Palladium-Catalyzed Allylic Cross-Coupling Reactions of Primary- and Secondary Homoallylic Electrophiles

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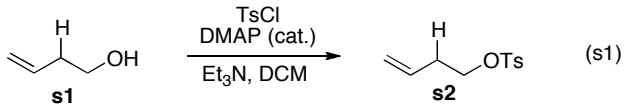
I. General information

MeOH, *t*AmOH, *i*PrOH, and NEt_3 were dried by distilling from CaH_2; DCM, Et_2O, and PhMe were dried by passing through a column of activated alumina; $CDCl_3$ was dried by passing through a plug of activated basic alumina. PhMe and *t*AmOH used in a glove box were degassed using freeze-pump-thaw technique prior to storing them in a glove box. PPh_3 was crystallized from Et_2O and stored in a glove box. Other phosphines were purchased and used as received. TsCl was purified by washing its solution in Et_2O with base, followed by crystallization from Et_2O. DMAP was crystallized from hot toluene. K_2CO_3 and Cs_2CO_3 were crushed and dried at 100 °C under vacuum and stored in a glove box. Flash column chromatography was performed using EM Reagent silica 60 (230-400 mesh). ^1H NMR were obtained at 300, 400, or 500 MHz and referenced to the residual $CHCl_3$ singlet at 7.26 ppm. ^{13}C NMR were obtained at 75, 100, or 125 MHz and referenced to the center line of the $CDCl_3$ triplet at 77.23 ppm. GC/MS data were obtained on a HP 5890 (EI) 20:1 split. ATR-FTIR spectra were obtained on a Bruker Tensor 37 FTIR spectrometer. The abbreviations s, d, t, q, p, sep, oct, dd, dt, bs, and m stand for the resonance multiplicities singlet, doublet, triplet, quartet, pentet, septet, octet, doublet of doublets, doublet of triplets, broad singlet, and multiplet, respectively. Optical rotations were obtained (Na D line) using a Perkin Elmer Model 343 Polarimeter fitted with a micro cell with a 1 dm path length; concentrations are reported in g/100 mL. SFC (super critical fluid chromatography) analysis was performed at 40 °C using a Thar instrument fitted with the indicated chiral stationary phase and detection using a diode array of 210-300 nm. Melting points were obtained on an electrothermal melting point apparatus and are uncorrected. Unless otherwise noted, glassware for all reactions was oven-dried at 110 °C and cooled in a dry atmosphere prior to use. HRMS data were obtained on an Agilent LCTOF.

II. General Experimental Procedures for Substrate Synthesis

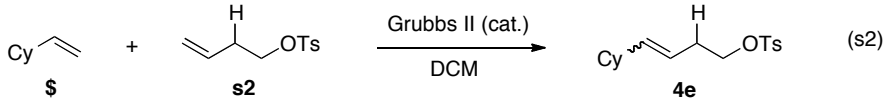
The following representative procedures are employed frequently in the synthesis of substrates. These reactions were not optimized.

A. Tosylation of Alcohols



To a dry 250 mL round-bottom flask equipped with a stirbar under N_2 were added 5.56 g of TsCl (29.0 mmol, 1.10 equiv), 326 mg of DMAP (2.70 mmol, 0.100 equiv), 7.40 mL of NEt_3 (54.0 mmol, 2.00 equiv), and 60 mL of DCM. The resulting mixture was cooled to 0° C, and a solution of 2.00 g of 3-buten-1-ol (27.0 mmol, 1.00 equiv) in 60 mL of DCM was added dropwise. The mixture was allowed to warm to room temperature and was allowed to stir overnight. The solution was then washed with sat. aq. $NaHCO_3$ (1 × 120 mL) and H_2O (1 × 120 mL). The combined aqueous layers were extracted with DCM (1 × 120 mL) and the combined organic layers were dried over Na_2SO_4, decanted, and concentrated in vacuo. The residue was purified by flash column chromatography.

B. Alkene Cross-Metathesis

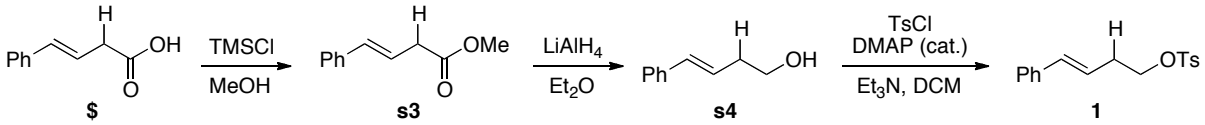


Into a dry 10 mL round-bottom flask equipped with a stirbar were added 327 mg of homoallyl tosylate (1.40 mmol, 1.00 equiv) and 3 mL of DCM, followed by 2.0 mL of vinylcyclohexane (14.0 mmol, 10.0 equiv) that had been passed through basic alumina, and 30 mg of Grubbs's 2nd generation catalyst (0.04 mmol, 2.5 mol%). The flask was equipped with a condenser and refluxed for 2 hours at 45 °C under N_2, at which time TLC showed consumption of homoallylic tosylate. After cooling to ambient temperature, 0.02 mL of di(ethylene glycol) vinyl ether (0.16 mmol, 10 mol%) was added and the reaction stirred for 30 min. The reaction was concentrated in vacuo and the residue was purified by flash column chromatography.

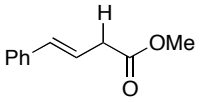
III. Preparation of Substrates

A. Preparation of Substrate 1

Scheme s1. Synthetic route to (*E*)-4-phenyl-3-butenyl tosylate **1**.

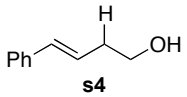


(*E*)-4-Phenyl-3-butenyl tosylate **1** was synthesized using the route outlined in Scheme s1. TMSCl-mediated esterification of (*E*)-4-phenyl-3-butenoic acid gave **s3**. Subsequent reduction gave alcohol **s4**. DMAP-catalyzed tosylation of **s4** afforded **1**.



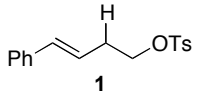
s3

(*E*)-methyl-4-phenyl-3-butenoate s3: to a dry 250 mL round-bottom flask equipped with a stirbar under N_2 were added 5.00 g of (*E*)-4-phenyl-3-butenoic acid (31 mmol, 1.00 equiv) and 40 mL of MeOH. The solution was cooled to 0 °C and 5.90 mL of TMSCl (46 mmol, 1.50 equiv) were added dropwise. The mixture was allowed to warm to room temperature and stirred overnight. The solvent was removed under reduced pressure, and the crude product **s3** (5.26 g, 30 mmol, 97% yield) was taken forward after comparison to published spectral data.[1]



s4

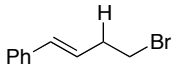
(*E*)-4-phenylbut-3-en-1-ol s4: to a dry 250 mL round-bottom flask equipped with a stirbar under N_2 were added 3.40 g of $LiAlH_4$ (90 mmol, 3.00 equiv) and 60 mL of Et_2O. The mixture was cooled to 0 °C, and a solution of 5.26 g (*E*)-methyl-4-phenyl-3-butenoate **s3** (30 mmol, 1.00 equiv) in 20 mL of Et_2O was added dropwise. The mixture was allowed to warm to room temperature, and quenched after 2.5 h by slow addition of 150 mL of 1 M HCl. The mixture was transferred to a separatory funnel, and the layers were separated. The aqueous layer was extracted with Et_2O (3 × 40 mL) and the combined organic layers were dried over $MgSO_4$, filtered, and concentrated in vacuo. The crude product **s4** (4.13 g, 27.8 mmol, 93% yield) was compared to published spectral data and taken on to the next step.[2]



1

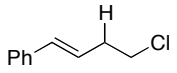
(*E*)-4-phenylbut-3-enyl tosylate 1. The general procedure for alcohol tosylation (section IIA) was used to prepare this compound, using 1.48 g of *(E)*-4-phenylbut-3-en-1-ol **s4** (10 mmol, 1.00 equiv), 2.01 g of TsCl (11 mmol, 1.10 equiv), 122 mg of DMAP (1.0 mmol, 0.100 equiv), and 2.79 mL of NEt_3 (20 mmol, 2.00 equiv), in 30 mL of DCM. Purification by flash column chromatography eluting with 700 mL of 12% EtOAc/hexanes → 200 mL 20% EtOAc/hexanes afforded **1** as a white solid (2.16 g, 71%). Its spectral data were compared to published ones.[3]

B. Preparation of Substrates 4a and 4b



4a

(*E*)-4-phenyl-3-butenyl bromide **4a** was prepared according to a published procedure.[4]

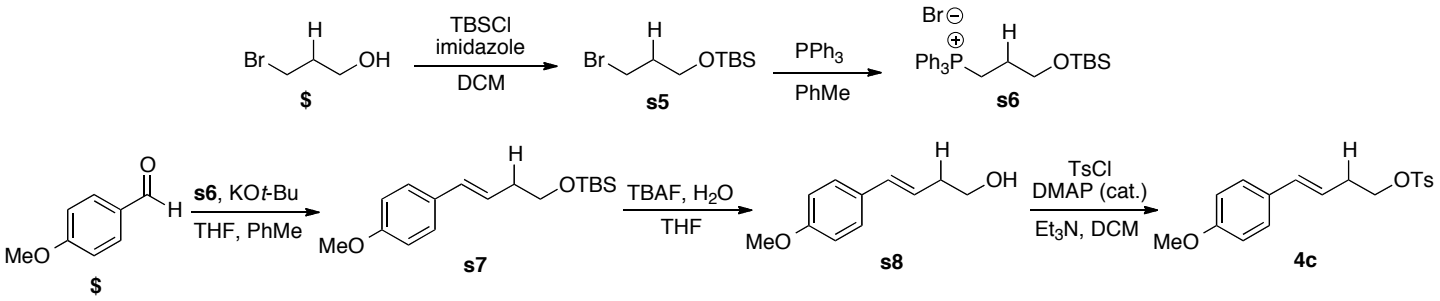


4b

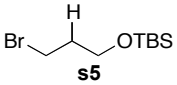
(*E*)-4-phenyl-3-butenyl chloride **4b** was prepared according to a published procedure[5] from cyclopropyl(phenyl)methanol, which was also prepared according to a published procedure.[4]

C. Preparation of Substrate 4c

Scheme s2. Synthetic route to (*E*)-4-(4-methoxyphenyl)but-3-en-1-yl tosylate **4c**.

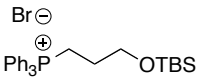


(*E*)-4-(4-methoxyphenyl)but-3-en-1-yl tosylate **4c** was synthesized as shown in Scheme s2. TBS-protection of 3-bromo-1-propanol gave **s5**, which gave the Wittig reagent **s6** upon treatment with PPh_3. Subsequent olefination of *para*-anisaldehyde gave protected homostyrenyl alcohol **s7**. TBAF deprotection afforded free alcohol **s8**, tosylation of which afforded the desired substrate **4c**.



s5

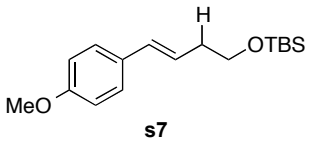
(3-Bromopropoxy)(tert-butyl)dimethylsilane**s5** was prepared according to a literature procedure.[6]



s6

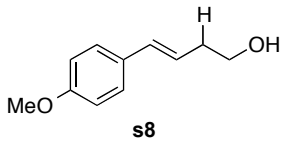
Preparation of (3-((tert-butyldimethylsilyl)oxy)propyl)triphenylphosphonium bromide **s6**: to a dry 25 mL round-bottom flask equipped with a stirbar under N_2 were added 2.69 g of PPh_3 (10.3 mmol, 1.30 equiv) and 5 mL of PhMe. While stirring, 2.00 g of **s5** (7.90 mmol, 1.00 equiv) were slowly added. The flask was equipped with a reflux condenser, and the mixture was heated to reflux for 3 h, during which time a white precipitate

formed. The mixture was allowed to cool to room temperature. The stirbar was removed, and the product was allowed to crystallize overnight. It was then filtered through a fritted funnel and dried at 80 °C under vacuum overnight. The product **s6** was isolated in 76% yield (3.09 g, 5.99 mmol) as a white solid. Its spectral data were compared to published ones.[7]



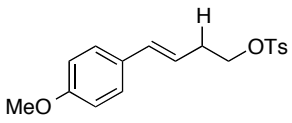
s7

Preparation of (*E*)-tert-butyl((4-(4-methoxyphenyl)but-3-en-1-yl)oxy)dimethylsilane **s7**: To a dry 100 mL round-bottom flask equipped with a stirbar under N_2 were added 2.68 g of **s6** (5.2 mmol, 1.3 equiv) followed by 30 mL of PhMe. A solution of 597 mg of KO*t*Bu (5.32 mmol, 1.33 mmol) in 10 mL of THF was added dropwise, and the orange mixture was stirred at room temperature for 4 h. The mixture was then cooled to –78 °C, and a solution of 487 μL of *para*-anisaldehyde (4.00 mmol, 1.00 equiv) in 8.0 mL of PhMe was added dropwise. The mixture was allowed to warm to room temperature overnight. It was then quenched with 30 mL of saturated aqueous NH_4Cl and stirred for 20 min. Then, sufficient H_2O to dissolve the resulting precipitate was added, and the layers were separated in a separatory funnel. The aqueous layer was extracted with Et_2O (3 × 40 mL), and the combined organic layers were washed with H_2O (1 × 40 mL) and brine (1 × 40 mL), and dried over $MgSO_4$. The crude product was purified by flash column chromatography eluting with 3% acetone/hexanes, and isolated in 74% yield (863 mg, 2.95 mmol). Its spectral data were compared to published ones.[8]



s8

(*E*)-4-(4-methoxyphenyl)but-3-en-1-ol **s8** was deprotected according to a published procedure[8] and its spectral data were compared to published ones.[9]

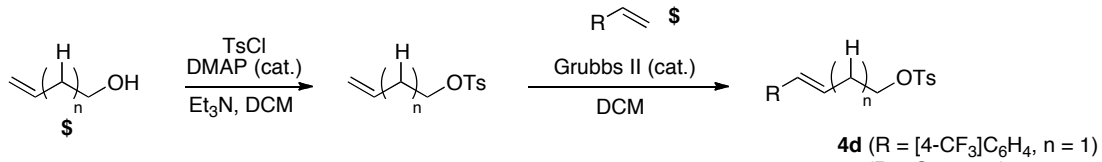


4c

(*E*)-4-(4-Methoxyphenyl)but-3-en-1-yl 4-methylbenzenesulfonate 4c. The general procedure for alcohol tosylation (section IIA) was used to prepare this compound from **s8**. The product was isolated as a colorless oil in 91% yield (789 mg, 2.38 mmol), R_f = 0.21 (20:80 acetone:hexanes). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.78 (d, *J* = 8.4 Hz, 2H), 7.30 (d, *J* = 7.8 Hz, 2H), 7.20 (d, *J* = 8.7 Hz, 2H), 6.83 (d, *J* = 9.0 Hz, 2H), 6.33 (d, *J* = 16 Hz, 1H), 5.84 (dt, *J* = 16, 6.9 Hz, 1H), 4.11 (t, *J* = 6.6 Hz, 2H), 3.80 (s, 3H), 2.52 (qd, *J* = 6.9, 1.8 Hz, 2H), 2.43 (s, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 159.3, 144.9, 133.3, 132.9, 130.0, 129.9, 128.2, 127.5, 121.7, 114.1, 70.06, 55.52, 32.71, 21.88; ATR-FTIR (thin film): 3032, 2996, 2956, 2840, 1604, 1576, 1509, 1462, 1453, 1440, 1381, 1345, 1305, 1284, 1241, 1172, 1095, 1049, 1030 cm^{-1}; HRMS (ESI-TOF) *m* / *z* calculated for $C_{18}H_{20}O_4NaS$ $[M+Na]^+$: 355.0980, found 355.0980.

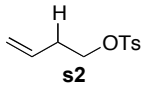
D. Preparation of Substrates 4d–4f

Scheme s3. Synthetic route to tosylates **4d–4f**.



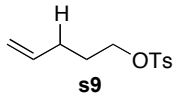
4d (R = [4-CF_3]C_6H_4, n = 1)
4e (R = Cy, n = 1)
4f (R = Ph, n = 2)

Tosylates **4d–4f** were synthesized using the tosylation/cross-metathesis sequence shown in Scheme s3.



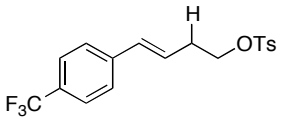
s2

3-buten-1-tosylate s2. The general procedure for alcohol tosylation (section IIA) was followed using 2.00 g of 3-buten-1-ol (27 mmol), 7.4 mL of Et_3N (54 mmol), 5.56 g of tosyl chloride (29 mmol), and 326 mg of DMAP (2.7 mmol) in 120 mL of DCM. Purification by flash column chromatography (0:100 → 30:70 EtOAc:hexanes) afforded **s2** as a colorless oil (5.35 g, 87%), R_f = 0.34 (20:80 EtOAc:hexanes, visualized by 254 nm light). The spectral data matched those reported by Heaps and Poulter.[10] ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.79 (d, *J* = 8.1 Hz, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 5.74-5.60 (m, 1H), 5.11-5.04 (m, 2H), 4.06 (t, *J* = 6.7 Hz, 2H), 2.45 (s, 3H), 2.43-2.36 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 145.0, 133.3, 132.6, 130.1, 128.1, 118.5, 69.66, 33.37, 21.89; ATR-FTIR (thin film): 1355, 1173, 1096 cm^{-1}.



s9

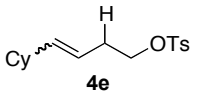
4-Penten-1-tosylate s9. The general procedure was followed using 0.58 mL of 4-penten-1-ol (5.0 mmol), 1.4 mL of Et_3N (10 mmol), 1.04 g of TsCl (5.5 mmol), and 61 mg of DMAP (0.50 mmol) in 25 mL of DCM. Purification by flash column chromatography (0:100 → 30:70 EtOAc/hexanes) afforded **s9** as a colorless oil (1.13 g, 94%), R_f = 0.47 (20:80 EtOAc:hexanes). The spectral data matched those reported by Mancheno and coworkers.[11] ^{1}H NMR (300 MHz; $CDCl_3$): δ 7.78 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.0 Hz, 2H), 5.75-5.61 (m, 1H), 4.97-4.91 (m, 2H), 4.02 (t, *J* = 6.3 Hz, 2H), 2.44 (s, 3H), 2.07 (q, *J* = 6.9 Hz, 2H), 1.73 (p, *J* = 6.9 Hz, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 144.9, 136.8, 133.3, 130.1, 128.1, 116.1, 70.03, 29.59, 28.18, 21.87.



4d

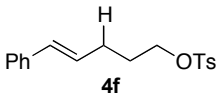
(*E*)-4-(4-(Trifluoromethyl)phenyl)but-3-en-1-yl 4-methylbenzenesulfonate 4d. The general procedure for alkene metathesis (section IIA) was followed using 156 mg of homoallyl tosylate **s2** (0.69 mmol), 0.5 mL of 4-(trifluoromethyl)styrene (3.4 mmol), and 58 mg of Grubbs's 2nd generation catalyst (0.07 mmol) in 3.0 mL of DCM. Purification by flash column chromatography (0:100 → 50:50 EtOAc:hexanes) afforded **4d** as a white powder (131 mg, 51%), mp 72 °C, R_f = 0.29 (20:80 EtOAc:hexanes). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.79-7.76

(m, 2H), 7.53 (d, J = 8.0 Hz, 2H), 7.35 (d, J = 8.0 Hz, 2H), 7.29 (d, J = 7.5 Hz, 2H), 6.42 (d, J = 16.0 Hz, 1H), 6.11 (dt, J = 16.0, 7.0 Hz, 1H), 4.15 (t, J = 6.5 Hz, 2H), 2.57 (qd, J = 6.5, 1.5 Hz, 2H), 2.41 (s, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 145.1, 140.5 (q, $J_{C–F}$ = 1.4 Hz), 133.2, 132.2, 130.1, 129.5 (q, $J_{C–F}$ = 32.1 Hz), 128.1, 127.1, 126.5, 125.7 (q, $J_{C–F}$ = 3.8 Hz), 124.3 (q, $J_{C–F}$ = 270.4 Hz), 69.49, 32.70, 21.82; ^{19}F NMR ($CDCl_3$, 282 MHz): δ –62.89; ATR-FTIR (neat): 2931, 1654, 1611, 1597, 1494, 1469, 1414, 1384, 1350, 1324, 1174, 1161, 1110, 1066, 1014 cm^{-1}; HRMS (ESI-TOF) m / z calculated for $C_{18}H_{17}O_3F_3NaS$ $[M+Na]^+$: 393.0748, found 393.0757.



4e

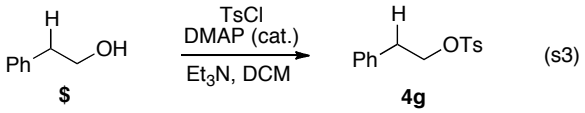
4-Cyclohexylbut-3-en-1-yl 4-methylbenzenesulfonate 4e. The general procedure for alkene metathesis was followed using 327 mg of homoallyl tosylate **s2** (0.14 mmol), 2.0 mL of vinylcyclohexane (1.4 mmol), and 30 mg of Grubbs's 2nd generation catalyst (0.04 mmol) in 3.0 mL of DCM. Purification by flash column chromatography (50:50 benzene:hexanes) afforded **4e**, an 87:13 mixture of *E* and *Z* isomers, as a beige oil (180 mg, 42%), R_f = 0.16 (50% benzene/hexanes). Selected spectral data for the major (*E*) isomer: ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.76 (dd, J = 8.0, 2.0 Hz, 2H), 7.32 (d, J = 7.0 Hz, 2H), 5.39 (dd, J = 15.5, 6.5 Hz, 1H), 5.16 (dt, J = 15.5, 7.0 Hz, 1H), 3.98 (dt, J = 7.0, 1.5 Hz, 2H), 2.42 (s, 3H), 2.29 (q, J = 7.0 Hz, 2H), 1.87-1.77 (m, 1H), 1.70-1.63 (m, 2H), 1.63-1.56 (m, 3H), 1.26-1.15 (m, 2H), 1.15-1.07 (m, 1H), 1.02-0.90 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 144.9, 140.6, 133.4, 130.0, 128.1, 121.2, 70.48, 40.81, 33.04, 32.36, 26.34, 26.20, 21.84. Selected spectral data for the minor (*Z*) isomer: ^{1}H NMR ($CDCl_3$, 500 MHz): δ 5.29 (t, J = 11.0 Hz, 1H), 5.08 (dt, J = 11.0, 7.0 Hz, 1H), 2.42 (s, 3H), 2.37 (q, J = 7.0 Hz, 2H), 2.15-2.06 (m, 1H), 1.49 (d, J = 9.0 Hz, 2H), 1.07-1.02 (m, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 144.9, 140.1, 133.4, 128.1, 120.9, 70.17, 36.61, 33.27, 27.49, 26.13, 26.01. Spectral data for the mixture: ATR-FTIR (thin film): 2922, 2849, 1598, 1448, 1360, 1174, 1097 cm^{-1}; HRMS (AP-TOF) m / z calculated for $C_{17}H_{24}O_3NaS$ $[M+Na]^+$ 331.1344, found 331.1349.



4f

(*E*)-5-Phenylpent-4-en-1-yl 4-methylbenzenesulfonate 4f. The general procedure for alcohol tosylation was followed using 360 mg of bis-homoallyl tosylate **s9** (1.5 mmol), 1.7 mL of styrene (15 mmol), and 13 mg of Grubbs's 2nd generation catalyst (0.02 mmol) in 3.0 mL of DCM. Purification by flash column chromatography (0:100 → 50:50 EtOAc:hexanes) afforded **4f** as a white solid (344 mg, 73%), R_f = 0.44 (20:80 EtOAc:hexanes, visualized by 254 nm light). The spectral data matched those reported by Mancheno and coworkers.[11] ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.79 (d, J = 8.1 Hz, 2 H), 7.37–7.27 (m, 6 H), 7.24–7.17 (m, 1 H), 6.30 (d, J = 16 Hz, 1 H), 6.05 (dt, J = 16, 7.2 Hz, 1 H), 4.07 (t, J = 6.6 Hz, 1 H), 2.42 (s, 3 H), 2.25 (q, J = 6.6 Hz, 2 H), 1.83 (p, J = 6.6 Hz, 2 H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 144.9, 137.5, 133.3, 131.5, 130.1, 128.7, 128.5, 128.1, 127.4, 126.2, 69.90, 28.87, 28.80, 21.85.

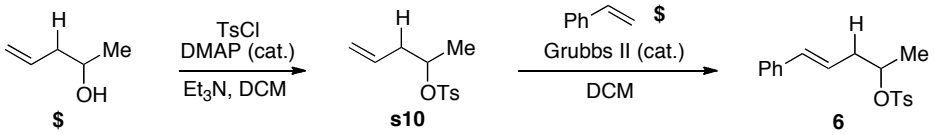
E. Preparation of Substrate 4g



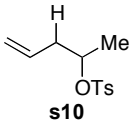
Phenethyl 4-methylbenzenesulfonate 4g. The general procedure for alcohol tosylation was followed using 1.96 mL of 2-phenylethanol (16.4 mmol), 4.56 mL of NEt_3 (32.7 mmol), 3.43 g of TsCl (18.0 mmol), and 200 mg of DMAP (1.64 mmol) in 40 mL of DCM. The product was purified by flash column chromatography eluting with 1 L of 10% EtOAc/hexanes → 300 mL of 20% EtOAc/hexanes. The product was isolated as a white solid in 98% yield (4.43g, 16.0 mmol). The spectral data were compared to published ones.[12]

F. Preparation of Substrate 6

Scheme s4. Synthetic route to secondary tosylate **6**.

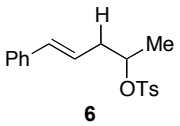


Secondary tosylate **6** was synthesized using the tosylation/cross-metathesis sequence shown in Scheme s4. Yields were not optimized.



s10

4-Penten-2-tosylate s10. The general procedure was followed using 0.30 mL of 4-penten-2-ol (2.9 mmol), 0.80 mL of Et_3N (5.7 mmol), 600 mg of TsCl (3.1 mmol), and 35 mg of DMAP (0.29 mmol) in 14 mL of DCM. Purification by flash column chromatography (0:100 → 30:70 EtOAc:hexanes) afforded the product as a colorless oil (282 mg, 41%), R_f = 0.29 (20:80 EtOAc:hexanes). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 1.25 (d, J = 6.8 Hz, 3H), 2.22-2.42 (m, 2H), 2.45 (s, 3H), 4.64 (sextet, J = 6.8 Hz, 1H), 5.01 (s, 1H), 4.98-5.08 (m, 2H), 5.52-5.68 (m, 1H), 7.33 (d, J = 8.1 Hz, 2H), 7.79 (d, J = 8.4 Hz, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 20.52, 21.87, 41.01, 79.58, 119.0, 128.0, 129.9, 132.5, 134.6, 144.7; ATR-FTIR (thin film): 2981, 1643, 1598, 1495, 1449, 1351, 1306, 1187, 1173, 1120, 1096, 1043, 1019 cm^{-1}; HRMS (ESI-TOF) m / z calculated for $C_{12}H_{16}O_3NaS$ $[M+Na]^+$: 263.0718, found 263.0722.



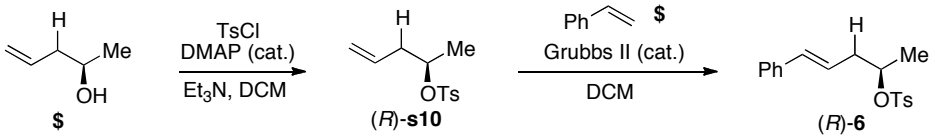
6

(*E*)-5-Phenylpent-4-en-2-yl 4-methylbenzenesulfonate 6. The general procedure was followed using 120 mg of 4-penten-2-tosylate **s10** (0.50 mmol), 0.23 mL of styrene (2.0 mmol), and 21 mg of Grubbs's 2nd generation catalyst (0.03 mmol) in 1.0 mL of 1,2-DCE. Purification by flash column chromatography (0:100 → 50:50 EtOAc:hexanes) afforded **6** as a white powder (66 mg, 42%), mp 70 °C, R_f = 0.33 (20:80 EtOAc:hexanes, visualized by 254 nm light). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.76 (d, J = 8.1 Hz, 2H), 7.34–7.17 (m, 7H), 6.33

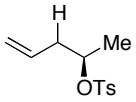
(d, J = 16 Hz, 1H), 5.87 (dt, J = 16, 7.2 Hz, 1H), 4.67 (sextet, J = 6.3 Hz, 1H), 2.58–2.38 (m, 2H), 2.36 (s, 3H), 1.36 (d, J = 6.3 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 144.7, 137.2, 134.3, 133.8, 129.9, 128.7, 128.0, 127.6, 126.4, 124.1, 79.89, 40.24, 21.84, 21.07; ATR-FTIR (thin film): 3029, 2891, 1595, 1493, 1450, 1380, 1343, 1307, 1293, 1170, 1130, 1097, 1020 cm^{-1}; HRMS (ESI-TOF) m / z calculated for $C_{18}H_{20}NaO_3S$ $[M+Na]^+$: 339.1031, found 339.1031.

G. Preparation of Substrate (*R*)-6

Scheme s5. Synthetic route to enantiomerically-enriched secondary tosylate (*R*)-**6**.

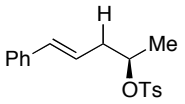


Enantiomerically-enriched secondary tosylate (*R*)-**6** was synthesized in 92% enantiomeric excess in two steps (41% overall yield) from commercially-available (*R*)-4-penten-2-ol using the tosylation/cross-metathesis sequence shown in Scheme s5. The reported yields are unoptimized.



(*R*)-**s10**

(*R*)-Pent-4-en-2-yl 4-methylbenzenesulfonate (*R*)-**s10**. The general procedure was followed using 0.60 mL of (*R*)-4-penten-2-ol (5.5 mmol), 1.5 mL of Et_3N (11 mmol), 1.15 g of tosyl chloride (6.1 mmol), and 67 mg of DMAP (0.55 mmol) in 28 mL of DCM. Purification by flash column chromatography (0:100 → 30:70 EtOAc:hexanes) afforded (*R*)-**s10** as a colorless oil (861 mg, 65%), R_f = 0.50 (20:80 EtOAc:hexanes, visualized by 254 nm light). The spectral data matched those reported by Randl and Blechert.[13] ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.78 (d, J = 8.3 Hz, 2H), 7.33 (d, J = 8.3 Hz, 2H), 5.66-5.52 (m, 1H), 5.06-4.99 (m, 2H), 4.63 (sextet, J = 6.2 Hz, 1H), 2.44 (s, 3H), 2.37-2.25 (m, 2H), 1.25 (d, J = 6.3 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 144.7, 134.6, 132.4, 129.9, 128.0, 119.0, 79.58, 41.00, 21.87, 20.51.

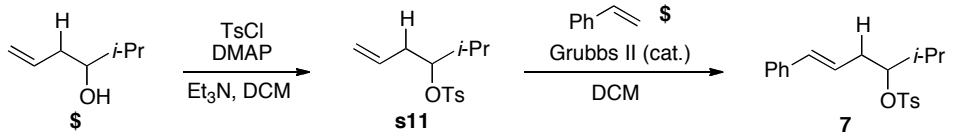


(*R*)-**6**

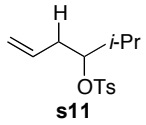
(*R*,*E*)-5-Phenylpent-4-en-2-yl 4-methylbenzenesulfonate (*R*)-**6**. The general procedure was followed using 226 mg of (*R*)-**s10** (0.50 mmol), 1.0 mL of styrene (9.4 mmol), and 40 mg of Grubbs's 2nd generation catalyst (0.05 mmol) in 2.0 mL of DCM. Purification by flash column chromatography (0:100 → 50:50 EtOAc:hexanes) afforded (*R*)-**6** as a white powder (187 mg, 63%), mp 66 °C, R_f = 0.33 (20:80 EtOAc:hexanes, visualized by 254 nm light), ee = 92% (Chiralcel® AD-H, 10:90 MeOH/CO_2 at 2 mL/min, 160 bar, and 40 °C), t_1 = 6.55 min (*R*), t_2 = 7.04 min (*S*). The spectral data matched those reported above for **6**. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.76 (d, J = 8.1 Hz, 2H), 7.34–7.17 (m, 7H), 6.33 (d, J = 16 Hz, 1H), 5.87 (dt, J = 16, 7.2 Hz, 1H), 4.67 (sextet, J = 6.3 Hz, 1H), 2.58–2.38 (m, 2H), 2.36 (s, 3H), 1.36 (d, J = 6.3 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 144.7, 137.1, 134.3, 133.8, 129.9, 128.7, 128.0, 127.6, 126.4, 124.1, 79.89, 40.24, 21.84, 21.07; ATR-FTIR (thin film): 3029, 2982, 1597, 1493, 1450, 1347, 1171 cm^{-1}.

H. Preparation of Substrate 7

Scheme s6. Synthetic route to secondary tosylate **7**.

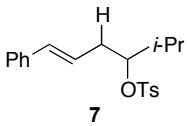


Secondary tosylate **7** was synthesized from commercially-available 2-methyl-5-hexen-3-ol by tosylation in the presence of stoichiometric DMAP, and then alkene cross metathesis (Scheme s6). The reported yields are unoptimized.



s11

2-Methylhex-5-en-3-ol s11. The general procedure was followed using 1.2 mL of 2-methyl-5-hexen-3-ol (8.7 mmol), 2.4 mL of Et_3N (17 mmol), 1.83 g of tosyl chloride (9.6 mmol), and 530 mg of DMAP (4.4 mmol) in 43 mL of DCM. Purification by flash column chromatography (0:100 → 30:70 benzene:hexanes) afforded **s11** as a colorless amorphous material (296 mg, 13%), R_f = 0.17 (20:80 benzene:hexanes, visualized by 254 nm light). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.77 (d, *J* = 8.4 Hz, 2H), 7.33-7.28 (m, 2H), 5.61 (ddt, *J* = 17, 10, 7.1 Hz, 1H), 5.04-4.95 (m, 2H), 4.42 (q, *J* = 5.6 Hz, 1H), 2.43 (s, 3H), 2.37-2.31 (m, 2H), 1.91 (octd, *J* = 6.8, 5.2 Hz, 1H), 0.85 (d, *J* = 6.8 Hz, 3H), 0.84 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 144.6, 134.8, 132.8, 129.8, 128.0, 118.5, 87.83, 35.95, 31.01, 21.86, 18.28, 17.53; ATR-FTIR (thin film): 2966, 1599, 1359, 1265, 1188, 1175, 1096 cm^{-1}; HRMS (ESI-TOF) *m* / *z* calculated for $C_{14}H_{20}O_3NaS$ [M+Na]$^+$: 291.1031, found 291.1038.

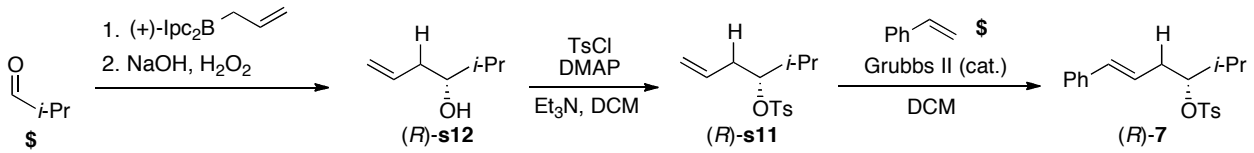


7

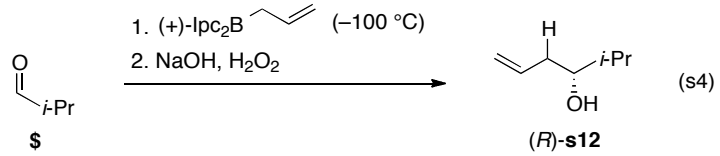
(*E*)-2-Methyl-6-phenylhex-5-en-3-yl 4-methylbenzenesulfonate 7. The general procedure was followed using 289 mg of secondary homoallylic tosylate **s11** (1.1 mmol), 1.2 mL of styrene (11 mmol), and 10 mg of Grubbs's 2nd generation catalyst in 2.2 mL of DCM. Purification by flash column chromatography (0:100 → 20:80 EtOAc:hexanes) afforded **7** as a white powder (194 mg, 51%), mp 71 °C, R_f = 0.36 (20:80 EtOAc:hexanes, visualized by 254 nm light). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.76 (d, *J* = 8.2 Hz, 2H), 7.30-7.27 (m, 2H), 7.22-7.19 (m, 5H), 6.31 (d, *J* = 16 Hz, 1H), 5.91 (dt, *J* = 16, 7.6 Hz, 1H), 4.50 (q, *J* = 5.7 Hz, 1H), 2.49 (t, *J* = 6.6 Hz, 2H), 2.35 (s, 3H), 2.05 (oct, *J* = 7.0 Hz, 1H), 0.92 (d, *J* = 6.8 Hz, 6H).; ^{13}C NMR ($CDCl_3$, 125 MHz): δ 144.6, 137.3, 134.7, 133.4, 129.8, 128.7, 127.9, 127.5, 126.4, 124.6, 88.09, 34.93, 31.56, 21.82, 18.09, 17.08; ATR-FTIR (thin film): 2968, 1595, 1491, 1449, 1347, 1169, 1094 cm^{-1}; HRMS (ESI-TOF) *m* / *z* calculated for $C_{20}H_{24}O_3NaS$ [M+Na]$^+$: 367.1344, found 367.1349.

I. Preparation of Substrate (*R*)-7

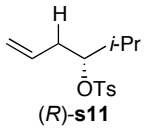
Scheme s7. Synthetic route to enantiomerically-enriched secondary tosylate (*R*)-**7**.



Enantiomerically-enriched secondary tosylate (*R*)-**7** was synthesized in 96% enantiomeric excess in four steps and three pots (11% overall yield) from isobutyraldehyde using a sequence of Brown asymmetric allylation, oxidation, tosylation of the resultant alcohol (requiring stoichiometric DMAP), and finally cross-metathesis. These yields are unoptimized.

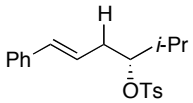


(*R*)-2-Methylhex-5-en-3-ol (*R*)-**s12**. To a flame-dried, N_2-purged 100 mL round-bottom flask charged with a stirbar was added 0.50 mL of freshly distilled isobutyraldehyde (5.5 mmol) and 27 mL of Et_2O. After cooling the flask to –100 °C, 5.5 mL of a 1.0 M solution of (+)-*B*-allyldiisopinocampheylborane solution in pentane (5.5 mmol) was added dropwise over 30 min. The resulting solution was stirred for an additional hour at –100 °C, at which point 1.1 mL of MeOH was added, and the reaction vessel was warmed to ambient temperature. Then, 2.2 mL of a 2.5 M aqueous NaOH solution and 2.75 mL of a 50% v/v solution of aqueous H_2O_2 was added, and the reaction was allowed to stir overnight. The aqueous and organic layers were separated and the aqueous layer was extracted with Et_2O (10 mL). The combined organic layers were washed with H_2O (10 mL), dried over $MgSO_4$, filtered, and concentrated *in vacuo* at –15 °C to give a colorless residue. Kugelrohr distillation (50 °C, 9 torr) afforded (*R*)-**s12** as a colorless oil (374 mg, 60%). The spectral data matched those reported by Fraunhoffer and coworkers.[14] ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.89-5.79 (m, 1H), 5.17-5.11 (m, 2H), 3.42-3.37 (m, 1H), 2.34-2.29 (m, 1H), 2.14-2.08 (m, 1H), 1.72-1.66 (m, 1H), 1.54 (br s, 1H), 0.94 (d, *J* = 8.5 Hz, 3H), 0.93 (d, *J* = 8.5 Hz, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 135.6, 118.2, 75.58, 39.06, 33.32, 18.92, 17.76; ATR-FTIR (thin film): 3400, 2918, 1720, 1452, 1368, 1274.



(*R*)-2-Methylhex-5-en-3-yl 4-methylbenzenesulfonate (*R*)-**s11**. The general procedure was followed using 374 mg of homoallylic alcohol (*R*)-**s12** (3.3 mmol), 0.9 mL of Et_3N (6.6 mmol), 686 mg of tosyl chloride (3.6 mmol), and 440 mg of DMAP (3.6 mmol) in 16 mL of DCM. Purification by flash column chromatography (0:100 → 30:70 benzene:hexanes) afforded (*R*)-**s11** as a colorless amorphous material (400 mg, 45%), R_f = 0.17 (20:80 benzene:hexanes, visualized by 254 nm light), $[\alpha]_D^{23}$ = –12° (c 0.06, $CHCl_3$). The spectral data matched those reported for **s11** above. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.77 (d, *J* = 8.4 Hz, 2H), 7.33-7.28 (m, 2H), 5.61 (ddt, *J* = 17, 10, 7.1 Hz, 1H), 5.04-4.95 (m, 2H), 4.42 (q, *J* = 5.6 Hz, 1H), 2.43 (s, 3H), 2.37-2.31 (m, 2H), 1.91 (pd, *J* = 6.8, 5.2 Hz, 1H), 0.85 (d, *J* = 6.8 Hz, 3H), 0.84 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ

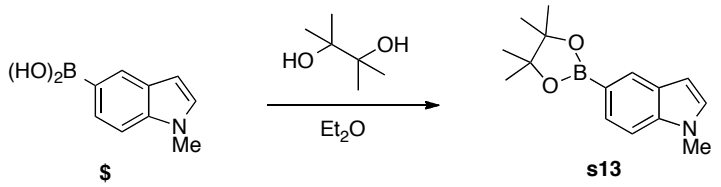
144.6, 134.8, 132.8, 129.8, 128.0, 118.5, 87.83, 35.95, 31.01, 21.86, 18.28, 17.53; ATR-FTIR (thin film): 2966, 1599, 1359, 1265, 1188, 1175, 1096 cm^{-1}.



(*R*)-**7**

(*R*,*E*)-2-Methyl-6-phenylhex-5-en-3-yl 4-methylbenzenesulfonate (*R*)-**7**. The general procedure was followed using 400 mg of (*R*)-**s11** (1.5 mmol), 1.7 mL of styrene (15 mmol), and 12 mg of Grubbs's 2nd generation catalyst in 3.0 mL of DCM. Purification by flash column chromatography (0:100 → 20:80 EtOAc:hexanes) afforded (*R*)-**s11** as a white powder (213 mg, 41%), mp 72 °C, R_f = 0.36 (20:80 EtOAc:hexanes, visualized by 254 nm light), ee = 96% (Chiralcel® AD-H, 1:99 → 50:50 MeOH/CO_2 at 2 mL/min over 10 min, 160 bar, and 40 °C), t_1 = 7.41 min (*R*), t_2 = 7.76 min (*S*). $[\alpha]_D^{23}$ = –11° (c 0.04, $CHCl_3$). The spectral data matched those reported for racemic **7** above. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.76 (d, *J* = 8.4 Hz, 2H), 7.36-7.26 (m, 2H), 7.24-7.16 (m, 5H), 6.31 (d, *J* = 16 Hz, 1H), 5.90 (dt, *J* = 16, 7.3 Hz, 1H), 4.50 (q, *J* = 5.6 Hz, 1H), 2.49 (ddd, J = 7.2, 6.1, 1.2 Hz, 2H), 2.35 (s, 3H), 2.05 (oct, *J* = 6.9 Hz, 1H), 0.92 (d, J = 6.9 Hz, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 144.6, 137.2, 134.6, 133.4, 129.9, 128.7, 127.9, 127.5, 126.4, 124.6, 88.10, 34.92, 31.55, 21.84, 18.09, 17.81; ATR-FTIR (thin film): 2967, 1595, 1491, 1449, 1358, 1169, 1094 cm^{-1}.

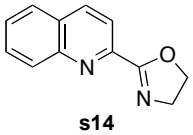
IV. Preparation of *N*-Methylindole-5-Boronic Acid Pinacol Ester



$ **s13** (s5)

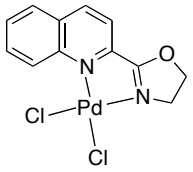
***N*-Methylindole-5-boronic acid pinacol ester s13**. Into a dry 20 mL scintillation vial equipped with a stirbar were added 78 mg of *N*-methylindole-5-boronic acid (0.43 mmol) and 52 mg of pinacol (0.43 mmol) in 1.0 mL of Et_2O. The mixture was stirred overnight at ambient temperature, after which it was concentrated *in vacuo*. Purification by flash column chromatography (0:100 → 30:70 EtOAc:hexanes) afforded the product as a white powder (105 mg, 75%), mp 107–109 °C, R_f = 0.45 (20:80 EtOAc:hexanes, visualized by 254 nm light). The spectral data matched those reported by Stadlwieser and coworkers.[15] ^{1}H NMR ($CDCl_3$, 300 MHz): δ 8.16 (s, 1H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.31 (d, *J* = 8.3 Hz, 1H), 7.03 (d, *J* = 3.0 Hz, 1H), 6.59 (d, *J* = 3.0 Hz, 1H), 3.78 (s, 3H), 1.36 (s, 12H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 138.8, 129.1, 129.0, 128.4, 127.8, 108.8, 101.9, 83.61, 33.04, 25.05; ATR-FTIR (thin film): 2975, 2927, 1609, 1515, 1441, 1335, 1299, 1270, 1256, 1211, 1195, 1138, 1109, 1089, 1070 cm^{-1}.

V. Preparation of Ligands and Catalysts



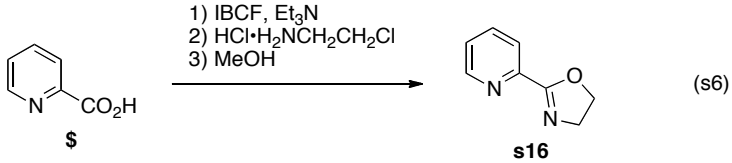
s14

2-(Quinolin-2-yl)-4,5-dihydrooxazole ("quinox") **s14** was prepared according to a published procedure.[16]



s15

$Pd(quinox)Cl_2$ **s15** was prepared according to published procedure.[16]

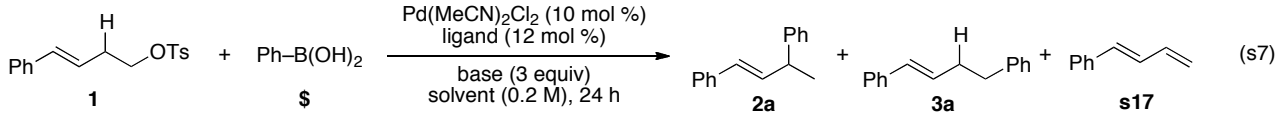


(s6)

2-(Pyridin-2-yl)-4,5-dihydrooxazole ("pyrox") **s16** was prepared analogously to quinox **s14** in a three step, single pot process (eq s6):[16] to an oven-dried 100 mL round bottomed flask with a magnetic stirbar was weighed 400 mg of 2-picolinic acid (3.25 mmol, 1.00 equiv). The flask was put under N_2 atmosphere, 32 mL of dry CH_2Cl_2 was added to the reaction flask, and the mixture was cooled to 0 °C. To the mixture was added 1.3 mL of NEt_3 (8.94 mmol, 2.75 equiv), followed by dropwise addition of 485 μL of IBCF over 30 min (3.74 mmol, 1.15 equiv). The mixture was stirred at 0 °C for 0.5 h. In a single portion, 433 mg of $HCl•H_2NCH_2CH_2Cl$ (3.74 mmol, 1.15 equiv) was added. After stirring for 10 min, the ice bath was removed and the mixture was allowed to warm to room temperature and stir an additional 2.5 h. The solvent was then evaporated under reduced pressure. To the residue was added 20 mL of MeOH along with 912 mg KOH (16 mmol, 5.00 equiv). The flask was fitted with a water condenser and the reaction mixture was heated to reflux overnight. It was then cooled to room temperature and the solvent was evaporated under reduced pressure. The oily residue was dissolved in CH_2Cl_2 (50 mL) and washed with H_2O (1 × 50 mL). The aqueous layer was extracted with CH_2Cl_2 (3 × 30 mL). The combined organic layers were washed with saturated aqueous NH_4Cl (1 × 50 mL) and brine (1 × 50 mL), dried over Na_2SO_4, filtered and concentrated under reduced pressure. The product was purified by flash column chromatography eluting with 5% MeOH/DCM, and isolated as a white solid in 87% yield (421 mg, 2.84 mmol). Its spectral data were compared to published ones.[17]

VI. Pd-Catalyzed Allylic C–H Functionalization Reactions of Homoallylic Tosylates

A. General procedures for the evaluation of ligands to phenylate homostyrenyl tosylate 1 with phenylboronic acid

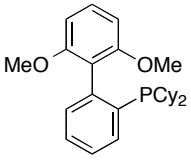
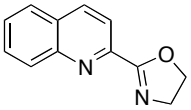
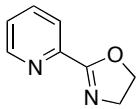
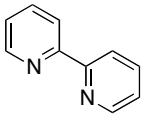
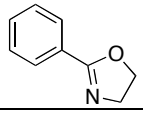


General procedure A (for phosphine ligands, eq s7). Inside a glove box, the catalyst was pre-formed by stirring a mixture of 4 mg of $Pd(MeCN)_2Cl_2$ (0.013 mmol) and a phosphine ligand (0.016 mmol) in 0.40 mL of PhMe for 30 min in a 4 mL vial. Into another 4 mL vial were added base (0.30 mmol, 3.00 equiv), 18 mg of phenylboronic acid (0.15 mmol, 1.50 equiv), 30 mg of homostyrenyl tosylate **1** (0.10 mmol, 1.00 equiv), and 2-methoxynaphthalene as internal standard. To these solids was then added 200 μL PhMe and the mixture was stirred. While stirring, 300 μL of the catalyst mixture were added (resulting in 10 mol % of $Pd(MeCN)_2Cl_2$ and 12 mol % of ligand). For ambient temperature reactions, the vial was sealed and stirred for 24 h before an aliquot was removed for analysis. For reactions performed at elevated temperature, the vial was removed from the glove box and stirred in an oil bath. After 24 h, it was cooled to room temperature, and an aliquot was removed for GC analysis. The products were initially identified based on GC/MS. For reactions performed in alcoholic solvents, a small amount (ca 5%) of PhMe was added to solubilize the starting material.

General procedure B (for bidentate amine ligands, eq s7). The catalyst was pre-formed by stirring a mixture of 4 mg of $Pd(MeCN)_2Cl_2$ (0.013 mmol) and ligand (0.016 mmol) in 400 μL *t*AmOH for 30 min in a dry 4 mL vial under N_2. Into another dry 4 mL vial under N_2 were added base (0.30 mmol, 3.00 equiv), 18 mg of phenylboronic acid (0.15 mmol, 1.50 equiv), 30 mg of homostyrenyl tosylate **1** (0.10 mmol, 1.00 equiv), and 2-methoxynaphthalene as internal standard. To the solids was then added 200 μL of *t*AmOH and the mixture was stirred. While stirring, 300 μL of the catalyst mixture were added (resulting in 10 mol % $Pd(MeCN)_2Cl_2$ and 12 mol % ligand). The vial was then capped and stirred vigorously at room temperature on a stir plate. Small samples were removed for GC analysis at the indicated times.

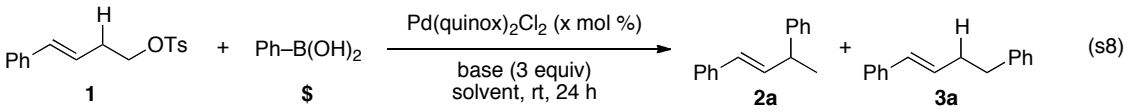
B. Tabular summary of ligand evaluation experiments

Table s1. Optimization of Reaction

entry	procedure	ligand	base	solvent	T (°C)	% yield **2a**+**3a**	**2a**:**3a**	% yield **s17**
1	A	P*t*-Bu_3	Cs_2CO_3	PhMe	80	55	95:5	41
2	A	PCy_3	Cs_2CO_3	PhMe	80	45	62:38	51
3	A	P*n*-Bu_3	Cs_2CO_3	PhMe	80	11	91:9	79
4	A	P(*o*-tol)$_3$	Cs_2CO_3	PhMe	80	32	3:97	13
5	A	PPh_3	Cs_2CO_3	PhMe	80	20	85:15	66
6	A		Cs_2CO_3	PhMe	80	14	29:71	76
7	A	$Cy_2PCH_2CH_2PCy_2$	Cs_2CO_3	PhMe	80	<5	n.d.	13
8	A	P*t*-Bu_3	Cs_2CO_3	PhMe	rt	53	>95:5	36
9	A	P*t*-Bu_3	K_2CO_3	PhMe	rt	44	>95:5	44
10	A	P*t*-Bu_3	K_2CO_3	*t*-AmOH	rt	80	>95:5	6
11[a]	A	P*t*-Bu_3	K_2CO_3	*t*-AmOH	rt	<2	n.d.	10
12	A	P(*o*-tol)$_3$	Cs_2CO_3	PhMe	80	31	<5:95	13
13	A	P(*o*-tol)$_3$	K_2CO_3	PhMe	80	54	<5:95	7
14	B		Cs_2CO_3	*t*-AmOH	rt	70	>95:5	n.d.
15	B		Cs_2CO_3	*t*-AmOH	rt	48	>95:5	n.d.
16	B		Cs_2CO_3	*t*-AmOH	rt	n.r.	n.a.	n.d.
17	B		$KF{\cdot}2H_2O$	*i*-PrOH	rt	n.r.	n.a.	n.d.

[a] Used 20 mol % of P*t*-Bu_3.

C. General Procedure for Reaction Optimization Using Pd(quinox)Cl_2



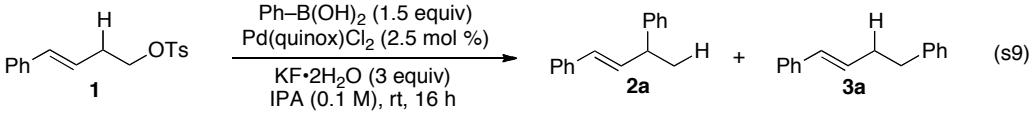
Optimization reactions using pre-formed Pd(quinox)Cl_2 **s15** were performed analogously to the general procedure B for ligand evaluation above with no addition of excess ligand (eq s8). Pd(quinox)Cl_2 was added directly to the reaction flask along with the other solids with purging under N_2 for ca 3 min prior to addition of solvent.

D. Tabular Summary of Reaction Optimization Using the Pd(quinox)Cl_2 Precatalyst

Table s2. Optimization of reactions using Pd(quinox)Cl_2 pre-catalyst

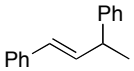
entry	x	base	solvent	[solvent]	% yield **2a**	**2a:3a**
1	10	Cs_2CO_3	*t*-AmOH	0.2 M	58	>20:1
2	10	Cs_2CO_3	*i*-PrOH	0.2 M	72	16:1
3	10	K_2CO_3	*t*-AmOH	0.2 M	57	23:1
4	10	K_2CO_3	*i*-PrOH	0.2 M	73	>20:1
5	10	KF·$2H_2O$	*t*-AmOH	0.2 M	90	>20:1
6	10	KF·$2H_2O$	*i*-PrOH	0.2 M	86	>20:1
7	2.5	KF·$2H_2O$	*i*-PrOH	0.2 M	90	>20:1
8	2.5	KF·$2H_2O$	*i*-PrOH	0.1 M	89	>20:1

E. Optimized General Procedure



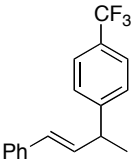
Into a dry 25 mL round-bottom flask equipped with a PTFE-lined stirbar were added 5 mg of Pd(quinox)Cl_2 (0.013 mmol, 2.5 mol %), 141 mg of KF·$2H_2O$ (1.50 mmol, 3.00 equiv), 91 mg of PhB$(OH)_2$ (0.750 mmol, 1.50 equiv), and 151 mg of homostyrenyl tosylate **1** (0.50 mmol, 1.00 equiv). The flask was equipped with a septum and N_2 line and was flushed with N_2 for ca 3 min. To the solids was then added 5 mL of isopropanol and the mixture was stirred vigorously for 16 h. The heterogeneous mixture was then partitioned between Et_2O and H_2O (20 mL each) and the organic layer was washed with saturated aqueous $NaHCO_3$ (1 × 20 mL). The combined aqueous layers were extracted with Et_2O (2 × 20 mL) and the combined organic layers were dried over Na_2SO_4, decanted, concentrated *in vacuo*. After analysis by ^{1}H NMR spectroscopy, the crude residue was purified by flash column chromatography (100% hexanes on silica gel) to afford a colorless oil.

F. Scope and Limitations of the Allylic C–H Aryl- and Vinylation Reaction



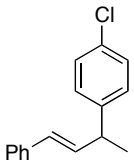
2a

(*E*)-But-1-ene-1,3-diyldibenzene 2a. The general procedure was followed. The product **2a** was purified by flash column chromatography eluting with 400 mL of 0.5% acetone/hexanes → 300 mL of 2% acetone/hexanes. The product was isolated as a colorless oil in an average 92% yield (experiment 1: 97 mg, 93%, >20:1 linear:branched; experiment 2: 93 mg, 90%, >20:1 linear:branched). The spectral data matched those reported by Liao and Sigman.[18]



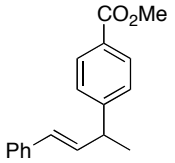
2b

(*E*)-1-(4-Phenylbut-3-en-2-yl)-4-(trifluoromethyl)benzene 2b. The general procedure was followed. The product **2b** was purified by flash column chromatography eluting with 400 mL of 0.5% acetone/hexanes → 300 mL of 2% acetone/hexanes. The product was isolated as a colorless oil in an average 81% yield (experiment 1: 106 mg, 76%, 13:1 linear:branched; experiment 2: 119 mg, 86%, 11:1 linear:branched), R_f = 0.39 (100% hexanes, visualized by 254 nm UV light). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60 (m, 2H), 7.43-7.22 (m, 7H), 6.49-6.32 (m, 2H), 3.63 (m, 1H), 1.51 (d, J = 7.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 149.8, 137.3, 134.1, 129.5, 129.1 (q, $J_{C–F}$ = 27.0 Hz), 128.7, 127.8, 127.5, 126.3, 125.6 (q, $J_{C–F}$ = 4.0 Hz), 124.4 (q, $J_{C–F}$ = 270.8 Hz), 42.59, 21.20; ATR-FTIR (thin film): 3026, 2968, 1618, 1495, 1448, 1417, 1322, 1162, 1114, 1067, 1014 cm^{-1}; HRMS (ESI-TOF) m / z calculated for $C_{17}H_{15}F_3Ag$ [M+Ag]$^+$: 383.0177, found 383.0190.



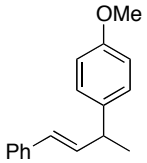
2c

(*E*)-1-Chloro-4-(4-phenylbut-3-en-2-yl)benzene 2c. The general procedure was followed. The product **2c** was purified by flash column chromatography, eluting with 400 mL of 0.5% acetone/hexanes → 300 mL of 3% acetone/hexanes. The product was isolated as a colorless oil in an average 73% yield (experiment 1: 92 mg, 76%, 11:1 linear:branched; experiment 2: 84 mg, 70%, 11:1 linear:branched). Its spectral data were compared to published ones.[19]



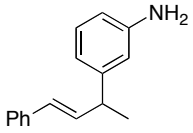
2d

(*E*)-Methyl 4-(4-phenylbut-3-en-2-yl)benzoate 2d. The general procedure was followed. The product **2d** was purified by flash column chromatography eluting with 2% acetone/hexanes. The product was isolated as a colorless oil in an average 82% yield (experiment 1: 110 mg, 80%, 11:1 linear:branched; experiment 2: 110 mg, 82%, 13:1 linear:branched). Its spectral data were compared to published ones.[18]



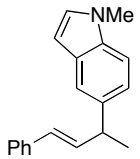
2e

(*E*)-1-Methoxy-4-(4-phenylbut-3-en-2-yl)benzene 2e. The general procedure was followed using 4-methoxyphenylboronic acid. The product **2e** was purified by flash column chromatography on Brockmann I activated basic alumina, eluting with 1% acetone/hexanes. The product was isolated as a colorless oil in an average 72% yield (experiment 1: 81 mg, 68%, 15:1 linear:branched; experiment 2: 90 mg, 75%, 15:1 linear:branched). Its spectral data were compared to published ones.[18]



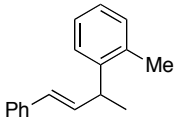
2f

(*E*)-3-(4-Phenylbut-3-en-2-yl)aniline 2f. The general procedure was followed using 151 mg of homostyrenyl tosylate **1** (0.50 mmol), 103 mg of 3-aminophenylboronic acid (0.75 mmol), 141 mg of $KF{\cdot}2H_2O$ (1.5 mmol), and 5 mg of $Pd(quinox)Cl_2$ (0.01 mmol) in 5 mL of isopropanol. Purification by flash column chromatography (0:100 → 30:70 EtOAc:hexanes) afforded **2f** as a yellow oil (94 mg, 84%), R_f = 0.30 (20% EtOAc:hexanes, visualized by 254 nm light). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.38 (d, J = 7.7 Hz, 2H), 7.31 (t, J = 7.6 Hz, 2H), 7.21 (t, J = 7.6 Hz, 1H), 7.13 (t, J = 7.8 Hz, 1H), 6.71 (d, J = 7.6 Hz, 1H), 6.62 (s, 1H), 6.57-6.55 (m, 1H), 6.43 (d, J = 16 Hz, 1H), 6.39 (dd, J = 16, 6.0 Hz, 1H), 3.67 (br s, 2H), 3.56 (p, J = 6.6 Hz, 1H), 1.46 (d, J = 7.0 Hz, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 147.2, 146.6, 137.9, 135.5, 129.6, 128.7, 128.6, 127.2, 126.4, 118.0, 114.4, 113.4, 42.74, 21.34; ATR-FTIR (thin film): 3023, 2962, 1616, 1602, 1492, 1447, 1291, 1165 cm^{-1}; HRMS (ESI-TOF) m / z calculated for $C_{16}H_{18}N$ $[M+H]^+$: 224.1439, found 224.1438.



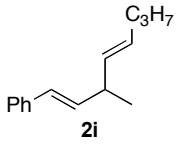
2g

(*E*)-1-Methyl-5-(4-phenylbut-3-en-2-yl)-1H-indole 2g. The general procedure was followed using 53 mg of homostyrenyl tosylate **1** (0.18 mmol), 86 mg of *N*-methylindole-5-boronic acid pinacol ester **s13** (0.26 mmol), 50 mg of $KF{\cdot}2H_2O$ (0.53 mmol), and 2 mg of $Pd(quinox)Cl_2$ (0.01 mmol) in 1.8 mL of isopropanol. Purification by flash column chromatography (0:100 → 30:70 benzene:hexanes) afforded **2i** as an orange oil (44 mg, 94%), R_f = 0.15 (10:90 benzene:hexanes, visualized by 254 nm light). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.56 (s, 1H), 7.42-7.38 (m, 2H), 7.33-7.30 (m, 3H), 7.23-7.18 (m, 2H), 7.06 (d, *J* = 3.1 Hz, 1H), 6.52 (dd, *J* = 16, 6.0 Hz, 1H), 6.48-6.45 (m, 2H), 3.80 (s, 3H), 3.79 (p, *J* = 7.0 Hz, 1H), 1.56 (d, *J* = 7.0 Hz, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 138.1, 136.8, 136.7, 135.8, 129.3, 128.9, 128.7, 128.1, 127.1, 126.4, 121.8, 119.1, 109.4, 101.0, 42.81, 33.10, 22.00; ATR-FTIR (thin film): 3022, 2959, 2924, 2868, 1598, 1512, 1489, 1446, 1421, 1339, 1244, 1154, 1078, 1007 cm^{-1}; HRMS (ESI-TOF) *m* / *z* calculated for $C_{19}H_{20}N$ $[M+H]^+$: 262.1596, found 262.1597.



2h

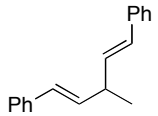
(*E*)-1-Methyl-2-(4-phenylbut-3-en-2-yl)benzene 2h. The general procedure was followed using 151 mg of homostyrenyl tosylate **1** (0.50 mmol), 164 mg of 2-methylphenylboronic acid pinacol ester (0.75 mmol), 141 mg of $KF{\cdot}2H_2O$ (1.5 mmol), and 5 mg of $Pd(quinox)Cl_2$ (0.01 mmol) in 5 mL of isopropanol. Purification by flash column chromatography (100% hexanes) afforded **2h** as a colorless oil (82 mg, 74%), R_f = 0.16 (100% hexanes, visualized by 254 nm light). The spectral data matched those reported by Liao and Sigman.[18] ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.37-7.33 (m, 2H), 7.31-7.25 (m, 3H), 7.23-7.10 (m, 4H), 6.38 (s, 1H), 6.37 (s, 1H), 3.90-3.83 (m, 1H), 2.38 (s, 3H), 1.45 (d, *J* = 7.0 Hz, 3H).; ^{13}C NMR ($CDCl_3$, 75 MHz): δ 143.8, 137.9, 135.9, 135.1, 130.7, 128.8, 128.7, 127.3, 126.6, 126.5, 126.4, 126.3, 38.33, 20.74, 19.80; ATR-FTIR (thin film): 3023, 2964, 2927, 2870, 1600, 1492, 1447, 1371, 1207, 1155 cm^{-1}.



2i

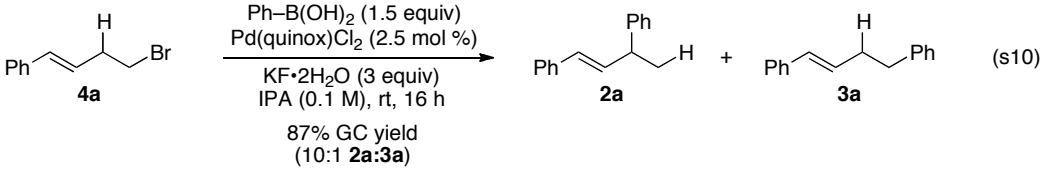
((1*E*,4*E*)-3-Methylocta-1,4-dien-1-yl)benzene 2i. The general procedure was followed using 151 mg of homostyrenyl tosylate **1** (0.50 mmol), 85 mg of 1-pentenylboronic acid (7.5 mmol), 141 mg of $KF{\cdot}2H_2O$ (1.5 mmol), and 5 mg of $Pd(quinox)Cl_2$ (0.05 mmol) in 5 mL of isopropanol. Purification by flash column chromatography (100% hexanes) afforded **2i** as a colorless oil (65 mg, 65%), R_f = 0.43 (100% hexanes, visualized by 254 nm light). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.37 (d, *J* = 7.5 Hz, 2H), 7.30 (t, *J* = 7.5 Hz, 2H), 7.20 (t, *J* = 7.5 Hz, 1H), 6.36 (d, *J* = 16 Hz, 1H), 6.19 (dd, *J* = 16, 6.9 Hz, 1H), 5.51-5.42 (m, 2H), 3.00 (sextet, 6.0 Hz, 1H), 2.03-1.99 (m, 2H), 1.41 (sextet, *J* = 7.0 Hz, 2H), 1.19 (d, *J* = 7.0 Hz, 3H), 0.92 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 138.1, 135.6, 134.3, 129.6, 128.7, 128.2, 127.1, 126.3, 39.95, 34.93, 22.88,

20.72, 13.91; ATR-FTIR (thin film): 3025, 2959, 2926, 2870, 1493, 1448, 1264 cm^{-1}; HRMS (ESI-TOF) *m* / *z* calculated for $C_{15}H_{20}Ag$ $[M+Ag]^+$: 307.0616, found 307.0632.

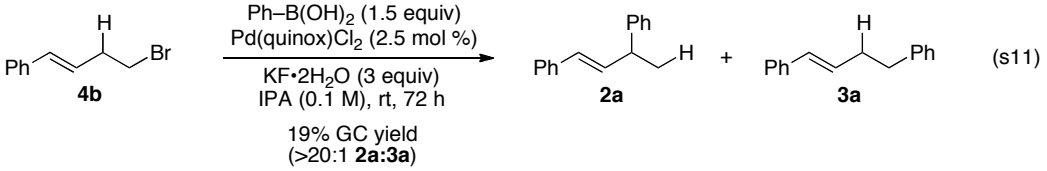


2j

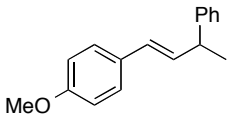
((1*E*,4*E*)-3-Methylpenta-1,4-diene-1,5-diyl)dibenzene 2j. The general procedure was followed using 151 mg of homostyrenyl tosylate **1** (0.50 mmol), 111 mg of (*E*)-styrenylboronic acid (0.75 mmol), 141 mg of $KF{\cdot}2H_2O$ (1.5 mmol), and 5 mg of $Pd(quinox)Cl_2$ (0.01 mmol) in 5 mL of isopropanol. After workup and concentration *in vacuo*, 0.1 mmol of CH_2Br_2 was added to the residue, and this mixture was diluted with $CDCl_3$ for NMR spectroscopy. ^1H NMR spectroscopy ($CDCl_3$, 300 MHz) revealed complete conversion of **1** to a 73% NMR yield of **2j**. This product was inseparable from (*E*,*E*)-1,4-diphenyl-1,3-butadiene using flash column chromatography. Selected spectral data for **2j**: ^1H NMR ($CDCl_3$, 300 MHz): δ 7.42 (d, *J* = 7.5 Hz, 4H), 7.34 (t, *J* = 7.5 Hz, 4H), 7.27-7.22 (m, 2H), 6.49 (d, *J* = 16 Hz, 2H), 6.30 (dd, *J* = 16, 6.9 Hz, 2H), 3.26 (sextet, *J* = 6.9 Hz, 1H), 1.35 (d, *J* = 6.6 Hz, 3H).



The general procedure was followed using 21 mg of homostyrenyl bromide **4a** (0.10 mmol), 18 mg of (*E*)-styrenylboronic acid (0.15 mmol), 28 mg of $KF{\cdot}2H_2O$ (0.30 mmol), and 1 mg of $Pd(quinox)Cl_2$ (0.003 mmol) in 1 mL of isopropanol using a portion of 2-methoxynaphthalene as an internal standard. After 16 h, an aliquot was removed and filtered through a plug of silica gel prior to GC analysis, which revealed an 87% yield of a 10:1 mixture of **2a**:**3a**.

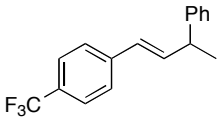


The general procedure was followed using 19 mg of homostyrenyl chloride **4b** (0.10 mmol), 18 mg of (*E*)-styrenylboronic acid (0.15 mmol), 28 mg of $KF{\cdot}2H_2O$ (0.30 mmol), and 1 mg of $Pd(quinox)Cl_2$ (0.003 mmol) in 1 mL of isopropanol using a portion of 2-methoxynaphthalene as an internal standard. After 72 h, an aliquot was removed and filtered through a plug of silica gel prior to GC analysis, which revealed a 19% yield of a >20:1 mixture of **2a**:**3a**.



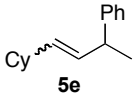
5c

(*E*)-1-Methoxy-4-(3-phenylbut-1-en-1-yl)benzene 5c. The general procedure was followed using homostyrenyl tosylate **4c**. The product **5c** was purified by flash column chromatography, eluting with 1.5% acetone/hexanes. The product was isolated as a colorless oil in an average 86% yield (experiment 1: 99 mg, 83%, 15:1 linear:branched; experiment 2: 107 mg, 89%, 15:1 linear:branched). Its spectral data were compared to published ones.[18]



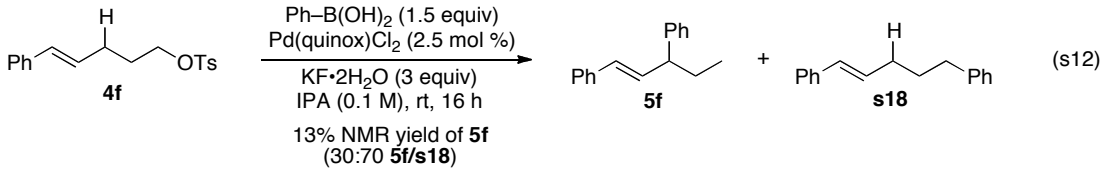
5d

(*E*)-1-(3-Phenylbut-1-en-1-yl)-4-(trifluoromethyl)benzene 5d. The general procedure was followed in two trials using 111 mg (0.30 mmol) and 69 mg (0.19 mmol) of homoallyl tosylate **4d**, respectively. Purification by flash column chromatography (100% hexanes) afforded **5d** as a colorless oil (65 mg, 78%, and 40 mg, 77%, respectively), R_f = 0.29 (100% hexanes, visualized by 254 nm UV light). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.56 (d, *J* = 8.4 Hz, 2H) 7.46 (d, *J* = 8.4 Hz, 2H), 7.41-7.33 (m, 2H), 7.33-7.23 (m, 3H), 6.53 (dd, *J* = 16, 6.0 Hz, 1 H), 6.45 (d, *J* = 16 Hz, 1H), 3.70 (p, *J* = 6.9 Hz, 1H), 1.52 (d, *J* = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 145.3, 141.3, 138.2, 128.9, 128.8, 127.6, 127.5, 126.7, 126.5, 126.5 (q, $J_{C–F}$ = 226.8 Hz), 125.7 (q, $J_{C–F}$ = 3.8 Hz), 42.88, 21.25; ^{19}F NMR ($CDCl_3$, 282 MHz): δ –62.79; ATR-FTIR (thin film): 3027, 2967, 1615, 1493, 1452, 1414, 1322, 1162, 1110, 1106, 1065, 1015 cm^{-1}; HRMS (ESI-TOF) *m* / *z* calculated for $C_{17}H_{15}F_3Ag$ $[M+Ag]^+$: 383.0177, found 383.0185.

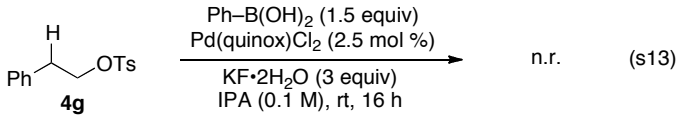


5e

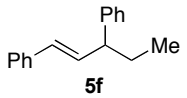
(4-Cyclohexylbut-3-en-2-yl)benzene 5e. The general procedure was followed using 132 mg of homoallyl tosylate **4e** (0.44 mmol). Purification by flash column chromatography (100% hexanes) afforded **5e**, an 93:7 mixture of *E* and *Z* isomers, as a colorless oil (69 mg, 73%), R_f = 0.45 (100% hexanes, visualized by 254 nm UV light). The spectral data for the major (*E*) isomer matched those reported by Liao and Sigman.[18] ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.32 (t, *J* = 7.6 Hz, 2H), 7.26-7.17 (m, 3H), 5.59 (dd, *J* = 16, 6.8 Hz, 1H), 5.45 (dd, *J* = 16, 6.4 Hz, 1H), 3.44 (p, *J* = 6.8 Hz, 1H), 2.02-1.91 (m, 1H), 1.80-1.63 (m, 5H), 1.37 (d, *J* = 7.2 Hz, 3H), 1.33-1.04 (m, 5H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 146.9, 135.5, 132.6, 128.5, 127.4, 126.1, 42.44, 40.88, 33.44, 26.49, 26.37, 21.90. Selected spectral data for the *Z* isomer: ^{1}H NMR ($CDCl_3$, 400 MHz): δ 5.25 (t, *J* = 10.4 Hz, 1H), 3.87-3.78 (m, 1H), 2.70 (dd, *J* = 8.0, 1.6 Hz, 2H), 2.49-2.36 (m, 2H), 2.36-2.28 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 142.5, 128.7, 128.6, 128.4, 127.1, 125.9, 36.85, 36.50, 34.80, 33.85, 29.97, 22.76. Selected spectral data for the mixture: ATR-FTIR (thin film): 3025, 2963, 2921, 2849, 1601, 1492, 1448, 1371, 1009 cm^{-1}.



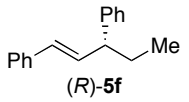
5f. The general procedure was followed using 158 mg of homoallylic tosylate **4f** (0.50 mmol), 91 mg of phenylboronic acid (0.75 mmol), 141 mg of $KF{\cdot}2H_2O$ (1.5 mmol), and 5 mg of $Pd(quinox)Cl_2$ (0.01 mmol) in 5 mL of isopropanol. After workup and concentration *in vacuo*, 7 μL of CH_2Br_2 (0.1 mmol) was added to the residue, and this mixture was diluted with $CDCl_3$ for NMR spectroscopy. ^{1}H NMR spectroscopy ($CDCl_3$, 300 MHz) revealed 67% conversion of **4f** to a 13% NMR yield of desired **5f**, a 30:70 mixture of **5f** and **s18**. The ^{1}H NMR spectral data of **5f** matched those reported by Sarkar and coworkers,[20] as well as that reported below. The linear isomer **s18** was previously reported by Tarasov and coworkers.[21] Selected spectral data for the linear isomer: ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.39–7.27 (m, 6 H), 7.25–7.17 (m, 4H), 6.40 (d, J = 16 Hz, 1 H), 6.25 (td, J = 16, 7.0 Hz, 1 H), 2.68 (t, J = 8.0 Hz, 2 H), 2.26 (q, J = 8.0 Hz, 2 H), 1.82 (p, J = 8.0 Hz, 1 H).



Attempted reaction of **4g**. The general procedure was followed using 28 mg of homobenzyl tosylate **4g** (0.10 mmol), 18 mg of phenylboronic acid (0.15 mmol), 28 mg of $KF{\cdot}2H_2O$ (0.30 mmol), and 1 mg of $Pd(quinox)Cl_2$ (0.001 mmol) in 1 mL of isopropanol. After stirring at ambient temperature for 16 h, the reaction mixture was taken up in Et_2O, filtered through a plug of silica gel, and concentrated *in vacuo*. To the resulting crude mixture was added 7 μL of CH_2Br_2 (0.1 mmol). ^{1}H NMR ($CDCl_3$, 300 MHz) showed that none of the starting material had been consumed.

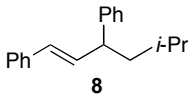


(*E*)-Pent-1-ene-1,3-diyldibenzene 5f. The general procedure was followed using 87 mg of secondary homoallylic tosylate **6** (0.27 mmol), 50 mg of phenylboronic acid (0.41 mmol), 77 mg of $KF{\cdot}2H_2O$ (0.62 mmol), and 10 mg of $Pd(quinox)Cl_2$ (0.03 mmol) in 2.7 mL of isopropanol. Purification by flash column chromatography (100% hexanes) afforded **5f** as a colorless oil (42 mg, 70%), R_f = 0.17 (100% hexanes, visualized by 254 nm light). The spectral data matched those reported above as well as those reported by Sarkar and coworkers.[20] ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.43–7.20 (m, 10 H), 6.47 (d, J = 16 Hz, 1 H), 6.39 (dd, J = 16, 6.9 Hz, 1 H), 3.70 (q, J = 7.2 Hz, 1 H), 1.90 (quintet of doublets, J = 7.5, 0.6 Hz, 2 H), 0.98 (t, J = 7.2 Hz, 3 H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 144.8, 137.9, 134.5, 129.7, 128.7 (2 C), 128.0, 127.3, 126.5, 126.4, 51.27, 29.07, 12.61; ATR-FTIR (thin film): 3028, 2963, 2925, 2874, 1723, 1494, 1451, 1268, 1026 cm^{-1}.



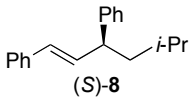
(*R*)-**5f**

(*R*,*E*)-pent-1-ene-1,3-diyldibenzene (*R*)-**5f**. The general procedure was followed using 158 mg of homoallylic tosylate (*R*)-**6** (0.50 mmol), 91 mg of phenylboronic acid (0.75 mmol), 141 mg of $KF{\cdot}2H_2O$ (1.5 mmol), and 19 mg of Pd(quinox)Cl_2 (0.05 mmol) in 5 mL of isopropanol. Purification by flash column chromatography (100% hexanes) afforded (*R*)-**5f** as a colorless oil (69 mg, 62%), R_f = 0.17 (100% hexanes, visualized by 254 nm light), ee = 40% (Chiralcel® AD-H, MeOH/CO_2 1:99 at 1 mL/min, 160 bar, and 40 °C), t_1 = 22.34 min (*R*), t_2 = 24.39 min (*S*). $[\alpha]_D^{23}$ = +13° (c 0.04, $CHCl_3$). The spectral data matched those reported above, as well as those of Sarkar and coworkers.[20]



8

(*E*)-(5-Methylhex-1-ene-1,3-diyl)dibenzene 8. The general procedure was followed using 85 mg of tosylate **7** (0.25 mmol), 45 mg of phenylboronic acid (0.37 mmol), 69 mg of $KF{\cdot}2H_2O$ (0.74 mmol), and 9 mg of Pd(quinox)Cl_2 (0.03 mmol) in 2.5 mL of isopropanol. Purification by flash column chromatography (100% hexanes) afforded **8** as a colorless oil (30 mg, 48%), R_f = 0.30 (100% hexanes, visualized by 254 nm light). The spectral data matched those reported below for (*S*)-**8**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.38-7.27 (m, 8H), 7.25-7.19 (m, 2H), 6.42 (d, *J* = 16 Hz, 1H), 6.35 (dd, *J* = 16, 7.7 Hz, 1H), 3.56 (q, *J* = 7.7 Hz, 1H), 1.72 (t, *J* = 7.4 Hz, 2H), 1.59 (septet, *J* = 6.7 Hz, 1H), 0.97 (d, *J* = 6.6 Hz, 3H), 0.95 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 145.0, 137.8, 134.8, 129.3, 128.8, 128.7, 127.9, 127.2, 126.4, 126.3, 47.12, 45.42, 25.67, 22.92, 22.86.

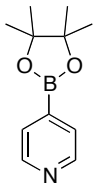


(*S*)-**8**

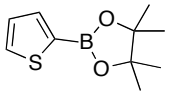
(*S*,*E*)-(5-Methylhex-1-ene-1,3-diyl)dibenzene (*S*)-**8**. The general procedure was followed using 120 mg of homostyrenyl tosylate (*R*)-**7** (0.35 mmol), 64 mg of phenylboronic acid (0.52 mmol), 98 mg of $KF{\cdot}2H_2O$ (1.0 mmol), and 20 mg of Pd(quinox)Cl_2 (0.05 mmol) in 3.5 mL of isopropanol. Purification by flash column chromatography (100% hexanes) afforded (*S*)-**8** as a colorless oil (45 mg, 52%), R_f = 0.30 (100% hexanes, visualized by 254 nm light), ee = 92% (Chiralcel® OJ-H, 100% CO_2 at 1.0 mL/min, 100 bar, and 40 °C), t_1 = 104.11 min (*R*), t_2 = 110.16 min (*S*). $[\alpha]_D^{23}$ = –10° (c 0.04, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.40-7.17 (m, 10H), 6.42 (d, *J* = 16 Hz, 1H), 6.34 (dd, *J* = 16, 7.1 Hz, 1H), 3.56 (q, *J* = 7.5 Hz, 1H), 1.72 (t, *J* = 7.4 Hz, 2H), 1.58 (septet, *J* = 6.6 Hz, 1H), 0.97 (d, *J* = 6.6 Hz, 3H), 0.95 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 145.0, 137.8, 134.8, 129.3, 128.8, 128.7, 127.9, 127.2, 126.4, 126.3, 47.12, 45.40, 25.67, 22.93, 22.86; ATR-FTIR (thin film): 3025, 2953, 2914, 2866, 1599, 1493, 1466, 1450, 1383, 1366, 1071 cm^{-1}; HRMS (ESI-TOF) *m* / *z* calculated for $C_{19}H_{22}Ag$ $[M+Ag]^+$: 357.0772, found 357.0789.

G. Non-Productive Pinacol Boronic Ester Transmetallating Reagents

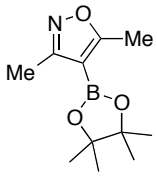
Based on ^{1}H NMR spectroscopy of the respective crude reaction mixtures, the following commercially-obtained pinacol boronic esters **s19**–**s22** did not afford either allylic C–H functionalization or cross-coupling products under the optimized conditions for the functionalization of **1**.



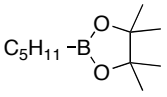
s19



s20



s21

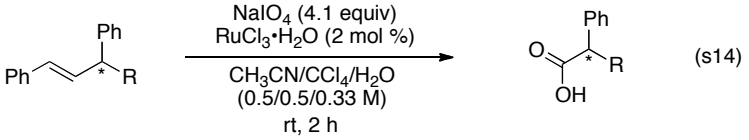


s22

VII. Determination of Absolute Configurations of (*R*)-5f and (*S*)-8

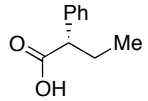
A. General Procedure for Sharpless Oxidative Cleavage of Alkenes

Previously characterized α-phenylalkanoic acids (including absolute configuration) were obtained from the Ru-catalyzed Sharpless oxidation of 3-alkyl-1,3-diphenyl-1-propenes as reported by Thalén and coworkers (eq s14).[22]



A solution of the allylic C–H functionalization product (1.0 mmol, 1.0 equiv) in CH_3CN (0.2 mL) was added to a 4 mL vial containing $NaIO_4$ (4.1 mmol, 4.1 equiv), $RuCl_3{\cdot}nH_2O$ (0.02 mmol, 2 mol %), and a stir bar. Then, CCl_4 (0.2 mL) and H_2O (0.3 mL) were added, and the mixture was capped and stirred for 2 h at ambient temperature, at which time TLC revealed the consumption of starting material. The reaction mixture was disolved in 5 mL of DCM and extracted with aqueous $NaHCO_3$ (3 x 5 mL). The combined aqueous phase was acidified with 2 M aqueous HCl and the aqueous phase was extracted with DCM (3 x 5 mL). The combined organic phase was dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The crude residue was taken up in $CHCl_3$ for the determination of optical rotation, which was compared to previously reported values for these compounds or their enantiomers. The concentration was estimated by assuming a quantitative yield.

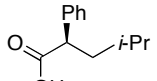
B. Oxidative Cleavage Products of (*R*)-5f and (*S*)-8



(*S*)-**s22**

(*S*)-2-Phenylbutanoic acid (*S*)-**s22**. The general procedure was followed using 26 mg of (*R*)-**5f** (1.2 mmol), 103 mg of $NaIO_4$ (4.8 mmol), and 1 mg of $RuCl_3{\cdot}nH_2O$ (0.01 mmol) in 0.3 mL, CH_3CN, 0.3 mL of CCl_4, and

0.4 mL of H_2O. Optical rotation for (*S*)-**s22**: $[\alpha]_D^{23}$ = +35° (c 0.04, $CHCl_3$). (*S*)-**22** was previously reported by Stivala and Zakarian, who found $[\alpha]_D^{23}$ = +70.7° (c 1.0, $CHCl_3$).[23]

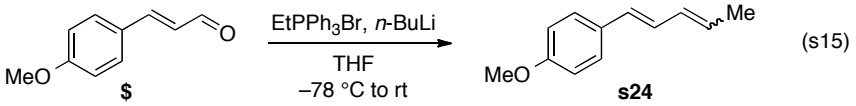


(*R*)-**s23**

(*R*)-4-Methyl-2-phenylpentanoic acid (*R*)-**s23**. The general procedure was followed using 22 mg of (*S*)-**8** (1.0 mmol), 87 mg of $NaIO_4$ (4.0 mmol), and 1 mg of $RuCl_3 \cdot nH_2O$ (0.01 mmol). Optical rotation for (*R*)-**s23**: $[\alpha]_D^{23}$ = –65° (c 0.05, $CHCl_3$). (*S*)-**23** was previously reported by Stivala and Zakarian, who found $[\alpha]_D^{23}$ = +59.0° (c 1.0, $CHCl_3$).[23]

VIII. Crossover Experiments

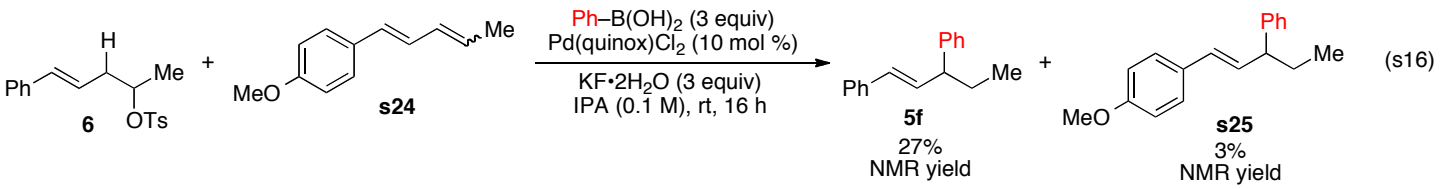
A. Preparation of 1-Methoxy-4-(1,3-pentadien-1-yl)benzene s24



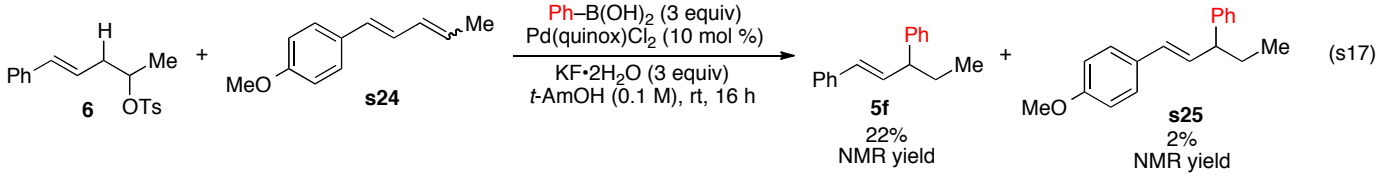
$ **s24** (s15)

To a dry 250 mL round-bottom flask equipped with a stirbar under N_2 were added 4.88 g (13 mmol, 1.30 equiv) of ethyltriphenylphosphonium bromide and 43 mL of THF. The flask was cooled to –78 °C and 5.6 mL of a 2.5 M solution of *n*-BuLi in hexanes (14 mmol, 1.40 equiv) was added dropwise. The reaction was allowed to warm to room temperature and stirred an additional 10 min before it was cooled to –78 °C. Then,1.66 g *trans*-4-methoxycinnamaldehyde (10 mmol, 1.00 equiv) was added slowly. The reaction was allowed to warm up to room temperature and stir overnight before being quenched with 50 mL of saturated aqueous NH_4Cl. THF was then removed in vacuo and the residue was extracted with Et_2O (2 x 50 mL) and washed with H_2O (1 x 100 mL). The organic phase was concentrated in vacuo and the residue was purified by flash column chromatography (100% hexanes) to afford **s24**, a 50:50 mixture of *E*,*E* and *E*,*Z* isomers, as a low-melting pale yellow solid (1.35 g, 77%), mp 45 °C, R_f = 0.56 (20:80 EtOAc:hexanes, visualized by 254 nm UV light). Selected spectral data for the *E*,*Z*-isomer: ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.39-7.29 (m, 2H), 6.97 (dd, *J* = 16, 11 Hz, 1H), 6.89-6.82 (m, 2H), 6.48 (d, *J* = 16 Hz, 1H), 6.25-6.13 (m, 1H), 5.55 (ddq, *J* = 11, 7.2, 1.0 Hz, 1H), 3.82 (s, 3H), 1.82 (d, *J* = 6.8 Hz, 3H). Selected spectral data for the *E*,*E*-isomer: ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.39-7.29 (m, 2H), 6.89-6.82 (m, 2H), 6.63 (dd, *J* = 16, 10 Hz, 1H), 6.38 (d, *J* = 16 Hz, 1H), 6.25-6.13 (m, 1H), 5.79 (ddq, *J* = 14, 6.8, 1.0 Hz, 1H), 3.82 (s, 3H), 1.86 (d, *J* = 6.8 Hz, 3H). Selected spectral data for the mixture: ^{13}C NMR ($CDCl_3$, 100 MHz): δ 159.3, 159.1, 134.1, 133.9, 132.2, 131.6, 130.7, 130.0, 129.5, 129.3, 128.9, 128.8, 128.7, 127.7, 127.6, 127.5, 126.2, 122.5, 114.3, 114.2, 55.50, 18.55, 13.81; ATR-FTIR (thin film): 3015, 2986, 2954, 2907, 2839, 2051, 2005, 1644, 1599, 1573, 1508, 1467, 1440, 1417, 1372, 1298, 1249, 1175, 1148, 1110, 1026 cm^{-1}; HRMS (AP-TOF) *m* / *z* calculated for $C_{12}H_{15}O$ $[M+H]^+$: 175.1123, found 175.1122.

B. Results of Crossover Experiments



The general allylic arylation procedure was followed using 32 mg of secondary tosylate **6** (0.10 mmol), 17 mg of diene **s24** (0.10 mmol), 18 mg of phenylboronic acid (0.15 mmol), 28 mg of KF·2H_2O (0.30 mmol), and 4 mg of Pd(quinox)Cl_2 (0.01 mmol) in 1 mL of isopropanol. After 16 h, the resulting heterogeneous mixture was filtered through a plug of SiO_2 with Et_2O and concentrated in vacuo. To the resulting crude mixture was added 7 µL of CH_2Br_2 (0.1 mmol). ^{1}H NMR spectroscopy ($CDCl_3$, 400 MHz) revealed a 27% yield of **5f** by comparing to the spectrum reported above, and a 3% yield of crossover product **s25**. The presence of crossover product **s25** was confirmed by GC-MS.



The general allylic C–H arylation procedure was followed using 32 mg of secondary tosylate **6** (0.10 mmol), 17 mg of diene **s24** (0.10 mmol), 18 mg of phenylboronic acid (0.15 mmol), 28 mg of KF·2H_2O (0.30 mmol), and 4 mg of Pd(quinox)Cl_2 (0.01 mmol) in 1 mL of *tert*-amyl alcohol. After 16 h, the resulting heterogeneous mixture was filtered through a plug of SiO_2 with Et_2O and concentrated in vacuo. To the resulting crude mixture was added 7 µL of CH_2Br_2 (0.1 mmol). ^{1}H NMR spectroscopy ($CDCl_3$, 300 MHz) revealed a 22% yield of **5f** by comparing to the spectrum reported above, and a 2% yield of crossover product **s25** which was also identified by GC-MS.

IX. References

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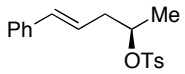
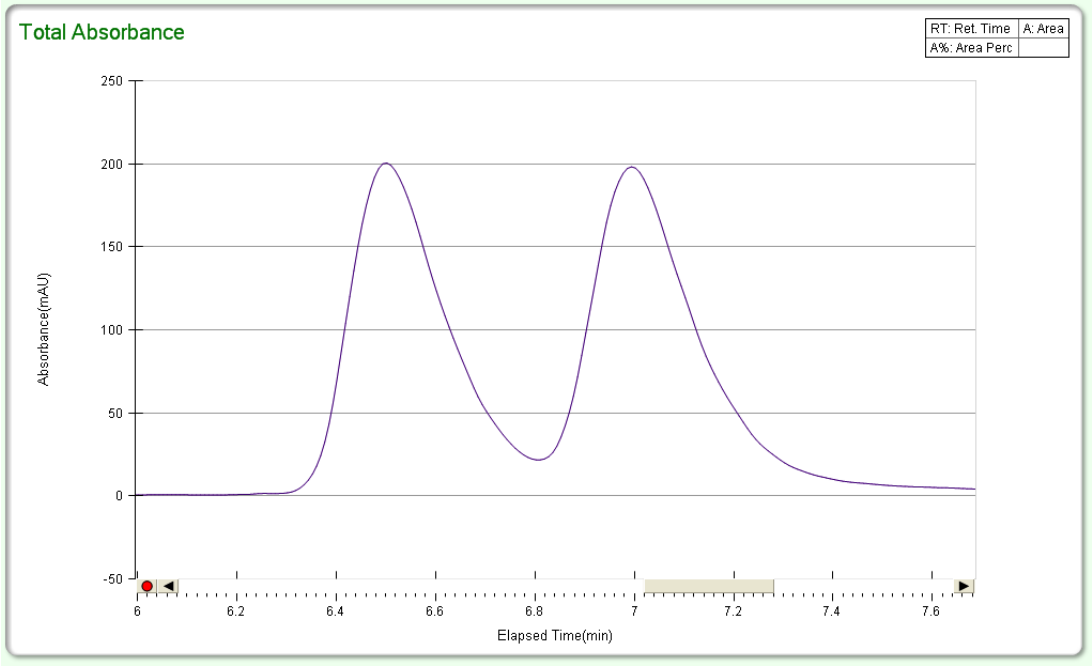


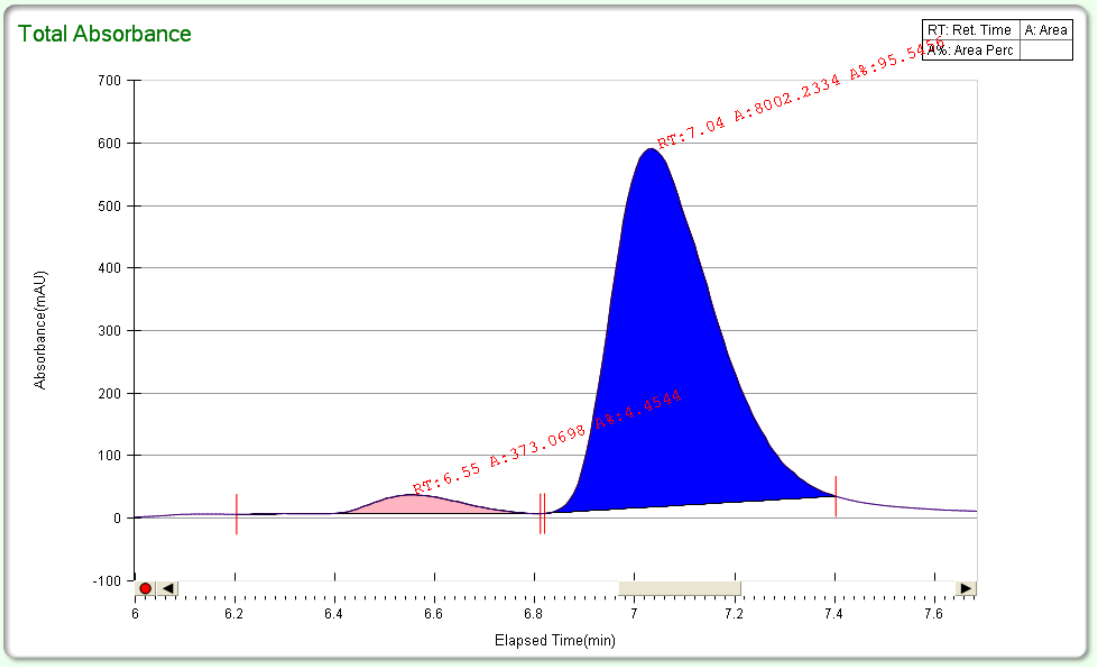
(*R*)-**6**

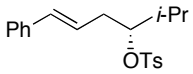
Separation of enantiomers by SFC. Chiralcel® AD-H column, 10:90 MeOH/CO_2 at 2 mL/min, 160 bar, and 40 °C; 6.55 min (*S*), 7.04 min (*R*).

6



(*R*)-**6**

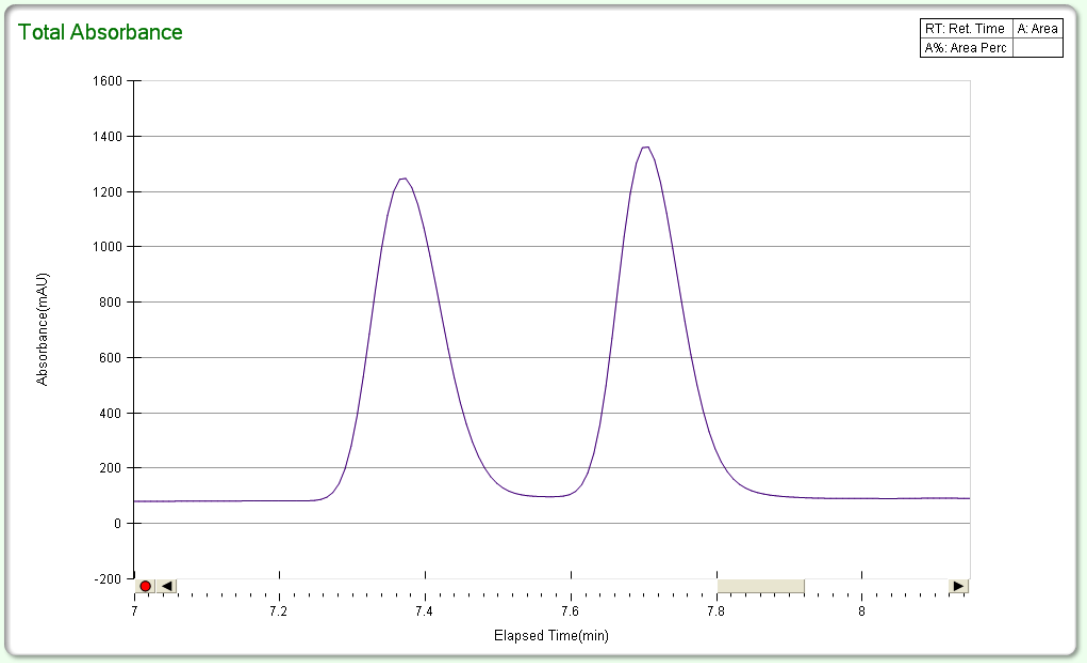




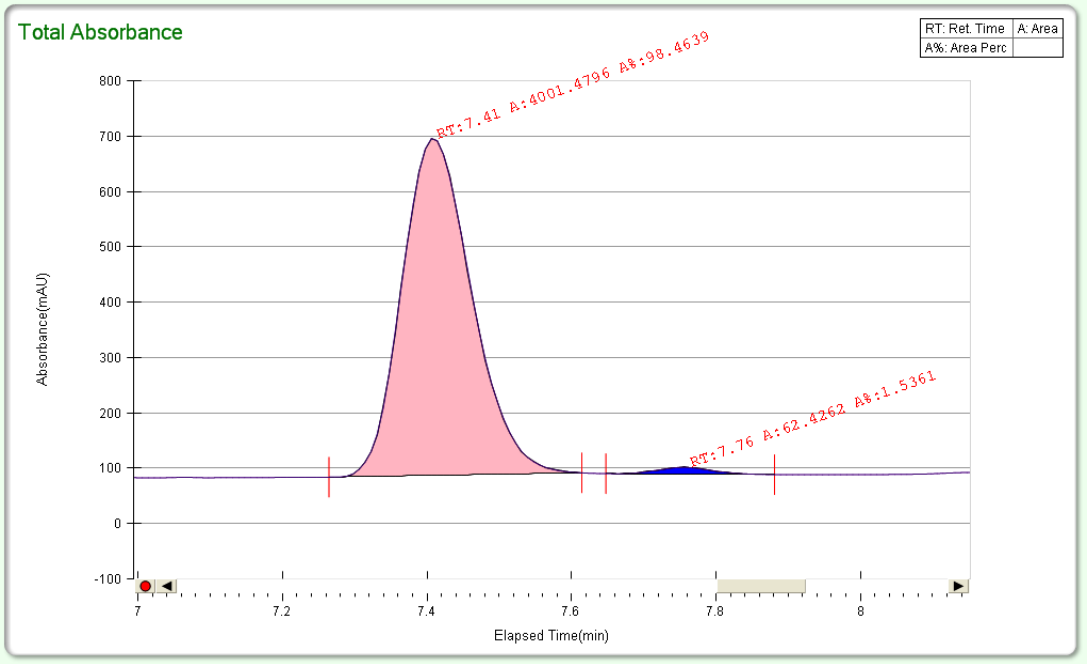
(*R*)-**7**

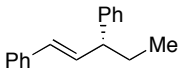
Separation of enantiomers by SFC. Chiralcel® AD-H, 1:99 → 50:50 MeOH/CO_2 (over 10 min) at 2 mL/min, 160 bar, and 40 °C; t_1 = 7.41 min (*R*), t_2 = 7.76 min (*S*).

7



(*R*)-**7**

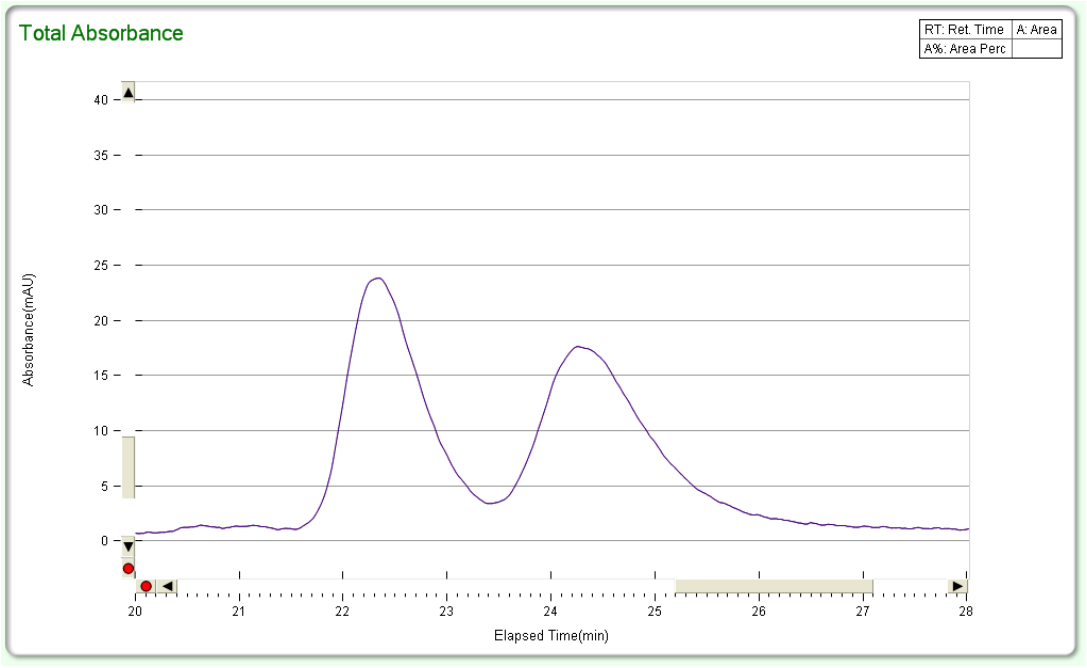




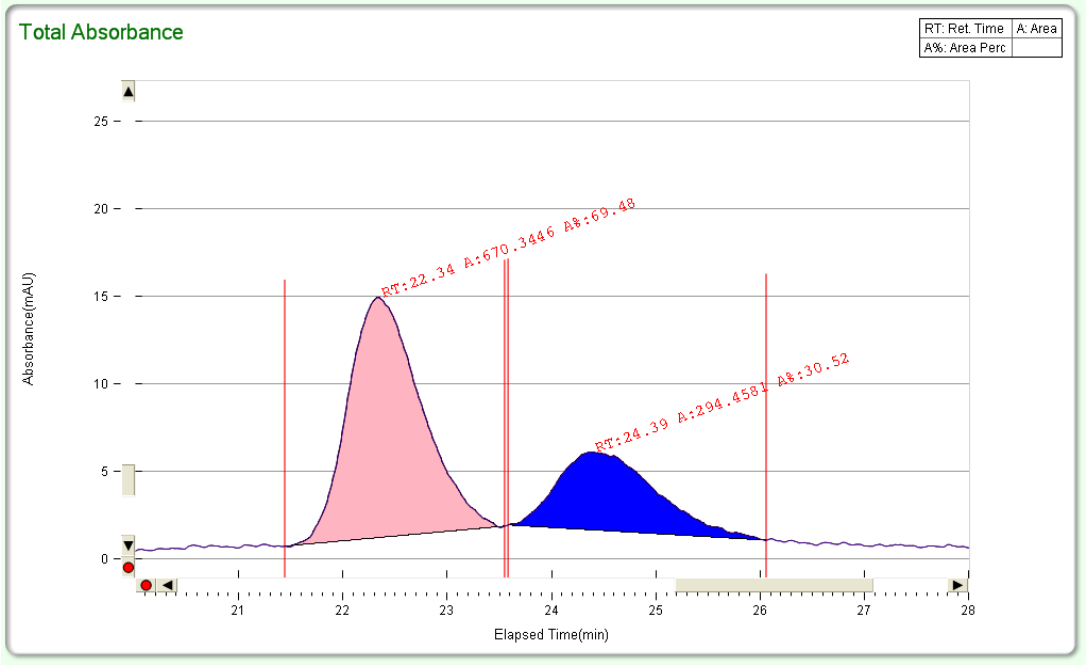
(*R*)-**5f**

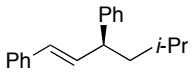
Separation of enantiomers by SFC. Chiralcel® AD-H, MeOH/CO_2 1:99 at 1 mL/min, 160 bar, and 40 °C; t_1 = 22.34 min (*R*), t_2 = 24.39 min (*S*).

5f



(*R*)-**5f**

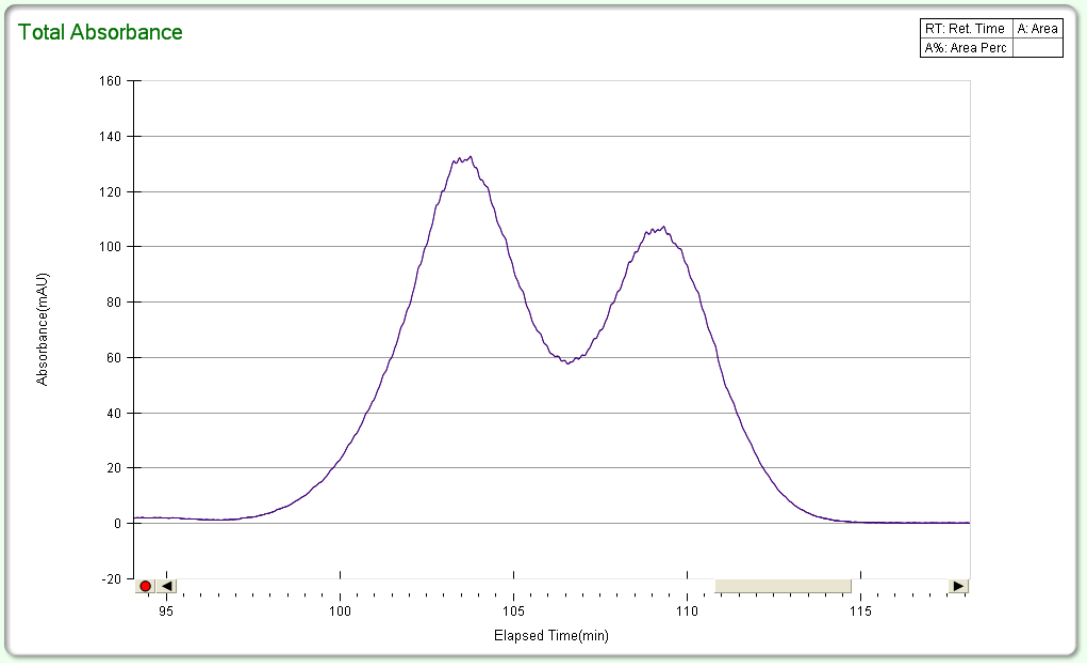




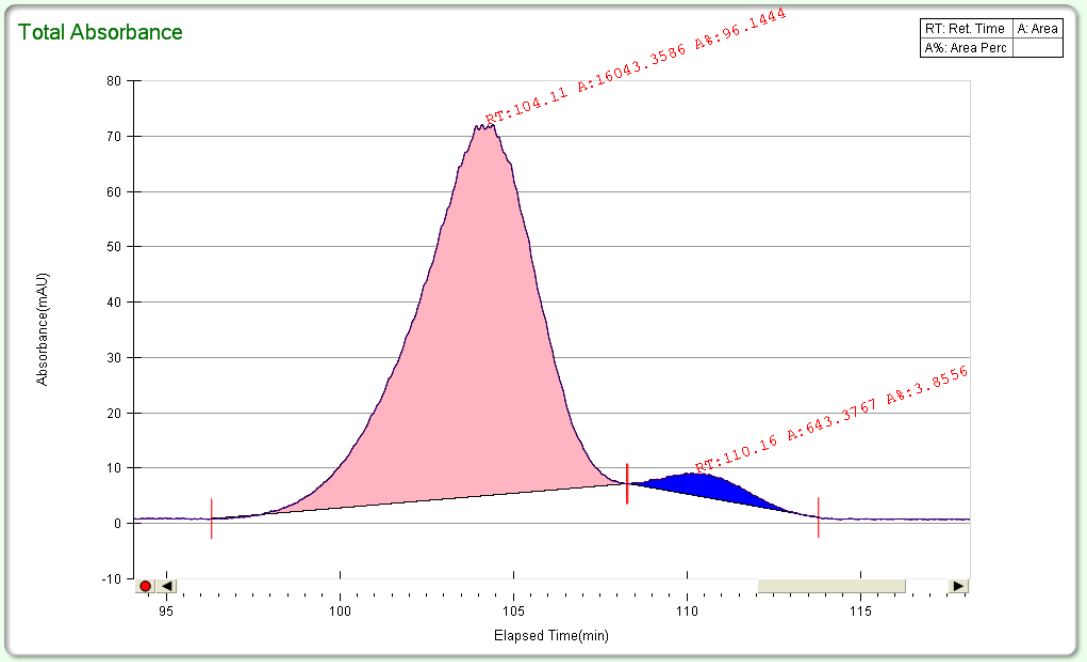
(*S*)-**8**

Separation of enantiomers by SFC. Chiralcel® OJ-H, 100% CO_2 at 1.0 mL/min, 100 bar, and 40 °C; t_1 = 104.11 min (*S*), t_2 = 110.16 min (*R*).

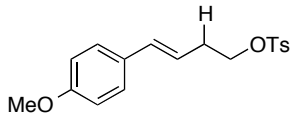
8



(*S*)-**8**

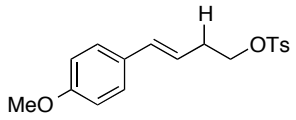


4c



BJSii040
^{1}H (300 MHz), $CDCl_3$

4c



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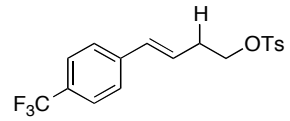
4d



BJSii002
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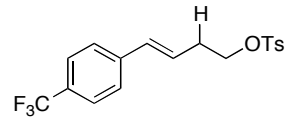
4d



BJSii002
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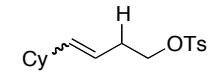
4e



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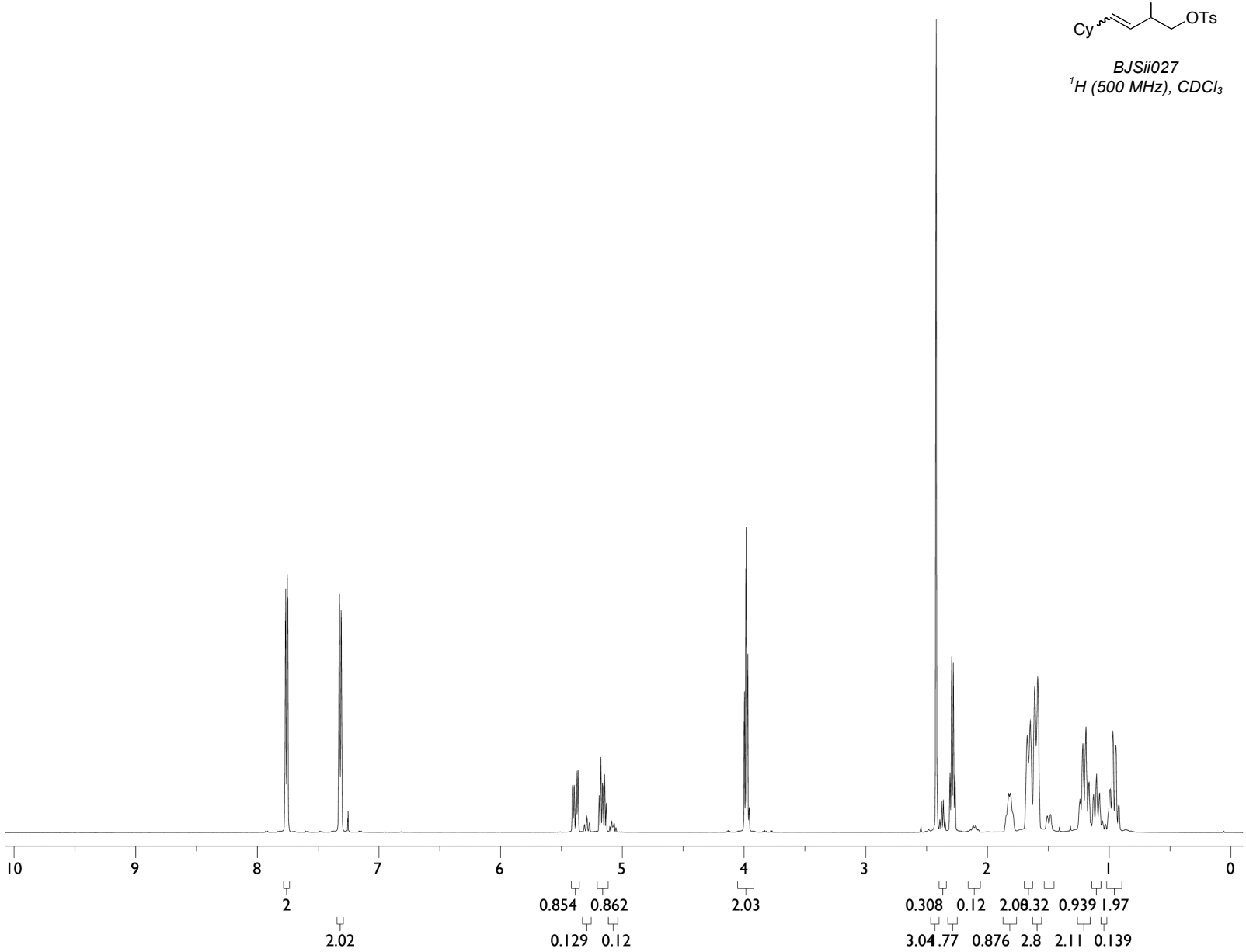

4e

BJSii027
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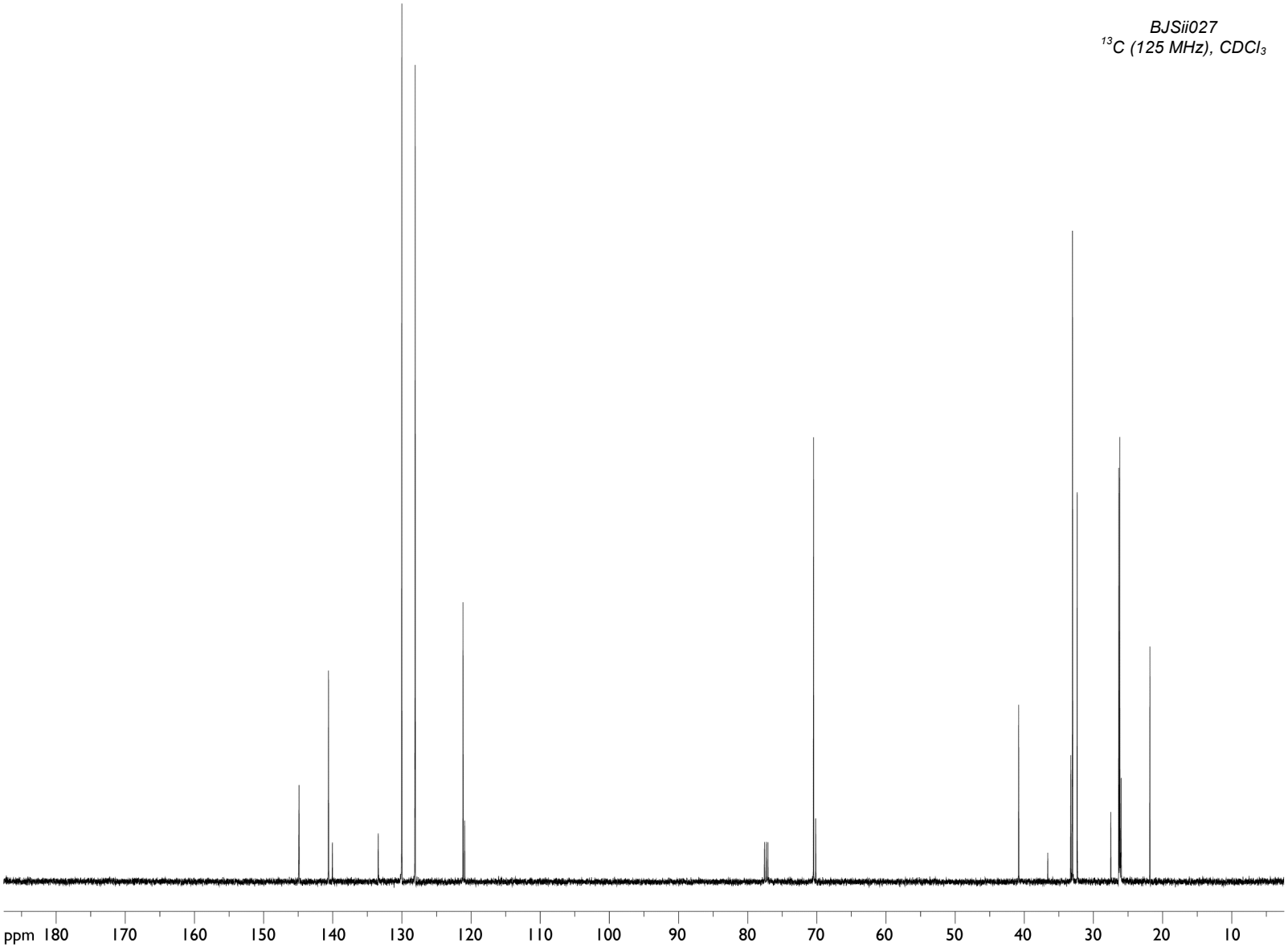
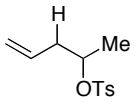


s10



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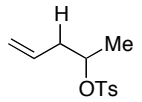
s10



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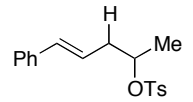
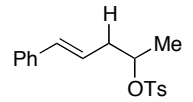
6



BJSi182
^{1}H (300 MHz), $CDCl_3$

6



BJSi182
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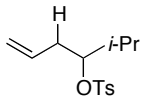
s11



BJSii078
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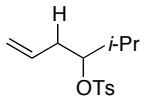
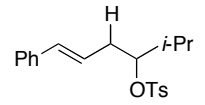
s11



BJSii078
^{13}C (75 MHz), $CDCl_3$

7



BJSii079
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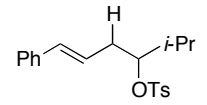
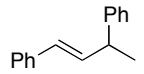
7



BJSii079
^{13}C (125 MHz), $CDCl_3$

2a



SMP3.5
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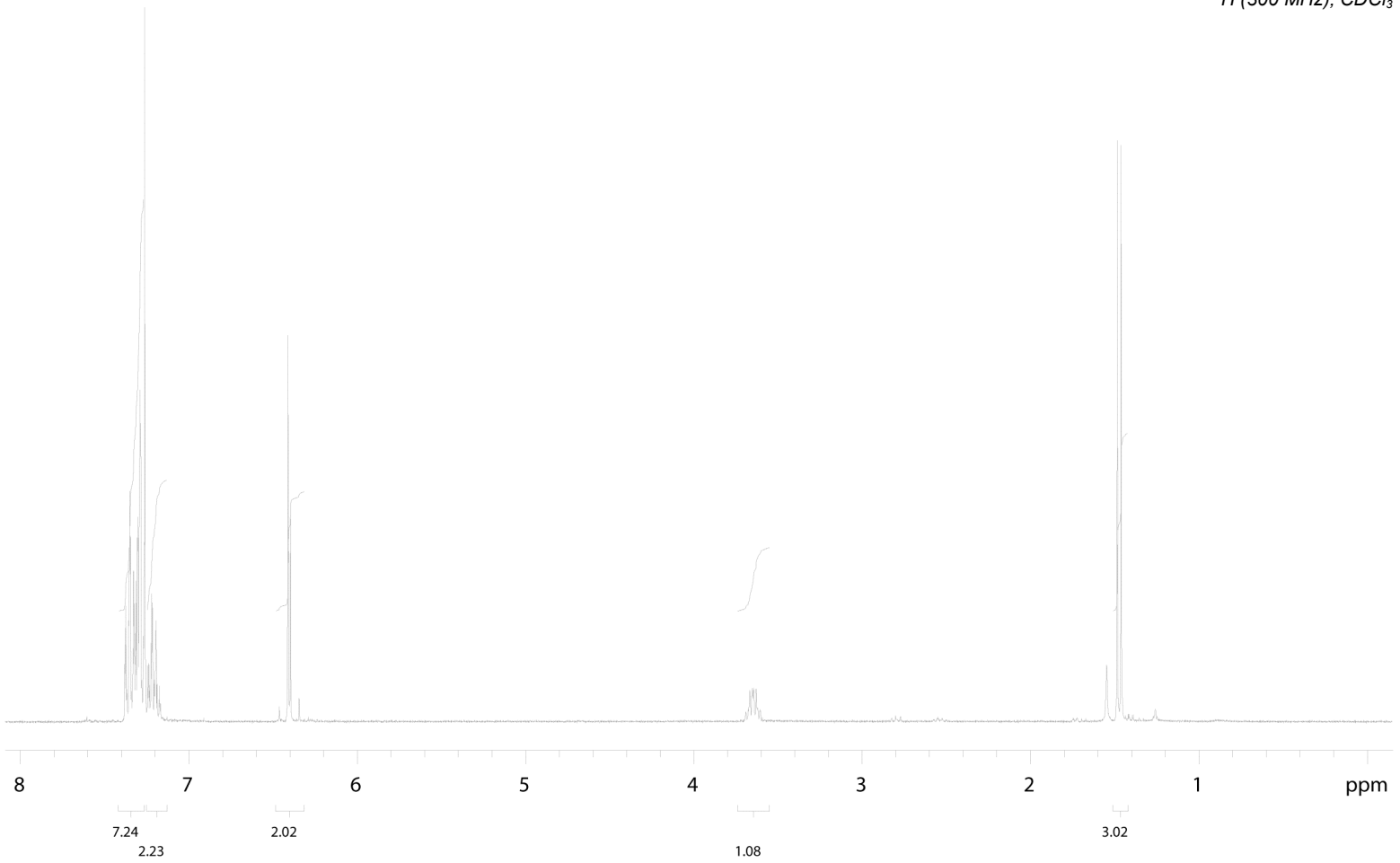
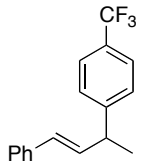


2b



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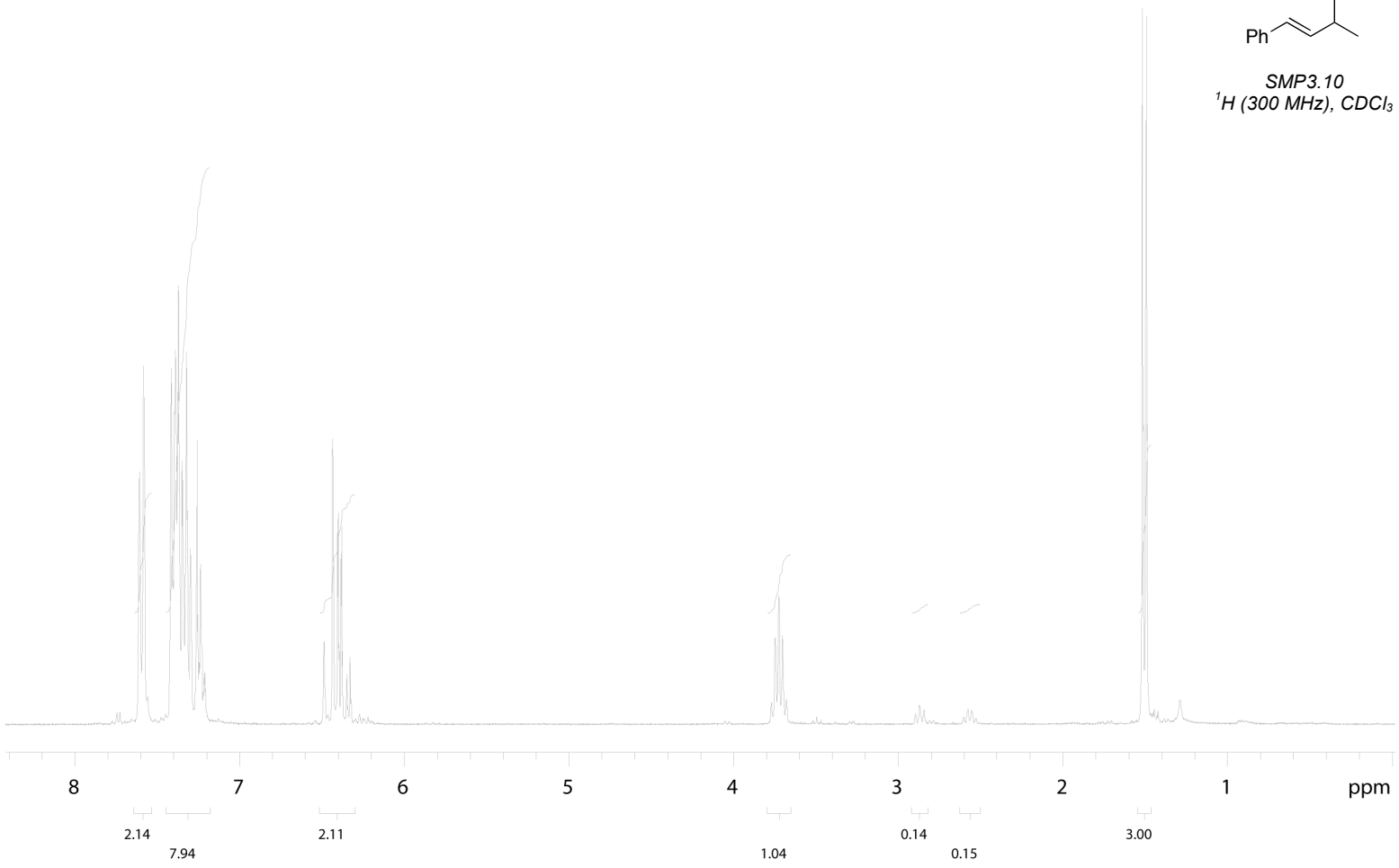
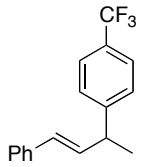
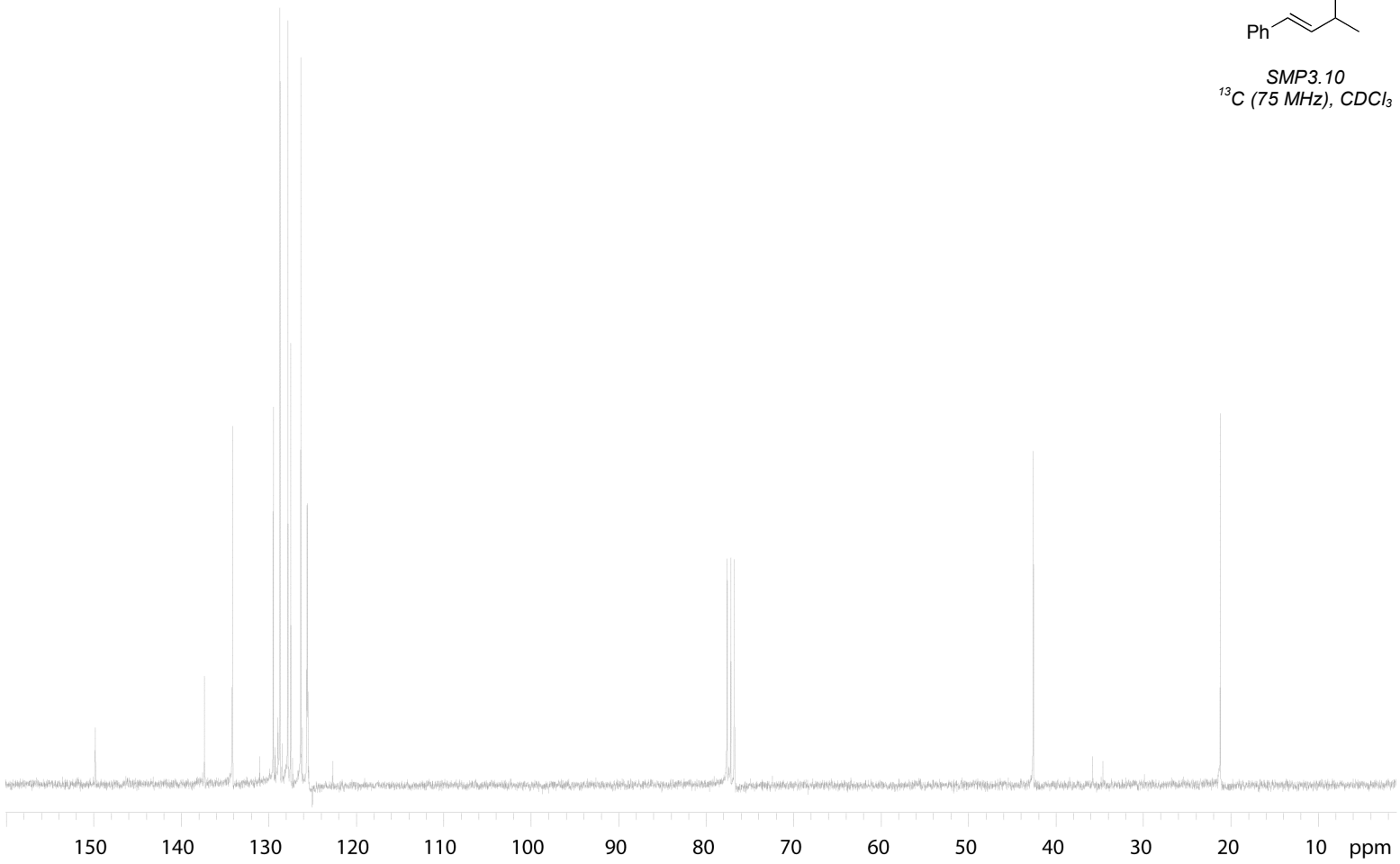


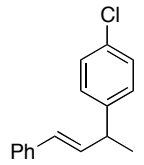
2b



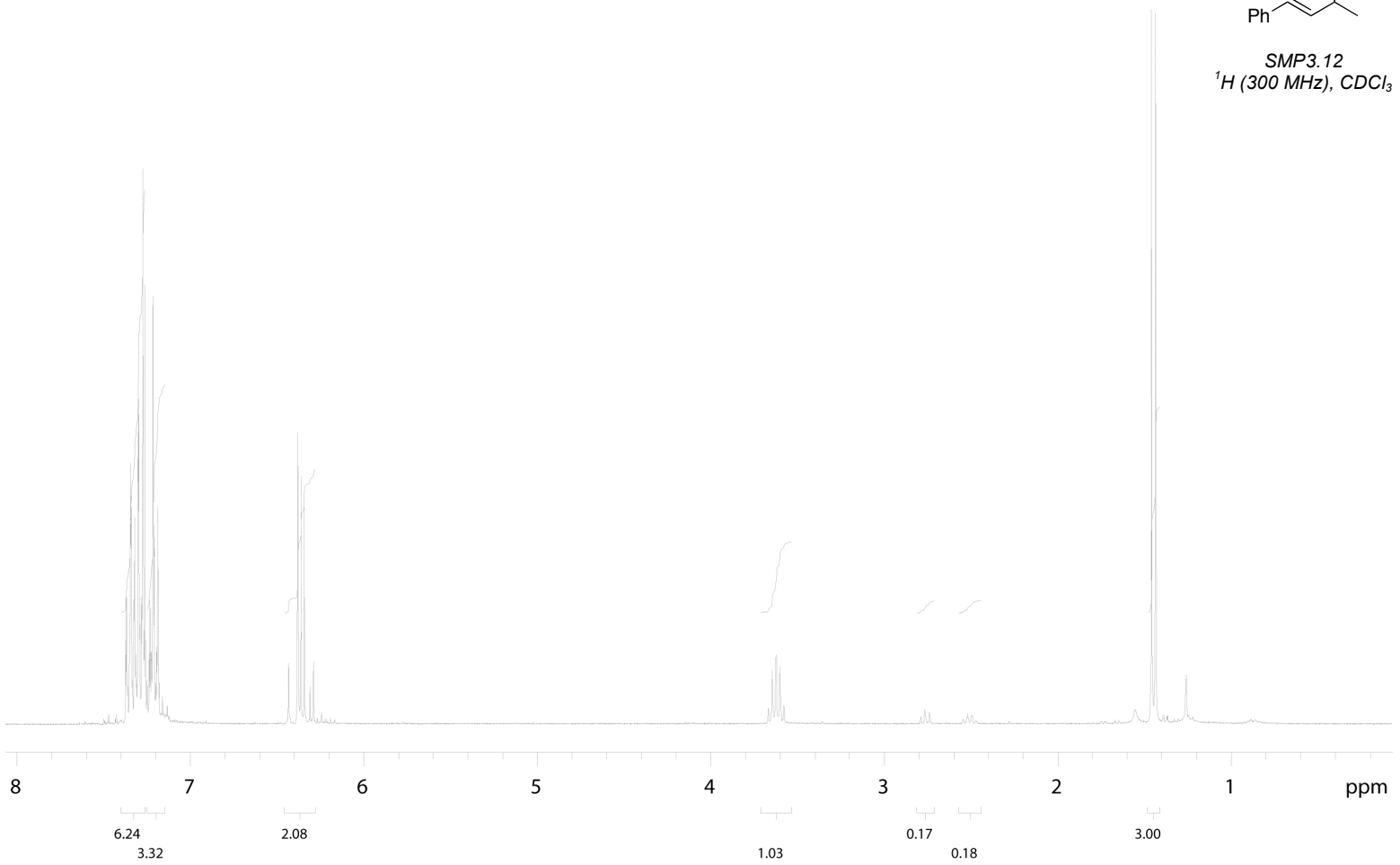
SMP3.10
^{13}C (75 MHz), $CDCl_3$



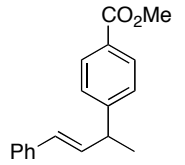
2c



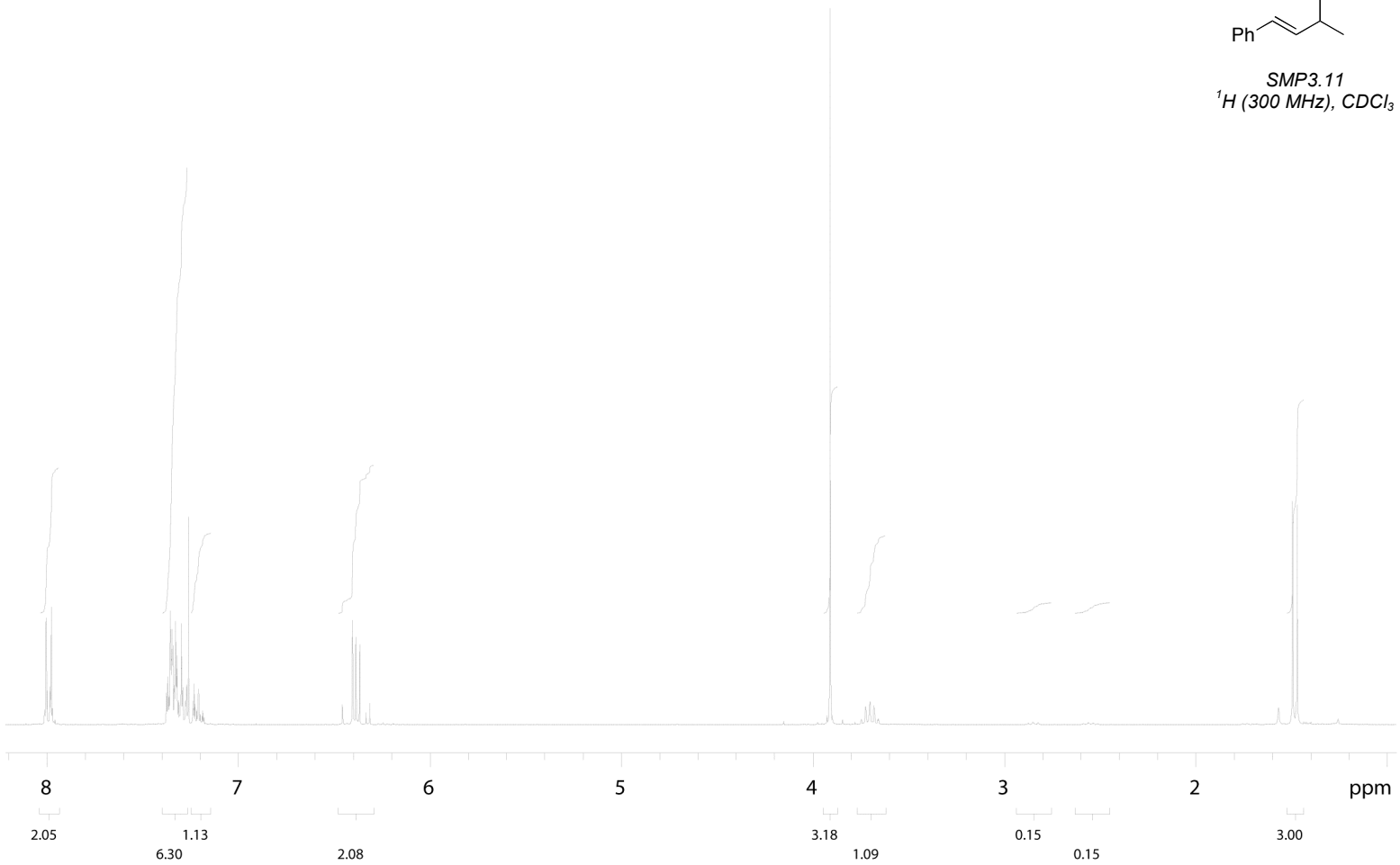
SMP3.12
^{1}H (300 MHz), $CDCl_3$



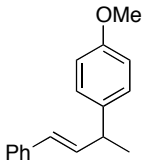
2d



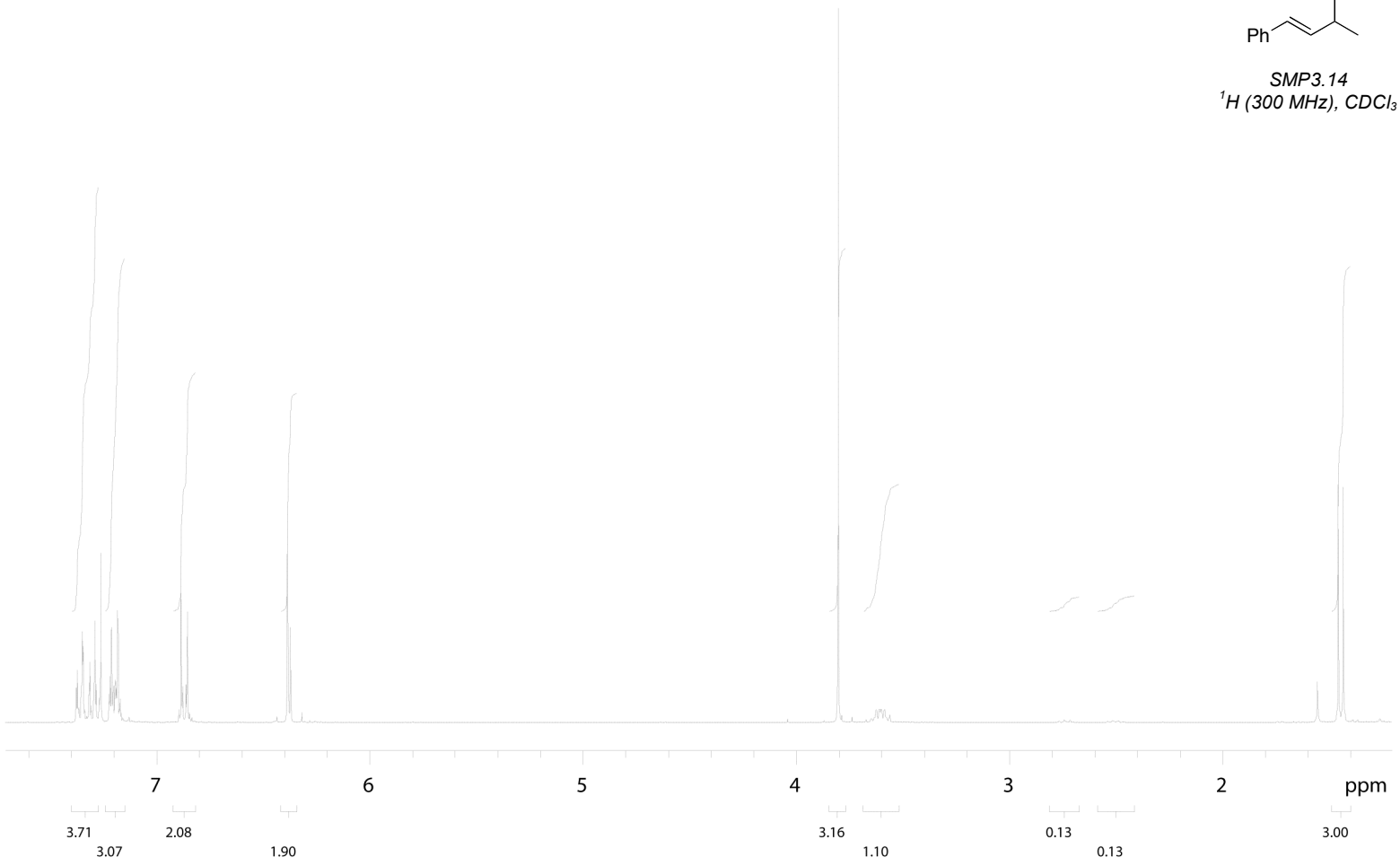
SMP3.11
^{1}H (300 MHz), $CDCl_3$

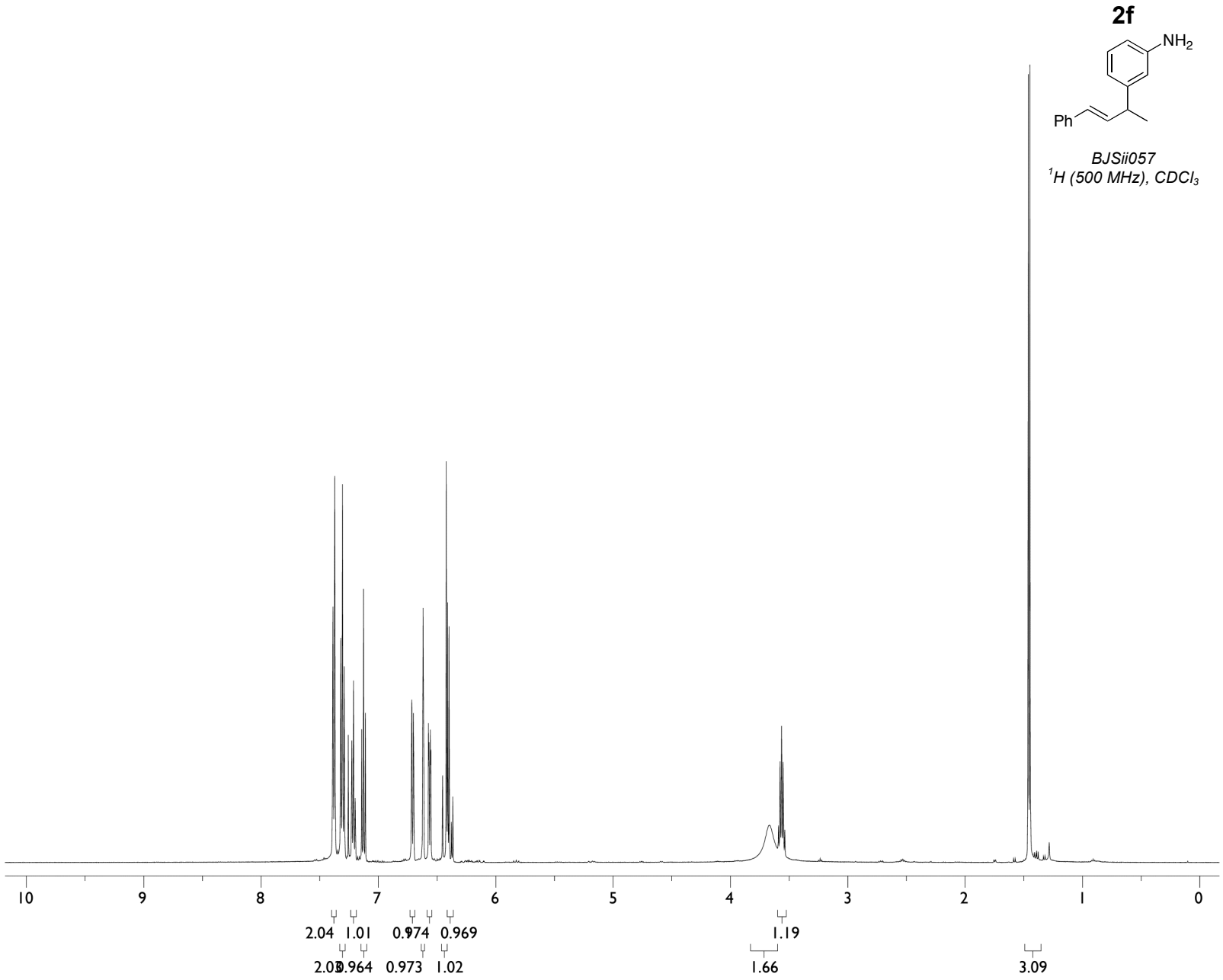


2e

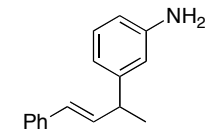


SMP3.14
^{1}H (300 MHz), $CDCl_3$



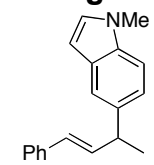

2f
NH2
Ph
BJSii057
1H (500 MHz), CDCl3
10
9
8
7
6
5
4
3
2
1
0
2.04
1.01
0.974
0.969
1.19
2.03
0.964
0.973
1.02
1.66
3.09

2f



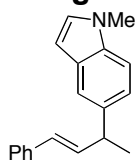
BJSii057
^{13}C (125 MHz), $CDCl_3$

2g

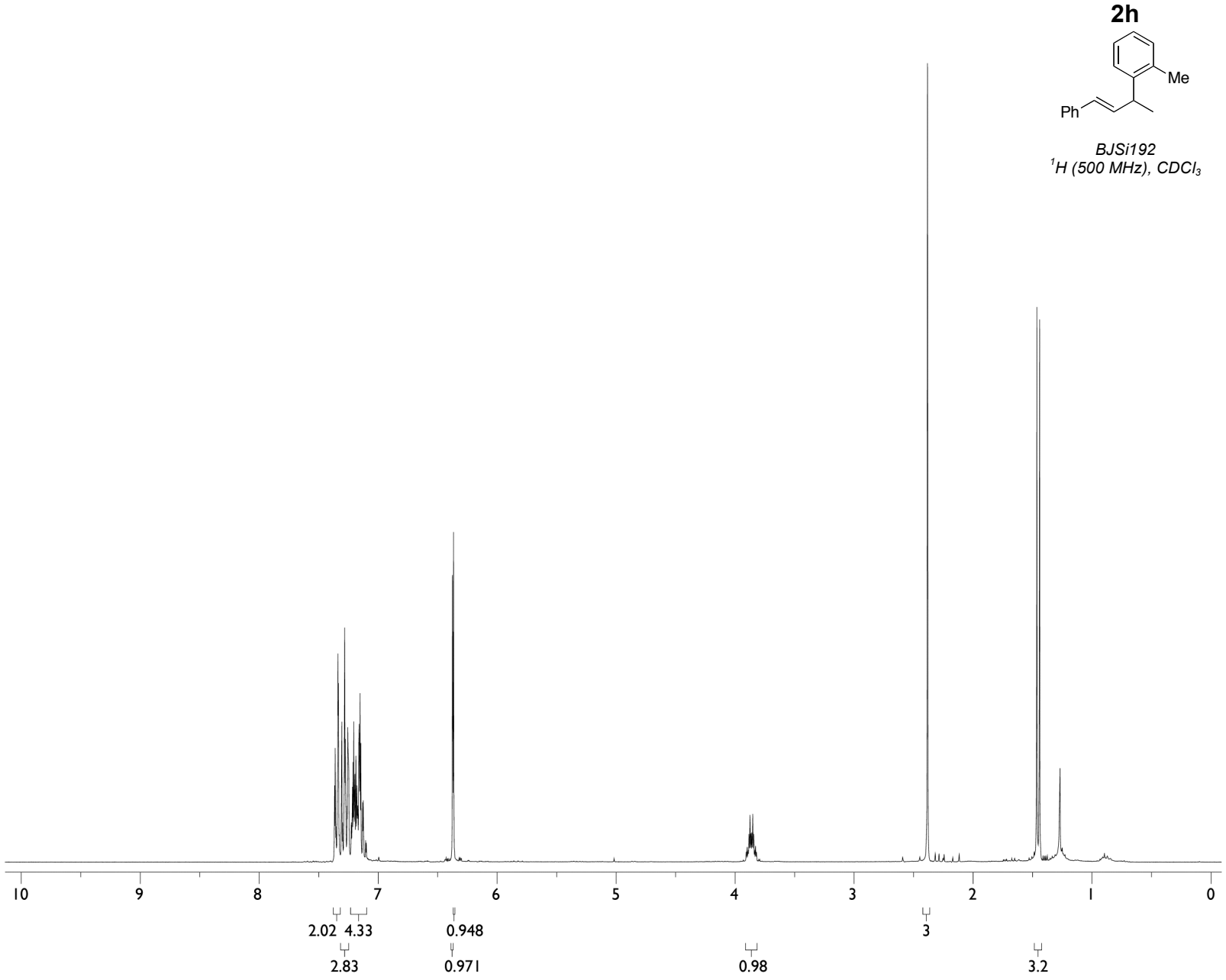


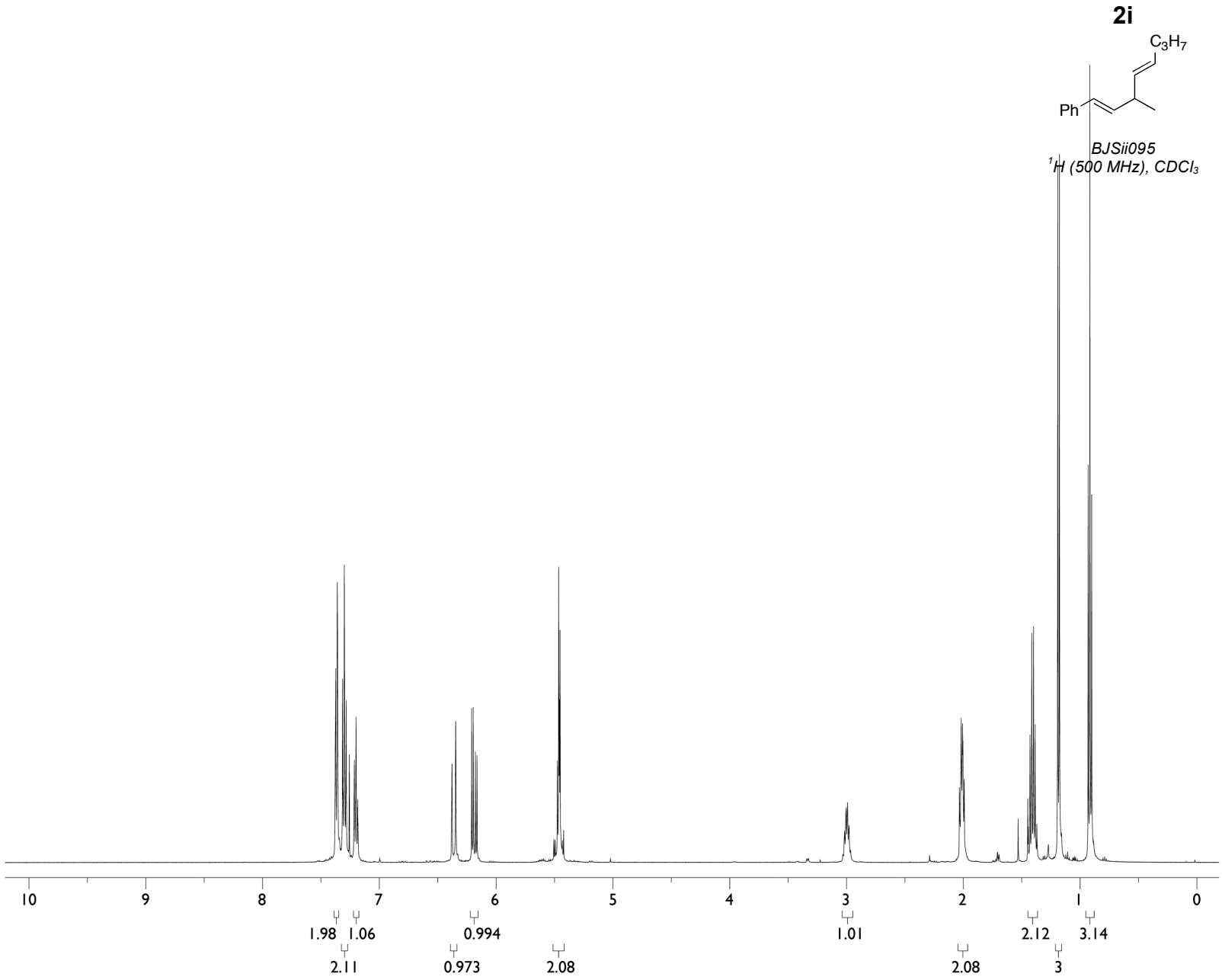
BJSii051
^{1}H (500 MHz), $CDCl_3$

2g

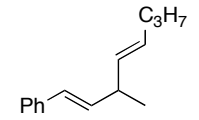


BJSii051
^{1}H (500 MHz), $CDCl_3$


2h
Me
Ph
BJSi192
1H (500 MHz), CDCl3
10
9
8
7
6
5
4
3
2
1
0
2.02
4.33
0.948
3
2.83
0.971
0.98
3.2

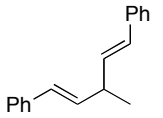

2i
C3H7
Ph
BJSii095
1H (500 MHz), CDCl3
10
9
8
7
6
5
4
3
2
1
0
1.98
1.06
0.994
1.01
2.12
3.14
2.11
0.973
2.08
2.08
3

2i



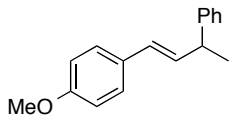
BJSii095
^{13}C (125 MHz), $CDCl_3$

2j

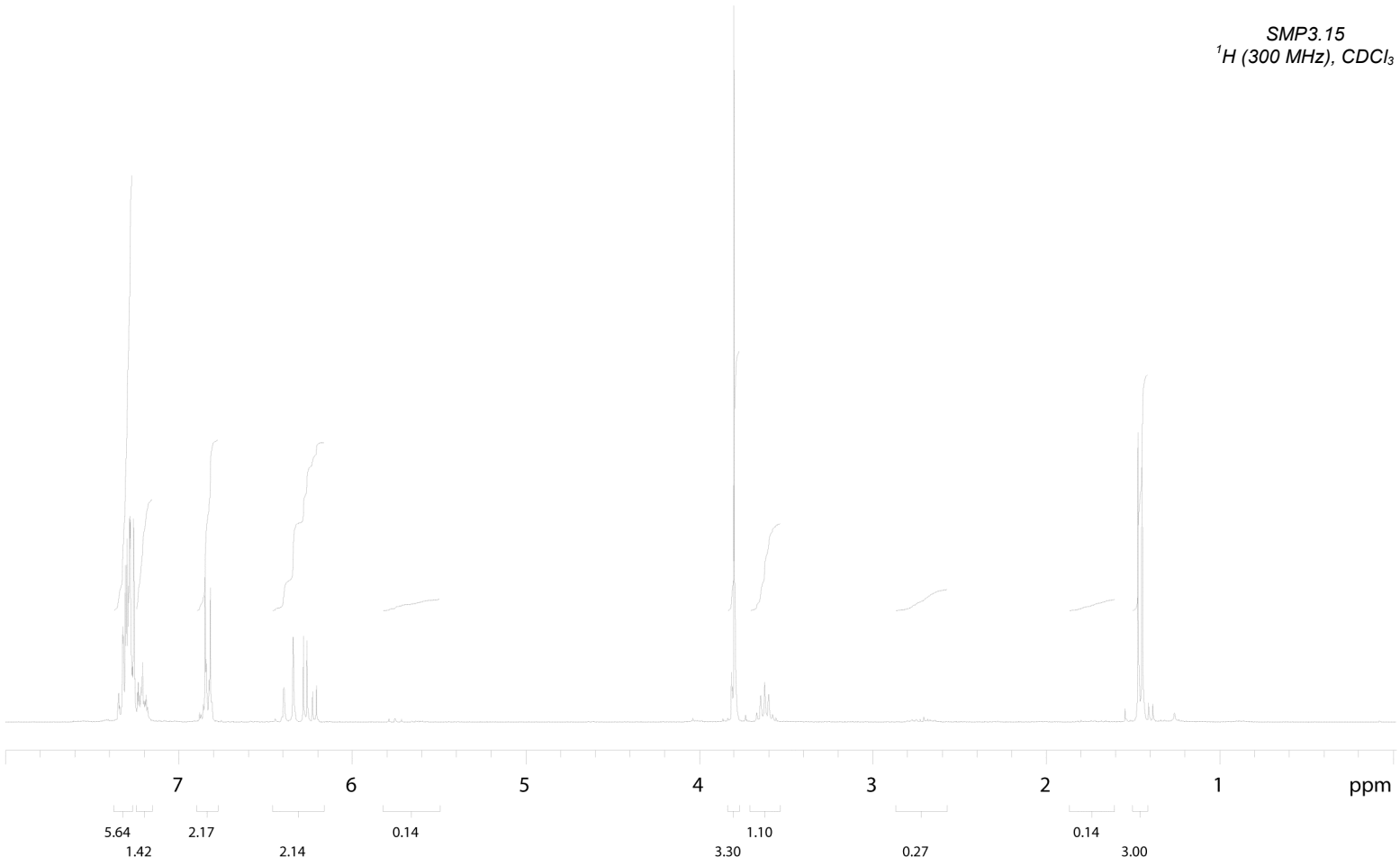


BJSii068
^{1}H (300 MHz), $CDCl_3$

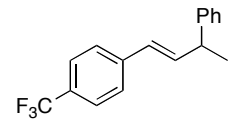
5c



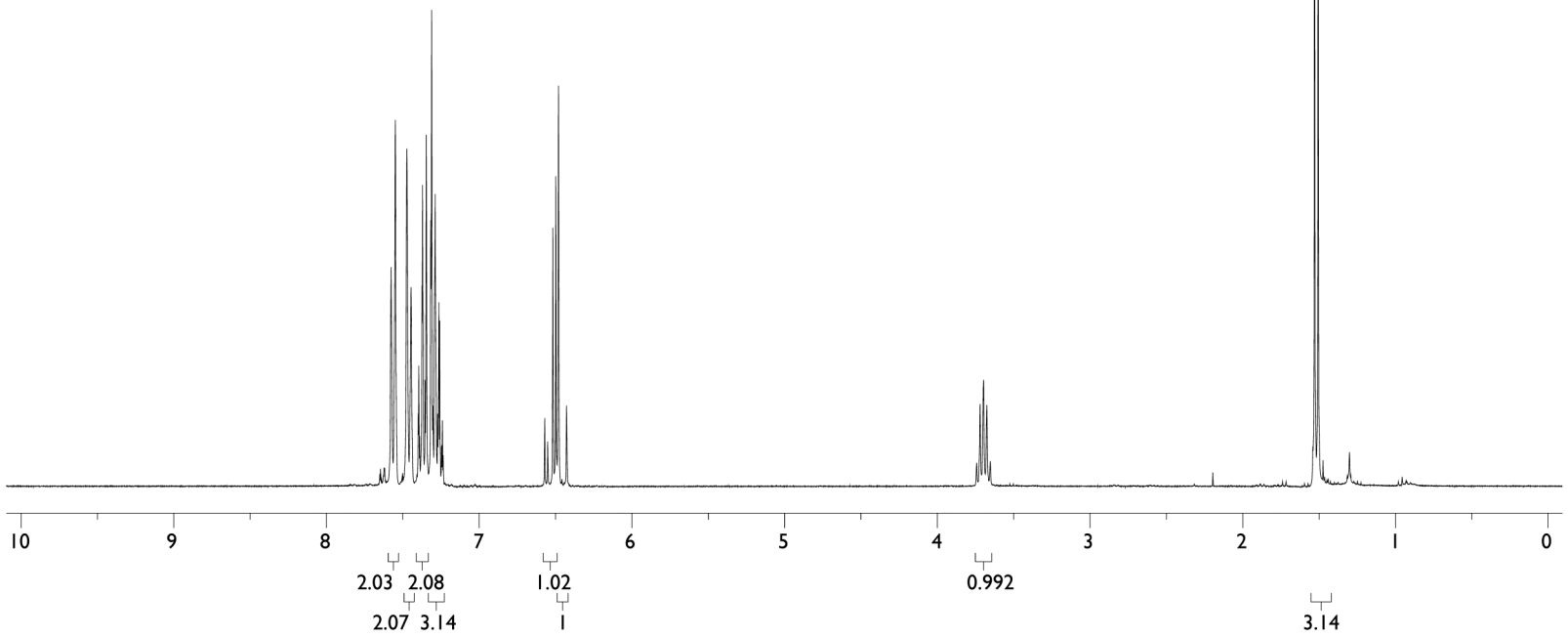
SMP3.15
^{1}H (300 MHz), $CDCl_3$



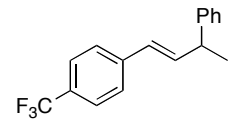
5d



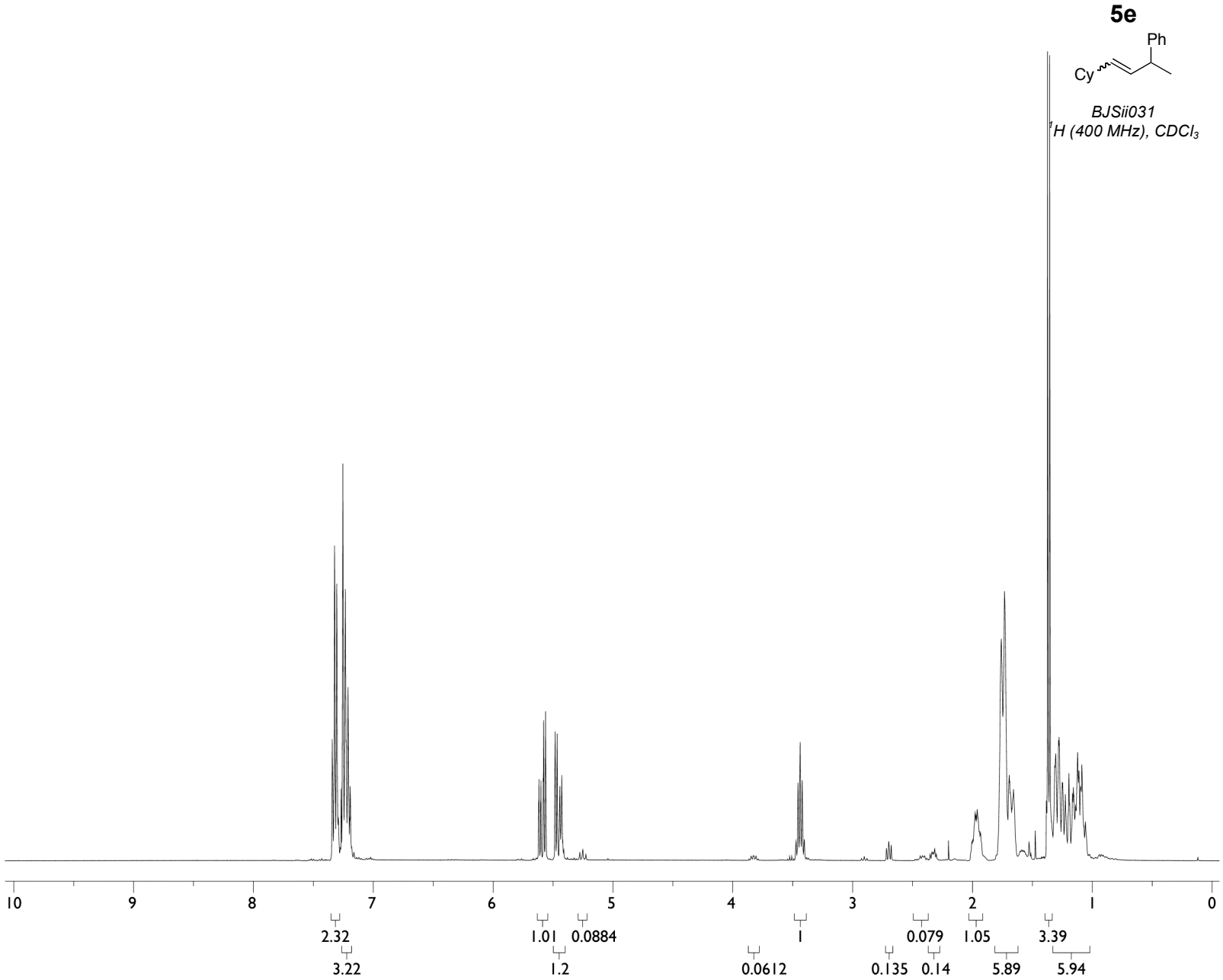
BJSii041
^{1}H (300 MHz), $CDCl_3$



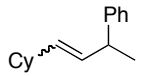
5d



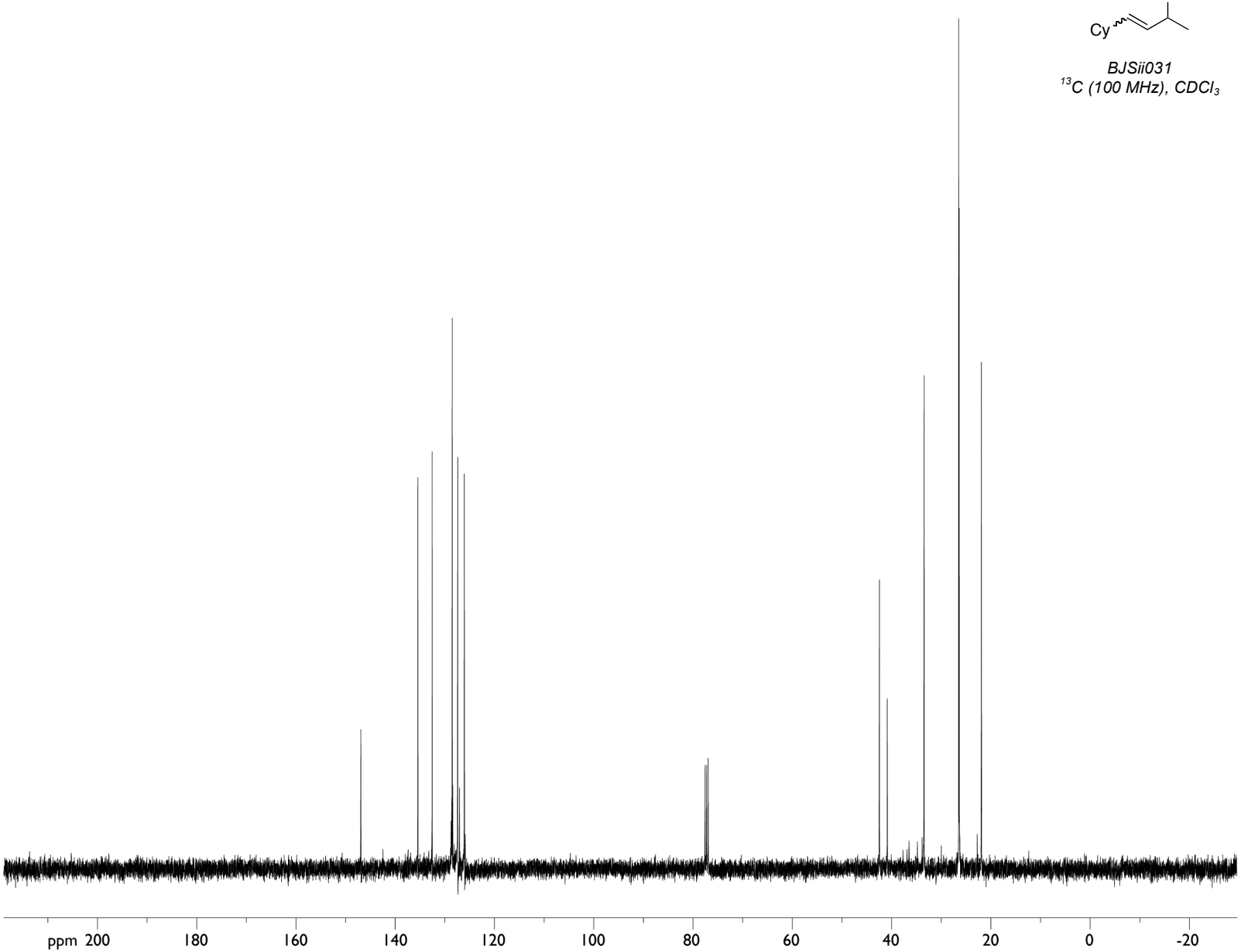
BJSii041
^{13}C (75 MHz), $CDCl_3$

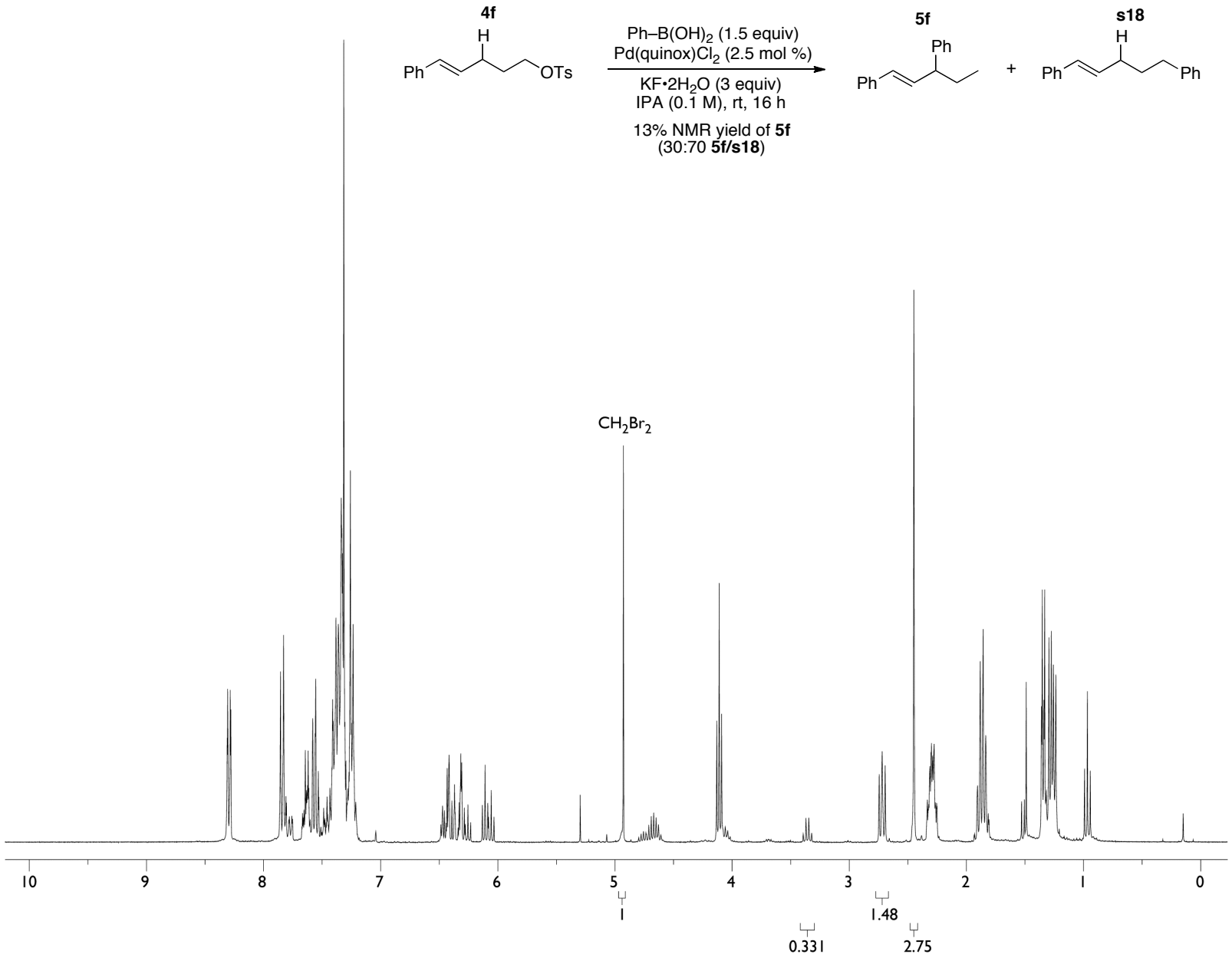

5e
Ph
Cy
BJSii031
^{1}H (400 MHz), $CDCl_3$
10
9
8
7
6
5
4
3
2
1
0
2.32
3.22
1.01
1.2
0.0884
0.0612
1
0.135
0.079
0.14
1.05
5.89
3.39
5.94

5e

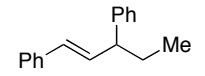


BJSii031
^{13}C (100 MHz), $CDCl_3$

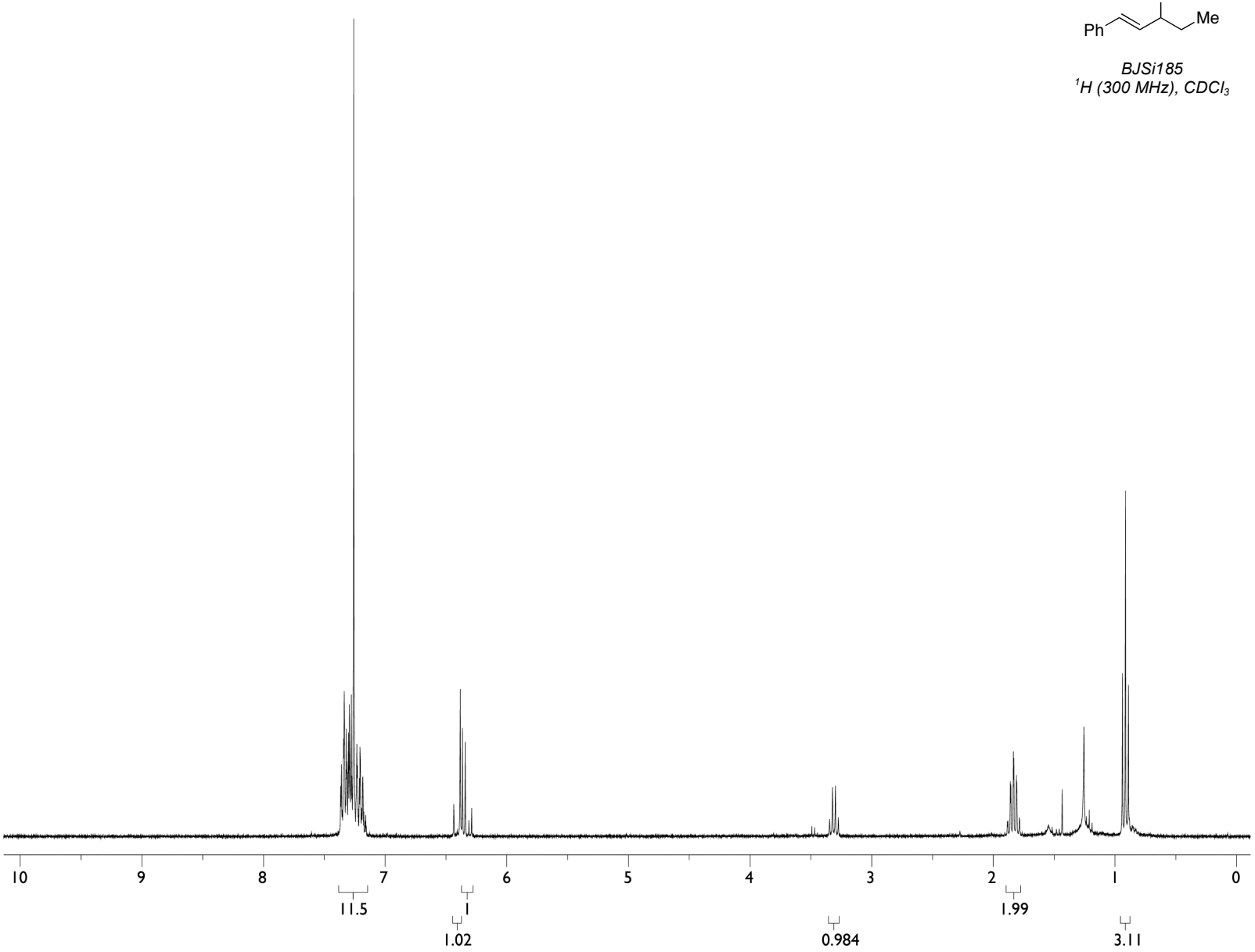



4f
H
Ph
OTs
Ph–B(OH)2 (1.5 equiv)
Pd(quinox)Cl2 (2.5 mol %)
KF•2H2O (3 equiv)
IPA (0.1 M), rt, 16 h
13% NMR yield of 5f
(30:70 5f/s18)
5f
Ph
Ph
+
s18
H
Ph
Ph
CH2Br2
10
9
8
7
6
5
4
3
2
1
0
1
1.48
0.331
2.75

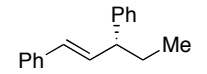
5f



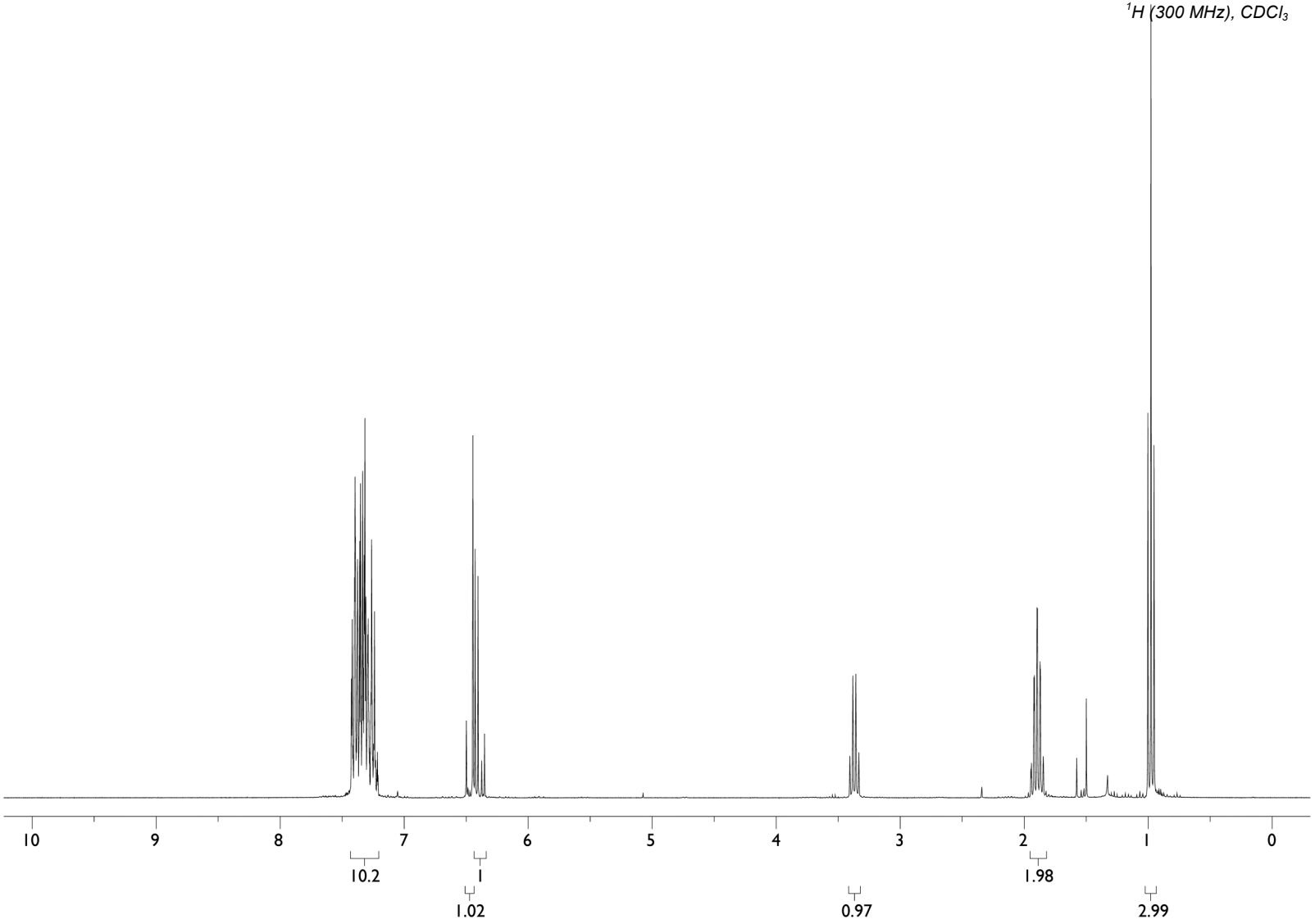
BJSi185
^{1}H (300 MHz), $CDCl_3$

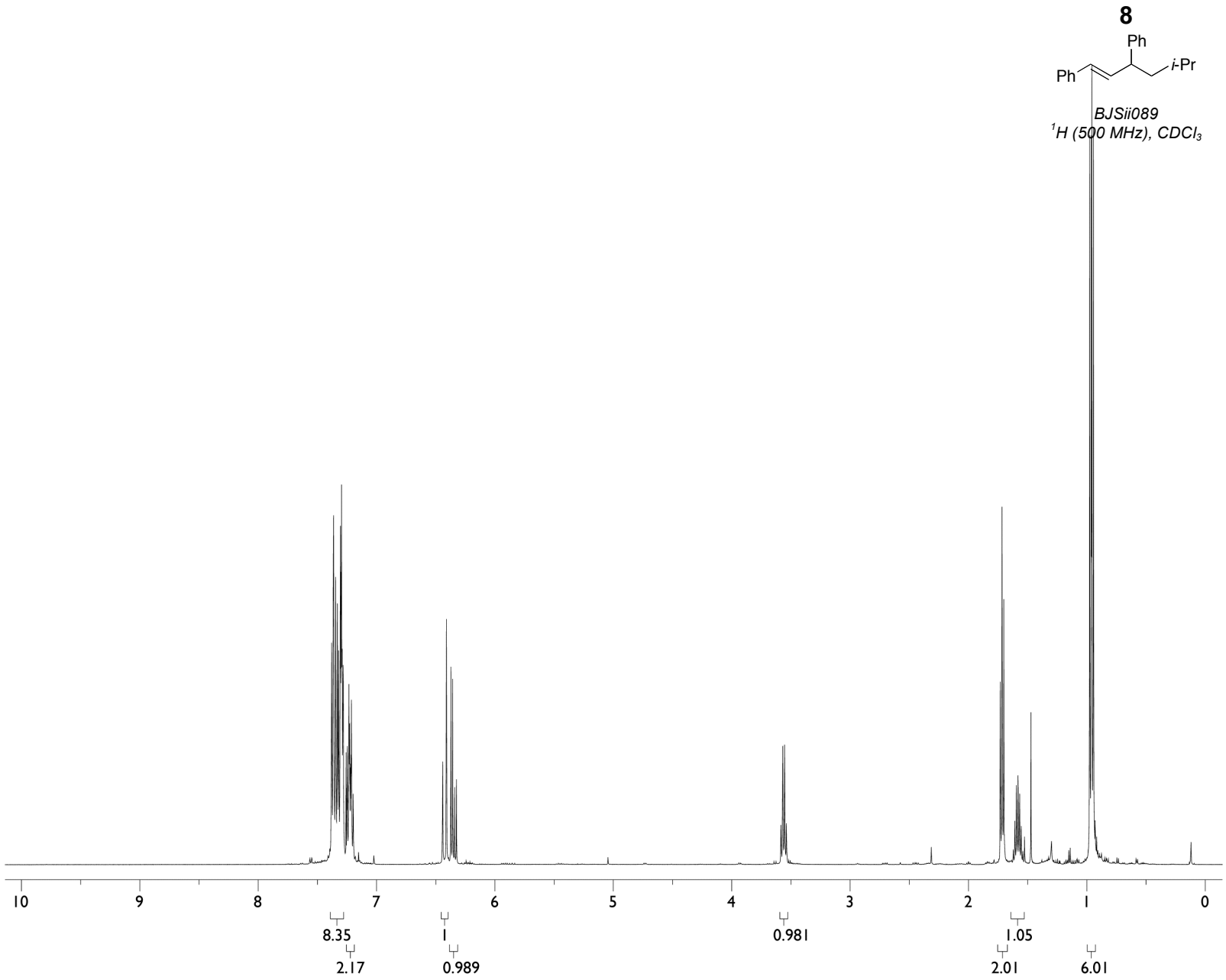


(*R*)-**5f**

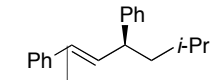


BJSii101
^{1}H (300 MHz), $CDCl_3$

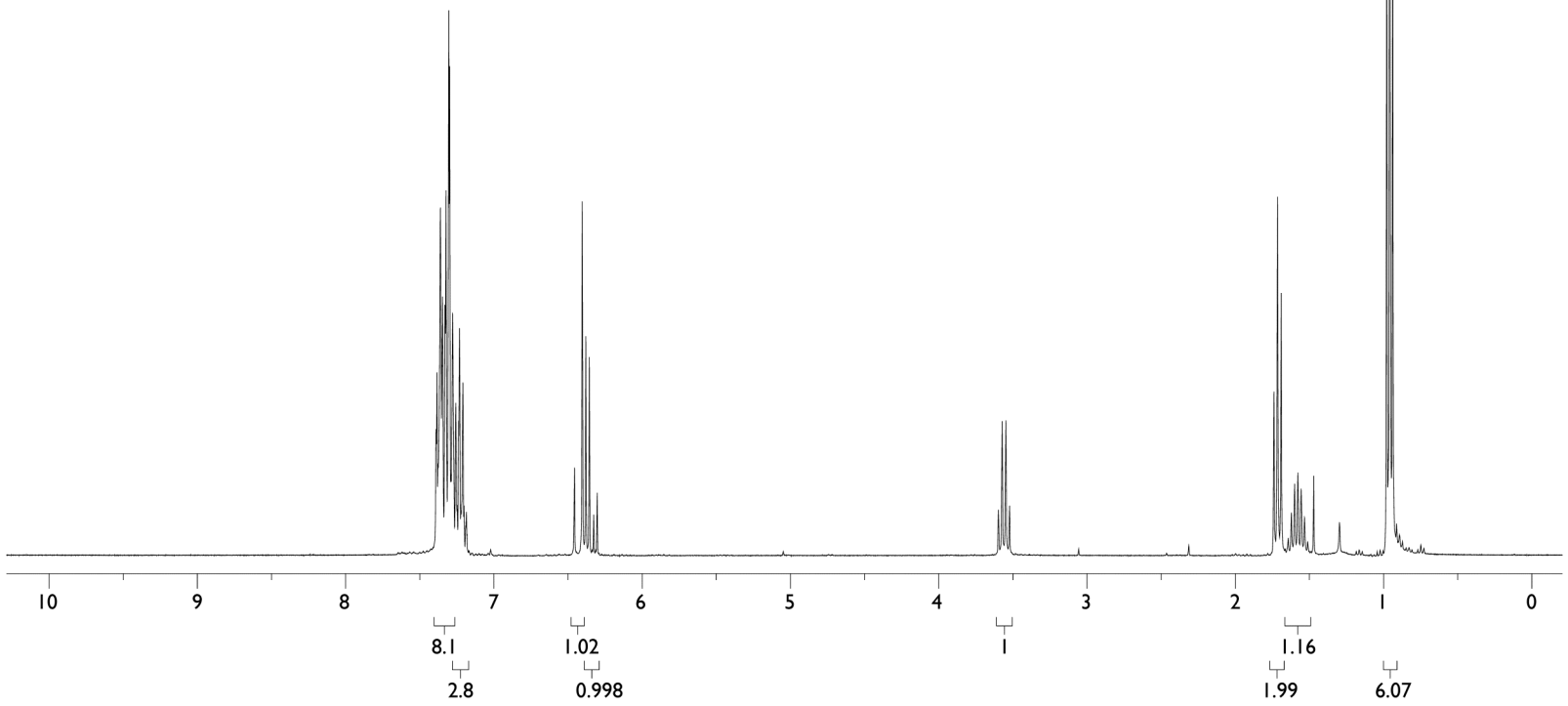



8
Ph
Ph
i-Pr
BJSii089
1H (500 MHz), CDCl3
10
9
8
7
6
5
4
3
2
1
0
8.35
2.17
1
0.989
0.981
1.05
2.01
6.01

(S)-**8**

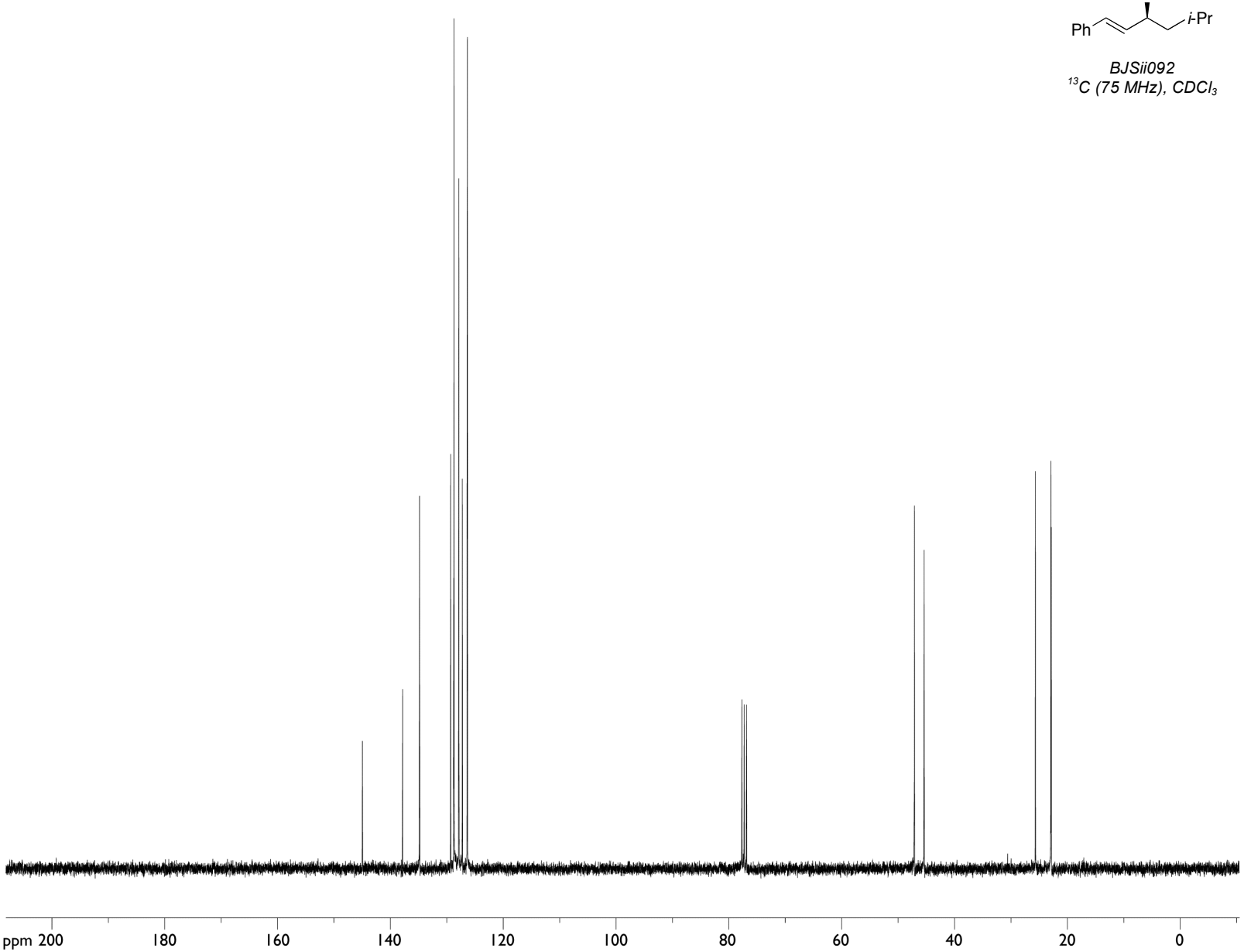


BJSii092
^{1}H (300 MHz), $CDCl_3$

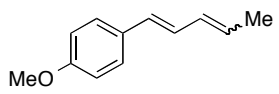


(S)-**8**

BJSii092
^{13}C (75 MHz), $CDCl_3$

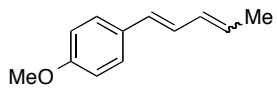


s24

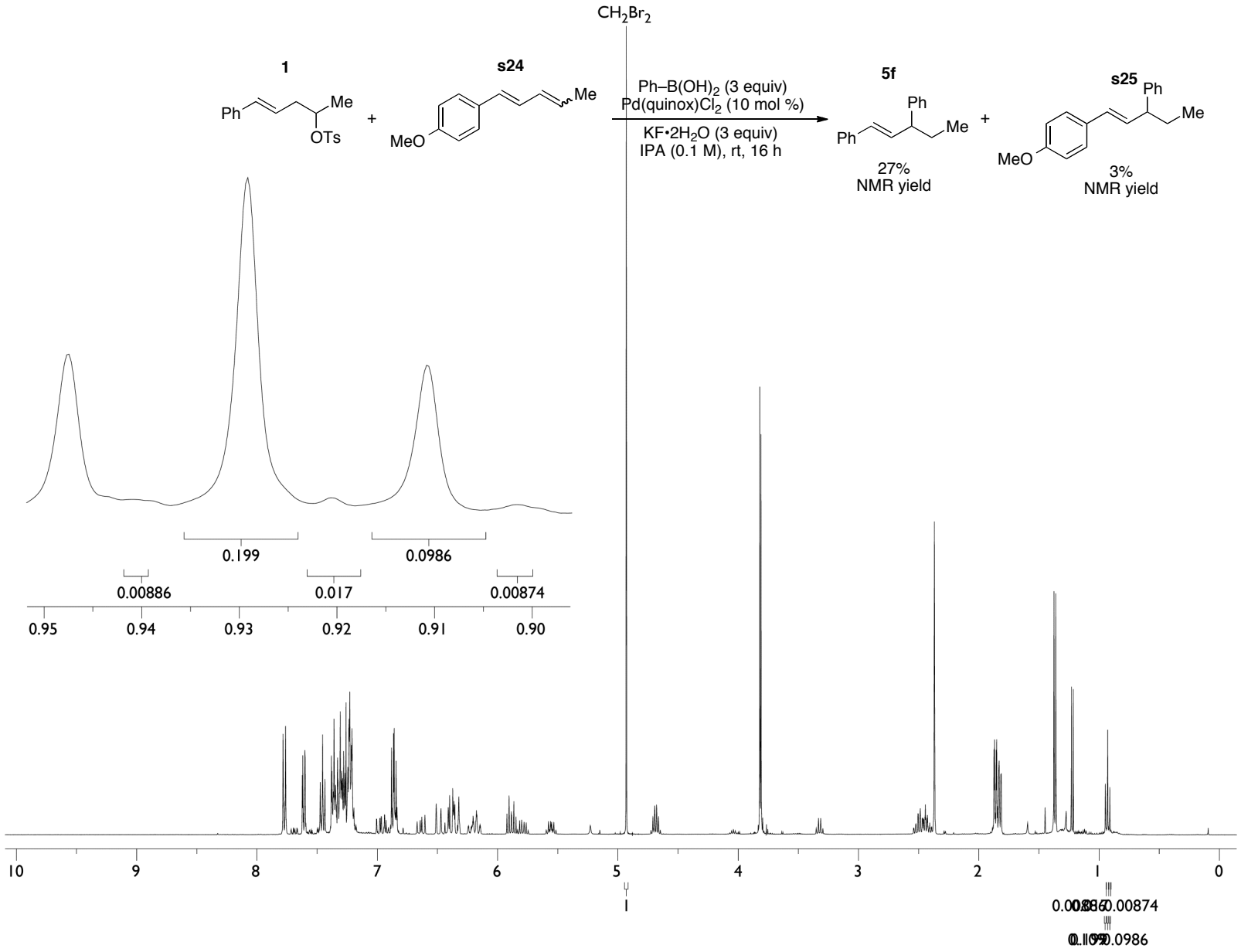


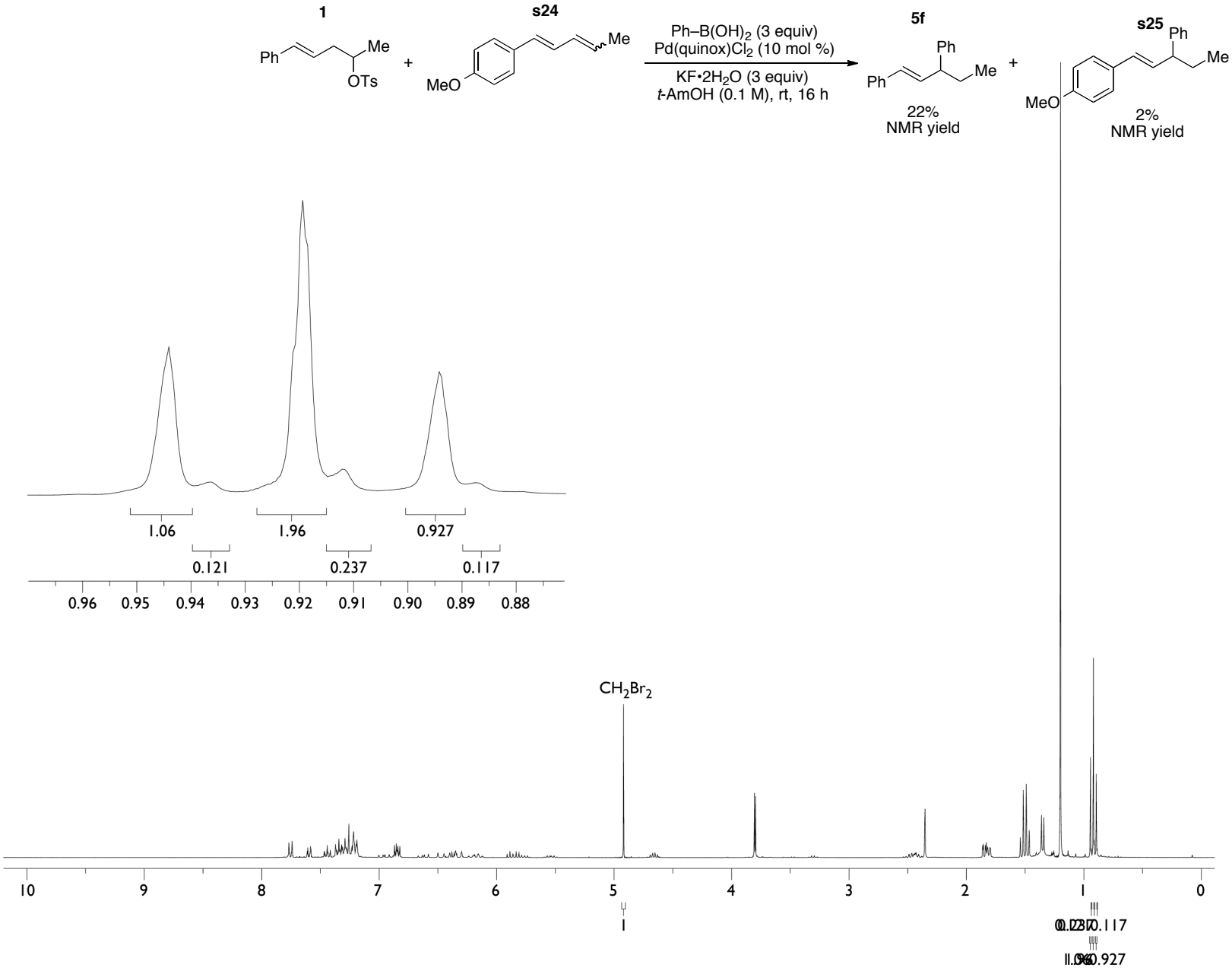
BJSii023
^{1}H (400 MHz), $CDCl_3$

s24



BJSii023
^{13}C (100 MHz), $CDCl_3$


CH2Br2
1
s24
Ph
Me
OTs
MeO
Me
Ph–B(OH)2 (3 equiv)
Pd(quinox)Cl2 (10 mol %)
KF•2H2O (3 equiv)
IPA (0.1 M), rt, 16 h
5f
Ph
Ph
Me
27%
NMR yield
s25
Ph
Me
MeO
3%
NMR yield
0.199
0.0986
0.00886
0.017
0.00874
0.95
0.94
0.93
0.92
0.91
0.90
10
9
8
7
6
5
4
3
2
1
0
1
0.00874
0.0986


1
s24
Ph
Me
OTs
MeO
Me
Ph–B(OH)2 (3 equiv)
Pd(quinox)Cl2 (10 mol %)
KF•2H2O (3 equiv)
t-AmOH (0.1 M), rt, 16 h
5f
Ph
Ph
Me
22%
NMR yield
s25
Ph
Me
MeO
2%
NMR yield
1.06
1.96
0.927
0.121
0.237
0.117
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
CH2Br2
10
9
8
7
6
5
4
3
2
1
0
1
0.927