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Supplementary Information

Metal-free molecular iodine-catalyzed direct sulfonylation of pyrazolones with sodium sulfinates leading to sulfonated pyrazoles at room temperature

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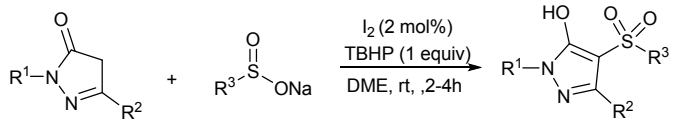
Contents

1. General information

All commercially available reagent grade chemicals were purchased from Aldrich, Acros, Alfa Aesar and Beijing Ouhe Chemical Company and used as received without further purification unless otherwise stated. All solvents were freshly distilled and dried according to standard procedures. ^{1}H NMR and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker Avance III 500 spectrometer with TMS as internal standard (500 MHz ^{1}H, 125 MHz ^{13}C) at room temperature, the chemical shifts (δ) were expressed in ppm and J values were given in Hz. The following abbreviations are used to indicate the multiplicity: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet). All first order splitting patterns were assigned on the basis of the appearance of the multiplet. Splitting patterns that could not be easily interpreted were designated as multiplet (m or brs). Mass analyses and HRMS were obtained on a Finnigan-LCQDECA mass spectrometer and a Bruker Daltonics Bio-TOF-Q mass spectrometer by the ESI method, respectively. FT-IR spectrum was performed using a Thermo Fisher Nicolet IS5. Column chromatography was performed on silica gel (200 - 300 mesh).

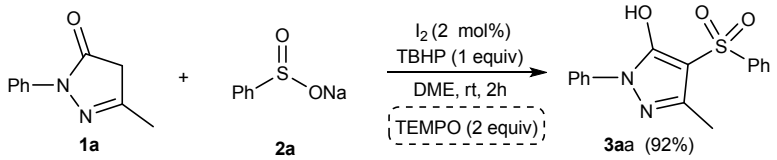
2. General procedure for molecular iodine-catalyzed sulfonylation of pyrazolones with sodium sulfinates leading to sulfonated pyrazoles



1,2-Dimethoxyethane (2 mL) was added to a mixture of pyrazolone **1** (0.25 mmol), sodium sulfinates **2** (0.5 mmol), I_2 (2 mol%), and TBHP (70% in water, 0.25 mmol) in a 25 mL round-bottomed flack at room temperature. The reaction vessel was allowed to stir at room temperature for 2-4h. After the reaction, the resulting mixture was concentrated under vacuum and the residue was purified by flash column chromatography using a mixture of dichloromethane and methanol as eluent to give the desired products.

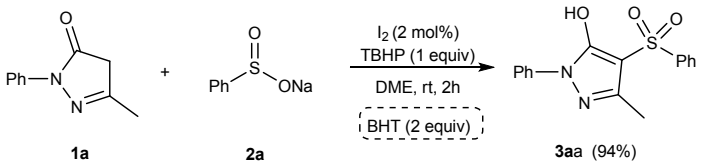
3. Preliminary mechanistic studies

3.1 The model reaction was performed in the presence of TEMPO



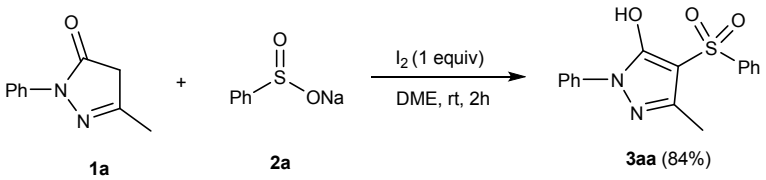
TEMPO (0.5 mmol) was added to a mixture of pyrazolone **1a** (0.25 mmol, 43.5 mg), sodium sulfinate **2a** (0.5 mmol, 82 mg), I_2 (2 mol%), TBHP (70% in water, 0.25 mmol) and 1,2-dimethoxyethane (2 mL) in a 25 mL round-bottomed flack at room temperature. The reaction vessel was allowed to stir at room temperature for 2h. After the reaction, the resulting mixture was concentrated under vacuum and the residue was purified by flash column chromatography using a mixture of dichloromethane and methanol as eluent to give the desired product **3aa** in 92% yield.

3.2 The model reaction was performed in the presence of BHT



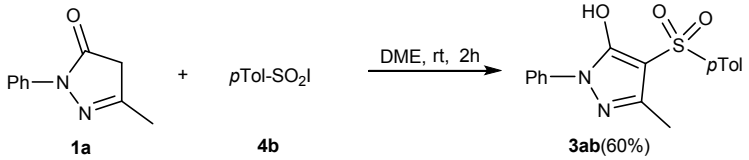
BHT (0.5 mmol, 110.2 mg) was added to a mixture of pyrazolone **1a** (0.25 mmol, 43.5 mg), sodium sulfinate **2a** (0.5 mmol, 82 mg), I_2 (2 mol%) and 1,2-dimethoxyethane (2 mL) in a 25 mL round-bottomed flack at room temperature under air. The reaction vessel was allowed to stir at room temperature for 2h. After the reaction, the resulting mixture was concentrated under vacuum and the residue was purified by flash column chromatography using a mixture of dichloromethane and methanol as eluent to give the desired product **3aa** in 94% yield.

3.3 The reaction of pyrazolone **1a** and sodium sulfinate **2a** in the presence of I_2 (1 equiv)



1,2-Dimethoxyethane (2 mL) was added to a mixture of pyrazolone **1** (0.25 mmol), sodium sulfinates **2** (0.5 mmol), and I_2 (0.25 mmol) in a 25 mL round-bottomed flack at room temperature. The reaction vessel was allowed to stir at room temperature for 2h. After the reaction, the resulting mixture was concentrated under vacuum and the residue was purified by flash column chromatography using a mixture of dichloromethane and methanol as eluent to give the desired product **3aa** in 84% yield.

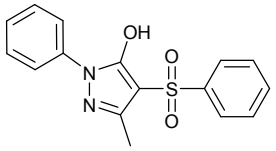
3.4 The reaction of pyrazolone **1a** and sulfonyl iodide **4b**



1,2-Dimethoxyethane (2 mL) was added to a mixture of pyrazolone **1a** (43.5mg,

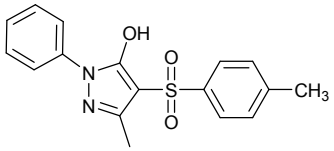
0.25 mmol), sulfonyl iodide **4b** (141mg, 0.5 mmol) and DME (2 mL) in a 25 mL round-bottomed flack at room temperature under air. The reaction vessel was allowed to stir at room temperature for 2h. After the reaction, the resulting mixture was concentrated under vacuum and the residue was purified by flash column chromatography using a mixture of dichloromethane and methanol as eluent to give the desired product **3ab** in 60% yield.

5. Characterization data of products 3aa-3la



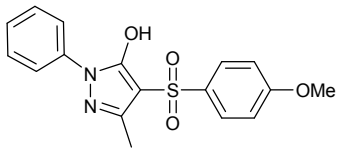
(3aa)

3-methyl-1-phenyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3aa** was obtained in 96% yield according to the general procedure (2h). Yellow solid, mp: 210.2-212.1 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.00 (d, J = 9.5 Hz, 2H), 7.84 (d, J = 9.7 Hz, 2H), 7.50 (t, J = 9.2 Hz, 1H), 7.42 (t, J = 7.3 Hz, 2H), 7.30 (t, J = 9.6 Hz, 2H), 7.12 (t, J = 9.1 Hz, 1H), 2.21 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 160.9, 147.0, 144.4, 138.7, 132.1, 128.7, 128.3, 125.8, 124.8, 121.0, 96.3, 12.7. IR (KBr): OH 3429cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{14}N_2O_3SNa$ $(M + Na)^+$ 337.0623, found 337.0616.



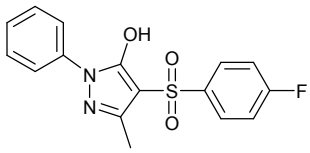
(3ab)

3-methyl-1-phenyl-4-tosyl-1H-pyrazol-5-ol, Compound **3ab** was obtained in 96% yield according to the general procedure (3h). Yellow solid, mp: 191.7-192.1 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.87 (d, J = 8.3 Hz, 2H), 7.84 (d, J = 8.3 Hz, 2H), 7.30 (t, J = 6.3 Hz, 2H), 7.23 (d, J = 6.2 Hz, 2H), 7.13 (t, J = 6.8 Hz, 1H), 2.37 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.6, 146.9, 143.0, 141.7, 139.2, 129.1, 128.2, 125.8, 124.4, 120.8, 95.5, 20.1, 12.7. IR (KBr): OH 3421cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{16}N_2O_3SNa$ $(M + Na)^+$ 351.0779, found 351.0781.



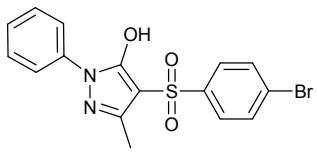
(3ac)

4-(4-methoxyphenylsulfonyl)-3-methyl-1-phenyl-1H-pyrazol-5-ol, Compound **3ac** was obtained in 85% yield according to the general procedure (2h). Yellow solid, mp: 191.5-192.8 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.92 (d, J = 8.9 Hz, 2H), 7.85 (d, J = 7.7 Hz, 2H), 7.31 (brs, 2H), 7.14 (brs, 1H), 6.90 (brs, 2H), 3.81 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.8, 161.4, 146,8, 139.1, 136.2, 128.2, 128.0, 124.5, 120.8, 113.7, 95.9, 54.8, 12.7. IR (KBr): OH 3438cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{16}N_2O_4S$ $(M + Na)^+$ 367.0728, found 367.0732.



(3ad)

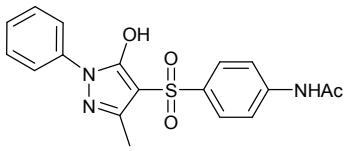
4-(4-fluorophenylsulfonyl)-3-methyl-1-phenyl-1H-pyrazol-5-ol, Compound **3ad** was obtained in 60% yield according to the general procedure (4h). Yellow solid, mp: 220.0-221.7 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.05-8.02 (m, 2H), 7.85 (d, J = 7.9 Hz, 2H), 7.30 (brs, 2H), 7.13 (brs, 3H), 2.19 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 164.8 (d, J = 252.2Hz), 161.8, 150.4, 146.8, 141.0, 139.2, 128.6 (d, J = 7.0 Hz), 128.1, 124.4, 120.8, 115.5 (d, J = 22.1 Hz), 95.0, 12.8. IR (KBr): OH 3421cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}FN_2O_3SNa$ $(M + Na)^+$ 355.0529, found 355.0531.



(3ae)

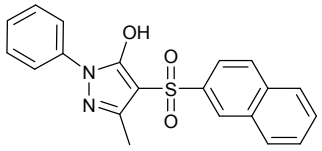
4-(4-bromophenylsulfonyl)-3-methyl-1-phenyl-1H-pyrazol-5-ol, Compound **3ae** was obtained in 90% yield according to the general procedure (4h). White solid, mp: 209.1-210.6 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.88 (d, J = 8.6 Hz, 2H), 7.84 (d, J = 7.9 Hz, 2H), 7.57 (brs, 2H), 7.32 (brs, 2H), 7.14 (brs, 1H), 2.20 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.7, 146.7, 143.8, 138.9, 131.8, 128.2, 127.5, 126.6, 124.6, 120.8, 94.6, 12.9. IR (KBr): OH 3420cm^{-1}; HRMS (ESI) calcd for

$C_{16}H_{14}BrN_2O_3S$ $(M + H)^+$ 392.9909, found 392.9911.



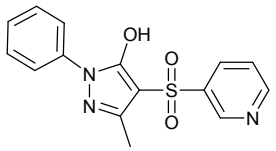
(3af)

N-(4-(5-hydroxy-3-methyl-1-phenyl-1H-pyrazol-4-ylsulfonyl)phenyl)acetamide, Compound **3af** was obtained in 89% yield according to the general procedure (3h). Yellow solid, 262.1-263.1°C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.91 (d, J = 8.0 Hz, 2H), 7.82 (d, J = 6.0 Hz, 2H), 7.63 (d, J = 6.0 Hz, 2H), 7.31 (t, J = 7.2 Hz, 2H), 7.13 (t, J = 6.9 Hz, 1H), 2.22 (s, 3H), 2.14 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 170.6, 161.5, 147.0, 142.3, 139.3, 139.1, 128.2, 126.8, 124.6, 120.9, 119.0, 96.2, 22.7, 12.9. IR(KBr): OH 3425cm^{-1}; HRMS (ESI) calcd for $C_{18}H_{17}N_3O_4SNa$ $(M + Na)^+$ 394.0837, found 394.0832.



(3ag)

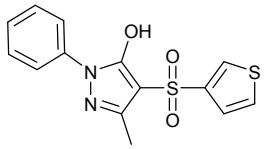
3-methyl-4-(naphthalen-2-ylsulfonyl)-1-phenyl-1H-pyrazol-5-ol, Compound **3ag** was obtained in 88% yield (78.2 mg) according to the general procedure (4h). White solid, mp: 221.2-222.8 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.54 (s, 1H), 7.94 (d, J = 8.4 Hz, 1H), 7.88 (d, J = 7.5 Hz, 2H), 7.78 (brs, 3H), 7.54 (t, J = 7.2 Hz, 1H), 7.48 (t, J = 6.6 Hz, 1H), 7.27 (brs, 2H), 7.09 (brs, 1H), 2.22 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.0, 146.8, 141.3, 139.2, 134.6, 132.0, 128.8, 128.2, 127.4, 127.0, 126.3, 124.4, 121.6, 120.7, 95.1, 12.9. IR(KBr): OH 3394cm^{-1}; HRMS (ESI) calcd for $C_{20}H_{16}N_2O_3SNa$ $(M + Na)^+$ 387.0779, found 387.0774.



(3ah)

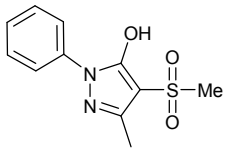
3-methyl-1-phenyl-4-(pyridin-3-ylsulfonyl)-1H-pyrazol-5-ol, Compound **3ah** was obtained in 87% yield according to the general procedure (4h). Yellow solid, mp: 231.7-232.7 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 9.11 (d, J = 2.0 Hz, 1H), 8.68 (s, 1H), 8.38 (d, J = 8.2 Hz, 1H), 7.83 (d, J = 8.2 Hz, 2H), 7.47 (brs, 1H), 7.30 (t, J =

7.0 Hz, 2H), 7.13 (t, J = 6.8 Hz, 1H), 2.22 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.0, 152.0, 146.8, 146.0, 141.7, 139.1, 134.2, 128.1, 124.5, 124.0, 120.8, 94.4, 12.9. IR(KBr): OH 3429cm^{-1}; HRMS (ESI) calcd for $C_{15}H_{13}N_2O_3SNa$ (M + Na)$^+$ 338.0575, found 338.0577.



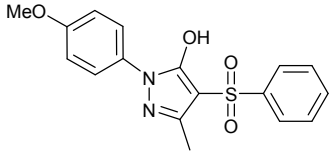
(3ai)

3-methyl-1-phenyl-4-(thiophen-3-ylsulfonyl)-1H-pyrazol-5-ol, Compound **3ai** was obtained in 66% yield according to the general procedure (4h). Yellow solid, mp: 210.7-212.6 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.83 (d, J = 8.1 Hz, 2H), 7.72 (dd, J_1 = 3.7 Hz, J_2 = 1.1 Hz, 1H), 7.68 (brs, 1H), 7.31 (t, J = 7.6 Hz, 2H), 7.14 (t, J = 7.3 Hz, 1H), 7.02 (brs, 1H), 2.26 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.1, 146.9, 146.5, 139.0, 131.2, 130.5, 128.2, 127.0, 124.6, 120.9, 96.6, 12.8. IR(KBr): OH 3360cm^{-1}; HRMS (ESI) calcd for $C_{14}H_{12}N_2O_3S_2Na$ (M + Na)$^+$ 343.0187, found 343.0189.



(3aj)

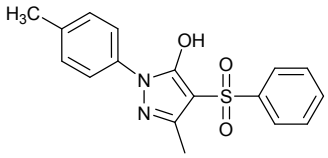
(5-methyl-4-(methylsulfonyl)-2-phenyl-1H-pyrazol-3(2H)-one, Compound **3aj** was obtained in 78% yield according to the general procedure (2h). White solid, mp: 241.3-242.9 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.81 (d, J = 7.9 Hz, 2H), 7.34 (t, J = 7.9 Hz, 2H), 7.17 (t, J = 7.4 Hz, 1H), 3.10 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.4, 146.8, 139.0, 128.2, 124.8, 121.1, 95.3, 44.2, 20.9, 12.6. IR(KBr): OH 3437cm^{-1}; HRMS (ESI) calcd for $C_{11}H_{12}N_2O_3NaS$ (M + Na)$^+$ 275.0466, found 275.0460.



(3ba)

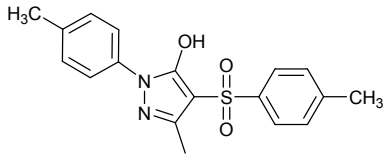
1-(4-methoxyphenyl)-3-methyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3ba** was obtained in 65% yield according to the general procedure (4h). White solid,

mp: 206.7-270.6 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.91 (d, J = 8.9 Hz, 2H), 7.85 (d, J = 7.7 Hz, 2H), 7.31 (brs, 2H), 7.13 (brs, 1H), 6.90 (brs, 2H), 3.81 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.8, 161.4, 146.8, 139.1, 136.2, 128.2, 128.0, 124.5, 120.8, 113.7, 95.9, 54.8, 12.7. IR(KBr): OH 3455cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{16}N_2O_4SNa$ $(M + Na)^+$ 367.0728, found 367.0731.



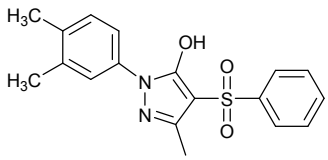
(3ca)

3-methyl-4-(phenylsulfonyl)-1-p-tolyl-1H-pyrazol-5-ol, Compound **3ca** was obtained in 98% yield according to the general procedure (2h). Yellow solid, mp: 222.1-222.7 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.00 (d, J = 7.5 Hz, 2H), 7.68 (d, J = 8.1 Hz, 2H), 7.54 (t, J = 7.4 Hz, 1H), 7.44 (t, J = 6.6 Hz, 2H), 7.11 (d, J = 6.6 Hz, 2H), 2.31 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.5, 146.6, 144.6, 136.7, 134.3, 132.0, 128.7, 128.6, 125.7, 121.0, 95.0, 19.6, 12.8. IR(KBr): OH 3421cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{16}N_2O_3SNa$ $(M + Na)^+$ 351.0779, found 351.0783.



(3cb)

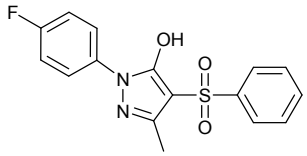
3-methyl-1-p-tolyl-4-tosyl-1H-pyrazol-5-ol, Compound **3cb** was obtained in 98% yield according to the general procedure (2h). White solid, mp: 229.7-230.8 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.86 (d, J = 8.2 Hz, 2H), 7.67 (d, J = 7.4 Hz, 2H), 7.22 (brs, 2H), 7.12 (d, J = 7.6 Hz, 2H), 2.37 (s, 3H), 2.31 (s, 3H), 2.16 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.4, 146.9, 143.3, 141.0, 136.6, 134.3, 129.1, 128.7, 125.9, 121.1, 95.0, 20.1, 19.6, 12.7. IR(KBr): OH 3438cm^{-1}; HRMS (ESI) calcd for $C_{18}H_{18}N_2O_3SNa$ $(M + Na)^+$ 365.0936, found 365.0937.



(3da)

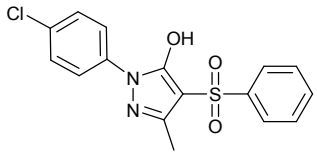
1-(3,4-dimethylphenyl)-3-methyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound

3da was obtained in 82% yield according to the general procedure (2h). Yellow solid, mp: 211.7-212.8 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.01 (d, J = 7.7 Hz, 2H), 7.55 (brs, 2H), 7.46 (brs, 3H), 7.07 (d, J = 7.9 Hz, 1H), 2.23 (s, 3H), 2.21 (s, 6H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.0, 146.5, 144.4, 136.5, 136.4, 133.3, 132.1, 129.3, 128.6, 125.9, 122.4, 118.8, 96.1, 18.6, 17.9, 12.6. IR(KBr): OH 3418cm^{-1}; HRMS (ESI) calcd for $C_{18}H_{18}N_2O_3SNa$ $(M + H)^+$ 365.0936, found 365.0939.



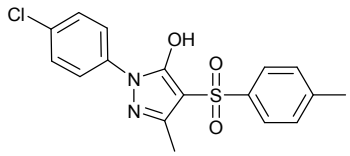
(3ea)

1-(4-fluorophenyl)-3-methyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3ea** was obtained in 91% yield according to the general procedure (2h). White solid, mp: 201.7-202.5 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.00 (d, J = 7.8 Hz, 2H), 7.85-7.82 (dd, J_1 = 8.5 Hz, J_2 = 5.0 Hz, 2H), 7.54 (t, J = 5.5 Hz, 1H), 7.47 (t, J = 6.4 Hz, 2H), 7.00 (brs, 2H), 2.18 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.9 159.8 (d, J = 244.3 Hz), 146.9, 145.0, 135.7, 132.1, 128.6, 125.7, 122.5 (d, J = 7.6 Hz), 114.7 (d J = 22.5 Hz), 94.9, 12.8. IR(KBr): OH 3412cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}FN_2O_3SNa$ $(M + Na)^+$ 355.0529, found 355.0533.



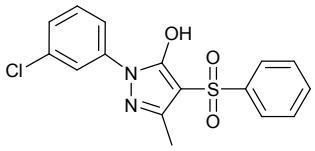
(3fa)

1-(4-chlorophenyl)-3-methyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3fa** was obtained in 95% yield according to the general procedure (4h). Yellow solid, mp: 241.9-242.7 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.00 (d, J = 7.7 Hz, 2H), 7.89 (d, J = 8.9 Hz, 2H), 7.53 (t, J = 6.7 Hz, 1H), 7.44 (t, J = 7.4 Hz, 2H), 7.22 (d, J = 7.4 Hz, 2H), 2.17 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.9, 147.2, 144.6, 138.0, 132.1, 129.1, 128.6, 128.1, 125.7, 121.5, 95.1, 12.8. IR(KBr): OH 3429cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}ClN_2O_3SNa$ $(M + Na)^+$ 371.0233, found 371.0237.



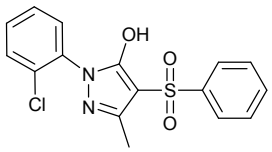
(3fb)

1-(4-chlorophenyl)-3-methyl-4-tosyl-1H-pyrazol-5-ol, Compound **3fb** was obtained in 98% yield according to the general procedure (2h). Yellow solid, mp: 219.7-220.6 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.87 (d, J = 2.5 Hz, 2H), 7.85 (d, J = 2.4 Hz, 2H), 7.22 (d, J = 6.6 Hz, 4H), 2.37 (s, 3H), 2.16 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.8, 147.3, 143.0, 141.7, 138.0, 129.3, 129.1, 128.1, 125.8, 121.6, 95.4, 20.1, 12.8. IR(KBr): OH 3428cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{15}ClN_2O_3SNa$ $(M + Na)^+$ 385.0390, found 385.0395.



(3ga)

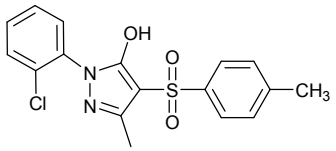
1-(3-chlorophenyl)-3-methyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3ga** was obtained in 95% yield according to the general procedure (2h). Yellow solid, mp: 232.1-233.2 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.02 (s, 1H), 7.99 (d, J = 7.7 Hz, 2H), 7.87 (d, J = 8.2 Hz, 1H), 7.53 (brs, 1H), 7.43 (brs, 2H), 7.24 (brs, 1H), 7.09 (brs, 1H), 2.18 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.2, 147.5, 144.5, 140.5, 133.7, 132.1, 129.4, 128.6, 125.7, 123.7, 119.8, 118.0, 95.2, 12.9. IR(KBr): OH 3438cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}ClN_2O_3SNa$ $(M + Na)^+$ 371.0233, found 371.0234.



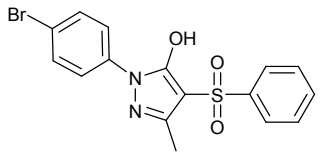
(3ha)

1-(2-chlorophenyl)-3-methyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3ha** was obtained in 93% yield according to the general procedure (2h). Yellow solid, mp: 221.7-222.9 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.99 (d, J = 7.4 Hz, 2H), 7.57 (t, J = 7.4 Hz, 1H), 7.52-7.48 (m, 3H), 7.40-7.32 (m, 3H), 2.17 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.2, 147.0, 144.7, 136.1, 132.6, 132.0, 130.3, 129.8, 129.3, 128.6, 127.1, 125.6, 94.1, 12.9. IR(KBr): OH 3429cm^{-1}; HRMS (ESI) calcd for

$C_{16}H_{13}ClN_2O_3SNa$ $(M + Na)^+$ 371.0233, found 371.0235.

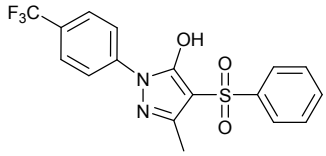


1-(2-chlorophenyl)-3-methyl-4-tosyl-1H-pyrazol-5-ol, Compound **3hb** was obtained in 92% yield according to the general procedure (2h). Yellow solid, mp: 211.7-212.9 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.86 (d, J = 8.2 Hz, 2H), 7.51 (d, J = 7.8 Hz, 1H), 7.38-7.32 (m, 3H), 7.28 (d, J = 7.4 Hz, 2H), 2.41 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.1, 147.0, 143.0, 141.6, 136.1, 132.6, 130.2, 129.7, 129.3, 129.1, 127.0, 125.8, 94.4, 20.1, 12.8. IR(KBr): OH 3428cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{15}ClN_2O_3SNa$ $(M + Na)^+$ 385.0390, found 385.0395.



(3ia)

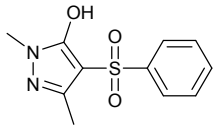
1-(4-bromophenyl)-3-methyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3ia** was obtained in 90% yield according to the general procedure (4h). Yellow solid, mp: 229.2-230.7 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.99 (d, J = 7.8 Hz, 2H), 7.83 (d, J = 7.8 Hz, 2H), 7.54 (brs, 1H), 7.45 (brs, 2H), 7.38 (brs, 2H), 2.16 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.0, 147.3, 144.5, 138.5, 132.1, 131.1, 128.6, 125.7, 121.8, 116.8, 95.0, 12.8. IR(KBr): OH 3429cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}BrN_2O_3SNa$ $(M + Na)^+$ 414.9728, found 414.9731.



(3ja)

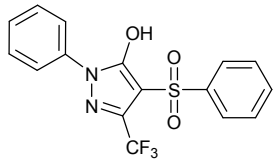
3-methyl-4-(phenylsulfonyl)-1-(4-(trifluoromethyl)phenyl)-1H-pyrazol-5-ol, Compound **3ja** was obtained in 74% yield according to the general procedure (4h). White solid, mp: 209.6-210.7 °C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 8.16 (d, J = 8.6 Hz, 2H), 8.01 (d, J = 7.7 Hz, 2H), 7.54-7.46 (m, 5H), 2.18 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 162.6, 147.9, 144.6, 142.4, 132.1 (d, J = 4.3 Hz), 128.6, 127.6, 125.7, 125.2 (d, J = 13.9 Hz), 124.4 (d, J = 278.7 Hz), 119.3, 95.2, 12.9.

IR(KBr): OH 3429cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{13}F_3N_2O_3SNa$ $(M + Na)^+$ 405.0497, found 405.0499.



(3ka)

1,3-dimethyl-4-(phenylsulfonyl)-1H-pyrazol-5-ol, Compound **3ka** was obtained in 60% yield according to the general procedure (2h). White solid, mp: 250.3-251.7 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.95 (d, J = 7.5 Hz, 2H), 7.56 (t, J = 6.7 Hz, 1H), 7.48 (t, J = 7.5 Hz, 2H), 3.36 (s, 3H), 2.13 (s, 3H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 160.2, 145.3, 132.0, 129.2, 128.6, 125.6, 96.4, 30.2, 12.4. IR(KBr): OH 3534cm^{-1}; HRMS (ESI) calcd for $C_{11}H_{12}N_2O_3SNa$ $(M + Na)^+$ 275.0466, found 275.0469.

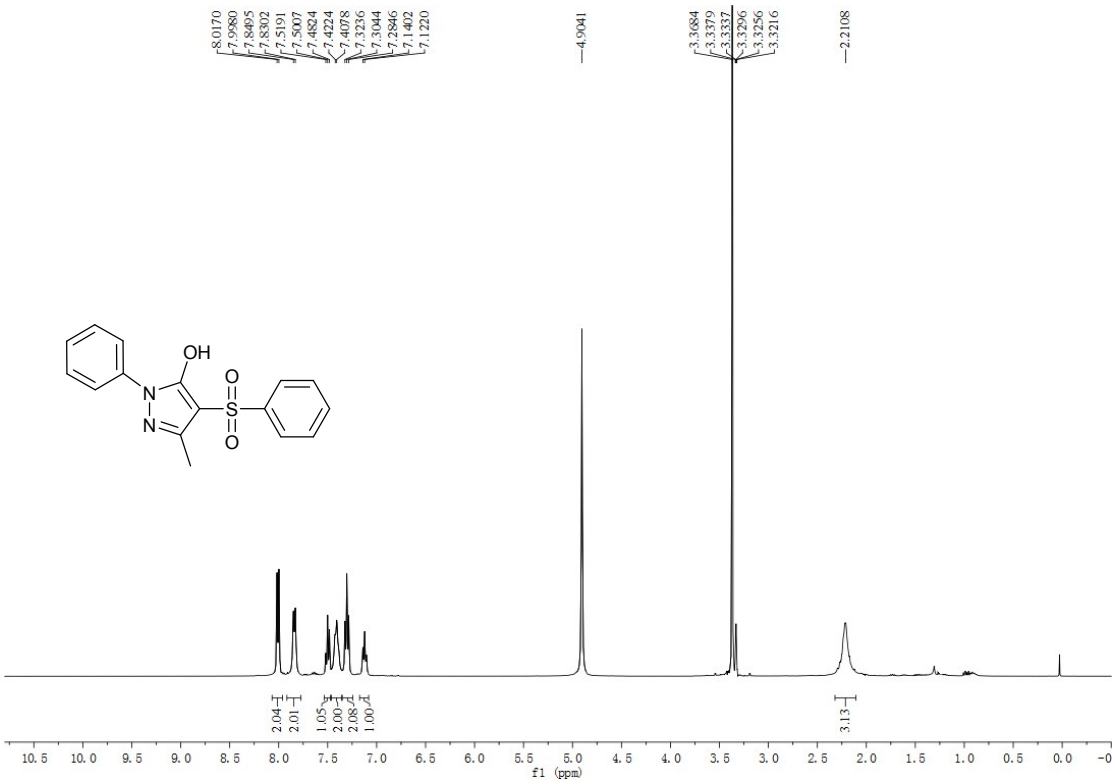


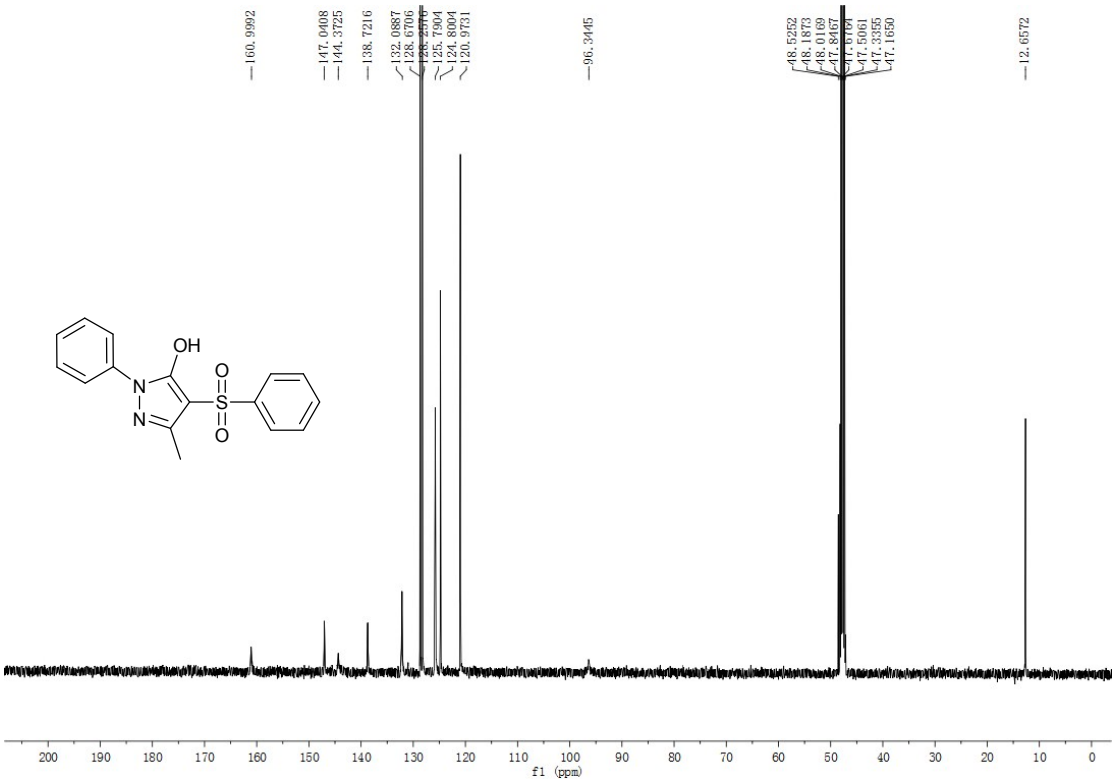
(3la)

1-phenyl-4-(phenylsulfonyl)-3-(trifluoromethyl)-1H-pyrazol-5-ol, Compound **3la** was obtained in 44% yield according to the general procedure (4h). Yellow solid, mp: 232.2-233.2 ^{o}C. ^{1}H NMR (CD_3OD, 500 MHz, ppm): δ 7.83 (d, J = 7.9 Hz, 2H), 7.73 (d, J = 7.9 Hz, 2H), 7.51-7.49 (m, 3H), 7.38 (t, J = 7.7 Hz, 2H), 7.22 (t, J = 7.4 Hz, 1H); ^{13}C NMR (CD_3OD, 125 MHz, ppm): 161.8, 143.8, 139.0, 130.2, 128.7, 128.3, 125.5, 125.2, 121.9 (d, J = 265.3 Hz), 121.3, 121.1 (d, J = 267.8 Hz), 99.9. IR(KBr): OH 3395cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{11}F_3N_2O_3SNa$ $(M + Na)^+$ 391.0340, found 391.0346.

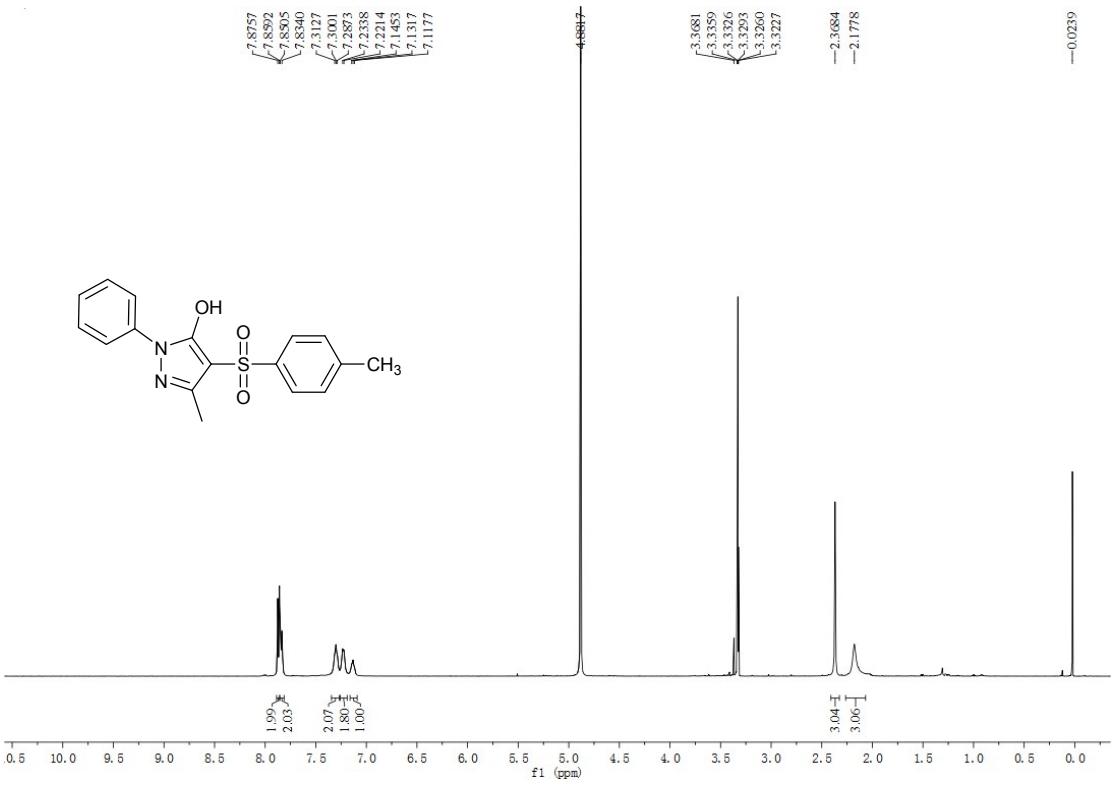
6. Copies of NMR spectra for compounds 3aa−3la

3aa





3ab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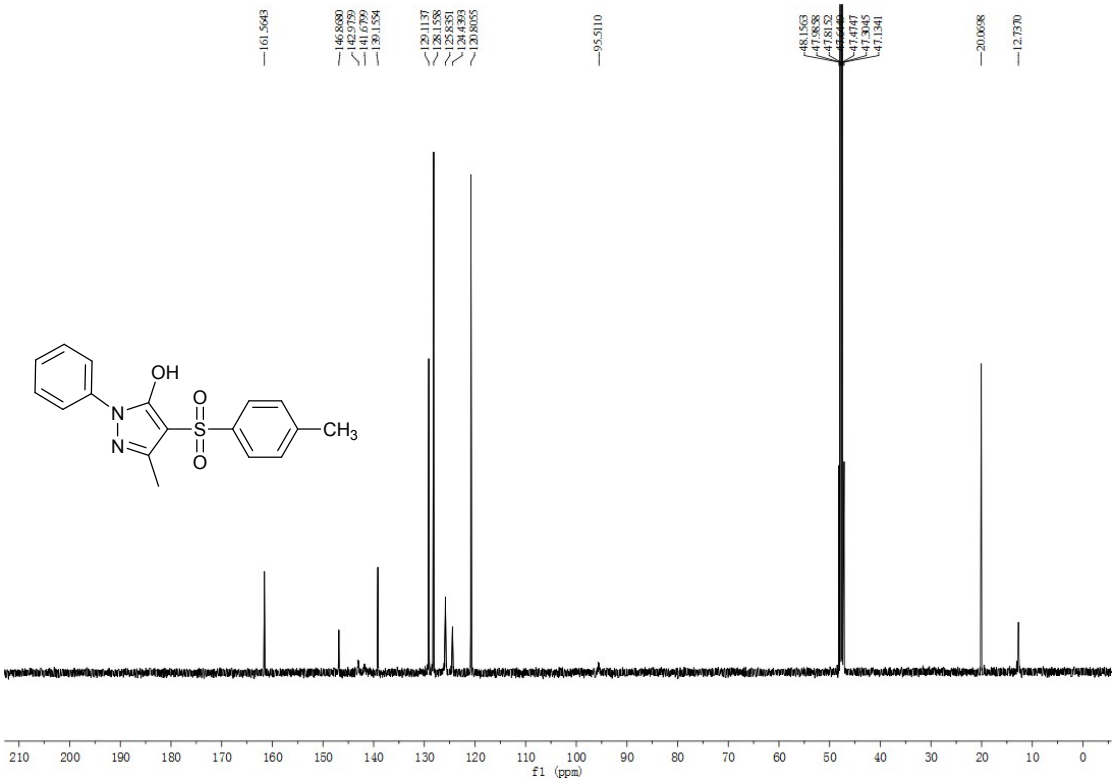
7.8505
7.8340
7.3127
7.3001
7.2873
7.2338
7.2214
7.1453
7.1317
7.1177
4.8817
3.3681
3.3359
3.3326
3.3293
3.3260
3.3227
2.3684
2.1778
0.0239
OH
N
N
O
S
O
CH3
1.99
2.03
2.07
1.80
1.00
3.04
3.06
f1 (ppm)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145.9759
141.6799
139.1594
129.1137
128.1598
125.8551
124.4393
120.8055
95.5110
48.1563
47.8838
47.6113
47.4047
47.3045
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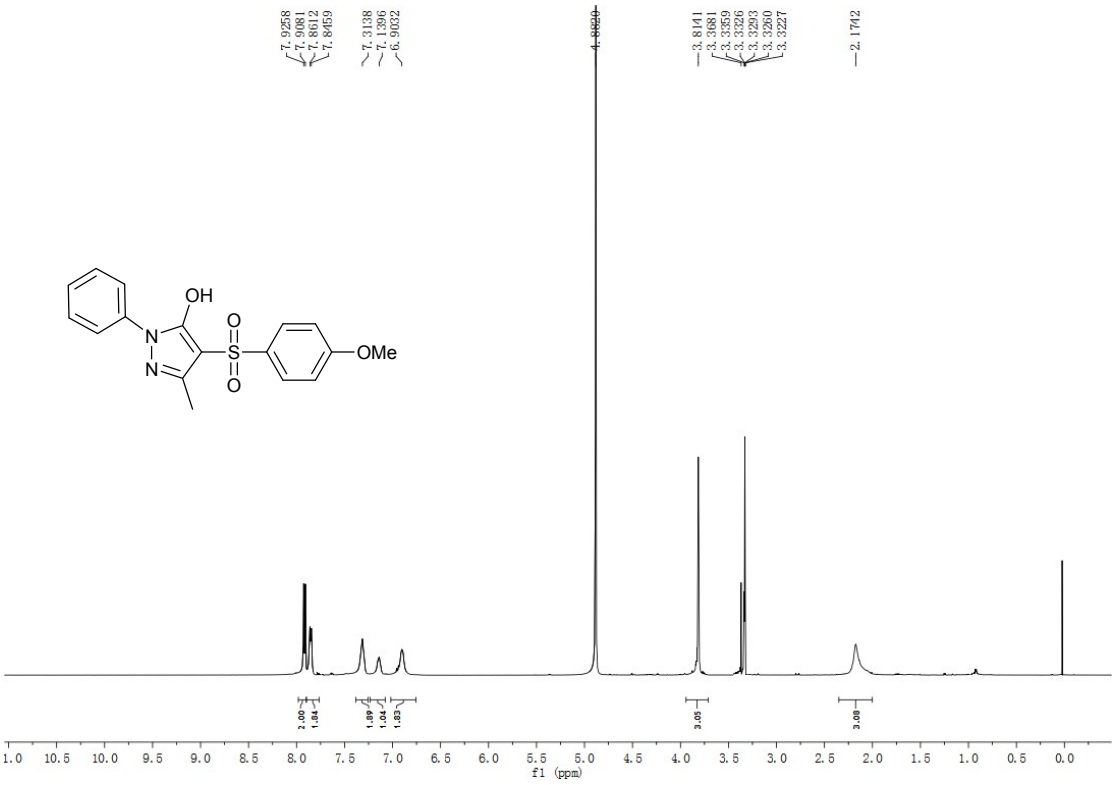
20.0698
12.7370
OH
N
N
O
S
O
CH3
f1 (ppm)

3ac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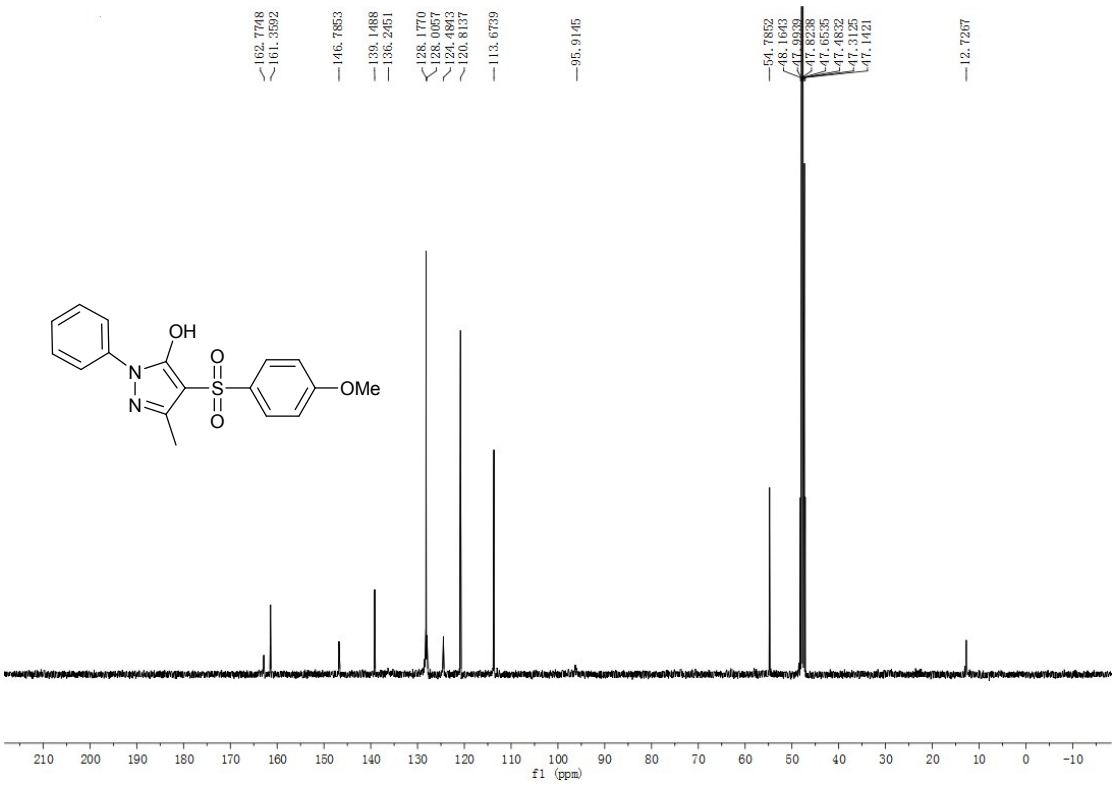
7.8612
7.8459
7.3138
7.1396
6.9032
4.8828
3.8141
3.3681
3.3359
3.3326
3.3293
3.3260
3.3227
2.1742
OH
N
N
O
S
O
OMe
f1 (ppm)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139.1488
136.2451
128.1770
128.0057
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120.8137
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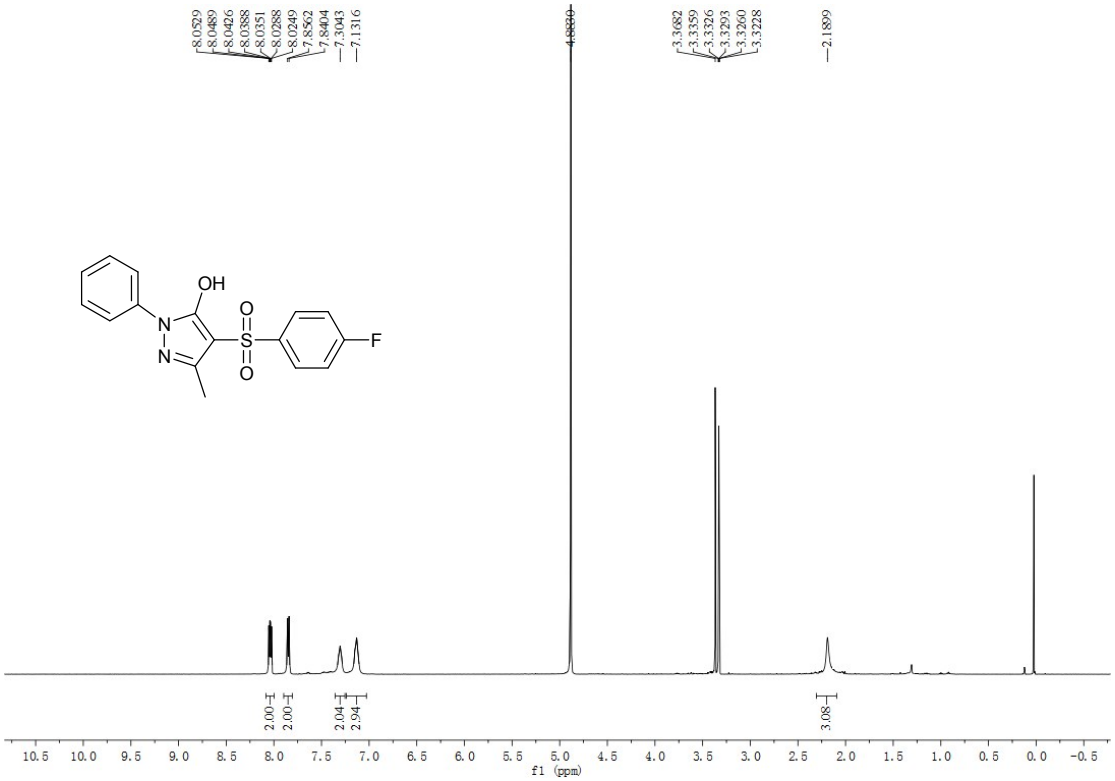
95.9145
54.7852
48.1643
47.9939
47.8238
47.6535
47.4832
47.3125
47.1421
12.7267
OH
N
N
O
S
O
OMe
f1 (ppm)

3ad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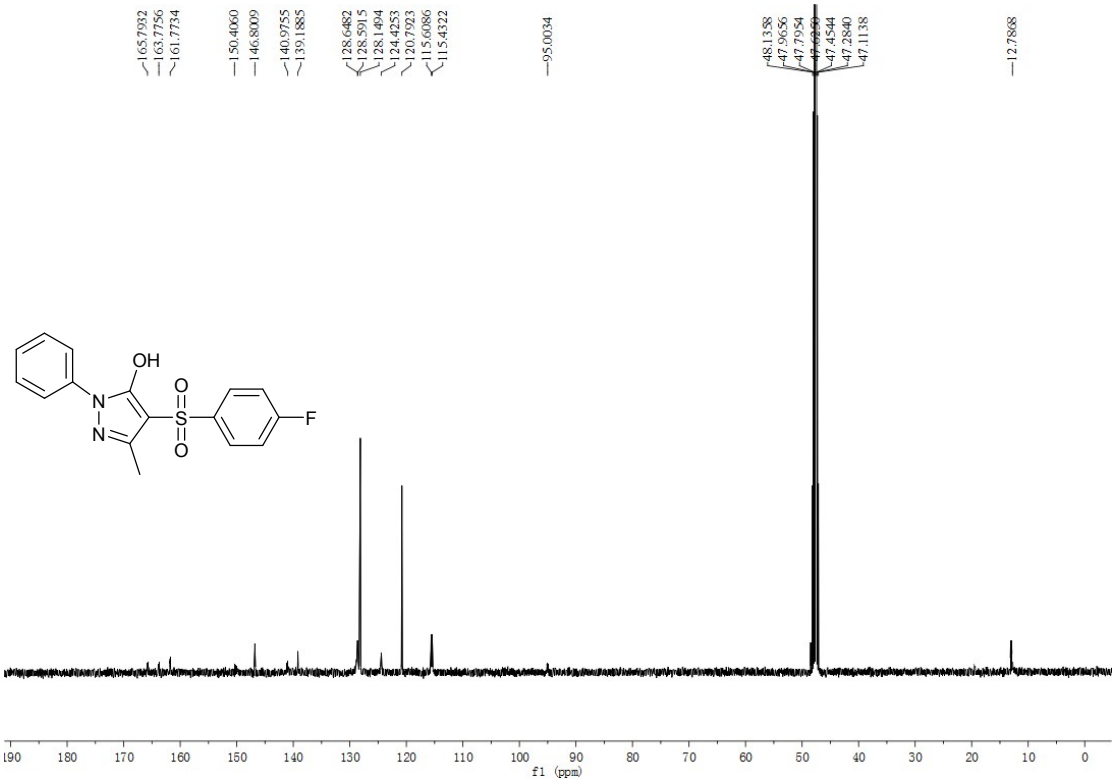
8.0489
8.0426
8.0388
8.0351
8.0288
8.0249
7.8562
7.8404
7.3043
7.1316
4.8880
3.3682
3.3359
3.3326
3.3293
3.3260
3.3228
2.1899
OH
N
N
O
S
O
F
2.00
2.00
2.04
2.94
3.08
f1 (ppm)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161.7734
150.4060
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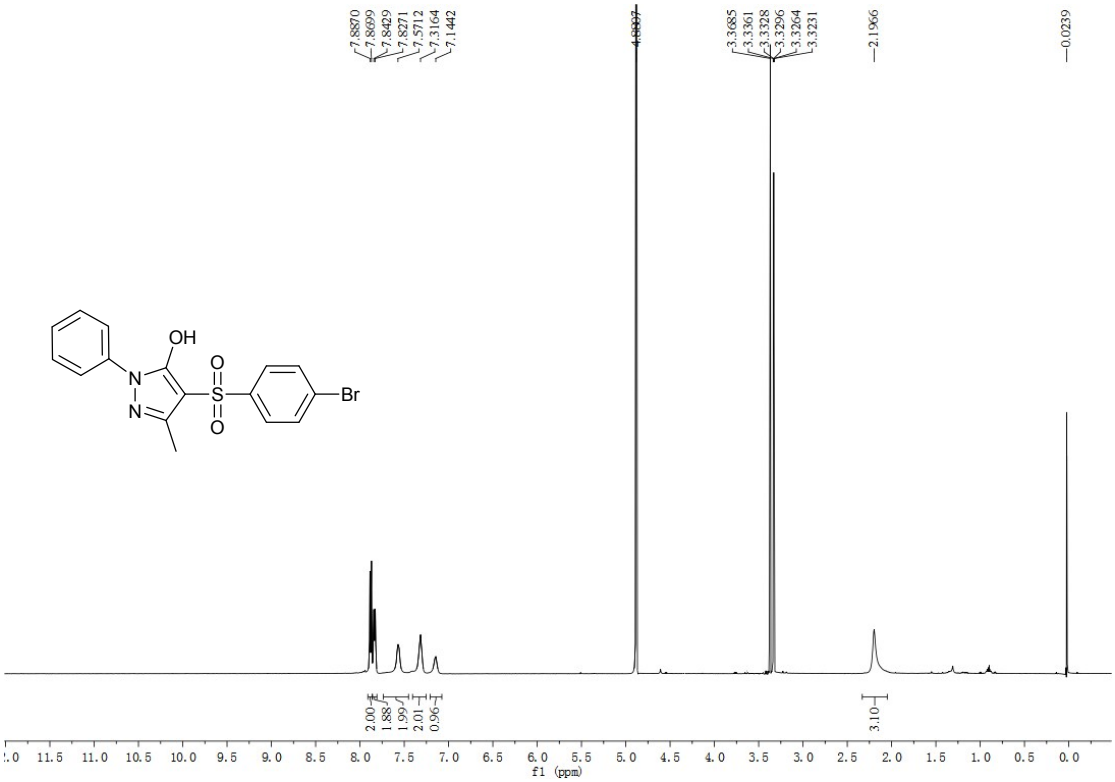
139.1885
128.6482
128.5915
128.1404
124.4253
120.7923
115.6086
115.4322
95.0034
48.1338
47.9656
47.7954
47.4544
47.2840
47.1138
12.7868
OH
N
N
O
S
O
F
f1 (ppm)

3ae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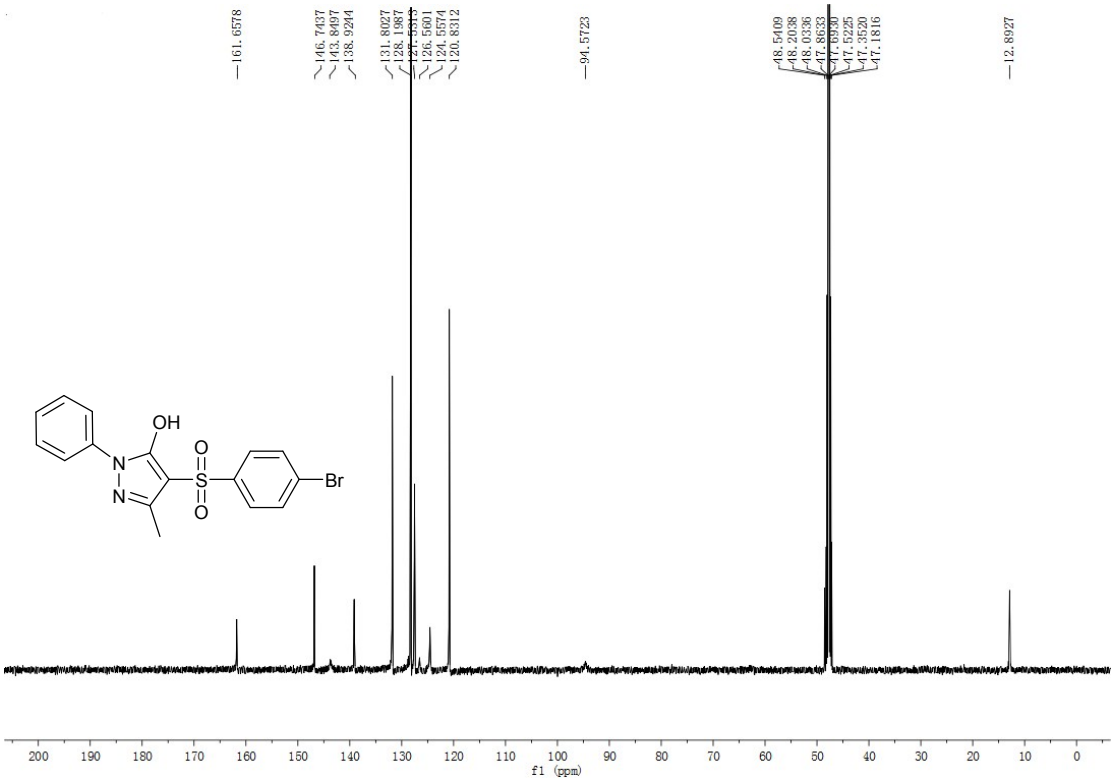
7.8429
7.8271
7.5712
7.3164
7.1442
4.8887
3.3685
3.3361
3.3328
3.3296
3.3264
3.3231
2.1966
0.0239
OH
N
N
O
S
O
Br
2.00
1.88
1.99
2.01
0.96
3.10
f1 (ppm)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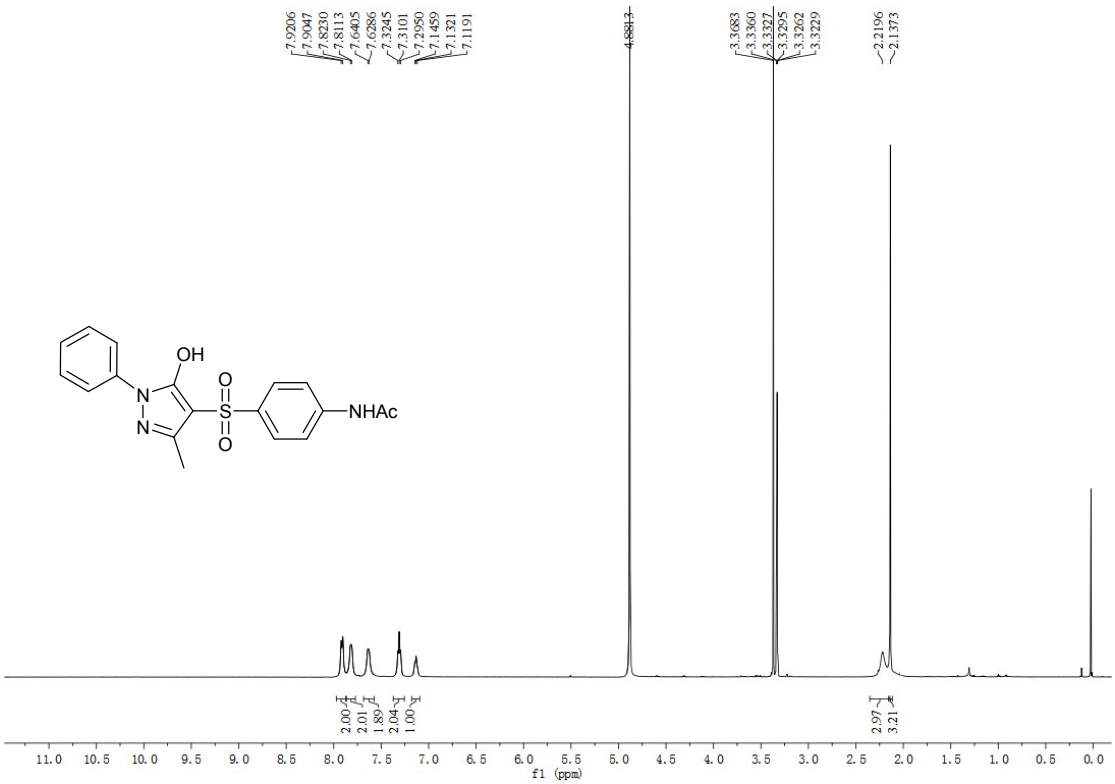
124.5574
120.8312
94.5723
18.5409
18.2038
18.0336
17.8633
17.6930
17.5225
17.3520
17.1816
12.8927
OH
N
N
O
S
O
Br
f1 (ppm)

3af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7.6286
7.3245
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7.2950
7.1459
7.1321
7.1191
4.8813
3.3683
3.3360
3.3327
3.3295
3.3262
3.3229
2.2196
2.1373
OH
N
N
O
S
O
NHAc
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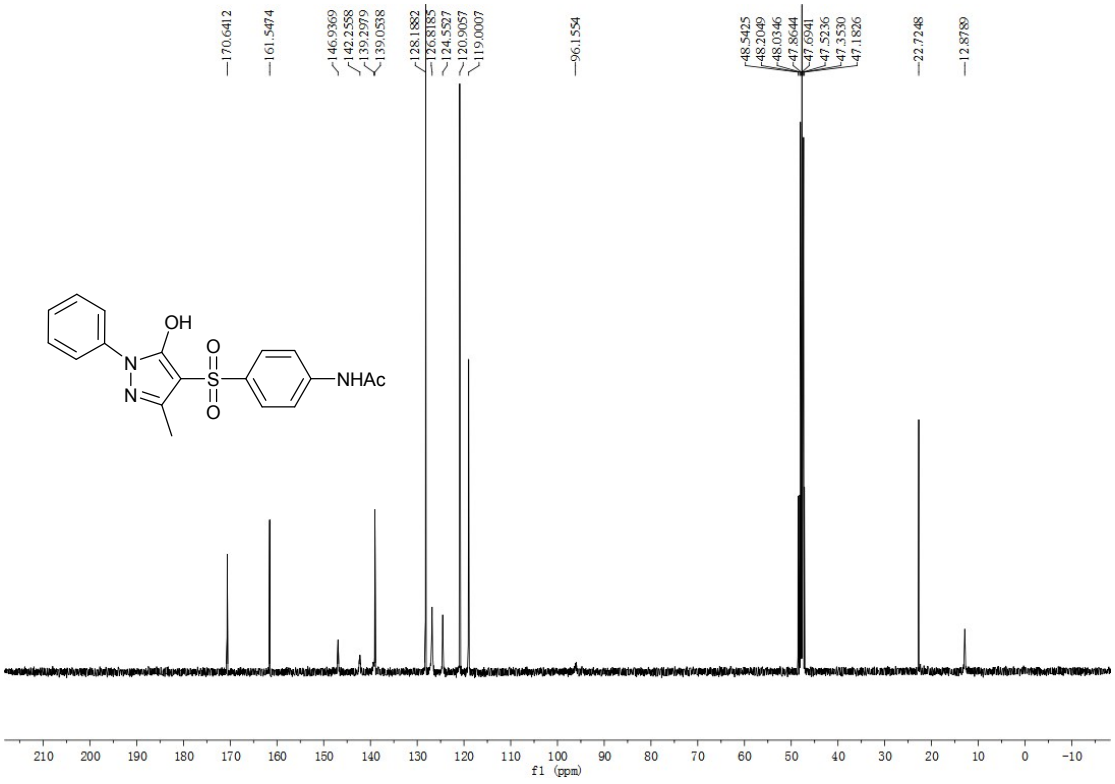
2.01
1.89
2.04
1.00
2.97
3.21
f1 (ppm)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146.9369
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139.2979
139.0538
128.1882
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124.5527
120.9057
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96.1554
48.5425
48.2049
48.0346
47.8644
47.6941
47.5236
47.3530
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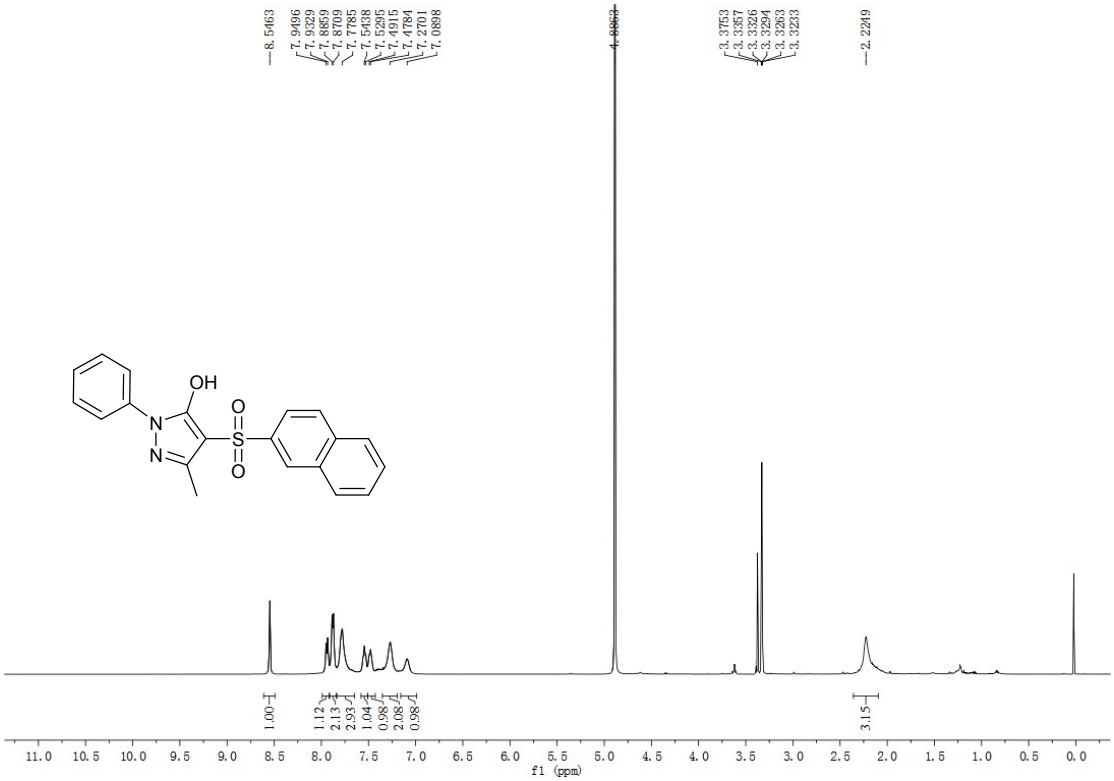
22.7248
12.8789
OH
N
N
O
S
O
NHAc
f1 (ppm)

3ag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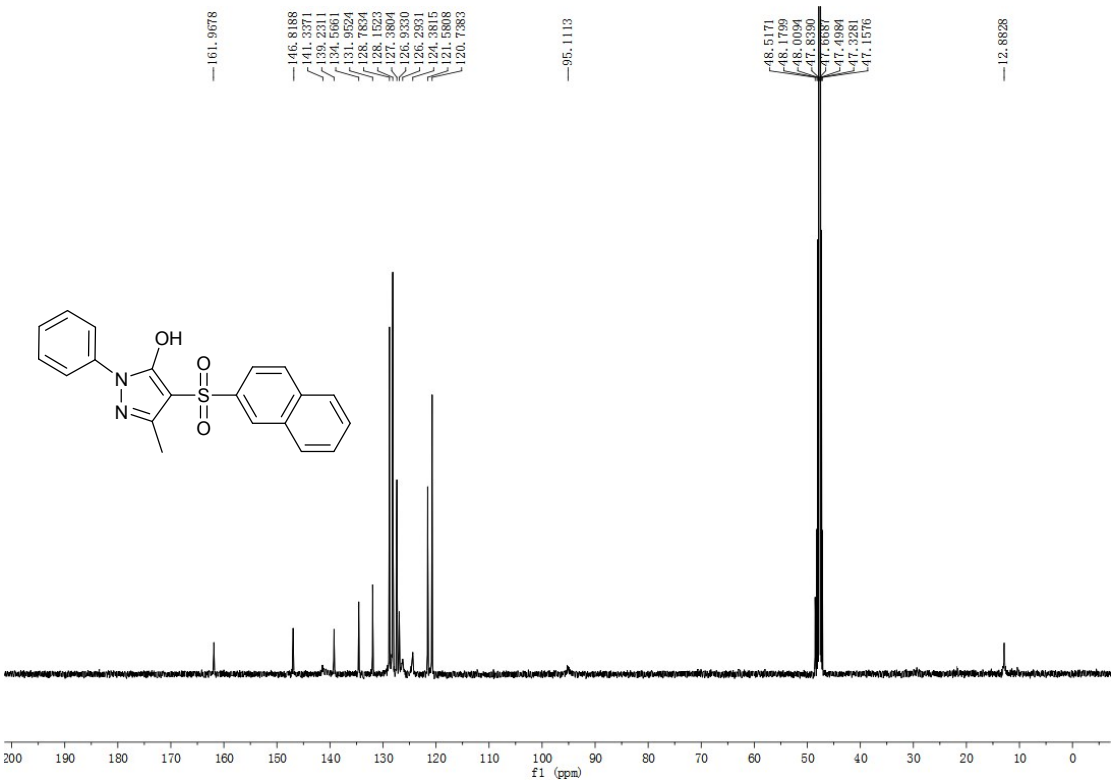
3.3326
3.3294
3.3263
3.3233
2.2249
OH
N
N
O
S
O
1.00
1.12
2.13
2.93
1.04
0.98
2.08
0.98
3.15
f1 (ppm)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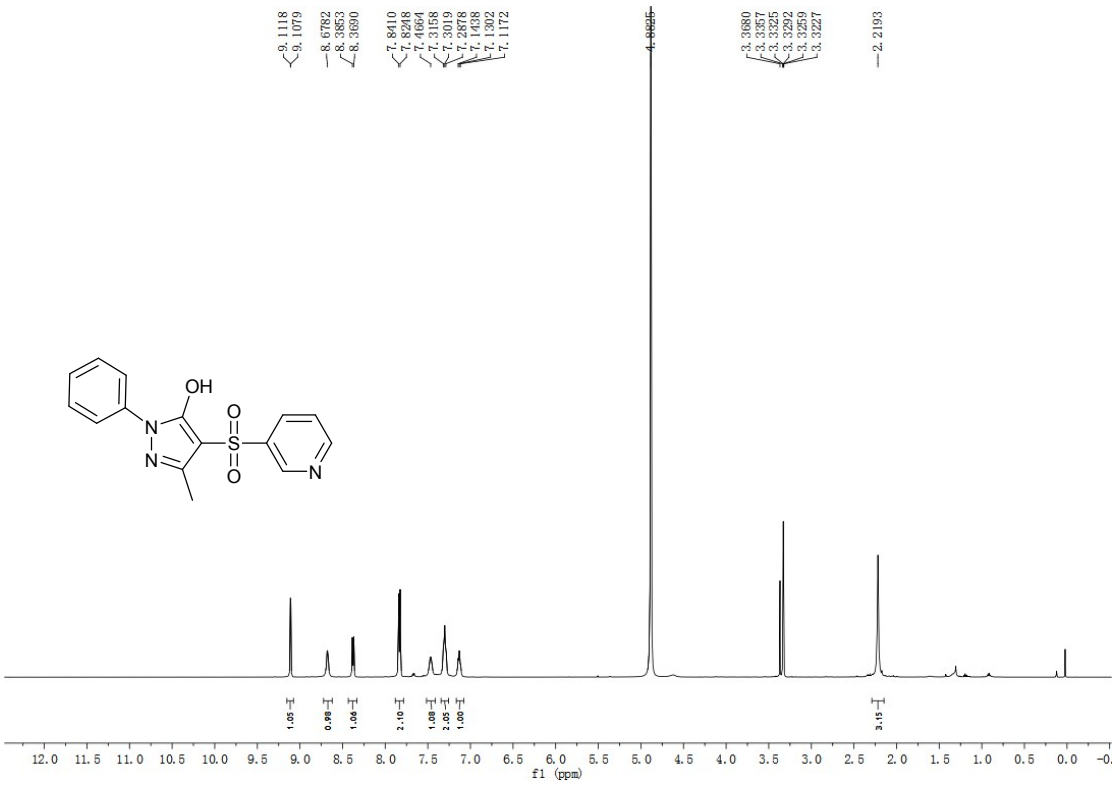
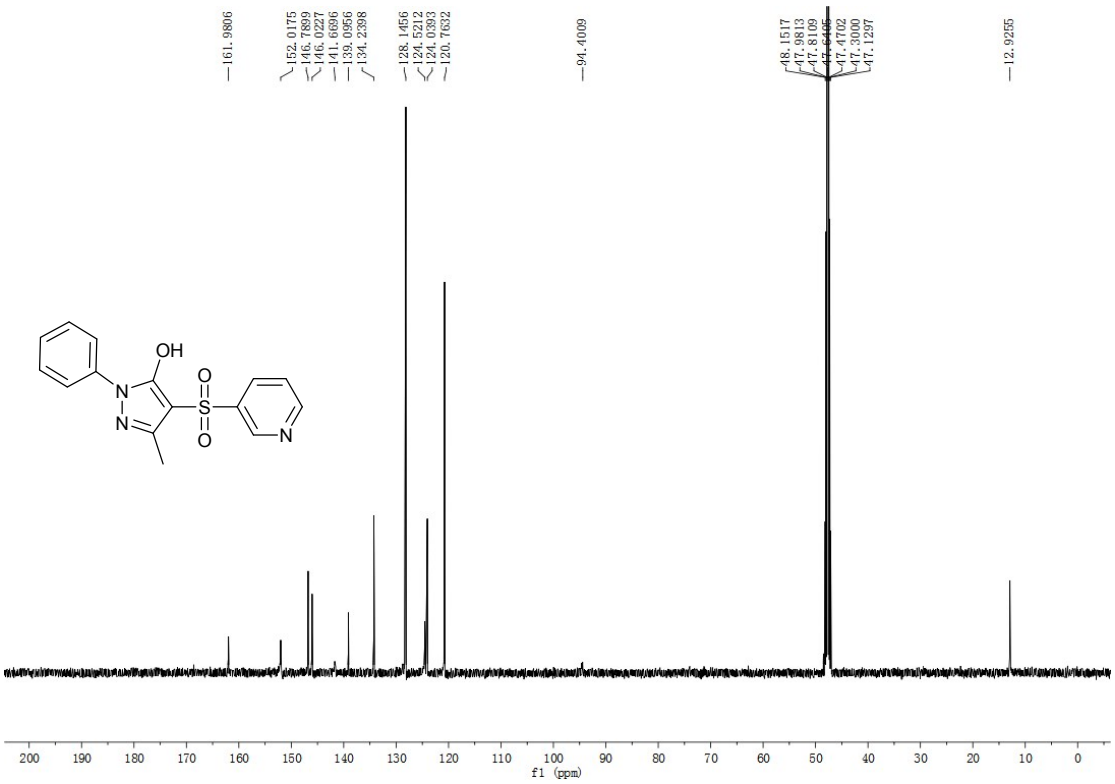
141.3371
139.2311
134.5661
131.9524
128.7834
128.1523
127.3804
126.9330
126.2931
124.3815
121.5808
120.7383
95.1113
48.5171
48.1799
48.0094
47.8390
47.6687
47.4984
47.3281
47.1576
12.8828
OH
N
N
O
S
O
f1 (ppm)

3ah


9.1118
9.1079
8.6782
8.3853
8.3690
7.8410
7.8298
7.4664
7.3158
7.3019
7.2878
7.1438
7.1302
7.1172
4.8825
3.3680
3.3357
3.3325
3.3292
3.3259
3.3227
2.2193
OH
O
S
O
N
N
1.05
0.98
1.06
2.10
1.08
2.05
1.00
3.15
f1 (ppm)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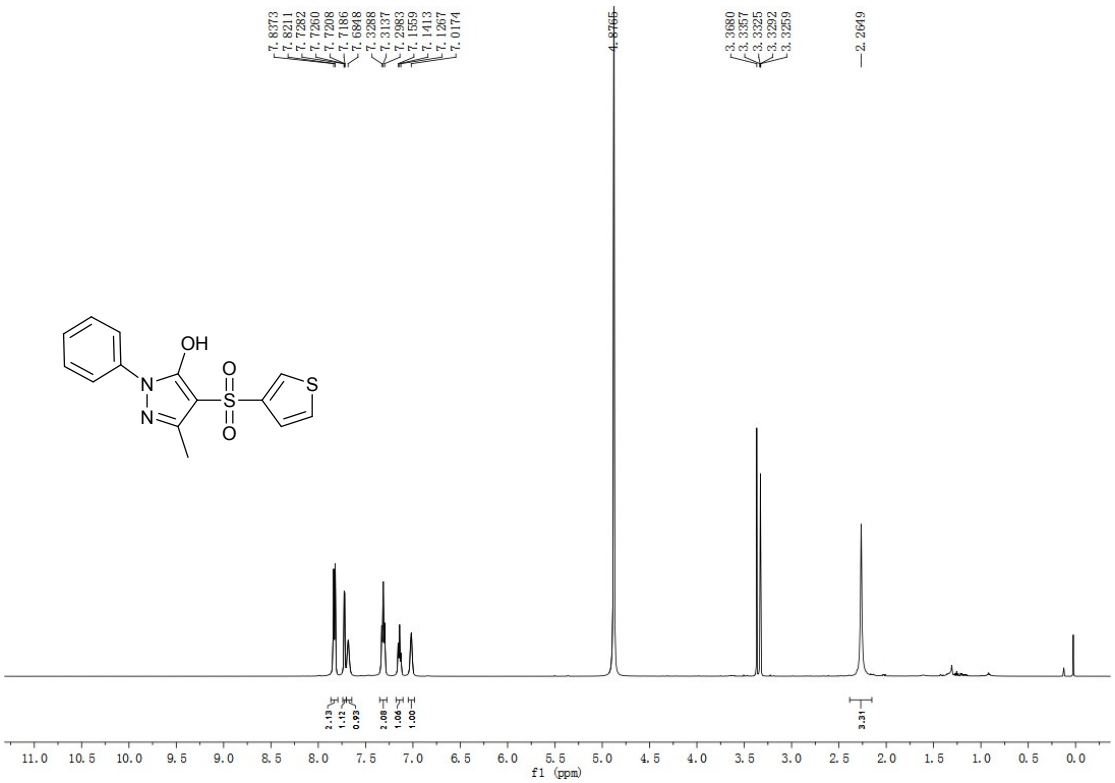
146.7899
146.0227
141.6696
139.0956
134.2398
128.1456
124.5212
124.0393
120.7632
94.4009
18.1517
17.9813
17.8109
17.6406
17.4702
17.3000
17.1297
12.9255
OH
O
S
O
N
N
f1 (ppm)

3ai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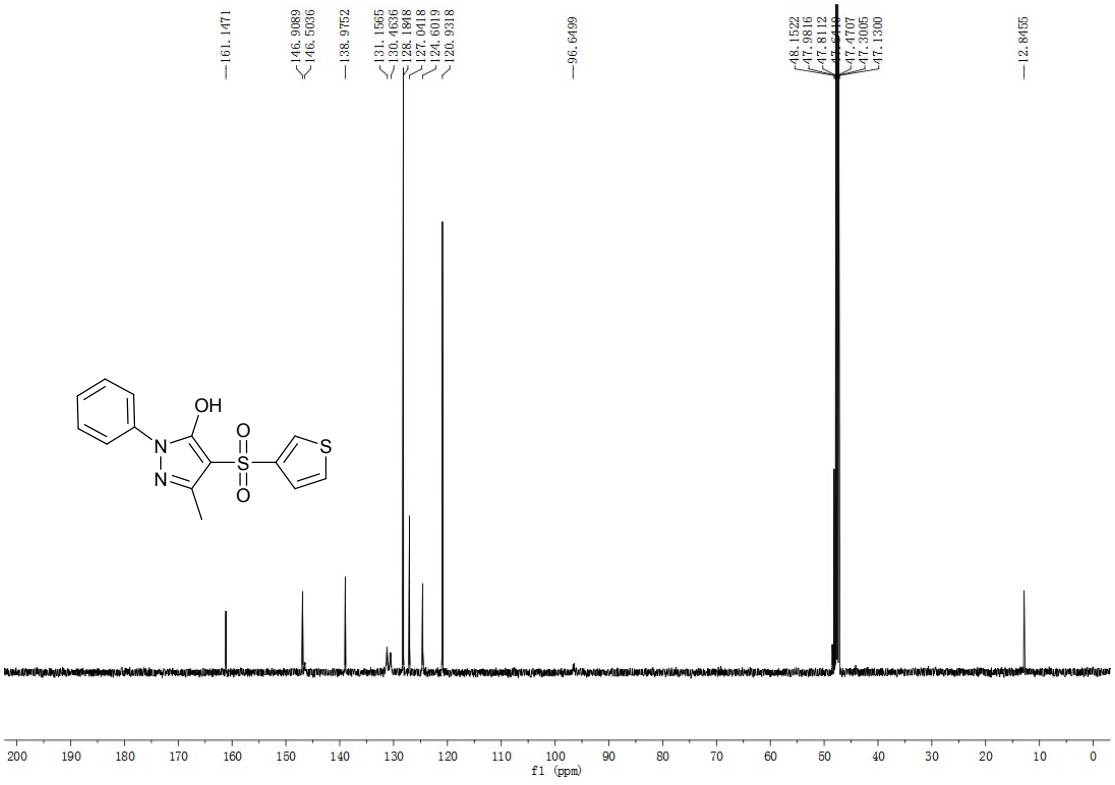
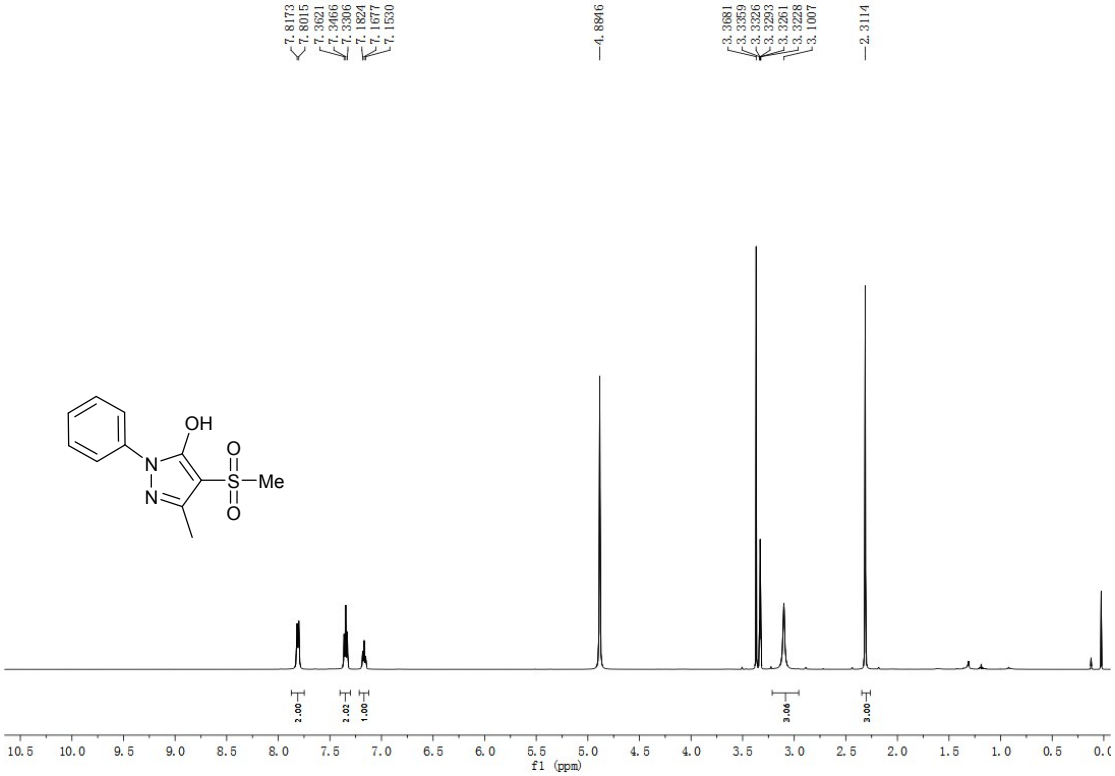
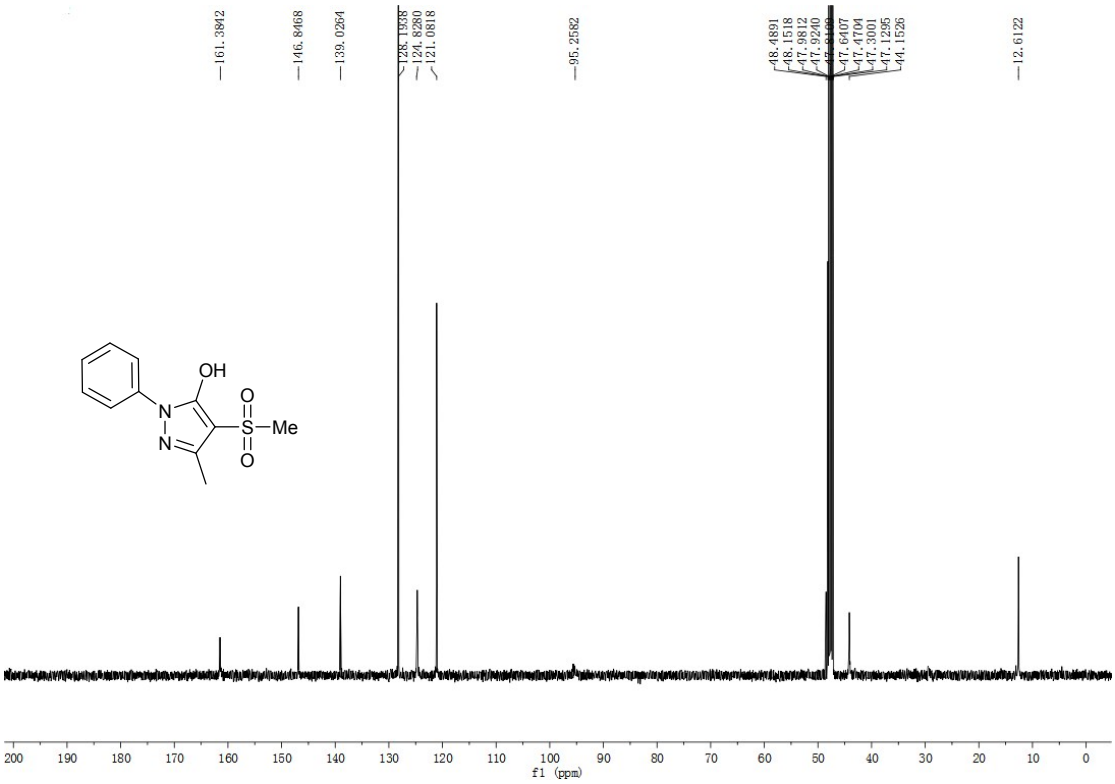
7.8211
7.7282
7.7260
7.7208
7.7186
7.6848
7.3288
7.3137
7.2983
7.1559
7.1413
7.1267
7.0174
4.8766
3.3680
3.3567
3.3325
3.3292
3.3259
2.2649
OH
N
N
O
S
O
S
2.13
1.12
0.93
2.08
1.04
1.00
3.31
f1 (ppm)


161.1471
146.9089
146.5036
138.9752
131.1565
130.4636
128.1848
127.0418
124.6019
120.9318
96.6499
18.1522
17.9816
17.8112
17.6410
17.4707
17.3005
17.1300
12.8455
OH
N
N
O
S
O
S
f1 (ppm)

3aj


7.8173
7.8015
7.3621
7.3466
7.3306
7.1824
7.1677
7.1530
4.8946
3.3681
3.3359
3.3326
3.3293
3.3261
3.3228
3.1007
2.3114
OH
N
N
O
S
O
Me
2.00
2.02
1.00
3.06
3.00
f1 (ppm)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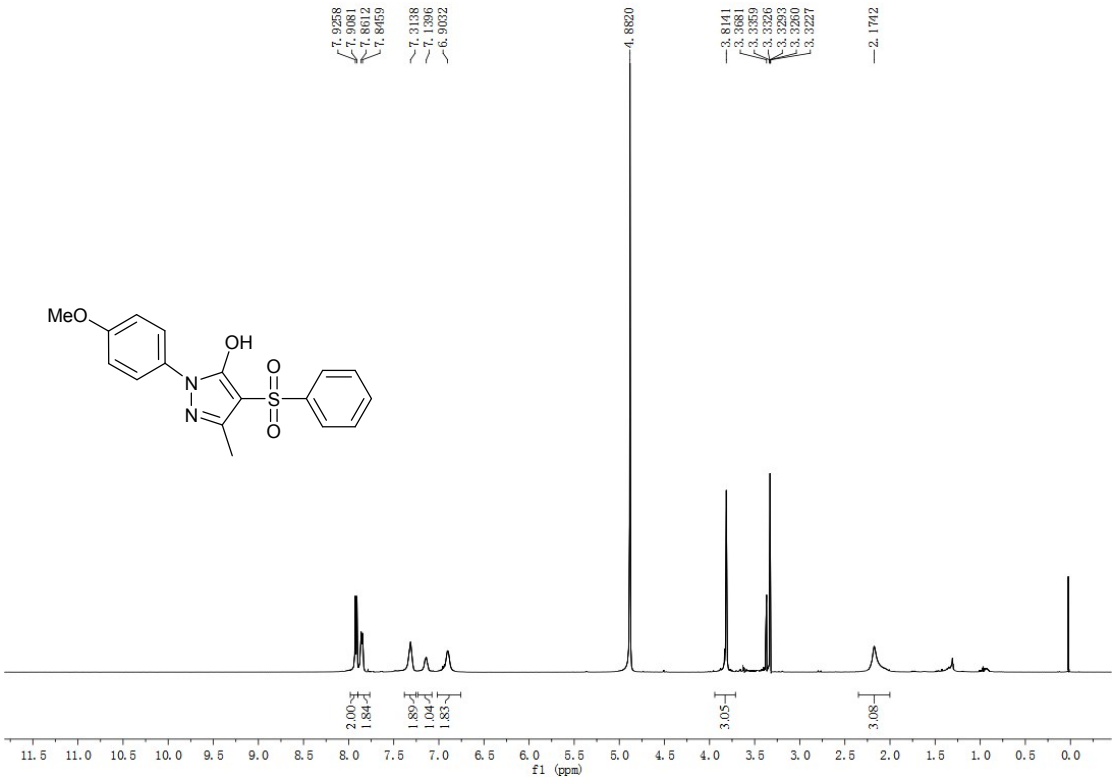
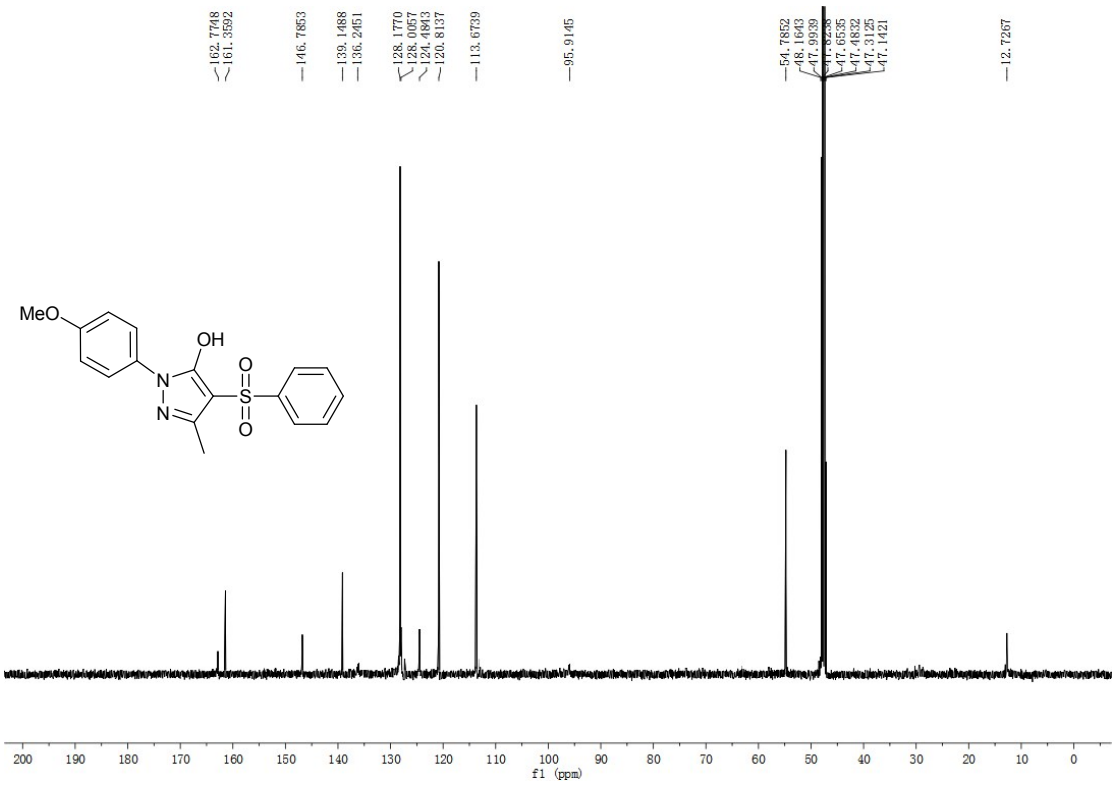
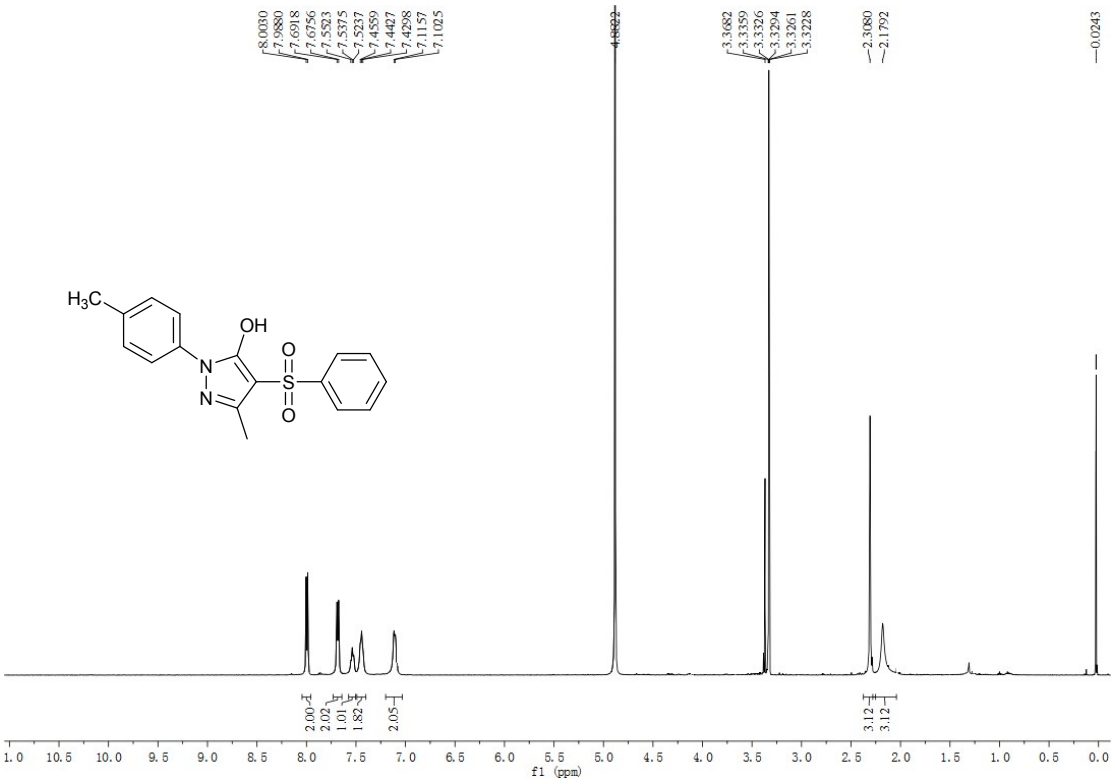
146.8468
139.0264
128.1938
124.8280
121.0818
95.2582
48.4891
48.1518
47.9812
47.9240
47.6407
47.4704
47.3001
47.1295
44.1526
12.6122
OH
N
N
O
S
O
Me
f1 (ppm)

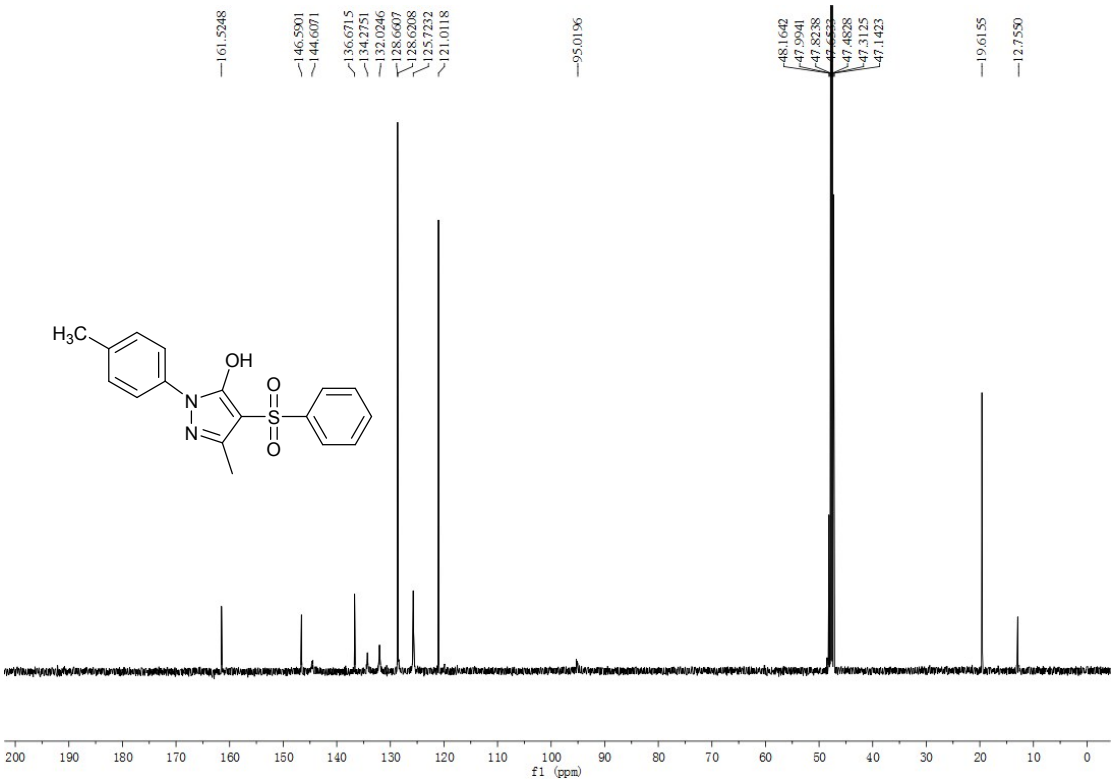
3ba


7.9258
7.9081
7.8612
7.8459
7.3138
7.1396
6.9032
4.8820
3.8141
3.3681
3.3659
3.3326
3.3293
3.3260
3.3227
2.1742
MeO
OH
N
N
O
S
O
2.00
1.84
1.89
1.04
1.83
3.05
3.08
11.5 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
f1 (ppm)

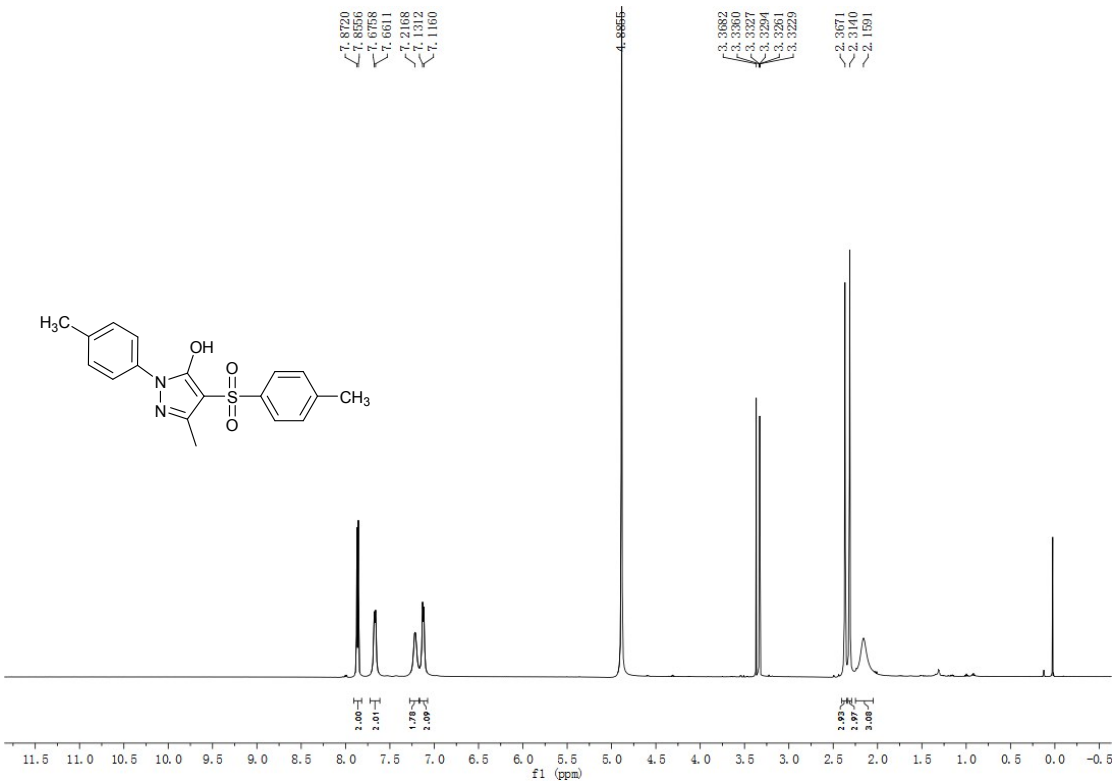

162.7748
161.3592
146.7853
139.1488
136.2451
128.1770
128.0057
124.4843
120.8137
113.6739
95.9145
54.7852
48.1643
47.9939
47.6535
47.4832
47.3125
47.1421
12.7267
MeO
OH
N
N
O
S
O
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

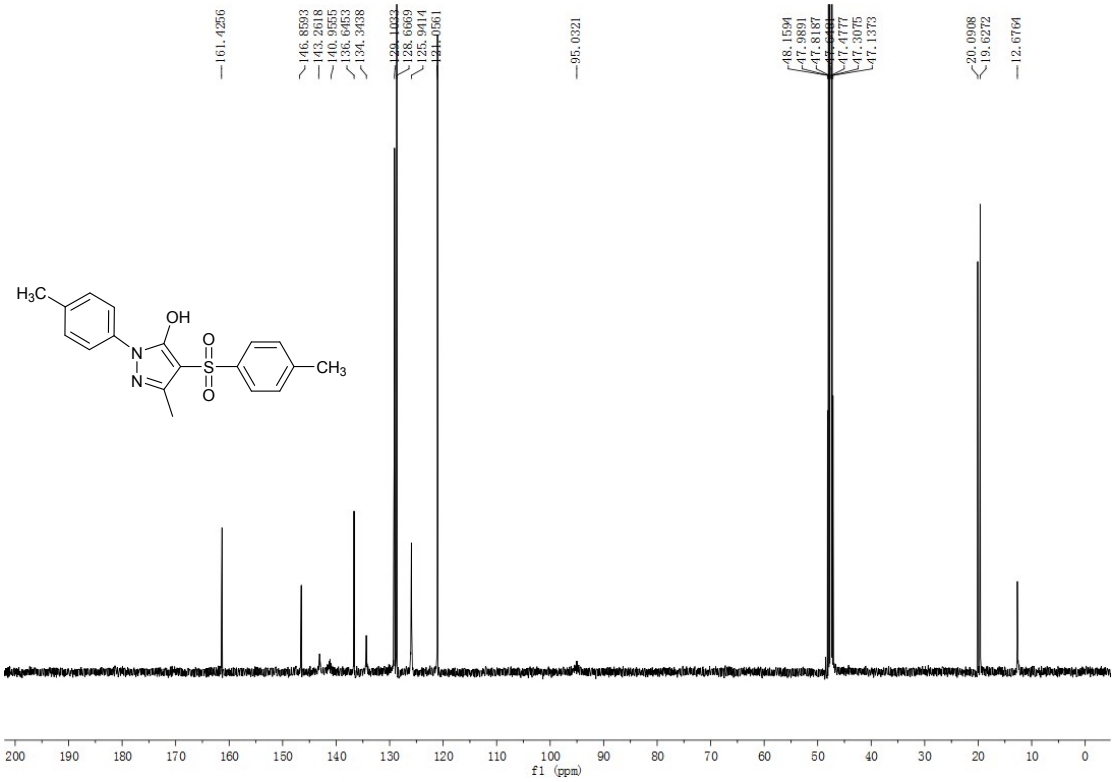
3ca


8.0030
7.9880
7.6918
7.6756
7.5523
7.5375
7.5237
7.4559
7.4427
7.4298
7.1157
7.1025
4.8822
3.3682
3.3559
3.3326
3.3294
3.3261
3.3228
2.3080
2.1792
0.0243
2.00
2.02
1.01
1.82
2.05
3.12
3.12
H3C
OH
N
N
O
S
O
O
f1 (ppm)

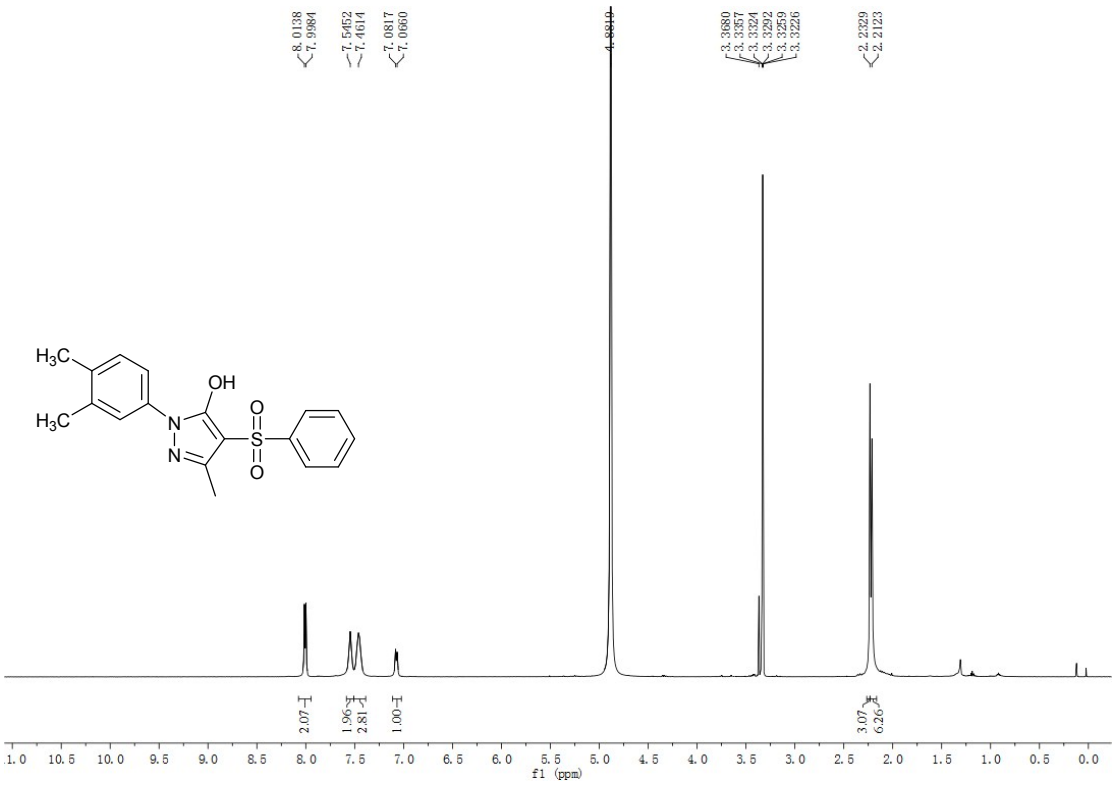

161.5248
146.5901
144.6071
136.6715
134.2751
132.0246
128.6607
128.6208
125.7232
121.0118
95.0196
48.1642
47.9941
47.8238
47.6535
47.4828
47.3125
47.1423
19.6155
12.7550
H3C
OH
N
N
O
S
O
O
f1 (ppm)

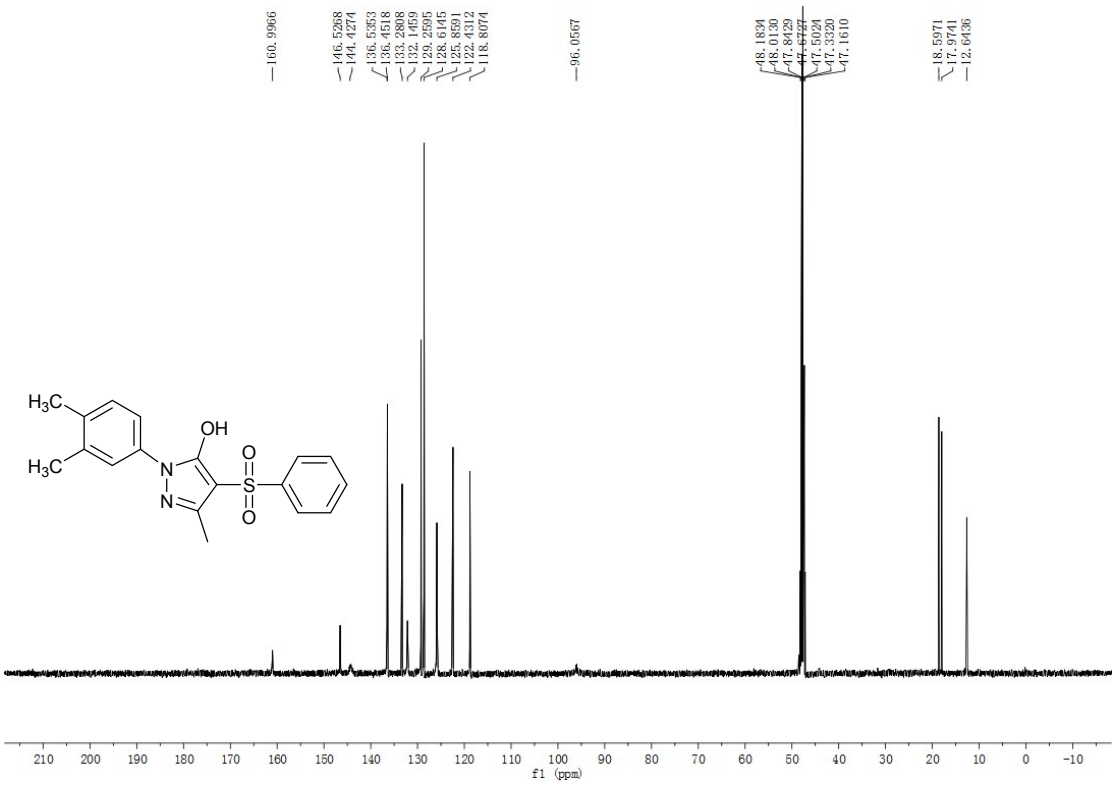
3cb


7.8720
7.8556
7.6758
7.6611
7.2168
7.1312
7.1160
4.8855
3.3682
3.3360
3.3327
3.3294
3.3261
3.3229
2.3671
2.3140
2.1591
H3C
OH
N
N
O
S
O
CH3
f1 (ppm)


161.4256
146.8593
143.2618
140.9555
136.6453
134.3438
129.1022
128.6669
125.9414
124.0561
95.0321
48.1594
47.9891
47.8187
47.4777
47.3075
47.1373
20.0908
19.6272
12.6764
H3C
OH
N
N
O
S
O
CH3
f1 (ppm)

3da


8.0138
7.9984
7.5452
7.4614
7.0817
7.0660
4.8810
3.3680
3.3557
3.3324
3.3292
3.3259
3.3226
2.2329
2.2123
2.07
1.96
2.81
1.00
3.07
6.26
f1 (ppm)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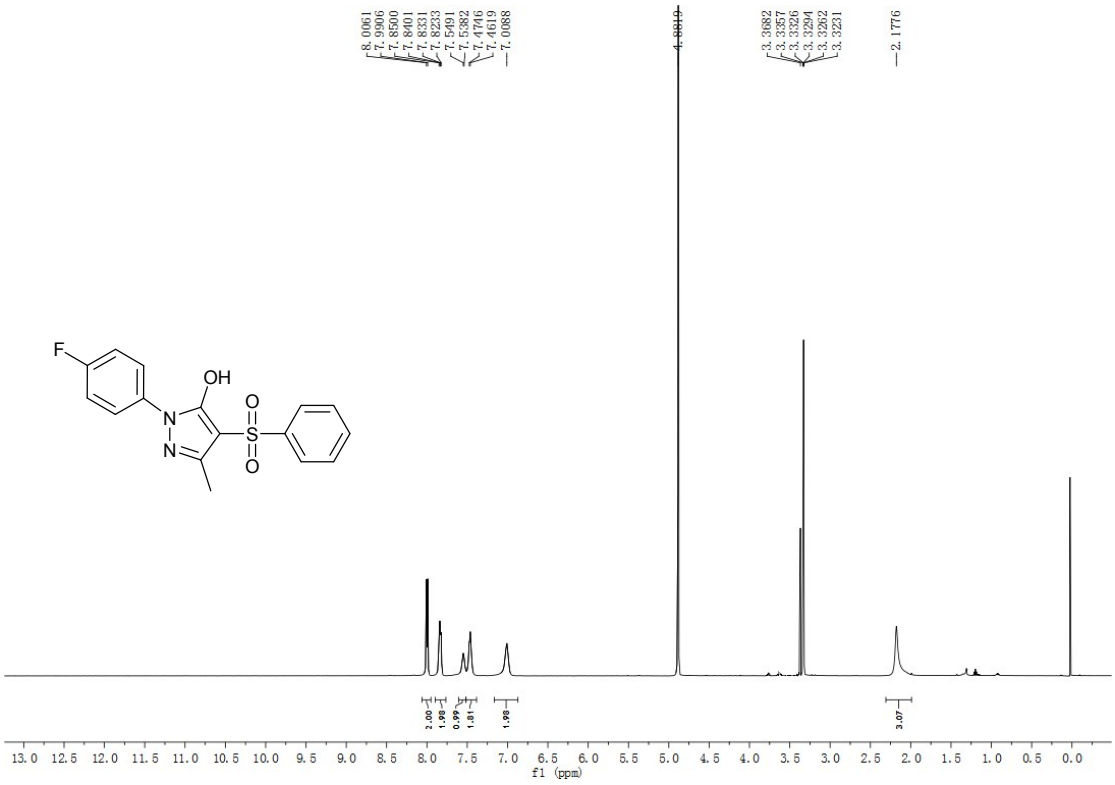
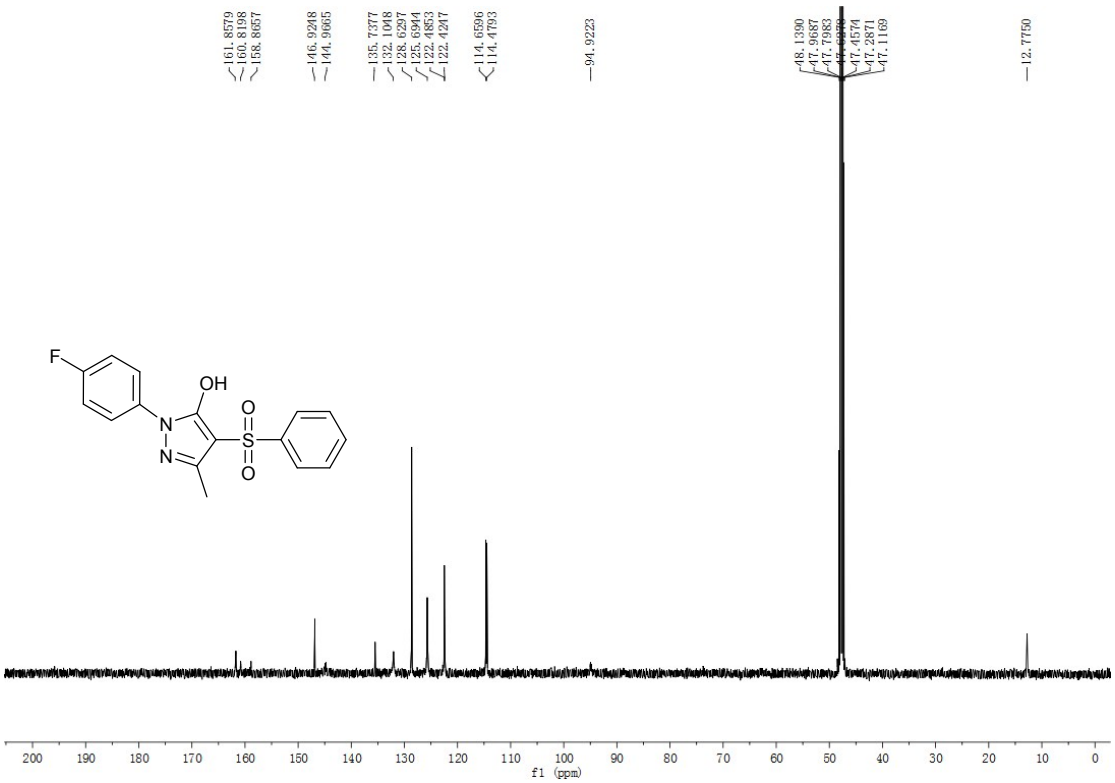
146.5268
144.4274
136.5353
136.4518
133.2808
132.1459
129.2595
128.6145
125.8591
122.4312
118.8074
96.0567
48.1894
48.0130
47.8429
47.6727
47.5024
47.3320
47.1610
18.5971
17.9741
12.6436
f1 (ppm)

3ea


8.0061
7.9906
7.8500
7.8401
7.8231
7.8223
7.5491
7.5382
7.4716
7.4619
7.0088
4.8811
3.3682
3.3357
3.3326
3.3294
3.3262
3.3231
2.1776
F
OH
N
N
S
O
O
2.00
1.98
0.99
1.81
1.98
3.07
13.0 12.5 12.0 11.5 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
f1 (ppm)


161.8579
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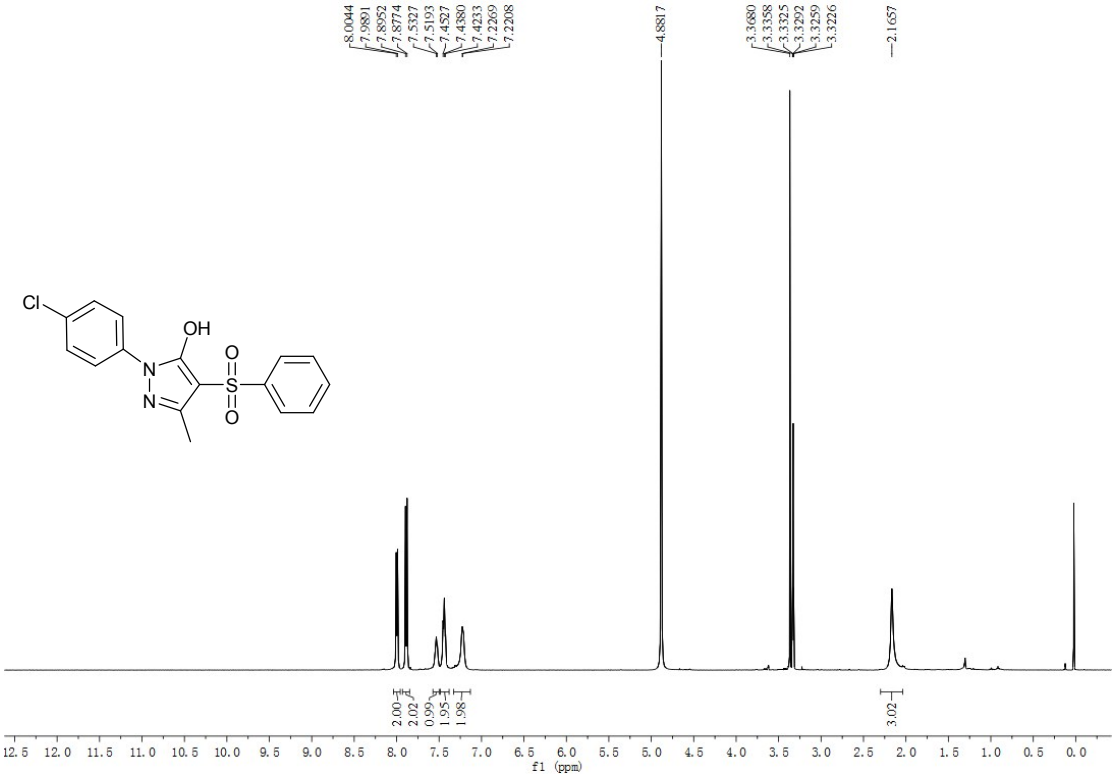
158.8657
146.9248
144.9665
135.7377
132.1048
128.6297
125.6944
122.4853
122.4247
114.6596
114.4793
94.9223
48.1390
47.9687
47.7983
47.4574
47.2871
47.1169
12.7750
F
OH
N
N
S
O
O
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

3fa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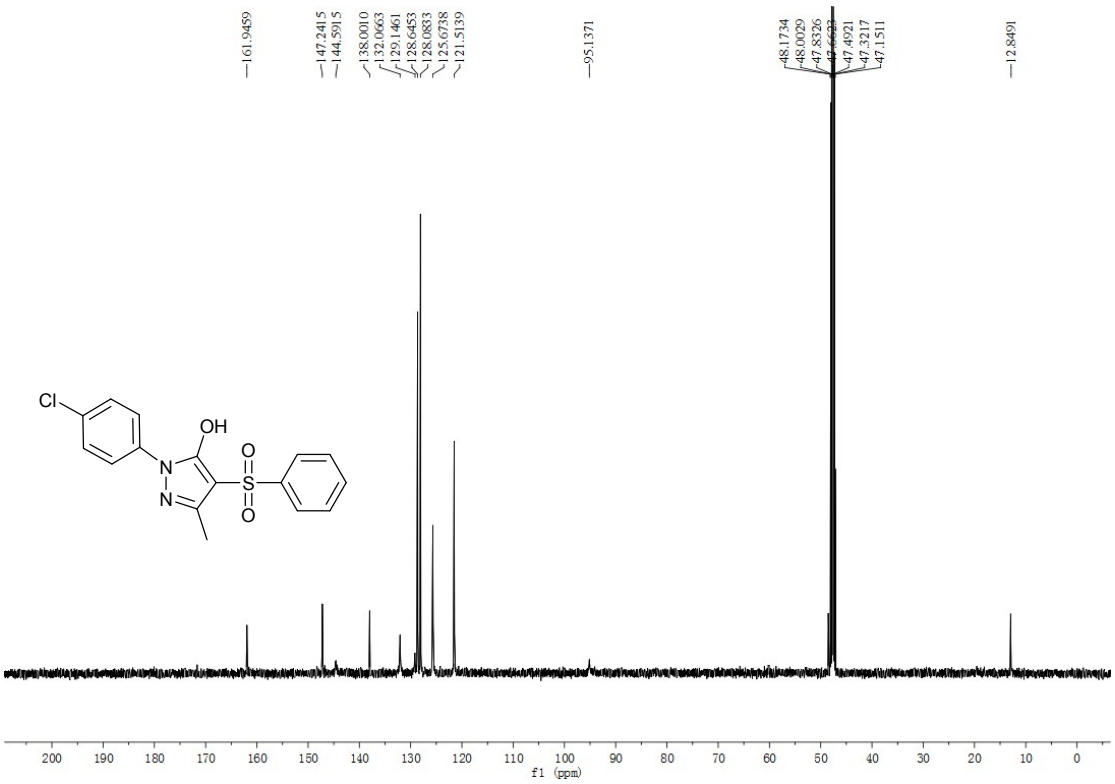
7.8952
7.8774
7.5327
7.5193
7.4527
7.4380
7.4233
7.2269
7.2208
4.8817
3.3680
3.3358
3.3325
3.3292
3.3259
3.3226
2.1657
Cl
OH
N
N
O
S
O
2.00
2.02
0.99
1.95
1.98
3.02
f1 (ppm)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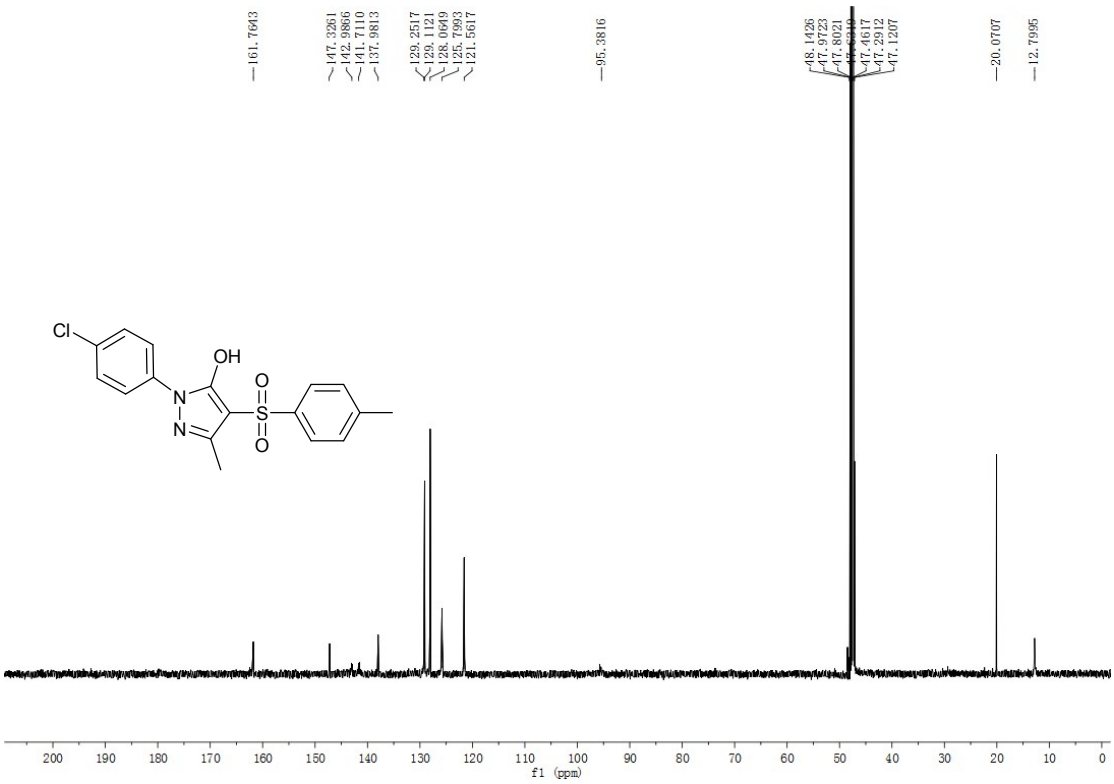
144.5915
138.0010
132.0663
129.1461
128.6453
128.0833
125.6738
121.5139
95.1371
48.1734
48.0029
47.8326
47.6623
47.4921
47.3217
47.1511
12.8491
Cl
OH
N
N
O
S
O
f1 (ppm)

3fb


7.8768
7.8719
7.8590
7.8556
7.2326
7.2195
4.8828
3.3681
3.3581
3.3326
3.3293
3.3261
3.3229
2.3703
2.1623
Cl
OH
N
N
O
S
O
O
2.06
2.06
4.00
3.17
3.05
12.0 11.5 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
f1 (ppm)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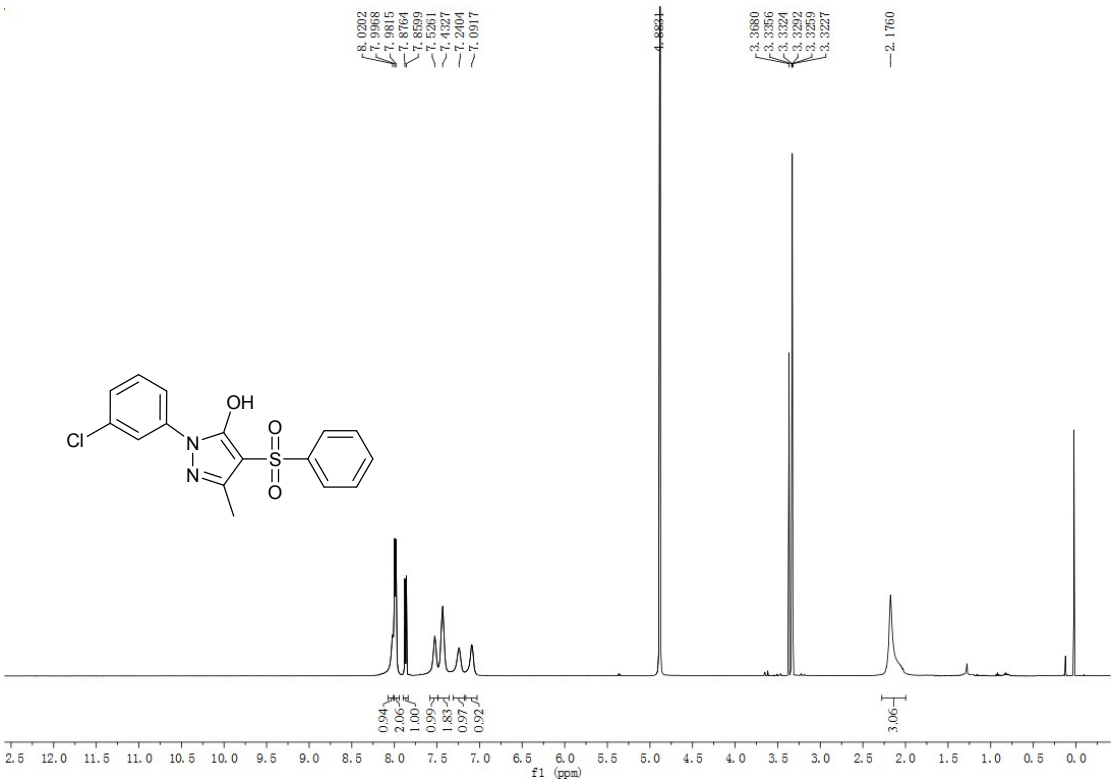
129.1121
128.0649
125.7993
121.5617
95.3816
18.1426
17.9723
17.8021
17.4617
17.2912
17.1207
20.0707
12.7995
Cl
OH
N
N
O
S
O
O
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

3ga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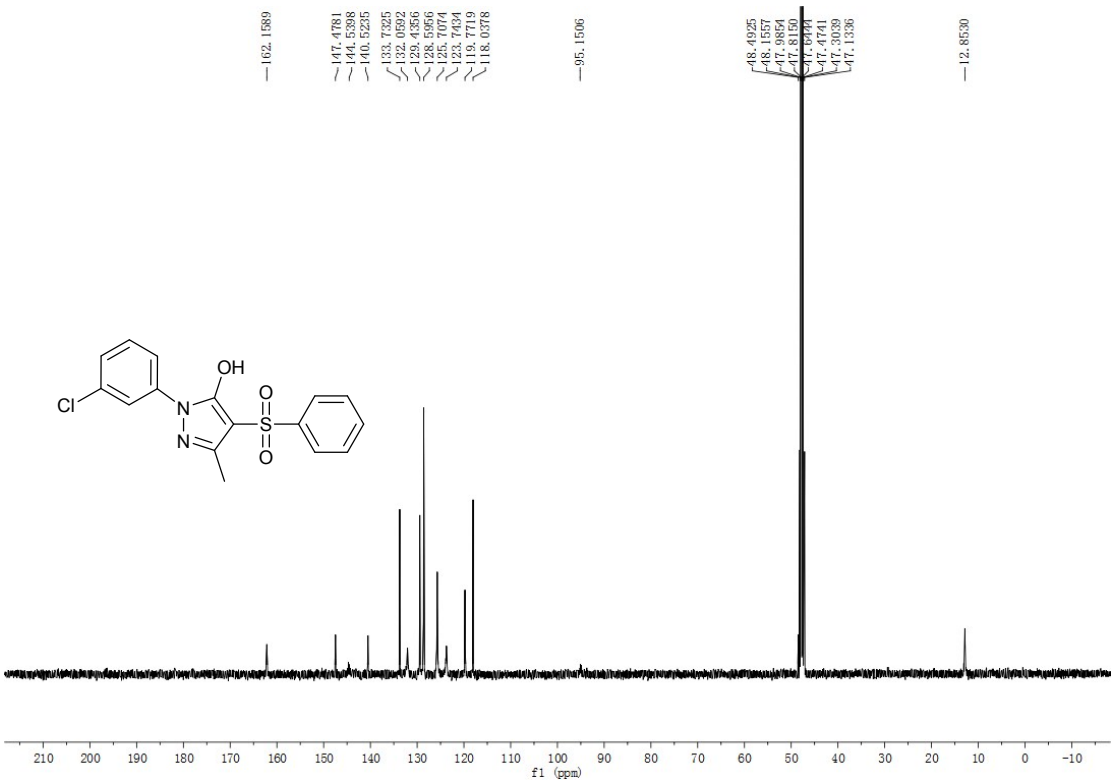
7.5261
7.4327
7.2404
7.0917
4.8821
3.3680
3.3356
3.3324
3.3292
3.3259
3.3227
2.1760
OH
Cl
N
N
O
S
O
0.94
2.06
1.00
0.99
1.83
0.97
0.92
3.06
f1 (ppm)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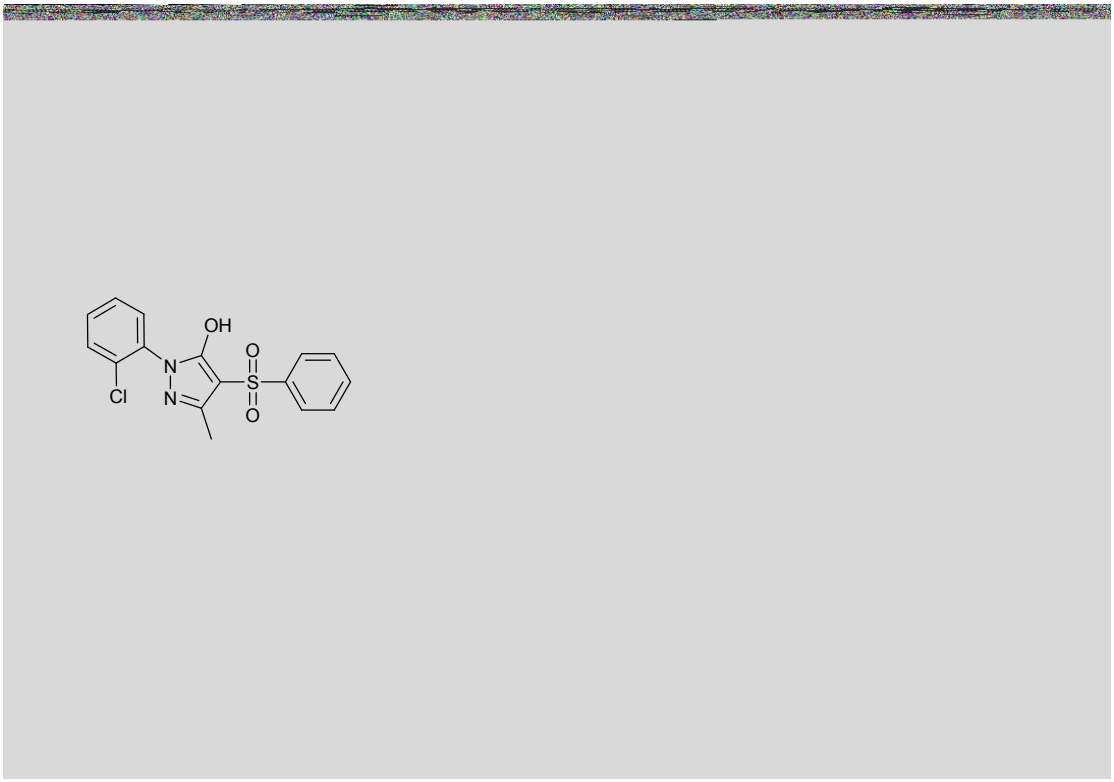
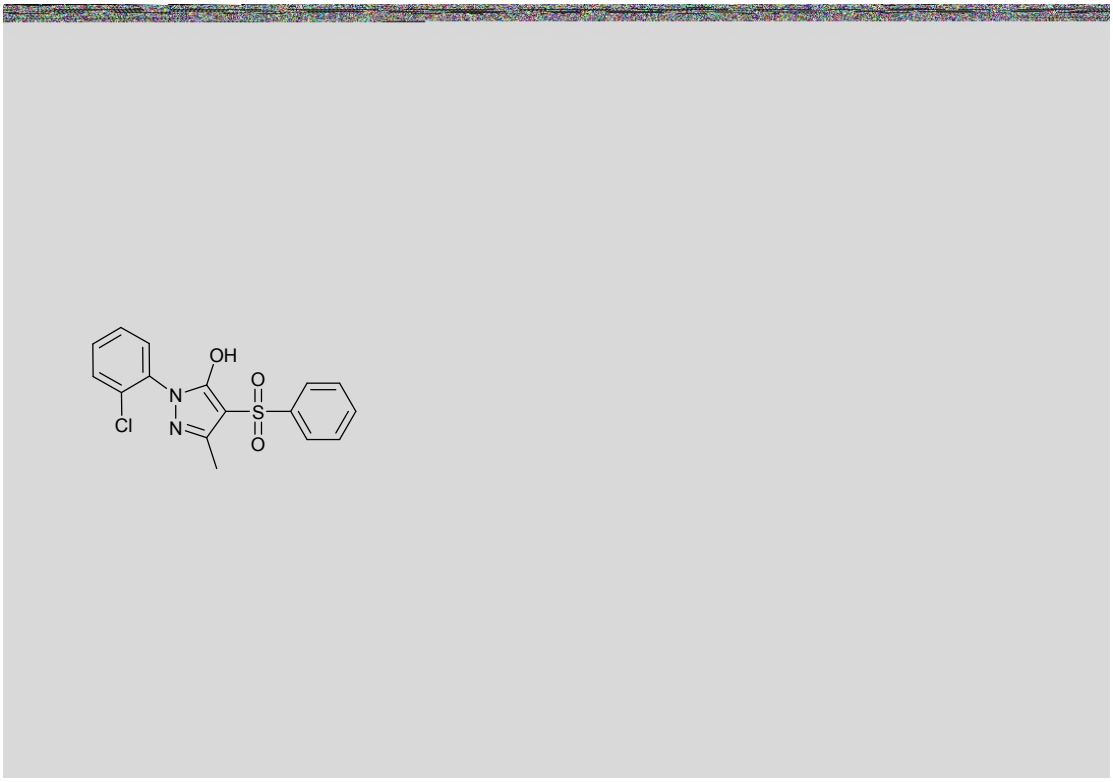
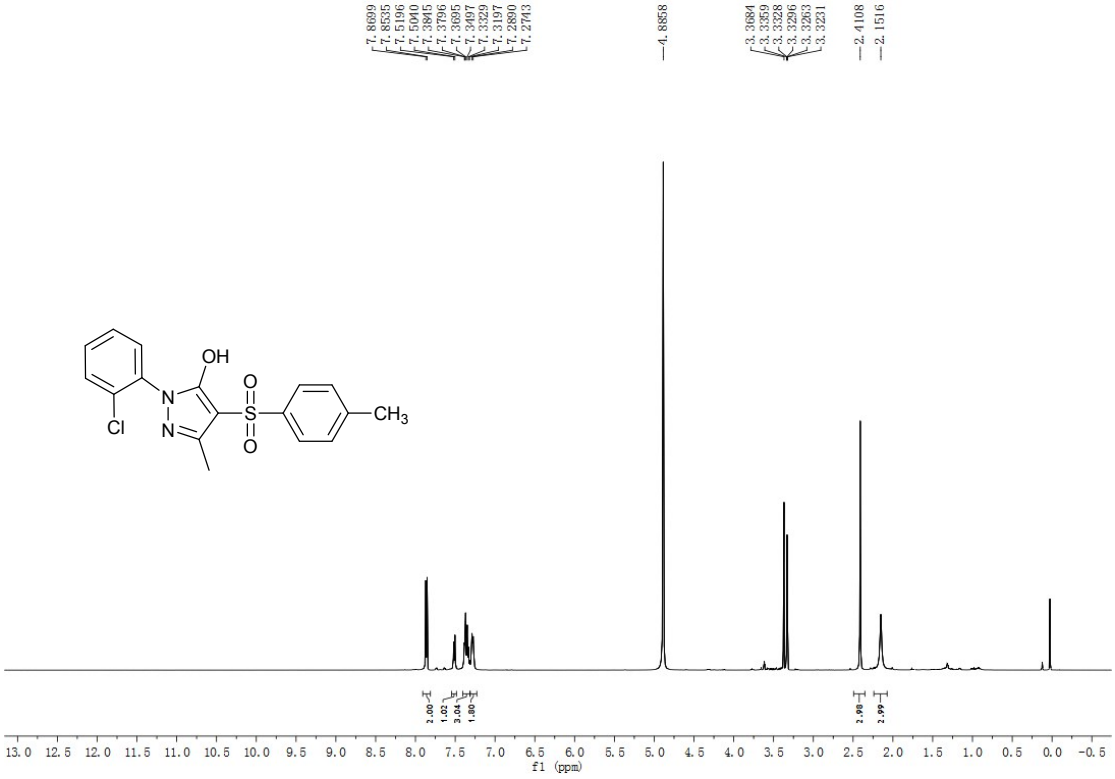
144.5398
140.5235
133.7325
132.0592
129.4356
128.5956
125.7074
123.7434
119.7719
118.0378
95.1506
48.4925
48.1557
47.9854
47.8150
47.6446
47.4741
47.3039
47.1336
12.8530
OH
Cl
N
N
O
S
O
f1 (ppm)

3ha





3hb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7.5196
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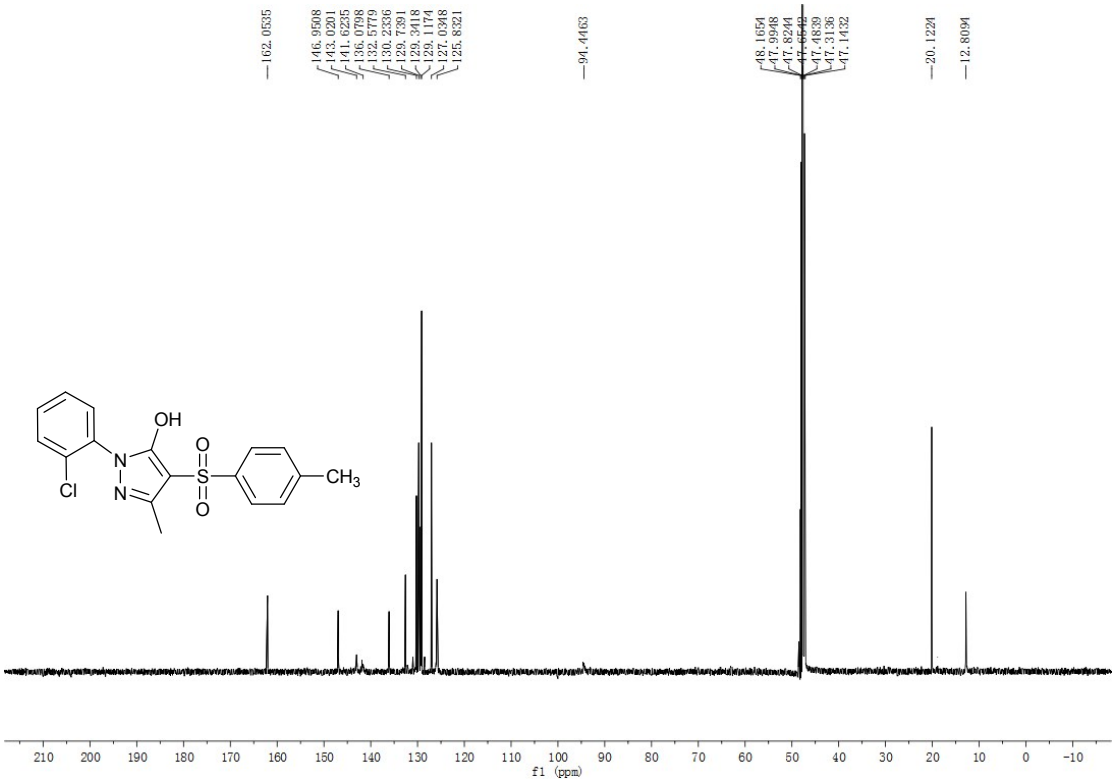
7.3845
7.3796
7.3695
7.3497
7.3329
7.3197
7.2890
7.2743
4.8858
3.3684
3.3359
3.3328
3.3296
3.3263
3.3231
2.4108
2.1516
OH
N
N
Cl
O
S
O
CH3
2.00
1.02
3.04
1.80
2.99
2.99
f1 (ppm)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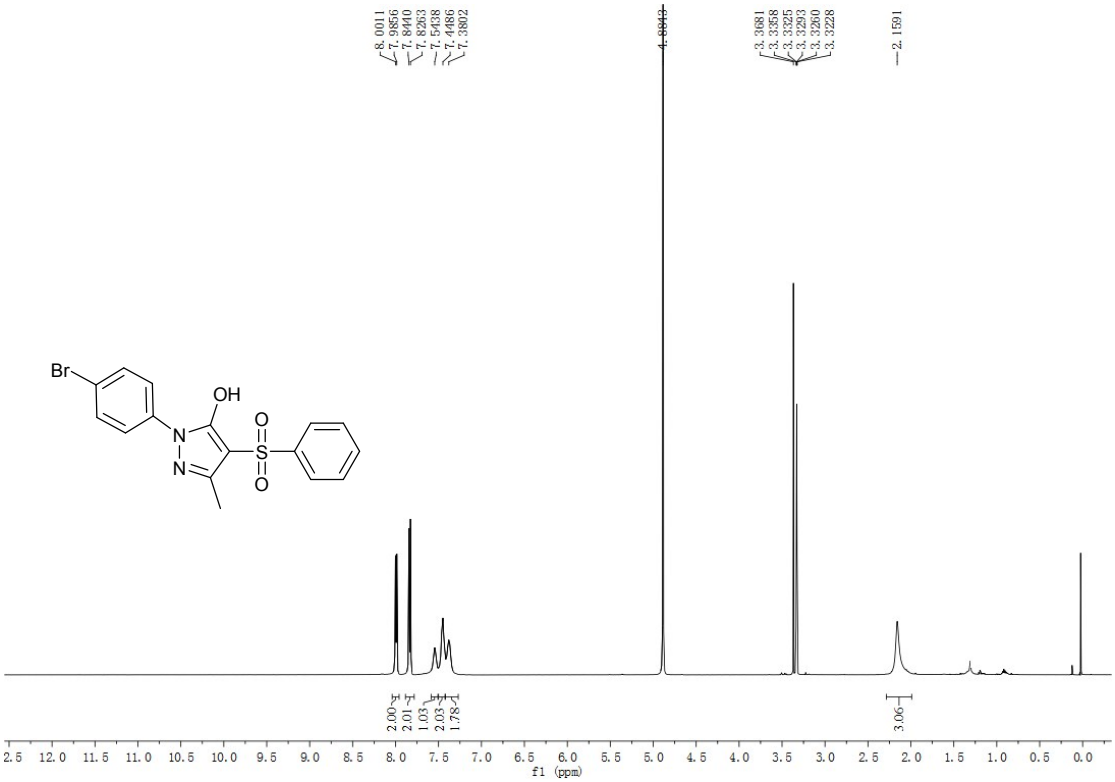
146.9508
143.0201
141.6235
136.0798
132.5779
130.2336
129.7391
129.3418
129.1174
127.0348
125.8321
94.4463
48.1654
47.9948
47.8244
47.6540
47.4839
47.3136
47.1432
20.1224
12.8094
OH
N
N
Cl
O
S
O
CH3
f1 (ppm)

3ia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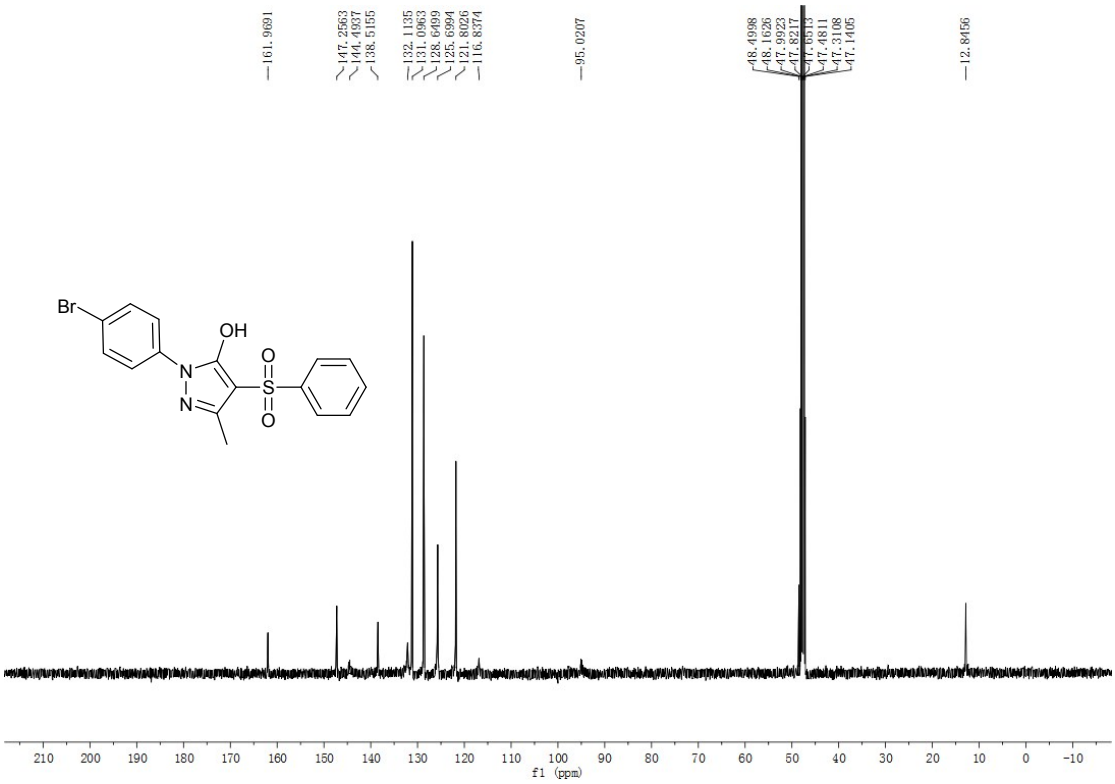
7.4486
7.3892
4.8843
3.3681
3.3358
3.3325
3.3293
3.3260
3.3228
2.1591
Br
OH
N
N
O
S
O
2.00
2.01
1.03
2.03
1.78
3.06
f1 (ppm)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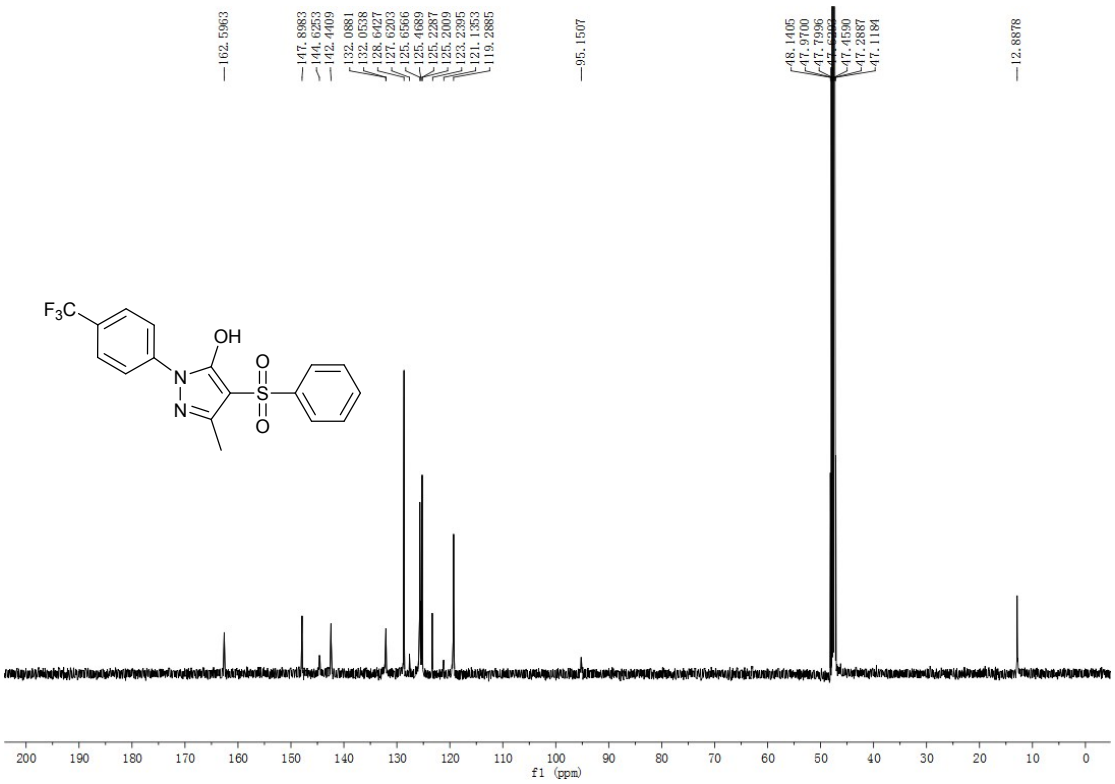
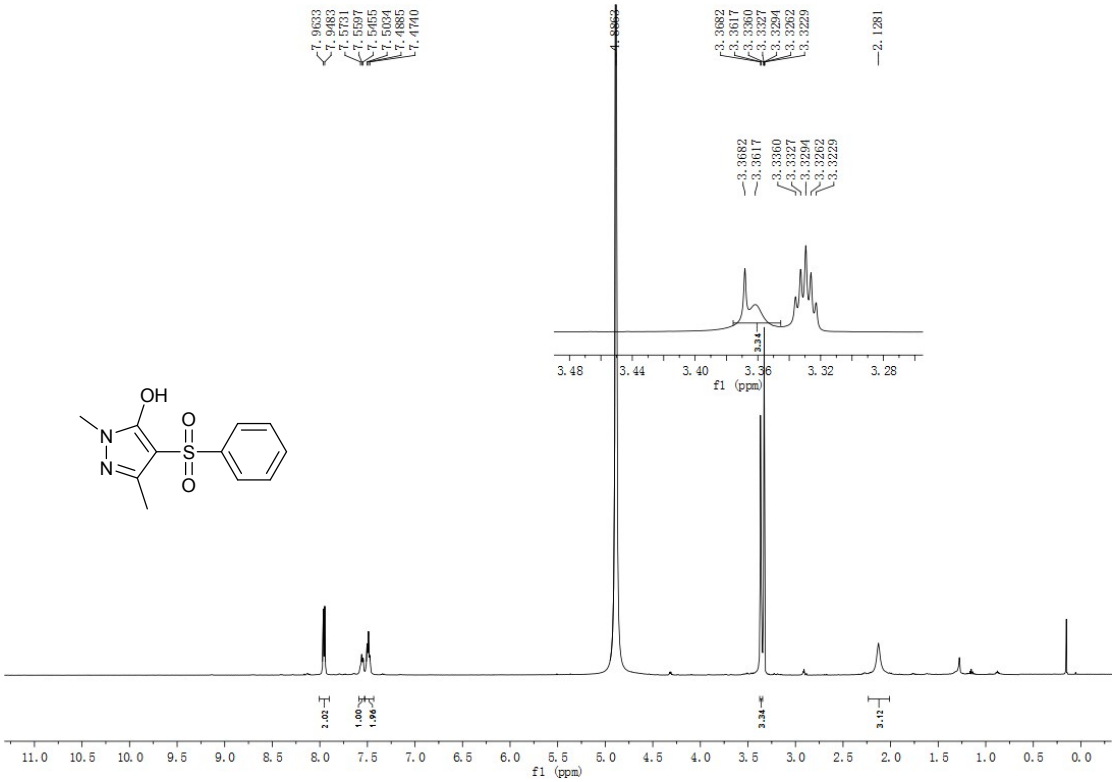
144.4937
138.5155
132.1135
131.0963
128.6499
125.6994
121.8026
116.8374
95.0207
48.4998
48.1626
47.9923
47.8217
47.6513
47.4811
47.3108
47.1405
12.8456
Br
OH
N
N
O
S
O
f1 (ppm)

3ja


8.1705
8.1534
8.0183
8.0030
7.5395
7.5061
7.4944
7.4714
7.4568
4.8821
3.3681
3.3556
3.3324
3.3293
3.3261
3.3230
2.1771
F3C
OH
N
N
O
S
O
O
2.01
1.98
4.04
3.09
f1 (ppm)


162.5963
147.8983
144.6253
142.4409
132.0881
132.0538
128.6427
127.6203
125.6566
125.4689
125.2287
125.2009
123.2395
121.1353
119.2885
95.1507
18.1405
17.9700
17.7996
17.6292
17.4590
17.2887
17.1184
12.8878
F3C
OH
N
N
O
S
O
O
f1 (ppm)

3ka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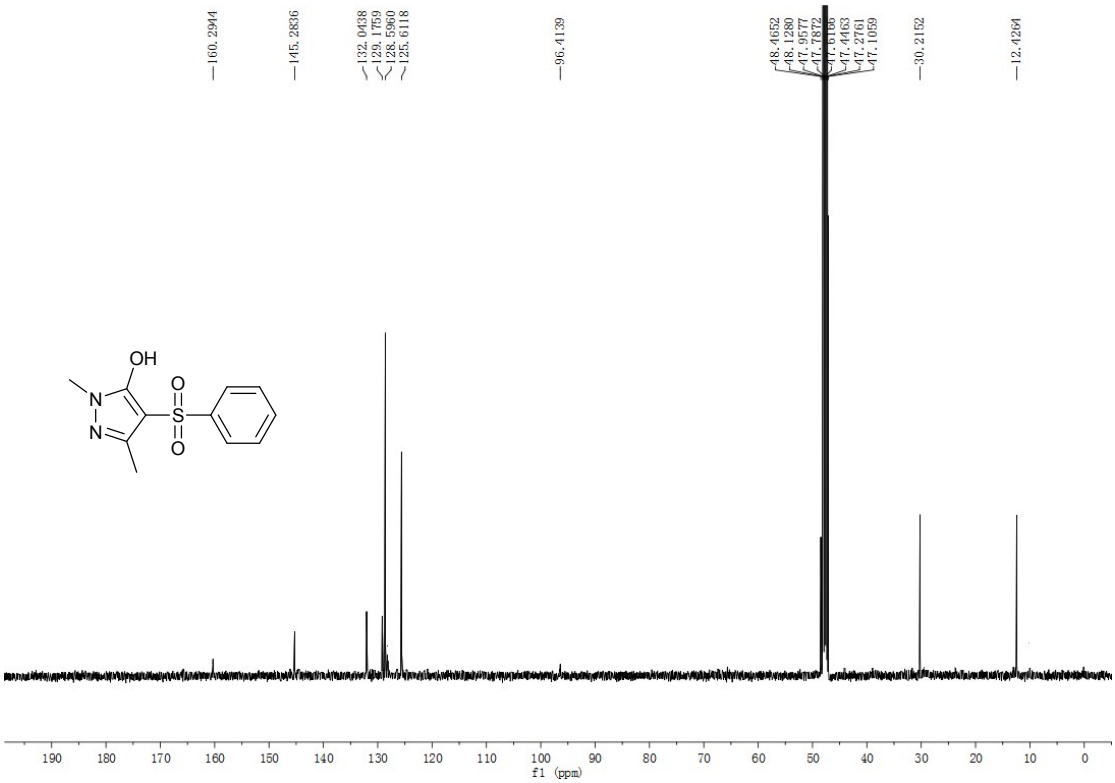
7.5731
7.5597
7.5455
7.5034
7.4885
7.4740
4.8862
3.3682
3.3617
3.3360
3.3327
3.3294
3.3262
3.3229
2.1281
OH
N
N
O
S
O
f1 (ppm)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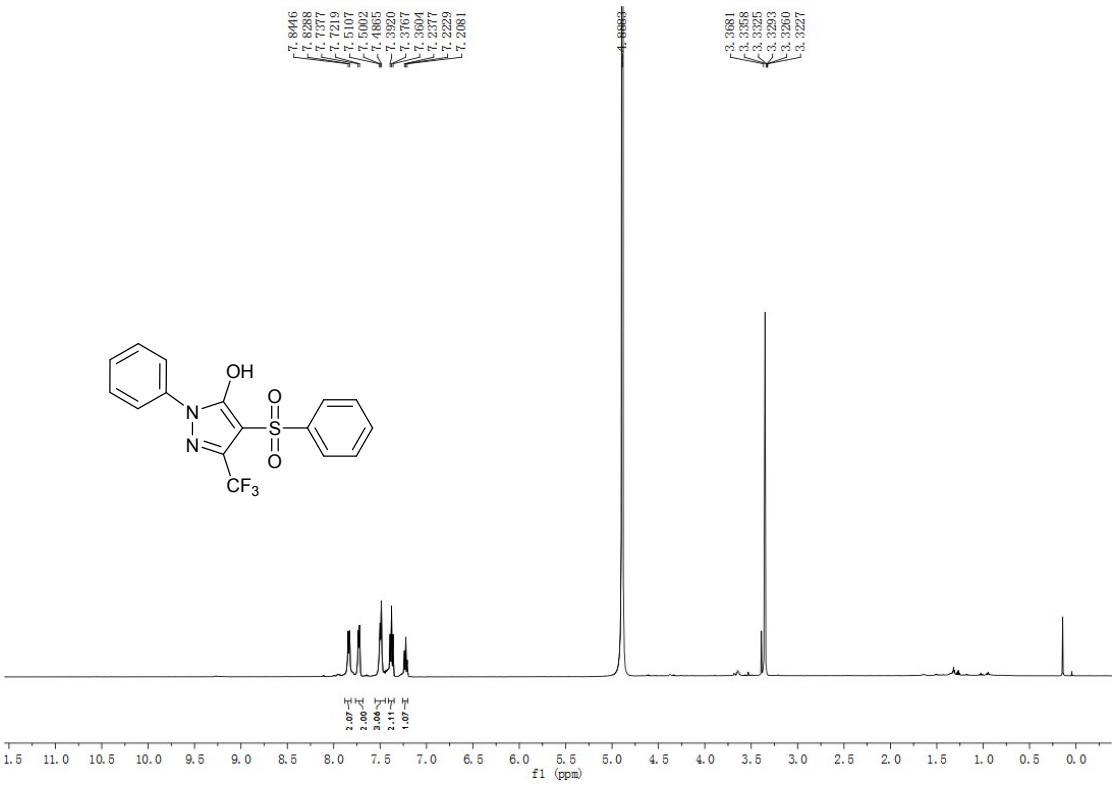
145.2836
132.0438
129.1759
128.5960
125.6118
96.4139
48.4652
48.1280
47.9577
47.7872
47.6186
47.4463
47.2761
47.1059
30.2152
12.4264
OH
N
N
O
S
O
f1 (ppm)

3la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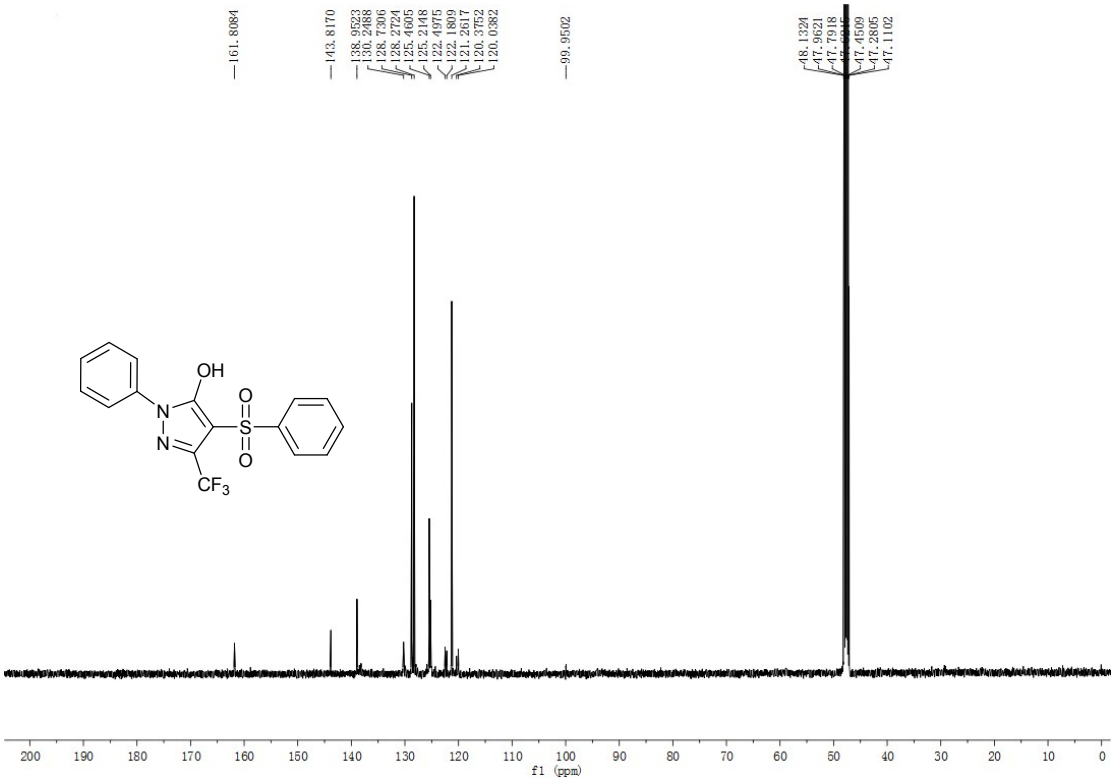
7.8288
7.7377
7.7219
7.5107
7.5002
7.4885
7.3920
7.3767
7.3604
7.2377
7.2229
7.2081
4.0883
3.3681
3.3558
3.3395
3.3293
3.3260
3.3227
OH
N
N
S
O
O
CF3
2.07
3.00
3.06
2.11
1.07
f1 (ppm)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143.8170
138.9523
130.2468
128.7306
128.2724
125.4605
125.2148
122.4975
122.1809
121.2617
120.3752
120.0382
99.9502
48.1324
47.9621
47.7918
47.4509
47.2805
47.1102
OH
N
N
S
O
O
CF3
f1 (ppm)