3$, 400MHz) for **2aa.**



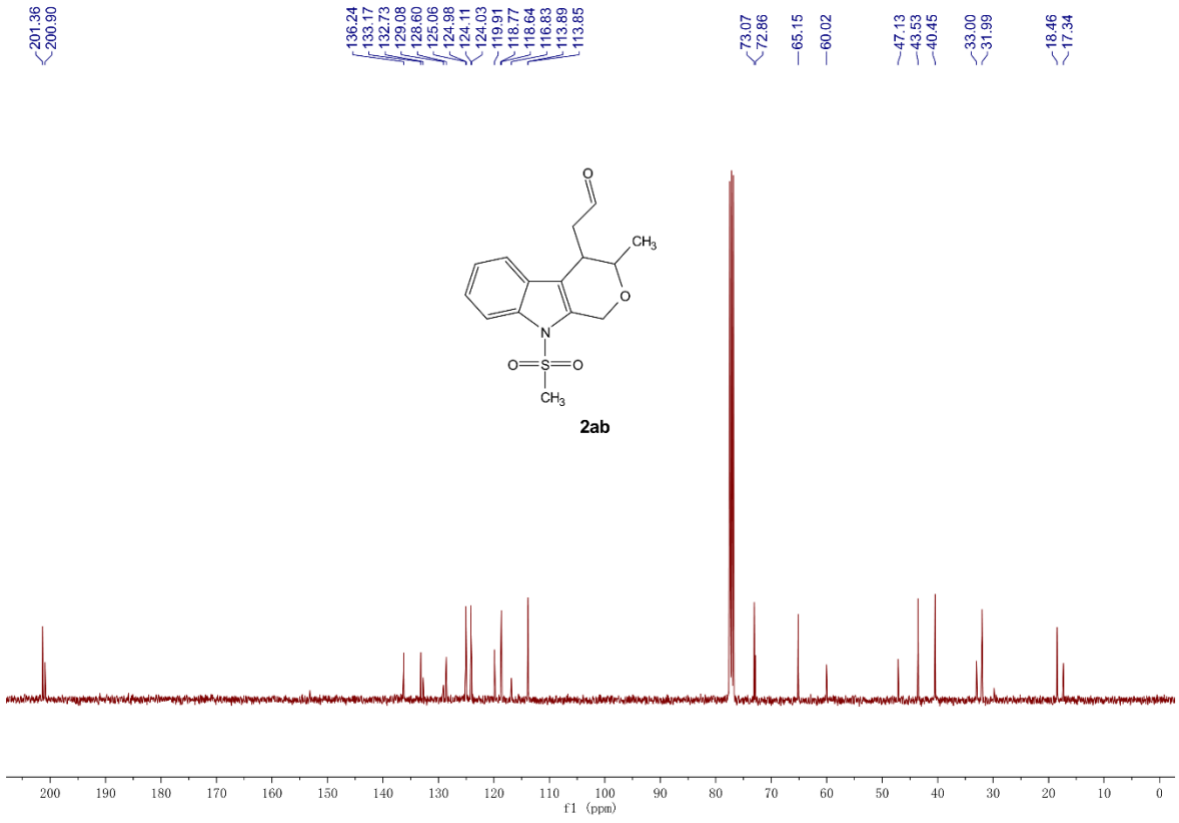
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2aa**.



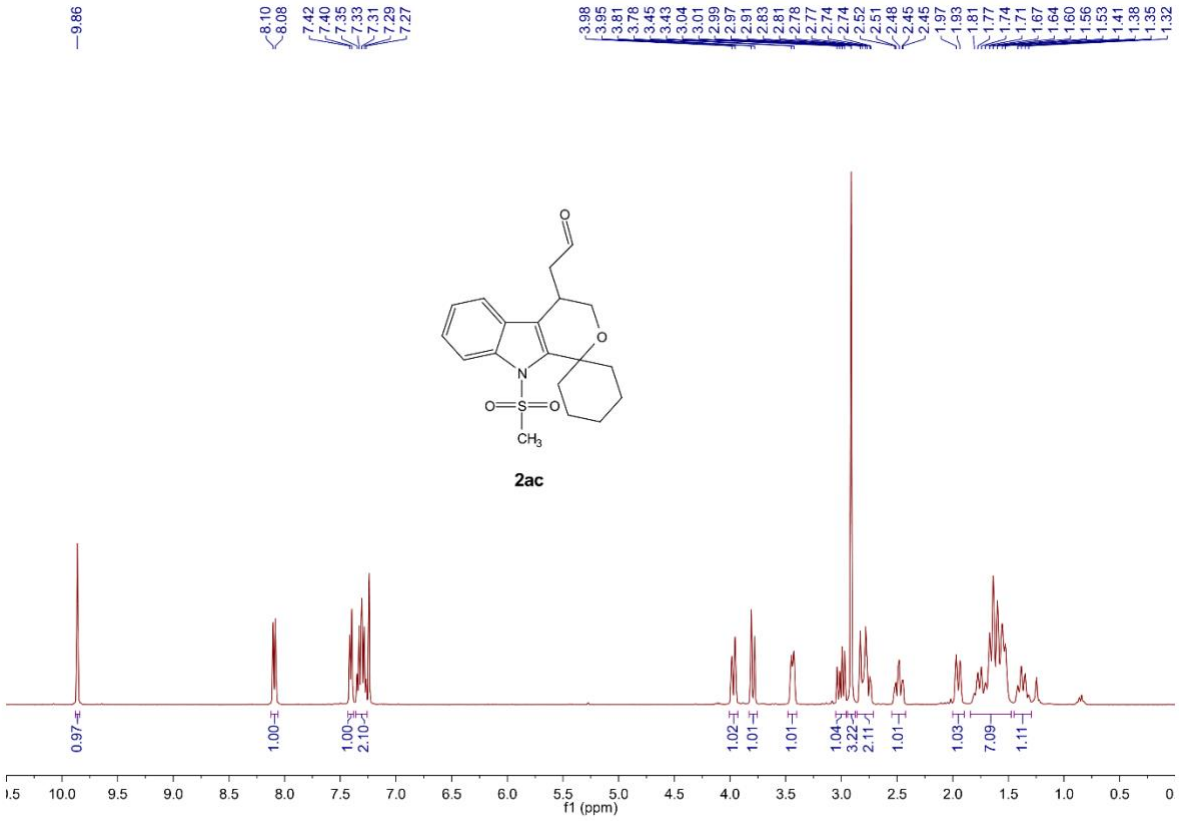
^{1}H NMR ($CDCl_3$, 400MHz) for **2ab.**



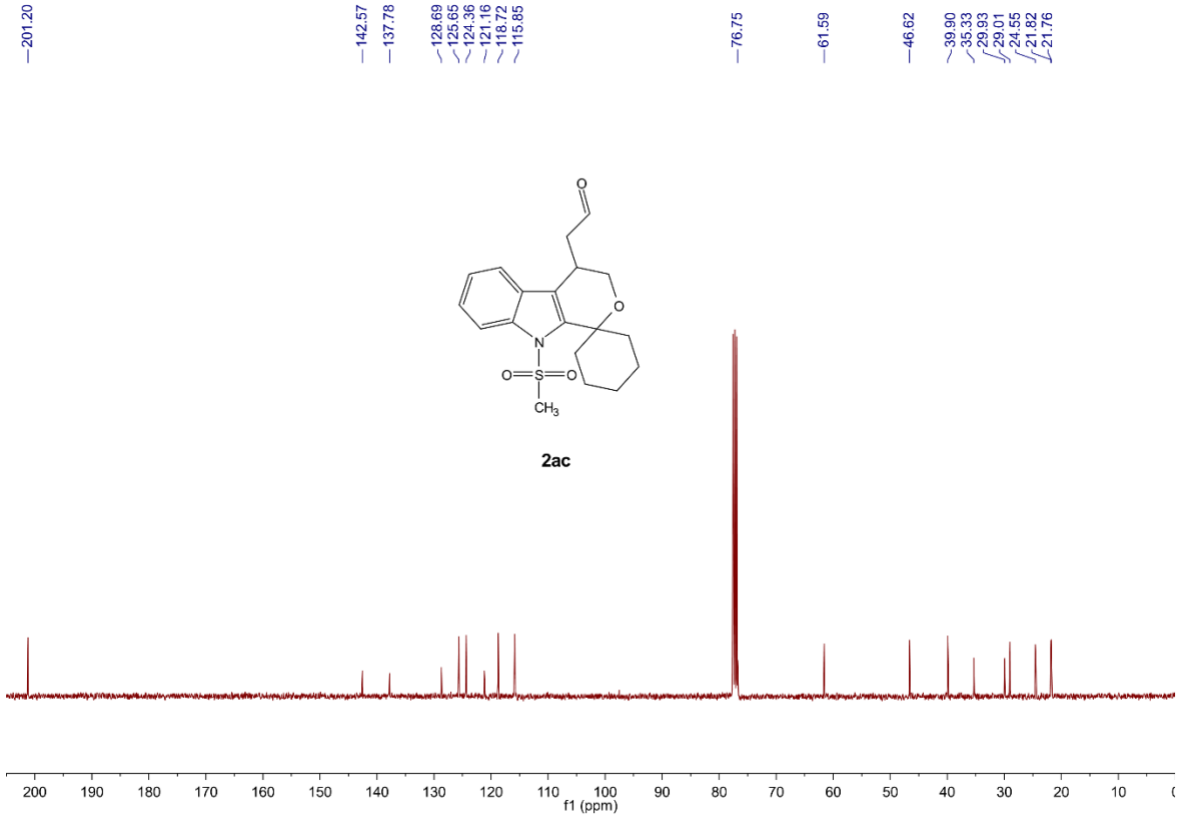
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2ab**.



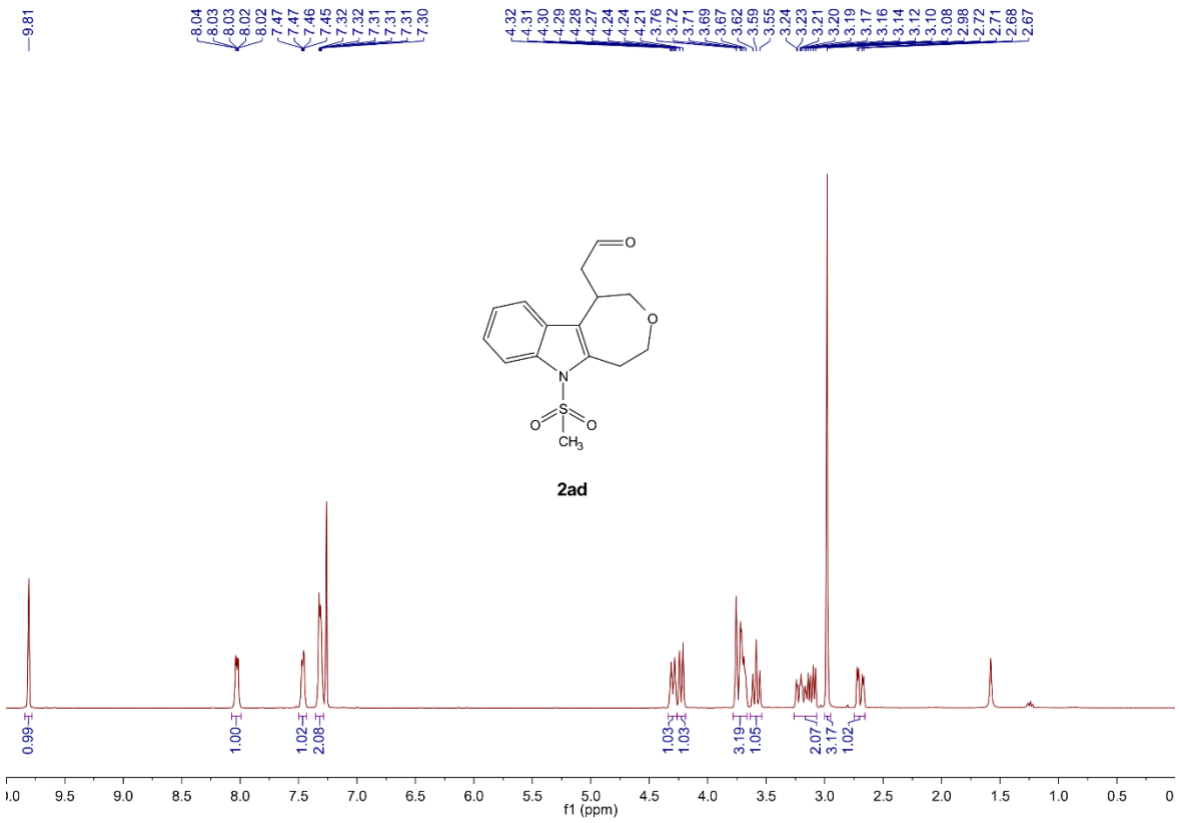
^{1}H NMR ($CDCl_3$, 400MHz) for **2ac.**



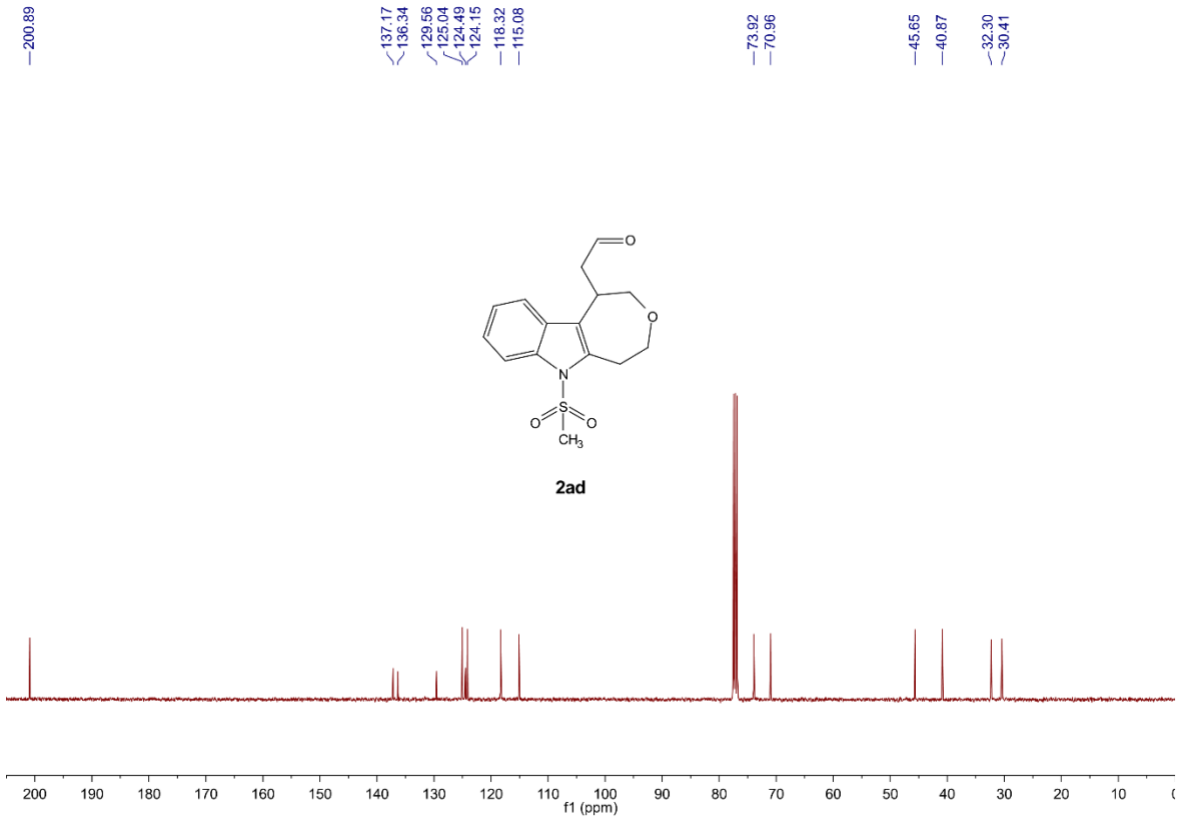
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2ac**.



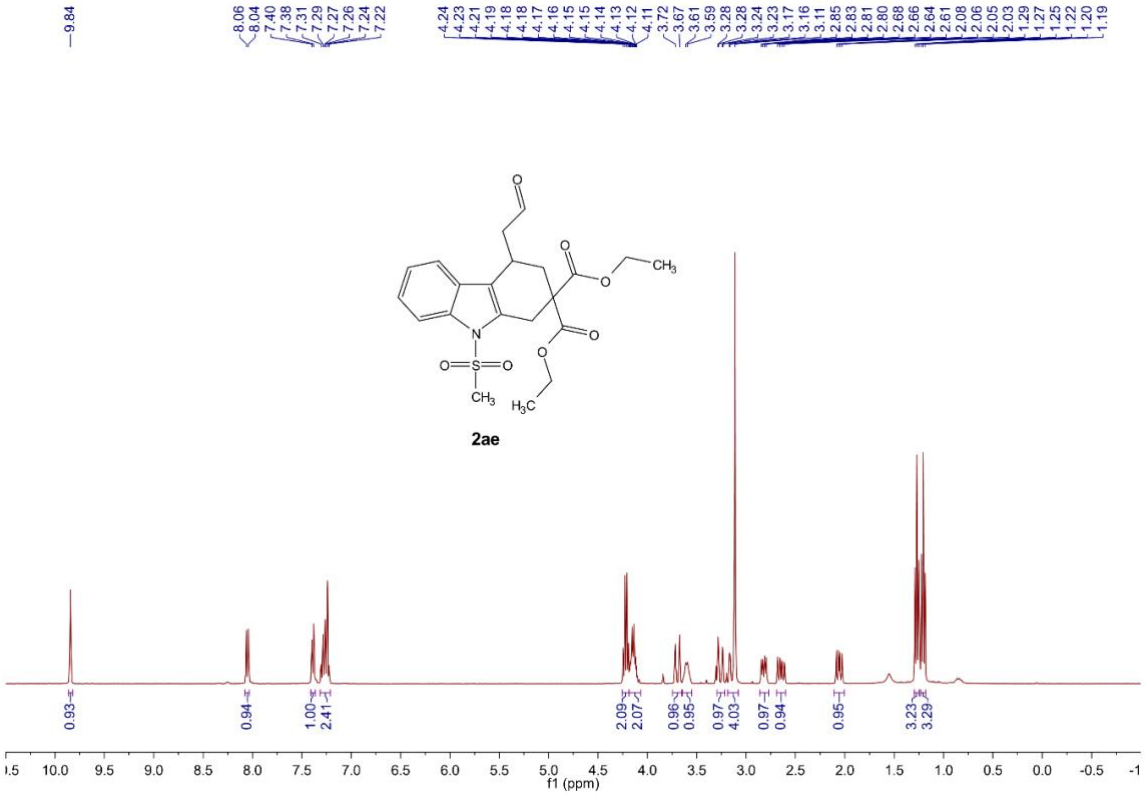
^{1}H NMR ($CDCl_3$, 400MHz) for **2ad.**



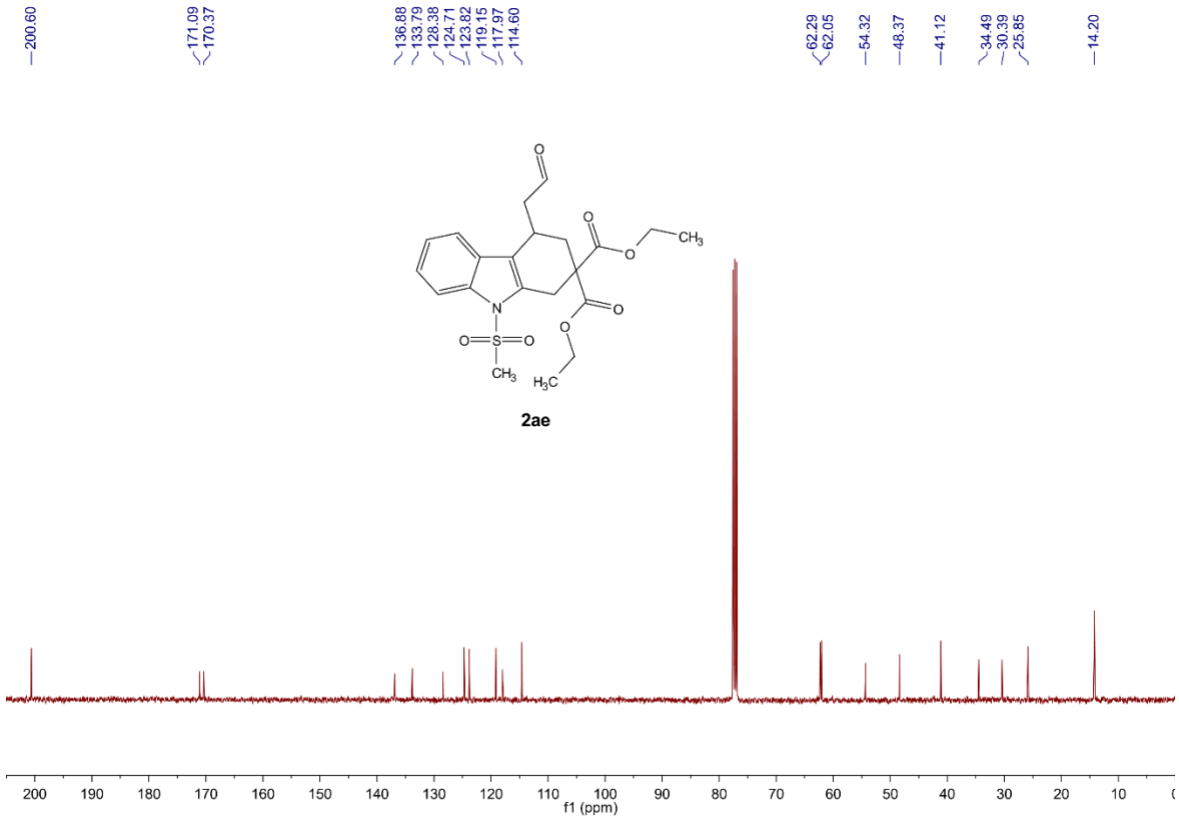
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2ad**.



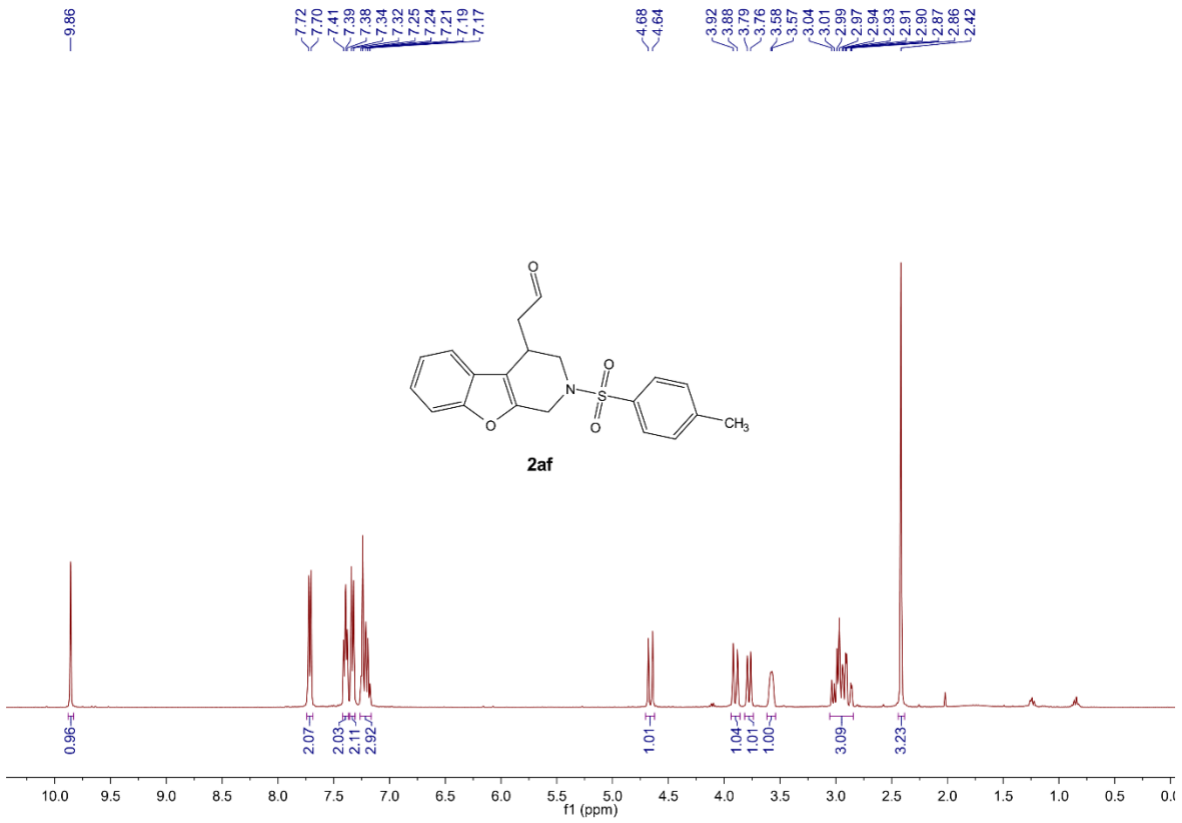
^{1}H NMR ($CDCl_3$, 400MHz) for **2ae.**



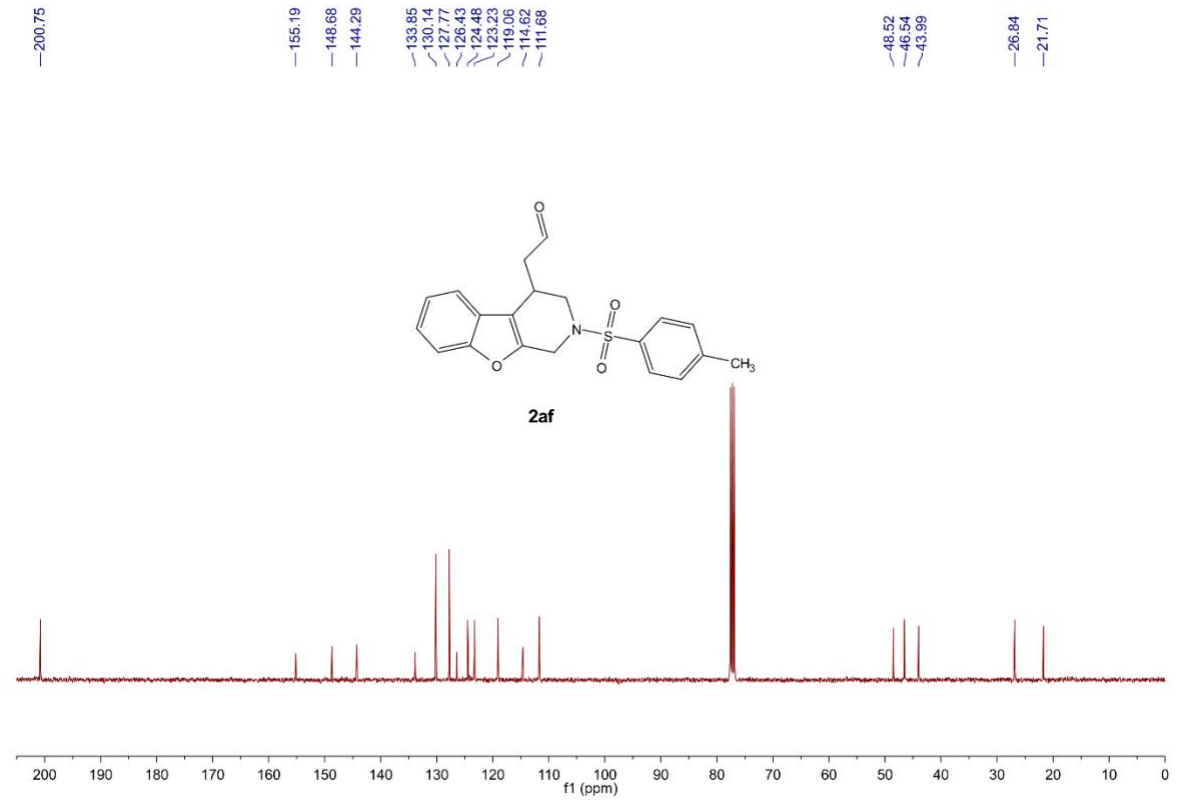
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2ae**.



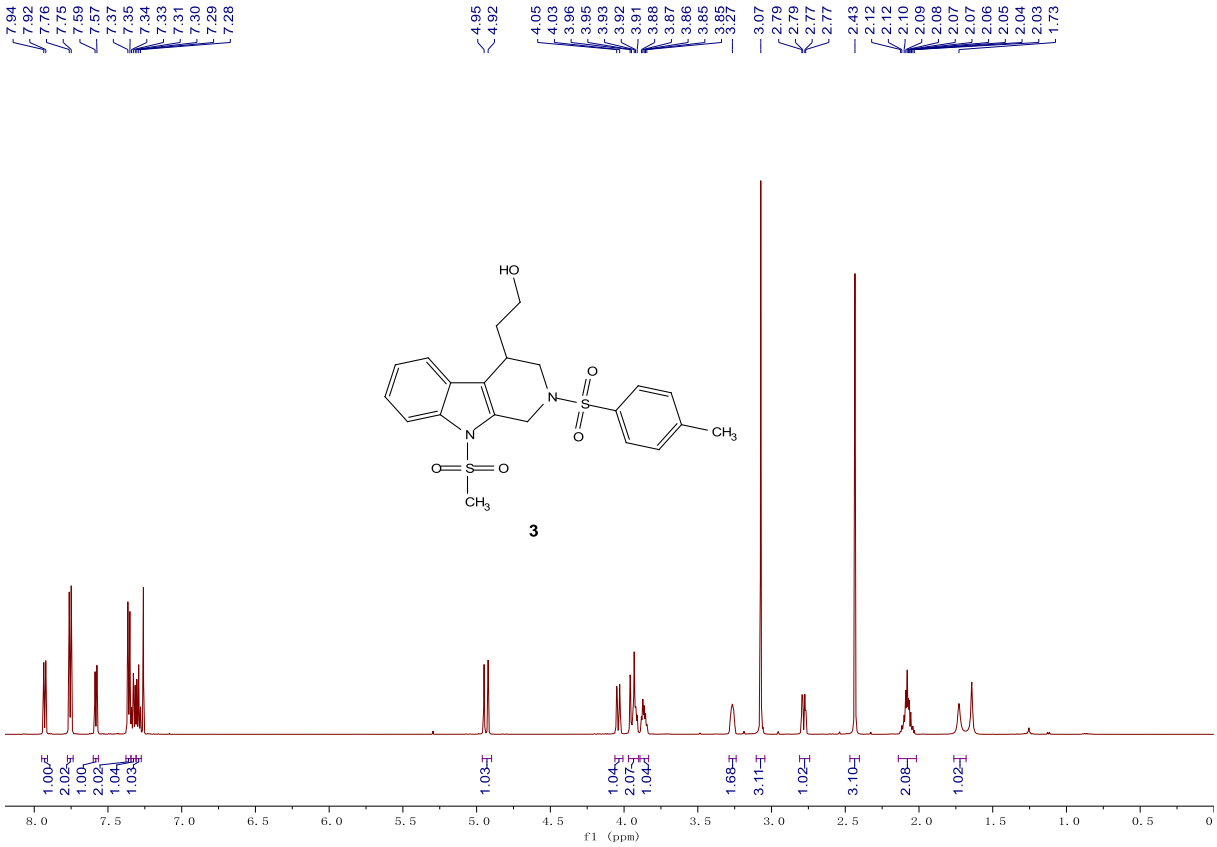
^{1}H NMR ($CDCl_3$, 400MHz) for **2af.**



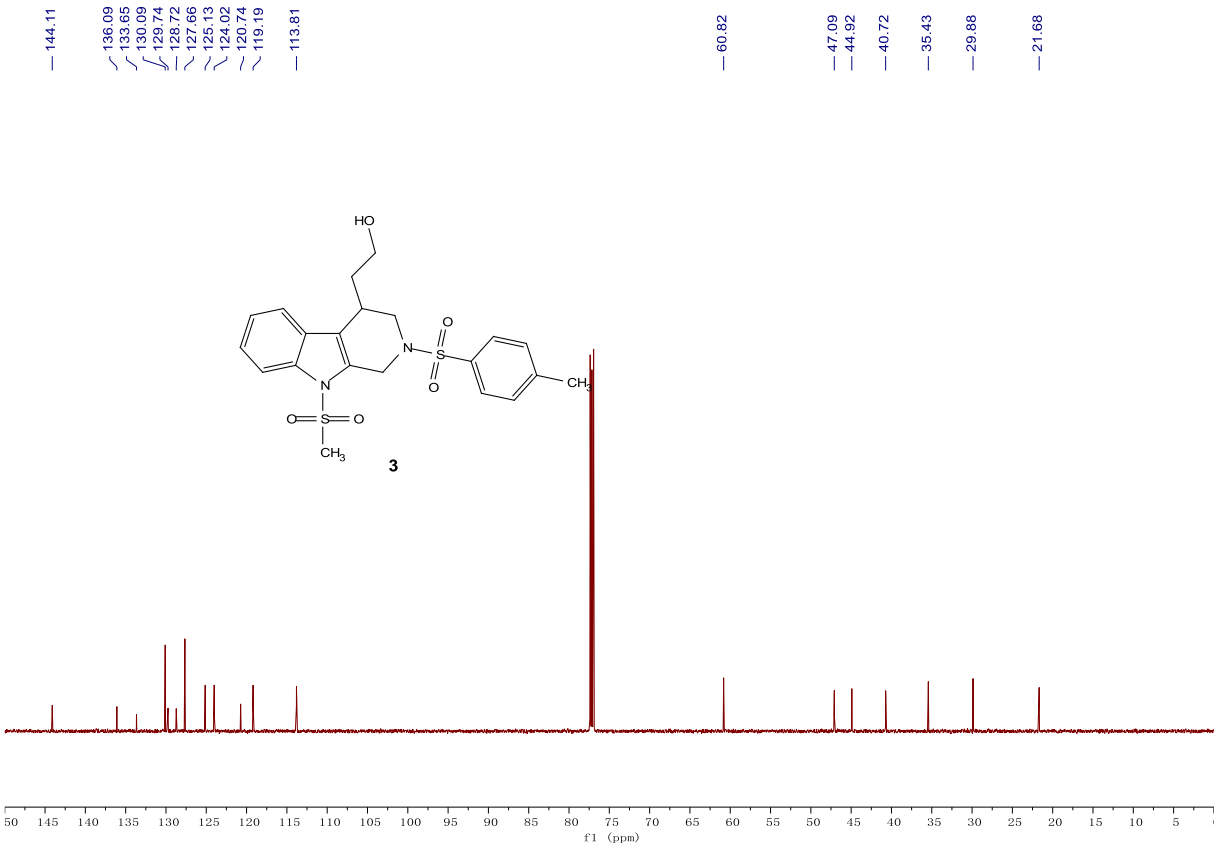
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **2af**.



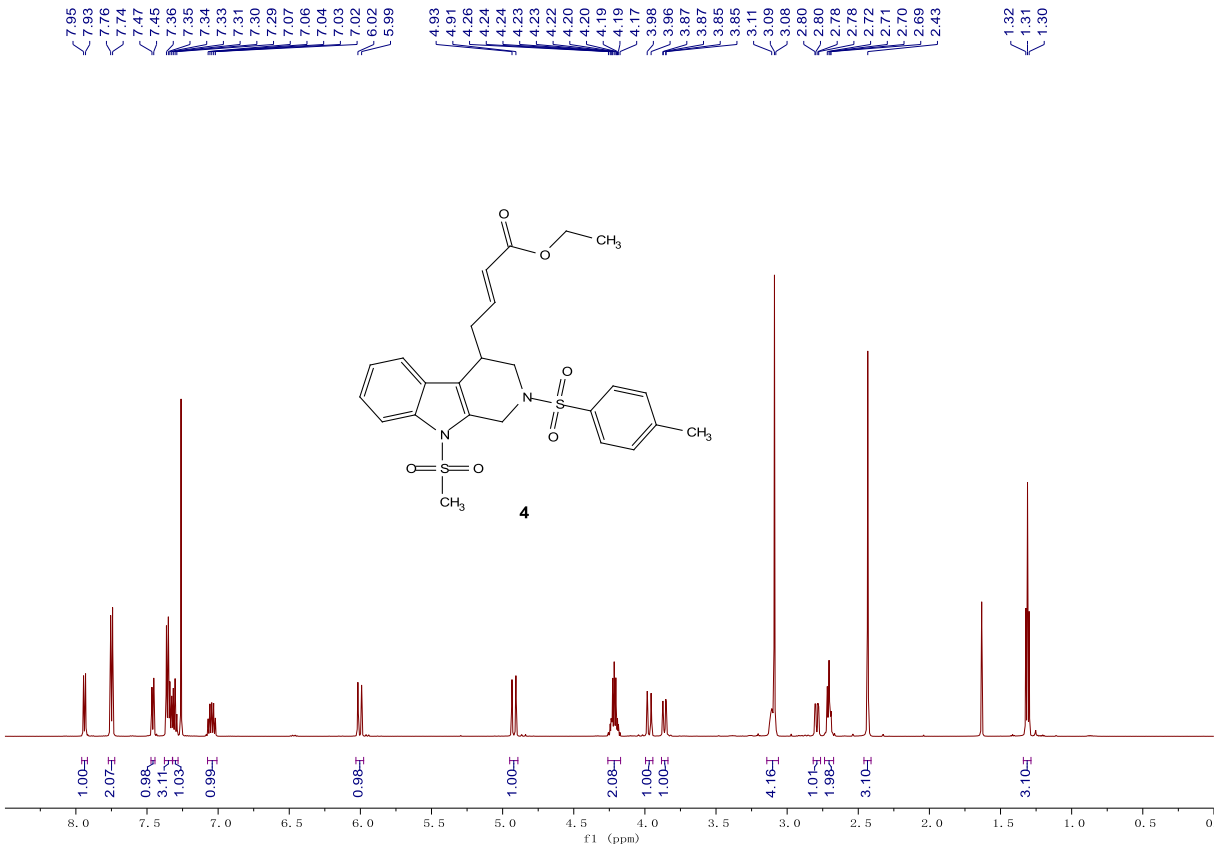
^{1}H NMR ($CDCl_3$, 600MHz) for **3.**



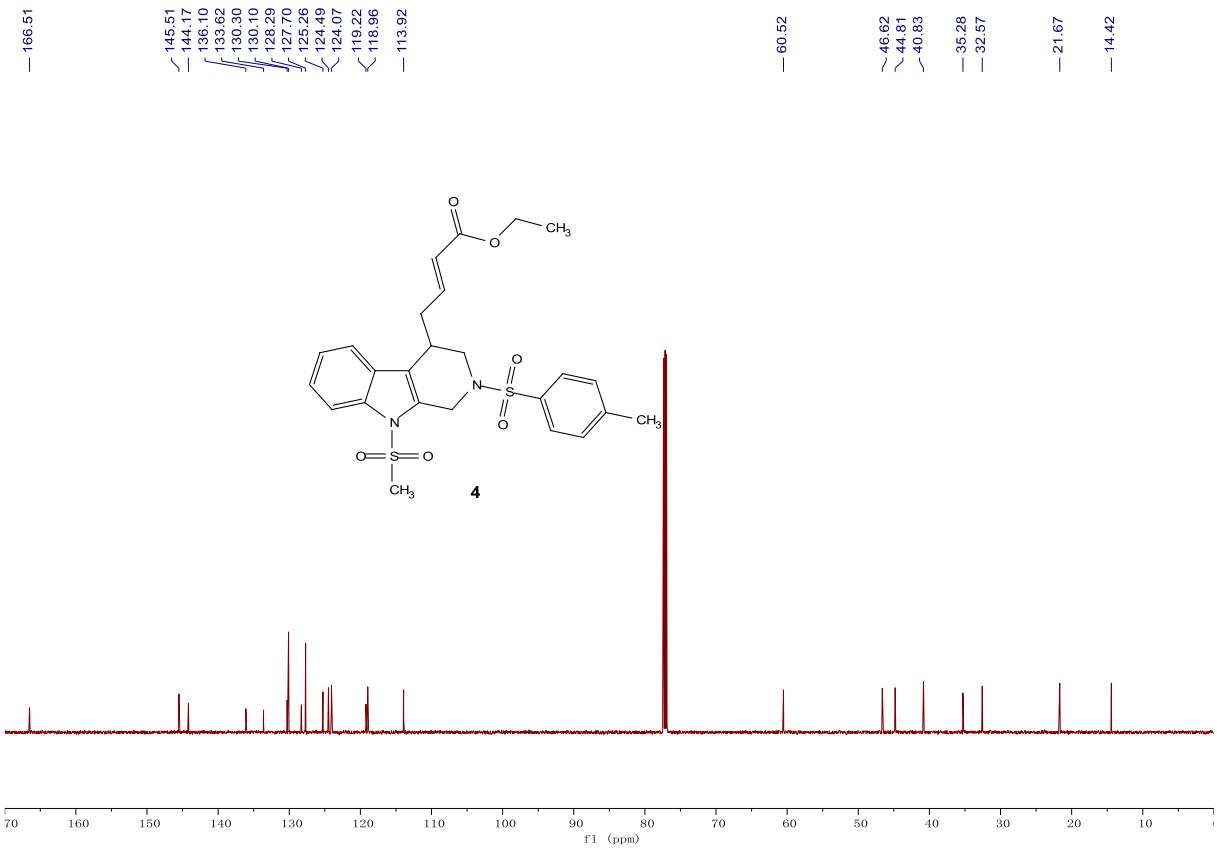
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **3**.



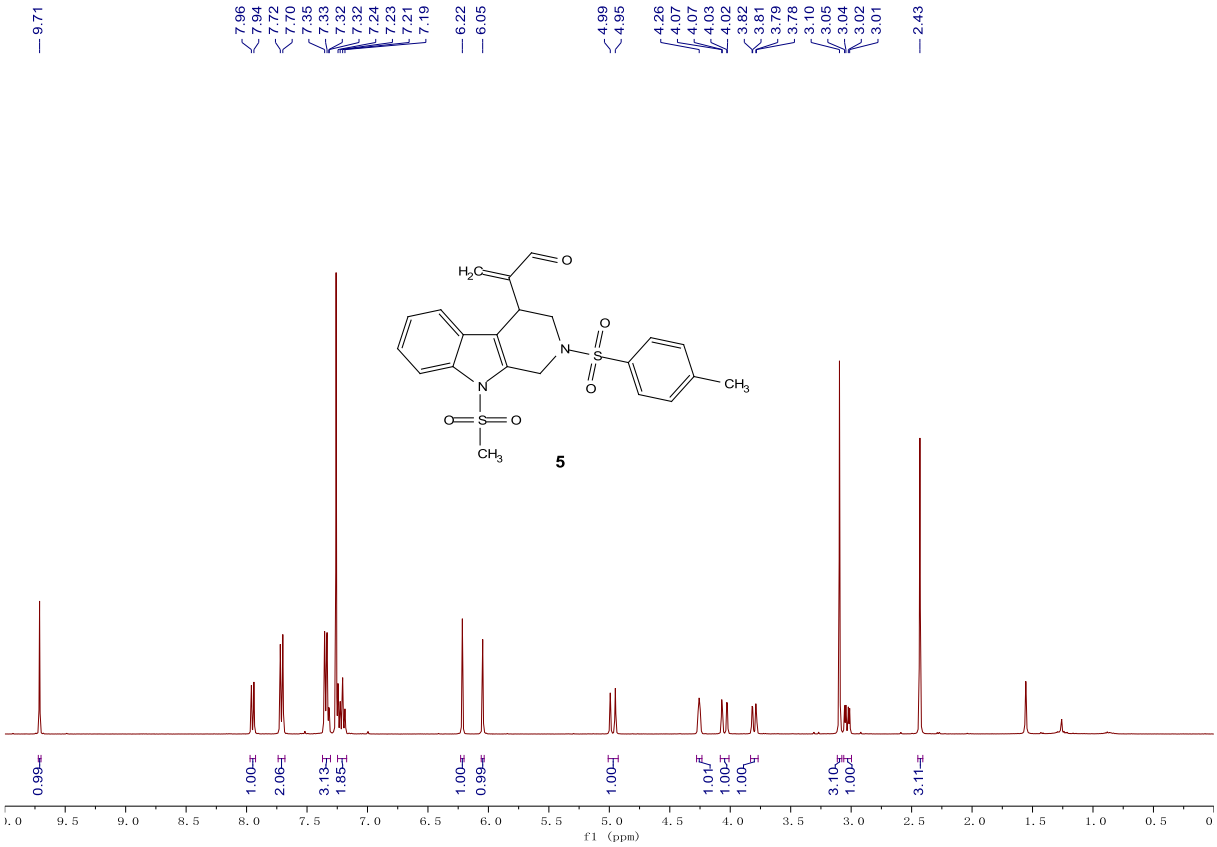
^{1}H NMR ($CDCl_3$, 600MHz) for **4.**



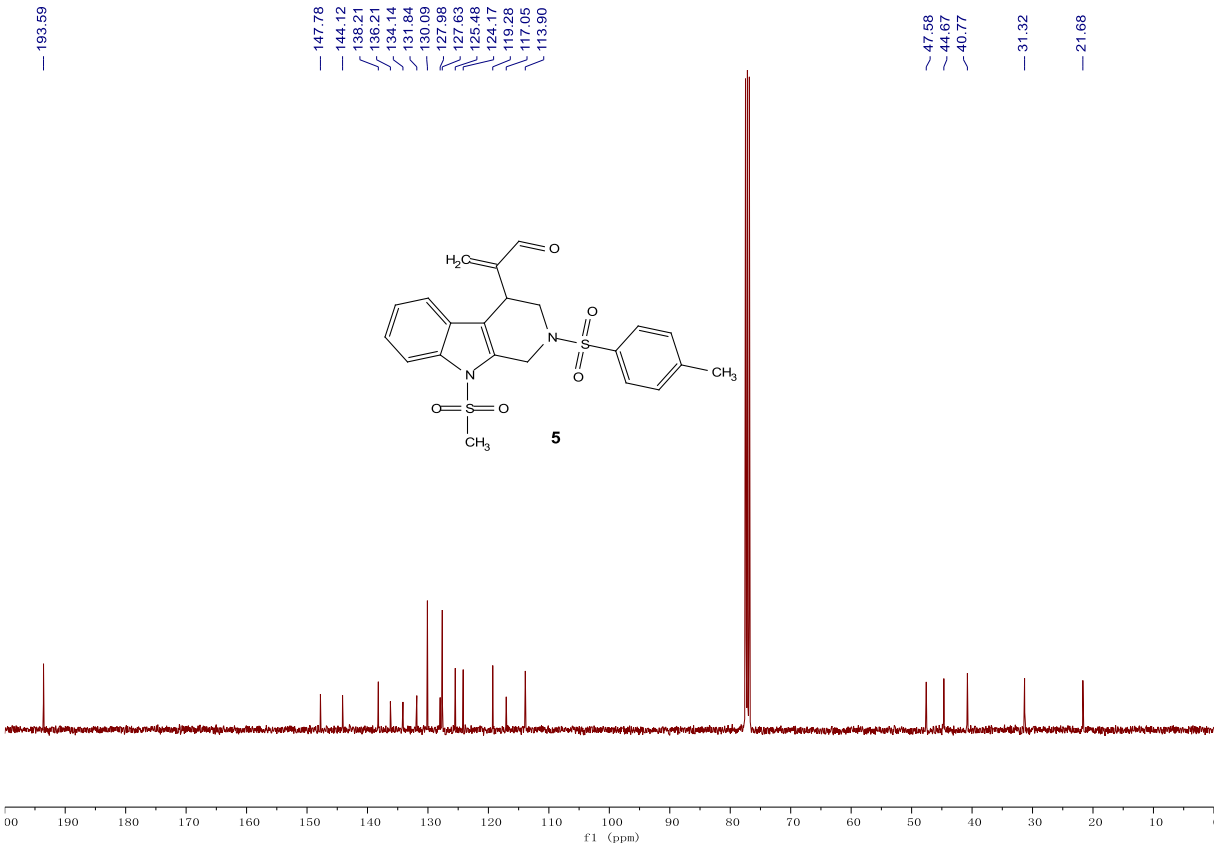
^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz) for **4**.



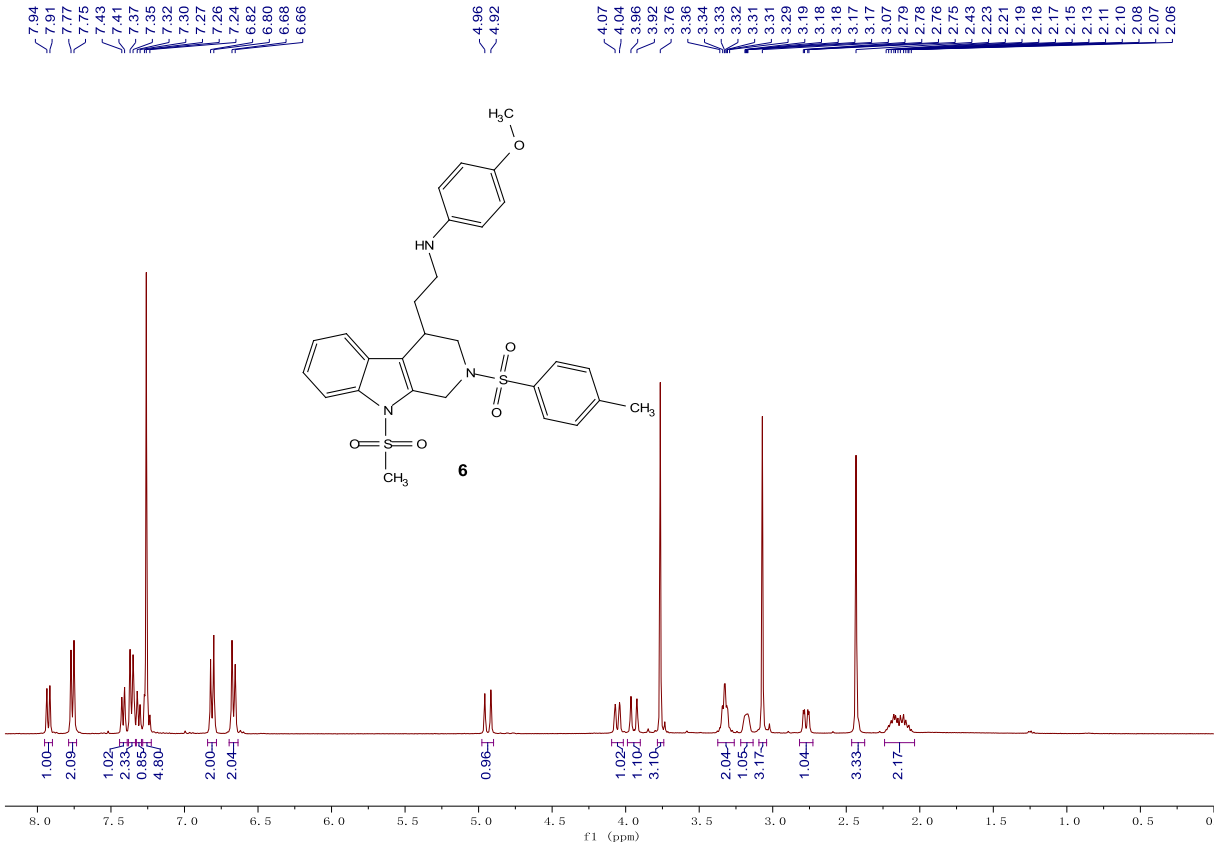
^{1}H NMR ($CDCl_3$, 400MHz) for **5.**



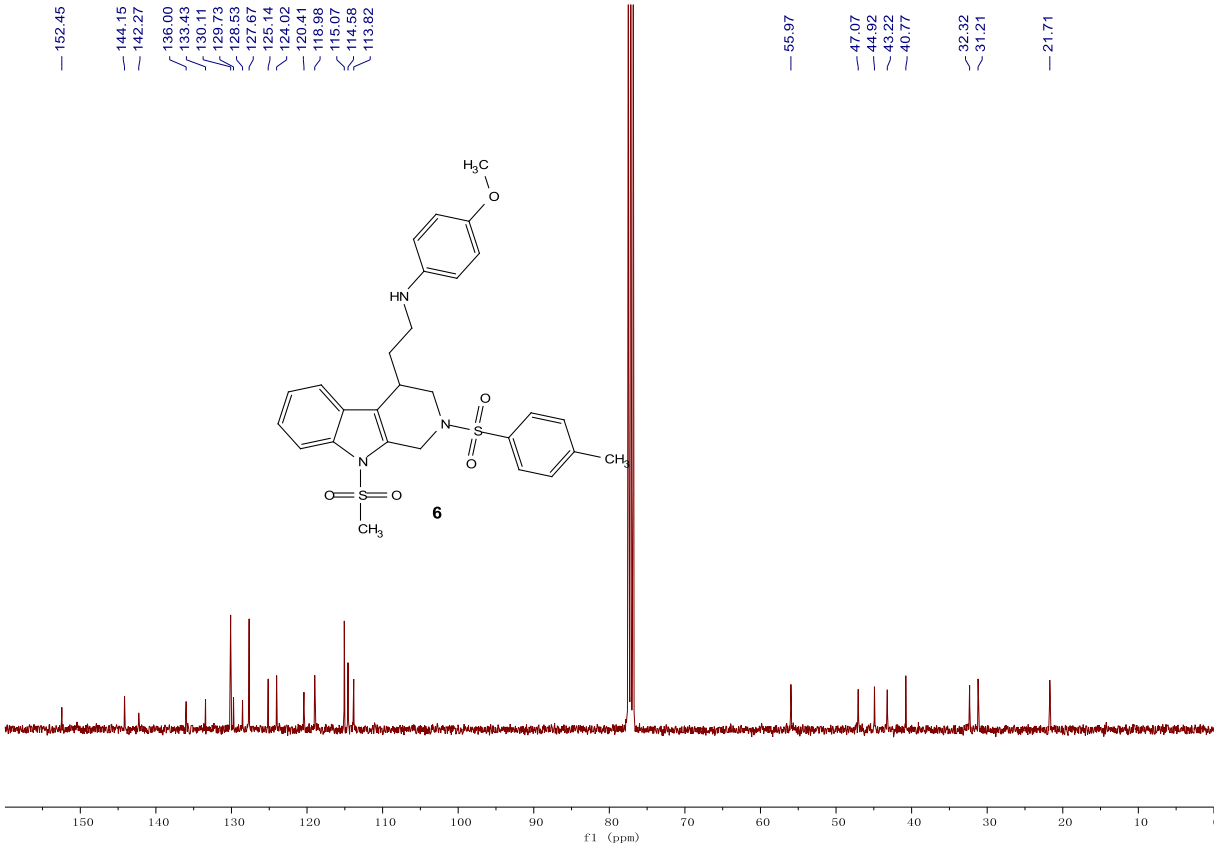
^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **5**.



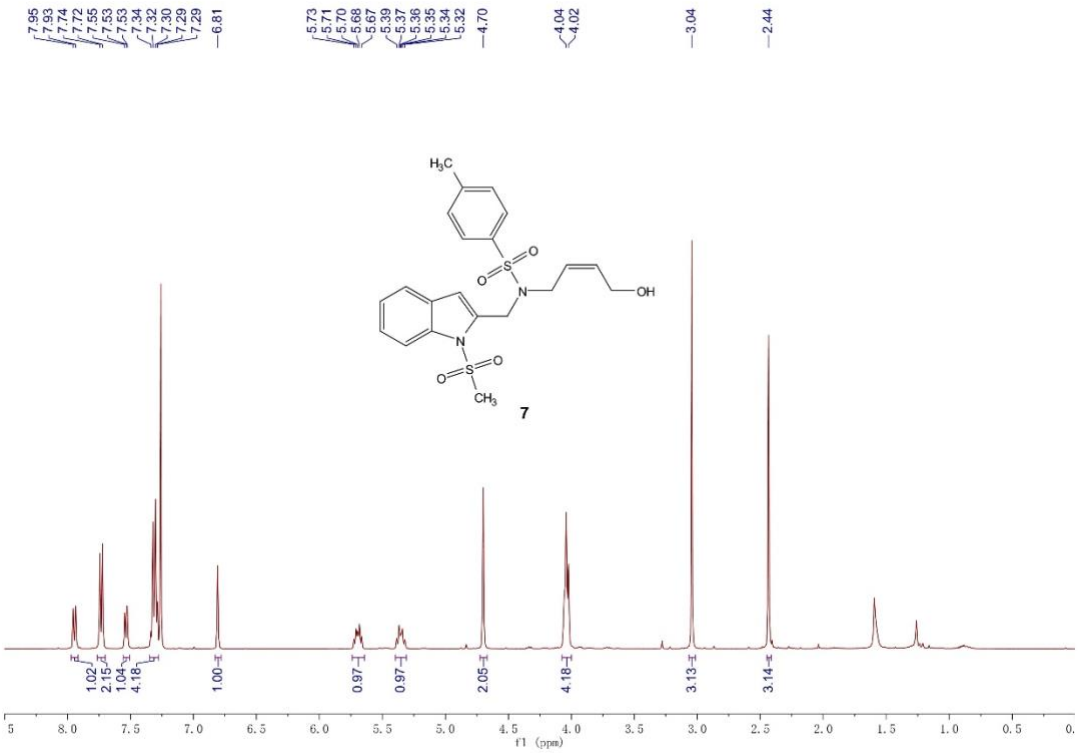
^{1}H NMR ($CDCl_3$, 400MHz) for **6.**



^{13}C{^{1}H} NMR ($CDCl_3$, 101 MHz) for **6**.



^{1}H NMR ($CDCl_3$, 400MHz) for **7.**



$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 101 MHz) for **7**.