Supporting Information

Palladium-catalyzed cascade cyclization of α,β-unsaturated N-tosylhydrazones with iodoarenes : access to 2H-chromenes and 2H-quinolines

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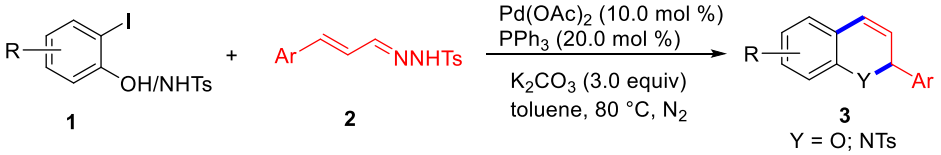
1. General considerations

All reactions were carried out under N_2 atmosphere. Materials were obtained from commercial suppliers or prepared according to standard procedures unless otherwise noted. Solvents were purified and dried according to standard methods prior to use. For product purification by flash column chromatography, silica gel (200~300 mesh) and light petroleum ether (bp. 60~90) are used. ^{1}H NMR spectra were recorded on a Bruker advance III 400 MHz in $CDCl_3$ and $^{13}C\{^1H\}$ NMR spectra were recorded on 101 MHz in $CDCl_3$ using TMS as internal standard. Data for ^{1}H NMR are recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet or unresolved, br = broad singlet, dd = doublet of doublet, dt = triplet of doublets, ddd = doublet of doublet of doublets, coupling constant (s) in Hz, integration). Data for ^{13}C NMR is reported in terms of chemical shift (δ, ppm). IR spectra were recorded on a FT-IR spectrometer and only major peaks were reported in cm^{-1}. High-resolution mass spectral analysis (HRMS) data were measured on a Bruker Apex II.

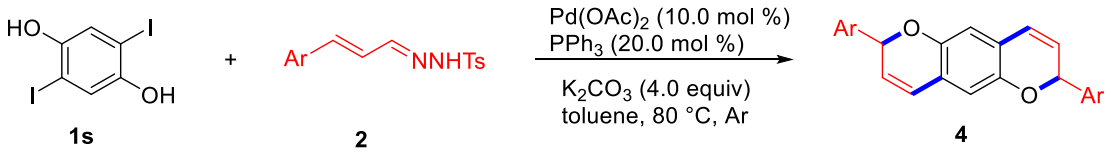
2. Preparation of substrates

Substrates **1a-1l** were purchased commercially. **1m-1r** were synthesized from the corresponding aniline derivatives according to the known literature.[1] Substrates **2a-2g** were prepared from the corresponding α,β-unsaturated aldehydes through the known literatures.[2]

3. Experiment procedure

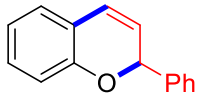


Substrates **1** (0.2 mmol, 1.0 equiv), α,β-unsaturated N-tosylhydrazones **2** (0.4 mmol, 2.0 equiv), , $Pd(OAc)_2$ (10 mol%), PPh_3 (20 mol%), K_2CO_3 (0.6 mmol, 3.0 equiv) were added to a sealed tube, toluene (2.0 mL) were added via syringe. The mixture was flushed with N_2 and then heated at 80 ℃ in an oil bath about for 12 h until completion (monitored by TLC). After cooling at room temperature, the reaction mixture was filtered through celite. The solvent in the filtrate was evaporated under reduced pressure. The residue was purified through silica gel chromatography to afford the products **3**.



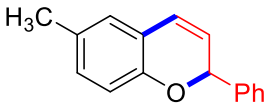
Substrate **1s** (0.2 mmol, 1.0 equiv), α,β-unsaturated N-tosylhydrazones **2** (0.6 mmol, 3.0 equiv), , $Pd(OAc)_2$ (10 mol%), PPh_3 (20 mol%), K_2CO_3 (0.8 mmol, 4.0 equiv) were added to a sealed tube, toluene (3.0 mL) were added via syringe. The mixture was flushed with N_2 and then heated at 80 ℃ in an oil bath about for 12 h until completion (monitored by TLC). After cooling at room temperature, the reaction mixture was filtered through celite. The solvent in the filtrate was evaporated under reduced pressure. The residue was purified through silica gel chromatography to afford the products **4**.

4. Spectra data



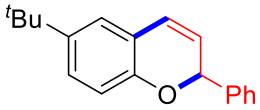
3a

2-phenyl-2H-chromene ***(3a)***[3]: Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 33 mg, 80% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (d, *J* = 7.3 Hz, 2H), 7.23 (dt, *J* = 12.6, 6.9 Hz, 3H), 6.99 (td, *J* = 7.7, 1.7 Hz, 1H), 6.89 (dd, *J* = 7.4, 1.6 Hz, 1H), 6.78-6.66 (m, 2H), 6.41 (dd, *J* = 9.8, 1.9 Hz, 1H), 5.80 (t, *J* = 2.6 Hz, 1H), 5.67 (dd, *J* = 9.9, 3.4 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.2, 140.9, 129.6, 128.8, 128.5, 127.1, 126.7, 125.0, 124.1, 121.4, 121.3, 116.1, 77.2.



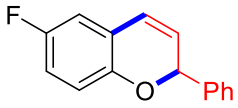
3b

6-methyl-2-phenyl-2H-chromene ***(3b)***[3]: Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 32 mg, 73% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (dt, *J* = 6.1, 1.5 Hz, 2H), 7.31-7.19 (m, 3H), 6.82 (dd, *J* = 8.2, 2.1 Hz, 1H), 6.73 (d, *J* = 2.1 Hz, 1H), 6.61 (d, *J* = 8.1 Hz, 1H), 6.40 (dd, *J* = 9.9, 1.9 Hz, 1H), 5.78 (dd, *J* = 3.4, 1.9 Hz, 1H), 5.70 (dd, *J* = 9.8, 3.4 Hz, 1H), 2.16 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 151.0, 141.0, 130.5, 130.0, 128.8, 128.4, 127.2, 127.1, 125.1, 124.2, 121.2, 115.8, 77.2, 20.7.



3c

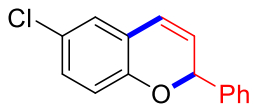
6-(tert-butyl)-2-phenyl-2H-chromene ***(3c)***[3]: Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 43 mg, 82% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 7.5 Hz, 2H), 7.30-7.17 (m, 3H), 7.04 (dd, *J* = 8.5, 2.5 Hz, 1H), 6.92 (d, *J* = 2.4 Hz, 1H), 6.64 (d, *J* = 8.4 Hz, 1H), 6.42 (dd, *J* = 9.8, 2.0 Hz, 1H), 5.79 (t, *J* = 2.6 Hz, 1H), 5.66 (dd, *J* = 9.9, 3.3 Hz, 1H), 1.19 (d, *J* = 1.5 Hz, 9H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 151.0, 144.0, 141.2, 128.7, 128.4, 127.1, 126.5, 124.9, 124.6, 123.7, 120.7, 115.4, 77.3, 34.2, 31.6.



3d

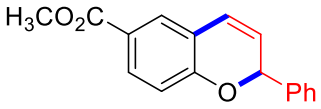
6-fluoro-2-phenyl-2H-chromene ***(3d)***: Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 36 mg, 79% yield. ^{1}H NMR (400

MHz, $CDCl_3$) δ 7.37-7.33 (m, 2H), 7.31-7.22 (m, 3H), 6.74-6.61 (m, 3H), 6.45-6.35 (m, 1H), 5.78 (d, *J* = 7.3 Hz, 2H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 157.5 (d, *J* = 239.1 Hz), 149.1 (d, *J* = 2.2 Hz), 140.4, 128.8, 128.6, 127.2, 126.4, 123.6 (d, *J* = 2.1 Hz), 122.4 (d, *J* = 8.4 Hz), 117.0 (d, *J* = 8.0 Hz), 115.5 (d, *J* = 23.2 Hz), 112.9 (d, *J* = 23.9 Hz), 77.22. ^{19}F NMR (376 MHz, $CDCl_3$) δ -123.10. HRMS (ESI-TOF) calcd for $C_{15}H_{12}FO$ $[M+H]^+$: 227.0867, found: 227.0873.



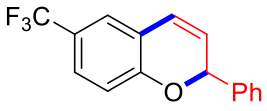
3e

6-chloro-2-phenyl-2H-chromene (***3e***): Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 35 mg, 72% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.39-7.23 (m, 5H), 6.96 (dd, *J* = 8.6, 2.6 Hz, 1H), 6.90 (d, *J* = 2.6 Hz, 1H), 6.62 (d, *J* = 8.6 Hz, 1H), 6.39 (dd, *J* = 9.9, 1.8 Hz, 1H), 5.86-5.72 (m, 2H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 151.7, 140.3, 129.1, 128.9, 128.7, 127.2, 126.3, 126.2, 125.9, 123.2, 122.7, 117.4, 77.4. HRMS (ESI-TOF) calcd for $C_{15}H_{12}ClO$ $[M+H]^+$: 243.0571, found: 243.0575.



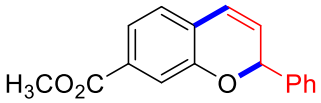
3f

methyl-2-phenyl-2H-chromene-6-carboxylate (***3f***): Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 50:1~20:1, v/v) affords the title compound as a colorless oil, 40 mg, 75% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.72 (dd, *J* = 8.4, 2.1 Hz, 1H), 7.63 (d, *J* = 2.2 Hz, 1H), 7.36-7.24 (m, 5H), 6.70 (d, *J* = 8.5 Hz, 1H), 6.47 (dd, *J* = 10.0, 1.9 Hz, 1H), 5.90 (dd, *J* = 3.3, 1.9 Hz, 1H), 5.74 (dd, *J* = 10.0, 3.4 Hz, 1H), 3.79 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 166.8, 157.2, 140.3, 131.6, 128.88, 128.8, 128.4, 127.1, 125.2, 123.3, 123.1, 120.7, 116.0, 78.0, 52.0. HRMS (ESI-TOF) calcd for $C_{17}H_{15}O_3$ $[M+H]^+$: 267.1016, found: 267.1016.



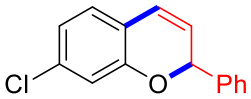
3g

2-phenyl-6-(trifluoromethyl)-2H-chromene (***3g***): Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1~50:1, v/v) affords the title compound as a colorless oil, 32 mg, 58% yield. ^1H NMR (400 MHz, $CDCl_3$) δ 7.37-7.25 (m, 6H), 7.20-7.15 (m, 1H), 6.74 (d, *J* = 8.5 Hz, 1H), 6.46 (dd, *J* = 9.9, 1.8 Hz, 1H), 5.90 (t, *J* = 2.6 Hz, 1H), 5.79 (dd, *J* = 9.9, 3.5 Hz, 1H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 155.8, 140.2, 129.0, 128.9, 127.2, 126.7 (q, *J* = 3.9 Hz), 126.0, 125.7, 123.8 (q, *J* = 3.7 Hz), 123.4 (d, *J* = 32.7 Hz), 123.1, 121.2, 116.3, 77.8. ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.73. HRMS (ESI-TOF) calcd for $C_{16}H_{12}F_3O$ $[M+H]^+$: 277.0835, found: 277.0833.



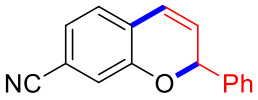
3h

methyl-2-phenyl-2H-chromene-7-carboxylate (***3h***): Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 50:1~20:1, v/v) affords the title compound as a colorless oil, 37 mg, 69% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.38-7.21 (m, 6H), 6.97 (d, *J* = 7.8 Hz, 1H), 6.52-6.43 (m, 1H), 5.85 (d, *J* = 8.4 Hz, 2H), 3.78 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 166.7, 153.0, 140.3, 131.0, 128.8, 128.7, 127.5, 127.1, 126.5, 125.6, 123.4, 122.8, 117.2, 77.3, 52.2. HRMS (ESI-TOF) calcd for $C_{17}H_{15}O_3$ $[M+H]^+$: 267.1016, found: 267.1016.



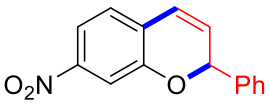
3i

7-chloro-2-phenyl-2H-chromene (***3i***): Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 37 mg, 77% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41-7.22 (m, 5H), 6.83 (d, *J* = 8.0 Hz, 1H), 6.77-6.67 (m, 2H), 6.41 (dd, *J* = 9.9, 1.8 Hz, 1H), 5.82 (dd, *J* = 3.5, 1.8 Hz, 1H), 5.72 (dd, *J* = 9.9, 3.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.8, 140.3, 134.4, 128.9, 128.7, 127.4, 127.1, 124.9, 123.2, 121.4, 119.9, 116.6, 77.4. HRMS (ESI-TOF) calcd for $C_{15}H_{12}ClO$ $[M+H]^+$: 243.0571, found: 243.0572.



3j

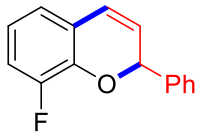
2-phenyl-2H-chromene-7-carbonitrile (***3j***): Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1~50:1, v/v) affords the title compound as a pale yellow oil, 31 mg, 67% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (m, 5H), 7.06 (dd, *J* = 7.7, 1.6 Hz, 1H), 6.98 (d, *J* = 7.7 Hz, 1H), 6.92 (d, *J* = 1.6 Hz, 1H), 6.51-6.44 (m, 1H), 5.95-5.84 (m, 2H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.2, 139.7, 128.98, 128.95, 128.2, 127.1, 125.6, 125.3, 122.9, 119.4, 118.8, 112.3, 77.6. HRMS (ESI-TOF) calcd for $C_{16}H_{12}NO$ $[M+H]^+$: 234.0913, found: 234.0911.



3k

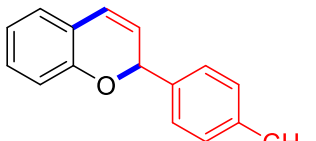
7-nitro-2-phenyl-2H-chromene (***3k***): Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 50:1~20:1, v/v) affords the title compound as a yellow viscous oil, 29 mg, 57% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (dd, *J* = 8.3, 2.2 Hz, 1H), 7.52 (d, *J* = 2.2 Hz,

1H), 7.40-7.24 (m, 5H), 7.04 (d, *J* = 8.2 Hz, 1H), 6.53 (d, *J* = 9.2 Hz, 1H), 6.00-5.89 (m, 2H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 153.4, 148.4, 139.5, 129.1, 129.0, 128.8, 127.2, 126.8, 122.7, 116.7, 111.6, 77.6. HRMS (ESI-TOF) calcd for $C_{15}H_{12}NO_3$ $[M+H]^+$: 254.0812, found: 254.0816.



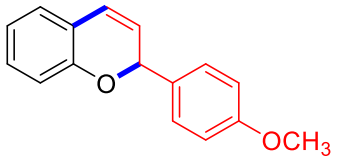
3l

8-fluoro-2-phenyl-2H-chromene (***3l***): Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 32 mg, 71% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40-7.34 (m, 2H), 7.31-7.22 (m, 3H), 6.83 (ddd, *J* = 10.3, 6.5, 3.3 Hz, 1H), 6.73-6.65 (m, 2H), 6.46 (dt, *J* = 9.9, 1.9 Hz, 1H), 5.88 (dd, *J* = 3.6, 1.8 Hz, 1H), 5.79 (dd, *J* = 9.9, 3.6 Hz, 1H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 151.1 (d, *J* = 245.7 Hz), 140.7 (d, *J* = 11.1 Hz), 140.2, 128.8, 128.7, 127.1, 125.7, 123.7 (d, *J* = 2.5 Hz), 123.6 (d, *J* = 3.8 Hz), 121.9 (d, *J* = 3.2 Hz), 120.8 (d, *J* = 7.1 Hz), 116.6 (d, *J* = 18.5 Hz), 76.85. ^{19}F NMR (376 MHz, $CDCl_3$) δ -137.64. HRMS (ESI-TOF) calcd for $C_{15}H_{12}FO$ $[M+H]^+$: 227.0867, found: 227.0867.



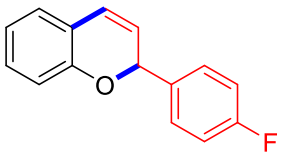
3m

2-(p-tolyl)-2H-chromene (***3m***)[3]: Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 34 mg, 76% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (d, *J* = 7.7 Hz, 2H), 7.09 (d, *J* = 7.7 Hz, 2H), 7.01 (t, *J* = 7.7 Hz, 1H), 6.91 (d, *J* = 7.5 Hz, 1H), 6.77 (t, *J* = 7.5 Hz, 1H), 6.68 (d, *J* = 8.1 Hz, 1H), 6.44 (d, *J* = 10.0 Hz, 1H), 5.85-5.76 (m, 1H), 5.69 (dd, *J* = 10.2, 3.4 Hz, 1H), 2.25 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 153.3, 138.3, 137.9, 129.5, 129.5, 127.2, 126.7, 125.1, 124.0, 121.5, 121.2, 116.1, 77.1, 21.3.



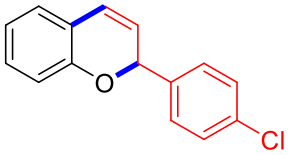
3n

2-(4-methoxyphenyl)-2H-chromene (***3n***)[3]: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1~50:1, v/v) affords the title compound as a colorless oil, 41 mg, 87% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.22 (m, 2H), 6.97 (td, *J* = 7.7, 1.7 Hz, 1H), 6.88 (dd, *J* = 7.4, 1.7 Hz, 1H), 6.79-6.71 (m, 3H), 6.65 (d, *J* = 8.1 Hz, 1H), 6.41 (dd, *J* = 9.8, 1.9 Hz, 1H), 5.74 (dd, *J* = 3.5, 1.9 Hz, 1H), 5.65 (dt, *J* = 9.8, 2.3 Hz, 1H), 3.64 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 159.8, 153.1, 132.9, 129.5, 128.7, 126.6, 125.0, 124.1, 121.4, 121.1, 116.1, 114.0, 76.8, 55.3.



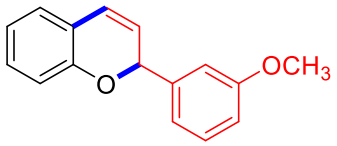
3o

*2-(4-fluorophenyl)-2H-chromene (**3o**)*[3]: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1, v/v) affords the title compound as a colorless oil, 32 mg, 70% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.30 (m, 2H), 7.07-6.92 (m, 4H), 6.79 (td, *J* = 7.4, 1.1 Hz, 1H), 6.69 (d, *J* = 8.1 Hz, 1H), 6.47 (dd, *J* = 9.9, 1.9 Hz, 1H), 5.81 (dd, *J* = 3.5, 1.9 Hz, 1H), 5.68 (dd, *J* = 9.9, 3.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 162.8 (d, *J* = 247.9 Hz), 153.0, 136.7 (d, *J* = 3.2 Hz), 129.7, 129.1 (d, *J* = 8.4 Hz), 126.8, 124.6, 124.4, 121.4, 121.3, 116.2, 115.7 (d, *J* = 21.6 Hz), 76.5.



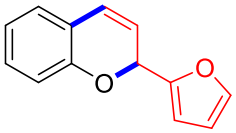
3p

*2-(4-chlorophenyl)-2H-chromene (**3p**)*[3]: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1, v/v) affords the title compound as a colorless oil, 36 mg, 75% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.22 (m, 4H), 7.03 (td, *J* = 7.7, 1.7 Hz, 1H), 6.93 (dd, *J* = 7.5, 1.7 Hz, 1H), 6.83-6.77 (m, 1H), 6.69 (d, *J* = 8.1 Hz, 1H), 6.46 (dd, *J* = 9.9, 1.9 Hz, 1H), 5.79 (dd, *J* = 3.5, 1.9 Hz, 1H), 5.68 (dd, *J* = 9.9, 3.5 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.0, 139.3, 134.3, 129.7, 128.9, 128.6, 126.8, 124.5, 124.4, 121.5, 121.3, 116.1, 76.4.



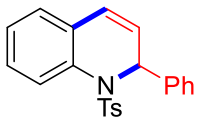
3q

*2-(3-methoxyphenyl)-2H-chromene (**3q**)*[3]: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1~50:1, v/v) affords the title compound as a colorless oil, 31 mg, 66% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20 (t, *J* = 7.9 Hz, 1H), 7.02 (td, *J* = 7.7, 1.7 Hz, 1H), 6.93 (ddd, *J* = 9.8, 7.4, 1.5 Hz, 3H), 6.78 (tdd, *J* = 6.1, 2.7, 1.2 Hz, 2H), 6.72 (dt, *J* = 8.1, 0.9 Hz, 1H), 6.43 (dd, *J* = 9.9, 2.0 Hz, 1H), 5.80 (dd, *J* = 3.4, 2.0 Hz, 1H), 5.70 (dd, *J* = 9.8, 3.4 Hz, 1H), 3.70 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.9, 153.3, 142.5, 129.8, 129.6, 126.7, 124.9, 124.1, 121.4, 121.3, 119.4, 116.1, 113.9, 112.6, 77.1, 55.3.



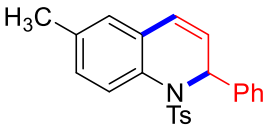
3r

*2-(furan-2-yl)-2H-chromene (**3r**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1~50:1, v/v) affords the title compound as a colorless oil, 23 mg, 57% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 1.8 Hz, 1H), 7.02 (td, *J* = 7.7, 1.7 Hz, 1H), 6.95 (dd, *J* = 7.5, 1.7 Hz, 1H), 6.79 (td, *J* = 7.4, 1.1 Hz, 1H), 6.71 (d, *J* = 8.1 Hz, 1H), 6.53 (dd, *J* = 9.8, 1.6 Hz, 1H), 6.32-6.21 (m, 2H), 5.84 (dd, *J* = 4.0, 1.6 Hz, 1H), 5.76 (dd, *J* = 9.7, 4.0 Hz, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.70, 152.68, 143.4, 129.6, 126.8, 125.6, 121.51, 121.45, 121.3, 116.4, 110.5, 109.6, 69.6. HRMS (ESI-TOF) calcd for $C_{13}H_{11}O_2$ $[M+H]^+$: 199.0754, found: 199.0755.



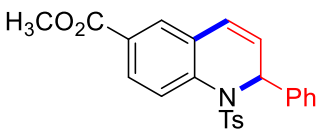
3s

*2-phenyl-1-tosyl-1,2-dihydroquinoline (**3s**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 5:1~3:1, v/v) affords the title compound as a white solid, Mp = 125-127 ℃, 46 mg, 64% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.0 Hz, 1H), 7.26 (dd, *J* = 7.4, 3.7 Hz, 4H), 7.20-7.11 (m, 4H), 7.08-6.98 (m, 3H), 6.89 (dd, *J* = 7.5, 1.7 Hz, 1H), 6.20 (d, *J* = 9.6 Hz, 1H), 5.95 (d, *J* = 5.9 Hz, 1H), 5.80 (dd, *J* = 9.6, 5.9 Hz, 1H), 2.27 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.5, 138.5, 136.2, 133.0, 129.2, 128.8, 128.5, 128.4, 128.0, 127.8, 127.5, 127.3, 126.6, 126.4, 125.6, 57.0, 21.7. HRMS (ESI-TOF) calcd for $C_{22}H_{20}NSO_2$ $[M+H]^+$: 362.1209, found: 362.1211.



3t

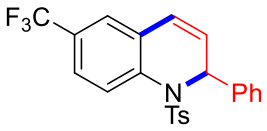
*6-methyl-2-phenyl-1-tosyl-1,2-dihydroquinoline (**3t**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 5:1~3:1, v/v) affords the title compound as a white solid, Mp = 138-140 ℃, 50 mg, 66% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.2 Hz, 1H), 7.30-7.20 (m, 4H), 7.13 (dtt, *J* = 8.2, 6.0, 3.0 Hz, 3H), 7.00 (d, *J* = 7.9 Hz, 2H), 6.91 (d, *J* = 7.9 Hz, 1H), 6.68 (s, 1H), 6.13 (d, *J* = 9.6 Hz, 1H), 5.90 (d, *J* = 5.9 Hz, 1H), 5.75 (ddd, *J* = 9.6, 5.9, 1.5 Hz, 1H), 2.25 (s, 3H), 2.17 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.4, 138.5, 136.3, 136.2, 130.3, 129.2, 129.0, 128.5, 127.9, 127.54, 127.48, 127.3, 126.9, 126.4, 125.7, 57.0, 21.6, 21.1. HRMS (ESI-TOF) calcd for $C_{23}H_{22}NSO_2$ $[M+H]^+$: 376.1366, found: 376.1366.



3u

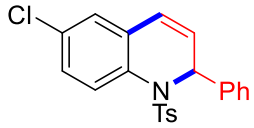
*methyl-2-phenyl-1-tosyl-1,2-dihydroquinoline-6-carboxylate (**3u**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 3:1~1:1, v/v) affords the title

compound as a white solid, Mp = 114-116 ℃, 49 mg, 58% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (dd, *J* = 8.5, 2.1 Hz, 1H), 7.67-7.59 (m, 2H), 7.30-7.22 (m, 4H), 7.18-7.13 (m, 3H), 7.02 (d, *J* = 8.0 Hz, 2H), 6.29 (d, *J* = 9.6 Hz, 1H), 6.01 (d, *J* = 6.0 Hz, 1H), 5.89 (dd, *J* = 9.6, 6.0 Hz, 1H), 3.79 (s, 3H), 2.26 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 166.5, 144.0, 138.2, 137.3, 136.0, 129.43, 129.42, 128.7, 128.3, 128.2, 127.9, 127.5, 127.4, 127.2, 127.0, 125.1, 57.3, 52.3, 21.6. HRMS (ESI-TOF) calcd for $C_{24}H_{22}NSO_4$ $[M+H]^+$: 420.1264, found: 420.1266.



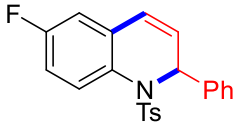
3v

2-phenyl-1-tosyl-6-(trifluoromethyl)-1,2-dihydroquinoline ***(3v)***: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 10:1~5:1, v/v) affords the title compound as a white solid, Mp = 133-125 ℃, 44 mg, 51% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.5 Hz, 1H), 7.37 (dd, *J* = 8.4, 2.1 Hz, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.25 (dd, *J* = 7.3, 2.0 Hz, 2H), 7.22-7.17 (m, 4H), 7.07 (d, *J* = 8.0 Hz, 2H), 6.29 (d, *J* = 9.5 Hz, 1H), 6.01 (d, *J* = 6.0 Hz, 1H), 5.94 (dd, *J* = 9.5, 5.9 Hz, 1H), 2.30 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 144.1, 138.0, 136.2, 136.1, 129.6, 128.8, 128.7, 128.5, 128.4 (d, *J* = 3.1 Hz), 127.6, 127.5, 127.2, 125.1 (t, *J* = 3.7 Hz), 124.8, 123.4 (d, *J* = 3.9 Hz), 57.2, 21.7. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -62.45. HRMS (ESI-TOF) calcd for $C_{23}H_{19}F_3NSO_2$ $[M+H]^+$: 430.1083, found: 430.1083.



3w

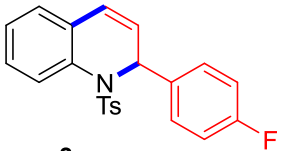
6-chloro-2-phenyl-1-tosyl-1,2-dihydroquinoline ***(3w)***: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 10:1~5:1, v/v) affords the title compound as a white solid, Mp = 117-119 ℃, 55 mg, 70% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (dd, *J* = 8.7, 1.6 Hz, 1H), 7.31-7.22 (m, 4H), 7.21-7.14 (m, 3H), 7.12-7.02 (m, 3H), 6.90 (t, *J* = 2.1 Hz, 1H), 6.15 (d, *J* = 9.5 Hz, 1H), 5.95 (d, *J* = 5.9 Hz, 1H), 5.86 (ddd, *J* = 9.6, 5.9, 1.7 Hz, 1H), 2.29 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.9, 137.9, 136.0, 132.0, 131.5, 130.1, 129.4, 129.1, 128.7, 128.3, 128.2, 128.1, 127.5, 127.3, 126.1, 124.8, 57.1, 21.7. HRMS (ESI-TOF) calcd for $C_{22}H_{19}ClNSO_2$ $[M+H]^+$: 396.0820, found: 396.0821.



3x

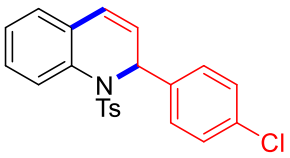
6-fluoro-2-phenyl-1-tosyl-1,2-dihydroquinoline ***(3x)***: Purification by column chromatography on

silica gel (petroleum ether/ethyl acetate = 10:1~5:1, v/v) affords the title compound as a white solid, Mp = 110-112 ℃, 49 mg, 65% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (dd, *J* = 8.9, 5.1 Hz, 1H), 7.27-7.21 (m, 4H), 7.16 (qd, *J* = 6.2, 3.2 Hz, 3H), 7.03 (d, *J* = 8.1 Hz, 2H), 6.82 (td, *J* = 8.6, 2.9 Hz, 1H), 6.60 (dd, *J* = 8.5, 2.9 Hz, 1H), 6.14 (d, *J* = 9.5 Hz, 1H), 5.94 (d, *J* = 5.9 Hz, 1H), 5.85 (dd, *J* = 9.5, 5.9 Hz, 1H), 2.28 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 160.9 (d, *J* = 246.7 Hz), 143.8, 137.9, 135.9, 130.4 (d, *J* = 8.8 Hz), 129.7 (d, *J* = 8.7 Hz), 129.3, 128.7 (d, *J* = 2.9 Hz), 128.6, 128.2 (d, *J* = 7.5 Hz), 127.5, 127.4, 125.0 (d, *J* = 2.51 Hz), 115.0 (d, *J* = 22.6 Hz), 112.7 (d, *J* = 22.9 Hz), 57.0, 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -115.03. HRMS (ESI-TOF) calcd for $C_{22}H_{19}FNSO_2$ $[M+H]^+$: 380.1115, found: 380.1116.



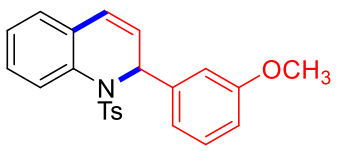
3y

*2-(4-fluorophenyl)-1-tosyl-1,2-dihydroquinoline (**3y**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 10:1~5:1, v/v) affords the title compound as a pale white solid, Mp = 117-119 ℃, 45 mg, 60% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.0 Hz, 1H), 7.28-7.20 (m, 4H), 7.14 (td, *J* = 7.7, 1.6 Hz, 1H), 7.09-7.00 (m, 3H), 6.90 (dd, *J* = 7.5, 1.7 Hz, 1H), 6.84 (t, *J* = 8.6 Hz, 2H), 6.22 (d, *J* = 9.6 Hz, 1H), 5.91 (d, *J* = 5.9 Hz, 1H), 5.77 (dd, *J* = 9.6, 5.9 Hz, 1H), 2.28 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 162.6 (d, *J* = 247.5 Hz), 143.7, 136.1, 134.1 (d, *J* = 3.2 Hz), 132.7, 129.4 (d, *J* = 8.4 Hz), 129.3, 128.6, 128.5, 127.8, 127.3, 126.7, 126.4, 126.3, 125.9, 115.4 (d, *J* = 21.6 Hz), 56.4, 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -114.32. HRMS (ESI-TOF) calcd for $C_{22}H_{19}FNSO_2$ $[M+H]^+$: 380.1115, found: 380.1115.



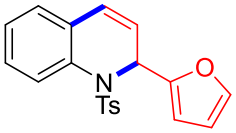
3z

*2-(4-chlorophenyl)-1-tosyl-1,2-dihydroquinoline (**3z**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 10:1~5:1, v/v) affords the title compound as a pale white solid, Mp = 129-131 ℃, 43 mg, 55% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.0 Hz, 1H), 7.22 (dd, *J* = 15.1, 8.2 Hz, 4H), 7.17-7.10 (m, 3H), 7.09-6.99 (m, 3H), 6.90 (dd, *J* = 7.6, 1.6 Hz, 1H), 6.22 (d, *J* = 9.5 Hz, 1H), 5.90 (d, *J* = 5.9 Hz, 1H), 5.77 (dd, *J* = 9.6, 5.9 Hz, 1H), 2.27 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 143.7, 137.0, 136.0, 133.9, 132.7, 129.3, 129.0, 128.7, 128.6, 127.7, 127.3, 126.8, 126.5, 126.1, 126.0, 56.3, 21.7. HRMS (ESI-TOF) calcd for $C_{22}H_{19}ClNSO_2$ $[M+H]^+$: 396.0820, found: 396.0824.



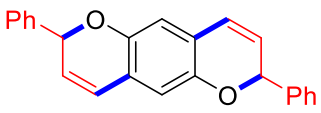
3aa

*2-(3-methoxyphenyl)-1-tosyl-1,2-dihydroquinoline (**3aa**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 10:1~5:1, v/v) affords the title compound as a white solid, Mp = 127-129 ℃, 52 mg, 67% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, *J* = 8.0 Hz, 1H), 7.25 (d, *J* = 8.1 Hz, 2H), 7.17-6.99 (m, 5H), 6.93-6.79 (m, 3H), 6.66 (dd, *J* = 8.2, 2.6 Hz, 1H), 6.18 (d, *J* = 9.5 Hz, 1H), 5.91 (d, *J* = 5.9 Hz, 1H), 5.79 (dd, *J* = 9.6, 5.9 Hz, 1H), 3.64 (s, 3H), 2.27 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.7, 143.6, 140.1, 136.2, 133.0, 129.5, 129.2, 128.7, 128.4, 127.7, 127.3, 126.6, 126.5, 126.4, 125.7, 119.8, 113.4, 113.2, 56.9, 55.3, 21.7. HRMS (ESI-TOF) calcd for $C_{23}H_{22}NSO_3$ $[M+H]^+$: 392.1315, found: 392.1315.



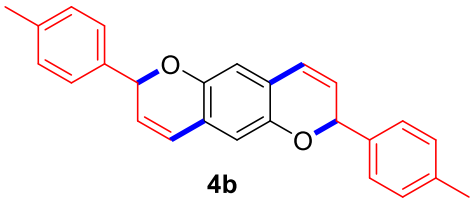
3ab

*2-(furan-2-yl)-1-tosyl-1,2-dihydroquinoline (**3ab**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 10:1~5:1, v/v) affords the title compound as a white solid, Mp = 110-112 ℃, 34 mg, 49% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, *J* = 8.1 Hz, 1H), 7.29-7.22 (m, 3H), 7.17-7.12 (m, 1H), 7.07 (td, *J* = 7.4, 1.3 Hz, 1H), 7.01 (d, *J* = 8.1 Hz, 2H), 6.91 (dd, *J* = 7.5, 1.6 Hz, 1H), 6.17 (d, *J* = 9.5 Hz, 1H), 6.09 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.04 (d, *J* = 5.8 Hz, 1H), 5.96 (d, *J* = 3.3 Hz, 1H), 5.72 (dd, *J* = 9.5, 5.8 Hz, 1H), 2.27 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 150.6, 143.7, 143.3, 136.1, 133.1, 129.2, 128.4, 128.2, 127.4, 126.6, 126.3, 124.0, 110.3, 109.0, 52.0, 21.7. HRMS (ESI-TOF) calcd for $C_{20}H_{18}NSO_3$ $[M+H]^+$: 352.1002, found: 352.1002.



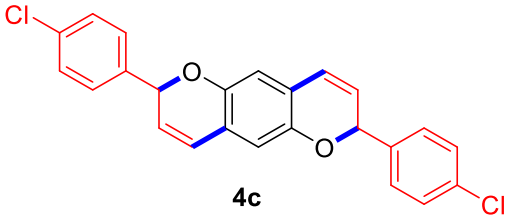
4a

*2,7-diphenyl-2,7-dihydropyrano[2,3-g]chromene (**4a**)*: Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 39 mg, 57% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 (d, *J* = 7.3 Hz, 4H), 7.33-7.24 (m, 6H), 6.42 (d, *J* = 1.9 Hz, 2H), 6.40-6.34 (m, 2H), 5.79-5.70 (m, 4H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 147.42, 147.35, 140.74, 140.69, 128.8, 128.5, 127.23, 127.22, 125.7, 125.6, 124.17, 124.15, 122.20, 122.18, 113.8, 113.7, 77.1, 77.0. HRMS (ESI-TOF) calcd for $C_{24}H_{19}O_2$ $[M+H]^+$: 339.1380, found: 339.1383.



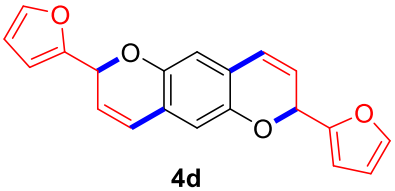
4b

2,7-di-p-tolyl-2,7-dihydropyrano[2,3-g]chromene (***4b***): Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 31 mg, 43% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.23 (m, 4H), 7.10 (d, *J* = 7.8 Hz, 4H), 6.46-6.31 (m, 4H), 5.79-5.65 (m, 4H), 2.27 (s, 6H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 147.3, 138.4, 137.7, 129.4, 127.31, 127.29, 125.72, 125.66, 124.15, 124.11, 122.21, 122.18, 113.73, 113.70, 77.4, 76.9, 21.4. HRMS (ESI-TOF) calcd for $C_{26}H_{23}O_2$ $[M+H]^+$: 367.1693, found: 367.1697.



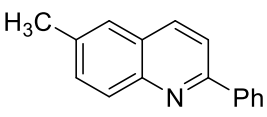
4c

2,7-bis(4-chlorophenyl)-2,7-dihydropyrano[2,3-g]chromene (***4c***): Purification by column chromatography on silica gel (petroleum ether) affords the title compound as a colorless oil, 32 mg, 39% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34-7.25 (m, 8H), 6.39 (d, *J* = 12.3 Hz, 4H), 5.72 (m, 4H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 147.20, 147.15, 139.1, 139.0, 134.3, 128.9, 128.7, 128.6, 125.1, 125.1, 124.47, 124.45, 122.2, 113.9, 113.8, 76.2, 76.1. HRMS (ESI-TOF) calcd for $C_{24}H_{17}Cl_2O_2$ $[M+H]^+$: 407.0600, found: 407.0603.



4d

2,7-di(furan-2-yl)-2,7-dihydropyrano[2,3-g]chromene (***4d***): Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1, v/v) affords the title compound as a colorless oil, 34 mg, 54% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 1.8 Hz, 2H), 6.43 (q, *J* = 3.7 Hz, 4H), 6.31-6.14 (m, 4H), 5.92-5.67 (m, 4H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 152.5, 146.9, 143.44, 143.40, 125.5, 122.2, 121.97, 121.95, 114.1, 110.5, 109.7, 69.5, 69.4. HRMS (ESI-TOF) calcd for $C_{20}H_{15}O_4$ $[M+H]^+$: 319.0965, found: 319.0968.



5

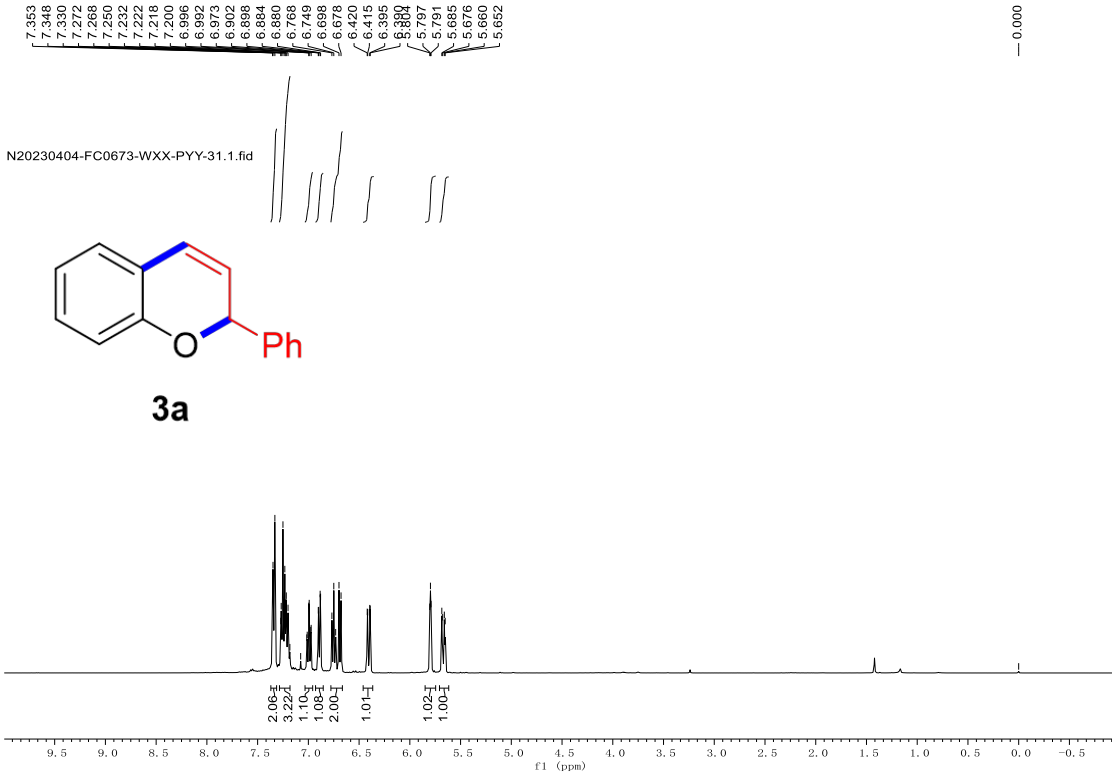
*6-methyl-2-phenylquinoline (**5**)*: Purification by column chromatography on silica gel (petroleum ether/ethyl acetate = 100:1, v/v) affords the title compound as a colorless oil, 29 mg, 66% yield. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07-8.01 (m, 2H), 7.98 (dd, *J* = 8.9, 3.5 Hz, 2H), 7.70 (d, *J* = 8.5 Hz, 1H), 7.42 (dd, *J* = 14.9, 7.4 Hz, 4H), 7.38-7.31 (m, 1H), 2.42 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 155.4, 145.8, 138.7, 135.1, 135.0, 130.9, 128.3, 128.1, 127.7, 126.4, 126.1, 125.3, 117.9, 20.5. HRMS (ESI-TOF) calcd for $C_{16}H_{14}N$ $[M+H]^+$: 220.1121, found: 220.1123.

5. References

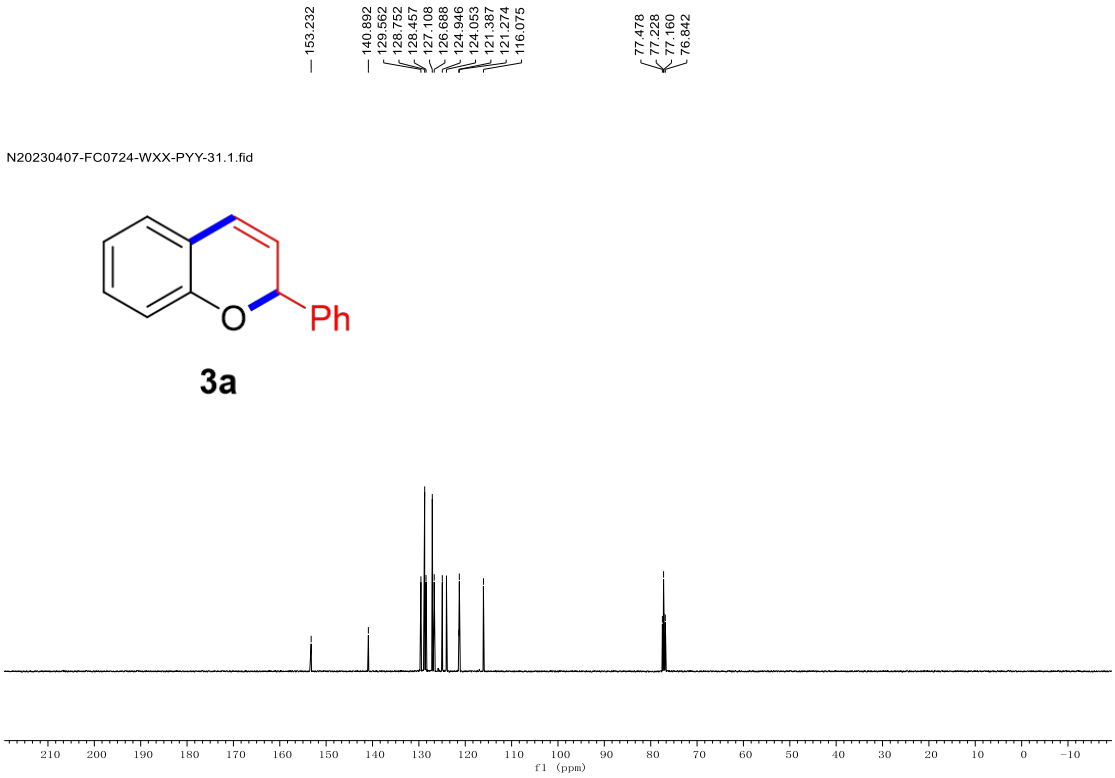
(1) (a) B.-S. Zhang, Z.-Q. Zhang, T.-J. Guo, J. C. A. Oliveira, S. Warratz, B.-J. Deng, Y.-M. Wang, J.-S. Zhou, X.-Y. Gou, X.-C. Wang, Z.-J. Quan and L. Ackermann, *Org. Lett.*, 2024, **26**, 4998; (b) D. Chaudhary and M. R. Kuram, *J. Org. Chem.*, 2024, **89**, 7347.
(2) (a) P.-X. Zhou, J.-Y. Luo, L.-B. Zhao, Y.-Y. Ye and Y.-M. Liang, *Chem. Commun.*, 2013, **49**, 3254; (b) Y.-Y. Ye, P.-X. Zhou, J.-Y. Luo, M.-J. Zhong and Y.-M. Liang, *Chem. Commun.*, 2013, **49**, 10190.
(3) Y. Xia, Y. Xia, Y. Zhang and J. Wang, *Org. Biomol. Chem.*, 2014, **12**, 9333.

6. NMR spectra

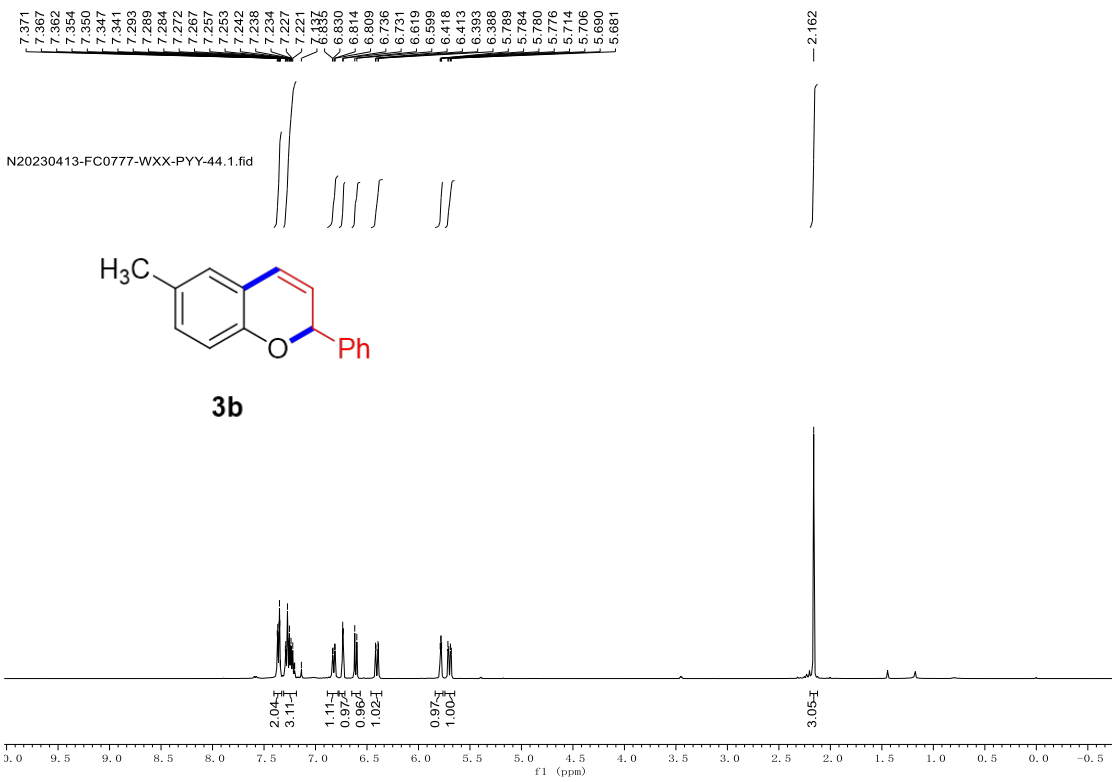
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3a**



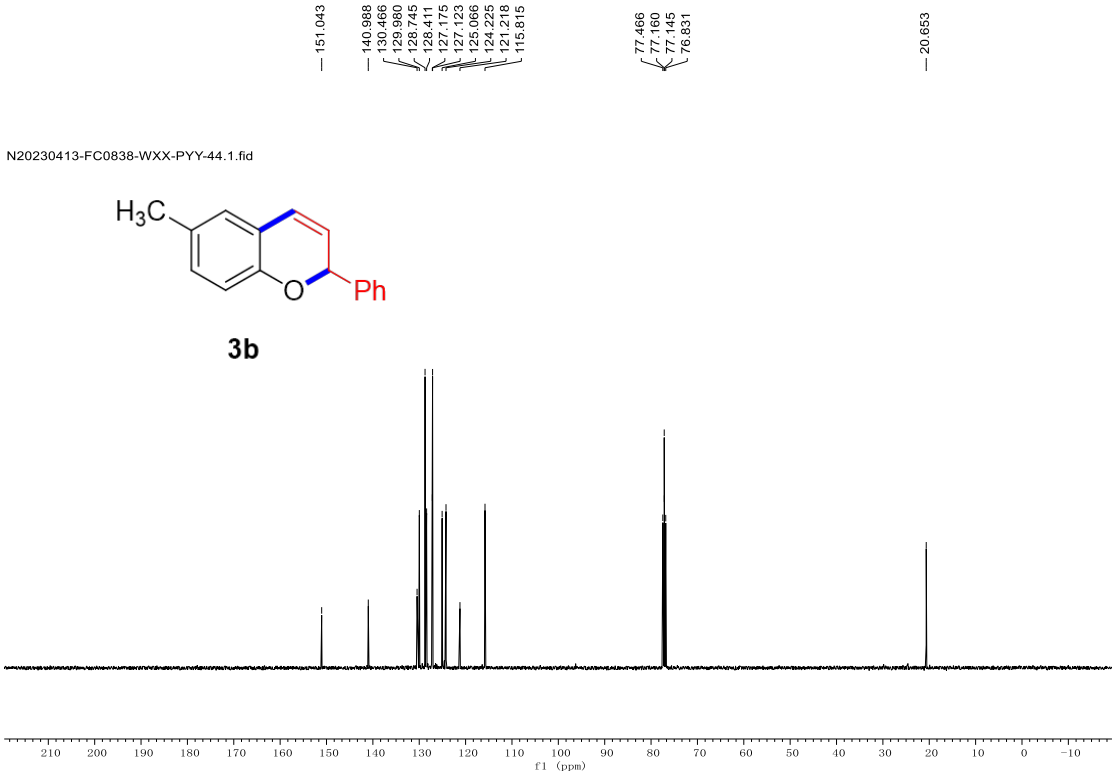
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3a**



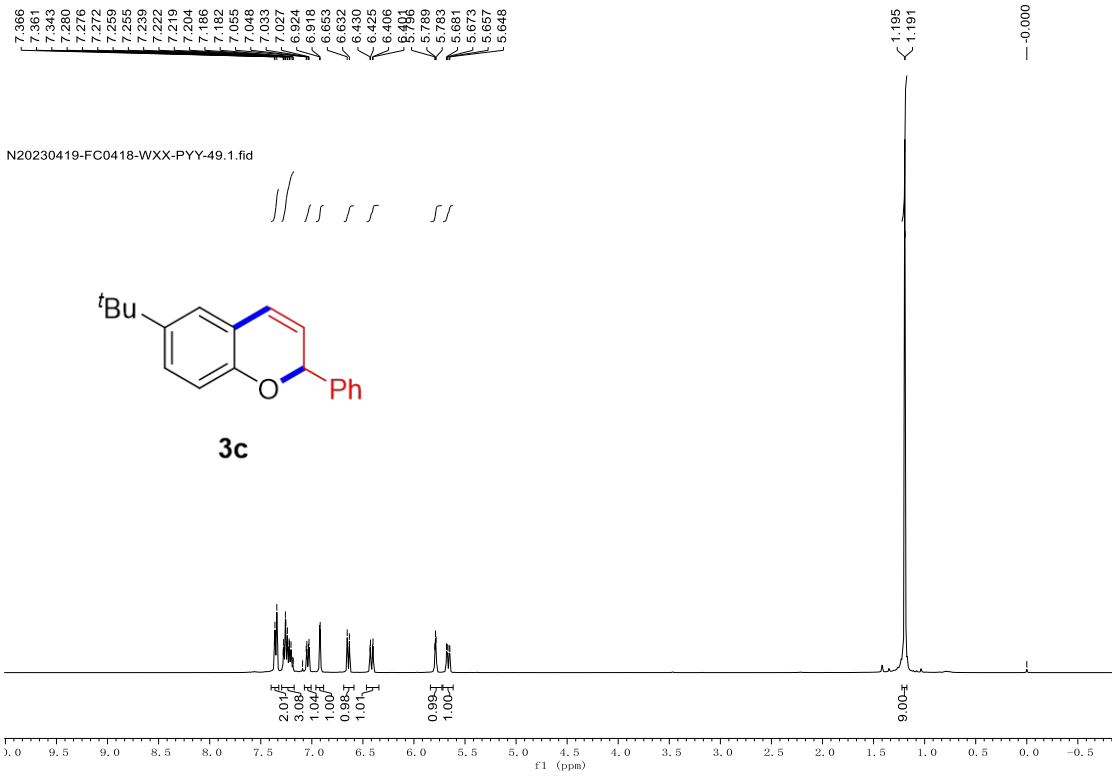
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3b**



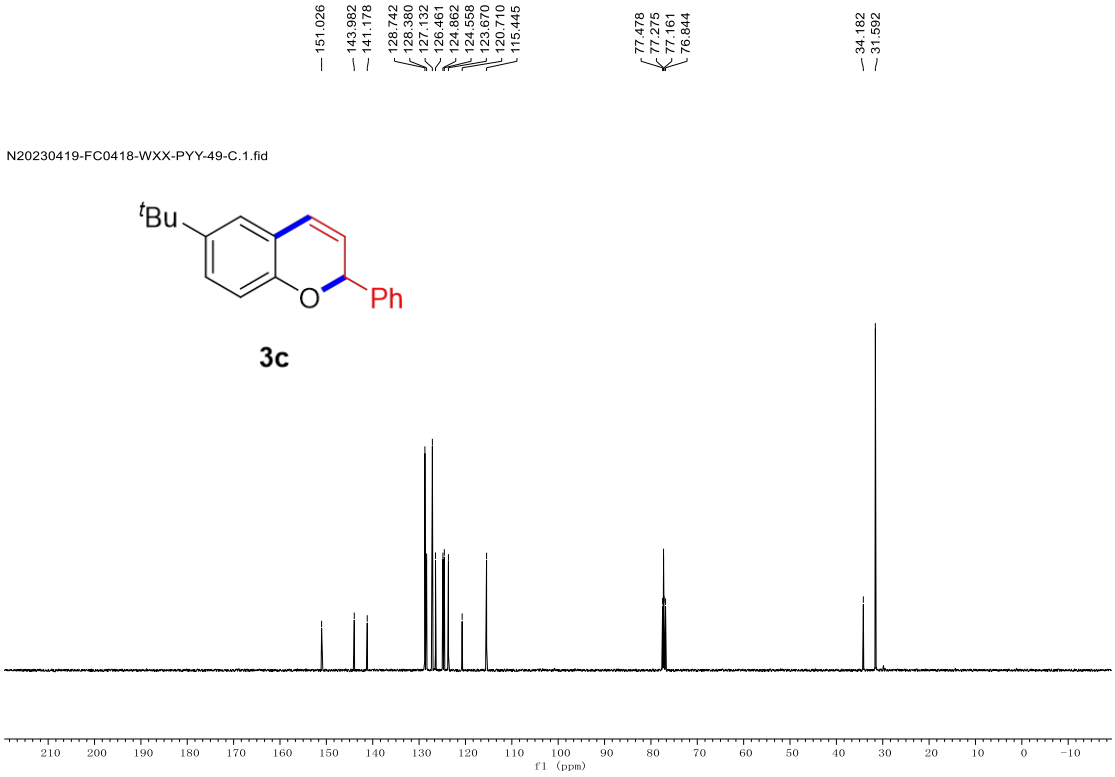
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3b**



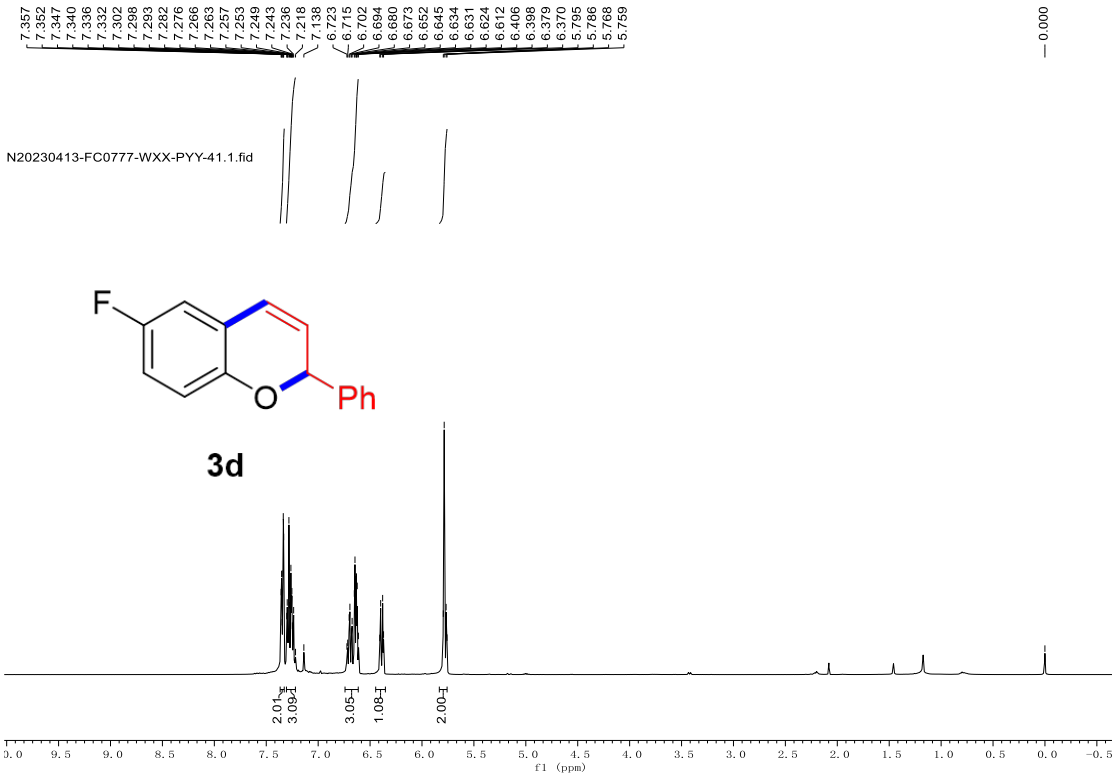
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3c**



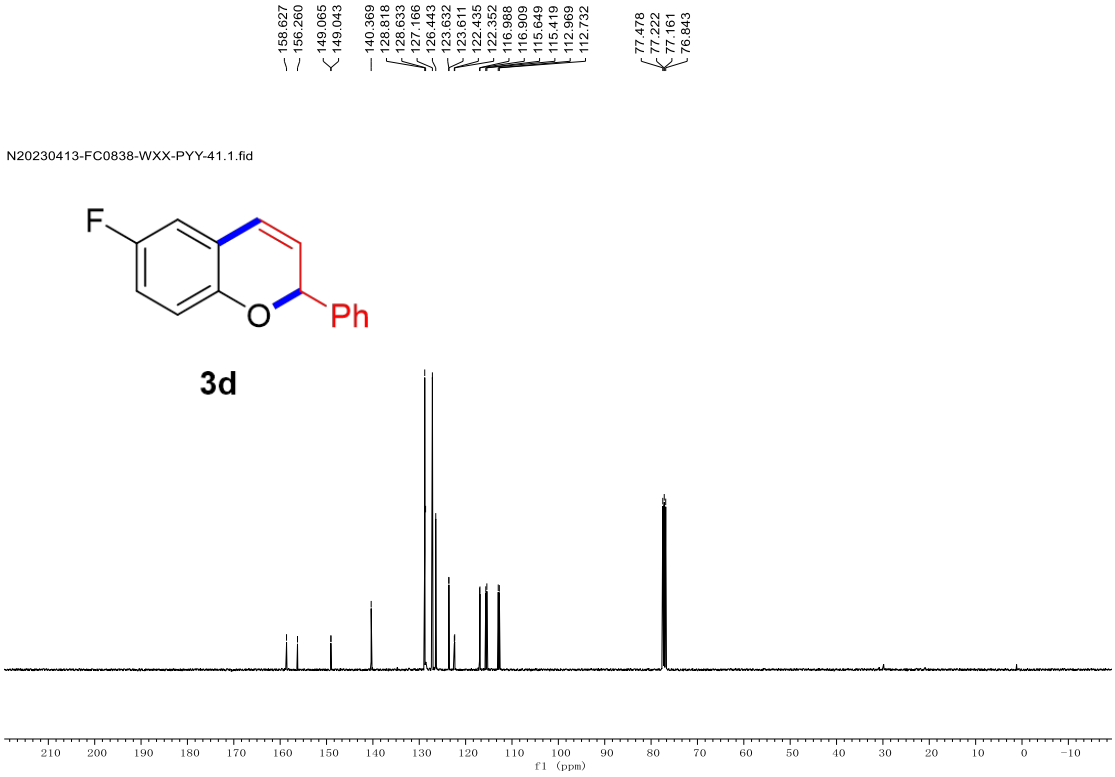
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3c**



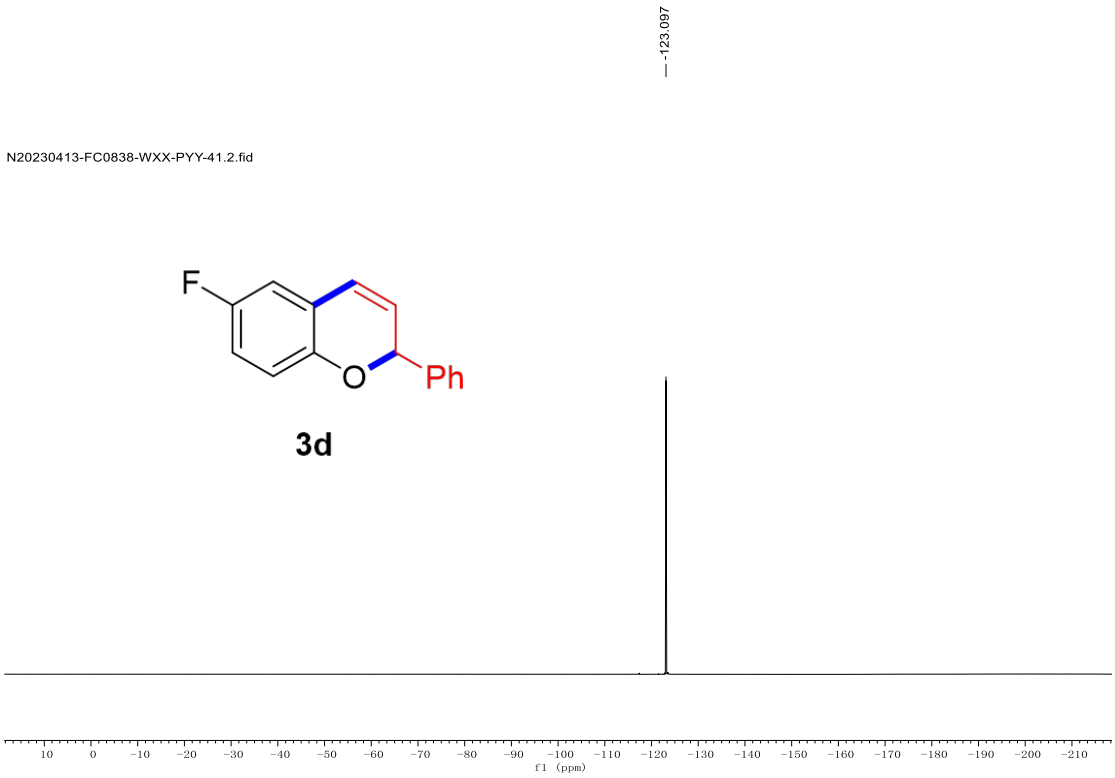
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3d**



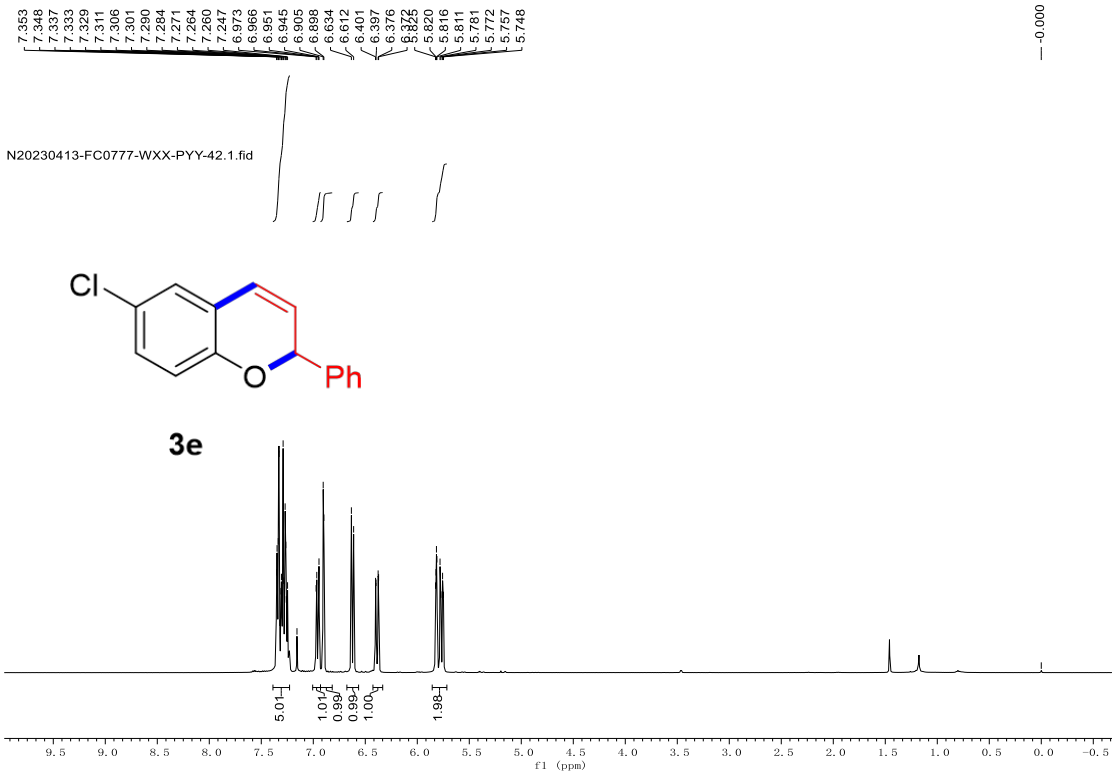
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3d**



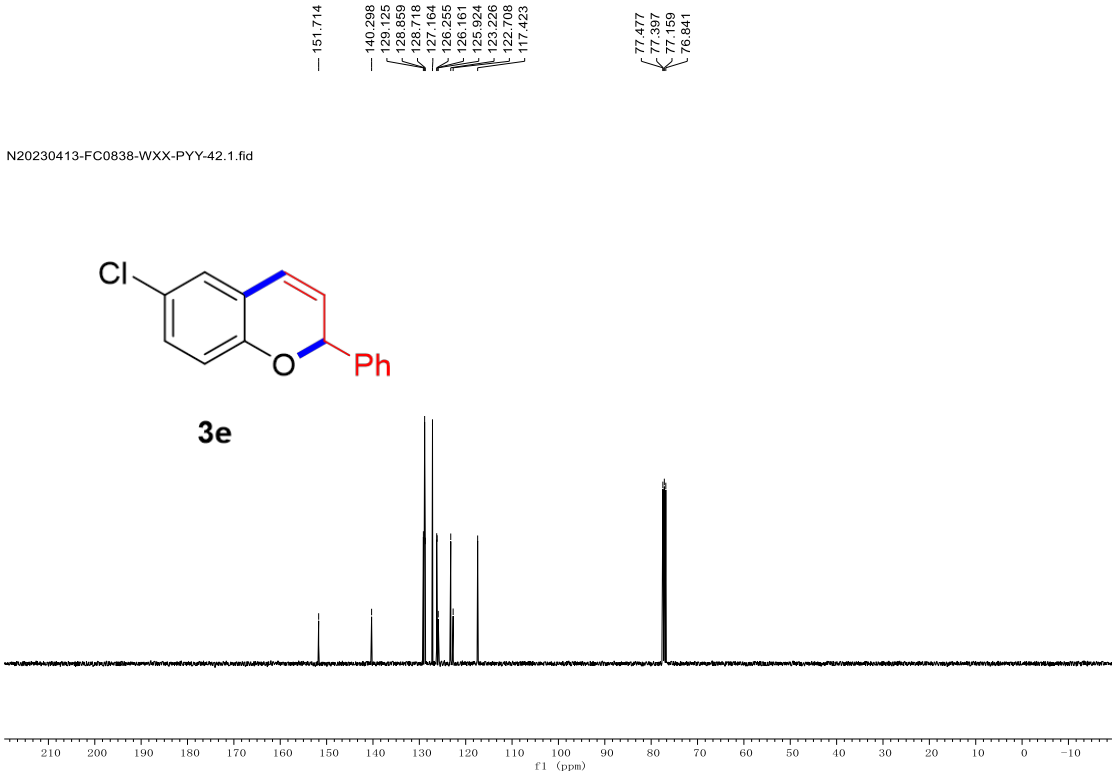
^{19}F NMR (376 MHz, $CDCl_3$) Spectrum of **3d**



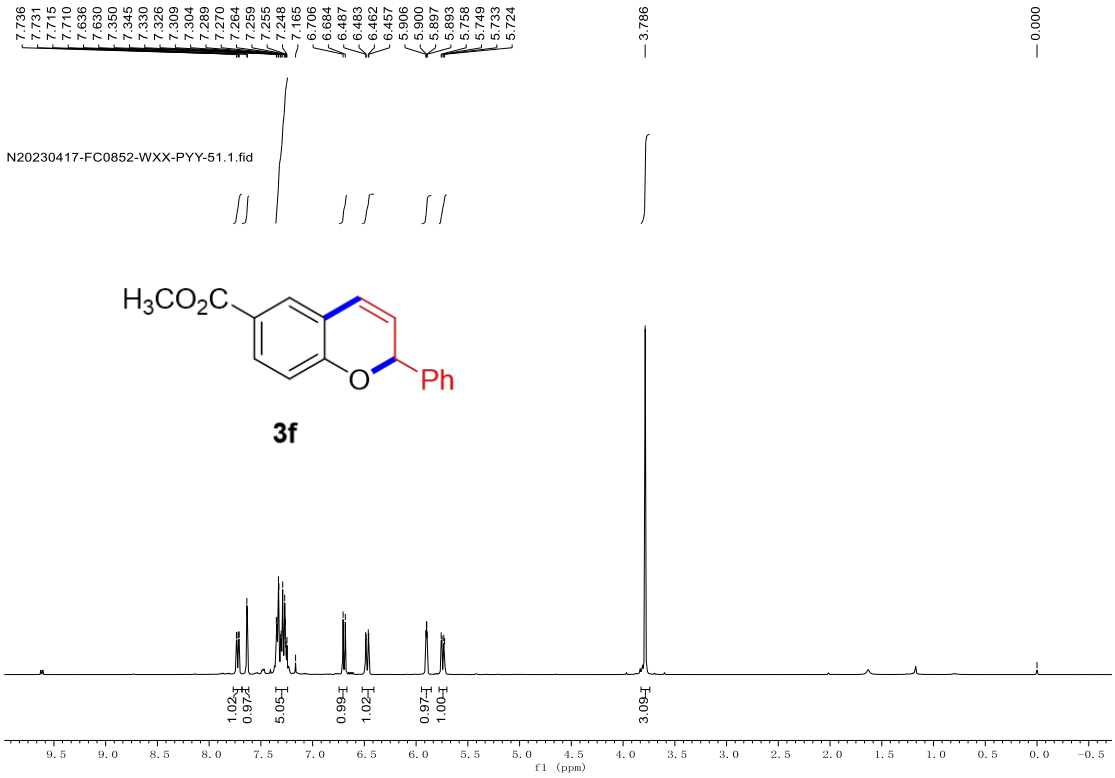
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3e**



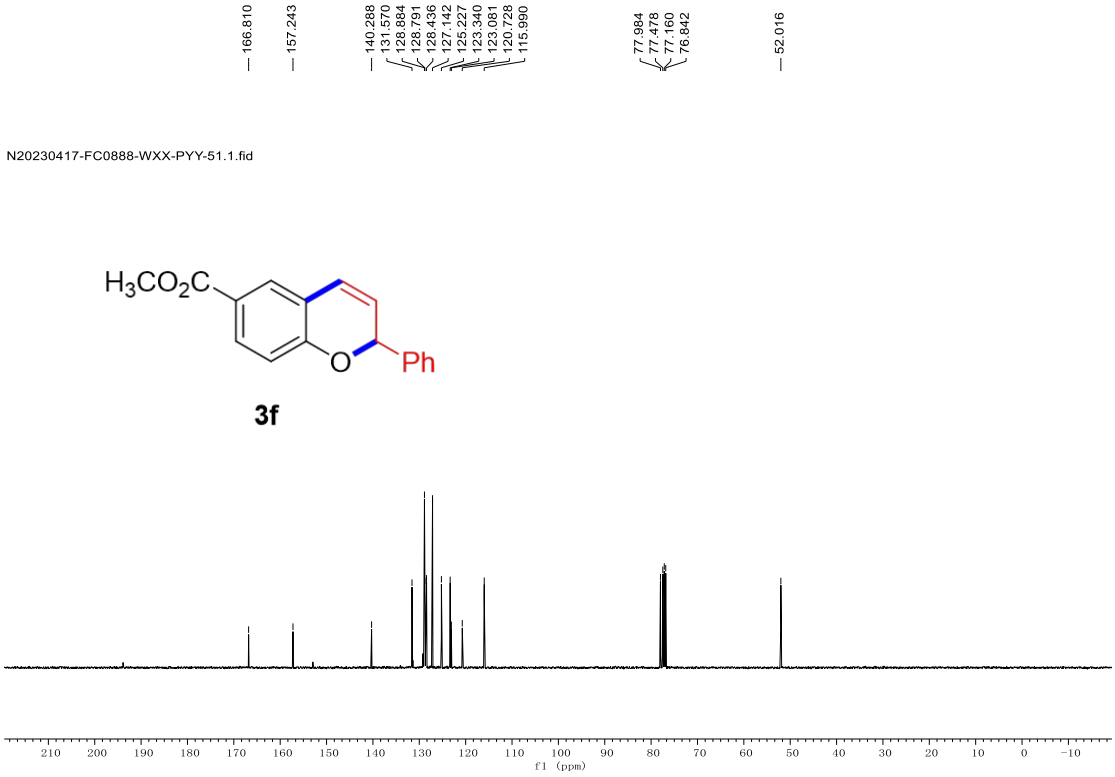
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3e**



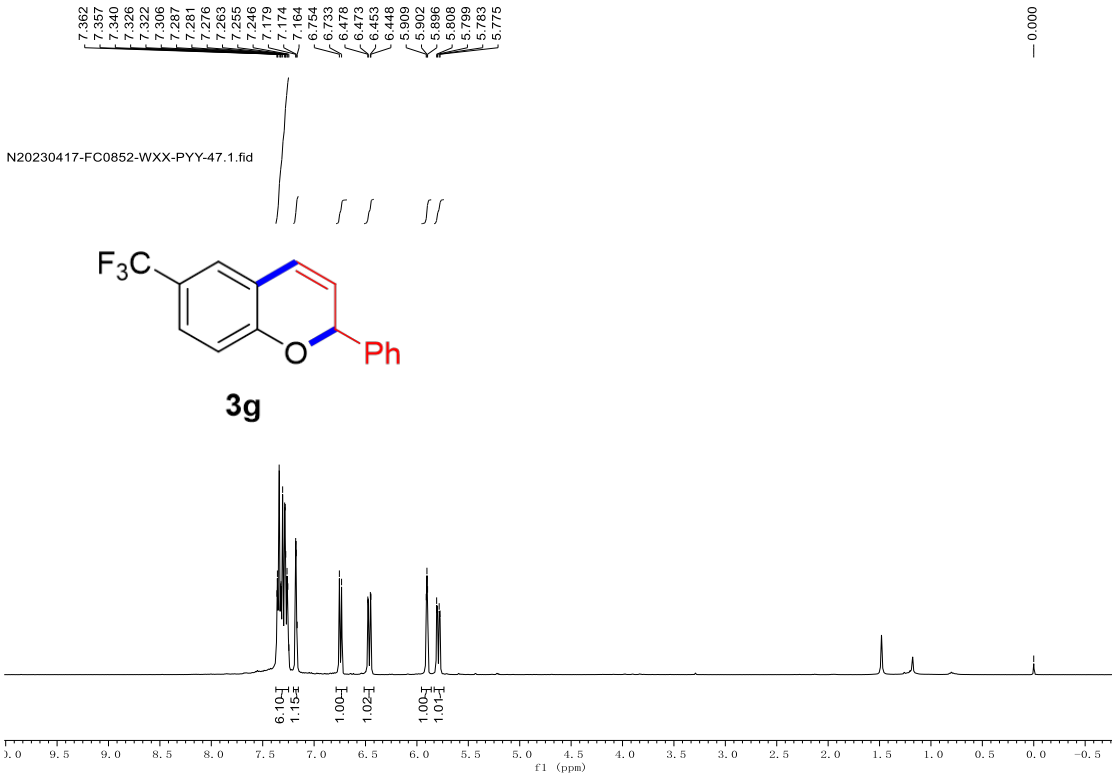
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3f**



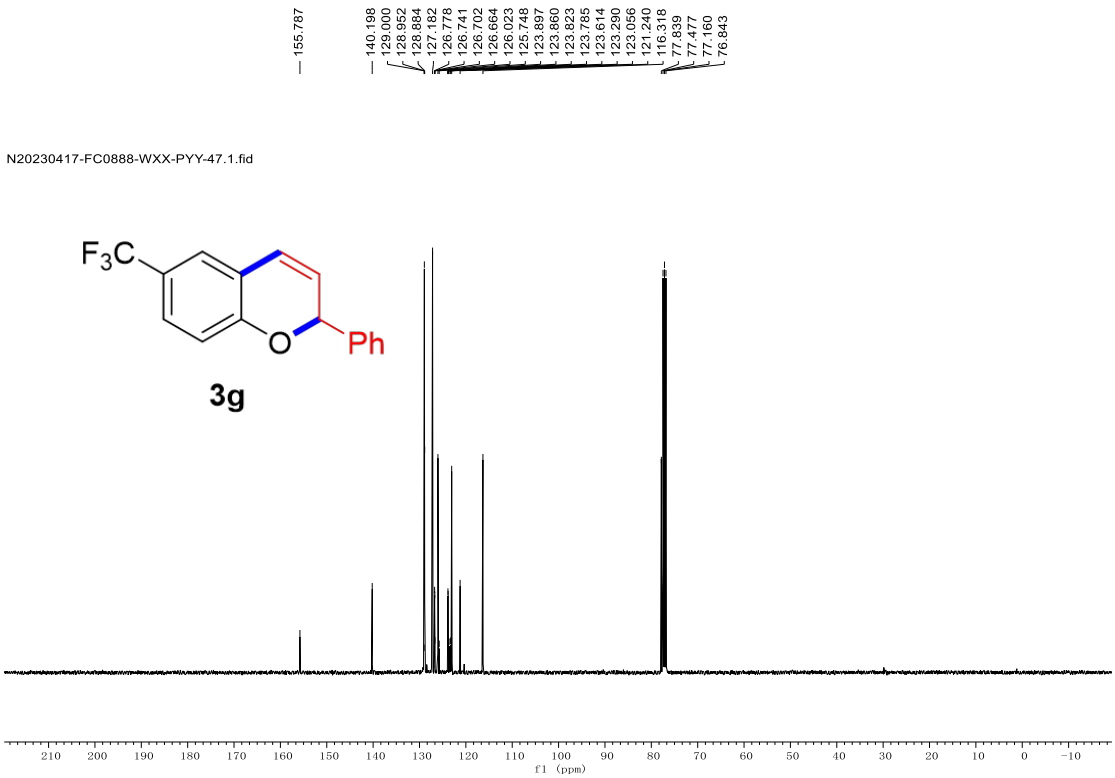
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3f**



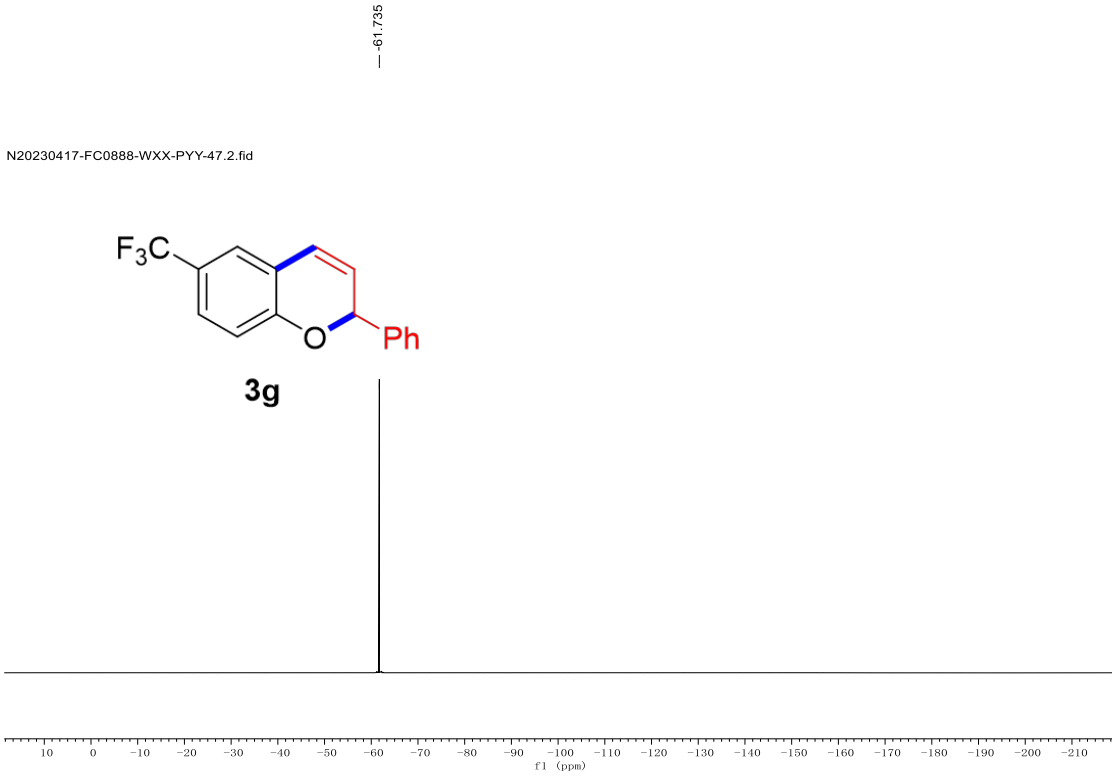
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3g**



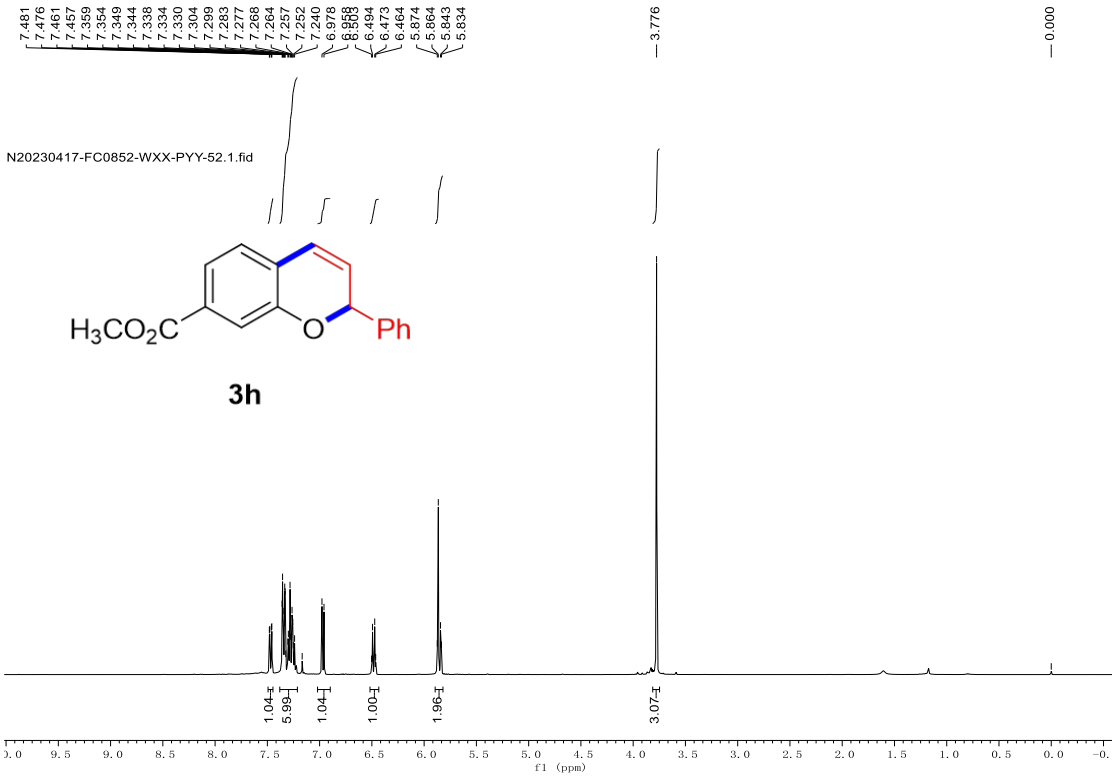
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3g**



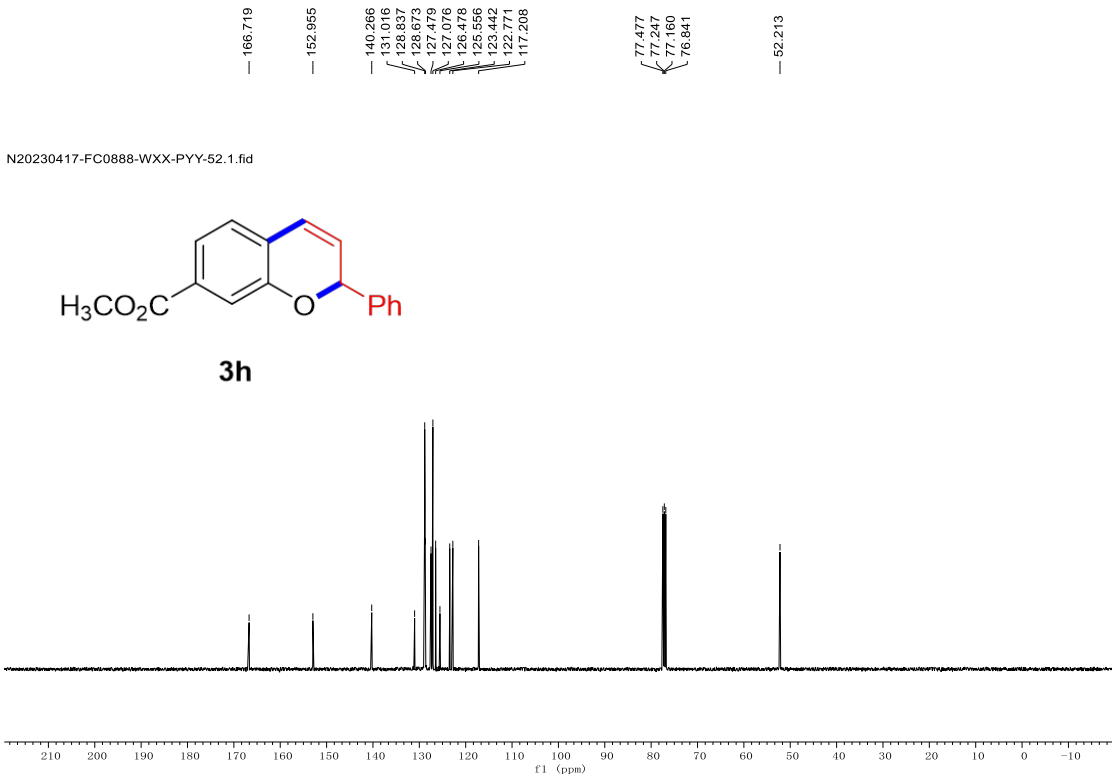
^{19}F NMR (376 MHz, $CDCl_3$) Spectrum of **3g**



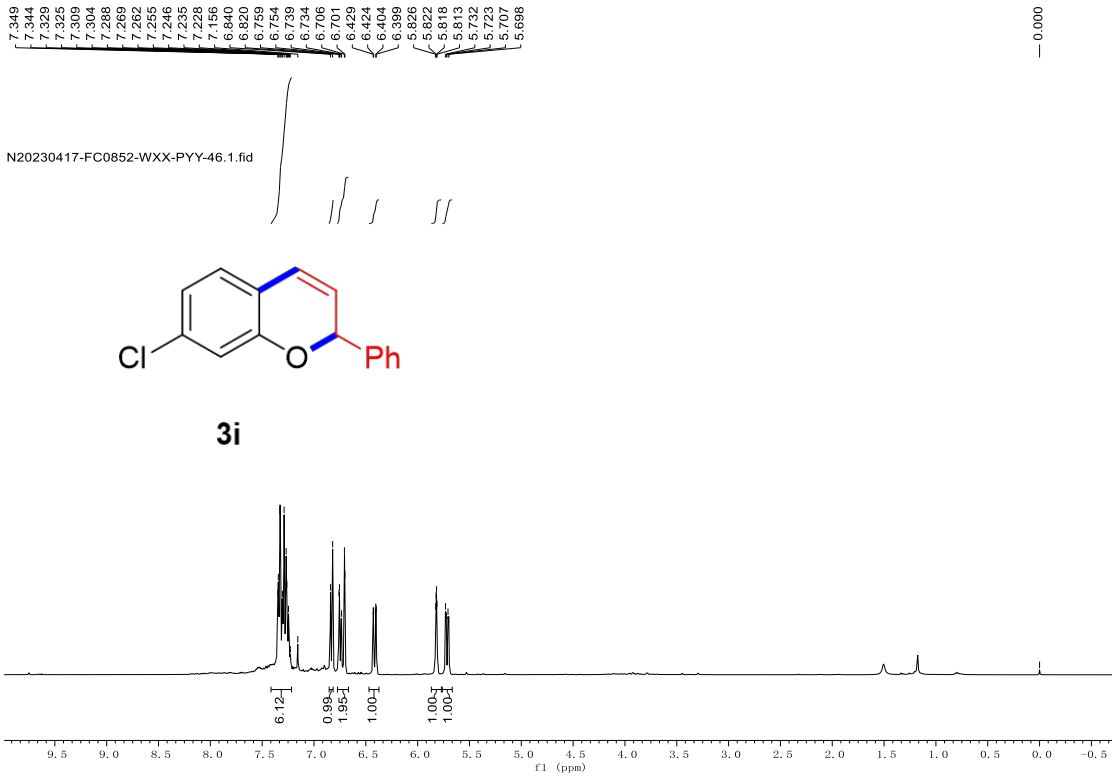
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3h**



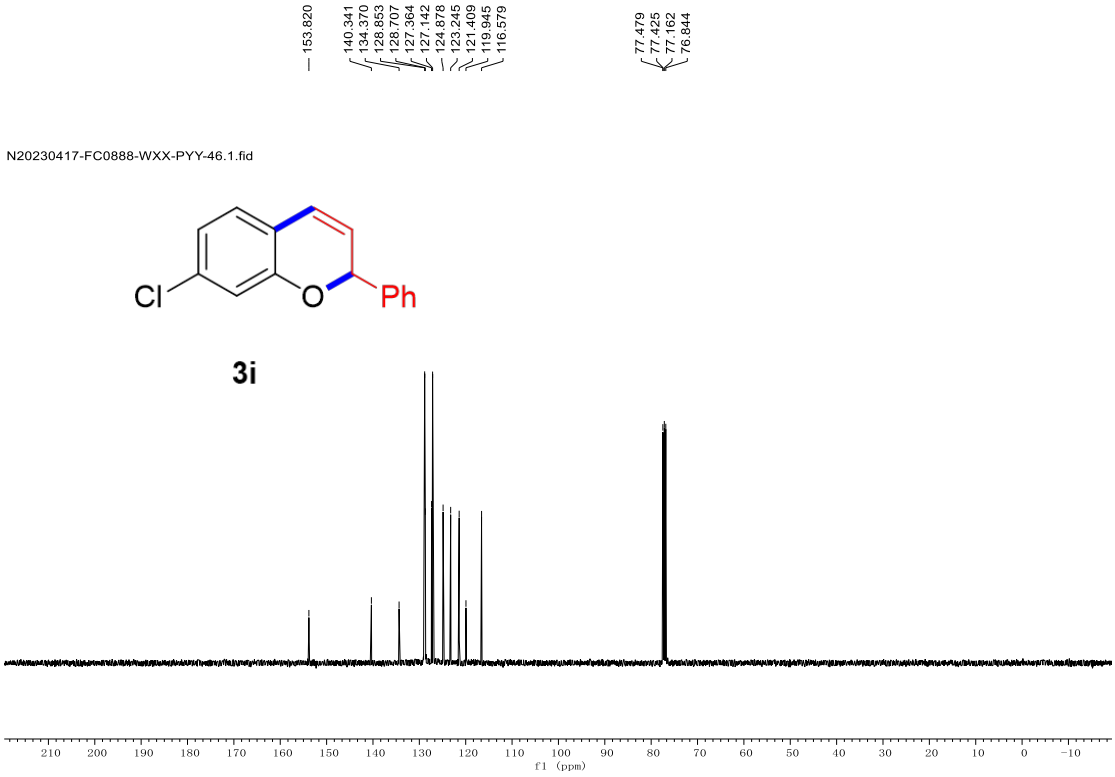
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3h**



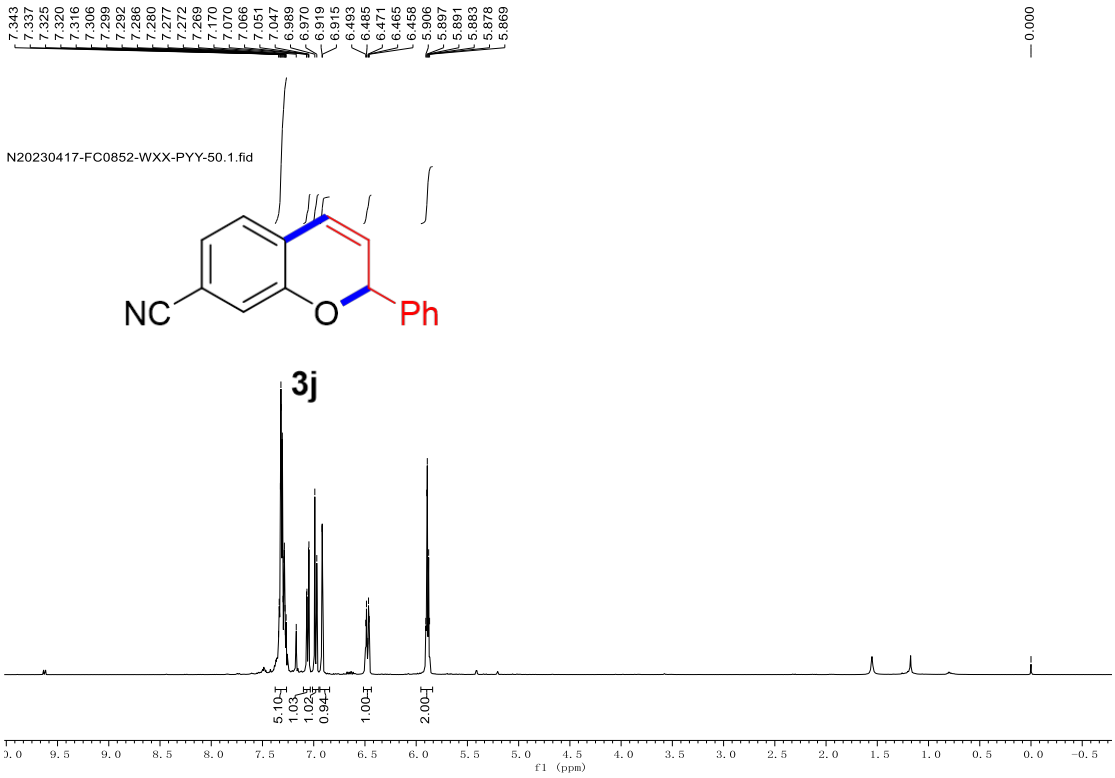
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3i**



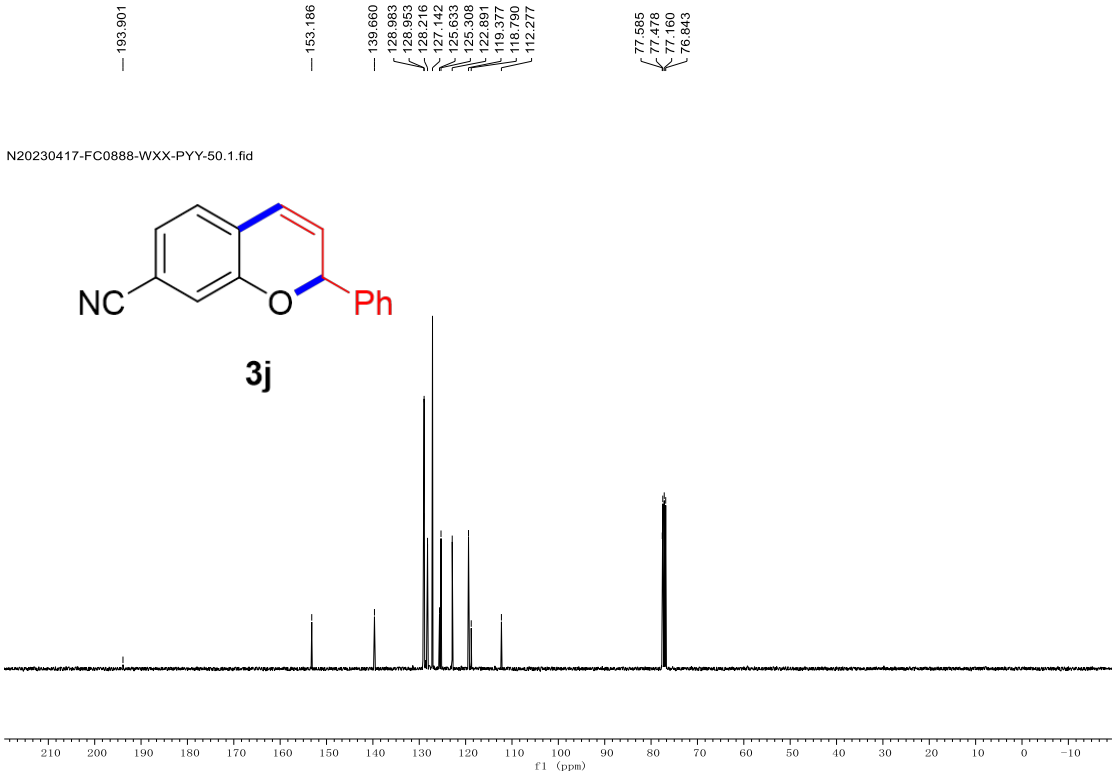
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3i**



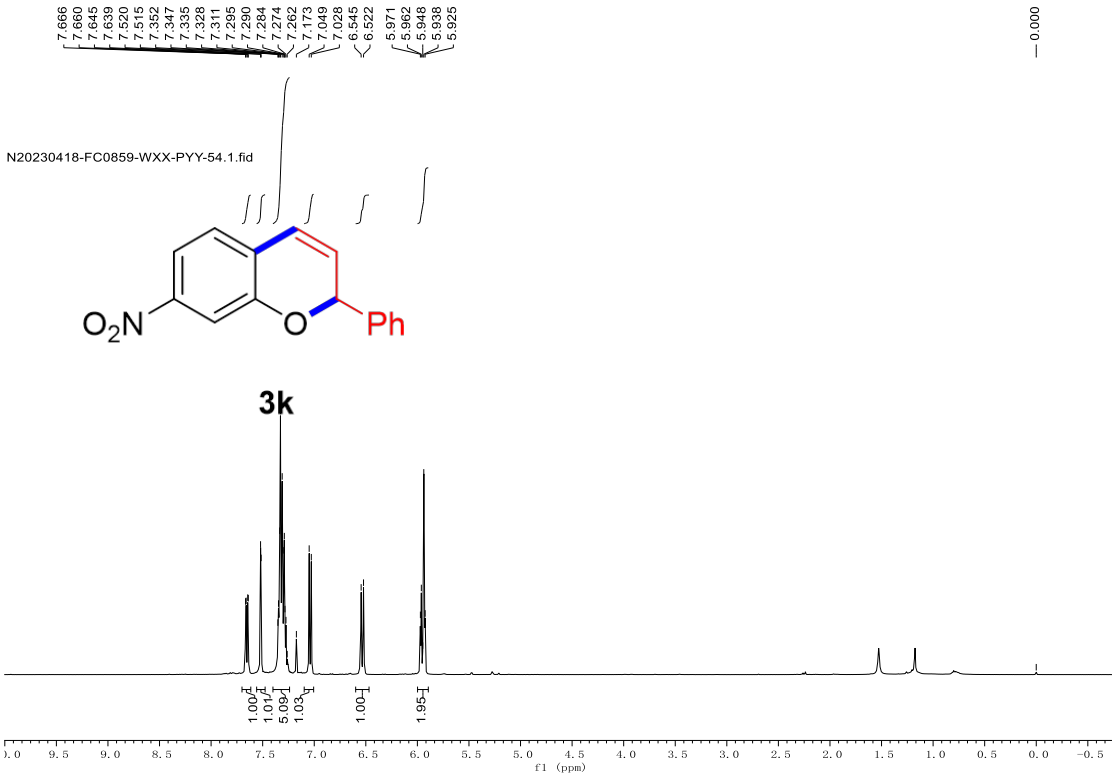
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3j**



^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3j**



^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3k**



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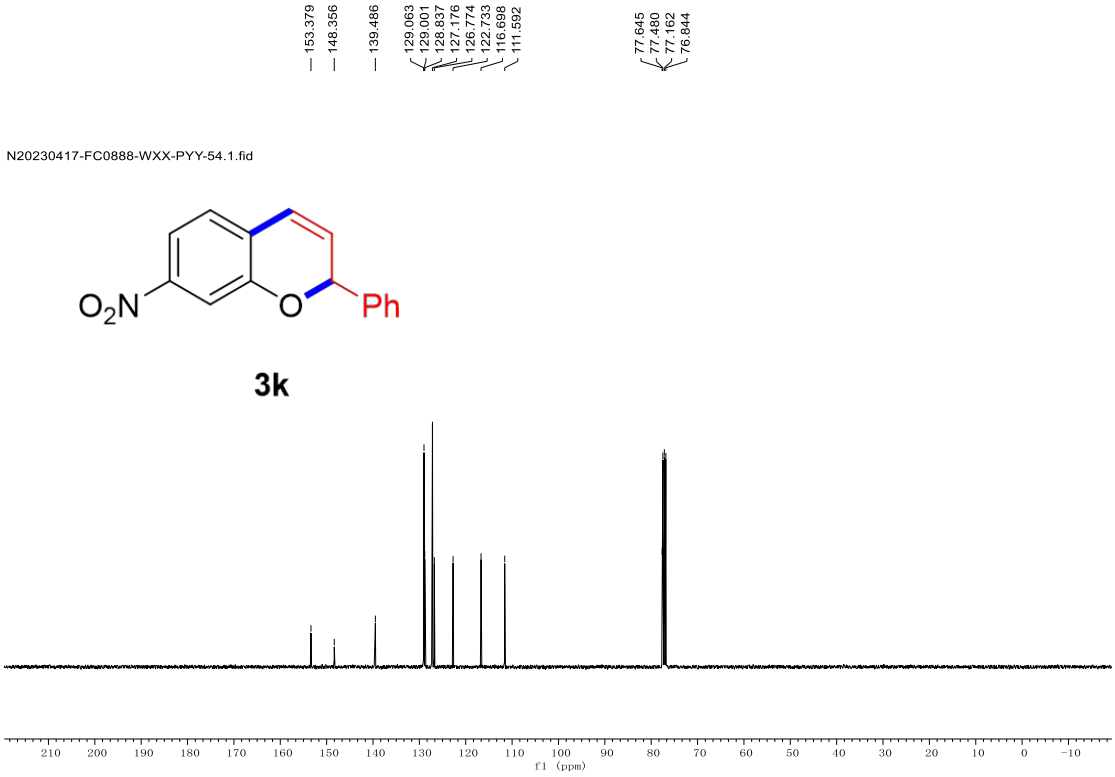
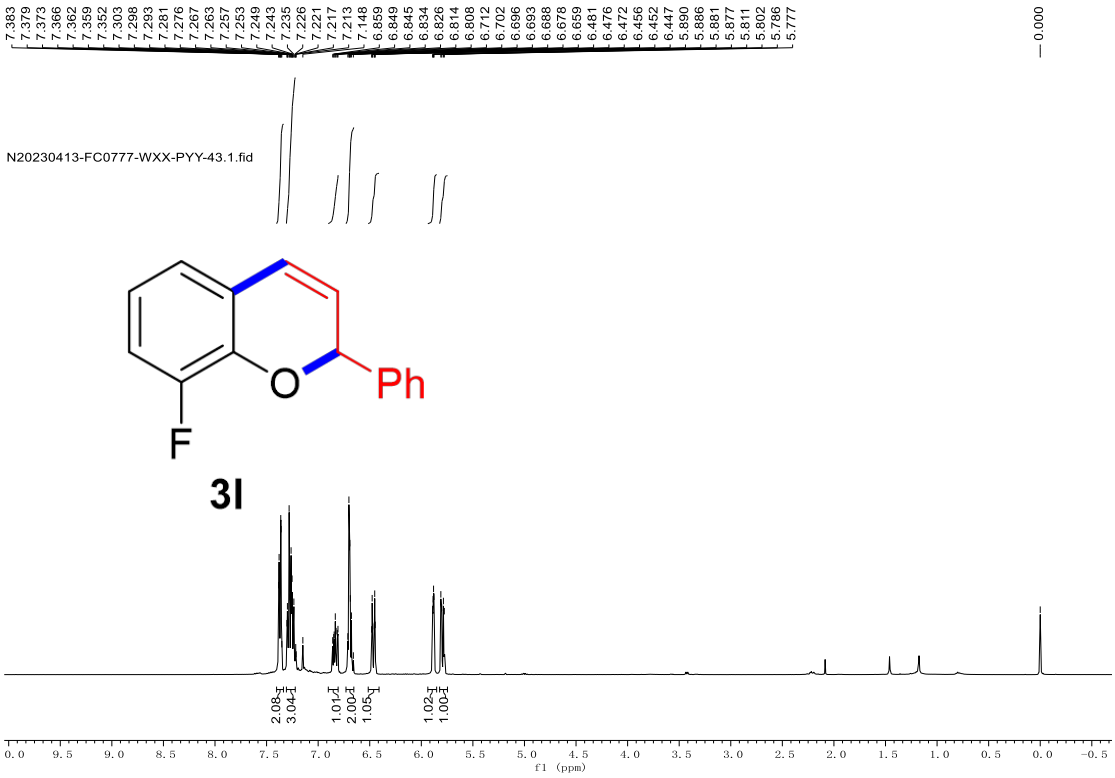
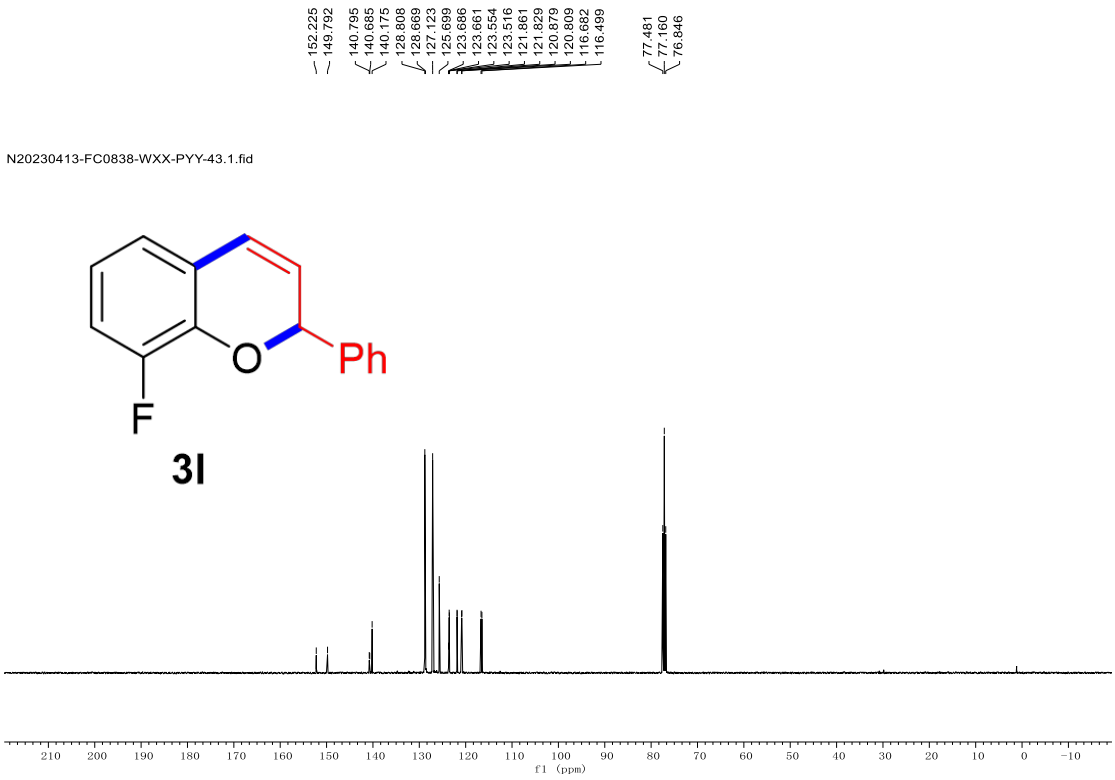


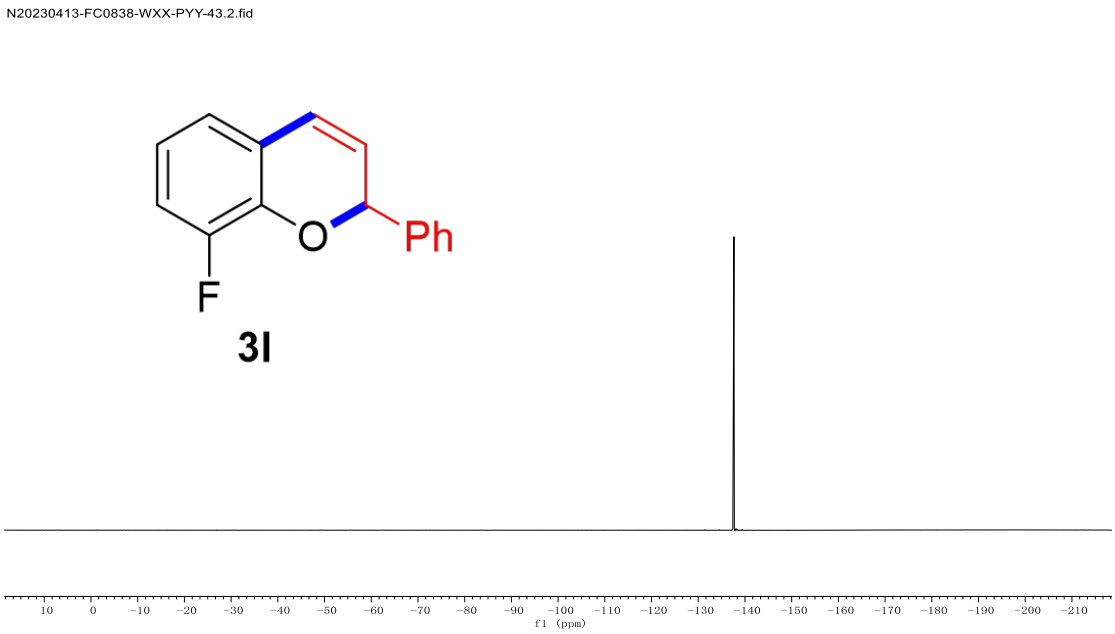
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3l**



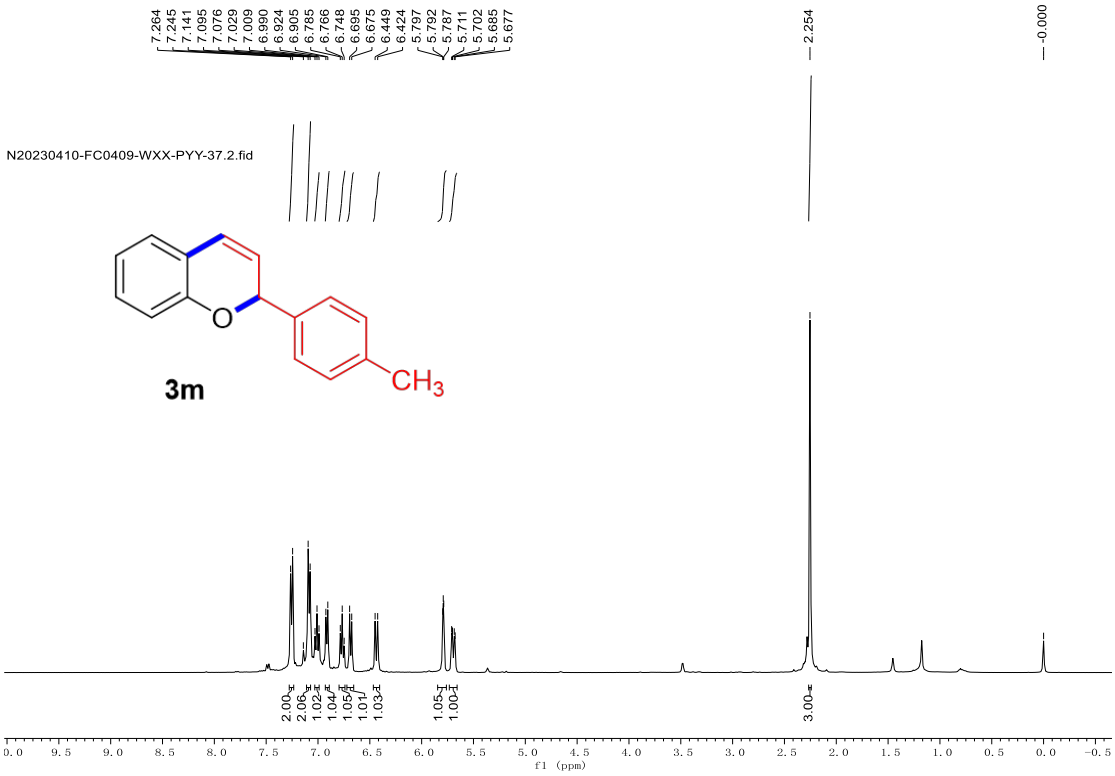
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3l**



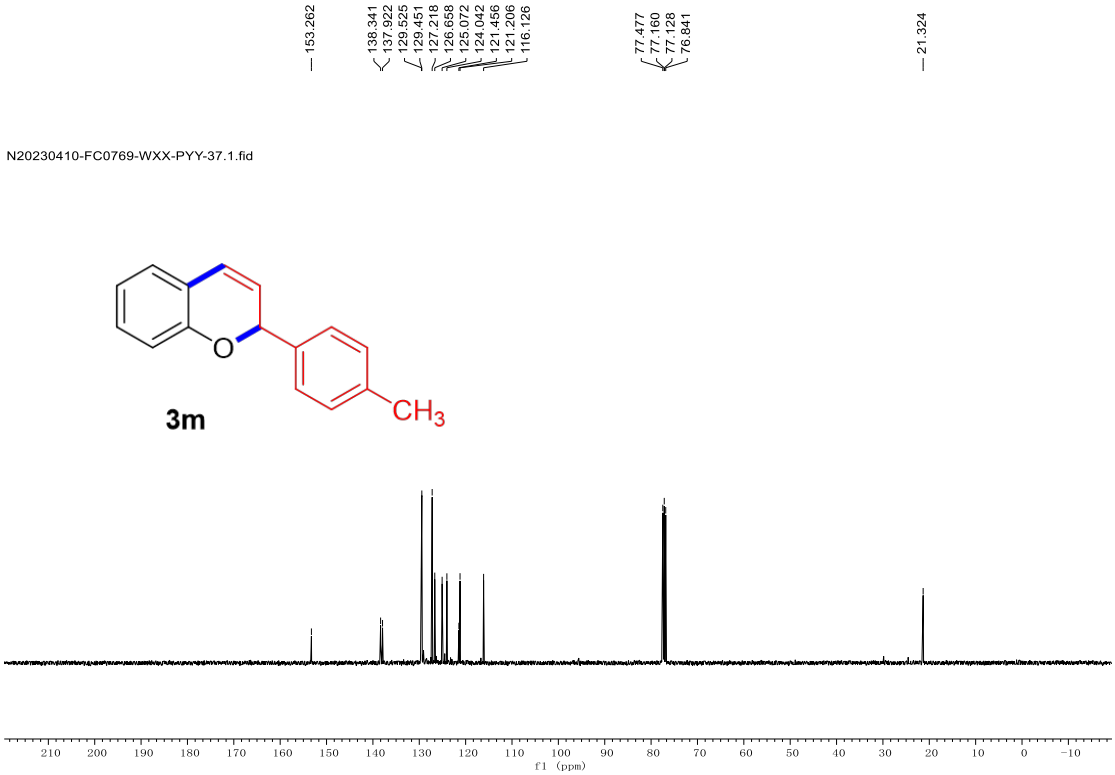
^{19}F NMR (376 MHz, $CDCl_3$) Spectrum of **3l**



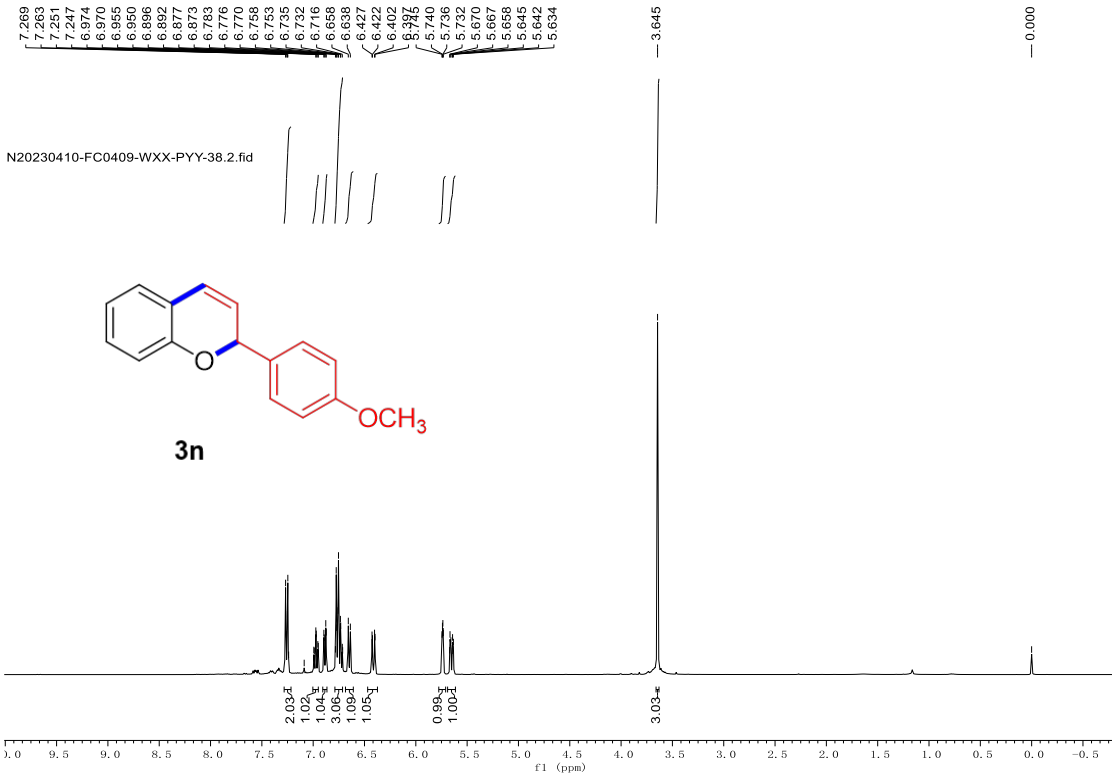
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3m**



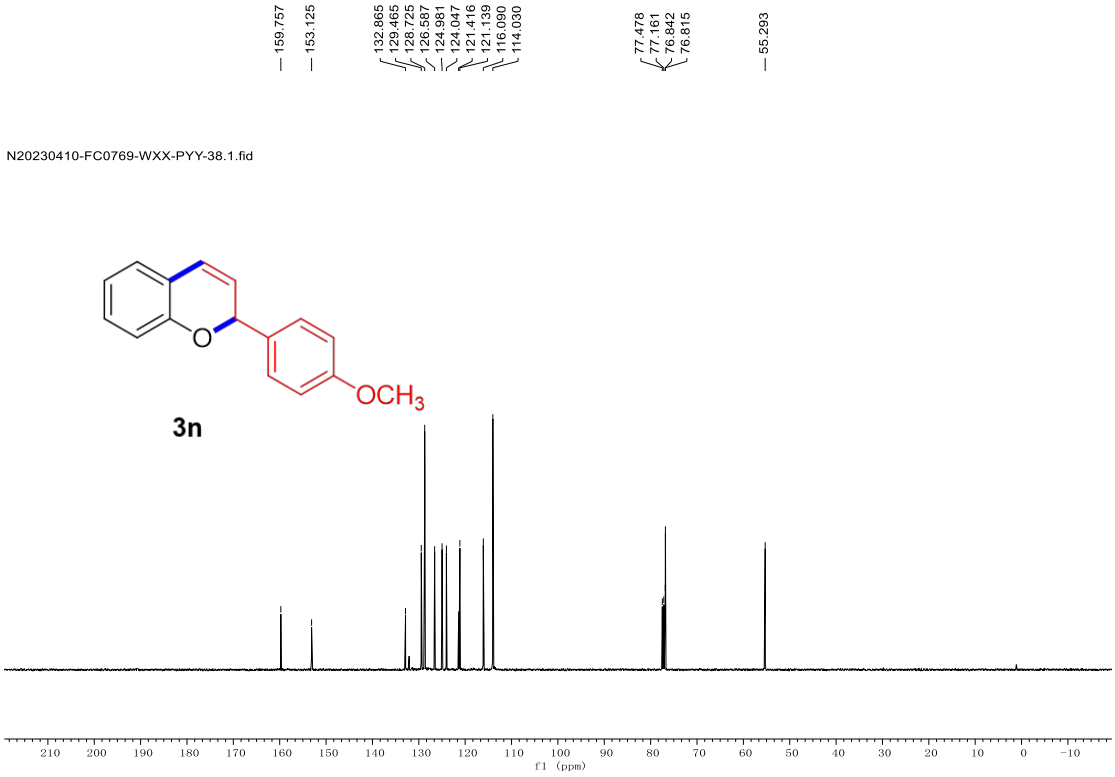
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3m**



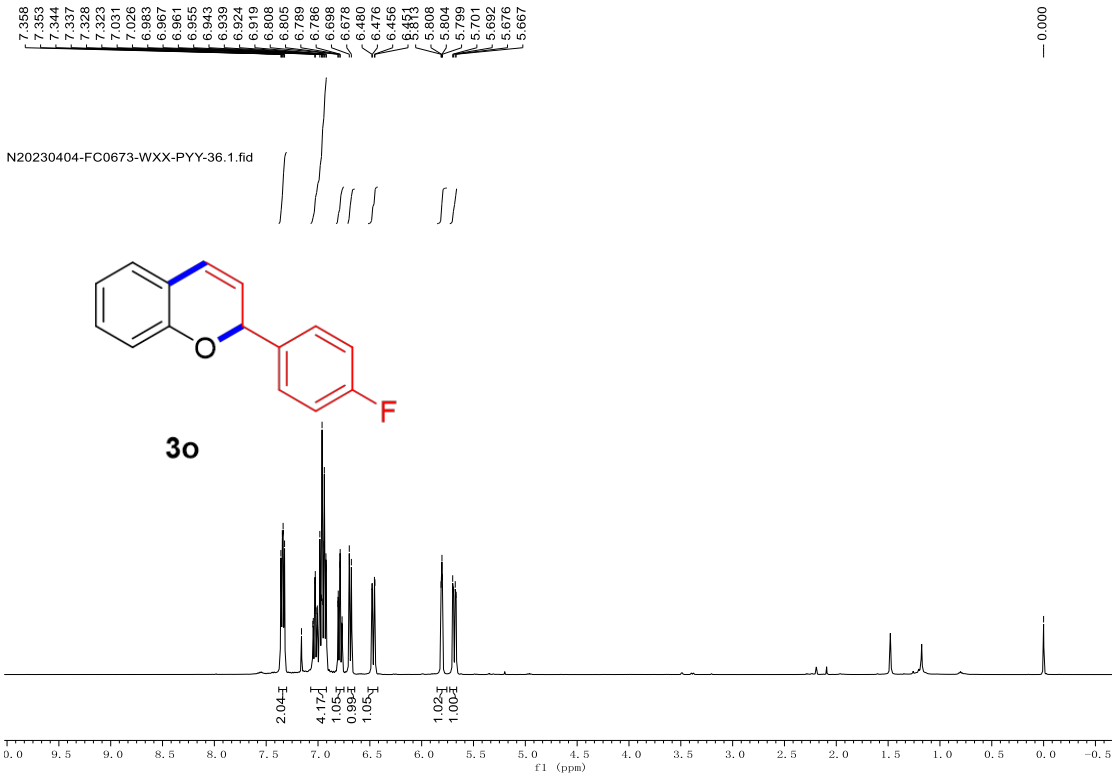
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3n**



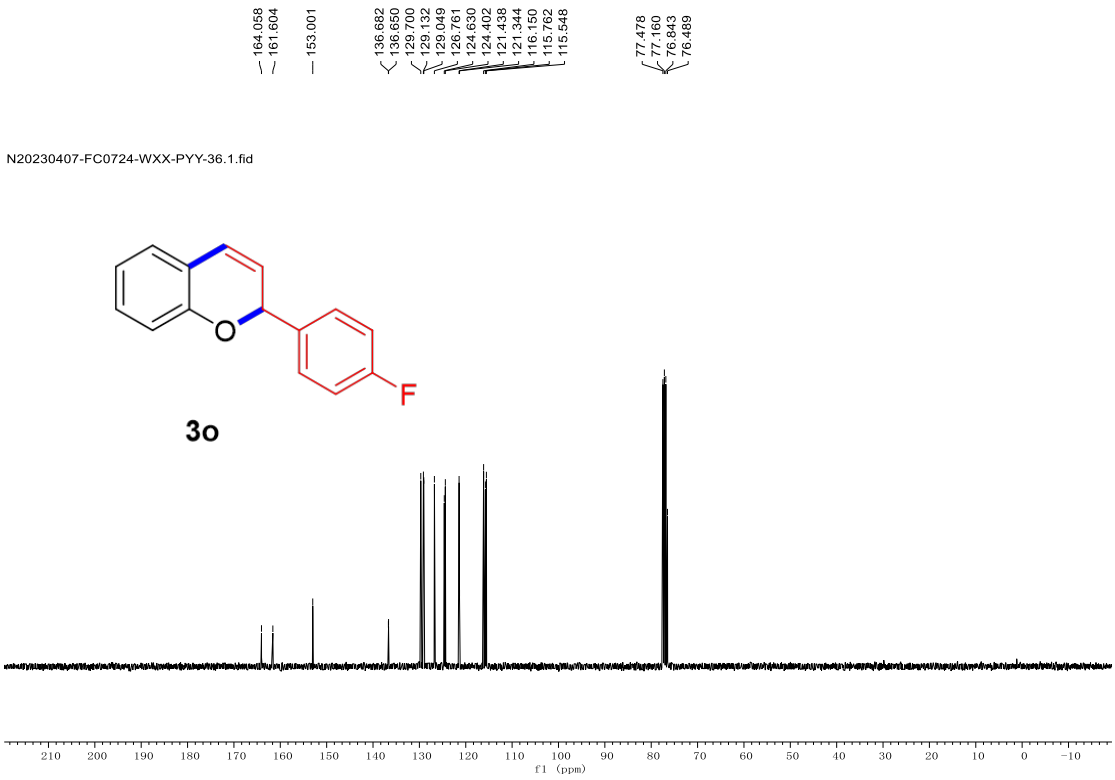
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3n**



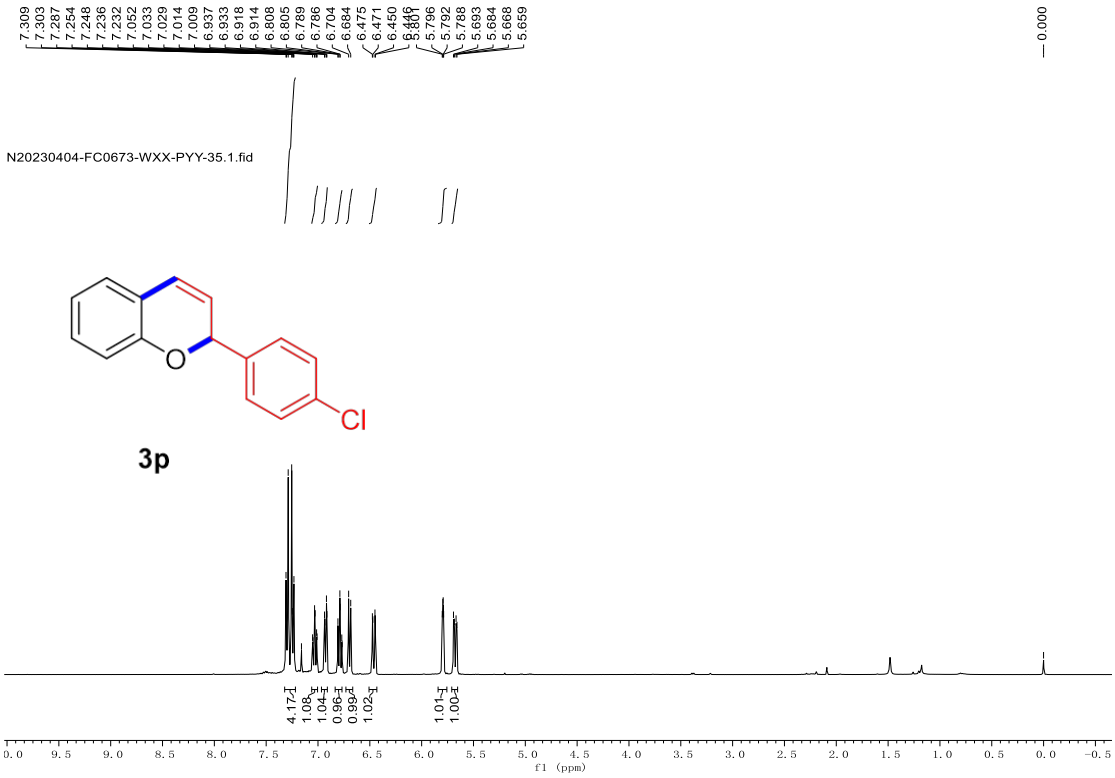
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3o**



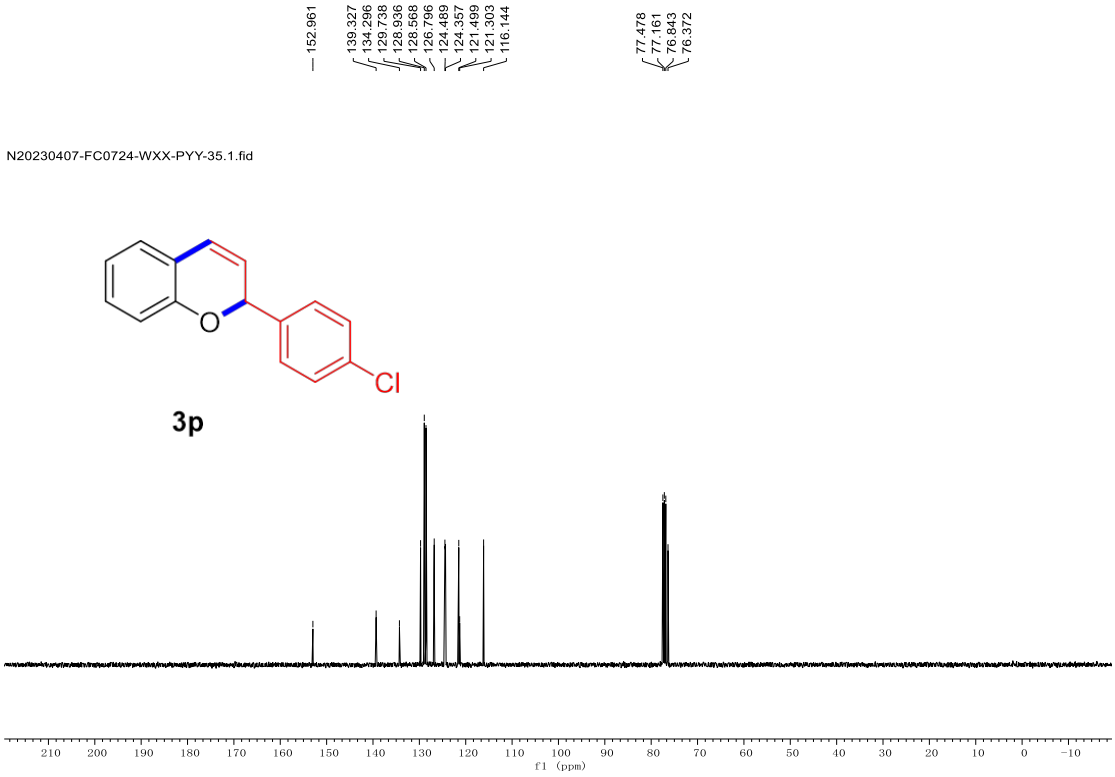
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3o**



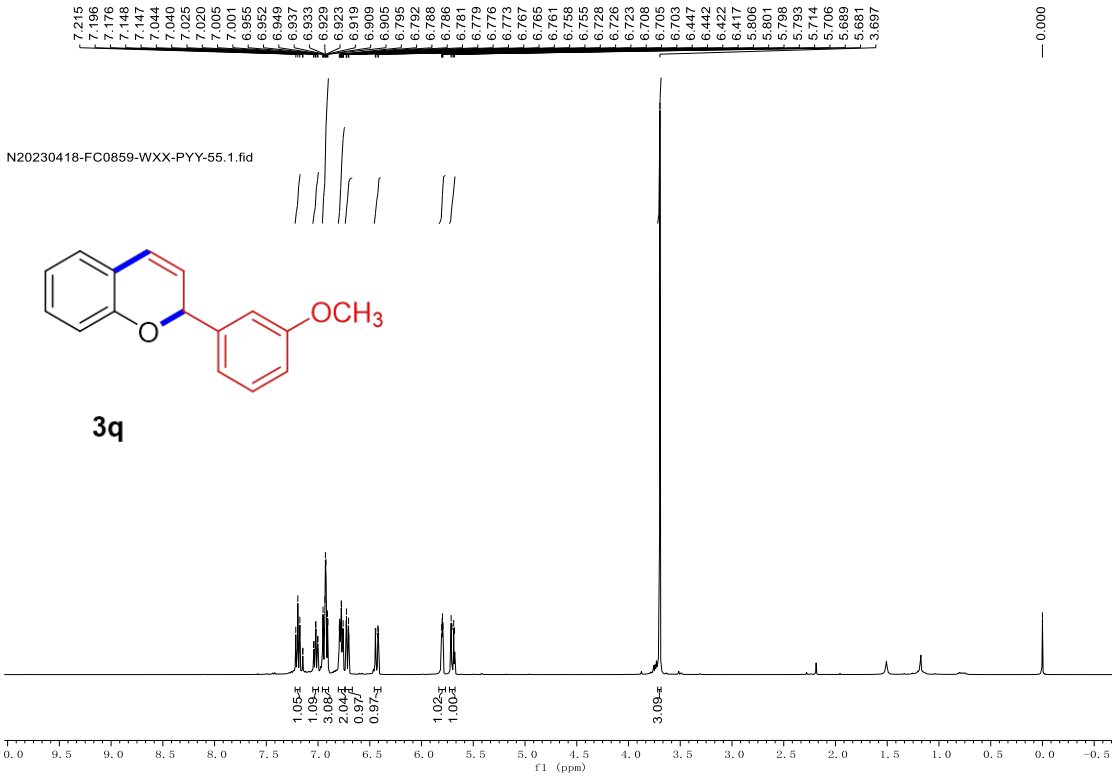
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3p**



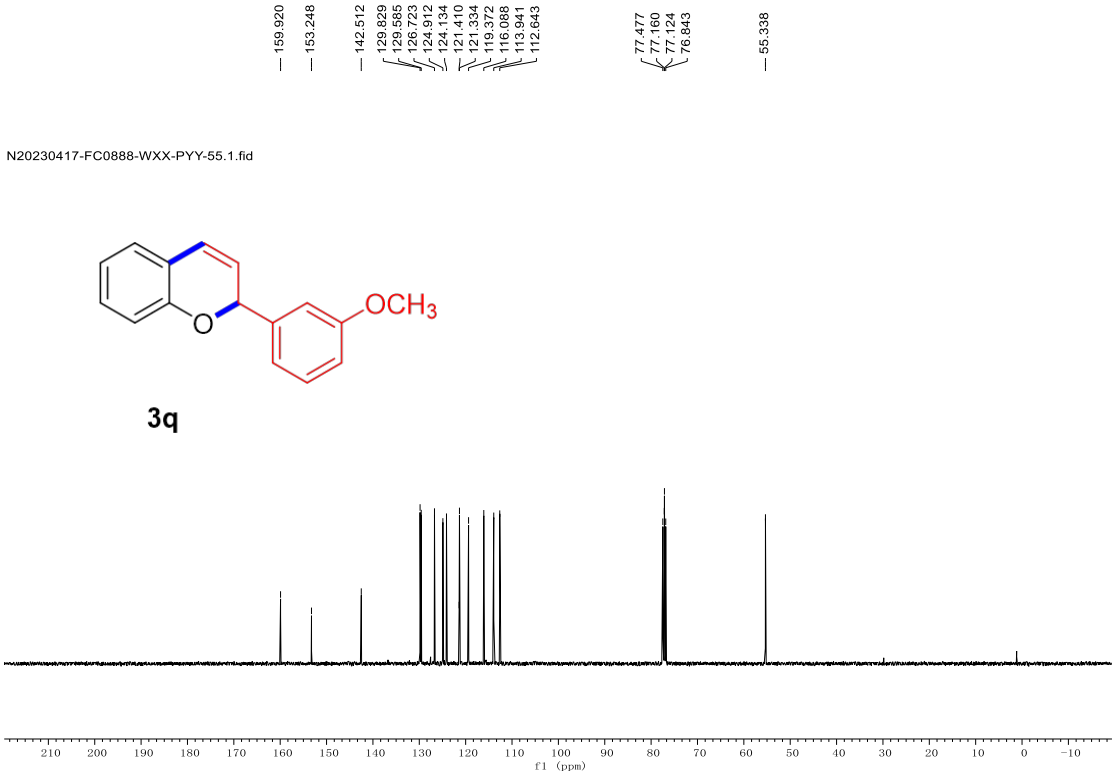
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3p**



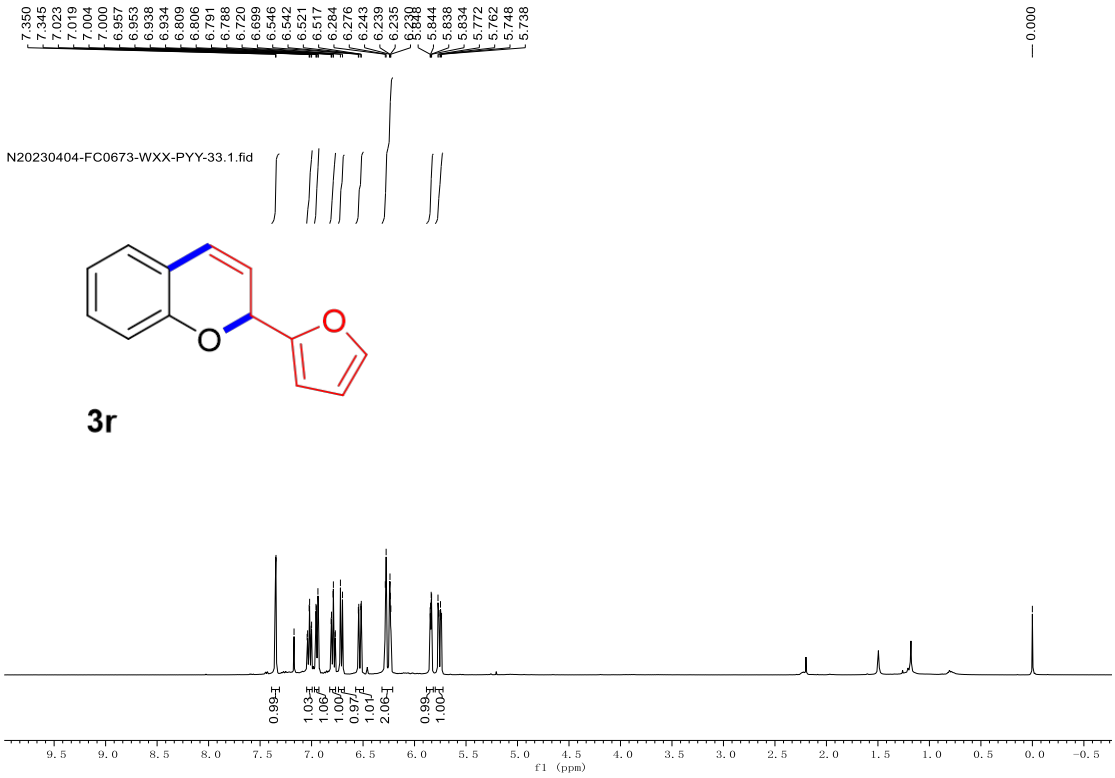
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3q**



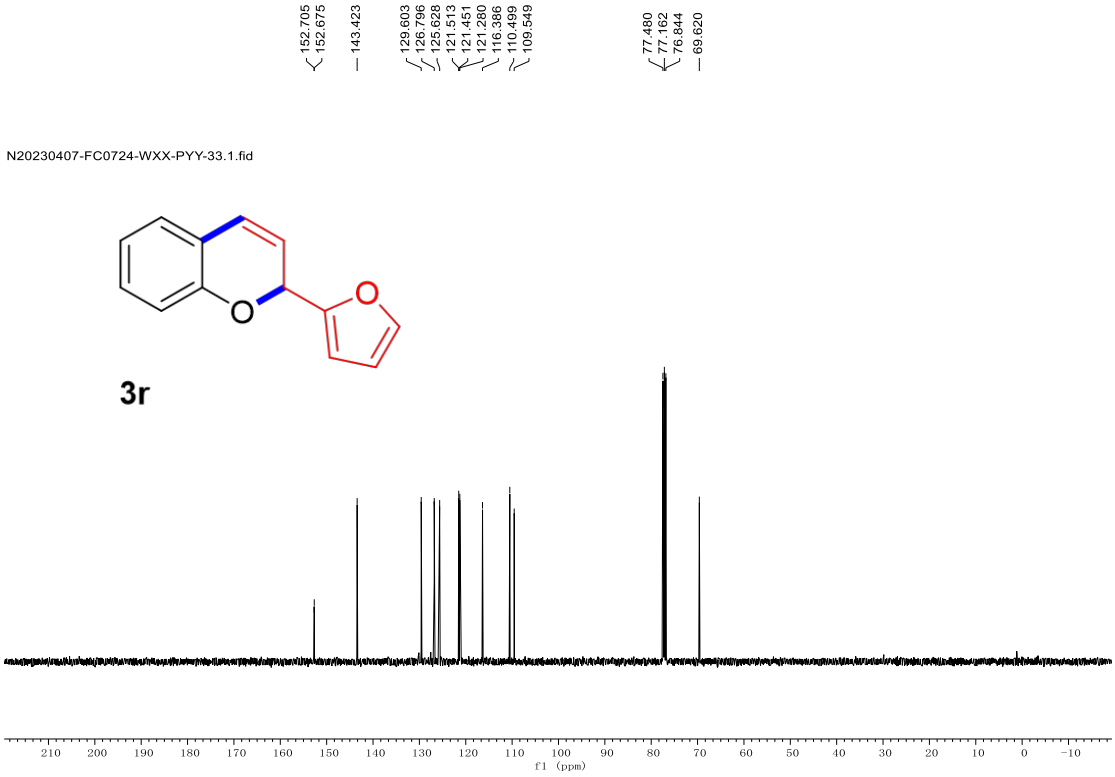
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3q**



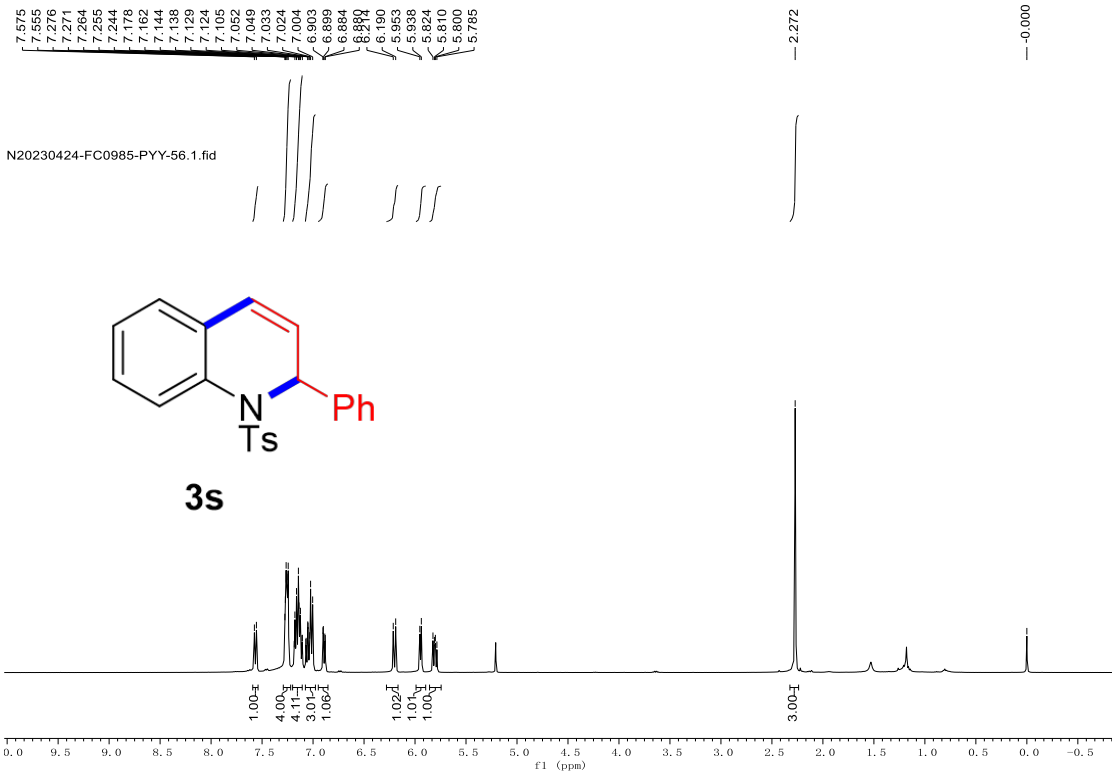
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3r**



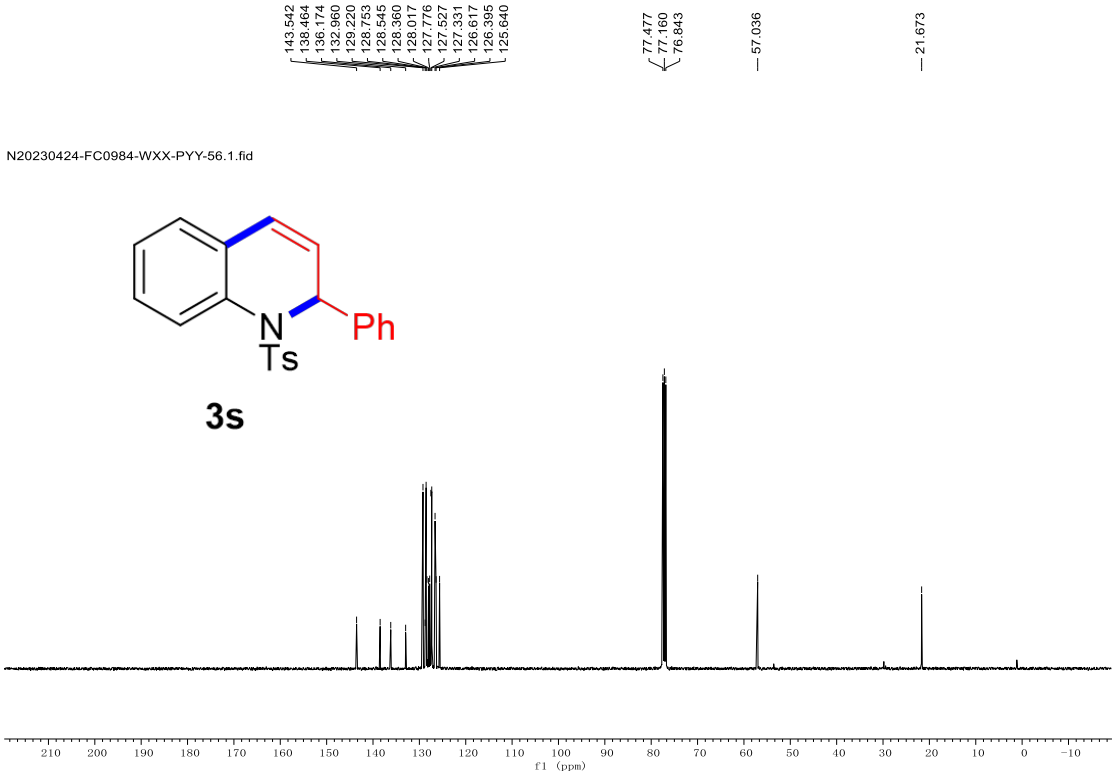
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3r**



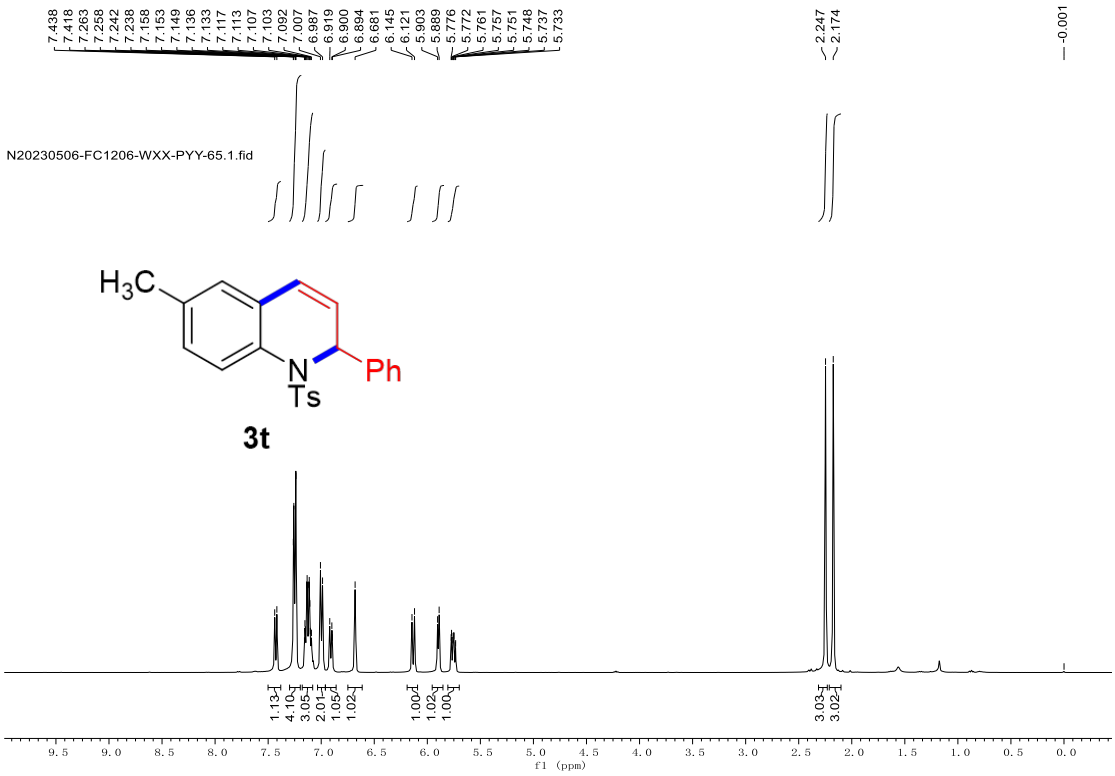
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3s**



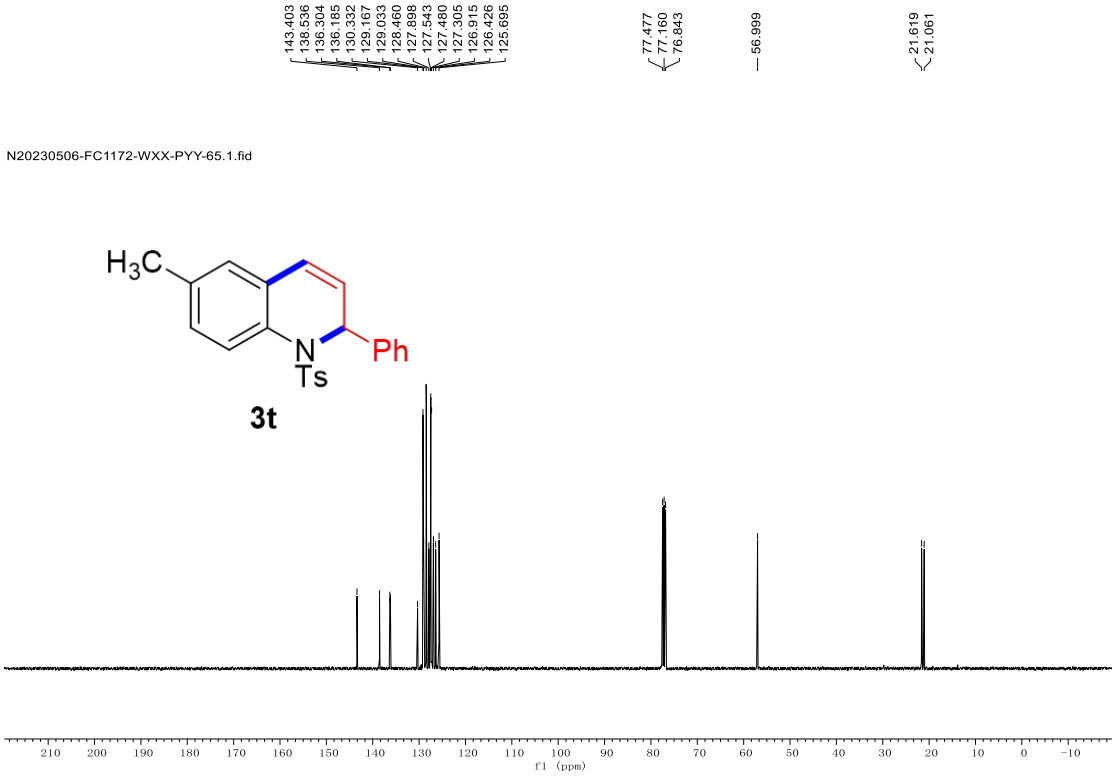
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3s**



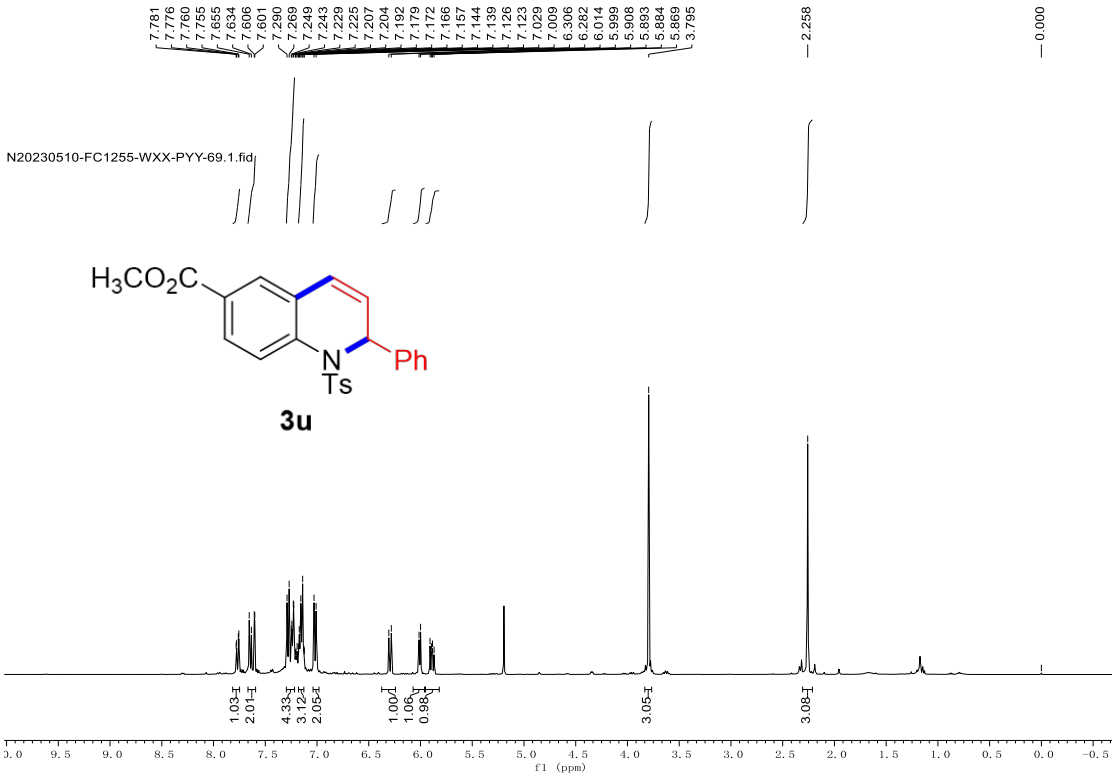
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3t**



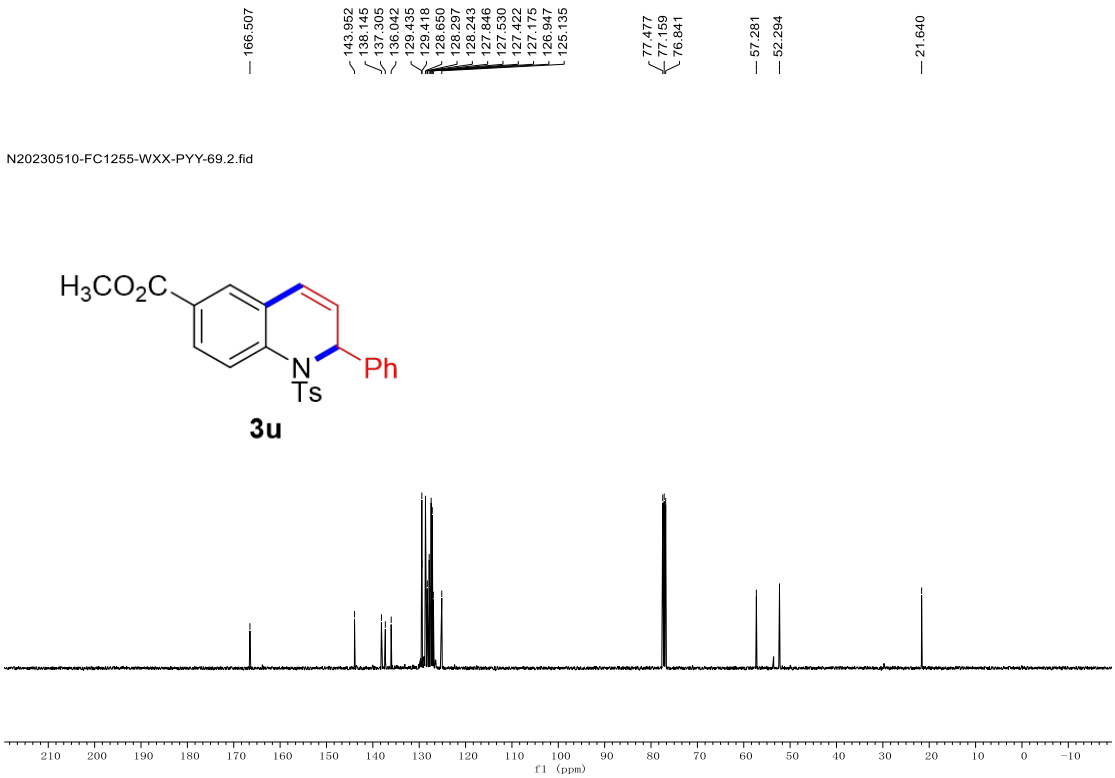
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3t**



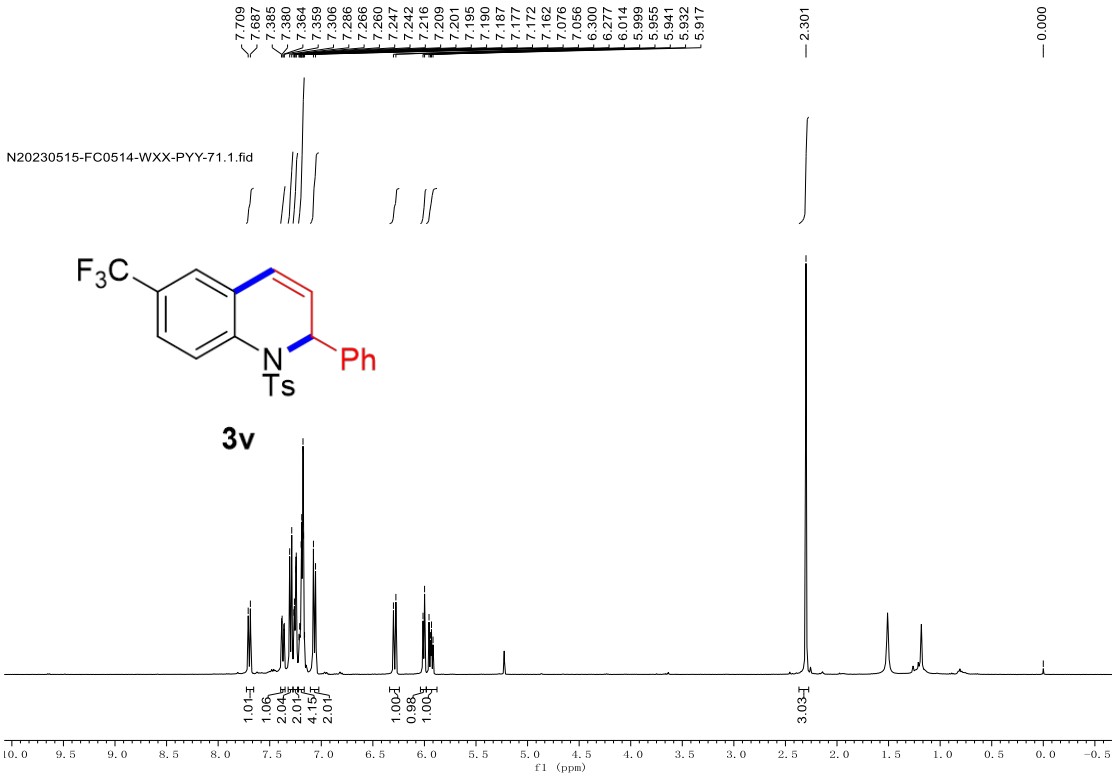
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3u**



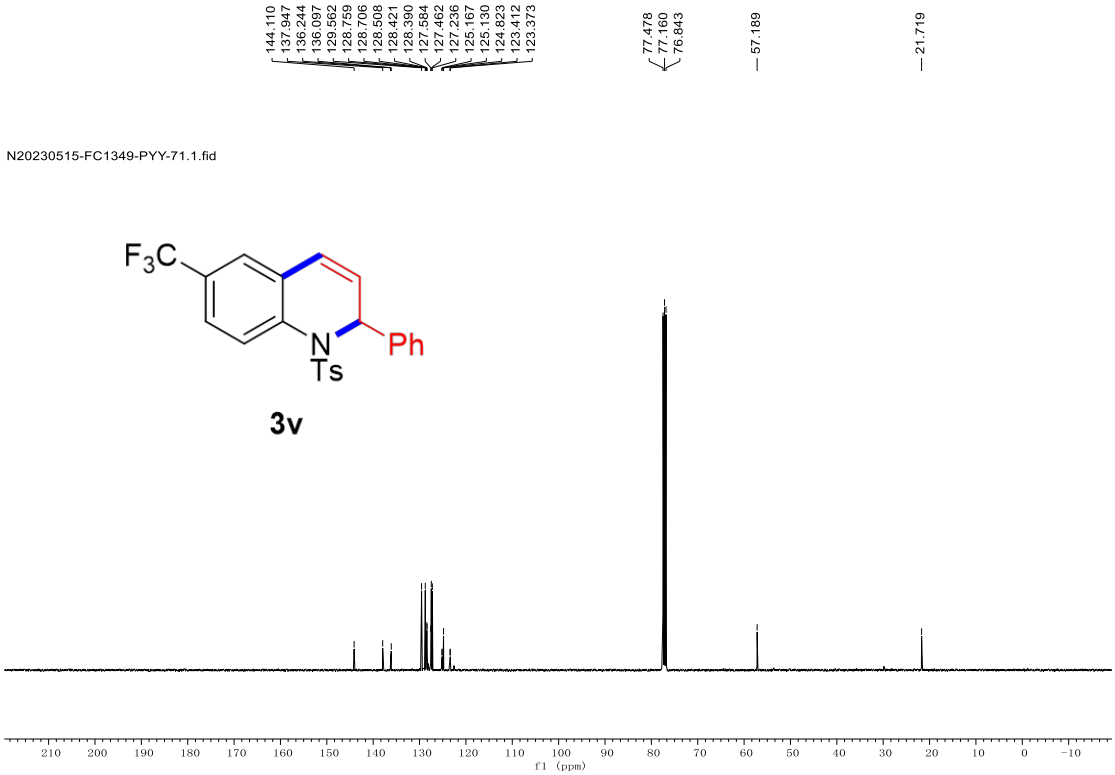
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3u**



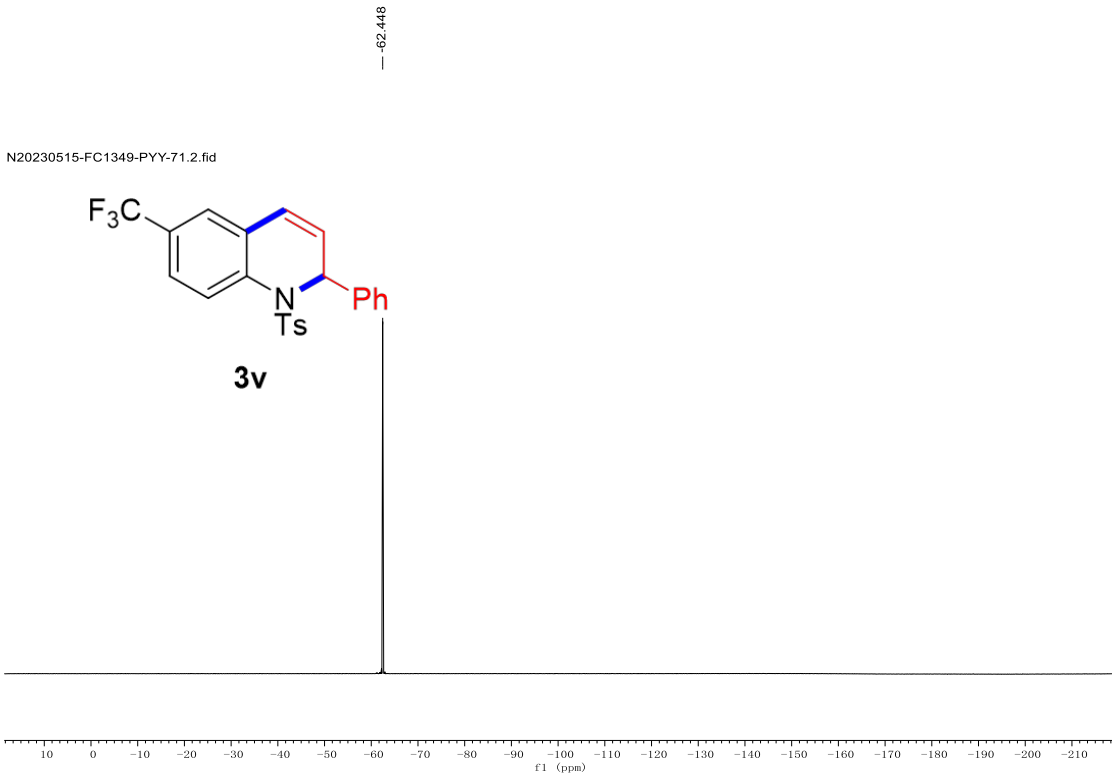
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3v**



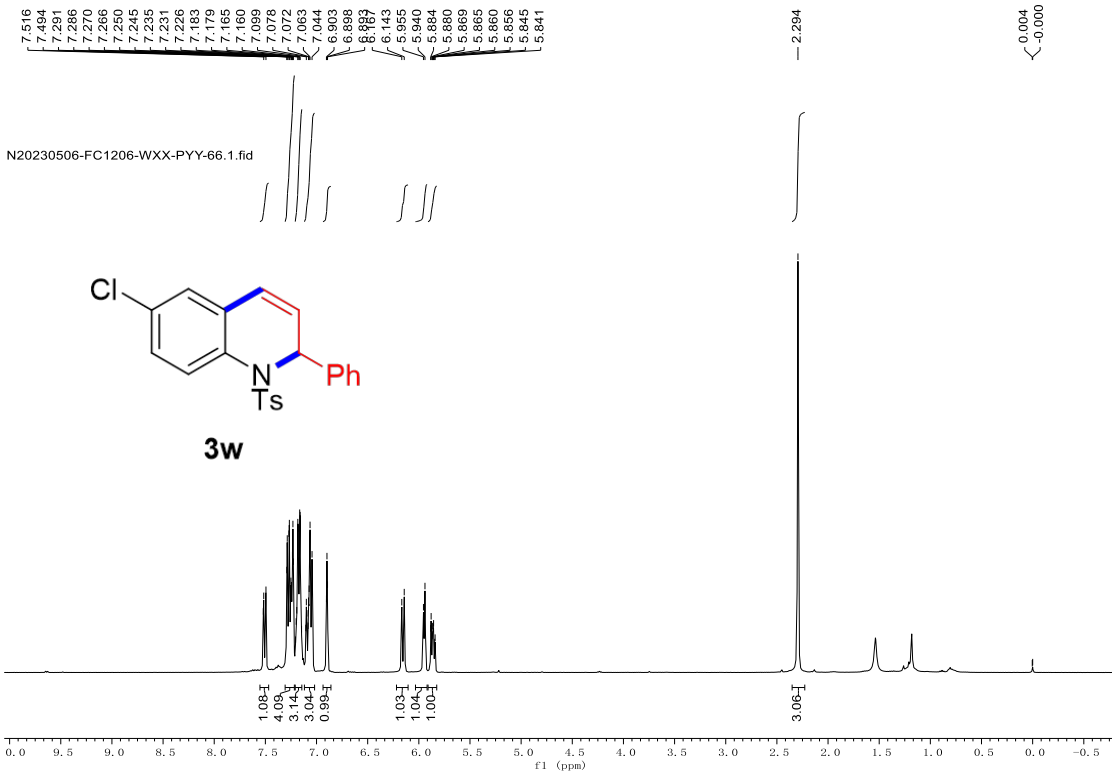
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3v**



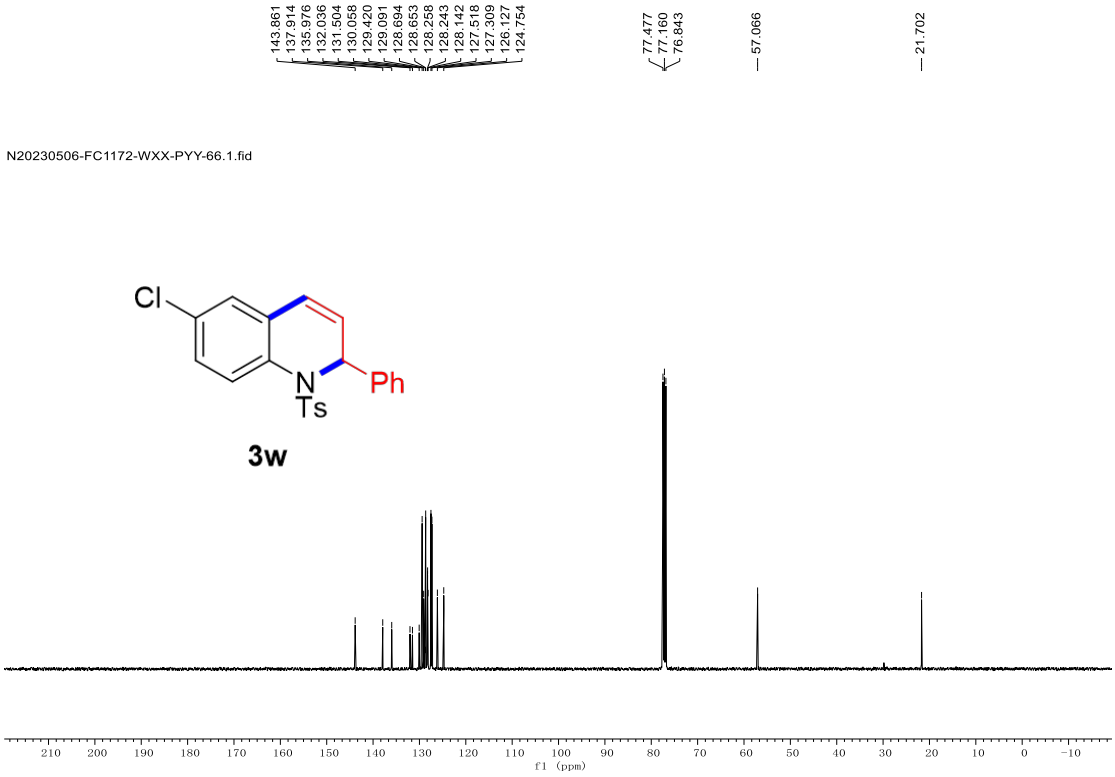
^{19}F NMR (376 MHz, $CDCl_3$) Spectrum of **3v**



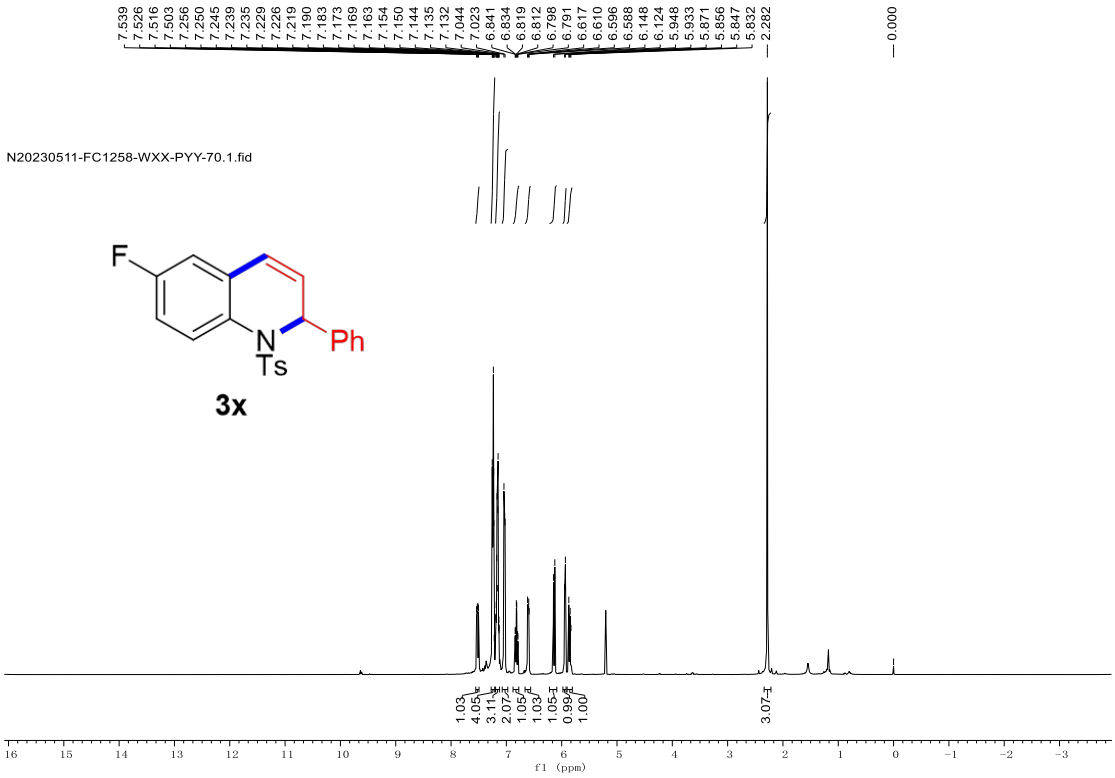
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3w**



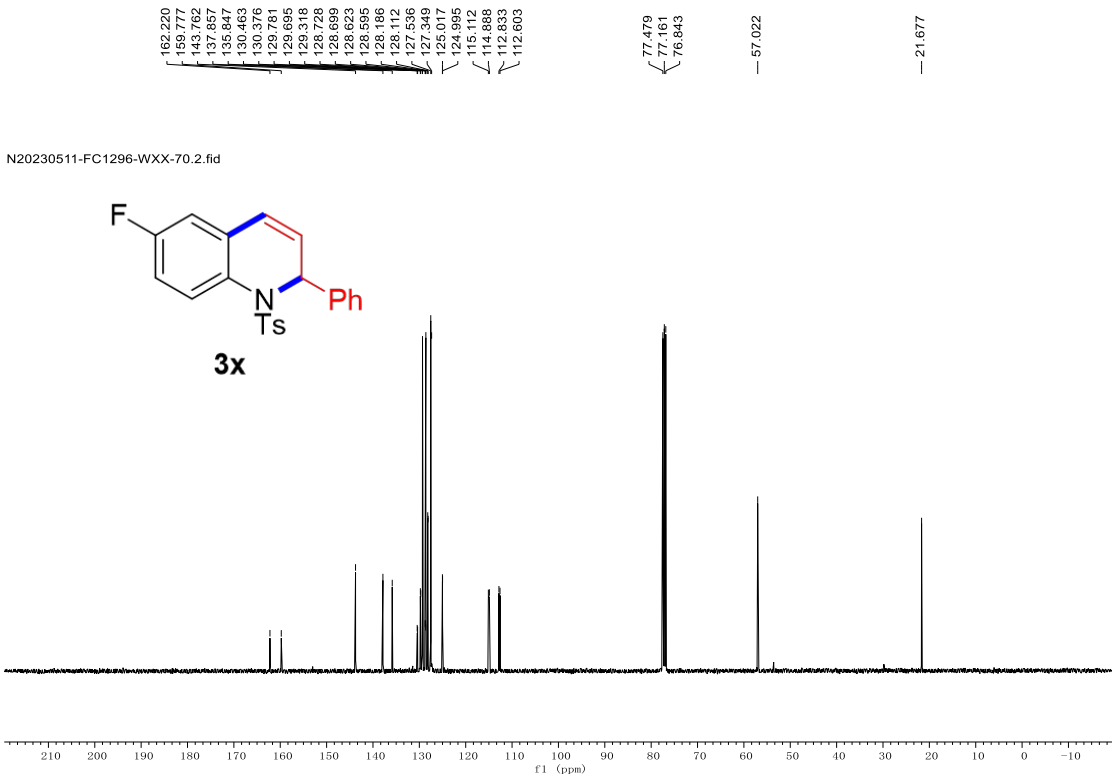
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3w**



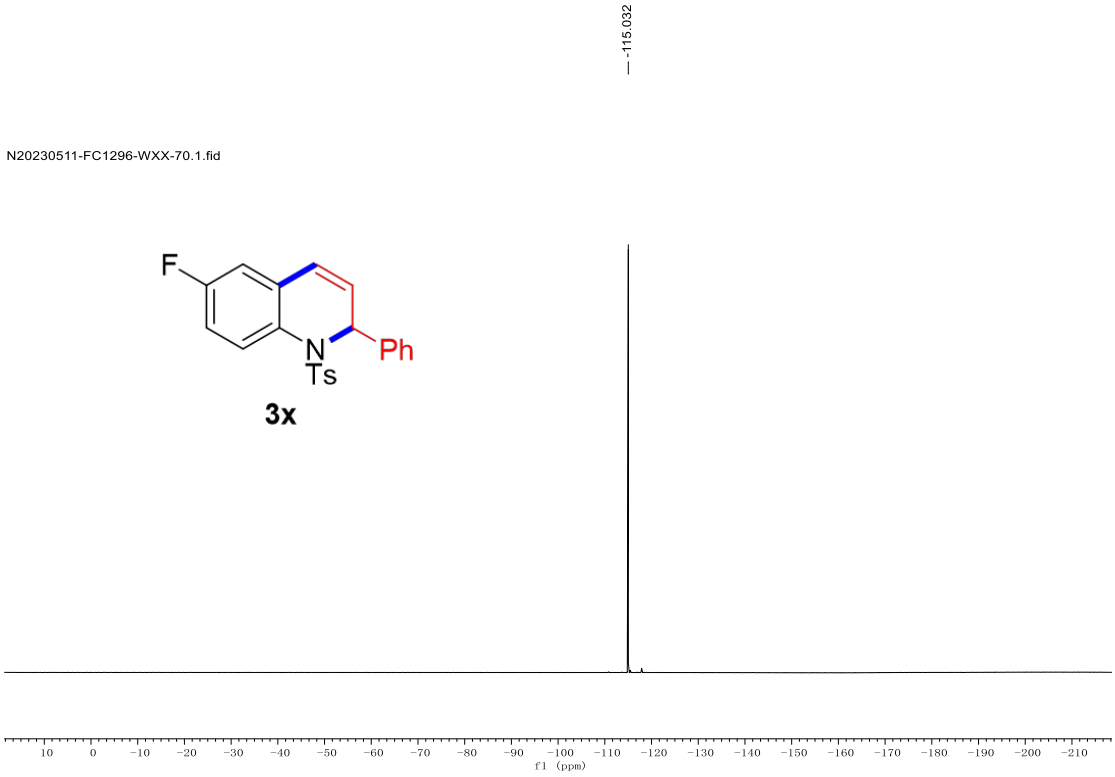
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3x**



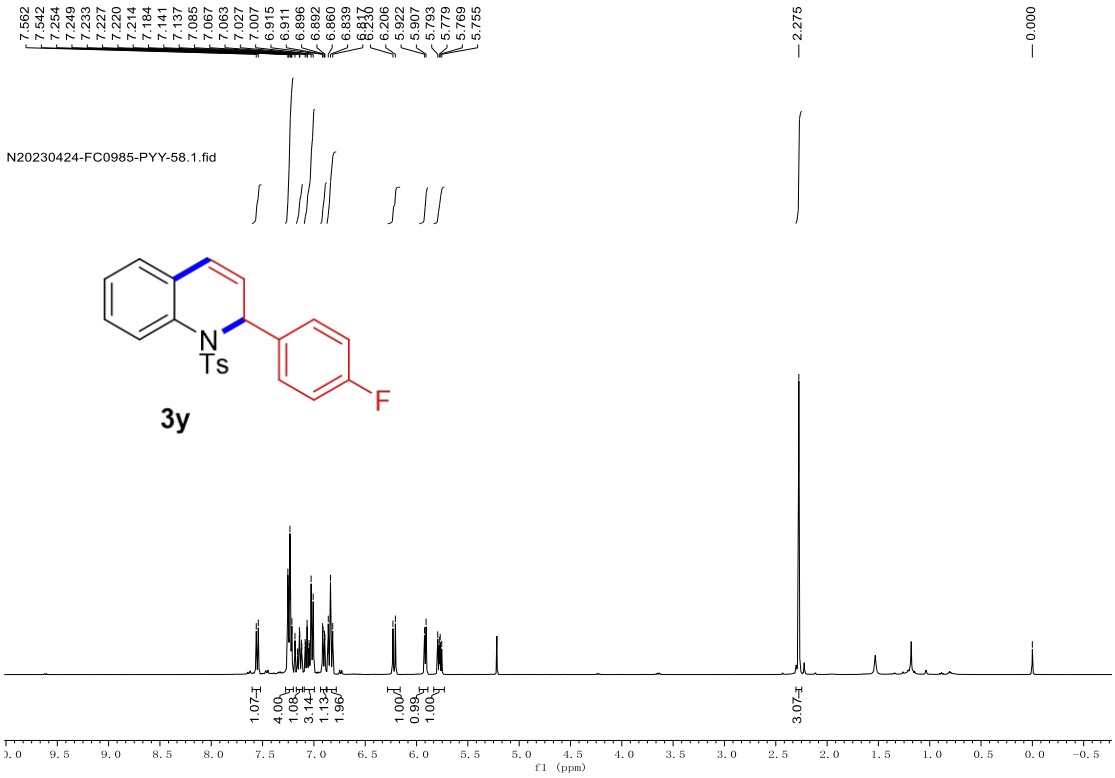
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3x**



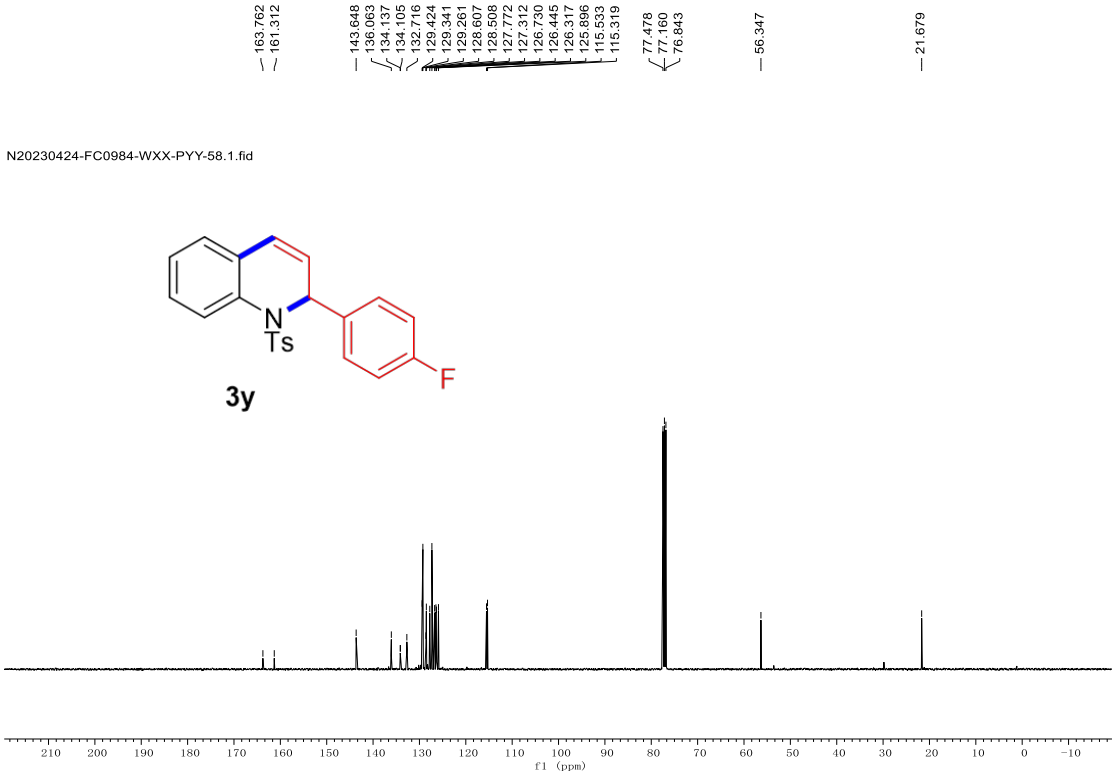
^{19}F NMR (376 MHz, $CDCl_3$) Spectrum of **3x**



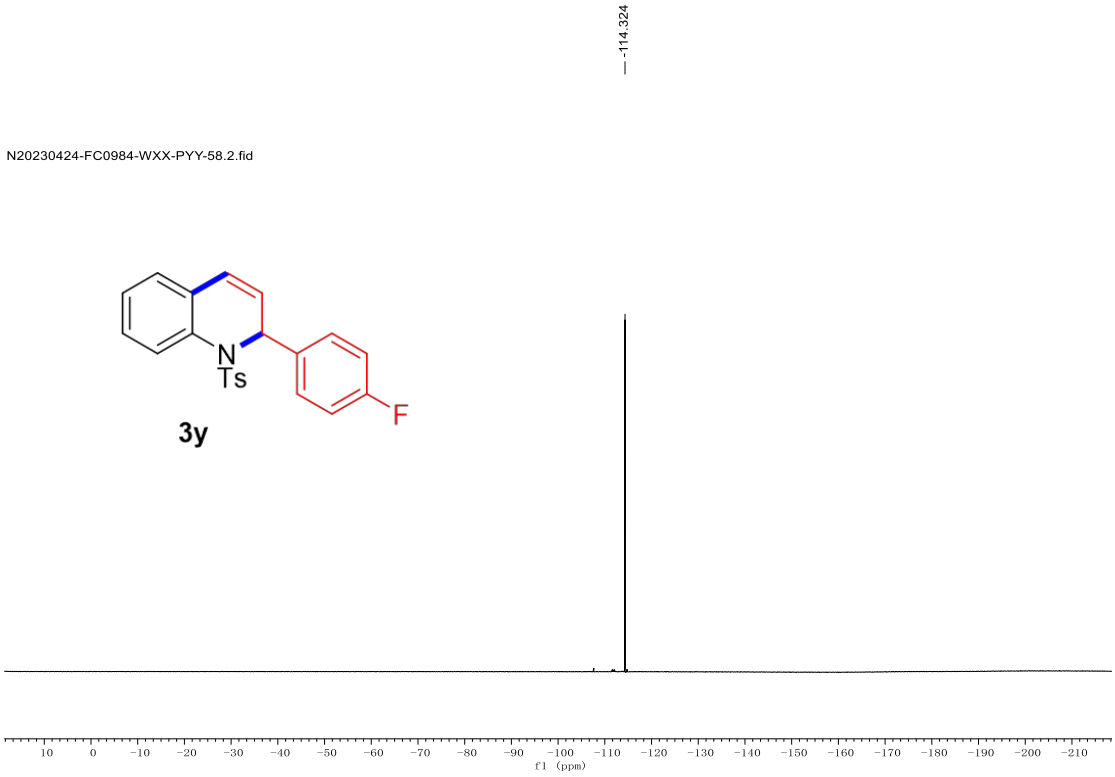
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3y**



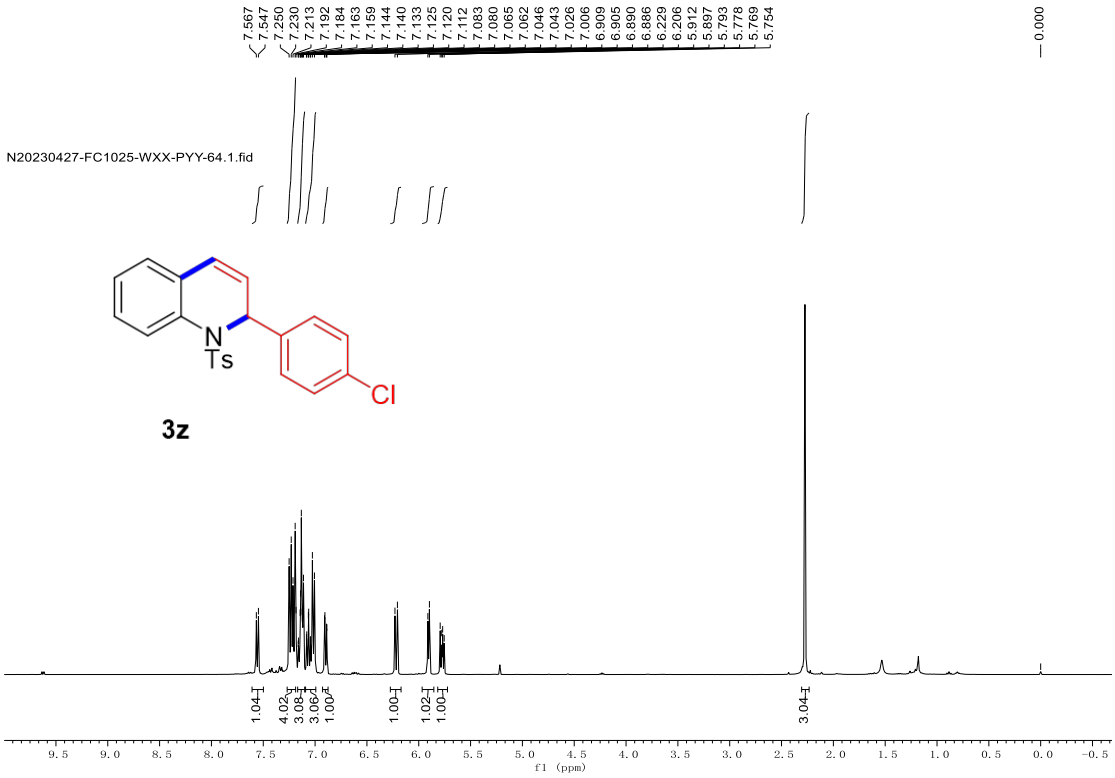
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3y**



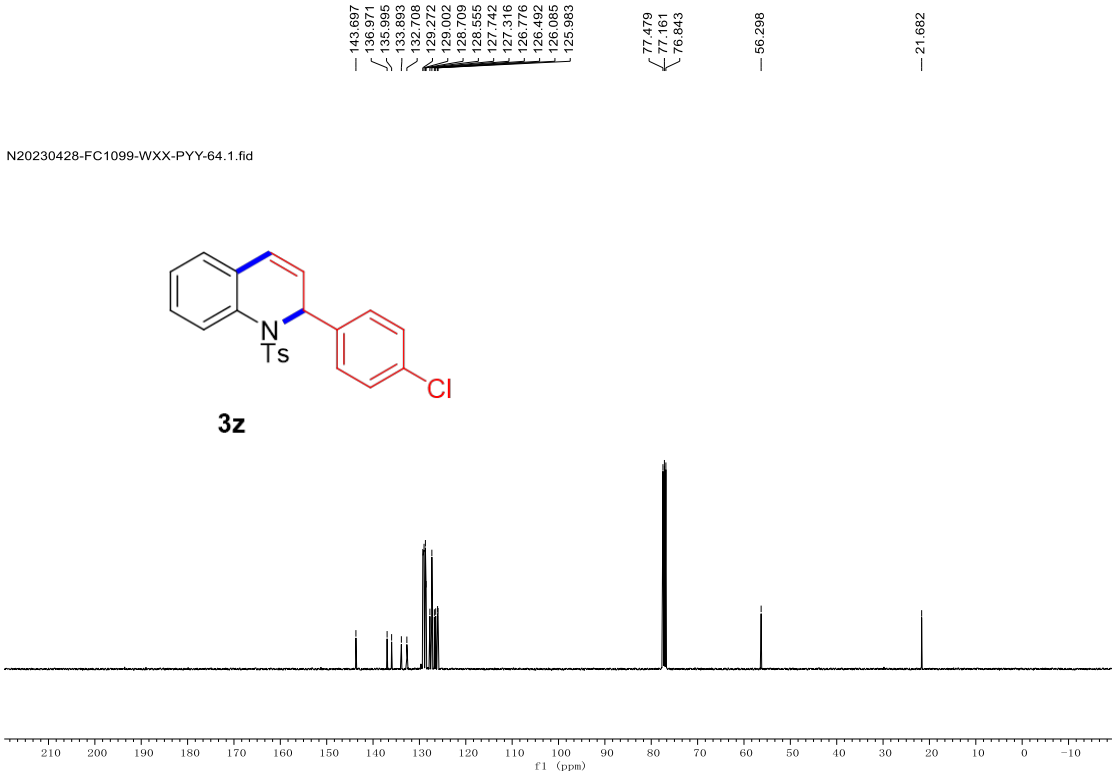
^{19}F NMR (376 MHz, $CDCl_3$) Spectrum of **3y**



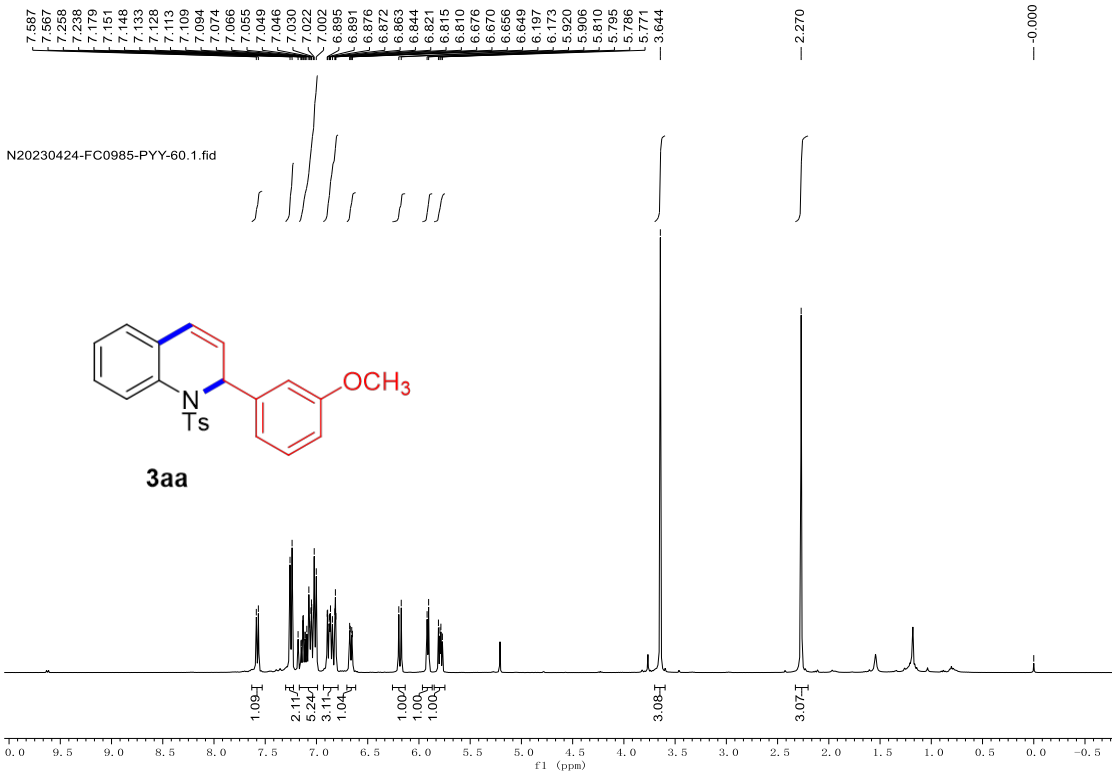
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3z**



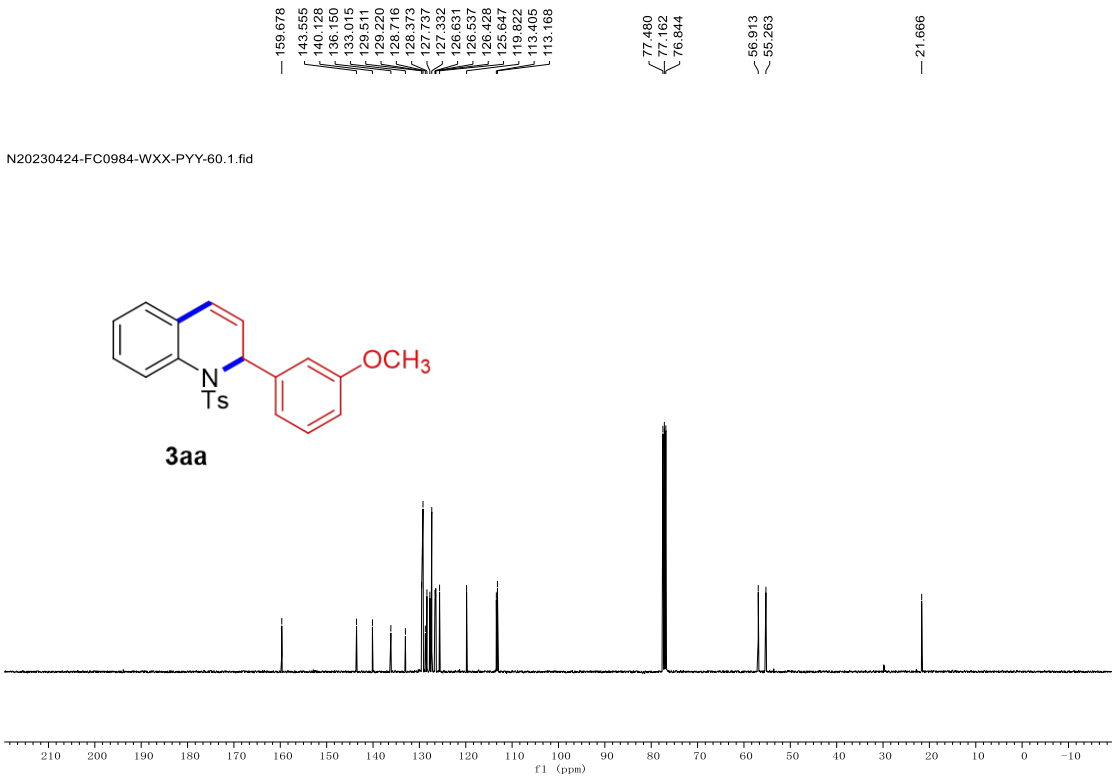
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3z**



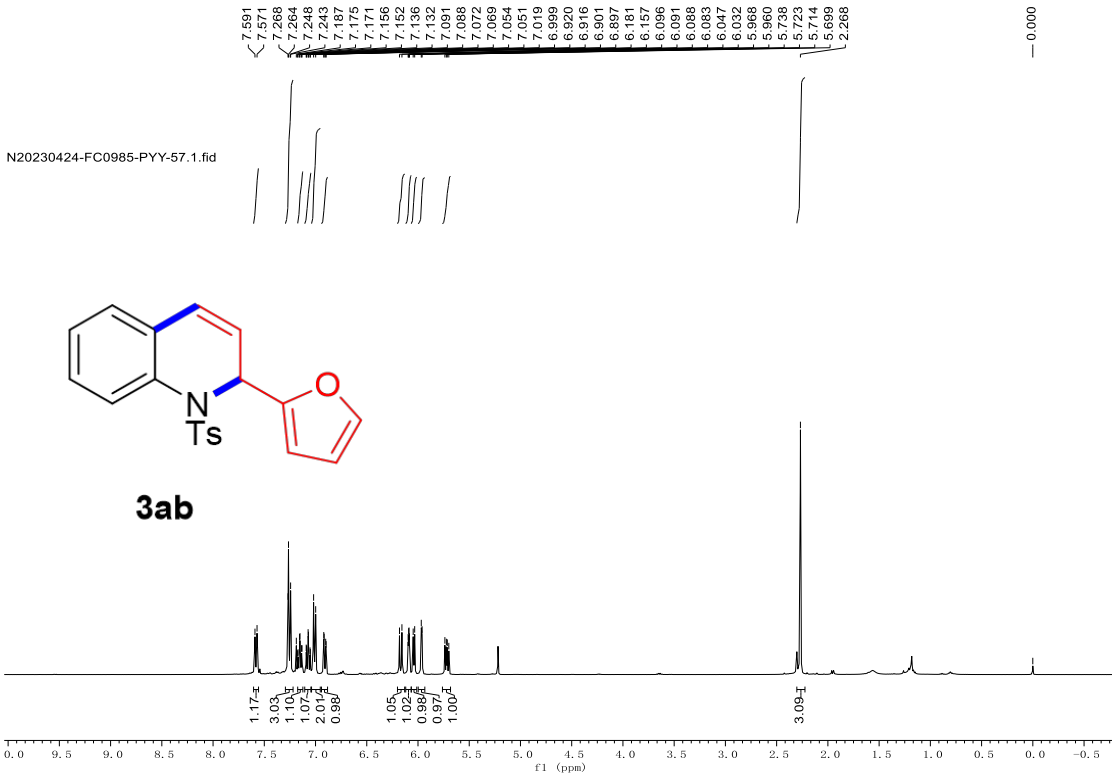
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3aa**



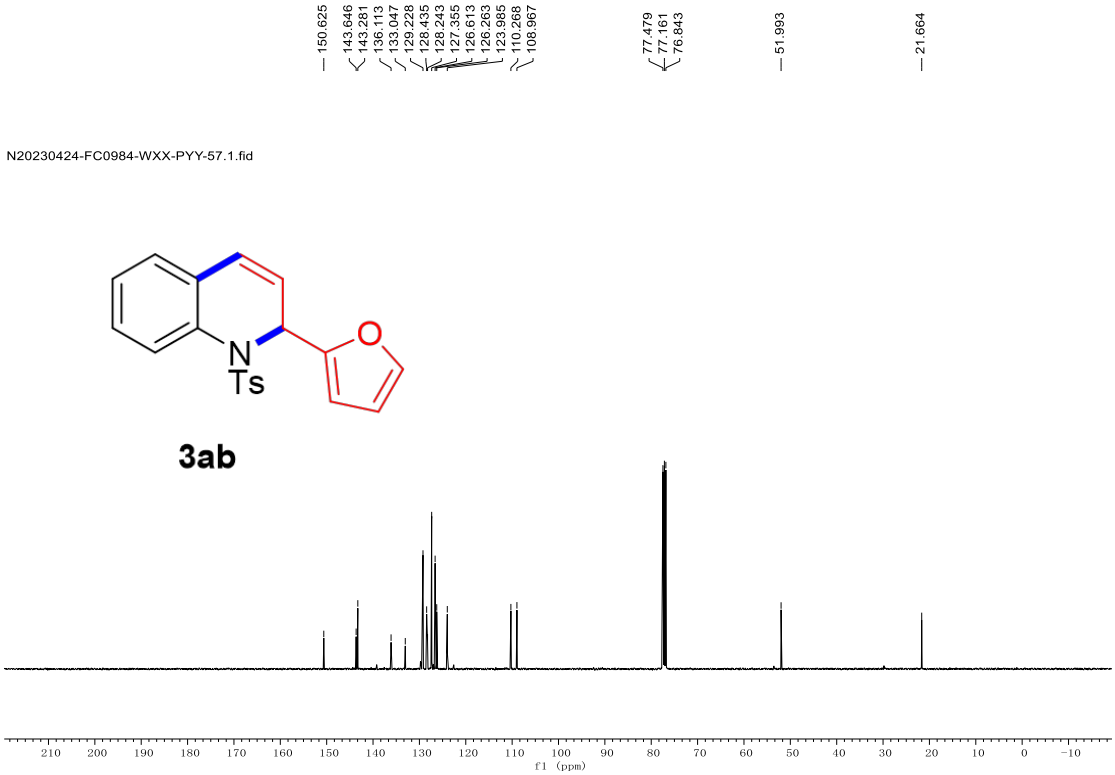
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3aa**



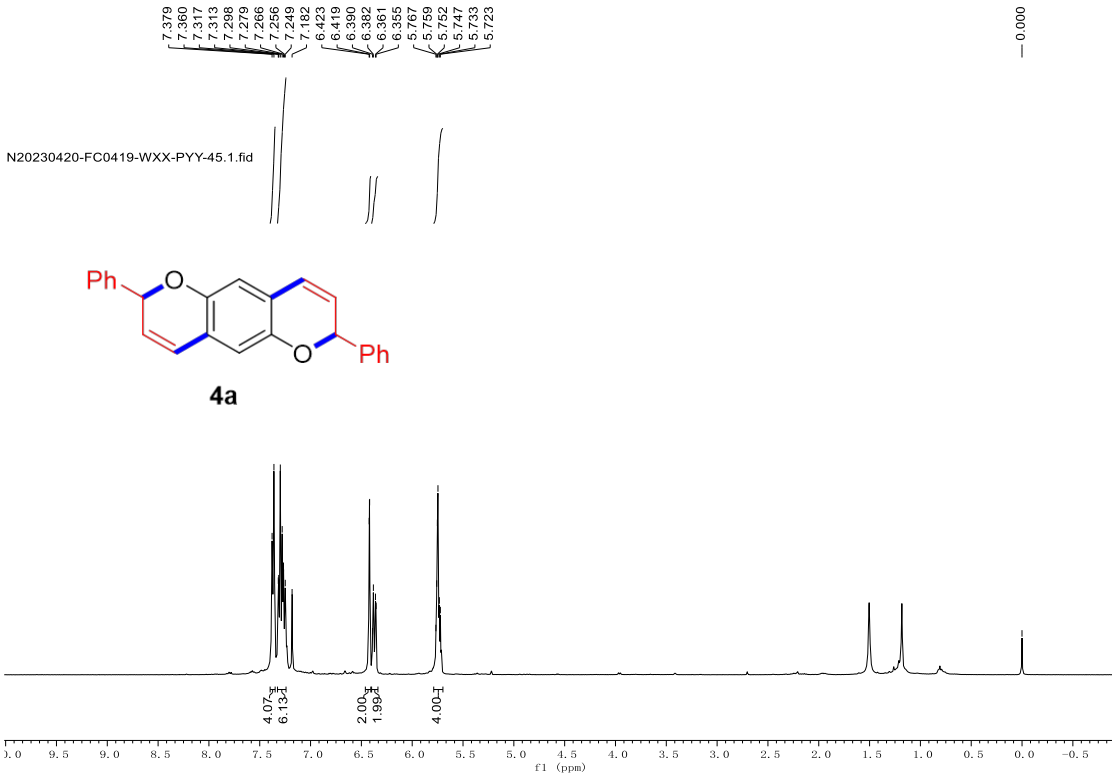
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **3ab**



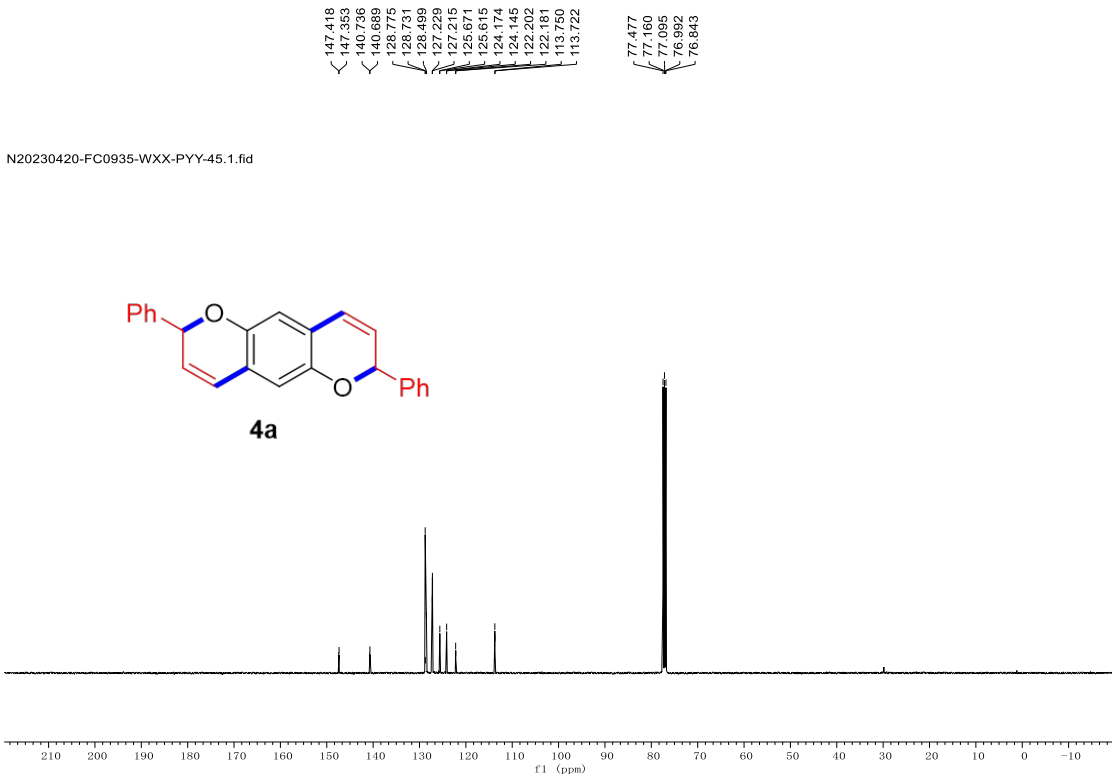
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **3ab**



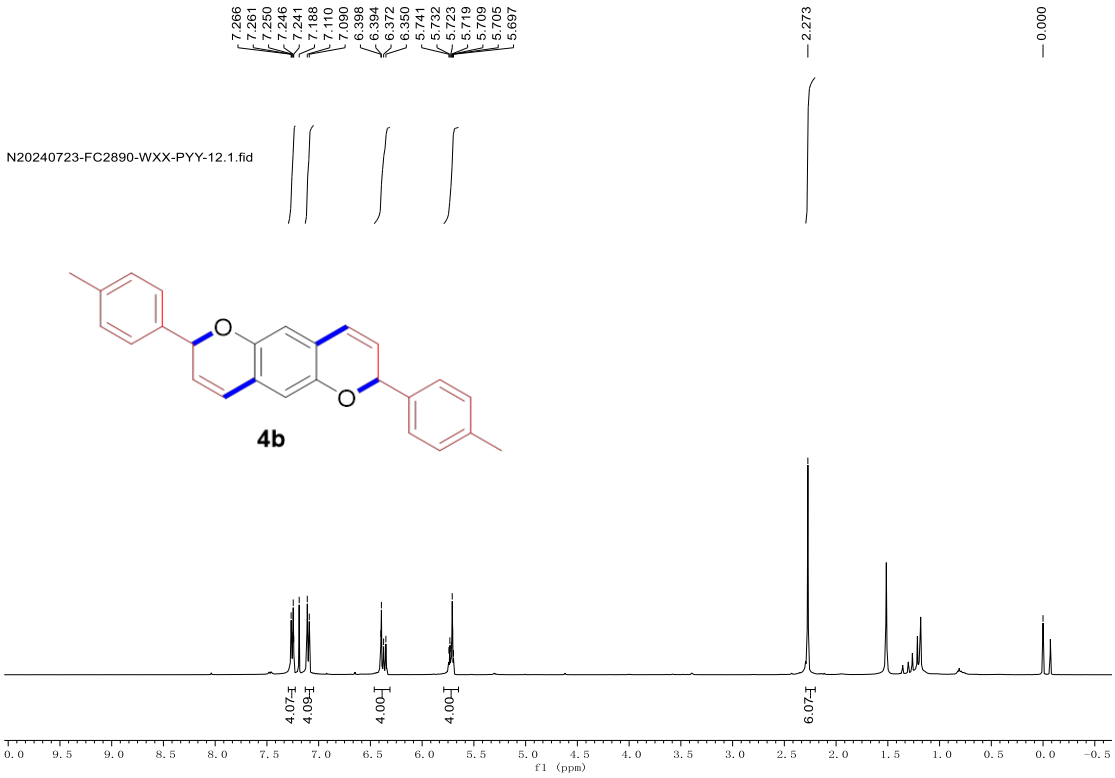
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **4a**



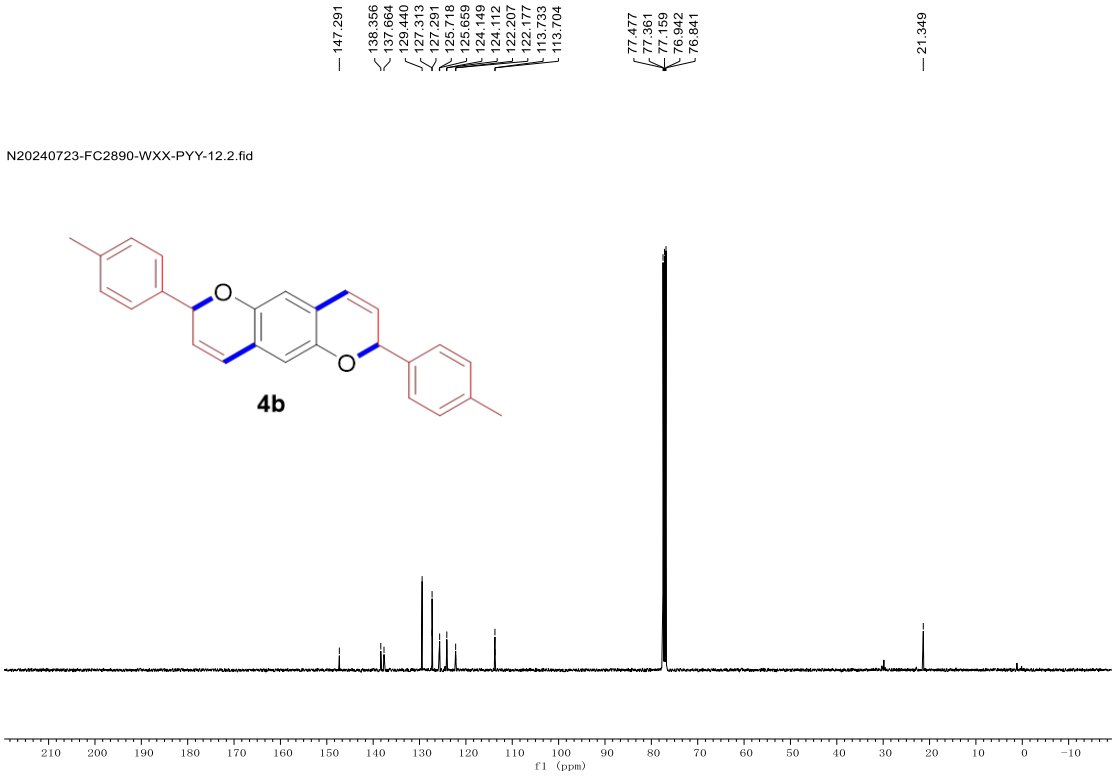
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **4a**



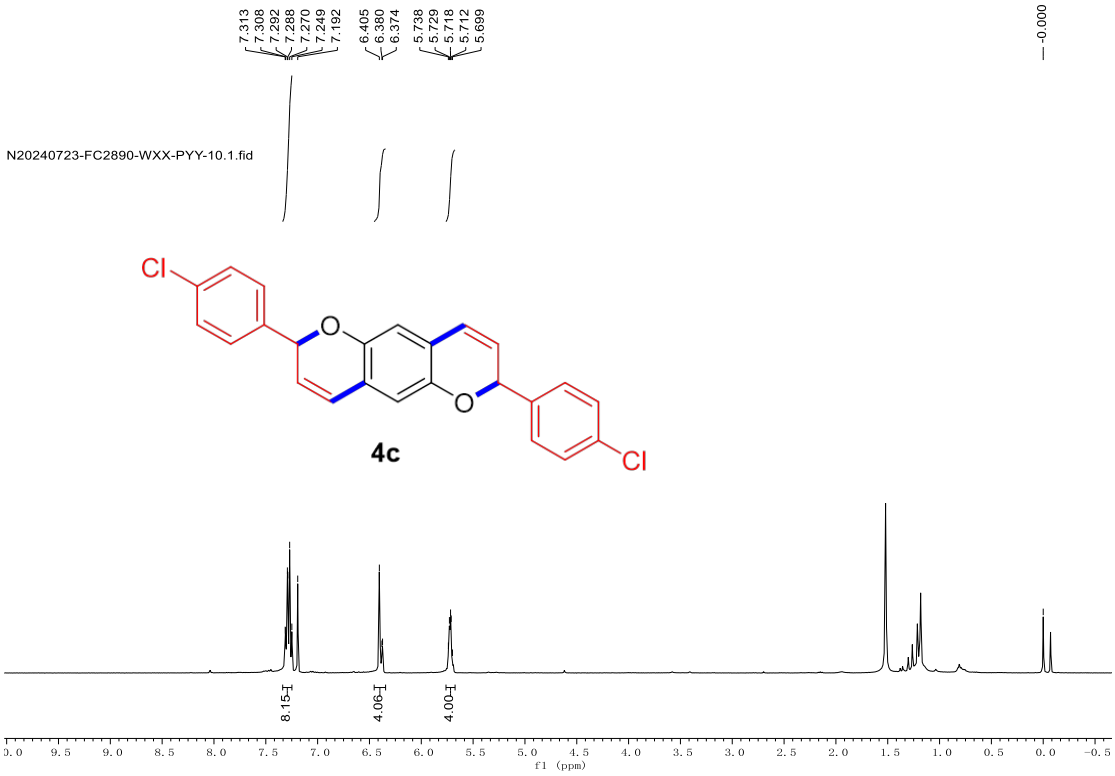
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **4b**



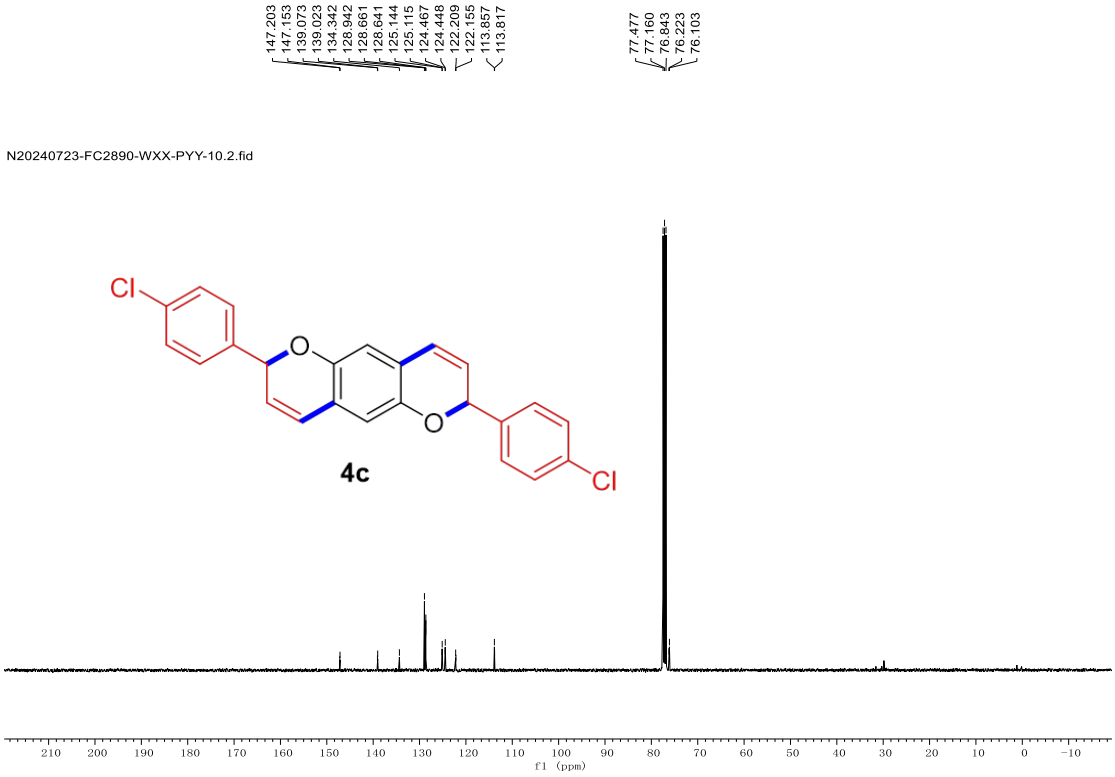
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **4b**



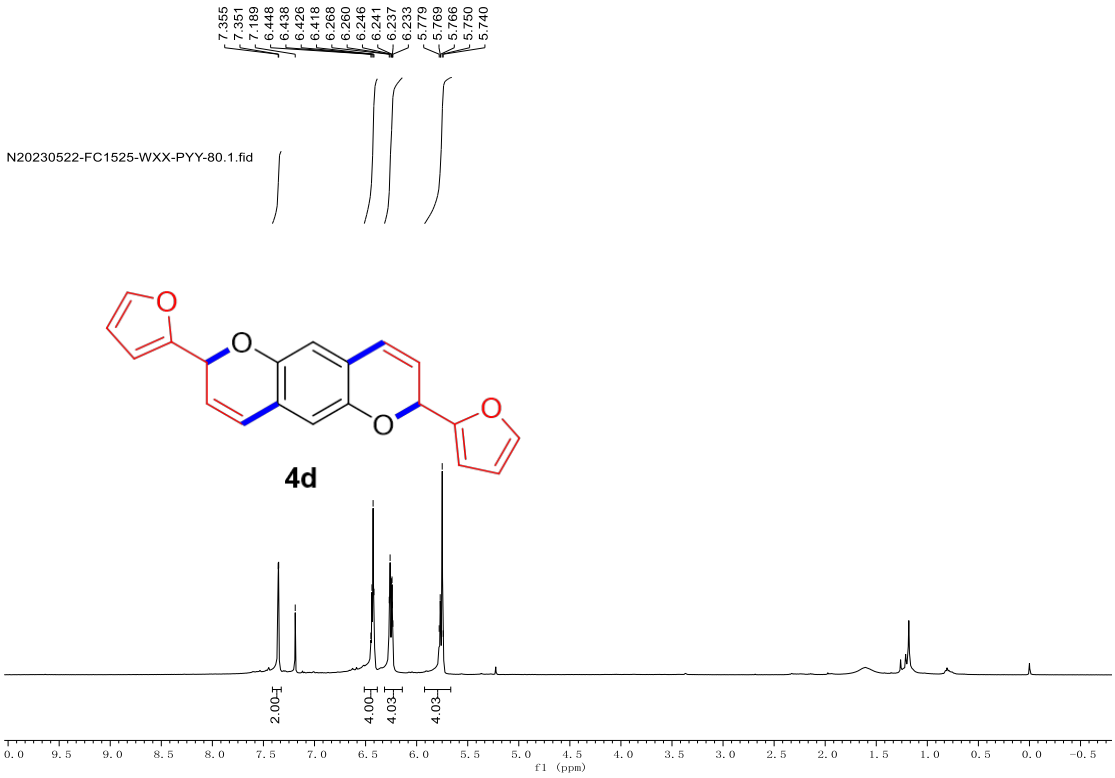
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **4c**



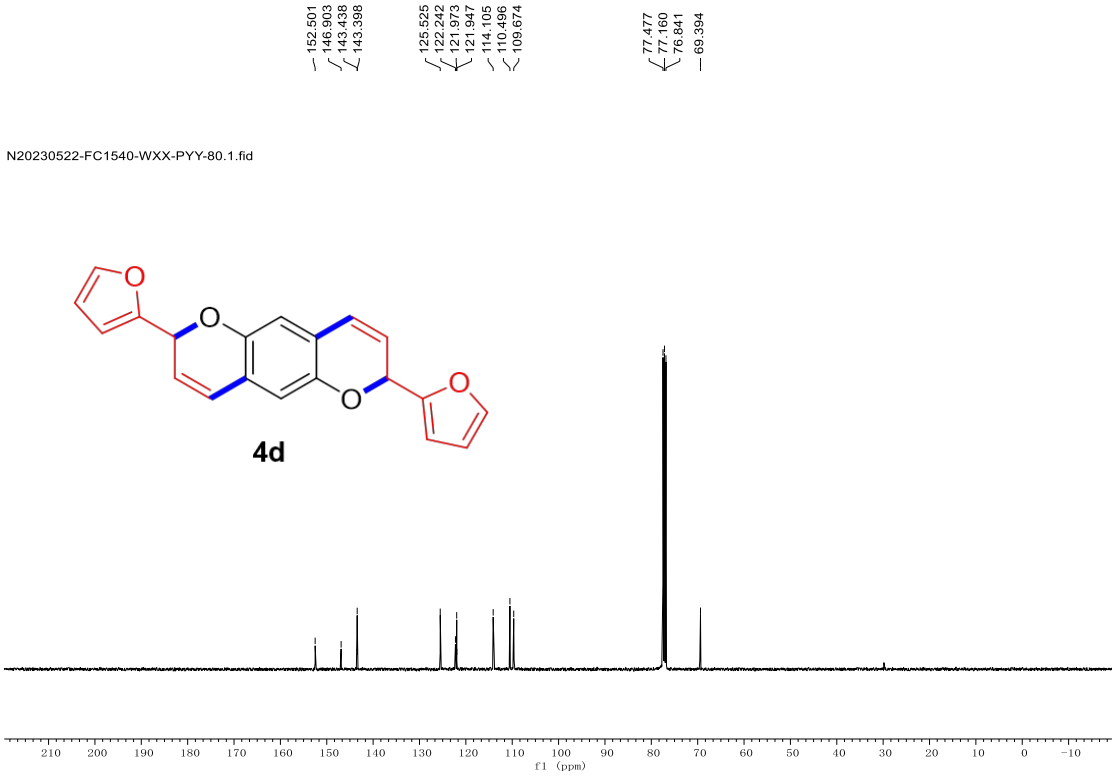
^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **4c**



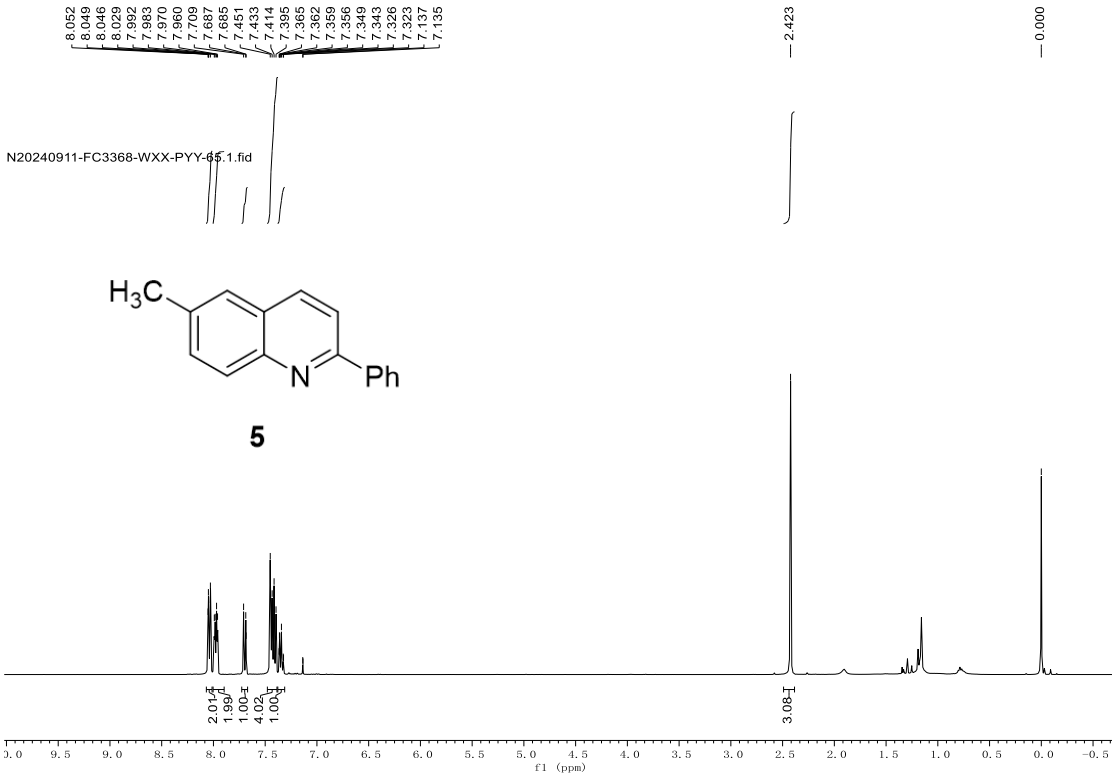
^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **4d**



^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **4d**



^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **5**



^{13}C{1H} NMR (101 MHz, $CDCl_3$) Spectrum of **5**