Supporting Information

Synthesis of Pyrrole Derivatives via Ordered Isocyanide Insertion Reaction Driven by Ring Strain Mediated by Non-covalent Bond Interactions

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1. General Information

Unless otherwise noted, all reagents were purchased from commercial suppliers without further purification. Oil bath was used for all required reactions with magnetic stirring. Column chromatography purifications were performed under "flash" conditions using 200-300 mesh silica gel. Analytical TLC was carried out on silica gel 60 F254 plates which were visualized by exposure to ultraviolet light. Melting points were determined with an X-4 model apparatus. Crystal was tested on a Bruker D8 Quest diffractometer. HRMS was measured on an Waters Xevo G2-XS Tof spectrometer. NMR spectra were recorded on a Bruker 400 spectrometer calibrated to $CDCl_3$ using tetramethylsilane (TMS) as internal standards. ^1H NMR spectral data are reported in terms of chemical shift (δ, ppm), multiplicity (s = single, d = doublet, t = triplet, q = quartet, m =multiplet), coupling constant (Hz), and integration. ^{13}C NMR spectral data are reported in terms of chemical shift.

All calculations in this work were performed using Gaussian 16 program package.[1] Full geometry optimizations were performed to locate all the stationary points, using the B3LYP[2] with the 6-31G(d,p)[3-4] basis for C, H, O, N, and Br; and Lanl2dz basis for Pd.[5] Dispersion corrections were computed with Grimme's D3(BJ) method in optimization.[6] Frequency analysis was carried out to verify the optimized geometry to be a minimum or transition structure and to obtain the thermal corrections for the Gibbs free energy with the SMD[7] solvation model. Intrinsic reaction coordinate (IRC) calculations[8] were performed to confirm the transition state (TS) structures connecting the expected minima. Single-point energy calculations were obtained at the B3LYP-D3(BJ) with 6-311+G(d,p) for C, H, O, N, and Br; and SDD for Pd of theory. Harmonic vibrational frequency was performed at the same level to guarantee that there is no imaginary frequency in the molecules, i.e. they locate on the minima of potential energy surface. Convergence parameters of the default threshold were retained (maximum force within 4.5×10^{-4} Hartrees/Bohr and root mean square (RMS) force within 3.0×10^{-4} Hartrees/Radian) to obtain the optimized structure. The optimal structure was identified given that all calculations

for structural optimization were successfully converged within the convergence threshold of no imaginary frequency, during the process of vibration analysis.

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2. General Procedure for the Preparation of 3, 4 and 5

General procedure for the preparation of compounds 3:

In an oven-dried Schlenk tube under N_2 atmosphere, a mixture of compounds **1** (0.5 mmol) and isocyanides **2** (2.0 mmol, 4.0 eqiuv.) were stirred in 1, 4-dioxane (3 mL) at room temperature. Then K_2CO_3 (104 mg, 0.75 mmol, 1.5 equiv) and $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 0.05 equiv.) were added. The mixtures were allowed to stir at boiling temperature for 8 h by oil bath and monitored by TLC. After completion, the solvent was removed under reduced pressure and the residue was purified by flash chromatography on silica gel with ethylacetate/petroleum ether (1:15-18) as the eluent to give **3a-t** in a yield of 69-83%.

General procedure for the preparation of compounds 4:

In a Schlenk tube, a mixture of compounds **1** (0.5 mmol) and isocyanides **2** (2.0 mmol, 4.0 eqiuv.) were stirred in DMSO (3 mL) at room temperature. Then Cs_2CO_3 (245 mg, 0.75 mmol, 1.5 equiv) and $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 0.05 equiv.) were added. The mixtures were allowed to stir at 90 ℃ for 4 h by oil bath and monitored by TLC. After completion, the solvent was removed under reduced pressure and the residue was purified by flash chromatography on silica gel with ethylacetate/petroleum ether (1:15) as the eluent to give **4a-f** in a yield of 51-65%.

General procedure for the preparation of compounds 5:

In an oven-dried Schlenk tube under N_2 atmosphere, a mixture of compounds **1** (0.5 mmol) and isocyanides **2** (2.0 mmol, 4.0 eqiuv.) were stirred in 1, 4-dioxane (3 mL) at room temperature. Then K_2CO_3 (104 mg, 0.75 mmol, 1.5 equiv) and $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 0.05 equiv.) were added. The mixtures were allowed to stir at boiling temperature for 8 h by oil bath and monitored by TLC. After completion, the solvent was removed and the residue was purified by flash chromatography on silica gel with ethylacetate/petroleum ether (1:15). Then additional solvent was added (TFA : DCE = 1:1, 3 mL), the mixtures were allowed to stir at 70 ℃ for 4 h by oil bath and monitored by TLC. After completion, the solvent was removed under reduced pressure and the residue was purified by flash chromatography on silica gel with ethylacetate/petroleum ether (1:25-30) as the eluent to give **5a-t** in a yield of 64-78%.

3. **X-ray Crystallography Data of 3a**

Crystal sample preparation of 3a: A solution of compound **3a** (0.04 g) in AcOEt (0.5 mL) was placed in a vial (10 mL). Then *petroleum ether* (5 mL) was added to the solution with a dropper. The single crystal **3a** was obtained by slowly evaporating mixed solvent at room temperature under the air conditions. A suitable crystal was selected and tested on a Bruker D8 Quest diffractometer. The crystal was kept at 296.0 K during data collection. Using Olex2,[9] the structure was solved with the SHELXT[10] structure solution program using Intrinsic Phasing and refined with the SHELXL[11] refinement package using Least Squares minimisation.

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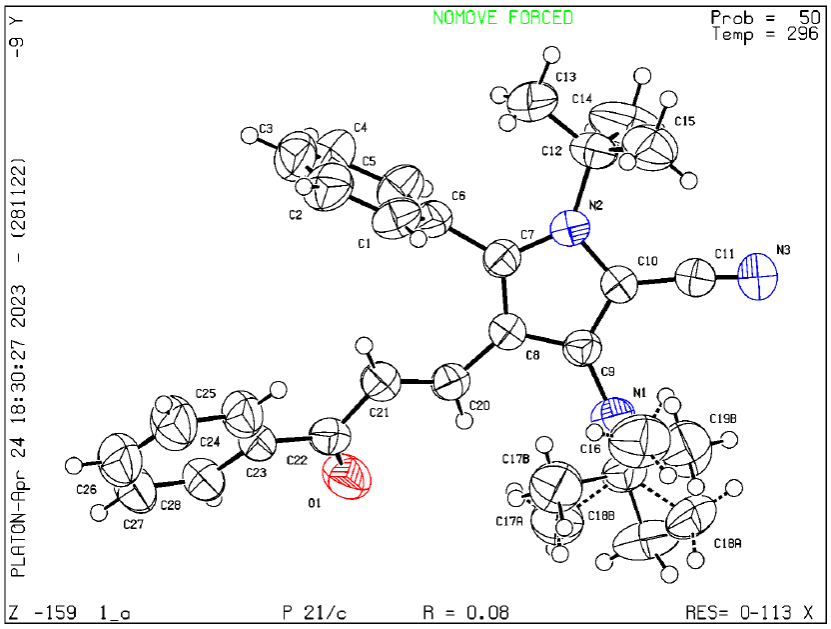


Figure S1. X-ray crystal structure of **3a** is drawn at the 50% probability.

Identification code	**3a**
Empirical formula	$C_{28}H_{31}N_3O$
Formula weight	425.56
Temperature	296(2) K
Wavelength	0.71073 Å
Crystal system	Monoclinic
Space group	$P2_1/c$
Unit cell dimensions	a = 11.328(11) Å α= 90 °.
b = 11.331(10) Å	β= 90.49(2) °.
c = 19.416(19) Å	γ = 90 °.
Volume	2492(4) $Å^3$
Z	4
Density (calculated)	1.134 Mg/m^3
Absorption coefficient	0.069 mm^{-1}
F(000)	912
Crystal size	0.200 x 0.200 x 0.200 mm^3
Theta range for data collection	2.542 to 24.999 °.
Index ranges	-11<=h<=13, -13<=k<=13, -21<=l<=22
Reflections collected	27496
Independent reflections	4352 [R(int) = 0.1267]
Completeness to theta = 24.999 °	99.1 %
Absorption correction	Semi-empirical from equivalents
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	4352 / 112 / 302
Goodness-of-fit on F^2	0.994
Final R indices [I>2sigma(I)]	R1 = 0.0831, wR2 = 0.2003
R indices (all data)	R1 = 0.2143, wR2 = 0.2607
Extinction coefficient	n/a
Largest diff. peak and hole	0.278 and -0.305 $e.Å^{-3}$

Table S1. Crystal data and structure refinement for **3a**.

4. Characterization Datas

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-oxo-3-phenylprop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3a):

Light yellow solid, yield: 0.162g (76%), ethylacetate/petroleum ether = 1:15, mp 193-194 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.66-6.70 (m, 12H), 3.05 (s, 1H), 1.59 (s, 9H), 1.31 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.9, 144.0, 139.8, 138.4, 136.6, 134.4, 132.2, 131.0, 129.3, 128.7, 128.3, 128.1, 119.1, 117.0, 116.8, 100.3, 62.2, 56.0, 32.3, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{31}N_3O$ 426.2540; Found: 426.2545.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-oxo-3-(4-(trifluoromethyl)phenyl)prop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3b):

Light yellow solid, yield: 0.182g (74%), ethylacetate/petroleum ether = 1:18, mp 179-182 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.71-6.60 (m, 11H), 3.02 (s, 1H), 1.58 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.9, 144.1, 141.3, 140.1, 138.0, 134.3, 133.4 (q, $J_{C\text{-}F}$ = 33.0 Hz), 131.0, 129.4, 128.7, 128.3, 125.2 (q, $J_{C\text{-}F}$ = 4.0 Hz), 123.7 (q, $J_{C\text{-}F}$ = 271.0 Hz), 118.4, 116.9, 116.6, 100.5, 62.4, 56.1, 32.3, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{30}F_3N_3O$ 494.2414; Found: 494.2419.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(4-methoxyphenyl)-3-oxoprop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3c):

Light yellow solid, yield: 0.157g (69%), ethylacetate/petroleum ether = 1:18, mp 165-168 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.02-6.65 (m, 11H), 3.86-3.84 (m, 3H), 1.57-1.29 (m, 18H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.3, 162.9, 162.8, 143.9, 140.8, 139.6, 138.9, 137.4, 135.7, 134.5, 131.8, 131.4, 131.1, 130.3, 130.2, 129.2, 128.7, 128.4, 127.9, 119.1, 117.0, 116.8, 116.3, 113.6, 113.5, 109.9, 100.2, 63.2, 62.1, 56.4, 56.0, 55.4, 51.3, 32.3, 30.3, 29.6, 28.2; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{33}N_3O_2$ 456.2646; Found: 456.2643.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-oxo-3-(p-tolyl)prop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3d):

Light yellow solid, yield: 0.160g (73%), ethylacetate/petroleum ether = 1:16, mp

212-215 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.55-6.68 (m, 11H), 3.03 (s, 1H), 2.37 (s, 3H), 1.57 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.4, 144.0, 142.9, 139.7, 136.1, 135.9, 134.4, 131.0, 129.2, 129.0, 128.6, 128.2, 119.2, 117.0, 116.8, 100.2, 62.1, 56.0, 32.3, 30.3, 21.5; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{33}N_3O$ 440.2696; Found: 440.2698.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(2-chlorophenyl)-3-oxoprop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3e):

Light yellow solid, yield: 0.181g (79%), ethylacetate/petroleum ether = 1:16, mp 144-147 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.41-6.18 (m, 11H), 2.44 (s, 1H), 1.54 (s, 9H), 1.20 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 194.6, 143.9, 140.4, 140.0, 139.2, 133.6, 130.9, 130.7, 130.5, 129.8, 129.3, 128.8, 128.5, 126.4, 123.7, 116.7, 116.4, 100.2, 62.3, 55.8, 32.2, 30.2; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{30}ClN_3O$ 460.2150; Found: 460.2159.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(2,4-dichlorophenyl)-3-oxoprop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3f):

Light yellow solid, yield: 0.171g (77%), ethylacetate/petroleum ether = 1:15, mp 167-169 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.47-6.25 (m, 10H), 2.97 (s, 1H)，1.57 (s, 9H), 1.22 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 193.2, 143.8, 140.6, 140.3, 137.6, 135.9, 133.5, 131.9, 130.7, 129.8, 129.7, 129.3, 128.5, 126.8, 123.1, 116.6, 116.4, 100.3, 62.3, 55.9, 32.2, 30.2; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{29}Cl_2N_3O$ 494.1761; Found: 494.1768.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(4-fluorophenyl)-3-oxoprop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3g):

Light yellow solid, yield: 0.197g (80%), ethylacetate/petroleum ether = 1:18, mp 177-180 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.66-6.62 (m, 11H), 3.03(s, 1H), 1.58 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ 188.3, 165.2 (d, $J_{C\text{-}F}$ = 252.0 Hz), 136.8, 134.8, 134.7, 134.4, 131.0, 130.5 (d, $J_{C\text{-}F}$ = 9.0 Hz), 129.2, 128.7, 118.6, 116.8 (d, $J_{C\text{-}F}$ = 23.0 Hz), 115.3 (d, $J_{C\text{-}F}$ = 22.0 Hz), 100.3, 62.2, 56.0, 32.3, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{30}FN_3O$ 444.2446; Found: 444.2452.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(4-cyanophenyl)-3-oxoprop-1-en-1-yl)-

5-phenyl-1H-pyrrole-2-carbonitrile (3h):

Light yellow solid, yield: 0.187g (83%), ethylacetate/petroleum ether = 1:18, mp 176-179 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.84-6.56 (m, 11H), 3.02 (s, 1H), 1.58 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.5, 144.2, 141.8, 140.1, 138.5, 134.2, 132.5, 132.1, 130.9, 130.2, 129.4, 128.7, 128.4, 118.0, 116.8, 115.2, 100.6, 62.4, 56.0, 32.2, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{30}N_4O$ 451.2492; Found: 451.2498.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(4-chlorophenyl)-3-oxoprop-1-en-1-yl)-5-(2-methoxyphenyl)-1H-pyrrole-2-carbonitrile (3i):

Light yellow solid, yield: 0.190g (78%), ethylacetate/petroleum ether = 1:18, mp 158-160 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.60-6.65 (m, 10H), 3.77 (s, 3H), 3.26 (s, 1H), 1.58 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.6, 158.0, 138.4, 137.4, 136.9, 136.5, 132.2, 131.2, 129.5, 128.5, 123.3, 120.9, 117.8, 116.7, 116.4, 111.2, 100.6, 62.0, 56.2, 55.6, 55.6, 31.3, 30.2; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}ClN_3O_2$ 490.2256; Found: 490.2260.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(4-chlorophenyl)-3-oxoprop-1-en-1-yl)-5-(p-tolyl)-1H-pyrrole-2-carbonitrile (3j):

Light yellow solid, yield: 0.189g (80%), ethylacetate/petroleum ether = 1:15, mp 193-196 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.58-6.57 (m, 10H), 3.16 (s, 1H), 2.48 (s, 3H), 1.58 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.6, 143.9, 140.2, 139.4, 138.5, 137.2, 136.8, 131.2, 130.8, 129.5, 129.4, 128.5, 118.3, 117.0, 116.7, 100.2, 62.2, 56.0, 50.3, 32.3, 30.3, 29.5, 21.4, 21.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}ClN_3O$ 474.2307; Found: 474.2317.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-5-(4-chlorophenyl)-4-(3-(4-chlorophenyl)-3-oxoprop-1-en-1-yl)-1H-pyrrole-2-carbonitrile (3k):

Light yellow solid, yield: 0.177g (72%), ethylacetate/petroleum ether = 1:15, mp 196-199 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.61-6.68 (m, 10H), 3.09 (s, 1H), 1.59 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.3, 143.7, 138.7, 138.3, 136.7, 136.6, 135.7, 132.7, 132.4, 129.4, 129.0, 128.7, 118.8, 117.2, 116.3, 100.8, 62.4, 56.2, 32.4, 30.2; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for

$C_{28}H_{29}Cl_2N_3O$ 494.1760; Found: 494.1768.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-(4-chlorophenyl)-3-oxoprop-1-en-1-yl)-5-(4-fluorophenyl)-1H-pyrrole-2-carbonitrile (3l):

Light yellow solid, yield: 0.179g (75%), ethylacetate/petroleum ether = 1:16, mp 206-208 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.64-6.80 (m, 10H), 3.02 (s, 1H), 1.57 (s, 9H), 1.27 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.5, 163.2 (d, $J_{C\text{-}F}$ = 250.0 Hz), 143.8, 138.8, 138.7, 137.0, 136.7, 132.8 (d, $J_{C\text{-}F}$ = 8.0 Hz), 130.0 (d, $J_{C\text{-}F}$ = 4.0 Hz), 129.4, 128.7, 118.8, 117.3, 116.5, 115.9 (d, $J_{C\text{-}F}$ = 22.0 Hz), 100.8, 62.3, 56.1, 32.3, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{29}ClFN_3O$ 478.2056; Found: 478.2062.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-5-(4-chlorophenyl)-4-(3-(4-fluorophenyl)-3-oxoprop-1-en-1-yl)-1H-pyrrole-2-carbonitrile (3m):

Light yellow solid, yield: 0.176g (74%), ethylacetate/petroleum ether = 1:15, mp 183-186 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.70-6.69 (m, 10H), 3.38 (s, 1H), 1.59 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.1, 165.2 (d, $J_{C\text{-}F}$ = 253.0 Hz), 143.8, 138.2, 136.4, 135.7, 134.7, 134.6, 132.8, 132.4, 130.5 (d, $J_{C\text{-}F}$ = 9.0 Hz), 129.0, 118.9, 117.2, 116.4, 115.5 (d, $J_{C\text{-}F}$ = 21.0 Hz), 100.7, 62.3, 56.1, 32.4, 30.2; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{29}ClFN_3O$ 478.2056; Found: 478.2058.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-5-(4-chlorophenyl)-4-(3-oxo-3-(p-tolyl)prop-1-en-1-yl)-1H-pyrrole-2-carbonitrile (3n):

Light yellow solid, yield: 0.170g (72%), ethylacetate/petroleum ether = 1:18, mp 160-163 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.59-6.76 (m, 10H), 3.20 (s, 1H), 2.39 (s, 3H), 1.58 (s, 9H), 1.29 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.2, 143.4, 143.1, 138.1, 135.7, 135.7, 135.7, 132.8, 132.5, 129.2, 129.0, 128.2, 119.7, 117.3, 116.5, 100.6, 62.3, 56.4, 32.4, 30.2, 21.6; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{32}ClN_3O$ 474.2307; Found: 474.2312.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-5-(4-chlorophenyl)-4-(3-oxo-3-phenylprop-1-en-1-yl)-1H-pyrrole-2-carbonitrile (3o):

Light yellow solid, yield: 0.179g (78%), ethylacetate/petroleum ether = 1:18, mp

210-212 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.67-6.76 (m, 11H), 3.02 (s, 1H), 1.59 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.7, 143.7, 138.3, 138.2, 136.2, 135.7, 132.8, 132.4, 132.4, 129.0, 128.5, 128.1, 119.5, 117.2, 116.5, 100.7, 62.3, 56.2, 32.4, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{30}ClN_3O$ 460.2150; Found: 460.2156.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-5-(4-fluorophenyl)-4-(3-oxo-3-phenylprop-1-en-1-yl)-1H-pyrrole-2-carbonitrile (3p):

Light yellow solid, yield: 0.166g (75%), ethylacetate/petroleum ether = 1:18, mp 211-213 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.71-6.86 (m, 11H), 3.08 (s, 1H), 1.57 (s, 9H), 1.29 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.9, 163.2 (d, $J_{C\text{-}F}$ = 249.0 Hz), 138.7, 138.3, 136.5, 132.9 (d, $J_{C\text{-}F}$ = 8.0 Hz), 132.3, 130.0 (d, $J_{C\text{-}F}$ = 4.0 Hz), 128.4, 128.1, 119.6, 117.3, 116.6, 115.9 (d, $J_{C\text{-}F}$ = 22.0 Hz), 100.7, 62.2, 56.3, 32.4, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{28}H_{30}FN_3O$ 444.2446; Found: 444.2449.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-oxo-3-(p-tolyl)prop-1-en-1-yl)-5-(p-tolyl)-1H-pyrrole-2-carbonitrile (3q):

Light yellow solid, yield: 0.161g (71%), ethylacetate/petroleum ether = 1:18, mp 189-192 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.56-6.64 (m, 10H), 2.98 (s, 1H), 2.48-2.38 (m, 6H), 1.58 (s, 9H), 1.28 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.3, 143.9, 142.8, 139.9, 139.2, 136.1, 135.9, 131.3, 130.8, 129.3, 128.9, 128.2, 118.8, 117.0, 116.8, 100.0, 62.0, 55.9, 32.3, 30.3, 21.5, 21.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{35}N_3O$ 454.2853; Found: 454.2862.

(*E*)-1-(*tert*-Butyl)-3-(*tert*-butylamino)-4-(3-oxo-3-phenylprop-1-en-1-yl)-5-(p-tolyl)-1H-pyrrole-2-carbonitrile (3r):

Light yellow solid, yield: 0.169g (77%), ethylacetate/petroleum ether = 1:18, mp 182-184 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.65-6.65 (m, 11H), 3.08 (s, 1H), 2.48 (s, 3H), 1.58 (s, 9H), 1.29 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.8, 143.9, 140.1, 139.3, 138.5, 136.7, 132.2, 131.3, 130.8, 129.4, 128.3, 128.1, 118.9, 117.0, 116.8, 100.1, 62.1, 56.1, 32.3, 30.3, 21.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{33}N_3O$ 440.2696; Found: 440.2697.

1-((3S,5S,7S)-Adamantan-1-yl)-3-(((3S,5S,7S)-adamantan-1-yl)amino)-4-((*E*)-3-(4-chlorophenyl)-3-oxoprop-1-en-1-yl)-5-(4-fluorophenyl)-1H-pyrrole-2-carbonitrile (3s):

Light yellow solid, yield: 0.234g (74%), ethylacetate/petroleum ether = 1:16, mp 286-289 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.62-6.64 (m, 10H), 2.97 (s, 1H), 2.23-1.61 (m, 30H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 188.5, 163.1 (d, J_{C-F} = 249.0 Hz), 143.0, 138.6, 138.3, 137.1, 136.8, 132.9 (d, J_{C-F} = 8.0 Hz), 130.6 (d, J_{C-F} = 4.0 Hz), 129.4, 128.7, 118.6, 117.5, 116.9, 115.7 (d, J_{C-F} = 21.0 Hz), 100.2, 64.3, 56.2, 44.0, 43.7, 36.2, 35.4, 30.2, 29.8; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{40}H_{41}ClFN_3O$ 634.2995; Found: 634.2998.

1-((3S,5S,7S)-Adamantan-1-yl)-3-(((3S,5S,7S)-adamantan-1-yl)amino)-4-((*E*)-3-oxo-3-(4-(trifluoromethyl)phenyl)prop-1-en-1-yl)-5-phenyl-1H-pyrrole-2-carbonitrile (3t):

Light yellow solid, yield: 0.263g (81%), ethylacetate/petroleum ether = 1:16, mp 289-291 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.69-6.42 (m, 11H), 2.98 (s, 1H), 2.25-1.62 (m, 30H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.0, 143.3, 141.4, 139.6, 138.1, 134.9, 133.3 (q, J_{C-F} = 32.0 Hz), 131.0, 129.2, 128.6, 128.3, 125.2 (q, J_{C-F} = 4.0 Hz), 123.7 (q, J_{C-F} = 271.0 Hz), 118.1, 117.1, 116.9, 99.8, 64.4, 56.1, 43.9, 43.7, 36.2, 35.5, 30.2, 29.8; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{41}H_{42}F_3N_3O$ 650.3353; Found: 650.3358.

(*E*)-2-((*Z*)-Benzylidene)-N-(*tert*-butyl)-5-oxo-5-phenylpent-3-enamide (4a):

White solid, yield: 0.093g (56%), ethylacetate/petroleum ether = 1:15, mp 156-158 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.96-6.84 (m, 13H), 5.58 (s, 1H), 1.41 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 190.0, 167.0, 143.9, 138.6, 138.0, 137.0, 134.4, 132.8, 129.5, 129.4, 128.6, 128.5, 128.4, 123.6, 51.9, 28.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{22}H_{23}NO_2$ 334.1802; Found: 334.1809.

(*E*)-2-((*Z*)-Benzylidene)-N-(*tert*-butyl)-5-(2,4-dichlorophenyl)-5-oxopent-3-enamide (4b):

White solid, yield: 0.130g (65%), ethylacetate/petroleum ether = 1:15, mp 132-135 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.53-6.78 (m, 11H), 5.52 (s, 1H), 1.38 (s, 9H);

^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 191.7, 166.5, 145.1, 139.5, 137.3, 137.1, 136.6, 134.1, 132.3, 130.6, 130.1, 129.8, 129.4, 128.6, 127.3, 127.1, 52.0, 28.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{22}H_{21}Cl_2NO_2$ 402.1022; Found: 402.1031.

(*E*)-2-((*Z*)-Benzylidene)-N-(*tert*-butyl)-5-oxo-5-(p-tolyl)pent-3-enamide (4c):

White solid, yield: 0.088g (51%), ethylacetate/petroleum ether = 1:15, mp 192-195 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.87-6.81 (m, 12H), 5.63 (s, 1H), 2.42 (m, 3H), 1.42 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.5, 167.0, 143.7, 143.5, 138.3, 137.0, 135.4, 134.4, 130.0, 129.3, 129.2, 128.6, 128.5, 123.5, 51.9, 28.4, 21.6; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{23}H_{25}NO_2$ 348.1958; Found: 348.1960.

(*E*)-2-((*Z*)-Benzylidene)-N-(*tert*-butyl)-5-(2-chlorophenyl)-5-oxopent-3-enamide (4d):

White solid, yield: 0.114g (62%), ethylacetate/petroleum ether = 1:15, mp 100-102 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.53-6.79 (m, 12H), 5.50 (s, 1H), 1.38 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 193.1, 166.6, 144.8, 139.1, 139.0, 136.8, 134.2, 131.6, 131.3, 130.3, 129.7, 129.6, 129.4, 128.6, 127.7, 126.9, 52.0, 28.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{22}H_{22}ClNO_2$ 368.1412; Found: 368.1417.

(*E*)-N-(*tert*-Butyl)-2-((*Z*)-4-chlorobenzylidene)-5-oxo-5-phenylpent-3-enamide (4e):

White solid, yield: 0.106g (58%), ethylacetate/petroleum ether = 1:15, mp 100-102 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.97-6.74 (m, 12H), 5.71 (s, 1H), 1.44 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 189.8, 166.8, 143.6, 137.8, 137.3, 136.9, 135.4, 132.9, 132.8, 130.6, 128.8, 128.6, 128.3, 123.7, 52.0, 28.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{22}H_{22}ClNO_2$ 368.1412; Found: 368.1415.

(*E*)-N-((3s,5s,7s)-Adamantan-1-yl)-2-((*Z*)-4-methylbenzylidene)-5-oxo-5-phenylpent-3-enamide (4f):

White solid, yield: 0.128g (60%), ethylacetate/petroleum ether = 1:15, mp 278-281 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.99-7.19 (m, 12H), 5.65 (s, 1H), 2.37(s, 3H), 2.13-1.73(m, 15H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 191.1, 167.4, 139.4,

139.3, 138.1, 137.8, 134.7, 133.0, 132.0, 130.1, 129.4, 128.6, 128.5, 126.4, 52.5, 41.6, 36.3, 29.4, 21.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{29}H_{31}NO_2$ 426.2428; Found: 426.2433.

6-(*tert*-Butyl)-2,5-diphenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5a):

Light yellow solid, yield: 0.126g (72%), ethylacetate/petroleum ether = 1:30, mp 223-225 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.21-7.40 (m, 12H), 1.81 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.3, 147.5, 139.4, 133.0, 130.9, 130.4, 130.0, 129.4, 129.1, 128.6, 128.2, 127.6, 117.4, 116.3, 116.0, 94.1, 63.8, 32.6; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{21}N_3$ 352.1808; Found: 352.1816.

6-(*tert*-Butyl)-2-(4-fluorophenyl)-5-phenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile(5b):

Light yellow solid, yield: 0.138g (75%), ethylacetate/petroleum ether = 1:30, mp 205-207 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.18-7.12 (m, 11H), 1.78 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 163.8 (d, $J_{C\text{-}F}$ = 248.0 Hz), 157.2, 147.4, 135.5 (d, $J_{C\text{-}F}$ = 3.0 Hz), 133.0, 130.9, 130.5, 130.2, 129.4 (d, $J_{C\text{-}F}$ = 8.0 Hz), 129.1, 128.2, 117.3, 116.0, 115.9, 115.5 (d, $J_{C\text{-}F}$ = 22.0 Hz), 94.1, 63.8, 32.6; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{20}FN_3$ 370.1714; Found: 370.1724.

6-(*tert*-Butyl)-5-phenyl-2-(p-tolyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5c):

Light yellow solid, yield: 0.128g (70%), ethylacetate/petroleum ether = 1:25, mp 213-215 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.08-7.25 (m, 11H), 2.41 (s, 3H), 1.77 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.3, 147.5, 139.5, 136.6, 133.1, 130.9, 130.4, 129.8, 129.3, 129.0, 128.2, 127.4, 117.3, 116.2, 94.0, 63.7, 32.6, 21.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{23}N_3$ 366.1965; Found: 366.1969.

6-(*tert*-Butyl)-2-(2-chlorophenyl)-5-phenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5d):

Light yellow solid, yield: 0.148g (77%), ethylacetate/petroleum ether = 1:25, mp 205-207 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.74-7.28 (m, 11H), 1.79 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.7, 147.1, 139.7, 132.9, 132.3, 132.0, 131.0, 130.4, 129.9, 129.8, 129.2, 128.8, 128.3, 127.0, 120.4, 117.2, 115.8, 94.3, 63.9,

32.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{20}ClN_3$ 386.1419; Found: 386.1420.

2-(3-Bromophenyl)-6-(*tert*-butyl)-5-phenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5e):

Light yellow solid, yield: 0.146g (68%), ethylacetate/petroleum ether = 1:28, mp 154-157 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.30-7.34 (m, 12H), 1.78 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 156.7, 147.3, 141.5, 132.9, 132.3, 130.9, 130.5, 130.5, 130.3, 130.1, 129.2, 128.3, 126.2, 122.9, 117.5, 116.0, 115.8, 94.3, 64.0, 32.6; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{20}BrN_3$ 430.0913; Found: 430.0913.

6-(*tert*-Butyl)-2-(2,4-dichlorophenyl)-5-phenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5f):

Light yellow solid, yield: 0.149g (71%), ethylacetate/petroleum ether = 1:30, mp 199-202 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.70-7.26 (m, 10H), 1.79 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 157.6, 147.0, 138.2, 135.1, 133.0, 132.9, 132.8, 131.0, 130.5, 129.7, 129.3, 129.1, 128.3, 127.4, 120.1, 117.3, 115.7, 94.4, 64.1, 32.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{19}Cl_2N_3$ 420.1029; Found: 420.1035.

6-(*tert*-Butyl)-5-phenyl-2-(4-(trifluoromethyl)phenyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5g):

Light yellow solid, yield: 0.136g (65%), ethylacetate/petroleum ether = 1:25, mp 223-225 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.29-7.38 (m, 11H), 1.79 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 156.7, 147.3, 142.7, 131.2, 130.9, 130.6, 130.5, 129.3, 128.3, 127.8, 125.5 (d, $J_{C\text{-}F}$ = 4.0 Hz), 122.8, 117.6, 116.1, 115.8, 94.4, 64.1, 32.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{20}F_3N_3$ 420.1682; Found: 420.1689.

6-(*tert*-Butyl)-2-(4-chlorophenyl)-5-phenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5h):

Light yellow solid, yield: 0.141g (73%), ethylacetate/petroleum ether = 1:25, mp 224-227 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.12-7.36 (m, 11H), 1.78 (s, 9H);

^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 157.0, 147.4, 137.8, 135.6, 132.9, 130.9, 130.5, 130.2, 129.2, 128.8, 128.7, 128.3, 117.4, 115.9, 115.8, 94.2, 63.9, 32.6; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{20}ClN_3$ 386.1419; Found: 386.1421.

6-(*tert*-Butyl)-2-(4-chlorophenyl)-5-(2-methoxyphenyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5i):

Light yellow solid, yield: 0.150g (72%), ethylacetate/petroleum ether = 1:25, mp 210-263 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.12-6.97 (m, 10H), 3.75 (m, 3H), 1.77 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.1, 156.8, 147.6, 137.9, 135.4, 131.9, 131.1, 130.3, 128.8, 128.7, 126.9, 121.9, 120.5, 117.1, 116.1, 115.6, 110.7, 94.2, 63.7, 55.3, 55.3, 31.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{22}ClN_3O$ 416.1524; Found: 416.1529.

6-(*tert*-Butyl)-2-(4-chlorophenyl)-5-(p-tolyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5j):

Light yellow solid, yield: 0.148g (74%), ethylacetate/petroleum ether = 1:30, mp 230-233 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.12-7.24 (m, 10H), 2.47 (s, 3H), 1.78 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 156.9, 147.4, 139.2, 137.8, 135.5, 130.8, 130.7, 130.4, 129.8, 129.0, 128.8, 128.7, 117.4, 116.0, 115.7, 93.9, 63.8, 32.6, 21.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{22}ClN_3$ 400.1575; Found: 400.1584.

6-(*tert*-Butyl)-2,5-bis(4-chlorophenyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5k):

Light yellow solid, yield: 0.145g (69%), ethylacetate/petroleum ether = 1:28, mp 238-240 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.13-7.32 (m, 10H), 1.78 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 157.0, 147.2, 137.6, 135.7, 135.5, 132.2, 131.4, 129.9, 128.9, 128.8, 128.7, 128.6, 117.5, 116.1, 115.6, 94.7, 64.0, 32.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{19}Cl_2N_3$ 420.1029; Found: 420.1033.

6-(*tert*-Butyl)-2-(4-chlorophenyl)-5-(4-fluorophenyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5l):

Light yellow solid, yield: 0.133g (66%), ethylacetate/petroleum ether = 1:30, mp 240-243 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.12-7.17 (m, 10H), 1.77 (s, 9H);

^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 163.1 (d, J_{C-F} = 249.0 Hz), 157.0, 147.2, 137.6, 135.6, 132.8 (d, J_{C-F} = 8.0 Hz), 129.9, 129.0, 128.8, 117.5, 116.0, 115.7, 115.5 (d, J_{C-F} = 22.0 Hz), 94.5, 63.9, 32.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{19}ClFN_3$ 404.1324; Found: 404.1325.

6-(*tert*-Butyl)-2-phenyl-5-(p-tolyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5m):

Light yellow solid, yield: 0.133g (73%), ethylacetate/petroleum ether = 1:30, mp 228-230 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.18-7.26 (m, 11H), 2.46 (s, 3H), 1.77 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.3, 147.5, 139.5, 139.1, 130.8, 130.7, 130.1, 130.0, 129.3, 128.9, 128.6, 127.6, 117.4, 116.2, 116.1, 94.0, 63.7, 32.6, 21.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{23}N_3$ 366.1965; Found: 366.1971.

6-(*tert*-Butyl)-5-(4-chlorophenyl)-2-phenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5n):

Light yellow solid, yield: 0.148g (77%), ethylacetate/petroleum ether = 1:30, mp 230-233 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.16-7.31 (m, 11H), 1.77 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.4, 147.3, 139.2, 135.4, 132.3, 131.5, 129.6, 129.5, 128.7, 128.6, 128.5, 127.6, 117.4, 116.6, 115.8, 94.6, 63.9, 32.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{20}ClN_3$ 386.1419; Found: 386.1427.

6-(*tert*-Butyl)-5-(4-fluorophenyl)-2-phenyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5o):

Light yellow solid, yield: 0.124g (67%), ethylacetate/petroleum ether = 1:25, mp 229-231 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.17-7.16 (m, 11H), 1.77 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 163.1 (d, J_{C-F} = 249.0 Hz), 158.4, 147.3, 139.3, 132.8 (d, J_{C-F} = 9.0 Hz), 129.7, 129.5, 129.0, 128.9, 128.6, 127.6, 117.6, 116.5, 115.8, 115.5 (d, J_{C-F} = 22.0 Hz), 94.5, 63.8, 32.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{24}H_{20}FN_3$ 370.1714; Found: 370.1722.

6-(*tert*-Butyl)-2, 5-di-p-tolyl-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5p):

Light yellow solid, yield: 0.121g (64%), ethylacetate/petroleum ether = 1:25, mp 208-210 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.08-7.23 (m, 10H), 7.44-7.23 (m, 8H), 2.46-2.41 (m, 6H), 1.77 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm)

158.2, 147.5, 139.5, 139.1, 136.6, 130.7, 130.0, 129.9, 129.3, 128.9, 127.4, 117.4, 116.2, 116.0, 93.7, 63.6, 45.6, 32.6, 21.4, 21.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{26}H_{25}N_3$ 380.2121; Found: 380.2125.

6-(*tert*-Butyl)-5-(4-chlorophenyl)-2-(p-tolyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5q):

Light yellow solid, yield: 0.140g (70%), ethylacetate/petroleum ether = 1:30, mp 231-234 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.07-7.27 (m, 10H), 2.42 (s, 3H), 1.77 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.2, 147.3, 139.6, 136.4, 135.3, 132.2, 131.5, 129.5, 129.3, 128.7, 128.5, 127.4, 117.3, 116.3, 115.8, 94.4, 63.8, 45.6, 32.7, 21.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{22}ClN_3$ 400.1575; Found: 400.1580.

6-(*tert*-Butyl)-5-(4-fluorophenyl)-2-(p-tolyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5r):

Light yellow solid, yield: 0.168g (71%), ethylacetate/petroleum ether = 1:25, mp 224-226 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.08-7.15 (m, 10H), 2.42 (s, 3H), 1.76 (s, 9H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 163.0 (d, $J_{C\text{-}F}$ = 249.0 Hz), 158.3, 147.4, 139.6, 136.5, 132.7 (d, $J_{C\text{-}F}$ = 8.0 Hz), 129.5, 129.4, 129.0 (d, $J_{C\text{-}F}$ = 3.0 Hz), 128.9, 127.4, 117.5, 116.3, 115.9, 115.4 (d, $J_{C\text{-}F}$ = 21.0 Hz), 94.3, 63.7, 32.7, 21.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{25}H_{22}FN_3$ 384.1871; Found: 384.1874.

6-((3s,5s,7s)-Adamantan-1-yl)-5-phenyl-2-(4-(trifluoromethyl)phenyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5s):

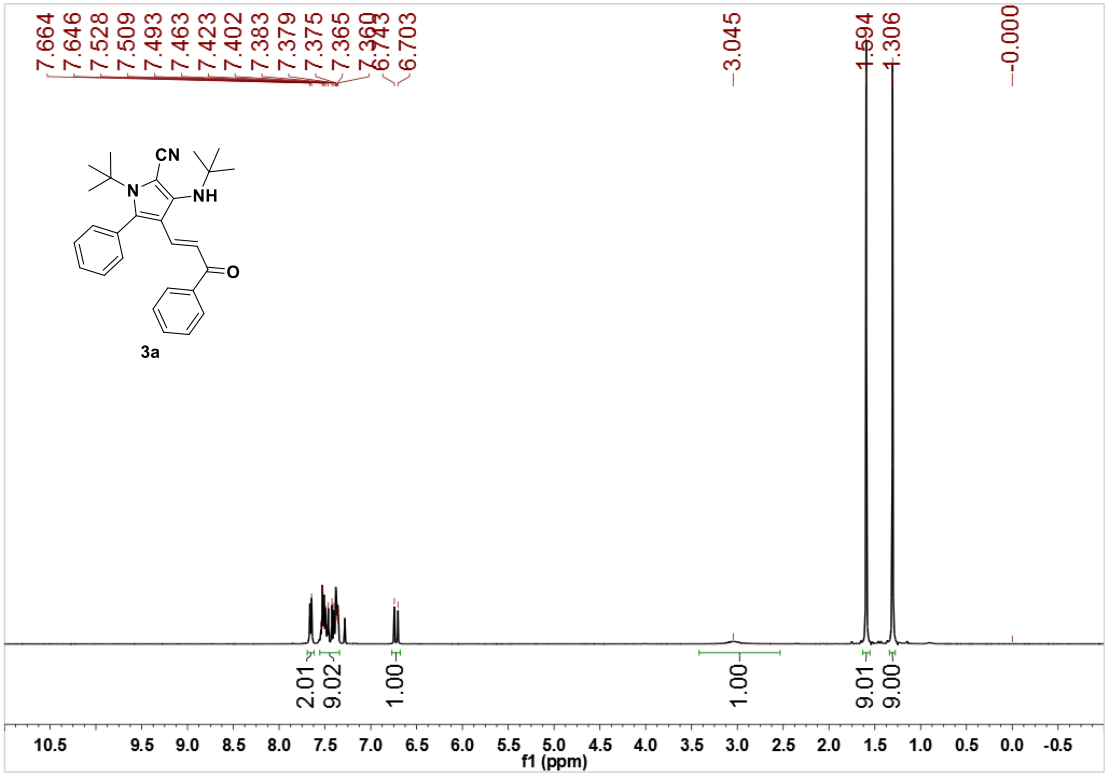
Light yellow solid, yield: 0.136g (78%), ethylacetate/petroleum ether = 1:28, mp 265-268 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.29-7.26 (m, 11H), 2.47-1.66 (m, 15H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 156.7, 147.3, 142.8, 133.3, 131.1 (q, $J_{C\text{-}F}$ = 32.0 Hz), 131.0, 130.5, 130.3, 129.1, 128.2, 127.9, 125.6 (q, $J_{C\text{-}F}$ = 4.0 Hz), 117.9, 116.1, 116.0, 93.6, 66.2, 44.4, 35.5, 30.4; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{31}H_{26}F_3N_3$ 498.2152; Found: 498.2159.

6-((3s,5s,7s)-Adamantan-1-yl)-2-(4-chlorophenyl)-5-(4-fluorophenyl)-6H-pyrrolo[3,4-*b*]pyridine-7-carbonitrile (5t):

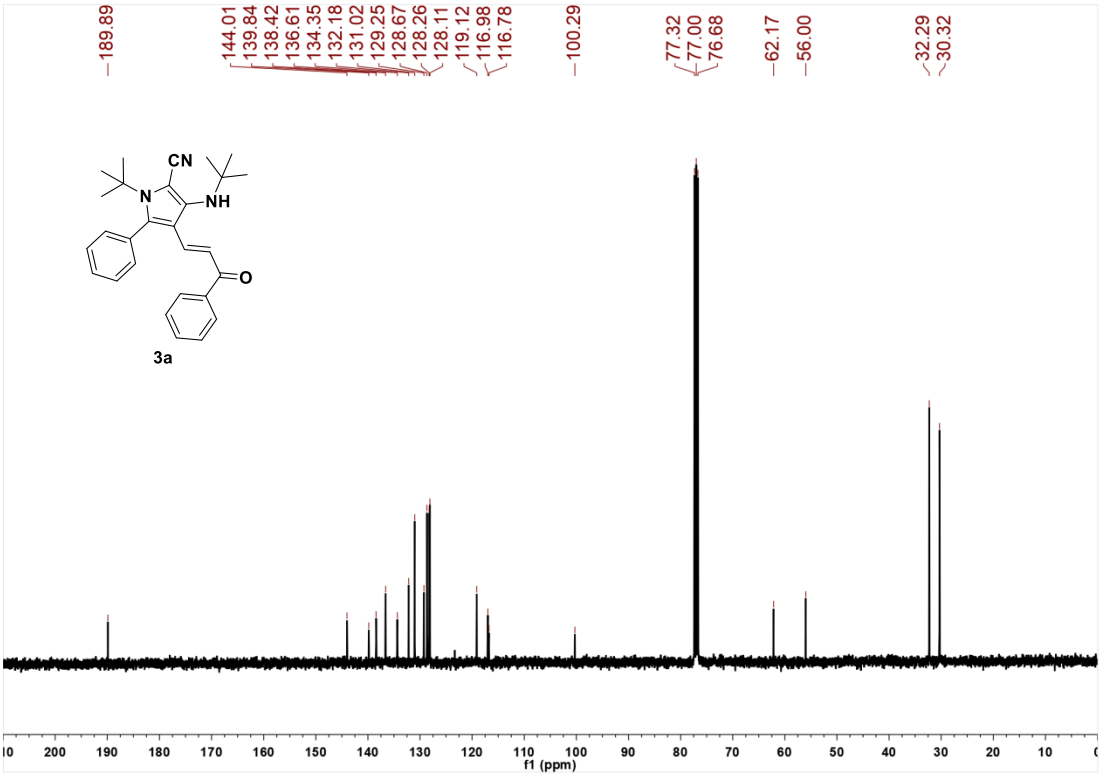
Light yellow solid, yield: 0.178g (74%), ethylacetate/petroleum ether = 1:30, mp

284-286 ℃. ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.12-7.15 (m, 10H), 2.43-1.70 (m, 15H); ^{13}C {^{1}H} NMR ($CDCl_3$, 100 MHz) δ (ppm) 163.0 (d, $J_{C\text{-}F}$ = 248.0 Hz), 157.0, 147.1, 137.7, 135.6, 132.8 (d, $J_{C\text{-}F}$ = 9.0 Hz), 129.9, 129.3 (d, $J_{C\text{-}F}$ = 4.0 Hz), 128.9, 128.8, 128.7, 117.8, 116.0, 115.9, 115.3 (d, $J_{C\text{-}F}$ = 22.0 Hz), 93.7, 66.0, 44.4, 35.5, 30.3; HRMS (ESI-TOF) m/z: $[M + H]^+$ Calcd for $C_{30}H_{25}ClFN_3$ 482.1794; Found: 482.1799.

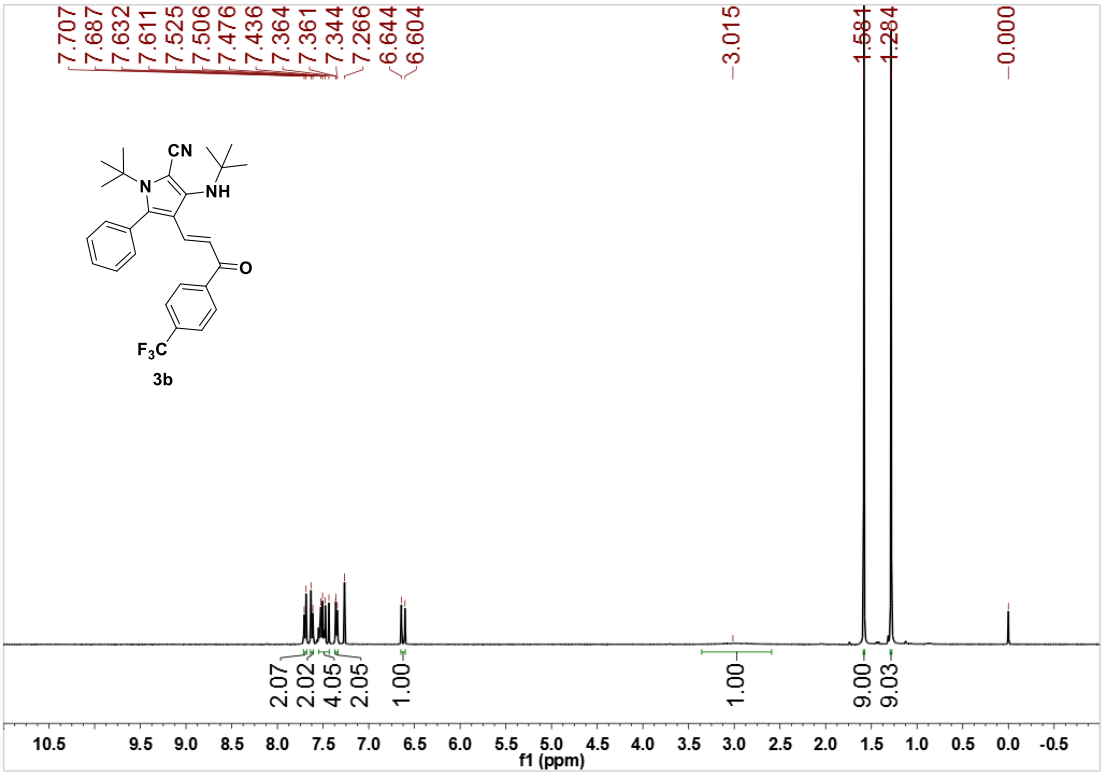
5. Copies of ^{1}H and ^{13}C NMR Spectrum



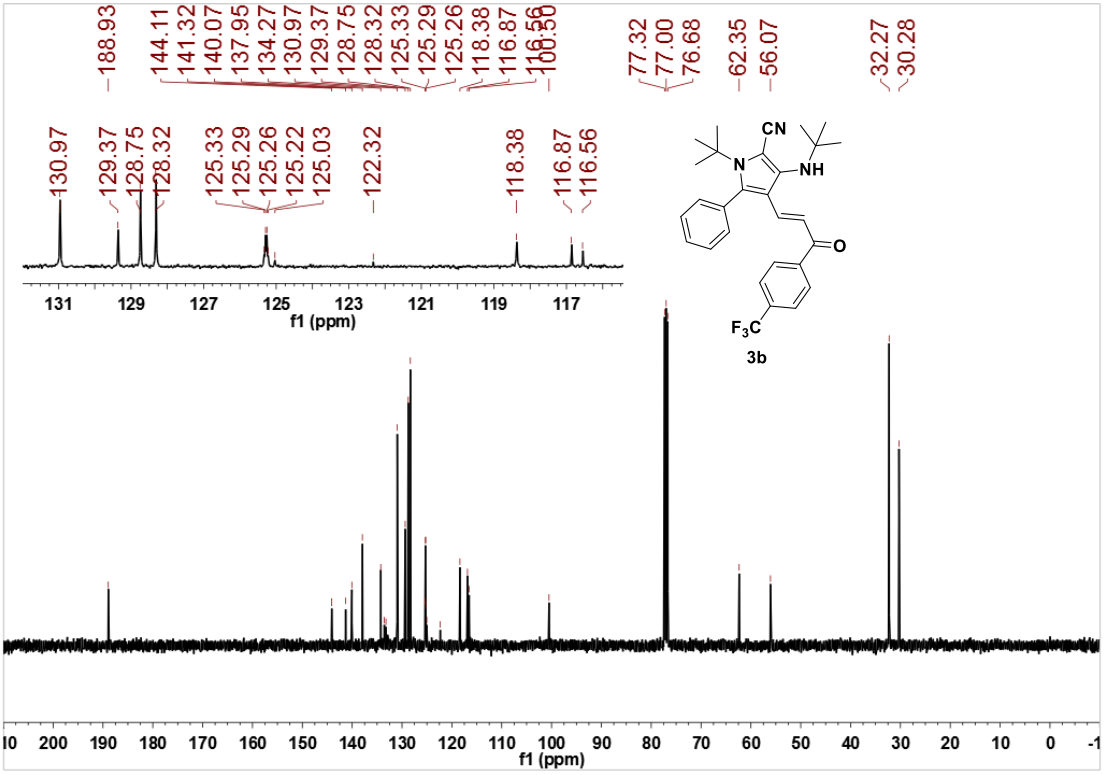
^{1}H NMR (400 MHz), $CDCl_3$



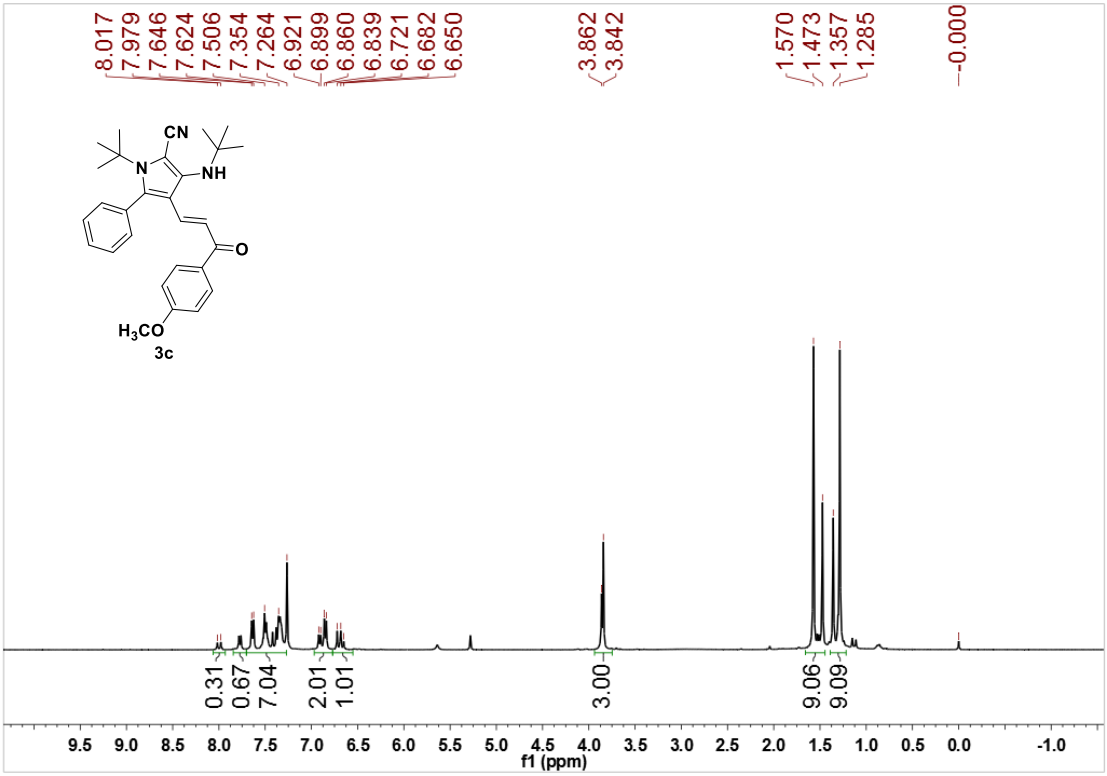
^{13}C NMR (100 MHz), $CDCl_3$



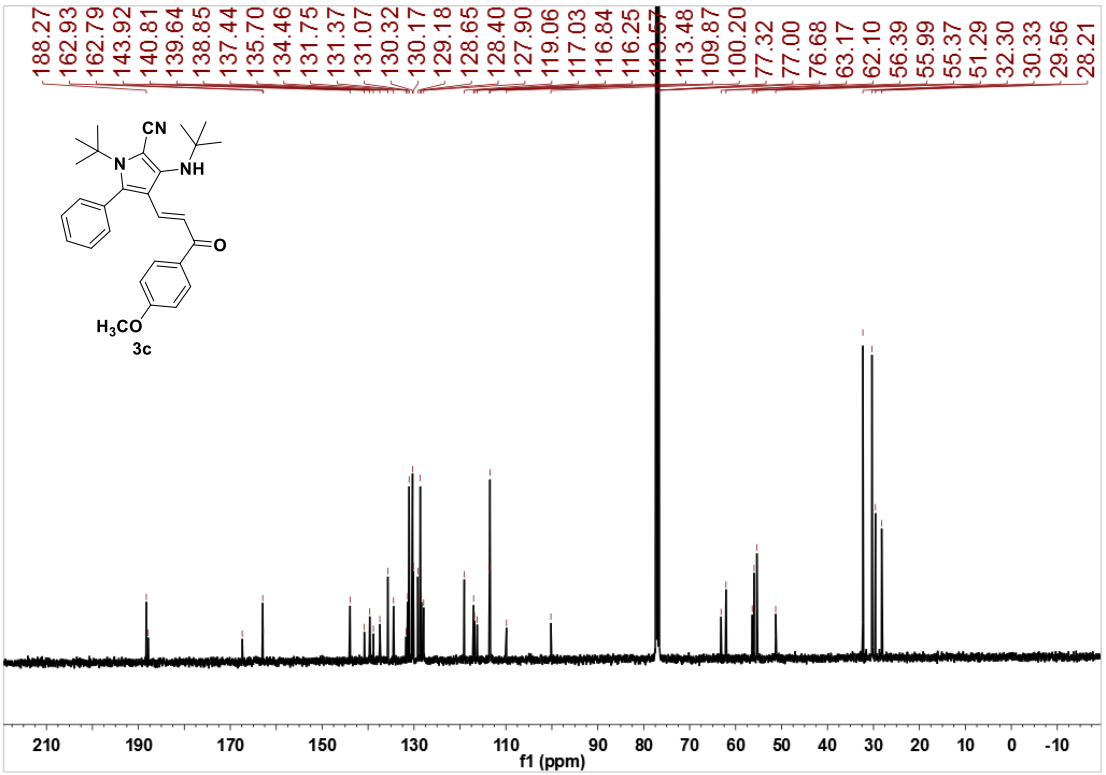
^{1}H NMR (400 MHz), $CDCl_3$



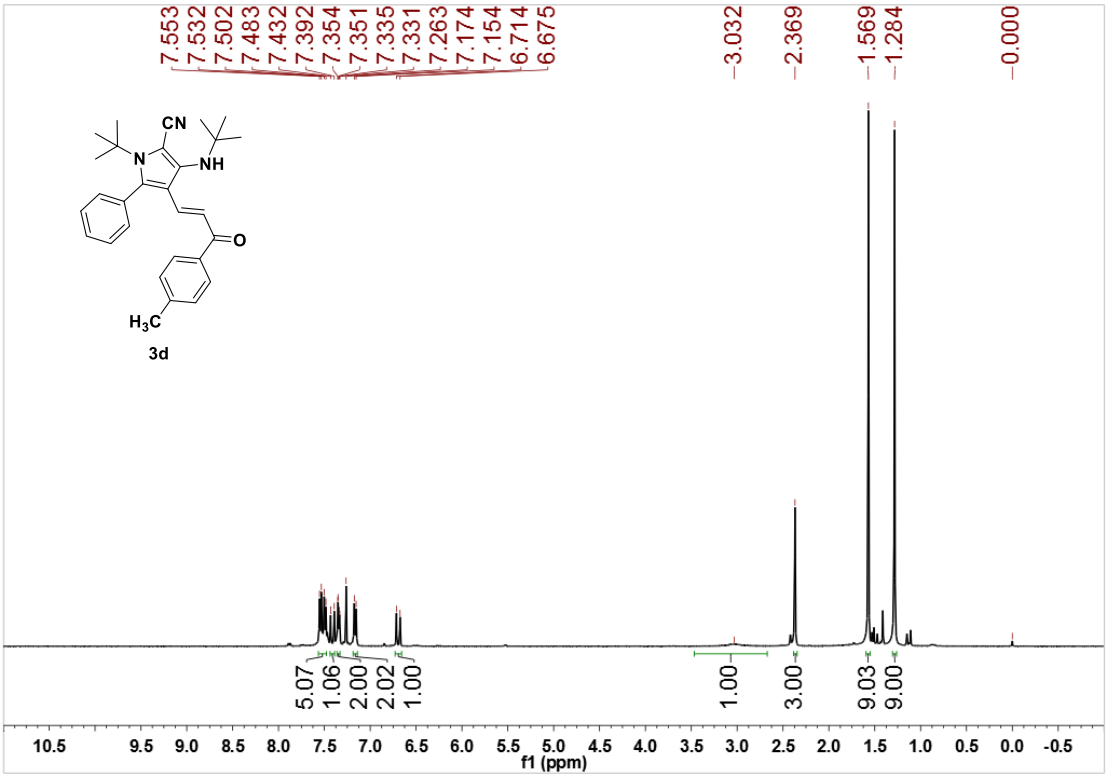
^{13}C NMR (100 MHz), $CDCl_3$



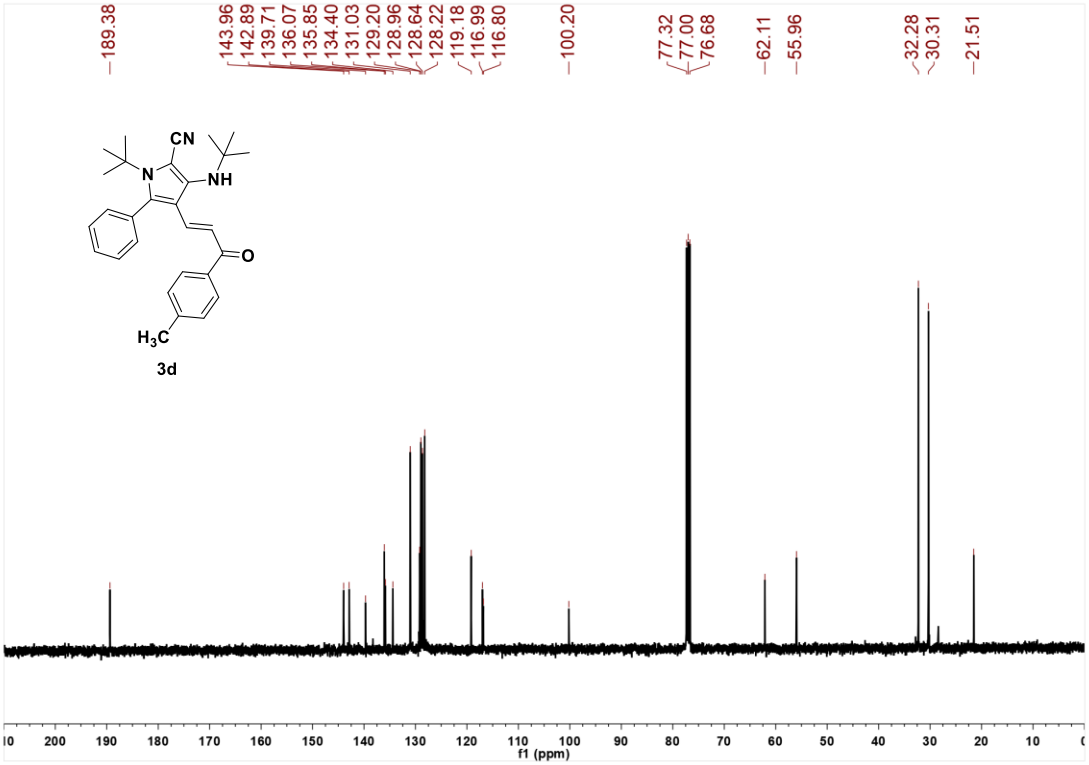
^{1}H NMR (400 MHz), $CDCl_3$



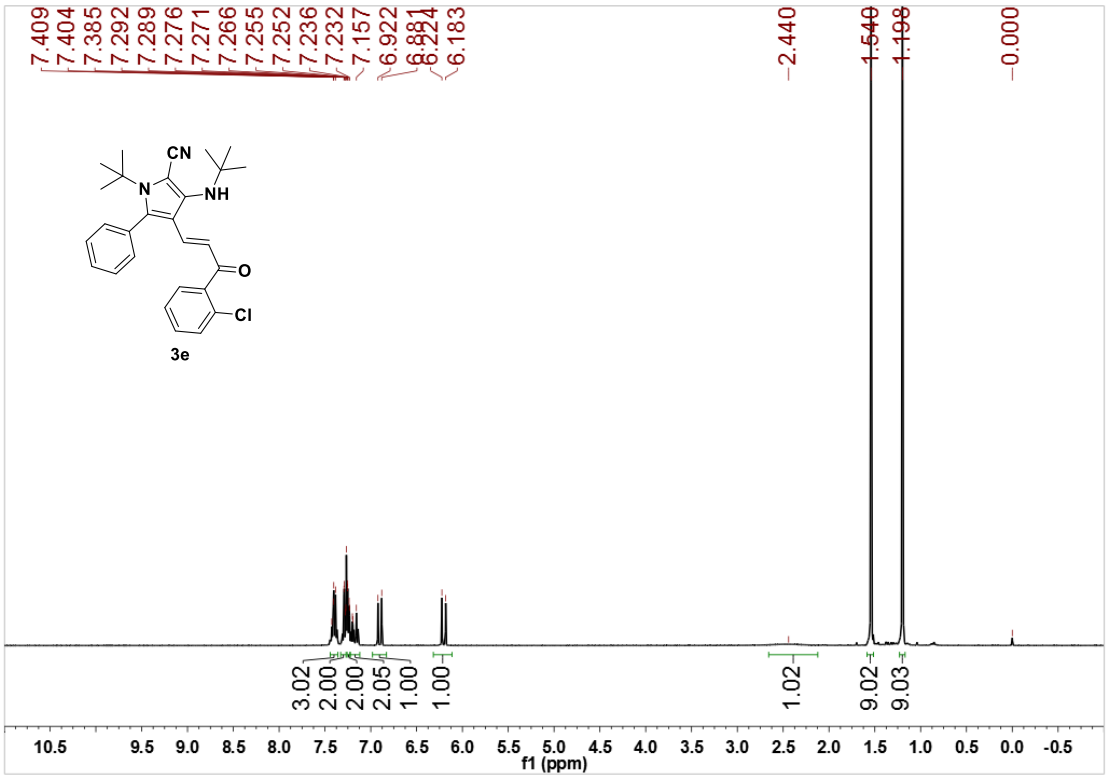
^{13}C NMR (100 MHz), $CDCl_3$



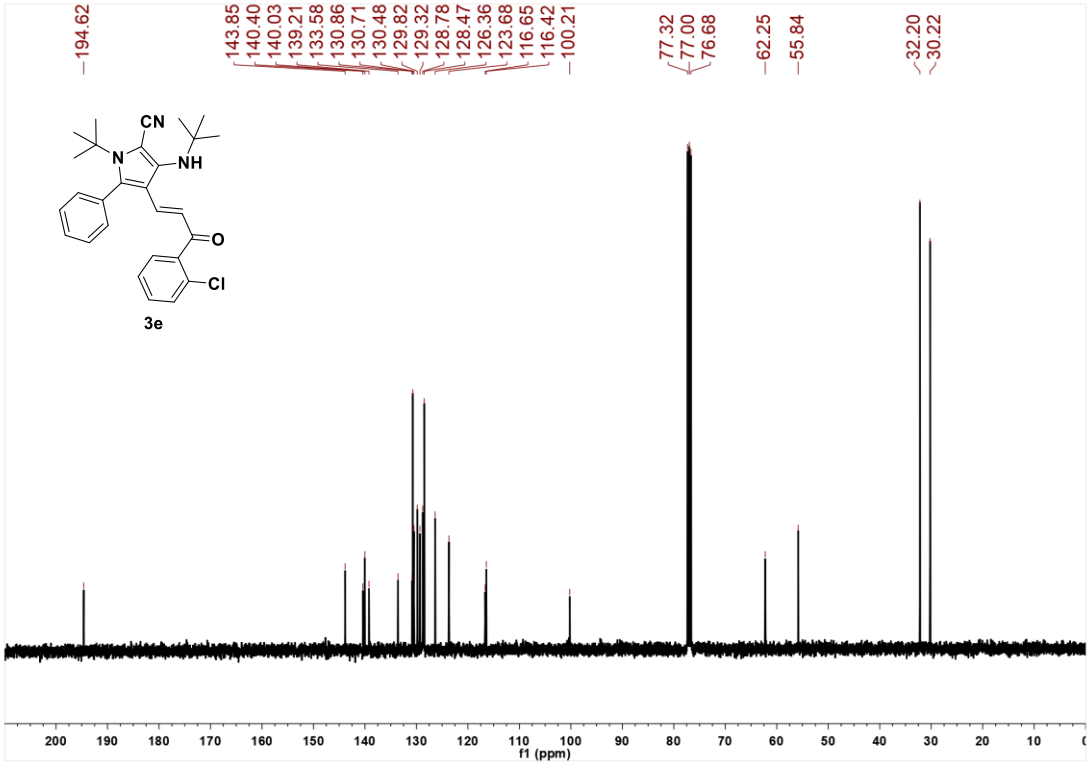
^{1}H NMR (400 MHz), $CDCl_3$



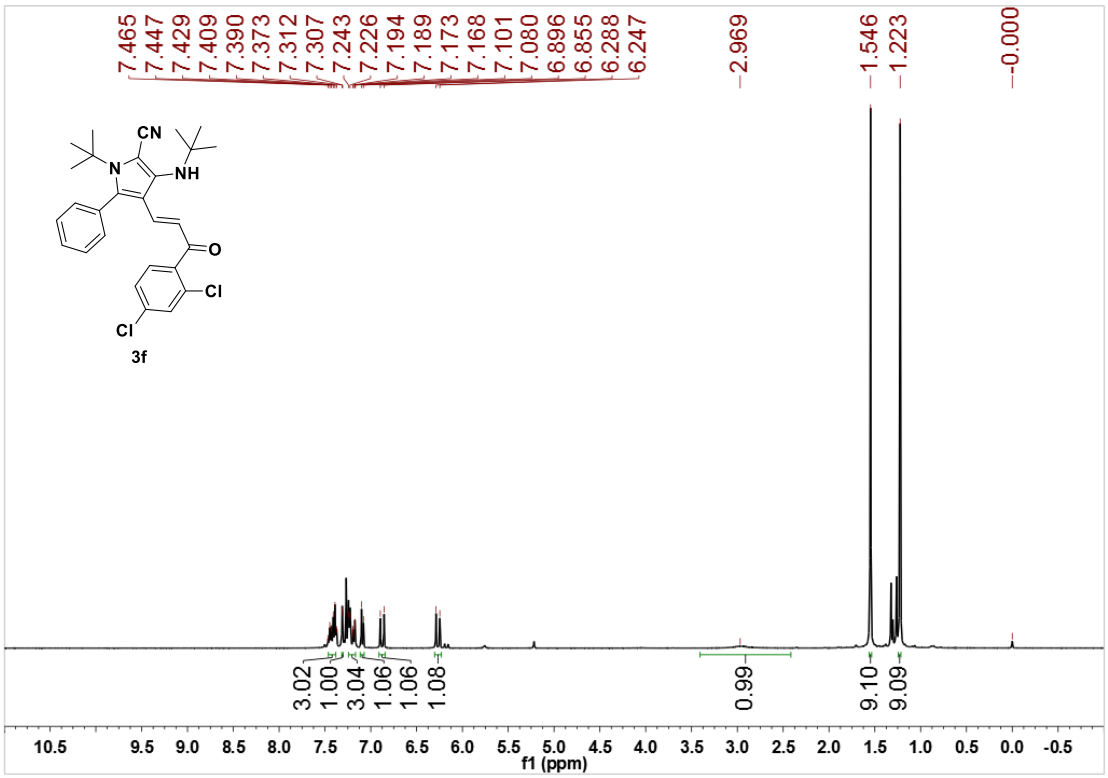
^{13}C NMR (100 MHz), $CDCl_3$



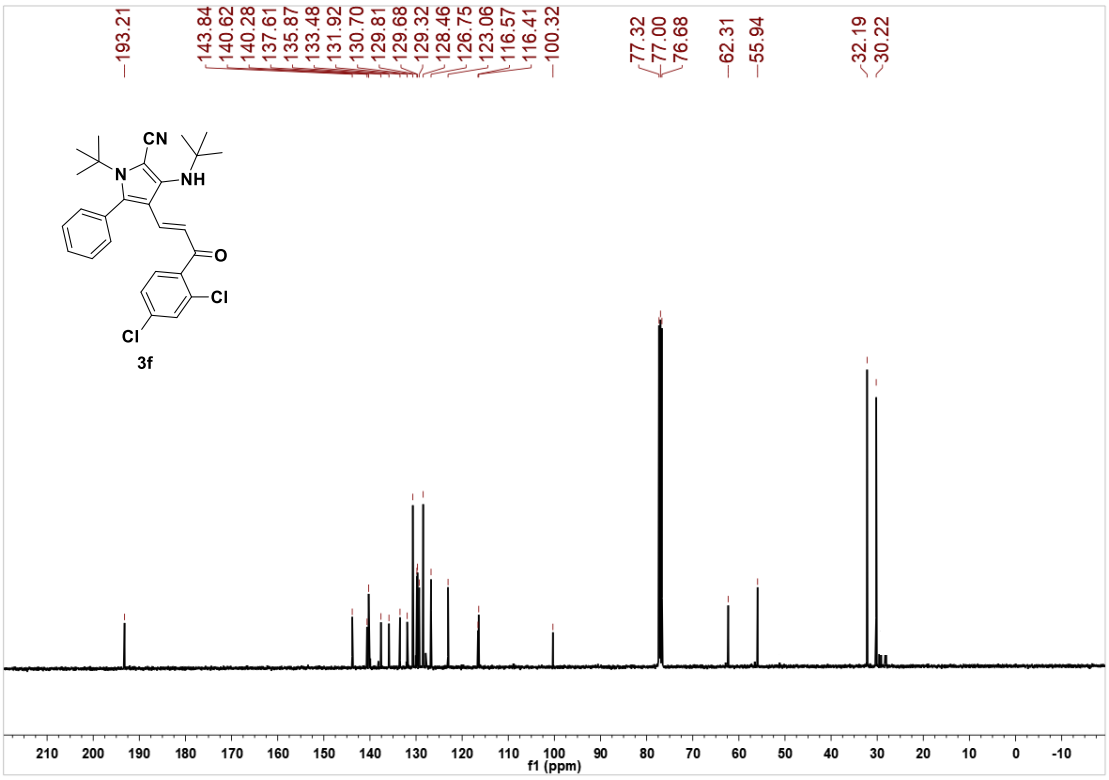
^{1}H NMR (400 MHz), $CDCl_3$



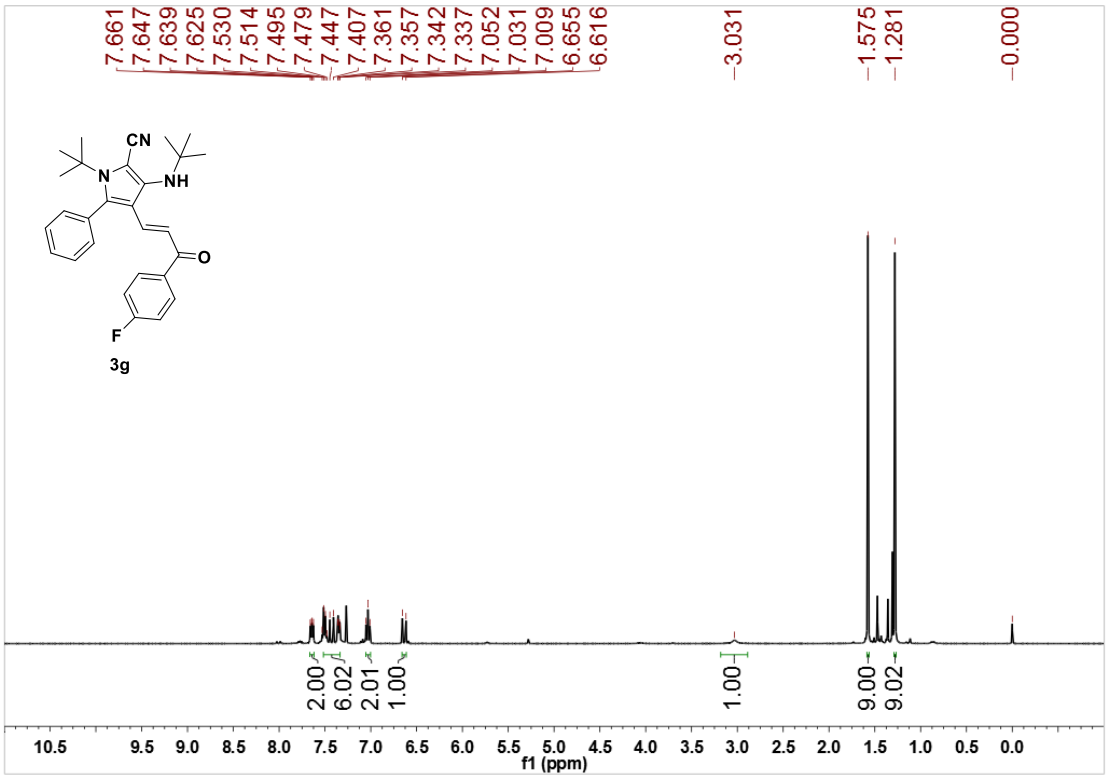
^{13}C NMR (100 MHz), $CDCl_3$



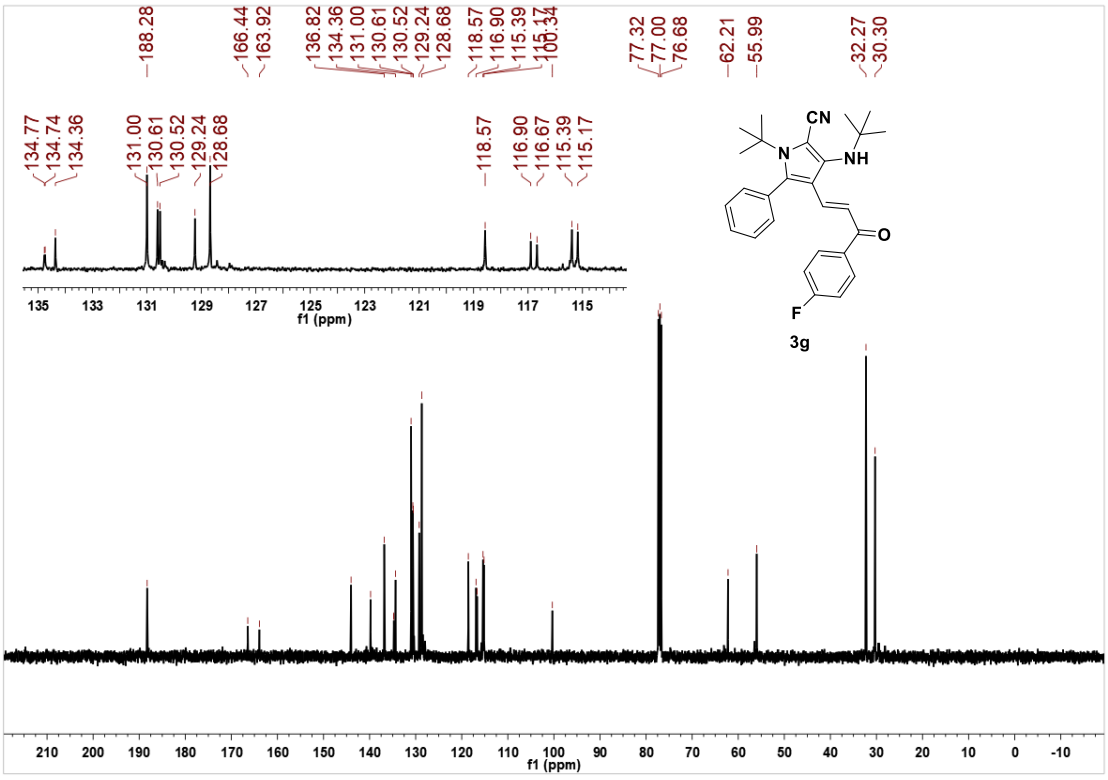
^{1}H NMR (400 MHz), $CDCl_3$



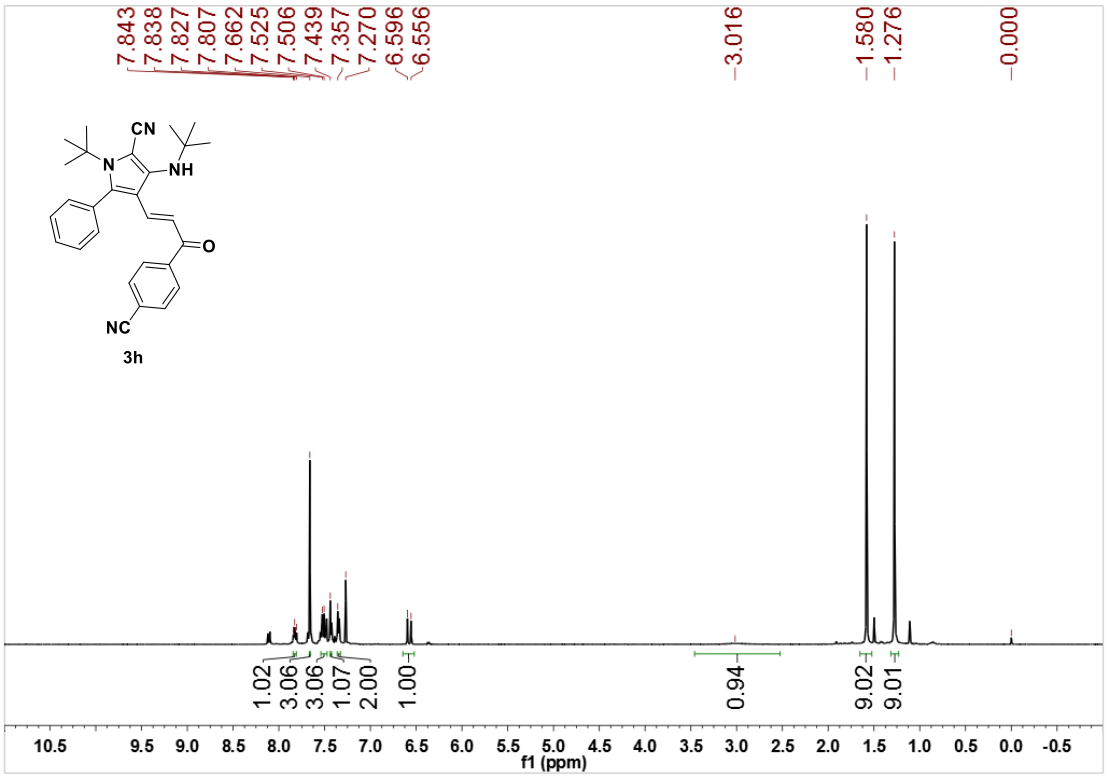
^{13}C NMR (100 MHz), $CDCl_3$



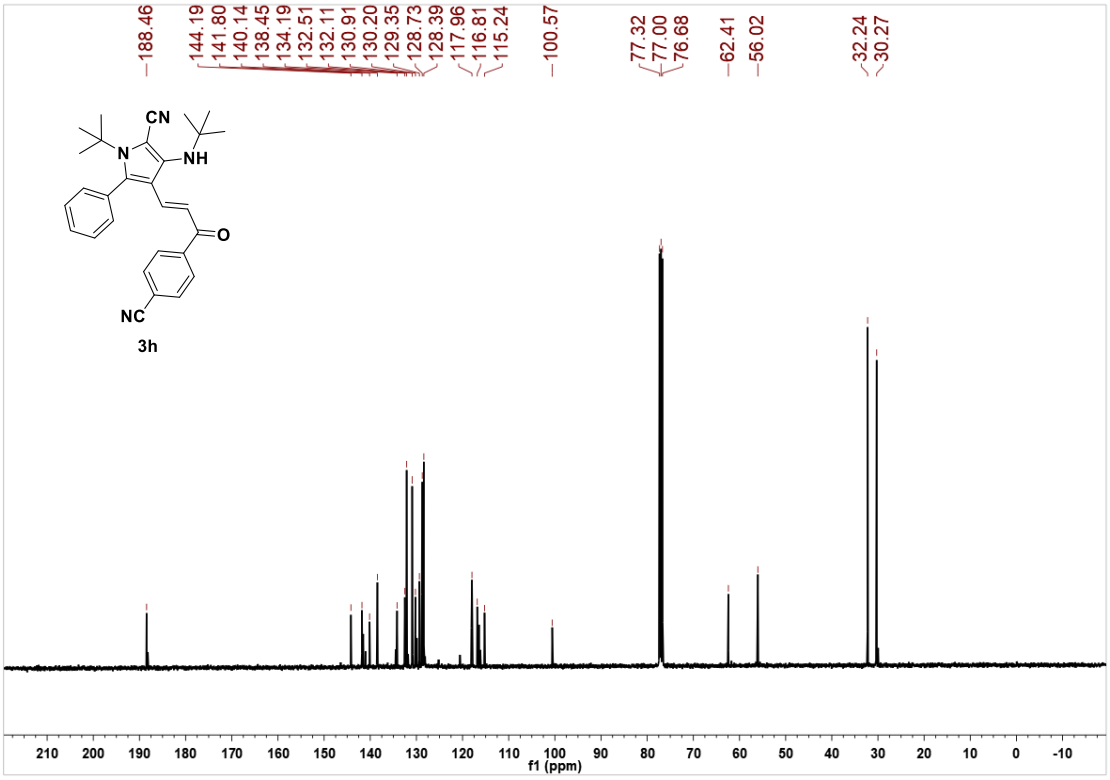
^{1}H NMR (400 MHz), $CDCl_3$



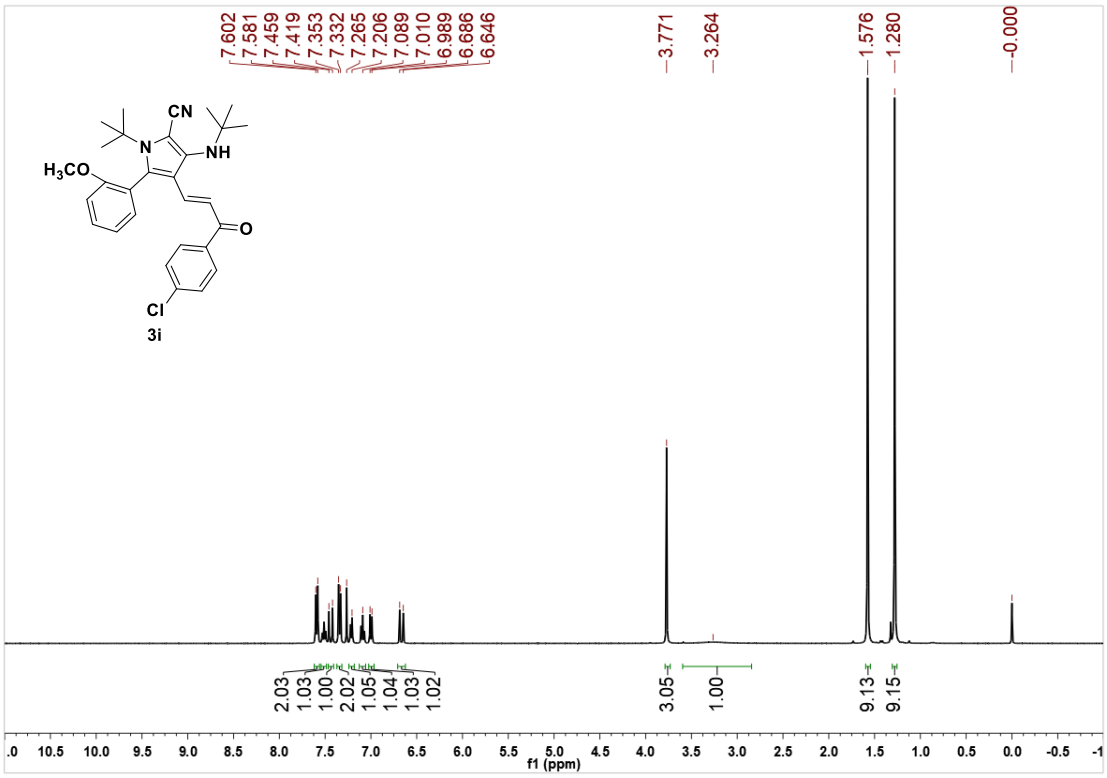
^{13}C NMR (100 MHz), $CDCl_3$



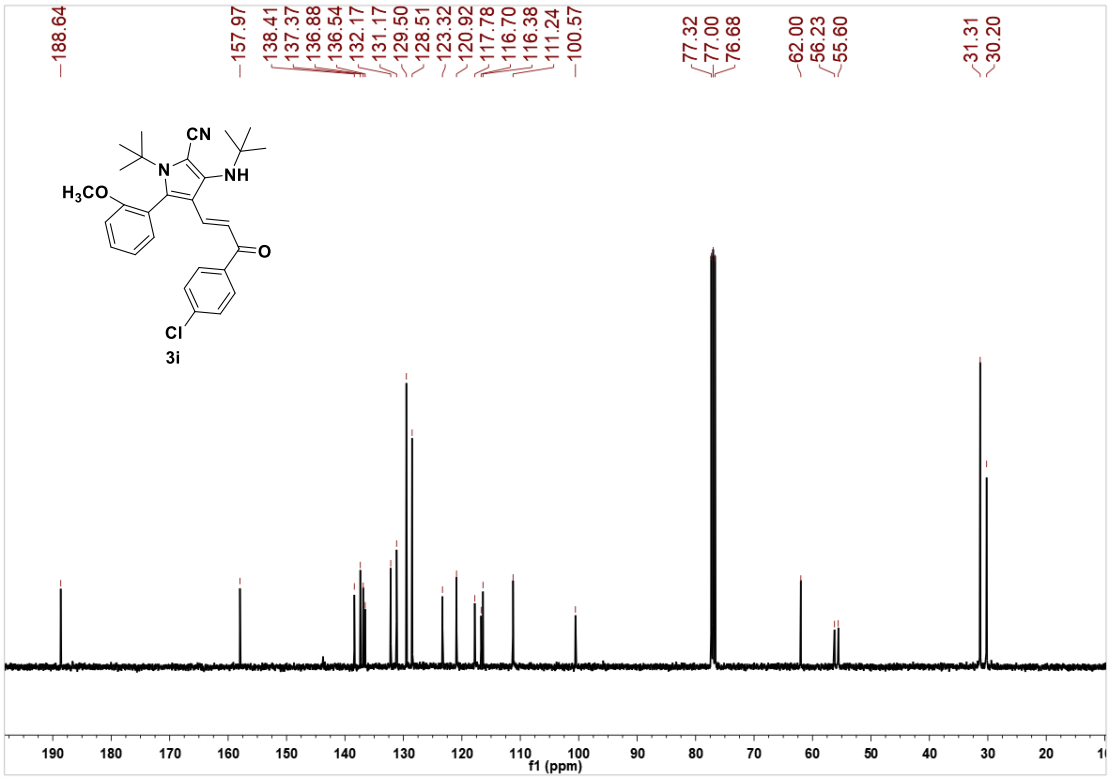
^{1}H NMR (400 MHz), $CDCl_3$



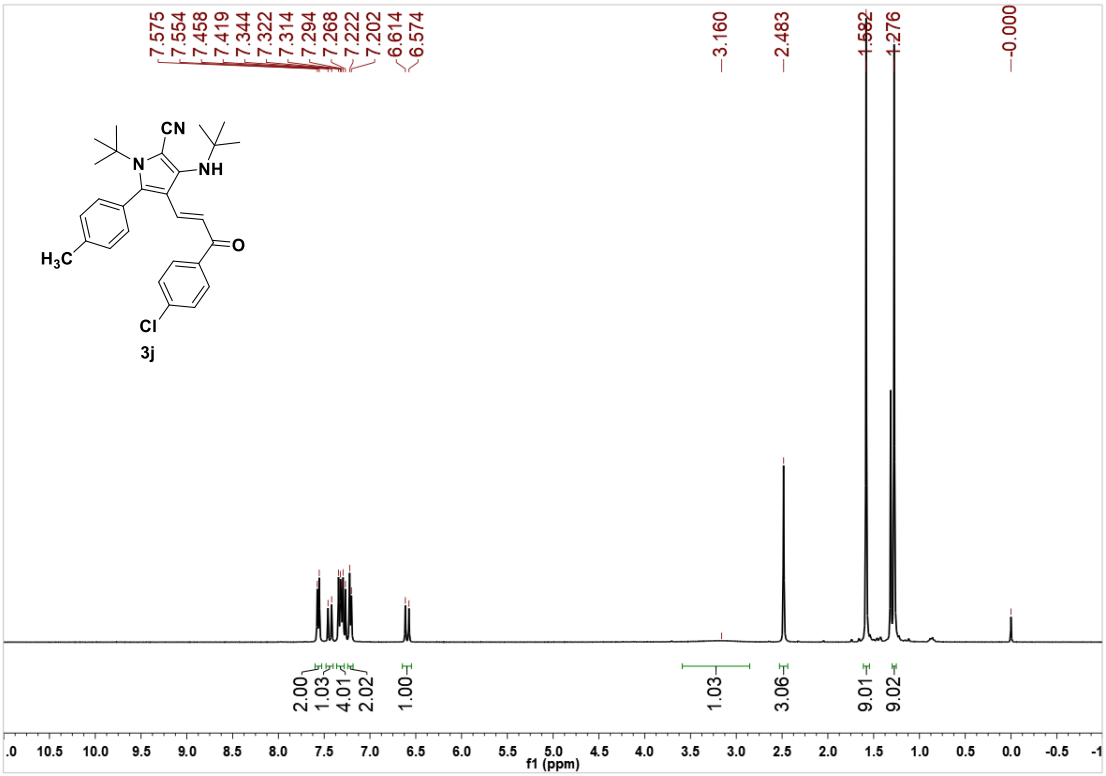
^{13}C NMR (100 MHz), $CDCl_3$



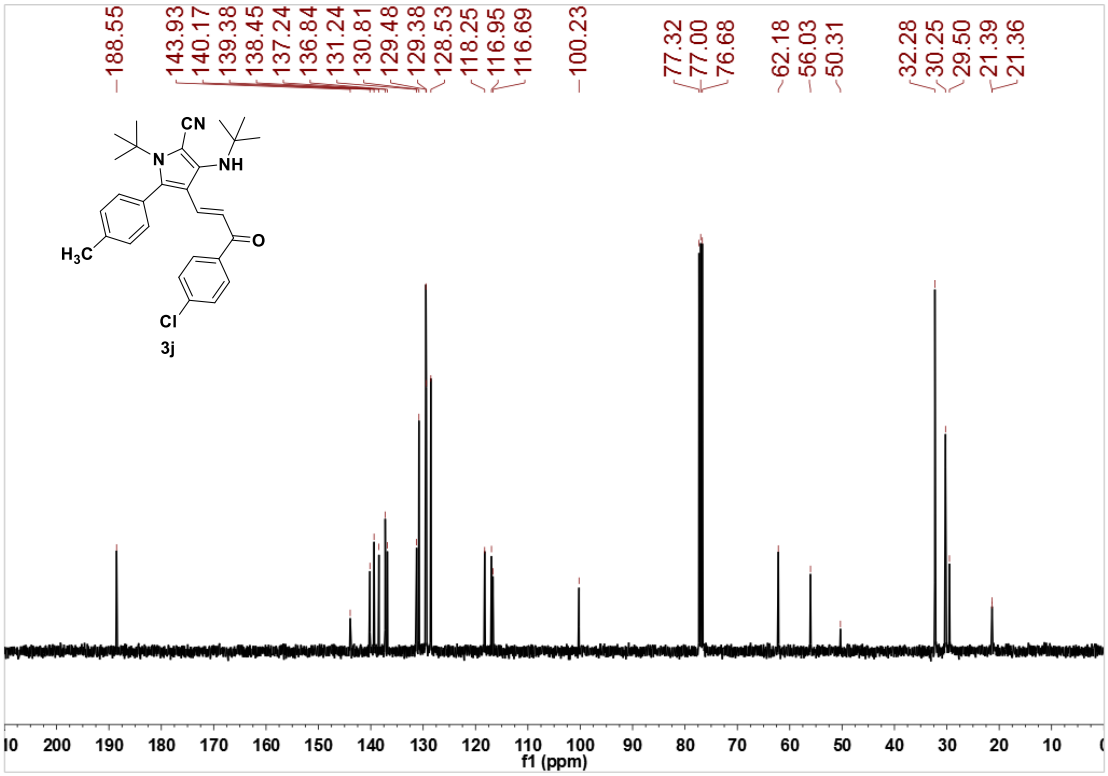
^{1}H NMR (400 MHz), $CDCl_3$



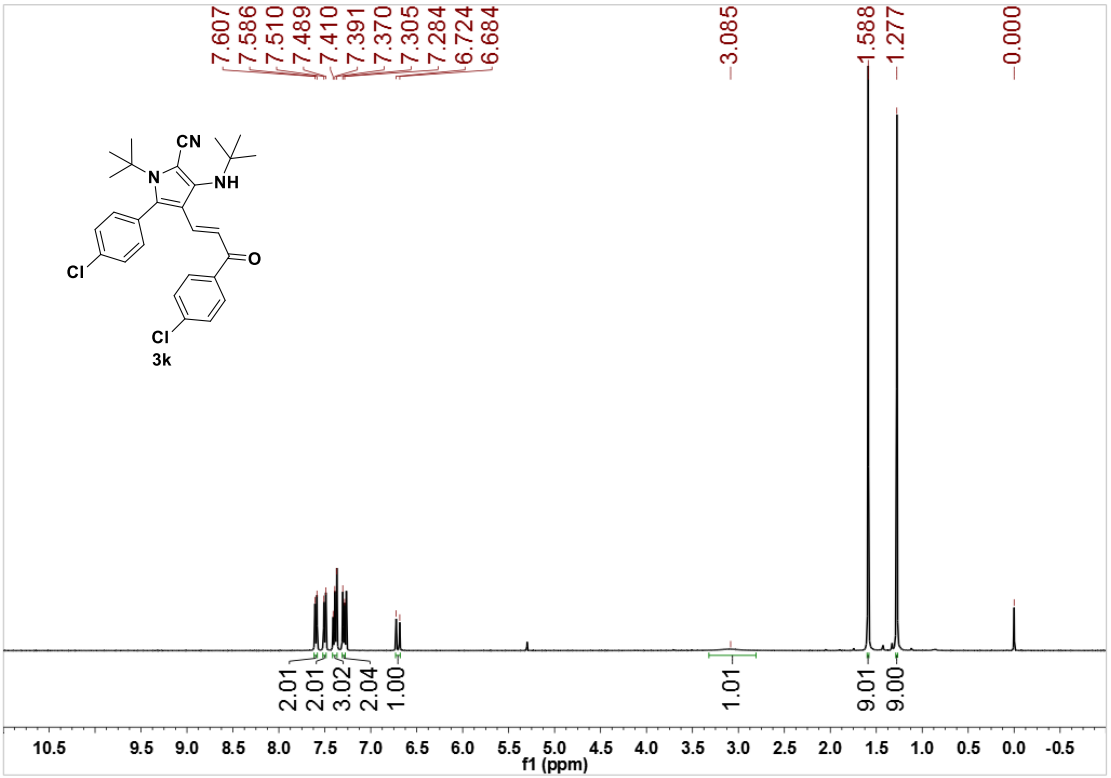
^{13}C NMR (100 MHz), $CDCl_3$



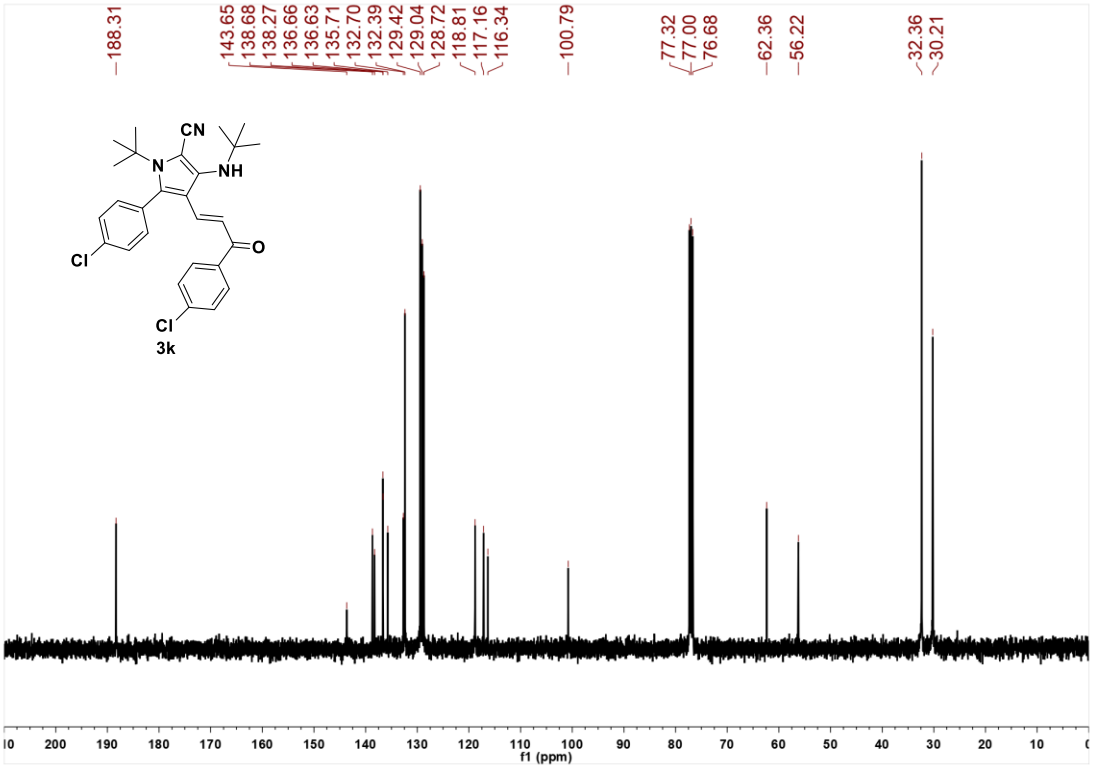
^{1}H NMR (400 MHz), $CDCl_3$



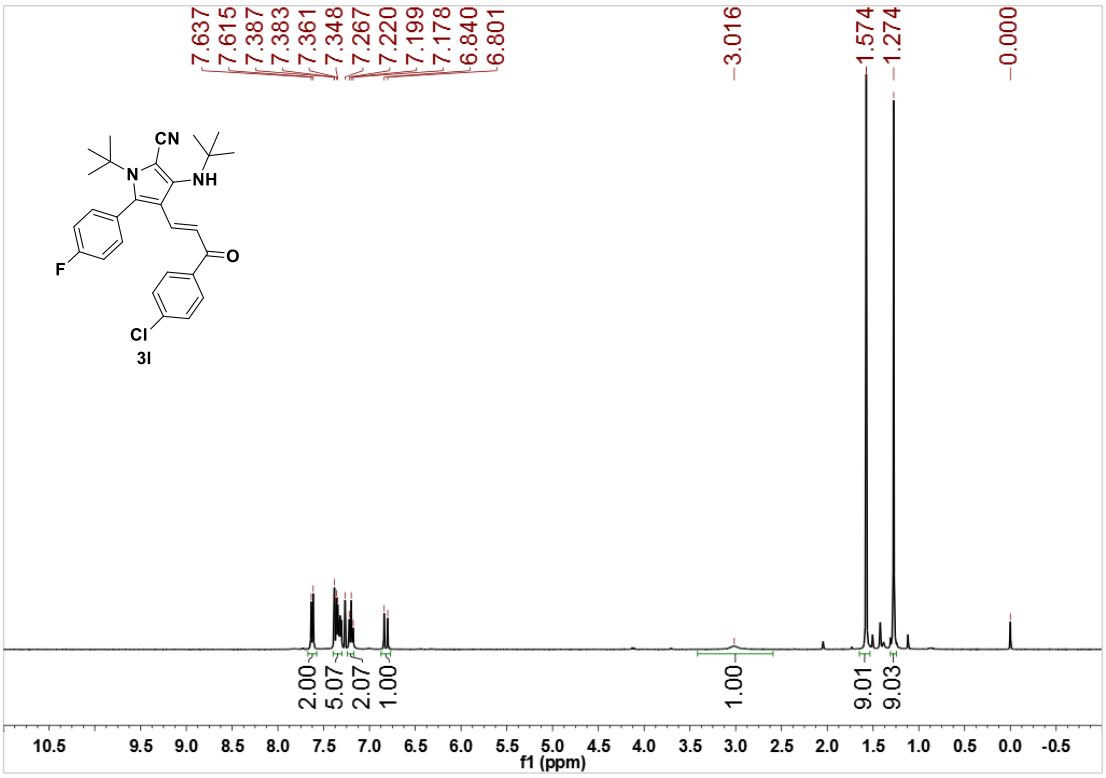
^{13}C NMR (100 MHz), $CDCl_3$



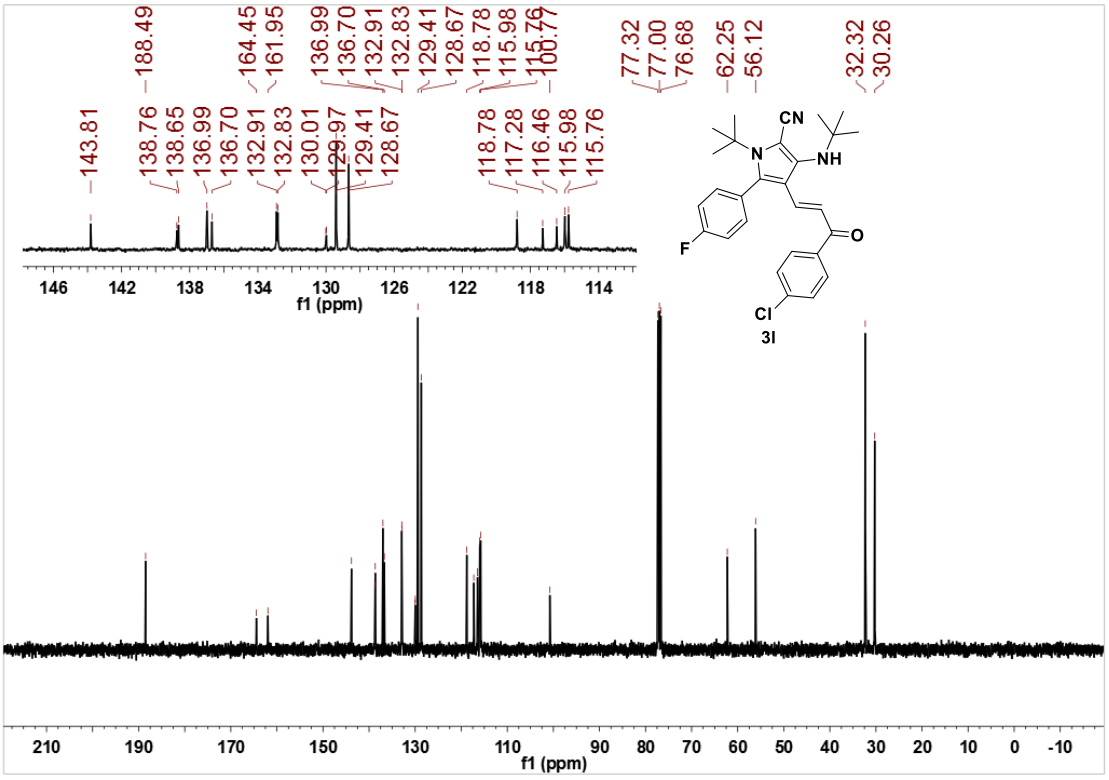
^{1}H NMR (400 MHz), $CDCl_3$



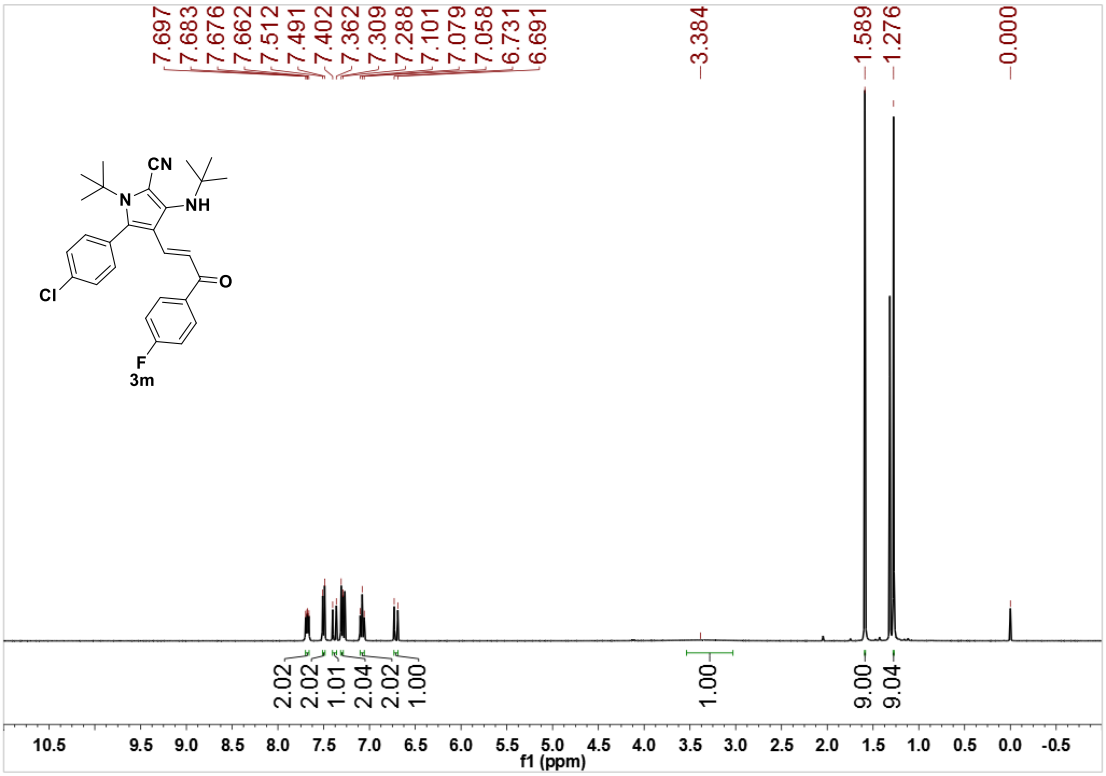
^{13}C NMR (100 MHz), $CDCl_3$



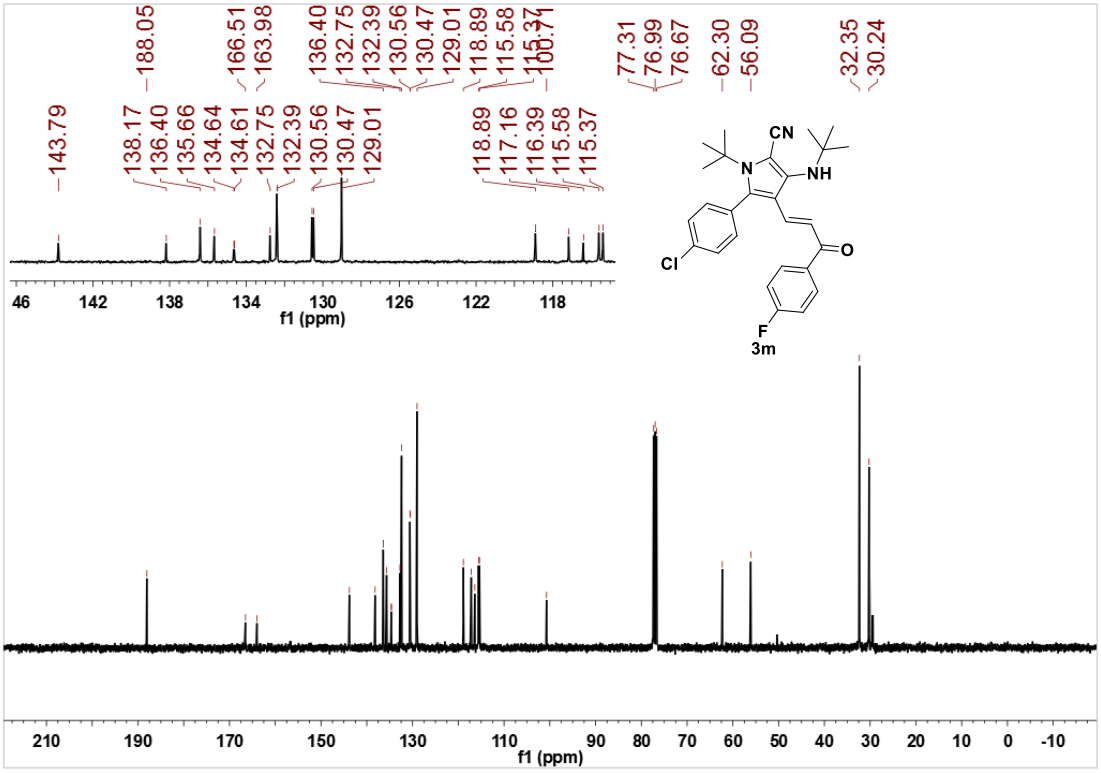
^{1}H NMR (400 MHz), $CDCl_3$



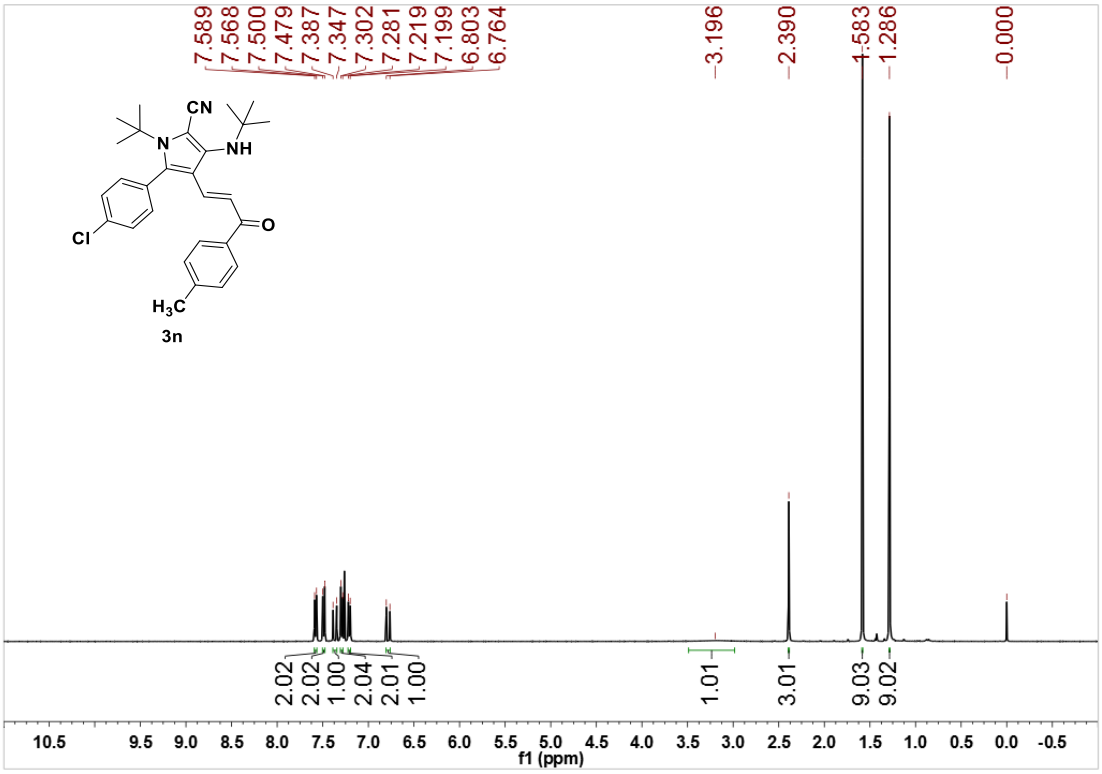
^{13}C NMR (100 MHz), $CDCl_3$



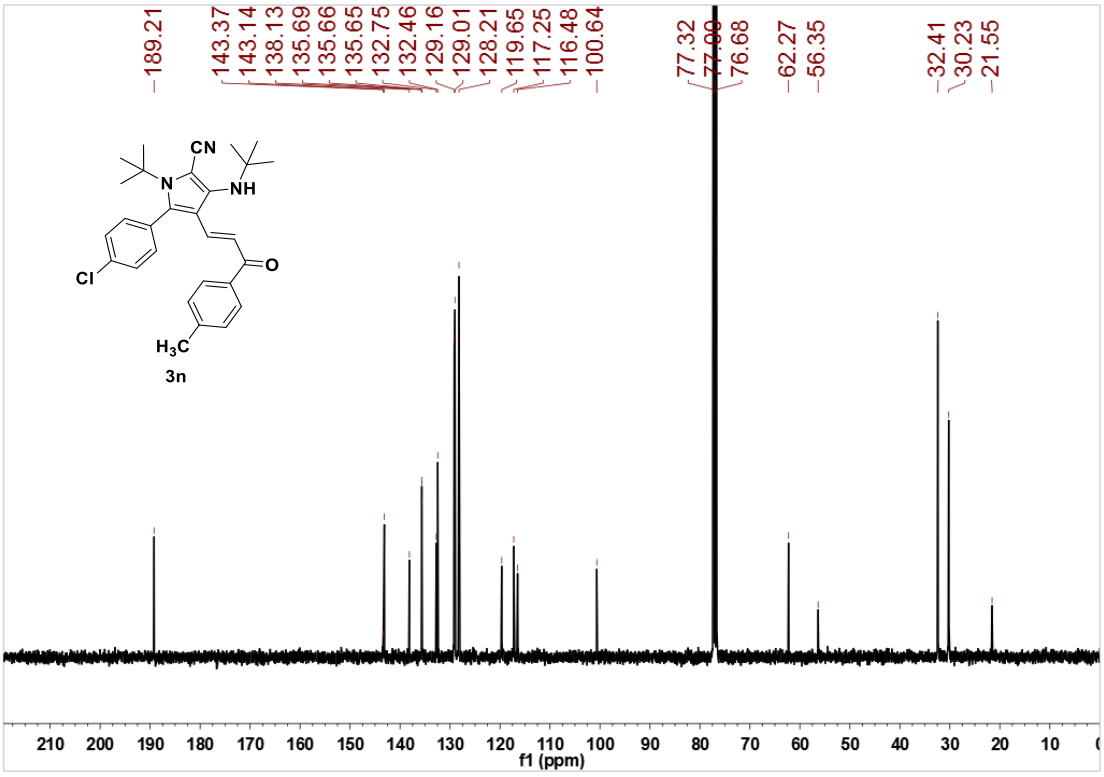
^{1}H NMR (400 MHz), $CDCl_3$



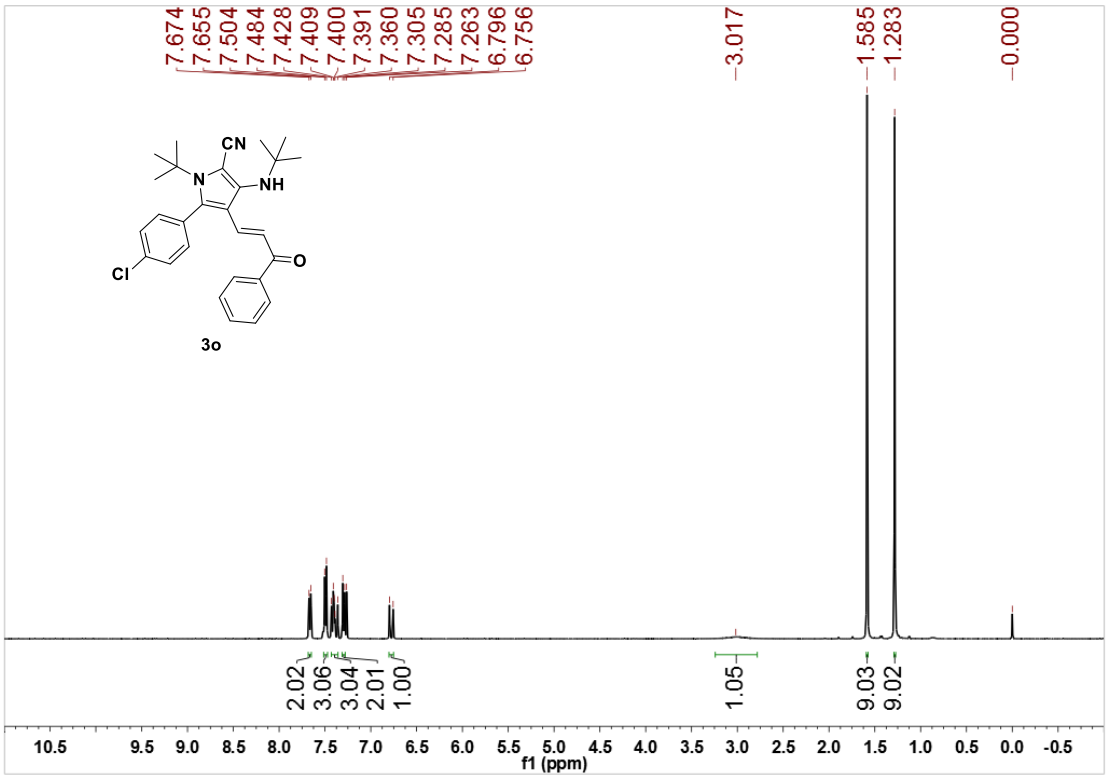
^{13}C NMR (100 MHz), $CDCl_3$



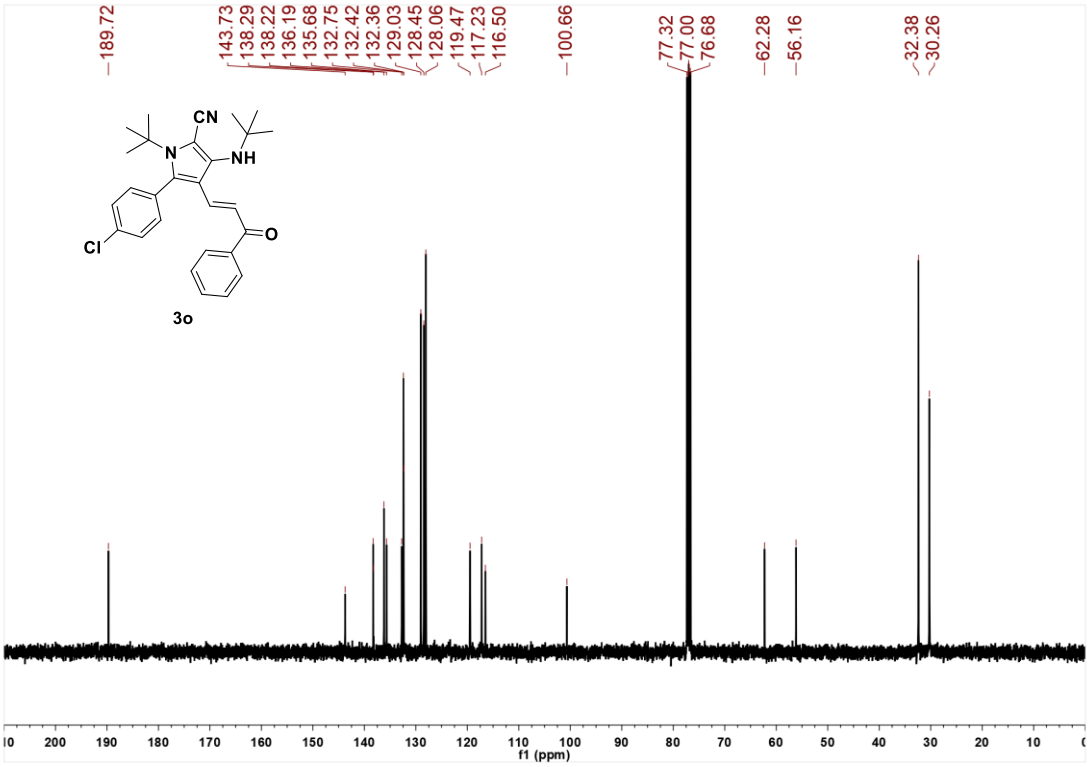
^{1}H NMR (400 MHz), $CDCl_3$



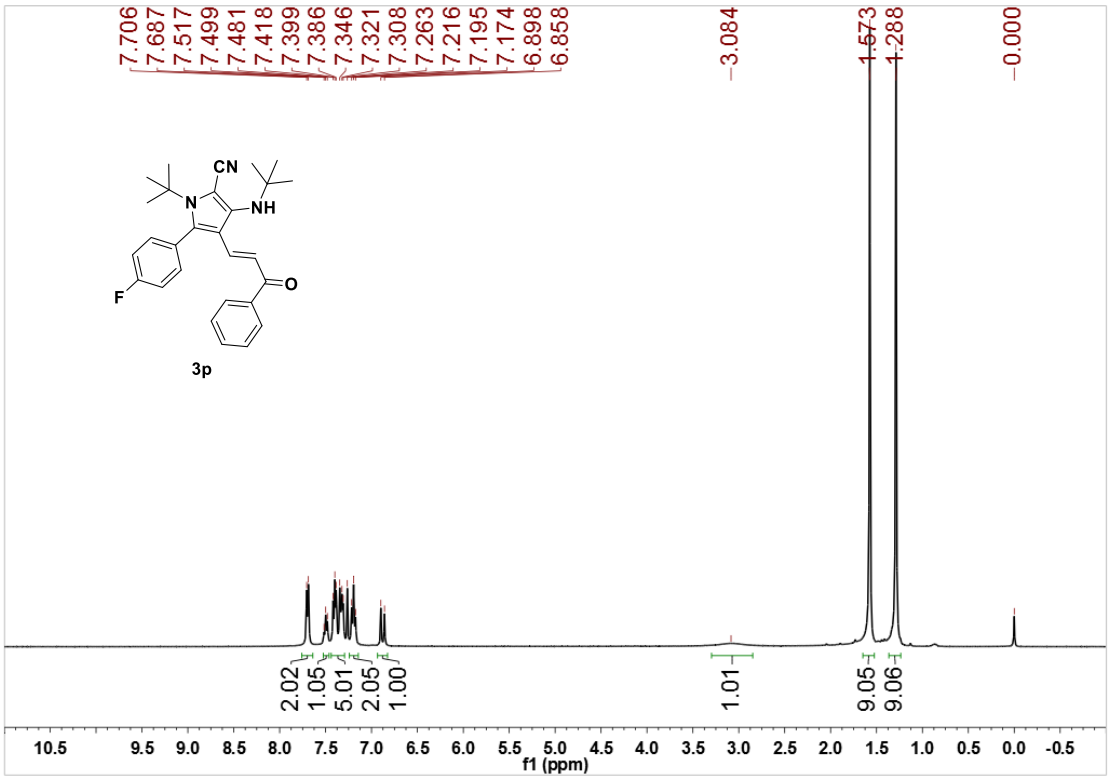
^{13}C NMR (100 MHz), $CDCl_3$



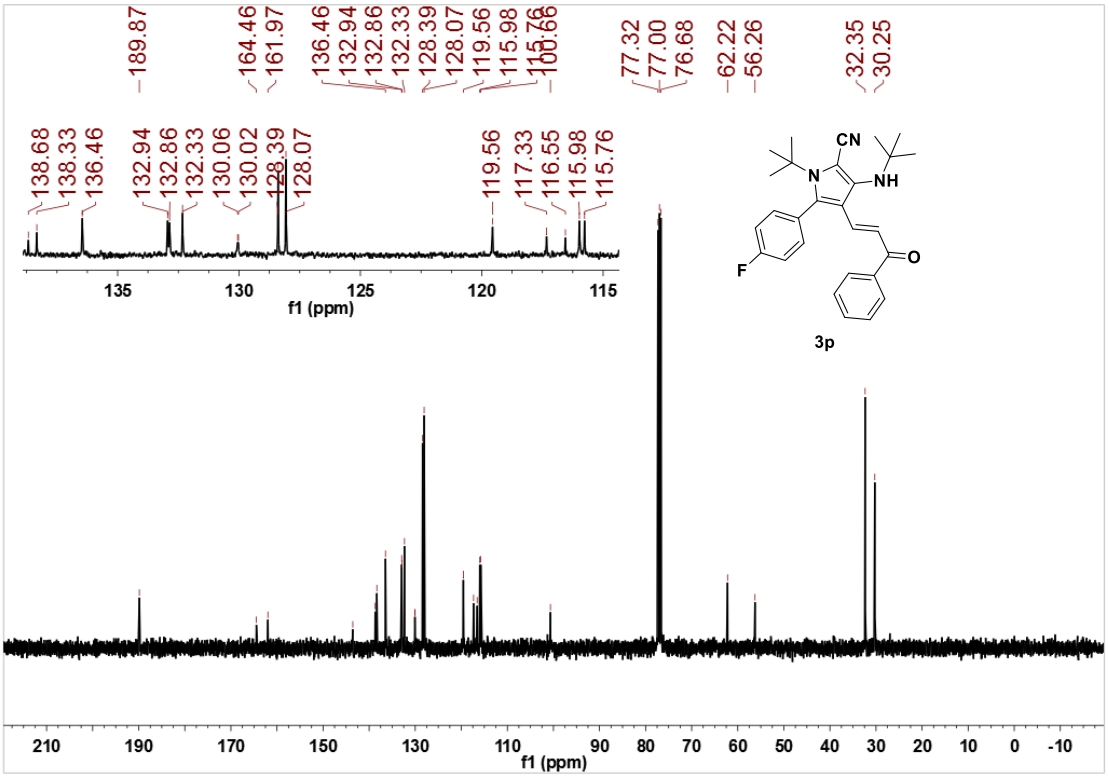
^{1}H NMR (400 MHz), $CDCl_3$



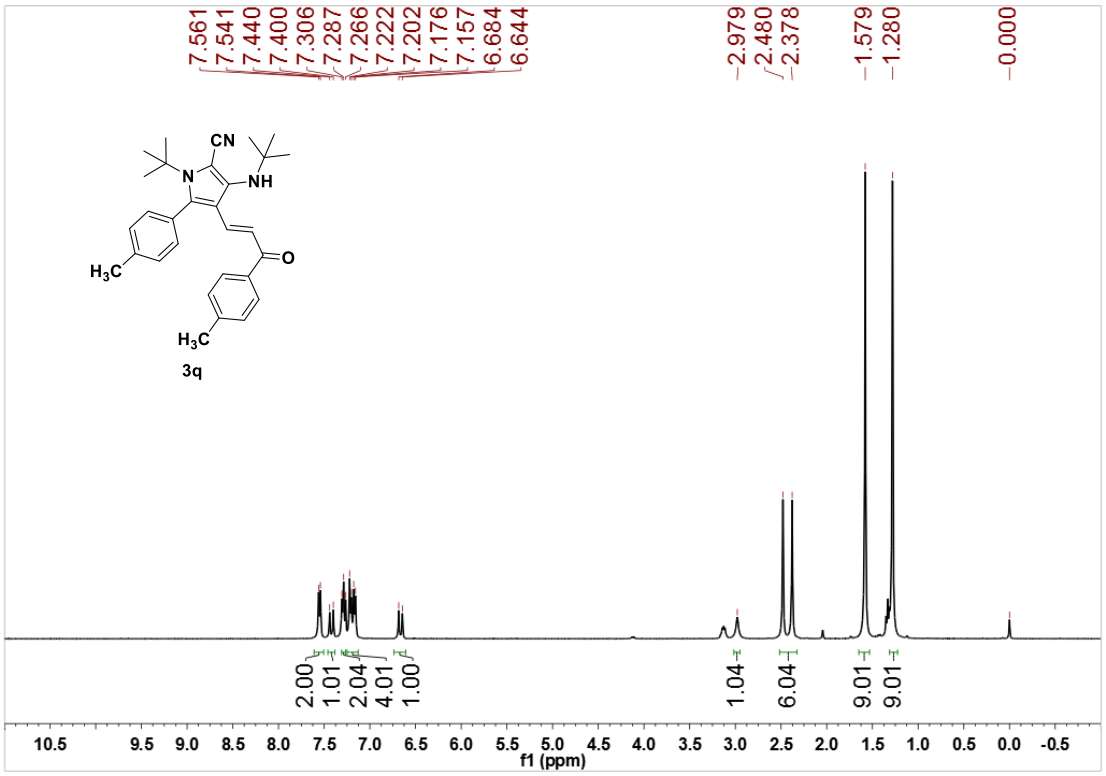
^{13}C NMR (100 MHz), $CDCl_3$



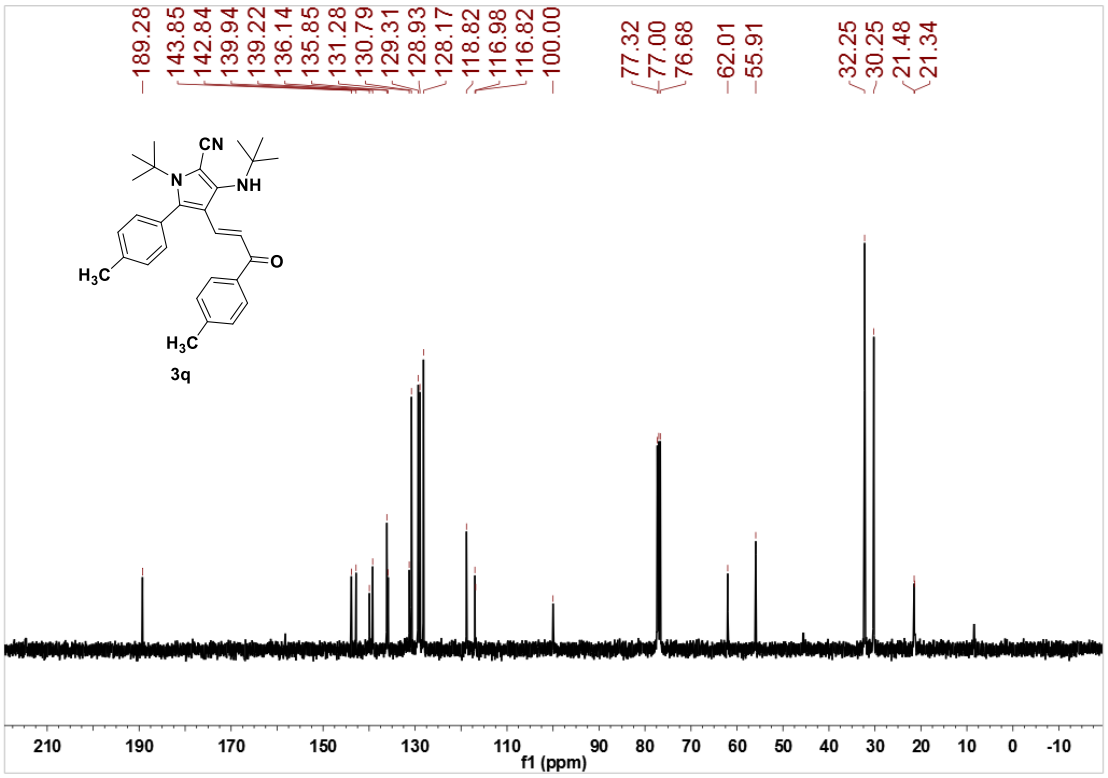
^{1}H NMR (400 MHz), $CDCl_3$



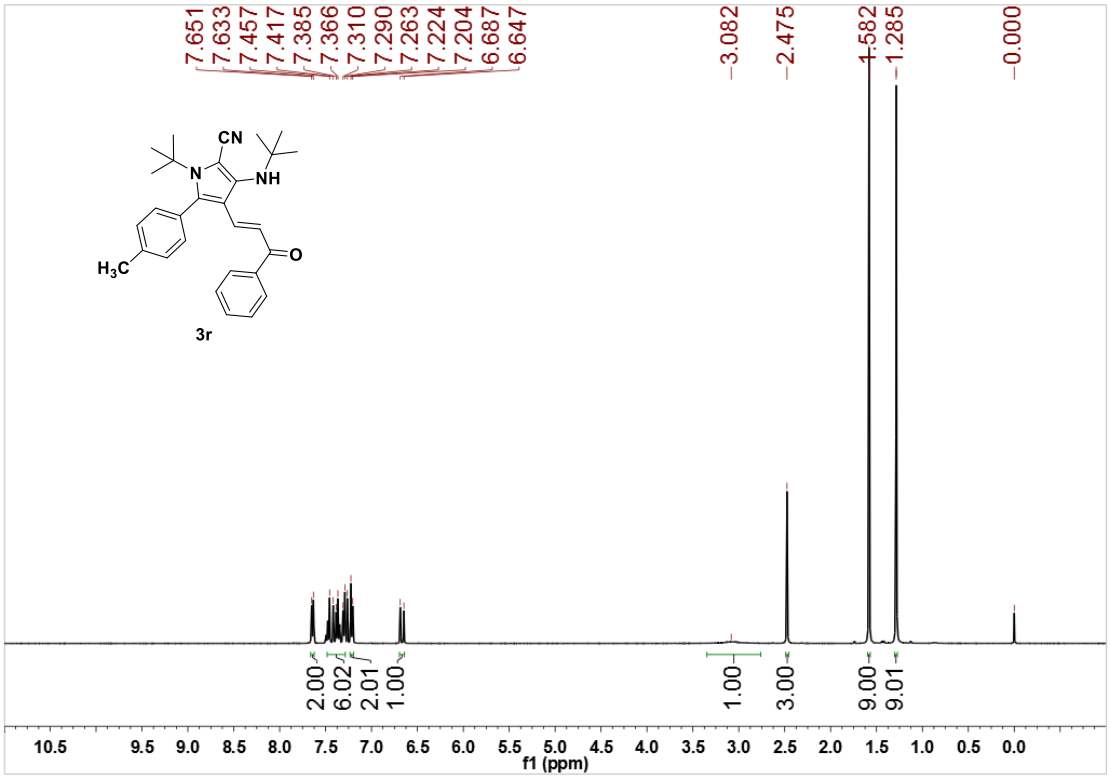
^{13}C NMR (100 MHz), $CDCl_3$



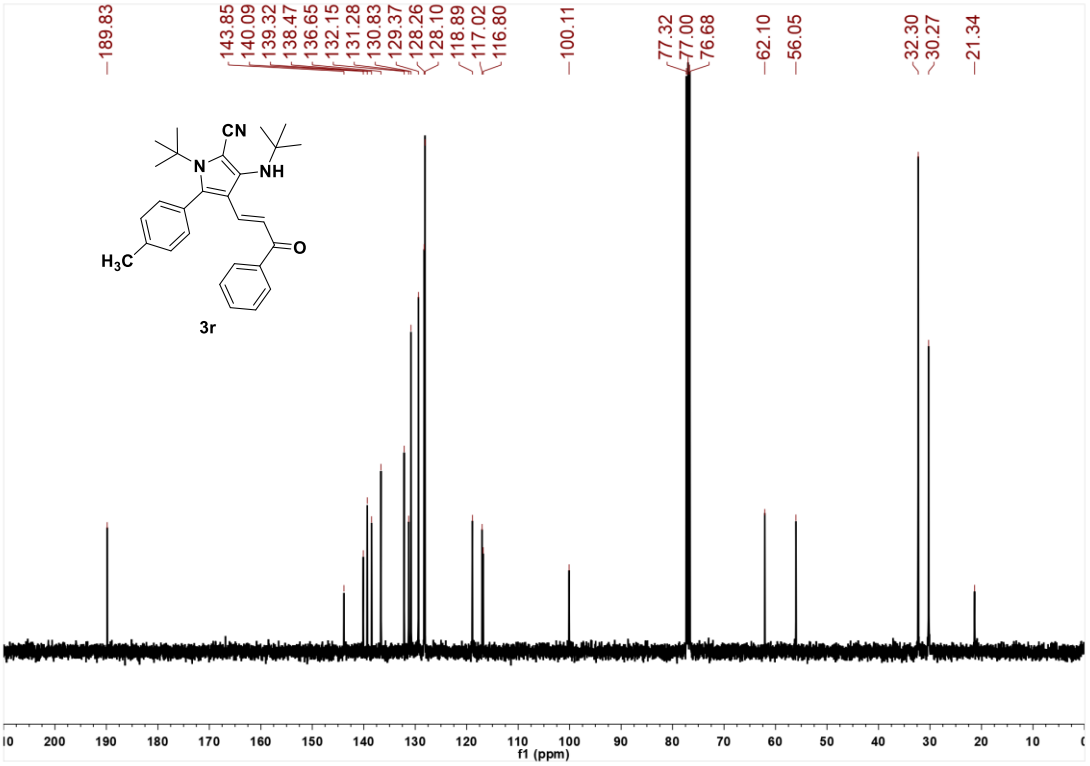
^{1}H NMR (400 MHz), $CDCl_3$



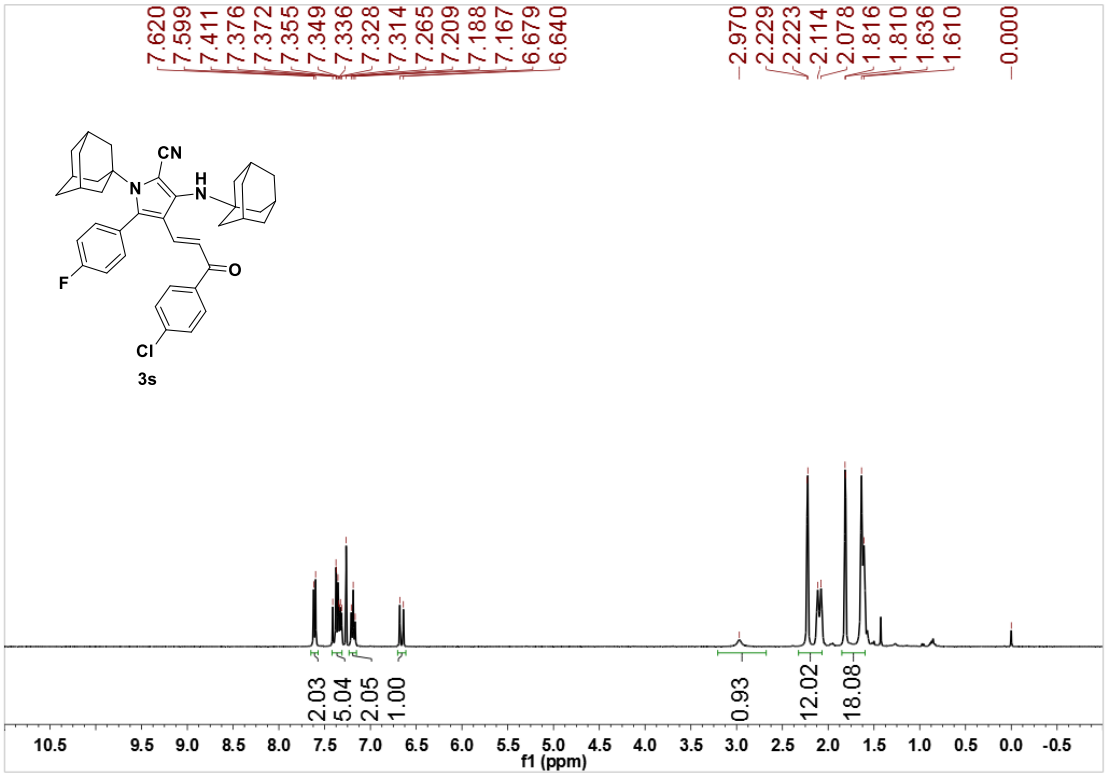
^{13}C NMR (100 MHz), $CDCl_3$



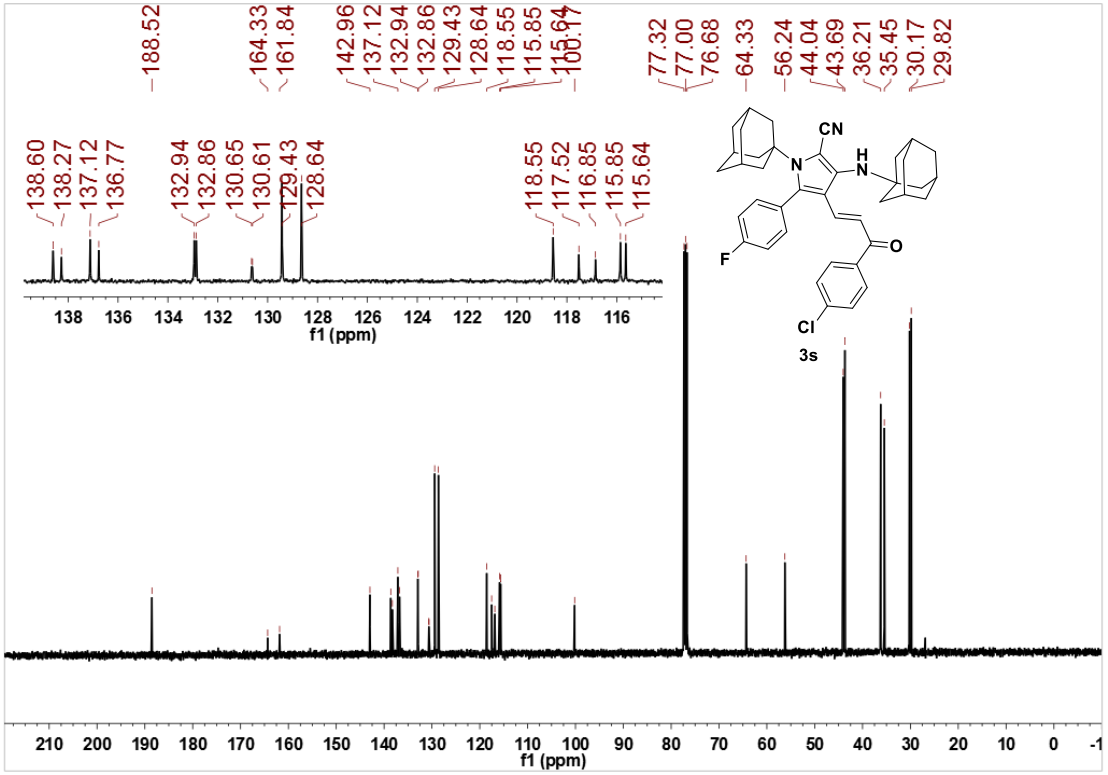
^{1}H NMR (400 MHz), $CDCl_3$



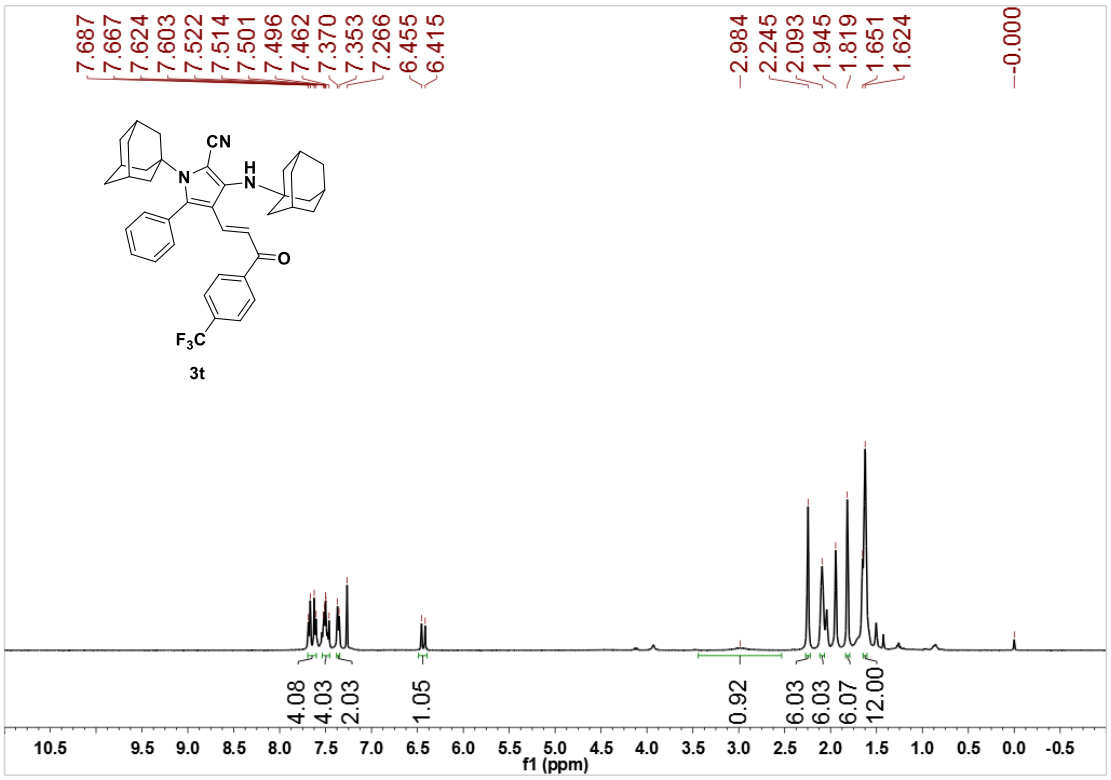
^{13}C NMR (100 MHz), $CDCl_3$



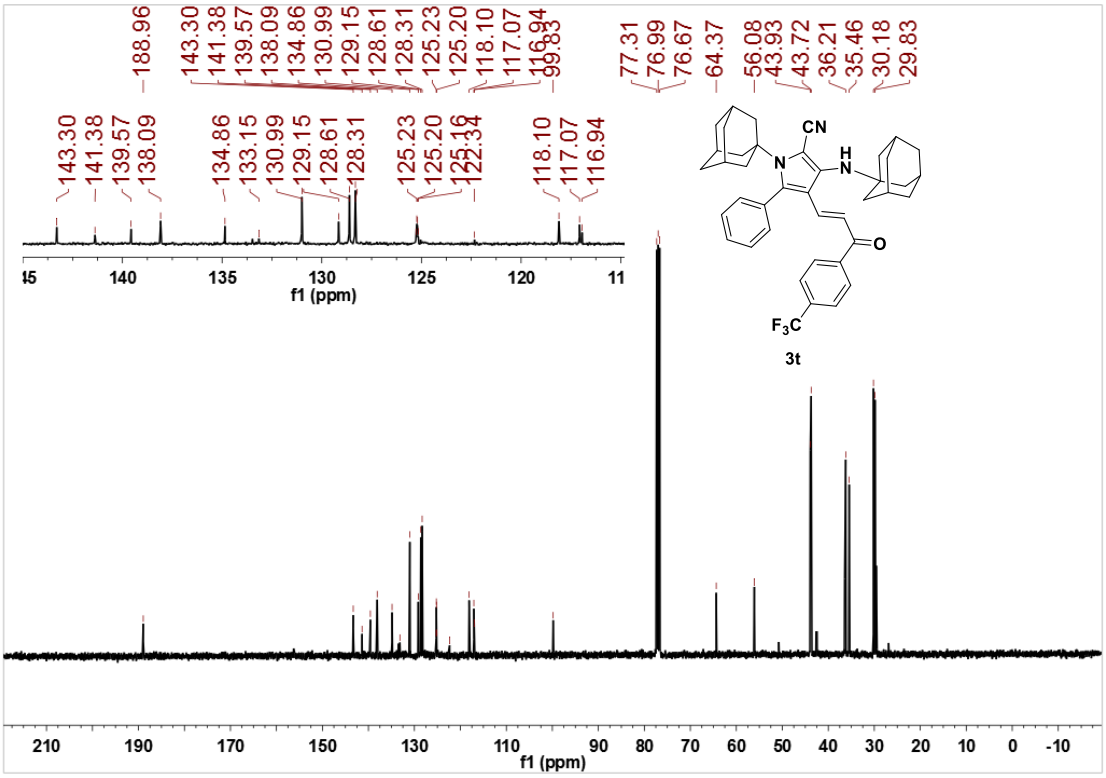
^{1}H NMR (400 MHz), $CDCl_3$



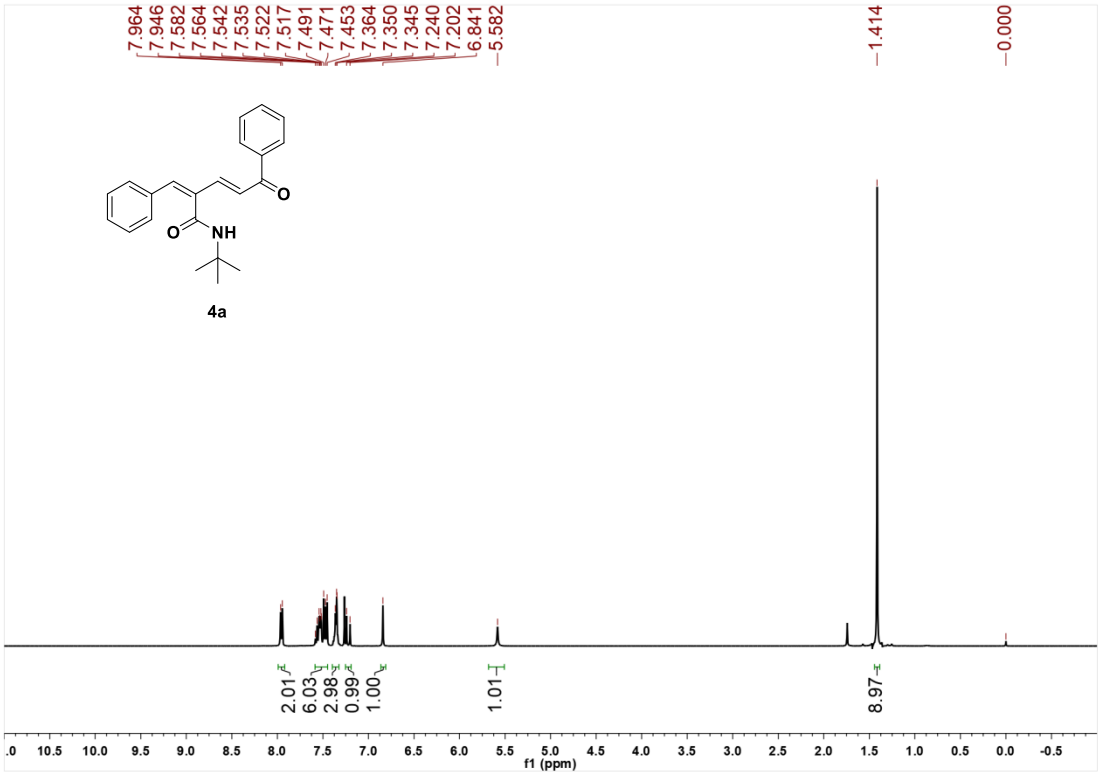
^{13}C NMR (100 MHz), $CDCl_3$



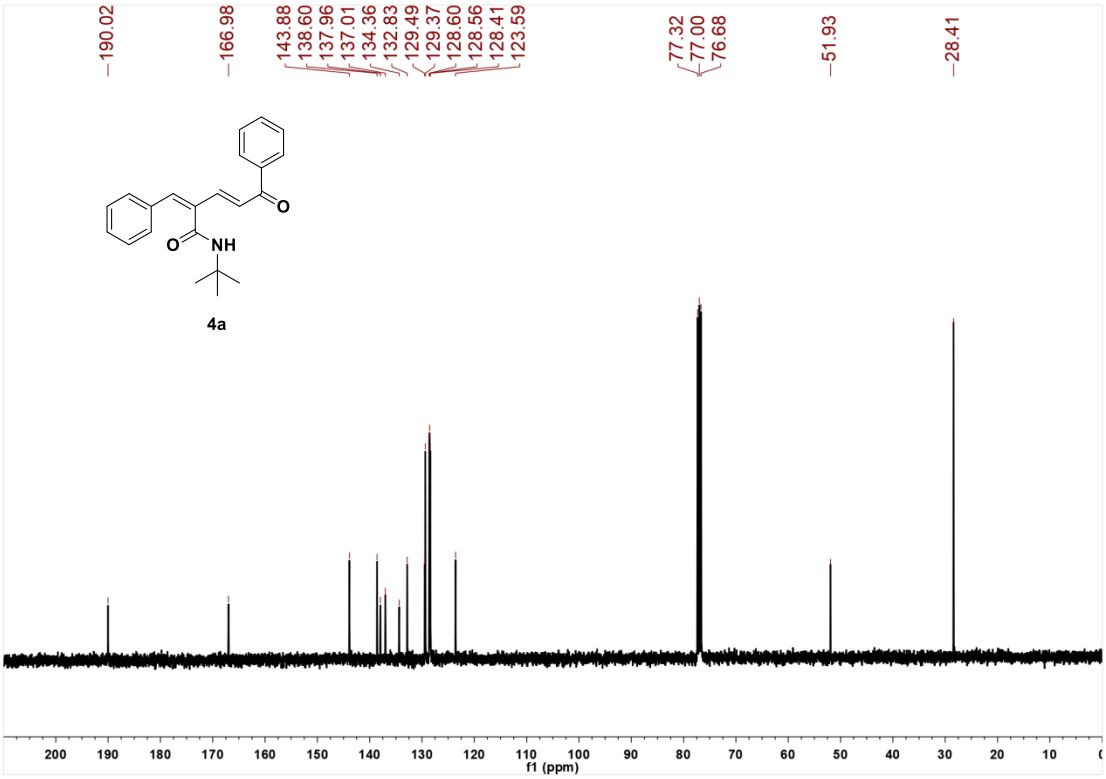
^{1}H NMR (400 MHz), $CDCl_3$



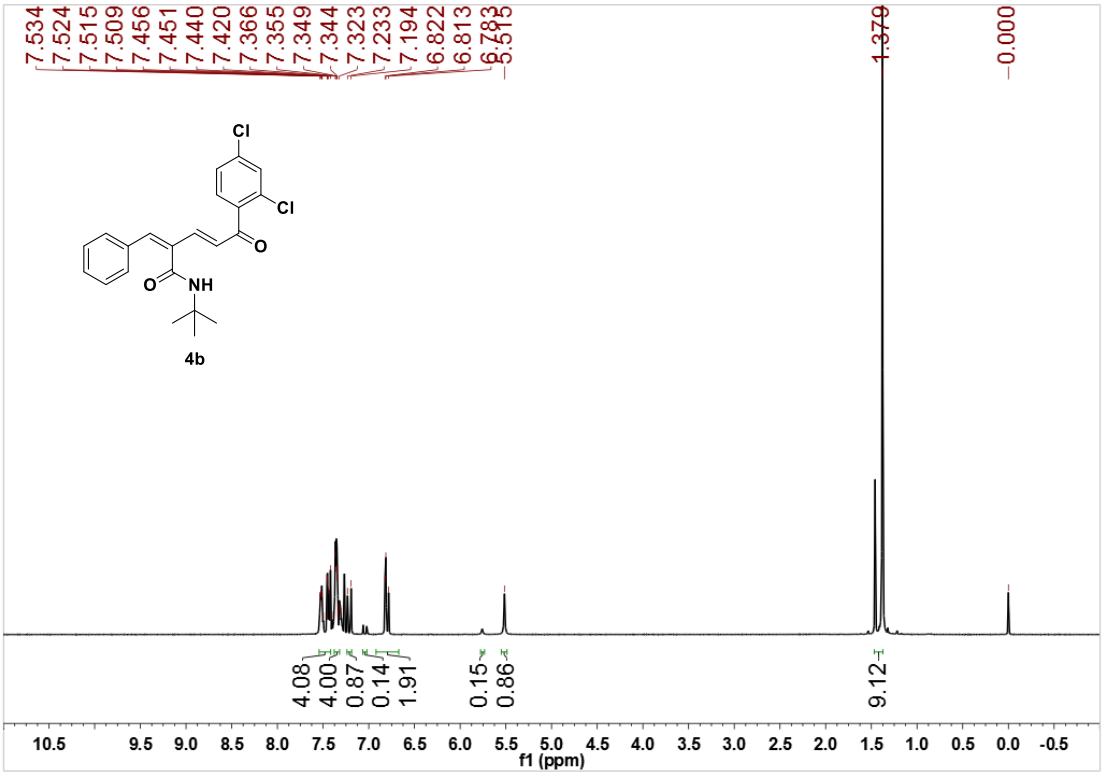
^{13}C NMR (100 MHz), $CDCl_3$



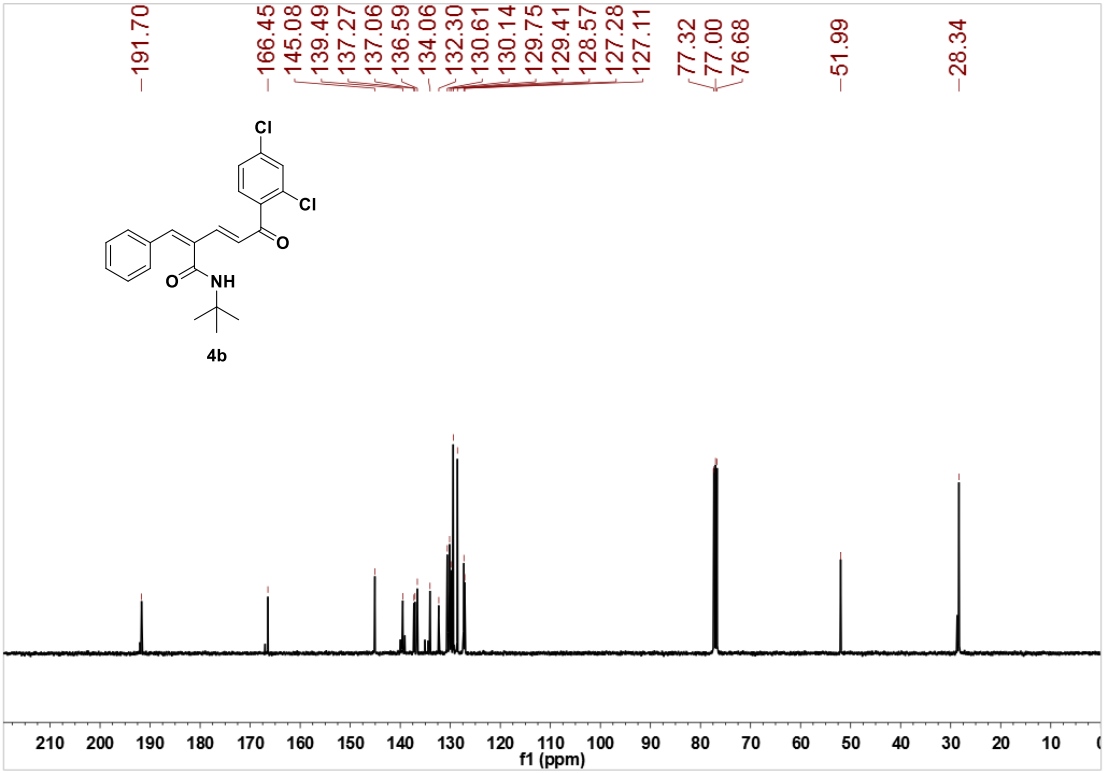
^{1}H NMR (400 MHz), $CDCl_3$



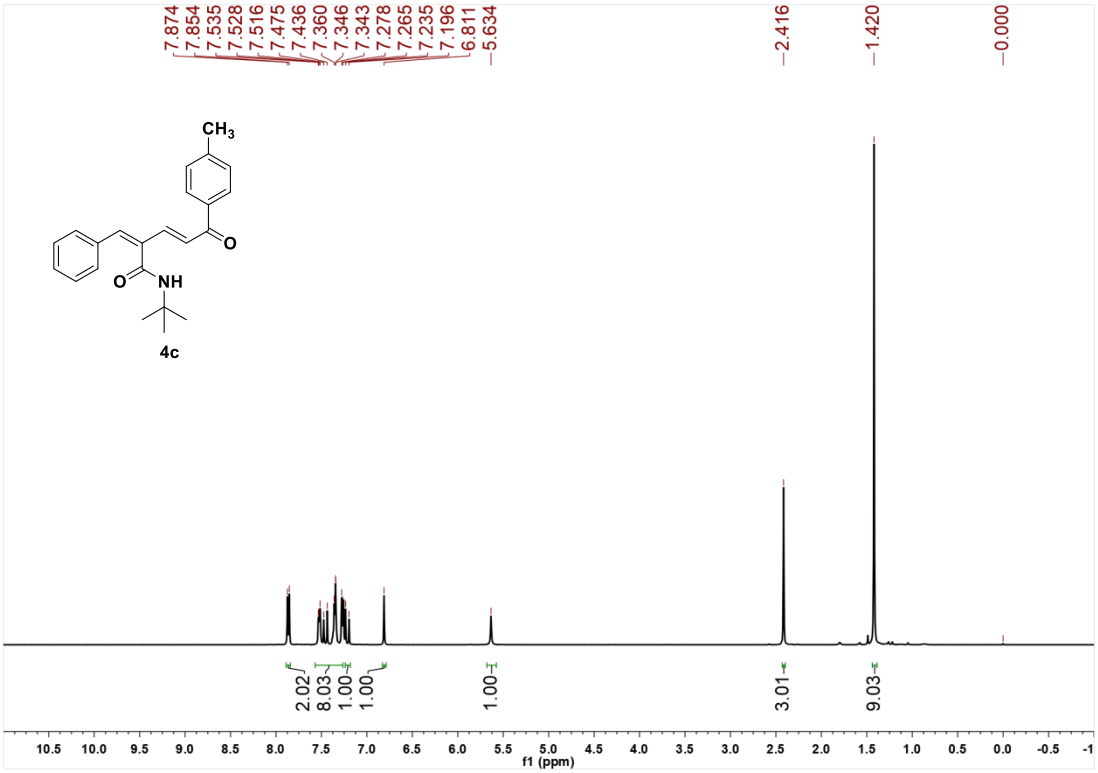
^{13}C NMR (100 MHz), $CDCl_3$



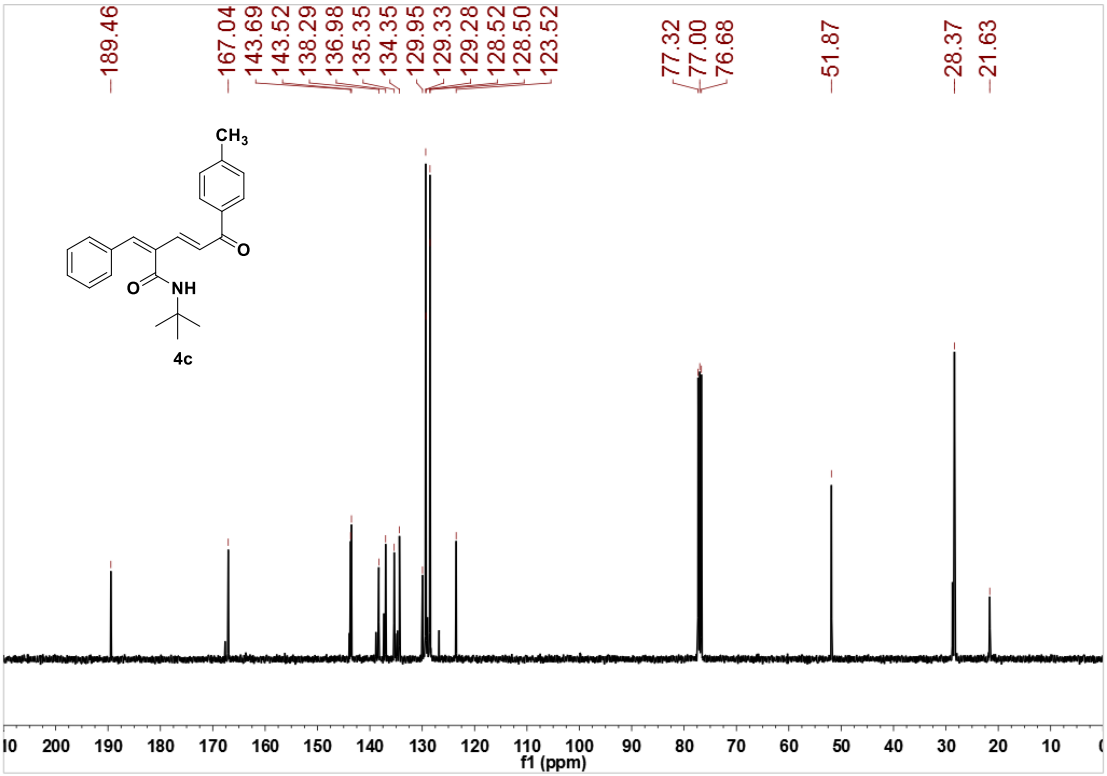
^{1}H NMR (400 MHz), $CDCl_3$



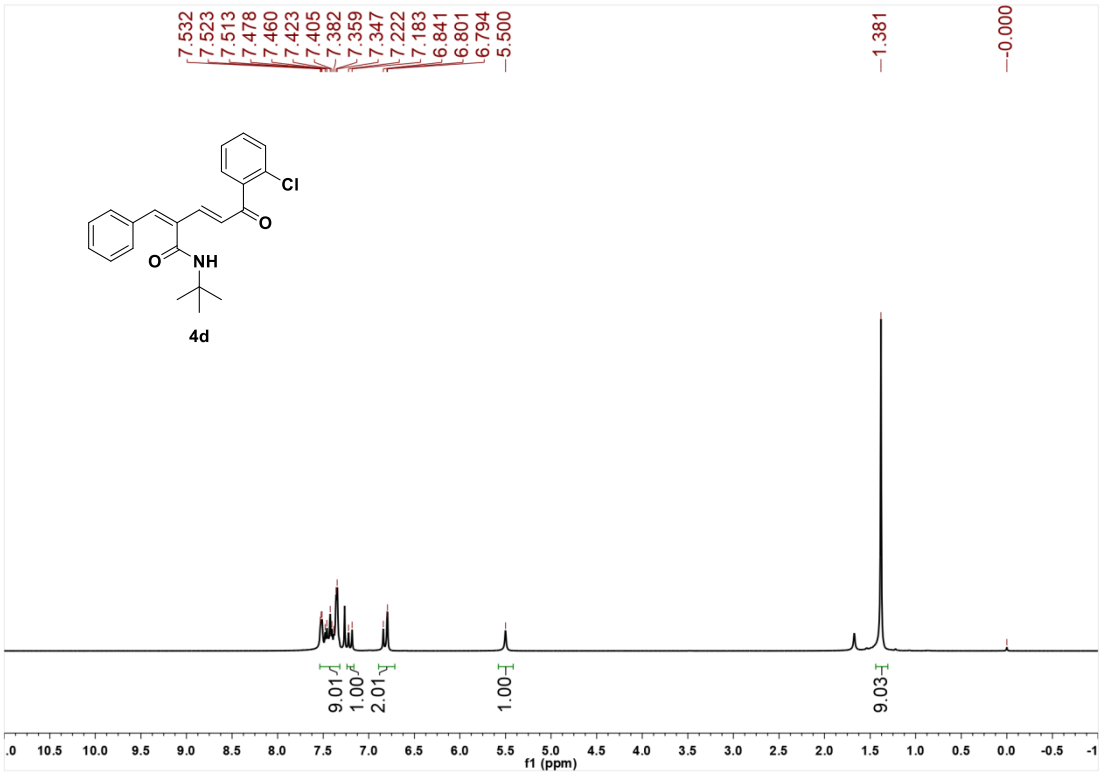
^{13}C NMR (100 MHz), $CDCl_3$



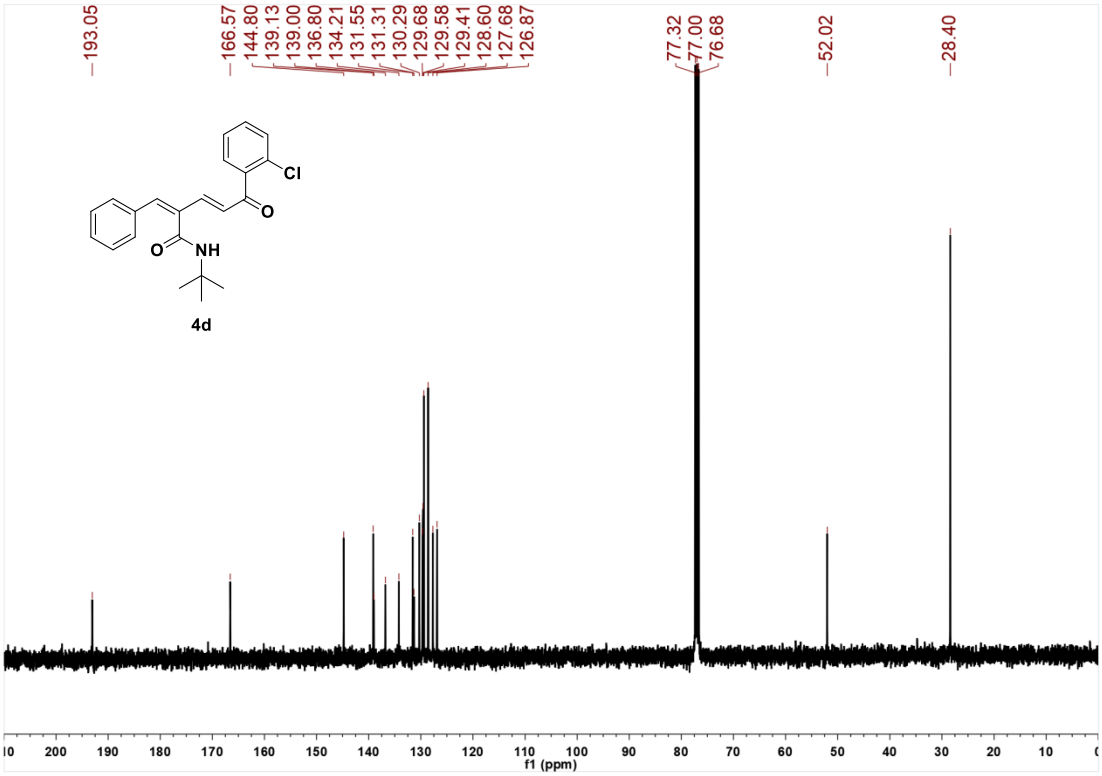
^{1}H NMR (400 MHz), $CDCl_3$



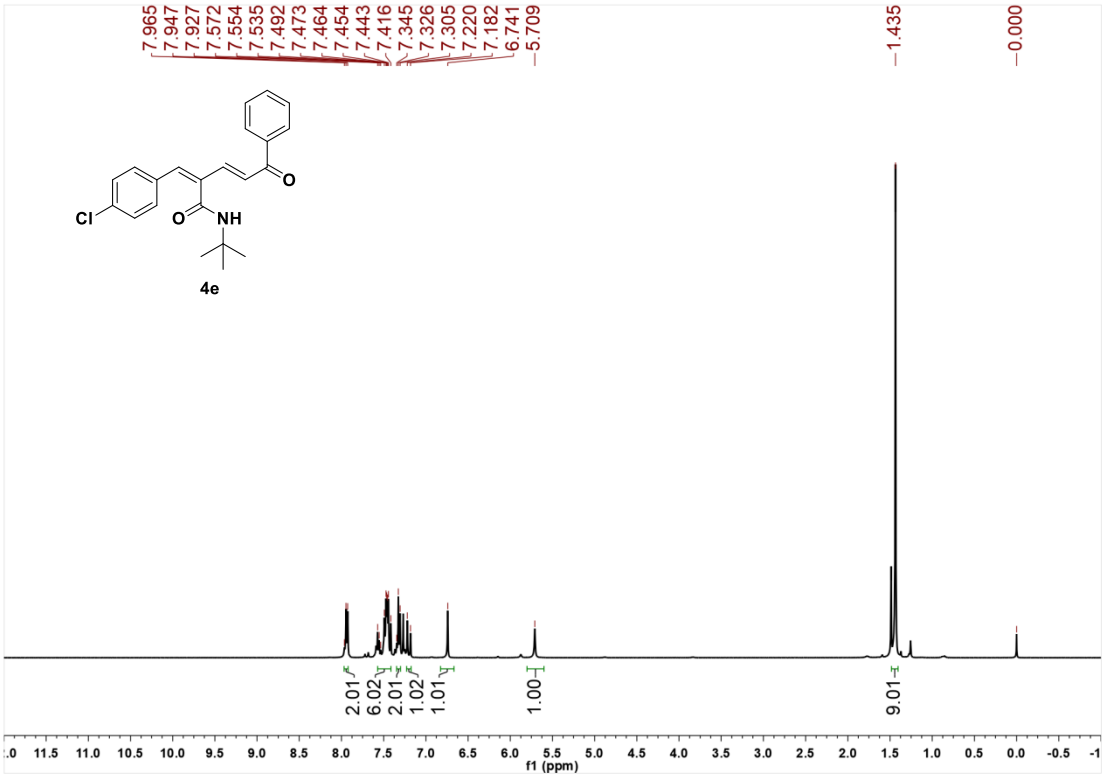
^{13}C NMR (100 MHz), $CDCl_3$



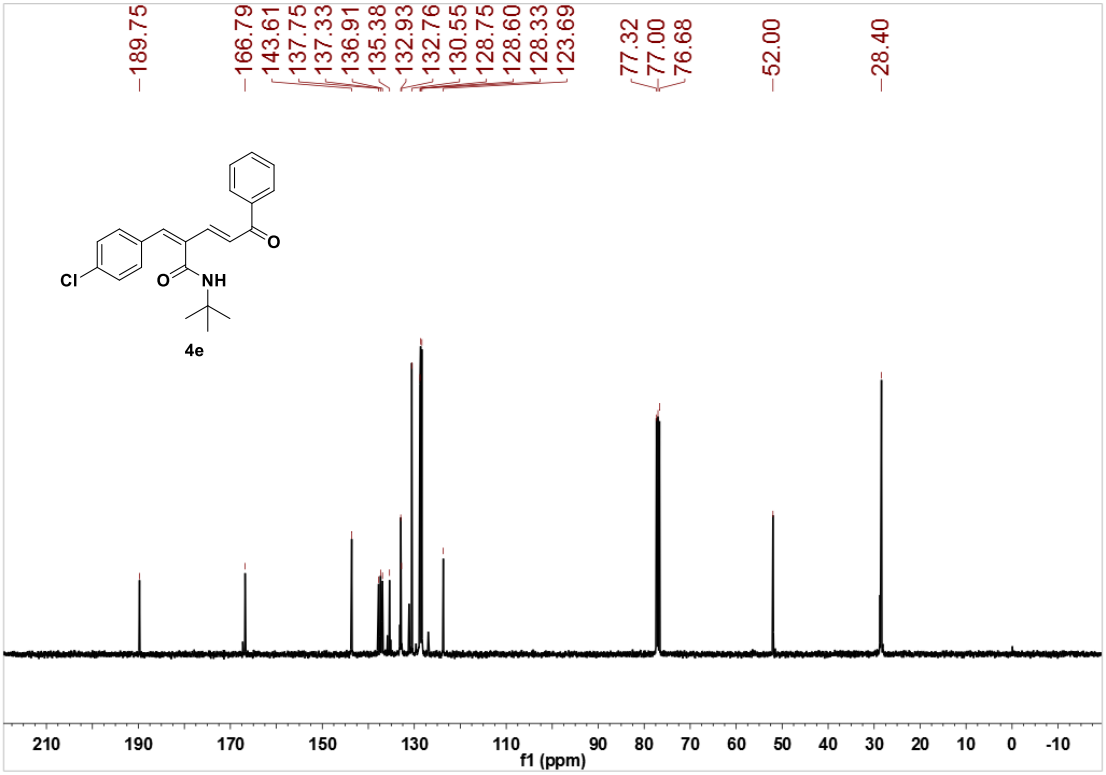
^{1}H NMR (400 MHz), $CDCl_3$



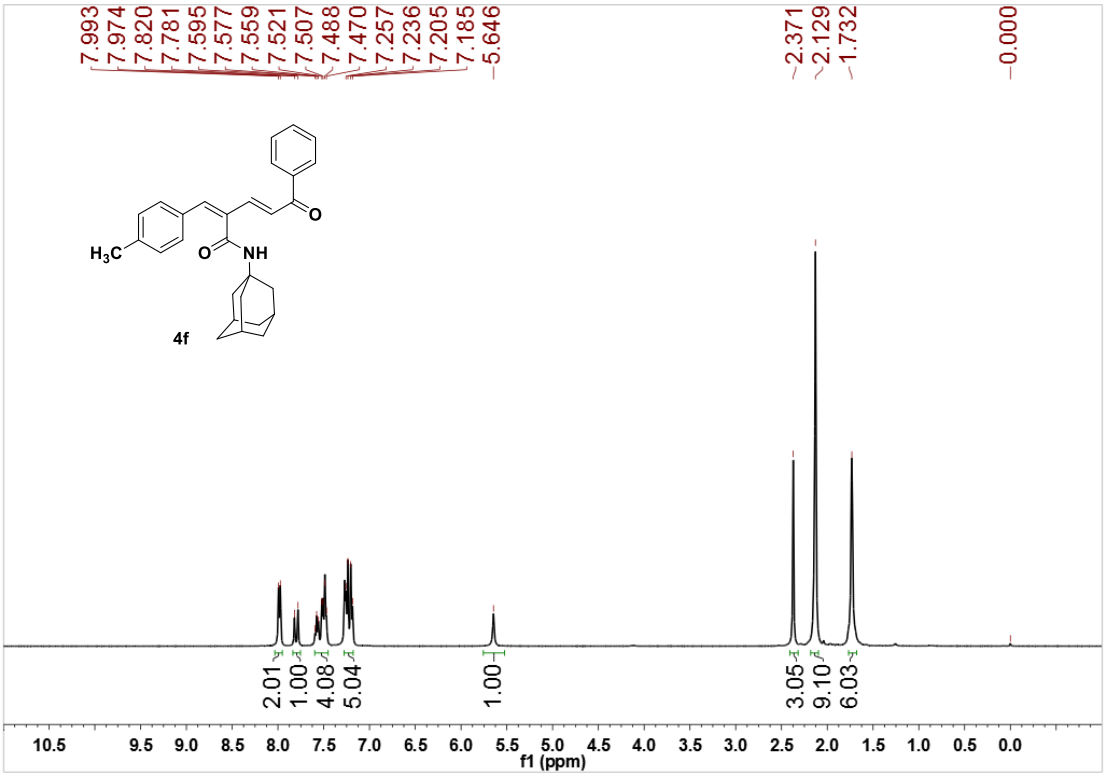
^{13}C NMR (100 MHz), $CDCl_3$



^{1}H NMR (400 MHz), $CDCl_3$



^{13}C NMR (100 MHz), $CDCl_3$



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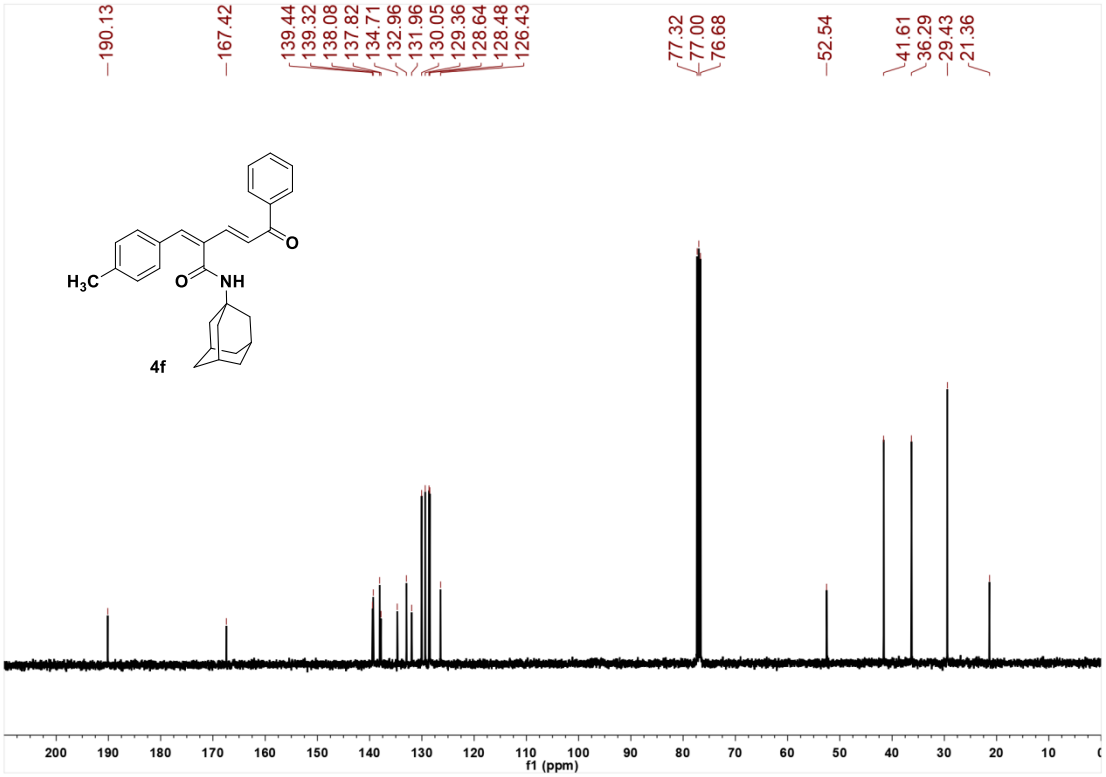
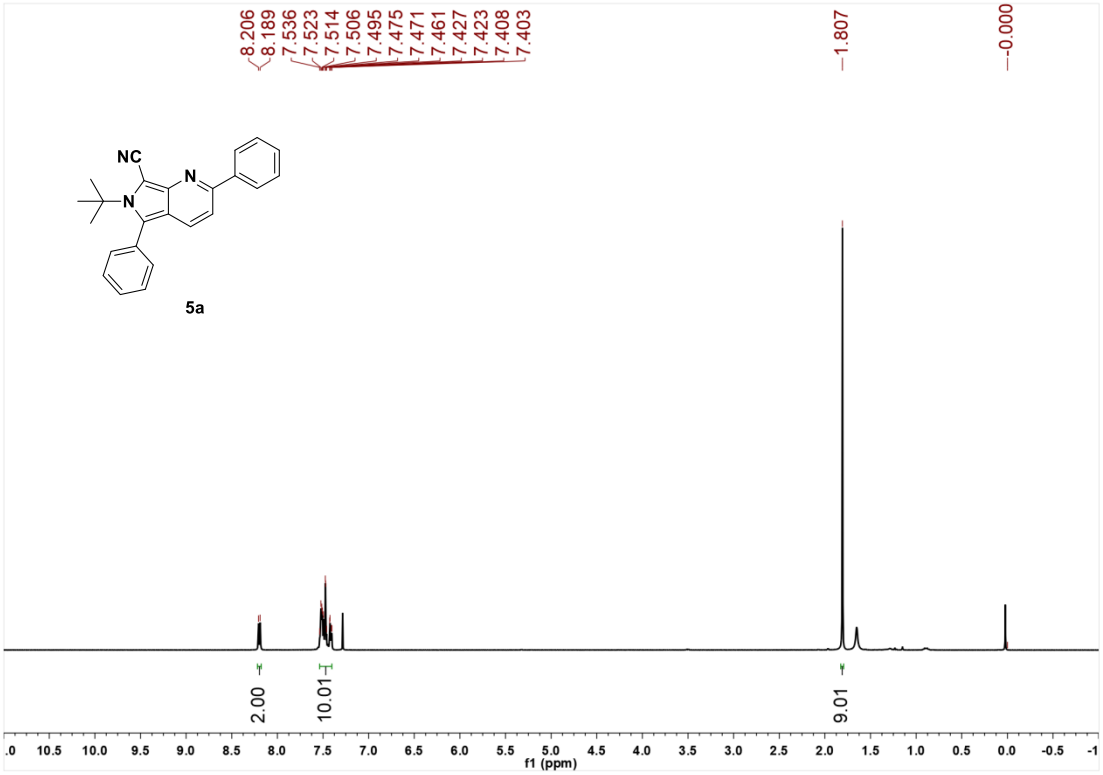
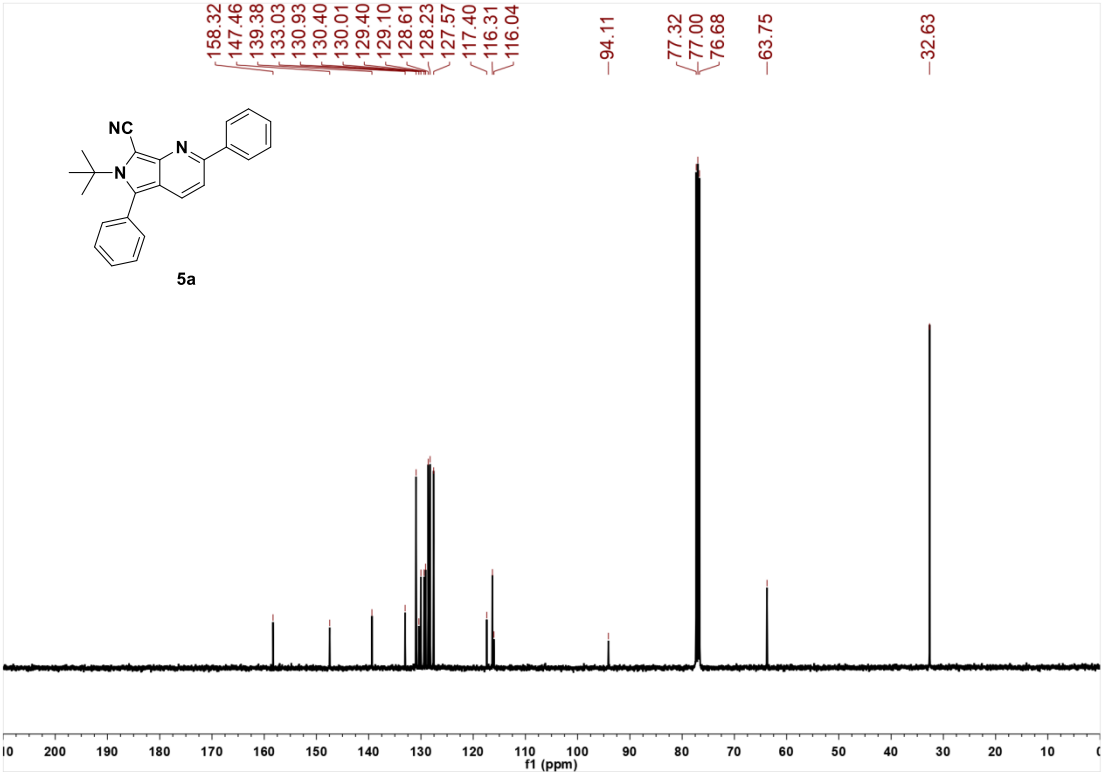


^{13}C NMR (100 MHz), $CDCl_3$



^{1}H NMR (400 MHz), $CDCl_3$



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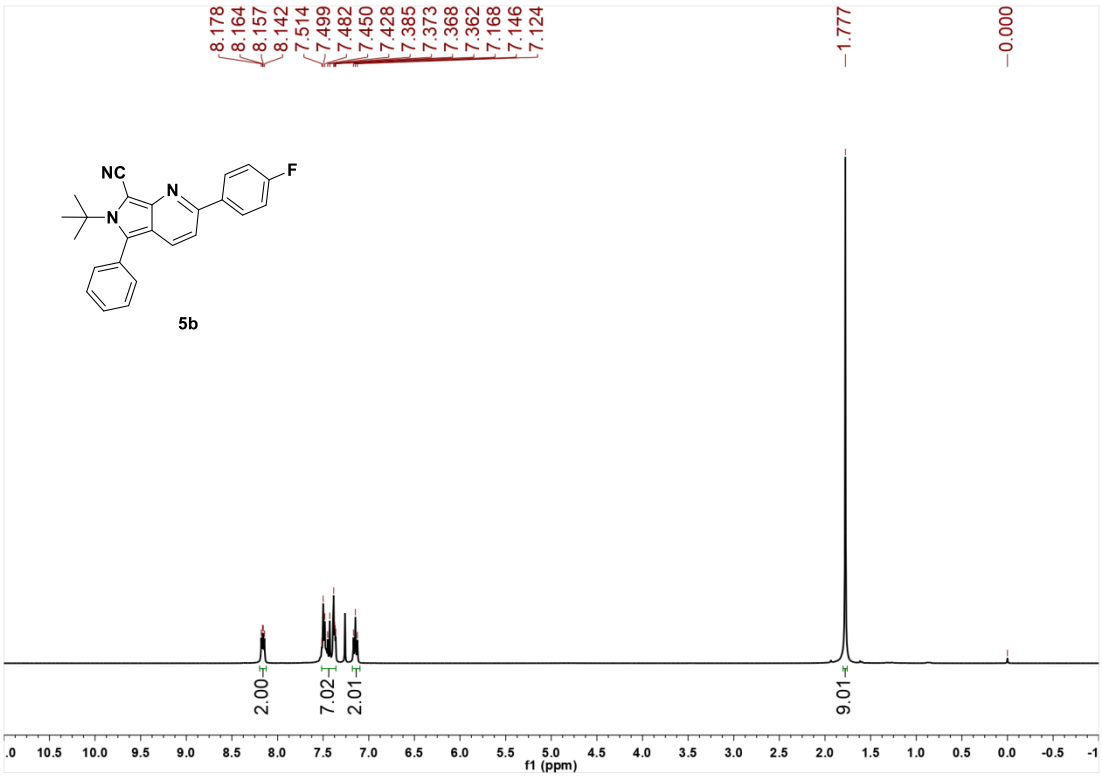
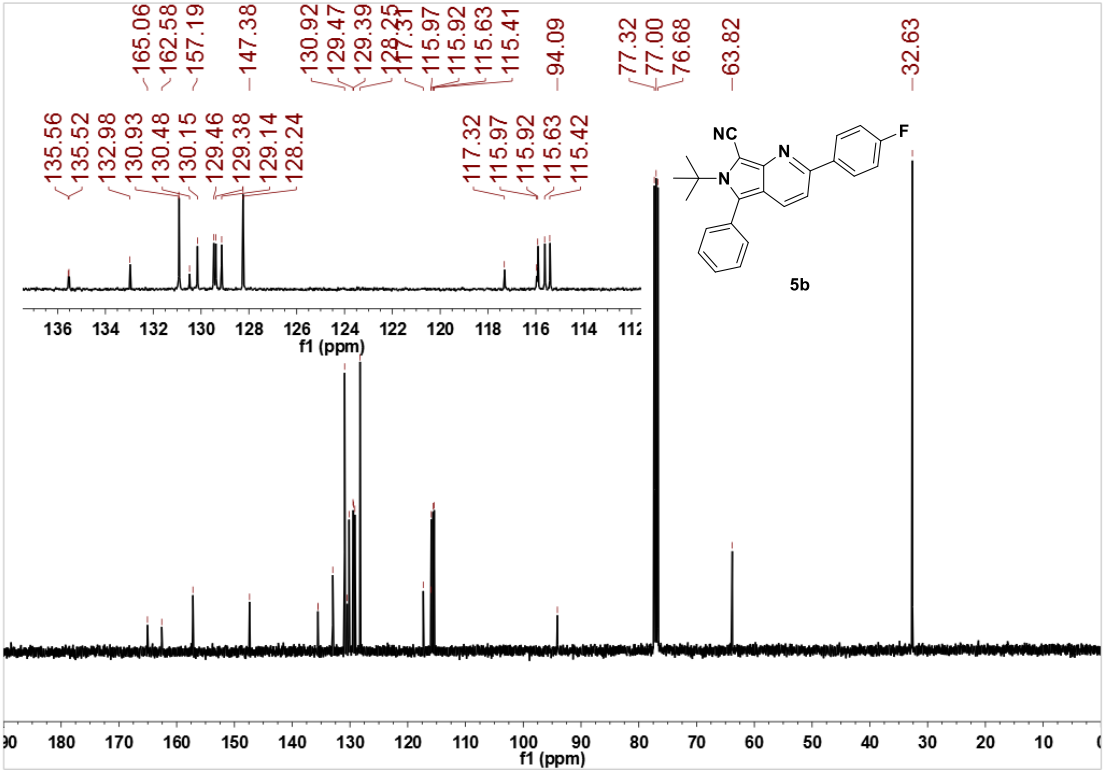
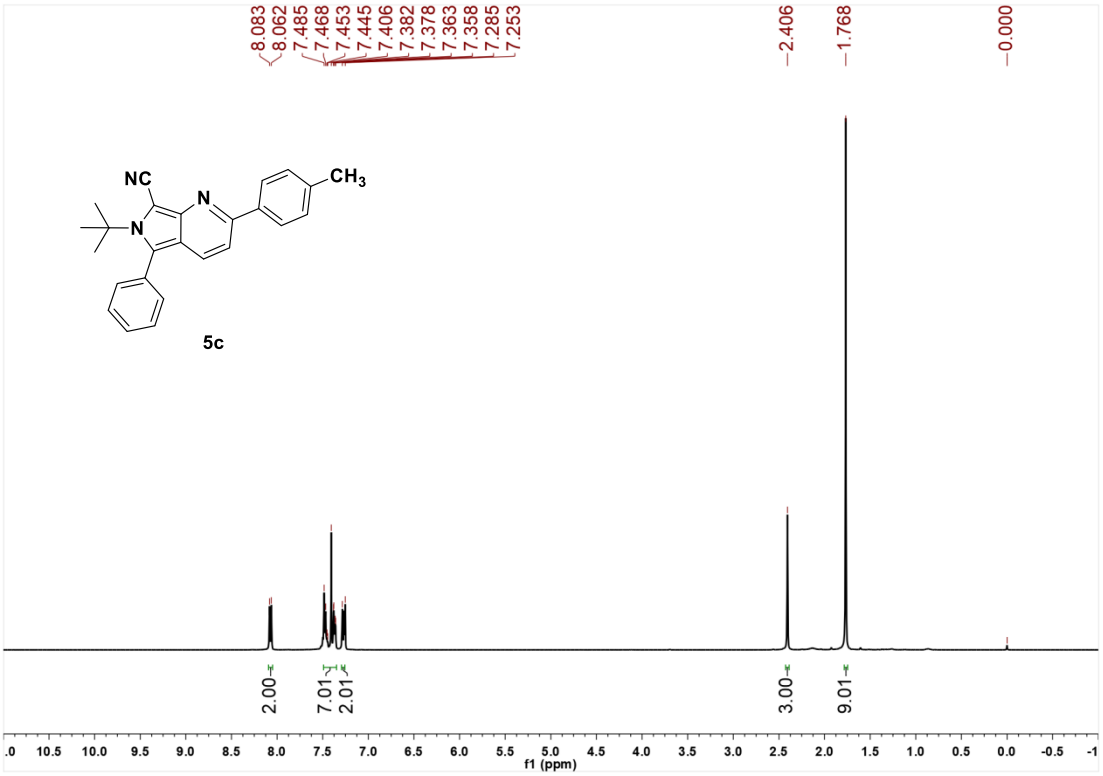


^{1}H NMR (400 MHz), $CDCl_3$



^{13}C NMR (100 MHz), $CDCl_3$



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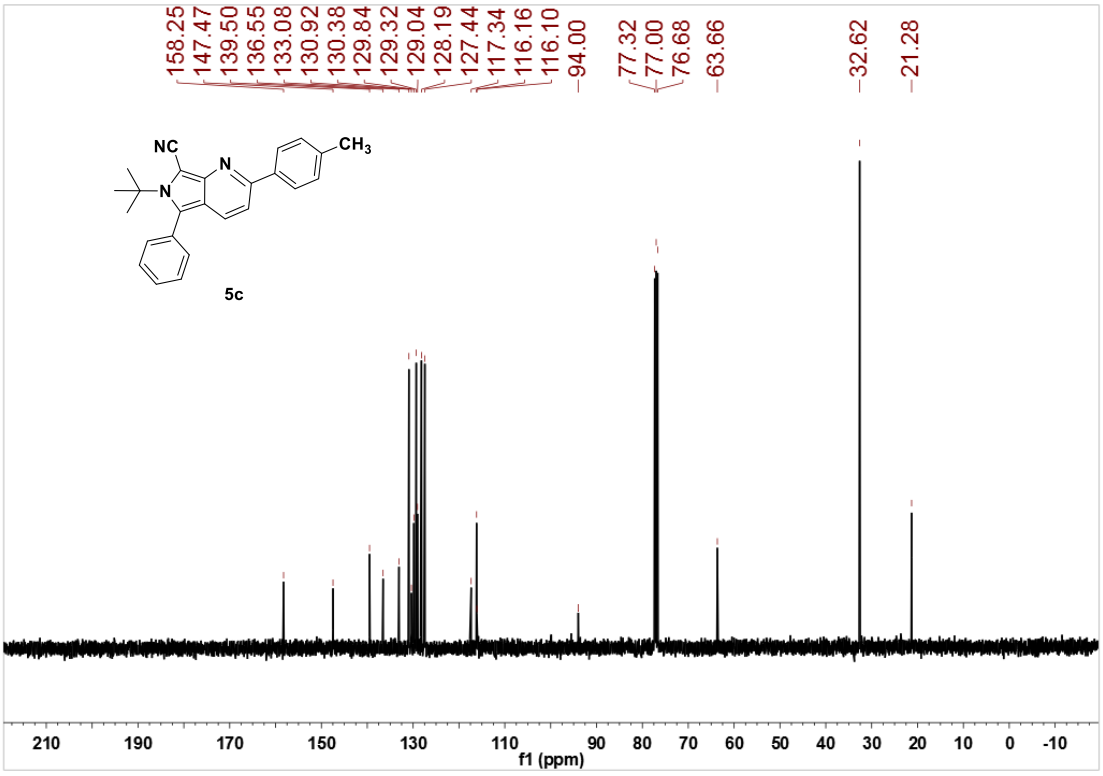
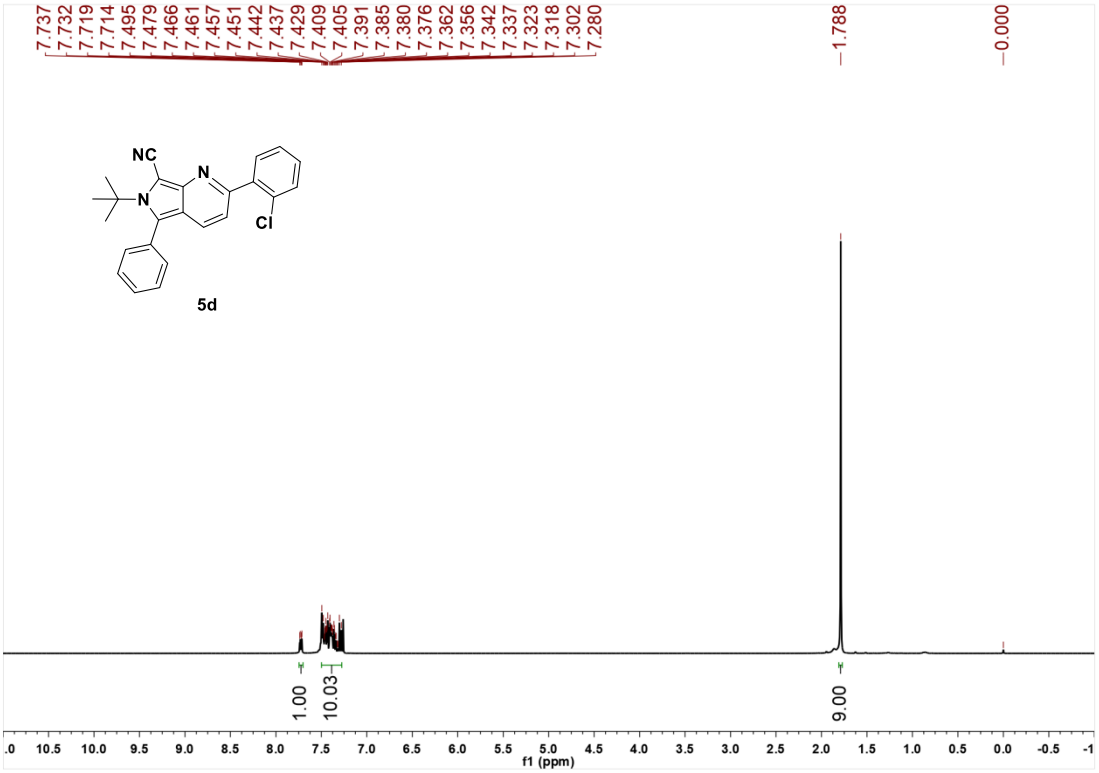


^{13}C NMR (100 MHz), $CDCl_3$



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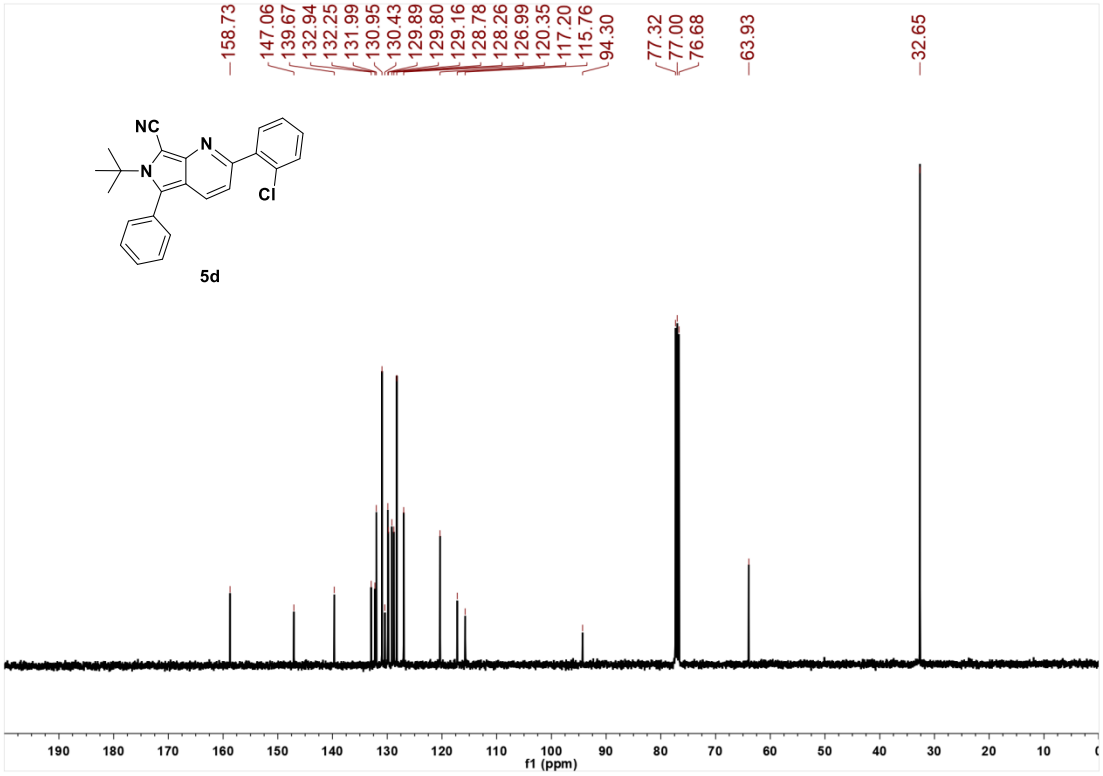

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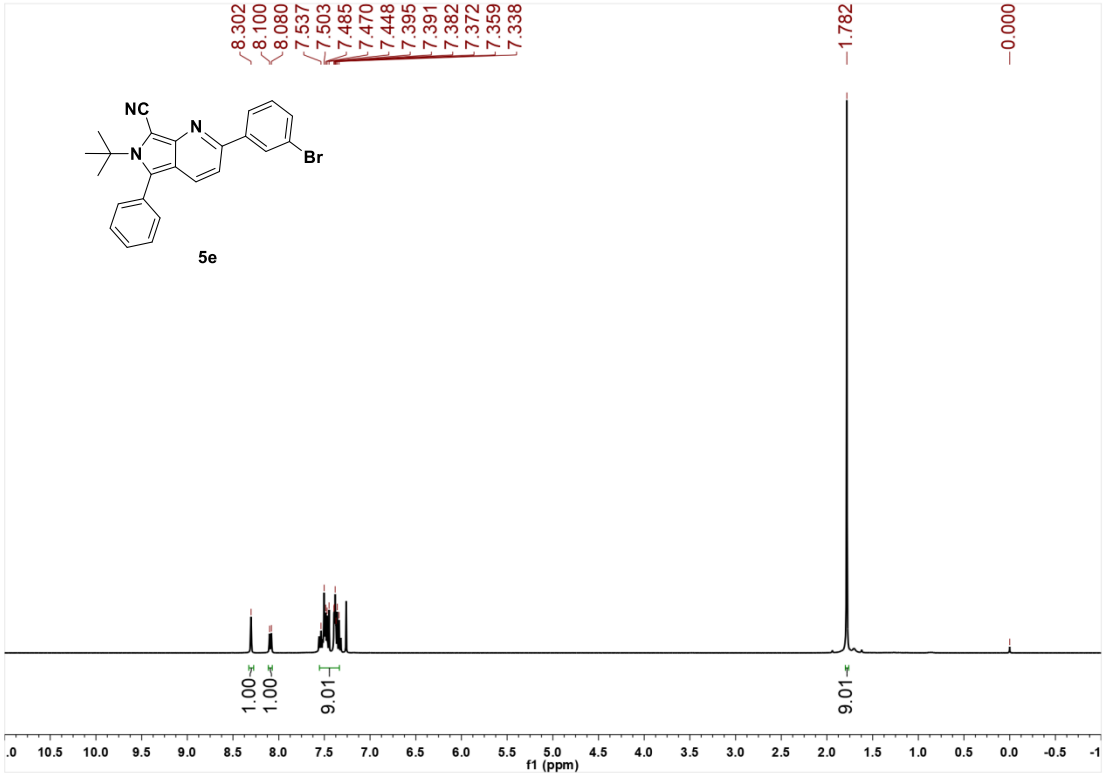

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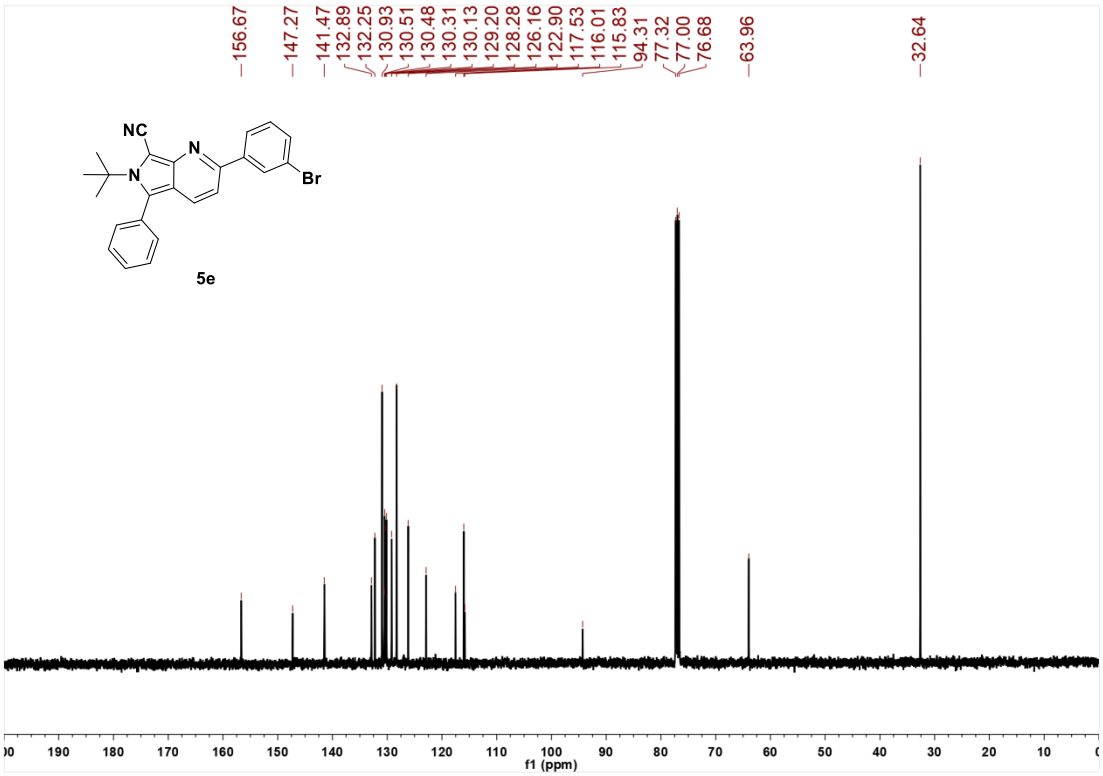

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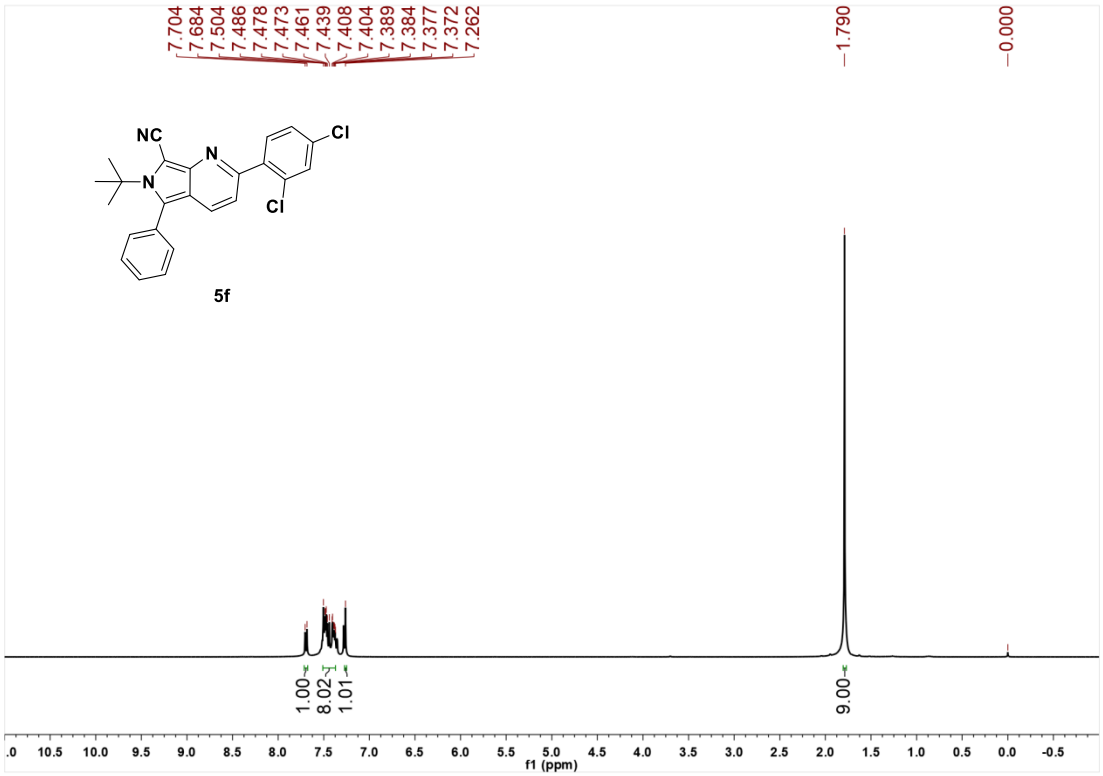

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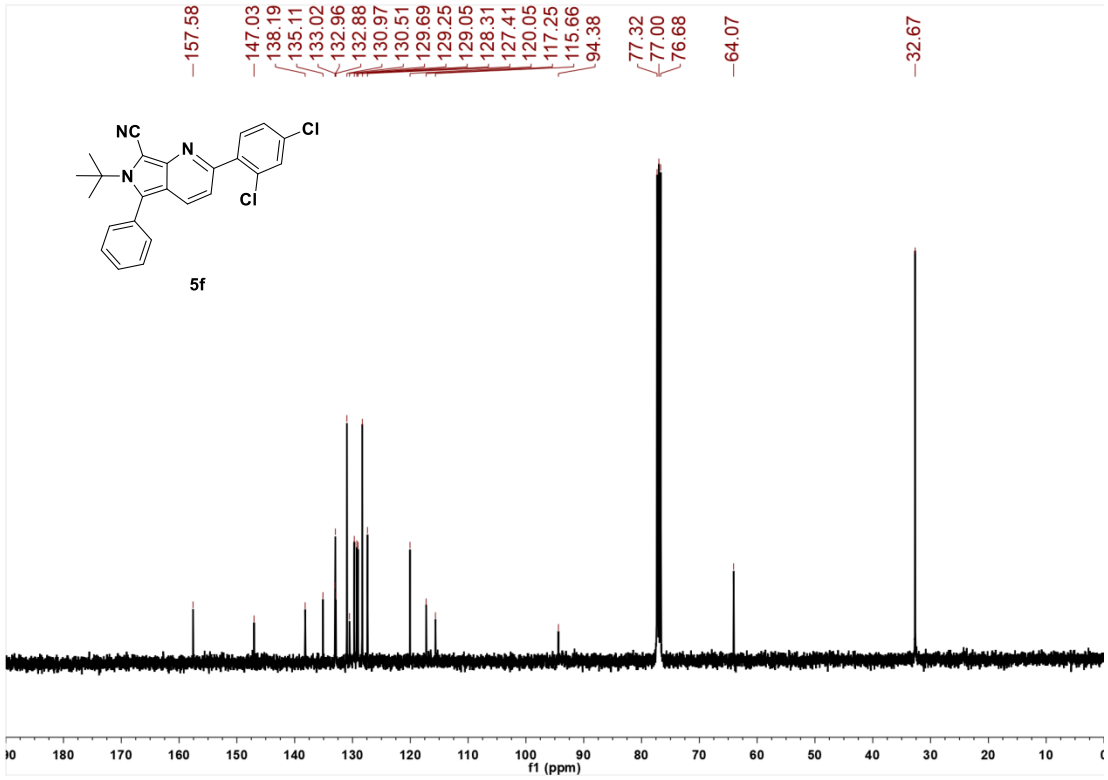

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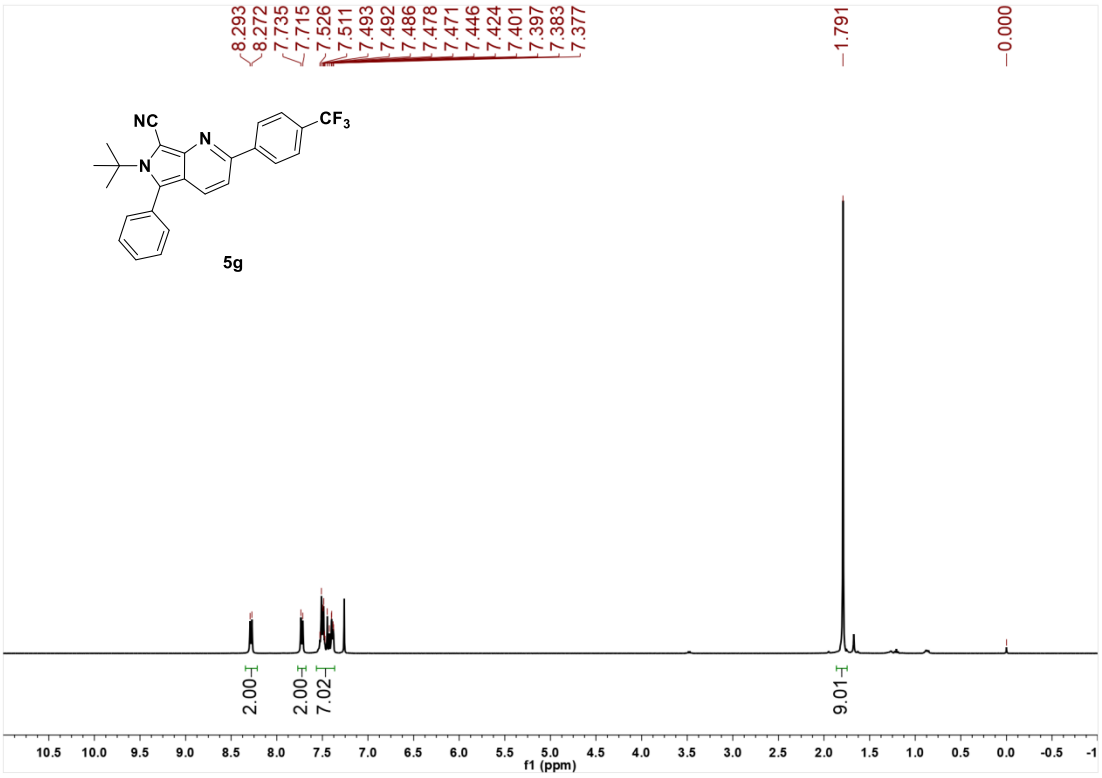
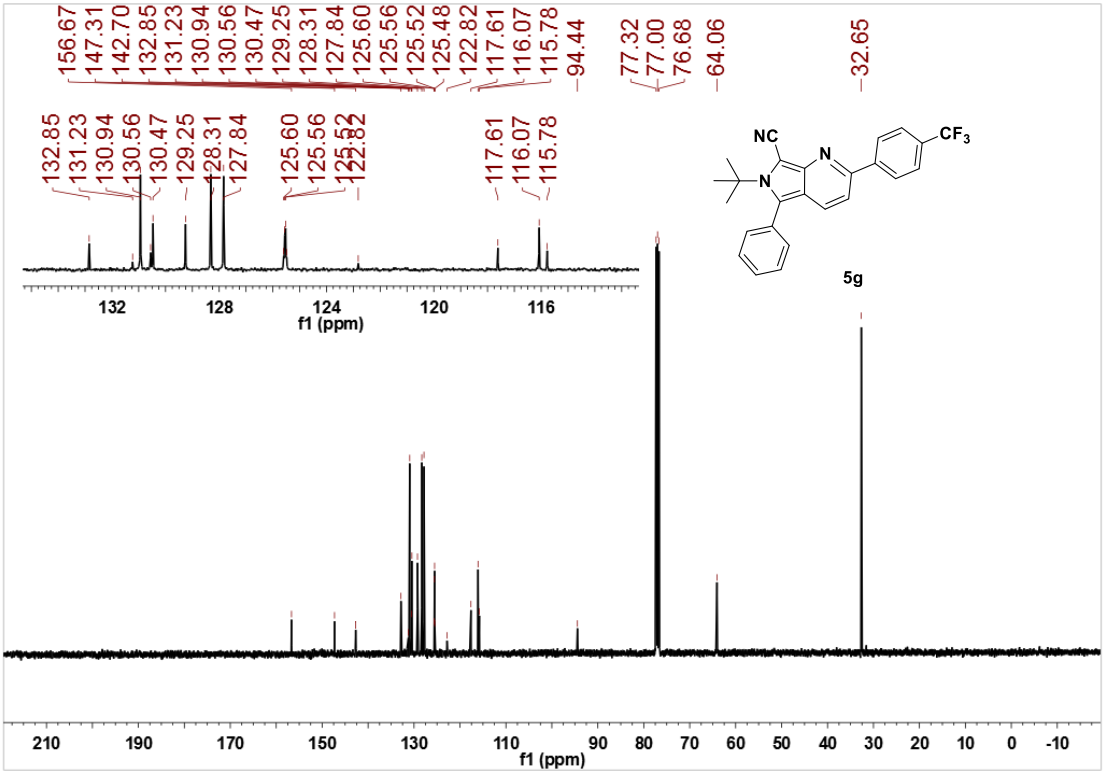
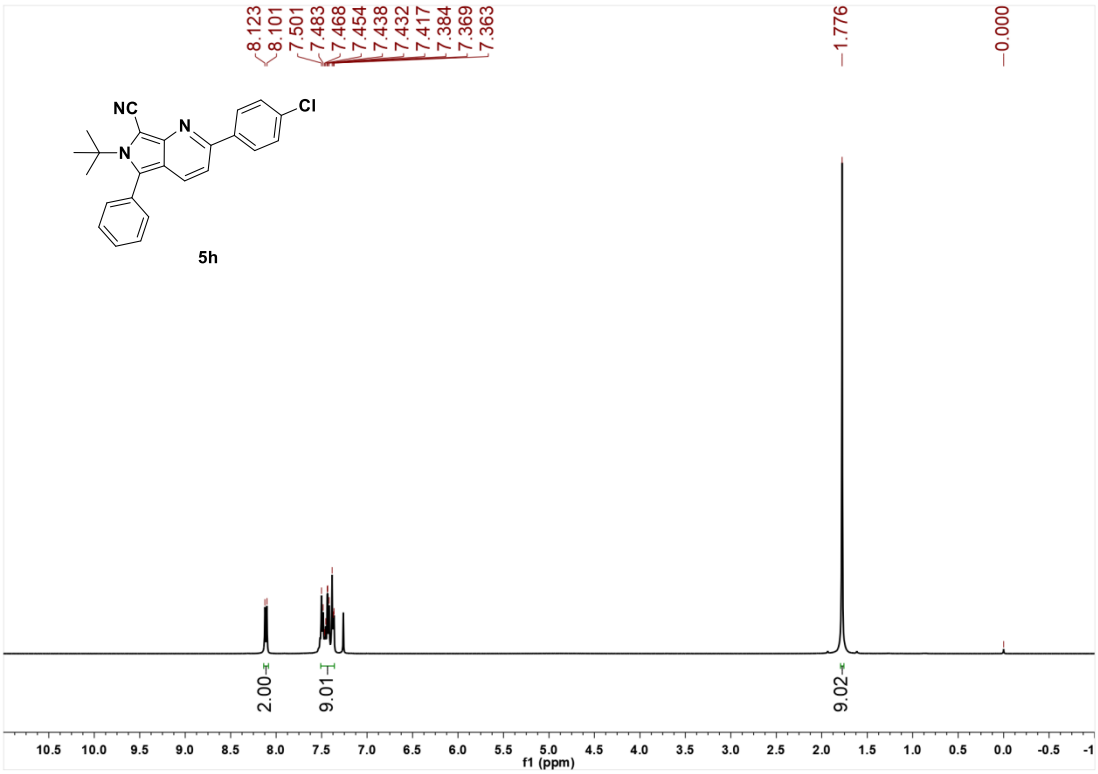


^{1}H NMR (400 MHz), $CDCl_3$



^{13}C NMR (100 MHz), $CDCl_3$



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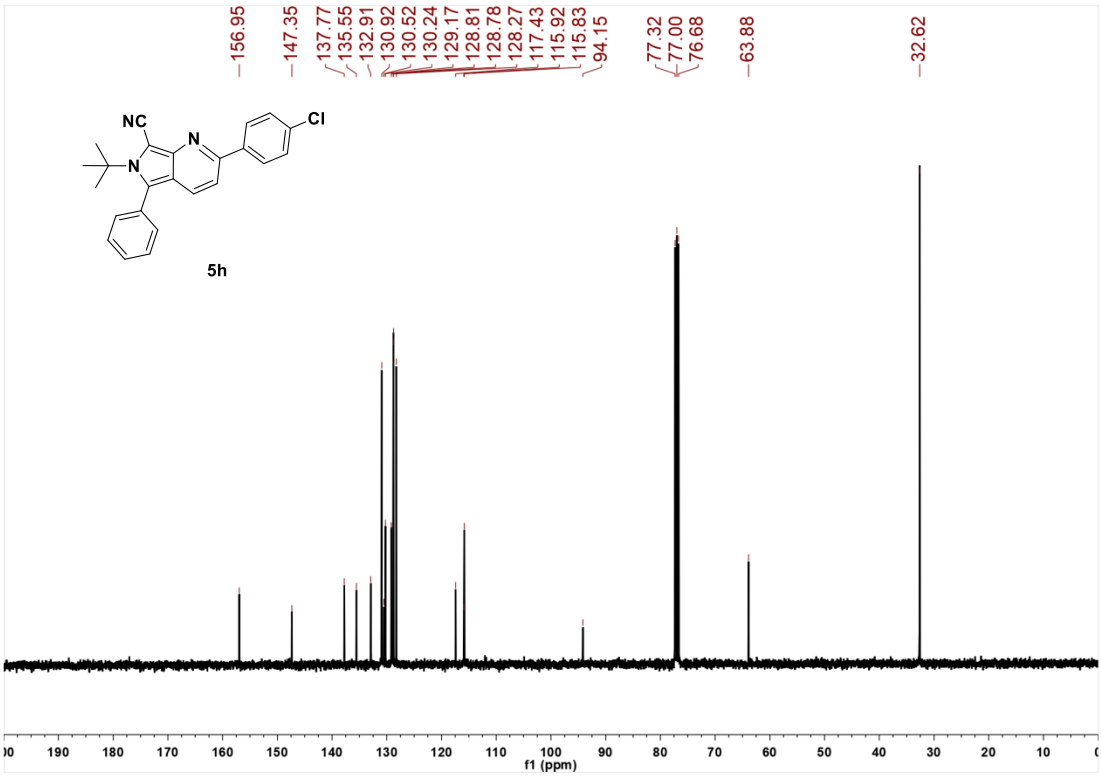

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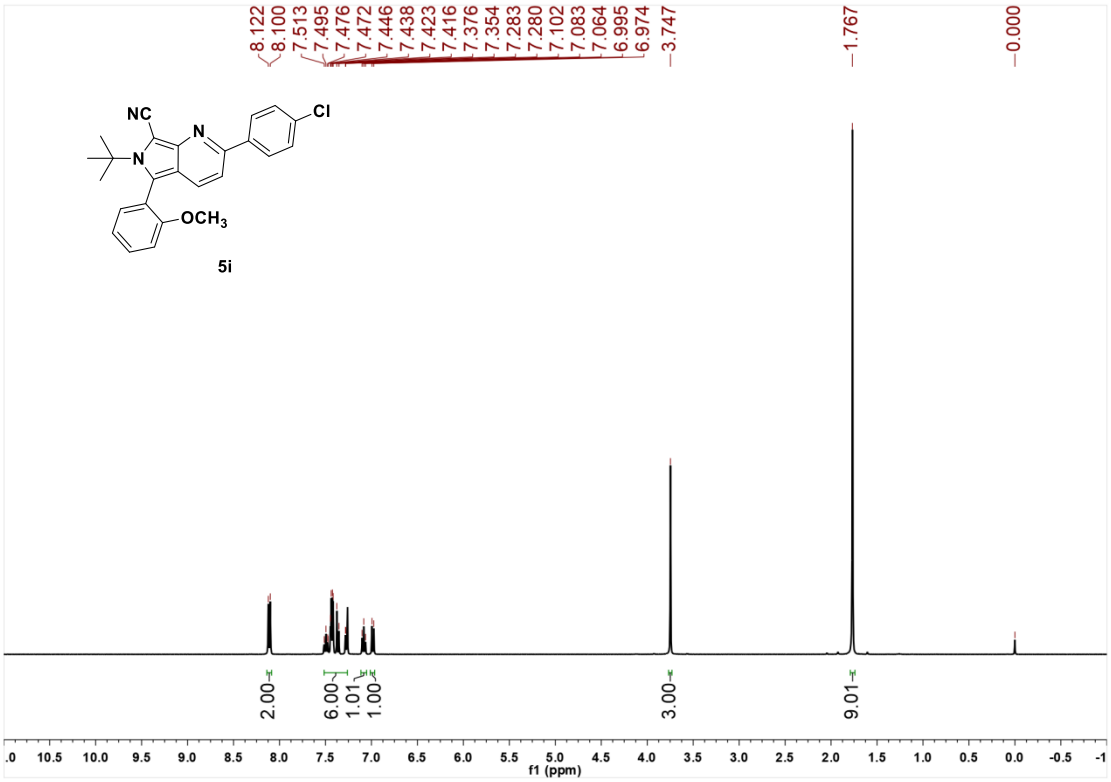

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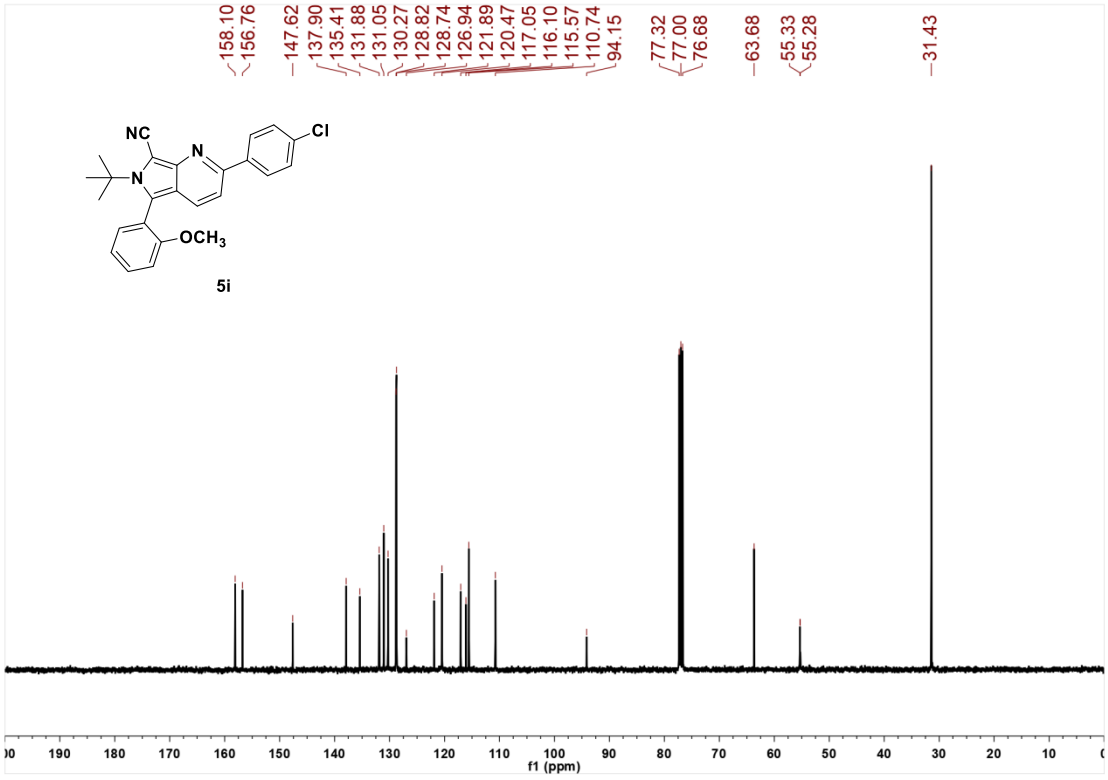

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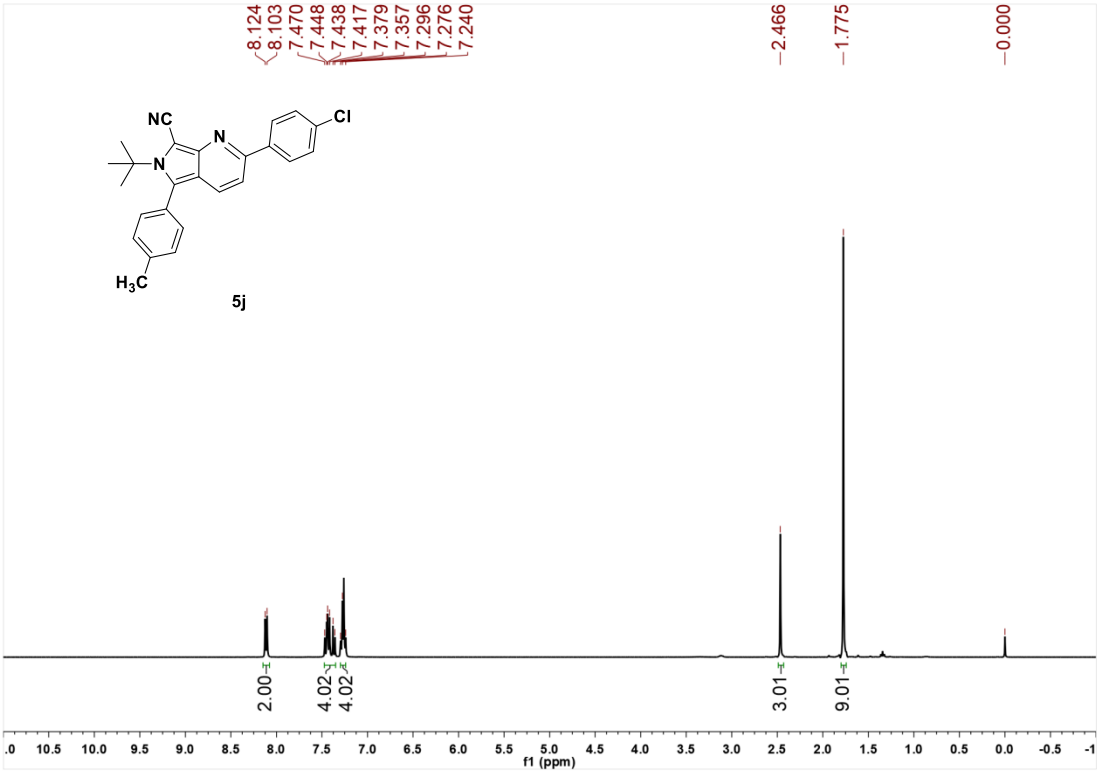

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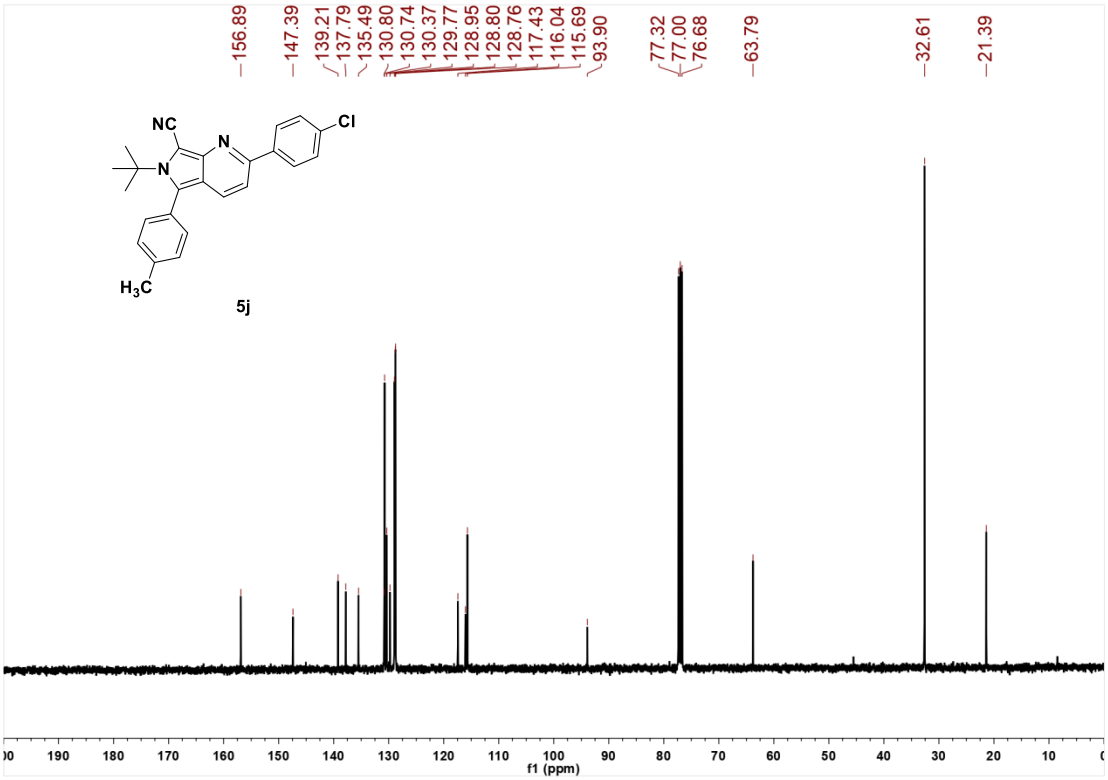

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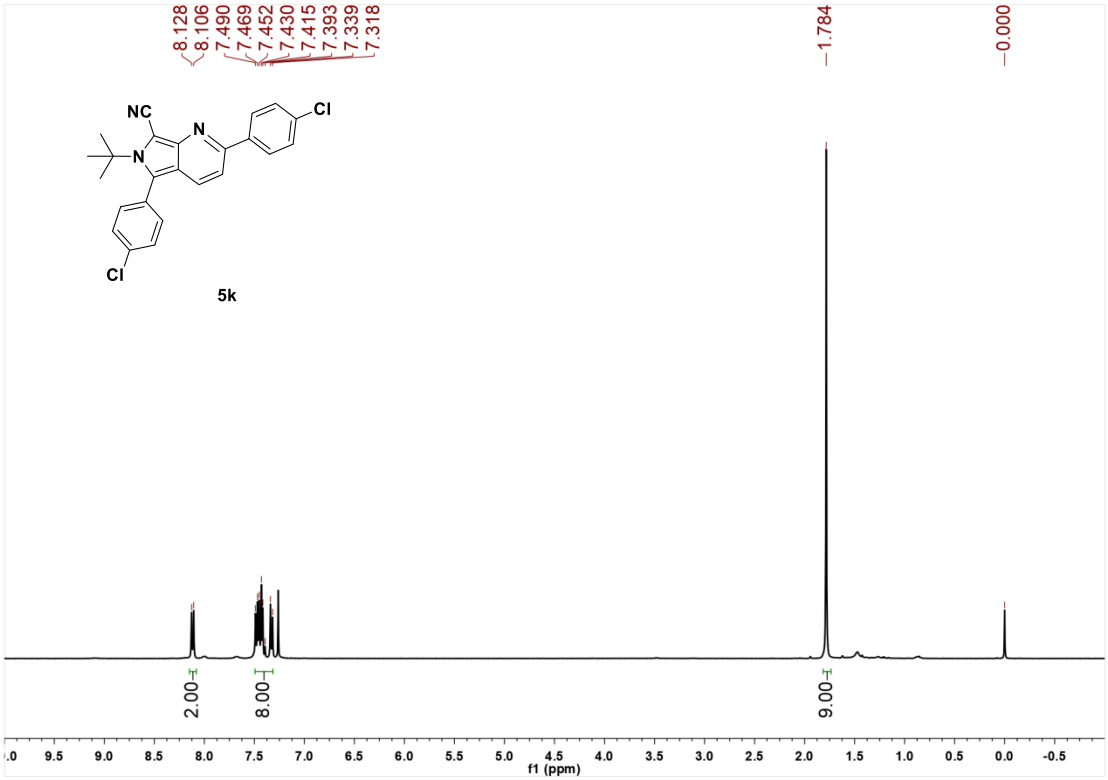

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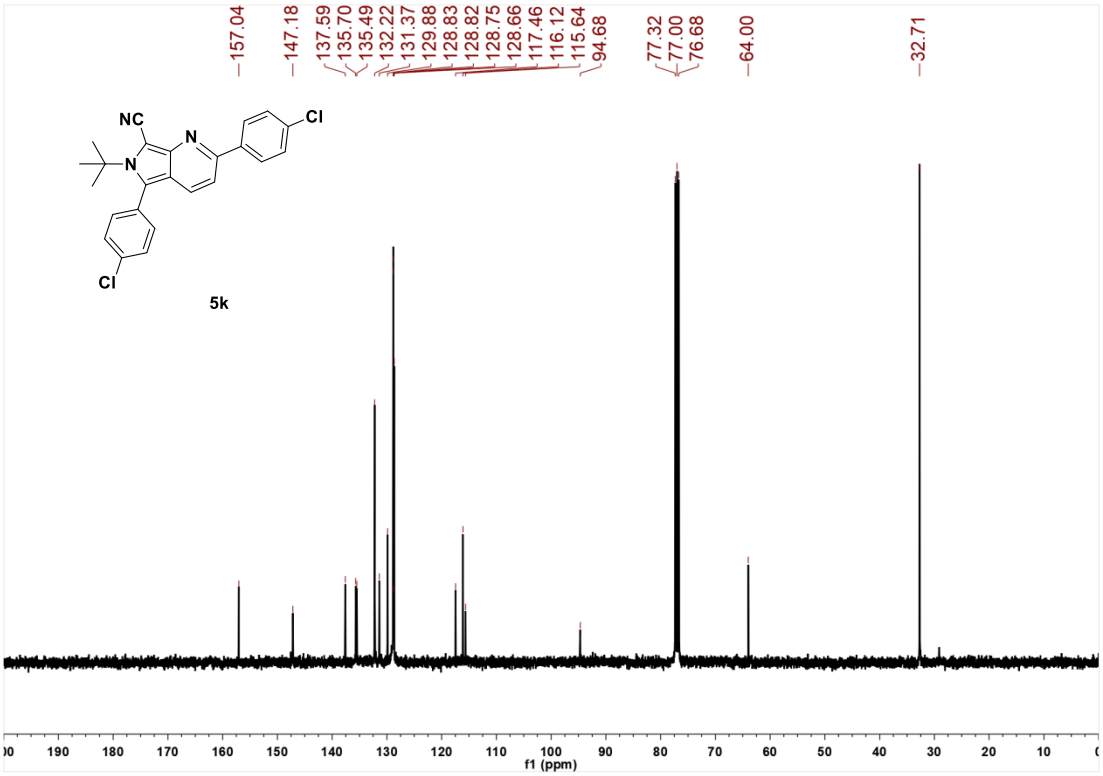

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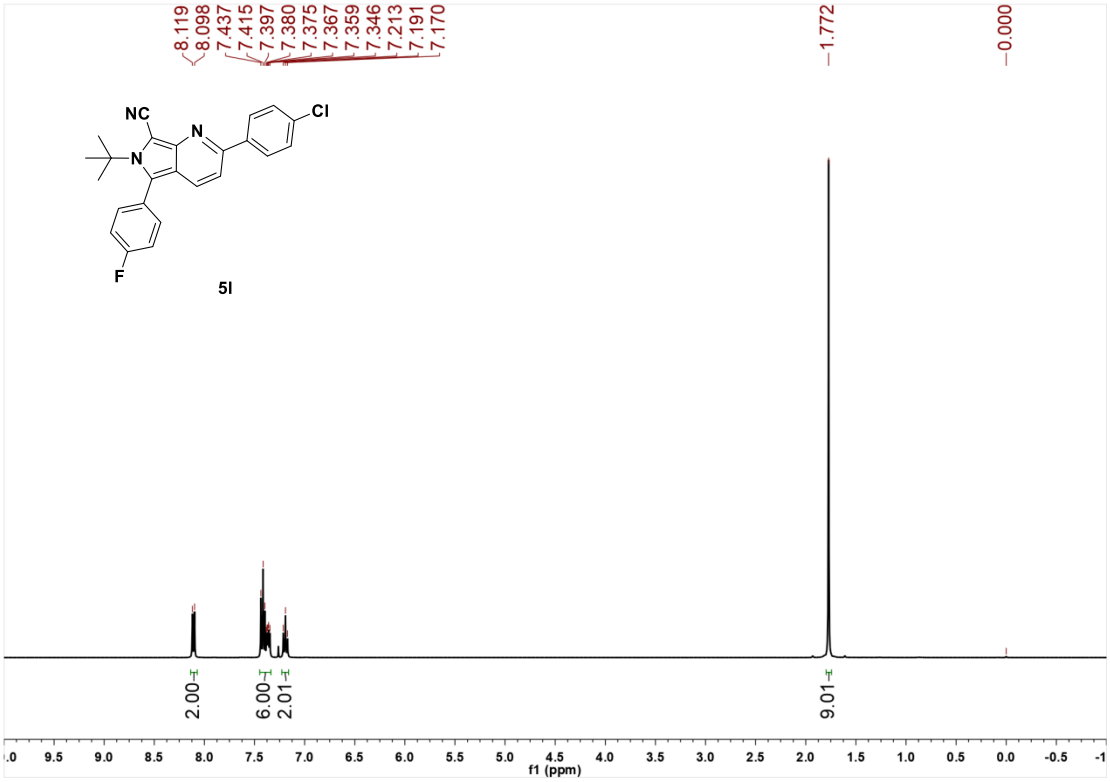

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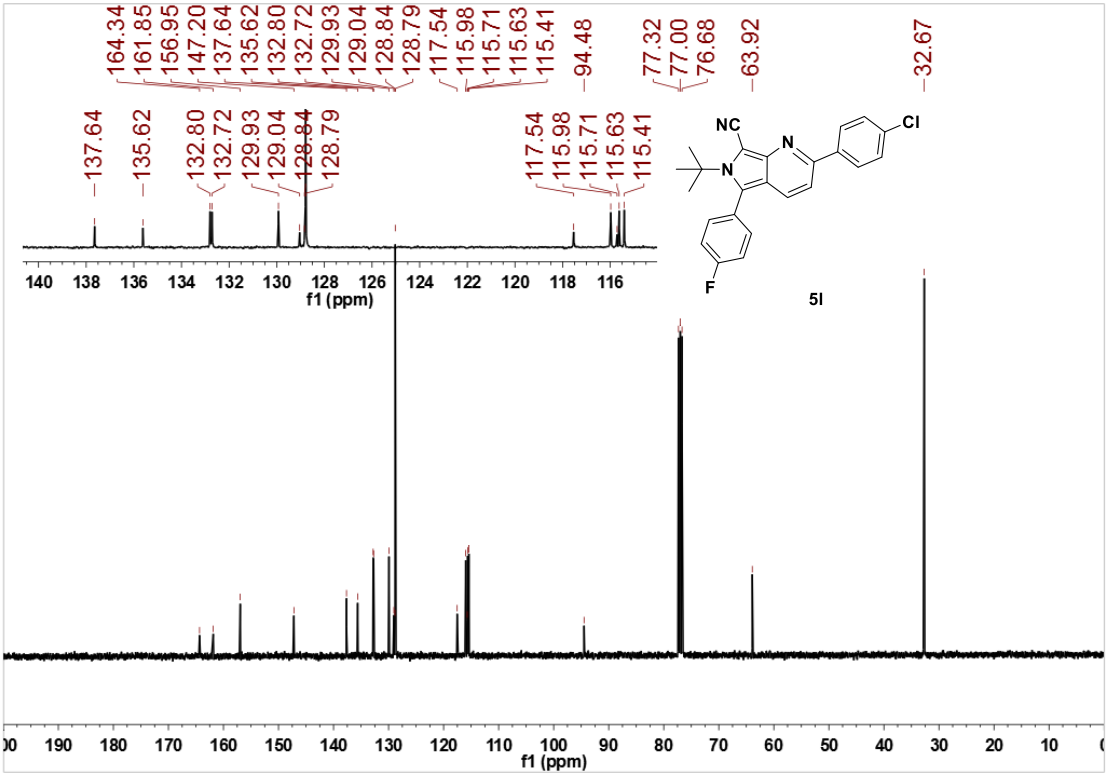

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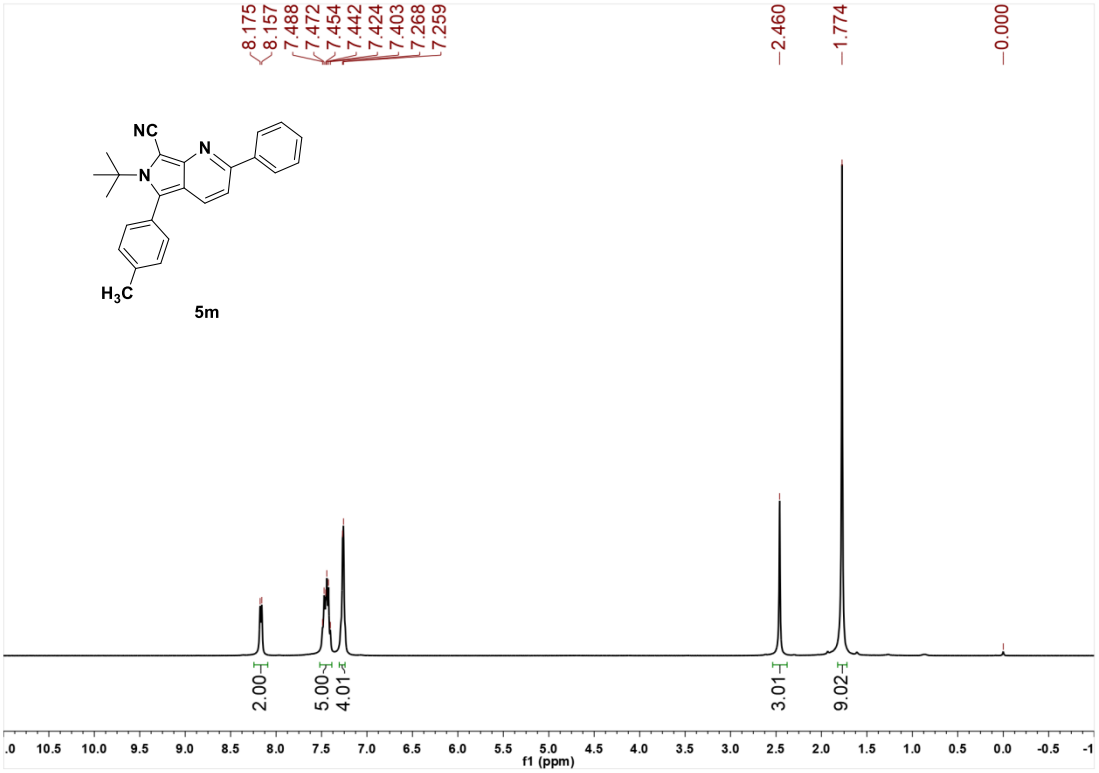
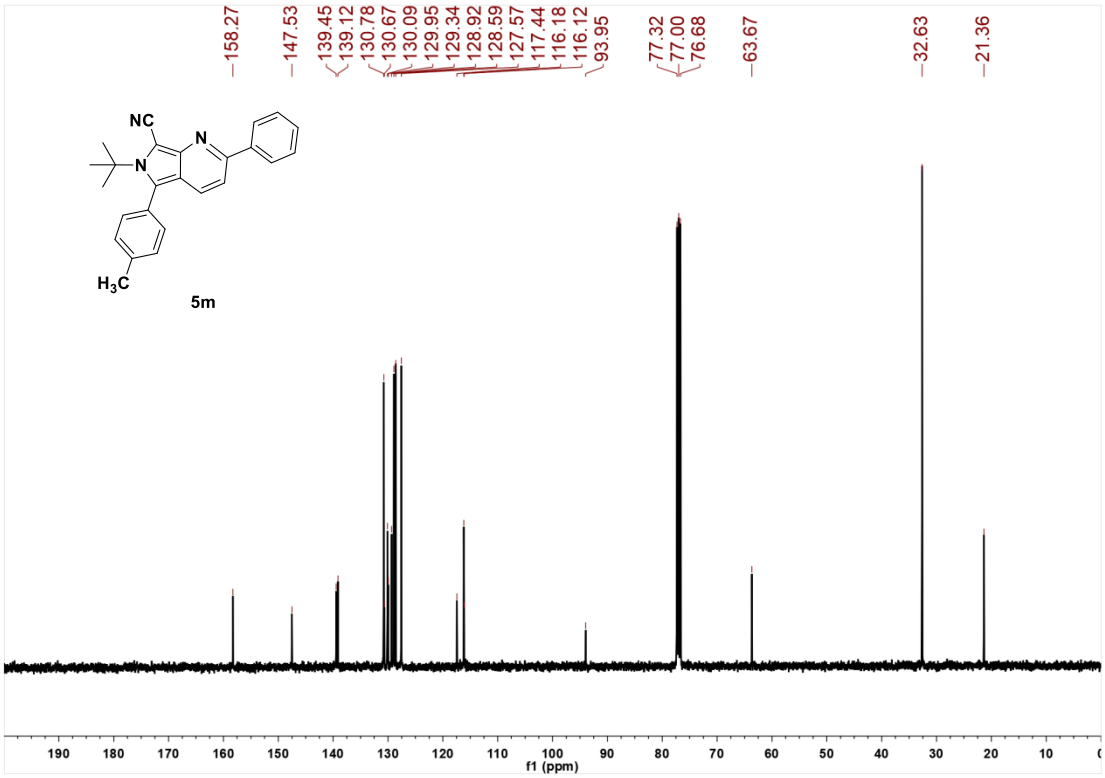


^{1}H NMR (400 MHz), $CDCl_3$



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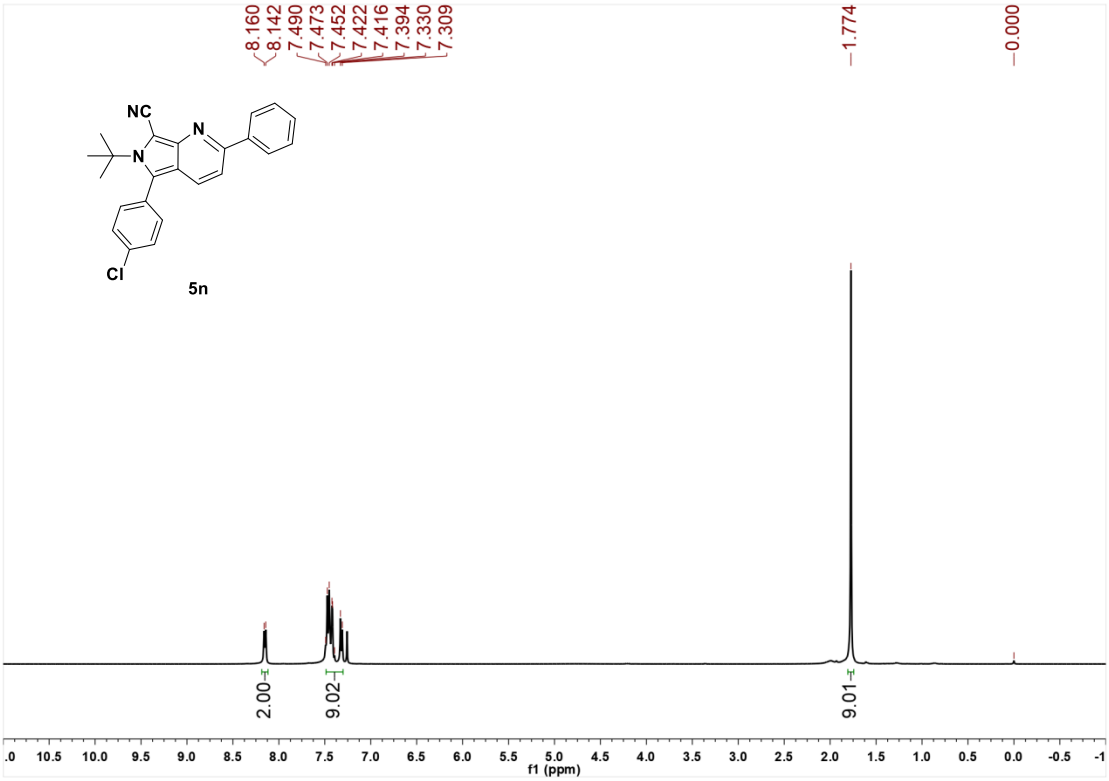
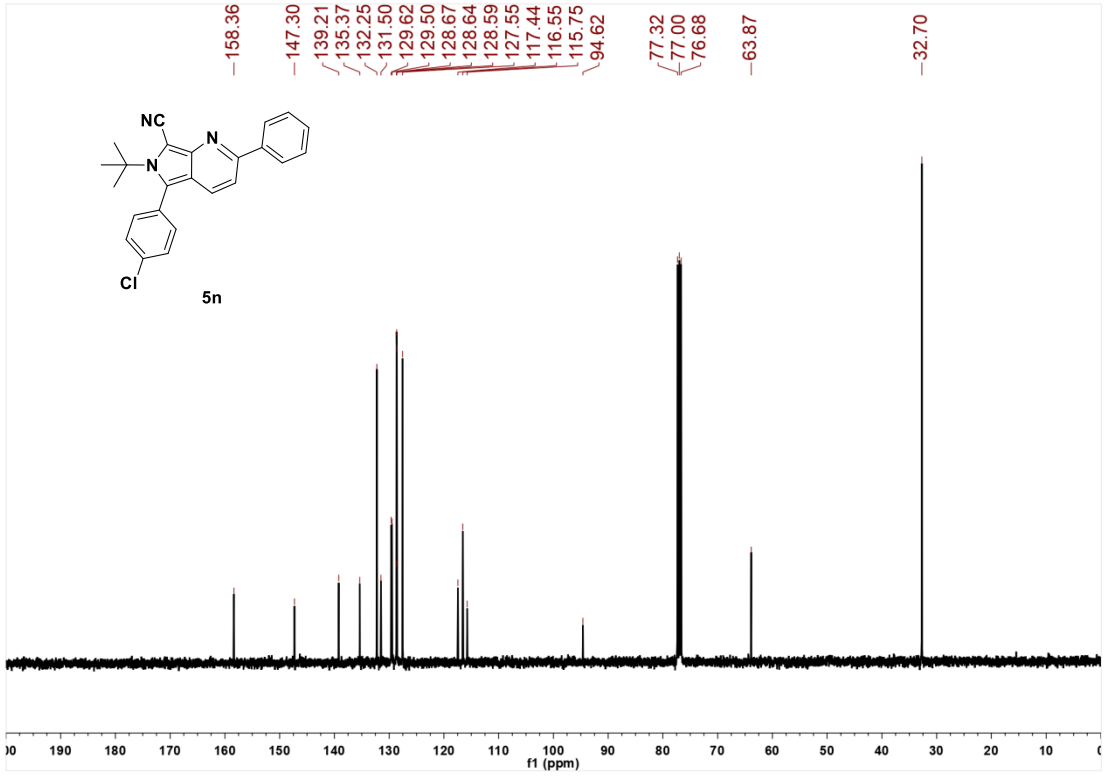
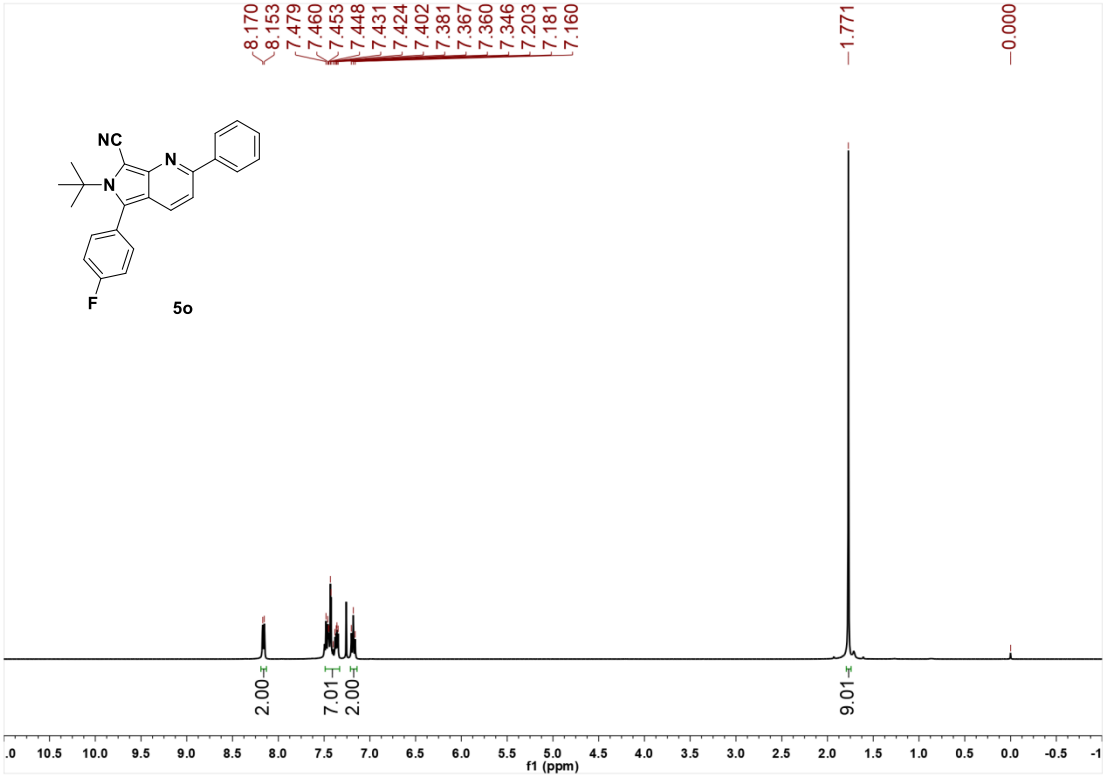


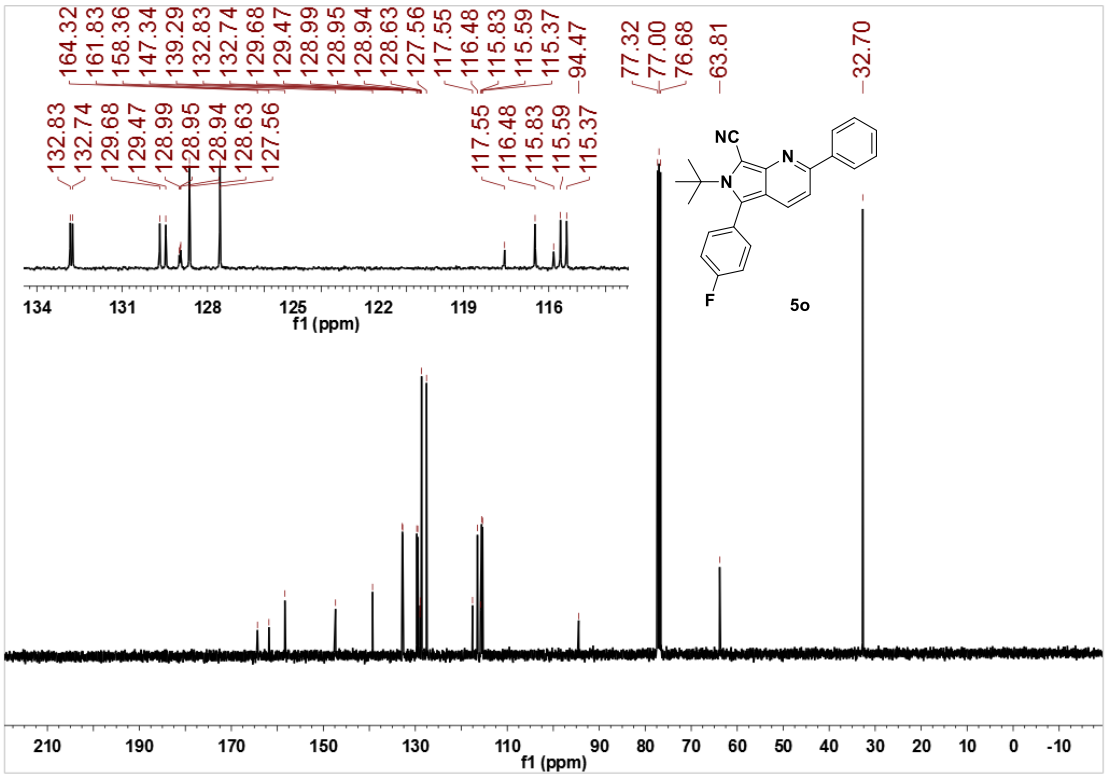
^{1}H NMR (400 MHz), $CDCl_3$



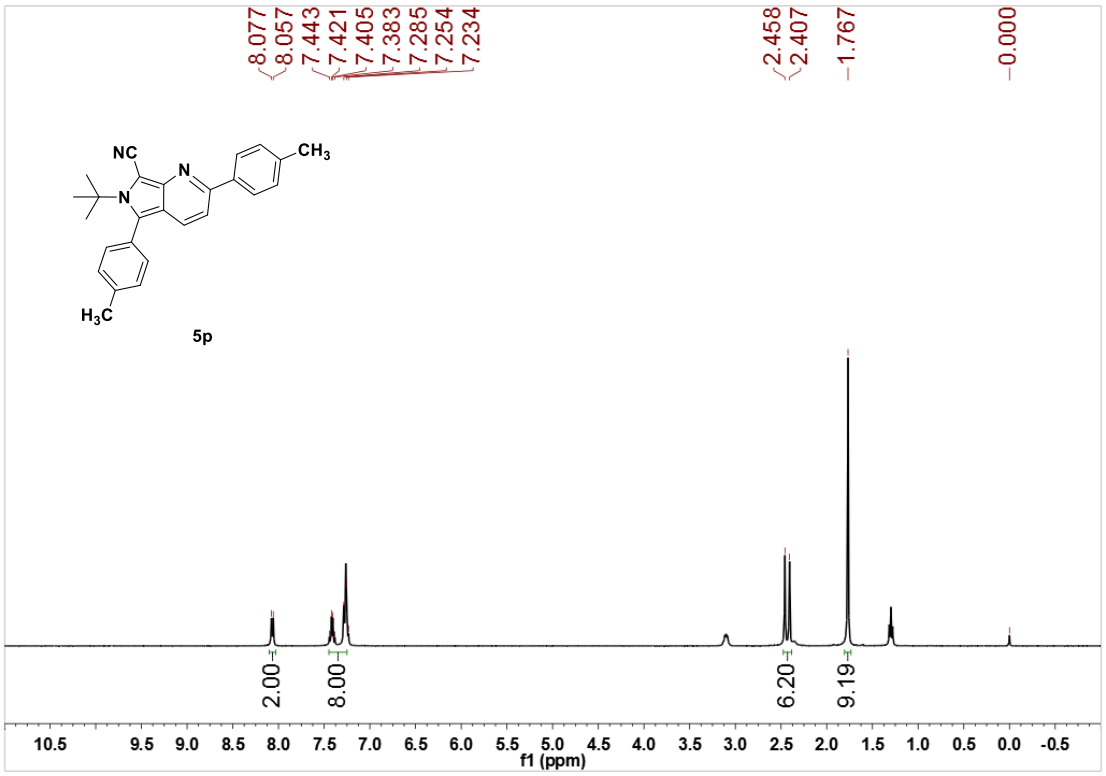
^{13}C NMR (100 MHz), $CDCl_3$



^{1}H NMR (400 MHz), $CDCl_3$



^{13}C NMR (100 MHz), $CDCl_3$



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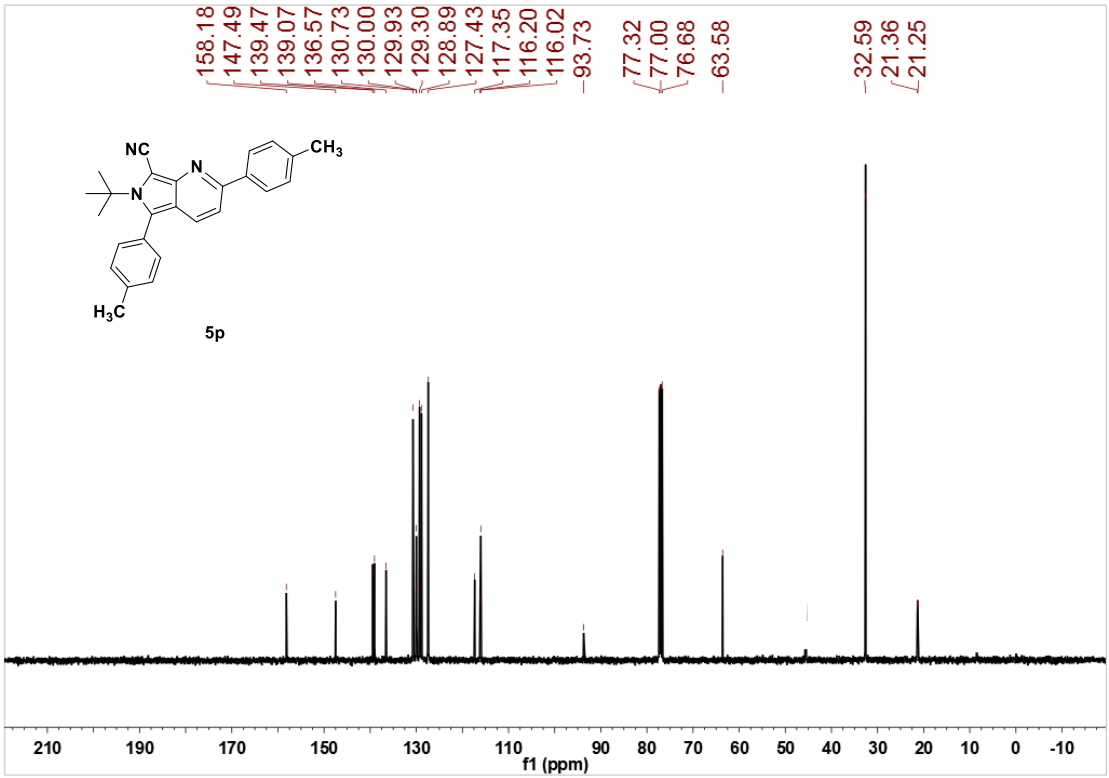

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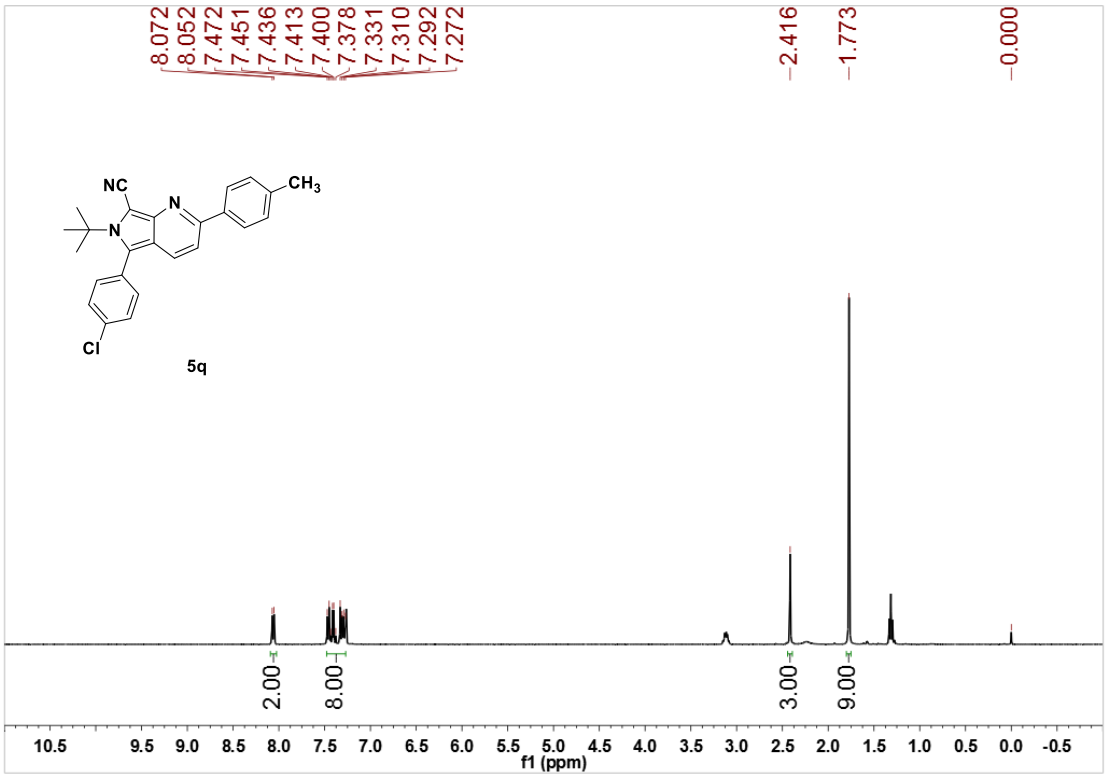

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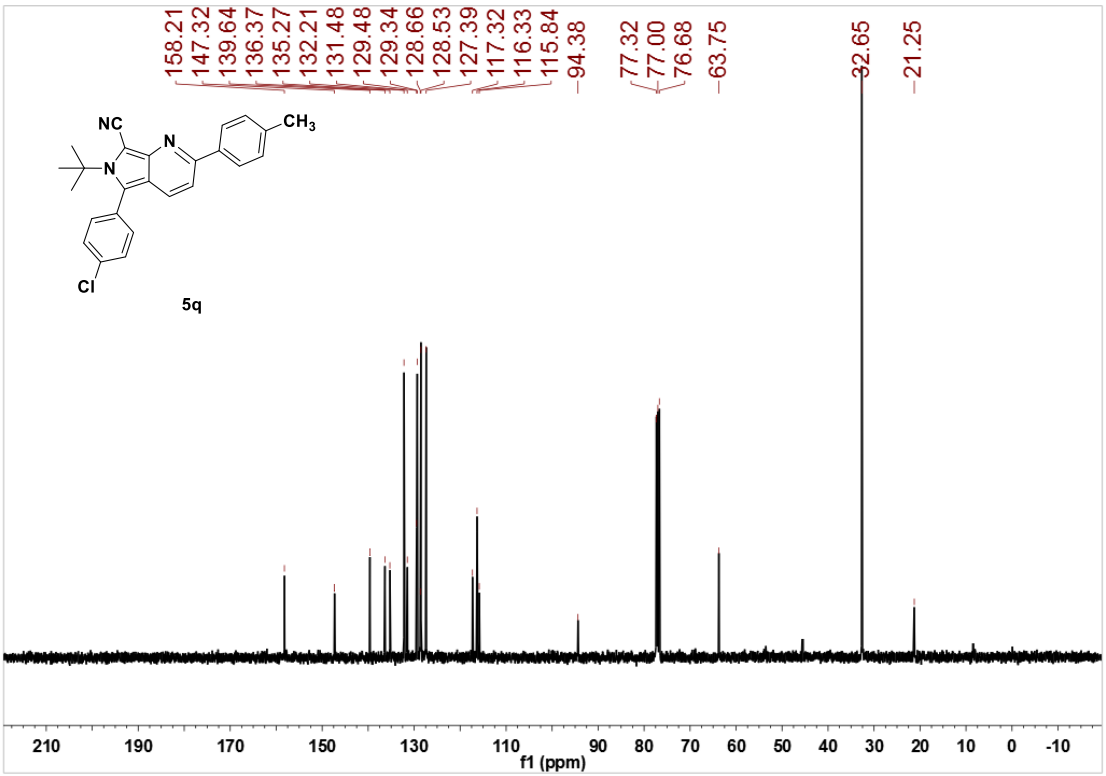
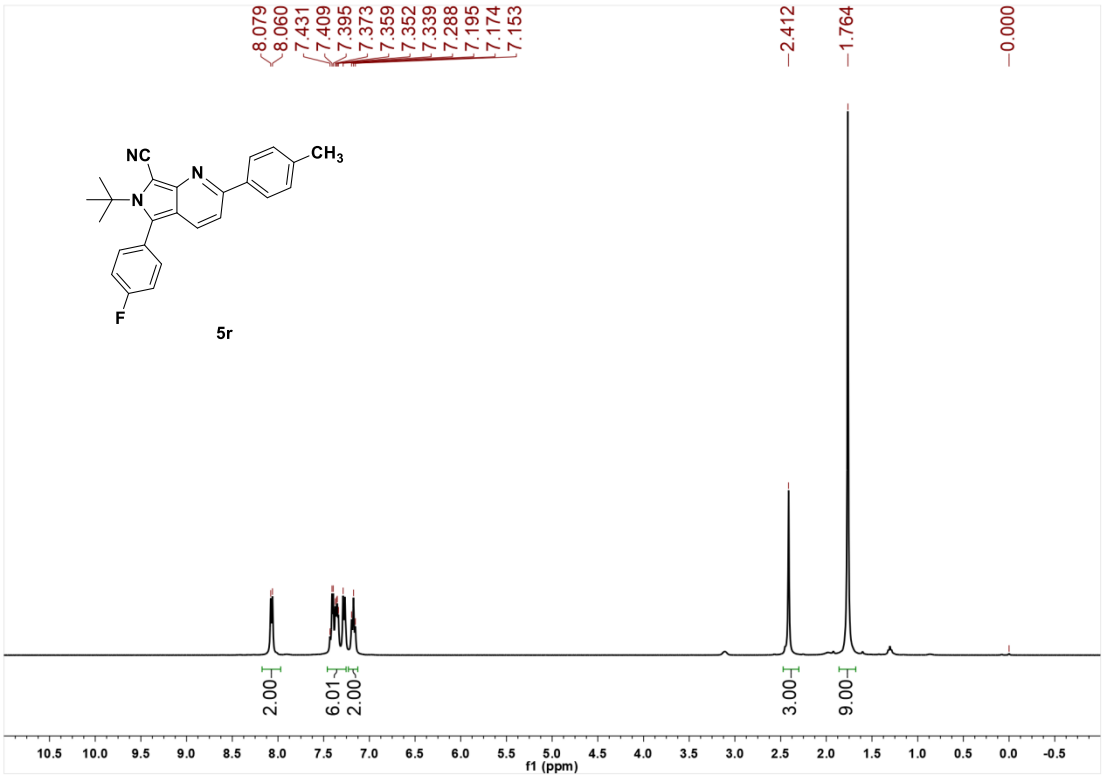
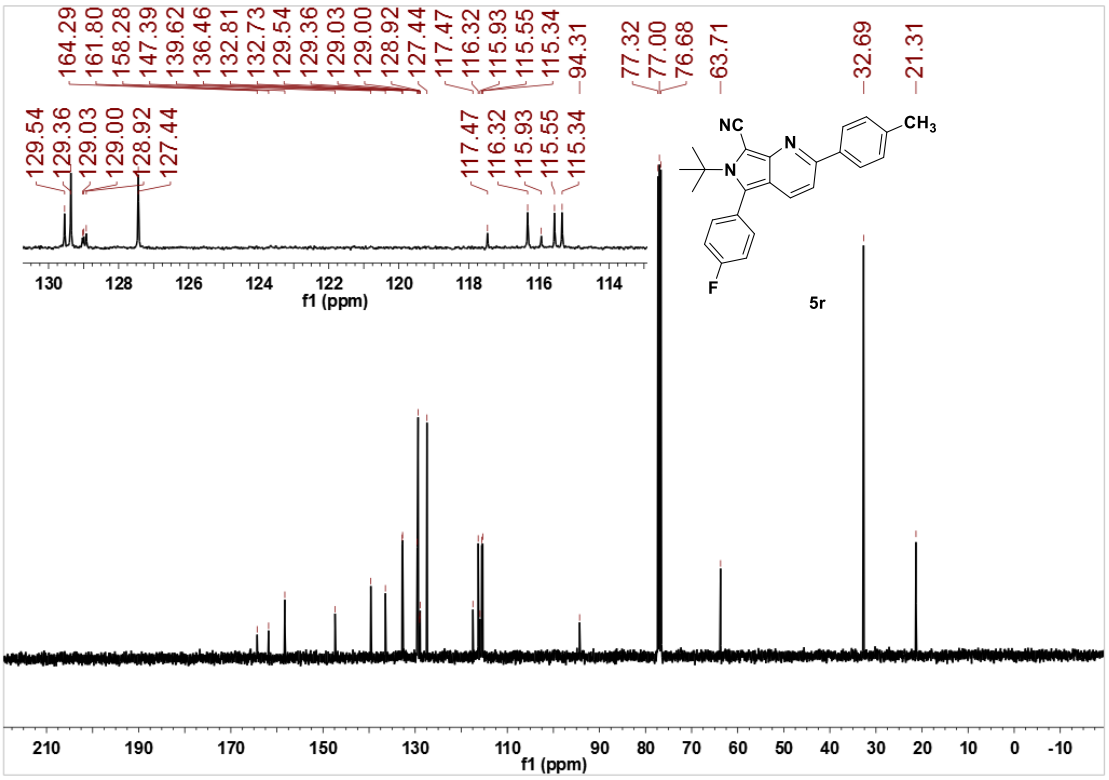


^{13}C NMR (100 MHz), $CDCl_3$



^{1}H NMR (400 MHz), $CDCl_3$



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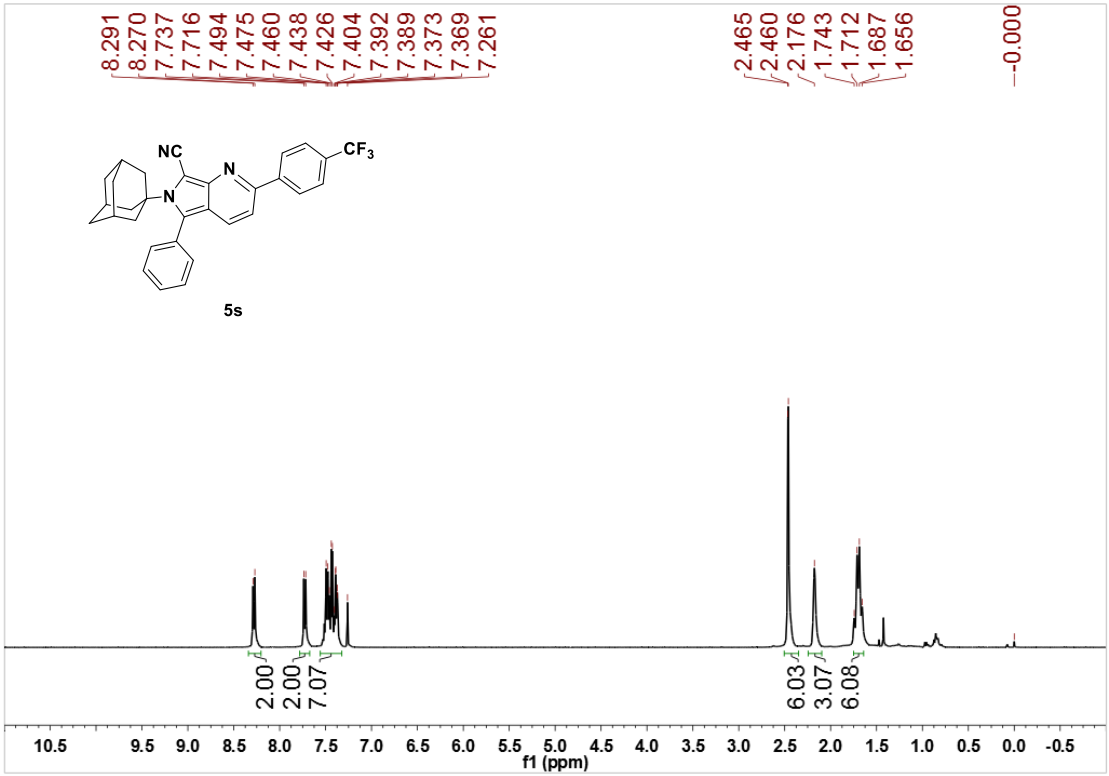
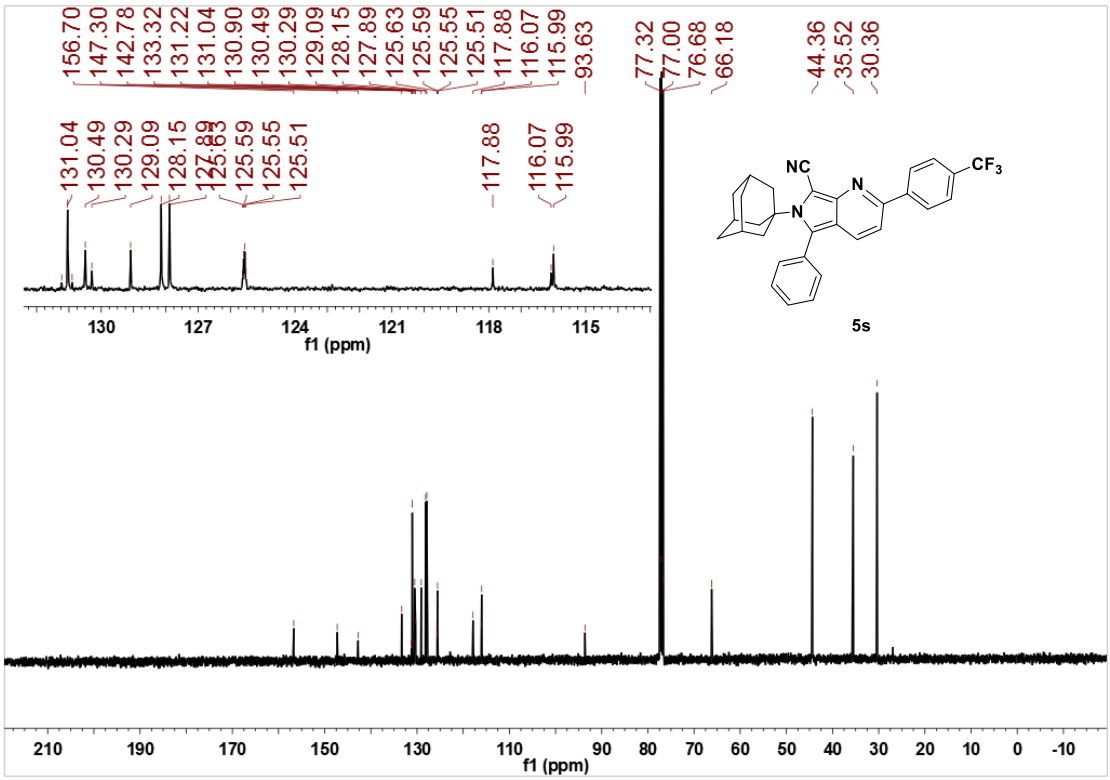
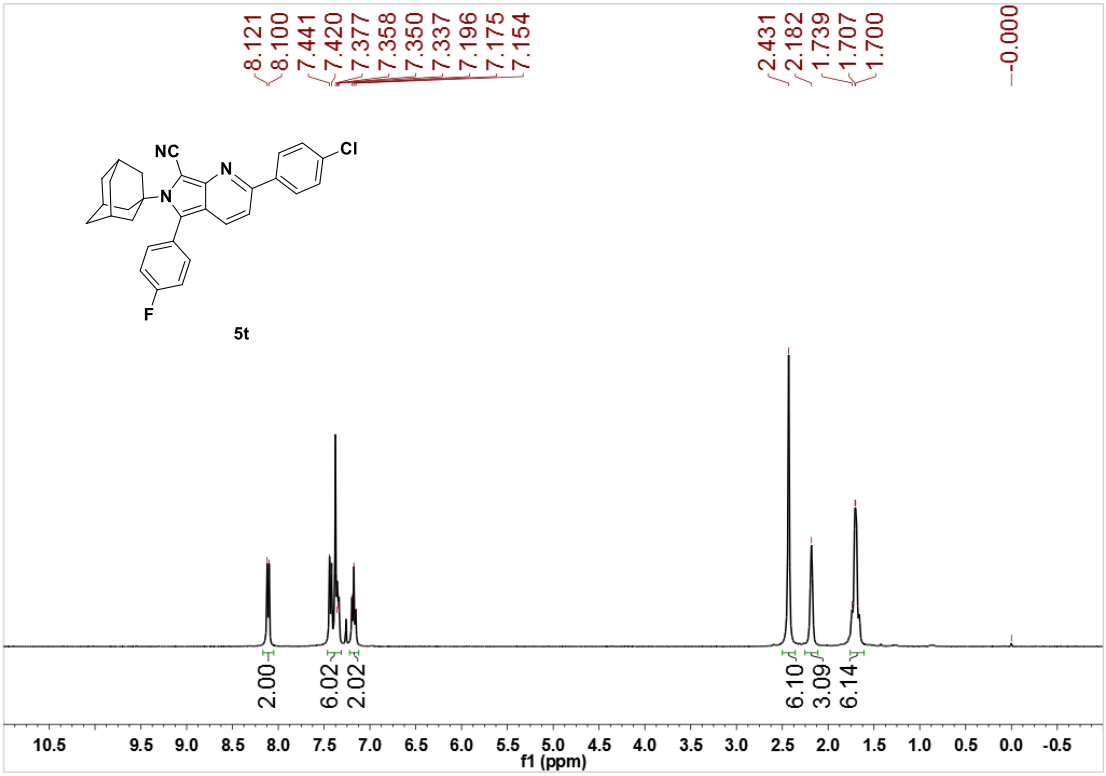


^{1}H NMR (400 MHz), $CDCl_3$



^{13}C NMR (100 MHz), $CDCl_3$



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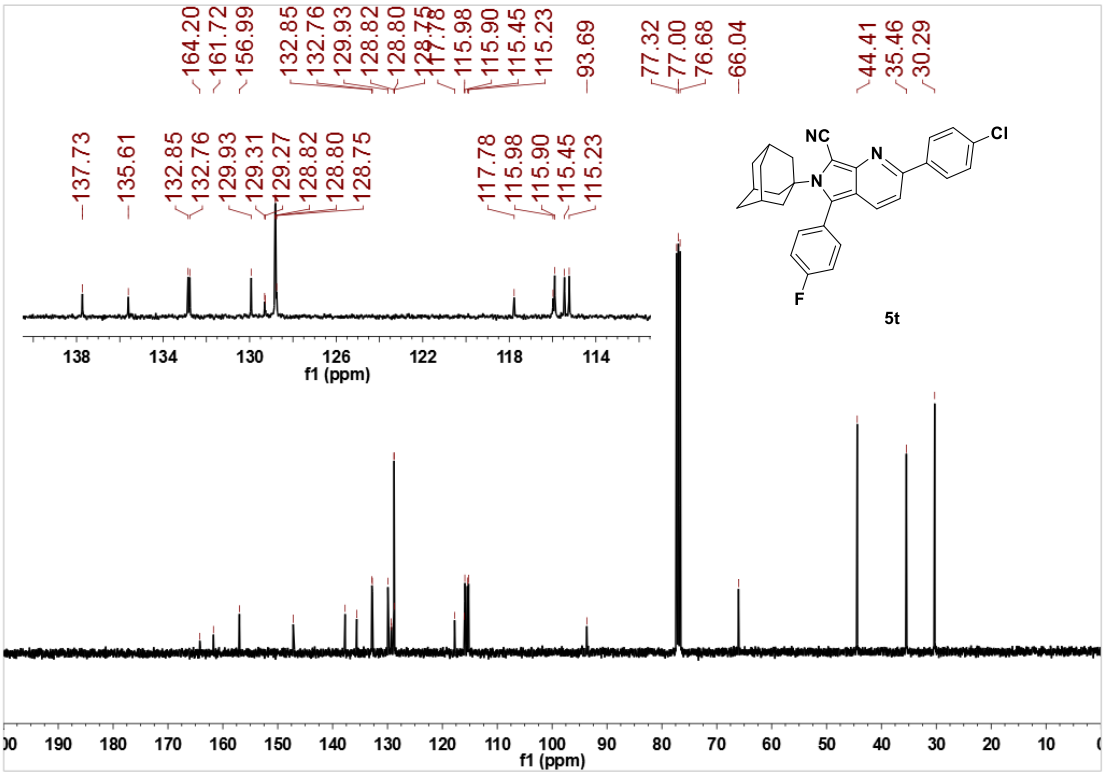

^{13}C NMR (100 MHz), $CDCl_3$

6. Copies of HRMS of 4c