Electronic Supplementary Material (ESI)

Copper-assisted preparation of pyridinyl sulfonate esters from hydroxypyridines and sodium sulfinates

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1. General

Unless otherwise stated, all reagents and solvents were purchased from commercial suppliers and used without further purification. $CDCl_3$ was purchased from Shanghai aladdin Biochemical Technology Co., Ltd. All test tubes and sealed vessels (50 mL) were purchased from Beijing Synthware Glass. The following abbreviations were used to describe NMR signals: s = singlet, d = doublet, t = triplet, m = mulitplet, dd = doublet of doublets, q = quartet.

2. Experimental sections

2.1 General Procedures for synthesis of compound of **3a**.

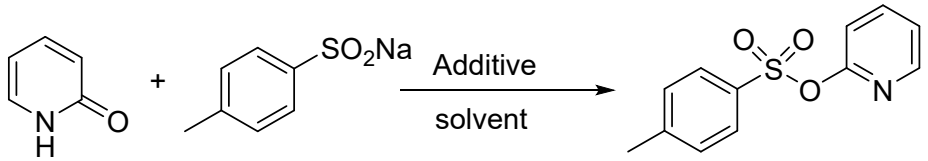
Add 2-hydroxypyridine (**1a**) (0.2 mmol), sodium 4-methylbenzenesulfinate (**2a**) (0.3 mmol) and $CuBr_2$ (1.0 equiv.) followed by 2 mL of MeCN to a 35ml test tube, the mixture was stirred at 90 °C for 6 hours. After cooling to room temperature, directly purified by flash chromatography (petroleum/ethyl acetate 4:1) to give the desired product **3a**.

2.2 General procedure for Sodium sulfinate synthesis. (**2b-2i**)[1]

Sodium 3-methylbenzenesulfinate (**2b**) was prepared by heating 2.04 g of 3-ethylbenzenesulphonyl chloride, 2.5 g of sodium sulfite and 1.7 g of sodium bicarbonate in 5 mL of water at 70 °C for 4 h. After cooling to room temperature, water was removed under vacuum. The residue was extracted by ethanol. The pure product (white solid) was obtained via recrystallization. Similarly, **2c-2i** were prepared from the corresponding sulphonyl chlorides.

2.3 Optimization of reaction conditions.

Table S1 Additive and Solvent Screening[a]

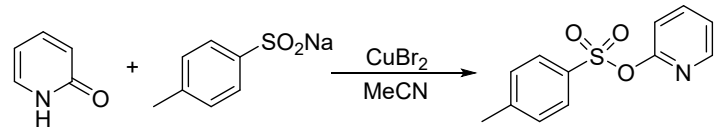


1a **2a** **3a**

Entry	Additive	Solvent	Yield (%)[b]
1	**$CuBr_2$**	**CH_3CN**	**24**
2	$Cu(OTf)_2$	CH_3CN	trace
3	$CuCl_2$	CH_3CN	trace
4	$Cu(OAc)_2$	CH_3CN	trace
5	CuBr	CH_3CN	trace
6	CuI	CH_3CN	0
7	CuO	CH_3CN	0
8	$PdCl_2$	CH_3CN	0
9	$Pd(OAc)_2$	CH_3CN	0
10	$Ni(OTf)_2$	CH_3CN	0
11	$NiCl_2$	CH_3CN	0
12	NHC-Cu	CH_3CN	0
13	NHC-Pd	CH_3CN	0
14	$FeCl_2$	CH_3CN	0
15	$FeCl_3$	CH_3CN	0
16	$CuBr_2$	DMF	0
17	$CuBr_2$	DMSO	0
18	$CuBr_2$	1,4-Dioxane	trace
19	$CuBr_2$	Toluene	trace
20	$CuBr_2$	EtOH	trace
21	$CuBr_2$	H_2O	0
22	$CuBr_2$	DCE	12

[a] Reaction conditions: **1a** (0.20 mmol), **2a** (0.20 mmol), additive (0.2 equiv.) in 2 mL solvent under air at 90 °C for 24 hours. [b] Isolated yield.

Table S2 Ligand Screening[a]

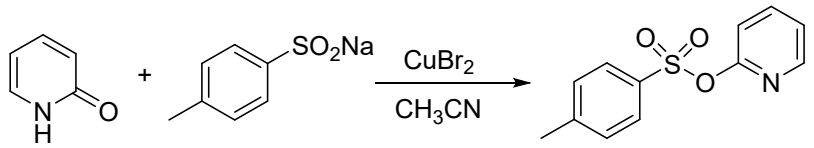


1a **2a** **3a**

Entry	Ligand	Yield (%)[b]
1	4,7-Dimethoxy-1,10-phenanthroline	trace
2	4,4'-Dimethyl-2,2'-bipyridyl	trace
3	4,4'-Dimethoxy-2,2'-bipyridyl	25
4	1,10-phenanthroline	20
5	2,2'-Bipyridine	trace
6	3,4,7,8-Tetramethyl-1,10-phenanthroline	trace
7	4,4'-Di-tert-butyl-2,2'-bipyridine	18

[a] Reaction conditions: **1a** (0.20 mmol), **2a** (0.20 mmol), Ligand (20 mol%), $CuBr_2$ (0.2 equiv.) in 2 mL solvent under air at 90 °C for 24 hours. [b] Isolated yield.

Table S3 Variation of molar ratio, time and the amount of additive in optimization of reaction conditions[a]

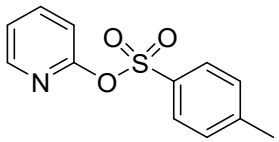


1a **2a** **3a**

Entry	$CuBr_2$ (equiv.)	Time (h)	**1a**:**2a** (mmol)	Yield (%)[b]
1	0.2	24	0.3:0.2	20
2	0.2	24	0.2:0.3	36
3	0.2	24	0.2:0.4	21
4	0.2	36	0.2:0.3	31
5	0.2	12	0.2:0.3	34
6	0.2	6	0.2:0.3	42
7	0.2	3	0.2:0.3	14
8[c]	0.2	6	0.2:0.3	20
9[d]	0.2	6	0.2:0.3	24
10	0.5	6	0.2:0.3	48
11	**1.0**	**6**	**0.2:0.3**	**78**
12	1.5	6	0.2:0.3	45

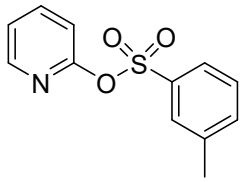
[a] Reaction conditions: **1a**, **2a** and $CuBr_2$ in 2 mL solvent under air at 90 °C. [b] Isolated yield. [c] 70°C. [d] 120 °C.

3. Data for the sulfonate esters products.



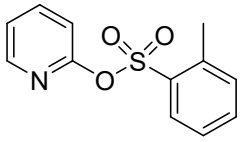
pyridin-2-yl 4-methylbenzenesulfonate (3a)[2]

Colorless solid; mp (48.9-51.2°C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (d, *J* = 3.5 Hz, 1H), 7.89 (d, *J* = 8.1 Hz, 2H), 7.77 (t, *J* = 7.7 Hz, 1H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.24 – 7.18 (m, 1H), 7.11 (d, *J* = 8.1 Hz, 1H), 2.45 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.98, 148.37, 145.27, 140.13, 133.64, 129.90, 128.63, 122.67, 116.05, 22.06.



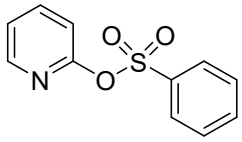
pyridin-2-yl 3-methylbenzenesulfonate (3b)

colorless liquid, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.27 (d, *J* = 6.8 Hz, 1H), 7.83 (s, 1H), 7.79 (m, *J* = 13.6, 7.6 Hz, 2H), 7.45 (m, *J* = 15.3, 7.7 Hz, 2H), 7.23 (dd, *J* = 7.3, 4.9 Hz, 1H), 7.12 (d, *J* = 8.2 Hz, 1H), 2.44 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.91, 148.37, 140.16, 139.44, 136.45, 135.04, 128.94, 128.77, 125.69, 122.72, 115.94, 21.35; HRMS (ESI) calcd for $C_{12}H_{11}NO_3S$ $(M + H)^+$ 250.0532, found 250.0535.



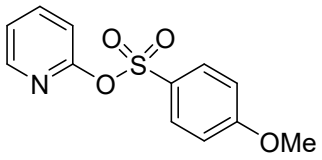
pyridin-2-yl 2-methylbenzenesulfonate (3c)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (d, *J* = 6.5 Hz, 1H), 7.97 (d, *J* = 7.9 Hz, 1H), 7.76 (t, *J* = 8.6 Hz, 1H), 7.53 (t, *J* = 7.5 Hz, 1H), 7.39 (d, *J* = 7.6 Hz, 1H), 7.31 (t, *J* = 7.7 Hz, 1H), 7.20 (dd, *J* = 7.3, 4.9 Hz, 1H), 7.13 (d, *J* = 8.2 Hz, 1H), 2.80 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.80, 148.45, 140.10, 138.87, 135.31, 134.12, 132.55, 130.19, 126.11, 122.72, 115.85, 20.58; HRMS (ESI) calcd for $C_{12}H_{11}NO_3S$ $(M + H)^+$ 250.0532, found 250.0532.



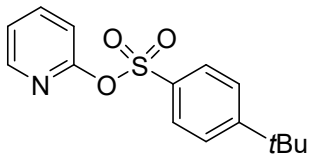
pyridin-2-yl benzenesulfonate (3d)[3]

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.25 (d, *J* = 6.7 Hz, 1H), 8.02 (d, *J* = 8.2 Hz, 2H), 7.81 – 7.75 (m, 1H), 7.67 (t, *J* = 7.5 Hz, 1H), 7.56 (t, *J* = 7.9 Hz, 2H), 7.23 (dd, *J* = 7.3, 4.9 Hz, 1H), 7.11 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.92, 148.34, 140.21, 136.67, 134.22, 129.11, 128.57, 122.77, 115.90.



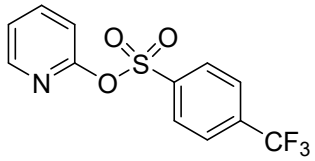
pyridin-2-yl 4-methoxybenzenesulfonate (3e)[4]

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.26 (d, *J* = 6.4 Hz, 1H), 7.93 (d, *J* = 8.9 Hz, 2H), 7.77 (t, *J* = 7.8 Hz, 1H), 7.22 (dd, *J* = 7.2, 5.0 Hz, 1H), 7.10 (d, *J* = 8.2 Hz, 1H), 7.00 (d, *J* = 8.9 Hz, 2H), 3.88 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 164.11, 157.01, 148.32, 140.13, 130.91, 127.83, 122.63, 115.96, 114.29, 55.76.



pyridin-2-yl 4-(tert-butyl)benzenesulfonate (3f)

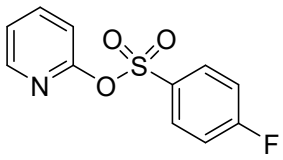
colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.28 (d, *J* = 6.4 Hz, 1H), 7.94 (d, *J* = 8.6 Hz, 2H), 7.78 (t, *J* = 7.8 Hz, 1H), 7.56 (d, *J* = 8.9 Hz, 2H), 7.23 (dd, *J* = 7.3, 4.9 Hz, 1H), 7.13 (d, *J* = 8.2 Hz, 1H), 1.35 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 158.19, 156.98, 148.35, 140.14, 133.59, 128.43, 126.15, 122.66, 115.95, 35.36, 31.04; HRMS (ESI) calcd for $C_{15}H_{17}NO_3S$ $(M + H)^+$ 292.1002, found 292.1008.



pyridin-2-yl 4-(trifluoromethyl)benzenesulfonate (3g)

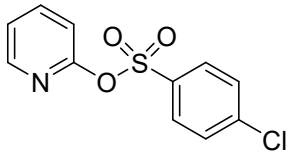
colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.24 (dd, *J* = 4.8, 1.8 Hz, 1H), 8.19 (d,

J = 8.4 Hz, 2H), 7.83 (m, *J* = 13.5, 8.0 Hz, 3H), 7.27 – 7.24 (m, 1H), 7.15 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.89, 148.25, 140.51, 140.48, 135.56 (q, JC-F=33.26 Hz), 129.26, 126.22 (q, JC-F=3.65 Hz), 123.02, 132.09 (q, JC-F=273.67 Hz), 115.74; HRMS (ESI) calcd for $C_{12}H_8F_3NO_3S$ $(M + H)^+$ 304.0250, found 304.0253.



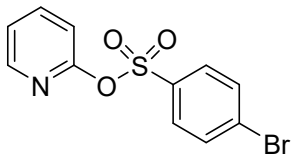
pyridin-2-yl 4-fluorobenzenesulfonate (3h)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.25 (dd, *J* = 4.7, 1.7 Hz, 1H), 8.09 – 8.03 (m, 2H), 7.80 (ddd, *J* = 8.1, 7.4, 2.0 Hz, 1H), 7.26 – 7.20 (m, 3H), 7.13 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 166.00 (d, *JC-F* = 257.5 Hz), 156.93, 148.28, 140.31, 132.73 (d, *JC-F* = 3.276 Hz), 131.61 (d, *JC-F* = 1.248 Hz), 122.84, 116.55, 116.37, 115.88; HRMS (ESI) calcd for $C_{11}H_8FNO_3S$ $(M + H)^+$ 254.0282, found 254.0285.



pyridin-2-yl 4-chlorobenzenesulfonate (3i)

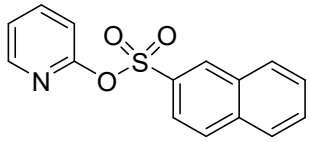
colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.24 (dd, *J* = 4.8, 1.8 Hz, 1H), 7.97 (d, *J* = 8.6 Hz, 2H), 7.82 – 7.77 (m, 1H), 7.53 (d, *J* = 8.6 Hz, 2H), 7.24 (dd, *J* = 6.7, 4.9 Hz, 1H), 7.13 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.88, 148.25, 140.86, 140.30, 135.22, 130.09, 129.40, 122.85, 115.81; HRMS (ESI) calcd for $C_{11}H_8ClNO_3S$ $(M + H)^+$ 269.9986, found 269.9992.



pyridin-2-yl 4-bromobenzenesulfonate (3j)

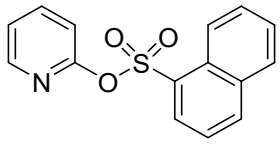
colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.24 (d, *J* = 3.0 Hz, 1H), 7.89 (d, *J* = 8.6 Hz, 2H), 7.80 (m, *J* = 7.8 Hz, 1H), 7.70 (d, *J* = 6.9 Hz, 2H), 7.24 (dd, *J* = 7.0, 5.2 Hz, 1H), 7.12 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.91, 148.29, 140.35, 135.82, 132.42, 130.15, 129.53, 122.89, 115.89; HRMS (ESI) calcd for

$C_{11}H_8BrNO_3S$ $(M + H)^+$ 313.9481, found 313.9482.



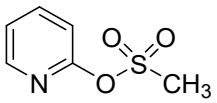
pyridin-2-yl naphthalene-2-sulfonate (3k)[3]

Colorless solid; mp (69.6-70.6°C); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.56 (s, 1H), 8.22 (d, *J* = 4.8 Hz, 1H), 8.00 (s, 2H), 7.96 (d, *J* = 8.1 Hz, 1H), 7.92 (d, *J* = 8.2 Hz, 1H), 7.76 (t, *J* = 7.8 Hz, 1H), 7.67 (t, *J* = 7.2 Hz, 1H), 7.62 (t, *J* = 7.3 Hz, 1H), 7.20 (dd, *J* = 7.1, 5.0 Hz, 1H), 7.13 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.98, 148.38, 140.21, 135.49, 133.54, 131.87, 130.52, 129.58, 129.54, 129.44, 128.04, 127.77, 123.09, 122.76, 115.91; HRMS (ESI) calcd for $C_{15}H_{11}NO_3S$ $(M + H)^+$ 286.0532, found 286.0537.



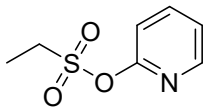
pyridin-2-yl naphthalene-1-sulfonate (3l)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.80 (d, *J* = 8.7 Hz, 1H), 8.29 (d, *J* = 7.4 Hz, 1H), 8.15 (m, *J* = 16.0, 6.6 Hz, 2H), 7.96 (d, *J* = 8.2 Hz, 1H), 7.76 – 7.68 (m, 2H), 7.66 – 7.61 (m, 1H), 7.56 – 7.51 (t, 1H), 7.18 – 7.13 (m, 1H), 7.03 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.91, 148.48, 140.10, 135.72, 134.09, 132.29, 130.81, 128.96, 128.92, 128.59, 127.28, 124.98, 124.01, 122.69, 115.62; HRMS (ESI) calcd for $C_{15}H_{11}NO_3S$ $(M + H)^+$ 286.0532, found 286.0532.



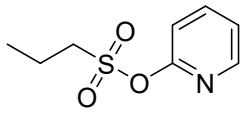
pyridin-2-yl methanesulfonate (3m)[2]

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.36 (dd, *J* = 4.9, 1.4 Hz, 1H), 7.87 – 7.81 (m, 1H), 7.30 (dd, *J* = 6.6, 5.7 Hz, 1H), 7.13 (d, *J* = 8.2 Hz, 1H), 3.51 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 157.47, 148.11, 140.60, 122.81, 115.72, 40.76.



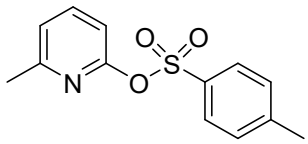
pyridin-2-yl ethanesulfonate (3n)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.35 (dd, *J* = 4.9, 1.9 Hz, 1H), 7.83 (m, *J* = 7.8, 1.8 Hz, 1H), 7.28 (m, *J* = 7.2, 4.8 Hz, 1H), 7.15 (d, *J* = 8.7 Hz, 1H), 3.69 (q, *J* = 7.4 Hz, 2H), 1.58 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 157.39, 148.19, 140.47, 122.72, 115.93, 48.06, 8.28; HRMS (ESI) calcd for $C_7H_9NO_3S$ $(M + H)^+$ 188.0376, found 188.0378.



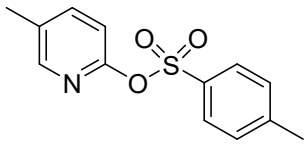
pyridin-2-yl propane-1-sulfonate (3o)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.35 (dd, *J* = 4.9, 1.9 Hz, 1H), 7.82 (td, *J* = 7.8, 2.0 Hz, 1H), 7.32 – 7.26 (m, 1H), 7.14 (d, *J* = 8.1 Hz, 1H), 3.70 – 3.60 (m, 2H), 2.12 – 2.01 (m, 2H), 1.14 (t, *J* = 7.5 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 157.40, 148.18, 140.45, 122.69, 115.93, 55.07, 17.34, 12.88; HRMS (ESI) calcd for $C_8H_{11}NO_3S$ $(M + H)^+$ 202.0532, found 202.0535.



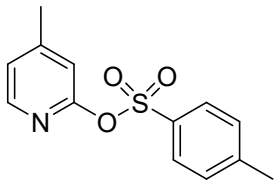
6-methylpyridin-2-yl 4-methylbenzenesulfonate (4a)[2]

Colorless solid; mp (69.1-70.3^{o}C); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (d, *J* = 8.4 Hz, 2H), 7.63 (t, *J* = 7.8 Hz, 1H), 7.34 (d, *J* = 8.5 Hz, 2H), 7.05 (d, *J* = 7.5 Hz, 1H), 6.90 (d, *J* = 8.1 Hz, 1H), 2.45 (s, 3H), 2.41 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 158.09, 156.24, 145.21, 140.13, 133.83, 129.55, 128.79, 122.06, 112.23, 23.81, 21.75.



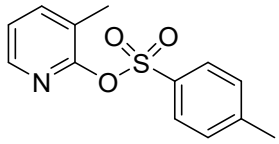
5-methylpyridin-2-yl 4-methylbenzenesulfonate (4b)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 (s, 1H), 7.85 (d, *J* = 8.2 Hz, 2H), 7.56 (d, *J* = 8.2 Hz, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.00 (d, *J* = 8.2 Hz, 1H), 2.44 (s, 3H), 2.30 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.94, 148.22, 145.27, 140.66, 133.58, 132.61, 129.73, 128.53, 115.51, 21.76, 17.72.



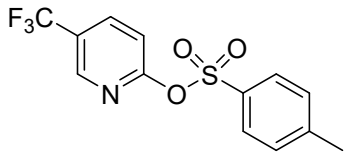
4-methylpyridin-2-yl 4-methylbenzenesulfonate (4c)[2]

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.09 (d, *J* = 5.1 Hz, 1H), 7.88 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.0 Hz, 2H), 7.03 (d, *J* = 5.6 Hz, 1H), 6.94 (s, 1H), 2.44 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 157.17, 152.07, 147.78, 145.26, 133.72, 129.70, 128.56, 123.88, 116.41, 21.76, 21.03.



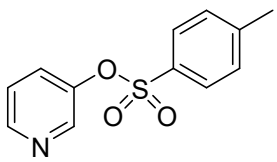
3-methylpyridin-2-yl 4-methylbenzenesulfonate (4d)[2]

Colorless solid; mp (65.3-65.8^{o}C); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 (d, *J* = 6.0 Hz, 1H), 7.95 (d, *J* = 8.3 Hz, 2H), 7.59 (d, *J* = 7.4 Hz, 1H), 7.36 (d, *J* = 8.1 Hz, 2H), 7.12 (dd, *J* = 7.4, 4.8 Hz, 1H), 2.46 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.14, 145.39, 145.10, 141.10, 134.52, 129.65, 128.62, 125.50, 122.68, 21.77, 16.15.



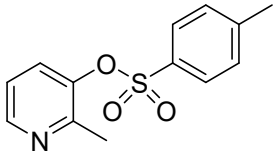
5-(trifluoromethyl)pyridin-2-yl 4-methylbenzenesulfonate (4e)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.45 (d, *J* = 5.1 Hz, 1H), 7.92 (d, *J* = 8.3 Hz, 2H), 7.44 (d, *J* = 5.1 Hz, 1H), 7.37 (d, *J* = 8.4 Hz, 2H), 7.31 (s, 1H), 2.47 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 157.59, 149.58, 145.86, 142.37 (q, *JC-F*=35 Hz), 133.25, 129.86, 128.74, 121.95 (q, *JC-F*=274 Hz), 118.29 (q, *JC-F*=3.28 Hz), 112.17 (q, *JC-F*=3.78 Hz) 21.79; HRMS (ESI) calcd for $C_{13}H_{10}F_3NO_3S$ $(M + H)^+$ 318.0406, found 318.0410.



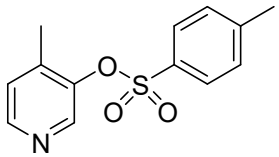
pyridin-3-yl 4-methylbenzenesulfonate(4f)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.51 (d, *J* = 4.6 Hz, 1H), 8.16 (d, *J* = 2.5 Hz, 1H), 7.70 (d, *J* = 8.3 Hz, 2H), 7.49 (d, *J* = 9.7 Hz, 1H), 7.37 – 7.30 (m, 3H), 2.46 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 148.07, 146.53, 146.12, 143.85, 131.56, 130.46, 130.08, 128.53, 124.34, 21.79.



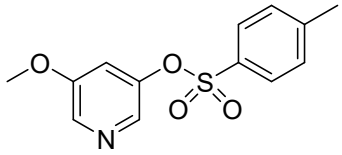
2-methylpyridin-3-yl 4-methylbenzenesulfonate (4g)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.39 (d, *J* = 4.6 Hz, 1H), 7.72 (d, *J* = 8.3 Hz, 2H), 7.47 (d, *J* = 9.5 Hz, 1H), 7.35 (d, *J* = 8.4 Hz, 2H), 7.15 (dd, *J* = 8.2, 4.7 Hz, 1H), 2.46 (s, 3H), 2.21 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.63, 147.38, 146.01, 144.94, 132.42, 130.24, 130.08, 128.39, 122.07, 21.77, 19.33; HRMS (ESI) calcd for $C_{13}H_{13}NO_3S$ $(M + H)^+$ 264.0689, found 264.0689.



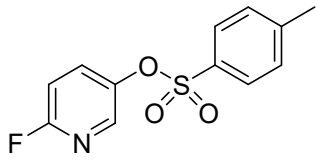
4-methylpyridin-3-yl 4-methylbenzenesulfonate (4h)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.35 (d, *J* = 4.7 Hz, 1H), 8.06 (s, 1H), 7.74 (m, *J* = 17.7, 8.3 Hz, 2H), 7.37 (d, *J* = 8.2 Hz, 2H), 7.17 (d, *J* = 4.8 Hz, 1H), 2.49 (s, 3H), 2.21 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 147.69, 146.05, 143.64, 141.65, 132.31, 130.44, 130.14, 128.51, 126.44, 21.81, 16.11; HRMS (ESI) calcd for $C_{13}H_{13}NO_3S$ $(M + H)^+$ 264.0689, found 264.0692.



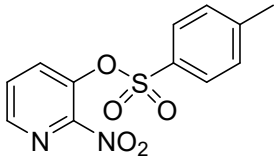
5-methoxypyridin-3-yl 4-methylbenzenesulfonate (4i)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (s, 1H), 7.72 (d, *J* = 6.9 Hz, 3H), 7.34 (d, *J* = 7.9 Hz, 2H), 7.04 (s, 1H), 3.83 (s, 3H), 2.46 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.21, 146.75, 146.07, 136.53, 135.45, 131.61, 130.05, 128.56, 115.09, 55.97, 21.79; HRMS (ESI) calcd for $C_{13}H_{13}NO_4S$ $(M + H)^+$ 280.0638, found 280.0643.



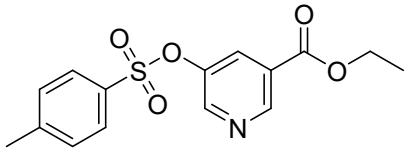
6-fluoropyridin-3-yl 4-methylbenzenesulfonate (4j)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77 – 7.67 (m, 3H), 7.56 (m, *J* = 9.1, 6.4, 2.9 Hz, 1H), 7.36 (d, *J* = 8.0 Hz, 2H), 6.92 (dd, *J* = 8.8, 3.4 Hz, 1H), 2.47 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 161.27 (d, *JC-F*=241 Hz) 146.32, 144.16 (d, *JC-F*=4.9 Hz), 141.47 (d, *JC-F*=16 Hz), 135.71 (d, *JC-F*=9.1 Hz), 131.20, 130.16, 128.59, 110.45 (d, *JC-F*=40.6 Hz), 22.05; HRMS (ESI) calcd for $C_{12}H_{10}FNO_3S$ $(M + H)^+$ 268.0438, found 268.0444.



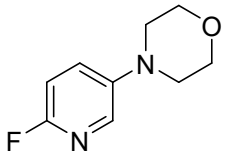
2-nitropyridin-3-yl 4-methylbenzenesulfonate (4k)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.45 (dd, *J* = 4.6, 1.4 Hz, 1H), 8.01 (dd, *J* = 8.3, 1.4 Hz, 1H), 7.74 (d, *J* = 8.4 Hz, 2H), 7.68 (dd, *J* = 8.3, 4.6 Hz, 1H), 7.37 (d, *J* = 8.1 Hz, 2H), 2.48 (s, 3H); 13C NMR (126 MHz, CDCl3) δ 150.86, 147.07, 146.25, 137.73, 135.06, 130.79, 130.34, 129.17, 128.67, 21.89; HRMS (ESI) calcd for $C_{12}H_{10}N_2O_5S$ $(M + H)^+$ 295.0383, found 295.0389.



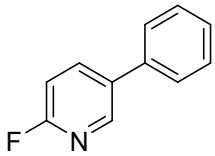
ethyl 5-(tosyloxy)nicotinate (4l)

colorless liquid**,** ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.11 (s, 1H), 8.33 (s, 1H), 8.06 – 8.01 (m, 1H), 7.73 (d, *J* = 8.3 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 4.41 (q, *J* = 7.1 Hz, 2H), 2.47 (s, 3H), 1.41 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 163.95, 149.05, 147.53, 146.35, 146.18, 131.42, 130.98, 130.19, 128.55, 127.45, 61.98, 21.81, 14.23; HRMS (ESI) calcd for $C_{15}H_{15}NO_5S$ $(M + H)^+$ 322.0744, found 322.0748.



4-(6-fluoropyridin-3-yl)morpholine (5a)[5]

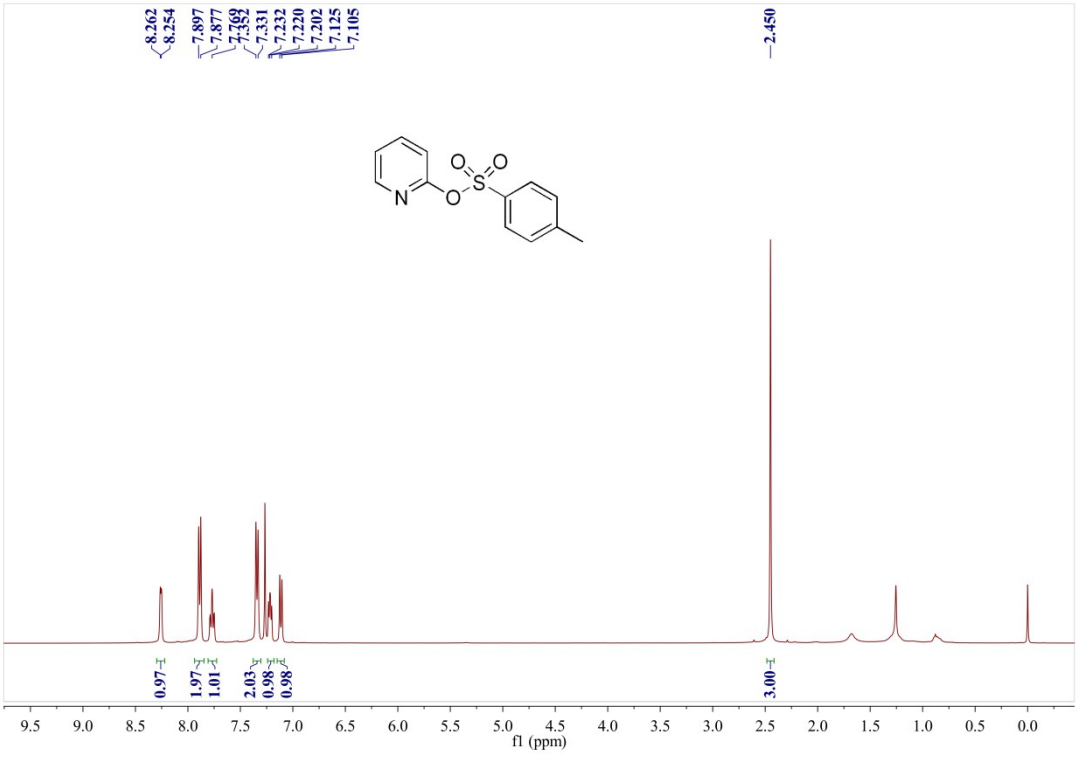
^{1}H NMR (500 MHz, DMSO) δ 7.75 (d, *J* = 2.9 Hz, 1H), 7.08 (dd, *J* = 8.9, 3.0 Hz, 1H), 6.72 (d, *J* = 9.0 Hz, 1H), 3.70 (t, *J* = 4.5 Hz, 4H), 3.23 (t, *J* = 4.5 Hz, 4H).

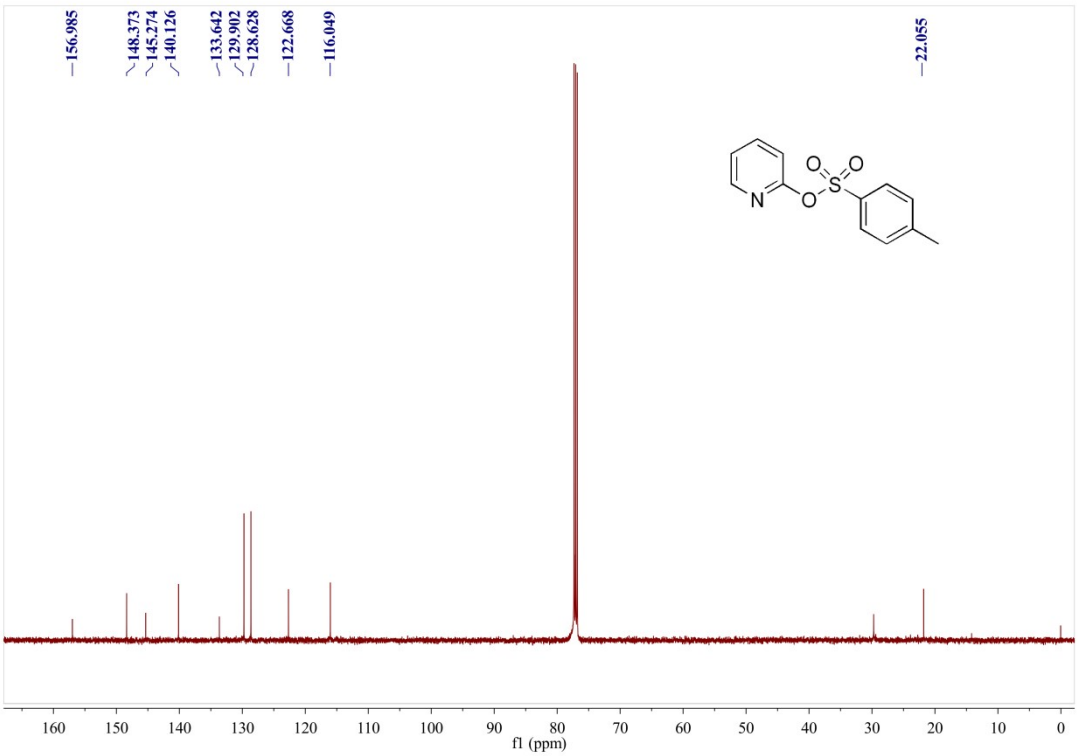


2-fluoro-5-phenylpyridine (5b)[6]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.35 (s, 1H), 7.90 (t, *J* = 8.0 Hz, 1H), 7.40 (m, *J* = 33.3, 19.9, 7.3 Hz, 5H), 6.95 (d, *J* = 2.8 Hz, 1H).

4. ^{1}H NMR and ^{13}C NMR spectra for compounds.

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133.642
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128.628
122.668
116.049
22.055
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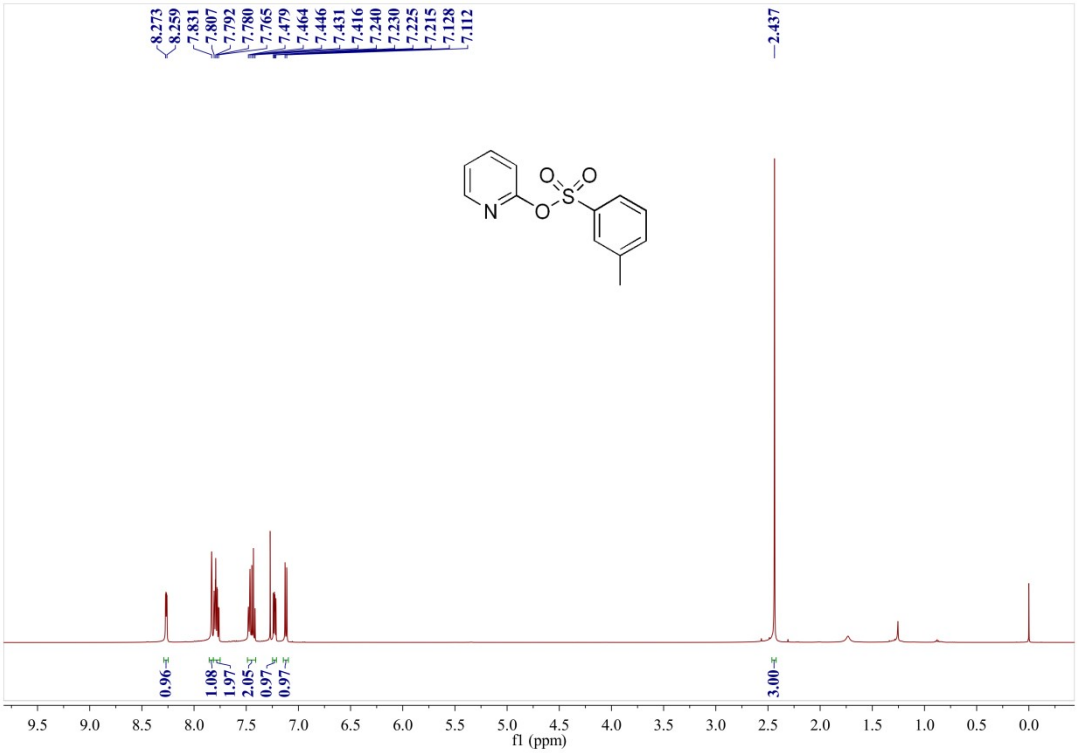
O
O
S
O
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.831
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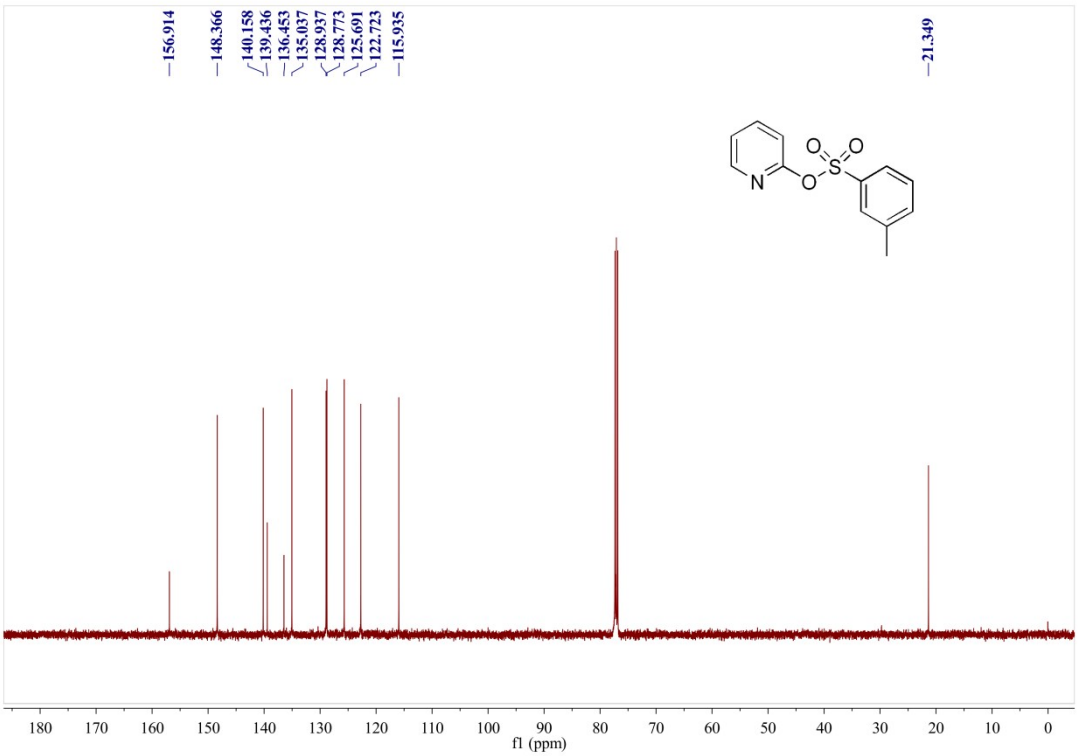
7.230
7.225
7.215
7.128
7.112
2.437
N
O
O
S
O
0.96
1.08
1.97
2.05
0.97
0.97
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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S
O
O
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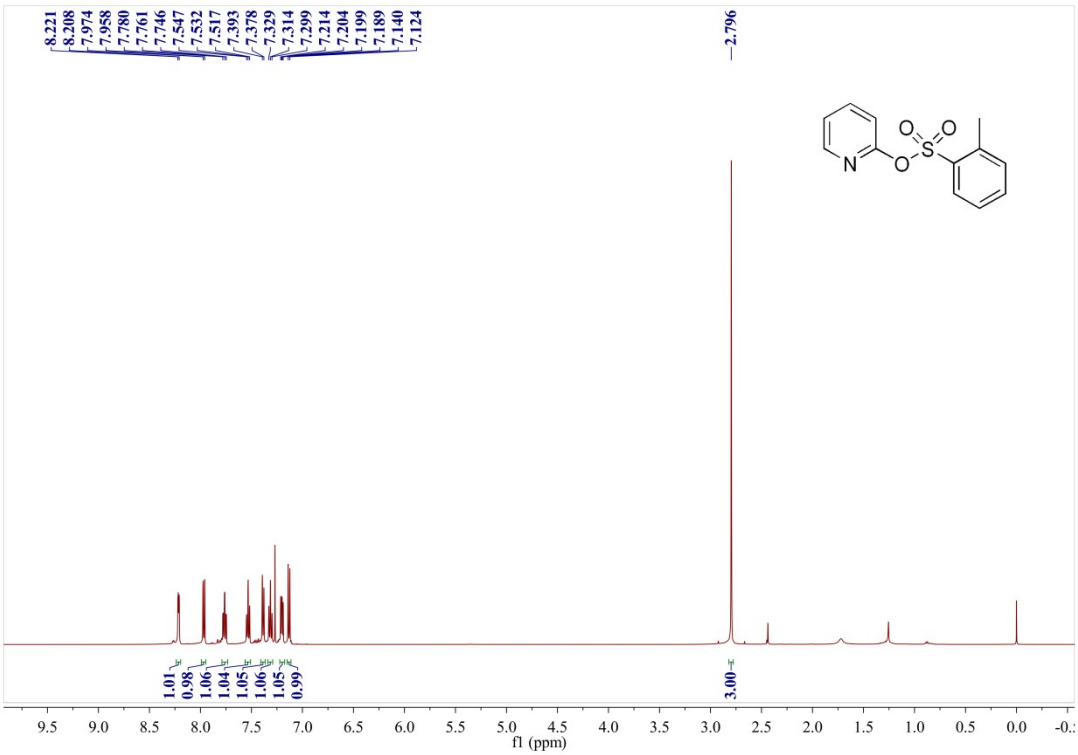
f1 (ppm)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8.208
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7.761
7.746
7.547
7.532
7.517
7.393
7.378
7.329
7.314
7.299
7.214
7.204
7.199
7.189
7.140
7.124
2.796
N
O
S
O
O
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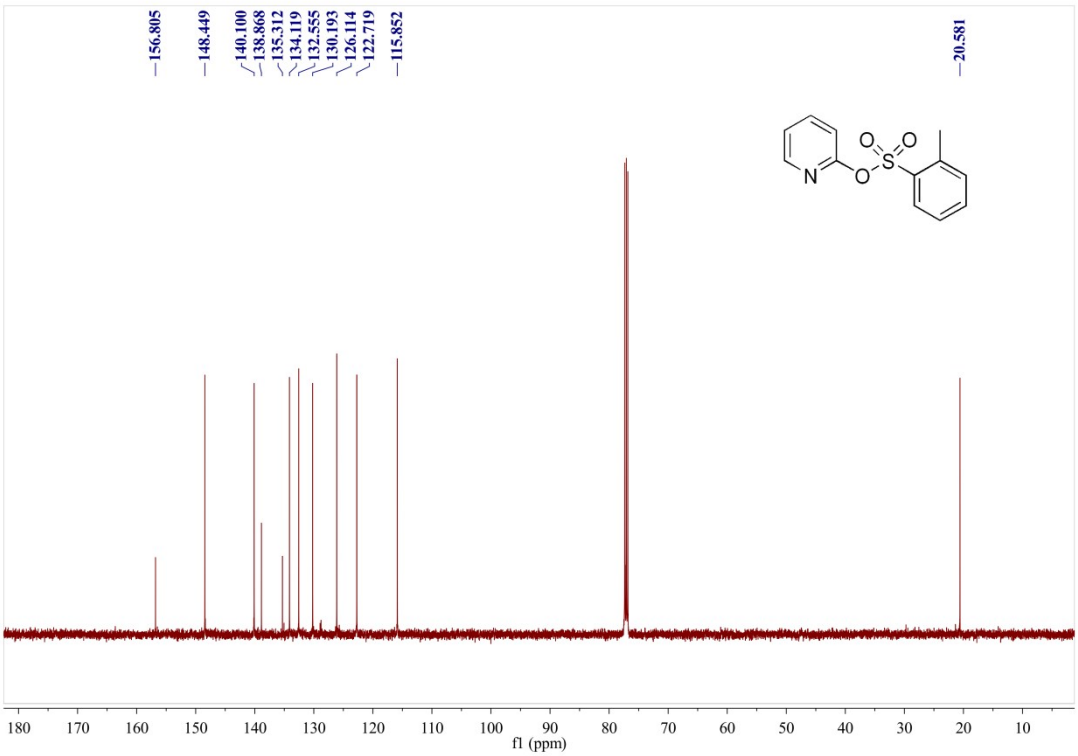
0.98
1.06
1.04
1.05
1.06
1.05
0.99
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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135.312
134.119
132.555
130.193
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O
O
S
O
N
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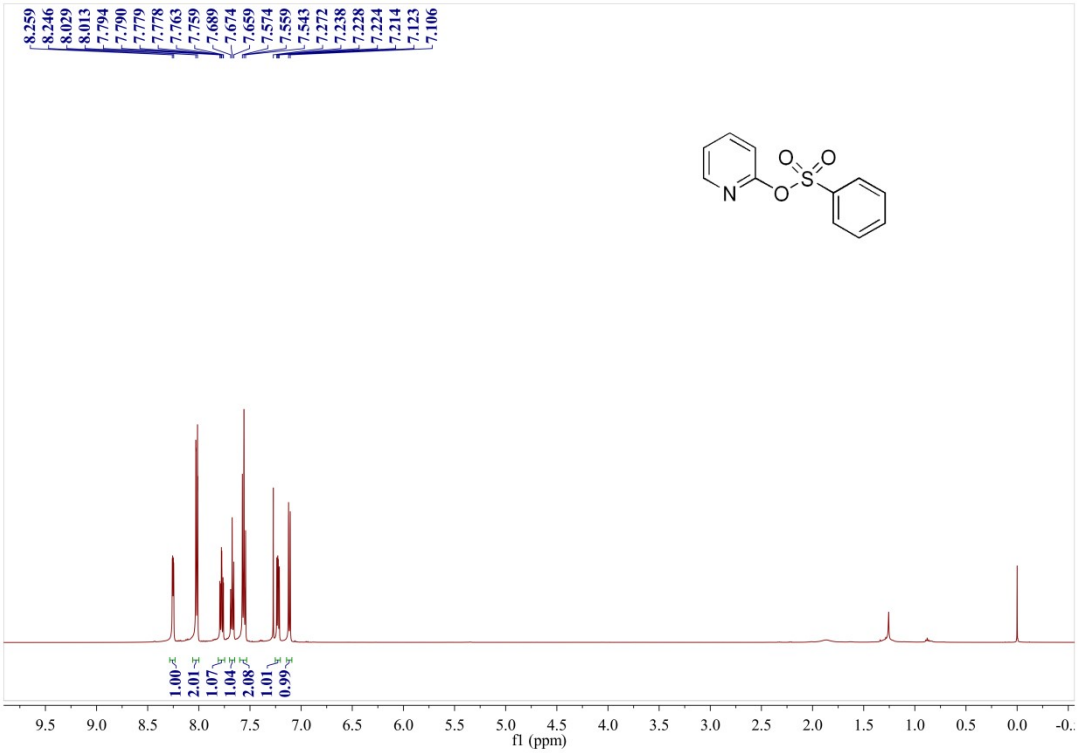
f1 (ppm)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8.013
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7.779
7.778
7.763
7.759
7.689
7.674
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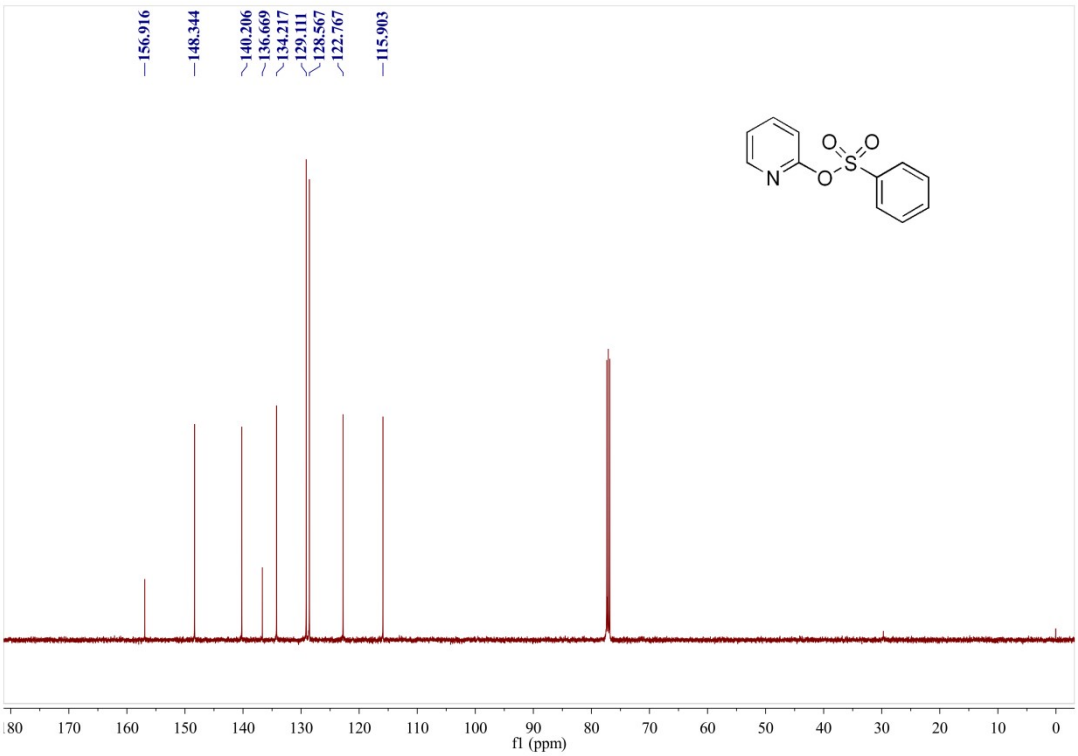
7.574
7.559
7.543
7.272
7.238
7.228
7.224
7.214
7.123
7.106
O
O
S
O
N
1.00
2.01
1.07
1.04
2.08
1.01
0.99
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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134.217
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115.903
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S
O
N
O
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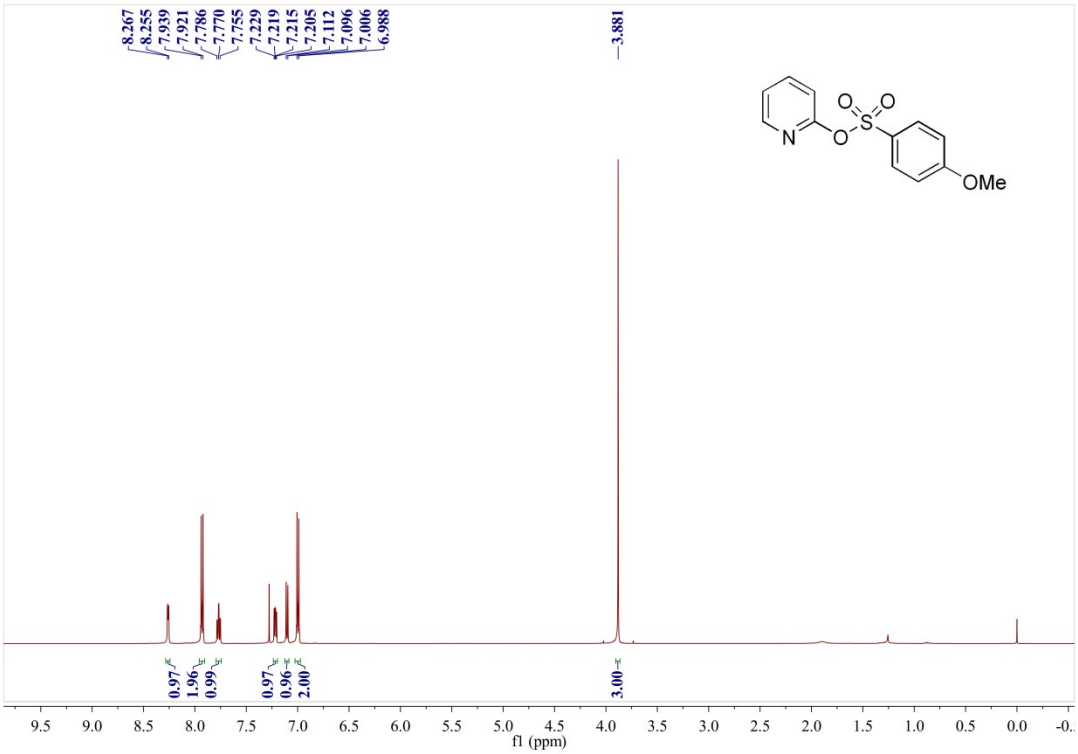
f1 (ppm)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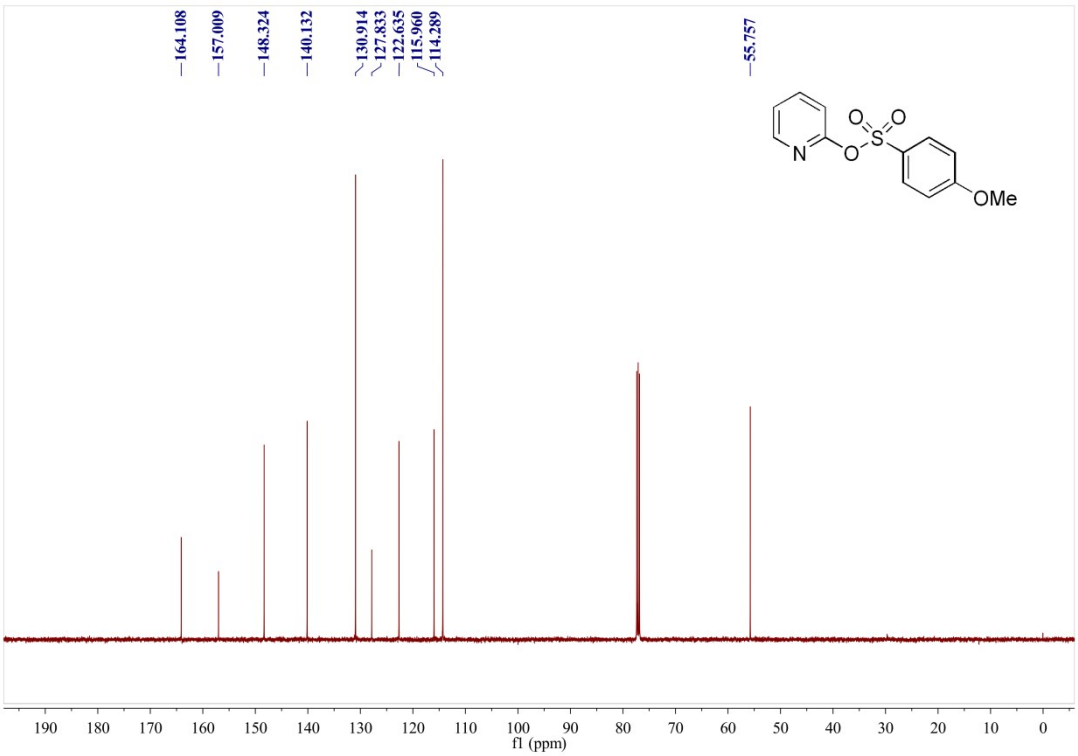
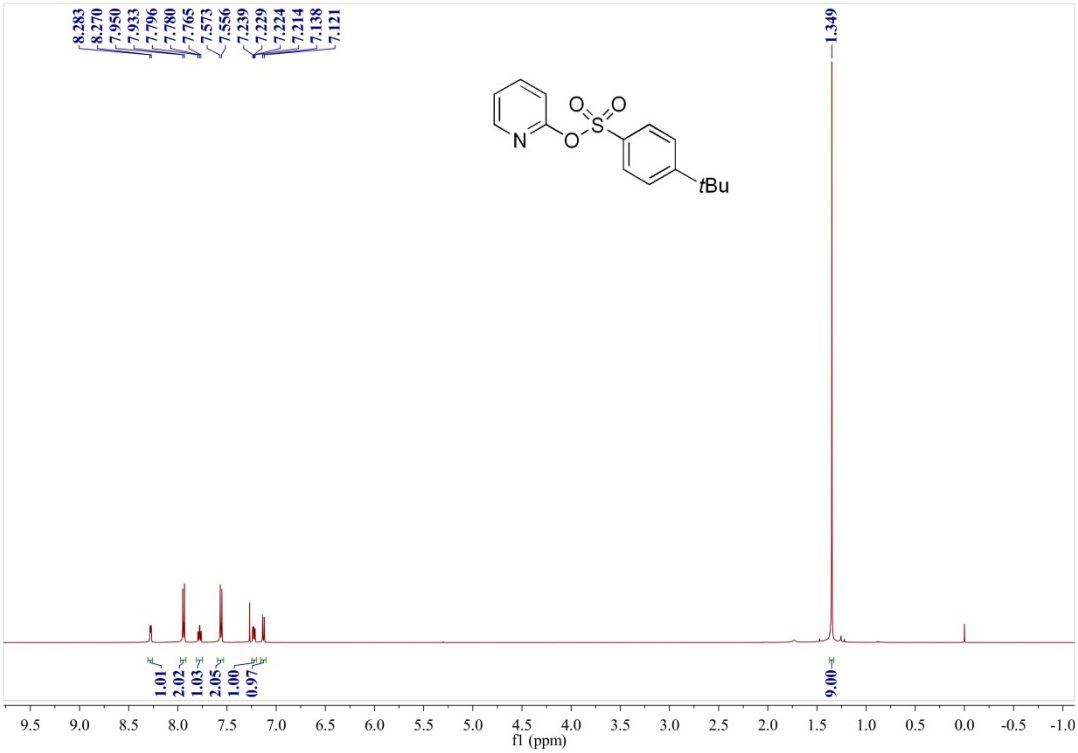
7.921
7.786
7.770
7.755
7.229
7.219
7.215
7.205
7.112
7.096
7.006
6.988
3.881
O
S
O
N
O
OMe
0.97
1.96
0.99
0.97
0.96
2.00
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


164.108
157.009
148.324
140.132
130.914
127.833
122.635
115.960
114.289
55.757
OMe
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.765
7.573
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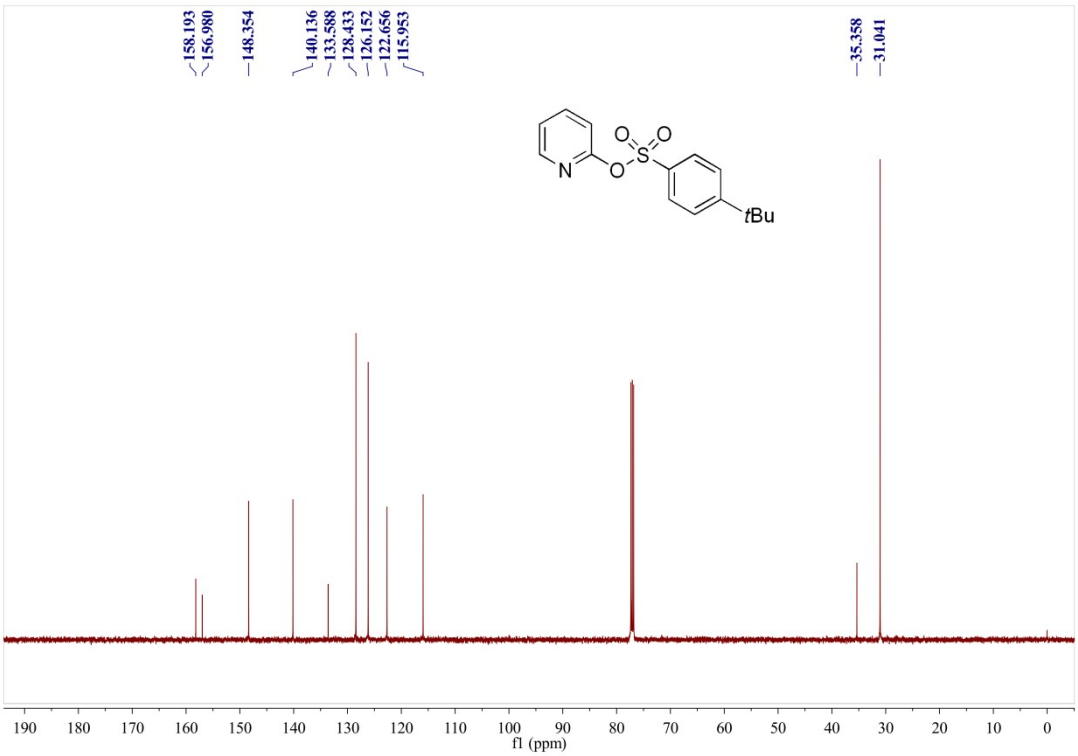
7.239
7.229
7.224
7.214
7.138
7.121
1.349
tBu
1.01
2.02
1.03
2.05
1.00
0.97
9.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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126.152
122.656
115.953
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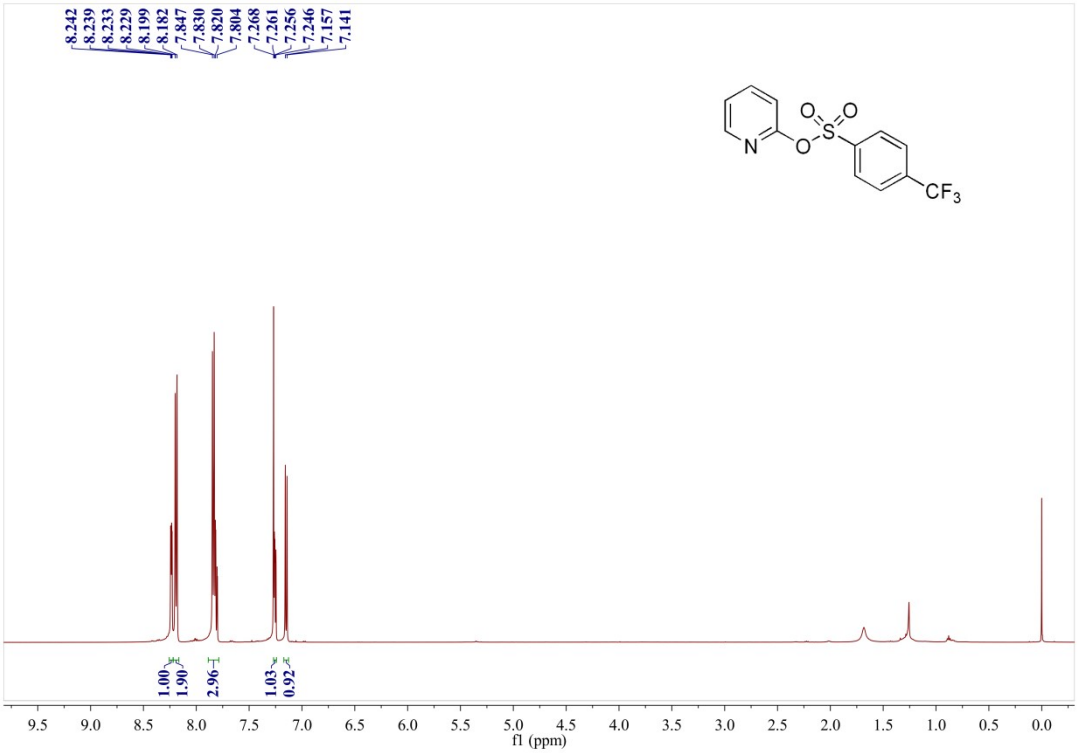
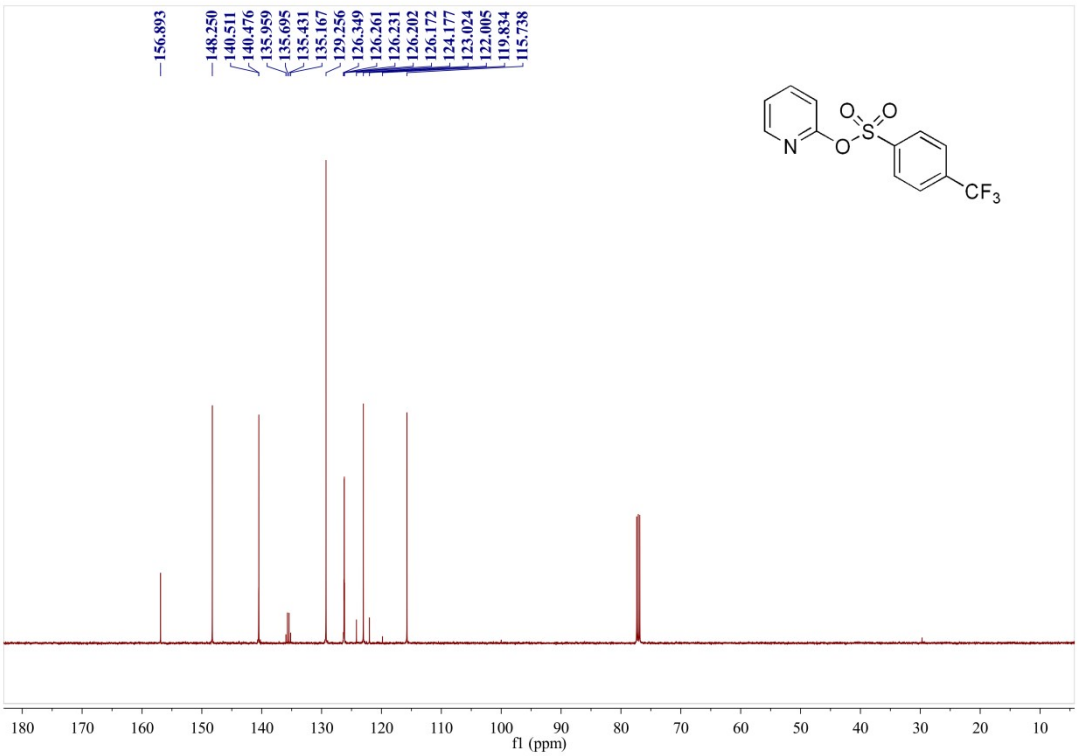
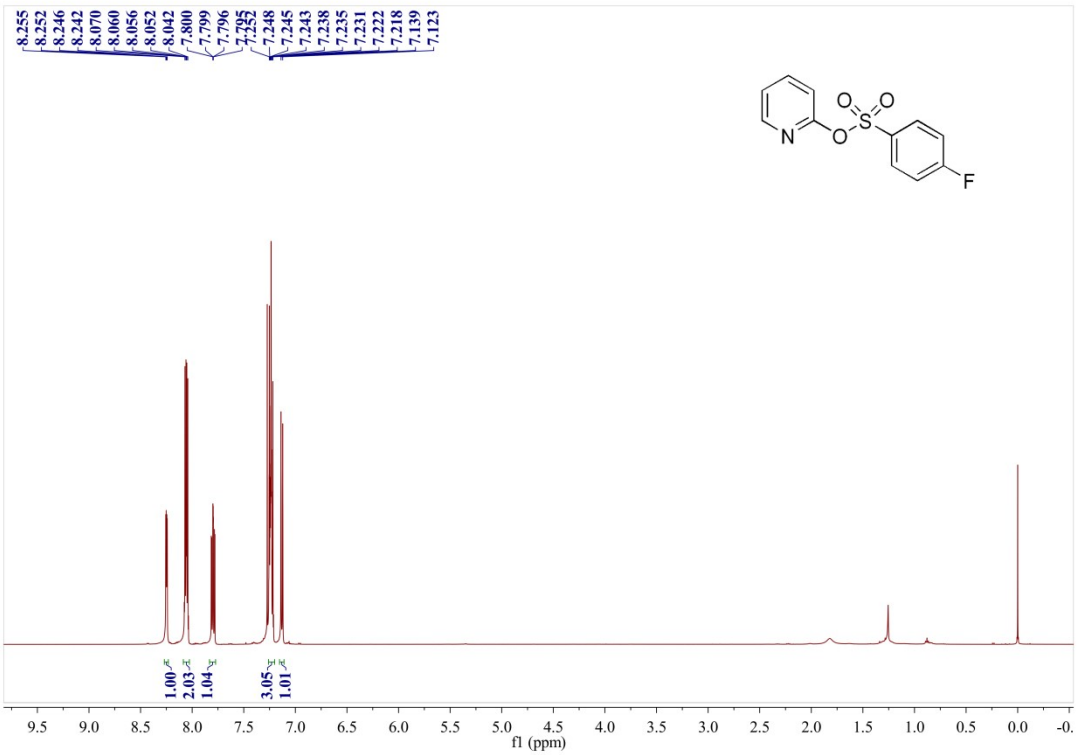
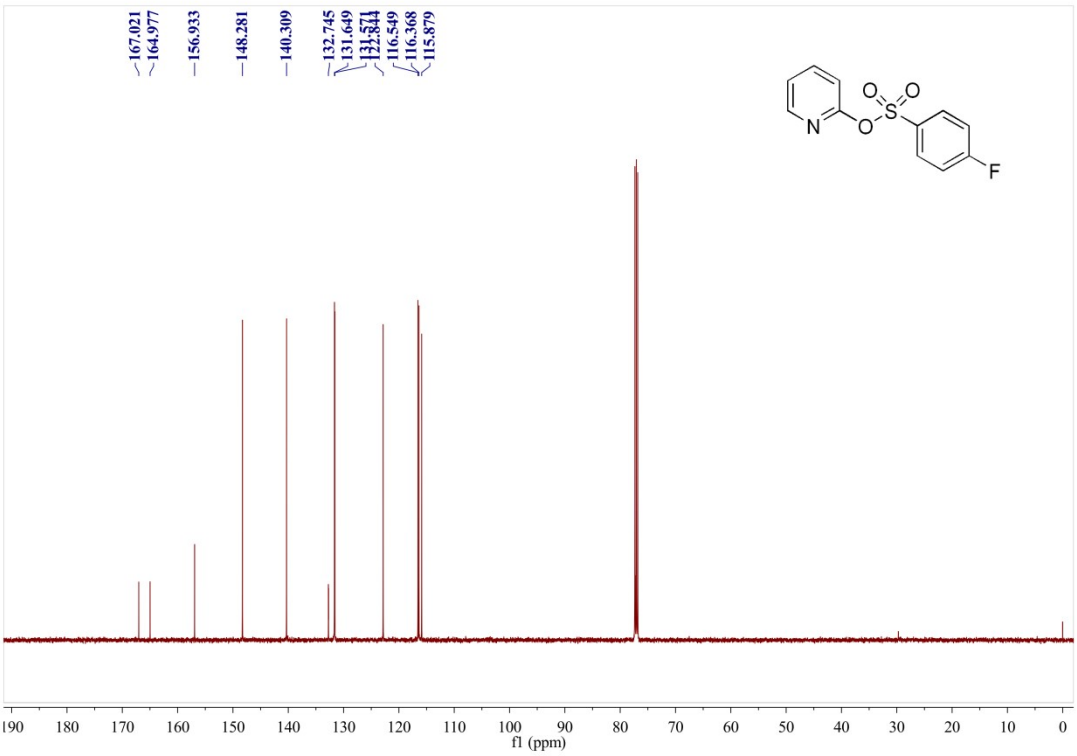
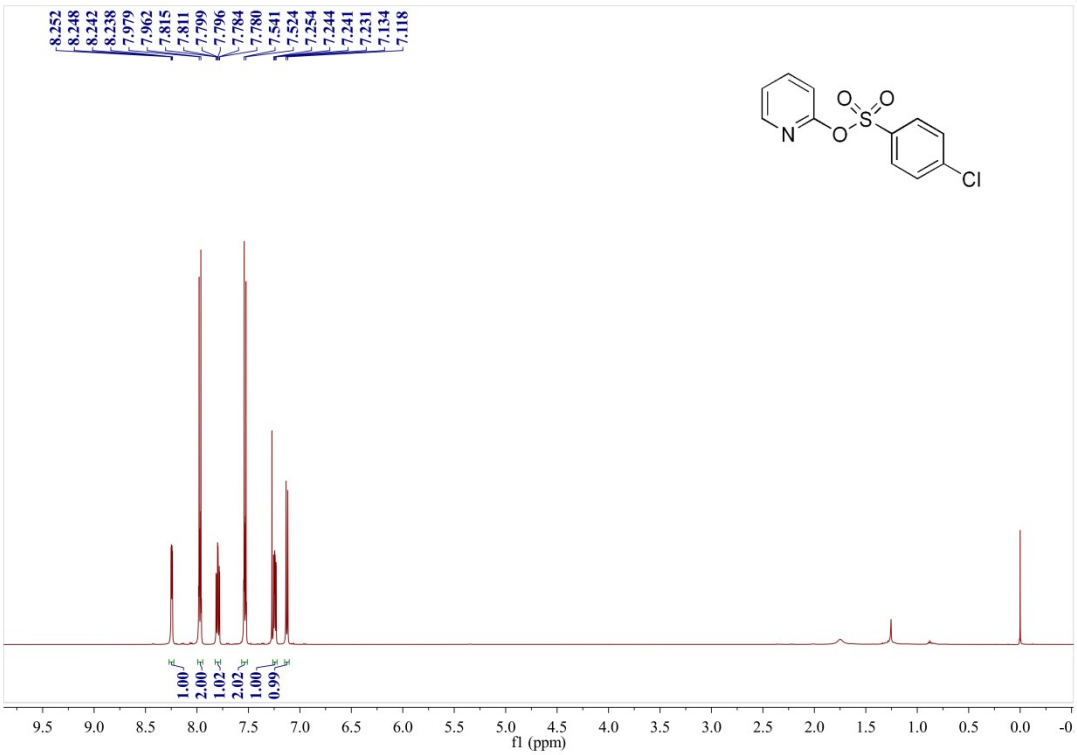
31.041
N
O
O
S
O
tBu
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

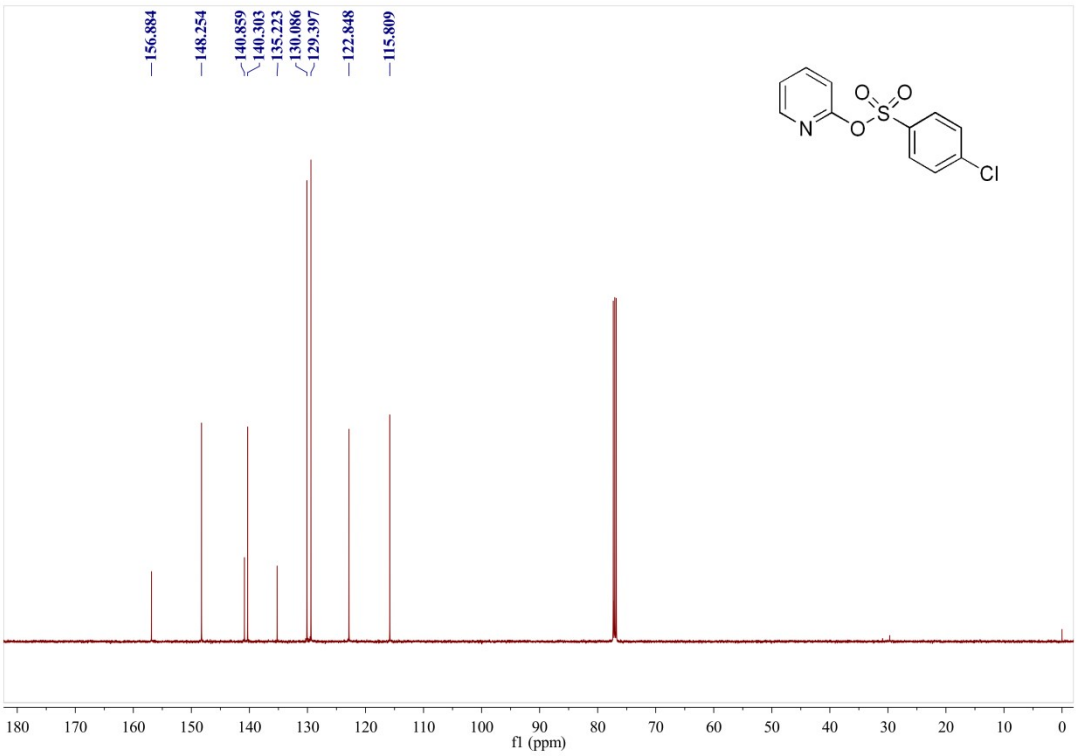

8.242
8.239
8.233
8.229
8.199
8.182
7.847
7.830
7.820
7.804
7.268
7.261
7.256
7.246
7.157
7.141
N
O
O
S
O
CF3
1.00
1.90
2.96
1.03
0.92
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

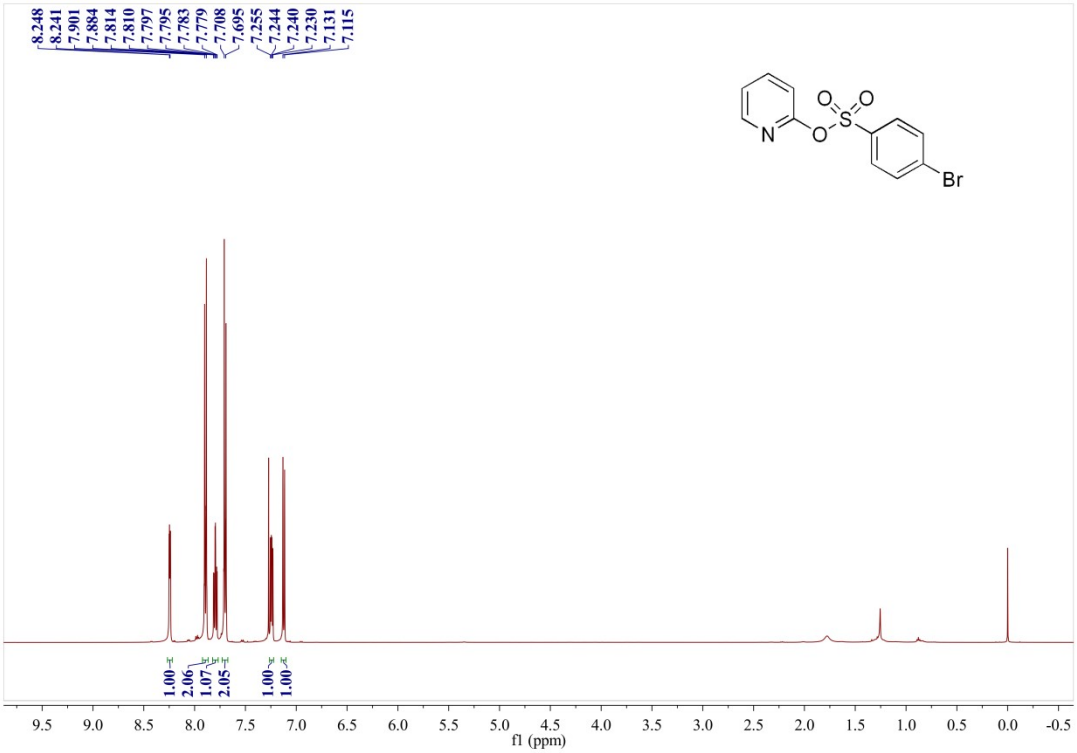

156.893
148.250
140.511
140.476
135.959
135.695
135.431
135.167
129.256
126.349
126.261
126.231
126.202
126.172
124.177
123.024
122.005
119.834
115.738
N
O
O
O
S
CF3
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

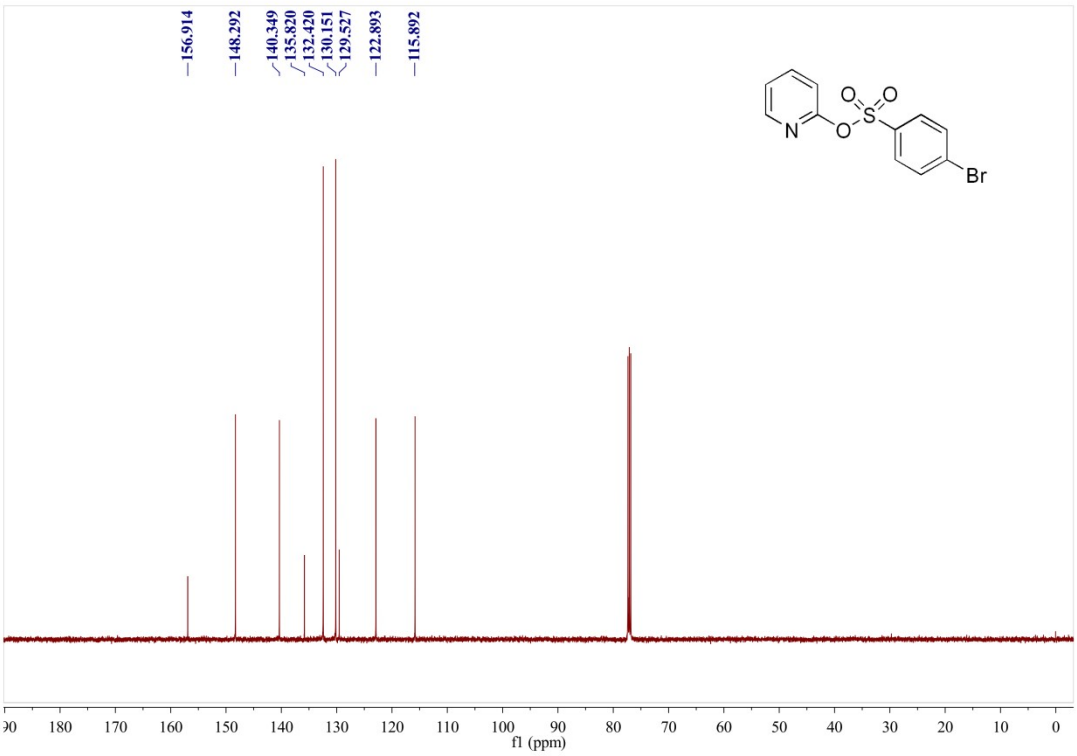

8.255
8.252
8.246
8.242
8.070
8.060
8.056
8.052
8.042
7.800
7.799
7.796
7.795
7.252
7.248
7.245
7.243
7.238
7.235
7.231
7.222
7.218
7.139
7.123
N
O
O
O
S
F
1.00
2.03
1.04
3.05
1.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.
f1 (ppm)

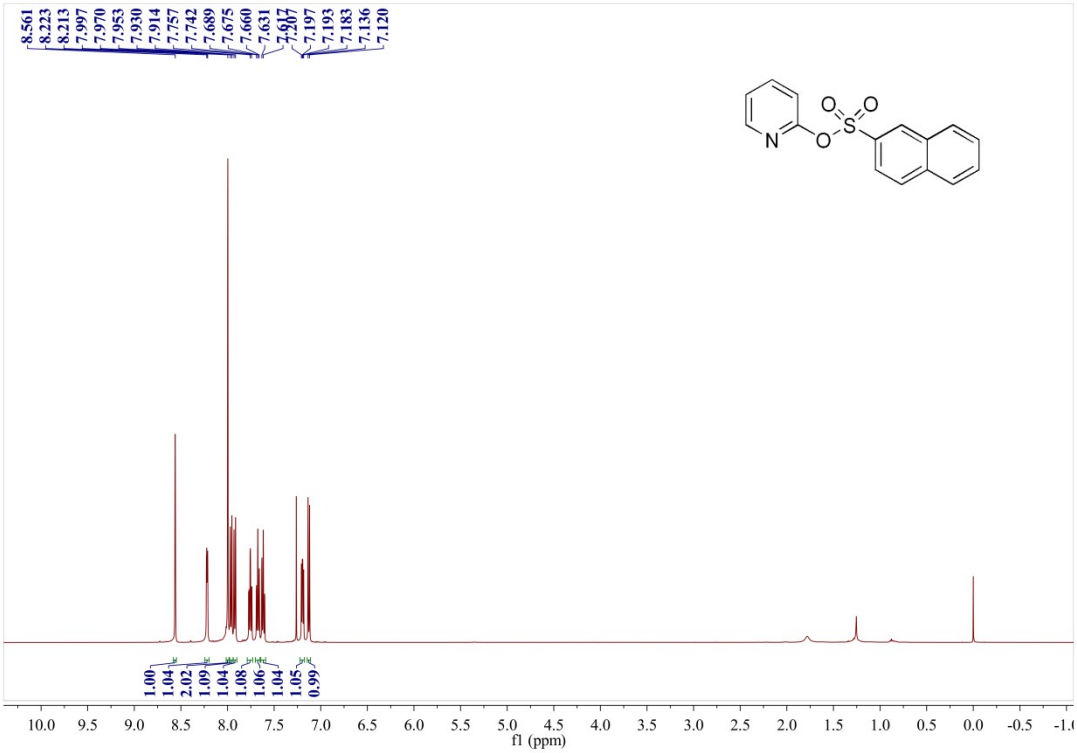

167.021
164.977
156.933
148.281
140.309
132.745
131.649
116.549
116.368
115.879
F
fl (ppm)

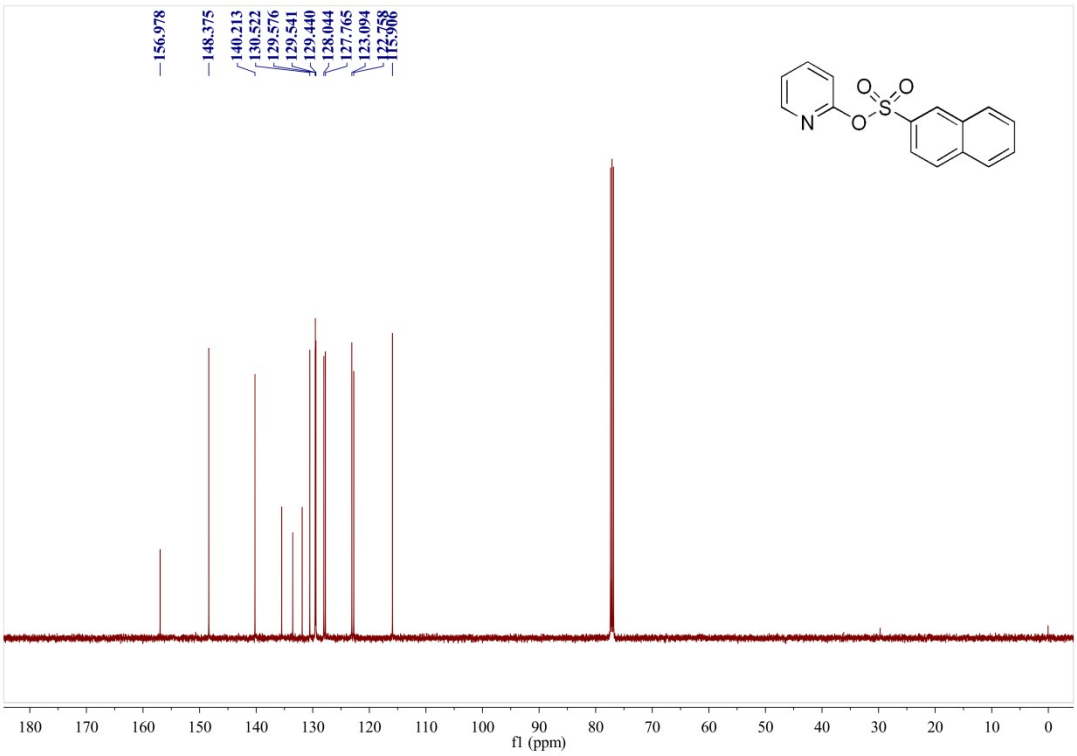

8.252
8.248
8.242
8.238
7.979
7.962
7.815
7.811
7.799
7.796
7.784
7.780
7.541
7.524
7.254
7.244
7.241
7.231
7.134
7.118
1.00
2.00
1.02
2.02
1.00
0.99
Cl
fl (ppm)

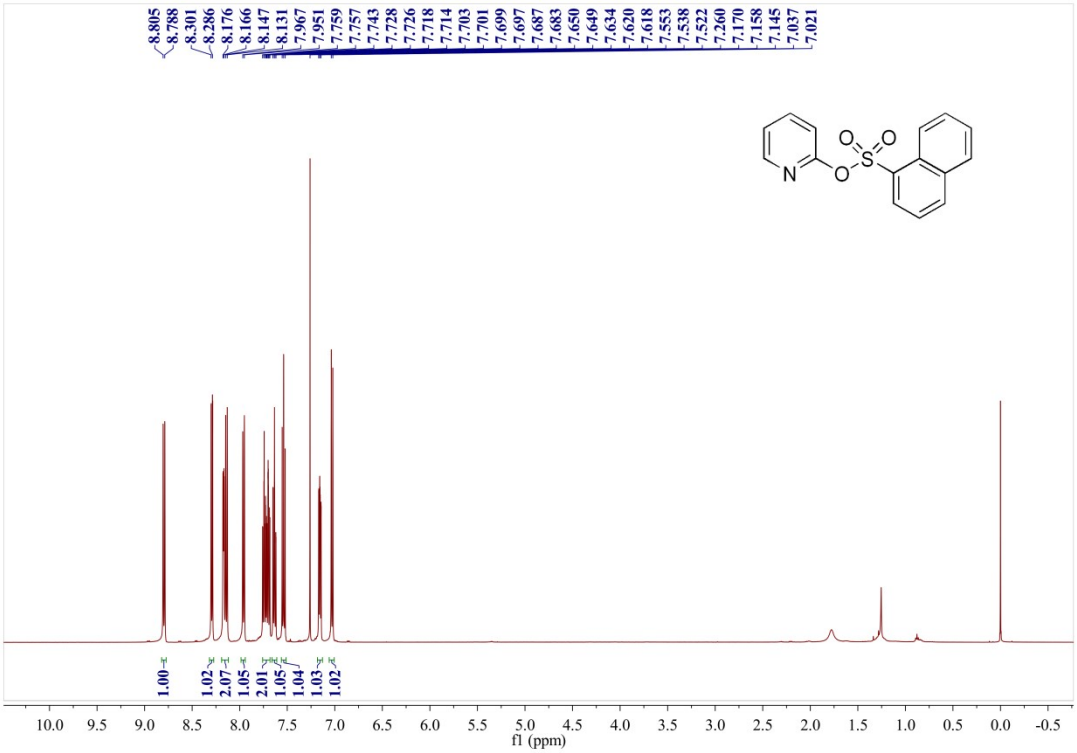

156.884
148.254
140.859
140.303
135.223
130.086
129.397
122.848
115.809
O
O
S
O
N
Cl
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

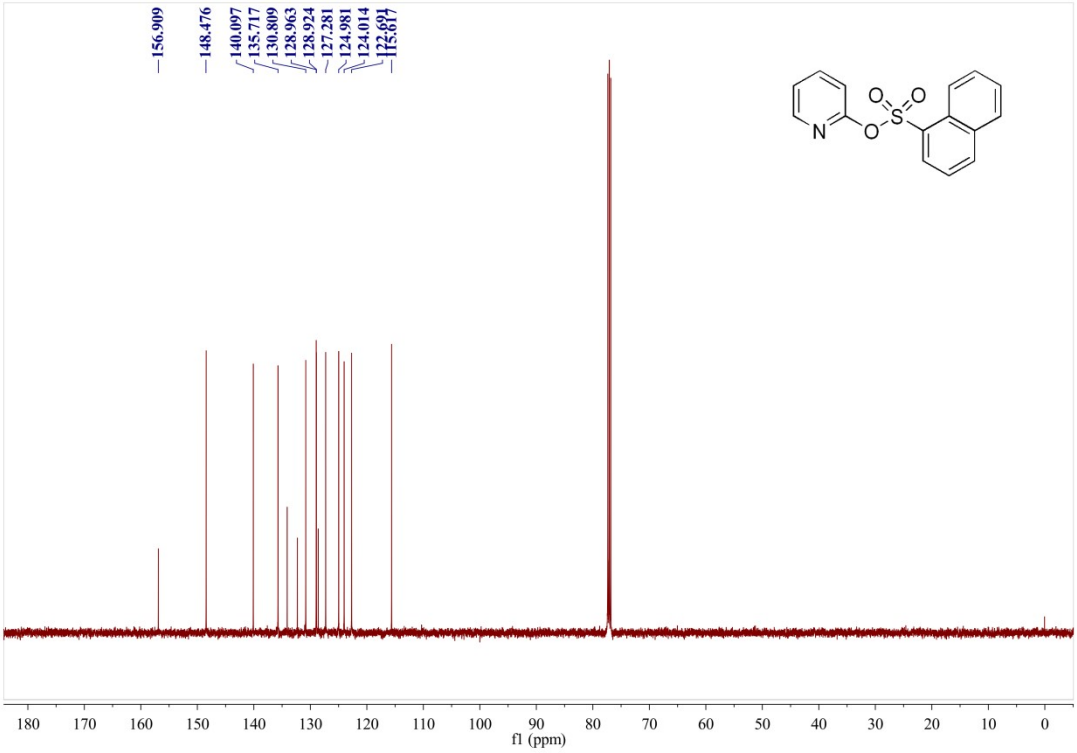

8.248
8.241
7.901
7.884
7.814
7.810
7.797
7.795
7.783
7.779
7.708
7.695
7.255
7.244
7.240
7.230
7.131
7.115
O
O
S
O
N
Br
1.00
2.06
1.07
2.05
1.00
1.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

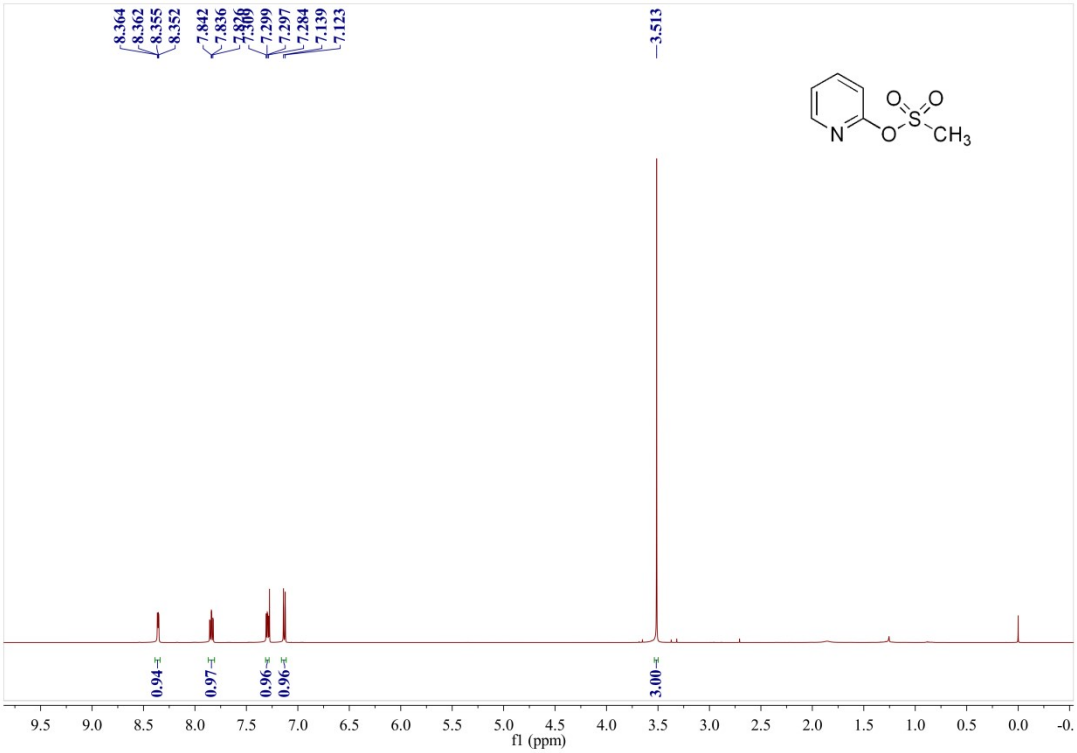

156.914
148.292
140.349
135.820
132.420
130.151
129.527
122.893
115.892
O
O
S
O
N
Br
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

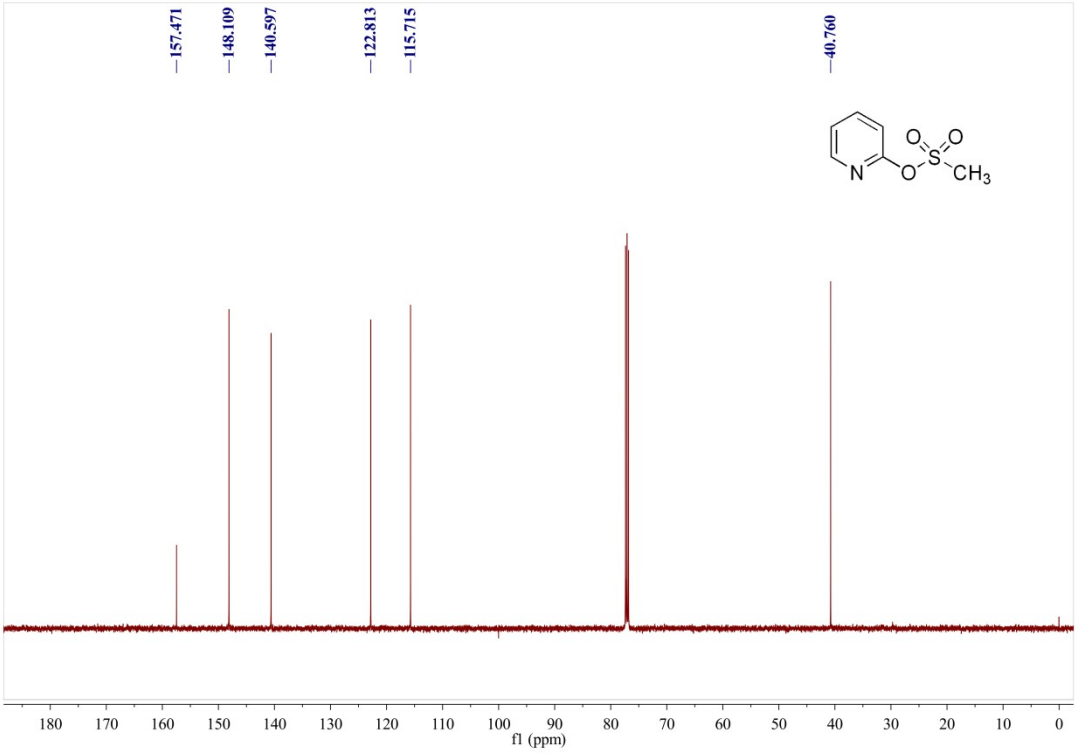

8.561
8.223
8.213
7.997
7.970
7.953
7.930
7.914
7.757
7.742
7.689
7.675
7.660
7.631
7.207
7.197
7.193
7.183
7.136
7.120
O
O
S
O
N
1.00
1.04
2.02
1.09
1.04
1.08
1.06
1.04
1.05
0.99
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

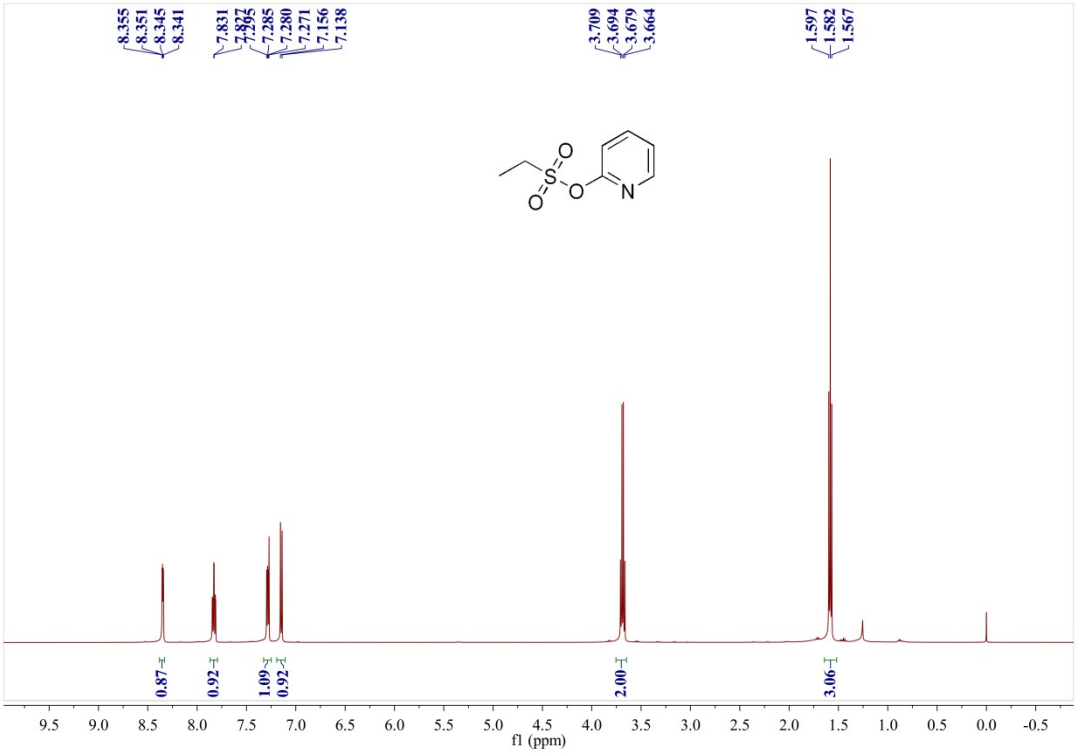

156.978
148.375
140.213
130.522
129.576
129.541
129.440
128.044
127.765
123.094
122.758
115.906
O
O
S
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

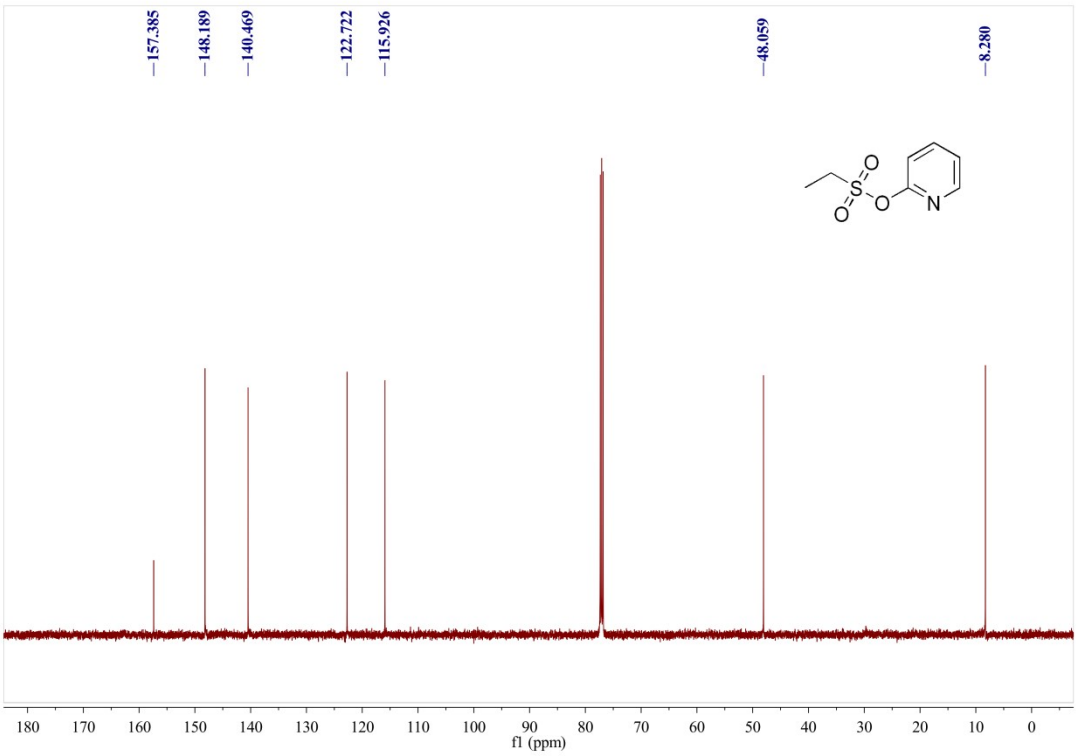

8.805
8.788
8.301
8.286
8.176
8.166
8.147
8.131
7.967
7.951
7.759
7.757
7.743
7.728
7.726
7.718
7.714
7.703
7.701
7.699
7.697
7.687
7.683
7.650
7.649
7.634
7.620
7.618
7.553
7.538
7.522
7.260
7.170
7.158
7.145
7.037
7.021
1.00
1.02
2.07
1.05
2.01
1.05
1.04
1.03
1.02
O
O
S
O
N
10.0 9.5 9.0 8.5 8.0 7.5 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)

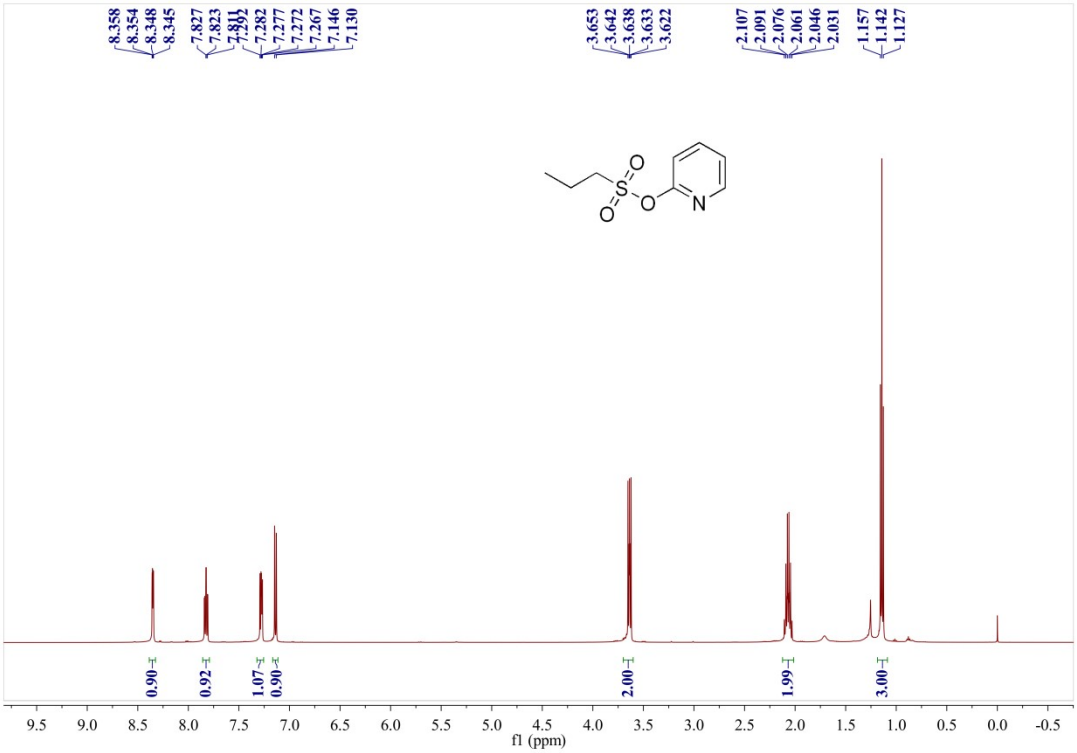

156.909
148.476
140.097
135.717
130.809
128.963
128.924
127.281
124.981
124.014
122.691
115.617
O
S
O
N
O
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

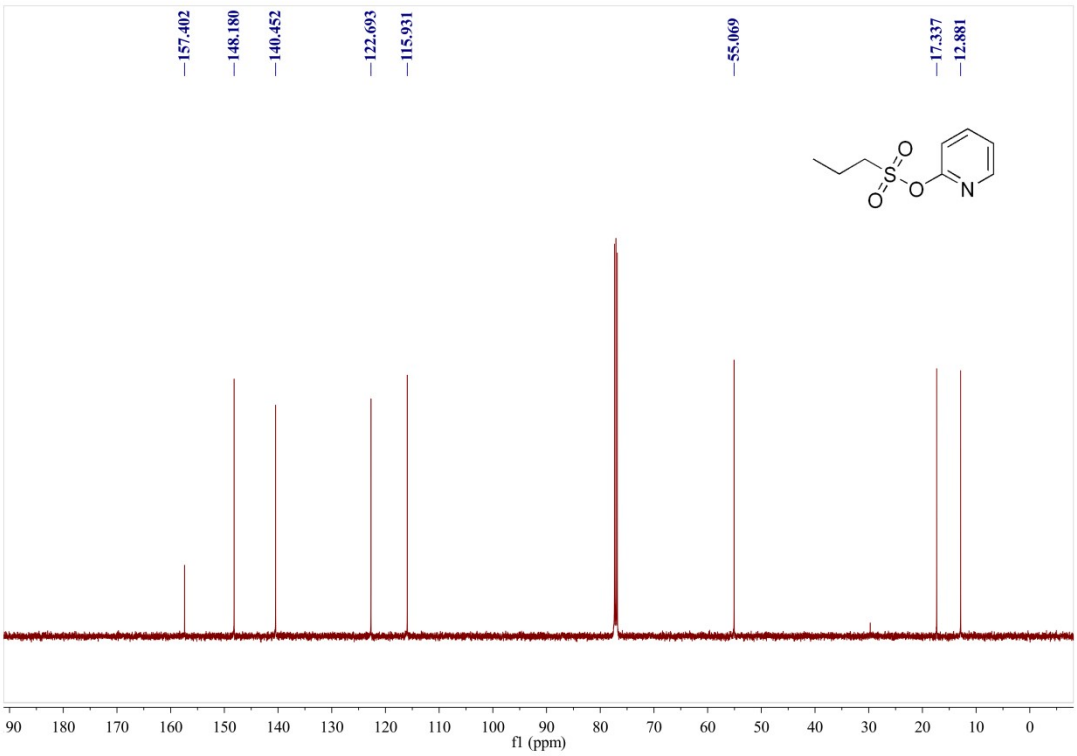

8.364
8.362
8.355
8.352
7.842
7.836
7.299
7.297
7.284
7.139
7.123
3.513
O
S
O
N
O
CH3
0.94
0.97
0.96
0.96
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

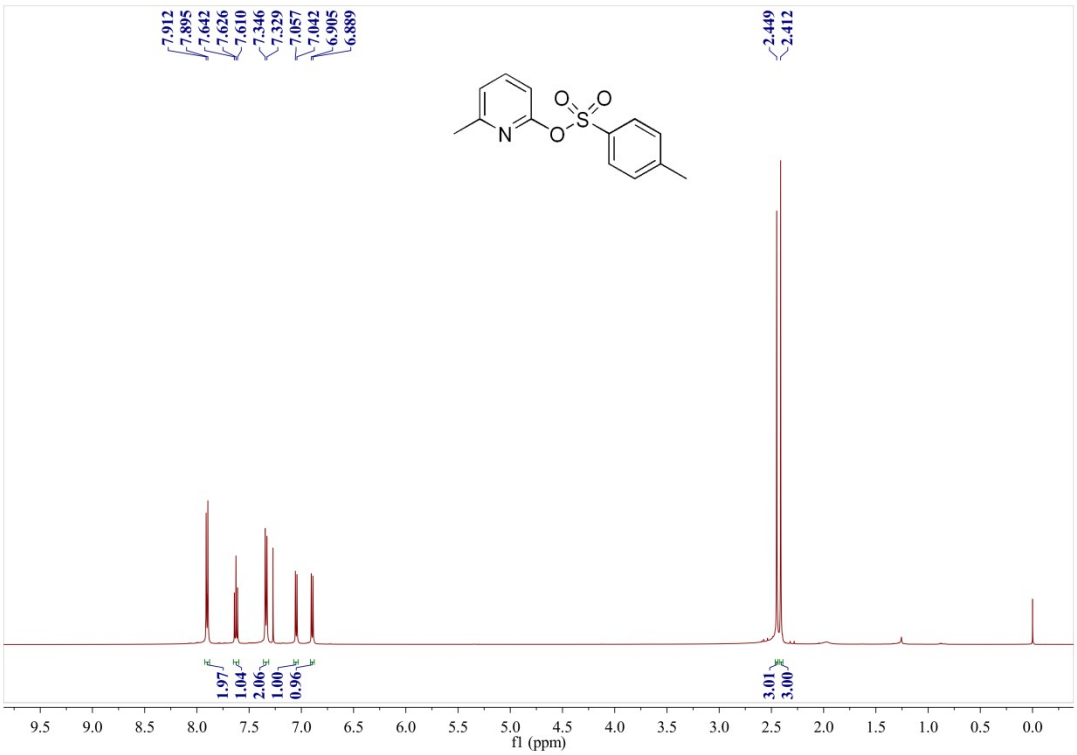

157.471
148.109
140.597
122.813
115.715
40.760
O
O
S
N
O
CH3
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

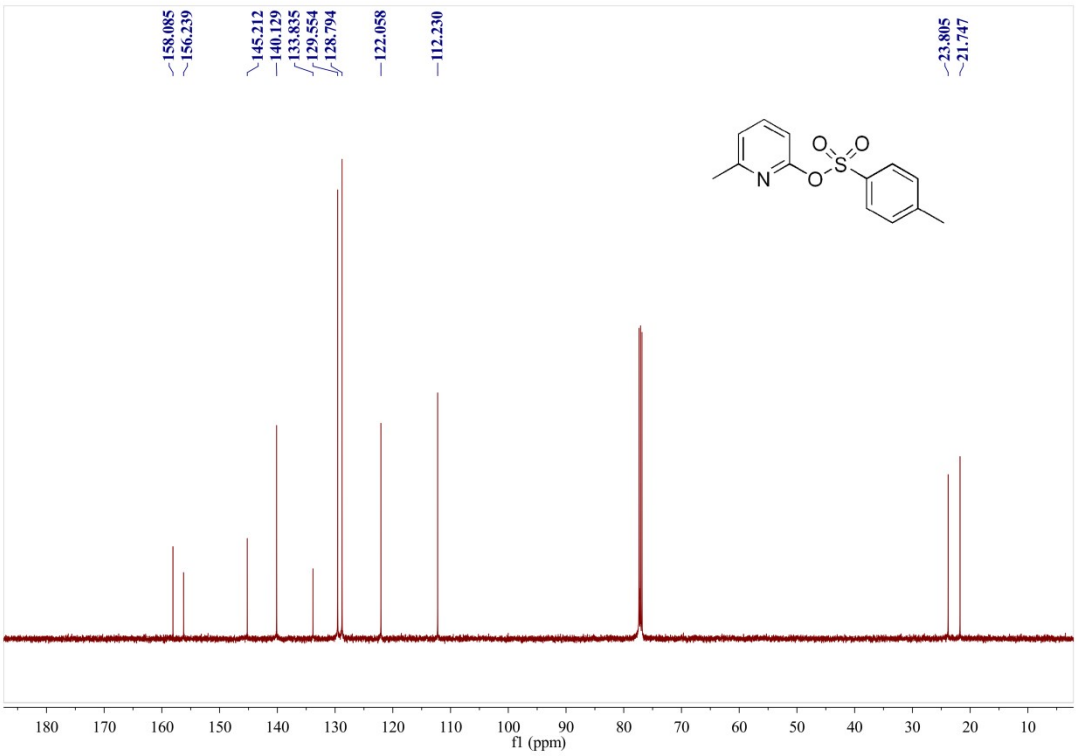

8.355
8.351
8.345
8.341
7.831
7.827
7.295
7.285
7.280
7.271
7.156
7.138
3.709
3.694
3.679
3.664
1.597
1.582
1.567
O
O
S
O
N
0.87
0.92
1.09
0.92
2.00
3.06
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

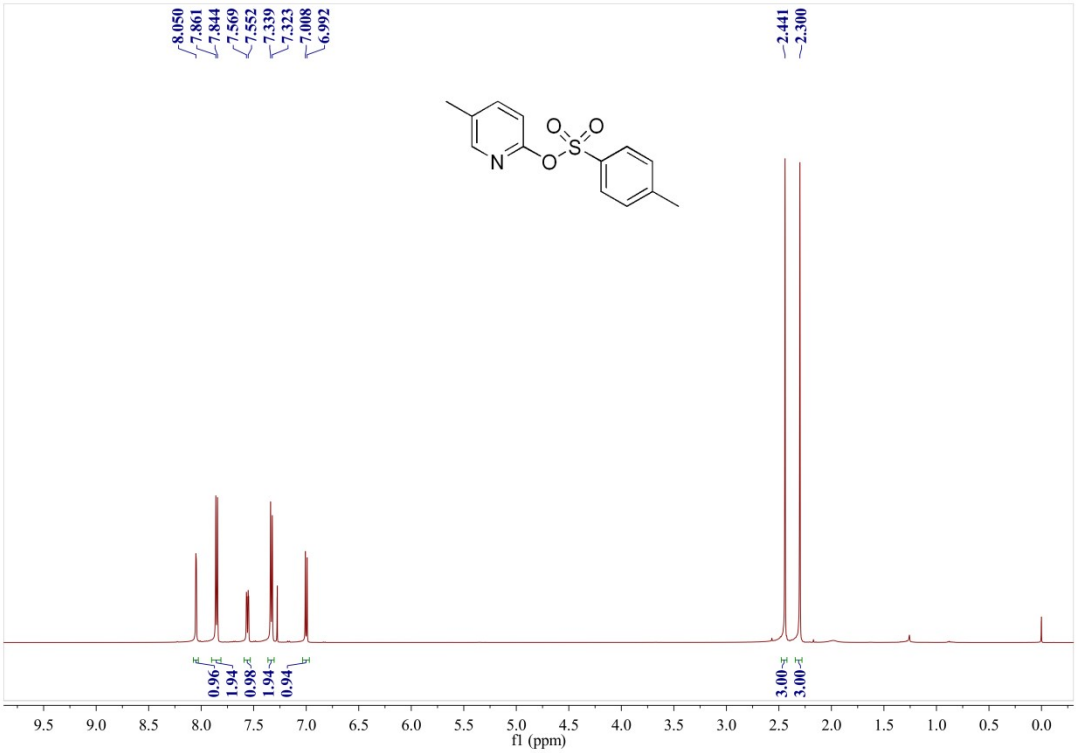

157.385
148.189
140.469
122.722
115.926
48.059
8.280
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.358
8.354
8.348
8.345
7.827
7.823
7.282
7.277
7.272
7.267
7.146
7.130
3.653
3.642
3.638
3.633
3.622
2.107
2.091
2.076
2.061
2.046
2.031
1.157
1.142
1.127
0.90
0.92
1.07
0.90
2.00
1.99
3.00
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)


157.402
148.180
140.452
122.693
115.931
55.069
17.337
12.881
O
S
O
O
N
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.912
7.895
7.642
7.626
7.610
7.346
7.329
7.057
7.042
6.905
6.889
2.449
2.412
N
O
S
O
O
1.97
1.04
2.06
1.00
0.96
3.01
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


158.085
156.239
145.212
140.129
133.835
129.554
128.794
122.058
112.230
23.805
21.747
O
O
S
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)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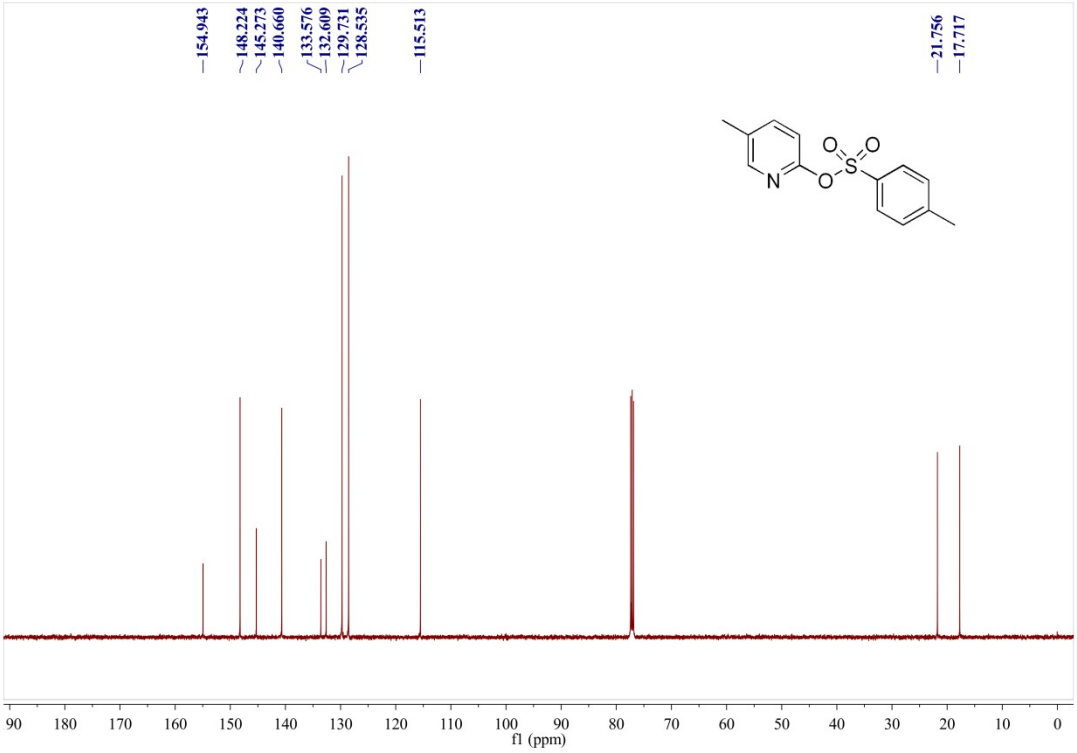
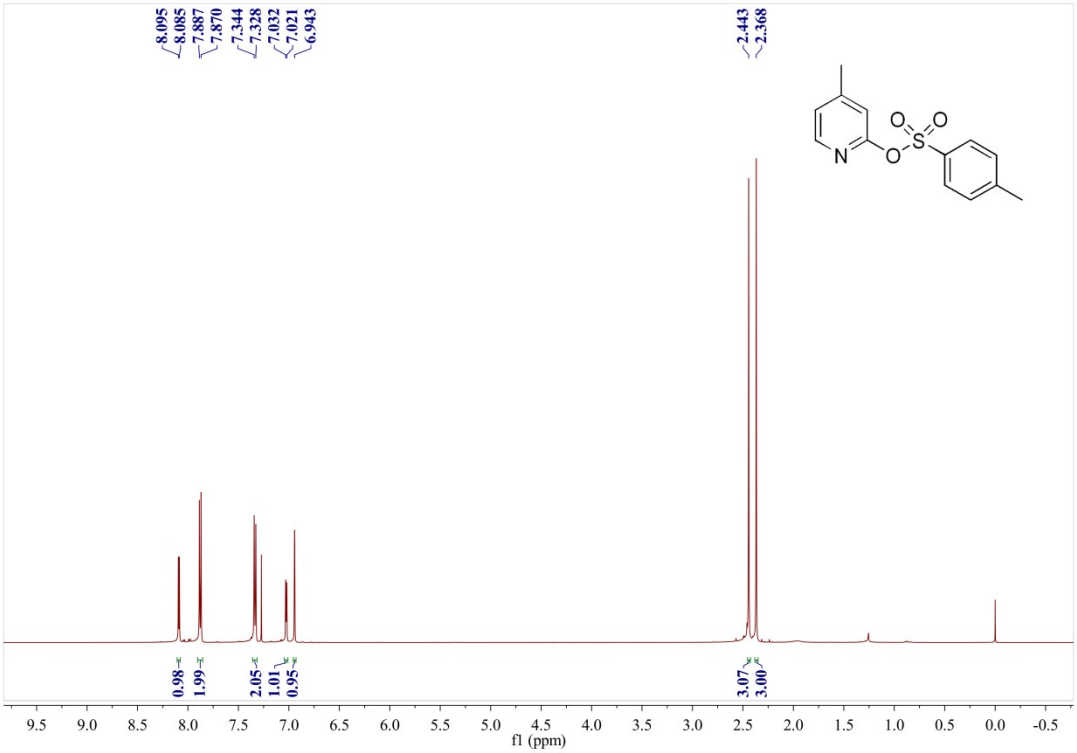
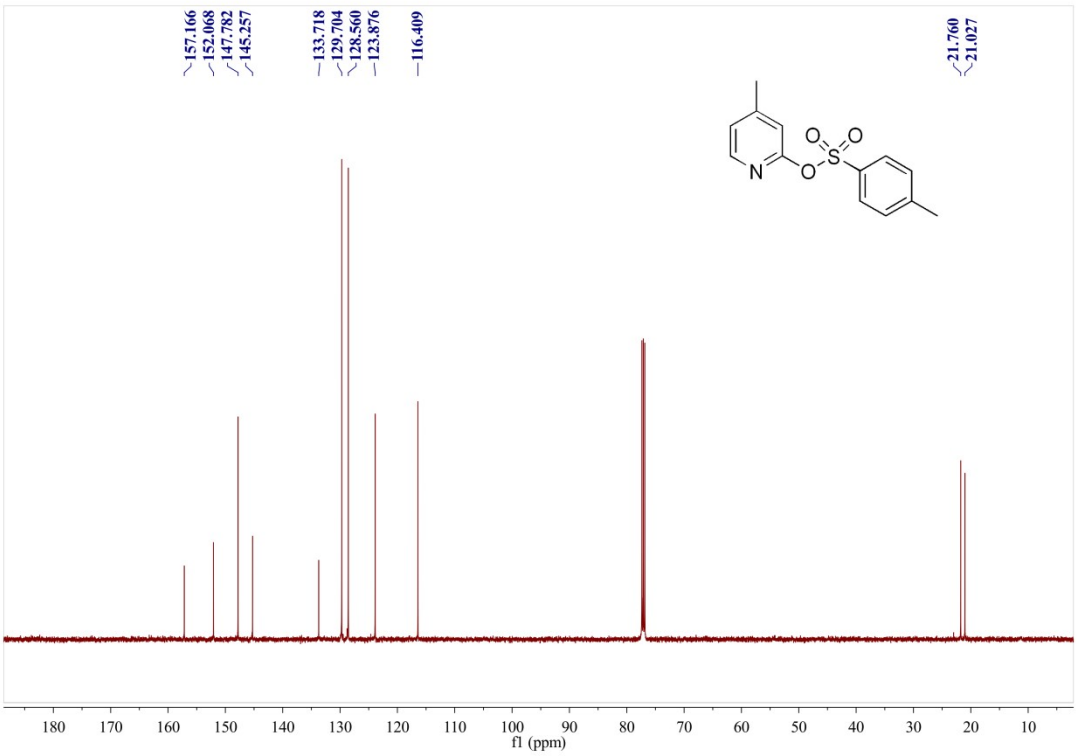
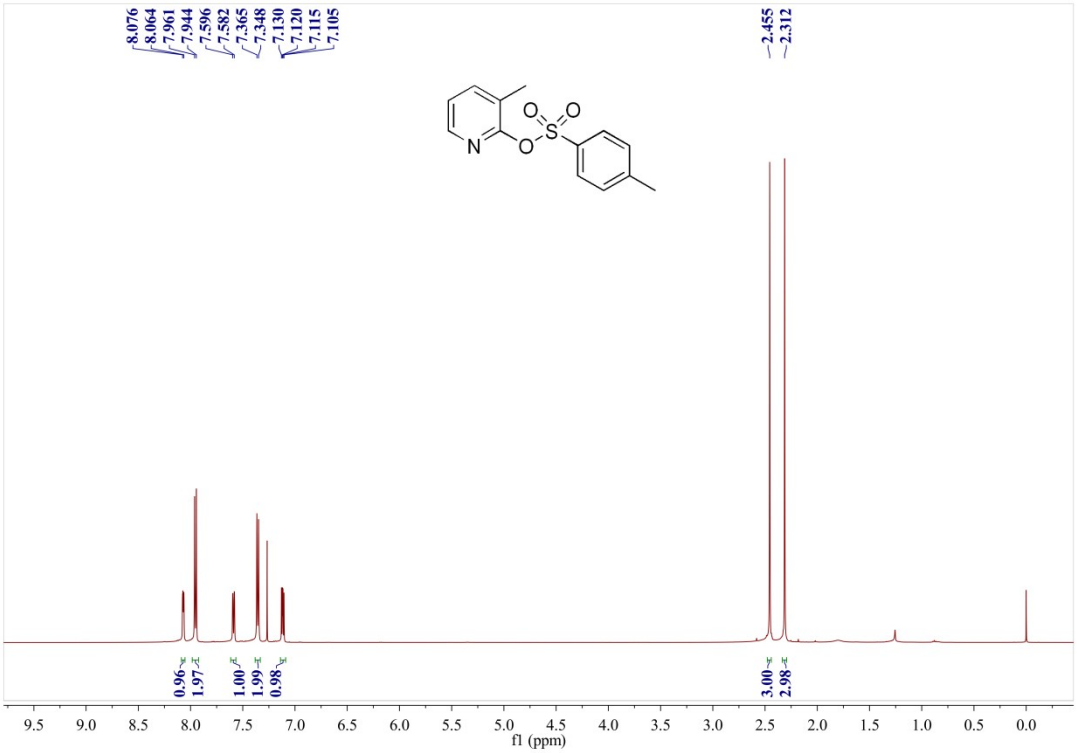
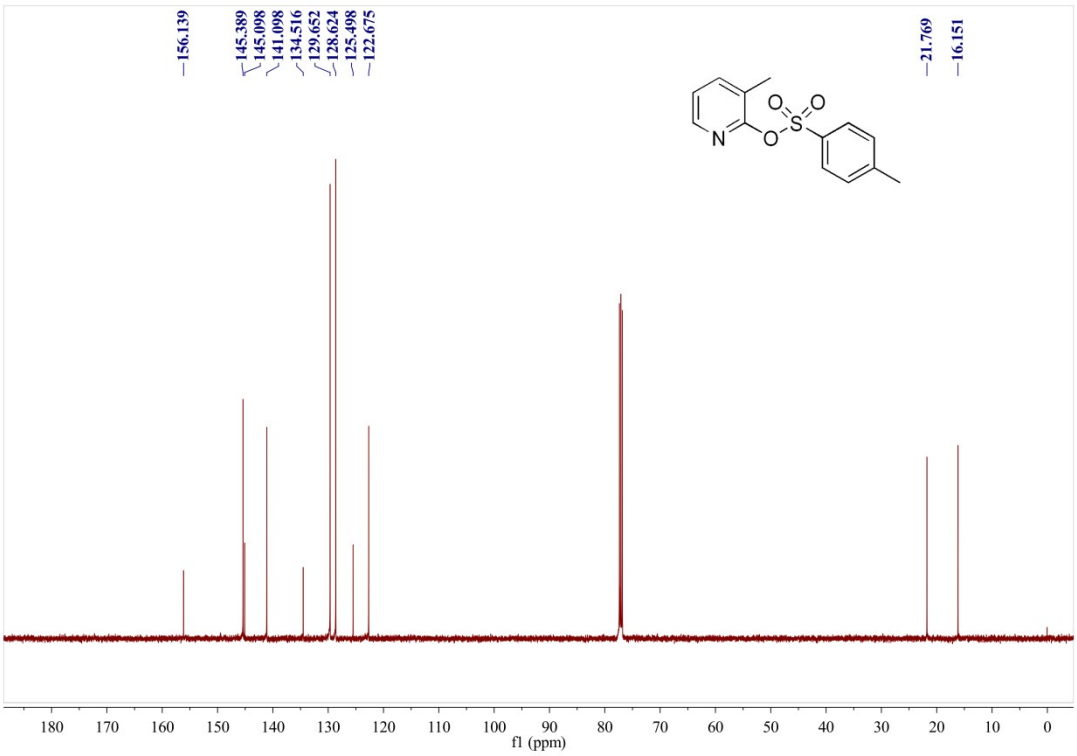
7.861
7.844
7.569
7.552
7.339
7.323
7.008
6.992
2.441
2.300
O
O
S
O
N
0.96
1.94
0.98
1.94
0.94
3.00
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

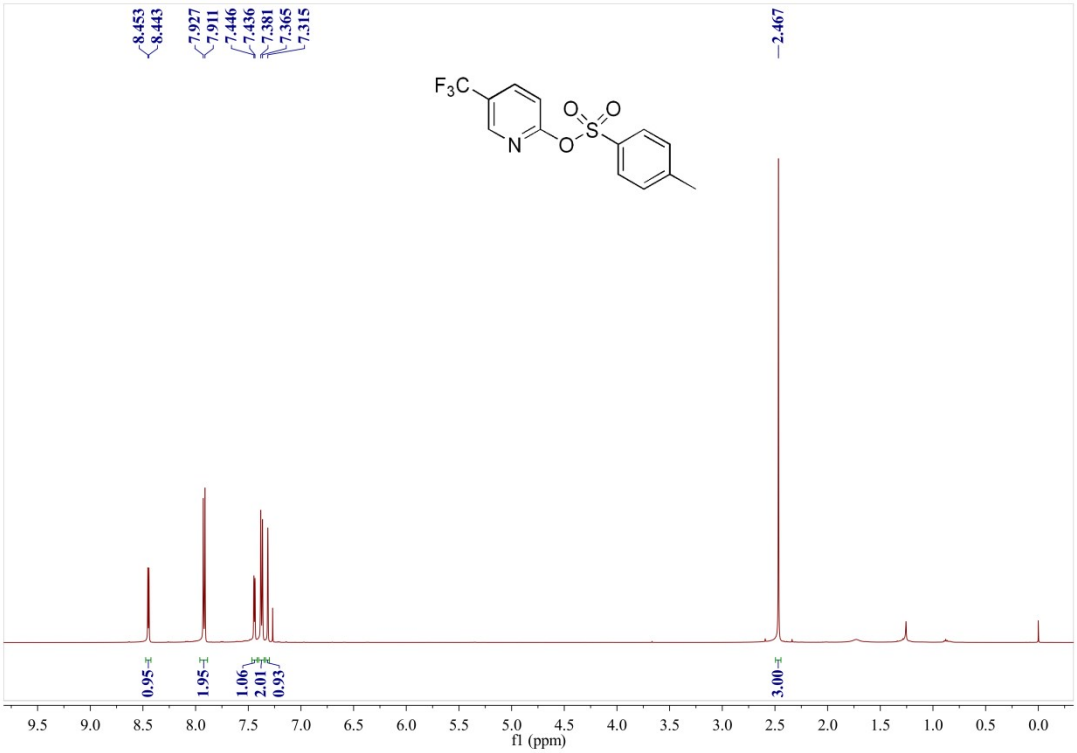

154.943
148.224
145.273
140.660
133.576
132.609
129.731
128.535
115.513
21.756
17.717
O
S
O
N
O
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

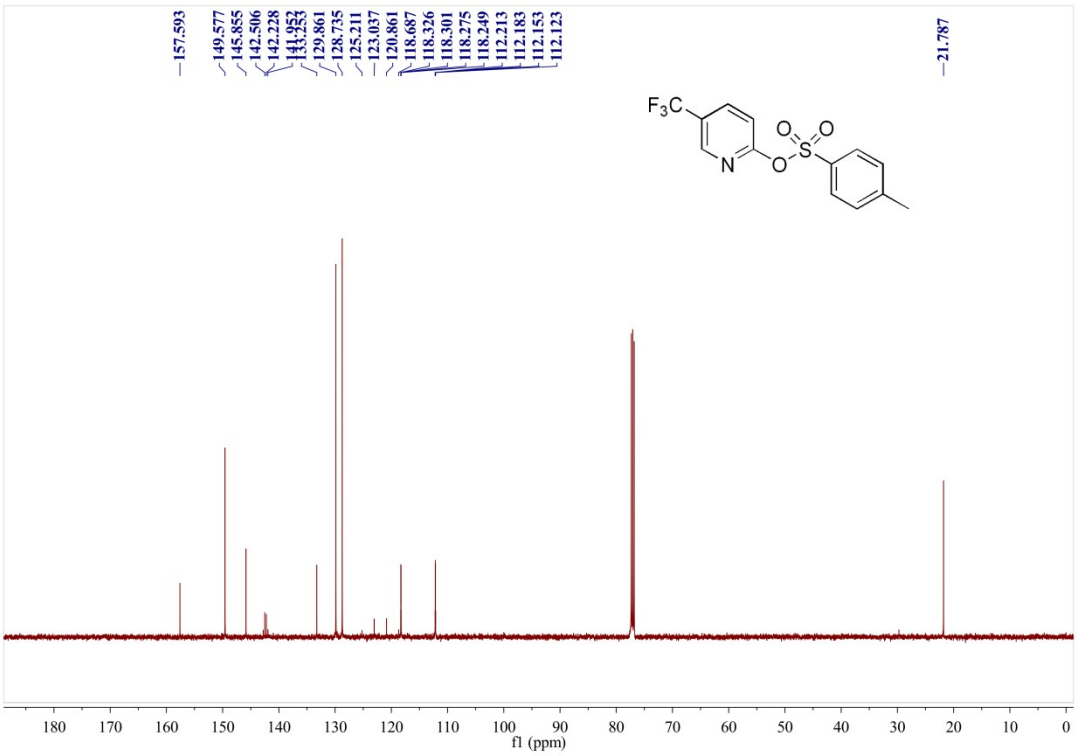

8.095
8.085
7.887
7.870
7.344
7.328
7.032
7.021
6.943
2.443
2.368
O
S
O
N
O
0.98
1.99
2.05
1.01
0.95
3.07
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

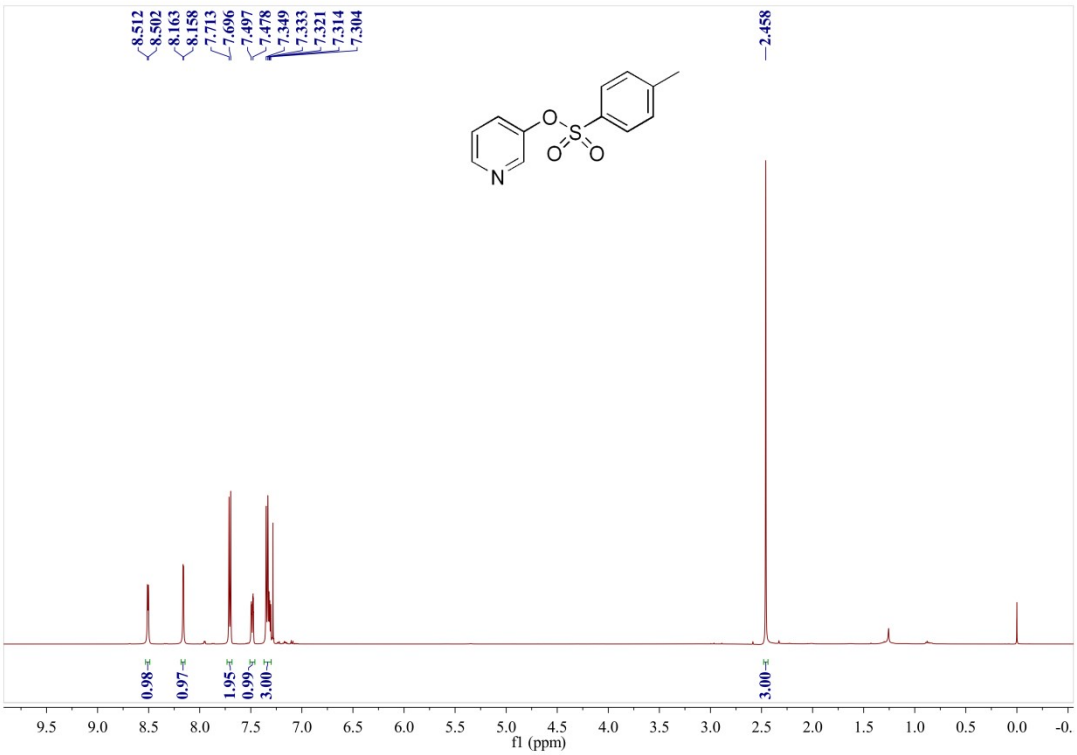

157.166
152.068
147.782
145.257
133.718
129.704
128.560
123.876
116.409
21.760
21.027
N
O
S
O
O
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

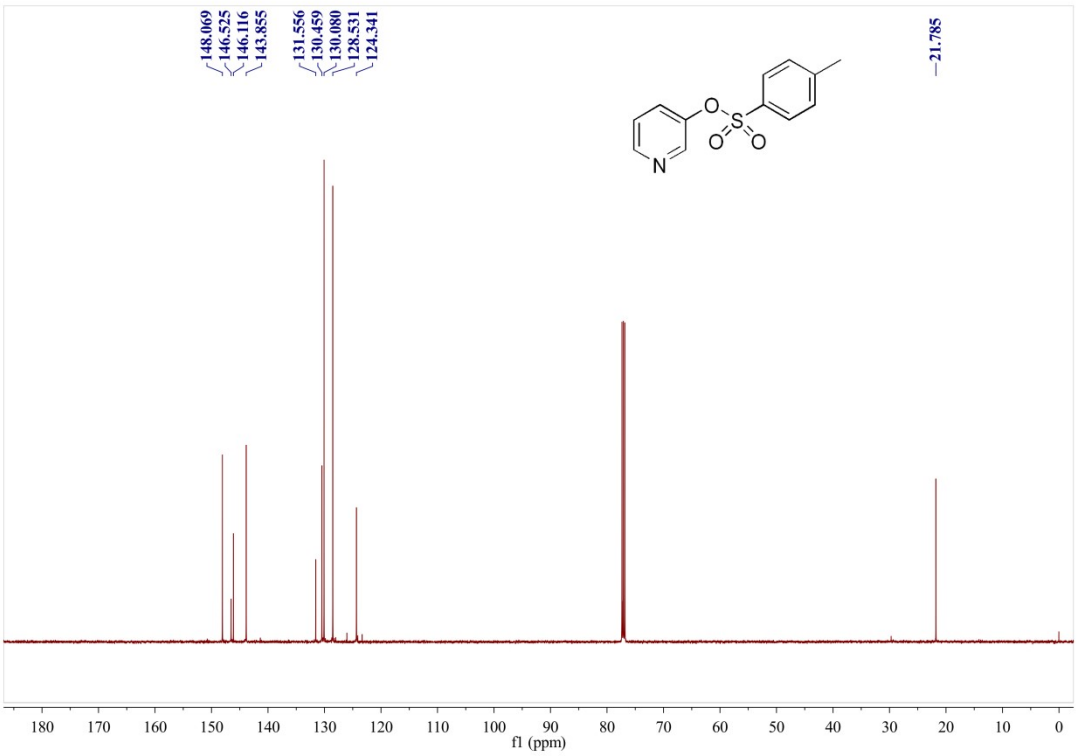

8.076
8.064
7.961
7.944
7.596
7.582
7.365
7.348
7.130
7.120
7.115
7.105
2.455
2.312
N
O
S
O
O
0.96
1.97
1.00
1.99
0.98
3.00
2.98
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

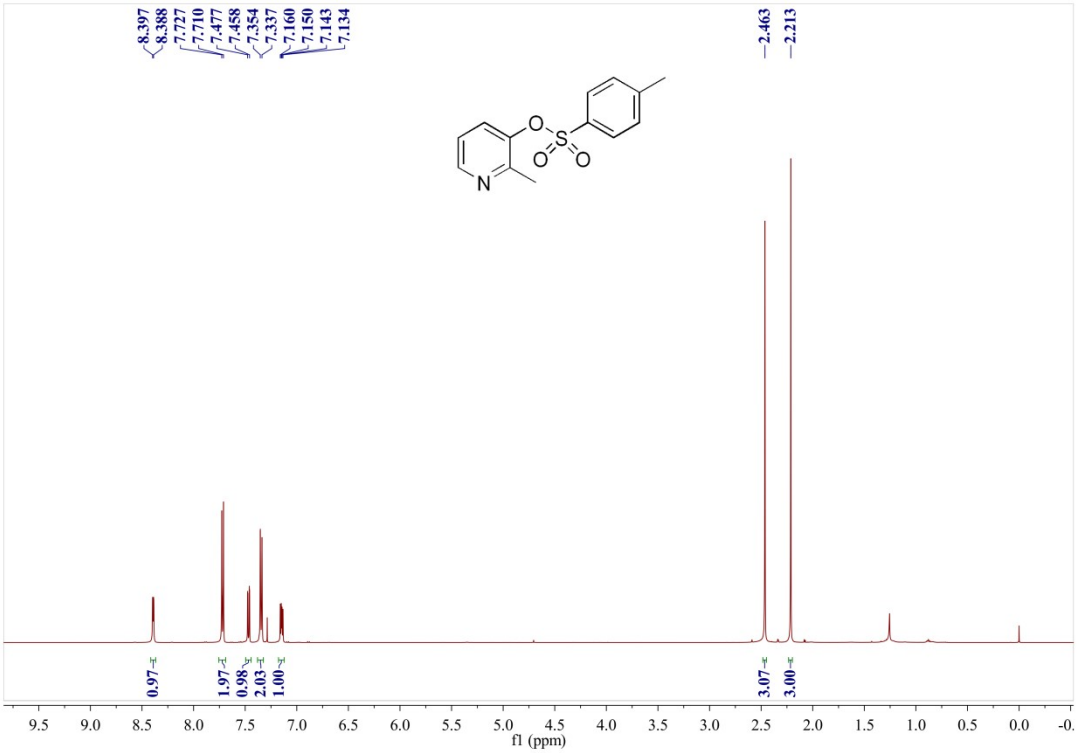

156.139
145.389
145.098
141.098
134.516
129.652
128.624
125.498
122.675
21.769
16.151
O
O
S
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

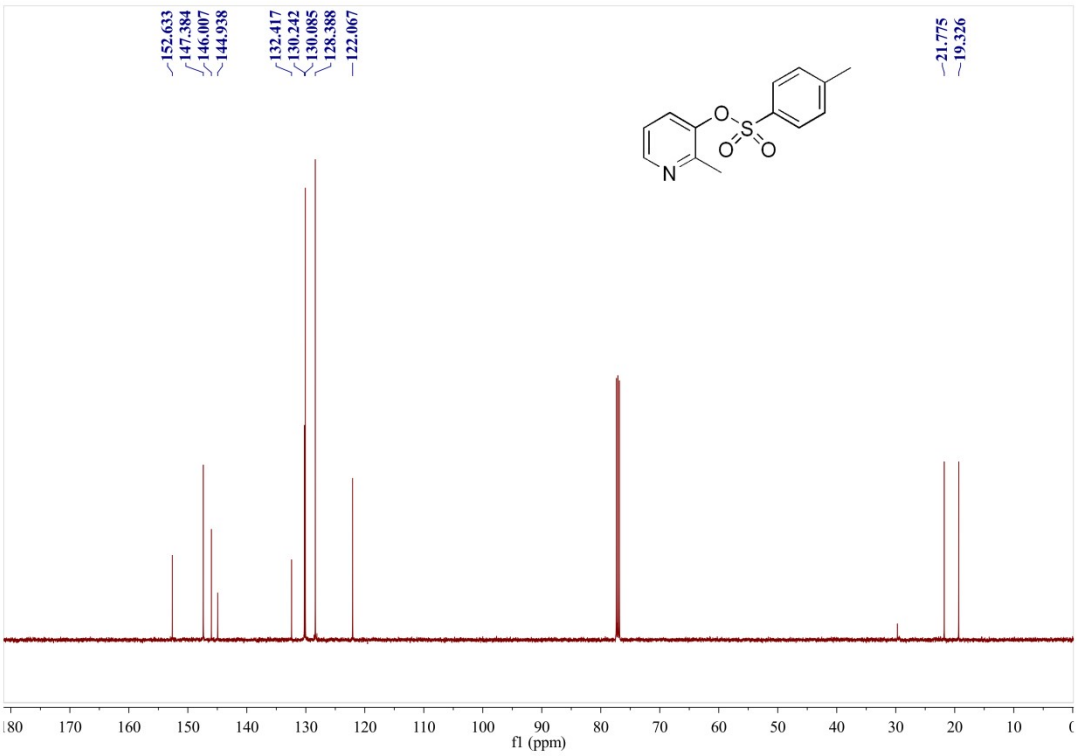

8.453
8.443
7.927
7.911
7.446
7.436
7.381
7.365
7.315
2.467
F3C
O
O
S
O
N
0.95
1.95
1.06
2.01
0.93
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

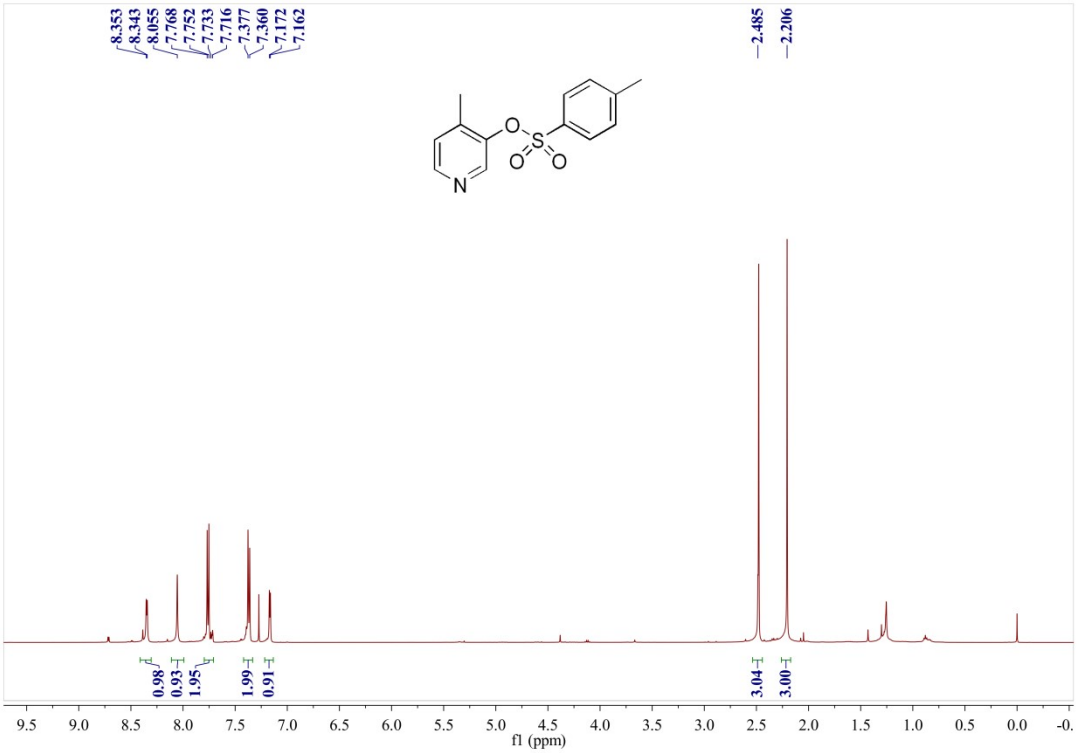

157.593
149.577
145.855
142.506
142.228
129.861
128.735
125.211
123.037
120.861
118.687
118.326
118.301
118.275
118.249
112.213
112.183
112.153
112.123
21.787
F3C
N
O
S
O
O
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

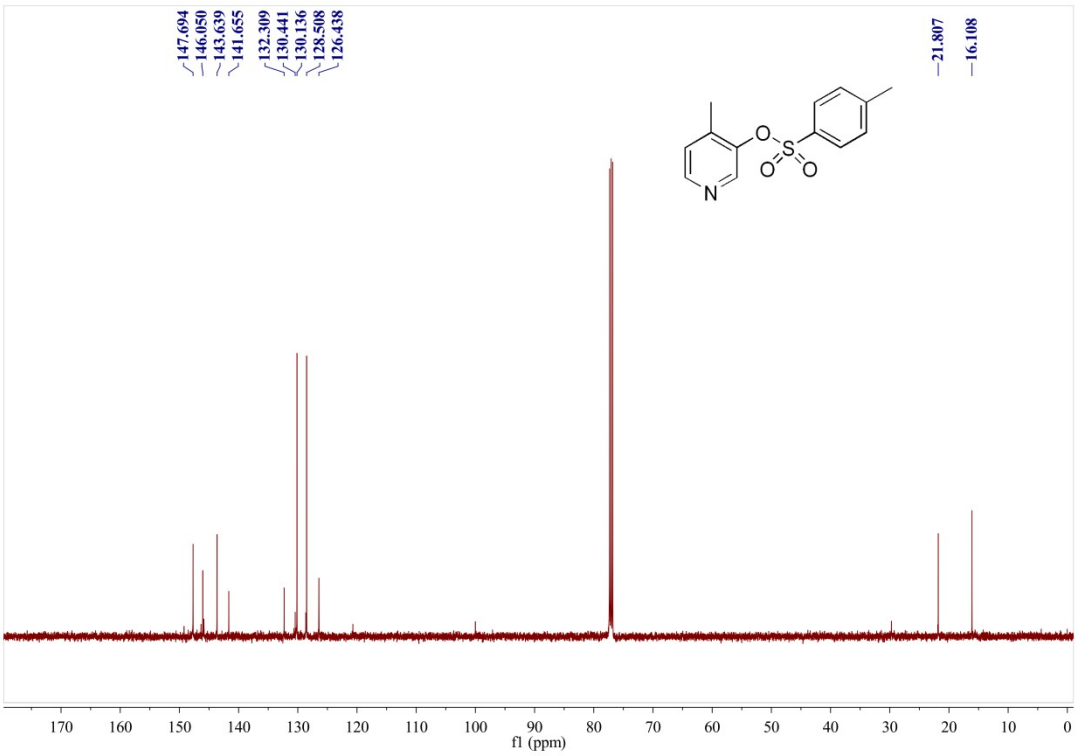

8.512
8.502
8.163
8.158
7.713
7.696
7.497
7.478
7.349
7.333
7.321
7.314
7.304
2.458
N
O
S
O
O
0.98
0.97
1.95
0.99
3.00
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.
f1 (ppm)

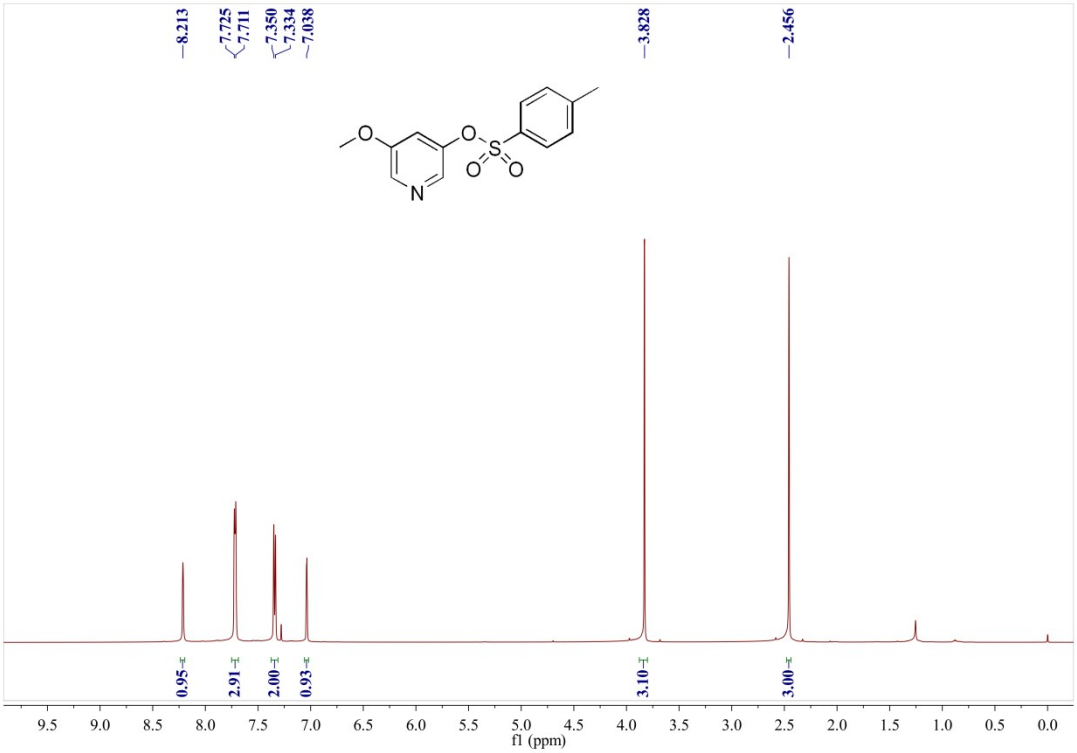

148.069
146.525
146.116
143.855
131.556
130.459
130.080
128.531
124.341
21.785
O
S
O
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

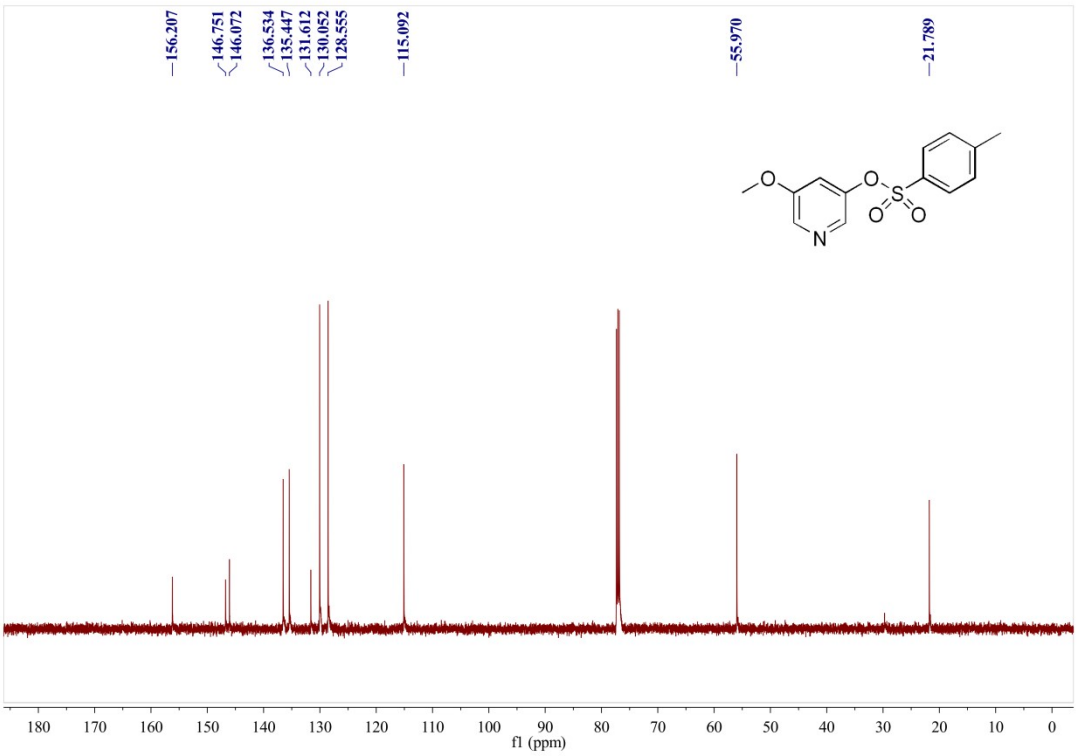

8.397
8.388
7.727
7.710
7.477
7.458
7.354
7.337
7.160
7.150
7.143
7.134
2.463
2.213
O
S
O
O
N
0.97
1.97
0.98
2.03
1.00
3.07
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

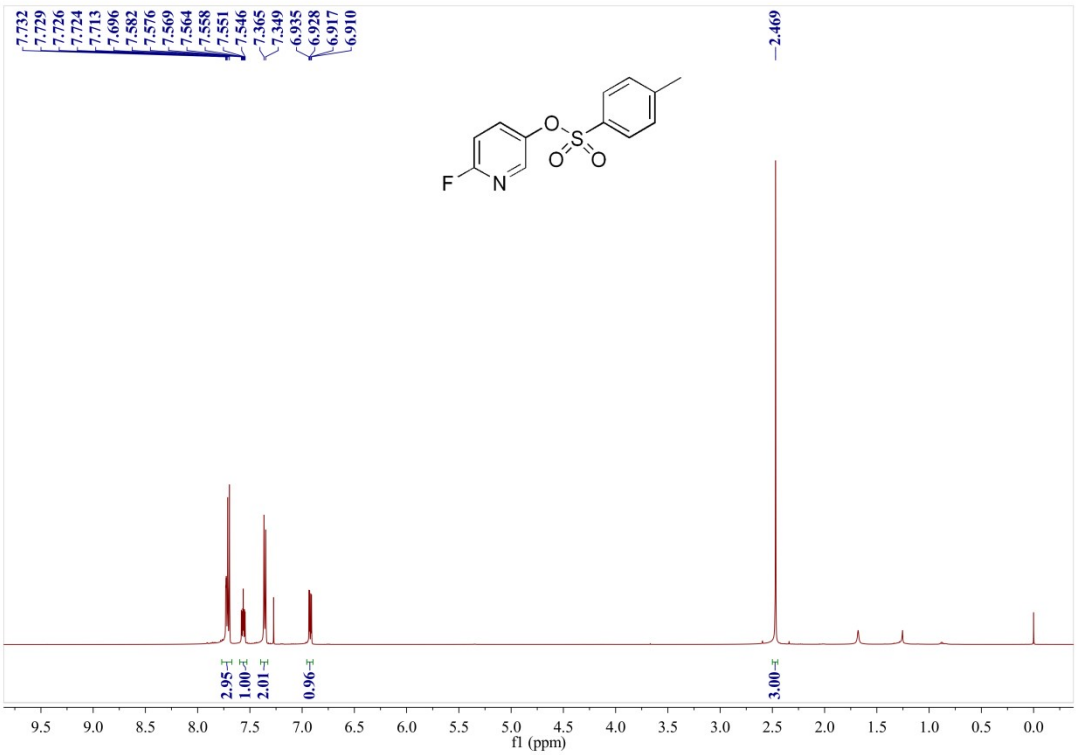

152.633
147.384
146.007
144.938
132.417
130.242
130.085
128.388
122.067
21.775
19.326
O
S
O
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

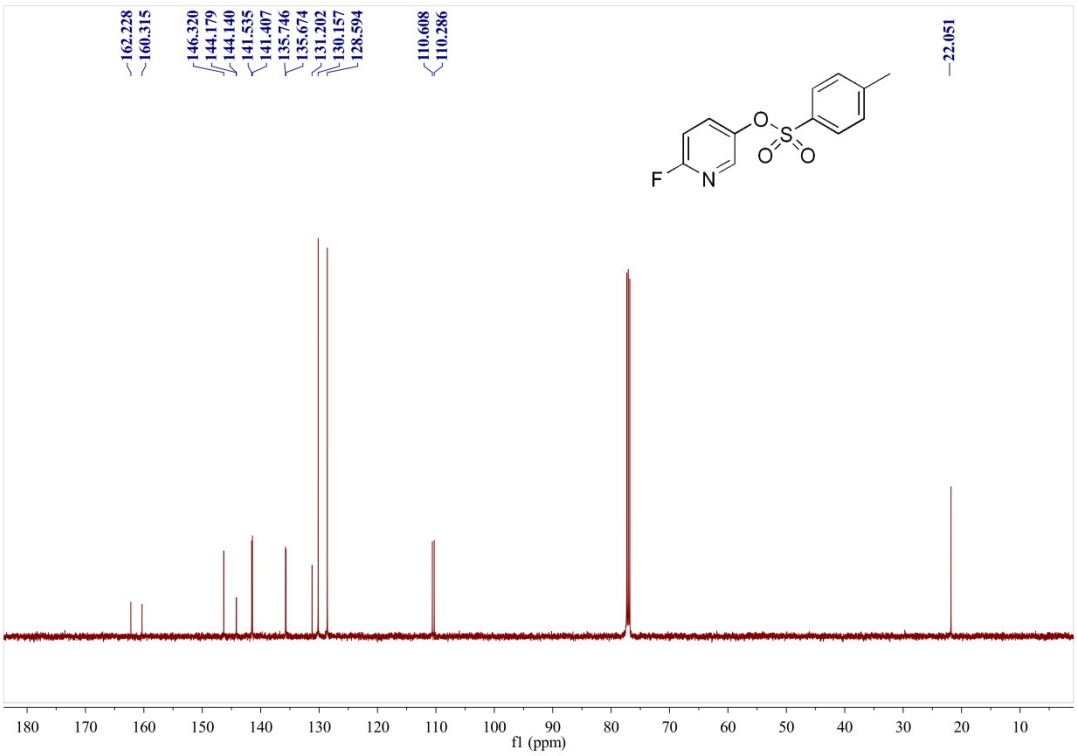

8.353
8.343
8.055
7.768
7.752
7.733
7.716
7.377
7.360
7.172
7.162
2.485
2.206
O
S
O
O
N
0.98
0.93
1.95
1.99
0.91
3.04
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

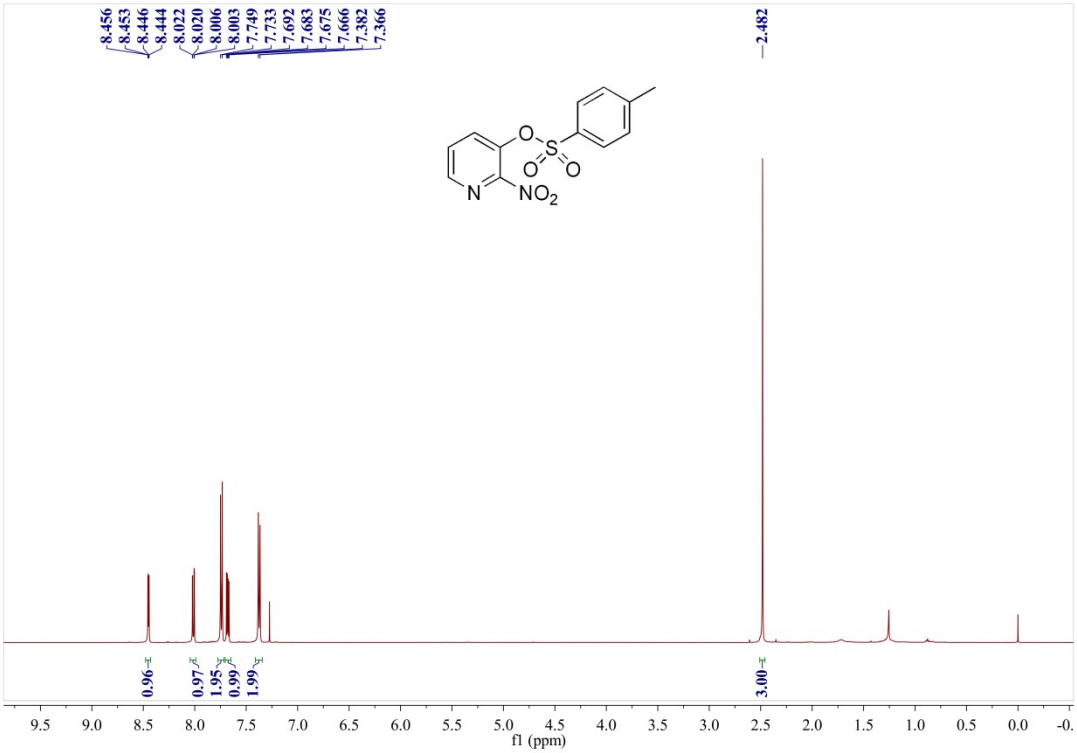

147.694
146.050
143.639
141.655
132.309
130.441
130.136
128.508
126.438
21.807
16.108
O
S
O
O
N
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

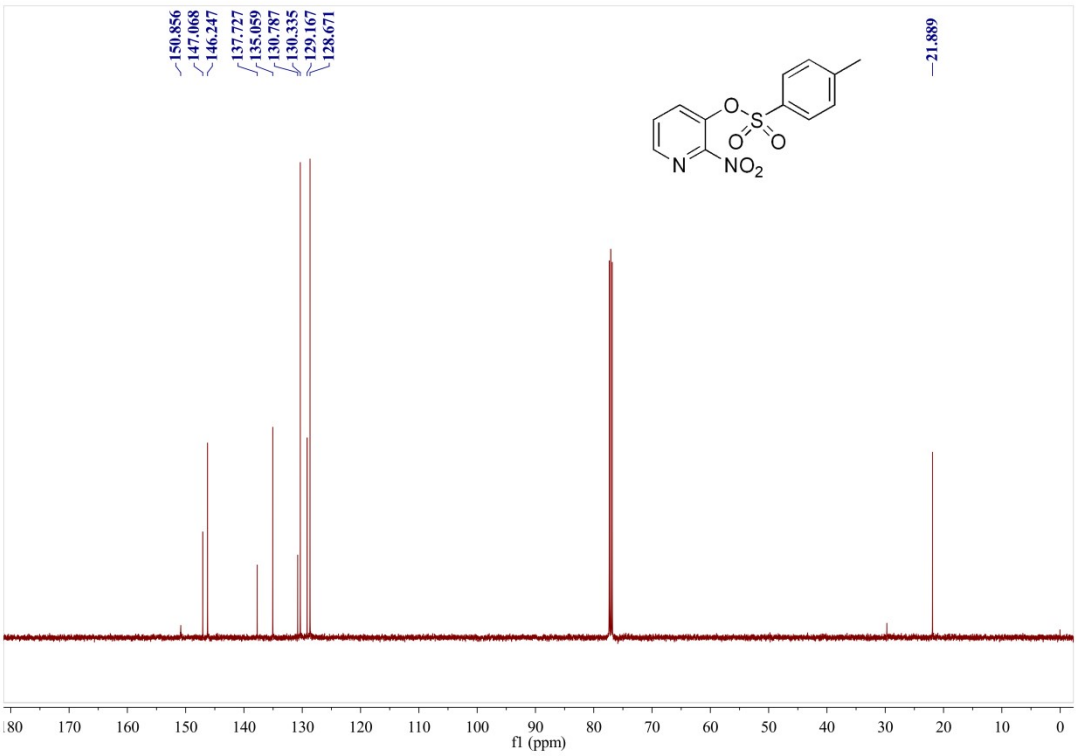

8.213
7.725
7.711
7.350
7.334
7.038
3.828
2.456
O
O
S
O
O
N
0.95
2.91
2.00
0.93
3.10
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

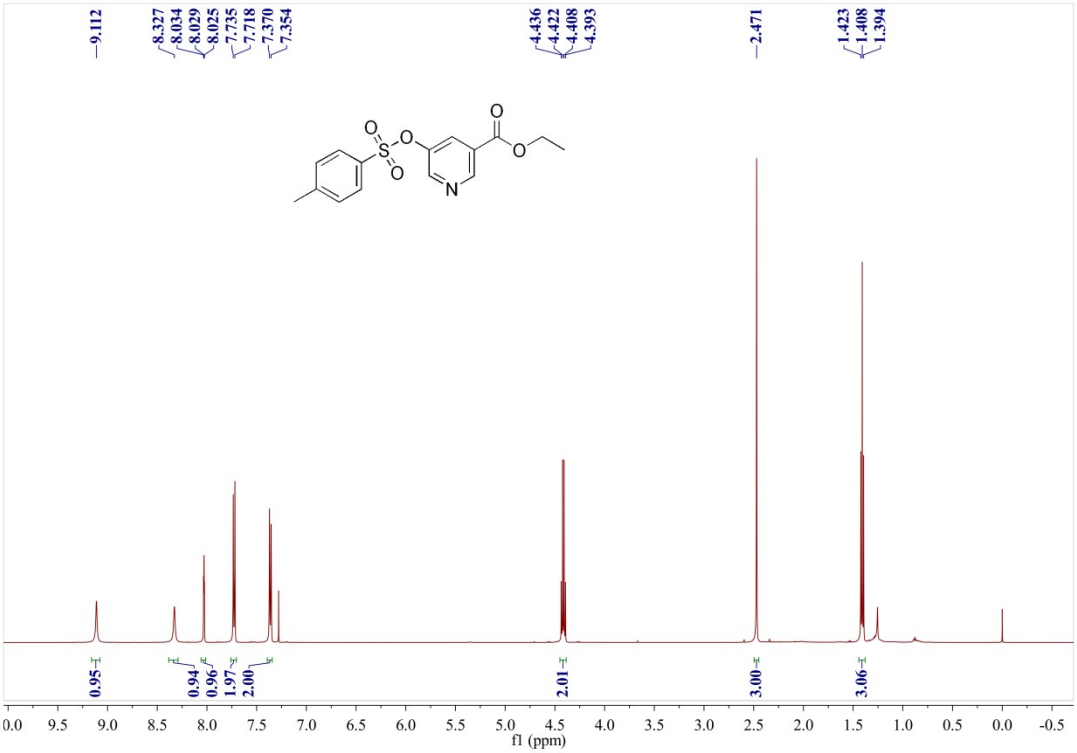

156.207
146.751
146.072
136.534
135.447
131.612
130.052
128.555
115.092
55.970
21.789
O
O
S
O
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

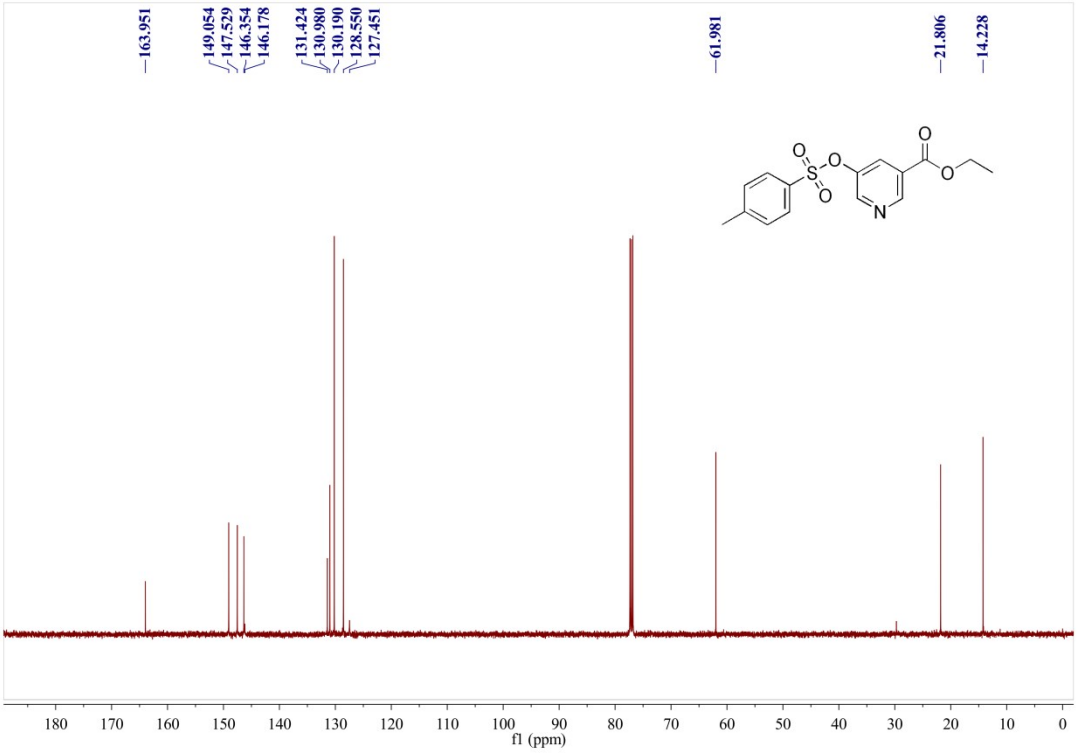

7.732
7.729
7.726
7.724
7.713
7.696
7.582
7.576
7.569
7.564
7.558
7.551
7.546
7.365
7.349
6.935
6.928
6.917
6.910
2.469
O
O
S
O
O
F
N
2.95
1.00
2.01
0.96
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

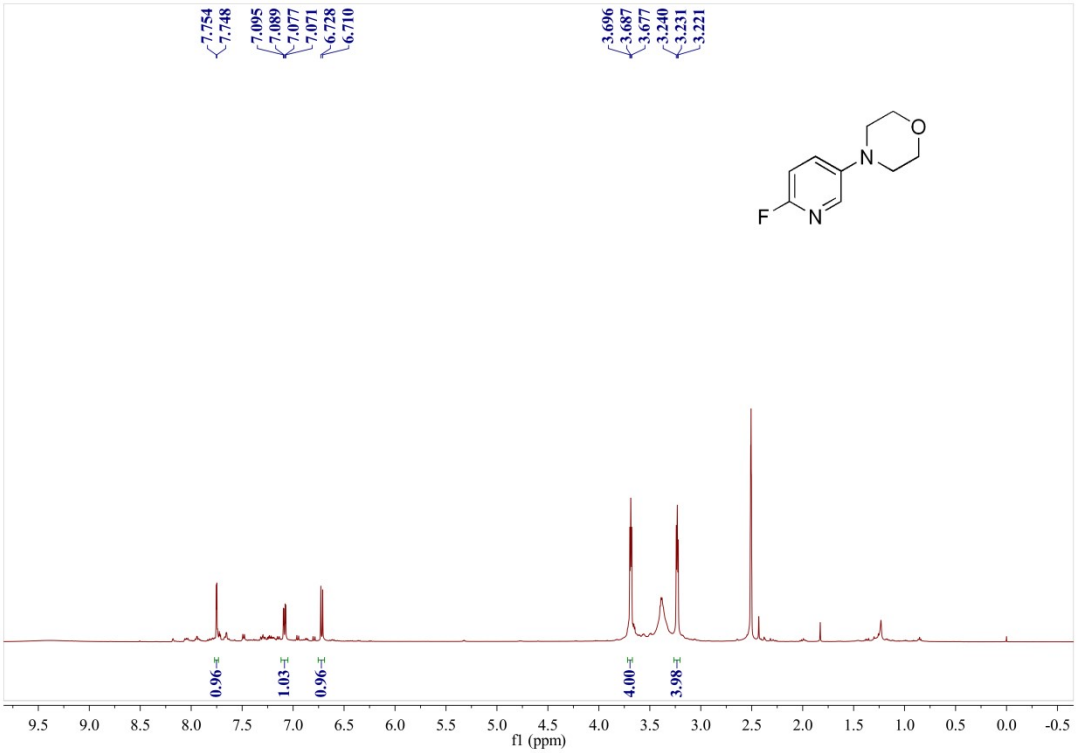

162.228
160.315
146.320
144.179
144.140
141.535
141.407
135.746
135.674
131.202
130.157
128.594
110.608
110.286
22.051
F
N
O
S
O
O
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

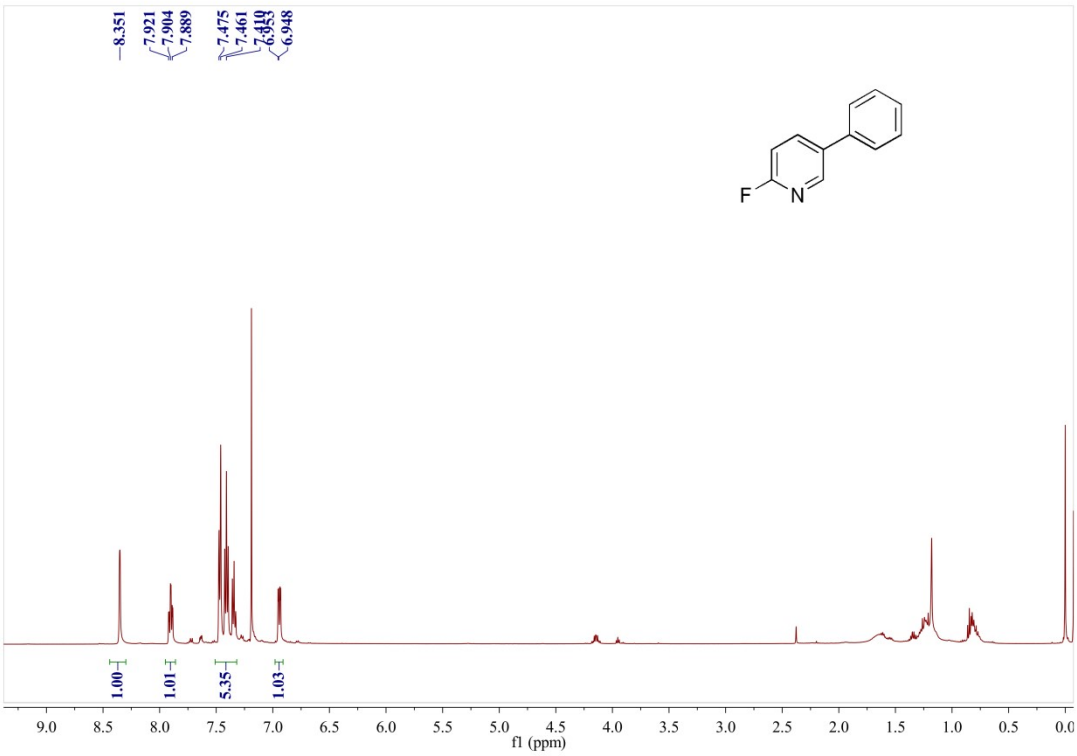

8.456
8.453
8.446
8.444
8.022
8.020
8.006
8.003
7.749
7.733
7.692
7.683
7.675
7.666
7.382
7.366
2.482
N
NO2
O
S
O
O
0.96
0.97
1.95
0.99
1.99
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.
f1 (ppm)


150.856
147.068
146.247
137.727
135.059
130.787
130.335
129.167
128.671
21.889
O
S
O
O
N
NO2
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


9.112
8.327
8.034
8.029
8.025
7.735
7.718
7.370
7.354
4.436
4.422
4.408
4.393
2.471
1.423
1.408
1.394
O
O
S
O
O
O
N
0.95
0.94
0.96
1.97
2.00
2.01
3.00
3.06
0.0 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)


163.951
149.054
147.529
146.354
146.178
131.424
130.980
130.190
128.550
127.451
61.981
21.806
14.228
O
O
S
O
O
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.754
7.748
7.095
7.089
7.077
7.071
6.728
6.710
3.696
3.687
3.677
3.240
3.231
3.221
N
O
F
N
0.96
1.03
0.96
4.00
3.98
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)



5. References.

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