Iron(III)-Catalyzed *α*-Cyanation and Carbonylation with 2-Pyridylacetonitrile: Divergent Synthesis of *α*-Amino Nitriles and Tetrahydroisoquinolinones

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Supporting Information

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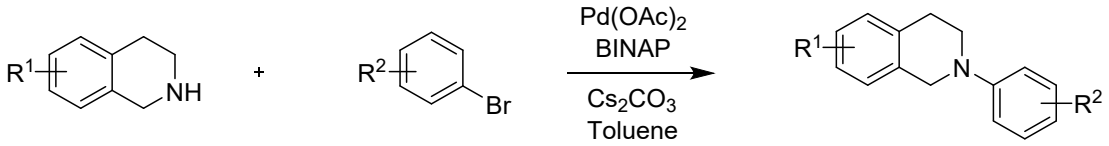
A. General method

Melting points were investigated using a melting point instrument and are uncorrected. ^{1}H and ^{13}C NMR spectra were obtained on a 400 MHz for ^{1}H NMR and 100 MHz for ^{13}C NMR. The chemical shifts are referenced to signals at 7.26 and 77.0 ppm, respectively, chloroform is solvent with TMS as the internal standard unless otherwise noted. High resolution mass spectra (HRMS) (TOF) were measured using an electrospray ionization (ESI) mass spectrometry. Silica gel (300-400 mesh) was used for flash column chromatograph, eluting (unless otherwise stated) with ethyl acetate/petroleum ether (PE) (60-90 ºC) mixture.

B. General procedure for the synthesis of *N*-aryl 1,2,3,4-tetrahydroisoquinolines



A' **B'** **1**

The *N*-aryl 1,2,3,4-tetrahydroisoquinolines were synthesized according to a known procedure.[1] To a solution of cesium carbonate (1.95 g, 6.0 mmol) in toluene (15 mL), **B'** (3.0 mmol), $Pd(OAc)_2$ (37 mg, 0.15 mmol), BINAP (186 mg, 0.3 mmol) and **A'** (4.5 mmol) were added in sequence. The reaction mixture was stirred at 100 ºC for 10 h. After the reaction was finished, ethyl acetate (5 mL) was added. Washed with saturated $NaHCO_3$ solution (3 × 5 mL), then the aqueous layer was extracted with ethyl acetate (3 × 5 mL). The organic layer was dried by Na_2SO_4 and concentrated under reduced pressure. The residue was separated by column chromatography to obtain pure sample.

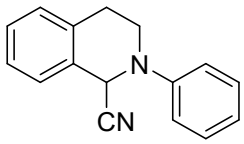
C. General procedure for the synthesis of *α*-amino nitriles

A mixture of *N*-aryl 1,2,3,4-tetrahydroisoquinoline (0.2 mmol), 2-pyridylacetonitrile (23.6 mg, 0.2 mmol), and $Fe(NO_3)_3{\cdot}9H_2O$ (16.2 mg, 0.04 mmol) in DMF (1.0 mL) was stirred at 50 ºC for 10 h in a sealed tube under 1 atm of oxygen. After the reaction was finished, water (5 mL) was added and the solution was extracted with ethyl acetate (3×5 mL), and the combined extract was dried with anhydrous $MgSO_4$. Solvent was removed, and the residue was separated by column chromatography to give the pure sample.

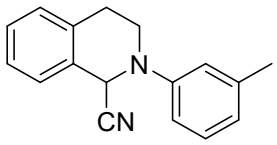
D. General procedure for the synthesis of *N*-aryl tetrahydroisoquinolinones

A mixture of *N*-aryl 1,2,3,4-tetrahydroisoquinoline (0.2 mmol), 2-pyridylacetonitrile (11.8 mg, 0.1 mmol), and $Fe(NO_3)_3 \cdot 9H_2O$ (24.2 mg, 0.06 mmol) in DMF (1.0 mL) was stirred at 100 °C for 16 h in a sealed tube under 1 atm of oxygen. After the reaction was finished, water (5 mL) was added and the solution was extracted with ethyl acetate (3×5 mL), and the combined extract was dried with anhydrous $MgSO_4$. Solvent was removed, and the residue was separated by column chromatography to give the pure sample.

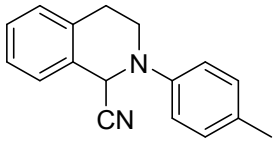
E. Analytical data



2-phenyl-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3a)[2]
Yellow solid (76.1 mg, 89%); mp = 89-91 °C; R_f = 0.44 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.40 – 7.35 (m, 2H), 7.31 (tt, *J* = 6.4, 3.4 Hz, 3H), 7.25 (d, *J* = 7.6 Hz, 1H), 7.10 (dd, *J* = 8.7, 0.9 Hz, 2H), 7.06 – 6.99 (m, 1H), 5.53 (s, 1H), 3.79 (dddd, *J* = 12.4, 5.9, 3.0, 1.1 Hz, 1H), 3.50 (ddd, *J* = 12.4, 10.7, 4.1 Hz, 1H), 3.17 (ddd, *J* = 16.4, 10.7, 6.0 Hz, 1H), 2.98 (dt, *J* = 16.3, 3.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 148.4, 134.6, 129.6, 129.5, 129.3, 128.7, 127.0, 126.8, 121.9, 117.7, 117.6, 53.2, 44.2, 28.5.

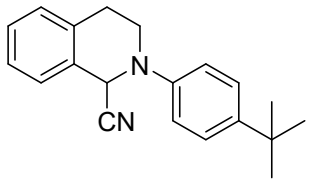


2-(*m*-tolyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3b)[2]
Yellow liquid (69.3 mg, 86%); R_f = 0.57(petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.36 – 7.29 (m, 3H), 7.28 – 7.26 (m, 1H), 7.25 (dd, *J* = 4.1, 2.6 Hz, 1H), 6.95 – 6.89 (m, 2H), 6.89 – 6.83 (m, 1H), 5.53 (s, 1H), 3.79 (dddd, *J* = 12.4, 5.9, 2.9, 1.1 Hz, 1H), 3.49 (ddd, *J* = 12.4, 10.8, 4.1 Hz, 1H), 3.17 (ddd, *J* = 16.5, 10.7, 6.0 Hz, 1H), 2.98 (dt, *J* = 16.3, 3.5 Hz, 1H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 148.4, 139.3, 134.6, 129.6, 129.3, 129.3, 128.7, 127.0, 126.8, 122.7, 118.3, 117.7, 114.6, 53.2, 44.1, 28.5, 21.7. HRMS (ESI): calcd. for $C_{17}H_{17}N_2$ $[M + H]^+$ 249.1386, found 249.1375.



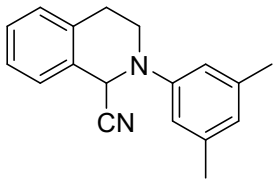
2-(*p*-tolyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3c)[2]

Brown solid (68.5 mg, 85%); mp = 108-110 °C; R_f = 0.44 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.36 – 7.29 (m, 3H), 7.23 (dd, J = 18.4, 7.1 Hz, 3H), 7.05 (d, J = 8.5 Hz, 2H), 5.50 (s, 1H), 3.76 – 3.70 (m, 1H), 3.51 – 3.43 (m, 1H), 3.18 (ddd, J = 16.7, 10.9, 6.1 Hz, 1H), 3.00 – 2.93 (m, 1H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.2, 134.4, 131.6, 130.0, 129.6, 129.3, 128.6, 127.0, 126.7, 118.2, 117.6, 53.9, 44.3, 28.5, 20.5.



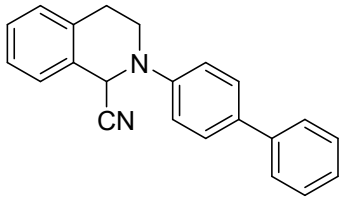
2-(4-(*tert*-butyl)phenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3d)[3]

Yellow solid (55.8 mg, 81%); mp = 106-108 °C; R_f = 0.38 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.42 – 7.38 (m, 2H), 7.35 – 7.27 (m, 3H), 7.24 (d, J = 7.2 Hz, 1H), 7.08 – 7.03 (m, 2H), 5.50 (s, 1H), 3.76 (dddd, J = 12.3, 6.0, 2.7, 1.1 Hz, 1H), 3.48 (ddd, J = 12.4, 10.9, 4.1 Hz, 1H), 3.17 (ddd, J = 16.7, 10.9, 6.0 Hz, 1H), 2.97 (dt, J = 16.3, 3.4 Hz, 1H), 1.34 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.0, 144.9, 134.6, 129.7, 129.4, 128.7, 127.0, 126.8, 126.4, 117.8, 117.6, 53.6, 44.3, 34.1, 31.4, 28.6. HRMS (ESI): calcd. for $C_{20}H_{23}N_2$ $[M + H]^+$ 291.1856, found 291.1867.



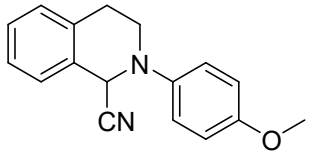
2-(3,5-dimethylphenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3e) [4]

Brown solid (62.6 mg, 82%); mp = 81-83 °C; R_f = 0.64 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.36 – 7.27 (m, 3H), 7.26 – 7.23 (m, 1H), 6.73 (s, 2H), 6.70 (s, 1H), 5.53 (s, 1H), 3.78 (dddd, J = 12.4, 5.9, 2.9, 1.1 Hz, 1H), 3.47 (ddd, J = 12.4, 10.8, 4.1 Hz, 1H), 3.17 (ddd, J = 16.6, 10.8, 6.0 Hz, 1H), 2.97 (dt, J = 16.3, 3.5 Hz, 1H), 2.35 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 148.4, 139.1, 134.6, 129.7, 129.3, 128.6, 127.0, 126.7, 123.7, 117.8, 115.5, 53.4, 44.1, 28.6, 21.6.



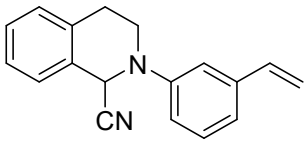
2-([1,1'-biphenyl]-4-yl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3f)[2]

Brown solid (48.4 mg, 75%); mp = 154-156 °C; R_f = 0.41 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.56 (dd, J = 10.5, 8.0 Hz, 4H), 7.40 (t, J = 7.6 Hz, 2H), 7.33 – 7.26 (m, 4H), 7.23 (d, J = 4.7 Hz, 1H), 7.12 (d, J = 8.7 Hz, 2H), 5.54 (s, 1H), 3.80 (ddd, J = 11.6, 5.0, 3.2 Hz, 1H), 3.50 (ddd, J = 12.4, 10.7, 4.1 Hz, 1H), 3.16 (ddd, J = 16.3, 10.5, 5.9 Hz, 1H), 2.97 (dt, J = 16.3, 3.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.4, 140.4, 134.5, 134.4, 129.4, 129.4, 128.7, 128.7, 128.1, 127.5, 127.0, 126.8, 126.8, 126.6, 117.4, 52.7, 44.1, 28.4.



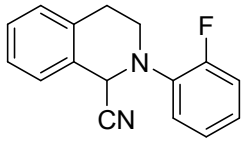
2-(4-methoxyphenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3g)[2]

Yellow solid (59.5mg, 78%); mp = 82-84 °C; R_f = 0.36 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.34 – 7.26 (m, 3H), 7.24 (d, J = 7.2 Hz, 1H), 7.13 – 7.08 (m, 2H), 6.96 – 6.91 (m, 2H), 5.39 (s, 1H), 3.81 (s, 3H), 3.64 – 3.56 (m, 1H), 3.49 – 3.41 (m, 1H), 3.17 (ddd, J = 17.1, 11.1, 6.3 Hz, 1H), 2.94 (ddd, J = 16.4, 3.6, 2.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 155.6, 142.5, 134.3, 129.6, 129.4, 128.6, 127.0, 126.6, 120.8, 117.5, 114.7, 55.4, 55.4, 44.8, 28.6.



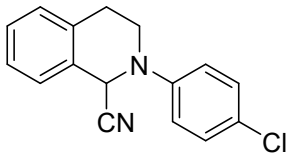
2-(3-vinylphenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3h)

Oil liquid (30.2 mg, 58%); R_f = 0.51 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.39 – 7.29 (m, 4H), 7.24 (s, 1H), 7.14 – 7.07 (m, 2H), 7.00 (dd, J = 8.0, 1.8 Hz, 1H), 6.73 (dd, J = 17.6, 10.9 Hz, 1H), 5.78 (d, J = 17.5 Hz, 1H), 5.53 (s, 1H), 5.29 (d, J = 11.0 Hz, 1H), 3.83 – 3.74 (m, 1H), 3.51 (ddd, J = 12.4, 10.8, 4.1 Hz, 1H), 3.17 (ddd, J = 16.5, 10.7, 6.0 Hz, 1H), 2.99 (dt, J = 16.3, 3.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 148.6, 138.9, 136.7, 134.5, 129.6, 129.5, 129.3, 128.7, 127.0, 126.8, 119.8, 117.6, 117.0, 115.6, 114.4, 53.2, 44.2, 28.52. HRMS (ESI): calcd. for $C_{18}H_{17}N_2$ $[M + H]^+$ 261.1386, found 261.1393.



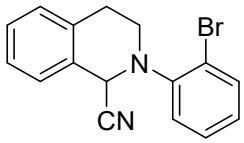
2-(2-fluorophenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3i)[4]

Brown solid (55.5 mg, 70%); mp = 95-97 °C; R_f = 0.46 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.35 – 7.26 (m, 4H), 7.25 – 7.22 (m, 1H), 6.82 (dd, J = 8.2, 2.2 Hz, 1H), 6.74 (dt, J = 11.5, 2.3 Hz, 1H), 6.68 (td, J = 8.2, 1.8 Hz, 1H), 5.50 (s, 1H), 3.78 – 3.71 (m, 1H), 3.48 (ddd, J = 12.4, 10.2, 4.2 Hz, 1H), 3.13 (ddd, J = 16.0, 10.2, 5.8 Hz, 1H), 2.98 (dt, J = 16.3, 3.9 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 163.8 (d, J = 244 Hz), 149.8 (d, J = 10 Hz), 134.5, 130.7 (d, J = 10 Hz), 129.2, 129.2, 128.9, 127.0, 117.5, 112.1 (d, J = 3 Hz), 108.0 (d, J = 21 Hz), 104.1, 103.9, 52.2, 44.0, 28.3.



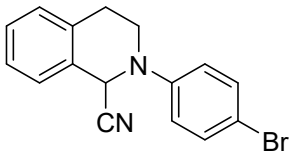
2-(4-chlorophenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3j)[4]

Yellow solid (56.7 mg, 76%); mp = 132-134 °C; R_f = 0.46 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.35 – 7.28 (m, 5H), 7.25 (d, J = 7.3 Hz, 1H), 7.03 – 6.99 (m, 2H), 5.46 (s, 1H), 3.72 (dddd, J = 12.3, 5.9, 3.1, 1.0 Hz, 1H), 3.47 (ddd, J = 12.3, 10.6, 4.1 Hz, 1H), 3.16 (ddd, J = 16.5, 10.6, 5.9 Hz, 1H), 2.98 (dt, J = 16.2, 3.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.0, 134.4, 129.5, 129.3, 129.2, 128.9, 127.0, 126.9, 118.8, 117.4, 53.1, 44.3, 28.4.



2-(2-bromophenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3k)[5]

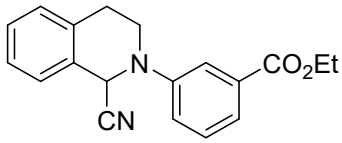
Yellow solid (33.3 mg, 52%); mp = 115-117 °C; R_f = 0.46 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.63 (dd, J = 8.0, 1.4 Hz, 1H), 7.43 – 7.38 (m, 1H), 7.37 – 7.30 (m, 2H), 7.27 (d, J = 3.7 Hz, 2H), 7.24 (d, J = 7.4 Hz, 1H), 7.12 – 7.06 (m, 1H), 5.54 (s, 1H), 3.64 (td, J = 11.8, 3.8 Hz, 1H), 3.44 (ddt, J = 12.0, 6.3, 1.4 Hz, 1H), 3.32 – 3.23 (m, 1H), 2.93 (dd, J = 16.5, 2.7 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.1, 134.1, 133.8, 129.6, 129.4, 128.8, 128.7, 127.0, 126.6, 123.7, 120.5, 117.3, 54.2, 45.8, 28.9.



2-(4-bromophenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3l)[4]

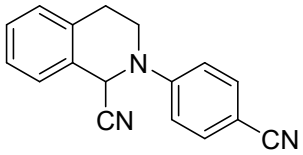
Yellow solid (46.8 mg, 73%); mp = 156-158 °C; R_f = 0.45 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.49 – 7.40 (m, 2H), 7.36 – 7.27 (m, 3H), 7.25 (d, J = 7.3 Hz, 1H), 6.98 – 6.93 (m, 2H), 5.47 (s, 1H), 3.76 – 3.67 (m, 1H), 3.46 (ddd, J = 12.3, 10.6, 4.1 Hz, 1H), 3.15 (ddd, J = 16.4, 10.5, 5.9 Hz, 1H), 2.98 (dt,

J = 16.4, 3.7 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.3, 134.3, 132.4, 129.3, 129.1, 128.9, 127.0, 126.9, 119.0, 117.4, 114.2, 52.7, 44.1, 28.3.



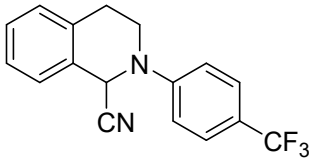
ethyl 3-(1-cyano-3,4-dihydroisoquinolin-2(1*H*)-yl)benzoate (3m)

Oil liquid (37.9 mg, 62%); R_f = 0.35 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.76 (s, 1H), 7.69 (d, J = 7.7 Hz, 1H), 7.43 (t, J = 7.9 Hz, 1H), 7.36 – 7.28 (m, 3H), 7.26 (dd, J = 6.6, 3.8 Hz, 2H), 5.59 (s, 1H), 4.40 (q, J = 7.1 Hz, 2H), 3.83 (ddd, J = 12.2, 5.2, 3.2 Hz, 1H), 3.58 – 3.45 (m, 1H), 3.17 (ddd, J = 16.4, 10.5, 5.9 Hz, 1H), 3.00 (dt, J = 16.3, 3.5 Hz, 1H), 1.41 (t, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.3, 148.2, 134.3, 131.7, 129.5, 129.2, 129.2, 128.8, 127.0, 126.9, 122.6, 121.2, 118.1, 117.4, 61.1, 52.6, 43.9, 28.3, 14.2. HRMS (ESI): calcd. for $C_{19}H_{19}N_2O_2$ $[M + H]^+$ 307.1441, found 307.1448.



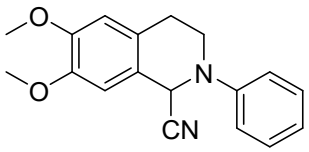
2-(4-cyanophenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3n)[4]

Yellow solid (39.4 mg, 51%); mp = 152-154 °C; R_f = 0.47 (petroleum ether / ethyl acetate = 3:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.67 – 7.57 (m, 2H), 7.40 – 7.32 (m, 3H), 7.28 (d, J = 7.1 Hz, 1H), 7.06 – 6.99 (m, 2H), 5.58 (s, 1H), 3.89 – 3.80 (m, 1H), 3.65 – 3.57 (m, 1H), 3.19 – 3.07 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 150.6, 134.6, 133.9, 129.3, 129.1, 128.8, 127.4, 127.0, 119.3, 117.3, 114.7, 102.7, 50.2, 43.8, 28.2.



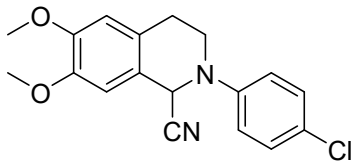
2-(4-(trifluoromethyl)phenyl)-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3o)[2]

Yellow solid (35.7 mg, 54%); mp = 93-95 °C; R_f = 0.41 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.60 (d, J = 8.5 Hz, 2H), 7.38 – 7.30 (m, 3H), 7.28 (s, 1H), 7.09 (d, J = 8.7 Hz, 2H), 5.58 (s, 1H), 3.86 (dt, J = 10.1, 4.7 Hz, 1H), 3.57 (ddd, J = 12.4, 9.6, 4.4 Hz, 1H), 3.17 (ddd, J = 15.3, 9.6, 5.5 Hz, 1H), 3.05 (dt, J = 16.2, 4.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 150.3, 134.6, 129.2, 129.1, 129.0, 127.2, 127.0, 126.9 (q, J = 4 Hz), 124.4 (q, J = 270 Hz), 122.5 (q, J = 33 Hz), 117.5, 115.3, 51.2, 43.9, 28.3.



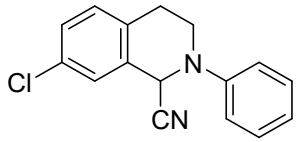
6,7-dimethoxy-2-phenyl-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3p)[2]

Yellow solid (44.2 mg, 65%); mp = 100-102 °C; R_f = 0.41 (petroleum ether / ethyl acetate = 3:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.38 – 7.33 (m, 2H), 7.08 (d, J = 7.8 Hz, 2H), 7.01 (t, J = 7.3 Hz, 1H), 6.75 (s, 1H), 6.68 (s, 1H), 5.45 (s, 1H), 3.88 (s, 6H), 3.80 – 3.75 (m, 1H), 3.44 (ddd, J = 12.4, 11.2, 4.0 Hz, 1H), 3.08 (ddd, J = 16.7, 11.1, 5.9 Hz, 1H), 2.88 – 2.81 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 149.3, 148.3, 148.0, 129.5, 126.8, 121.8, 121.0, 117.8, 117.6, 111.5, 109.3, 56.0, 55.9, 53.0, 44.1, 28.0.



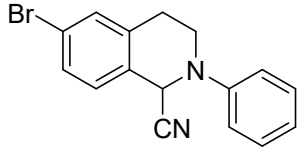
2-(4-chlorophenyl)-6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3q)[2]

Brown solid (38.4 mg, 63%); mp = 150-152 °C; R_f = 0.39 (petroleum ether / ethyl acetate = 3:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.32 – 7.27 (m, 2H), 7.01 – 6.97 (m, 2H), 6.70 (d, J = 23.2 Hz, 2H), 5.39 (s, 1H), 3.88 (s, 3H), 3.87 (s, 3H), 3.69 (ddd, J = 7.3, 5.1, 1.3 Hz, 1H), 3.44 – 3.37 (m, 1H), 3.11 – 3.02 (m, 1H), 2.87 – 2.80 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 149.4, 148.1, 147.0, 129.4, 126.9, 126.6, 120.6, 118.9, 117.5, 111.5, 109.2, 56.0, 55.9, 52.9, 44.2, 27.9.

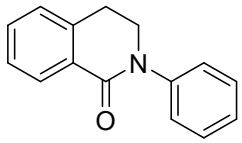


7-chloro-2-phenyl-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3r)[6]

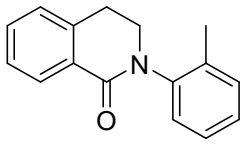
Yellow solid (61.2 mg, 82%); mp = 113-115 °C; R_f = 0.47 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.41 – 7.35 (m, 2H), 7.33 – 7.27 (m, 2H), 7.18 (d, J = 8.4 Hz, 1H), 7.07 (ddd, J = 14.7, 8.0, 0.9 Hz, 3H), 5.47 (s, 1H), 3.78 (dddd, J = 12.5, 6.0, 2.6, 1.2 Hz, 1H), 3.46 (ddd, J = 12.5, 11.0, 4.1 Hz, 1H), 3.11 (ddd, J = 16.7, 10.9, 6.0 Hz, 1H), 2.93 (dt, J = 16.5, 3.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 148.0, 133.0, 132.3, 131.1, 130.7, 129.6, 129.0, 126.9, 122.2, 117.8, 117.1, 52.9, 44.1, 28.0.



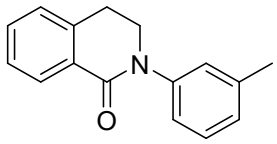
6-bromo-2-phenyl-1,2,3,4-tetrahydroisoquinoline-1-carbonitrile (3s)[6]
Brown liquid (50.0 mg, 78%); R_f = 0.52 (petroleum ether / ethyl acetate = 10:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.43 – 7.35 (m, 4H), 7.19 – 7.16 (m, 1H), 7.06 (ddd, *J* = 14.7, 8.0, 4.4 Hz, 3H), 5.47 (s, 1H), 3.77 (dddd, *J* = 12.5, 5.9, 2.6, 1.0 Hz, 1H), 3.45 (ddd, *J* = 12.5, 10.9, 4.0 Hz, 1H), 3.14 (ddd, *J* = 16.7, 10.8, 6.1 Hz, 1H), 2.94 (dt, *J* = 16.5, 3.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 148.1, 136.8, 132.2, 130.0, 129.6, 128.6, 128.5, 122.6, 122.2, 117.8, 117.2, 52.9, 43.8, 28.3.



2-phenyl-3,4-dihydroisoquinolin-1(2*H*)-one (4a)[7]
White solid (76.2 mg, 85%); mp = 95-97 °C; R_f = 0.31 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.49 – 7.45 (m, 1H), 7.44 – 7.34 (m, 5H), 7.28 – 7.26 (m, 1H), 7.25 – 7.23 (m, 1H), 4.08 – 3.89 (m, 2H), 3.15 (t, *J* = 6.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 143.1, 138.3, 132.0, 129.7, 128.9, 128.7, 127.2, 126.9, 126.2, 125.3, 49.4, 28.6.

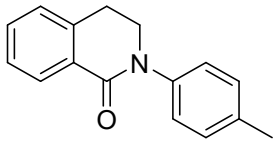


2-(*o*-tolyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4b)[7]
Brown solid (60.7 mg, 72%); mp = 55-57 °C; R_f = 0.37 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.16 (dd, *J* = 7.7, 1.0 Hz, 1H), 7.47 (td, *J* = 7.5, 1.4 Hz, 1H), 7.38 (dd, *J* = 9.4, 4.6 Hz, 1H), 7.30 (t, *J* = 7.8 Hz, 1H), 7.26 – 7.22 (m, 2H), 7.17 (d, *J* = 7.9 Hz, 1H), 7.08 (d, *J* = 7.6 Hz, 1H), 3.99 – 3.95 (m, 2H), 3.14 (t, *J* = 6.5 Hz, 2H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 143.0, 138.8, 138.3, 131.9, 129.7, 128.8, 128.7, 128.2, 127.1, 126.9, 126.2, 122.3, 49.5, 28.6, 21.4. HRMS (ESI): calcd. for $C_{16}H_{16}NO$ $[M + H]^+$ 238.1226, found 238.1233.



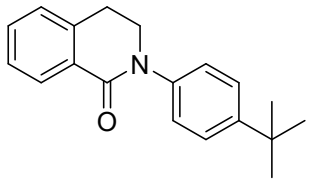
2-(*m*-tolyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4c)[7]
Yellow solid (66.6 mg, 79%); mp = 58-60 °C; R_f = 0.32 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.16 (dd, *J* = 7.7, 1.0 Hz, 1H), 7.47 (td, *J* = 7.4, 1.4 Hz, 1H), 7.38 (t, *J* = 7.1 Hz, 1H), 7.30 (t, *J* = 7.8 Hz, 1H), 7.26 – 7.21 (m, 2H), 7.17 (d, *J* = 7.8 Hz, 1H), 7.08 (d, *J* = 7.6 Hz, 1H), 4.00 – 3.95 (m, 2H), 3.14 (t, *J* = 6.5 Hz, 2H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 143.0,

138.8, 138.3, 132.0, 129.7, 128.8, 128.7, 127.3, 126.9, 126.2, 125.4, 122.3, 49.5, 28.6, 21.4. HRMS (ESI): calcd. for $C_{16}H_{16}NO$ $[M + H]^+$ 238.1226, found 238.1223.



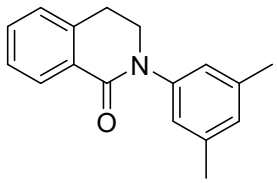
2-(*p*-tolyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4d)[7]

Yellow solid (68.3 mg, 81%); mp = 104-106 °C; R_f = 0.30 (petroleum ether / ethyl acetate = 5:1); ^1H NMR (400 MHz, $CDCl_3$): δ = 8.15 (dd, J = 7.7, 1.1 Hz, 1H), 7.46 (td, J = 7.4, 1.4 Hz, 1H), 7.37 (t, J = 7.0 Hz, 1H), 7.29 (t, J = 6.5 Hz, 2H), 7.23 (t, J = 8.1 Hz, 3H), 3.99 – 3.94 (m, 2H), 3.14 (t, J = 6.5 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 140.5, 138.3, 136.0, 131.9, 129.8, 129.5, 128.7, 127.1, 126.9, 125.2, 49.5, 28.6, 21.0. HRMS (ESI): calcd. for $C_{16}H_{16}NO$ $[M + H]^+$ 238.1226, found 238.1235



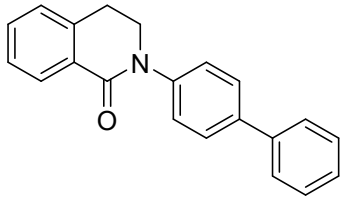
2-(4-(*tert*-butyl)phenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4e)[7]

White solid (46.6 mg, 65%); mp = 135-137 °C; R_f = 0.44 (petroleum ether / ethyl acetate = 5:1); ^1H NMR (400 MHz, $CDCl_3$): δ = 8.17 (dd, J = 7.7, 1.0 Hz, 1H), 7.49 – 7.44 (m, 2H), 7.43 (d, J = 2.1 Hz, 1H), 7.38 (t, J = 7.6 Hz, 1H), 7.34 – 7.31 (m, 2H), 7.24 (d, J = 7.5 Hz, 1H), 4.00 – 3.97 (m, 2H), 3.13 (t, J = 6.5 Hz, 2H), 1.34 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.1, 149.0, 140.3, 138.2, 131.9, 129.7, 128.6, 127.1, 126.8, 125.8, 124.6, 49.3, 34.4, 31.3, 28.5. HRMS (ESI): calcd. for $C_{19}H_{22}NO$ $[M + H]^+$ 280.1696, found 280.1708.



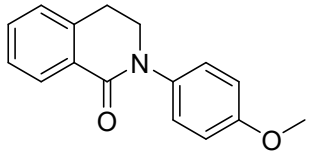
2-(3,5-dimethylphenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4f)

Yellow solid (49.4 mg, 62%); mp = 93-95 °C; R_f = 0.30 (petroleum ether / ethyl acetate = 5:1); ^1H NMR (400 MHz, $CDCl_3$): δ = 8.15 (d, J = 7.0 Hz, 1H), 7.46 (td, J = 7.4, 1.3 Hz, 1H), 7.37 (t, J = 7.3 Hz, 1H), 7.24 (d, J = 7.5 Hz, 1H), 7.00 (s, 2H), 6.91 (s, 1H), 3.95 (t, J = 6.5 Hz, 2H), 3.13 (t, J = 6.5 Hz, 2H), 2.34 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.3, 143.0, 138.6, 138.3, 131.9, 129.3, 128.7, 128.2, 127.1, 126.9, 123.2, 49.6, 28.6, 21.3. HRMS (ESI): calcd. for $C_{17}H_{18}NO$ $[M + H]^+$ 252.1383, found 252.1379.



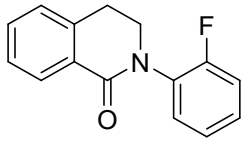
2-([1,1'-biphenyl]-4-yl)-3,4-dihydroisoquinolin-1(2*H*)-one (4g)[8]

Yellow solid (40.1 mg, 60%); mp = 168-170 °C; R_f = 0.57 (petroleum ether / ethyl acetate = 3:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.18 (dd, J = 7.7, 1.1 Hz, 1H), 7.66 – 7.59 (m, 4H), 7.50 – 7.43 (m, 5H), 7.37 (ddd, J = 10.2, 7.3, 4.3 Hz, 2H), 7.27 (s, 1H), 4.08 – 4.02 (m, 2H), 3.18 (t, J = 6.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.3, 142.3, 140.6, 139.1, 138.3, 132.1, 129.7, 128.8, 127.6, 127.3, 127.2, 127.1, 127.0, 125.5, 49.4, 28.6. HRMS (ESI): calcd. for $C_{21}H_{18}NO$ $[M + H]^+$ 300.1383, found 300.1383.



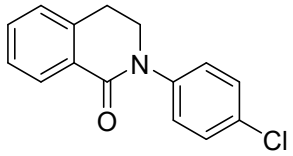
2-(4-methoxyphenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4h)[8]

Yellow solid (55.3 mg, 70%); mp = 121-123 °C; R_f = 0.32 (petroleum ether / ethyl acetate = 3:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.15 (dd, J = 7.7, 1.1 Hz, 1H), 7.45 (td, J = 7.4, 1.4 Hz, 1H), 7.38 – 7.34 (m, 1H), 7.31 – 7.27 (m, 2H), 7.22 (d, J = 7.5 Hz, 1H), 6.95 – 6.91 (m, 2H), 3.95 – 3.90 (m, 2H), 3.81 (s, 3H), 3.12 (t, J = 6.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 157.7, 138.2, 136.0, 131.8, 129.6, 128.5, 127.0, 126.8, 126.5, 114.1, 55.4, 49.6, 28.5. HRMS (ESI): calcd. for $C_{16}H_{16}NO_2$ $[M + H]^+$ 254.1176, found 254.1169.



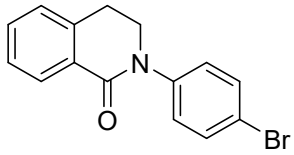
2-(2-fluorophenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4i)[8]

Yellow solid (53.1 mg, 64%); mp = 68-70 °C; R_f = 0.35 (petroleum ether / ethyl acetate =5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.15 (dd, J = 7.7, 0.8 Hz, 1H), 7.48 (td, J = 7.4, 1.3 Hz, 1H), 7.41 – 7.33 (m, 2H), 7.23 (d, J = 6.5 Hz, 1H), 7.20 – 7.14 (m, 2H), 6.98 – 6.93 (m, 1H), 3.99 (t, J = 6.5 Hz, 2H), 3.15 (t, J = 6.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.1, 162.6 (d, J = 245 Hz), 144.4 (d, J = 10 Hz), 138.2, 132.2, 129.8 (d, J = 9 Hz), 129.4, 128.8, 127.2, 127.0, 120.6 (d, J = 3 Hz), 113.0 (d, J = 21 Hz), 112.7 (d, J = 24 Hz), 49.2, 28.5. HRMS (ESI): calcd. for $C_{15}H_{13}FNO$ $[M + H]^+$ 242.0976, found 242.0976.



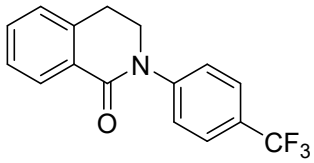
2-(4-chlorophenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4j)[7]

White solid (55.2 mg, 71%); mp = 149-151 °C; R_f = 0.43 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.14 (dd, J = 7.7, 1.1 Hz, 1H), 7.48 (td, J = 7.5, 1.4 Hz, 1H), 7.41 – 7.38 (m, 1H), 7.35 (ddd, J = 9.0, 5.6, 2.4 Hz, 4H), 7.24 (s, 1H), 4.03 – 3.89 (m, 2H), 3.15 (t, J = 6.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 141.5, 138.2, 132.2, 131.6, 129.4, 129.0, 128.8, 127.3, 127.0, 126.5, 49.3, 28.5.



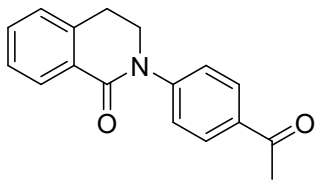
2-(4-bromophenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4k)[7]

Yellow solid (41.2 mg, 62%); mp = 162-164 °C; R_f = 0.43 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.14 (dd, J = 7.7, 1.0 Hz, 1H), 7.55 – 7.51 (m, 2H), 7.48 (td, J = 7.5, 1.4 Hz, 1H), 7.38 (t, J = 7.3 Hz, 1H), 7.30 – 7.27 (m, 2H), 7.24 (s, 1H), 3.99 – 3.95 (m, 2H), 3.15 (t, J = 6.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.1, 142.1, 138.2, 132.2, 131.9, 129.4, 128.8, 127.3, 127.0, 126.9, 119.4, 49.2, 28.5. HRMS (ESI): calcd. for $C_{15}H_{13}BrNO$ $[M + H]^+$ 302.0175, found 302.0176.



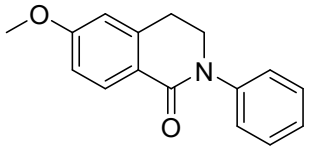
2-(4-(trifluoromethyl)phenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4l)[7]

Yellow solid (34.4 mg, 50%); mp = 165-167 °C; R_f = 0.47 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.18 – 8.14 (m, 1H), 7.67 (d, J = 8.5 Hz, 2H), 7.51 (ddd, J = 9.6, 8.8, 4.9 Hz, 3H), 7.40 (t, J = 7.4 Hz, 1H), 7.27 (s, 1H), 4.06 – 4.01 (m, 2H), 3.17 (t, J = 6.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 146.1, 138.2, 132.4, 129.3, 128.9, 127.9 (q, J = 32 Hz), 127.4, 127.0, 125.9 (q, J = 4 Hz), 125.1, 124.0 (q, J = 247 Hz), 49.1, 28.5. HRMS (ESI): calcd. for $C_{16}H_{13}F_3NO$ $[M + H]^+$ 292.0944, found 292.0949.



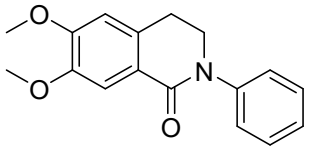
2-(4-acetylphenyl)-3,4-dihydroisoquinolin-1(2*H*)-one (4m)[7]

Yellow solid (22.8 mg, 43%); mp = 156-158 °C; R_f = 0.40 (petroleum ether / ethyl acetate = 2:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.16 (d, J = 7.7 Hz, 1H), 8.03 – 7.98 (m, 2H), 7.54 – 7.46 (m, 3H), 7.39 (t, J = 7.5 Hz, 1H), 7.25 (d, J = 6.8, 1H), 4.05 (t, J = 6.4 Hz, 2H), 3.17 (t, J = 6.4 Hz, 2H), 2.61 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 197.1, 164.1, 147.2, 138.2, 134.4, 132.4, 129.3, 129.0, 128.9, 127.3, 127.0, 124.6, 49.0, 28.5, 26.5.



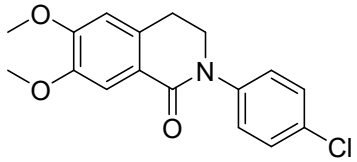
6-methoxy-2-phenyl-3,4-dihydroisoquinolin-1(2*H*)-one (4n)[9]

White solid (55.3 mg, 70%); mp = 140-142 °C; R_f = 0.33 (petroleum ether / ethyl acetate = 3:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.10 (d, J = 8.7 Hz, 1H), 7.43 – 7.36 (m, 4H), 7.26 – 7.20 (m, 1H), 6.88 (dd, J = 8.7, 2.5 Hz, 1H), 6.72 (d, J = 2.5 Hz, 1H), 3.98 (t, J = 6.5 Hz, 2H), 3.87 (s, 3H), 3.10 (t, J = 6.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 162.5, 143.2, 140.4, 130.9, 128.8, 126.0, 125.3, 122.5, 112.7, 111.9, 55.4, 49.3, 29.0. HRMS (ESI): calcd. for $C_{16}H_{16}NO_2$ $[M + H]^+$ 254.1176, found 254.1174.



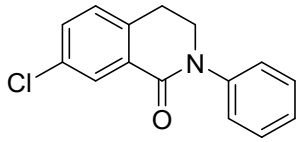
6,7-dimethoxy-2-phenyl-3,4-dihydroisoquinolin-1(2*H*)-one (4o)[8]

Yellow solid (41.0 mg, 58%); mp = 163-165 °C; R_f = 0.51 (petroleum ether / ethyl acetate = 1:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.66 (s, 1H), 7.43 – 7.41 (m, 1H), 7.39 – 7.36 (m, 3H), 7.26 – 7.22 (m, 1H), 6.69 (s, 1H), 4.00 – 3.96 (m, 2H), 3.95 (s, 3H), 3.93 (s, 3H), 3.07 (t, J = 6.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 152.2, 148.1, 143.3, 132.1, 128.8, 126.1, 125.3, 122.2, 110.9, 109.2, 56.1, 49.6, 28.2. HRMS (ESI): calcd. for $C_{17}H_{18}NO_3$ $[M + H]^+$ 284.1281, found 284.1289.



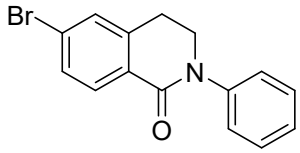
2-(4-chlorophenyl)-6,7-dimethoxy-3,4-dihydroisoquinolin-1(2*H*)-one (4p)[7]

Yellow solid (34.1 mg, 54%); mp = 170-172 °C; R_f = 0.33 (petroleum ether / ethyl acetate = 2:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.63 (s, 1H), 7.37 – 7.34 (m, 2H), 7.32 – 7.29 (m, 2H), 6.68 (s, 1H), 4.01 – 3.94 (m, 2H), 3.94 (s, 3H), 3.92 (s, 3H), 3.06 (t, J = 6.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.2, 152.3, 148.1, 141.7, 132.1, 131.3, 128.8, 126.5, 121.8, 110.8, 109.2, 56.1, 49.5, 28.1. HRMS (ESI): calcd. for $C_{17}H_{17}ClNO_3$ $[M + H]^+$ 318.0891, found 318.0892.



7-chloro-2-phenyl-3,4-dihydroisoquinolin-1(2*H*)-one (4q)[10]

Yellow solid (62.2 mg, 80%); mp = 115-117 °C; R_f = 0.40 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.12 (d, J = 2.2 Hz, 1H), 7.44 – 7.39 (m, 3H), 7.38 – 7.35 (m, 2H), 7.28 – 7.26 (m, 1H), 7.19 (d, J = 8.1 Hz, 1H), 3.99 – 3.95 (m, 2H), 3.10 (t, J = 6.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.9, 142.7, 136.5, 133.1, 131.9, 131.2, 128.9, 128.5, 128.4, 126.4, 125.2, 49.2, 28.0.



6-bromo-2-phenyl-3,4-dihydroisoquinolin-1(2*H*)-one (4r)[10]

Yellow solid (31.2 mg, 47%); mp = 172-174 °C; R_f = 0.37 (petroleum ether / ethyl acetate = 5:1); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.01 (d, J = 8.3 Hz, 1H), 7.53 – 7.49 (m, 1H), 7.44 – 7.40 (m, 3H), 7.38 – 7.35 (m, 2H), 7.28 (dd, J = 5.0, 3.6 Hz, 1H), 4.01 – 3.97 (m, 2H), 3.13 (t, J = 6.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 163.5, 142.8, 140.1, 130.6, 130.5, 129.9, 129.0, 128.6, 126.7, 126.5, 125.3, 49.2, 28.4.

F. Reference

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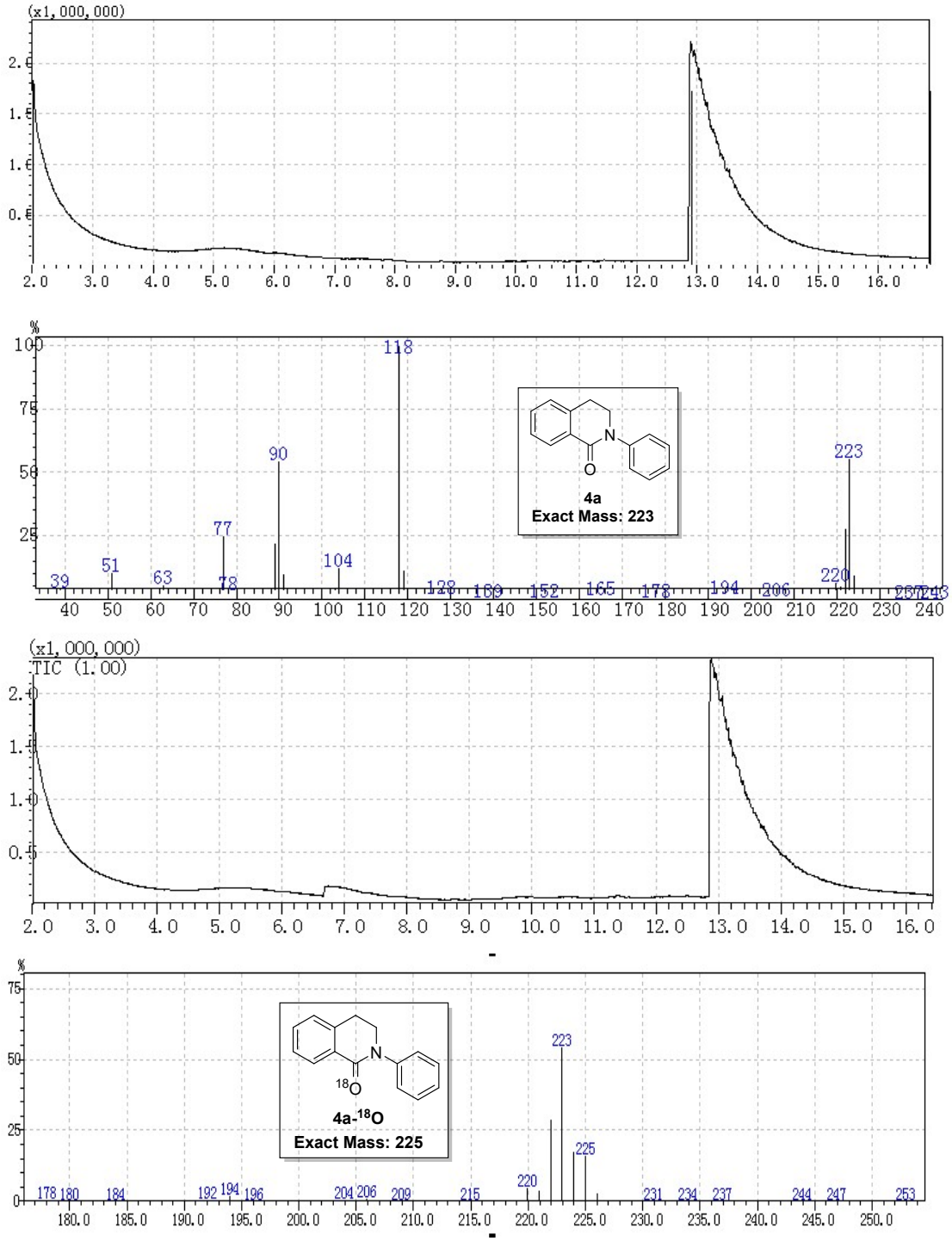
G. GC-MS spectra of 3a and 3a-O^{18}



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

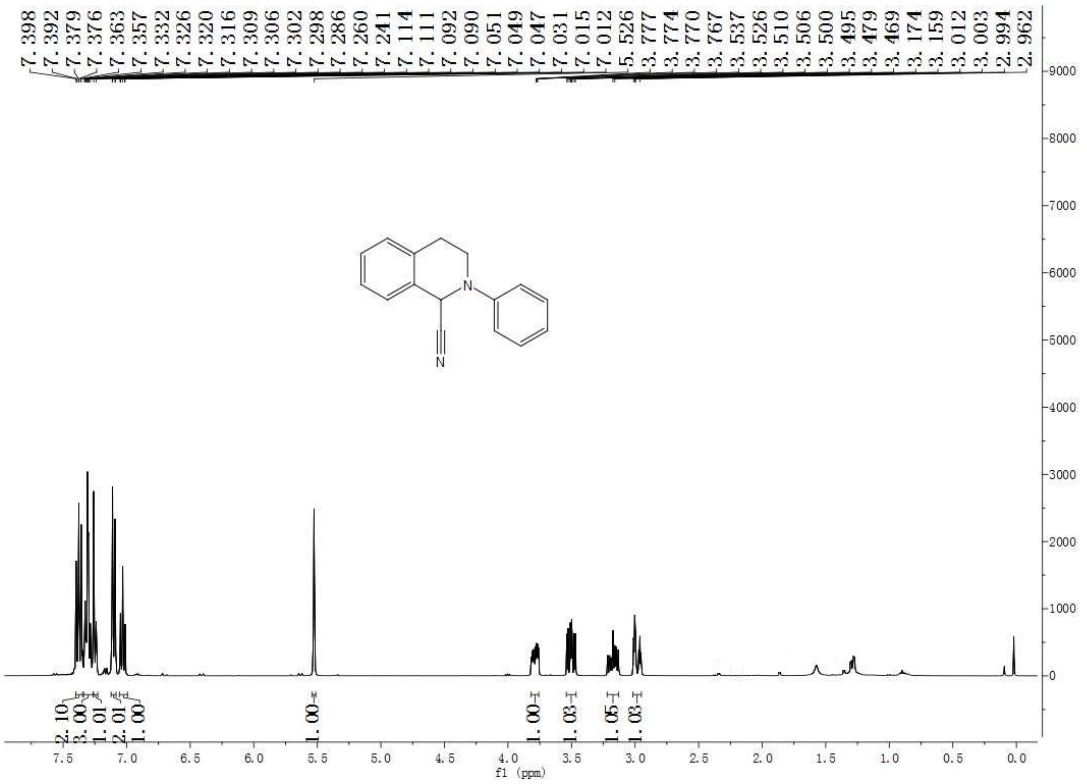


Figure S1. ^{1}H NMR Spectrum of 3a (400 MHz, $CDCl_3$)

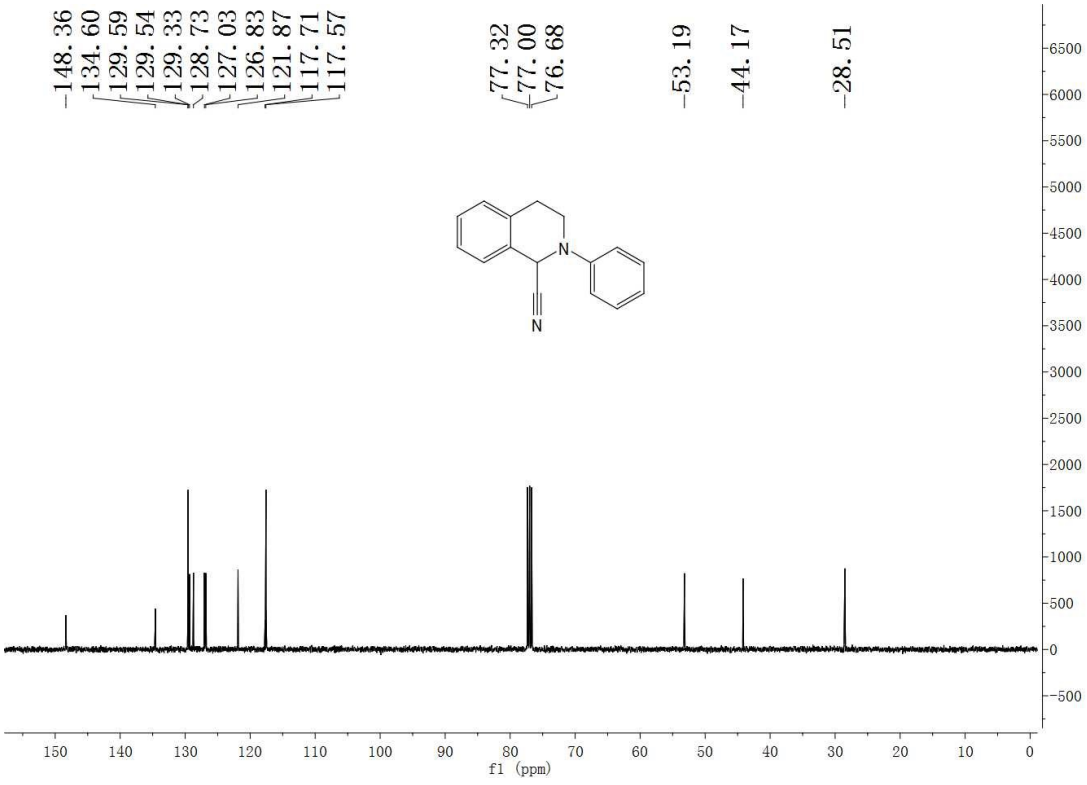


Figure S2. ^{13}C NMR Spectrum of 3a (100 MHz, $CDCl_3$)

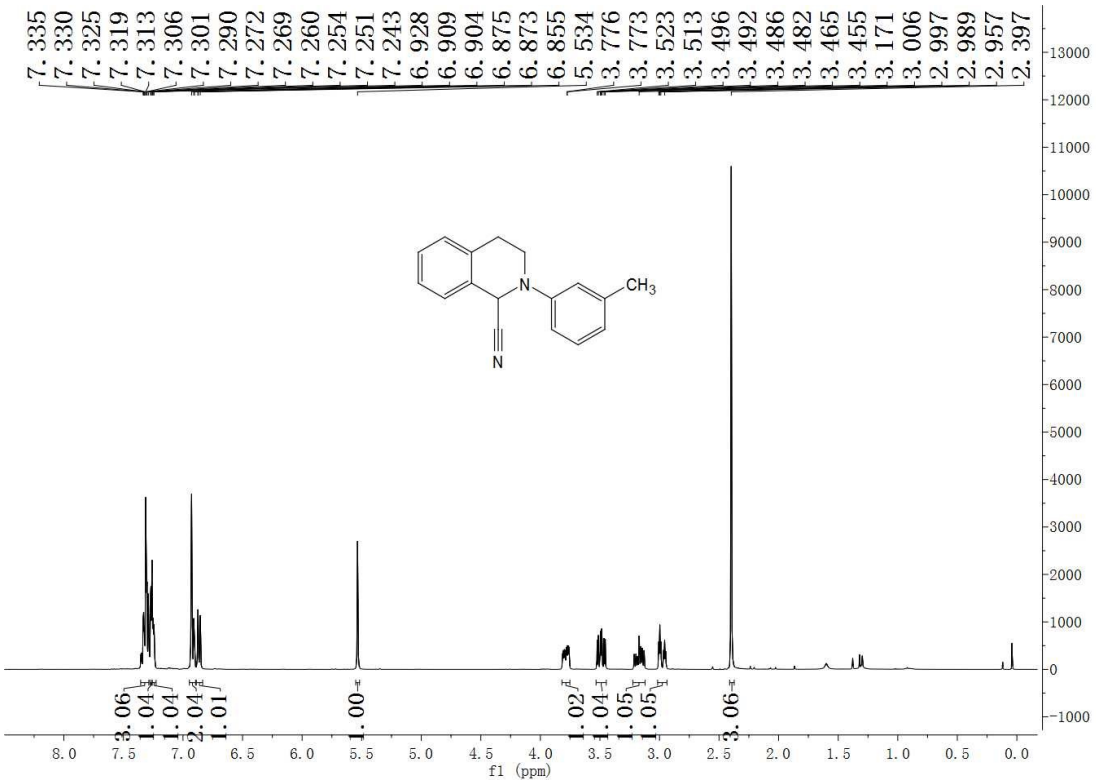


Figure S3. ^{1}H NMR Spectrum of 3b (400 MHz, $CDCl_3$)

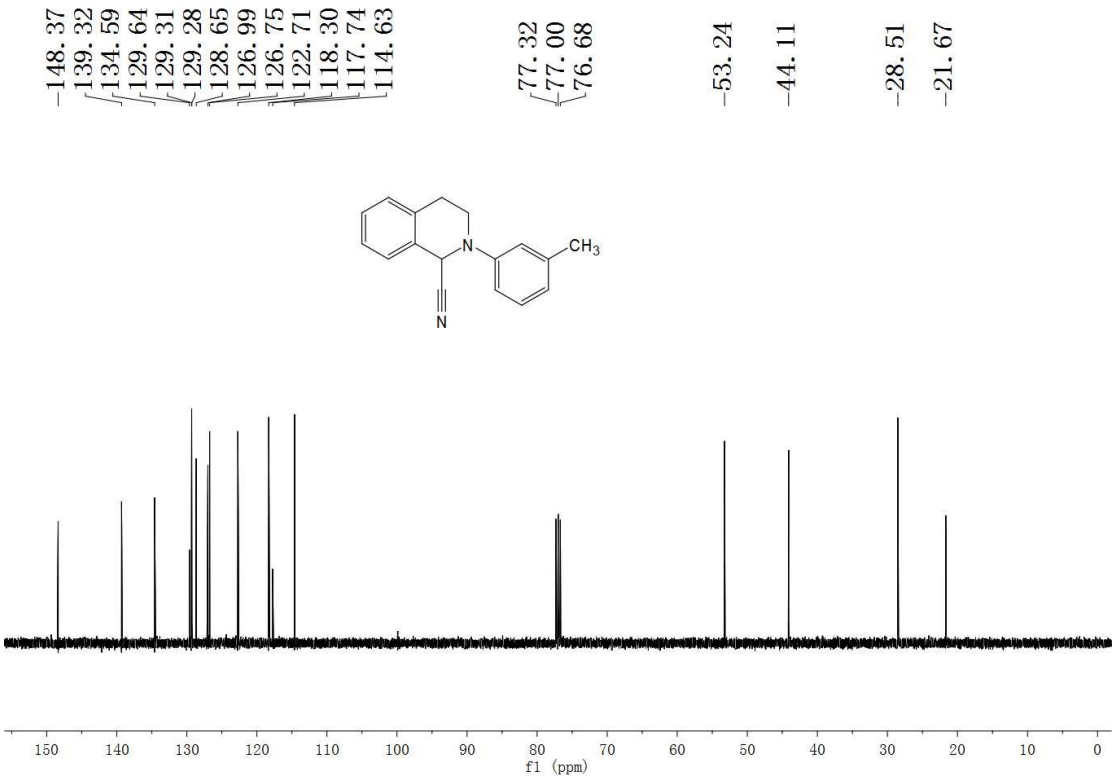


Figure S4. ^{13}C NMR Spectrum of 3b (100 MHz, $CDCl_3$)

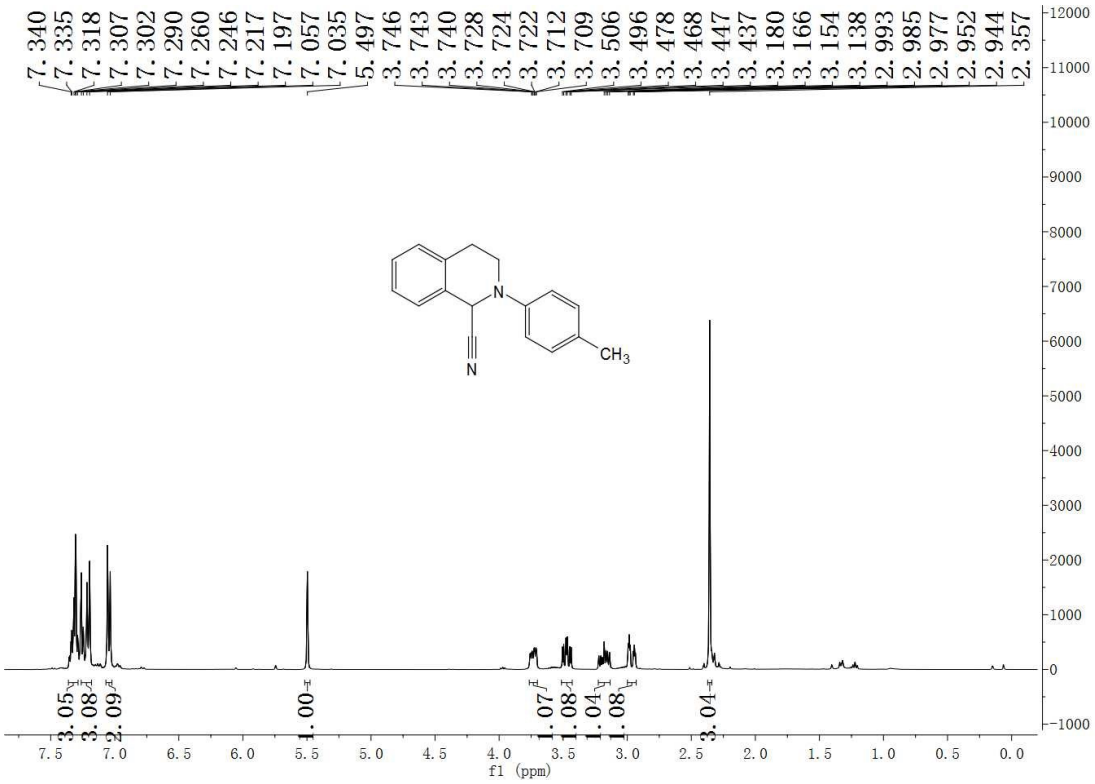


Figure S5. ^{1}H NMR Spectrum of 3c (400 MHz, $CDCl_3$)

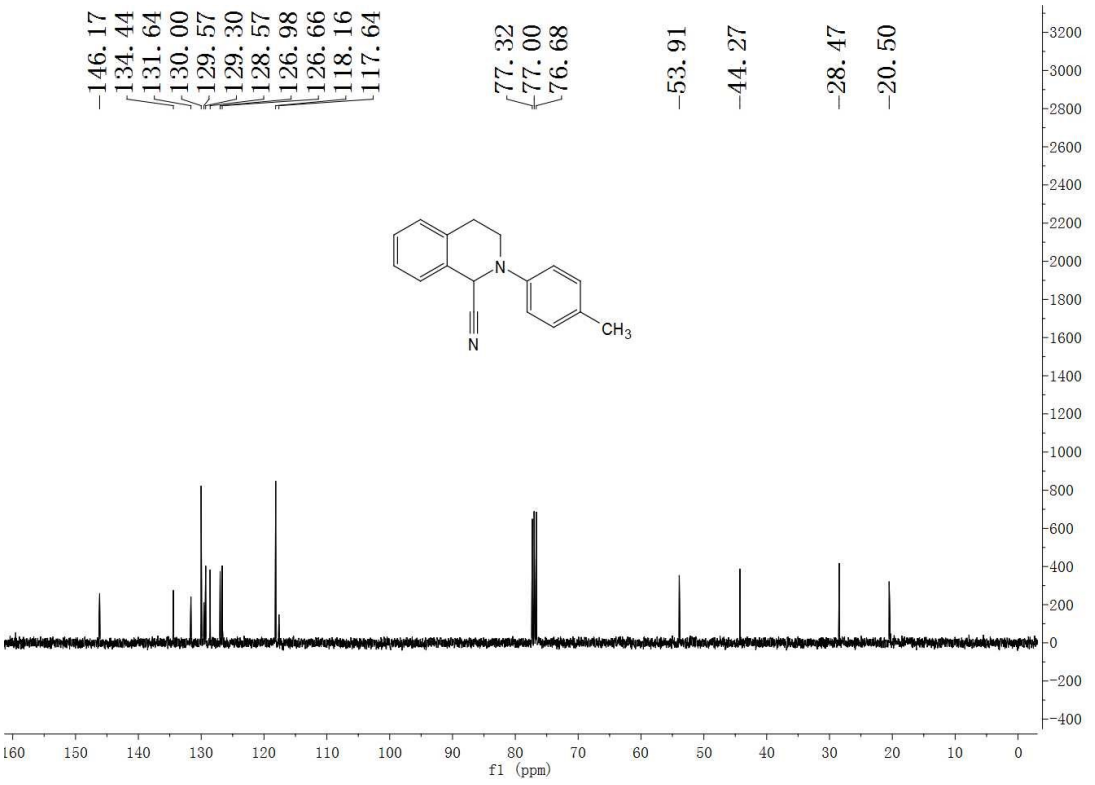


Figure S6. ^{13}C NMR Spectrum of 3c (100 MHz, $CDCl_3$)

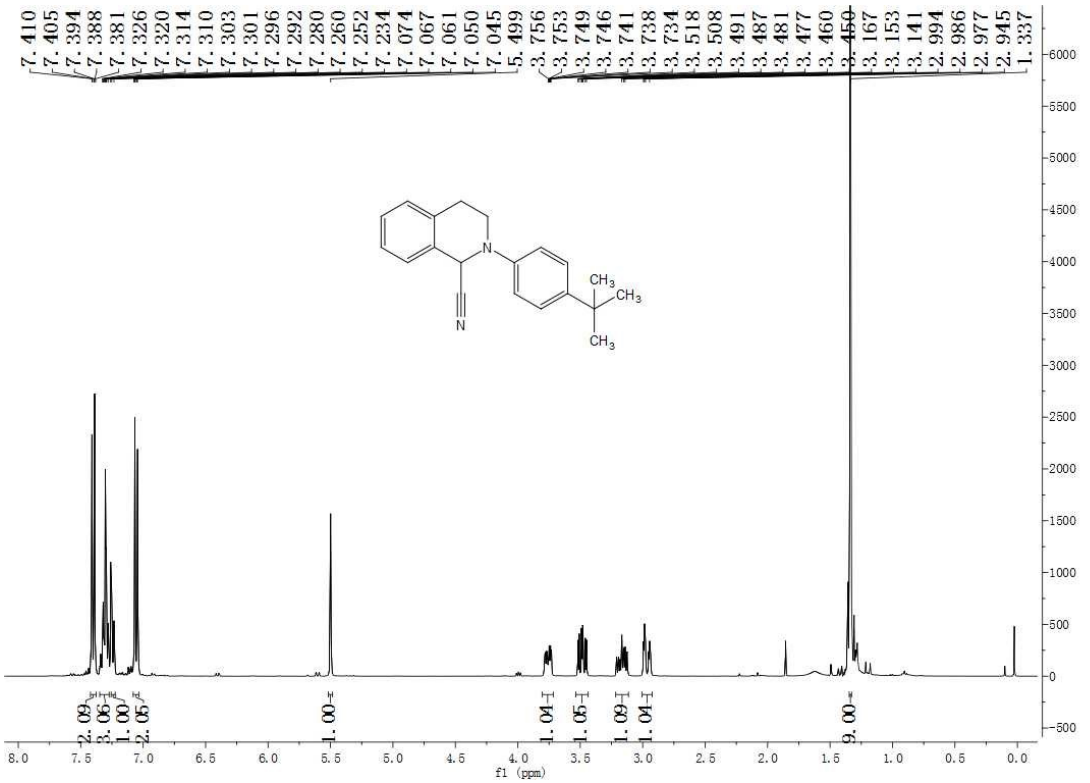


Figure S7. ^{1}H NMR Spectrum of 3d (400 MHz, $CDCl_3$)

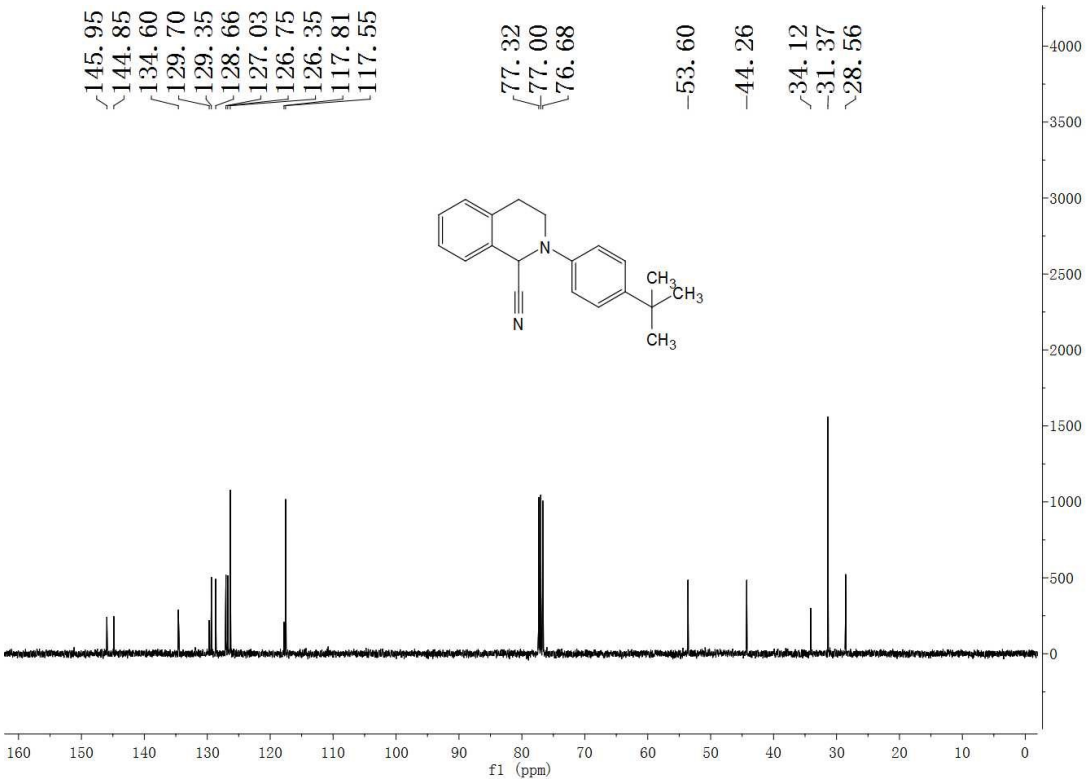


Figure S8. ^{13}C NMR Spectrum of 3d (100 MHz, $CDCl_3$)

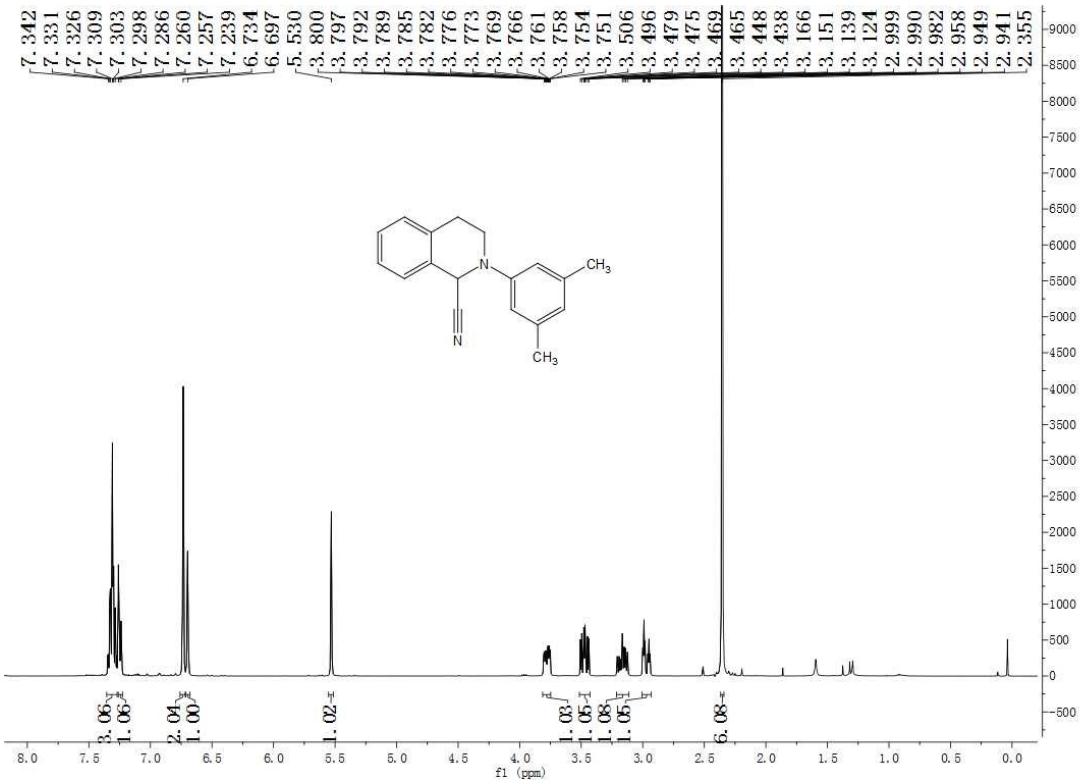


Figure S9. ^{1}H NMR Spectrum of 3e (400 MHz, $CDCl_3$)

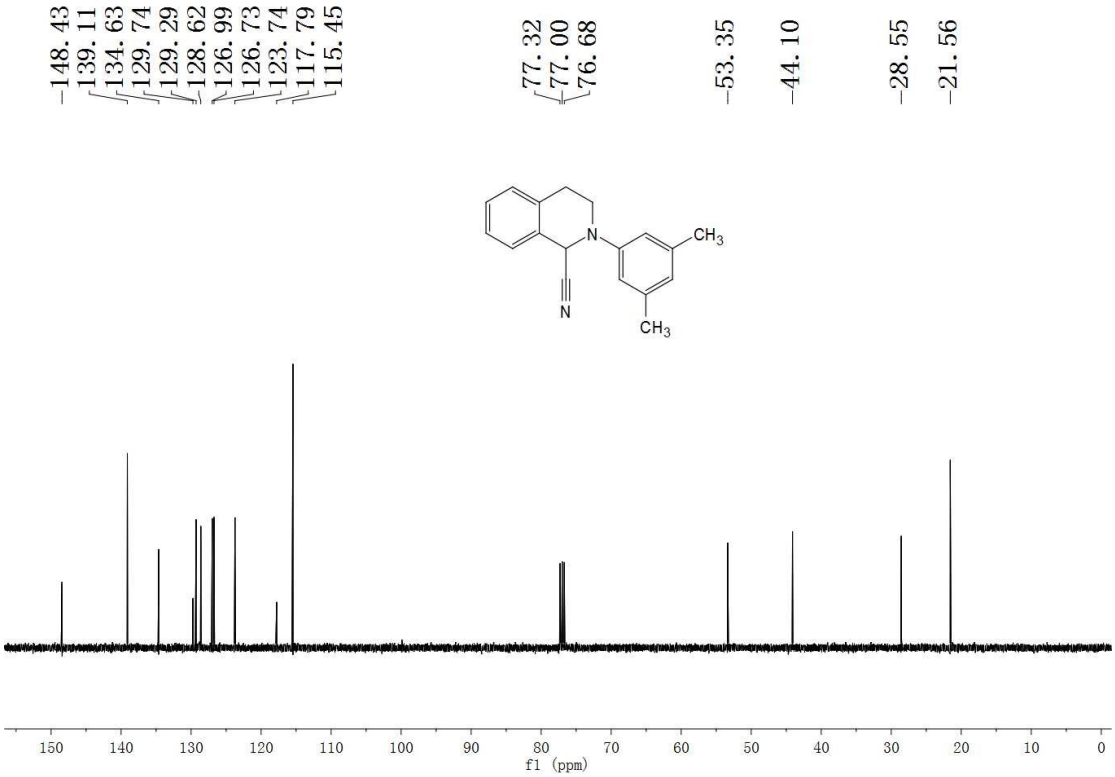


Figure S10. ^{13}C NMR Spectrum of 3e (100 MHz, $CDCl_3$)

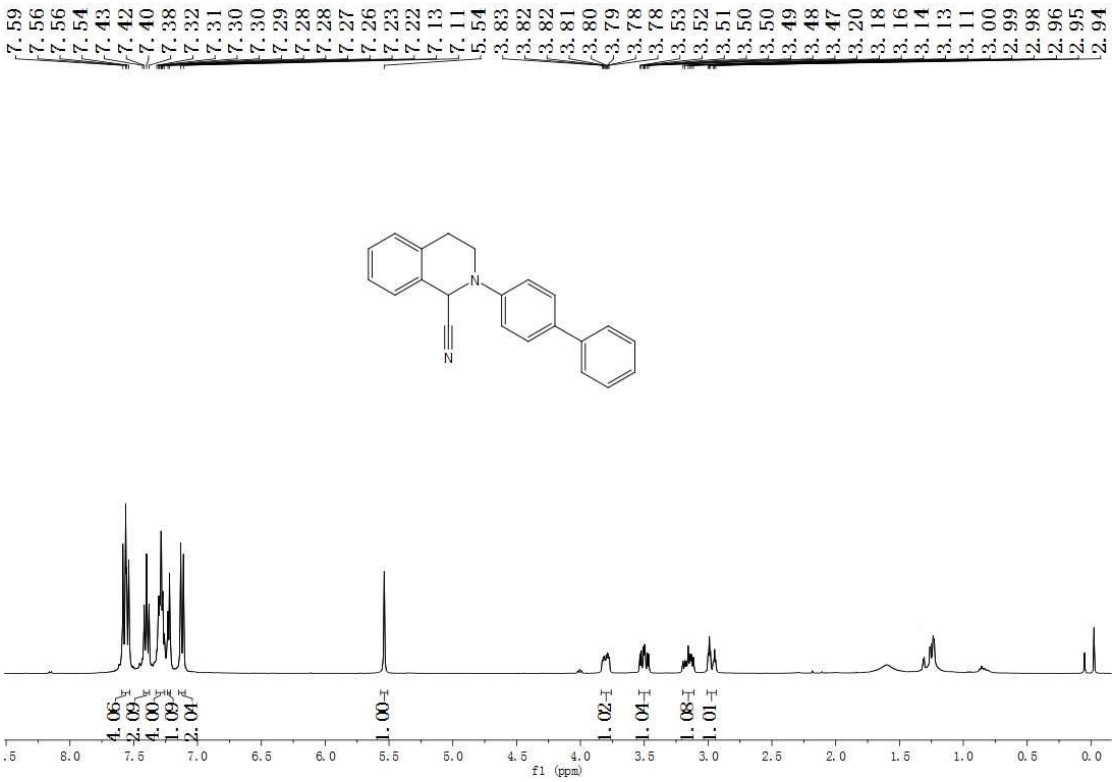


Figure S11. ^{1}H NMR Spectrum of 3f (400 MHz, $CDCl_3$)

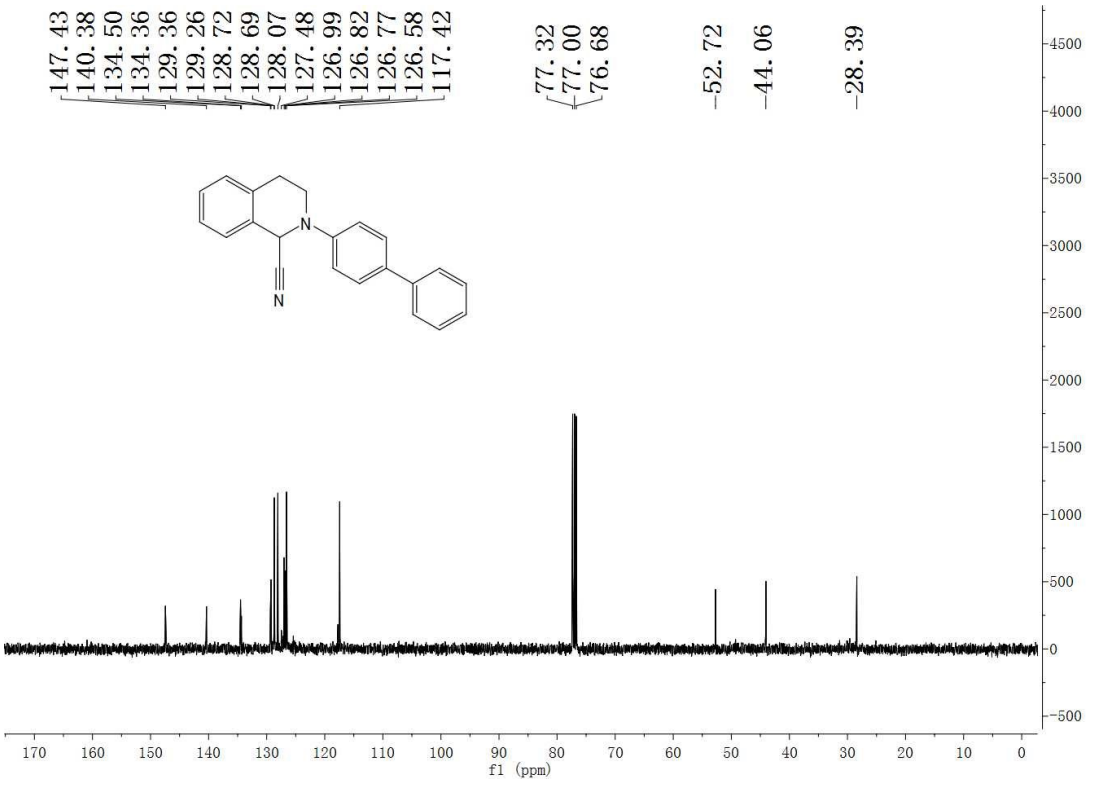


Figure S12. ^{13}C NMR Spectrum of 3f (100 MHz, $CDCl_3$)

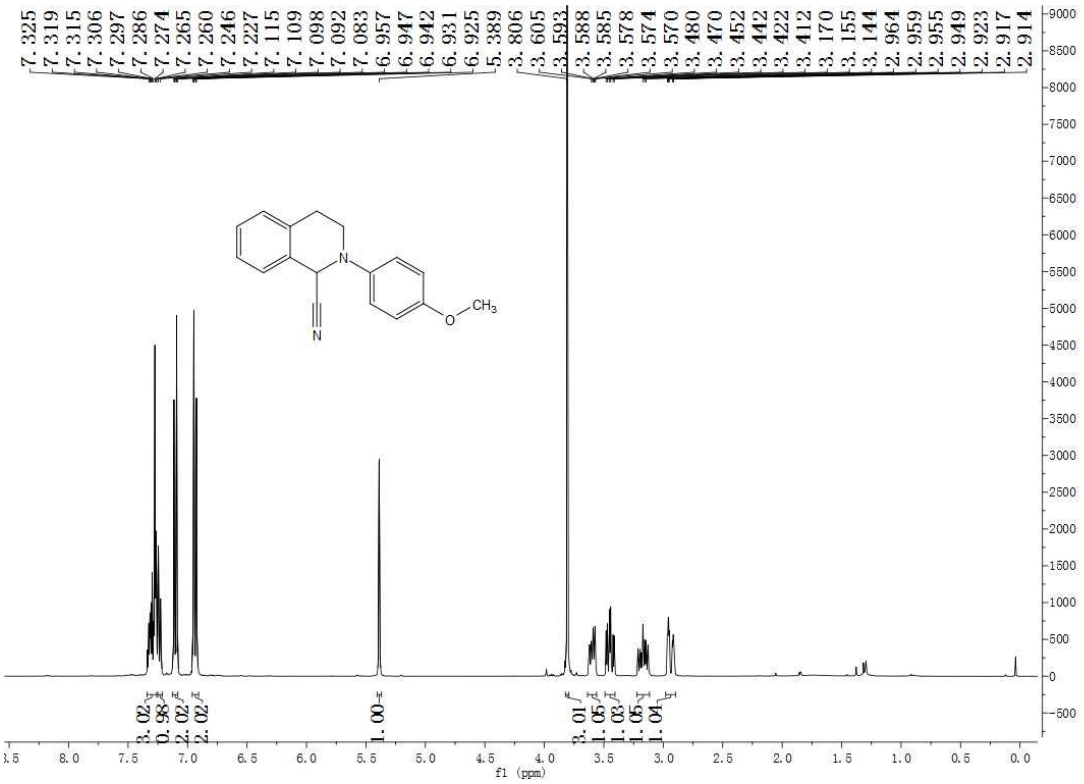


Figure S13. ^{1}H NMR Spectrum of 3g (400 MHz, $CDCl_3$)

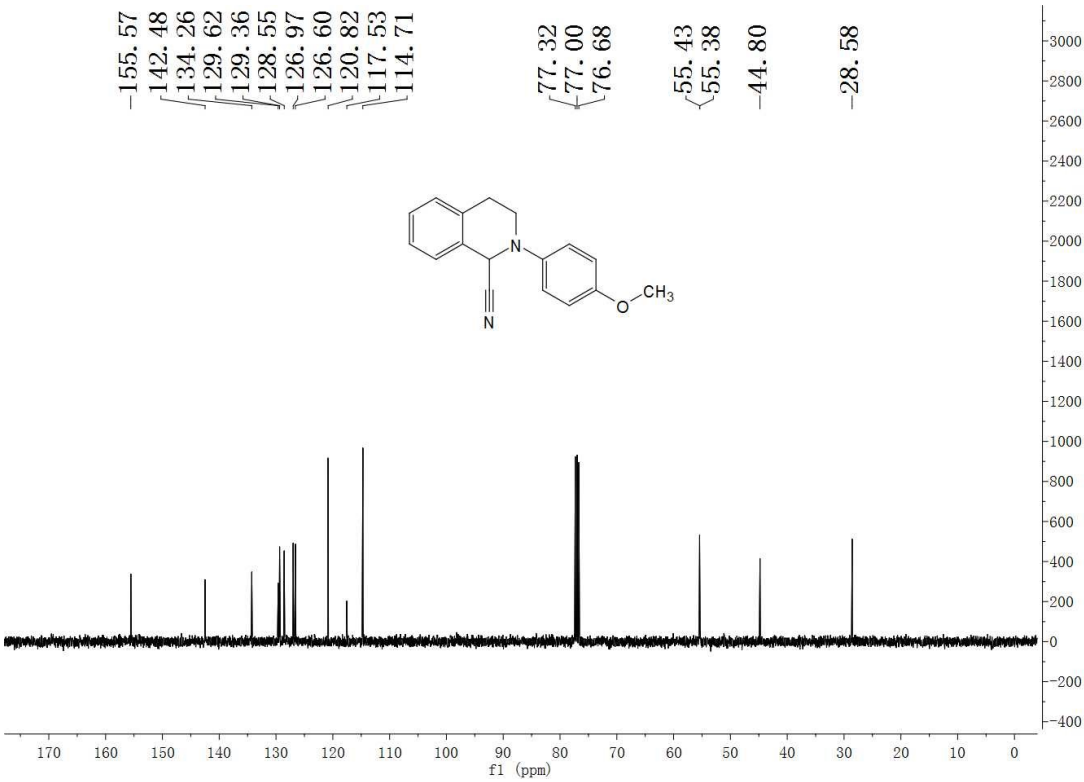


Figure S14. ^{13}C NMR Spectrum of 3g (100 MHz, $CDCl_3$)

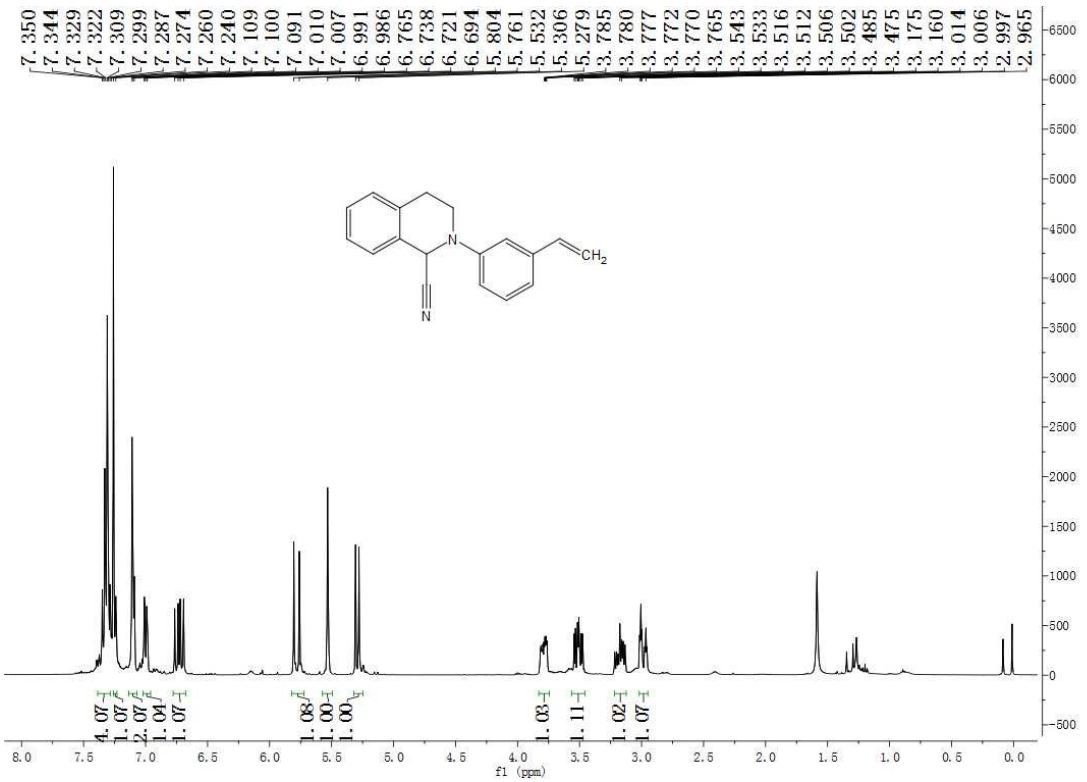


Figure S15. ^{1}H NMR Spectrum of 3h (400 MHz, $CDCl_3$)

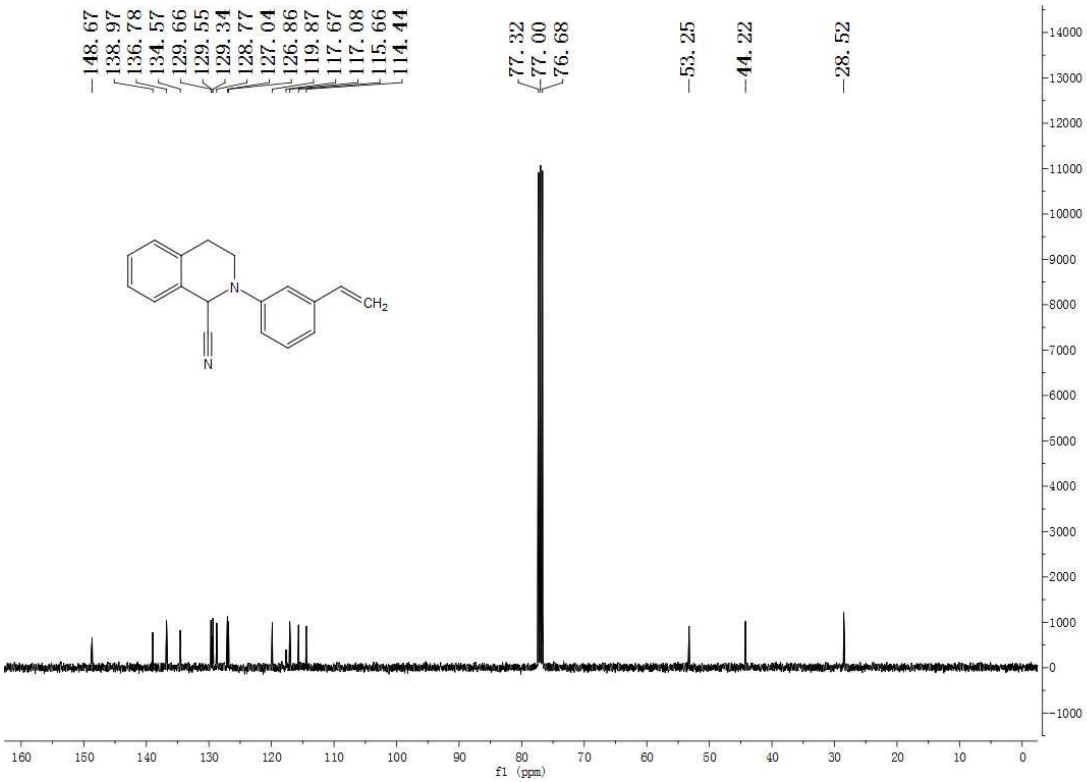


Figure S16. ^{13}C NMR Spectrum of 3h (100 MHz, $CDCl_3$)

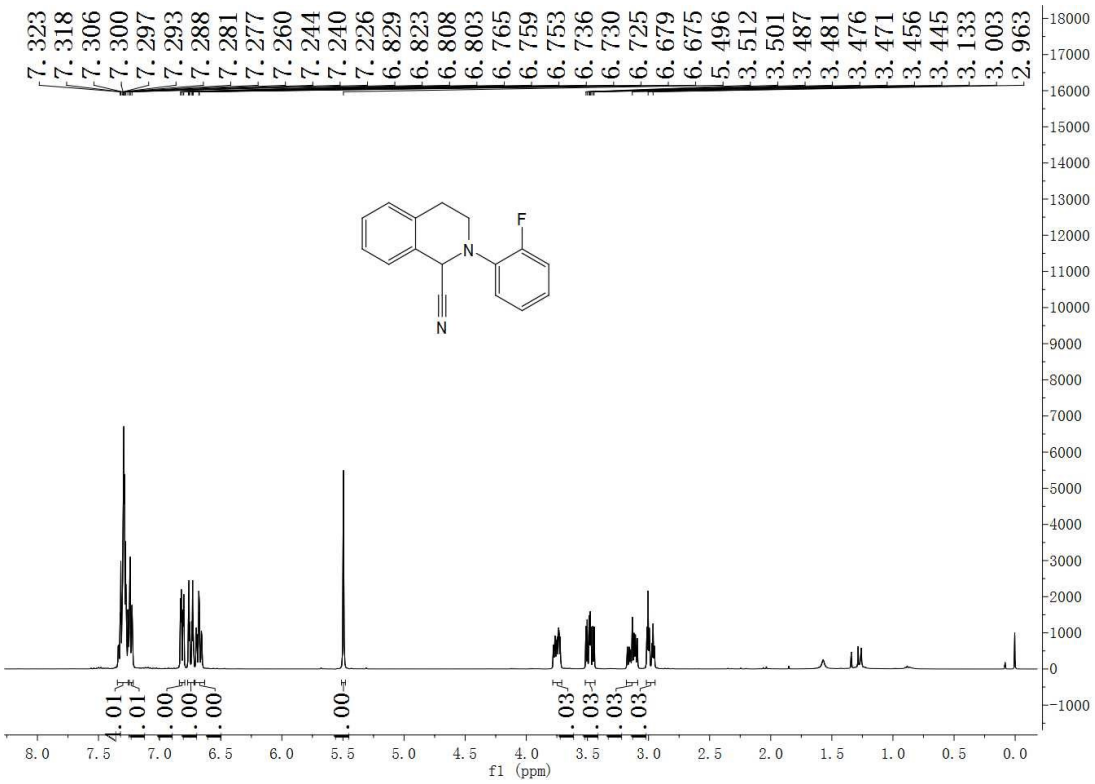


Figure S17. ^{1}H NMR Spectrum of 3i (400 MHz, $CDCl_3$)

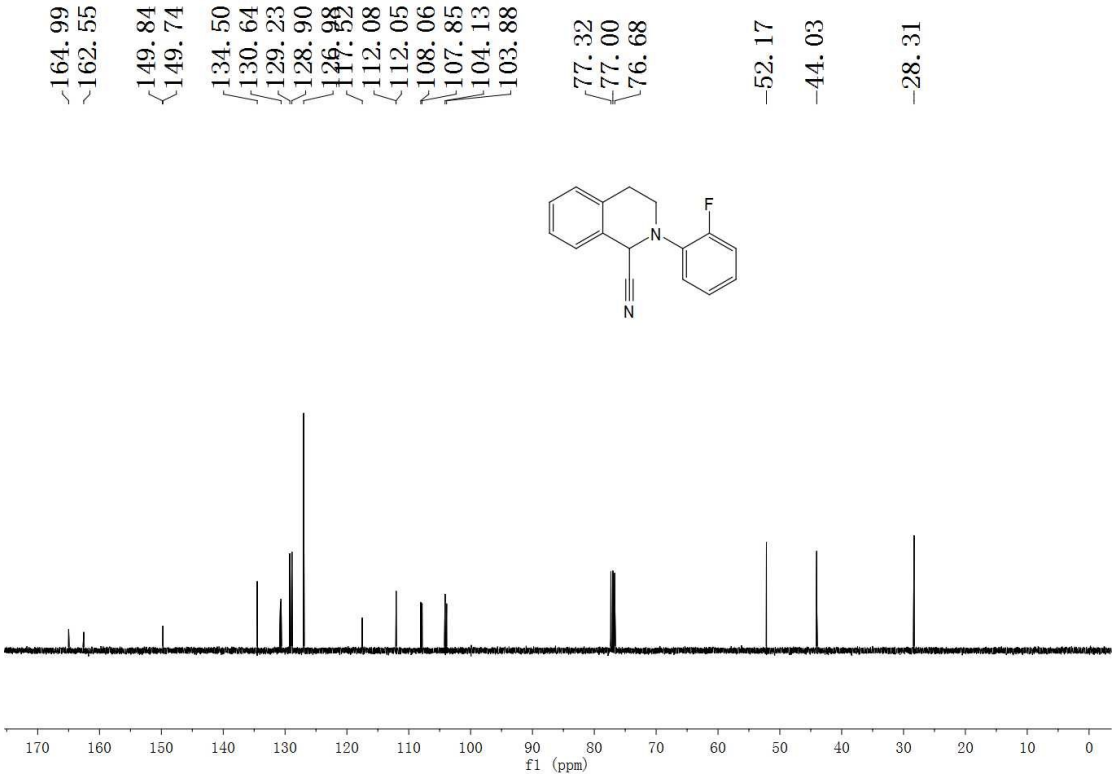


Figure S18. ^{13}C NMR Spectrum of 3i (100 MHz, $CDCl_3$)

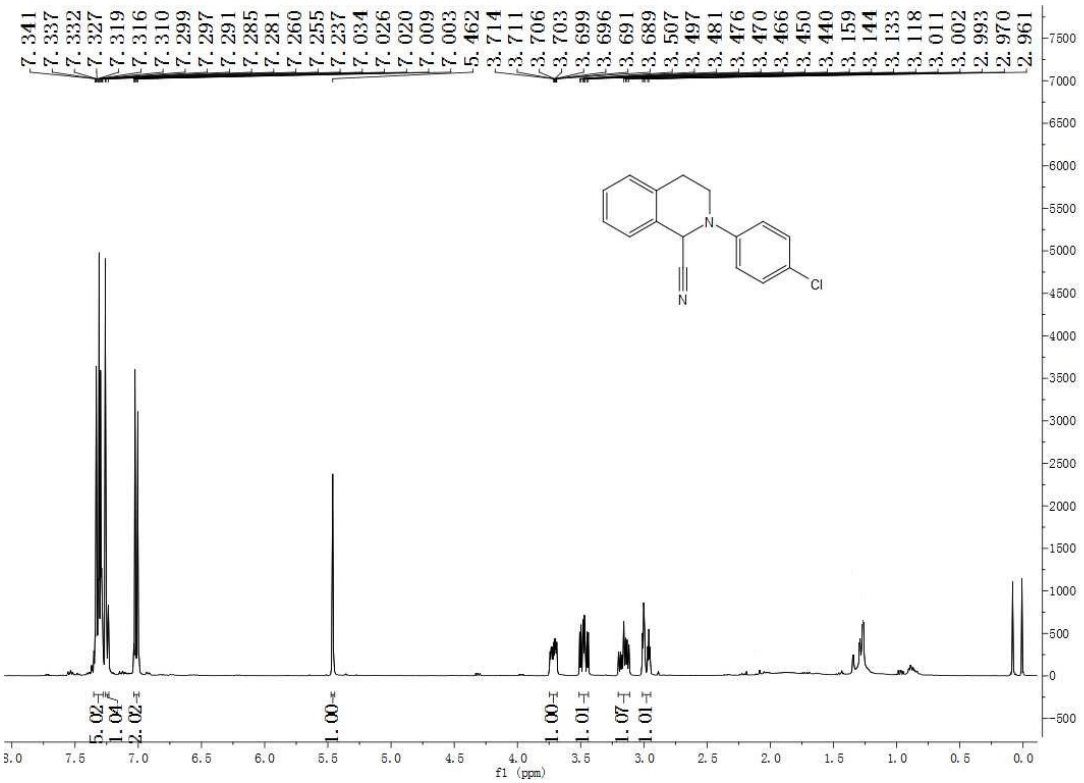


Figure S19. ^{1}H NMR Spectrum of 3j (400 MHz, $CDCl_3$)

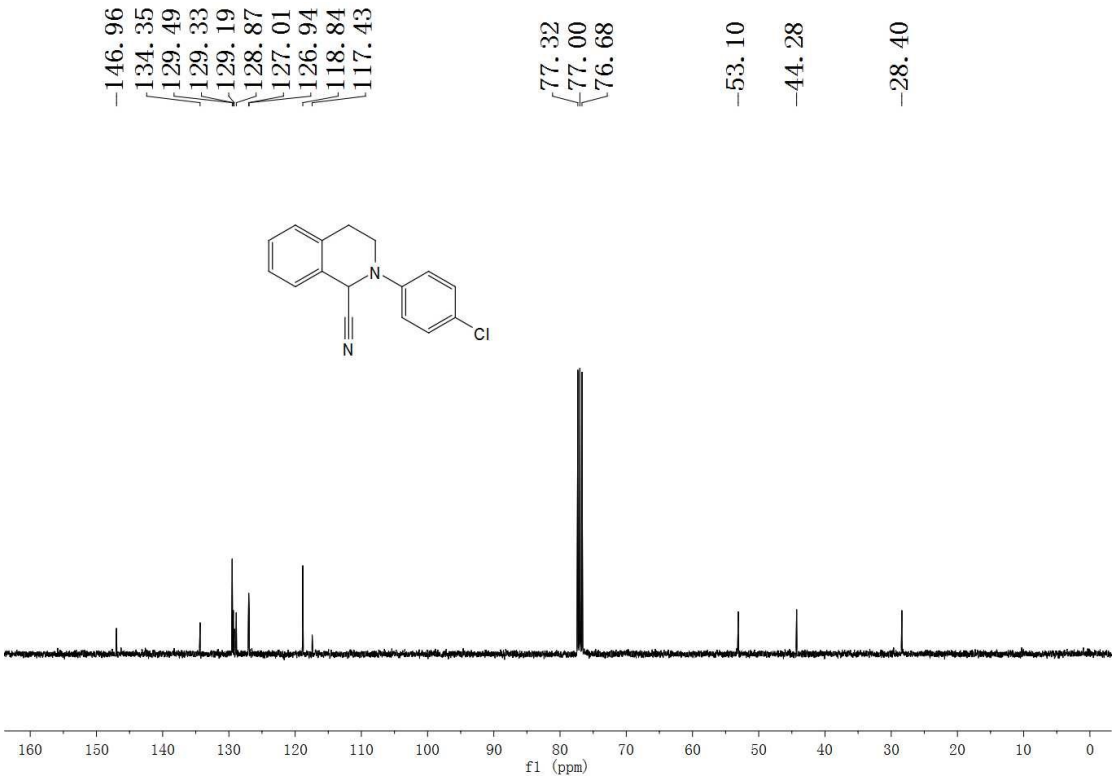


Figure S20. ^{13}C NMR Spectrum of 3j (100 MHz, $CDCl_3$)

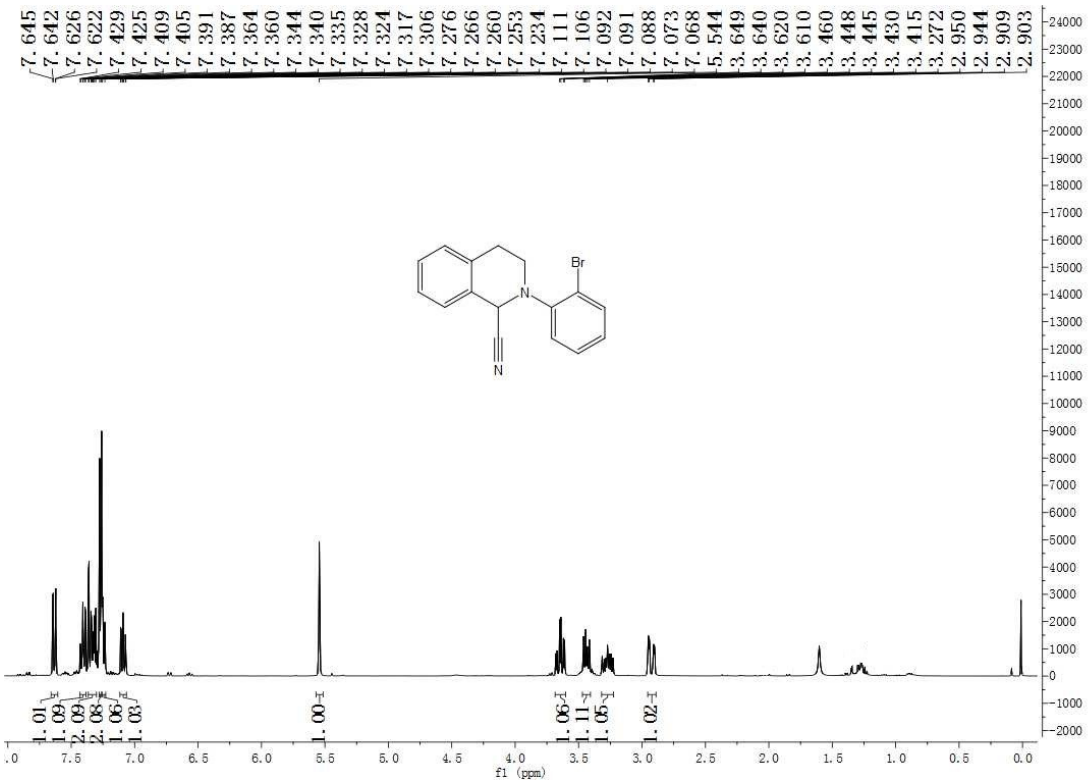


Figure S21. ^{1}H NMR Spectrum of 3k (400 MHz, $CDCl_3$)

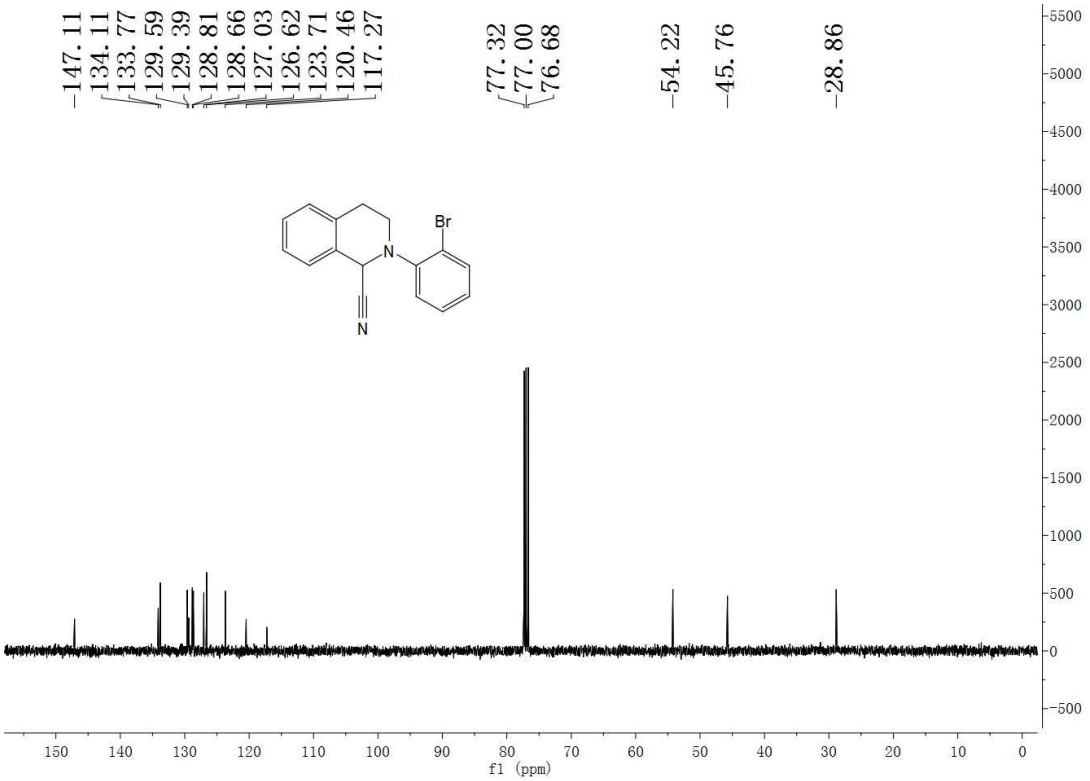


Figure S22. ^{13}C NMR Spectrum of 3k (100 MHz, $CDCl_3$)

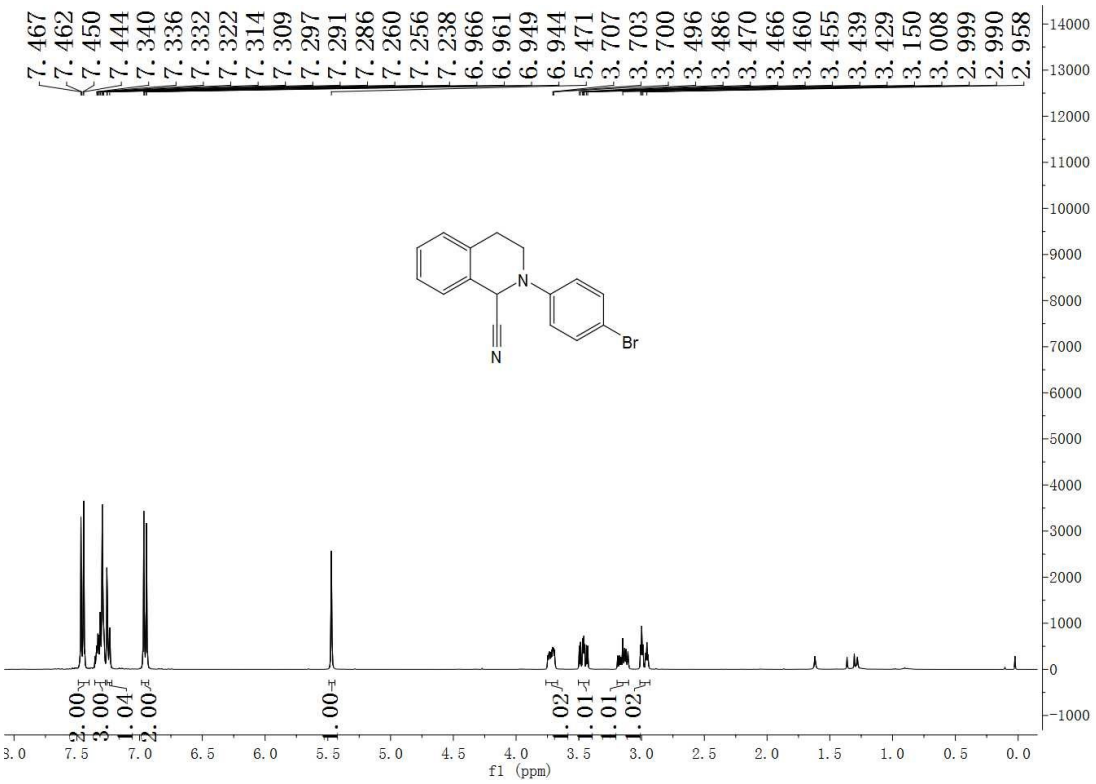


Figure S23. ^{1}H NMR Spectrum of 3l (400 MHz, $CDCl_3$)

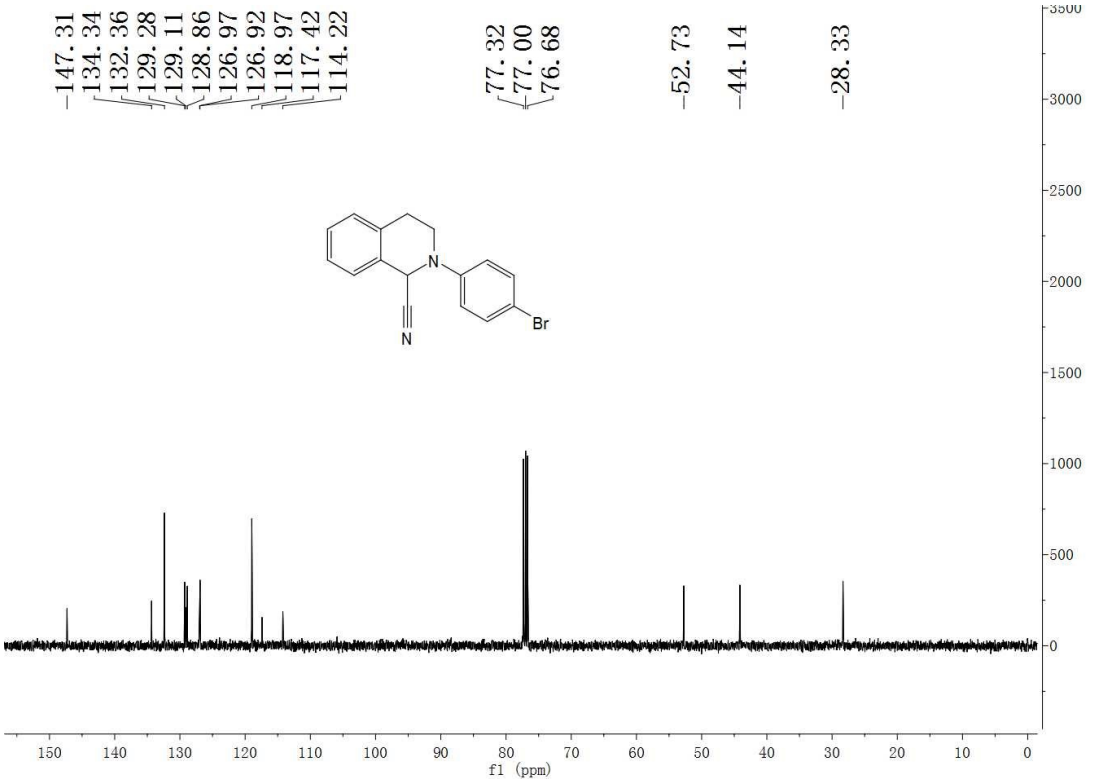


Figure S24. ^{13}C NMR Spectrum of 3l (100 MHz, $CDCl_3$)

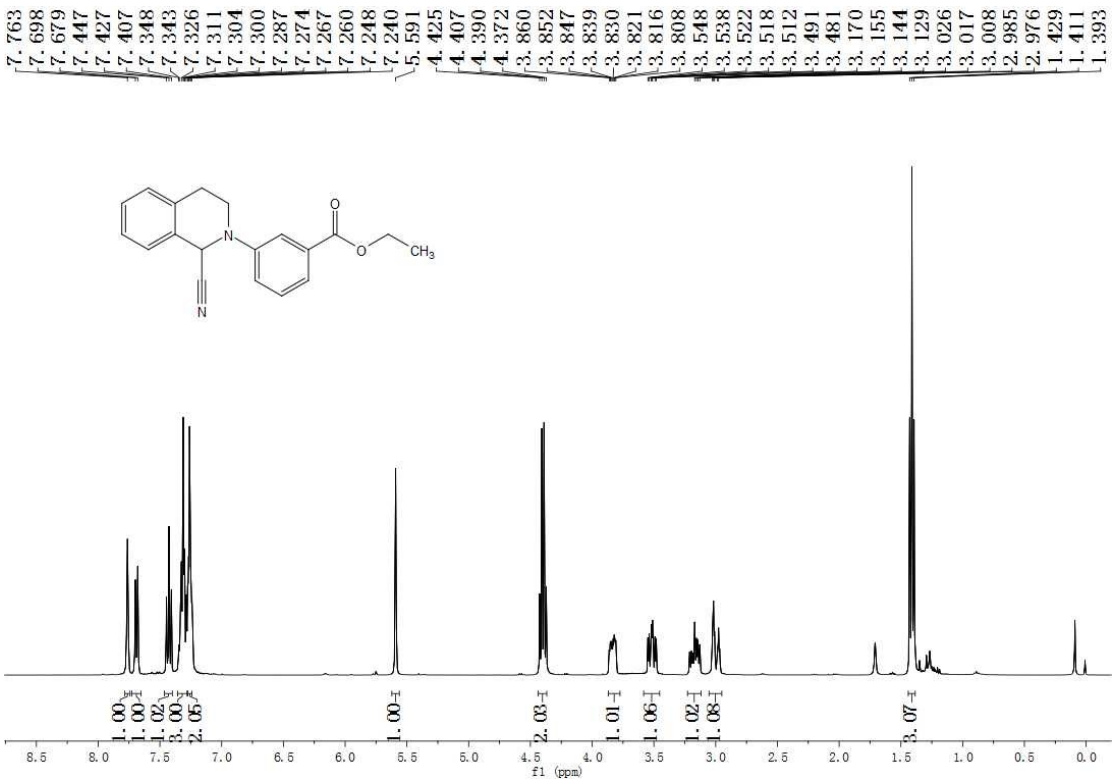


Figure S25. ^{1}H NMR Spectrum of 3m (400 MHz, $CDCl_3$)

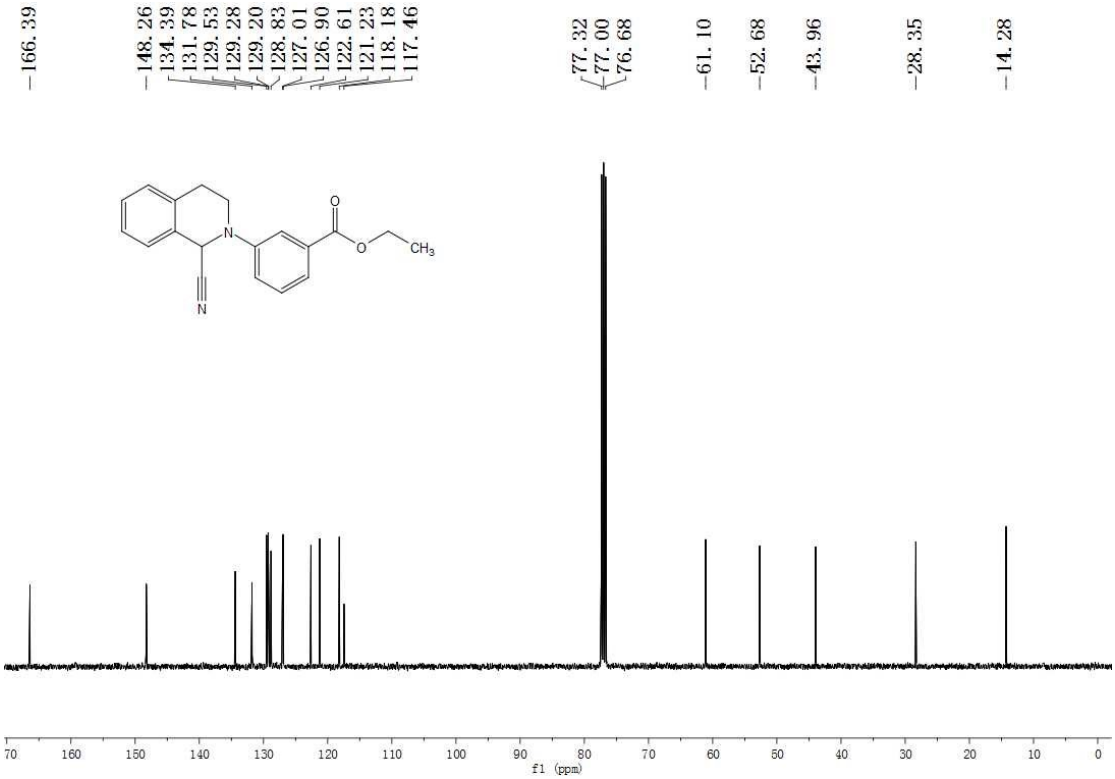


Figure S26. ^{13}C NMR Spectrum of 3m (100 MHz, $CDCl_3$)

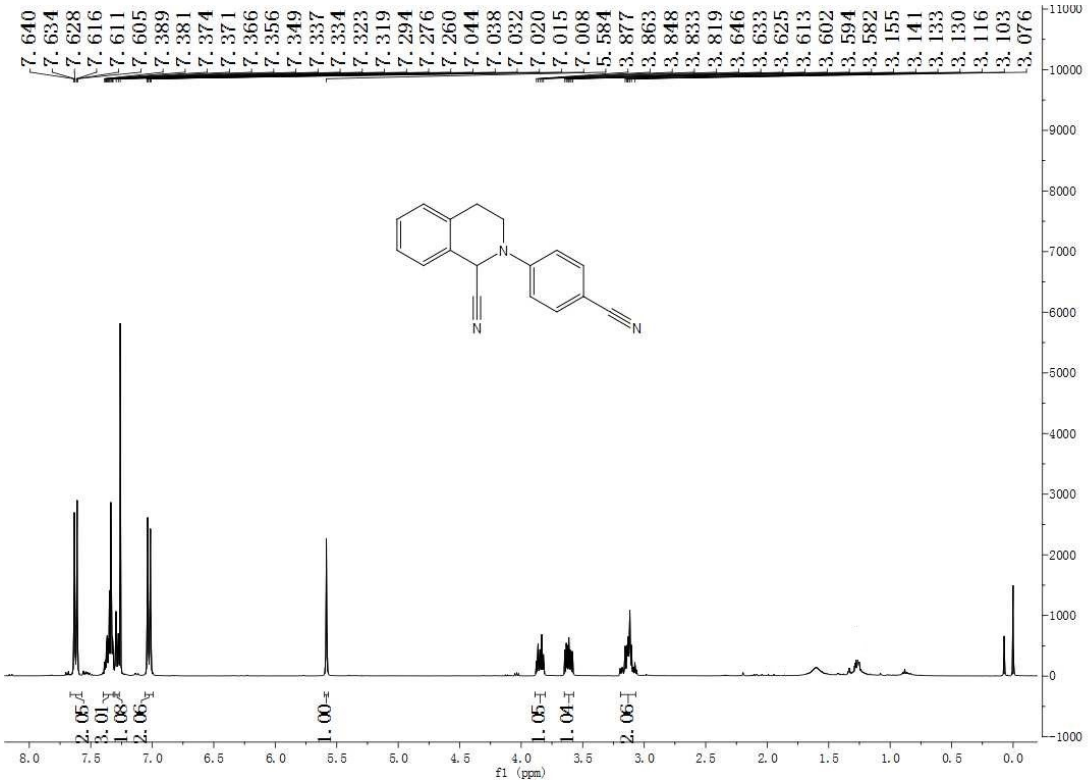


Figure S27. ^{1}H NMR Spectrum of 3n (400 MHz, $CDCl_3$)

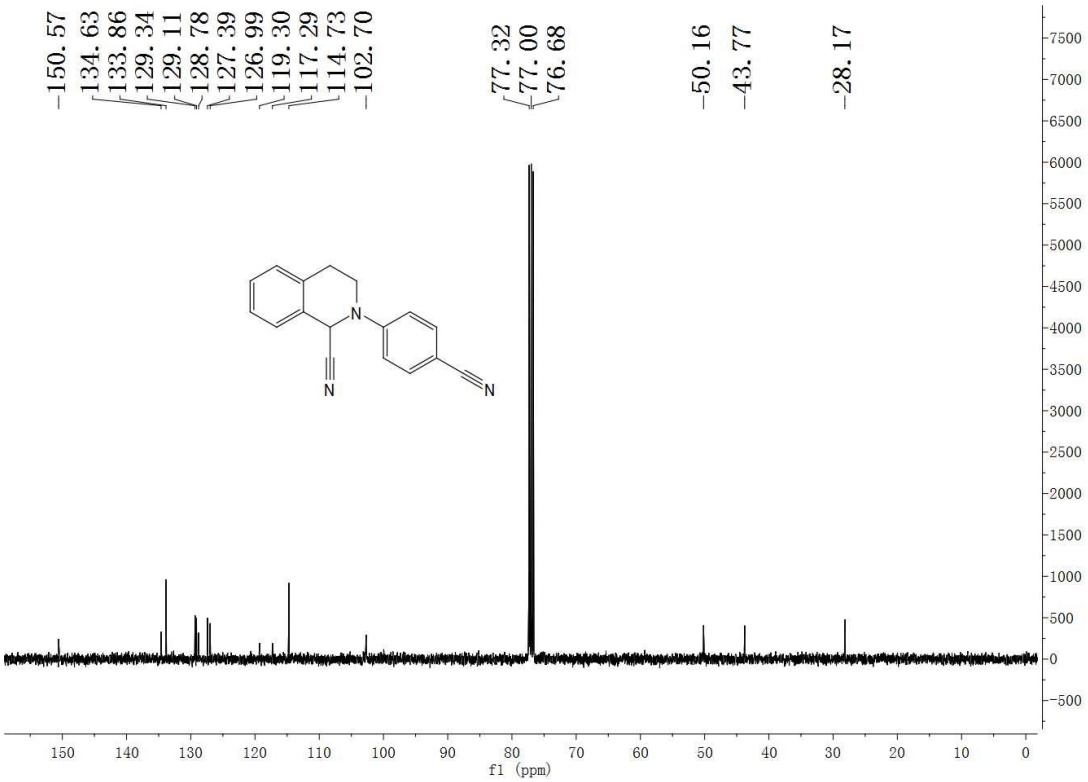


Figure S28. ^{13}C NMR Spectrum of 3n (100 MHz, $CDCl_3$)

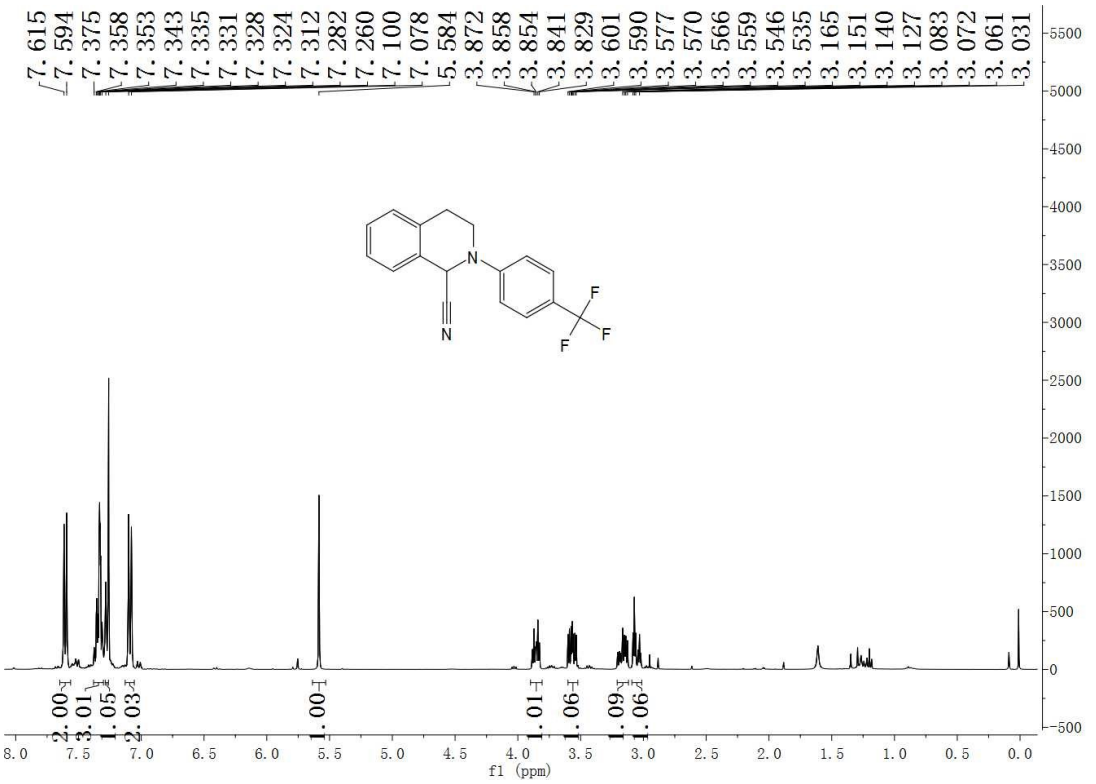


Figure S29. ^{1}H NMR Spectrum of 3o (400 MHz, $CDCl_3$)

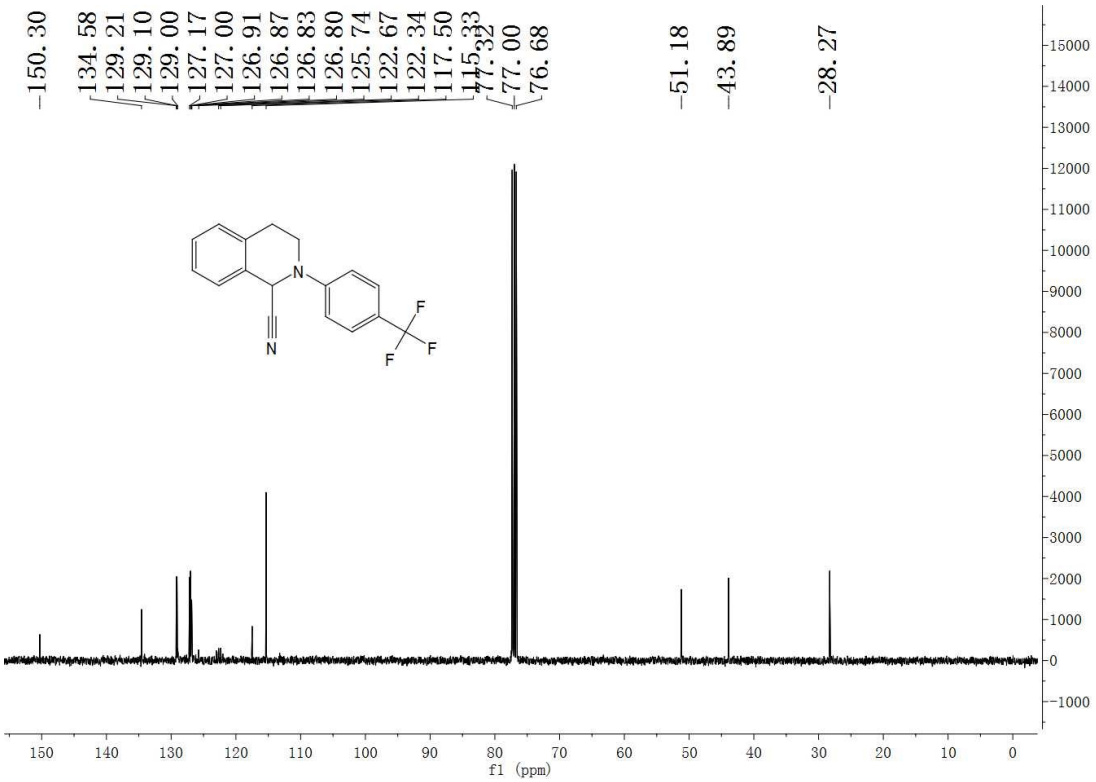


Figure S30. ^{13}C NMR Spectrum of 3o (100 MHz, $CDCl_3$)

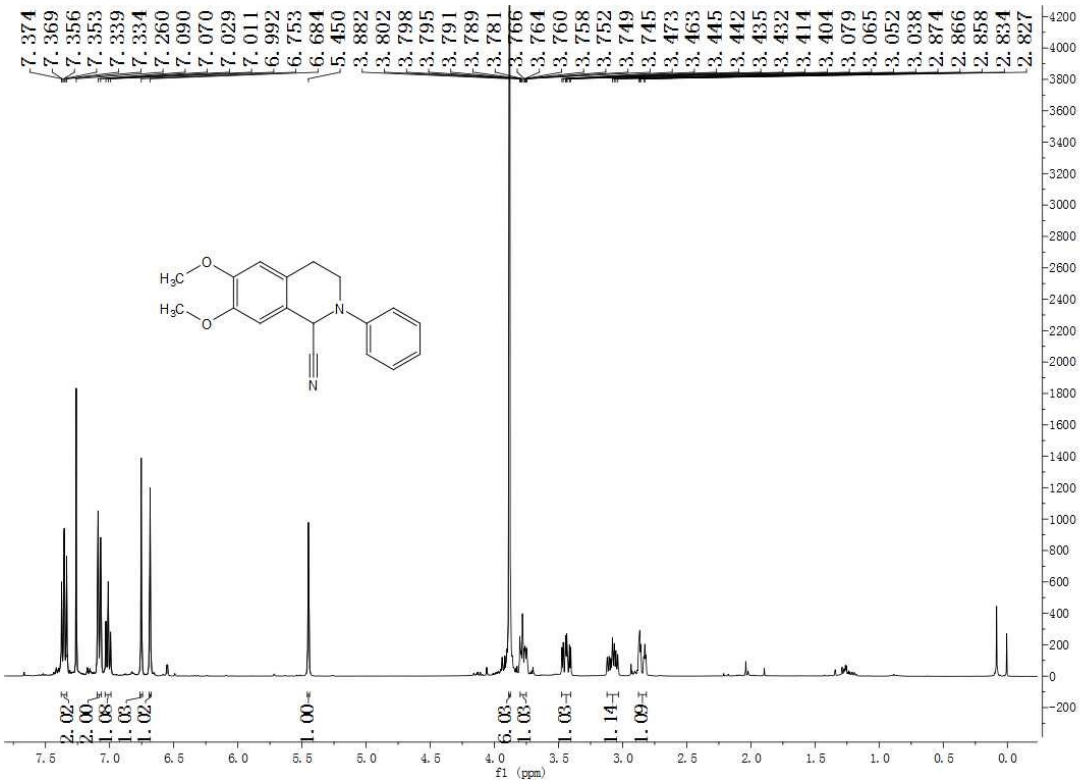


Figure S31. ^{1}H NMR Spectrum of 3p (400 MHz, $CDCl_3$)

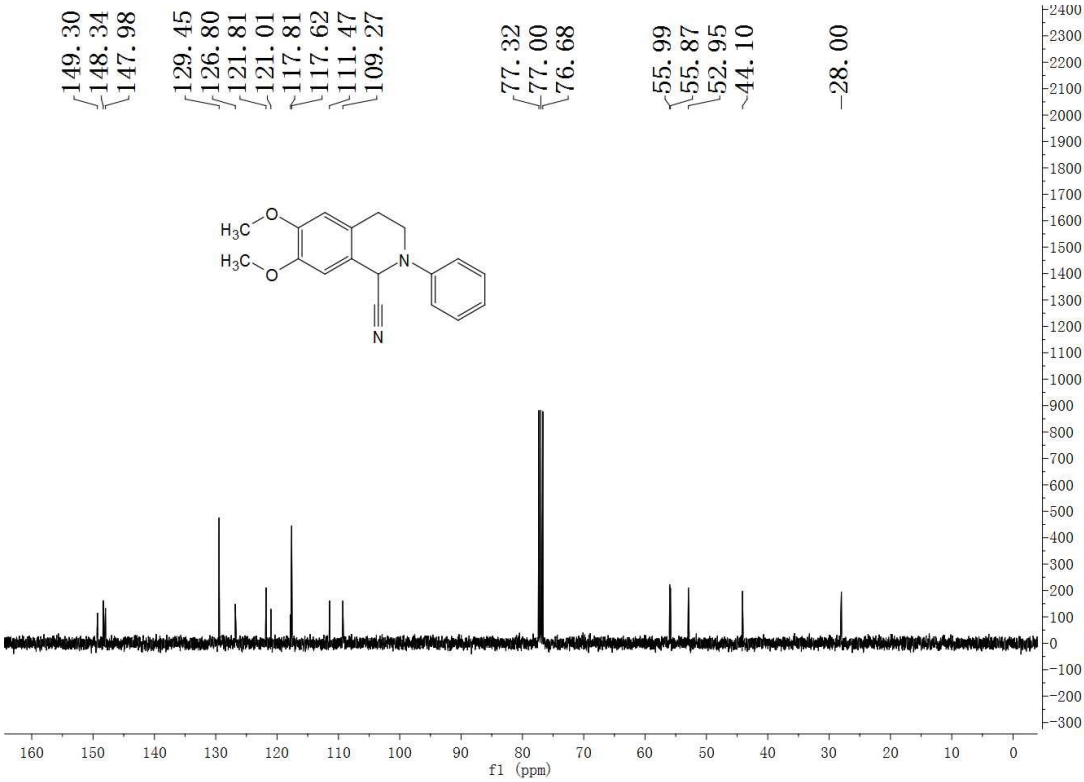


Figure S32. ^{13}C NMR Spectrum of 3p (100 MHz, $CDCl_3$)

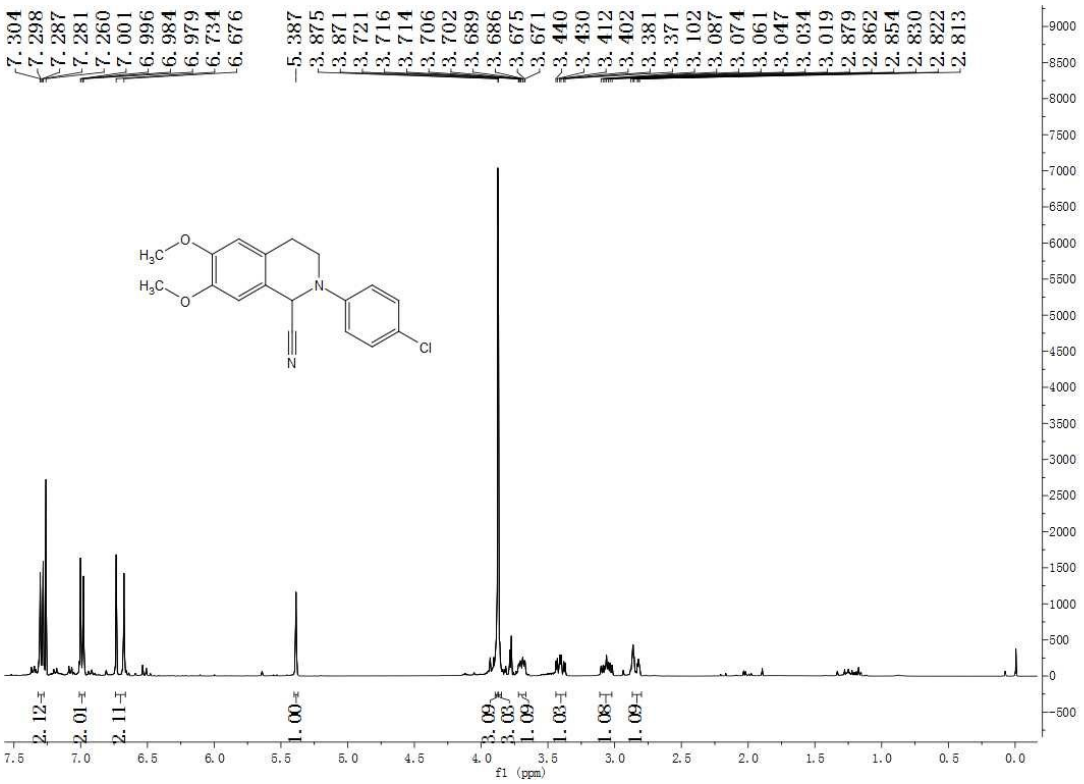


Figure S33. ^{1}H NMR Spectrum of 3q (400 MHz, $CDCl_3$)

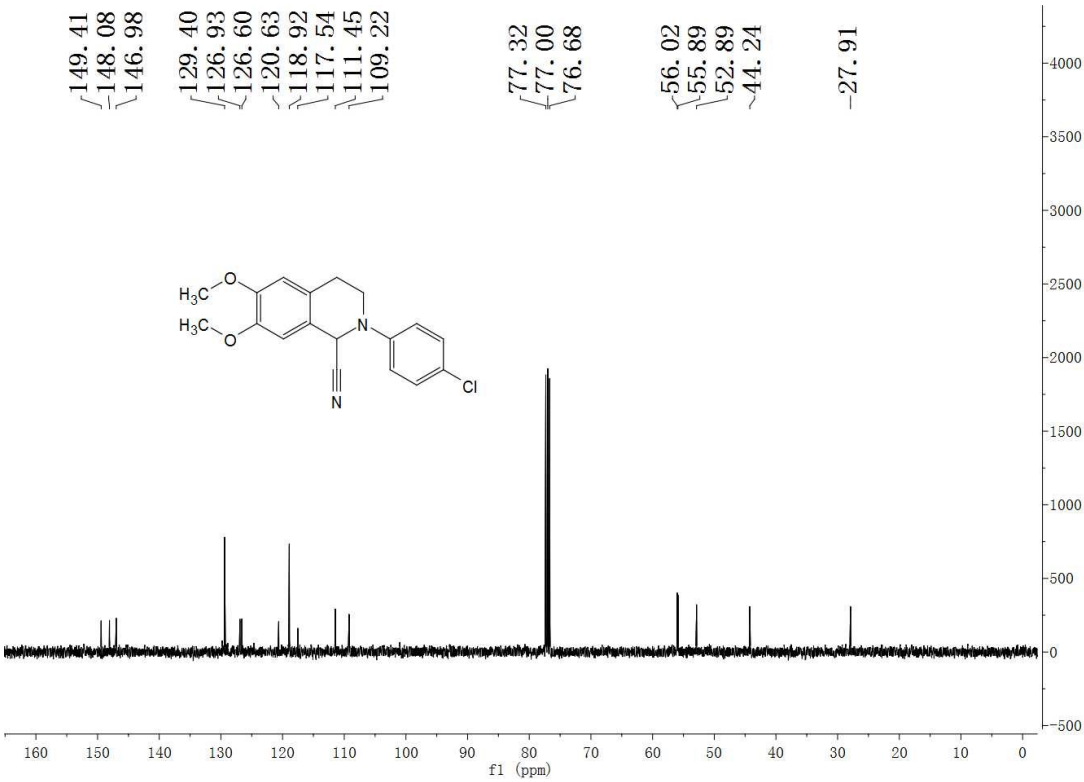


Figure S34. ^{13}C NMR Spectrum of 3q (100 MHz, $CDCl_3$)

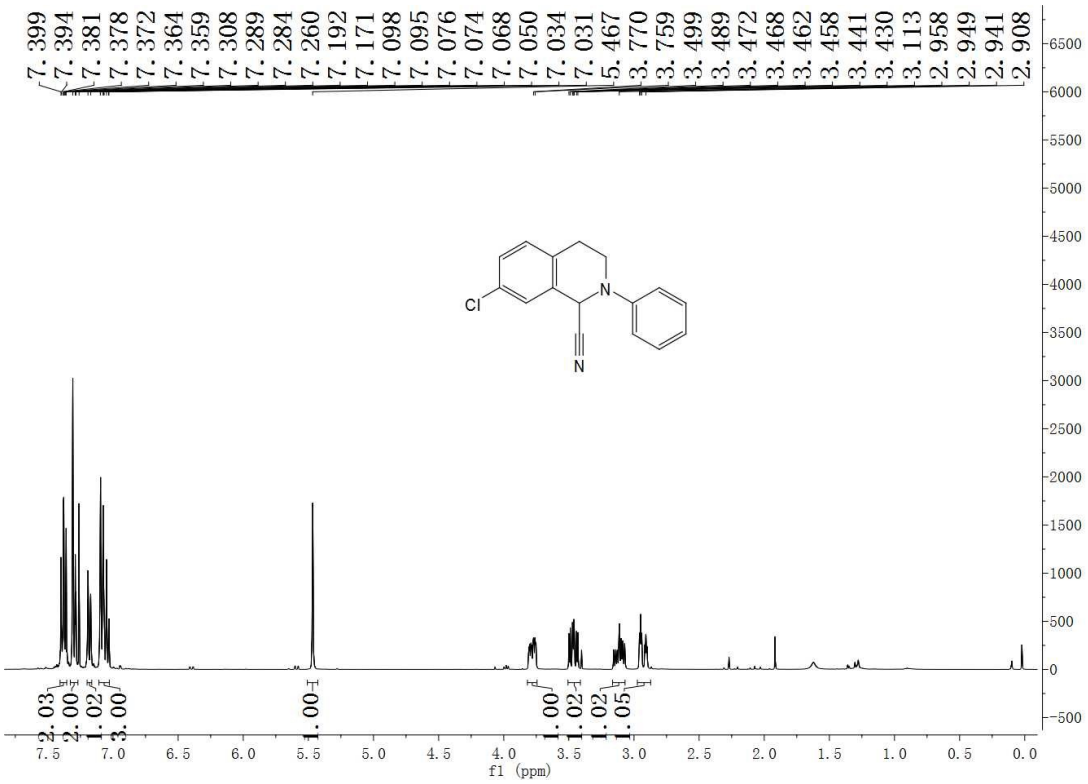


Figure S35. ^{1}H NMR Spectrum of 3r (400 MHz, $CDCl_3$)

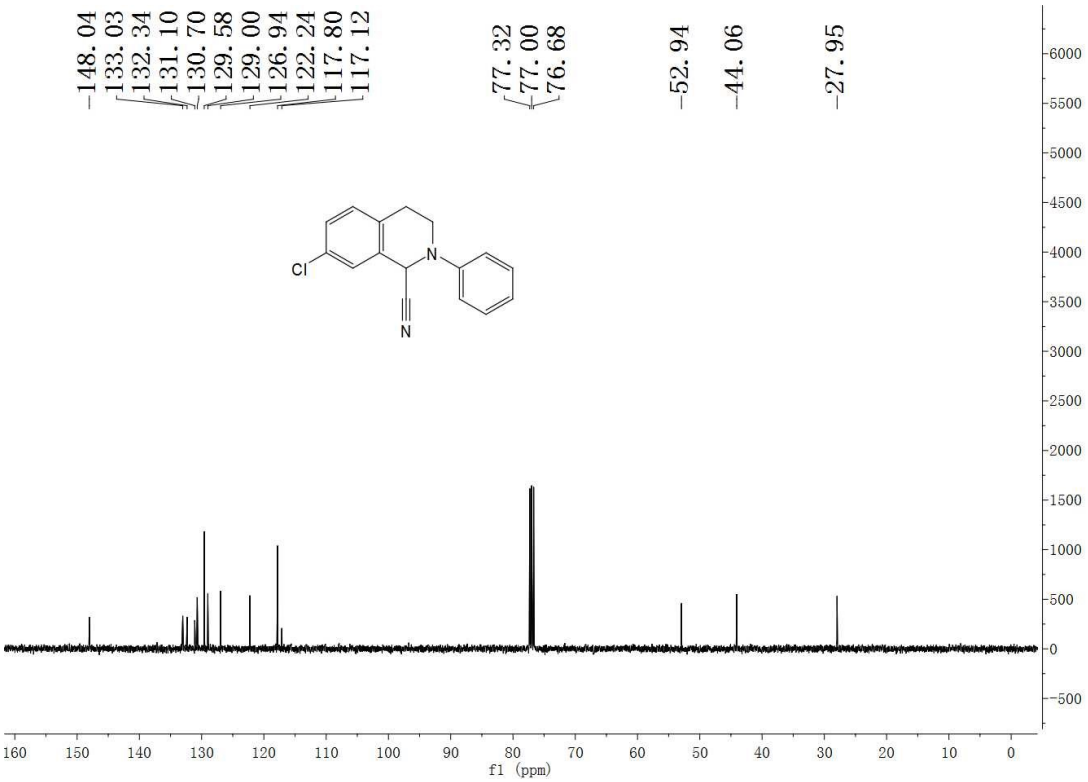


Figure S36. ^{13}C NMR Spectrum of 3r (100 MHz, $CDCl_3$)

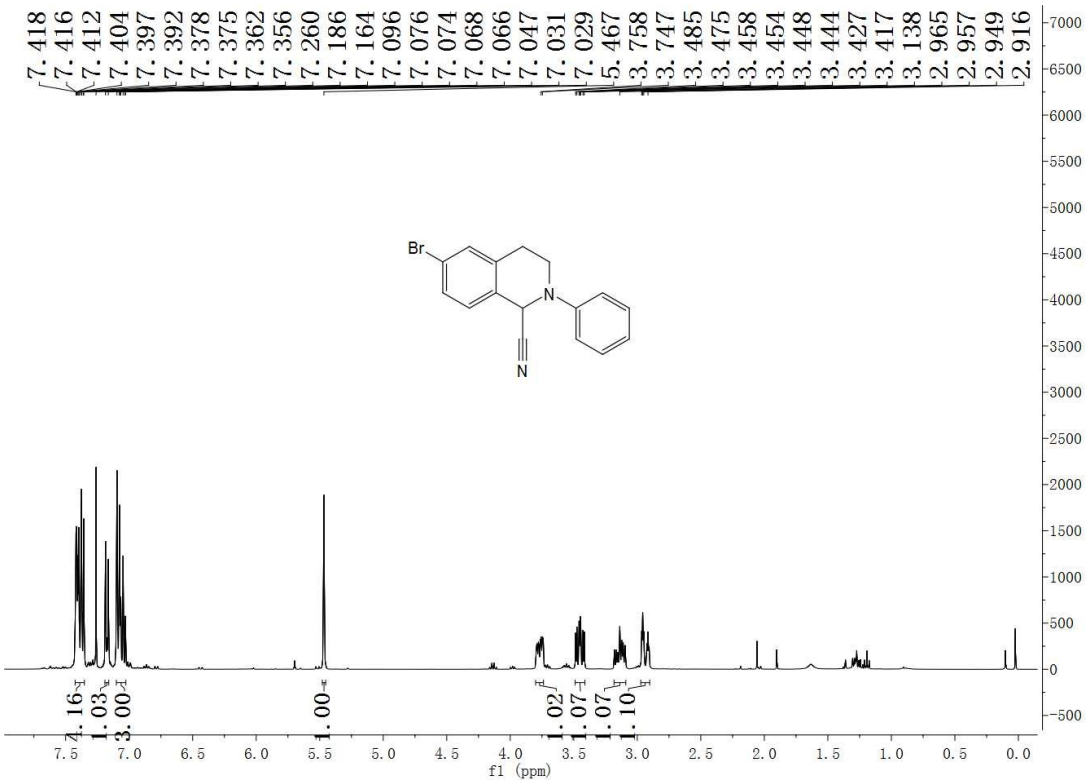


Figure S37. ^{1}H NMR Spectrum of 3s (400 MHz, $CDCl_3$)

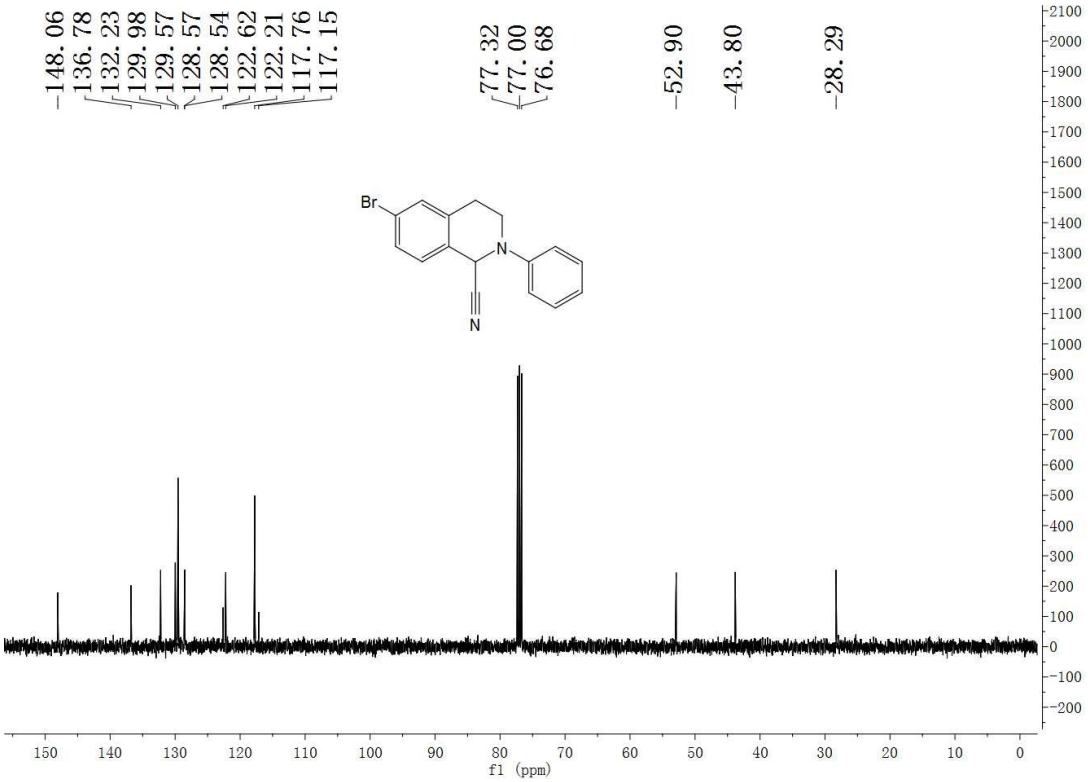


Figure S38. ^{13}C NMR Spectrum of 3s (100 MHz, $CDCl_3$)

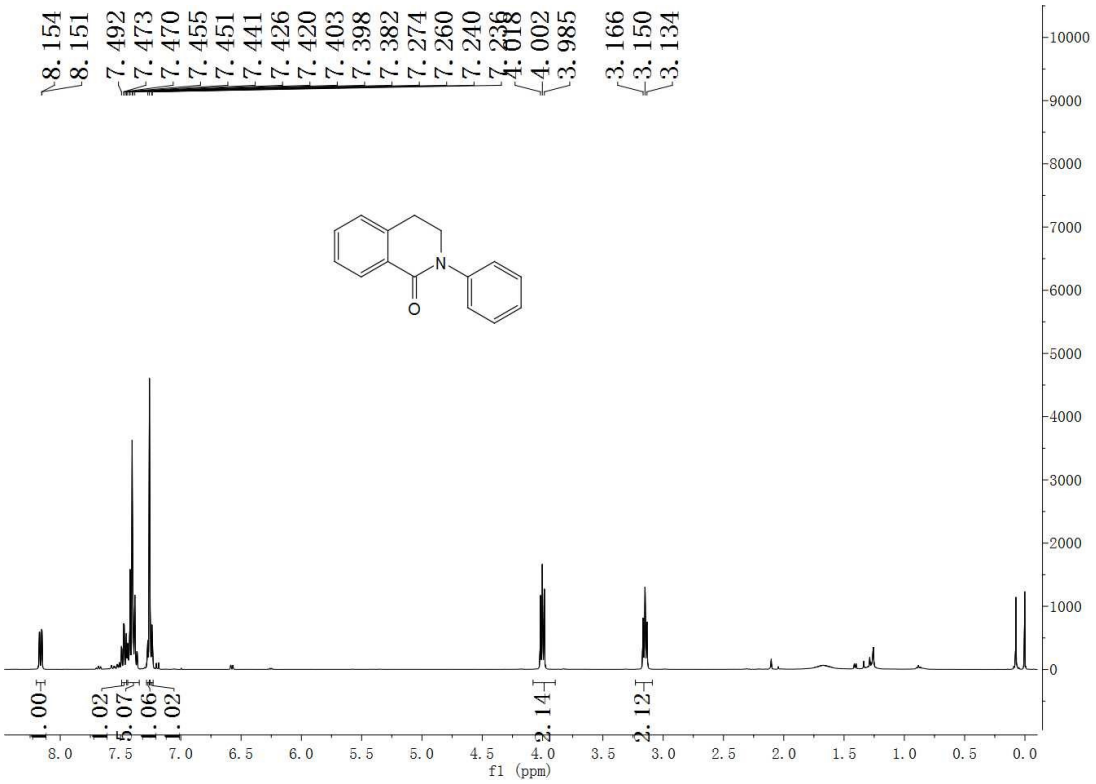


Figure S39. ^{1}H NMR Spectrum of 4a (400 MHz, $CDCl_3$)

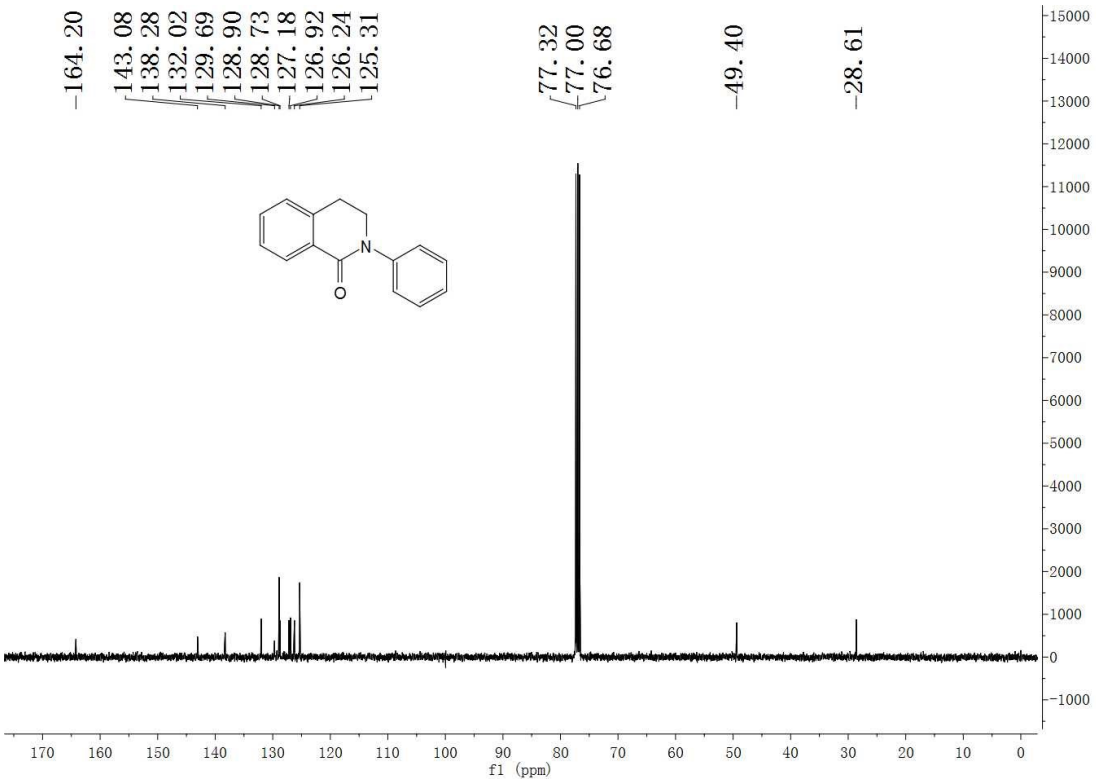


Figure S40. ^{13}C NMR Spectrum of 4a (100 MHz, $CDCl_3$)

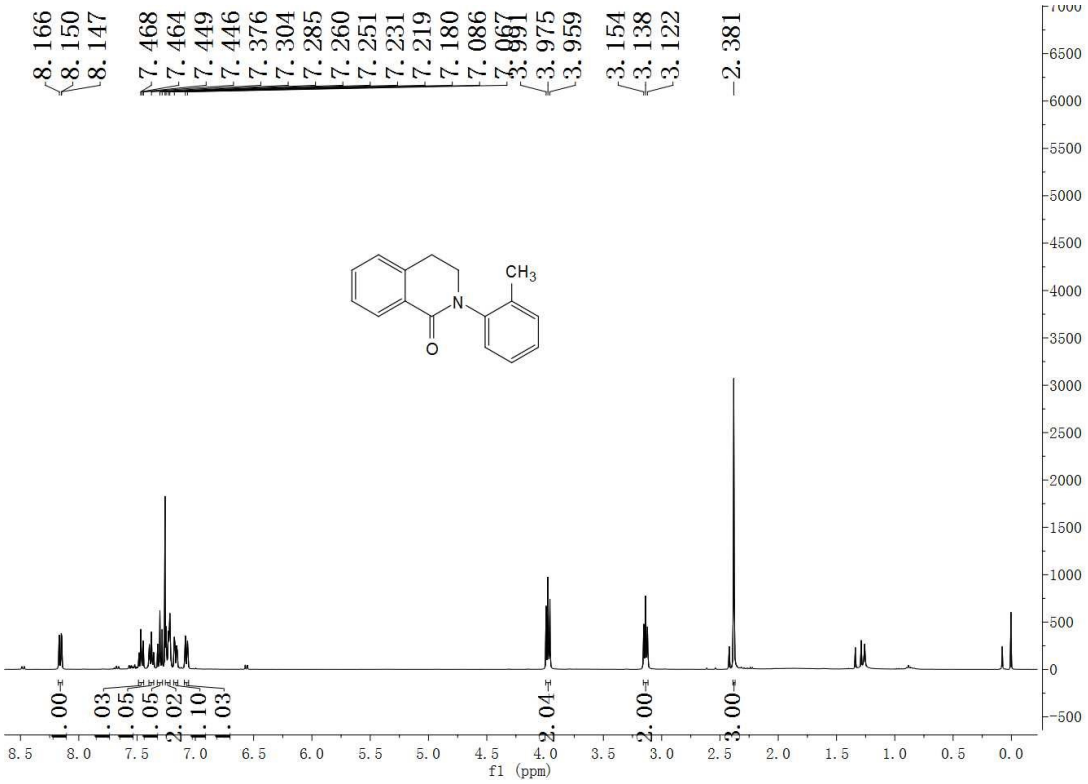


Figure S41. ^{1}H NMR Spectrum of 4b (400 MHz, $CDCl_3$)

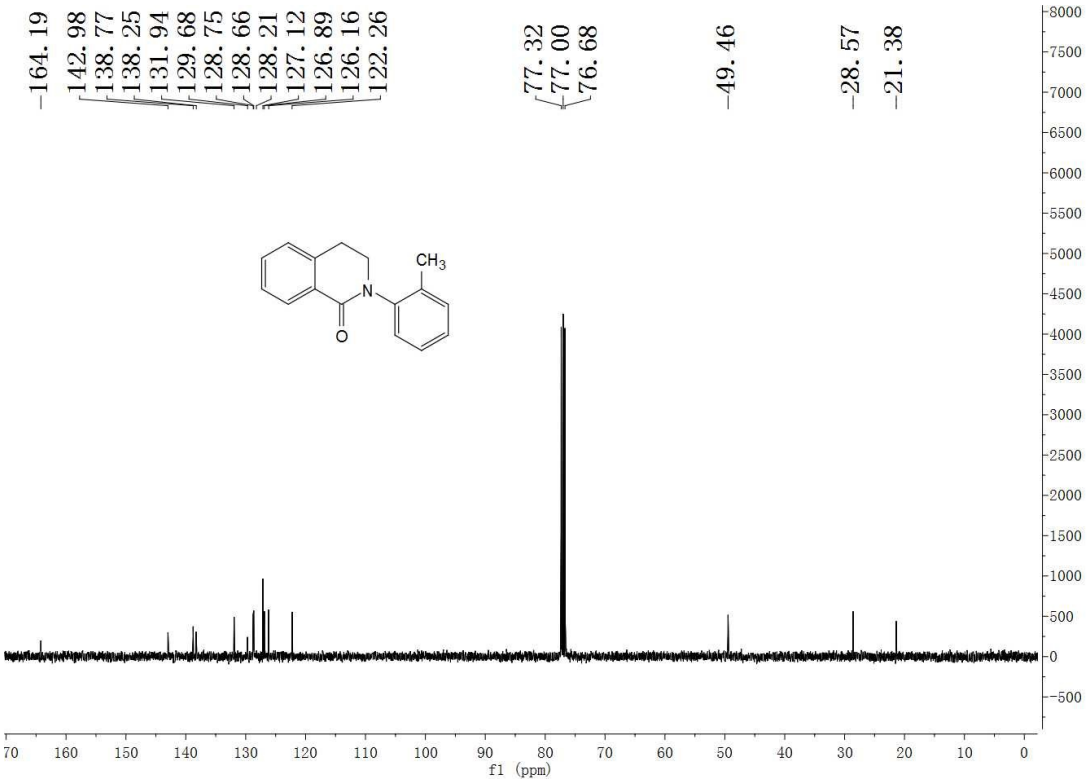


Figure S42. ^{13}C NMR Spectrum of 4b (100 MHz, $CDCl_3$)

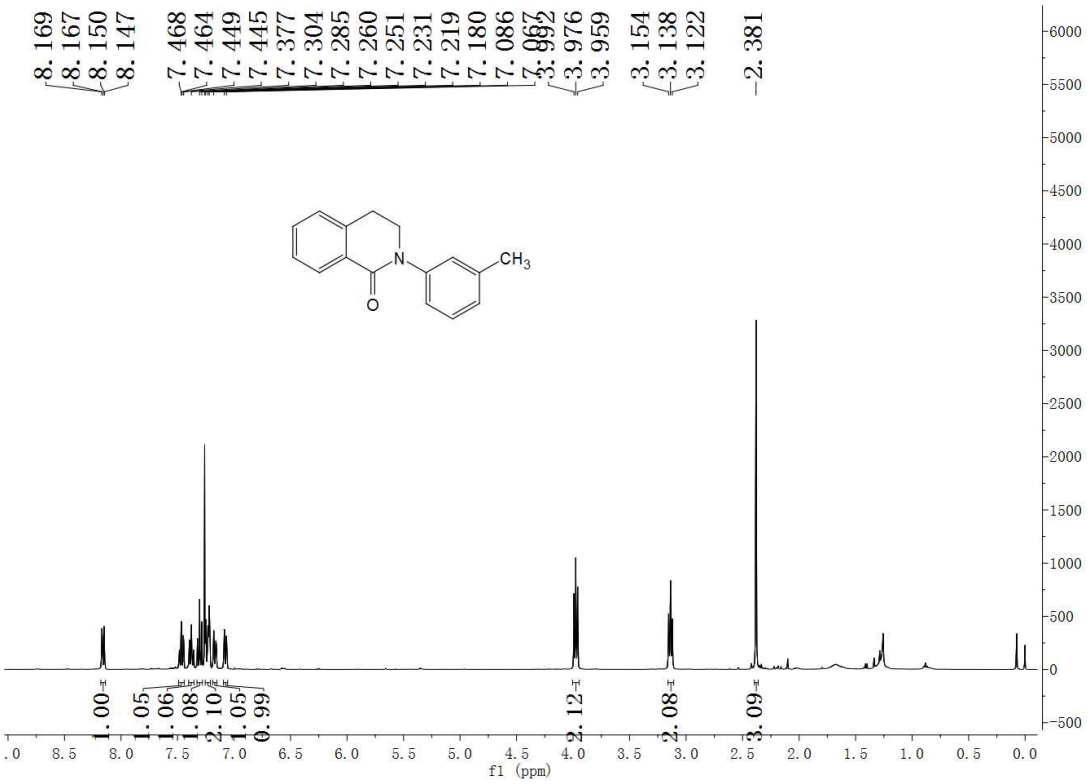


Figure S43. ^{1}H NMR Spectrum of 4c (400 MHz, $CDCl_3$)

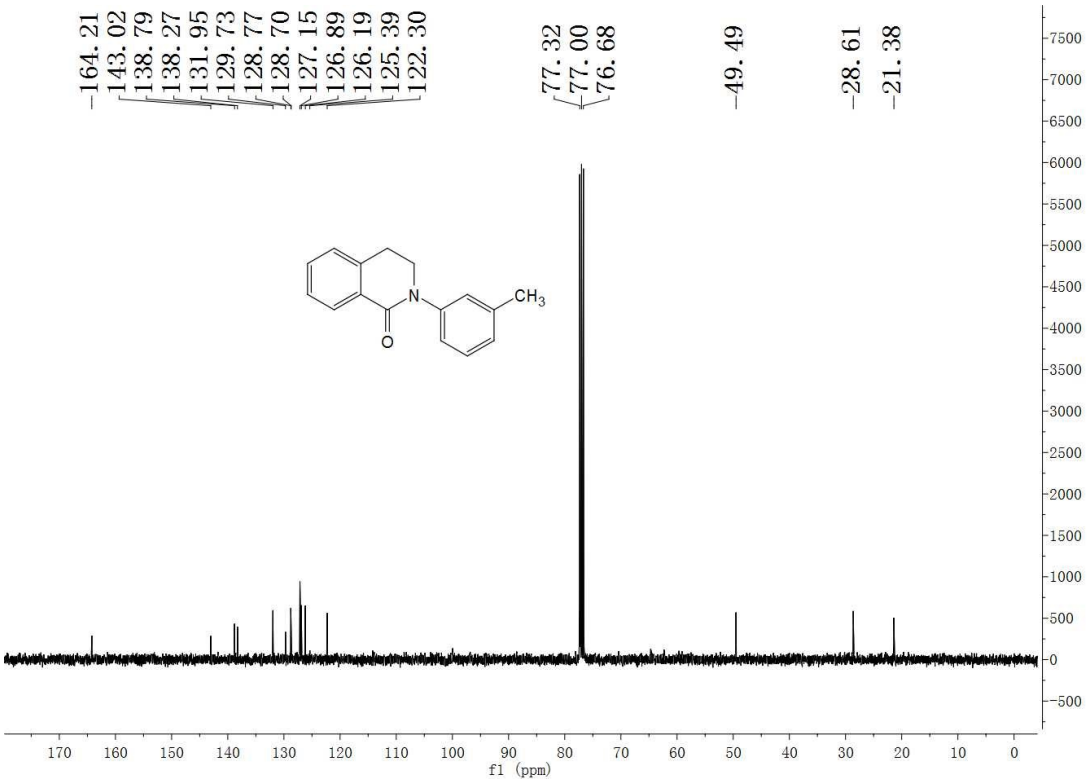


Figure S44. ^{13}C NMR Spectrum of 4c (100 MHz, $CDCl_3$)

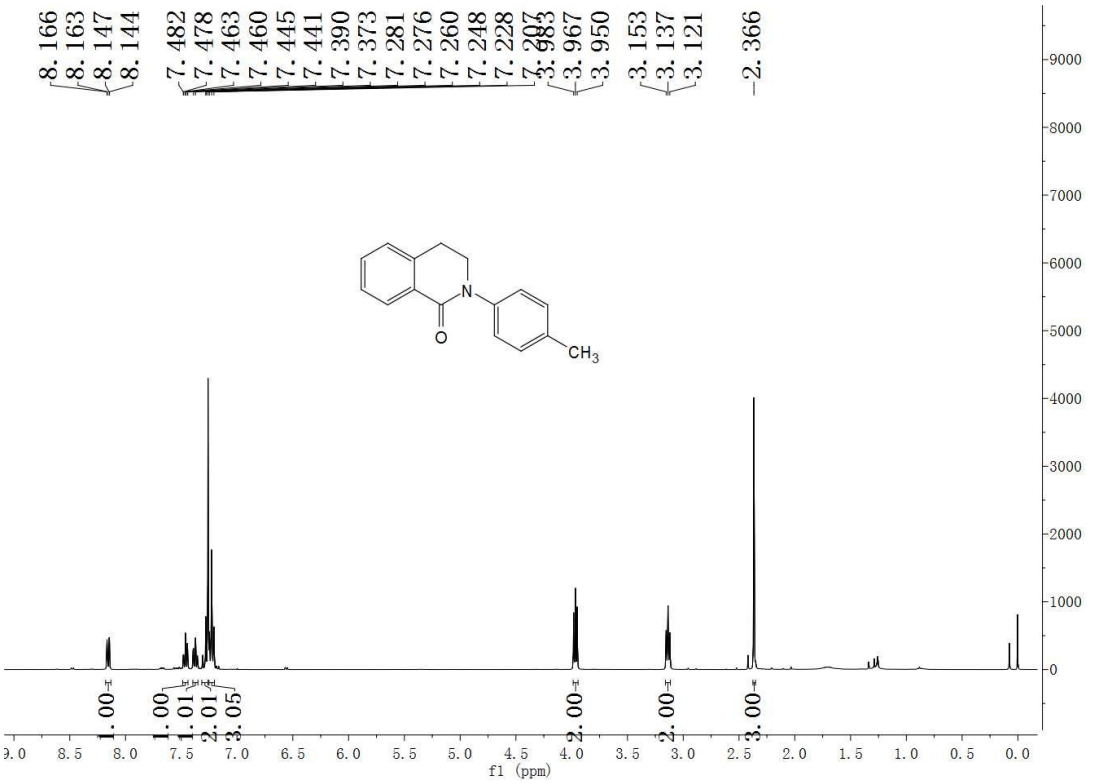


Figure S45. ^{1}H NMR Spectrum of 4d (400 MHz, $CDCl_3$)

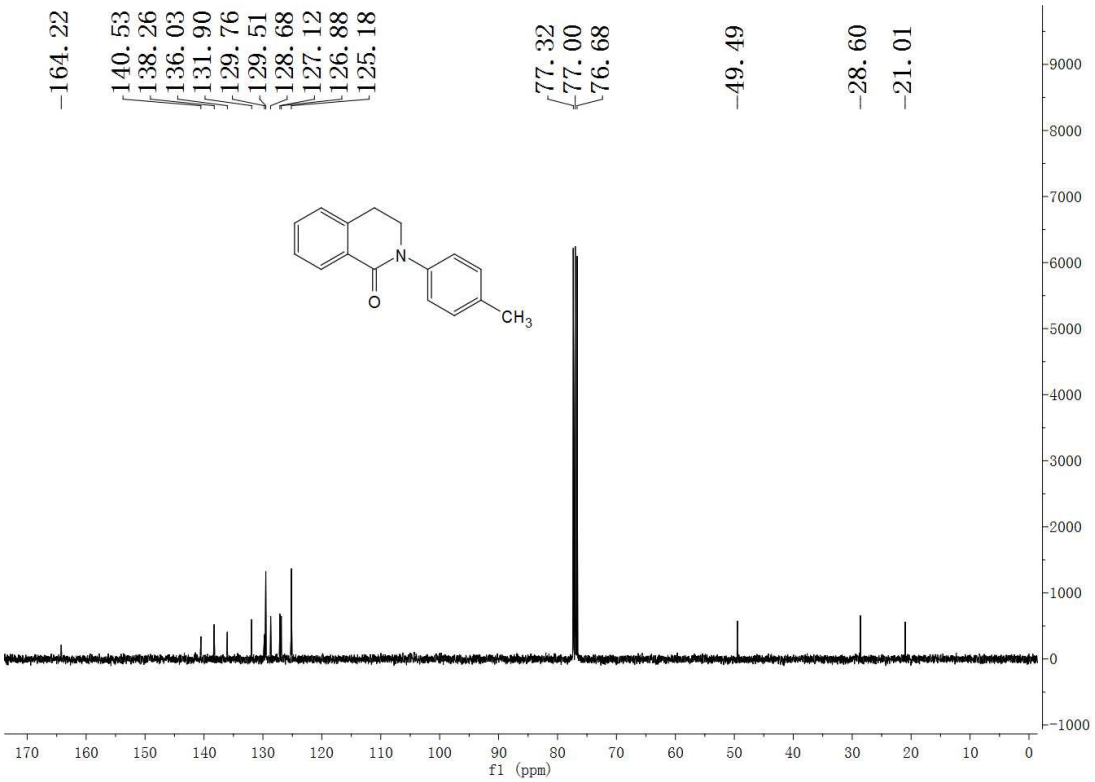


Figure S46. ^{13}C NMR Spectrum of 4d (100 MHz, $CDCl_3$)

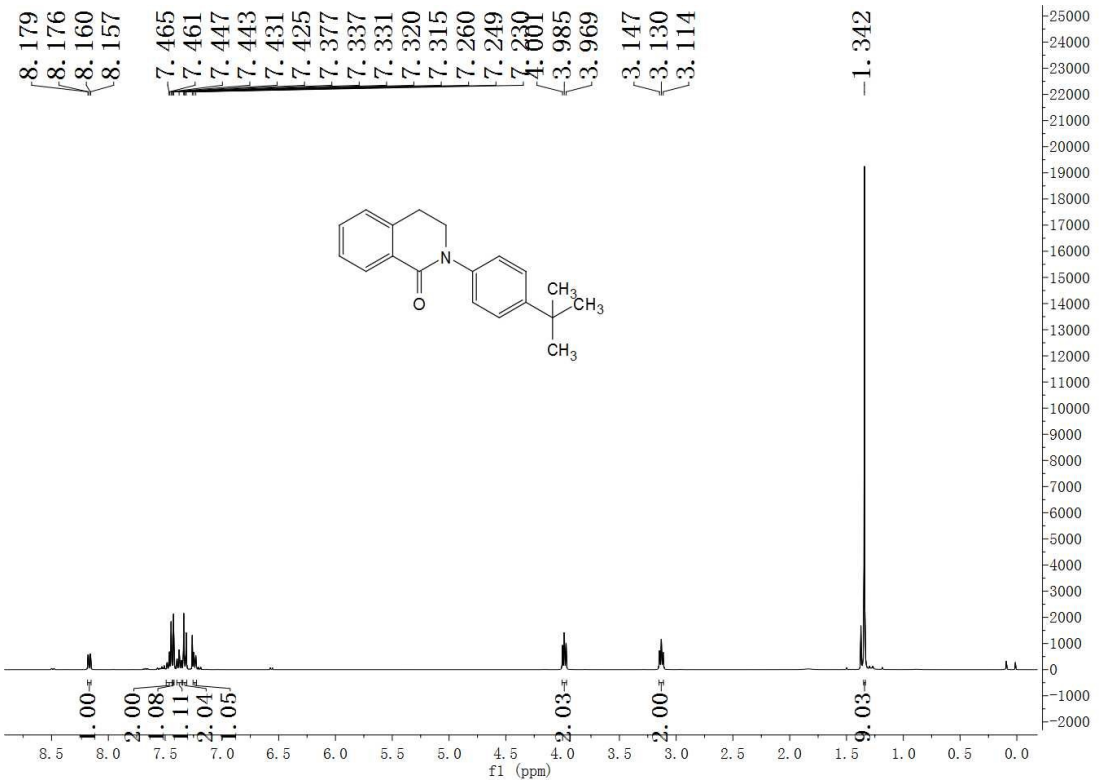


Figure S47. ^{1}H NMR Spectrum of 4e (400 MHz, $CDCl_3$)

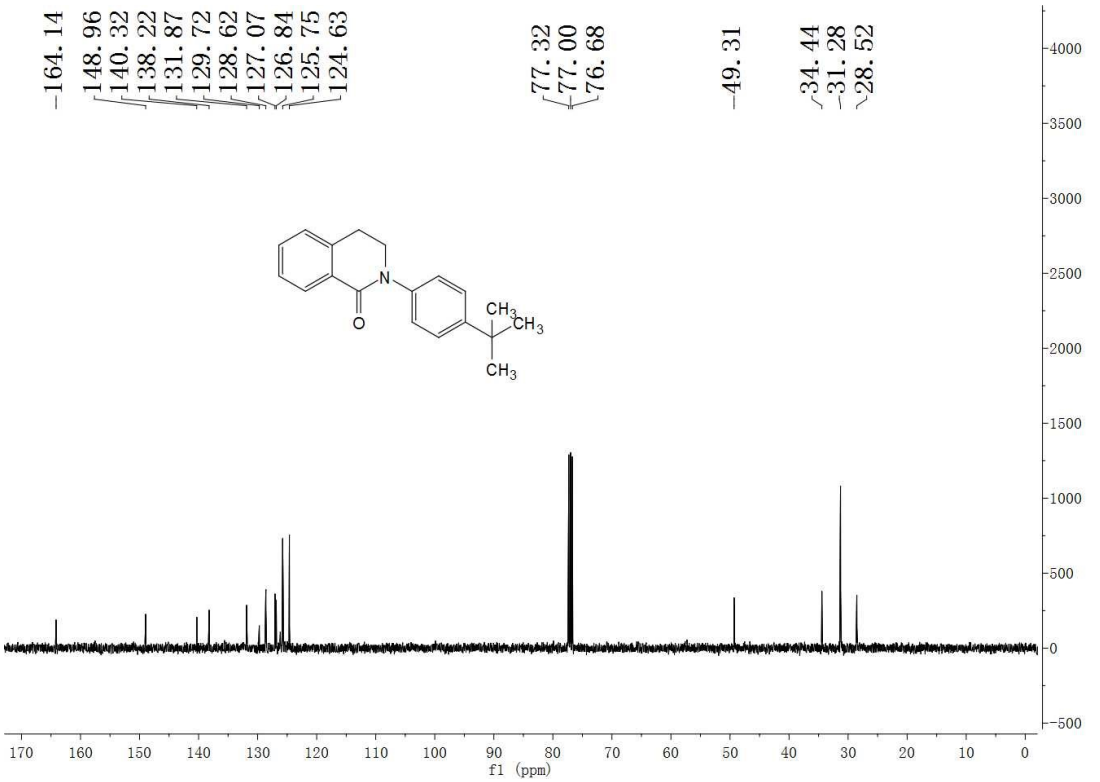


Figure S48. ^{13}C NMR Spectrum of 4e (100 MHz, $CDCl_3$)

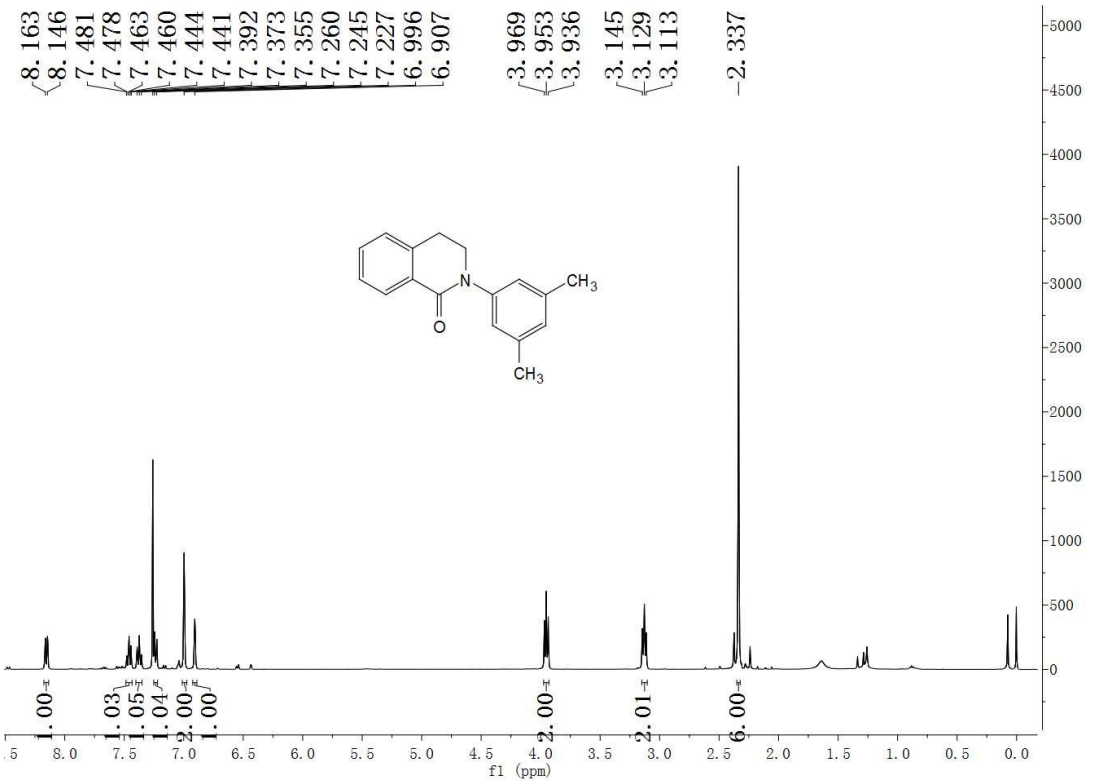


Figure S49. ^{1}H NMR Spectrum of 4f (400 MHz, $CDCl_3$)

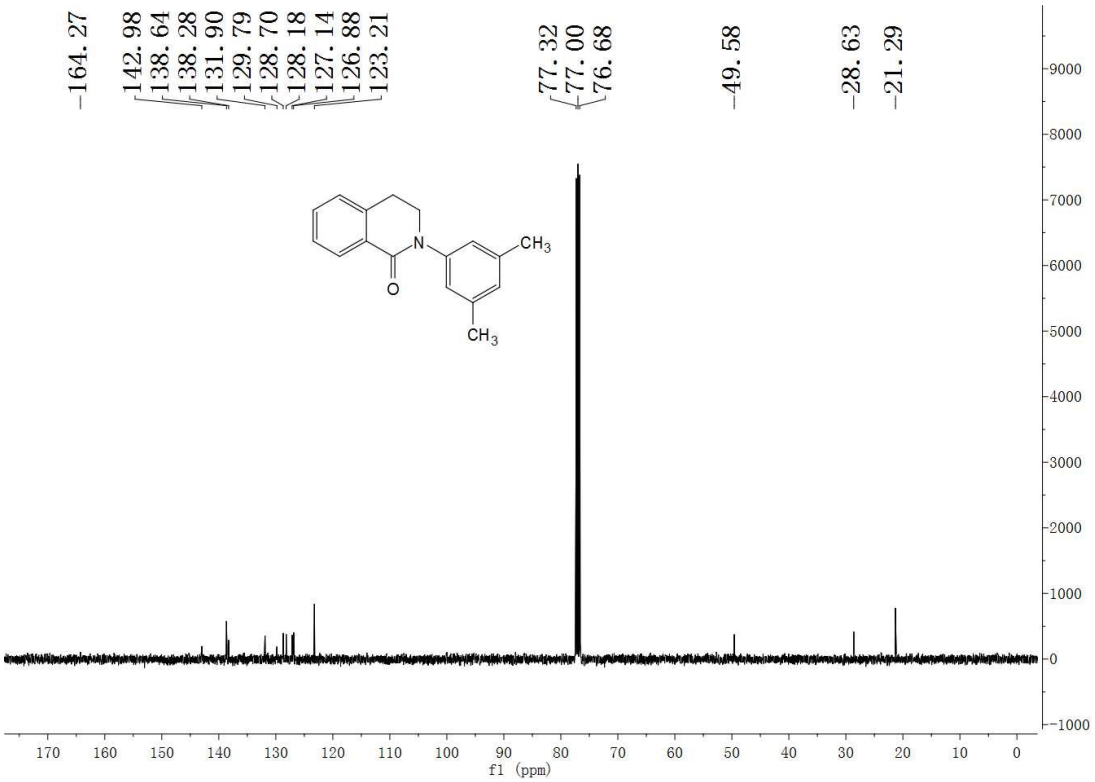


Figure S50. ^{13}C NMR Spectrum of 4f (100 MHz, $CDCl_3$)

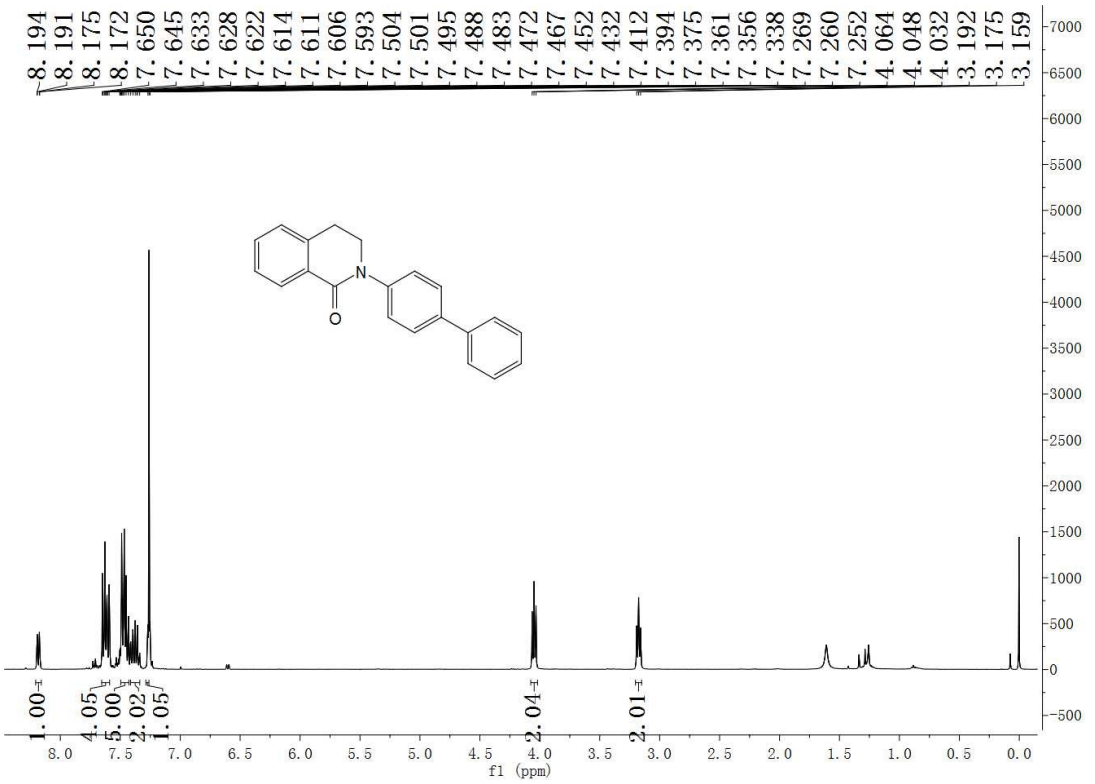


Figure S51. ^{1}H NMR Spectrum of 4g (400 MHz, $CDCl_3$)

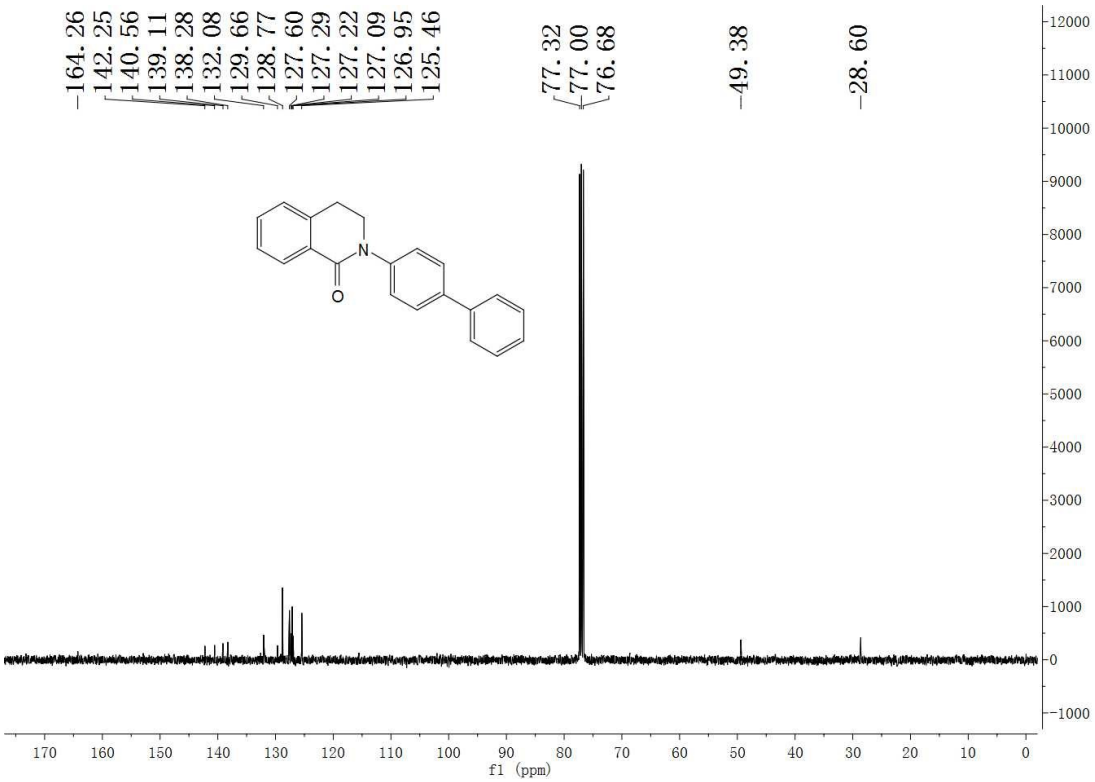


Figure S52. ^{13}C NMR Spectrum of 4g (100 MHz, $CDCl_3$)

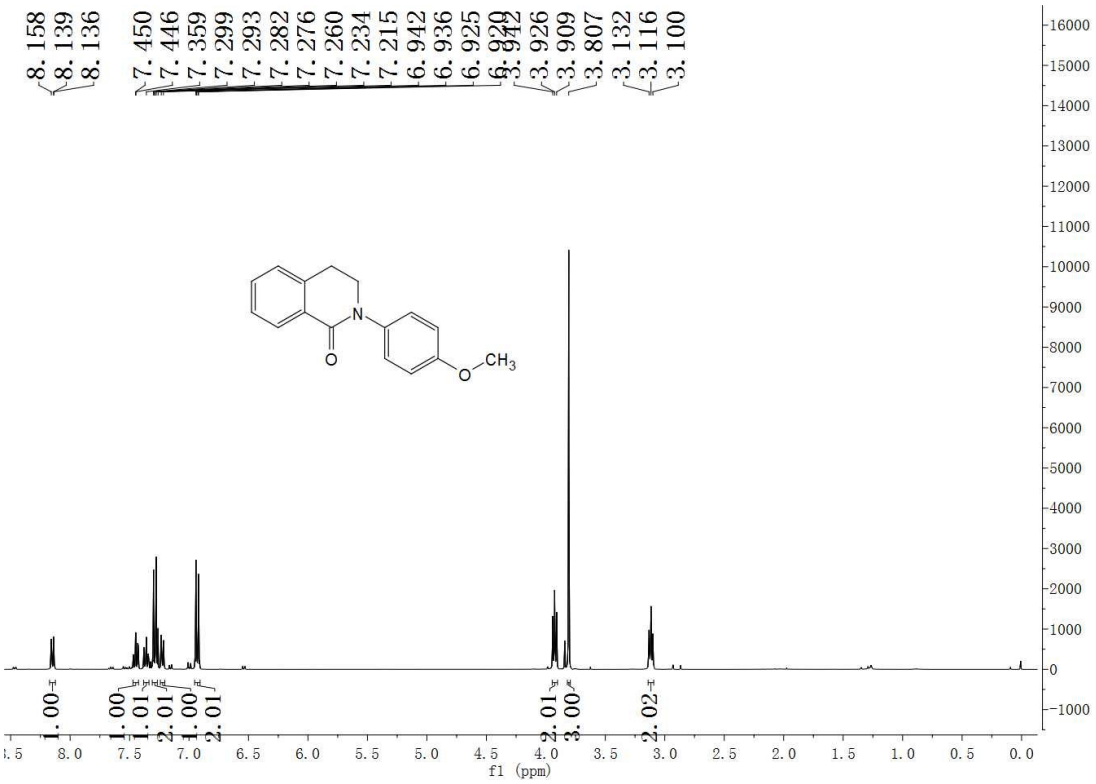


Figure S53. ^{1}H NMR Spectrum of 4h (400 MHz, $CDCl_3$)

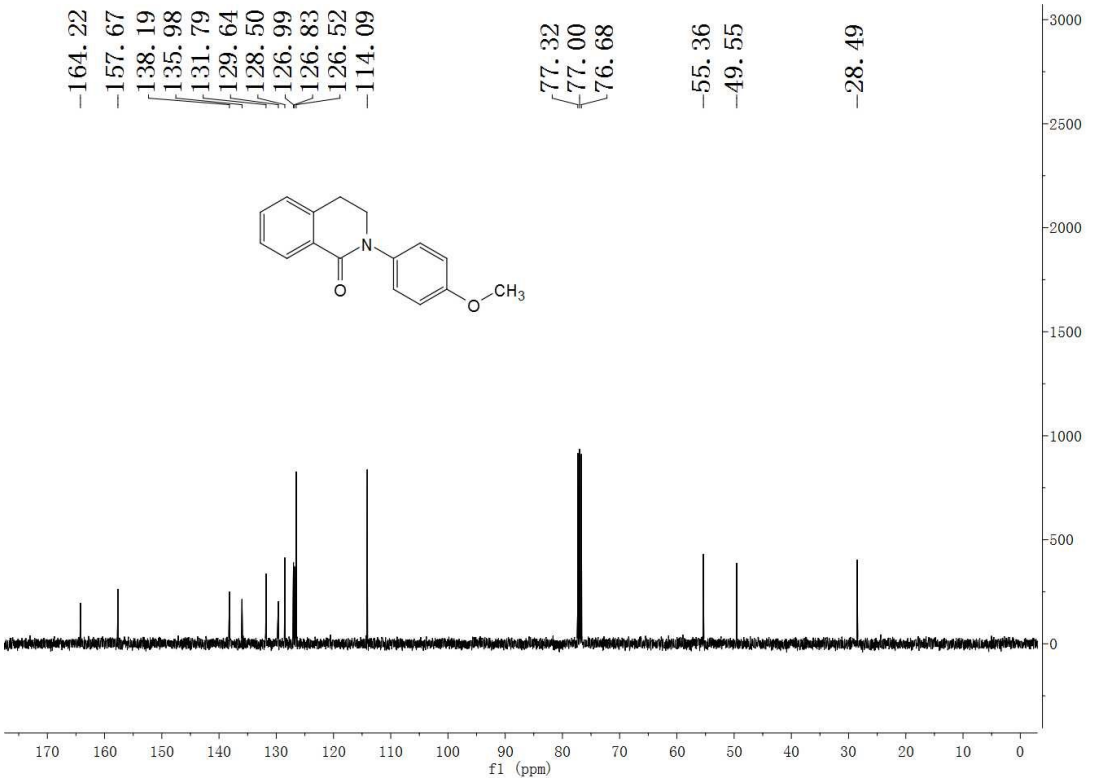


Figure S54. ^{13}C NMR Spectrum of 4h (100 MHz, $CDCl_3$)

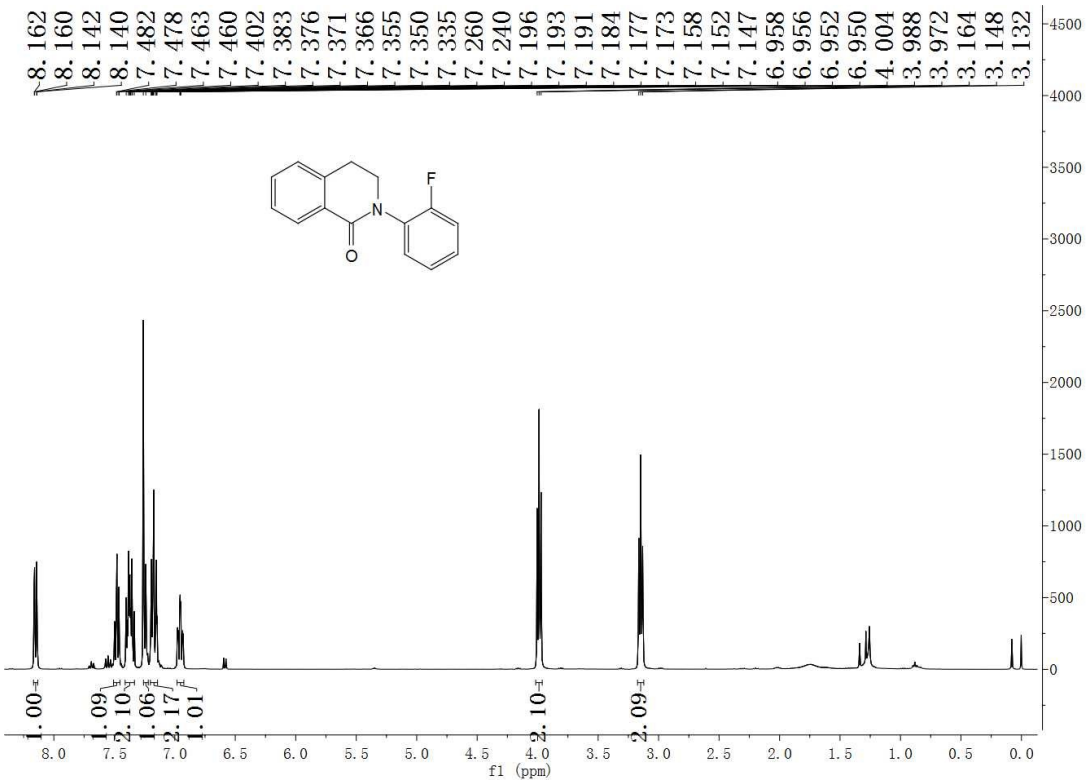


Figure S55. ^{1}H NMR Spectrum of 4i (400 MHz, $CDCl_3$)

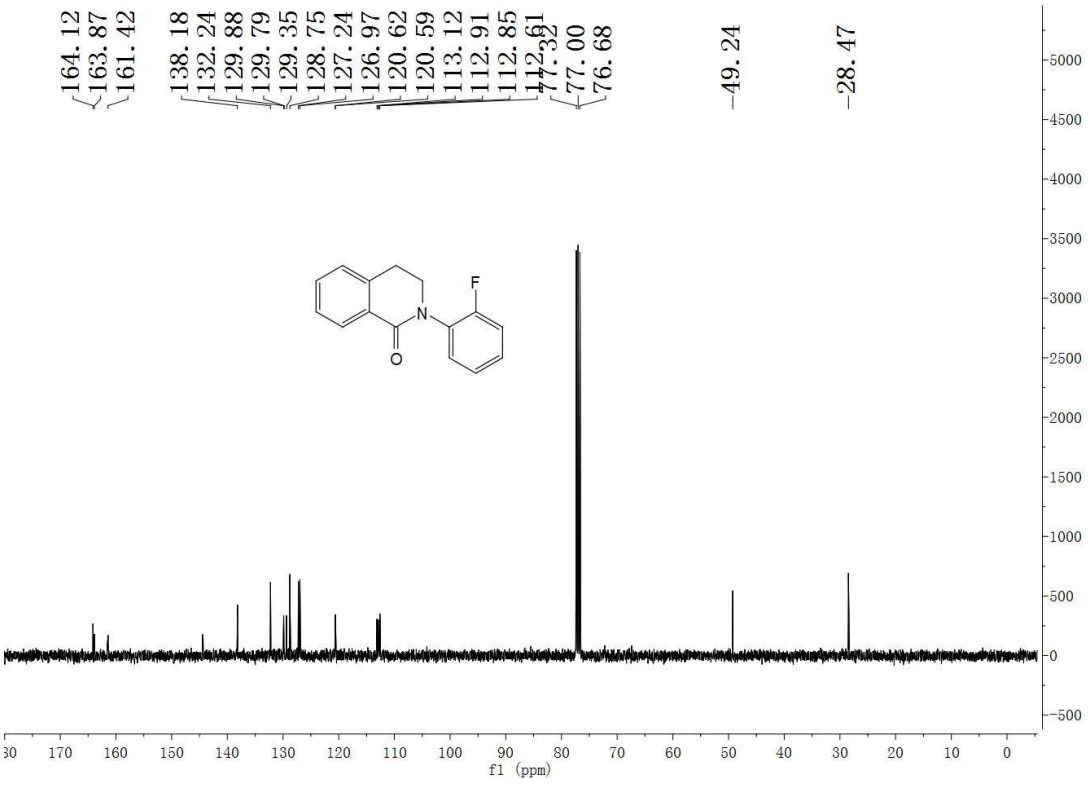


Figure S56. ^{13}C NMR Spectrum of 4i (100 MHz, $CDCl_3$)

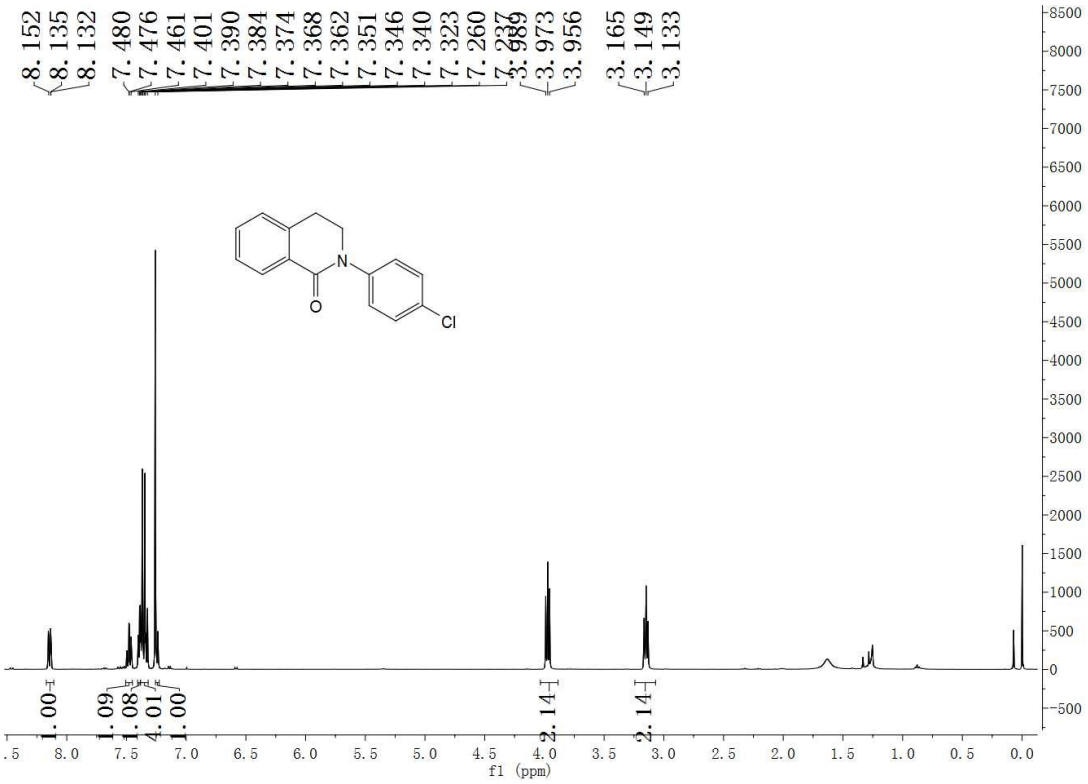


Figure S57. ^{1}H NMR Spectrum of 4j (400 MHz, $CDCl_3$)

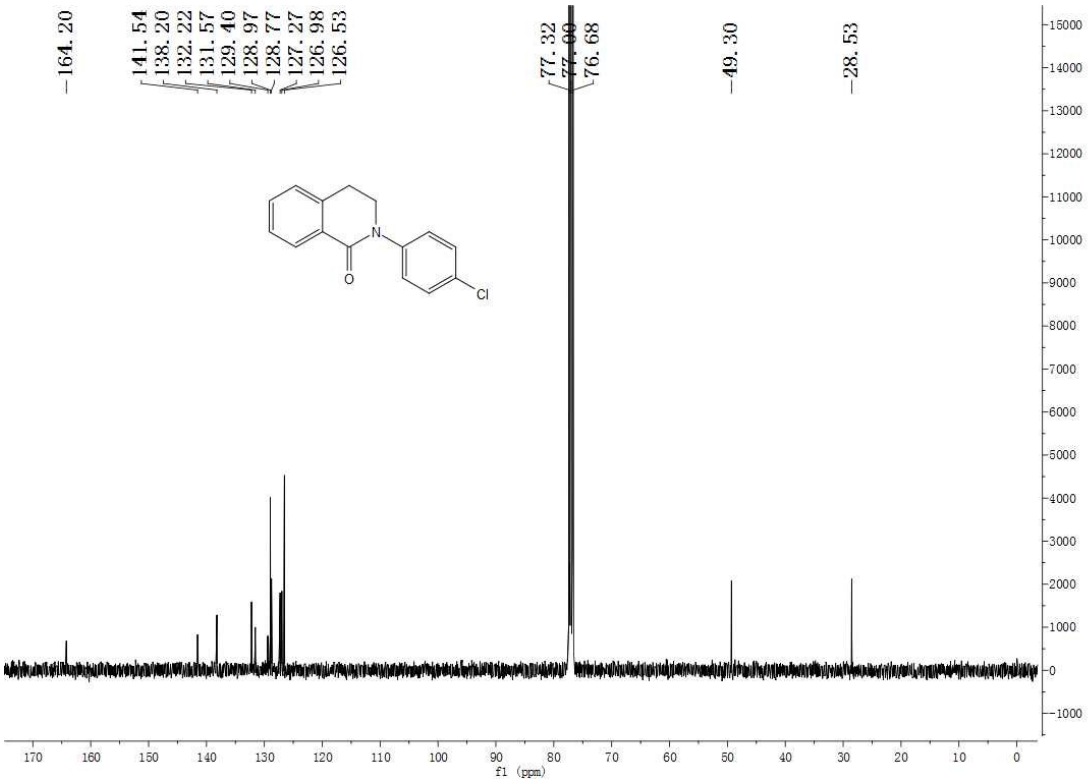


Figure S58. ^{13}C NMR Spectrum of 4j (100 MHz, $CDCl_3$)

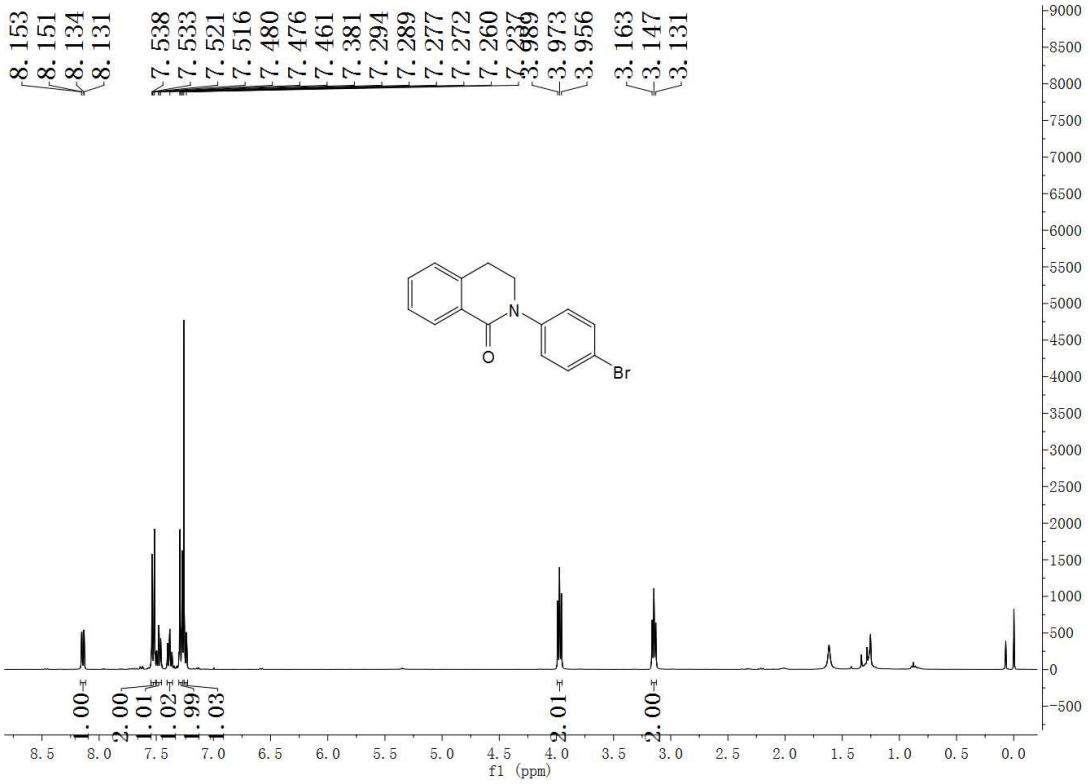


Figure S59. ^{1}H NMR Spectrum of 4k (400 MHz, $CDCl_3$)

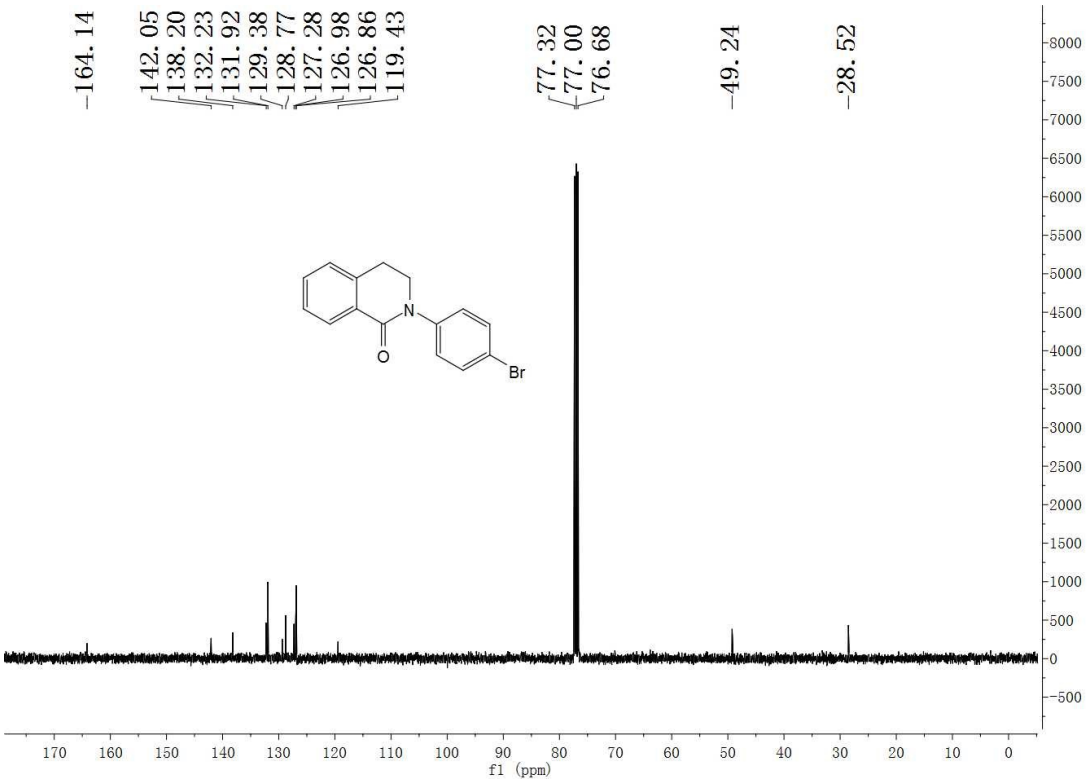


Figure S60. ^{13}C NMR Spectrum of 4k (100 MHz, $CDCl_3$)

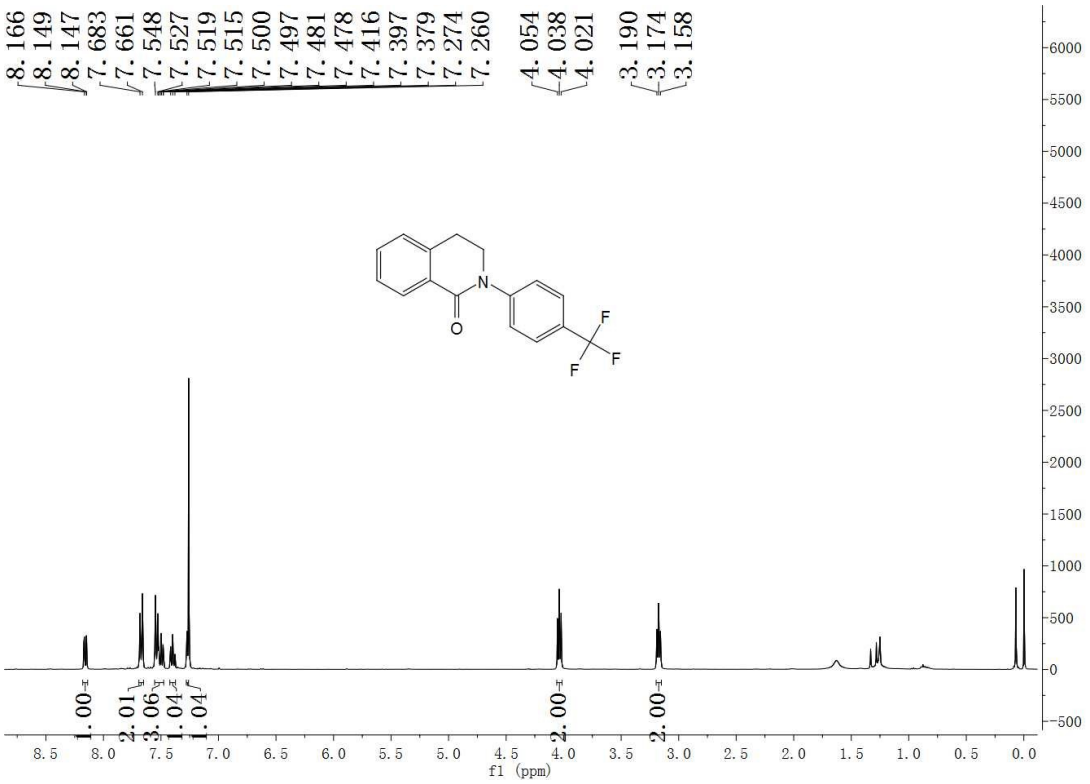


Figure S61. ^{1}H NMR Spectrum of 4l (400 MHz, $CDCl_3$)

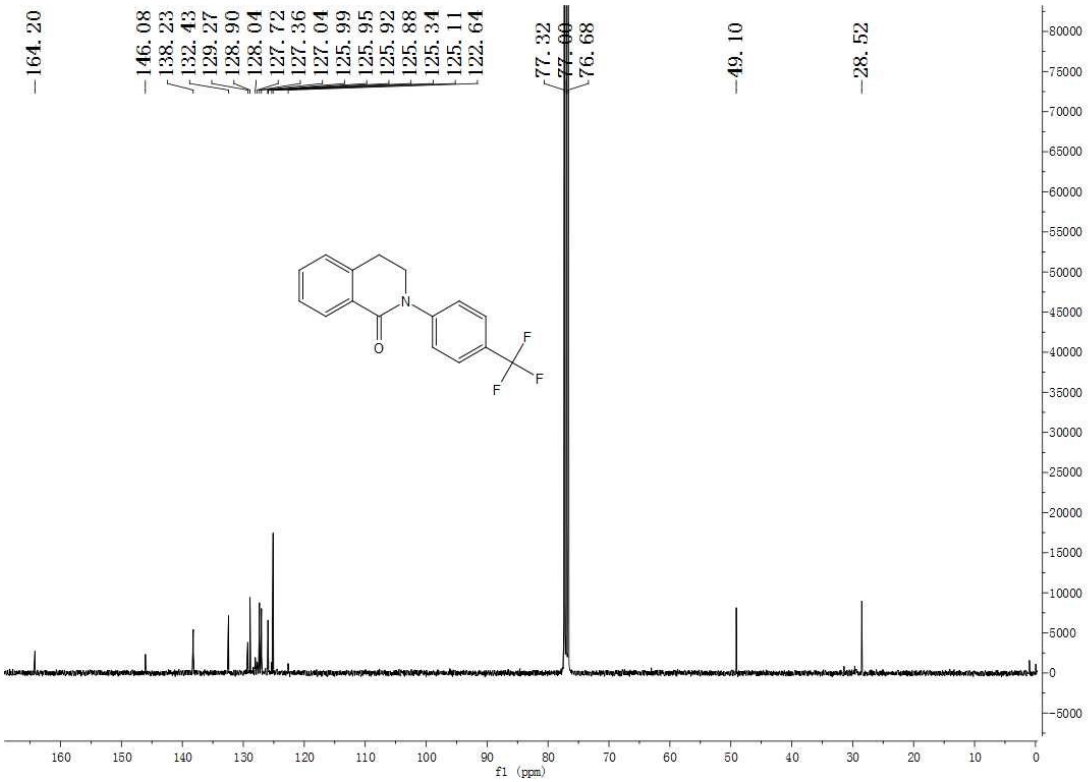


Figure S62. ^{13}C NMR Spectrum of 4l (100 MHz, $CDCl_3$)

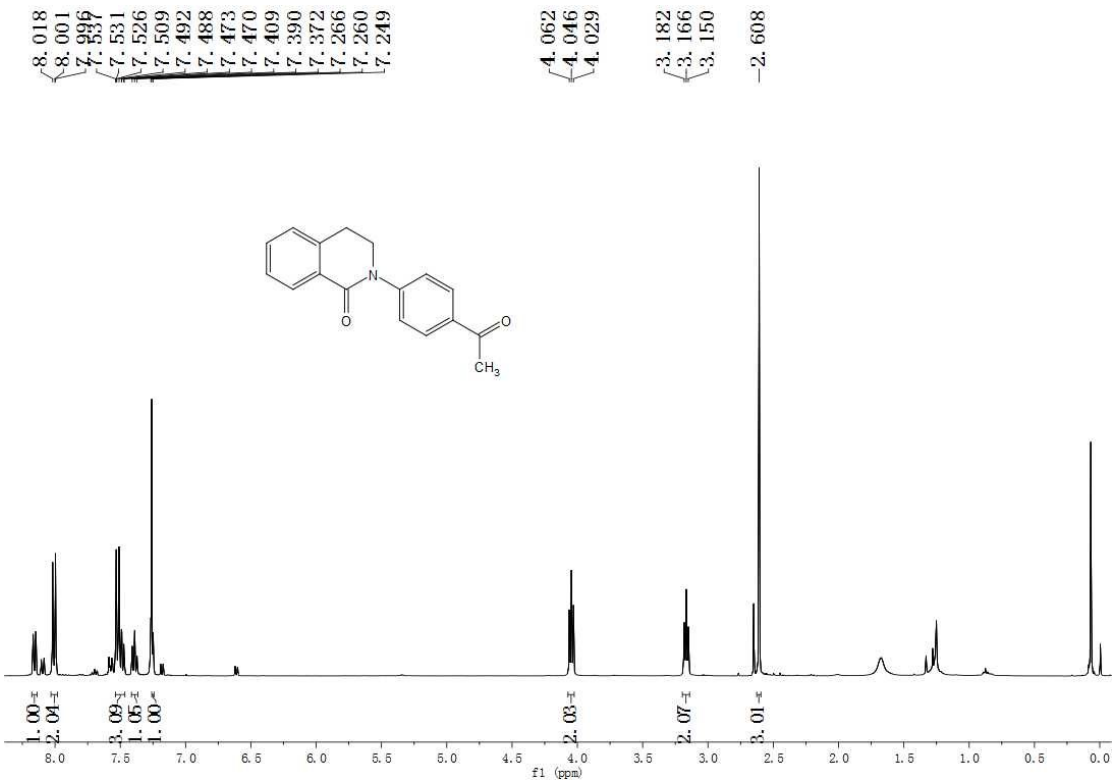


Figure S63. ^{1}H NMR Spectrum of 4m (400 MHz, $CDCl_3$)

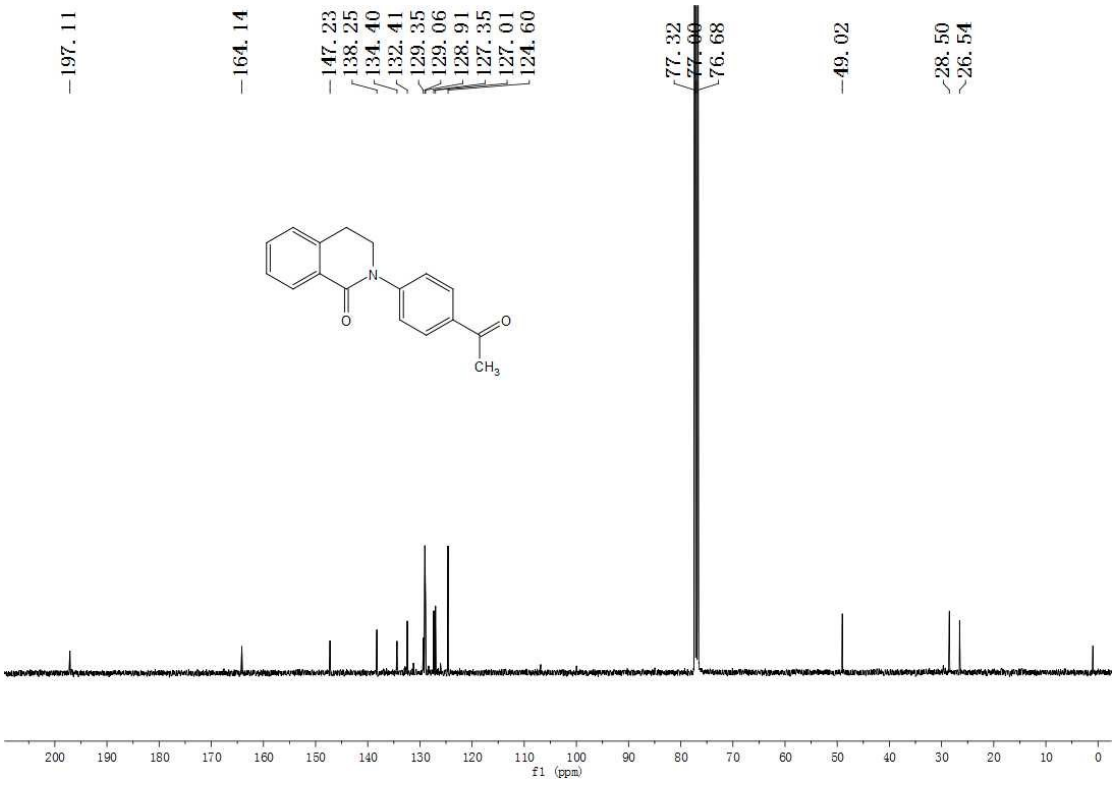


Figure S64. ^{13}C NMR Spectrum of 4m (100 MHz, $CDCl_3$)

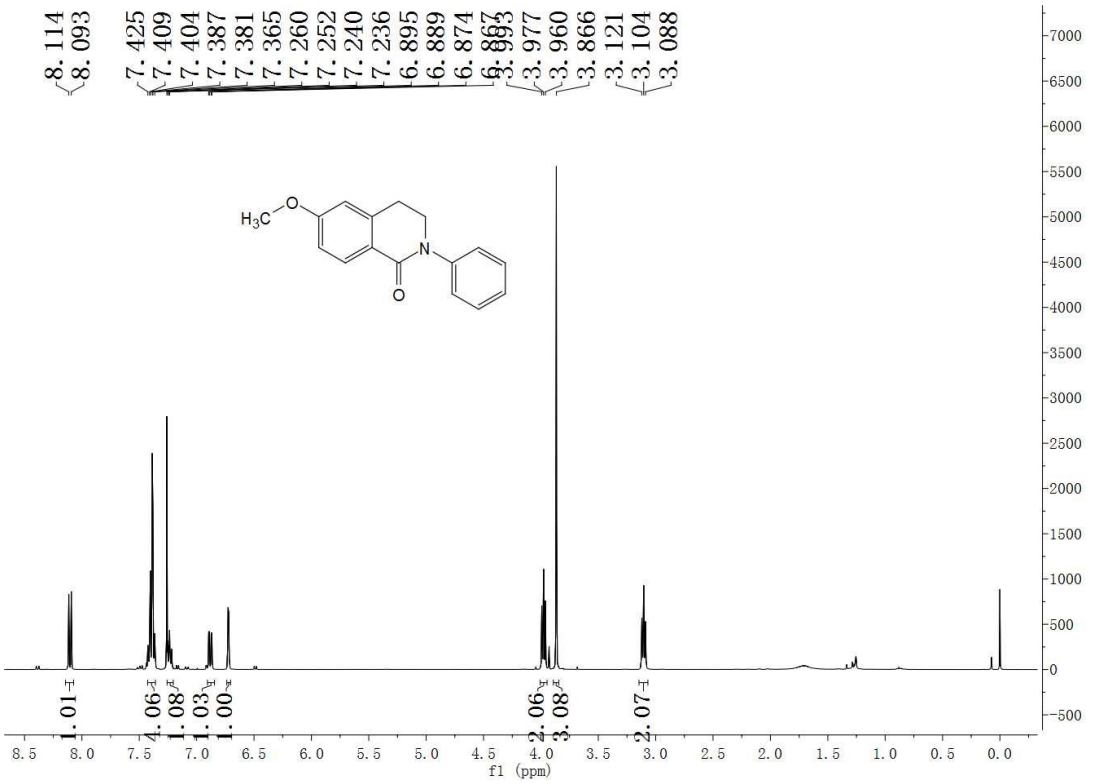


Figure S65. ^{1}H NMR Spectrum of 4n (400 MHz, $CDCl_3$)

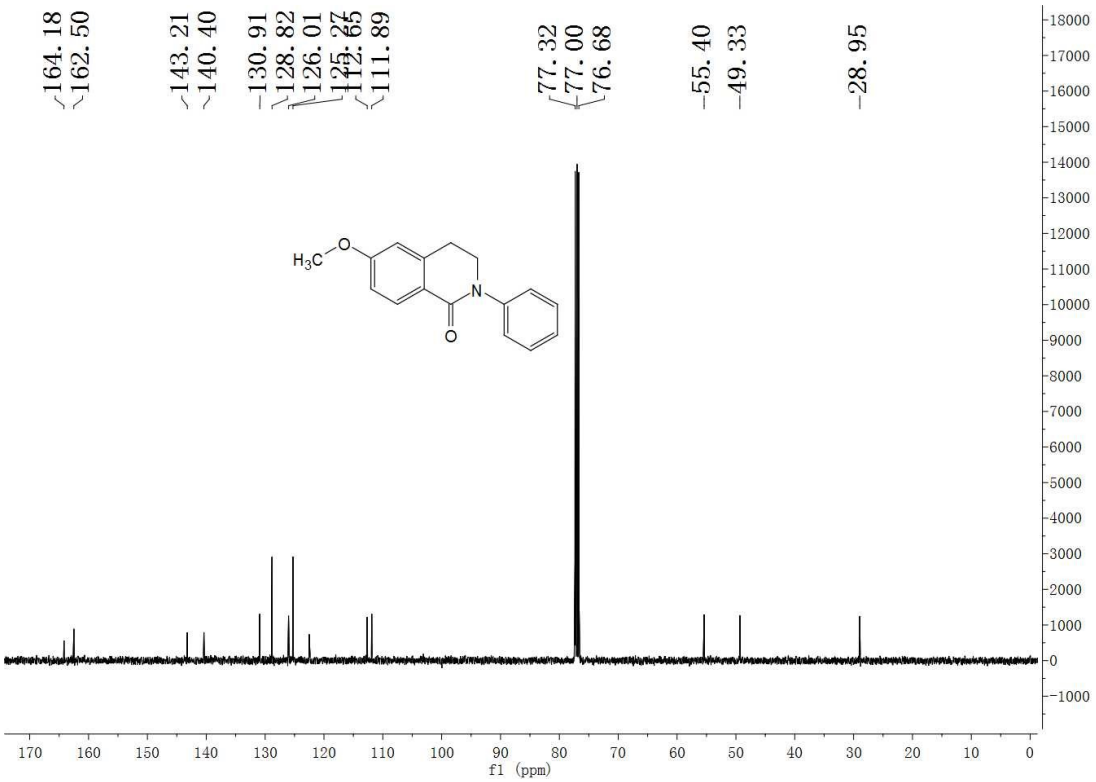


Figure S66. ^{13}C NMR Spectrum of 4n (100 MHz, $CDCl_3$)

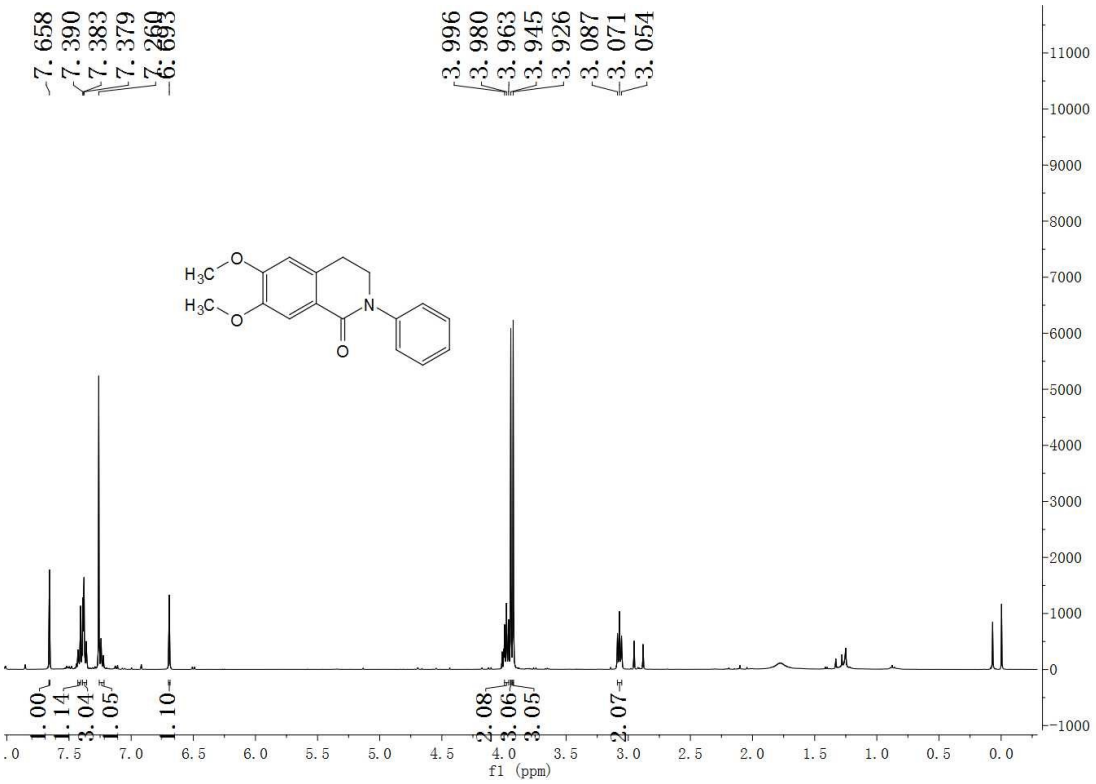


Figure S67. ^{1}H NMR Spectrum of 4o (400 MHz, $CDCl_3$)

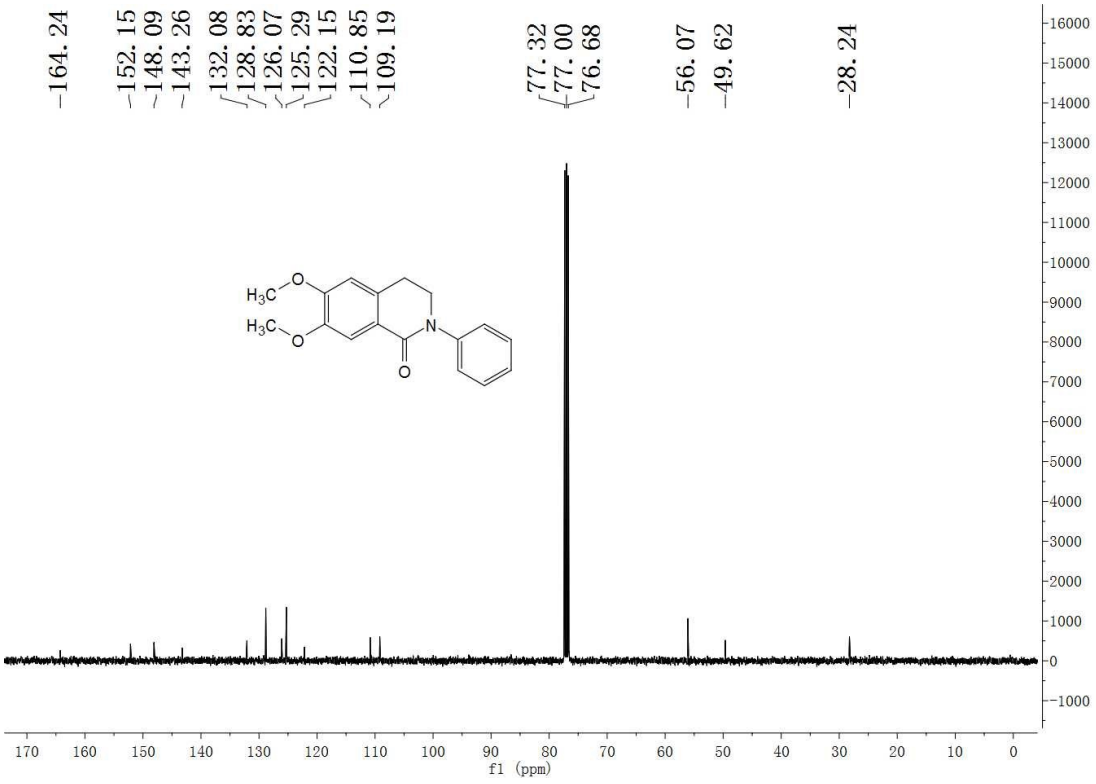


Figure S68. ^{13}C NMR Spectrum of 4o (100 MHz, $CDCl_3$)

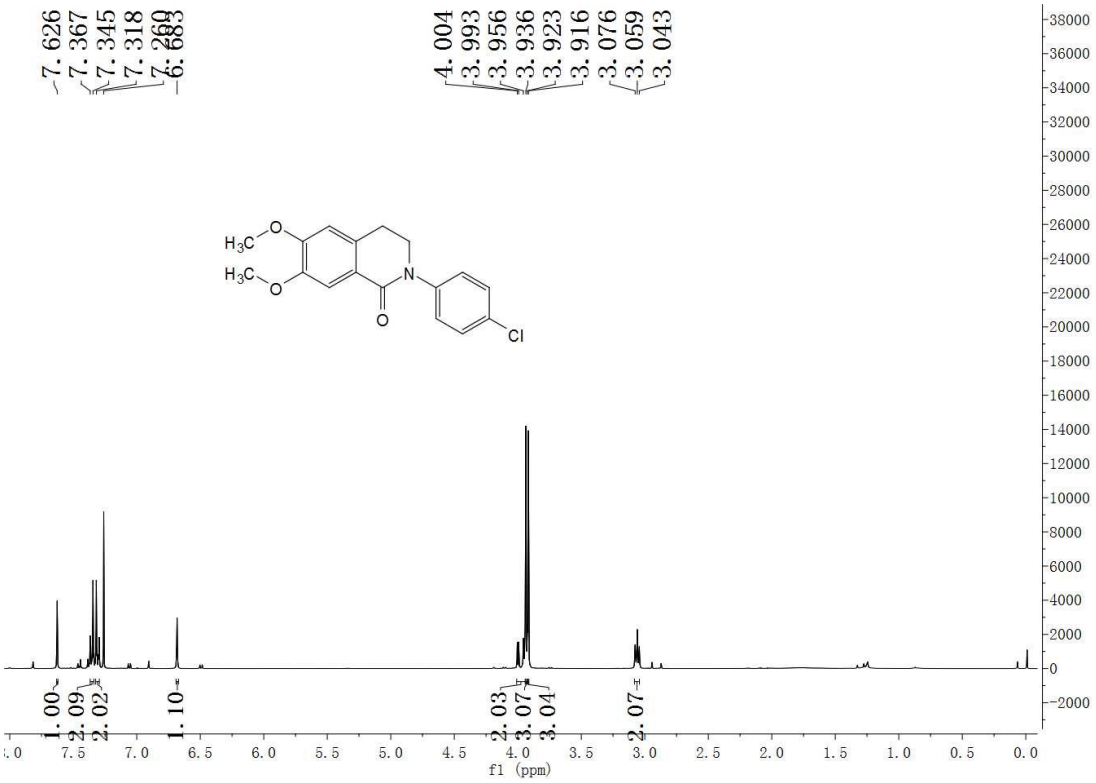


Figure S69. ^{1}H NMR Spectrum of 4p (400 MHz, $CDCl_3$)

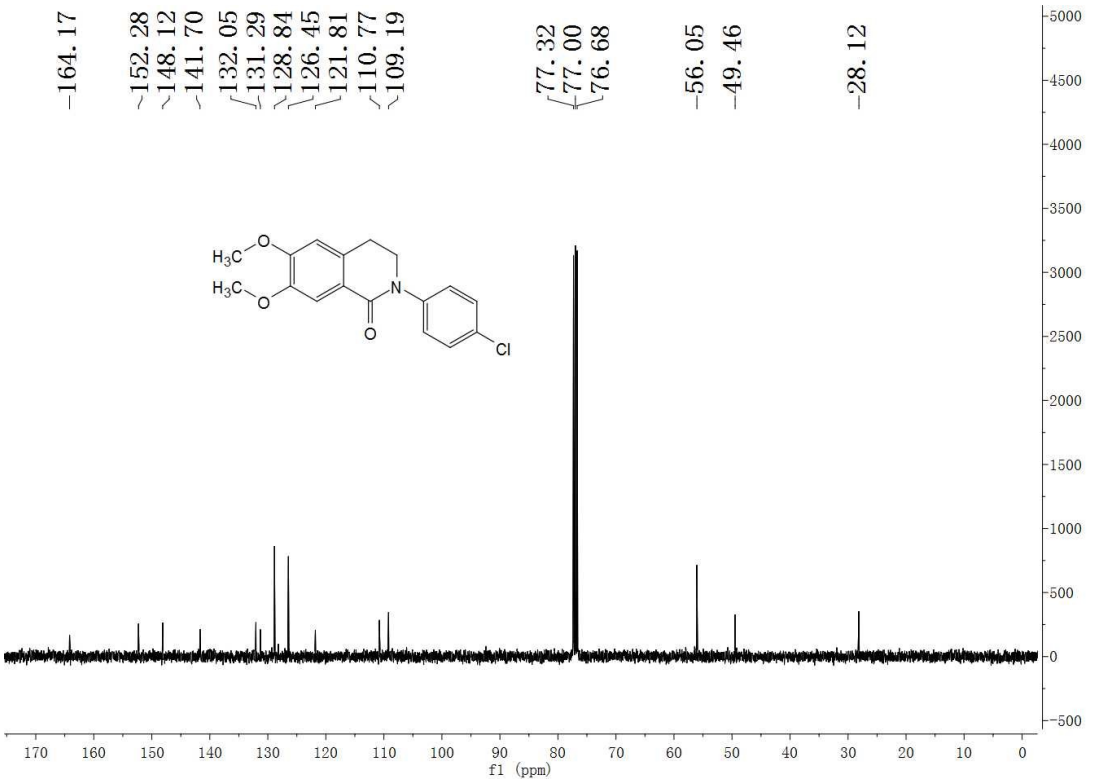


Figure S70. ^{13}C NMR Spectrum of 4p (100 MHz, $CDCl_3$)

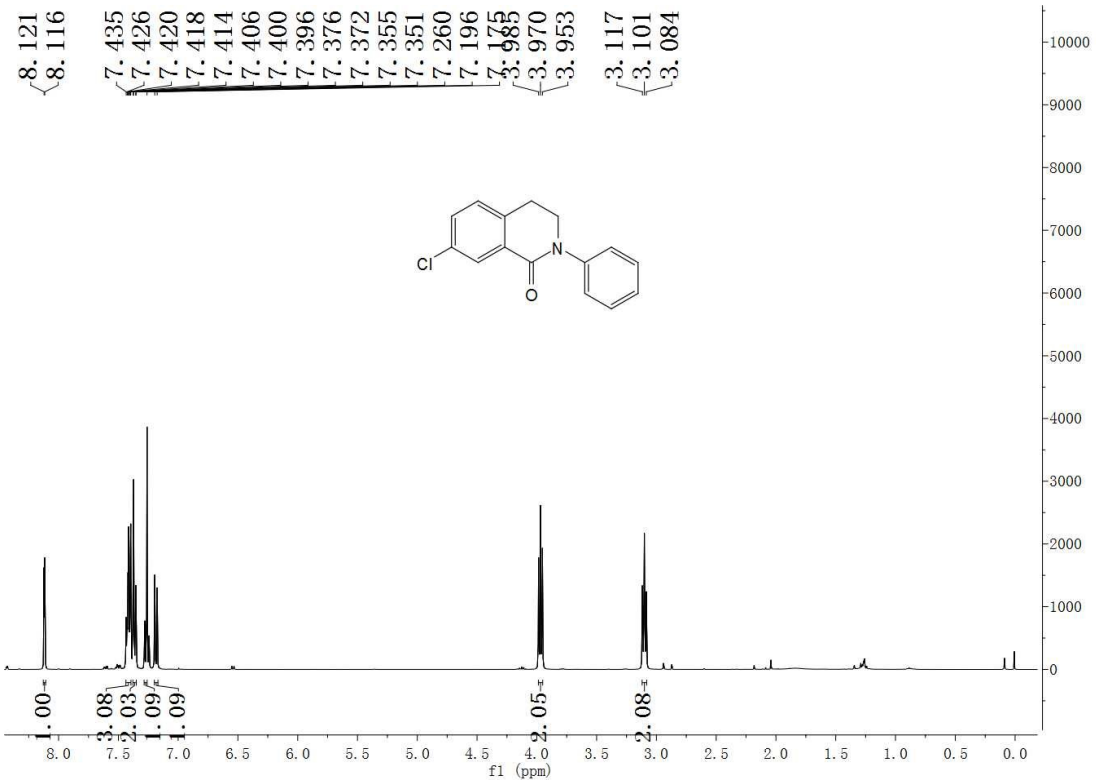


Figure S71. ^{1}H NMR Spectrum of 4q (400 MHz, $CDCl_3$)

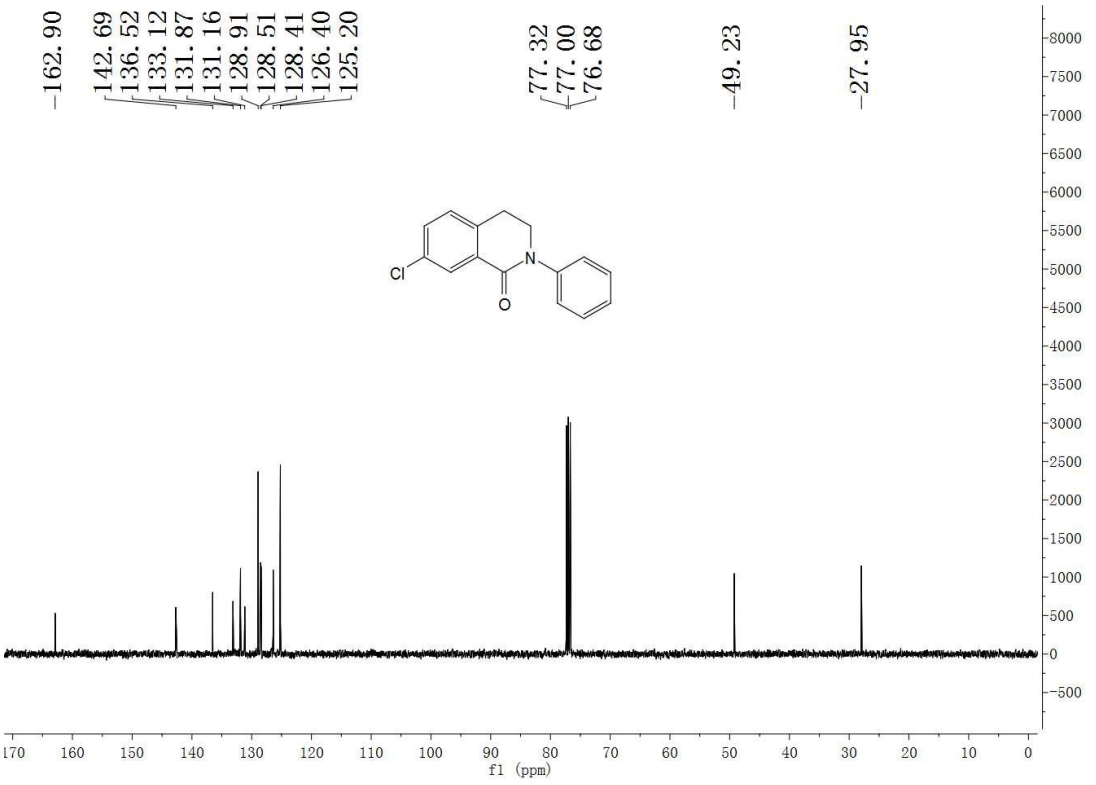


Figure S72. ^{13}C NMR Spectrum of 4q (100 MHz, $CDCl_3$)

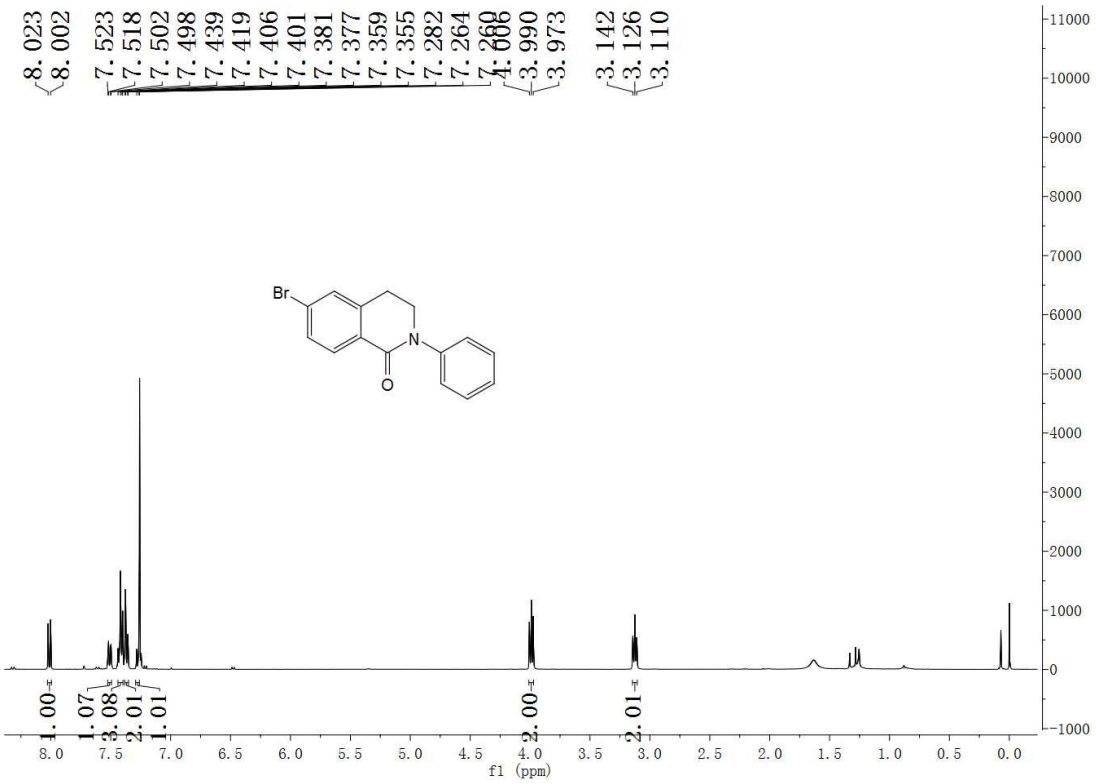


Figure S73. ^{1}H NMR Spectrum of 4r (400 MHz, $CDCl_3$)

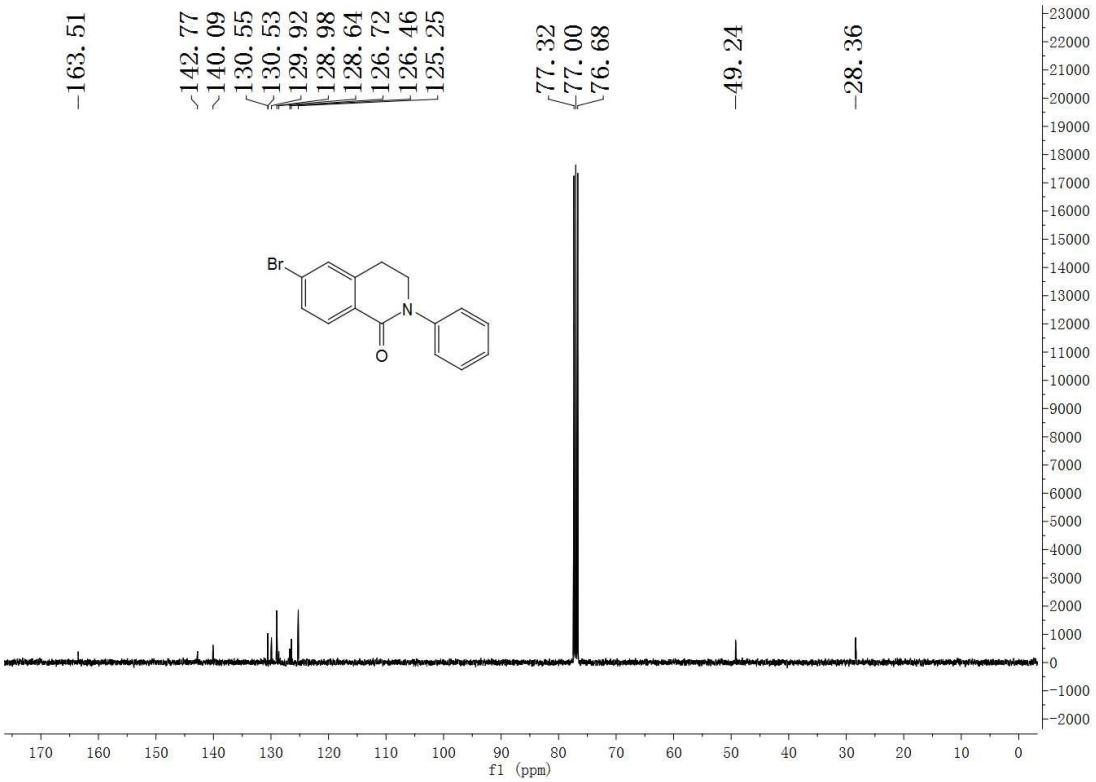


Figure S74. ^{13}C NMR Spectrum of 4r (100 MHz, $CDCl_3$)