Ethyl lactate participated three-component dehydrogenative reactions: biomass feedstock in diversity oriented quinoline synthesis

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Contents

General experimental information

All experiments were carried out at open atmosphere. All chemicals and solvents used in our experiments were obtained from commercial sources and used directly without further treatment. ^{1}H and ^{13}C NMR were recorded in 400 MHz apparatus. The frequencies for ^{1}H NMR and ^{13}C NMR test are 400 MHz and 100 MHz, respectively. The chemical shifts of most of compounds were reported in ppm with TMS as internal standard. Melting points were tested in X-4A instrument without correcting temperature and the HRMS were obtained under ESI model.

General experimental information for quinoline synthesis

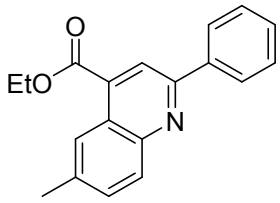
To a 25 mL round-bottom flask were added amine **1** (0.3 mmol), aldehyde **2** (0.2 mmol), and ethyl/methyl lactate **3** (2.0 mL) and $FeCl_3$ (0.02 mmol). Then

the mixture was stirred at 110 °C for 12 h. Subsequently the reaction mixture was mixed with water (10 mL), and the resulting suspension was extracted with ethyl acetate (3 × 10 mL). The combined organic phase was dried over anhydrous Na_2SO_4 and filtrated. The solution was evaporated under reduced pressure to remove the solvent. Purification of the residue by flash silica gel column chromatography using petroleum ether (PET) as eluent afforded pure product.

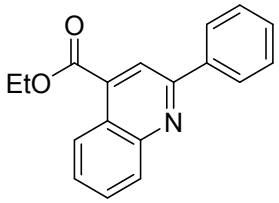
Scale-up synthesis of 4j

To a 25 mL round-bottom flask were charged with m-chloroaniline (10 mmol), benzaldehydes (10 mmol), EL (4 mL) and $FeCl_3$ (1 mmol). The resulting mixture was stirred at 110 °C for 12 h under air atmosphere. Upon completion, the vessel was allowed to cool down to room temperature, and 10 mL water was added. The resulting suspension was then extracted with ethyl acetate (3 × 15 mL). The combined organic solution was dried with anhydrous Na_2SO_4. After filtration, the solution was employed to reduced pressure to remove the solvent, and the residue was subjected to flash silica gel column chromatography to afford pure product with the elution of petroleum ether.

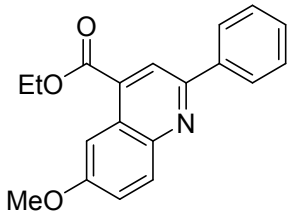
Characterization data of all products



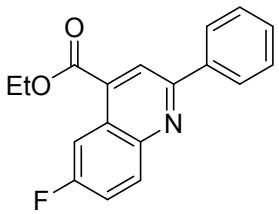
Ethyl 6-methyl-2-phenylquinoline-4-carboxylate (4a).[1] Yellow solid, m.p. 76-78 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.42 (s, 1 H), 8.24 (s, 1 H), 8.13-8.06 (m, 2 H), 8.02 (d, *J* = 8.8 Hz, 1 H), 7.49 (dd, *J* = 8.6, 1.8 Hz, 1 H), 7.44 (t, *J* = 7.2 Hz, 2H), 7.37 (t, *J* = 7.2 Hz, 1 H), 4.44 (q, *J* = 7.1 Hz, 2 H), 2.48 (s, 3 H), 1.40 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 155.8, 147.9, 139.0, 137.9, 135.3, 132.1, 130.0, 129.5, 128.9, 127.4, 124.3, 124.1, 120.1, 61. 8, 22.1, 14.4.



Ethyl 2-phenylquinoline-4-carboxylate (**4b**).[1] Yellow liquid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.74 (d, *J* = 8.4 Hz, 1 H), 8.38 (s, 1 H), 8.26 – 8.16 (m, 3 H), 7.76 (t, *J* = 7.6 Hz, 1 H), 7.61 (t, *J* = 7.2 Hz, 1 H), 7.54 (d, *J* = 7.3 Hz, 2 H), 7.48 (t, *J* = 7.2 Hz, 1 H), 4.54 (q, *J* = 7.1 Hz, 2 H), 1.49 (d, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.4, 156.7, 149.2, 138.8, 136.1, 130.3, 129.9, 129.7, 128.9, 127.7, 127.5, 125.4, 124.0, 120.2, 61.9, 14.4.

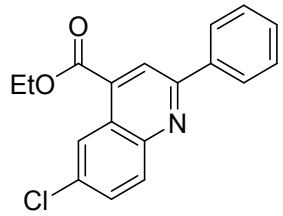


Ethyl 6-methoxy-2-phenylquinoline-4-carboxylate (**4c**). Yellow solid, m.p. 67-69 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.41 (s, 1 H), 8.21 (d, *J* = 2.8 Hz, 1 H), 8.16 (d, *J* = 7.2 Hz, 2 H), 8.11 (d, *J* = 9.2 Hz, 1 H), 7.52 (t, *J* = 7.4 Hz, 2 H), 7.46 (d, *J* = 7.2 Hz, 1 H), 7.41 (dd, *J* = 9.2, 2.8 Hz, 1 H), 4.53 (q, *J* = 7.1 Hz, 2 H), 3.97 (s, 3 H), 1.50 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 159.0, 154.2, 145.7, 139.0, 133.8, 131.7, 129.3, 128.9, 127.2, 125.5, 122.8, 120.6, 103.3, 61.7, 55.6, 14.4; ESI-HRMS: Calcd for $C_{19}H_{18}NO_3$ $[M+H]^+$ 308.1281, found 308.1280.

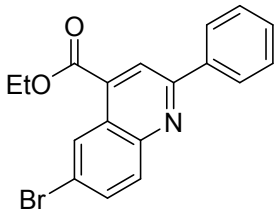


Ethyl 6-fluoro-2-phenylquinoline-4-carboxylate (**4d**).[1] Yellow solid, m.p. 65-68 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.49 (dd, *J* = 10.8, 2.8 Hz, 1 H), 8.45 (s, 1 H), 8.25 – 8.15 (m, 3 H), 7.57 – 7.45 (m, 4 H), 4.54 (q, *J* = 7.1 Hz, 2 H), 1.50 (t, J = 7.1 Hz, 3 H);

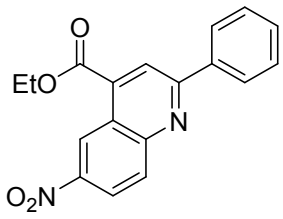
^{13}C NMR (100 MHz, $CDCl_3$): δ 165.96, 162.66 (d, J_{C-F} = 247.0 Hz), 156.04, 146.49, 138.52, 135.11, 132.70 (d, J_{C-F} = 9.0 Hz), 129.77, 128.96, 127.36, 125.01 (d, J_{C-F} = 11.0 Hz), 121.10, 120.28 (d, J_{C-F} = 26.0 Hz), 109.64 (d, J_{C-F} = 25.0 Hz), 62.02, 14.33.



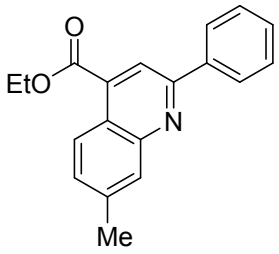
Ethyl 6-chloro-2-phenylquinoline-4-carboxylate (**4e**). Yellow solid, m.p. 78-80 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.73 (d, *J* = 2.4 Hz, 1 H), 8.33 (s, 1 H), 8.13 – 8.00 (m, 3 H), 7.60 (dd, *J* = 9.0, 2.2 Hz, 1 H), 7.48 – 7.36 (m, 3 H), 4.45 (q, *J* = 7.1 Hz, 2 H), 1.42 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.8, 156.9, 147.6, 138.4, 135.0, 133.9, 131.7, 130.9, 130.0, 129.0, 127.4, 124.6, 121.0, 62.1, 14.3; ESI-HRMS: Calcd for $C_{18}H_{15}ClNO_2$ $[M+H]^+$ 312.07185, found 312.0785.



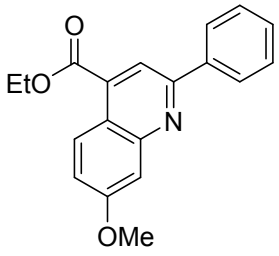
Ethyl 6-bromo-2-phenylquinoline-4-carboxylate (**4f**). Yellow solid, m.p. 100-102 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.99 (d, *J* = 2.0 Hz, 1 H), 8.41 (s, 1 H), 8.18 (d, *J* = 7.2 Hz, 2 H), 8.06 (d, *J* = 9.2 Hz, 1 H), 7.82 (d, *J* = 9.2 Hz, 1 H), 7.57 – 7.46 (m, 3 H), 4.54 (q, *J* = 7.1 Hz, 2 H), 1.50 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.8, 157.0, 147.85, 138.4, 134.9, 133.4, 131.8, 130.0, 129.0, 127.9, 127.5, 125.1, 122.3, 121.0, 62.1, 14.3; ESI-HRMS: Calcd for $C_{18}H_{15}BrNO_2$ $[M+H]^+$ 356.0280, found 356.0280.



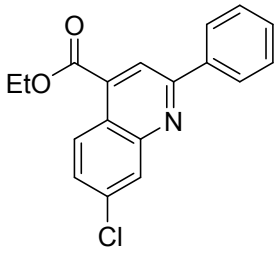
Ethyl 6-nitro-2-phenylquinoline-4-carboxylate (**4g**). Yellow solid, m.p. 152-154 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.79 (d, *J* = 2.4 Hz, 1 H), 8.57 (s, 1 H), 8.51 (dd, *J* = 9.2, 2.4 Hz, 1 H), 8.32 (d, *J* = 9.2 Hz, 1 H), 8.28 – 8.22 (m, 2 H), 7.63 – 7.53 (m, 3 H), 4.61 (q, *J* = 7.1 Hz, 2 H), 1.55 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.3, 160.1, 151.13, 146.2, 137.7, 137.4, 131.8, 130.9, 129.1, 127.8, 123.4, 122.9, 122.9, 121.9, 62.6, 14.3; ESI-HRMS: Calcd for $C_{18}H_{15}N_2O_4$ $[M+H]^+$ 323.1026, found 323.1026.



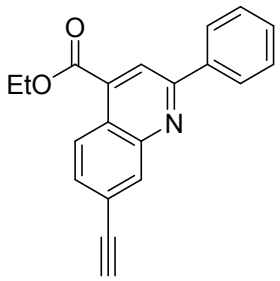
Ethyl 7-mEthyl-2-phenylquinoline-4-carboxylate (**4h**). Brown solid, m.p. 98-101 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.62 (d, J = 8.8 Hz, 1H), 8.31 (s, 1 H), 8.22 – 8.15 (m, 2 H), 8.01 (s, 1 H), 7.53 (t, *J* = 7.3 Hz, 2 H), 7.49 – 7.43 (m, 2 H), 4.53 (q, *J* = 7.1 Hz, 2 H), 2.57 (s, 3 H), 1.49 (d, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 156.7, 149.5, 140.2, 139.0, 135.9, 130.0, 129.6, 129.3, 128.9, 127.5, 125.1, 122.1, 119.4, 61.8, 21.7, 14.4; ESI-HRMS: Calcd for $C_{19}H_{18}NO_2$ $[M+H]^+$ 292.1332, found 292.1331.



Ethyl 7-methoxy-2-phenylquinoline-4-carboxylate (**4i**). Yellow solid, m.p. 83-85 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.64 (d, *J* = 9.6 Hz, 1 H), 8.23 (s, 1 H), 8.17 (d, *J* = 7.2 Hz, 2 H), 7.58 – 7.50 (m, 3 H), 7.48 (d, *J* = 7.2 Hz, 1 H), 7.30 – 7.24 (m, 1 H), 4.53 (q, *J* = 7.1 Hz, 2 H), 3.98 (s, 3 H), 1.49 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 160.9, 157.2, 151.2, 139.0, 135.9, 129.6, 128.9, 127.5, 126.5, 120.9, 119.3, 118.0, 108.1, 61.8, 55.6, 14.3; ESI-HRMS: Calcd for $C_{19}H_{18}NO_3$ $[M+H]^+$ 308.1281, found 308.1280.

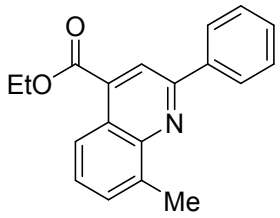


Ethyl 7-chloro-2-phenylquinoline-4-carboxylate (**4j**). White solid, m.p. 89-91 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.71 (d, *J* = 8.8 Hz, 1 H), 8.37 (s, 1 H), 8.23 – 8.13 (m, 3 H), 7.59 – 7.44 (m, 4 H), 4.53 (q, *J* = 7.1 Hz, 2 H), 1.49 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.0, 157.8, 149.7, 138.3, 135.9, 135.9, 130.1, 129.1, 129.0., 128.6, 127.5, 126.9, 122.5, 120.3, 62.1, 14.3; ESI-HRMS: Calcd for $C_{18}H_{15}ClNO_2$ $[M+H]^+$ 312.0785, found 312.0785.

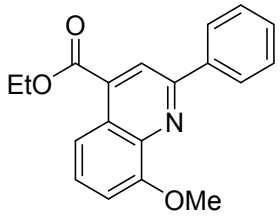


Ethyl 7-ethynyl-2-phenylquinoline-4-carboxylate (**4k**). Yellow liquid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.71 (d, *J* = 8.4 Hz, 1 H), 8.38 (d, *J* = 4.4 Hz, 2 H), 8.19 (d, *J* = 6.8 Hz, 2 H), 7.65 (dd, *J* = 8.8, 1.2 Hz, 1 H), 7.58 – 7.46 (m, 3 H), 4.54 (d, *J* = 7.2 Hz, 2 H), 3.27 (s, 1 H), 1.50 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.05, 157.48, 148.73, 138.42, 135.89, 134.12, 130.39, 129.98, 128.96, 127.51, 125.66,

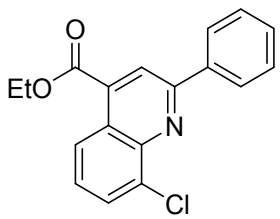
124.06, 123.76, 120.77, 82.99, 79.50,0 62.04, 14.33; ESI-HRMS: Calcd for $C_{20}H_{16}NO_2$ $[M+H]^+$ 302.1175, found 302.1173.



Ethyl 8-methyl-2-phenylquinoline-4-carboxylate (**4l**).[2] Yellow liquid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.53 (d, *J* = 8.4 Hz, 1 H), 8.38 (s, 1 H), 8.28 (d, *J* = 7.2 Hz, 2 H), 7.62 (d, *J* = 7.2 Hz, 1 H), 7.57 – 7.44 (m, 4 H), 4.54 (q, *J* = 7.1 Hz, 2 H), 2.92 (s, 3 H), 1.50 (d, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.8, 154.8, 148.1, 139.1, 138.1, 136.5, 130.0, 129.6, 128.9 127.4, 124.0, 123.2, 119.2, 61.8, 18.5, 14.4.

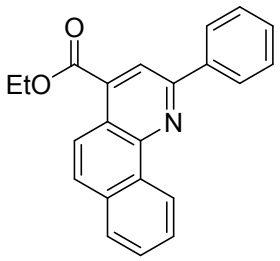


Ethyl 8-methoxy-2-phenylquinoline-4-carboxylate (**4m**)**.** Yellow liquid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.39 (s, 1 H), 8.27 (d, *J* = 7.2 Hz, 1 H), 8.22 (d, *J* = 7.2 Hz, 2 H), 7.56 – 7.49 (m, 3 H), 7.45 (d, *J* = 7.2 Hz, 1 H), 7.10 (d, *J* = 7.6 Hz, 1 H), 4.53 (d, *J* = 7.2 Hz, 2 H), 4.10 (s, 3 H), 1.49 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.57, 155.75, 155.53, 141.30, 139.01, 136.31, 129.55, 128.86, 127.93, 127.62, 125.15, 120.50, 117.12, 108.40, 61.91, 56.27, 14.34; ESI-HRMS: Calcd for $C_{19}H_{18}NO_3$ $[M+H]^+$ 308.1281, found 308.1280.

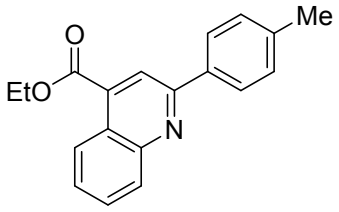


Ethyl 8-chloro-2-phenylquinoline-4-carboxylate (**4n**). Yellow solid, m.p. 92-94 ^{o}C;

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.57 (d, *J* = 8.0 Hz, 1 H), 8.36 (s, 1 H), 8.22 (d, *J* = 8.0 Hz, 2 H), 7.79 (d, *J* = 8.0 Hz, 1 H), 7.50 – 7.36 (m, 4 H), 4.45 (d, *J* = 7.0 Hz, 2 H), 1.41 (d, *J* = 8.0 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.07, 156.76, 145.29, 138.29, 136.69, 134.62, 130.15, 130.08, 128.99, 127.63, 127.37, 125.43, 124.50, 120.48, 62.13, 14.33; ESI-HRMS: Calcd for $C_{18}H_{15}ClNO_2$ $[M+H]^+$ 312.0785, found 312.0785.

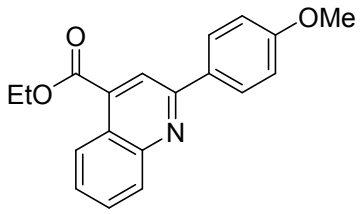


Ethyl 2-phenylbenzo[h]quinoline-4-carboxylate (**4o**). Yellow solid, m.p. 99-101 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.44 (d, *J* = 8.0 Hz, 1 H), 8.56 (d, *J* = 8.4 Hz, 1 H), 8.41 (s, 1 H), 8.32 (d, *J* = 7.2 Hz, 2 H), 7.88 – 7.77 (m, 2 H), 7.74 – 7.62 (m, 2 H), 7.54 (t, *J* = 7.6 Hz, 2 H), 7.46 (t, *J* = 7.2 Hz, 1 H), 4.52 (q, *J* = 7.1 Hz, 2 H), 1.48 (t, *J* = 7.0 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.7, 154.8, 147.4, 139.0, 136.0, 133.5, 131.7, 129.6, 128.9, 128.9, 128.6, 127.6, 127.4, 127.1, 125.2, 122.6, 122.4, 119.5, 61.9, 14.4; ESI-HRMS: Calcd for $C_{22}H_{18}NO_2$ $[M+H]^+$ 328.1332, found 328.1331.

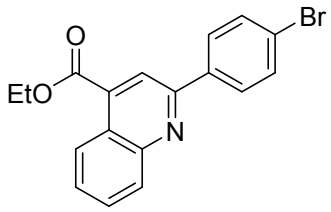


Ethyl 2-(p-tolyl)quinoline-4-carboxylate (**4p**). Yellow liquid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.71 (d, *J* = 8.4 Hz, 1 H), 8.34 (s, 1 H), 8.20 (d, *J* = 8.4 Hz, 1 H), 8.09 (d, *J* = 7.6 Hz, 2 H), 7.72 (t, *J* = 7.8 Hz, 1 H), 7.61 – 7.53 (m, 1 H), 7.31 (d, *J* = 8.0 Hz, 2 H), 4.52 (q, *J* = 7.1 Hz, 2 H), 2.41 (s, 3 H), 1.47 (t, J = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 156.6, 149.2, 139.9, 136.0, 136.0, 130.2, 129.8, 129.7, 127.5,

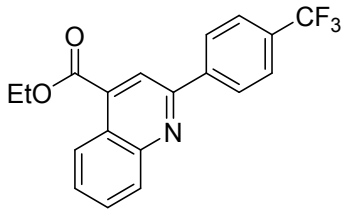
127.4, 125.4, 123.9, 120.0, 61.9, 21.4, 14.4; ESI-HRMS: Calcd for $C_{19}H_{18}NO_2$ $[M+H]^+$ 292.1332, found 292.1330.



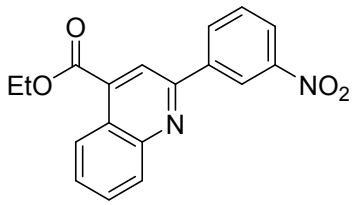
Ethyl 2-(4-methoxyphenyl)quinoline-4-carboxylate (**4q**). Brown solid, m.p. 79-81 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 8.61 (d, *J* = 8.4 Hz, 1 H), 8.24 (s, 1 H), 8.09 (t, *J* = 8.4 Hz, 3 H), 7.65 (t, *J* = 7.2 Hz, 1H), 7.49 (t, *J* = 7.3 Hz, 1H), 6.96 (d, *J* = 8.8 Hz, 2H), 4.45 (q, *J* = 7.1 Hz, 2 H), 3.79 (s, 3 H), 1.40 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 161.2, 156.2, 149.2, 136.0, 131.4, 130.0, 129.8, 128.9, 127.3, 125.4, 123.7, 119.8, 114.3, 61.9, 55.4, 14.4; ESI-HRMS: Calcd for $C_{19}H_{18}NO_3$ $[M+H]^+$ 308.1281, found 308.1280.



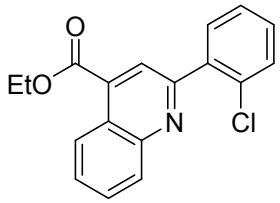
Ethyl 2-(4-bromophenyl)quinoline-4-carboxylate (**4r**).[3] Yellow solid, m.p. 96-98 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 8.73 (d, *J* = 8.4 Hz, 1 H), 8.33 (s, 1 H), 8.20 (d, *J* = 8.4 Hz, 1 H), 8.08 (d, *J* = 8.4 Hz, 2 H), 7.77 (t, *J* = 7.6 Hz, 1 H), 7.69 – 7.59 (m, 3 H), 4.55 (q, *J* = 7.1 Hz, 2 H), 1.50 (d, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.3, 155.4, 149.2, 137.6, 136.4, 132.1, 130.3, 130.1, 129.0, 128.0, 125.5, 124.4, 124.1, 119.7, 62.0, 14.4.



Ethyl 2-(4-(trifluoromethyl)phenyl)quinoline-4-carboxylate (**4s**). Yellow solid, m.p. 80-82 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.74 (d, *J* = 8.0 Hz, 1 H), 8.36 (s, 1 H), 8.29 (d, *J* = 8.0 Hz, 2 H), 8.20 (d, *J* = 8.4 Hz, 1 H), 7.77 (d, *J* = 8.0 Hz, 3 H), 7.63 (d, *J* = 8.0 Hz, 1 H), 4.55 (q, *J* = 8.0 Hz, 2 H), 1.50 (t, *J* = 8.0 Hz, 3 H); ^{13}C NMR (100 MHz, CDCl3): δ 166.16, 154.93, 149.22, 142.04, 136.39, 131.57 (q, $J_{C\text{-}F}$ = 32.5 Hz), 130.43, 130.10, 128.26, 127.72, 125.79 (q, $J_{C\text{-}F}$ = 4.0 Hz), 125.49, 124.30, 122.80, 119.85, 62.02, 14.31 (Note: probably because of the signal overlap, the theoretical quadruple carbon signal with $J_{C\text{-}F} \approx 268$ Hz has not been clearly detected in the present ^{13}C NMR spectrum); ESI-HRMS: Calcd for $C_{19}H_{15}FNO_2$ $[M+H]^+$ 346.1049, found 346.1050.

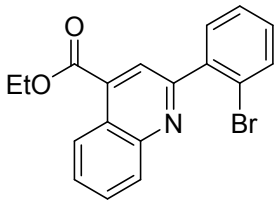


Ethyl 2-(3-nitrophenyl)quinoline-4-carboxylate (**4t**). Yellow solid, m.p. 116-118 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.08 (s, 1 H), 8.77 (d, *J* = 8.0 Hz, 1 H), 8.58 (d, *J* = 8.0 Hz, 1 H), 8.42 (s, 1 H), 8.34 (d, *J* = 8.0 Hz, 1 H), 8.25 (d, *J* = 8.0 Hz, 1 H), 7.82 (d, *J* = 7.6 Hz, 1 H), 7.76 – 7.64 (m, 2 H), 4.58 (d, *J* = 8.0 Hz, 2 H), 1.53 (d, *J* = 8.0 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.08, 153.82, 149.21, 148.96, 140.47, 136.82, 133.18, 130.43, 130.37, 129.88, 128.54, 125.54, 124.43, 124.22, 122.36, 119.41, 62.17, 14.36; ESI-HRMS: Calcd for $C_{18}H_{15}N_2O_4$ $[M+H]^+$ 323.1026, found 323.1025.

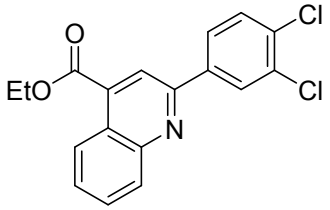


Ethyl 2-(2-chlorophenyl)quinoline-4-carboxylate (**4u**). White solid, m.p. 70-72 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.73 (d, *J* = 8.4 Hz, 1 H), 8.22 – 8.11 (m, 2 H), 7.74 – 7.66 (m, 1 H), 7.65 – 7.56 (m, 2 H), 7.46 – 7.40 (m, 1 H), 7.38 – 7.28 (m, 2 H), 4.44 (q, *J* = 7.2 Hz, 2 H), 1.38 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100MHz, $CDCl_3$): δ 166.2,

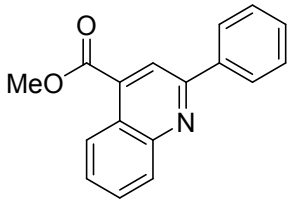
156.9, 149.0, 138.9, 135.1, 132.5, 131.7, 130.2, 130.2, 129.9, 128.3, 127.3, 125.5, 124.1, 124.0, 61.9, 14.3; ESI-HRMS: Calcd for $C_{18}H_{15}ClNO_2$ $[M+H]^+$ 312.0785, found 312.0785.



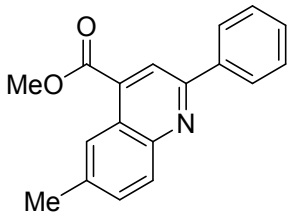
Ethyl 2-(2-bromophenyl)quinoline-4-carboxylate (**4v**). White solid, m.p. 79-81 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.82 (d, *J* = 8.0 Hz, 1 H), 8.25-8.17 (m, 2 H), 7.77 (d, *J* = 8.0 Hz, 1 H), 7.73 – 7.64 (m, 3 H), 7.44 (d, *J* = 8.0 Hz, 1 H), 7.32 – 7.27 (m, 1 H), 4.51 (d, *J* = 8.0 Hz, 2 H), 1.45 (d, *J* = 6.0 Hz, 3 H); ^{13}C NMR (100 MHz, CDCl3): δ 166.1, 158.2, 148.9, 140.9, 134.9, 133.4, 131.6, 130.3, 130.2, 129.9, 128.3, 127.8, 125.5, 124.1, 123.9, 121.9, 61.9, 14.3; ESI-HRMS: Calcd for $C_{18}H_{15}BrNO_2$ $[M+H]^+$ 356.0280, found 356.0282.



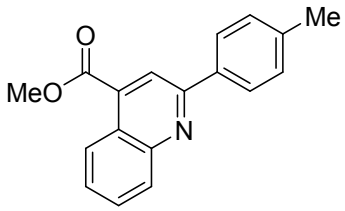
Ethyl 2-(3,4-dichlorophenyl)quinoline-4-carboxylate (**4w**). Yellow solid, m.p. 61-63 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.61 (d, *J* = 8.8 Hz, 1 H), 8.23 – 8.13 (m, 2 H), 8.10 – 8.02 (m, 1 H), 7.92 – 7.84 (m, 1 H), 7.65 (t, *J* = 8.4 Hz, 1), 7.55 – 7.48 (m, 1 H), 7.47 – 7.40 (m, 1 H), 4.45 (q, *J* = 7.1 Hz, 2 H), 1.41 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.1, 153.8, 149.1, 138.5, 136.4, 134.0, 133.3, 130.8, 130.3, 130.2, 129.2, 128.2, 126.4, 125.5, 124.2, 119.3, 62.1, 14.4; ESI-HRMS: Calcd for $C_{18}H_{14}Cl_2NO_2$ [M+H]+ 346.0396, found 346.0396.



Methyl 2-phenylquinoline-4-carboxylate (**4x**).[4] Yellow solid, m.p. 56-58 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.62 (d, *J* = 8.4 Hz, 1 H), 8.27 (s, 1 H), 8.14 – 8.04 (m, 3 H), 7.63 (t, *J* = 7.6 Hz, 1 H), 7.49 (t, *J* = 7.6 Hz, 1 H), 7.41 (t, *J* = 7.4 Hz, 2 H), 7.35 (t, *J* = 7.2 Hz, 1 H), 3.93 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.8, 156.6, 149.3, 138.8, 135.6, 130.3, 129.9, 129.7, 128.9, 127.8, 127.5, 125.4, 124.0, 120.3, 52.7.



Methyl 6-methyl-2-phenylquinoline-4-carboxylate (**4y**). Yellow solid, m.p. 92-94 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.48 (s, 1 H), 8.32 (s, 1 H), 8.16 (d, *J* = 4.0 Hz, 2 H), 8.09 (d, *J* = 8.0 Hz, 1 H), 7.55 (d, *J* = 8.0 Hz, 1 H), 7.50 (d, *J* = 6.0 Hz, 2 H), 7.44 (d, *J* = 8.0 Hz, 1 H), 4.03 (s, 3 H), 2.54 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.92, 155.66, 147.91, 138.87, 137.98, 134.81, 132.15, 129.98, 129.52, 128.88, 127.35, 124.24, 124.02, 120.18, 52.60, 22.11; ESI-HRMS: Calcd for $C_{18}H_{16}NO_2$ $[M+H]^+$ 278.1175, found 278.1176.



Methyl 2-(p-tolyl)quinoline-4-carboxylate (**4z**).[5] White solid, m.p. 68-71 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.71 (d, *J* = 8.8 Hz, 1 H), 8.36 (s, 1 H), 8.20 (d, *J* = 8.4 Hz, 1 H), 8.10 (d, *J* = 8.0 Hz, 2 H), 7.76 – 7.69 (m, 1 H), 7.61 – 7.54 (m, 1 H), 7.32 (d, *J* = 7.6 Hz, 2 H), 4.04 (s, 3 H), 2.42 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.9,

156.6, 149.3, 139.9, 136.0, 135.5, 130.2, 129.8, 129.7, 127.6, 127.3, 125.4, 123.9, 120.2, 52.7, 21.4.

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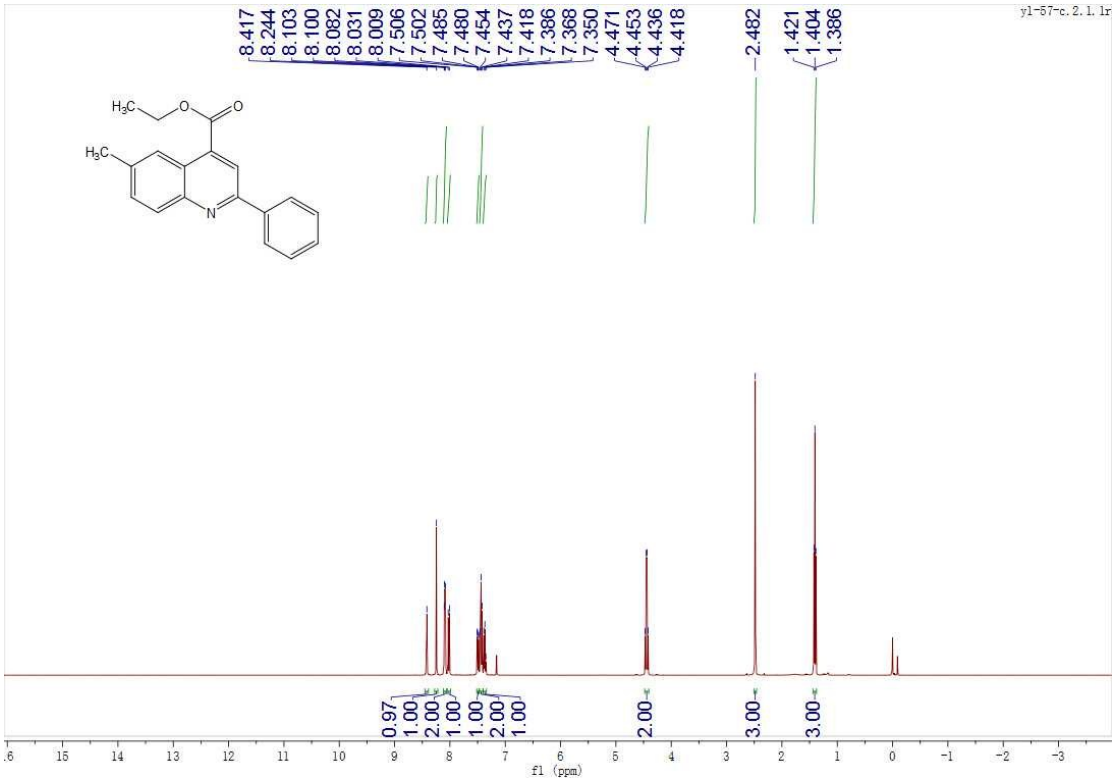
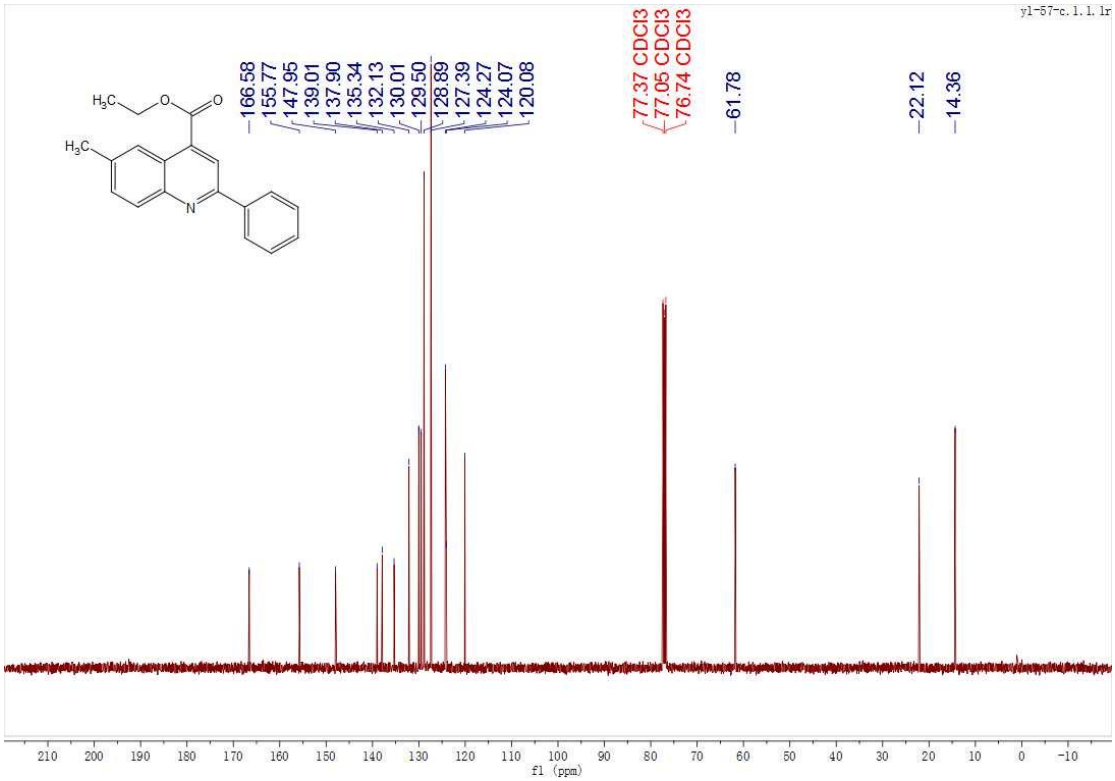
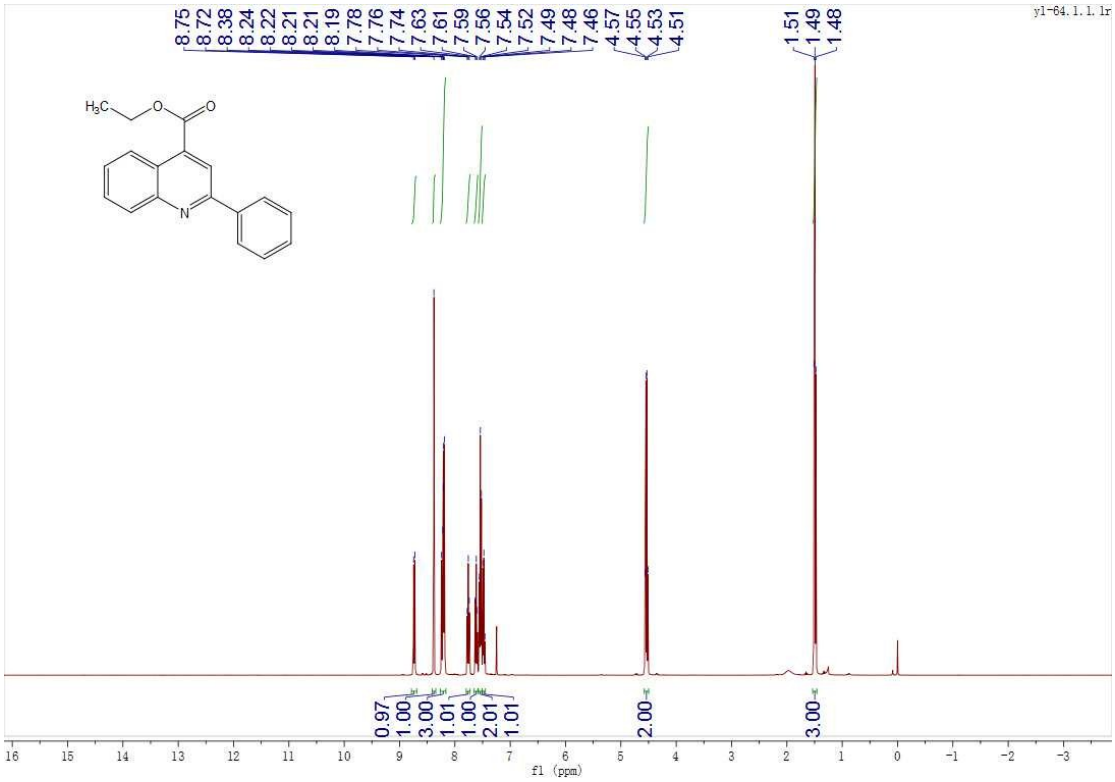
^{1}H and ^{13}C NMR spectra for all products

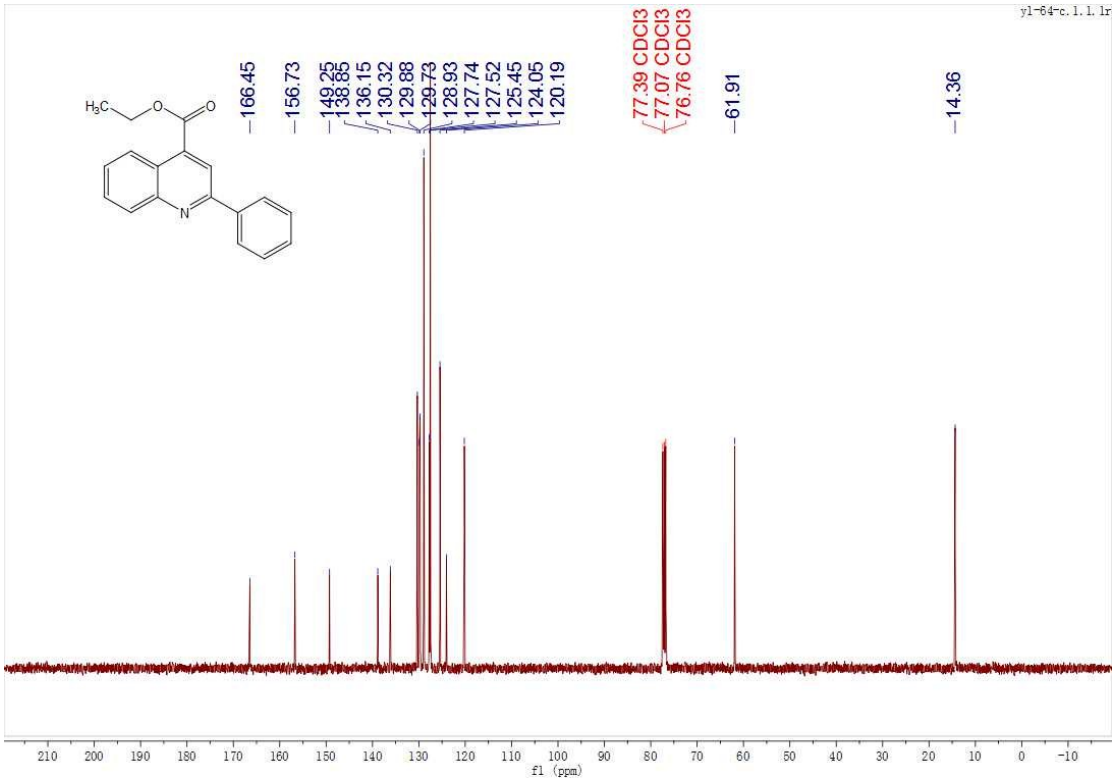
^{1}H and ^{13}C NMR of **4a**



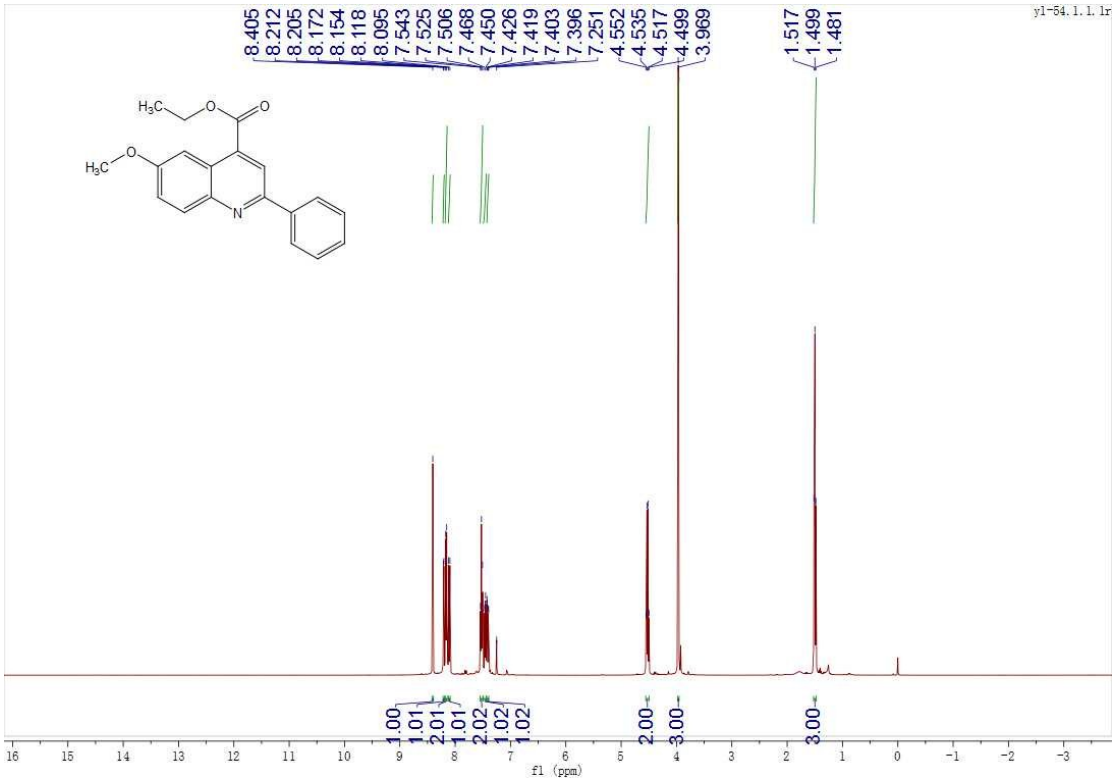


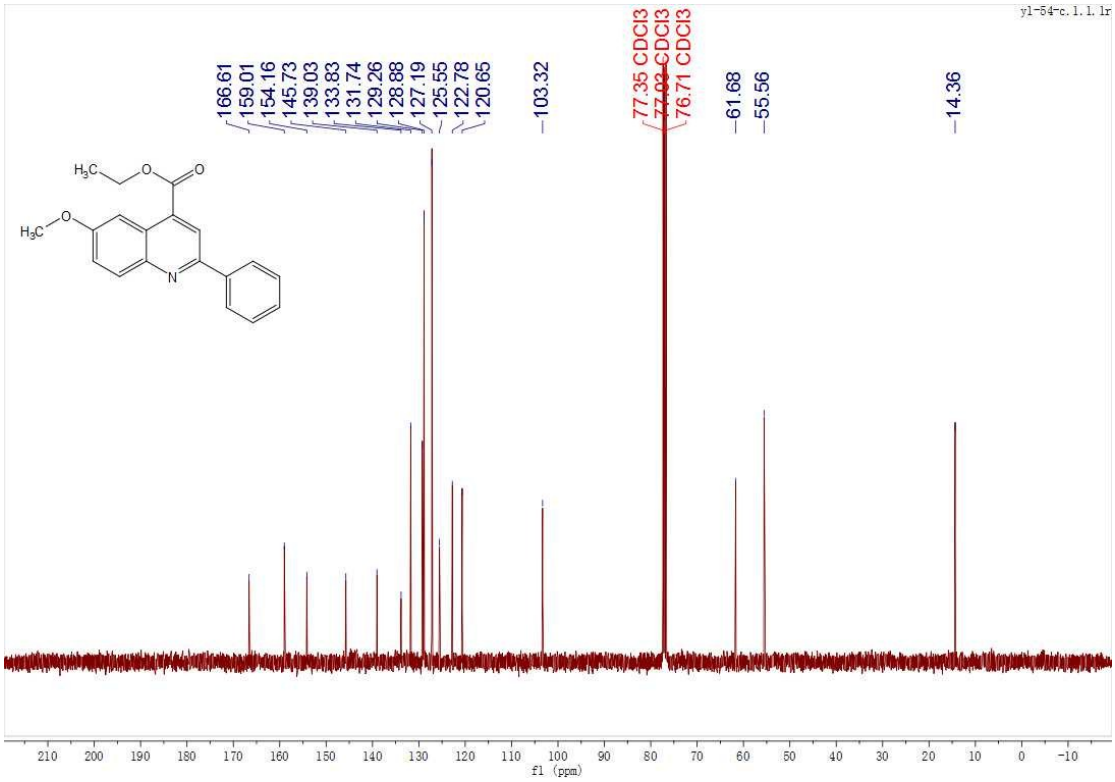
^{1}H and ^{13}C NMR of **4b**



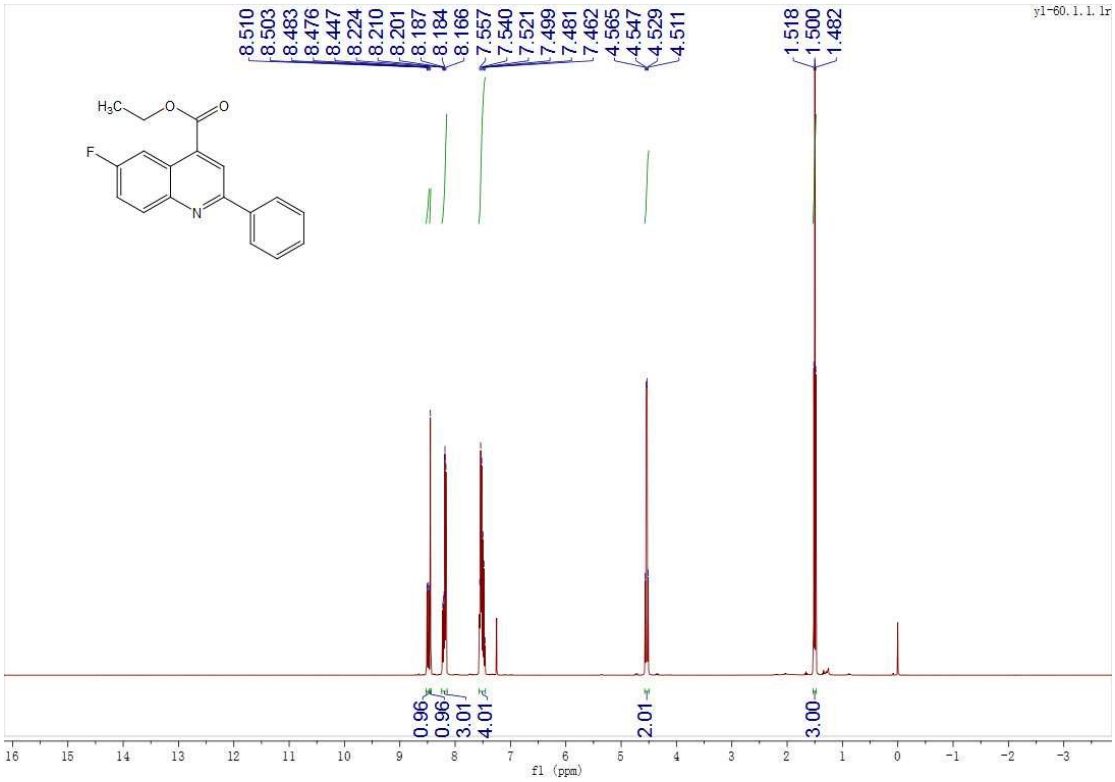


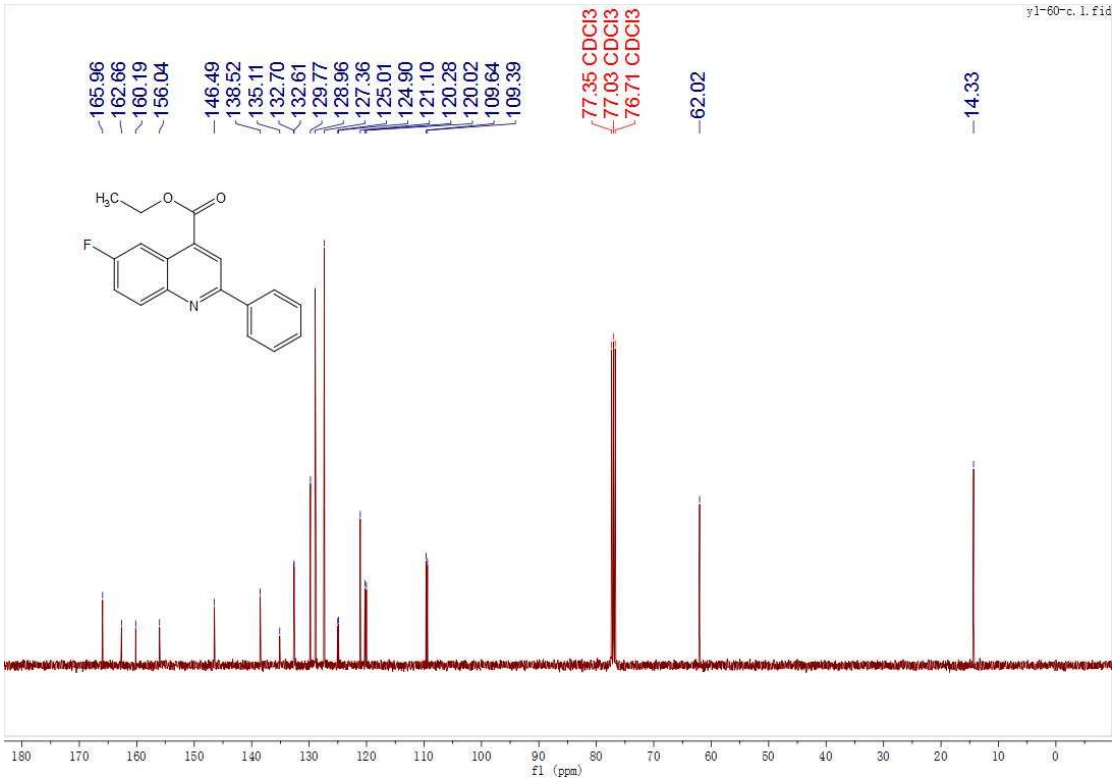
^{1}H and ^{13}C NMR of **4c**



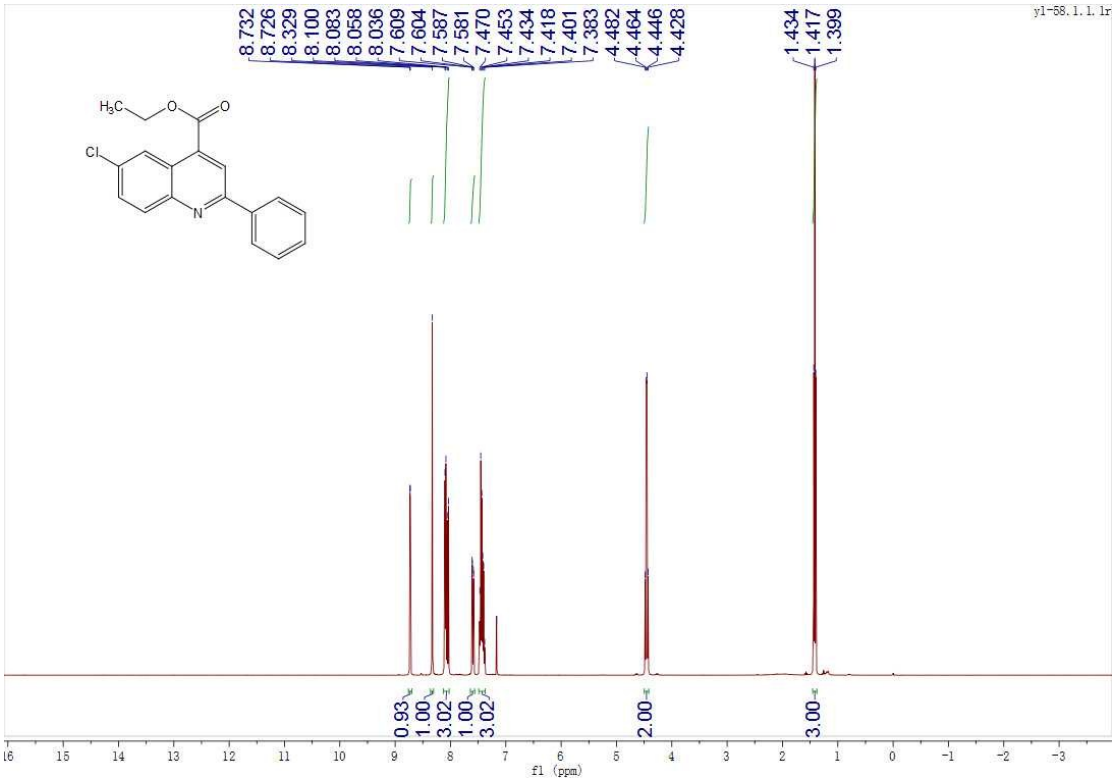


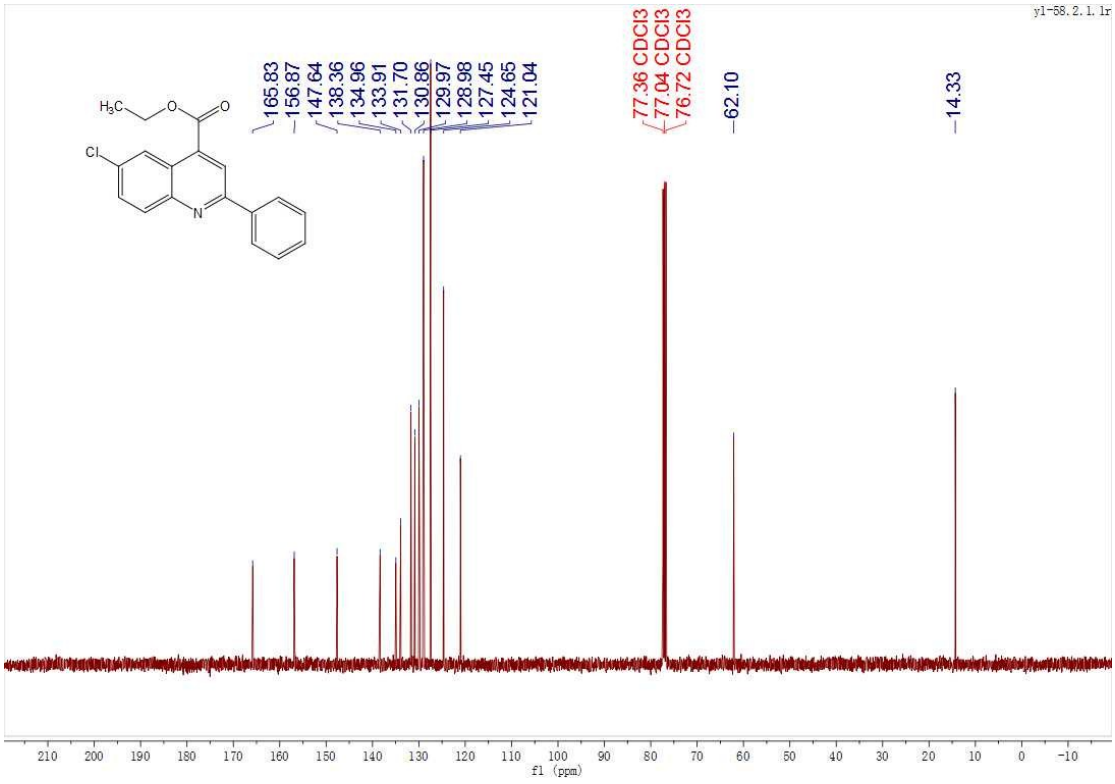
^{1}H and ^{13}C NMR of **4d**



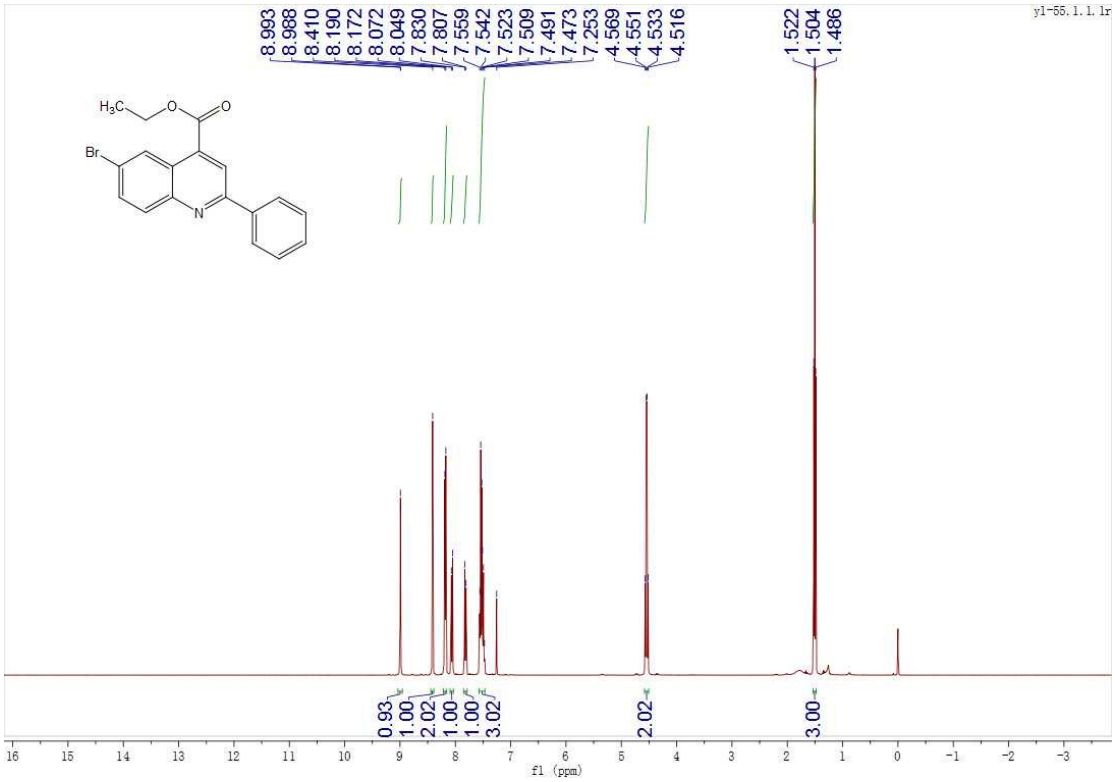


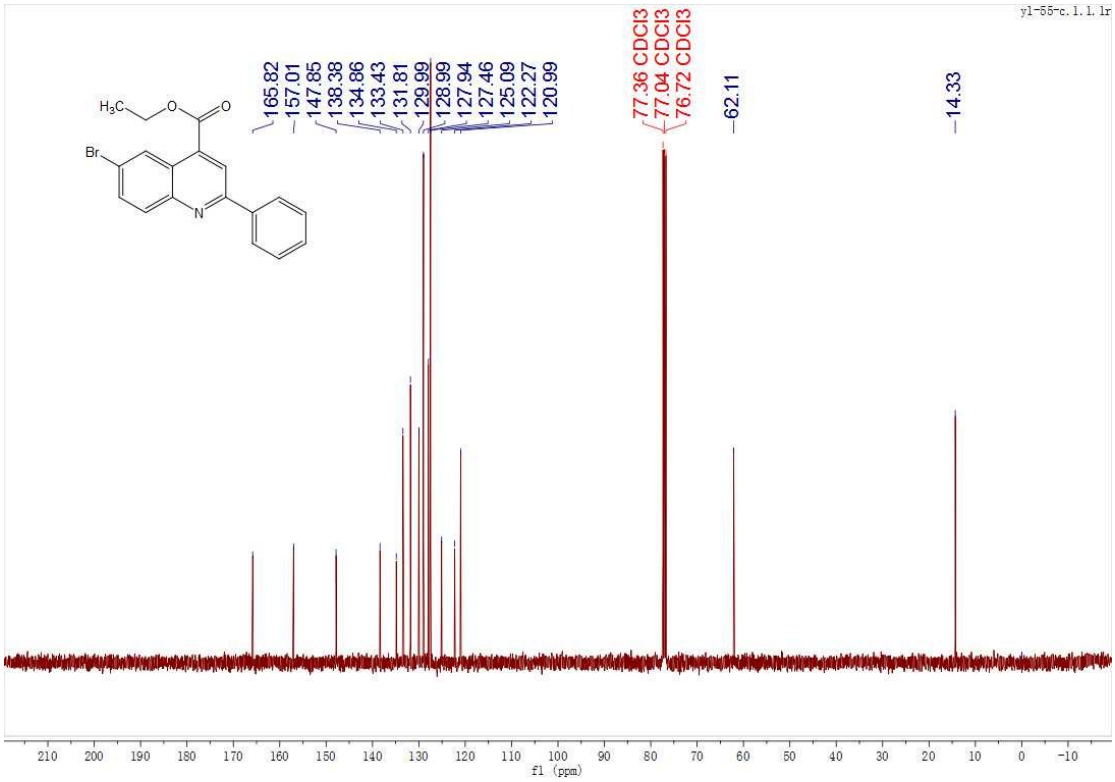
^{1}H and ^{13}C NMR of **4e**



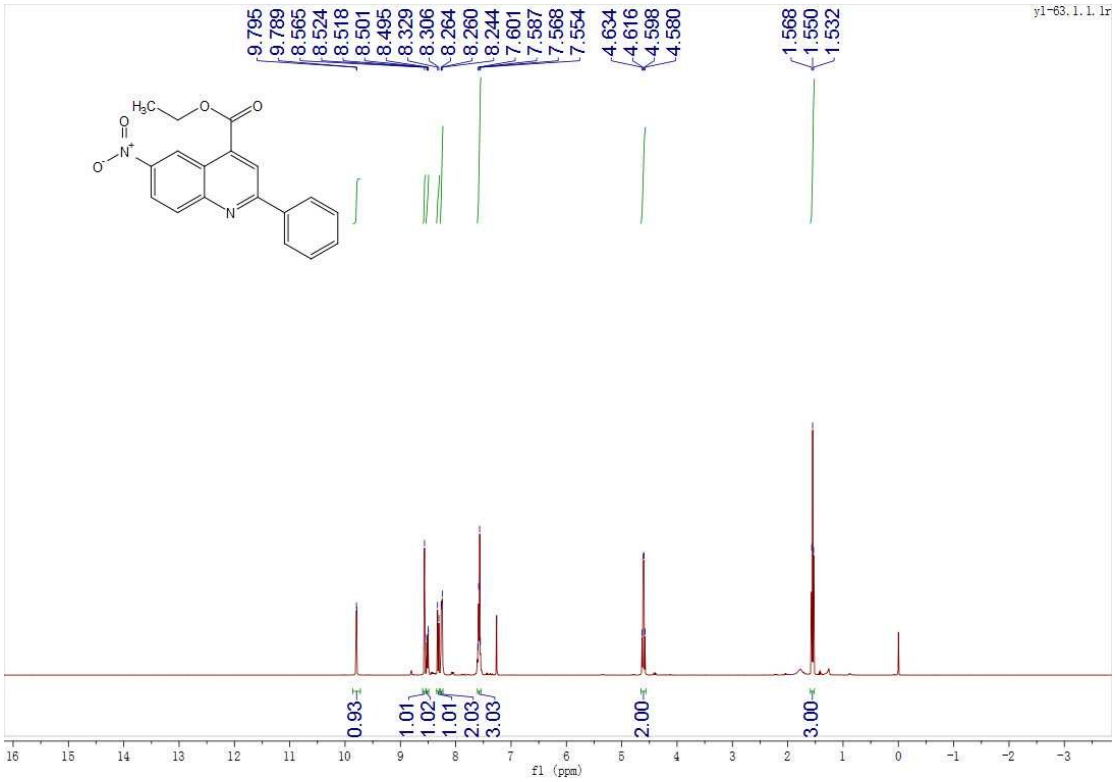


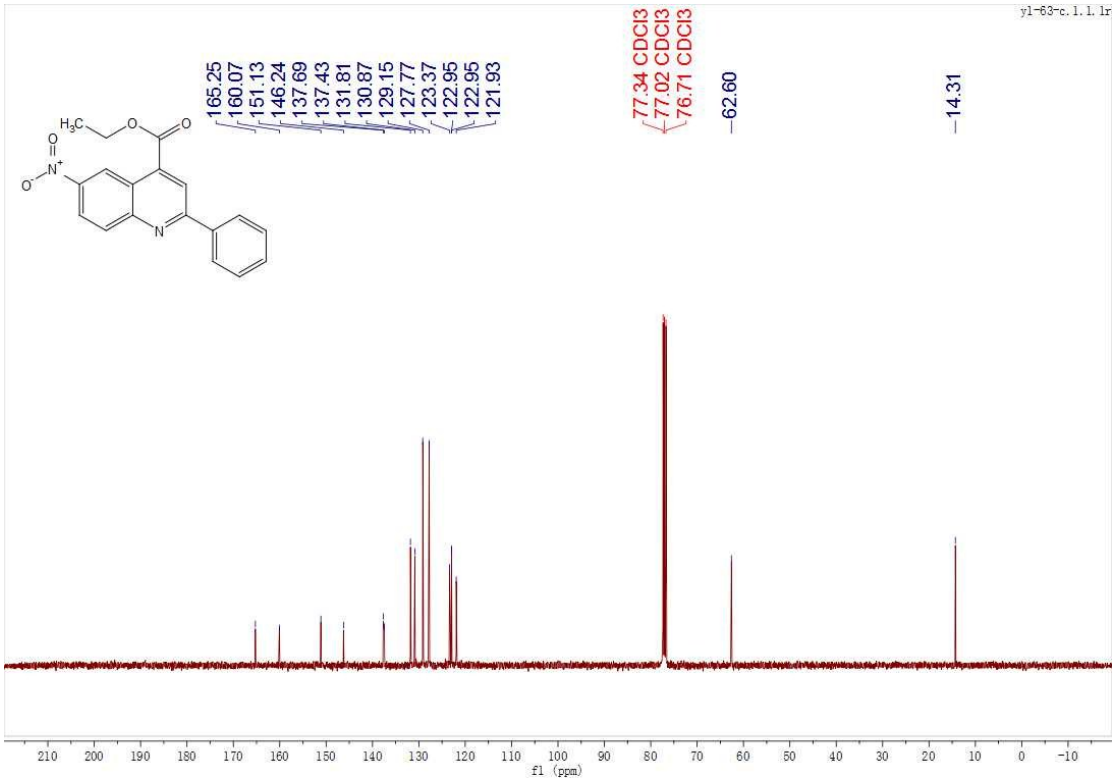
^{1}H and ^{13}C NMR of **4f**



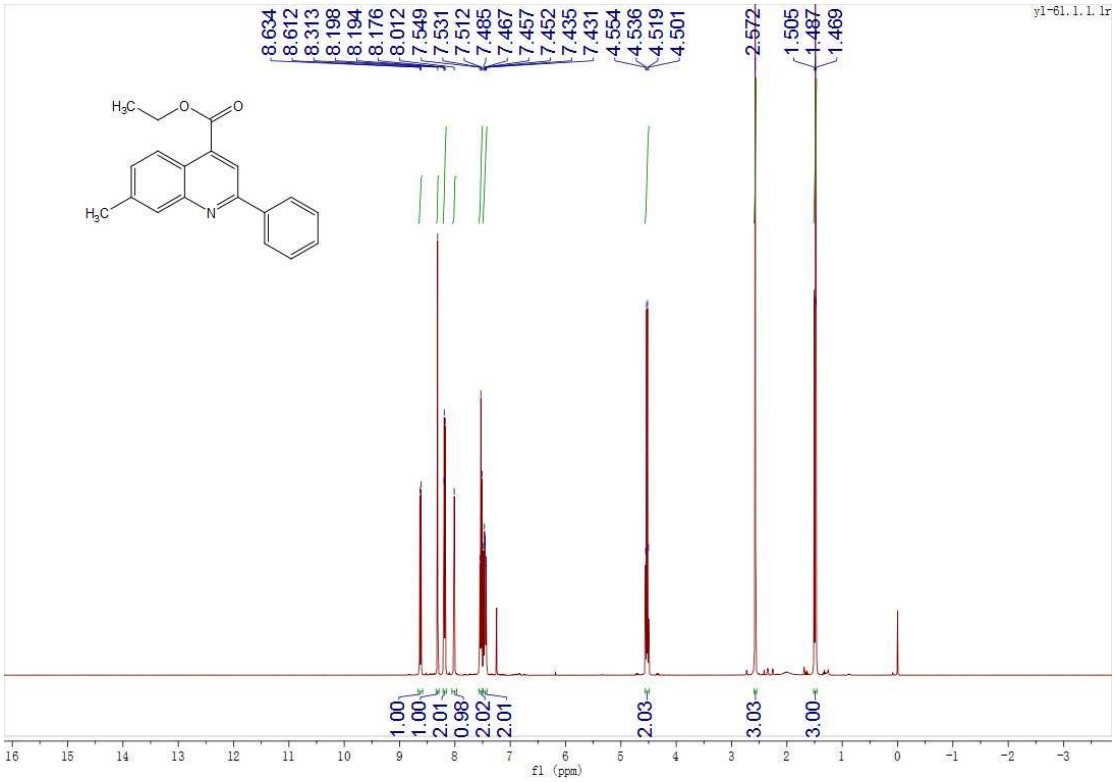


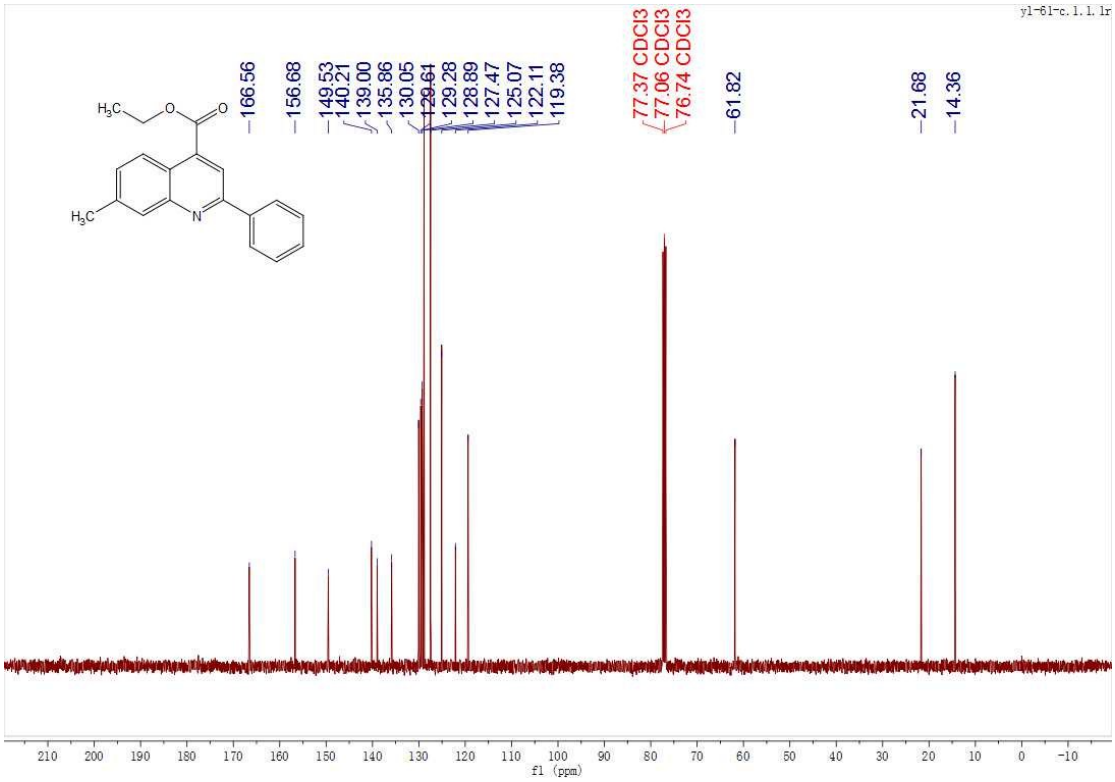
^{1}H and ^{13}C NMR of **4g**



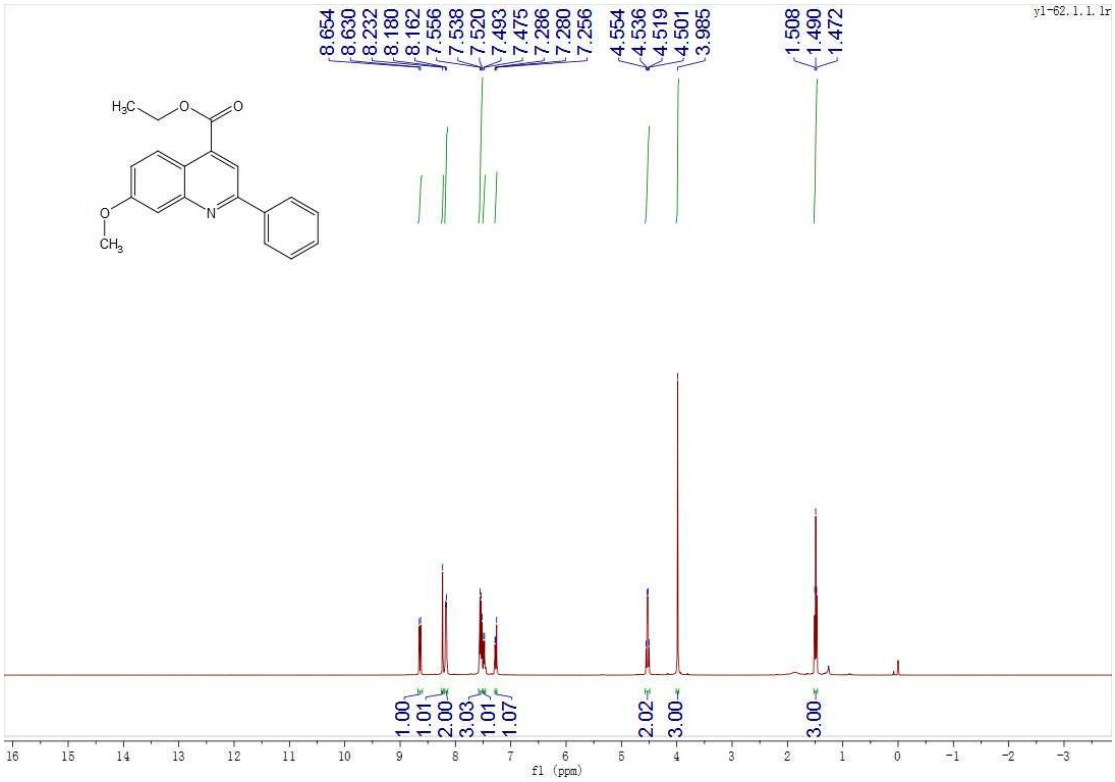


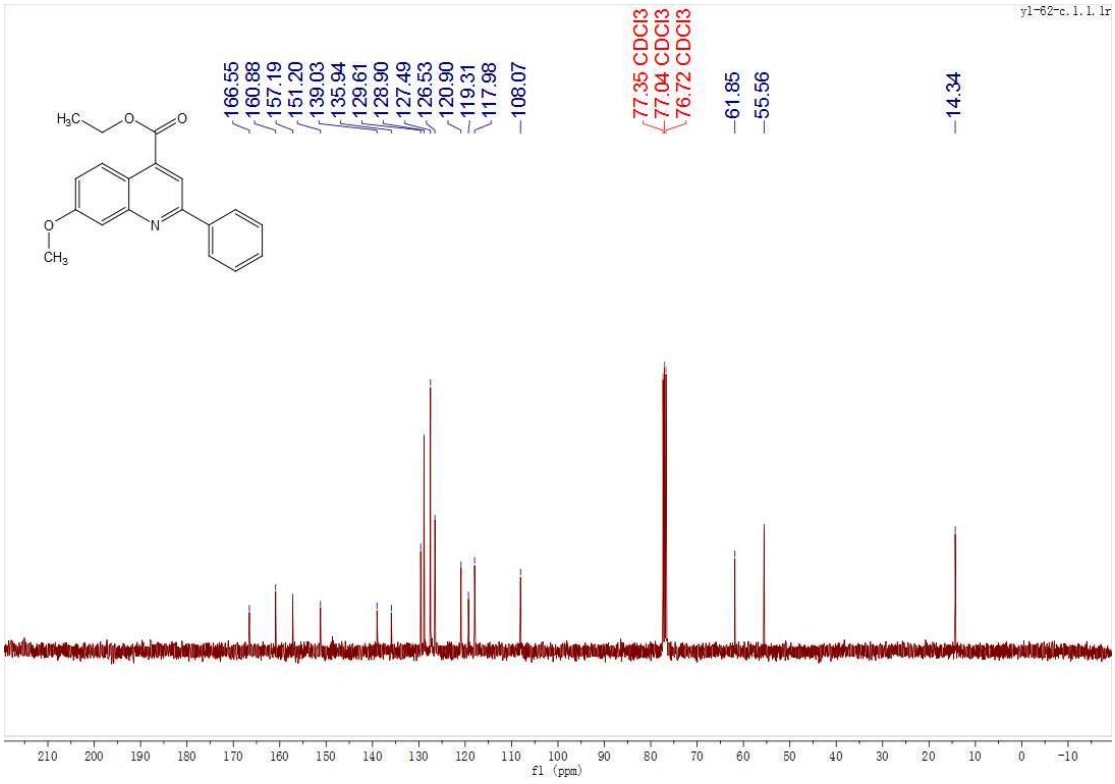
^{1}H and ^{13}C NMR of **4h**



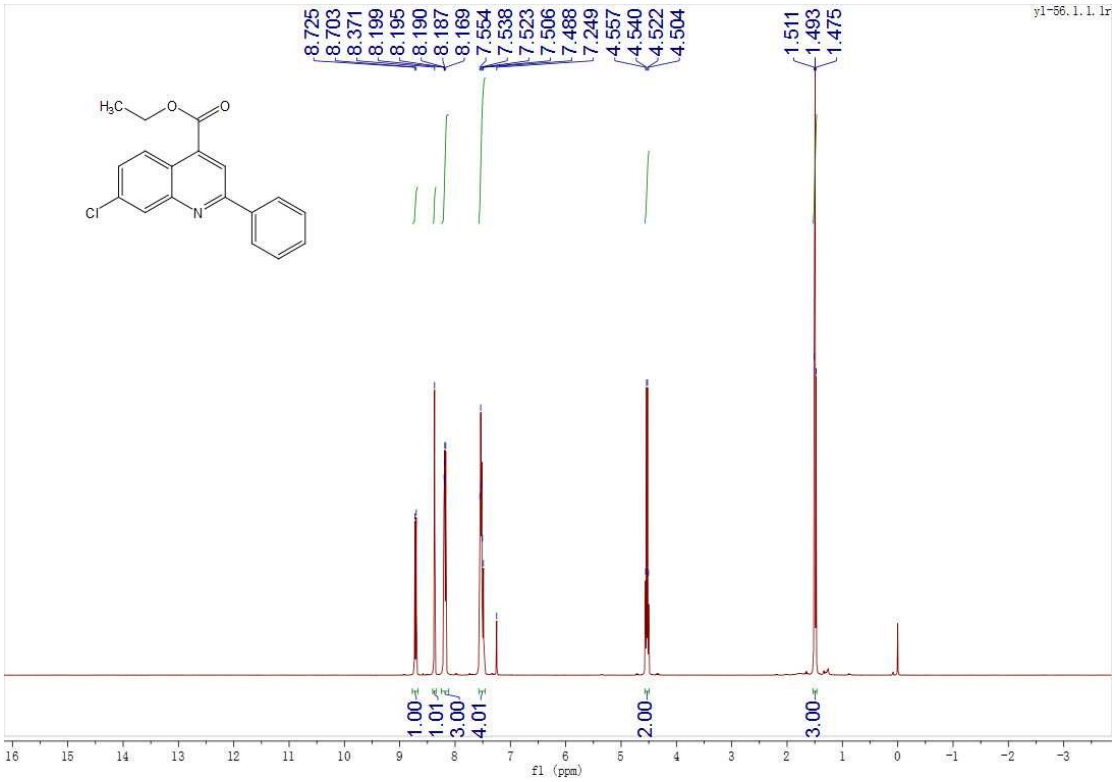


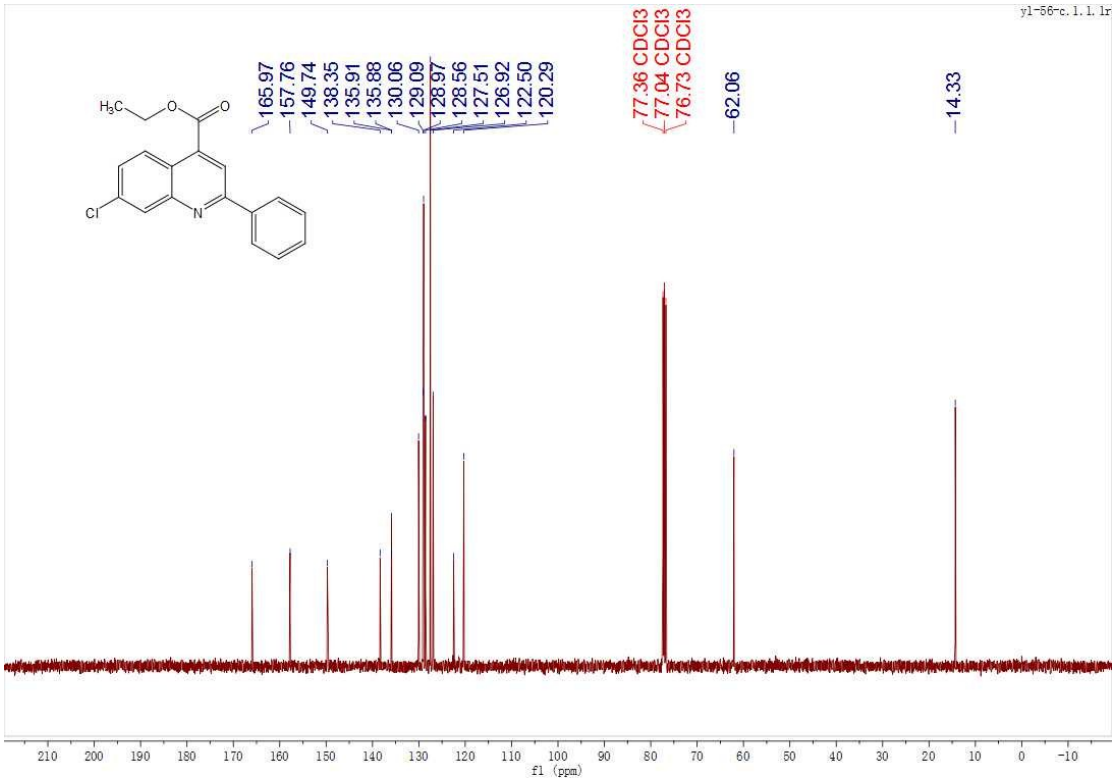
^{1}H and ^{13}C NMR of **4i**



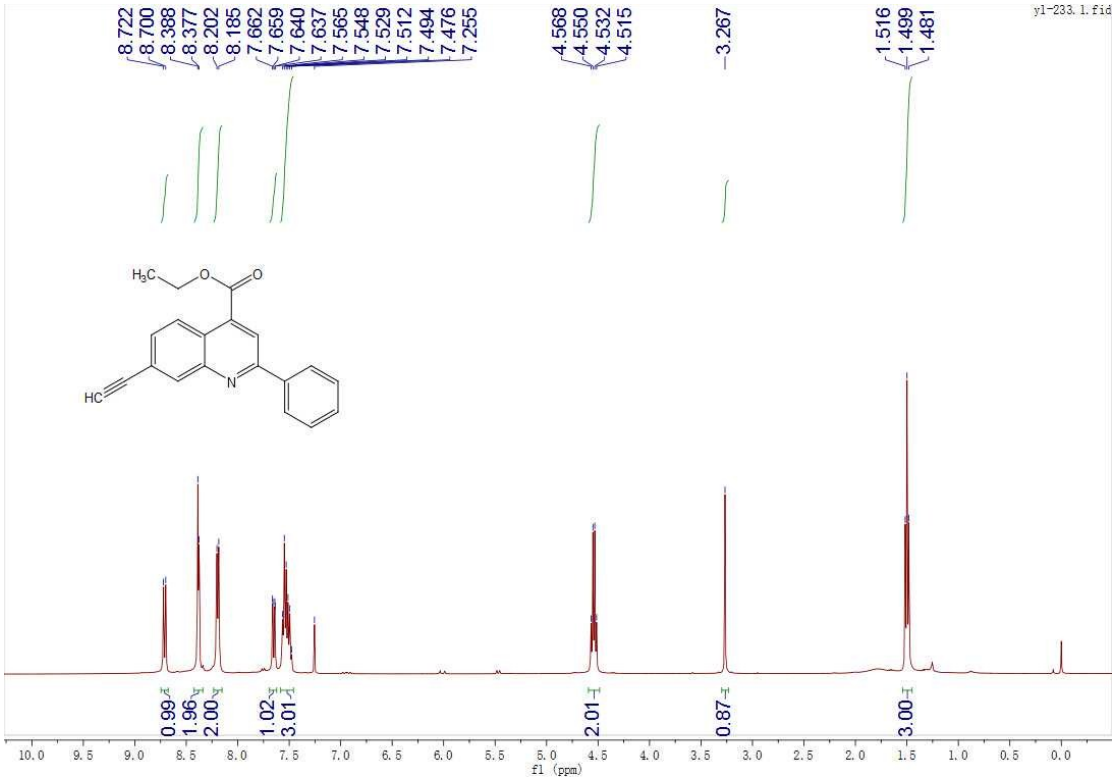


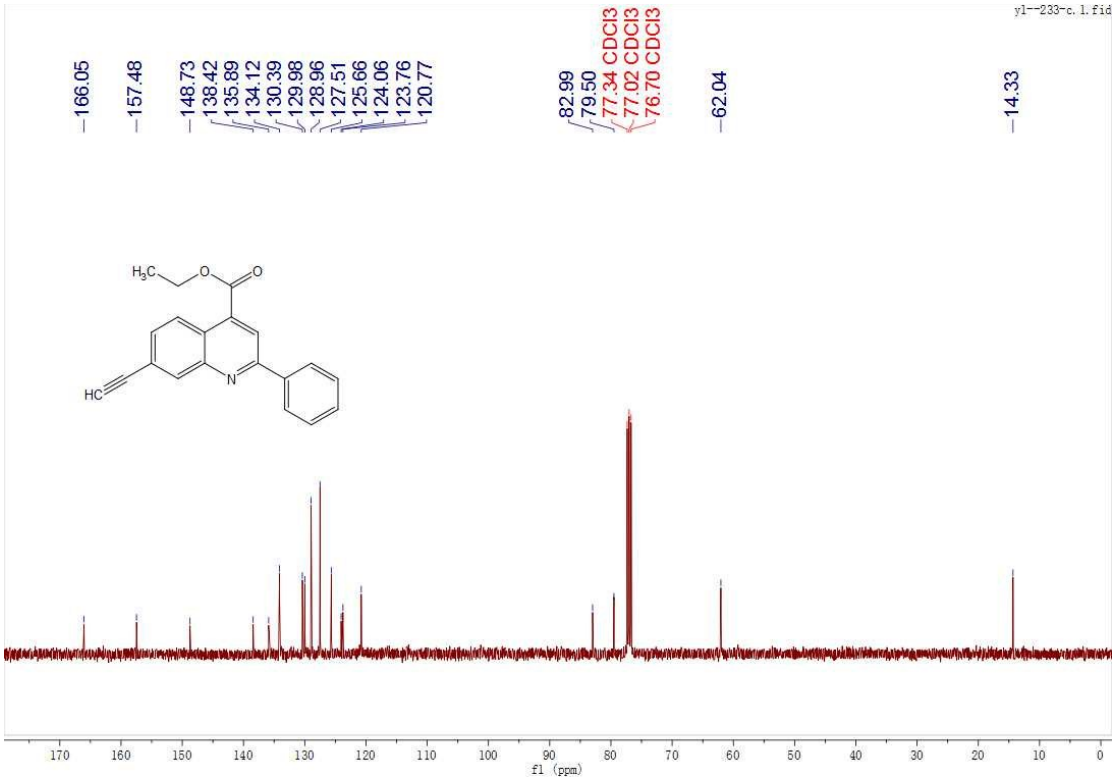
^{1}H and ^{13}C NMR of **4j**



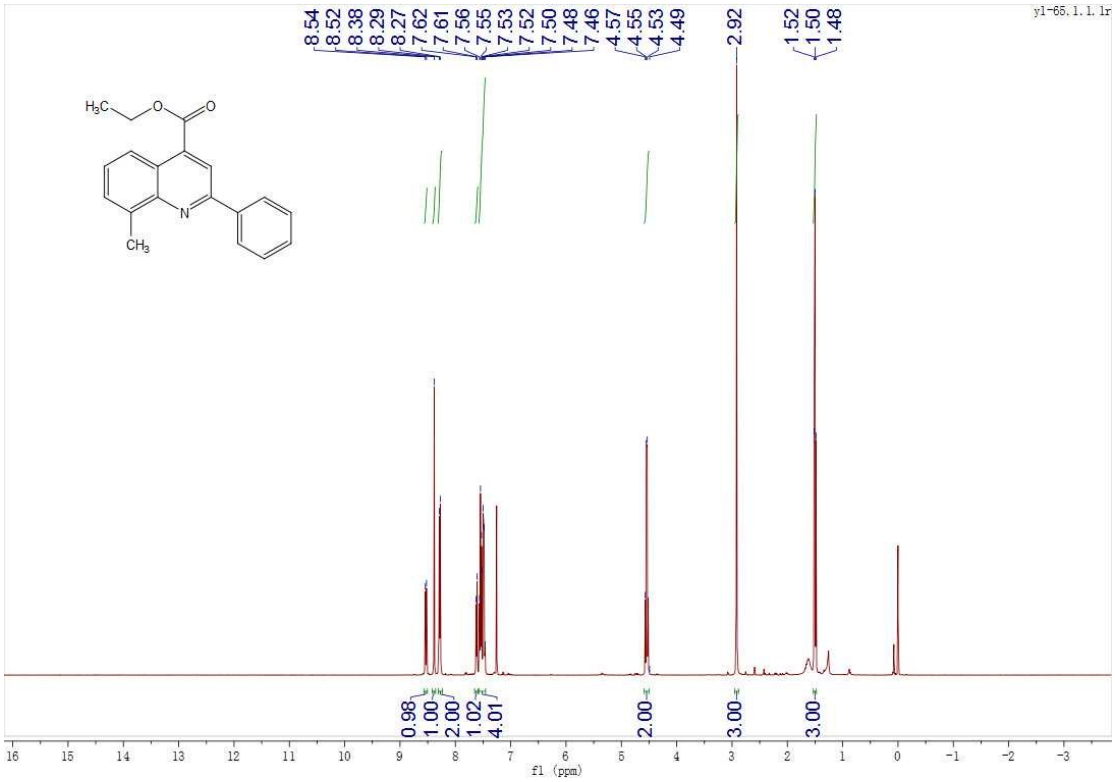


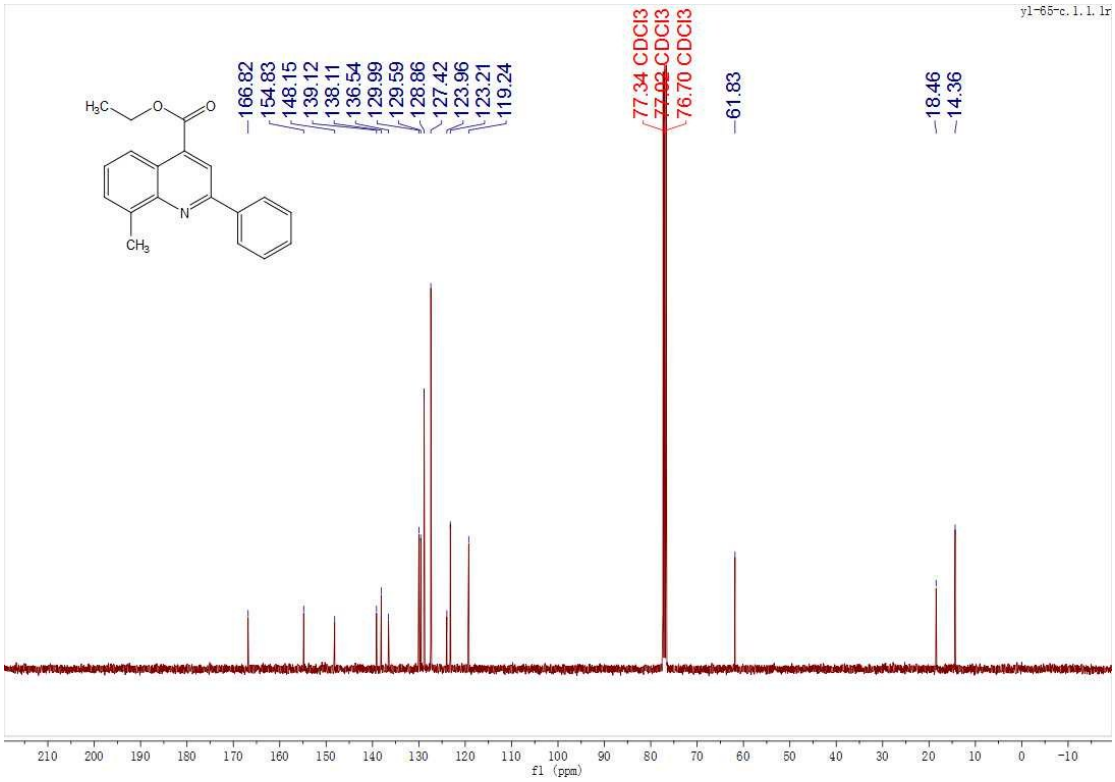
^{1}H and ^{13}C NMR of **4k**



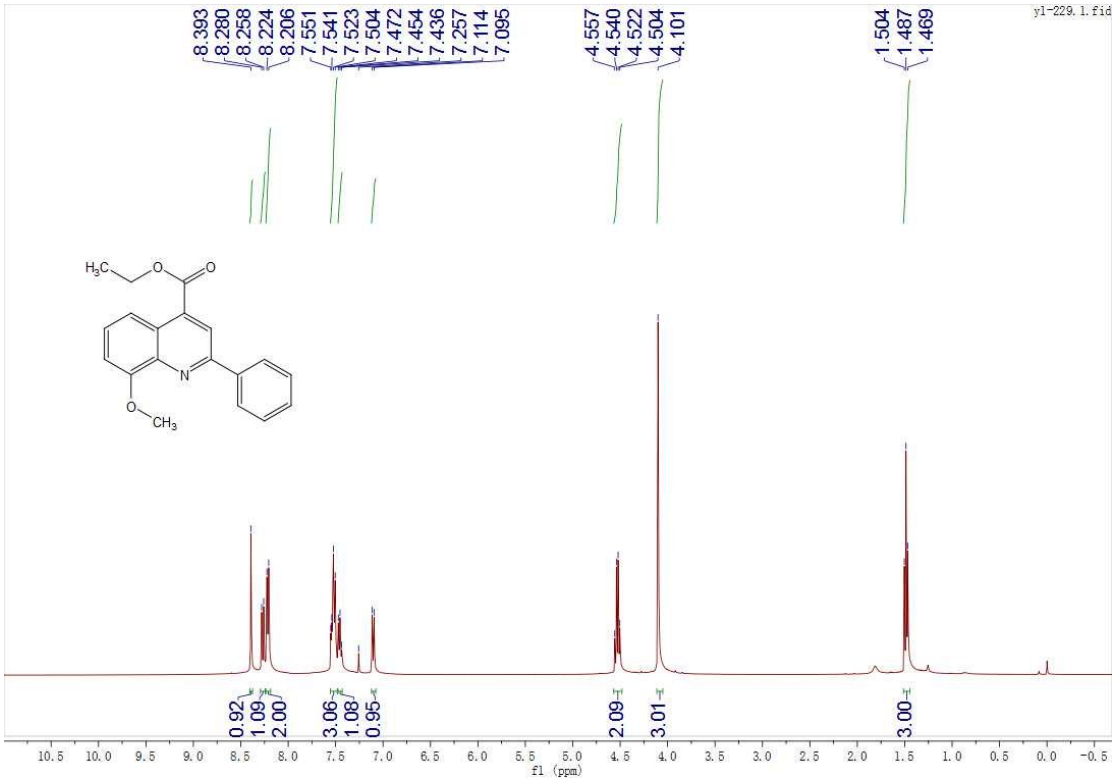


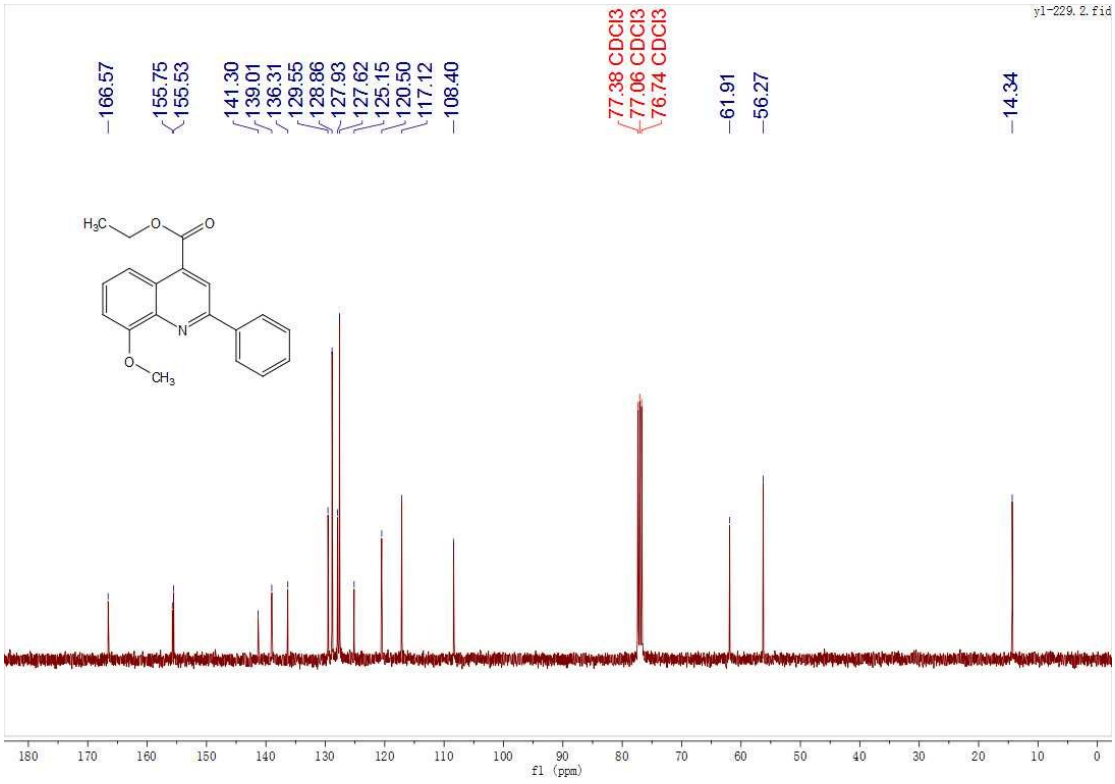
^{1}H and ^{13}C NMR of **4l**



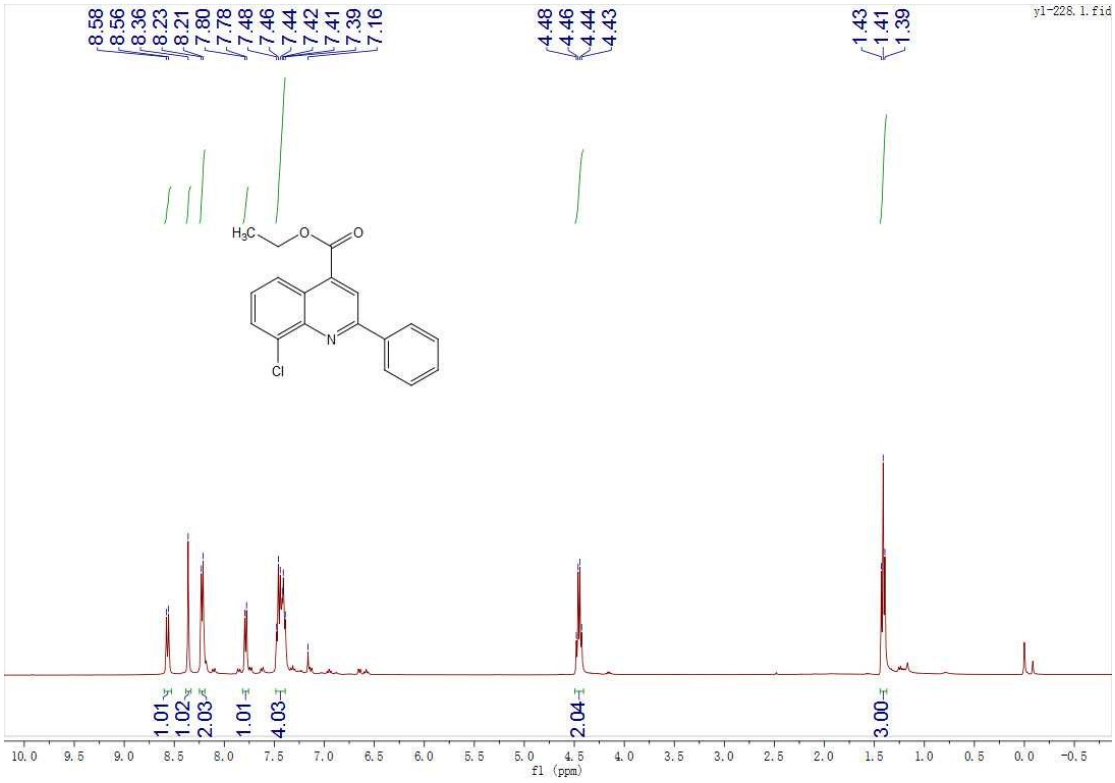


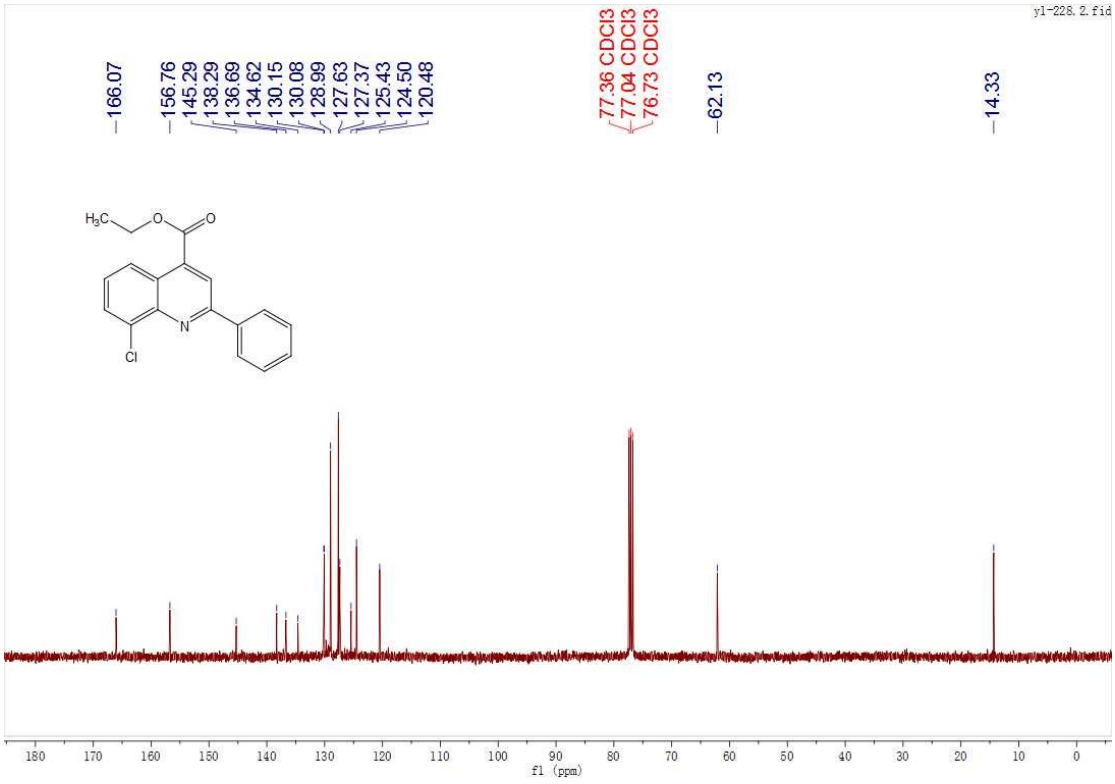
^{1}H and ^{13}C NMR of **4m**



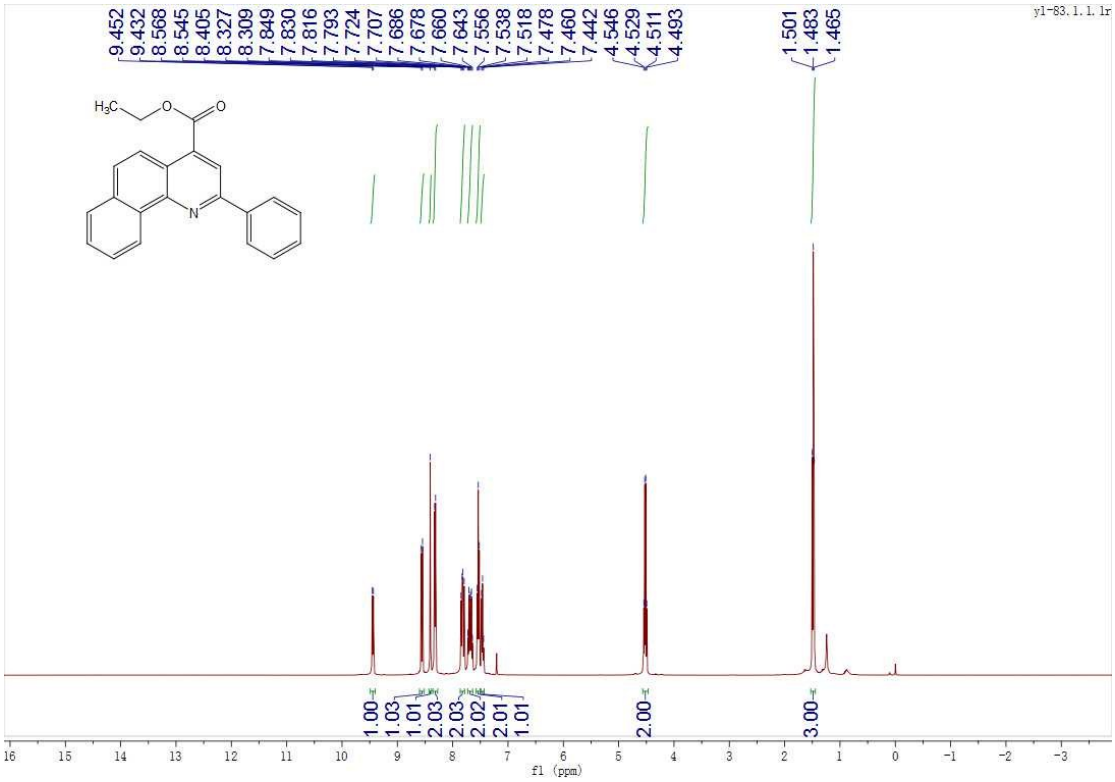


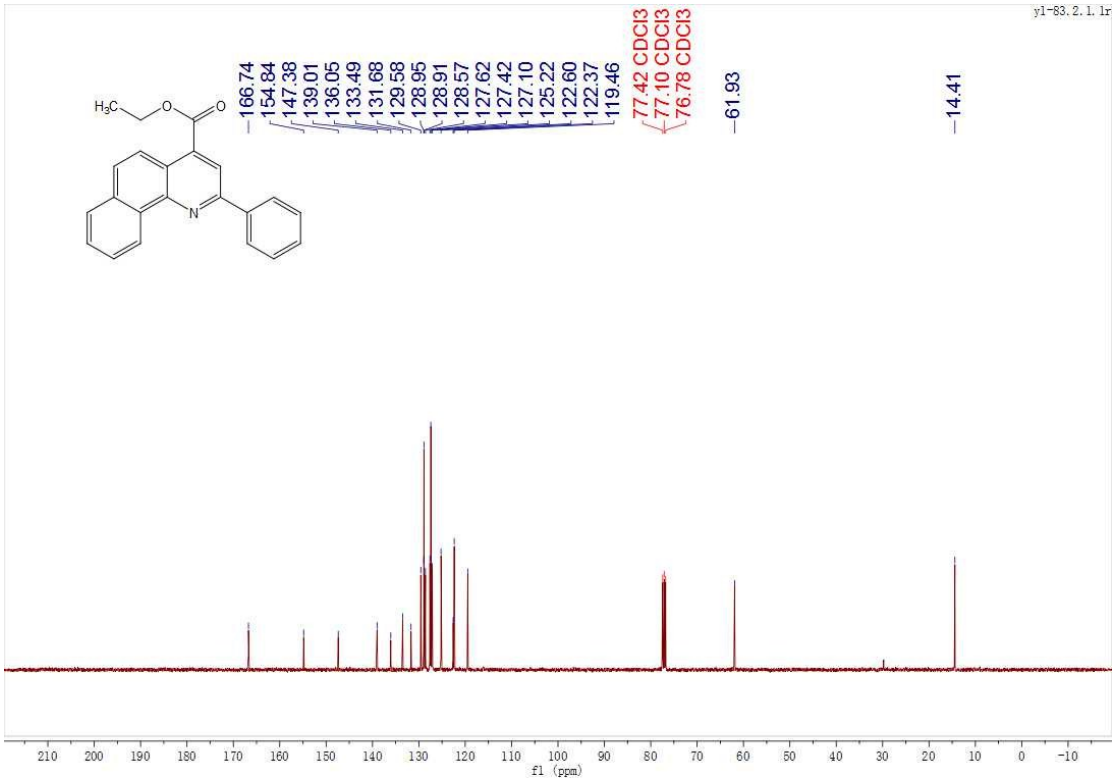
^{1}H and ^{13}C NMR of **4n**



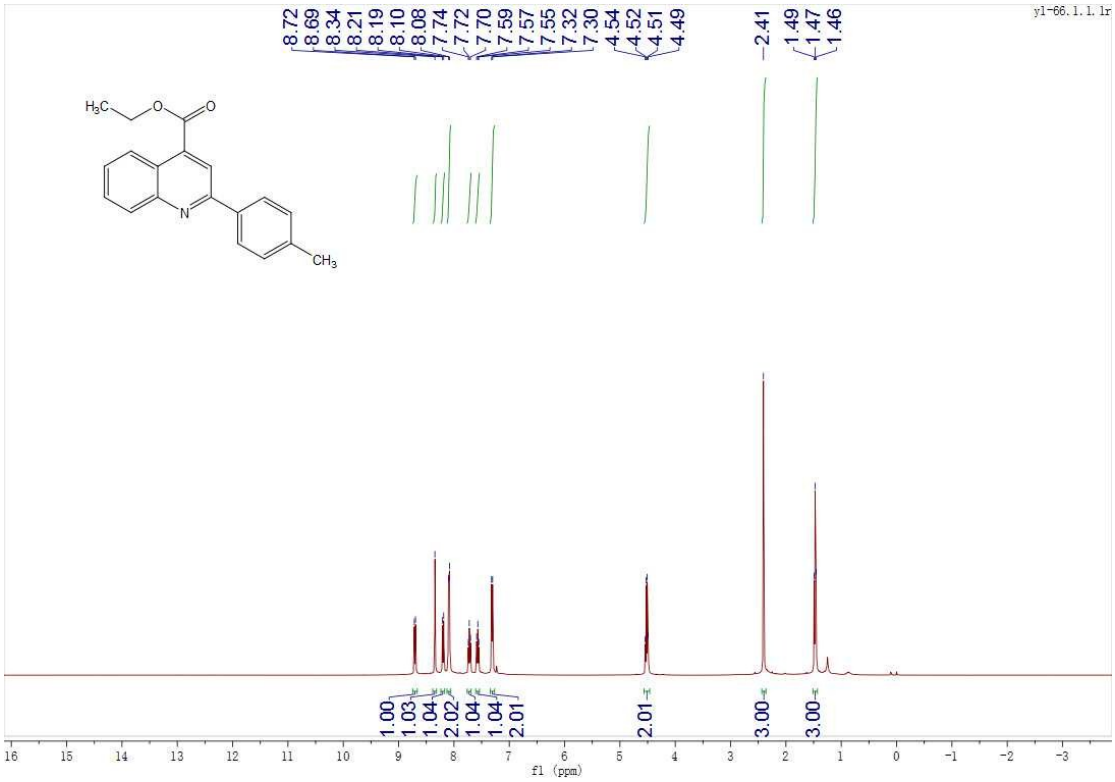


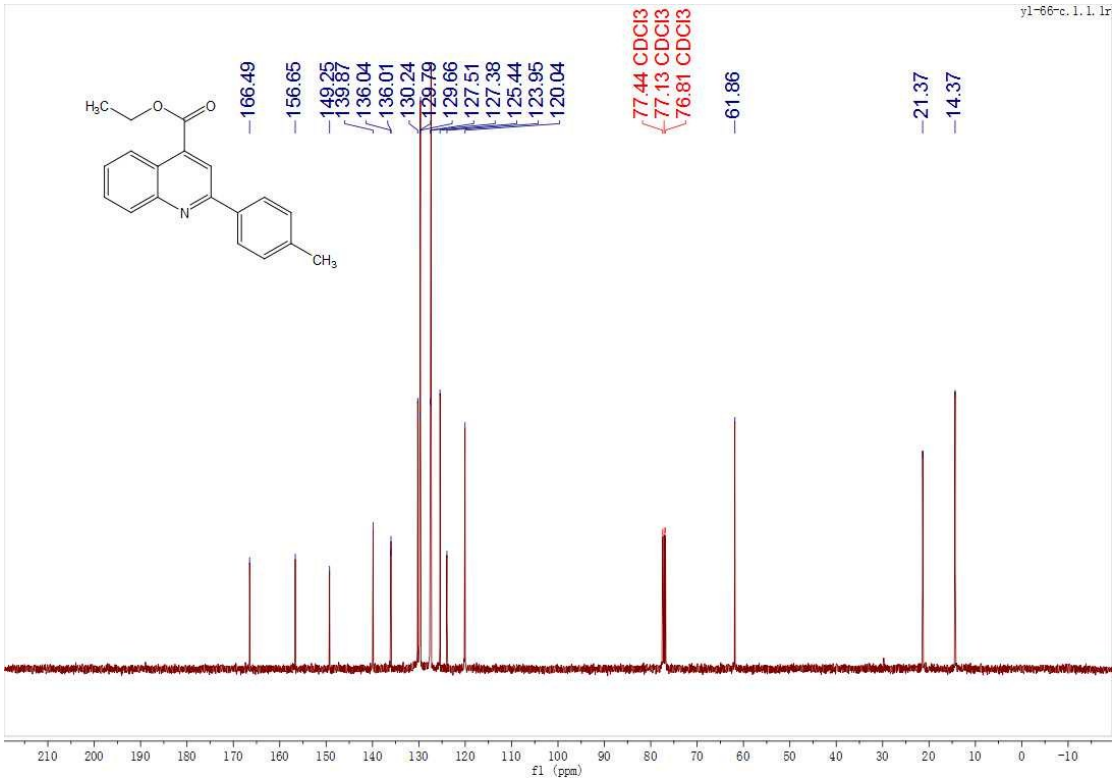
^{1}H and ^{13}C NMR of **4o**



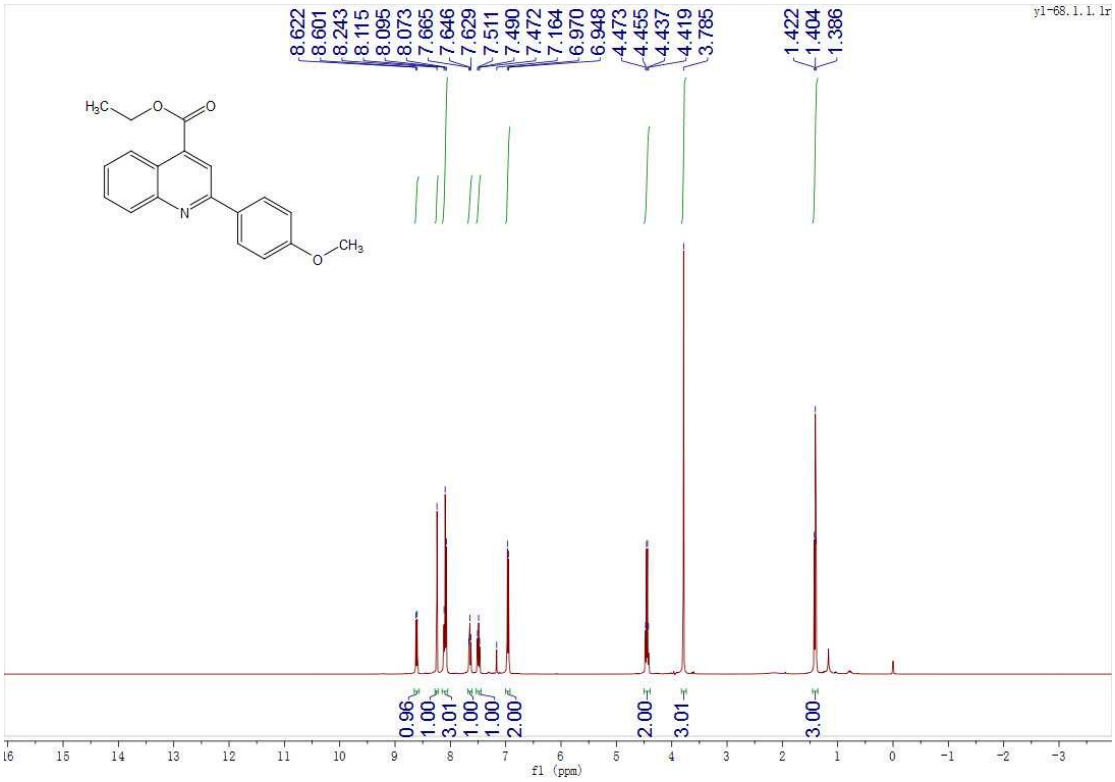


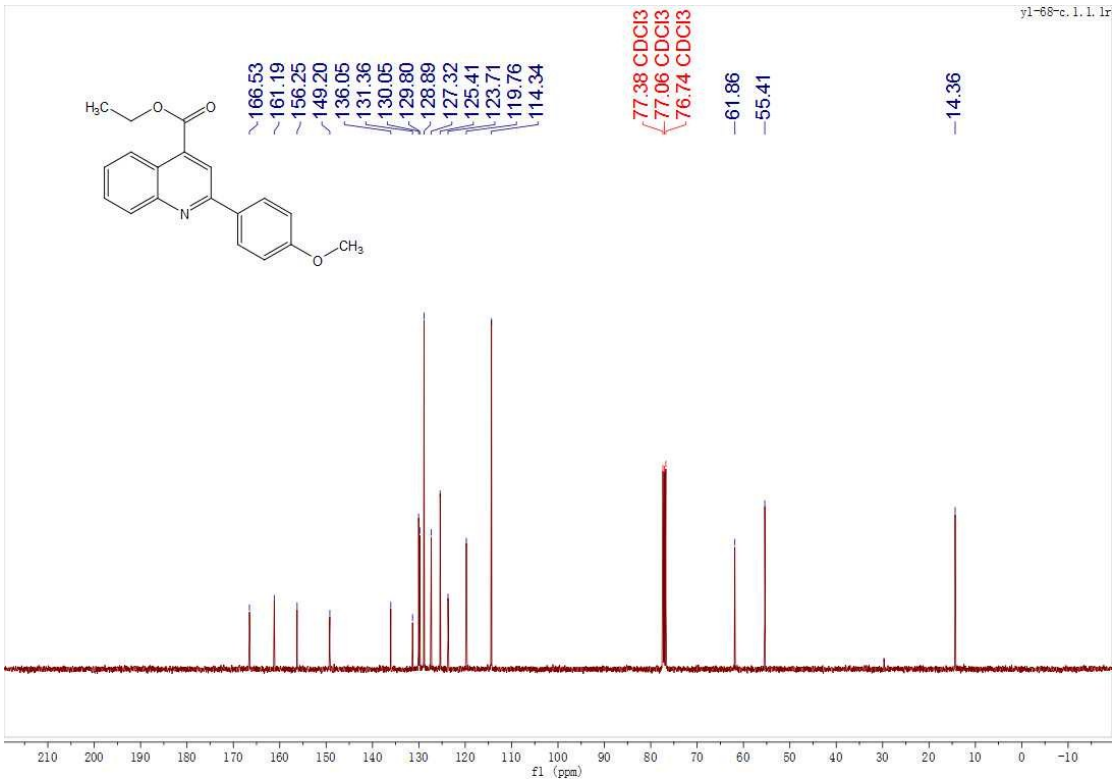
^{1}H and ^{13}C NMR of **4p**



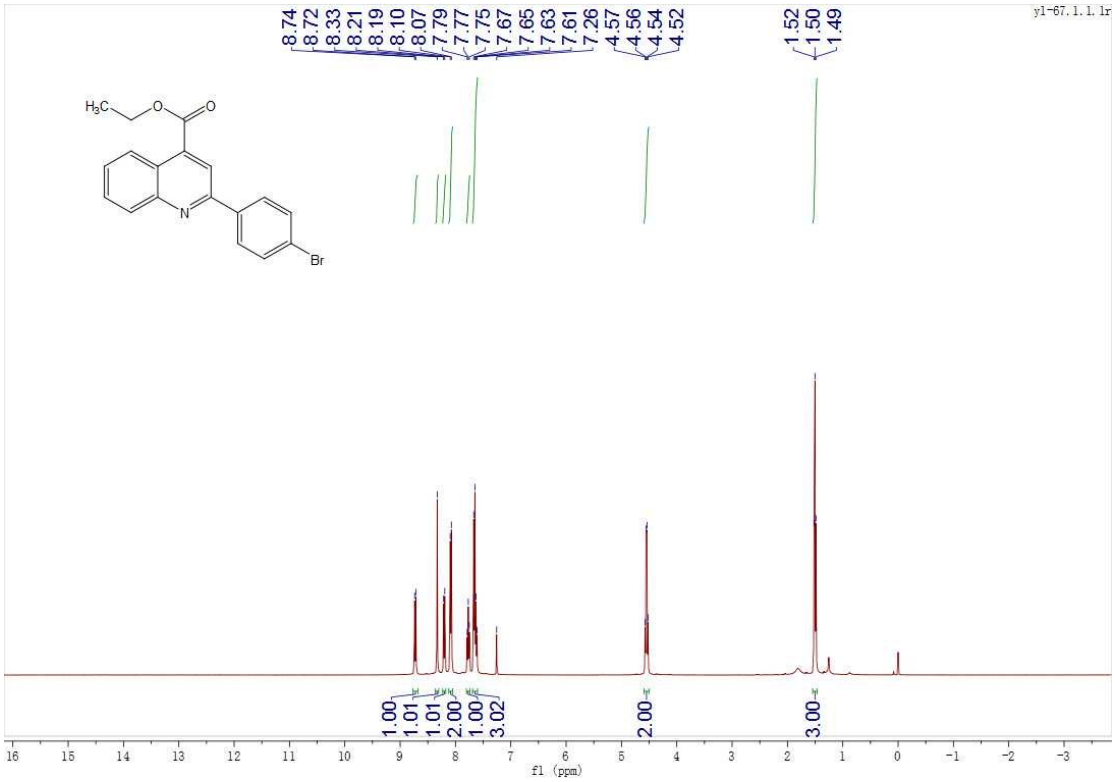


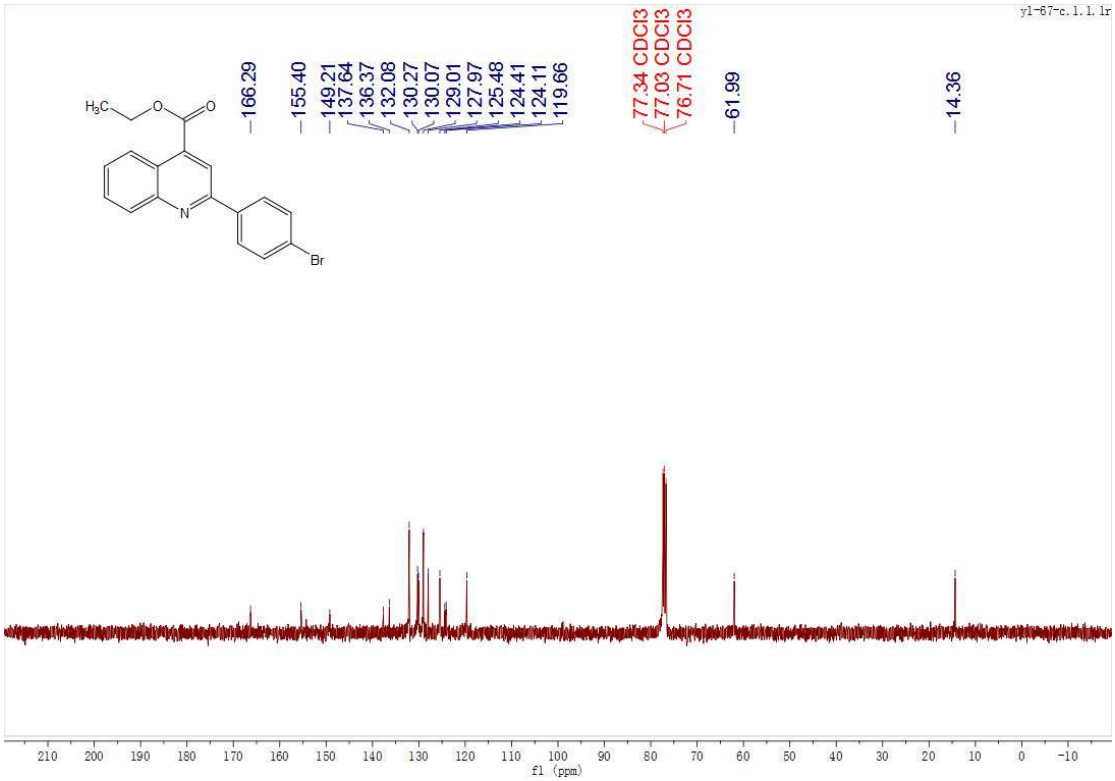
^{1}H and ^{13}C NMR of **4q**



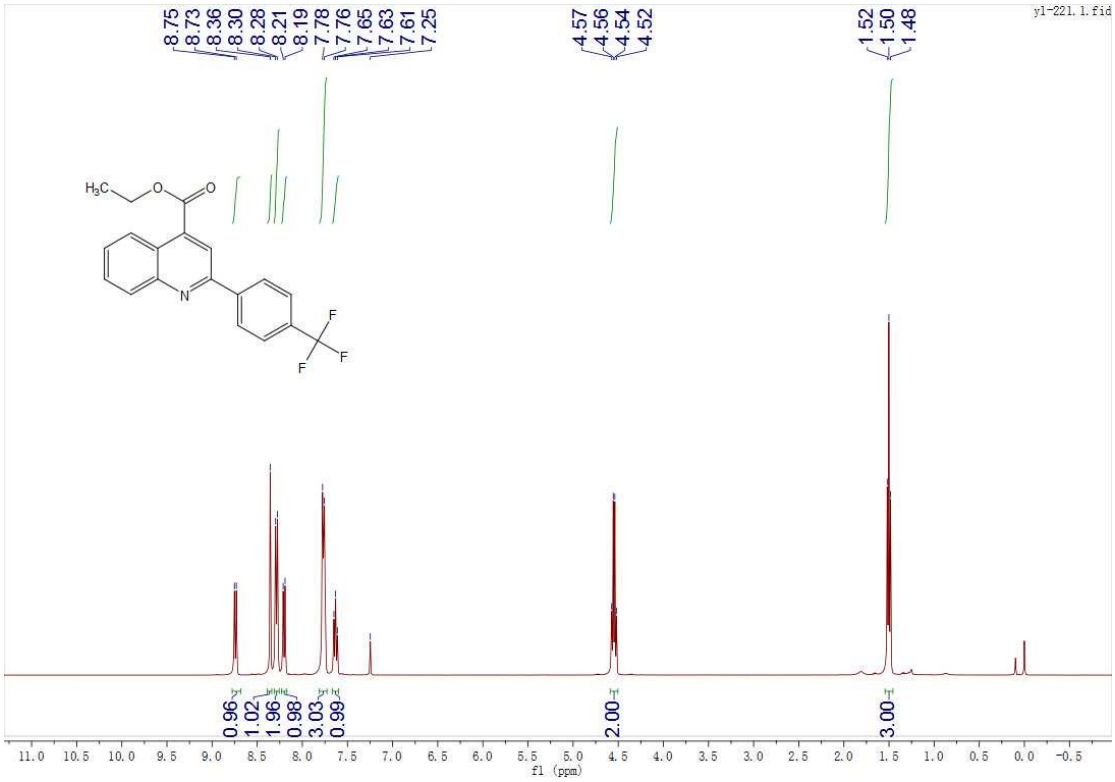


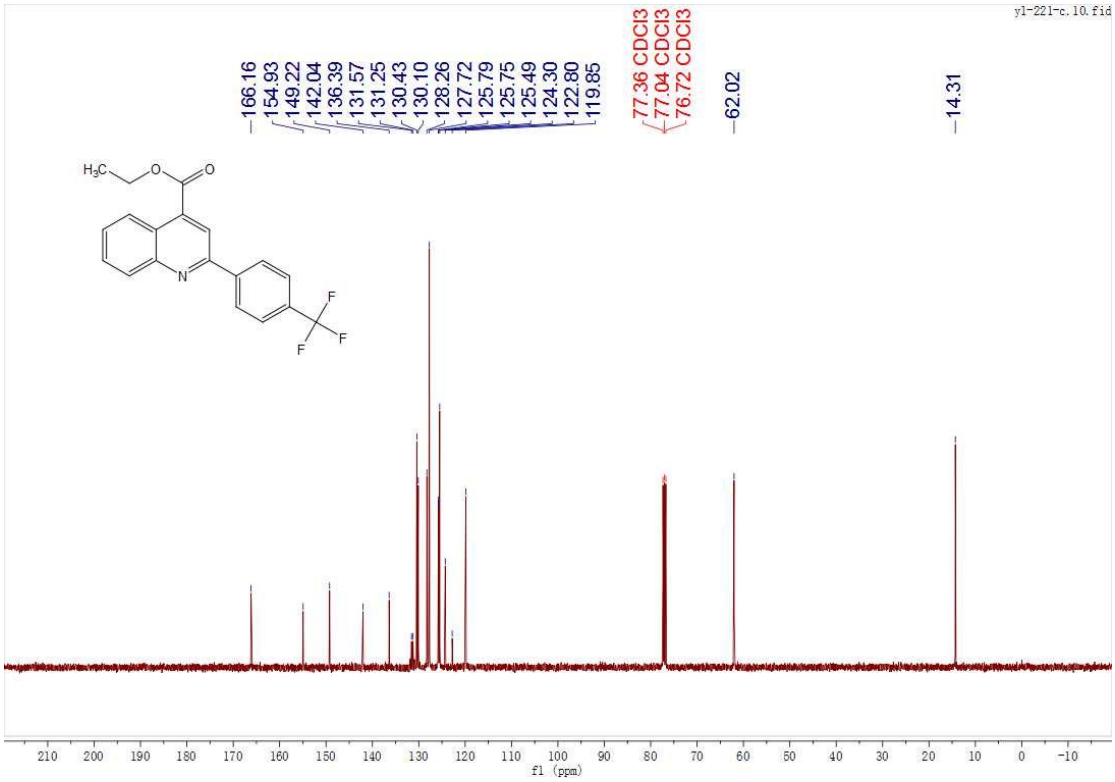
^{1}H and ^{13}C NMR of **4r**



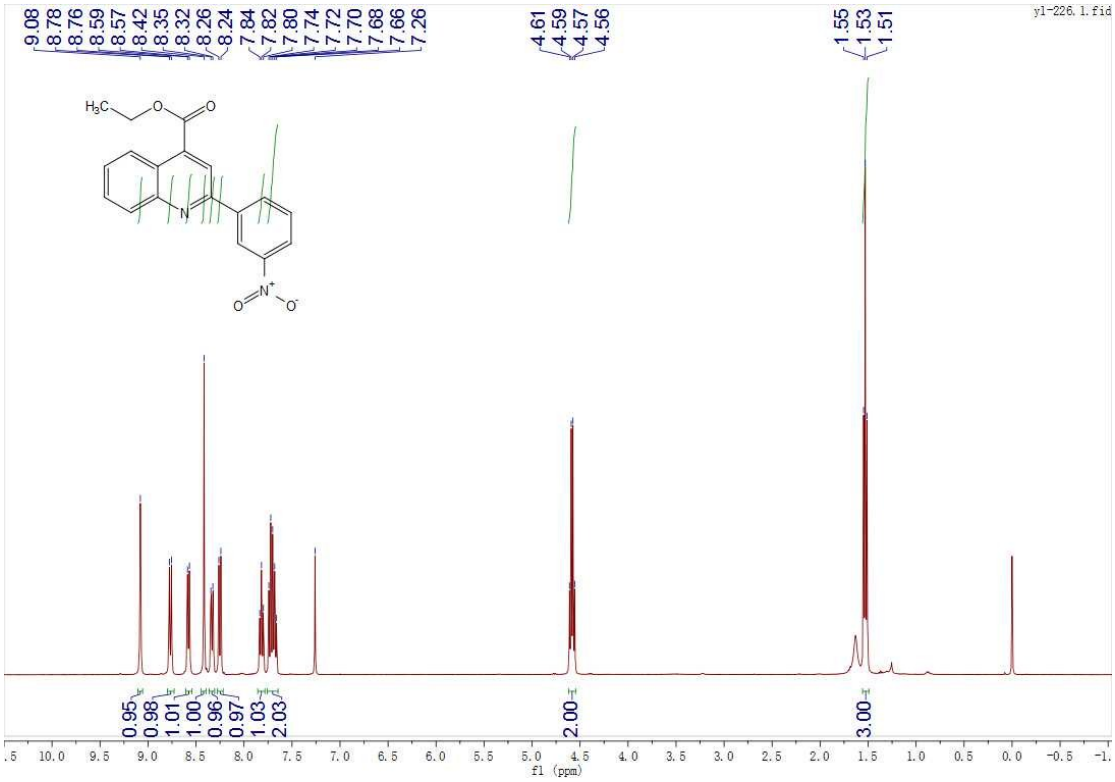


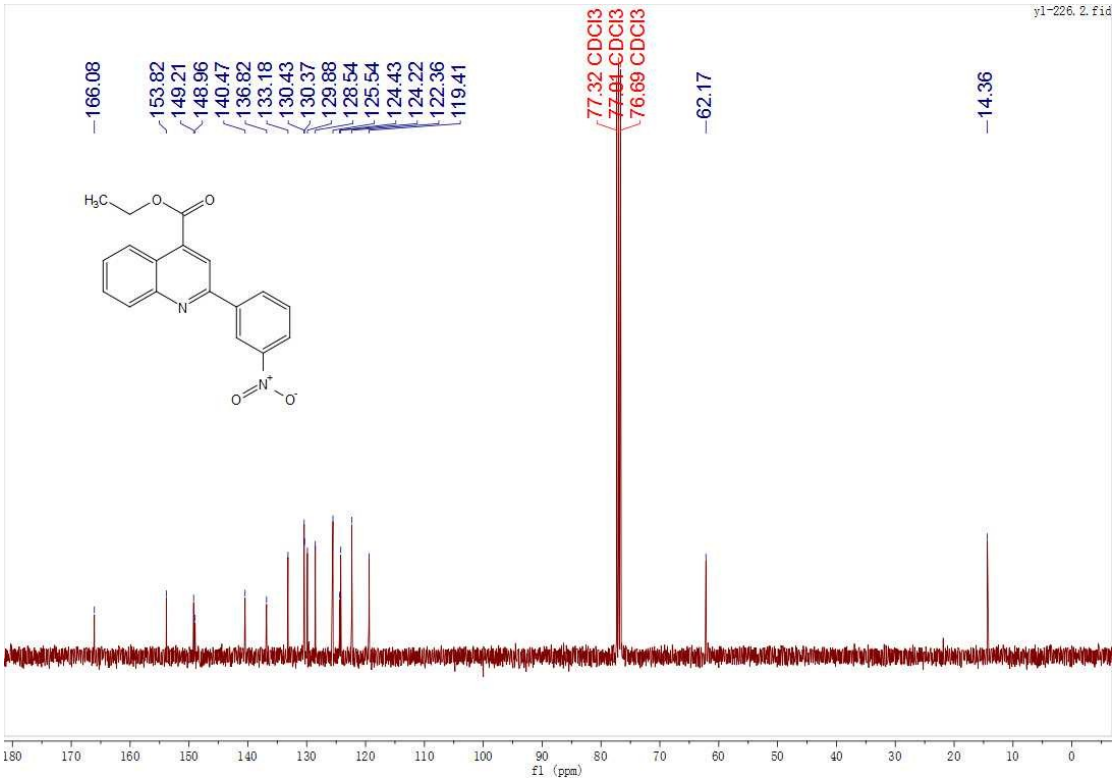
^{1}H and ^{13}C NMR of **4s**



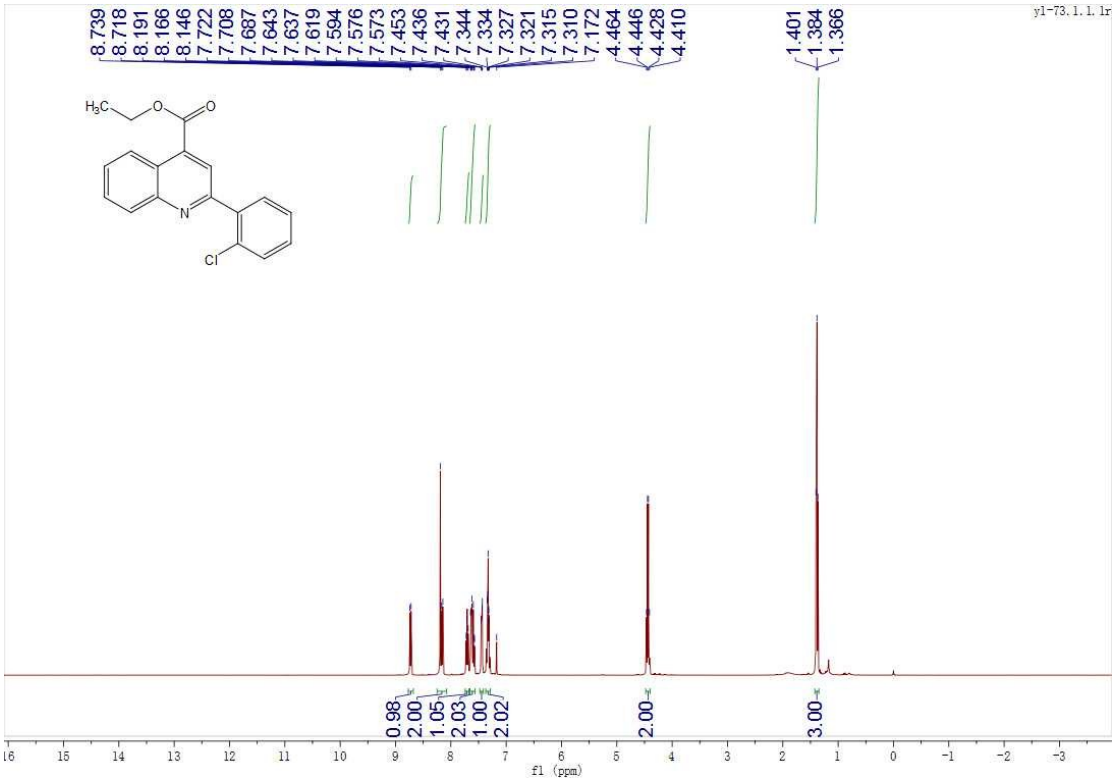


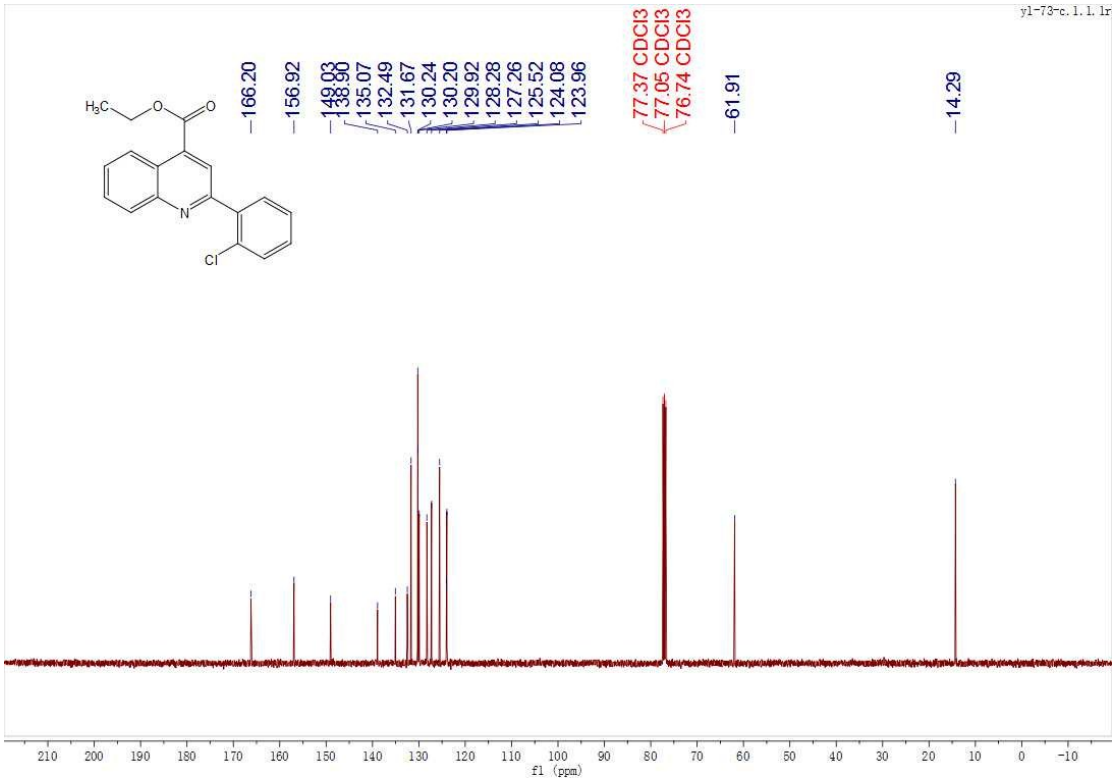
^{1}H and ^{13}C NMR of **4t**



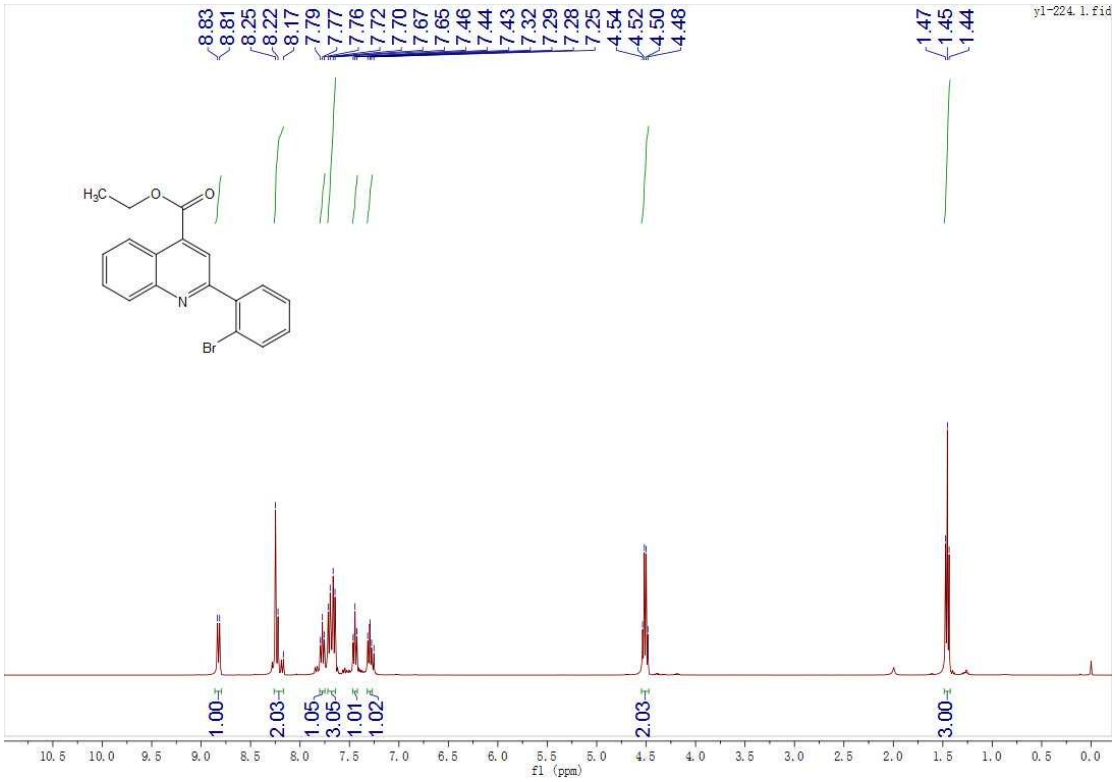


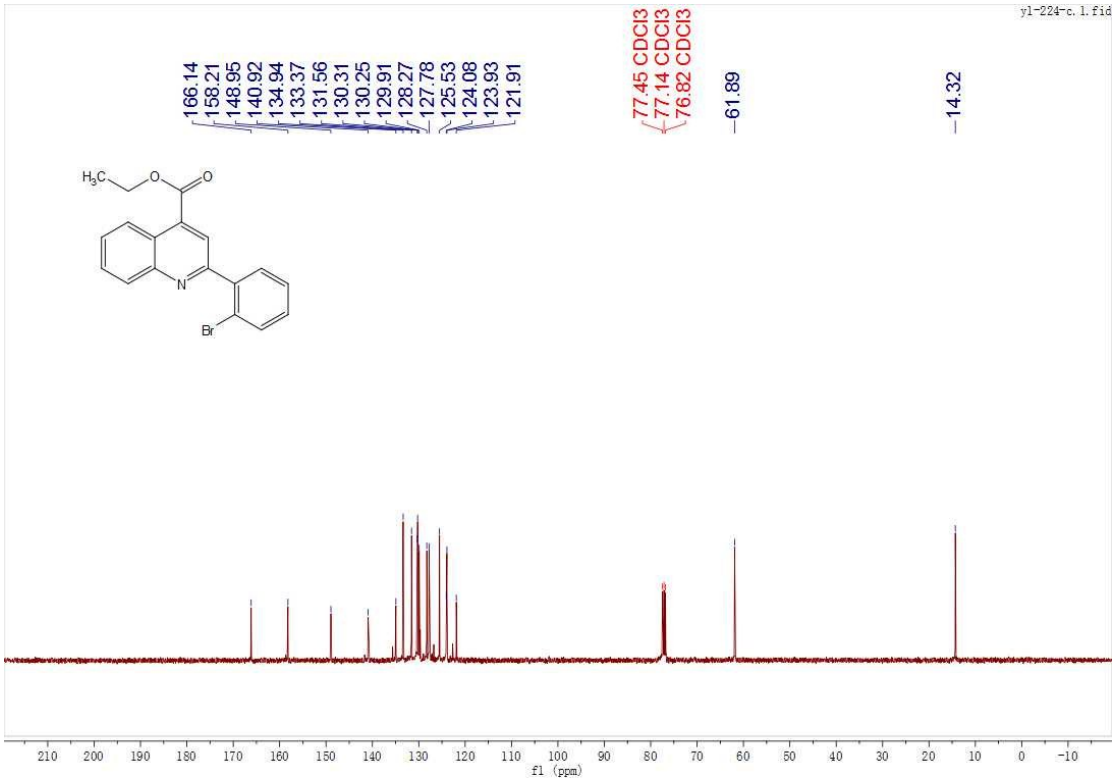
^{1}H and ^{13}C NMR of **4u**



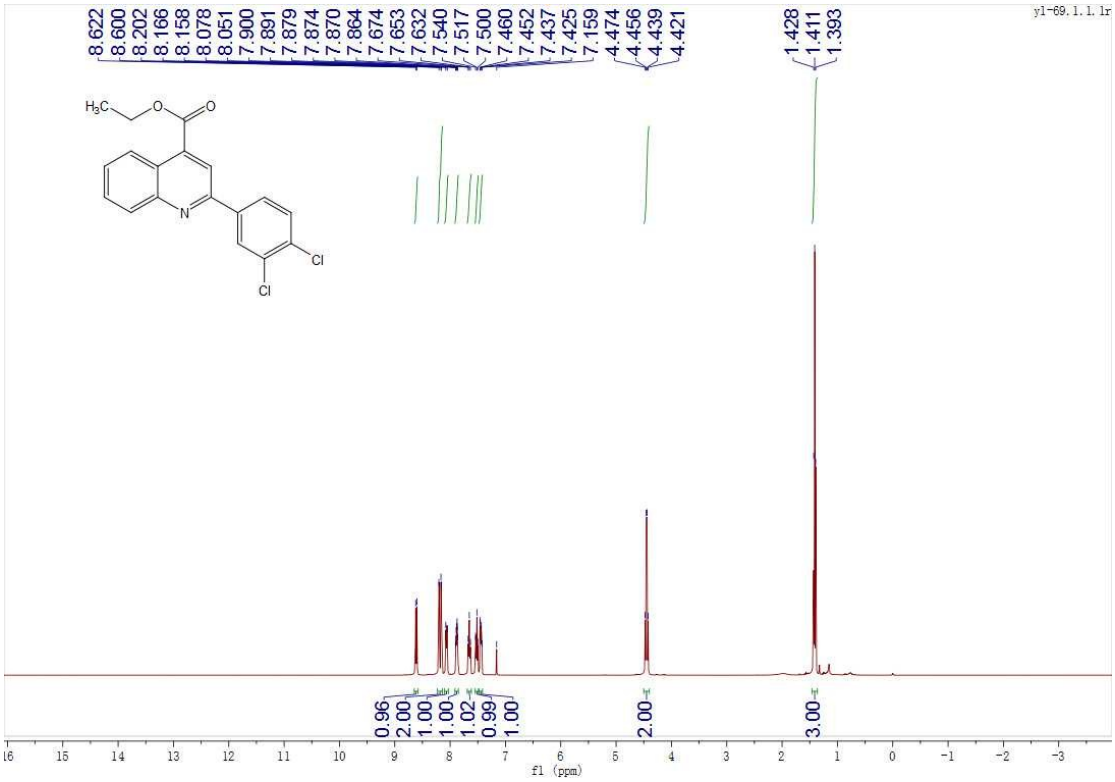


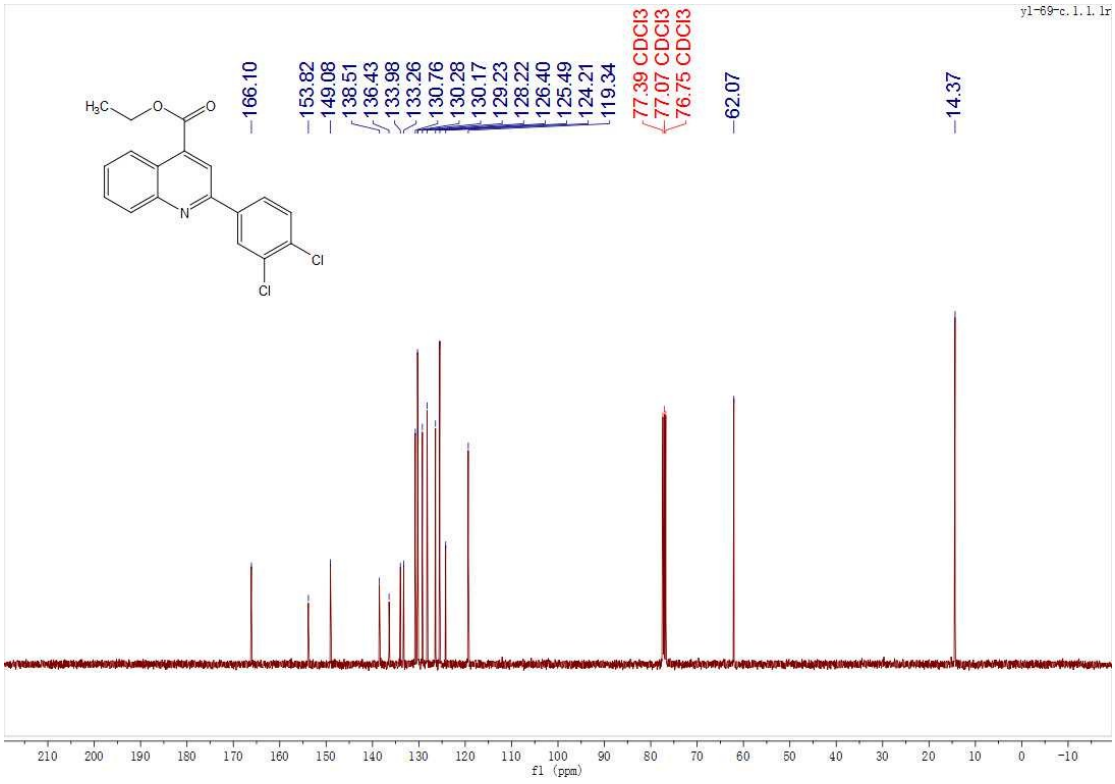
^{1}H and ^{13}C NMR of **4v**



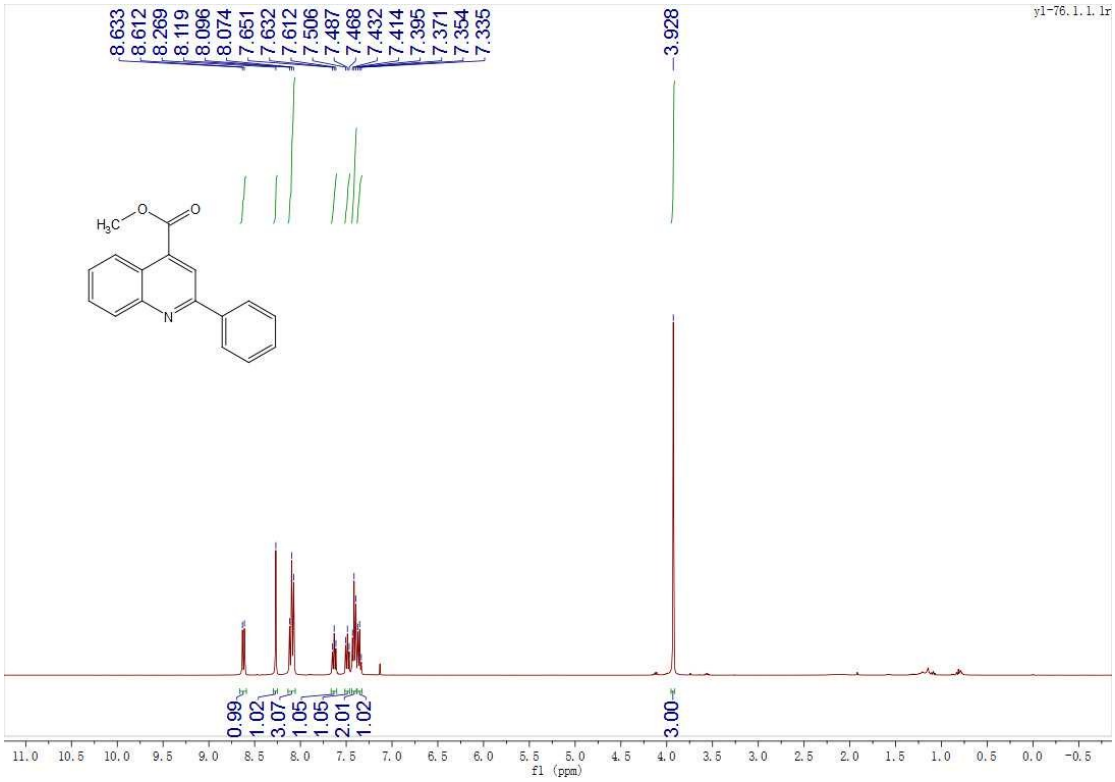


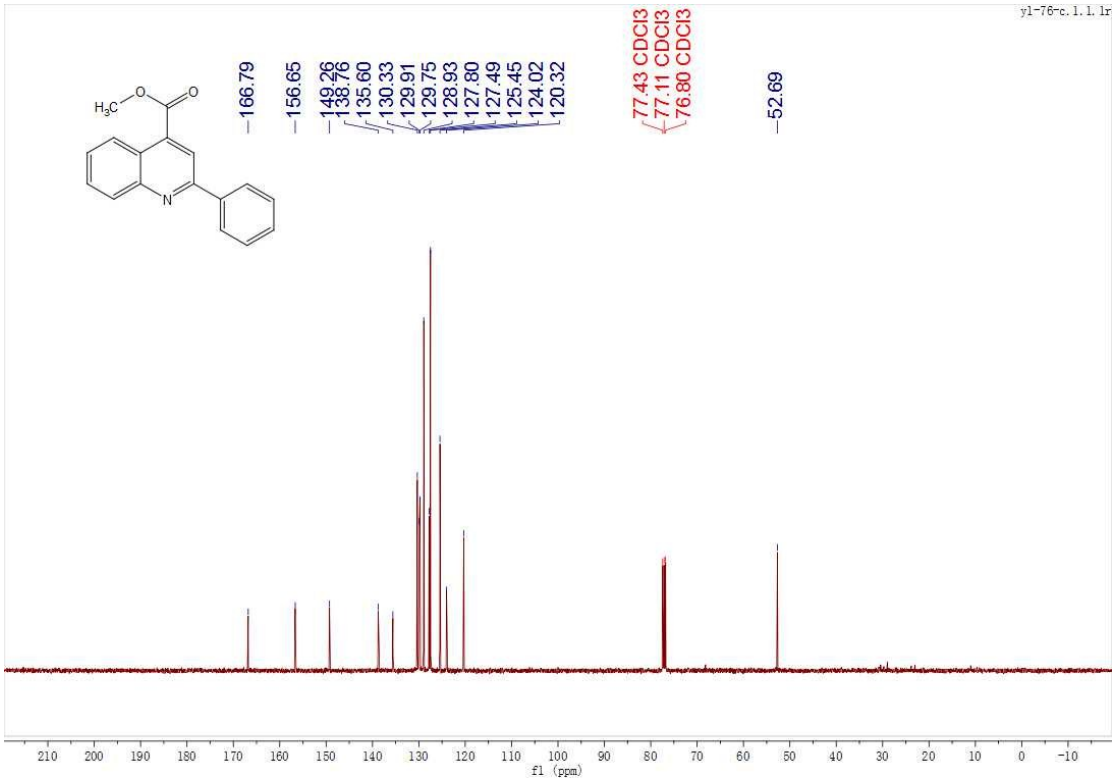
^{1}H and ^{13}C NMR of **4w**



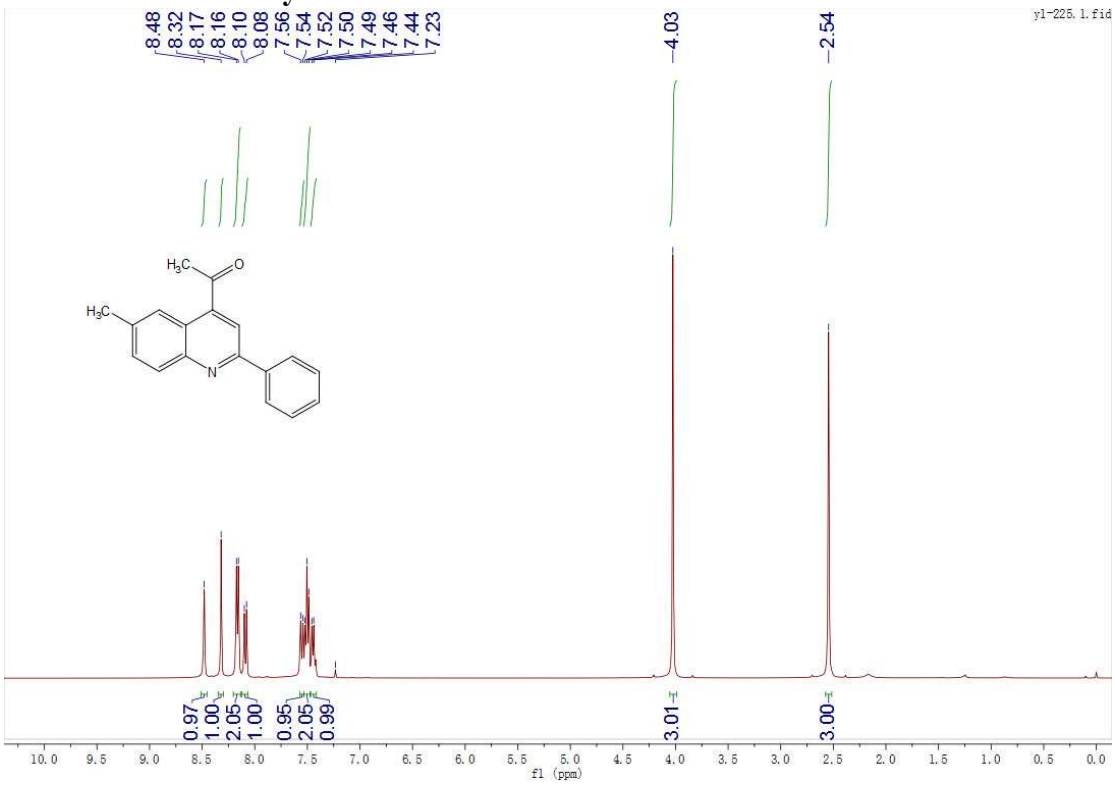


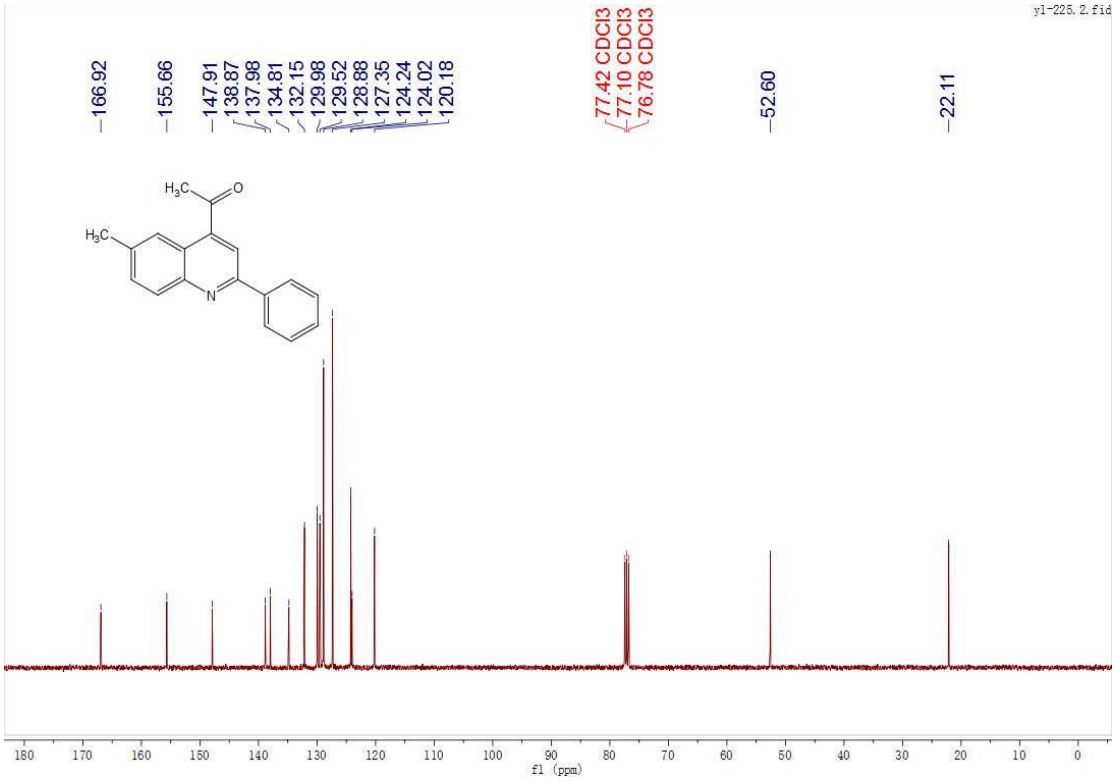
^{1}H and ^{13}C NMR of **4x**





^{1}H and ^{13}C NMR of **4y**





^{1}H and ^{13}C NMR of **4z**