Electronic Supplementary Information for

Rhodium(III)-Catalyzed Annulation of Arenes with Alkynes Assisted by an Internal Oxidizing N-O Bond

Zisong Qi[a], Guo-Dong Tang[ab], Cheng-Ling Pan[b]* and Xingwei Li[a]*

[a]*Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023, China*

E-mail: xwli@dicp.ac.cn

[b]*Laboratory of Multiscale Materials and Molecular Catalysis, School of Materials Science and Engineering, Anhui University of Science and Technology, Huainan 232001, China*

E-mail: clpan@aust.edu.cn

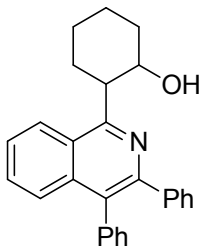
CONCENTS

I. General Information

All chemicals were obtained from commercial sources and were used as received unless otherwise noted. Diphenylacetylene was obtained from commercial sources. Other diarylacetylenes[1] and dihydroisoxazoles[2] were prepared by following literature reports. $[RhCp^*Cl_2]_2$ was prepared from $RhCl_3 \cdot xH_2O$ according to a literature procedure.[3] All reactions were carried out using Schlenk techniques or in a nitrogen-filled glove box. NMR spectra were recorded on a 400 MHz or 500 MHz NMR spectrometer in the solvent indicated. The chemical shift is given in dimensionless δ values and is frequency referenced relative to TMS in ^1H and ^{13}C NMR spectroscopy. HRMS data were obtained on a Q-TOF analyzer. Column chromatography was performed on silica gel (300-400 mesh) using ethyl acetate (EA)/petroleum ether (PE).

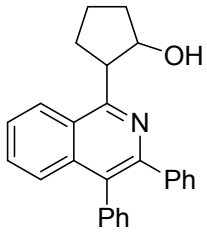
II. Typical Experimental Procedure for the Synthesis of 3.

Heterocycle **1** (0.20 mmol), alkyne **2** (0.24 mmol), $[RhCp^*Cl_2]_2$ (4 mol %), CsOAc (30 mol %), and HFIP (2 mL) were charged into a pressure tube. The reaction mixture was stirred at 60 °C for 12 h. After cooled to room temperature, the solvent was removed under reduced pressure and the residue was purified by silica gel chromatography using PE/EA to afford the desired product **3**. ***The substrates and products are cis***.

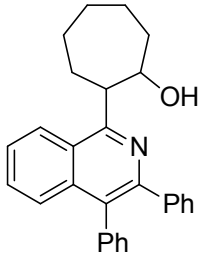


*2-(3,4-Diphenylisoquinolin-1-yl)cyclohexanol (**3aa**)*: White solid (57.6 mg, 76%); mp 110-111 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 8.24 – 8.18 (m, 1H), 7.70 (dt, J = 6.9, 3.0

Hz, 1H), 7.63 – 7.57 (m, 2H), 7.40 – 7.32 (m, 5H), 7.29 – 7.25 (m, 1H), 7.24 – 7.14 (m, 5H), 4.56 (s, 1H), 3.65 (d, *J* = 11.6 Hz, 1H), 2.26 – 2.14 (m, 1H), 2.10 (d, *J* = 13.2 Hz, 1H), 2.00 – 1.82 (m, 3H), 1.71 – 1.57 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 148.0, 140.6, 137.4, 136.8, 131.6, 131.5, 130.4, 130.3, 129.6, 128.6, 128.5, 127.9, 127.6, 127.3, 127.1, 126.9, 125.1, 124.7, 68.3, 43.5, 33.2, 28.2, 26.8, 19.9; HRMS: $[M + H]^+$ calculated for $C_{27}H_{26}NO$: 380.2014, found 380.2018.

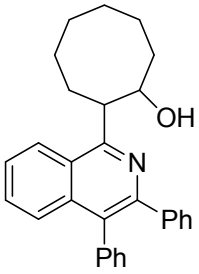


*2-(3,4-Diphenylisoquinolin-1-yl)cyclopentanol (**3ba**)*: White solid (48.9 mg, 67%); mp 99-100 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25 – 8.20 (m, 1H), 7.72 – 7.67 (m, 1H), 7.62 – 7.57 (m, 3H), 7.39 – 7.31 (m, 5H), 7.26 – 7.22 (m, 2H), 7.20 – 7.13 (m, 3H), 4.81 (s, 1H), 3.80 (ddd, *J* = 11.3, 8.3, 3.1 Hz, 1H), 2.42 – 2.31 (m, 1H), 2.28 – 2.12 (m, 2H), 2.07 – 1.87 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.0, 147.9, 140.4, 137.3, 136.7, 131.6, 131.4, 130.5, 130.3, 129.6, 128.6, 128.5, 127.9, 127.6, 127.3, 127.1, 126.7, 126.3, 125.0, 75.9, 46.0, 34.8, 31.2, 22.8; HRMS: $[M + H]^+$ calculated for $C_{26}H_{24}NO$: 366.1858, found 366.1856.

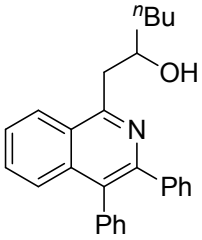


*2-(3,4-Diphenylisoquinolin-1-yl)cycloheptanol (**3ca**)*: White solid (61.3 mg, 78%); mp 100-101 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 – 8.13 (m, 1H), 7.73 – 7.66 (m, 1H), 7.66 – 7.55 (m, 2H), 7.35 (s, 5H), 7.30 – 7.23 (m, 1H), 7.22 – 7.13 (m, 4H), 6.67 (s, 1H), 4.65 (s, 1H), 3.74 (d, *J* = 10.5 Hz, 1H), 2.54 – 2.37 (m, 1H), 2.21 – 2.06 (m, 1H), 2.03 – 1.74 (m, 7H), 1.73 – 1.59 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.0, 148.0, 140.7, 137.4, 136.9, 131.6, 131.5, 130.34, 130.29, 129.4, 128.6, 128.5, 127.9, 127.5, 127.3, 127.1, 126.9, 124.7, 124.5, 71.3, 45.8, 36.1, 28.5, 27.9, 27.4, 21.9; HRMS: [M

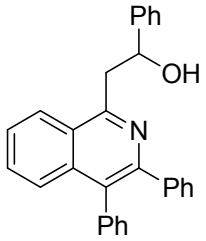
+ H]$^+$ calculated for $C_{28}H_{28}NO$: 394.2171, found 394.2172.



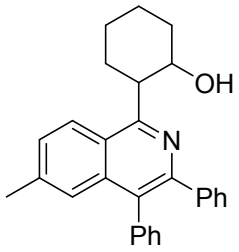
*2-(3,4-Diphenylisoquinolin-1-yl)cyclooctanol (**3da**)*: Pale yellow solid (60.2 mg, 74%); mp 99-100 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 – 8.20 (m, 1H), 7.70 (dt, *J* = 6.7, 2.9 Hz, 1H), 7.64 – 7.56 (m, 2H), 7.40 – 7.30 (m, 5H), 7.26 (dd, *J* = 6.7, 1.3 Hz, 1H), 7.23 – 7.12 (m, 4H), 7.07 (s, 1H), 4.51 – 4.43 (m, 1H), 4.01 (d, *J* = 9.2 Hz, 1H), 2.64 – 2.53 (m, 1H), 2.08 – 1.97 (m, 3H), 1.95 – 1.80 (m, 5H), 1.74 – 1.52 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 147.9, 140.6, 137.4, 137.0, 131.5, 130.34, 130.26, 129.4, 128.54, 128.49, 127.9, 127.5, 127.3, 127.1, 126.9, 124.8, 124.7, 71.8, 40.4, 32.7, 29.6, 27.8, 27.4, 25.0, 21.2; HRMS: [M + H]$^+$ calculated for $C_{29}H_{30}NO$: 408.2327, found 408.2329.



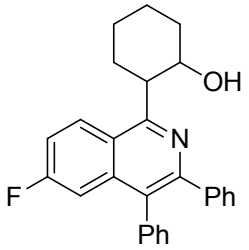
*1-(3,4-Diphenylisoquinolin-1-yl)hexan-2-ol (**3ea**)*: White solid (50.3 mg, 66%); mp 62-64 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 – 8.05 (m, 1H), 7.64 – 7.55 (m, 1H), 7.54 – 7.46 (m, 2H), 7.30 – 7.21 (m, 5H), 7.17 – 7.05 (m, 5H), 5.88 (s, 1H), 4.37 – 4.25 (m, 1H), 3.53 (dd, 16.5, 1.8 Hz, 1H), 3.19 (dd, 16.5, 9.7 Hz, 1H), 1.77 – 1.65 (m, 1H), 1.64 – 1.56 (m, 1H), 1.55 – 1.39 (m, 2H), 1.39 – 1.28 (m, 2H), 0.87 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.7, 148.3, 140.6, 137.3, 136.3, 131.4, 130.3, 130.2, 129.5, 128.38, 128.35, 127.7, 127.4, 127.2, 126.9, 126.5, 126.0, 124.7, 70.0, 39.2, 37.0, 28.1, 22.9, 14.2; HRMS: [M + H]$^+$ calculated for $C_{27}H_{28}NO$: 382.2171, found 382.2169.



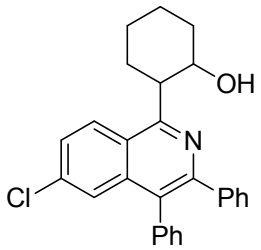
*2-(3,4-Diphenylisoquinolin-1-yl)-1-phenylethanol (**3fa**)*: Pale yellow solid (38.5 mg, 48%); mp 171-172 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 – 8.10 (m, 1H), 7.74 – 7.67 (m, 1H), 7.59 (ddd, *J* = 11.1, 7.0, 5.3 Hz, 4H), 7.45 – 7.29 (m, 8H), 7.27 – 7.18 (m, 5H), 6.51 (s, 1H), 5.58 – 5.49 (m, 1H), 3.83 (dd, *J* = 16.7, 2.1 Hz, 1H), 3.58 (dd, *J* = 16.7, 10.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.2, 148.5, 144.4, 140.6, 137.3, 136.57, 131.6, 131.5, 130.6, 130.3, 130.0, 128.6, 128.56, 128.55, 127.9, 127.6, 127.5, 127.4, 127.2, 126.7, 126.2, 126.1, 124.8, 72.5, 42.0; HRMS: $[M + H]^+$ calculated for $C_{29}H_{24}NO$: 402.1858, found 402.1861.



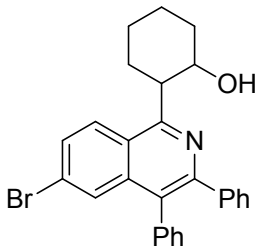
*2-(6-Methyl-3,4-diphenylisoquinolin-1-yl)cyclohexanol (**3ga**)*: Pale yellow solid (62.9 mg, 80%); mp 125-126 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8.6 Hz, 1H), 7.45 (s, 1H), 7.43 – 7.40 (m, 1H), 7.39 – 7.29 (m, 6H), 7.25 (dd, *J* = 6.2, 1.8 Hz, 1H), 7.22 – 7.18 (m, 1H), 7.18 – 7.14 (m, 3H), 4.55 (s, 1H), 3.61 (dd, *J* = 7.2, 5.6 Hz, 1H), 2.43 (s, 3H), 2.25 – 2.13 (m, 1H), 2.09 (d, *J* = 13.2 Hz, 1H), 1.99 – 1.83 (m, 3H), 1.71 – 1.55 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 148.1, 140.8, 140.7, 137.5, 137.1, 131.6, 131.5, 130.3, 129.2, 129.1, 128.5, 128.5, 127.8, 127.5, 127.2, 125.7, 124.6, 123.4, 68.3, 43.5, 33.2, 28.2, 26.8, 22.3, 20.0; HRMS: $[M + H]^+$ calculated for $C_{28}H_{28}NO$: 394.2171, found 394.2169.



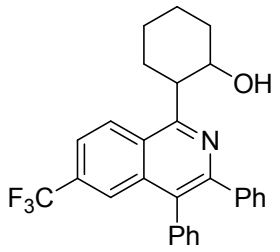
*2-(6-Fluoro-3,4-diphenylisoquinolin-1-yl)cyclohexanol (**3ha**)*: White solid (54.8 mg, 69%); mp 208-209 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (dd, *J* = 9.2, 5.6 Hz, 1H), 7.41 – 7.28 (m, 7H), 7.24 (dd, *J* = 6.7, 1.9 Hz, 1H), 7.22 – 7.16 (m, 4H), 7.13 (s, 1H), 4.55 (s, 1H), 3.63 – 3.55 (m, 1H), 2.21 (qd, *J* = 13.0, 3.3 Hz, 1H), 2.10 (d, *J* = 12.9 Hz, 1H), 2.00 – 1.82 (m, 3H), 1.70 – 1.55 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 163.5 (d, $J_{C\text{-}F}$ = 251.1 Hz), 149.0, 140.2, 139.0 (d, $J_{C\text{-}F}$ = 9.7 Hz), 136.9, 131.4, 131.3, 130.2, 129.3 (d, $J_{C\text{-}F}$ = 5.2 Hz), 128.8, 128.7, 127.98, 127.95, 127.9, 127.8, 127.6, 122.3 (d, $J_{C\text{-}F}$ = 0.8 Hz), 117.3 (d, $J_{C\text{-}F}$ = 25.1 Hz), 110.6 (d, $J_{C\text{-}F}$ = 22.1 Hz), 68.2, 43.8, 33.1, 28.3, 26.8, 19.9; HRMS: $[M + H]^+$ calculated for $C_{27}H_{25}FNO$: 398.1920, found 398.1921.



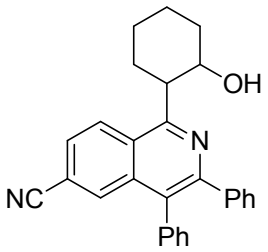
*2-(6-Chloro-3,4-diphenylisoquinolin-1-yl)cyclohexanol (**3ia**)*: White solid (57.8 mg, 70%); mp 129-130 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 9.0 Hz, 1H), 7.67 (d, *J* = 2.0 Hz, 1H), 7.53 (dd, *J* = 9.0, 2.1 Hz, 1H), 7.41 – 7.35 (m, 3H), 7.31 (ddd, *J* = 6.3, 3.7, 1.3 Hz, 2H), 7.24 (dd, *J* = 5.9, 2.0 Hz, 1H), 7.21 – 7.16 (m, 4H), 7.12 (s, 1H), 4.55 (s, 1H), 3.64 – 3.53 (m, 1H), 2.19 (qd, *J* = 13.0, 3.3 Hz, 1H), 2.09 (d, *J* = 12.1 Hz, 1H), 2.00 – 1.79 (m, 3H), 1.72 – 1.56 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 149.2, 140.2, 137.9, 137.0, 136.6, 131.41, 131.35, 130.2, 128.81, 128.76, 128.7, 128.00, 127.95, 127.9, 127.60, 126.57, 125.7, 123.3, 68.2, 43.7, 33.0, 28.2, 26.7, 19.8; HRMS: $[M + H]^+$ calculated for $C_{27}H_{25}ClNO$: 414.1625, found 414.1623.



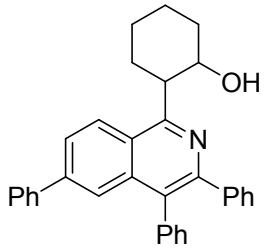
*2-(6-Bromo-3,4-diphenylisoquinolin-1-yl)cyclohexanol (**3ja**)*: Pale yellow solid (67.8 mg, 74%); mp 133-134 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, J = 9.0 Hz, 1H), 7.85 (d, J = 1.9 Hz, 1H), 7.66 (dd, J = 9.0, 1.9 Hz, 1H), 7.42 – 7.34 (m, 3H), 7.34 – 7.29 (m, 2H), 7.23 (dd, J = 5.9, 1.9 Hz, 1H), 7.21 – 7.14 (m, 4H), 7.01 (s, 1H), 4.54 (s, 1H), 3.58 (d, J = 11.2 Hz, 1H), 2.19 (qd, J = 13.0, 3.2 Hz, 1H), 2.09 (d, J = 12.4 Hz, 1H), 2.00 – 1.88 (m, 2H), 1.84 (d, J = 12.2 Hz, 1H), 1.70 – 1.54 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 149.2, 140.2, 138.2, 136.6, 131.41, 131.35, 130.6, 130.2, 129.1, 128.8, 128.7, 128.6, 127.94, 127.89, 127.6, 126.5, 125.6, 123.5, 68.2, 43.7, 33.1, 28.2, 26.7, 19.8; HRMS: $[M + H]^+$ calculated for $C_{27}H_{25}BrNO$: 458.1120, found 458.1118.



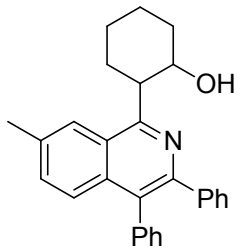
*2-(3,4-Diphenyl-6-(trifluoromethyl)isoquinolin-1-yl)cyclohexanol (**3ka**)*: White solid (54.5 mg, 61%); mp 128-129 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.34 (d, J = 8.9 Hz, 1H), 8.02 (s, 1H), 7.77 (dd, J = 8.8, 1.6 Hz, 1H), 7.44 – 7.37 (m, 3H), 7.36 – 7.30 (m, 2H), 7.28 – 7.23 (m, 1H), 7.23 – 7.16 (m, 4H), 6.92 (s, 1H), 4.58 (s, 1H), 3.66 (d, J = 11.2 Hz, 1H), 2.21 (qd, J = 12.8, 3.1 Hz, 1H), 2.11 (d, J = 13.0 Hz, 1H), 2.00 – 1.82 (m, 3H), 1.74 – 1.54 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.0, 149.5, 140.0, 136.3, 136.2, 132.0 (q, $J_{C\text{-}F}$ = 32.4 Hz), 131.4, 131.3, 130.23, 130.19, 128.9, 128.8, 128.13, 128.05, 127.8, 126.2, 126.0, 123.9 (q, $J_{C\text{-}F}$ = 271.2 Hz), 124.5 (q, $J_{C\text{-}F}$ = 4.5 Hz), 122.7 (q, $J_{C\text{-}F}$ = 3.0 Hz), 68.2, 43.9, 33.1, 28.2, 26.8, 19.8; HRMS: $[M + H]^+$ calculated for $C_{28}H_{25}F_3NO$: 448.1888, found 448.1888.



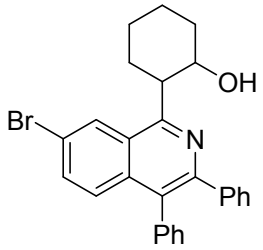
*1-(2-Hydroxycyclohexyl)-3,4-diphenylisoquinoline-6-carbonitrile (**3la**)*: White solid (49.3 mg, 61%); mp 167-168 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31 (d, *J* = 8.8 Hz, 1H), 8.09 (s, 1H), 7.78 – 7.71 (m, 1H), 7.42 (s, 3H), 7.33 (dd, *J* = 6.5, 2.9 Hz, 2H), 7.28 – 7.17 (m, 5H), 6.74 (s, 1H), 4.56 (s, 1H), 3.63 (d, *J* = 11.5 Hz, 1H), 2.28 – 2.14 (m, 1H), 2.11 (d, *J* = 12.5 Hz, 1H), 2.00 – 1.80 (m, 3H), 1.71 – 1.57 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 150.0, 139.6, 136.2, 135.8, 133.1, 131.31, 131.26, 130.2, 129.5, 129.01, 128.99, 128.3, 128.1, 128.0, 127.5, 126.3, 125.7, 118.5, 114.1, 68.1, 43.9, 33.0, 28.2, 26.7, 19.8; HRMS: $[M + H]^+$ calculated for $C_{28}H_{25}N_2O$: 405.1967, found 405.1965.



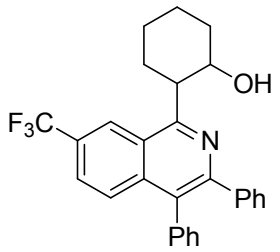
*2-(3,4,6-Triphenylisoquinolin-1-yl)cyclohexanol (**3ma**)*: White solid (70.0 mg, 67%); mp 166-167 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, *J* = 8.8 Hz, 1H), 7.89 (d, *J* = 1.4 Hz, 1H), 7.85 (dd, *J* = 8.7, 1.7 Hz, 1H), 7.58 – 7.51 (m, 2H), 7.46 – 7.40 (m, 2H), 7.40 – 7.32 (m, 6H), 7.30 (d, *J* = 7.8 Hz, 1H), 7.27 – 7.22 (m, 2H), 7.22 – 7.15 (m, 3H), 4.58 (s, 1H), 3.67 (d, *J* = 11.6 Hz, 1H), 2.31 – 2.15 (m, 1H), 2.11 (d, *J* = 13.3 Hz, 1H), 2.01 – 1.87 (m, 3H), 1.71 – 1.57 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 148.5, 143.0, 140.6, 140.4, 137.3, 137.2, 131.6, 131.5, 130.3, 129.8, 129.1, 128.63, 128.59, 128.3, 127.9, 127.68, 127.65, 127.4, 126.7, 125.4, 124.6, 124.1, 68.3, 43.6, 33.2, 28.2, 26.8, 20.0; HRMS: $[M + H]^+$ calculated for $C_{33}H_{30}NO$: 456.2327, found 456.2326.



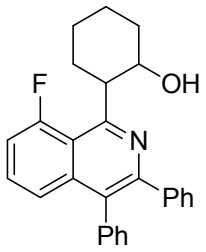
*2-(7-Methyl-3,4-diphenylisoquinolin-1-yl)cyclohexanol (**3na**)*: White solid (56.6 mg, 72%); mp 131-132 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (s, 1H), 7.60 (d, *J* = 8.7 Hz, 1H), 7.42 (d, *J* = 8.7 Hz, 1H), 7.40 – 7.30 (m, 6H), 7.25 (d, *J* = 5.7 Hz, 1H), 7.23 – 7.13 (m, 4H), 4.54 (s, 1H), 3.62 (d, *J* = 12.0 Hz, 1H), 2.58 (s, 3H), 2.25 – 2.13 (m, 1H), 2.10 (d, *J* = 13.5 Hz, 1H), 2.00 – 1.84 (m, 3H), 1.72 – 1.53 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.1, 147.2, 140.6, 137.5, 137.0, 135.0, 132.6, 131.51, 131.47, 130.3, 129.4, 128.50, 128.46, 127.9, 127.5, 127.2, 126.8, 125.2, 123.6, 68.3, 43.3, 33.2, 28.1, 26.8, 22.2, 19.9; HRMS: $[M + H]^+$ calculated for $C_{28}H_{28}NO$: 394.2171, found 394.2171.



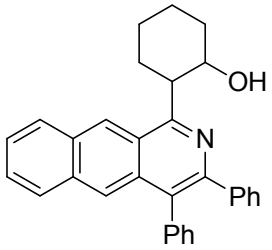
*2-(7-Bromo-3,4-diphenylisoquinolin-1-yl)cyclohexanol (**3oa**)*: White solid (55.8 mg, 61%); mp 148-149 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32 (s, 1H), 7.65 (dd, *J* = 9.1, 1.3 Hz, 1H), 7.58 (d, *J* = 9.1 Hz, 1H), 7.40 – 7.29 (m, 5H), 7.28 – 7.15 (m, 5H), 7.00 (s, 1H), 4.53 (s, 1H), 3.55 (d, *J* = 11.8 Hz, 1H), 2.18 (tt, *J* = 13.1, 6.6 Hz, 1H), 2.09 (d, *J* = 12.5 Hz, 1H), 1.99 – 1.80 (m, 3H), 1.74 – 1.57 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 148.5, 140.1, 136.7, 135.4, 133.8, 131.41, 131.36, 130.2, 129.5, 128.9, 128.69, 128.65, 128.0, 127.8, 127.6, 127.0, 126.2, 121.3, 68.2, 43.6, 33.1, 28.1, 26.7, 19.8; HRMS: $[M + H]^+$ calculated for $C_{27}H_{25}BrNO$: 458.1120, found 458.1122.



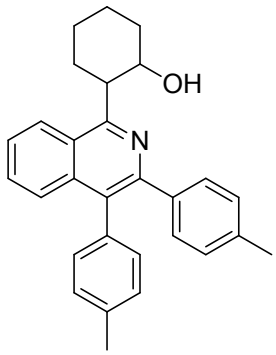
*2-(3,4-Diphenyl-7-(trifluoromethyl)isoquinolin-1-yl)cyclohexanol (**3pa**)*: White solid (55.4 mg, 62%); mp 137-138 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.47 (s, 1H), 7.84 (d, *J* = 8.9 Hz, 1H), 7.75 (dd, *J* = 9.0, 1.5 Hz, 1H), 7.44 – 7.31 (m, 5H), 7.29 – 7.17 (m, 5H), 6.91 (d, *J* = 1.3 Hz, 1H), 4.57 (s, 1H), 3.66 (d, *J* = 11.2 Hz, 1H), 2.23 (qd, *J* = 12.9, 3.1 Hz, 1H), 2.11 (d, *J* = 13.2 Hz, 1H), 2.02 – 1.82 (m, 3H), 1.67 (dd, *J* = 27.1, 13.7 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 150.1, 139.9, 138.4, 136.6, 131.41, 131.35, 130.3, 129.5, 128.80 (q, J_{C-F} = 32.4 Hz), 128.78, 128.75, 128.3, 128.04, 127.98, 127.8, 125.93 (q, J_{C-F} = 3.0 Hz), 125.10 (q, J_{C-F} = 270.8 Hz), 124.05, 122.5 (q, J_{C-F} = 4.5 Hz), 68.2, 43.7, 33.0, 28.4, 26.7, 19.8; HRMS: $[M + H]^+$ calculated for $C_{28}H_{25}F_3NO$: 448.1888, found 448.1896.



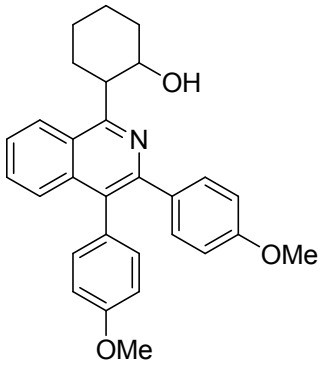
*2-(8-Fluoro-3,4-diphenylisoquinolin-1-yl)cyclohexanol (**3qa**)*: White solid (42.9 mg, 54%); mp 108-109 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 – 7.45 (m, 2H), 7.40 – 7.29 (m, 5H), 7.28 – 7.22 (m, 2H), 7.22 – 7.16 (m, 4H), 6.91 (s, 1H), 4.57 (s, 1H), 3.84 (d, *J* = 11.6 Hz, 1H), 2.19 – 2.01 (m, 2H), 1.99 – 1.86 (m, 3H), 1.68 – 1.53 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.4 (d, J_{C-F} = 7.6 Hz), 159.8 (d, J_{C-F} = 254.8 Hz), 148.7, 140.1, 139.5 (d, J_{C-F} = 3.1 Hz), 137.2, 131.4, 130.5, 130.4, 130.2, 128.9 (d, J_{C-F} = 3.1 Hz), 128.7, 128.6, 128.0, 127.8, 127.6, 123.1 (d, J_{C-F} = 4.1 Hz), 116.2 (d, J_{C-F} = 12.5 Hz), 112.7 (d, J_{C-F} = 24.3 Hz), 68.4, 47.5 (d, J_{C-F} = 11.7 Hz), 33.2, 28.3, 27.0, 20.0; HRMS: $[M + H]^+$ calculated for $C_{27}H_{25}FNO$: 398.1920, found 398.1922.



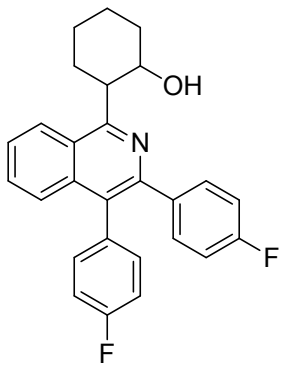
*2-(3,4-Diphenylbenzo[g]isoquinolin-1-yl)cyclohexanol (**3ra**)*: White solid (27.4 mg, 32%); mp 90-91 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.91 – 7.84 (m, 1H), 7.79 (dd, *J* = 9.8, 3.7 Hz, 2H), 7.56 – 7.48 (m, 2H), 7.25 – 7.11 (m, 10H), 6.85 (s, 1H), 4.13 (dt, *J* = 7.5, 3.9 Hz, 1H), 3.30 (dd, *J* = 16.5, 7.4 Hz, 1H), 2.03 – 1.90 (m, 1H), 1.64 – 1.54 (m, 3H), 1.46 (s, 3H), 1.19 – 1.03 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.6, 141.9, 141.1, 139.9, 137.4, 133.7, 132.5, 131.5, 130.9, 130.5, 130.1, 129.5, 128.5, 128.32, 128.26, 128.0, 127.8, 127.7, 127.4, 127.3, 126.9, 79.8, 47.4, 25.60, 25.58, 22.3, 20.3; HRMS: $[M + H]^+$ calculated for $C_{31}H_{28}NO$: 430.2171, found 430.2170.



*2-(3,4-Di-p-tolylisoquinolin-1-yl)cyclohexanol (**3ab**)*: White solid (56.1 mg, 69%); mp 143-144 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (dd, *J* = 6.6, 3.0 Hz, 1H), 7.69 (dt, *J* = 6.8, 3.2 Hz, 1H), 7.56 (dq, *J* = 6.6, 3.3 Hz, 2H), 7.33 (s, 1H), 7.26 (d, *J* = 8.1 Hz, 2H), 7.21 – 7.08 (m, 4H), 6.99 (d, *J* = 7.9 Hz, 2H), 4.55 (s, 1H), 3.62 (d, *J* = 11.7 Hz, 1H), 2.39 (s, 3H), 2.27 (s, 3H), 2.24 – 2.13 (m, 1H), 2.13 – 2.05 (m, 1H), 1.99 – 1.82 (m, 3H), 1.70 – 1.54 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 147.9, 137.8, 137.10, 137.05, 137.0, 134.4, 131.32, 131.28, 130.20, 130.15, 129.29, 129.27, 129.25, 128.7, 126.9, 126.8, 124.9, 124.7, 68.3, 43.4, 33.1, 28.1, 26.8, 21.5, 21.3, 19.9; HRMS: $[M + H]^+$ calculated for $C_{29}H_{30}NO$: 408.2327, found 408.2325.

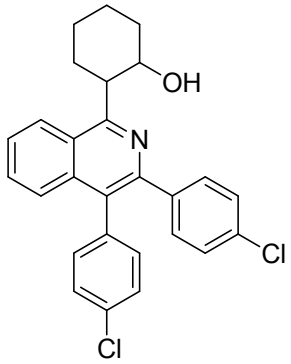


*2-(3,4-Bis(4-methoxyphenyl)isoquinolin-1-yl)cyclohexanol (**3ac**)*: White solid (59.7 mg, 68%); mp 125-126 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 – 8.10 (m, 1H), 7.77 – 7.66 (m, 1H), 7.62 – 7.51 (m, 2H), 7.36 – 7.27 (m, 3H), 7.17 (d, J = 8.0 Hz, 1H), 7.13 (d, J = 8.0 Hz, 1H), 6.92 (t, J = 6.1 Hz, 2H), 6.74 (d, J = 8.6 Hz, 2H), 4.55 (s, 1H), 3.84 (s, 3H), 3.75 (s, 3H), 3.62 (d, J = 12.0 Hz, 1H), 2.25 – 2.03 (m, 2H), 2.00 – 1.82 (m, 3H), 1.72 – 1.52 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 159.0, 158.8, 147.7, 137.2, 133.2, 132.5, 132.5, 131.5, 130.2, 129.6, 128.6, 126.8, 126.7, 124.8, 124.7, 114.11, 114.07, 113.4, 68.3, 55.4, 55.3, 43.4, 33.1, 28.1, 26.8, 19.9; HRMS: $[M + H]^+$ calculated for $C_{29}H_{30}NO_3$: 440.2226, found 440.2227.

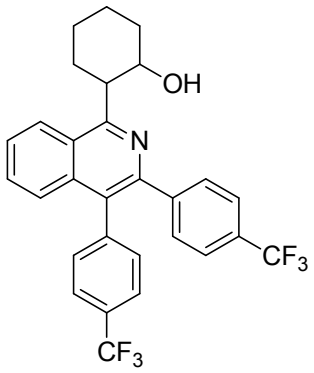


*2-(3,4-Bis(4-fluorophenyl)isoquinolin-1-yl)cyclohexanol (**3ad**)*: White solid (60.6 mg, 73%); mp 236-237 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (dd, J = 6.1, 3.3 Hz, 1H), 7.71 – 7.58 (m, 3H), 7.29 (dd, J = 8.6, 5.5 Hz, 2H), 7.25 – 7.15 (m, 2H), 7.14 – 7.04 (m, 3H), 6.90 (t, J = 8.7 Hz, 2H), 4.55 (s, 1H), 3.65 (d, J = 12.1 Hz, 1H), 2.26 – 2.05 (m, 2H), 2.01 – 1.83 (m, 3H), 1.74 – 1.57 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2, 162.4 (d, $J_{C\text{-}F}$ = 246.0 Hz), 162.2 (d, $J_{C\text{-}F}$ = 246.2 Hz), 147.2, 136.8, 136.5 (d, $J_{C\text{-}F}$ = 3.3 Hz), 133.09 (d, $J_{C\text{-}F}$ = 9.4 Hz), 133.08 (d, $J_{C\text{-}F}$ = 7.1 Hz), 133.06, 132.0, 131.9, 130.7, 128.5, 127.3, 126.6, 125.1, 124.9, 115.9 (d, $J_{C\text{-}F}$ = 21.3 Hz), 115.8 (d, $J_{C\text{-}$

$_F$ = 21.3 Hz), 115.0 (d, J_{C-F} = 21.3 Hz), 68.3, 43.6, 33.1, 28.2, 26.8, 19.9. HRMS: [M + H]$^+$ calculated for $C_{27}H_{24}F_2NO$: 416.1826, found 416.1825.

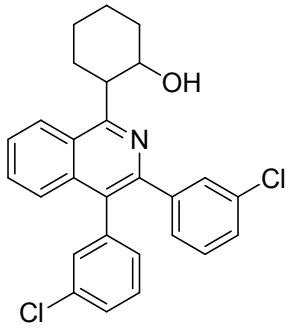


*2-(3,4-Bis(4-chlorophenyl)isoquinolin-1-yl)cyclohexanol (**3ae**)*: White solid (64.5 mg, 72%); mp 260-261 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 – 8.16 (m, 1H), 7.71 – 7.58 (m, 3H), 7.37 (t, *J* = 6.0 Hz, 2H), 7.26 (d, *J* = 8.1 Hz, 2H), 7.22 – 7.11 (m, 4H), 6.98 (s, 1H), 4.53 (s, 1H), 3.65 (d, *J* = 12.3 Hz, 1H), 2.27 – 2.01 (m, 2H), 2.00 – 1.81 (m, 3H), 1.72 – 1.54 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.5, 146.9, 138.8, 136.5, 135.5, 133.9, 133.7, 132.8, 132.7, 131.5, 130.8, 129.1, 129.0, 128.5, 128.3, 127.5, 126.5, 125.2, 124.9, 68.3, 43.6, 33.1, 28.1, 26.7, 19.9; HRMS: [M + H]$^+$ calculated for $C_{27}H_{24}Cl_2NO$: 448.1235, found 448.1236.

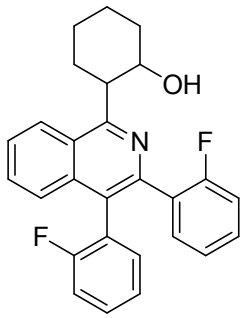


*2-(3,4-Bis(4-(trifluoromethyl)phenyl)isoquinolin-1-yl)cyclohexanol (**3af**)*: White solid (71.1 mg, 69%); mp 136-137 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 – 8.21 (m, 1H), 7.74 – 7.64 (m, 4H), 7.64 – 7.58 (m, 1H), 7.51 – 7.35 (m, 6H), 6.85 (s, 1H), 4.55 (s, 1H), 3.69 (d, *J* = 11.9 Hz, 1H), 2.20 (qd, *J* = 13.4, 3.3 Hz, 1H), 2.10 (d, *J* = 11.9 Hz, 1H), 2.02 – 1.86 (m, 3H), 1.73 – 1.57 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.0, 146.6, 143.7, 140.8, 136.3, 131.9, 131.8, 131.2, 130.5, 130.3 (q, J_{C-F} = 32.5 Hz), 129.7 (q, J_{C-F} = 32.4 Hz), 128.77, 127.9, 126.5, 125.8 (q, J_{C-F} = 3.6 Hz), 125.4, 125.12

(q, $J_{C\text{-}F}$ = 3.8 Hz), 125.06, 124.2 (q, $J_{C\text{-}F}$ = 270.3 Hz), 68.3, 43.8, 33.1, 28.2, 26.7, 19.9; HRMS: $[M + H]^+$ calculated for $C_{29}H_{24}F_6NO$: 516.1762, found 516.1756.

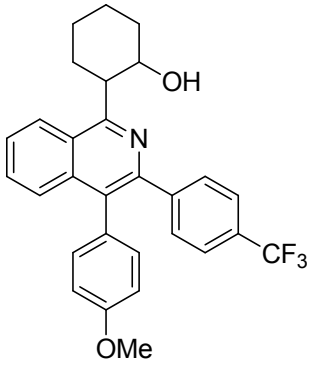


*2-(3,4-Bis(3-chlorophenyl)isoquinolin-1-yl)cyclohexanol (**3ag**)*: White solid (59.1 mg, 66%); mp 135-136 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 – 8.18 (m, 1H), 7.69 – 7.61 (m, 3H), 7.40 – 7.23 (m, 5H), 7.23 – 7.05 (m, 5H), 6.85 (s, 1H), 4.54 (s, 1H), 3.66 (d, *J* = 11.4 Hz, 1H), 2.28 – 2.04 (m, 2H), 1.99 – 1.82 (m, 3H), 1.69 – 1.58 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.6, 146.7, 142.0, 138.8, 136.4, 134.6, 134.0, 131.33, 131.28, 130.9, 130.2, 130.0, 129.72, 129.66, 129.3, 128.6, 128.4, 128.1, 127.8, 127.6, 126.6, 125.2, 124.9, 68.2, 43.7, 33.1, 28.1, 26.8, 19.9; HRMS: $[M + H]^+$ calculated for $C_{27}H_{24}Cl_2NO$: 448.1235, found 448.1238.



*2-(3,4-Bis(2-fluorophenyl)isoquinolin-1-yl)cyclohexanol (**3ah**)*: White solid (58.9 mg, 71%); mp 113-114 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 – 7.50 (m, 1H), 7.38 – 7.32 (m, 2H), 7.30 – 7.23 (m, 1H), 7.21 – 7.12 (m, 2H), 7.09 (td, *J* = 7.4, 1.7 Hz, 1H), 7.05 – 6.85 (m, 6H), 4.20 (dt, *J* = 7.2, 3.6 Hz, 1H), 3.42 (dt, *J* = 9.5, 7.2 Hz, 1H), 2.05 (dd, *J* = 14.7, 3.2 Hz, 1H), 1.67 – 1.44 (m, 5H), 1.21 – 1.07 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 160.5 (d, $J_{C\text{-}F}$ = 247.7 Hz), 160.3 (d, $J_{C\text{-}F}$ = 247.3 Hz), 142.2, 137.7, 132.6 (d, $J_{C\text{-}F}$ = 3.5 Hz), 130.7, 130.1 (d, $J_{C\text{-}F}$ = 8.2 Hz), 129.9, 129.7 (d, $J_{C\text{-}F}$ = 3.0 Hz), 129.5, 129.4 (d, $J_{C\text{-}F}$ = 8.3 Hz), 129.1, 128.0, 127.6 (d, $J_{C\text{-}F}$ = 14.1 Hz), 127.2 (d, $J_{C\text{-}F}$ = 3.0 Hz), 125.0 (d, $J_{C\text{-}F}$ = 14.0 Hz), 124.3 (d, $J_{C\text{-}F}$ = 3.4 Hz), 123.8 (d, $J_{C\text{-}F}$ =

3.5 Hz), 116.2 (d, $J_{C\text{-}F}$ = 21.8 Hz), 115.7 (d, $J_{C\text{-}F}$ = 21.8 Hz), 80.0, 47.3, 25.8, 25.4, 22.3, 20.4; HRMS: $[M + H]^+$ calculated for $C_{27}H_{24}F_2NO$: 416.1826, found 416.1827.

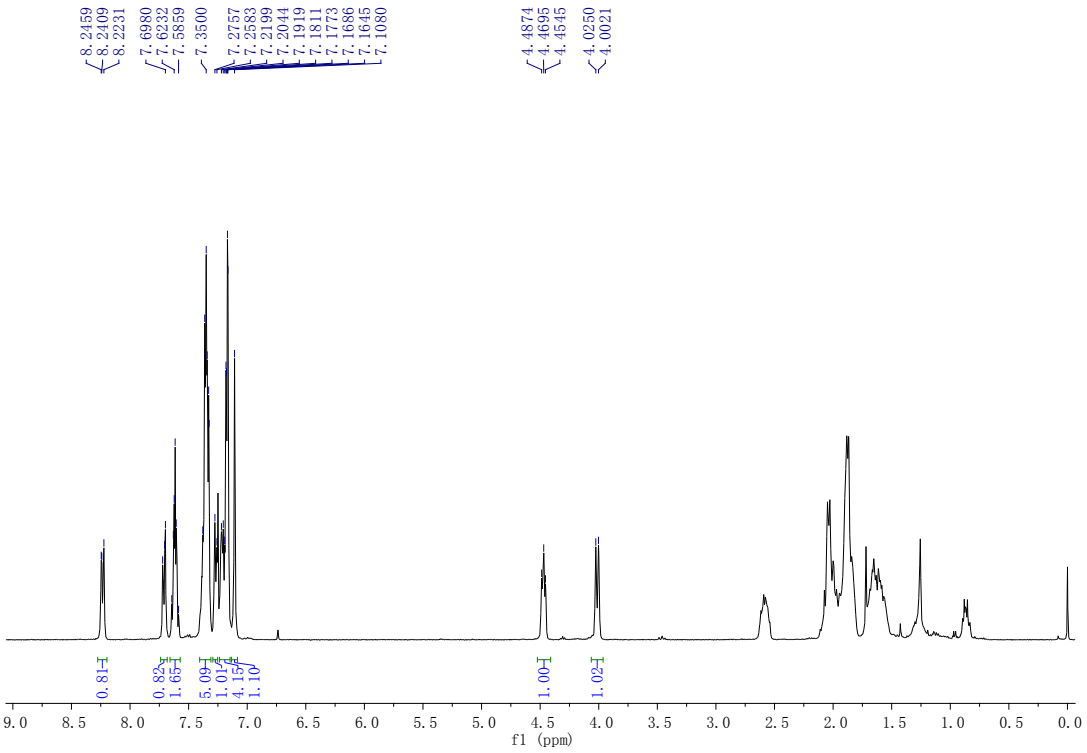


2-(4-(4-methoxyphenyl)-3-(4-(trifluoromethyl)phenyl)isoquinolin-1-yl)cyclohexanol ***(3ai)***: White solid (58.2 mg, 61%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (dd, J = 6.7, 3.0 Hz, 1H), 7.76 (dt, J = 6.9, 3.2 Hz, 1H), 7.67 – 7.61 (m, 2H), 7.46 (s, 4H), 7.19 – 7.10 (m, 2H), 7.02 (s, 1H), 6.97 – 6.90 (m, 2H), 4.54 (s, 1H), 3.86 (s, 3H), 3.69 – 3.61 (m, 1H), 2.24 – 2.13 (m, 1H), 2.13 – 2.05 (m, 1H), 2.01 – 1.84 (m, 3H), 1.69 – 1.59 (m, 4H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.0, 159.4, 146.7, 144.5, 137.1, 132.6, 132.5, 130.6, 130.5, 130.0, 129.2 (q, $J_{C\text{-}F}$ = 32.2 Hz), 128.8, 127.5, 127.1, 124.9 (q, $J_{C\text{-}F}$ = 3.8 Hz), 124.8, 124.4 (q, $J_{C\text{-}F}$ = 273.9 Hz), 114.3, 68.4, 55.5, 43.6, 33.2, 28.2, 26.8, 19.9. HRMS: $[M + H]^+$ calculated for $C_{29}H_{27}F_3NO_2$: 478.1994, found 478.1992.

III. KIE Studies

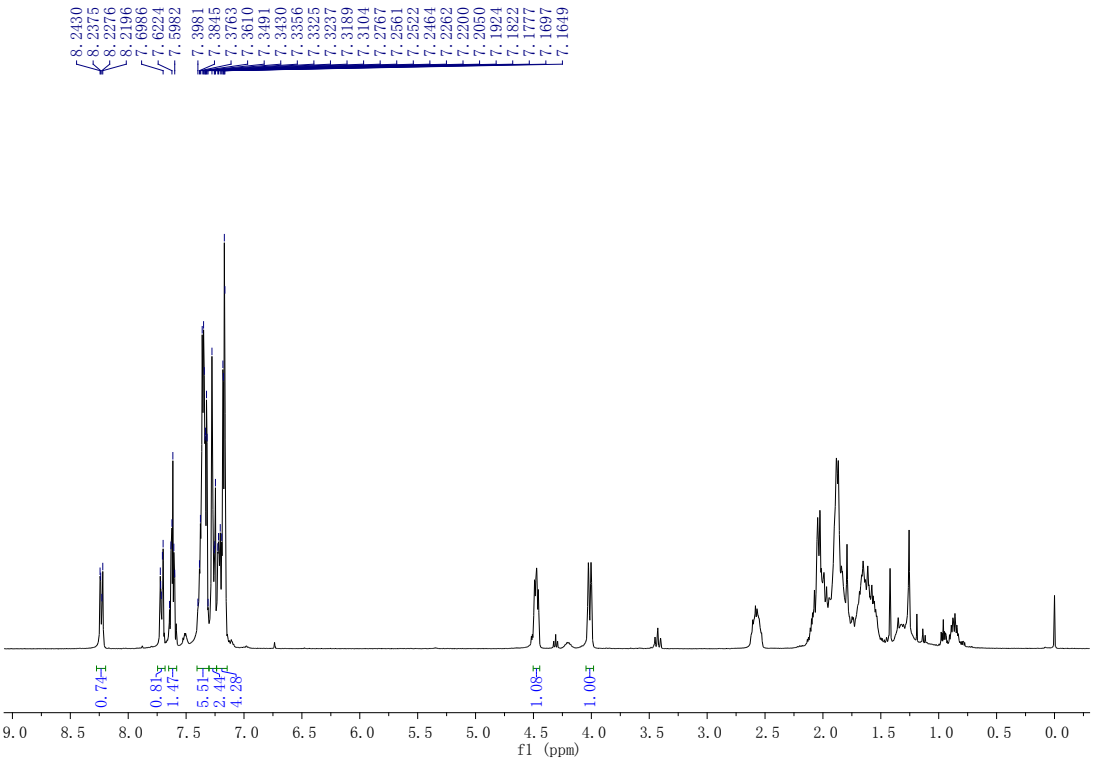
KIE determined from an intermolecular competition

A mixture of **1d** and **1d-*d*$_5$** (1:1 ratio, 0.4 mmol in total), diphenylacetylene (0.2 mmol), $[Cp^*RhCl_2]_2$ (4 mol%,), and CsOAc (30 mol%) were charged into a pressure tube, to which was added HFIP (2 mL) under N_2. The reaction mixture was stirred at 60 °C for 90 min. After cooled to room temperature, the solvent was removed under reduced pressure and the residue was purified by silica gel chromatography using EA/PE to afford the product mixture. KIE value (k_H/k_D = 0.82/(1-0.82) = 4.6) was determined by ^{1}H NMR analysis.



KIE determined from two parallel reactions

A mixture of **1d** (0.2 mmol), diphenylacetylene (0.2 mmol), $[Cp^*RhCl_2]_2$ (4 mol%,), and CsOAc (30 mol%) were charged into a pressure tube, to which was added HFIP (2 mL) under N_2. The reaction mixture was stirred at 60 °C for 60 min. A parallel reaction, **1d-d_5** instead of **1d**, was carried out at same conditions. After cooled to room temperature, combined the two parallel reactions, the solvent was removed under reduced pressure and the residue was purified by silica gel chromatography using EA/PE to afford the product mixture. KIE value (k_H/k_D = 0.74/(1-0.74) = 2.8) was determined by ^{1}H NMR analysis.



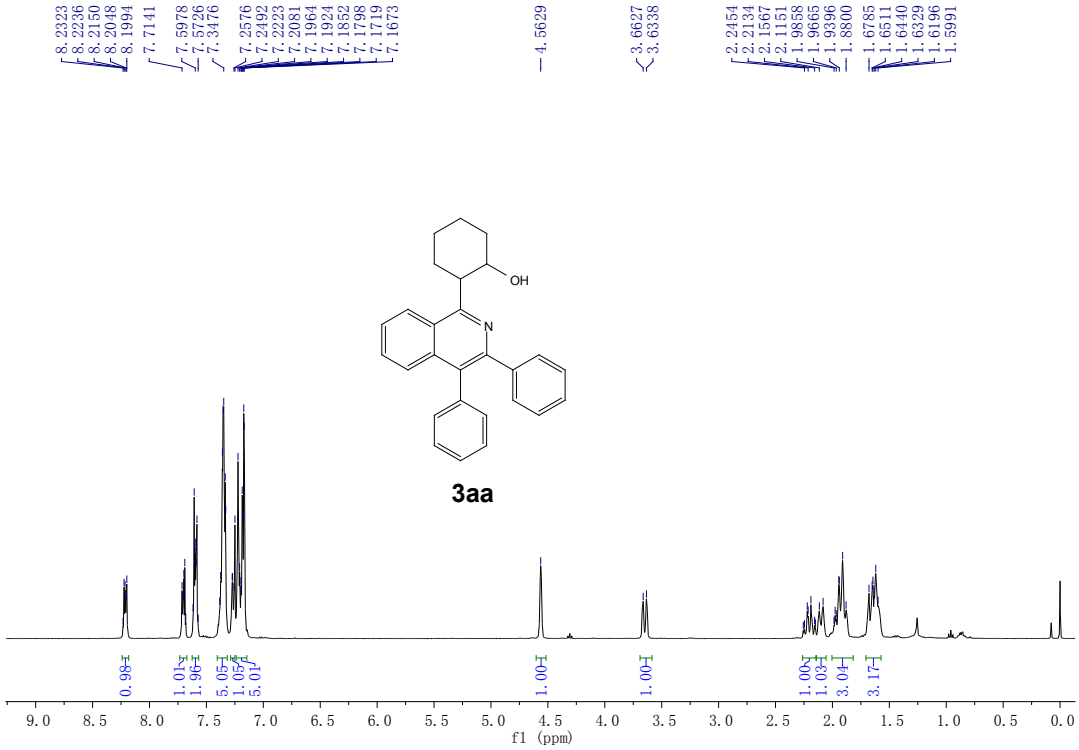
Reference

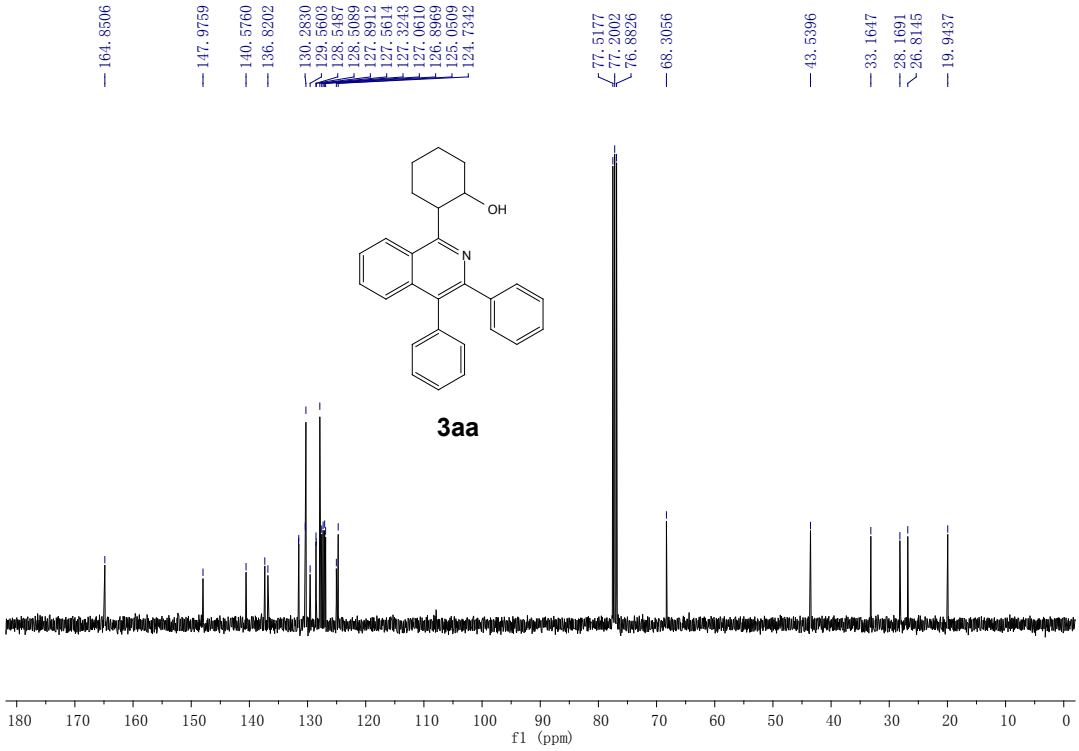
(1) M. J. Mio, L. C. Kopel, J. B. Braun, T. L. Gadzikwa, K. L. Hull, R. G. Brisbois, C. J. Markworth and P. A. Grieco, *Org. Lett.* 2002, **4**, 3199.

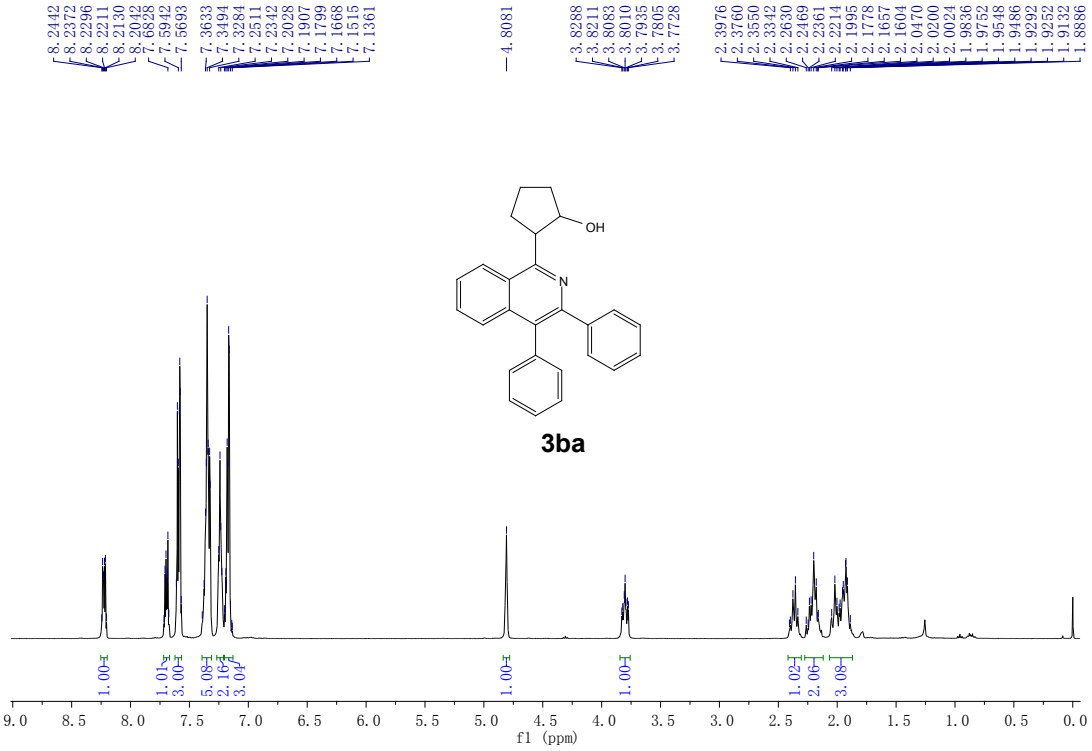
(2) C. Xiang, T. Li and J. Yan, *Synthetic Commun.* 2014, **44**, 682.

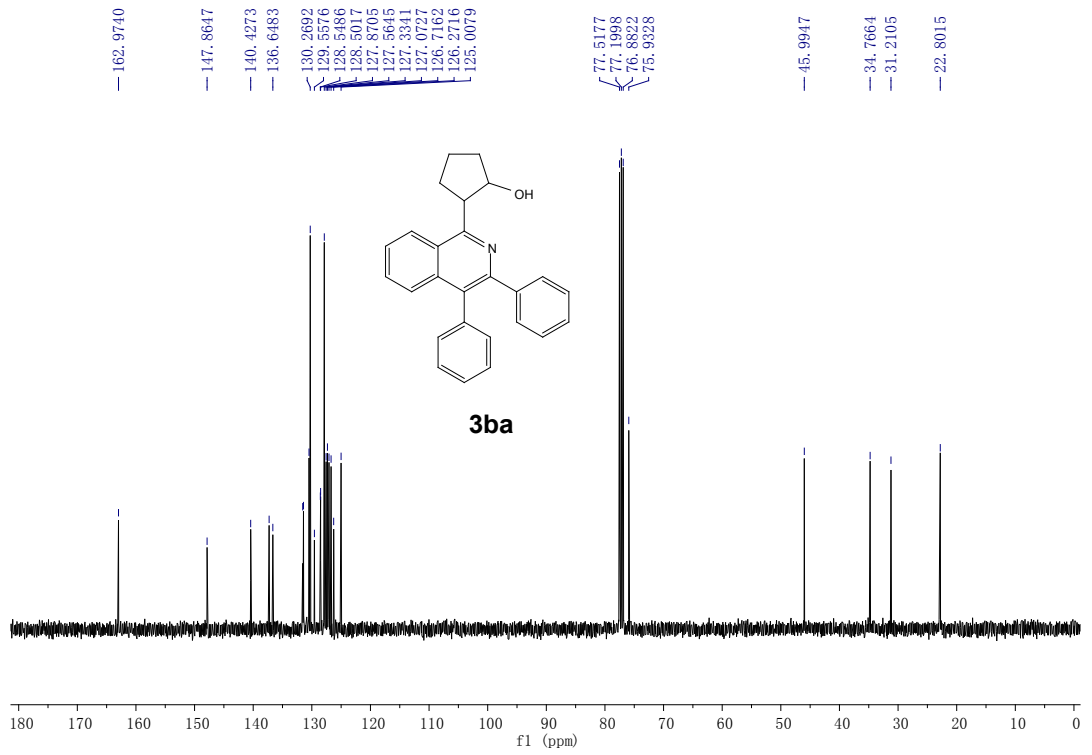
(3) K.-i. Fujita, Y. Takahashi, M. Owaki, K. Yamamoto and R. Yamaguchi, *Org. Lett.* 2004, **6**, 2785.

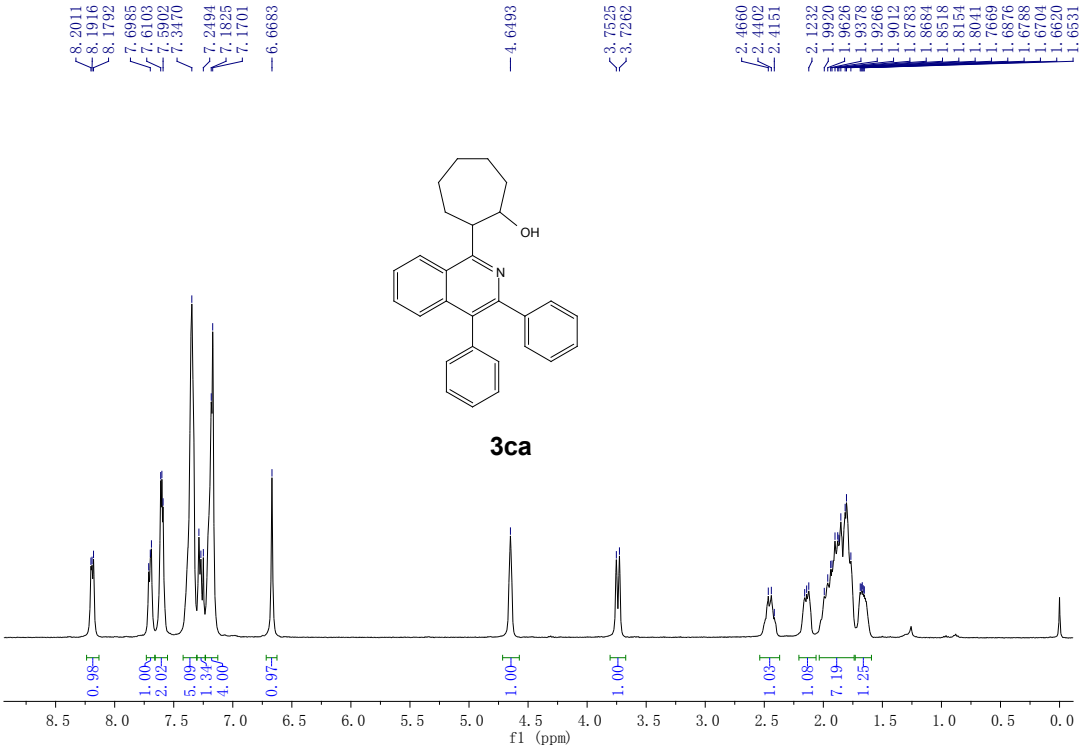
IV. NMR Spectra

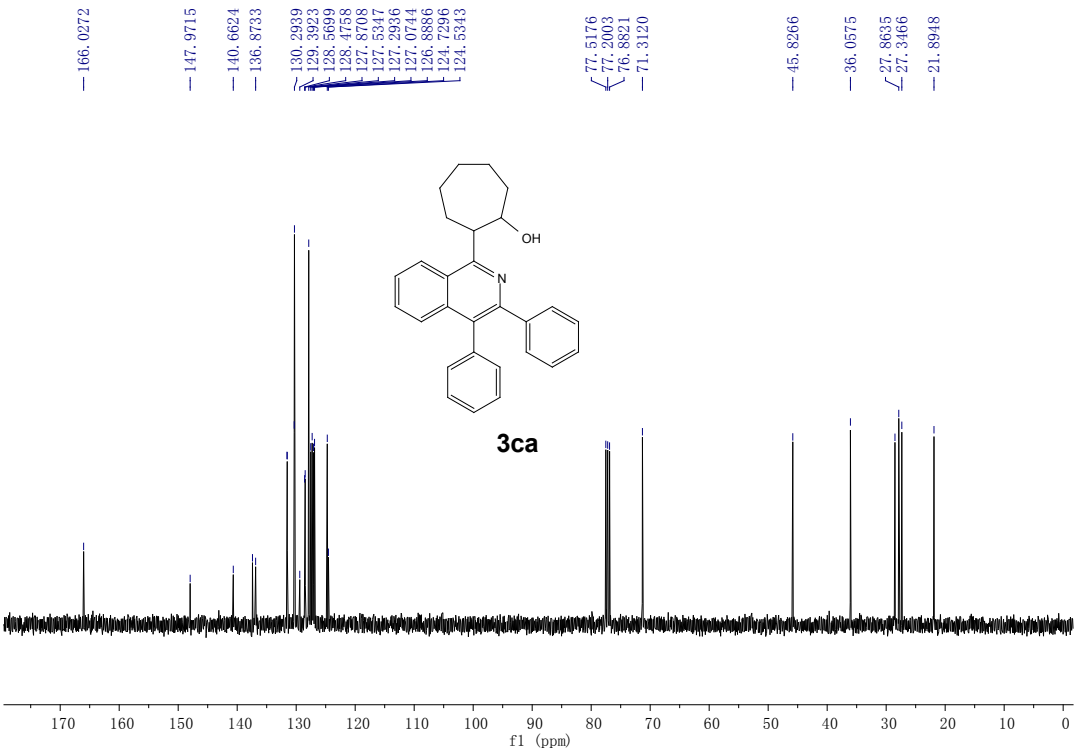


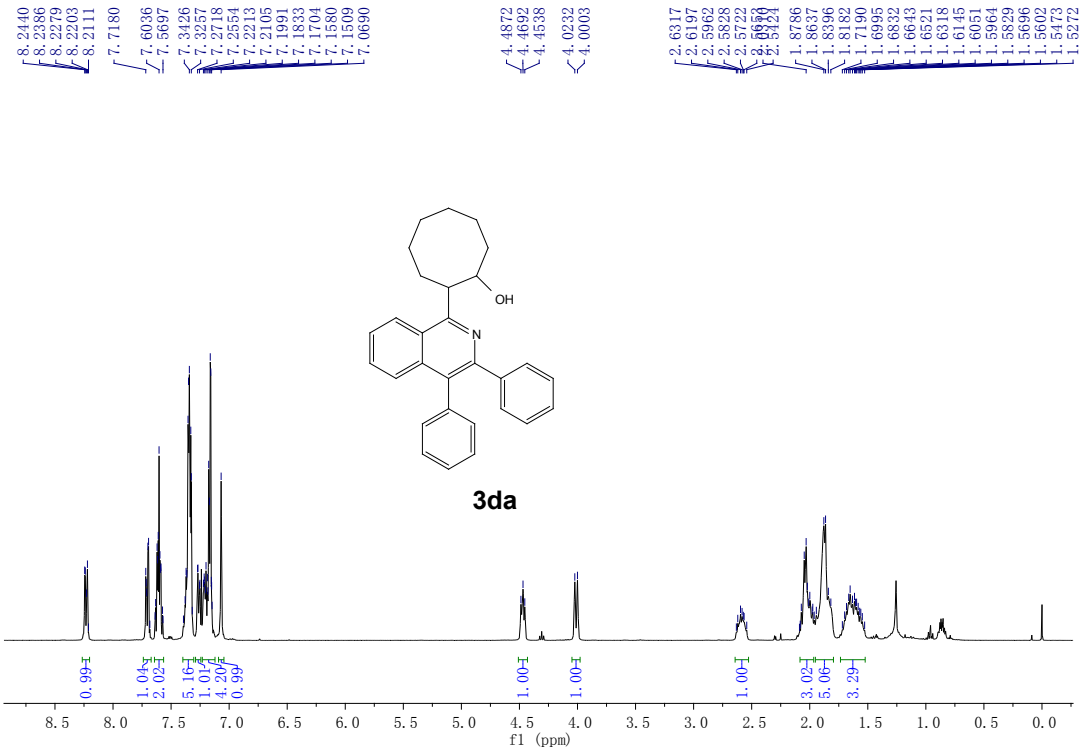


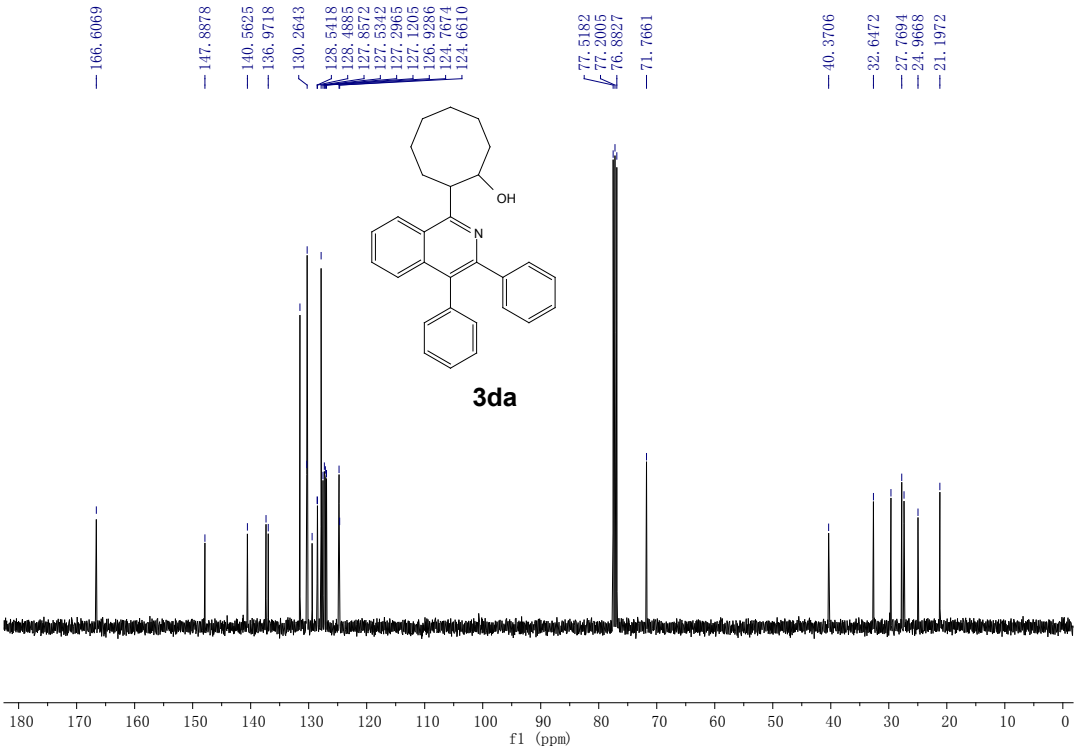

8.2442
8.2372
8.2296
8.2211
8.2130
8.2042
7.6828
7.5942
7.5693
7.3633
7.3494
7.3284
7.2511
7.2342
7.2028
7.1907
7.1799
7.1668
7.1515
7.1361
4.8081
3.8288
3.8211
3.8083
3.8010
3.7935
3.7805
3.7728
2.3976
2.3760
2.3550
2.3342
2.2630
2.2469
2.2361
2.2214
2.1995
2.1778
2.1657
2.1604
2.0470
2.0200
2.0024
1.9936
1.9752
1.9548
1.9486
1.9292
1.9252
1.9132
1.8886
OH
N
3ba
1.00
1.01
3.00
5.09
2.16
3.04
1.00
1.00
1.02
2.06
3.08
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

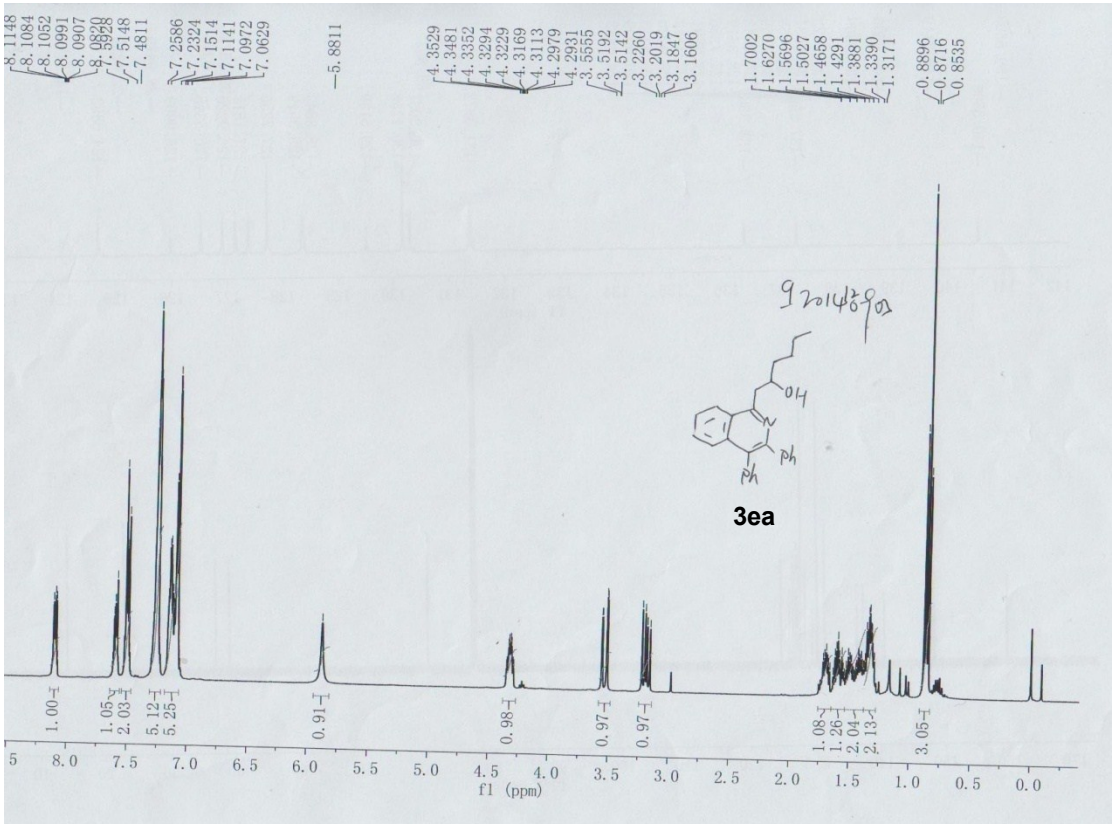

162.9740
147.8647
140.4273
136.6483
130.2692
129.5576
128.5486
128.5017
127.8705
127.5645
127.3341
127.0727
126.7162
126.2716
125.0079
77.5177
77.1998
76.8822
75.9328
45.9947
34.7664
31.2105
22.8015
OH
N
3ba
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

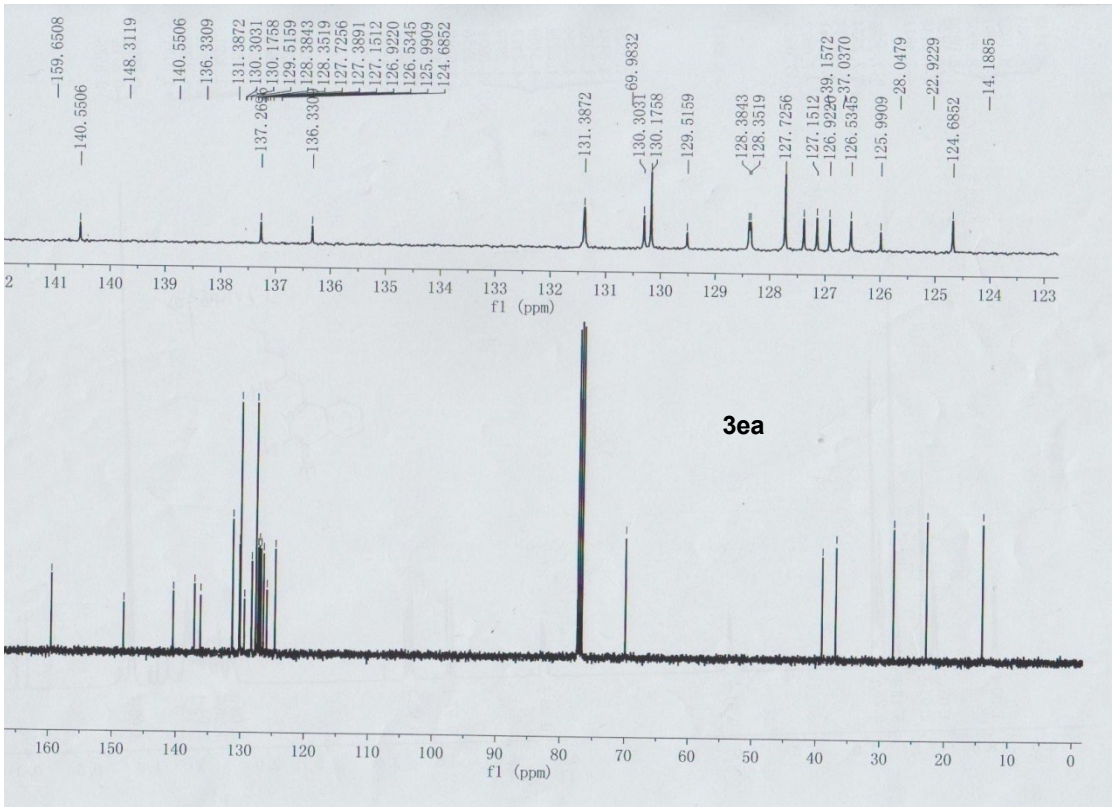

8.2011
8.1916
8.1792
7.6985
7.6103
7.5902
7.3470
7.2494
7.1825
7.1701
6.6683
4.6493
3.7525
3.7262
2.4660
2.4402
2.4151
2.1232
1.9920
1.9626
1.9378
1.9266
1.9012
1.8783
1.8684
1.8518
1.8154
1.8041
1.7669
1.6876
1.6788
1.6704
1.6620
1.6531
OH
N
3ca
0.98
1.00
2.02
5.09
1.34
4.00
0.97
1.00
1.00
1.03
1.08
7.19
1.25
f1 (ppm)

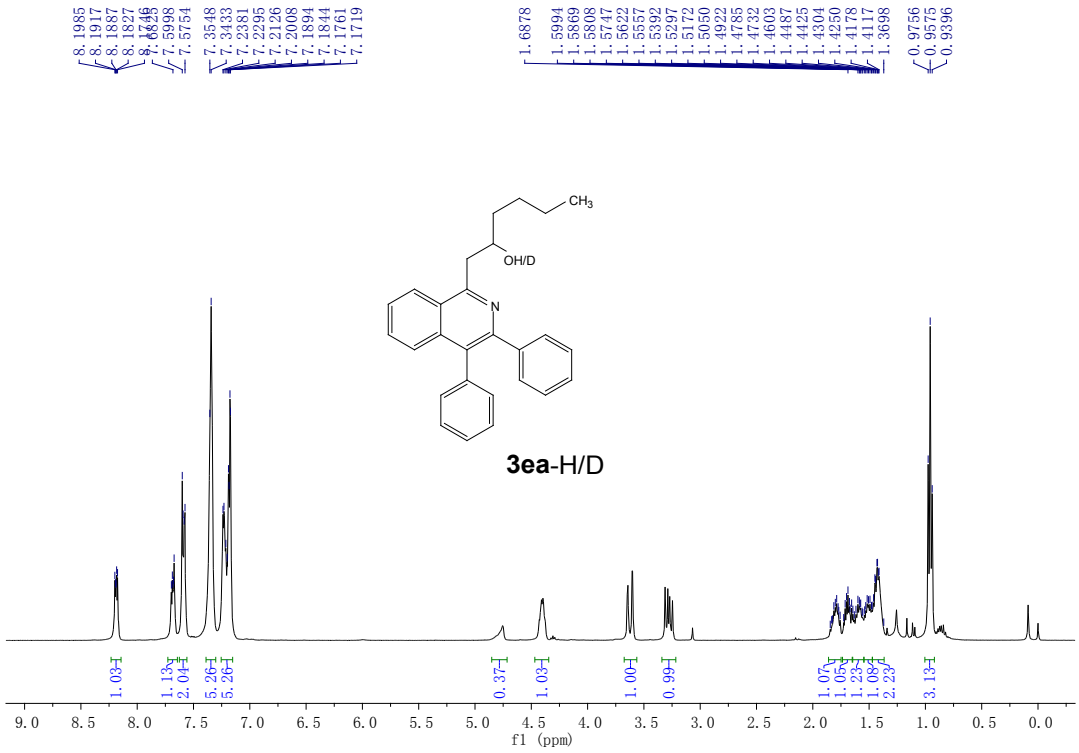

166.0272
147.9715
140.6624
136.8733
130.2939
129.3923
128.5699
128.4758
127.8708
127.5347
127.2936
127.0744
126.8886
124.7296
124.5343
77.5176
77.2003
76.8821
71.3120
45.8266
36.0575
27.8635
27.3466
21.8948
OH
N
3ca
f1 (ppm)

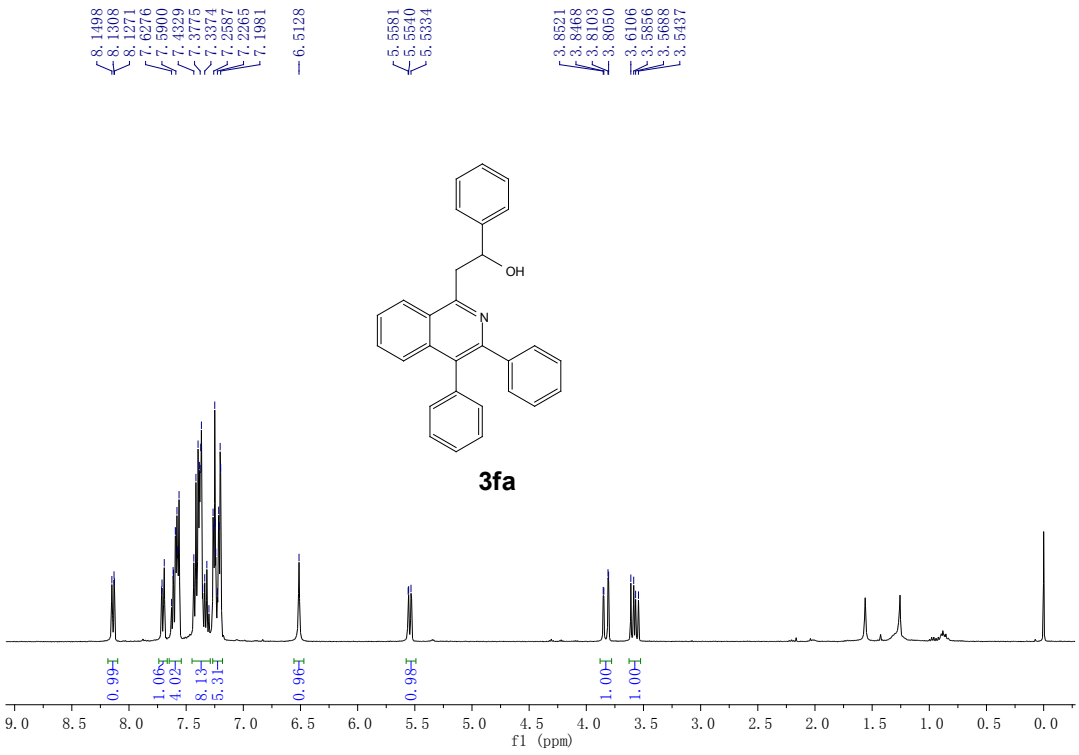

8.2440
8.2386
8.2279
8.2203
8.2111
7.7180
7.6036
7.5697
7.3426
7.3257
7.2718
7.2554
7.2213
7.2105
7.1991
7.1833
7.1704
7.1580
7.1509
7.0690
4.4872
4.4692
4.4538
4.0232
4.0003
2.6317
2.6197
2.5962
2.5828
2.5722
1.8786
1.8637
1.8396
1.8182
1.7190
1.6995
1.6832
1.6643
1.6521
1.6318
1.6145
1.6051
1.5964
1.5829
1.5696
1.5602
1.5473
1.5272
OH
N
3da
0.99
1.04
2.02
5.16
1.01
4.20
0.99
1.00
1.00
1.00
3.02
5.06
3.29
f1 (ppm)

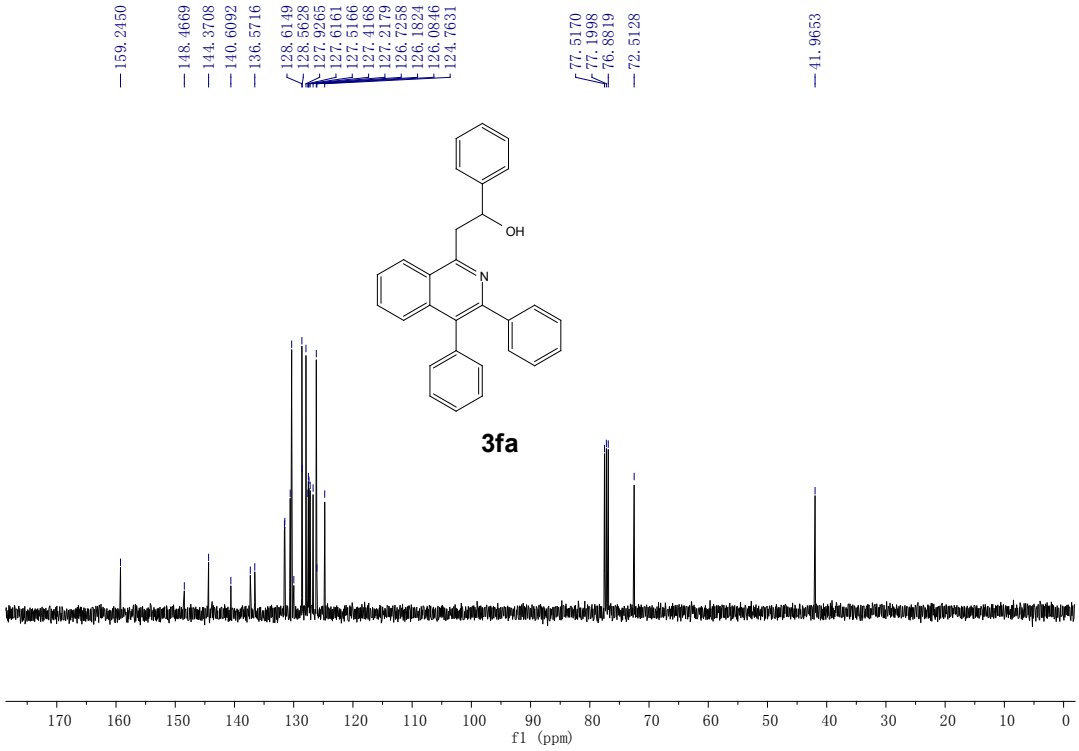

166.6069
147.8878
140.5625
136.9718
130.2643
128.5418
128.4885
127.8572
127.5342
127.2965
127.1205
126.9286
124.7674
124.6610
77.5182
77.2005
76.8827
71.7661
40.3706
32.6472
27.7694
24.9668
21.1972
OH
N
3da
f1 (ppm)

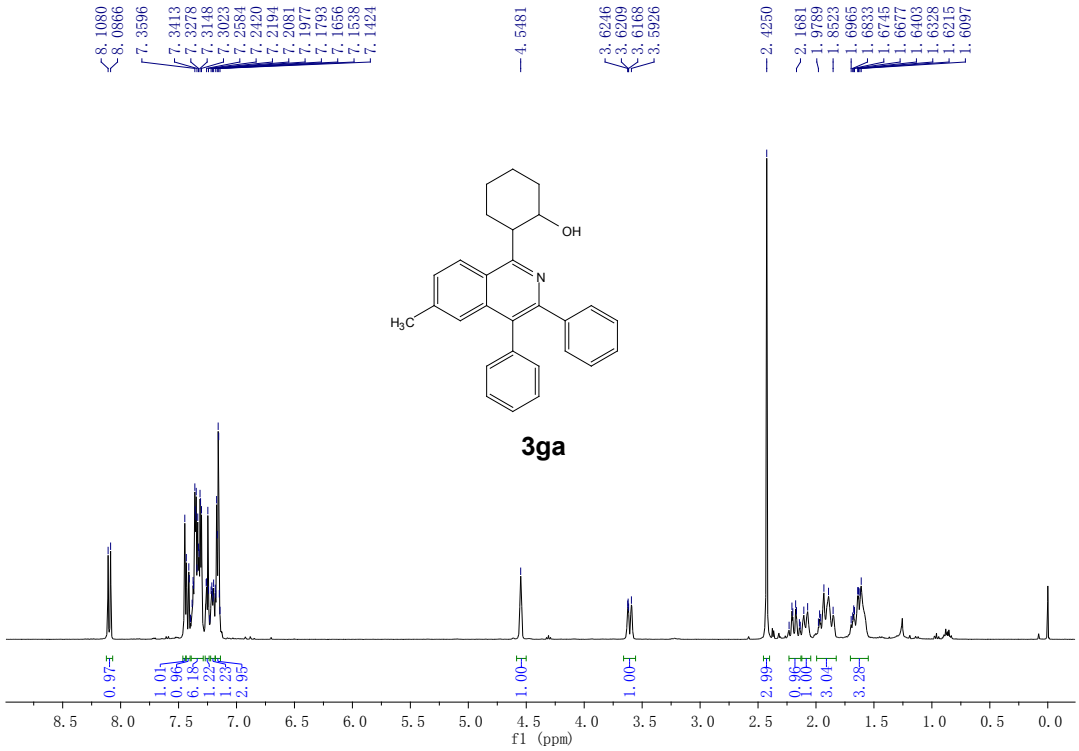

3ea
f1 (ppm)

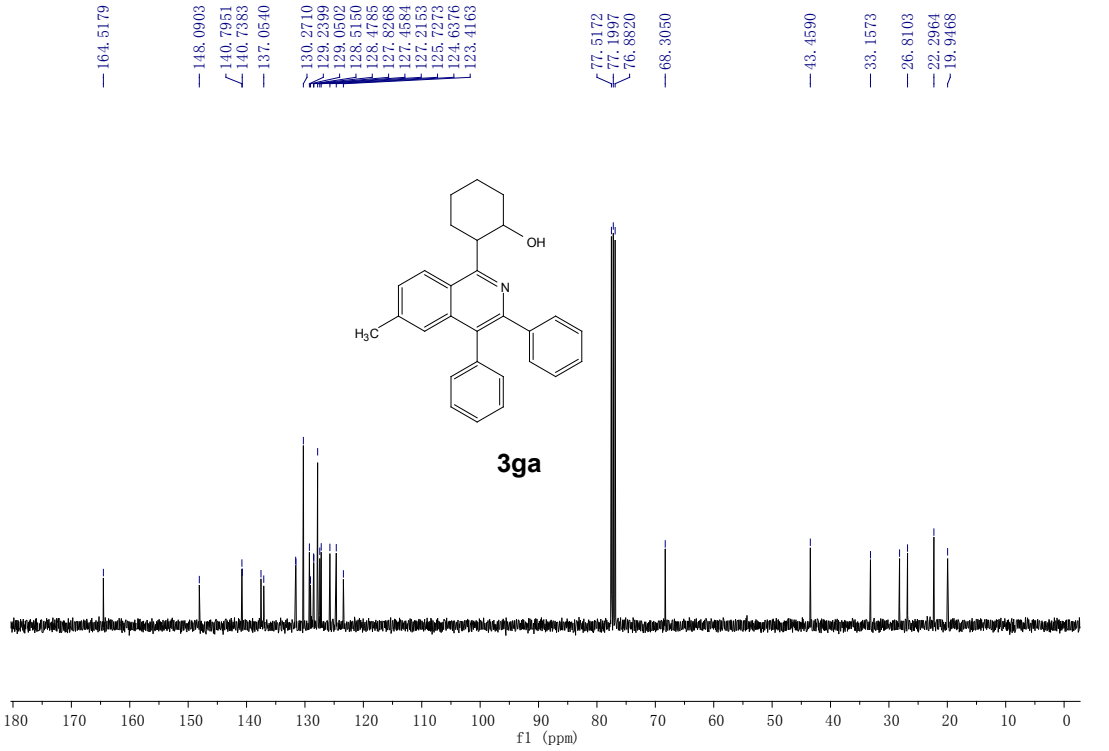

3ea
f1 (ppm)
f1 (ppm)

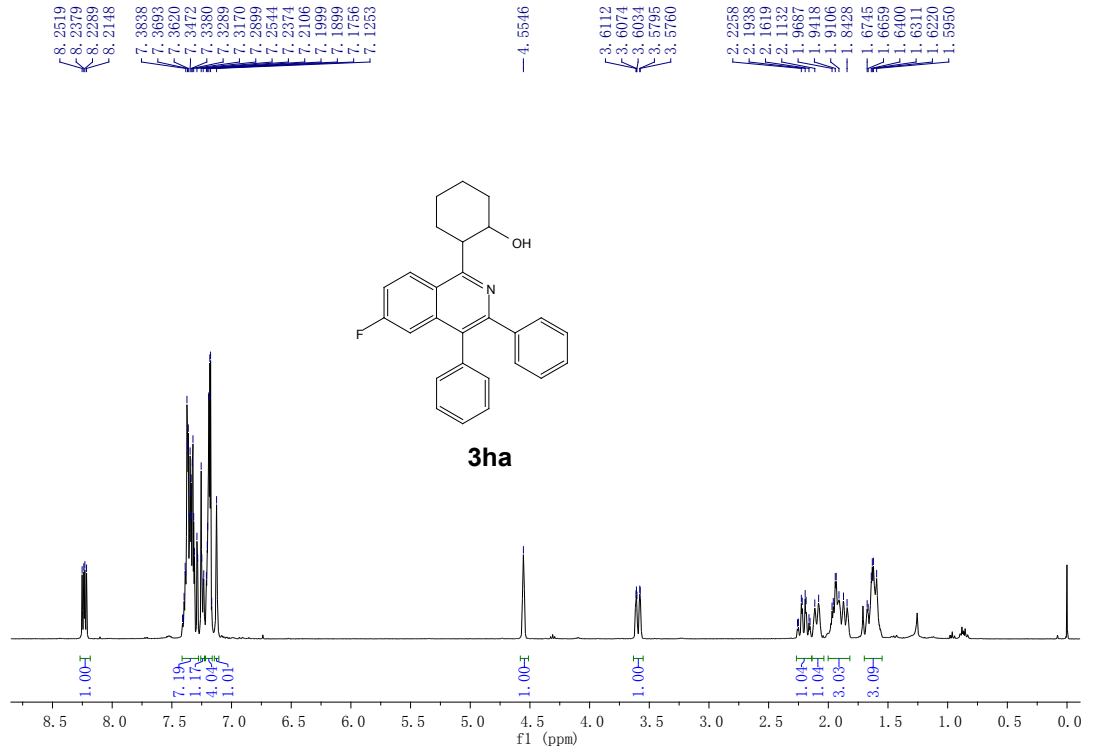

8.1985
8.1917
8.1887
8.1827
7.5998
7.5754
7.3548
7.3433
7.2381
7.2295
7.2126
7.2008
7.1894
7.1844
7.1761
7.1719
1.6878
1.5994
1.5869
1.5808
1.5747
1.5622
1.5557
1.5392
1.5297
1.5172
1.5050
1.4922
1.4785
1.4732
1.4603
1.4487
1.4425
1.4304
1.4250
1.4178
1.4117
1.3698
0.9756
0.9575
0.9396
CH3
OH/D
N
3ea-H/D
1.03
1.13
2.04
5.26
5.26
0.37
1.03
1.00
0.99
1.07
1.05
1.23
1.09
2.23
3.13
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

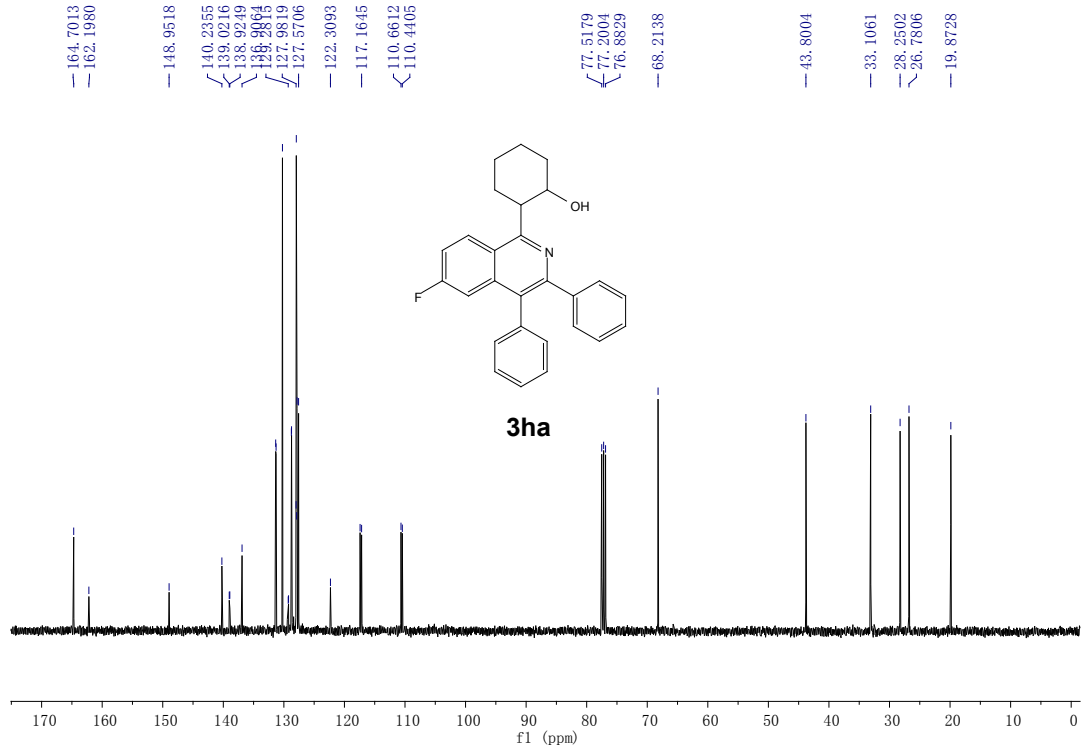

8.1498
8.1308
8.1271
7.6276
7.5900
7.4329
7.3775
7.3374
7.2587
7.2265
7.1981
6.5128
5.5581
5.5540
5.5334
3.8521
3.8468
3.8103
3.8050
3.6106
3.5856
3.5688
3.5437
OH
N
3fa
0.99
1.06
4.02
8.13
5.31
0.96
0.98
1.00
1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

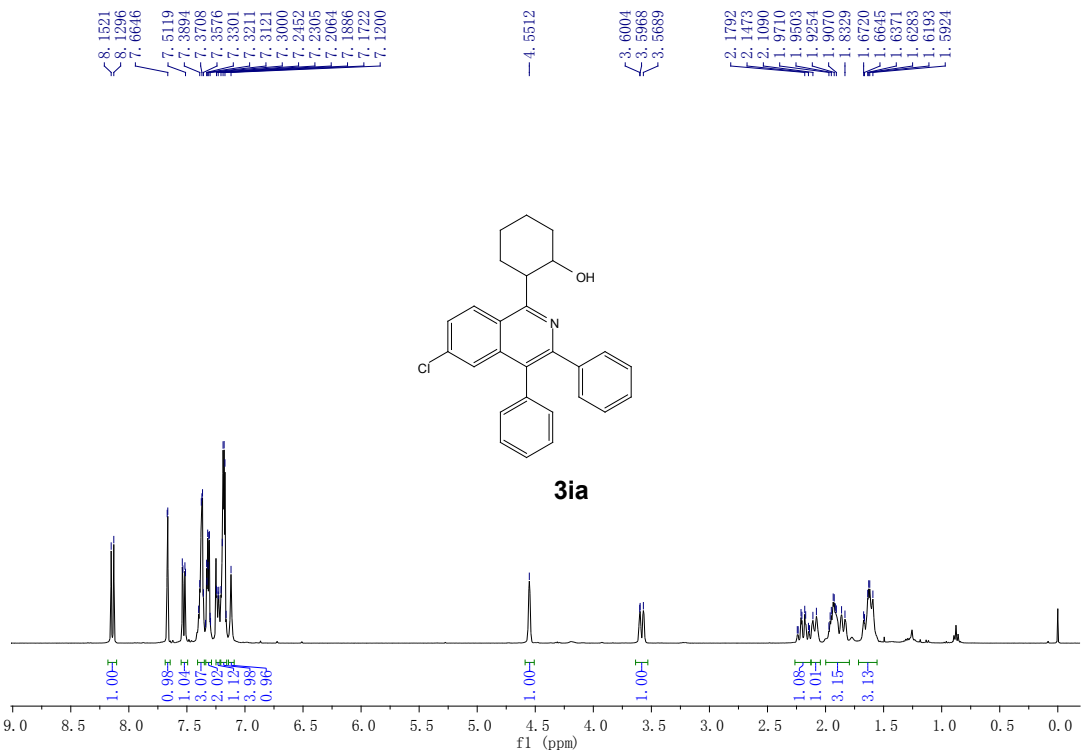

159.2450
148.4669
144.3708
140.6092
136.5716
128.6149
128.5628
127.9265
127.6161
127.5166
127.4168
127.2179
126.7258
126.1824
126.0846
124.7631
77.5170
77.1998
76.8819
72.5128
41.9653
OH
N
3fa
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

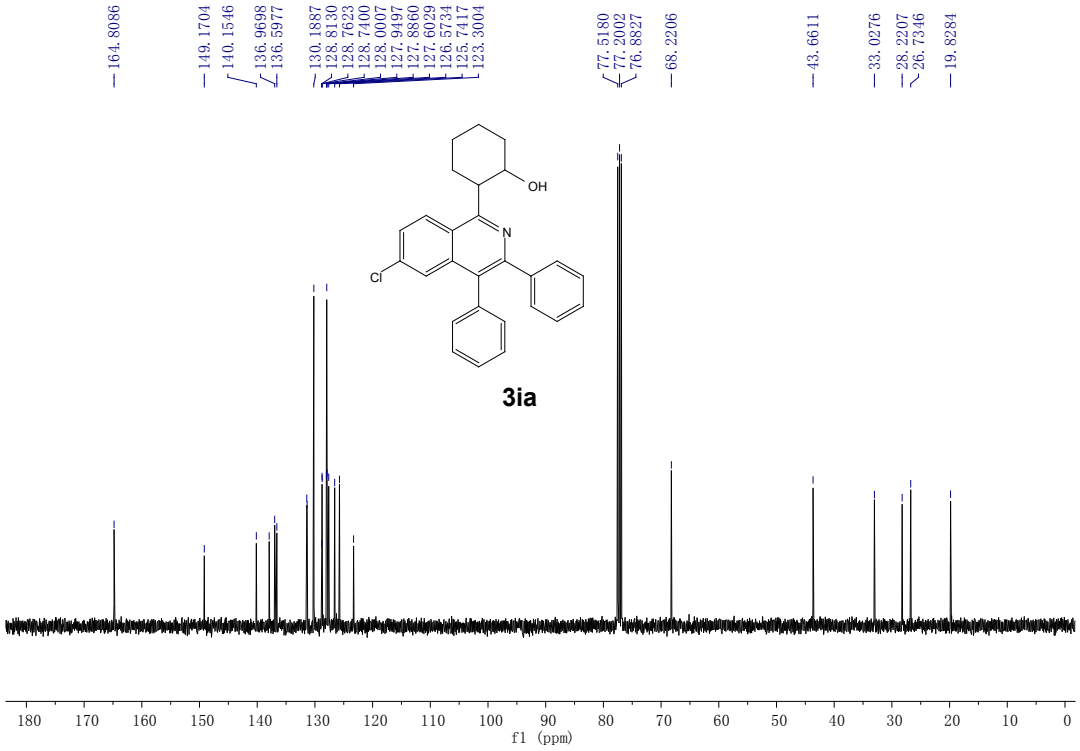

8.1080
8.0866
7.3596
7.3413
7.3278
7.3148
7.3023
7.2584
7.2420
7.2194
7.2081
7.1977
7.1793
7.1656
7.1538
7.1424
4.5481
3.6246
3.6209
3.6168
3.5926
2.4250
2.1681
1.9789
1.8523
1.6965
1.6833
1.6745
1.6677
1.6403
1.6328
1.6215
1.6097
OH
N
H3C
3ga
0.97
1.01
0.96
6.18
1.22
1.23
2.95
1.00
1.00
2.99
0.86
1.00
3.04
3.28
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

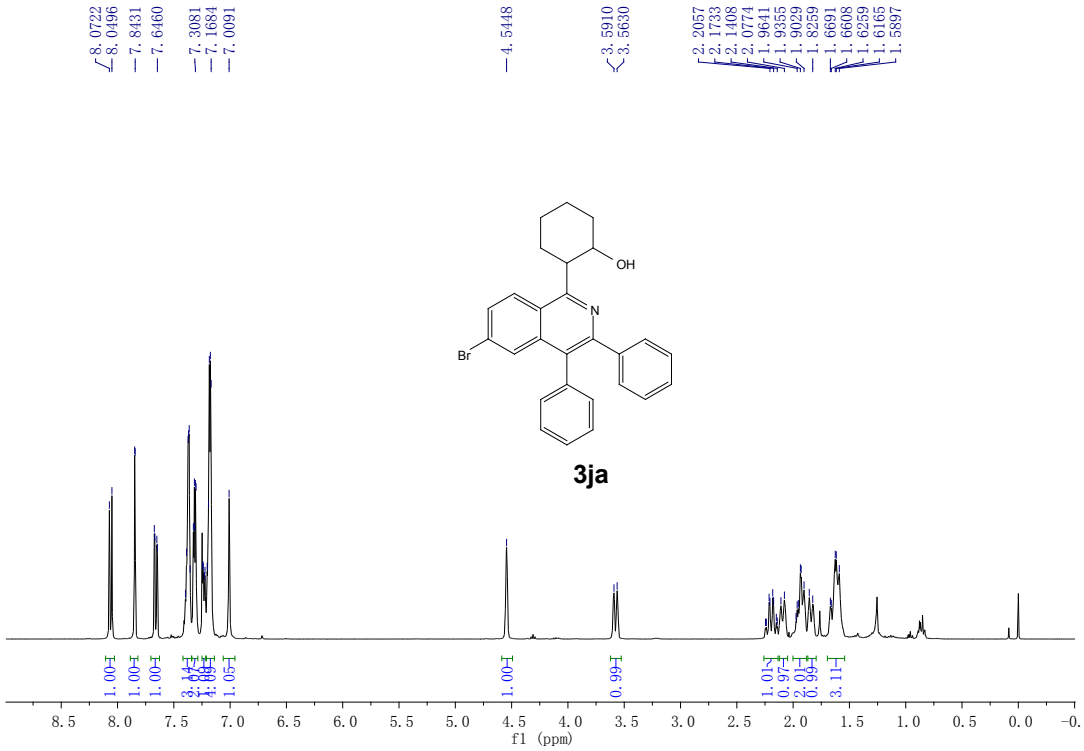

164.5179
148.0903
140.7951
140.7383
137.0540
130.2710
129.2399
129.0502
128.5150
128.4785
127.8268
127.4584
127.2153
125.7273
124.6376
123.4163
77.5172
77.1997
76.8820
68.3050
43.4590
33.1573
26.8103
22.2964
19.9468
OH
N
H3C
3ga
f1 (ppm)

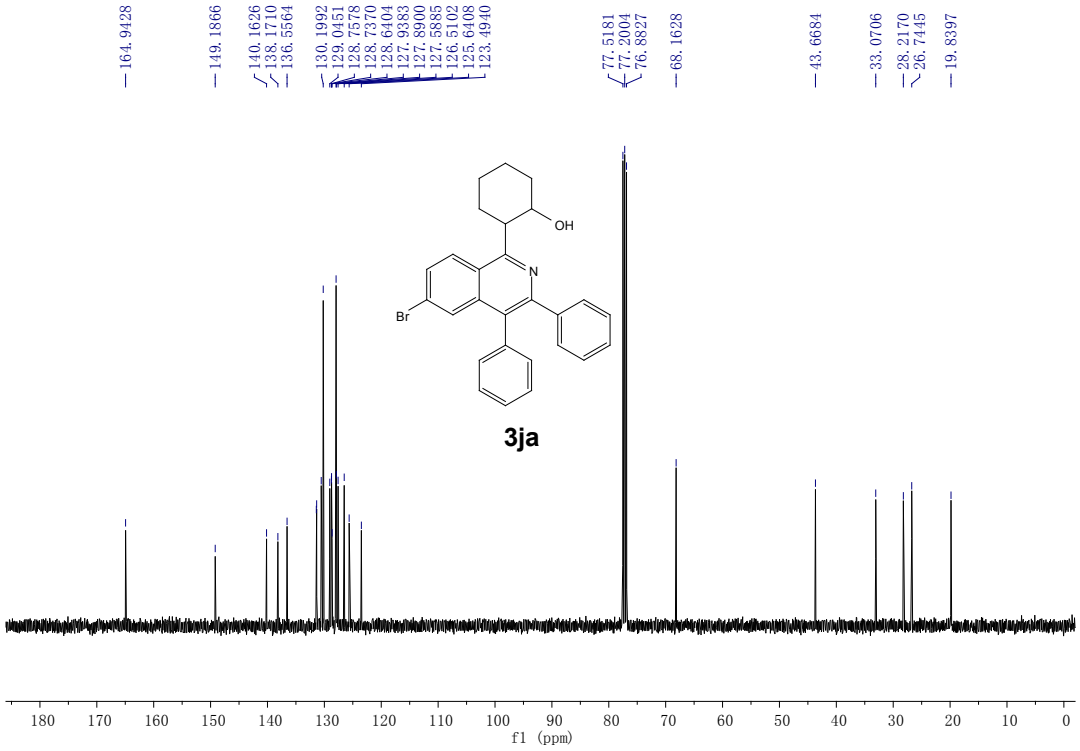

8.2519
8.2379
8.2289
8.2148
7.3838
7.3693
7.3620
7.3472
7.3380
7.3289
7.3170
7.2899
7.2544
7.2374
7.2106
7.1999
7.1899
7.1756
7.1253
4.5546
3.6112
3.6074
3.6034
3.5795
3.5760
2.2258
2.1938
2.1619
2.1132
1.9687
1.9418
1.9106
1.8428
1.6745
1.6659
1.6400
1.6311
1.6220
1.5950
OH
N
F
3ha
f1 (ppm)

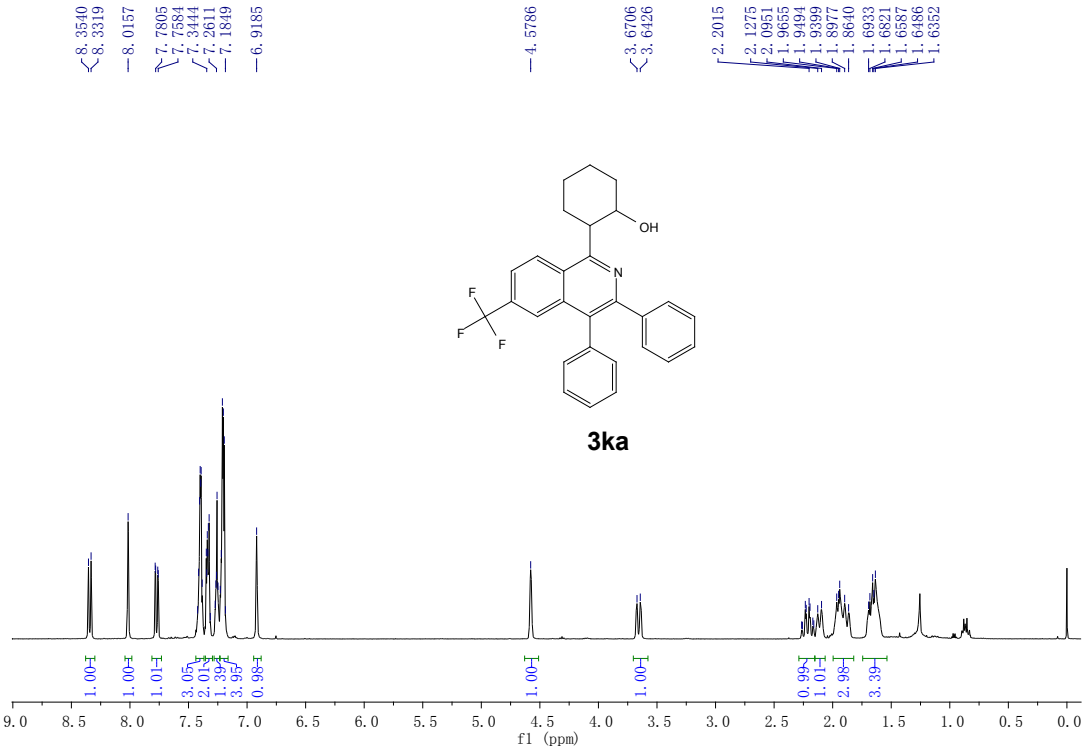

164.7013
162.1980
148.9518
140.2355
139.0216
138.9249
129.2815
127.9819
127.5706
122.3093
117.1645
110.6612
110.4405
77.5179
77.2004
76.8829
68.2138
43.8004
33.1061
28.2502
26.7806
19.8728
OH
N
F
3ha
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

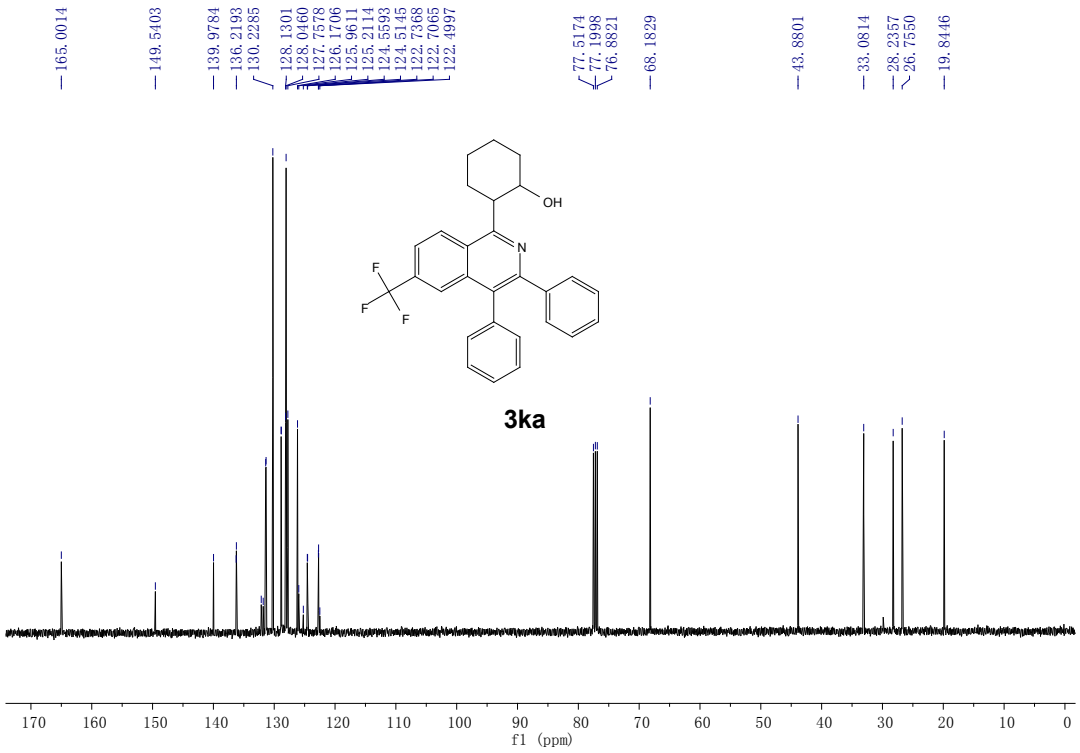

8.1521
8.1296
7.6646
7.5119
7.3894
7.3708
7.3576
7.3301
7.3211
7.3121
7.3000
7.2452
7.2305
7.2064
7.1886
7.1722
7.1200
4.5512
3.6004
3.5968
3.5689
2.1792
2.1473
2.1090
1.9710
1.9503
1.9254
1.9070
1.8329
1.6720
1.6645
1.6371
1.6283
1.6193
1.5924
OH
N
Cl
3ia
1.00
0.98
1.04
3.07
2.02
1.12
3.99
0.96
1.00
1.00
1.08
1.01
3.15
3.13
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

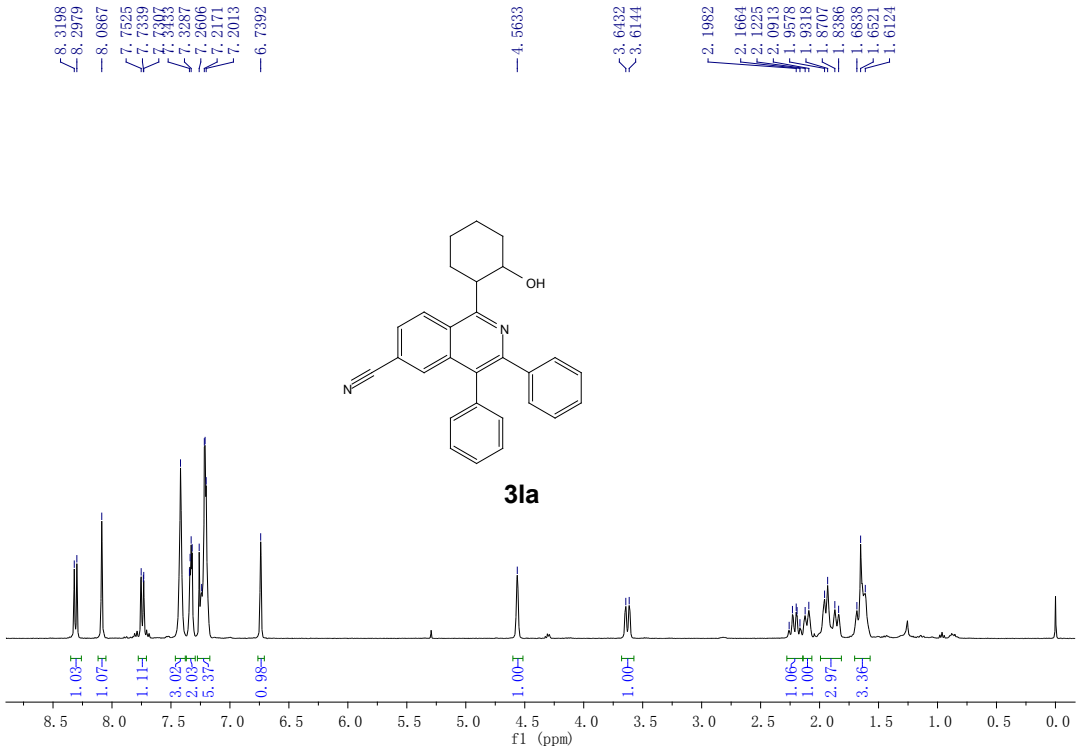

164.8086
149.1704
140.1546
136.9698
136.5977
130.1887
128.8130
128.7623
128.7400
128.0007
127.9497
127.8860
127.6029
126.5734
125.7417
123.3004
77.5180
77.2002
76.8827
68.2206
43.6611
33.0276
28.2207
26.7346
19.8284
OH
N
Cl
3ia
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

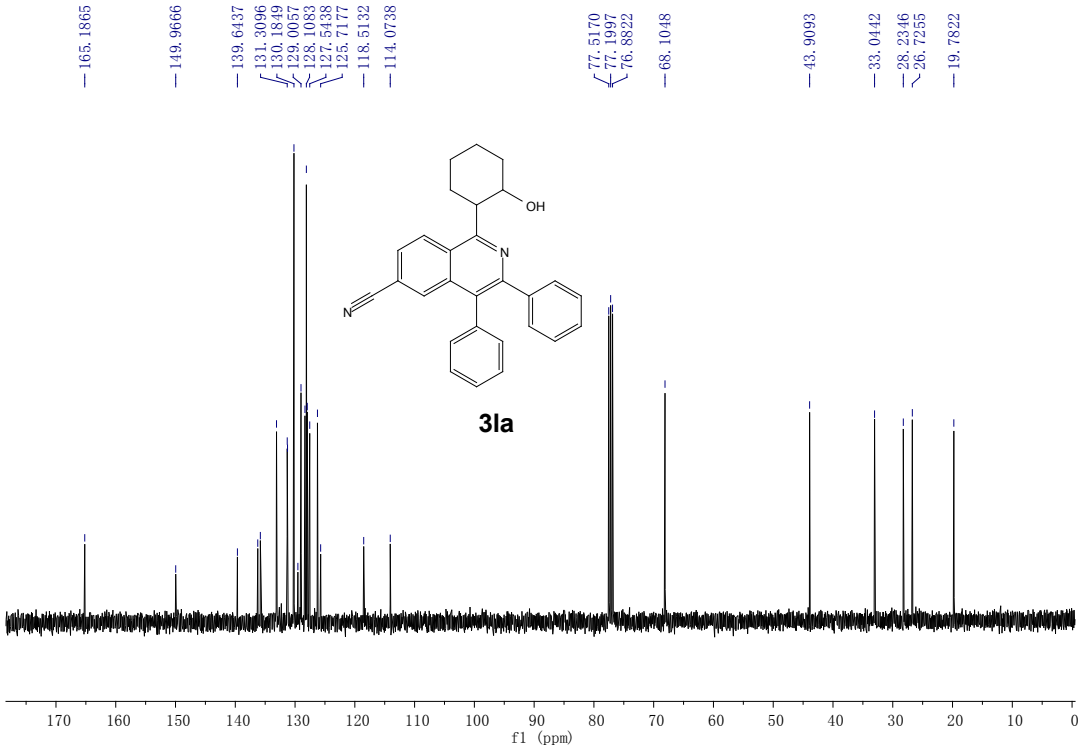

8.0722
8.0496
7.8431
7.6460
7.3081
7.1684
7.0091
4.5448
3.5910
3.5630
2.2057
2.1733
2.1408
2.0774
1.9641
1.9355
1.9029
1.8259
1.6691
1.6608
1.6259
1.6165
1.5897
OH
N
Br
3ja
1.00
1.00
1.00
3.14
4.07
1.05
1.00
0.99
1.01
0.97
2.01
0.99
3.11
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.
f1 (ppm)

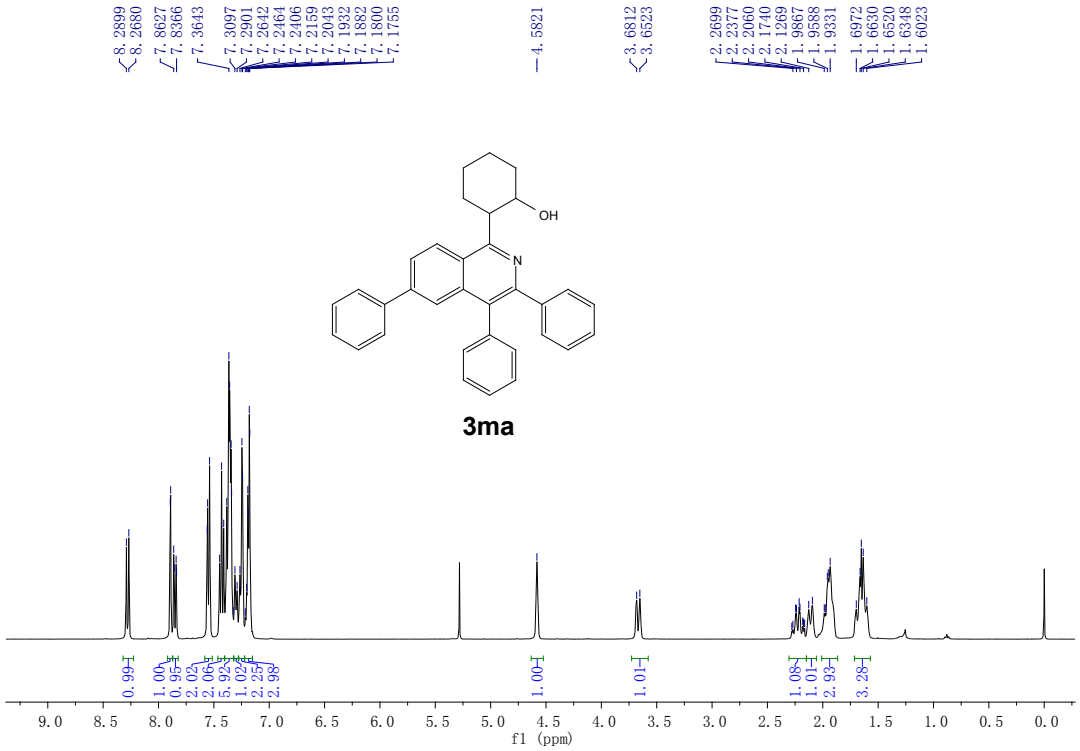

164.9428
149.1866
140.1626
138.1710
136.5564
130.1992
129.0451
128.7578
128.7370
128.6404
127.9383
127.8900
127.5885
126.5102
125.6408
123.4940
77.5181
77.2004
76.8827
68.1628
43.6684
33.0706
28.2170
26.7445
19.8397
OH
N
Br
3ja
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

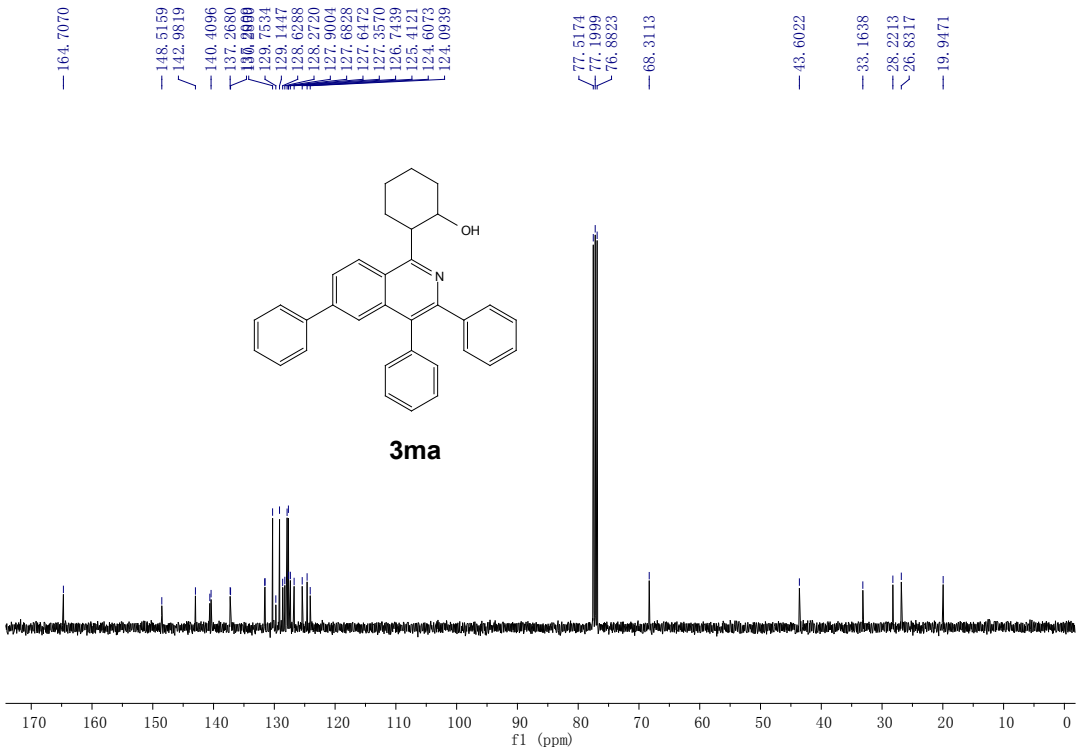

8.3540
8.3319
8.0157
7.7805
7.7584
7.3444
7.2611
7.1849
6.9185
4.5786
3.6706
3.6426
2.2015
2.1275
2.0951
1.9655
1.9494
1.9399
1.8977
1.8640
1.6933
1.6821
1.6587
1.6486
1.6352
OH
N
F
F
F
3ka
1.00
1.00
1.01
3.05
2.01
1.39
3.95
0.98
1.00
1.00
0.99
1.01
2.98
3.39
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

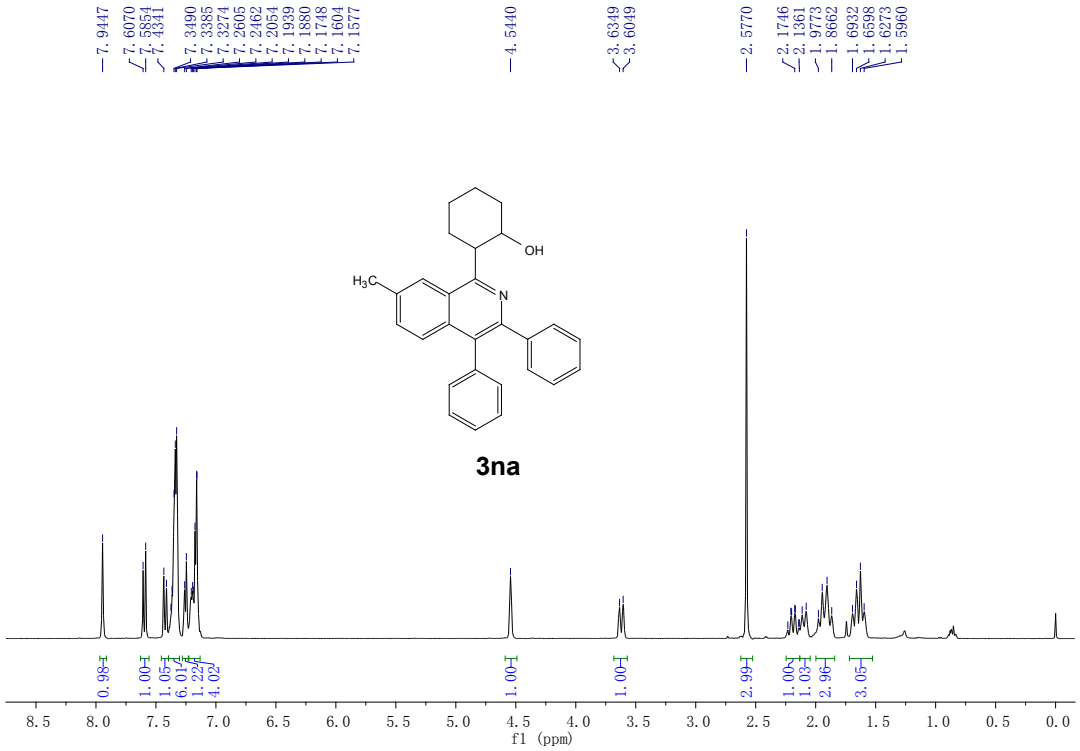

165.0014
149.5403
139.9784
136.2193
130.2285
128.1301
128.0460
127.7578
126.1706
125.9611
125.2114
124.5593
124.5145
122.7368
122.7065
122.4997
77.5174
77.1998
76.8821
68.1829
43.8801
33.0814
28.2357
26.7550
19.8446
OH
N
F
F
F
3ka
f1 (ppm)

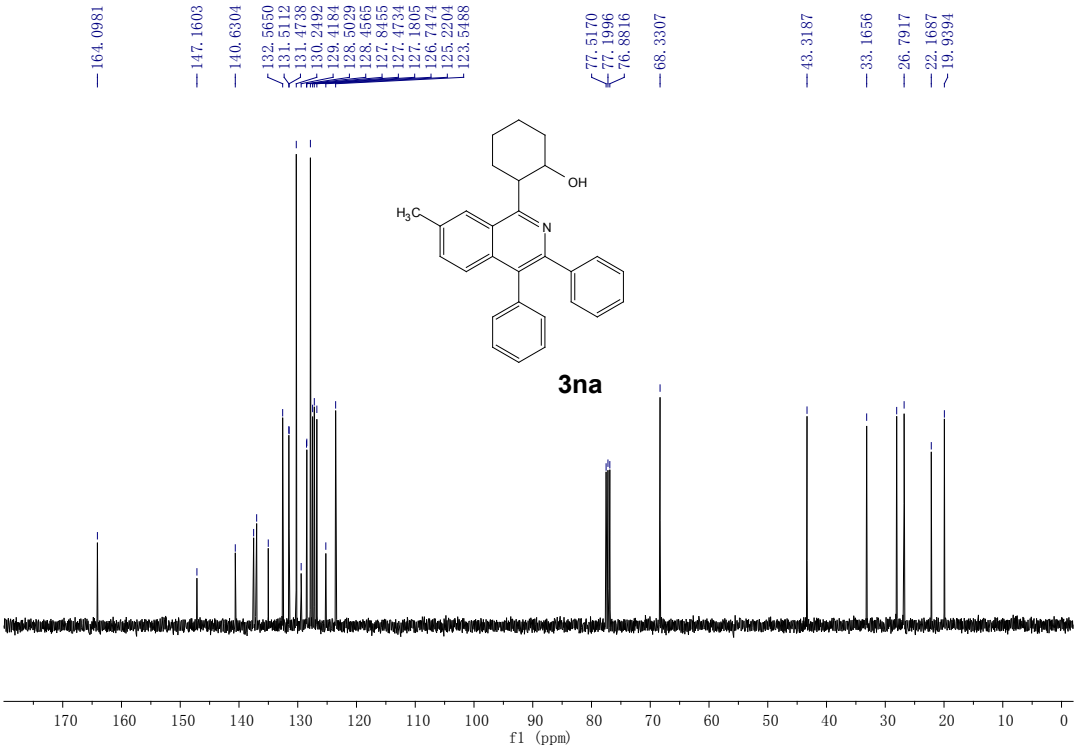

8.3198
8.2979
8.0867
7.7525
7.7339
7.7307
7.3433
7.3287
7.2606
7.2171
7.2013
6.7392
4.5633
3.6432
3.6144
2.1982
2.1664
2.1225
2.0913
1.9578
1.9318
1.8707
1.8386
1.6838
1.6521
1.6124
OH
N
N
3la
1.03
1.07
1.11
3.02
2.03
5.37
0.98
1.00
1.00
1.06
1.00
2.97
3.36
f1 (ppm)

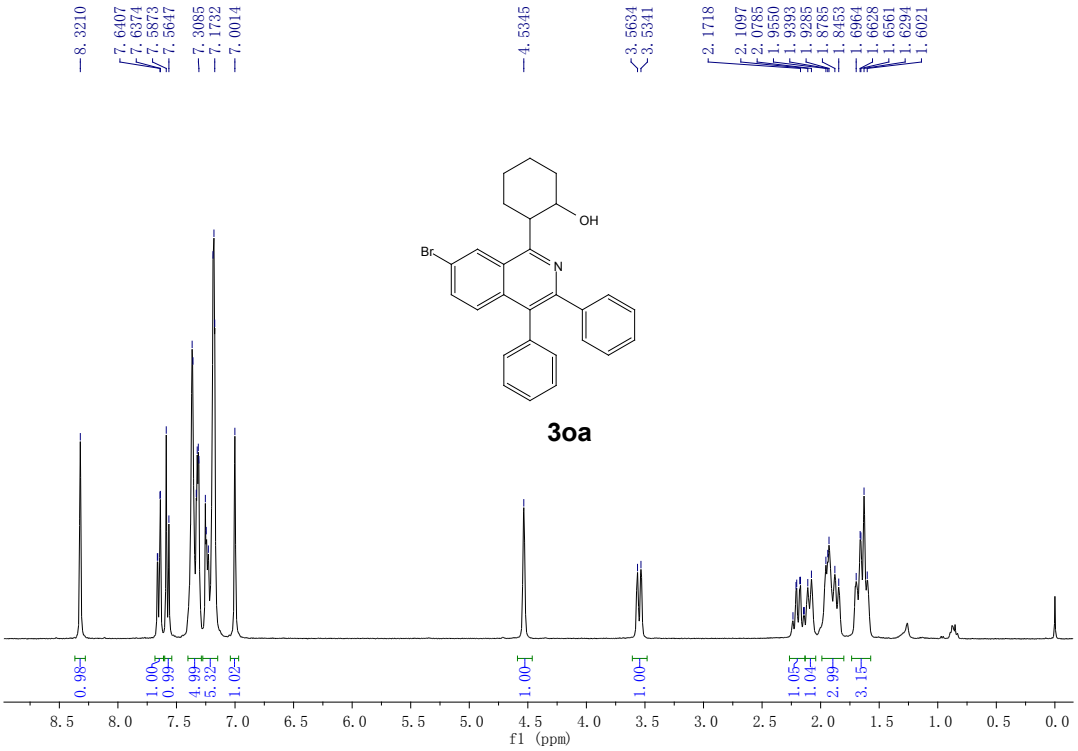

165.1865
149.9666
139.6437
131.3096
130.1849
129.0057
128.1083
127.5438
125.7177
118.5132
114.0738
77.5170
77.1997
76.8822
68.1048
43.9093
33.0442
28.2346
26.7255
19.7822
OH
N
N
3la
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

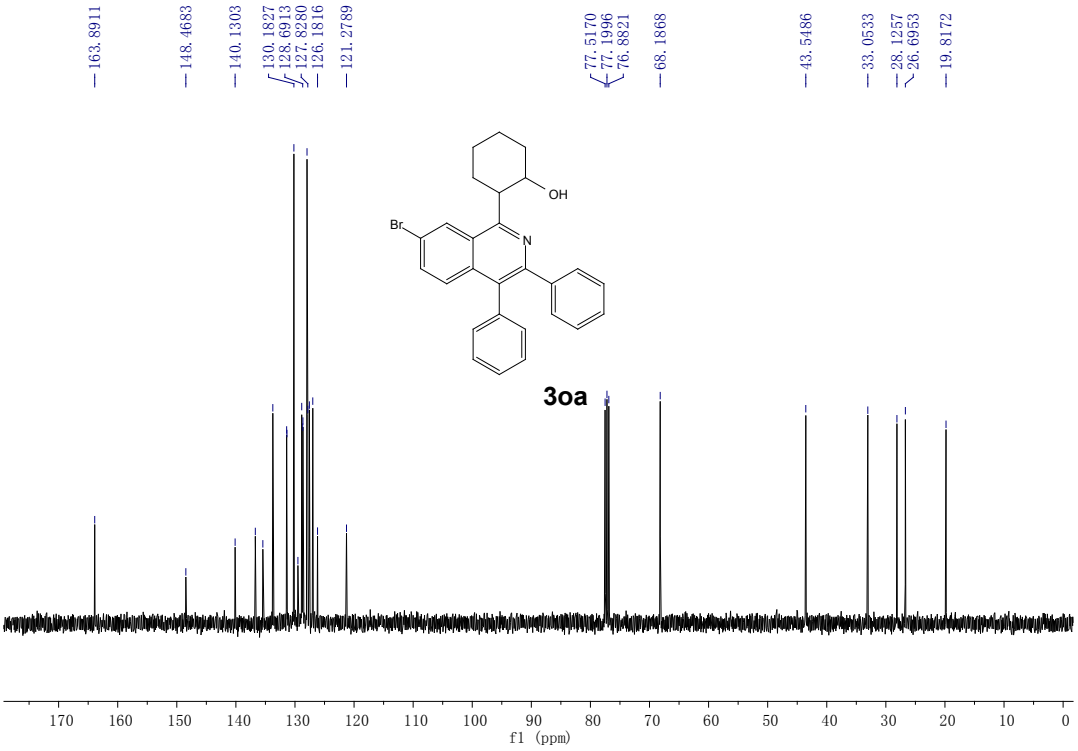

8.2899
8.2680
7.8627
7.8366
7.3643
7.3097
7.2901
7.2642
7.2464
7.2406
7.2159
7.2043
7.1932
7.1882
7.1800
7.1755
4.5821
3.6812
3.6523
2.2699
2.2377
2.2060
2.1740
2.1269
1.9867
1.9588
1.9331
1.6972
1.6630
1.6520
1.6348
1.6023
OH
N
3ma
0.99
1.00
0.95
2.02
2.06
5.92
1.02
2.25
2.98
1.00
1.01
1.08
1.01
2.93
3.28
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

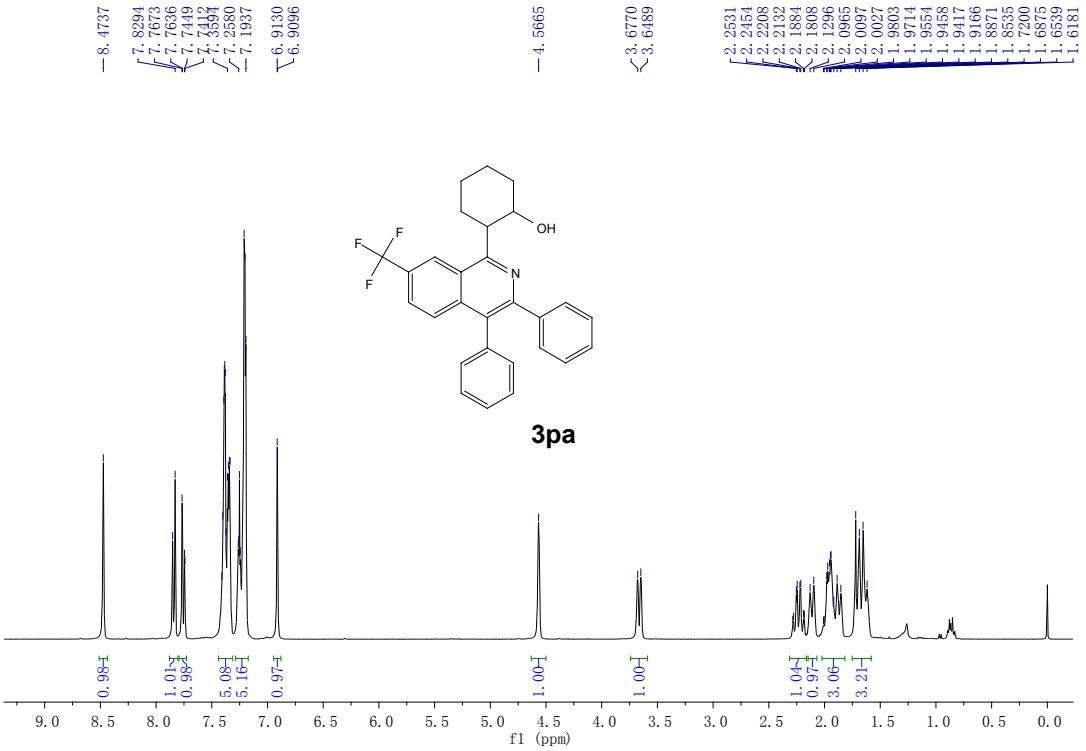

164.7070
148.5159
142.9819
140.4096
137.2680
129.7534
129.1447
128.6288
128.2720
127.9004
127.6828
127.6472
127.3570
126.7439
125.4121
124.6073
124.0939
77.5174
77.1999
76.8823
68.3113
43.6022
33.1638
28.2213
26.8317
19.9471
OH
N
3ma
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

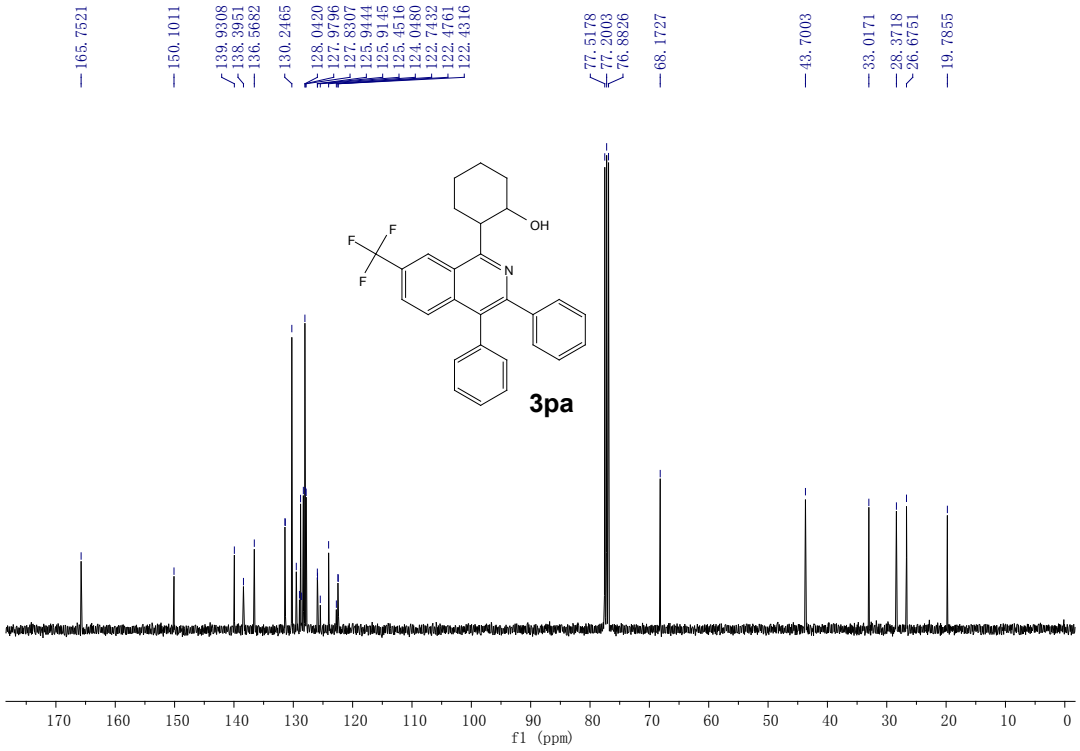

7.9447
7.6070
7.5854
7.4341
7.3490
7.3385
7.3274
7.2605
7.2462
7.2054
7.1939
7.1880
7.1748
7.1604
7.1577
4.5440
3.6349
3.6049
2.5770
2.1746
2.1361
1.9773
1.8662
1.6932
1.6598
1.6273
1.5960
OH
H3C
N
3na
0.98
1.00
1.05
6.01
1.22
4.02
1.00
1.00
2.99
1.00
1.03
2.96
3.05
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

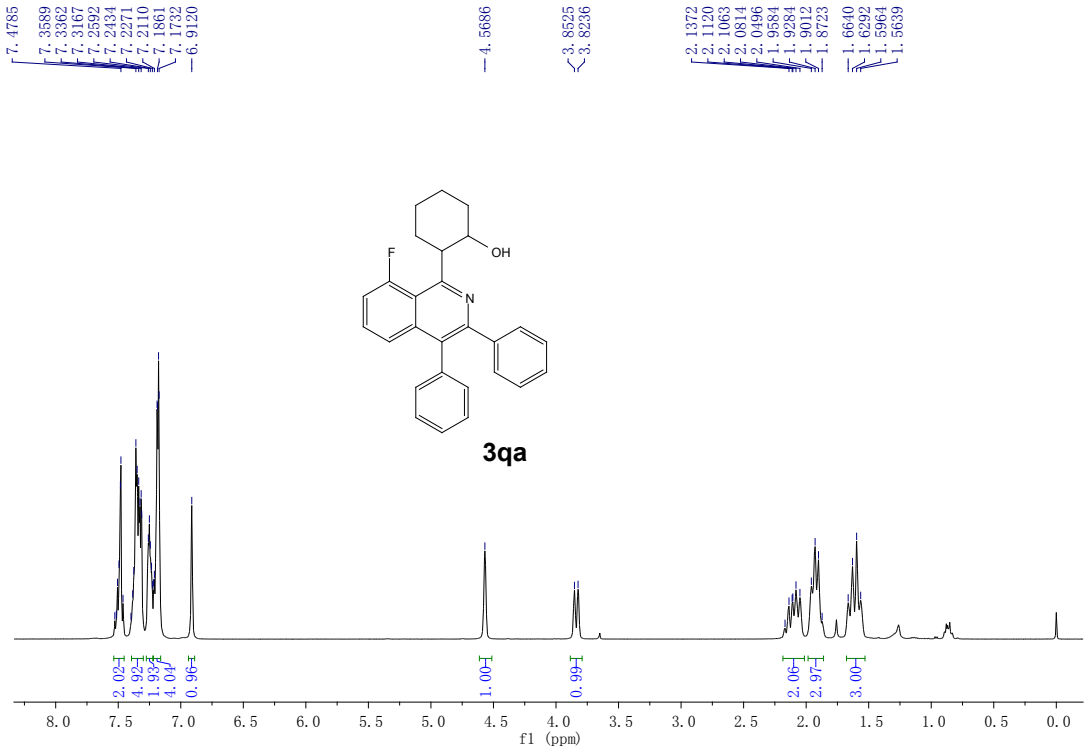

164.0981
147.1603
140.6304
132.5650
131.5112
131.4738
130.2492
129.4184
128.5029
128.4565
127.8455
127.4734
127.1805
126.7474
125.2204
123.5488
77.5170
77.1996
76.8816
68.3307
43.3187
33.1656
26.7917
22.1687
19.9394
OH
H3C
N
3na
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

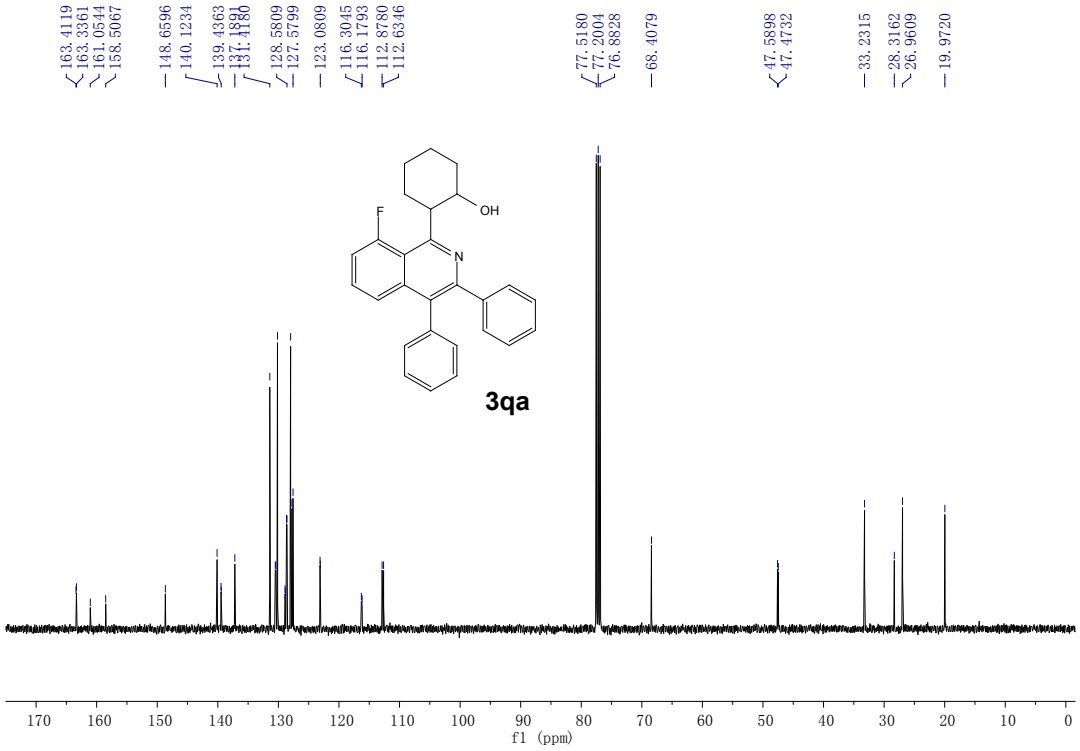

8.3210
7.6407
7.6374
7.5873
7.5647
7.3085
7.1732
7.0014
4.5345
3.5634
3.5341
2.1718
2.1097
2.0785
1.9550
1.9393
1.9285
1.8785
1.8453
1.6964
1.6628
1.6561
1.6294
1.6021
OH
Br
N
3oa
0.98
1.00
0.99
4.99
5.32
1.02
1.00
1.00
1.05
1.04
2.99
3.15
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

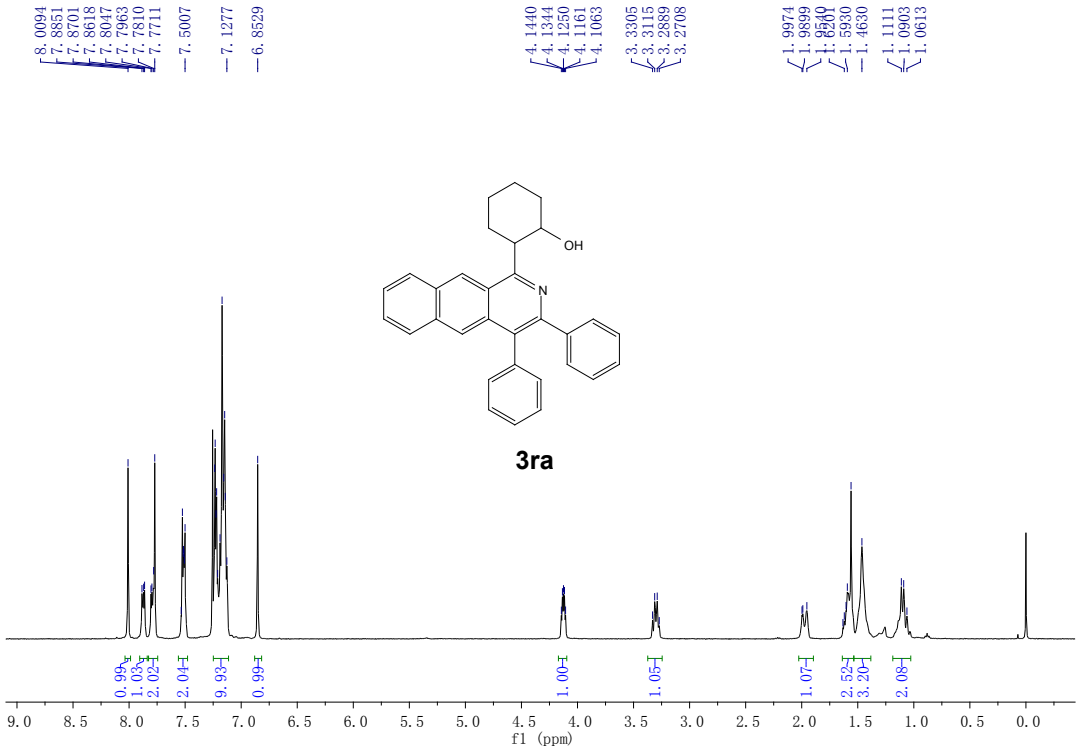

163.8911
148.4683
140.1303
130.1827
128.6913
127.8280
126.1816
121.2789
77.5170
77.1996
76.8821
68.1868
43.5486
33.0533
28.1257
26.6953
19.8172
OH
Br
N
3oa
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

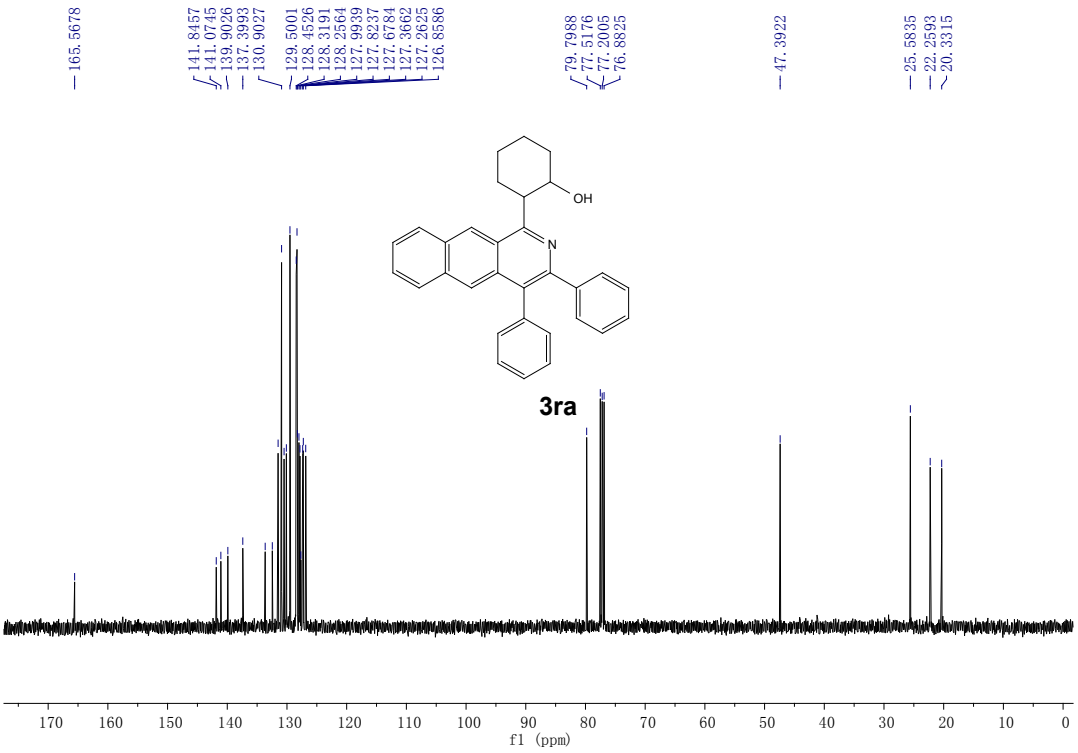

8.4737
7.8294
7.7673
7.7636
7.7449
7.7412
7.7394
7.2580
7.1937
6.9130
6.9096
4.5665
3.6770
3.6489
2.2531
2.2454
2.2208
2.2132
2.1884
2.1808
2.1296
2.0965
2.0097
2.0027
1.9803
1.9714
1.9554
1.9458
1.9417
1.9166
1.8871
1.8535
1.7200
1.6875
1.6539
1.6181
OH
F
F
F
N
3pa
0.98
1.01
0.98
5.08
5.16
0.97
1.00
1.00
1.04
0.97
3.06
3.21
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

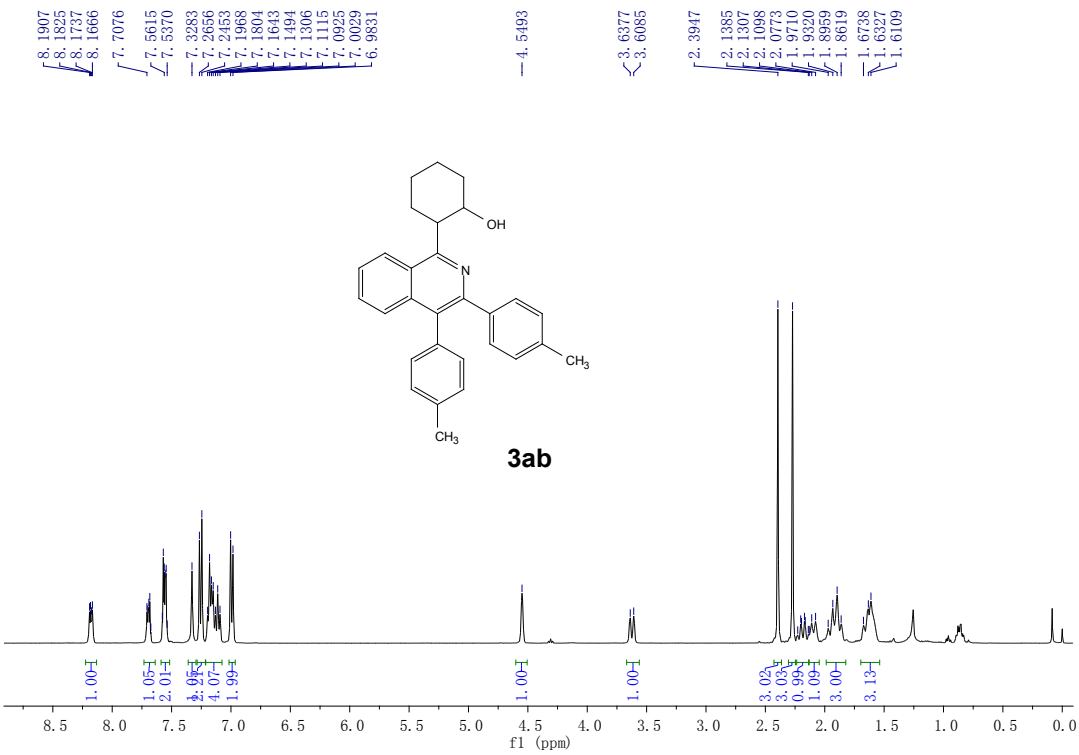

165.7521
150.1011
139.9308
138.3951
136.5682
130.2465
128.0420
127.9796
127.8307
125.9444
125.9145
125.4516
124.0480
122.7432
122.4761
122.4316
77.5178
77.2003
76.8826
68.1727
43.7003
33.0171
28.3718
26.6751
19.7855
OH
F
F
F
N
3pa
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

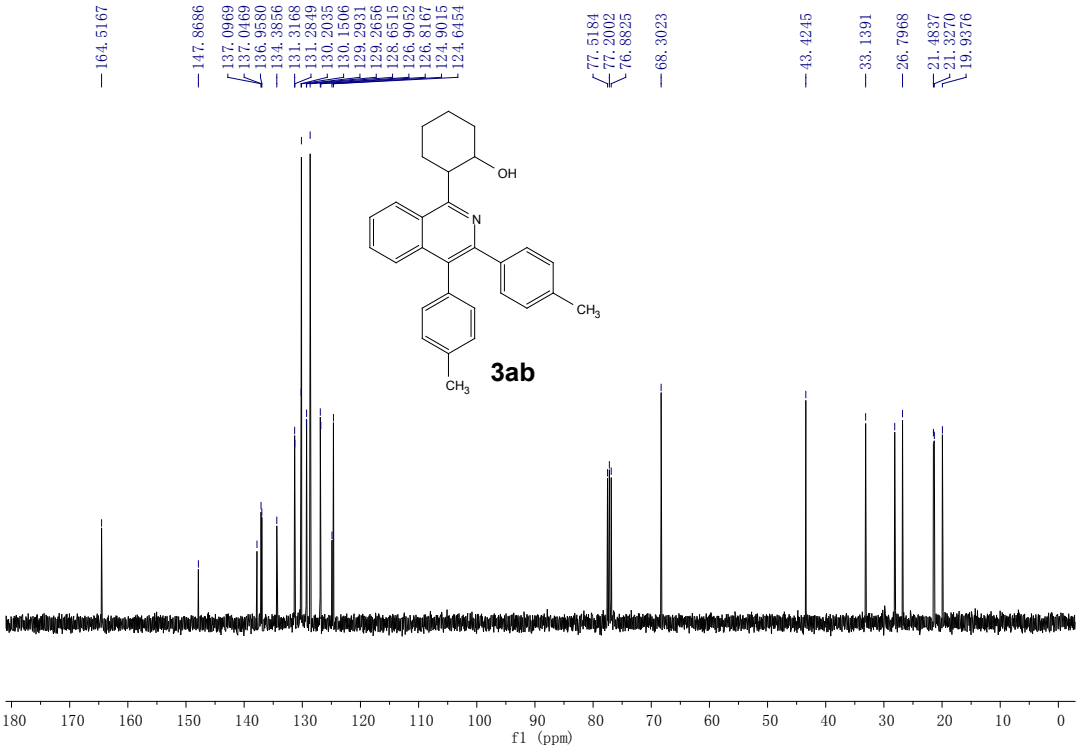

7.4785
7.3589
7.3362
7.3167
7.2592
7.2434
7.2271
7.2110
7.1861
7.1732
6.9120
4.5686
3.8525
3.8236
2.1372
2.1120
2.1063
2.0814
2.0496
1.9584
1.9284
1.9012
1.8723
1.6640
1.6292
1.5964
1.5639
OH
F
N
3qa
2.02
4.92
1.93
4.04
0.96
1.00
0.99
2.06
2.97
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

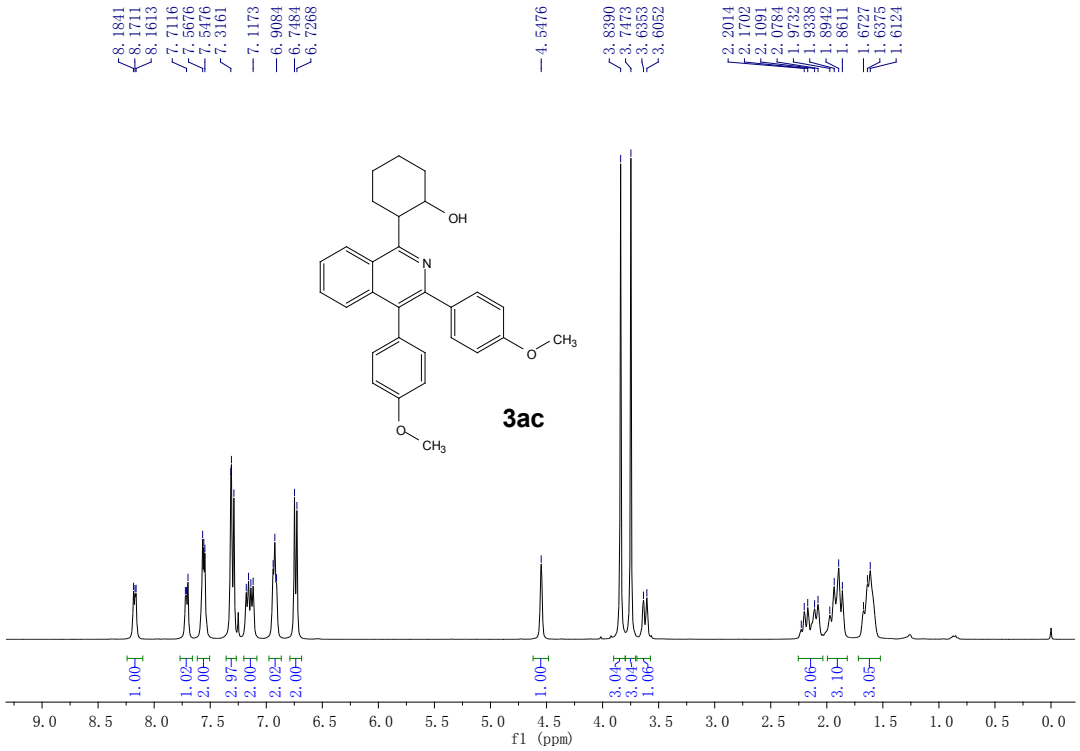

163.4119
163.3361
161.0544
158.5067
148.6596
140.1234
139.4363
131.4180
128.5809
127.5799
123.0809
116.3045
116.1793
112.8780
112.6346
77.5180
77.2004
76.8828
68.4079
47.5898
47.4732
33.2315
28.3162
26.9609
19.9720
F
OH
N
3qa
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

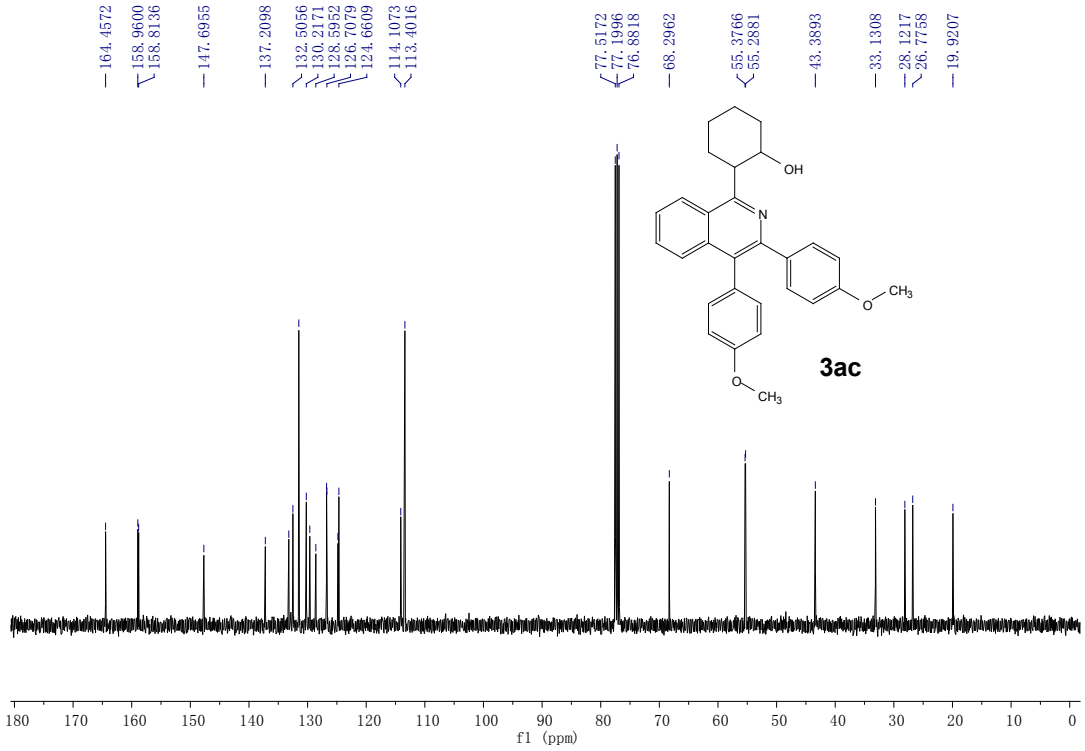

8.0094
7.8851
7.8701
7.8618
7.8047
7.7963
7.7810
7.7711
7.5007
7.1277
6.8529
4.1440
4.1344
4.1250
4.1161
4.1063
3.3305
3.3115
3.2889
3.2708
1.9974
1.9899
1.5930
1.4630
1.1111
1.0903
1.0613
OH
N
3ra
0.99
1.03
2.02
2.04
9.93
0.99
1.00
1.05
1.07
2.52
3.20
2.08
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

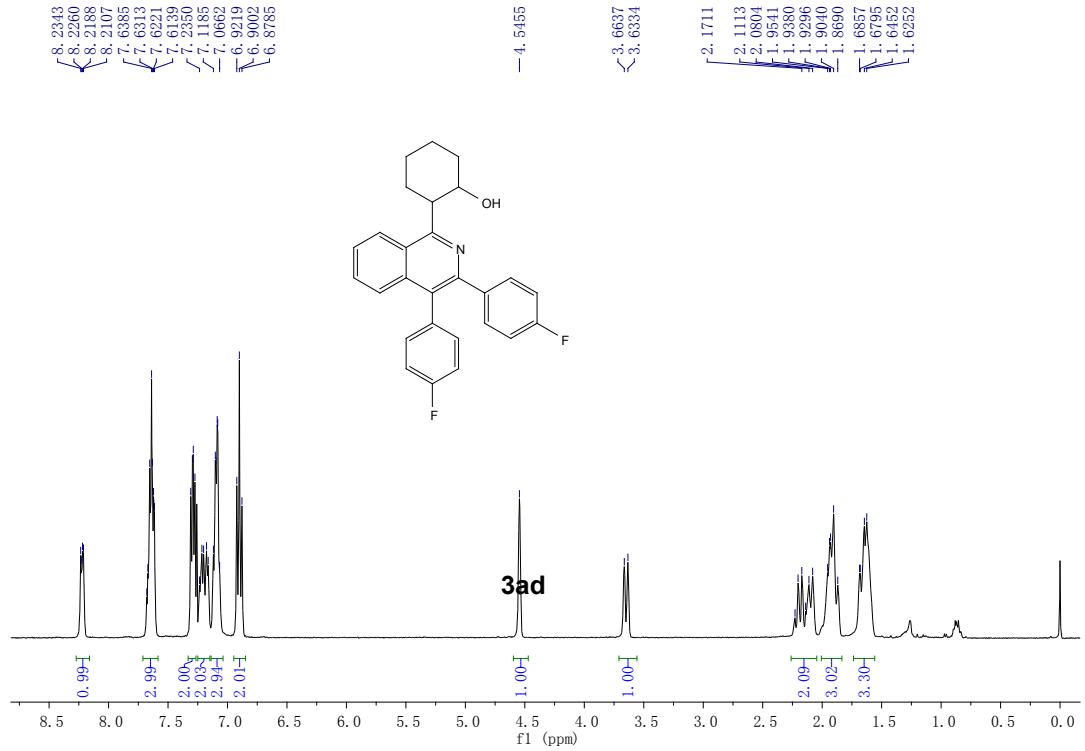

165.5678
141.8457
141.0745
139.9026
137.3993
130.9027
129.5001
128.4526
128.3191
128.2564
127.9939
127.8237
127.6784
127.3662
127.2625
126.8586
79.7988
77.5176
77.2005
76.8825
47.3922
25.5835
22.2593
20.3315
OH
N
3ra
f1 (ppm)

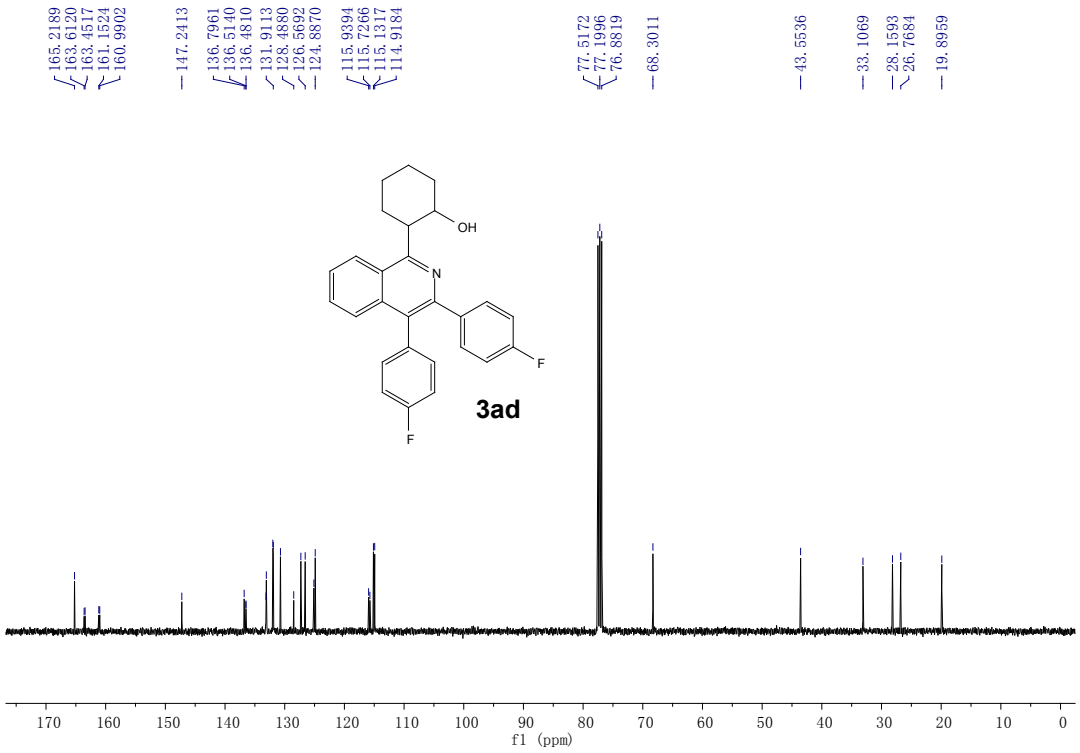

8.1907
8.1825
8.1737
8.1666
7.7076
7.5615
7.5370
7.3283
7.2656
7.2453
7.1968
7.1804
7.1643
7.1494
7.1306
7.1115
7.0925
7.0029
6.9831
4.5493
3.6377
3.6085
2.3947
2.1385
2.1307
2.1098
2.0773
1.9710
1.9320
1.8959
1.8619
1.6738
1.6327
1.6109
OH
N
CH3
CH3
3ab
1.00
1.05
2.01
1.95
4.07
1.99
1.00
1.00
3.02
3.03
0.99
1.09
3.00
3.13
f1 (ppm)

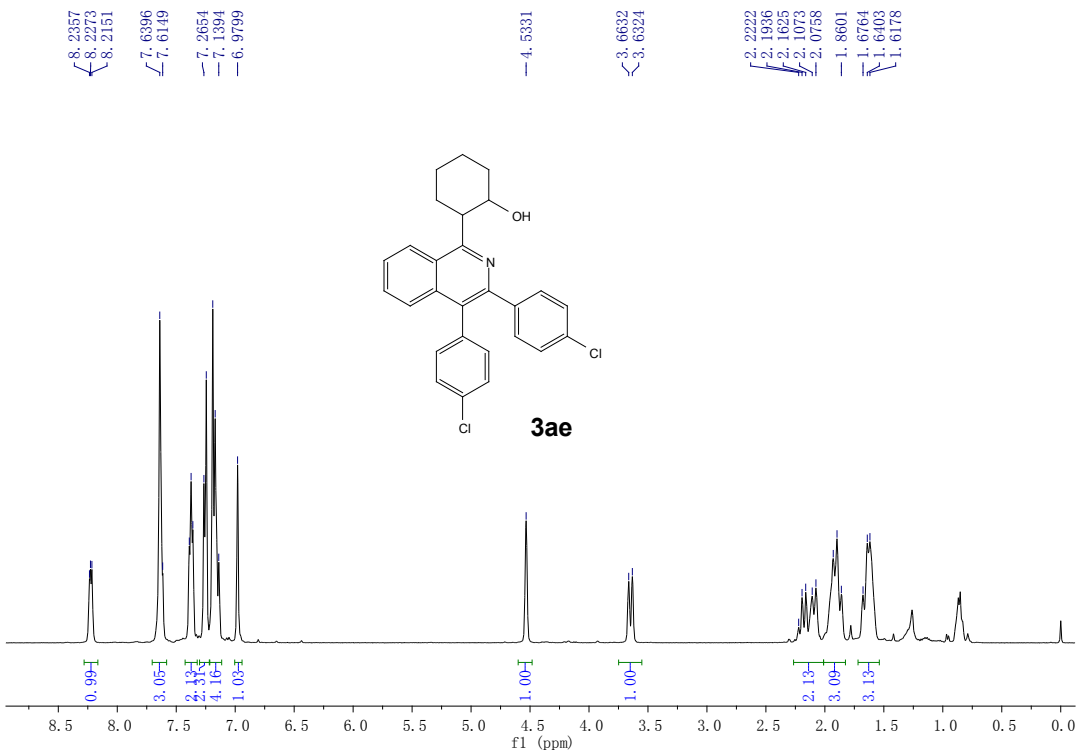

164.5167
147.8686
137.0969
137.0469
136.9580
134.3856
131.3168
131.2849
130.2035
130.1506
129.2931
129.2656
128.6515
126.9052
126.8167
124.9015
124.6454
77.5184
77.2002
76.8825
68.3023
43.4245
33.1391
26.7968
21.4837
21.3270
19.9376
OH
N
CH3
CH3
3ab
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

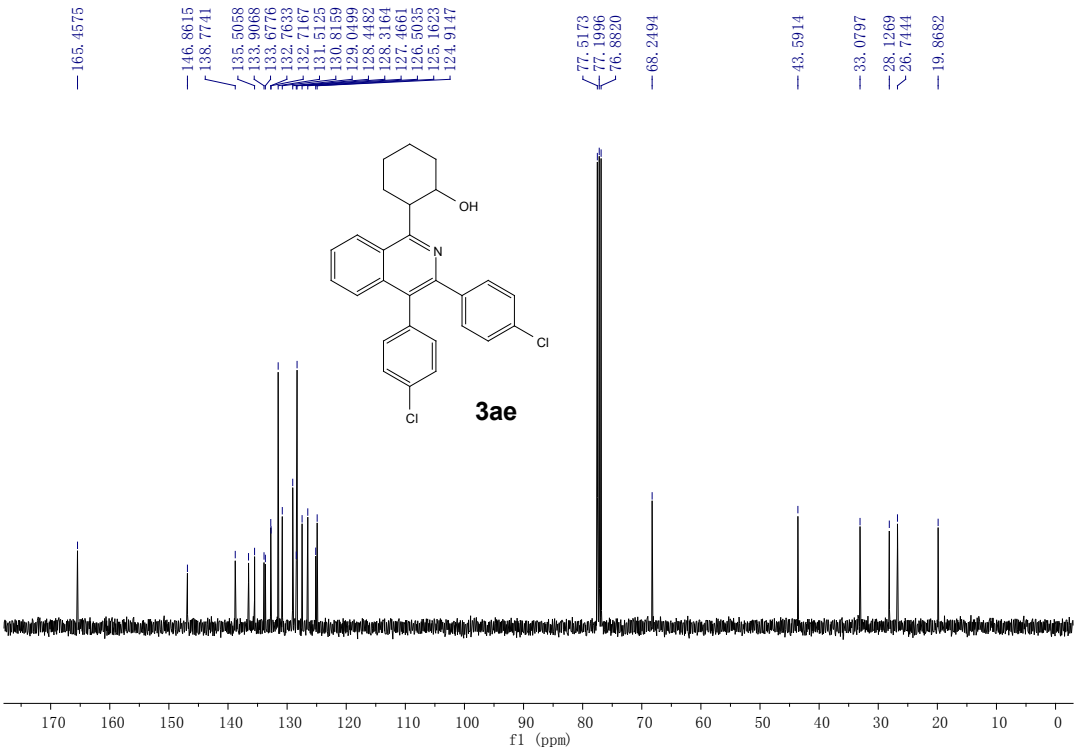

8.1841
8.1711
8.1613
7.7116
7.5676
7.5476
7.3161
7.1173
6.9084
6.7484
6.7268
4.5476
3.8390
3.7473
3.6353
3.6052
2.2014
2.1702
2.1091
2.0784
1.9732
1.9338
1.8942
1.8611
1.6727
1.6375
1.6124
OH
N
O
CH3
O
CH3
3ac
1.00
1.02
2.00
2.97
2.00
2.02
2.00
1.00
3.04
3.04
1.06
2.06
3.10
3.05
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

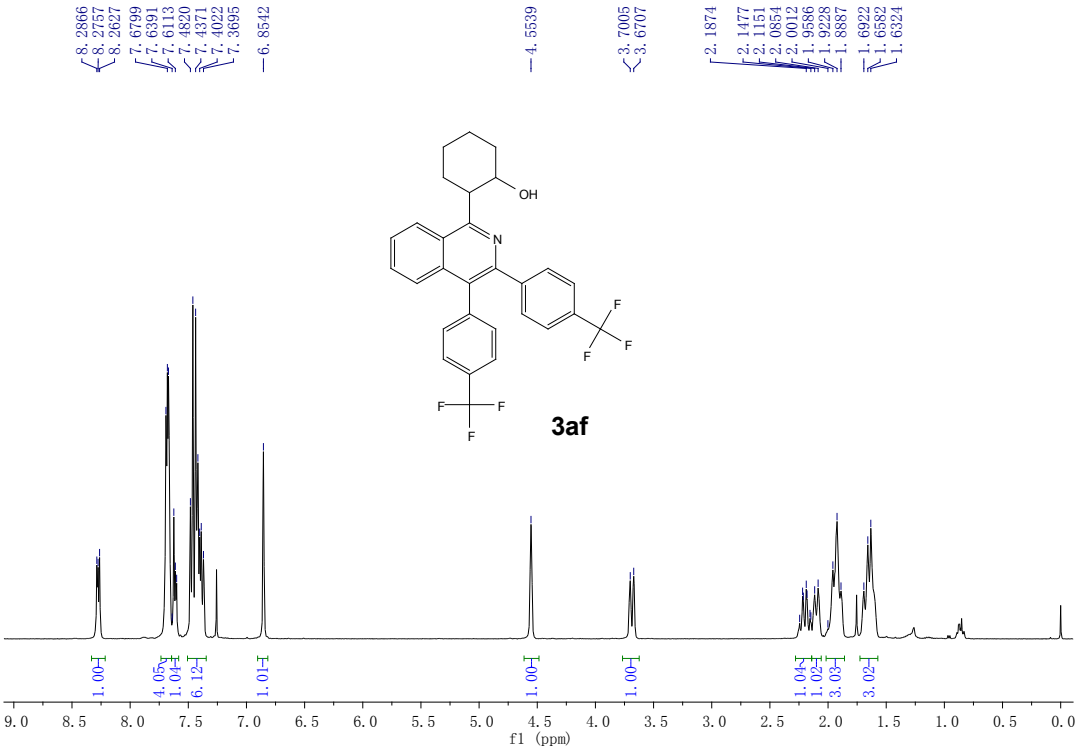

164.4572
158.9600
158.8136
147.6955
137.2098
132.5056
130.2171
128.5952
126.7079
124.6609
114.1073
113.4016
77.5172
77.1996
76.8818
68.2962
55.3766
55.2881
43.3893
33.1308
28.1217
26.7758
19.9207
OH
N
O
CH3
O
CH3
3ac
f1 (ppm)

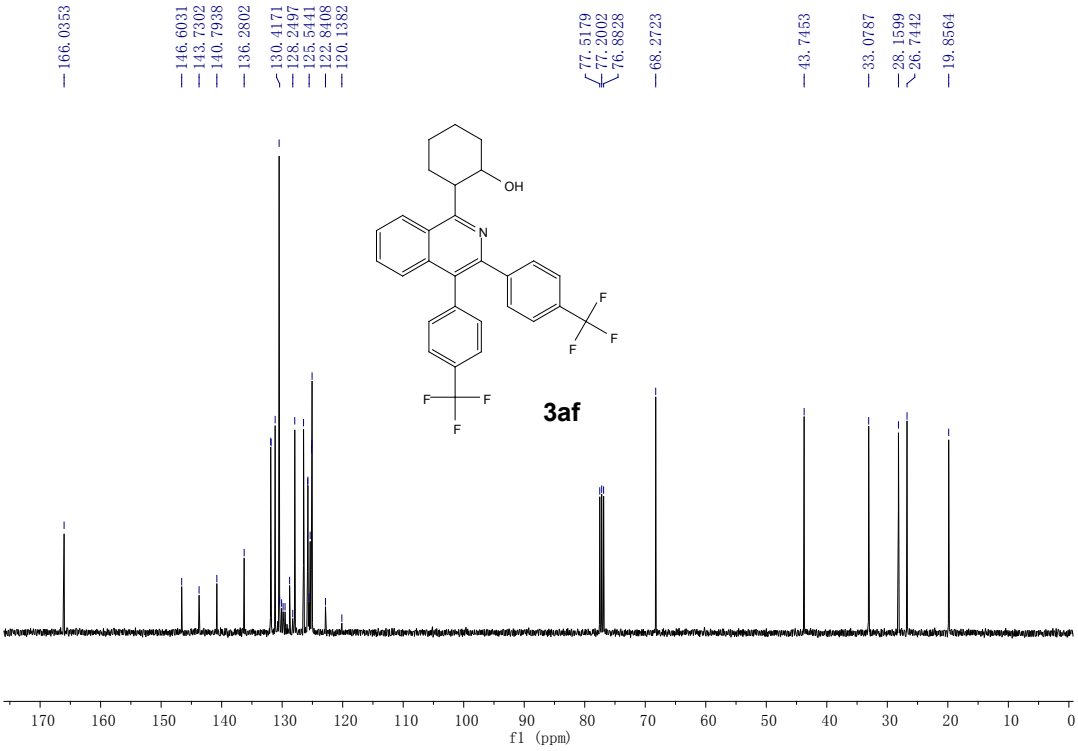

8.2343
8.2260
8.2188
8.2107
7.6385
7.6313
7.6221
7.6139
7.2350
7.1185
7.0662
6.9219
6.9002
6.8785
4.5455
3.6637
3.6334
2.1711
2.1113
2.0804
1.9541
1.9380
1.9296
1.9040
1.8690
1.6857
1.6795
1.6452
1.6252
OH
N
F
F
3ad
0.99
2.99
2.00
2.03
2.94
2.01
1.00
1.00
2.09
3.02
3.30
f1 (ppm)

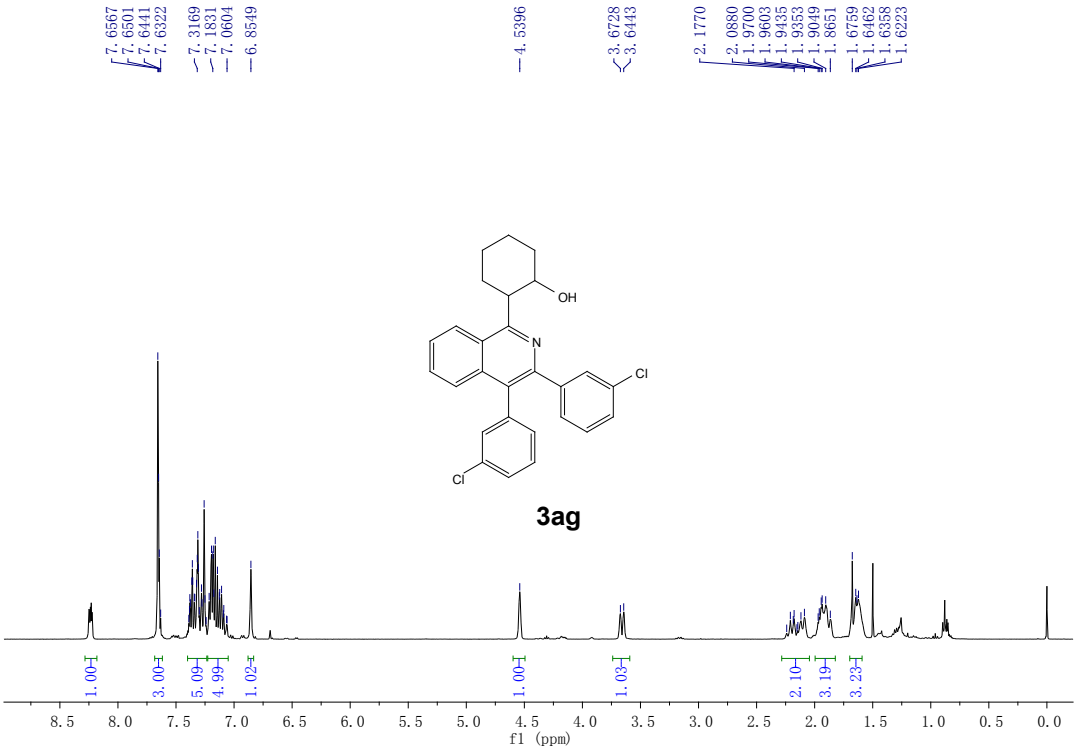

165.2189
163.6120
163.4517
161.1524
160.9902
147.2413
136.7961
136.5140
136.4810
131.9113
128.4880
126.5692
124.8870
115.9394
115.7266
115.1317
114.9184
77.5172
77.1996
76.8819
68.3011
43.5536
33.1069
28.1593
26.7684
19.8959
OH
N
F
F
3ad
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

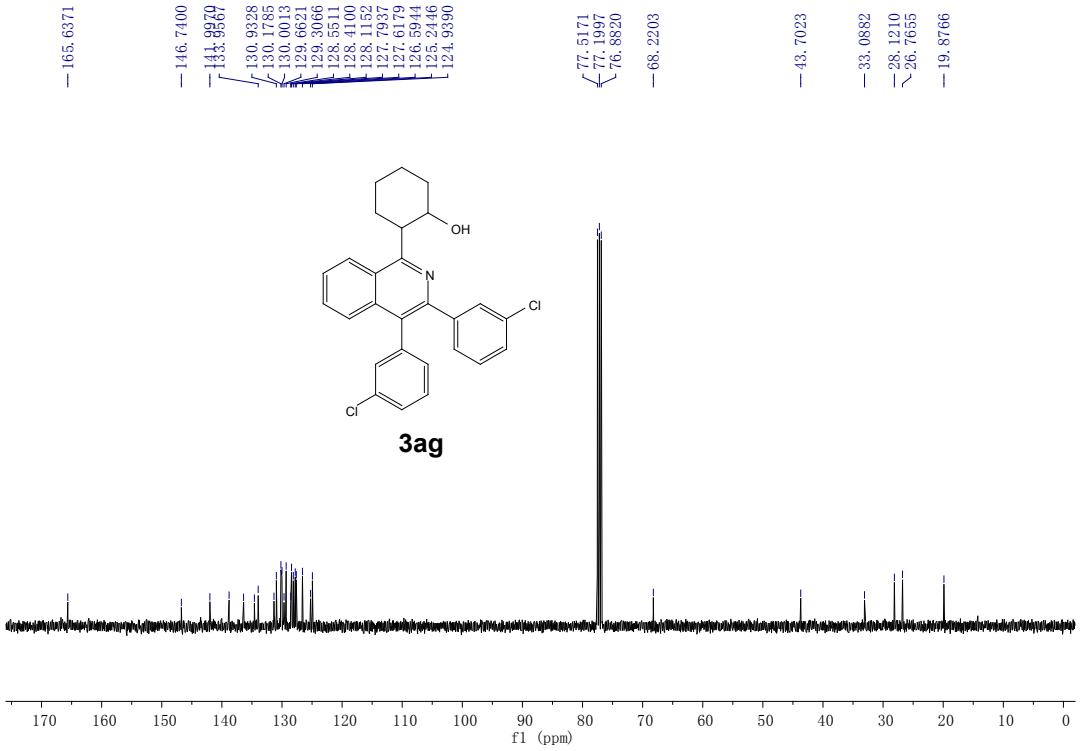

8.2357
8.2273
8.2151
7.6396
7.6149
7.2654
7.1394
6.9799
4.5331
3.6632
3.6324
2.2222
2.1936
2.1625
2.1073
2.0758
1.8601
1.6764
1.6403
1.6178
OH
N
Cl
Cl
3ae
0.99
3.05
2.13
2.32
4.16
1.03
1.00
1.00
2.13
3.09
3.13
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

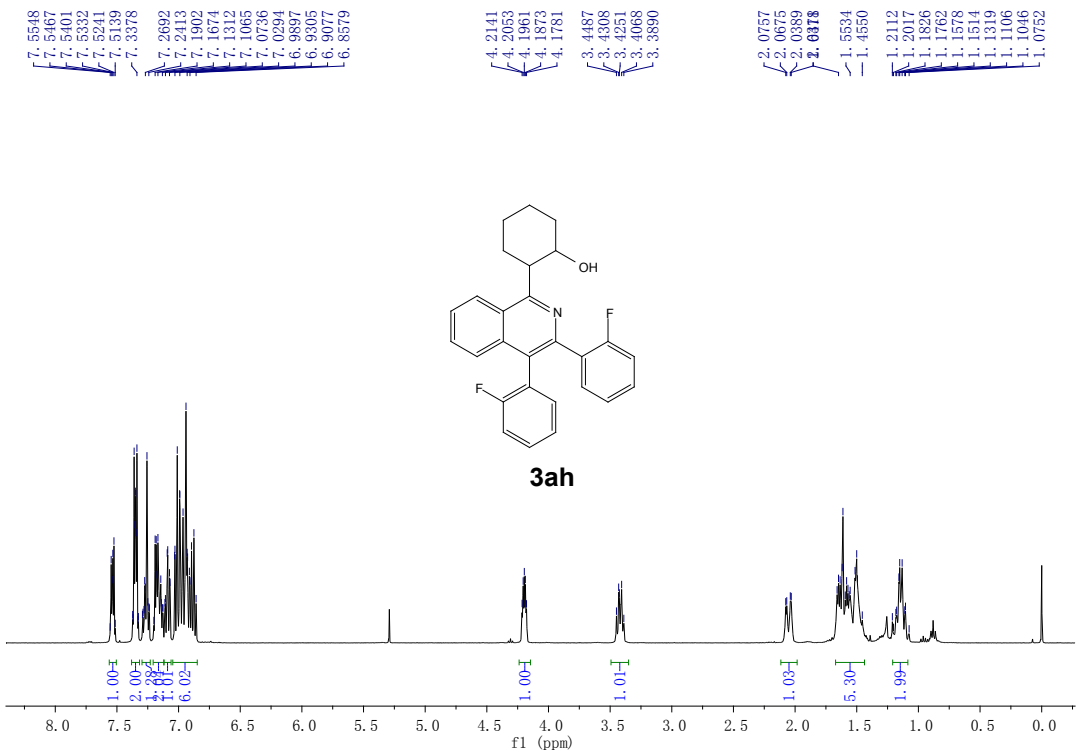

165.4575
146.8615
138.7741
135.5058
133.9068
133.6776
132.7633
132.7167
131.5125
130.8159
129.0499
128.4482
128.3164
127.4661
126.5035
125.1623
124.9147
77.5173
77.1996
76.8820
68.2494
43.5914
33.0797
28.1269
26.7444
19.8682
OH
N
Cl
Cl
3ae
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

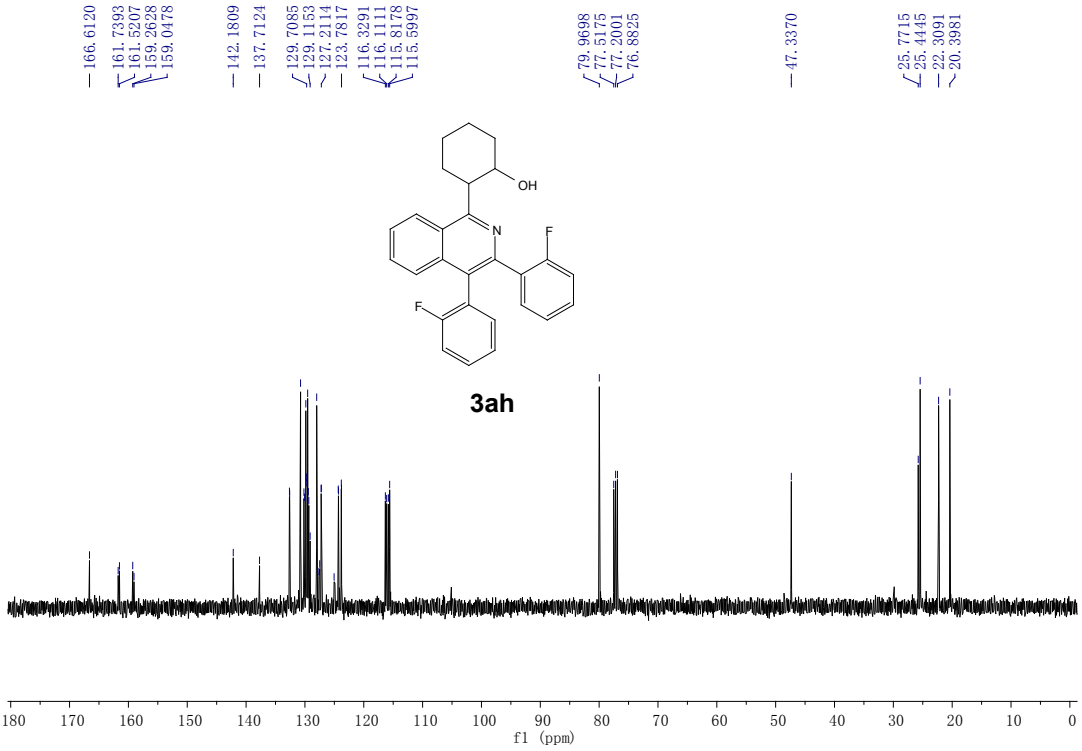

8.2866
8.2757
8.2627
7.6799
7.6391
7.6113
7.4820
7.4371
7.4022
7.3695
6.8542
4.5539
3.7005
3.6707
2.1874
2.1477
2.1151
2.0854
2.0012
1.9586
1.9228
1.8887
1.6922
1.6582
1.6324
OH
N
F
F
F
F
F
F
3af
1.00
4.05
1.04
6.12
1.01
1.00
1.00
1.04
1.02
3.03
3.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

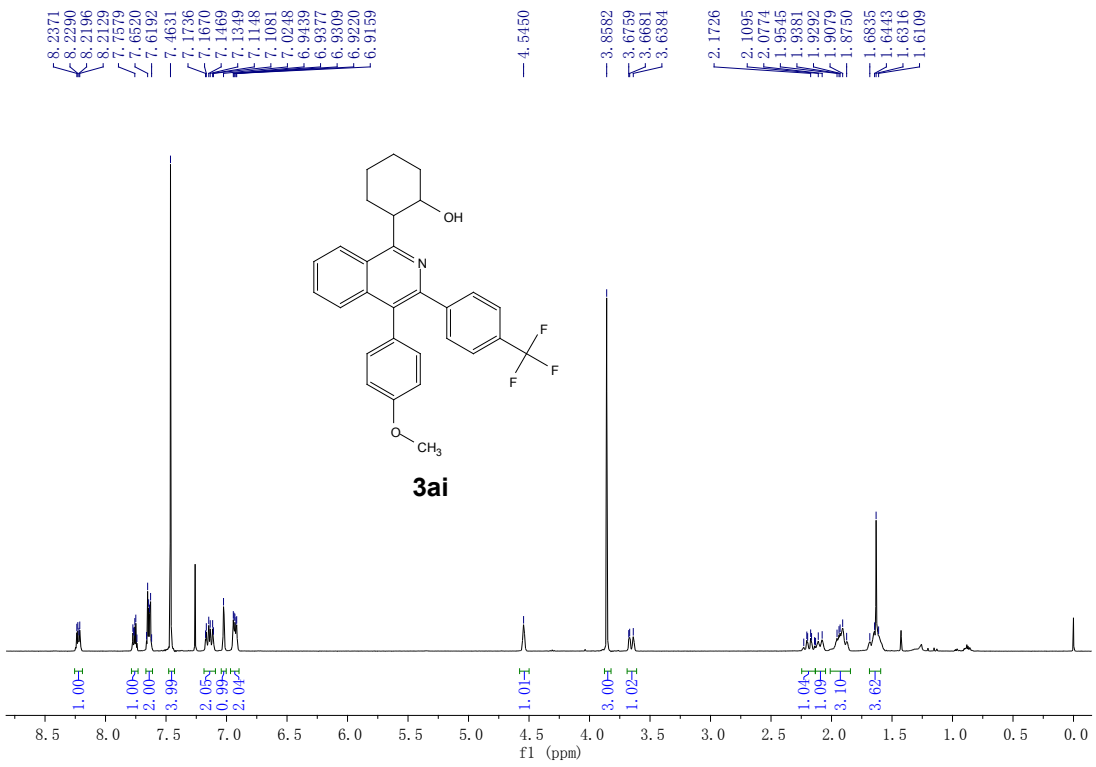

166.0353
146.6031
143.7302
140.7938
136.2802
130.4171
128.2497
125.5441
122.8408
120.1382
77.5179
77.2002
76.8828
68.2723
43.7453
33.0787
28.1599
26.7442
19.8564
OH
N
F
F
F
F
F
F
3af
f1 (ppm)

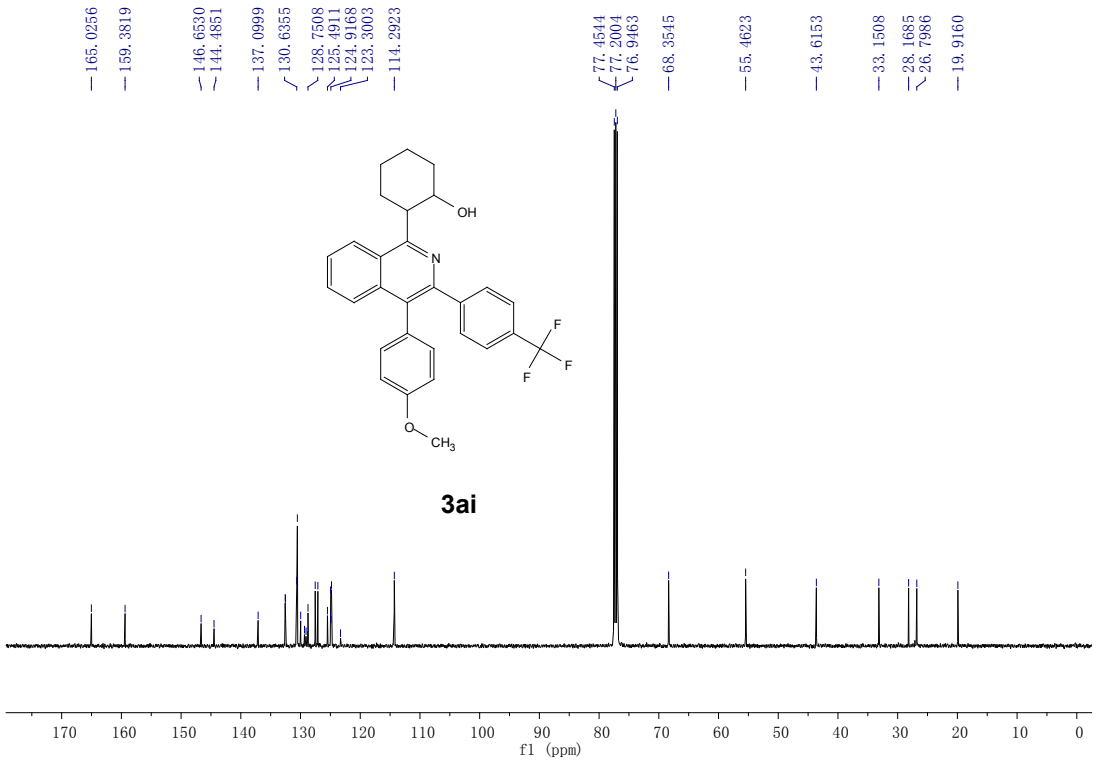

7.6567
7.6501
7.6441
7.6322
7.3169
7.1831
7.0604
6.8549
4.5396
3.6728
3.6443
2.1770
2.0880
1.9700
1.9603
1.9435
1.9353
1.9049
1.8651
1.6759
1.6462
1.6358
1.6223
OH
N
Cl
Cl
3ag
1.00
3.00
5.09
4.99
1.02
1.00
1.03
2.10
3.19
3.23
f1 (ppm)


165.6371
146.7400
141.9970
133.9567
130.9328
130.1785
130.0013
129.6621
129.3066
128.5511
128.4100
128.1152
127.7937
127.6179
126.5944
125.2446
124.9390
77.5171
77.1997
76.8820
68.2203
43.7023
33.0882
28.1210
26.7655
19.8766
OH
N
Cl
Cl
3ag
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

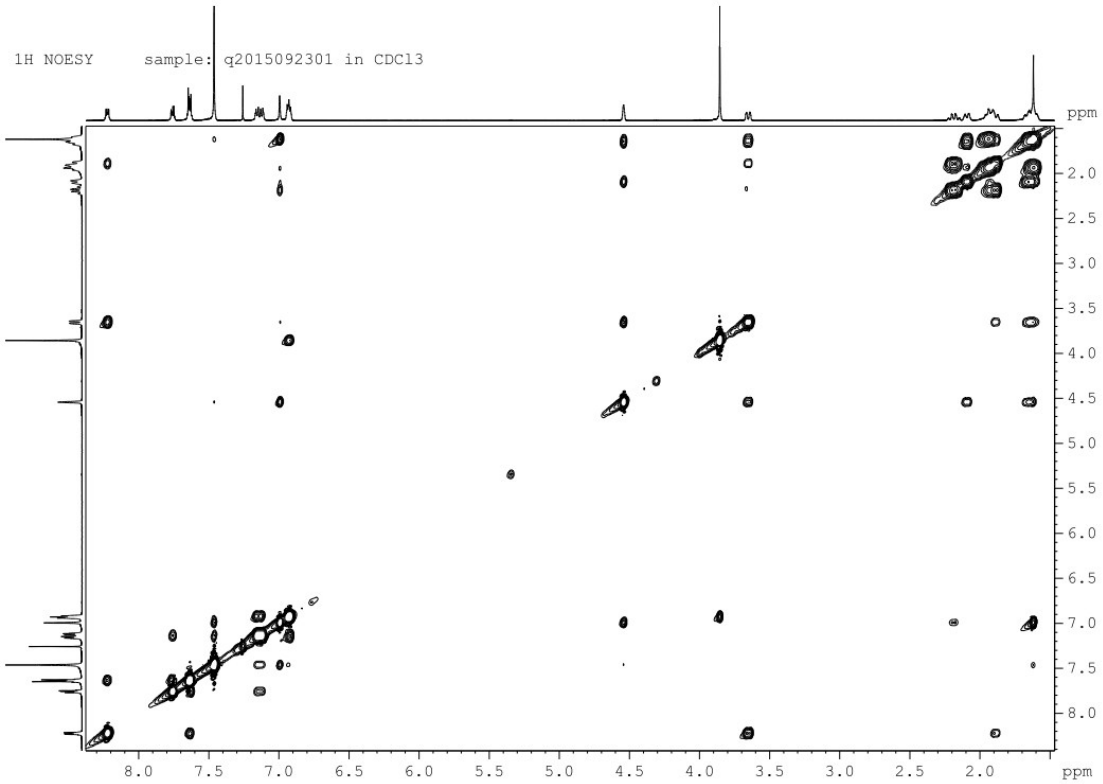

7.5548
7.5467
7.5401
7.5332
7.5241
7.5139
7.3378
7.2692
7.2413
7.1902
7.1674
7.1312
7.1065
7.0736
7.0294
6.9897
6.9305
6.9077
6.8579
4.2141
4.2053
4.1961
4.1873
4.1781
3.4487
3.4308
3.4251
3.4068
3.3890
2.0757
2.0675
2.0389
1.5534
1.4550
1.2112
1.2017
1.1826
1.1762
1.1578
1.1514
1.1319
1.1106
1.1046
1.0752
OH
N
F
F
3ah
1.00
2.00
1.01
1.01
6.02
1.00
1.01
1.03
5.30
1.99
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


166.6120
161.7393
161.5207
159.2628
159.0478
142.1809
137.7124
129.7085
129.1153
127.2114
123.7817
116.3291
116.1111
115.8178
115.5997
79.9698
77.5175
77.2001
76.8825
47.3370
25.7715
25.4445
22.3091
20.3981
OH
N
F
F
3ah
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

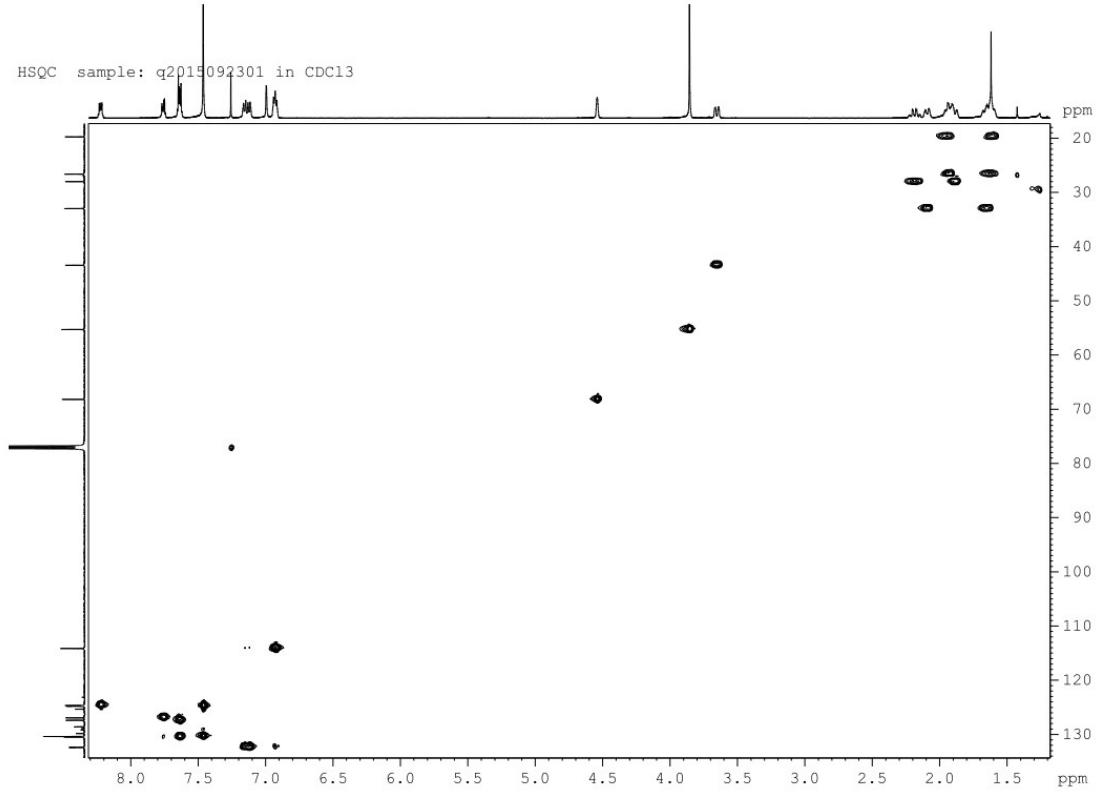

8.2371
8.2290
8.2196
8.2129
7.7579
7.6520
7.6192
7.4631
7.1736
7.1670
7.1469
7.1349
7.1148
7.1081
7.0248
6.9439
6.9377
6.9309
6.9220
6.9159
4.5450
3.8582
3.6759
3.6681
3.6384
2.1726
2.1095
2.0774
1.9545
1.9381
1.9292
1.9079
1.8750
1.6835
1.6443
1.6316
1.6109
OH
N
F
F
F
O
CH3
3ai
1.00
1.00
2.00
3.99
2.05
0.99
2.04
1.01
3.00
1.02
1.04
1.09
3.10
3.62
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


165.0256
159.3819
146.6530
144.4851
137.0999
130.6355
128.7508
125.4911
124.9168
123.3003
114.2923
77.4544
77.2004
76.9463
68.3545
55.4623
43.6153
33.1508
28.1685
26.7986
19.9160
OH
N
F
F
F
O
CH3
3ai
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

NOESY of **3ai**


1H NOESY
sample: q2015092301 in CDCl3
ppm
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
ppm

HSQC of **3ai**



HMBC of **3ai**