Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry

Electronic Supplementary Information for

Rhodium(III)-Catalyzed Oxidative Mono- and Di-olefination of Isonicotinamides

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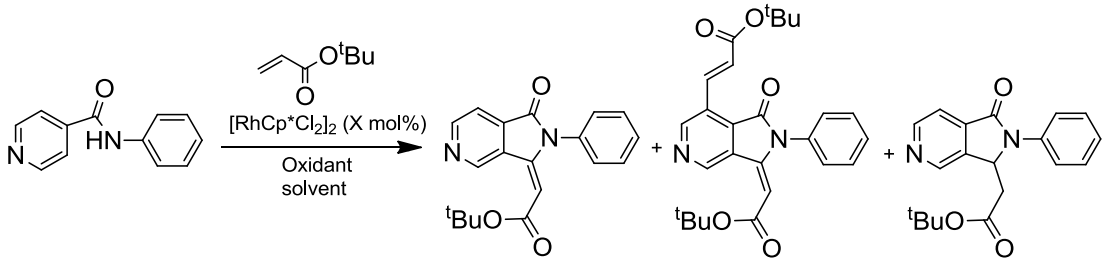
^{1}H and ^{13}C NMR spectra ..... **Error! Bookmark not defined.**

General Considerations

All rhodium-catalyzed reactions were carried out using standard Schlenk techniques or in a nitrogen-filled drybox. All solvents were distilled under N_2 before use. ^1H and ^{13}C NMR spectra were recorded using $CDCl_3$ solvent on a Bruker 400 MHz or 500 MHz spectrometer at 298K. The chemical shift is given indimensionless δ values and is frequency referenced relative to TMS in ^1H and ^{13}C NMR spectroscopy. High-resolution mass spectra were obtained on an Agilent LC-Q-TOF-MS spectrometer. $[Cp^*RhCl_2]_2$ was purchased from the Strem Chemicals. All other reagents were obtained from commercial sources and were used as received.

Experimental Section

General procedure for the preparation of compounds **2aa-2af, 2ba-2na** and **3aa-3ma**

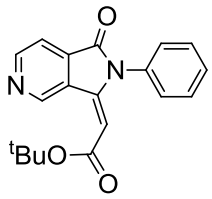


Method A. Compound **1a** (99 mg, 0.50 mmol), *tert*-butyl acrylate (96 mg, 0.75 mmol), anhydrous $Cu(OAc)_2$ (382 mg, 2.1 mmol) and $[RhCp^*Cl_2]_2$ (6.2 mg, 2 mol%) were charged into a sealed tube. After filled with nitrogen, anhydrous CH_3CN (5 mL) was added via a syringe and the mixture was stirred at 110 ^oC for 12 h. The mixture was then allowed to cool to room temperature. The mixture was diluted with water and extracted with ethyl acetate, followed by removal of the solvent under reduced pressure. The residue was purified by column chromatography on silica gel using petroleum ether and ethyl acetate as the eluents. Yield of **2aa**: 111 mg (69%).

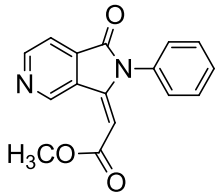
Method B. Compound **1a** (99 mg, 0.50 mmol), *tert*-butyl acrylate (160 mg, 1.25 mmol), anhydrous $Cu(OAc)_2$ (543 mg, 3 mmol) and $[RhCp^*Cl_2]_2$ (6.2 mg, 2 mol%) were charged into a sealed tube. After purged with nitrogen, anhydrous THF (5 mL) was added via a syringe and the mixture was stirred at 110 ^oC for 12 h. The mixture

was then allowed to cool to room temperature. The mixture was diluted with water and extracted with ethyl acetate. The crude product was purified by column chromatography on silica gel using petroleum ether and ethyl acetate as the eluents. Yield of **3aa**: 90 mg (40%).

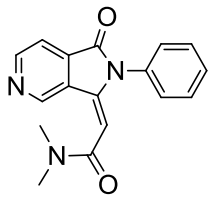
Analytical Data of Products of 2aa-2af, 2ba-2na, 3aa-3ma and 4aa



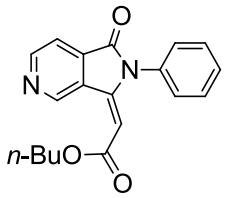
2aa (yellowish solid), yield: 69%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.27 (s, 1H), 8.96 (d, J = 4.6 Hz, 1H), 7.83 (d, J = 4.7 Hz, 1H), 7.58 (t, J = 7.6 Hz, 2H), 7.53 (t, J = 7.4 Hz, 1H), 7.32 (d, J = 7.6 Hz, 2H), 5.57 (s, 1H), 1.52 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.21, 164.81, 151.84, 149.62, 146.52, 136.60, 133.29, 129.84, 129.28, 128.66, 128.56, 116.66, 104.55, 81.45, 28.08. HRMS (ESI): Calcd for $[C_{19}H_{18}N_2O_3 + H]^+$ 323.1396; Found 323.1401.



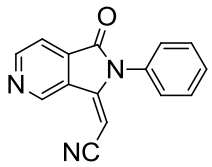
2ab (white solid), yield: 71%. (method A). ^{1}H NMR (500 MHz, $CDCl_3$) δ 10.31 (s, 1H), 8.98 (d, J = 4.0 Hz, 1H), 7.83 (d, J = 4.7 Hz, 1H), 7.57 (t, J = 7.5 Hz, 2H), 7.51 (t, J = 7.3 Hz, 1H), 7.31 (d, J = 7.3 Hz, 2H), 5.63 (s, 1H), 3.79 (s, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.74, 165.18, 152.20, 149.57, 147.79, 136.54, 133.08, 129.86, 129.39, 128.56, 128.31, 116.70, 101.73, 51.75. HRMS (ESI): Calcd for $[C_{16}H_{12}N_2O_3 + H]^+$ 281.0926; Found 281.0923.



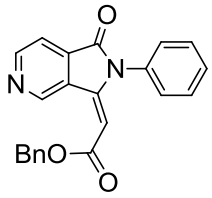
2ac (yellow solid), yield: 78%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 9.62 (s, 1H), 8.92 (s, 1H), 7.83 (d, J = 4.6 Hz, 1H), 7.57 (t, J = 7.5 Hz, 2H), 7.51 (t, J = 7.3 Hz, 1H), 7.36 (d, J = 7.7 Hz, 2H), 5.85 (s, 1H), 3.10 (s, 3H), 2.99 (s, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.54, 164.72, 151.33, 150.46, 147.67, 142.21, 136.41, 133.45, 129.88, 129.24, 128.57, 128.51, 104.48, 38.04, 35.26. HRMS (ESI): Calcd for $[C_{17}H_{15}N_3O_2 + H]^+$ 294.1243; Found 294.1247.



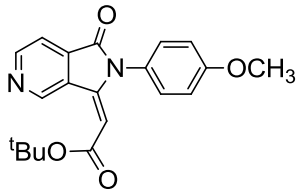
2ad (white solid), yield: 74%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.31 (s, 1H), 8.98 (s, 1H), 7.84 (d, J = 4.5 Hz, 1H), 7.58 (t, J = 7.3 Hz, 2H), 7.52 (t, J = 7.3 Hz, 1H), 7.32 (d, J = 7.6 Hz, 2H), 5.63 (s, 1H), 4.21 (t, J = 6.7 Hz, 2H), 1.73-1.58 (m, 2H), 1.26-1.38 (m, 7.2 Hz, 2H), 0.93 (t, J = 7.3 Hz, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.54, 165.28, 152.16, 149.68, 147.57, 136.58, 133.14, 129.92, 129.41, 128.98, 128.63, 116.74, 102.35, 64.77, 30.58, 19.03, 13.61.HRMS (ESI): Calcd for $[C_{19}H_{18}N_2O_3 + H]^+$ 323.1396; Found 323.2394.



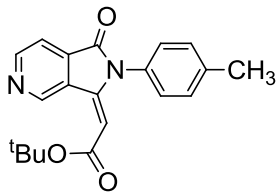
2ae (white solid), yield: 56%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 9.88 (s, 1H), 9.07 (d, J = 4.5 Hz, 1H), 7.90 (d, J = 4.8 Hz, 1H), 7.61 (t, J = 7.3 Hz, 2H), 7.55 (t, J = 7.3 Hz, 1H), 7.33 (d, J = 7.5 Hz, 2H), 5.08 (s, 1H).^{13}C NMR (126 MHz, $CDCl_3$) δ 164.31, 153.19, 151.17, 145.64, 135.72, 132.07, 130.20, 129.91, 129.03, 128.01, 117.53, 116.45, 76.14.HRMS (ESI): Calcd for $[C_{15}H_9N_3O + H]^+$ 248.0824; Found 248.0821.



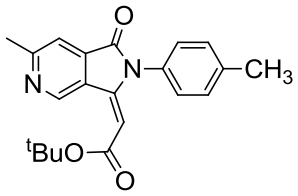
2af (yellow solid), yield: 73%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.34 (s, 1H), 8.98 (d, J = 4.8 Hz, 1H), 7.83 (d, J = 4.8 Hz, 1H), 7.55 (t, J = 7.3 Hz, 2H), 7.49 (t, J = 7.3 Hz, 1H), 7.40-7.25 (m, 7H), 5.66 (s, 1H), 5.23 (s, 2H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.29, 165.25, 152.31, 149.77, 148.16, 136.59, 135.45, 133.06, 129.95, 129.48, 128.61, 128.60, 128.56, 128.46, 128.23, 116.76, 101.85, 66.72. HRMS (ESI): Calcd for $[C_{22}H_{16}N_2O_3 + H]^+$ 357.1239; Found 357.1241.



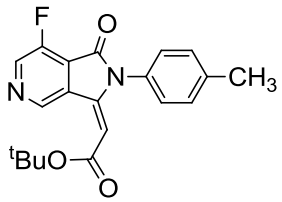
2ba (red-brown solid), yield: 35%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.24 (s, 1H), 8.92 (d, J = 3.8 Hz, 1H), 7.79 (d, J = 4.7 Hz, 1H), 7.20 (d, J = 8.8 Hz, 2H), 7.05 (d, J = 8.8 Hz, 2H), 5.53 (s, 1H), 3.85 (s, 3H), 1.50 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.46, 164.88, 160.05, 151.83, 149.58, 146.89, 136.63, 129.76, 128.52, 125.58, 116.59, 115.12, 104.47, 81.36, 55.46, 28.08.HRMS (ESI): Calcd for $[C_{20}H_{20}N_2O_4 + H]^+$ 353.1501; Found 353.1502.



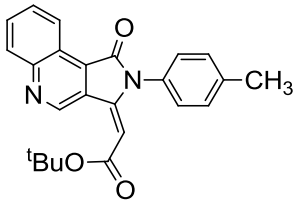
2ca (white solid), yield: 53%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.24 (s, 1H), 8.91 (s, 1H), 7.77 (d, J = 4.0 Hz, 1H), 7.33 (d, J = 7.9 Hz, 2H), 7.16 (d, J = 8.0 Hz, 2H), 5.53 (s, 1H), 2.40 (s, 3H), 1.48 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.21, 164.76, 151.74, 149.49, 146.60, 139.29, 136.51, 130.39, 129.65, 128.26, 126.53, 116.51, 104.34, 81.21, 27.97, 21.11.HRMS (ESI): Calcd for $[C_{20}H_{20}N_2O_3 + H]^+$ 337.1552; Found 337.1551.



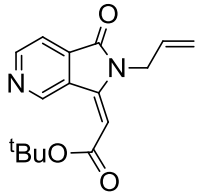
2da (white solid), yield: 58%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.12 (s, 1H), 7.65 (s, 1H), 7.36 (d, J = 8.1 Hz, 2H), 7.19 (d, J = 8.2 Hz, 2H), 5.52 (s, 1H), 2.75 (s, 3H), 2.45 (s, 3H), 1.52 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.44, 164.93, 161.55, 148.83, 146.83, 139.19, 137.22, 130.61, 130.36, 128.31, 125.91, 115.92, 103.42, 81.05, 28.02, 24.82, 21.12.HRMS (ESI): Calcd for $[C_{21}H_{22}N_2O_3 + H]^+$ 351.1709; Found 351.1706.



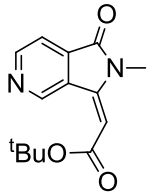
2ea (yellow solid), yield: 41%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.10 (s, 1H), 8.74 (s, 1H), 7.37 (d, J = 8.0 Hz, 2H), 7.17 (d, J = 8.0 Hz, 2H), 5.59 (s, 1H), 2.45 (s, 3H), 1.51 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 164.70, 161.97, 153.47 (d, $J_{F\text{-}C}$ = 272.3 Hz), 145.68, 145.63, 145.52, 140.78 (d, J = 20.9 Hz), 139.65, 130.60, 130.17 (d, J = 5.3 Hz), 128.41, 122.75 (d, J = 10.7 Hz, 1H), 105.51, 81.65, 28.09, 21.25. HRMS (ESI): Calcd for $[C_{20}H_{19}FN_2O_3 + H]^+$ 355.1458; Found 355.1256.



2fa (yellow solid), yield: 66%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.38 (s, 1H), 8.97 (d, J = 8.2 Hz, 1H), 8.22 (d, J = 8.5 Hz, 1H), 7.82 (t, J = 7.6 Hz, 1H), 7.67 (t, J = 7.6 Hz, 1H), 7.37 (d, J = 8.0 Hz, 2H), 7.26 (d, J = 8.2 Hz, 2H), 5.67 (s, 1H), 2.45 (s, 3H), 1.55 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 166.13, 164.82, 149.09, 148.21, 146.07, 139.13, 131.37, 131.05, 130.56, 130.33, 129.32, 128.72, 128.56, 127.13, 124.37, 121.90, 105.16, 81.42, 28.04, 21.14.HRMS (ESI): Calcd for $[C_{24}H_{22}N_2O_3 + H]^+$ 387.1709; Found 387.1710.

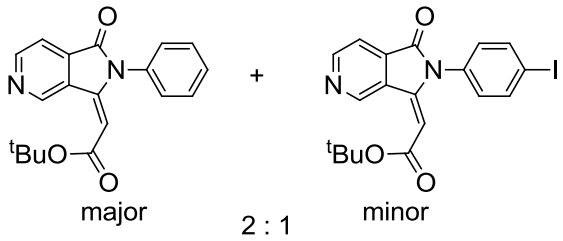


2ga (yellow solid), yield: 29%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.20 (s, 1H), 8.89 (d, J = 4.8 Hz, 1H), 7.76 (d, J = 4.7 Hz, 1H), 5.89-5.79 (m, 1H), 5.77 (s, 1H), 5.27 (d, J = 10.4 Hz, 1H), 5.20 (d, J = 17.2 Hz, 1H), 4.46 (d, J = 5.1 Hz, 2H), 1.57 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.30, 164.75, 151.63, 149.53, 144.47, 136.77, 130.84, 128.70, 117.76, 116.43, 103.49, 81.43, 42.07, 28.16.HRMS (ESI): Calcd for $[C_{16}H_{18}N_2O_3 + H]^+$ 287.1396; Found 287.1398.

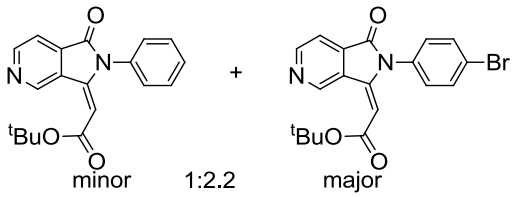


2ha Yellow Solid, yield: 52%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.18 (s, 1H), 8.88 (d, J = 4.5 Hz, 1H), 7.72 (d, J = 5.8 Hz, 1H), 5.77 (s, 1H), 3.30 (s, 3H), 1.58 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.42, 164.65, 151.66, 149.30, 145.83, 137.05, 128.48, 116.28, 102.67, 81.32, 28.14, 26.43.HRMS (ESI): Calcd for

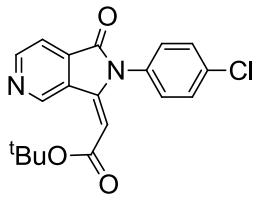
$[C_{14}H_{16}N_2O_3 + H]^+$ 261.1239; Found 261.1236.



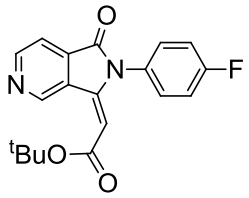
2ia (mixture of two coupled products) yield: 62%. (method A).Selected ^{1}H NMR (500 MHz, $CDCl_3$) of the major product δ: 10.38 (s, 1H), 9.07 (d, J = 4.6 Hz, 1H), 7.90 (d, J = 8.5 Hz, 1H), 7.57 (t, J = 7.8 Hz, 2H), 7.51 (t, J = 7.4 Hz, 1H), 7.32 (d, J = 1.4 Hz, 2H), 5.57 (s, 1H), 1.52 (s, 9H).Selected ^{1}H NMR (500 MHz, $CDCl_3$) of the minor product δ: 10.38 (s, 1H), 9.07 (d, J = 4.6 Hz, 1H), 7.85 (t, J = 7.9 Hz, 2H), 7.07 (d, J = 8.6 Hz, 1H), 5.57 (s, 1H), 1.52 (s, 9H).Selected ^{13}C NMR (101 MHz, $CDCl_3$) of the major product δ: 165.06, 164.83, 152.11, 149.91, 146.29, 136.59, 133.17, 129.85, 129.31, 128.76, 128.61, 117.01, 104.76, 81.48, 28.08.Selected ^{13}C NMR (101 MHz, $CDCl_3$) of the minor product δ: 164.69, 164.50, 139.11, 136.36, 132.87, 130.42, 129.15, 126.71,119.63, 95.13, 81.64, 27.67.



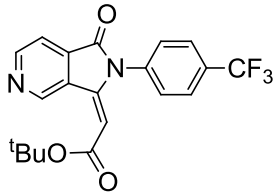
2ja (mixture of two coupled products) yield: 66%. (method A).Selected ^{1}H NMR (400 MHz, $CDCl_3$) of the major product δ: 10.28 (s, 1H), 8.95 (d, J = 4.1 Hz, 1H), 7.80 (d, J = 5.0 Hz, 1H), 7.58 (t, J = 7.4 Hz, 2H), 7.51 (t, J = 7.4 Hz, 1H), 7.33 (d, J = 7.3 Hz, 2H), 5.57 (s, 1H), 1.53 (s, 9H).Selected ^{1}H NMR (400 MHz, $CDCl_3$) of the minor product δ: 10.28 (s, 1H), 8.95 (d, J = 4.1 Hz, 1H), 7.80 (d, J = 5.0 Hz, 1H), 7.70 (d, J = 8.6 Hz, 2H), 7.22 (d, J = 8.6 Hz, 2H), 5.56 (s, 1H), 1.52 (s, 9H).Selected ^{13}C NMR (101 MHz, $CDCl_3$) of the major product δ: 165.08, 164.67, 151.75, 149.50, 146.42, 136.42, 133.13, 129.73, 129.17, 128.54, 128.31, 116.53, 104.41, 81.28, 27.96.Selected ^{13}C NMR (101 MHz, $CDCl_3$) of the minor product δ: 164.89, 164.47, 151.87, 149.58, 146.03, 136.18, 133.01, 132.12, 130.21, 123.29, 104.48, 81.45, 27.60.



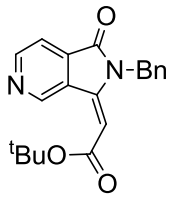
2ka (orange solid), yield: 80%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.29 (s, 1H), 8.99 (s, 1H), 7.84 (d, J = 4.6 Hz, 1H), 7.57 (d, J = 8.6 Hz, 2H), 7.28 (d, J = 8.6 Hz, 2H), 5.55 (s, 1H), 1.53 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.21, 164.69, 152.05, 149.79, 146.28, 136.42, 135.44, 131.76, 130.25, 130.07, 116.79, 116.75, 104.71, 81.71, 28.13. HRMS (ESI): Calcd for $[C_{19}H_{17}ClN_2O_3 + H]^+$ 357.1006; Found 357.1008.



2la Yellow Solid, yield: 42%. (method A). ^{1}H NMR (500 MHz, $CDCl_3$) δ 10.23 (s, 1H), 8.92 (dd, J = 4.7, 2.9 Hz, 1H), 7.79-7.74 (m, 1H), 7.30-7.18 (m, 4H), 5.49 (s, 1H), 1.49 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.25, 164.66, 162.70 (d, $J_{F\text{-}C}$ = 249.9 Hz), 151.96, 149.69, 146.49, 136.37, 130.57 (d, $J_{F\text{-}C}$ = 8.9 Hz), 129.10 (d, $J_{F\text{-}C}$ = 3.1 Hz), 128.42, 116.97 (d, $J_{F\text{-}C}$ = 23.0 Hz), 116.60, 104.52, 81.54, 28.06. HRMS (ESI): Calcd for $[C_{19}H_{17}FN_2O_3 + H]^+$ 341.1301; Found 341.1303.

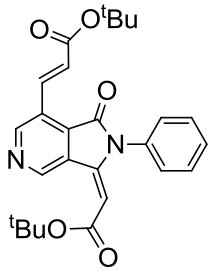


2ma (yellow solid), yield: 72%. (method A).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.30 (s, 1H), 8.97 (s, 1H), 7.82-7.87 (m, 3H), 7.50 (d, J = 8.1 Hz, 2H), 5.58 (s, 1H), 1.54 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 164.94, 164.48, 152.00, 149.74, 145.83, 136.56, 136.16, 131.27(q, $J_{F\text{-}C}$ = 33.0 Hz), 129.19, 128.43, 126.99, 123.51(q, $J_{F\text{-}C}$ = 272.5 Hz), 116.68, 104.67, 81.72, 28.01.HRMS (ESI): Calcd for $[C_{20}H_{17}F_3N_2O_3 + H]^+$ 391.1270; Found 391.1277.

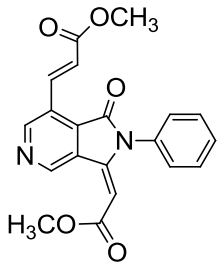


2na Yellow Solid, yield: 45%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.19 (s, 1H), 8.92 (d, J = 4.5 Hz, 1H), 7.81 (d, J = 5.6 Hz, 1H), 7.35 (t, J = 7.3 Hz, 2H), 7.29 (t, J = 7.3 Hz, 1H), 7.24 (d, J = 6.9 Hz, 2H), 5.75 (s, 1H), 5.04 (s, 2H), 1.53 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.84, 164.66, 151.69, 149.61, 144.47, 136.75,

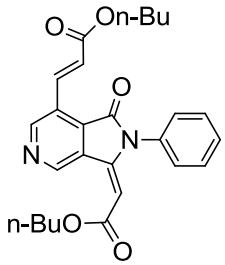
135.23, 128.92, 128.81, 128.44, 127.80, 126.84, 116.57, 103.86, 81.52, 43.52, 28.14.HRMS (ESI): Calcd for $[C_{20}H_{20}N_2O_3 + H]^+$ 337.1552; Found 337.1556.



3aa Yellow Solid, yield: 40%. (method B).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.24 (s, 1H), 9.13 (s, 1H), 8.57 (d, J = 16.4 Hz, 1H), 7.61-7.56 (m, 2H), 7.52 (t, J = 6.2 Hz, 1H), 7.31 (d, J = 7.1 Hz, 2H), 6.70 (d, J = 16.3 Hz, 1H), 5.56 (s, 1H), 1.53 (s, 9H), 1.52 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.17, 164.95, 164.81, 149.62, 145.69, 134.40, 133.19, 132.41, 129.92, 129.43, 128.72, 128.62, 127.24, 126.12, 126.11, 104.76, 81.60, 81.10, 28.10, 28.06. HRMS (ESI): Calcd for $[C_{26}H_{28}N_2O_5 + H]^+$ 449.2076; Found 449.2075.

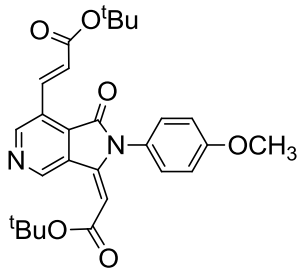


3ab Yellow Solid, yield: 70%. (method B).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.31 (s, 1H), 9.16 (s, 1H), 8.69 (d, J = 16.4 Hz, 1H), 7.53-7.58 (m, 1H), 7.30 (d, J = 7.2 Hz, 2H), 6.78 (d, J = 16.4 Hz, 1H), 5.66 (s, 1H), 3.82 (s, 3H), 3.79 (s, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ 166.10, 165.76, 165.11, 149.94, 149.87, 146.89, 135.57, 132.90, 132.51, 129.95, 129.58, 128.59, 128.44, 126.90, 123.67, 102.17, 51.98, 51.92. HRMS (ESI): Calcd for $[C_{20}H_{16}N_2O_5 + H]^+$ 365.1137; Found 365.1133.

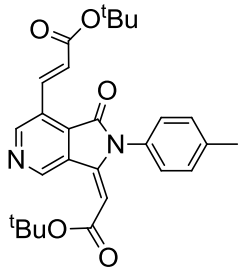


3ad White Solid, yield: 67%. (method B).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.36 (s, 1H), 9.23 (s, 1H), 8.72 (d, J = 16.4 Hz, 1H), 7.70-7.53 (m, 3H), 7.37 (d, J = 7.8 Hz, 2H), 6.84 (d, J = 16.4 Hz, 1H), 5.70 (s, 1H), 4.33-4.19 (m, 4H), 1.81-1.63 (m, 4H),

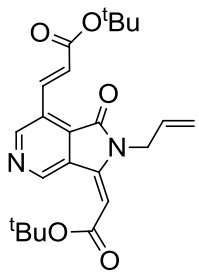
1.55-1.35 (m, 4H), 1.04-0.94 (m, 6H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.75, 165.48, 165.09, 149.79, 149.75, 146.61, 135.23, 132.96, 132.52, 129.96, 129.55, 128.63, 128.55, 127.07, 124.23, 102.67, 64.87, 64.80, 30.60, 30.58, 19.07, 19.04, 13.65, 13.61. HRMS (ESI): Calcd for $[C_{26}H_{28}N_2O_5 + H]^+$ 449.2076; Found 449.2078.



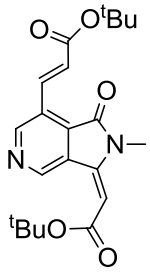
3ba (red-brown solid), yield: 11%. Reaction condition: **3b (**0.5 mmol**)**, *tert*-Butyl acrylate (2.5 equiv), $Cu(OAc)_2$ (6 equiv), $[RhCp^*Cl_2]_2$ (2 mol%), $AgSbF_6$(8 mol%), THP(5 mL), 110 ^oC, 12 h, sealed tube under N_2. ^{1}H NMR (500 MHz, $CDCl_3$) δ 10.22 (s, 1H), 9.11 (s, 1H), 8.56 (d, J = 16.4 Hz, 1H), 7.26 (s, 1H), 7.21 (d, J = 8.9 Hz, 2H), 7.07 (d, J = 8.9 Hz, 2H), 6.69 (d, J = 16.3 Hz, 1H), 5.55 (s, 1H), 3.91-3.82 (m, 3H), 1.53 (s, 9H), 1.52 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.48, 165.05, 164.94, 160.22, 149.67, 146.10, 134.53, 132.50, 129.86, 128.84, 128.63, 127.20, 126.07, 125.52, 115.26, 104.73, 81.58, 81.15, 55.58, 28.16, 28.10. HRMS (ESI): Calcd for $[C_{27}H_{30}N_2O_6 + H]^+$ 492.2260; Found 492.2264.



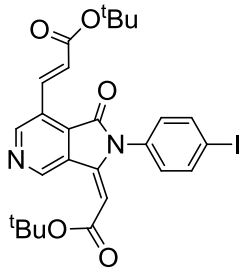
3ca (yellow solid), yield: 50%. (method B).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.24 (s, 1H), 9.12 (s, 1H), 8.58 (d, J = 18.7 Hz, 1H), 7.37 (d, J = 7.9 Hz, 2H), 7.19 (d, J = 8.0 Hz, 2H), 6.70 (d, J = 18.9 Hz, 1H), 5.57 (d, J = 2.2 Hz, 1H), 2.45 (s, 3H), 1.54-1.51 (m, 18H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.11, 164.80, 164.72, 149.53, 149.47, 145.74, 139.41, 134.35, 132.29, 130.44, 130.32, 128.46, 128.28, 126.97, 125.83, 104.50, 81.31, 80.86, 27.98, 27.93, 21.11.HRMS (ESI): Calcd for $[C_{27}H_{30}N_2O_5 + H]^+$ 463.2233; Found 463.2235.



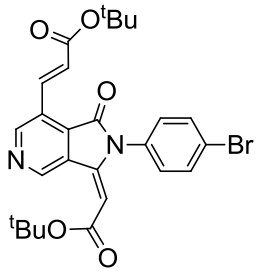
3ga (yellow solid), yield: 19%. (method B).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.17 (s, 1H), 9.06 (s, 1H), 8.58 (d, J = 16.4 Hz, 1H), 6.66 (d, J = 16.3 Hz, 1H), 5.91-5.79 (m, 1H), 5.77 (s, 1H), 5.24 (dd, J = 38.5, 13.8 Hz, 2H), 4.45 (d, J = 5.0 Hz, 2H), 1.57 (s, 9H), 1.56 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 165.13, 165.02, 164.74, 149.56, 149.31, 143.69, 134.55, 132.63, 130.74, 128.71, 126.91, 125.80, 117.87, 103.59, 81.54, 81.12, 42.08, 28.17, 28.10.HRMS (ESI): Calcd for $[C_{23}H_{28}N_2O_5 + H]^+$ 413.2076; Found 413.2075.



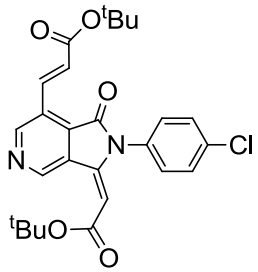
3ha (white solid), yield: 35%. (method B).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.15 (s, 1H), 9.05 (s, 1H), 8.56 (d, J = 16.4 Hz, 1H), 6.66 (d, J = 16.3 Hz, 1H), 5.77 (s, 1H), 3.30 (s, 3H), 1.58 (s, 9H), 1.56 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.16, 164.97, 164.60, 149.29, 149.22, 144.98, 134.49, 132.85, 128.45, 126.67, 125.54, 102.82, 81.39, 81.03, 28.11, 28.03, 26.40.HRMS (ESI): Calcd for $[C_{21}H_{26}N_2O_5 + H]^+$ 387.1920; Found 387.1923.



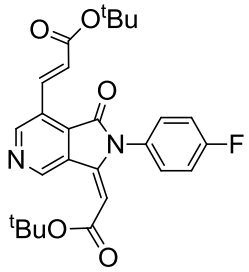
3ia (yellow solid), yield: 53%. (method B).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.24 (s, 1H), 9.13 (s, 1H), 8.55 (d, J = 16.3 Hz, 1H), 7.91 (d, J = 8.6 Hz, 2H), 7.07 (d, J = 8.5 Hz, 0H), 6.69 (d, J = 16.3 Hz, 0H), 5.56 (s, 1H), 1.53 (s, 9H), 1.53 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 164.91, 164.87, 164.59, 149.70, 149.68, 145.24, 139.17, 138.28, 134.23, 132.81, 132.09, 130.49, 128.68, 126.11, 104.78, 95.25, 81.73, 81.13, 28.08, 28.03.HRMS (ESI): Calcd for $[C_{26}H_{27}IN_2O_5 + H]^+$ 575.1043; Found 575.1042.



3ja Yellow Solid, yield: 65%. (method B).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.24 (s, 1H), 9.13 (s, 1H), 8.55 (d, J = 16.4 Hz, 1H), 7.72 (d, J = 8.6 Hz, 2H), 7.20 (d, J = 8.6 Hz, 2H), 6.69 (d, J = 16.3 Hz, 1H), 5.54 (s, 1H), 1.53 (s, 9H), 1.52 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.01, 164.93, 164.63, 149.75, 149.73, 145.34, 134.27, 133.25, 132.14, 130.37, 180, 28.128.49, 127.23, 126.18, 123.62, 104.83, 81.79, 81.20, 28.11, 28.06.HRMS (ESI): Calcd for $[C_{26}H_{27}BrN_2O_5 + H]^+$ 527.1182; Found 527.1184.

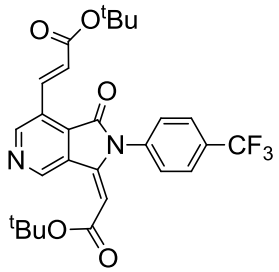


3ka Yellow Solid, yield: 43%. (method B).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.24 (s, 1H), 9.13 (s, 1H), 8.55 (d, J = 16.4 Hz, 1H), 7.56 (d, J = 8.6 Hz, 2H), 7.28 (d, J = 8.6 Hz, 2H), 6.69 (d, J = 16.3 Hz, 1H), 5.55 (s, 1H), 1.53 (s, 9H), 1.53 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 164.96, 164.82, 164.54, 149.66, 149.61, 145.33, 135.41, 134.18, 132.05, 131.52, 130.17, 130.02, 128.40, 127.11, 126.05, 104.74, 81.67, 81.07, 28.03, 27.98.HRMS (ESI): Calcd for $[C_{26}H_{27}ClN_2O_5 + H]^+$ 483.1687; Found 483.1684.

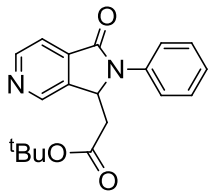


3la Yellow Solid, yield: 44%. (method B).^{1}H NMR (500 MHz, $CDCl_3$) δ 10.24 (s, 1H), 9.14 (s, 1H), 8.55 (d, J = 16.3 Hz, 1H), 7.33-7.26 (m, 4H), 6.69 (d, J = 16.3 Hz, 1H), 5.53 (s, 1H), 1.53 (s, 9H), 1.53 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.22, 164.90, 164.66, 162.80 (d, $J_{F\text{-}C}$ = 250.2 Hz), 149.71, 145.67, 134.29, 134.02, 132.15, 130.63 (d, $J_{F\text{-}C}$ = 8.9 Hz), 128.95 (d, $J_{F\text{-}C}$ = 3.2 Hz), 127.19, 126.12, 117.08 (d, $J_{F\text{-}C}$ =

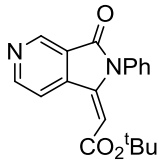
23.0 Hz), 116.97, 104.75, 81.71, 81.14, 28.08, 28.04.HRMS (ESI): Calcd for $[C_{26}H_{27}FN_2O_5 + H]^+$ 467.1982; Found 467.1980.



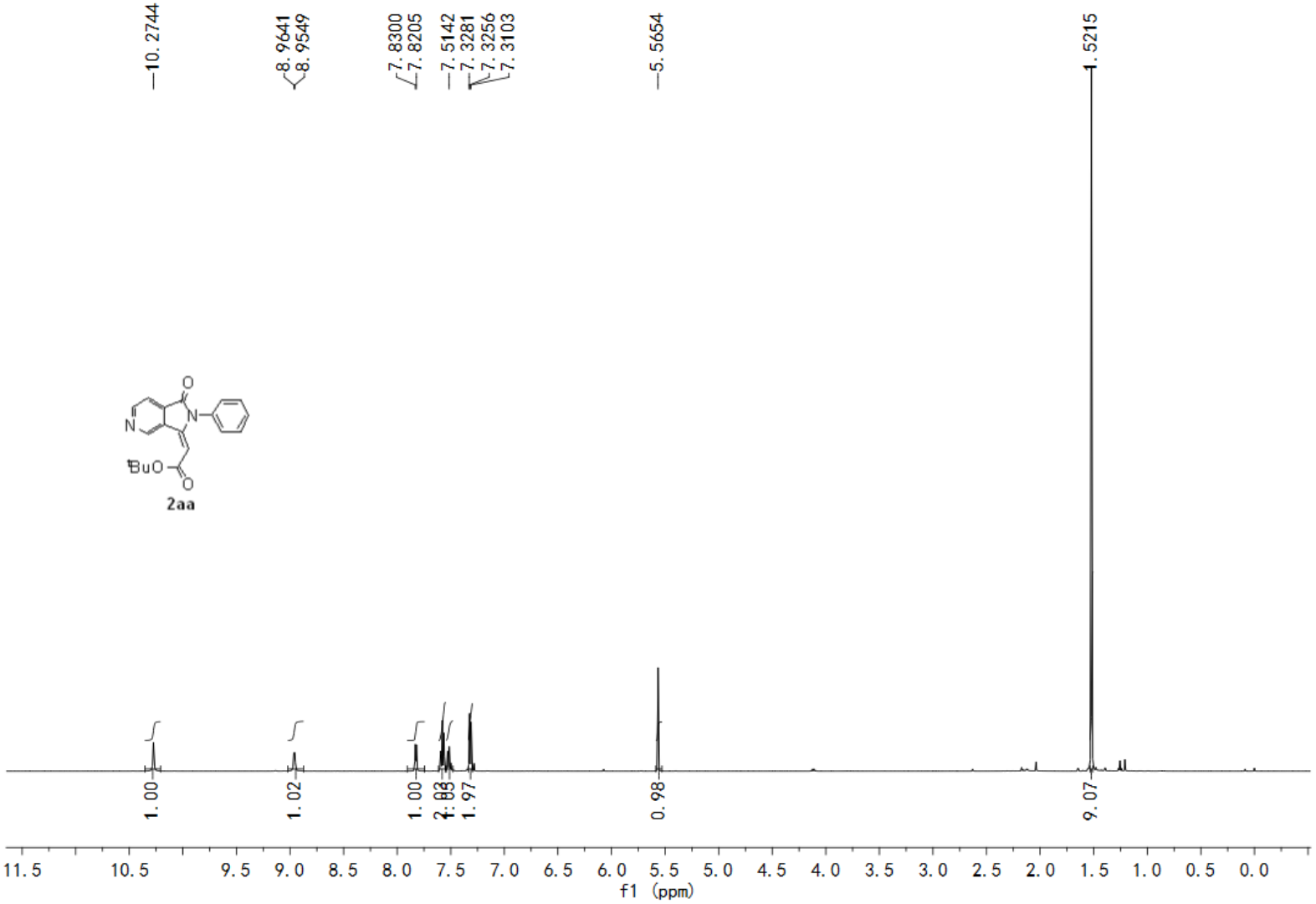
3ma Yellow Solid, yield: 24%. (method B).^{1}H NMR (400 MHz, $CDCl_3$) δ 10.25 (s, 1H), 9.15 (s, 1H), 8.55 (d, J = 16.4 Hz, 1H), 7.87 (d, J = 8.3 Hz, 2H), 7.49 (d, J = 8.2 Hz, 2H), 6.70 (d, J = 16.3 Hz, 1H), 5.56 (s, 1H), 1.53 (s, 9H), 1.53 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 164.91, 164.87, 164.51, 149.79, 145.05, 136.48, 134.16, 131.98, 131.49(q, $J_{F\text{-}C}$ = 33.0 Hz), 129.29, 128.48, 127.29, 127.09(q, $J_{F\text{-}C}$ = 3.6 Hz), 126.28, 123.54(q, $J_{F\text{-}C}$ = 272.5 Hz), 104.87, 81.91, 81.20, 28.08, 28.04, 27.68. HRMS (ESI): Calcd for $[C_{27}H_{27}F_3N_2O_5 + H]^+$ 517.1950; Found 517.1952.

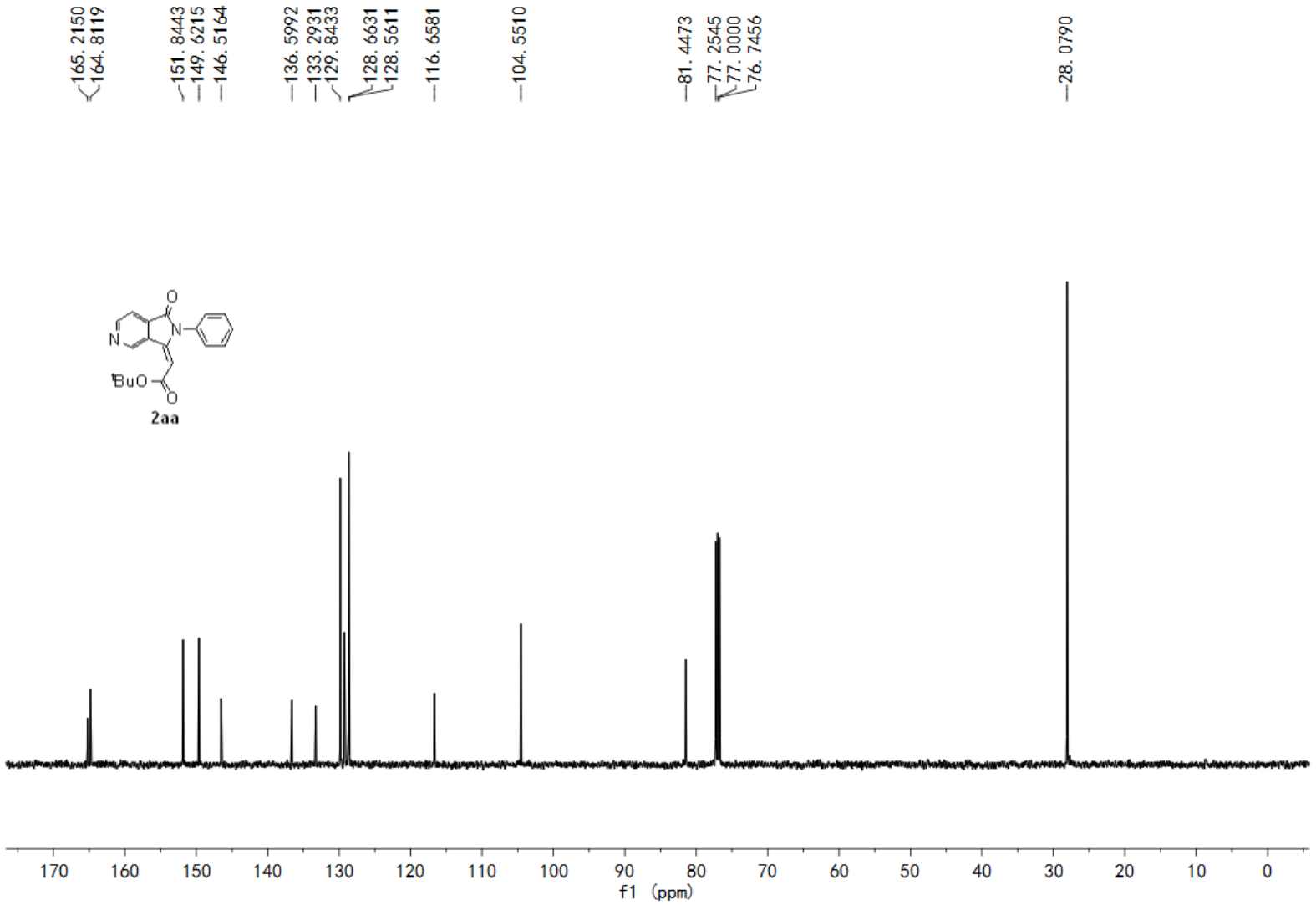


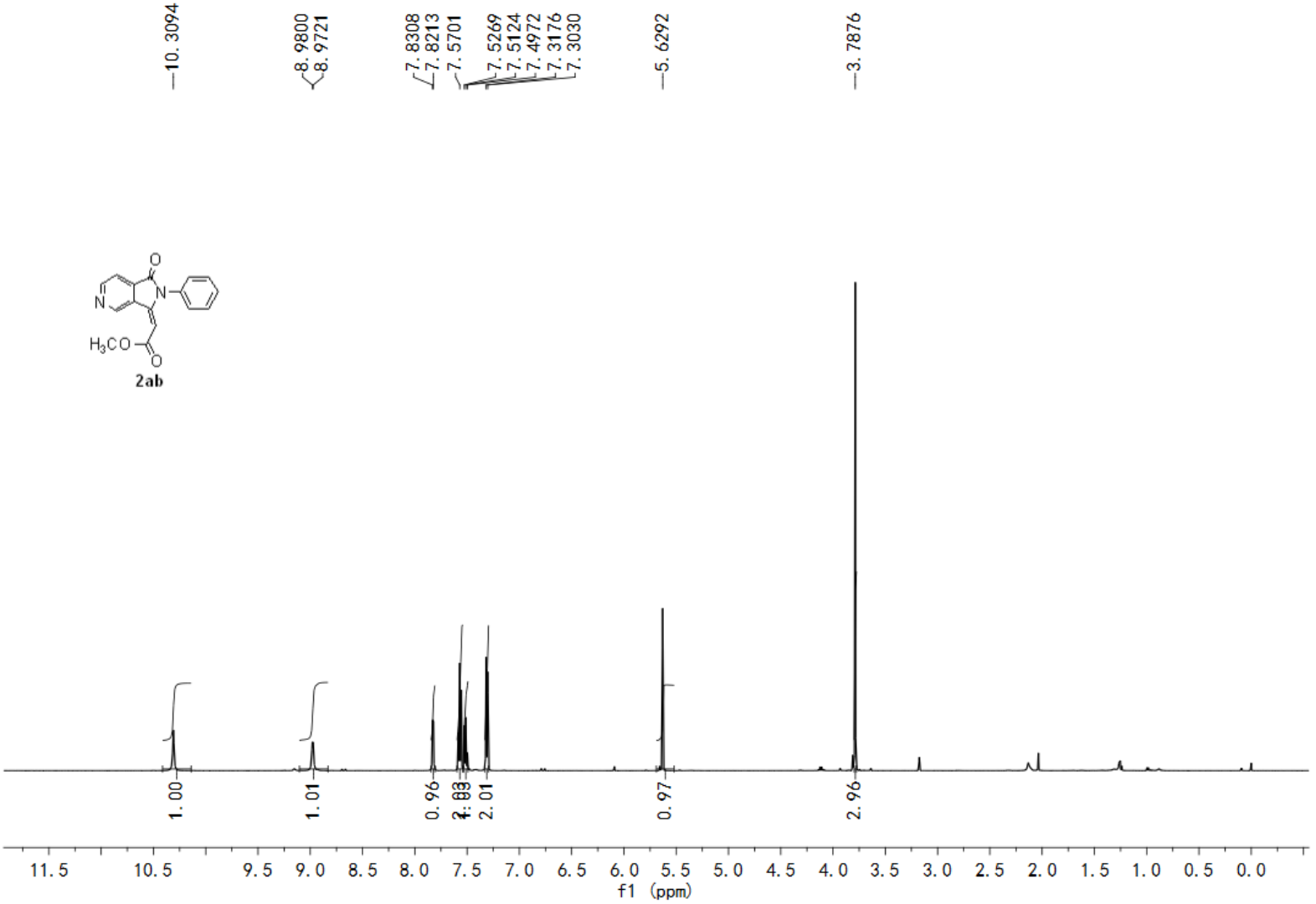
4aa Yellowish Solid, yield: 23%. (method A).^{1}H NMR (500 MHz, $CDCl_3$) δ 8.98 (s, 1H), 8.96 (s, 1H), 7.82 (d, J = 4.7 Hz, 1H), 7.56 (dd, J = 8.6, 1.1 Hz, 2H), 7.51-7.45 (m, 2H), 7.31 (t, J = 7.4 Hz, 1H), 5.64 (dd, J = 8.6, 3.8 Hz, 1H), 2.96 (dd, J = 16.3, 3.8 Hz, 1H), 2.48 (dd, J = 16.3, 8.6 Hz, 1H), 1.36 (s, 9H).^{13}C NMR (126 MHz, $CDCl_3$) δ 168.86, 165.14, 149.94, 145.28, 139.66, 135.74, 129.45, 126.65, 124.10, 117.79, 117.79, 82.06, 57.14, 37.99, 27.88. HRMS (ESI): Calcd for $[C_{19}H_{20}N_2O_3 + H]^+$ 325.1552; Found 325.1554.

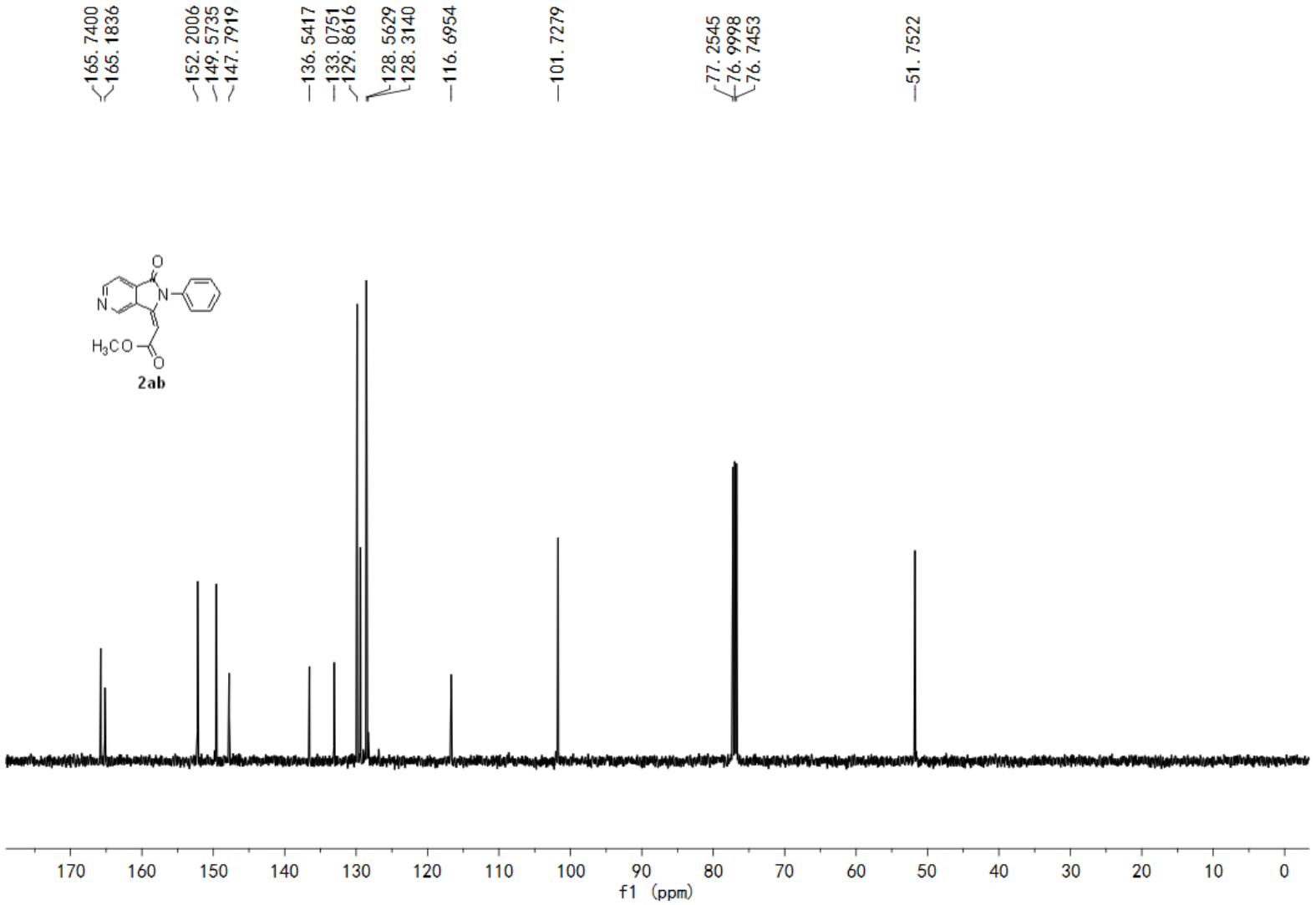


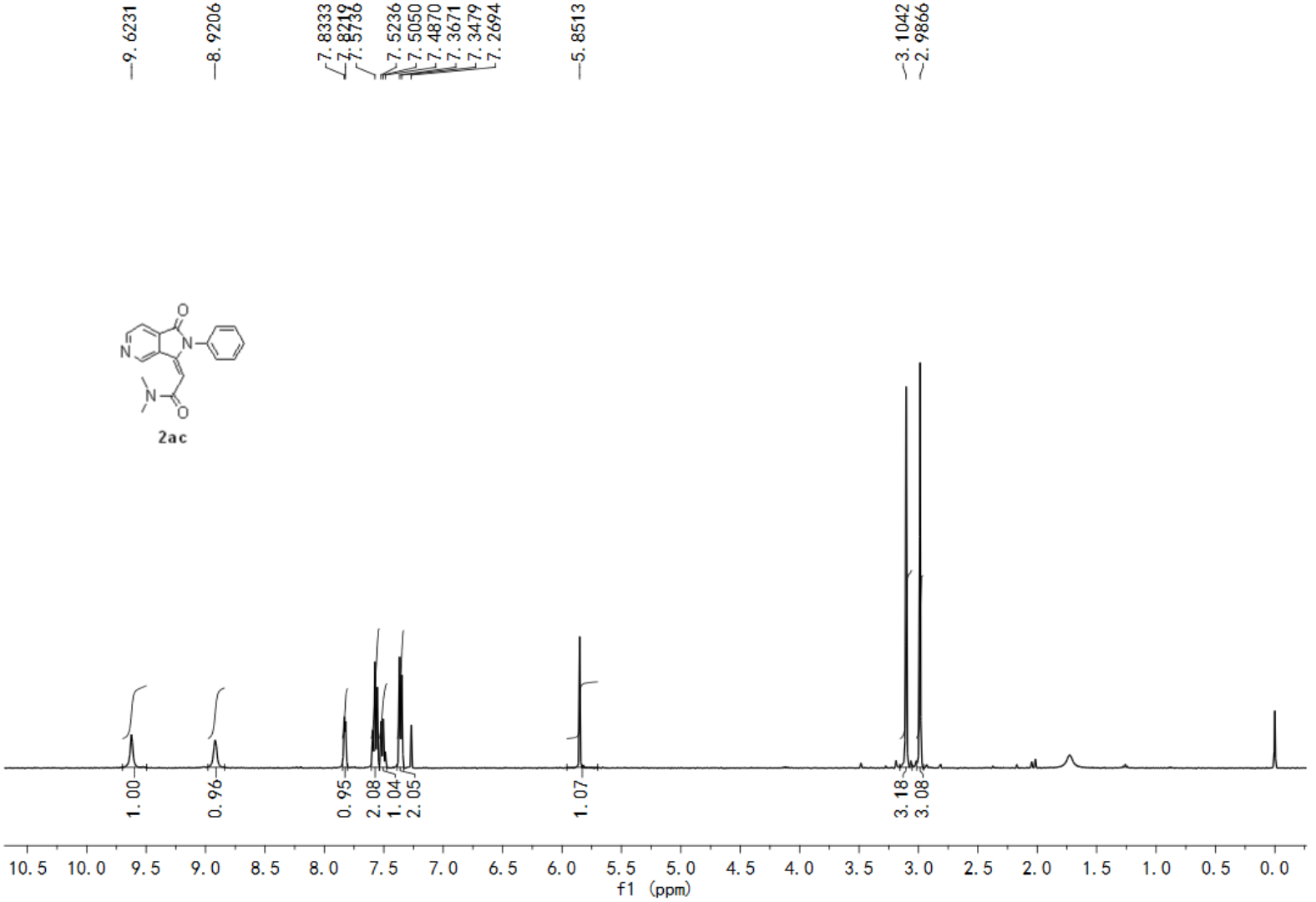
5aa. White sold, yield: 51% (method A). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.22 (s, 1H), 8.98 (d, J = 5.3 Hz, 1H), 8.93 (d, J = 5.3 Hz, 1H), 7.57 (t, J = 7.6 Hz, 2H), 7.50 (t, J = 7.3 Hz, 1H), 7.30 (d, J = 7.6 Hz, 2H), 5.60 (s, 1H), 1.50 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.6, 164.8, 154.3, 147.0, 145.7 140.8, 133.3, 129.9, 129.3, 128.7, 124.1, 121.5, 105.8, 81.6, 28.10. HRMS (ESI): Calcd for $[C_{19}H_{18}N_2O_3 + H]^+$ 323.1396; Found 323.1406.

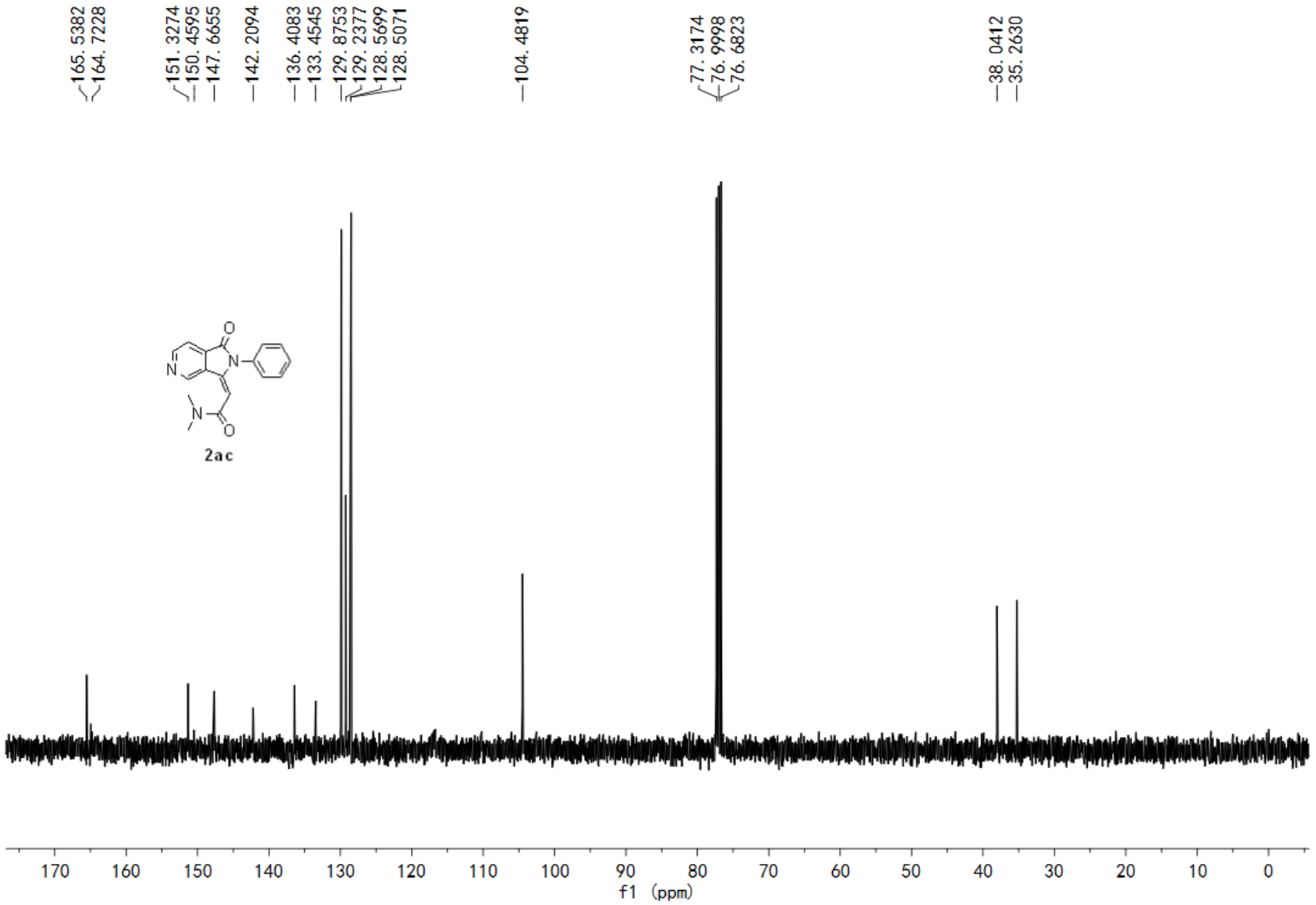


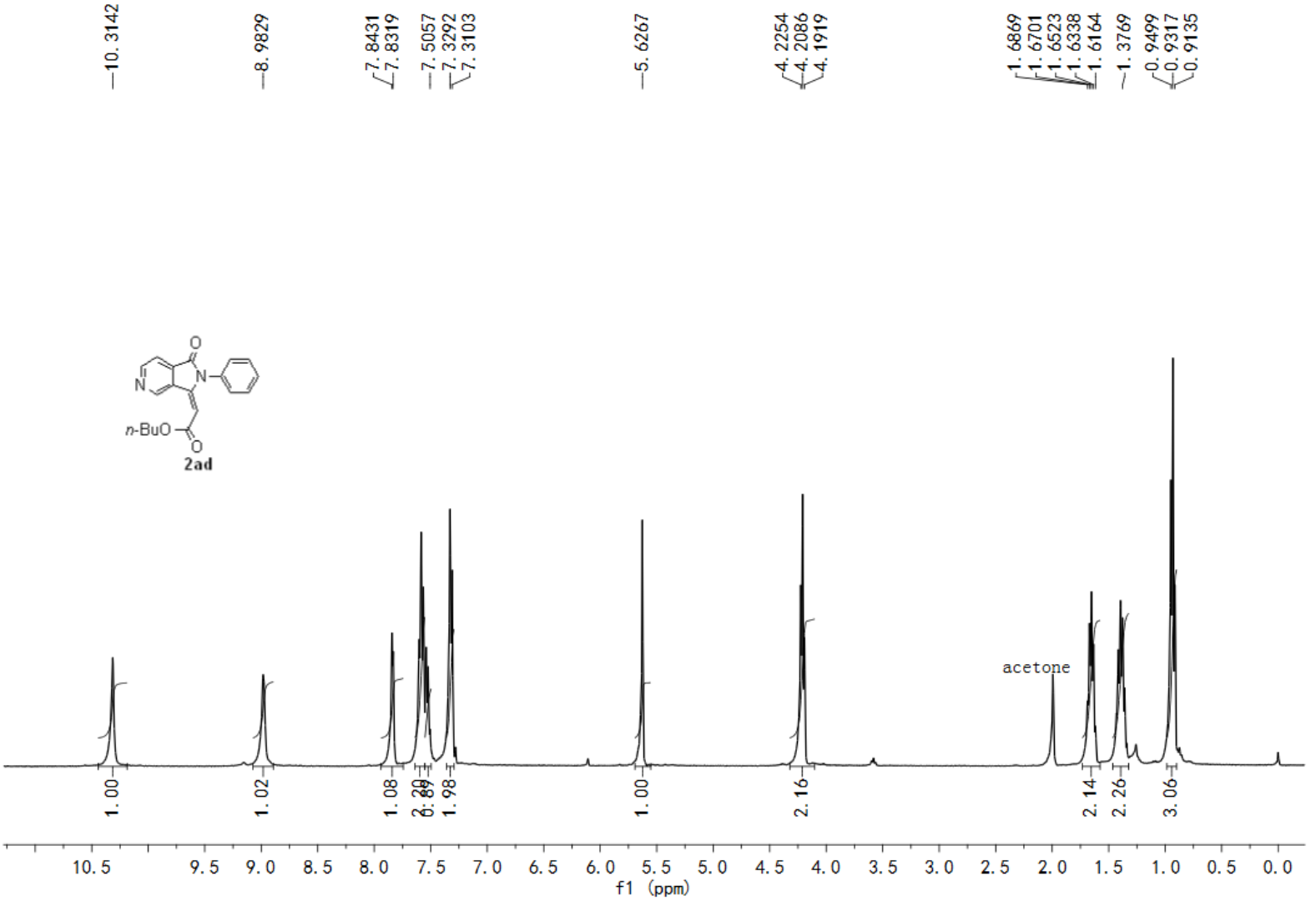


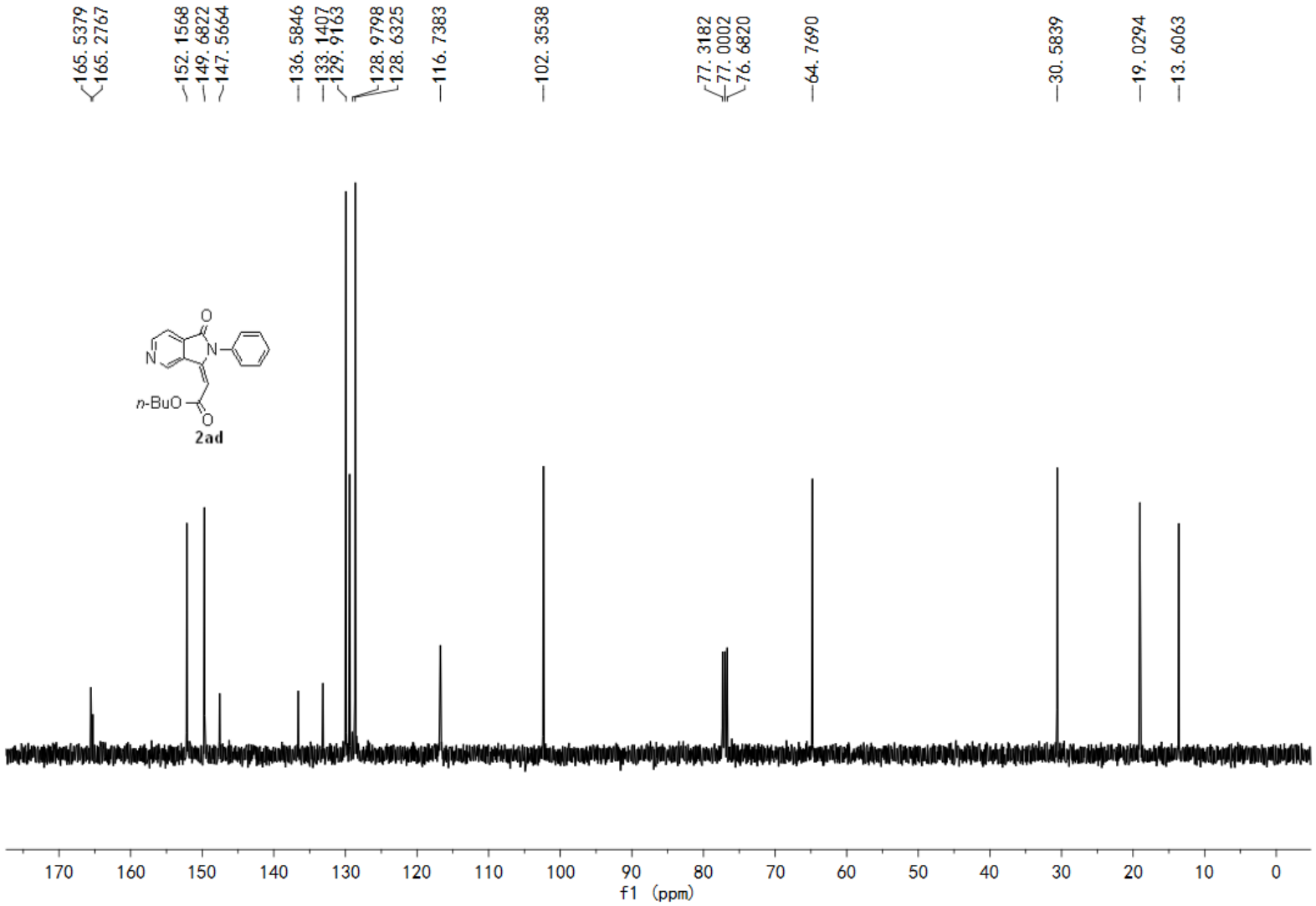


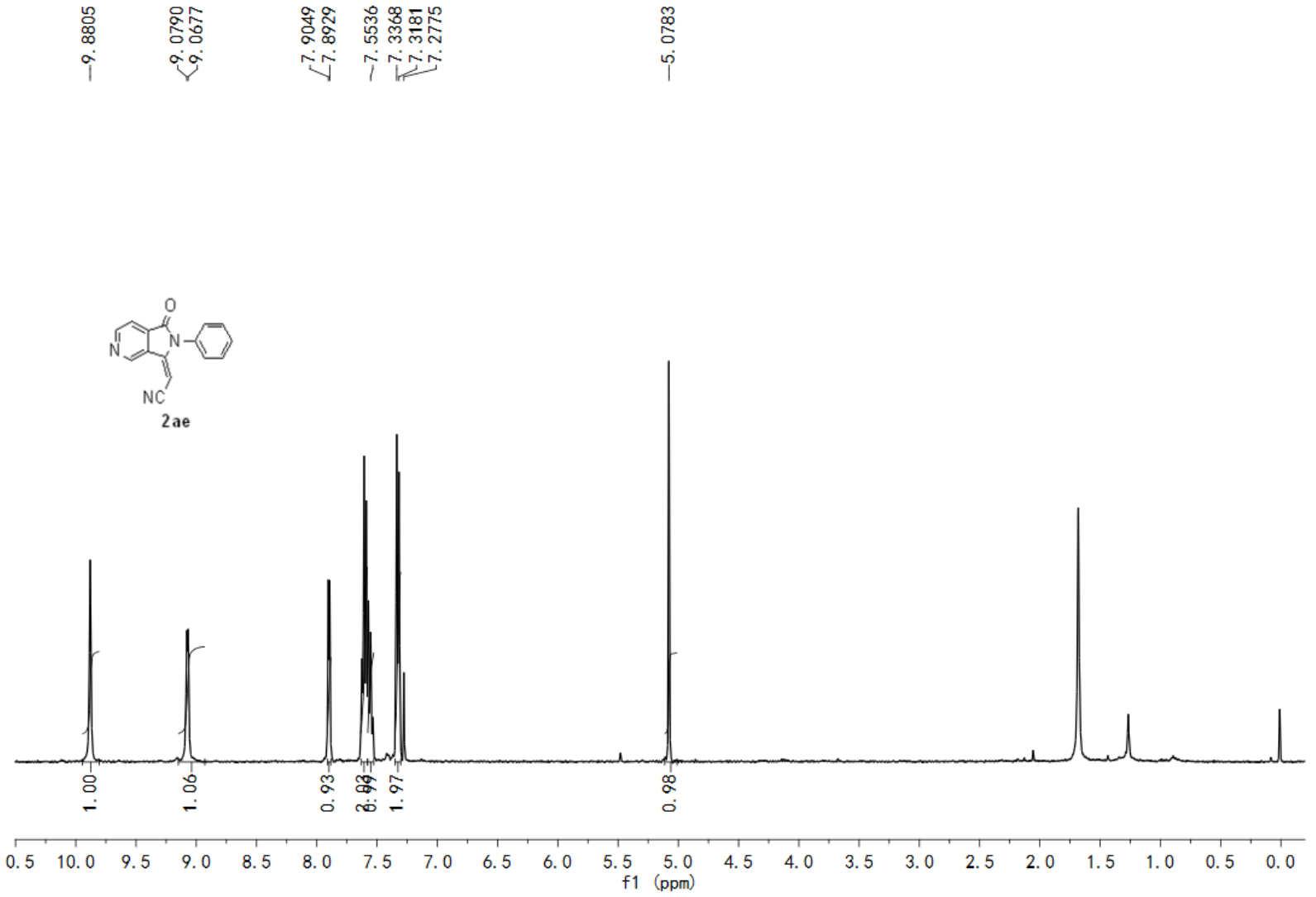


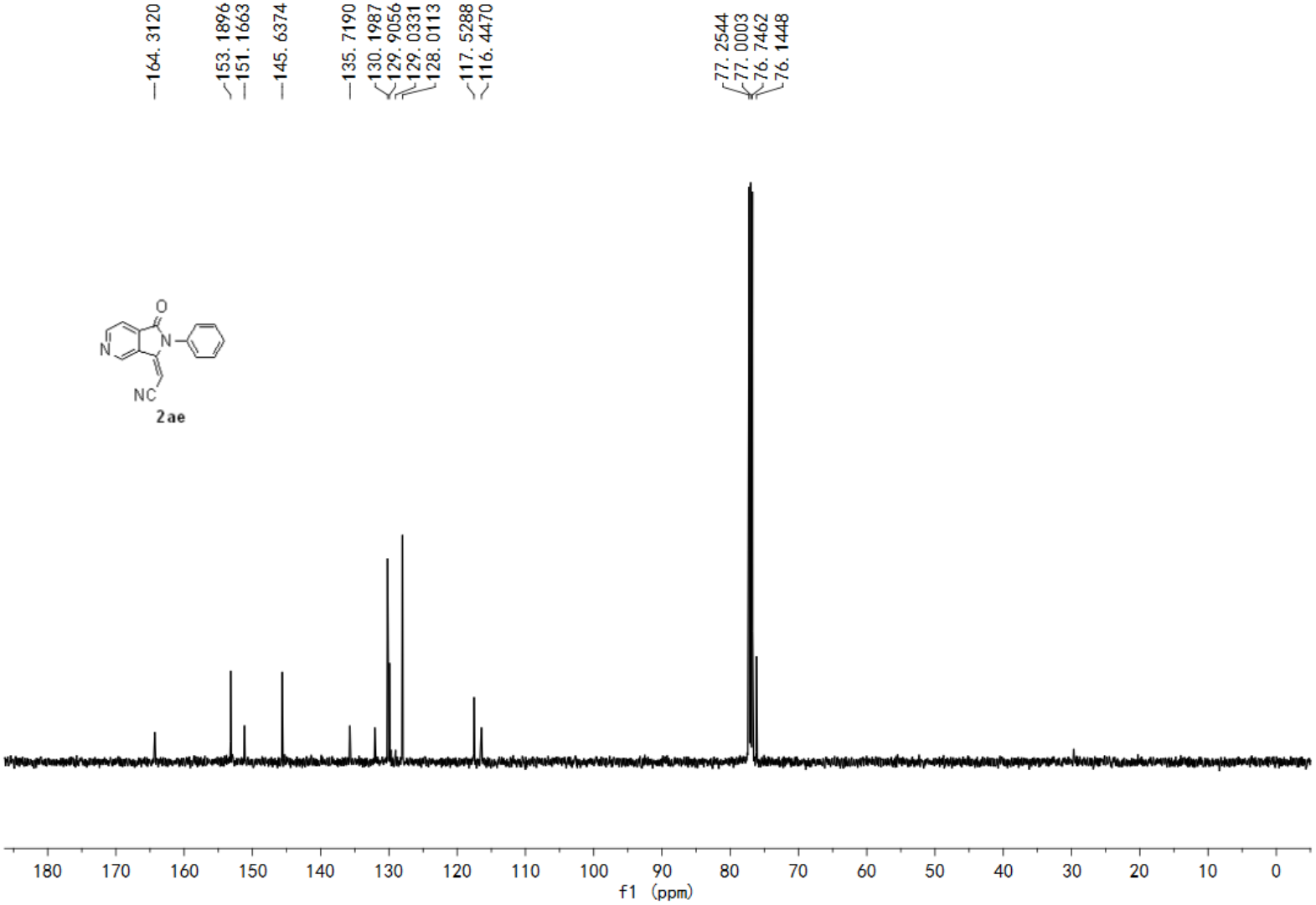


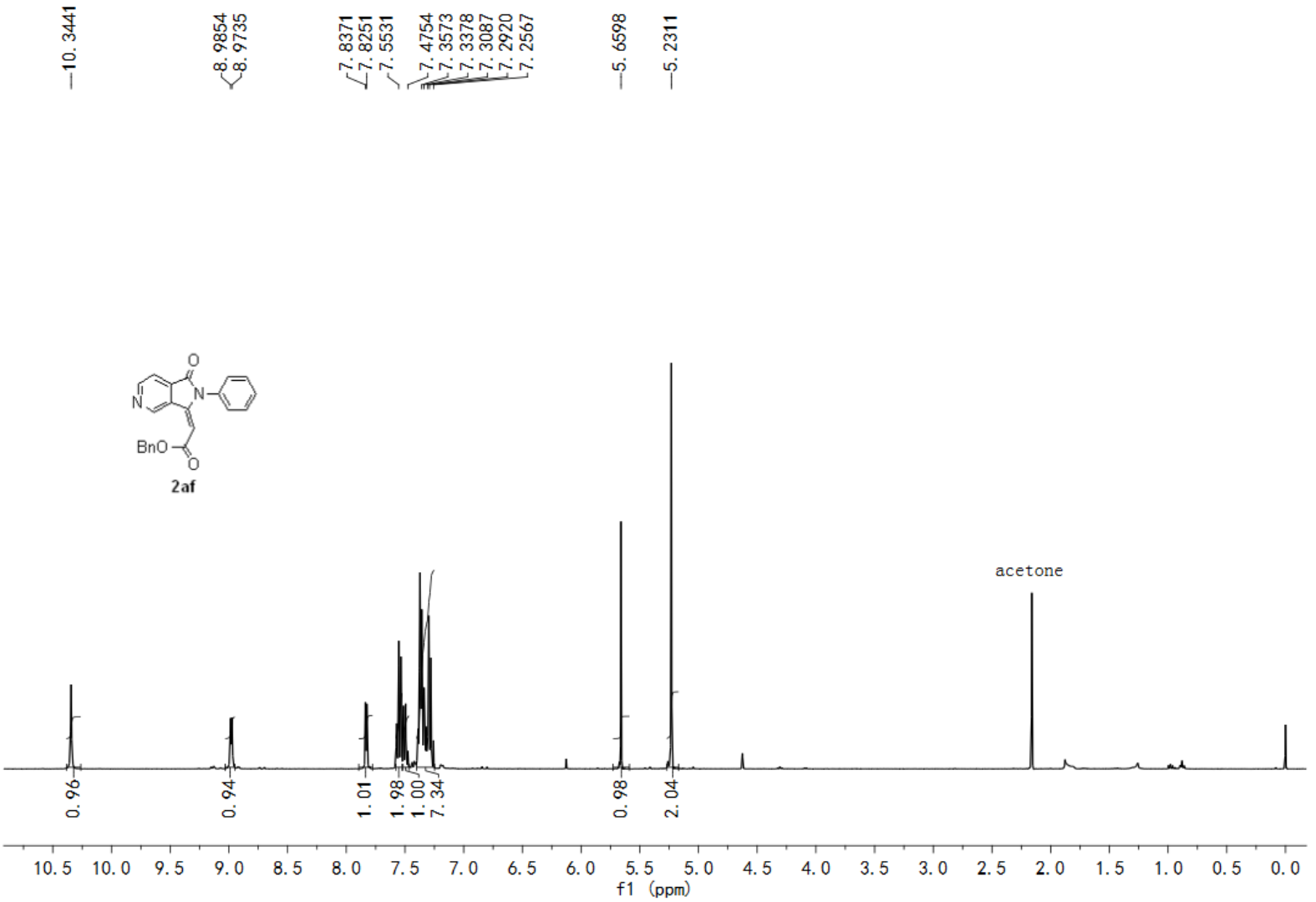


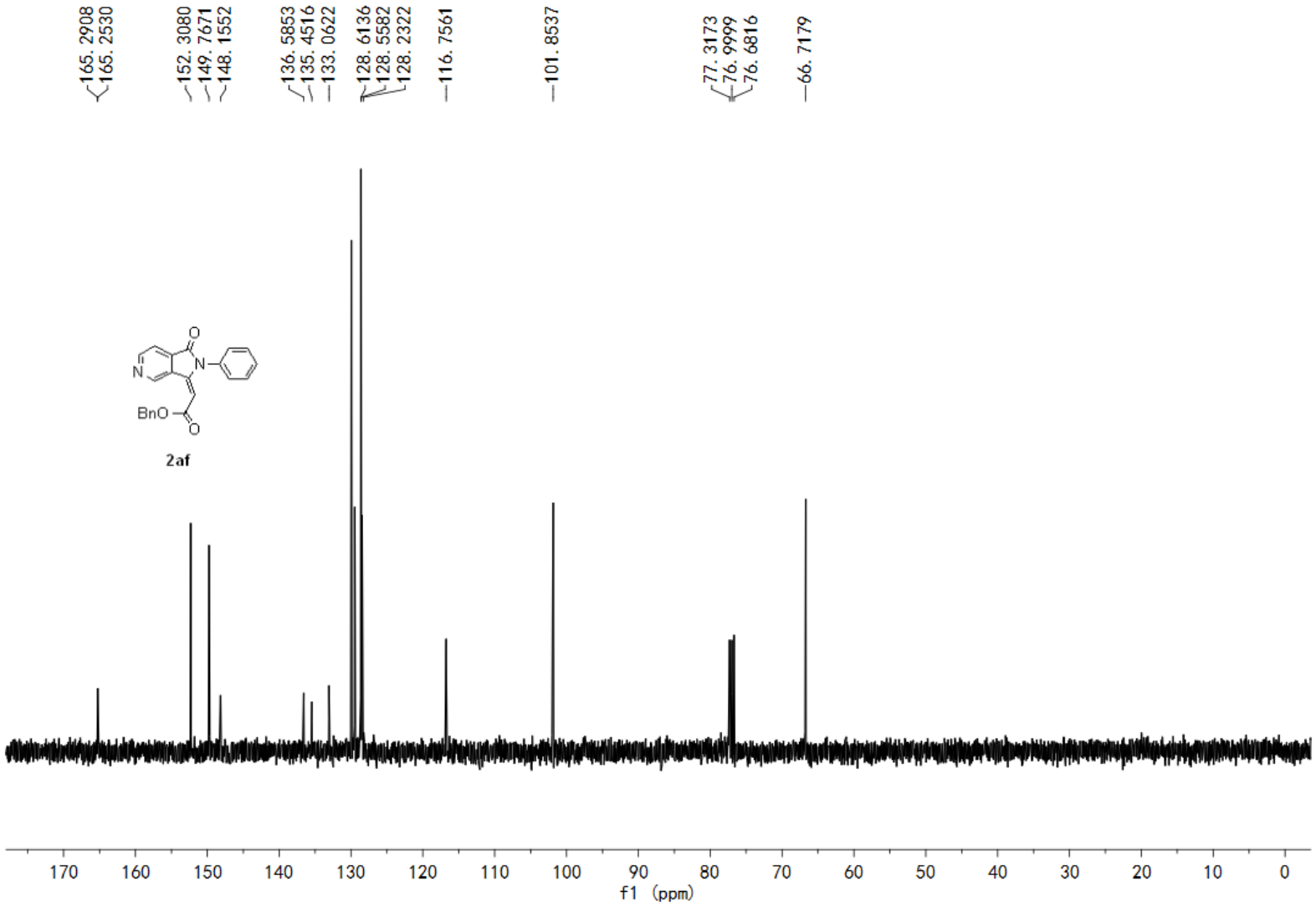


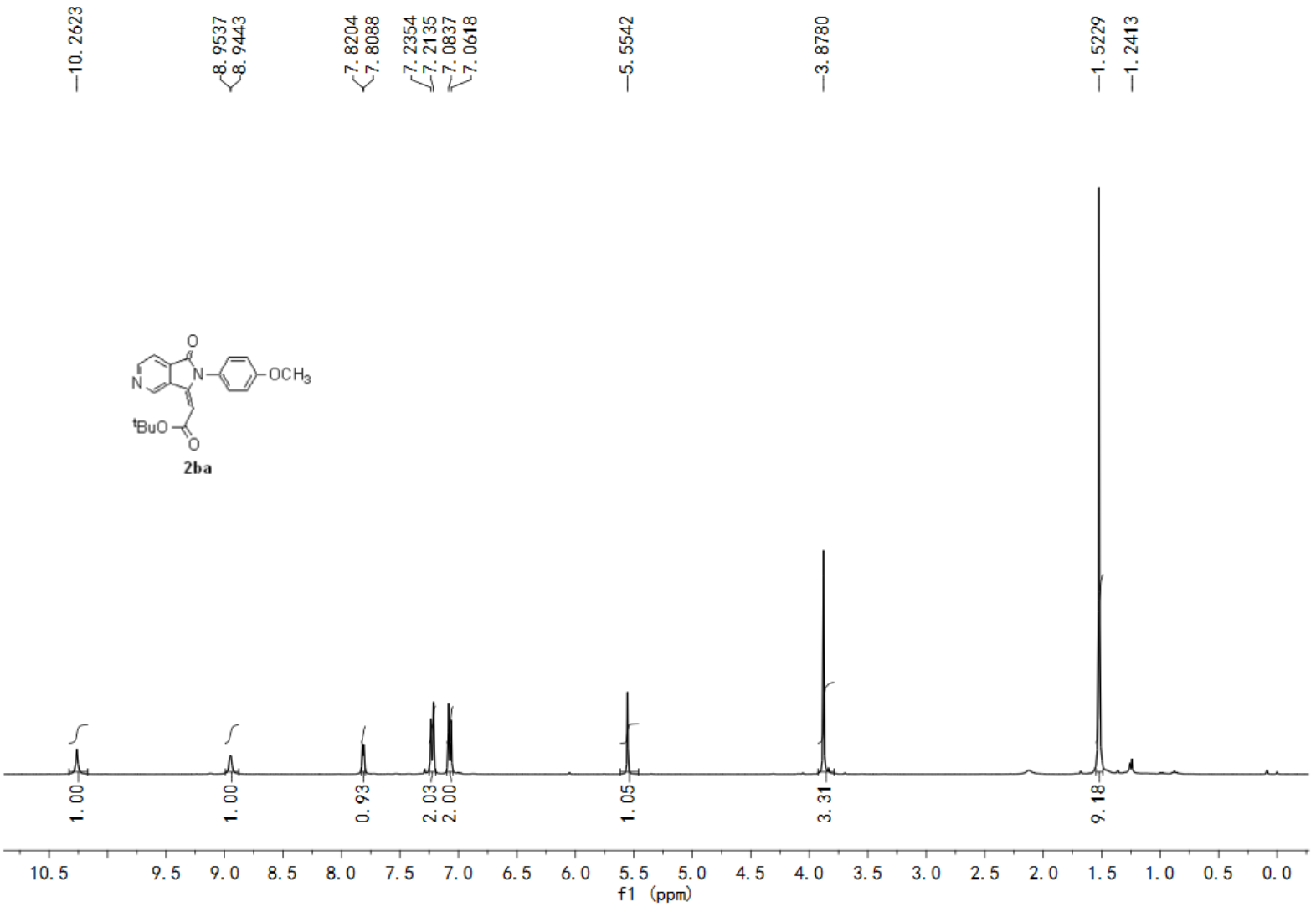


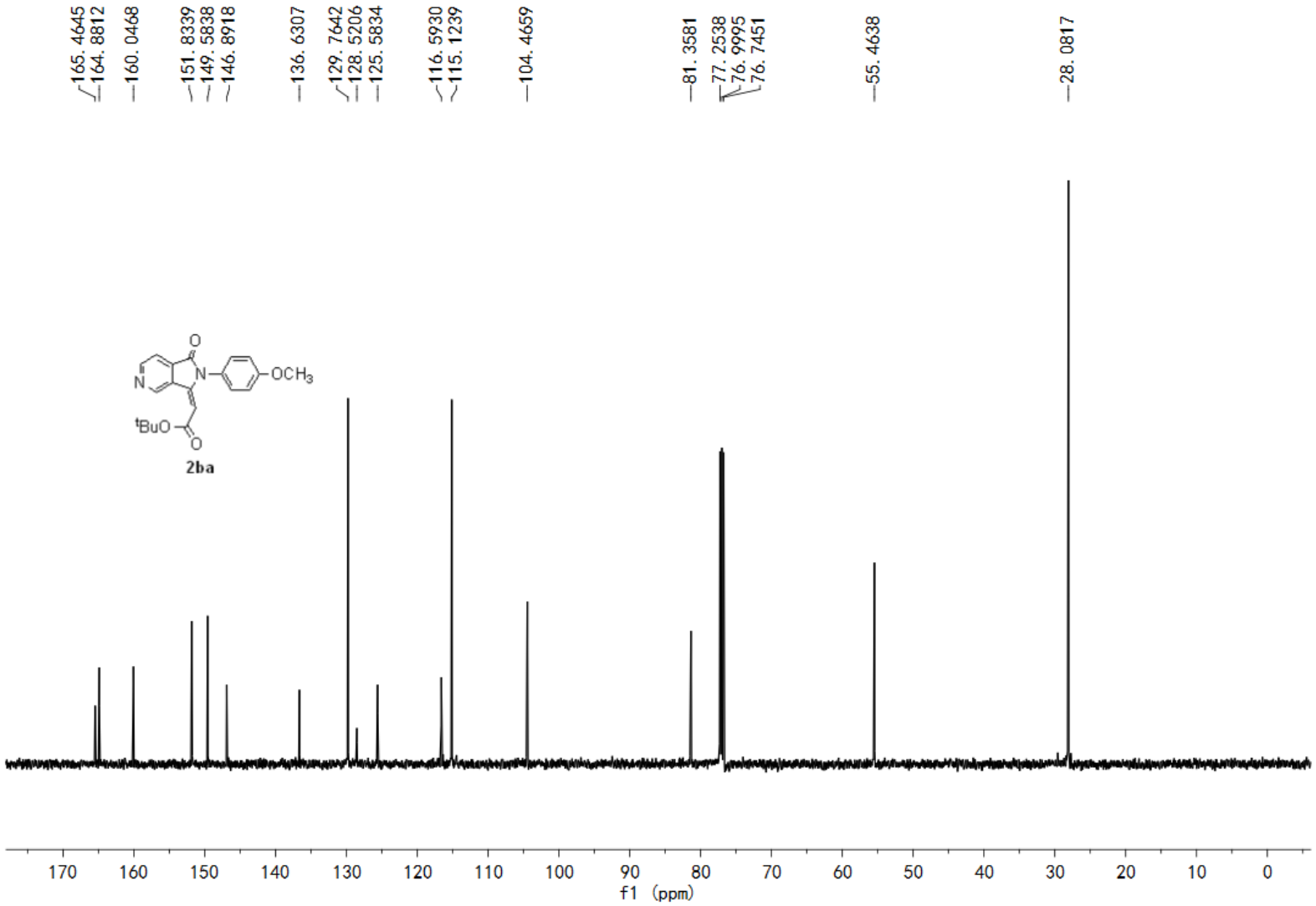


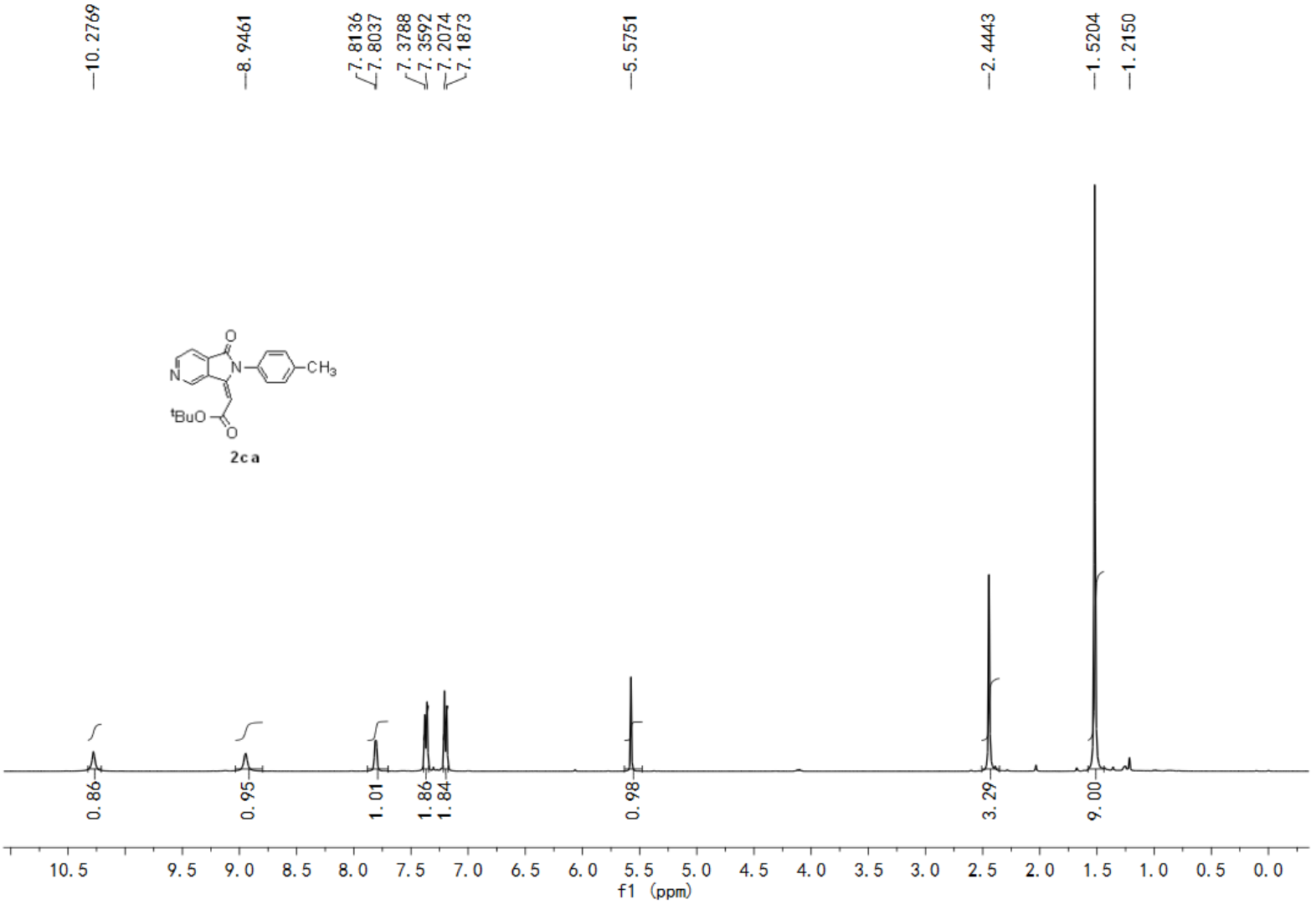


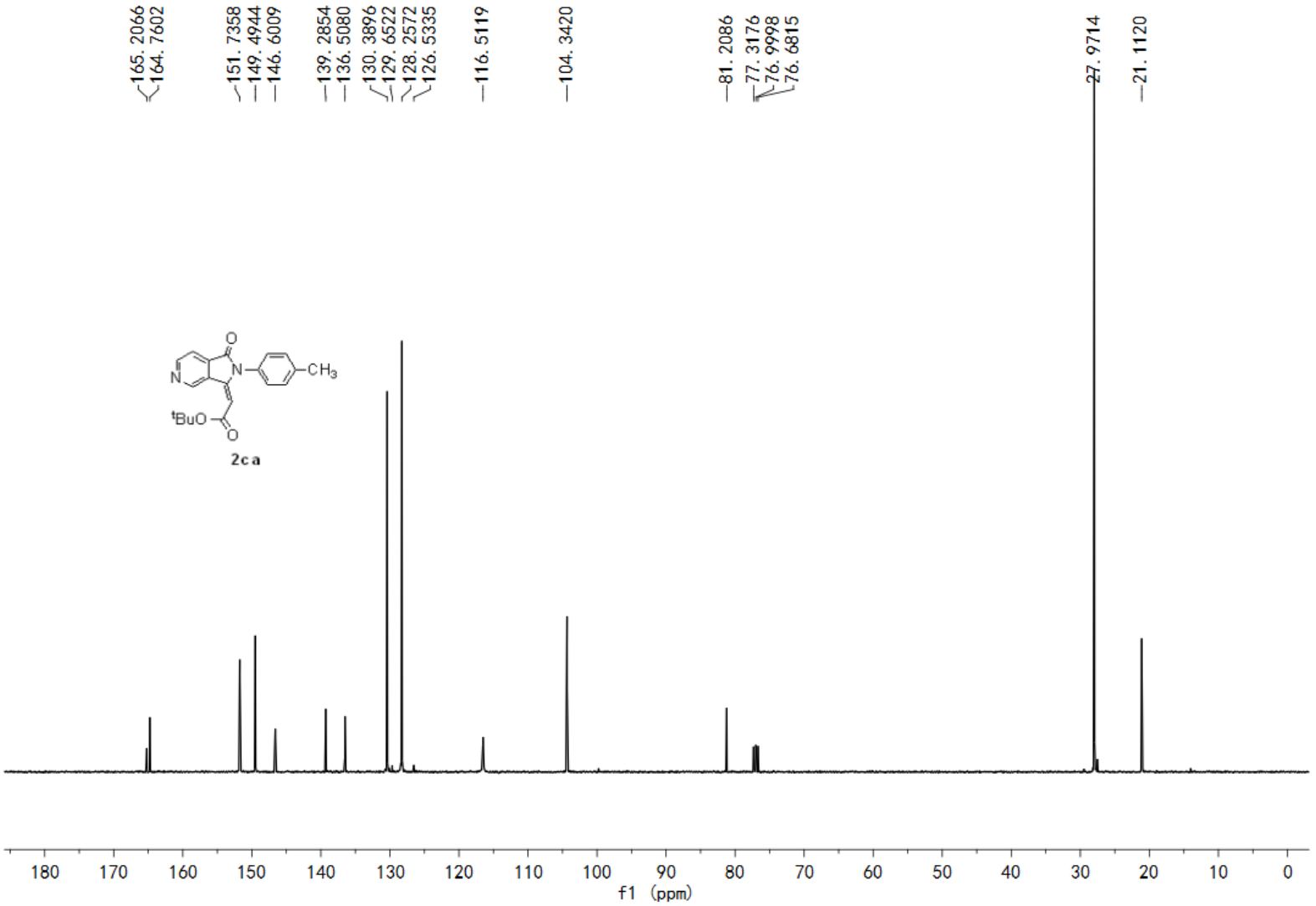


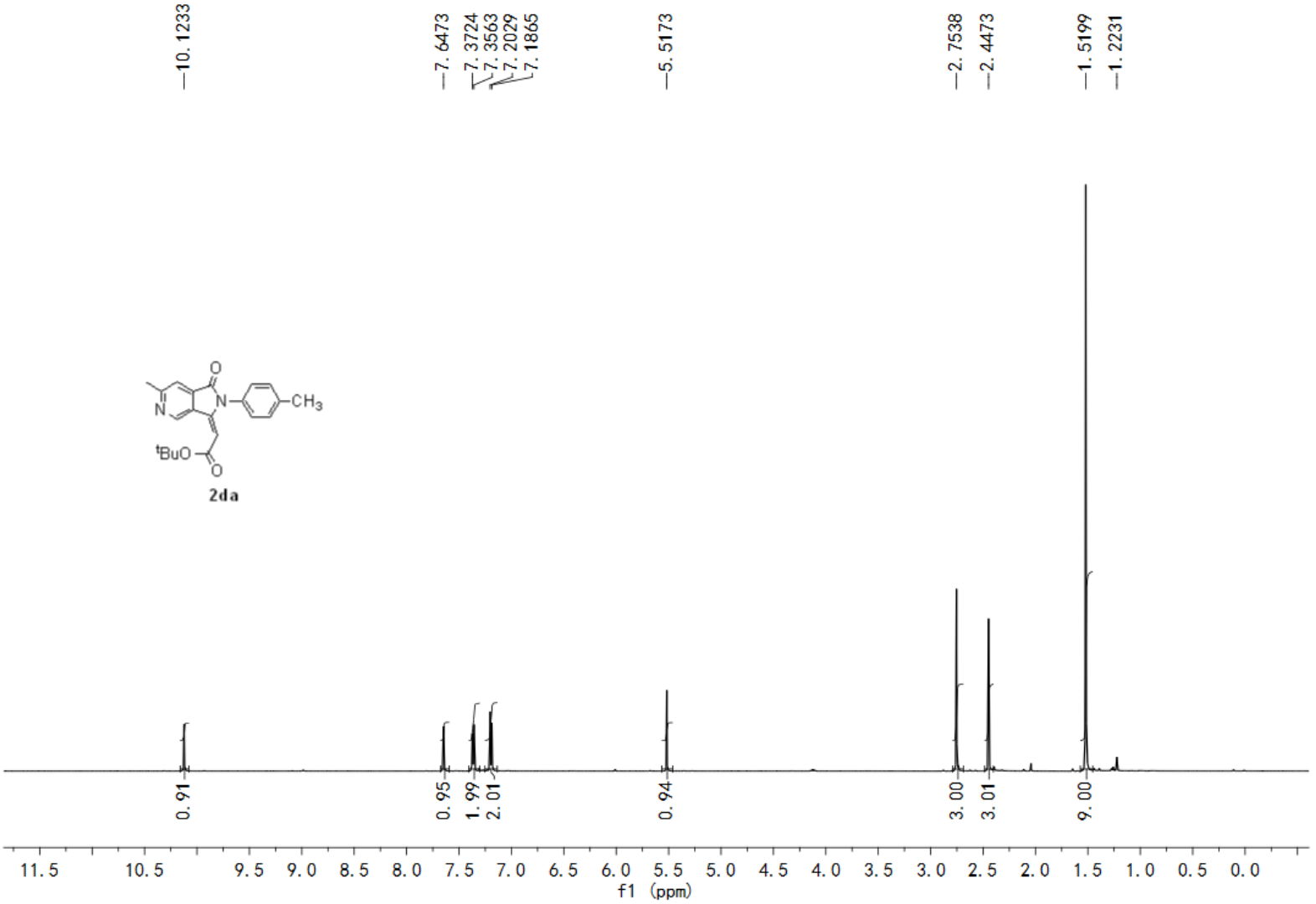












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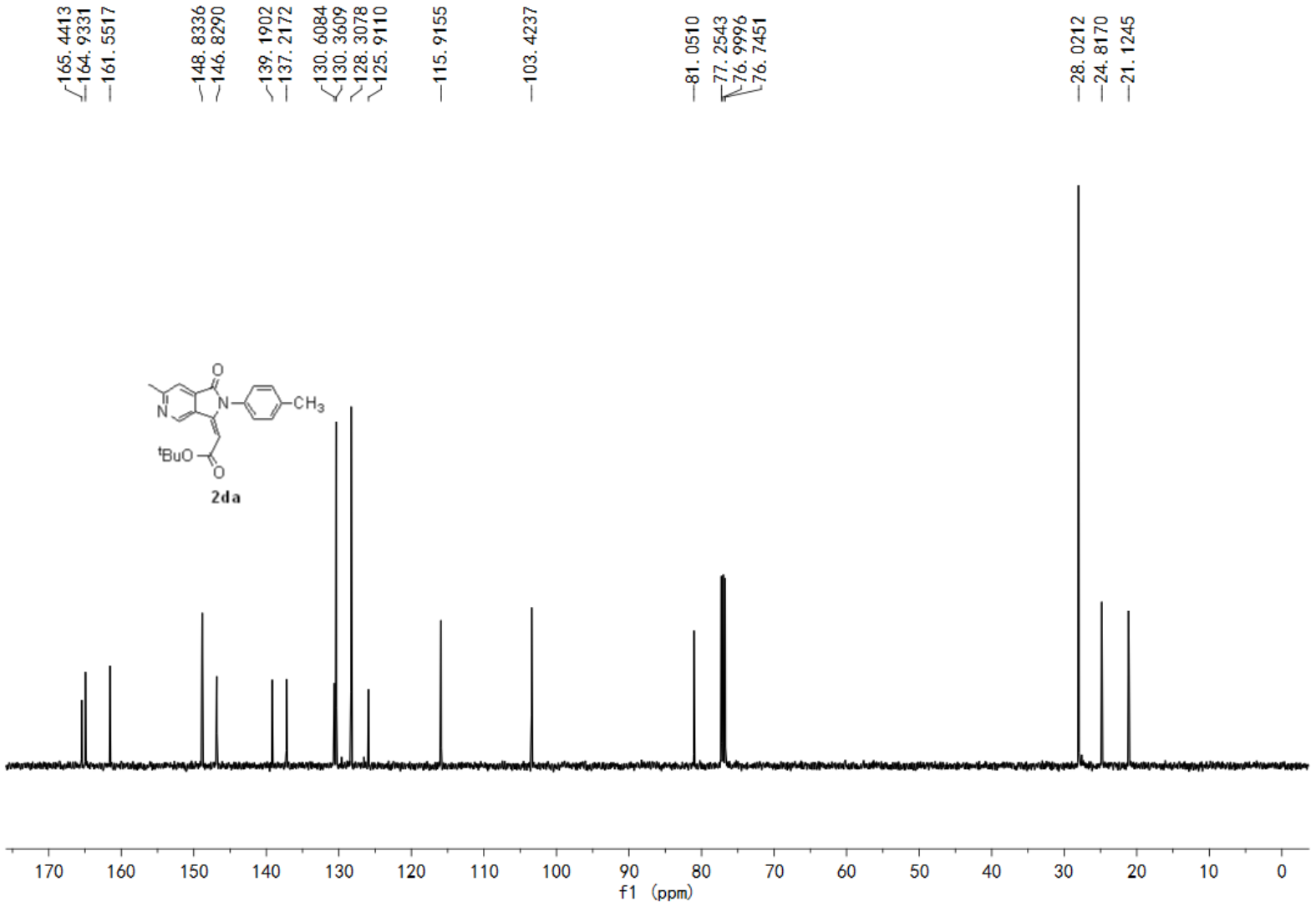

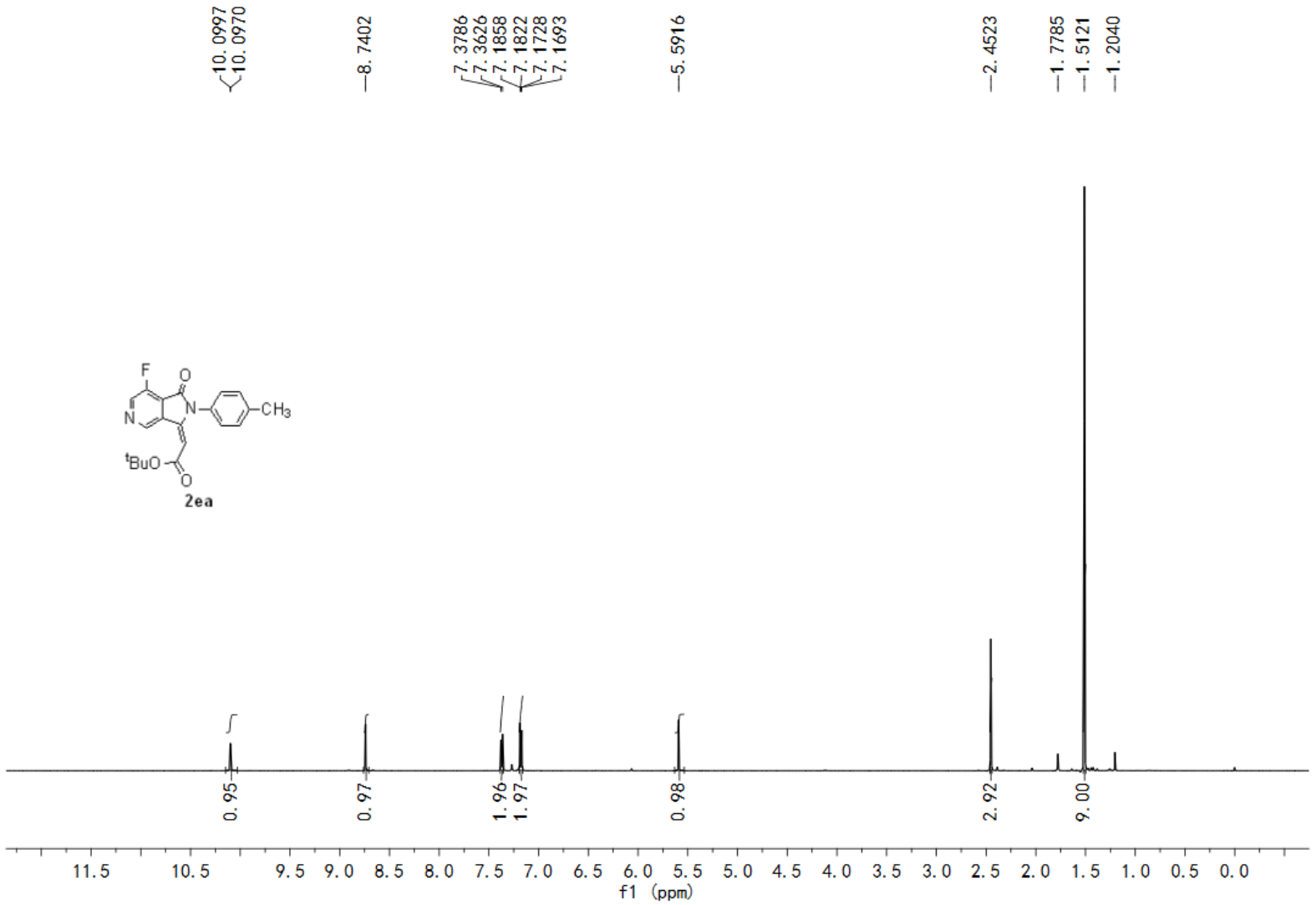
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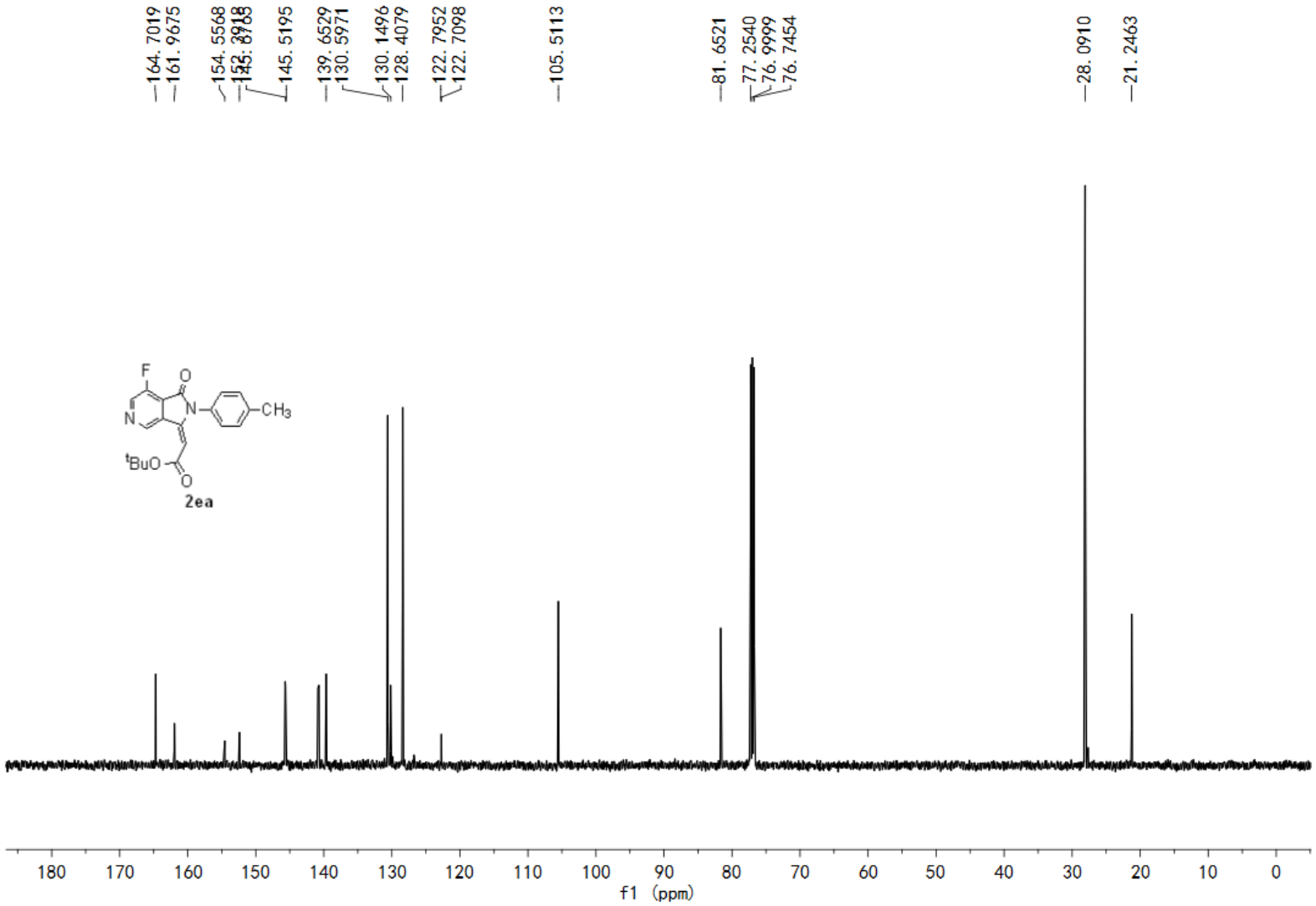

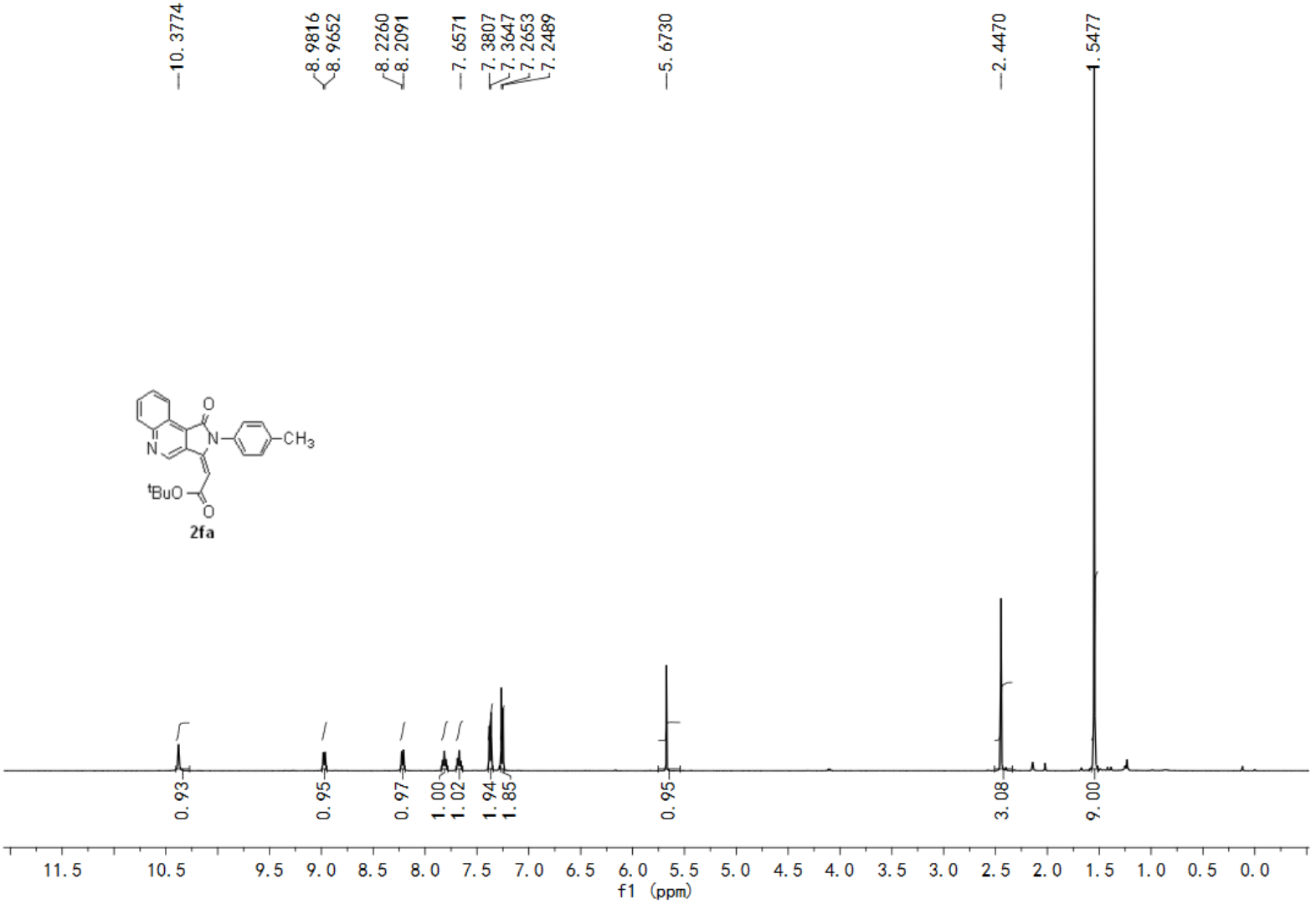

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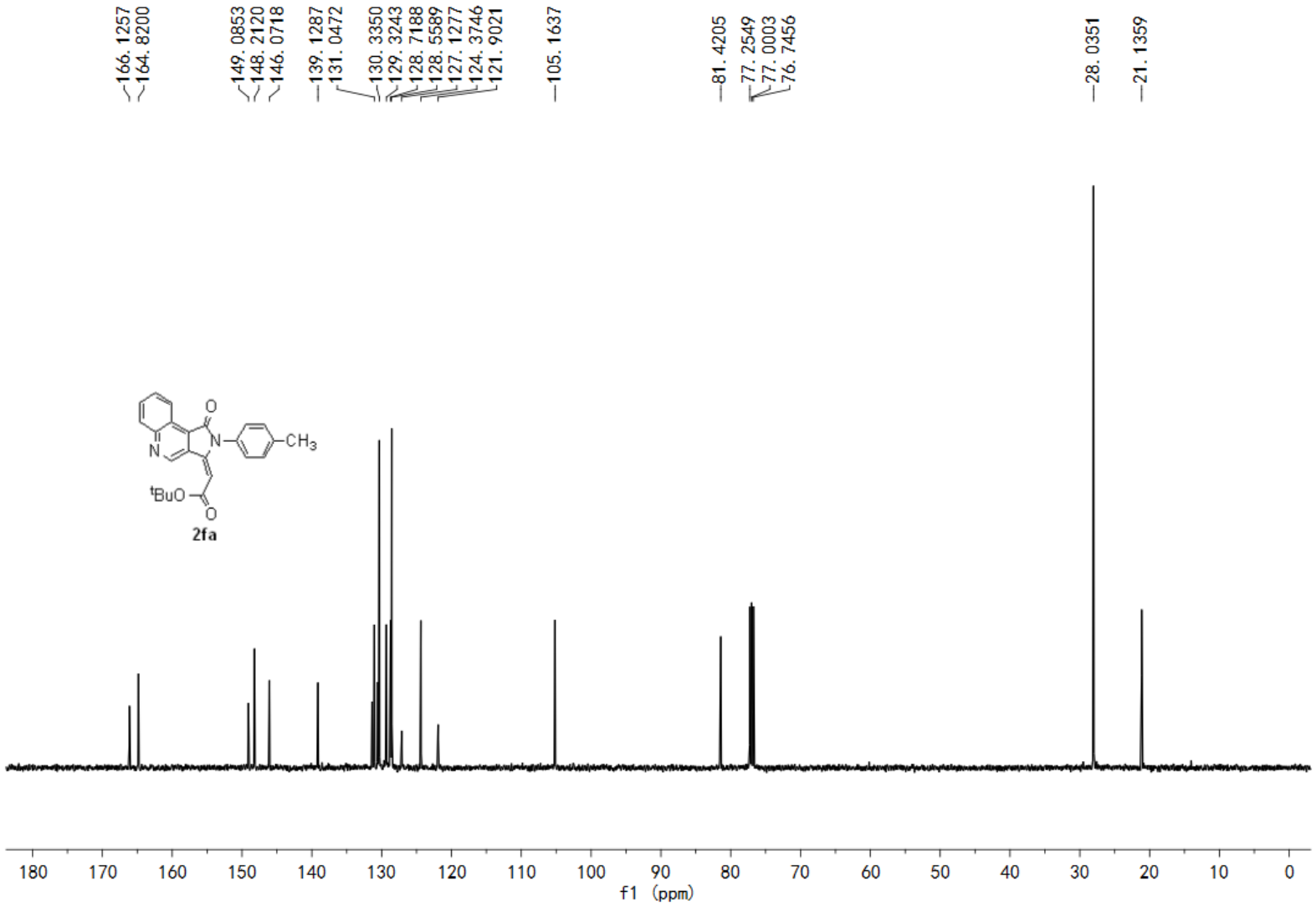

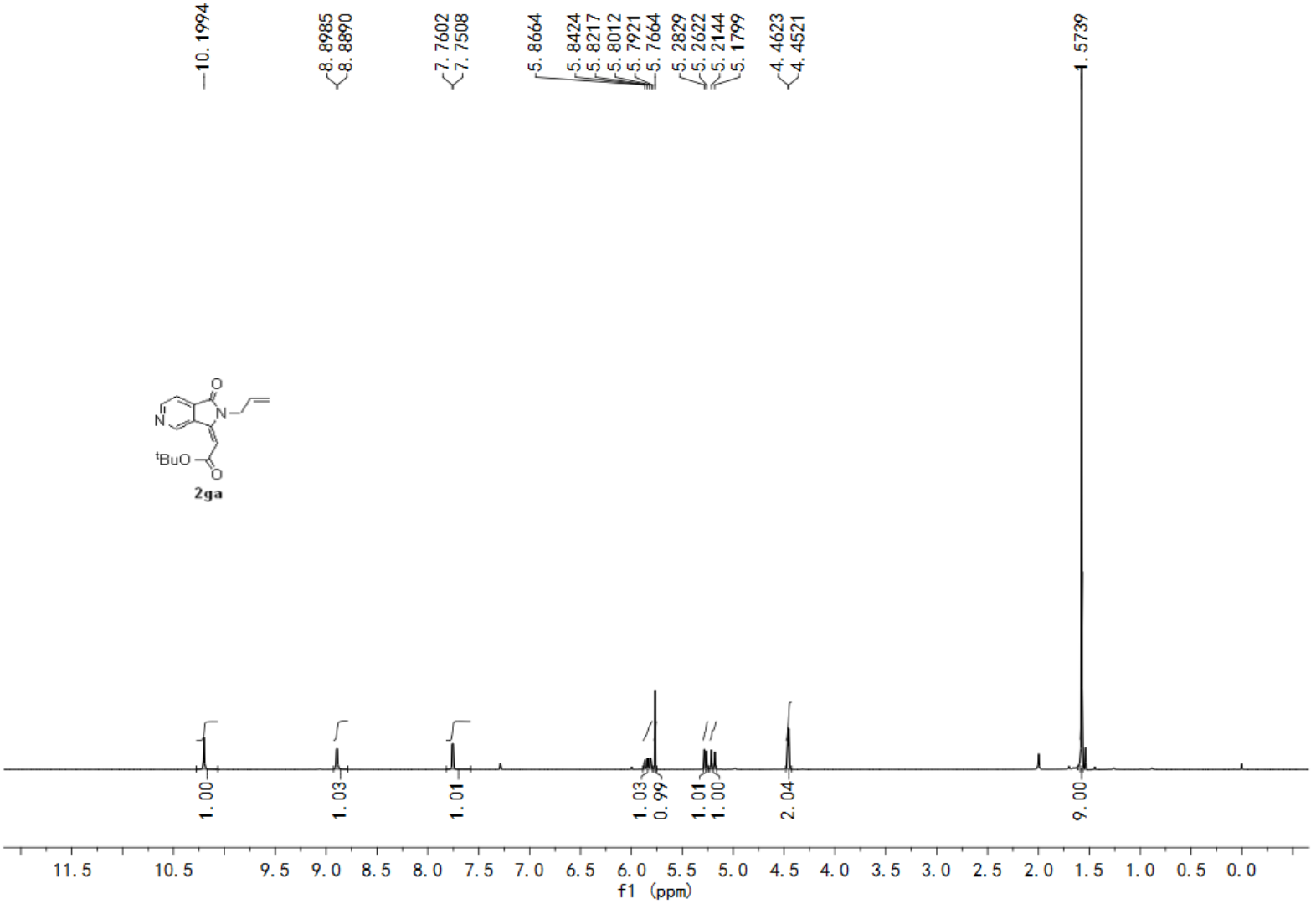

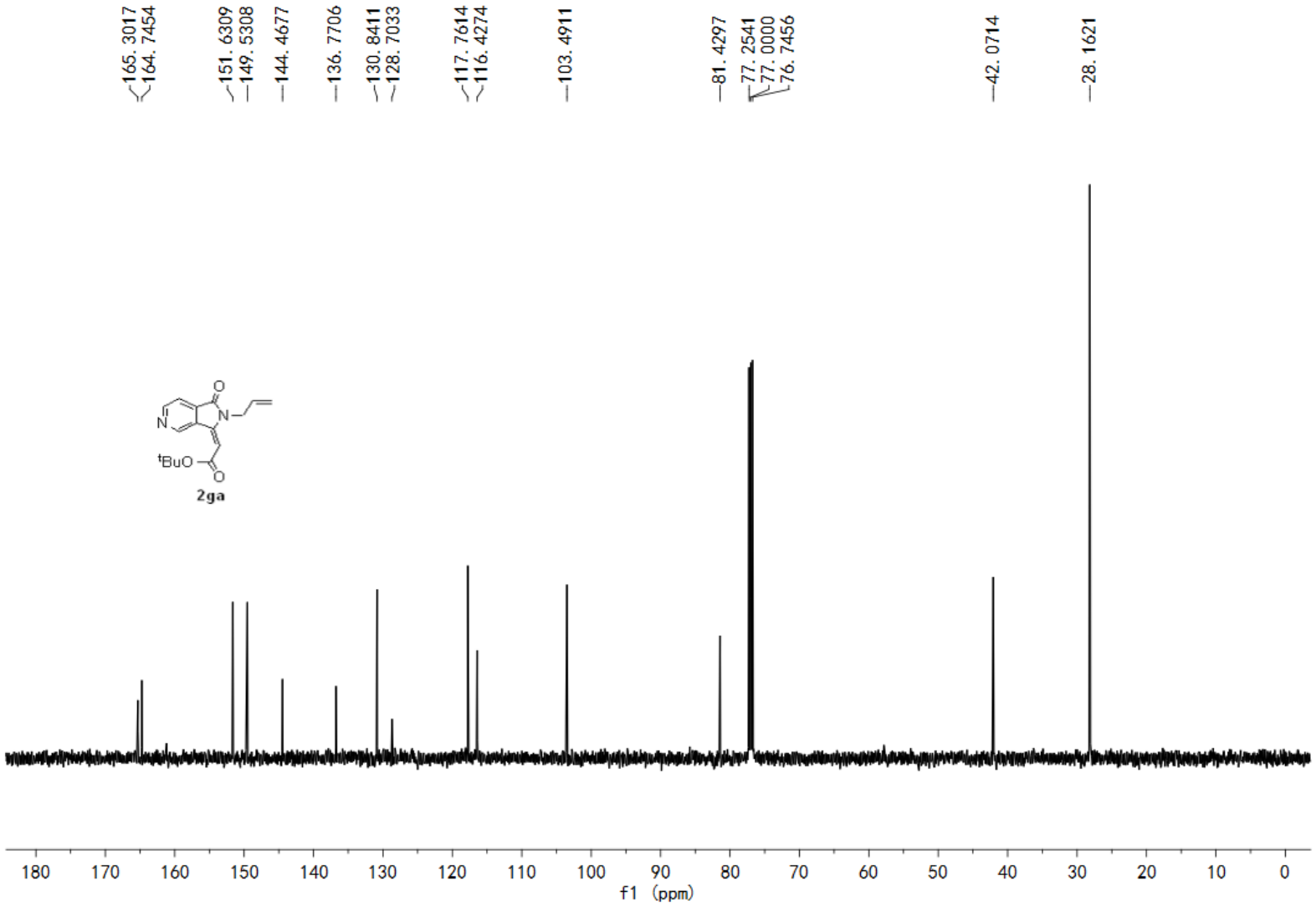

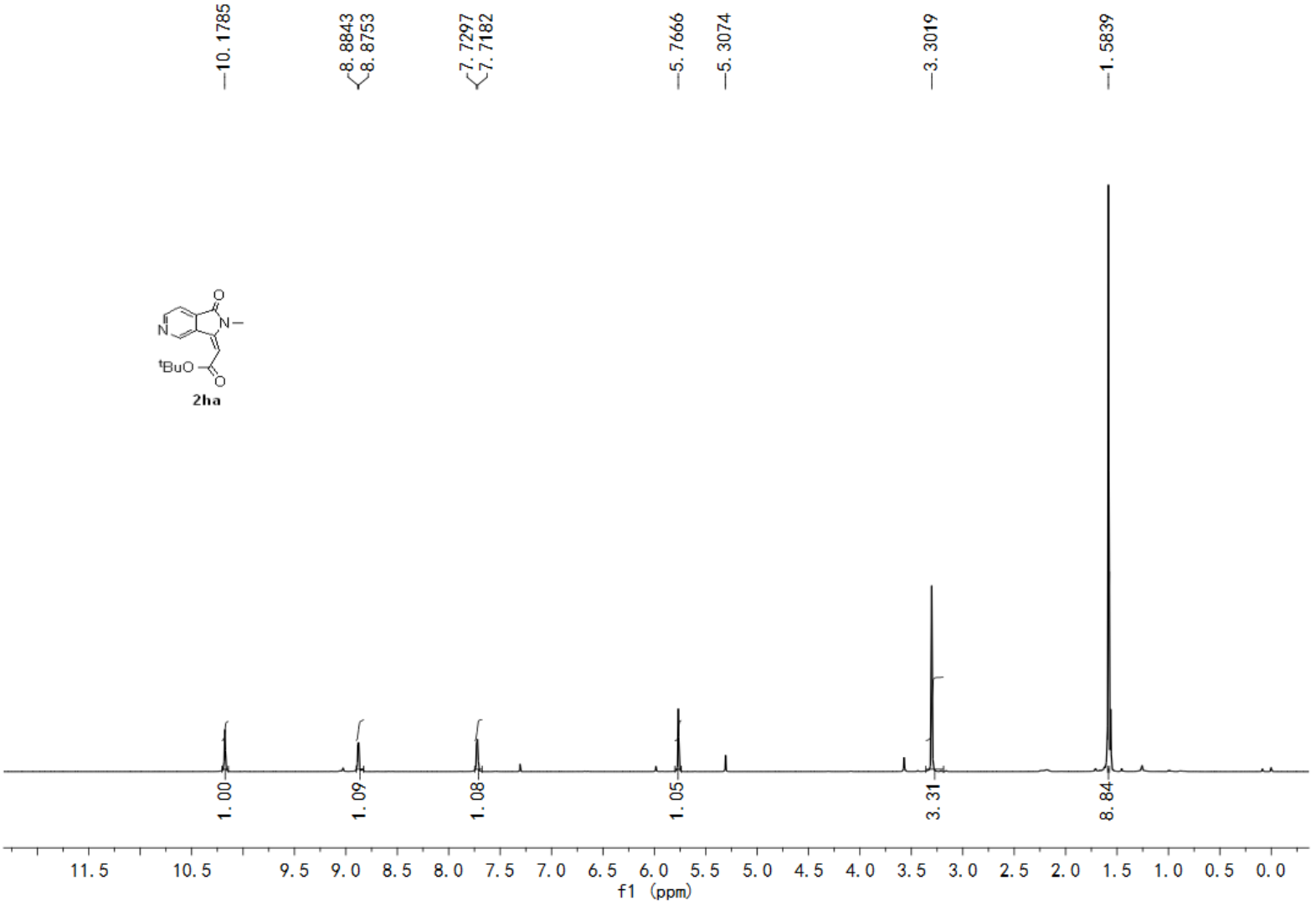

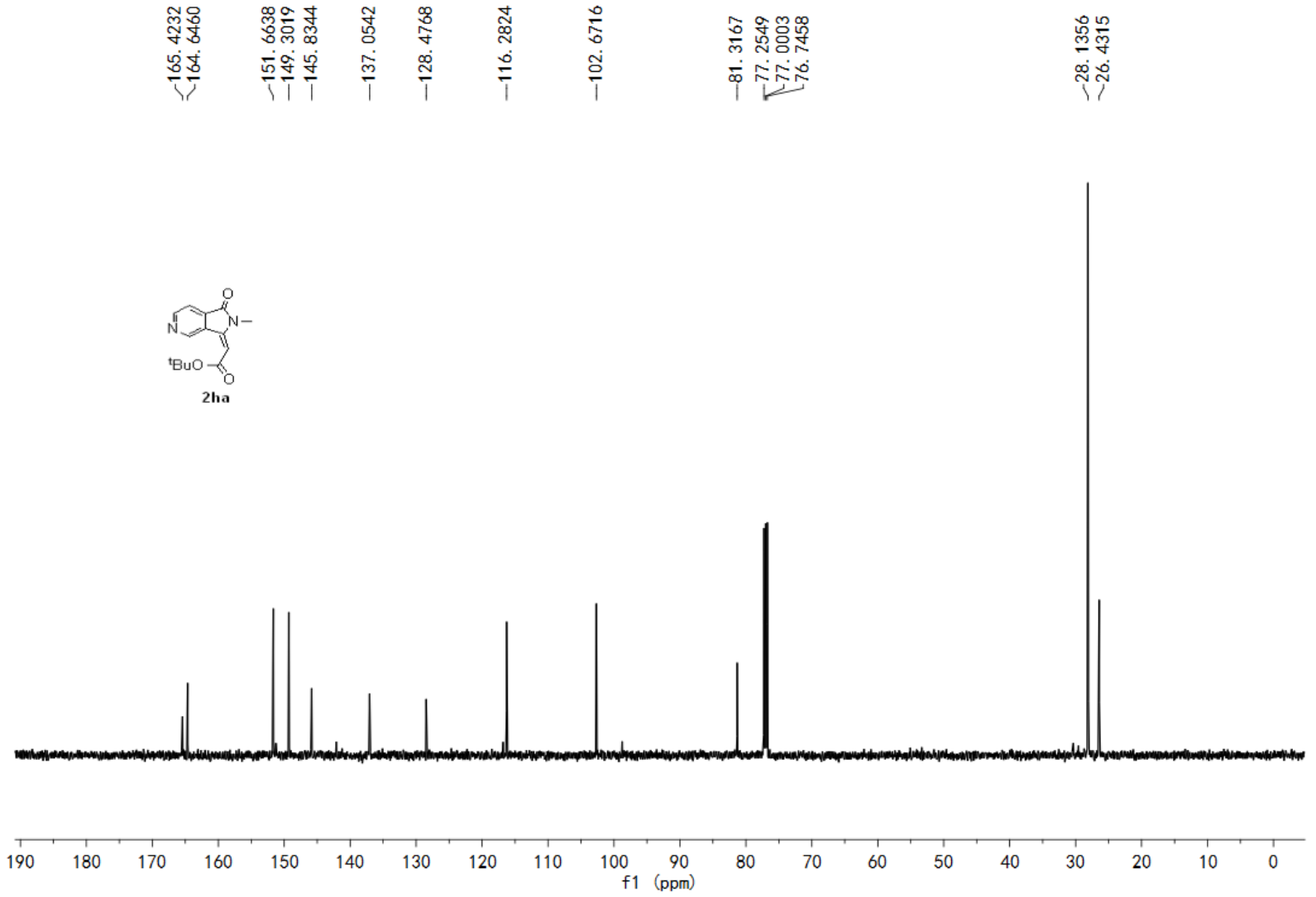

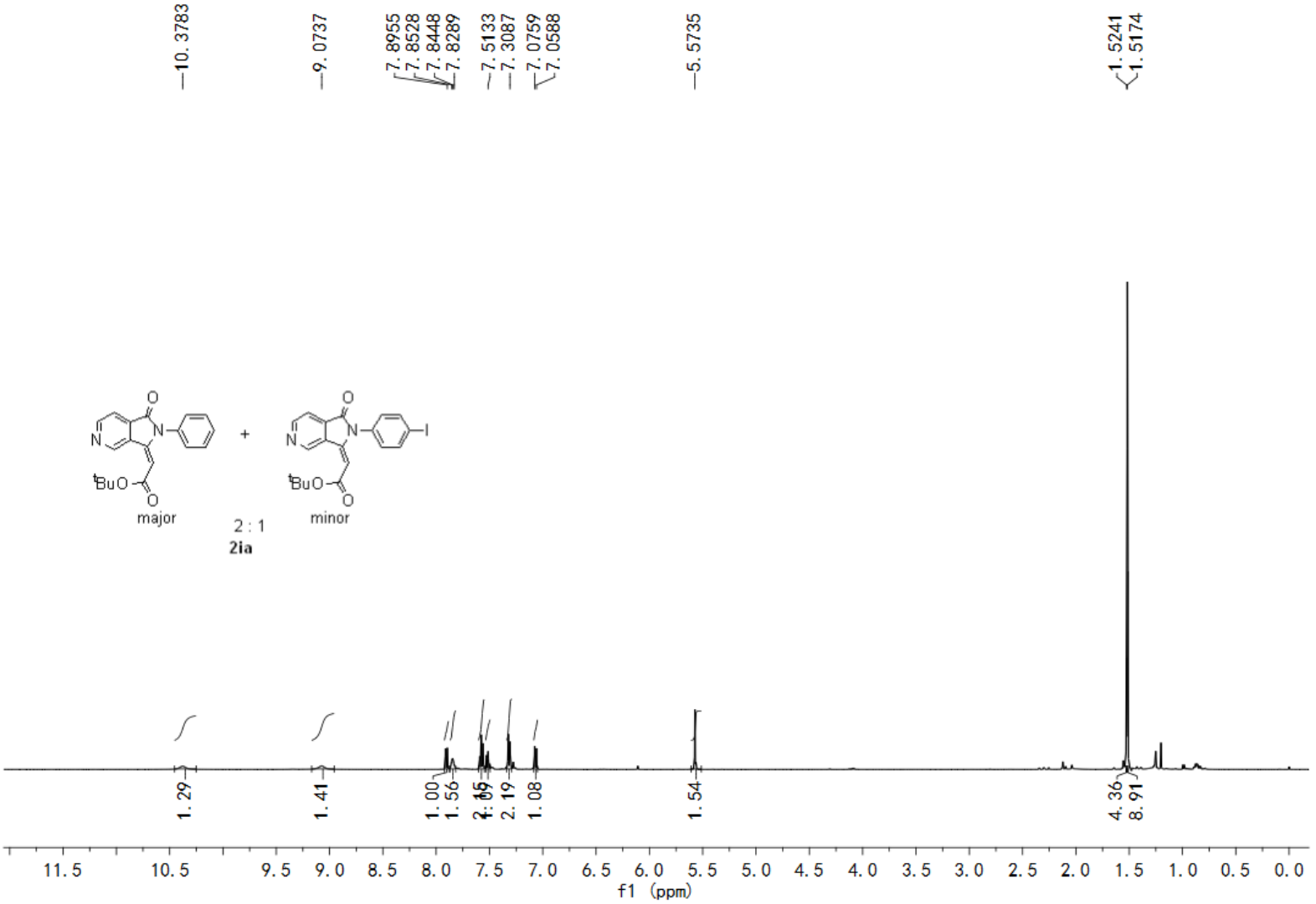

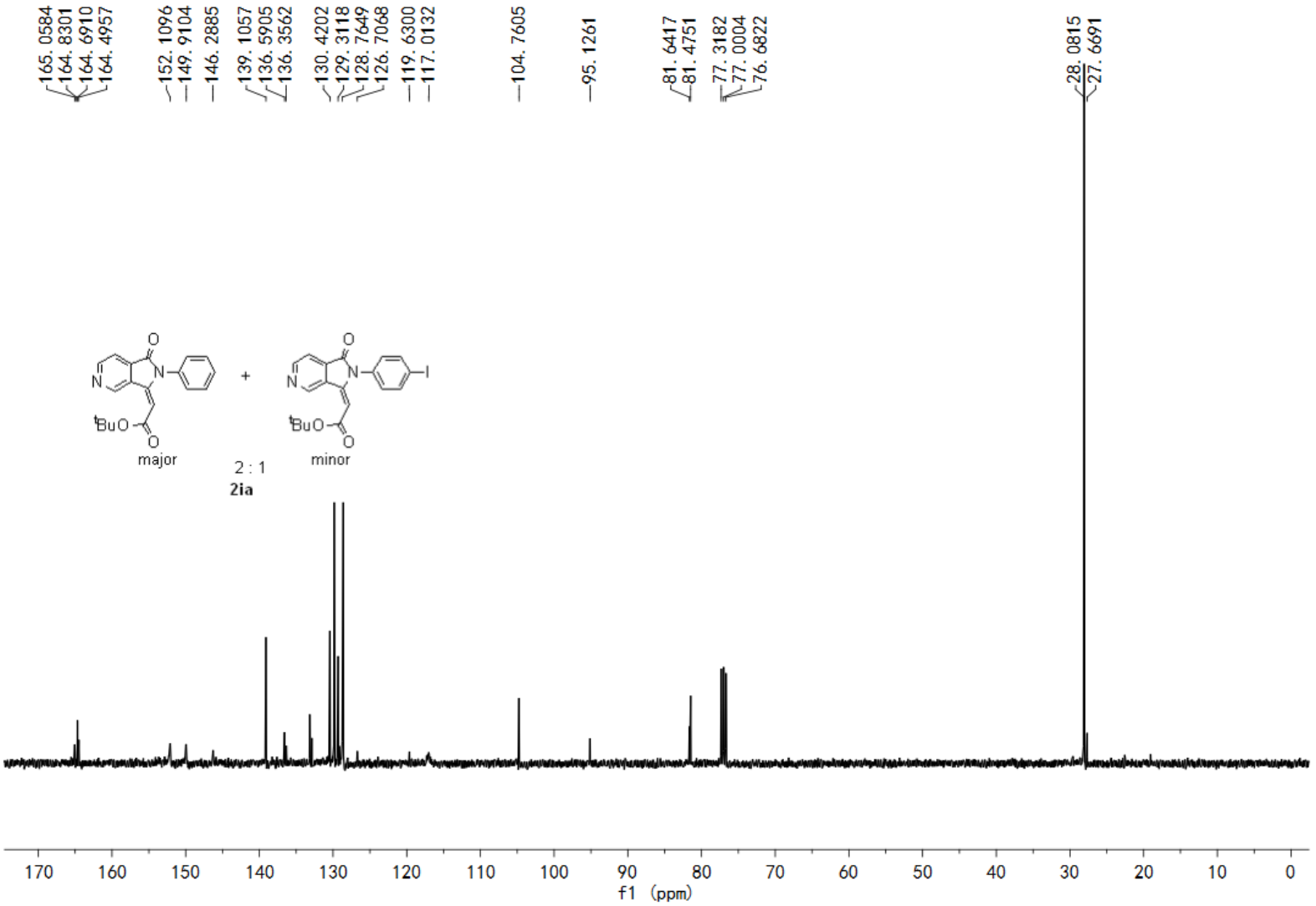

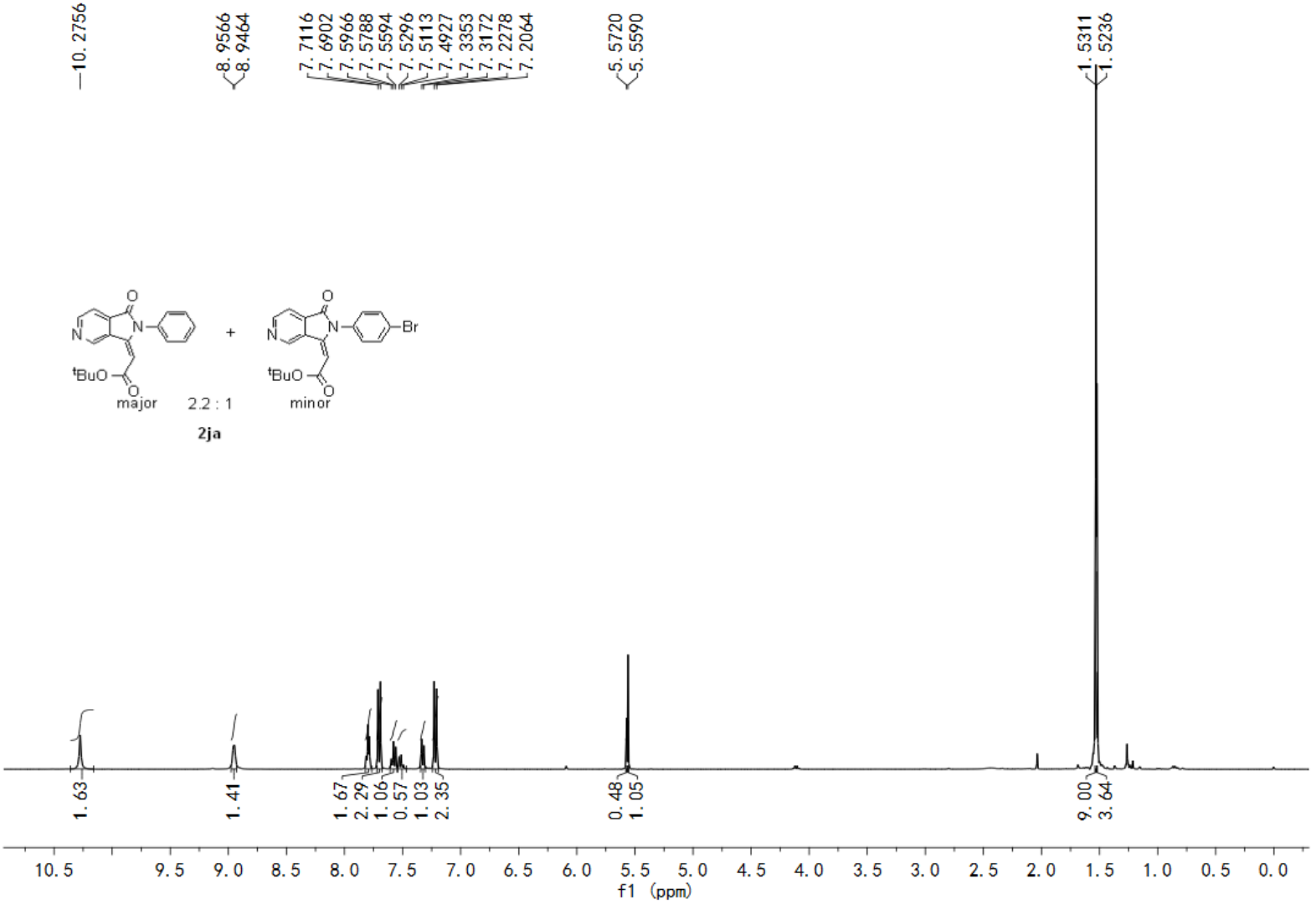

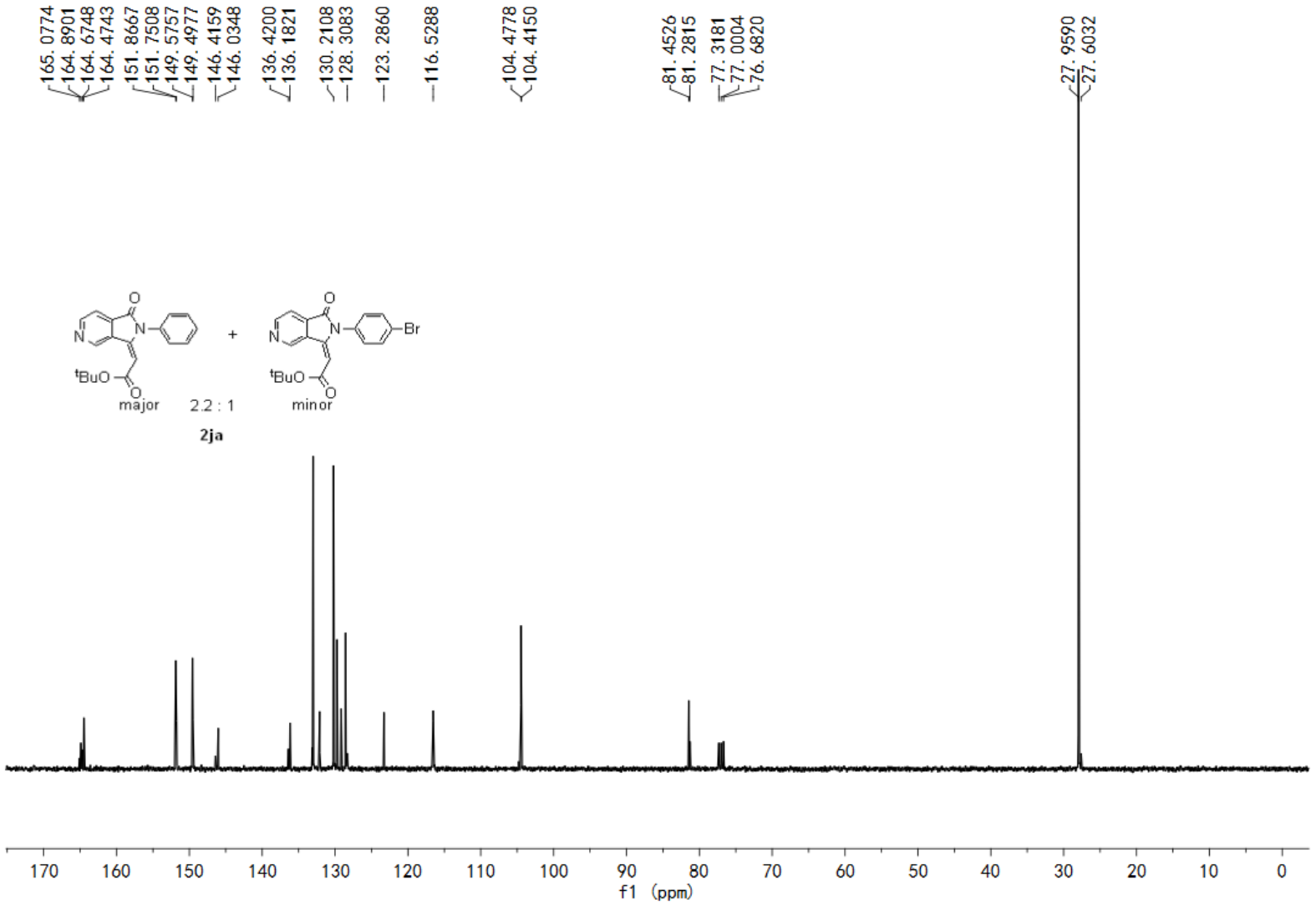

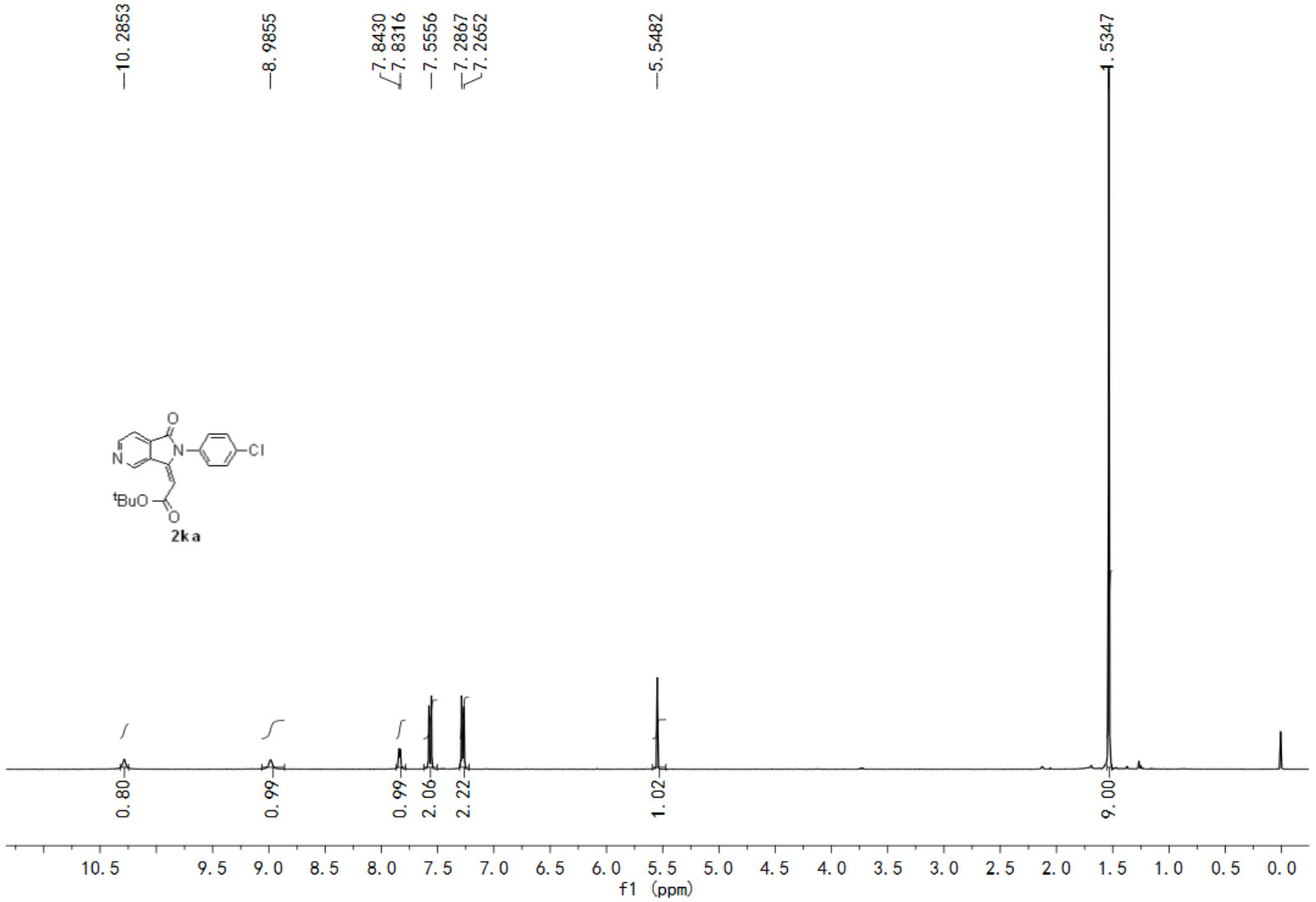

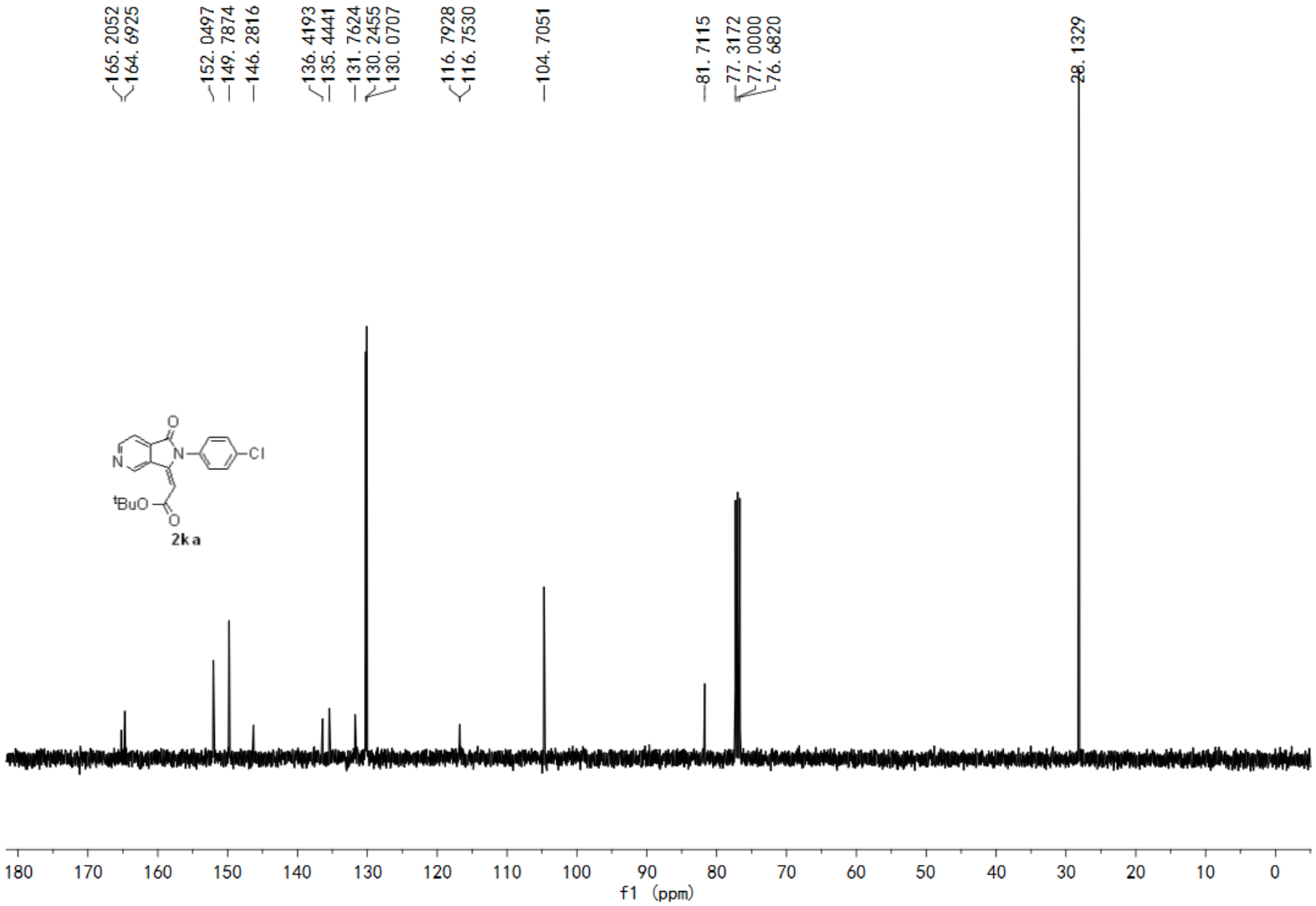

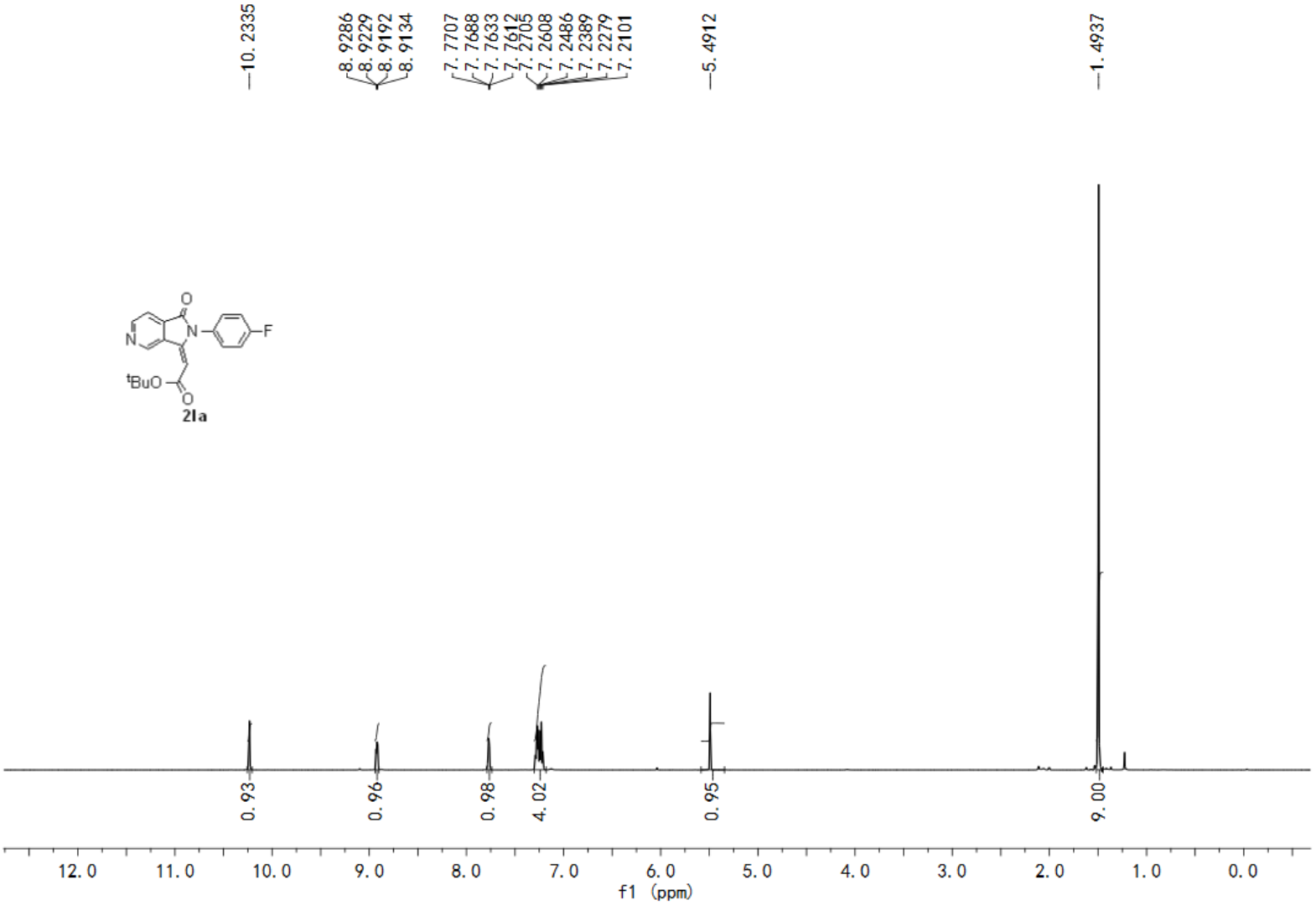

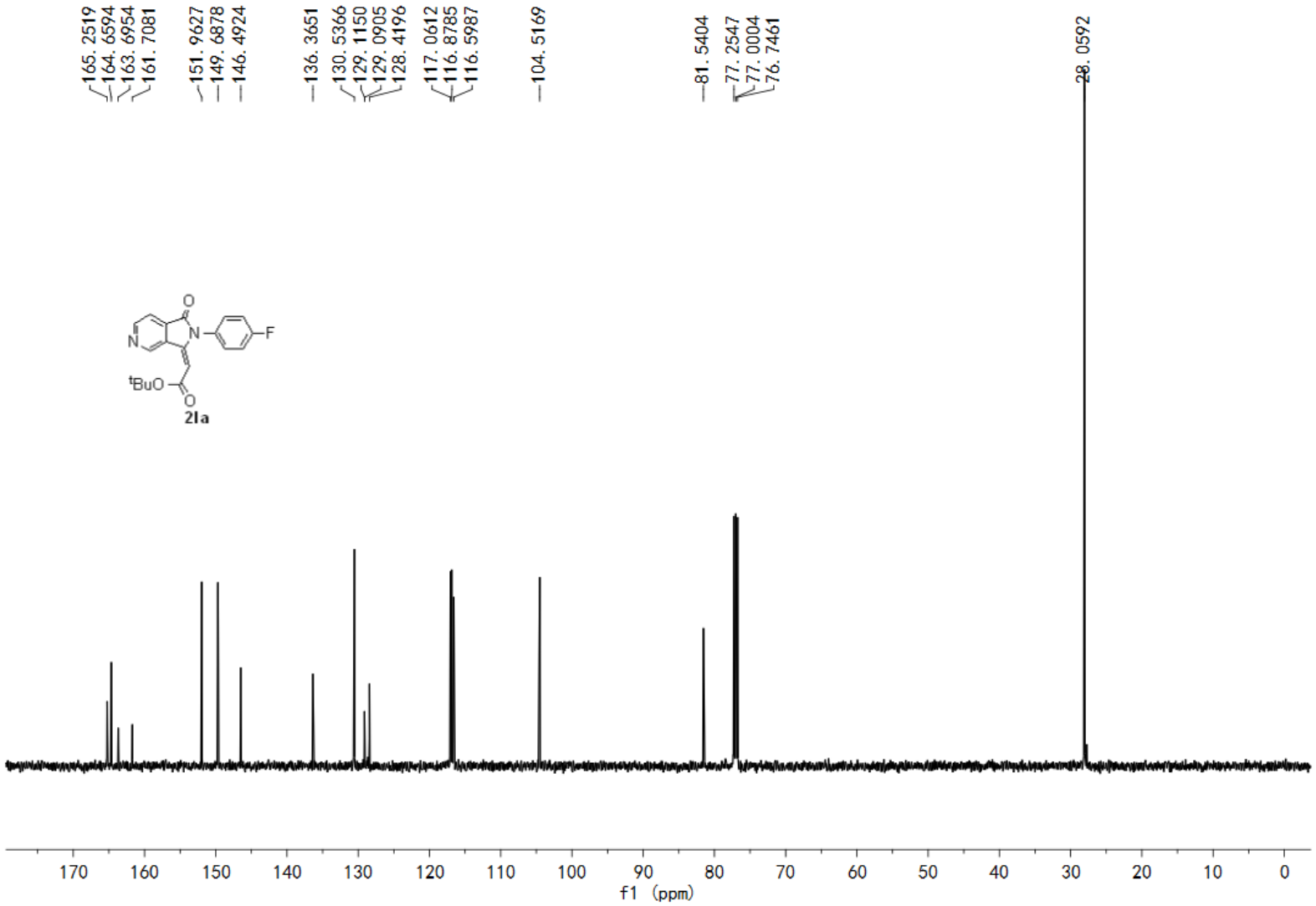

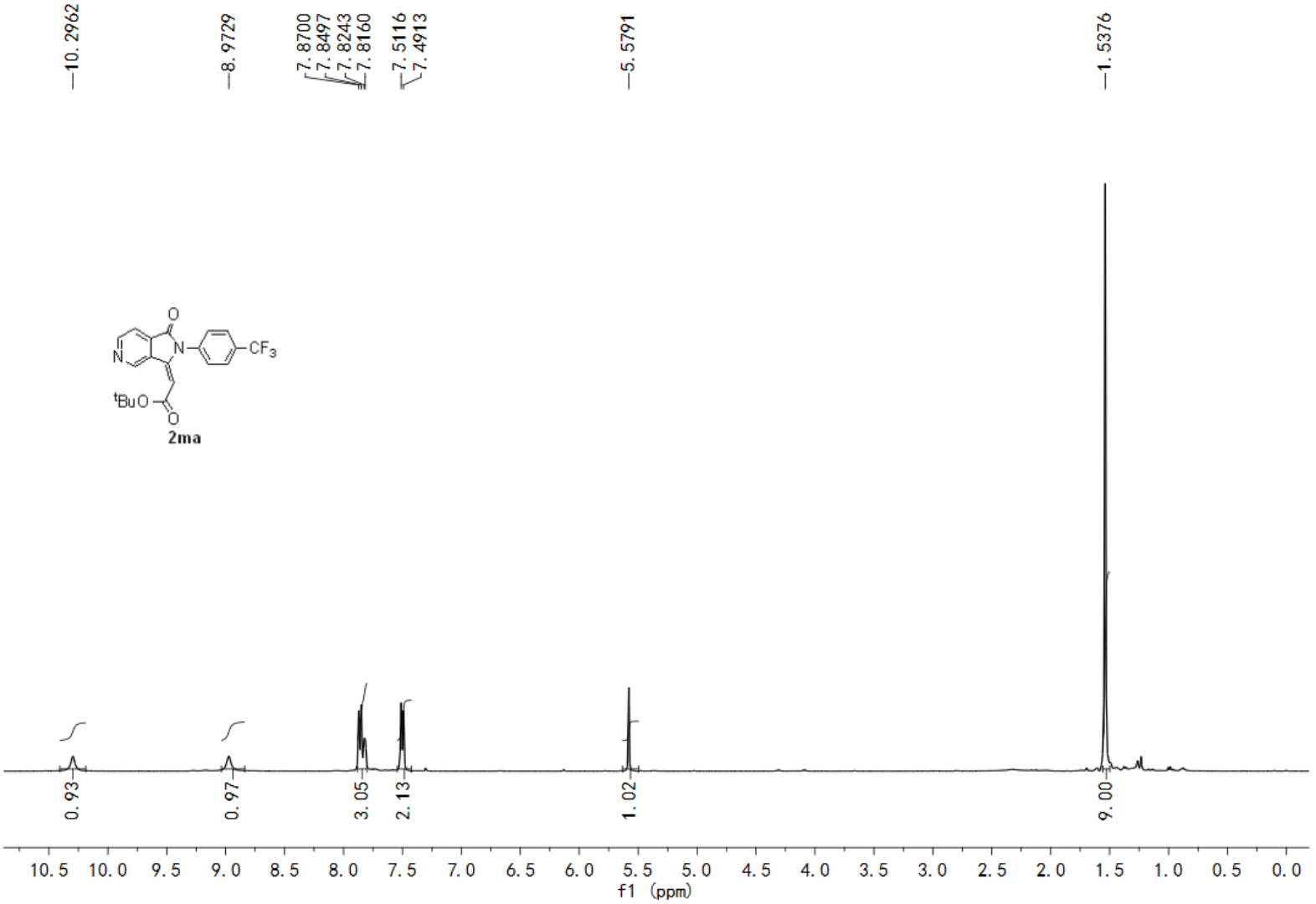

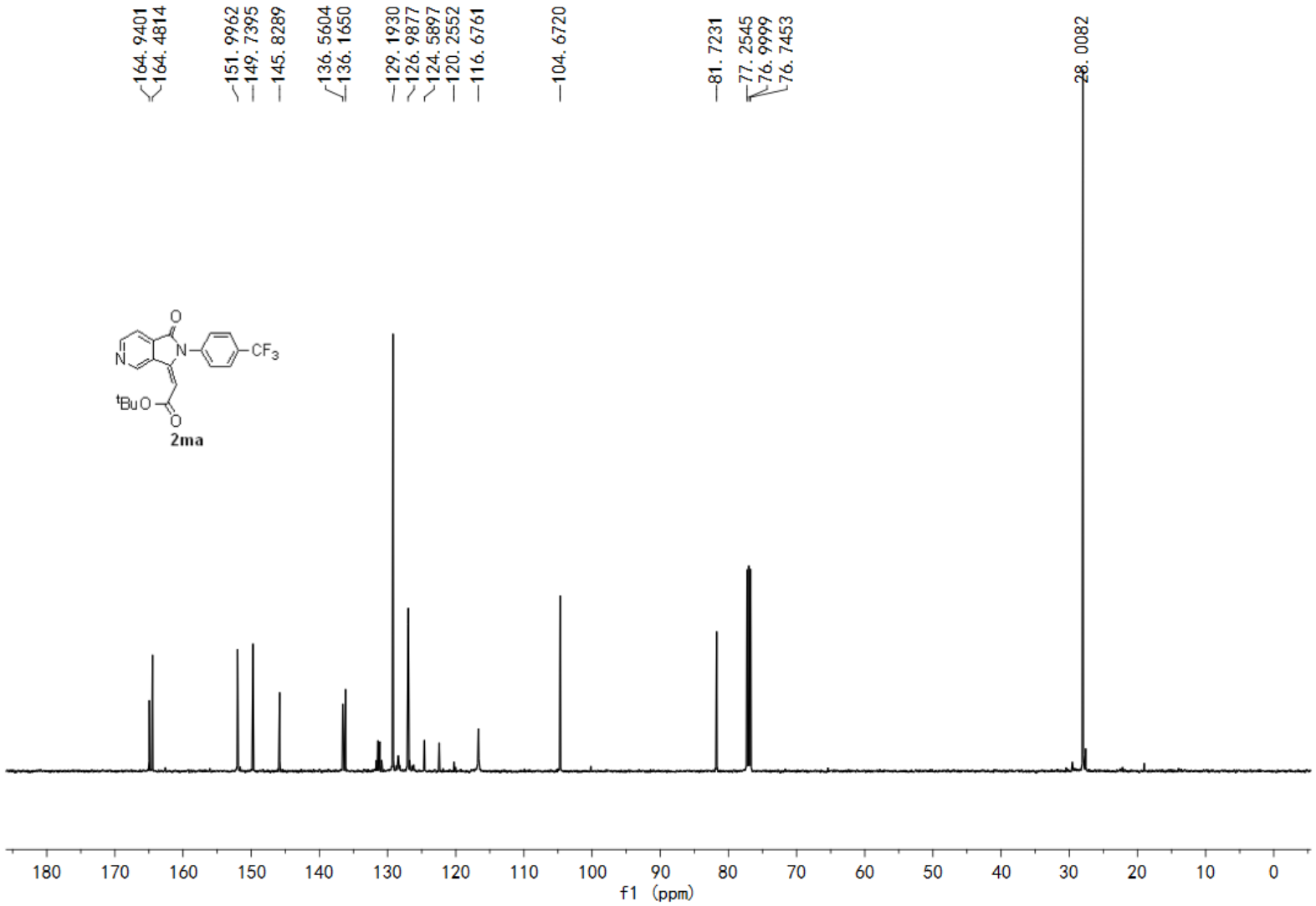

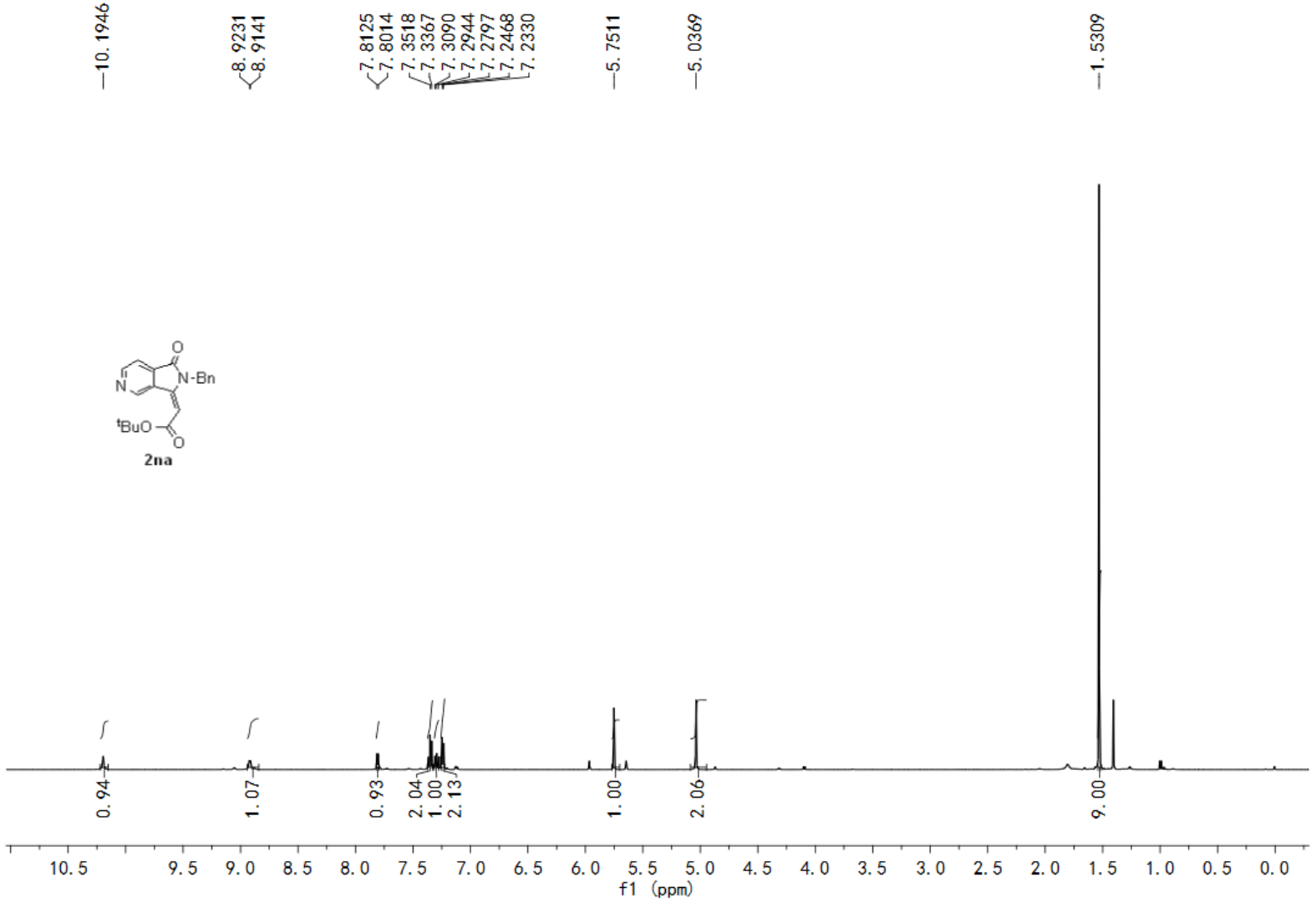

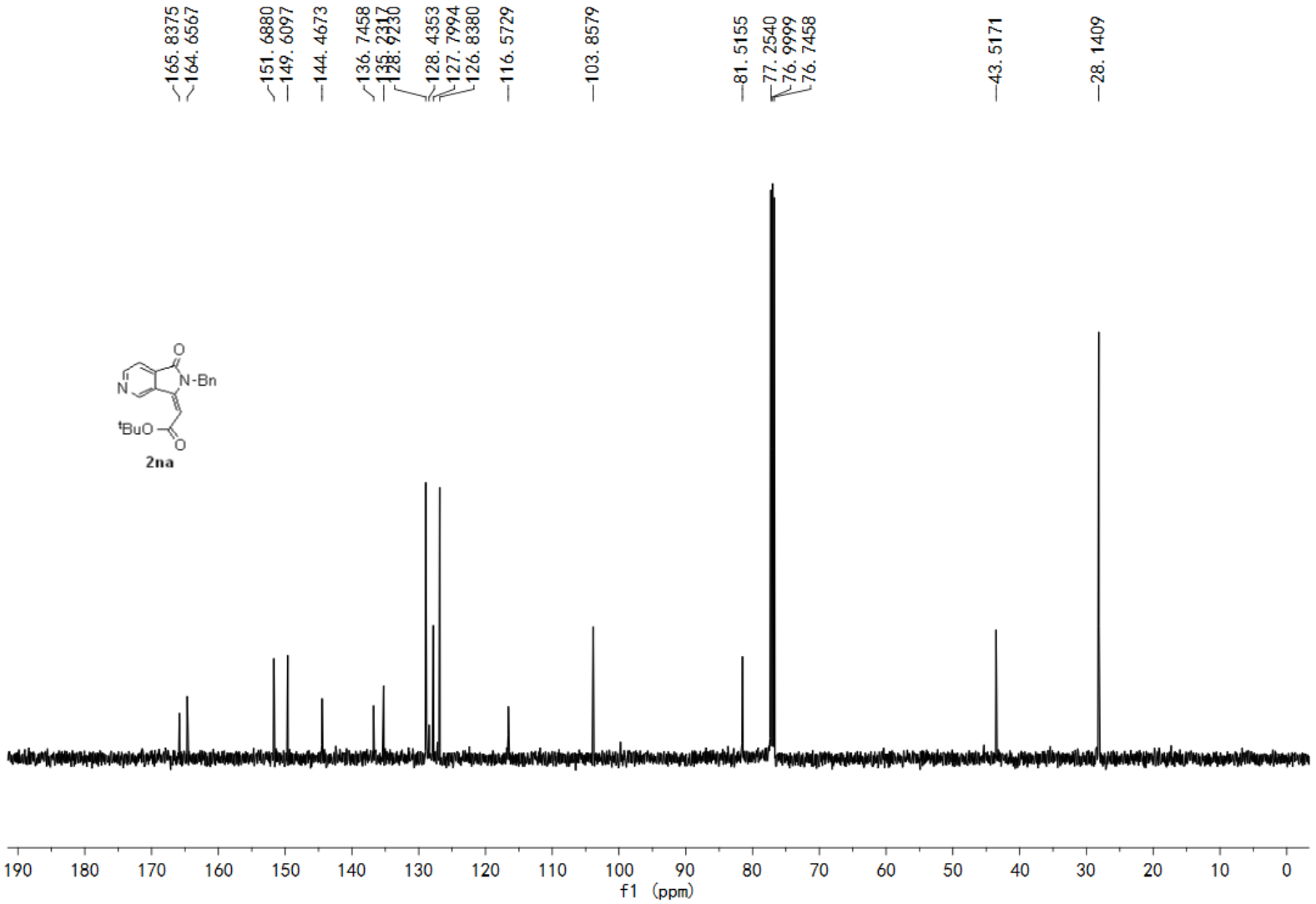

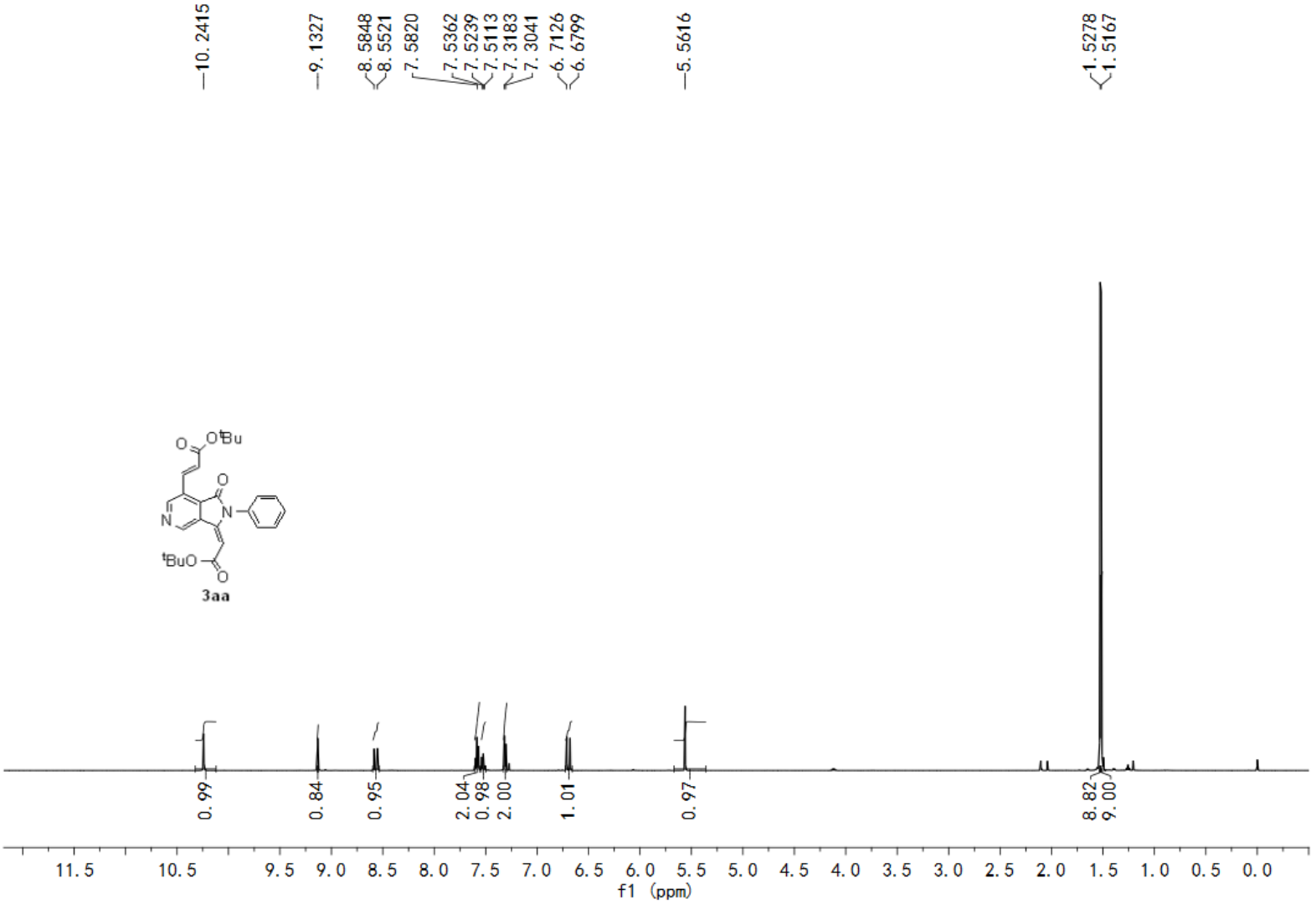

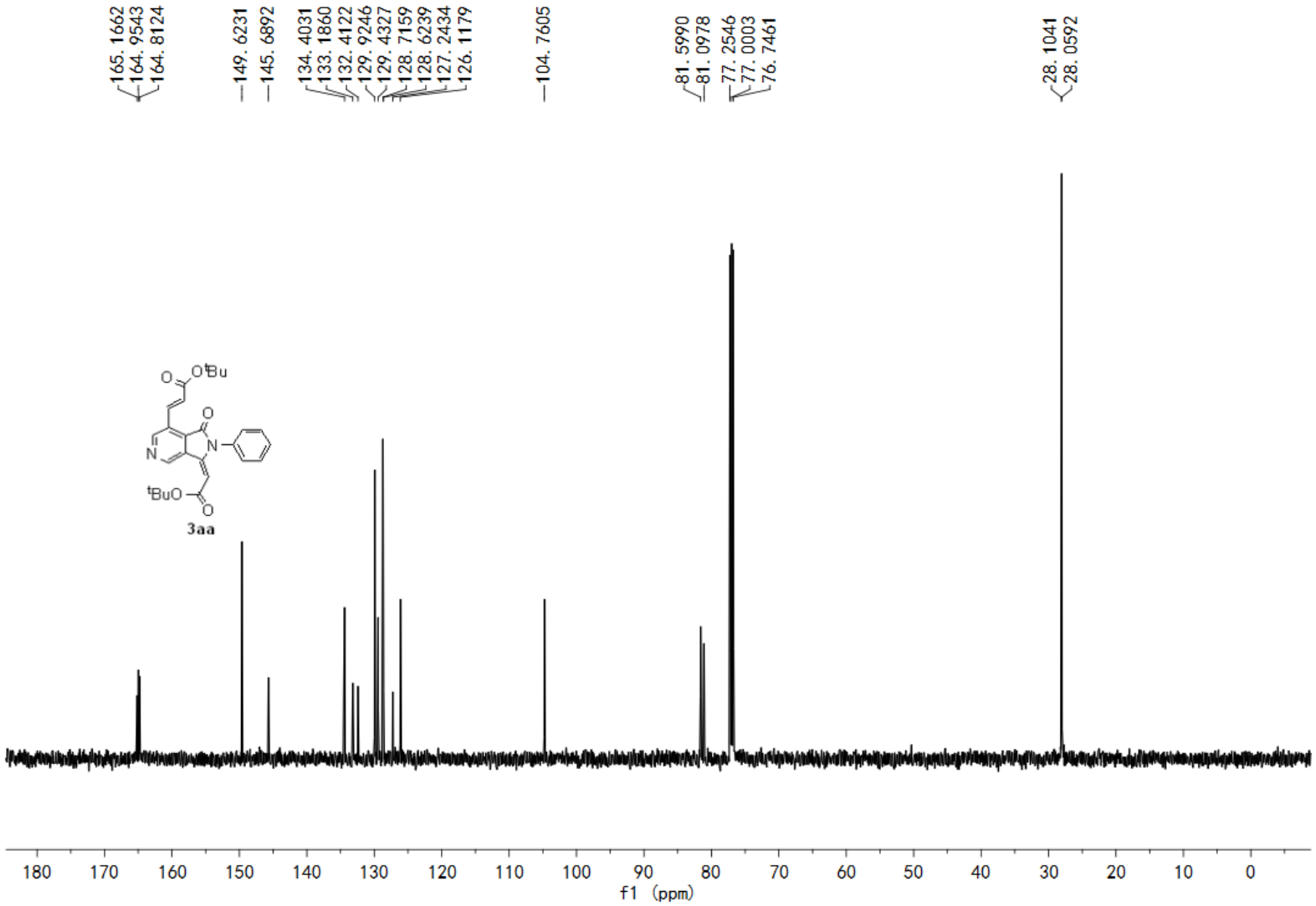

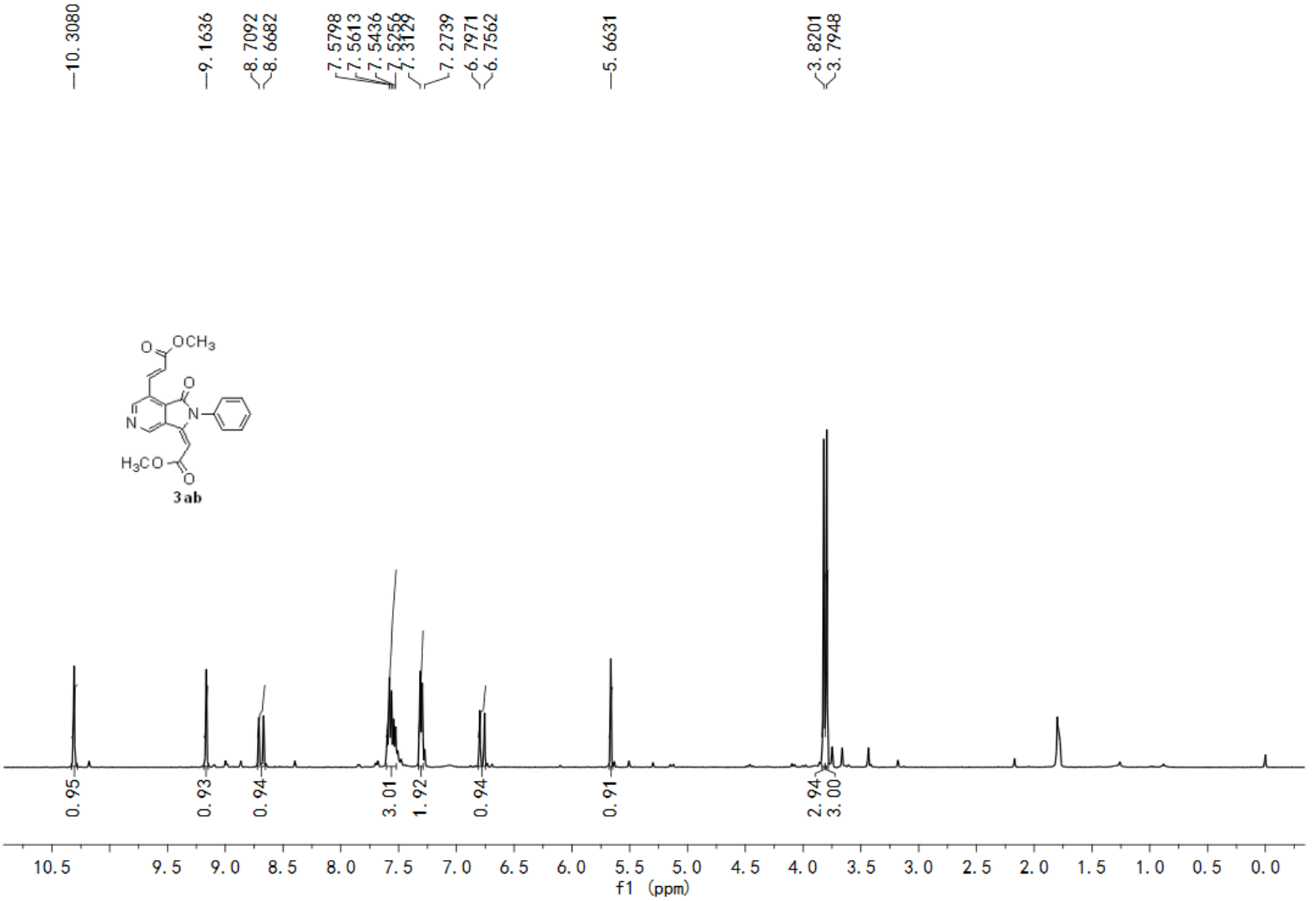

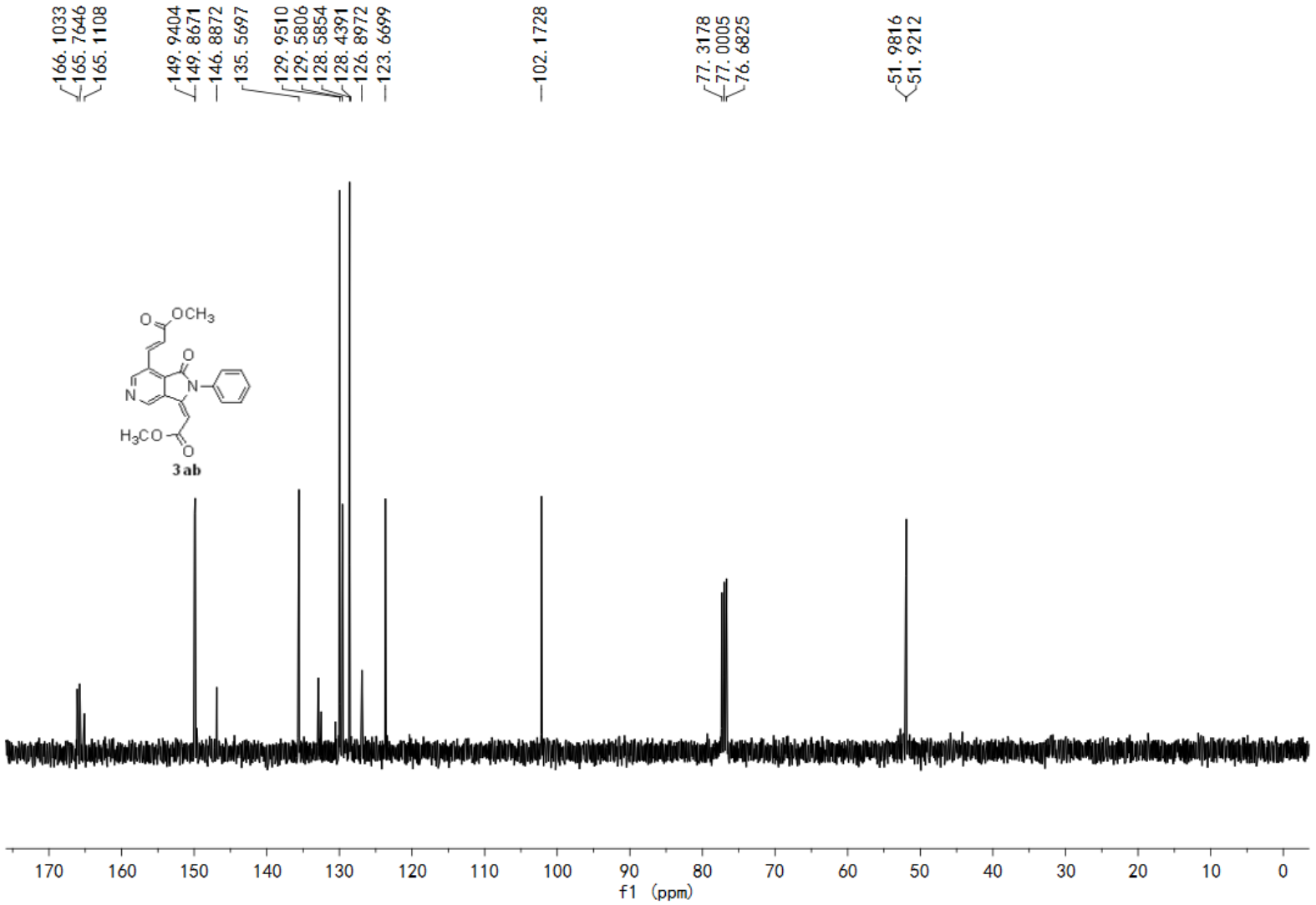

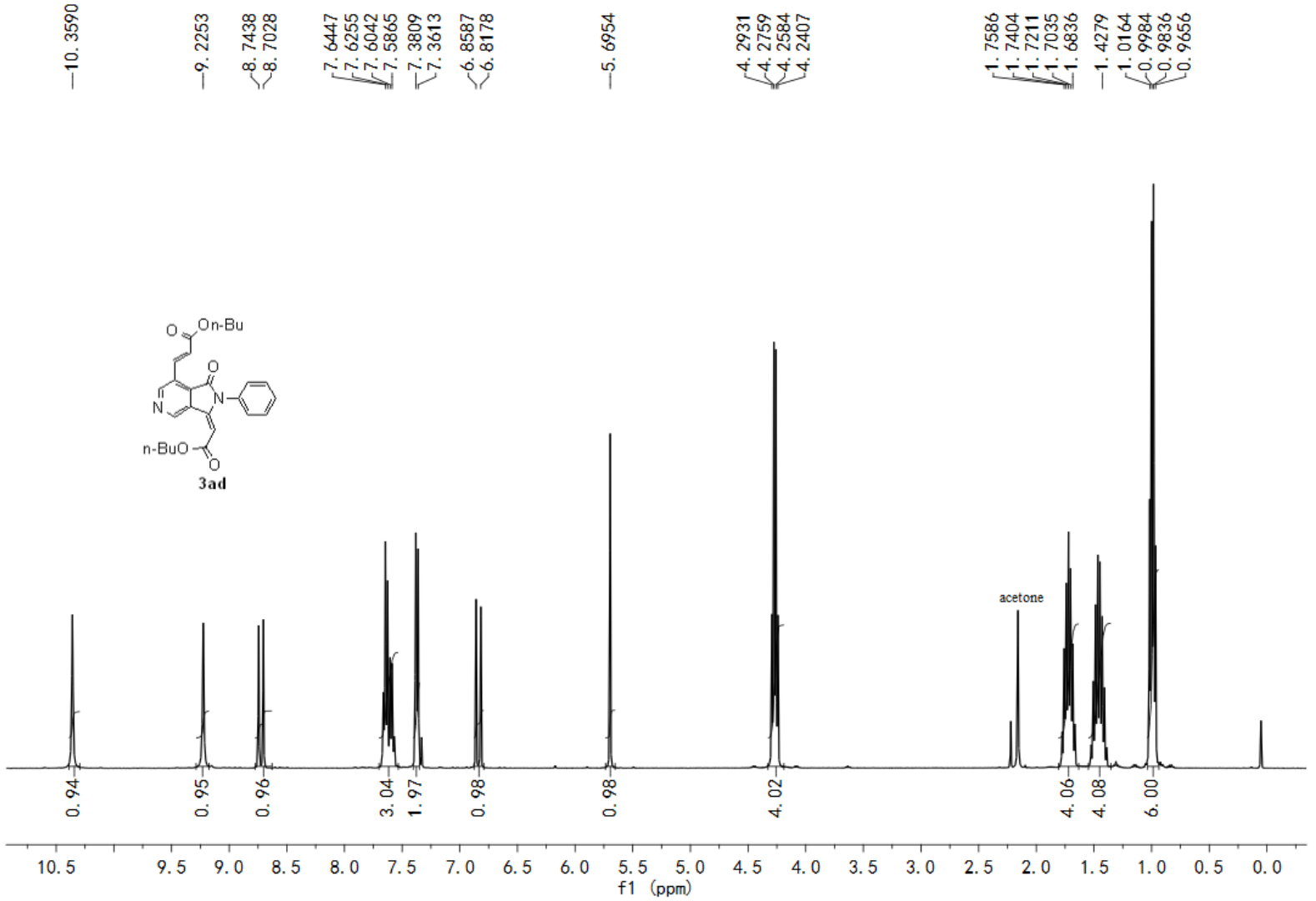

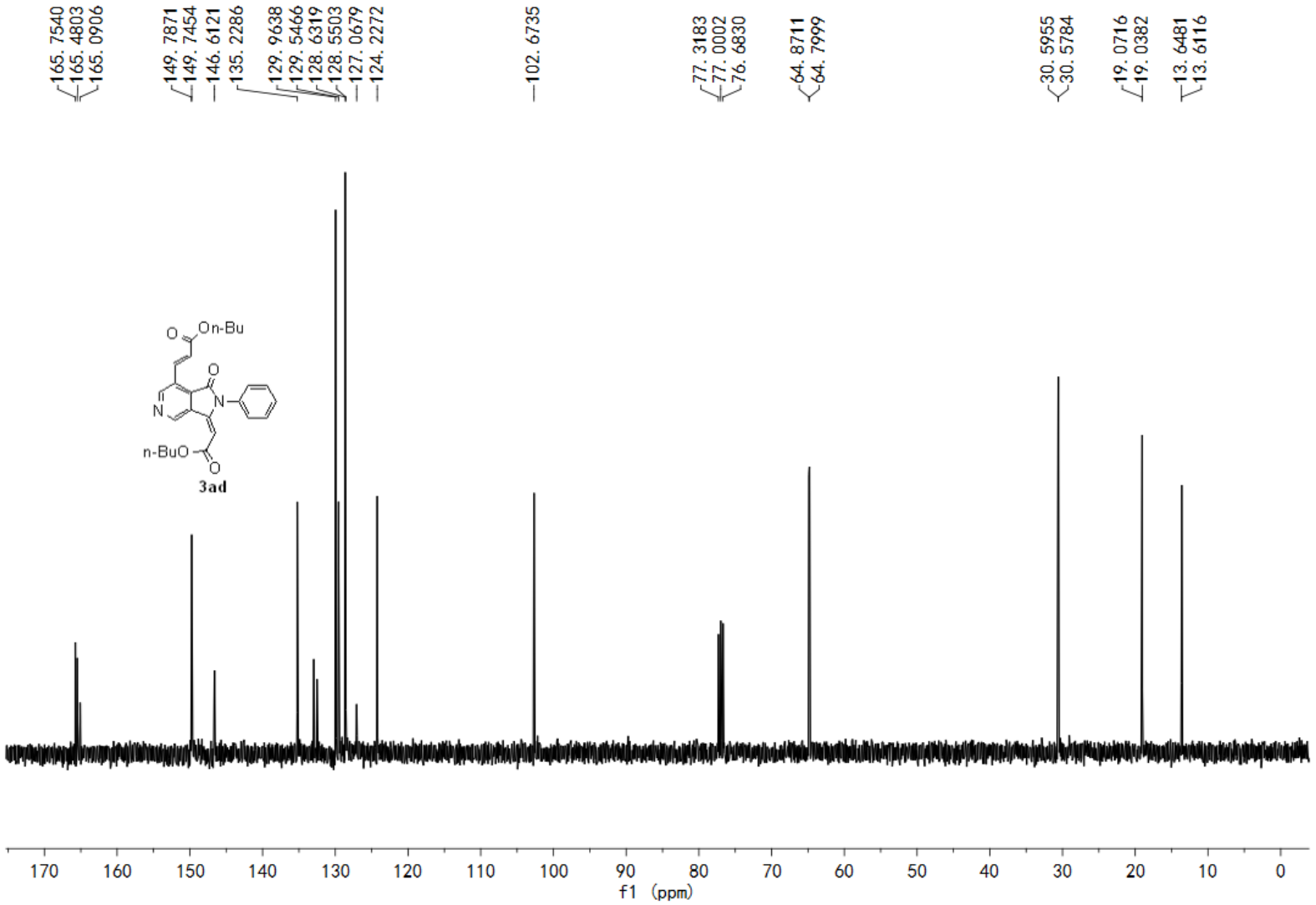

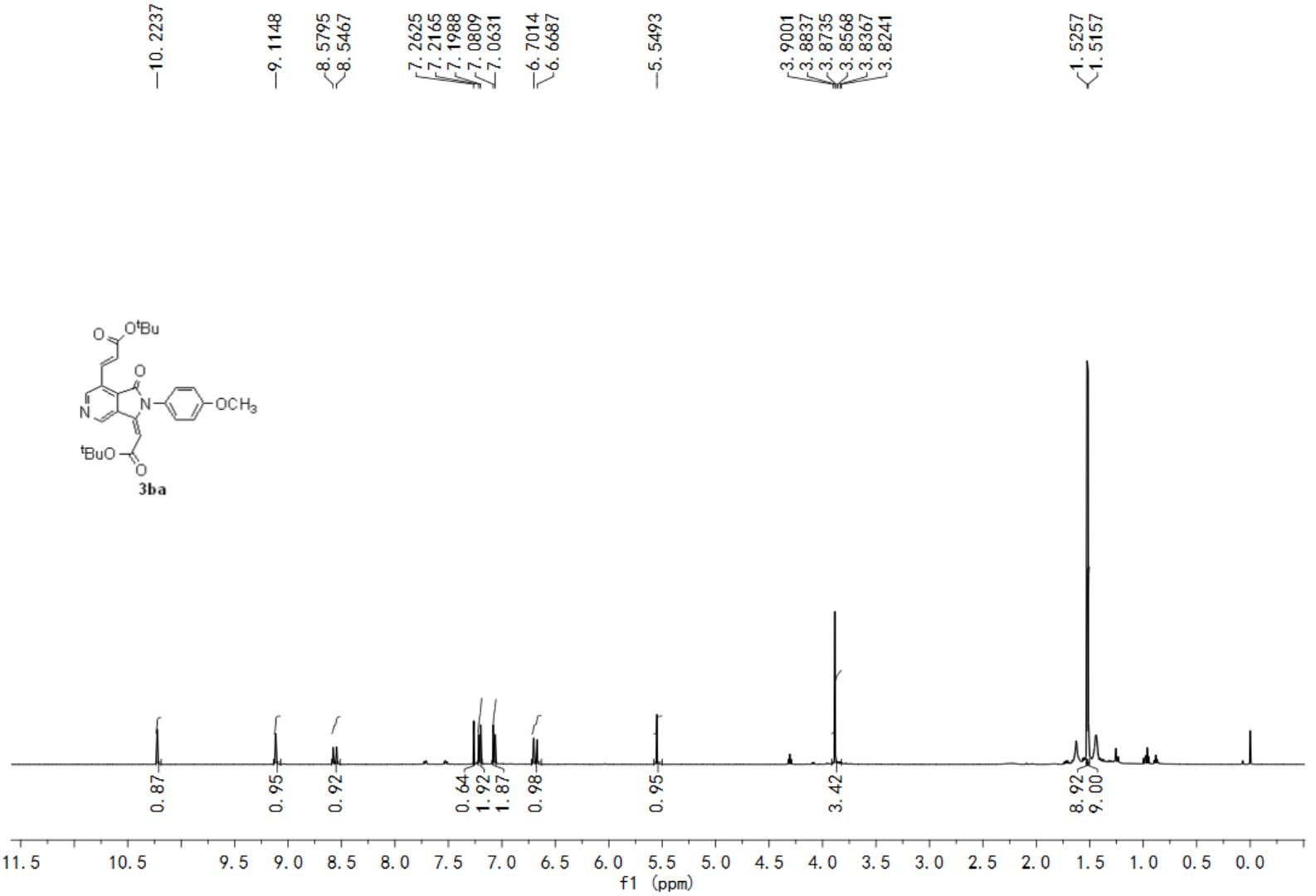
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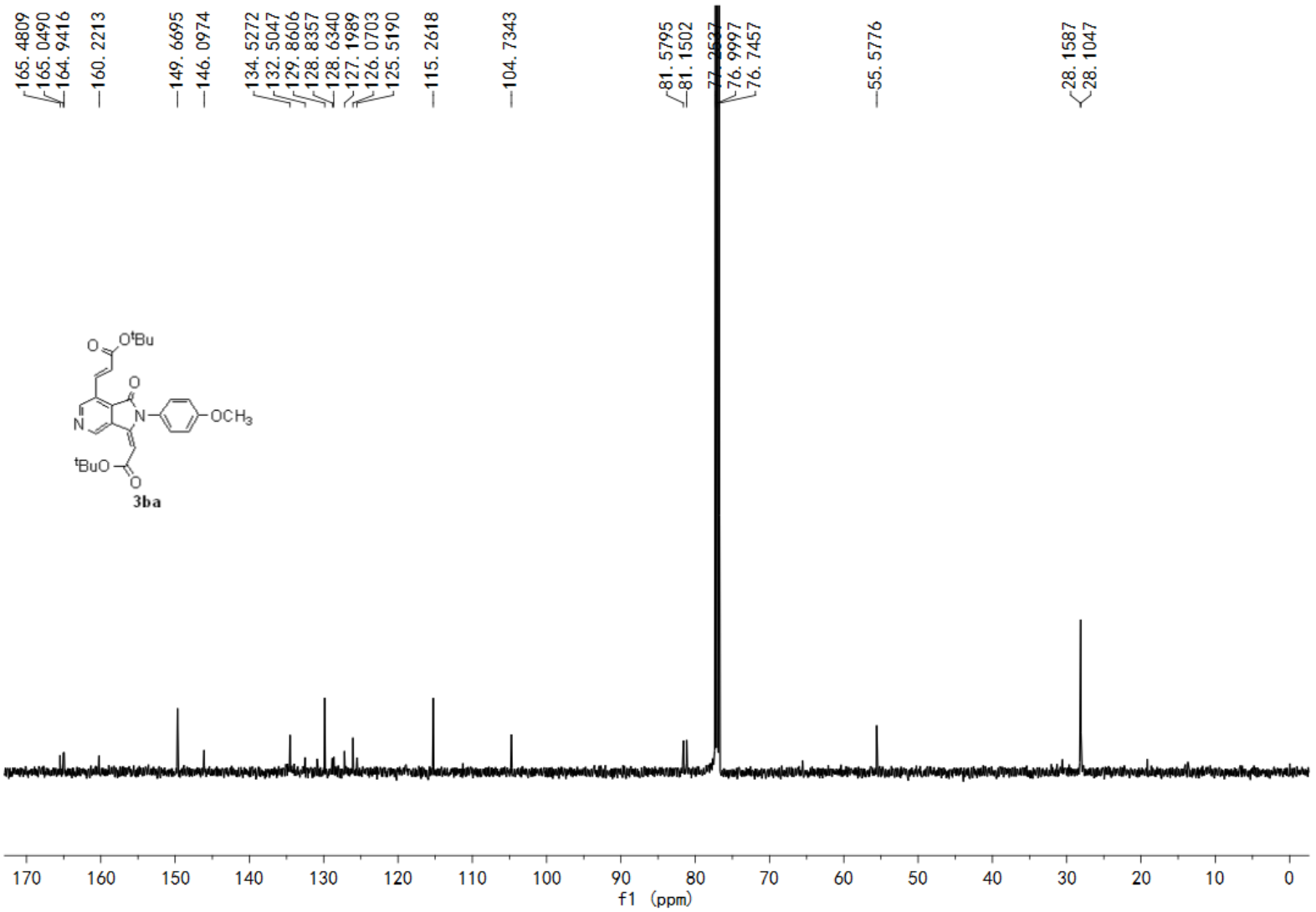

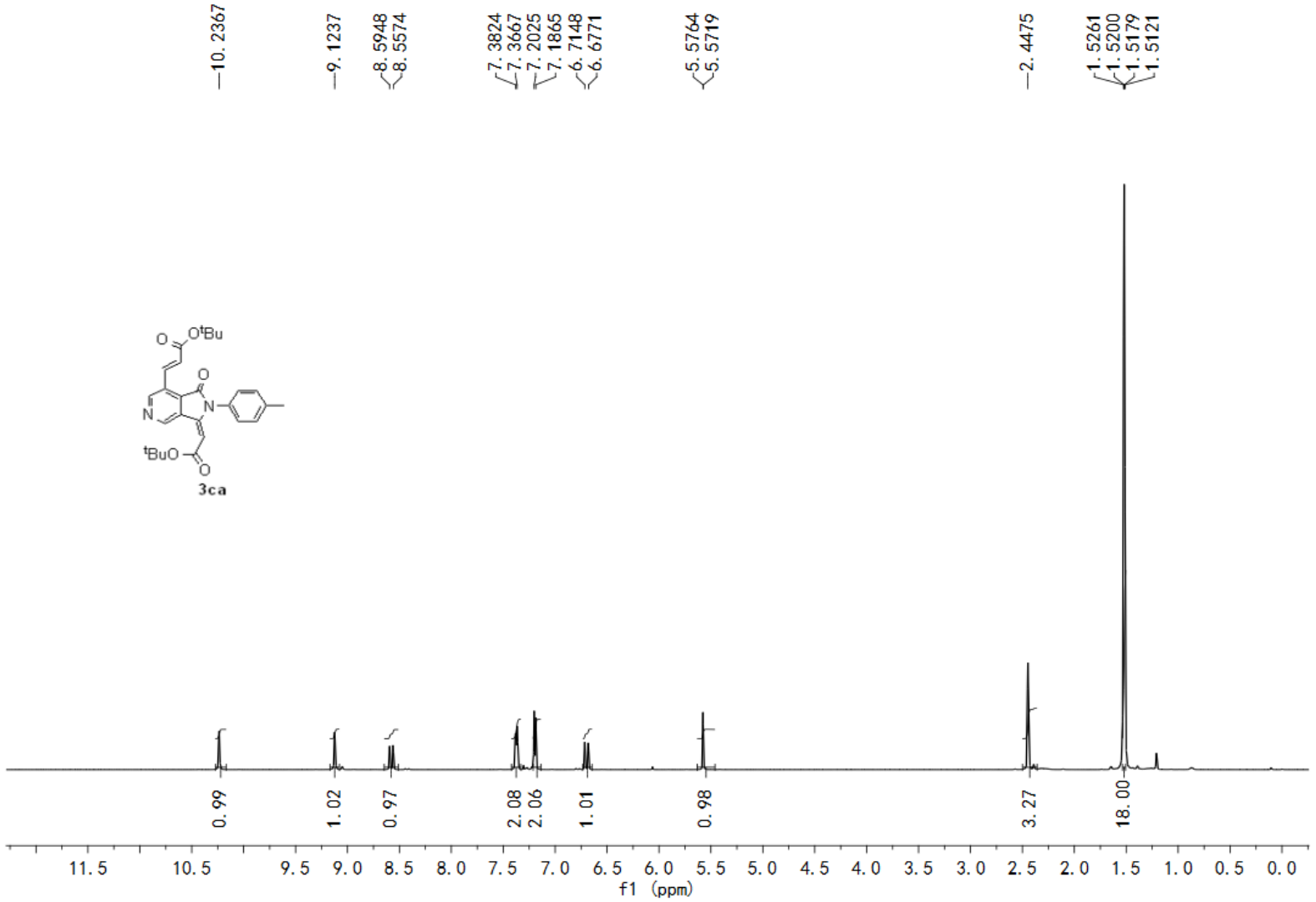

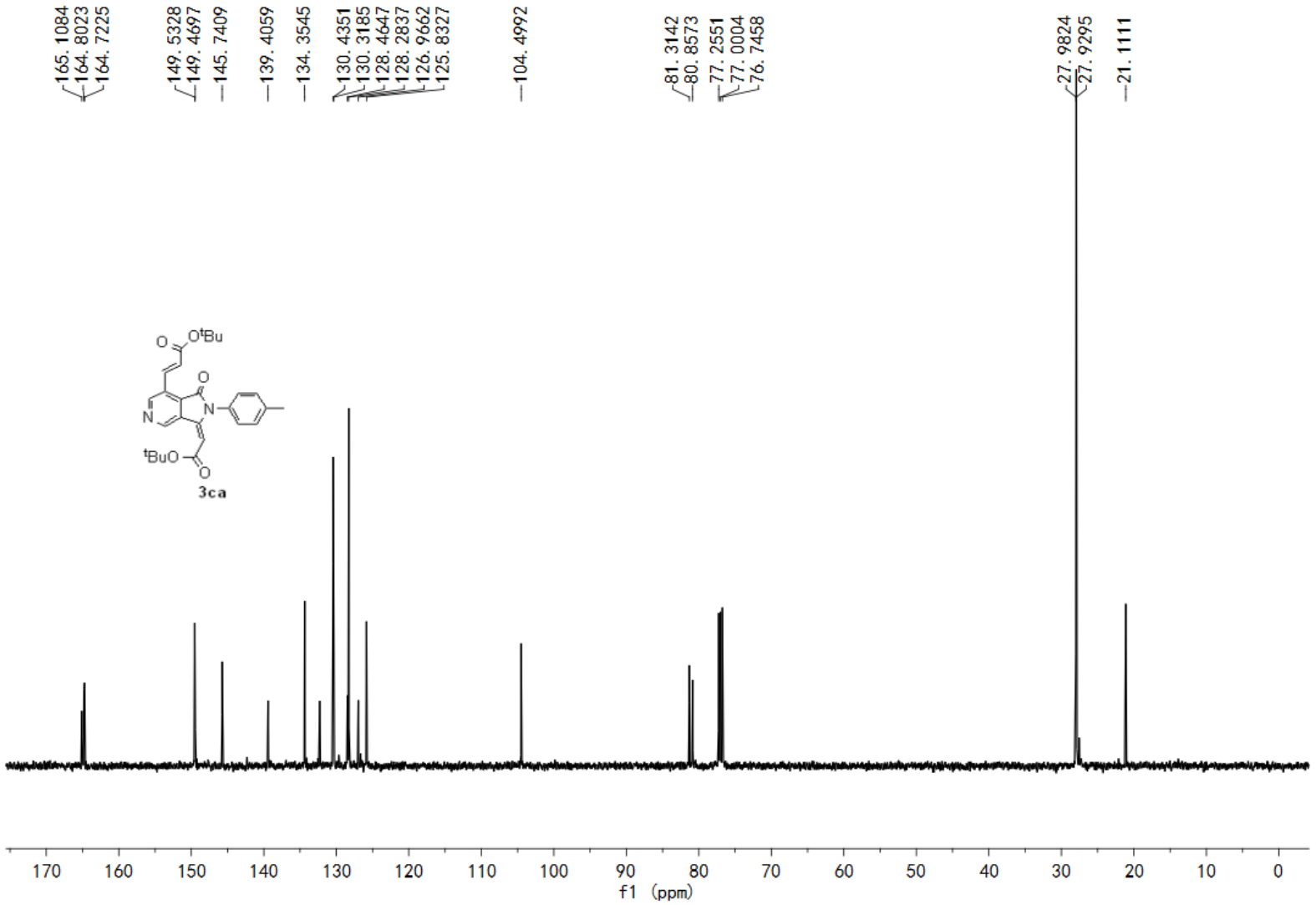

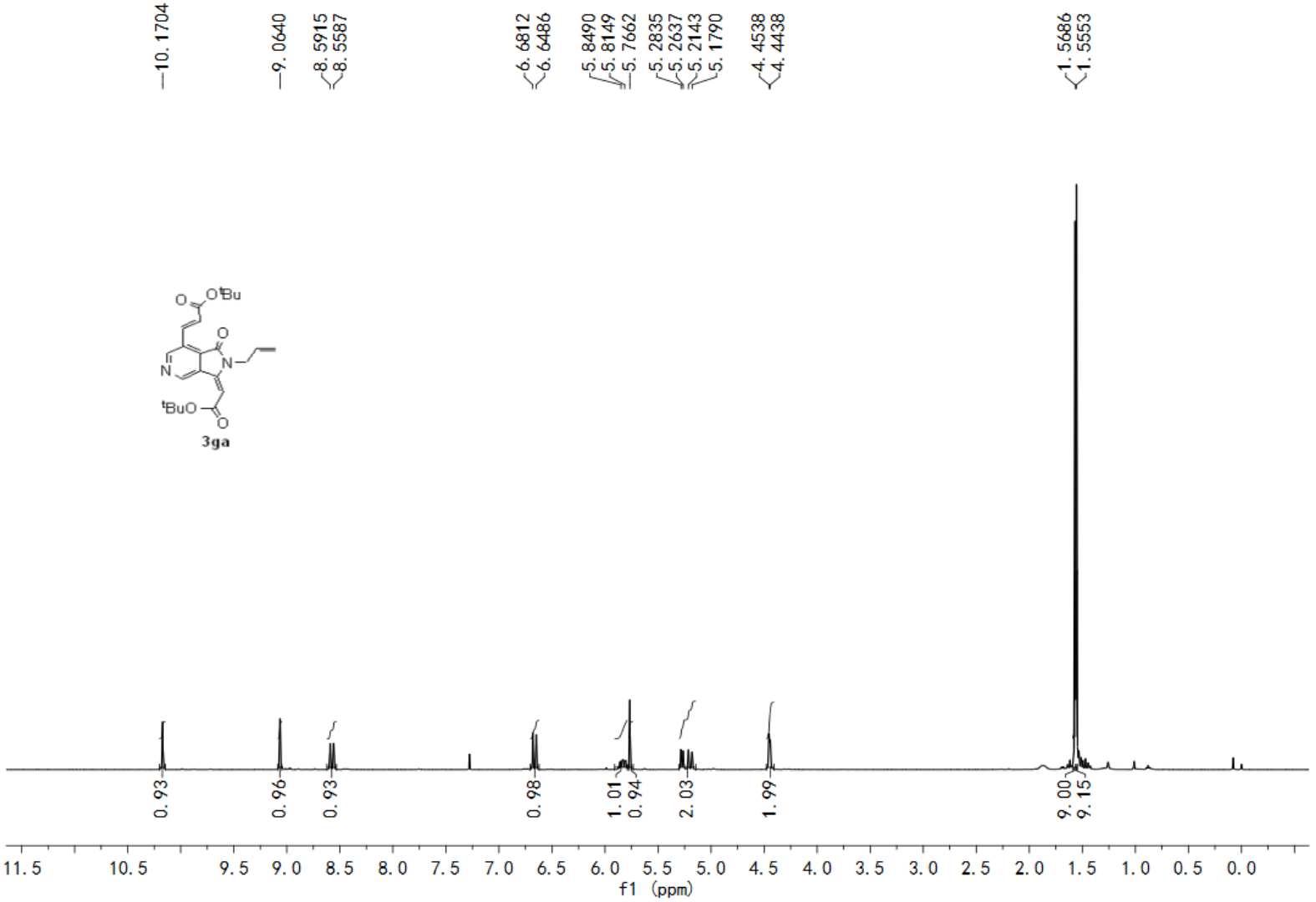

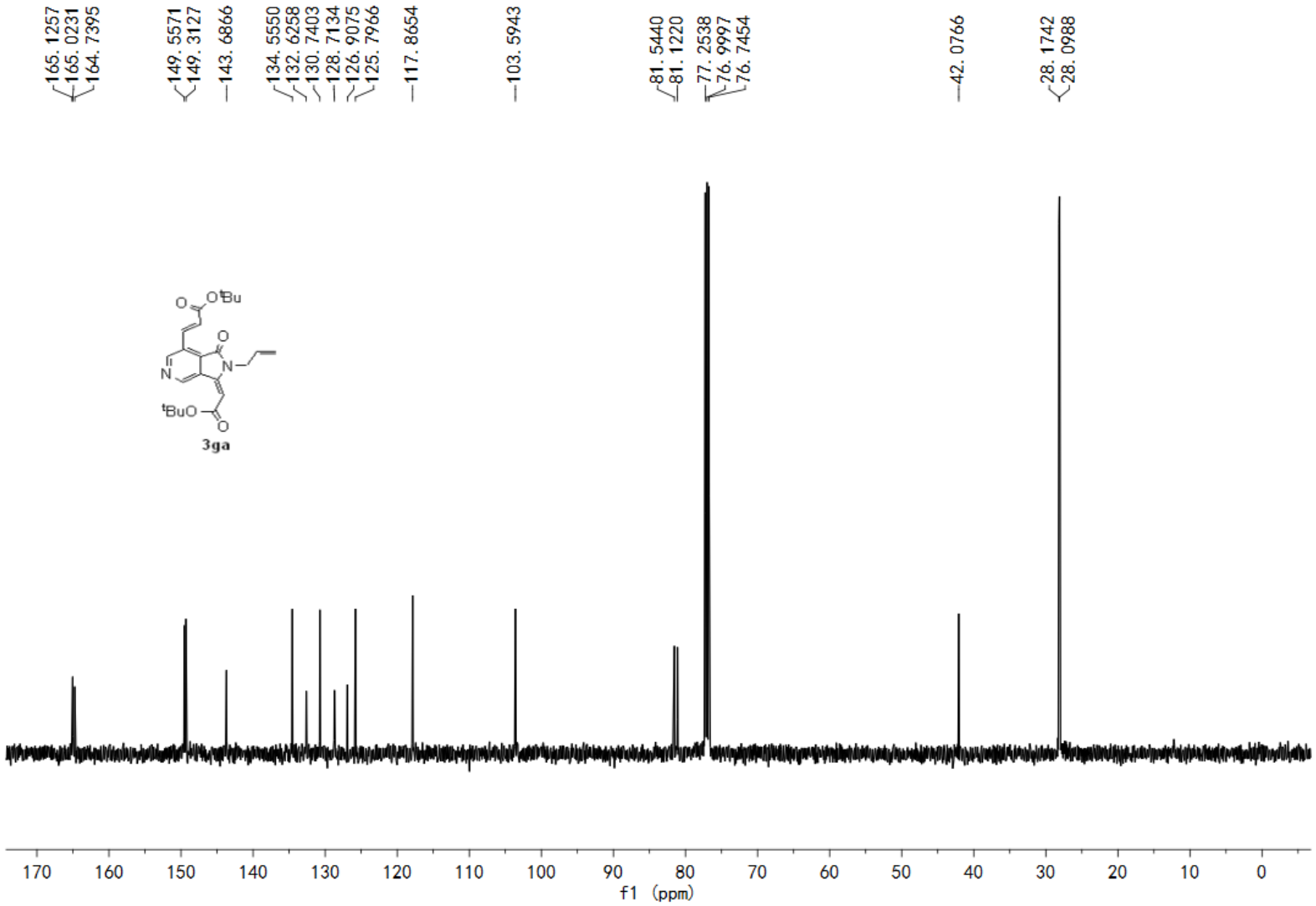

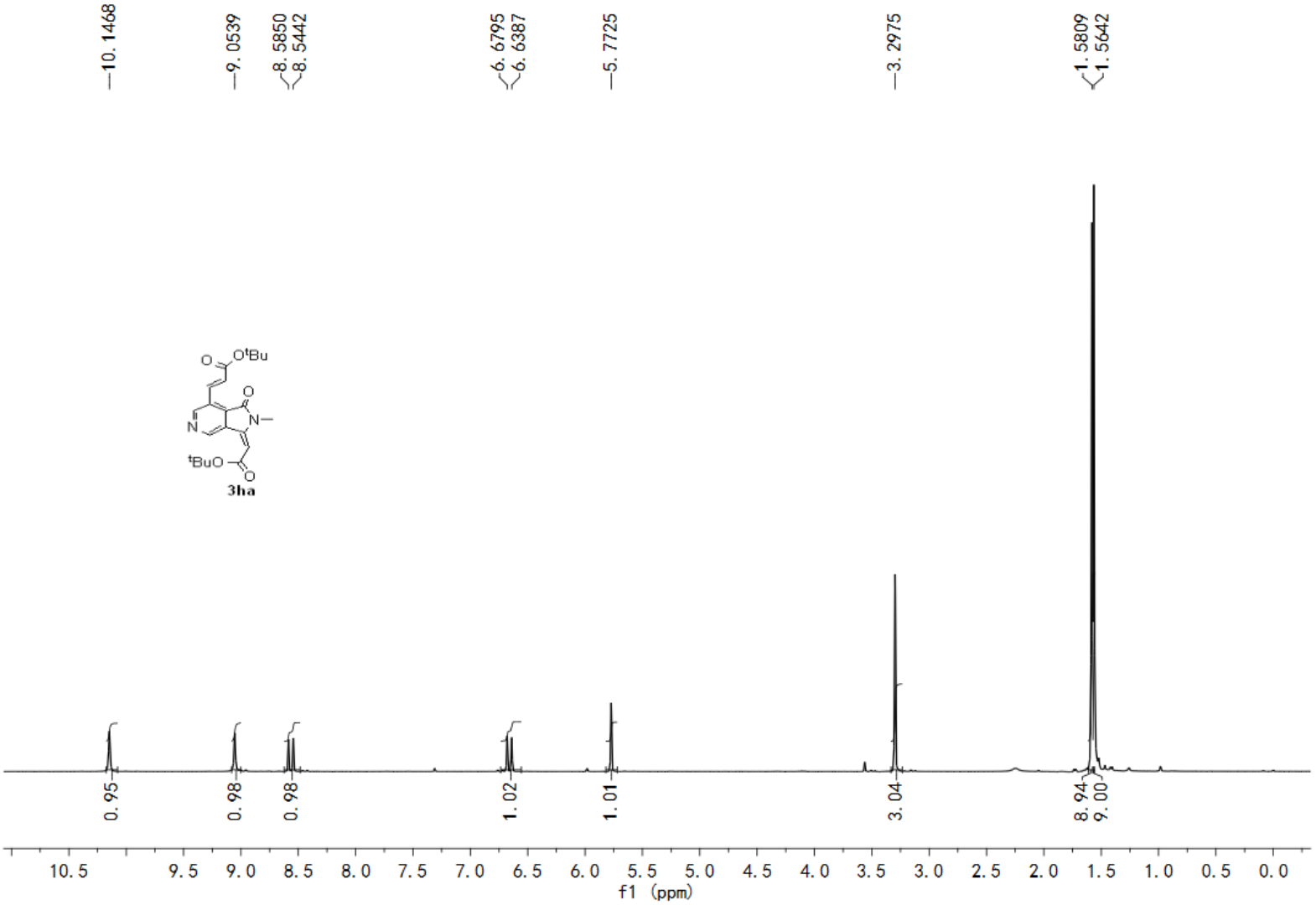

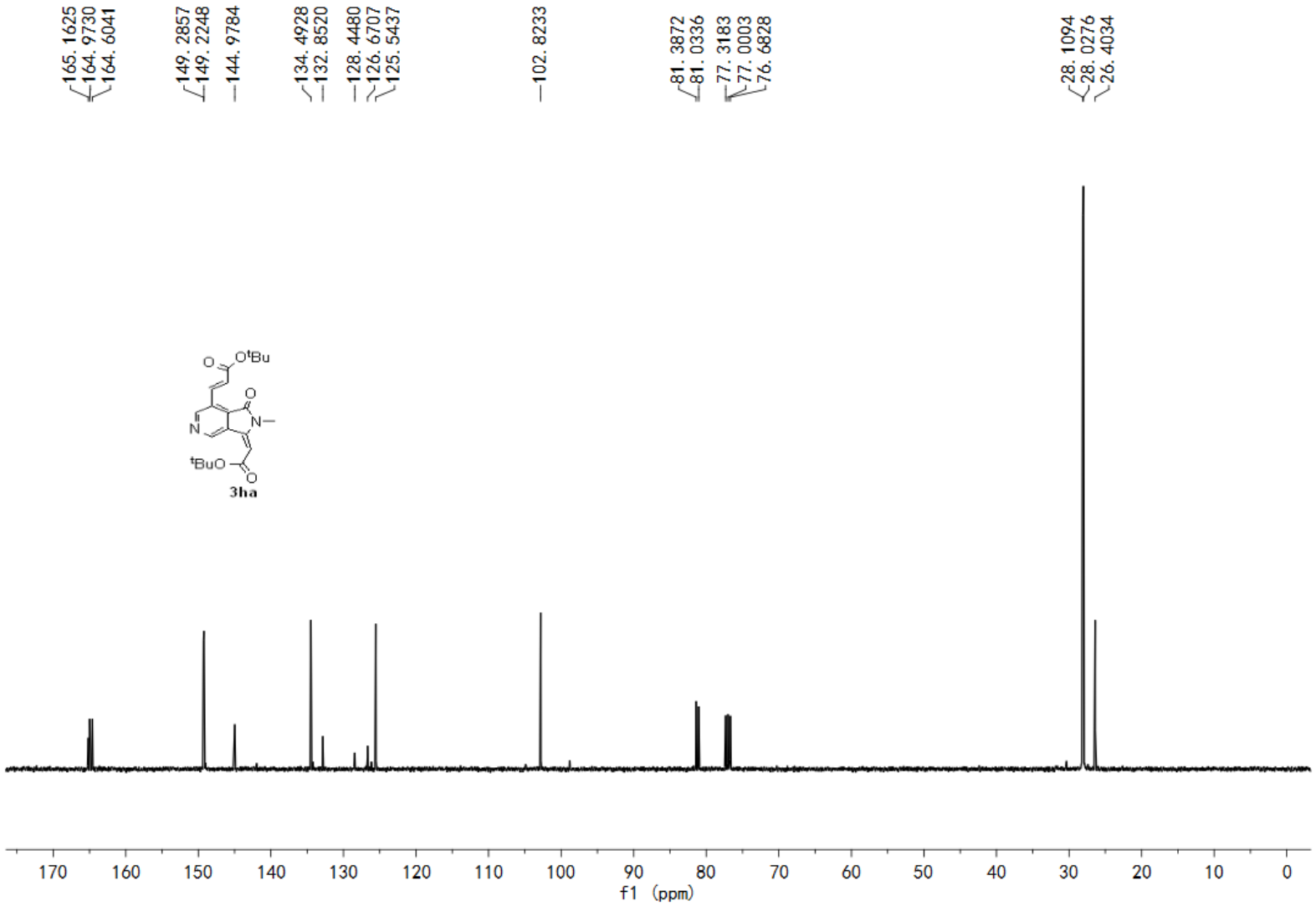

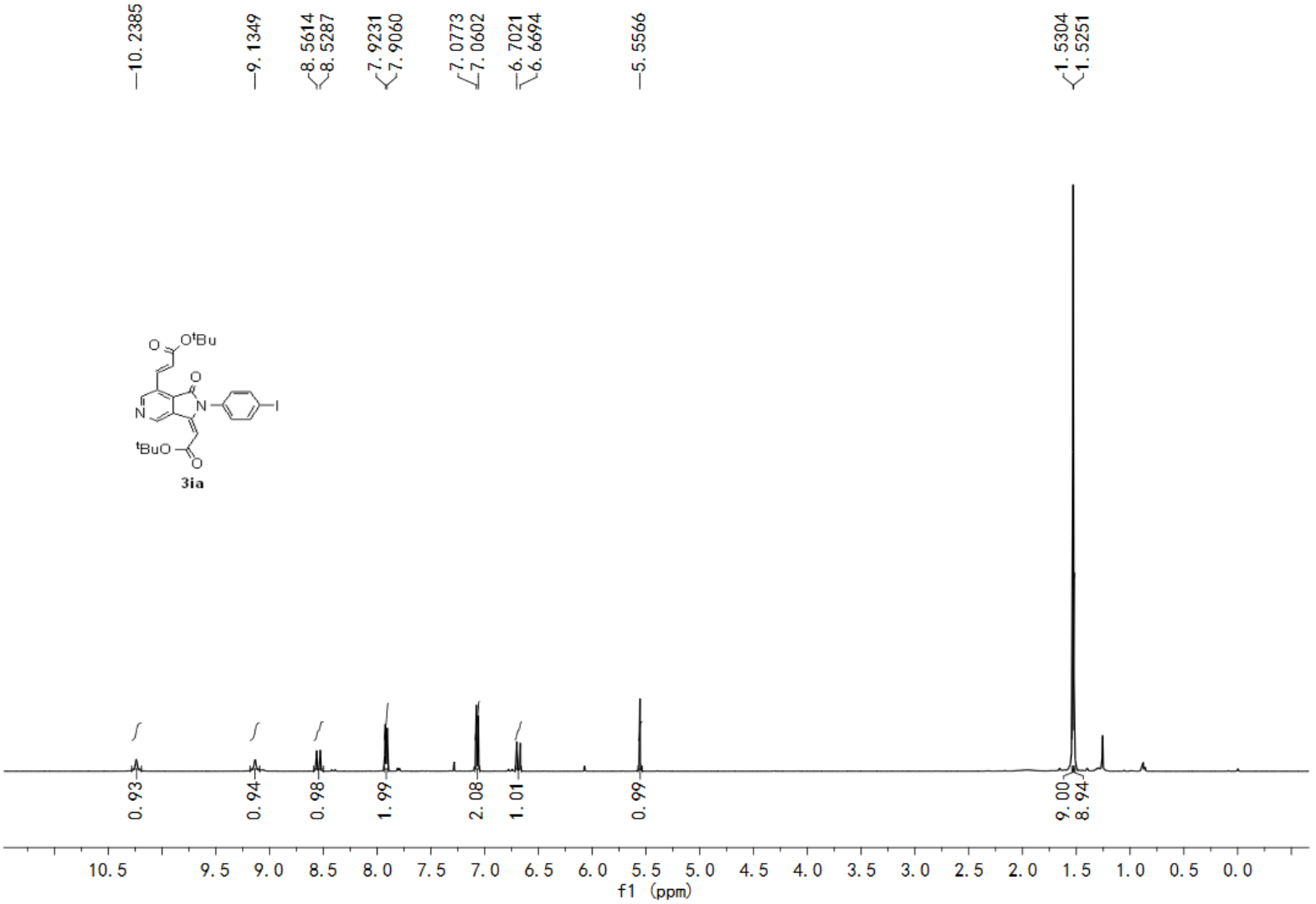

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