Supporting Information

Enantioselective Copper-Catalyzed Hydrophosphination of Alkenyl Isoquinolines

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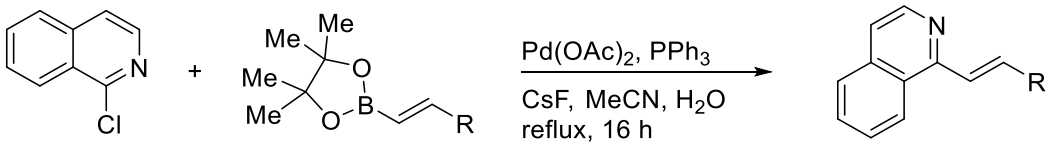
Table of Contents

1. General information

All the air or moisture sensitive reactions and manipulations were performed under an atmosphere of argon by using standard Schlenk techniques and Drybox (Mikrouna, Supper 1220/750). ^{1}H NMR and ^{13}C NMR spectra were recorded on Bruker-Avance 400 or 500 MHz spectrometer. $CDCl_3$ was used as solvent. Chemical shifts (δ) were reported in ppm with tetramethylsilane as internal standard, and *J* values were given in Hz. The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, dd = double of doublets, t = triplet, q = quartet, m = multiplet. Flash column chromatograph was carried out using 200-300 mesh silica gel at medium pressure. High resolution mass spectra (HRMS) were recorded on a LC-TOF spectrometer. ESI-HRMS data were acquired using a Thermo LTQ Orbitrap XL Instrument equipped with an ESI source. Optical rotation was obtained on a Rudolph Research Analytical (Atopol I). HPLC analysis was performed on Agilent 1260 series, UV detection monitored at 230 or 220 nm. Toluene, tetrahydrofuran, 1,4-dioxane and ethylene glycol dimethyl ether were dried and distilled before use according to the standard methods. Anisole was obtained from J&K Scientific. Melting points were measured on MP-450 (Hanon) melting point apparatus and uncorrected.

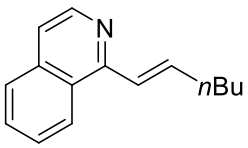
2. Preparation of alkenyl isoquinolines

A general procedure for the synthesis of alkenyl isoquinolines 1a-e[1], 1z and 1aa



A solution of 1-chloroisoquinoline (818 mg, 5.00 mmol), alkenylboronic esters (5.50 mmol), $Pd(OAc)_2$ (56 mg, 0.25 mmol), PPh_3 (262 mg, 1.00 mmol), and CsF (1.52 g, 10.0 mmol) in MeCN (80 mL) and H_2O (20 mL) was heated to reflux for 16 h. The mixture was cooled to room temperature, and partitioned between CH_2Cl_2 (100 mL) and H_2O (50 mL). The aqueous layer was extracted with CH_2Cl_2, and the organic layer was washed with brine, dried over anhydrous Na_2SO_4, and evaporated. The residue was purified by column chromatography on silica gel to give desired products **1a-e, 1z and 1aa** in 46-87% yields.

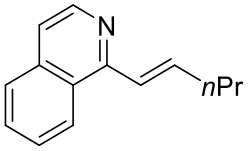
(*E*)-1-(hex-1-en-1-yl)isoquinoline 1a



Light yellow oil, 46% yield; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.47 (d, *J* = 5.6 Hz, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 7.77 (d, *J* = 8.2 Hz, 1H), 7.65-7.62 (m, 1H), 7.58-7.55 (m, 1H), 7.50 (d, *J* = 5.6 Hz, 1H), 7.29-7.26 (m, 1H), 7.09-7.03 (m, 1H), 2.42-2.37 (m, 2H), 1.60-1.54 (m, 2H), 1.47-1.40 (m, 2H), 0.95 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 155.3, 142.3, 139.7, 136.6, 129.8, 127.1, 126.9, 126.2, 125.0, 124.8, 119.5, 33.1, 31.1, 22.4, 14.0. HRMS (ESI) m/z:

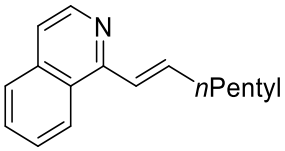
calcd for $C_{15}H_{18}N$ $[M+H]^+$ 212.1434, found 212.1431.

(*E*)-1-(pent-1-en-1-yl)isoquinoline 1b



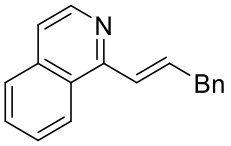
Light yellow oil, 87% yield; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.47 (d, *J* = 5.6 Hz, 1H), 8.26-8.23 (m, 1H), 7.78-7.75 (m, 1H), 7.65-7.61 (m, 1H), 7.58-7.54 (m, 1H), 7.50-7.48 (m, 1H), 7.29-7.26 (m, 1H), 7.08-7.03 (m, 1H), 2.39-2.35 (m, 2H), 1.65-1.56 (m, 2H), 1.03-1.00 (m, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 155.2, 142.3, 139.5, 136.6, 129.8, 127.1, 126.9, 126.2, 125.2, 124.8, 119.5, 35.5, 22.2, 13.9. HRMS (ESI) m/z: calcd for $C_{14}H_{16}N$ $[M+H]^+$ 198.1277, found 198.1275.

(*E*)-1-(hept-1-en-1-yl)isoquinoline 1c



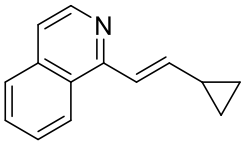
Yellow oil, 67% yield; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.47 (d, *J* = 5.6 Hz, 1H), 8.25 (d, *J* = 8.5 Hz, 1H), 7.78 (d, *J* = 8.1 Hz, 1H), 7.66-7.64 (m, 1H), 7.59-7.55 (m, 1H), 7.50 (d, *J* = 5.6 Hz, 1H), 7.29-7.26 (m, 1H), 7.09-7.03 (m, 1H), 2.41-2.37 (m, 2H), 1.62-1.52 (m, 2H), 1.41-1.36 (m, 4H), 0.92 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 155.3, 142.3, 139.8, 136.6, 129.8, 127.1, 126.9, 126.2, 125.0, 124.8, 119.4, 33.4, 31.6, 28.7, 22.6, 14.1. HRMS (ESI) m/z: calcd for $C_{16}H_{20}N$ $[M+H]^+$ 226.1590, found 226.1587.

(*E*)-1-(3-phenylprop-1-en-1-yl)isoquinoline 1d



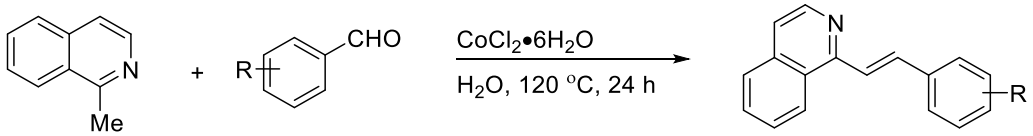
Yellow solid, 73% yield; m.p. 55-56 ºC;^{1}H NMR (500 MHz, $CDCl_3$): δ 8.45 (d, *J* = 5.6 Hz, 1H), 8.17 (d, *J* = 8.4 Hz, 1H), 7.75 (d, *J* = 8.1 Hz, 1H), 7.62 (t, *J* = 7.0 Hz, 1H), 7.55-7.52 (m, 1H), 7.48 (d, *J* = 5.6 Hz, 1H), 7.33-7.29 (m, 4H), 7.26-7.17 (m, 3H), 3.71 (d, *J* = 6.5 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.9, 142.4, 139.4, 137.7, 136.6, 129.8, 128.9, 128.6, 127.2, 127.1, 126.4, 126.3, 126.2, 124.7, 119.7, 39.6. HRMS (ESI) m/z: calcd for $C_{18}H_{16}N$ $[M+H]^+$ 246.1277, found 246.1275.

(*E*)-1-(2-cyclopropylvinyl)isoquinoline 1e



Light yellow solid, 73% yield; m.p. 63-64 ºC; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.43 (d, *J* = 5.6 Hz, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 7.75 (d, *J* = 8.1 Hz, 1H), 7.62 (t, *J* = 7.2 Hz, 1H), 7.55 (t, *J* = 8.1 Hz, 1H), 7.46 (d, *J* = 5.6 Hz, 1H), 7.39 (d, *J* = 15.0 Hz, 1H), 6.58 (dd, *J* = 15.0, 9.8 Hz, 1H), 1.80-1.1.73 (m, 1H), 0.95-0.91 (m, 2H), 0.72-0.69 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.8, 143.7, 142.3, 136.7, 129.7, 127.1, 126.9, 125.9, 124.7, 122.3, 119.2, 15.4, 8.1. HRMS (ESI) m/z: calcd for $C_{14}H_{14}N$ $[M+H]^+$ 196.1121, found 196.1118.

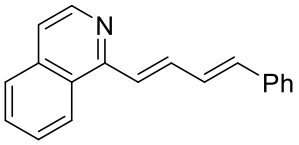
A general procedure for the synthesis of alkenyl quinolines 1f-u[2]



To a 50 mL screw-capped reaction vial equipped with a magnetic stir bar, $CoCl_2$•$6H_2O$ (1.0 mol%, 0.05 mmol, 13.7 mg), 1-methylisoquinoline (5 mmol, 0.76g), aldehyde (10 mmol) and H_2O (3 mL) were added. The resulting mixture was placed into a preheated oil bath at 120 °C with vigorous stirring. After 24 h, the reaction mixture was taken out of the oil bath, allowed to cool to room temperature and poured into H_2O (10 mL). The aqueous layer was then extracted with ethyl acetate (20 mL x 2). The organic layer was washed with brine (40 mL), dried over Na_2SO_4 and solvent removed under reduced pressure. The residue was purified by column chromatography on silica gel to give the alkenylation products **1f-u**.

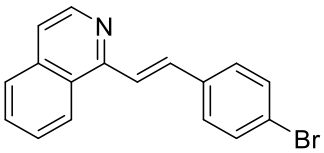
Alkenyl isoquinoline **1g**, **1h**, **1i**, **1j**, **1k** were known compounds.[3]

1-((1*E*,3*E*)-4-phenylbuta-1,3-dien-1-yl)isoquinoline 1f



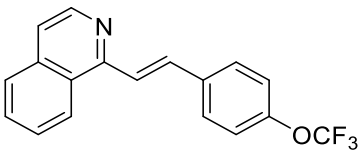
Light yellow solid, 73% yield; m.p. 120-121 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.55 (d, *J* = 5.6 Hz, 1H), 8.29 (d, *J* = 8.5 Hz, 1H), 7.85-7.79 (m, 2H), 7.66 (t, *J* = 7.0 Hz, 1H), 7.60 (t, *J* = 8.0 Hz, 1H), 7.56 (d, *J* = 14.9 Hz, 1H), 7.53-7.50 (m, 3H), 7.37 (t, *J* = 7.5 Hz, 1H), 7.29-7.26 (m, 2H), 7.16 (dd, *J* = 15.5, 11.1 Hz, 1H), 6.90 (d, *J* = 15.5 Hz, 1H)). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.5, 142.6, 137.1, 136.7, 136.5, 136.2, 129.9, 128.8, 128.1, 127.3, 127.2, 126.8, 126.6, 124.4, 119.8. HRMS (ESI) m/z: calcd for $C_{19}H_{16}N$ $[M+H]^+$ 258.1277, found 258.1275.

(*E*)-1-(4-bromostyryl)isoquinoline 1l



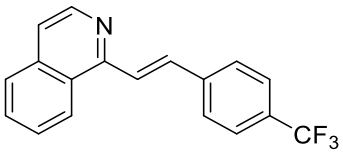
Light yellow solid, 40% yield; m.p. 135-136 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.56 (d, *J* = 5.6 Hz, 1H), 8.34 (d, *J* = 8.4 Hz, 1H), 7.98 (d, *J* = 15.6 Hz, 1H), 7.91 (d, *J* = 15.6 Hz, 1H), 7.83 (d, *J* = 8.1 Hz, 1H), 7.69 (t, *J* = 7.5 Hz, 1H), 7.65-7.62 (m, 1H), 7.68-7.52 (m, 5H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.2, 142.5, 136.8, 135.9, 134.5, 131.9, 130.0, 128.9, 127.4, 127.3, 126.8, 124.3, 123.5, 122.5, 120.2. HRMS (ESI) m/z: calcd for $C_{17}H_{13}BrN$ $[M+H]^+$ 310.0226, found 310.0222.

(*E*)-1-(4-(trifluoromethoxy)styryl)isoquinoline 1m



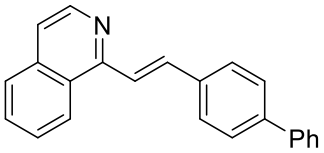
Light yellow solid, 64% yield; m.p. 100-101 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.56 (d, *J* = 5.6 Hz, 1H), 8.34 (d, *J* = 8.5 Hz, 1H), 7.96 (s, 2H), 7.83 (d, *J* = 8.2 Hz, 1H), 7.71-7.68 (m, 3H), 7.65-7.62 (m, 1H), 7.58 (d, *J* = 5.6 Hz, 1H), 7.26 (d, *J* = 8.1 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.1, 149.2 (d, *J* = 1.6 Hz), 142.5, 136.8, 135.6, 134.2, 130.0, 128.7, 127.4 (d, *J* = 6.8 Hz), 126.8, 124.3, 123.7, 123.6 (q, *J* = 256.1 Hz), 121.2, 120.3, 119.5. HRMS (ESI) m/z: calcd for $C_{18}H_{13}F_3ON$ $[M+H]^+$ 316.0944, found 316.0940.

(*E*)-1-(4-(trifluoromethyl)styryl)isoquinoline 1n



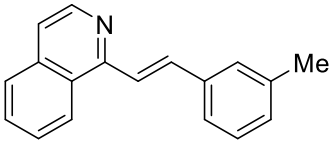
Light yellow solid, 74% yield; m.p. 118-119 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.56 (d, *J* = 5.6 Hz, 1H), 8.33 (d, *J* = 8.5 Hz, 1H), 8.01 (dd, *J* = 33.8, 15.6 Hz, 2H), 7.82 (d, *J* = 8.2 Hz, 1H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.70-7.61 (m, 4H), 7.57 (d, *J* = 5.5 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 153.8, 142.5, 140.3, 136.7, 134.1, 130.0, 129.9 (q, *J* = 270.3 Hz), 127.5, 127.44, 127.42, 126.8, 125.7 (q, *J* = 3.6 Hz), 125.2, 124.2, 120.6. HRMS (ESI) m/z: calcd for $C_{18}H_{13}F_3N$ $[M+H]^+$ 300.0995, found 300.0991.

(*E*)-1-(2-([1,1'-biphenyl]-4-yl)vinyl)isoquinoline 1o



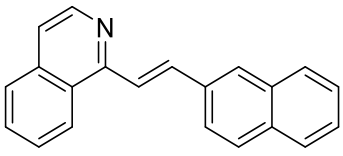
Light yellow solid, 65% yield; m.p. 143-144 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.58 (d, *J* = 5.6 Hz, 1H), 8.40 (d, *J* = 8.3 Hz, 1H), 8.05 (s, 2H), 7.84 (d, *J* = 7.9 Hz, 1H), 7.79 (d, *J* = 8.3 Hz, 2H), 7.71-7.63 (m, 6H), 7.57 (d, *J* = 5.6 Hz, 1H), 7.47 (t, *J* = 7.4 Hz, 2H), 7.38 (t, *J* = 7.4 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.5, 142.5, 141.3, 140.6, 136.8, 136.0, 135.4, 130.0, 128.9, 127.9, 127.53, 127.48, 127.37, 127.2, 127.0, 126.8, 124.5, 122.8, 120.0. HRMS (ESI) m/z: calcd for $C_{23}H_{18}N$ $[M+H]^+$ 308.1434, found 308.1429.

(*E*)-1-(3-methylstyryl)isoquinoline 1p



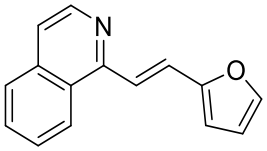
Light yellow solid, 54% yield; m.p. 101-102 °C;^{1}H NMR (500 MHz, $CDCl_3$): δ 8.57 (d, *J* = 5.6 Hz, 1H), 8.38 (d, *J* = 8.4 Hz, 1H), 8.02-7.95 (m, 2H), 7.82 (d, *J* = 8.1 Hz, 1H), 7.68 (t, *J* = 5.7 Hz, 1H), 7.62 (t, *J* = 8.2 Hz, 1H), 7.56 (d, *J* = 5.6 Hz, 1H), 7.53-7.50 (m, 2H), 7.32 (t, *J* = 7.6 Hz, 1H), 7.16 (d, *J* = 7.5 Hz, 1H), 2.42 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.6, 142.5, 138.3, 136.9, 136.8, 136.0, 129.9, 129.5, 128.7, 128.0, 127.3, 127.2, 126.8, 124.8, 124.5, 122.6, 119.9, 21.5. HRMS (ESI) m/z: calcd for $C_{18}H_{16}N$ $[M+H]^+$ 246.1277, found 246.1274.

(*E*)-1-(2-(naphthalen-2-yl)vinyl)isoquinoline 1q



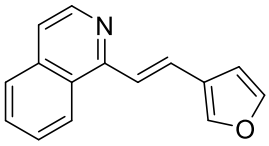
Light yellow solid, 61% yield; m.p. 209-210 °C;^{1}H NMR (500 MHz, $CDCl_3$): δ 8.59 (d, *J* = 5.5 Hz, 1H), 8.44 (d, *J* = 8.5 Hz, 1H), 8.15 (d, *J* = 3.9 Hz, 2H), 8.06 (s, 1H), 7.93-7.92 (m, 1H), 7.89-7.88 (m, 2H), 7.85 (d, *J* = 21.9 Hz, 2H), 7.72-7.51 (m, 1H), 7.68-7.64 (m, 1H), 7.58 (d, *J* = 5.6 Hz, 1H), 7.53-7.47 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.6, 142.5, 136.8, 135.9, 134.4, 133.7, 133.6, 130.0, 128.44, 128.36, 128.32, 127.8, 127.4, 127.3, 126.8, 126.5, 126.4, 124.5, 123.9, 123.1, 120.0. HRMS (ESI) m/z: calcd for $C_{21}H_{16}N$ $[M+H]^+$ 282.1277, found 282.1273.

(*E*)-1-(2-(furan-2-yl)vinyl)isoquinoline 1r



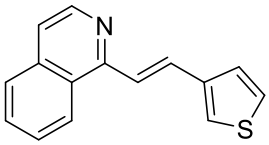
Yellow solid, 57% yield; m.p. 116-117 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.52 (d, *J* = 5.6 Hz, 1H), 8.40 (d, *J* = 8.4 Hz, 1H), 7.92 (d, *J* = 15.4 Hz, 1H), 7.82-7.78 (m, 2H), 7.66-7.63 (m, 1H), 7.51-7.58 (m, 1H), 7.52-7.49 (m, 2H), 6.54 (d, *J* = 3.3 Hz, 1H), 6.48-6.47 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.2, 153.2, 143.1, 142.5, 136.7, 129.9, 127.24, 127.17, 126.7, 124.4, 122.7, 120.7, 119.8, 112.1, 111.9. HRMS (ESI) m/z: calcd for $C_{15}H_{12}NO$ $[M+H]^+$ 222.0913, found 222.0911.

(*E*)-1-(2-(furan-3-yl)vinyl)isoquinoline 1s



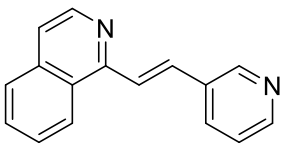
Gray solid, 45% yield; m.p. 85-86 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.52 (d, *J* = 5.6 Hz, 1H), 8.30 (d, *J* = 8.5 Hz, 1H), 7.87 (d, *J* = 15.5 Hz, 1H), 7.80 (d, *J* = 15.5 Hz, 1H), 7.70-7.64 (m, 3H), 7.59 (t, *J* = 8.1 Hz, 1H), 7.52 (d, *J* = 5.6 Hz, 1H), 7.47 (s, 1H), 6.81 (s, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.6, 144.0, 143.0, 142.4, 136.7, 129.9, 127.3, 127.1, 126.5, 125.7, 124.5, 124.4, 122.5, 119.7, 107.5. HRMS (ESI) m/z: calcd for $C_{15}H_{12}NO$ $[M+H]^+$ 222.0913, found 222.0911.

(*E*)-1-(2-(thiophen-3-yl)vinyl)isoquinoline 1t



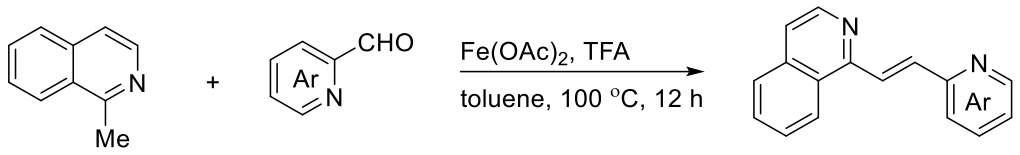
Light yellow solid, 62% yield; m.p. 115-116 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.54 (d, *J* = 5.6 Hz, 1H), 8.32 (d, *J* = 8.4 Hz, 1H), 7.99 (d, *J* = 15.5 Hz, 1H), 7.83-7.80 (m, 2H), 7.67 (t, *J* = 7.0 Hz, 1H), 7.61 (t, *J* = 7.1 Hz, 1H), 7.54 (d, *J* = 5.6 Hz, 1H), 7.51 (d, *J* = 5.1 Hz, 1H), 7.48 (d, *J* = 2.5 Hz, 1H), 7.37-7.36 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.6, 142.5, 139.9, 136.7, 129.9, 129.8, 127.3, 127.1, 126.6, 126.4, 125.2, 125.1, 124.4, 122.6, 119.8. HRMS (ESI) m/z: calcd for $C_{15}H_{12}NS$ $[M+H]^+$ 238.0685, found 238.0682.

(*E*)-1-(2-(pyridin-3-yl)vinyl)isoquinoline 1u



White solid, 75% yield; m.p. 123-124 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.90 (s, 1H), 8.56-8.54 (m, 2H), 8.32 (d, *J* = 8.2 Hz, 1H), 8.05-8.02 (m, 1H), 7.98-7.93 (m, 2H), 7.82 (d, *J* = 7.8 Hz, 1H), 7.68 (t, *J* = 6.9 Hz, 1H), 7.63-7.61 (m, 1H), 7.58-7.57 (m, 1H), 7.33-7.31 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 153.7, 149.4, 149.2, 142.5, 136.7, 133.7, 132.6, 132.1, 130.1, 127.5, 127.4, 126.7, 124.7, 124.2, 123.7, 120.5. HRMS (ESI) m/z: calcd for $C_{16}H_{13}N_2$ $[M+H]^+$ 233.1073, found 233.1071.

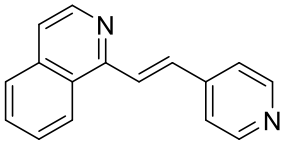
Synthesis of alkenyl isoquinolines 1v-w



A 50 mL Schlenk tube was charged with $Fe(OAc)_2$ (0.5 mmol, 58 mg) in toluene (10 mL), followed by the addition of 1-methylisoquinoline (5 mmol, 0.76 g), aldehyde (7.5 mmol) and CF_3COOH (0.5 mmol, 57 mg). The reaction was carried out at 100 °C for 12 h. The mixture was cooled to room temperature and diluted with EtOAc (30 mL) and H_2O (30 mL). The aqueous layer was extracted with EtOAc (30 mL x 2). The organic layer was washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under vacuum. The residue was purified by column chromatography on silica gel to get alkenyl isoquinolines **1v-w**.

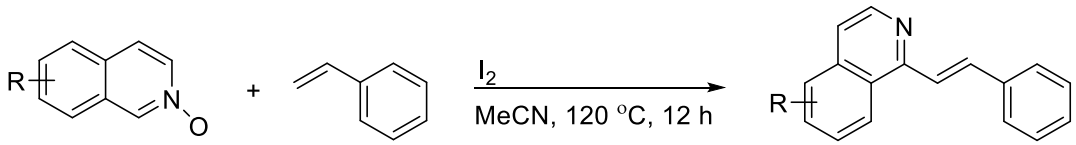
Alkenyl isoquinoline **1v** was known compound.[3]

(*E*)-1-(2-(pyridin-4-yl)vinyl)isoquinoline 1w



Yellow solid, 76% yield; m.p. 125-126 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.62-8.61 (m, 2H), 8.55 (d, *J* = 8.5 Hz, 1H), 8.31 (d, *J* = 8.4 Hz, 1H), 8.13 (d, *J* = 15.6 Hz, 1H), 7.86 (d, *J* = 15.6 Hz, 1H), 7.81 (d, *J* = 8.2 Hz, 1H), 7.69-7.66 (m, 1H), 7.63-7.58 (m, 2H), 7.49-7.48 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 153.3, 150.3, 144.1, 142.5, 136.7, 133.0, 130.1, 127.6, 127.5, 127.1, 126.9, 124.1, 121.5, 120.9. HRMS (ESI) m/z: calcd for $C_{16}H_{13}N_2$ $[M+H]^+$ 233.1073, found 233.1071.

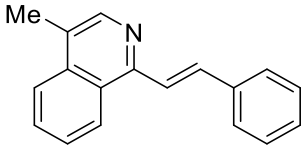
Synthesis of alkenyl isoquinolines 1ab-ah[4]



The quinoline N-oxide (5 mmol), styrene (1.04g, 10 mmol,) and I_2 (126.9 mg, 1 mmol) in 3 mL MeCN were stirred in a dry reaction tube at 120 °C under air atmosphere. The reaction mixture was stirred for 12 h. When the reaction was completed, the crude mixture was cooled to room temperature and and concentrated under vacuum. The residue was purified by column chromatography on silica gel to get alkenyl isoquinolines **1ab-ah**.

Alkenyl isoquinoline **1ae** and **1ag** were known compounds.[3]

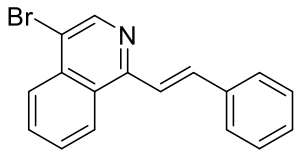
(*E*)-4-methyl-1-styrylisoquinoline 1ab



Light yellow solid, 45% yield; m.p. 107-108 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.42 (s, 1H), 8.38 (d, *J* = 8.5 Hz, 1H), 8.02-7.90 (m, 3H), 7.74-7.69 (m, 3H), 7.62 (t, *J* = 8.1 Hz, 1H), 7.42 (t, *J* = 7.4 Hz, 2H), 7.33 (t, *J* = 7.4 Hz, 1H), 2.63 (s, 3H). ^{13}C NMR (125

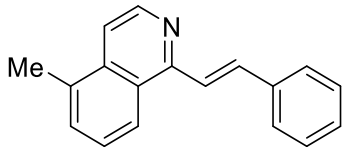
MHz, $CDCl_3$): δ 153.1, 142.5, 137.1, 136.0, 135.0, 129.7, 128.8, 128.4, 127.4, 126.8, 126.6, 126.2, 124.9, 123.8, 123.1, 16.3. HRMS (ESI) m/z: calcd for $C_{18}H_{16}N$ $[M+H]^+$ 246.1277, found 246.1274.

(*E*)-4-bromo-1-styrylisoquinoline 1ac



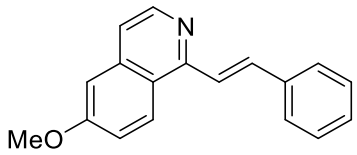
Light yellow solid, 35% yield; m.p. 94-95 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 8.73-8.72 (m, 1H), 8.35-8.3 (m, 1H), 8.19-8.17 (m, 1H), 8.00-7.90 (m, 2H), 7.80-7.77 (m, 1H), 7.70-7.65 (m, 3H), 7.424 (t, *J* = 7.4 Hz, 1H), 7.36 (t, *J* = 7.3 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.0, 144.2, 136.7, 136.6, 135.2, 131.1, 128.9, 128.8, 128.1, 127.8, 127.5, 126.6, 124.8, 122.1, 118.3. HRMS (ESI) m/z: calcd for $C_{17}H_{13}BrN$ $[M+H]^+$ 310.0226, found 310.0222.

(*E*)-5-methyl-1-styrylisoquinoline 1ad



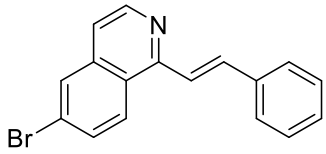
Light yellow solid, 52% yield; m.p. 103-104 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 8.51 (d, *J* = 5.6 Hz, 1H), 8.24 (d, *J* = 8.7 Hz, 1H), 7.98 (s, 2H), 7.71-7.70 (m, 2H), 7.58 (s, 1H), 7.48-7.40 (m, 4H), 7.36-7.32 (m, 1H), 2.54 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.2, 142.6, 140.2, 137.1, 137.0, 135.6, 129.5, 128.8, 128.6, 127.4, 126.2, 125.2, 124.3, 123.0, 119.6, 21.9. HRMS (ESI) m/z: calcd for $C_{18}H_{16}N$ $[M+H]^+$ 246.1277, found 246.1274.

(*E*)-6-methoxy-1-styrylisoquinoline 1af



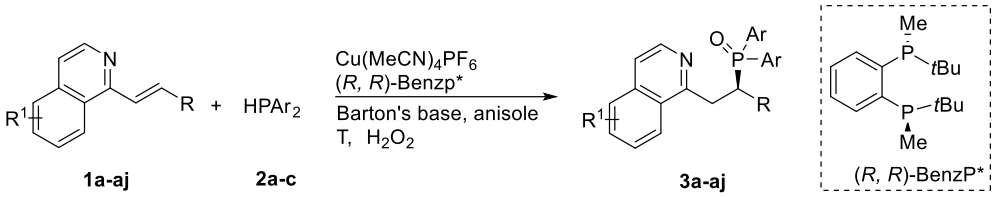
Yellow solid, 50% yield; m.p. 101-102 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 8.49 (d, *J* = 5.6 Hz, 1H), 8.26 (d, *J* = 9.3 Hz, 1H), 7.93 (d, *J* = 4.5 Hz, 2H), 7.68 (d, *J* = 7.5 Hz, 2H), 7.46 (d, *J* = 7.5 Hz, 1H), 7.41 (t, *J* = 7.4 Hz, 2H), 7.33 (t, *J* = 7.3 Hz, 1H), 7.25-7.23 (m, 1H), 7.06-7.05 (m, 1H), 3.94 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 160.5, 153.9, 143.0, 138.9, 136.9, 135.7, 128.8, 128.6, 127.4, 126.4, 122.9, 122.5, 120.1, 119.4, 104.7, 55.5. HRMS (ESI) m/z: calcd for $C_{18}H_{16}NO$ $[M+H]^+$ 262.1226, found 262.1224.

(*E*)-6-bromo-1-styrylisoquinoline 1ah



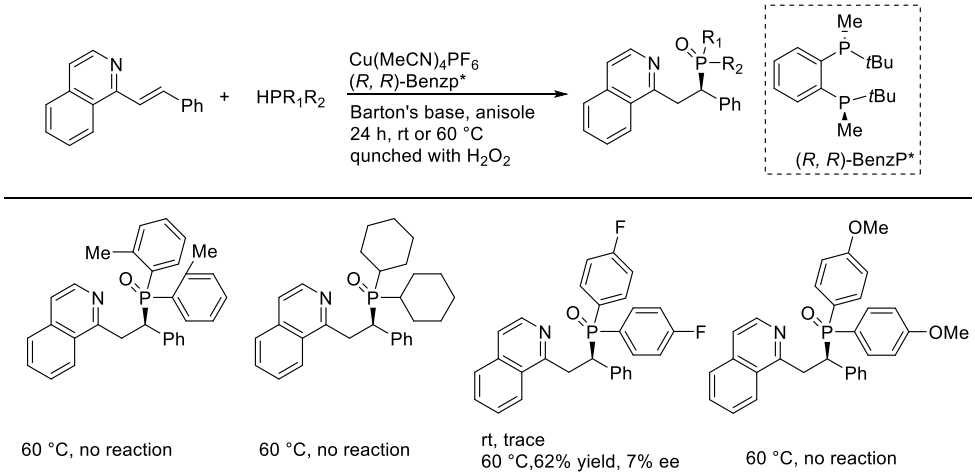
Light yellow solid, 42% yield; m.p. 96-97 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 8.57 (d, *J* = 5.6 Hz, 1H), 8.21 (d, *J* = 9.0 Hz, 1H), 8.00-7.97 (m, 2H), 7.90 (d, *J* = 15.6 Hz, 1H), 7.70-7.67 (m, 3H), 7.45 (d, *J* = 5.6 Hz, 1H), 7.43-7.40 (m, 2H), 7.37-7.34 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 154.8, 143.6, 137.9, 136.7, 136.6, 130.7, 129.4, 128.9, 128.8, 127.5, 126.3, 125.1, 124.7, 122.2, 118.8. HRMS (ESI) m/z: calcd for $C_{17}H_{13}BrN$ $[M+H]^+$ 310.0226, found 310.0222.

3. A typical procedure for Cu(I)-catalyzed 1,4-conjugate hydrophosphination of alkenyl isoquinolines



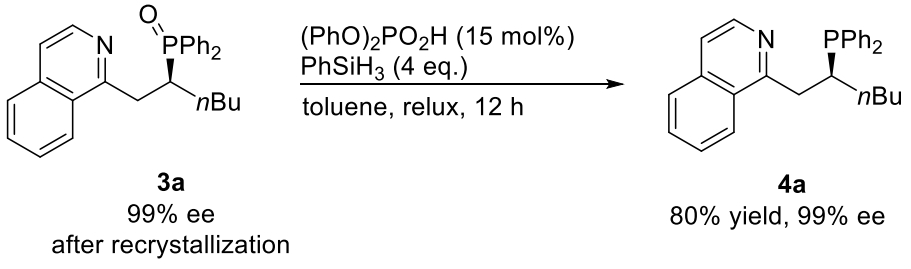
In an argen-filled glovebox, a flame-dried screw-cap reaction tube equipped with a magnetic stir bar was charged with $Cu(MeCN)_4PF_6$ (0.02 mmol, 7.4 mg) and (*R, R*)-BenzP* (0.022 mmol, 6.2 mg). Anisole (1 mL) was added, then the mixture was stirred at room temperature for 15 min. Alkenyl isoquinolines **1** (0.20 mmol), Barton's base (0.3 mmol) and diarylphophines **2** (0.3 mmol) were added. The Schleck reaction vial was sealed with a rubber plug and taken out glovebox. The resulting solution was allowed to stir at 0°C or room temperature. When the reaction completed (monitored by TLC), the reaction mixture was quenched by 30% H_2O_2 aqueous solution (100 μL) and was stirred for additional 20 minutes at room temperature. The organic solvent was removed and the residue was purified by column chromatography to give hydrophosphination products. The ee values of **3** were determined by HPLC.

Other diarylphophines tried:



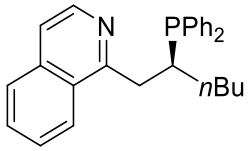
4. Preparation of 4a, 7 and 8

Preparation of 4a: performed by the procedure of Masahiro Terada and coworkers.[5]



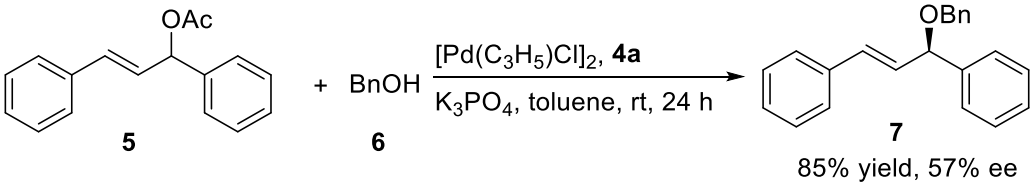
To a solution of **3a** (82.6 mg, 0.2 mmol) and diphenyl phosphate (7.6 mg, 0.03 mmol) in toluene (2.0 mL) were added phenylsilane (86.6 mg, 0.8 mmol). The reaction mixture was degassed under an argen atmosphere and refluxed using a heating mantle for 12 h. After the resulting mixture was cooled to room temperature, the resulting mixture was directly passed through flash colum chromatography to give **4a** as a colorless oil. The enantiomeric excess was determined by HPLC analysis (the corresponding oxidized compound **3a**).

(*S*)-1-(2-(diphenylphosphaneyl)hexyl)isoquinoline 4a



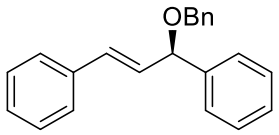
Colorless oil, 80% yield; $[\alpha]^{20}_{D}$ = 18.0 (c = 0.4, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.48 (d, *J* = 5.6 Hz, 1H), 7.83 (d, *J* = 8.5 Hz, 1H), 7.79 (d, *J* = 8.1 Hz, 1H), 7.69-7.62 (m, 5H), 7.51-7.47 (m, 2H), 7.40-7.34 (m, 3H), 7.32-7.29 (m, 3H), 3.45-3.32 (m, 2H), 3.30-3.25 (m, 1H), 1.62-31.44 (m, 2H), 1.42-1.33 (m, 1H), 1.29-1.20 (m, 1H), 1.15-1.07 (m, 2H), 0.71 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 160.8 (d, *J* = 10.7 Hz), 141.8, 137.2 (d, *J* = 14.0 Hz), 137.1 (d, *J* = 15.3 Hz), 136.1, 134.1, 134.0, 133.8 (d, *J* = 19.0 Hz), 129.6, 128.8 (d, *J* = 10.0 Hz), 128.4 (d, *J* = 6.6 Hz), 128.3 (d, *J* = 7.2 Hz), 127.4, 127.3, 126.8, 125.1, 119.3, 36.2 (d, *J* = 16.5 Hz), 35.5 (d, *J* = 12.7 Hz), 30.7 (d, *J* = 13.5 Hz), 29.5 (d, *J* = 10.8 Hz), 22.9, 13.8. ^{31}P NMR (200 MHz, $CDCl_3$): δ -3.8; HRMS (ESI) m/z: calcd for $C_{27}H_{29}NP$ $[M+H]^+$ 398.2032, found 398.2026.

The use of ligand 4a in Pd-catalyzed asymmetric allylic etherification



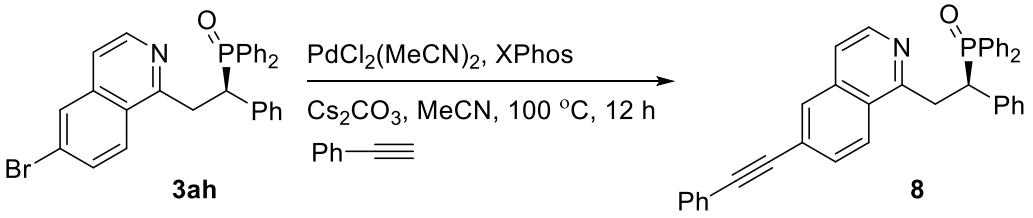
A dried 10 mL Schlenk tube equipped with a magnetic stirring bar was charged with $[Pd(C_3H_5)Cl]_2$ (1.8 mg, 0.005 mmol) and ligand **4a** (6.0 mg, 0.015 mmol) in a glove box under Ar atmosphere. Anhydrous toluene (1 mL) was added, then the mixture was stirred at room temperature for 20 min. (*E*)-1,3-diphenylallyl acetate **5** (50.4 mg, 0.20 mmol), K_3PO_4 (63.7 mg, 0.3 mmol) and benzyl alcohol **6** (32.4 mg, 0.3 mmol) were added. The Schleck reaction vial was sealed with a rubber plug and taken out glovebox. The resulting solution was allowed to stir at room temperature for 24 h. The reaction mixture was diluted with ethyl acetate (10 mL) and water (10 mL). The aqueous layer was extracted with EtOAc (10 mL x 2). The organic layer was washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated under vacuum. After removal of the solvent, the crude mixture was purified by column chromatography affording the product **7**. The ee value of **7** was determined by HPLC.

(*R, E*)-(3-(benzyloxy)prop-1-ene-1,3-diyl)dibenzene 7[5]



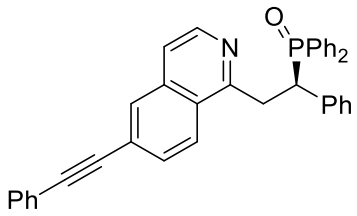
85% yield; *ee* was determined to be 57% by HPLC analysis with a Chiralcel OJ-H column (hexane/2-propanol 96:4, 1.0 mL/min, 254 nm); t_r (minor) = 15.45 min, t_r (major) = 17.93 min.

Preparation of 8:



An oven-dried 10 mL screw-cap reaction tube with magnetic stir bar was charged with $Pd(MeCN)_2Cl_2$ (1.3 mg, 5 mol %), XPhos (7.2 mg, 15 mol %), Cs_2CO_3 (81.5 mg, 2.5 equiv), **3ah** (36.3 mg, 0.10 mmol), phenylacetylene (14 μL, 1.3 equiv) and MeCN (1 mL, 0.1 M) under argon. The mixture was then stirred vigorously at 100 °C for 12 h. After completion (monitored by TLC), the reaction mixture was diluted with ethyl acetate (5 mL), then passing through a short pad of silica gel layer and eluted with ethyl acetate (20 mL). After removal of the solvent, the crude mixture was purified by column chromatography affording the product **8**.

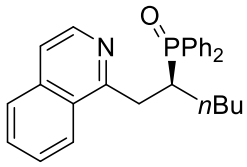
(*R*)-diphenyl(1-phenyl-2-(6-(phenylethynyl)isoquinolin-1-yl)ethyl)phosphine oxide 8



Yellow solid, 89% yield; $[\alpha]^{20}_D$ = 44.4 (c = 0.6, $CHCl_3$); *ee* was determined to be 82% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 75:25, 1.0 mL/min, 220 nm); t_r (major) = 14.71 min, t_r (minor) = 17.32 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.38 (d, *J* = 5.7 Hz, 1H), 8.05-7.99 (m, 3H), 7.83 (s, 1H), 7.57-7.54 (m, 3H), 7.53-7.49 (m, 2H), 7.45-7.42 (m, 3H), 7.38-7.36 (m, 5H), 7.32-7.29 (m, 2H), 7.24-7.21 (m, 2H), 7.04 (t, *J* = 7.2 Hz, 2H), 7.01-6.98 (m, 1H), 4.81-4.77 (m, 1H), 4.19-4.12 (m, 1H), 3.87-3.81 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.2 (d, *J* = 11.8 Hz), 142.2, 136.2 (d, *J* = 5.3 Hz), 135.7, 132.6 (d, *J* = 161.2 Hz), 131.8 (d, *J* = 55.8 Hz), 131.7, 131.6 (d, *J* = 2.4 Hz), 131.3 (d, *J* = 8.9 Hz), 131.22 (d, *J* = 2.6 Hz), 131.0 (d, *J* = 8.9 Hz), 130.1, 130.0 (d, *J* = 2.6 Hz), 129.6, 128.8, 128.7 (d, *J* = 11.6 Hz), 128.5, 128.1 (d, *J* = 11.7 Hz), 128.0 (d, *J* = 1.5 Hz), 126.8 (d, *J* = 1.6 Hz), 126.4, 125.2, 124.8, 125.2, 124.8, 122.7, 119.0, 91.8, 88.7, 45.0 (d, *J* = 68.1 Hz), 33.8. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.2; HRMS (ESI) m/z: calcd for $C_{27}H_{29}NP$ $[M+H]^+$ 534.1981, found 534.1979.

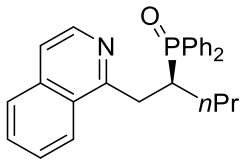
5. Characterization data (^{1}H NMR, ^{13}C NMR, ^{31}P NMR, ^{19}F NMR, HRMS, and HPLC) of the products

(*S*)-(1-(isoquinolin-1-yl)hexan-2-yl)diphenylphosphine oxide 3a



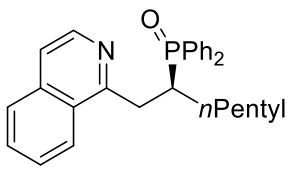
White solid, 94% yield; m.p. 95-96 °C; $[\alpha]^{20}_D$ = 5.2 (c = 0.6, $CHCl_3$); *ee* was determined to be 90% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 1.0 mL/min, 220 nm); t_r (major) = 11.43 min, t_r (minor) = 20.05 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.41 (d, *J* = 5.7 Hz, 1H), 8.11 (d, *J* = 8.5 Hz, 1H), 7.92-7.88 (m, 2H), 7.79-7.75 (m, 2H), 7.71 (d, *J* = 8.2 Hz, 1H), 7.60 (t, *J* = 7.0 Hz, 1H), 7.52 (t, *J* = 8.1 Hz, 1H), 7.47-7.44 (m, 3H), 7.42 (d, *J* = 5.7 Hz, 1H), 7.24-7.18 (m, 3H), 3.69-3.63 (m, 2H), 3.57-3.50 (m, 1H), 1.80-1.71 (m, 1H), 1.65-1.59 (m, 1H), 1.17-1.12 (m, 1H), 1.10-0.98 (m, 3H), 0.58 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.1 (d, *J* = 10.8 Hz), 141.4, 136.0, 133.5 (d, *J* = 56.7 Hz), 132.7 (d, *J* = 56.1 Hz), 131.4, 131.3, 131.1, 131.0, 130.9 (d, *J* = 8.5 Hz), 130.8 (d, *J* = 8.8 Hz), 129.8, 128.6 (d, *J* = 11.4 Hz), 128.2 (d, *J* = 11.2 Hz), 127.3, 127.1 (d, *J* = 8.3 Hz), 125.0, 119.5, 35.5 (d, *J* = 71.2 Hz), 32.0, 30.8, 21.0 (d, *J* = 9.2 Hz), 14.2. ^{31}P NMR (200 MHz, $CDCl_3$): δ 37.0; HRMS (ESI) m/z: calcd for $C_{27}H_{29}NOP$ $[M+H]^+$ 414.1981, found 414.1975.

(*S*)-(1-(isoquinolin-1-yl)pentan-2-yl)diphenylphosphine oxide 3b



Colorless oil, 96% yield; $[\alpha]^{20}_D$ = 4.7 (c = 0.6, $CHCl_3$); *ee* was determined to be 86% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 0.5 mL/min, 220 nm); t_r (major) = 11.84 min, t_r (minor) = 22.47 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.39 (d, *J* = 5.7 Hz, 1H), 8.07 (d, *J* = 8.5 Hz, 1H), 7.91-7.87 (m, 2H), 7.79-7.75 (m, 2H), 7.67 (d, *J* = 8.1 Hz, 1H), 7.57-7.54 (m, 1H), 7.49-7.40 (m, 4H), 7.39 (d, *J* = 5.7 Hz, 1H), 7.22-7.16 (m, 3H), 3.74-3.68 (m, 1H), 3.67-3.60 (m, 1H), 3.56-3.49 (m, 1H), 1.77-1.68 (m, 1H), 1.67-1.57 (m, 1H), 1.23-1.14 (m, 1H), 1.11-1.03 (m, 1H), 0.61 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.0 (d, *J* = 10.6 Hz), 141.4, 136.0, 133.4 (d, *J* = 55.9 Hz), 132.7 (d, *J* = 55.2 Hz), 131.4, 131.3, 131.1 (d, *J* = 2.6 Hz), 130.8 (d, *J* = 8.5 Hz), 129.8, 128.6 (d, *J* = 13.4 Hz), 128.2 (d, *J* = 11.4 Hz), 127.3, 127.1 (d, *J* = 8.1 Hz), 125.1, 119.4, 35.8 (d, *J* = 71.0 Hz), 31.9, 29.8 (d, *J* = 8.9 Hz), 28.2, 22.6, 13.6. ^{31}P NMR (200 MHz, $CDCl_3$): δ 37.2; HRMS (ESI) m/z: calcd for $C_{26}H_{27}NOP$ $[M+H]^+$ 400.1825, found 400.1819.

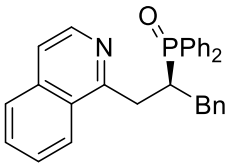
(S)-(1-(isoquinolin-1-yl)heptan-2-yl)diphenylphosphine oxide 3c



Light yellow oil, 95% yield; m.p. 95-96 °C; $[\alpha]^{20}_D$ = 6.2 (c = 0.4, $CHCl_3$); *ee* was determined to be 84% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 1.0 mL/min, 220 nm); t_r (major) = 11.52 min, t_r (minor) = 21.08 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.40 (d, *J* = 5.7 Hz, 1H), 8.11 (d, *J* = 8.4 Hz, 1H), 7.91-7.7.87 (m, 2H), 7.78-

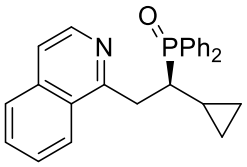
7.45 (m, 2H), 7.70 (d, J = 8.0 Hz, 1H), 7.59 (t, J = 7.1 Hz, 1H), 7.51 (t, J = 7.8 Hz, 1H), 7.46-7.43 (m, 3H), 7.41 (d, J = 5.7 Hz, 1H), 7.24-7.18 (m, 3H), 3.67-3.61 (m, 2H), 3.57-3.50 (m, 1H), 1.79-1.69 (m, 1H), 1.66-1.57 (m, 1H), 1.17-1.10 (m, 1H), 1.05-0.94 (m, 5H), 0.62 (t, J = 6.5 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.1 (d, J = 10.8 Hz), 141.4, 136.0, 133.2 (d, J = 56.2 Hz), 132.5 (d, J = 52.8 Hz), 131.5 (d, J = 2.5 Hz), 131.1 (d, J = 2.5 Hz), 131.0 (d, J = 8.0 Hz), 130.8 (d, J = 8.7 Hz), 129.8, 128.6 (d, J = 11.1 Hz), 128.2 (d, J = 11.1 Hz), 127.3, 127.2 (d, J = 2.5 Hz), 125.1, 119.5, 35.9 (d, J = 71.9 Hz), 31.9, 31.6, 28.5, 27.4 (d, J = 9.1 Hz), 22.1, 13.8. ^{31}P NMR (200 MHz, $CDCl_3$): δ 37.5; HRMS (ESI) m/z: calcd for $C_{28}H_{31}NOP$ $[M+H]^+$ 428.2138, found 428.2131.

(*S*)- (1-(isoquinolin-1-yl)-3-phenylpropan-2-yl)diphenylphosphine oxide 3d



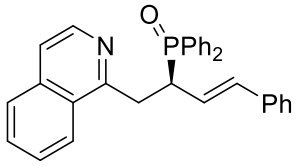
Yellow oil, 80% yield; $[\alpha]^{20}_D$ = 4.5 (c = 0.4, $CHCl_3$); *ee* was determined to be 80% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 230 nm); t_r (minor) = 8.39 min, t_r (major) = 12.42 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.27 (d, J = 5.8 Hz, 1H), 7.97 (d, J = 8.6 Hz, 1H), 7.89-7.85 (m, 2H), 7.77-7.74 (m, 2H), 7.61 (d, J = 8.1 Hz, 1H), 7.53 (t, J = 7.3 Hz, 1H), 7.45 (t, J = 8.1 Hz, 1H), 7.41-7.35 (m, 3H), 7.27 (d, J = 5.7 Hz, 1H), 7.18-7.12 (m, 3H), 6.99-6.88 (m, 5H), 4.16-4.10 (m, 1H), 3.68-2.3.61 (m, 1H), 3.58-3.51 (m, 1H), 3.18-3.12 (m, 1H), 2.99-2.92 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.6 (d, J = 8.9 Hz), 141.2, 139.1 (d, J = 10.2 Hz), 135.8, 133.0 (d, J = 47.4 Hz), 132.3 (d, J = 47.1 Hz), 131.4 (d, J = 2.5 Hz), 131.0 (d, J = 2.5 Hz), 130.9, 130.8, 130.7, 130.6, 129.7, 129.0, 128.6 (d, J = 11.7 Hz), 128.1 (d, J = 11.7 Hz), 127.9, 127.0 (d, J = 14.2 Hz), 125.8, 125.0, 119.3, 37.8 (d, J = 71.7 Hz), 34.2, 31.5. ^{31}P NMR (200 MHz, $CDCl_3$): δ 36.2; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NOP$ $[M+H]^+$ 448.1825, found 448.1830.

(*R*)-(1-cyclopropyl-2-(isoquinolin-1-yl)ethyl)diphenylphosphine oxide 3e



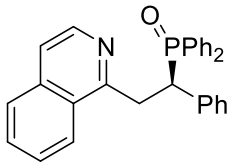
White solid, 92% yield; m.p. 148-149 °C; $[\alpha]^{20}_D$ = 4.7 (c = 1.21, $CHCl_3$); *ee* was determined to be 82% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 0.5 mL/min, 220 nm); t_r (major) = 34.97 min, t_r (minor) = 38.23 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.38 (d, J = 5.7 Hz, 1H), 8.21 (d, J = 8.5 Hz, 1H), 7.89-7.82 (m, 4H), 7.70 (d, J = 8.1 Hz, 1H), 7.59 (t, J = 7.1 Hz, 1H), 7.51 (t, J = 7.4 Hz, 1H), 7.47-7.40 (m, 4H), 7.32-7.26 (m, 3H), 3.75-3.62 (m, 2H), 2.82-2.76 (m, 1H), 1.17-1.13 (m, 1H), 0.05-0.02 (m, 1H), -0.05-(-0.11) (m, 1H), -0.42-(-0.52) (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.8 (d, J = 11.6 Hz), 141.4, 136.0, 133.5 (d, J = 95.2 Hz), 132.6 (d, J = 92.8 Hz), 130.9 (d, J = 8.8 Hz), 131.41, 131.39, 131.35 (d, J = 9.1 Hz), 131.31, 129.8, 128.4 (d, J = 11.5 Hz), 128.3 (d, J = 11.6 Hz), 127.8, 127.1, 125.4, 119.5, 42.8 (d, J = 70.6 Hz), 33.3, 10.5, 5.72, 4.1 (d, J = 12.8 Hz). ^{31}P NMR (200 MHz, $CDCl_3$): δ 35.9; HRMS (ESI) m/z: calcd for $C_{26}H_{25}NOP$ $[M+H]^+$ 398.1668, found 398.1662.

(*R*, *E*)-(1-(isoquinolin-1-yl)-4-phenylbut-3-en-2-yl)diphenylphosphine oxide 3f



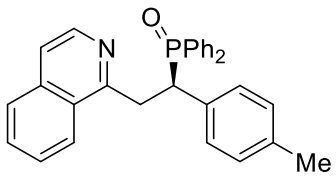
White solid, 70% yield; m.p. 154-155 °C; $[\alpha]^{20}_{D}$ = 47.2 (0.6, $CHCl_3$); *ee* was determined to be 86% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 80:20, 1.0 mL/min, 220 nm); t_r (minor) = 24.15 min, t_r (major) = 29.28 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.40 (d, *J* = 5.7 Hz, 1H), 8.19 (d, *J* = 8.5 Hz, 1H), 7.98-7.94 (m, 2H), 7.88-7.84 (m, 2H), 7.71 (d, *J* = 8.0 Hz, 1H), 7.60-7.53 (m, 2H), 7.46-7.41 (m, 7H), 7.14-7.06 (m, 3H), 7.00 (d, *J* = 8.6 Hz, 2H), 6.24-6.12 (m, 2H), 4.39-4.33 (m, 1H), 3.89-3.75 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.4 (d, *J* = 12.9 Hz), 141.6, 136.8 (d, *J* = 2.7 Hz), 136.82, 136.1, 135.1 (d, *J* = 17.3 Hz), 132.2 (d, *J* = 5.2 Hz), 131.76 (d, *J* = 2.5 Hz), 131.71 (d, *J* = 2.5 Hz), 131.5 (d, *J* = 8.8 Hz), 131.3 (d, *J* = 8.6 Hz), 129.9, 128.7 (d, *J* = 11.0 Hz), 128.5 (d, *J* = 11.5 Hz), 128.3, 127.5, 127.3 (d, *J* = 5.7 Hz), 127.28, 126.15, 126.14, 125.1, 124.0 (d, *J* = 7.3 Hz), 119.6, 43.4 (d, *J* = 68.5 Hz), 32.4. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.2; HRMS (ESI) m/z: calcd for $C_{31}H_{27}NOP$ $[M+H]^+$ 460.1825, found 460.1818.

(*R*)-(2-(isoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3g



White solid, 87% yield; m.p. 159-160 °C; $[\alpha]^{20}_{D}$ = 153.7 (c = 0.6, $CHCl_3$); *ee* was determined to be 92% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 1.0 mL/min, 220 nm); t_r (major) = 13.93 min, t_r (minor) = 11.64 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 1.4 Hz, 1H), 8.06-7.99 (m, 3H), 7.62-7.60 (m, 1H), 7.53-7.49 (m, 3H), 7.44-7.37 (m, 6H), 7.33-7.32 (m, 1H), 7.28-7.26 (m, 1H), 7.22-7.19 (m, 2H), 7.02 (t, *J* = 1.8 Hz, 2H), 6.98-6.95 (m, 1H), 4.86-4.84 (m, 1H), 4.23-4.16 (m, 1H) 3.87-3.81 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.0 (d, *J* = 12.4 Hz), 141.4, 136.3 (d, *J* = 5.4 Hz), 135.9, 132.7 (d, *J* = 60.1 Hz), 131.9 (d, *J* = 54.5 Hz), 131.6 (d, *J* = 2.3 Hz), 131.3 (d, *J* = 8.5 Hz), 131.2 (d, *J* = 2.5 Hz), 131.0 (d, *J* = 8.7 Hz), 130.1 (d, *J* = 5.6 Hz), 129.8, 128.7 (d, *J* = 11.1 Hz), 128.1, 128.0, 127.4, 127.0, 126.73, 126.72, 125.0, 119.4, 44.8 (d, *J* = 67.8 Hz), 33.9. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.4; HRMS (ESI) m/z: calcd for $C_{29}H_{25}NOP$ $[M+H]^+$ 434.1668, found 434.1661.

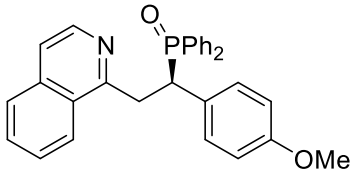
(*R*)-(2-(isoquinolin-1-yl)-1-(*p*-tolyl)ethyl)diphenylphosphine oxide 3h



White solid, 75% yield; m.p. 178-179 °C; $[\alpha]^{20}_{D}$ = 148.3 (c = 0.6, $CHCl_3$); *ee* was determined to be 91% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 1.0 mL/min, 220 nm); t_r (minor) = 11.44 min, t_r (major) = 13.25 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 1.4 Hz, 1H), 8.04 (d, *J* = 2.1 Hz, 1H), 7.98 (t, *J* = 2.2 Hz, 2H), 7.63-7.62 (m, 1H), 7.56-7.51 (m, 3H), 7.46-7.43 (m, 1H), 7.38-7.33 (m, 4H), 7.31-7.26 (m, 3H), 7.23-7.20 (m, 2H), 6.82 (d, *J* = 1.9 Hz, 2H), 4.88-4.84 (m, 1H), 4.18-4.11 (m, 1H), 3.87-3.81 (m, 1H), 2.09 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.1 (d, *J* = 12.0 Hz),

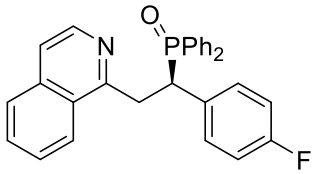
141.4, 136.2 (d, J = 2.4 Hz), 133.1 (d, J = 5.3 Hz), 132.8 (d, J = 50.8 Hz), 132.0 (d, J = 45.0 Hz), 131.53, 131.51, 131.3 (d, J = 8.6 Hz), 131.18, 131.16, 131.1 (d, J = 8.9 Hz), 129.9, 129.8 (d, J = 14.6 Hz), 128.7, 128.6 (d, J = 11.3 Hz), 128.1 (d, J = 11.6 Hz), 127.4, 127.0, 125.0, 119.4, 44.2 (d, J = 68.3 Hz), 34.0, 30.0. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.3; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NOP$ $[M+H]^+$ 448.1825, found 448.1818.

(*R*)-(2-(isoquinolin-1-yl)-1-(4-methoxyphenyl)ethyl)diphenylphosphine oxide 3i



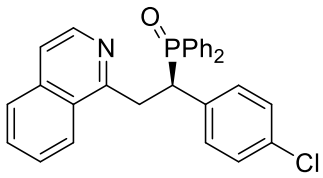
White solid, 80% yield; m.p. 181-182 °C; $[\alpha]^{20}_D$ = 143.3 (c = 0.7, $CHCl_3$); *ee* was determined to be 83% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 90:10, 1.0 mL/min, 220 nm); t_r (minor) = 12.81 min, t_r (major) = 14.30 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.36 (d, J = 5.6 Hz, 1H), 8.06-8.01 (m, 3H), 7.63 (d, J = 8.1 Hz, 1H), 7.58-7.50 (m, 3H), 7.46-7.41 (m, 4H), 7.35-7.30 (m, 4H), 7.25-7.22 (m, 2H), 6.57 (d, J = 8.6 Hz, 2H), 4.85-4.81 (m, 1H), 4.20-4.13 (m, 1H), 3.83-3.78 (m, 1H), 3.58 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.3 (d, J = 2.2 Hz), 158.2 (d, J = 12.6 Hz), 141.5, 135.9, 132.9 (d, J = 55.3 Hz), 132.1 (d, J = 49.1 Hz), 131.6 (d, J = 2.3 Hz), 131.3 (d, J = 8.6 Hz), 131.18 (d, J = 2.5 Hz), 131.06, 131.05, 131.02 (d, J = 5.4 Hz), 129.7, 128.7 (d, J = 11.2 Hz), 128.1, 128.08 (d, J = 11.7 Hz), 127.4, 127.0 (d, J = 4.3 Hz), 124.9, 119.4, 113.4, 55.0, 43.8 (d, J = 68.7 Hz), 33.9. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.4; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NO_2P$ $[M+H]^+$ 464.1774, found 464.1767.

(*R*)-(1-(4-fluorophenyl)-2-(isoquinolin-1-yl)ethyl)diphenylphosphine oxide 3j



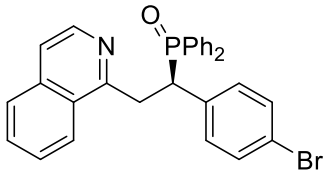
White solid, 64% yield; m.p. 171-172 °C; $[\alpha]^{20}_D$ = 138.7 (c = 0.6, $CHCl_3$); *ee* was determined to be 83% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 99:1, 0.5 mL/min, 230 nm); t_r (minor) = 28.45 min, t_r (major) = 30.33 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, J = 5.7 Hz, 1H), 8.04-8.00 (m, 3H), 7.65 (d, J = 8.1 Hz, 1H), 7.56-7.50 (m, 3H), 7.48-7.43 (m, 4H), 7.37-7.30 (m, 4H), 7.26-7.23 (m, 2H), 6.72 (t, J = 8.7 Hz, 2H), 4.86-4.82 (m, 1H), 4.18-4.11 (m, 1H), 3.81-3.75 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 162.6 (d, J = 2.5 Hz), 160.7 (d, J = 2.5 Hz), 157.8 (d, J = 12.6 Hz), 141.5, 135.9, 132.7, 132.1 (t, J = 5.4 Hz), 131.9 (d, J = 63.8 Hz), 131.7 (d, J = 2.5 Hz), 131.5 (dd, J = 7.5, 5.9 Hz), 131.3, 131.2. 130.9 (d, J = 8.8 Hz), 129.8, 128.8 (d, J = 11.0 Hz), 128.2 (d, J = 11.6 Hz), 127.4, 127.1 (d, J = 2.8 Hz), 124.8, 119.5, 114.9 (d, J = 21.8 Hz), 43.8 (d, J = 68.1 Hz), 33.9. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.1; ^{19}F NMR (376 MHz, $CDCl_3$): δ -115.8; HRMS (ESI) m/z: calcd for $C_{29}H_{24}FNOP$ $[M+H]^+$ 452.1574, found 452.1567.

(*R*)-(1-(4-chlorophenyl)-2-(isoquinolin-1-yl)ethyl)diphenylphosphine oxide 3k



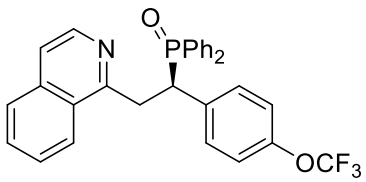
White solid, 80% yield; m.p. 215-216 °C; $[\alpha]^{20}_D$ = 148.0 (c = 0.6, $CHCl_3$); *ee* was determined to be 74% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 0.5 mL/min, 220 nm); t_r (minor) = 15.97 min, t_r (major) = 17.22 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 5.7 Hz, 1H), 8.03-8.00 (m, 3H), 7.65 (d, *J* = 8.1 Hz, 1H), 7.56-7.52 (m, 3H), 7.46-7.43 (m, 4H), 7.36-7.30 (m, 4H), 7.26-7.23 (m, 2H), 7.00 (d, *J* = 8.4 Hz, 2H), 4.89-4.85 (m, 1H), 4.18-4.11 (m, 1H), 3.81-3.75 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.6 (d, *J* = 12.3 Hz), 135.9, 135.1 (d, *J* = 5.3 Hz), 132.54 (d, *J* = 2.8 Hz), 132.51, 132.1 (d, *J* = 42.3 Hz), 131.8 (d, *J* = 2.3 Hz), 131.41, 131.39, 131.31, 131.30, 131.27 (d, *J* = 8.7 Hz), 130.9 (d, *J* = 8.9 Hz), 129.8, 128.8 (d, *J* = 11.1 Hz), 128.2, 128.1, 127.4, 127.1, 124.7, 119.5, 43.9 (d, *J* = 65.3 Hz), 33.7. ^{31}P NMR (200 MHz, $CDCl_3$): δ 33.9; HRMS (ESI) m/z: calcd for $C_{29}H_{24}ClNOP$ $[M+H]^+$ 468.1279, found 468.1273.

(*R*)-(1-(4-bromophenyl)-2-(isoquinolin-1-yl)ethyl)diphenylphosphine oxide 3l



White solid, 70% yield; m.p. 230-231 °C; $[\alpha]^{20}_D$ = 165.4 (c = 0.6, $CHCl_3$); *ee* was determined to be 84% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (minor) = 7.80 min, t_r (major) = 8.42 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 5.7 Hz, 1H), 8.04-7.99 (m, 3H), 7.67 (d, *J* = 8.1 Hz, 1H), 7.57-7.52 (m, 3H), 7.49-7.44 (m, 4H), 7.38-7.32 (m, 2H), 7.28-7.26 (m, 4H), 7.16 (d, *J* = 8.3 Hz, 2H), 4.88-4.84 (m, 1H), 4.17-4.10 (m, 1H), 3.81-3.75 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.5 (d, *J* = 12.5 Hz), 141.4, 135.9, 135.6 (d, *J* = 5.3 Hz), 132.5 (d, *J* = 56.7 Hz), 131.8, 131.7, 131.4 (d, *J* = 2.5 Hz), 131.3, 131.2 (d, *J* = 4.7 Hz), 131.06, 131.05, 130.9 (d, *J* = 8.9 Hz), 129.8, 128.8 (d, *J* = 11.1 Hz), 128.2 (d, *J* = 11.7 Hz), 127.4, 127.2, 124.7, 120.8 (d, *J* = 2.8 Hz), 119.5, 43.9 (d, *J* = 67.7 Hz), 33.7. ^{31}P NMR (200 MHz, $CDCl_3$): δ 33.7; HRMS (ESI) m/z: calcd for $C_{29}H_{24}BrNOP$ $[M+H]^+$ 512.0773, found 512.0768.

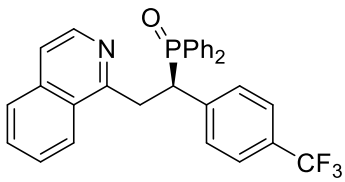
(*R*)-(2-(isoquinolin-1-yl)-1-(4-(trifluoromethoxy)phenyl)ethyl)diphenylphosphine oxide 3m



White solid, 94% yield; m.p. 182-183 °C; $[\alpha]^{20}_D$ = 139.4 (c = 0.6, $CHCl_3$); *ee* was determined to be 81% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 0.5 mL/min, 220 nm); t_r (minor) = 13.32 min, t_r (major) = 14.20 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.36 (d, *J* = 5.7 Hz, 1H), 8.04-8.01 (m, 3H), 7.65 (d, *J* = 8.1 Hz, 1H), 7.55-7.49 (m, 3H), 7.47-7.40 (m, 6H), 7.37 (d, *J* = 5.7 Hz, 1H), 7.32-7.29 (m, 1H), 7.24-7.20 (m, 2H), 6.89 (d, *J* = 8.3 Hz, 2H), 4.91-4.87 (m, 1H), 4.19-4.13 (m, 1H), 3.84-3.78 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.5 (d, *J* = 12.2 Hz), 147.9, 141.5, 135.9, 135.4 (d, *J* = 5.3 Hz), 132.5 (d, *J* = 99.2 Hz), 131.84, 131.82 (d, *J* = 2.5 Hz), 131.4, 131.3, 131.2, 131.1,

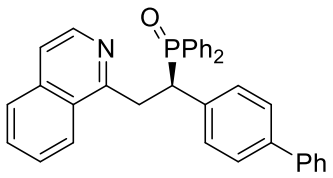
130.9 (d, J = 8.9 Hz), 129.8, 128.8 (d, J = 11.3 Hz), 128.1 (d, J = 11.6 Hz), 127.4, 127.1, 124.7, 123.4 (q, J = 255.3 Hz), 120.4, 119.6, 44.0 (d, J = 67.7 Hz), 33.8. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.2; ^{19}F NMR (376 MHz, $CDCl_3$): δ -57.9; HRMS (ESI) m/z: calcd for $C_{30}H_{24}F_3NO_2P$ $[M+H]^+$ 518.1491, found 518.1487.

(*R*)-(2-(isoquinolin-1-yl)-1-(4-(trifluoromethyl)phenyl)ethyl)diphenylphosphine oxide 3n



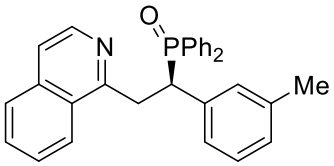
White solid, 90% yield; m.p. 235-236 °C; $[\alpha]$ $^{20}_D$ = 129.8 (c = 0.8, $CHCl_3$); *ee* was determined to be 74% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 90:10, 0.5 mL/min, 220 nm); t_r (minor) = 10.29 min, t_r (major) = 11.01 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.37 (d, J = 5.4 Hz, 1H), 8.07-8.05 (m, 3H), 7.69 (d, J = 8.0 Hz, 1H), 7.59-7.54 (m, 5H), 7.51-7.47 (m, 4H), 7.40 (d, J = 5.3 Hz, 1H), 7.34-7.27 (m, 5H), 5.00 (s, 1H), 4.26-4.19 (m, 1H), 3.88-3.83 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.3 (d, J = 12.2 Hz), 141.4, 140.9 (d, J = 5.2 Hz), 135.9, 132.3 (d, J = 63.0 Hz), 131.9 (d, J = 2.3 Hz), 131.5 (d, J = 2.4 Hz), 131.3 (d, J = 2.4 Hz), 131.0, 130.9 (d, J = 8.7 Hz), 130.4 (d, J = 5.5 Hz), 129.9, 128.8 (d, J = 11.4 Hz), 128.2 (d, J = 11.7 Hz), 127.3, 127.2 (d, J = 4.3 Hz), 125.2 (q, J = 270.4 Hz), 124.8, 124.6, 119.6, 119.6, 44.4 (d, J = 67.0 Hz), 33.7. ^{31}P NMR (200 MHz, $CDCl_3$): δ 33.9; ^{19}F NMR (376 MHz, $CDCl_3$): δ -57.9; HRMS (ESI) m/z: calcd for $C_{30}H_{24}F_3NOP$ $[M+H]^+$ 502.1542, found 502.1534.

(*R*)-(1-([1,1'-biphenyl]-4-yl)-2-(isoquinolin-1-yl)ethyl)diphenylphosphine oxide 3o



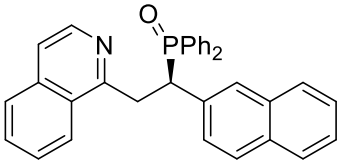
White solid, 66% yield; m.p. 196-197 °C; $[\alpha]$ $^{20}_D$ = 162.7 (c = 0.7, $CHCl_3$); *ee* was determined to be 80% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (minor) = 10.45 min, t_r (major) = 11.50 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.39 (d, J = 5.6 Hz, 1H), 8.11 (d, J = 8.5 Hz, 1H), 8.05-8.01 (m, 2H), 7.67 (d, J = 8.5 Hz, 1H), 7.58-7.54 (m, 3H), 7.49-7.42 (m, 8H), 7.38 (d, J = 5.6 Hz, 1H), 7.35-7.28 (m, 5H), 7.26-7.22 (m, 3H), 4.94-4.90 (m, 1H), 4.26-20 (m, 1H), 3.90-3.84 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.0 (d, J = 12.4 Hz), 141.5, 140.7, 139.2 (d, J = 2.5 Hz), 132.8 (d, J = 61.4 Hz), 132.0 (d, J = 55.7 Hz), 131.6 (d, J = 2.5 Hz), 131.4, 131.3, 131.27, 131.25, 131.1 (d, J = 8.9 Hz), 130.5 (d, J = 5.7 Hz), 129.8, 128.7, 128.62, 128.6, 128.1 (d, J = 11.6 Hz), 127.5, 127.1, 127.08, 126.8, 126.6, 125.0, 119.5, 44.4 (d, J = 69.5 Hz), 33.8. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.3; HRMS (ESI) m/z: calcd for $C_{35}H_{29}NOP$ $[M+H]^+$ 510.1981, found 510.1975.

(*R*)-(2-(isoquinolin-1-yl)-1-(*m*-tolyl)ethyl)diphenylphosphine oxide 3p



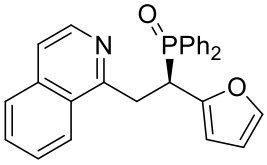
White solid, 89% yield; m.p. 103-104 °C; $[\alpha]^{20}_{D}$ = 134.2 (c = 0.6, $CHCl_3$); *ee* was determined to be 81% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 1.0 mL/min, 220 nm); t_r (minor) = 11.67 min, t_r (major) = 15.95 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 1.4 Hz, 1H), 8.04 (d, *J* = 2.1 Hz, 1H), 7.98 (t, *J* = 2.2 Hz, 2H), 7.63-7.62 (m, 1H), 7.56-7.51 (m, 3H), 7.46-7.43 (m, 1H), 7.38-7.33 (m, 4H), 7.31-7.26 (m, 3H), 7.23-7.20 (m, 2H), 6.82 (d, *J* = 1.9 Hz, 2H), 4.88-4.84 (m, 1H), 4.18-4.11 (m, 1H), 3.87-3.81 (m, 1H), 2.09 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.1 (d, *J* = 12.0 Hz), 141.4, 136.2 (d, *J* = 2.4 Hz), 133.1 (d, *J* = 5.3 Hz), 132.8 (d, *J* = 50.8 Hz), 132.0 (d, *J* = 45.0 Hz), 131.53, 131.51, 131.3 (d, *J* = 8.6 Hz), 131.18, 131.16, 131.1 (d, *J* = 8.9 Hz), 129.9, 129.8 (d, *J* = 14.6 Hz), 128.7, 128.6 (d, *J* = 11.3 Hz), 128.1 (d, *J* = 11.6 Hz), 127.4, 127.0, 125.0, 119.4, 44.2 (d, *J* = 68.3 Hz), 34.0, 30.0. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.3; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NOP$ $[M+H]^+$ 448.1825, found 448.1818.

(*R*)-(2-(isoquinolin-1-yl)-1-(naphthalen-2-yl)ethyl)diphenylphosphine oxide 3q



White solid, 70% yield; m.p. 192-193 °C; $[\alpha]^{20}_{D}$ = 148.2 (c = 0.5, $CHCl_3$); *ee* was determined to be 77% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 98:2, 1.0 mL/min, 220 nm); t_r (minor) = 19.87 min, t_r (major) = 21.98 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 5.7 Hz, 1H), 8.12 (d, *J* = 8.5 Hz, 1H), 8.06-8.01 (m, 2H), 7.85 (s, 1H), 7.65-7.61 (m, 3H), 7.55-7.50 (m, 5H), 7.47-7.41 (m, 4H), 7.33-7.29 (m, 3H), 7.26-7.23 (m, 1H), 7.18-7.15 (m, 2H), 5.06-5.02 (m, 1H), 4.33-26 (m, 1H), 3.95-3.89 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.9 (d, *J* = 12.1 Hz), 141.4, 135.9, 134.1 (d, *J* = 5.5 Hz), 133.1 (d, *J* = 1.5 Hz), 132.6 (d, *J* = 34.6 Hz), 132.2, 131.8 (d, *J* = 29.0 Hz), 131.6 (d, *J* = 2.5 Hz), 131.34, 131.26, 131.24, 131.0 (d, *J* = 8.9 Hz), 129.7, 129.0 (d, *J* = 6.7 Hz), 128.7 (d, *J* = 11.1 Hz), 128.3 (d, *J* = 5.1 Hz), 128.1 (d, *J* = 32.0 Hz), 127.8, 127.5, 127.4, 127.36, 127.0, 125.6 (q, *J* = 18.6 Hz), 124.9, 124.6, 119.5, 44.7 (d, *J* = 67.7 Hz), 34.0. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.2; HRMS (ESI) m/z: calcd for $C_{33}H_{27}NOP$ $[M+H]^+$ 484.1825, found 484.1819.

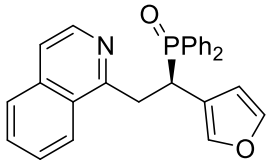
(*R*)-(1-(furan-2-yl)-2-(isoquinolin-1-yl)ethyl)diphenylphosphine oxide 3r



White solid, 83% yield; m.p. 135-136 °C; $[\alpha]^{20}_{D}$ = 92.5 (c = 0.6, $CHCl_3$); *ee* was determined to be 88% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 70:30, 1.0 mL/min, 220 nm); t_r (minor) = 19.44 min, t_r (major) = 24.21 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 5.7 Hz, 1H), 8.12 (d, *J* = 8.5 Hz, 1H), 7.95-7.91 (m, 2H), 7.68-7.62 (m, 3H), 7.58-7.55 (m, 1H), 7.50-7.47 (m, 1H), 7.45-7.38 (m, 5H), 7.35-7.32 (m, 2H), 7.06 (s, 1H), 6.07-6.03 (m, 2H), 5.05-5.00 (m, 1H), 4.17-4.11 (m, 1H), 3.84-3.78 (m, 1H). ^{13}C NMR (125

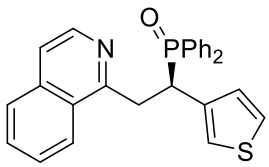
MHz, $CDCl_3$): δ 157.8 (d, *J* = 12.1 Hz), 141.62, 141.60, 141.58, 136.0, 132.1 (d, *J* = 26.1 Hz), 131.8 (d, *J* = 2.7 Hz), 131.6 (d, *J* = 2.7 Hz), 131.4, 131.3, 131.27 (d, *J* = 9.2 Hz), 131.1, 129.8, 128.7 (d, *J* = 11.4 Hz), 128.2 (d, *J* = 11.8 Hz), 127.3, 127.1, 114.9, 119.6, 110.5 (d, *J* = 2.5 Hz), 109.1 (d, *J* = 6.2 Hz), 39.7 (d, *J* = 70.1 Hz), 32.0. ^{31}P NMR (200 MHz, $CDCl_3$): δ 32.6; HRMS (ESI) m/z: calcd for $C_{27}H_{23}NO_2P$ $[M+H]^+$ 424.1461, found 424.1454.

(*R*)-(1-(furan-3-yl)-2-(isoquinolin-1-yl)ethyl)diphenylphosphine oxide 3s



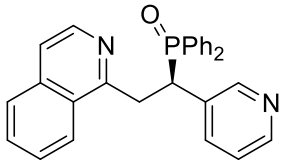
White solid, 93% yield; m.p. 175-176 °C; [α] $^{20}_D$ = 74.2 (c = 0.6, $CHCl_3$); *ee* was determined to be 87% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 98:2, 0.5 mL/min, 220 nm); t_r (minor) = 20.21 min, t_r (major) = 21.21 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.39 (d, *J* = 5.6 Hz, 1H), 8.08 (d, *J* = 8.5 Hz, 1H), 7.99-7.95 (m, 2H), 7.71-7.67 (m, 3H), 7.57 (t, *J* = 7.6 Hz, 1H), 7.50-7.47 (m, 1H), 7.42-7.38 (m, 5H), 7.35-7.32 (m, 2H), 7.17 (s, 1H), 7.06 (s, 1H), 6.37 (s, 1H), 4.81-4.77 (m, 1H), 4.03-3.96 (m, 1H), 3.70-3.64 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.1 (d, *J* = 12.6 Hz), 142.3, 141.4 (d, *J* = 8.6 Hz), 136.0, 132.1 (d, *J* = 52.71 Hz), 131.8 (d, *J* = 51.6 Hz), 131.7 (d, *J* = 2.5 Hz), 131.24, 131.17, 131.1, 131.0, 129.8, 128.7 (d, *J* = 11.4 Hz), 128.3 (d, *J* = 11.6 Hz), 127.5, 127.1, 124.9, 119.7 (d, *J* = 5.9 Hz), 119.5, 110.5 (d, *J* = 4.0 Hz), 35.6 (d, *J* = 71.0 Hz), 33.2. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.0; HRMS (ESI) m/z: calcd for $C_{27}H_{23}NO_2P$ $[M+H]^+$ 424.1461, found 424.1454.

(*R*)-(2-(isoquinolin-1-yl)-1-(thiophen-3-yl)ethyl)diphenylphosphine oxide 3t



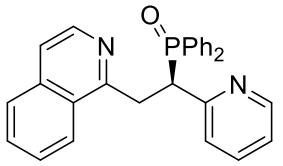
White solid, 72% yield; m.p. 174-175 °C; [α] $^{20}_D$ = 99.1 (c = 0.6, $CHCl_3$); *ee* was determined to be 84% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (minor) = 8.72 min, t_r (major) = 9.38 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.37 (d, *J* = 5.8 Hz, 1H), 8.04 (d, *J* = 8.6 Hz, 1H), 8.00-7.96 (m, 2H), 7.65 (t, *J* = 8.3 Hz, 1H), 7.57-7.52 (m, 3H), 7.46-7.42 (m, 4H), 7.37 (d, *J* = 5.7 Hz, 1H), 7.35-7.32 (m, 1H), 7.28-7.24 (m, 2H), 7.09 (s, 1H), 7.06 (d, *J* = 5.0 Hz, 1H), 6.96-6.94 (m, 1H), 5.01-5.00 (m, 1H), 4.13-4.07 (m, 1H), 3.79-3.73 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.1 (d, *J* = 12.6 Hz), 141.5, 136.1 (d, *J* = 5.4 Hz), 135.9, 132.8, 132.1 (d, *J* = 12.0 Hz), 131.7 (d, *J* = 2.5 Hz), 131.34, 131.32, 131.30, 131.27, 131.0 (d, *J* = 8.8 Hz), 129.8, 128.9 (d, *J* = 3.9 Hz), 128.7 (d, *J* = 11.3 Hz, 1H), 128.1 (d, *J* = 11.8 Hz, 1H), 127.4, 127.1, 124.9, 124.7, 123.8 (d, *J* = 7.3 Hz), 119.5, 40.5 (d, *J* = 67.8 Hz), 34.0. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.0; HRMS (ESI) m/z: calcd for $C_{27}H_{23}NOPS$ $[M+H]^+$ 440.1232, found 440.1227.

(*R*)-(2-(isoquinolin-1-yl)-1-(pyridin-3-yl)ethyl)diphenylphosphine oxide 3u



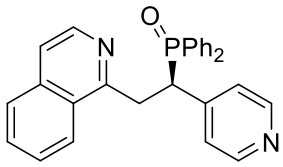
White solid, 86% yield; m.p. 184-185 °C; $[\alpha]_D^{20}$ = 166.7 (c = 0.7, $CHCl_3$); *ee* was determined to be 91% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 230 nm); t_r (minor) = 22.33 min, t_r (major) = 24.72 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.36 (s, 1H), 8.33 (dd, *J* = 5.6, 3.5 Hz, 1H), 8.18 (s, 1H), 8.05-7.97 (m, 4H), 7.63 (t, *J* = 7.1 Hz, 1H), 7.56-7.52 (m, 3H), 7.47-7.44 (m, 4H), 7.34 (t, *J* = 5.5 Hz, 1H), 7.31-7.28 (m, 1H), 7.24-7.23 (m, 2H), 7.02-6.99 (m, 1H), 4.93-4.89 (m, 1H), 4.20-4.13 (m, 1H), 3.81-3.76 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.0 (d, *J* = 12.9 Hz), 151.6 (d, *J* = 6.9 Hz), 147.9 (d, *J* = 2.3 Hz), 141.5, 136.8 (d, *J* = 4.7 Hz), 135.9, 132.5 (d, *J* = 5.2 Hz), 132.2 (d, *J* = 54.4 Hz), 131.9 (d, *J* = 2.6 Hz), 131.6 (d, *J* = 2.4 Hz), 131.4 (d, *J* = 50.1 Hz), 131.2 (d, *J* = 8.6 Hz), 130.8 (d, *J* = 8.7 Hz), 129.9, 128.9 (d, *J* = 11.3 Hz), 128.4 (d, *J* = 11.8 Hz), 127.3, 127.2, 124.5, 123.1 (d, *J* = 1.3 Hz), 119.6, 41.8 (d, *J* = 67.9 Hz), 33.4. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.0; HRMS (ESI) m/z: calcd for $C_{28}H_{24}N_2OP$ $[M+H]^+$ 435.1621, found 435.1616.

(*R*)-(2-(isoquinolin-1-yl)-1-(pyridin-2-yl)ethyl)diphenylphosphine oxide 3v



White solid, 92% yield; m.p. 125-126 °C; $[\alpha]_D^{20}$ = 74.7 (c = 0.6, $CHCl_3$); *ee* was determined to be 71% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 80:20, 1.0 mL/min, 210 nm); t_r (minor) = 8.41 min, t_r (major) = 10.32 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.30 (d, *J* = 5.6, 1H), 8.24 (d, *J* = 4.4 Hz, 1H), 8.06 (d, *J* = 8.5 Hz, 1H), 7.99-7.95 (m, 2H), 7.68-7.64 (m, 3H), 7.55 (t, *J* = 7.1 Hz, 1H), 7.47-7.39 (m, 5H), 7.38-7.31 (m, 3H), 7.27-7.24 (m, 2H), 6.87-6.85 (m, 1H), 5.11-5.07 (m, 1H), 4.41-4.34 (m, 1H), 3.93-3.87 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.0 (d, *J* = 12.5 Hz), 156.6 (d, *J* = 4.6 Hz), 148.8, 148.6, 136.0, 135.9, 132.3 (d, *J* = 5.0 Hz), 131.7 (d, *J* = 2.5 Hz), 131.5 (d, *J* = 8.7 Hz), 131.4, 131.3, 131.2 (d, *J* = 4.7 Hz), 129.7, 128.6 (d, *J* = 11.6 Hz), 128.1 (d, *J* = 11.8 Hz), 127.2, 127.1, 127.0, 125.0, 124.6 (d, *J* = 3.8 Hz), 121.6 (d, *J* = 1.6 Hz), 119.4, 47.9 (d, *J* = 65.4 Hz), 33.0. ^{31}P NMR (200 MHz, $CDCl_3$): δ 33.7; HRMS (ESI) m/z: calcd for $C_{28}H_{24}N_2OP$ $[M+H]^+$ 435.1621, found 435.1616.

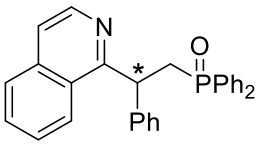
(*R*)-(2-(isoquinolin-1-yl)-1-(pyridin-4-yl)ethyl)diphenylphosphine oxide 3w



White solid, 97% yield; m.p. 184-185 °C; $[\alpha]_D^{20}$ = 107.3 (c = 0.7, $CHCl_3$); *ee* was determined to be 81% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 93:7, 0.5 mL/min, 220 nm); t_r (minor) = 30.21 min, t_r (major) = 33.01 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.33-8.27 (d, *J* = 5.6 Hz, 1H), 8.27 (s, 2H), 8.06-8.00 (m, 3H), 7.68 (d, *J* = 8.0 Hz, 1H), 7.58-7.53 (m, 3H), 7.51-7.46 (m, 4H), 7.39-7.31 (m, 4H), 7.28-7.25 (m, 2H), 4.92-4.88 (m, 1H), 4.23-4.17 (m, 1H), 3.82-3.76 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 156.9 (d,

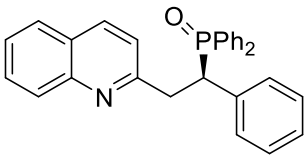
J = 12.1 Hz), 149.2, 146.0 (d, *J* = 4.8 Hz), 141.4, 135.9, 132.99, 131.97, 131.6 (d, *J* = 2.6 Hz), 131.57 (d, *J* = 46.0 Hz), 131.2 (d, *J* = 8.8 Hz), 130.9 (d, *J* = 9.1 Hz), 129.9, 128.9, 128.8, 128.4 (d, *J* = 11.9 Hz), 127.3, 127.2, 125.4, 124.5, 119.7, 44.1 (d, *J* = 66.4 Hz), 33.1. ^{31}P NMR (200 MHz, $CDCl_3$): δ 33.3; HRMS (ESI) m/z: calcd for $C_{28}H_{24}N_2OP$ $[M+H]^+$ 435.1621, found 435.1616.

(2-(isoquinolin-1-yl)-2-phenylethyl)diphenylphosphine oxide 3x



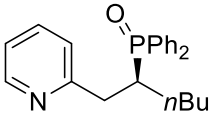
White solid, 93% yield; m.p. 136-137 °C; [α] $^{20}_D$ = -115 (c = 0.5, $CHCl_3$); *ee* was determined to be 53% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (major) = 9.79 min, t_r (minor) = 12.04 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.31 (d, *J* = 5.7 Hz, 1H), 8.28 (d, *J* = 8.5 Hz, 1H), 7.67-7.64 (m, 3H), 7.54-7.46 (m, 4H), 7.39-7.29 (m, 6H), 7.18-7.15 (m, 1H), 7.11-7.06 (m, 4H), 7.01-6.98 (m, 1H), 5.75-5.70 (m, 1H), 3.95-3.88 (m, 1H), 3.18-3.12 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 160.5 (d, *J* = 5.5 Hz), 143.2 (d, *J* = 8.8 Hz), 141.1, 136.6, 133.7 (d, *J* = 24.3 Hz), 132.9 (d, *J* = 23.8 Hz), 131.3 (d, *J* = 2.4 Hz), 130.9 (d, *J* = 2.7 Hz), 130.7, 130.6, 130.5, 129.7, 128.5, 128.4 (d, *J* = 11.7 Hz), 128.2, 127.9 (d, *J* = 11.7 Hz), 127.2 (d, *J* = 12.9 Hz), 126.7, 126.6, 125.1, 119.9, 41.3 (d, *J* = 1.3 Hz), 36.5 (d, *J* = 68.6 Hz).^{31}P NMR (200 MHz, $CDCl_3$): δ 31.0; HRMS (ESI) m/z: calcd for $C_{29}H_{25}NOP$ $[M+H]^+$ 434.1668, found 434.1661.

(*R*)-diphenyl(1-phenyl-2-(quinolin-2-yl)ethyl)phosphine oxide 3y



White solid, 73% yield; m.p. 192-193 °C; [α] $^{20}_D$ = -111 (c = 0.6, $CHCl_3$); *ee* was determined to be 54% by HPLC analysis with a Chiralcel AD-H column (hexane/2-propanol 70:30, 1.0 mL/min, 220 nm); t_r (minor) = 9.69 min, t_r (major) = 12.11 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.04-8.01 (m, 4H), 7.77 (d, *J* = 8.5 Hz, 1H), 7.66-7.64 (m, 2H), 7.51-7.42 (m, 6H), 7.32-7.28 (m, 3H), 7.24-7.21 (m, 2H), 7.07-7.02 (m, 3H), 6.93 (d, *J* = 8.4 Hz, 1H), 4.55 (dd, *J* = 14.8, 7.0 Hz, 1H), 3.70-3.67 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 159.3 (d, *J* = 12.8 Hz), 147.8, 135.8, 132.6 (d, *J* = 61.5 Hz), 131.8 (d, *J* = 56.2 Hz), 131.6 (d, *J* = 2.2 Hz), 131.5 (d, *J* = 8.5 Hz), 131.4, 131.2 (d, *J* = 2.4 Hz), 131.1 (d, *J* = 8.8 Hz), 131.1 (d, *J* = 5.7 Hz), 129.2, 128.8 (d, *J* = 13.2 Hz), 128.6, 128.1, 128.06 (d, *J* = 12.2 Hz), 127.5, 126.8 (d, *J* = 2.0 Hz), 126.8, 125.8, 122.4, 46.1 (d, *J* = 67.6 Hz), 33.6. ^{31}P NMR (200 MHz, $CDCl_3$): δ 33.7; HRMS (ESI) m/z: calcd for $C_{29}H_{25}NOP$ $[M+H]^+$ 434.1668, found 434.1661.

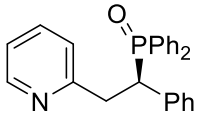
(*S*)-diphenyl(1-(pyridin-2-yl)hexan-2-yl)phosphine oxide 3z



White solid, 76% yield; m.p. 87-88 °C; [α] $^{20}_D$ = 31.8 (c = 0.9, $CHCl_3$); *ee* was determined to be 87% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 90:10, 0.5 mL/min, 210 nm); t_r (minor) =

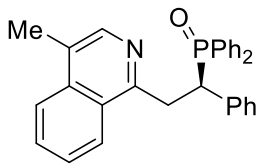
15.31 min, t_r (major) = 17.52 min; ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.45 (d, *J* = 3.9 Hz, 1H), 7.85-7.77 (m, 4H), 7.42-7.28 (m, 7H), 6.99-7.34 (m, 2H), 3.21-3.12 (m, 2H), 3.00-2.91 (m, 1H), 1.69-1.58 (m, 1H), 1.51-1.46 (m, 1H), 1.18-1.10 (m, 1H), 1.08-0.96 (m, 3H), 0.59 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ 158.5 (d, *J* = 11.6 Hz), 148.1, 135.1, 132.3 (d, *J* = 38.8 Hz), 131.7 (d, *J* = 37.5 Hz), 130.4, 130.2, 130.0, 129.9, 129.8, 127.5, 127.4 (d, *J* = 5.4 Hz), 127.3, 123.1, 120.2, 35.6, 35.1 (d, *J* = 4.9 Hz), 28.7 (d, *J* = 8.3 Hz), 26.7, 21.5, 12.5. ^{31}P NMR (300 MHz, $CDCl_3$): δ 31.4; HRMS (ESI) m/z: calcd for $C_{23}H_{26}NOP$ $[M+H]^+$ 364.1825, found 364.1829.

(*R*)-diphenyl(1-phenyl-2-(pyridin-2-yl)ethyl)phosphine oxide 3aa



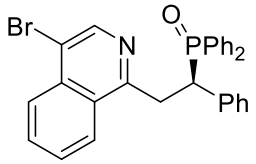
White solid, 65% yield; m.p. 148-149 °C; [α] $^{20}_D$ = 55.0 (c = 1.0, $CHCl_3$); *ee* was determined to be 84% by HPLC analysis with a Chiralcel AD-H column (hexane/2-propanol 80:20, 1.0 mL/min, 210 nm); t_r (major) = 19.31 min, t_r (minor) = 21.10 min; ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.36 (d, *J* = 2.8 Hz, 1H), 7.97-7.95 (m, 2H), 7.43-7.38 (m, 5H), 7.22-7.18 (m, 2H), 7.15-7.11 (m, 4H), 6.85 (t, *J* = 5.3 Hz, 1H), 6.69 (d, *J* = 7.5 Hz, 1H), 4.27 (dd, *J* = 14.9, 8.0 Hz, 1H), 3.39 (t, *J* = 7.5 Hz, 2H). ^{13}C NMR (150 MHz, $CDCl_3$): δ 157.6 (d, *J* = 13.4 Hz), 148.1, 134.9, 134.6 (d, *J* = 5.2 Hz), 131.6 (d, *J* = 67.2 Hz), 131.0 (d, *J* = 61.9 Hz), 130.7 (d, *J* = 2.1 Hz), 130.4 (d, *J* = 8.5 Hz), 130.1 (d, *J* = 2.0 Hz), 129.9 (d, *J* = 8.8 Hz), 128.9 (d, *J* = 5.6 Hz), 127.7 (d, *J* = 11.1 Hz), 127.0, 126.9, 125.7 (d, *J* = 1.6 Hz), 123.1, 120.2, 45.2 (d, *J* = 68.3 Hz), 36.9. ^{31}P NMR (300 MHz, $CDCl_3$): δ 33.2; HRMS (ESI) m/z: calcd for $C_{25}H_{23}NOP$ $[M+H]^+$ 384.1512, found 384.1517.

(*R*)-(2-(4-methylisoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3ab



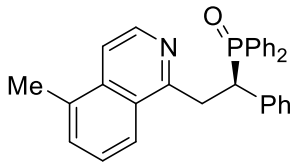
White solid, 75% yield; m.p. 220-221 °C; [α] $^{20}_D$ = 125.7 (c = 0.6, $CHCl_3$); *ee* was determined to be 78% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (minor) = 9.16 min, t_r (major) = 10.38 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.12 (s, 1H), 8.10 (d, *J* = 8.4 Hz, 1H), 8.00-7.96 (m, 2H), 7.79 (d, *J* = 8.4 Hz, 1H), 7.59 (t, *J* = 7.4 Hz, 1H), 7.51-7.46 (m, 3H), 7.44-7.37 (m, 5H), 7.32-7.29 (m, 1H), 7.24-7.20 (m, 2H), 7.04 (t, *J* = 7.1 Hz, 2H), 7.00-6.97 (m, 1H), 4.85-4.81 (m, 1H), 4.18-4.11 (m, 1H), 3.86-3.80 (m, 1H), 2.47 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 156.2 (d, *J* = 12.0 Hz), 141.4, 136.5 (d, *J* = 5.3 Hz), 135.4, 132.9 (d, *J* = 60.1 Hz), 132.6 (d, *J* = 63.6 Hz), 131.4 (d, *J* = 2.5 Hz), 131.2 (d, *J* = 8.5 Hz), 131.1 (d, *J* = 2.5 Hz), 131.0 (d, *J* = 8.8 Hz), 130.1 (d, *J* = 5.6 Hz), 129.5, 128.6 (d, *J* = 11.3 Hz), 128.0 (d, *J* = 11.7 Hz), 127.9, 126.8, 126.6 (d, *J* = 1.8 Hz), 126.5, 125.6, 125.4, 123.5, 44.7 (d, *J* = 68.3 Hz), 33.7, 15.9. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.3; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NOP$ $[M+H]^+$ 448.1825, found 448.1818.

(*R*)-(2-(4-bromoisoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3ac



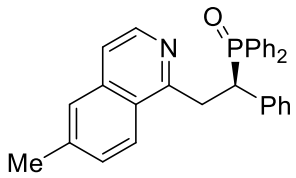
White solid, 78% yield; m.p. 187-188 °C; $[\alpha]_D^{20}$ = 111.7 (c = 0.7, $CHCl_3$); *ee* was determined to be 79% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 210 nm); t_r (minor) = 7.59 min, t_r (major) = 8.26 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.53 (s, 1H), 8.09 (d, *J* = 8.5 Hz, 1H), 8.01 (d, *J* = 8.4 Hz, 1H), 7.97-7.93 (m, 2H), 7.65 (t, *J* = 7.8 Hz, 1H), 7.54-7.47 (m, 3H), 7.43-7.36 (m, 5H), 7.32-7.29 (m, 1H), 7.24-7.20 (m, 2H), 7.06 (t, *J* = 7.1 Hz, 2H), 7.02-6.99 (m, 1H), 4.79-4.75 (m, 1H), 4.15-4.08 (m, 1H), 3.86-3.80 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.7 (d, *J* = 12.3 Hz), 143.2, 136.2 (d, *J* = 4.9 Hz), 134.5, 132.6 (d, *J* = 64.2 Hz), 131.8 (d, *J* = 58.6 Hz), 131.6 (d, *J* = 2.6 Hz), 131.2, 131.1, 131.0, 130.9, 130.0 (d, *J* = 5.6 Hz), 128.6 (d, *J* = 11.5 Hz), 128.08, 128.06, 127.97, 127.95, 126.8 (d, *J* = 2.2 Hz), 126.4, 125.4, 118.2, 44.7 (d, *J* = 68.4 Hz), 33.9. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.0; HRMS (ESI) m/z: calcd for $C_{29}H_{24}BrNOP$ $[M+H]^+$ 512.0773, found 512.0768.

(*R*)-(2-(5-methylisoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3ad



White solid, 77% yield; m.p. 169-170 °C; $[\alpha]_D^{20}$ = 153.4 (c = 0.6, $CHCl_3$); *ee* was determined to be 86% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (minor) = 9.29 min, t_r (major) = 10.18 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.39 (d, *J* = 6.0 Hz, 1H), 8.04-8.00 (m, 2H), 7.94 (d, *J* = 8.0 Hz, 1H), 7.53-7.49 (m, 2H), 7.47 (d, *J* = 5.9 Hz, 1H), 7.43-7.42 (m, 3H), 7.38-7.35 (m, 4H), 7.31-7.28 (m, 1H), 7.23-7.20 (m, 2H), 7.04 (t, *J* = 7.2 Hz, 2H), 7.00-6.95 (m, 1H), 4.87-4.83 (m, 1H), 4.24-4.17 (m, 1H), 3.86-3.81 (m, 1H), 2.53 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.4 (d, *J* = 13.1 Hz), 141.4, 136.4 (d, *J* = 5.4 Hz), 135.3, 133.8, 132.8 (d, *J* = 60.9 Hz), 132.0 (d, *J* = 55.6 Hz), 131.6 (d, *J* = 2.5 Hz), 131.4 (d, *J* = 8.4 Hz), 131.2 (d, *J* = 2.5 Hz), 131.0 (d, *J* = 8.9 Hz), 130.1, 130.09 (d, *J* = 1.5 Hz), 128.7 (d, *J* = 11.5 Hz), 128.0, 127.9, 127.4, 126.7 (d, *J* = 1.8 Hz), 126.5, 123.0, 115.8, 44.8 (d, *J* = 68.3 Hz), 34.0, 19.0. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.3; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NOP$ $[M+H]^+$ 448.1825, found 448.1818.

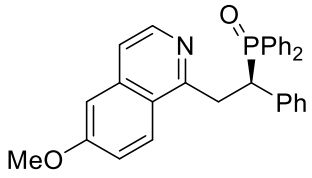
(*R*)-(2-(6-methylisoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3ae



White solid, 73% yield; m.p. 172-173 °C; $[\alpha]_D^{20}$ = 167.8 (c = 0.4, $CHCl_3$); *ee* was determined to be 87% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 96:4, 0.5 mL/min, 220 nm); t_r (minor) = 19.21 min, t_r (major) = 20.61 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.30 (d, *J* = 5.7 Hz, 1H), 8.05-8.01 (m, 2H), 7.94 (d, *J* = 8.6 Hz, 1H), 7.53-7.49 (m, 2H), 7.43-7.41 (m, 3H), 7.38-7.36 (m, 3H), 7.30-7.24 (m, 3H), 7.23-7.19 (m, 2H), 7.02 (t, *J* = 7.3 Hz, 2H), 6.97-6.94 (m, 1H), 4.85-4.81 (m, 1H), 4.20-4.14 (m, 1H), 3.81-3.76 (m,

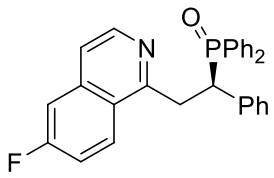
1H), 2.42 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 157.7 (d, *J* = 12.6 Hz), 141.6, 140.0, 136.3 (d, *J* = 5.4 Hz), 136.2, 132.8 (d, *J* = 59.5 Hz), 132.0 (d, *J* = 54.2 Hz), 131.6 (d, *J* = 2.3 Hz), 131.4 (d, *J* = 8.5 Hz), 131.2 (d, *J* = 2.6 Hz), 131.0 (d, *J* = 8.6 Hz), 130.1 (d, *J* = 5.7 Hz), 129.2, 128.7 (d, *J* = 11.1 Hz), 128.0, 127.9, 126.7 (d, *J* = 2.4 Hz), 125.9, 125.8, 124.8, 118.9, 44.8 (d, *J* = 70.5 Hz), 33.7, 27.1. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.4; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NOP$ $[M+H]^+$ 448.1825, found 448.1818.

(*R*)-(2-(6-methoxyisoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3af



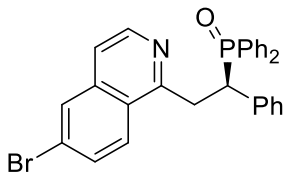
White solid, 82% yield; m.p. 149-150 °C; $[\alpha]_D^{20}$ = 142.1 (c = 0.6, $CHCl_3$); *ee* was determined to be 89% by HPLC analysis with a Chiralcel AD-H column (hexane/2-propanol 80:20, 1.0 mL/min, 230 nm); t_r (major) = 20.40 min, t_r (minor) = 24.18 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.28 (d, *J* = 5.7 Hz, 1H), 8.04-8.00 (m, 2H), 7.96 (d, *J* = 9.3 Hz, 1H), 7.52-7.50 (m, 2H), 7.44-7.42 (m, 3H), 7.36-7.32 (m, 2H), 7.31-7.27 (m, 1H), 7.25-7.19 (m, 3H), 7.08 (dd, *J* = 9.3, 2.5 Hz, 1H), 7.02 (t, *J* = 7.1 Hz, 2H), 6.98-6.95 (m, 1H), 6.88 (d, *J* = 2.5 Hz, 1H), 4.86-4.76 (m, 1H), 4.14-4.08 (m, 1H), 3.84 (s, 3H), 3.79-3.73 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 160.2, 157.6 (d, *J* = 12.6 Hz), 142.2, 138.0, 136.3 (d, *J* = 5.1 Hz), 132.9 (d, *J* = 63.0 Hz), 132.1 (d, *J* = 58.2 Hz), 131.6 (d, *J* = 2.6 Hz), 131.4 (d, *J* = 8.5 Hz), 131.1 (d, *J* = 2.6 Hz), 131.0 (d, *J* = 8.6 Hz), 130.1 (d, *J* = 5.7 Hz), 128.6 (d, *J* = 11.0 Hz), 128.0, 127.9, 126.9, 126.7 (d, *J* = 2.3 Hz), 123.2, 119.6, 118.7, 104.6, 55.4, 45.0 (d, *J* = 68.2 Hz), 33.8. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.1; HRMS (ESI) m/z: calcd for $C_{30}H_{27}NO_2P$ $[M+H]^+$ 464.1774, found 464.1767.

(*R*)-(2-(6-fluoroisoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3ag



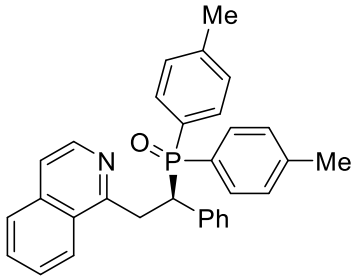
White solid, 88% yield; m.p. 167-168 °C; $[\alpha]_D^{20}$ = 105.0 (c = 0.5, $CHCl_3$); *ee* was determined to be 82% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 97:3, 1.0 mL/min, 220 nm); t_r (minor) = 10.29 min, t_r (major) = 10.94 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.34 (d, *J* = 5.7 Hz, 1H), 8.08 (dd, *J* = 9.1, 5.4 Hz, 1H), 8.01-7.98 (m, 2H), 7.54-7.50 (m, 3H), 7.39-7.38 (m, 5H), 7.27-7.24 (m, 1H), 7.19-7.14 (m, 4H), 7.02 (t, *J* = 7.3 Hz, 2H), 6.97-6.94 (m, 1H), 4.82-4.78 (m, 1H), 4.17-4.11 (m, 1H), 3.86-3.80 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 163.7 (d, *J* = 253.1 Hz), 161.7, 158.2 (d, *J* = 11.9 Hz), 142.5, 137.6 (d, *J* = 10.4 Hz), 136.6 (d, *J* = 5.3 Hz), 132.6 (d, *J* = 54.3 Hz), 131.8 (d, *J* = 49.0 Hz), 131.6 (d, *J* = 2.4 Hz), 131.3, 131.2 (d, *J* = 3.9 Hz), 131.0 (d, *J* = 8.8 Hz), 130.0 (d, *J* = 5.9 Hz), 128.7 (d, *J* = 11.4 Hz), 128.4 (d, *J* = 9.4 Hz), 128.1, 128.0, 126.8 (d, *J* = 1.6 Hz), 125.7, 119.1 (d, *J* = 4.9 Hz), 117.4 (d, *J* = 25.0 Hz), 110.2 (d, *J* = 20.3 Hz), 44.9 (d, *J* = 67.4 Hz), 34.1. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.2; ^{19}F NMR (376 MHz, $CDCl_3$): δ -108.5; HRMS (ESI) m/z: calcd for $C_{29}H_{24}FNOP$ $[M+H]^+$ 452.1574, found 452.1567.

(*R*)-(2-(6-bromoisoquinolin-1-yl)-1-phenylethyl)diphenylphosphine oxide 3ah



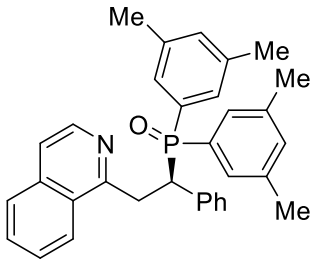
White solid, 93% yield; m.p. 196-197 °C; $[\alpha]_D^{20}$ = 130.3 (c = 0.7, $CHCl_3$); *ee* was determined to be 82% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (minor) = 9.52 min, t_r (major) = 10.21 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.57 (d, *J* = 5.7 Hz, 1H), 8.01-7.98 (m, 2H), 7.90 (d, *J* = 9.0 Hz, 1H), 7.74 (s, 1H), 7.51-7.47 (m, 3H), 7.41 (s, 3H), 7.36 (d, *J* = 7.4 Hz, 2H), 7.29-7.267 (m, 1H), 7.21-7.18 (m, 3H), 7.02 (t, *J* = 7.3 Hz, 2H), 6.98-6.95 (m, 1H), 4.78-4.74 (m, 1H), 4.14-4.08 (m, 1H), 3.82-3.77 (m, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.5 (d, *J* = 12.4 Hz), 142.6, 137.0, 136.2 (d, *J* = 5.3 Hz), 132.6 (d, *J* = 52.5 Hz), 131.8 (d, *J* = 46.6 Hz), 131.7 (d, *J* = 2.2 Hz), 131.3, 131.25, 131.22, 131.0 (d, *J* = 8.7 Hz), 130.4, 130.0 (d, *J* = 5.7 Hz), 129.1, 128.1, 128.0, 126.8, 126.7, 125.8, 124.5, 118.3, 45.0 (d, *J* = 68.0 Hz), 44.5. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.0; HRMS (ESI) m/z: calcd for $C_{29}H_{24}BrNOP$ $[M+H]^+$ 512.0773, found 512.0768.

(*R*)-(2-(isoquinolin-1-yl)-1-phenylethyl)di-p-tolylphosphine oxide 3ai



White solid, 97% yield; m.p. 190-191 °C; $[\alpha]_D^{20}$ = 144.0 (c = 0.6, $CHCl_3$); *ee* was determined to be 88% by HPLC analysis with a Chiralcel OD-H column (hexane/2-propanol 95:5, 1.0 mL/min, 220 nm); t_r (minor) = 8.59 min, t_r (major) = 9.60 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.35 (d, *J* = 5.7 Hz, 1H), 7.90-7.86 (m, 2H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.51-7.48 (m, 1H), 7.41 (s, 3H), 7.43-7.38 (m, 5H), 7.32 (d, *J* = 5.6 Hz, 1H), 7.21-7.19 (m, 2H), 7.04-7.00 (m, 4H), 6.98-6.95 (m, 1H), 4.81-4.77 (m, 1H), 4.20-4.13 (m, 1H), 3.85-3.79 (m, 1H), 2.29 (s, 3H), 2.21 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.3 (d, *J* = 12.5 Hz), 141.9 (d, *J* = 2.7 Hz), 141.5, 141.4 (d, *J* = 2.7 Hz), 136.7 (d, *J* = 5.3 Hz), 135.9, 131.1 (d, *J* = 8.6 Hz), 131.0 (d, *J* = 9.0 Hz), 130.14, 130.09, 129.7 (d, *J* = 64.7 Hz), 129.4 (d, *J* = 11.4 Hz), 128.9 (d, *J* = 59.9 Hz), 128.8, 128.7, 127.9, 127.4, 127.0 (d, *J* = 6.4 Hz), 126.6 (d, *J* = 2.1 Hz), 125.0, 119.3, 45.0 (d, *J* = 68.1 Hz), 34.0, 21.52, 21.47. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.6; HRMS (ESI) m/z: calcd for $C_{31}H_{29}NOP$ $[M+H]^+$ 462.1981, found 462.1976.

(*R*)-bis(3,5-dimethylphenyl)(2-(isoquinolin-1-yl)-1-phenylethyl)phosphine oxide 3aj



White solid, 91% yield; m.p. 74-75 °C; $[\alpha]_D^{20}$ = 119.5 (c = 0.8, $CHCl_3$); *ee* was determined to be 86% by HPLC analysis with a Chiralcel IC column (hexane/2-propanol 90:10, 1.0 mL/min, 220 nm); t_r (major) = 26.24 min, t_r (minor) = 29.48 min; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.33 (d, *J* = 5.6 Hz, 1H), 8.06 (d, *J* = 8.3 Hz, 1H), 7.60-7.55 (m, 3H), 7.49 (t, *J* = 7.5 Hz, 1H), 7.44-7.39 (m, 3H), 7.29 (d, *J* = 5.5 Hz, 1H), 7.10 (d, *J* = 11.5 Hz, 2H), 7.05 (t, *J* = 7.4 Hz, 1H), 7.00-6.97 (m, 2H),

6.88 (s, 1H), 4.76-4.72 (m, 1H), 4.14-4.07 (m, 1H), 3.92-3.86 (m, 1H), 2.26 (s, 6H), 2.14 (s, 6H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 158.4 (d, J = 11.6 Hz), 141.4, 138.2 (d, J = 11.7 Hz), 137.5 (d, J = 12.0 Hz), 136.9 (d, J = 5.3 Hz), 135.9, 133.3 (d, J = 2.53 Hz), 132.9 (d, J = 2.6 Hz), 132.4 (d, J = 55.1 Hz), 131.7 (d, J = 49.3 Hz), 130.1 (d, J = 5.7 Hz), 129.6, 129.0 (d, J = 8.9 Hz), 128.7 (d, J = 8.54 Hz), 127.9, 127.3, 127.0, 126.9, 126.6 (d, J = 1.7 Hz), 125.1, 119.4, 45.0 (d, J = 67.4 Hz), 34.0, 21.3, 21.2. ^{31}P NMR (200 MHz, $CDCl_3$): δ 34.6; HRMS (ESI) m/z: calcd for $C_{33}H_3NOP$ $[M+H]^+$ 490.2294, found 490.2287.

6. References

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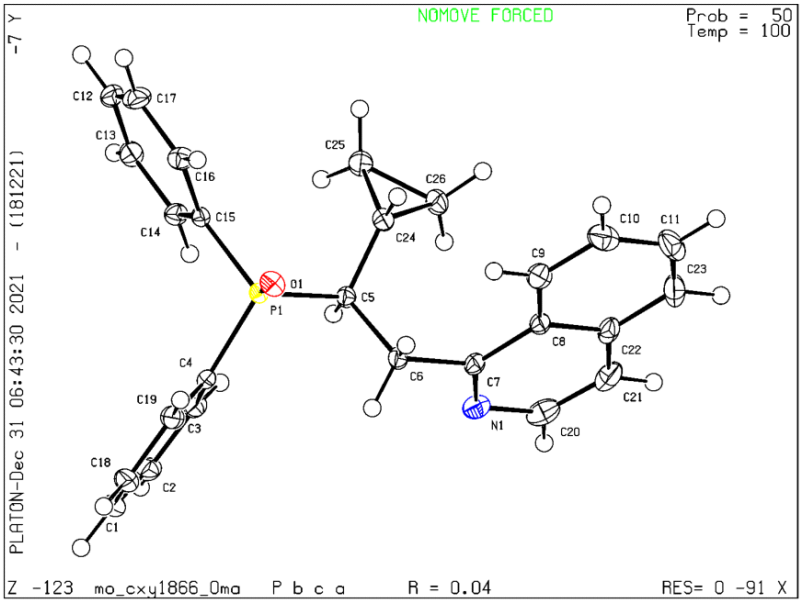
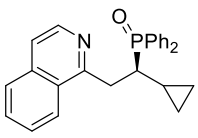
7. Crystal data and structure refinement of 3e

Crystal data and structure refinement of 3e





3e

Table S1. Crystal data and structure refinement for cxy1866 (18 Dec. 2021).

Identification code	mo_cxy1866_0ma
Empirical formula	$C_{26}H_{24}NOP$

Formula weight	397.43
Temperature/K	100.0
Crystal system	orthorhombic
Space group	Pbca
a/Å	18.1535(9)
b/Å	11.2621(5)
c/Å	20.3773(10)
α/ Å	90
β/ Å	90
γ/ Å	90
Volume/Å^3	4166.1(3)
Z	8
ρ_{calc}g/cm^3	1.267
μ/mm^{-1}	0.149
F(000)	1680.0
Crystal size/mm^3	0.42 × 0.39 × 0.38
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/° 3.998 to 61.222	
Index ranges	-25 ≤ h ≤ 25, -16 ≤ k ≤ 16, -29 ≤ l ≤ 29
Reflections collected	112968
Independent reflections	6399 [R_{int} = 0.0782, R_{sigma} = 0.0305]
Data/restraints/parameters	6399/0/262
Goodness-of-fit on F2	1.025
Final R indexes [I>=2σ (I)]	R_1 = 0.0414, wR_2 = 0.0988
Final R indexes [all data]	R_1 = 0.0640, wR_2 = 0.1101
Largest diff. peak/hole / e Å-3	0.40/-0.40

Table 2 Fractional Atomic Coordinates (×10^4) and Equivalent Isotropic Displacement Parameters (Å^2×10^3) for mo_cxy1866_0ma. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{IJ} tensor.

Atom	***x***	***y***	***z***	**U(eq)**
P1	2531.3(2)	5010.3(3)	3016.1(2)	11.37(8)

Atom	*x*	*y*	*z*	U(eq)
O1	2431.6(5)	6301.9(8)	3151.7(4)	17.20(19)
N1	621.4(6)	2764.6(10)	4063.9(6)	21.1(2)
C1	1636.9(8)	4062.9(14)	974.0(7)	24.4(3)
C2	1821.5(7)	3154.9(12)	1403.0(7)	21.4(3)
C3	2064.1(7)	3414.4(11)	2035.0(6)	16.7(2)
C4	2135.6(6)	4596.4(11)	2235.1(6)	13.3(2)
C5	2110.2(7)	4058.8(11)	3636.1(6)	14.0(2)
C6	1301.0(7)	4476.8(12)	3719.7(6)	16.7(2)
C7	899.4(7)	3792.9(11)	4247.7(6)	15.4(2)
C8	848.3(7)	4226.2(11)	4906.8(6)	15.7(2)
C9	1153.4(7)	5322.0(12)	5119.3(7)	21.0(3)
C10	1101.6(9)	5663.7(14)	5761.6(8)	28.9(3)
C11	733.0(9)	4949.3(16)	6223.2(7)	32.3(4)
C12	4998.6(7)	4136.4(13)	2894.1(7)	22.6(3)
C13	4489.0(7)	3248.4(12)	2765.6(6)	20.2(3)
C14	3738.8(7)	3483.9(11)	2802.0(6)	16.4(2)
C15	3495.6(7)	4624.0(11)	2961.0(6)	12.6(2)
C16	4008.0(7)	5515.8(12)	3087.5(6)	18.5(3)
C17	4757.2(8)	5261.9(13)	3056.7(7)	23.6(3)
C18	1682.0(8)	5232.9(13)	1177.2(7)	23.0(3)
C19	1933.9(7)	5502.0(12)	1803.6(6)	17.8(2)
C20	276.4(8)	2082.6(13)	4525.5(8)	26.6(3)
C21	197.5(8)	2404.5(13)	5163.8(8)	26.6(3)
C22	484.7(7)	3505.9(12)	5375.8(7)	20.7(3)
C23	431.7(8)	3901.0(15)	6035.8(7)	29.9(3)
C24	2545.0(7)	4099.0(12)	4268.6(6)	17.2(2)
C25	3190.7(8)	3275.6(14)	4375.6(7)	24.1(3)
C26	2484.7(8)	3076.7(13)	4744.3(7)	23.2(3)

Table 3 Anisotropic Displacement Parameters ($Å^2 \times 10^3$) for cxy0894_0m. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+\ldots]$.

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
P1	12.69(14)	10.66(14)	10.75(13)	-0.36(10)	0.34(11)	1.48(10)
O1	22.1(5)	12.1(4)	17.4(4)	-2.3(3)	-0.8(4)	3.2(3)
N1	16.8(5)	20.9(6)	25.7(6)	-3.2(5)	-1.2(5)	0.5(4)
C1	19.5(6)	38.8(8)	15.0(6)	-4.8(6)	-1.3(5)	-4.8(6)
C2	16.9(6)	25.3(7)	22.0(6)	-9.0(5)	0.0(5)	-2.5(5)
C3	13.4(5)	17.7(6)	19.0(6)	-2.1(5)	1.1(5)	-0.5(4)

C4	10.4(5)	16.4(5)	13.0(5)	-0.8(4)	1.0(4)	-1.0(4)
C5	13.1(5)	16.6(5)	12.3(5)	0.9(4)	1.2(4)	2.2(4)
C6	14.1(6)	22.8(6)	13.3(5)	1.7(5)	1.8(4)	3.7(5)
C7	12.0(5)	18.4(6)	15.8(5)	-0.1(5)	1.7(4)	3.8(4)
C8	12.1(5)	20.3(6)	14.7(5)	1.0(5)	0.9(4)	4.8(4)
C9	19.1(6)	22.6(6)	21.4(6)	-2.5(5)	0.6(5)	4.7(5)
C10	26.4(7)	34.1(8)	26.1(7)	-12.3(6)	-5.3(6)	10.9(6)
C11	33.1(8)	47.5(10)	16.3(6)	-5.2(6)	-0.4(6)	19.3(7)
C12	12.8(6)	36.5(8)	18.5(6)	7.6(6)	-0.1(5)	2.2(5)
C13	19.0(6)	23.6(6)	18.0(6)	0.3(5)	0.6(5)	7.4(5)
C14	15.6(6)	16.3(6)	17.3(6)	-1.1(5)	-0.7(5)	1.1(4)
C15	13.1(5)	13.9(5)	10.8(5)	0.9(4)	0.2(4)	-1.3(4)
C16	18.9(6)	16.0(6)	20.7(6)	1.7(5)	-2.8(5)	-2.8(5)
C17	17.2(6)	27.8(7)	25.9(7)	6.5(6)	-4.5(5)	-8.5(5)
C18	21.2(7)	32.1(7)	15.6(6)	5.5(5)	-2.7(5)	-4.2(5)
C19	17.8(6)	18.6(6)	17.1(6)	1.8(5)	-0.8(5)	-2.1(5)
C20	19.3(7)	19.8(6)	40.8(9)	1.3(6)	-2.4(6)	-2.5(5)
C21	16.3(6)	28.7(7)	34.8(8)	12.5(6)	4.3(6)	1.0(5)
C22	14.1(6)	27.0(7)	21.0(6)	7.0(5)	4.0(5)	7.3(5)
C23	25.5(7)	44.8(9)	19.3(7)	10.6(6)	7.7(6)	15.4(7)
C24	16.9(6)	20.6(6)	14.2(5)	0.4(5)	0.2(5)	1.1(5)
C25	17.4(6)	35.9(8)	18.9(6)	7.5(6)	-0.3(5)	7.4(6)
C26	20.7(6)	33.5(8)	15.5(6)	9.4(5)	0.2(5)	2.7(6)

Table 4 Bond Lengths for mo_cxy1866_0ma.

Atom	Atom	Length/Å		Atom	Atom	Length/Å
P1	O1	1.4917(9)		C9	C10	1.368(2)
P1	C4	1.8072(12)		C10	C11	1.407(2)
P1	C5	1.8244(12)		C11	C23	1.356(2)
P1	C15	1.8073(12)		C12	C13	1.387(2)
N1	C7	1.3175(17)		C12	C17	1.381(2)
N1	C20	1.3665(19)		C13	C14	1.3895(18)
C1	C2	1.386(2)		C14	C15	1.3959(17)
C1	C18	1.384(2)		C15	C16	1.3930(17)
C2	C3	1.3921(18)		C16	C17	1.3912(19)
C3	C4	1.3983(17)		C18	C19	1.3894(18)
C4	C19	1.3954(17)		C20	C21	1.358(2)
C5	C6	1.5520(17)		C21	C22	1.413(2)

C5	C24	1.5120(17)		C22	C23	1.420(2)
C6	C7	1.5107(17)		C24	C25	1.5104(18)
C7	C8	1.4321(17)		C24	C26	1.5090(18)
C8	C9	1.4202(19)		C25	C26	1.5023(19)
C8	C22	1.4166(18)				

Table 5 Bond Angles for mo_cxy1866_0ma.

Atom	**Atom**	**Atom**	**Angle/°**		**Atom**	**Atom**	**Atom**	**Angle/°**
O1	P1	C4	111.49(6)		C9	C10	C11	120.77(15)
O1	P1	C5	113.18(5)		C23	C11	C10	120.09(14)
O1	P1	C15	111.33(6)		C17	C12	C13	119.69(12)
C4	P1	C5	106.97(6)		C12	C13	C14	120.39(12)
C4	P1	C15	105.56(5)		C13	C14	C15	119.87(12)
C15	P1	C5	107.91(5)		C14	C15	P1	122.83(9)
C7	N1	C20	118.29(12)		C16	C15	P1	117.50(10)
C18	C1	C2	119.96(13)		C16	C15	C14	119.67(12)
C1	C2	C3	120.33(12)		C17	C16	C15	119.76(13)
C2	C3	C4	119.93(12)		C12	C17	C16	120.63(13)
C3	C4	P1	122.63(9)		C1	C18	C19	120.14(13)
C19	C4	P1	118.08(9)		C18	C19	C4	120.39(12)
C19	C4	C3	119.19(12)		C21	C20	N1	123.89(14)
C6	C5	P1	107.12(8)		C20	C21	C22	119.23(13)
C24	C5	P1	110.73(9)		C8	C22	C23	119.41(14)
C24	C5	C6	113.04(10)		C21	C22	C8	117.93(13)
C7	C6	C5	112.35(10)		C21	C22	C23	122.66(13)
N1	C7	C6	115.50(11)		C11	C23	C22	120.81(14)
N1	C7	C8	122.77(12)		C25	C24	C5	120.65(11)
C8	C7	C6	121.70(11)		C26	C24	C5	119.13(11)
C9	C8	C7	123.83(12)		C26	C24	C25	59.68(9)
C22	C8	C7	117.88(12)		C26	C25	C24	60.12(9)
C22	C8	C9	118.28(12)		C25	C26	C24	60.21(9)
C10	C9	C8	120.63(14)					

Table 6 Torsion Angles for mo_cxy1866_0ma.

A	**B**	**C**	**D**	**Angle/°**		**A**	**B**	**C**	**D**	**Angle/°**
P1	C4	C19	C18	174.88(10)		C6	C5	C24	C26	82.98(14)
P1	C5	C6	C7	-177.20(9)		C6	C7	C8	C9	0.95(19)
P1	C5	C24	C25	-86.79(13)		C6	C7	C8	C22	-177.71(11)

P1	C5	C24	C26	-156.82(10)		C7	N1	C20	C21	0.5(2)
P1	C15	C16	C17	179.49(10)		C7	C8	C9	C10	-178.09(13)
O1	P1	C4	C3	-170.82(10)		C7	C8	C22	C21	0.17(18)
O1	P1	C4	C19	12.88(12)		C7	C8	C22	C23	179.22(12)
O1	P1	C5	C6	51.50(10)		C8	C9	C10	C11	-1.2(2)
O1	P1	C5	C24	-72.18(10)		C8	C22	C23	C11	-0.9(2)
O1	P1	C15	C14	-176.39(10)		C9	C8	C22	C21	-178.57(12)
O1	P1	C15	C16	3.90(11)		C9	C8	C22	C23	0.49(18)
N1	C7	C8	C9	178.96(12)		C9	C10	C11	C23	0.8(2)
N1	C7	C8	C22	0.30(18)		C10	C11	C23	C22	0.2(2)
N1	C20	C21	C22	0.0(2)		C12	C13	C14	C15	0.8(2)
C1	C2	C3	C4	-1.21(19)		C13	C12	C17	C16	-0.5(2)
C1	C18	C19	C4	-0.7(2)		C13	C14	C15	P1	179.76(10)
C2	C1	C18	C19	2.0(2)		C13	C14	C15	C16	-0.53(18)
C2	C3	C4	P1	-173.76(10)		C14	C15	C16	C17	-0.23(19)
C2	C3	C4	C19	2.49(18)		C15	P1	C4	C3	68.15(11)
C3	C4	C19	C18	-1.55(19)		C15	P1	C4	C19	-108.15(10)
C4	P1	C5	C6	-71.68(9)		C15	P1	C5	C6	175.16(8)
C4	P1	C5	C24	164.64(8)		C15	P1	C5	C24	51.48(10)
C4	P1	C15	C14	-55.26(11)		C15	C16	C17	C12	0.8(2)
C4	P1	C15	C16	125.03(10)		C17	C12	C13	C14	-0.2(2)
C5	P1	C4	C3	-46.60(12)		C18	C1	C2	C3	-1.1(2)
C5	P1	C4	C19	137.10(10)		C20	N1	C7	C6	177.50(11)
C5	P1	C15	C14	58.84(11)		C20	N1	C7	C8	-0.63(19)
C5	P1	C15	C16	-120.87(10)		C20	C21	C22	C8	-0.3(2)
C5	C6	C7	N1	-83.20(14)		C20	C21	C22	C23	-179.31(14)
C5	C6	C7	C8	94.95(14)		C21	C22	C23	C11	178.12(14)
C5	C24	C25	C26	-108.00(14)		C22	C8	C9	C10	0.56(19)
C5	C24	C26	C25	110.49(13)		C24	C5	C6	C7	-54.95(14)
C6	C5	C24	C25	153.00(12)						

Table 7 Hydrogen Atom Coordinates (Å×10^4) and Isotropic Displacement Parameters (Å^2×10^3) for mo_cxy1866_0ma.

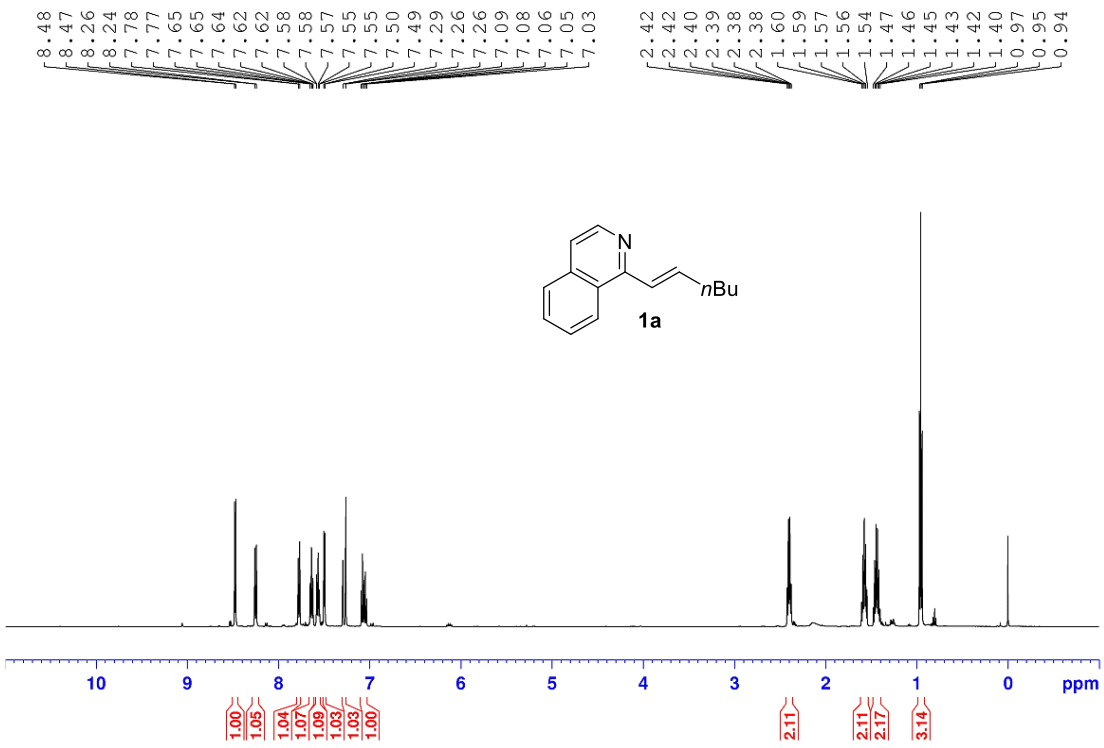
Atom	*x*	*y*	*z*	U(eq)
H1	1479.48	3881.79	540.77	29
H2	1782.28	2351.7	1264.95	26
H3	2180.99	2789.07	2330.04	20
H5	2108.26	3223.51	3469.66	17
H6A	1296.8	5332.02	3831.96	20

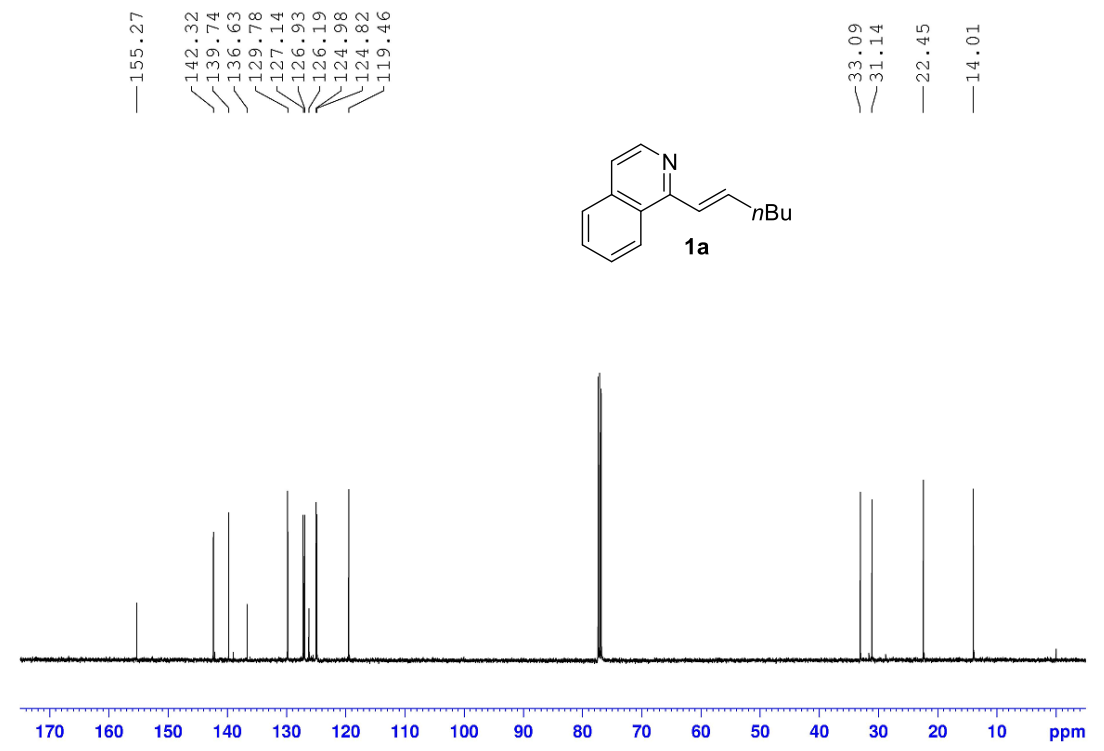
H6B	1037.56	4377.62	3297.84	20
H9	1395.71	5822.29	4812.23	25
H10	1317.05	6391.87	5897.76	35
H11	695.23	5201.73	6666.76	39
H12	5511.07	3971.42	2870.32	27
H13	4653.95	2474.62	2652.1	24
H14	3392.06	2870.25	2718.9	20
H16	3846.47	6294.47	3194.43	22
H17	5106.13	5868.33	3148.39	28
H18	1540.4	5853.63	887.78	28
H19	1968.96	6307.18	1939.01	21
H20	80.15	1338.89	4391.98	32
H21	-47.89	1895.31	5464.33	32
H23	182.13	3425.08	6350.03	36
H24	2592.48	4902.14	4473.56	21
H25A	3315.49	2711.78	4019.86	29
H25B	3618.19	3585.49	4623.88	29
H26A	2479.03	3264.09	5218.92	28
H26B	2176.35	2390.43	4614.94	28

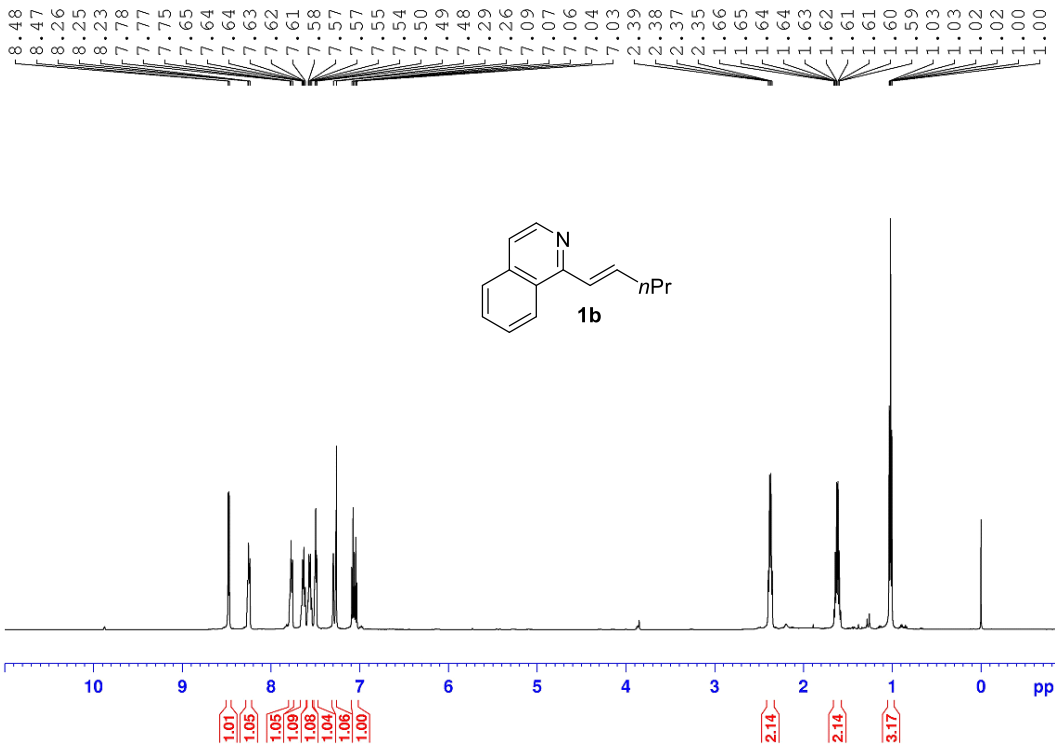
Crystal structure determination of [mo_cxy1866_0ma]

Crystal Data for $C_{26}H_{24}NOP$ (M =397.43 g/mol): orthorhombic, space group Pbca (no. 61), a = 18.1535(9) Å, b = 11.2621(5) Å, c = 20.3773(10) Å, V = 4166.1(3) Å^3, Z = 8, T = 100.0 K, μ(MoKα) = 0.149 mm^{-1}, *Dcalc* = 1.267 g/cm^3, 112968 reflections measured (3.998° ≤ 2Θ ≤ 61.222°), 6399 unique (R_{int} = 0.0782, R_{sigma} = 0.0305) which were used in all calculations. The final R_1 was 0.0414 (I > 2σ(I)) and wR_2 was 0.1101 (all data).

8. Copies of ^{1}H NMR, ^{13}C NMR, ^{19}F NMR and HPLC spectra of the products



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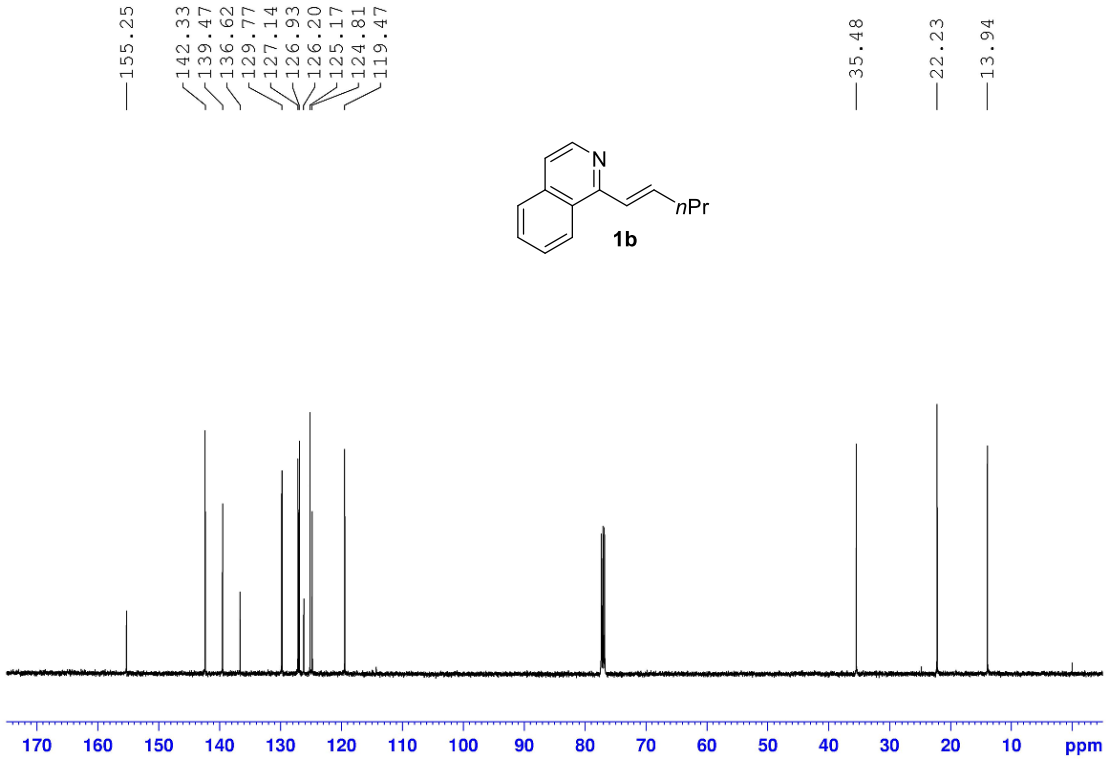
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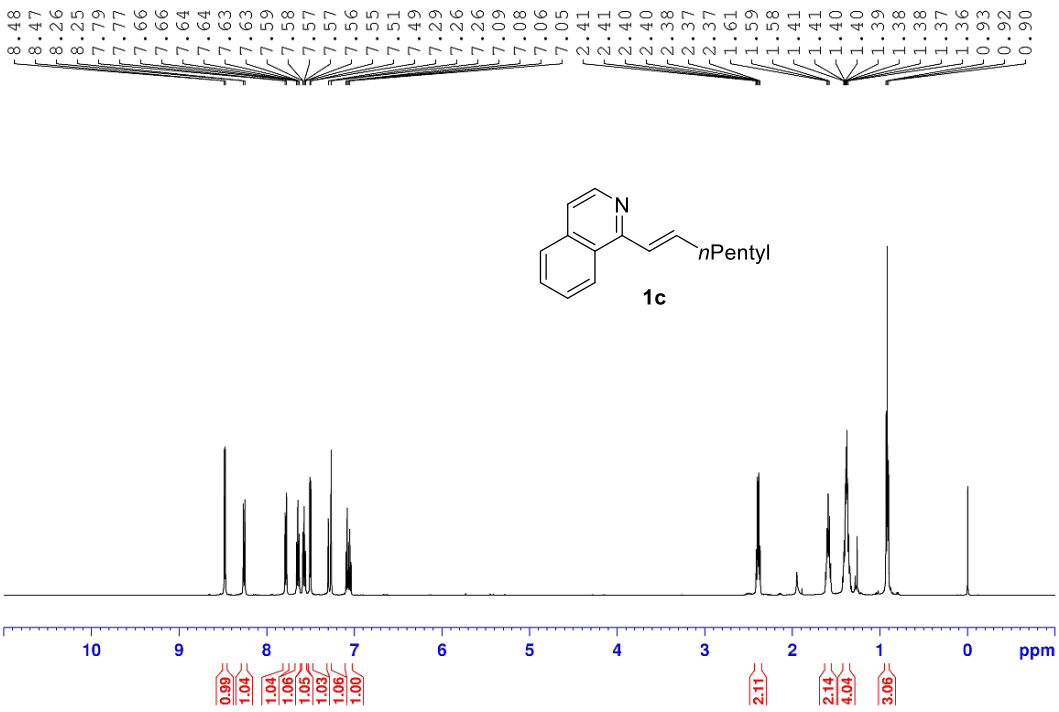
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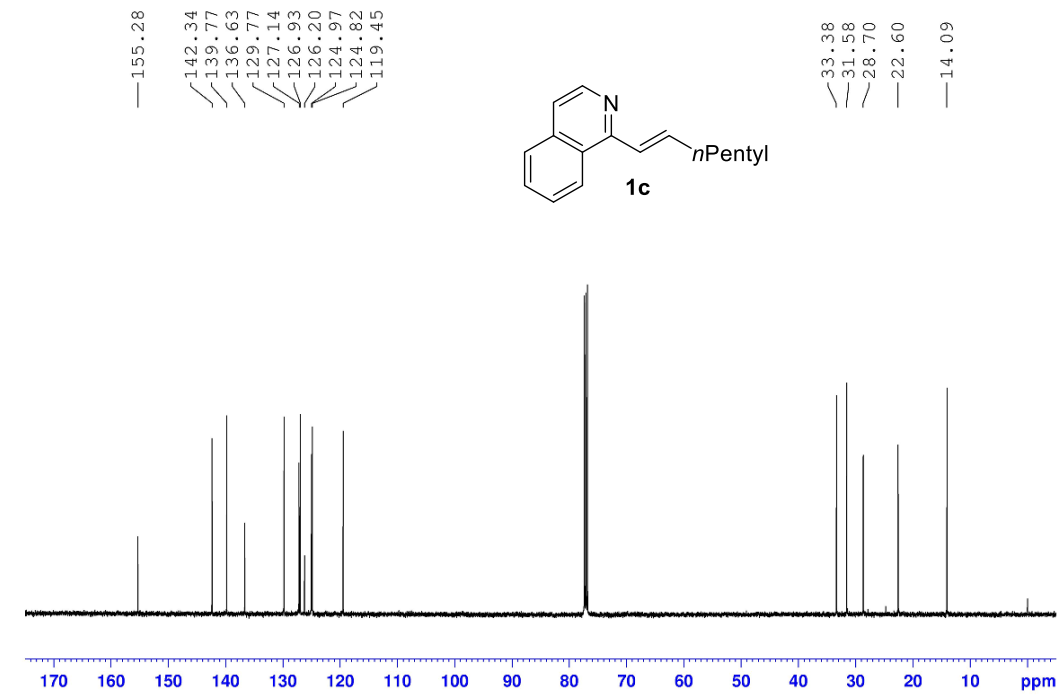
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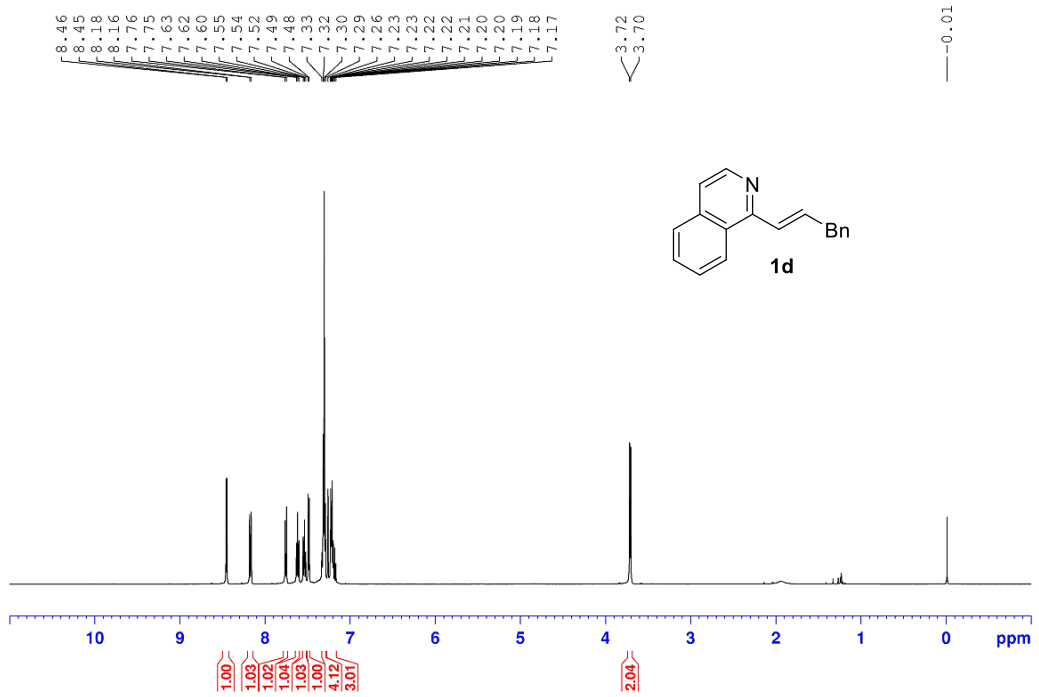
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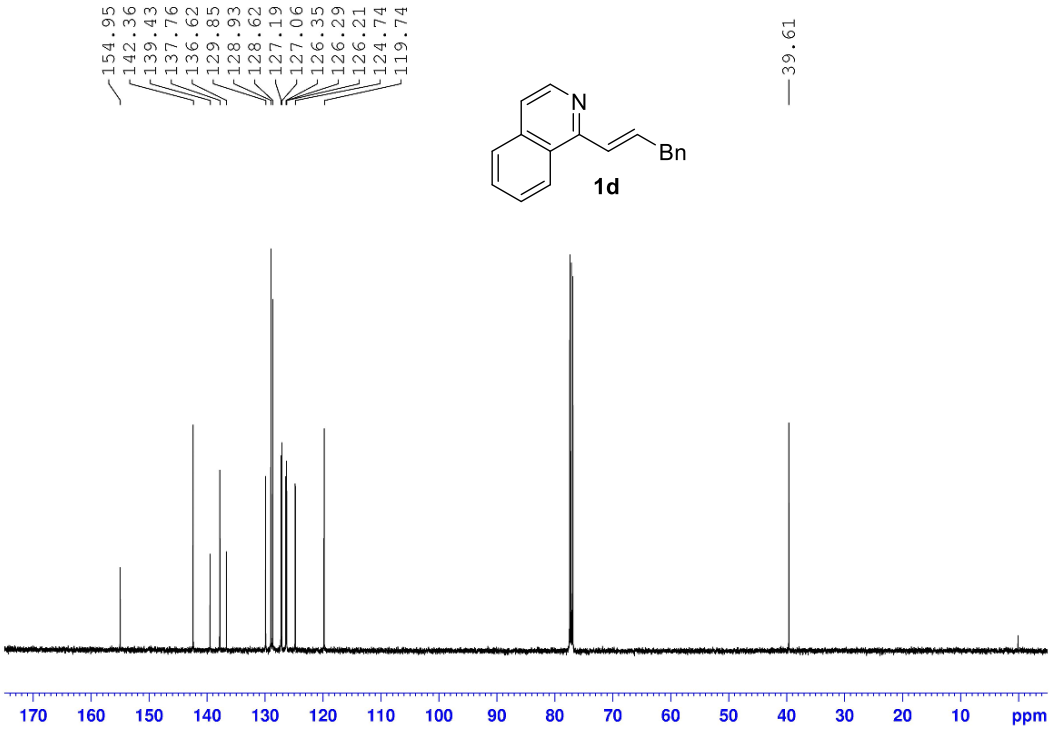
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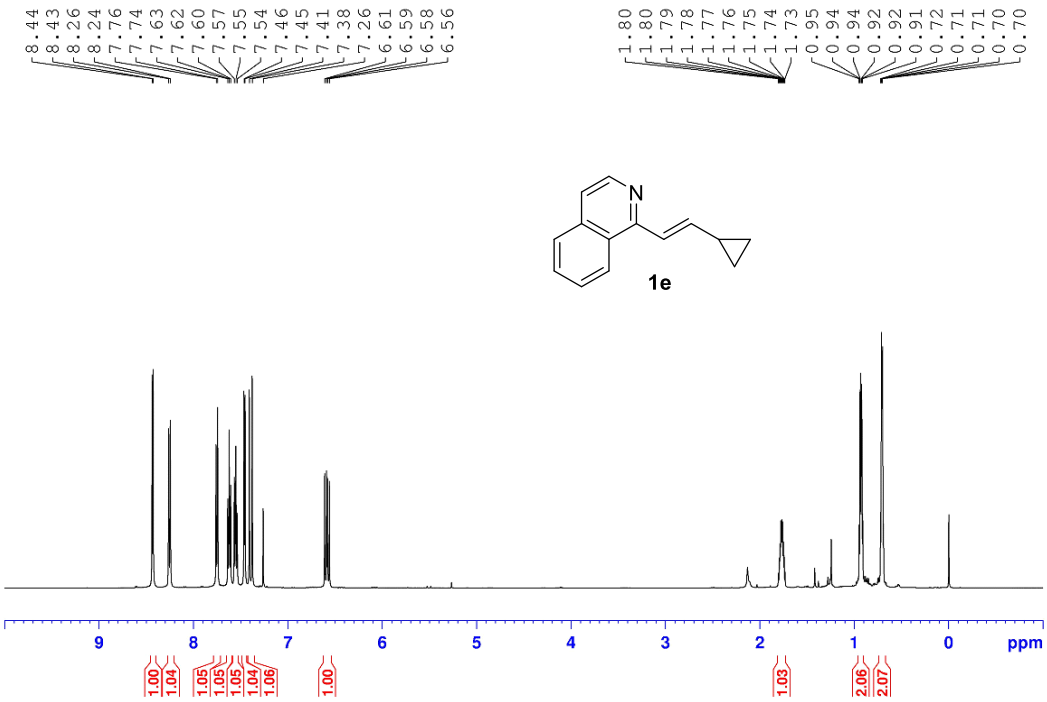
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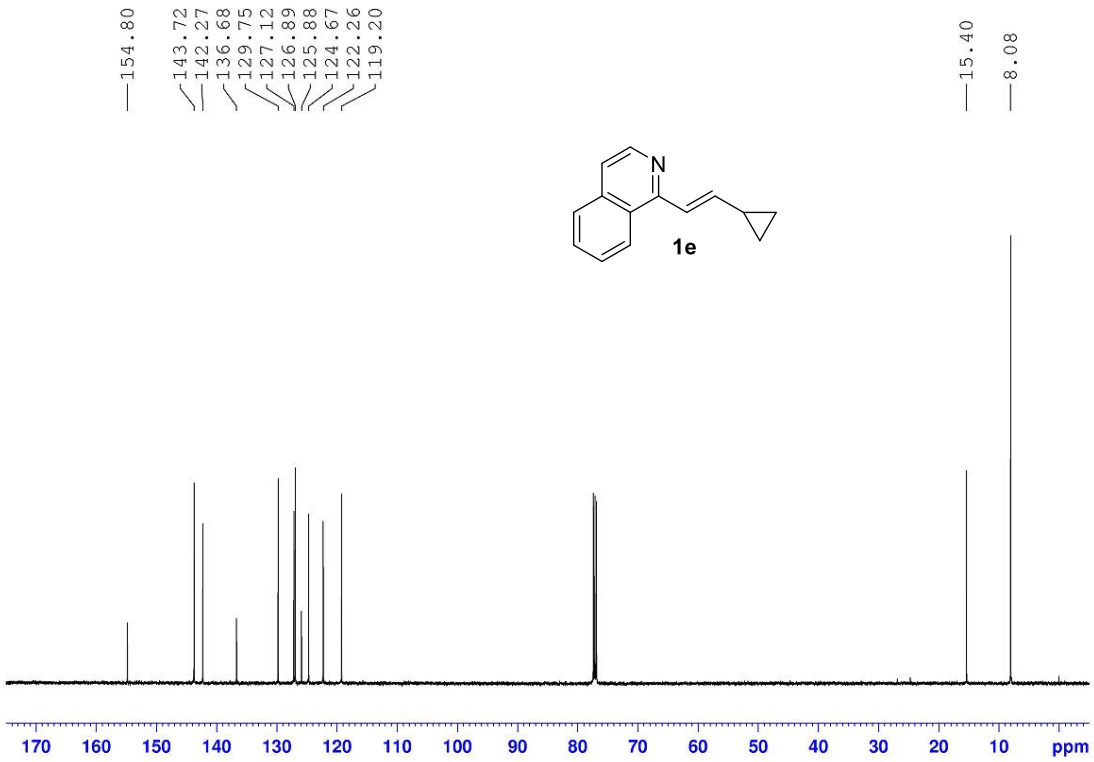
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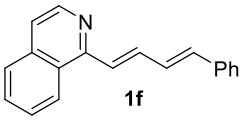
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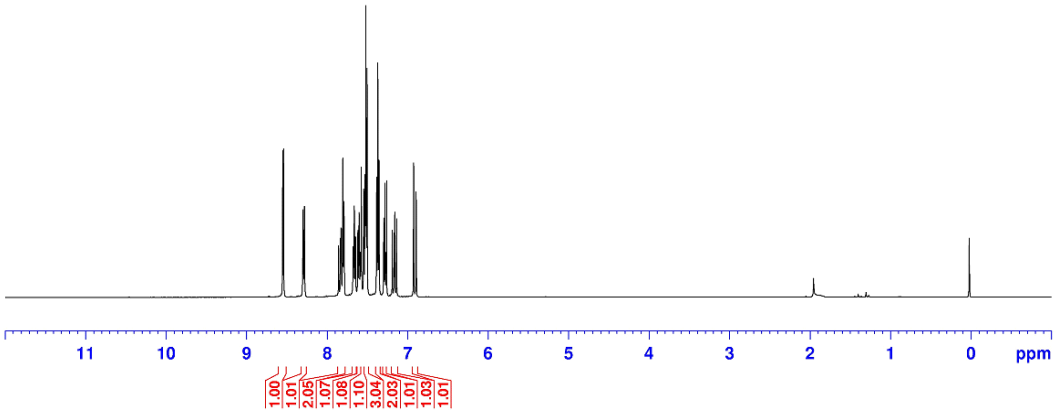
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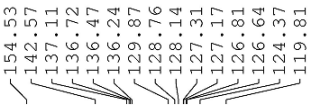
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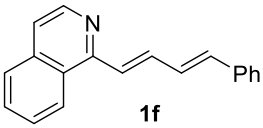
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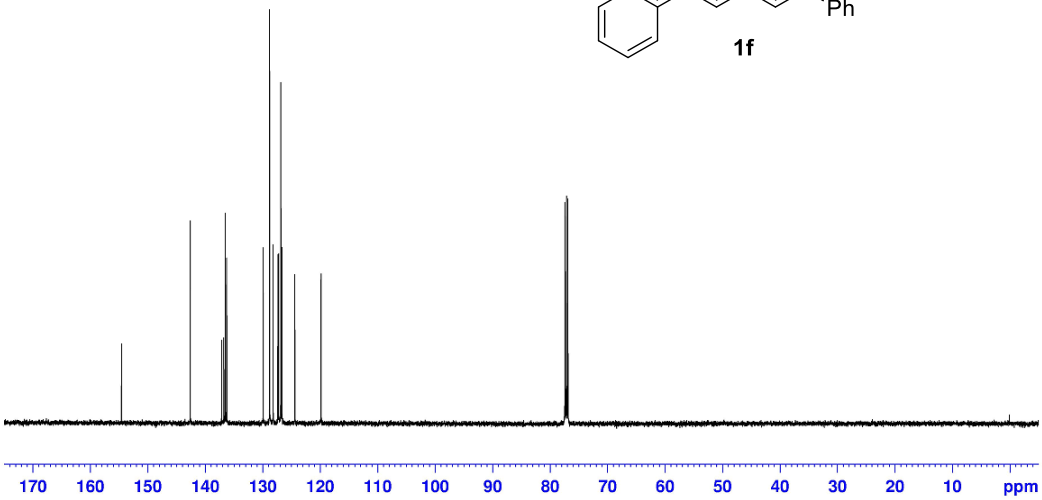
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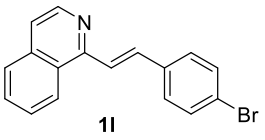
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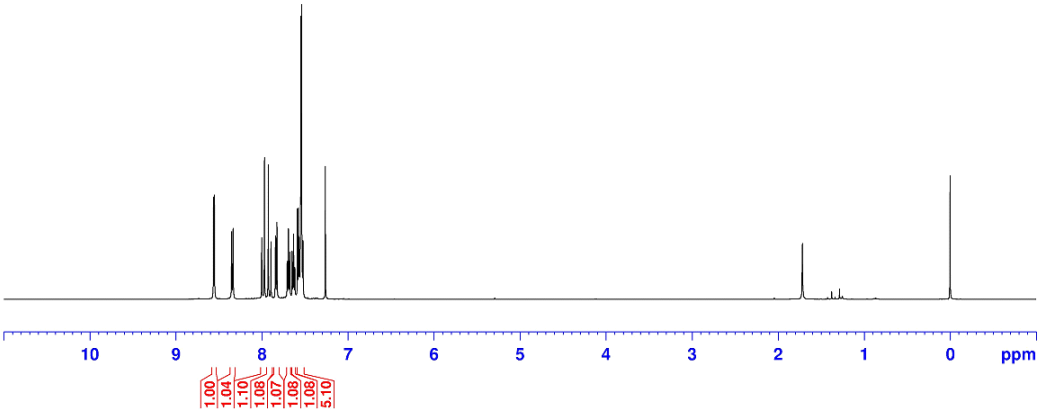
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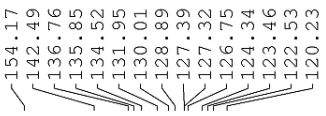
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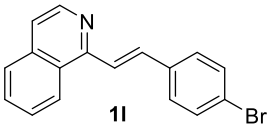
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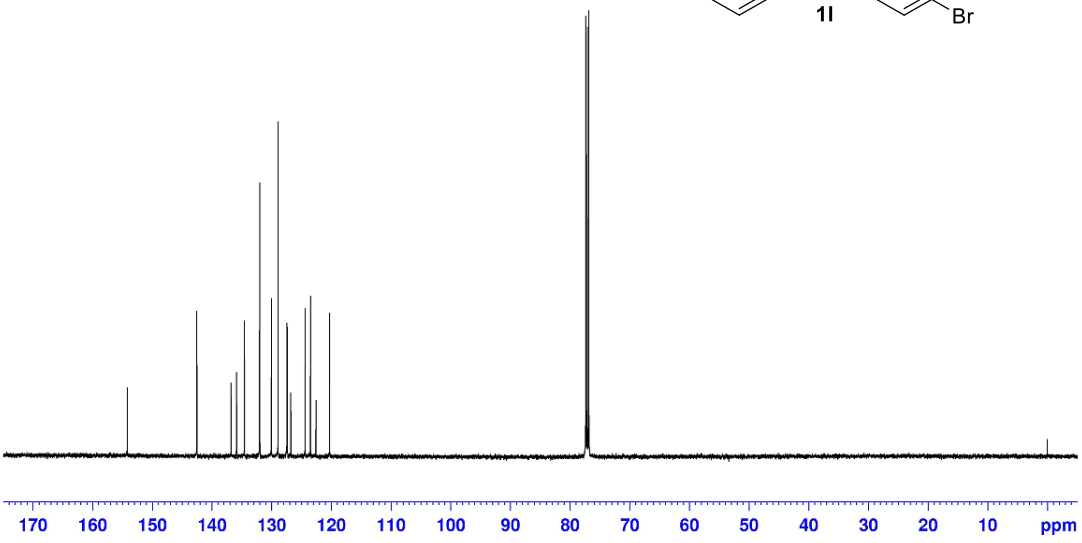
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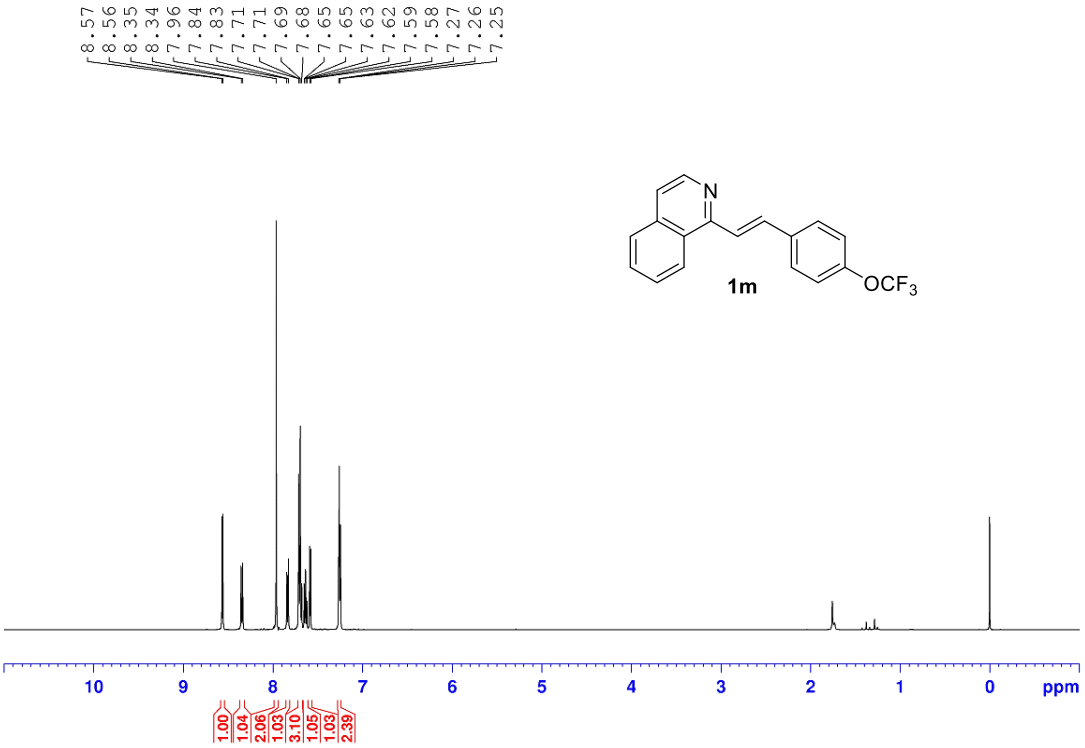
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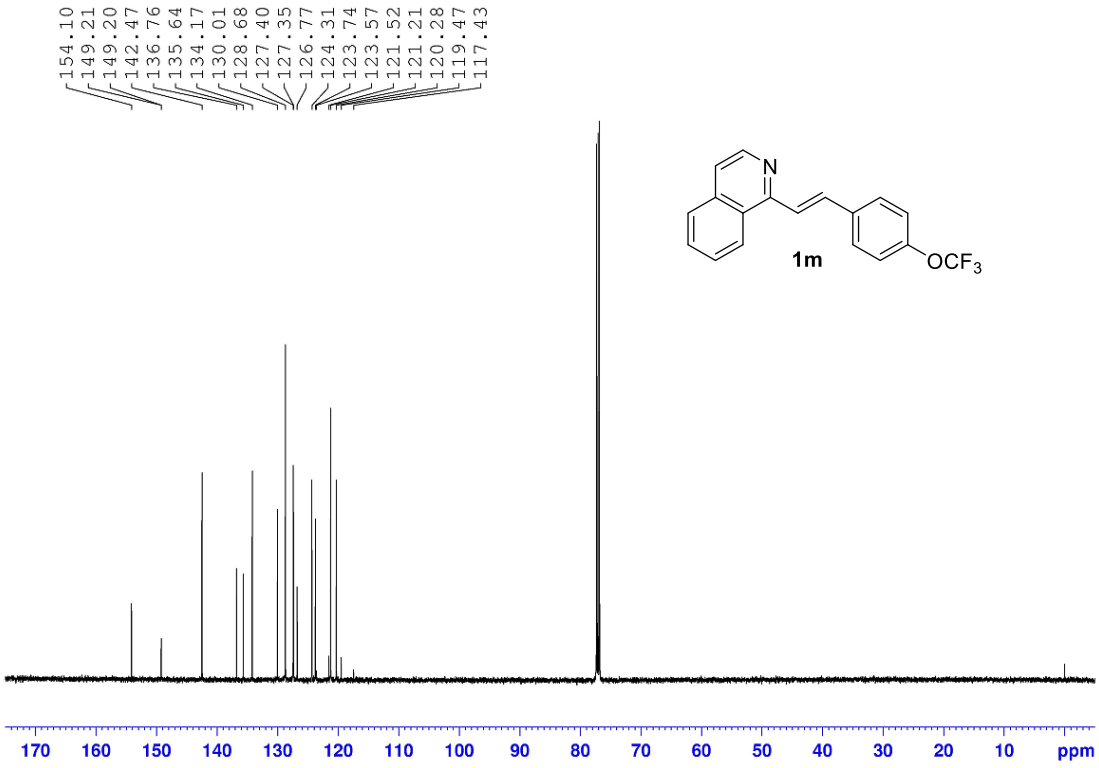
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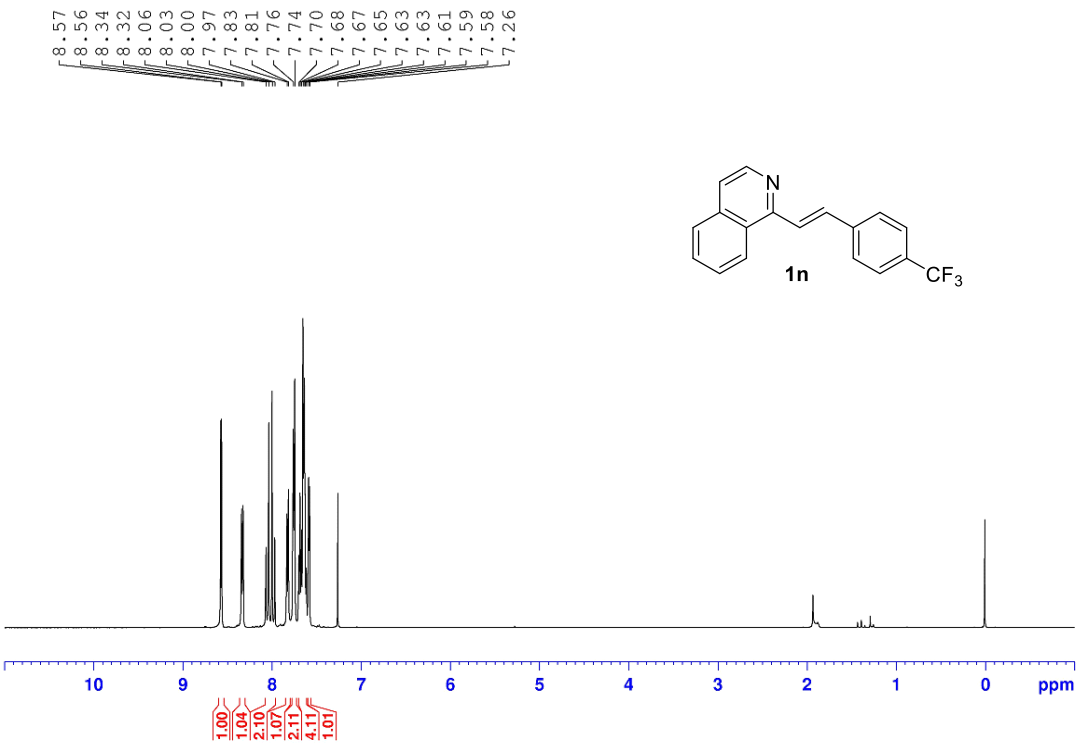
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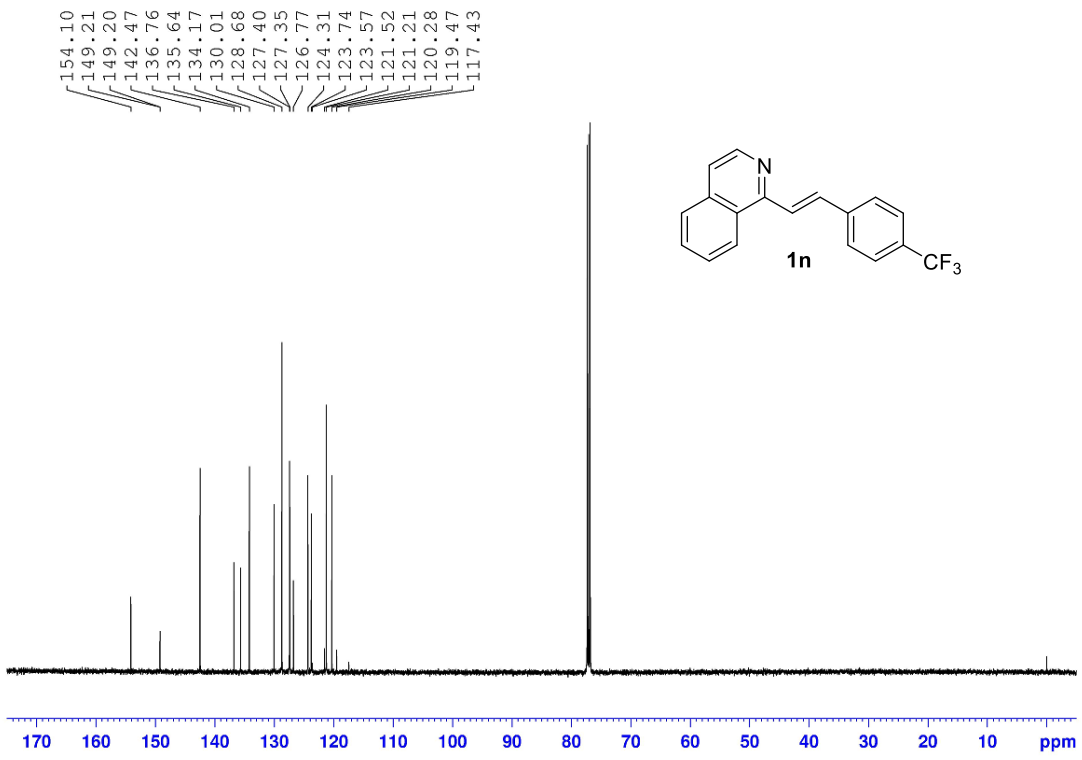
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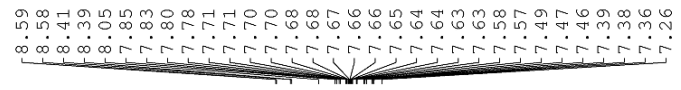
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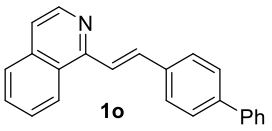
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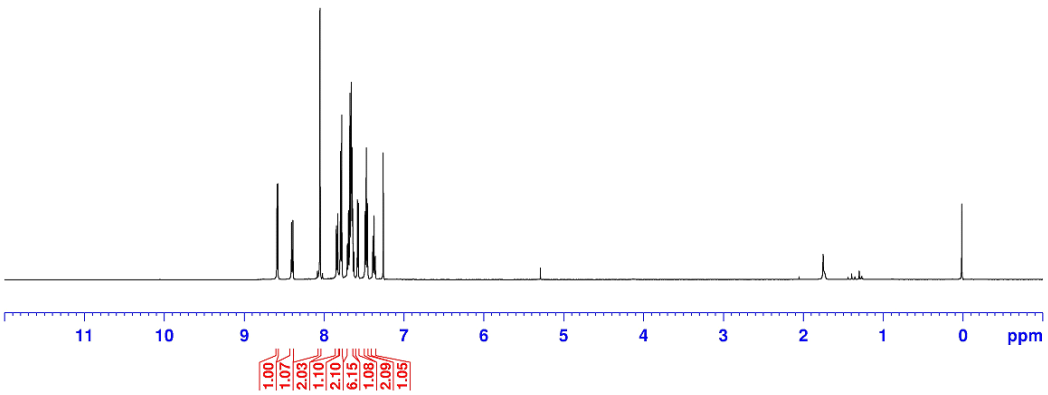
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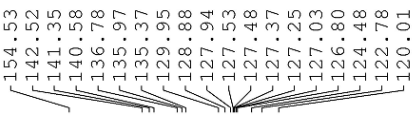
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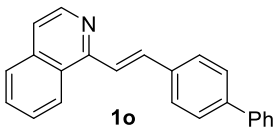
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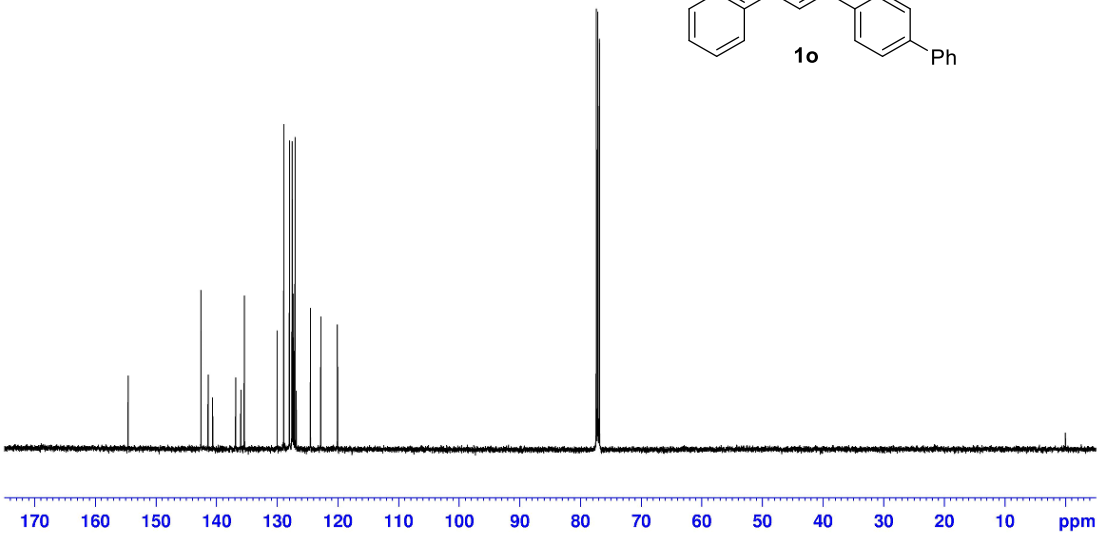
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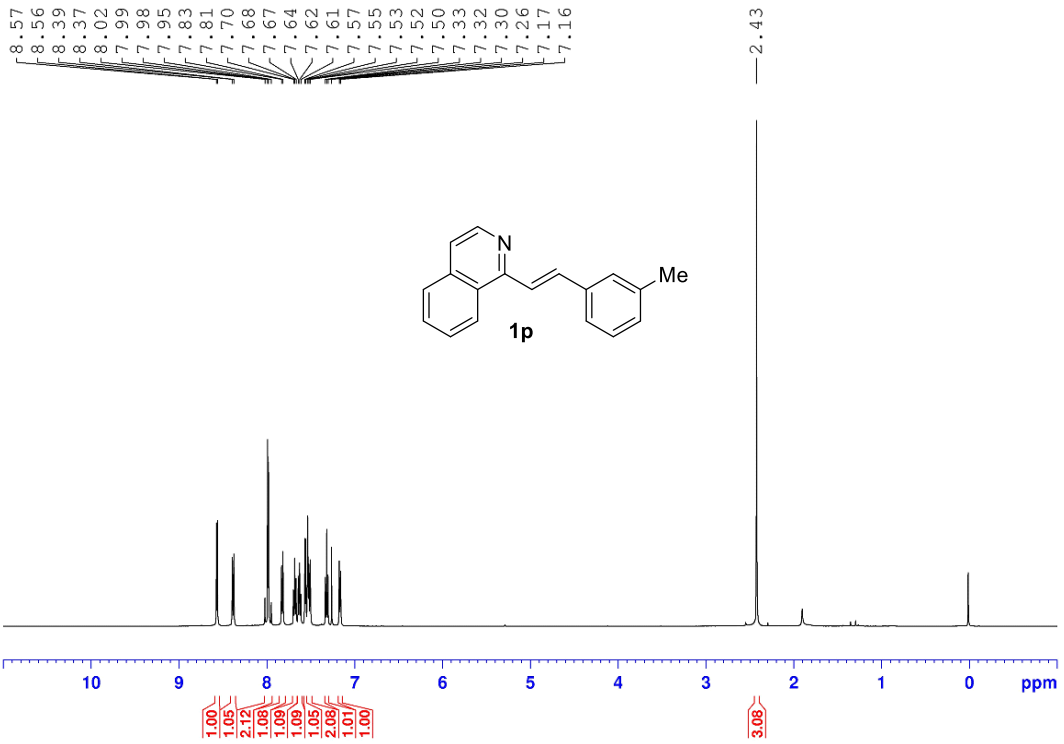
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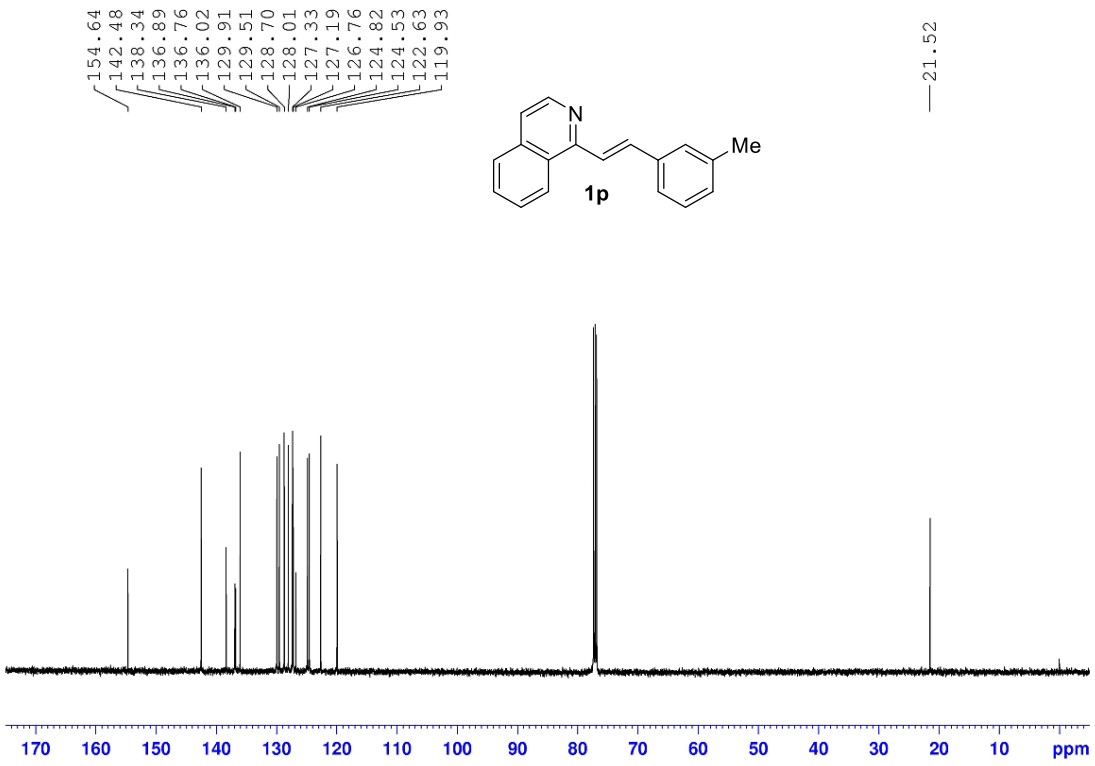
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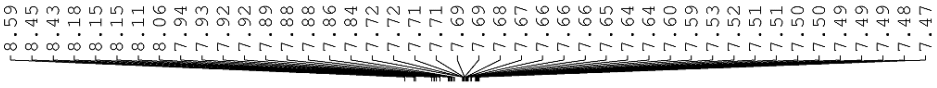
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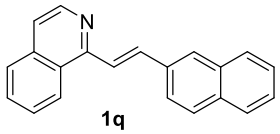
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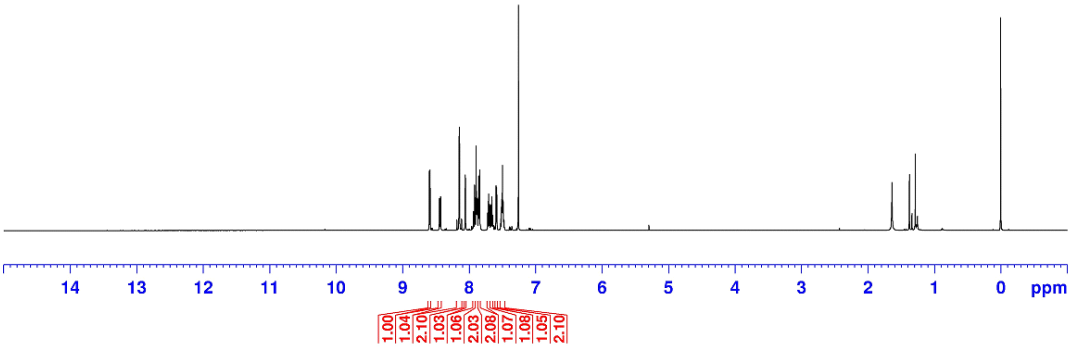
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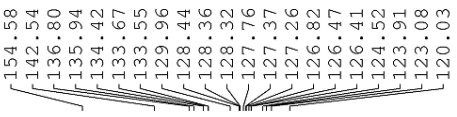
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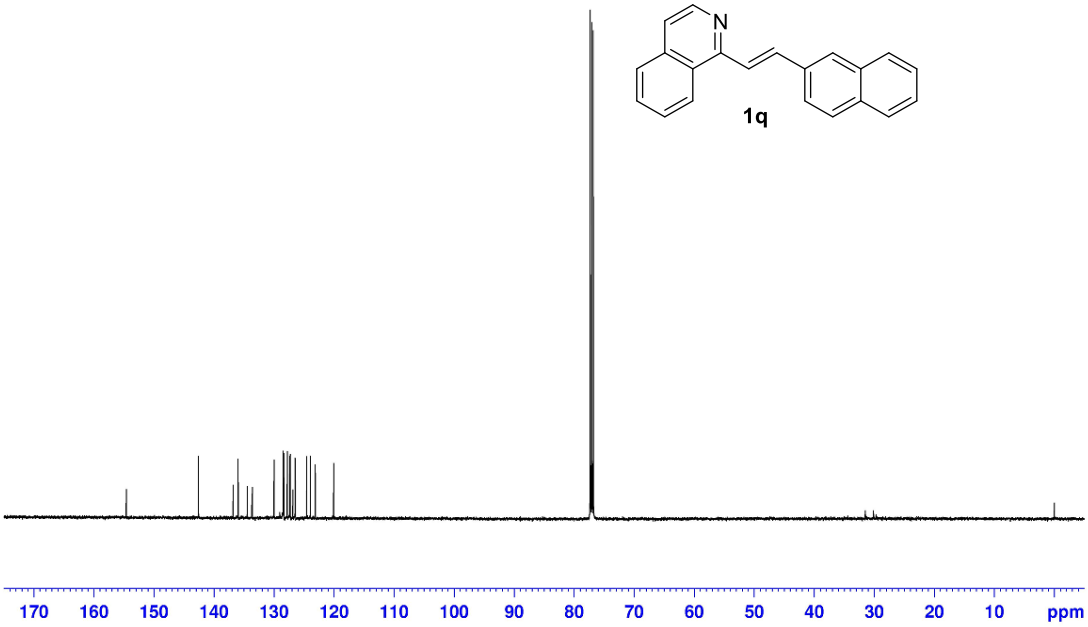
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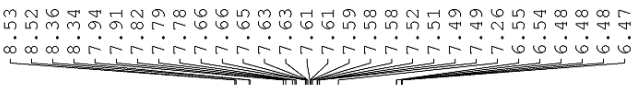
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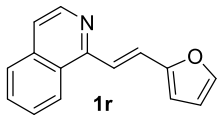
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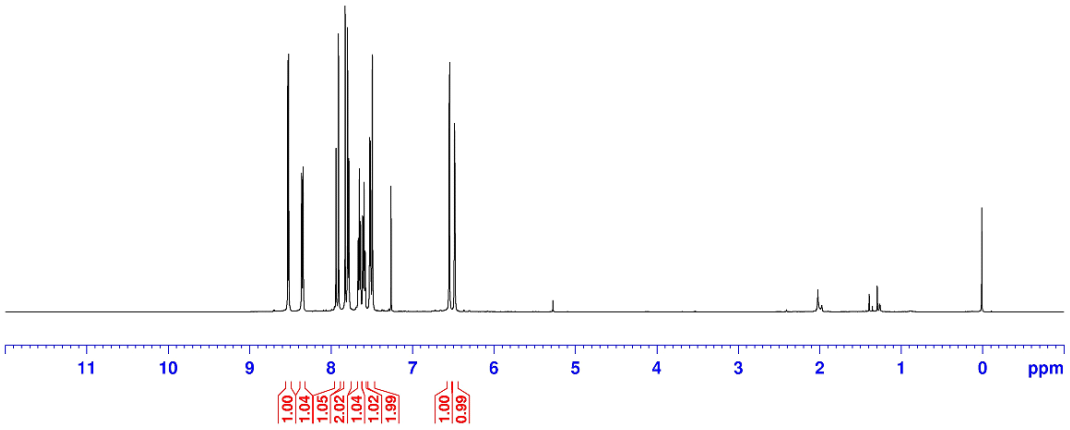
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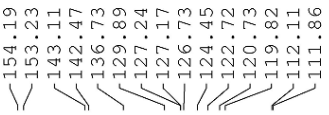
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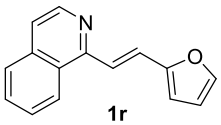
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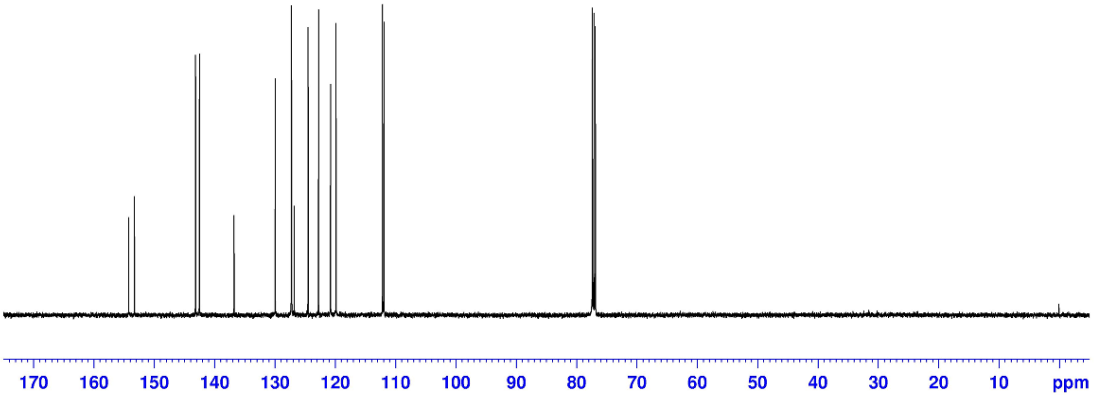
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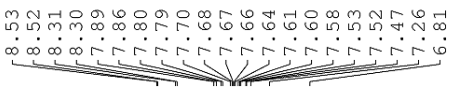
10
ppm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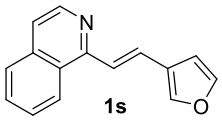
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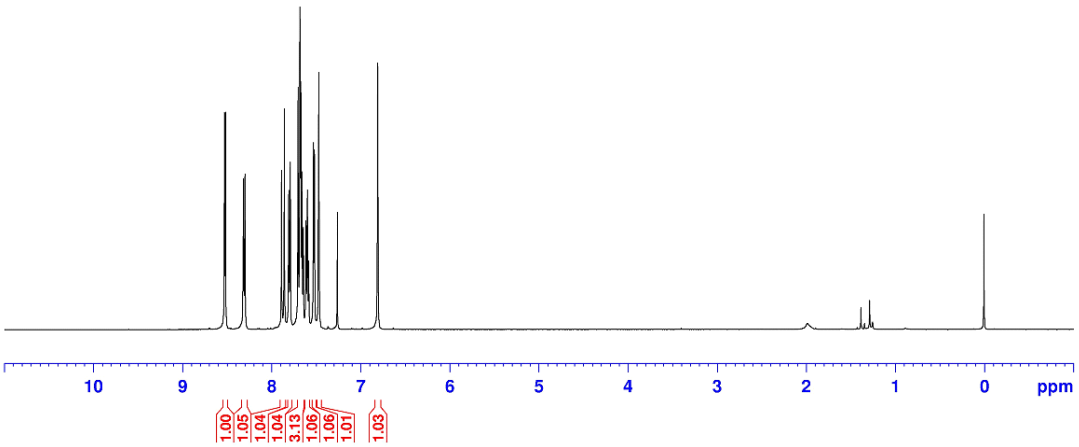
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1.04
1.04
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1.06
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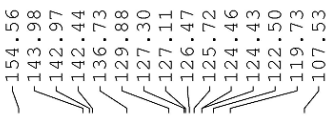
1.03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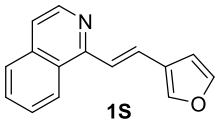
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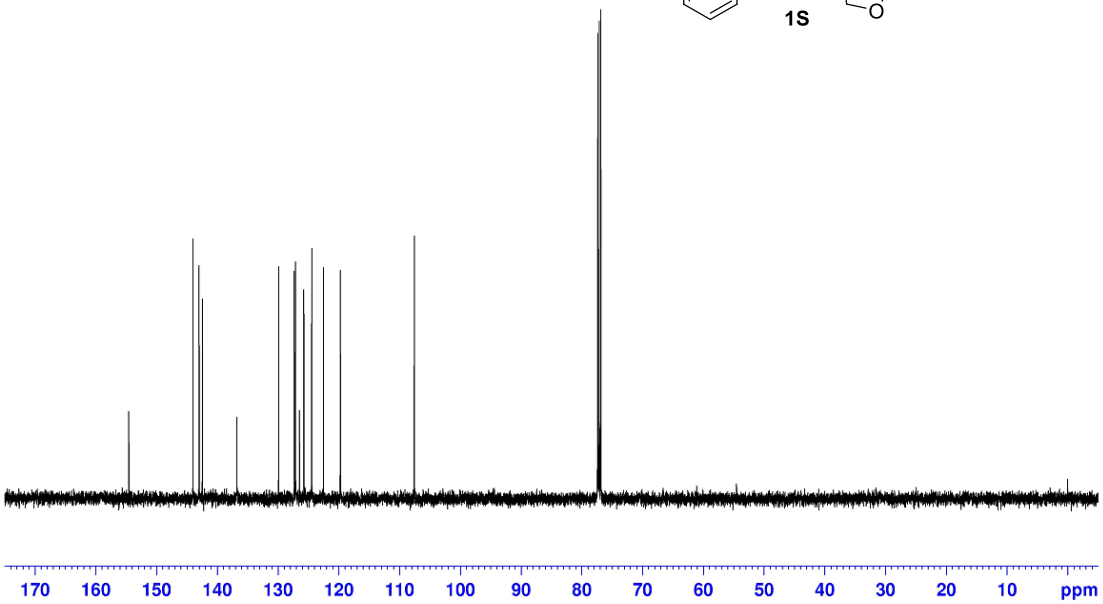
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20
10
ppm


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8.01
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7.65
7.63
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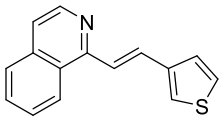
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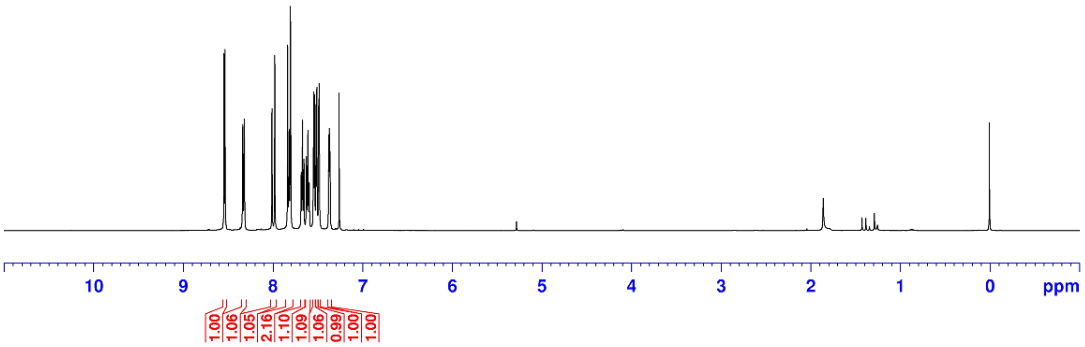
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1.09
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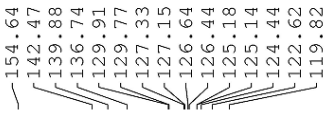
1.00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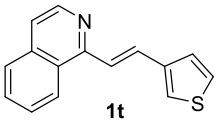
119.82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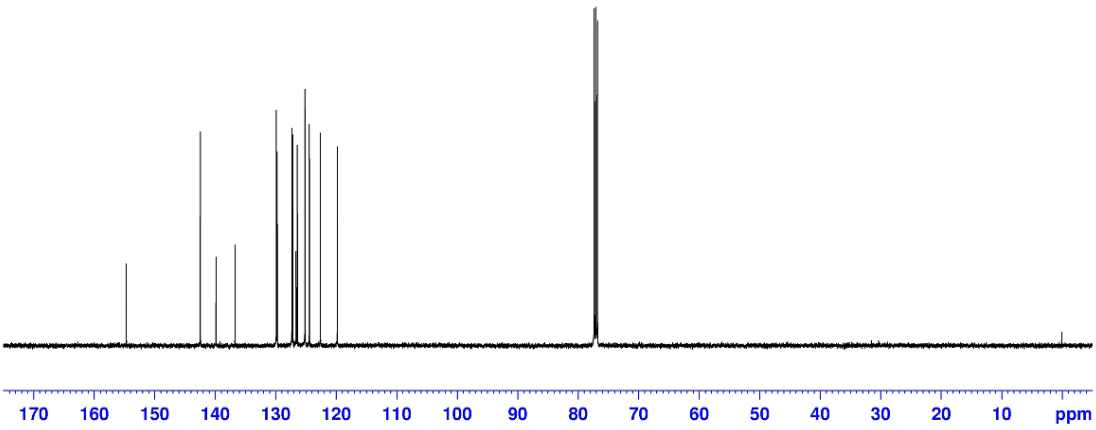
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20
10
ppm


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8.54
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8.31
8.05
8.03
8.02
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7.96
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7.81
7.69
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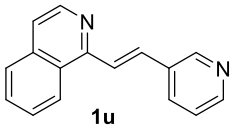
7.31
7.26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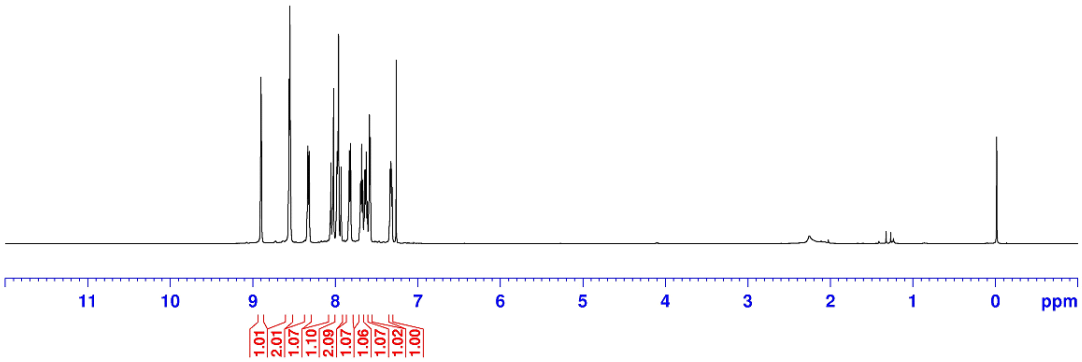
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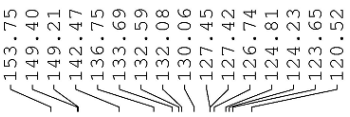
1.02
1.00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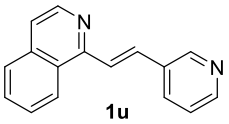
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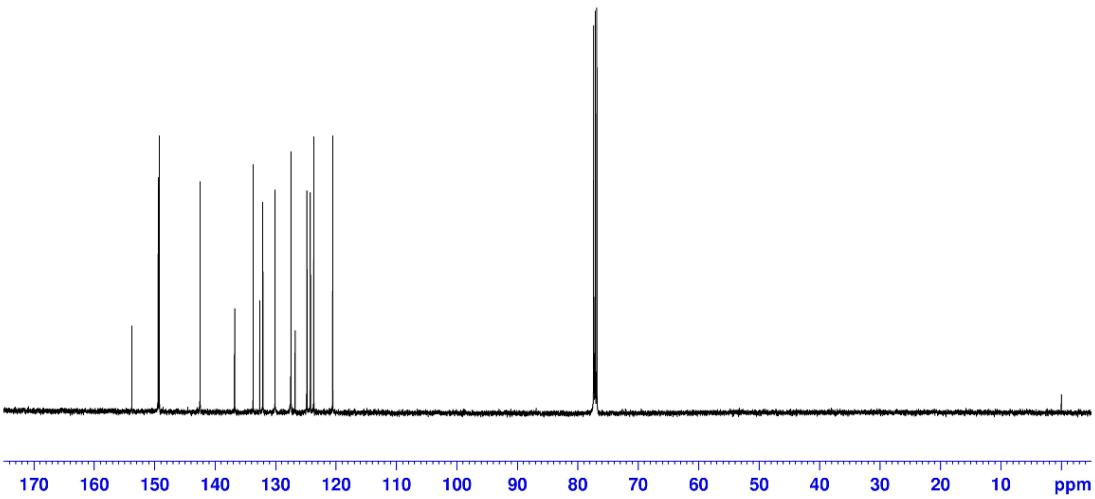
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10
ppm


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7.85
7.82
7.81
7.69
7.67
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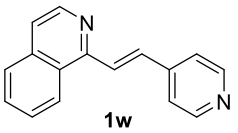
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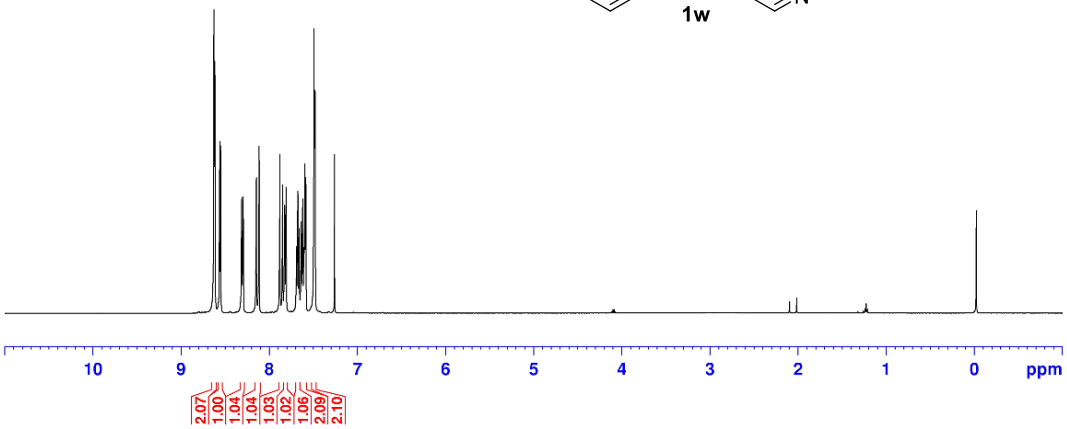
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1.04
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1.06
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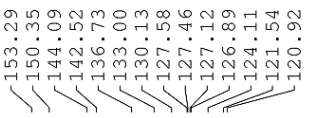
2.10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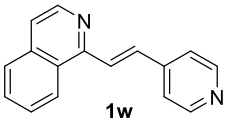
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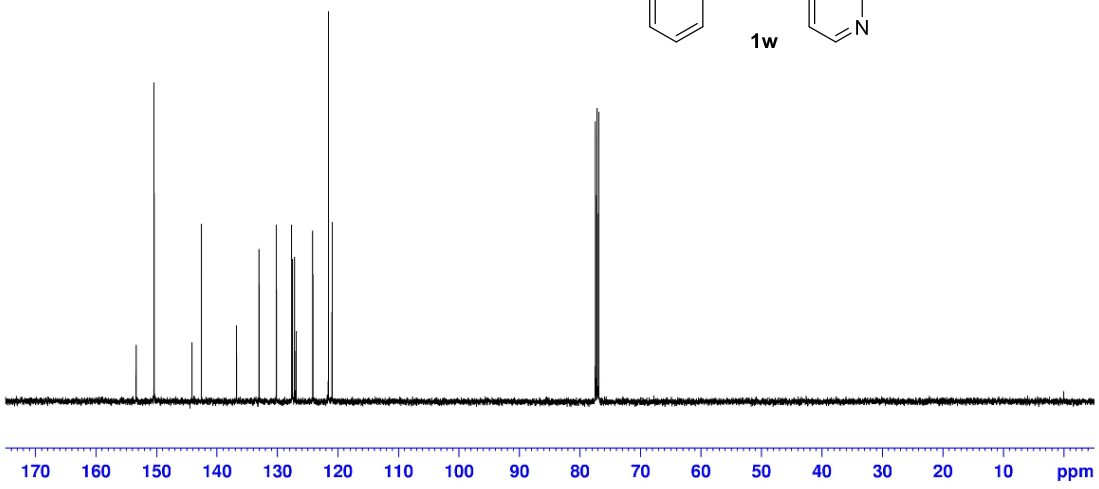
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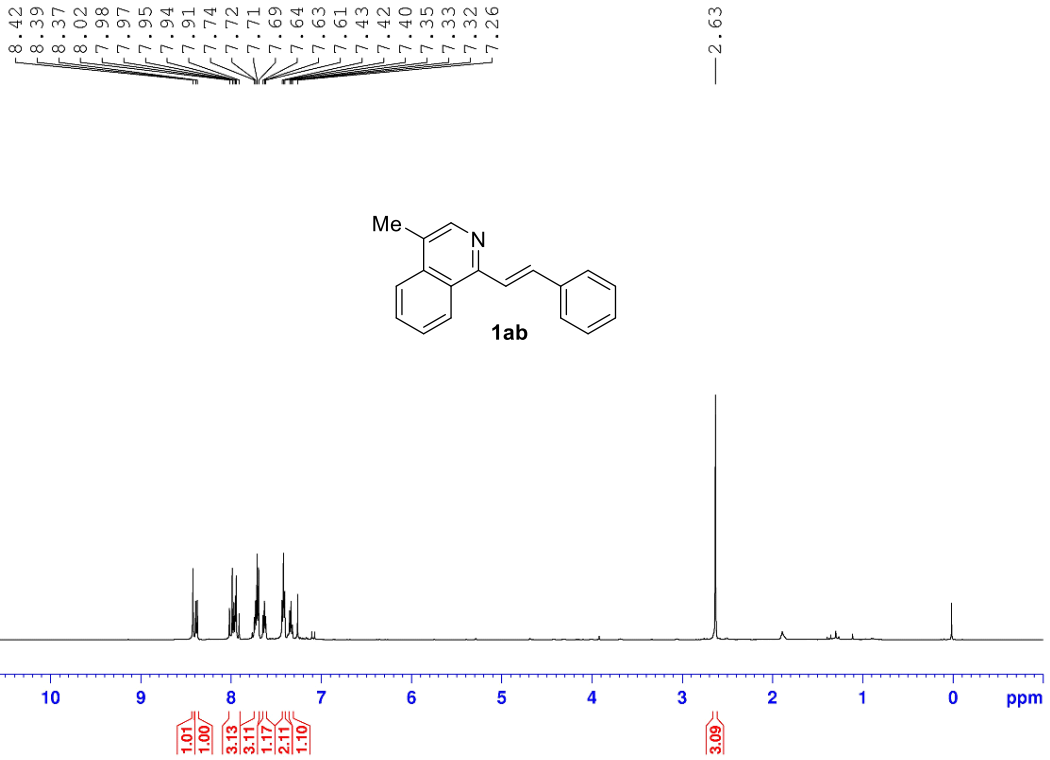
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7.64
7.63
7.61
7.43
7.42
7.40
7.35
7.33
7.32
7.26
2.63
Me
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1ab
10
9
8
7
6
5
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1.00
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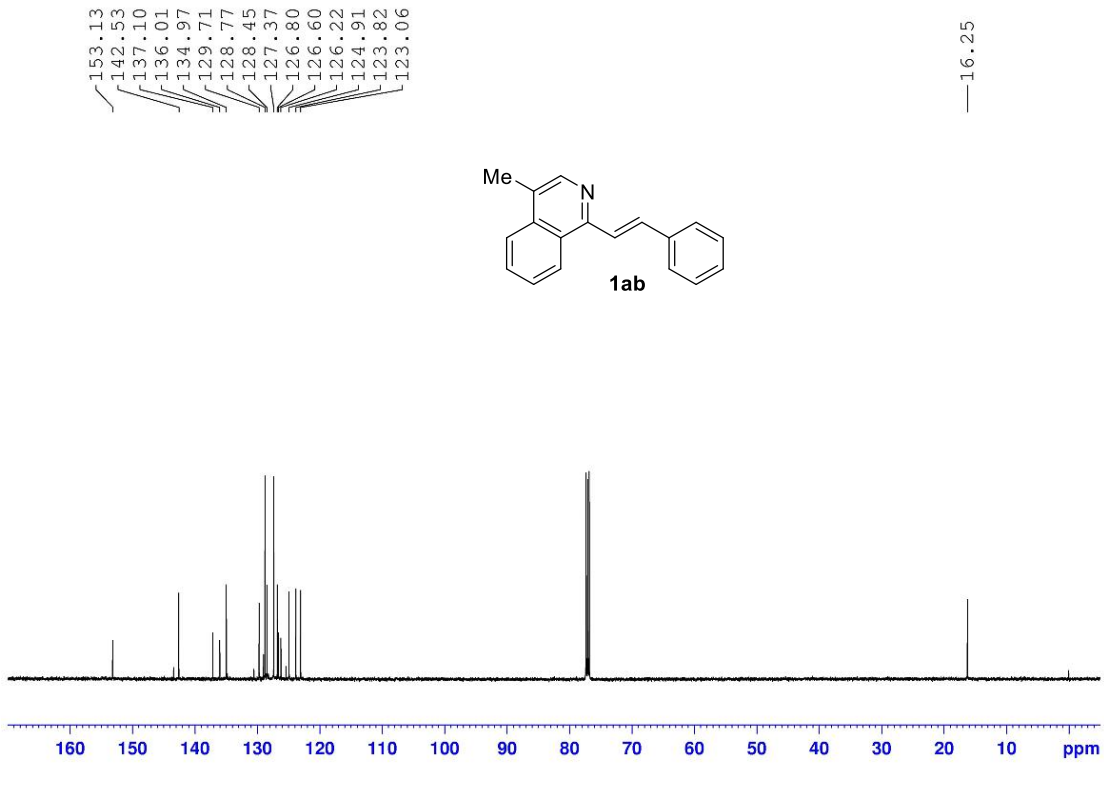
3.09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124.91
123.82
123.06
16.25
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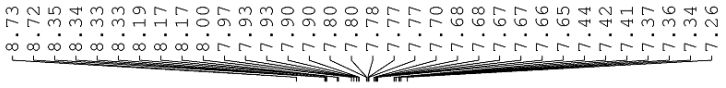
30
20
10
ppm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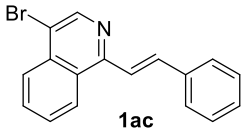
7.26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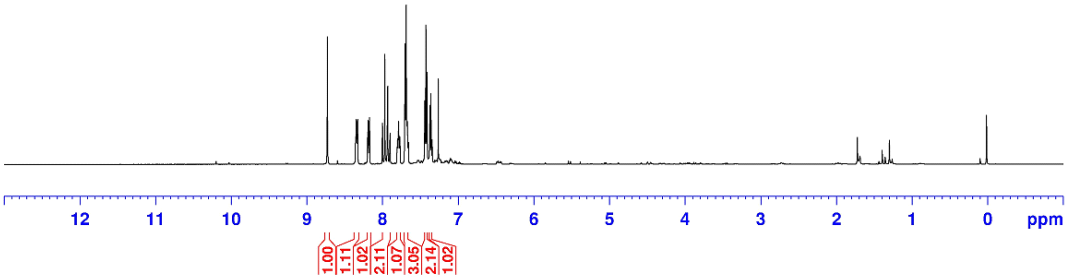
1ac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1.11
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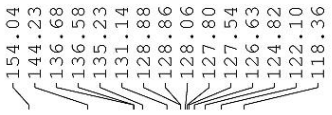
1.02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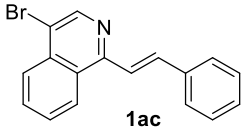
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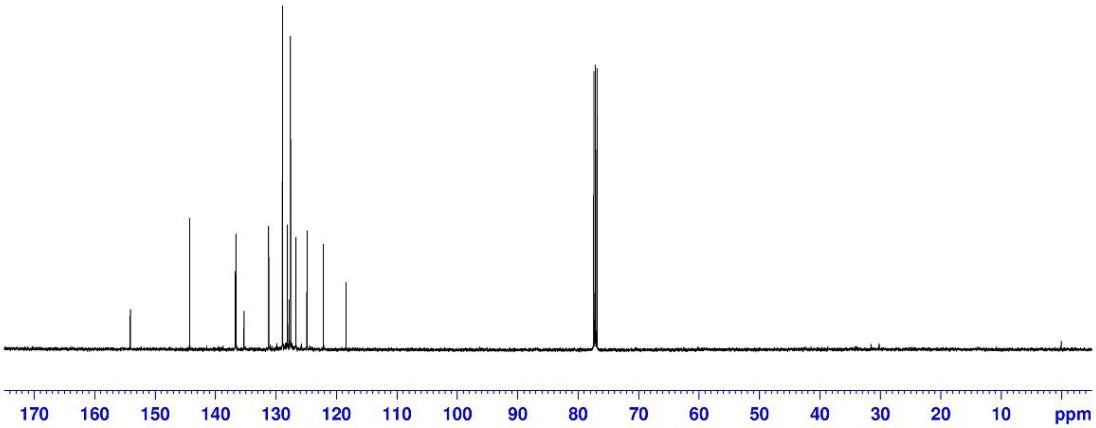
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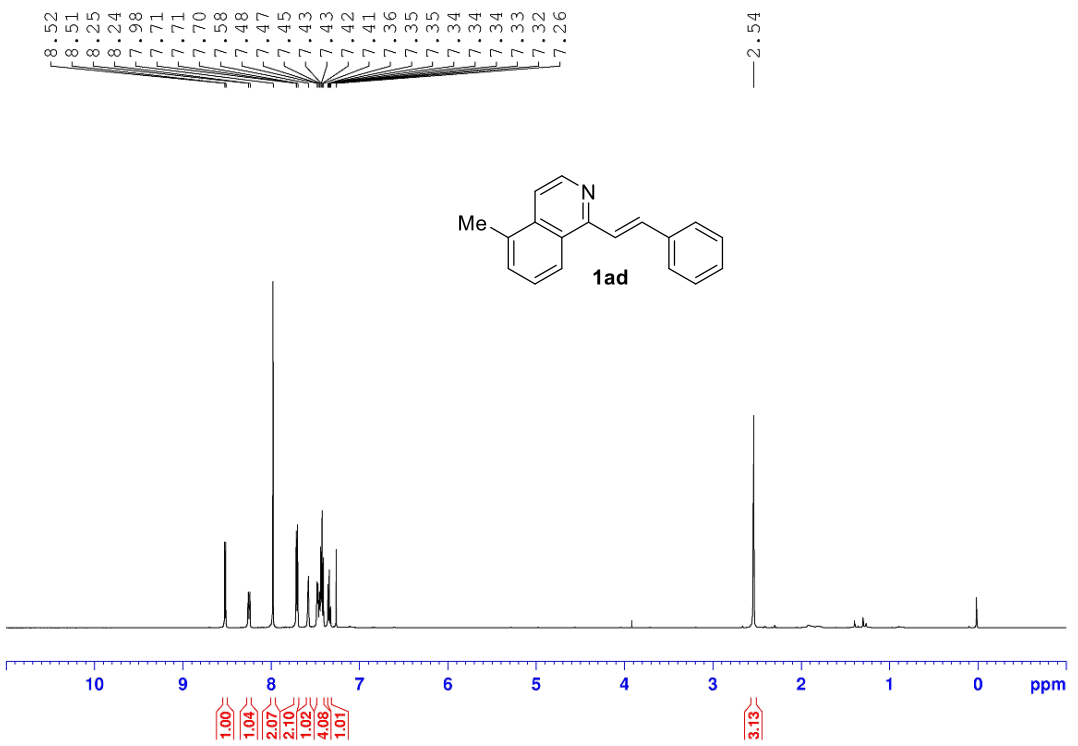
10
ppm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7.43
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7.41
7.36
7.35
7.35
7.34
7.34
7.34
7.33
7.32
7.26
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7
6
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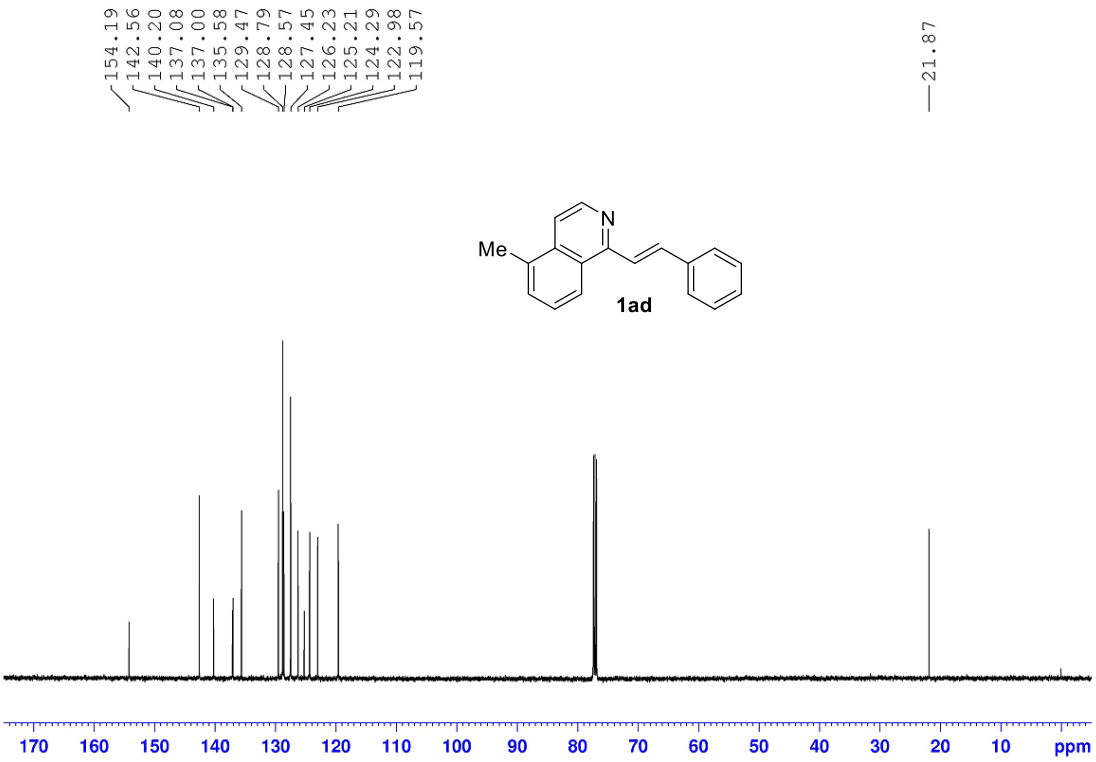
3.13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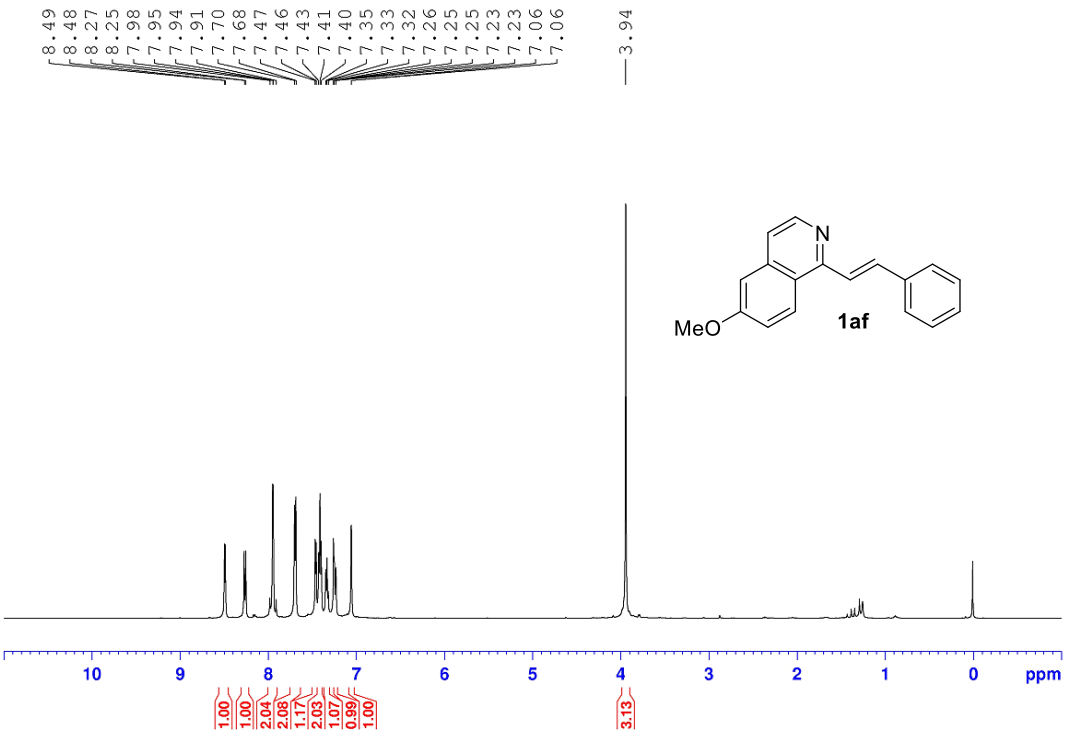
30
20
10
ppm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7.40
7.35
7.33
7.32
7.26
7.25
7.25
7.23
7.06
7.06
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MeO
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7
6
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4
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2.03
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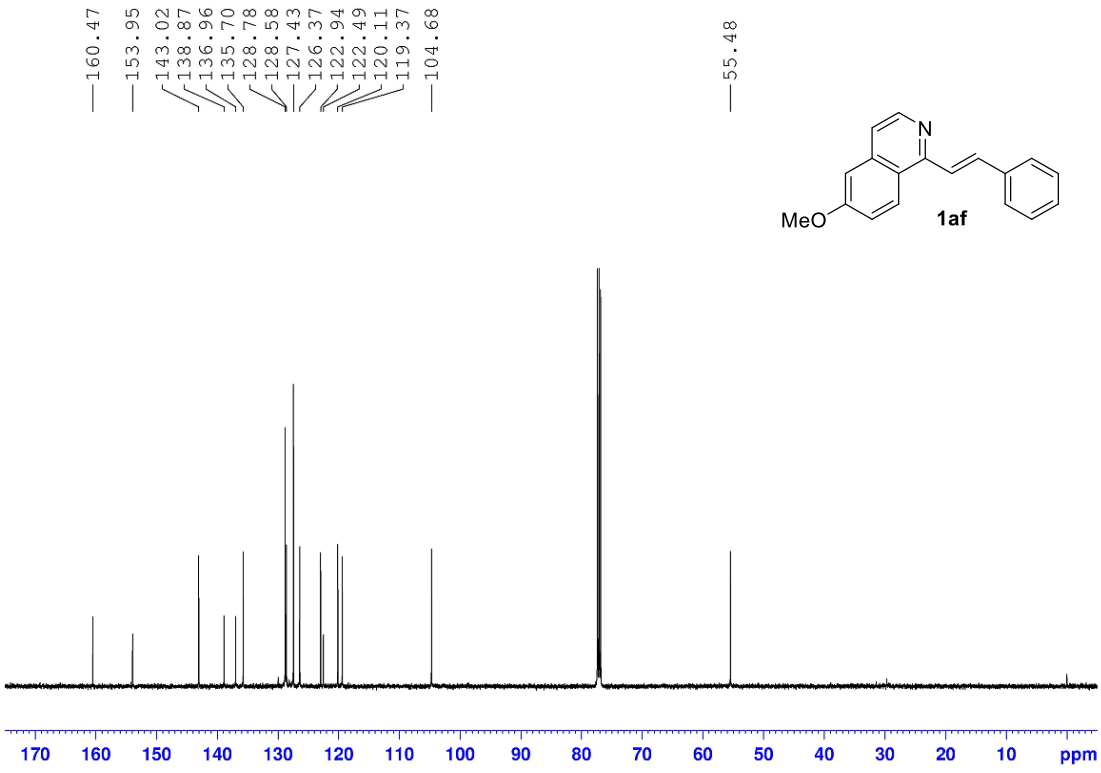
3.13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128.58
127.43
126.37
122.94
122.49
120.11
119.37
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55.48
N
MeO
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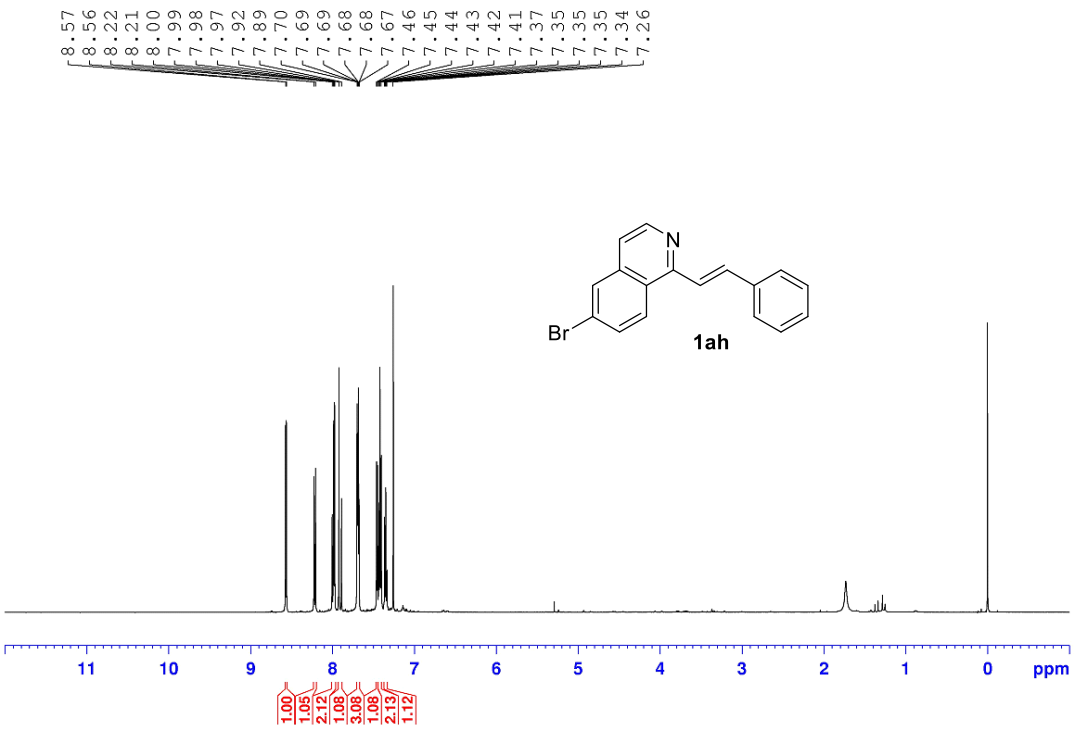
ppm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7.69
7.68
7.68
7.67
7.46
7.45
7.44
7.43
7.42
7.41
7.37
7.35
7.35
7.35
7.34
7.26
N
Br
1ah
11
10
9
8
7
6
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1.08
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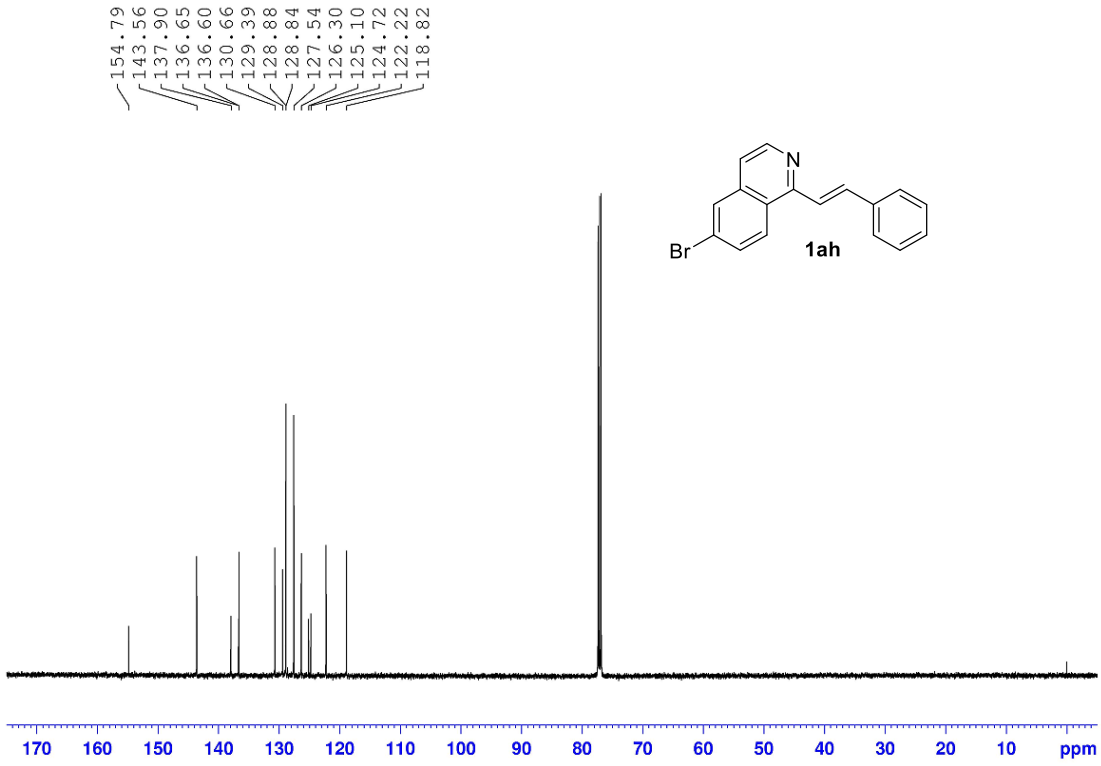
1.08
2.13
1.12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127.54
126.30
125.10
124.72
122.22
118.82
N
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140
130
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100
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70
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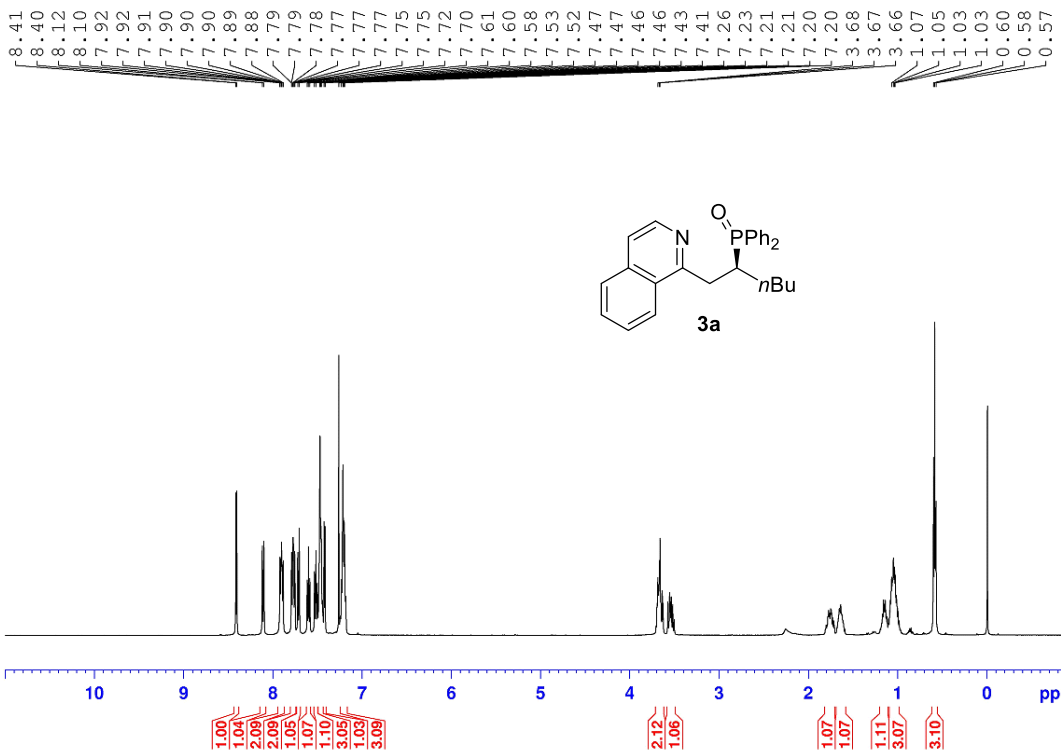
ppm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7.90
7.90
7.89
7.88
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7.79
7.78
7.77
7.77
7.77
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7.75
7.72
7.70
7.61
7.60
7.58
7.53
7.52
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7.26
7.23
7.21
7.21
7.20
7.20
3.68
3.67
3.66
1.07
1.05
1.03
1.03
0.60
0.58
0.57
O
PPh2
N
nBu
3a
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
1.04
2.09
2.09
1.05
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1.07
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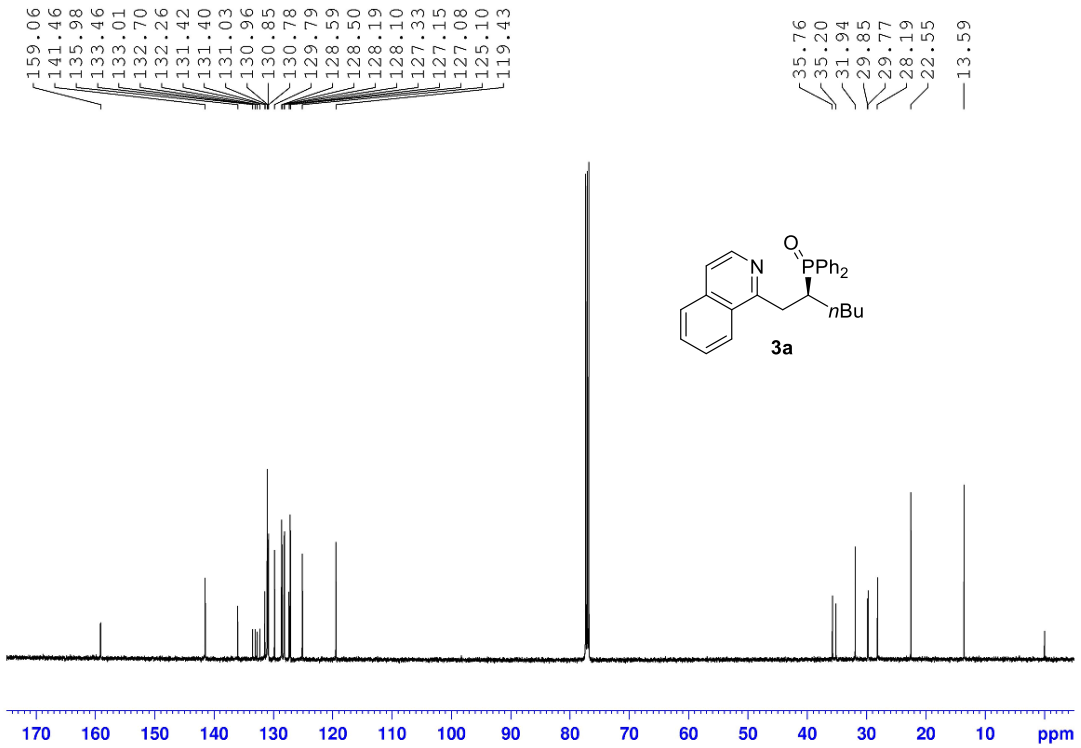
3.07
3.10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131.03
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130.78
129.79
128.59
128.50
128.19
128.10
127.33
127.15
127.08
125.10
119.43
35.76
35.20
31.94
29.85
29.77
28.19
22.55
13.59
O
PPh2
N
nBu
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140
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110
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30
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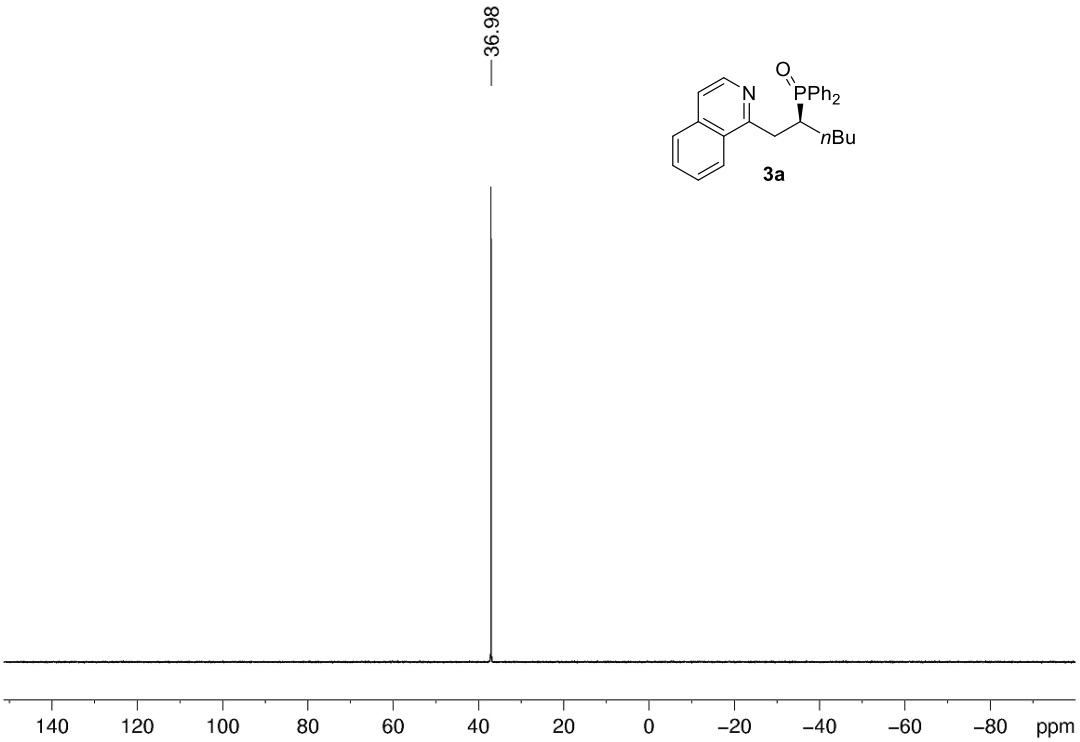
10
ppm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O
PPh2
N
nBu
3a
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120
100
80
60
40
20
0
−20
−40
−60
−80
ppm


8.40
8.39
8.08
8.06
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7.91
7.90
7.90
7.89
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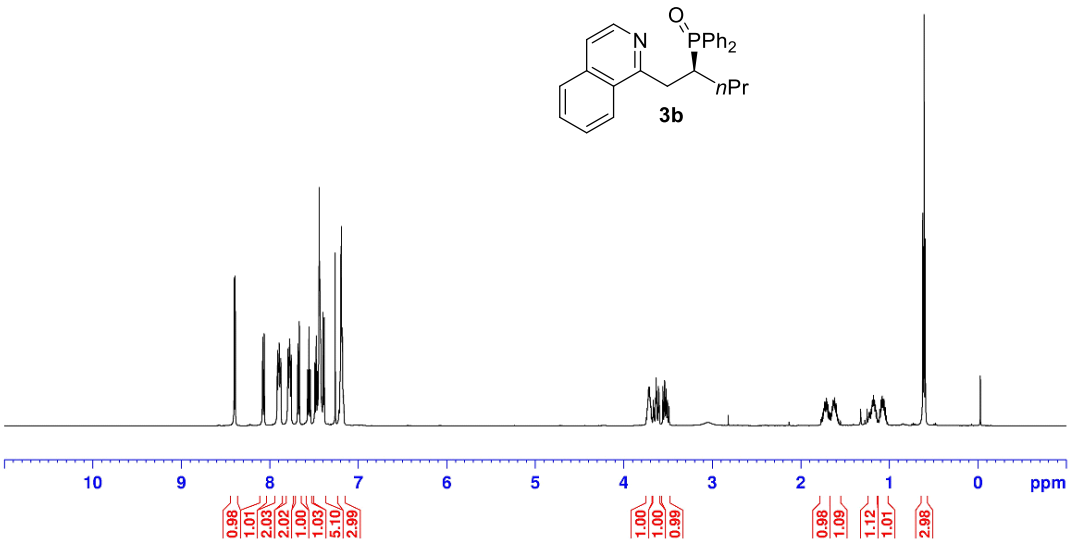
0.61
0.59


O
PPh2
N
nPr
3b
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2
1
0
ppm
0.98
1.01
2.03
2.02
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0.98
1.09
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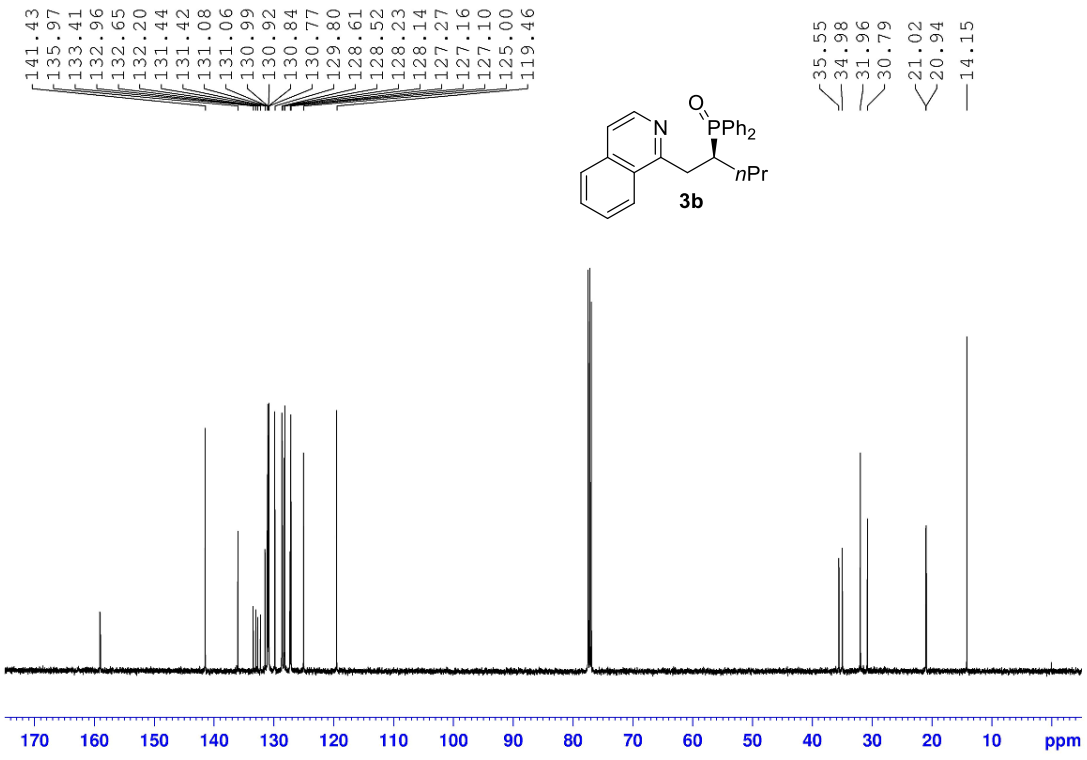
1.01
2.98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130.77
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127.16
127.10
125.00
119.46
35.55
34.98
31.96
30.79
21.02
20.94
14.15
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PPh2
N
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3b
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70
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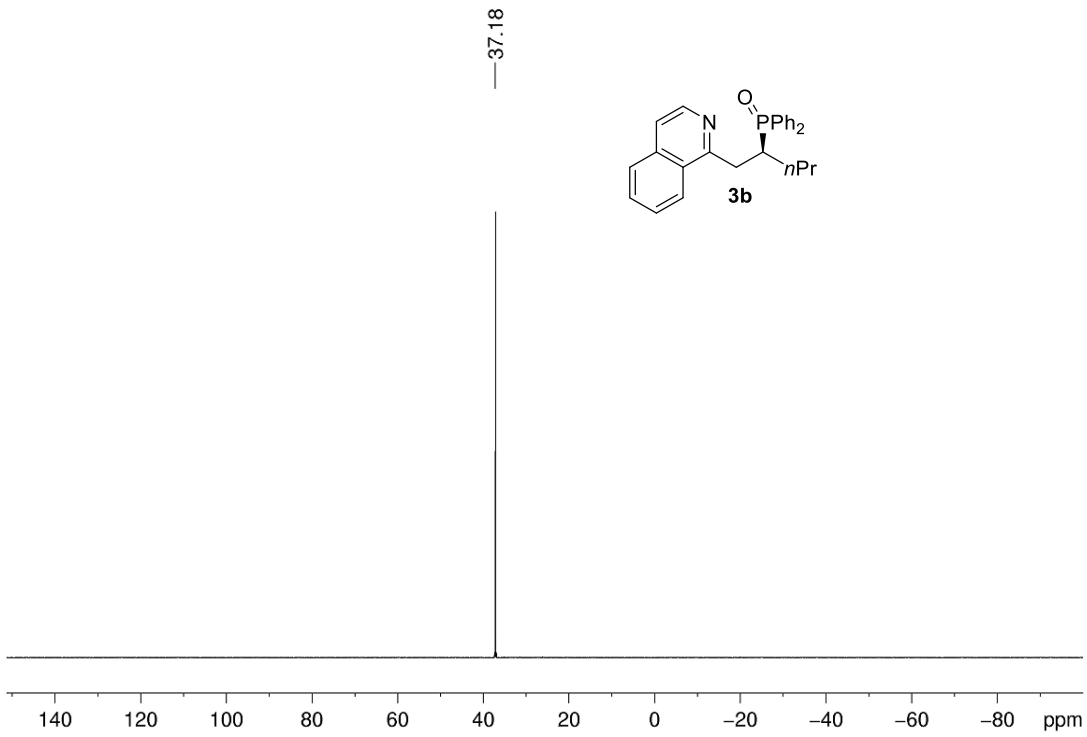
30
20
10
ppm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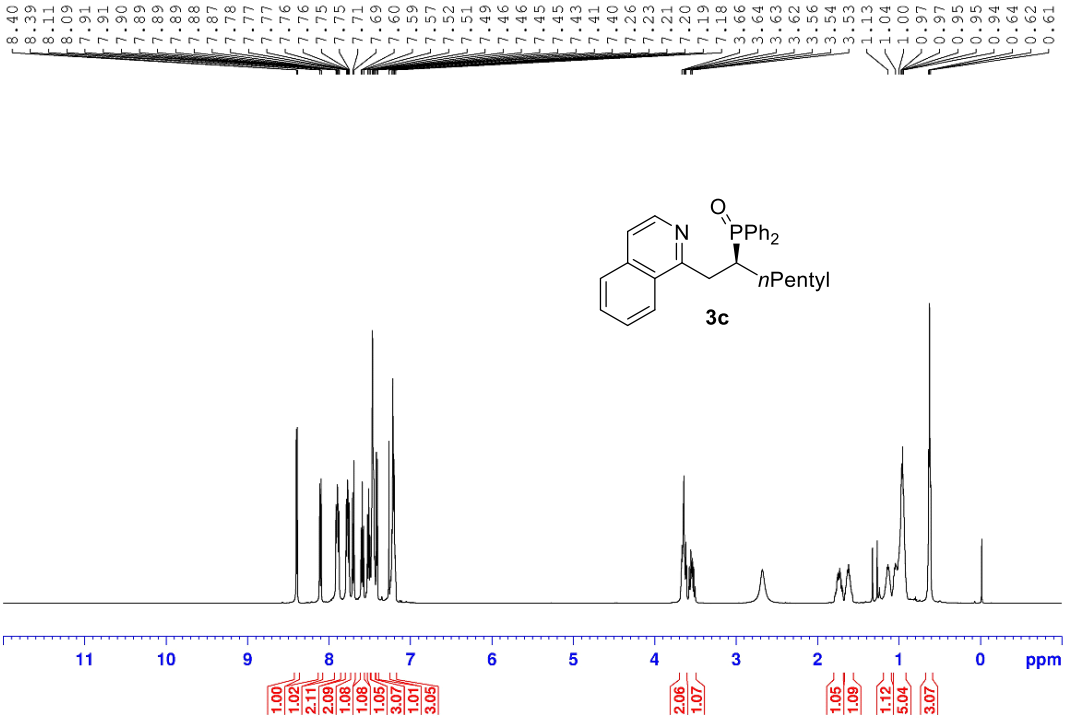
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7.76
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7.71
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7.57
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7.51
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7.46
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7.45
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7.19
7.18
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3.63
3.62
3.56
3.54
3.53
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0.97
0.95
0.95
0.94
0.64
0.62
0.61
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PPh2
N
nPentyl
3c
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10
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8
7
6
5
4
3
2
1
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1.02
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2.09
1.08
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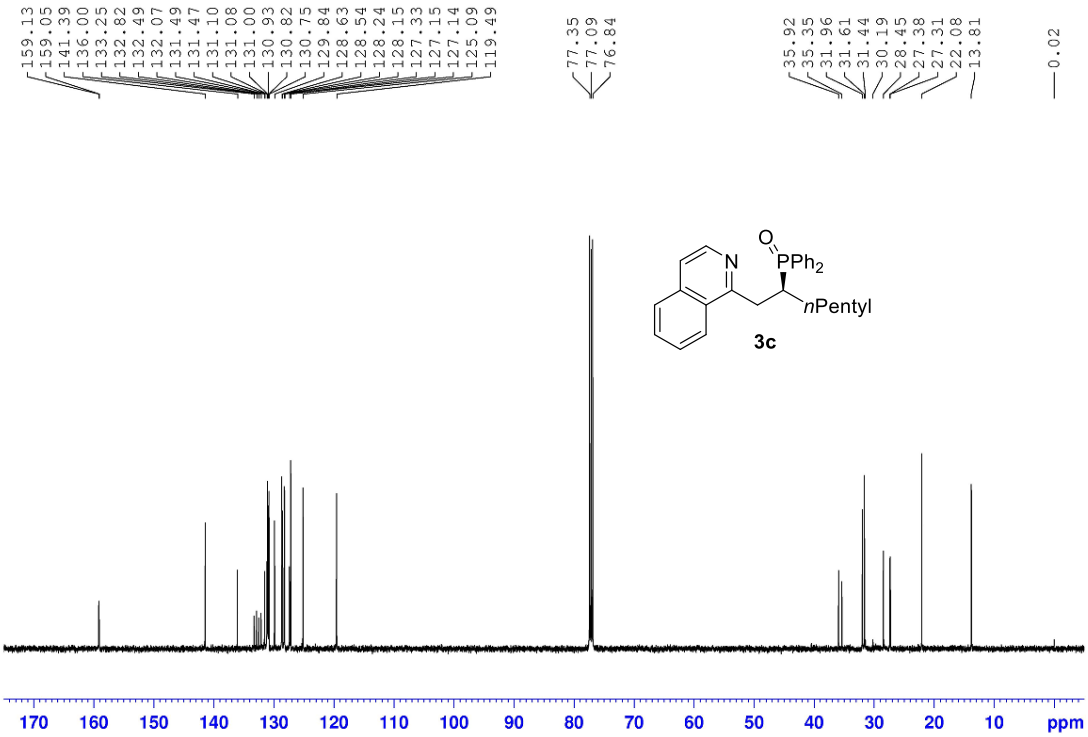
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N
nPentyl
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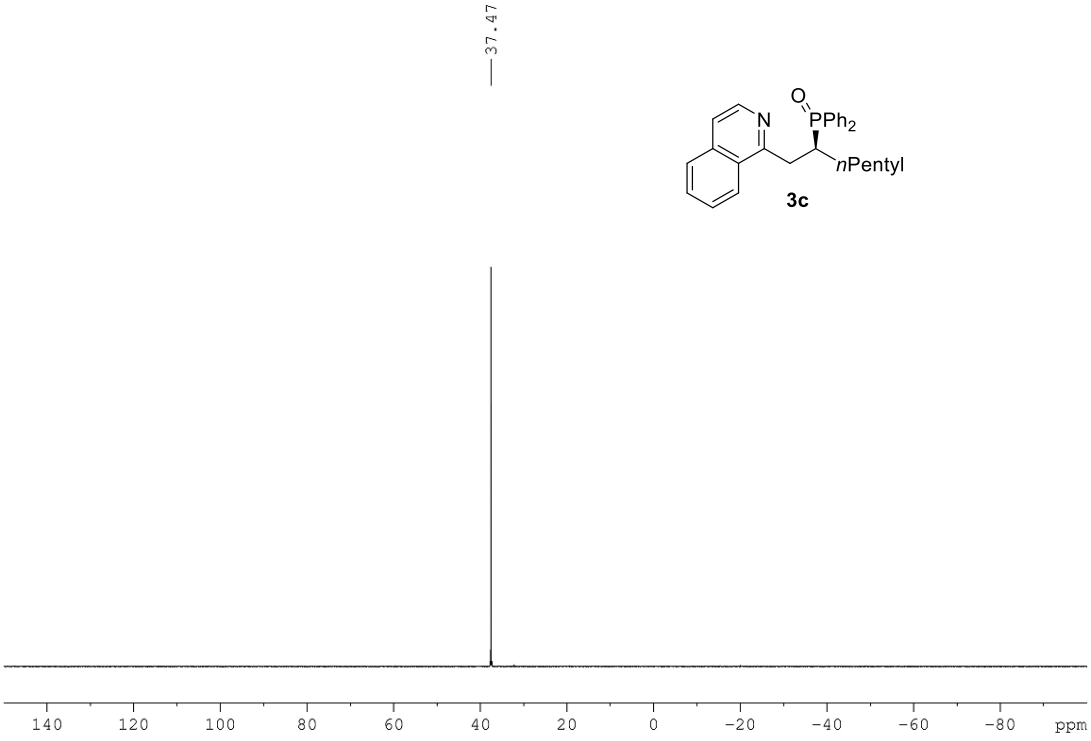
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-60
-80
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7.53
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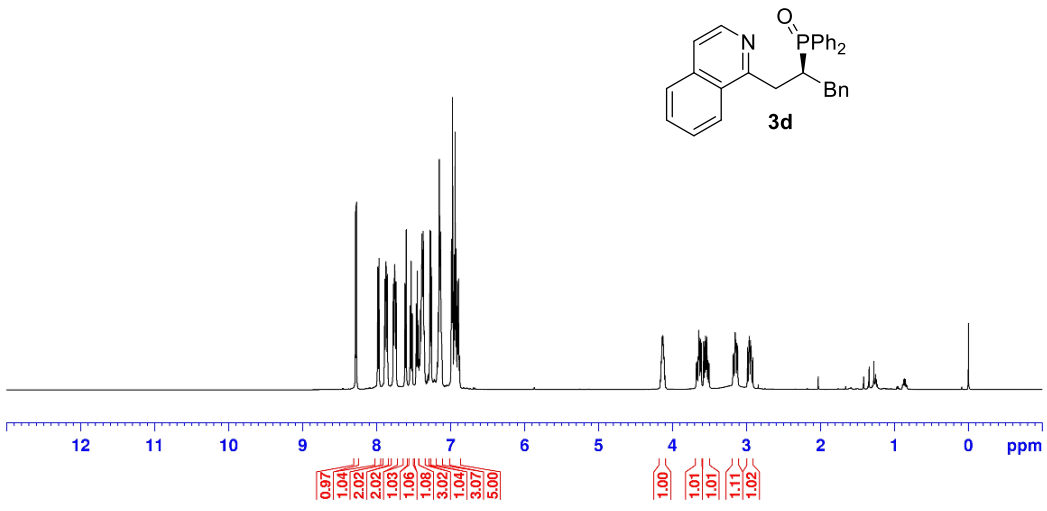
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2.02
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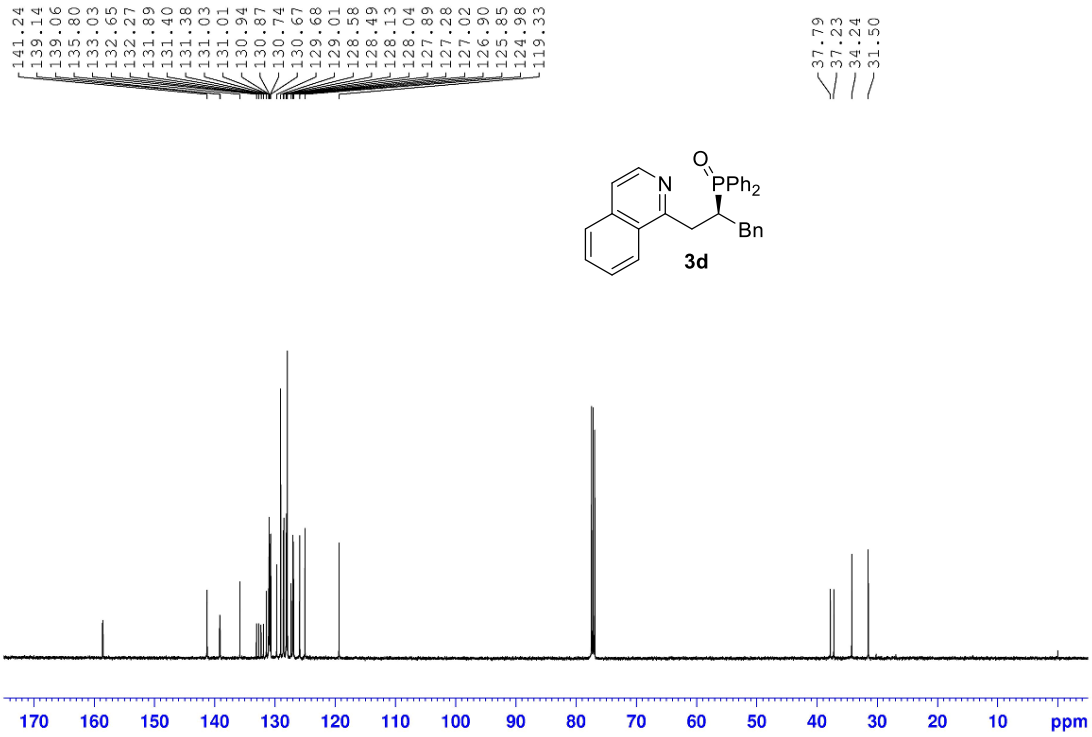
1.02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128.13
128.04
127.89
127.28
127.02
126.90
125.85
124.98
119.33
37.79
37.23
34.24
31.50
O
PPh2
N
Bn
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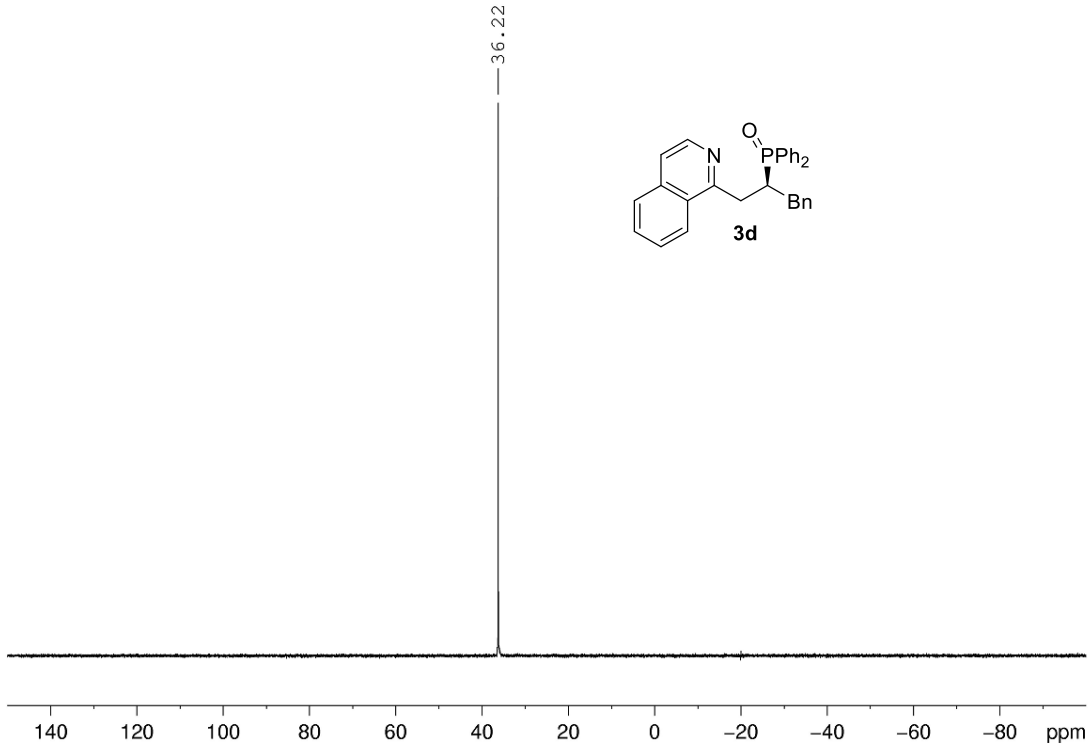
ppm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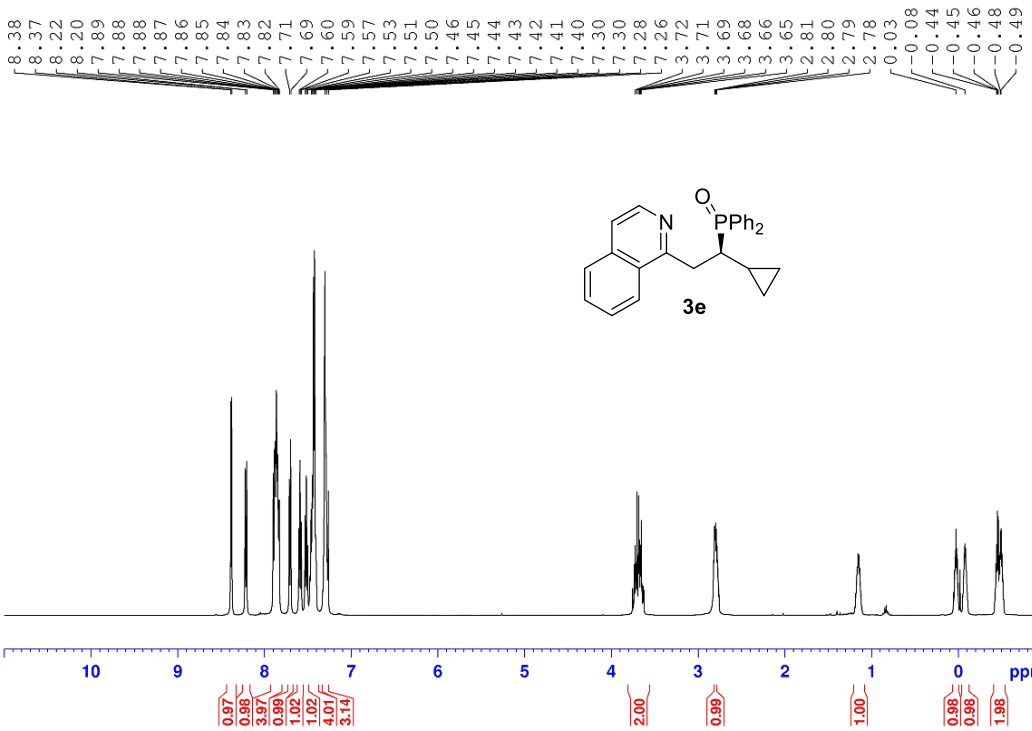
−60
−80
ppm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7.82
7.71
7.69
7.60
7.59
7.57
7.53
7.51
7.50
7.46
7.45
7.44
7.43
7.42
7.41
7.40
7.30
7.30
7.28
7.26
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3.71
3.69
3.68
3.66
3.65
2.81
2.80
2.79
2.78
0.03
-0.08
-0.44
-0.45
-0.46
-0.48
-0.49
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PPh2
N
3e
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8
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6
5
4
3
2
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ppm
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0.98
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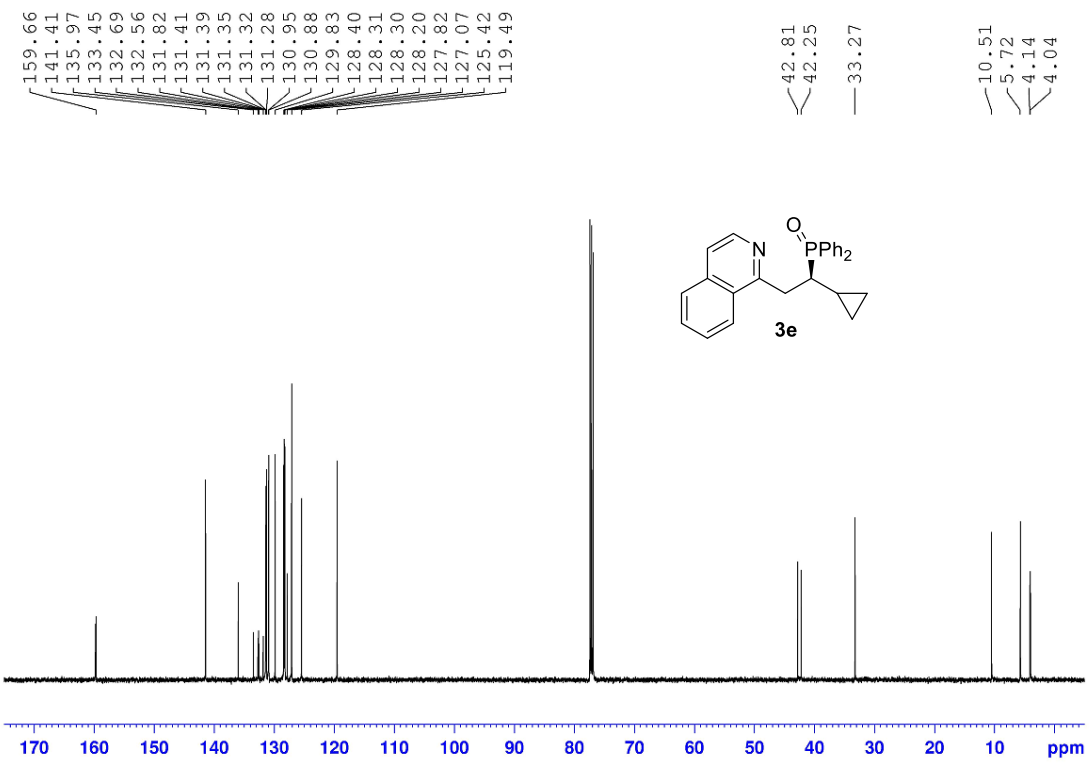
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128.31
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128.20
127.82
127.07
125.42
119.49
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42.25
33.27
10.51
5.72
4.14
4.04
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PPh2
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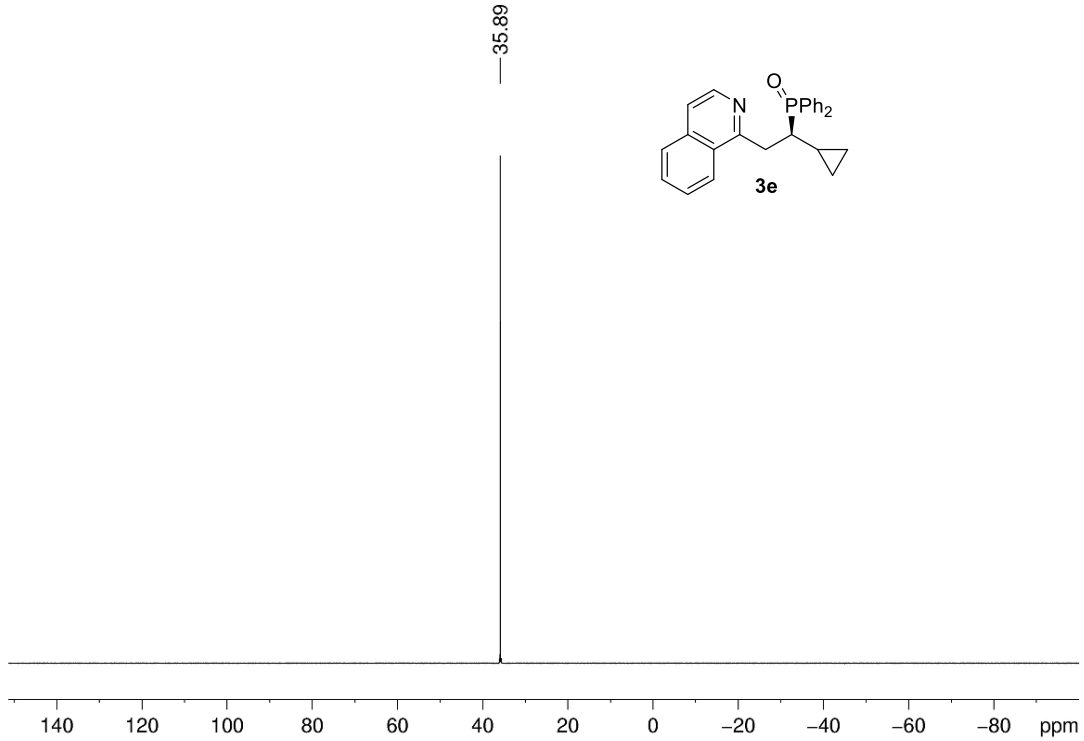
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ppm


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7.58
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7.42
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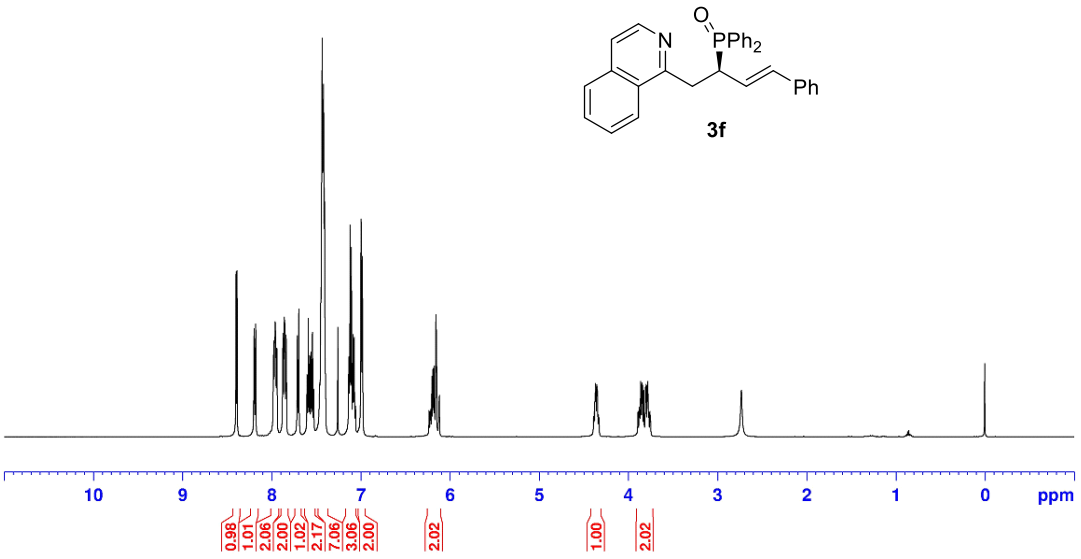
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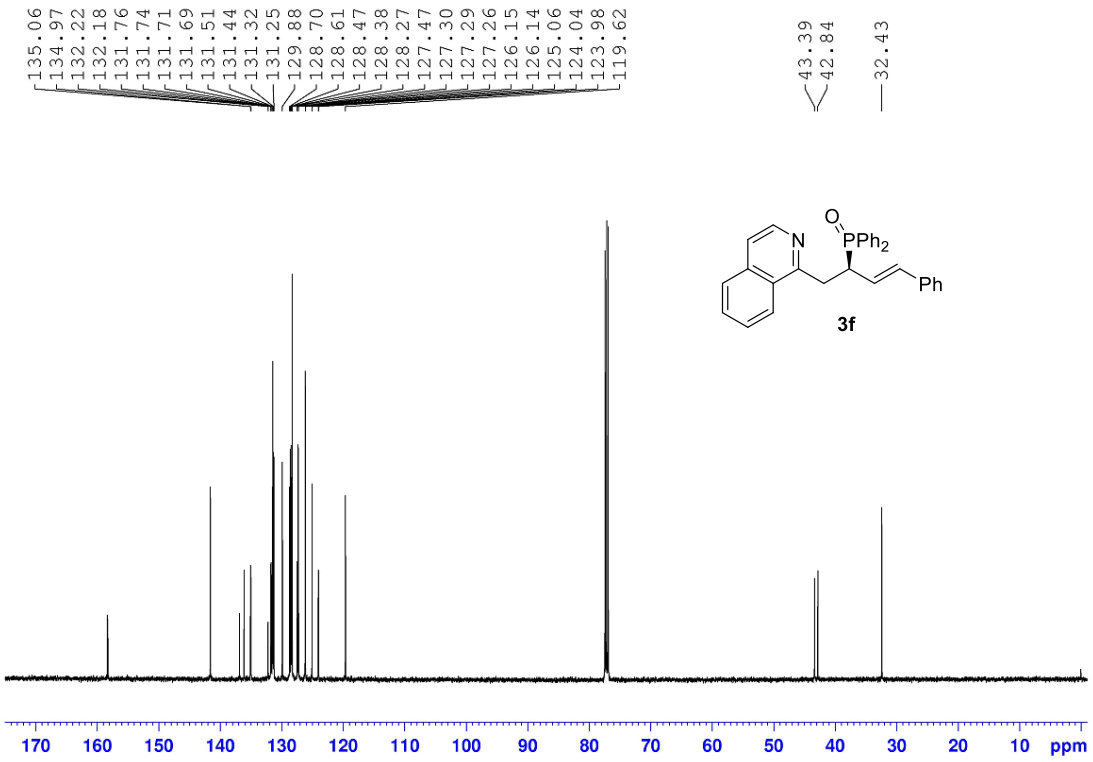
2.02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127.30
127.29
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126.15
126.14
125.06
124.04
123.98
119.62
43.39
42.84
32.43
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PPh2
N
Ph
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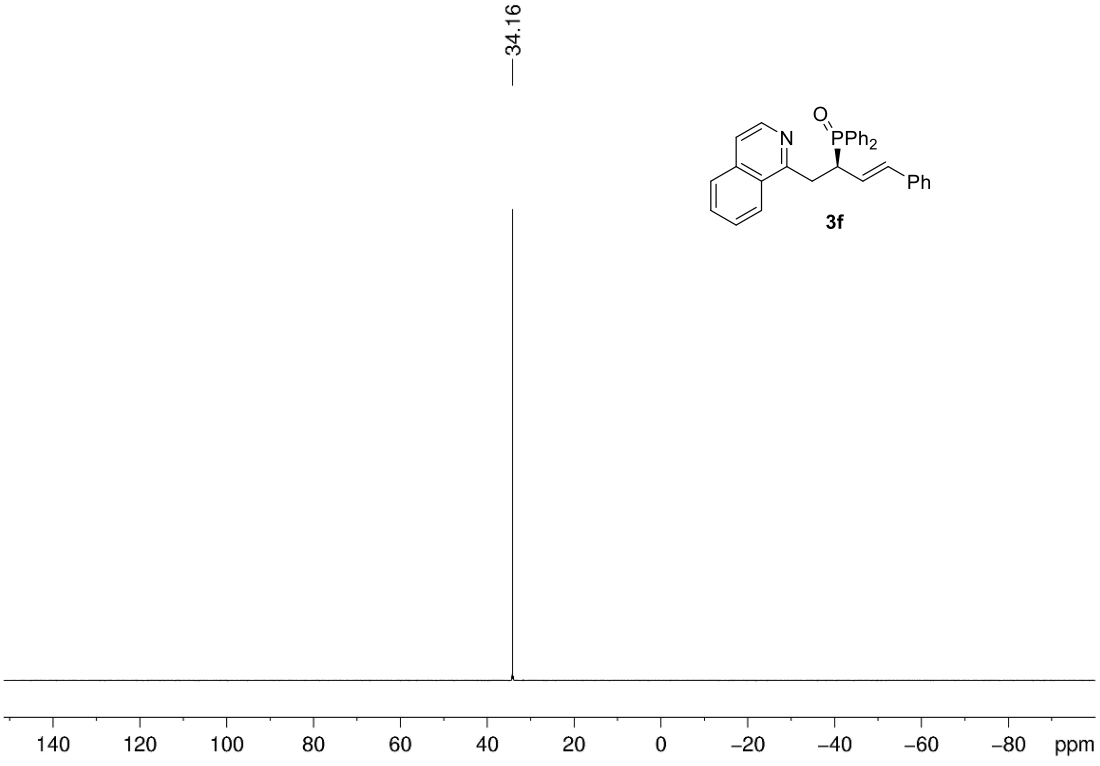
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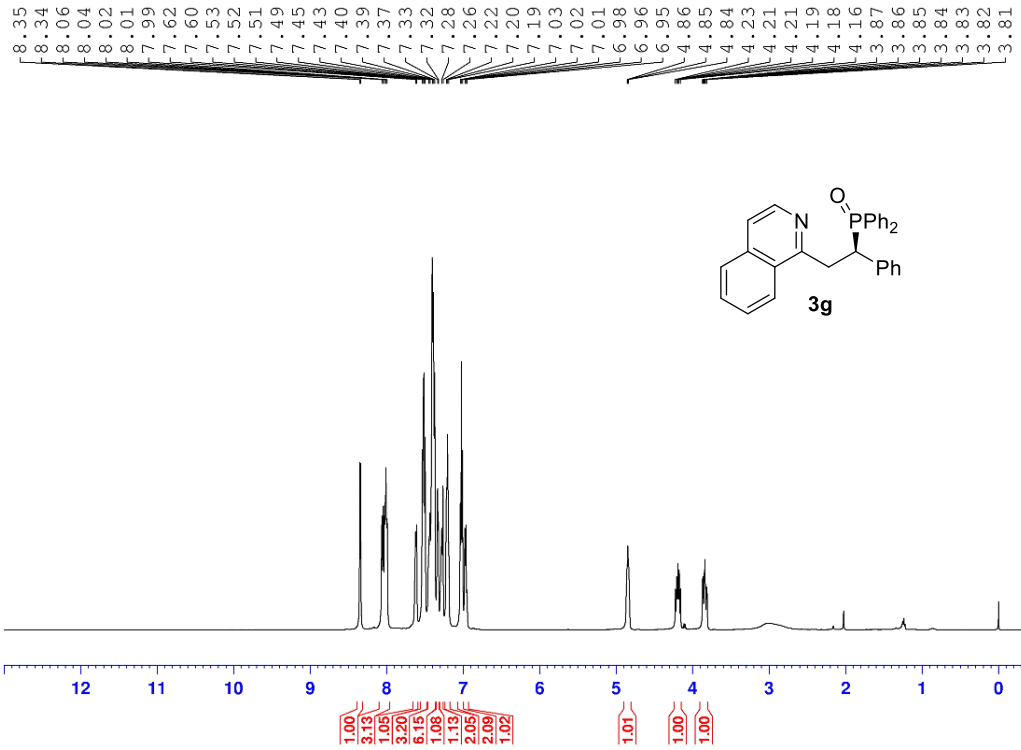
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7.45
7.43
7.40
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7.33
7.32
7.28
7.26
7.22
7.20
7.19
7.03
7.02
7.01
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6.96
6.95
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4.85
4.84
4.23
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4.21
4.19
4.18
4.16
3.87
3.86
3.85
3.84
3.83
3.82
3.81
O
PPh2
N
Ph
3g
12
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10
9
8
7
6
5
4
3
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1
0
ppm
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1.13
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2.09
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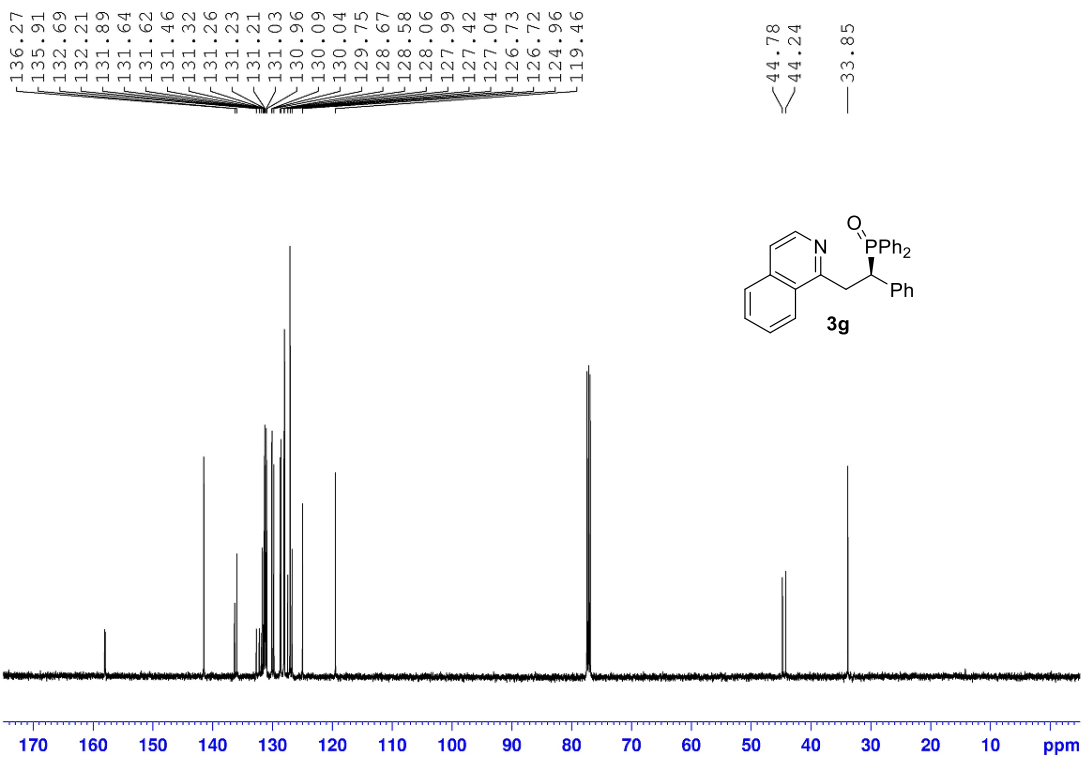
1.00
1.00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130.04
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128.58
128.06
127.99
127.42
127.04
126.73
126.72
124.96
119.46
44.78
44.24
33.85
O
PPh2
N
Ph
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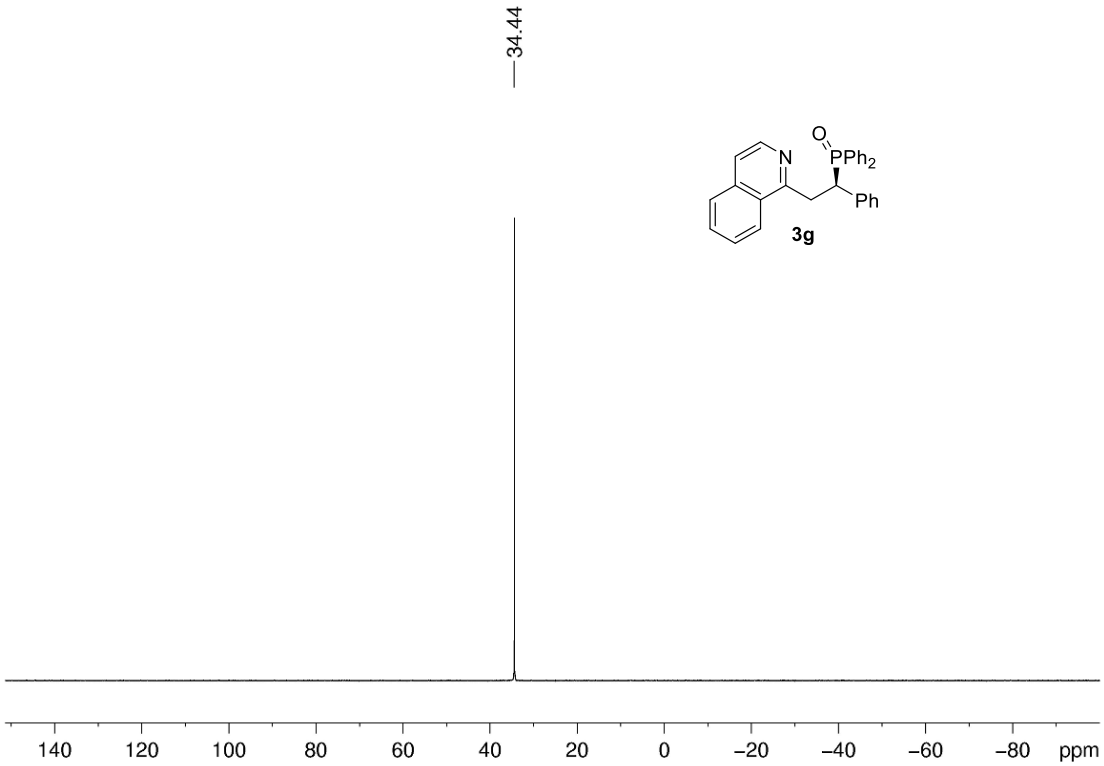
ppm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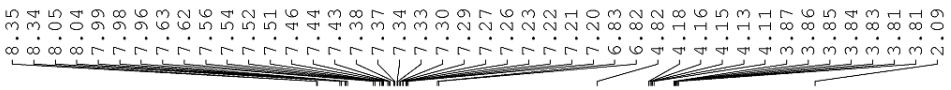
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7.98
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7.62
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7.54
7.52
7.51
7.46
7.44
7.43
7.38
7.37
7.34
7.33
7.30
7.29
7.27
7.26
7.23
7.22
7.21
7.20
6.83
6.82
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4.18
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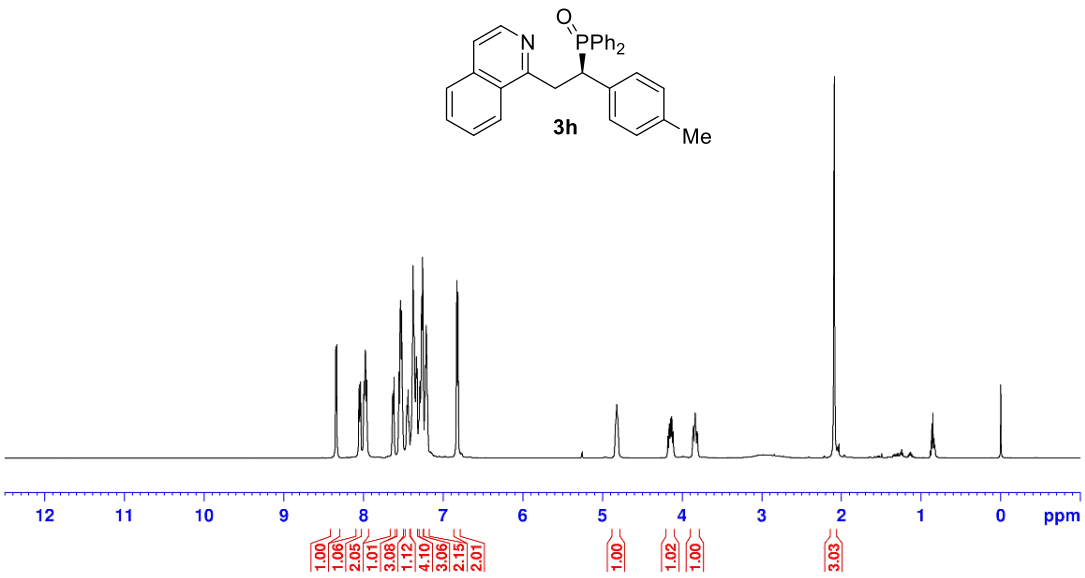
3.81
2.09


O
PPh2
N
3h
Me
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10
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8
7
6
5
4
3
2
1
0
ppm
1.00
1.06
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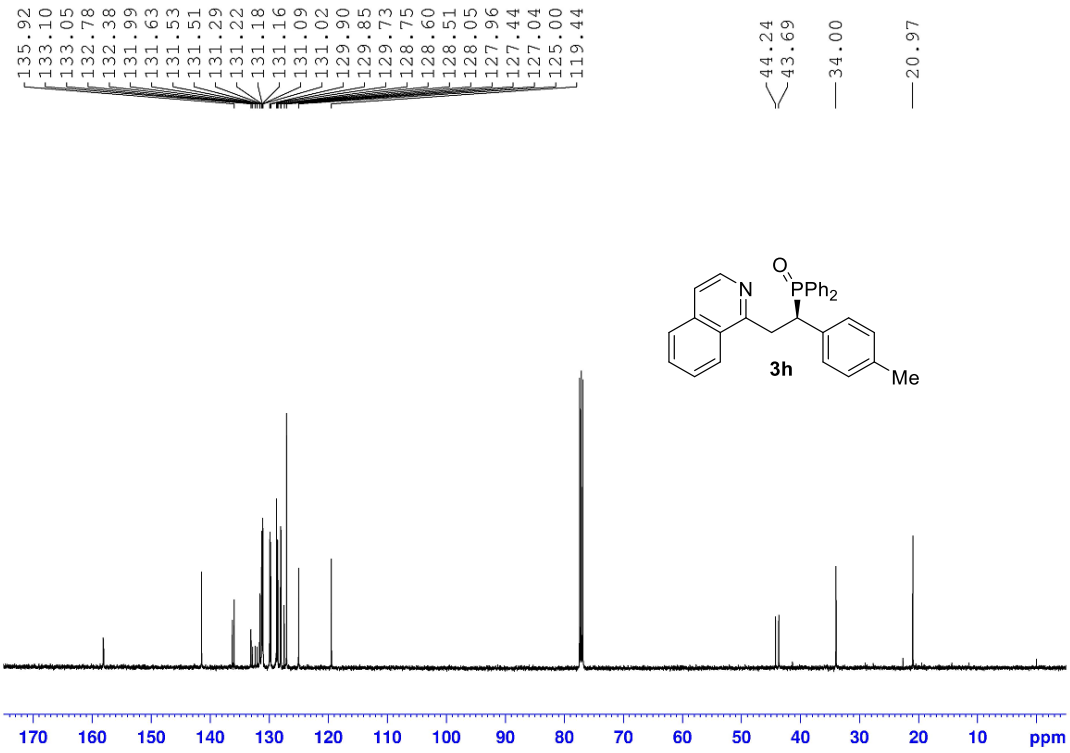
4.10
3.06
2.15
2.01
1.00
1.02
1.00
3.03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127.44
127.04
125.00
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O
PPh2
N
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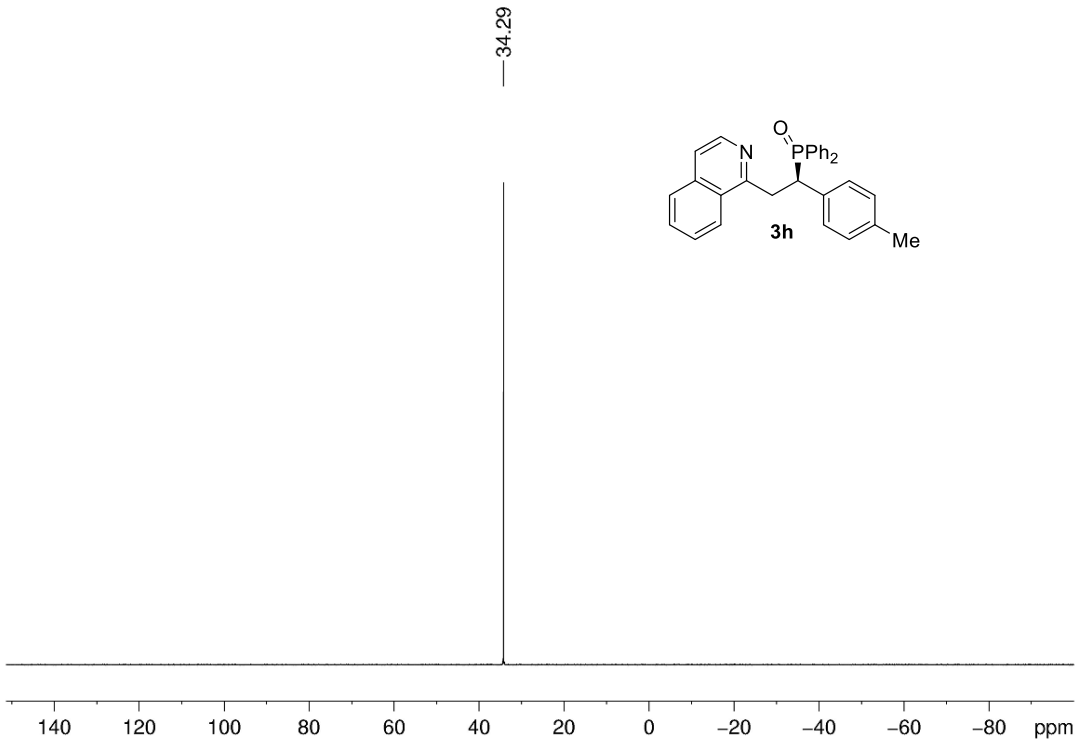
ppm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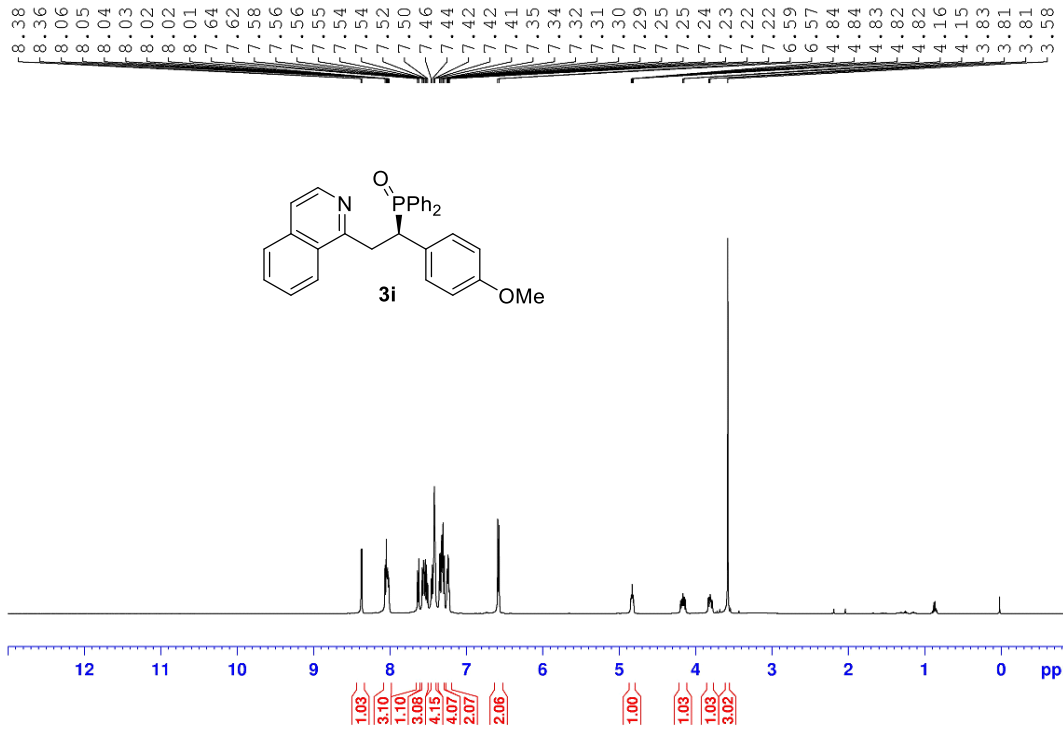
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4.84
4.83
4.82
4.82
4.16
4.15
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3.81
3.81
3.58
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PPh2
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OMe
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11
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9
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6
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2.06
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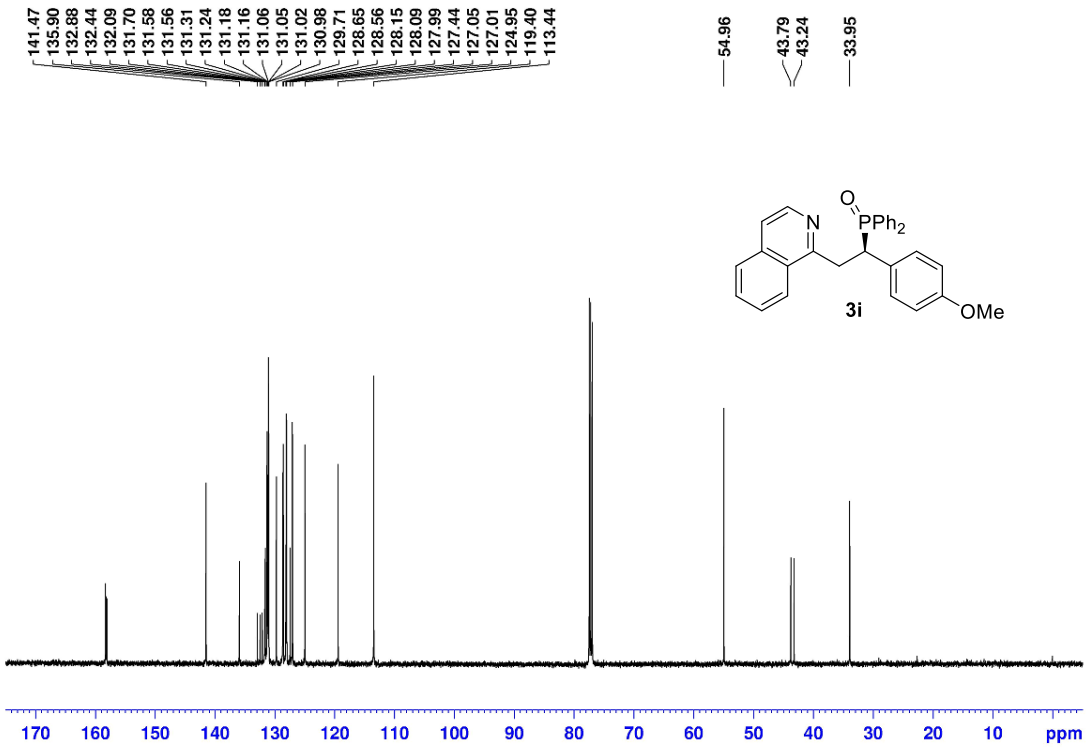
1.03
1.03
3.02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127.05
127.01
124.95
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43.79
43.24
33.95
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PPh2
N
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OMe
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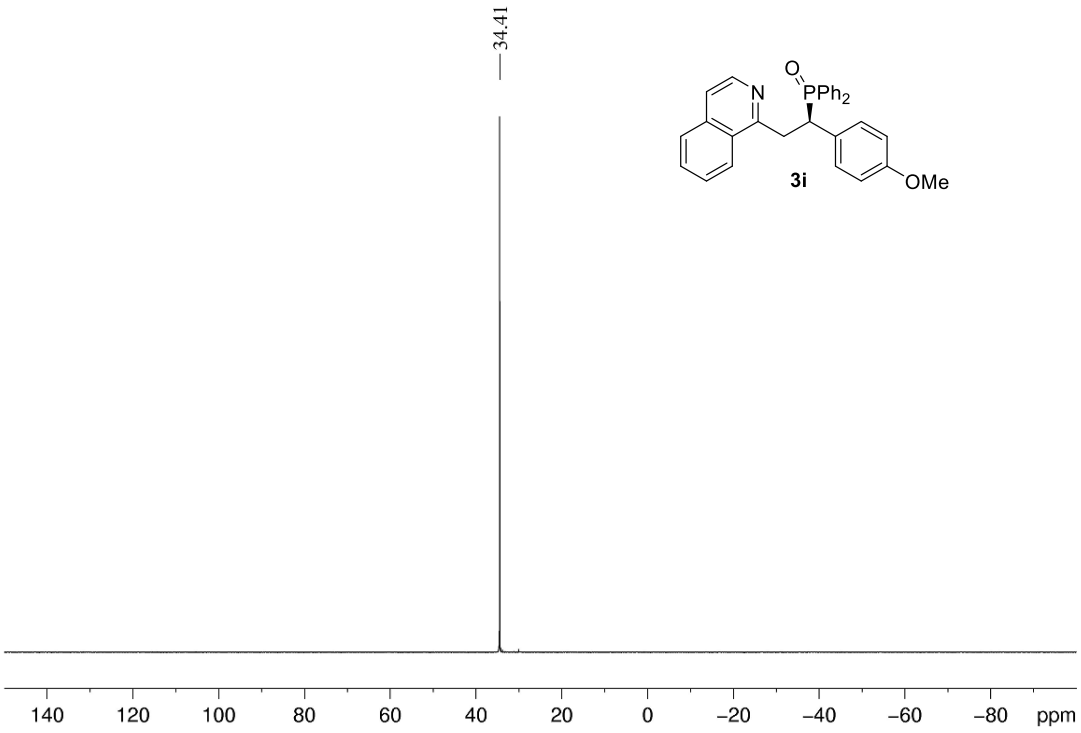
ppm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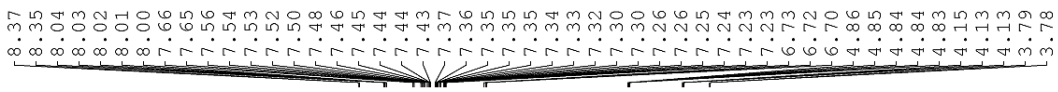
ppm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4.84
4.83
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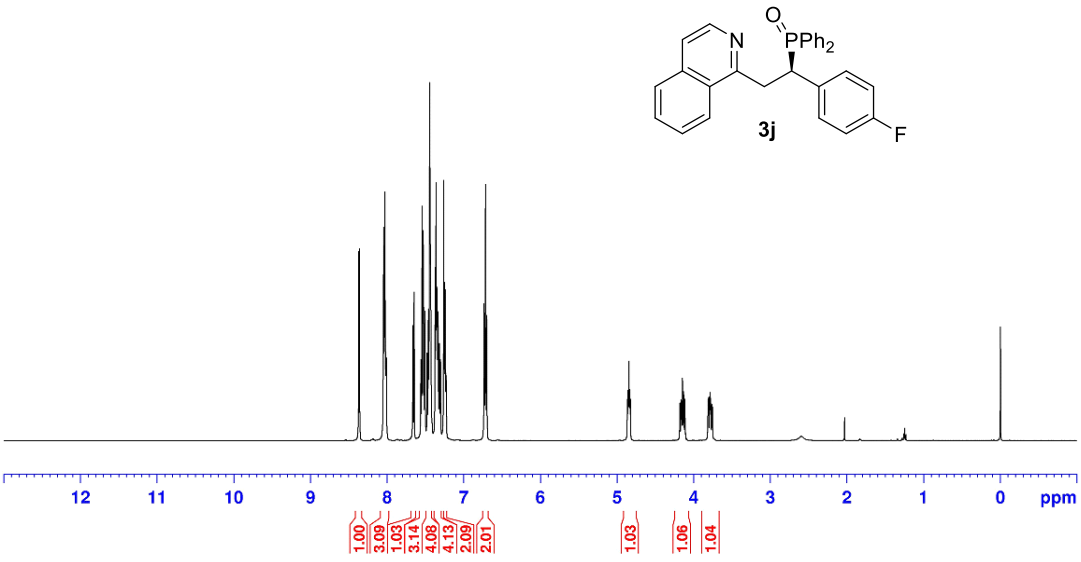
3.78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PPh2
N
3j
F
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10
9
8
7
6
5
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3
2
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1.03
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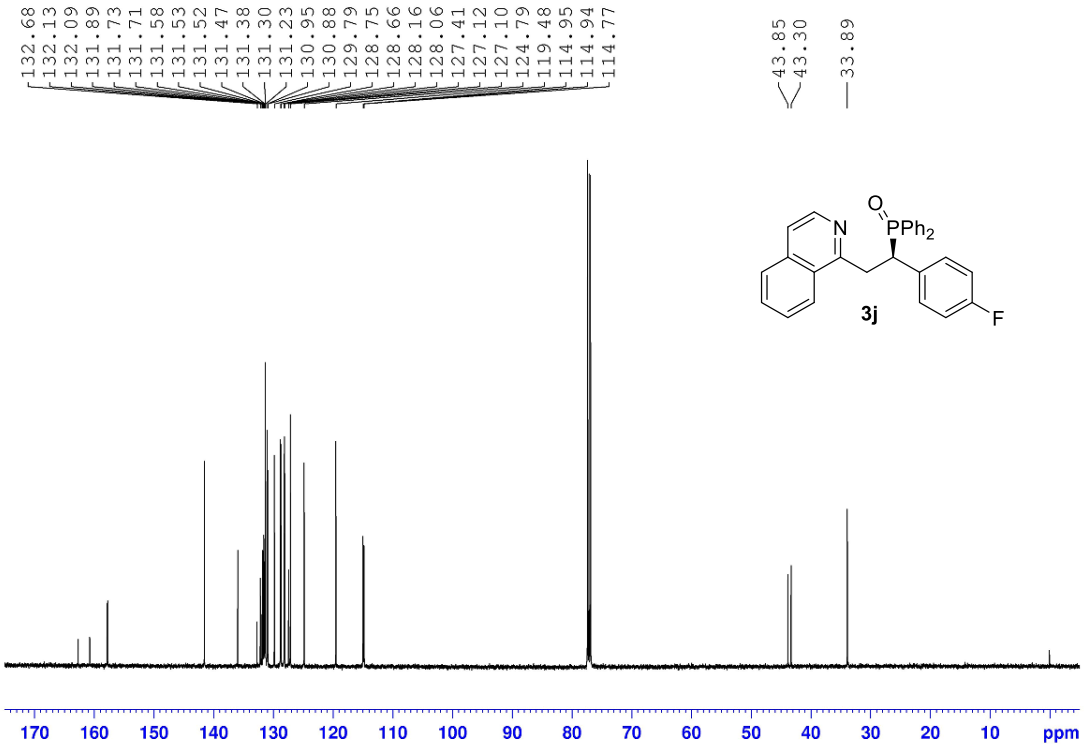
1.06
1.04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130.88
129.79
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128.66
128.16
128.06
127.41
127.12
127.10
124.79
119.48
114.95
114.94
114.77
43.85
43.30
33.89
O
PPh2
N
F
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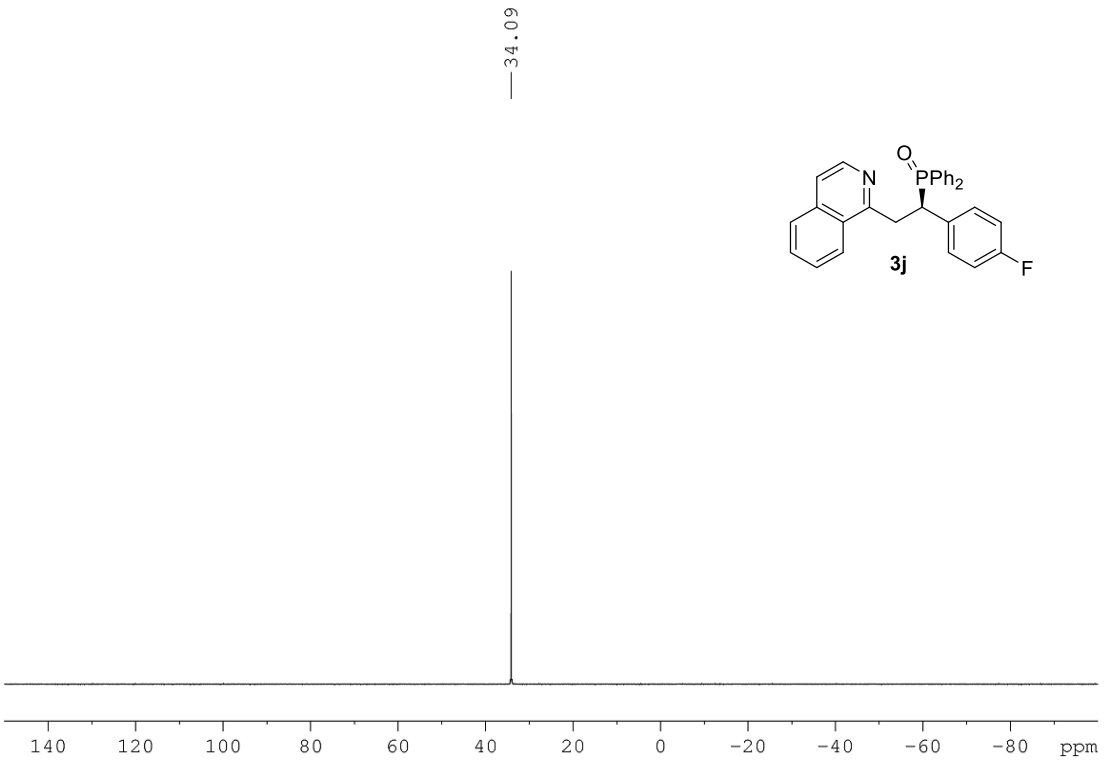
10
ppm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80
60
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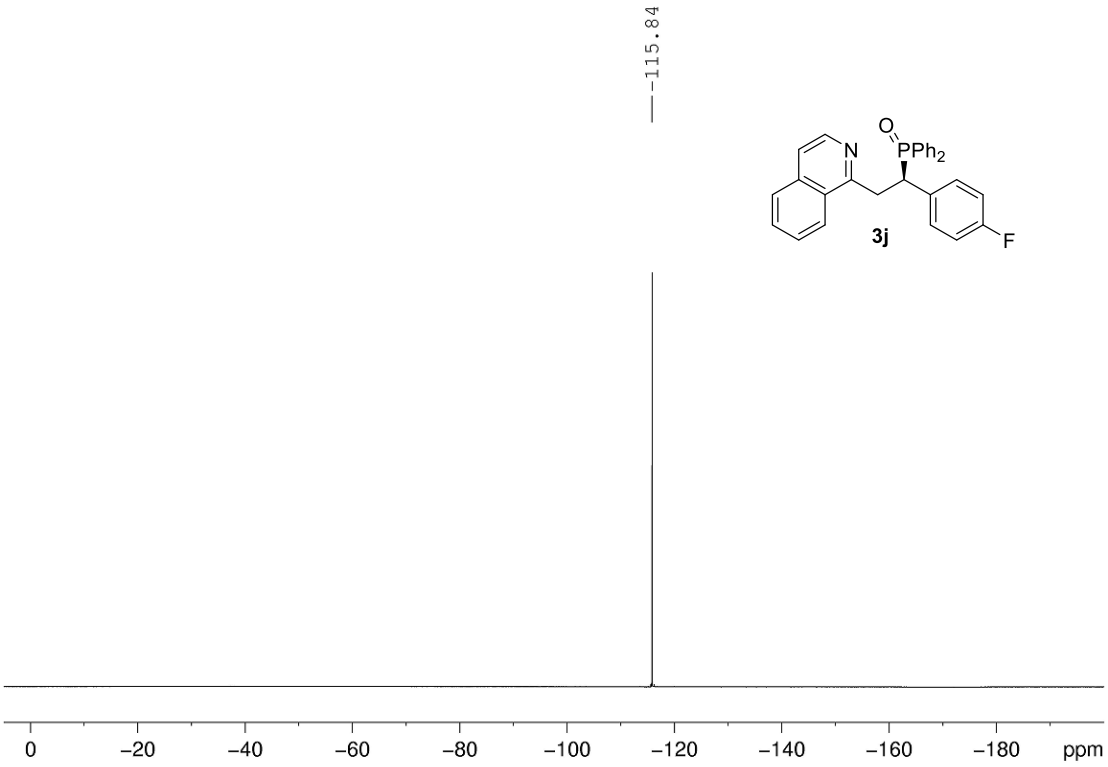
-60
-80
ppm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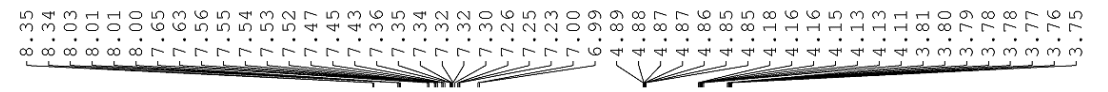
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7.52
7.47
7.45
7.43
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7.35
7.34
7.32
7.32
7.30
7.26
7.25
7.23
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4.88
4.87
4.87
4.86
4.85
4.85
4.18
4.16
4.16
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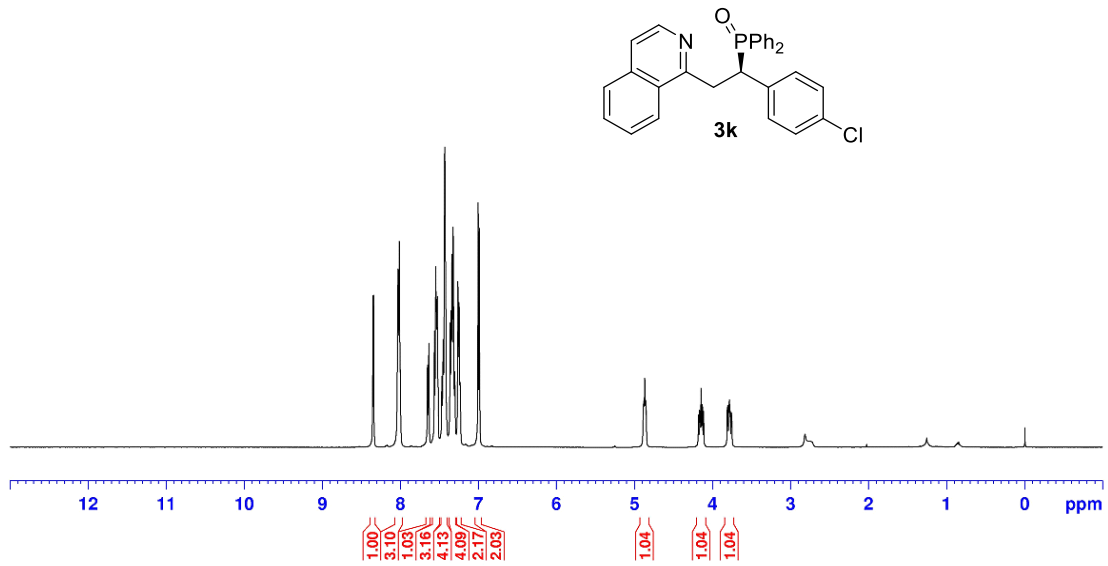
3.78
3.78
3.77
3.76
3.75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N
3k
Cl
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10
9
8
7
6
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2
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1.03
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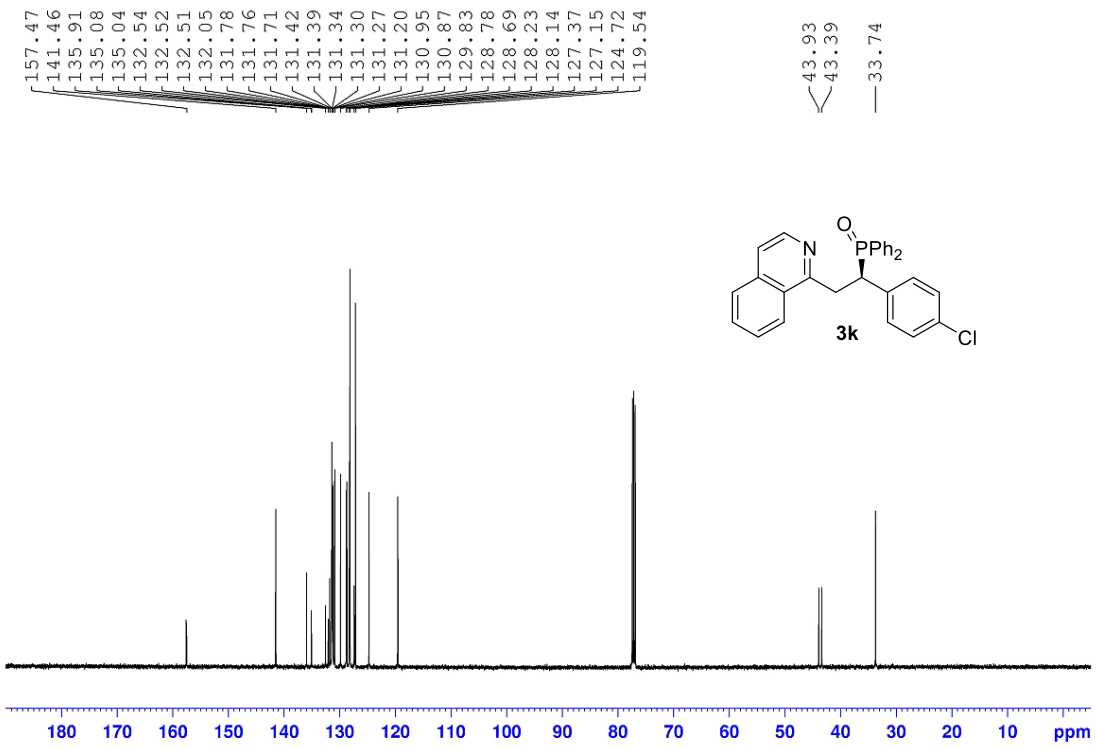
1.04
1.04
1.04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128.78
128.69
128.23
128.14
127.37
127.15
124.72
119.54
43.93
43.39
33.74
O
PPh2
N
Cl
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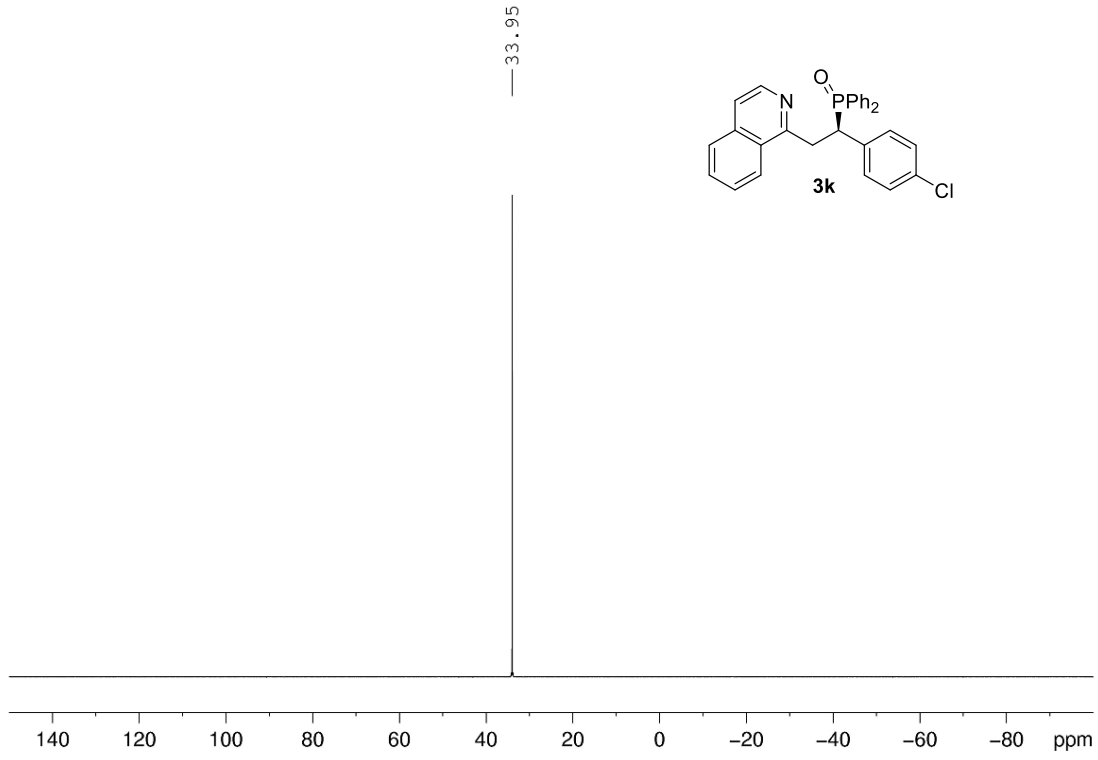
10
ppm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40
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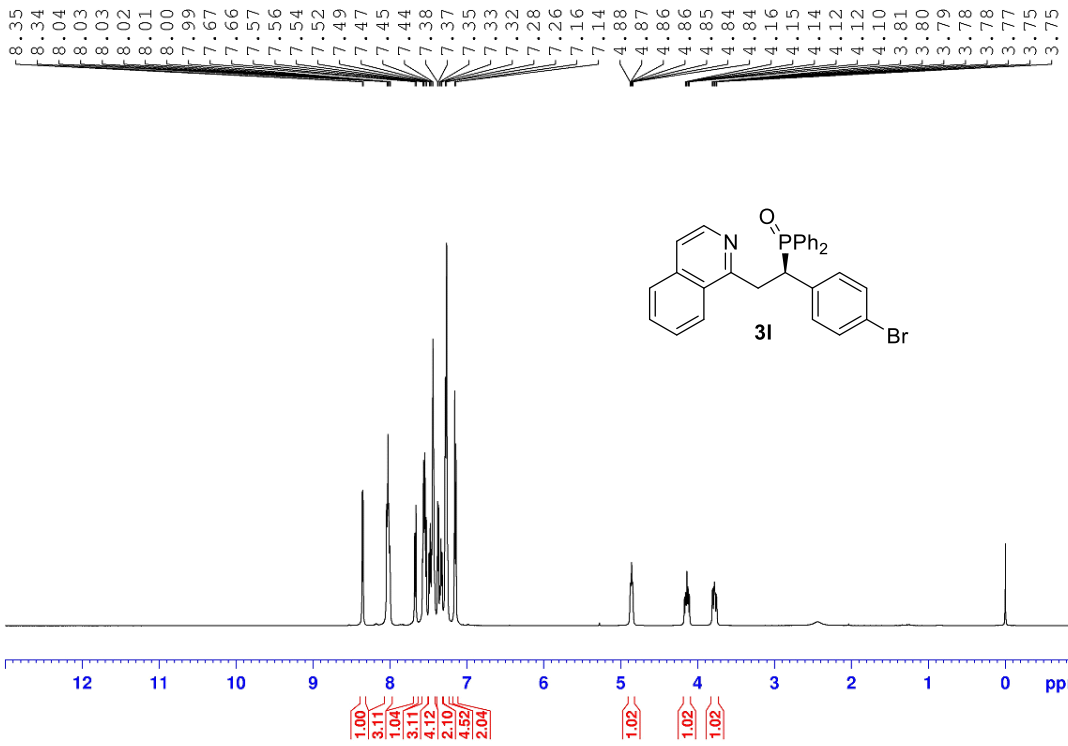
−60
−80
ppm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7.57
7.56
7.54
7.52
7.49
7.47
7.45
7.44
7.38
7.37
7.35
7.33
7.32
7.28
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7.16
7.14
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4.87
4.86
4.86
4.85
4.84
4.84
4.16
4.15
4.14
4.12
4.12
4.10
3.81
3.80
3.79
3.78
3.78
3.77
3.75
3.75
O
PPh2
N
Br
3l
12
11
10
9
8
7
6
5
4
3
2
1
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1.04
3.11
4.12
2.10
4.52
2.04
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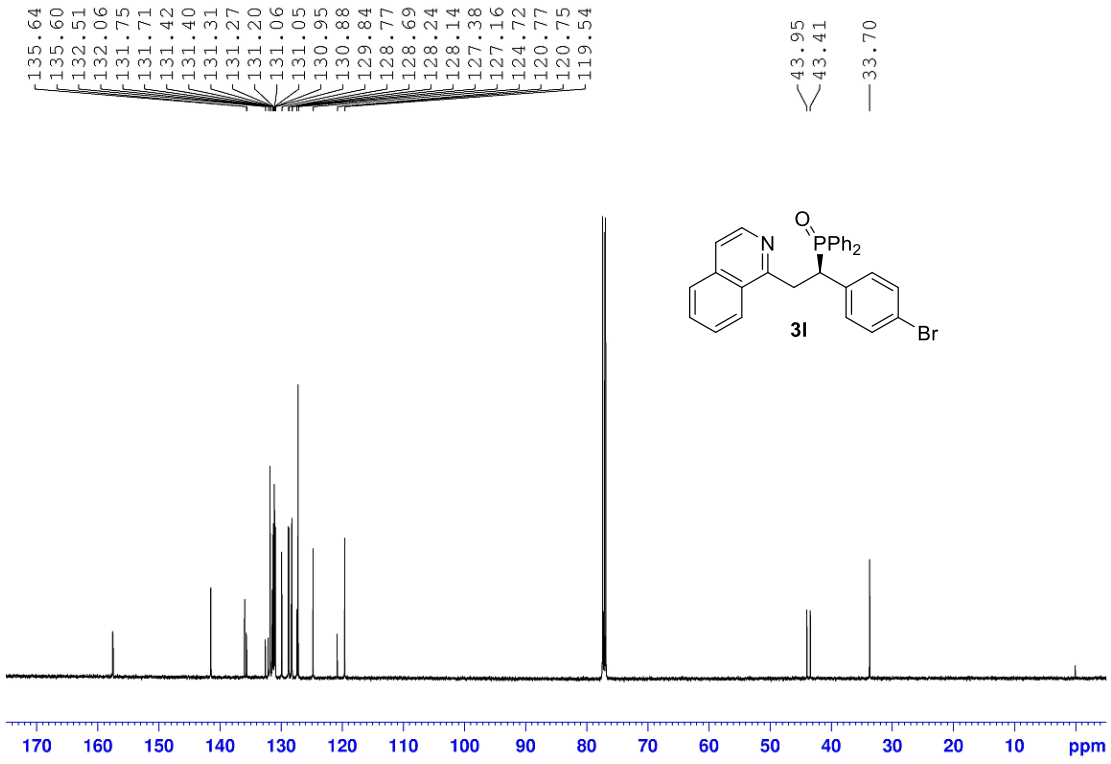
1.02
1.02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129.84
128.77
128.69
128.24
128.14
127.38
127.16
124.72
120.77
120.75
119.54
43.95
43.41
33.70
O
PPh2
N
Br
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150
140
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70
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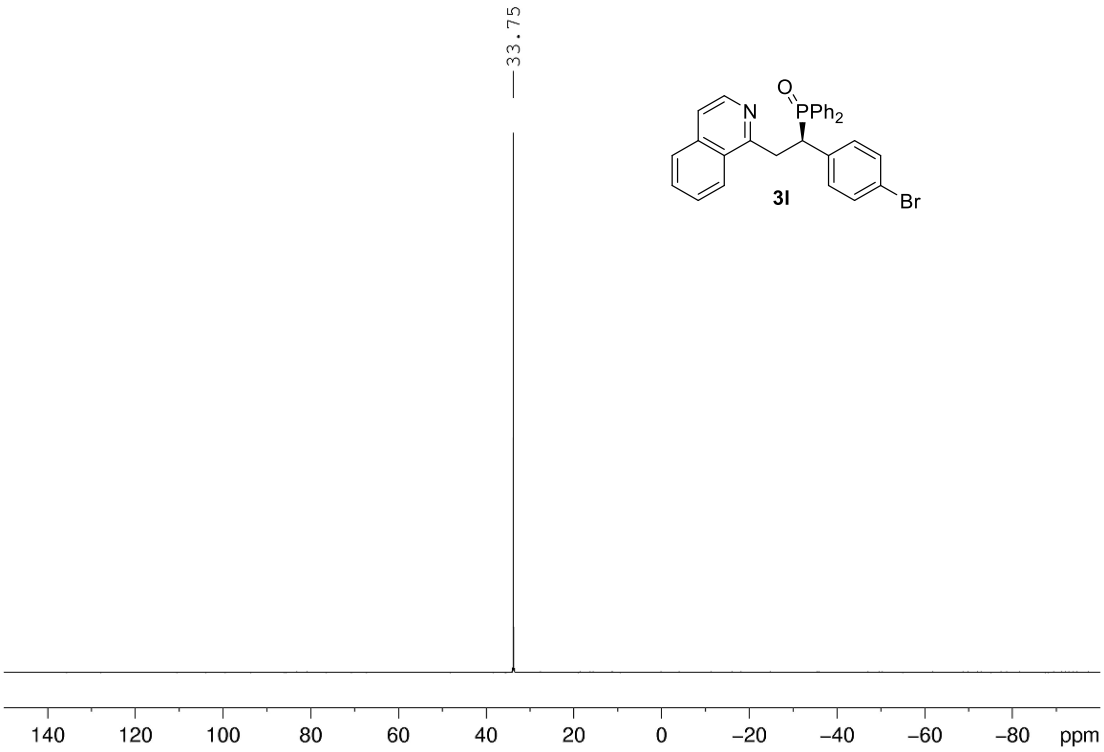
40
30
20
10
ppm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N
Br
3l
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100
80
60
40
20
0
−20
−40
−60
−80
ppm


8.36
8.35
8.05
8.04
8.03
8.02
8.01
7.65
7.64
7.55
7.53
7.52
7.51
7.49
7.49
7.49
7.47
7.47
7.45
7.44
7.44
7.43
7.42
7.42
7.40
7.40
7.37
7.36
7.30
7.29
7.26
7.24
7.23
7.22
7.22
7.21
7.20
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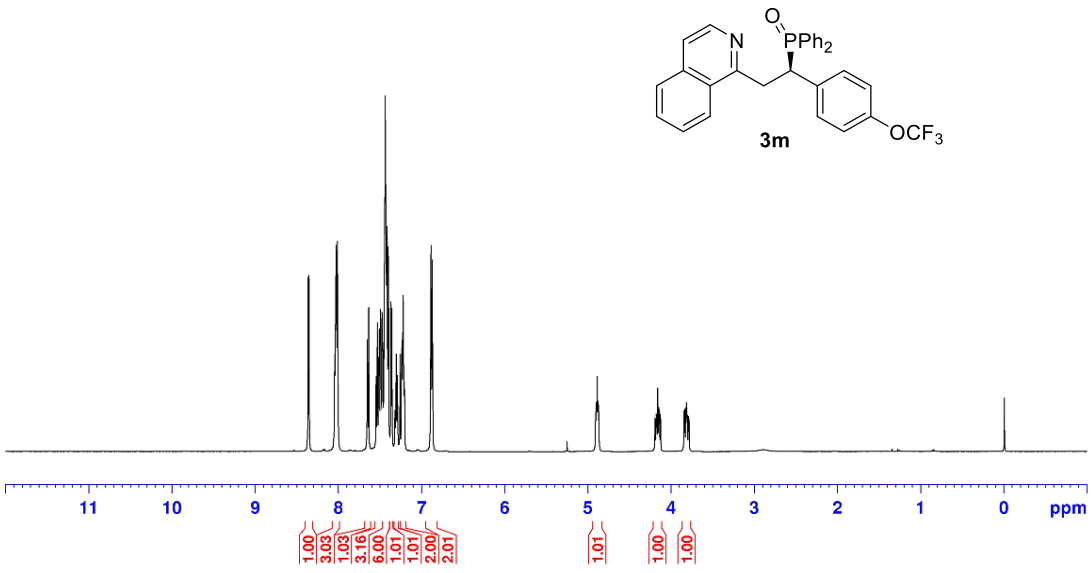
4.90
4.89
4.88
4.87
4.16
4.15
3.82
3.82
3.81


O
PPh2
N
OCF3
3m
11
10
9
8
7
6
5
4
3
2
1
0
ppm
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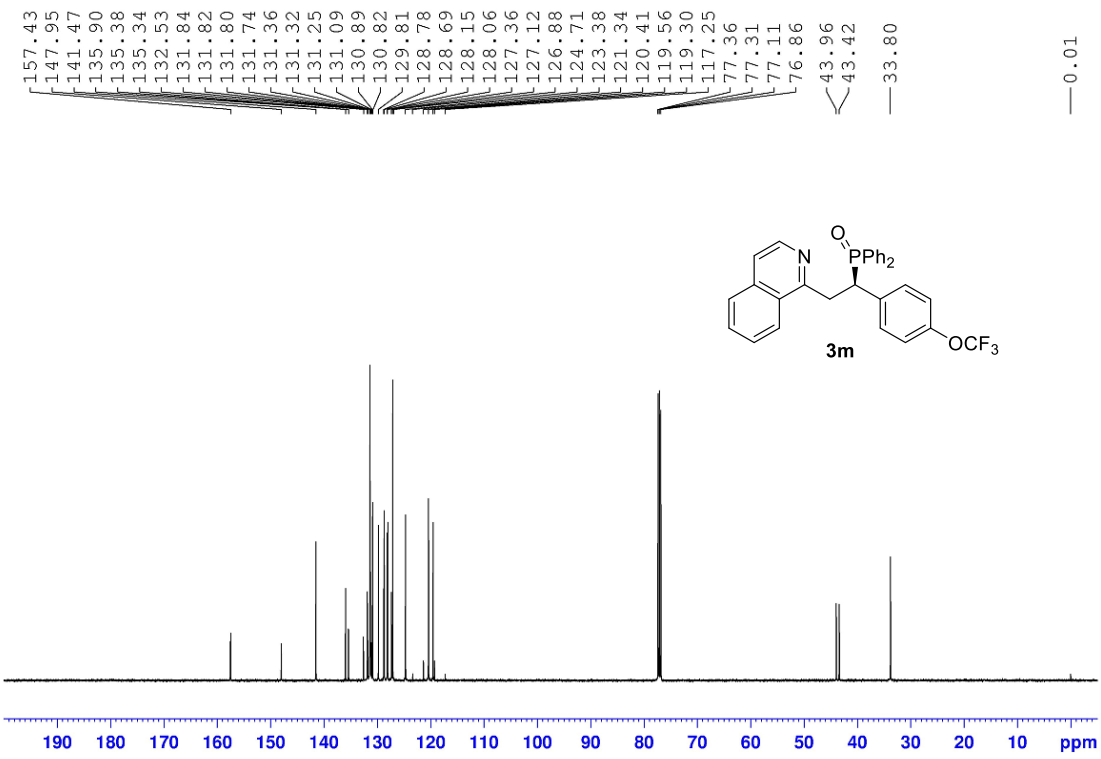
1.03
3.16
6.00
1.01
1.01
2.00
2.01
1.01
1.00
1.00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131.32
131.25
131.09
130.89
130.82
129.81
128.78
128.69
128.15
128.06
127.36
127.12
126.88
124.71
123.38
121.34
120.41
119.56
119.30
117.25
77.36
77.31
77.11
76.86
43.96
43.42
33.80
0.01
O
PPh2
N
OCF3
3m
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150
140
130
120
110
100
90
80
70
60
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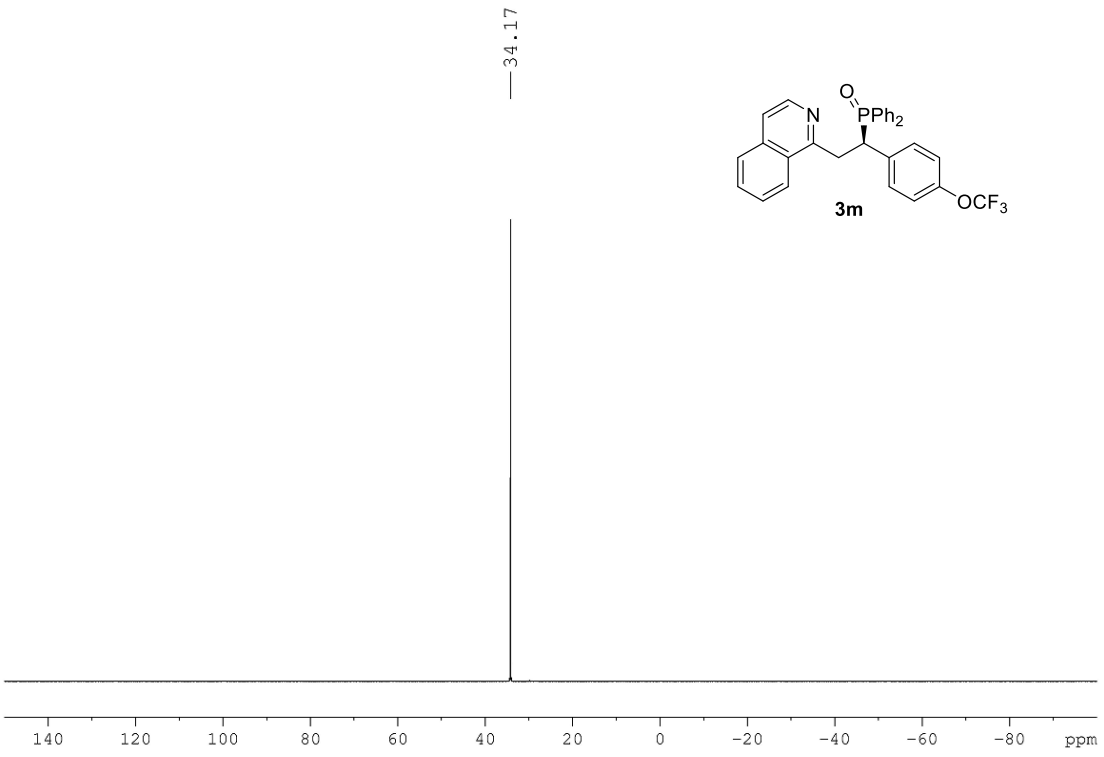
40
30
20
10
ppm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PPh2
N
OCF3
3m
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120
100
80
60
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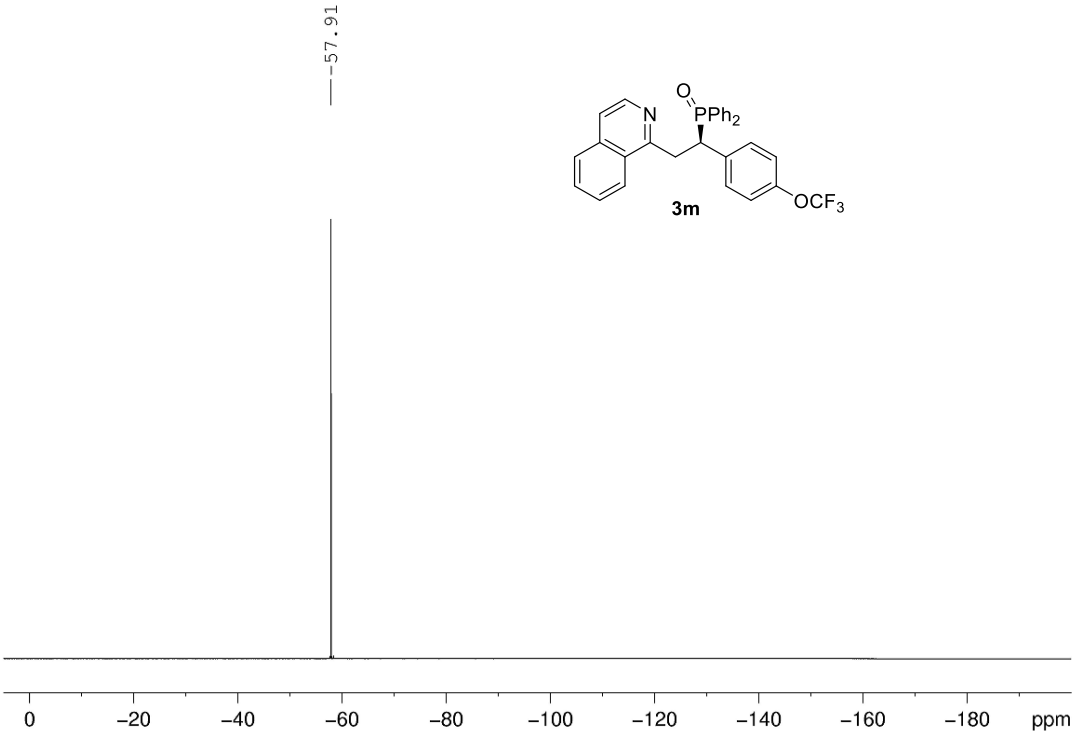
20
0
-20
-40
-60
-80
ppm


-57.91
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N
OCF3
3m
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−20
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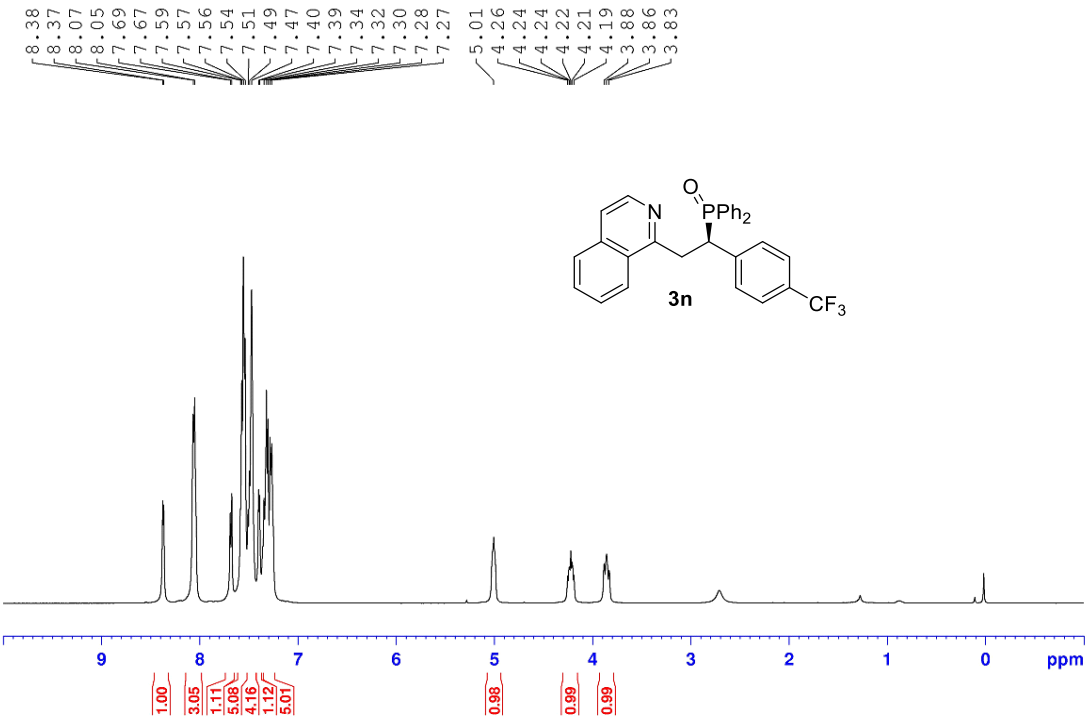
−60
−80
−100
−120
−140
−160
−180
ppm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7.56
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7.51
7.49
7.47
7.40
7.39
7.34
7.32
7.30
7.28
7.27
5.01
4.26
4.24
4.24
4.22
4.21
4.19
3.88
3.86
3.83
O
PPh2
N
CF3
3n
9
8
7
6
5
4
3
2
1
0
ppm
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3.05
1.11
5.08
4.16
1.12
5.01
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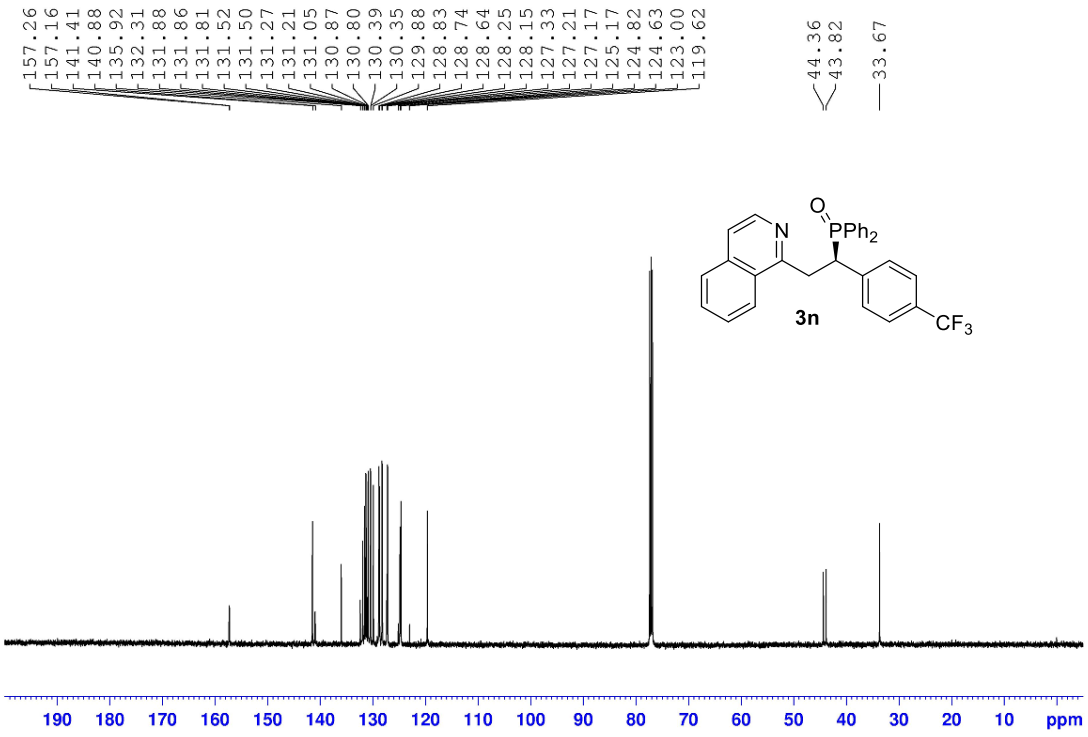
0.99
0.99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131.05
130.87
130.80
130.39
130.35
129.88
128.83
128.74
128.64
128.25
128.15
127.33
127.21
127.17
125.17
124.82
124.63
123.00
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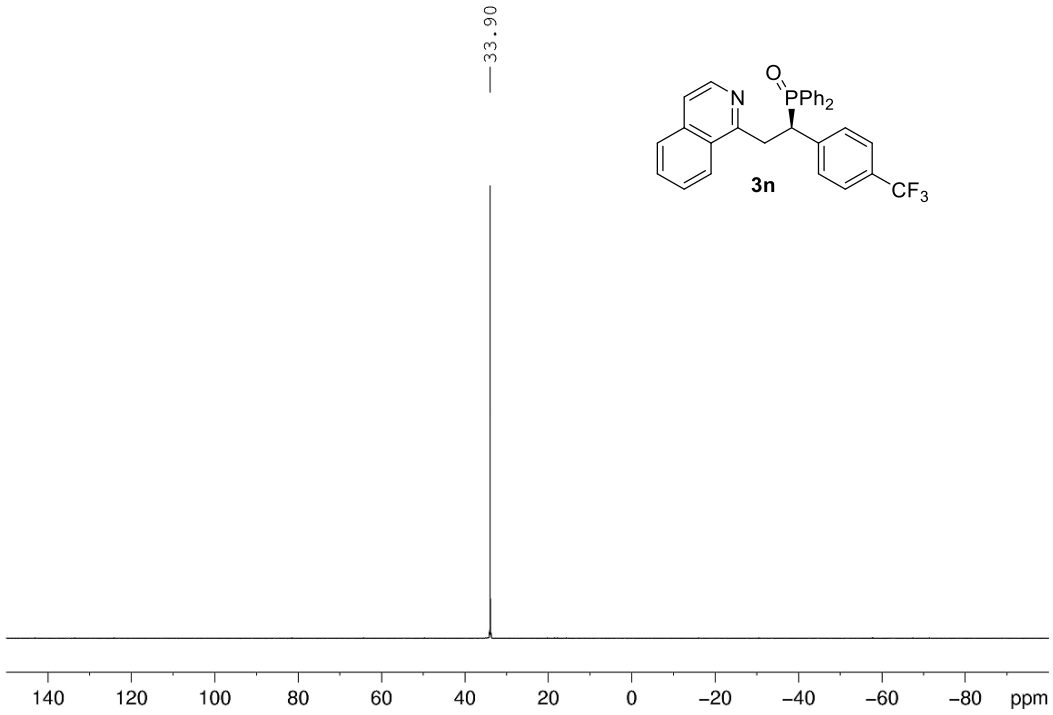
43.82
33.67
O
PPh2
N
3n
CF3
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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N
3n
CF3
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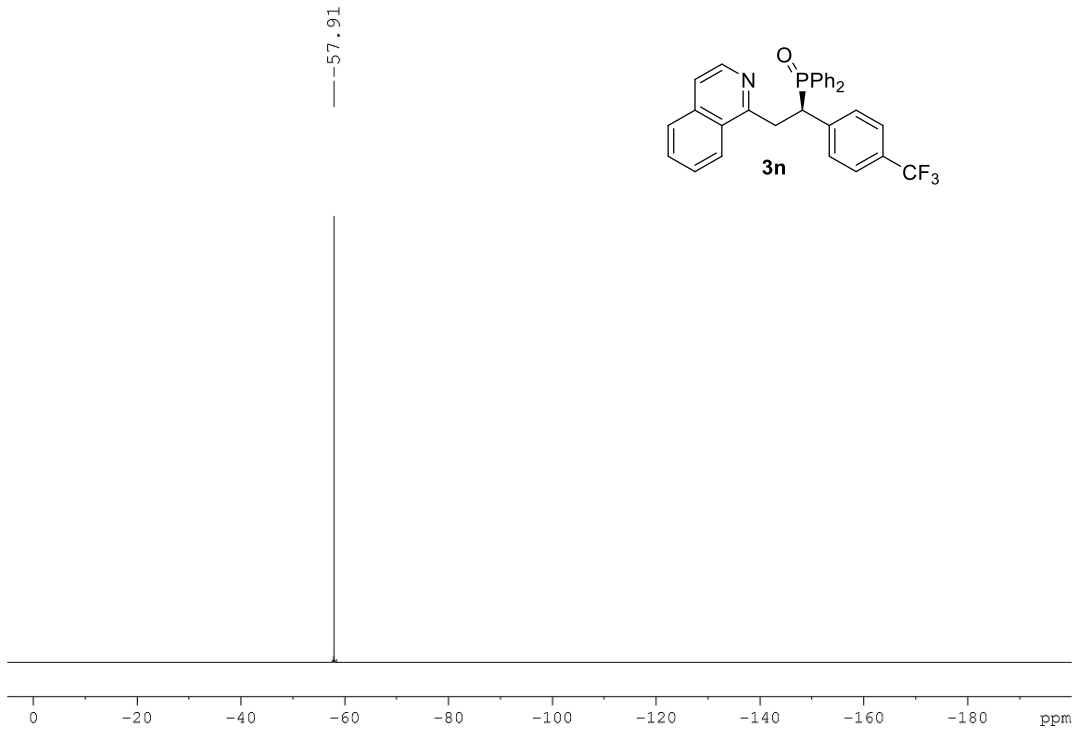
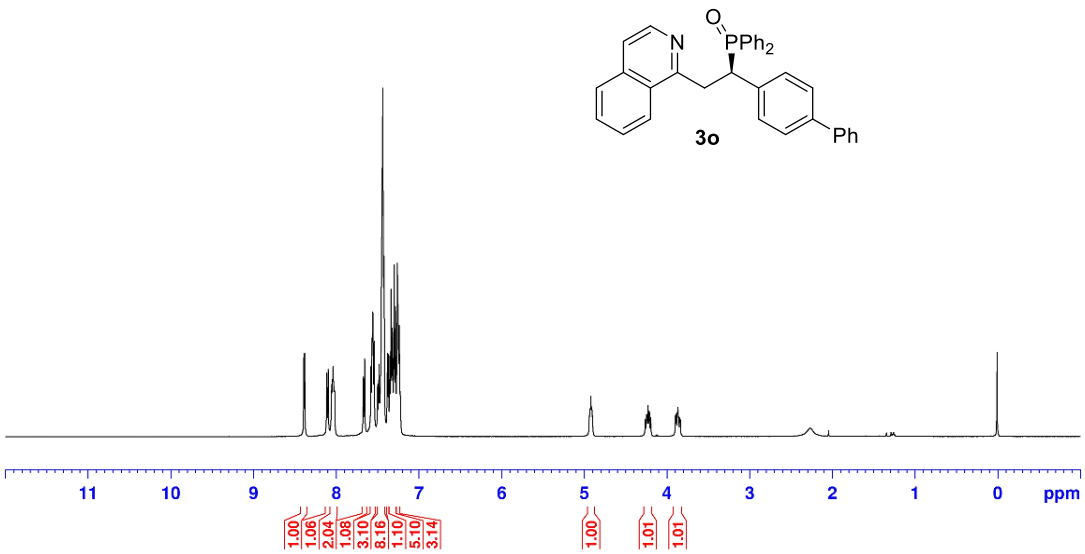
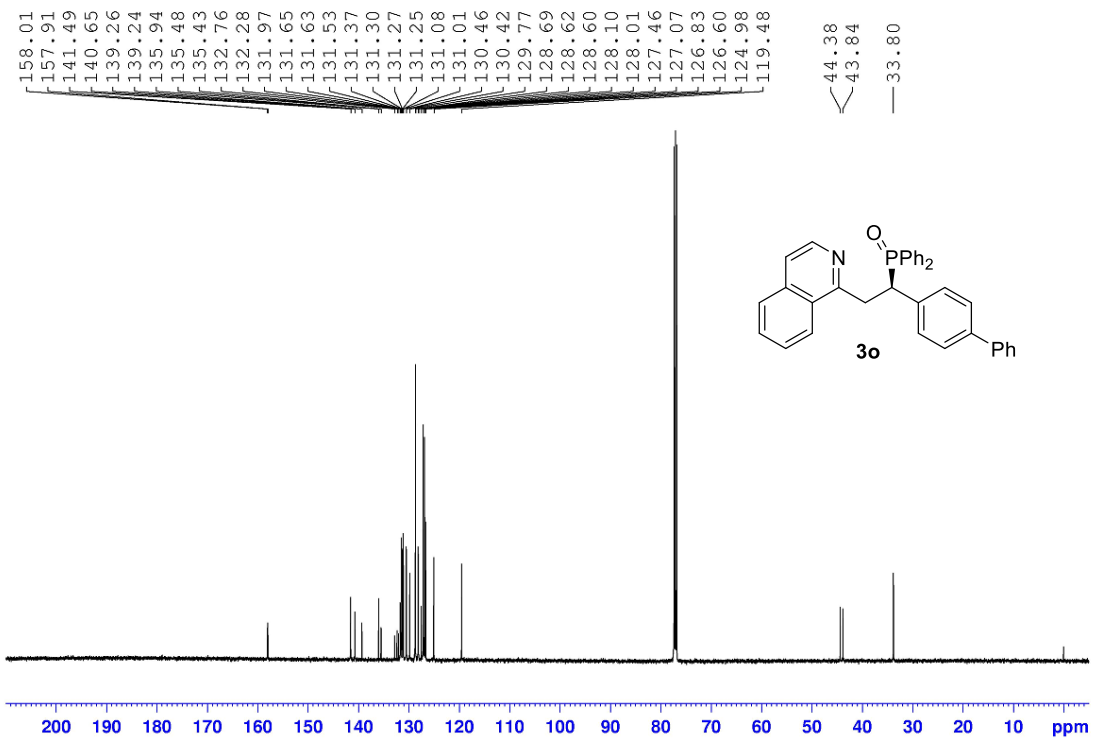

-57.91
O
PPh2
N
3n
CF3
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm


8.39
8.38
8.11
8.09
8.05
8.04
8.03
8.02
8.01
7.67
7.65
7.58
7.56
7.55
7.54
7.49
7.48
7.46
7.44
7.42
7.38
7.37
7.35
7.34
7.32
7.30
7.28
7.26
7.25
7.24
7.24
7.23
4.94
4.93
4.93
4.92
4.91
4.91
4.90
4.25
4.24
4.23
4.22
4.21
3.90
3.89
3.88
3.87
3.86


O
PPh2
N
3o
Ph
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
1.06
2.04
1.08
3.10
8.16
1.10
5.10
3.14
1.00
1.01
1.01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157.91
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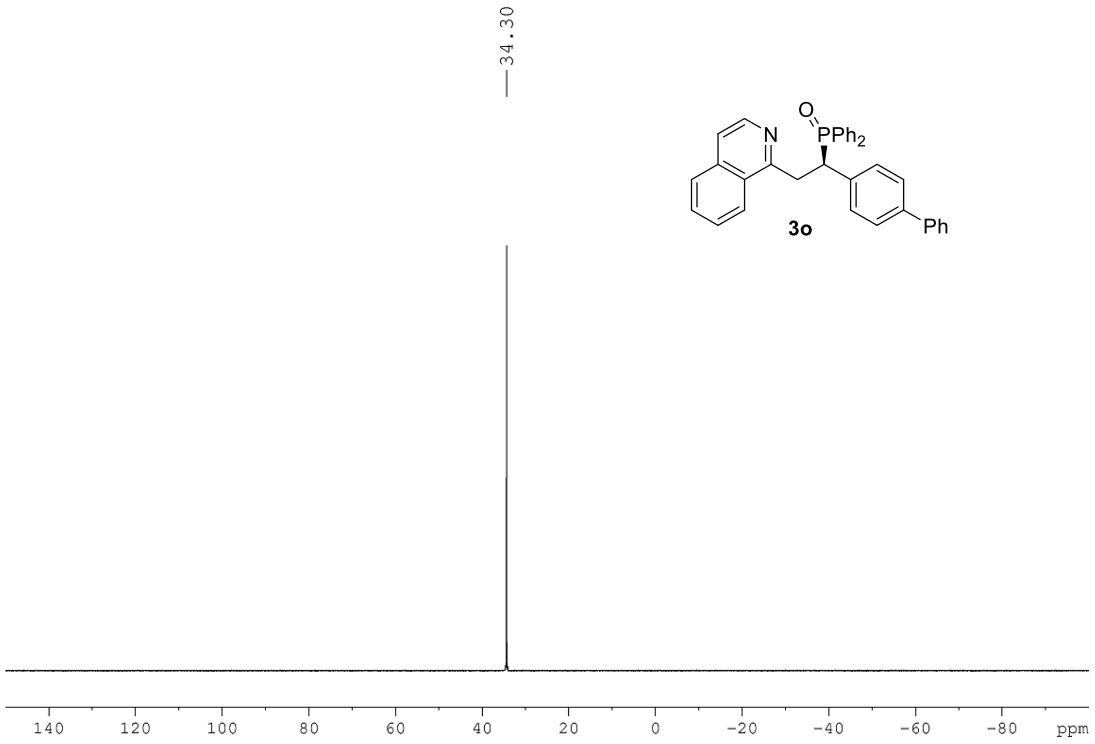
140.65
139.26
139.24
135.94
135.48
135.43
132.76
132.28
131.97
131.65
131.63
131.53
131.37
131.30
131.27
131.25
131.08
131.01
130.46
130.42
129.77
128.69
128.62
128.60
128.10
128.01
127.46
127.07
126.83
126.60
124.98
119.48
44.38
43.84
33.80
O
PPh2
N
Ph
3o
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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N
Ph
3o
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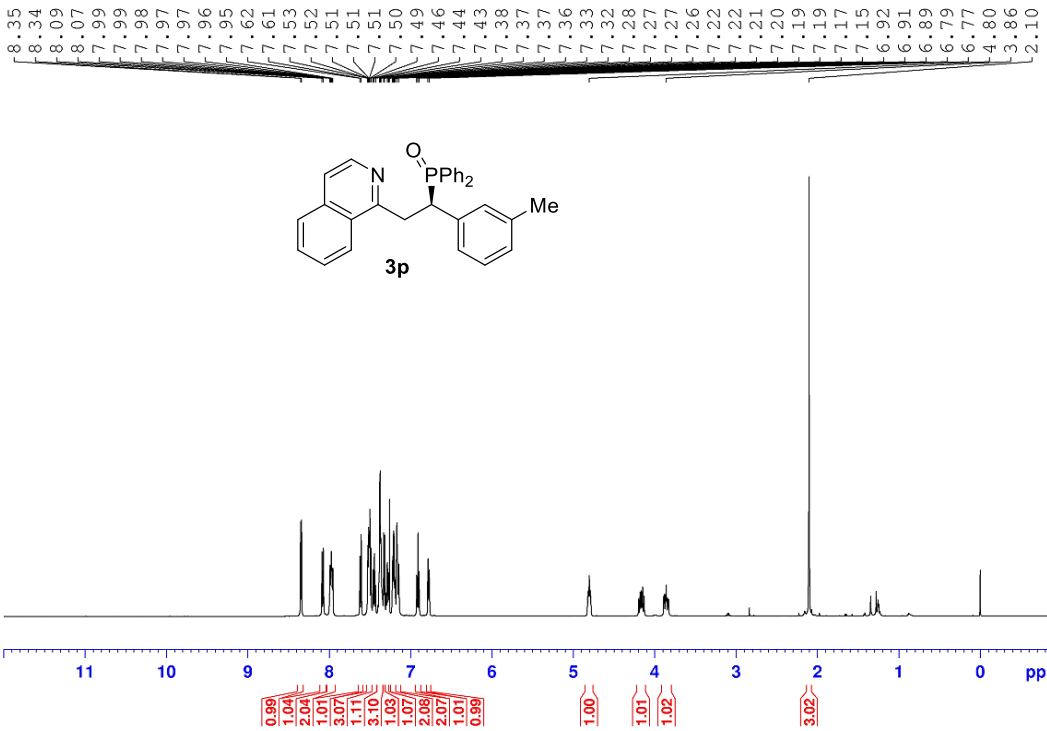
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7.98
7.97
7.97
7.96
7.95
7.62
7.61
7.53
7.52
7.51
7.51
7.50
7.49
7.46
7.44
7.43
7.38
7.37
7.37
7.36
7.33
7.32
7.28
7.27
7.27
7.26
7.22
7.22
7.21
7.20
7.19
7.19
7.17
7.15
6.92
6.91
6.89
6.79
6.77
4.80
3.86
2.10
O
PPh2
N
Me
3p
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.99
1.04
2.04
1.01
3.07
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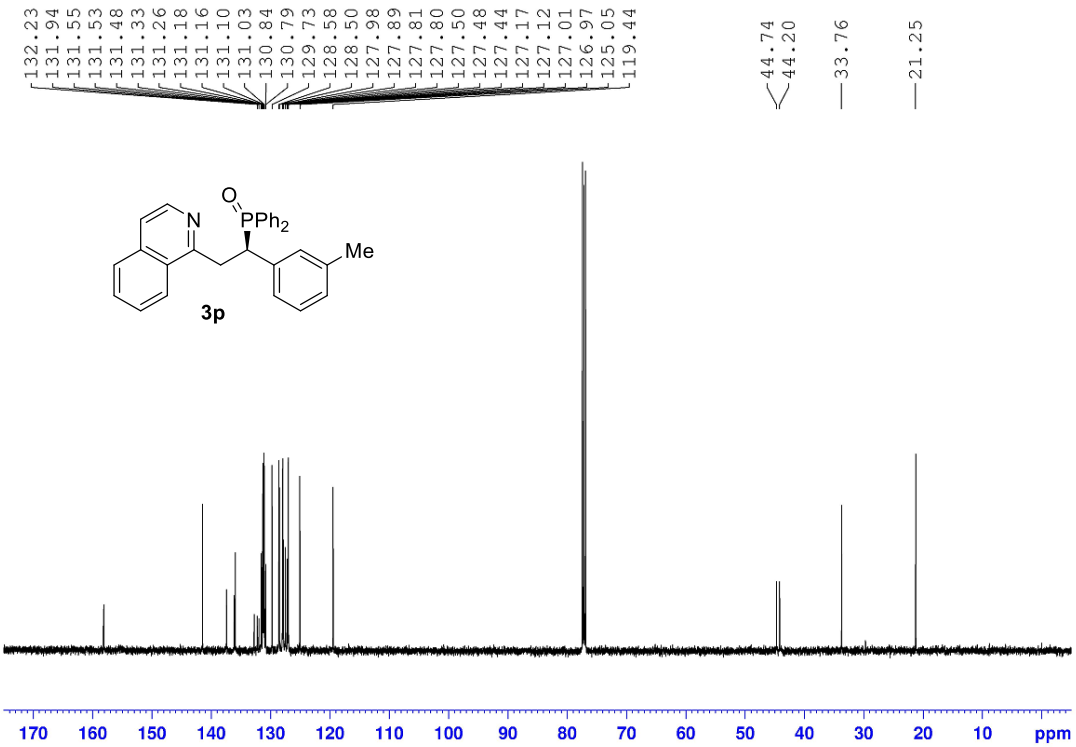
1.07
2.06
2.07
1.01
0.99
1.00
1.01
1.02
3.02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129.73
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127.89
127.81
127.80
127.50
127.48
127.44
127.17
127.12
127.01
126.97
125.05
119.44
44.74
44.20
33.76
21.25
O
PPh2
N
Me
3p
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140
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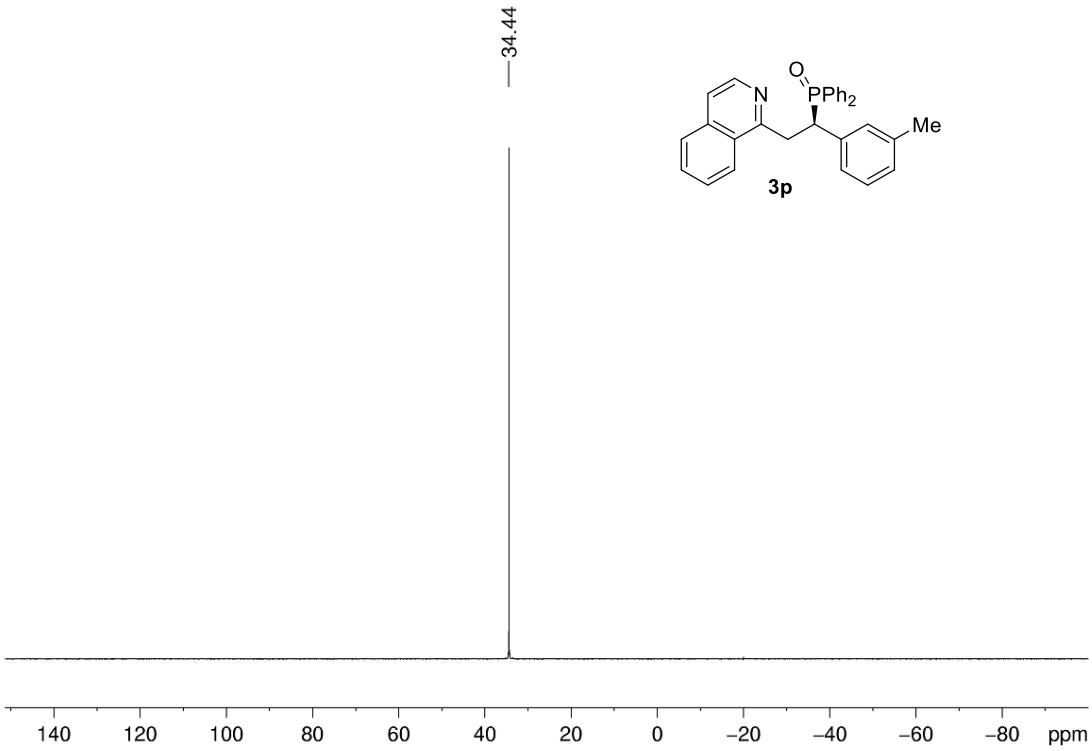
10
ppm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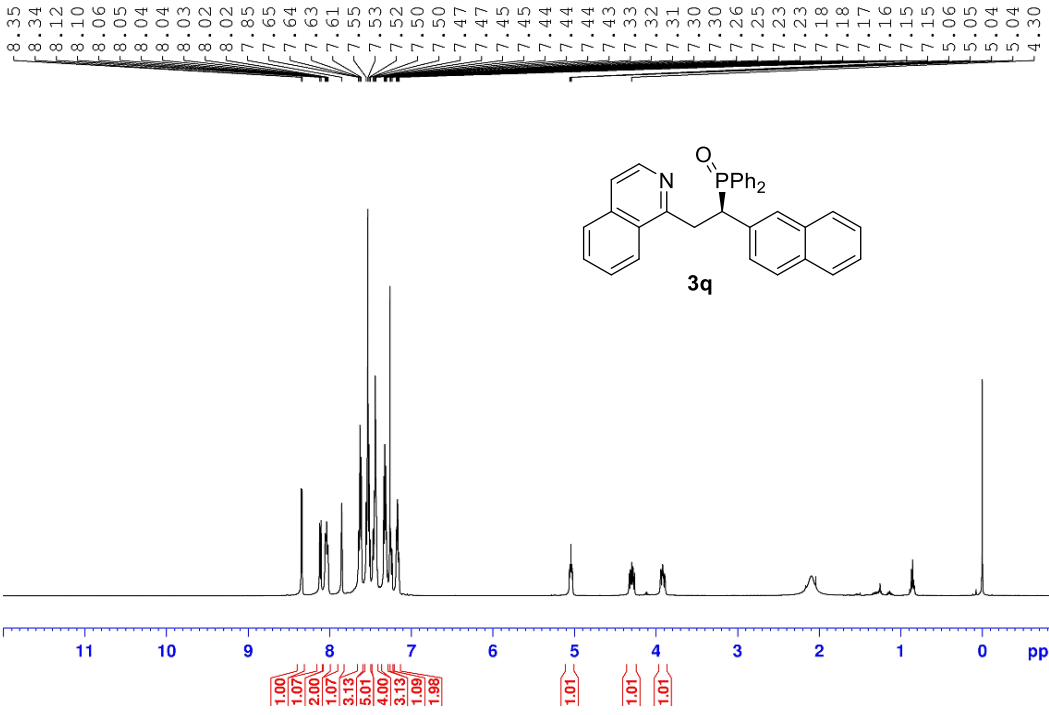
ppm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8.02
8.02
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7.63
7.61
7.55
7.53
7.52
7.50
7.50
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7.44
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7.44
7.43
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7.32
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7.30
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7.18
7.17
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7.15
5.06
5.05
5.04
5.04
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PPh2
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ppm
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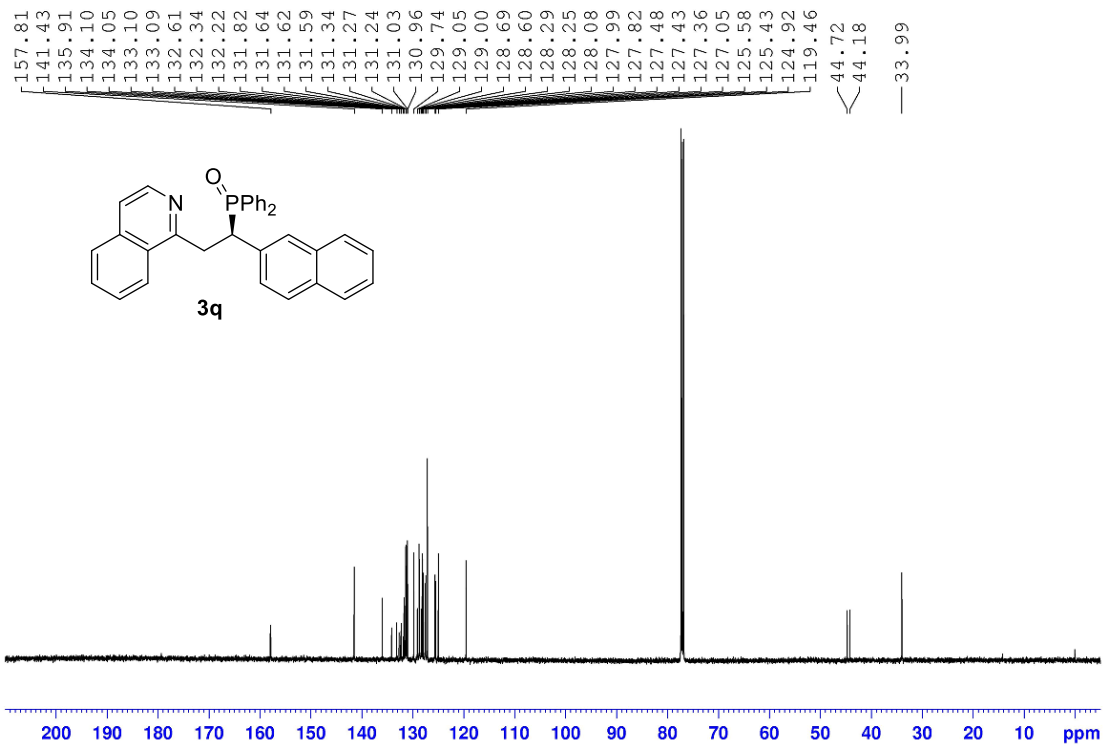
1.01
1.01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131.62
131.59
131.34
131.27
131.24
131.03
130.96
129.74
129.05
129.00
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128.60
128.29
128.25
128.08
127.99
127.82
127.48
127.43
127.36
127.05
125.58
125.43
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44.18
33.99
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PPh2
N
3q
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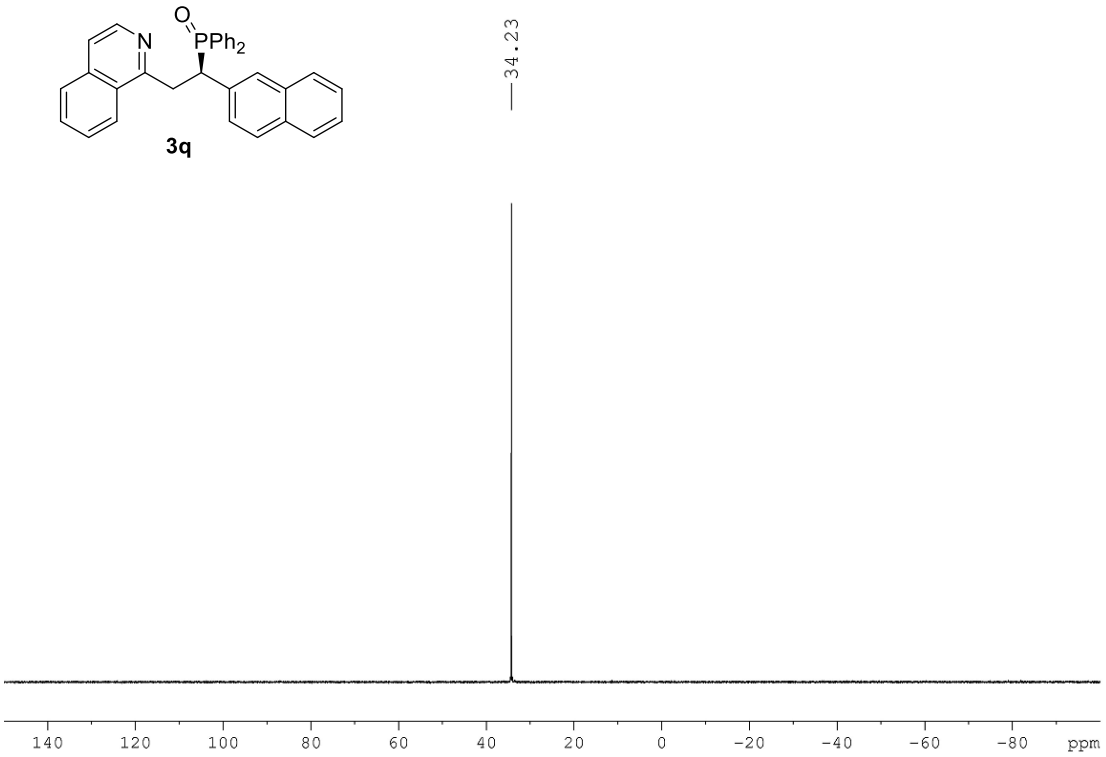
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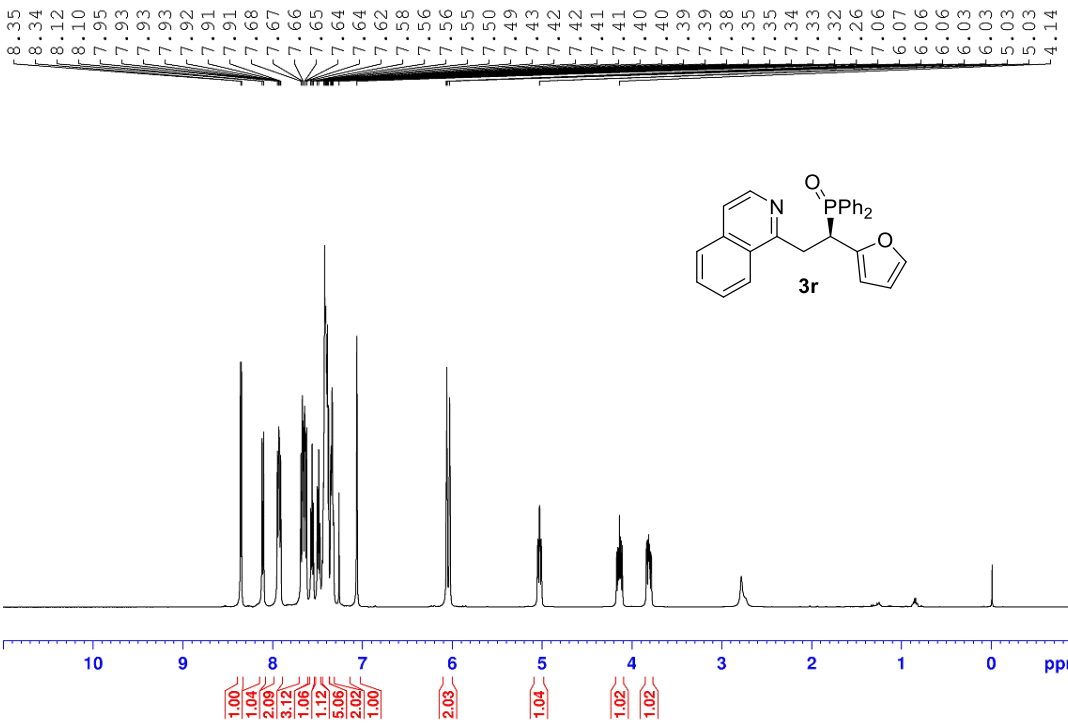
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7.91
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7.66
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7.64
7.64
7.62
7.58
7.56
7.56
7.55
7.50
7.49
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7.42
7.42
7.41
7.41
7.40
7.40
7.39
7.39
7.38
7.35
7.35
7.34
7.33
7.32
7.26
7.06
6.07
6.06
6.06
6.03
6.03
5.03
5.03
4.14
O
PPh2
N
O
3r
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
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5.06
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1.00
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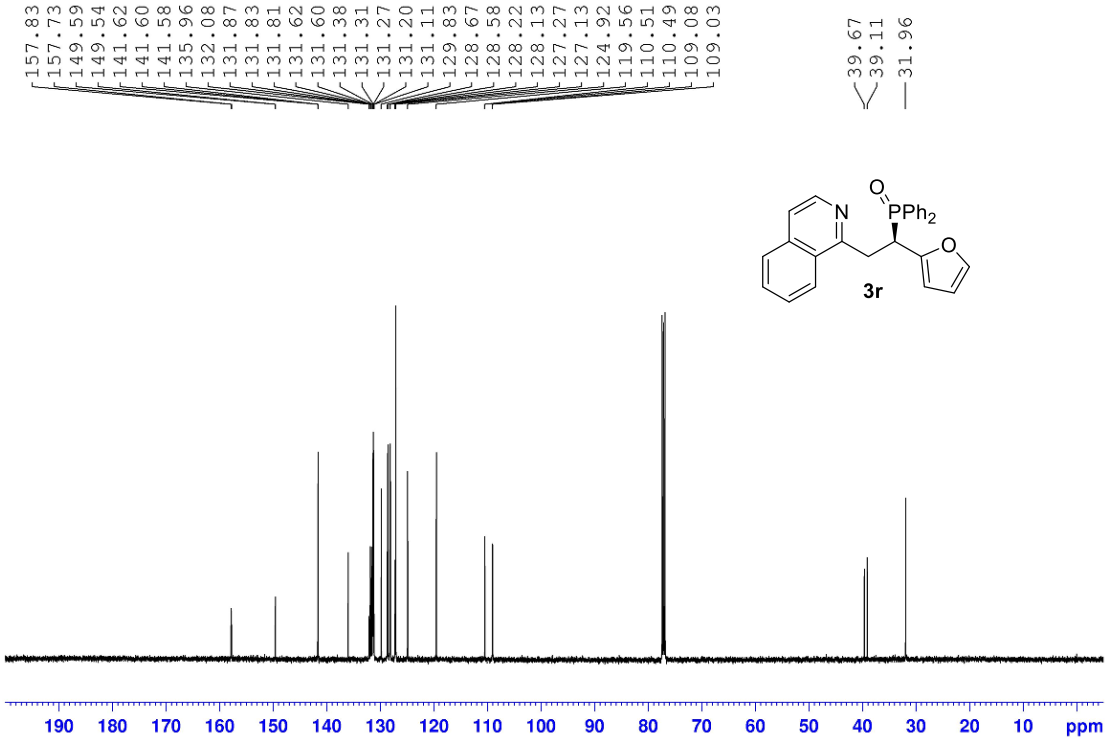
1.02
1.02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131.27
131.20
131.11
129.83
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128.58
128.22
128.13
127.27
127.13
124.92
119.56
110.51
110.49
109.08
109.03
39.67
39.11
31.96
O
PPh2
N
O
3r
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150
140
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70
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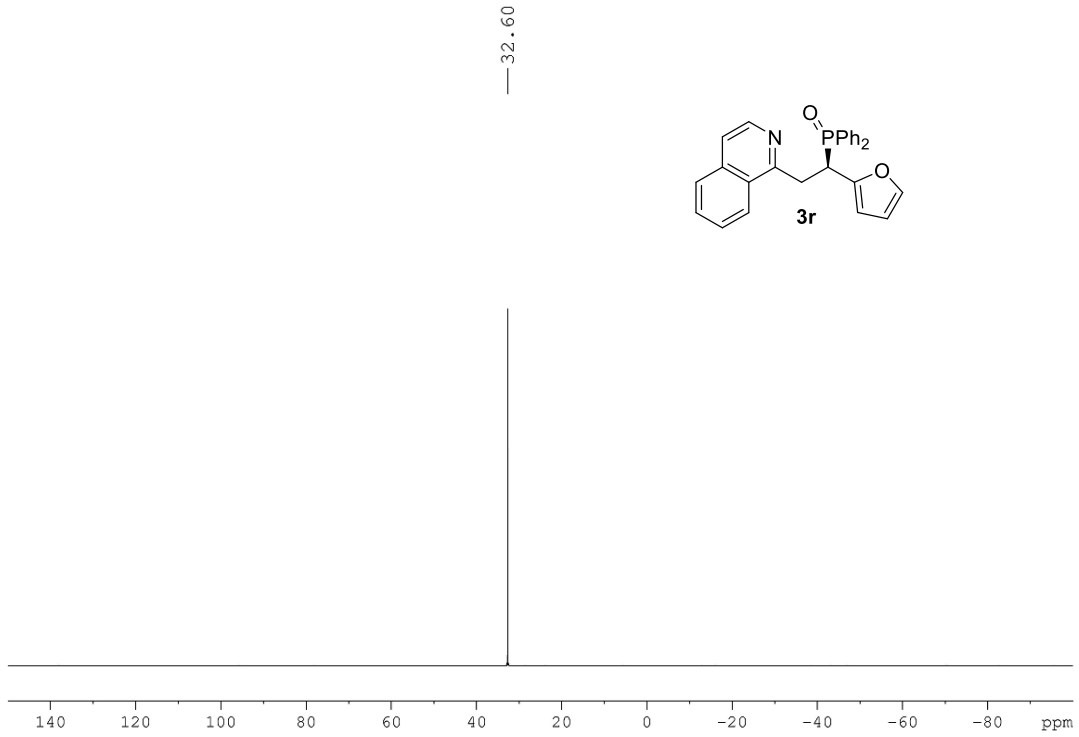
30
20
10
ppm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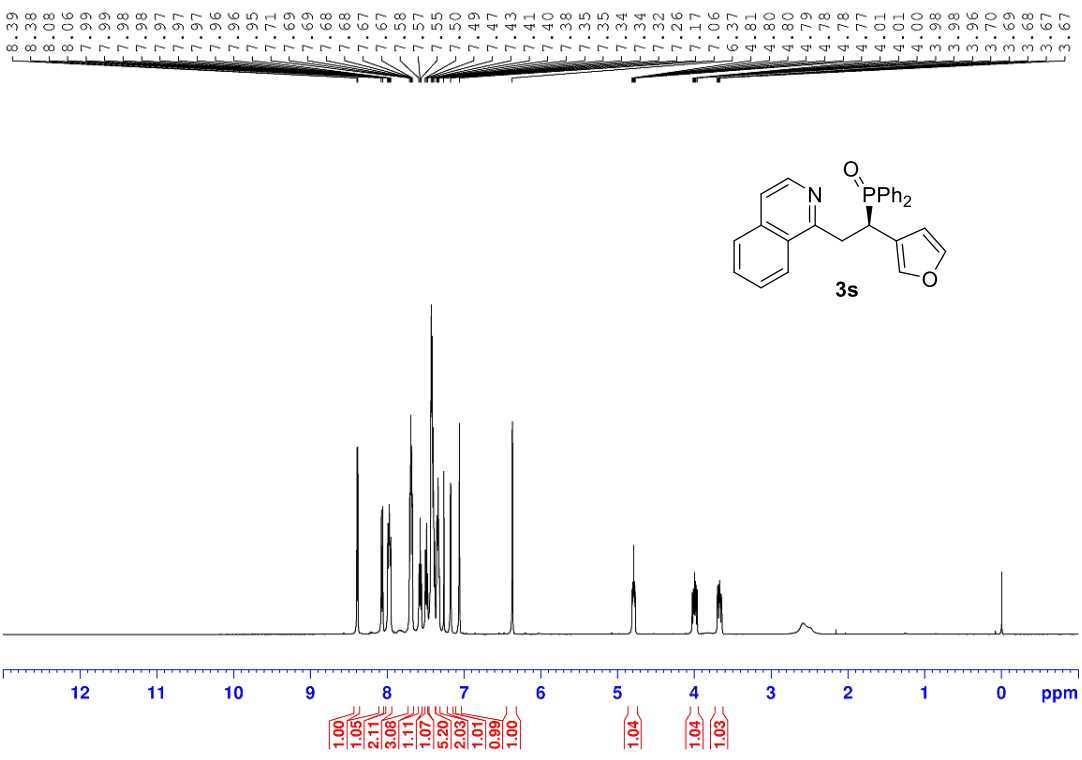
-60
-80
ppm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7.97
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7.95
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7.68
7.68
7.67
7.67
7.58
7.57
7.55
7.50
7.49
7.47
7.43
7.41
7.40
7.38
7.35
7.35
7.34
7.34
7.32
7.26
7.17
7.06
6.37
4.81
4.80
4.80
4.79
4.78
4.78
4.77
4.01
4.01
4.00
3.98
3.98
3.96
3.70
3.69
3.68
3.67
3.67
O
PPh2
N
O
3s
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
1.05
2.11
3.08
1.11
1.07
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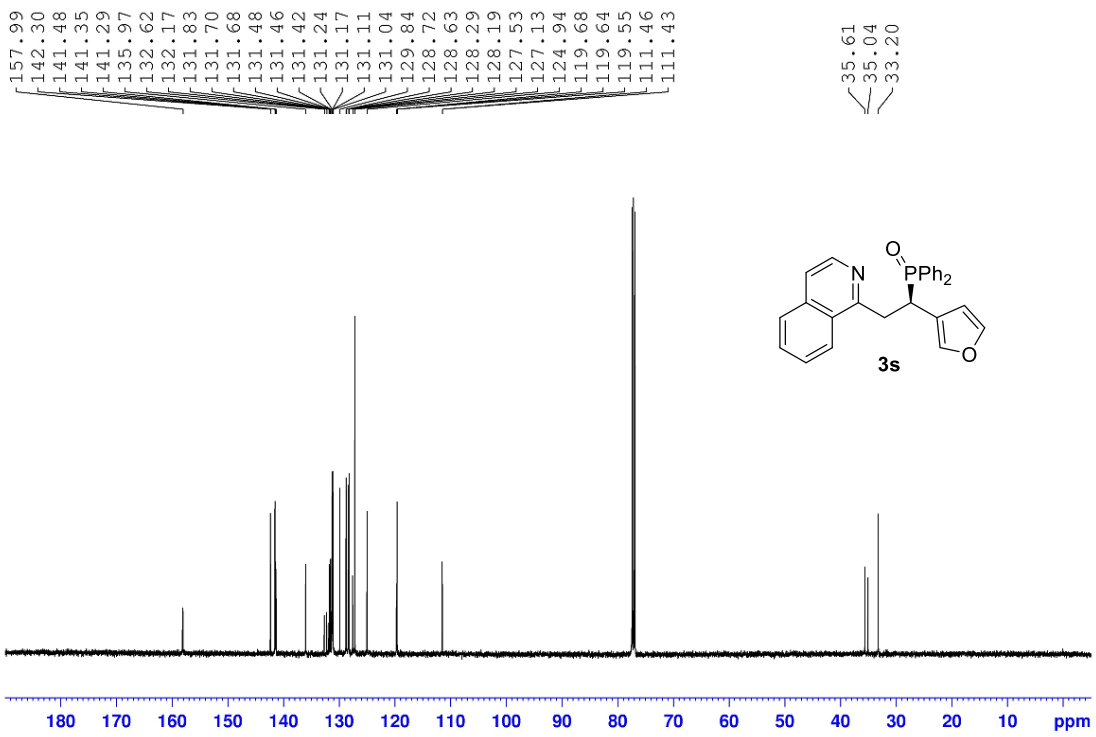
2.03
1.01
0.99
1.00
1.04
1.04
1.03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131.24
131.17
131.11
131.04
129.84
128.72
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128.29
128.19
127.53
127.13
124.94
119.68
119.64
119.55
111.46
111.43
35.61
35.04
33.20
O
PPh2
N
O
3s
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140
130
120
110
100
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70
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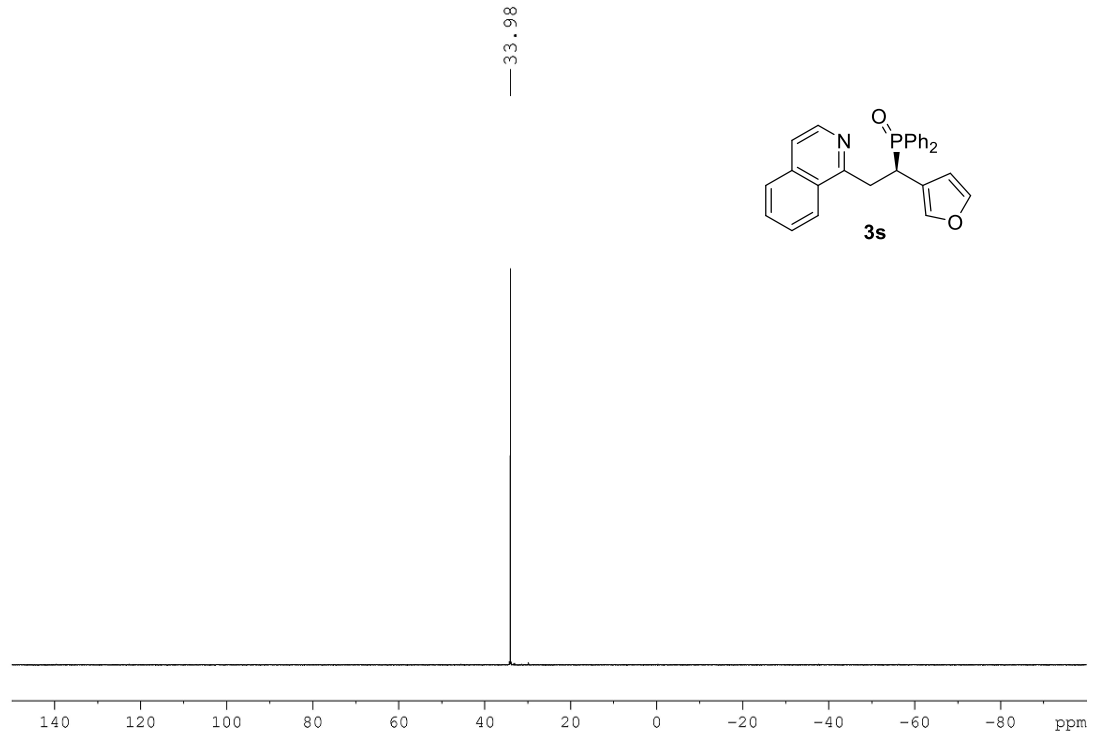
30
20
10
ppm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O
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40
20
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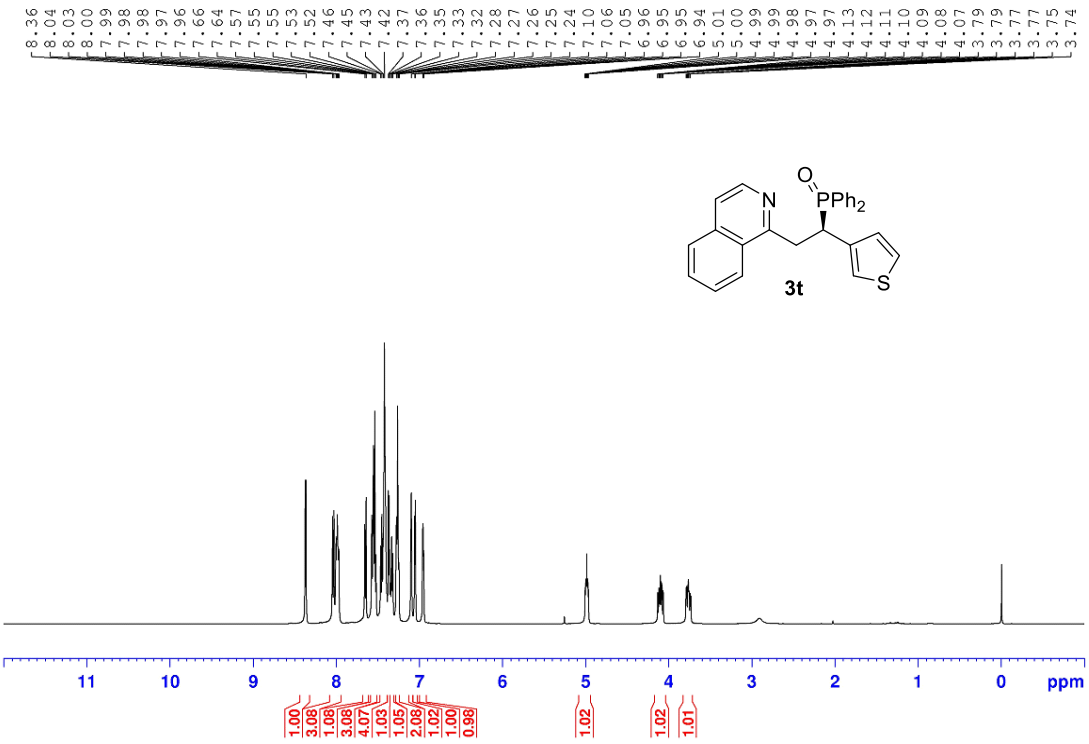
-20
-40
-60
-80
ppm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7.66
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7.57
7.55
7.55
7.53
7.52
7.46
7.45
7.43
7.42
7.37
7.36
7.35
7.33
7.32
7.28
7.27
7.26
7.25
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7.05
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6.95
6.94
5.01
5.00
4.99
4.99
4.98
4.97
4.97
4.13
4.12
4.11
4.10
4.09
4.08
4.07
3.79
3.79
3.77
3.77
3.75
3.74
O
PPh2
N
S
3t
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
3.08
1.08
3.08
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1.03
1.05
2.08
1.02
1.00
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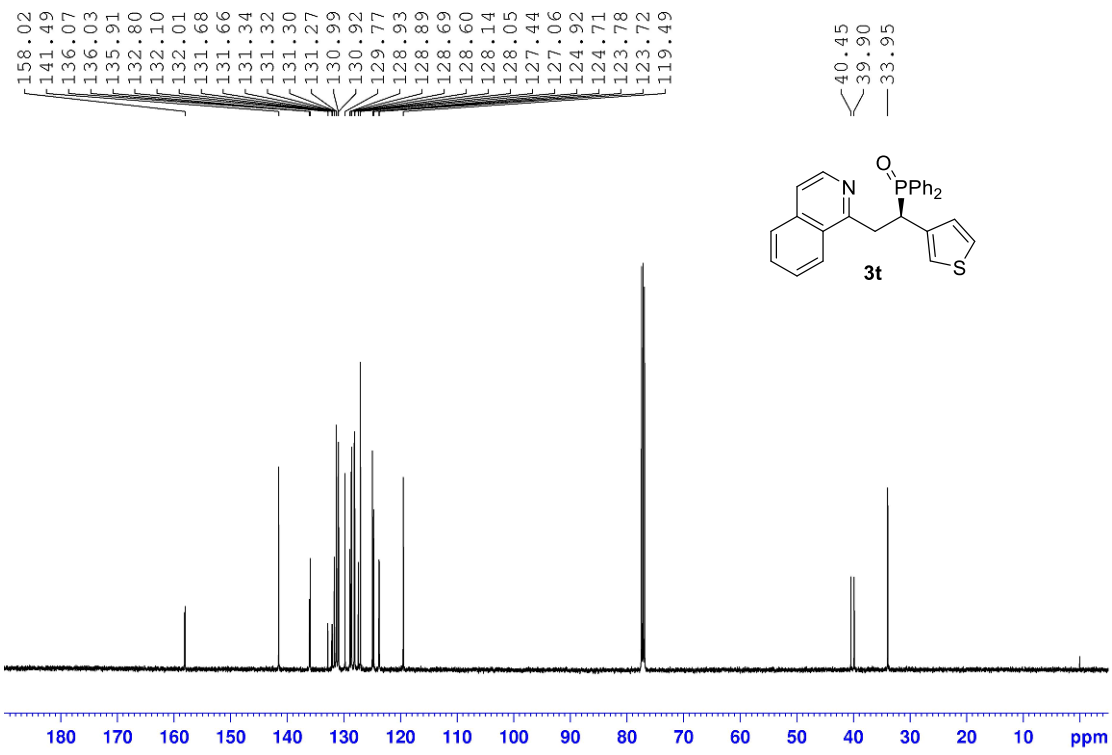
1.02
1.01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129.77
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128.89
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128.05
127.44
127.06
124.92
124.71
123.78
123.72
119.49
40.45
39.90
33.95
O
PPh2
N
S
3t
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150
140
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120
110
100
90
80
70
60
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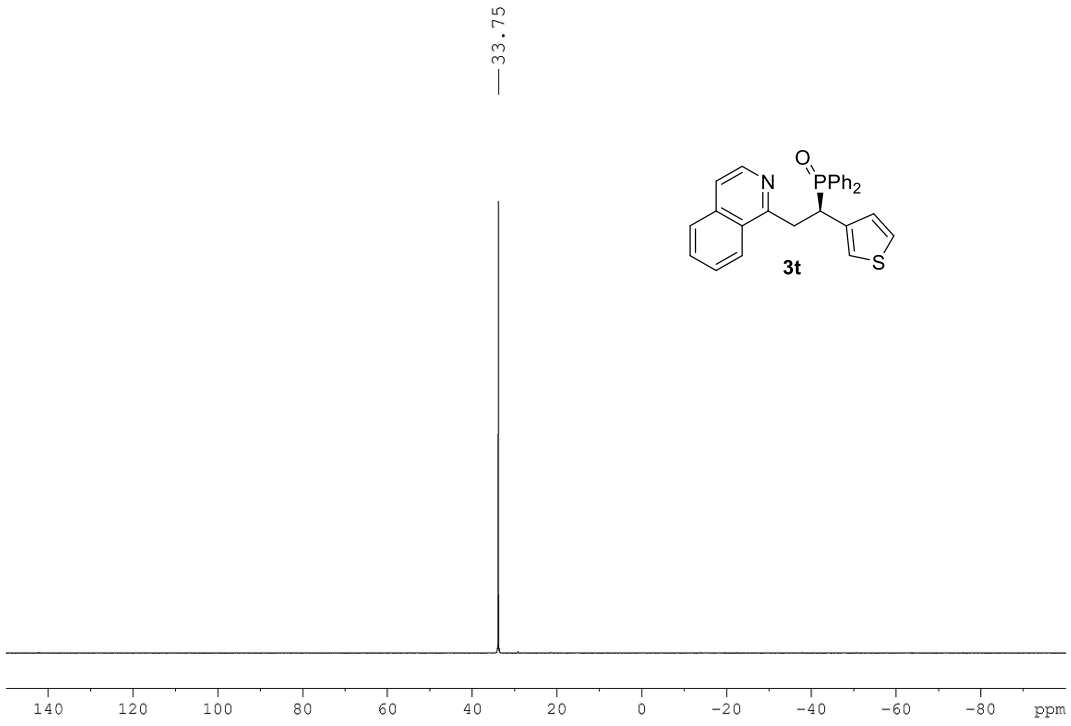
30
20
10
ppm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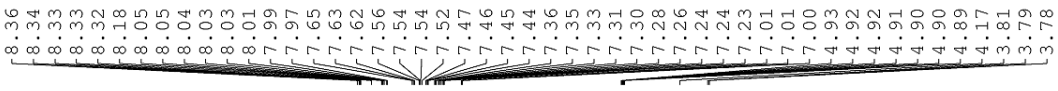
ppm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8.05
8.04
8.03
8.03
8.01
7.99
7.97
7.65
7.63
7.62
7.56
7.54
7.54
7.52
7.47
7.46
7.45
7.44
7.36
7.35
7.33
7.31
7.30
7.28
7.26
7.24
7.24
7.23
7.01
7.01
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4.92
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4.90
4.90
4.89
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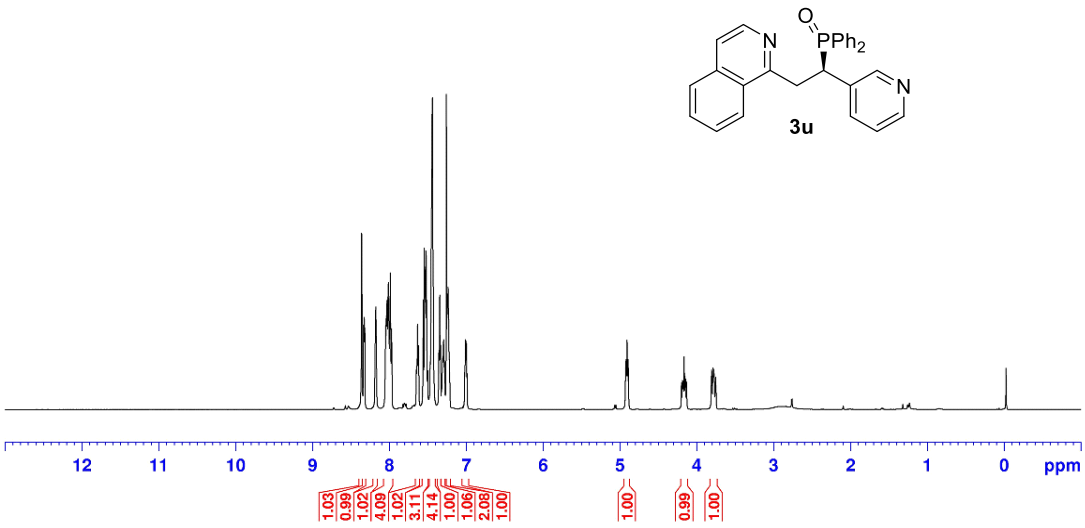
3.79
3.78


O
PPh2
N
N
3u
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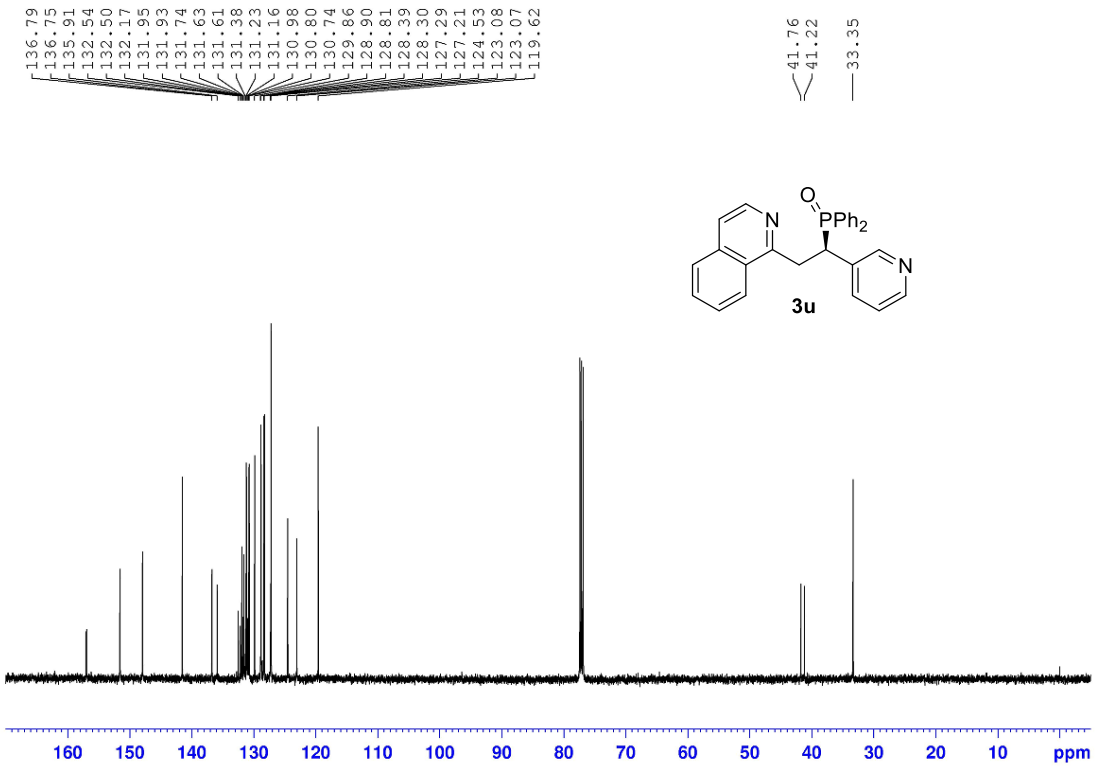
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.03
0.99
1.02
4.09
1.02
3.11
4.14
1.00
1.06
2.08
1.00
1.00
0.99
1.00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129.86
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128.81
128.39
128.30
127.29
127.21
124.53
123.08
123.07
119.62
41.76
41.22
33.35
O
PPh2
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150
140
130
120
110
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90
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70
60
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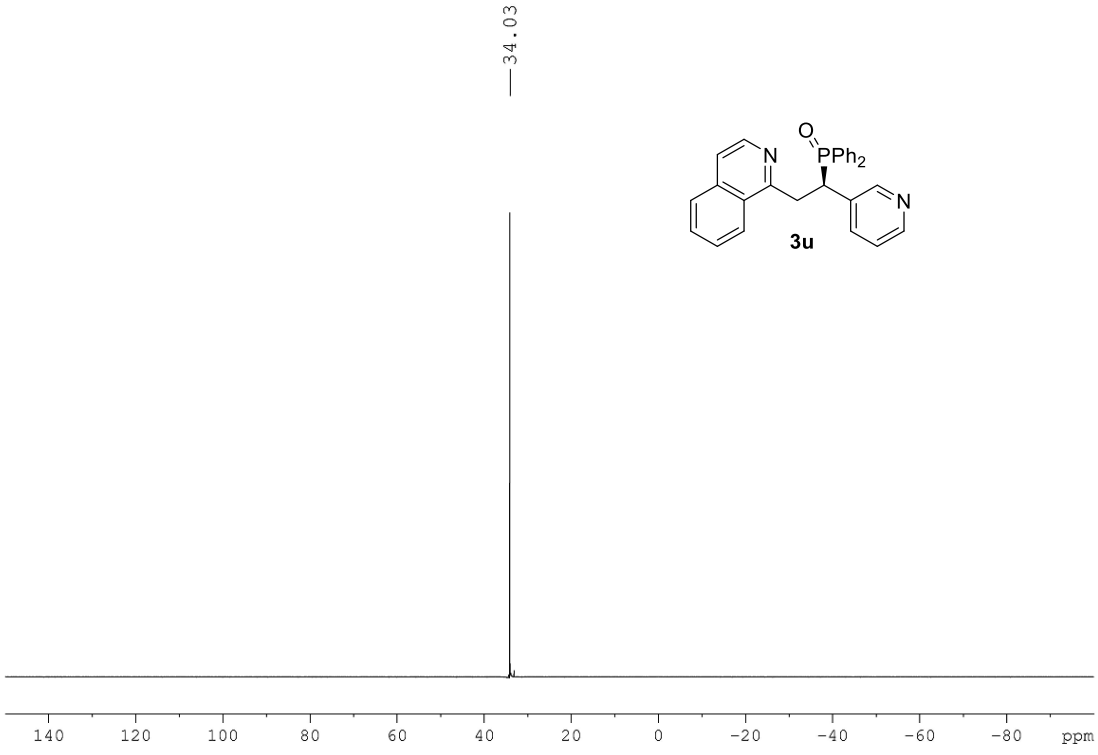
30
20
10
ppm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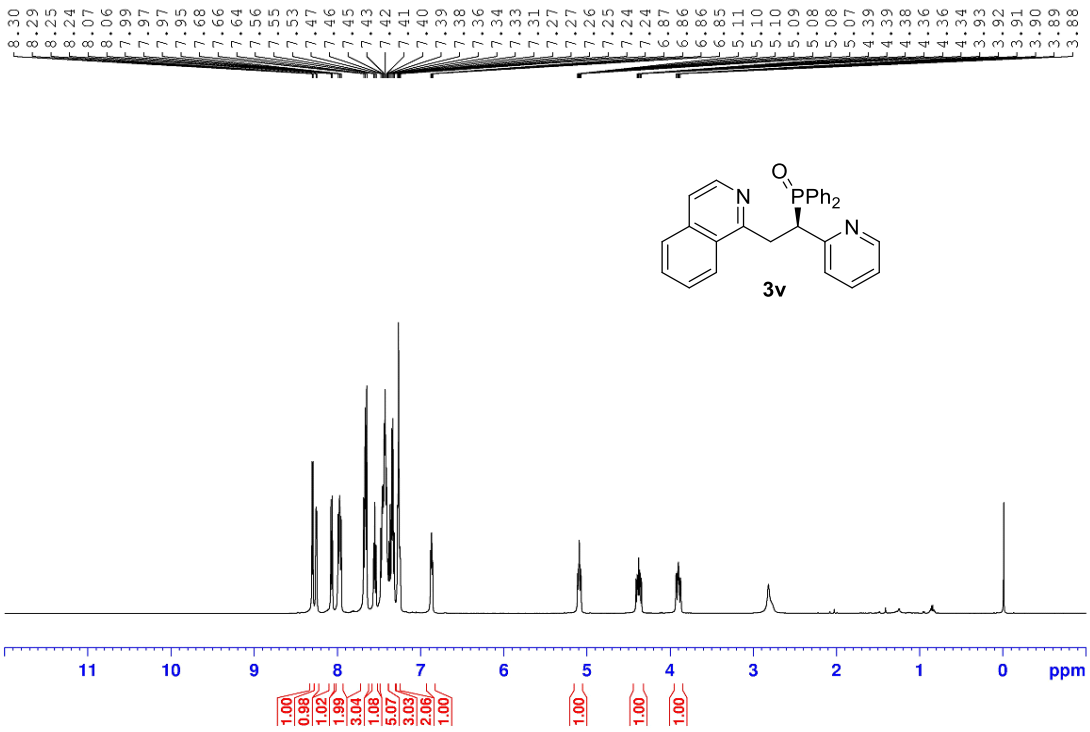
-40
-60
-80
ppm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7.97
7.97
7.95
7.68
7.66
7.64
7.56
7.55
7.53
7.47
7.46
7.45
7.43
7.42
7.41
7.40
7.39
7.38
7.36
7.34
7.33
7.31
7.27
7.27
7.26
7.25
7.24
7.24
6.87
6.86
6.86
6.85
5.11
5.10
5.10
5.09
5.08
5.08
5.07
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4.39
4.38
4.36
4.36
4.34
3.93
3.92
3.91
3.90
3.89
3.88
O
PPh2
N
N
3v
11
10
9
8
7
6
5
4
3
2
1
0
ppm
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1.99
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1.08
5.07
3.03
2.06
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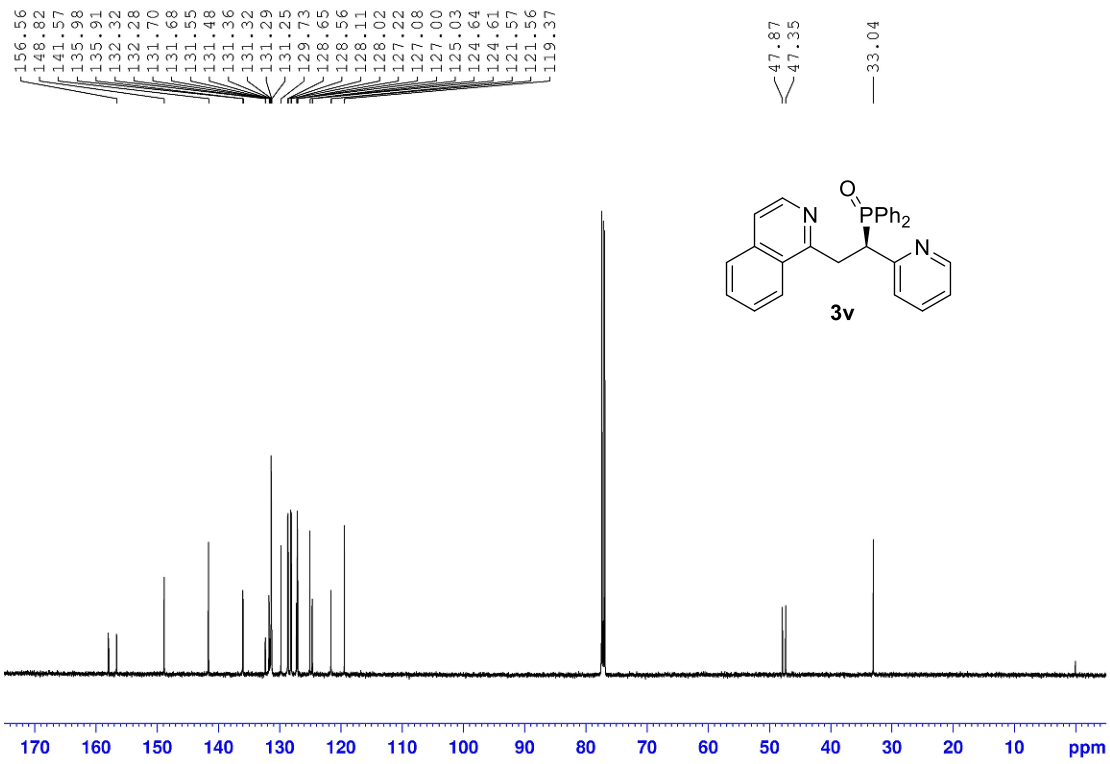
1.00
1.00
1.00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131.29
131.25
129.73
128.65
128.56
128.11
128.02
127.22
127.08
127.00
125.03
124.64
124.61
121.57
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47.87
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O
PPh2
N
N
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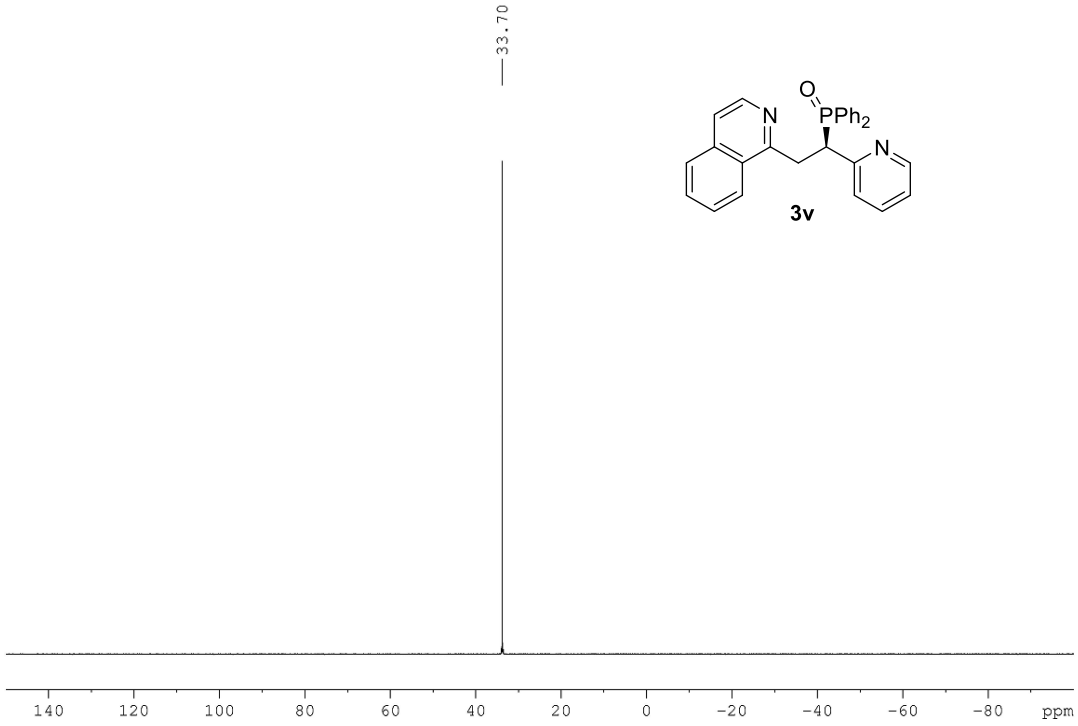
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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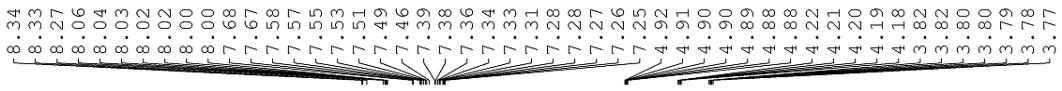
-60
-80
ppm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8.03
8.02
8.02
8.00
8.00
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7.58
7.57
7.55
7.53
7.51
7.49
7.46
7.39
7.38
7.36
7.34
7.33
7.31
7.28
7.28
7.27
7.26
7.25
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4.91
4.90
4.90
4.89
4.88
4.88
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4.19
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3.82
3.80
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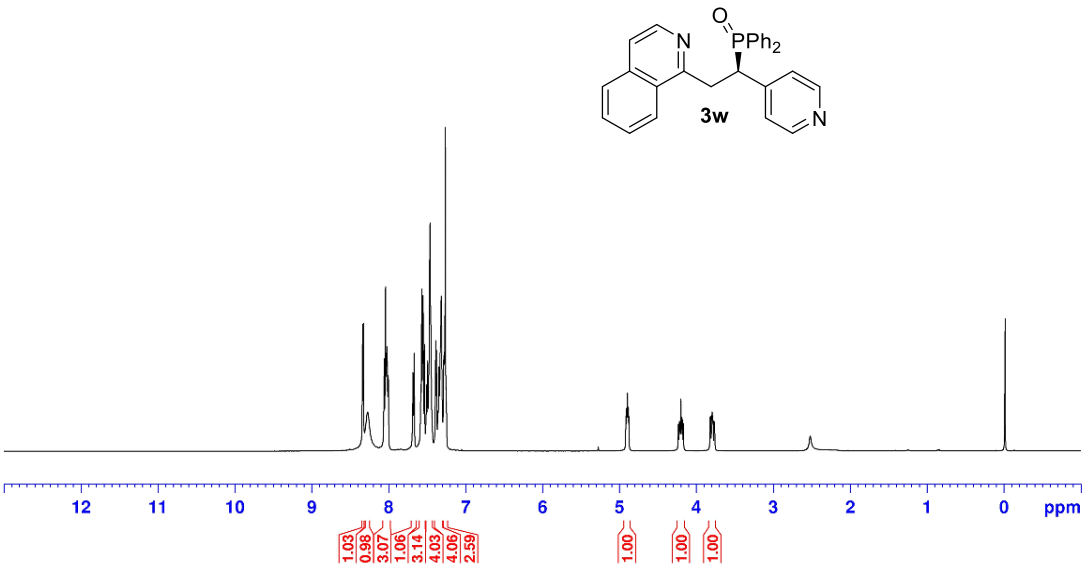
3.78
3.77


O
PPh2
N
N
3w
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.03
0.98
3.07
1.06
3.14
4.03
4.06
2.59
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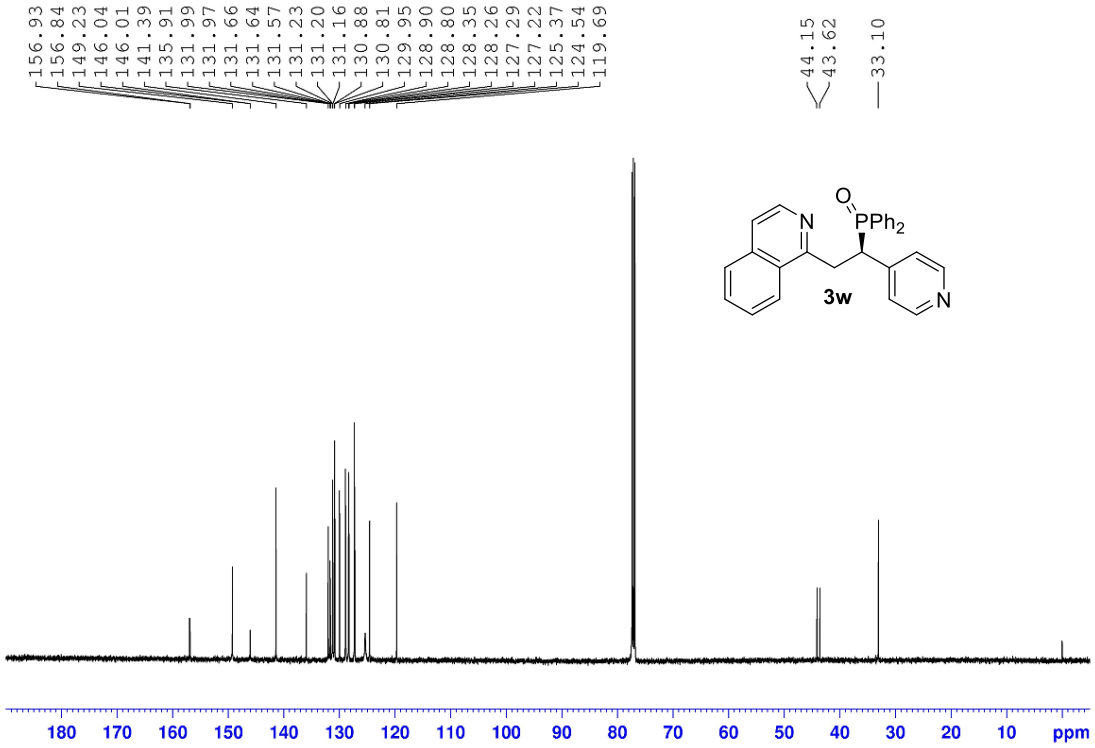
1.00
1.00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130.81
129.95
128.90
128.80
128.35
128.26
127.29
127.22
125.37
124.54
119.69
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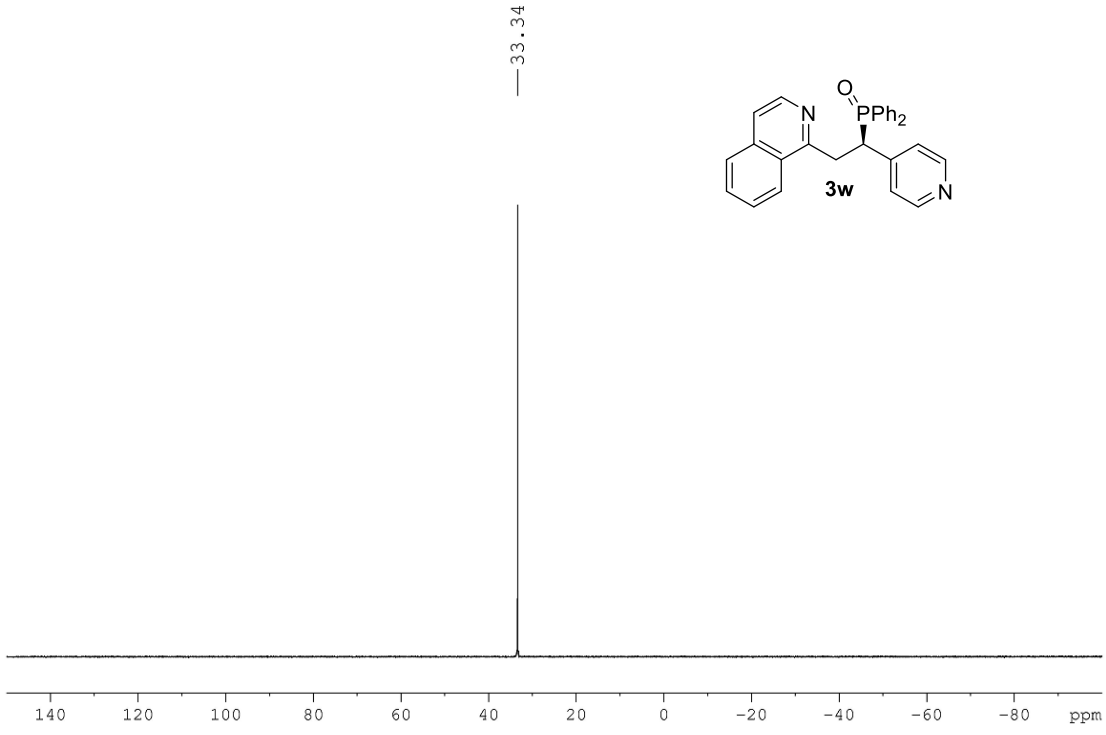
43.62
33.10
O
PPh2
N
N
3w
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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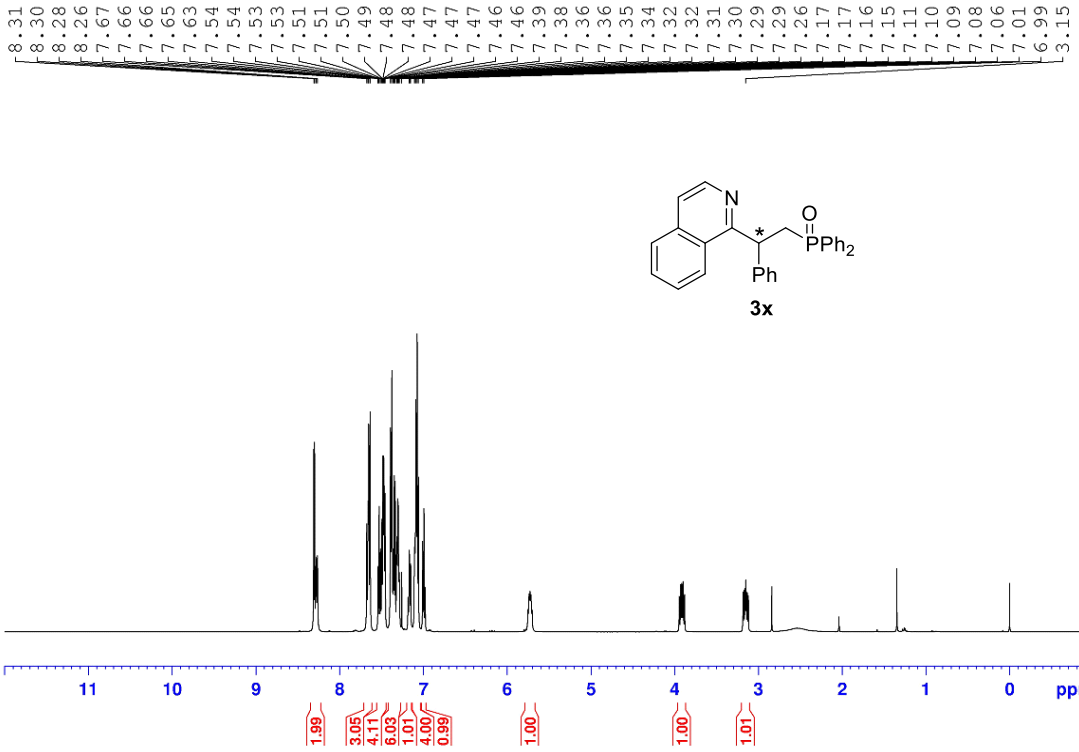
O
PPh2
N
N
3w
140 120 100 80 60 40 20 0 -20 -40 -60 -80 ppm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7.53
7.51
7.51
7.50
7.49
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7.48
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7.47
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7.32
7.32
7.31
7.30
7.29
7.29
7.26
7.17
7.17
7.16
7.15
7.11
7.10
7.09
7.08
7.06
7.01
6.99
3.15
N
O
PPh2
Ph
*
3x
11
10
9
8
7
6
5
4
3
2
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4.11
6.03
1.01
4.00
0.99
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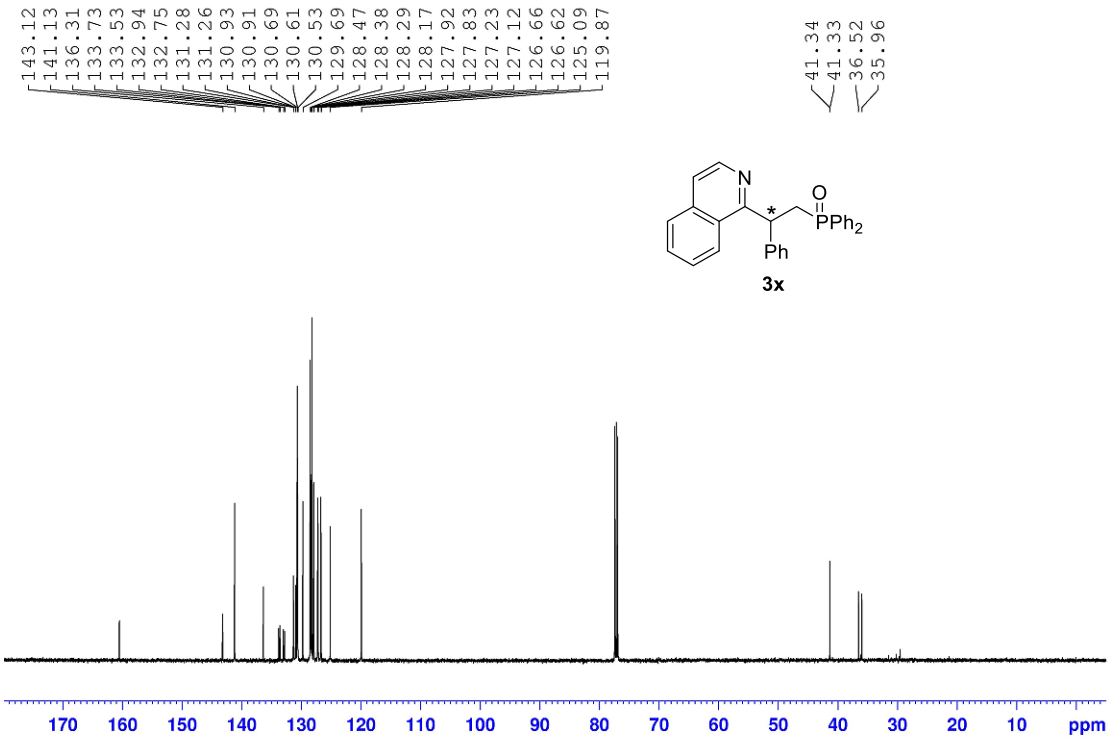
1.00
1.01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130.53
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128.29
128.17
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127.23
127.12
126.66
126.62
125.09
119.87
41.34
41.33
36.52
35.96
N
O
PPh2
Ph
*
3x
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
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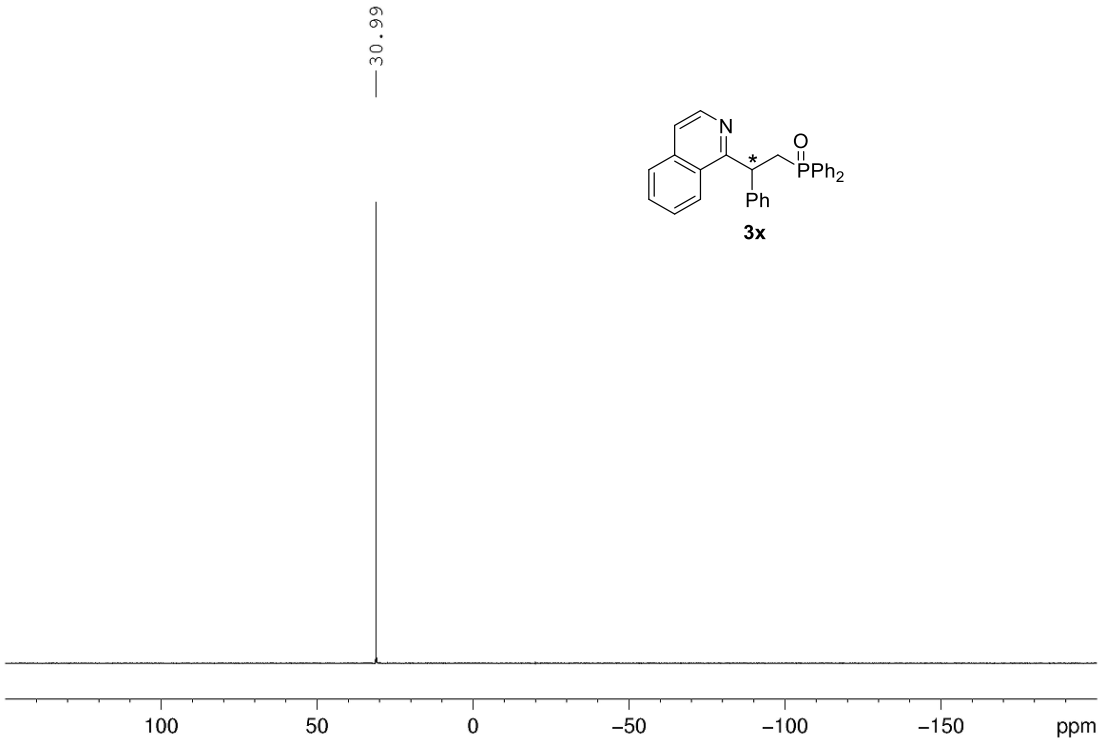
ppm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−150
ppm


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7.04
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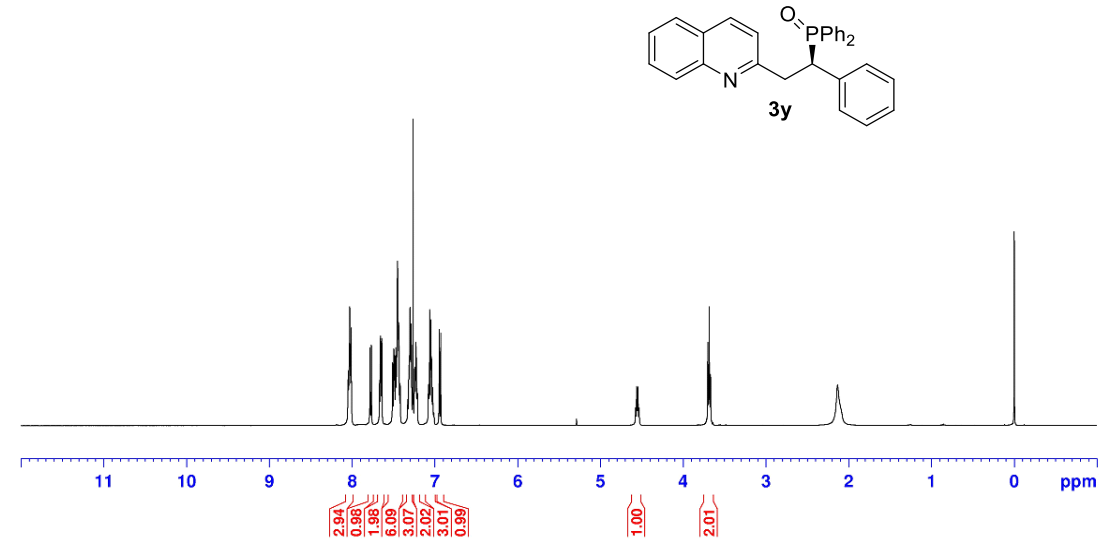
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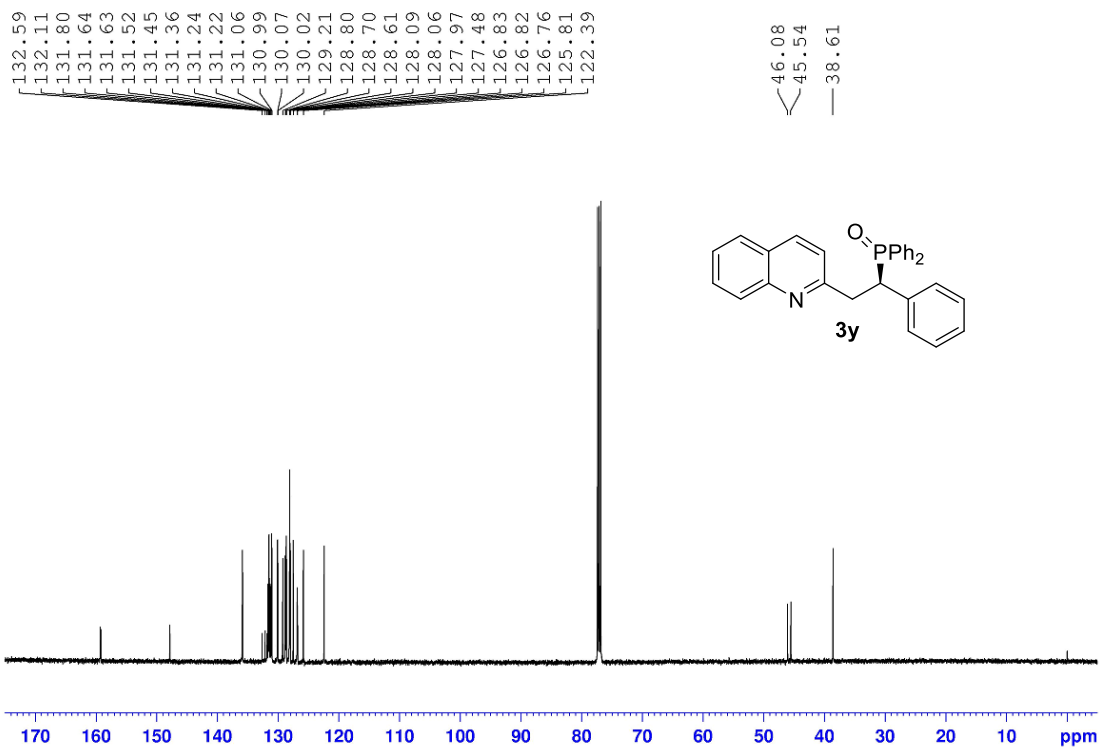
1.00
2.01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128.61
128.09
128.06
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127.48
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O
PPh2
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10
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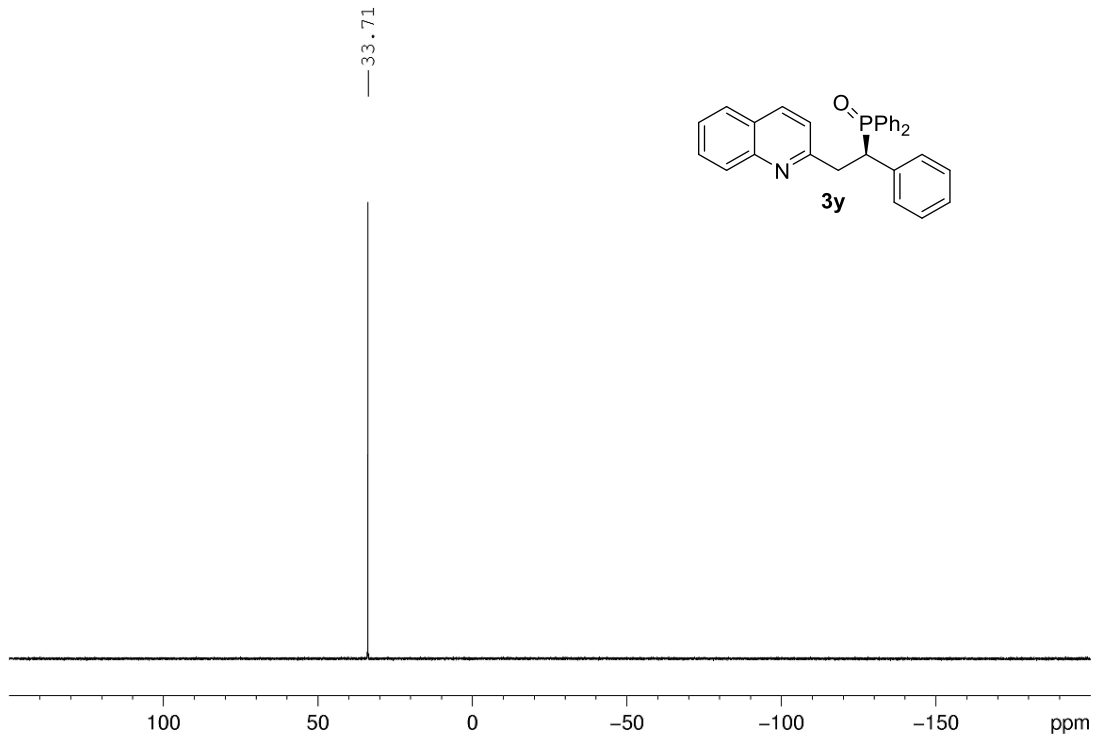
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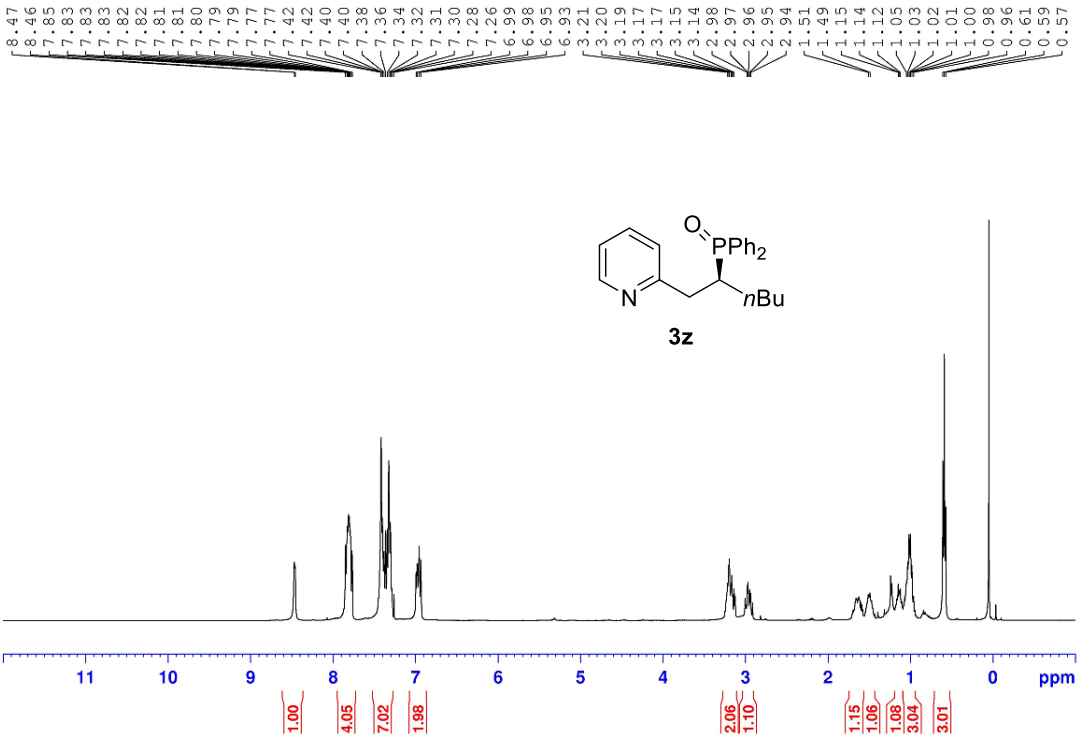
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7.40
7.40
7.38
7.36
7.34
7.32
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7.30
7.28
7.26
6.99
6.98
6.95
6.93
3.21
3.20
3.19
3.17
3.17
3.15
3.14
2.98
2.97
2.96
2.95
2.94
1.51
1.49
1.15
1.14
1.12
1.05
1.03
1.02
1.01
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0.57
O
PPh2
N
nBu
3z
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10
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8
7
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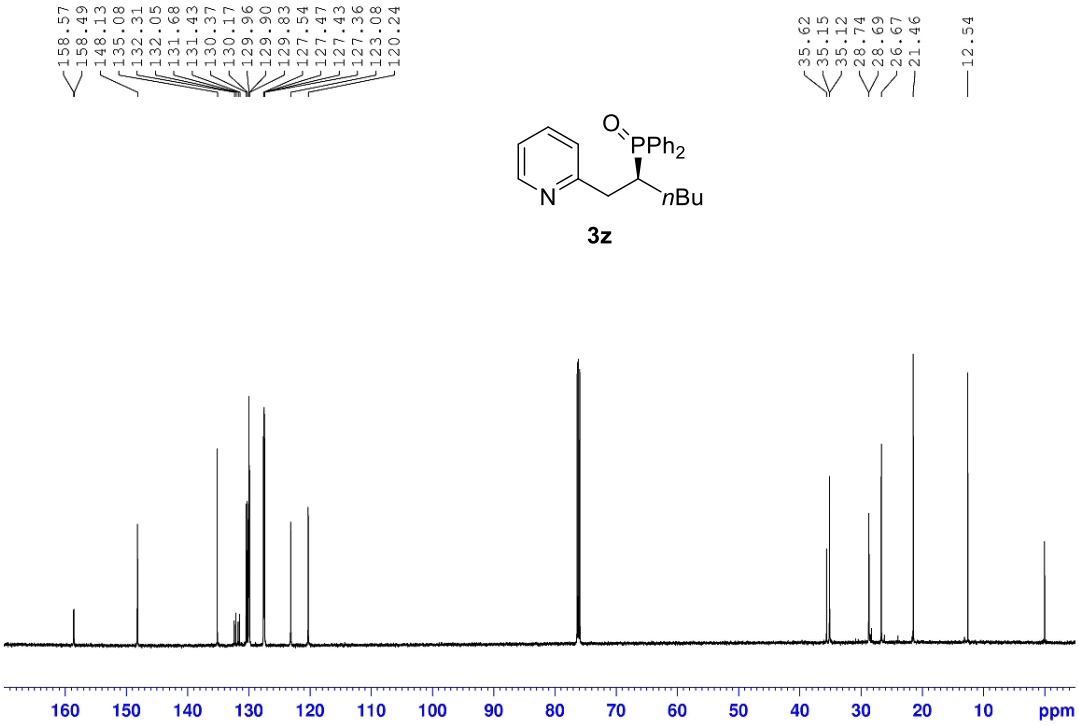
3.01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127.47
127.43
127.36
123.08
120.24
35.62
35.15
35.12
28.74
28.69
26.67
21.46
12.54
O
PPh2
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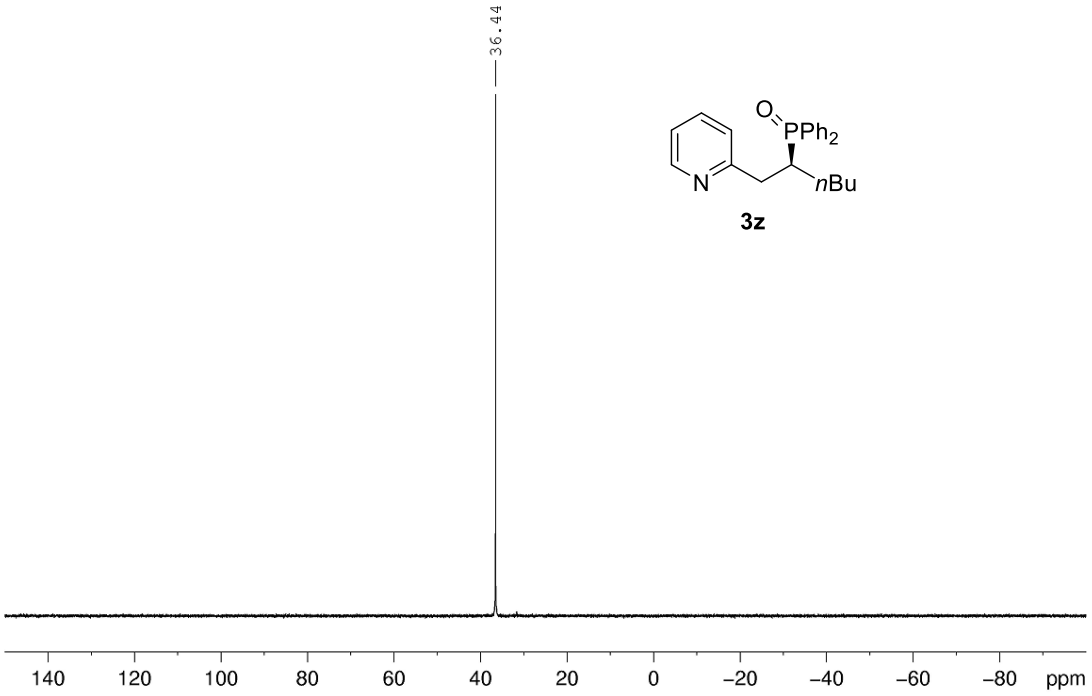
10
ppm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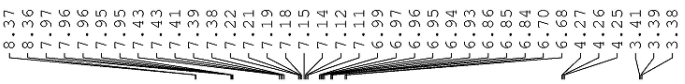
−80
ppm

3z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7.21
7.19
7.18
7.15
7.14
7.12
7.11
6.99
6.97
6.96
6.95
6.94
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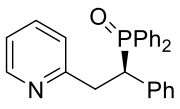
3.41
3.39
3.38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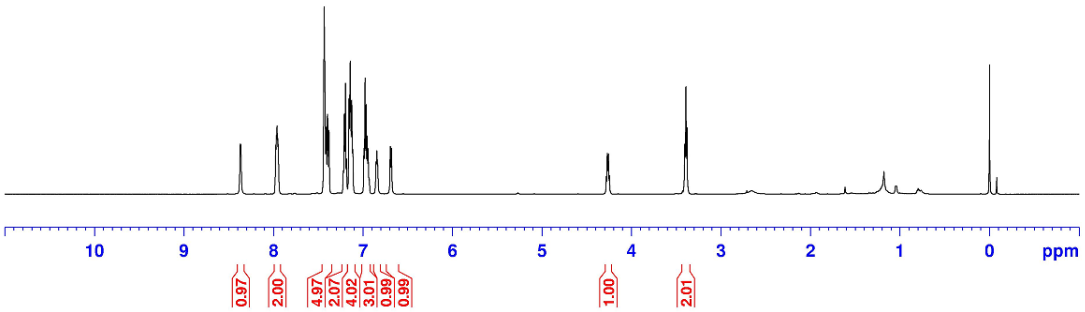
N
Ph

3aa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4
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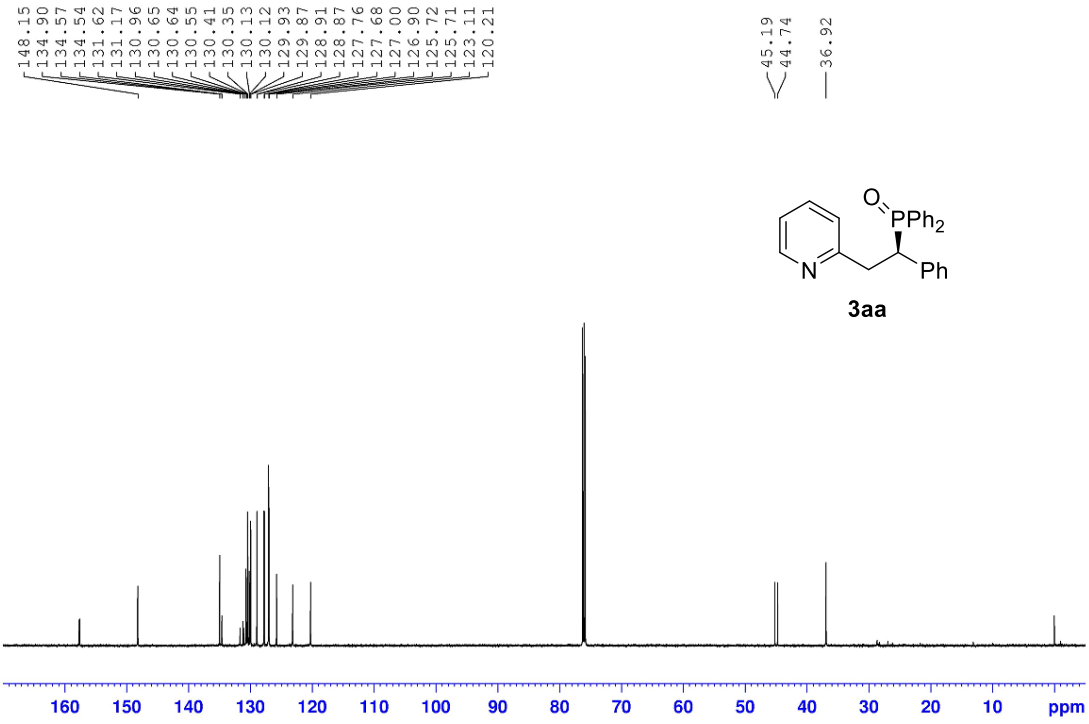
4.02
3.01
0.99
0.99
1.00
2.01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130.35
130.13
130.12
129.93
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128.91
128.87
127.76
127.68
127.00
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125.72
125.71
123.11
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36.92
O
PPh2
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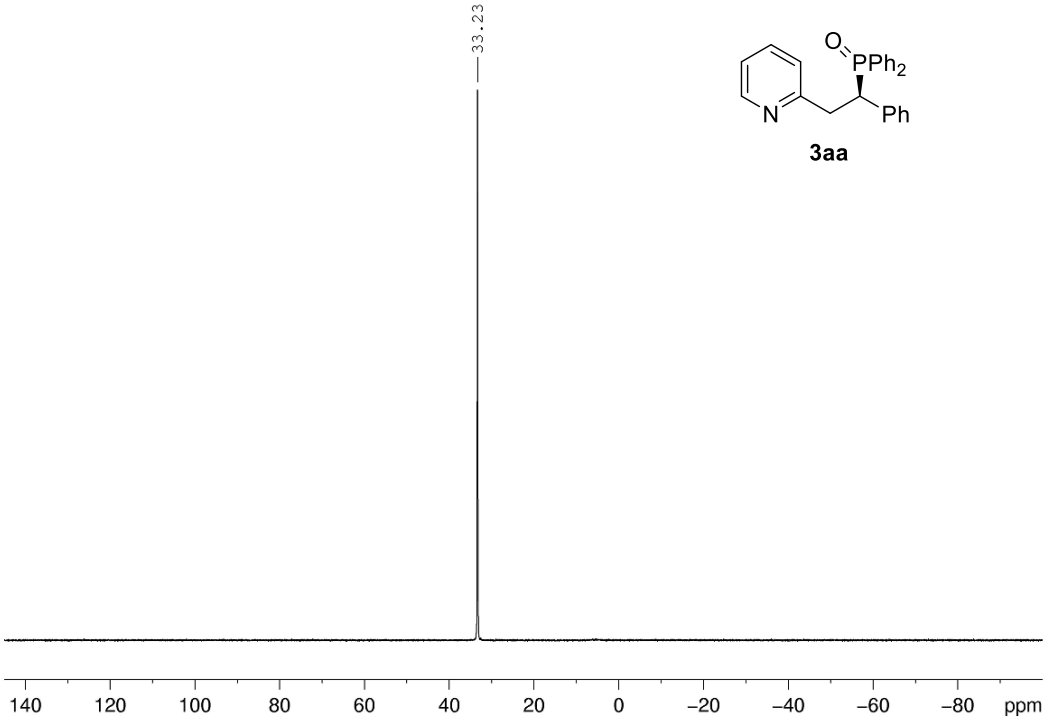
ppm

3aa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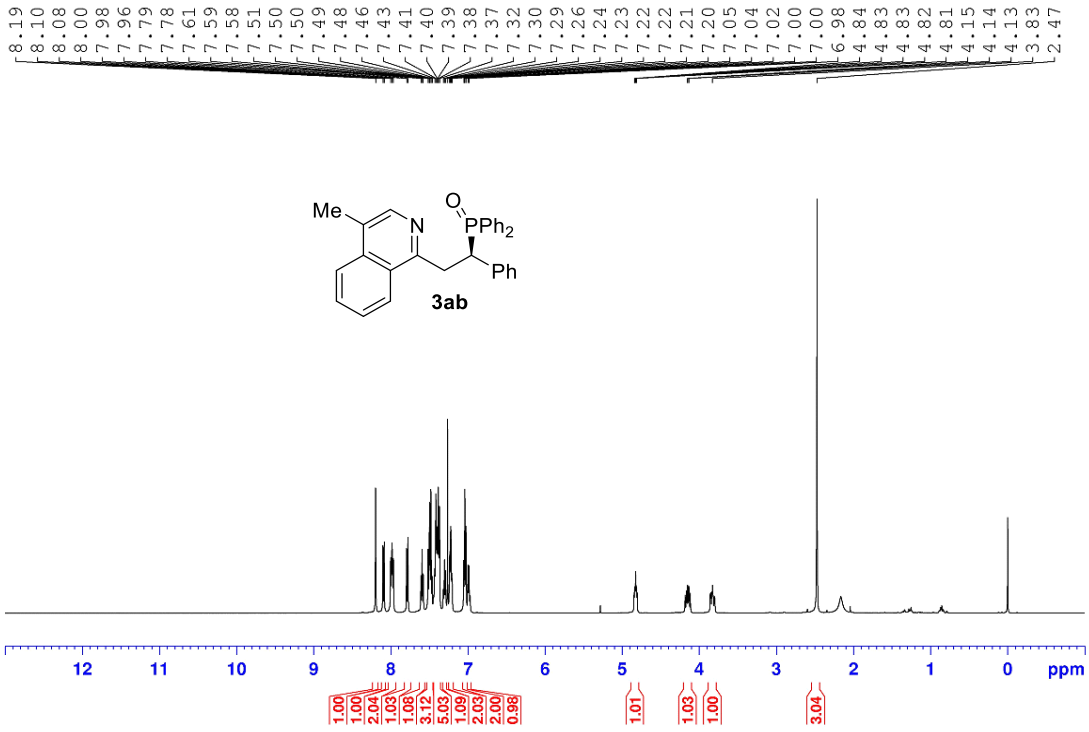
−80
ppm

3aa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7.49
7.48
7.46
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7.41
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7.39
7.38
7.37
7.32
7.30
7.29
7.26
7.24
7.23
7.22
7.22
7.21
7.20
7.05
7.04
7.02
7.00
7.00
6.98
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4.83
4.83
4.82
4.81
4.15
4.14
4.13
3.83
2.47
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N
O
PPh2
Ph
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10
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8
7
6
5
4
3
2
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ppm
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1.00
2.04
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1.00
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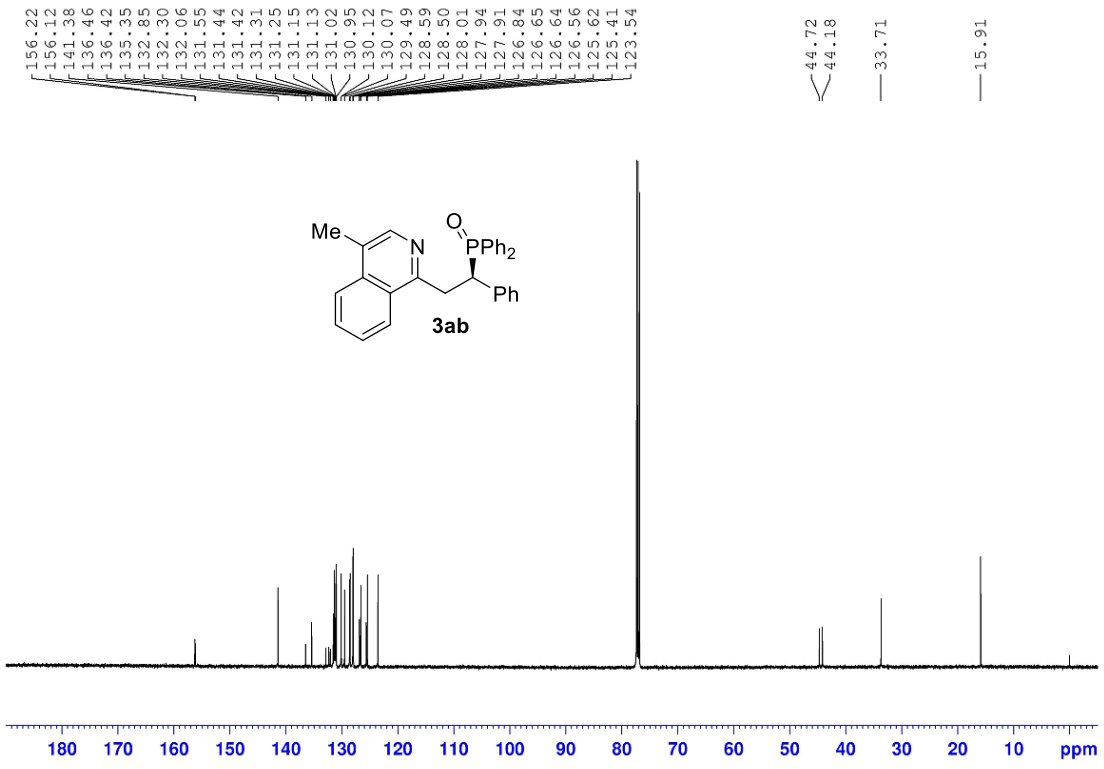
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130.12
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128.50
128.01
127.94
127.91
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126.65
126.64
126.56
125.62
125.41
123.54
44.72
44.18
33.71
15.91
Me
N
O
PPh2
Ph
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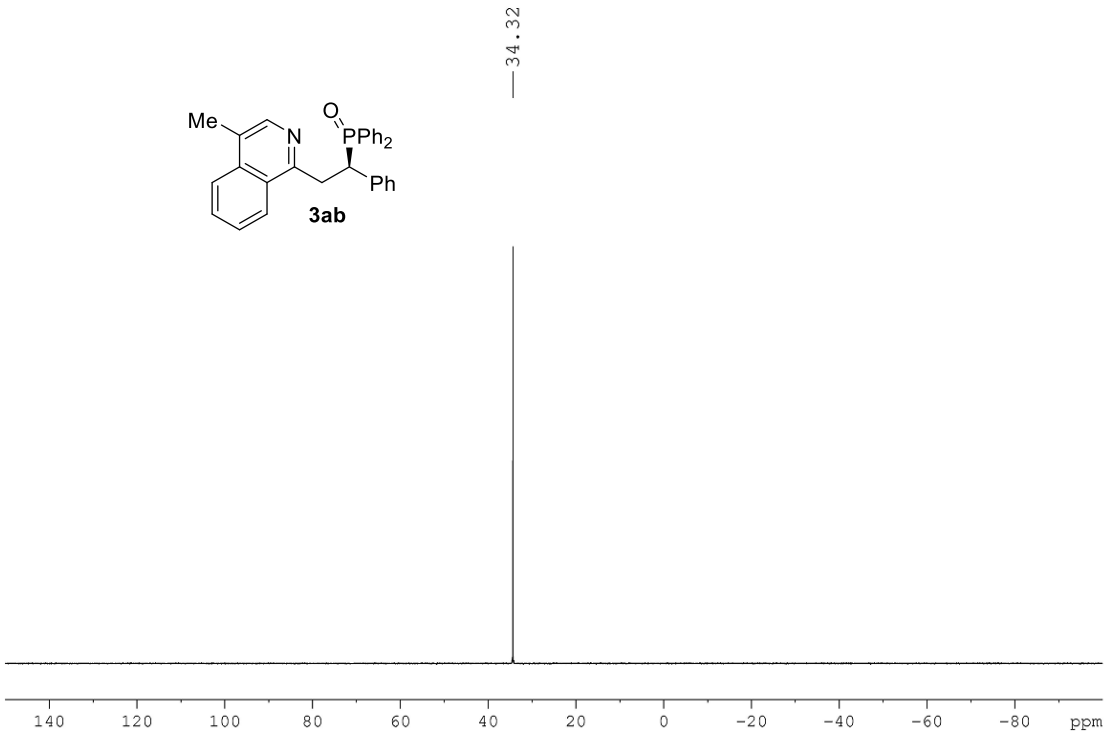
ppm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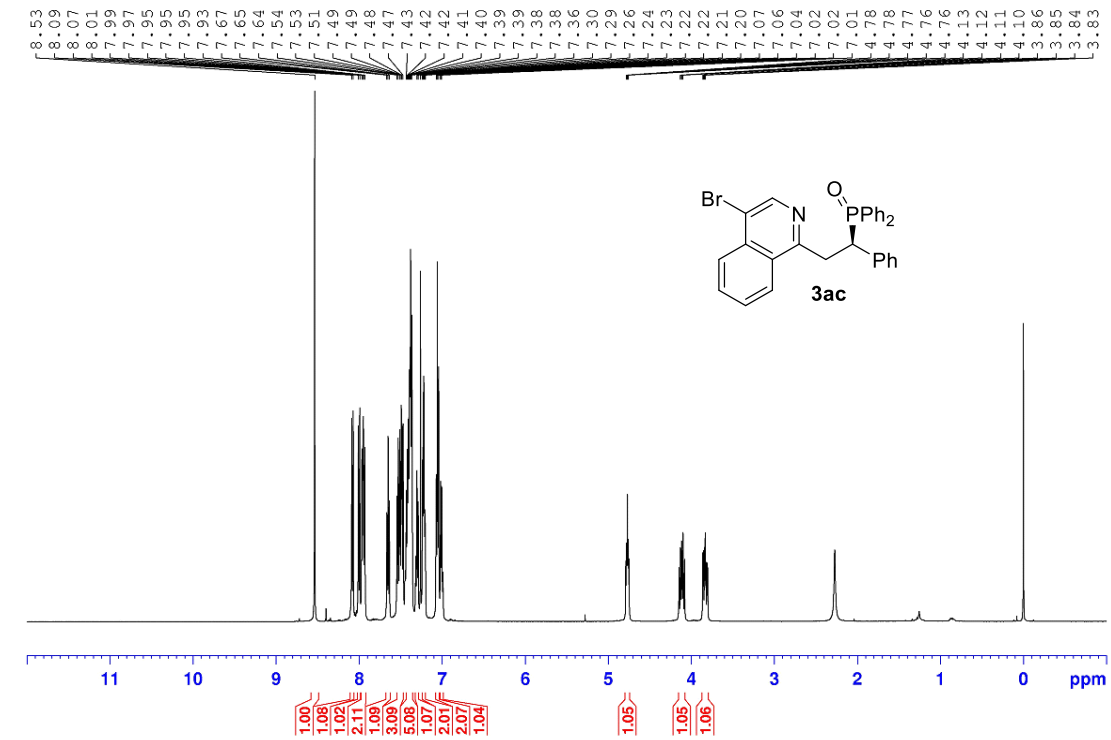
ppm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7.64
7.54
7.53
7.51
7.49
7.49
7.48
7.47
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7.42
7.42
7.41
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7.38
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7.29
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7.24
7.23
7.22
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7.21
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7.06
7.04
7.02
7.01
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4.78
4.77
4.76
4.76
4.13
4.12
4.11
4.10
3.86
3.85
3.84
3.83
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O
PPh2
Ph
3ac
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10
9
8
7
6
5
4
3
2
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ppm
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1.08
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2.01
2.07
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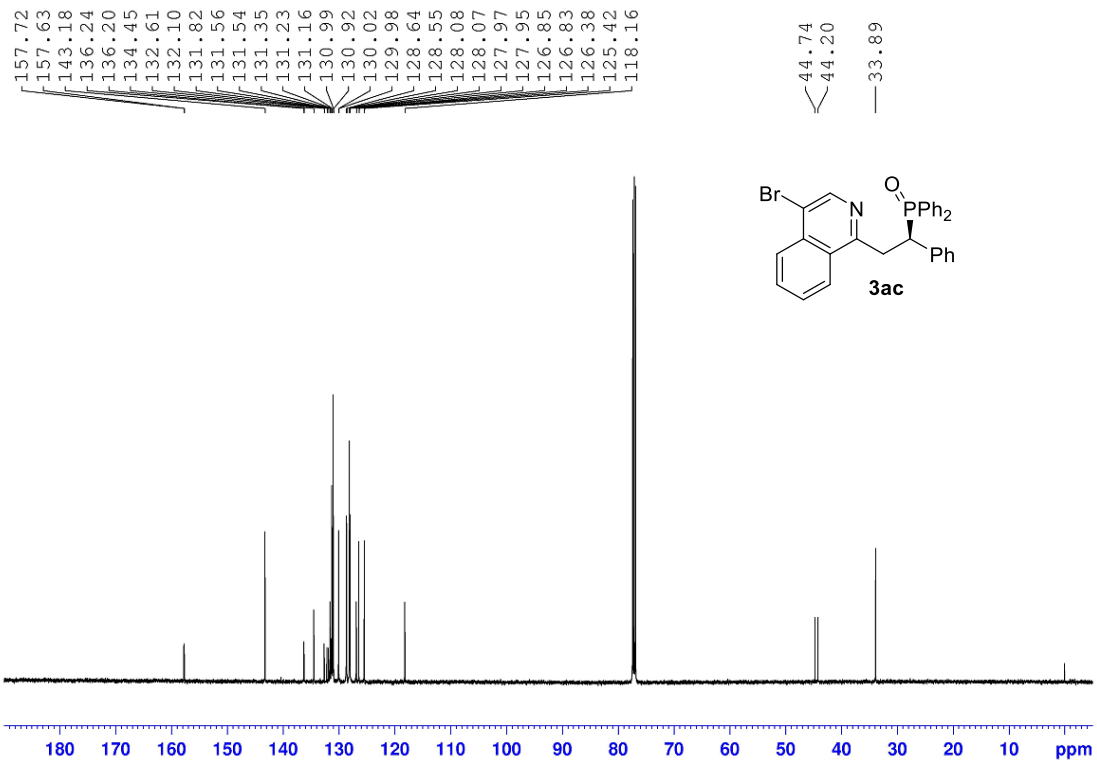
1.05
1.06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126.38
125.42
118.16
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44.20
33.89
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PPh2
Ph
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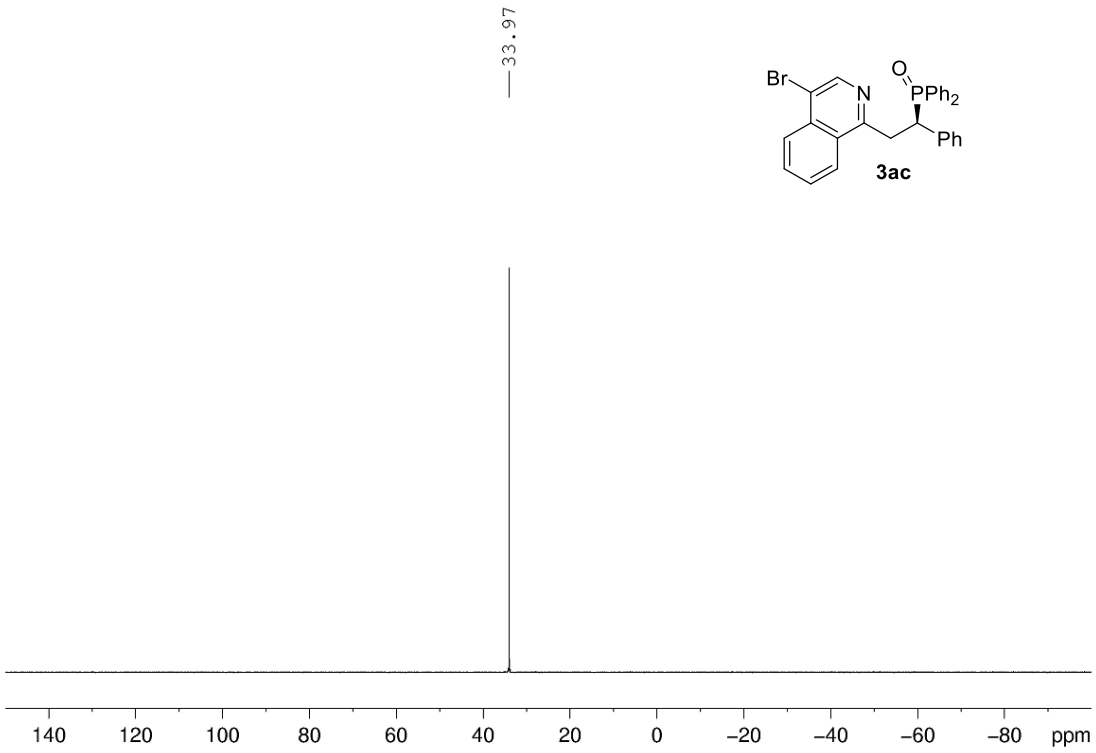
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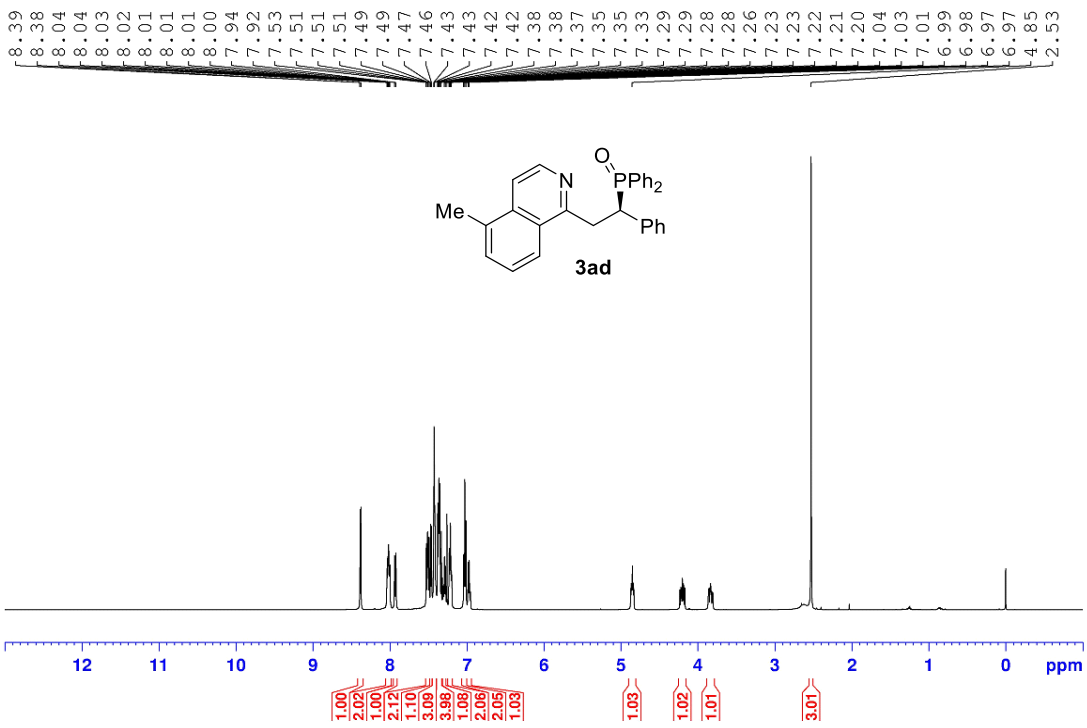
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8.00
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7.92
7.53
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7.51
7.51
7.49
7.49
7.47
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7.43
7.42
7.42
7.38
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7.23
7.22
7.21
7.20
7.04
7.03
7.01
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6.98
6.97
6.97
4.85
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O
PPh2
N
Me
Ph
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7
6
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ppm
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2.02
1.00
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2.06
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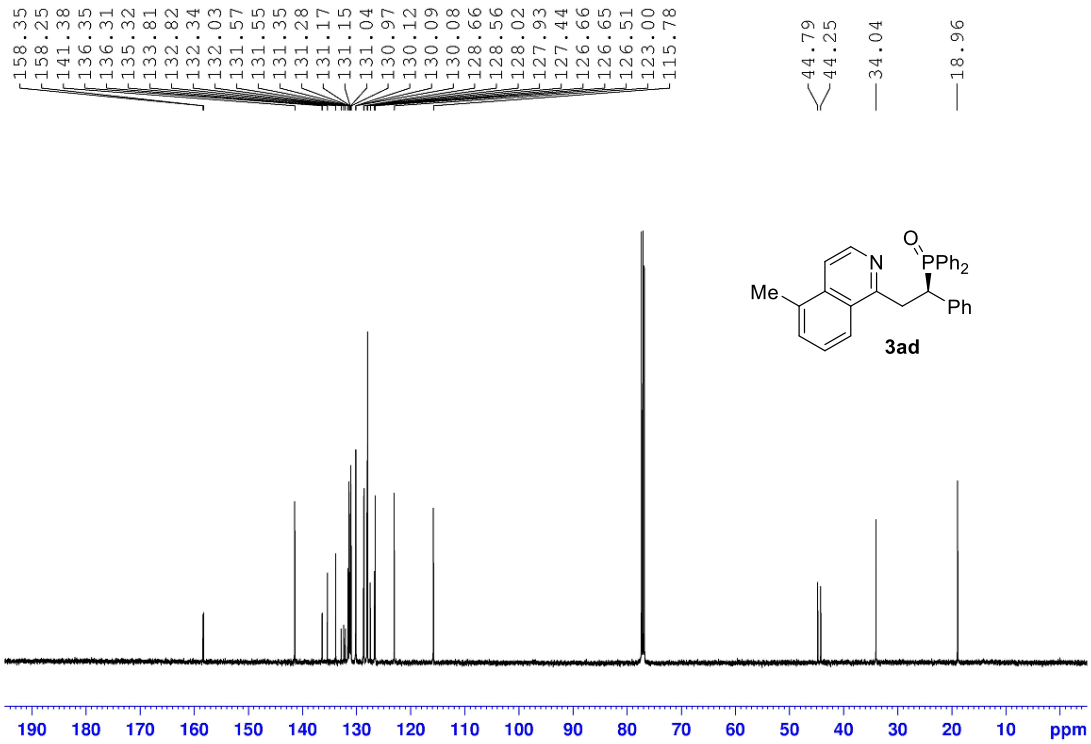
1.03
1.03
1.02
1.01
3.01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130.12
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Me
Ph
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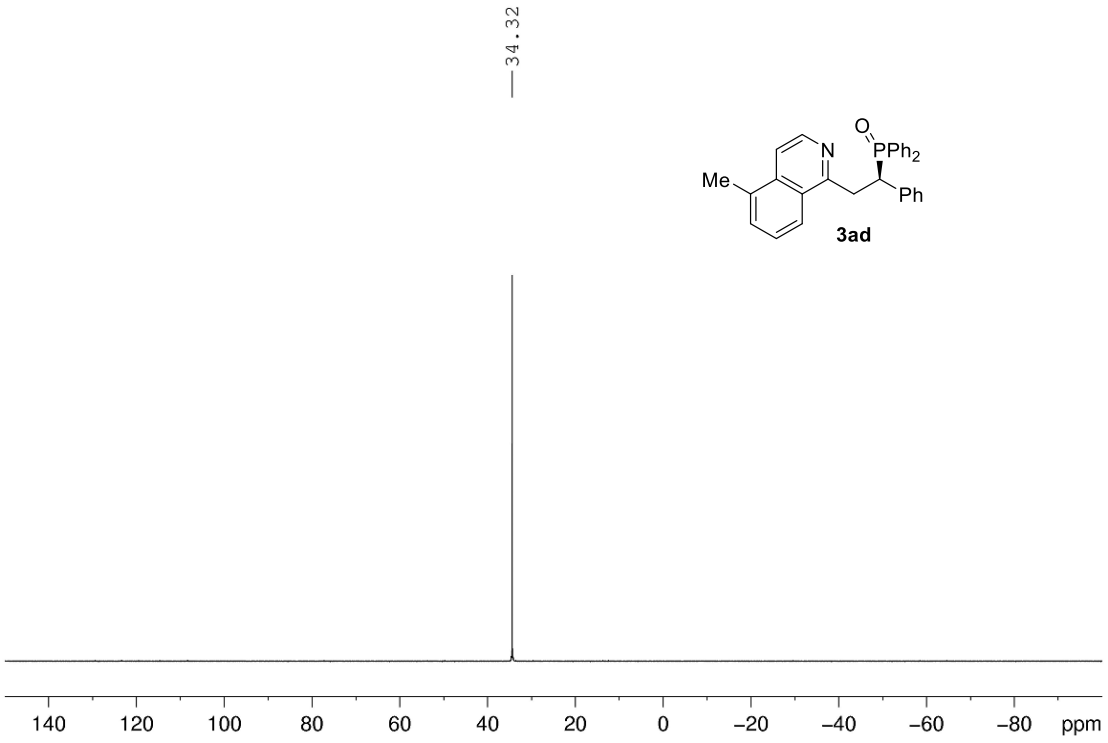
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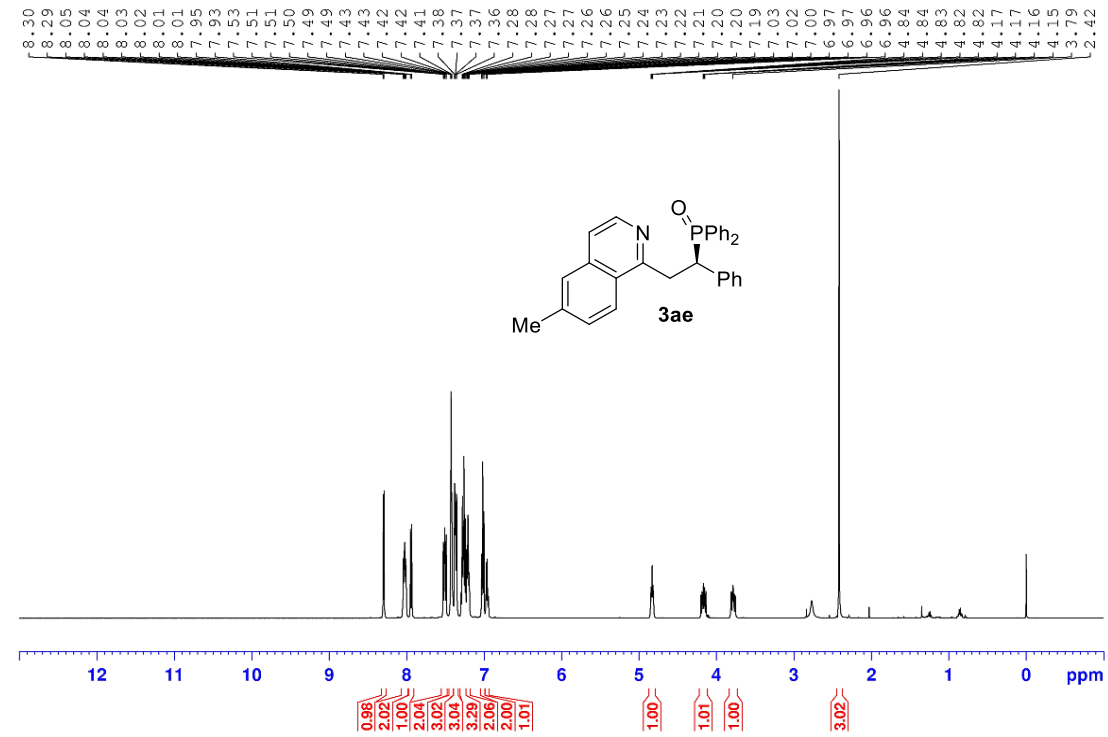
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7.50
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7.49
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7.43
7.42
7.42
7.41
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7.26
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7.24
7.23
7.22
7.21
7.20
7.20
7.19
7.03
7.02
7.00
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6.97
6.96
6.96
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4.84
4.83
4.82
4.82
4.17
4.17
4.16
4.15
3.79
2.42
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Ph
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1.01
1.00
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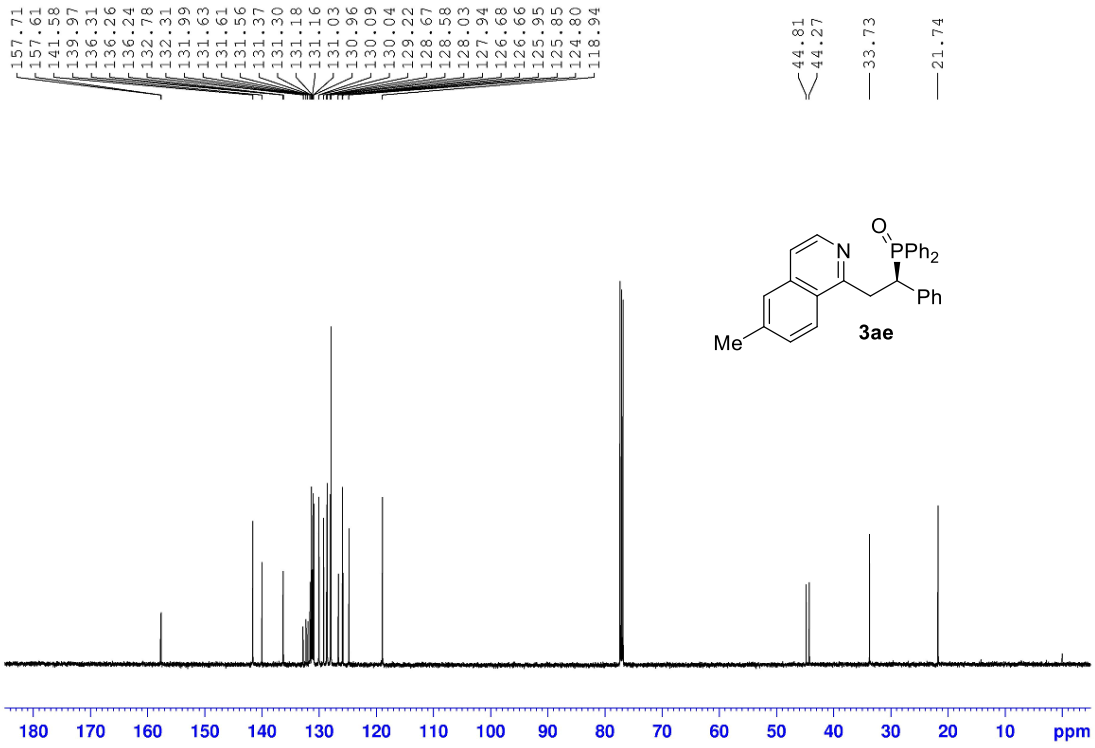
1.00
3.02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131.16
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130.09
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128.58
128.03
127.94
126.68
126.66
125.95
125.85
124.80
118.94
44.81
44.27
33.73
21.74
O
PPh2
N
Ph
Me
3ae
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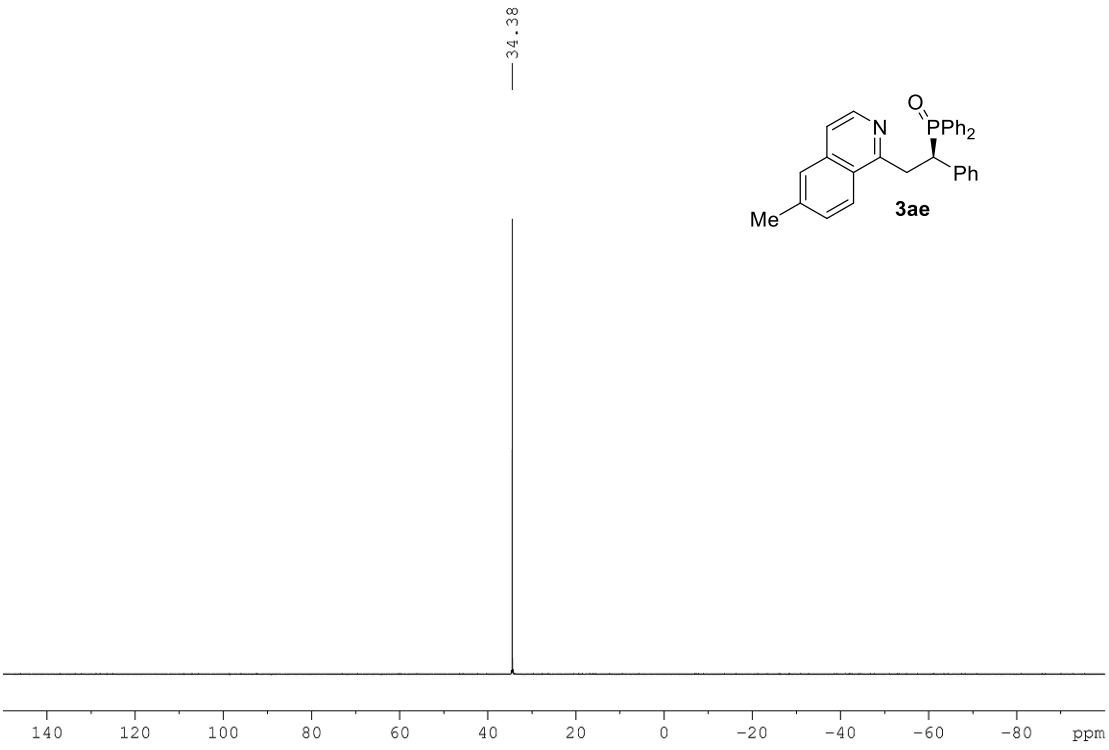
10
ppm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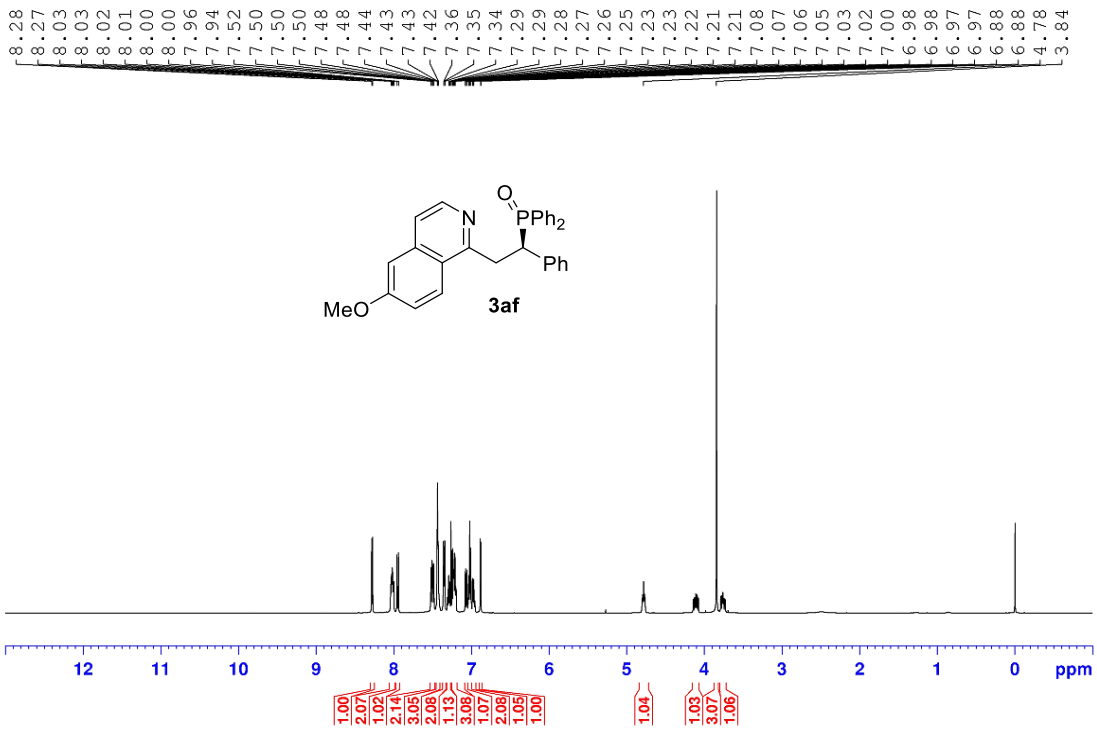
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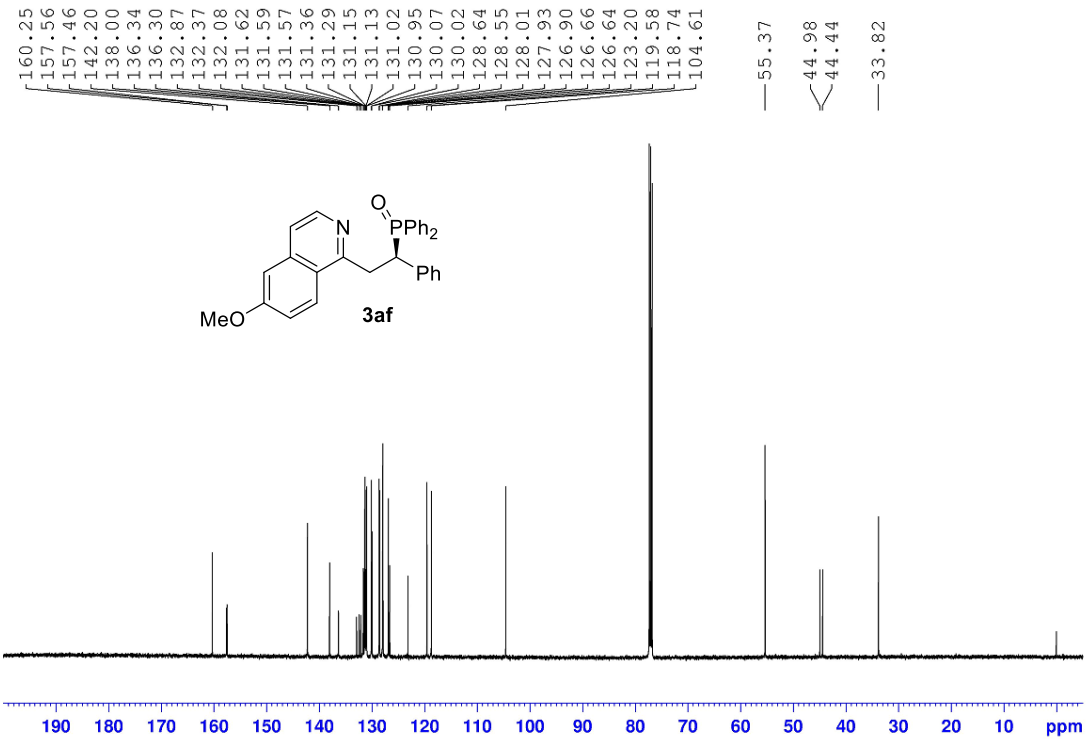
7.29
7.28
7.27
7.26
7.25
7.23
7.23
7.22
7.21
7.21
7.08
7.07
7.06
7.05
7.03
7.02
7.00
6.98
6.98
6.97
6.97
6.88
6.88
4.78
3.84
O
PPh2
N
Ph
MeO
3af
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
2.07
1.02
2.14
3.05
2.08
1.13
3.08
1.07
2.08
1.05
1.00
1.04
1.03
3.07
1.06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131.36
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131.13
131.02
130.95
130.07
130.02
128.64
128.55
128.01
127.93
126.90
126.66
126.64
123.20
119.58
118.74
104.61
55.37
44.98
44.44
33.82
O
PPh2
N
Ph
MeO
3af
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140
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100
90
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70
60
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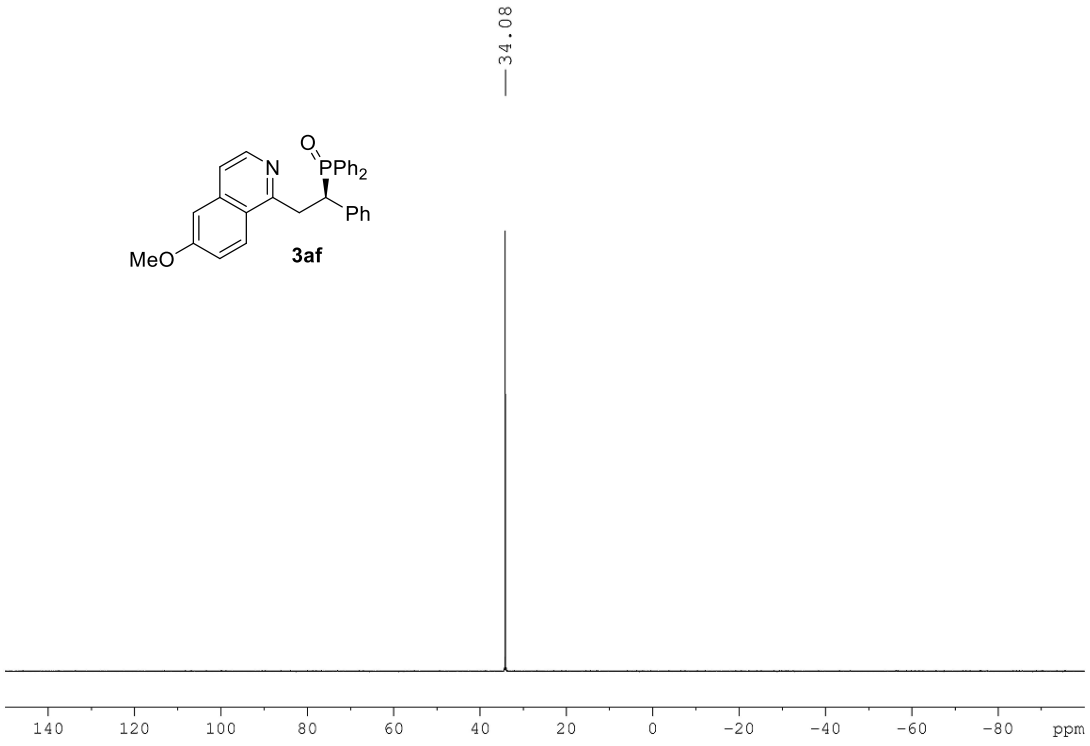
40
30
20
10
ppm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-40
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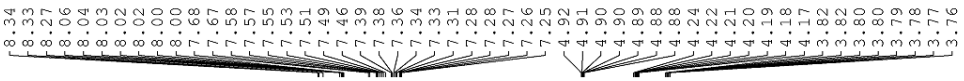
-80
ppm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8.02
8.00
8.00
7.68
7.67
7.58
7.57
7.55
7.53
7.51
7.49
7.46
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7.38
7.36
7.34
7.33
7.31
7.28
7.28
7.27
7.26
7.25
4.92
4.91
4.90
4.90
4.89
4.88
4.88
4.24
4.22
4.21
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4.17
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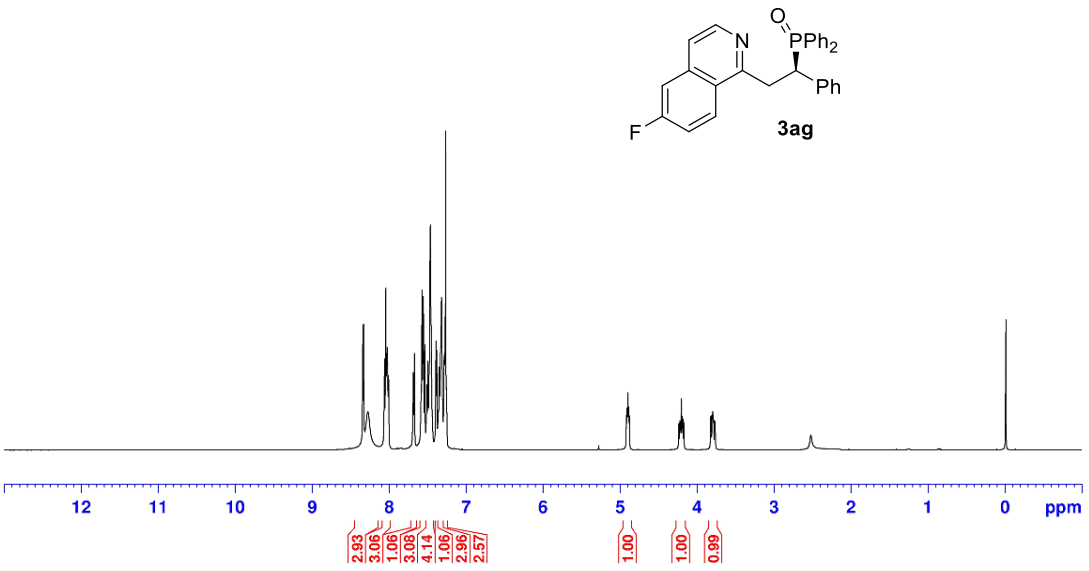
3.80
3.79
3.78
3.77
3.76


O
PPh2
N
Ph
F
3ag
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
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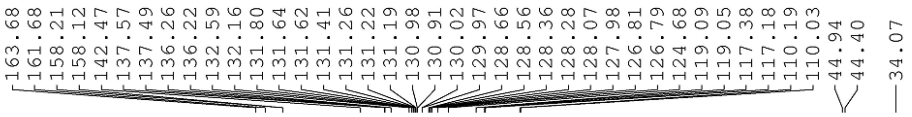
3.06
1.06
3.08
4.14
1.06
2.96
2.57
1.00
1.00
0.99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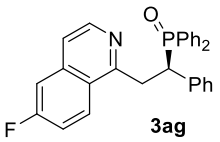
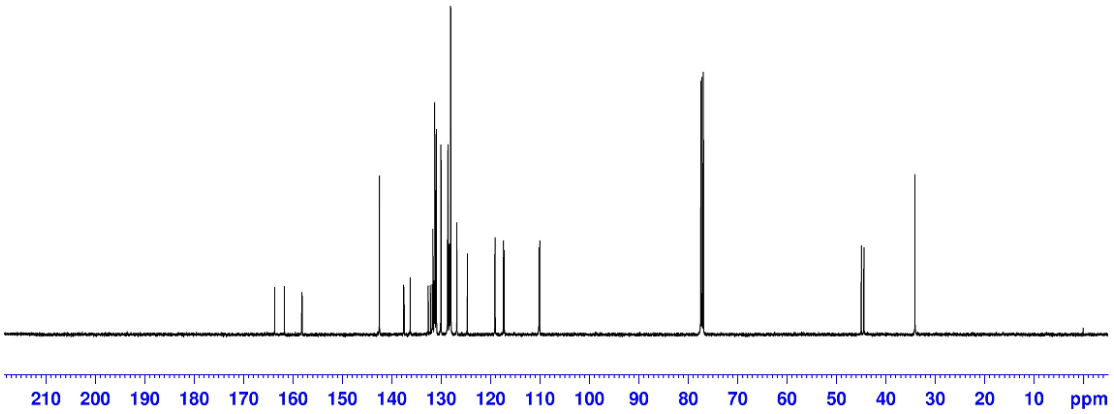
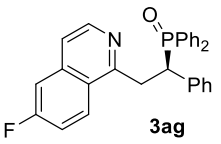
161.68
158.21
158.12
142.47
137.57
137.49
136.26
136.22
132.59
132.16
131.80
131.64
131.62
131.41
131.26
131.22
131.19
130.98
130.91
130.02
129.97
128.66
128.56
128.36
128.28
128.07
127.98
126.81
126.79
124.68
119.09
119.05
117.38
117.18
110.19
110.03
44.94
44.40
34.07

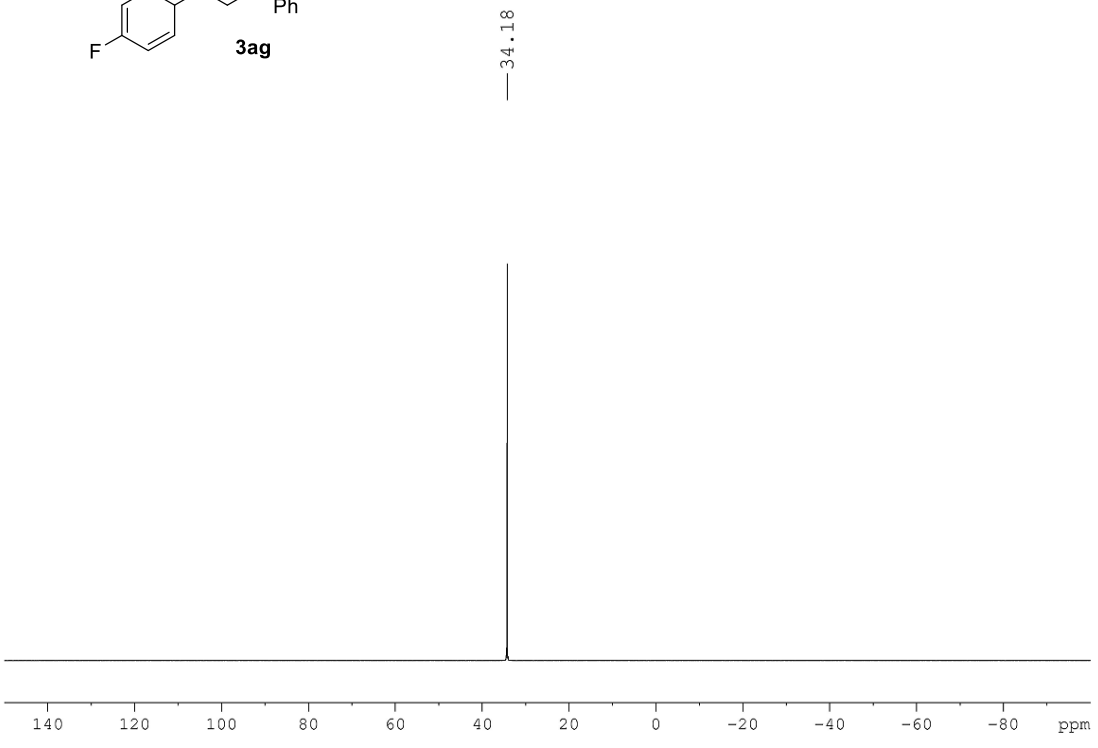

O
PPh2
N
Ph
F

3ag


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

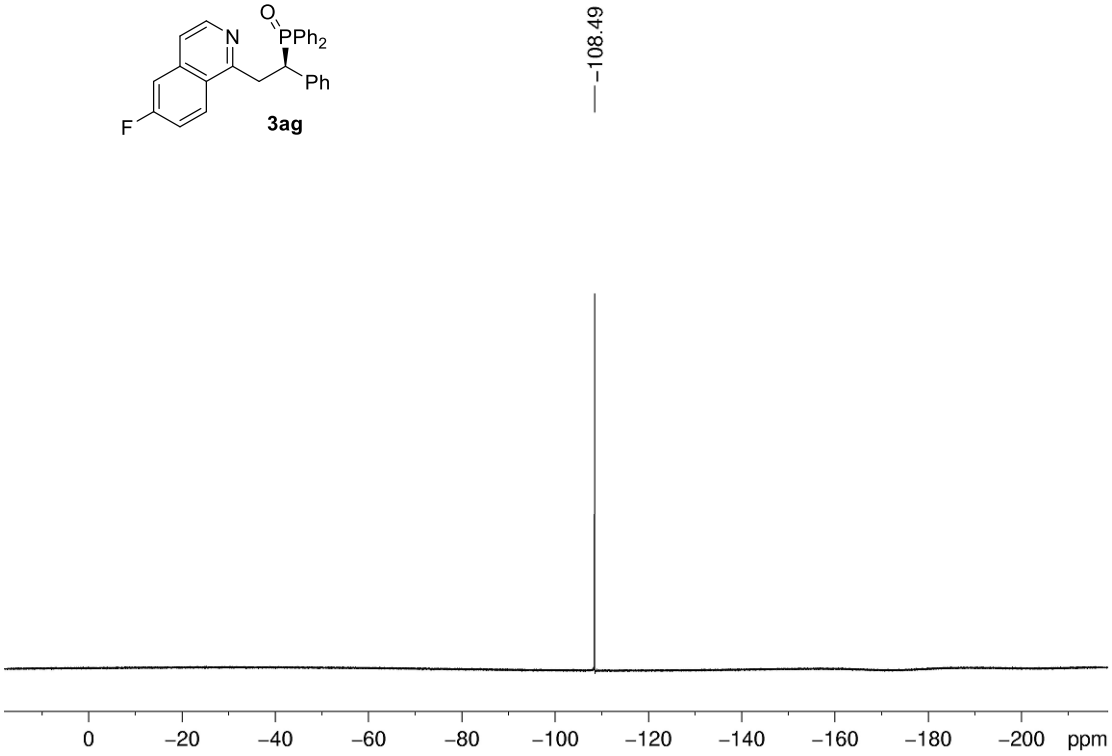

O
PPh2
N
Ph
F

3ag


34.18
140 120 100 80 60 40 20 0 -20 -40 -60 -80 ppm

O
PPh2
N
Ph
F

3ag


-108.49
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
ppm


8.35
8.34
8.01
8.00
7.99
7.98
7.90
7.88
7.74
7.51
7.49
7.47
7.41
7.36
7.34
7.29
7.27
7.26
7.21
7.20
7.18
7.04
7.02
7.01
6.98
6.97
6.95
4.78
4.77
4.76
4.75
4.74
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3.82
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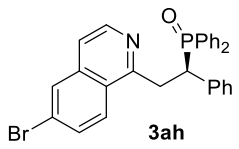
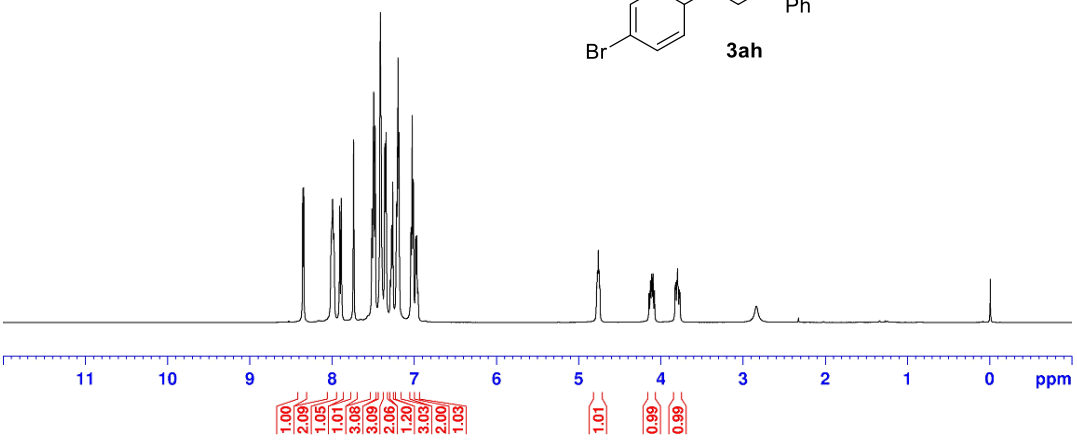
3.80
3.79
3.77
3.77


O
PPh2
N
Ph
Br

3ah


11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
2.09
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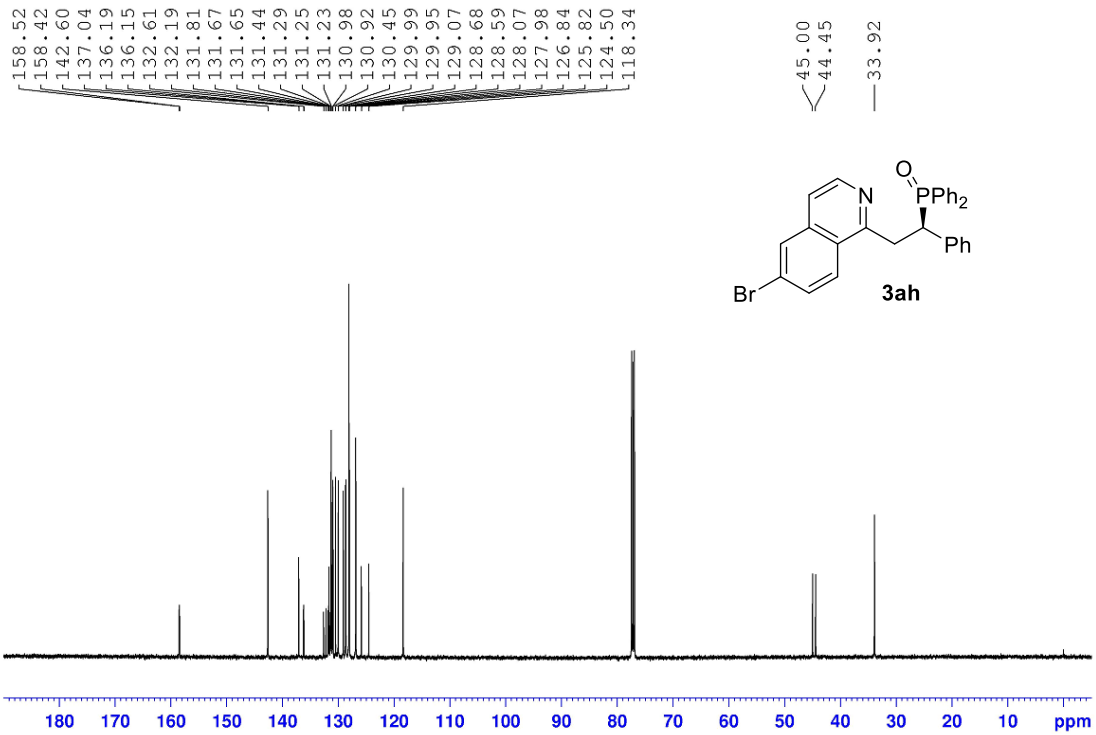
1.01
3.08
3.09
2.06
1.20
3.03
2.00
1.03
1.01
0.99
0.99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132.19
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131.67
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131.29
131.25
131.23
130.98
130.92
130.45
129.99
129.95
129.07
128.68
128.59
128.07
127.98
126.84
125.82
124.50
118.34
45.00
44.45
33.92
O
PPh2
N
Ph
Br
3ah
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


33.99
O
PPh2
N
Ph
Br
3ah
140
120
100
80
60
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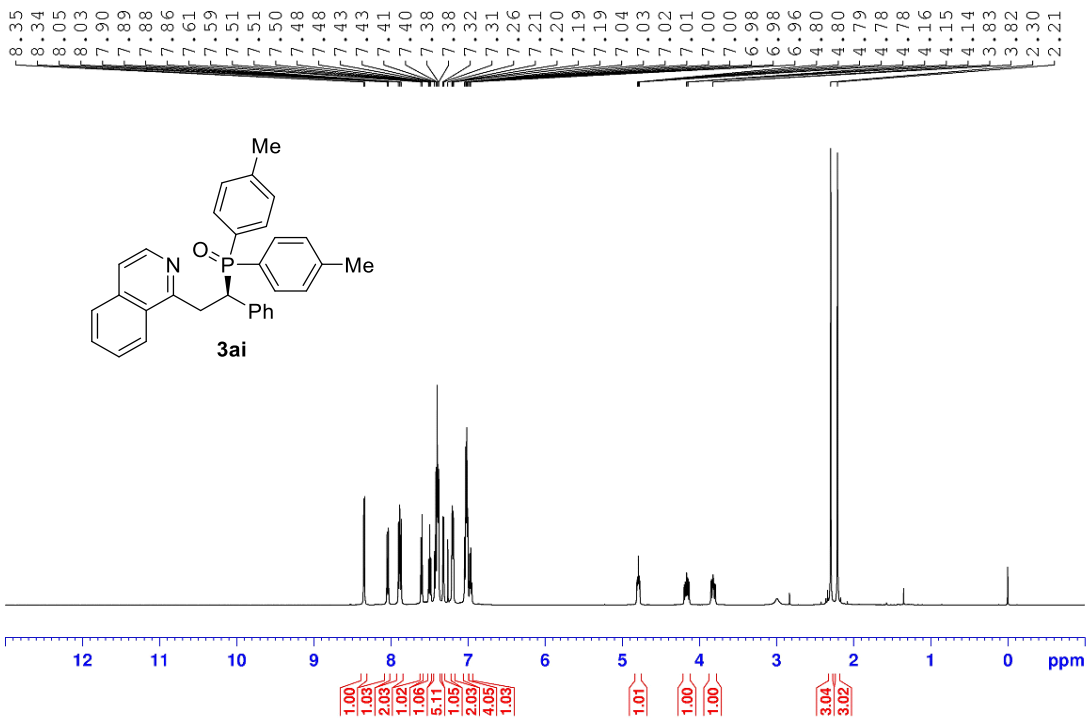
20
0
-20
-40
-60
-80
ppm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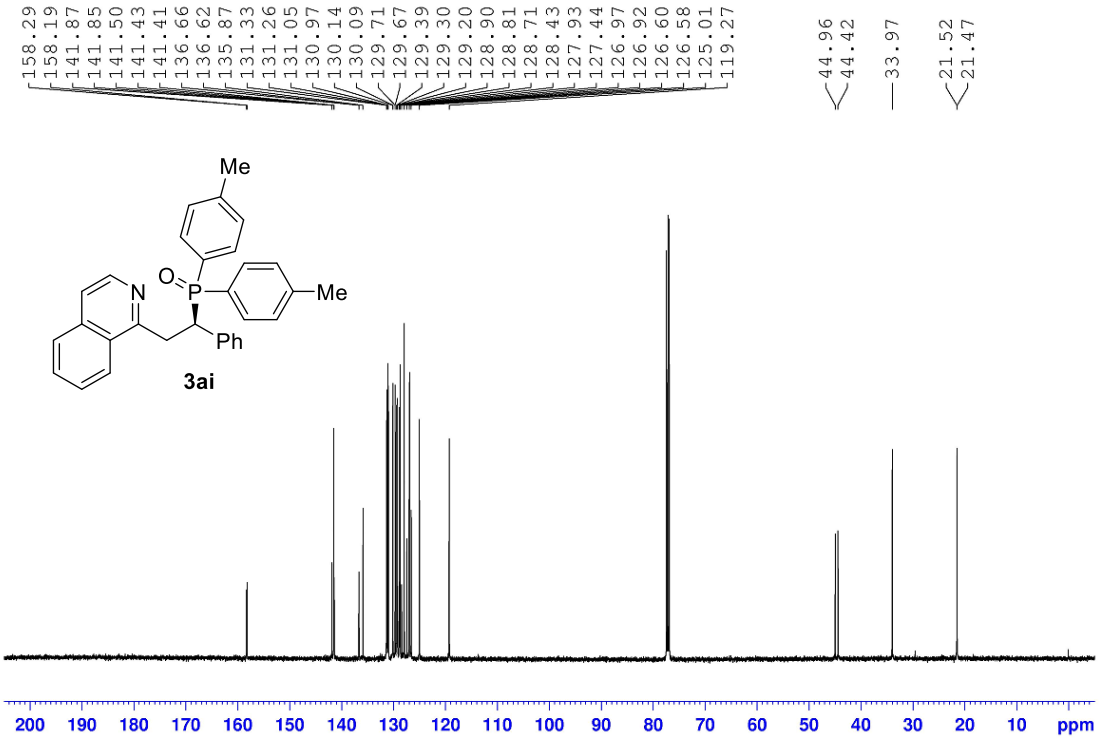
7.51
7.50
7.48
7.48
7.43
7.43
7.41
7.40
7.38
7.32
7.31
7.26
7.21
7.20
7.19
7.19
7.04
7.03
7.02
7.01
7.00
7.00
6.98
6.98
6.96
4.80
4.80
4.79
4.78
4.78
4.16
4.15
4.14
3.83
3.82
2.30
2.21
Me
O
P
N
Me
Ph
3ai
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
1.03
2.03
1.02
1.06
5.11
1.05
2.03
4.05
1.03
1.01
1.00
1.00
3.04
3.02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131.05
130.97
130.14
130.09
129.71
129.67
129.39
129.30
129.20
128.90
128.81
128.71
128.43
127.93
127.44
126.97
126.92
126.60
126.58
125.01
119.27
44.96
44.42
33.97
21.52
21.47
Me
O
P
N
Me
Ph
3ai
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70
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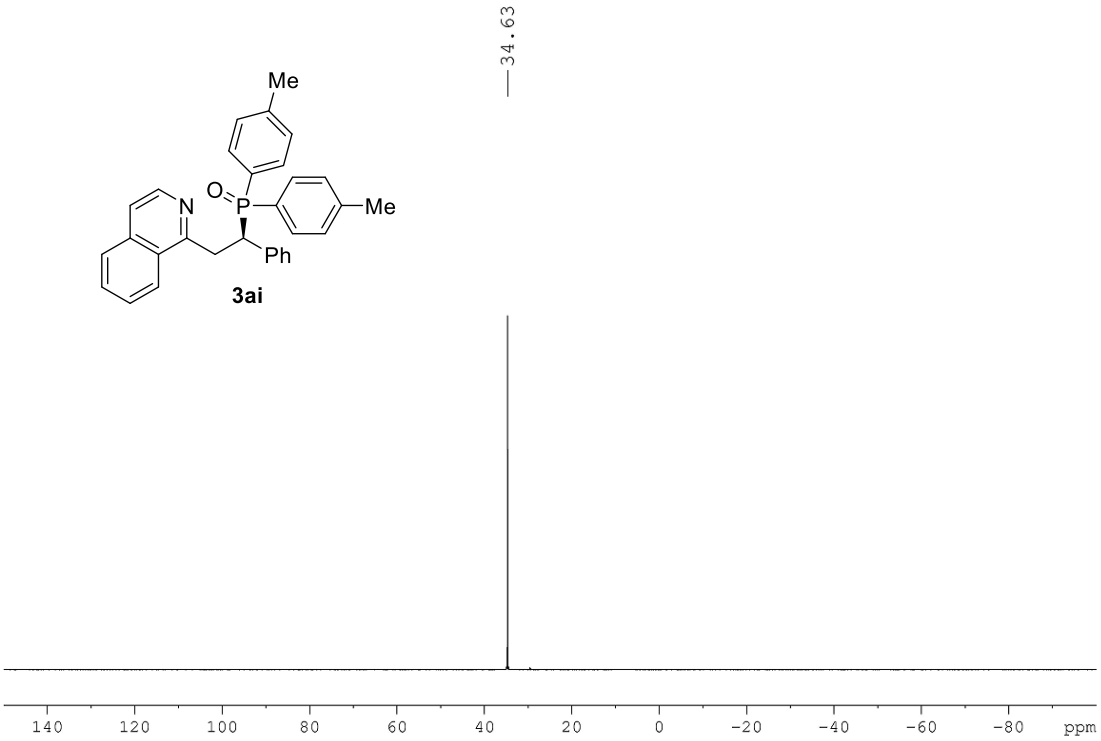
40
30
20
10
ppm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Me
O
P
N
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Ph
3ai
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80
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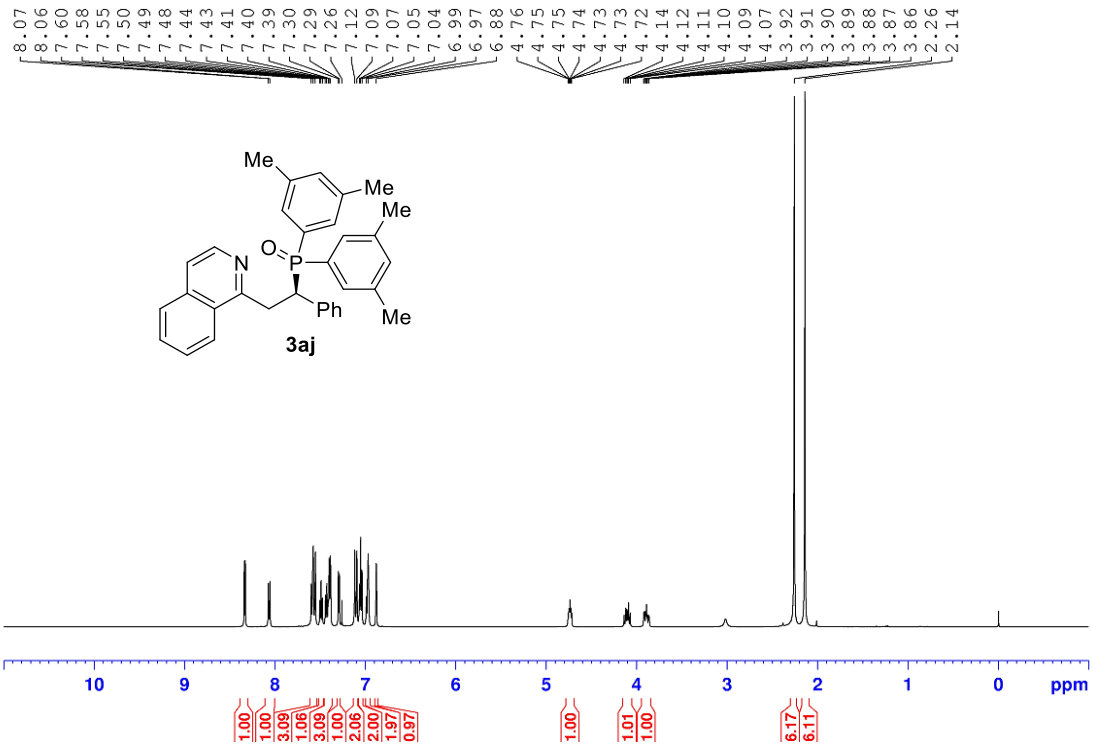
-60
-80
ppm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7.39
7.30
7.29
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7.12
7.09
7.07
7.05
7.04
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6.97
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4.75
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4.73
4.72
4.14
4.12
4.11
4.10
4.09
4.07
3.92
3.91
3.90
3.89
3.88
3.87
3.86
2.26
2.14
Me
Me
Me
O
P
N
Ph
Me
3aj
10
9
8
7
6
5
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3
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ppm
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1.00
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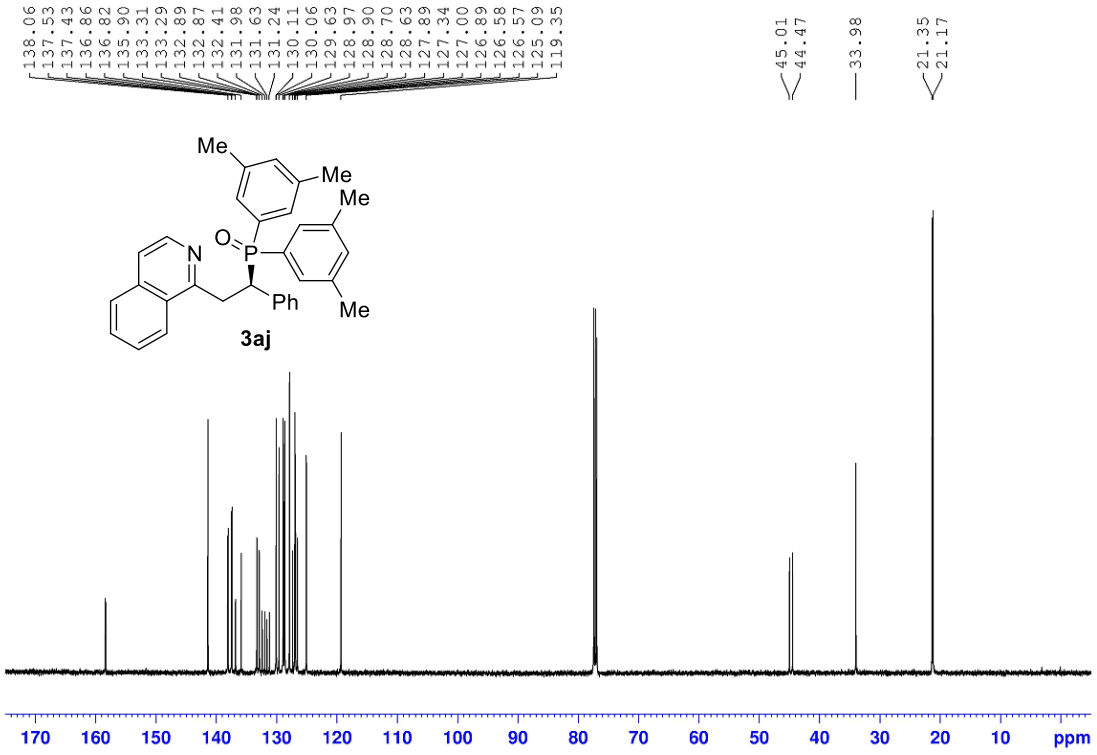
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130.06
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127.89
127.34
127.00
126.89
126.58
126.57
125.09
119.35
45.01
44.47
33.98
21.35
21.17
Me
Me
Me
O
P
N
Ph
Me
3aj
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150
140
130
120
110
100
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60
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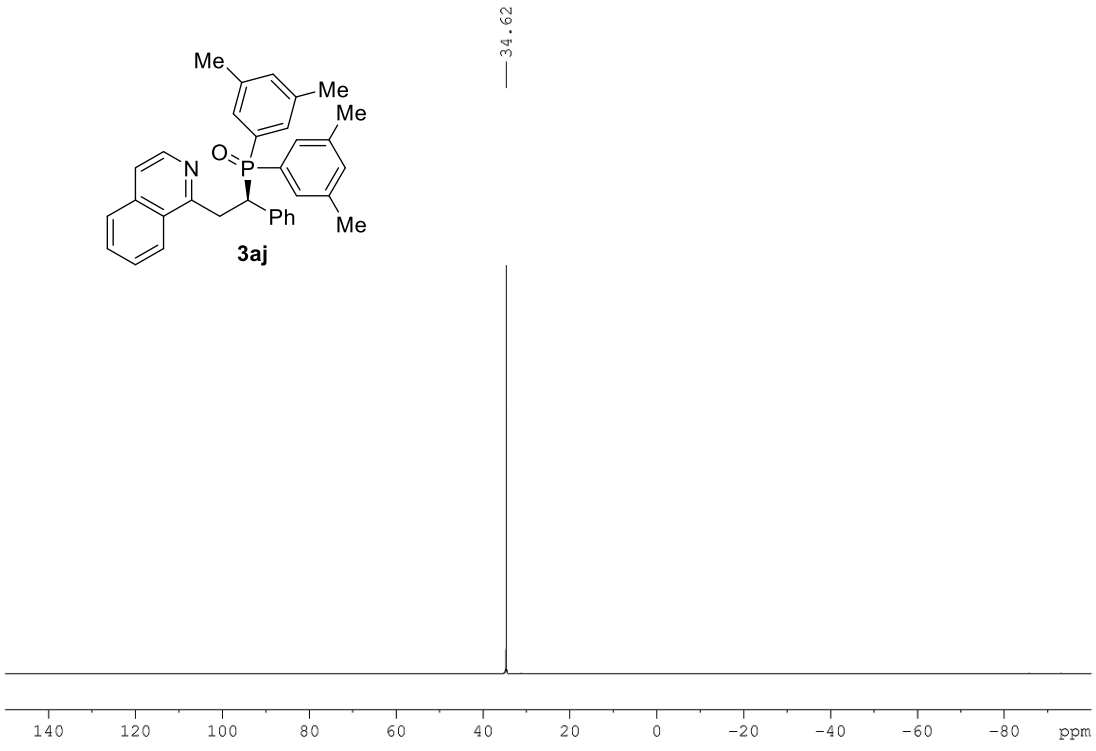
30
20
10
ppm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Me
Me
Me
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3aj
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20
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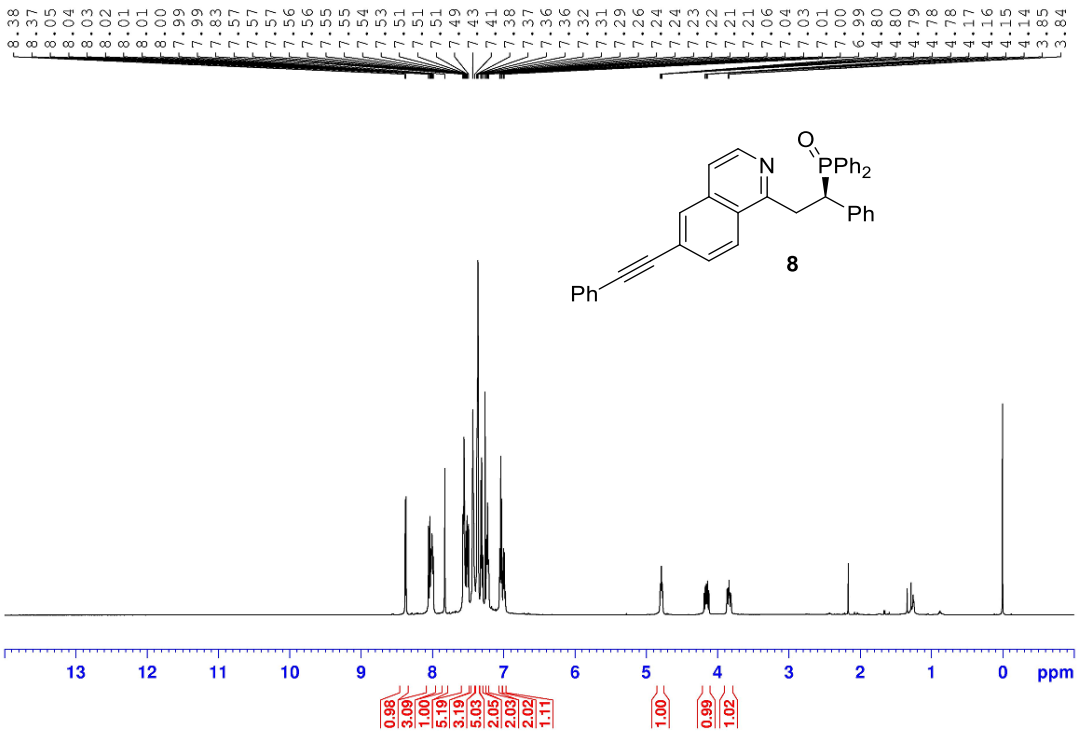
-20
-40
-60
-80
ppm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7.57
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7.51
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7.41
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7.36
7.32
7.31
7.29
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7.22
7.21
7.21
7.06
7.04
7.03
7.01
7.00
6.99
4.80
4.79
4.78
4.78
4.17
4.16
4.15
4.14
3.85
3.84
O
PPh2
N
Ph
Ph
8
13
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.98
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2.02
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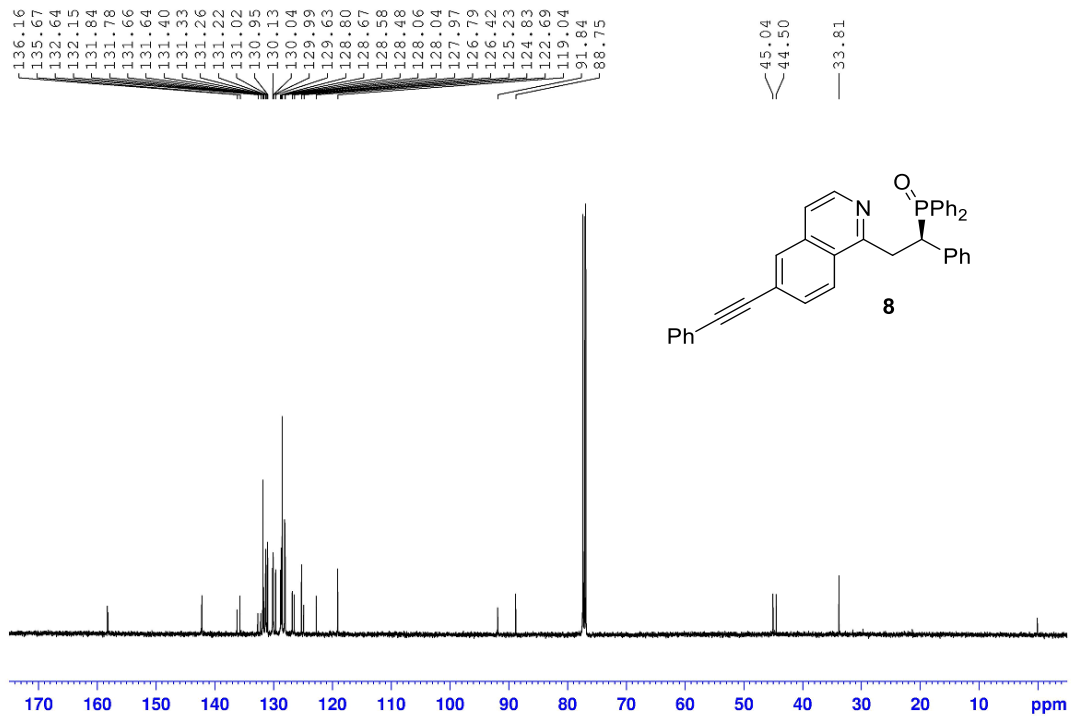
1.02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131.22
131.02
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130.04
129.99
129.63
128.80
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128.58
128.48
128.06
128.04
127.97
126.79
126.42
125.23
124.83
122.69
119.04
91.84
88.75
45.04
44.50
33.81
O
PPh2
N
Ph
Ph
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140
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120
110
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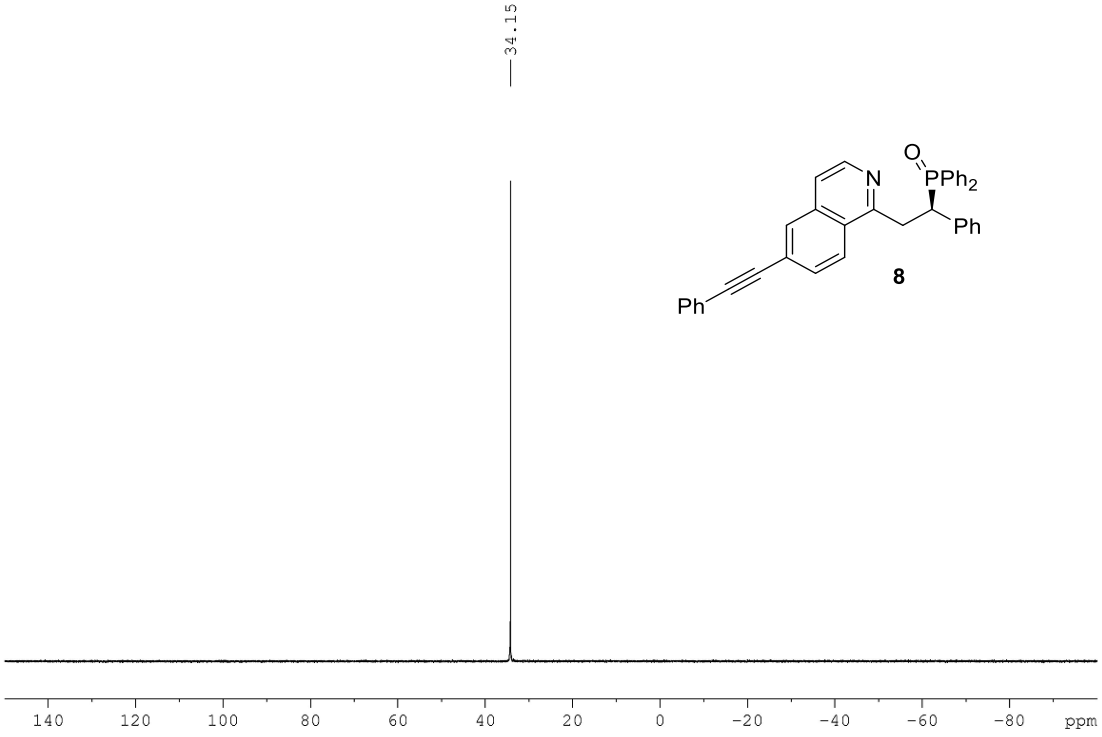
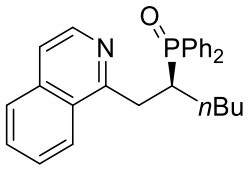
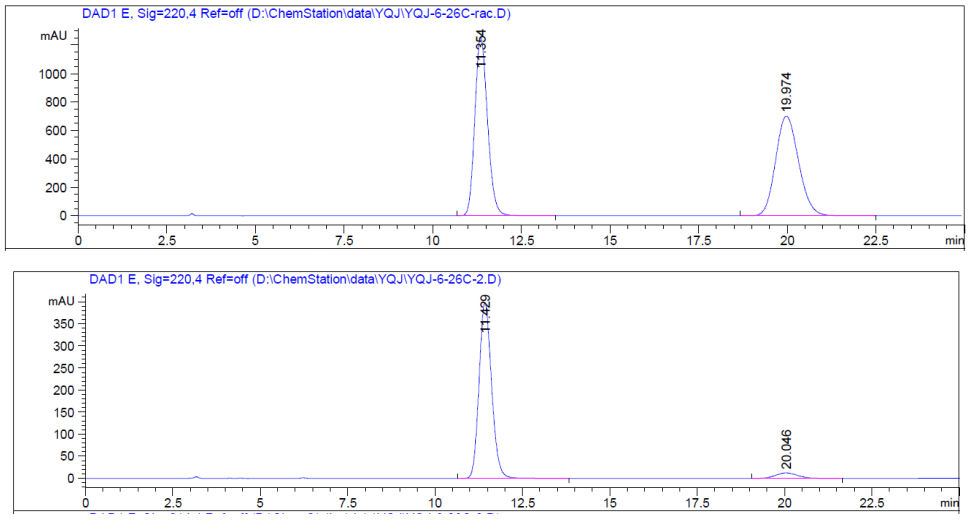
30
20
10
ppm

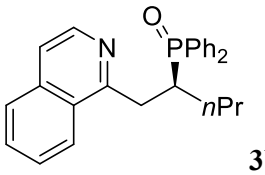




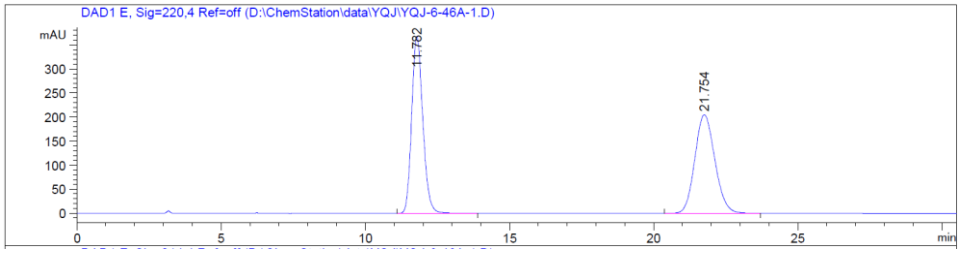
3a

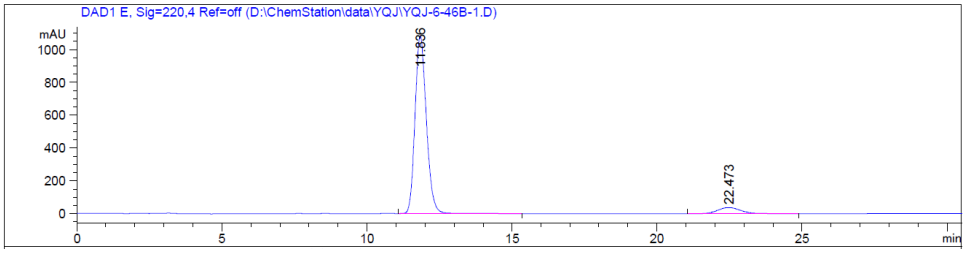


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.429	BB	0.3851	9924.44531	397.70752	94.8299
2	20.046	BB	0.6760	541.07361	12.23334	5.1701

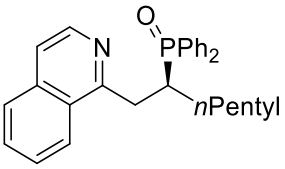


3b

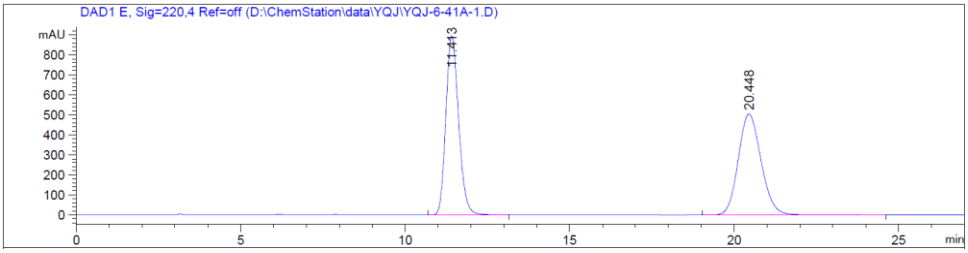


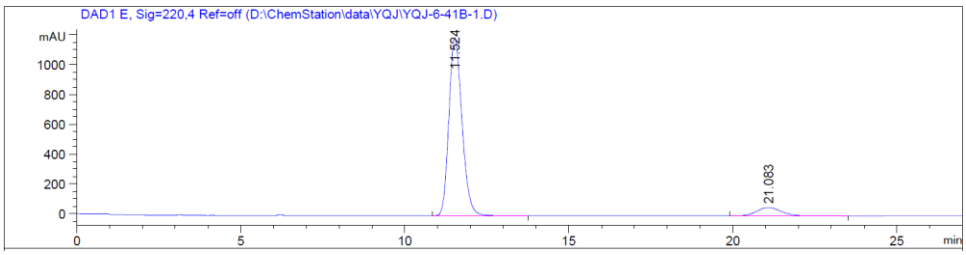


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.836	BB	0.4205	2.93964e4	1083.67822	93.2209
2	22.473	BB	0.8539	2137.73413	38.13985	6.7791

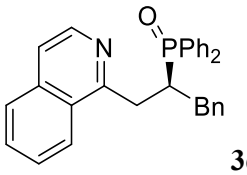


3c

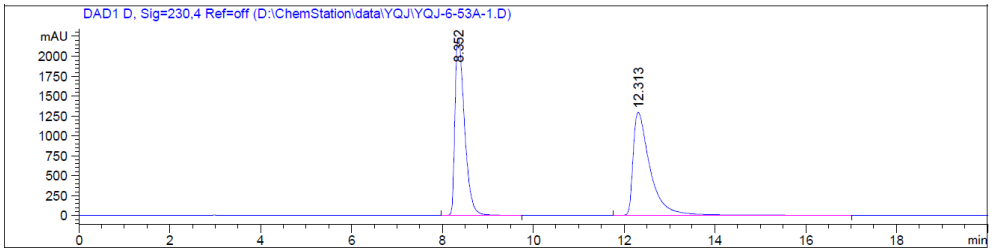


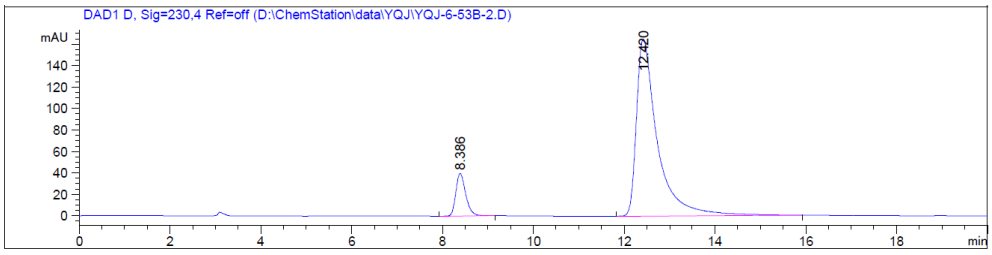


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.524	BB	0.4306	3.31498e4	1191.49487	92.0744
2	21.083	BB	0.7841	2853.48022	56.03237	7.9256

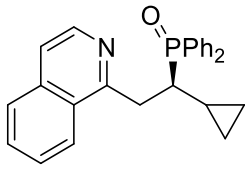


3d

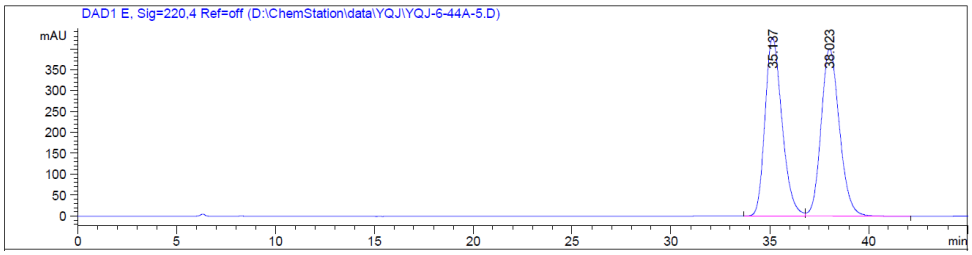


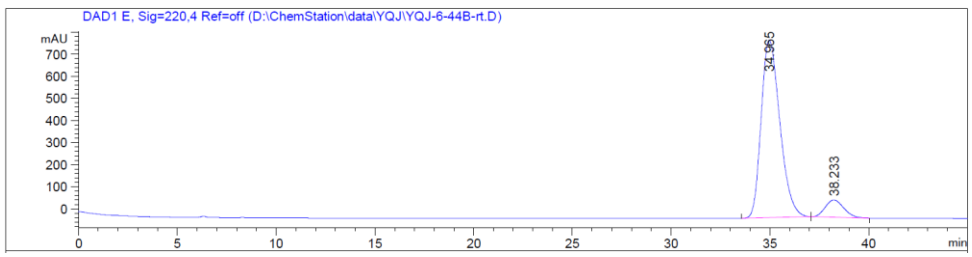


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.386	BB	0.2334	604.41193	39.75169	10.2231
2	12.420	BB	0.4667	5307.80322	165.25458	89.7769

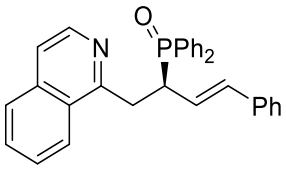


3e

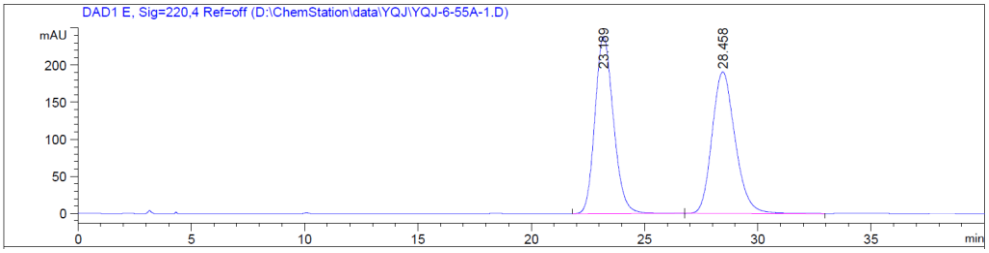


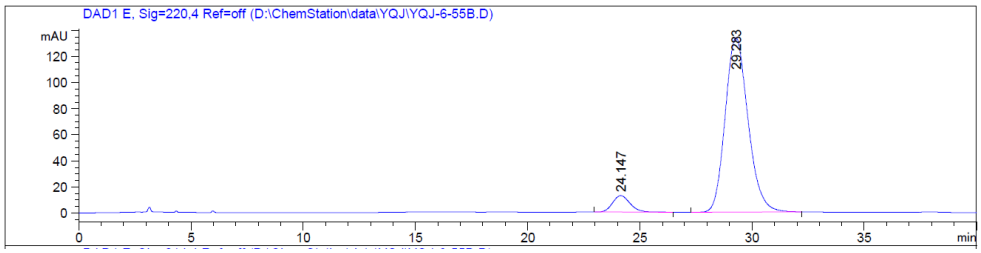


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	34.965	BB	1.0289	5.28156e4	803.43445	91.2214
2	38.233	BB	1.0157	5082.64063	78.26283	8.7786

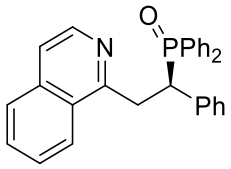


3f

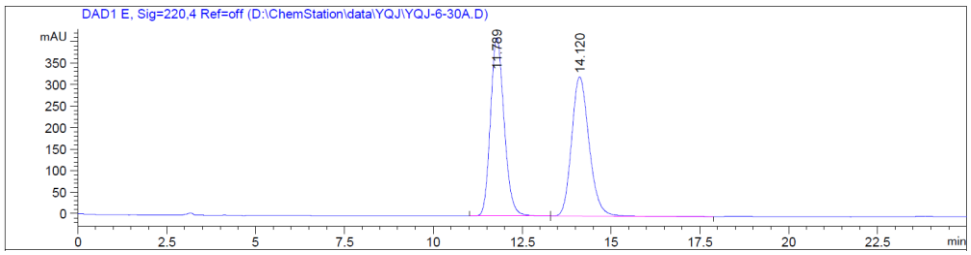


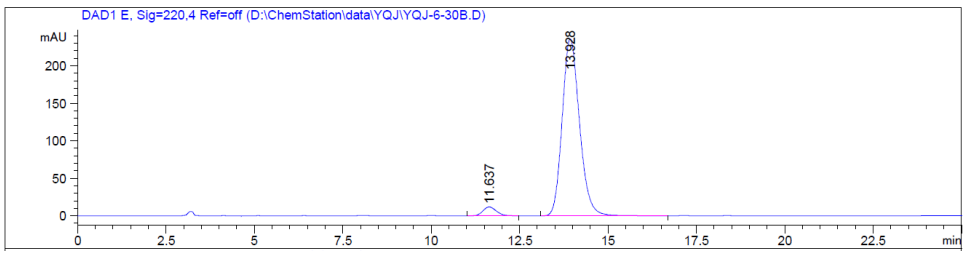


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.147	BB	0.8110	696.42694	12.63533	6.8451
2	29.283	BB	1.0831	9477.73535	133.69102	93.1549

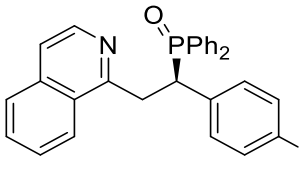


3g

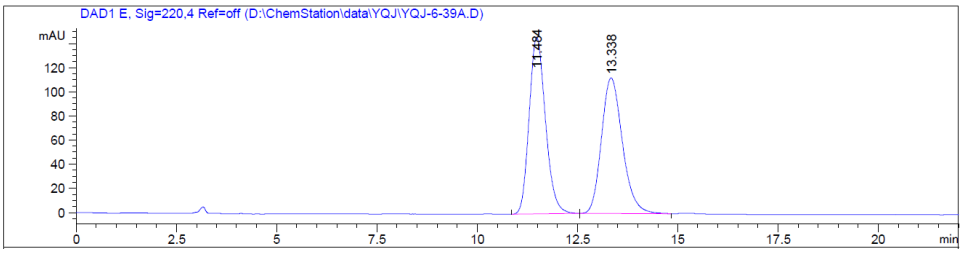


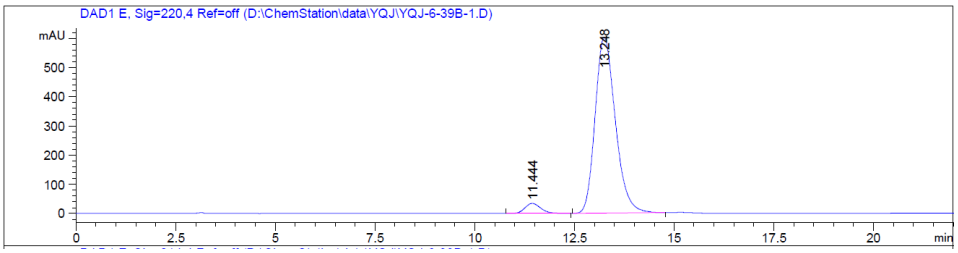


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.637	BB	0.4088	313.73672	11.85365	3.7525
2	13.928	BB	0.5255	8046.94336	236.20525	96.2475

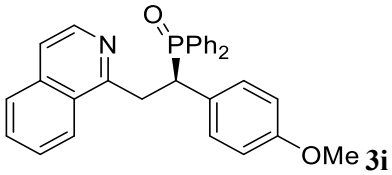


3h

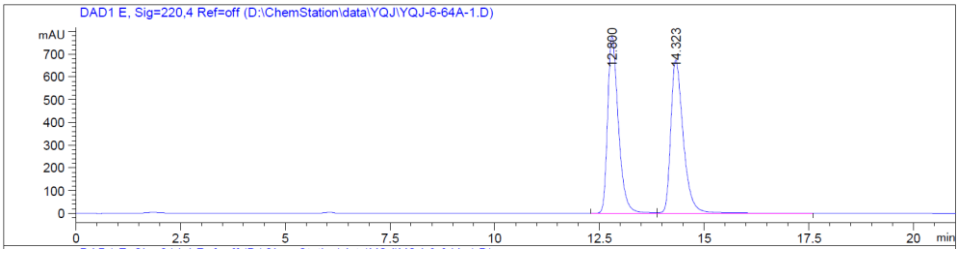


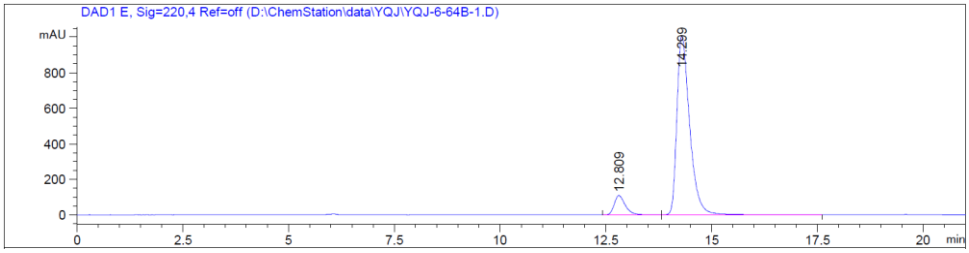


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.444	BB	0.4268	944.69141	34.35314	4.2541
2	13.248	BB	0.5433	2.12619e4	603.06189	95.7459

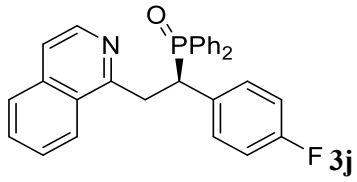


3i

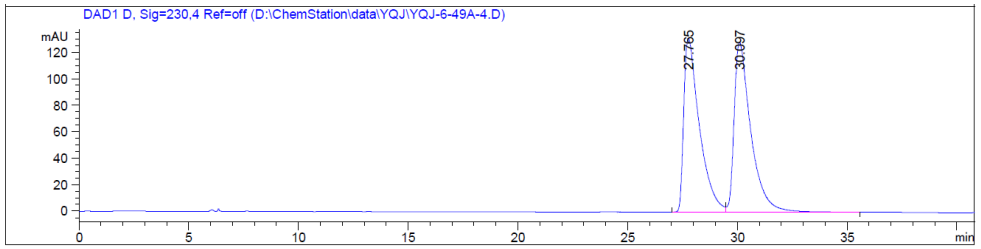


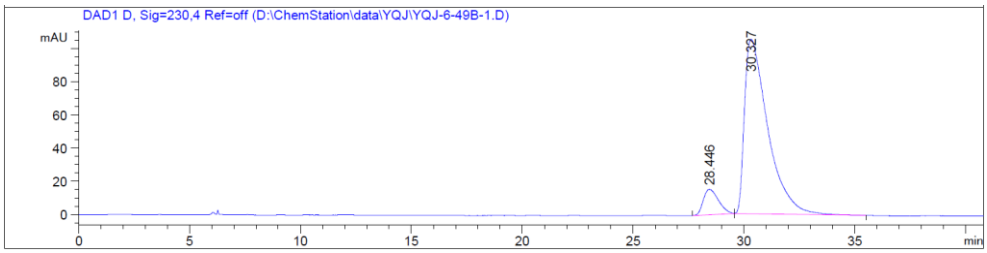


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.809	BB	0.2750	1956.72766	108.16792	8.4807
2	14.299	BB	0.3189	2.11159e4	1005.73932	91.5193

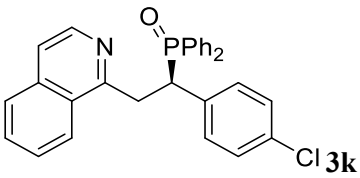


3j

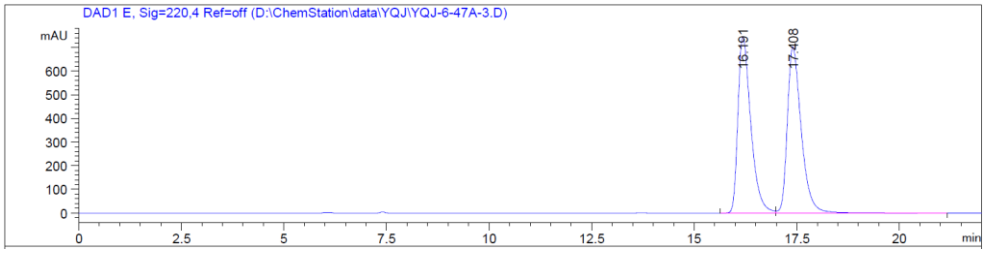


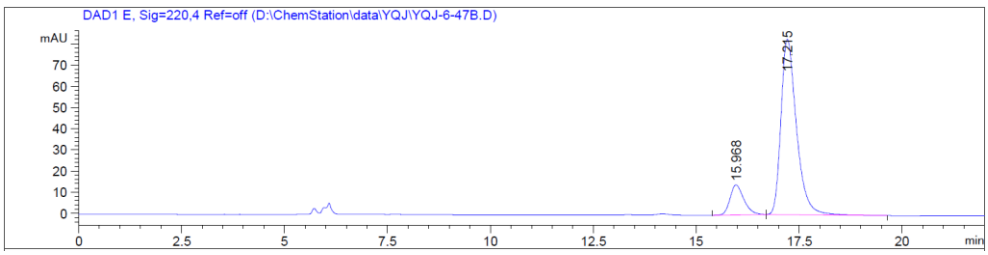


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	28.446	BB	0.7275	716.52228	15.21234	8.5601
2	30.327	BB	1.1157	7654.00635	104.84689	91.4399

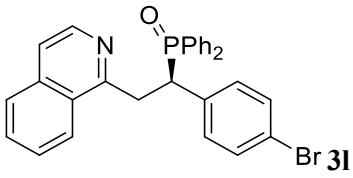


3k





Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.968	BB	0.3555	331.99643	14.16057	13.2011
2	17.215	BB	0.3996	2182.92578	82.79558	86.7989



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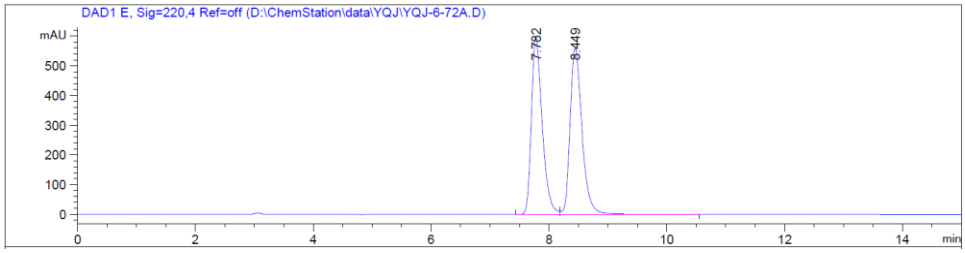
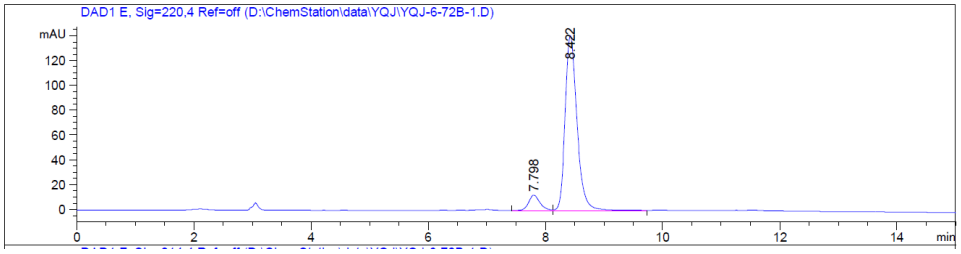
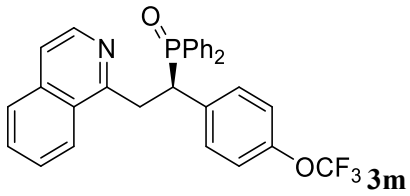
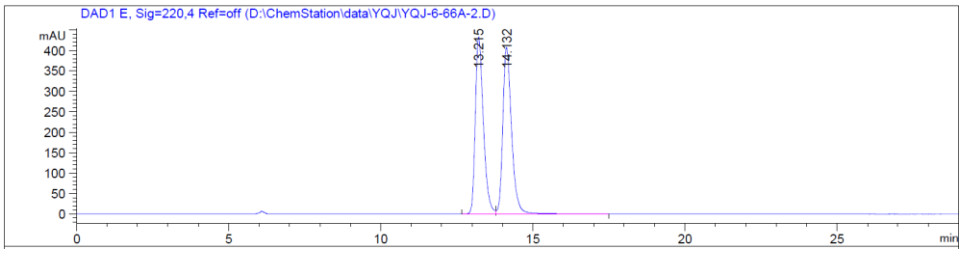


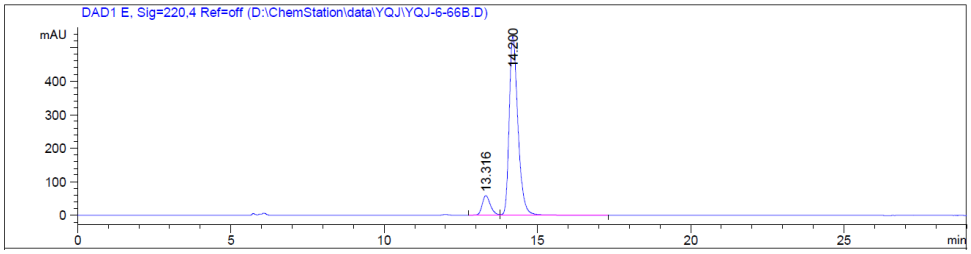


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.798	BV	0.2010	164.64848	12.39413	7.7495
2	8.422	VB	0.2125	1959.98535	140.68675	92.2505

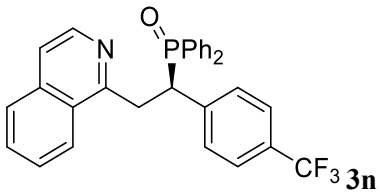


3m

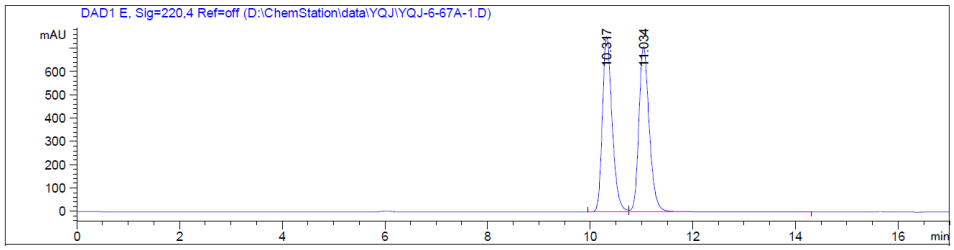


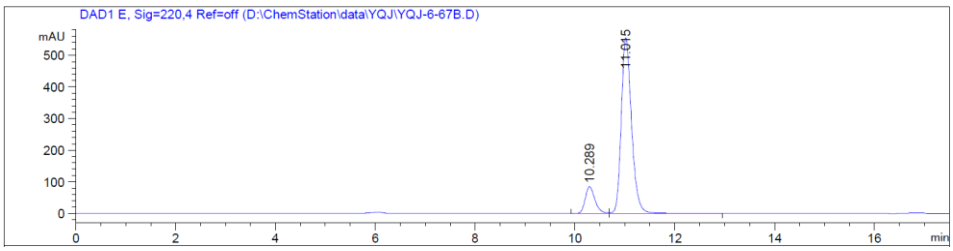


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.316	BV	0.2906	1121.09253	58.76810	9.4994
2	14.200	VB	0.3058	1.06807e4	532.93268	90.5006

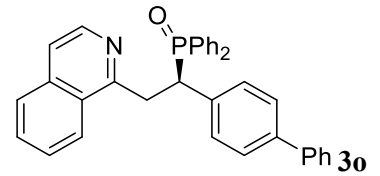


3n

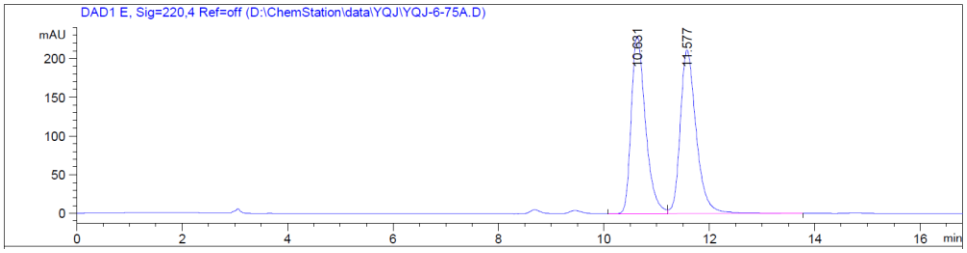


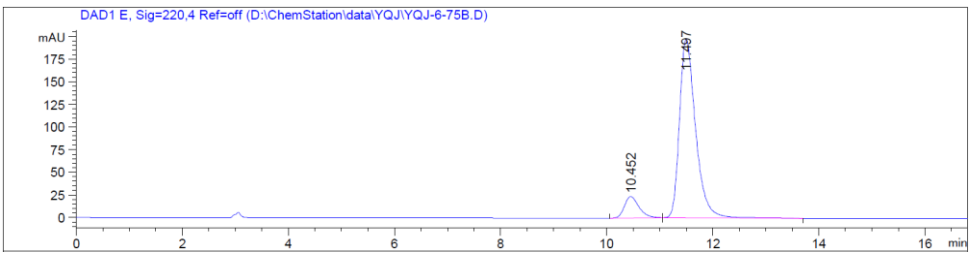


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.289	BV	0.2064	1147.58838	84.54351	12.6018
2	11.015	VB	0.2193	7958.98340	554.86871	87.3982

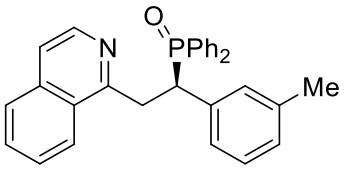


3o

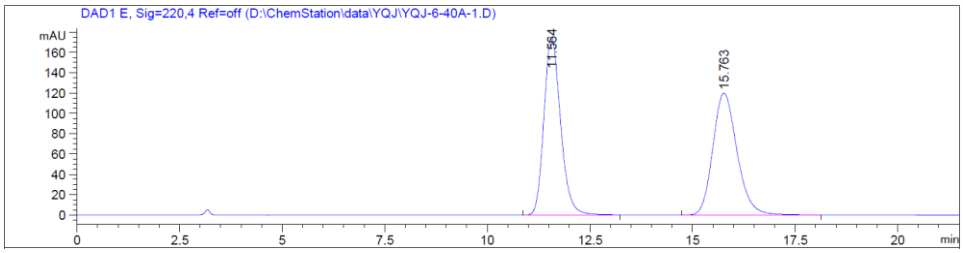


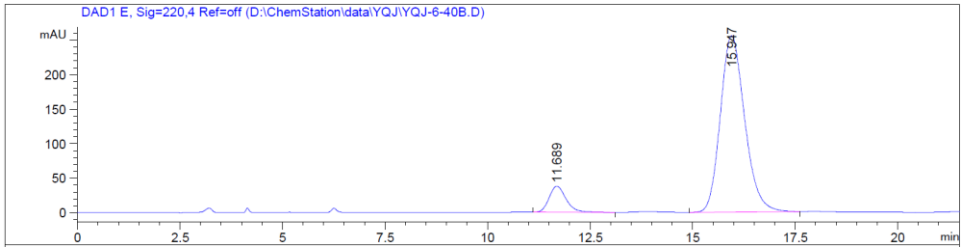


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.452	BB	0.2887	449.05002	23.73730	9.7635
2	11.497	BB	0.3192	4150.23047	197.48311	90.2365

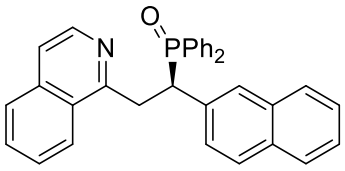


3p

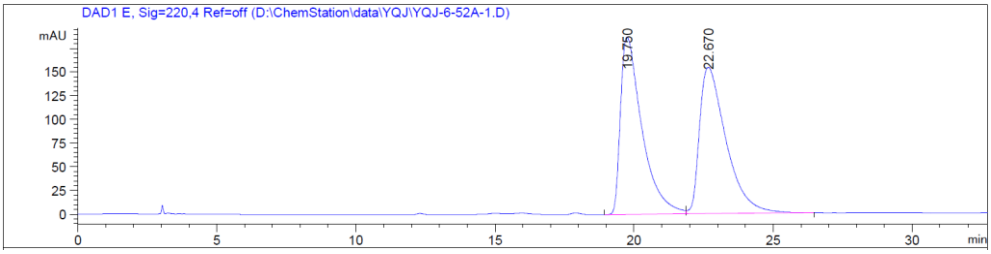


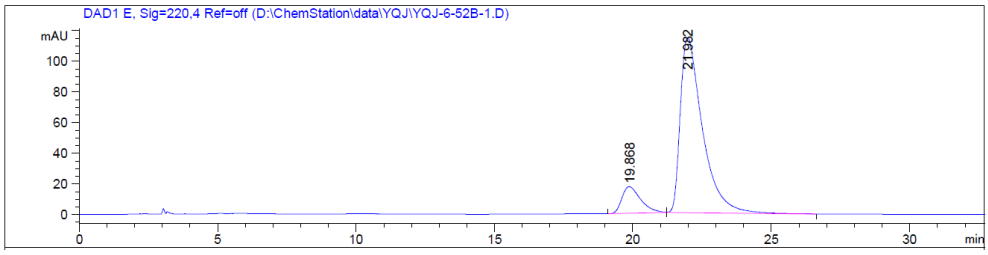


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.689	BB	0.4409	1085.15613	37.80371	9.3362
2	15.947	BB	0.6370	1.05379e4	255.58505	90.6638

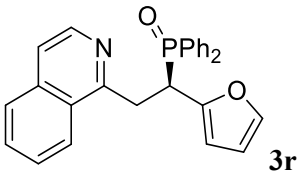


3q

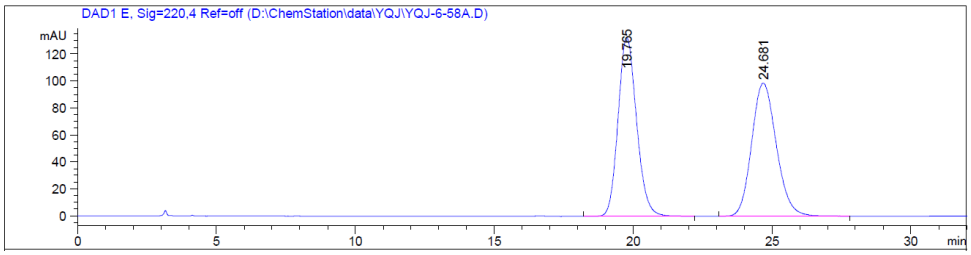


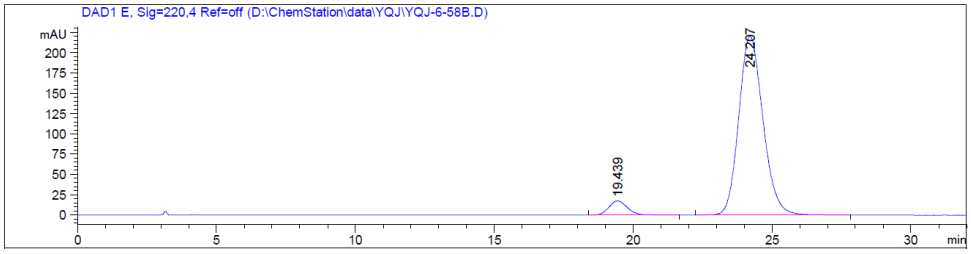


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.868	BB	0.6989	806.75586	17.33565	11.3236
2	21.982	BB	0.8295	6317.79834	114.18504	88.6764

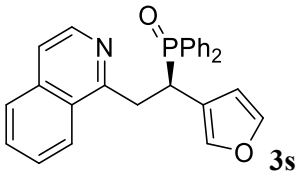


3r

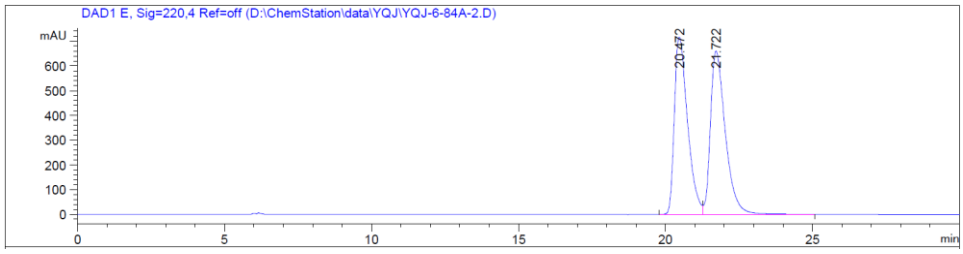


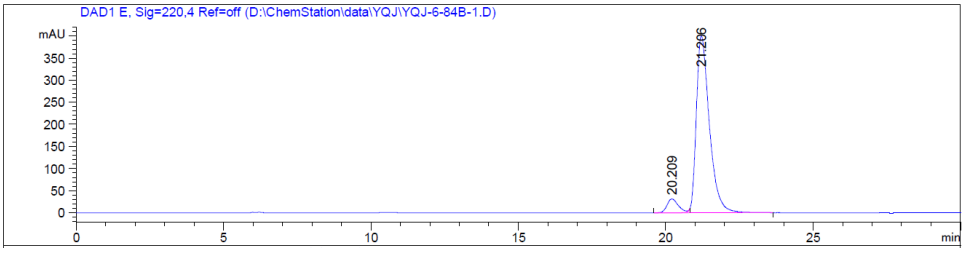


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.439	BB	0.6939	820.58801	17.47355	5.7930
2	24.207	BB	0.9359	1.33446e4	219.93776	94.2070

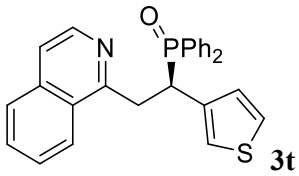


3s

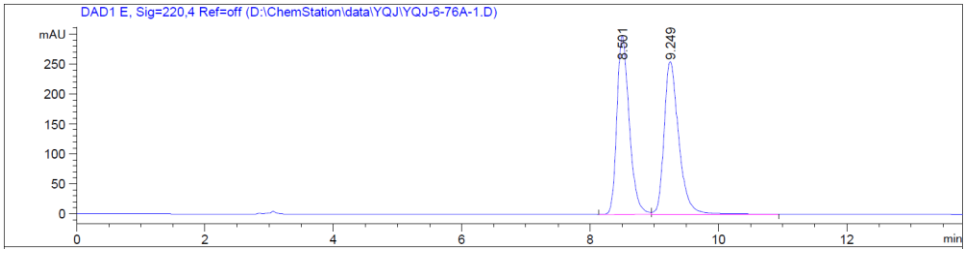


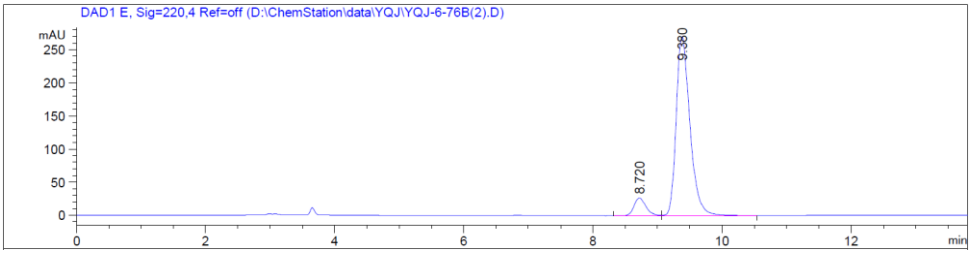


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.209	BV E	0.4077	828.83881	31.22442	6.3198
2	21.206	VB R	0.4663	1.22861e4	400.02533	93.6802

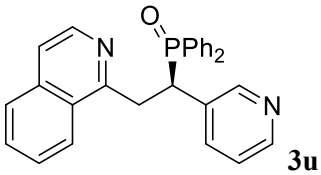


3t

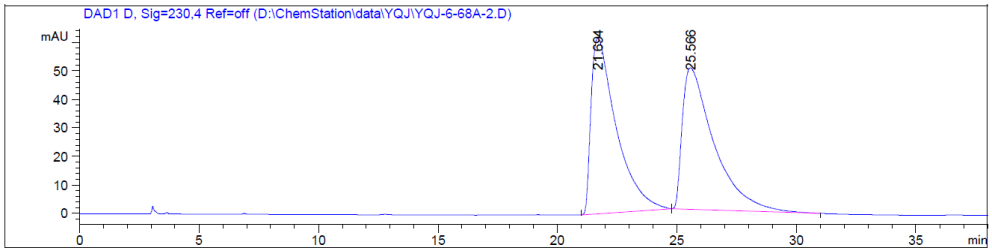


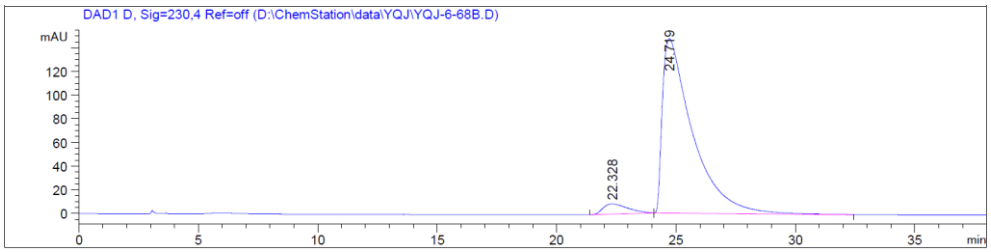


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.720	BV	0.1968	345.94144	26.76179	7.9528
2	9.380	VB	0.2265	4003.99048	270.77197	92.0472

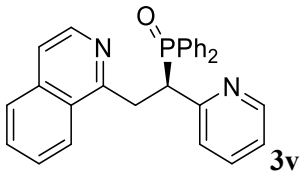


3u

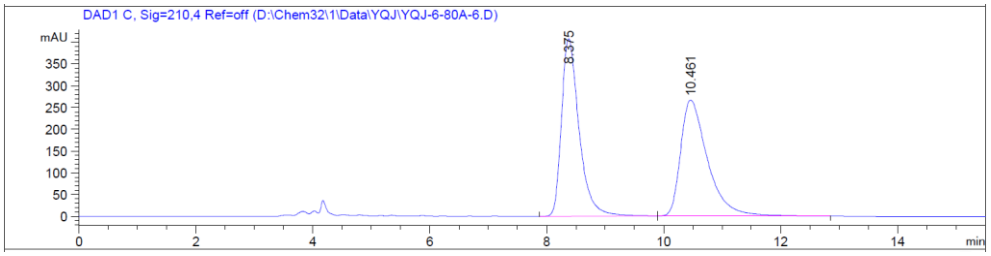


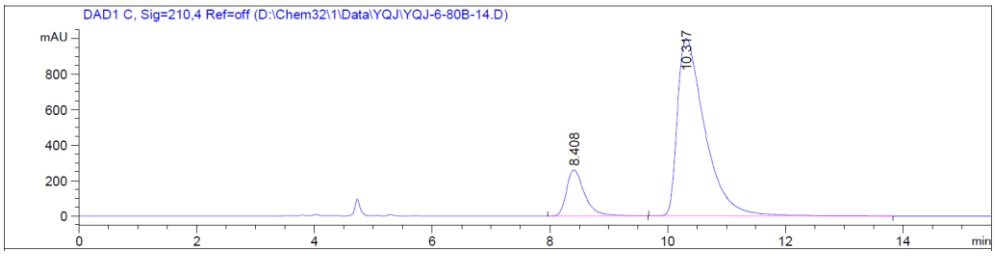


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	22.328	BB	0.9741	621.65222	8.63255	4.5944
2	24.719	BB	1.2544	1.29090e4	147.59764	95.4056

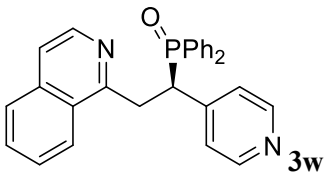


3v





Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.408	BB	0.3199	5492.47510	260.54111	14.5136
2	10.317	BB	0.4834	3.23513e4	999.95404	85.4864



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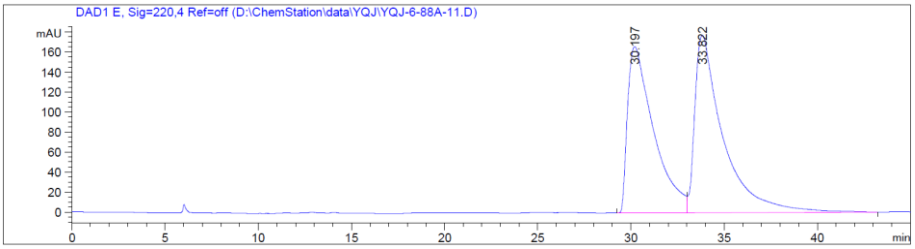
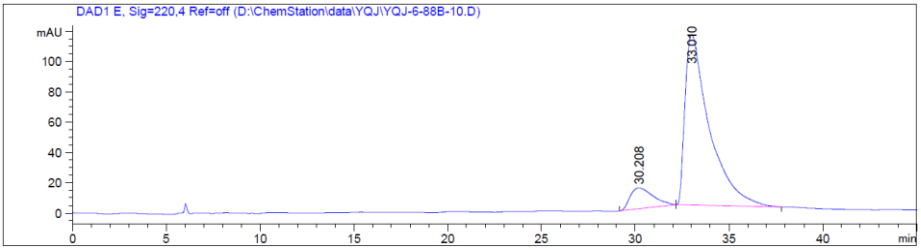
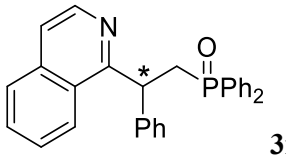
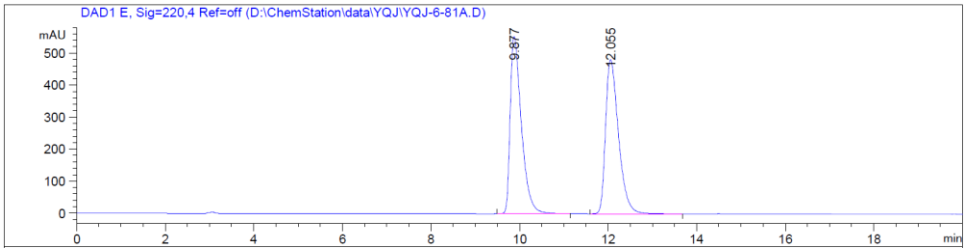


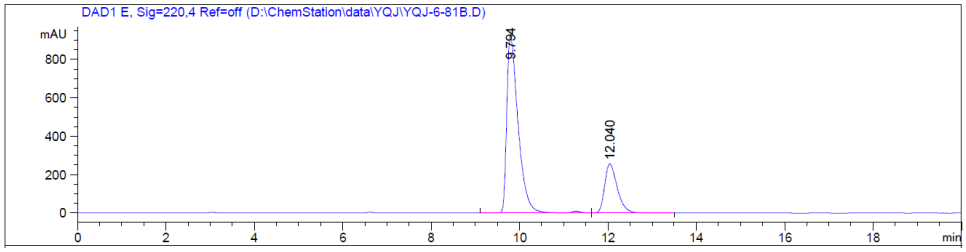


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.208	BB	1.0191	1169.71838	13.71418	10.3286
2	33.010	BB	1.2931	1.01553e4	112.50748	89.6714

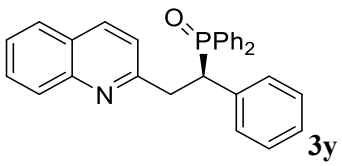


3x





Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.794	BV R	0.2678	1.66016e4	924.13495	76.4617
2	12.040	VB	0.3047	5110.71924	256.25525	23.5383



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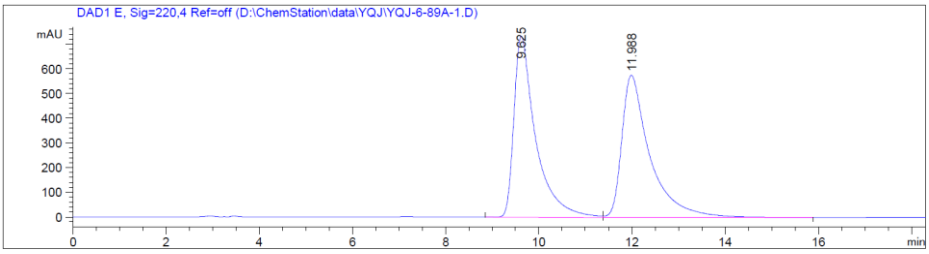
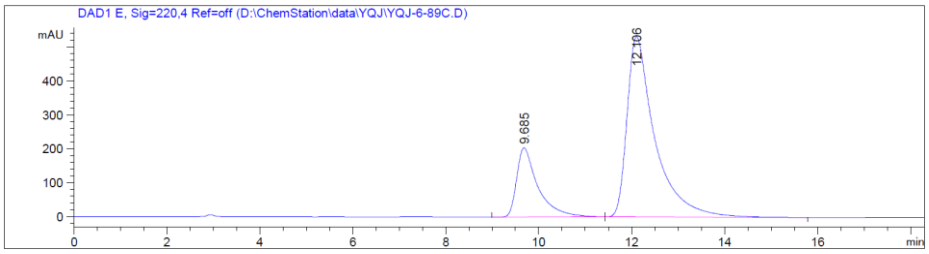
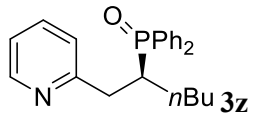




Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.685	BB	0.4612	6478.93311	203.62070	22.6766
2	12.106	BB	0.5991	2.20920e4	531.35138	77.3234



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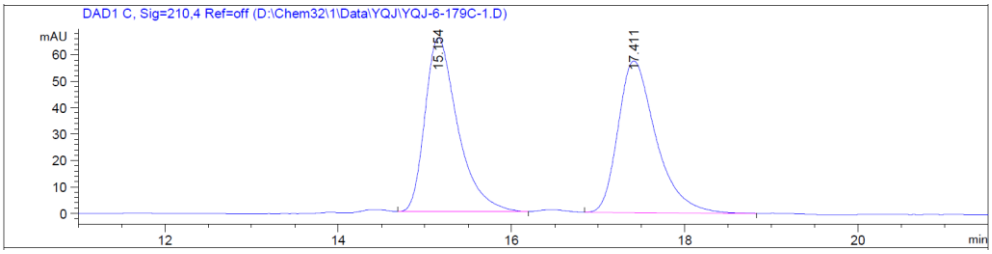
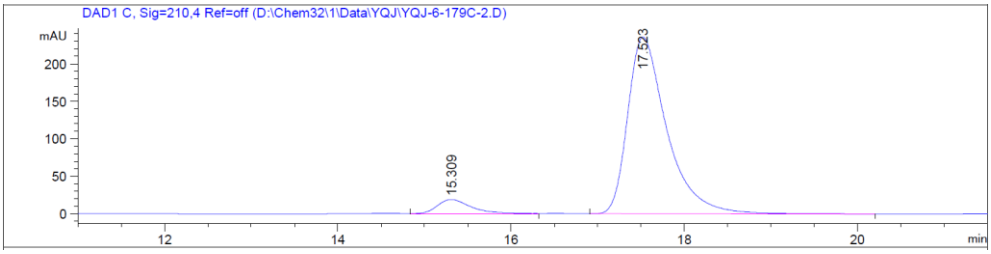
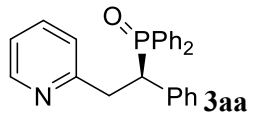
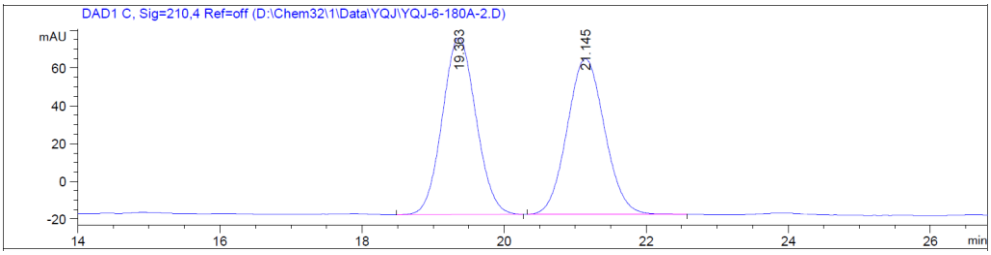


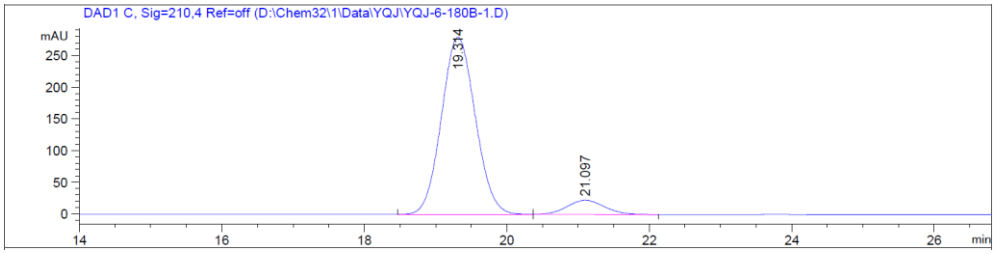


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.309	BB	0.3910	500.66428	18.90267	6.3010
2	17.523	BB	0.4701	7445.10400	235.94881	93.6990

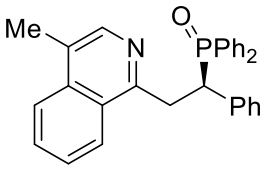


3aa





Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.314	BB	0.5145	9215.66797	279.62097	91.9277
2	21.097	BB	0.5421	809.23901	22.26251	8.0723



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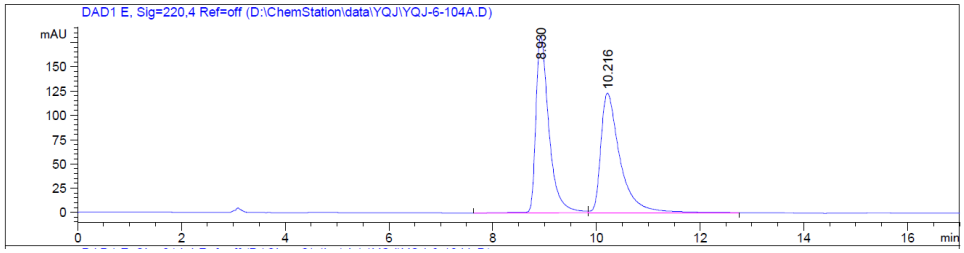
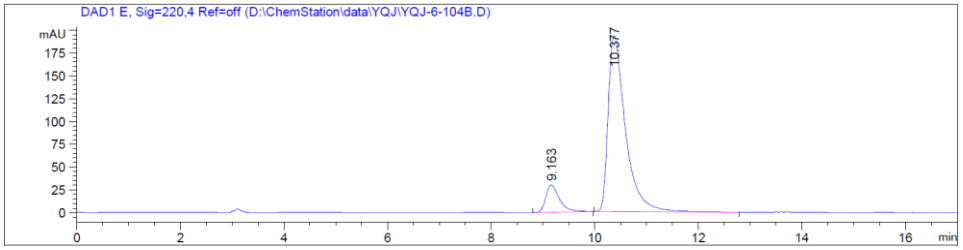
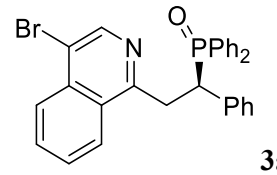
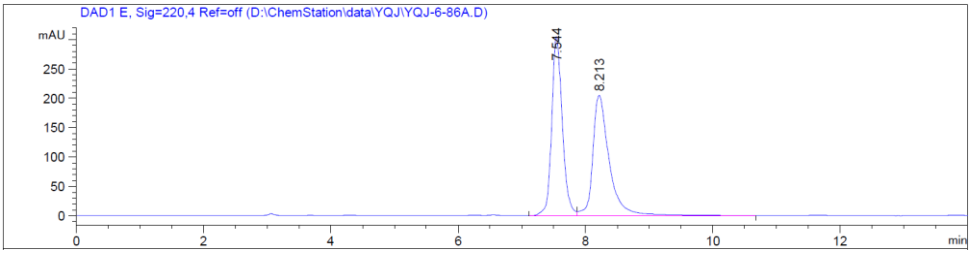


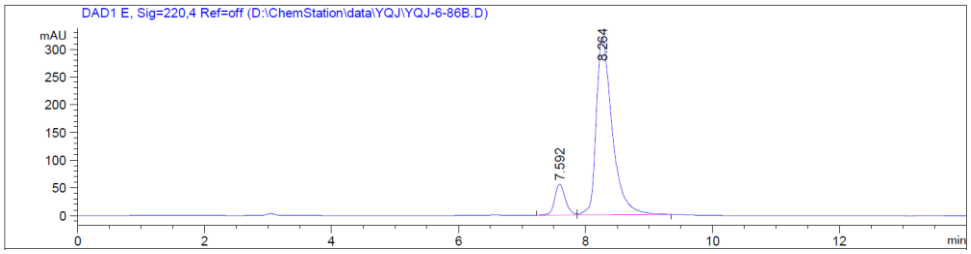


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.163	BB	0.2729	543.02759	30.04548	10.8051
2	10.377	BB	0.3471	4482.64014	192.92268	89.1949

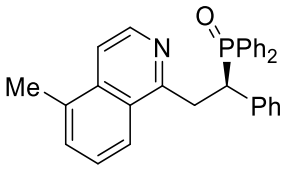


3ac





Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.592	BV	0.1781	645.65576	55.36412	10.3730
2	8.264	VB	0.2609	5578.74707	320.73578	89.6270



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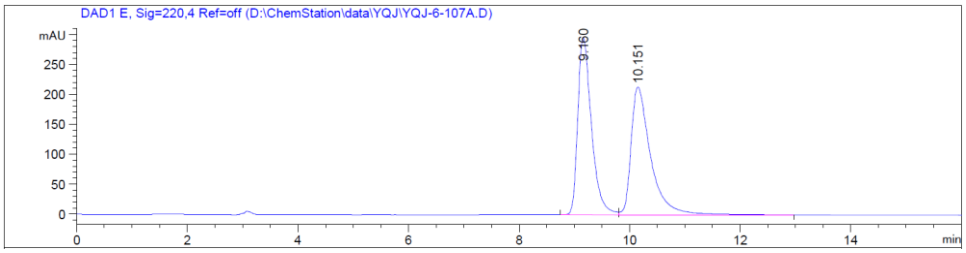
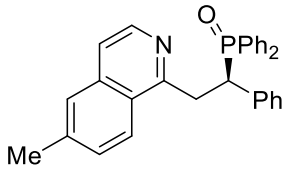


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.288	BV	0.2671	810.40826	46.09163	7.1503
2	10.182	VB	0.3281	1.05235e4	479.46295	92.8497



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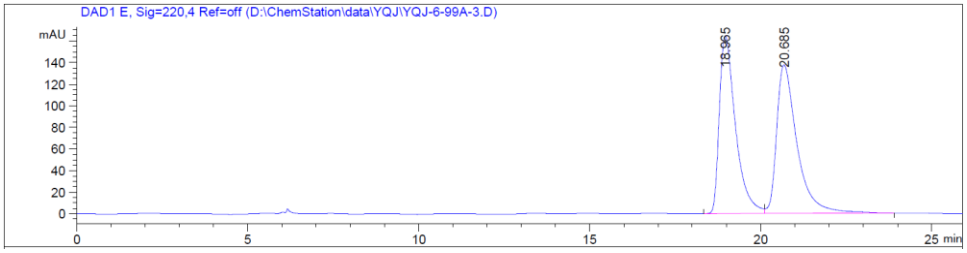
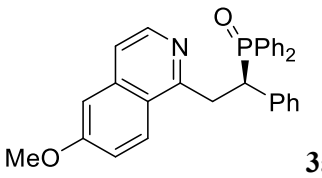


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.208	BV E	0.5149	1173.55005	34.66728	6.4854
2	20.605	VB R	0.6046	1.69218e4	421.26306	93.5146



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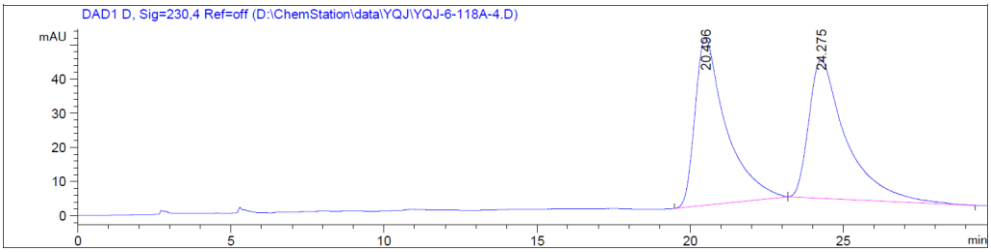
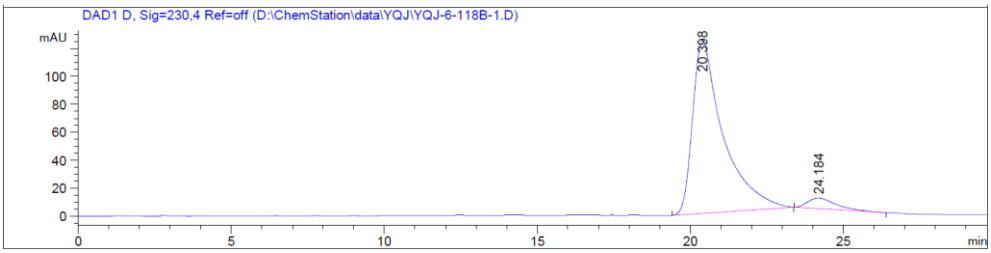
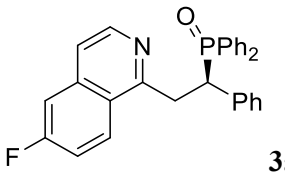




Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.398	BB	0.9748	8566.12500	124.48142	94.5459
2	24.184	BB	0.8884	494.15903	7.54244	5.4541



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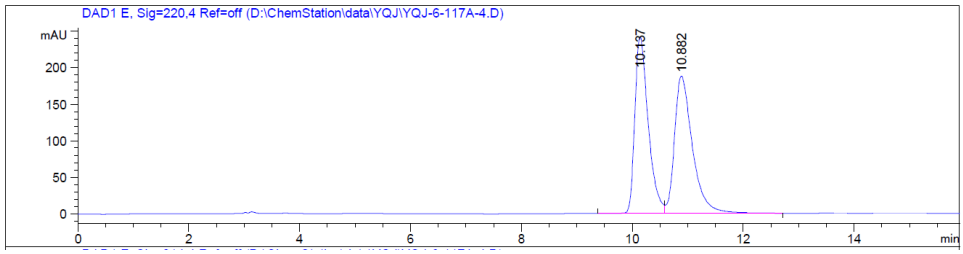
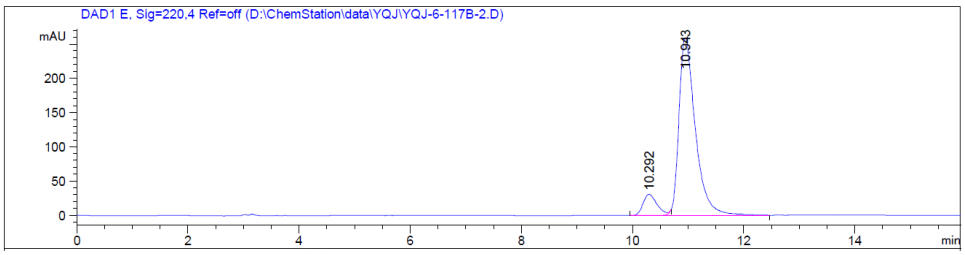
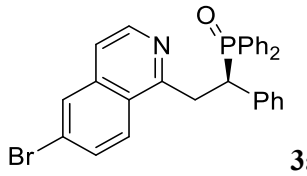




Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.292	BV E	0.2680	536.00275	30.66053	9.1870
2	10.943	VB R	0.3087	5298.38965	259.00854	90.8130



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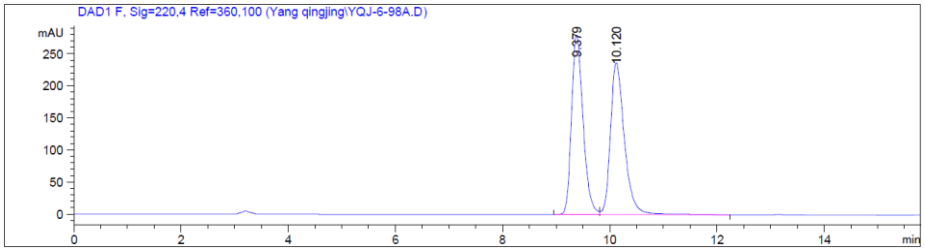
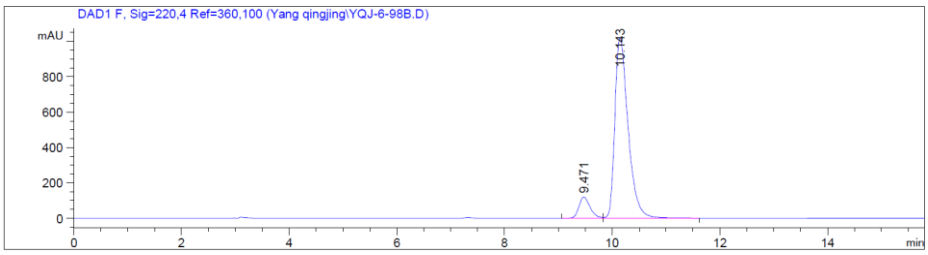
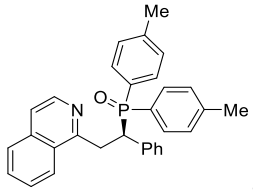
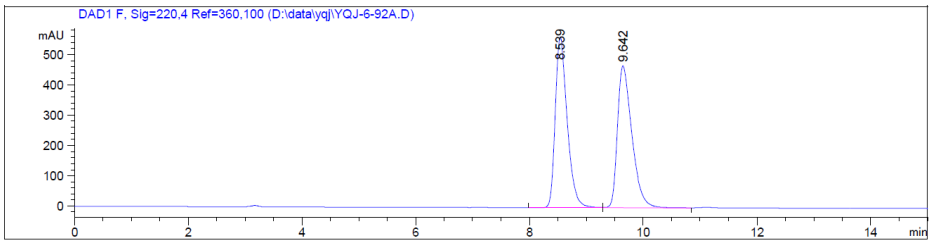


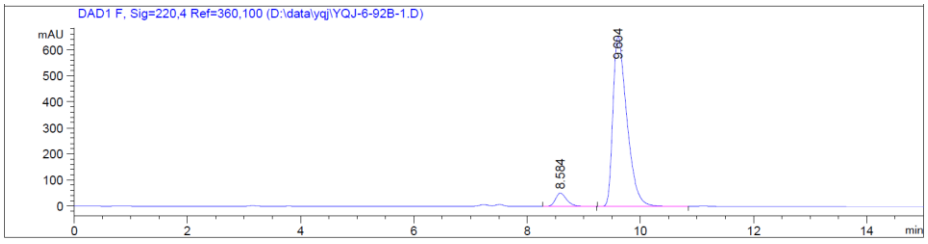


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.471	BV	0.2229	1732.35388	119.67129	9.0595
2	10.143	VB	0.2586	1.73896e4	1021.37421	90.9405

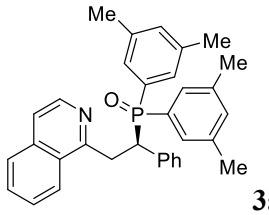


3ai

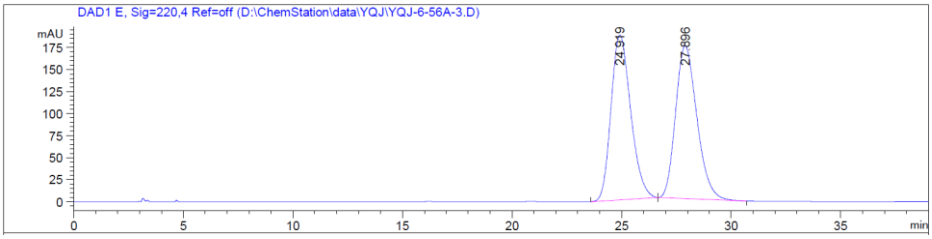


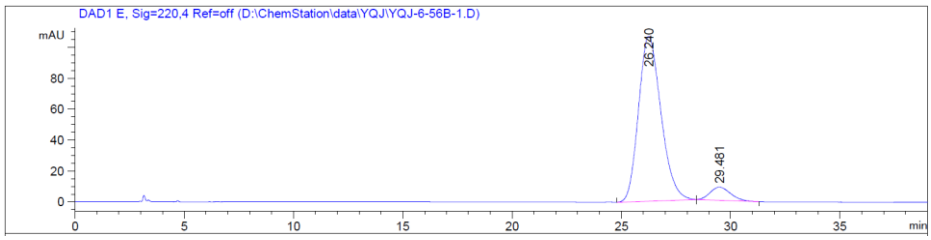


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.584	BB	0.2137	726.45953	51.77318	6.0852
2	9.604	BB	0.2622	1.12116e4	653.36737	93.9148

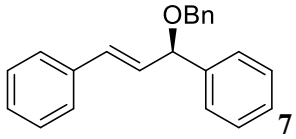


3aj

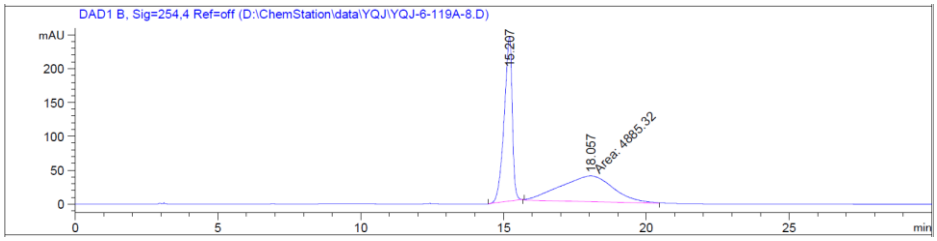


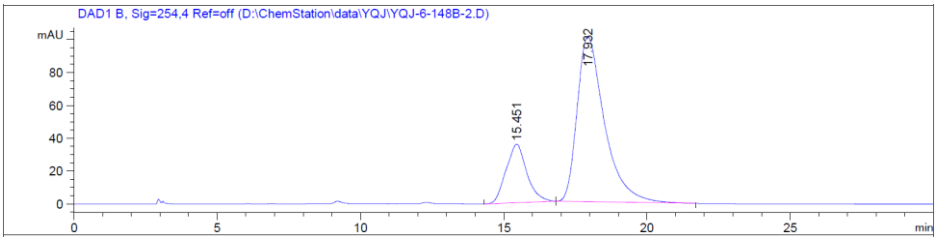


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	26.240	BB	1.1009	7606.93359	106.81522	93.2690
2	29.481	BB	0.8328	548.97363	8.50787	6.7310

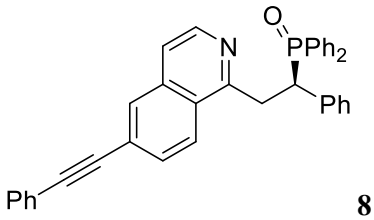


7

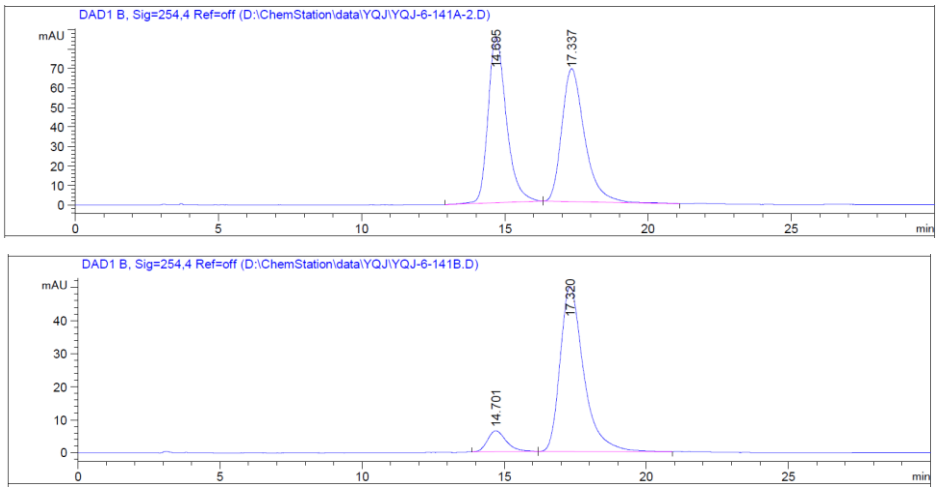




Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.451	BB	0.7083	1795.39270	35.60445	21.2308
2	17.932	BB	0.9859	6661.14600	100.67923	78.7692



8



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.701	BB	0.6463	293.42194	6.35928	9.2397
2	17.320	BB	0.8598	2882.22705	49.90268	90.7603