Electronic Supplementary Material (ESI) for ChemComm.

Reaction of Prop-2-ynylsulfonium Salts and Sulfonyl-protected β-amino Ketones to Epoxide-fused 2-methylenepyrrolidines and S-containing Pyrroles

Tingting Jia, [a,b] Gongruixue Zeng, [a] Chong Zhang,[a] Linghui Zeng,[a] Wenya Zheng, [a] Siyao Li, [a] Keyi Wu,[a] Jiaan Shao,*[a,b] Jiankang Zhang*[a,b] and Huajian Zhu*[a,b]

[a]*School of Medicine, Zhejiang University City College, Hangzhou, 310015, PR China. E-mail: zhuhj@zucc.edu.cn, zjk0125@yeah.net, shaoja@zucc.edu.cn.*
[b]*College of Pharmaceutical Sciences, Zhejiang University, Hangzhou, 310058, PR China.*

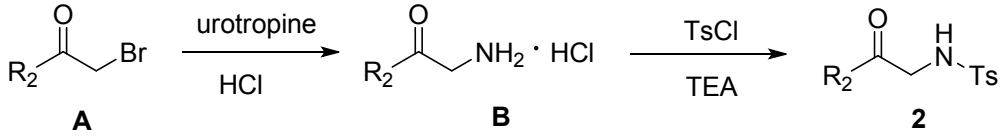
Supporting Information

Contents

1. General information

All the solvents were used from commercially available sources without any purification. Yield referred to isolated compounds, unless noted otherwise. Reactions were monitored by TLC using a UV lamp as a visualizing agent. The ^{1}H NMR and ^{13}C NMR spectra were recorded at 400MHz and 100MHz, respectively, in DMSO-D_6 solutions with shifts referenced to tetramethylsilane (TMS). All *J* values are in Hz. The following abbreviations are used to indicate the multiplicity: s, singlet; d, doublet: t, triplet; q, quartet; m, multiplet. LC-MS equipment was used to record mass spectra for isolated compounds where appropriate.

2. General procedure for the synthesis of 2

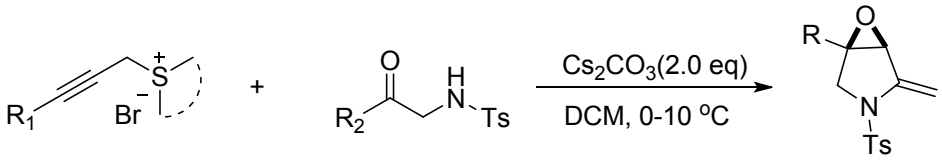


A **B** **2**

Urotropine (15 mmol) was added to a solution of **A** (15 mmol) in 75 mL of dichloromethane (DCM). The reaction mixture was stirred at 50 °C for 4 h. Then, the reaction mixture was filtered and thoroughly washed with DCM and ethanol to yield a white solid. This solid was suspended in a mixture of ethanol (75 mL) and concentrated hydrochloric acid (7.5 mL). The mixture was heated to reflux for 2 h. After being cooled down to room temperature, a white precipitate was removed by filtration and the filtrate was collected and concentrated under reduced pressure to obtain **B**.

To a stirred solution of **B** (10 mmol) in H_2O (10 mL) was added a corresponding *p*-toluenesulfonyl chloride (10 mmol) in acetone (25 mL) dropwise at 10 ^{o}C. Triethylamine (22 mmol) was then added dropwise with vigorous stirring. The resulting mixture was further stirred at the same temperature for about 1.5 h. After completion, the acetone was evaporated under reduced pressure and the precipitate was collected by vacuum filtration. Then, the precipitate was purified by recrystallized from ethanol to afford the desired product **C**.

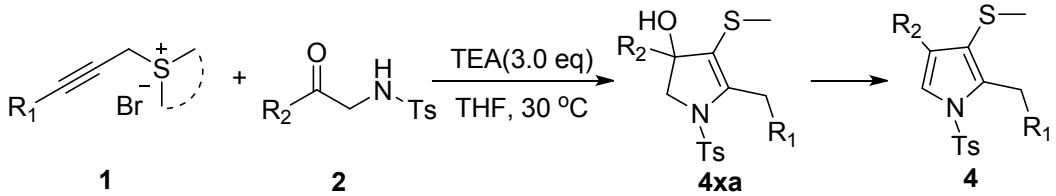
3. General procedure for the synthesis of 3



1 **2** **3**

1 (2.0 eq, 1.0 mmol) was added to a mixture of **2** (1.0 eq, 0.5 mmol) and Cs_2CO_3 (2.0 eq, 1.0 mmol) in DCM (5 mL). The resulting suspension was stirred at 0 ^{o}C for 1 h, and then warmed up to 10 ^{o}C. After the completion of the reaction (monitored by TLC), the reaction mixture was filtrated. The filtrate was concentrated and the residue was purified by flash column chromatography (petroleum ether: ethyl acetate = 10:1) to afford the product **3**.

4. General procedure for the the synthesis of 4xa and 4



1 **2** **4xa** **4**

To a stirred solution of 2 (1.0 eq, 0.5 mmol) in THF (10 mL) was added 9.0 equivalents of sulfonium salt **1** (4.5 mmol) slowly. Then, 3.0 equivalents of triethylamine (TEA, 1.5 mmol) were added and the reaction mixture was stirred at 30 ^{o}C until complete consumption of starting material. After filtration and evaporation, the residue was purified by flash column chromatography (petroleum ether: ethyl acetate = 10:1) to afford the product **4xa** or **4**. In addition, TEA was added to the reaction mixture with MsCl at 0 ^{o}C to accelerate the transformation from **4xa** to **4.**

5. References

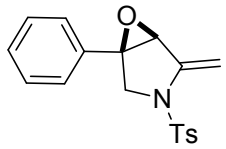
1. M. Gunther, J. Lategahn, M. Juchum, E. Doring, M. Keul, J. Engel, H. L. Tumbrink, D. Rauh and S. Laufer, *J. Med. Chem.*, 2017, **60**, 5613.

2. I. V. Magedov, G. Luchetti, N. M. Evdokimov, M. Manpadi, W. F. A. Steelant, S. Van Slambrouck, P. Tongwa, M. Y. Antipin and A. Kornienko, *Bioorg. Med. Chem. Lett.*, 2008, **18**, 1392.

3. X. D. Li, M. Chen, X. Xie, N. Sun, S. Li and Y. H. Liu, *Org. Lett.*, 2015, **17**, 2984.

4. P. J. Wang, Y. Xiong, Y. Q. Qin, J. J. Zhang, N. N. Yi, J. N. Xiang and W. Deng, *Catal. Commun.*, 2019, **131**, 7.

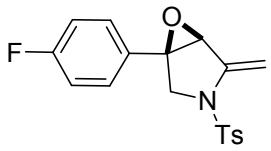
6. Analytical Data



(1*R*, 5*S*/1*S*, 5*R*)-4-methylene-1-phenyl-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3a)

Yellow oil, yield: 86%.

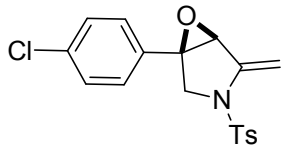
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.42 (s, 1H), 7.40 (s, 1H), 7.39-7.33 (m, 5H), 5.20 (s, 1H), 4.92 (s, 1H), 4.35 (d, *J* = 12.4 Hz, 1H), 4.26 (s, 1H), 4.18 (d, *J* = 12.4 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.3, 141.9, 134.3, 132.8, 129.7, 128.9, 128.7, 127.5, 126.4, 97.8, 64.3, 63.5, 52.4, 21.1. HRMS (ESI) calcd for $C_{18}H_{18}NO_3S$ $(M+H)^+$: 328.1002, found: 328.1003.



(1*R*, 5*S*/1*S*, 5*R*)-1-(4-fluorophenyl)-4-methylene-3-tosyl-6-oxa-3-azabicyclo[3.1.0] hexane (3b)

Yellow oil, yield: 96%.

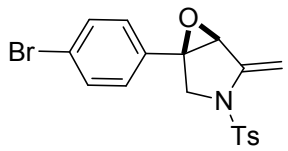
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.46 (dd, *J* = 8.8, 5.4 Hz, 2H), 7.41 (d, *J* = 8.1 Hz, 2H), 7.22 (t, *J* = 8.9 Hz, 2H), 5.20 (s, 1H), 4.91 (s, 1H), 4.36 (d, *J* = 12.4 Hz, 1H), 4.28 (s, 1H), 4.20 (d, *J* = 12.5 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 163.2 (d, *J* = 244 Hz), 144.2, 141.8, 134.2, 129.7, 129.1 (d, *J* = 2.9 Hz), 128.8 (d, *J* = 8.4 Hz), 127.5, 115.6 (d, *J* = 21.6 Hz), 97.8, 64.2, 63.1, 52.4, 21.1. HRMS (ESI) calcd for $C_{18}H_{17}FNO_3S$ $(M+H)^+$: 346.0908, found: 346.0910.



(1*R*, 5*S*/1*S*, 5*R*)-1-(4-chlorophenyl)-4-methylene-3-tosyl-6-oxa-3-azabicyclo[3.1.0] hexane (3c)

Yellow oil, yield: 82%.

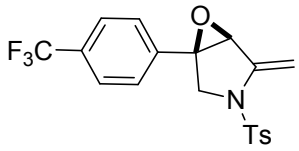
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.48-7.43 (m, 4H), 7.41 (s, 1H), 7.39 (s, 1H), 5.21 (s, 1H), 4.91 (s, 1H), 4.37 (d, *J* = 12.5 Hz, 1H), 4.28 (s, 1H), 4.19 (d, *J* = 12.4 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.2, 141.7, 134.2, 133.6, 131.8, 129.7, 128.6, 128.4, 127.5, 97.9, 64.4, 63.0, 52.3, 21.1. HRMS (ESI) calcd for $C_{18}H_{17}ClNO_3S$ $(M+H)^+$: 362.0612, found: 362.0607.



(1*R*, 5*S*/1*S*, 5*R*)-1-(4-bromophenyl)-4-methylene-3-tosyl-6-oxa-3-azabicyclo[3.1.0] hexane (3d)

Yellow oil, yield: 50%.

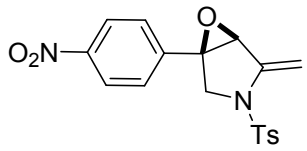
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.59 (d, *J* = 8.5 Hz, 2H), 7.41 (d, *J* = 8.1 Hz, 2H), 7.37 (d, *J* = 8.5 Hz, 2H), 5.20 (s, 1H), 4.91 (s, 1H), 4.37 (d, *J* = 12.5 Hz, 1H), 4.28 (s, 1H), 4.19 (d, *J* = 12.4 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.2, 141.7, 134.2, 132.3, 131.5, 129.7, 128.7, 127.5, 122.1, 97.9, 64.4, 63.1, 52.2, 21.1. HRMS (ESI) calcd for $C_{18}H_{17}BrNO_3S$ $(M+H)^+$: 406.0107, found: 406.0110.



(1*R*, 5*S*/1*S*, 5*R*)-4-methylene-3-tosyl-1-(4-(trifluoromethyl)phenyl)-6-oxa-3-azabicyclo[3.1.0]hexane (3e)

Yellow solid, yield: 63%.

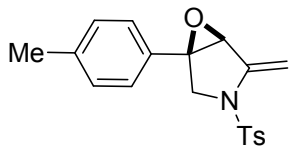
^{1}H NMR (400 MHz, DMSO) δ 7.76 (s, 1H), 7.74 (s, 2H), 7.72 (s, 1H), 7.64 (d, *J* = 8.2 Hz, 2H), 7.41 (d, *J* = 8.2 Hz, 2H), 5.23 (s, 1H), 4.93 (s, 1H), 4.46 (d, *J* = 12.5 Hz, 1H), 4.33 (s, 1H), 4.23 (d, *J* = 12.6 Hz, 1H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.3, 141.6, 137.6, 134.2, 129.7, 129.2 (d, *J* = 32.1 Hz), 127.5, 127.4, 125.5 (q, *J* = 3.8 Hz), 98.1, 64.7, 63.0, 52.2, 21.1. HRMS (ESI) calcd for $C_{19}H_{17}F_3NO_3S$ $(M+H)^+$: 396.0876, found: 396.0877.



(1*R*, 5*S*/1*S*, 5*R*)-4-methylene-1-(4-nitrophenyl)-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3f)

White solid, yield: 51%.

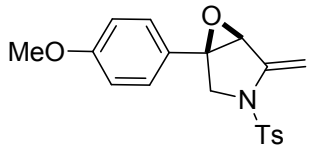
^{1}H NMR (400 MHz, DMSO) δ 8.23 (d, *J* = 8.9 Hz, 2H), 7.71 (dd, *J* = 12.5, 8.6 Hz, 4H), 7.42 (d, *J* = 8.0 Hz, 2H), 5.24 (s, 1H), 4.94 (s, 1H), 4.50 (d, *J* = 12.5 Hz, 1H), 4.36 (s, 1H), 4.25 (d, *J* = 12.5 Hz, 1H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 147.6, 144.3, 141.4, 140.3, 134.1, 129.7, 127.9, 127.5, 123.6, 98.3, 65.1, 63.0, 52.1, 21.1. HRMS (ESI) calcd for $C_{18}H_{17}N_2O_5S$ $(M+H)^+$: 373.0853, found: 373.0845.



(1*R*, 5*S*/1*S*, 5*R*)-4-methylene-1-(p-tolyl)-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3g)

Yellow oil, yield: 82%.

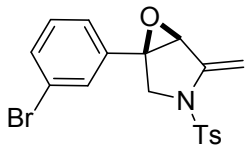
^{1}H NMR (400 MHz, DMSO) δ 7.73 (d, *J* = 8.3 Hz, 2H), 7.40 (d, *J* = 8.1 Hz, 2H), 7.28 (d, *J* = 8.1 Hz, 2H), 7.19 (d, *J* = 8.1 Hz, 2H), 5.20 (s, 1H), 4.90 (s, 1H), 4.33 (d, *J* = 12.4 Hz, 1H), 4.24 (s, 1H), 4.17 (d, *J* = 12.4 Hz, 1H), 2.39 (s, 3H), 2.29 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.2, 141.9, 138.3, 134.2, 129.7, 129.7, 129.2, 127.5, 126.3, 97.6, 64.1, 63.4, 52.4, 21.1, 20.8. HRMS (ESI) calcd for $C_{19}H_{20}NO_3S$ $(M+H)^+$: 342.1158, found: 342.1158.



(1*R*, 5*S*/1*S*, 5*R*)-1-(4-methoxyphenyl)-4-methylene-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3h)

Yellow oil, yield: 89%.

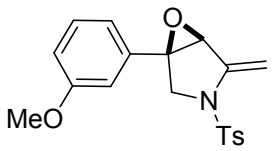
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.41 (d, *J* = 8.1 Hz, 2H), 7.32 (d, *J* = 8.7 Hz, 2H), 6.93 (d, *J* = 8.8 Hz, 2H), 5.19 (s, 1H), 4.89 (s, 1H), 4.30 (d, *J* = 12.4 Hz, 1H), 4.25 (s, 1H), 4.19 (s, 1H), 3.74 (s, 3H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 159.6, 144.2, 142.0, 134.2, 129.7, 127.9, 127.5, 124.5, 114.0, 97.5, 64.0, 63.3, 55.3, 52.5, 21.1. HRMS (ESI) calcd for $C_{19}H_{20}NO_4S$ $(M+H)^+$: 358.1108, found: 358.1105.



(1*R*, 5*S*/1*S*, 5*R*)-1-(3-bromophenyl)-4-methylene-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3i)

Yellow oil, yield: 63%.

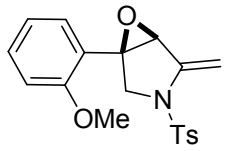
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.62 (s, 1H), 7.58 (d, *J* = 7.9 Hz, 1H), 7.42 (t, *J* = 8.9 Hz, 3H), 7.35 (t, *J* = 7.8 Hz, 1H), 5.20 (s, 1H), 4.90 (s, 1H), 4.39 (d, *J* = 12.5 Hz, 1H), 4.33 (s, 1H), 4.22 (d, *J* = 12.5 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.2, 141.6, 135.5, 134.2, 131.8, 130.8, 129.7, 129.2, 127.5, 125.6, 122.0, 97.9, 64.4, 62.9, 52.2, 21.1. HRMS (ESI) calcd for $C_{18}H_{17}BrNO_3S$ $(M+H)^+$: 406.0107, found: 406.0108.



(1*R*, 5*S*/1*S*, 5*R*)-1-(3-methoxyphenyl)-4-methylene-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3j)

Yellow oil, yield: 63%.

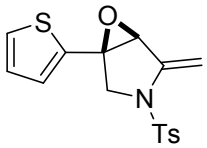
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.41 (d, *J* = 8.1 Hz, 2H), 7.29 (t, *J* = 7.8 Hz, 1H), 6.98 (d, *J* = 7.9 Hz, 1H), 6.93 (d, *J* = 8.2 Hz, 2H), 5.21 (s, 1H), 4.90 (s, 1H), 4.37 (d, *J* = 12.5 Hz, 1H), 4.26 (s, 1H), 4.18 (d, *J* = 12.5 Hz, 1H), 3.74 (s, 3H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 159.5, 144.2, 141.8, 134.3, 134.2, 129.8, 129.7, 127.5, 118.6, 114.7, 111.7, 97.7, 64.3, 63.4, 55.3, 52.5, 21.1. HRMS (ESI) calcd for $C_{19}H_{20}NO_4S$ $(M+H)^+$: 358.1108, found: 358.1109.



(1*R*, 5*S*/1*S*, 5*R*)-1-(2-methoxyphenyl)-4-methylene-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3k)

White solid, yield: 78%.

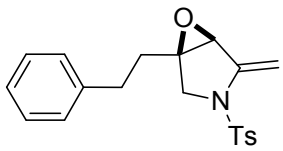
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.44 (d, *J* = 8.1 Hz, 2H), 7.40-7.34 (m, 1H), 7.22 (d, *J* = 6.3 Hz, 1H), 7.05 (d, *J* = 8.3 Hz, 1H), 6.94 (t, *J* = 7.4 Hz, 1H), 5.20 (s, 1H), 4.90 (s, 1H), 4.14 (s, 1H), 4.05 (d, *J* = 12.0 Hz, 1H), 3.97 (d, *J* = 12.0 Hz, 1H), 3.77 (s, 3H), 2.41 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 157.5, 144.3, 142.0, 134.1, 130.6, 129.8, 128.5, 127.4, 120.9, 120.4, 111.2, 97.1, 62.7, 62.5, 55.7, 53.9, 21.1. HRMS (ESI) calcd for $C_{19}H_{20}NO_4S$ $(M+H)^+$: 358.1108, found: 358.1106.



(1*R*, 5*S*/1*S*, 5*R*)-4-methylene-1-(thiophen-2-yl)-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3l)

Yellow oil, yield: 81%.

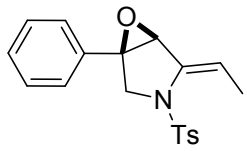
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.57 (dd, *J* = 5.0, 0.9 Hz, 1H), 7.41 (d, *J* = 8.1 Hz, 2H), 7.37 (dd, *J* = 3.5, 1.0 Hz, 1H), 7.06 (dd, *J* = 5.0, 3.7 Hz, 1H), 5.22 (s, 1H), 4.94 (s, 1H), 4.35 (d, *J* = 12.5 Hz, 1H), 4.31 (s, 1H), 4.22 (d, *J* = 12.5 Hz, 1H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.2, 141.3, 135.7, 134.0, 129.6, 127.6, 127.4, 126.9, 98.3, 65.6, 61.3, 52.6, 21.0. HRMS (ESI) calcd for $C_{16}H_{16}NO_3S_2$ $(M+H)^+$: 334.0566, found: 334.0569.



(1*R*, 5*S*/1*S*, 5*R*)-4-methylene-1-phenethyl-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3m)

White oil, yield: 94%.

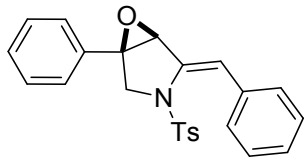
^{1}H NMR (400 MHz, DMSO) δ 7.64 (d, *J* = 8.2 Hz, 2H), 7.41 (d, *J* = 8.1 Hz, 2H), 7.27 (t, *J* = 7.4 Hz, 2H), 7.18 (t, *J* = 6.5 Hz, 3H), 5.10 (s, 1H), 4.78 (s, 1H), 3.80 (s, 1H), 3.75 (d, *J* = 3.0 Hz, 2H), 2.59 (t, *J* = 7.7 Hz, 2H), 2.40 (s, 3H), 2.15 – 1.98 (m, 2H). ^{13}C NMR (100 MHz, DMSO) δ 144.0, 142.2, 140.8, 134.2, 129.6, 128.3, 128.2, 127.2, 126.0, 96.7, 63.4, 60.9, 53.1, 30.3, 30.2, 21.0. HRMS (ESI) calcd for $C_{20}H_{22}NO_3S$ $(M+H)^+$: 356.1315, found: 356.1316.



(1*R*, 5*S*/1*S*, 5*R*)-4-ethylidene-1-phenyl-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3n)

White oil, yield: 92%.

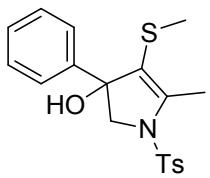
^{1}H NMR (400 MHz, DMSO) δ 7.64 (d, *J* = 8.3 Hz, 2H), 7.41 – 7.33 (m, 7H), 5.92 (q, *J* = 7.2 Hz, 1H), 4.48 (s, 1H), 4.27 (d, *J* = 12.8 Hz, 1H), 4.16 – 4.08 (m, 1H), 2.38 (s, 3H), 1.81 (d, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, DMSO) δ 143.9, 135.4, 134.6, 133.1, 129.6, 128.8, 128.6, 127.6, 126.5, 112.6, 63.7, 60.5, 51.8, 21.1, 13.2. HRMS (ESI) calcd for $C_{19}H_{20}NO_3S$ $(M+H)^+$: 342.1158, found: 342.1160.



(1*R*, 5*S*/1*S*, 5*R*)-4-benzylidene-1-phenyl-3-tosyl-6-oxa-3-azabicyclo[3.1.0]hexane (3o)

Yellow solid, yield: 91%.

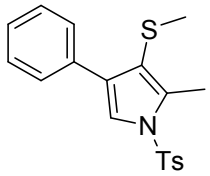
^{1}H NMR (400 MHz, DMSO) δ 7.71 (d, *J* = 8.2 Hz, 2H), 7.44-7.38 (m, 4H), 7.38-7.30 (m, 7H), 7.28 (t, *J* = 7.0 Hz, 1H), 7.03 (s, 1H), 4.40 (d, *J* = 13.1 Hz, 1H), 4.26 (d, *J* = 12.4 Hz, 2H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.2, 136.7, 135.1, 134.3, 132.6, 129.7, 128.9, 128.8, 128.5, 128.3, 127.5, 127.3, 126.6, 117.3, 64.8, 62.2, 51.6, 21.2. HRMS (ESI) calcd for $C_{24}H_{22}NO_3S$ $(M+H)^+$: 404.1315, found: 404.1314.



5-methyl-4-(methylthio)-3-phenyl-1-tosyl-2,3-dihydro-1*H*-pyrrol-3-ol (4aa)

White solid, yield: 68%.

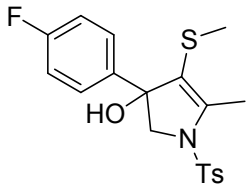
^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.1 Hz, 2H), 7.48 (d, *J* = 8.0 Hz, 2H), 7.19-7.11 (m, 3H), 6.90 – 6.84 (m, 2H), 5.93 (s, 1H), 3.85 (d, *J* = 11.8 Hz, 1H), 3.65 (d, *J* = 11.8 Hz, 1H), 2.45 (s, 3H), 2.30 (s, 3H), 1.80 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.9, 144.5, 143.5, 133.5, 130.3, 127.7, 127.6, 126.9, 125.3, 121.9, 82.0, 64.8, 21.1, 18.2, 14.2. HRMS (ESI) calcd for $C_{19}H_{22}NO_3S_2$ $(M+H)^+$: 376.1036, found: 376.1031.



2-methyl-3-(methylthio)-4-phenyl-1-tosyl-1*H*-pyrrole (4a)

White solid, yield: 66%.

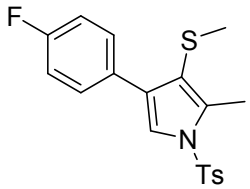
^{1}H NMR (400 MHz, DMSO) δ 7.88 (d, *J* = 8.4 Hz, 2H), 7.71 – 7.65 (m, 2H), 7.62 (s, 1H), 7.47 (d, *J* = 8.1 Hz, 2H), 7.40 (t, *J* = 7.5 Hz, 2H), 7.31 (t, *J* = 7.3 Hz, 1H), 2.43 (s, 3H), 2.38 (s, 3H), 1.95 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.8, 134.7, 134.1, 133.0, 130.6, 128.4, 128.2, 127.7, 127.2, 127.1, 118.8, 116.7, 21.1, 19.0, 11.6. HRMS (ESI) calcd for $C_{19}H_{20}NO_2S_2$ $(M+H)^+$: 358.0930, found: 358.0929.



3-(4-fluorophenyl)-5-methyl-4-(methylthio)-1-tosyl-2,3-dihydro-1*H*-pyrrol-3-ol (4ba)

White solid, yield: 75%.

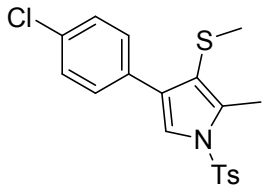
^{1}H NMR (400 MHz, DMSO) δ 7.73 (d, *J* = 8.2 Hz, 2H), 7.47 (d, *J* = 8.1 Hz, 2H), 6.98 (t, *J* = 8.8 Hz, 2H), 6.91 (dd, *J* = 8.7, 5.7 Hz, 2H), 6.01 (s, 1H), 3.86 (d, *J* = 11.9 Hz, 1H), 3.66 (d, *J* = 11.9 Hz, 1H), 2.45 (s, 3H), 2.30 (s, 3H), 1.83 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 161.0 (d, *J* = 241.6 Hz), 144.4, 143.6, 141.0(d, *J* = 2.8 Hz), 133.4, 130.2, 127.5, 127.2 (d, *J* = 8.2 Hz), 121.4, 114.3 (d, *J* = 21.2 Hz), 81.6, 64.5, 21.0, 18.1, 14.1. HRMS (ESI) calcd for $C_{19}H_{21}FNO_3S_2$ $(M+H)^+$: 394.0941, found: 394.0937.



4-(4-fluorophenyl)-2-methyl-3-(methylthio)-1-tosyl-1*H*-pyrrole (4b)

White solid, yield: 72%.

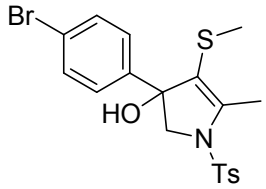
^{1}H NMR (400 MHz, DMSO) δ 7.88 (d, *J* = 8.0 Hz, 2H), 7.76 – 7.66 (m, 2H), 7.64 (s, 1H), 7.47 (d, *J* = 8.0 Hz, 2H), 7.24 (t, *J* = 8.7 Hz, 2H), 2.42 (s, 3H), 2.39 (s, 3H), 1.95 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 161.5 (d, *J* = 242.8 Hz), 145.8, 134.7, 134.1, 130.6, 129.7 (d, *J* = 8.0 Hz), 129.4 (d, *J* = 3.0 Hz), 127.2, 127.1, 118.8, 116.5, 115.2 (d, *J* = 21.1 Hz), 21.1, 19.0, 11.6. HRMS (ESI) calcd for $C_{19}H_{19}FNO_2S_2$ $(M+H)^+$: 376.0836, found: 376.0838.



4-(4-chlorophenyl)-2-methyl-3-(methylthio)-1-tosyl-1*H*-pyrrole (4c)

White solid, yield: 50%.

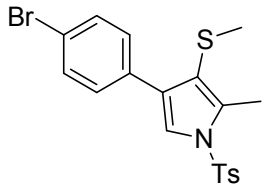
^{1}H NMR (400 MHz, DMSO) δ 7.89 (d, *J* = 8.3 Hz, 2H), 7.73 (d, *J* = 8.5 Hz, 2H), 7.70 (s, 1H), 7.47 (dd, *J* = 7.9, 5.7 Hz, 4H), 2.42 (s, 3H), 2.39 (s, 3H), 1.96 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.9, 134.6, 134.3, 131.6, 130.6, 129.4, 128.4, 127.1, 126.8, 119.2, 116.4, 21.1, 19.0, 11.6. HRMS (ESI) calcd for $C_{19}H_{19}ClNO_2S_2$ $(M+H)^+$: 392.0540, found: 392.0541.



3-(4-bromophenyl)-5-methyl-4-(methylthio)-1-tosyl-2,3-dihydro-1*H*-pyrrol-3-ol (4da)

White solid, yield: 37%.

^{1}H NMR (400 MHz, DMSO) δ 7.72 (d, *J* = 8.1 Hz, 2H), 7.47 (d, *J* = 8.0 Hz, 2H), 7.35 (d, *J* = 8.4 Hz, 2H), 6.84 (d, *J* = 8.4 Hz, 2H), 6.06 (s, 1H), 3.85 (d, *J* = 12.0 Hz, 1H), 3.65 (d, *J* = 11.9 Hz, 1H), 2.45 (s, 3H), 2.29 (s, 3H), 1.84 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 144.6, 144.4, 144.0, 133.5, 130.6, 130.4, 127.7, 127.5, 121.2, 120.1, 81.9, 64.5, 21.2, 18.3, 14.2. HRMS (ESI) calcd for $C_{19}H_{21}BrNO_3S_2$ $(M+H)^+$: 454.0141, found: 454.0144.

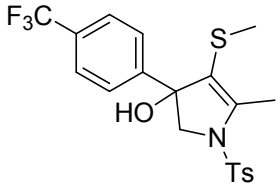


4-(4-bromophenyl)-2-methyl-3-(methylthio)-1-tosyl-1*H*-pyrrole (4d)

White solid, yield: 36%.

^{1}H NMR (400 MHz, DMSO) δ 7.89 (d, *J* = 8.3 Hz, 2H), 7.70 (s, 1H), 7.68 (s, 1H), 7.66 (s, 1H), 7.59 (d, *J* = 8.5 Hz, 2H), 7.48 (d, *J* = 8.2 Hz, 2H), 2.42 (s, 3H), 2.39 (s,

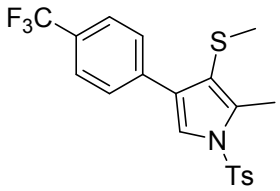
3H), 1.96 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.9, 134.6, 134.3, 132.2, 131.3, 130.6, 129.7, 127.1, 126.8, 120.4, 119.1, 116.4, 21.1, 19.0, 11.6. HRMS (ESI) calcd for $C_{19}H_{19}BrNO_2S_2$ $(M+H)^+$: 436.0035, found: 436.0029.



5-methyl-4-(methylthio)-1-tosyl-3-(4-(trifluoromethyl)phenyl)-2,3-dihydro-1*H*-pyrrol-3-ol (4ea)

White solid, yield: 52%.

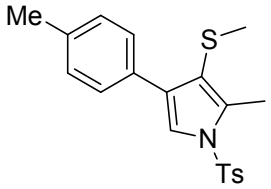
^{1}H NMR (400 MHz, DMSO) δ 7.74 (d, *J* = 8.2 Hz, 2H), 7.53 (d, *J* = 8.3 Hz, 2H), 7.47 (d, *J* = 8.1 Hz, 2H), 7.12 (d, *J* = 8.2 Hz, 2H), 6.18 (s, 1H), 3.90 (d, *J* = 12.0 Hz, 1H), 3.71 (d, *J* = 12.0 Hz, 1H), 2.45 (s, 3H), 2.31 (s, 3H), 1.86 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 149.5, 144.4, 144.3, 133.5, 130.3, 127.5, 127.4 (d, *J* = 31.4 Hz), 126.1, 124.6 (q, *J* = 3.7 Hz), 124.2 (d, *J* = 270.3 Hz), 120.8, 81.9, 64.3, 21.0, 18.2, 14.1. HRMS (ESI) calcd for $C_{20}H_{21}F_3NO_3S_2$ $(M+H)^+$: 444.0909, found: 444.0904.



2-methyl-3-(methylthio)-1-tosyl-4-(4-(trifluoromethyl)phenyl)-1*H*-pyrrole (4e)

White oil, yield: 51%.

^{1}H NMR (400 MHz, DMSO) δ 7.95 (d, *J* = 8.1 Hz, 2H), 7.91 (d, *J* = 8.4 Hz, 2H), 7.81 (s, 1H), 7.76 (d, *J* = 8.3 Hz, 2H), 7.48 (d, *J* = 8.2 Hz, 2H), 2.44 (s, 3H), 2.39 (s, 3H), 1.98 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 146.0, 137.2, 134.6, 134.5, 130.6, 128.2, 127.5 (d, *J* = 31.5 Hz), 127.2, 126.6, 125.2 (q, *J* = 3.8 Hz), 124.3 (d, *J* = 270.2 Hz), 120.0, 116.3, 21.1, 19.1, 11.6. HRMS (ESI) calcd for $C_{20}H_{19}F_3NO_2S_2$ $(M+H)^+$: 426.0804, found: 426.0805.

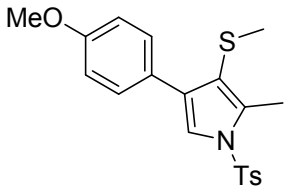


2-methyl-3-(methylthio)-4-(p-tolyl)-1-tosyl-1*H*-pyrrole (4f)

White solid, yield: 48%.

^{1}H NMR (400 MHz, DMSO) δ 7.88 (d, *J* = 8.3 Hz, 2H), 7.59 (s, 1H), 7.57 (s, 2H), 7.47 (d, *J* = 8.2 Hz, 2H), 7.21 (d, *J* = 8.0 Hz, 2H), 2.42 (s, 3H), 2.38 (s, 3H), 2.32 (s, 3H), 1.94 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.8, 136.4, 134.8, 134.0, 130.6, 130.1, 129.0, 128.1, 127.5, 127.1, 118.4, 116.7, 21.1, 20.8, 19.0, 11.7. HRMS (ESI)

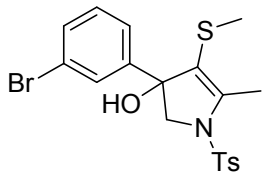
calcd for $C_{20}H_{22}NO_2S_2$ $(M+H)^+$: 372.1086, found: 372.1089.



4-(4-methoxyphenyl)-2-methyl-3-(methylthio)-1-tosyl-1*H*-pyrrole (4g)

White solid, yield: 58%.

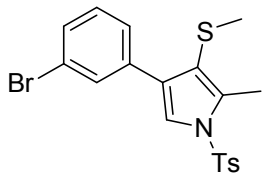
^{1}H NMR (400 MHz, DMSO) δ 7.86 (d, *J* = 8.3 Hz, 2H), 7.60 (d, *J* = 8.6 Hz, 2H), 7.53 (s, 1H), 7.46 (d, *J* = 8.2 Hz, 2H), 6.96 (d, *J* = 8.7 Hz, 2H), 3.77 (s, 3H), 2.41 (s, 3H), 2.38 (s, 3H), 1.94 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 158.7, 145.9, 134.9, 134.0, 130.7, 129.0, 128.1, 127.1, 125.4, 118.1, 116.8, 114.0, 55.2, 21.2, 19.0, 11.8. HRMS (ESI) calcd for $C_{20}H_{21}NO_3S_2$ $(M+H)^+$: 388.1036, found: 388.1034.



3-(3-bromophenyl)-5-methyl-4-(methylthio)-1-tosyl-2,3-dihydro-1*H*-pyrrol-3-ol (4ha)

White solid, yield: 59%.

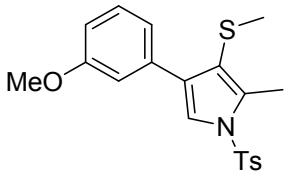
^{1}H NMR (400 MHz, DMSO) δ 7.73 (d, *J* = 8.2 Hz, 2H), 7.47 (d, *J* = 8.1 Hz, 2H), 7.37 (d, *J* = 8.0 Hz, 1H), 7.12 (t, *J* = 7.9 Hz, 1H), 7.01 (s, 1H), 6.82 (d, *J* = 7.8 Hz, 1H), 6.13 (s, 1H), 3.87 (d, *J* = 12.1 Hz, 1H), 3.63 (d, *J* = 12.1 Hz, 1H), 2.44 (s, 3H), 2.31 (s, 3H), 1.85 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 147.7, 144.7, 144.4, 133.2, 130.4, 130.0, 129.8, 128.3, 127.5, 124.5, 121.3, 121.2, 81.8, 64.5, 21.3, 18.4, 14.2. HRMS (ESI) calcd for $C_{19}H_{21}BrNO_3S_2$ $(M+H)^+$: 454.0141, found: 454.0140.



4-(3-bromophenyl)-2-methyl-3-(methylthio)-1-tosyl-1*H*-pyrrole (4h)

White solid, yield: 56%.

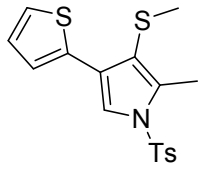
^{1}H NMR (400 MHz, DMSO) δ 7.93 – 7.90 (m, 2H), 7.89 (s, 1H), 7.77 – 7.72 (m, 2H), 7.50 (dd, *J* = 8.0, 1.0 Hz, 1H), 7.47 (d, *J* = 8.2 Hz, 2H), 7.36 (t, *J* = 7.9 Hz, 1H), 2.42 (s, 3H), 2.38 (s, 3H), 1.97 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.9, 135.4, 134.6, 134.4, 130.6, 130.5, 130.0, 129.8, 127.1, 126.6, 126.4, 121.7, 119.6, 116.3, 21.1, 19.1, 11.6. HRMS (ESI) calcd for $C_{19}H_{19}BrNO_2S_2$ $(M+H)^+$: 436.0035, found: 436.0039.



4-(3-methoxyphenyl)-2-methyl-3-(methylthio)-1-tosyl-1*H*-pyrrole (4i)

White solid, yield: 68%.

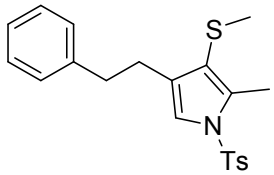
^{1}H NMR (400 MHz, DMSO) δ 7.88 (d, *J* = 8.3 Hz, 2H), 7.66 (s, 1H), 7.47 (d, *J* = 8.2 Hz, 2H), 7.34 – 7.25 (m, 3H), 6.88 (d, *J* = 7.6 Hz, 1H), 3.78 (s, 3H), 2.43 (s, 3H), 2.38 (s, 3H), 1.96 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 159.3, 145.8, 134.8, 134.3, 134.1, 130.6, 129.4, 127.9, 127.1, 119.9, 119.0, 116.6, 113.0, 112.8, 55.0, 21.1, 19.0, 11.6. HRMS (ESI) calcd for $C_{20}H_{22}NO_3S_2$ $(M+H)^+$: 388.1036, found: 388.1035.



2-methyl-3-(methylthio)-4-(thiophen-2-yl)-1-tosyl-1*H*-pyrrole (4k)

Green solid, yield: 48%.

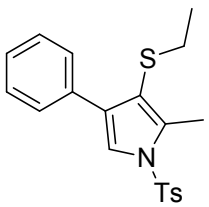
^{1}H NMR (400 MHz, DMSO) δ 7.88 (d, *J* = 8.3 Hz, 2H), 7.75 (s, 1H), 7.53 (d, *J* = 3.4 Hz, 1H), 7.49 (t, *J* = 7.2 Hz, 3H), 7.09 (dd, *J* = 5.0, 3.7 Hz, 1H), 2.42 (s, 3H), 2.39 (s, 3H), 2.06 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.9, 134.9, 134.6, 134.0, 130.6, 127.2, 127.1, 125.5, 124.8, 122.6, 117.8, 116.1, 21.1, 19.3, 11.6. HRMS (ESI) calcd for $C_{17}H_{18}NO_2S_3$ $(M+H)^+$: 364.0494, found: 364.0496.



2-methyl-3-(methylthio)-4-phenethyl-1-tosyl-1*H*-pyrrole (4l)

White oil, yield: 31%.

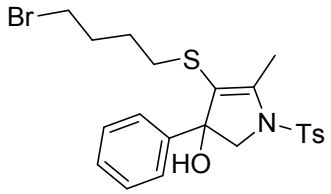
^{1}H NMR (400 MHz, DMSO) δ 7.67 (d, *J* = 8.3 Hz, 2H), 7.45 (d, *J* = 8.0 Hz, 2H), 7.27 (t, *J* = 7.3 Hz, 2H), 7.22-7.15 (m, 3H), 7.12 (s, 1H), 2.86 (t, *J* = 7.7 Hz, 2H), 2.72 (t, *J* = 7.7 Hz, 2H), 2.39 (s, 3H), 2.32 (s, 3H), 2.05 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.4, 141.5, 135.1, 133.3, 130.5, 128.4, 128.3, 128.2, 126.6, 125.8, 118.6, 118.2, 34.9, 26.8, 21.1, 19.1, 11.6. HRMS (ESI) calcd for $C_{21}H_{24}NO_2S_2$ $(M+H)^+$: 386.1243, found: 386.1248.



3-(ethylthio)-2-methyl-4-phenyl-1-tosyl-1*H*-pyrrole (4m)

White solid, yield: 86%.

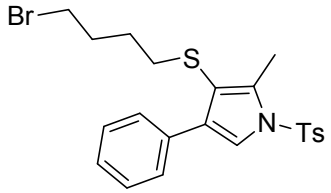
^{1}H NMR (400 MHz, DMSO) δ 7.87 (d, *J* = 8.4 Hz, 2H), 7.72 – 7.66 (m, 2H), 7.63 (s, 1H), 7.47 (d, *J* = 8.2 Hz, 2H), 7.39 (t, *J* = 7.5 Hz, 2H), 7.30 (t, *J* = 7.3 Hz, 1H), 2.42 (s, 3H), 2.38 (s, 3H), 2.30 (q, *J* = 7.3 Hz, 2H), 0.83 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, DMSO) δ 145.8, 135.1, 134.7, 133.1, 130.5, 128.7, 128.3, 127.8, 127.2, 127.0, 119.0, 114.7, 29.1, 21.1, 14.1, 11.9. HRMS (ESI) calcd for $C_{20}H_{22}NO_2S_2$ $(M+H)^+$: 372.1086, found: 372.1087.



4-((4-bromobutyl)thio)-5-methyl-3-phenyl-1-tosyl-2,3-dihydro-1*H*-pyrrol-3-ol (4na)

White solid, yield: 44%.

^{1}H NMR (400 MHz, DMSO) δ 7.76 (d, *J* = 8.2 Hz, 2H), 7.49 (d, *J* = 8.1 Hz, 2H), 7.16 (d, *J* = 6.9 Hz, 3H), 6.92 – 6.87 (m, 2H), 5.88 (s, 1H), 3.88 (d, *J* = 12.0 Hz, 1H), 3.75 (d, *J* = 12.0 Hz, 1H), 2.46 (s, 3H), 2.30 (s, 3H), 2.02 – 1.94 (m, 1H), 1.67-1.54 (m, 2H), 1.37 – 1.22 (m, 5H). ^{13}C NMR (100 MHz, DMSO) δ 145.0, 144.8, 144.4, 133.4, 130.2, 127.6, 127.5, 126.8, 125.3, 119.8, 81.6, 64.6, 34.4, 33.2, 31.0, 27.4, 21.1, 14.4. HRMS (ESI) calcd for $C_{22}H_{27}BrNO_3S_2$$(M+H)^+$: 496.0610, found: 496.0606.

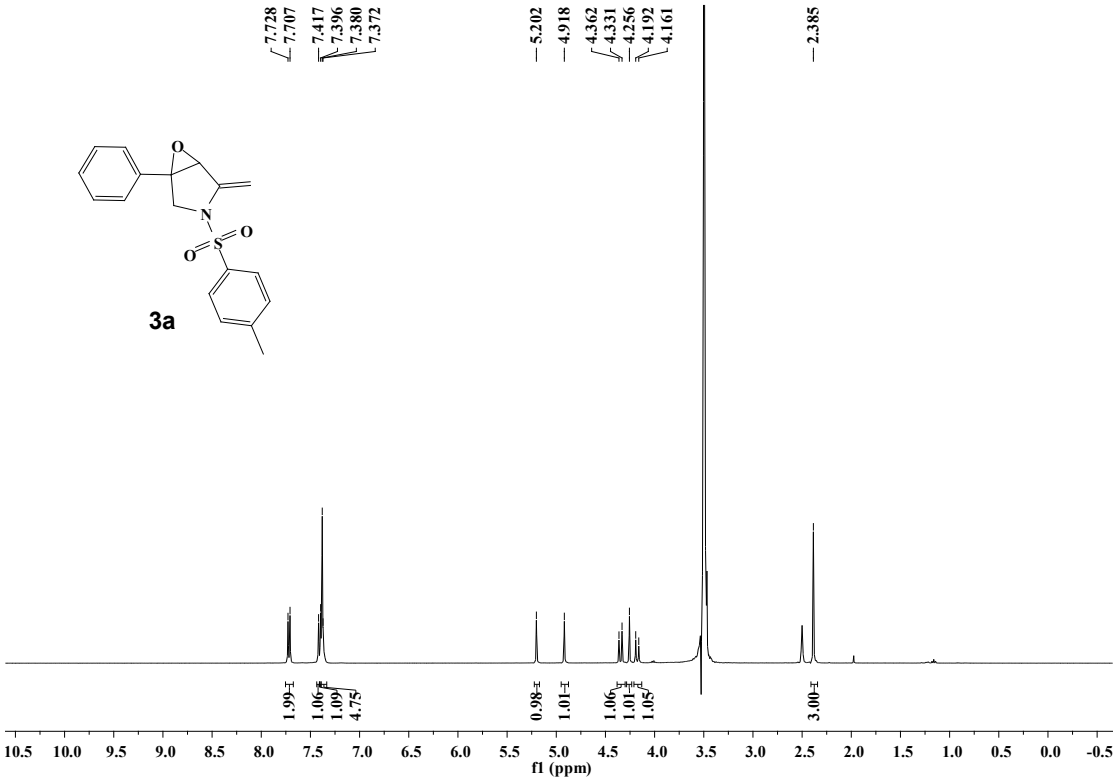


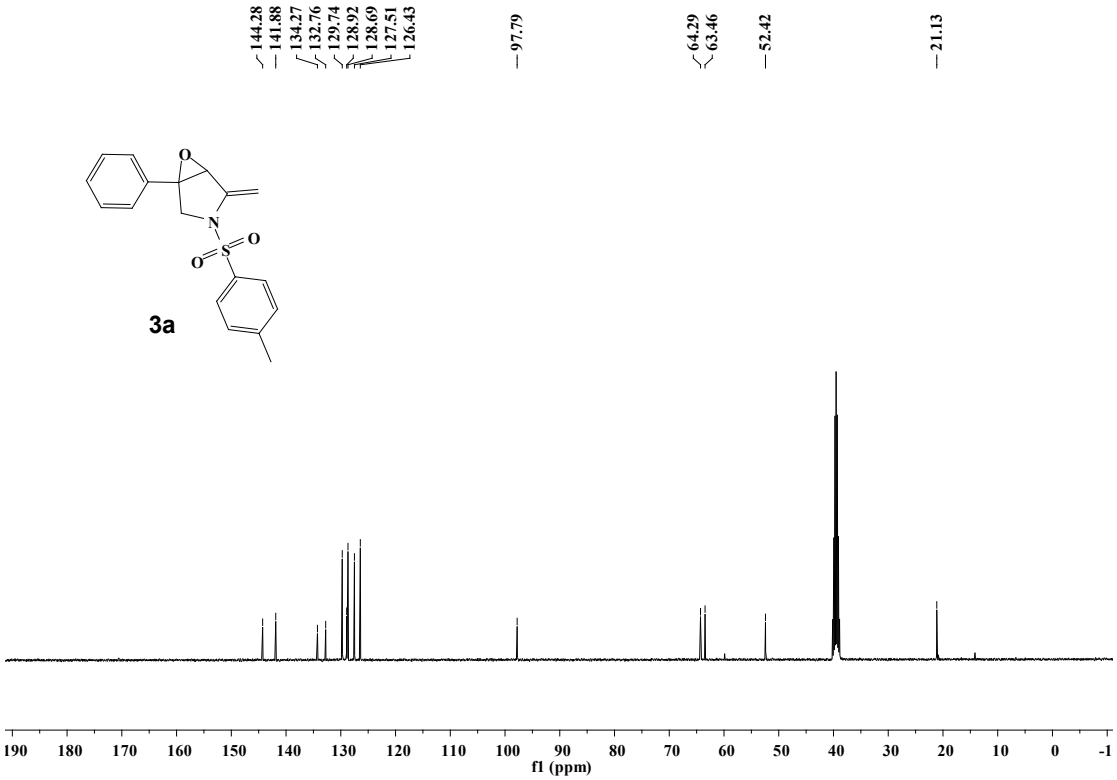
3-((4-bromobutyl)thio)-2-methyl-4-phenyl-1-tosyl-1*H*-pyrrole (4n)

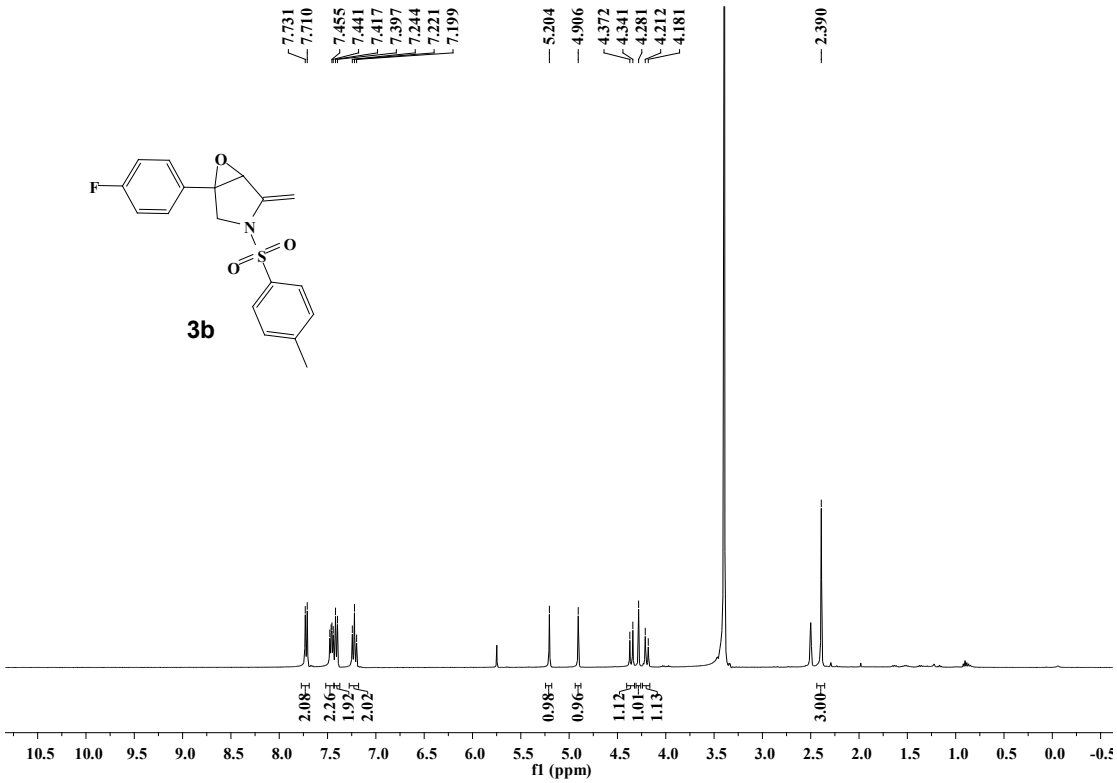
Yellow oil, yield: 43%.

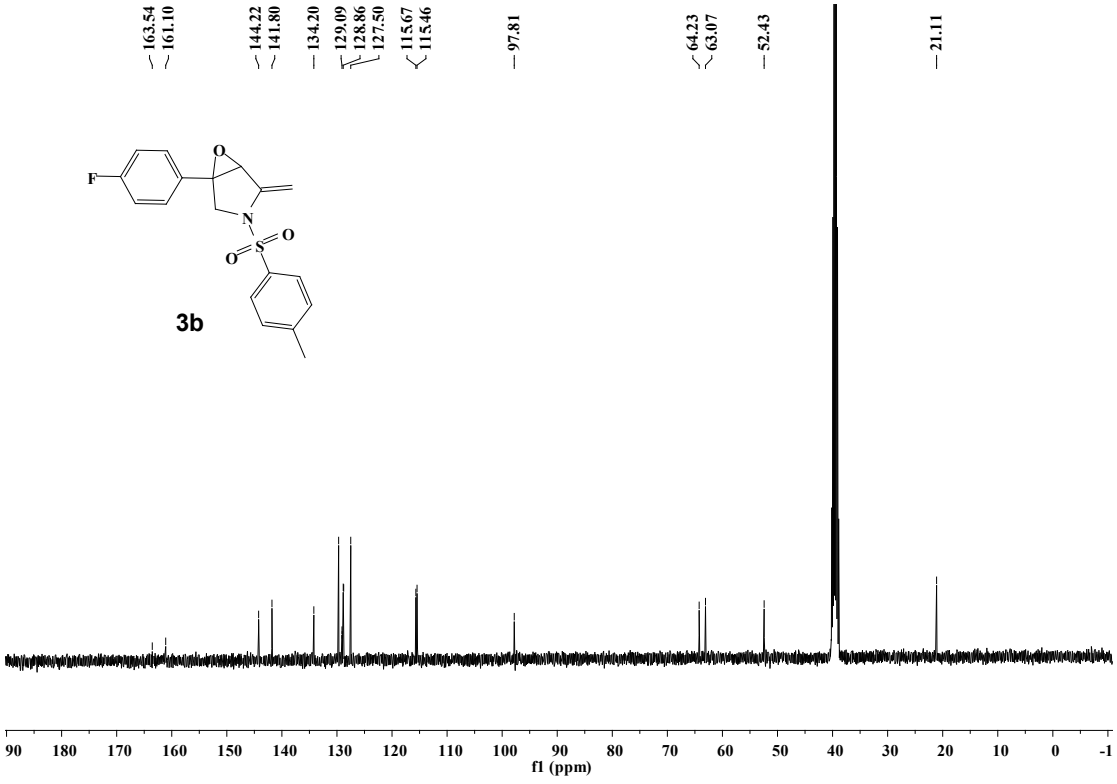
^{1}H NMR (400 MHz, DMSO) δ 7.87 (d, *J* = 8.4 Hz, 2H), 7.68 (d, *J* = 7.1 Hz, 2H), 7.63 (s, 1H), 7.47 (d, *J* = 8.1 Hz, 2H), 7.40 (t, *J* = 7.5 Hz, 2H), 7.31 (t, *J* = 7.3 Hz, 1H), 3.23 (t, *J* = 6.6 Hz, 2H), 2.42 (s, 3H), 2.38 (s, 3H), 2.31 (t, *J* = 7.0 Hz, 2H), 1.65 – 1.56 (m, 2H), 1.28-1.18 (m, 2H). ^{13}C NMR (100 MHz, DMSO) δ 145.7, 134.9, 134.7, 133.0, 130.5, 128.7, 128.3, 127.9, 127.2, 127.0, 119.0, 114.6, 34.2, 34.0, 30.6, 26.8, 21.1, 11.9. HRMS (ESI) calcd for $C_{22}H_{25}BrNO_2S_2$ $(M+H)^+$: 478.0505, found: 478.0506.

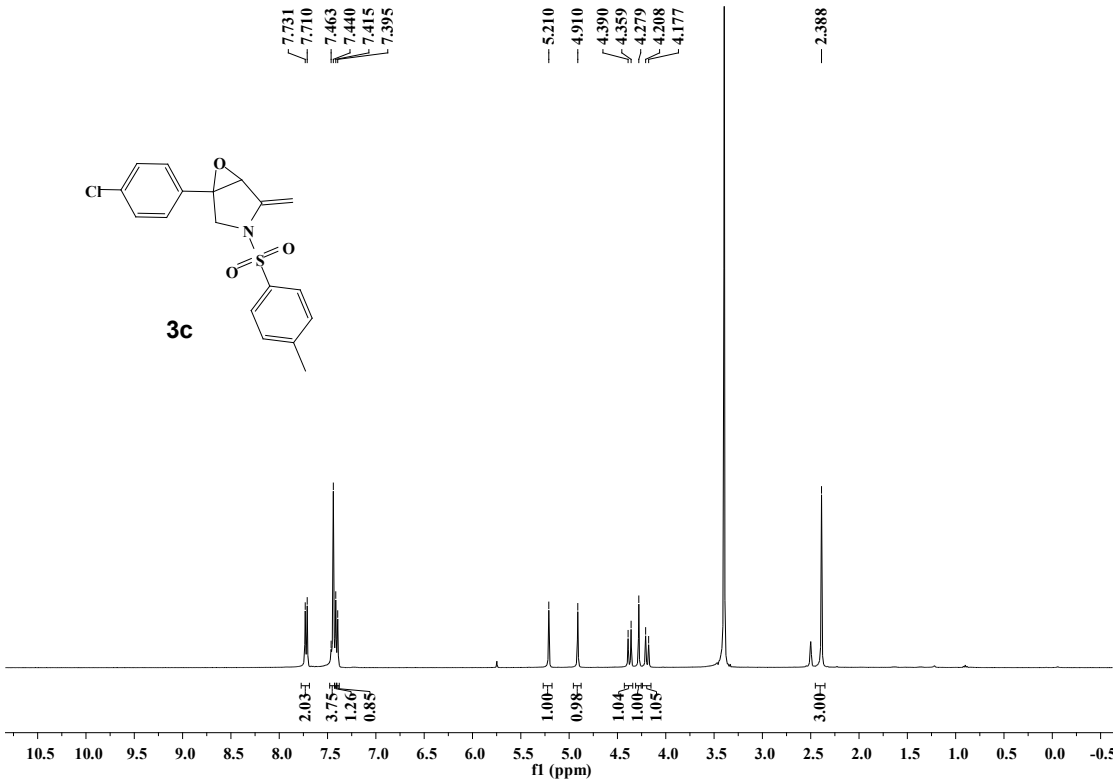
7. ^{1}H and ^{13}C NMR Spectra

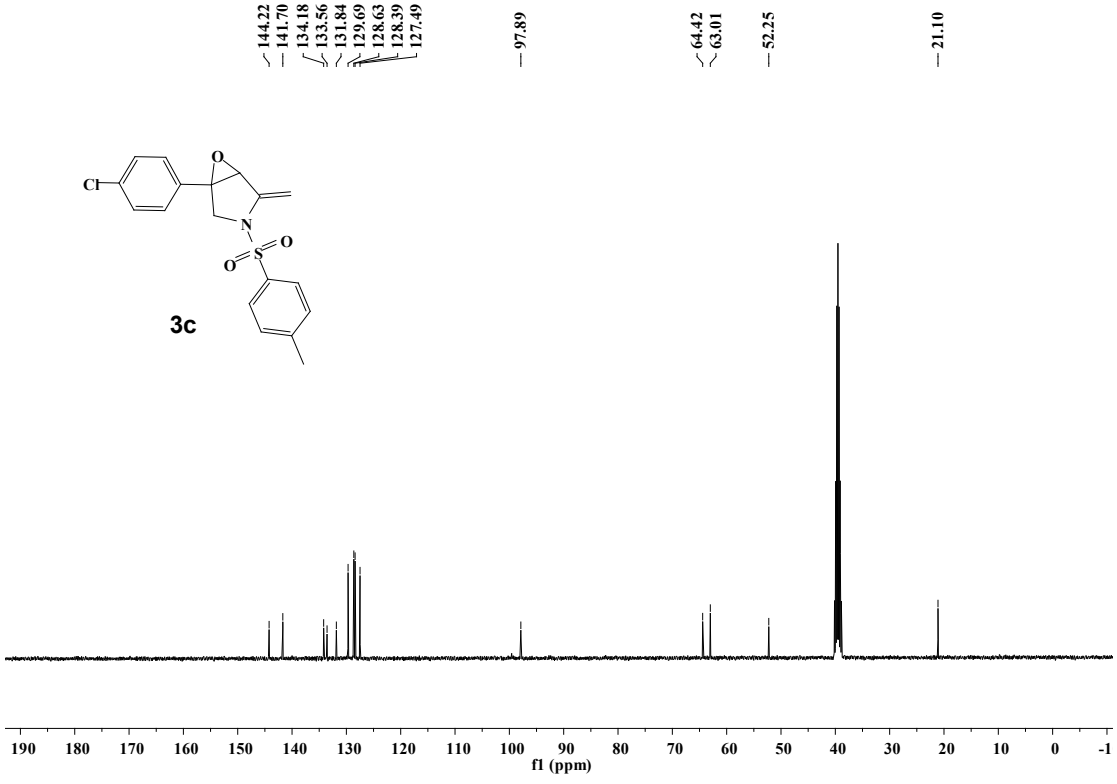


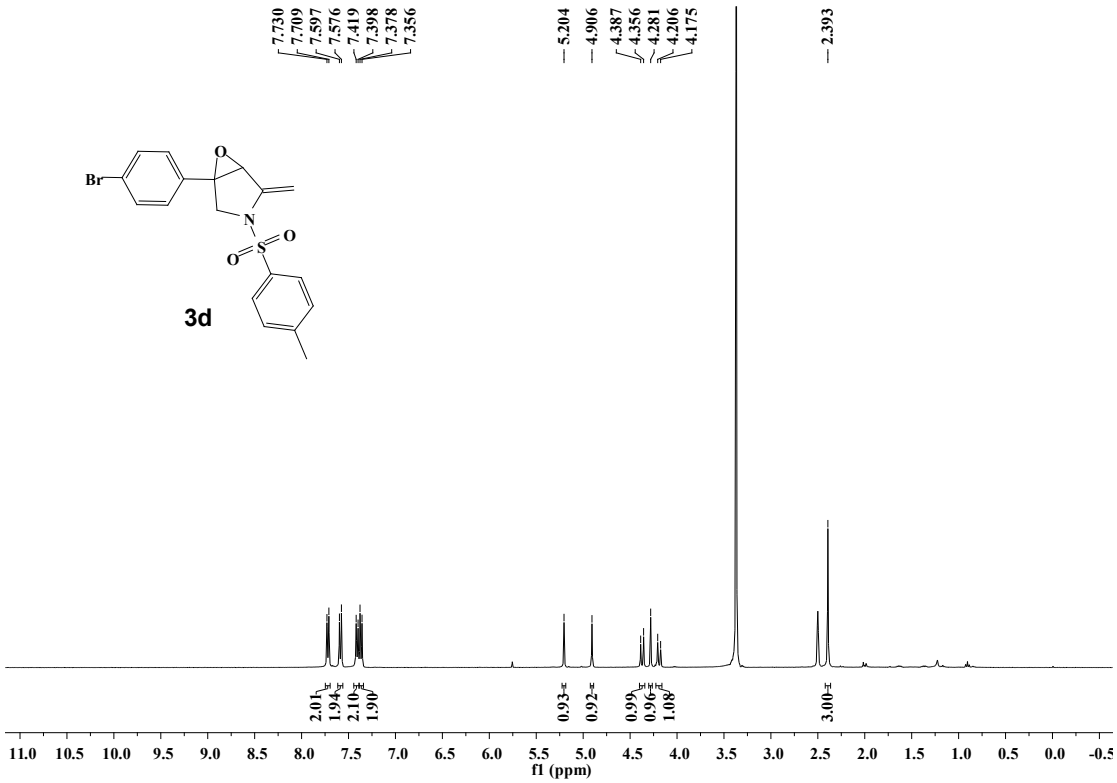


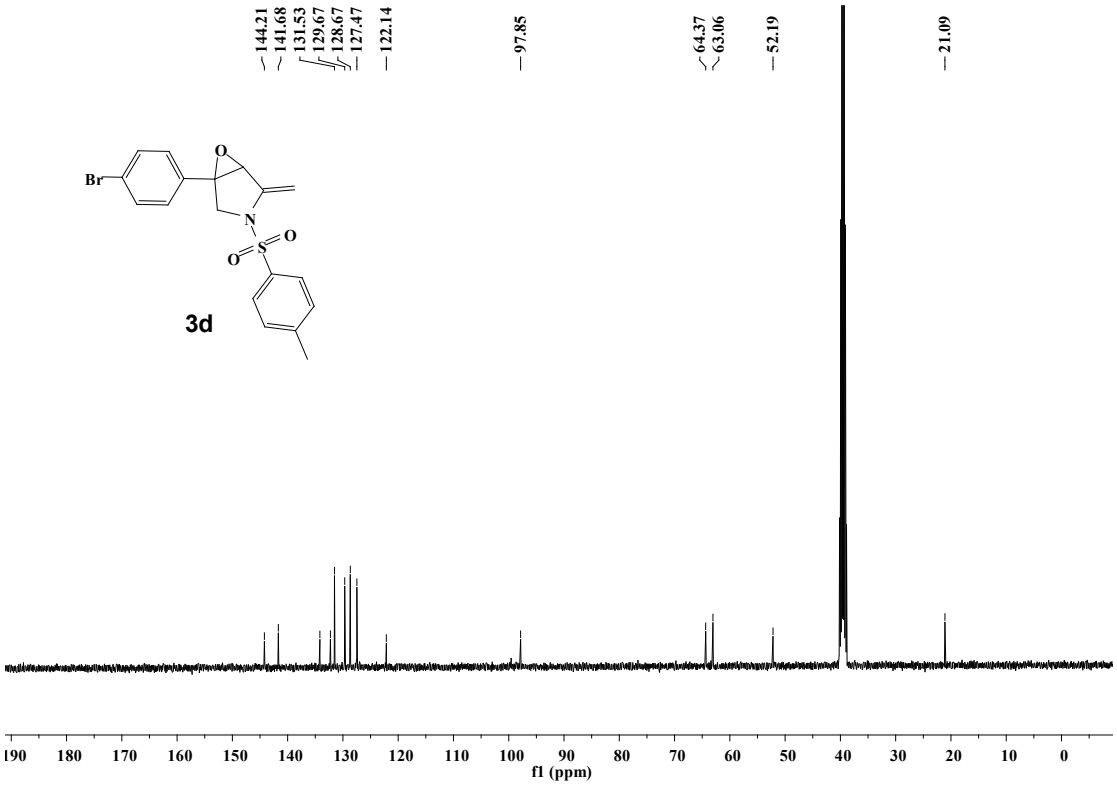

7.731
7.710
7.455
7.441
7.417
7.397
7.244
7.221
7.199
5.204
4.906
4.372
4.341
4.281
4.212
4.181
2.390
F
O
N
S
O
O
3b
2.08
2.26
1.92
2.02
0.98
0.96
1.12
1.01
1.13
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

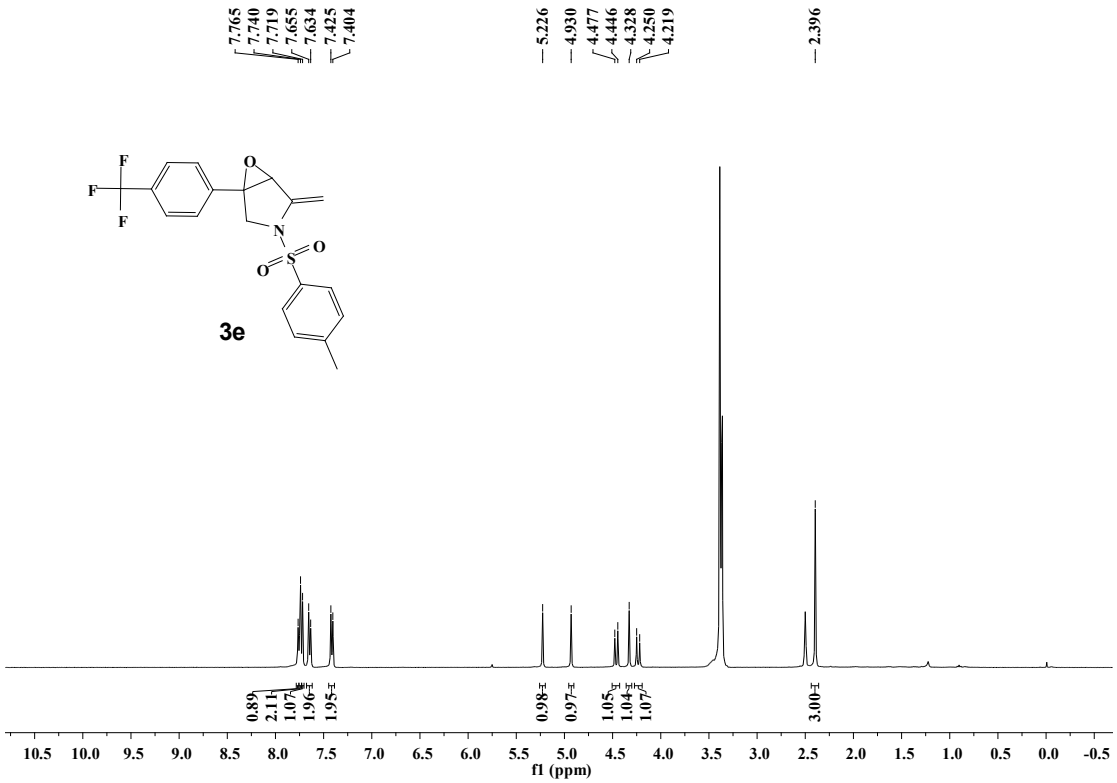

163.54
161.10
144.22
141.80
134.20
129.09
128.86
127.50
115.67
115.46
97.81
64.23
63.07
52.43
21.11
F
O
N
S
O
O
3b
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

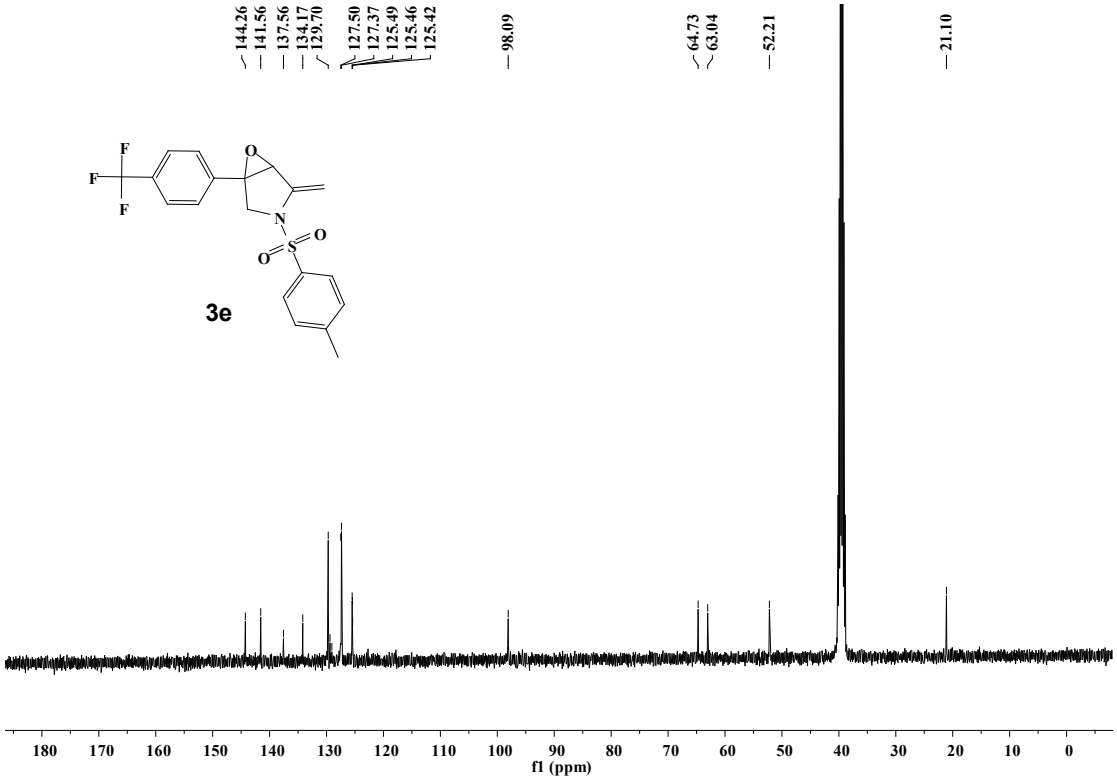

7.731
7.710
7.463
7.440
7.415
7.395
5.210
4.910
4.390
4.359
4.279
4.208
4.177
2.388
Cl
O
N
S
O
O
3c
2.03
3.75
1.26
0.85
1.00
0.98
1.04
1.00
1.05
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

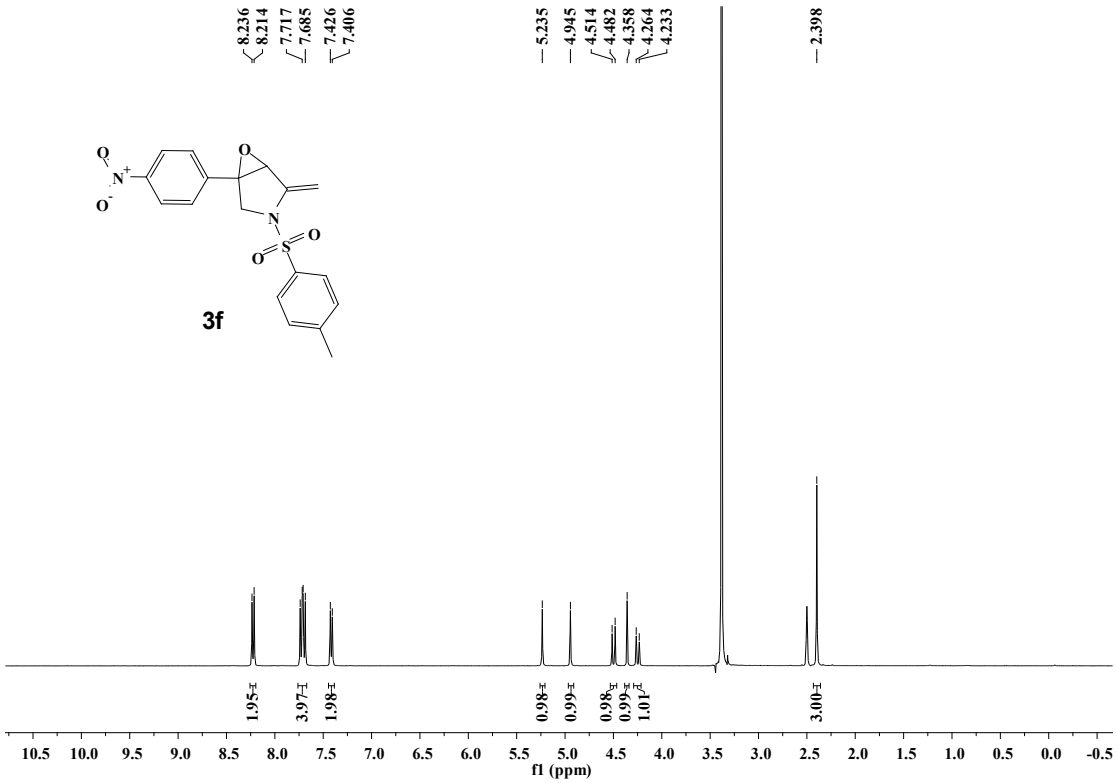

144.22
141.70
134.18
133.56
131.84
129.69
128.63
128.39
127.49
97.89
64.42
63.01
52.25
21.10
Cl
O
N
S
O
O
3c
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

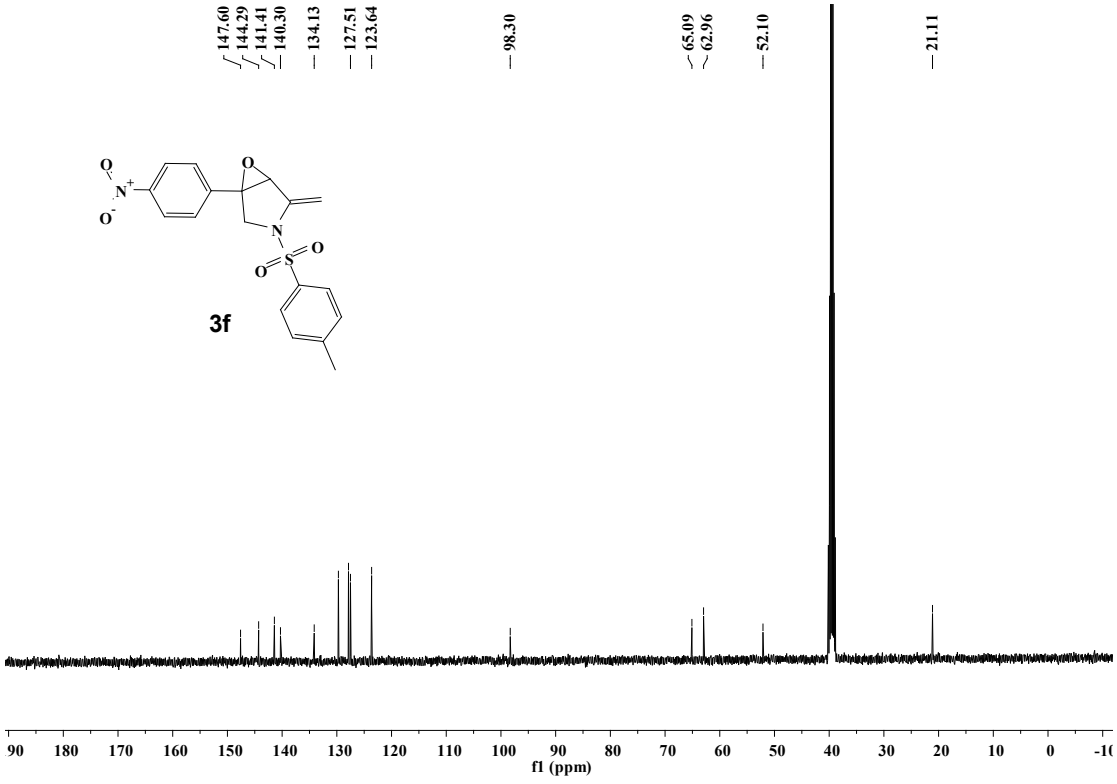

7.730
7.709
7.597
7.576
7.419
7.398
7.378
7.356
5.204
4.906
4.387
4.356
4.281
4.206
4.175
2.393
Br
O
N
S
O
O
3d
2.01
1.94
2.10
1.90
0.93
0.92
0.99
0.96
1.08
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

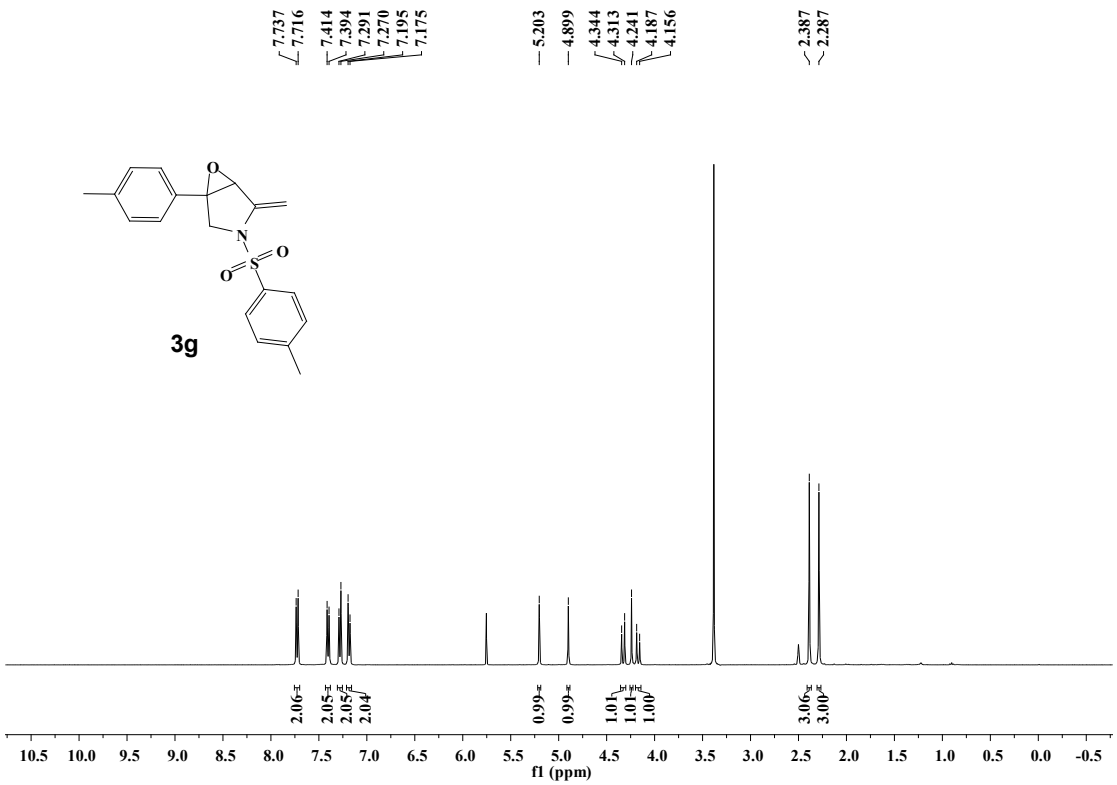

144.21
141.68
131.53
129.67
128.67
127.47
122.14
97.85
64.37
63.06
52.19
21.09
Br
O
N
S
O
O
3d
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

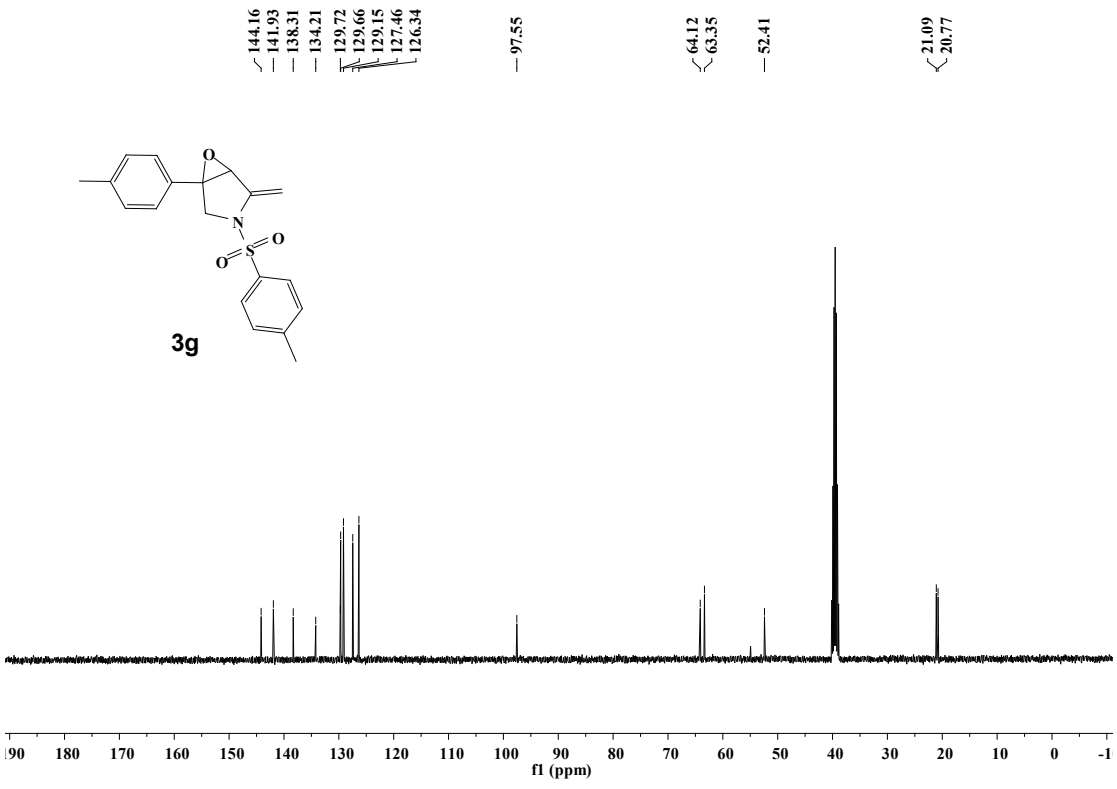

7.765
7.740
7.719
7.655
7.634
7.425
7.404
5.226
4.930
4.477
4.446
4.328
4.250
4.219
2.396
F
F
F
O
N
S
O
O
3e
0.89
2.11
1.07
1.96
1.95
0.98
0.97
1.05
1.04
1.07
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

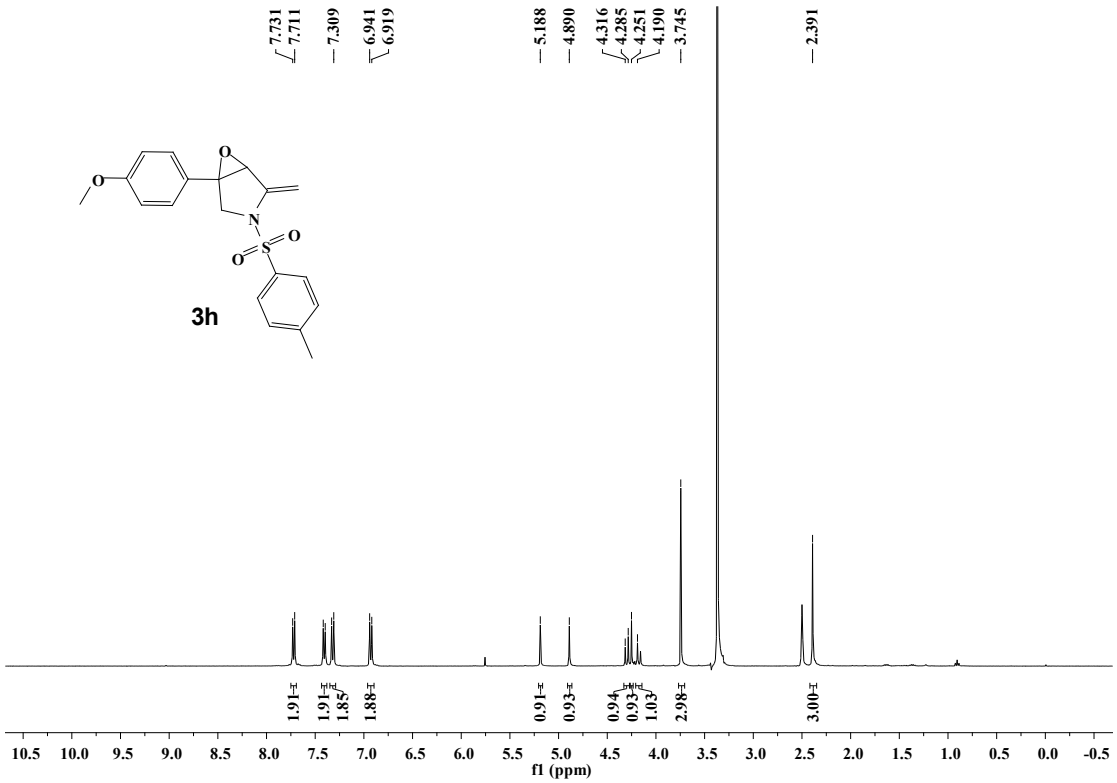

144.26
141.56
137.56
134.17
129.70
127.50
127.37
125.49
125.46
125.42
98.09
64.73
63.04
52.21
21.10
F
F
F
O
N
S
O
O
3e
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

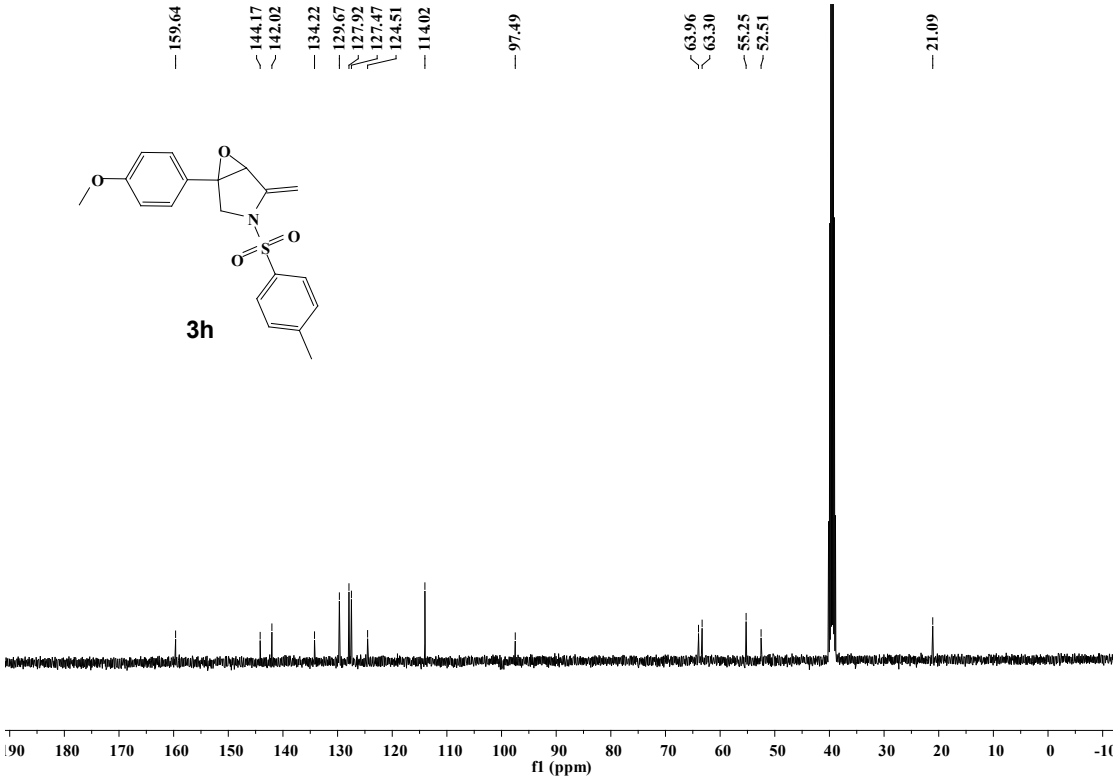

8.236
8.214
7.717
7.685
7.426
7.406
5.235
4.945
4.514
4.482
4.358
4.264
4.233
2.398
3f
1.95
3.97
1.98
0.98
0.99
0.98
0.99
1.01
3.00
f1 (ppm)

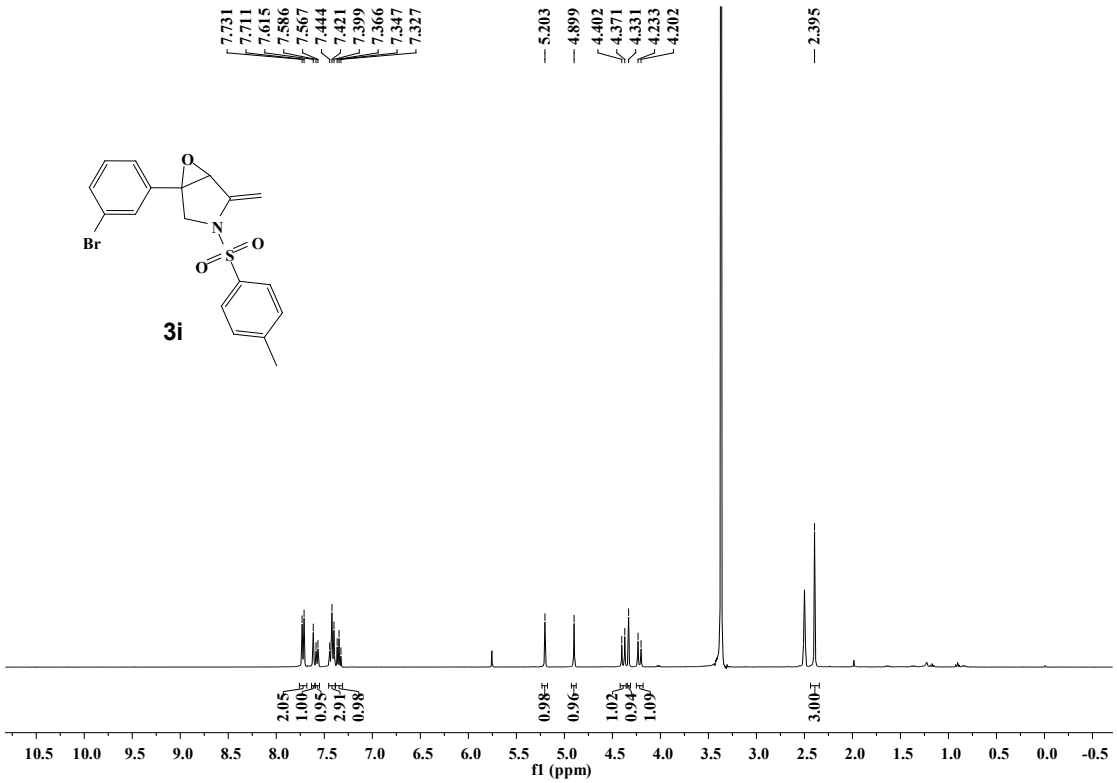

147.60
144.29
141.41
140.30
134.13
127.51
123.64
98.30
65.09
62.96
52.10
21.11
3f
f1 (ppm)

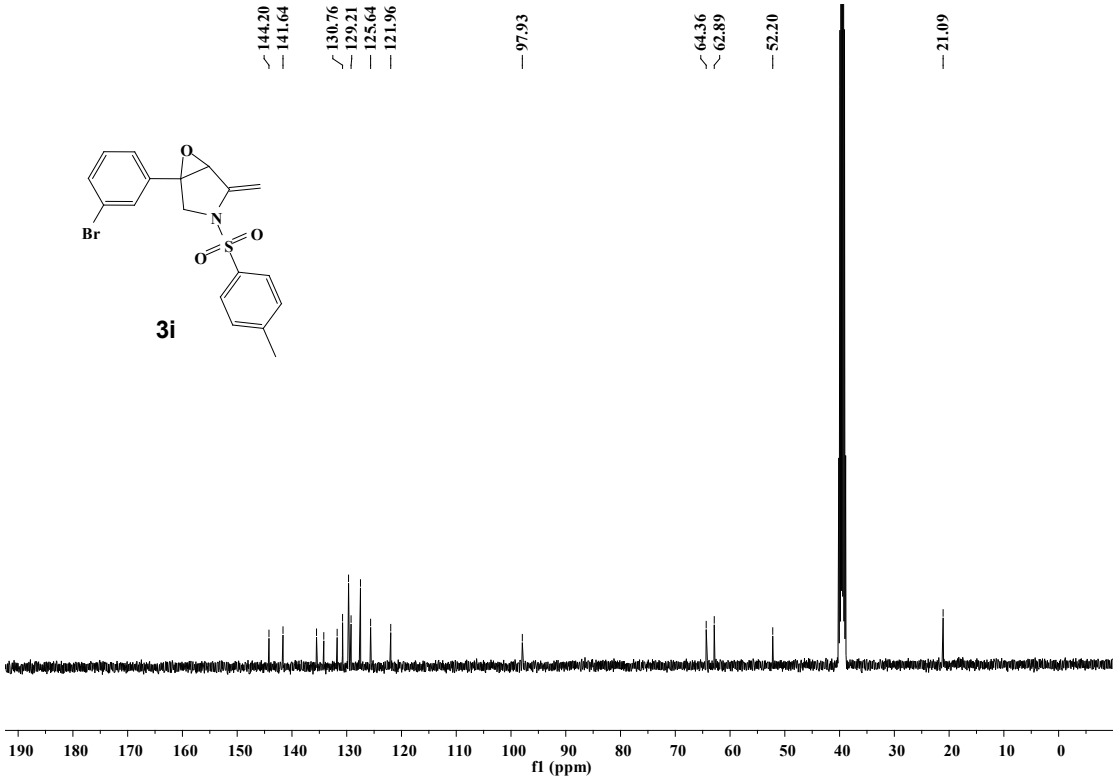

7.737
7.716
7.414
7.394
7.291
7.270
7.195
7.175
5.203
4.899
4.344
4.313
4.241
4.187
4.156
2.387
2.287
3g
2.06
2.05
2.05
2.04
0.99
0.99
1.01
1.01
1.00
3.06
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

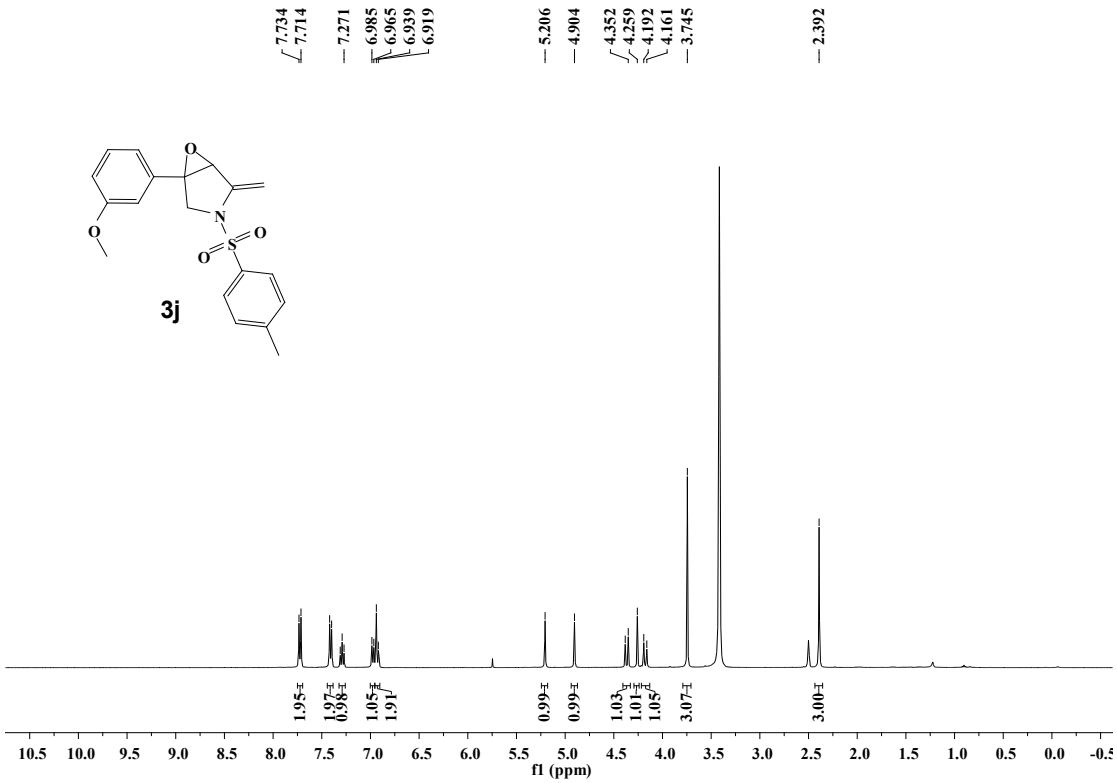

144.16
141.93
138.31
134.21
129.72
129.66
129.15
127.46
126.34
97.55
64.12
63.35
52.41
21.09
20.77
3g
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

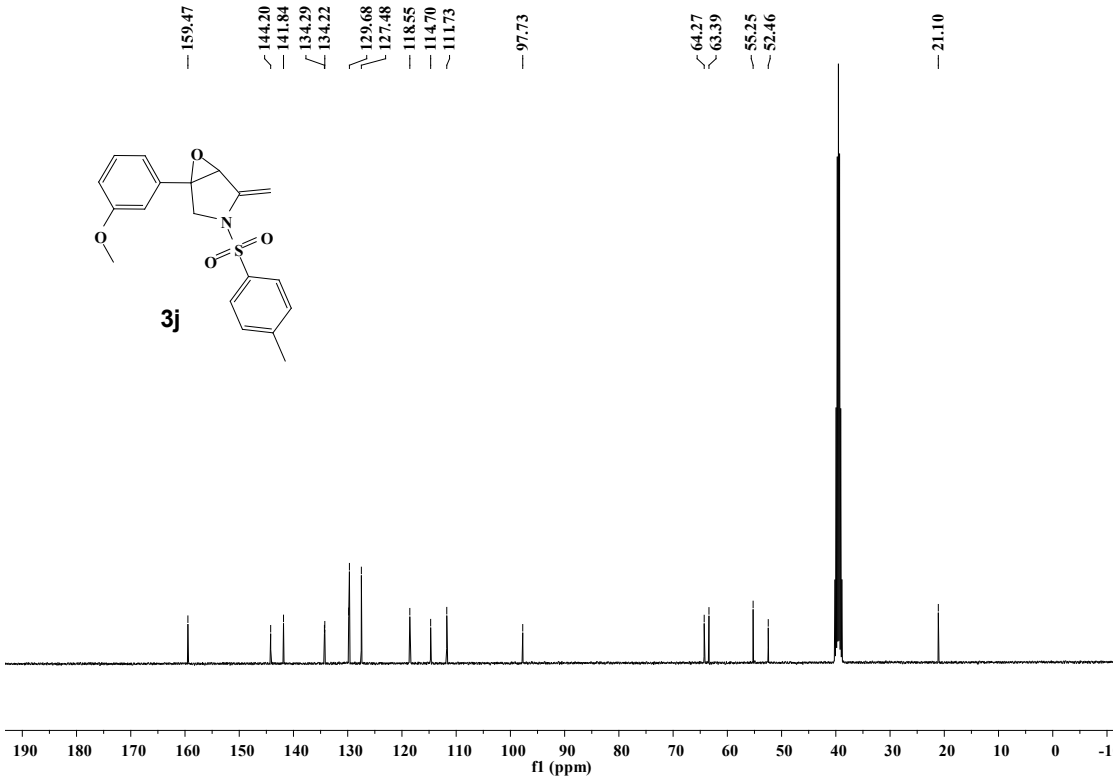

7.731
7.711
7.309
6.941
6.919
5.188
4.890
4.316
4.285
4.251
4.190
3.745
2.391
O
O
N
S
O
O
3h
1.91
1.91
1.85
1.88
0.91
0.93
0.94
0.93
1.03
2.98
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

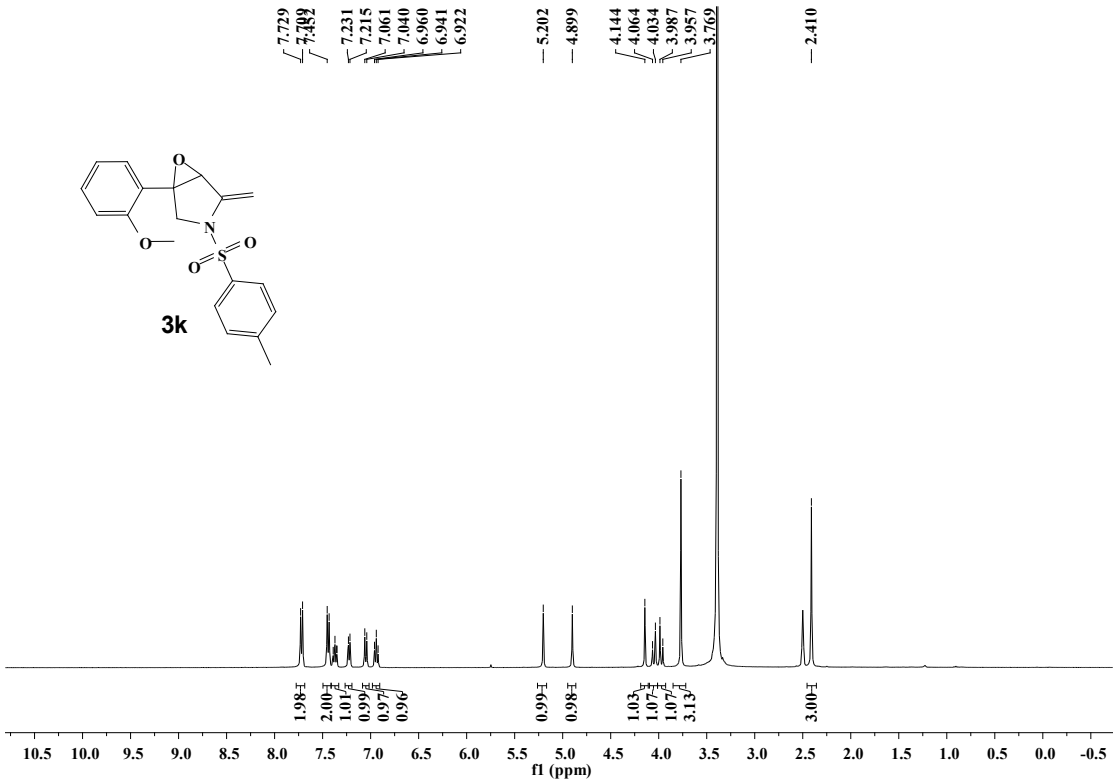

159.64
144.17
142.02
134.22
129.67
127.92
127.47
124.51
114.02
97.49
63.96
63.30
55.25
52.51
21.09
O
O
N
S
O
O
3h
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

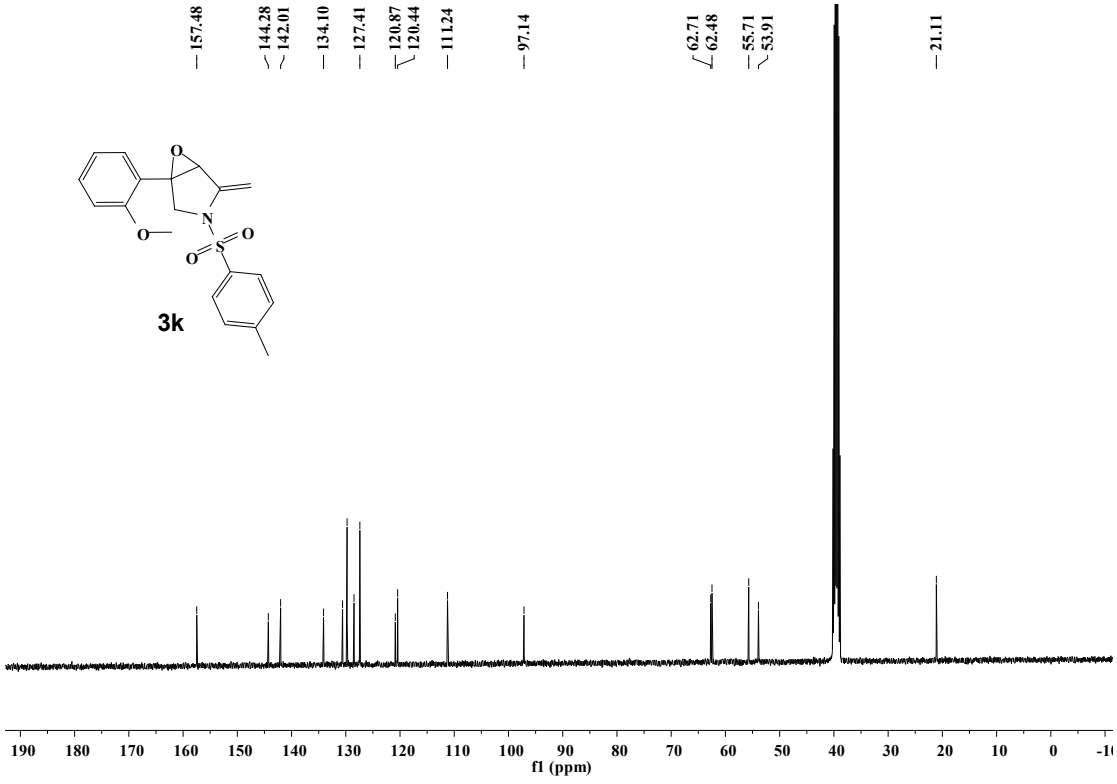

7.731
7.711
7.615
7.586
7.567
7.444
7.421
7.399
7.366
7.347
7.327
5.203
4.899
4.402
4.371
4.331
4.233
4.202
2.395
Br
O
N
S
O
O
3i
2.05
1.00
0.95
2.91
0.98
0.98
0.96
1.02
0.94
1.09
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

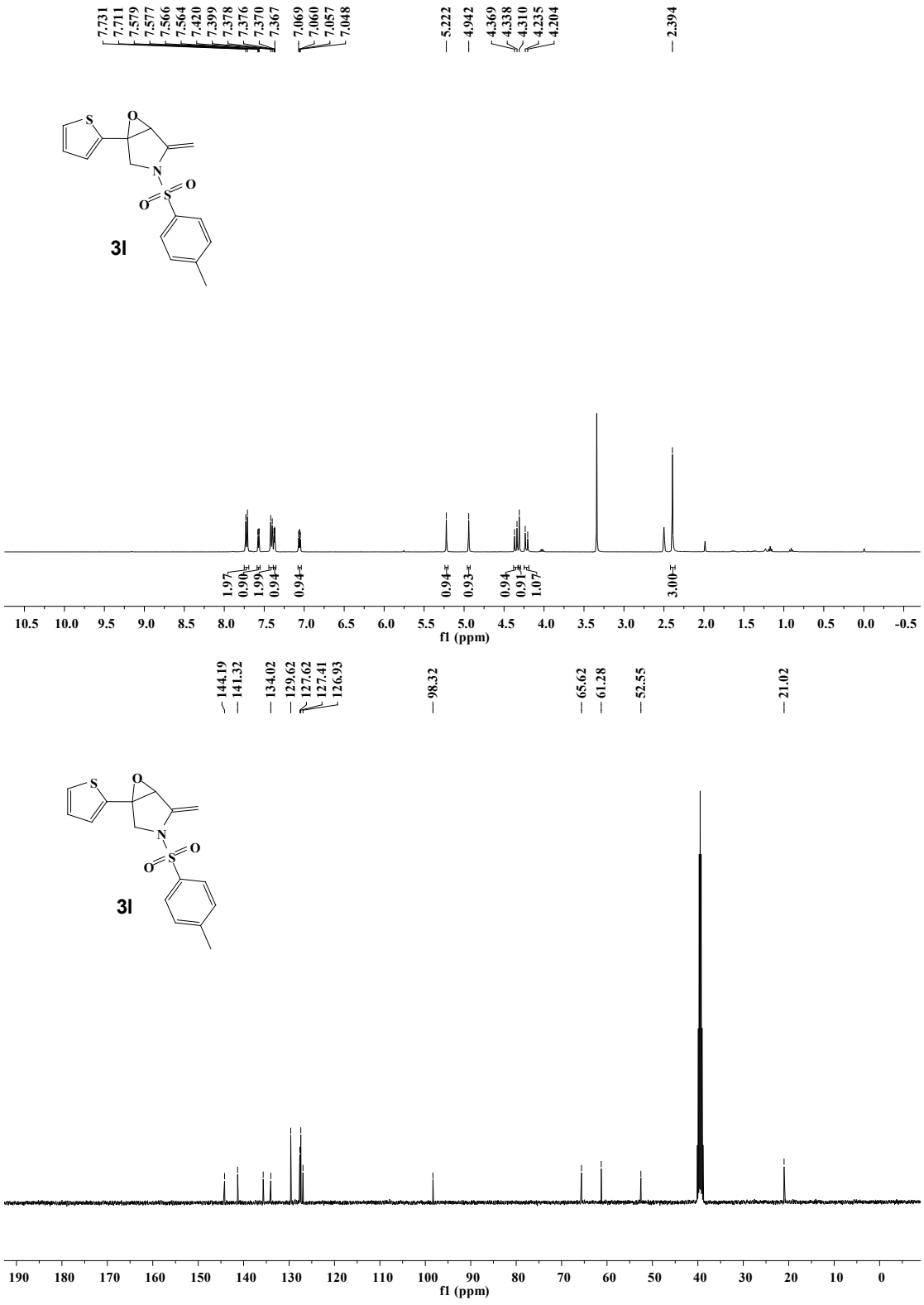

144.20
141.64
130.76
129.21
125.64
121.96
97.93
64.36
62.89
52.20
21.09
Br
O
N
S
O
O
3i
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

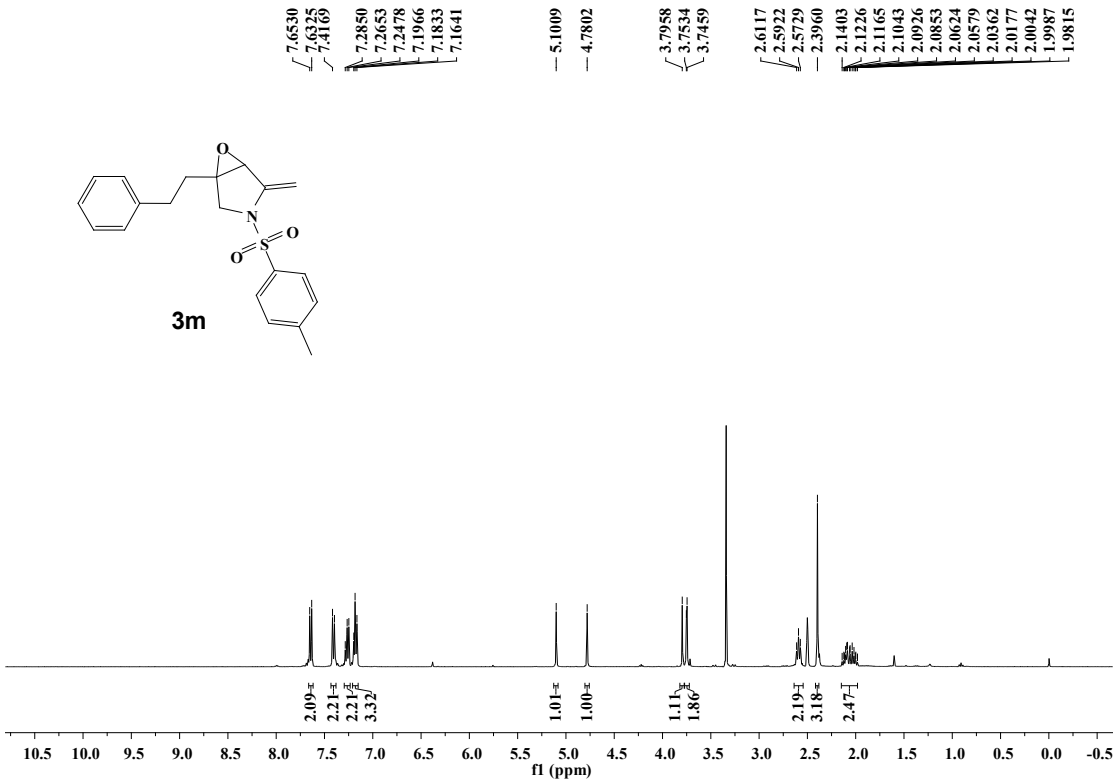

7.734
7.714
7.271
6.985
6.965
6.939
6.919
5.206
4.904
4.352
4.259
4.192
4.161
3.745
2.392
3j
1.95
1.97
0.98
1.05
1.91
0.99
0.99
1.03
1.01
1.05
3.07
3.00
f1 (ppm)

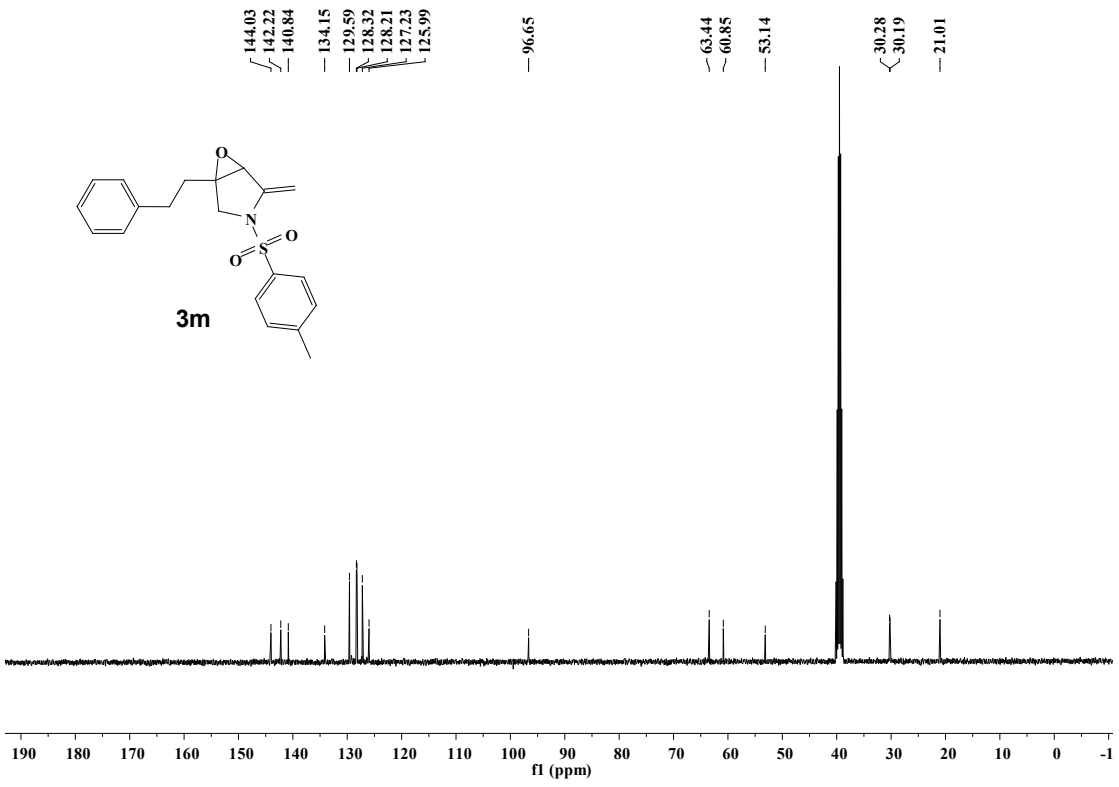

159.47
144.20
141.84
134.29
134.22
129.68
127.48
118.55
114.70
111.73
97.73
64.27
63.39
55.25
52.46
21.10
3j
f1 (ppm)

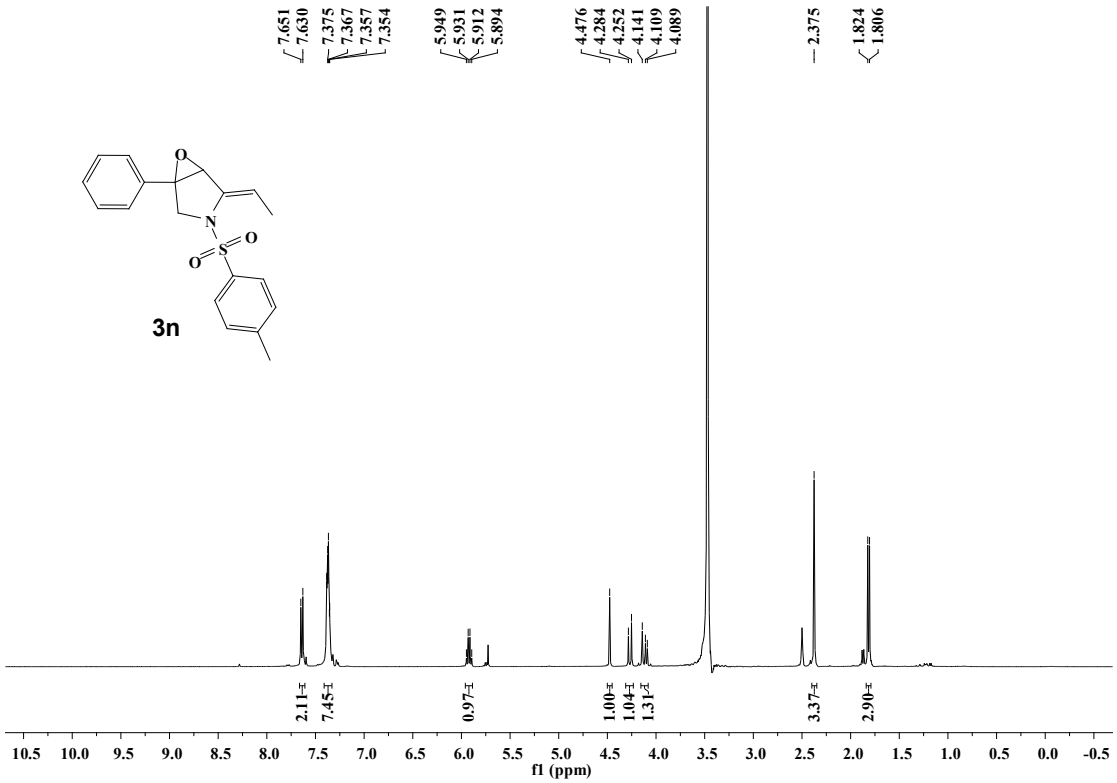

7.729
7.709
7.452
7.231
7.215
7.061
7.040
6.960
6.941
6.922
5.202
4.899
4.144
4.064
4.034
3.987
3.957
3.769
2.410
3k
1.98
2.00
1.01
0.99
0.97
0.96
0.99
0.98
1.03
1.07
1.07
3.13
3.00
fl (ppm)

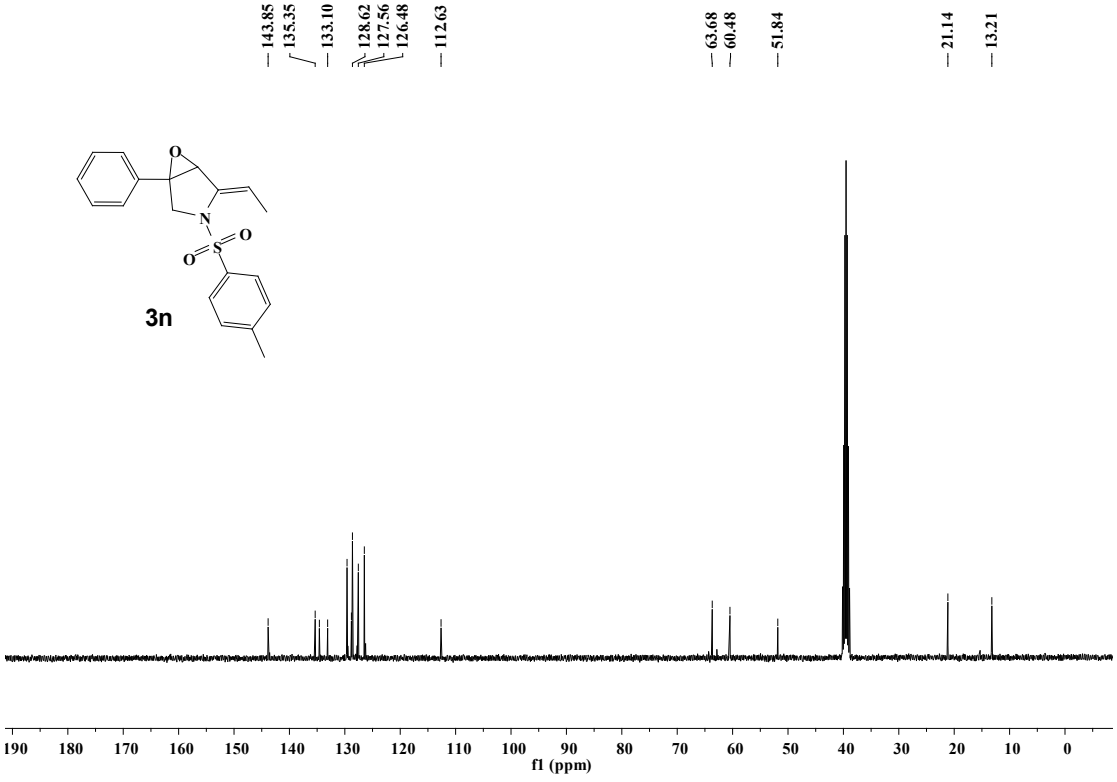

157.48
144.28
142.01
134.10
127.41
120.87
120.44
111.24
97.14
62.71
62.48
55.71
53.91
21.11
3k
fl (ppm)

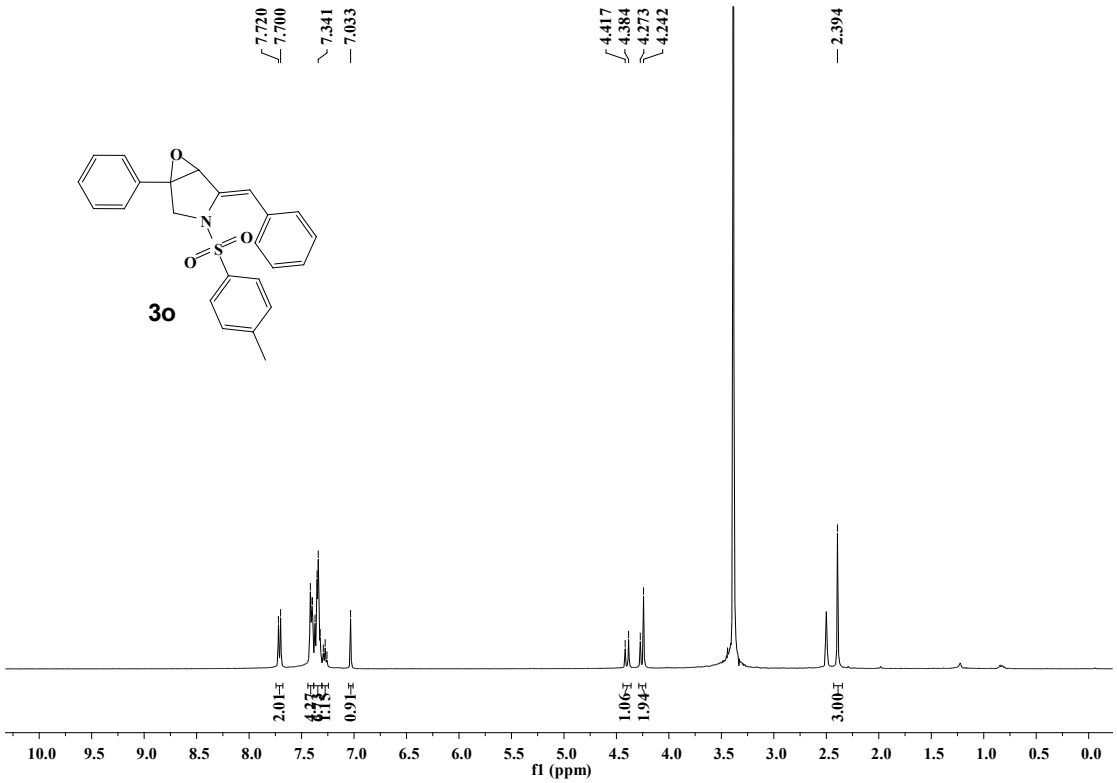

7.731
7.711
7.579
7.577
7.566
7.564
7.420
7.399
7.378
7.376
7.370
7.367
7.069
7.060
7.057
7.048
5.222
4.942
4.369
4.338
4.310
4.235
4.204
2.394
3l
1.97
0.90
1.99
0.94
0.94
0.94
0.93
0.94
0.91
1.07
3.00
f1 (ppm)
144.19
141.32
134.02
129.62
127.62
127.41
126.93
98.32
65.62
61.28
52.55
21.02
3l
f1 (ppm)

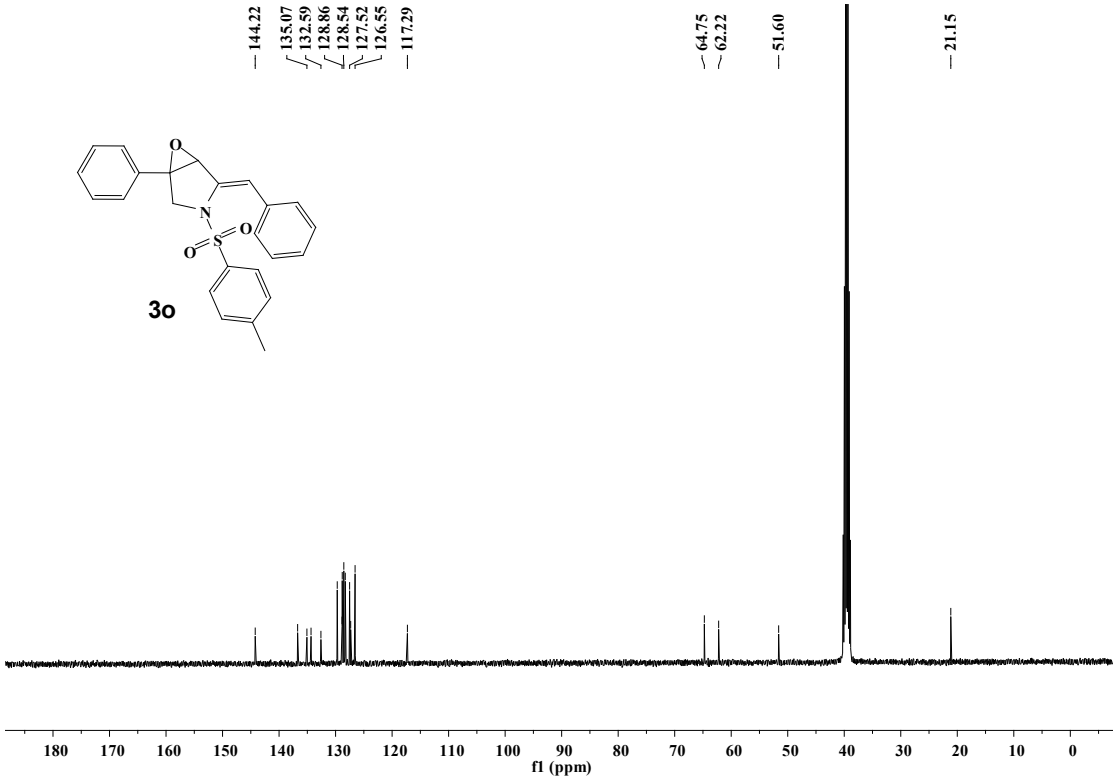

7.6530
7.6325
7.4169
7.2850
7.2653
7.2478
7.1966
7.1833
7.1641
5.1009
4.7802
3.7958
3.7534
3.7459
2.6117
2.5922
2.5729
2.3960
2.1403
2.1226
2.1165
2.1043
2.0926
2.0853
2.0624
2.0579
2.0362
2.0177
2.0042
1.9987
1.9815
3m
2.09
2.21
2.21
3.32
1.01
1.00
1.11
1.86
2.19
3.18
2.47
f1 (ppm)

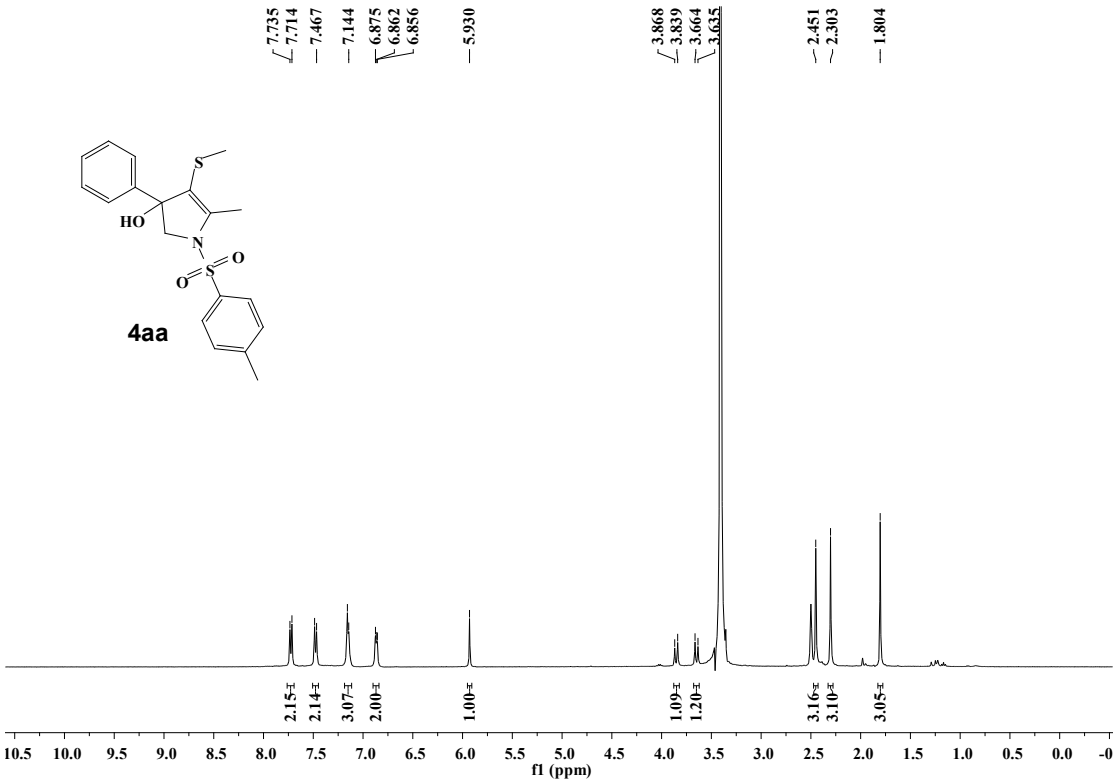

144.03
142.22
140.84
134.15
129.59
128.32
128.21
127.23
125.99
96.65
63.44
60.85
53.14
30.28
30.19
21.01
3m
f1 (ppm)

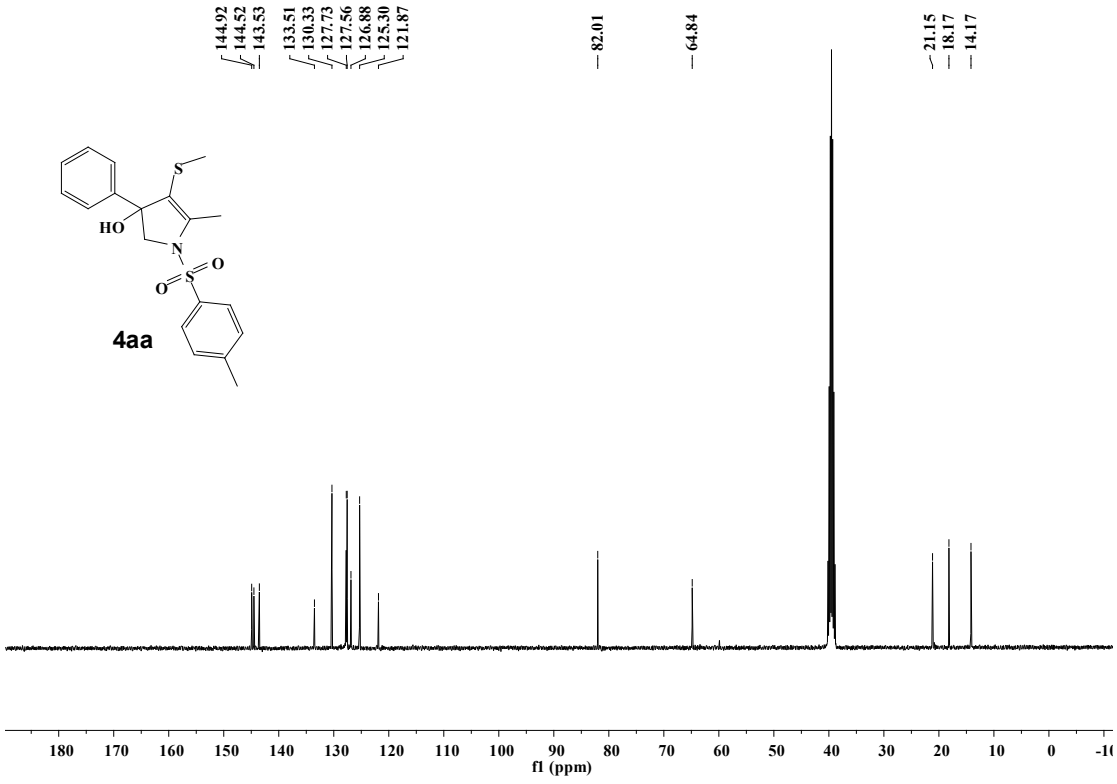

7.651
7.630
7.375
7.367
7.357
7.354
5.949
5.931
5.912
5.894
4.476
4.284
4.252
4.141
4.109
4.089
2.375
1.824
1.806
3n
2.11
7.45
0.97
1.00
1.04
1.31
3.37
2.90
f1 (ppm)

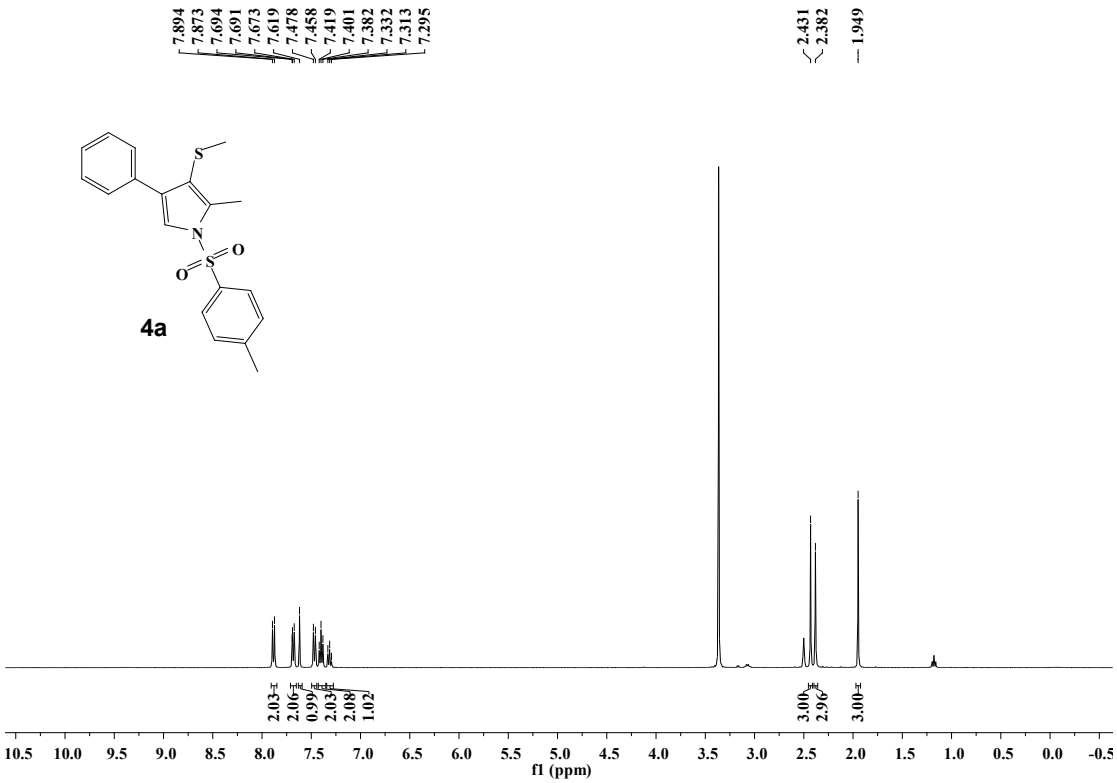

143.85
135.35
133.10
128.62
127.56
126.48
112.63
63.68
60.48
51.84
21.14
13.21
3n
f1 (ppm)

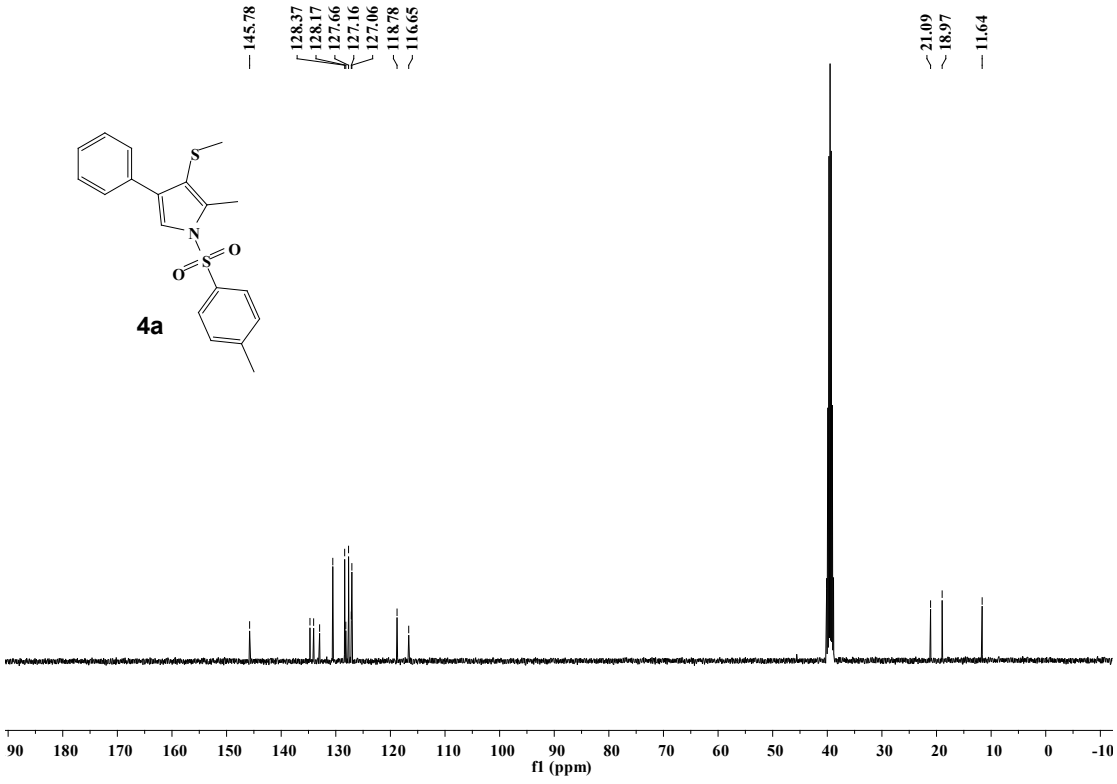

7.720
7.700
7.341
7.033
4.417
4.384
4.273
4.242
2.394
2.01
0.91
1.06
1.94
3.00
3o
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

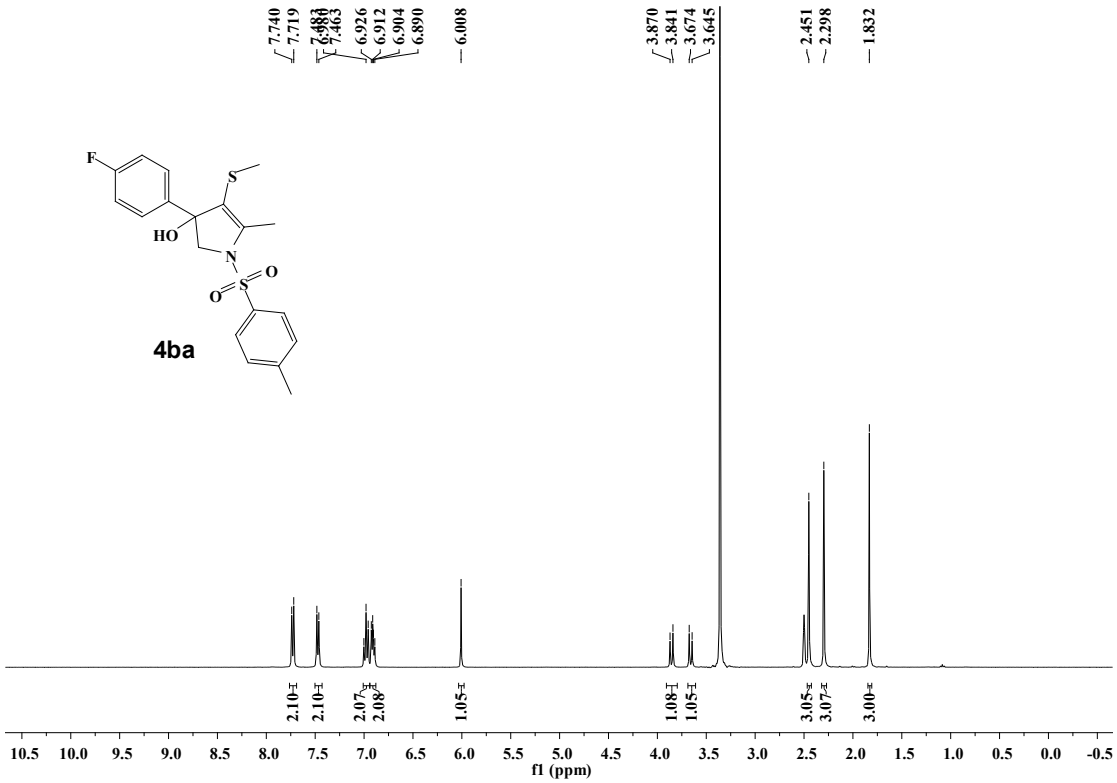

144.22
135.07
132.59
128.86
128.54
127.52
126.55
117.29
64.75
62.22
51.60
21.15
3o
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

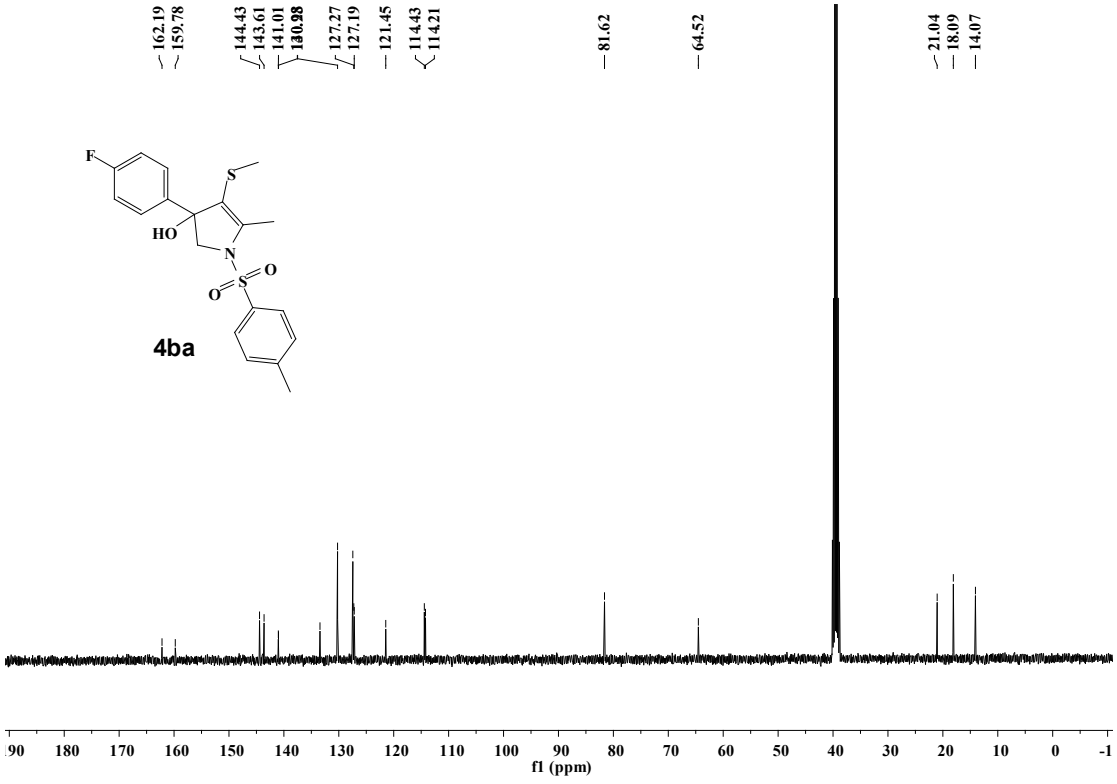

7.735
7.714
7.467
7.144
6.875
6.862
6.856
5.930
3.868
3.839
3.664
3.635
2.451
2.303
1.804
HO
S
N
O
O
S
O
4aa
2.15
2.14
3.07
2.00
1.00
1.09
1.20
3.16
3.10
3.05
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)

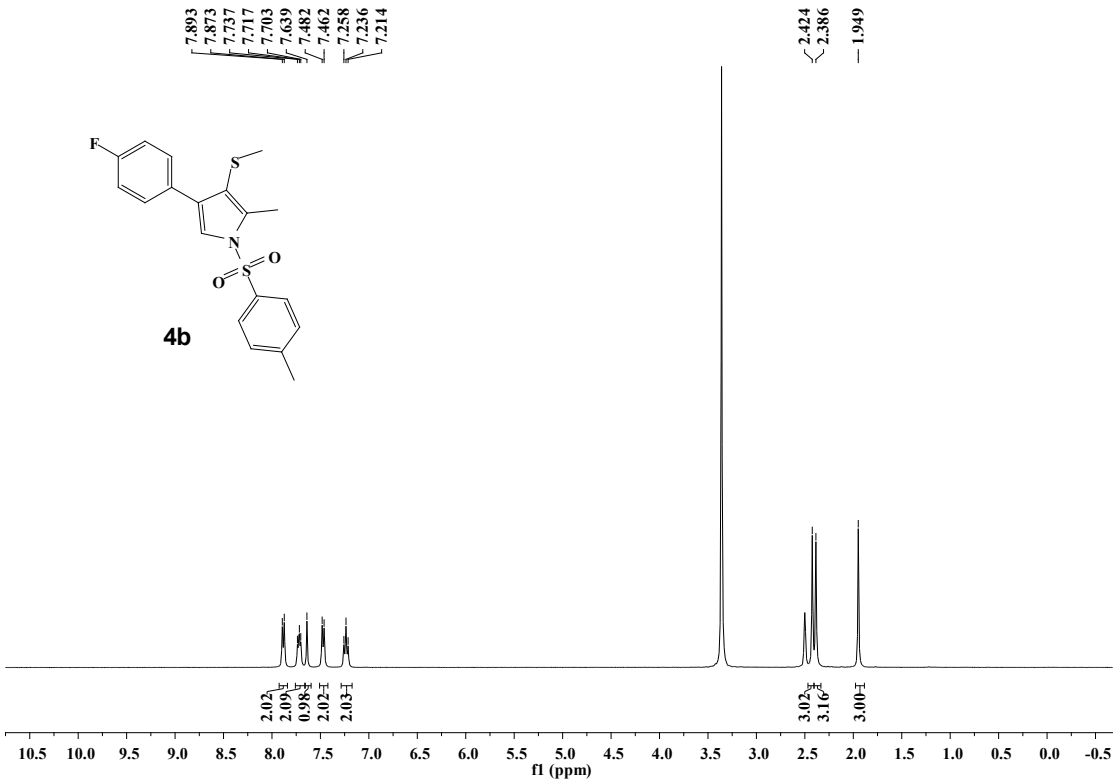

144.92
144.52
143.53
133.51
130.33
127.73
127.56
126.88
125.30
121.87
82.01
64.84
21.15
18.17
14.17
HO
S
N
O
O
S
O
4aa
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1(
f1 (ppm)

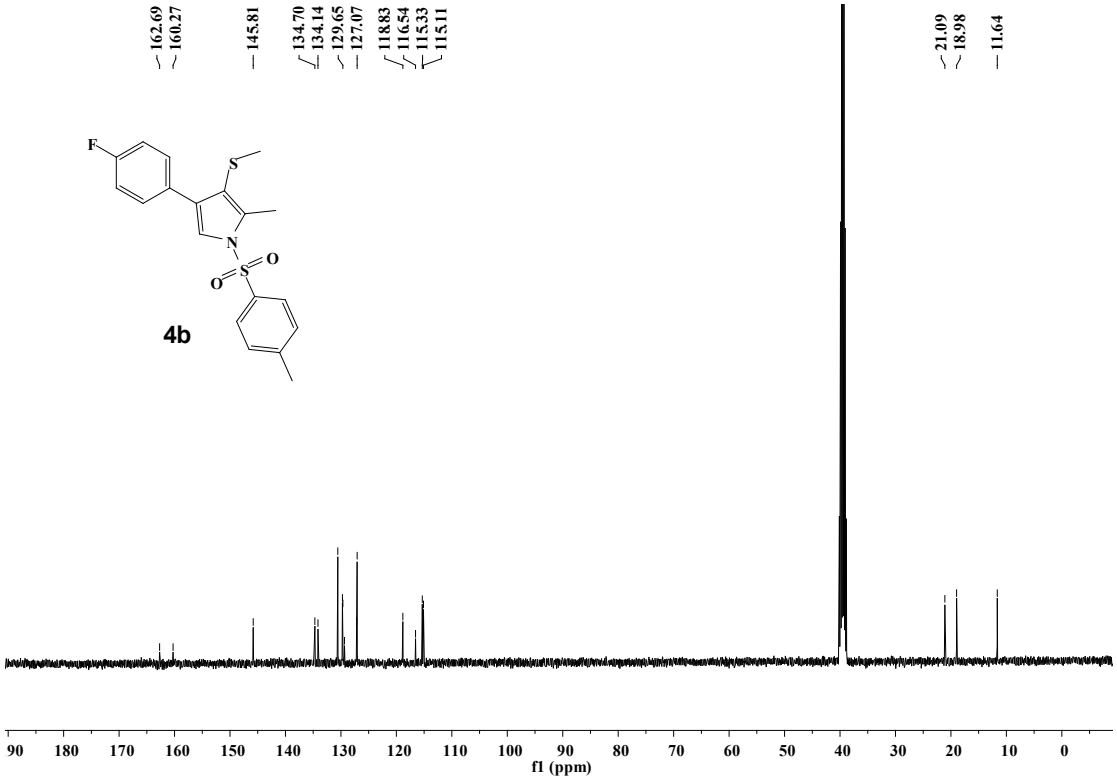

7.894
7.873
7.694
7.691
7.673
7.619
7.478
7.458
7.419
7.401
7.382
7.332
7.313
7.295
2.431
2.382
1.949
4a
2.03
2.06
0.99
2.03
2.08
1.02
3.00
2.96
3.00
f1 (ppm)

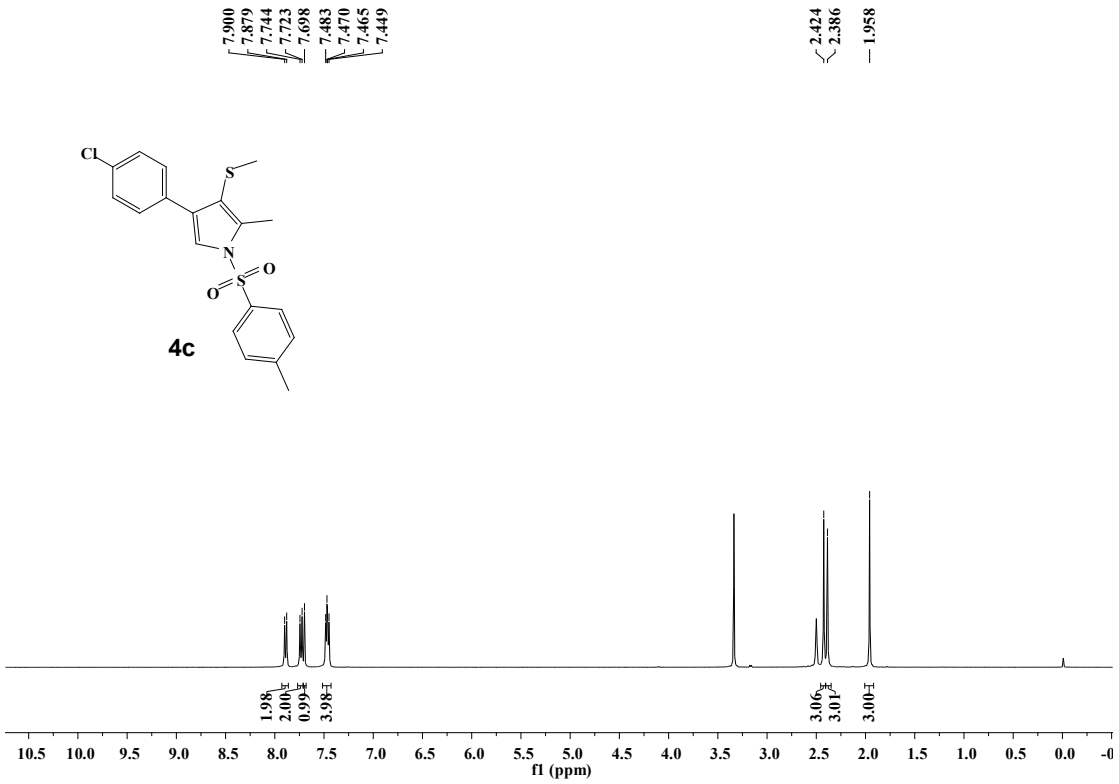

145.78
128.37
128.17
127.66
127.16
127.06
118.78
116.65
21.09
18.97
11.64
4a
f1 (ppm)

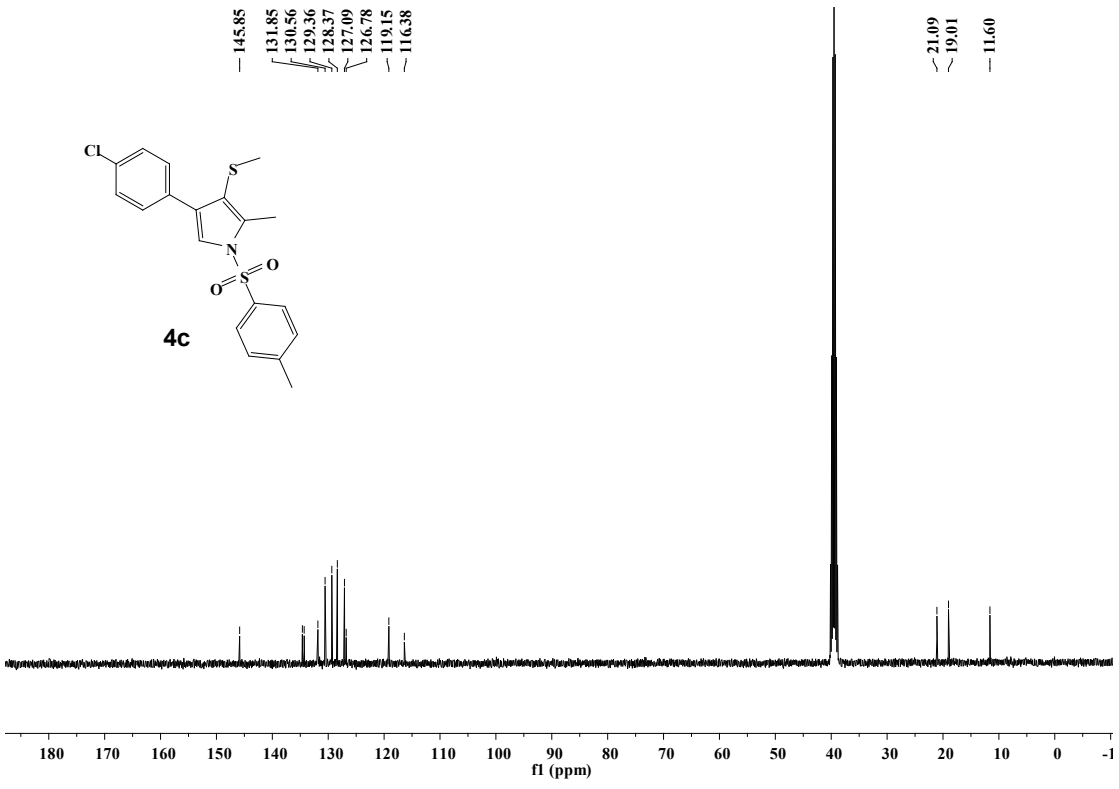

7.740
7.719
7.483
7.463
6.926
6.912
6.904
6.890
6.008
3.870
3.841
3.674
3.645
2.451
2.298
1.832
F
S
HO
N
O
O
S
O
4ba
2.10
2.10
2.07
2.08
1.05
1.08
1.05
3.05
3.07
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

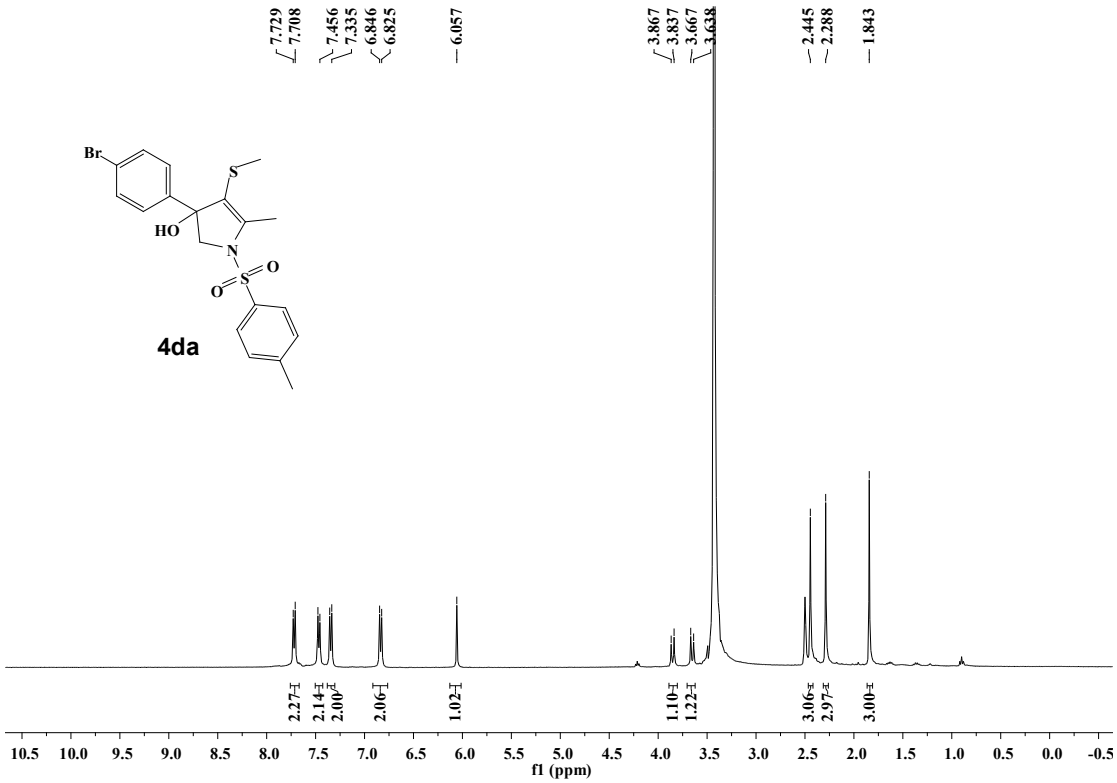

162.19
159.78
144.43
143.61
141.01
130.98
127.27
127.19
121.45
114.43
114.21
81.62
64.52
21.04
18.09
14.07
F
S
HO
N
O
O
S
O
4ba
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

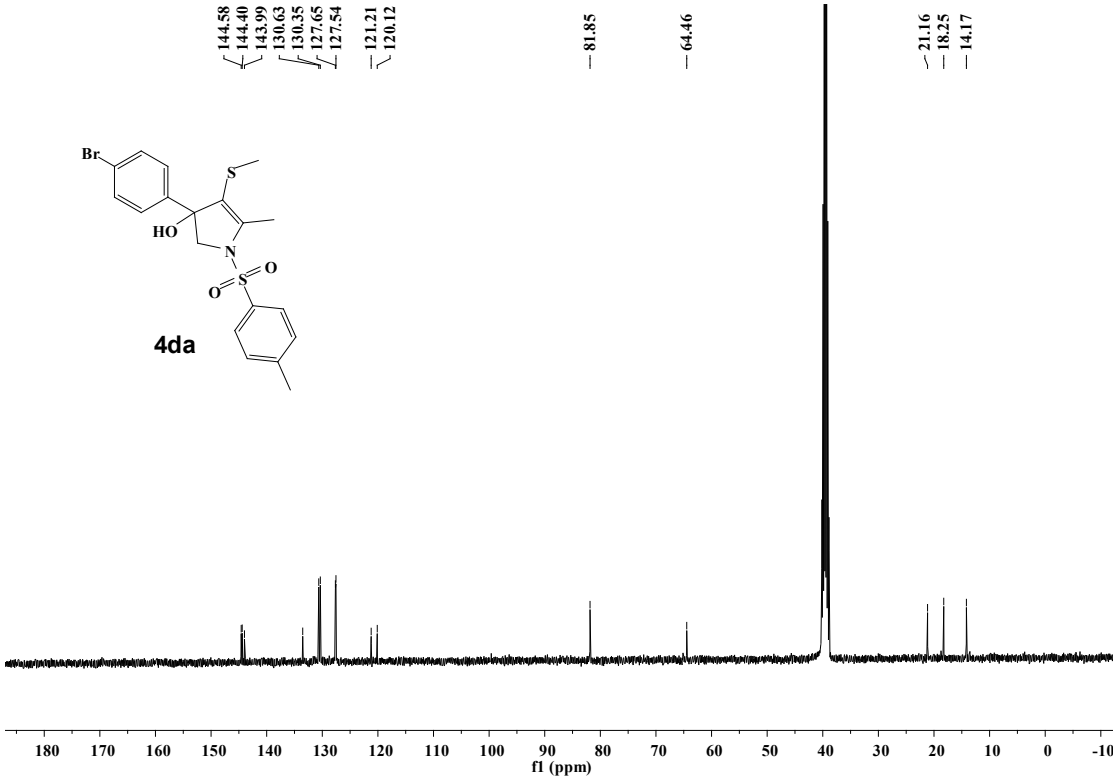

7.893
7.873
7.737
7.717
7.703
7.639
7.482
7.462
7.258
7.236
7.214
2.424
2.386
1.949
F
S
N
O
O
S
O
4b
2.02
2.09
0.98
2.02
2.03
3.02
3.16
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

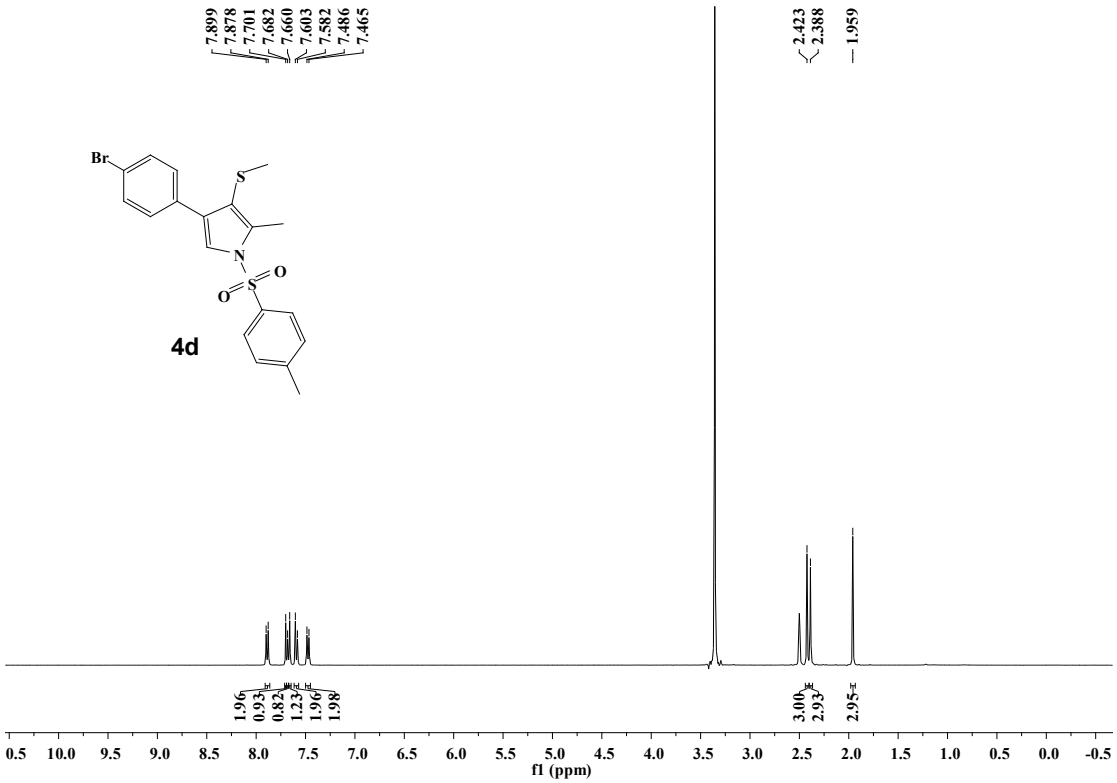

162.69
160.27
145.81
134.70
134.14
129.65
127.07
118.83
116.54
115.33
115.11
21.09
18.98
11.64
F
S
N
O
O
S
O
4b
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

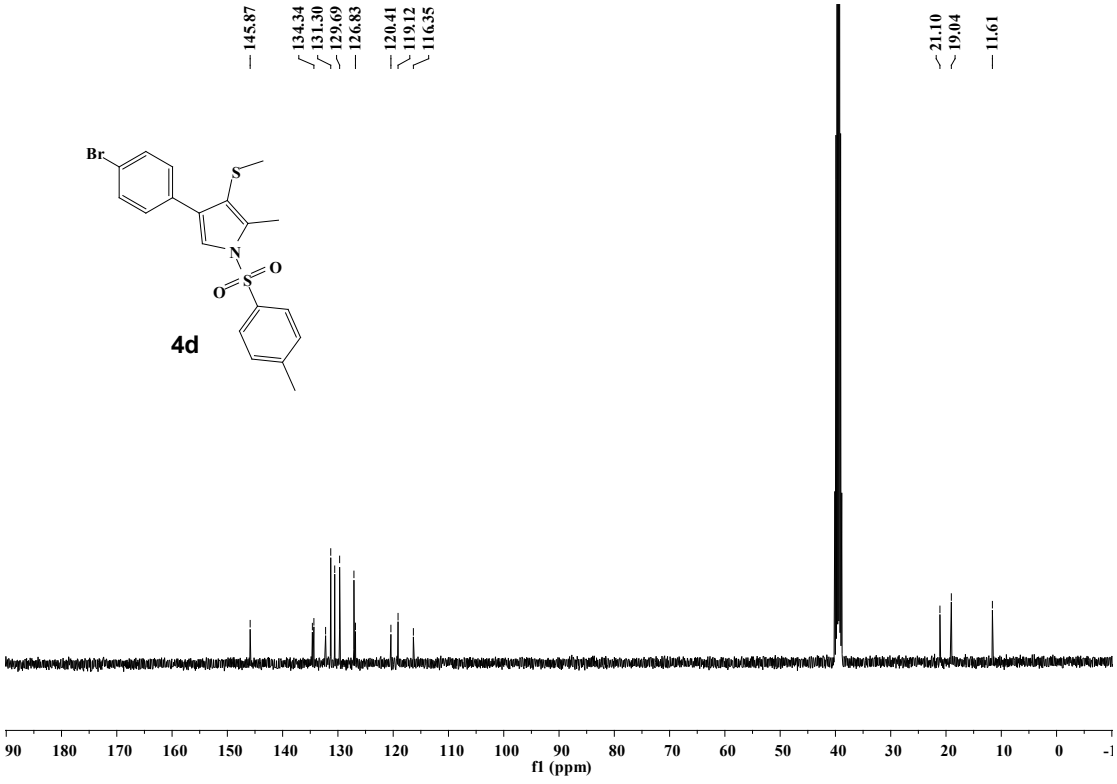

7.900
7.879
7.744
7.723
7.698
7.483
7.470
7.465
7.449
2.424
2.386
1.958
Cl
S
N
O
O
S
O
4c
1.98
2.00
0.99
3.98
3.06
3.01
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

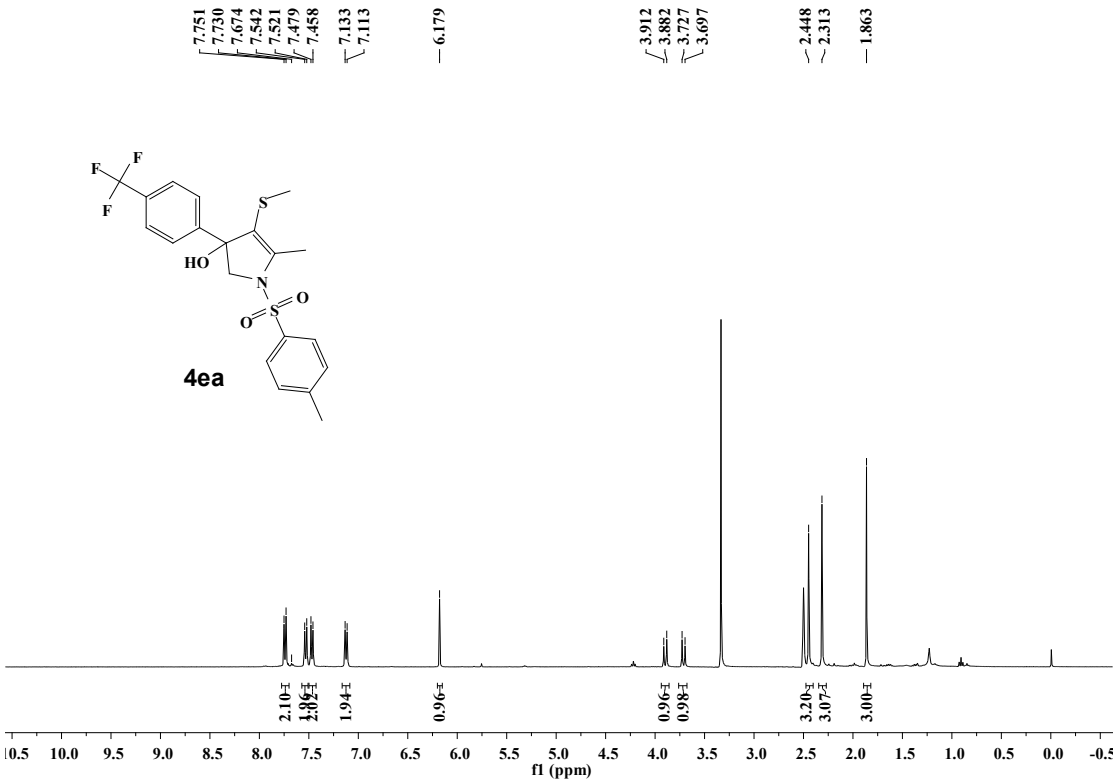

145.85
131.85
130.56
129.36
128.37
127.09
126.78
119.15
116.38
21.09
19.01
11.60
Cl
S
N
O
O
S
O
4c
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

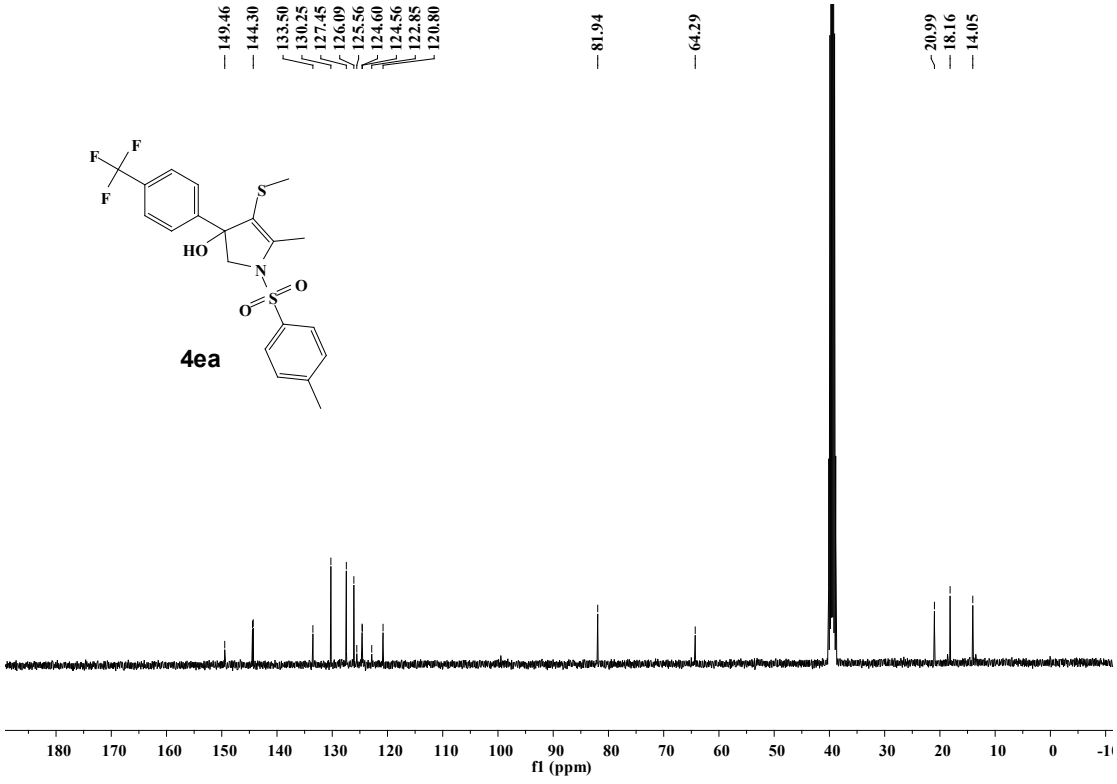

7.729
7.708
7.456
7.335
6.846
6.825
6.057
3.867
3.837
3.667
3.638
2.445
2.288
1.843
Br
S
HO
N
O
O
S
O
4da
2.27
2.14
2.00
2.06
1.02
1.10
1.22
3.06
2.97
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

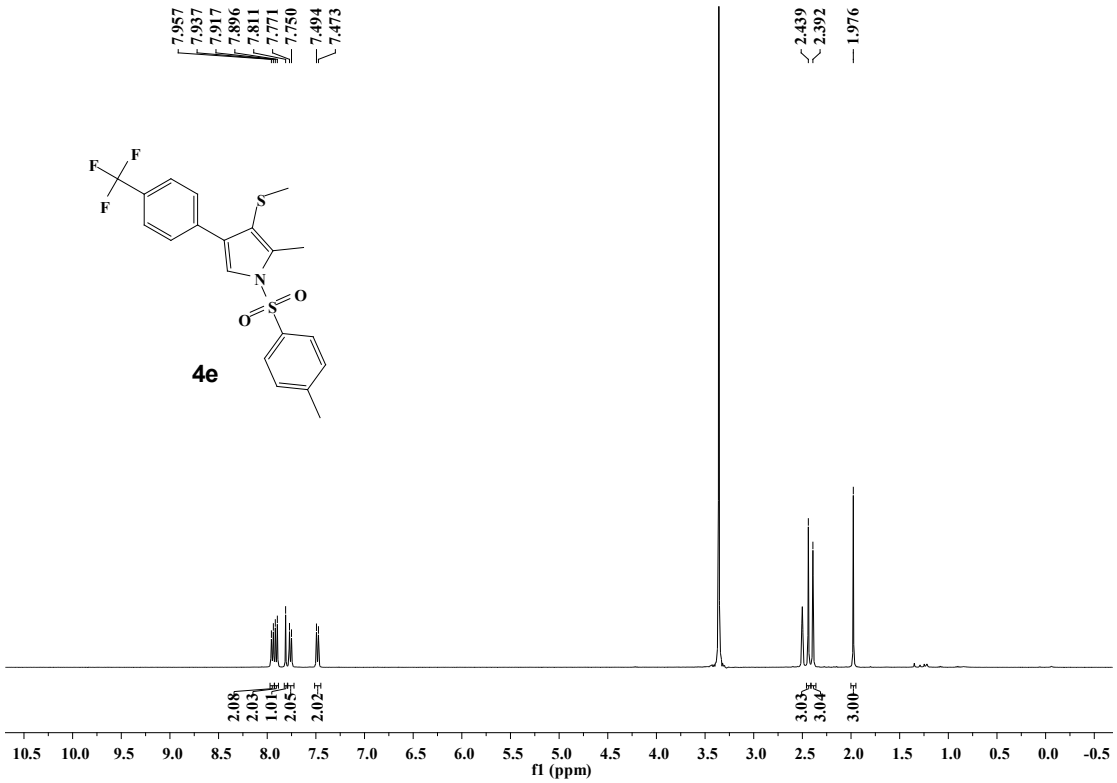

144.58
144.40
143.99
130.63
130.35
127.65
127.54
121.21
120.12
81.85
64.46
21.16
18.25
14.17
Br
S
HO
N
O
O
S
O
4da
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

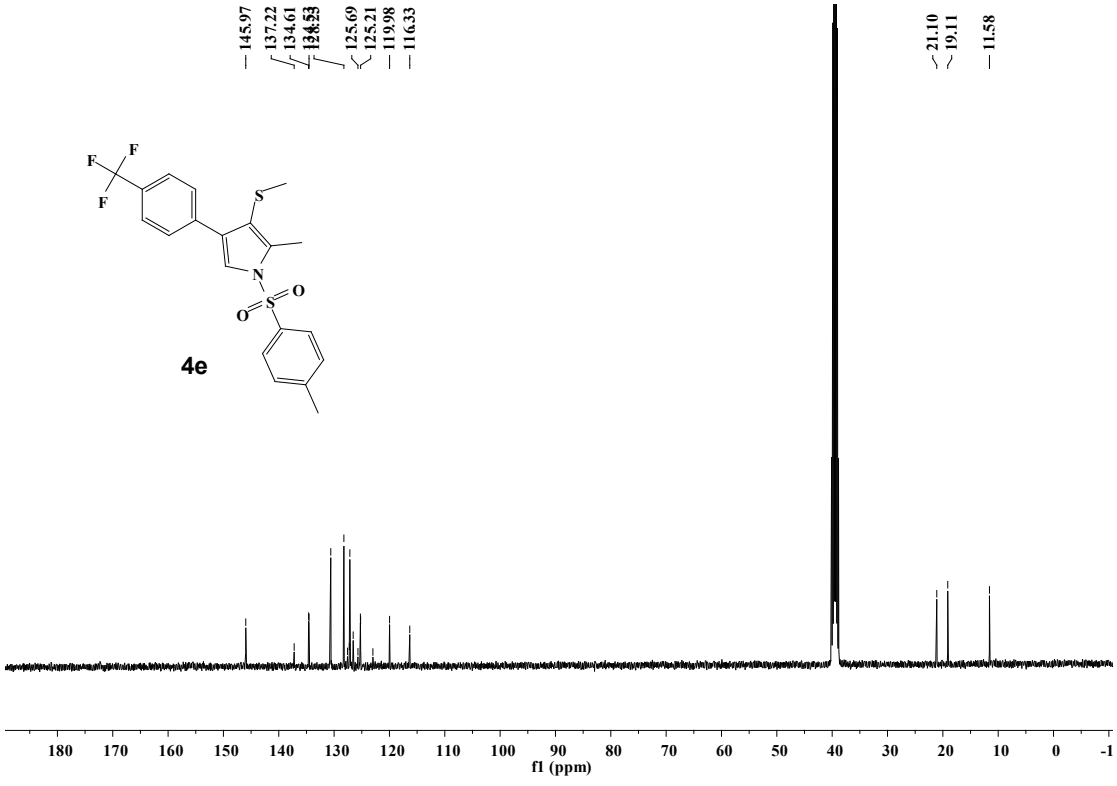

7.899
7.878
7.701
7.682
7.660
7.603
7.582
7.486
7.465
2.423
2.388
1.959
Br
S
N
O
O
S
O
4d
1.96
0.93
0.82
1.23
1.96
1.98
3.00
2.93
2.95
0.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

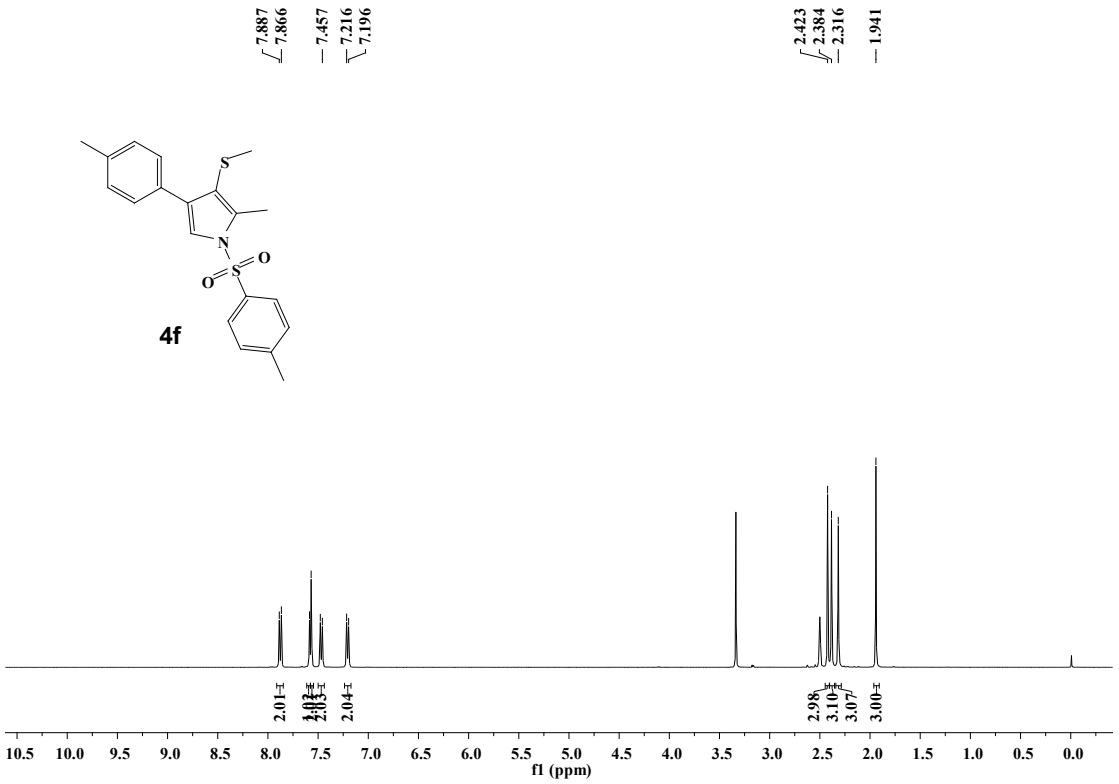

145.87
134.34
131.30
129.69
126.83
120.41
119.12
116.35
21.10
19.04
11.61
Br
S
N
O
O
S
O
4d
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

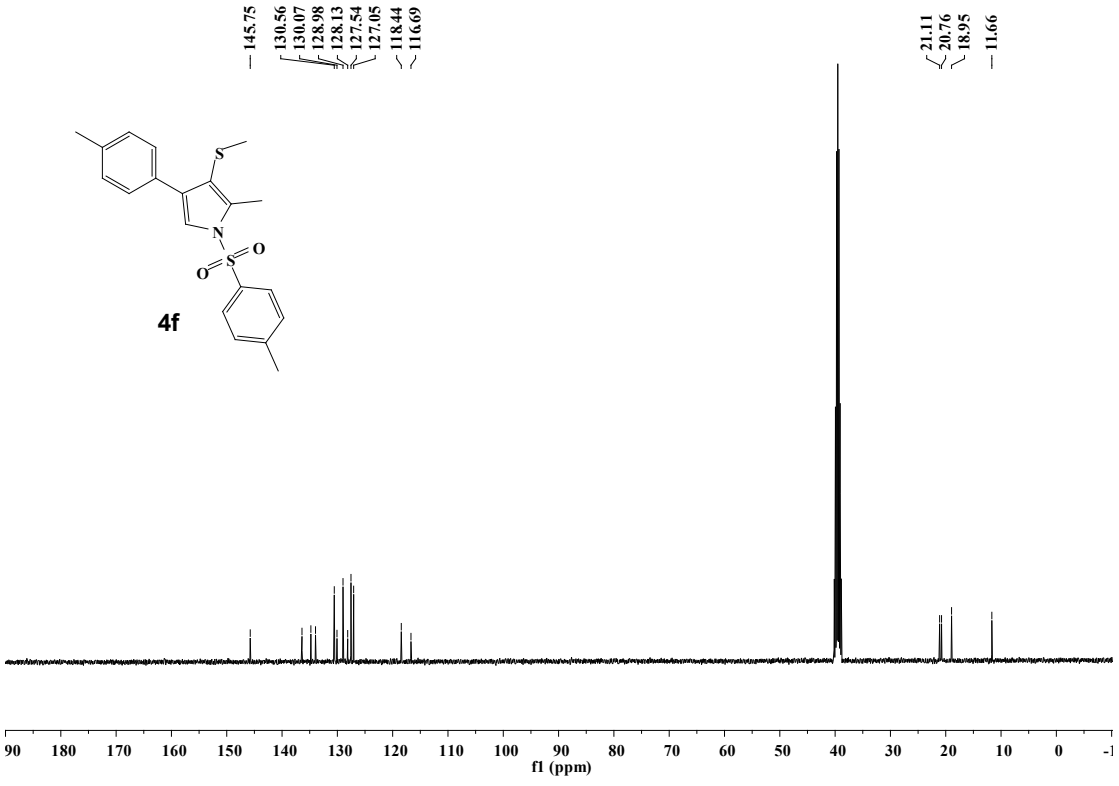

7.751
7.730
7.674
7.542
7.521
7.479
7.458
7.133
7.113
6.179
3.912
3.882
3.727
3.697
2.448
2.313
1.863
F
F
F
S
HO
N
O
O
S
O
4ea
2.10
1.96
2.02
1.94
0.96
0.96
0.98
3.20
3.07
3.00
f1 (ppm)

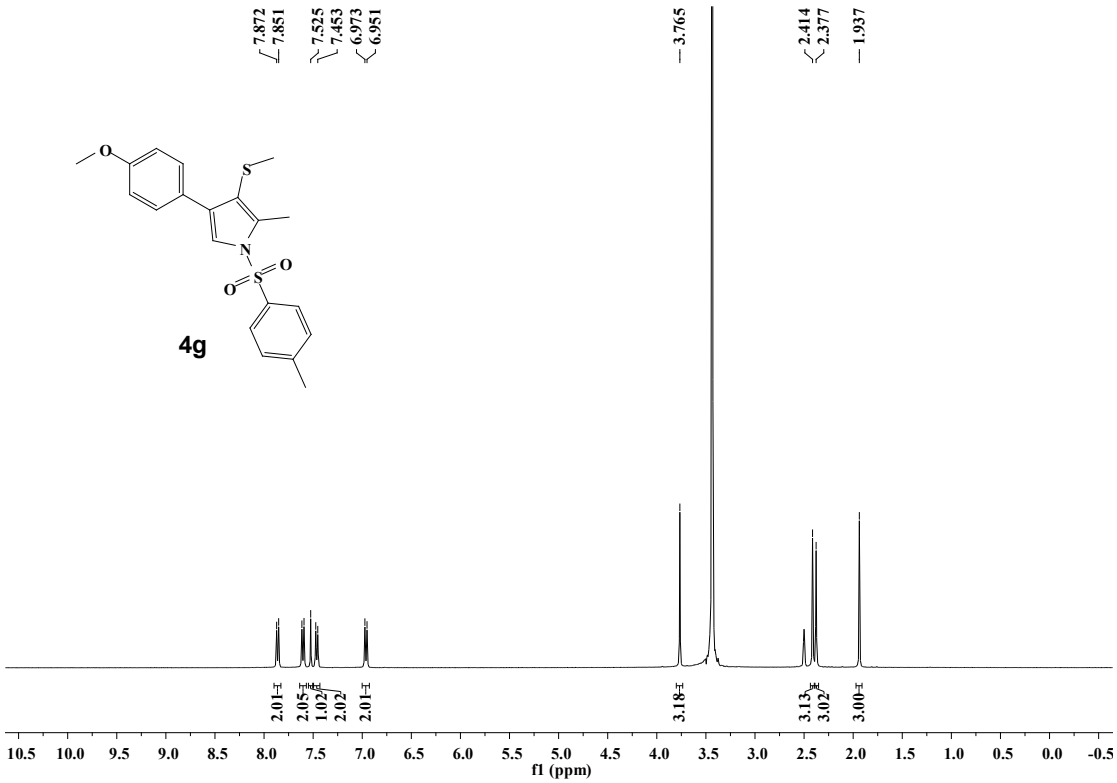

149.46
144.30
133.50
130.25
127.45
126.09
125.56
124.60
124.56
122.85
120.80
81.94
64.29
20.99
18.16
14.05
F
F
F
S
HO
N
O
O
S
O
4ea
f1 (ppm)

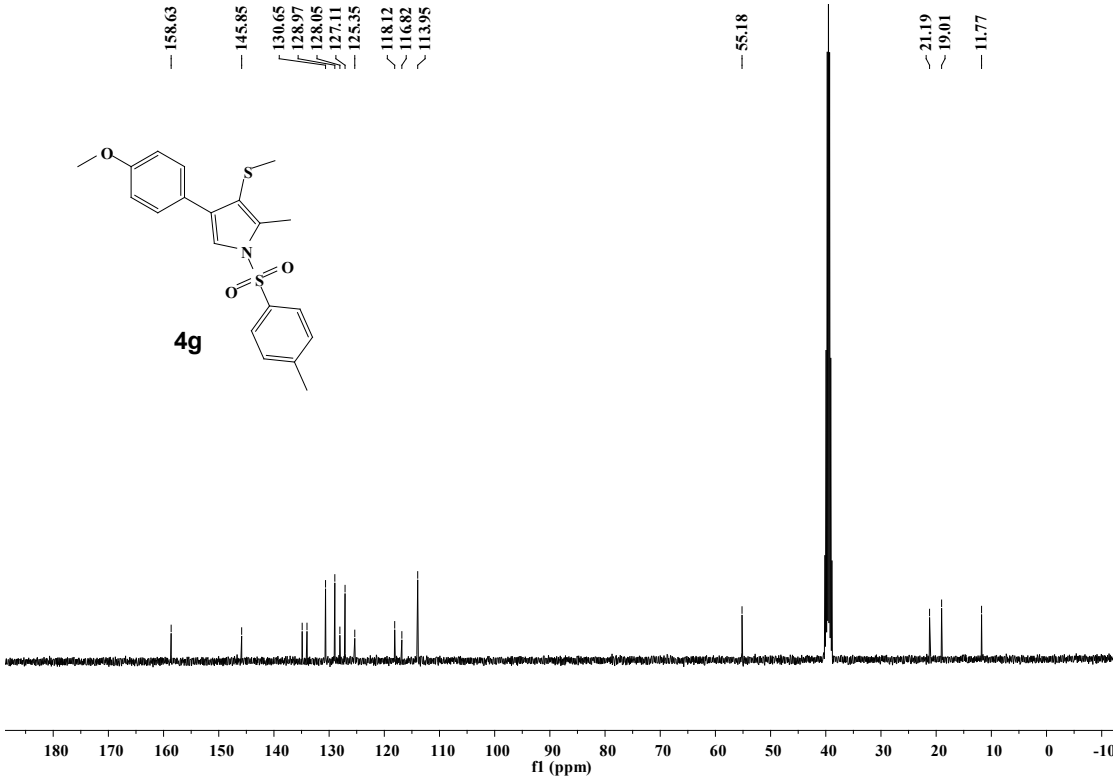

7.957
7.937
7.917
7.896
7.811
7.771
7.750
7.494
7.473
2.439
2.392
1.976
F
F
F
S
N
O
O
S
O
4e
2.08
2.03
1.01
2.05
2.02
3.03
3.04
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

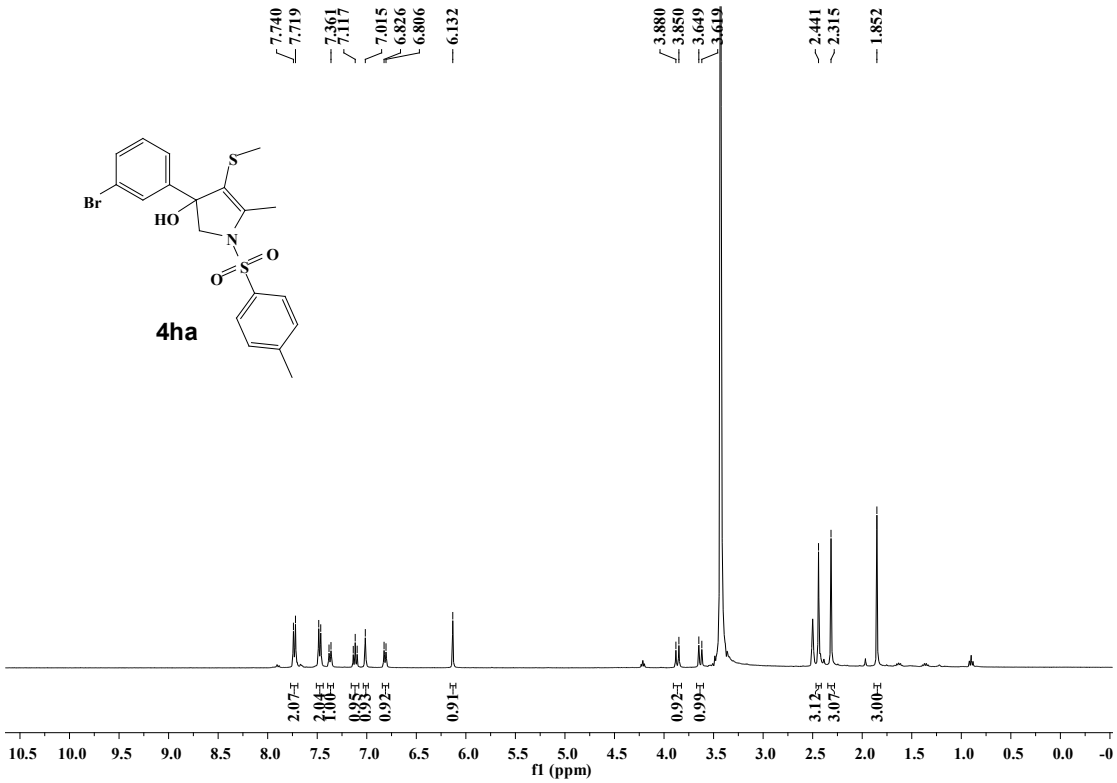

145.97
137.22
134.61
125.69
125.21
119.98
116.33
21.10
19.11
11.58
F
F
F
S
N
O
O
S
O
4e
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

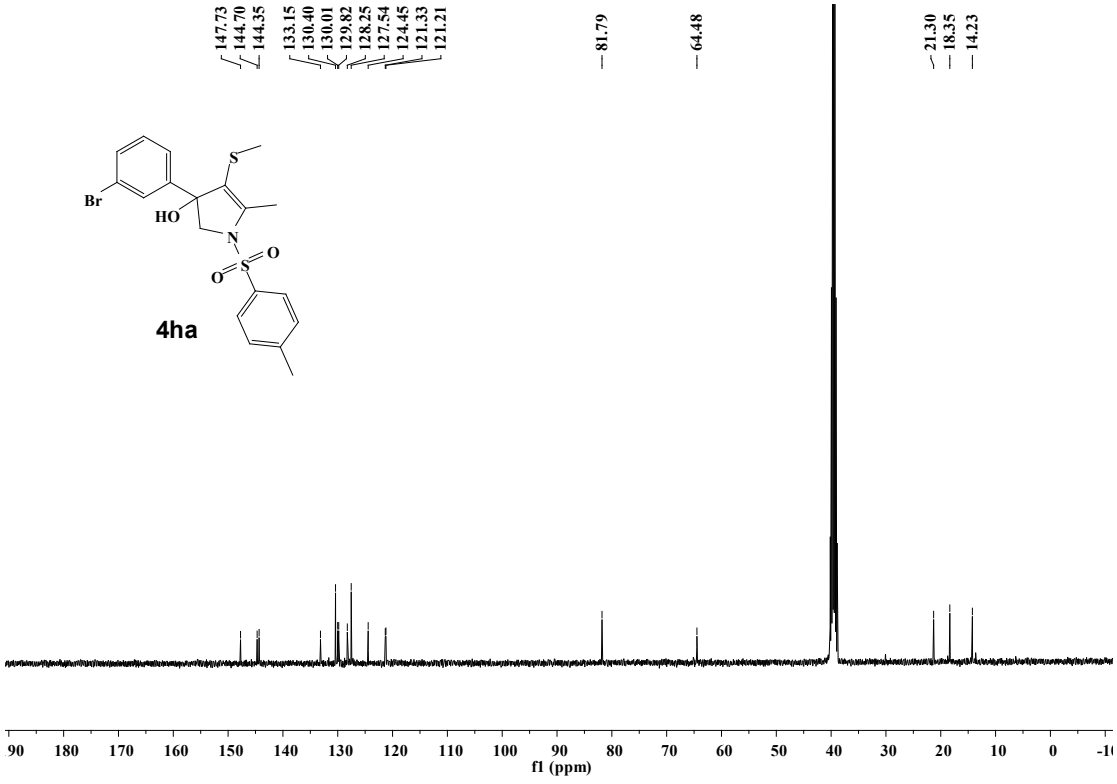

7.887
7.866
7.457
7.216
7.196
2.423
2.384
2.316
1.941
4f
2.01
2.04
2.98
3.10
3.07
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

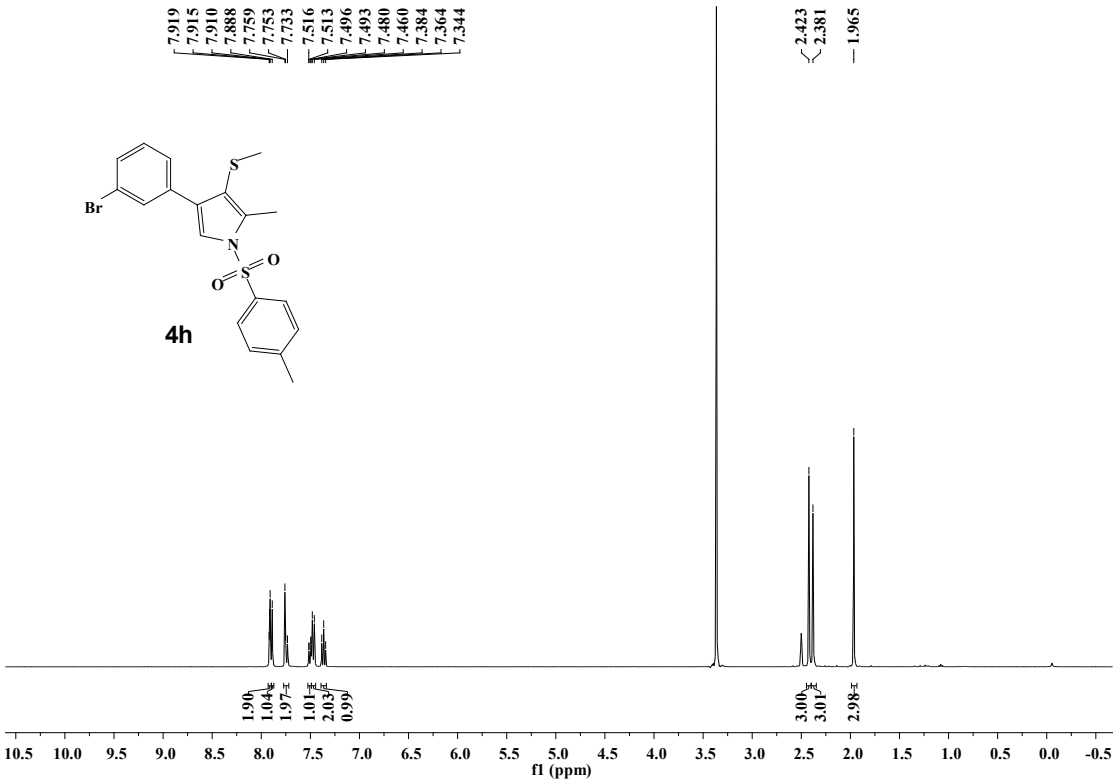

145.75
130.56
130.07
128.98
128.13
127.54
127.05
118.44
116.69
21.11
20.76
18.95
11.66
4f
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

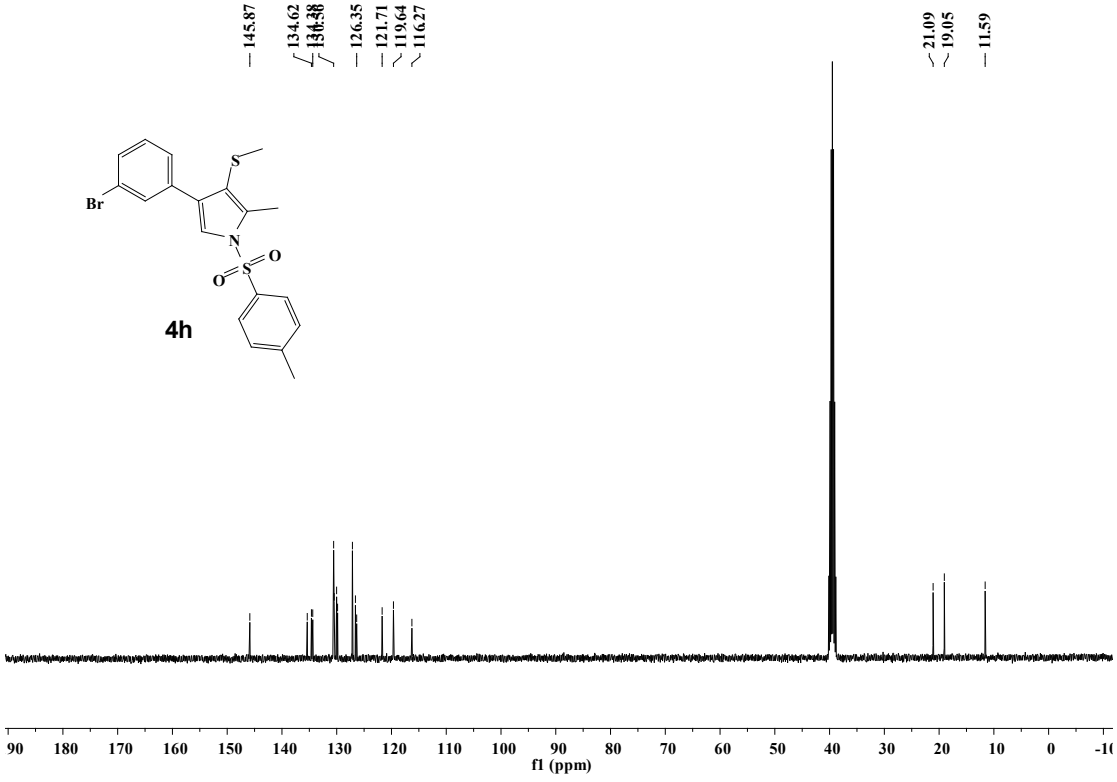

7.872
7.851
7.525
7.453
6.973
6.951
3.765
2.414
2.377
1.937
4g
2.01
2.05
1.02
2.02
2.01
3.18
3.13
3.02
3.00
fl (ppm)

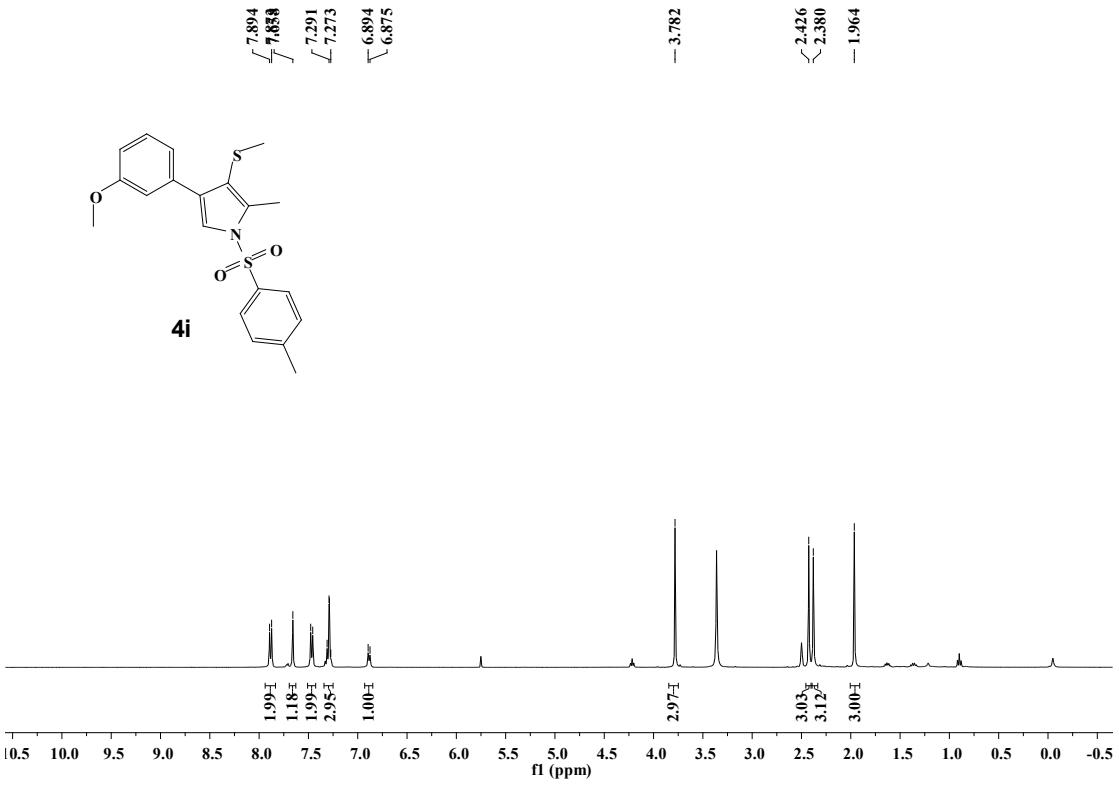

158.63
145.85
130.65
128.97
128.05
127.11
125.35
118.12
116.82
113.95
55.18
21.19
19.01
11.77
4g
fl (ppm)

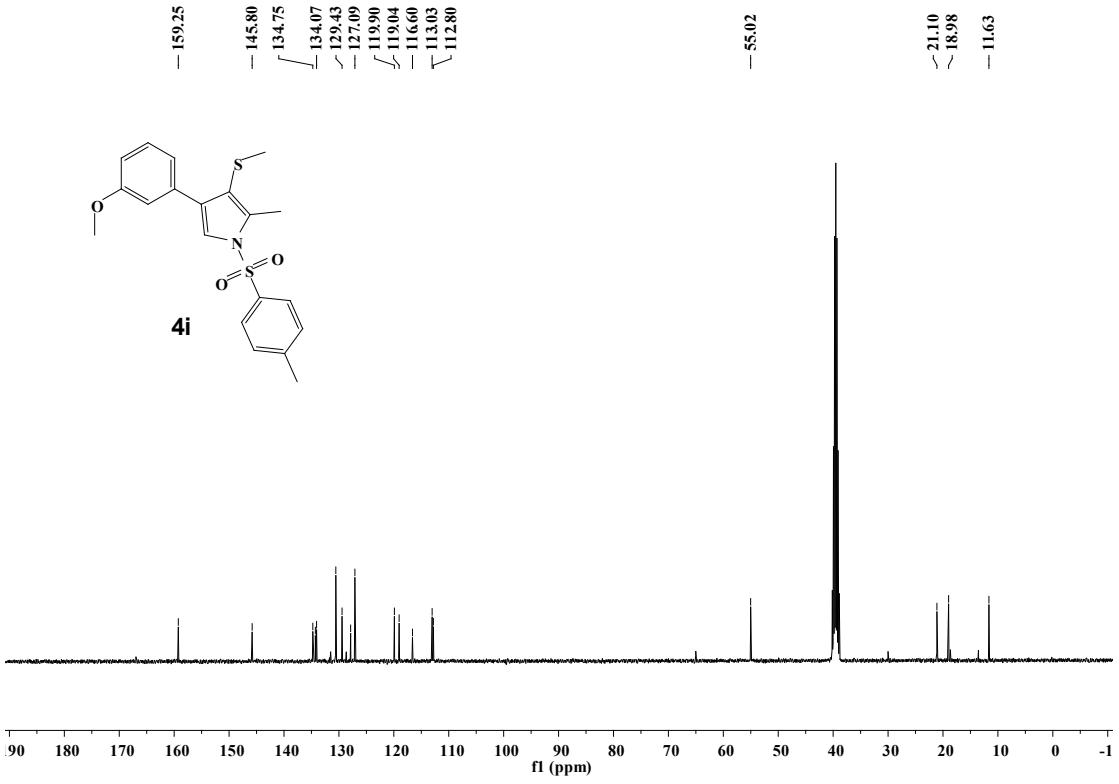

7.740
7.719
7.361
7.117
7.015
6.826
6.806
6.132
3.880
3.850
3.649
3.619
2.441
2.315
1.852
Br
HO
S
N
O
O
S
O
4ha
2.07
2.04
1.00
0.95
0.93
0.92
0.91
0.92
0.99
3.12
3.07
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)

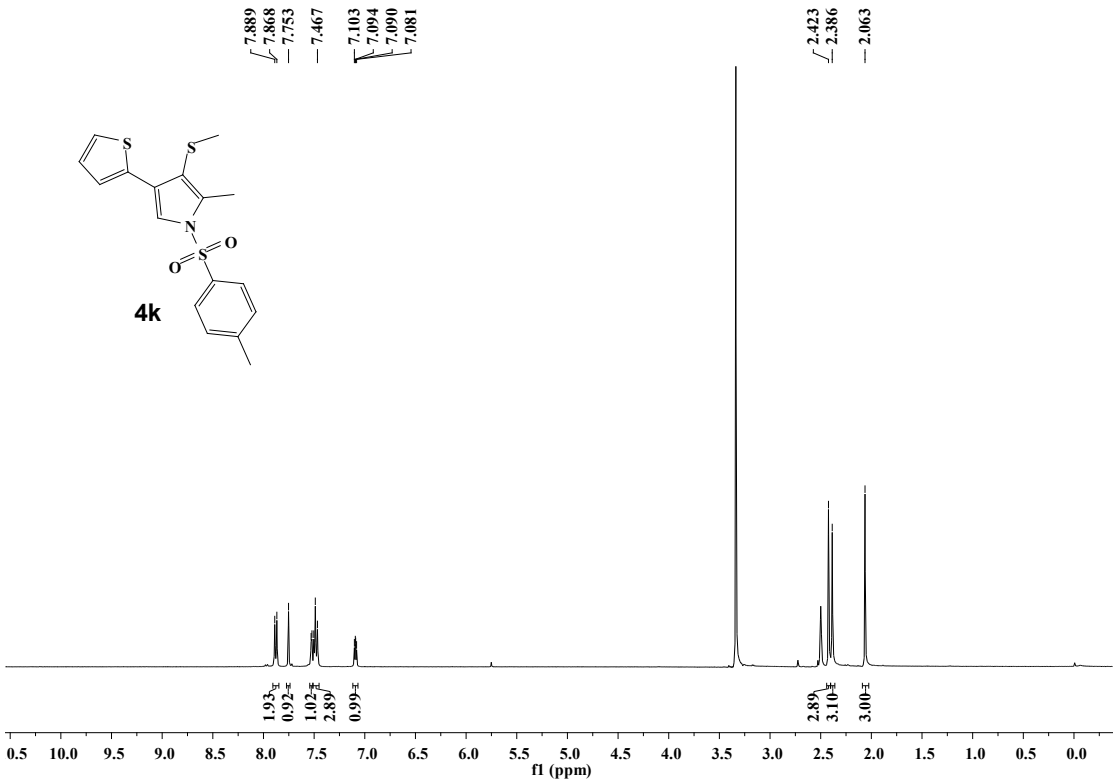

147.73
144.70
144.35
133.15
130.40
130.01
129.82
128.25
127.54
124.45
121.33
121.21
81.79
64.48
21.30
18.35
14.23
Br
HO
S
N
O
O
S
O
4ha
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)

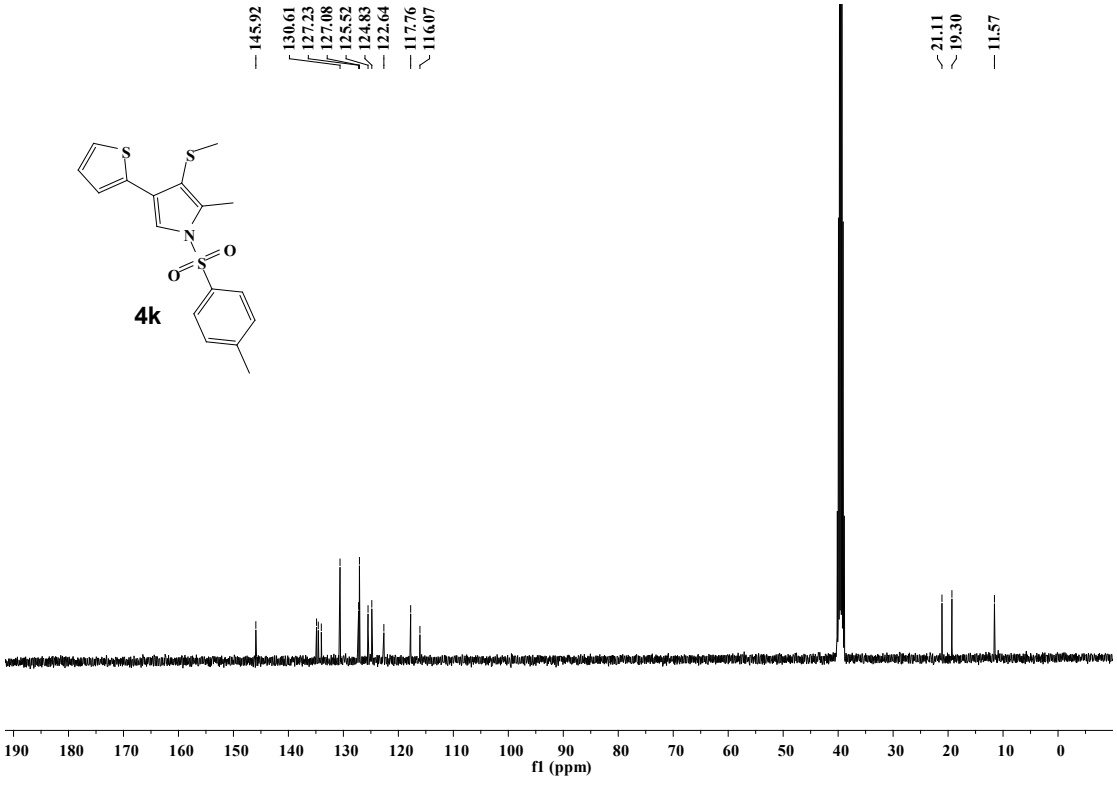

7.919
7.915
7.910
7.888
7.759
7.753
7.733
7.516
7.513
7.496
7.493
7.480
7.460
7.384
7.364
7.344
2.423
2.381
1.965
Br
S
N
O
O
S
O
4h
1.90
1.04
1.97
1.01
2.03
0.99
3.00
3.01
2.98
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

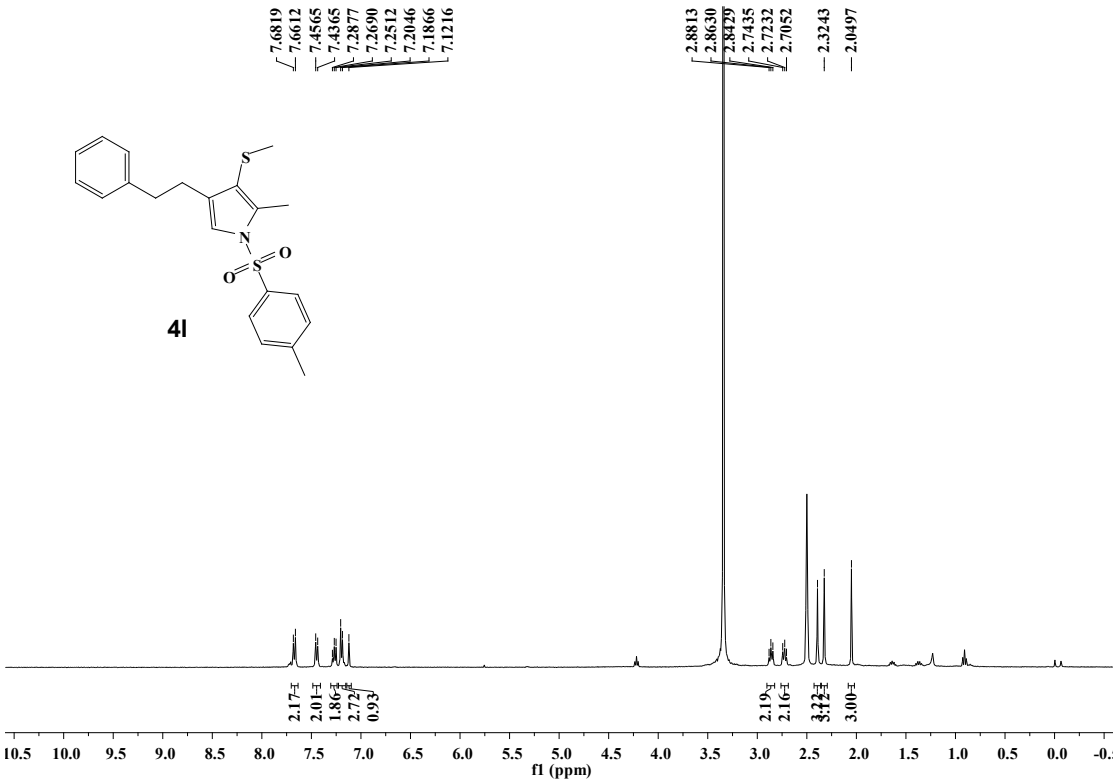

145.87
134.62
126.35
121.71
119.64
116.27
21.09
19.05
11.59
Br
S
N
O
O
S
O
4h
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

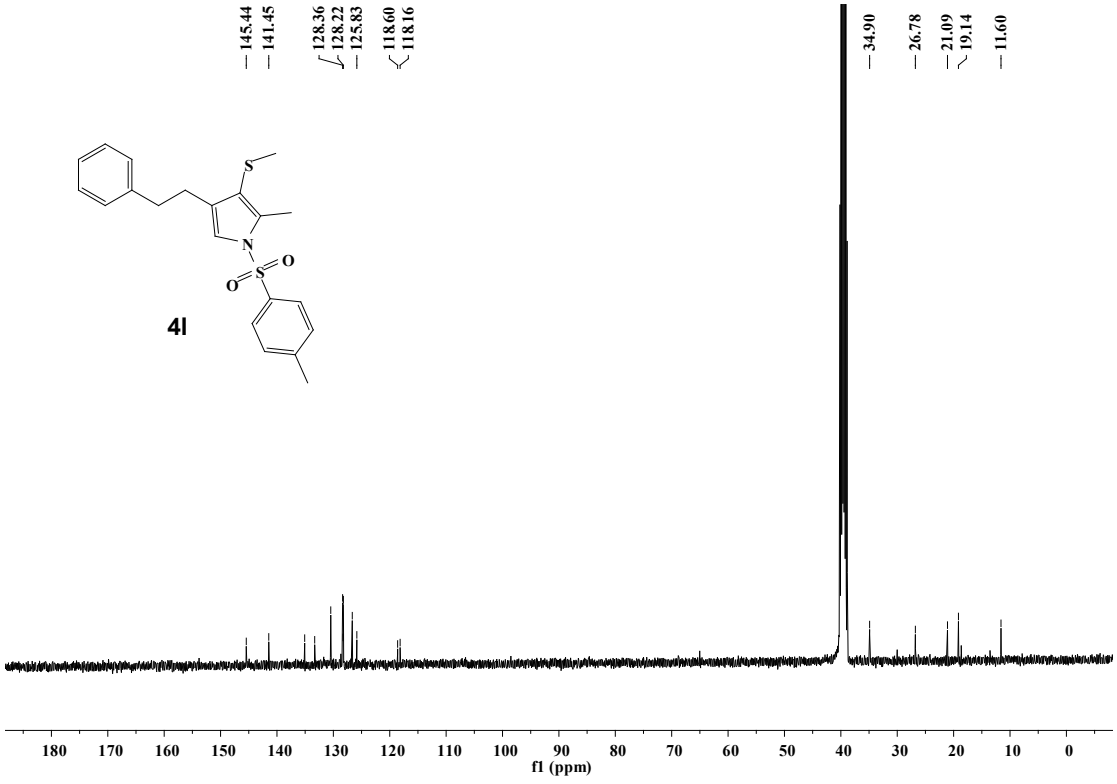

7.894
7.873
7.291
7.273
6.894
6.875
3.782
2.426
2.380
1.964
4i
1.99
1.18
1.99
2.95
1.00
2.97
3.03
3.12
3.00
fl (ppm)

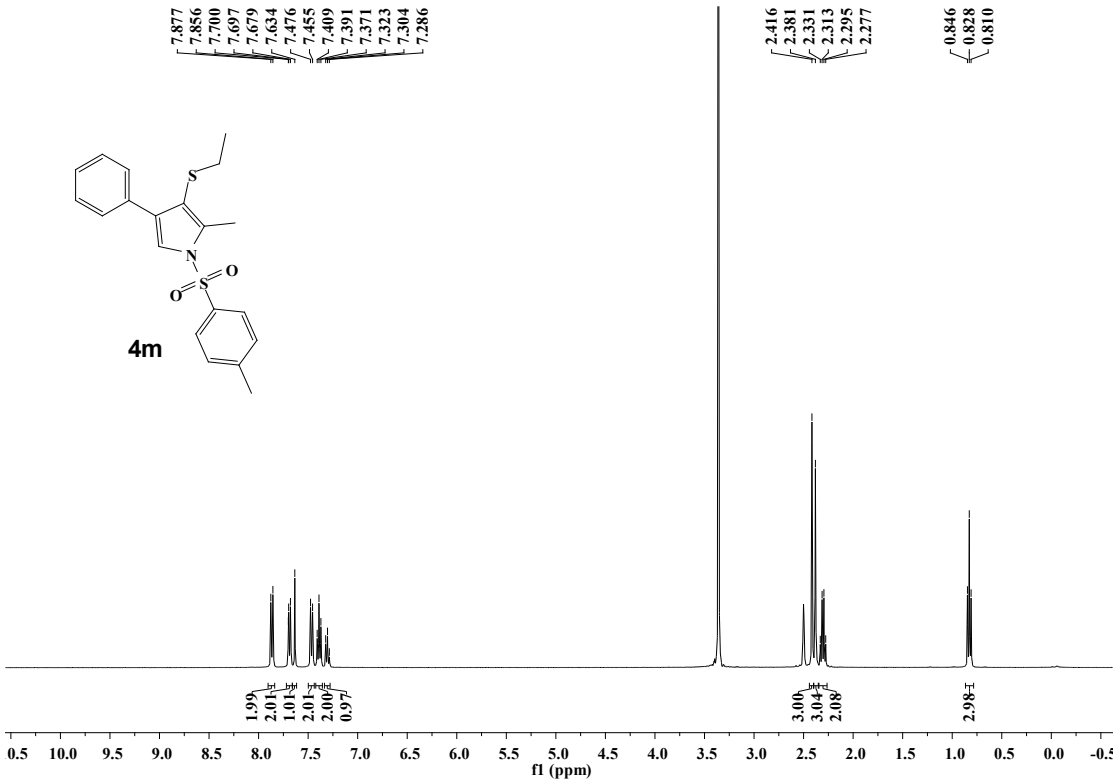

159.25
145.80
134.75
134.07
129.43
127.09
119.90
119.04
116.60
113.03
112.80
55.02
21.10
18.98
11.63
4i
fl (ppm)

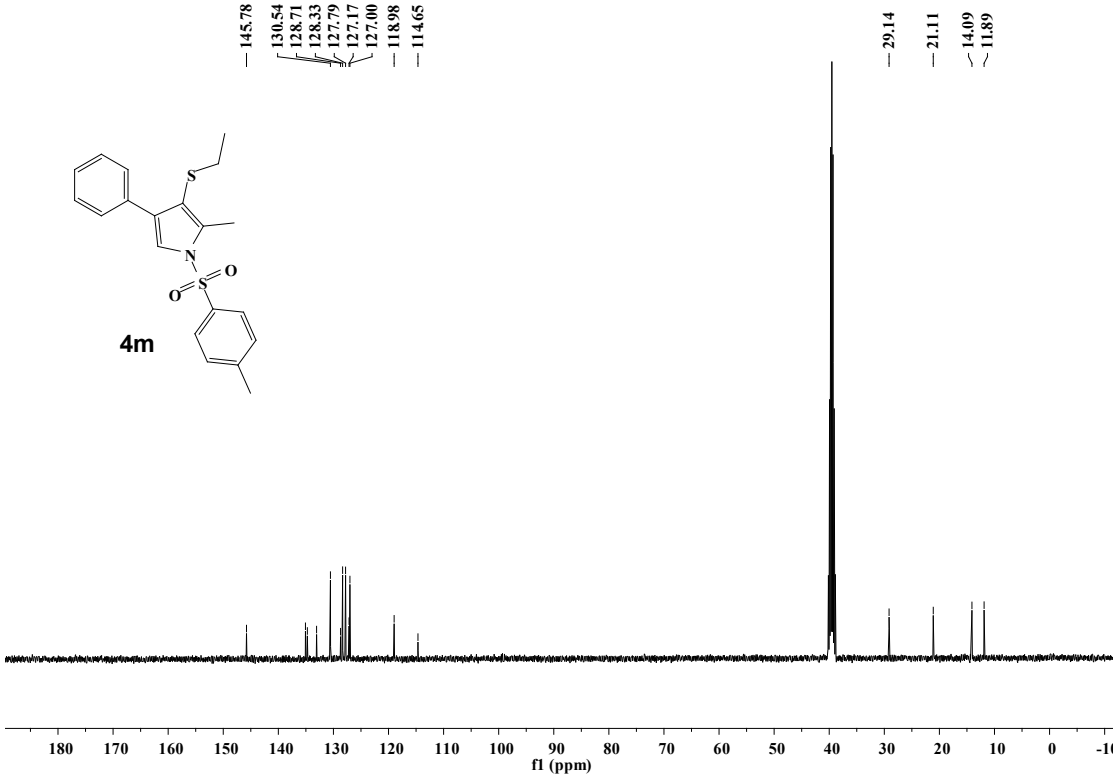

7.889
7.868
7.753
7.467
7.103
7.094
7.090
7.081
2.423
2.386
2.063
4k
1.93
0.92
1.02
2.89
0.99
2.89
3.10
3.00
0.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

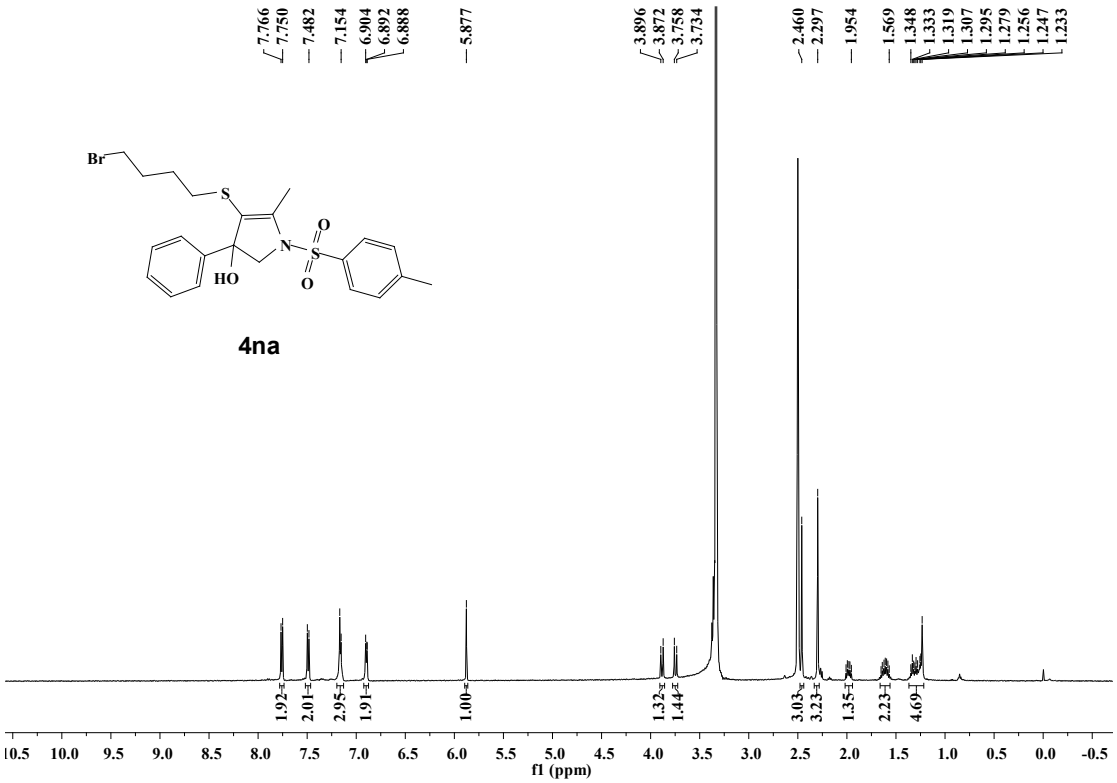

145.92
130.61
127.23
127.08
125.52
124.83
122.64
117.76
116.07
21.11
19.30
11.57
4k
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.6819
7.6612
7.4565
7.4365
7.2877
7.2690
7.2512
7.2046
7.1866
7.1216
2.8813
2.8630
2.8429
2.7435
2.7232
2.7052
2.3343
2.0497
4l
2.17
2.01
1.86
2.72
0.93
2.19
2.16
3.00
fl (ppm)

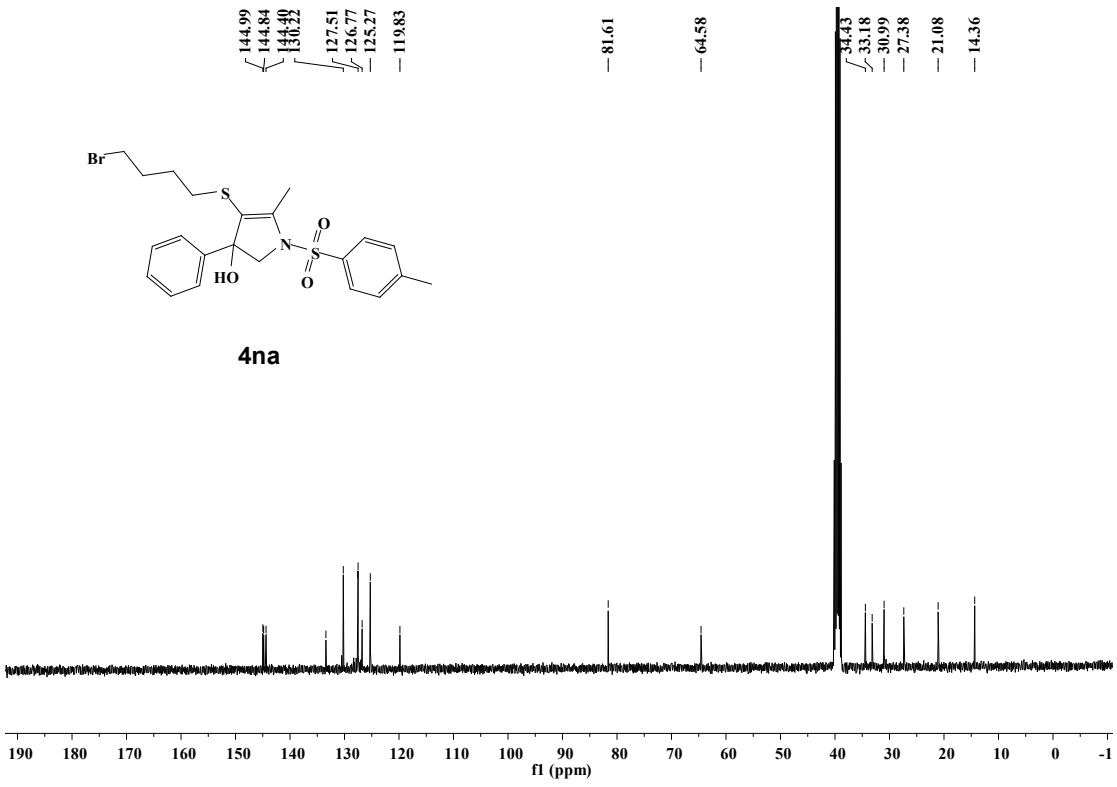

145.44
141.45
128.36
128.22
125.83
118.60
118.16
34.90
26.78
21.09
19.14
11.60
4l
fl (ppm)


7.877
7.856
7.700
7.697
7.679
7.634
7.476
7.455
7.409
7.391
7.371
7.323
7.304
7.286
2.416
2.381
2.331
2.313
2.295
2.277
0.846
0.828
0.810
4m
1.99
2.01
1.01
2.01
2.00
0.97
3.00
3.04
2.08
2.98
f1 (ppm)

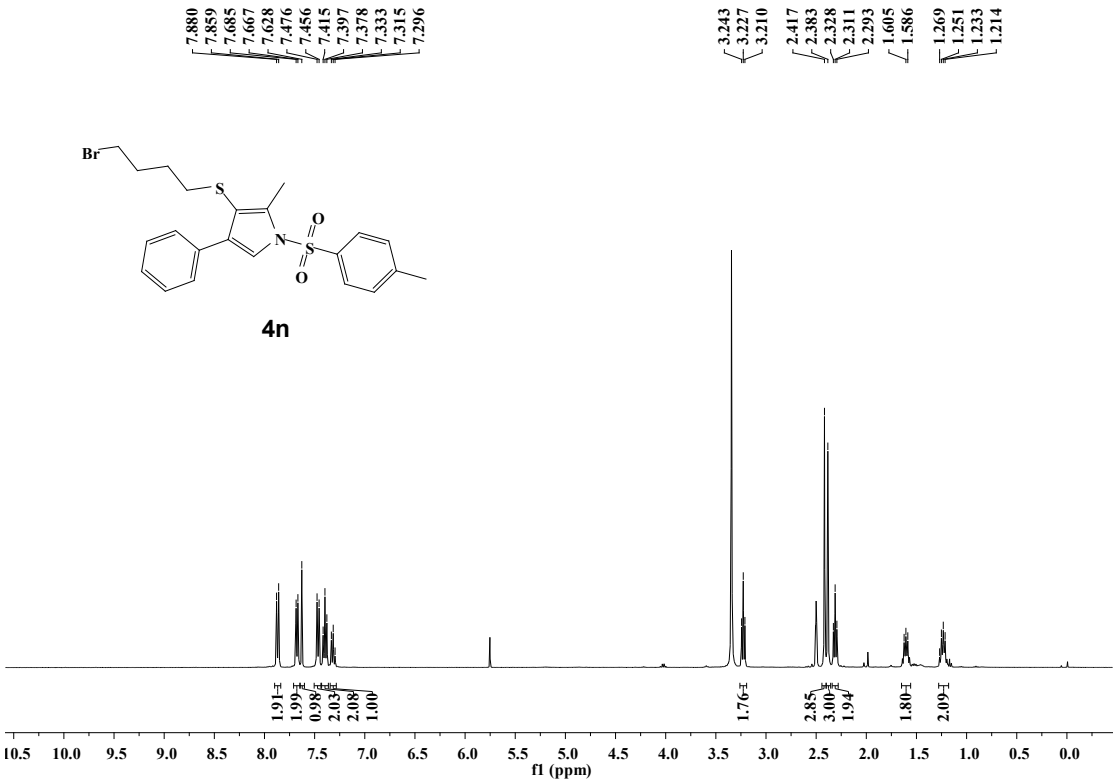

145.78
130.54
128.71
128.33
127.79
127.17
127.00
118.98
114.65
29.14
21.11
14.09
11.89
4m
f1 (ppm)

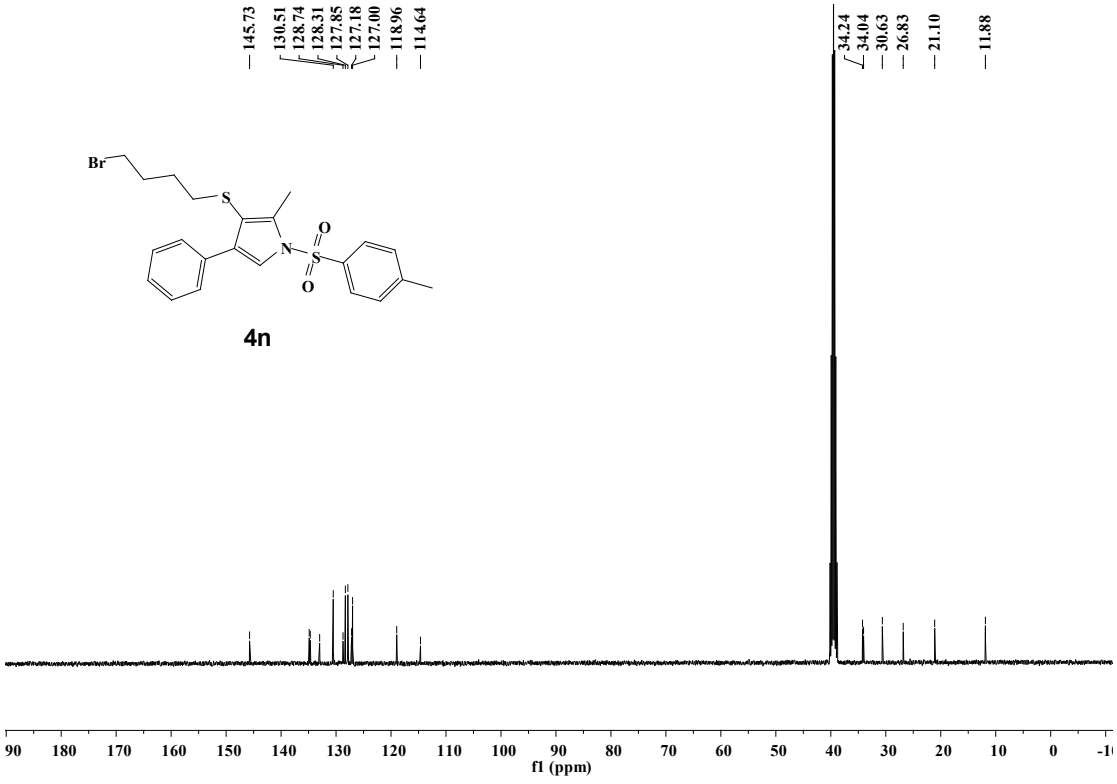

7.766
7.750
7.482
7.154
6.904
6.892
6.888
5.877
3.896
3.872
3.758
3.734
2.460
2.297
1.954
1.569
1.348
1.333
1.319
1.307
1.295
1.279
1.256
1.247
1.233
Br
S
N
O
S
O
HO
1.92
2.01
2.95
1.91
1.00
1.32
1.44
3.03
3.23
1.35
2.23
4.69
f1 (ppm)

4na


144.99
144.84
144.40
130.22
127.51
126.77
125.27
119.83
81.61
64.58
34.43
33.18
30.99
27.38
21.08
14.36
Br
S
N
O
S
O
HO
f1 (ppm)

4na


7.880
7.859
7.685
7.667
7.628
7.476
7.456
7.415
7.397
7.378
7.333
7.315
7.296
3.243
3.227
3.210
2.417
2.383
2.328
2.311
2.293
1.605
1.586
1.269
1.251
1.233
1.214
Br
S
O
N
S
O
4n
1.91
1.99
0.98
2.03
2.08
1.00
1.76
2.85
3.00
1.94
1.80
2.09
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


145.73
130.51
128.74
128.31
127.85
127.18
127.00
118.96
114.64
34.24
34.04
30.63
26.83
21.10
11.88
Br
S
O
N
S
O
4n
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

8. X-ray crystal structure analysis of 3f and 4g

(1) X-ray crystal structure analysis of 3f

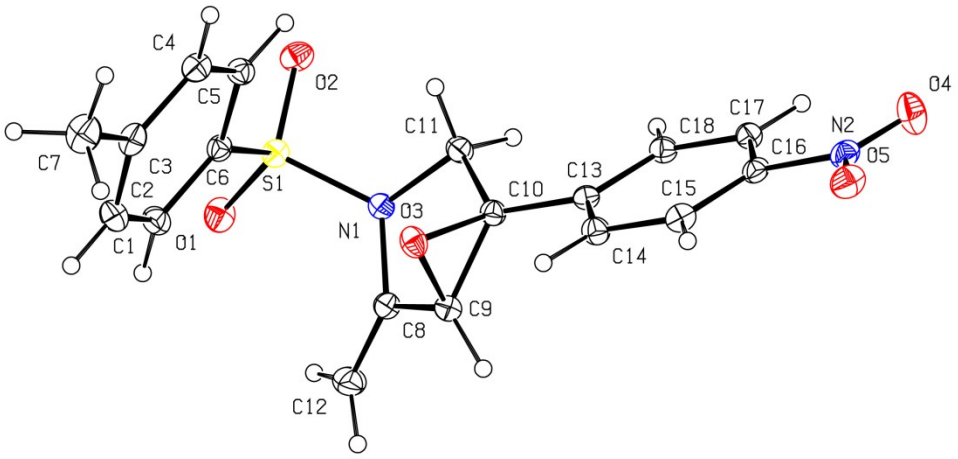


Table 1 Crystal data and structure refinement for 200903_SJA20200812_2_0ma (3f).

Identification code	200903_SJA20200812_2_0ma
Empirical formula	$C_{18}H_{16}N_2O_5S$
Formula weight	372.39
Temperature/K	170.0
Crystal system	monoclinic
Space group	$P2_1/c$
a/Å	8.2430(2)
b/Å	28.1258(8)
c/Å	7.5353(2)
α/°	90
β/°	105.1650(10)
γ/°	90
Volume/Å^3	1686.15(8)
Z	4
ρ_{calc}g/cm^3	1.467
μ/mm^{-1}	0.226
F(000)	776.0
Crystal size/mm^3	0.48 × 0.42 × 0.26
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	5.12 to 54.226
Index ranges	$-10 \le h \le 9$, $-33 \le k \le 36$, $-9 \le l \le 9$
Reflections collected	14151
Independent reflections	3723 [R_{int} = 0.0319, R_{sigma} = 0.0271]
Data/restraints/parameters	3723/0/236
Goodness-of-fit on F^2	1.065

Final R indexes [I>=2σ (I)]	R_1 = 0.0367, wR_2 = 0.0936
Final R indexes [all data]	R_1 = 0.0393, wR_2 = 0.0962
Largest diff. peak/hole / e Å^{-3}	0.38/-0.35

(2) X-ray crystal structure analysis of 4g

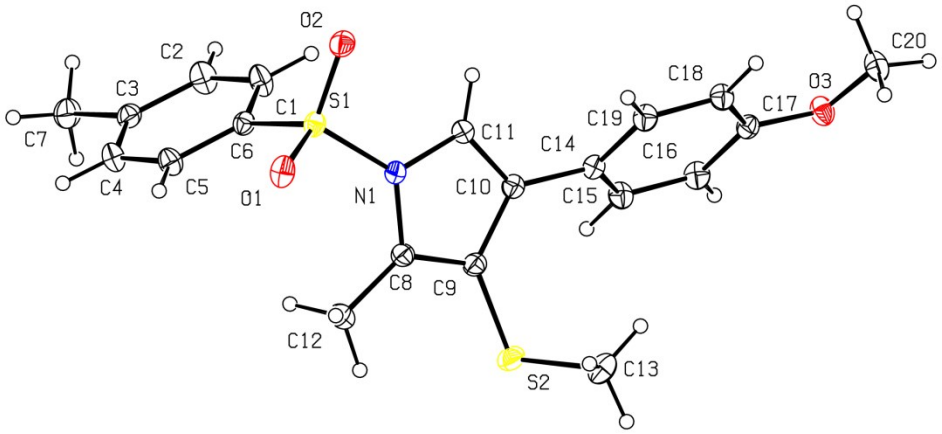


Table 1 Crystal data and structure refinement for 200903_SJA20200812_1_0m (4g).

Identification code	200903_SJA20200812_1_0m
Empirical formula	$C_{20}H_{21}NO_3S_2$
Formula weight	387.50
Temperature/K	170.0
Crystal system	monoclinic
Space group	$P2_1/c$
a/Å	14.1295(4)
b/Å	9.5636(3)
c/Å	14.5227(4)
α/°	90
β/°	102.4220(10)
γ/°	90
Volume/Å^3	1916.49(10)
Z	4
ρ_{calc}g/cm^3	1.343
μ/mm^{-1}	0.297
F(000)	816.0
Crystal size/mm^3	0.46 × 0.28 × 0.19
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	5.138 to 54.224
Index ranges	-18 ≤ h ≤ 18, -11 ≤ k ≤ 12, -18 ≤ l ≤ 18
Reflections collected	29095

Independent reflections	4226 [R_{int} = 0.0277, R_{sigma} = 0.0196]
Data/restraints/parameters	4226/0/239
Goodness-of-fit on F^2	1.051
Final R indexes [I>=2σ (I)]	R_1 = 0.0308, wR_2 = 0.0852
Final R indexes [all data]	R_1 = 0.0338, wR_2 = 0.0878
Largest diff. peak/hole / e $Å^{-3}$	0.45/-0.32