Supporting Information for

Copper-Catalyzed Three-component Carboboration of Alkynes and Alkenes

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Contents

General Remarks.

All manipulations of oxygen- and moisture-sensitive materials were conducted with a standard Schlenk technique under a purified argon atmosphere. Nuclear magnetic resonance spectra were taken on a Varian 400-MR (^{1}H, 400 MHz; ^{13}C, 100 MHz) spectrometer or a Varian System 500 (^{1}H, 500 MHz; ^{13}C, 125 MHz) spectrometer using residual chloroform (^{1}H, δ = 7.26) or $CDCl_3$ (^{13}C, δ = 77.0) as an internal standard. ^{1}H NMR data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, br = broad, m = multiplet), coupling constants (Hz), integration. High-resolution mass spectra were obtained with a Thermo Fisher Scientific LTQ Orbitrap XL. Preparative recycling gel permeation chromatography was performed with JAI LC-908 or JAI LC-9201 equipped with JAI GEL-1H and -2H columns (chloroform as an eluent). Column chromatography was carried out using Merck Kieselgel 60. Unless otherwise noted, commercially available reagents were used without purification. Toluene and THF were distilled from sodium/benzophenone ketyl. DMF and DMI were distilled from CaH_2. Acetonitrile was distilled from P_2O_5.

Alkynes.

1,2-Bis(4-methoxyphenyl)ethyne (**1b**), 1-(4-methoxyphenyl)-2-phenylethyne (**1c**), 1-(4-bromophenyl)-2-phenylethyne (**1d**) and 1-phenyl-2-(2-thienyl)ethyne (**1e**) were prepared according to literature procedures.[1,2]

Carbon Electrophiles.

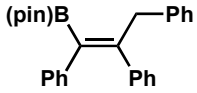
Cinnamyl diethyl phosphate (**3i**)[3] and methyl 4-methylbenzenesulfonate (**3k**)[4] were prepared according to literature.

Cu-Catalyzed Carboboration of Alkynes: A General Procedure.

A schlenk tube equipped with a magnetic stirring bar was charged with $Cu(OAc)_2$ (6.0 μmol), tricyclohexylphosphine (25wt% solution in toluene, 0.021 mmol), an alkyne (0.30 mmol), bis(pinacolato)diboron (0.39 mmol), a carbon electrophile (0.90 mmol), potassium *tert*-butoxide (1 M solution in THF, 0.45 mmol) and DMF (0.55 mL). The mixture was stirred at 50 °C for the period as specified in Tables 2 and 3, diluted with ethyl acetate before filtration through a Celite plug. The organic solution was washed two times with brine and dried over $MgSO_4$. Evaporation of the solvent followed by silica gel-column chromatography (hexane/ethyl acetate as an eluent) or gel permeation chromatography (chloroform as an eluent) gave the product.

In ^{13}C NMR spectra, boron-bound carbons were not detected because of quadrupolar relaxation.

(*Z*)-4,4,5,5-Tetramethyl-2-(1,2,3-triphenylprop-1-en-1-yl)-1,3,2-dioxaborolane (4aa)



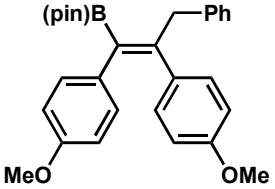
Isolated in 67% as a pale yellow solid: mp 124.7–126.2 ℃

^1H NMR ($CDCl_3$) δ 1.31 (s, 12 H), 4.06 (s, 2 H), 6.78–6.81 (m, 2 H), 6.96–7.00 (m, 6 H), 7.05 (t, *J* = 7.0 Hz, 2 H), 7.12 (t, *J* = 7.0 Hz, 1 H), 7.18–7.23 (m, 4 H)

^{13}C NMR ($CDCl_3$) δ 24.74, 44.43, 83.81, 125.36, 125.83, 126.18, 127.37, 127.46, 128.08, 129.07, 129.193, 129.64, 139.60, 141.43, 141.84, 151.59

HRMS Calcd for $C_{27}H_{29}O_2BNa$: $[M+Na]^+$, 419.21528. Found: *m/z*, 419.21613

(*Z*)-2-(1,2-Bis(4-methoxyphenyl)-3-phenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ba)



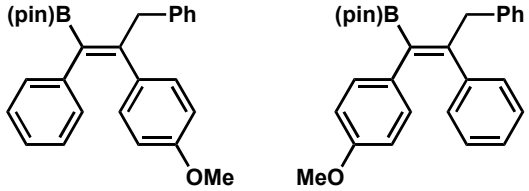
Isolated in 67% as a pale yellow solid: mp 123.7–125.8 ℃

^1H NMR ($CDCl_3$) δ 1.30 (s, 12 H), 3.67 (s, 3 H), 3.71 (s, 3 H), 4.02 (s, 2 H), 6.54 (d, *J* = 8.7 Hz, 2 H), 6.62 (d, *J* = 8.7 Hz, 2 H), 6.75 (d, *J* = 8.6 Hz, 2 H), 6.89 (d, *J* = 8.6 Hz, 2 H), 7.12 (t, *J* = 7.3 Hz), 7.18–7.24 (m, 4 H)

^{13}C NMR ($CDCl_3$) δ 24.69, 44.39, 54.89, 54.93, 83.66, 112.83, 112.99, 125.68, 128.01, 128.97, 130.36, 130.71, 133.91, 134.23, 139.91, 149.90, 157.15, 157.67

HRMS Calcd for $C_{29}H_{33}O_4BNa$: $[M+Na]^+$, 479.23641. Found: *m/z*, 479.23651

A mixture of (*Z*)-2-(2-(4-methoxyphenyl)-1,3-diphenylprop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ca) and (*Z*)-2-(1-(4-methoxyphenyl)-2,3-diphenylprop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4'ca)



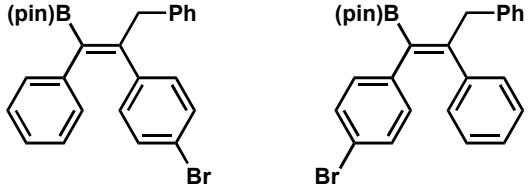
Isolated in 84% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 1.21 (s), 1.23 (s), 3.56 (s), 3.59 (s), 3.96 (s), 3.97 (s), 6.44 (d, *J* = 8.7 Hz), 6.51 (d, *J* = 8.7 Hz), 6.66 (d, *J* = 8.8 Hz), 6.72–6.74 (m), 6.81 (d, *J* = 8.5 Hz), 6.90–6.93 (m), 6.97–7.04 (m), 7.09–7.17 (m)

^{13}C NMR ($CDCl_3$) δ 24.68, 24.71, 44.35, 44.43, 54.85, 54.89, 83.67, 83.71, 112.77, 112.93, 125.19, 125.73, 126.02, 127.40, 127.49, 128.00, 128.02, 128.98, 129.01, 129.18, 129.66, 130.33, 130.66, 133.65, 134.10, 139.67, 139.84, 141.73, 142.01, 150.52, 150.95, 157.27, 157.79

HRMS Calcd for $C_{28}H_{31}O_3BNa$: $[M+Na]^+$, 449.22585.Found: m/z, 449.22574

A mixture of (*Z*)-2-(2-(4-bromophenyl)-1,3-diphenylprop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4da) and (*Z*)-2-(1-(4-bromophenyl)-2,3-diphenylprop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4'da)



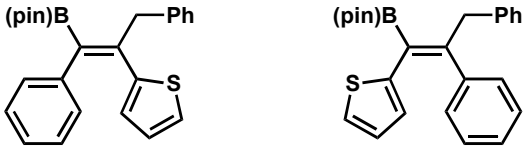
Isolated in 58% as a colorless solid: mp 92.3–94.8 ℃

^{1}H NMR ($CDCl_3$) δ 1.30 (s), 1.30 (s), 4.02 (s), 4.06 (s), 6.65 (d, *J* = 8.3 Hz), 6.76–6.77 (m), 6.83 (d, *J* = 8.6 Hz), 6.94–7.21 (m)

^{13}C NMR ($CDCl_3$) δ 24.71, 44.18, 44.32, 83.90, 119.34, 120.18, 125.56, 125.98, 126.98, 126.39, 127.54, 127.66, 128.07, 128.18, 129.00, 129.02, 129.04, 129.51, 130.56, 130.86, 131.39, 139.18, 139.31, 140.52, 140.71, 141.02, 141.49, 150.16, 152.98

HRMS Calcd for $C_{27}H_{28}O_2BBrNa$: $[M+Na]^+$, 497.12579.Found: m/z, 497.12579

A mixture of (*Z*)-2-(1,3-diphenyl-2-(thiophen-2-yl)prop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ea) and (*Z*)-2-(2,3-diphenyl-1-(thiophen-2-yl)prop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4'ea)



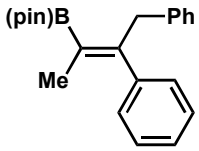
Isolated in 49% as a pale yellow solid: mp 92.3–94.8 ℃

^{1}H NMR ($CDCl_3$) δ 1.24 (s), 1.40 (s), 3.92 (s), 4.14 (s), 6.55 (d, J = 3.7 Hz), 6.65 (t, J = 4.4 Hz), 6.75–6.78 (m), 6.86 (dd, J = 7.3, 2.1 Hz), 6.95–6.98 (m), 7.13–7.28 (m), 7.36 (d, J = 7.8 Hz)

^{13}C NMR ($CDCl_3$) δ 24.60, 24.09, 43.97, 45.64, 83.77, 84.25, 125.08, 125.66, 125.71, 125.80, 125.97, 126.00, 126.14, 126.98, 127.08, 127.83, 128.07, 128.12, 128.19, 128.72, 129.02, 129.28, 129.30, 139.79, 139.86, 141.63, 141.87, 142.94, 143.15, 143.48, 149.85

HRMS Calcd for $C_{25}H_{27}O_2BNaS$: $[M+Na]^+$, 425.17170.Found: m/z, 425.17188

(*Z*)-2-(3,4-Diphenylbut-2-en-2-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4fa)



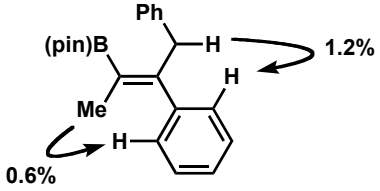
Isolated in 54% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 1.35 (s, 12 H), 1.61 (s, 3 H), 4.00 (s, 2 H), 6.85 (d, J = 7.0 Hz, 2 H), 7.07–7.22 (m, 10 H)

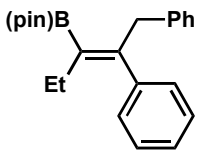
^{13}C NMR ($CDCl_3$) δ 18.36, 24.58, 43.90, 83.28, 125.53, 126.13, 127.68, 127.82, 128.09, 129.07, 140.15, 142.77, 153.55

HRMS Calcd for $C_{22}H_{27}O_2BNa$: $[M+Na]^+$, 357.19963. Found: *m/z*, 357.19980

The stereochemistry was determined by NOE as shown below:



(*Z*)-2-(1,2-Diphenylpent-2-en-3-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ga)



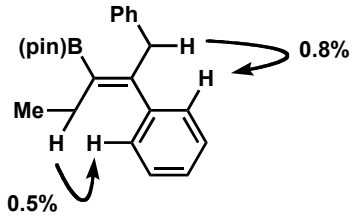
Isolated in 50% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 0.89 (t, *J* = 7.5 Hz, 3 H), 1.35 (s, 12 H), 1.98 (q, *J* = 7.5 Hz, 2 H), 3.92 (s, 2 H), 6.81 (dd, *J* = 7.9, 1.5 Hz, 2 H), 7.05 (d, *J* = 7.4 Hz, 2 H), 7.09–7.19 (m, 8 H)

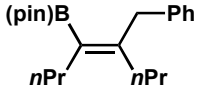
^{13}C NMR ($CDCl_3$) δ 14.99, 24.86, 25.65, 44.35, 83.30, 125.56, 126.07, 127.56, 127.84, 128.06, 129.13, 139.97, 142.61, 151.74

HRMS Calcd for $C_{23}H_{29}O_2BNa$: $[M+Na]^+$, 371.21528. Found: *m/z*, 371.21543

The stereochemistry was determined by NOE as shown below:



(*E*)-2-(5-Benzyloct-4-en-4-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ha)



Isolated in 57% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 0.85 (t, *J* = 7.3 Hz, 3 H), 0.92 (t, *J* = 7.5 Hz, 3 H), 1.26 (s, 12 H), 1.30–1.42 (m, 4 H), 1.93 (t, *J* = 7.9 Hz, 2 H), 2.16 (t, *J* = 7.7 Hz, 2 H), 3.66 (s, 2 H), 7.16 (t, *J* = 6.8 Hz, 1 H), 7.22–7.27 (m, 4 H)

^{13}C NMR ($CDCl_3$) δ 14.31, 14.52, 21.87, 23.74, 24.76, 33.00, 33.53, 41.68, 82.87, 125.55, 128.01, 128.90, 141.36, 151.56

HRMS Calcd for $C_{21}H_{33}O_2BNa$: $[M+Na]^+$, 351.24658. Found: *m/z*, 351.24658

A mixture of (*E*)-2-(3-benzyloct-2-en-2-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ia) and (*E*)-4,4,5,5-tetramethyl-2-(2-methyl-1-phenyloct-2-en-3-yl)-1,3,2-dioxaborolane (4'ia)

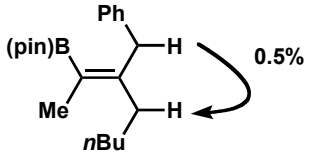
Isolated in 46% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 0.84 (t, *J* = 6.8 Hz), 0.88 (t, *J* = 6.6 Hz), 1.21–1.35 (m), 1.59 (s), 1.75 (s), 1.96 (t, *J* = 7.7 Hz), 2.16 (t, *J* = 7.1 Hz), 3.66 (s), 3.72 (s), 7.15–7.18 (m), 7.22–7.26 (m)

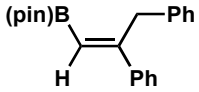
^{13}C NMR ($CDCl_3$) δ 14.00, 14.07, 16.30, 18.10, 22.49, 22.62, 24.56, 24.78, 27.47, 29.73, 30.93, 31.08, 31.92, 32.16, 41.59, 44.30, 82.90, 83.15, 125.58, 125.62, 128.02, 128.07, 128.87, 128.96, 141.15, 141.31, 147.97, 154.19

HRMS Calcd for $C_{21}H_{33}O_2BNa$: $[M+Na]^+$, 351.24658.Found: m/z, 351.24661

The regiochemistry was determined by NOE as shown below:



(*E*)-2-(2,3-Diphenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ja)



Isolated in 44% as a pale yellow solid: mp 56.1–58.5 ℃

^{1}H NMR ($CDCl_3$) δ 1.29 (s, 12 H), 4.27 (s, 2 H), 5.85 (s, 1 H), 7.18–7.25 (m, 6 H), 7.40 (dd, *J* = 8.0, 1.5 Hz, 2 H)

^{13}C NMR ($CDCl_3$) δ 24.80, 39.28, 83.09, 125.64, 126.65, 127.78, 128.10, 128.55, 128.85, 140.24, 142.92, 160.35

HRMS Calcd for $C_{21}H_{25}O_2BNa$: $[M+Na]^+$, 343.18398. Found: *m/z*, 343.18431

The regiochemistry was determined by the coupling constants.

A mixture of (*E*)-4,4,5,5-tetramethyl-2-(1-phenylnon-2-en-3-yl)-1,3,2-dioxaborolane (4ka) and (*Z*)-2-(2-benzyloct-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4'ka)

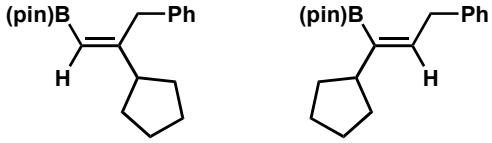
Isolated in 51% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 0.84 (t, *J* = 7.0 Hz), 0.86 (t, *J* = 7.0 Hz), 1.19–1.27 (m), 1.28 (s), 1.29 (s), 1.35–1.42 (m), 1.97 (t, *J* = 7.6 Hz), 2.11 (t, *J* = 7.4 Hz), 3.68 (d, *J* = 7.7 Hz), 3.77 (s), 5.25 (s), 6.11 (t, *J* = 7.6 Hz), 7.16–7.29 (m)

^{13}C NMR ($CDCl_3$) δ 14.07, 14.10, 22.54, 22.61, 24.82, 27.60, 28.97, 30.18, 31.70, 31.77, 36.83, 37.62, 38.22, 40.93, 82.76, 82.95, 125.67, 125.78, 128.13, 128.28, 128.60, 128.87, 140.53, 141.58, 143.75, 165.14

HRMS Calcd for $C_{21}H_{33}O_2BNa$: $[M+Na]^+$, 351.24658.Found: m/z, 351.24661

A mixture of (*E*)-2-(2-cyclopentyl-3-phenylprop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4la) and (*E*)-2-(1-cyclopentyl-3-phenylprop-1-enyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4'la)



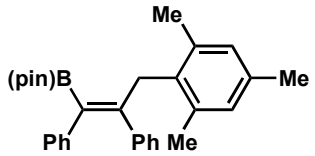
Isolated in 48% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 1.27 (s), 1.30 (s), 1.36–1.76 (m), 2.33 (m), 2.52 (m), 3.62 (d, *J* = 7.8 Hz), 3.83 (s), 5.33 (s), 6.06 (t, *J* = 7.5 Hz), 7.17 (t, *J* = 6.9 Hz), 7.21–7.29 (m)

^{13}C NMR ($CDCl_3$) δ 24.80, 24.84, 24.98, 25.08, 31.96, 32.40, 37.77, 41.18, 46.71, 47.08, 82.74, 83.02, 125.67, 125.68, 128.08, 128.27, 128.59, 128.83, 139.67, 140.70, 141.55, 168.32

HRMS Calcd for $C_{20}H_{29}O_2BNa$: $[M+Na]^+$, 335.2128.Found: m/z, 335.21561

(*Z*)-2-(3-Mesityl-1,2-diphenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ab)



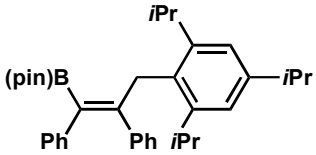
Isolated in 67% as a pale yellow solid: mp 134.4–135.3 ℃

^{1}H NMR ($CDCl_3$) δ 1.39 (s, 12 H), 2.18 (s, 6 H), 2.25 (s, 3H), 4.18 (s, 2 H), 6.56 (dt, *J* = 6.8 Hz, 1.2 Hz, 2 H), 6.75 (s, 2 H), 6.88–6.98 (m, 6 H), 7.04 (t, *J* = 7.2 Hz, 2 H)

^{13}C NMR ($CDCl_3$) δ 20.43, 20.79, 24.85, 38.25, 83.64, 124.99, 125.68, 126.70, 127.19, 128.67, 128.86, 129.92, 132.41, 135.33, 137.66, 141.19, 141.74, 152.28

HRMS Calcd for $C_{30}H_{35}O_2BNa$: $[M+Na]^+$, 461.26223. Found: *m/z*, 461.26196

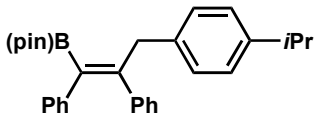
(*Z*)-2-(1,2-Diphenyl-3-(2,4,6-triisopropylphenyl)prop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ac)



Isolated in 60% as a pale yellow solid: mp 124.7–126.8 ℃

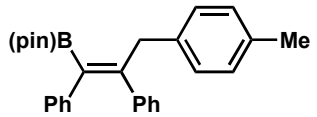
^{1}H NMR ($CDCl_3$) δ 1.05 (m, 12 H), 1.25 (d, J = 7.0 Hz), 1.37 (s, 12 H), 2.86 (m, J = 7.0 Hz, 1 H), 3.15 (m, J = 7.0 Hz, 2 H), (s, 2 H), 6.43 (d, J = 6.9 Hz, 2 H), 6.82–6.94 (m, 8 H), 7.00 (t, J = 7.3 Hz, 2 H)
^{13}C NMR ($CDCl_3$) δ 24.13, 24.85, 29.09, 34.09, 35.80, 83.62, 120.67, 124.89, 125.61, 126.60, 127.19, 129.28, 129.37, 129.73, 140.98, 141.92, 146.86, 147.86, 153.88,
HRMS Calcd for $C_{36}H_{47}O_2BNa$: $[M+Na]^+$, 545.35613. Found: *m/z*, 545.35583

(*Z*)-2-(3-(4-Isopropylphenyl)-1,2-diphenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ad)



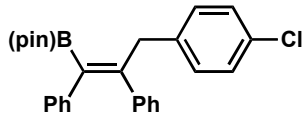
Isolated in 70% as a colorless solid: mp 107.9–109.3 ℃
^{1}H NMR ($CDCl_3$) δ 1.24 (d, J = 7.0 Hz, 6 H), 1.34 (s, 12 H), 2.87 (m, J = 6.9 Hz, 1 H), 4.08 (s, 2 H), 6.85–6.87 (m, 2 H), 7.00–7.04 (m, 6 H), 7.07–7.11 (m, 4 H), 7.19 (d, J = 8.2 Hz, 2 H),
^{13}C NMR ($CDCl_3$) δ 24.00, 24.72, 33.59, 43.95, 83.73, 125.26, 126.09, 127.29, 127.40, 128.90, 129.23, 129.64, 136.91, 141.55, 142.02, 146.20, 151.84
HRMS Calcd for $C_{30}H_{35}O_2BNa$: $[M+Na]^+$, 461.26223. Found: *m/z*, 461.26193

(*Z*)-2-(1,2-Diphenyl-3-(*p*-tolyl)prop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ae)



Isolated in 57% as a colorless solid: mp 111.3–113.7 ℃
^{1}H NMR ($CDCl_3$) δ 1.32 (s, 12 H), 2.28 (s, 3 H), 4.03 (s, 2 H), 6.81–6.82 (m, 2 H), 6.97–7.02 (m, 8 H), 7.06 (t, J = 7.56, 2 H), 7.12 (d, J = 7.5 Hz, 2 H)
^{13}C NMR ($CDCl_3$) δ 21.01, 24.71, 83.76, 125.28, 126.10, 127.31, 127.42, 128.77, 128.90, 129.20, 129.63, 135.17, 136.42, 141.48, 141.88, 151.73
HRMS Calcd for $C_{28}H_{31}O_2BNa$: $[M+Na]^+$, 433.23093. Found: *m/z*, 433.23062

(*Z*)-2-(3-(4-Chlorophenyl)-1,2-diphenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4af)



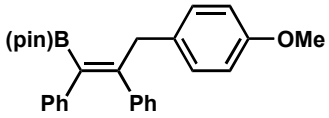
Isolated in 46% as a colorless solid: mp 136.0–137.7 ℃

^{1}H NMR ($CDCl_3$) δ 1.33 (s, 12 H), 4.04 (s, 2 H), 6.80–6.81 (m, 2 H), 6.96–7.02 (m, 6 H), 7.07 (t, *J* = 7.0 Hz, 2 H), 7.17 (s, 4 H)

^{13}C NMR ($CDCl_3$) δ 24.73, 43.73, 83.87, 125.44, 126.31, 127.47, 127.48, 128.16, 129.13, 129.58, 130.36, 131.57, 138.07, 141.22, 141.49, 151.16

HRMS Calcd for $C_{27}H_{28}O_2BClNa$: $[M+Na]^+$, 453.17631. Found: *m/z*, 453.17618

(*Z*)-2-(3-(4-Methoxyphenyl)-1,2-diphenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ag)



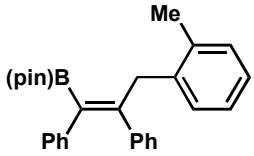
Isolated in 45% as a pale yellow solid: mp 128.0–130.0 ℃

^{1}H NMR ($CDCl_3$) δ 1.33 (s, 12 H), 3.75 (s, 3 H), 4.00 (s, 2 H), 6.76 (d, *J* = 8.7 Hz, 2 H), 6.80–6.81 (m, 2H), 6.97–7.01 (m, 6 H), 7.06 (t, *J* = 7.5 Hz, 2 H), 7.15 (d, *J* = 8.6 Hz, 2 H)

^{13}C NMR ($CDCl_3$) δ 24.73, 43.58, 55.11, 83.78, 113.45, 125.30, 126.11, 127.33, 127.43, 129.20, 129.62, 129.96, 131.60, 141.43, 141.85, 151.88, 157.72

HRMS Calcd for $C_{28}H_{31}O_3BNa$: $[M+Na]^+$, 449.22585. Found: *m/z*, 449.22571

(*Z*)-2-(1,2-Diphenyl-3-(*o*-tolyl)prop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ah)



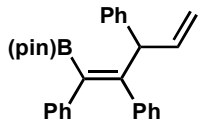
Isolated in 61% as a pale yellow solid: mp 83.3–84.6 ℃

^{1}H NMR ($CDCl_3$) δ 1.27 (s, 12 H), 2.25 (s, 3 H), 4.14 (s, 2 H), 6.87–6.89 (m, 2 H), 7.01–7.13 (m, 10 H), 7.15–7.18 (m, 1 H), 7.47 (d, *J* = 7.5 Hz, 1 H),

^{13}C NMR ($CDCl_3$) δ 19.78, 24.60, 40.97, 83.62, 125.31, 125.78, 125.82, 126.12, 127.30, 127.44, 128.93, 128.95, 129.60, 129.66, 136.43, 138.27, 141.59, 142.23, 151.35

HRMS Calcd for $C_{28}H_{31}O_2BNa$: $[M+Na]^+$, 433.23093. Found: *m/z*, 433.23044

(*Z*)-4,4,5,5-Tetramethyl-2-(1,2,3-triphenylpenta-1,4-dien-1-yl)-1,3,2-dioxaborolane (4ai)



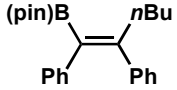
Isolated in 51% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 1.32 (s, 12 H), 5.12 (d, *J* = 8.6 Hz, 1 H), 5.22 (d, *J* = 10.1 Hz, 1 H), 5.35 (d, *J* = 16.9 Hz, 1 H), 6.08 (ddd, *J* = 18.1, 9.0, 9.0 Hz, 1 H), 6.55 (d, *J* = 7.2 Hz, 2 H), 6.90–7.02 (m, 8 H), 7.21 (t, *J* = 7.1 Hz, 1 H), 7.27–7.33 (m, 4 H)

^{13}C NMR ($CDCl_3$) δ 24.75, 24.78, 56.51, 83.84, 116.82, 125.27, 126.07, 126.17, 126.87, 127.32, 128.07, 128.30, 129.41, 130.19, 138.19, 139.56, 141.10, 142.11, 153.79

HRMS Calcd for $C_{29}H_{31}O_2BNa$: $[M+Na]^+$, 445.23093. Found: *m/z*, 445.23080

(*Z*)-2-(1,2-Diphenylhex-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4aj)



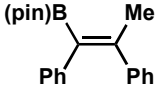
Isolated in 60% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 0.88 (t, *J* = 6.9 Hz, 3 H), 1.33–1.36 (m, 16 H), 2.70 (t, *J* = 7.3 Hz, 2 H), 6.94 (d, *J* = 7.8 Hz, 2 H), 6.98–6.99 (m, 3 H), 7.03–7.13 (m, 5 H)

^{13}C NMR ($CDCl_3$) δ 13.98, 22.73, 24.73, 31.15, 38.68, 83.55, 125.09, 126.12, 127.39, 127.51, 129.05, 129.54, 141.46, 142.20, 153.39

HRMS Calcd for $C_{24}H_{31}O_2BNa$: $[M+Na]^+$, 385.23093. Found: *m/z*, 385.23157

(*Z*)-2-(1,2-Diphenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4ak)



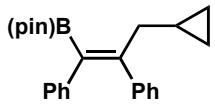
Isolated in 39% as a pale yellow solid: mp 110.3–112.3 ℃

^{1}H NMR ($CDCl_3$) δ 1.34 (s, 12 H), 2.38(s, 3 H), 6.92–6.94 (m, 2 H), 6.99–7.02 (m, 3 H), 7.05–7.13 (m, 5 H)

^{13}C NMR ($CDCl_3$) δ 24.73, 24.99, 83.63, 125.18, 126.25, 127.45, 127.58, 128.55, 129.62, 141.7, 143.62, 149.02

HRMS Calcd for $C_{21}H_{25}O_2BNa$: $[M+Na]^+$, 343.18398. Found: *m/z*, 343.18433

(*Z*)-2-(3-Cyclopropyl-1,2-diphenylprop-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4al)



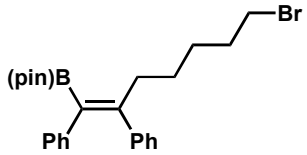
Isolated in 30% as a pale yellow solid: mp 90.9–92.6 ℃

^{1}H NMR ($CDCl_3$) δ 0.11–0.14 (m, 2 H), 0.31–0.35 (m, 2 H), 0.66–0.74 (m, 1 H), 1.31 (s, 12 H), 2.61 (d, *J* = 7.0 Hz, 2 H), 6.93–6.95 (m, 2 H), 6.94–7.13 (m, 8 H)

^{13}C NMR ($CDCl_3$) δ 4.38, 10.35, 24.73, 43.07, 83.61, 125.14, 126.08, 127.39, 127.47, 129.15, 129.61, 141.38, 142.48, 152.90

HRMS Calcd for $C_{24}H_{29}O_2BNa$: $[M+Na]^+$, 383.21528. Found: *m/z*, 383.21555

(*Z*)-2-(7-Bromo-1,2-diphenylhept-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (4am)



Isolated in 36% as a pale yellow solid: mp 87.4–89.0 ℃

^{1}H NMR ($CDCl_3$) δ 1.33 (s, 12 H), 1.36–1.48 (m, 4 H), 1.83 (m, *J* = 7.1 Hz, 2 H), 2.71 (t, *J* = 7.5 Hz, 2 H), 3.37 (t, *J* = 6.9 Hz, 2 H), 6.91 (d, *J* = 7.8 Hz, 2 H), 6.95–6.99 (m, 3 H), 7.02–7.12 (m, 5 H)

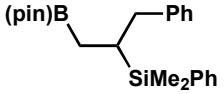
^{13}C NMR ($CDCl_3$) δ 24.76, 27.88, 27.91, 32.56, 33.95, 38.50, 83.63, 125.17, 126.25, 127.42, 127.60, 127.96, 129.04, 129.56, 141.42, 142.00, 153.14

HRMS Calcd for $C_{25}H_{32}O_2BBrNa$: $[M+Na]^+$, 477.15709.Found: m/z, 477.15704

Cu-Catalyzed Carboboration of Alkenes: A General Procedure.

A schlenk tube equipped with a magnetic stirring bar was charged with SIMesCuCl (6.0 μmol), an alkene (0.30 mmol), bis(pinacolato)diboron (0.39 mmol), benzyl chloride (0.90 mmol), potassium *tert*-butoxide (1 M solution in THF, 0.45 mmol), and DMF (0.55 mL). The mixture was stirred at RT for the period as specified in Scheme 2, diluted with ethyl acetate before filtration through a Celite plug. The organic solution was washed two times with brine and dried over $MgSO_4$. Evaporation of the solvent followed by gel permeation chromatography (chloroform as an eluent) gave the product. In ^{13}C NMR spectra, boron–bound carbons were not detected because of quadrupolar relaxation.

Dimethyl(phenyl)(1-phenyl-3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-2-yl)silane (6aa)



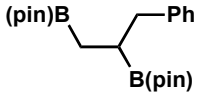
Isolated in 85% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 0.23 (s, 3 H), 0.23 (s, 3 H), 0.75 (dd, *J* = 16.3, 7.4 Hz, 1 H), 0.89 (dd, *J* = 16.2, 6.4 Hz, 1H), 1.14 (s, 6 H), 1.16 (s, 6 H), 1.52–1.57 (m, 1 H), 2.49 (dd, *J* = 13.8, 9.8 Hz, 1 H), 2.76 (dd, *J* = 13.9, 5.7 Hz, 1 H), 7.12–7.16 (m, 3 H), 7.21–7.24 (m, 2 H), 7.33–7.35 (m, 3 H), 7.52–7.54 (m, 2 H)

^{13}C NMR ($CDCl_3$) δ -4.27, -4.21, 22.10, 24.79, 24.96, 38.45, 82.79, 82.87, 125.53, 127.57, 127.98, 128.68, 129.10, 134.10, 138.60, 142.42

HRMS Calcd for $C_{23}H_{33}O_2BNaSi$: $[M+Na]^+$, 403.22351.Found: m/z, 403.22391

2,2'-(3-Phenylpropane-1,2-diyl)bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolane) (6ba)



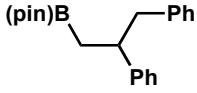
Isolated in 68% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 0.82 (d, *J* = 7.9, 2 H), 1.16 (s, 6 H), 1.19 (s, 6 H), 1.22 (s, 12 H), 1.46 (m, *J* = 7.9 Hz), 2.60 (dd, *J* = 13.4, 8.5 Hz, 1 H), 2.79 (dd, *J* = 13.7, 7.4 Hz), 7.13 (t, *J* = 7.0 Hz, 1 H), 7.18–7.24 (m, 4 H)

^{13}C NMR ($CDCl_3$) δ 24.74, 24.77, 24.82, 24.89, 39.48, 82.86, 82.93, 125.45, 127.91, 129.09, 142.31

HRMS Calcd for $C_{21}H_{34}O_4B_2Na$: $[M+Na]^+$, 395.25354.Found: m/z, 395.25458

2-(2,3-Diphenylpropyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (6ca)



Isolated in 65% as a pale yellow oil

^{1}H NMR ($CDCl_3$) δ 1.06 (s, 6 H), 1.08 (s, 6 H), 1.15–1.25 (m, 2 H), 2.84–2.93 (m, 2 H), 3.11–3.18 (m, 1 H), 7.05 (d, *J* = 7.0 Hz, 2 H), 7.12–7.24 (m, 8 H)

^{13}C NMR ($CDCl_3$) δ 24.53, 24.65, 43.57, 46.17, 82.89, 125.68, 125.84, 127.50, 127.90, 127.94, 129.31, 140.69, 146.41

HRMS Calcd for $C_{21}H_{27}O_2BNa$: $[M+Na]^+$, 345.19963.Found: m/z, 345.19992

References

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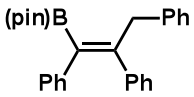
2. Mio, M. J.; Kopel, L. C.; Braum, J. B.; Gadzikwa, T. L.; Hull, K. L.; Brisbois, R. G.; Markworth, C. J.; Grieco, P. A. *Org. Lett*. **2002**, *4*, 3199.
3. Murahashi, S.; Taniguchi, Y.; Imada, Y.; Tanigawa, Y. *J. Org. Chem.* **1989**, *54*, 3292.
4. Kazemi, F.; Massah, A. R.; Javaherian, M. *Tetrahedron* **2007**, *63*, 5083.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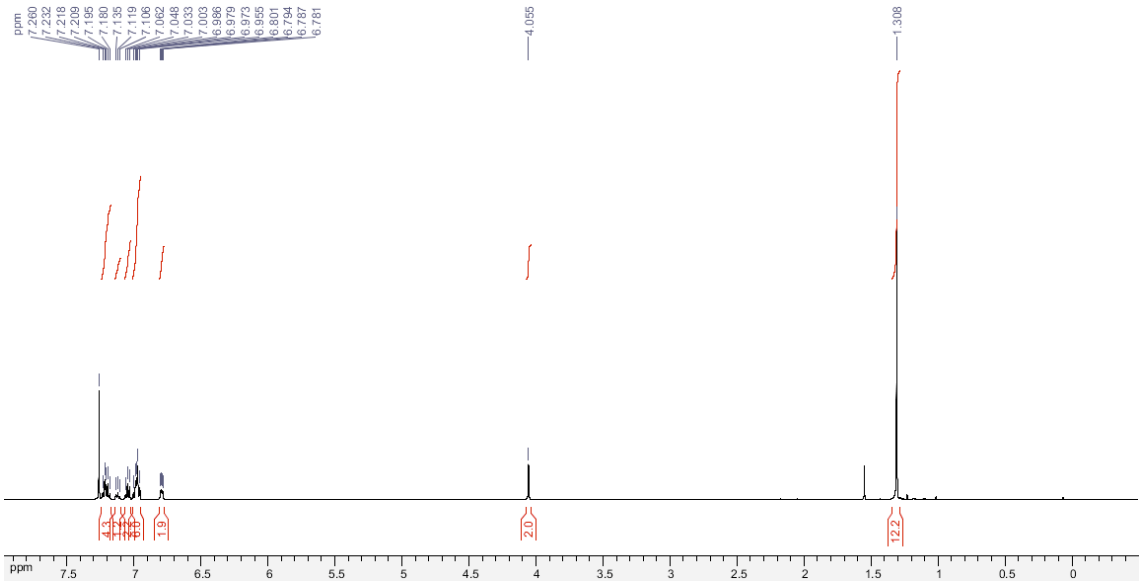
Ph
Ph
Ph

4aa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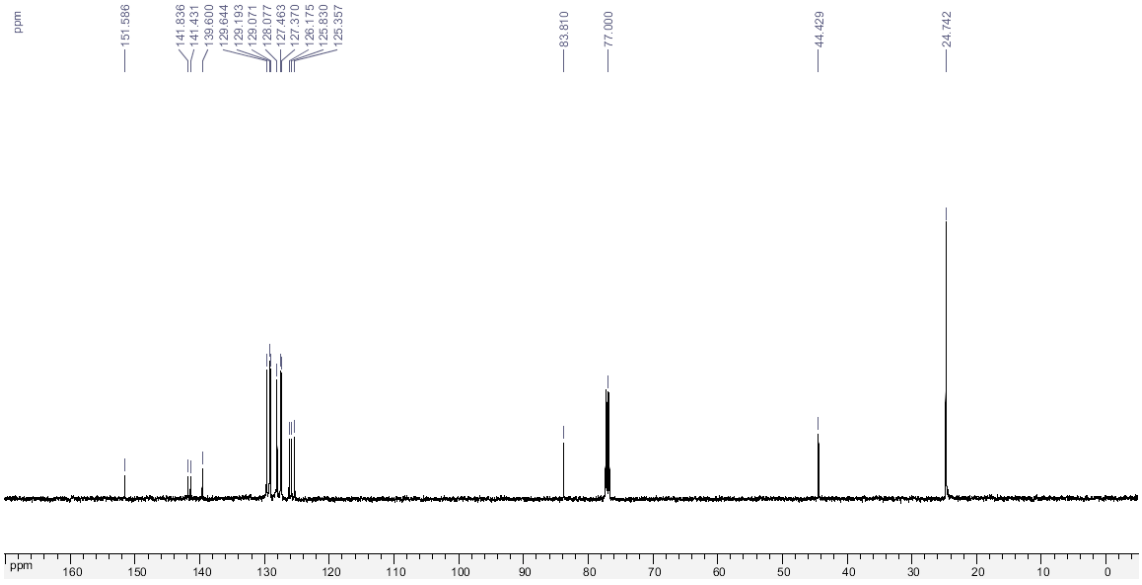
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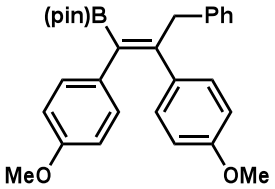
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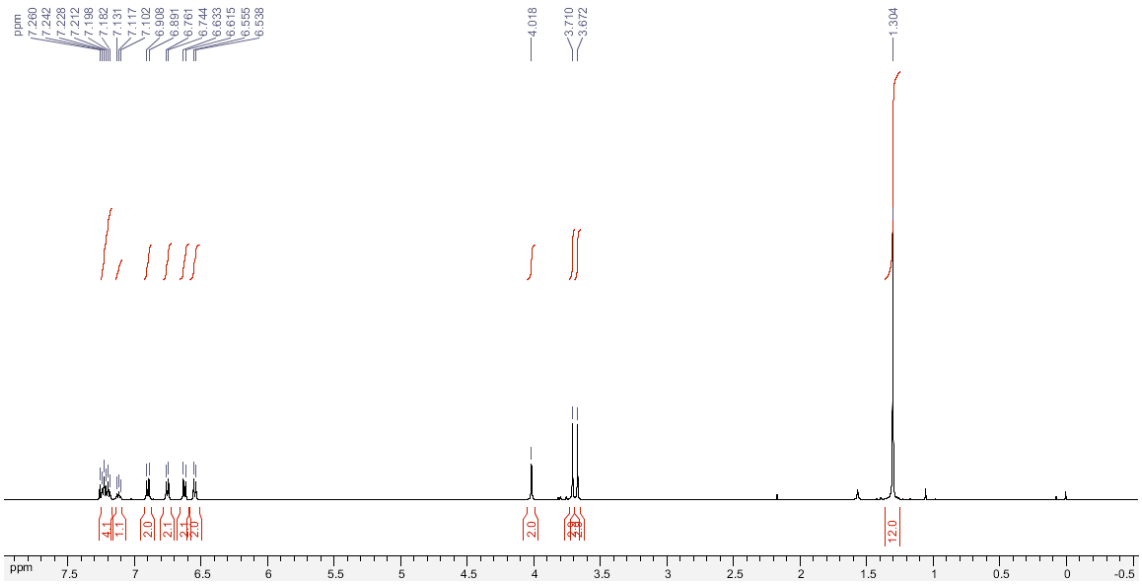
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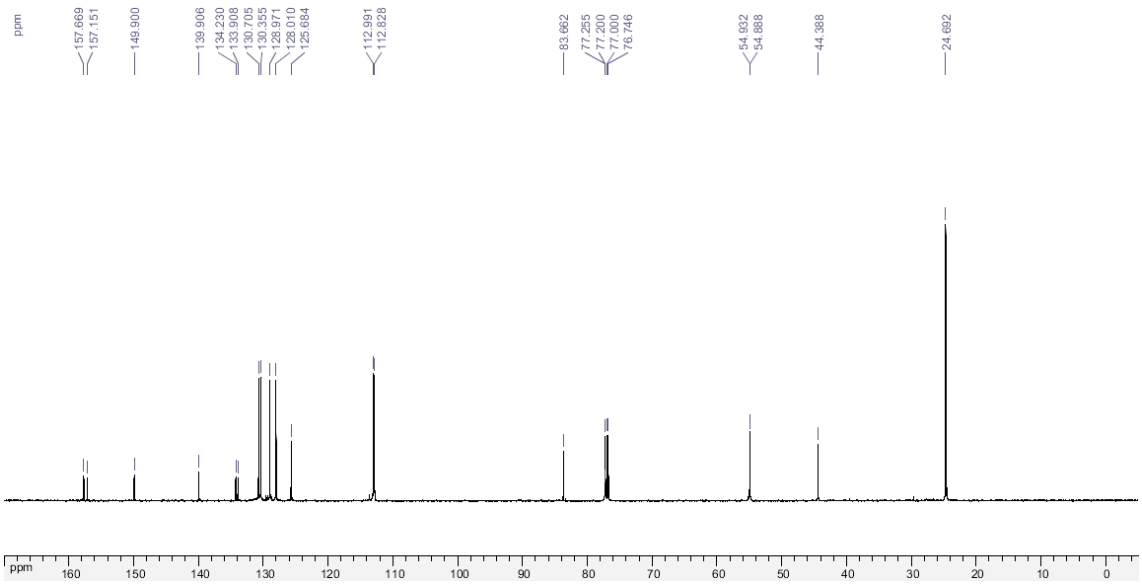
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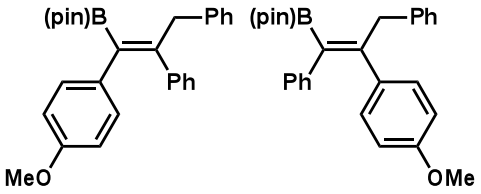
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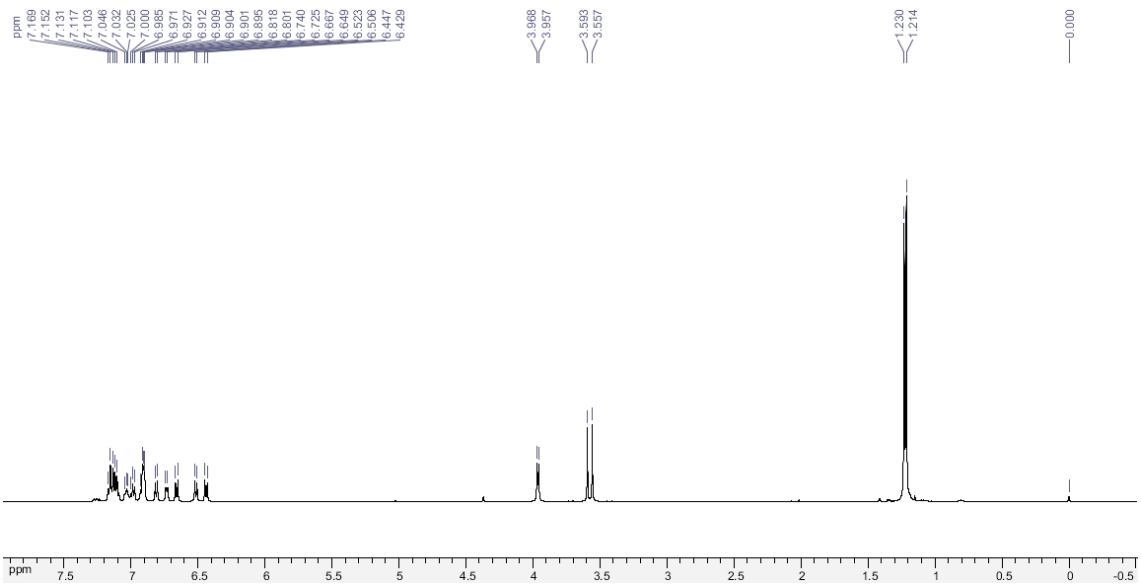
OMe

4ca, 4'ca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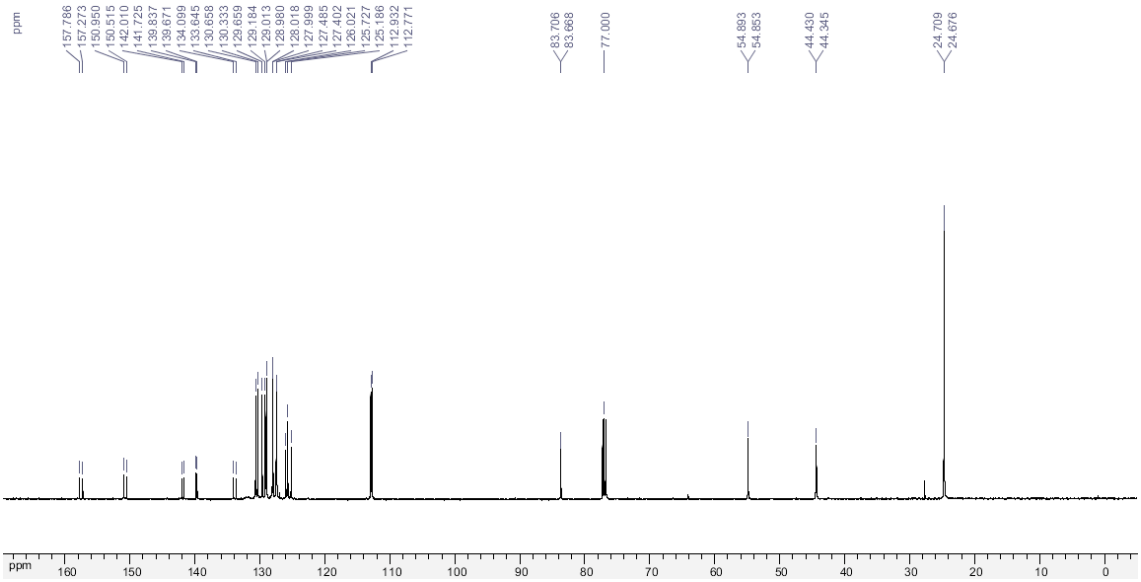
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157.273
150.950
150.515
142.010
141.725
139.837
139.671
134.099
133.645
130.658
130.333
129.959
129.184
129.013
128.980
128.018
127.999
127.485
127.402
126.021
125.727
125.186
112.932
112.771
83.706
83.668
77.000
54.893
54.853
44.430
44.345
24.709
24.676
ppm
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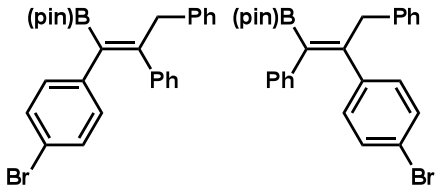
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0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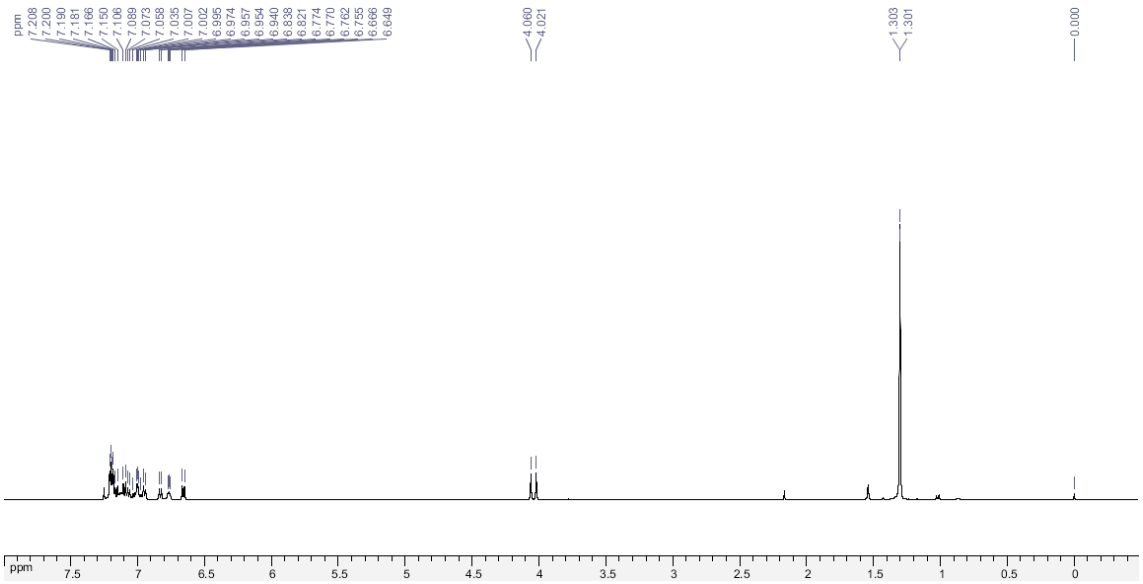
Ph
Ph
Br
(pin)B
Ph
Ph
Br

4da, 4'da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7.200
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7.181
7.166
7.150
7.106
7.089
7.073
7.058
7.035
7.007
7.002
6.995
6.974
6.957
6.954
6.940
6.838
6.821
6.774
6.770
6.762
6.755
6.666
6.649
4.060
4.021
1.303
1.301
0.000
ppm
7.5
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6.5
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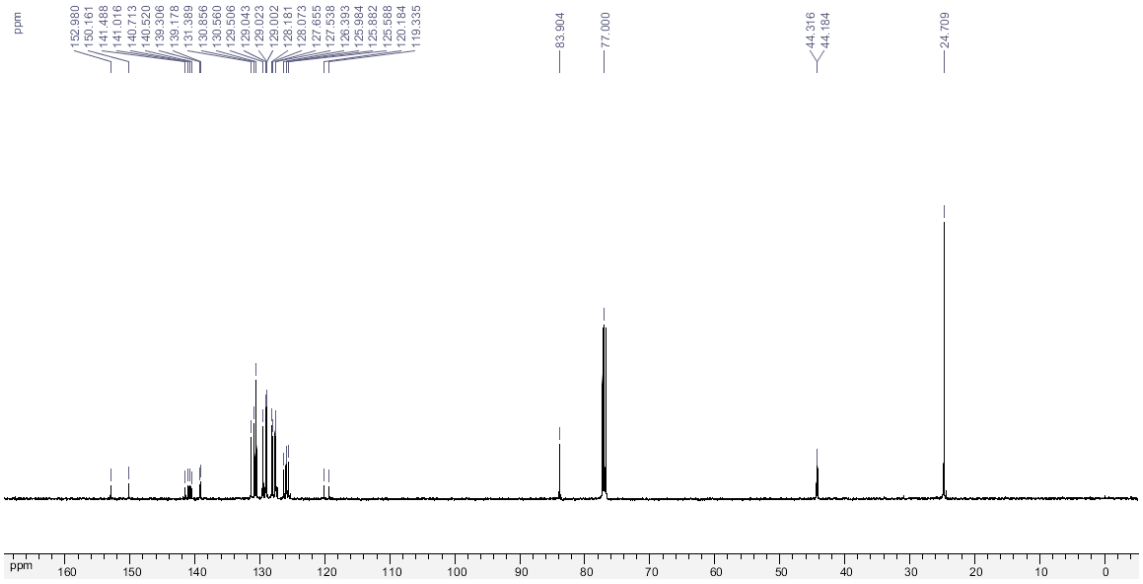
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


ppm
152.980
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141.488
141.016
140.713
140.520
139.306
139.178
131.389
130.856
130.560
129.506
129.043
129.023
129.002
128.181
128.073
127.655
127.538
126.393
125.984
125.882
125.588
120.184
119.335
83.904
77.000
44.316
44.184
24.709
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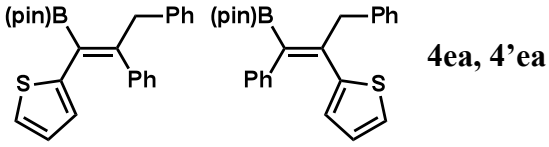
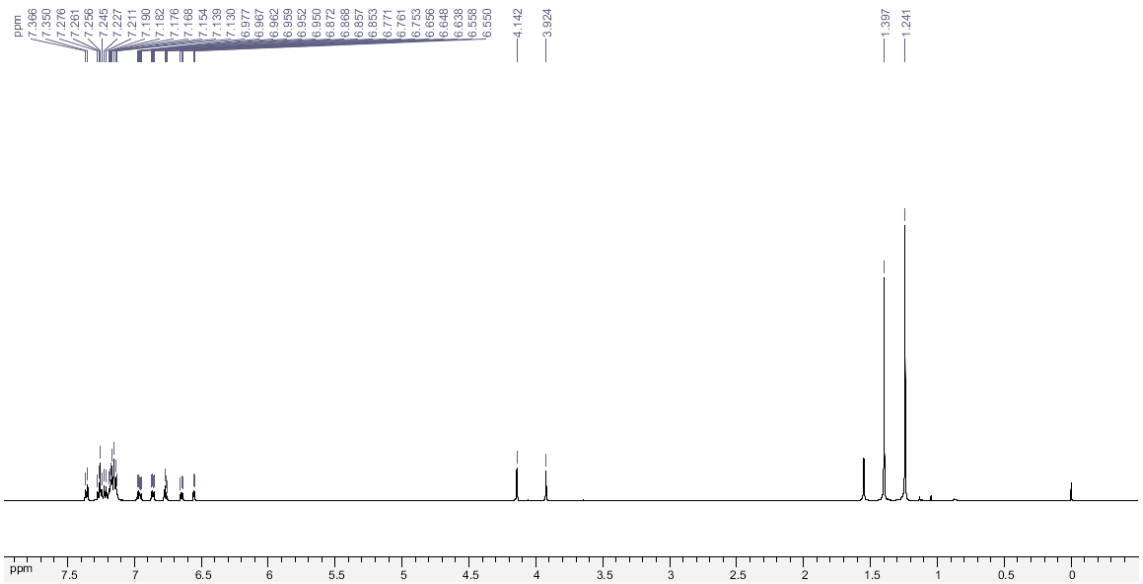

(pin)B
Ph
S
Ph
(pin)B
Ph
Ph
S

4ea, 4'ea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7.366
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7.276
7.261
7.256
7.245
7.227
7.211
7.190
7.182
7.176
7.168
7.154
7.139
7.130
6.977
6.967
6.962
6.959
6.952
6.950
6.872
6.868
6.857
6.853
6.771
6.761
6.753
6.656
6.648
6.638
6.558
6.550
4.142
3.924
1.397
1.241
ppm
7.5
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6.5
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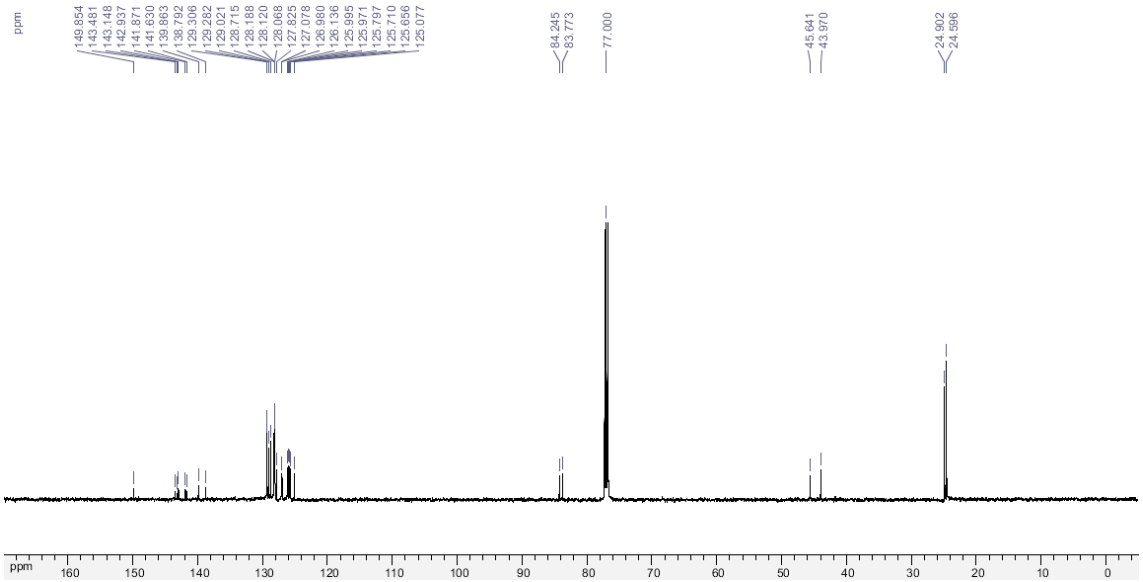
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


ppm
149.854
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143.148
142.937
141.871
141.630
139.863
138.792
129.306
129.282
129.021
128.715
128.188
128.120
128.068
127.825
127.078
126.980
126.136
125.995
125.971
125.797
125.710
125.656
125.077
84.245
83.773
77.000
45.641
43.970
24.902
24.596
ppm
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150
140
130
120
110
100
90
80
70
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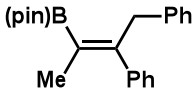
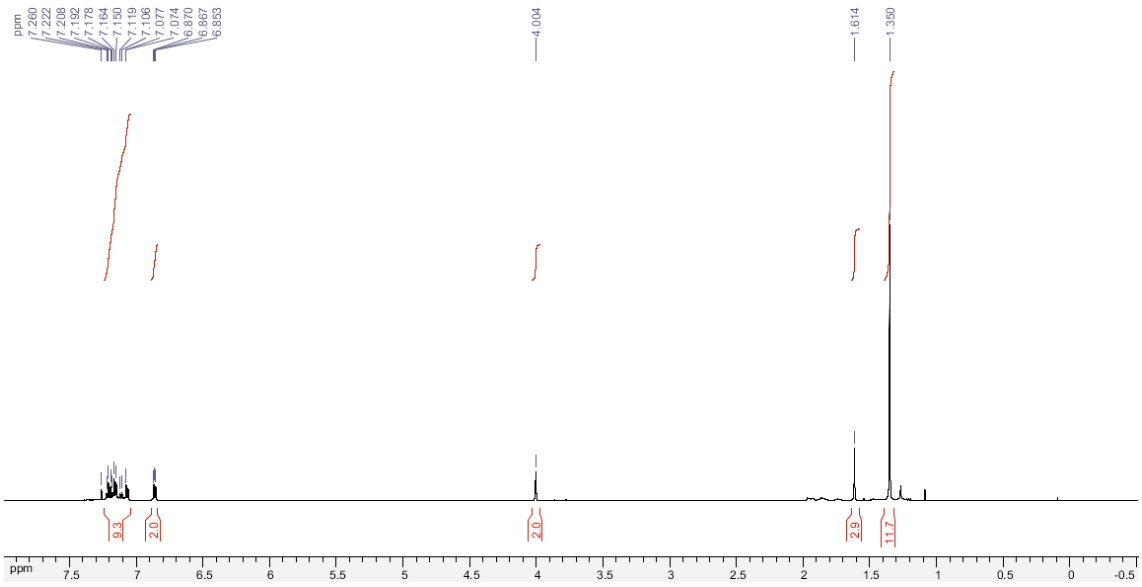
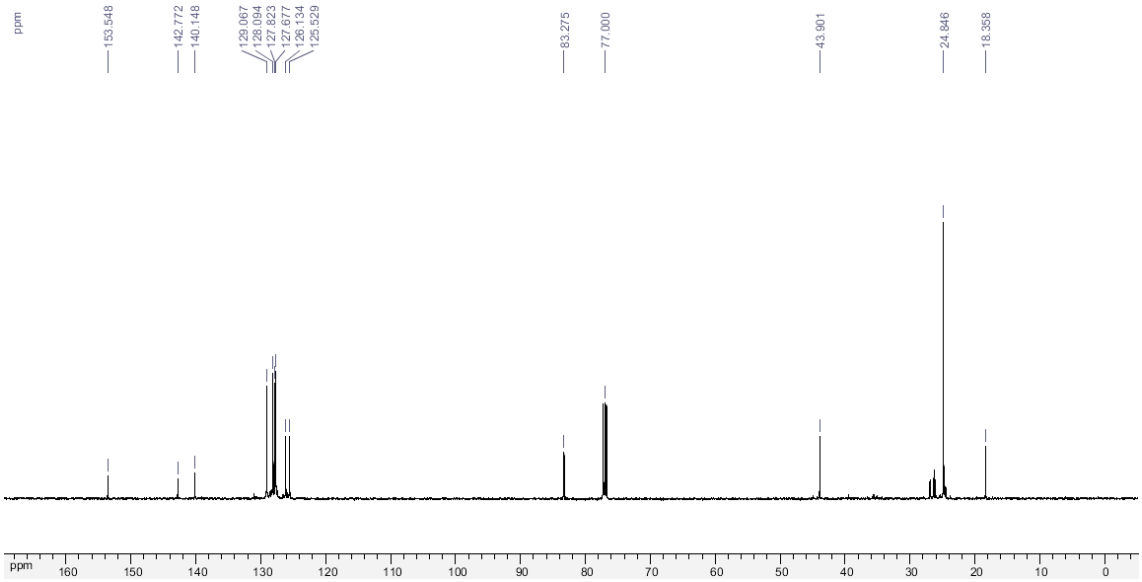
30
20
10
0


(pin)B
Ph
Me
Ph

4fa


ppm
7.260
7.222
7.208
7.192
7.178
7.164
7.150
7.119
7.106
7.077
7.074
6.870
6.867
6.853
4.004
1.614
1.350
9.3
2.0
2.0
2.9
11.7
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5


ppm
153.548
142.772
140.148
129.067
128.094
127.823
127.677
126.134
125.529
83.275
77.000
43.901
24.846
18.358
ppm
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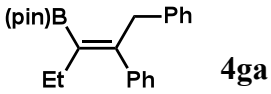
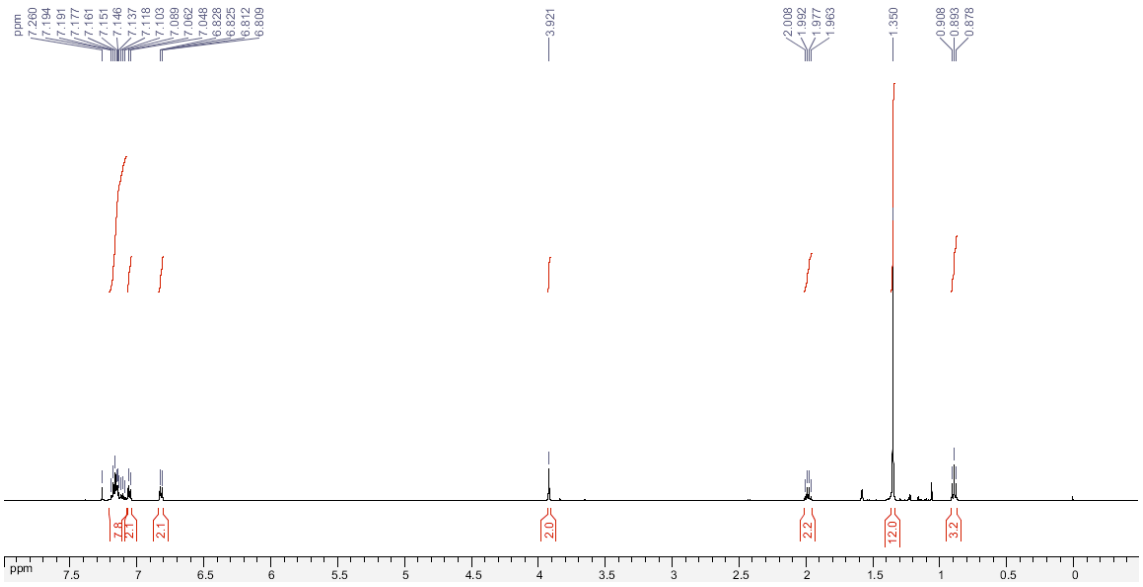
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


(pin)B
Ph
Et
Ph

4ga


ppm
7.260
7.194
7.191
7.177
7.161
7.151
7.146
7.137
7.118
7.103
7.089
7.062
7.048
6.828
6.825
6.812
6.809
3.921
2.008
1.992
1.977
1.963
1.350
0.908
0.893
0.878
7.8
2.1
2.1
2.0
2.2
12.0
3.2
ppm
7.5
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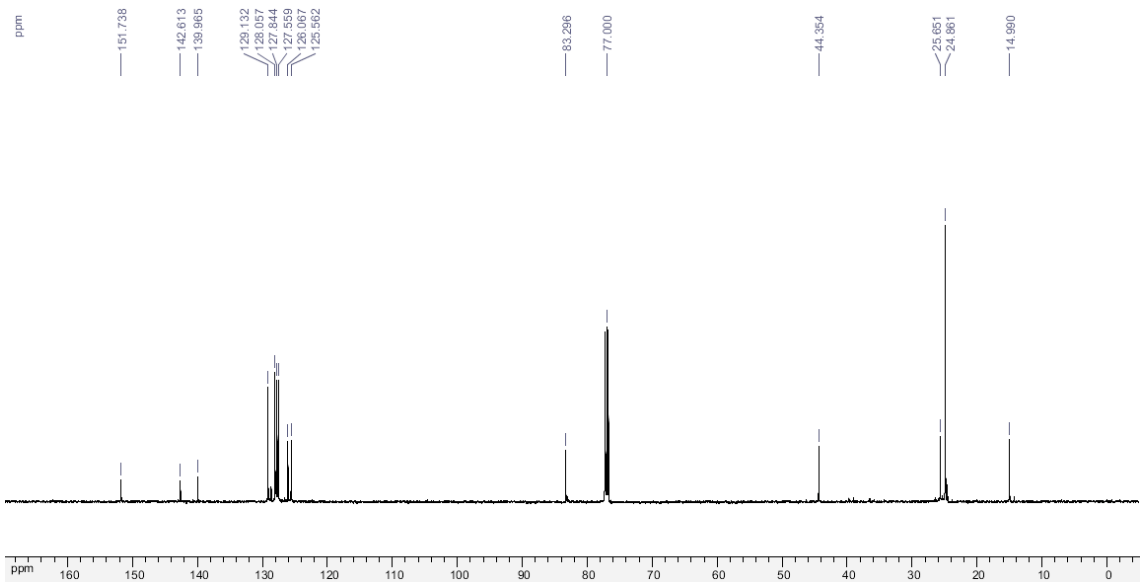
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


ppm
151.738
142.613
139.965
129.132
128.057
127.844
127.559
126.067
125.562
83.296
77.000
44.354
25.651
24.861
14.990
ppm
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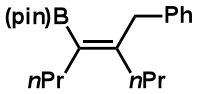
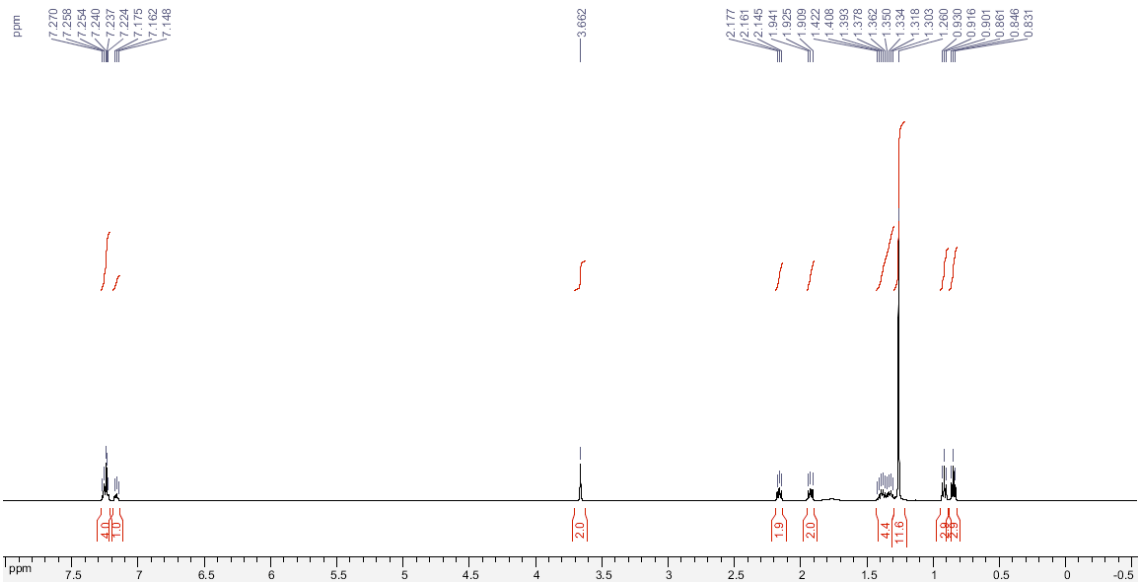
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


(pin)B
Ph
nPr
nPr

4ha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7.254
7.240
7.237
7.224
7.175
7.162
7.148
3.662
2.177
2.161
2.145
1.941
1.925
1.909
1.422
1.408
1.393
1.378
1.362
1.350
1.334
1.318
1.303
1.260
0.930
0.916
0.901
0.861
0.846
0.831
4.0
1.0
2.0
1.9
2.0
4.4
11.6
2.0
2.9
ppm
7.5
7
6.5
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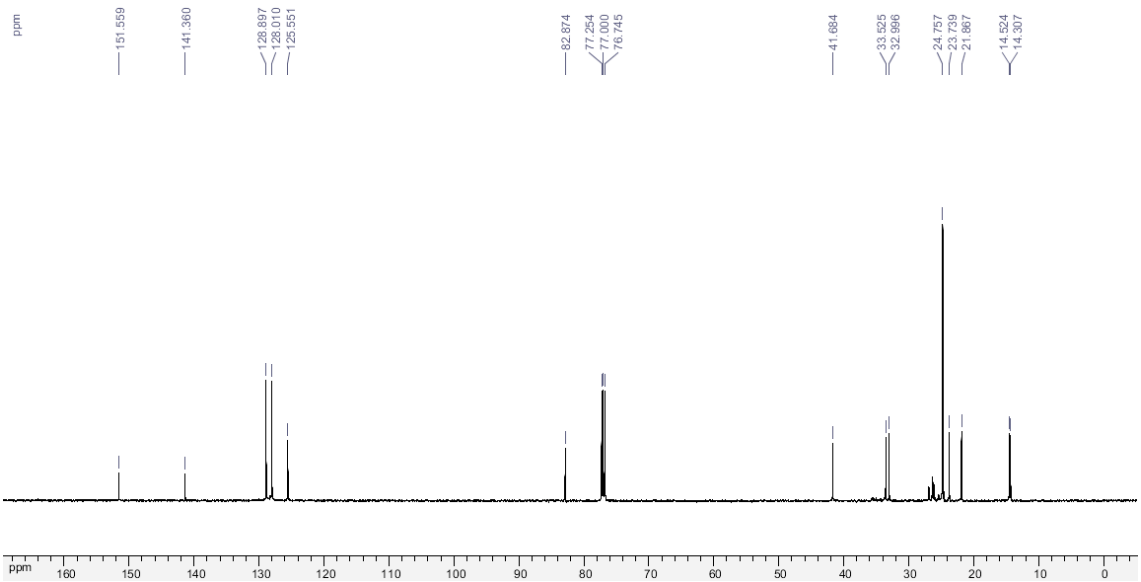
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5


ppm
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128.897
128.010
125.551
82.874
77.254
77.000
76.745
41.684
33.525
32.996
24.757
23.739
21.867
14.524
14.307
ppm
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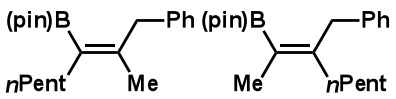
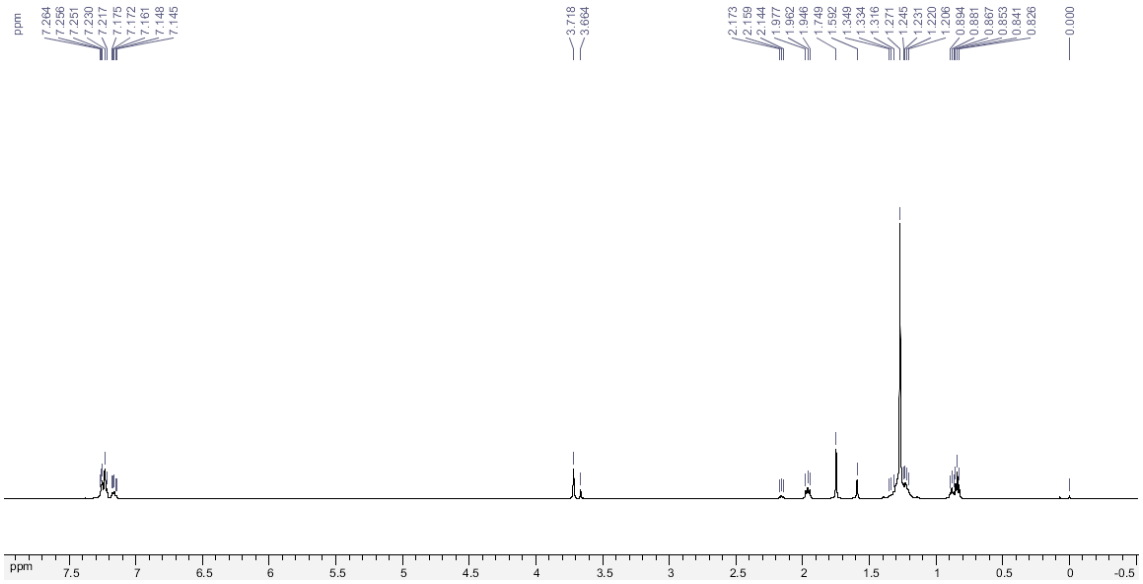
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


(pin)B
Ph
nPent
Me
(pin)B
Ph
Me
nPent

4ia, 4'ia


ppm
7.264
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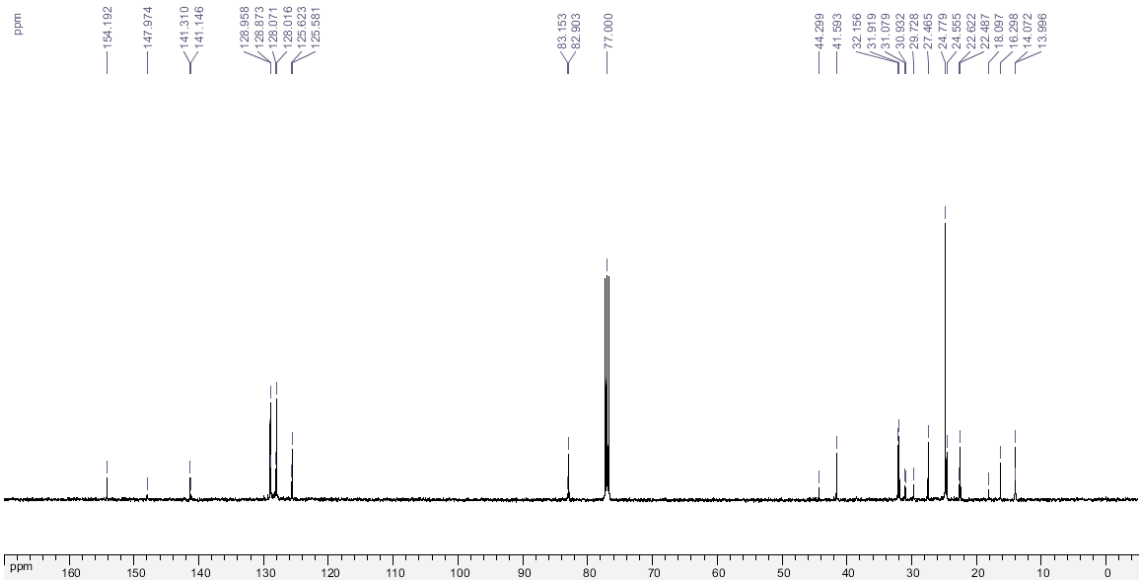
7.230
7.217
7.175
7.172
7.161
7.148
7.145
3.718
3.664
2.173
2.159
2.144
1.977
1.962
1.946
1.749
1.592
1.349
1.334
1.316
1.271
1.245
1.231
1.220
1.206
0.894
0.881
0.867
0.853
0.841
0.826
0.000
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5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141.146
128.958
128.873
128.071
128.016
125.623
125.581
83.153
82.903
77.000
44.299
41.593
32.156
31.919
31.079
30.932
29.728
27.465
24.779
24.555
22.622
22.487
18.097
16.298
14.072
13.996
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140
130
120
110
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70
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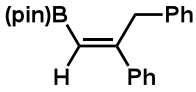
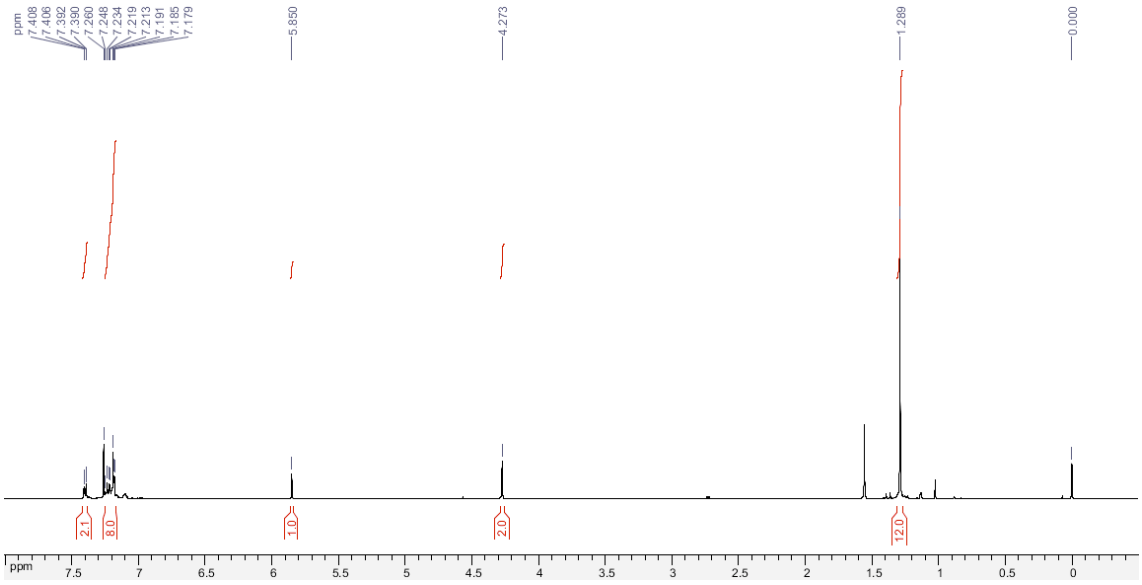

(pin)B
Ph
H
Ph

4ja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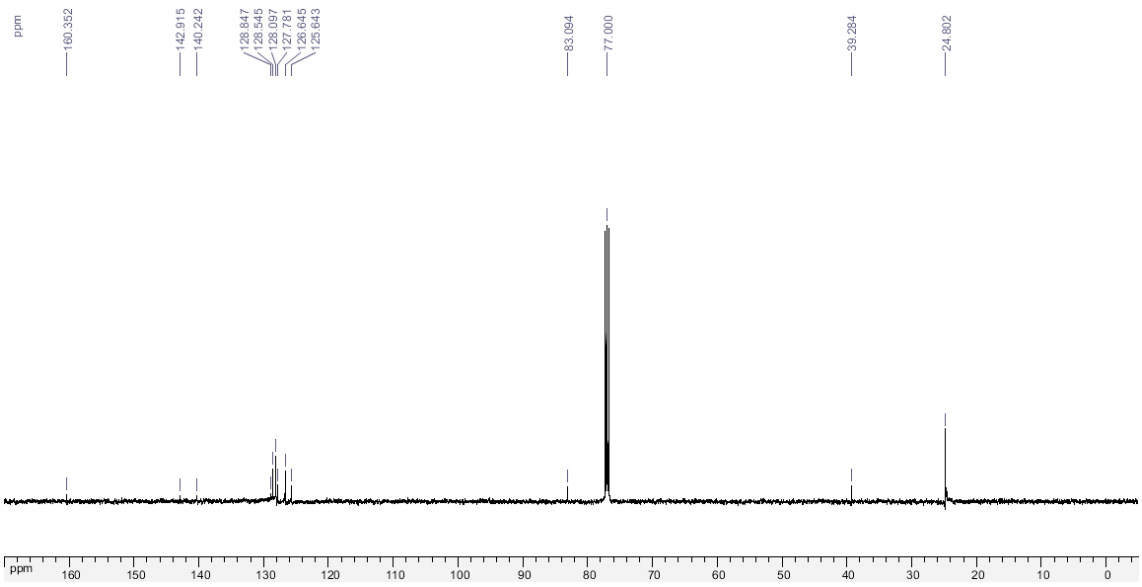
7.390
7.260
7.248
7.234
7.219
7.213
7.191
7.185
7.179
5.850
4.273
1.289
0.000
2.1
8.0
1.0
2.0
12.0
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


ppm
160.352
142.915
140.242
128.847
128.545
128.097
127.781
126.645
125.643
83.094
77.000
39.284
24.802
ppm
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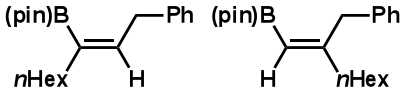
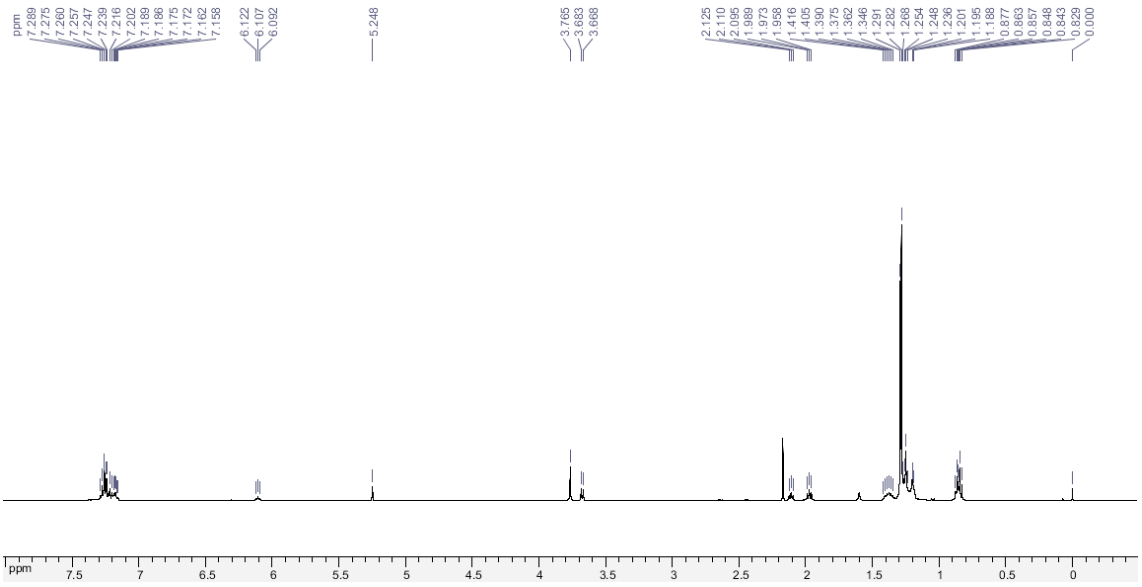
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


(pin)B
Ph
nHex
H
(pin)B
Ph
H
nHex

4ka, 4'ka


ppm
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7.257
7.247
7.239
7.216
7.202
7.189
7.186
7.175
7.172
7.162
7.158
6.122
6.107
6.092
5.248
3.765
3.683
3.668
2.125
2.110
2.095
1.989
1.973
1.958
1.416
1.405
1.390
1.375
1.362
1.346
1.291
1.282
1.268
1.254
1.248
1.236
1.201
1.195
1.188
0.877
0.863
0.857
0.848
0.843
0.829
0.000
ppm
7.5
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6.5
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5.5
5
4.5
4
3.5
3
2.5
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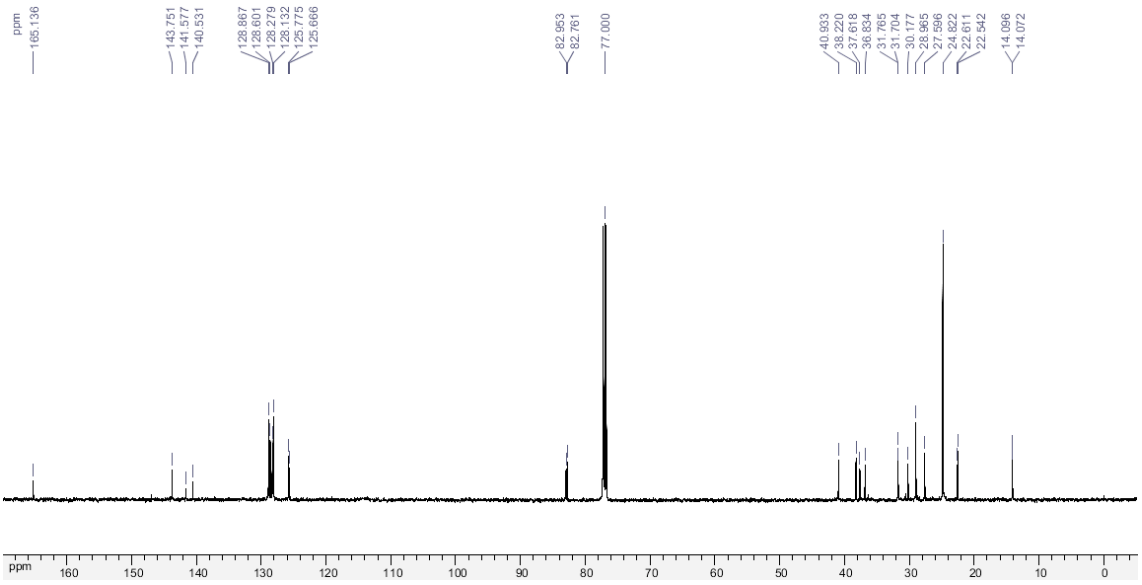
1.5
1
0.5
0


ppm
165.136
143.751
141.577
140.531
128.867
128.601
128.279
128.132
125.775
125.666
82.953
82.761
77.000
40.933
38.220
37.618
36.834
31.765
31.704
30.177
28.965
27.896
24.822
22.611
22.542
14.096
14.072
ppm
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140
130
120
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70
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40
30
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10
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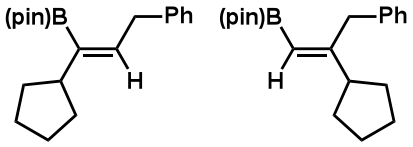
(pin)B
Ph
H
(pin)B
Ph
H

4la, 4'la


ppm
7.291
7.276
7.257
7.245
7.222
7.207
7.187
7.173
7.158
6.078
6.063
6.047
5.334
3.830
3.624
3.608
2.549
2.532
2.515
2.499
2.480
2.364
2.347
2.330
2.313
2.296
1.762
1.691
1.641
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1.521
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1.382
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1.299
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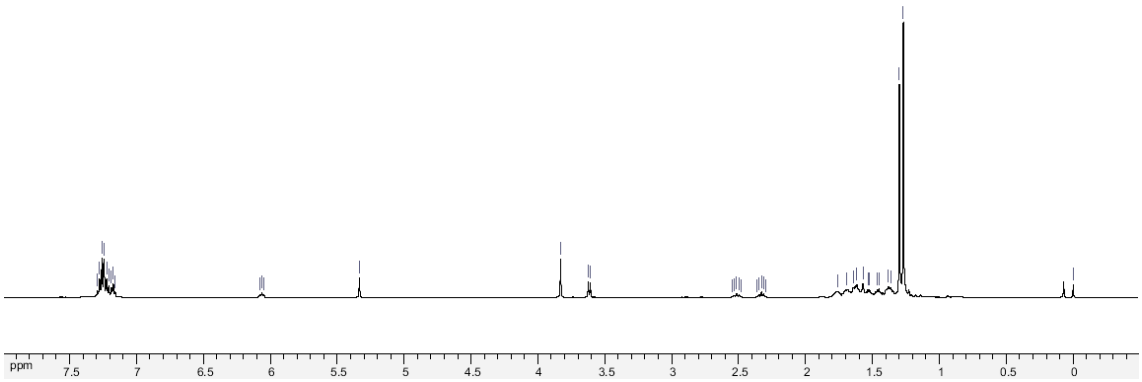
0.000


ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


ppm
168.323
141.549
140.700
139.665
128.828
128.586
128.269
128.077
125.681
125.668
83.016
82.740
77.000
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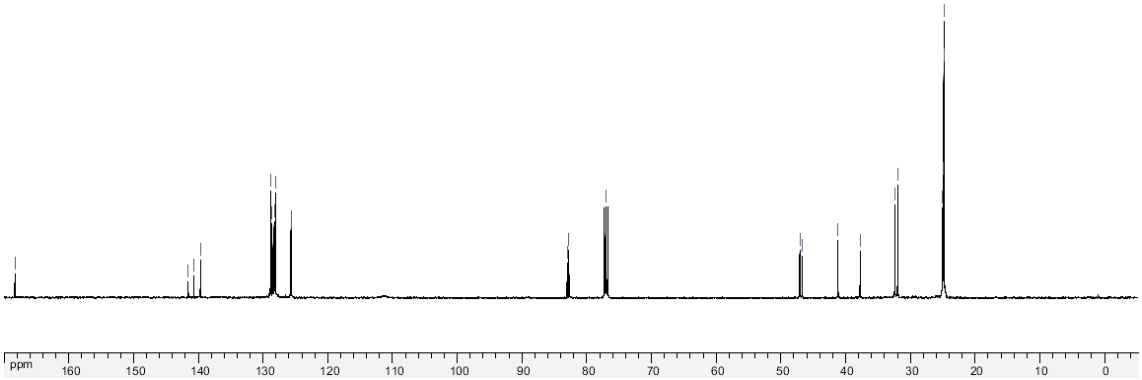
31.961
25.077
24.983
24.839
24.796


ppm
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150
140
130
120
110
100
90
80
70
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50
40
30
20
10
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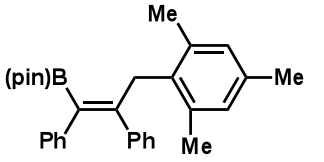
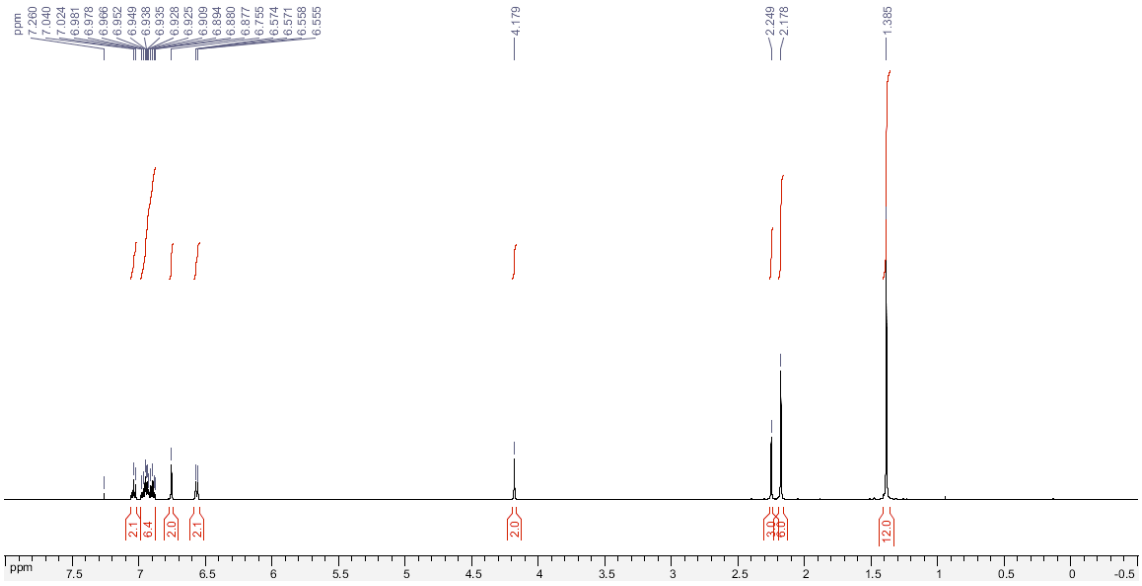

Me
(pin)B
Me
Ph
Ph
Me

4ab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7.040
7.024
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6.978
6.966
6.952
6.949
6.938
6.935
6.928
6.925
6.909
6.894
6.880
6.877
6.755
6.574
6.571
6.558
6.555
4.179
2.249
2.178
1.385
2.1
6.4
2.0
2.1
2.0
3.0
6.0
12.0
ppm
7.5
7
6.5
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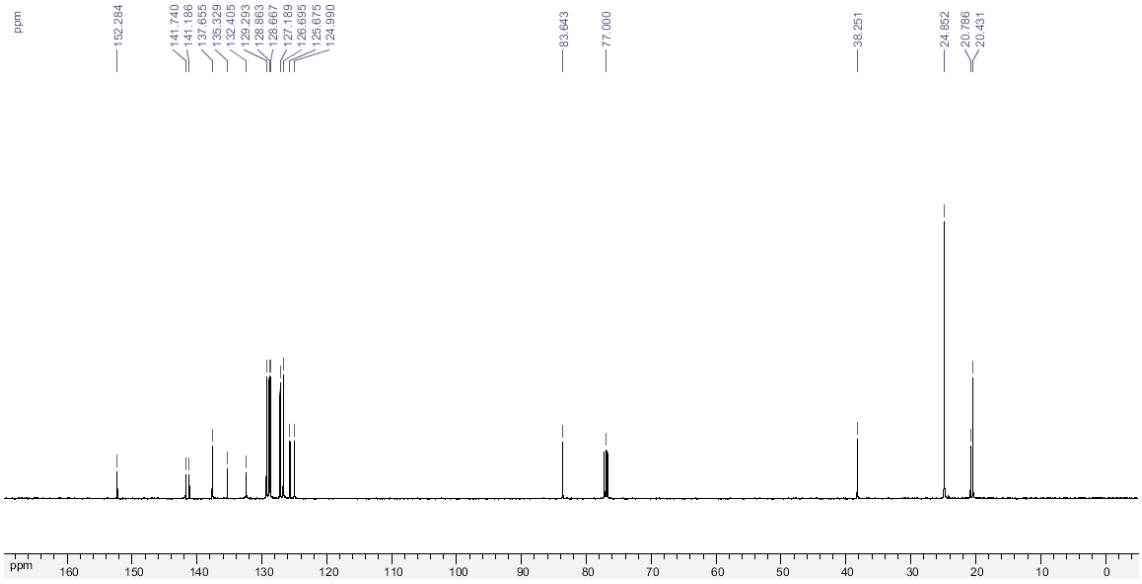
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5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152.284
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141.186
137.655
135.329
132.405
129.293
128.863
128.667
127.189
126.695
125.675
124.990
83.643
77.000
38.251
24.852
20.786
20.431
ppm
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150
140
130
120
110
100
90
80
70
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50
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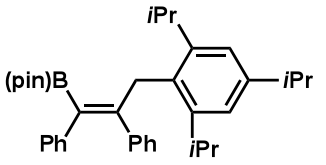
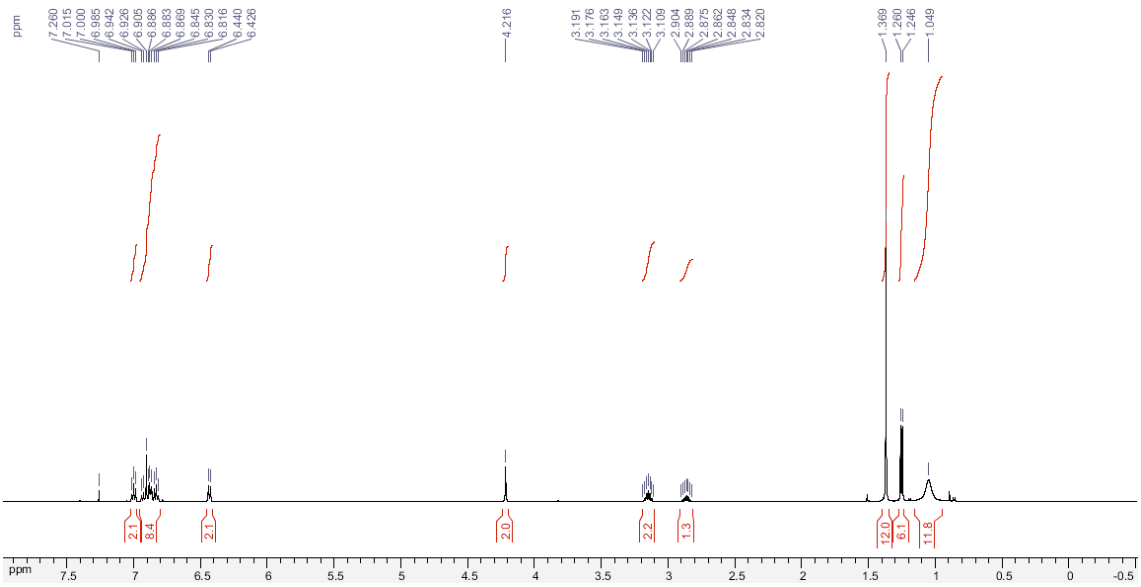
30
20
10
0


iPr
(pin)B
iPr
Ph
Ph
iPr

4ac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7.000
6.985
6.942
6.926
6.905
6.886
6.883
6.869
6.845
6.830
6.516
6.440
6.426
4.216
3.191
3.176
3.163
3.149
3.136
3.122
3.109
2.904
2.889
2.875
2.862
2.848
2.834
2.820
1.369
1.260
1.246
1.049
2.1
8.4
2.1
2.0
2.2
1.3
12.0
6.1
11.8
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
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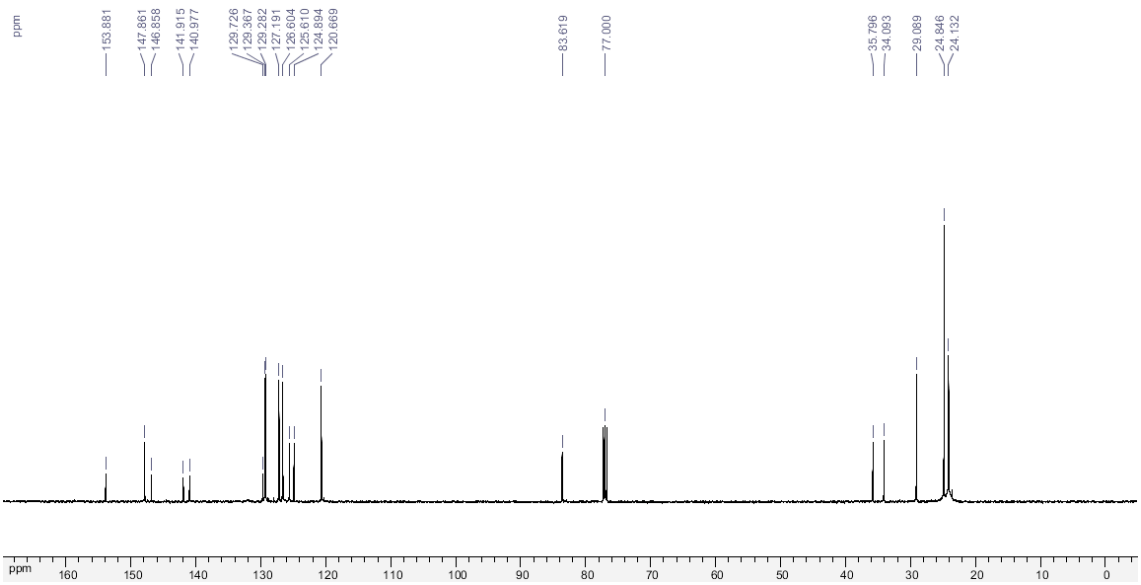
-0.5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127.191
126.604
125.610
124.894
120.669
83.619
77.000
35.796
34.093
29.089
24.846
24.132
ppm
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150
140
130
120
110
100
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80
70
60
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40
30
20
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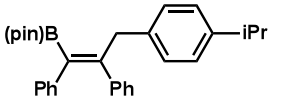
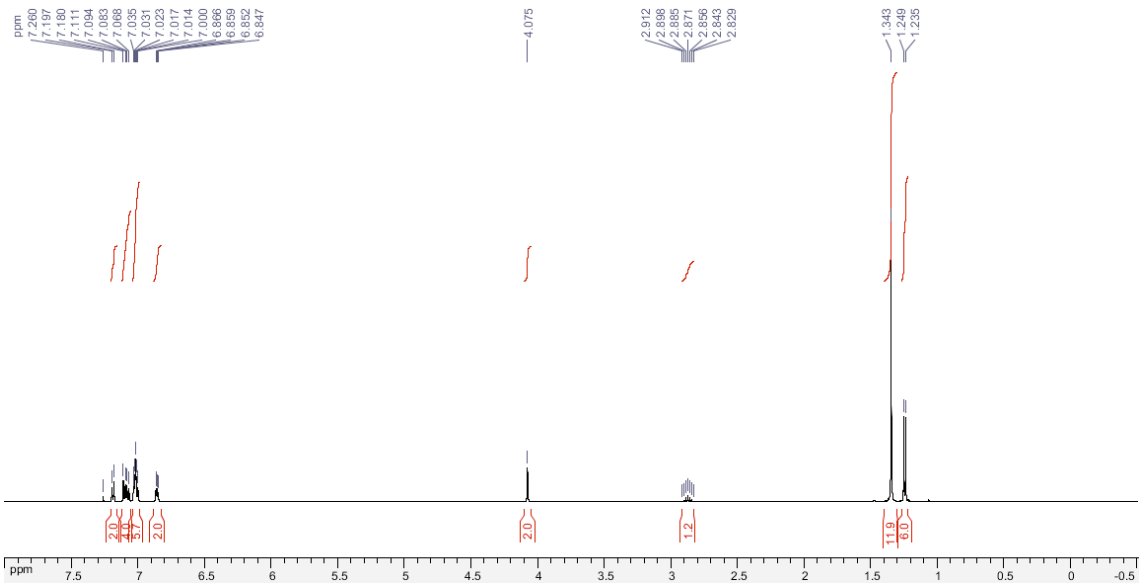

(pin)B
iPr
Ph
Ph

4ad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7.111
7.094
7.083
7.068
7.035
7.031
7.023
7.017
7.014
7.000
6.866
6.859
6.852
6.847
4.075
2.912
2.898
2.885
2.871
2.856
2.843
2.829
1.343
1.249
1.235
2.0
4.0
5.7
2.0
2.0
1.2
11.9
6.0
ppm
7.5
7
6.5
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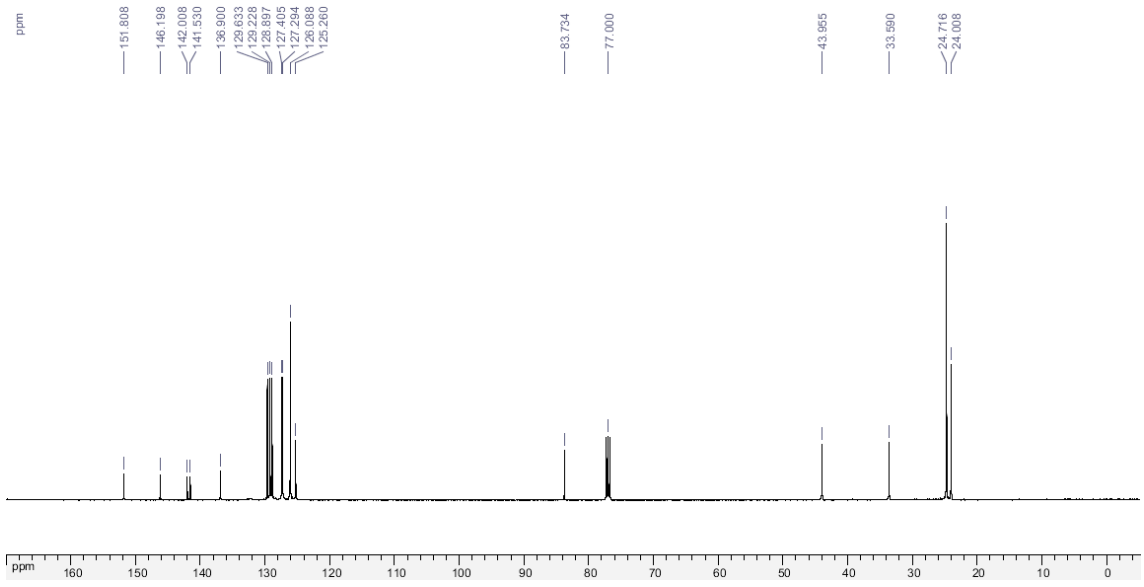
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5


ppm
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142.008
141.530
138.900
129.633
129.228
128.897
127.405
127.294
126.088
125.260
83.734
77.000
43.955
33.590
24.716
24.008
ppm
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70
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30
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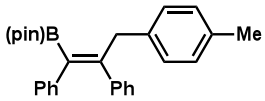
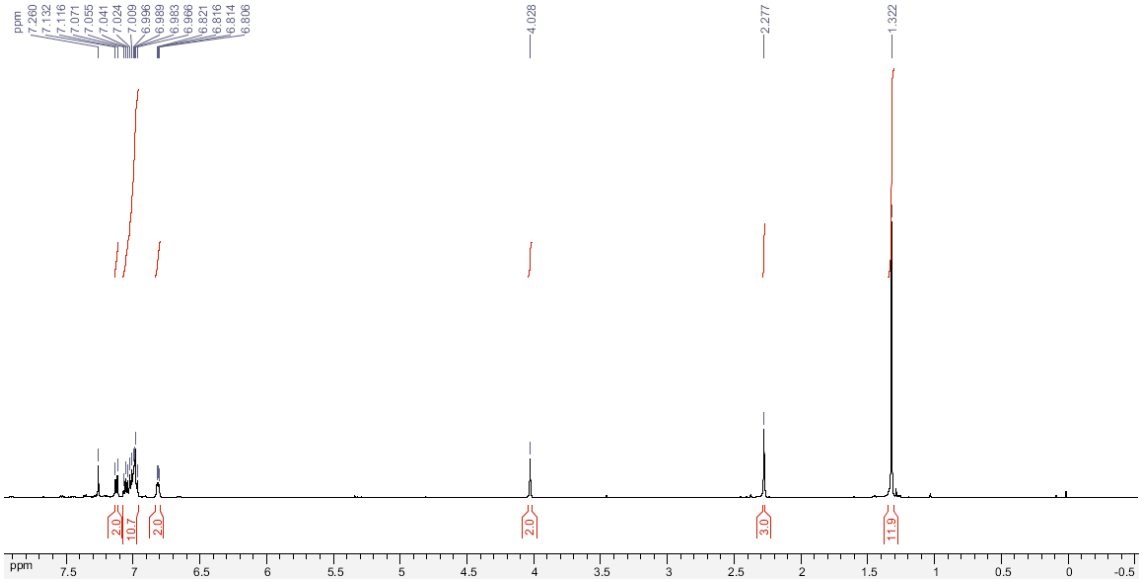
10
0


(pin)B
Me
Ph
Ph

4ae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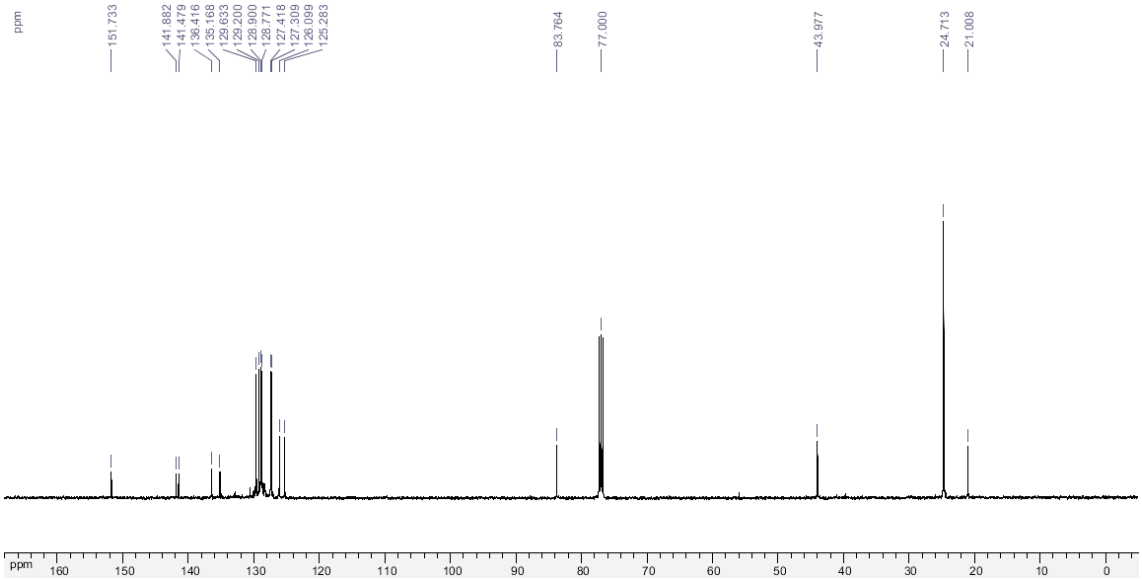
7.116
7.071
7.055
7.041
7.024
7.009
6.996
6.989
6.983
6.966
6.821
6.816
6.814
6.806
4.028
2.277
1.322
2.0
10.7
2.0
2.0
3.0
11.9
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5


ppm
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136.416
135.168
129.633
129.200
128.900
128.771
127.418
127.309
126.099
125.283
83.764
77.000
43.977
24.713
21.008
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140
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120
110
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70
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30
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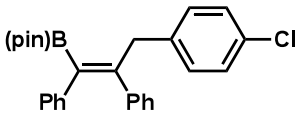
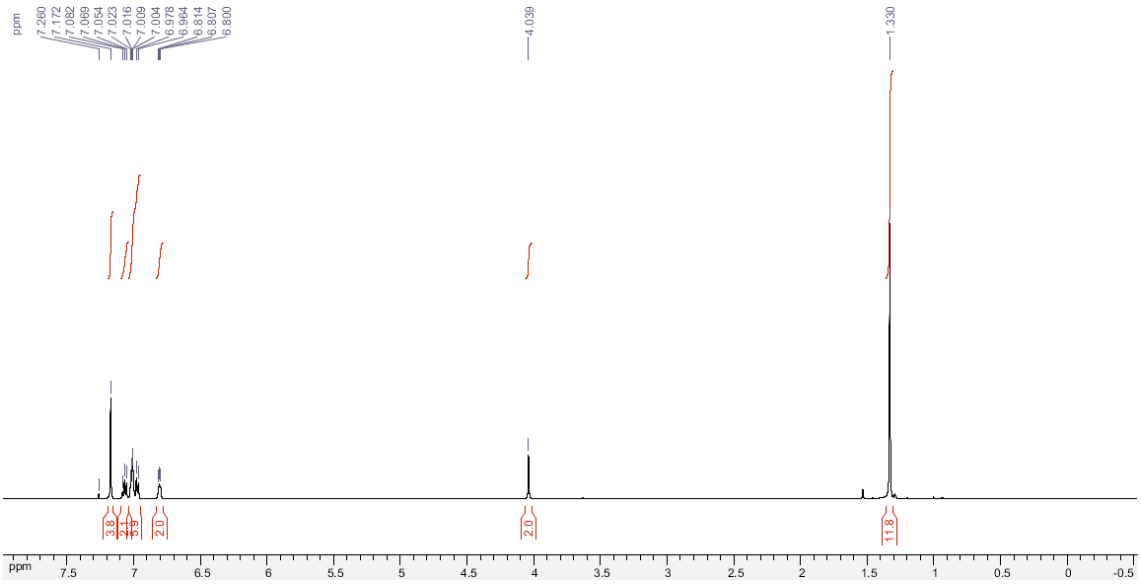
10
0


(pin)B
Cl
Ph
Ph

4af


ppm
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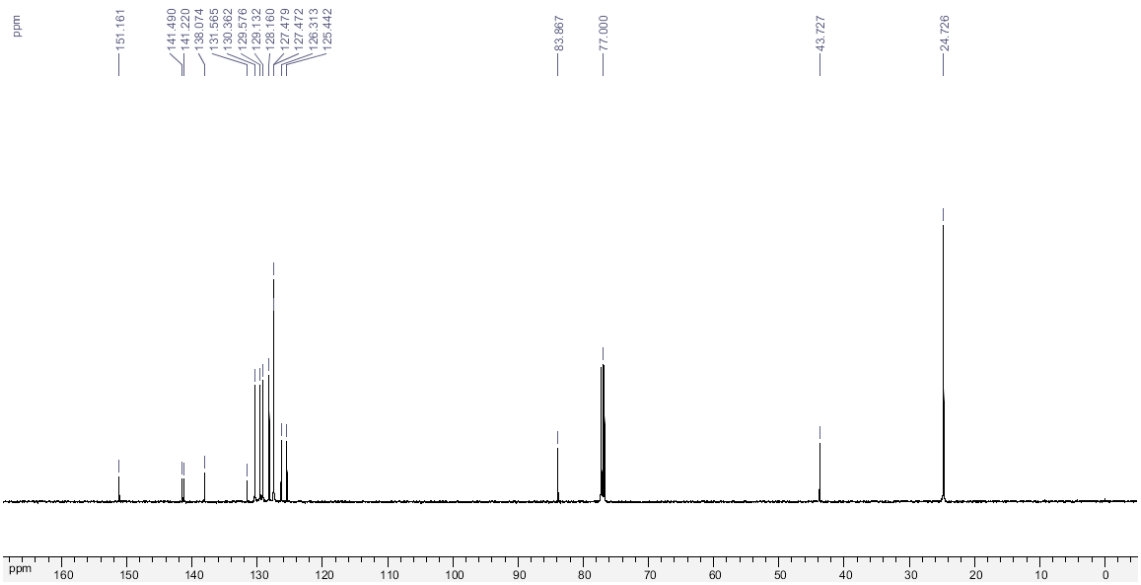
7.082
7.069
7.054
7.023
7.016
7.009
7.004
6.978
6.964
6.814
6.807
6.800
4.039
1.330
3.8
2.1
1.9
2.0
2.0
11.8
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5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141.220
138.074
131.565
130.362
129.576
129.132
128.160
127.479
127.472
126.313
125.442
83.867
77.000
43.727
24.726
ppm
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150
140
130
120
110
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70
60
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30
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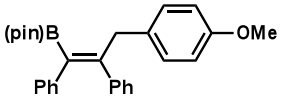
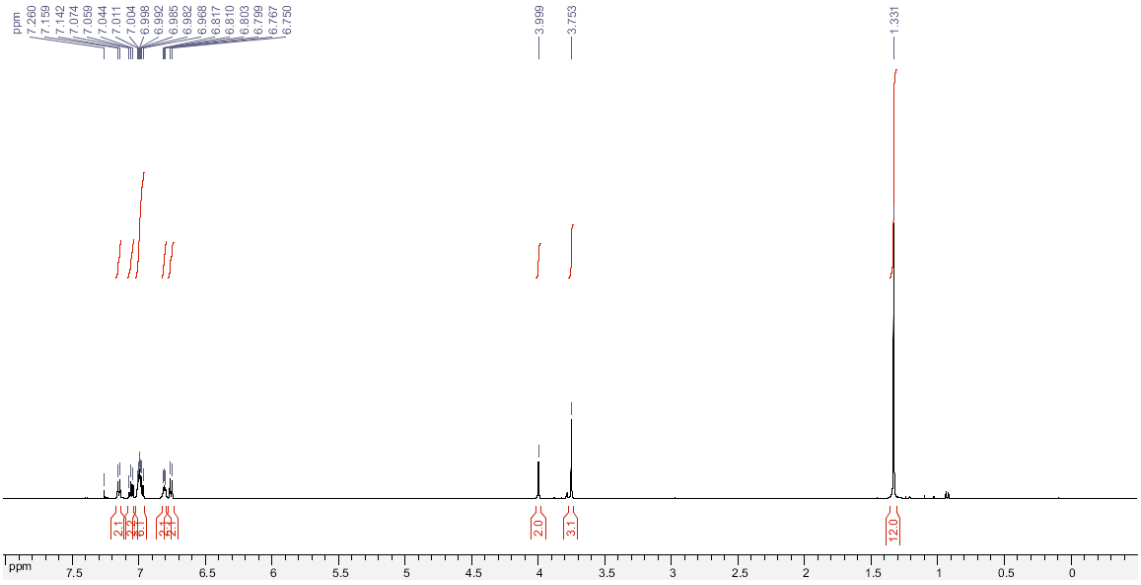
10
0


(pin)B
OMe
Ph
Ph

4ag


ppm
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7.074
7.059
7.044
7.011
7.004
6.998
6.992
6.985
6.982
6.968
6.817
6.810
6.803
6.799
6.767
6.750
3.999
3.753
1.331
2.1
2.1
6.1
2.1
2.1
2.0
3.1
12.0
ppm
7.5
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6.5
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5.5
5
4.5
4
3.5
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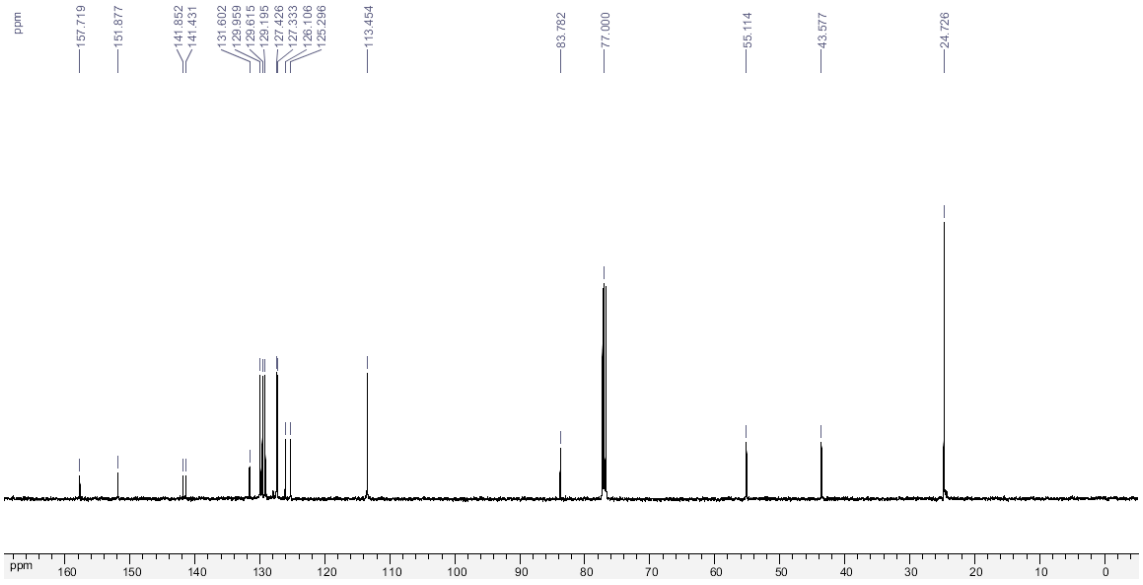
2.5
2
1.5
1
0.5
0


ppm
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141.431
131.602
129.959
129.615
129.195
127.426
127.333
126.106
125.296
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77.000
55.114
43.577
24.726
ppm
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150
140
130
120
110
100
90
80
70
60
50
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30
20
10
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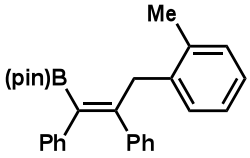
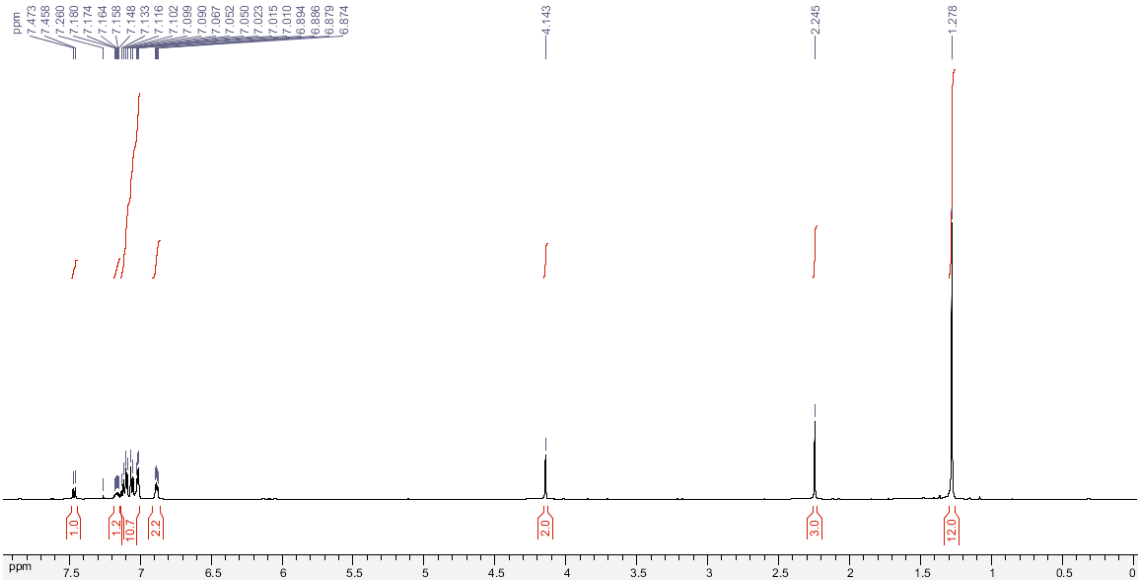

Me
(pin)B
Ph
Ph

4ab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7.164
7.158
7.148
7.133
7.116
7.102
7.099
7.090
7.067
7.052
7.050
7.023
7.015
7.010
6.894
6.886
6.879
6.874
4.143
2.245
1.278
1.0
1.2
10.7
2.2
2.0
3.0
12.0
ppm
7.5
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5.5
5
4.5
4
3.5
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2.5
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1
0.5
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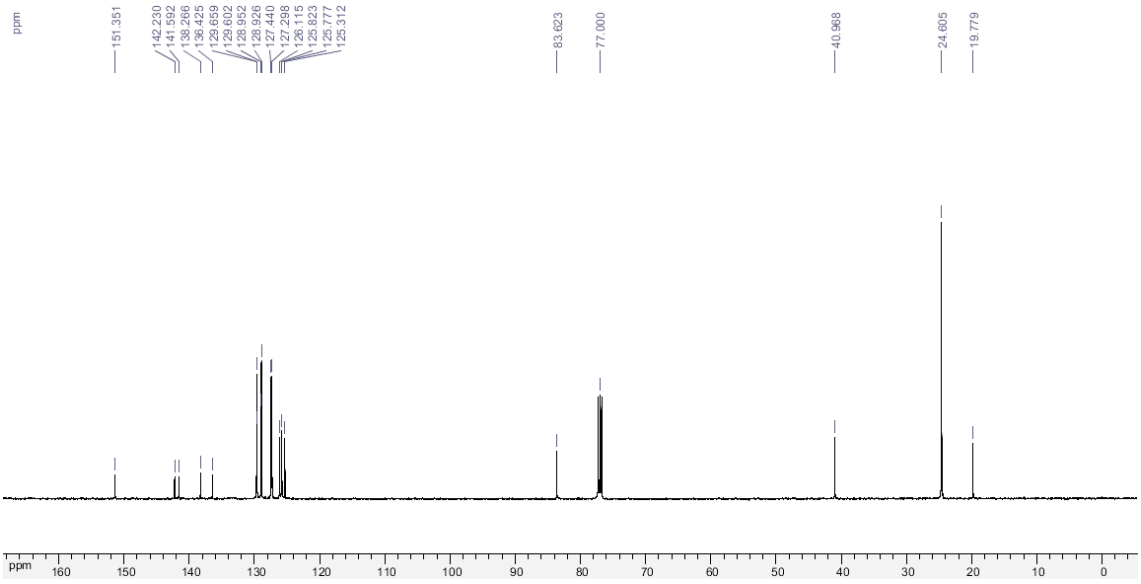
ppm
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129.602
128.952
128.926
127.440
127.298
126.115
125.823
125.777
125.312
83.623
77.000
40.968
24.605
19.779
ppm
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150
140
130
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110
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70
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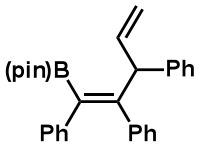
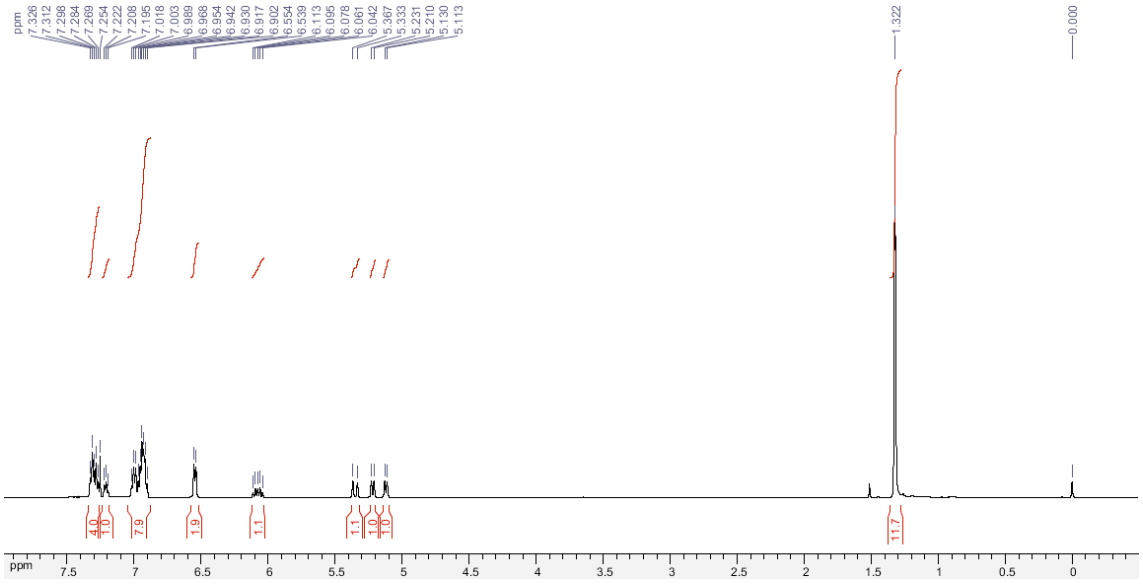
30
20
10
0


(pin)B
Ph
Ph
Ph

4ai


ppm
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7.269
7.254
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7.195
7.018
7.003
6.989
6.968
6.954
6.942
6.930
6.917
6.902
6.554
6.539
6.113
6.095
6.078
6.061
6.042
5.367
5.333
5.231
5.210
5.130
5.113
1.322
0.000
4.0
1.0
7.9
1.9
1.1
1.1
1.0
1.0
11.7
ppm
7.5
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6.5
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5.5
5
4.5
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3.5
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2.5
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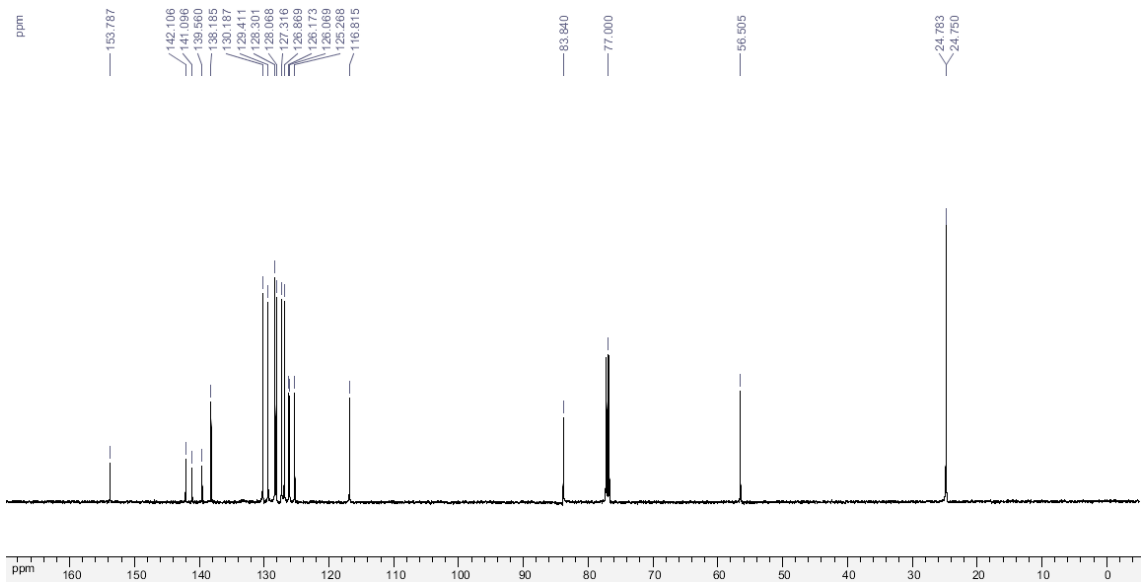
1.5
1
0.5
0


ppm
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139.560
138.185
130.187
129.411
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128.068
127.316
126.869
126.173
126.069
125.268
116.815
83.840
77.000
56.505
24.783
24.750
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150
140
130
120
110
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70
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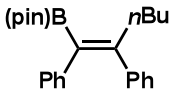
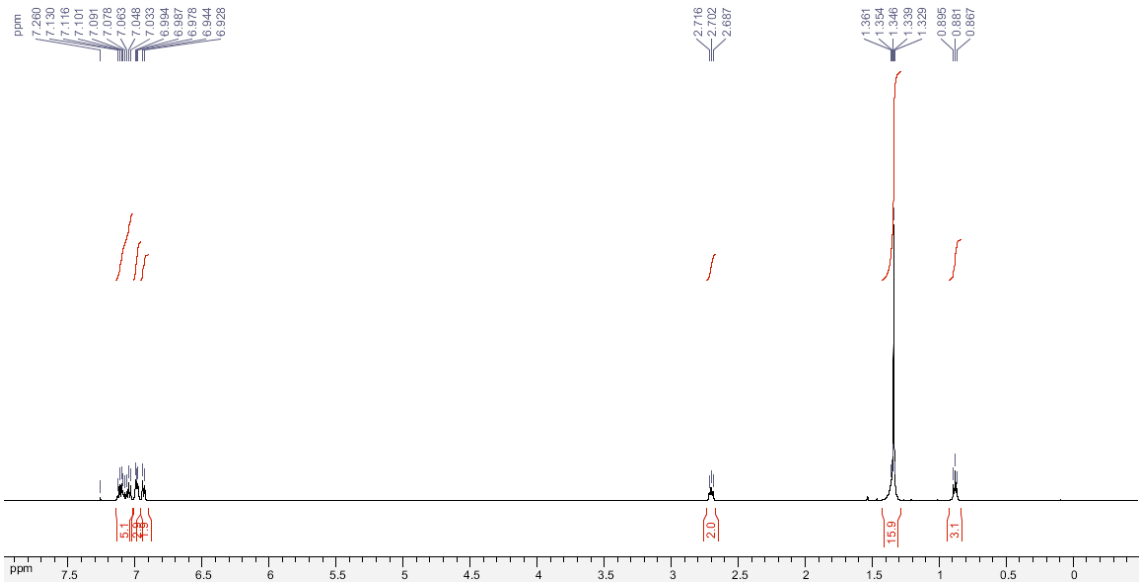

(pin)B
nBu
Ph
Ph

4aj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7.101
7.091
7.078
7.063
7.048
7.033
6.994
6.987
6.978
6.944
6.928
2.716
2.702
2.687
1.361
1.354
1.346
1.339
1.329
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0.881
0.867
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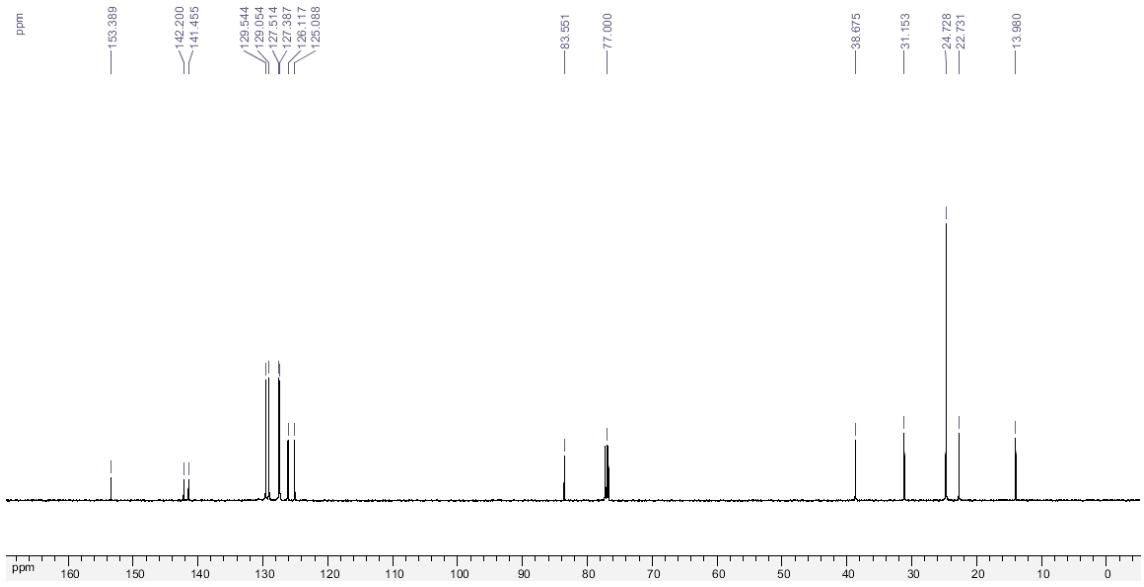
4.3
4.3
1.9
2.0
15.9
3.1


ppm
153.389
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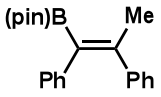
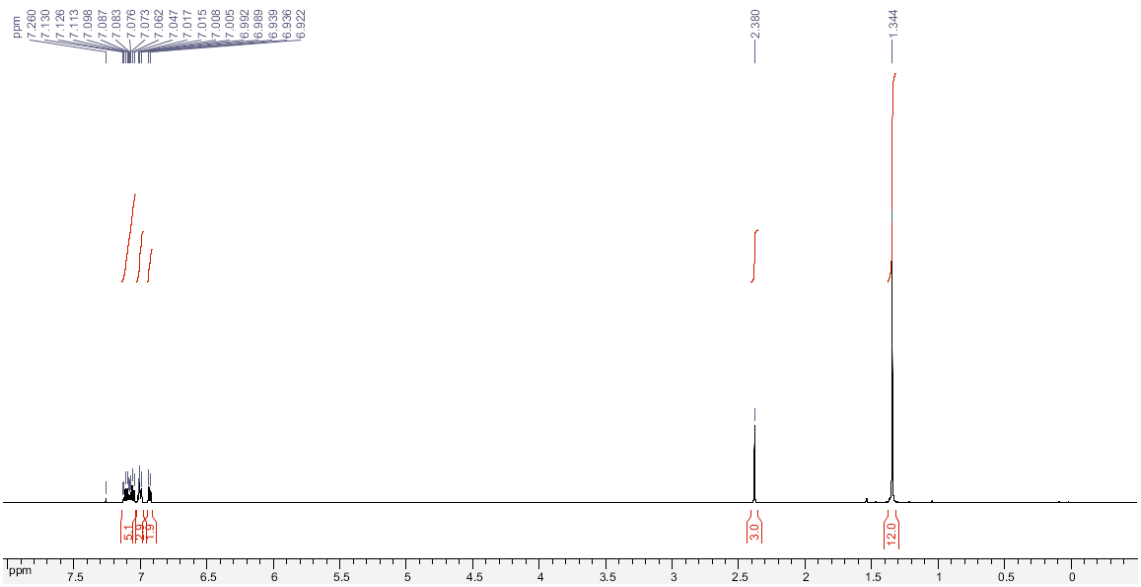
141.455
129.544
129.054
127.514
127.387
126.117
125.088
83.551
77.000
38.675
31.153
24.728
22.731
13.980


(pin)B
Me
Ph
Ph

4ak


ppm
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7.126
7.113
7.098
7.087
7.083
7.076
7.073
7.062
7.047
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7.015
7.008
7.005
6.992
6.989
6.939
6.936
6.922
2.380
1.344
4.1
4.0
3.9
3.0
12.0
ppm
7.5
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6.5
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5.5
5
4.5
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3.5
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2.5
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1.5
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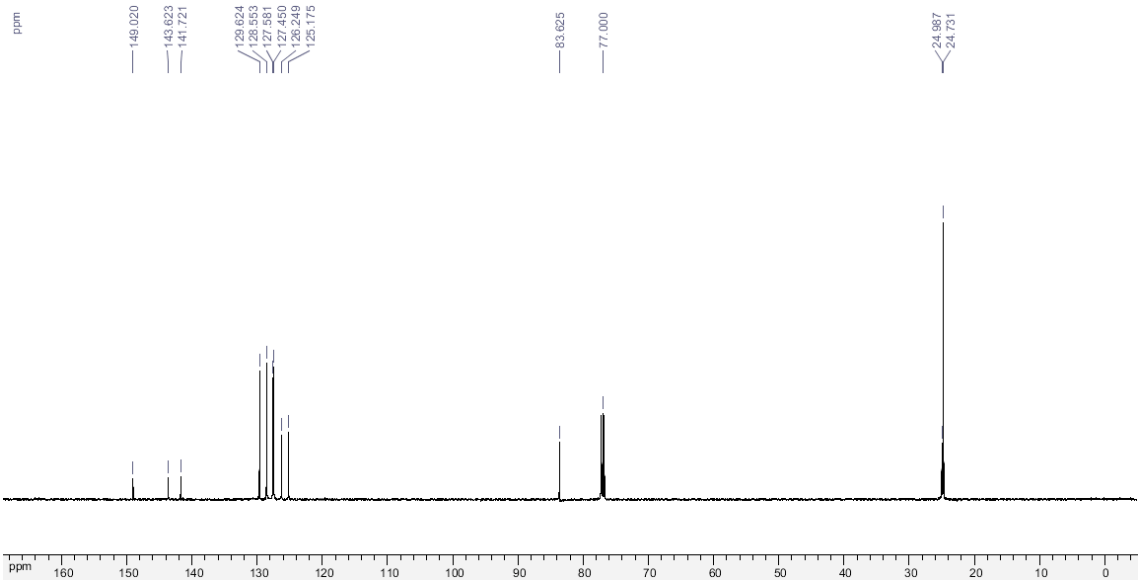
0


ppm
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129.624
128.553
127.581
127.450
126.249
125.175
83.625
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24.987
24.731
ppm
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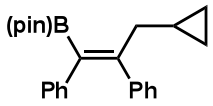
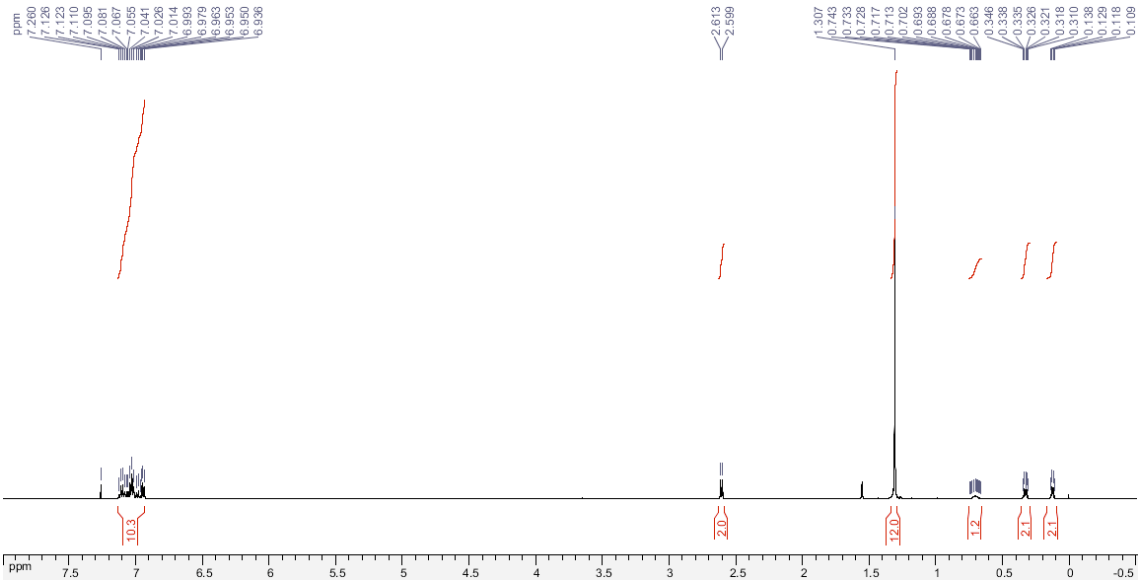
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


(pin)B
Ph
Ph

4al


ppm
7.260
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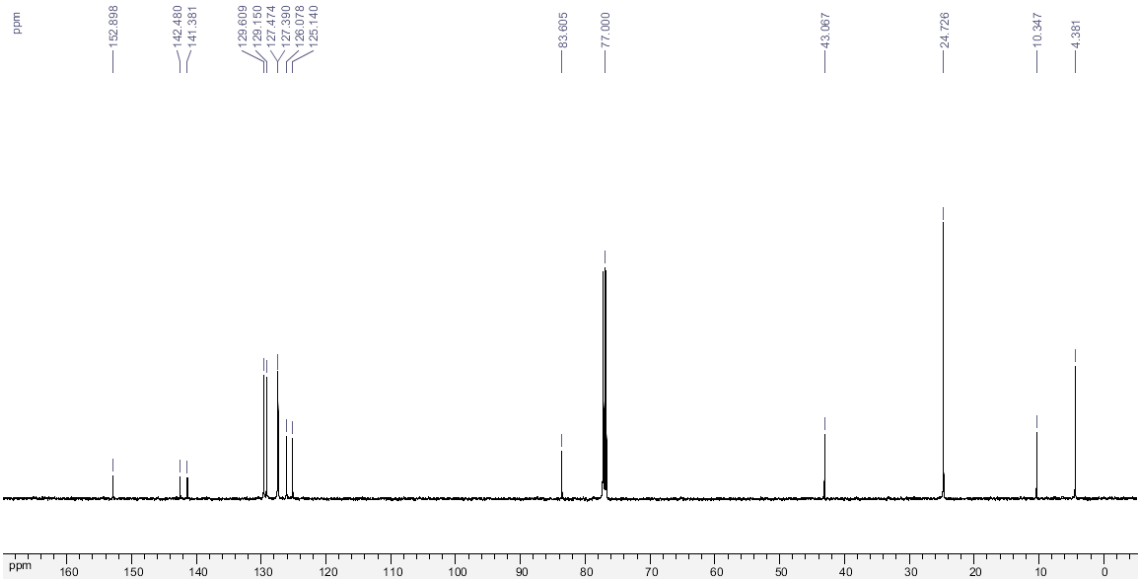
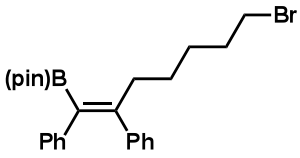
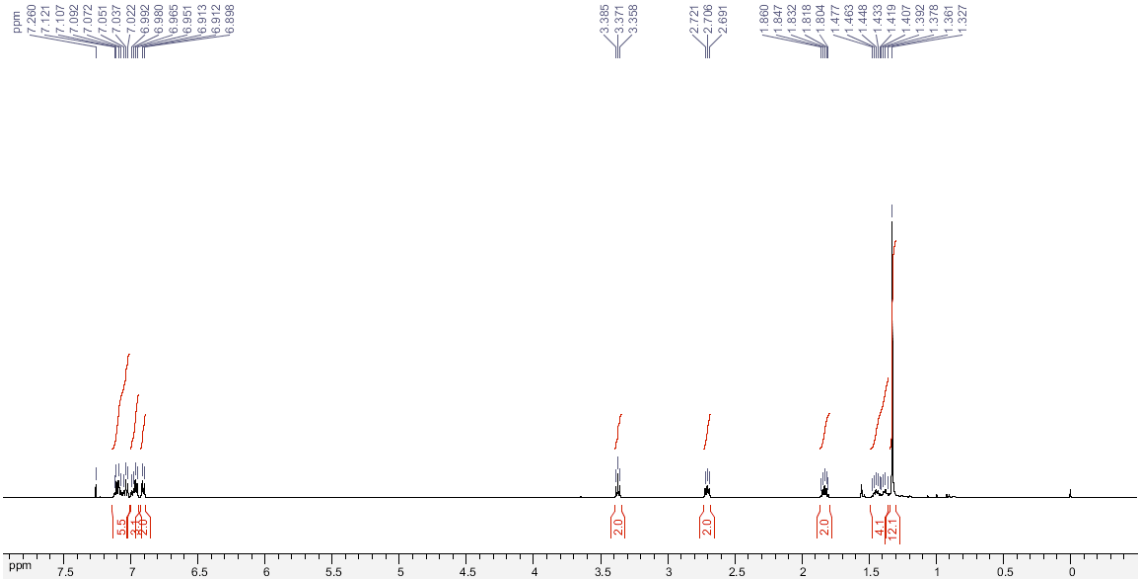
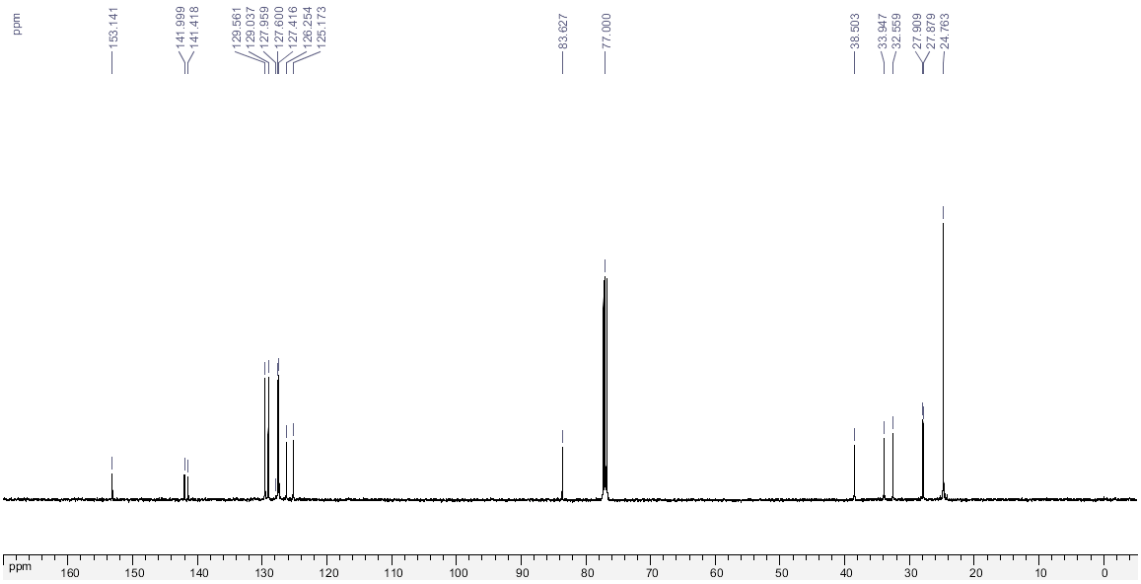
7.123
7.110
7.095
7.081
7.067
7.055
7.041
7.026
7.014
6.993
6.979
6.963
6.953
6.950
6.936
2.613
2.599
1.307
0.743
0.733
0.728
0.717
0.713
0.702
0.693
0.688
0.678
0.673
0.663
0.346
0.338
0.335
0.326
0.321
0.318
0.310
0.138
0.129
0.118
0.109
10.3
2.0
12.0
1.2
2.1
2.1
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5

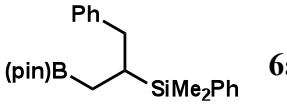

ppm
152.898
142.480
141.381
129.609
129.150
127.474
127.390
126.078
125.140
83.605
77.000
43.067
24.726
10.347
4.381
ppm
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


Br
(pin)B
Ph
Ph

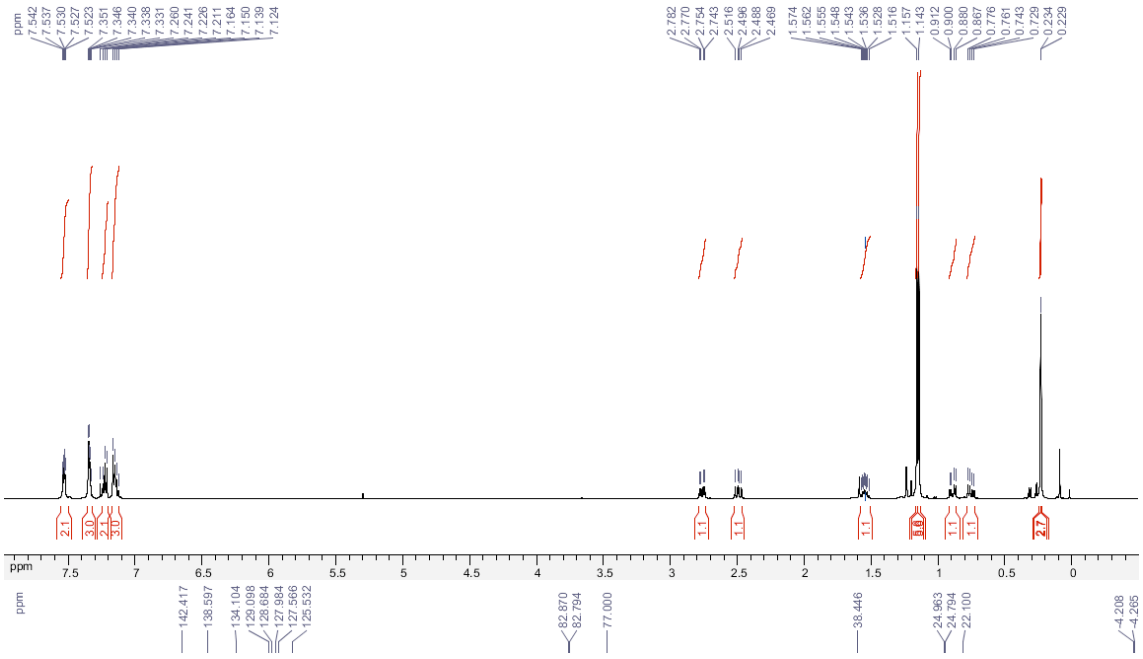
4am

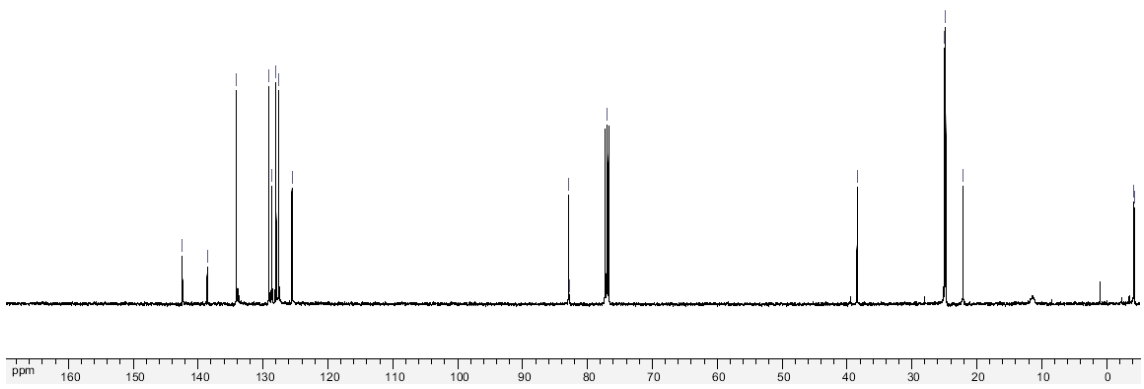

ppm
7.260
7.121
7.107
7.092
7.072
7.051
7.037
7.022
6.992
6.980
6.965
6.951
6.913
6.912
6.898
3.385
3.371
3.358
2.721
2.706
2.691
1.860
1.847
1.832
1.818
1.804
1.477
1.463
1.448
1.433
1.419
1.407
1.392
1.378
1.361
1.327
5.5
3.0
2.0
2.0
2.0
4.1
12.1
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

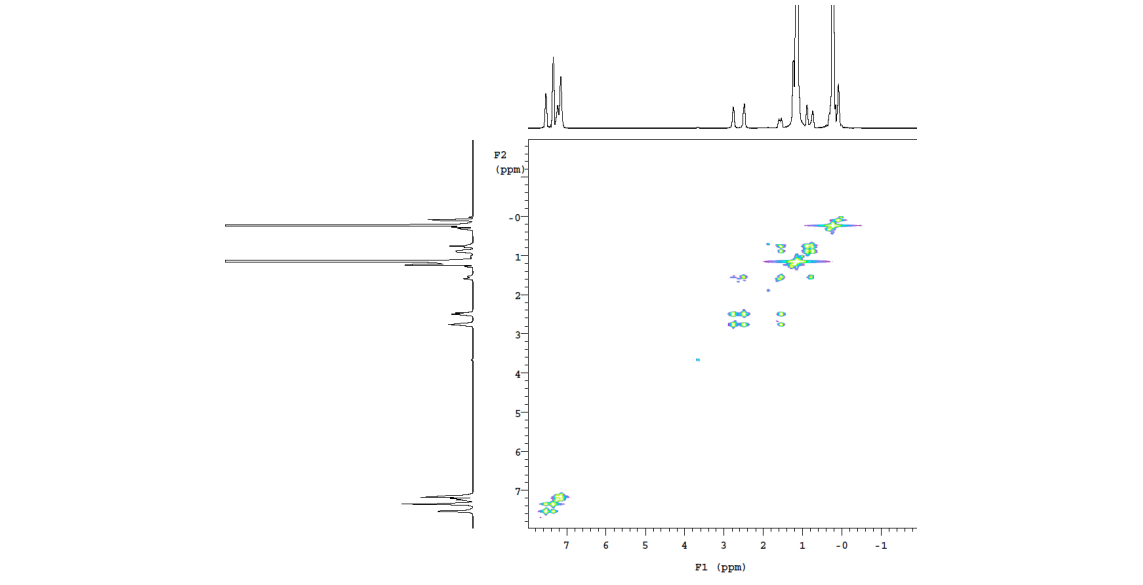

ppm
153.141
141.999
141.418
129.561
129.037
127.959
127.600
127.416
126.254
125.173
83.627
77.000
38.503
33.947
32.559
27.909
27.879
24.763
ppm
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

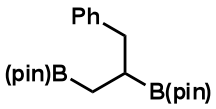


6aa

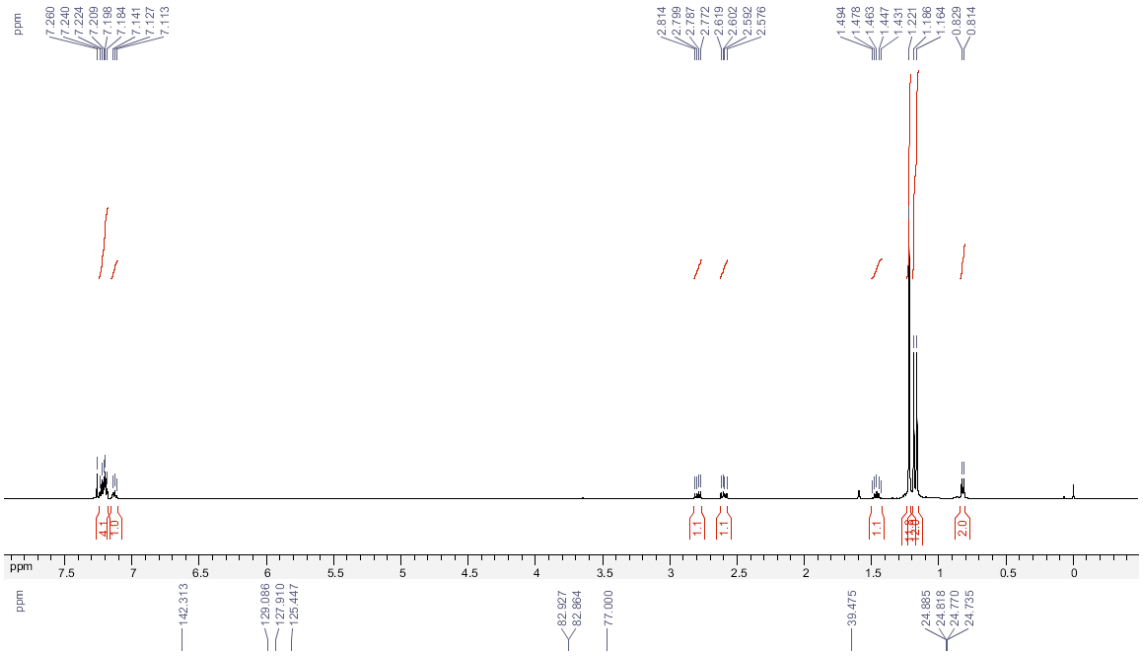


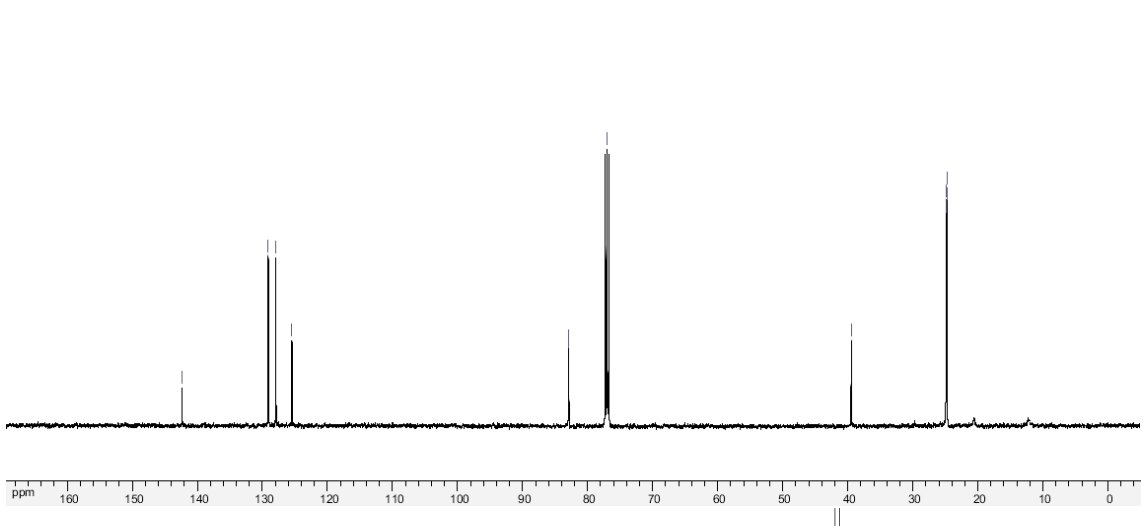


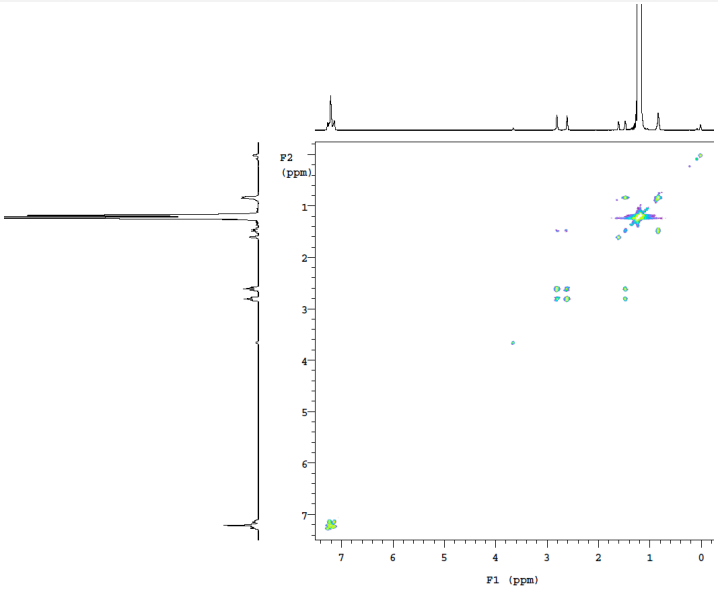


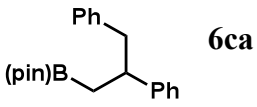

Ph
(pin)B
B(pin)

6ba

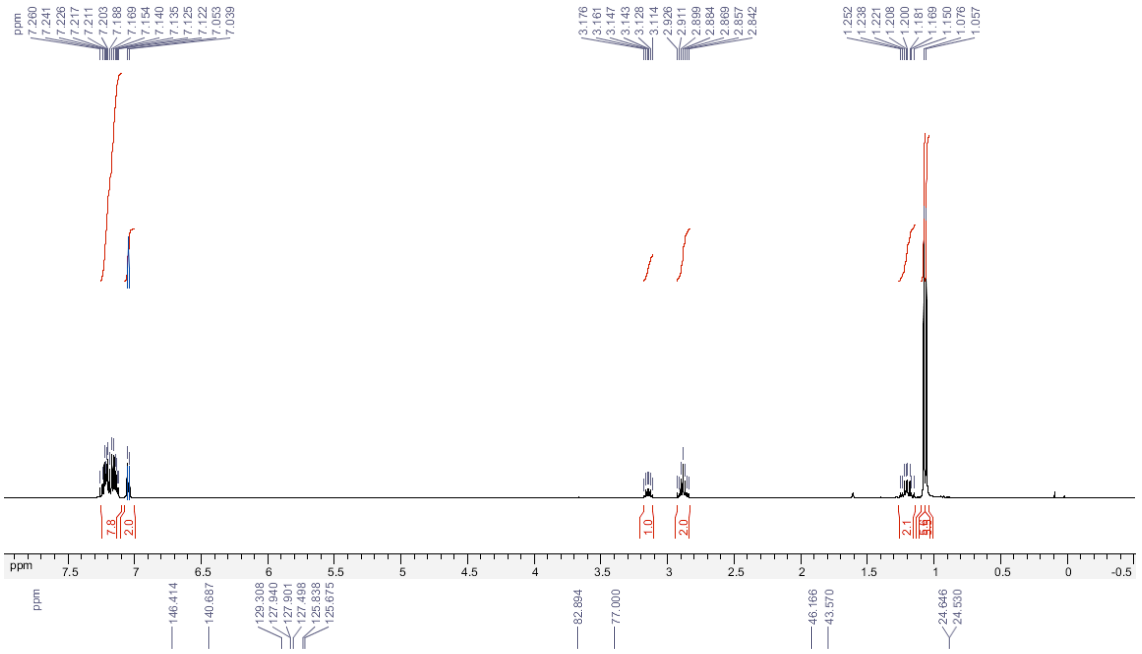

ppm
7.260
7.240
7.224
7.209
7.198
7.184
7.141
7.127
7.113
2.814
2.799
2.787
2.772
2.619
2.602
2.592
2.576
1.494
1.478
1.463
1.447
1.431
1.221
1.186
1.164
0.829
0.814
4.1
1.0
1.1
1.1
1.1
1.8
2.0
ppm
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


ppm
142.313
129.086
127.910
125.447
82.927
82.864
77.000
39.475
24.885
24.818
24.770
24.735
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

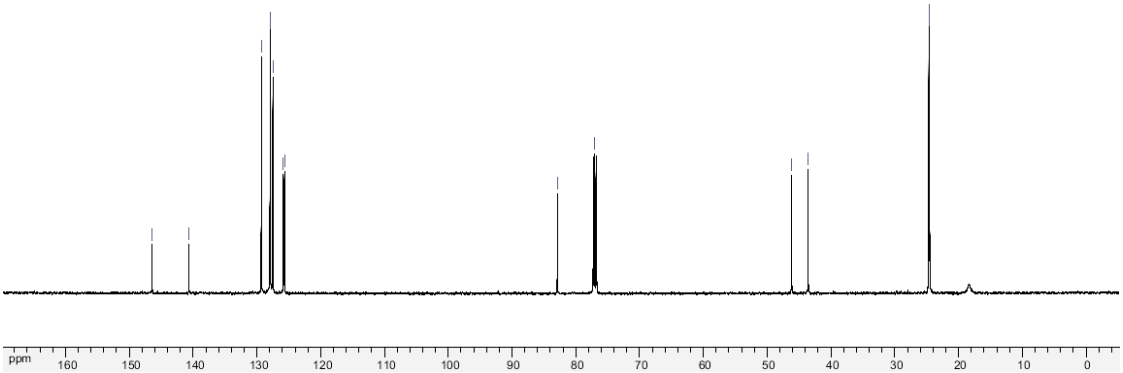

F2
(ppm)
1
2
3
4
5
6
7
7
6
5
4
3
2
1
0
F1 (ppm)

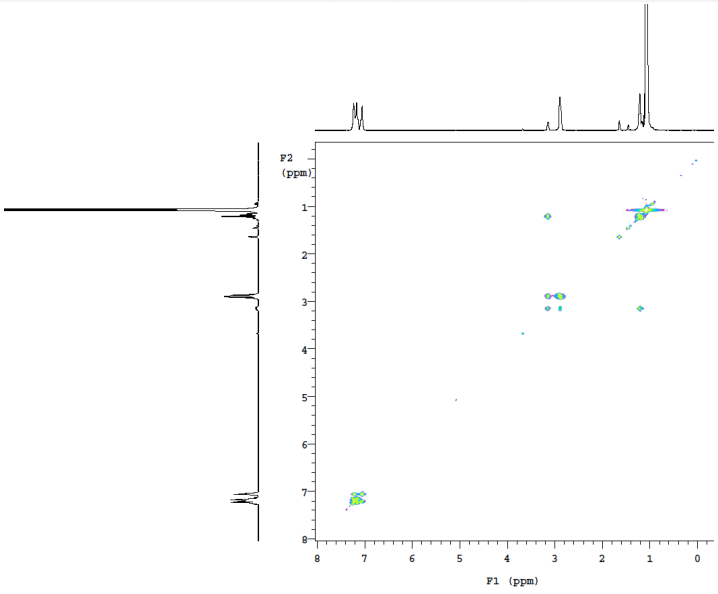

Ph
(pin)B
Ph

6ca


7.260
7.241
7.226
7.217
7.211
7.203
7.188
7.169
7.154
7.140
7.135
7.125
7.122
7.053
7.039
3.176
3.161
3.147
3.143
3.128
3.114
2.926
2.911
2.899
2.884
2.869
2.857
2.842
1.252
1.238
1.221
1.208
1.200
1.181
1.169
1.150
1.076
1.057
7.8
2.0
1.0
2.0
2.1
6.9
ppm

146.414
140.687
129.308
127.940
127.901
127.498
125.838
125.675
82.894
77.000
46.166
43.570
24.646
24.530
ppm


ppm


F2 (ppm)
F1 (ppm)