Supporting Information

Cobalt-Catalyzed and 2-(1-Methylhydrazinyl)pyridine-Assisted Cyclization of Thiophene-2-Carbohydrazides with Maleimides: Efficient Synthesis of Heteroaryl-Fused Pyridones

Hua Zhao,[‡a,b] Taimin Wang,[‡a,c] Zhineng Qing,[a] and Hongbin Zhai[*a,d,e]

[a] State Key Laboratory of Chemical Oncogenomics, Guangdong Provincial Key Lab of Nano-Micro Materials Research, School of Chemical Biology and Biotechnology, Shenzhen Graduate School of Peking University, Shenzhen 518055, China

[b] Institute of Drug Discovery Technology, Ningbo University, Ningbo 315211, Zhejiang, China

[c] Institute of Marine Biomedicine, Shenzhen Polytechnic, Shenzhen 518055, China

[d] The State Key Laboratory of Applied Organic Chemistry, College of Chemistry and Chemical Engineering, Lanzhou University, Lanzhou 730000, China

[e] Collaborative Innovation Center of Chemical Science and Engineering (Tianjin), Tianjin 300071, China

‡ These authors contributed equally to this work.

Email: zhaihb@pku.edu.cn

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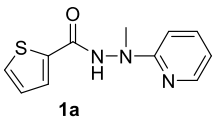
1. Materials and methods

All reactions were carried out under Argon atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. All the chemicals were purchased commercially, and used without further purification. Anhydrous THF was distilled from sodium-benzophenone. Dichloromethane and was distilled from calcium hydride. Thin-layer chromatography (TLC) was conducted with 0.25 mm Tsingdao silica gel plates (60F-254) and visualized by exposure to UV light (254 nm) or stained with potassium permanganate. Flash column chromatography was performed on Tsingdao silica gel (200-300 mesh) and neutral/basic aluminum oxide (200-300mesh). ^{1}H NMR spectra were recorded on Bruker spectrometers (at 300, 400 or 500 MHz) and reported relative to deuterated solvent signals or tetramethylsilane internal standard signals. Data for ^{1}H NMR spectra were reported as follows: chemical shift (δ/ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad.), coupling constant (*J*/Hz) and integration. ^{13}C NMR spectra were recorded on Bruker Spectrometers (100 or 125 MHz). Data for ^{13}C NMR spectra were reported in terms of chemical shift. ^{19}F NMR spectra were recorded on Bruker Spectrometers (376 MHz). High-resolution mass spectrometry (HRMS) was conducted on Bruker Apex IV RTMS.

2. General procedure for the synthesis of starting materials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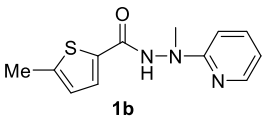
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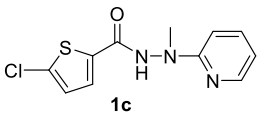
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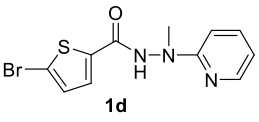
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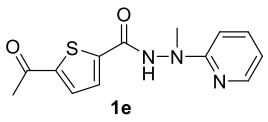
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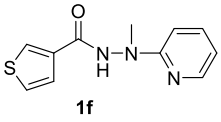
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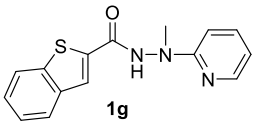
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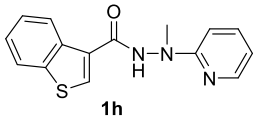
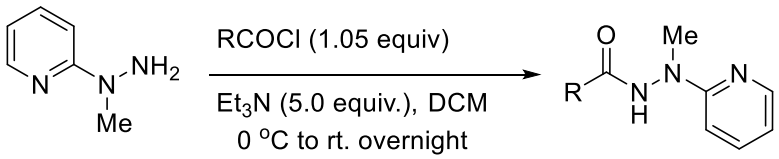
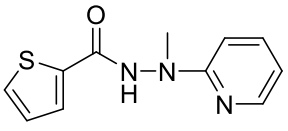

1h

Representative Method : (1a-1h)[1]

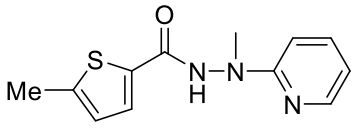


To a stirred mixture of 2-(1-methylhydrazinyl)pyridine1 (1.0 equiv, 5 mmol) and Et_3N (5.0 equiv) in dry CH_2Cl_2 (0.2 to 0.5 M) was added Thiophene chloride (1.05 equiv) dropwise under Ar atmosphere at 0 °C. Kept the reaction mixture stirred at 0 oC for about 0.5 h, then the resulting mixture was warmed to room temperature and stirred overnight at this temperature. Upon completion of the reaction indicated by TLC, The reaction mixture was washed with H_2O and extracted with CH_2Cl_2 (20 mL) for three times. The combined organic phases were washed with brine, dried over with anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by column chromatography (*n*-hexanes/EtOAc = 3:1 to 1:1) to afford the corresponding product. The product gives two sets of NMR signals, owing to the presence of rotamers around the amide.


1a

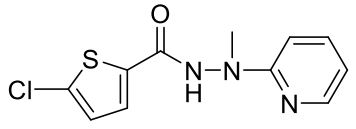
N'-Methyl-N'-(pyridin-2-yl)thiophene-2-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1a** as a solid. **^{1}HNMR** (400 MHz, DMSO-d_6) δ 10.82 (s, 1H), 8.16 – 8.15 (m, 1H), 7.91 (d, *J* = 4.0

Hz, 1H), 7.88 – 7.87 (m, 1H), 7.56 – 7.52 (m, 1H), 7.22 (dd, *J* = 5.0, 4.0 Hz, 1H), 6.74 – 6.70 (m, 2H), 3.32 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 161.1, 160.0, 147.8, 138.0, 137.7, 132.3, 129.5, 128.6, 114.3, 107.2, 38.2. **HRMS** m/z ($[M+H]^+$) called for $C_{11}H_{12}N_3OS$: 234.0701, found: 234.0696.



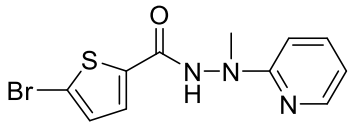
1b

N',5-Dimethyl-N'-(pyridin-2-yl)thiophene-2-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1b** as a solid. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 10.68 (s, 1H), 8.15 (d, *J* = 4.4 Hz, 1H), 7.70 (d, *J* = 3.6 Hz, 1H), 7.55 – 7.51 (m, 1H), 6.91 (d, *J* = 3.2 Hz, 1H), 6.72 – 6.69 (m, 2H), 3.30 (s, 3H), 2.49 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 161.0, 160.1, 147.8, 146.3, 138.0, 135.1, 129.8, 127.1, 114.2, 107.2, 38.2, 15.7. **HRMS** m/z ($[M+H]^+$) called for $C_{12}H_{14}N_3OS$: 248.0858, found: 248.0850.



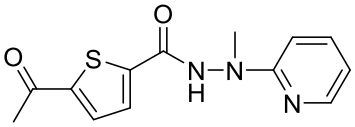
1c

5-Chloro-N'-methyl-N'-(pyridin-2-yl)thiophene-2-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1c** as a solid. Spectra for the major rotamer: **^{1}H NMR** (400 MHz, DMSO-d_6) δ 10.92 (s, 1H), 8.16 (dd, *J* = 3.6, 1.2 Hz, 1H), 7.80 – 7.77 (m, 1H), 7.55 (dd, *J* = 8.4, 7.2 Hz, 1H), 7.28 – 7.26 (m, 1H), 6.74 – 6.71 (m, 2H), 3.31 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 160.1, 159.8, 147.8, 138.1, 136.9, 134.5, 129.6, 128.8, 114.5, 107.2, 38.2. **HRMS** m/z ($[M+H]^+$) called for $C_{11}H_{11}ClN_3OS$: 268.0311, found: 268.0305.



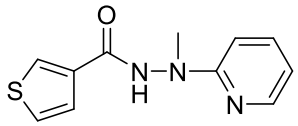
1d

5-Bromo-N'-methyl-N'-(pyridin-2-yl)thiophene-2-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1d** as a solid. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 10.88 (s, 1H), 8.16 – 8.15 (m, 1H), 7.72 (d, *J* = 4.0 Hz, 1H), 7.57 – 7.53 (m, 1H), 7.37 (d, *J* = 4.0 Hz, 1H), 6.74 – 6.71 (m, 2H), 3.29 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 160.0, 159.8, 147.8, 139.5, 138.1, 132.3, 130.3, 118.3, 114.5, 107.2, 38.2. **HRMS** m/z ($[M+H]^+$) called for $C_{11}H_{11}BrN_3OS$: 311.9806, found: 311.9803.



1e

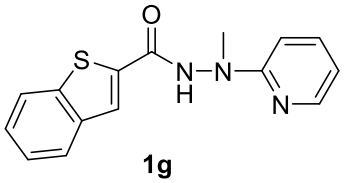
5-Acetyl-N'-methyl-N'-(pyridin-2-yl)thiophene-2-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1e** as a solid. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.04 (s, 1H), 8.18 – 8.16 (m, 1H), 7.99 (d, *J* = 4.0 Hz, 1H), 7.93 (d, *J* = 4.0 Hz, 1H), 7.58 – 7.54 (m, 1H), 6.76 – 6.73 (m, 2H), 3.32 (s, 3H), 2.59 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 191.4, 160.1, 159.4, 147.5, 147.2, 143.7, 137.7, 133.9, 129.8, 114.2, 106.9, 37.8, 26.8. **HRMS** m/z ($[M+H]^+$) called for $C_{13}H_{14}N_3O_2S$: 276.0807, found: 276.0803.



1f

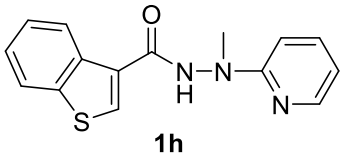
N'-Methyl-N'-(pyridin-2-yl)thiophene-3-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1f** as a solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.83 (s, 1H), 8.13 (d, *J* = 3.6 Hz, 1H), 7.97 (s, 1H), 7.43 – 7.40 (m, 2H), 7.18 (dd, *J* = 4.4, 2.8 Hz, 1H), 6.67 – 6.65 (m, 2H), 3.29 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 162.5, 159.3, 147.2, 137.8, 135.0, 129.5, 126.5, 126.4, 114.6, 107.2, 38.7. **HRMS** m/z ($[M+H]^+$) called for $C_{11}H_{12}N_3OS$: 234.0701, found: 234.0701.



1g

N'-Methyl-N'-(pyridin-2-yl)benzo[b]thiophene-2-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1g** as a solid. **^{1}H NM**R (400 MHz, DMSO-d_6) δ 11.05 (s, 1H), 8.22 (s, 1H), 8.17 – 8.15 (m, 1H), 8.06 – 8.04 (m, 1H), 8.00 – 7.98 (m, 1H), 7.56 – 7.52 (m, 1H), 7.50 – 7.44 (m, 2H), 6.77 (d, *J* = 8.8 Hz, 1H), 6.71 (ddd, *J* = 6.8, 4.8, 0.8 Hz, 1H), 3.33 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 161.6, 159.9, 147.8, 140.8, 139.5, 138.1, 137.7, 127.1, 126.4, 125.9, 125.6, 123.3, 114.4, 107.3, 38.2. **HRMS** m/z ($[M+H]^+$) called for $C_{15}H_{14}N_3OS$: 284.0858, found: 284.0852.



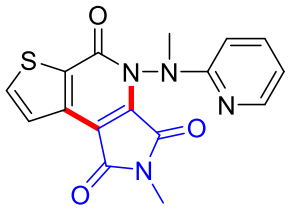
1h

N'-Methyl-N'-(pyridin-2-yl)benzo[b]thiophene-3-carbohydrazide: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **1h** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.80 (s, 1H), 8.45 (d, *J* = 8.0 Hz, 1H), 8.20 (d, *J* = 4.4 Hz, 1H), 8.08 (s, 1H), 7.84 – 7.82 (m, 1H), 7.52 – 7.47 (m, 1H), 7.45 – 7.37 (m, 2H), 6.79 (d, *J* = 8.4 Hz, 1H), 6.73 (t, *J* = 6.0 Hz, 1H), 3.45 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 163.2, 159.2, 147.6, 140.0, 137.8, 136.8, 130.5, 129.4, 125.3, 124.5, 122.4,

114.8, 107.2, 39.1. **HRMS** m/z ([M+H]$^+$) called for $C_{15}H_{14}N_3OS$: 284.0858, found: 284.0849.

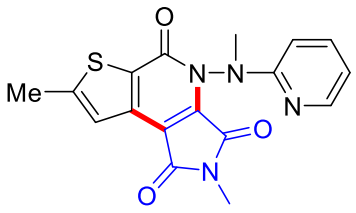
3. General procedure for cobalt-catalyzed Cyclization of Thiophene-2-Carbohydrazides with Maleimides

A mixture of Thiophene-2-Carbohydrazides (0.20 mmol), maleimide (0.4 mmol), $Co(OAc)_2{\cdot}4H_2O$ (0.04 mmol), Ag_2CO_3 (0.4 mmol), NaOPiv (0.4 mmol) and DCE (2.0 mL) was added to a 25 mL sealed tube. The tube was stirred at 120 °C for 12 h. After cooling to room temperature, the reaction mixture was diluted with 5.0 mL of ethyl acetate and filtered through a plug of celite, followed by washing with 70 mL of ethyl acetate. The combined residue was concentrated under reduced pressure, and then the resulting crude product was purified by column chromatography on to provide the product.



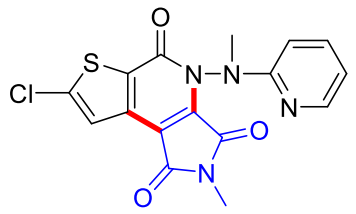
3aa

2-Methyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3aa** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (ddd, *J* = 4.8, 2.0, 0.8 Hz, 1H), 7.94 (d, *J* = 5.2 Hz, 1H), 7.83 (d, *J* = 5.2 Hz, 1H), 7.58 – 7.54 (m, 1H), 6.75 (ddd, *J* = 7.2, 4.8, 0.8 Hz, 1H), 6.62 (d, *J* = 8.4 Hz, 1H), 3.58 (s, 3H), 3.07 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.9, 161.9, 157.5, 157.0, 148.1, 138.7, 138.1, 137.2, 137.1, 134.9, 123.1, 115.7, 109.7, 106.0, 38.2, 24.0. **HRMS** m/z ([M+H]$^+$) called for $C_{16}H_{12}ClN_4O_3S$: 341.0708, found: 341.0710.



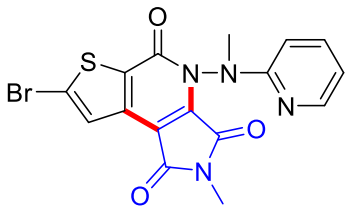
3ba

2,7-Dimethyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ba** as a solid. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.10 (d, *J* = 5.0 Hz, 1H), 7.57 – 7.53 (m, 1H), 7.51 (d, *J* = 1.0 Hz, 1H), 6.75 (ddd, *J* = 7.0, 5.0, 0.5 Hz, 1H), 6.59 (d, *J* = 8.0 Hz, 1H), 3.57 (s, 3H), 3.07 (s, 3H), 2.68 (d, *J* = 1.0 Hz, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 176.6, 166.1, 161.9, 157.1, 153.4, 148.1, 138.6, 138.0, 137.9, 133.3, 121.2, 115.5, 109.4, 106.0, 38.2, 23.9, 16.4. **HRMS** m/z ($[M+H]^+$) called for $C_{17}H_{15}N_4O_3S$: 355.0865, found: 355.0862.



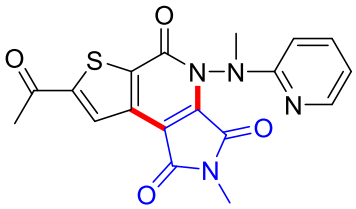
3ca

7-Chloro-2-methyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ca** as a solid. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.06 (dd, *J* = 5.0, 1.0 Hz, 1H), 7.68 (s, 1H), 7.60 – 7.56 (m, 1H), 6.76 (ddd, *J* = 7.5, 5.0, 1.0 Hz), 6.65 (d, *J* = 8.5 Hz, 1H), 3.56 (s, 3H), 3.07 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 165.5, 161.6, 156.8, 156.4, 148.1, 143.4, 139.6, 138.1, 136.9, 133.0, 122.2, 115.8, 108.8, 106.0, 38.3, 24.0. **HRMS** m/z ($[M+H]^+$) called for $C_{16}H_{12}ClN_4O_3S$: 375.0319, found: 375.0313.



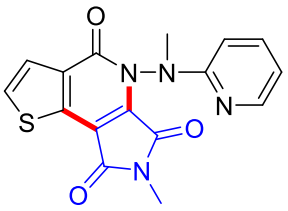
3da

7-Bromo-2-methyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d] pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3da** as a solid.**^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.06 (d, *J* = 4.0 Hz, 1H), 7.83 (s, 1H), 7.59 – 7.56 (m, 1H), 6.76 (dd, *J* = 7.0, 5.0 Hz, 1H), 6.65 (d, *J* = 8.5 Hz, 1H), 3.56 (s, 3H), 3.07 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 165.5, 161.6, 156.8, 156.3, 148.1, 139.4, 138.1, 137.6, 135.7, 126.8, 125.9, 115.8, 108.5, 106.0, 38.2, 24.0. **HRMS** m/z ($[M+H]^+$) called for $C_{16}H_{12}BrN_4O_3S$: 418.9813, found: 418.9806.



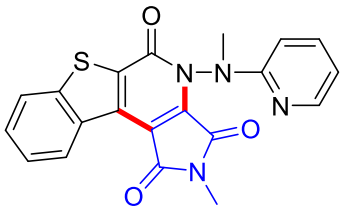
3ea

7-Acetyl-2-methyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d] pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ea** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.30 (s, 1H), 8.06 (d, *J* = 4.4 Hz, 1H), 7.63 – 7.59 (m, 1H), 6.79 (dd, *J* = 7.2, 5.2 Hz, 1H), 6.70 (d, *J* = 8.4 Hz, 1H), 3.59 (s, 3H), 3.11 (s, 3H), 2.73 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 191.0, 165.7, 161.6, 157.6, 156.7, 153.2, 148.1, 139.6, 138.8, 138.2, 136.9, 126.3, 115.9, 106.1, 38.3, 27.2, 24.1. **HRMS** m/z ($[M+H]^+$) called for $C_{18}H_{15}N_4O_4S$: 383.0814, found: 383.0814.



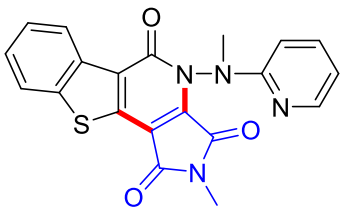
3fa

7-Methyl-5-(methyl(pyridin-2-yl)amino)-4H-pyrrolo[3,4-b]thieno[2,3-d]pyridine-4,6,8(5H,7H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3fa** as a solid.**^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 4.0 Hz, 1H), 7.77 (d, *J* = 5.2 Hz, 1H), 7.63 (d, *J* = 5.2 Hz, 1H), 7.60 – 7.56 (m, 1H), 6.77 (dd, *J* = 6.4, 4.8 Hz, 1H), 6.64 (d, *J* = 8.4 Hz, 1H), 3.58 (s, 3H), 3.10 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.4, 161.6, 157.9, 157.0, 148.1, 138.0, 137.8, 136.7, 134.7, 130.0, 126.2, 115.6, 109.8, 106.0, 38.2, 24.1. **HRMS** m/z ($[M+H]^+$) called for $C_{16}H_{12}ClN_4O_3S$: 341.0708, found: 341.0712.



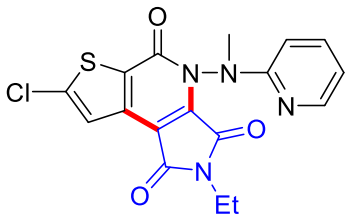
3ga

2-Methyl-4-(methyl(pyridin-2-yl)amino)-1H-benzo[4,5]thieno[3,2-d]pyrrolo[3,4-b]pyridine-1,3,5(2H,4H)-trione：Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ga** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.52 – 9.48 (m, 1H), 8.09 (dt, *J* = 4.8, 1.2 Hz, 1H), 8.00 – 7.97 (m, 1H), 7.67 – 7.63 (m, 2H), 7.62 – 7.58 (m, 1H), 6.78 (ddd, *J* = 7.2, 4.8, 0.8 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 1H), 3.64 (s, 3H), 3.16 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.2, 161.5, 157.8, 156.8, 148.1, 142.8, 139.2, 138.1, 135.9, 134.9, 134.1, 129.0, 128.6, 126.0, 123.0, 115.7, 110.7, 106.0, 38.2, 24.2. **HRMS** m/z ($[M+H]^+$) called for **$C_{20}H_{15}N_4O_3S$**: 391.0865, found: 391.0861.



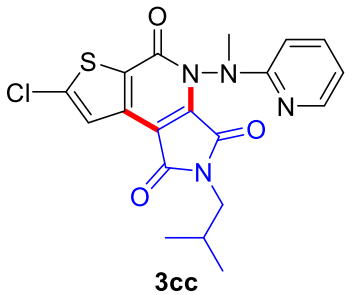
3ha

2-Methyl-4-(methyl(pyridin-2-yl)amino)-1H-benzo[4,5]thieno[2,3-d]pyrrolo[3,4-b]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ha** as a solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.86 – 8.84 (m, 1H), 8.10 – 8.09 (m, 1H), 7.99 – 7.97 (m, 1H), 7.62 – 7.55 (m, 3H), 6.79 (dd, *J* = 7.2, 4.8 Hz, 1H), 6.70 (d, *J* = 8.4 Hz, 1H), 3.65 (s, 3H), 3.14 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.4, 161.3, 157.7, 157.0, 148.1, 140.5, 140.2, 138.4, 138.1, 135.4, 127.5, 127.3, 126.2, 125.5, 122.5, 115.8, 109.2, 106.0, 38.3, 24.2. **HRMS** m/z ($[M+H]^+$) called for **$C_{20}H_{15}N_4O_3S$**: 391.0865, found: 391.0866.



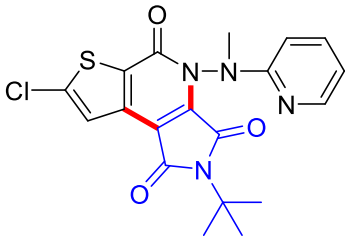
3cb

7-Chloro-2-ethyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cb** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 4.0 Hz, 1H), 7.69 (s, 1H), 7.61 – 7.56 (m, 1H), 6.77 (dd, *J* = 6.8, 4.8 Hz, 1H), 6.66 (d, *J* = 8.4 Hz, 1H), 3.64 (qd, *J* = 7.2, 1.6 Hz, 2H), 3.57 (s, 3H), 1.22 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.3, 161.3, 156.8, 156.4, 148.0, 143.3, 139.3, 138.1, 136.9, 132.9, 122.2, 115.8, 108.7, 106.0, 38.3, 33.2, 13.9. **HRMS** m/z ($[M+H]^+$) called for $C_{17}H_{14}ClN_4O_3S$: 389.0475, found: 389.0470.



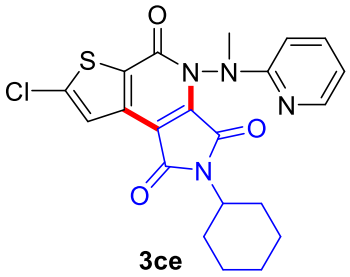
3cc

7-Chloro-2-isobutyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cc** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.06 (dd, *J* = 5.2, 2.0 Hz, 1H), 7.69 (s, 1H), 7.60 – 7.58 (m, 1H), 6.76 (dd, *J* = 7.2, 4.8 Hz, 1H), 6.66 (d, *J* = 8.4 Hz, 1H), 3.57 (s, 3H), 3.37 (d, *J* = 7.2 Hz, 2H), 2.06 – 1.96 (m, 1H), 0.89 (d, *J* = 6.4 Hz, 3H), 0.87 (d, *J* = 6.8 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.8, 161.8, 156.8, 156.5, 148.0, 143.3, 139.2, 138.1, 136.9, 133.0, 122.3, 115.8, 108.6, 106.0, 45.5, 38.3, 27.9, 20.0, 19.9. **HRMS** m/z ($[M+H]^+$) called for $C_{19}H_{18}ClN_4O_3S$: 417.0788, found: 417.0781.



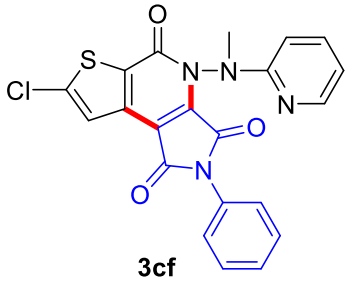
3cd

2-(tert-Butyl)-7-chloro-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cd** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 4.4 Hz, 1H), 7.69 (s, 1H), 7.60 – 7.55 (m, 1H), 6.77 (dd, *J* = 7.2, 5.2 Hz, 1H), 6.62 (d, *J* = 8.4 Hz, 1H), 3.56 (s, 3H), 1.61 (s, 9H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.8, 162.3, 156.9, 156.6, 148.0, 143.2, 138.0, 136.9, 133.0, 122.2, 115.6, 108.7, 106.0, 58.5, 38.3, 29.0. **HRMS** m/z ($[M+H]^+$) called for $C_{19}H_{18}ClN_4O_3S$: 417.0788, found: 417.0784.



3ce

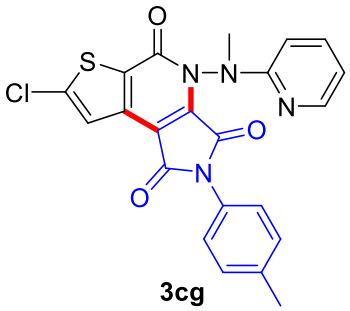
7-Chloro-2-cyclohexyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ce** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 – 8.09 (m, 1H), 7.69 (s, 1H), 7.62 – 7.57 (m, 1H), 6.78 (dd, *J* = 6.8, 5.2 Hz, 1H), 6.65 (d, *J* = 8.4 Hz, 1H), 3.98 (tt, *J* = 12.4, 4.0 Hz, 1H), 3.58 (s, 3H), 2.14 – 1.99 (m, 2H), 1.84 (d, *J* = 11.2 Hz, 2H), 1.71 (d, *J* = 14.0 Hz, 2H), 1.34 – 1.24 (m, 4H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.6, 161.4, 156.8, 156.5, 148.0, 143.3, 138.8, 138.1, 137.0, 132.9, 122.2, 115.7, 108.6, 106.0, 51.3, 38.3, 30.0, 25.9, 25.0. **HRMS** m/z ($[M+H]^+$) called for $C_{21}H_{20}ClN_4O_3S$: 443.0945, found: 443.0937.



3cf

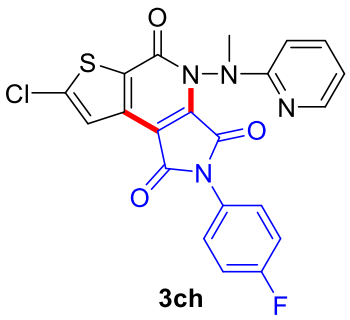
7-Chloro-4-(methyl(pyridin-2-yl)amino)-2-phenyl-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cf** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 4.4 Hz, 1H), 7.75 (s, 1H), 7.62 – 7.58 (m, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.39 – 7.35 (m, 3H), 6.78 (dd, *J* = 6.8, 4.8 Hz, 1H), 6.71 (d, *J* = 8.8 Hz, 1H), 3.60 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 164.4, 160.4, 156.7, 156.5, 148.0, 143.6, 139.0, 138.2, 136.9,

133.5, 130.8, 129.1, 128.2, 126.3, 122.4, 115.9, 108.6, 106.1, 38.4. **HRMS** m/z ($[M+H]^+$) called for $C_{21}H_{14}ClN_4O_3S$: 437.0475, found: 437.0466.



3cg

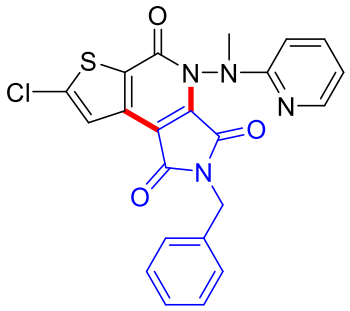
7-Chloro-4-(methyl(pyridin-2-yl)amino)-2-(p-tolyl)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cg** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 4.0 Hz, 1H), 7.75 (s, 1H), 7.63 – 7.54 (m, 1H), 7.26 (d, *J* = 7.6 Hz, 2H), 7.22 (d, *J* = 8.4 Hz, 2H), 6.78 (dd, *J* = 7.2, 5.6 Hz, 1H), 6.70 (d, *J* = 8.4 Hz, 1H), 3.60 (s, 3H), 2.38 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 164.5, 160.5, 156.7, 156.5, 148.0, 143.5, 139.0, 138.3, 138.1, 136.9, 133.4, 129.7, 128.1, 126.2, 122.4, 115.9, 108.6, 106.1, 38.4, 21.2. **HRMS** m/z ($[M+H]^+$) called for $C_{22}H_{16}ClN_4O_3S$: 451.0632, found: 451.0622.



3ch

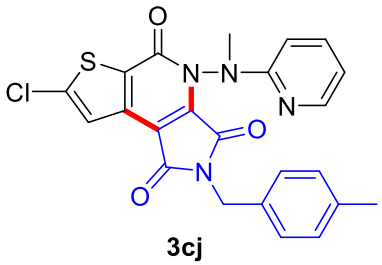
7-Chloro-2-(4-fluorophenyl)-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ch** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (dd, *J* = 4.8, 0.8 Hz, 1H), 7.74 (s, 1H), 7.63 – 7.58 (m, 1H), 7.36 – 7.32 (m,

2H), 7.17 – 7.12 (m, 2H), 6.79 (dd, *J* = 6.8, 5.2 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 1H), 3.59 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 164.3, 163.2, 160.5 (d, *J* = 36 Hz), 156.6 (d, *J* = 22.0 Hz), 148.0, 143.7, 139.0, 138.2, 136.8, 133.5, 128.2 (d, *J* = 8.0 Hz), 126.7, 122.3, 116.2, 116.0, 115.9, 108.5, 106.1, 38.4. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -112.6. **HRMS** m/z ($[M+H]^+$) called for $C_{21}H_{13}ClFN_4O_3S$: 455.0381, found: 455.0376.



3ci

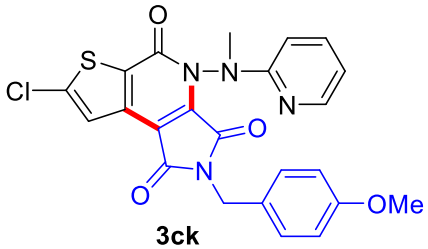
2-Benzyl-7-chloro-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d] pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ci** as a solid. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.06 (dd, *J* = 4.5, 0.5 Hz,1H), 7.68 (s, 1H), 7.60-7.57 (m, 1H), 7.37 – 7.35 (m, 2H), 7.33 – 7.28 (m, 3H), 6.77 (dd, *J* = 6.5, 5.0 Hz, 1H), 6.66 (d, *J* = 8.5 Hz, 1H), 4.75 (d, *J* = 14.5 Hz, 1H), 4.68 (d, *J* = 15.0 Hz, 1H), 3.56 (s, 3H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 165.2, 161.2, 156.8, 156.4, 148.0, 143.4, 139.5, 138.1, 136.9, 135.9, 133.1, 128.7, 128.6, 128.0, 122.2, 115.8, 108.7, 106.1, 41.8, 38.3. **HRMS** m/z ($[M+H]^+$) called for $C_{22}H_{16}ClN_4O_3S$: 451.0632, found: 451.0623.



3cj

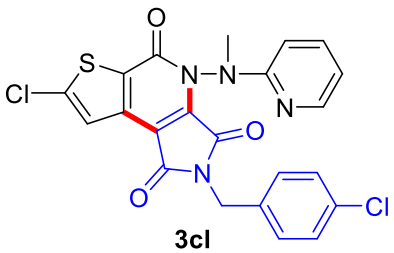
7-Chloro-4-(methyl(pyridin-2-yl)amino)-2-(4-methylbenzyl)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general

procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cj** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (dd, *J* = 4.8, 0.8 Hz, 1H), 7.69 (s, 1H), 7.62-2.58 (m, 1H), 7.27 (d, *J* = 8.4 Hz, 2H), 7.13 (d, *J* = 8.0 Hz, 2H), 6.79 (dd, *J* = 6.8, 5.2 Hz, 1H), 6.67 (d, *J* = 8.4 Hz, 1H), 4.73 (d, *J* = 14.4 Hz, 1H), 4.66 (d, *J* = 14.4 Hz, 1H), 3.57 (s, 3H), 2.33 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.2, 161.2, 156.8, 156.4, 148.0, 143.4, 139.4, 138.1, 137.8, 136.9, 133.0, 132.9, 129.4, 128.6, 122.2, 115.8, 108.7, 106.1, 41.6, 38.4, 21.1. **HRMS** m/z ($[M+H]^+$) called for $C_{23}H_{18}ClN_4O_3S$: 465.0788, found: 465.0784.



3ck

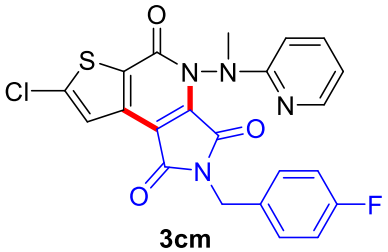
7-**Chloro-2-(4-methoxybenzyl)-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione**: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3ck** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 4.0 Hz, 1H), 7.69 (s, 1H), 7.62 – 7.58 (m, 1H), 7.31 (d, *J* = 8.4 Hz, 2H), 6.84 (d, *J* = 8.8 Hz, 2H), 6.79 (dd, *J* = 7.2, 5.2 Hz, 1H), 6.66 (d, *J* = 8.4 Hz, 1H), 4.70 (d, *J* = 14.8 Hz, 1H), 4.63 (d, *J* = 14.8 Hz, 1H), 3.78 (s, 3H), 3.57 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.2, 161.2, 159.3, 156.8, 156.4, 148.0, 143.4, 139.4, 138.1, 136.9, 133.0, 130.2, 128.1, 122.2, 115.8, 114.1, 108.7, 106.1, 55.3, 41.3, 38.3. **HRMS** m/z ($[M+H]^+$) called for $C_{23}H_{18}ClN_4O_4S$: 481.0737, found: 481.0734.



3cl

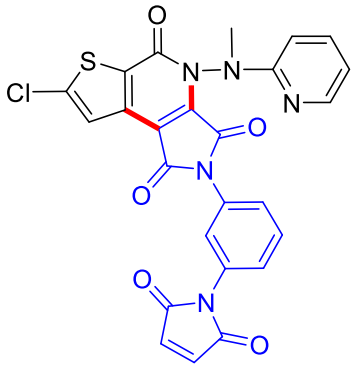
7-Chloro-2-(4-chlorobenzyl)-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thi

eno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cl** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.07 (dd, *J* = 4.8, 0.8 Hz, 1H), 7.69 (s, 1H), 7.63-7.58 (m, 1H), 7.32 – 7.28 (m, 4H), 6.79 (dd, *J* = 6.8, 5.2 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 1H), 4.73 (d, *J* = 14.8 Hz, 1H), 4.66 (d, *J* = 14.8 Hz, 1H), 3.57 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.1, 161.1, 156.8, 156.4, 148.0, 143.5, 139.4, 138.2, 136.8, 134.3, 134.0, 133.2, 130.1, 128.9, 122.2, 115.9, 108.6, 106.1, 41.1, 38.4. **HRMS** m/z ($[M+H]^+$) called for $C_{22}H_{15}Cl_2N_4O_3S$: 485.0242, found: 485.0237.



3cm

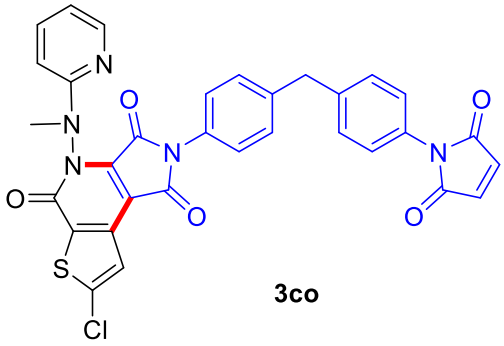
7-Chloro-2-(4-fluorobenzyl)-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cm** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 4.0 Hz, 1H), 7.67 (s, 1H), 7.61 – 7.57 (m, 1H), 7.34 (dd, *J* = 8.8, 5.6 Hz, 2H), 6.98 (t, *J* = 8.8 Hz, 2H), 6.78 (dd, *J* = 6.8, 4.8 Hz, 1H), 6.67 (d, *J* = 8.4 Hz, 1H), 4.71 (d, *J* = 14.8 Hz, 1H), 4.65 (d, *J* = 14.8 Hz, 1H), 3.56 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.1, 163.7, 161.1, 156.6 (d, *J* = 39.0 Hz), 148.0, 143.5, 139.4, 138.2, 136.8, 133.1, 131.7, 130.5 (d, *J* = 8.0 Hz), 122.2, 115.9, 115.7, 115.5, 108.6, 106.1, 41.1, 38.4. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -113.8. **HRMS** m/z ($[M+H]^+$) called for $C_{22}H_{15}ClFN_4O_3S$: 469.0537, found: 469.0533.



3cn

7-Chloro-2-(3-(2,5-dioxo-2,5-dihydro-1H-pyrrol-1-yl)phenyl)-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione:

Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3cn** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 4.0 Hz, 1H), 7.75 (s, 1H), 7.63-7.59 (m, 1H), 7.56 (t, *J* = 8.0 Hz, 1H), 7.51 (t, *J* = 2.0 Hz, 1H), 7.44 – 7.39 (m, 2H), 6.87 (s, 2H), 6.80 – 6.77 (m, 1H), 6.71 (d, *J* = 8.4 Hz, 1H), 3.60 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 169.0, 163.9, 160.0, 156.6, 156.5, 148.1, 143.7, 138.9, 138.2, 136.7, 134.3, 133.6, 131.9, 131.6, 129.5, 125.0, 124.9, 123.0, 122.4, 116.0, 108.5, 106.0, 38.4. **HRMS** m/z ($[M+H]^+$) called for $C_{25}H_{15}ClN_5O_5S$: 532.0482, found: 532.0476.



3co

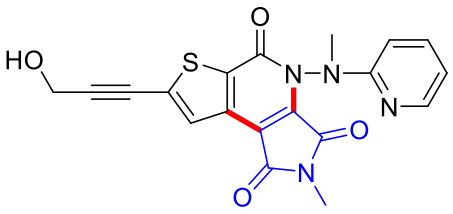
7-Chloro-2-(4-(4-(2,5-dioxo-2,5-dihydro-1H-pyrrol-1-yl)benzyl)phenyl)-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione:

Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **3co** as a solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (dd, *J* = 4.8, 0.8 Hz, 1H),

7.74 (s, 1H), 7.61 – 7.57 (m, 1H), 7.28 – 7.26 (m, 8H), 6.83 (s, 2H), 6.77 (ddd, *J* = 7.2, 4.8, 0.8 Hz, 1H), 6.69 (d, *J* = 8.4 Hz, 1H), 4.03 (s, 2H), 3.59 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 169.5, 164.4, 160.4, 156.7, 156.5, 148.0, 143.6, 140.6, 140.30, 139.0, 138.1, 136.9, 134.2, 133.4, 129.7, 129.4, 129.0, 126.4, 126.2, 122.4, 115.9, 108.6, 106.0, 41.1, 38.4. **HRMS** m/z ($[M+H]^+$) called for $C_{32}H_{21}ClN_5O_5S$: 622.0952, found:622.0944.

4. Synthetic Applications of thiophene-fused pyridones

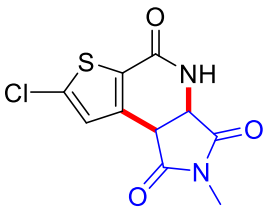
Procedure for the Pd-catalyzed Sonogashira coupling reaction: To an oven-dried flask (10 mL) charged with the bromide **3da** (83.4 mg, 0.2 mmol), bis(triphenylphosphine)palladium(II) chloride (14.0 mg, 10 mol %), CuI (7.6 mg , 20 mol %) was added anhydrous THF (1.5 mL), propargyl alcohol **4** (56.0 mg, 5.0 equiv) and Et_3N (0.4 mL) under N_2 atmosphere. After being stirred for 6 h at 40 °C , the reaction mixture was concentrated under reduced pressure and purified by column chromatography on silica gel, eluting with n-hexanes/EtOAc (4:1 ~ 2:1, v/v), to afford corresponding product **5**.



5

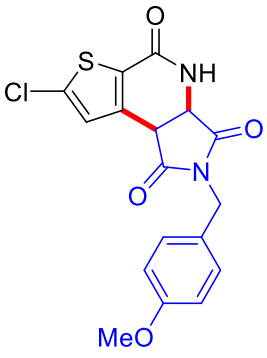
7-(3-Hydroxyprop-1-yn-1-yl)-2-methyl-4-(methyl(pyridin-2-yl)amino)-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (*n*-hexanes/EtOAc = 20:1 to 10:1) to afford the corresponding product **5** as a solid. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 8.08 (s, 1H), 7.80 (s, 1H), 7.61 (t, *J* = 7.6 Hz, 1H), 6.81 (dd, *J* = 6.8, 5.2 Hz, 1H), 6.75 (s, 1H), 5.57 (t, *J* = 6.0 Hz, 1H), 4.40 (d, *J* = 6.0 Hz, 2H), 3.46 (s, 3H), 2.96 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 165.9, 161.9, 157.4, 156.4, 148.0, 140.3, 138.7, 137.3, 133.5, 133.4, 130.2, 126.6, 115.8, 106.8, 100.5, 76.0, 50.0, 37.7, 24.2. **HRMS** m/z ($[M+H]^+$) called for **$C_{19}H_{15}N_4O_4S$**: 395.0714, found: 395.0809.

General experiment procedure for reductive removal of the directing group[2]: An oven-dried 25 mL two-neck round bottom flask was charged with **3** (0.1 mmol). After purging with Ar three times, 5 mL fresh distilled THF and 1 mL MeOH was added, followed by SmI_2 (0.1M in THF, 20 equiv) was added dropwise at 0 °C. After 5 minutes, the mixture was stirred overnight. After that the mixture was quenched with 5 mL saturated aqueous $Na_2S_2O_3$ and extracted with DCM, dried over Na_2SO_4, filtered, and concentrated under reduced pressure and the product was obtained via column chromatography.



6

7-Chloro-2-methyl-1H-pyrrolo[3,4-b]thieno[3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (DCM/MeOH = 20:1 to 10:1) to afford the corresponding product **6** as a solid. Spectra for the major rotamer:**^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.91 (s, 1H), 7.62 (s, 1H), 6.91 (d, *J* = 9.6 Hz, 1H), 5.60 (d, *J* = 8.8 Hz, 1H), 2.87 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 164.9, 158.2, 153.6, 139.9, 139.5, 128.5, 122.1, 105.2, 80.3, 25.9. **HRMS** m/z ([M+H]$^+$) called for $C_{10}H_8ClN_2O_3S$: 270.9944, found: 270.9909.



7

(3aR,8bS)-7-Chloro-2-(4-methoxybenzyl)-3a,8b-dihydro-1H-pyrrolo[3,4-b]thieno [3,2-d]pyridine-1,3,5(2H,4H)-trione: Prepared according to the general procedure, purified by silica gel column chromatography (DCM/MeOH = 20:1 to 10:1) to afford the corresponding product **7** as a solid. Spectra for the major rotamer: **^{1}H NMR** (500 MHz, DMSO-d_6) δ 12.89 (s, 1H), 7.64 (s, 1H), 7.22 (d, *J* = 8.5 Hz, 2H), 7.05 (d, *J* = 9.0 Hz, 1H), 6.87 (d, *J* = 8.5 Hz, 2H), 5.47 (d, *J* = 8.5 Hz, 1H), 4.75 (d, *J* = 15.5 Hz, 1H), 4.18 (d, *J* = 15.5 Hz, 1H), 3.70 (s, 3H). **^{13}C NMR** (125 MHz, DMSO-d_6) δ 164.9, 159.0, 158.2, 153.7, 139.9, 139.6, 130.1, 129.6, 122.2, 114.6, 114.4, 105.0, 78.6, 55.6, 41.8. **HRMS** m/z ($[M+H]^+$) called for **$C_{17}H_{14}ClN_2O_4S$**: 377.0363, found: 377.0360.

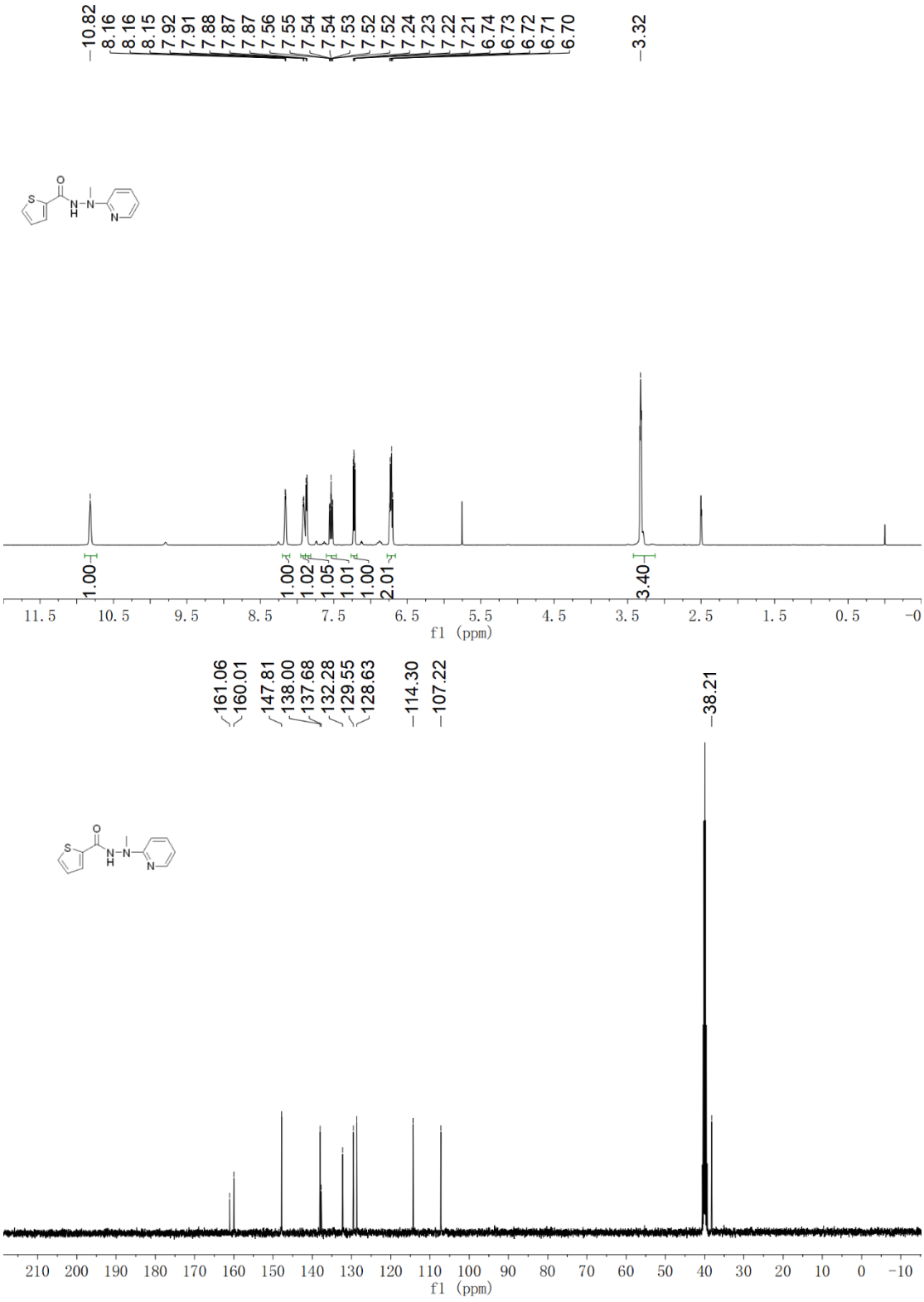
5. References

1. (a) Stadler, A.-M.; Lehn, J.-M. *J. Am. Chem. Soc.* **2014**, *136*, 3400. (b) Radunsky, C.; Kösters, J.; Letzel, M.; Yogendra, S.; Schwickert, C.; Manck, S.; Sarkar, B.; Pöttgen, R.; Weigand, J.; Neugebauer, J.; Müller, J. *Eur. J. Inorg. Chem.* **2015,** *24***,** 4006. (c) Stadler, A.-M.; Karmazin, L.; Bailly, C. *Angew. Chem. Int. Ed.* **2015**, 54, 14570.

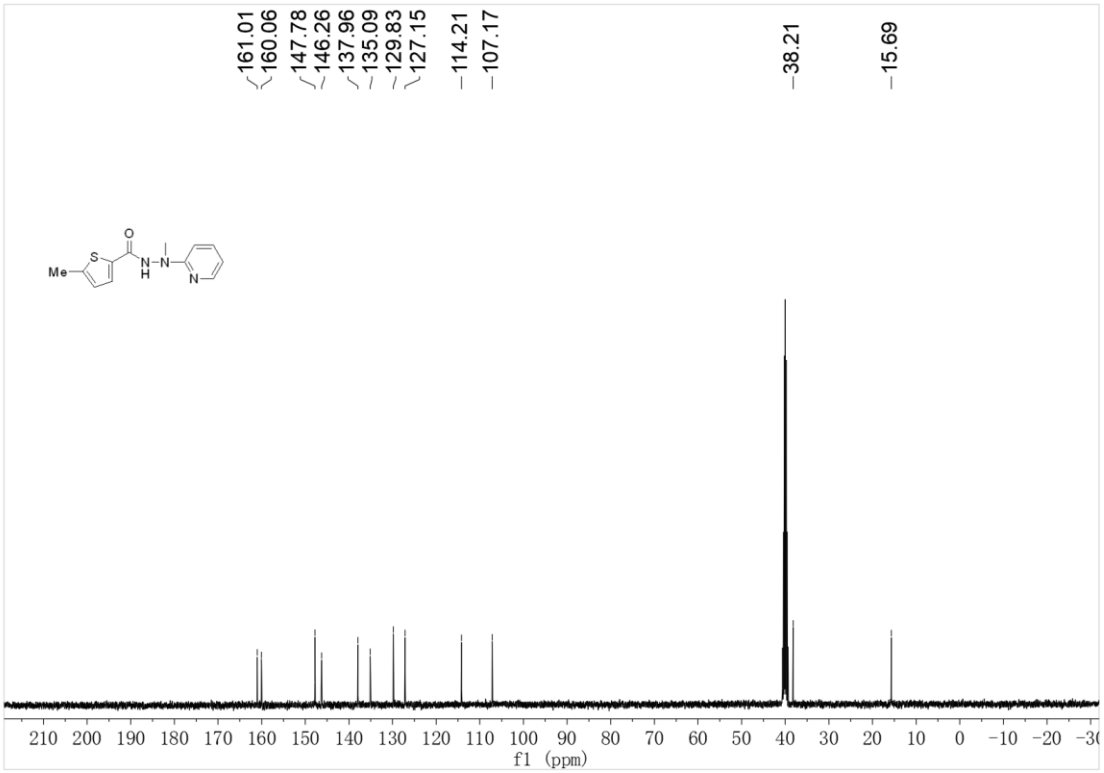
2. Zhao, H.; Shao, X.; Wang, T.; Zhai, S.; Qiu, S.; Tao, C.; Wang, H.; Zhai, H. *Chem. Commun.* **2018**, *54*, 4927.

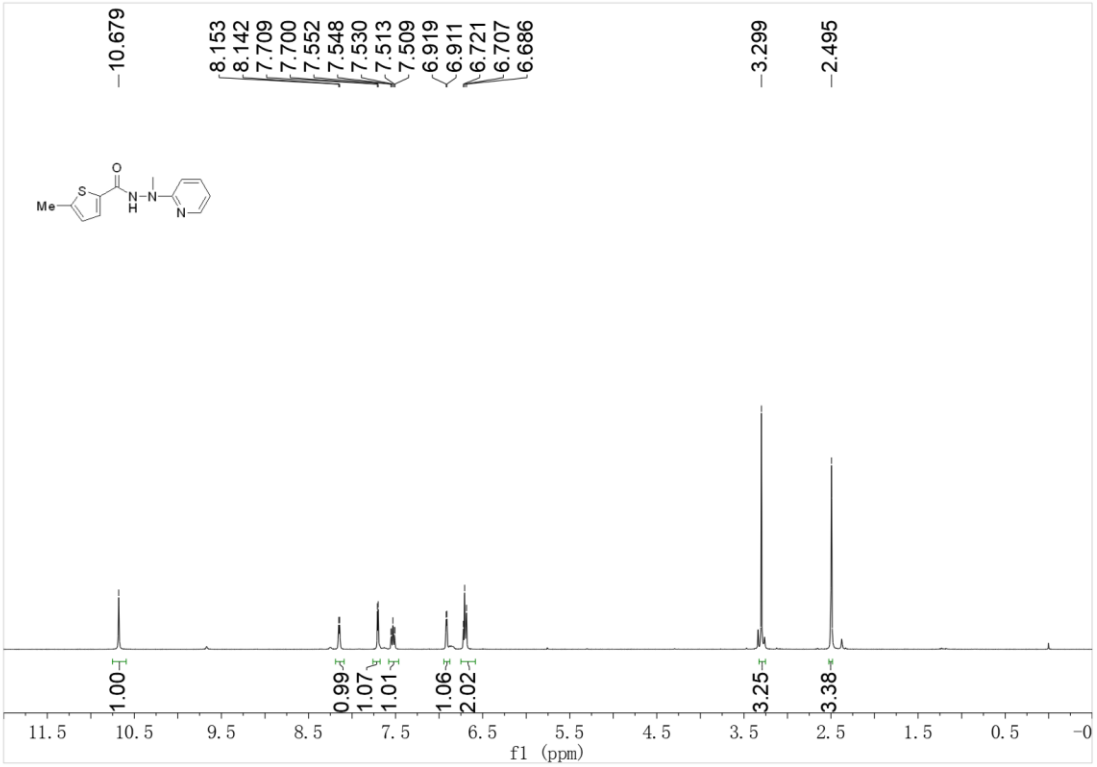
6. ^{1}H, ^{13}C and ^{19}F NMR Spectra

^{1}H, ^{13}C NMR spectra of compound **1a**

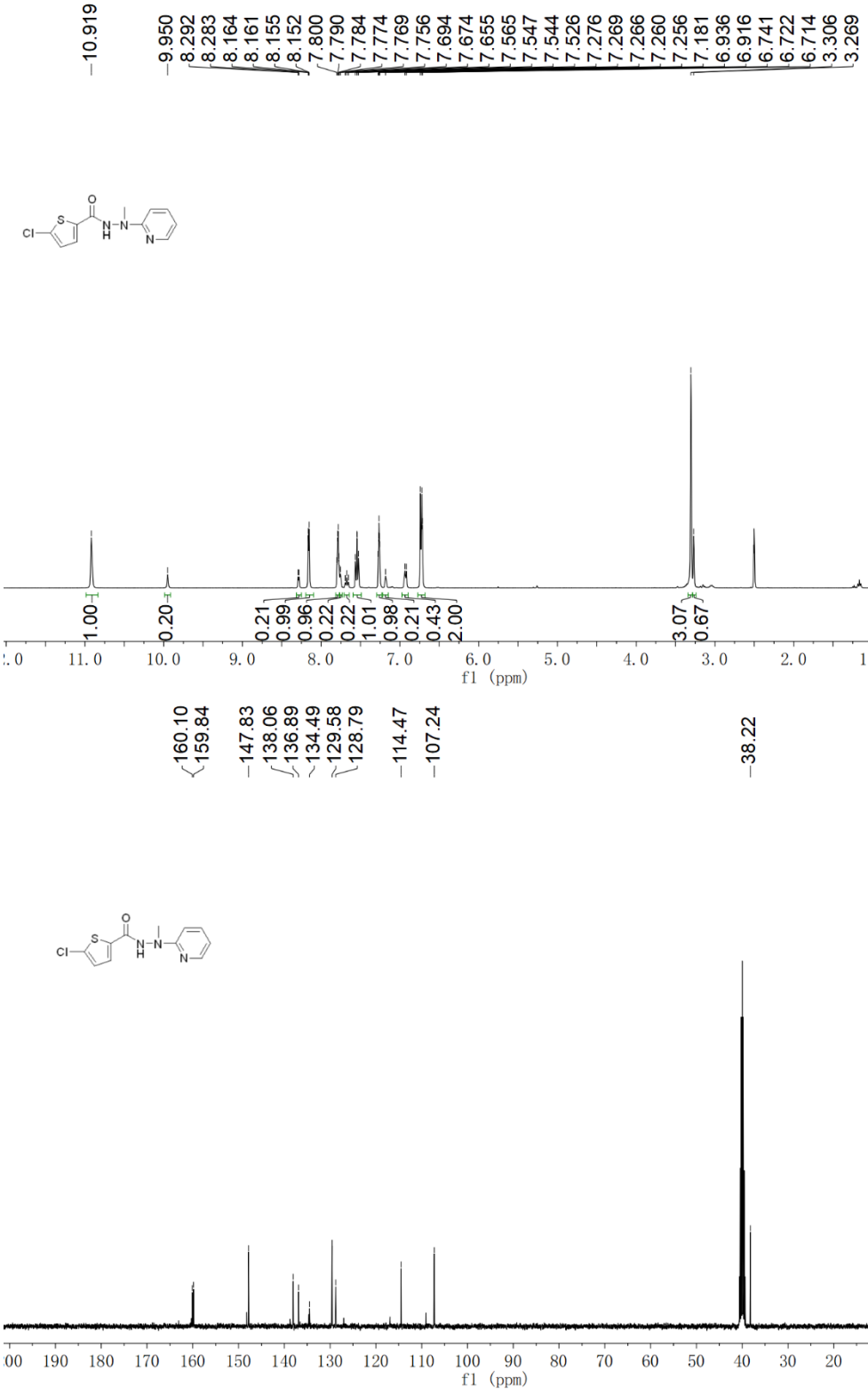


^{1}H, ^{13}C NMR spectra of compound **1b**

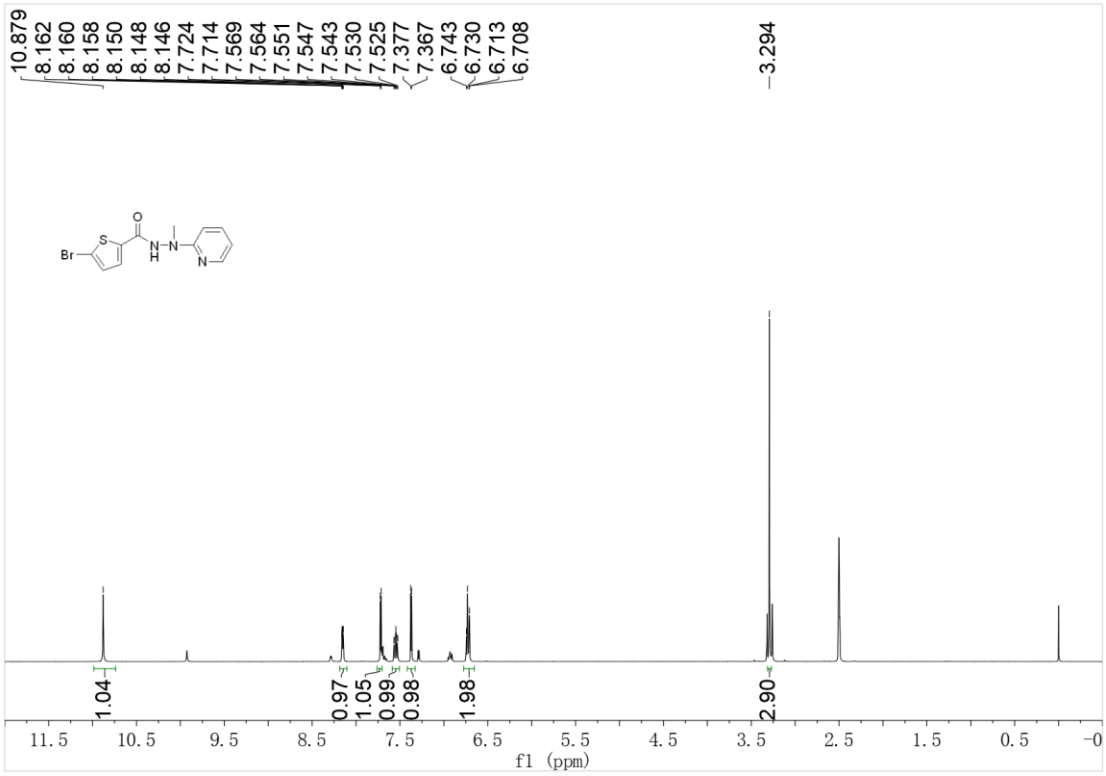


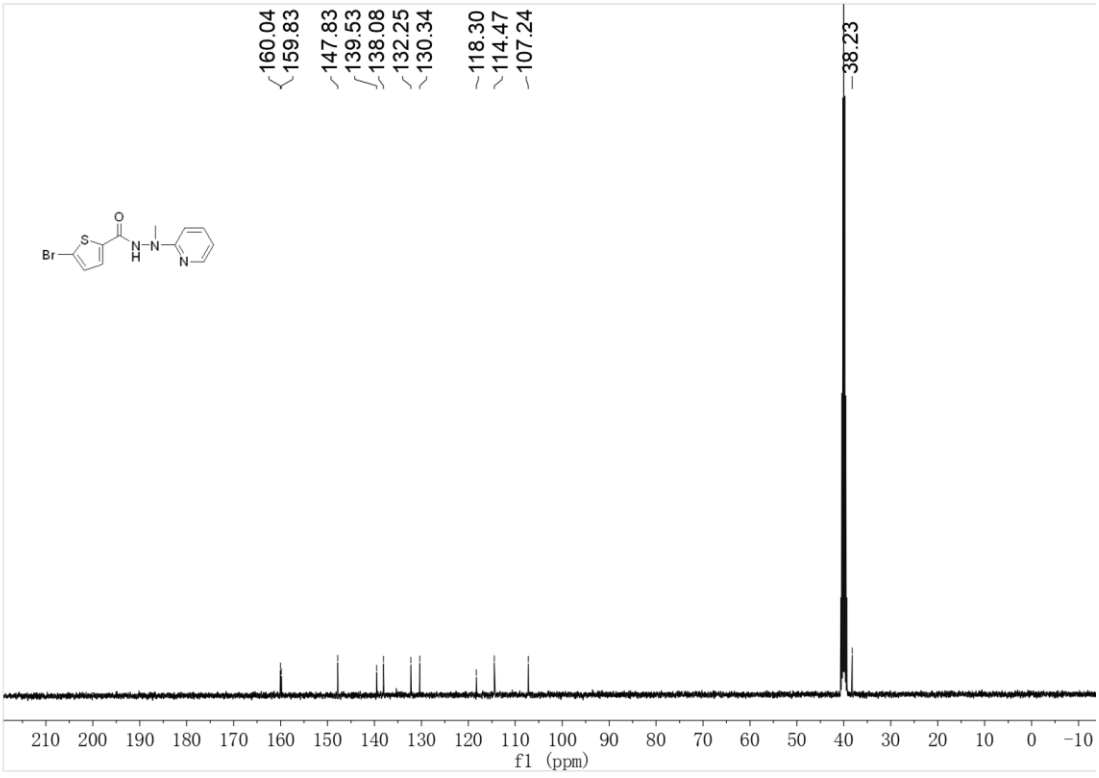


^{1}H, ^{13}C NMR spectra of compound **1c**

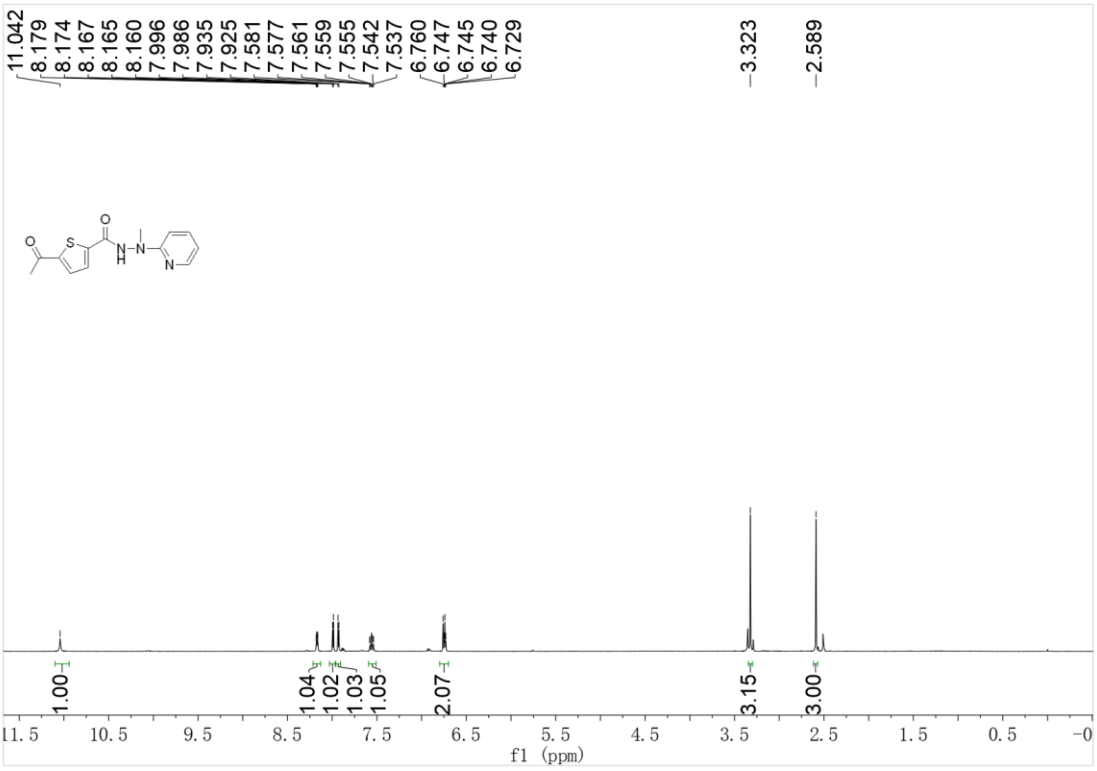


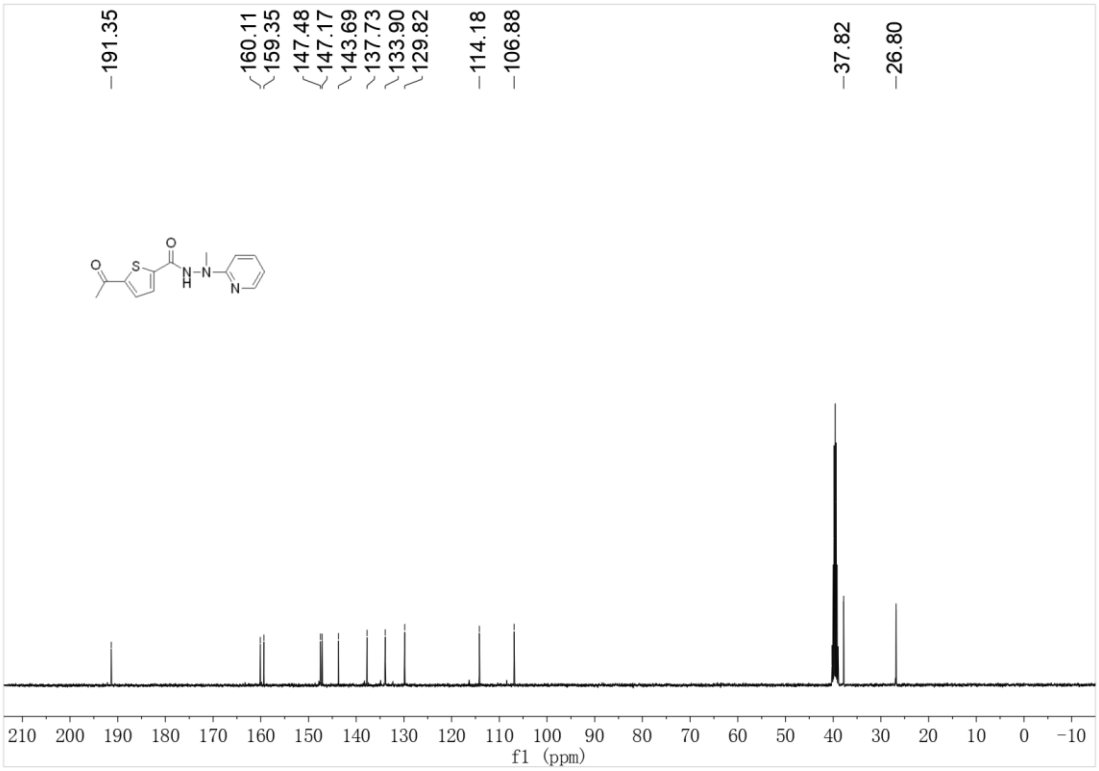
^{1}H, ^{13}C NMR spectra of compound **1d**



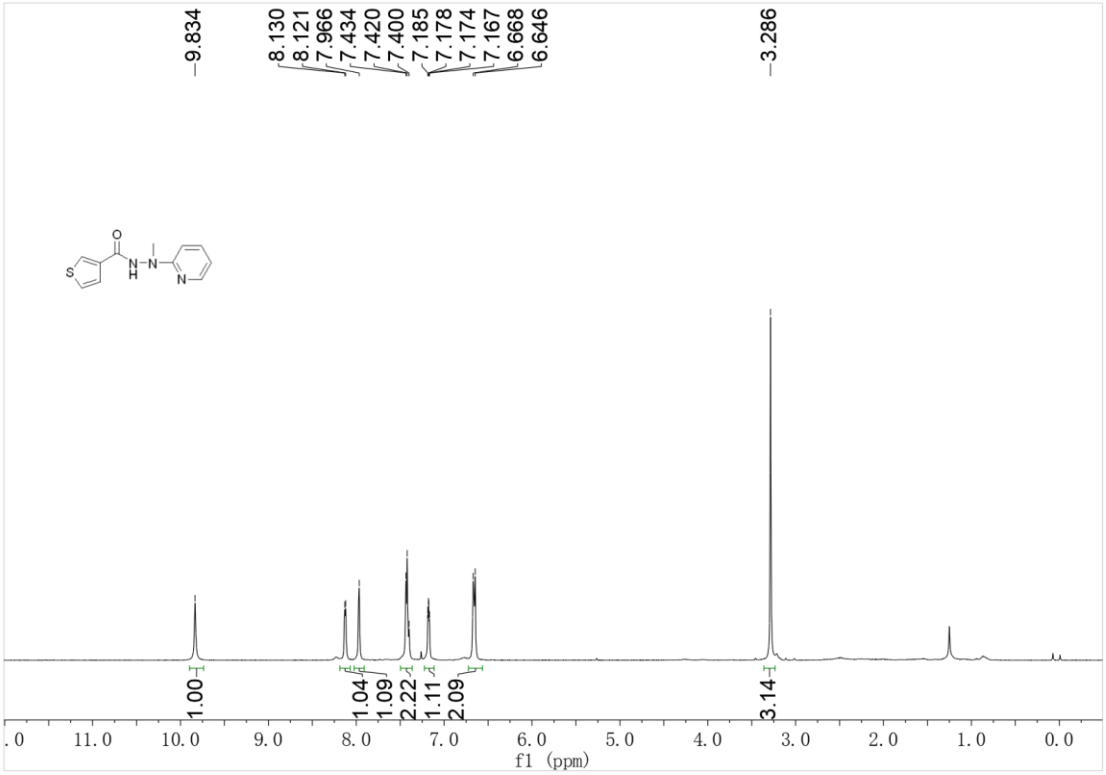


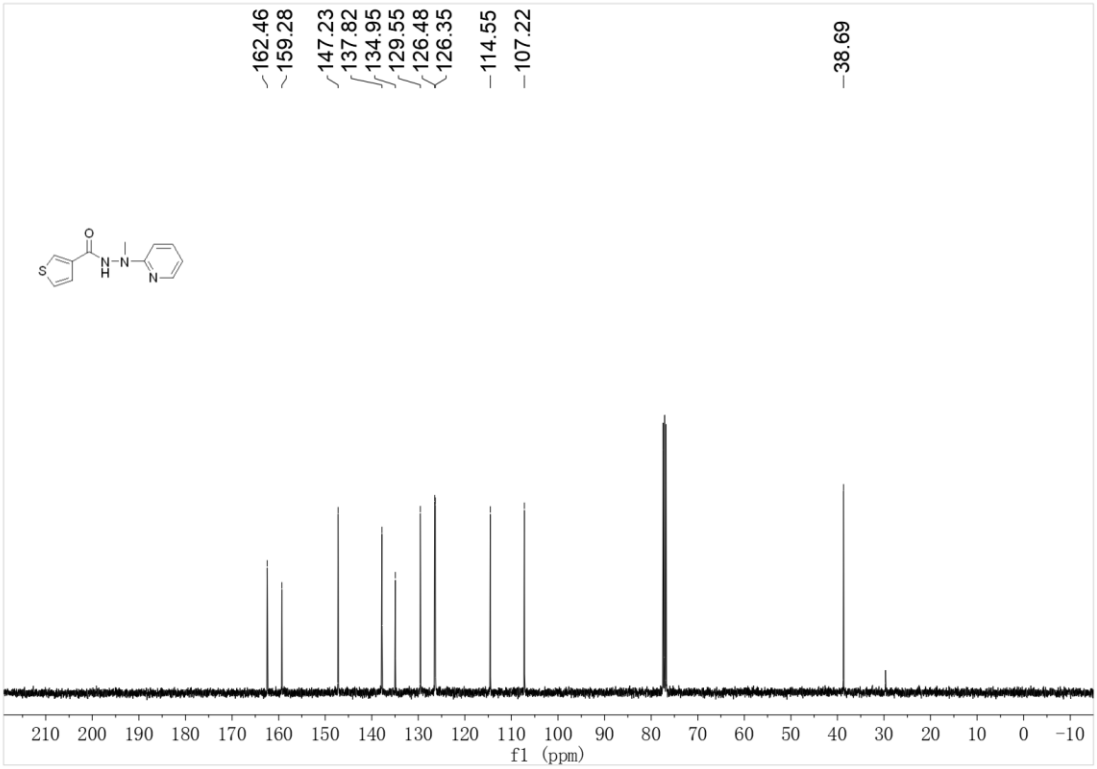
^{1}H, ^{13}C NMR spectra of compound **1e**



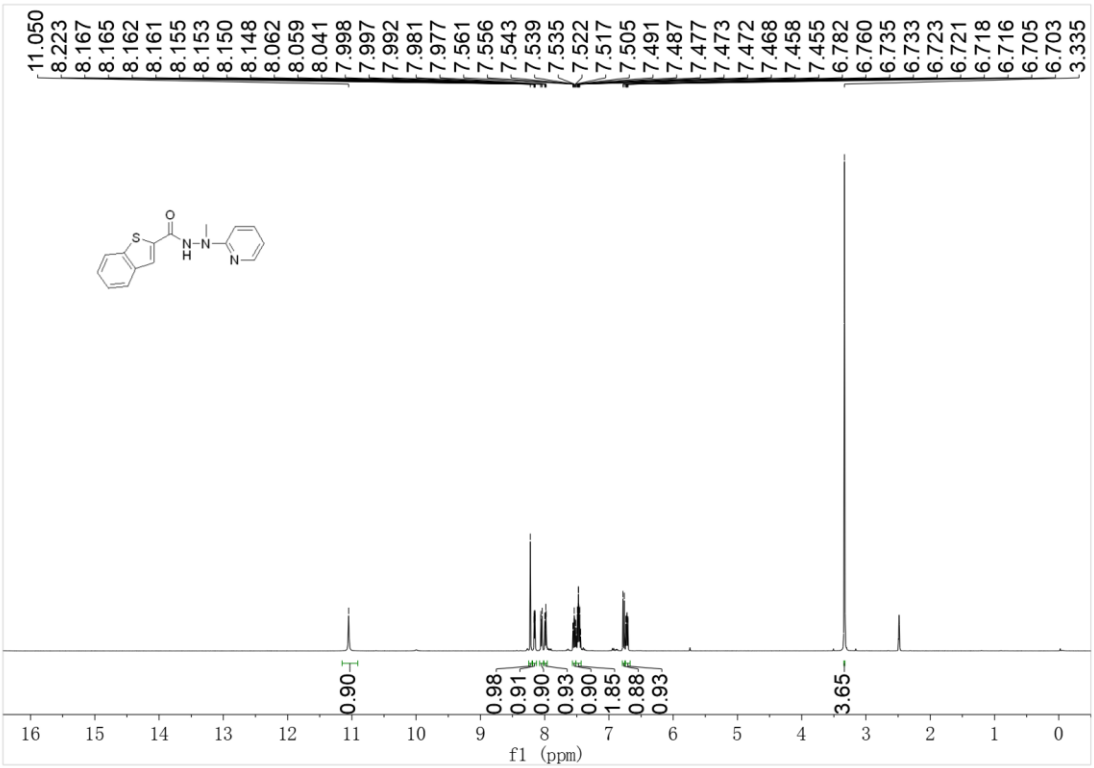


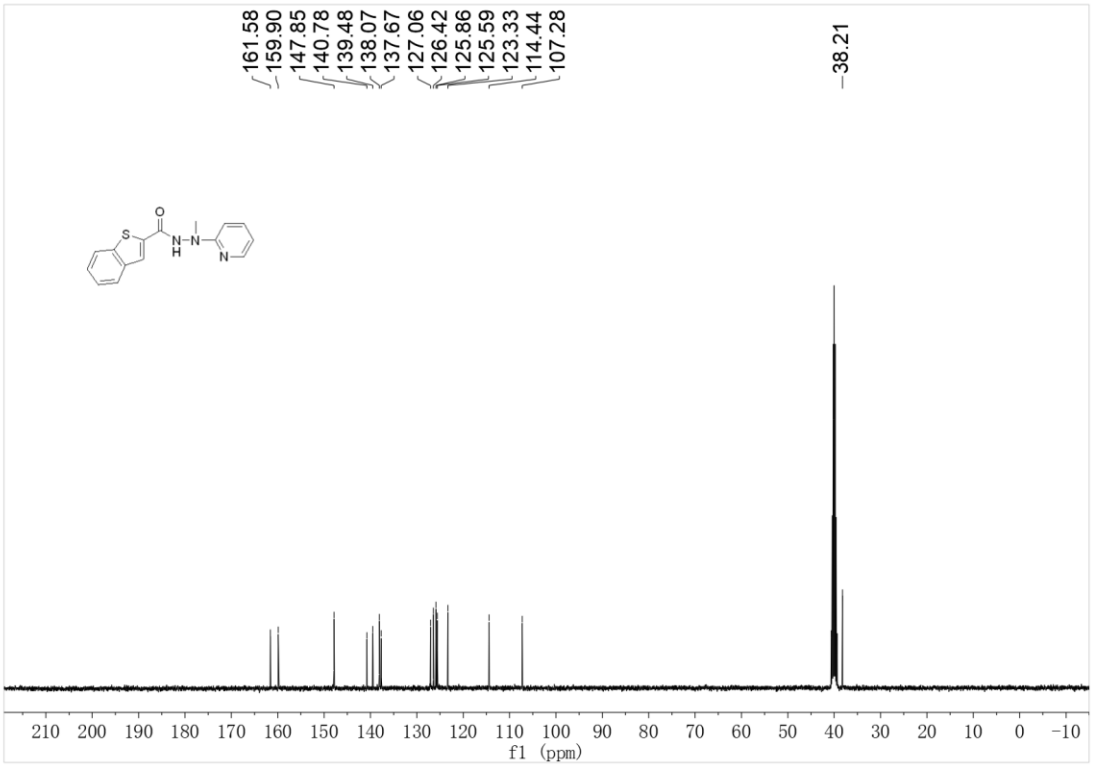
^{1}H, ^{13}C NMR spectra of compound **1f**



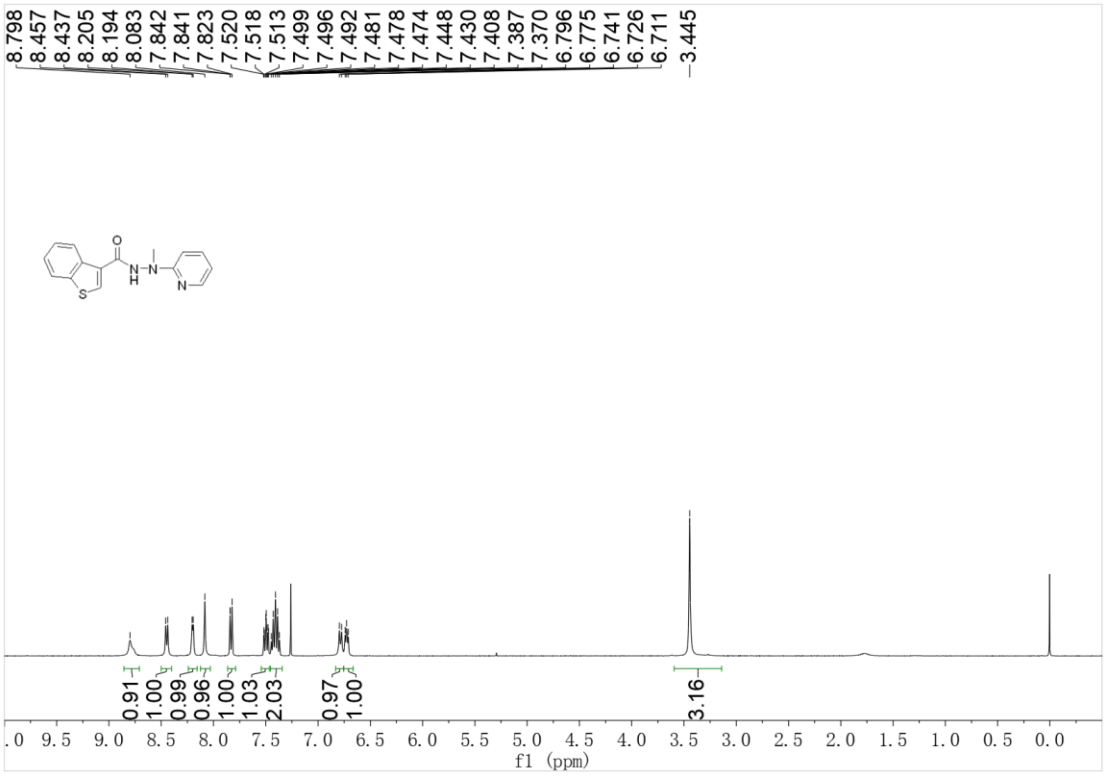


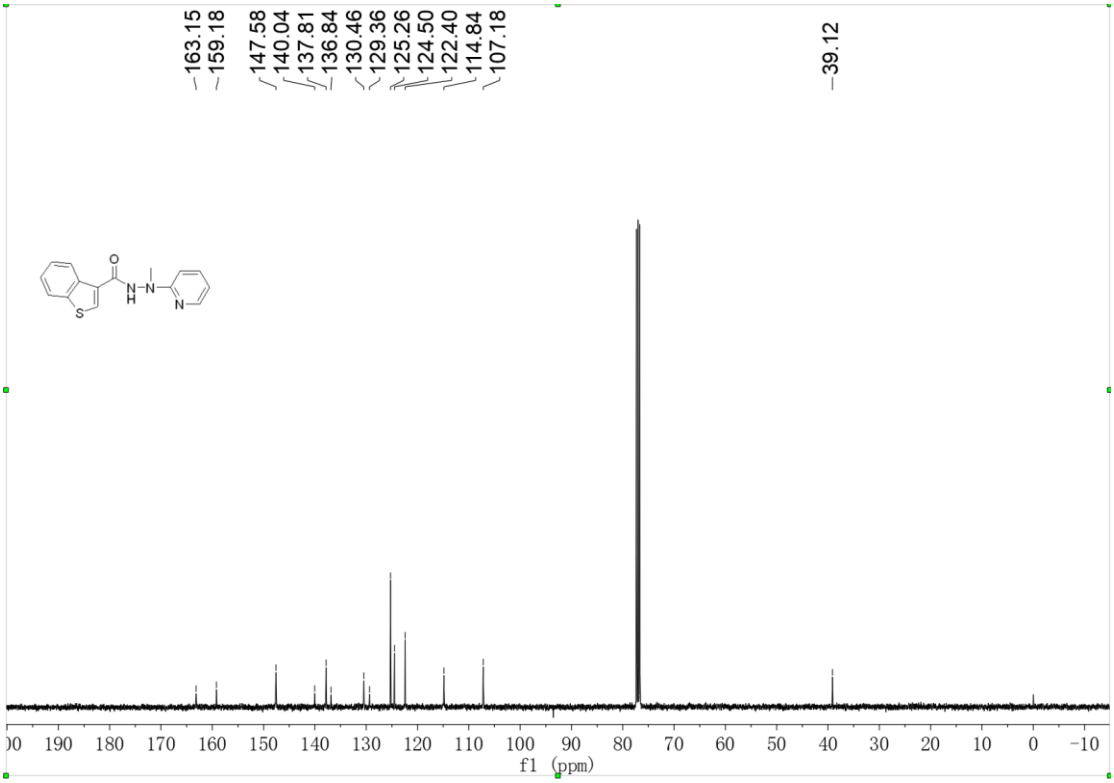
^{1}H, ^{13}C NMR spectra of compound **1g**



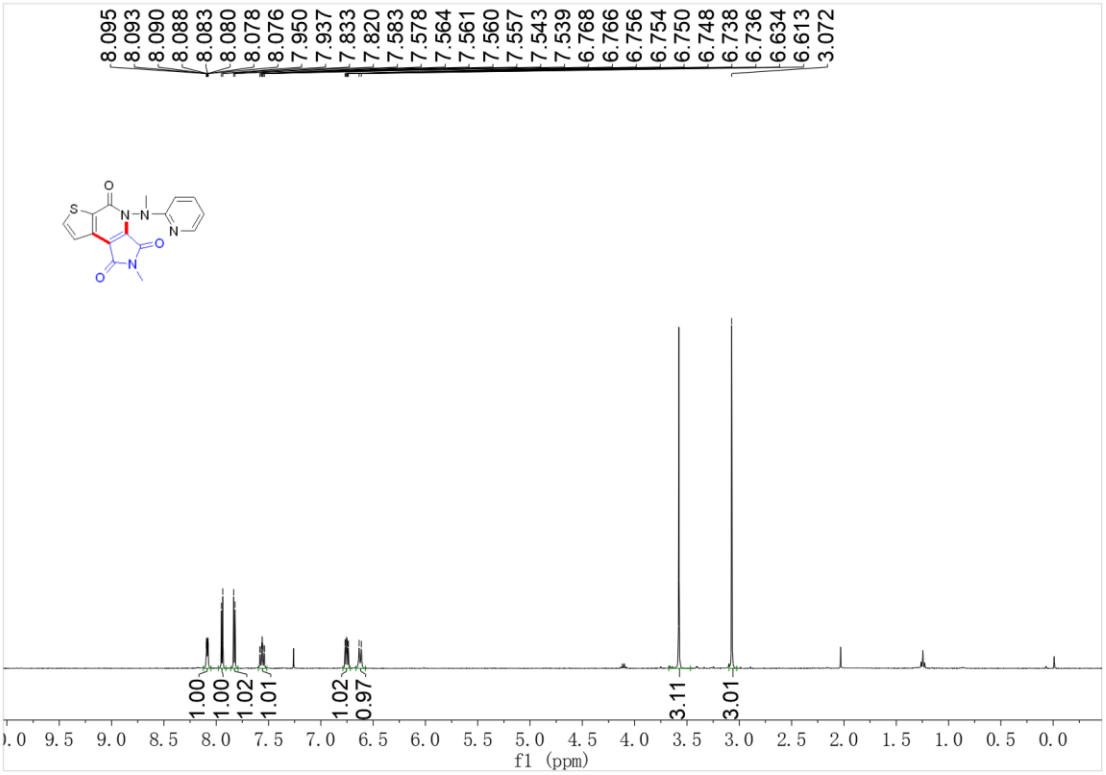


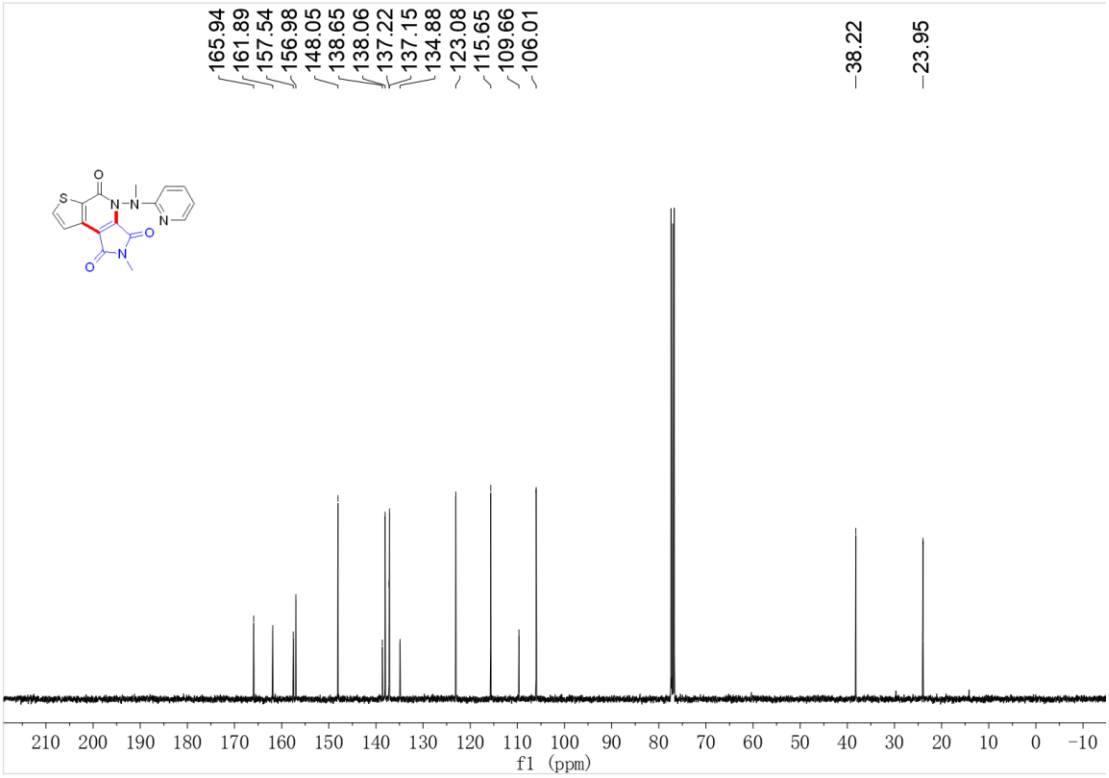
^{1}H, ^{13}C NMR spectra of compound **1h**



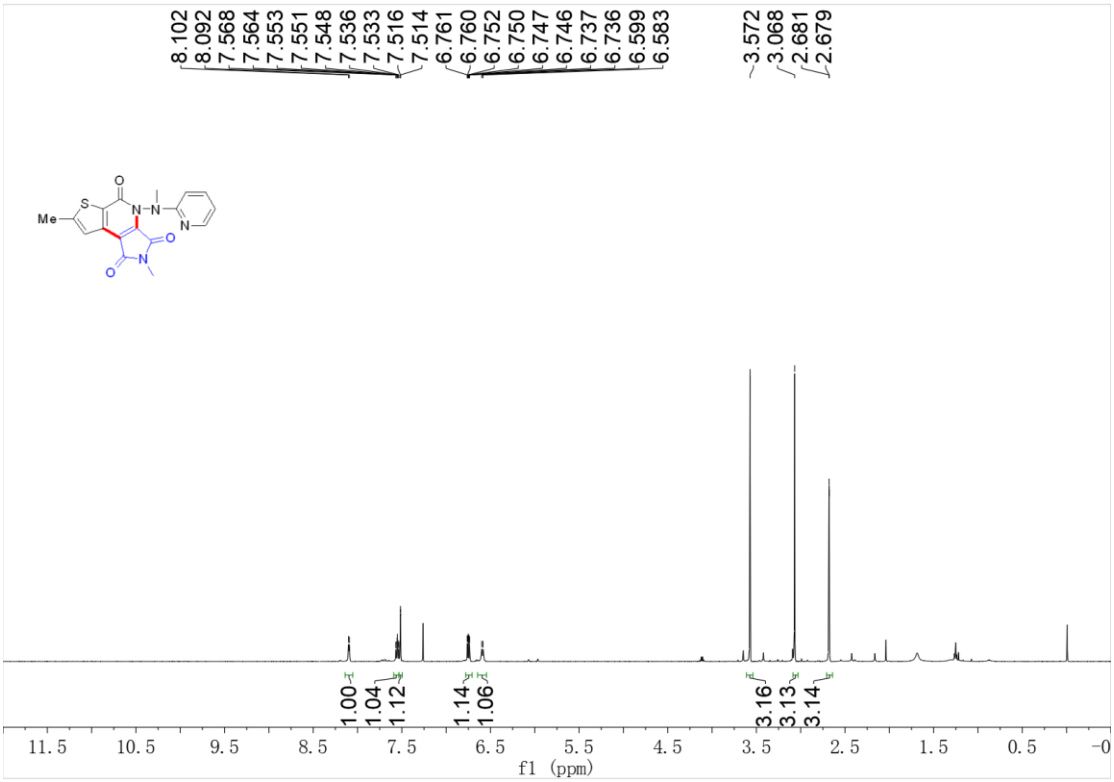


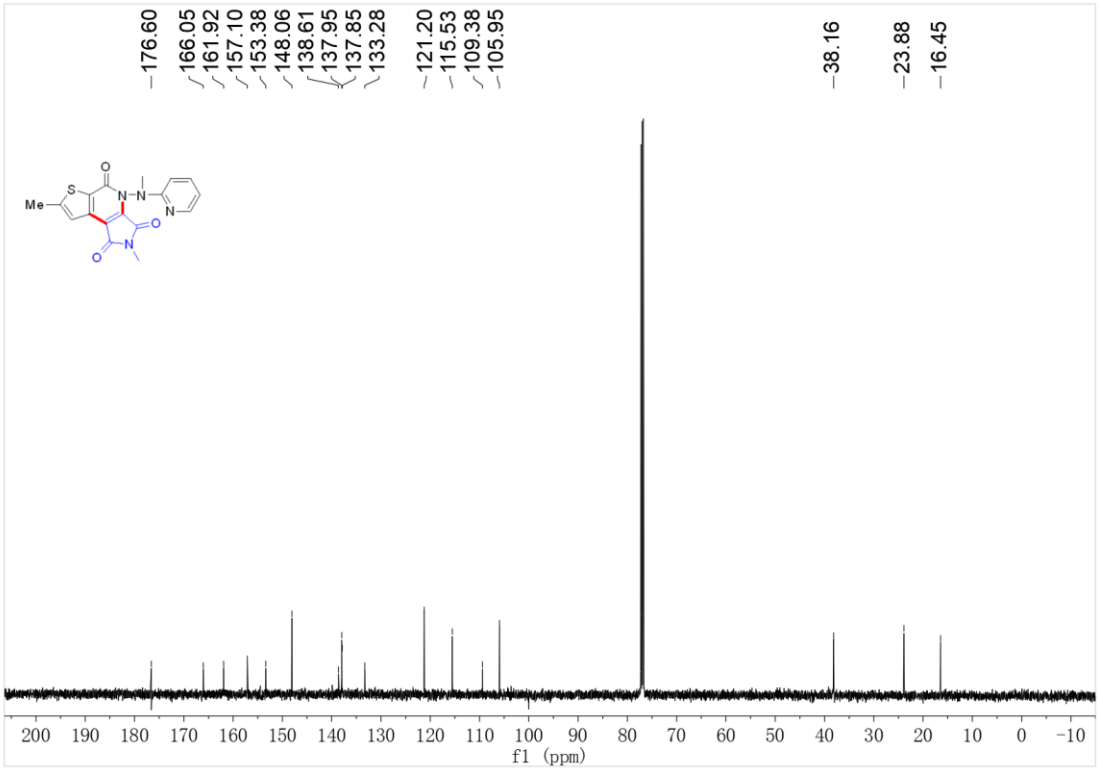
^{1}H, ^{13}C NMR spectra of compound **3aa**



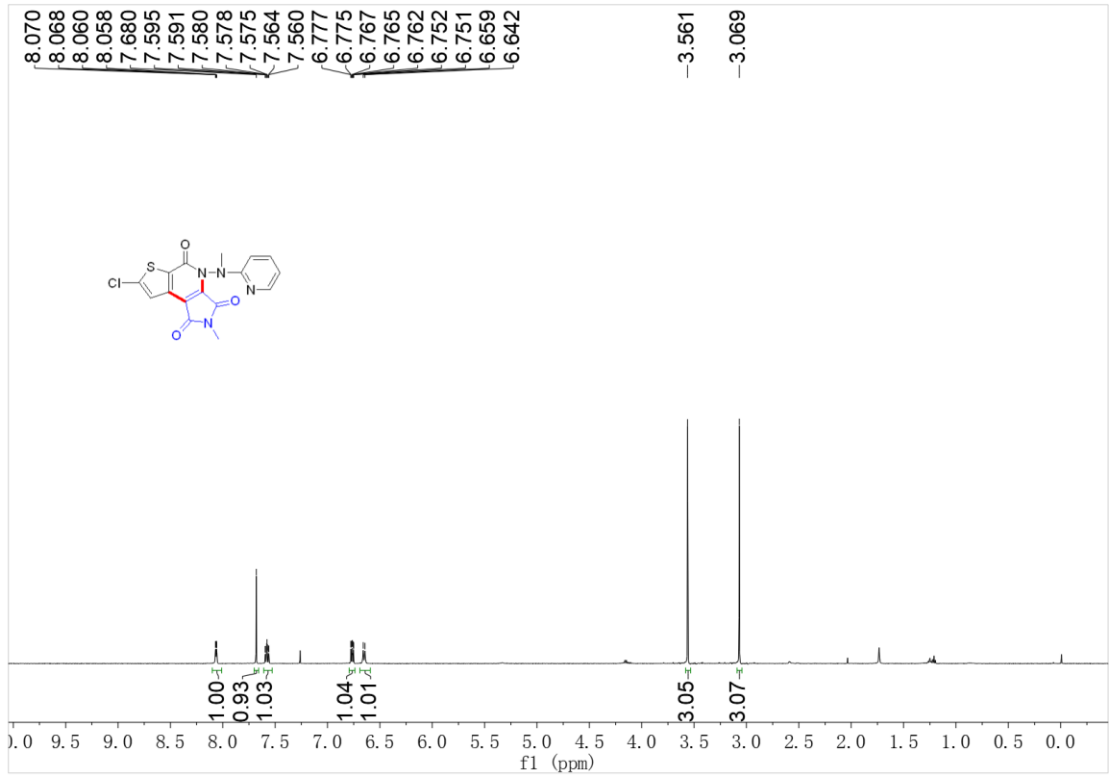


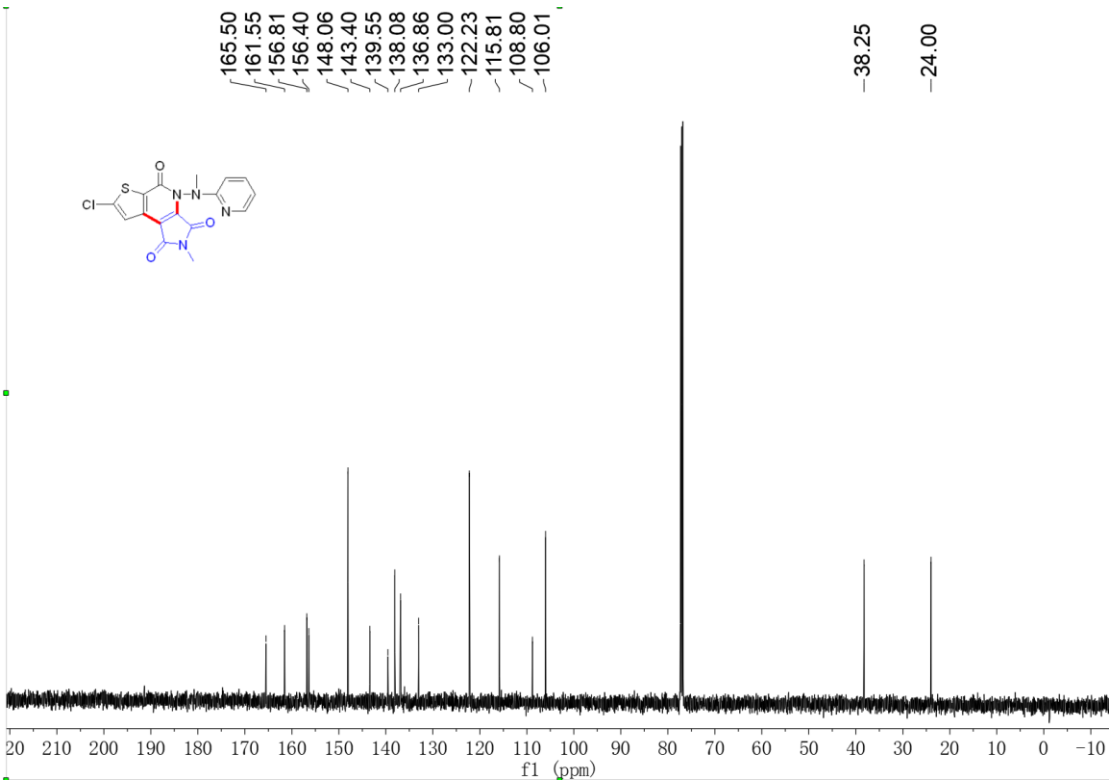
^{1}H, ^{13}C NMR spectra of compound **3ba**



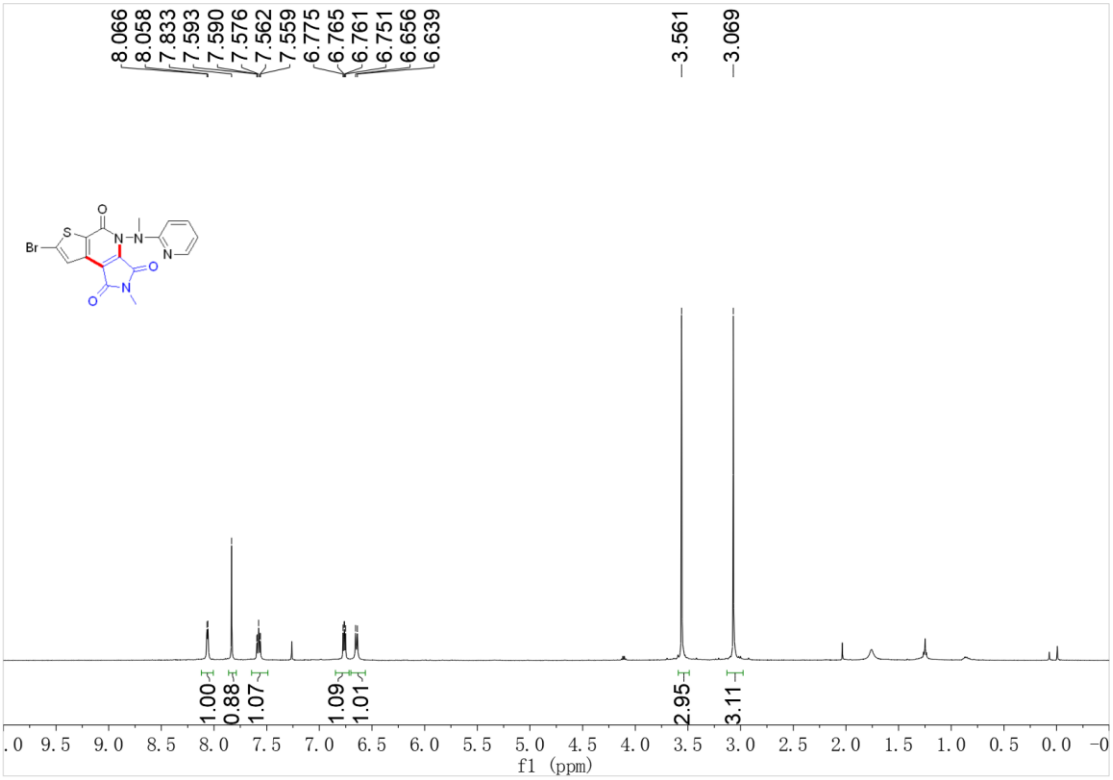


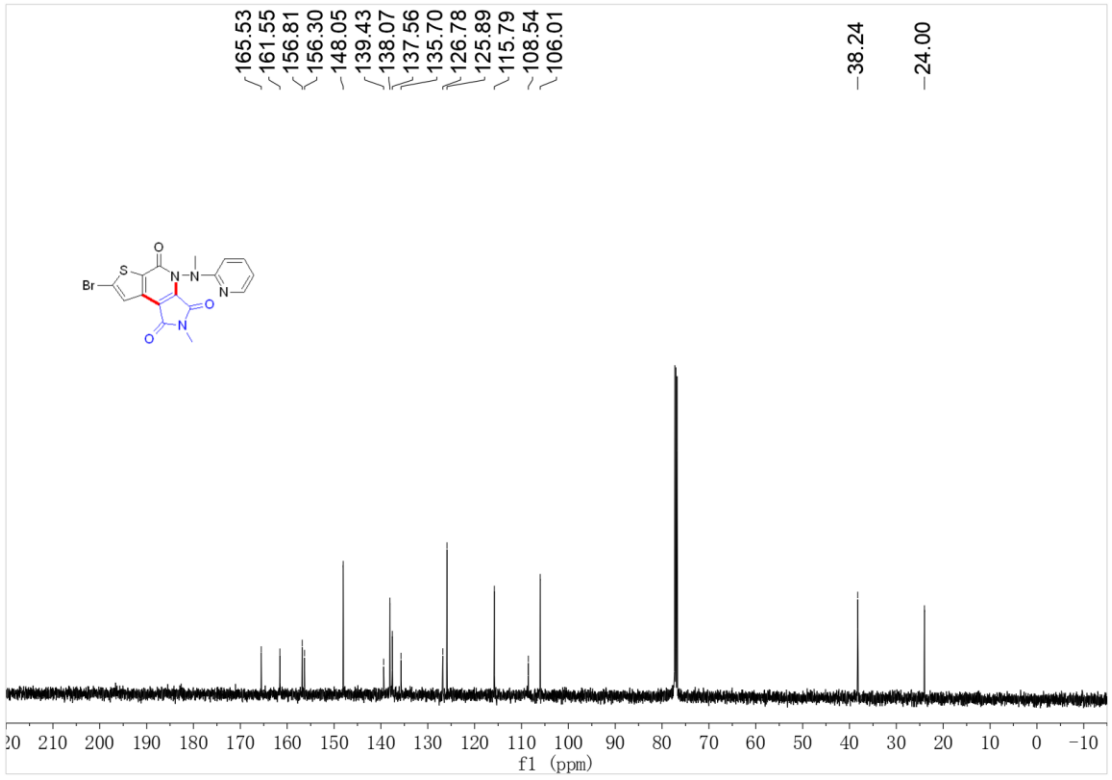
^{1}H, ^{13}C NMR spectra of compound **3ca**



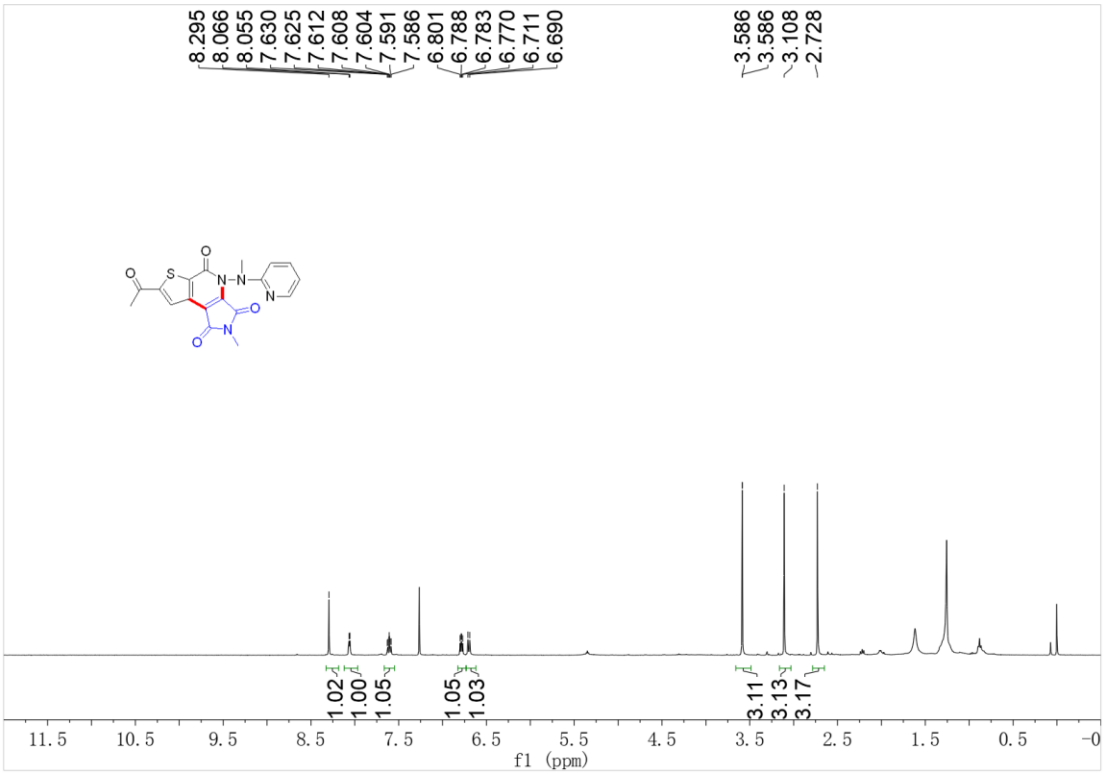


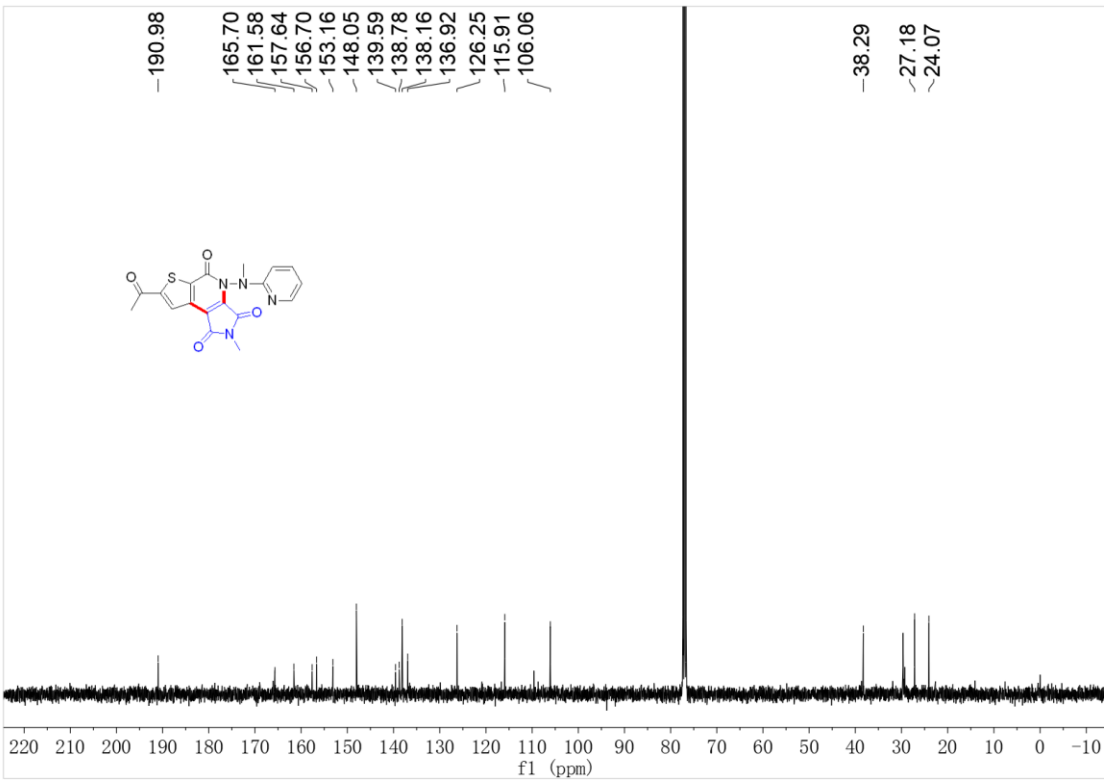
^{1}H, ^{13}C NMR spectra of compound **3da**



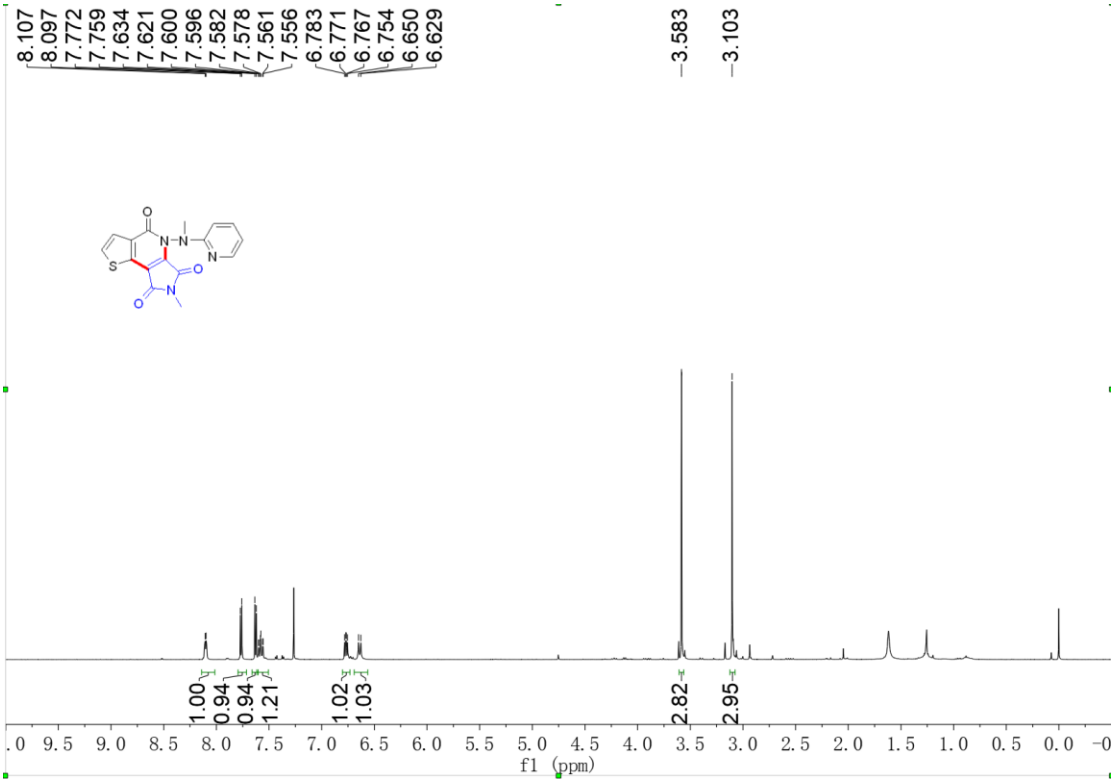


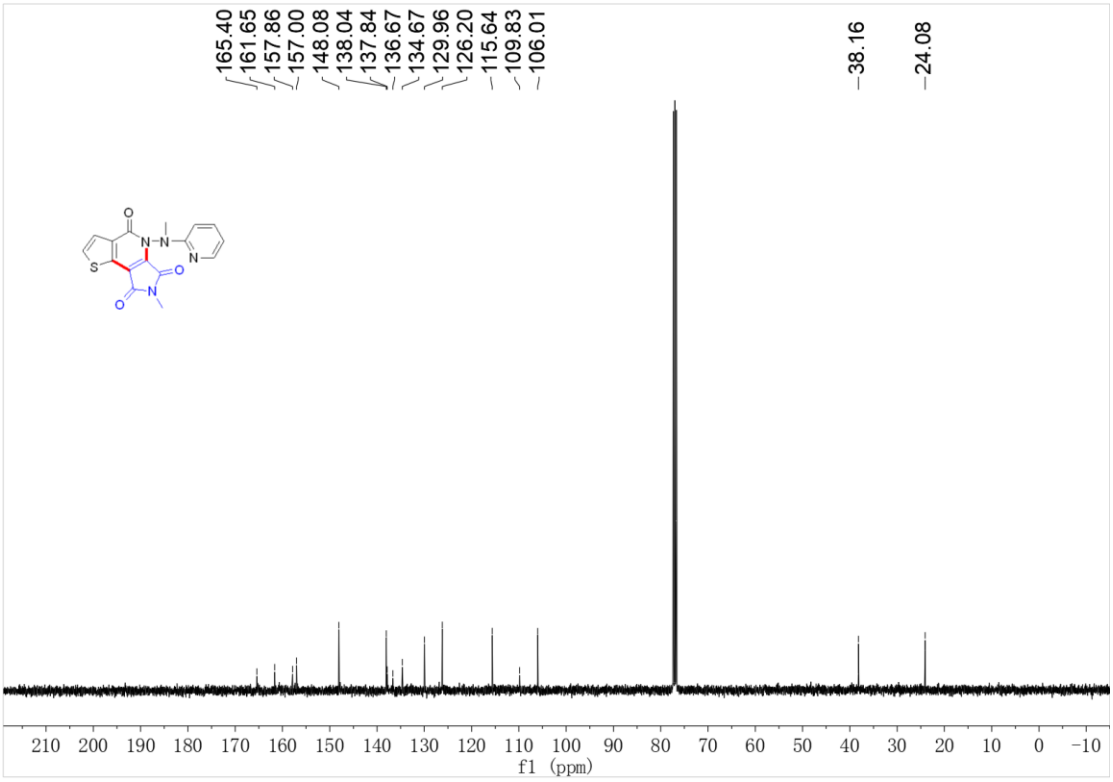
^{1}H, ^{13}C NMR spectra of compound **3ea**



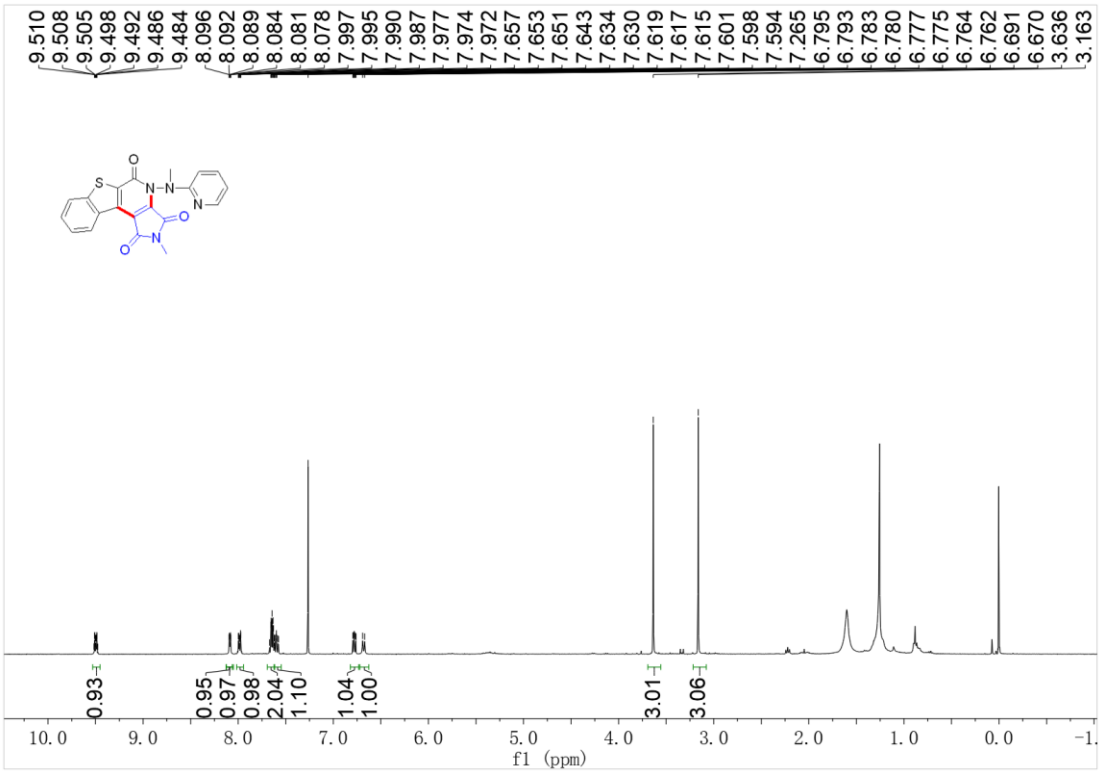


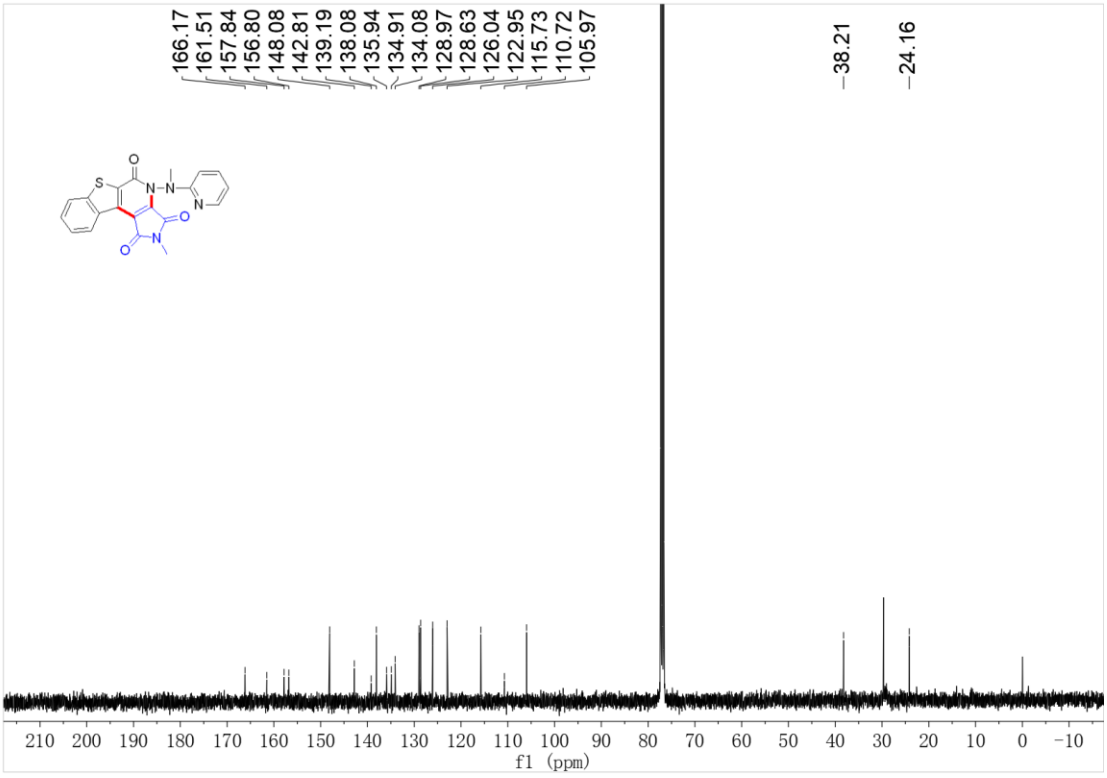
^{1}H, ^{13}C NMR spectra of compound **3fa**



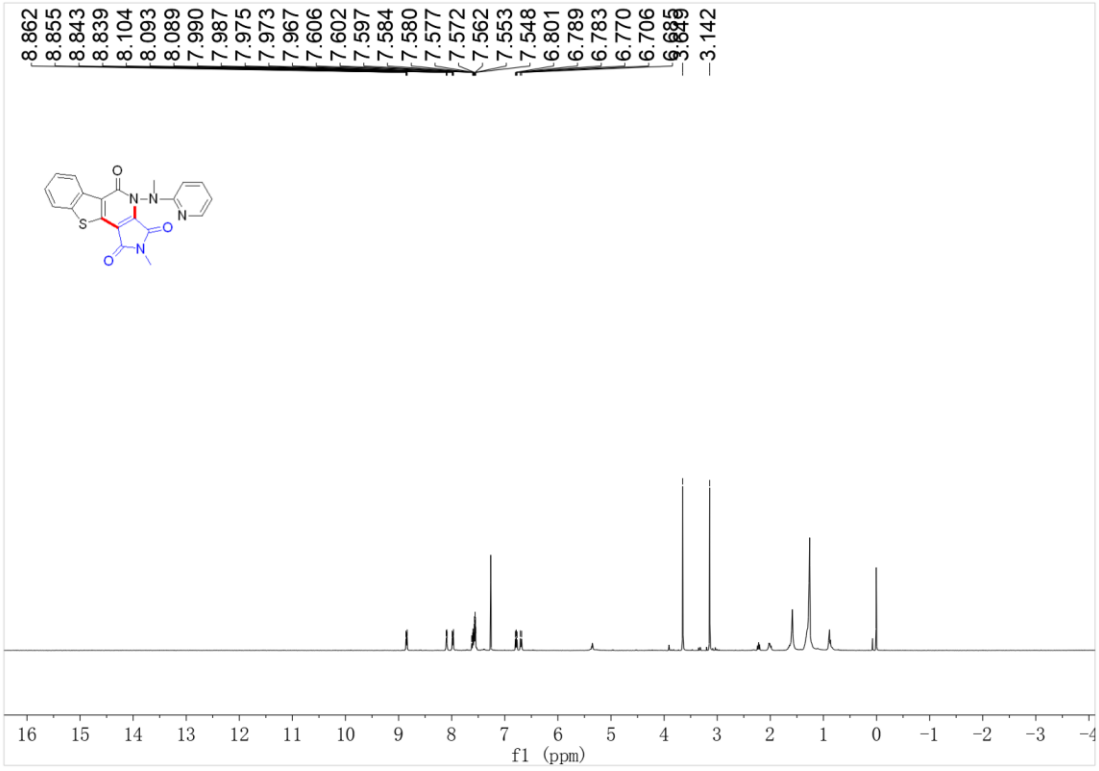


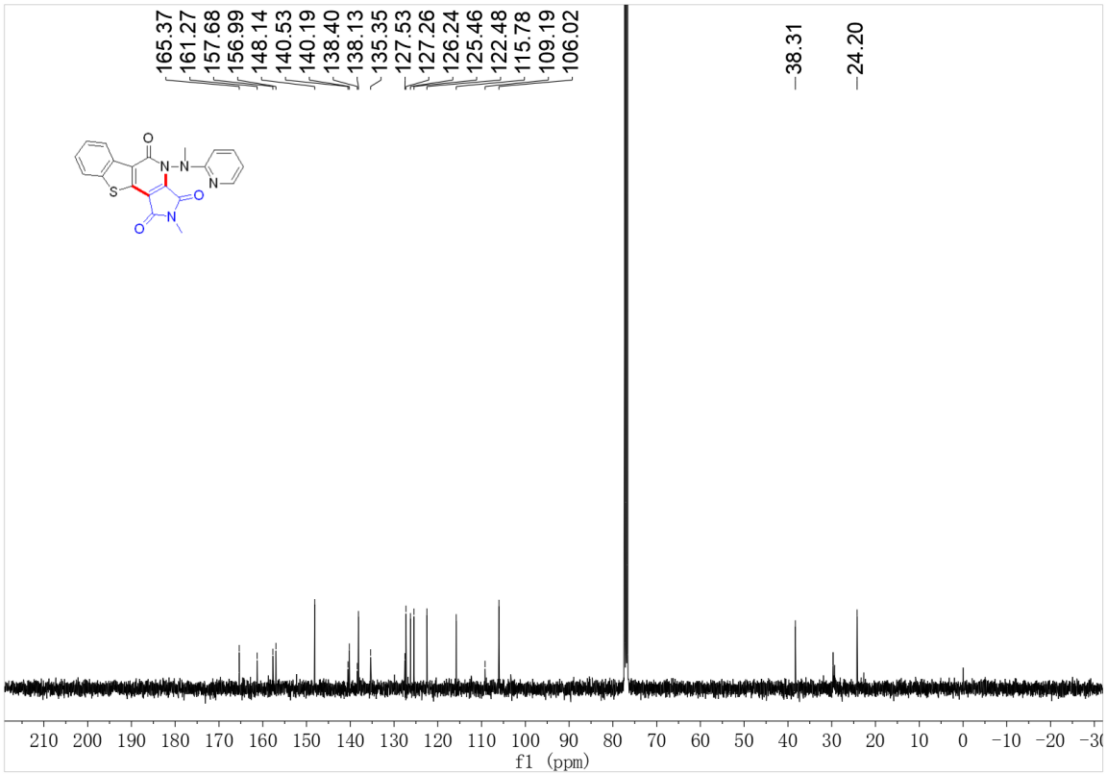
^{1}H, ^{13}C NMR spectra of compound **3ga**



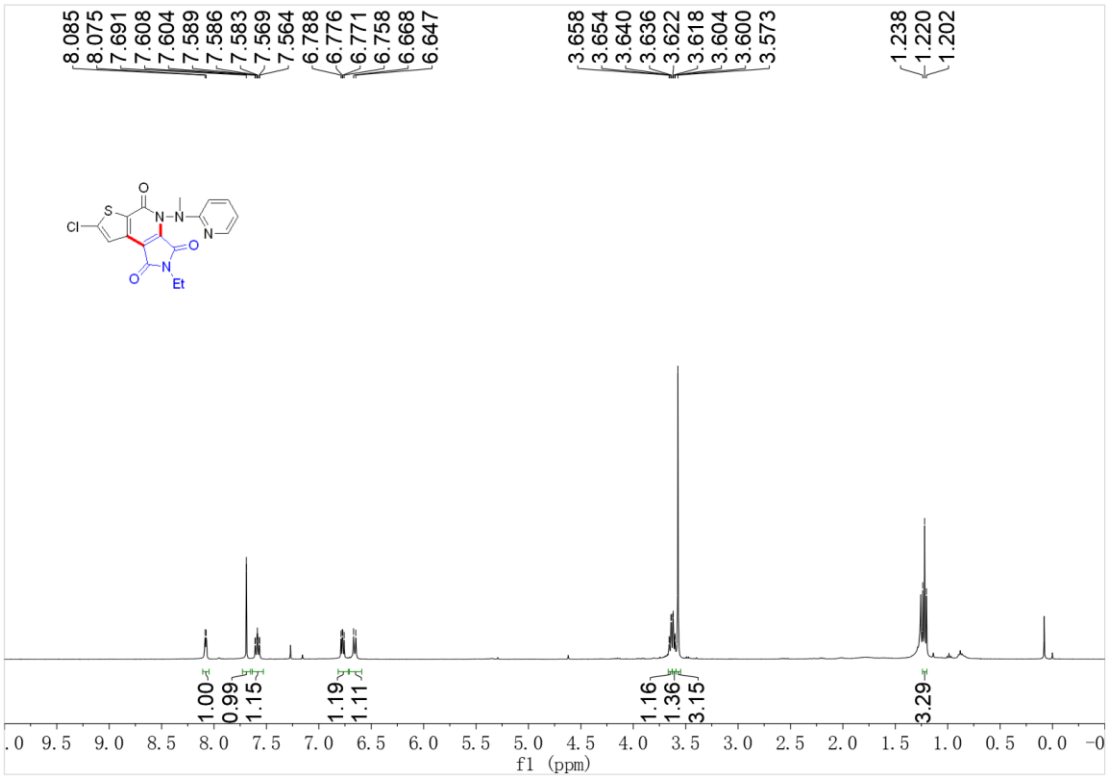


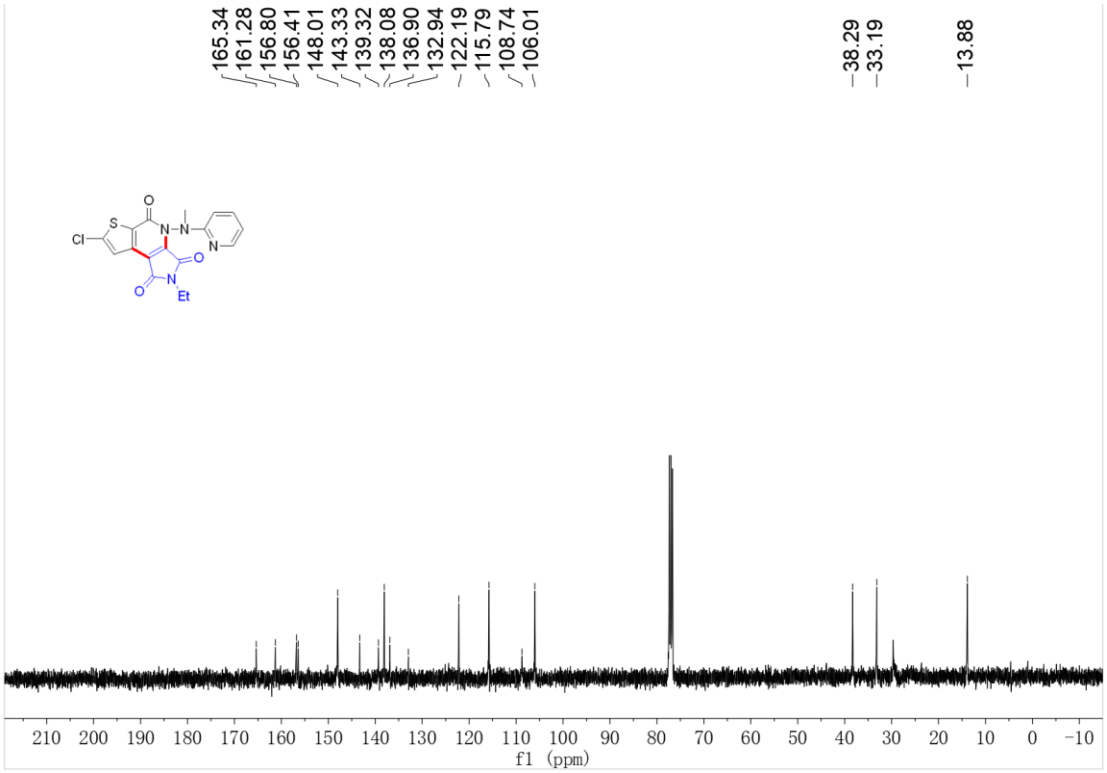
^{1}H, ^{13}C NMR spectra of compound **3ha**



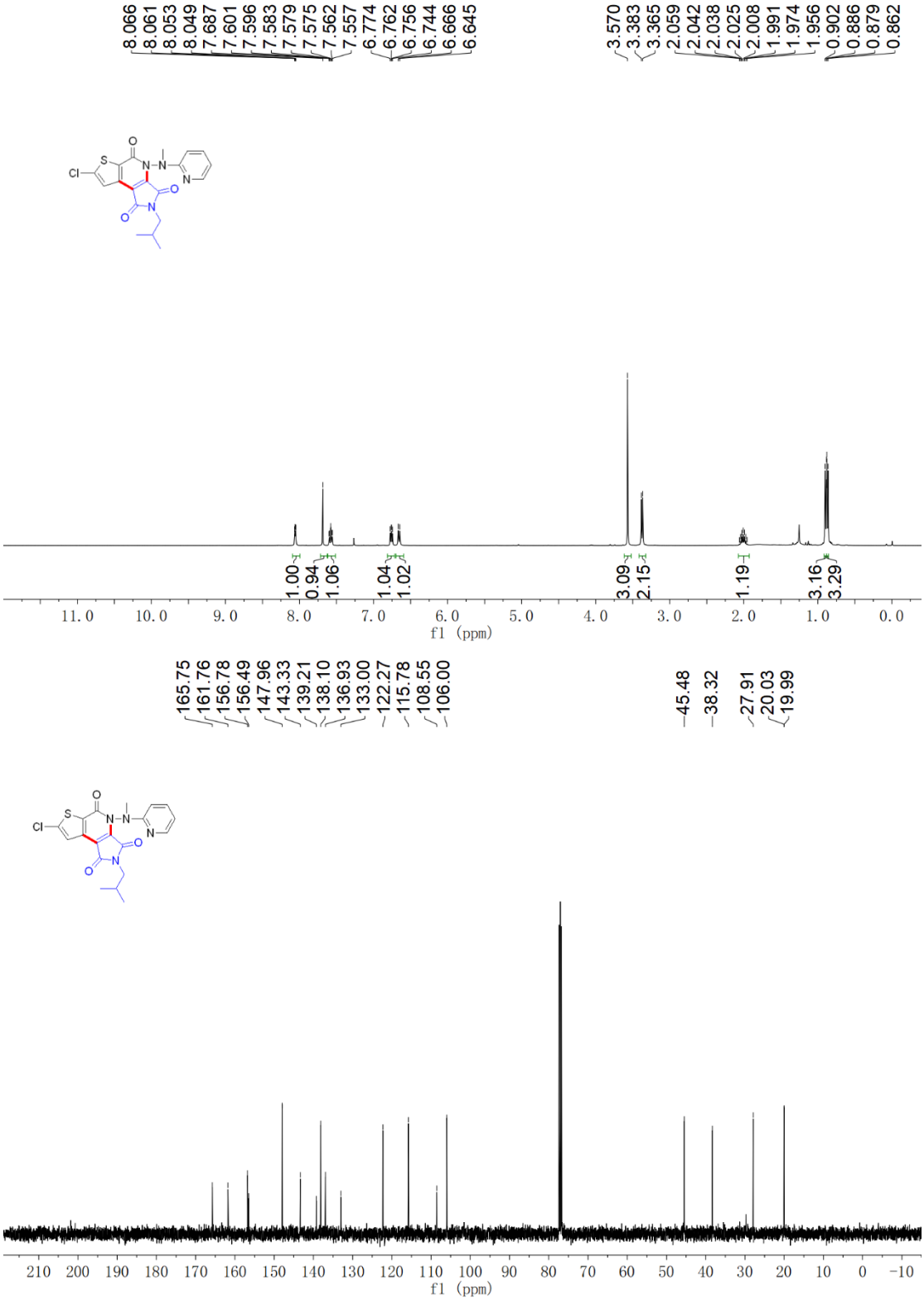


^{1}H, ^{13}C NMR spectra of compound **3cb**

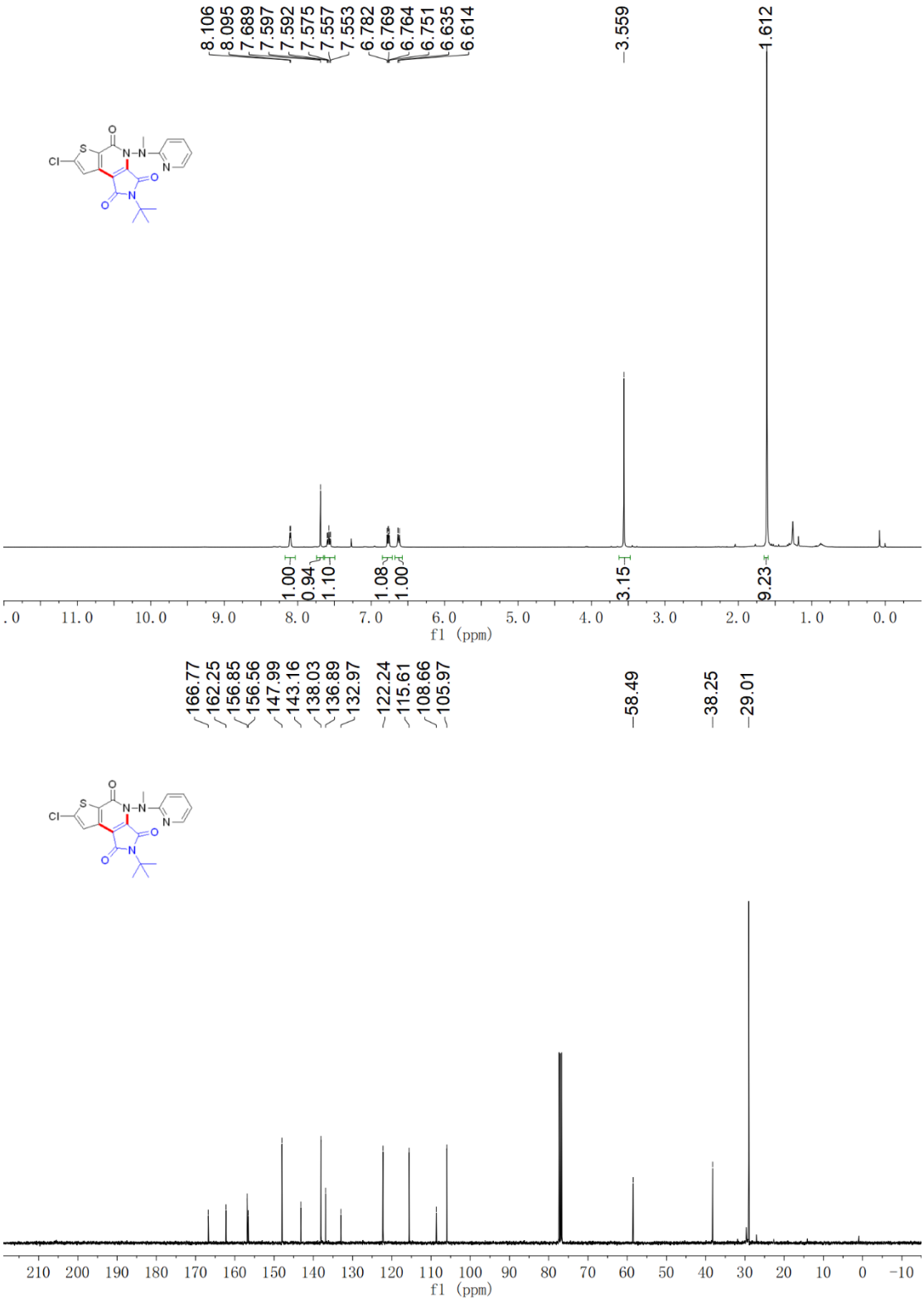




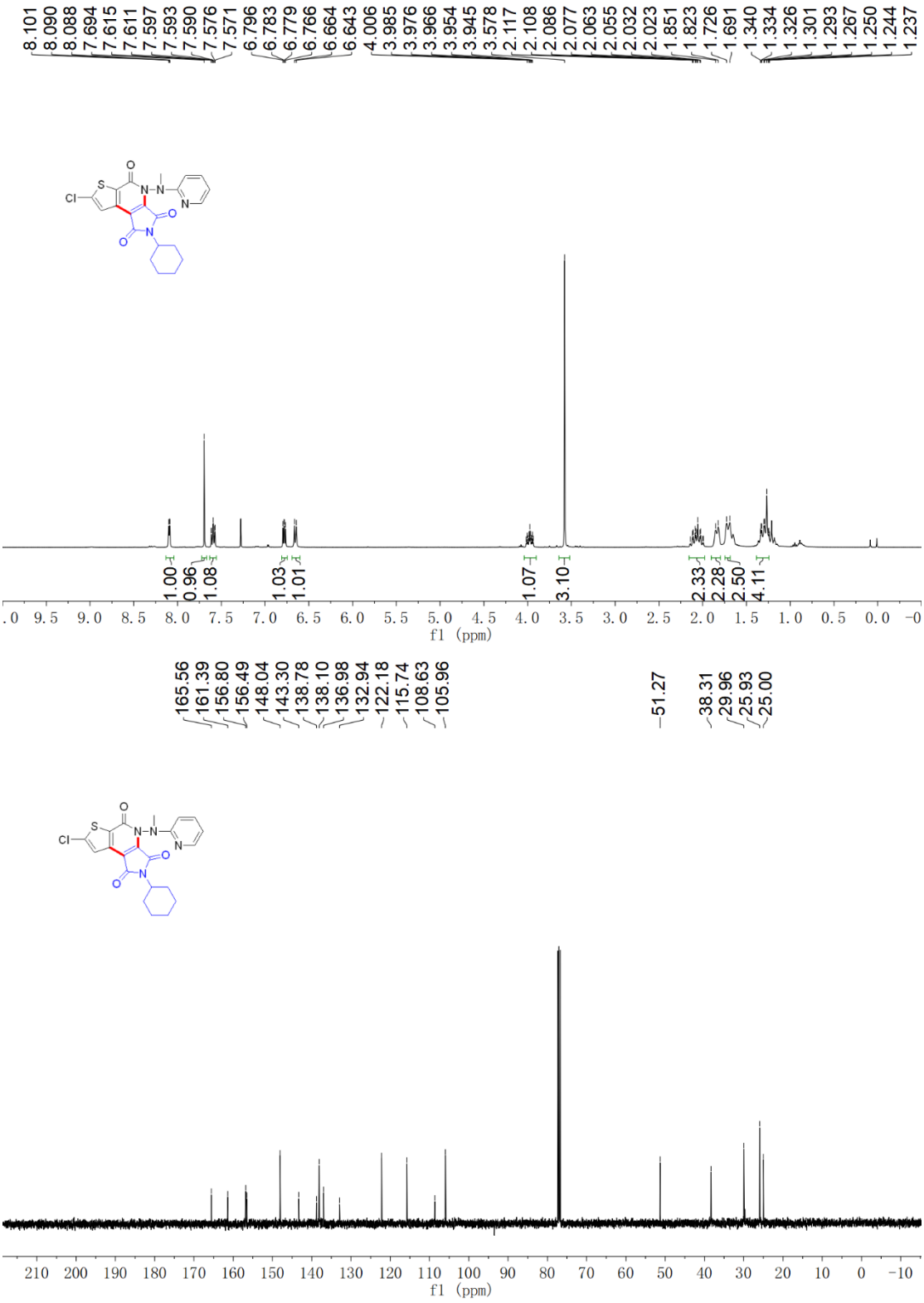
^{1}H, ^{13}C NMR spectra of compound **3cc**



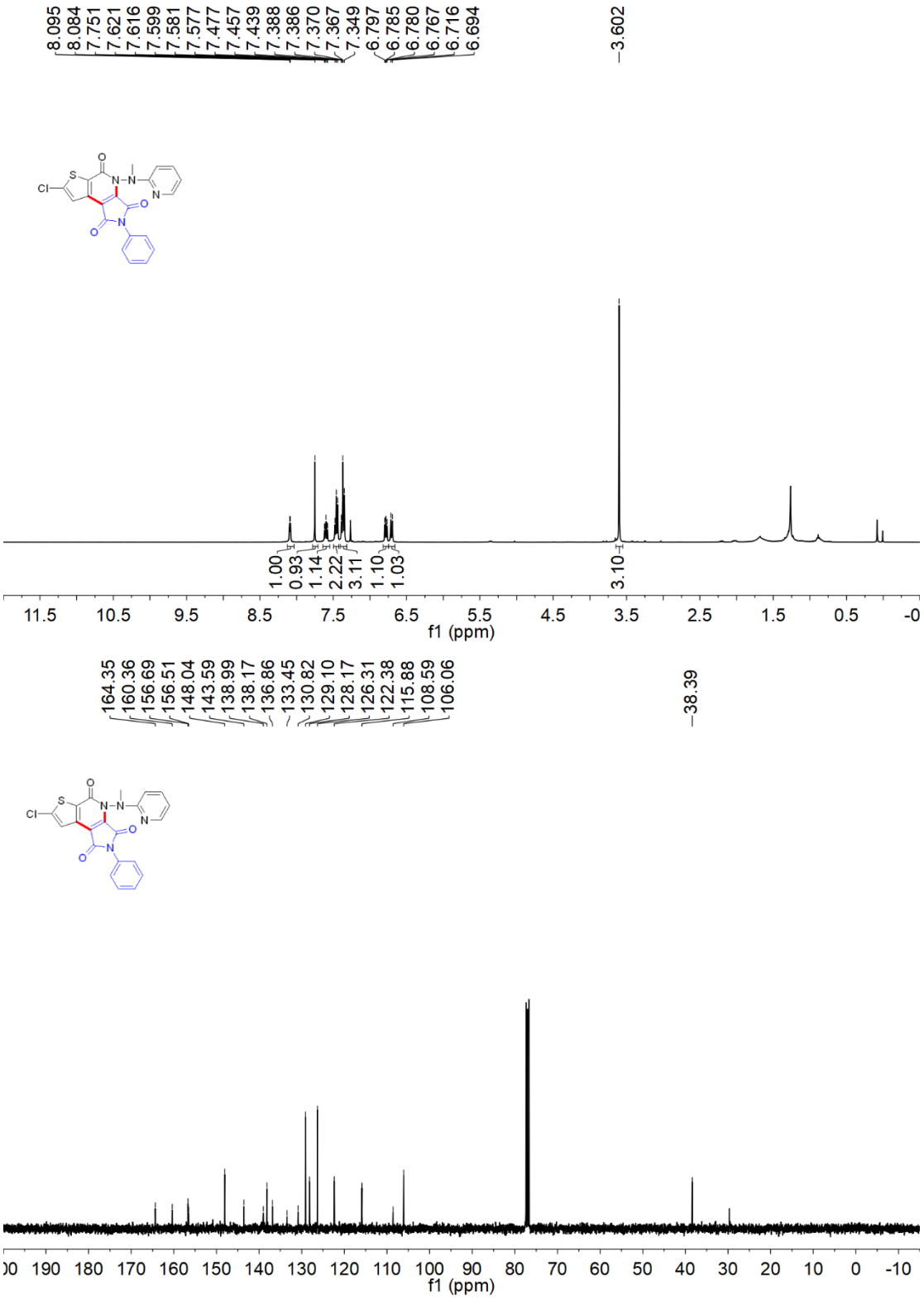
^{1}H, ^{13}C NMR spectra of compound **3cd**



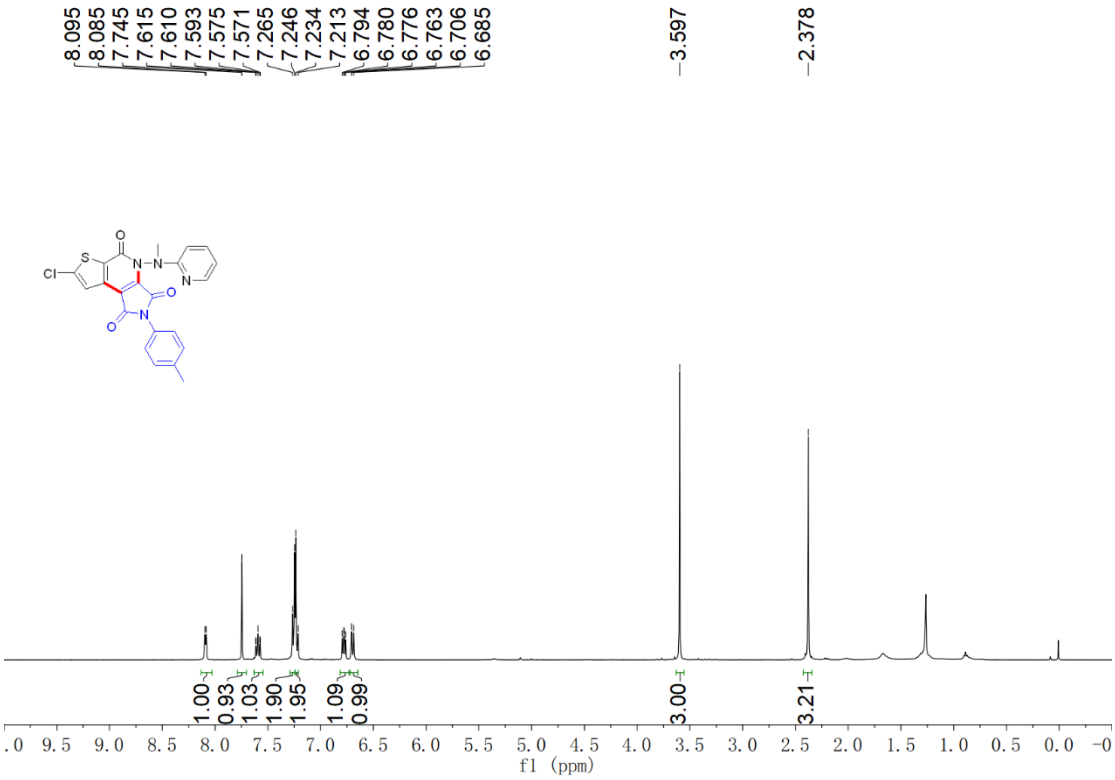
^{1}H, ^{13}C NMR spectra of compound **3ce**

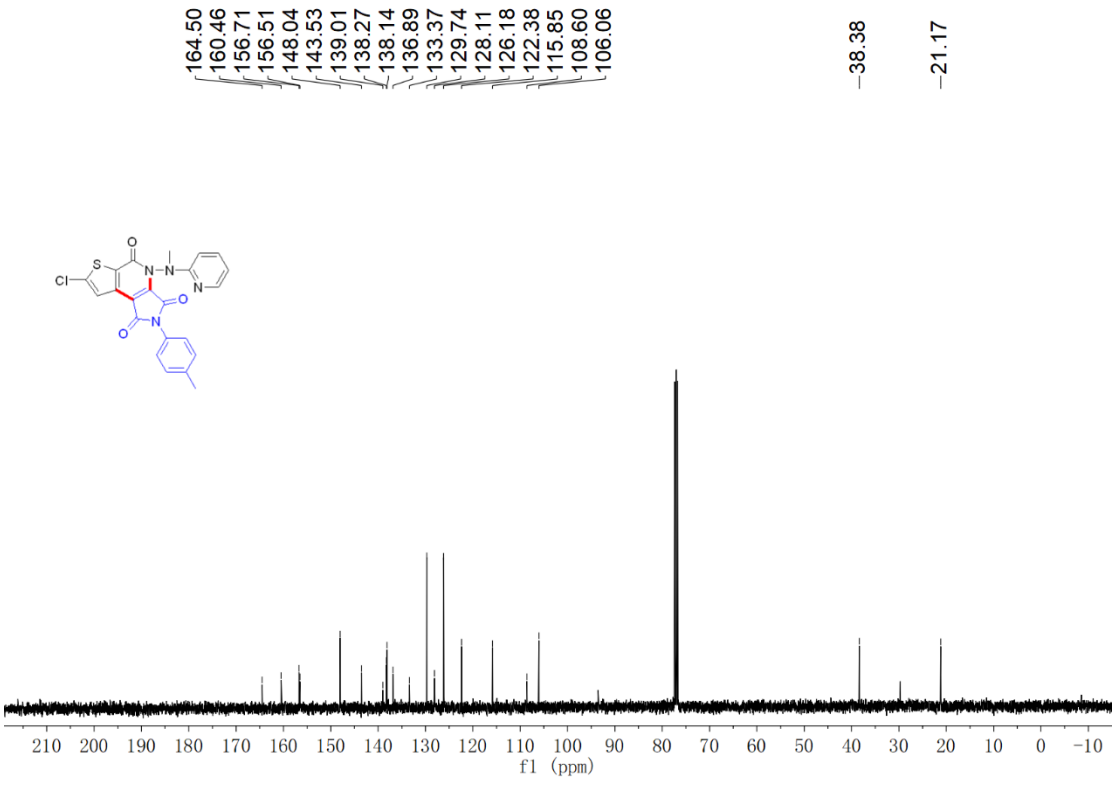


^{1}H, ^{13}C NMR spectra of compound **3cf**

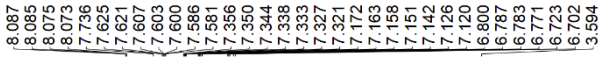


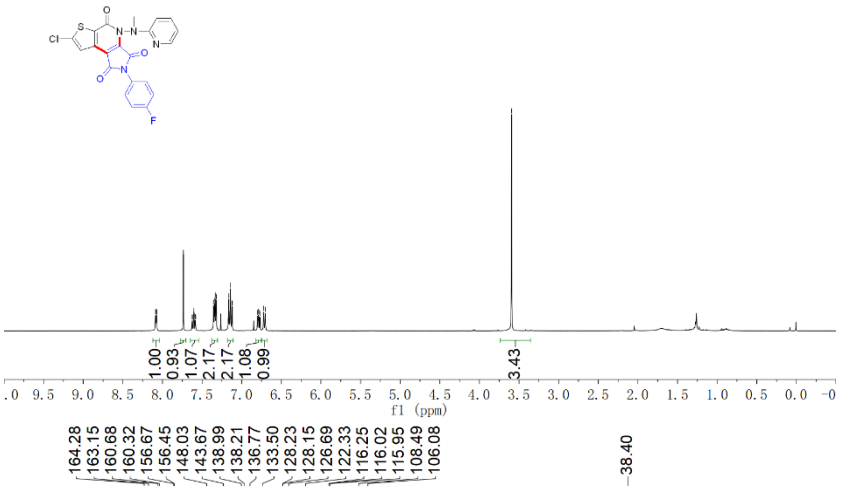
^{1}H, ^{13}C NMR spectra of compound **3cg**

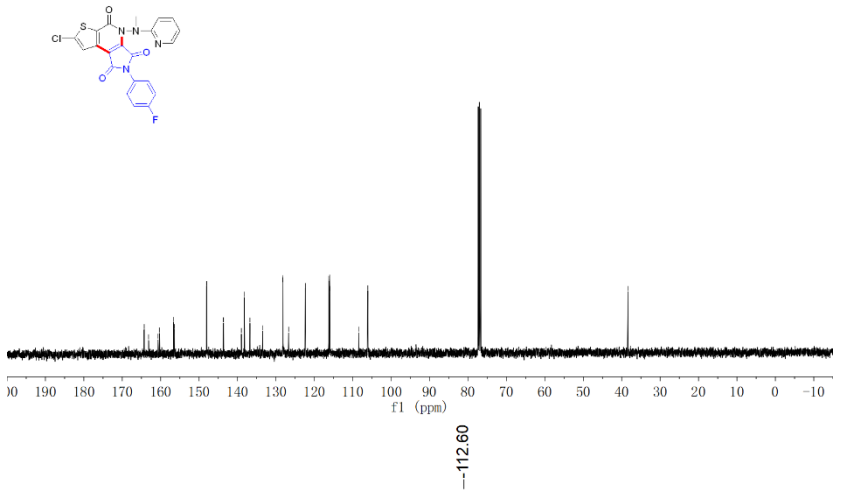


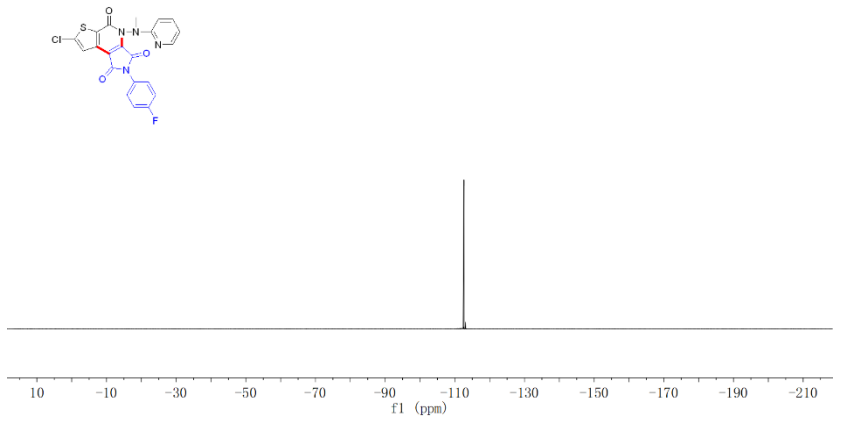


^{1}H, ^{13}C, ^{19}F NMR spectra of compound **3ch**

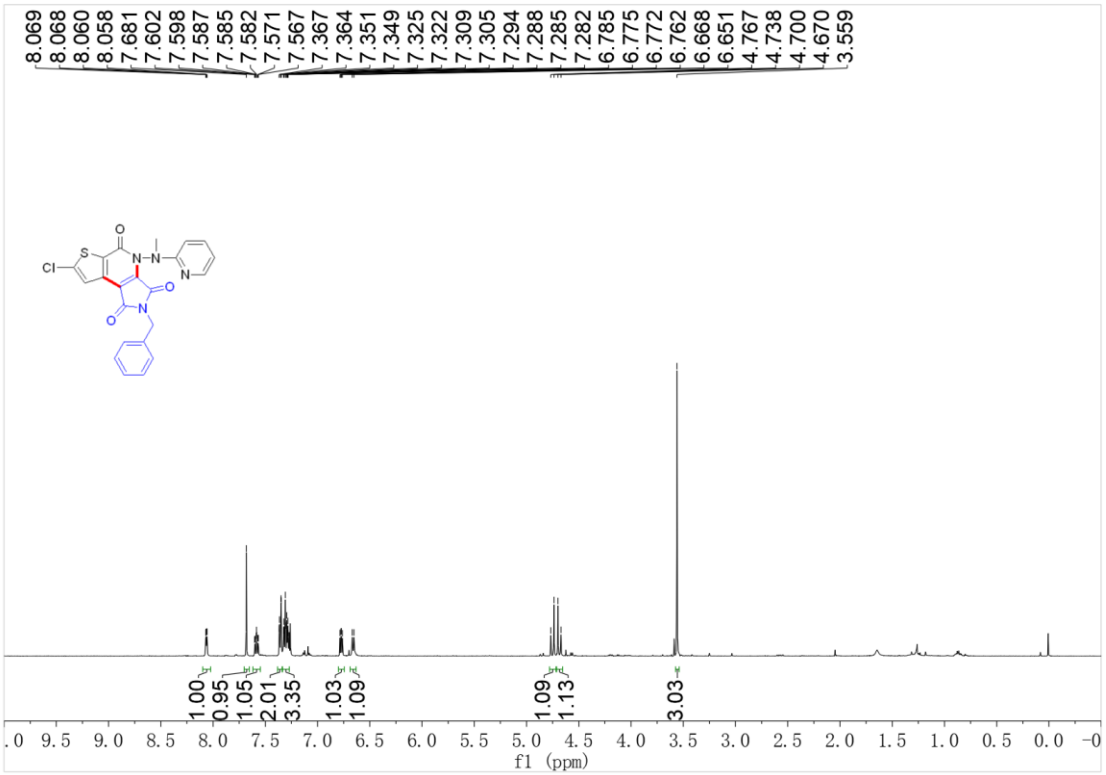


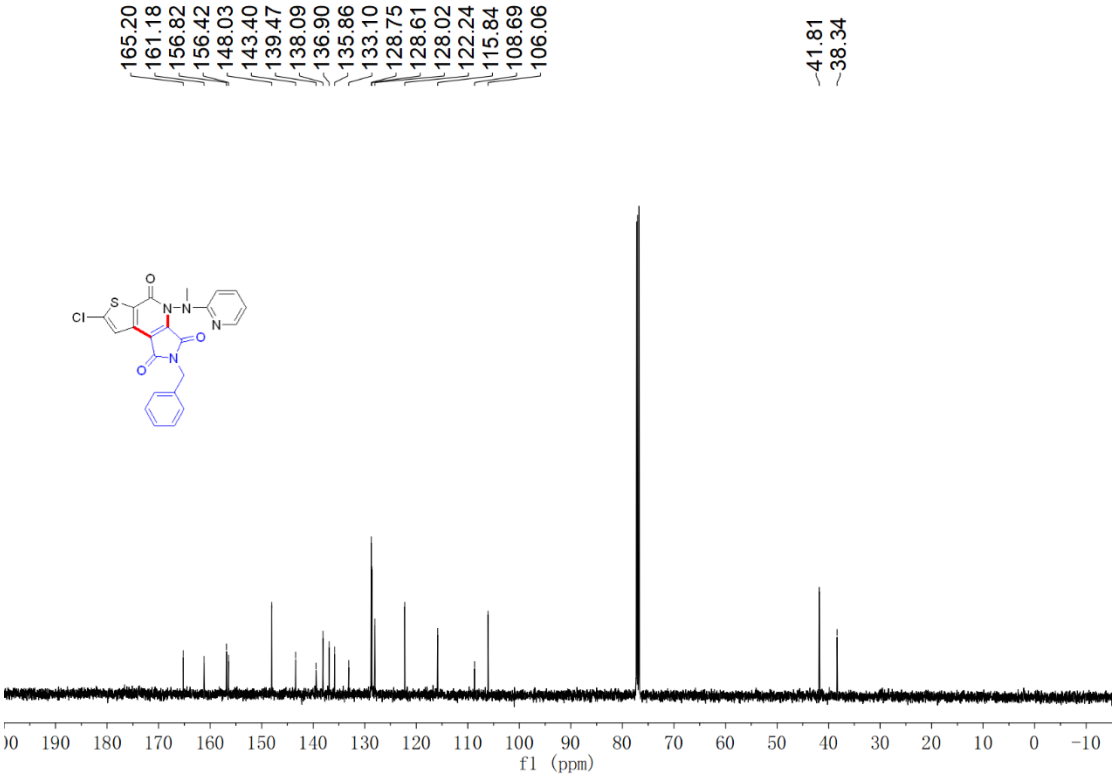




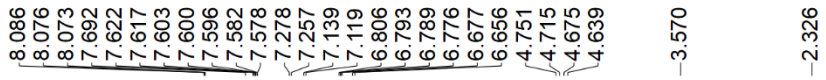


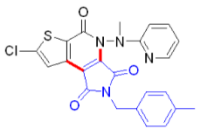
^{1}H, ^{13}C NMR spectra of compound **3ci**

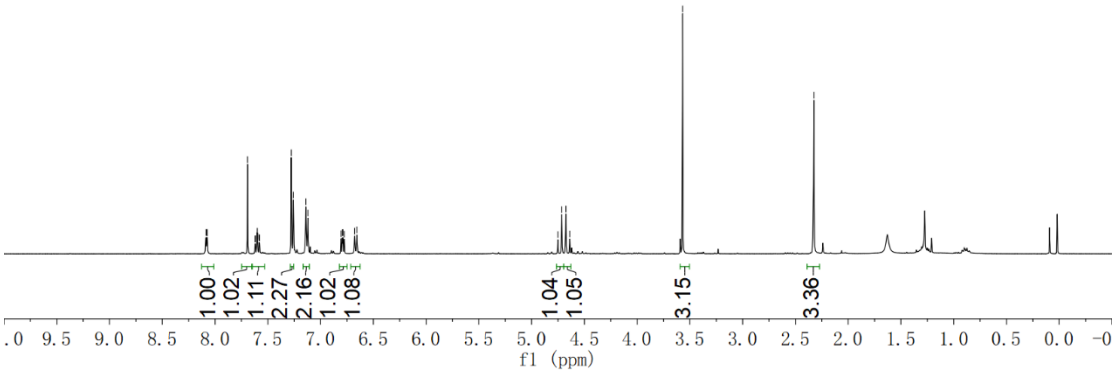


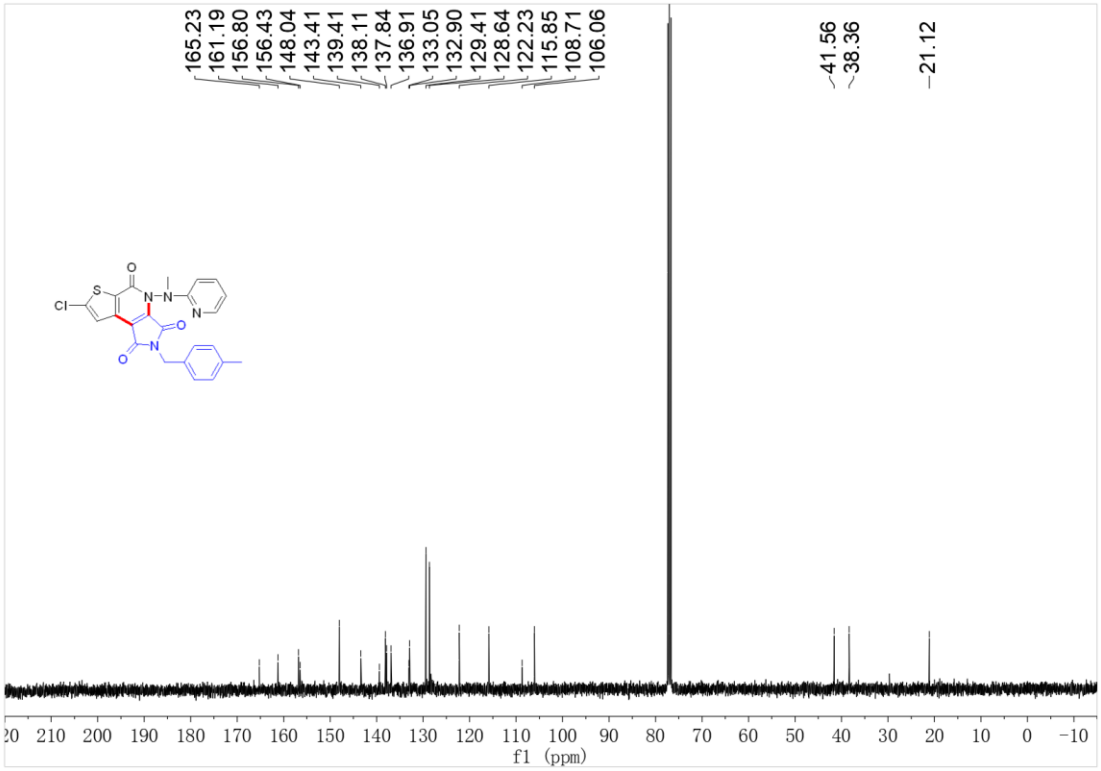


^{1}H, ^{13}C NMR spectra of compound **3cj**

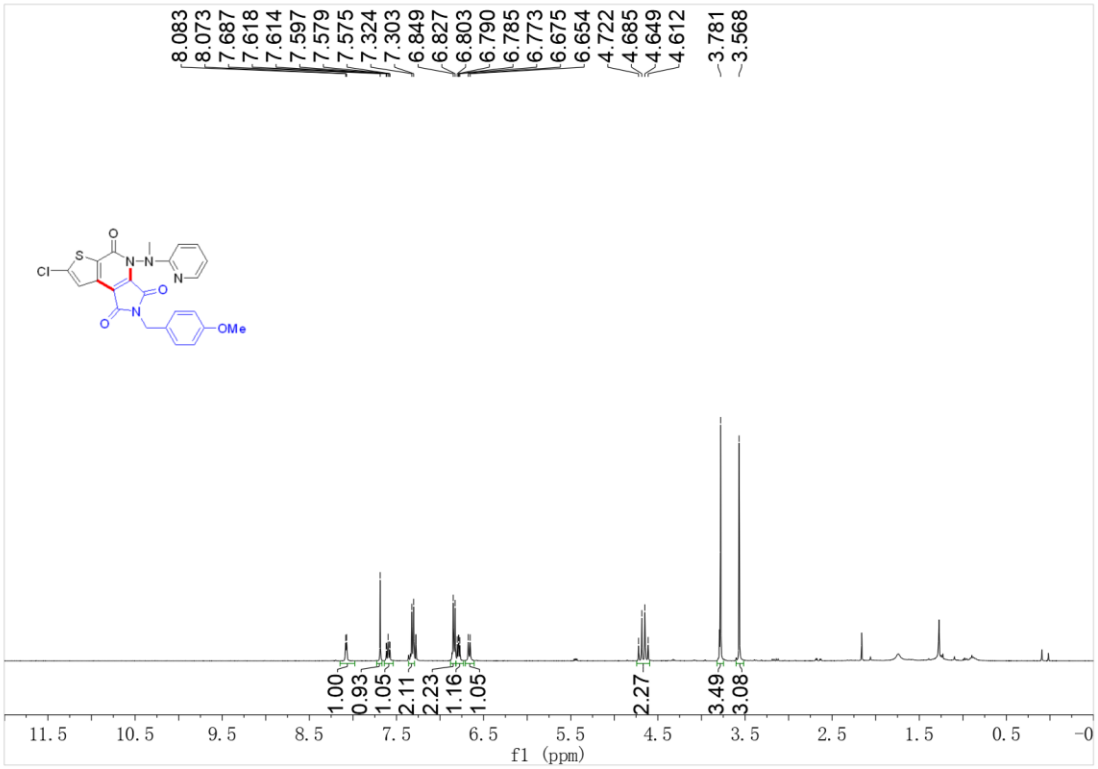


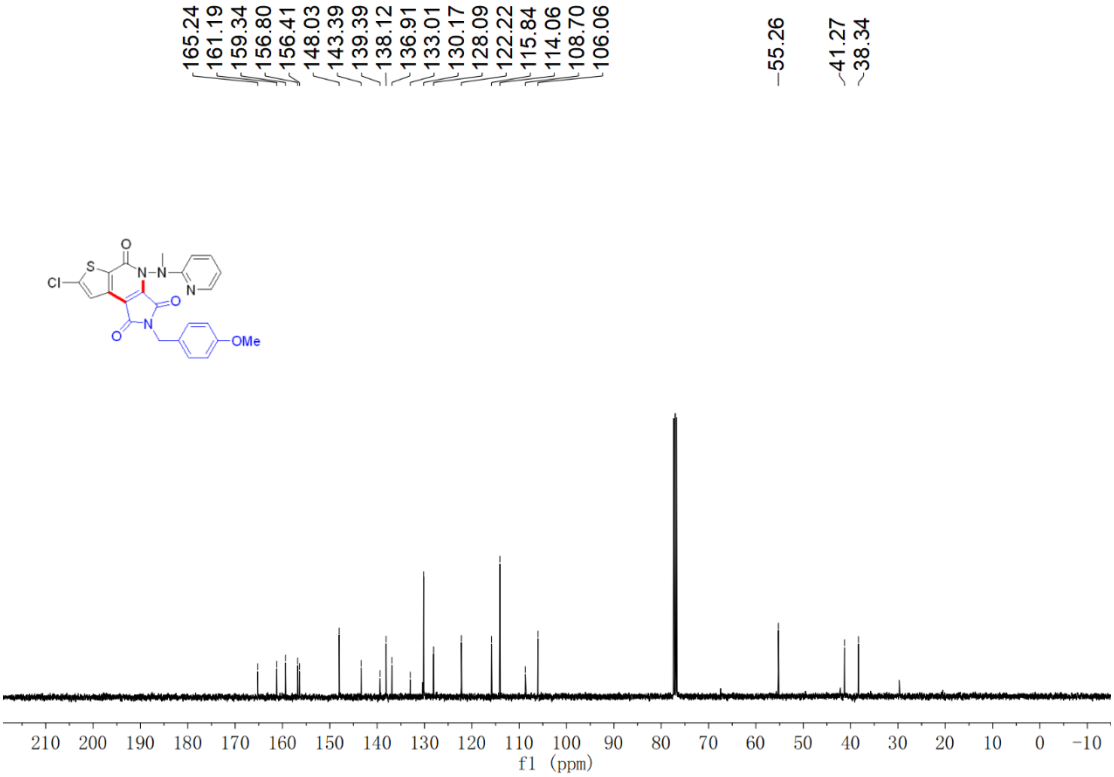




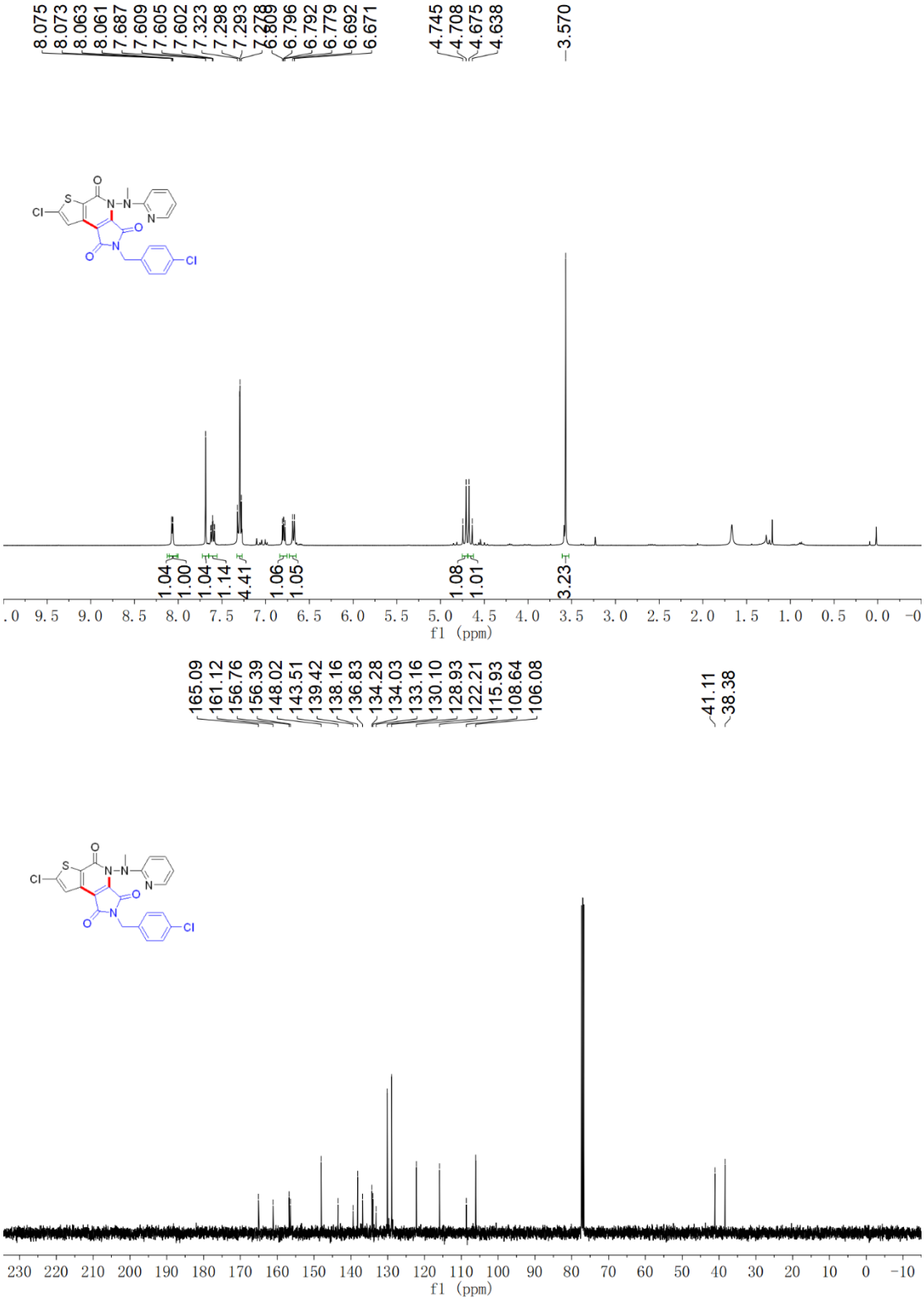


^{1}H, ^{13}C NMR spectra of compound **3ck**

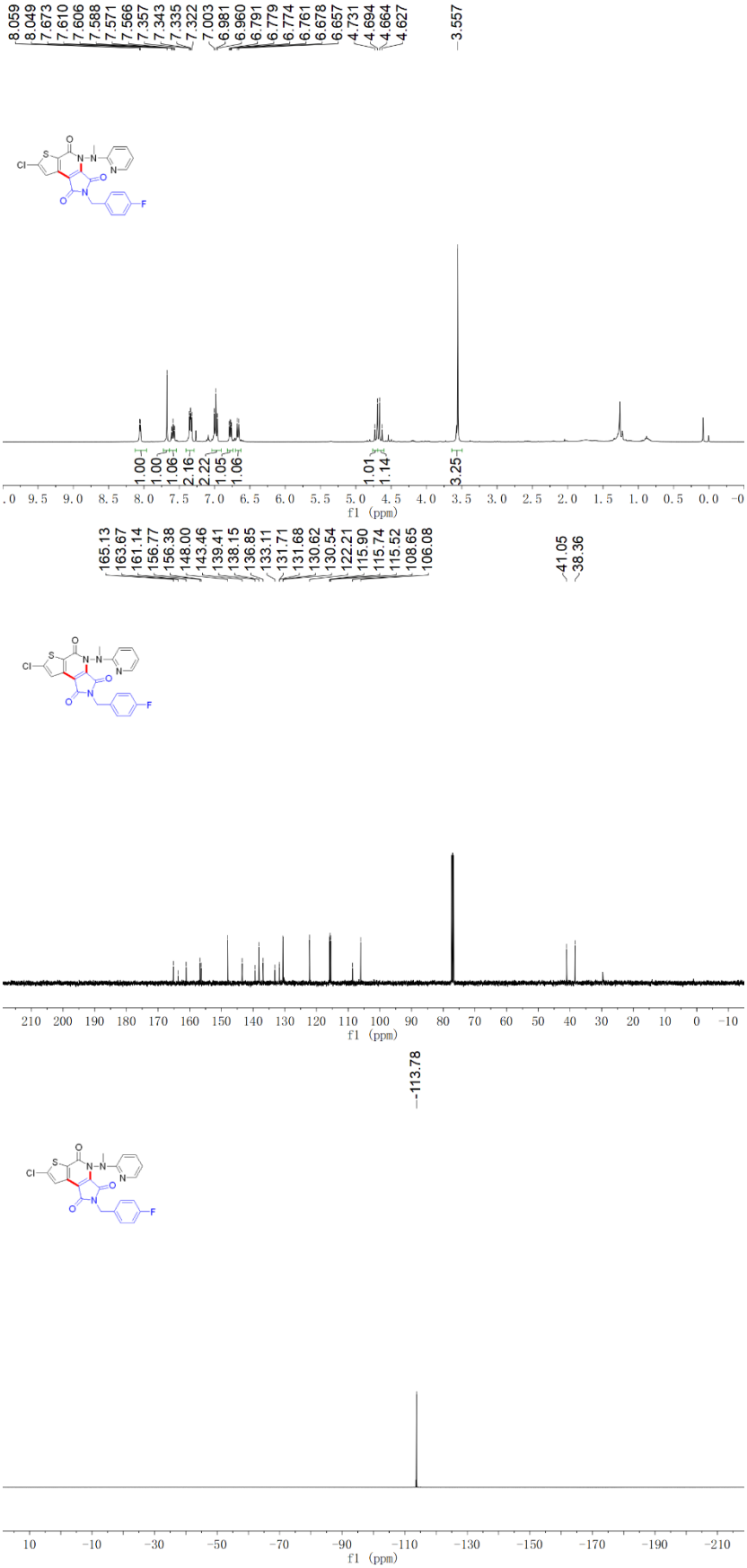




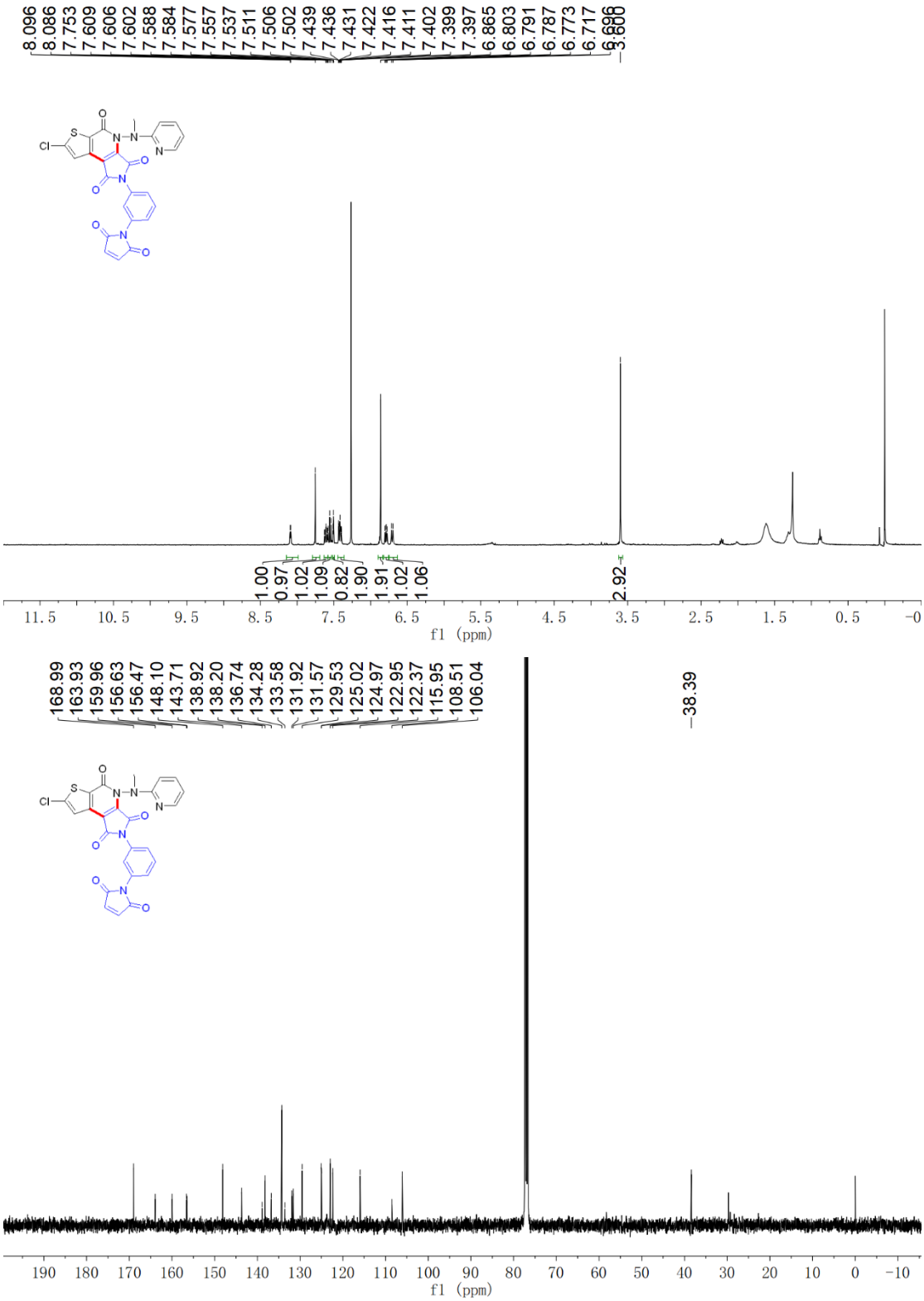
^{1}H, ^{13}C NMR spectra of compound **3cl**



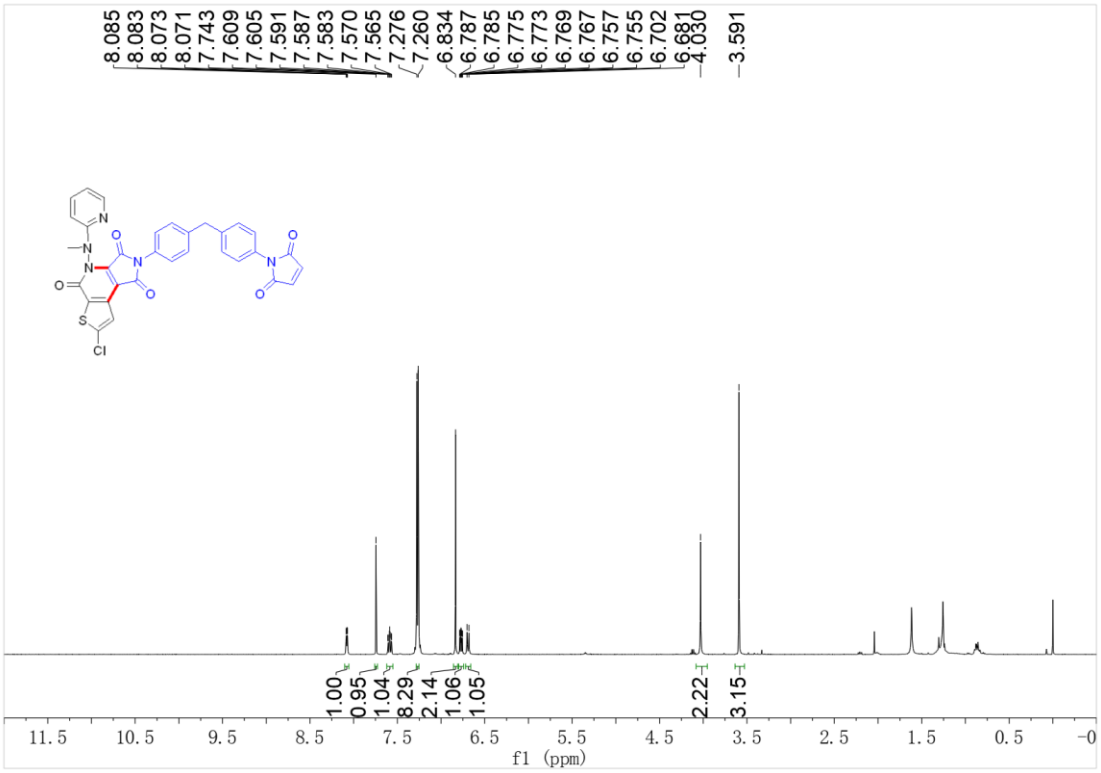
^{1}H, ^{13}C, $^{19}FNMR$ spectra of compound **3cm**

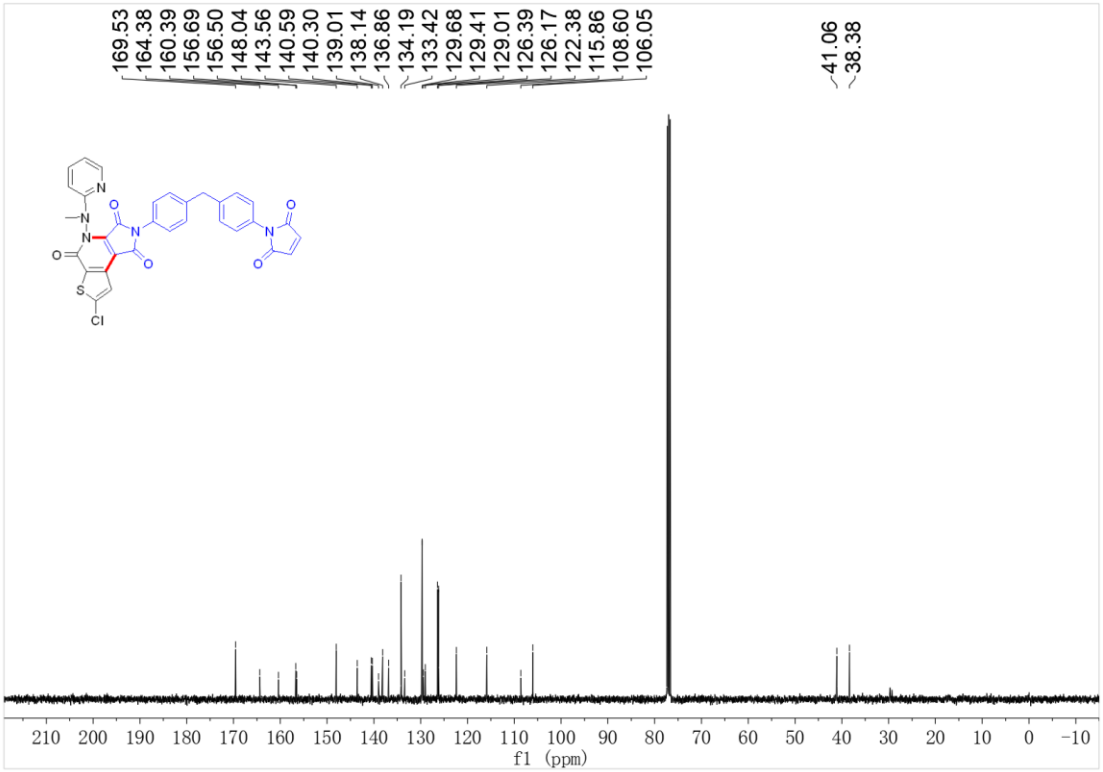


^{1}H, ^{13}C NMR spectra of compound **3cn**

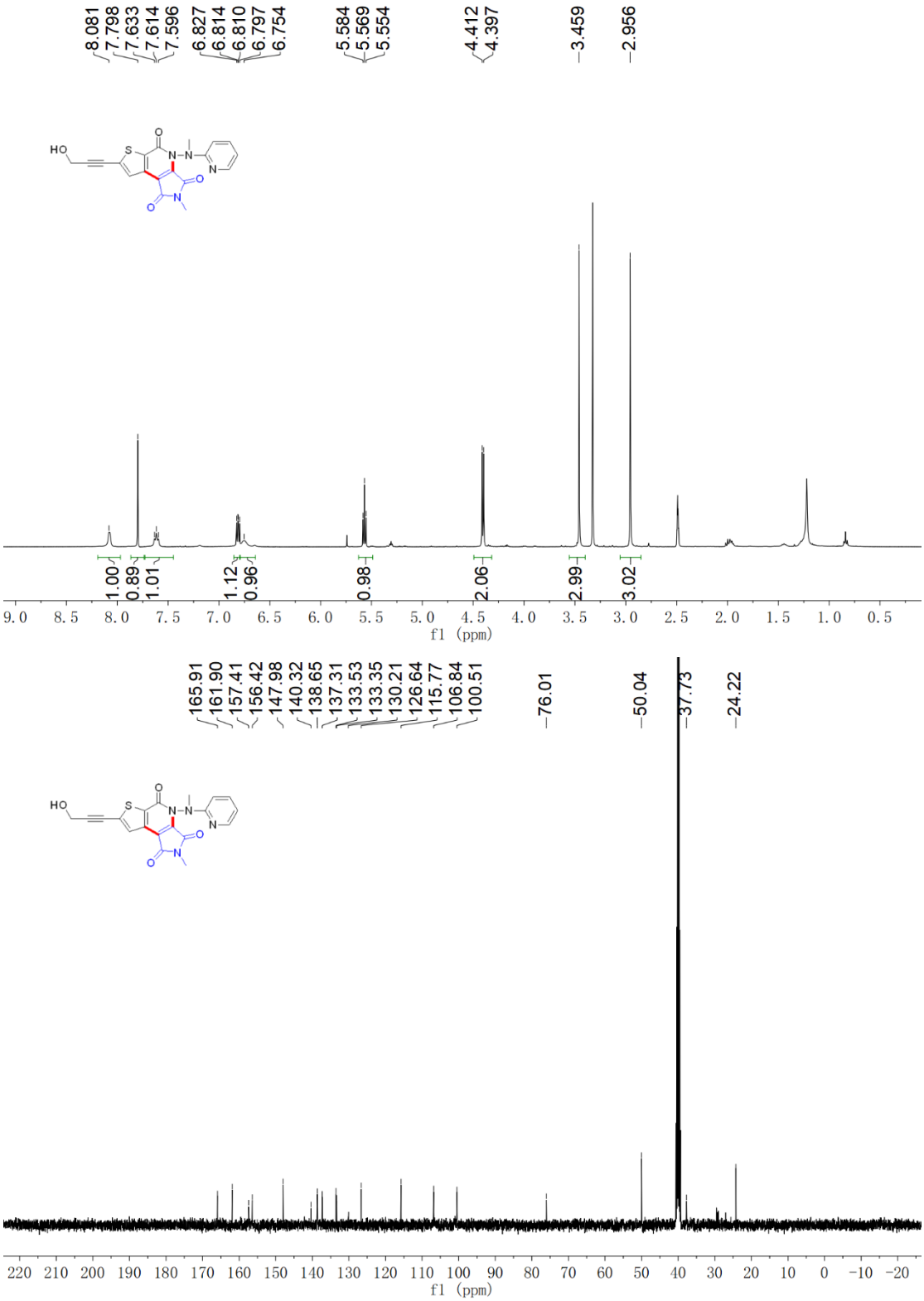


^{1}H, ^{13}C NMR spectra of compound **3co**

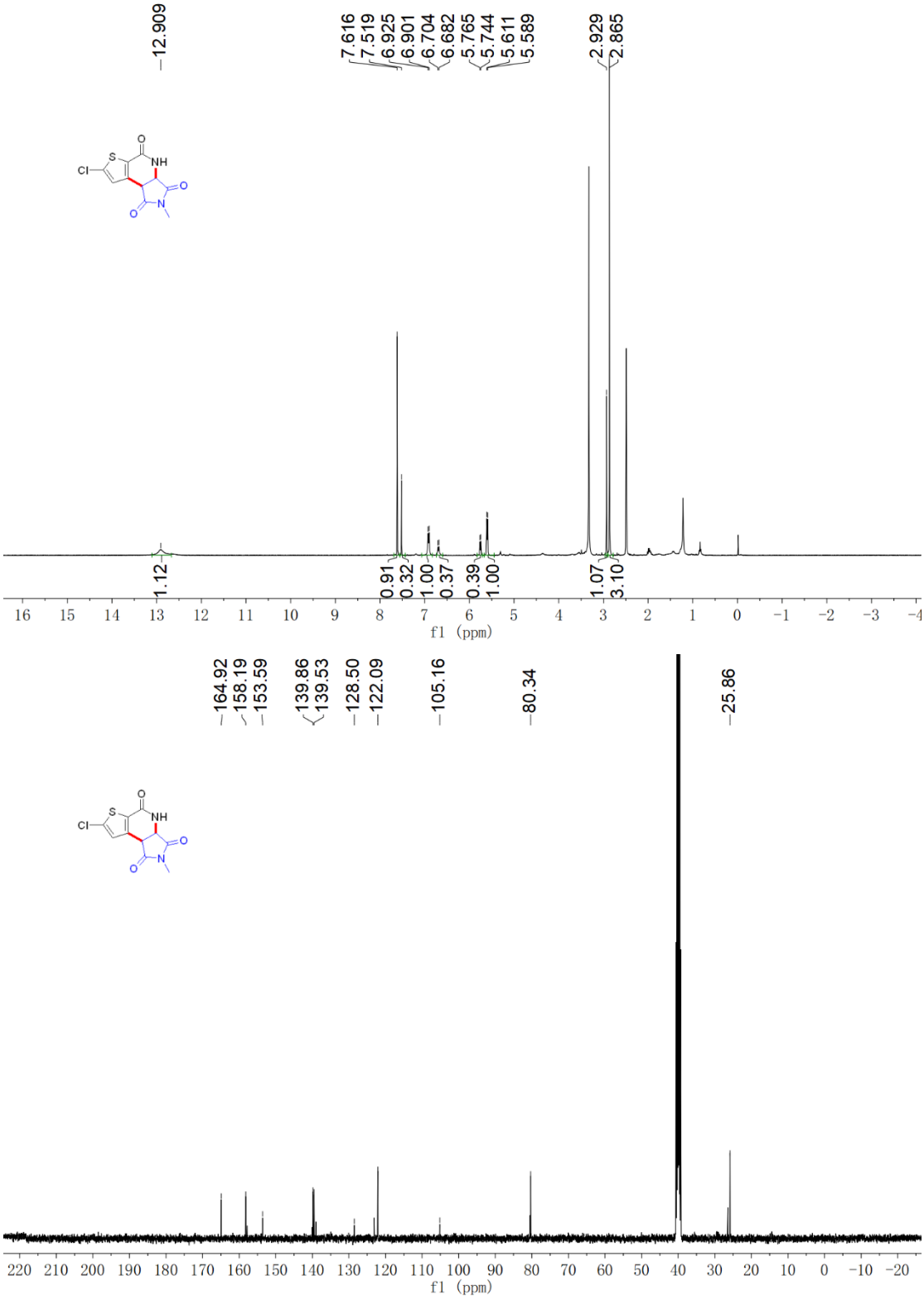




^{1}H, ^{13}C NMR spectra of compound **5**



^{1}H, ^{13}C NMR spectra of compound **6**



^{1}H, ^{13}C NMR spectra of compound **7**