Selective and synergistic cobalt(III)-catalyzed three-component C–H bond addition to dienes and aldehydes

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Supplementary Information

Supplementary Methods 1

1. General Information 2

2. Preparation of Starting Materials 2

3. Preparation of C–H Bond Substrate **12** 3

4. Procedures for Co(III)-Catalyzed Three-Component Synthesis 5

5. Mechanism Experiments 40

6. Synthesis of Lasalocid A Derivative **15** 49

7. Derivatization of Three-Component Product **4ar** to Give **4ar'** 54

8. X-Ray Crystallographic Data 55

9. NMR Data 60

Supplementary Tables 122

Supplementary References 123

Supplementary Methods

1. General Information:

Unless otherwise indicated, all Co(III)-catalyzed reactions were set up in a N_2 filled glovebox, using glassware that was oven-dried (150 °C) and evacuated while hot prior to use. Unless otherwise indicated, all reactions for substrate preparation were carried out on the benchtop under a N_2 atmosphere. Solvents were purified by elution through a column of activated alumina under N_2 before use. Unless otherwise noted, all reagents were purchased from commercial sources and used without further purification. Commercial aldehydes were distilled prior to use. Products and starting materials were visualized on TLC using UV-light or by staining with $KMnO_4$ or p-anisaldehyde. The diastereoselectivity of the reactions was evaluated by NMR analysis of the unpurified and purified material. Flash-column chromatography was preformed on SiliaFlash® P60 (230-400 mesh) silica gel, and preparative thin-layer chromatrography, plates from Analtech (1 mm SiO_2, 20 x 20 cm) were used. NMR chemical shifts are reported in ppm relative to $CDCl_3$ (7.26 ppm for ^1H and 77.16 ppm for ^{13}C) or relative to C_6D_6 (7.16 ppm for ^1H and 128.39 ppm for ^{13}C). Trifluoroacetic acid (set to -76.55 ppm in $CDCl_3$) was used as a standard for ^{19}F NMR chemical shifts. For IR spectra, only partial data are provided. Melting points are reported uncorrected. High-resolution mass spectra (HRMS) were obtained using electrospray ionization (ESI) on a time of flight (TOF) mass spectrometer.

2. Preparation of Starting Materials:

Catalysts/Additives:

$[Cp^*Co(C_6H_6)][B(C_6F_5)_4]_2$[1], $[Cp^*RhCl_2]_2$[2], $[Cp^*Co(MeCN)_3][SbF_6]_2$[3], $[Cp^*Co(CO)I_2]$[4], and 5% Pd/C(en) [5] were each synthesized according to a published literature procedure.

Substrates:

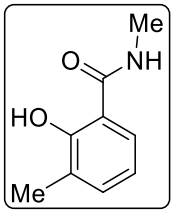
Phenyl(pyrrolidin-1-yl)methanone[6], pyrrolidin-1-yl(*m*-tolyl)methanone[6], (4-methoxyphenyl)-(pyrrolidin-1-yl)methanone[6], pyrrolidin-1-yl(4-(trifluoromethyl)phenyl)methanone[7], benzo-[d][1,3]dioxol-5-yl(pyrrolidin-1-yl)methanone[8], 2-phenyl-1-(pyrrolidin-1-yl)prop-2-en-1-one[9], 2-methyl-1-(pyrrolidin-1-yl)prop-2-en-1-one[10], (*E*)-hexa-3,5-dien-1-ylbenzene[11], (*E*:*Z* = 1:1) hexa-

3,5-dien-1-ylbenzene[12], (*E*)-deca-1,3-diene[13], (*E*)-((penta-2,4-dien-1-yloxy)methyl)benzene[14,15], (*E*)-4,8-dimethylnona-1,3,7-triene[16] were each synthesized according to literature procedures. All other substrates were purchased from commercial sources and used without further purification.

Preparation of [4 M] butadiene solution:

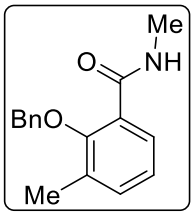
A 100 mL-graduate cylinder with a rounded glass joint was purged with N_2 and cooled to –15 °C. This was then attached to a gas canister of butadiene that was placed in an ice bath. The gas canister was then opened and butadiene gas was allowed to flow into the graduated cylinder, where it condensed at the bottom of the cylinder. 16.3 mL of butadiene was added to the cylinder while being maintained at –15 °C (density at –15 °C is ~0.6643 g/mL[17]). Following this, the butadiene was diluted by syringing in freshly distilled THF up to the 50-mL mark of the graduated cylinder. This solution was gently swirled to ensure homogeneity, and was then transferred to a N_2-purged 50-mL schlenk flask via syringe. The flask containing the solution was then stored in a glovebox freezer at –22 °C.

3. Preparation of C–H Bond Substrate 12:



2-Hydroxy-*N*,3-dimethylbenzamide: To a 50-mL round-bottom flask was added a stir bar and 2-hydroxy-3-methylbenzoic acid (609 mg, 4.00 mmol, 1.0 equiv). The flask was placed under nitrogen to which was added thionyl chloride (4.0 mL). The reaction mixture was then refluxed for 2 h and then was cooled to room temperature. The mixture was then concentrated under vacuum to remove the thionyl chloride, leaving a residual oil. The flask containing the residual oil was then placed back under nitrogen, and 10 mL of dichloromethane was added. The solution was then cooled to 0 °C, followed by successive dropwise addition of methylamine (4.0 mL of a [2 M] solution in THF, 2.0 equiv) and triethylamine (0.65 mL, 4.7 mmol, 1.2 equiv) with stirring. After both amines were added, the mixture was stirred for 5 min before removing the ice bath and letting warm to room temperature. The mixture was stirred at room temperature for 2 h, and the dichloromethane was removed under vacuum. The residue was dissolved in a minimal amount of

ethyl acetate and was purified by silica gel chromatography using ethyl acetate as the eluent to afford the product (550.0 mg, 83%) as a white solid (mp: 110–111 °C). IR (film): 3388, 2936, 2605, 1640, 1588, 1481, 1326, 1292, 895, 751 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.58 (s, 1H), 7.26–7.24 (m, 1H), 7.17 (d, *J* = 7.9 Hz, 1H), 6.73 (t, *J* = 7.7 Hz, 1H), 6.34 (s, 1H), 3.01 (d, *J* = 4.9 Hz, 3H), 2.26 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$): δ 171.16, 159.97, 134.97, 127.80, 122.84, 118.05, 113.55, 26.59, 15.92; HRMS (ESI/[M+H]+) calcd. for $C_9H_{12}NO_2^+$: 166.0863. Found 166.0864.

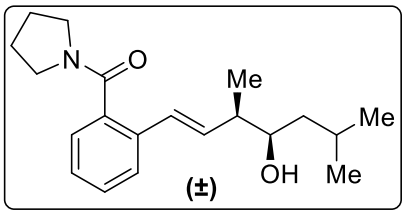


2-(Benzyloxy)-*N*,3-dimethylbenzamide (12): To a 50-mL round-bottom flask was added a stir bar, 2-hydroxy-*N*,3-dimethylbenzamide (330 mg, 2.00 mmol, 1.0 equiv), and 5 mL of *N*,*N*-dimethylformamide (DMF). The flask was placed under nitrogen to which was added K_2CO_3 (553 mg, 4.00 mmol, 2.0 equiv) and benzyl bromide (0.31 mL, 2.6 mmol, 1.3 equiv). The reaction mixture was then stirred at room temperature for 16 h and then was transferred to a separatory funnel with 100 mL of ethyl acetate. The organic layer was then washed successively with 100 mL of 1N HCl and 100 mL brine before being dried over Na_2SO_4 and concentrated. The residue was dissolved in a minimal amount of ethyl acetate and was purified by silica gel chromatography using a 1:1 mixture of ethyl acetate/hexanes as the eluent to afford the product (450.0 mg, 88%) as a white solid (mp: 74–75 °C). IR (film): 3416, 2934, 1655, 1533, 1458, 1296, 1216, 979, 766, 703 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.92 (d, *J* = 7.6 Hz, 1H), 7.64 (s, 1H), 7.46–7.38 (m, 5H), 7.33 (d, *J* = 7.3 Hz, 1H), 7.16 (t, *J* = 7.6 Hz, 1H), 4.84 (s, 2H), 2.87 (d, *J* = 4.9 Hz, 3H), 2.39 (s, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$): δ 166.49, 155.19, 136.30, 134.43, 131.78, 129.46, 128.92, 128.83, 128.43, 127.31, 124.83, 76.53, 26.43, 16.41; HRMS (ESI/[M+H]+) calcd. for $C_{16}H_{18}NO_2^+$: 256.1332. Found 256.1331.

4. Procedures for Co(III)-Catalyzed Three-Component Synthesis:

General Procedure for aldehyde and C–H bond substrate scope.

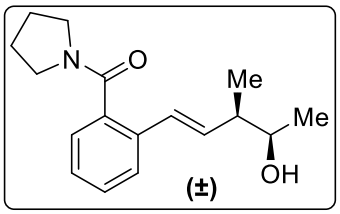
In a N_2-filled glove box, a 0.5–2.0 mL microwave vial was charged with $[Cp^*Co(C_6H_6)[B(C_6F_5)_4]_2$[1] (65.2 mg, 0.0400 mmol, 0.20 equiv), and the indicated C–H bond partner (**1**) (0.200 mmol, 1.0 equiv). Following this, 67 µL of a [0.6 M] stock solution of acetic acid in 1,4-dioxane followed by 333 µL of 1,4-dioxane was added. The corresponding aldehyde (**3**) (0.600 mmol, 3.0 equiv) was then added. Finally, 100 µL of a [4 M] stock solution of 1,3-butadiene in THF was added (0.400 mmol, 2.0 equiv). The reaction vial was then equipped with a magnetic stir bar, sealed with a microwave cap, and taken outside the glove box. The reaction mixture was then stirred at 50 °C in a preset oil bath for 20 h. The reaction mixture was then allowed to cool to room temperature. The reaction mixture was filtered through a small celite plug, (1 cm long in a pipette), and washed with ethyl acetate. The resulting mixture was then concentrated and purified by the corresponding chromatographic method to afford the desired product.



(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)phenyl)(pyrrolidin-1-yl)-methanone (4a): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4a** (54.8 mg, 87% yield) as a colorless oil. IR (film): 3380 (br), 2954, 2875, 1612, 1452, 1428, 982, 909, 727 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.47 (d, *J* = 7.8 Hz, 1H), 7.31–7.28 (ddd, *J* = 8.0, 5.8, 3.1 Hz, 1H), 7.24–7.20 (m, 2H), 6.43 (d, *J* = 15.9 Hz, 1H), 6.14 (dd, *J* = 15.9, 8.0 Hz, 1H), 3.65–3.58 (m, 3H), 3.09 (t, *J* = 6.8 Hz, 2H), 2.39–2.32 (m, 1H), 1.95–1.89 (m, 2H), 1.84–1.74 (m, 4H), 1.36–1.30 (m, 1H), 1.25–1.19 (m, 1H), 1.06 (d, *J* = 6.9 Hz, 3H), 0.90 (d, *J* = 6.6 Hz, 3H), 0.88 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.79, 136.49, 136.11, 134.07, 129.02, 127.29, 127.25, 126.28, 126.11, 73.12,

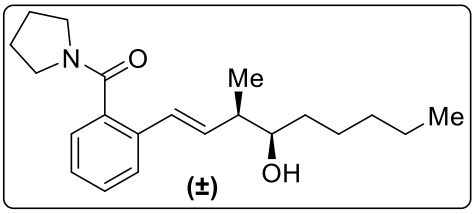
48.32, 45.62, 43.82, 43.47, 26.08, 24.75, 24.72, 23.88, 21.80, 15.04; HRMS (ESI/$[M+H]^+$) calcd. for $C_{20}H_{30}NO_2^+$: 316.2271. Found 316.2272.

For isolation at 5 mol % catalyst loading, slightly different conditions were used:
In a N_2-filled glove box, a 0.5–2.0 mL microwave vial was charged with $[Cp^*Co(C_6H_6)][B(C_6F_5)_4]_2$[1] (16.3 mg, 0.0100 mmol, 0.05 equiv), pivalic acid (4.1 mg, 0.040 mmol, 0.20 equiv), and phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv). Following this, 400 µL of 1,4-dioxane was added, followed by the addition of 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). Finally, 100 µL of a [4 M] stock solution of 1,3-butadiene in THF was added (0.400 mmol, 2.0 equiv). The reaction vial was then equipped with a magnetic stir bar, sealed with a microwave cap, and taken outside the glove box. The reaction mixture was then stirred at 50 °C in a preset oil bath for 20 h. The reaction mixture was then allowed to cool to room temperature. The reaction mixture was filtered through a small celite plug, (1 cm long in a pipette), and washed with ethyl acetate. The resulting mixture was then concentrated and purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4a** (43.9 mg, 70% yield) as a colorless oil. The spectroscopic data matches that of the above conditions.

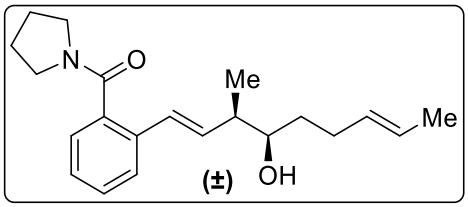


(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3-methylpent-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4b): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and acetaldehyde (26.4 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of MeCN. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4b**

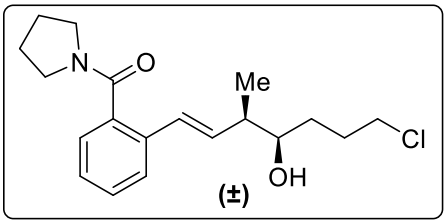
(44.2 mg, 81% yield) as a white solid (mp: 92–94 °C). IR (film): 3365 (br), 2961, 2878, 1612, 1452, 1431, 1078, 991, 755 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.46 (d, *J* = 7.8 Hz, 1H), 7.30–7.27 (m, 1H), 7.24–7.20 (m, 2H), 6.44 (d, *J* = 15.8 Hz, 1H), 6.12 (dd, *J* = 15.9, 8.0 Hz, 1H), 3.73–3.68 (m, 1H), 3.63 (t, *J* = 7.0 Hz, 2H), 3.09 (t, *J* = 6.8 Hz, 2H), 2.38–2.31 (m, 1H), 2.00 (s, 1H), 1.94–1.89 (m, *J* = 6.8 Hz, 2H), 1.84–1.79 (m, *J* = 6.7 Hz, 2H), 1.14 (d, *J* = 6.3 Hz, 3H), 1.06 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$). δ 169.77, 136.45, 135.61, 134.06, 129.01, 127.50, 127.30, 126.26, 126.15, 71.25, 48.32, 45.62, 44.66, 26.05, 24.71, 20.37, 15.61; HRMS (ESI/$[M+H]^+$) calcd. for $C_{17}H_{24}NO_2^+$: 274.1802. Found 274.1801.



(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3-methylnon-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4c): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and hexanal (60.1 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4c** (51.4 mg, 78% yield) as a colorless oil. IR (film): 3391 (br), 2931, 2873, 1612, 1452, 1427, 1340, 969, 728 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.46 (d, *J* = 7.8 Hz, 1H), 7.31–7.27 (m, 1H), 7.24–7.20 (m, 2H), 6.43 (d, *J* = 15.9 Hz, 1H), 6.14 (dd, *J* = 15.9, 8.0 Hz, 1H), 3.63 (t, *J* = 7.0 Hz, 2H), 3.50 (m, 1H), 3.09 (t, *J* = 6.8 Hz, 2H), 2.41–2.37 (m, 1H), 1.95–1.89 (m, 2H), 1.84–1.79 (m, 3H), 1.49–1.45 (m, 2H), 1.37–1.24 (m, 6H), 1.06 (d, *J* = 6.8 Hz, 3H), 0.86 (t, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.78, 136.46, 136.21, 134.07, 129.01, 127.28, 127.14, 126.28, 126.11, 75.24, 48.31, 45.62, 43.43, 34.39, 31.99, 26.07, 25.90, 24.71, 22.76, 15.04, 14.16; HRMS (ESI/$[M+H]^+$) calcd. for $C_{21}H_{32}NO_2^+$: 330.2428. Found 330.2427.

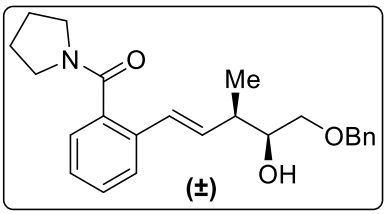


(±)-(2-((1*E*,3*R*,4*R*,7*E*)-4-Hydroxy-3-methylnona-1,7-dien-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4d): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and (*E*)-hex-4-enal (58.8 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4d** (53.6 mg, 82% yield) as a colorless oil. IR (film): 3396 (br), 2934, 2878, 1611, 1451, 1427, 966, 911, 753, 729 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 7.8 Hz, 1H), 7.29 – 7.25 (m, 1H), 7.22–7.18 (m, 2H), 6.41 (d, *J* = 15.9 Hz, 1H), 6.10 (dd, *J* = 15.9, 8.0 Hz, 1H), 5.46–5.33 (m, 2H), 3.61 (t, *J* = 7.0 Hz, 2H), 3.51–3.46 (m, 1H), 3.06 (t, *J* = 6.7 Hz, 2H), 2.38–2.30 (m, 1H), 2.18–2.10 (m, 1H), 2.04–1.93 (m, 2H), 1.91–1.86 (m, 2H), 1.82–1.76 (m, 2H), 1.59 (d, *J* = 4.9 Hz, 3H), 1.55–1.47 (m, 1H), 1.43–1.33 (m, 1H), 1.04 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.78, 136.43, 136.10, 134.04, 131.07, 129.00, 127.27, 127.19, 126.26, 126.15, 125.45, 74.76, 48.31, 45.61, 43.59, 34.19, 29.36, 26.02, 24.69, 18.00, 15.23. HRMS (ESI/$[M+H]^+$) calcd. for $C_{21}H_{30}NO_2^+$: 328.2271. Found 328.2275.

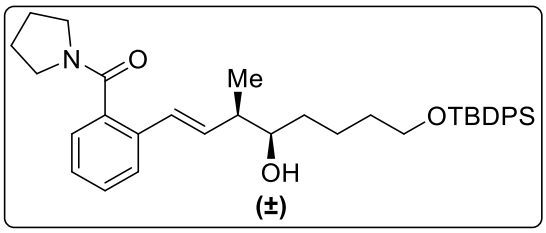


(±)-(2-((3*R*,4*R*,*E*)-7-Chloro-4-hydroxy-3-methylhept-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4e): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 4-chlorobutanal (63.6 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4e** (54.0 mg, 81% yield) as a colorless oil. IR (film): 3387 (br), 2957, 2876, 1609, 1452, 1427, 969, 912, 753, 730 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.44 (d, *J* = 7.8 Hz, 1H), 7.29–7.25 (m, 1H), 7.23–7.17 (m, 2H), 6.40 (d, *J* = 15.8 Hz, 1H), 6.08 (dd, *J* = 15.9, 8.1 Hz, 1H), 3.63–3.59 (m, 2H), 3.54–3.46 (m, 3H), 3.10–3.06 (m, 2H), 2.77 (s, 1H), 2.39–2.31 (m, 1H), 1.99–1.89 (m, 3H), 1.82–1.72 (m, 3H), 1.68–1.60 (m, 1H), 1.46–

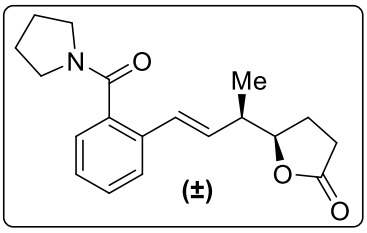
1.36 (m, 1H), 1.04 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.84, 136.21, 135.79, 134.04, 129.11, 127.43, 127.33, 126.27, 126.21, 74.49, 48.43, 45.71, 45.35, 43.67, 31.51, 29.41, 26.06, 24.69, 15.25. HRMS (ESI/$[M+H]^+$) calcd. for $C_{19}H_{27}ClNO_2^+$: 336.1725. Found 336.1728.



(±)-(2-((3*R*,4*S*,*E*)-5-(Benzyloxy)-4-hydroxy-3-methylpent-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4f): Slightly modified conditions: Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 2-(benzyloxy)acetaldehyde (90.1 mg, 0.600 mmol, 3.0 equiv). The concentration of the reaction was 0.1 M with respect to the C–H bond substrate. The product was then purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4f** (62.9 mg, 83% yield) as a colorless oil. IR (film): 3344 (br), 2972, 2879, 1609, 1452, 1428, 1072, 909, 729 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.43 (d, J = 7.8 Hz, 1H), 7.34–7.29 (m, 5H), 7.28–7.26 (m, 1H), 7.23–7.21 (m, 2H), 6.44 (d, J = 15.8 Hz, 1H), 6.12 (dd, J = 15.9, 8.3 Hz, 1H), 4.52 (s, 2H), 3.71–3.69 (m, 1H), 3.62 (t, J = 7.0 Hz, 2H), 3.56 (dd, J = 9.5, 3.2 Hz, 1H), 3.42 (dd, J = 9.6, 7.4 Hz, 1H), 3.07 (t, J = 6.8 Hz, 2H), 2.56 (d, J = 4.0 Hz, 1H), 2.51–2.44 (m, J = 7.0 Hz, 1H), 1.93–1.87 (m, 2H), 1.82–1.77 (m, J = 6.7 Hz, 2H), 1.13 (d, J = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.63, 138.02, 136.49, 135.16, 133.77, 128.98, 128.50, 127.81, 127.77, 127.36, 127.10, 126.27, 126.01, 73.75, 73.45, 72.84, 48.25, 45.57, 40.80, 26.03, 24.68, 16.26; HRMS (ESI/$[M+H]^+$) calcd. for $C_{24}H_{30}NO_3^+$: 380.2220. Found 380.2228.

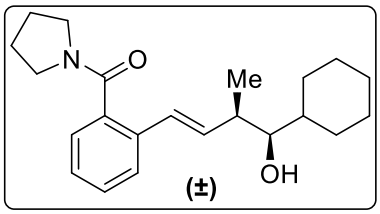


(±)-(2-((3*R*,4*R*,*E*)-8-((*Tert*-butyldiphenylsilyl)oxy)-4-hydroxy-3-methyloct-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4g): Slightly modified conditions: Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 5-((*tert*-butyldiphenylsilyl)oxy)pentanal (204.1 mg, 0.600 mmol, 3.0 equiv). The concentration of the reaction was 0.1 M with respect to the C–H bond substrate. The product was then purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4g** (60.3 mg, 53% yield) as a colorless oil. IR (film): 3418 (br), 2931, 2859, 1613, 1452, 1427, 1107, 969, 909, 731 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 6.2 Hz, 4H), 7.46 (d, *J* = 7.8 Hz, 1H), 7.42–7.35 (m, 6H), 7.32–7.29 (m, 1H), 7.24–7.23 (m, 2H), 6.45 (d, *J* = 15.9 Hz, 1H), 6.14 (dd, *J* = 15.9, 7.9 Hz, 1H), 3.67–3.63 (m, 4H), 3.51 (s, 1H), 3.10 (t, *J* = 6.7 Hz, 2H), 2.41–2.35 (m, 1H), 1.95–1.89 (m, 2H), 1.84–1.79 (m, 2H), 1.67 (s, 1H), 1.61–1.53 (m, 3H), 1.51–1.46 (m, 1H), 1.43–1.33 (m, 2H), 1.07 (d, *J* = 6.9 Hz, 3H), 1.04 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.79, 136.51, 136.13, 135.67, 134.17, 134.09, 129.63, 129.04, 127.70, 127.33, 127.29, 126.32, 126.17, 75.18, 63.96, 48.34, 45.64, 43.43, 34.14, 32.64, 27.00, 26.09, 24.74, 22.55, 19.33, 14.94. HRMS (ESI/$[M+H]^+$) calcd. for $C_{36}H_{48}NO_3Si^+$: 570.3398. Found 570.3412.

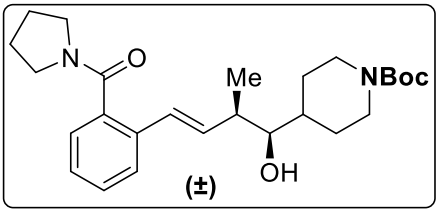


(±)-(*R*)-5-((*R*,*E*)-4-(2-(Pyrrolidine-1-carbonyl)phenyl)but-3-en-2-yl)dihydrofuran-2(3H)-one (4h): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and methyl 4-oxobutanoate (69.6 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of MeCN. Reverse

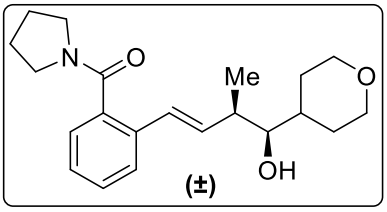
phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4h** (61.4 mg, 98% yield) as a colorless oil. IR (film): 2971, 2877, 1769, 1618, 1451, 1420, 1340, 1167, 972, 728 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.44 (d, *J* = 8.1 Hz, 1H), 7.30–7.27 (m, 1H), 7.25–7.19 (m, 2H), 6.50 (d, *J* = 15.9 Hz, 1H), 6.03 (dd, *J* = 15.8, 8.1 Hz, 1H), 4.35 (q, *J* = 7.3 Hz, 1H), 3.61 (t, *J* = 7.0 Hz, 2H), 3.06 (t, *J* = 6.7 Hz, 2H), 2.60–2.53 (m, 1H), 2.49–2.45 (m, 2H), 2.23 –2.17 (m, 1H), 1.98–1.89 (m, 3H), 1.84–1.79 (m, 2H), 1.15 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 177.04, 169.39, 136.62, 133.20, 131.94, 129.03, 128.84, 127.73, 126.28, 125.91, 83.59, 48.34, 45.58, 42.23, 28.81, 26.01, 25.40, 24.64, 16.30. HRMS (ESI/$[M+H]^+$) calcd. for $C_{19}H_{24}NO_3^+$: 314.1751. Found 314.1750.



(±)-(2-((3*R*,4*R*,*E*)-4-Cyclohexyl-4-hydroxy-3-methylbut-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4i): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and cyclohexanecarbaldehyde (67.3 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4i** (36.2 mg, 53% yield) as a colorless oil. IR (film): 3402 (br), 2925, 2852, 1612, 1450, 1428, 972, 908, 726 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.33–7.29 (m, 1H), 7.24–7.22 (m, 2H), 6.45 (d, *J* = 15.5 Hz, 1H), 6.17 (dd, *J* = 15.9, 7.8 Hz, 1H), 3.65 (t, *J* = 7.0 Hz, 2H), 3.26 (t, *J* = 5.8 Hz, 1H), 3.12–3.09 (m, 2H), 2.55–2.49 (m, 1H), 1.97–1.91 (m, 3H), 1.86–1.81 (m, 2H), 1.76–1.73 (m, 2H), 1.66–1.58 (m, 3H), 1.46–1.39 (m, 1H), 1.25–1.10 (m, 4H), 1.07 (d, *J* = 6.8 Hz, 3H), 1.04–0.97 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.81, 137.05, 136.48, 134.07, 129.02, 127.28, 126.57, 126.31, 126.06, 79.25, 48.31, 45.63, 40.76, 39.86, 29.95, 27.74, 26.55, 26.42, 26.16, 26.10, 24.75, 14.44; HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{32}NO_2^+$: 342.2428. Found 342.2429.

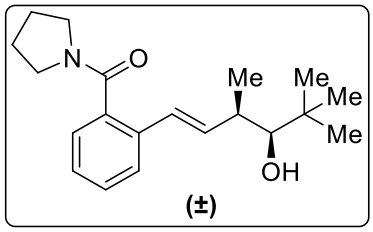


(±)-*tert*-Butyl 4-((1*R*,2*R*,*E*)-1-hydroxy-2-methyl-4-(2-(pyrrolidine-1-carbonyl)phenyl)but-3-en-1-yl)piperidine-1-carboxylate (4j): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and *tert*-butyl 4-formylpiperidine-1-carboxylate (128 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 60:40 mixture of ethyl acetate: dichloromethane as the eluent to afford the product **4j** (71.3 mg, 81% yield) as a light yellow oil. IR (film): 3429 (br), 2972, 2875, 1687, 1613, 1424, 1365, 1165, 972, 730 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.44 (d, *J* = 7.8 Hz, 1H), 7.31–7.28 (m, 1H), 7.24–7.20 (m, 2H), 6.43 (d, *J* = 15.9 Hz, 1H), 6.13 (dd, *J* = 15.9, 7.7 Hz, 1H), 4.10 (bs, 2H), 3.62 (t, *J* = 7.0 Hz, 2H), 3.26 (t, *J* = 5.7 Hz, 1H), 3.09 (t, *J* = 6.7 Hz, 2H), 2.66–2.58 (m, 2H), 2.51–2.45 (m, 1H), 2.15 (s, 1H), 1.95–1.89 (m, 2H), 1.85–1.79 (m, 3H), 1.58–1.48 (m, 2H), 1.43 (s, 9H), 1.32–1.26 (m, 1H), 1.20–1.14 (m, 1H), 1.06 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.82, 154.90, 136.72, 136.35, 134.03, 129.09, 127.36, 126.97, 126.34, 126.24, 79.38, 78.15, 53.94, 48.41, 45.66, 43.88, 39.65, 39.16, 29.36, 28.79, 28.57, 27.37, 26.10, 24.72.; HRMS (ESI/$[M+H]^+$) calcd. for $C_{26}H_{39}N_2O_4^+$: 443.2904. Found 443.2905.



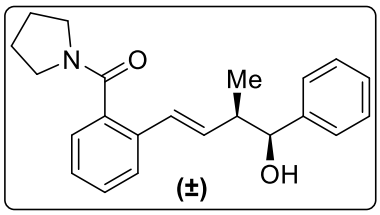
(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3-methyl-4-(tetrahydro-2H-pyran-4-yl)but-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4k): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and tetrahydro-2H-pyran-4-carbaldehyde (68.4 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of MeCN. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq.

$NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4k** (60.4 mg, 88% yield) as a colorless oil. IR (film): 3403 (br), 2972, 2877, 1611, 1452, 1427, 1093, 970, 911, 727 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.45 (d, *J* = 7.8 Hz, 1H), 7.30–7.27 (m, 1H), 7.23–7.19 (m, 2H), 6.42 (d, *J* = 16.0 Hz, 1H), 6.15 (dd, *J* = 15.9, 7.7 Hz, 1H), 3.97–3.93 (m, 2H), 3.62 (t, *J* = 7.0 Hz, 2H), 3.37–3.28 (m, 2H), 3.25 (s, 1H), 3.09 (t, *J* = 6.8 Hz, 2H), 2.50–2.44 (m, 1H), 2.24 (s, 1H), 1.94–1.89 (m, 2H), 1.84–1.79 (m, 2H), 1.76–1.74 (m, 1H), 1.68–1.61 (m, 1H), 1.48–1.33 (m, 3H), 1.04 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.79, 136.83, 136.34, 134.03, 129.05, 127.31, 126.84, 126.30, 126.19, 78.26, 68.07, 67.77, 48.37, 45.62, 39.31, 38.12, 29.51, 28.48, 26.07, 24.69, 13.77. HRMS (ESI/$[M+H]^+$) calcd. for $C_{21}H_{30}NO_3^+$: 344.2220. Found 344.2224.

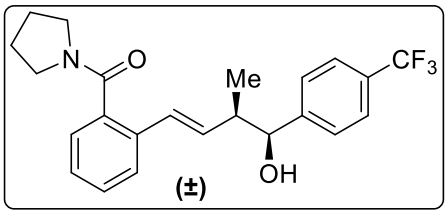


(±)-(2-((3*R*,4*S*,*E*)-4-Hydroxy-3,5,5-trimethylhex-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4l): Slightly modified conditions: Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (70.0 mg, 0.400 mmol, 1.0 equiv), 1,3-butadiene (0.800 mmol, 2.0 equiv), and pivaldehyde (103.2 mg, 1.200 mmol, 3.0 equiv). The reaction was conducted at 0.4 mmol scale to obtain a sufficient amount of product for characterization purposes. The concentration of the reaction was [1.0 M] with respect to the C–H bond substrate, and the reaction solution was heated to 70 °C for 20 h. The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of MeCN. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4l** (18.0 mg, 14% yield) as a colorless oil. IR (film): 3418 (br), 2953, 2873, 1612, 1452, 1426, 1099, 971, 752, 730 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.8 Hz, 1H), 7.31–7.28 (m, 1H), 7.24–7.21 (m, 2H), 6.37 (d, *J* = 15.8 Hz, 1H), 6.21 (dd, *J* = 15.8, 8.4 Hz, 1H), 3.64 (t, *J* = 7.1 Hz, 2H), 3.23 (d, *J* = 4.7 Hz, 1H), 3.08 (t, *J* = 6.6 Hz, 2H), 2.60–2.54 (m, 1H), 1.95–1.90 (m,

2H), 1.85–1.80 (m, 2H), 1.73 (s, 1H), 1.10 (d, J = 6.8 Hz, 3H), 0.94 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.80, 139.08, 136.37, 133.97, 129.05, 127.23, 126.19, 125.76, 124.94, 81.93, 48.32, 45.63, 39.91, 36.07, 26.96, 26.06, 24.76, 16.47. HRMS (ESI/$[M+H]^+$) calcd. for $C_{20}H_{30}NO_2^+$: 316.2271. Found 316.2274.

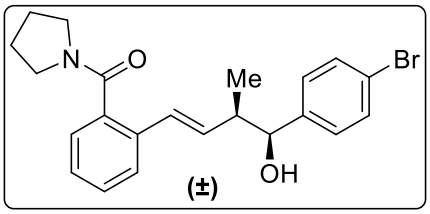


(±)-(2-((3*R*,4*S*,*E*)-4-Hydroxy-3-methyl-4-phenylbut-1-en-1-yl)phenyl)(pyrrolidin-1-yl)-methanone (4m): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and benzaldehyde (63.6 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4m** (59.6 mg, 89% yield) as a colorless oil. IR (film): 3386 (br), 2968, 2882, 1604, 1452, 1427, 1027, 910, 729 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.38 (d, J = 7.8 Hz, 1H), 7.27–7.24 (m, 5H), 7.22–7.15 (m, 3H), 6.33 (d, J = 15.9 Hz, 1H), 6.10 (dd, J = 15.8, 7.7 Hz, 1H), 4.60 (d, J = 5.6 Hz, 1H), 3.57 (t, J = 7.0 Hz, 2H), 2.99–2.88 (m, 2H), 2.70–2.63 (m, J = 6.8 Hz, 1H), 2.55 (s, 1H), 1.88–1.83 (m, J = 6.9 Hz, 2H), 1.76–1.71 (m, J = 6.7 Hz, 2H), 1.03 (d, J = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.69, 142.82, 136.42, 135.16, 133.92, 129.02, 128.10, 127.35, 127.29, 127.20, 126.59, 126.21, 125.82, 77.67, 48.19, 45.58, 44.57, 26.02, 24.64, 15.14; HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{26}NO_2^+$: 336.1958. Found 336.1965.

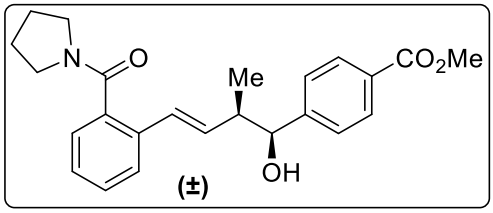


(±)-(2-((3*R*,4*S*,*E*)-4-Hydroxy-3-methyl-4-(4-(trifluoromethyl)phenyl)but-1-en-1-yl)phenyl)-(pyrrolidin-1-yl)methanone (4n): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 4-(trifluoromethyl)benzaldehyde (104.4 mg, 0.600 mmol, 3.0 equiv). The product was then purified

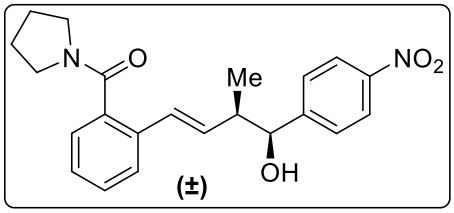
by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4n** (76.6 mg, 95% yield) as a colorless oil. IR (film): 3371 (br), 2973, 2878, 1609, 1431, 1323, 1161, 1119, 1066, 729 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.53 (d, *J* = 8.1 Hz, 2H), 7.39 (m, 3H), 7.28 (t, *J* = 7.5 Hz, 1H), 7.21 (t, *J* = 7.4 Hz, 1H), 7.18–7.16 (m, 1H), 6.37 (d, *J* = 15.9 Hz, 1H), 6.11 (dd, *J* = 15.9, 7.7 Hz, 1H), 4.68 (d, *J* = 5.0 Hz, 1H), 3.58 (t, *J* = 7.0 Hz, 2H), 3.28 (s, 1H), 3.04–2.95 (m, 2H), 2.69–2.63 (m, 1H), 1.91–1.85 (m, 2H), 1.74–1.79 (m, 2H), 0.99 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.77, 147.00, 136.28, 134.85, 133.85, 129.31 (q, *J* = 32.4), 129.15, 127.63, 127.43, 126.90, 126.25, 125.99, 124.94 (q, *J* = 3.8), 124.31 (q, *J* = 272.5), 76.72, 48.38, 45.65, 44.46, 26.01, 24.66, 14.55; ^{19}F NMR (471 MHz, $CDCl_3$): δ -63.21 (s, 3F); HRMS (ESI/$[M+H]^+$) calcd. for $C_{23}H_{25}F_3NO_2^+$: 404.1832. Found 404.1844.



(±)-(2-((3*R*,4*S*,*E*)-4-(4-Bromophenyl)-4-hydroxy-3-methylbut-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4o): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 4-bromobenzaldehyde (111 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4o** (76 mg, 92% yield) as a colorless oil. IR (film): 3371 (br), 2972, 2879, 1607, 1452, 1429, 1009, 727 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.38 (m, 3H), 7.29–7.25 (m, *J* = 7.5, 1.6 Hz, 1H), 7.22–7.18 (td, *J* = 7.4, 1.3 Hz, 1H), 7.16–7.12 (m, 3H), 6.31 (d, *J* = 16.0 Hz, 1H), 6.07 (dd, *J* = 15.9, 7.7 Hz, 1H), 4.54 (d, *J* = 5.5 Hz, 1H), 3.56 (t, *J* = 7.0 Hz, 2H), 3.18 (s, 1H), 3.00–2.89 (m, 2H), 2.64–2.57 (m, 1H), 1.89–1.84 (m, 2H), 1.79–1.73 (m, 2H), 1.00 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.68, 142.05, 136.31, 134.85, 133.82, 131.03, 129.06, 128.38, 127.35, 127.33, 126.19, 125.83, 120.93, 76.85, 48.27, 45.58, 44.50, 26.01, 24.64, 15.02; HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{25}BrNO_2^+$: 414.1063. Found 414.1080.

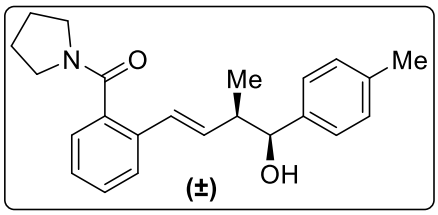


(±)-Methyl-4-((1*S*,2*R*,*E*)-1-hydroxy-2-methyl-4-(2-(pyrrolidine-1-carbonyl)phenyl)but-3-en-1-yl)benzoate (4p): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and methyl 4-formylbenzoate (98.5 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 60:40 mixture of ethyl acetate: hexanes as the eluent to afford the product **4p** (74 mg, 94% yield) as a colorless oil. IR (film): 3362 (br), 2973, 2880, 1718, 1608, 1433, 1276, 1107, 727 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.95 (d, *J* = 8.1 Hz, 2H), 7.39 (d, *J* = 7.8 Hz, 1H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.29–7.26 (m, 1H), 7.23–7.17 (m, 2H), 6.36 (d, *J* = 15.9 Hz, 1H), 6.09 (dd, *J* = 15.9, 7.6 Hz, 1H), 4.68 (d, *J* = 5.2 Hz, 1H), 3.89 (s, 3H), 3.58 (t, *J* = 7.0 Hz, 2H), 3.02–2.92 (m, 3H), 2.71–2.64 (m, 1H), 1.90–1.85 (m, 2H), 1.78–1.72 (m, 2H), 1.01 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.70, 167.09, 148.19, 136.42, 134.82, 133.86, 129.41, 129.11, 129.09, 127.62, 127.42, 126.58, 126.26, 125.93, 77.10, 52.16, 48.32, 45.62, 44.55, 26.02, 24.66, 14.76; HRMS (ESI/$[M+H]^+$) calcd. for $C_{24}H_{28}NO_4^+$: 394.2013. Found 394.2012.

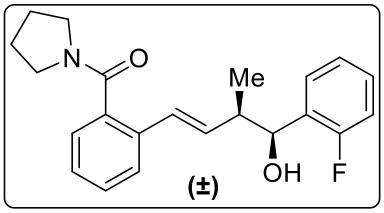


(±)-(2-((3*R*,4*S*,*E*)-4-Hydroxy-3-methyl-4-(4-nitrophenyl)but-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4q): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 4-nitrobenzaldehyde (90.6 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4q** (68.4 mg, 90% yield) as a colorless oil. IR (film): 3346 (br), 2972, 2880, 1605, 1515, 1453, 1431, 1342, 728 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 8.11 (d, *J* = 8.8 Hz, 2H), 7.43 (d, *J* = 8.2 Hz, 2H), 7.38 (d, *J* = 7.8 Hz, 1H), 7.29–7.26 (m, 1H), 7.20 (t, *J* = 7.0 Hz, 1H), 7.15 (d, *J* = 7.4 Hz, 1H), 6.36 (d, *J* = 15.9 Hz, 1H), 6.09 (dd, *J* = 15.9, 7.7 Hz, 1H), 4.71 (s, 1H), 3.67 (m, 1H), 3.58 (t, *J* = 6.9 Hz, 2H), 3.06–2.97 (m,

2H), 2.68–2.62 (m, 1H), 1.91–1.86 (m, 2H), 1.80–1.74 (m, 2H), 0.96 (d, J = 6.7 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.75, 150.70, 147.05, 136.18, 134.74, 133.83, 129.20, 127.84, 127.48, 127.34, 126.28, 126.08, 123.22, 76.34, 48.47, 45.69, 44.48, 26.04, 24.66, 14.32; HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{25}N_2O_4^+$: 381.1809. Found 381.1801.

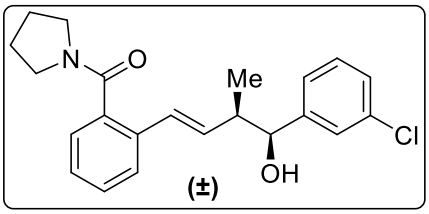


(±)-(2-((3*R*,4*S*,*E*)-4-Hydroxy-3-methyl-4-(*p*-tolyl)but-1-en-1-yl)phenyl)(pyrrolidin-1-yl)-methanone (4r): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and *p*-tolualdehyde (72.1 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4r** (51 mg, 94:6 dr, 73% yield) as a colorless oil. IR (film): 3374 (br), 2969, 2875, 1609, 1452, 1428, 967, 909, 727 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.41 (d, J = 7.8 Hz, 1H), 7.29–7.26 (m, 1H), 7.23–7.17 (m, 4H), 7.10 (d, J = 7.9 Hz, 2H), 6.37 (d, J = 15.9 Hz, 1H), 6.12 (dd, J = 15.9, 7.6 Hz, 1H), 4.59 (d, J = 5.7 Hz, 1H), 3.60 (t, J = 7.0 Hz, 2H), 3.02–2.92 (m, 2H), 2.72–2.65 (m, 1H), 2.31 (s, 3H), 1.91–1.85 (m, 2H), 1.78–1.73 (m, 2H), 1.06 (d, J = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.68, 139.82, 136.94, 136.50, 135.27, 133.99, 129.00, 128.83, 127.27, 127.16, 126.53, 126.22, 125.83, 77.64, 48.18, 45.56, 44.48, 26.01, 24.66, 21.21, 15.25; HRMS (ESI/$[M+H]^+$) calcd. for $C_{23}H_{28}NO_2^+$: 350.2115. Found 350.2124.

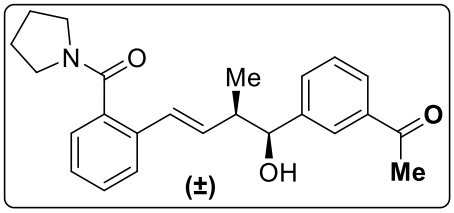


(±)-(2-((3*R*,4*S*,*E*)-4-(2-Fluorophenyl)-4-hydroxy-3-methylbut-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4s): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 2-fluorobenzaldehyde (74.5 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50

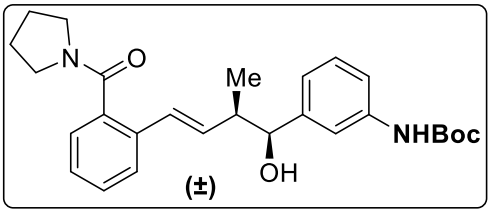
mixture of ethyl acetate: hexanes as the eluent to afford the product **4s** (60.0 mg, 85% yield) as a colorless oil. IR (film): 3368 (br), 2973, 2876, 1608, 1452, 1429, 1217, 967, 753 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.45–7.41 (m, 2H), 7.30–7.26 (m, 1H), 7.23–7.18 (m, 3H), 7.10 (t, *J* = 7.5 Hz, 1H), 6.98–6.94 (m, 1H), 6.36 (d, *J* = 15.9 Hz, 1H), 6.14 (dd, *J* = 15.9, 7.8 Hz, 1H), 4.97 (d, *J* = 5.6 Hz, 1H), 3.60 (t, *J* = 7.0 Hz, 2H), 3.04–2.99 (m, 1H), 2.96–2.91 (m, 1H), 2.75–2.69 (m, 2H), 1.91–1.86 (m, 2H), 1.80–1.74 (m, 2H), 1.07 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.72, 159.75 (d, *J* = 245.2), 136.46, 135.00, 133.97, 130.14 (d, *J* = 13.2), 129.07, 128.67 (d, *J* = 8.2), 128.27 (d, *J* = 4.5), 127.52, 127.35, 126.21, 125.95, 124.03 (d, *J* = 3.35), 115.06 (d, *J* = 22.2), 71.31, 48.22, 45.61, 44.06, 26.05, 24.66, 14.98; ^{19}F NMR (471 MHz, $CDCl_3$): δ -119.32 (s, 1F); HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{25}FNO_2^+$: 354.1864. Found 354.1862.



(±)-(2-((3*R*,4*S*,*E*)-4-(3-Chlorophenyl)-4-hydroxy-3-methylbut-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4t): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-chlorobenzaldehyde (84.3 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4t** (66.4 mg, 90% yield) as a colorless oil. IR (film): 3351 (br), 2972, 2878, 1608, 1453, 1430, 1193, 907, 726 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.40 (d, *J* = 7.9 Hz, 1H), 7.29–7.26 (m, 2H), 7.22–7.13 (m, 5H), 6.34 (d, *J* = 15.9 Hz, 1H), 6.10 (dd, *J* = 15.9, 7.6 Hz, 1H), 4.58 (d, *J* = 5.3 Hz, 1H), 3.58 (t, *J* = 7.0 Hz, 2H), 3.13–3.10 (m, 1H), 3.02–2.92 (m, 2H), 2.66–2.59 (m, 1H), 1.91–1.85 (m, 2H), 1.79–1.74 (m, 2H), 1.01 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.72, 145.24, 136.34, 135.01, 134.00, 133.88, 129.31, 129.08, 127.41, 127.35, 127.29, 126.71, 126.21, 125.94, 124.79, 76.78, 48.27, 45.62, 44.52, 26.03, 24.65, 14.75; HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{25}ClNO_2^+$: 370.1568. Found 370.1573.

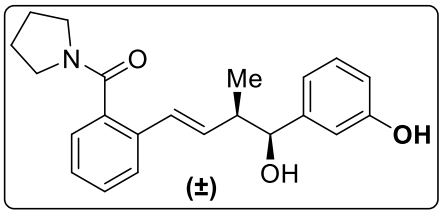


(±)-1-(3-((1*S*,2*R*,*E*)-1-Hydroxy-2-methyl-4-(2-(pyrrolidine-1-carbonyl)phenyl)but-3-en-1-yl)phenyl)ethan-1-one (4u): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-acetylbenzaldehyde (88.9 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of MeCN. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4u** (71.1 mg, 87% yield) as a light yellow oil. IR (film): 3388 (br), 2973, 2879, 1681, 1607, 1428, 1272, 911, 727, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.87 (s, 1H), 7.80 (d, *J* = 7.7 Hz, 1H), 7.49 (d, *J* = 7.6 Hz, 1H), 7.39–7.36 (m, 2H), 7.28–7.25 (m, 1H), 7.21–7.16 (m, 2H), 6.36 (d, *J* = 15.9 Hz, 1H), 6.10 (dd, *J* = 15.9, 7.6 Hz, 1H), 4.69 (d, *J* = 5.2 Hz, 1H), 3.58 (t, *J* = 7.0 Hz, 2H), 3.03–2.95 (m, 3H), 2.71–2.65 (m, 1H), 2.54 (s, 3H), 1.90–1.85 (m, 2H), 1.79–1.74 (m, 2H), 1.00 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 198.39, 169.71, 143.54, 136.90, 136.34, 135.04, 133.93, 131.38, 129.10, 128.33, 127.59, 127.37, 127.24, 126.44, 126.24, 125.96, 77.00, 48.31, 45.62, 44.49, 26.78, 26.04, 24.64, 14.66; HRMS (ESI/$[M+H]^+$) calcd. for $C_{24}H_{28}NO_3^+$: 378.2064. Found 378.2067.



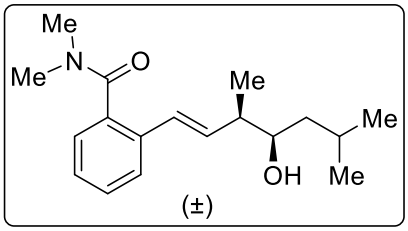
(±)-*tert*-Butyl (3-((1*S*,2*R*,*E*)-1-hydroxy-2-methyl-4-(2-(pyrrolidine-1-carbonyl)phenyl)but-3-en-1-yl)phenyl)carbamate (4v): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and *tert*-butyl (3-formylphenyl)carbamate (132.8 mg, 0.6002 mmol, 3.0 equiv). The product was then purified by

silica gel chromatography using a 35:65 mixture of ethyl acetate: dichloromethane as the eluent to afford the product **4v** (82.4 mg, 92% yield) as a light yellow waxy solid. IR (film): 3301 (br), 2976, 2880, 1721, 1608, 1543, 1432, 1236, 1156, 979 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.41 (d, *J* = 7.7 Hz, 1H), 7.29–7.26 (m, 3H), 7.22–7.17 (m, 3H), 6.91 (d, *J* = 7.5 Hz, 1H), 6.76 (s, 1H), 6.36 (d, *J* = 15.9 Hz, 1H), 6.08 (dd, *J* = 15.9, 7.7 Hz, 1H), 4.55 (s, 1H), 3.57–3.55 (m, 2H), 3.05–2.96 (m, 2H), 2.74 (s, 1H), 2.69–2.62 (m, 1H), 1.90–1.84 (m, 2H), 1.80–1.75 (m, 2H), 1.49 (s, 9H), 1.00 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (151 MHz, $CDCl_3$): δ 169.80, 152.94, 143.61, 138.40, 136.19, 135.28, 134.08, 129.13, 128.68, 127.42, 127.28, 126.29, 126.21, 121.30, 117.58, 116.76, 80.49, 77.37, 48.37, 45.63, 44.34, 28.45, 26.04, 24.64, 15.05; HRMS (ESI/$[M+H]^+$) calcd. for $C_{27}H_{35}N_2O_4^+$: 451.2591. Found 451.2595.

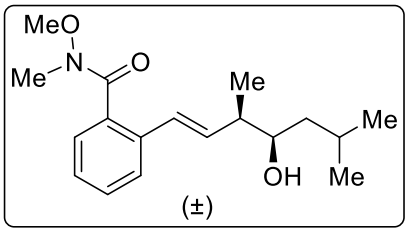


(±)-(2-((3*R*,4*S*,*E*)-4-Hydroxy-4-(3-hydroxyphenyl)-3-methylbut-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4w): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-hydroxybenzaldehyde (73.3 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of MeCN. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4w** (67.5 mg, 97% yield) as a light yellow waxy solid. IR (film): 3294 (br), 2972, 2880, 1585, 1453, 1434, 1260, 1228, 967, 728 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.12 (s, 1H), 7.35 (d, *J* = 7.7 Hz, 1H), 7.27–7.24 (m, 1H), 7.21–7.16 (m, 2H), 7.06 (t, *J* = 7.7 Hz, 1H), 6.78 (s, 1H), 6.70–6.68 (m, 2H), 6.32 (d, *J* = 15.9 Hz, 1H), 6.04 (dd, *J* = 15.9, 7.7 Hz, 1H), 4.45 (d, *J* = 5.5 Hz, 1H), 3.62–3.52 (m, 2H), 3.09–2.93 (m, 3H), 2.63–2.59 (m, 1H), 1.88–1.83 (m, 2H), 1.78–1.72 (m, 2H), 0.98 (d, *J* = 6.7 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 170.27, 156.70, 143.98, 135.67, 135.63, 134.17, 129.28, 129.06, 127.28, 127.26, 126.66,

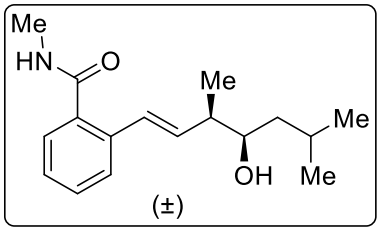
126.16, 118.42, 114.87, 113.97, 77.69, 48.48, 45.82, 44.11, 25.95, 24.60, 15.68; HRMS (ESI/[M+H]$^+$) calcd. for $C_{22}H_{26}NO_3^+$: 352.1907. Found 352.1909.



(±)-2-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-*N*,*N*-dimethylbenzamide (4x): Derived from *N*,*N*-dimethylbenzamide (29.8 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4x** (40.3 mg, 70% yield) as a colorless oil. IR (film): 3410 (br), 2954, 2926, 2868, 1619, 1396, 1069, 981, 751, 729 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.31 (t, *J* = 7.5 Hz, 1H), 7.23 (t, *J* = 7.4 Hz, 1H), 7.19 (d, *J* = 7.4 Hz, 1H), 6.39 (d, *J* = 15.9 Hz, 1H), 6.13 (dd, *J* = 15.9, 8.0 Hz, 1H), 3.62–3.60 (m, 1H), 3.12 (s, 3H), 2.78 (s, 3H), 2.40–2.33 (m, 1H), 1.82–1.67 (m, 2H), 1.37–1.31 (m, 1H), 1.27–1.22 (m, 1H), 1.07 (d, *J* = 6.8 Hz, 3H), 0.92–0.88 (m, 6H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$): δ 171.41, 136.10, 135.33, 134.44, 129.02, 127.32, 127.19, 126.50, 126.00, 73.15, 43.84, 43.50, 38.61, 34.85, 24.79, 23.92, 21.83, 15.06; HRMS (ESI/[M+H]+) calcd. for $C_{18}H_{28}NO_2^+$: 290.2115. Found 290.2112.

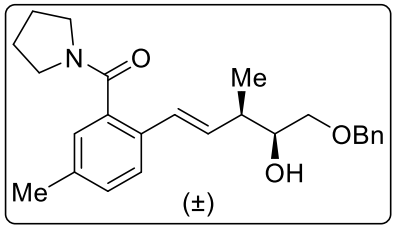


(±)-(2-(3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-*N*-methoxy-*N*-methylbenzamide (4y): Derived from *N*-methoxy-*N*-methylbenzamide (33.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4y** (34.1 mg, 56% yield) as a colorless oil. IR (film): 3441 (br), 2955, 2933, 2869, 1635, 1461, 1420, 1382, 983, 750, 730 cm^{-1}; ^1H NMR (500 MHz at 60 °C, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.34 (t, *J* = 7.5 Hz, 1H), 7.29–7.26 (m, 1H), 7.25–7.22 (m, 1H), 6.51 (d, *J* = 15.9 Hz, 1H), 6.13 (dd, *J* = 15.9, 7.7 Hz, 1H), 3.67–3.63 (m, 1H), 3.53 (s, 3H), 3.28 (s, 3H), 2.44–2.38 (m, 1H), 1.85–1.77 (m, 1H), 1.55 (s, 1H), 1.39–1.30 (m, 2H), 1.10 (d, *J* = 6.8 Hz, 3H), 0.95 (d, *J* = 6.7 Hz, 3H), 0.92 (d, *J* = 6.5 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz at 60 °C, $CDCl_3$): δ 136.19, 135.47, 134.26, 129.47, 127.88, 126.99, 126.83, 126.06, 73.36, 61.22, 43.75, 43.70, 25.09, 23.83, 22.04, 14.71; HRMS (ESI/[M+H]+) calcd. for $C_{18}H_{28}NO_3^+$: 306.2064. Found 306.2061.



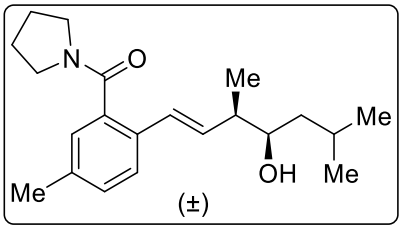
(±)-2-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-*N*-methylbenzamide (4z): Slightly modified conditions: Derived from *N*-methylbenzamide (27.0 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The reaction was run at 30 °C for 30 h. The product was then purified by C18 reverse phase column

chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4z** (32.8 mg, 60% yield) as a colorless oil. IR (film): 3292 (br), 2955, 2926, 2869, 1632, 1541, 1409, 980, 909, 730 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.45 (d, *J* = 7.8 Hz, 1H), 7.41 (d, *J* = 7.6 Hz, 1H), 7.34 (t, *J* = 7.6 Hz, 1H), 7.22 (t, *J* = 7.5 Hz, 1H), 6.68 (d, *J* = 15.9 Hz, 1H), 6.07–6.03 (m, 2H), 3.65–3.64 (m, 1H), 2.95 (d, *J* = 4.8 Hz, 3H), 2.44–2.39 (m, 1H), 2.00 (s, 1H), 1.81–1.74 (m, 1H), 1.37–1.32 (m, 1H), 1.25–1.23 (m, 1H), 1.08 (d, *J* = 6.9 Hz, 3H), 0.92–0.88 (m, 6H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 170.33, 136.31, 136.22, 134.97, 130.19, 128.39, 127.60, 127.12, 126.84, 73.07, 43.46, 43.18, 26.85, 24.79, 23.90, 21.85, 14.67; HRMS (ESI/[M+H]+) calcd. for $C_{17}H_{26}NO_2^+$: 276.1958. Found 276.1959.

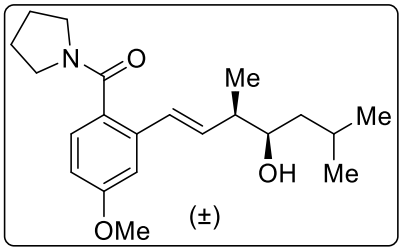


(±)-(2-((3*R*,4*S*,*E*)-5-(Benzyloxy)-4-hydroxy-3-methylpent-1-en-1-yl)-5-methylphenyl)-(pyrrolidin-1-yl)methanone (4aa): Derived from pyrrolidin-1-yl(m-tolyl)methanone[6] (37.9 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 2-(benzyloxy)acetaldehyde (90.1 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4aa** (51.1 mg, 65% yield) as a light yellow oil. IR (film): 3394 (br), 2972, 2923, 2874, 1605, 1451, 1097, 910, 728, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.35–7.31 (m, 5H), 7.29–7.26 (m, 1H), 7.10 (d, *J* = 8.0 Hz, 1H), 7.04 (s, 1H), 6.39 (d, *J* = 15.8 Hz, 1H), 6.06 (dd, *J* = 15.8, 8.3 Hz, 1H), 4.52 (s, 2H), 3.69 (dt, *J* = 7.2, 3.1 Hz, 1H), 3.62 (t, *J* = 7.0 Hz, 2H), 3.56

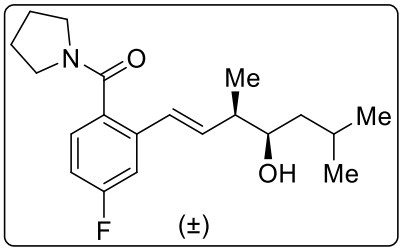
(dd, *J* = 9.5, 3.1 Hz, 1H), 3.42 (dd, *J* = 9.5, 7.6 Hz, 1H), 3.08 (t, *J* = 6.8 Hz, 2H), 2.49–2.42 (m, 2H), 2.32 (s, 3H), 1.93–1.88 (m, 2H), 1.83–1.77 (m, 2H), 1.12 (d, *J* = 6.8 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$): δ 169.86, 138.06, 137.34, 136.44, 134.10, 130.92, 129.81, 128.54, 127.85, 127.80, 127.05, 126.78, 125.98, 73.85, 73.49, 72.91, 48.24, 45.59, 40.83, 26.05, 24.72, 21.13, 16.38; HRMS (ESI/[M+H]+) calcd. for $C_{25}H_{32}NO_3^+$: 394.2377. Found 394.2373.



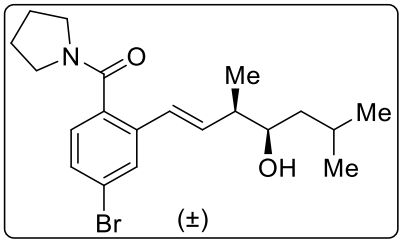
(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-5-methylphenyl)(pyrrolidin-1-yl)methanone (4ab): Derived from pyrrolidin-1-yl(*m*-tolyl)methanone[6] (37.9 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4, and concentrated to afford the product **4ab** (50.8 mg, 77% yield) as a colorless oil. IR (film): 3400 (br), 2953, 2925, 2871, 1607, 1442, 980, 921, 811, 728 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.36 (d, *J* = 8.0 Hz, 1H), 7.11 (dd, *J* = 8.0, 1.8 Hz, 1H), 7.04 (d, *J* = 1.8 Hz, 1H), 6.40 (d, *J* = 15.7 Hz, 1H), 6.09 (dd, *J* = 15.9, 8.0 Hz, 1H), 3.65–3.60 (m, 3H), 3.11 (t, *J* = 6.8 Hz, 2H), 2.36–2.34 (m, 1H), 2.32 (s, 3H), 1.94–1.91 (m, 2H), 1.85–1.78 (m, 3H), 1.54 (s, 1H), 1.36–1.31 (m, 1H), 1.26–1.22 (m, 1H), 1.06 (d, *J* = 6.8 Hz, 3H), 0.91 (d, *J* = 6.7 Hz, 3H), 0.89 (d, *J* = 6.5 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$): δ 169.97, 137.29, 136.46, 134.95, 131.15, 129.85, 127.26, 126.80, 126.04, 73.21, 48.31, 45.63, 43.83, 43.47, 26.10, 24.79, 24.77, 23.92, 21.83, 21.17, 15.10; HRMS (ESI/[M+H]+) calcd. for $C_{21}H_{32}NO_2^+$: 330.2428. Found 330.2425.



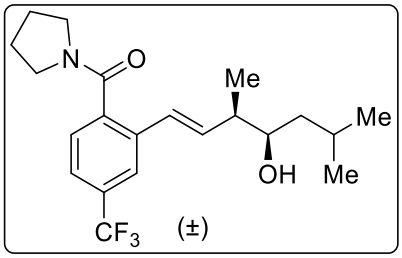
(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-4-methoxyphenyl)(pyrrolidin-1-yl)methanone (4ac): Derived from (4-methoxyphenyl)(pyrrolidin-1-yl)methanone[6] (41.1 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4, and concentrated to afford the product **4ac** (62.3 mg, 90% yield) as a colorless oil. IR (film): 3395 (br), 2954, 2928, 2872, 1602, 1437, 1239, 1167, 980, 729, 595 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.12 (d, *J* = 8.4 Hz, 1H), 6.94 (d, *J* = 2.5 Hz, 1H), 6.76 (dd, *J* = 8.4, 2.5 Hz, 1H), 6.36 (d, *J* = 15.8 Hz, 1H), 6.03 (dd, *J* = 15.8, 7.9 Hz, 1H), 3.81 (s, 3H), 3.55–3.49 (m, 3H), 3.18–3.15 (m, 2H), 2.37–2.30 (m, 2H), 1.91–1.86 (m, 2H), 1.84–1.80 (m, 2H), 1.72–1.63 (m, 1H), 1.29–1.15 (m, 2H), 0.99 (d, *J* = 6.9 Hz, 3H), 0.86 (d, *J* = 6.7 Hz, 3H), 0.83 (d, *J* = 6.6 Hz, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$): δ 170.00, 160.25, 136.43, 136.24, 128.59, 127.92, 127.64, 112.70, 111.66, 72.94, 55.44, 48.88, 45.78, 43.33, 42.73, 26.11, 24.71, 24.65, 23.74, 21.76, 14.56; HRMS (ESI/[M+H]+) calcd. for $C_{21}H_{32}NO_3^+$: 346.2377. Found 346.2379.



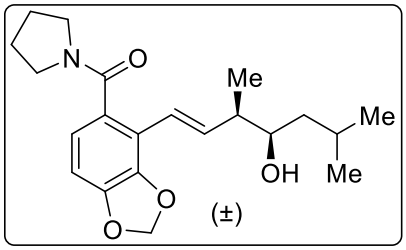
(±)-(4-Fluoro-2-((3*R*,4*R*,*E*)-4-hydroxy-3,6-dimethylhept-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4ad): Derived from (4-fluorophenyl)(pyrrolidin-1-yl)methanone (38.6 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4, and concentrated to afford the product **4ad** (62.0 mg, 93% yield) as a colorless oil. IR (film): 3389 (br), 2955, 2926, 2872, 1608, 1438, 1413, 1160, 966, 728 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.22–7.16 (m, 2H), 6.92 (td, *J* = 8.3, 2.5 Hz, 1H), 6.40 (d, *J* = 15.9 Hz, 1H), 6.18 (dd, *J* = 15.9, 7.9 Hz, 1H), 3.66–3.52 (m, 3H), 3.09 (t, *J* = 6.8 Hz, 2H), 2.42–2.29 (m, 1H), 1.95–1.90 (m, 2H), 1.86–1.73 (m, 4H), 1.35–1.30 (m, 1H), 1.24–1.16 (m, 1H), 1.05 (d, *J* = 6.8 Hz, 3H), 0.90 (d, *J* = 6.7 Hz, 3H), 0.87 (d, *J* = 6.6 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 168.98, 163.01 (d, *J* = 247.3 Hz), 137.47, 136.80 (d, *J* = 8.0 Hz), 132.59 (d, *J* = 3.1 Hz), 128.31 (d, *J* = 8.7 Hz), 126.27 (d, *J* = 2.5 Hz), 114.32 (d, *J* = 21.9 Hz), 112.51 (d, *J* = 22.4 Hz), 73.01, 48.42, 45.75, 43.75, 43.49, 26.09, 24.74, 24.71, 23.87, 21.78, 14.94; ^{19}F NMR (471 MHz, $CDCl_3$): δ -113.10–-113.15 (m, 1F); HRMS (ESI/[M+H]+) calcd. for $C_{20}H_{29}FNO_2^+$: 334.2177. Found 334.2175.



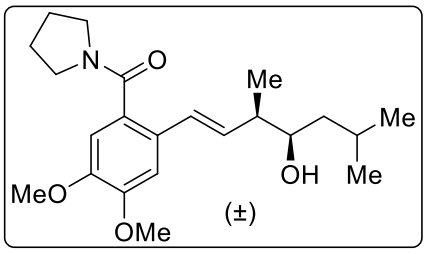
(±)-(4-Bromo-2-((3*R*,4*R*,*E*)-4-hydroxy-3,6-dimethylhept-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4ae): Derived from (4-bromophenyl)(pyrrolidin-1-yl)methanone (50.8 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4, and concentrated to afford the product **4ae** (69.0 mg, 87% yield) as a colorless oil. IR (film): 3400 (br), 2954, 2927, 2875, 1613, 1586, 1437, 907, 819, 728 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.63 (s, 1H), 7.36 (d, *J* = 8.1 Hz, 1H), 7.10 (d, *J* = 8.0 Hz, 1H), 6.36 (d, *J* = 15.8 Hz, 1H), 6.18 (dd, *J* = 15.9, 7.8 Hz, 1H), 3.64–3.61 (m, 3H), 3.09 (t, *J* = 6.7 Hz, 2H), 2.39–2.33 (m, 1H), 1.95–1.90 (m, 2H), 1.87–1.70 (m, 4H), 1.36–1.30 (m, 1H), 1.25–1.16 (m, 1H), 1.06 (d, *J* = 6.8 Hz, 3H), 0.91 (d, *J* = 6.8 Hz, 3H), 0.88 (d, *J* = 6.5 Hz, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$): δ 168.77, 137.70, 136.29, 135.24, 130.21, 128.97, 127.96, 125.96, 123.22, 73.04, 48.34, 45.74, 43.82, 43.48, 26.09, 24.77, 24.69, 23.87, 21.80, 14.93; HRMS (ESI/[M+H]+) calcd. for $C_{20}H_{29}BrNO_2^+$: 394.1376. Found 394.1378.



(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-4-(trifluoromethyl)phenyl)-(pyrrolidin-1-yl)methanone (4af): Derived from pyrrolidin-1-yl(4-(trifluoromethyl)-phenyl)methanone[7] (48.6 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4, and concentrated to afford the product **4af** (62.1 mg, 81% yield) as a colorless oil. IR (film): 3419 (br), 2956, 2928, 2877, 1612, 1443, 1328, 1167, 1125, 730 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.72 (s, 1H), 7.48 (d, *J* = 7.9 Hz, 1H), 7.34 (d, *J* = 7.9 Hz, 1H), 6.43 (d, *J* = 15.9 Hz, 1H), 6.26 (dd, *J* = 15.9, 7.9 Hz, 1H), 3.66–3.61 (m, 3H), 3.08 (t, *J* = 6.8 Hz, 2H), 2.41–2.35 (m, 1H), 1.96–1.73 (m, 6H), 1.36–1.31 (m, 1H), 1.23–1.18 (m, 1H), 1.06 (d, *J* = 6.9 Hz, 3H), 0.90 (d, *J* = 6.7 Hz, 3H), 0.87 (d, *J* = 6.6 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 168.41, 139.45, 138.29, 134.99, 131.26 (q, *J* = 32.4 Hz), 126.94, 125.87, 123.92 (q, *J* = 3.6 Hz), 123.92 (q, *J* = 273.1 Hz), 123.03 (q, *J* = 3.8 Hz), 72.94, 48.26, 45.76, 43.84, 43.46, 26.07, 24.74, 24.64, 23.83, 21.77, 14.84; ^{19}F NMR (471 MHz, $CDCl_3$): δ -63.71 (s, 3F); HRMS (ESI/[M+H]+) calcd. for $C_{21}H_{29}F_3NO_2^+$: 384.2145. Found 384.2136.

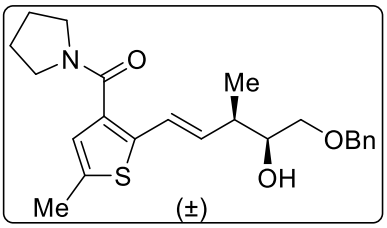


(±)-(4-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)benzo[d][1,3]dioxol-5-yl)-(pyrrolidin-1-yl)methanone (4ag): Derived from benzo[d][1,3]dioxol-5-yl(pyrrolidin-1-yl)methanone[8] (43.8 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography eluting with a 50:50 mixture of ethyl acetate:hexanes to afford the product **4ag** (66.5 mg, 93% yield) as a colorless oil. IR (film): 3409 (br), 2955, 2872, 1608, 1426, 1247, 1060, 912, 807, 727 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ 6.74 (d, *J* = 7.9 Hz, 1H), 6.68 (d, *J* = 7.9 Hz, 1H), 6.42 (dd, *J* = 16.1, 8.0 Hz, 1H), 6.26 (dd, *J* = 16.1, 0.7 Hz, 1H), 6.00 (s, 2H), 3.62–3.60 (m, 3H), 3.14 (t, *J* = 6.8 Hz, 2H), 2.36–2.30 (m, 1H), 1.94–1.89 (m, 2H), 1.84–1.74 (m, 3H), 1.66 (s, 1H), 1.36–1.31 (m, 1H), 1.25–1.21 (m, 1H), 1.05 (d, *J* = 6.8 Hz, 3H), 0.90 (d, *J* = 6.7 Hz, 3H), 0.88 (d, *J* = 6.6 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$): δ 169.06, 147.73, 144.98, 139.61, 130.82, 122.04, 120.00, 117.21, 106.88, 101.10, 72.96, 48.38, 45.57, 44.33, 43.31, 25.95, 24.62, 24.61, 23.74, 21.68, 14.71; HRMS (ESI/[M+H]+) calcd. for $C_{21}H_{30}NO_4^+$: 360.2169. Found 360.2166.



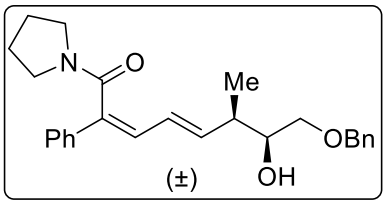
(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-4,5-dimethoxyphenyl)(pyrrolidin-1-yl)methanone (4ah): Derived from (3,4-dimethoxyphenyl)(pyrrolidin-1-yl)methanone (47.1 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography eluting with a 30:60:10 mixture of acetone:hexanes:dichloromethane to afford the product as a colorless oil. Due to the difficult separation of the two regioisomers, there were a few mixed fractions

obtained from the first purification. The mixed fractions were then concentrated and resubjected to silica gel chromatography using the same eluent mentioned above. The combined fractions for the major regioisomer were concentrated to afford the product **4ah** (45.1 mg, 60% yield) as a colorless oil. IR (film): 3375 (br), 2954, 2873, 1603, 1453, 1432, 1263, 1093, 914, 727 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 6.93 (s, 1H), 6.74 (s, 1H), 6.37 (d, *J* = 15.9 Hz, 1H), 6.04 (dd, *J* = 15.8, 7.9 Hz, 1H), 3.90 (s, 3H), 3.86 (s, 3H), 3.64–3.61 (m, 3H), 3.12 (t, *J* = 6.7 Hz, 2H), 2.39–2.32 (m, 1H), 1.95–1.90 (m, 2H), 1.85–1.74 (m, 3H), 1.56 (s, 1H), 1.37–1.31 (m, 1H), 1.26–1.21 (m, 1H), 1.06 (d, *J* = 6.8 Hz, 3H), 0.92–0.88 (m, 6H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$): δ 169.59, 149.48, 148.55, 134.03, 129.21, 127.10, 127.03, 109.30, 108.43, 73.18, 56.14, 56.08, 48.35, 45.74, 43.72, 43.49, 26.09, 24.81, 24.77, 23.87, 21.84, 14.95; HRMS (ESI/[M+H]+) calcd. for $C_{22}H_{34}NO4^{+}$: 376.2482. Found 376.2481.

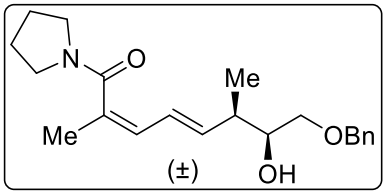


(±)-(2-((3*R*,4*S*,*E*)-5-(Benzyloxy)-4-hydroxy-3-methylpent-1-en-1-yl)-5-methylthiophen-3-yl)(pyrrolidin-1-yl)methanone (4ai): Slightly modified conditions: Derived from (5-methylthiophen-3-yl)(pyrrolidin-1-yl)methanone (39.1 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 2-(benzyloxy)acetaldehyde (45.1 mg, 0.300 mmol, 1.5 equiv). Only 17 µL of the acetic acid solution was used, (5 mol % acetic acid), along with 83 µL of dioxane. The reaction was run at 30 °C. The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4ai** (57.5 mg, 72% yield) as a colorless oil. IR (film): 3366 (br), 2967, 2920, 2872, 1605, 1432, 1102, 910, 728, 697 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35–7.27 (m, 5H), 6.61 (d, *J* = 0.8 Hz, 1H), 6.55 (d, *J* = 15.7 Hz, 1H), 5.90 (dd, *J* = 15.7, 8.4 Hz, 1H), 4.52 (s, 2H), 3.67 (td, *J* = 7.3, 3.0 Hz, 1H), 3.60–3.54 (m, 3H), 3.40 (dd, *J* = 9.4, 7.7 Hz, 1H), 3.29 (t, *J* = 6.7

Hz, 2H), 2.48–2.41 (m, 2H), 2.40 (s, 3H), 1.93–1.89 (m, 2H), 1.85–1.81 (m, 2H), 1.12 (d, *J* = 6.8 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$): δ 165.84, 139.06, 138.03, 137.84, 134.29, 133.14, 128.53, 127.84, 127.80, 124.81, 122.28, 73.78, 73.48, 72.93, 48.64, 45.84, 40.69, 26.17, 24.60, 16.26, 15.43; HRMS (ESI/[M+H]+) calcd. for $C_{23}H_{30}NO_3S^+$: 400.1941. Found 400.1940.



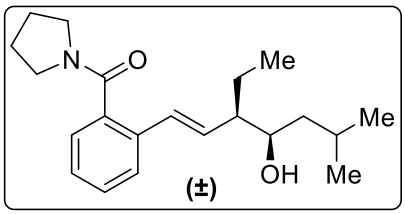
(±)-(2*Z*,4*E*,6*R*,7*S*)-8-(Benzyloxy)-7-hydroxy-6-methyl-2-phenyl-1-(pyrrolidin-1-yl)octa-2,4-dien-1-one (4aj): Derived from 2-phenyl-1-(pyrrolidin-1-yl)prop-2-en-1-one[9] (40.3 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.400 mmol, 2.0 equiv), and 2-(benzyloxy)acetaldehyde (90.1 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4aj** (40.4 mg, 50% yield) as a yellow oil. IR (film): 3400 (br), 2973, 2918, 2875, 1610, 1452, 1438, 1074, 730, 695 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.40–7.39 (m, 2H), 7.37–7.35 (m, 1H), 7.34–7.29 (m, 6H), 7.27–7.24 (m, 1H), 6.57 (d, *J* = 11.1 Hz, 1H), 6.22 (dd, *J* = 15.0, 11.1 Hz, 1H), 5.88 (dd, *J* = 15.1, 8.4 Hz, 1H), 4.53 (s, 2H), 3.69–3.63 (m, 3H), 3.55 (dd, *J* = 9.5, 3.0 Hz, 1H), 3.40 (dd, *J* = 9.4, 7.8 Hz, 1H), 3.18 (t, *J* = 6.7 Hz, 2H), 2.47–2.41 (m, 2H), 1.92–1.87 (m, 2H), 1.83–1.78 (m, 2H), 1.11 (d, *J* = 6.8 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$): δ 168.37, 140.51, 138.04, 137.56, 135.74, 128.92, 128.57, 128.02, 127.90, 127.81, 127.13, 127.10, 125.59, 73.78, 73.51, 72.93, 47.39, 45.31, 40.64, 25.98, 24.66, 16.24; HRMS (ESI/[M+H]+) calcd. for $C_{26}H_{32}NO_3^+$: 406.2377. Found 406.2375.



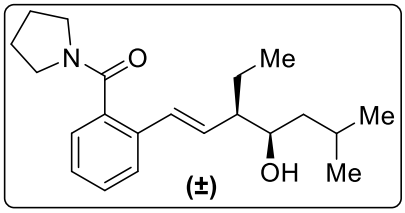
(±)-(2*Z*,4*E*,6*R*,7*S*)-8-(benzyloxy)-7-hydroxy-2,6-dimethyl-1-(pyrrolidin-1-yl)octa-2,4-dien-1-one (4ak): Slightly modified conditions: Derived from 2-methyl-1-(pyrrolidin-1-yl)prop-2-en-1-one[10] (27.8 mg, 0.200 mmol, 1.0 equiv), 1,3-butadiene (0.800 mmol, 4.0 equiv), and 2-(benzyloxy)acetaldehyde (90.1 mg, 0.600 mmol, 3.0 equiv). Acetic acid (2.4 mg, 0.040 mmol, 0.2 equiv) was added to the vial first before adding the other materials, and no dioxane was added (Concentration of C–H bond substrate is [1 M] with respect to the 1,3-butadiene solution). The product was then purified by silica gel chromatography eluting with ethyl acetate to afford the product **4ak** (27.3 mg, 40% yield) as a light yellow oil. IR (film): 3396 (br), 2971, 2874, 1599, 1451, 1431, 1101, 972, 733, 698 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.36–7.27 (m, 5H), 5.99–5.88 (m, 2H), 5.61 (dd, *J* = 14.8, 8.4 Hz, 1H), 4.51 (s, 2H), 3.63–3.59 (m, 1H), 3.53–3.51 (m, 3H), 3.36–3.33 (m, 1H), 3.29 (t, *J* = 6.3 Hz, 2H), 2.37–2.30 (m, 2H), 1.93 (s, 3H), 1.91–1.83 (m, 4H), 1.06 (d, *J* = 6.8 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$): δ 170.28, 138.05, 137.24, 133.78, 128.58, 127.95, 127.90, 127.80, 126.78, 73.80, 73.50, 72.96, 47.37, 45.18, 40.39, 26.09, 24.64, 20.20, 16.38; HRMS (ESI/[M+H]+) calcd. for $C_{21}H_{30}NO_3^+$: 344.2220. Found 344.2216.

General procedure for diene substrate scope.

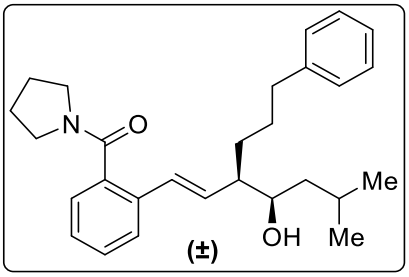
In a N_2-filled glove box, a 0.5–2.0 mL microwave vial was charged with $[Cp^*Co(C_6H_6)[B(C_6F_5)_4]_2$[1] (65.2 mg, 0.0400 mmol, 0.20 equiv), the indicated C–H bond partner (**1**) (0.200 mmol, 1.0 equiv) and corresponding aldehyde (**3**) (0.600 mmol, 3.0 equiv). Following this, 67 µL of a [0.6 M] stock solution of acetic acid in 1,4-dioxane, prepared from 180 mg (3.00 mmol) of acetic acid diluted to 5.0 mL with 1,4-dioxane, was added to the solid mixture, followed by 133 µL of 1,4-dioxane (20 mol % total acetic acid in reaction, 0.2 mL of total dioxane volume). Finally, diene (**2**) was added (0.400 mmol, 2.0 equiv). The reaction vial was then equipped with a magnetic stir bar, sealed with a microwave cap, and taken outside the glove box. The reaction mixture was stirred at 50 °C in a preset oil bath for 20 h. The reaction vial was allowed to cool to room temperature. The reaction mixture was filtered through a small celite plug, (1 cm long in a pipette), and washed with ethyl acetate. The resulting mixture was then concentrated and purified by the corresponding chromatographic method to afford the desired product.



(±)-(2-((3*R*,4*R*,*E*)-3-Ethyl-4-hydroxy-6-methylhept-1-en-1-yl)phenyl)(pyrrolidin-1-yl)-methanone (4al): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), (*E*)-1,3-pentadiene (27.2 mg, 0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 40:60 mixture of ethyl acetate: hexanes as the eluent to afford the product **4al** (53.3 mg, 81% yield) as a colorless oil. IR (film): 3381 (br), 2954, 2872, 1612, 1452, 1426, 1018, 969, 752 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.32–7.28 (m, 1H), 7.25–7.20 (m, 2H), 6.44 (d, *J* = 15.8 Hz, 1H), 5.96 (dd, *J* = 15.8, 9.4 Hz, 1H), 3.65–3.59 (m, 3H), 3.10 (t, *J* = 6.7 Hz, 2H), 2.13–2.06 (m, 1H), 1.95–1.88 (m, 2H), 1.84–1.75 (m, 4H), 1.69–1.59 (m, 1H), 1.36–1.19 (m, 3H), 0.90–0.84 (m, 9H); ^{13}C NMR (101 MHz, $CDCl_3$): δ 169.78, 136.49, 134.16, 133.94, 129.19, 129.00, 127.33, 126.18, 126.09, 72.47, 52.54, 48.32, 45.60, 43.54, 26.01, 24.72, 24.65, 24.02, 23.26, 21.62, 12.20; HRMS (ESI/$[M+H]^+$) calcd. for $C_{21}H_{32}NO_2^+$: 330.2428. Found 330.2436.

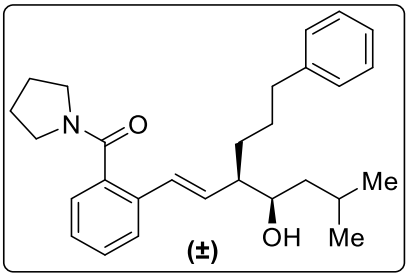


(±)-(2-((3*R*,4*R*,*E*)-3-Ethyl-4-hydroxy-6-methylhept-1-en-1-yl)phenyl)(pyrrolidin-1-yl)-methanone (4al): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), (*Z*)-1,3-pentadiene (27.2 mg, 0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4al** (46.7 mg, 71% yield) as a colorless oil. IR (film): 3381 (br), 2954, 2872, 1612, 1452, 1427, 969, 909, 728 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.32–7.29 (m, 1H), 7.25–7.20 (m, 2H), 6.45 (d, *J* = 15.8 Hz, 1H), 5.97 (dd, *J* = 15.8, 9.3 Hz, 1H), 3.65–3.60 (m, 3H), 3.10 (t, *J* = 6.8 Hz, 2H), 2.13–2.07 (m, 1H), 1.94–1.89 (m, 2H), 1.84–1.77 (m, 3H), 1.68–1.61 (m, 2H), 1.36–1.23 (m, 3H), 0.88 (m, 9H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.77, 136.52, 134.15, 133.97, 129.26, 129.01, 127.36, 126.21, 126.11, 72.51, 52.55, 48.34, 45.62, 43.55, 26.03, 24.73, 24.68, 24.03, 23.29, 21.64, 12.21; HRMS (ESI/$[M+H]^+$) calcd. for $C_{21}H_{32}NO_2^+$: 330.2428. Found 330.2433.

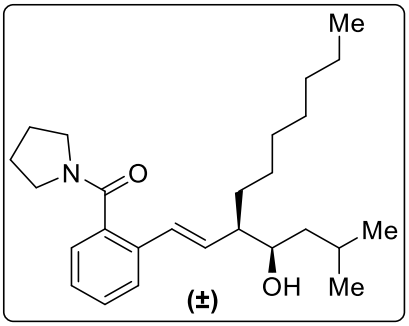


(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-6-methyl-3-(3-phenylpropyl)hept-1-en-1-yl)phenyl)-(pyrrolidin-1-yl)methanone (4am): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), (*E*)-hexa-3,5-dien-1-ylbenzene[11] (63.2 mg, 0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4am** (65.4 mg, 78% yield) as a colorless oil. IR (film): 3406 (br), 2951, 1612, 1452, 1427, 969, 909, 730 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.32–7.29 (m, 1H), 7.26–7.20 (m, 4H), 7.15 (m, 3H), 6.45 (d, *J* = 15.8 Hz, 1H), 5.99 (dd, *J* = 15.8, 9.5 Hz, 1H), 3.60

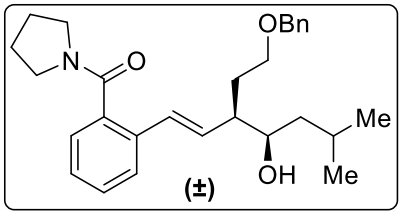
(m, 3H), 3.09–3.01 (m, 2H), 2.67–2.61 (m, 1H), 2.59–2.53 (m, 1H), 2.23 (m, 1H), 1.87–1.62 (m, 8H), 1.56–1.50 (m, 1H), 1.43–1.37 (m, 1H), 1.33–1.21 (m, 2H), 0.90 (d, 6.6 Hz, 3H), 0.88 (d, 6.6 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.71, 142.47, 136.51, 134.23, 133.86, 129.14, 129.01, 128.41, 128.35, 127.38, 126.21, 126.10, 125.77, 72.67, 50.71, 48.33, 45.58, 43.55, 36.13, 30.02, 29.70, 25.90, 24.68, 24.66, 24.00, 21.65; HRMS (ESI/$[M+H]^+$) calcd. for $C_{28}H_{38}NO_2^+$: 420.2897. Found 420.2893.



(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-6-methyl-3-(3-phenylpropyl)hept-1-en-1-yl)phenyl)-(pyrrolidin-1-yl)methanone (4am): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), (*E*:*Z* = 1:1) hexa-3,5-dien-1-ylbenzene[12] (63.2 mg, 0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4am** (63.7 mg, 76% yield) as a colorless oil. IR (film): 3406 (br), 2950, 1612, 1452, 1427, 969, 909, 729 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.33–7.29 (m, 1H), 7.25–7.20 (m, 4H), 7.17–7.13 (m, 3H), 6.45 (d, *J* = 15.8 Hz, 1H), 5.99 (dd, *J* = 15.8, 9.4 Hz, 1H), 3.60 (m, 3H), 3.09–3.02 (m, 2H), 2.67–2.53 (m, 2H), 2.26–2.20 (m, 1H), 1.87–1.62 (m, 8H), 1.57–1.49 (m, 1H), 1.43–1.37 (m, 1H), 1.33–1.20 (m, 2H), 0.90 (d, *J* = 6.6 Hz, 3H), 0.88 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.72, 142.47, 136.52, 134.22, 133.87, 129.18, 129.02, 128.42, 128.37, 127.40, 126.22, 126.12, 125.79, 72.70, 50.72, 48.34, 45.59, 43.55, 36.14, 30.03, 29.71, 25.92, 24.69, 24.67, 24.00, 21.65; HRMS (ESI/$[M+H]^+$) calcd. for $C_{28}H_{38}NO_2^+$: 420.2897. Found 420.2897.

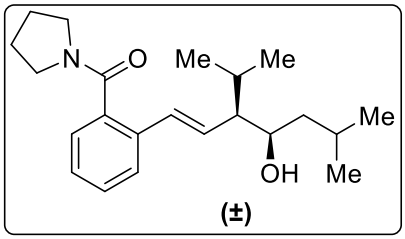


(±)-(2-((*R*,*E*)-3-((*R*)-1-Hydroxy-3-methylbutyl)dec-1-en-1-yl)phenyl)(pyrrolidin-1-yl)-methanone (4an): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), (*E*)-deca-1,3-diene[13] (55.3 mg, 0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4an** (66.3 mg, 83% yield) as a colorless oil. IR (film): 3419 (br), 2952, 2923, 2855, 1614, 1453, 1426, 969, 753 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.48 (d, *J* = 7.8 Hz, 1H), 7.31–7.28 (m, 1H), 7.24–7.20 (m, 2H), 6.43 (d, *J* = 15.8 Hz, 1H), 5.98 (dd, *J* = 15.8, 9.4 Hz, 1H), 3.66–3.58 (m, 3H), 3.10 (t, *J* = 6.8 Hz, 2H), 2.21–2.15 (m, 1H), 1.94–1.89 (m, 2H), 1.84–1.76 (m, 3H), 1.72 (s, 1H), 1.58–1.53 (m, 1H), 1.32–1.23 (m, 13H), 0.90–0.83 (m, 9H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.76, 136.49, 134.53, 133.94, 129.00, 128.97, 127.33, 126.21, 126.08, 72.75, 50.71, 48.32, 45.60, 43.45, 31.98, 30.36, 29.84, 29.37, 27.77, 26.03, 24.72, 24.68, 24.02, 22.75, 21.65, 14.18; HRMS (ESI/$[M+H]^+$) calcd. for $C_{26}H_{42}NO_2^+$: 400.3210. Found 400.3221.



(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-6-methyl-3-(3-phenylpropyl)hept-1-en-1-yl)phenyl)-(pyrrolidin-1-yl)methanone (4ao): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), (*E*)-((penta-2,4-dien-1-yloxy)methyl)benzene[14,15] (69.6 mg, 0.400 mmol, 2.0 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4ao** (69.3 mg, 80% yield) as a colorless oil. IR (film): 3385 (br), 2951, 2872, 1612, 1452, 1423, 1100, 969, 735 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.45 (d, *J* = 7.8 Hz, 1H),

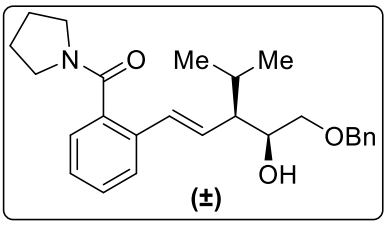
7.32–7.27 (m, 5H), 7.26–7.21 (m, 3H), 6.45 (d, *J* = 15.8 Hz, 1H), 6.05 (dd, *J* = 15.8, 9.3 Hz, 1H), 4.49 (s, 2H), 3.62 (m, 3H), 3.57–3.53 (m, 1H), 3.49–3.45 (m, 1H), 3.12–3.05 (m, 2H), 2.42–2.37 (m, 1H), 2.20 (s, 1H), 1.95–1.87 (m, 3H), 1.83–1.70 (m, 4H), 1.36–1.30 (m, 1H), 1.27–1.22 (m, 1H), 0.90 (d, *J* = 6.6 Hz, 3H), 0.88 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$): δ 169.67, 138.33, 136.55, 133.91, 133.84, 129.02, 128.96, 128.48, 127.77, 127.70, 127.43, 126.28, 126.14, 73.15, 72.35, 68.39, 48.37, 47.80, 45.60, 43.88, 30.89, 26.06, 24.70, 23.99, 21.69; HRMS (ESI/$[M+H]^+$) calcd. for $C_{28}H_{38}NO_3^+$: 436.2846. Found 436.2865.



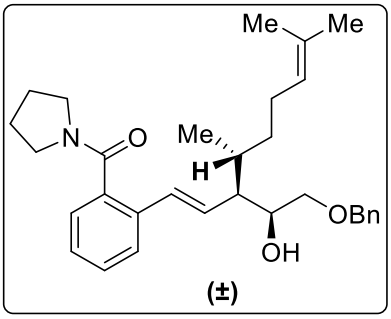
(±)

(±)-(2-((3*R*,4*R*,*E*)-4-Hydroxy-3-isopropyl-6-methylhept-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4ap): Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 4-methyl-1,3-pentadiene (60.1 mg, ~0.467 mmol based upon the ~64% purity of the commercial diene as determined by NMR, ~2.34 equiv), and 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0 equiv). The product was then purified by C18 reverse phase column chromatography with loading of the crude material onto the column as a solution in a minimal amount of MeCN. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product as a mixture of diastereomers (40.0 mg, 58% combined yield, 92:8 dr). The major diastereomer was purified by silica gel chromatography eluting with a 50:50 ethyl acetate:hexanes mixture to obtain the major diastereomer of product **4ap** (35.6 mg, 52% yield) as a colorless oil. IR (film): 3385 (br), 2953, 2871, 1614, 1453, 1427, 972, 909, 753, 728 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.7 Hz, 1H), 7.33–7.30 (m, 1H), 7.26–7.22 (m, 2H), 6.44 (d, *J* = 15.8 Hz, 1H), 5.92 (dd, *J* = 15.7, 9.8 Hz, 1H), 3.79–3.76 (m, 1H), 3.65 (t, *J* = 7.0 Hz, 2H), 3.11 (t, *J* = 6.8 Hz, 2H), 2.03–1.98 (m, 1H), 1.97–1.90 (m, 3H), 1.85–1.81 (m, 3H), 1.47 (d, *J* = 7.6 Hz, 1H), 1.28–1.18 (m, 2H), 0.91–0.88 (m, 12H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.72,

136.61, 134.00, 131.89, 130.64, 129.04, 127.45, 126.24, 126.19, 69.96, 57.55, 48.40, 45.63, 43.64, 28.17, 26.04, 24.75, 24.64, 24.25, 21.49, 21.28, 19.51; HRMS (ESI/$[M+H]^+$) calcd. for $C_{22}H_{34}NO_2^+$: 344.2584. Found 344.2580.



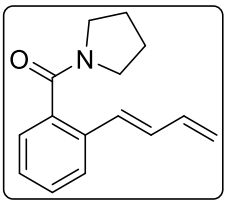
(±)-(2-((3*R*,4*S*,*E*)-5-(Benzyloxy)-4-hydroxy-3-isopropylpent-1-en-1-yl)phenyl)(pyrrolidin-1-yl)methanone (4aq): Slightly modified conditions: Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), 4-methyl-1,3-pentadiene (60.1 mg, ~0.467 mmol based upon the ~64% purity of the commercial diene as determined by NMR, ~2.34 equiv), and 2-(benzyloxy)acetaldehyde (90.1 mg, 0.600 mmol, 3.0 equiv). The concentration of the reaction was 0.1 M with respect to the C–H bond substrate. The product was purified by C18 reverse phase column chromatography with loading of the crude material onto the column as a solution in a minimal amount of MeCN. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing product were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4aq** (54.0 mg, 66% yield) as a colorless oil. IR (film): 3410 (br), 2956, 2871, 1613, 1452, 1423, 1089, 973, 909, 730 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 7.2 Hz, 1H), 7.34–7.27 (m, 6H), 7.25–7.21 (m, 2H), 6.42 (d, *J* = 15.7 Hz, 1H), 5.93 (dd, *J* = 15.7, 10.0 Hz, 1H), 4.54–4.47 (m, 2H), 3.89–3.85 (m, 1H), 3.63 (t, *J* = 6.9 Hz, 2H), 3.58 (dd, *J* = 9.6, 2.8 Hz, 1H), 3.35 (dd, *J* = 9.6, 7.5 Hz, 1H), 3.07 (t, *J* = 6.8 Hz, 2H), 2.51 (s, 1H), 2.26 – 2.13 (m, 2H), 1.93–1.86 (m, 2H), 1.83–1.76 (m, 2H), 0.90 (d, *J* = 6.4 Hz, 3H), 0.88 (d, *J* = 6.4 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.62, 138.01, 136.64, 133.67, 130.27, 130.01, 128.97, 128.53, 127.84, 127.81, 127.49, 126.18, 126.07, 73.73, 73.50, 70.38, 52.85, 48.31, 45.58, 27.22, 25.97, 24.72, 21.55, 17.16; HRMS (ESI/$[M+H]^+$) calcd. for $C_{26}H_{34}NO_3^+$: 408.2533. Found 408.2536.



(±)-(2-((3*R*,4*R*,*E*)-3-((*S*)-2-(Benzyloxy)-1-hydroxyethyl)-4,8-dimethylnona-1,7-dien-1-yl)-phenyl)(pyrrolidin-1-yl)methanone (4ar): Slightly modified conditions: Derived from phenyl(pyrrolidin-1-yl)methanone[6] (**1a**) (35.0 mg, 0.200 mmol, 1.0 equiv), (*E*)-4,8-dimethylnona-1,3,7-triene[16] (60.1 mg, 0.4 mmol, 2.0 equiv), and 2-(benzyloxy)acetaldehyde (90.1 mg, 0.600 mmol, 3.0 equiv). The concentration of the reaction was 0.1 M with respect to the C–H bond substrate. The product was purified by silica gel chromatography using a 60:40 mixture of ethyl acetate: hexanes as the eluent to afford the product **4ar** (54.9 mg, 58% yield) as a colorless oil. IR (film): 3401 (br), 2964, 2915, 2875, 1614, 1452, 1424, 1102, 909, 731 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 (d, *J* = 7.8 Hz, 1H), 7.34–7.29 (m, 5H), 7.27–7.21 (m, 3H), 6.42 (d, *J* = 15.7 Hz, 1H), 5.96 (dd, *J* = 15.8, 10.1 Hz, 1H), 5.06 (t, *J* = 7.3 Hz, 1H), 4.52 (d, *J* = 11.7 Hz, 1H), 4.49 (d, *J* = 11.7 Hz, 1H), 3.89–3.86 (m, 1H), 3.63 (t, *J* = 7.0 Hz, 2H), 3.58 (dd, *J* = 9.5, 2.7 Hz, 1H), 3.35 (dd, *J* = 9.5, 7.5 Hz, 1H), 3.06 (t, *J* = 6.8 Hz, 2H), 2.46 (d, *J* = 4.0 Hz, 1H), 2.30–2.26 (m, 1H), 2.13–2.08 (m, 1H), 2.04–1.95 (m, 2H), 1.93–1.87 (m, 2H), 1.82–1.77 (m, 2H), 1.65 (s, 3H), 1.58 (s, 3H), 1.28–1.22 (m, 1H), 1.16–1.11 (m, 1H), 0.92 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.60, 138.00, 136.67, 133.58, 131.32, 130.07, 129.94, 128.96, 128.53, 127.84, 127.53, 126.19, 126.04, 124.71, 73.90, 73.50, 70.08, 51.11, 48.29, 45.56, 36.13, 31.83, 25.97, 25.91, 25.82, 24.68, 17.77, 14.31; HRMS (ESI/$[M+H]^+$) calcd. for $C_{31}H_{42}NO_3^+$: 476.3159. Found 476.3153.

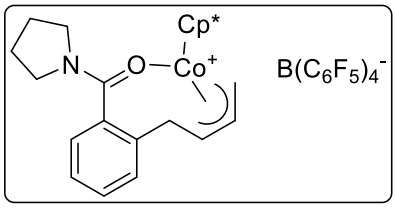
5. Mechanism Experiments:

Preparation of (*E*)-(2-(buta-1,3-dien-1-yl)phenyl)(pyrrolidin-1-yl)methanone (5):



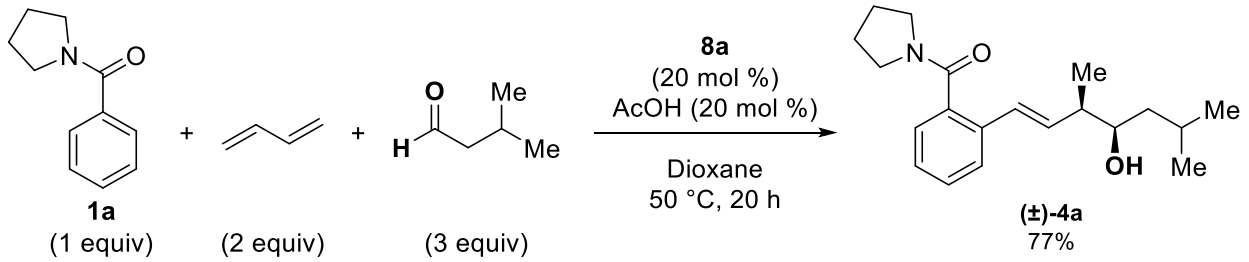
In a N_2-filled glove box, a 0.5–2.0 mL microwave vial was charged with $[Cp^*Co(C_6H_6)[B(C_6F_5)_4]_2$[1] (163.0 mg, 0.1000 mmol, 0.20 equiv), and phenyl(pyrrolidin-1-yl)methanone[6] (87.6 mg, 0.500 mmol, 1.0 equiv). Following this, a 0.6 M stock solution of acetic acid in 1,4-dioxane was prepared from 180 mg (3.00 mmol) of acetic acid diluted to 5.0 mL with 1,4-dioxane. 167 µL of this solution was added to the solid mixture, followed by 833 µL of 1,4-dioxane (20 mol % total acetic acid in reaction, 1.0 mL of total dioxane volume). Finally, 250 µL of a freshly made [4 M] stock solution of 1,3-butadiene in THF was added (1.00 mmol, 2.0 equiv). The reaction vial was then equipped with a magnetic stir bar, sealed with a microwave cap and taken outside the glove box, and the reaction mixture was stirred at 50 °C in a preset oil bath for 20 h. The reaction vial was then uncapped, and the reaction mixture allowed to cool to room temperature. The reaction mixture was filtered through a small celite plug, (1 cm long in a pipette) and washed with ethyl acetate. The resulting mixture was then concentrated and a crude NMR was taken in $CDCl_3$ using a known amount of 1,3,5-trimethoxybenzene as an external standard. The NMR yield of the desired product **5** was 12% along with 85% recovery of the C–H bond substrate. The NMR sample was then concentrated and the resulting residue was purified by silica gel chromatography eluting with ethyl acetate to afford the product **5** (2.7 mg, 2%) as a colorless waxy solid. IR (film): 2974, 2876, 1621, 1449, 1419, 1339, 1005, 969, 754, 659 cm^{-1}; ^1H NMR (500 MHz, C_6D_6): δ 7.36 (d, *J* = 7.8 Hz, 1H), 7.19 (m, 1H), 7.04 (t, *J* = 7.5 Hz, 1H), 6.97 (t, *J* = 7.5 Hz, 1H), 6.93 (d, *J* = 15.7 Hz, 1H), 6.73 (dd, *J* = 15.5, 10.5 Hz, 1H), 6.31 (dt, *J* = 16.9, 10.2 Hz, 1H), 5.17 (d, *J* = 16.8 Hz, 1H), 4.98 (d, *J* = 10.0 Hz, 1H), 3.56 (t, *J* = 7.0 Hz, 2H), 2.69 (t, *J* = 6.6 Hz, 2H), 1.28–1.23 (m, 2H), 1.14–1.08 (m, 2H); $^{13}C\{^1H\}$ NMR (151 MHz, C_6D_6): δ 168.89, 138.72, 138.00, 134.38, 132.35, 130.65, 129.15, 128.05, 127.39, 126.13, 118.59, 48.32, 45.96, 26.36, 24.84; HRMS (ESI/[M+H]+) calcd. for $C_{15}H_{18}NO^+$: 228.1383. Found 228.1387.

Preparation of Co(III)-allyl species 8a:



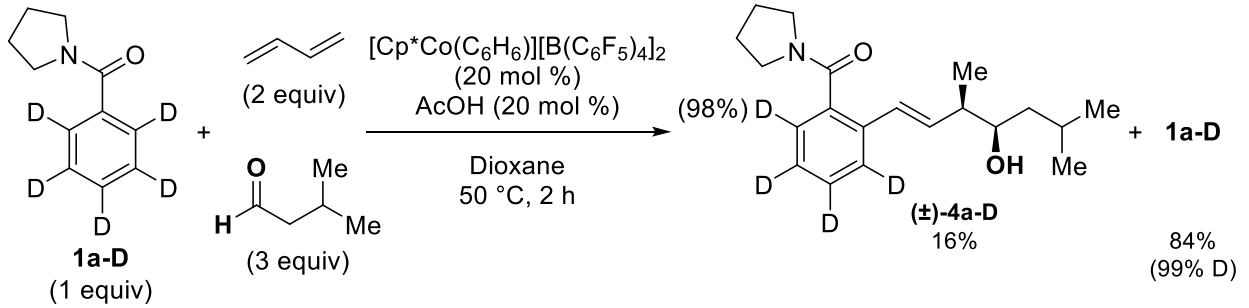
In a N_2-filled glove box, a 0.5–2.0 mL microwave vial was charged with $[Cp^*Co(C_6H_6)][B(C_6F_5)_4]_2$[1] (326.1 mg, 0.2000 mmol, 1.0 equiv), and phenyl(pyrrolidin-1-yl)methanone[6] (35.0 mg, 0.200 mmol, 1.0 equiv). The mixture was dissolved in 900 µL of 1,4-dioxane, followed by the addition of acetic acid (12.0 mg, 0.200 mmol, 1.0 equiv). Finally, 100 µL of a freshly made [4 M] stock solution of 1,3-butadiene in THF was added (0.400 mmol, 2.0 equiv). The reaction vial was then equipped with a magnetic stir bar, sealed with a microwave cap, and taken outside the glove box. The reaction mixture was then stirred at 50 °C in a preset oil bath for 20 h. The reaction vial was then uncapped, and the reaction mixture was allowed to cool to room temperature. The reaction mixture was filtered through a small celite plug, (1 cm long in a pipette), and washed with ethyl acetate. The resulting mixture was then concentrated and purified by silica gel chromatography eluting with a 3:1 mixture of dichloromethane/hexanes to afford the product **8a** (54.8 mg, 25%) as a dark orange solid (mp: 165–166 °C). IR (film): 1643, 1587, 1556, 1511, 1461, 1275, 1083, 978, 756, 661 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.60 (t, *J* = 7.4 Hz, 1H), 7.53 (d, *J* = 7.5 Hz, 1H), 7.43 (t, *J* = 7.4 Hz, 1H), 7.38 (d, *J* = 7.3 Hz, 1H), 5.08–5.03 (m, 1H), 4.79 (d, *J* = 8.0 Hz, 1H), 3.92–3.86 (m, 1H), 3.57–3.51 (m, 2H), 3.40–3.35 (m, 1H), 3.22–3.18 (m, 1H), 2.41 (dd, *J* = 13.8, 5.1 Hz, 1H), 2.18 (d, J = 14.1 Hz, 1H), 2.02–1.90 (m, 3H), 1.69–1.61 (m, 1H), 1.17 (s, 15H), 0.79–0.73 (m, 1H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$): δ 173.00, 149.44–149.16 (m), 147.46–147.23 (m), 138.48, 137.48–137.15 (m), 135.59–135.25 (m), 132.65, 130.72, 130.43, 128.34, 126.93, 96.40, 95.35, 78.32, 68.60, 51.85, 47.62, 33.50, 26.13, 24.07, 8.87; HRMS (ESI/[M+H]+) calcd. for $C_{25}H_{33}NOCo^+$: 422.1889. Found 422.1888.

Evaluating Co(III)-allyl species 8a as a catalyst for the three-component transformation:



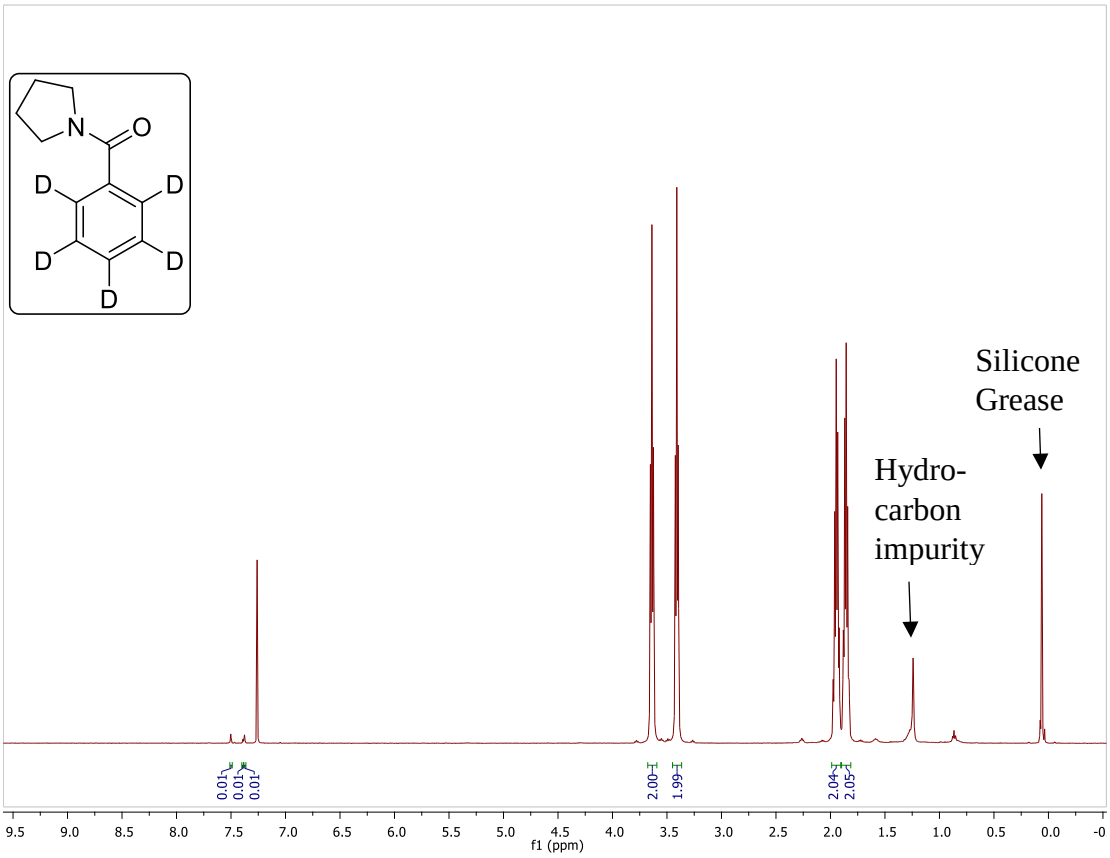
In a N_2-filled glove box, a 0.5–2.0 mL microwave vial was charged with **8a** (11.0 mg, 0.00999 mmol, 0.20 equiv), and phenyl(pyrrolidin-1-yl)methanone[6] (8.8 mg, 0.0502 mmol, 1.0 equiv). Following this, 17 µL of a 0.6 M stock solution of acetic acid in 1,4-dioxane was added to the solid mixture, followed by 83 µL of 1,4-dioxane. Then, 3-methylbutanal (12.9. mg, 0.150 mmol, 3.0 equiv) was added to the reaction mixture. Finally, 25 µL of a [4 M] stock solution of 1,3-butadiene in THF was added (0.100 mmol, 2.0 equiv). The reaction vial was then equipped with a magnetic stir bar, sealed with a microwave cap, and taken outside the glove box. The reaction mixture was then stirred at 50 °C in a preset oil bath for 20 h. The reaction mixture was then allowed to cool to room temperature. The reaction mixture was extracted with sat. $NaHCO_3$ and ethyl acetate, and the ethyl acetate layer was removed. The aqueous layer was washed 3 times with ethyl acetate and the combined organic layers were concentrated. A known amount of 1,3,5-trimethoxybenzene external standard was added to the concentrated mixture and analyzed by ^1H NMR using $CDCl_3$ as solvent to obtain an NMR yield of 77% for three-component product **4a**.

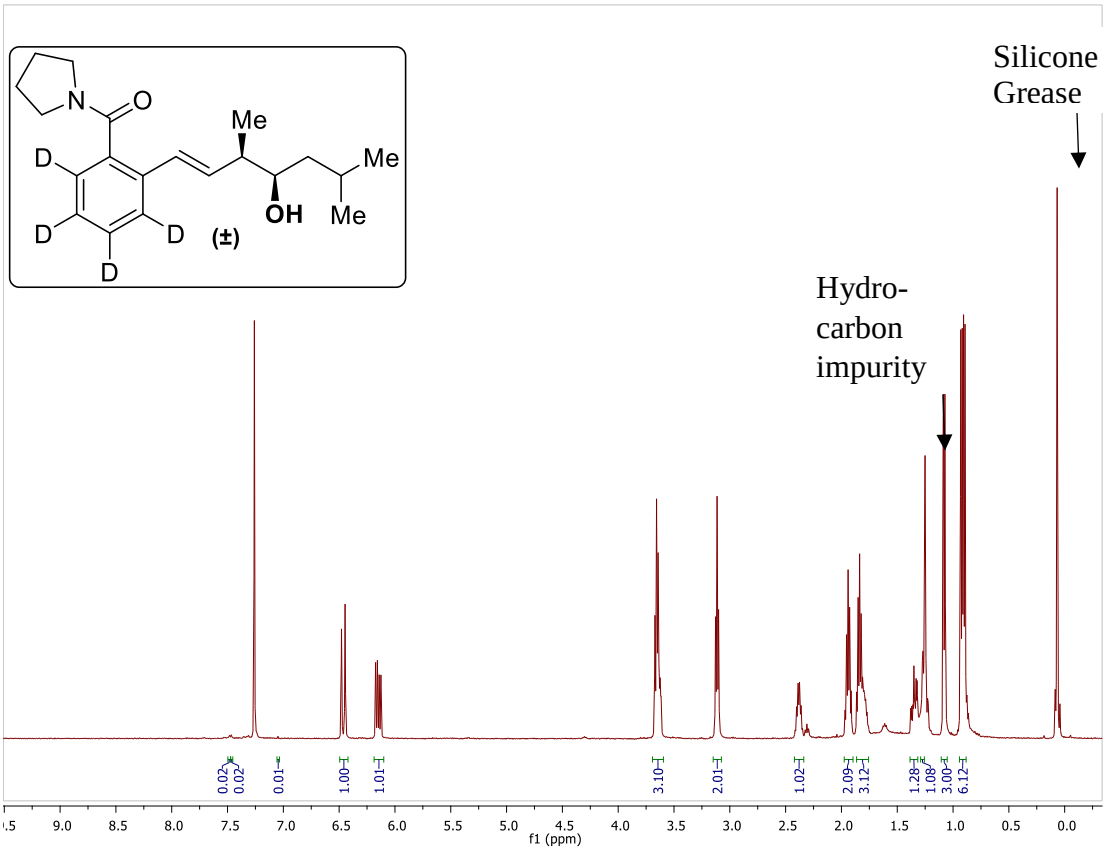
H/D Scrambling Experiment:



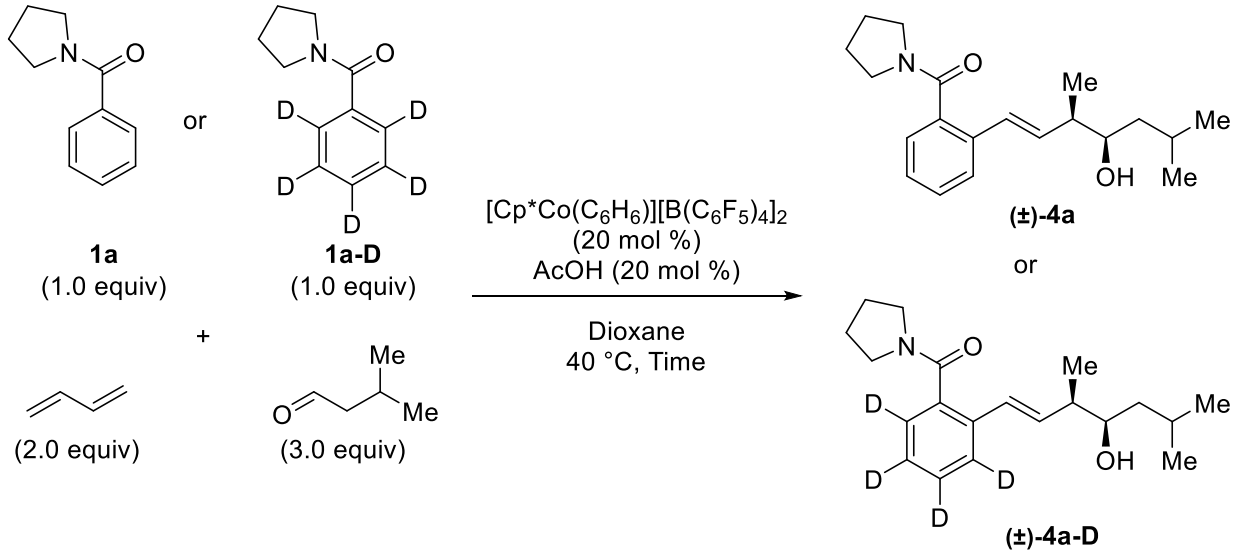
In a N_2-filled glove box, a 0.5–2.0 mL microwave vial containing a stir bar was charged with $[Cp^*Co(C_6H_6)][B(C_6F_5)_4]_2$[1] (65.2 mg, 0.0400 mmol, 0.20 equiv), and **1a-D** (36.1 mg, 0.200 mmol, 1.0 equiv). Following this, 67 µL of a 0.6 M stock solution of acetic acid in 1,4-dioxane was added to the vial, followed by 333 µL of 1,4-dioxane. Then, 3-methylbutanal (51.7 mg, 0.600 mmol, 3.0

equiv) was added to the reaction mixture. Finally, 100 µL of a [4 M] stock solution of 1,3-butadiene in THF was added to the reaction mixture (0.400 mmol, 2.0 equiv), and the vial was immediately capped once the butadiene was added. The reaction vial was then taken outside the glove box and stirred at 50 °C in a preset oil bath for 2 h. The reaction vial was allowed to cool to room temperature. The reaction mixture was extracted with sat. $NaHCO_3$ and ethyl acetate, and the ethyl acetate layer was removed. The aqueous layer was washed 3 times with ethyl acetate and the combined organic layers were concentrated. A known amount of 1,3,5-trimethoxybenzene external standard was added to the concentrated mixture and was analyzed by ^1H NMR using $CDCl_3$ as solvent to determine 16% of **4a-D** was formed along with 84% of **1a-D** recovered. The reaction mixture was then purified by C18 reverse phase column chromatography with loading of the isolated material onto the column as a solution in a minimal amount of DMSO. Reverse phase purification was performed with 15.5 g of reverse phase media and a 100 column volume gradient from 10 to 90% CH_3CN:H_2O containing 0.1% TFA. Fractions containing **4a-D** were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to afford the product **4a-D** (9.9 mg, 15% yield) as a colorless oil. Additionally, fractions containing **1a-D** were combined and diluted with sat. aq. $NaHCO_3$ (100 mL) and extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layers were then dried over Na_2SO_4 and concentrated to recover the starting material **1a-D** (29.9 mg, 83% yield) as a colorless oil. The ^1H NMR in $CDCl_3$ for each compound was taken to ascertain the amount of deuterium scrambling. The spectra are shown below.


N
O
D
D
D
D
D
Silicone
Grease
Hydro-
carbon
impurity
0.01
0.01
0.01
2.00
1.99
2.04
2.05
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)

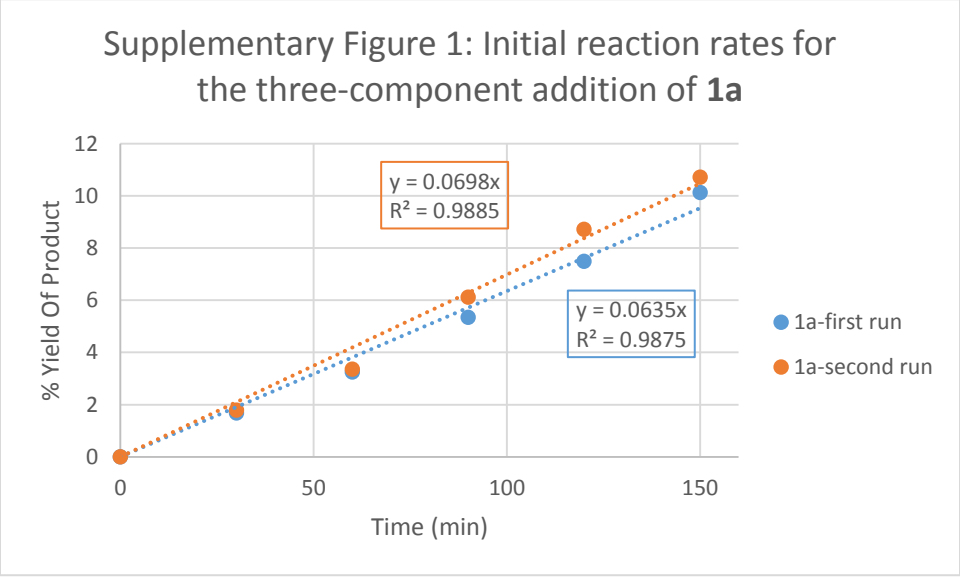

N
O
Me
D
Me
OH
Me
D
D
(±)
D
Silicone
Grease
Hydro-
carbon
impurity
0.02
0.02
0.01
1.00
1.01
3.10
2.01
1.02
2.09
3.12
1.28
1.08
3.00
6.12
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

Initial rate measurements and KIE determination:

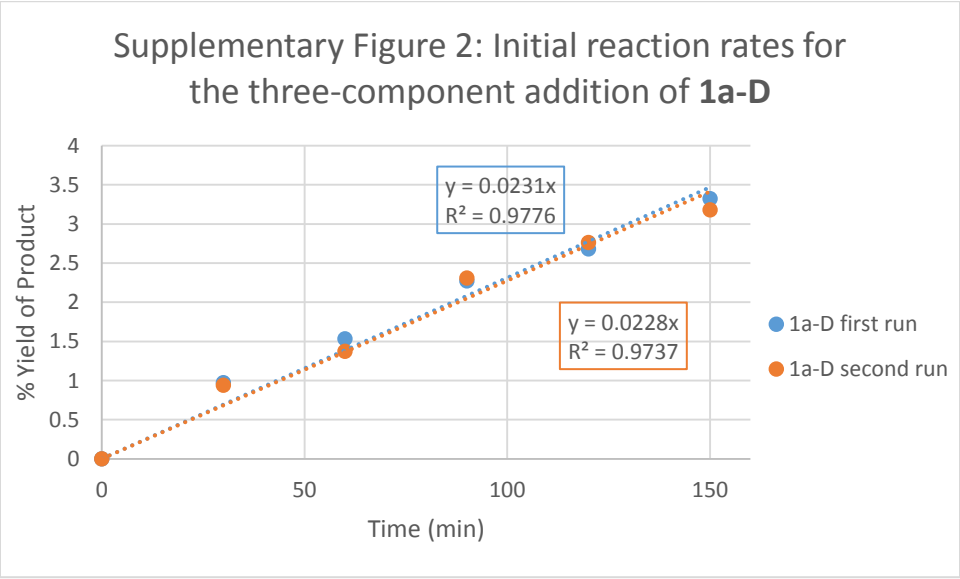


In a N_2-filled glove box, five 0.5–2.0 mL microwave vials containing stir bars were charged with $[Cp^*Co(C_6H_6)][B(C_6F_5)_4]_2$[1] (32.6 mg, 0.0200 mmol, 0.20 equiv), and either **1a** (17.6 mg, 0.100 mmol, 1.0 equiv) or **1a-D** (18.1 mg, 0.100 mmol, 1.0 equiv). Following this, 33 µL of a 0.6 M stock solution of acetic acid in 1,4-dioxane was added to each vial, followed by 167 µL of 1,4-dioxane to each vial. Then, 3-methylbutanal (25.8 mg, 0.300 mmol, 3.0 equiv) was added to each vial. Finally, 50 µL of a [4 M] stock solution of 1,3-butadiene in THF was added to each vial (0.200 mmol, 2.0 equiv), with each vial being immediately capped once the butadiene was added. The reaction vials were then taken outside the glove box and stirred at 40 °C in a preset oil bath for set times (0.5, 1.0, 1.5, 2.0, and 2.5 h). At the designated time each reaction mixture was extracted with sat. $NaHCO_3$ and ethyl acetate, and the ethyl acetate layer was removed. The aqueous layer was washed 3 times with ethyl acetate and the combined organic layers were concentrated. A known amount of 1,3,5-trimethoxybenzene external standard was added to each of the concentrated mixtures and each mixture was analyzed by ^1H NMR using $CDCl_3$ as solvent to obtain NMR yields of the three-component products **4a** and **4a-D**.

Initial rates for **1a** (First Run)		
Time (min)	Yield of Product **4a** (%)	
0	0	
30	1.68	
60	3.25	
90	5.34	
120	7.49	
150	10.1	
Initial rates for **1a** (Second Run)		
Time (min)	Yield of Product **4a** (%)	
0	0	
30	1.78	
60	3.36	
90	6.11	
120	8.71	
150	10.7	
Average of both runs		
Time (min)	Yield of Product **4a** (%)	Standard Deviation (%)
0	0	0
30	1.73	0.0707
60	3.31	0.0778
90	5.73	0.544
120	8.10	0.863
150	10.4	0.410

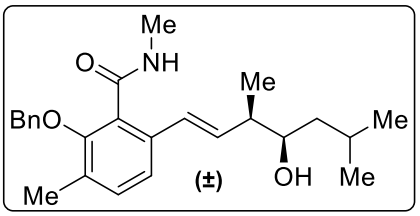


Initial rates for **1a-D** (First Run)		
Time (min)	Yield of Product **4a-D** (%)	
0	0	
30	0.970	
60	1.53	
90	2.27	
120	2.68	
150	3.32	
Initial rates for **1a-D** (Second Run)		
Time (min)	Yield of Product **4a-D** (%)	
0	0	
30	0.940	
60	1.37	
90	2.31	
120	2.76	
150	3.18	
Average of both runs		
Time (min)	Yield of Product **4a-D** (%)	Standard Deviation (%)
0	0	0
30	0.955	0.0212
60	1.45	0.113
90	2.29	0.0283
120	2.72	0.0566
150	3.25	0.099



Initial rates for **1a**	
Slope First Run	0.0635
Slope Second Run	0.0698
Average Slope	0.0667
Standard Deviation	0.00445
Initial Rates for **1a-D**	
Slope First Run	0.0231
Slope Second Run	0.0228
Average Slope	0.0230
Standard Deviation	0.000210
KIE	2.90
Standard Deviation	0.196

6. Synthesis of Lasalocid A Derivative 15:



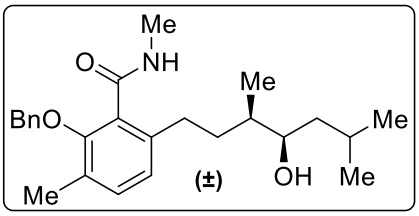
(±)-2-(Benzyloxy)-6-((3*R*,4*R*,*E*)-4-Hydroxy-3,6-dimethylhept-1-en-1-yl)-*N*,3-dimethyl-benzamide (13): In a N_2-filled glove box, a 0.5–2.0 mL microwave vial containing a stir bar was charged with $[Cp^*Co(C_6H_6)[B(C_6F_5)_4]_2$[1] (130.4 mg, 0.07998 mmol, 0.20 equiv), and **12** (102.1 mg, 0.3999 mmol, 1.0 equiv). Following this, 134 µL of a 0.6 M stock solution of acetic acid in 1,4-dioxane was added to the vial, followed by 466 µL of 1,4-dioxane. Then, 3-methylbutanal (103.4 mg, 1.200 mmol, 3.0 equiv) was added to the reaction mixture. Finally, 400 µL of a commercial [2 M] solution of 1,3-butadiene in THF was added to the reaction mixture (0.800 mmol, 2.0 equiv), and the vial was immediately capped once the butadiene was added. The reaction vial was then taken outside the glove box and stirred at 50 °C in a preset oil bath for 20 h. The reaction vial was allowed to cool to room temperature. The mixture was then concentrated, redissolved in a minimal amount of ethyl acetate, and purified by silica gel chromatography using a 20:80 mixture of ethyl acetate/dichloromethane as the eluent to afford the product **13** (110.4 mg, 70%) as an off-white solid (mp: 44–46 °C). IR (film): 3341 (br), 2953, 1639, 1408, 1253, 1058, 1014, 981, 734, 698 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.43 (d, *J* = 7.1 Hz, 2H), 7.38 (t, *J* = 7.3 Hz, 2H), 7.34 (t, *J* = 7.2 Hz, 1H), 7.20 (d, *J* = 8.0 Hz, 1H), 7.12 (d, *J* = 8.0 Hz, 1H), 6.49 (d, *J* = 15.9 Hz, 1H), 6.09 (dd, *J* = 15.9, 8.1 Hz, 1H), 6.02–5.99 (m, 1H), 4.84 (s, 2H), 3.63–3.62 (m, 1H), 2.86 (d, *J* = 4.9 Hz, 3H), 2.42–2.37 (m, 1H), 2.25 (s, 3H), 1.83–1.76 (m, 2H), 1.38–1.33 (m, 1H), 1.27–1.22 (m, 1H), 1.08 (d, *J* = 6.9 Hz, 3H), 0.92 (d, *J* = 6.7 Hz, 3H), 0.90 (d, *J* = 6.6 Hz, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 168.59, 153.69, 137.12, 135.25, 135.18, 131.98, 130.41, 130.36, 128.66, 128.53, 128.40, 127.43, 121.91, 76.55, 73.13, 43.59, 43.29, 26.64, 24.79, 23.92, 21.85, 16.23, 14.85; HRMS (ESI/[M+H]+) calcd. for $C_{25}H_{34}NO_3^+$: 396.2533. Found 396.2540.

For isolation at 20 mol % catalyst loading on the benchtop:

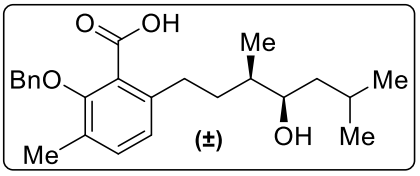
On the benchtop, a 0.5–2.0 mL microwave vial containing a stir bar was charged with $[Cp^*Co(C_6H_6)[B(C_6F_5)_4]_2$[1] (130.4 mg, 0.07998 mmol, 0.20 equiv), and **12** (102.1 mg, 0.3999 mmol, 1.0 equiv). The vial was then equipped with a magnetic stir bar, sealed with a microwave

cap and purged with N_2. Following this, 134 µL of a 0.6 M stock solution of acetic acid in 1,4-dioxane was added to the vial, followed by 466 µL of 1,4-dioxane. Then, 3-methylbutanal (103.4 mg, 1.200 mmol, 3.0 equiv) was added to the reaction mixture. Finally, 400 µL of a commercial [2 M] solution of 1,3-butadiene in THF was added. The reaction mixture was then stirred at 50 °C in a preset oil bath for 20 h. The reaction mixture was then allowed to cool to room temperature. The reaction mixture was filtered through a small celite plug, (1 cm long in a pipette), and washed with ethyl acetate. The resulting mixture was then concentrated and purified by silica gel chromatography using a 20:80 mixture of ethyl acetate/dichloromethane as the eluent to afford the product **13** (107.1 mg, 68% yield) as a colorless oil. The spectroscopic data matches that of the above conditions.

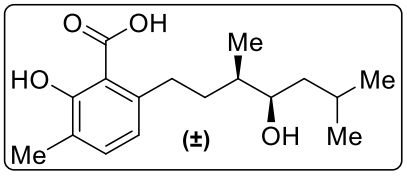
For isolation at 5 mol % catalyst loading on benchtop, slightly different conditions were used:
On the benchtop, a 0.5–2.0 mL microwave vial was charged with $[Cp^*Co(C_6H_6)[B(C_6F_5)_4]_2$[1] (32.6 mg, 0.0200 mmol, 0.05 equiv), pivalic acid (8.2 mg, 0.080 mmol, 0.20 equiv), and **12** (102.1 mg, 0.3999 mmol, 1.0 equiv). The vial was then equipped with a magnetic stir bar, sealed with a microwave cap and purged with N_2. Following this, 600 µL of 1,4-dioxane was added, followed by the addition of 3-methylbutanal (103.4 mg, 1.200 mmol, 3.0 equiv). Finally, 400 µL of a commercial [2 M] solution of 1,3-butadiene in THF was added (0.800 mmol, 2.0 equiv). The reaction vial was then stirred at 50 °C in a preset oil bath for 20 h. The reaction mixture was then allowed to cool to room temperature. The reaction mixture was filtered through a small celite plug, (1 cm long in a pipette), and washed with ethyl acetate. The resulting mixture was then concentrated and purified by silica gel chromatography using a 20:80 mixture of ethyl acetate/dichloromethane as the eluent to afford the product **13** (94.5 mg, 60% yield) as a colorless oil. The spectroscopic data matches that of the above conditions.



(±)-2-(Benzyloxy)-6-((3*R*,4*R*)-4-hydroxy-3,6-dimethylheptyl)-*N*,3-dimethylbenzamide (14): In N_2-filled glovebox, a 10-mL round bottom flask was charged with **13** (158.2 mg, 0.4000 mmol, 1.0 equiv) and 15.8 mg of 5% Pd/C(en)[5] (10% weight of the substrate). The flask was then equipped with a stir bar and 2.0 mL of distilled methanol. The flask was then sealed with a rubber septa and brought out of the glove box to stir at room temperature. The flask was then equipped with a hydrogen balloon and the flask was purged with H_2 using an outlet needle. This purging process was repeated, and after the second H_2-purge, the flask was equipped with a full hydrogen balloon to maintain a H_2-atmosphere. The reaction mixture was then stirred for 24 h before removing the hydrogen balloon and unsealing the flask to air. The reaction was filtered over a celite plug and washed with dichloromethane, with the filtrate being concentrated. The remaining residue was diluted in minimal amounts of dichloromethane and was purified by silica gel chromatography using a 40:60 mixture of ethyl acetate:hexanes as the eluent to afford the product **14** (116.9 mg, 74%) as an colorless waxy solid. IR (film): 3345 (br), 2952, 2872, 1638, 1540, 1455, 1257, 1008, 981, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.42 (d, *J* = 7.1 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 2H), 7.35–7.33 (m, 1H), 7.12 (d, *J* = 7.7 Hz, 1H), 6.93 (d, *J* = 7.7 Hz, 1H), 6.00–5.97 (m, 1H), 4.84 (s, 2H), 3.73–3.72 (m, 1H), 2.90 (d, *J* = 4.9 Hz, 3H), 2.76–2.71 (m, 1H), 2.63–2.57 (m, 1H), 2.27 (s, 3H), 1.96 (d, *J* = 4.5 Hz, 1H), 1.80–1.72 (m, 2H), 1.52–1.40 (m, 3H), 1.19–1.14 (m, 1H), 0.94–0.89 (m, 9H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$): δ 169.08, 153.87, 140.40, 137.23, 132.01, 130.91, 129.07, 128.68, 128.46, 128.38, 125.66, 76.56, 71.44, 43.48, 38.57, 35.83, 31.17, 26.70, 25.01, 23.76, 22.23, 16.15, 13.94; HRMS (ESI/[M+H]+) calcd. for $C_{25}H_{36}NO_3^+$: 398.2690. Found 398.2694.

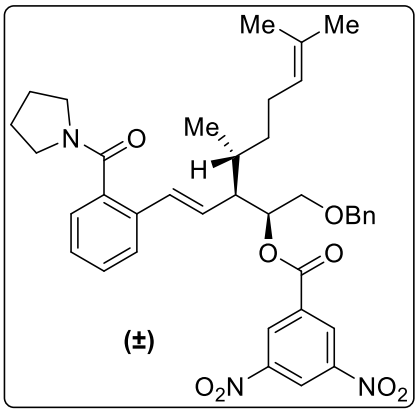


(±)-2-(Benzyloxy)-6-((3*R*,4*R*)-4-hydroxy-3,6-dimethylheptyl)-3-methylbenzoic acid: In a N_2-filled 10-mL round bottom flask, **14** (81.9 mg, 0.206 mmol, 1.0 equiv) was added followed by a stir bar. Following this, 1.0 mL of acetic anhydride and 0.2 mL of acetic acid were added to the flask, and the mixture was cooled to 0 °C with stirring. The mixture was stirred for 5 min at this temperature before adding sodium nitrite (313.0 mg, 4.537 mmol, 22.0 equiv) in 4 equal portions spaced 10 min apart. After all of the sodium nitrite was added, the reaction mixture was stirred at 0 °C for 5 h. The reaction mixture was then filtered over celite and washed with dichloromethane. After concentration, the mixture was extracted with ethyl acetate and 5% Na_2CO_3 soln. The organic layer was removed, and the aqueous layer was extracted three times with ethyl acetate. The combined organic layers were dried over sodium sulfate and concentrated. The crude mixture was then transferred to a 0.5–2.0 mL microwave vial using 1.2 mL of ethanol. The vial was then charged with KOH (115.6 mg, 2.060 mmol, 10.0 equiv) and equipped with a stir bar. The vial was then sealed with a microwave cap and the reaction mixture was stirred at 90 °C for 14 h. The reaction mixture was then extracted with ethyl acetate and 1 M HCl (pH of the aqueous layer should be 1-2). The organic layer was removed and the aqueous layer was extracted three more times with ethyl acetate. The combined organic layers were dried over sodium sulfate and concentrated. The remaining residue was diluted in minimal amounts of dichloromethane and was purified by silica gel chromatography using a 30:70:1 mixture of ethyl acetate:hexanes:acetic acid as the eluent to afford the product (67.7 mg, 85%) as a white solid (mp: 87–89 °C). IR (film): 3364 (br), 2951, 2867, 1696, 1454, 1369, 1251, 976, 746, 692 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 7.44 (d, *J* = 7.1 Hz, 2H), 7.35–7.28 (m, 3H), 7.18 (d, *J* = 7.7 Hz, 1H), 6.95 (d, *J* = 7.7 Hz, 1H), 6.78 (broad s, 1H), 4.94 (s, 2H), 3.74–3.72 (m, 1H), 2.77–2.66 (m, 2H), 2.28 (s, 3H), 1.81–1.70 (m, 2H), 1.55–1.44 (m, 2H), 1.42–1.37 (m, 1H), 1.19–1.14 (m, 1H), 0.89–0.86 (m, 9H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$): δ 171.56, 154.38, 140.16, 137.03, 132.96, 129.27, 128.58, 128.20, 127.49, 125.67, 76.35, 72.52, 43.07, 38.42, 35.32, 31.68, 24.86, 23.64, 22.17, 16.15, 13.87; HRMS (ESI/[M+H]+) calcd. for $C_{24}H_{31}O_3^+$: 367.2268. Found 367.2272.



(±)-2-Hydroxy-6-((3*R*,4*R*)-4-hydroxy-3,6-dimethylheptyl)-3-methylbenzoic acid (15): In a N_2-filled 10-mL round bottom flask, (±)-2-(Benzyloxy)-6-((3*R*,4*R*)-4-hydroxy-3,6-dimethylheptyl)-3-methylbenzoic acid (38.5 mg, 0.100 mmol, 1.0 equiv) was added followed by a stir bar. Following this, 20.0 mg of 10% Pd/C was added, along with 1.0 mL of ethyl acetate. The flask was then equipped with a hydrogen balloon, and the reaction mixture was stirred for 20 h at room temperature. After this time, the reaction mixture was then filtered over celite and washed with dichloromethane. The filtrate was concentrated to afford the product **15** (29.1 mg, 99%) as a colorless waxy solid. IR (film): 3379 (br), 2955, 2927, 2870, 1647, 1458, 1415, 1243, 1155, 1032 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.19 (d, *J* = 7.4 Hz, 1H), 6.65 (d, *J* = 7.4 Hz, 1H), 3.91–3.89 (m, 1H), 3.13–3.09 (m, 1H), 2.81–2.76 (m, 1H), 2.22 (s, 3H), 1.78–1.70 (m, 2H), 1.62–1.58 (m, 1H), 1.50–1.41 (m, 2H), 1.30–1.23 (m, 2H), 0.93–0.91 (m, 9H); $^{13}C\{^{1}H\}$ NMR (126 MHz, $CDCl_3$): δ 173.42, 161.39, 144.64, 135.76, 124.75, 121.91, 72.84, 43.01, 38.49, 36.18, 34.52, 24.93, 23.54, 22.33, 16.12, 13.75; HRMS (ESI/[M–(-OH)]+) calcd. for $C_{17}H_{25}O_3^+$: 277.1798. Found 277.1793.

7. Derivatization of Three-Component Product 4ar to Give 4ar':



To an oven-dried microwave vial was added 3,5-dinitrobenzoyl chloride (53.0 mg, 0.230 mmol, 1.15 equiv) and a stir bar. The vial was then capped with a microwave cap and equipped with a N_2-inlet. This was then followed by the addition of 0.5 mL of pyridine, and the solution was cooled to 0 °C. Then **4ar** (95.1 mg, 0.200 mmol, 1.0 equiv) was dissolved in 1.0 mL of pyridine, and the solution was transferred to the reaction vial via syringe (total pyridine: 1.5 mL). The vial was kept at 0 °C for 10-15 min and then allowed to warm to rt. At this point, the reaction mixture was stirred at rt overnight. The reaction was quenched with water followed by addition of a saturated solution of $CuSO_4 \cdot 5H_2O$, and resulting mixture was extracted with ethyl acetate. The organic extract was dried over Na_2SO_4 and concentrated under reduced pressure. The product was purified by silica gel chromatography using a 50:50 mixture of ethyl acetate: hexanes as the eluent to afford the product **4ar'** (67.3 mg, 50% yield) as an off-white solid (mp: 154–156 °C). IR (film): 2963, 2920, 2877, 1733, 1623, 1549, 1426, 1344, 1272, 1169 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 9.22 (t, *J* = 2.2 Hz, 1H), 9.13 (d, *J* = 2.1 Hz, 2H), 7.44 (d, *J* = 7.2 Hz, 1H), 7.35–7.32 (m, 1H), 7.31–7.28 (m, 1H), 7.24 (d, *J* = 7.6 Hz, 1H), 7.21–7.17 (m, 5H), 6.55 (d, *J* = 15.7 Hz, 1H), 6.01 (dd, *J* = 15.7, 10.1 Hz, 1H), 5.60–5.56 (m, 1H), 5.01 (t, *J* = 5 Hz, 1H), 4.53 (d, *J* = 12.0 Hz, 1H), 4.42 (d, *J* = 12.1 Hz, 1H), 3.76–3.73 (m, 1H), 3.68–3.66 (m, 1H), 3.62 (t, *J* = 7.0 Hz, 2H), 3.07 (t, *J* = 6.8 Hz, 2H), 2.80–2.75 (m, 1H), 2.04–1.99 (m, 1H), 1.95–1.88 (m, 3H), 1.83–1.78 (m, 2H), 1.75–1.73 (m, 1H), 1.59 (s, 3H), 1.56 (s, 3H), 1.36–1.30 (m, 1H), 1.22–1.15 (m, 1H), 0.93 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.44, 162.30, 148.76, 137.77, 136.79, 134.14, 133.18, 131.83, 131.56, 129.60, 129.11, 128.44, 127.95, 127.80, 127.77, 127.73, 126.30, 126.18, 124.12, 122.44, 75.45, 73.19, 70.64, 48.62, 48.42, 45.61, 35.72, 32.28, 25.97, 25.77, 25.72, 24.70, 17.81, 14.63; HRMS (ESI/$[M+H]^+$) calcd. for $C_{38}H_{44}N_3O_8^+$: 670.3123. Found 670.3127.

8. X-Ray Crystallographic Data:

Experimental

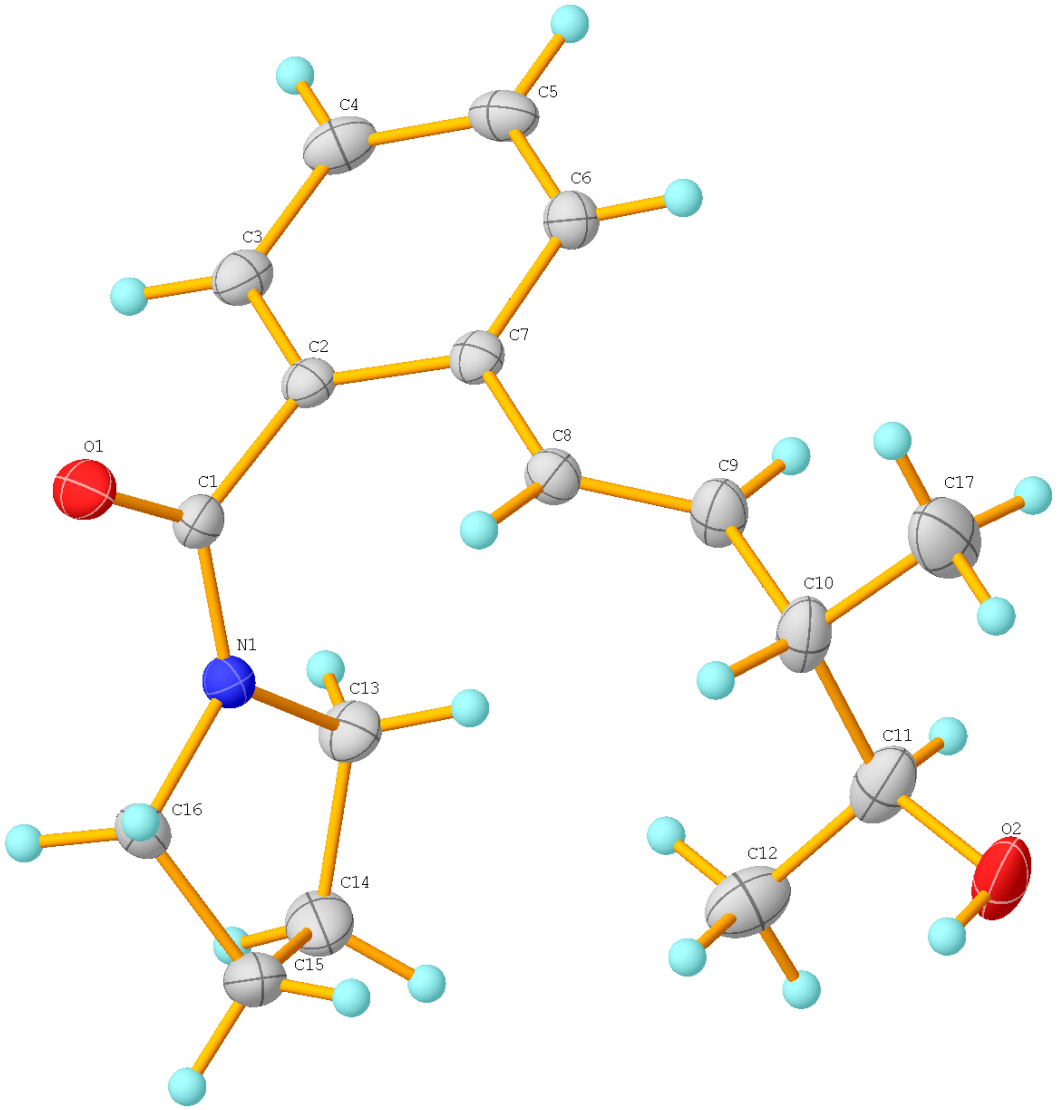
Low-temperature diffraction data (ω-scans) were collected on a Rigaku MicroMax-007HF diffractometer coupled to a Dectris Pilatus3R detector with Mo Kα (λ = 0.71073 Å) for the structure of **4b** and a Saturn994+ CCD detector with Cu Kα (λ = 1.54178 Å) for the structure of **4ar'** and **8a**. The diffraction images were processed and scaled using Rigaku Oxford Diffraction software (Rigaku Oxford Diffraction (2014). *CrysAlis PRO*. Rigaku Oxford Diffraction, The Woodlands, Texas). The structure was solved with SHELXT and was refined against F^2 on all data by full-matrix least squares with SHELXL[18]. There are two, high-level CIFcheck alerts associated with the X-ray data presented here. In the structure model of **4b**, there may be additional disordered atom positions for the OH group (oxygen labeled O2). The largest difference map peak near O2 (0.96 e-/$Å^3$) suggests additional positions for the proton. However, additional atomic position parameters did not vastly improve the model. In the structure model of **4ar'**, the merged integrating residual R_{int} was high. This is likely due to the weak, non-uniform diffraction produced by the needle morphology of the crystal. All non-hydrogen atoms were refined anisotropically. Unless stated otherwise, hydrogen atoms were included in the model at geometrically calculated positions and refined using a riding model. The isotropic displacement parameters of all hydrogen atoms were fixed to 1.2 times the U value of the atoms to which they are linked (1.5 times for methyl and alcohol groups). The full numbering scheme of compound **4b**, **4ar'**, and **8a** can be found in the full details of the X-ray structure determination (CIF), which is included as Supporting Information. CCDC number 1812525 (**4b**), 1826301 (**4ar'**), and 1812526 (**8a**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Center via www.ccdc.cam.ac.uk/data_request/cif.

Supplementary Table 1. Details of X-ray crystal structures **4b, 4ar'**, and **8a**.

Compound	**4b**	**4ar'**	**8a**
Identification Code	007c-17046	007a-18008	007b-17127
Empirical formula	$C_{17}H_{23}NO_2$	$C_{38}H_{43}N_3O_8$	$C_{49}H_{33}BCoF_{20}NO$
Formula Weight	273.36	669.75	1101.50
Wavelength (Å)	0.71073	1.54184	1.54184
Crystal system	Monoclinic	Monoclinic	Monoclinic
Space group	$P2_1/n$	$P2_1/c$	$P2_1/c$
a (Å)	8.7695(5)	11.8710(4)	18.0669(5)
b (Å)	10.6371(7)	16.6940(6)	15.1063(3)
c (Å)	16.4806(11)	17.5399(6)	17.2791(4)
α (deg)	90	90	90
β (deg)	97.925(6)	95.547(3)	109.190(3)
γ (deg)	90	90	90
V (Å^3)	1522.66(17)	3459.7(2)	4453.8(2)
Z	4	4	4
ρ (calculated, g/cm^3)	1.192	1.286	1.643
μ (mm^{-1})	0.077	0.739	4.159
Index Range	$-11 \le h \le 11$ $-13 \le k \le 13$ $-21 \le l \le 21$	$-14 \le h \le 14$ $-19 \le k \le 19$ $-20 \le l \le 20$	$-21 \le h \le 21$ $-17 \le k \le 17$ $-20 \le l \le 20$
Reflections collected	15175	121891	150268
Independent reflections	3484 [R(int) = 0.0651]	6104 [R(int) = 0.2844]	7868 [R(int) = 0.1520]
Observed reflections (I > 2sigma(I))	2466	3808	5871
Data / restraints / parameters	3484 / 0 / 184	6104 / 0 / 445	7868 / 2 / 669
*R*1, w*R*2 (I > 2*σ*(I))	0.0627, 0.1477	0.0917, 0.2409	0.0489, 0.1060
*R*1, *wR*2 (all data)	0.0933, 0.1618	0.1372, 0.2861	0.0733, 0.1185
GOF	1.046	1.053	1.016
Largest diff. peak and hole (e.Å^{-3})	0.955 and -0.413	0.449 and -0.423	0.375 and -0.463

Crystal details for compound 4b

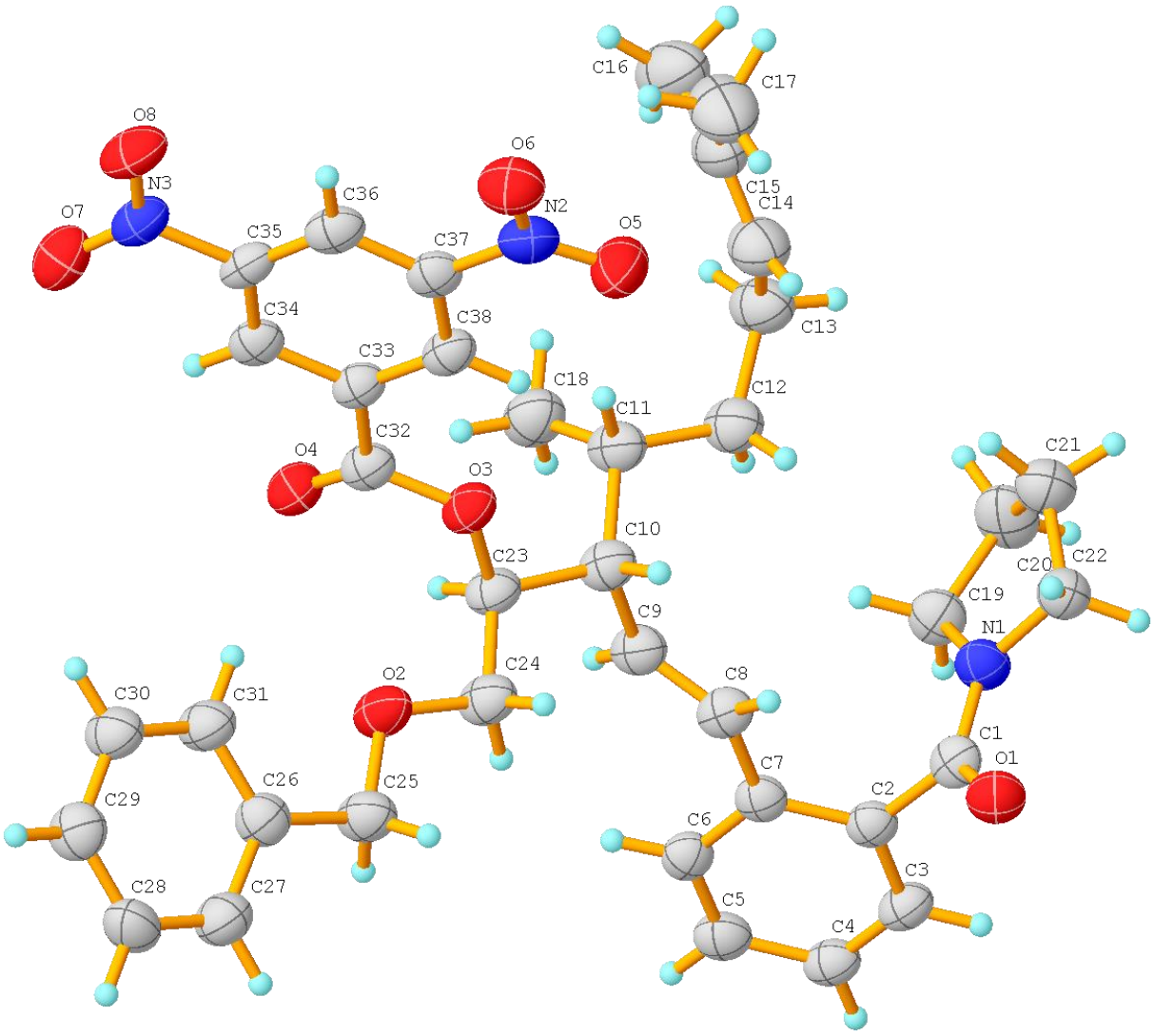
Single crystals of **4b** were obtained by slow addition of ethyl ether (~0.3 mL) in a concentrated solution of product **4b** in dichloromethane (roughly 10 mg in 0.1 mL). The mixture was allowed to slowly evaporate to yield the desired crystals.



Supplementary Figure 3. The complete numbering scheme of **4b** with 50% thermal ellipsoid probability levels. The hydrogen atoms are shown as circles for clarity.

Crystal details for compound 4ar'

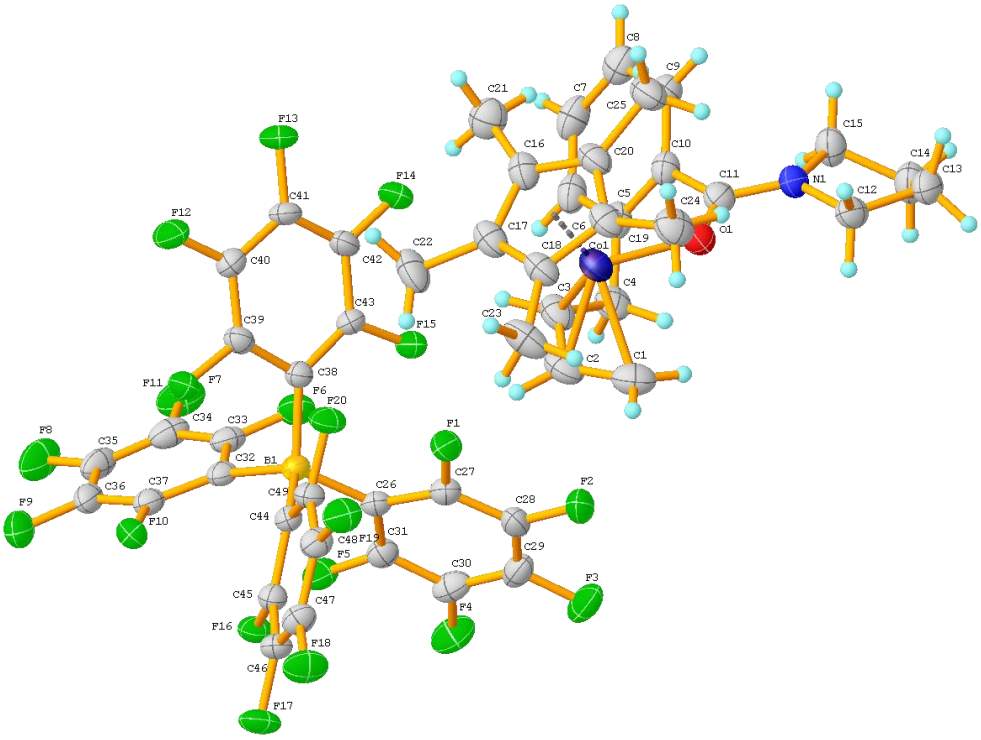
Single crystals of **4ar'** were obtained by slow addition of pentane (~0.3 mL) in a concentrated solution of product **4ar'** in dichloromethane (roughly 10 mg in 0.1 mL). The mixture was allowed to slowly evaporate to yield the desired crystals.



Supplementary Figure 4. The complete numbering scheme of **4ar'** with 50% thermal ellipsoid probability levels. The hydrogen atoms are shown as circles for clarity.

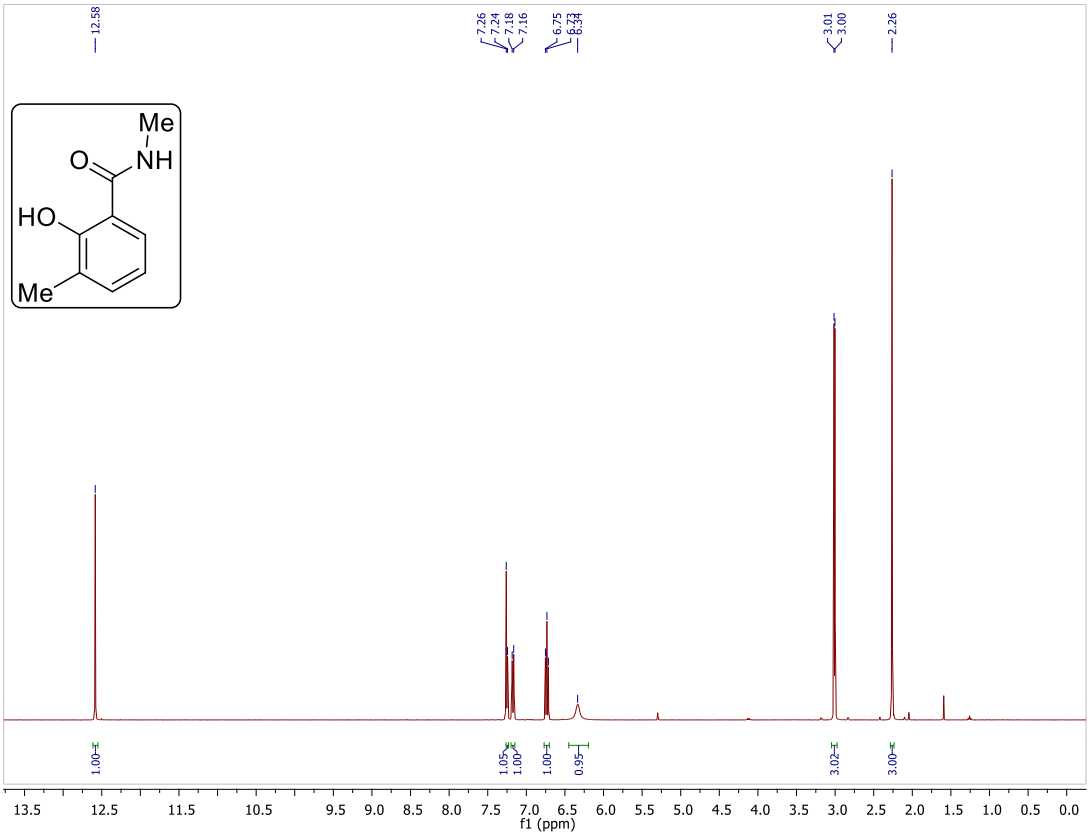
Crystal and refinement details for Co-allyl species 8a

Single crystals of **8a** were obtained by slow addition of pentane (~0.3 mL) in a concentrated solution of product **8a** in dichloromethane (roughly 10 mg in 0.1 mL). The mixture was allowed to slowly evaporate to yield the desired crystals. The hydrogen atoms H1a and H2a were found in the difference map and semi-freely refined with C-H distance restraints of 0.99(2) Å.



Supplementary Figure 5. The complete numbering scheme of **8a** with 50% thermal ellipsoid probability levels. The hydrogen atoms are shown as circles for clarity.

9. NMR Data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6.73
6.34
3.01
3.00
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O
HO
Me
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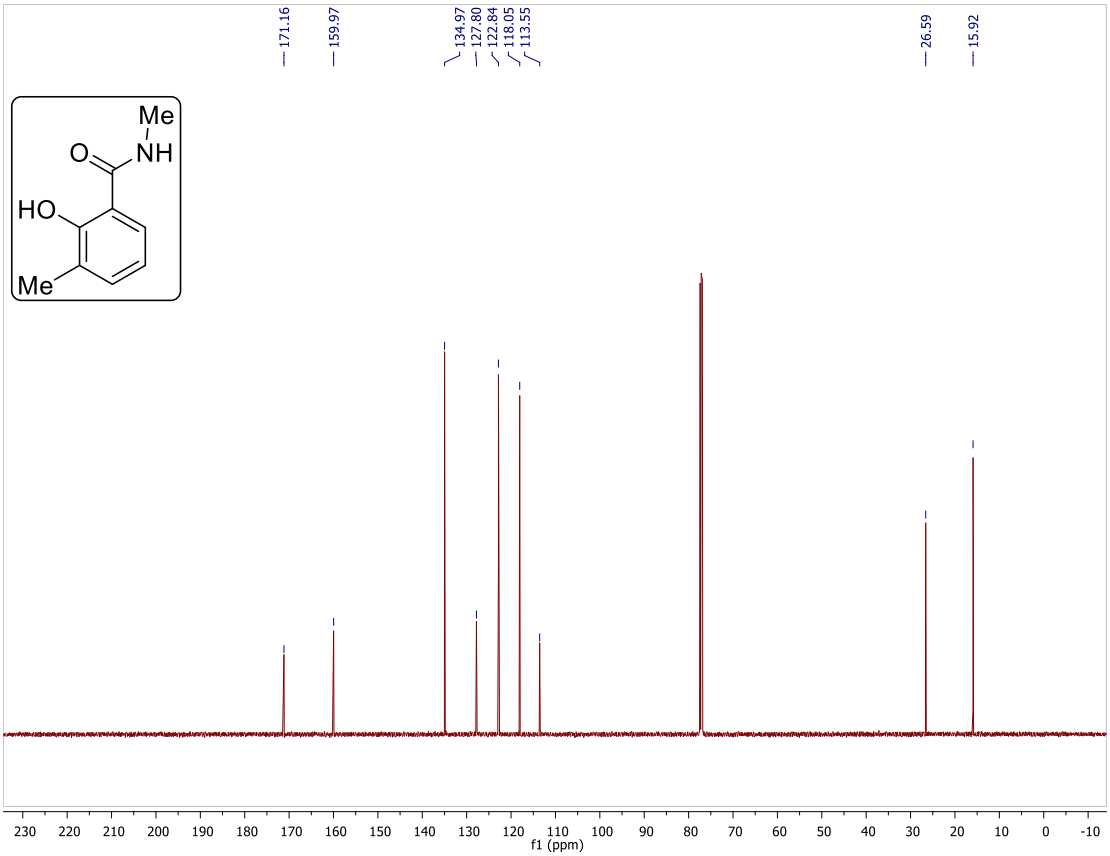
1.05
1.00
1.00
0.95
3.02
3.00
f1 (ppm)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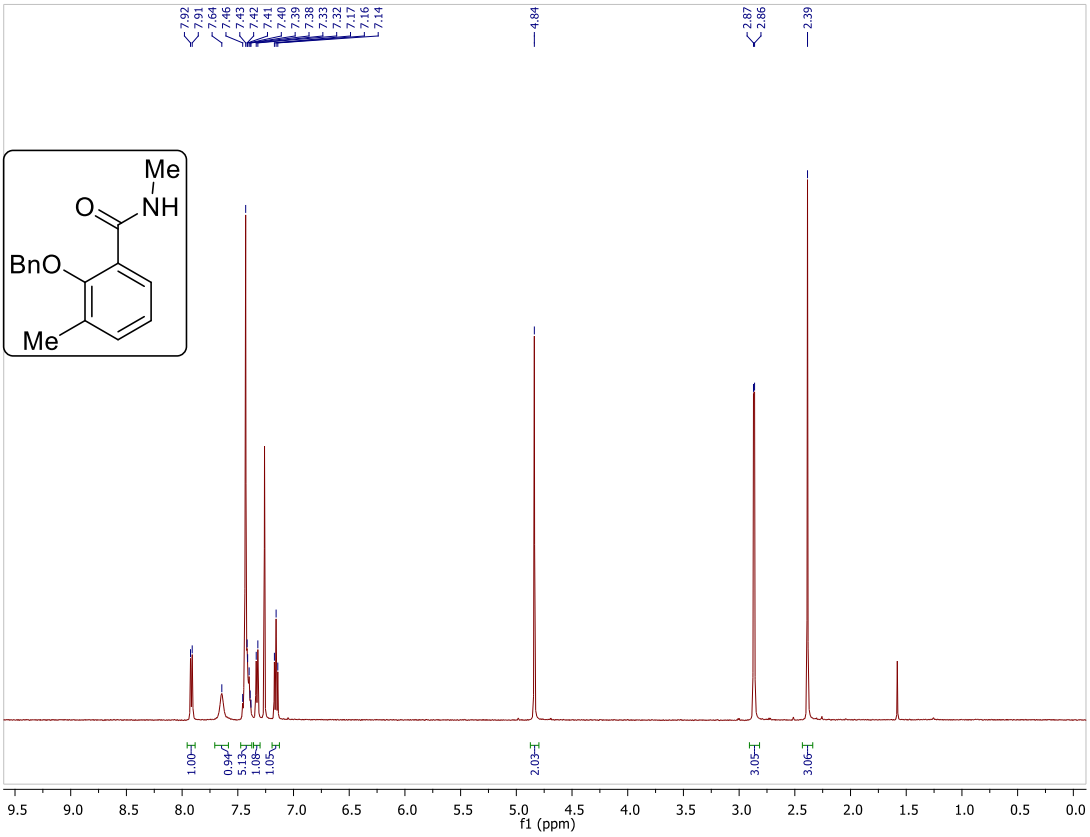
O
HO
Me
f1 (ppm)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7.91
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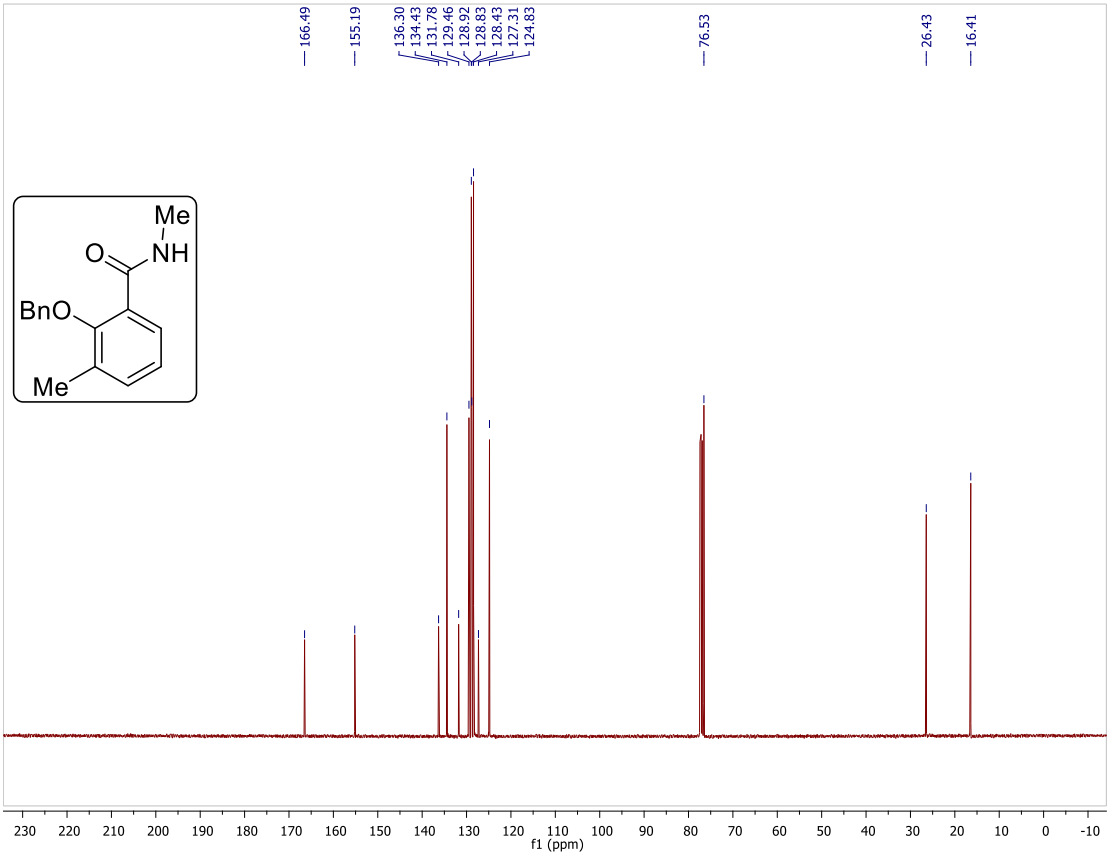
7.46
7.43
7.42
7.41
7.40
7.39
7.38
7.33
7.32
7.17
7.16
7.14
4.84
2.87
2.86
2.39
Me
O
NH
BnO
Me
1.00
0.94
5.13
1.08
1.05
2.03
3.05
3.06
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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155.19
136.30
134.43
131.78
129.46
128.92
128.83
128.43
127.31
124.83
76.53
26.43
16.41
Me
O
NH
BnO
Me
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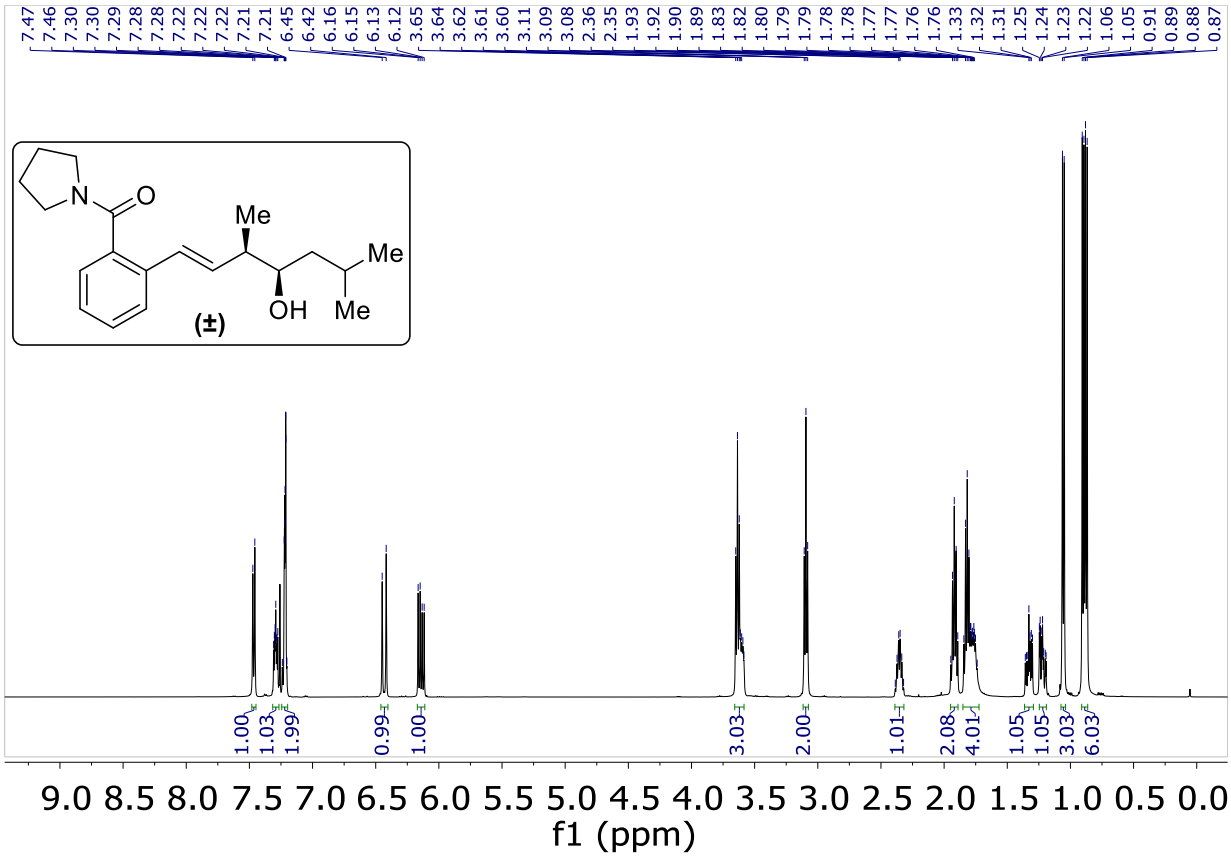
f1 (ppm)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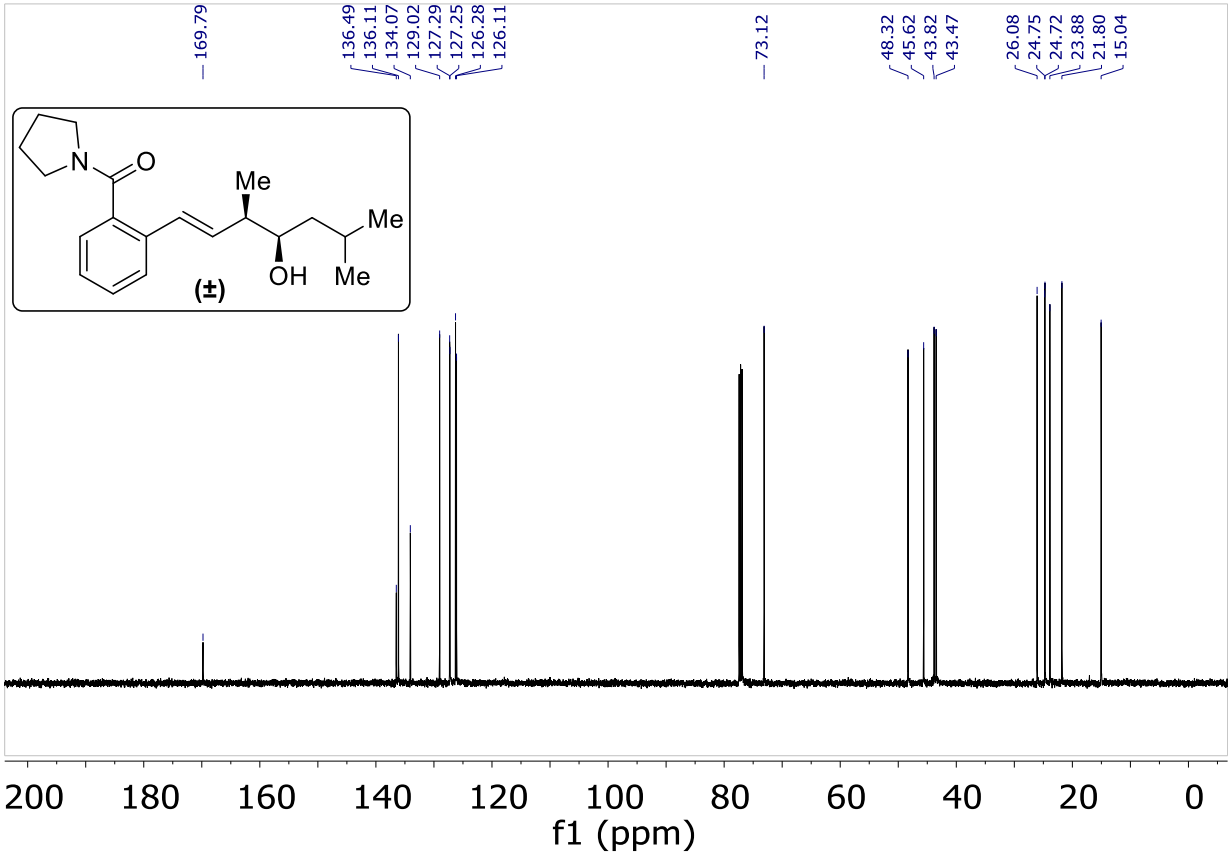
N
O
Me
Me
OH
Me
(±)
1.00 1.03 1.99 0.99 1.00 3.03 2.00 1.01 2.08 4.01 1.05 1.05 3.03 6.03
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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73.12
48.32 45.62 43.82 43.47
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OH
Me
(±)
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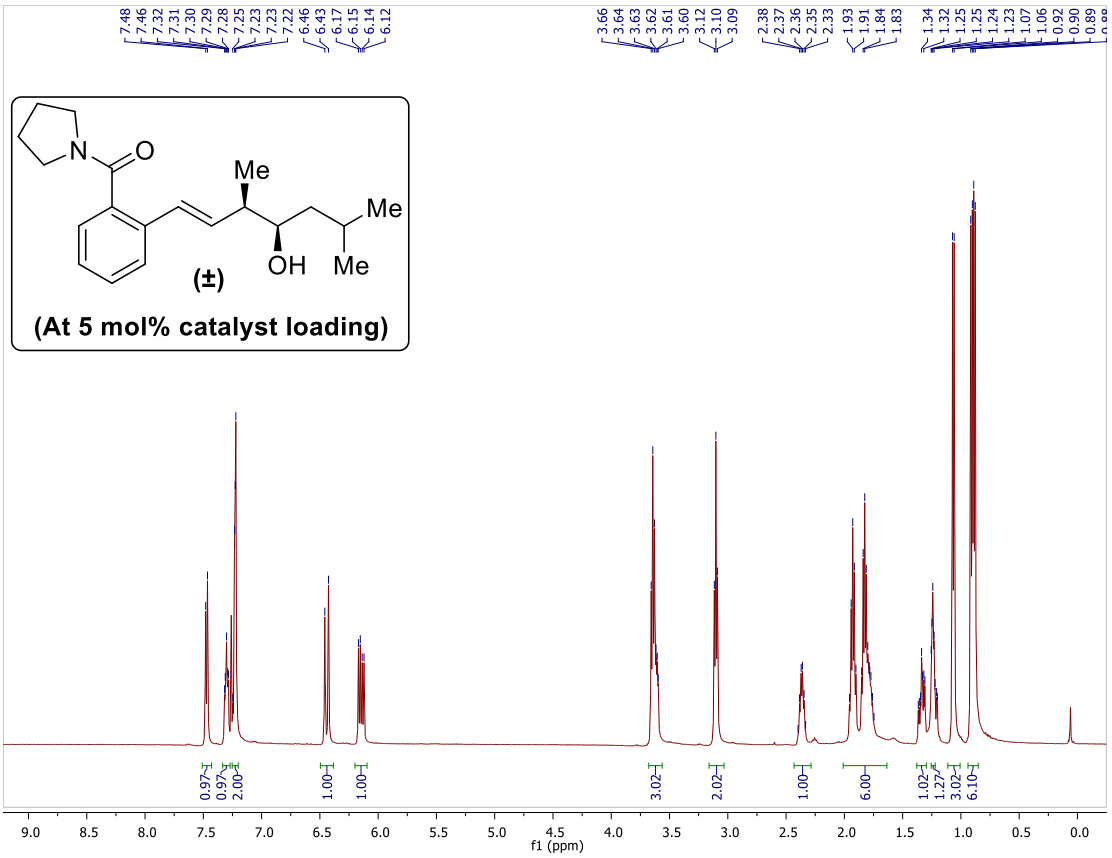
f1 (ppm)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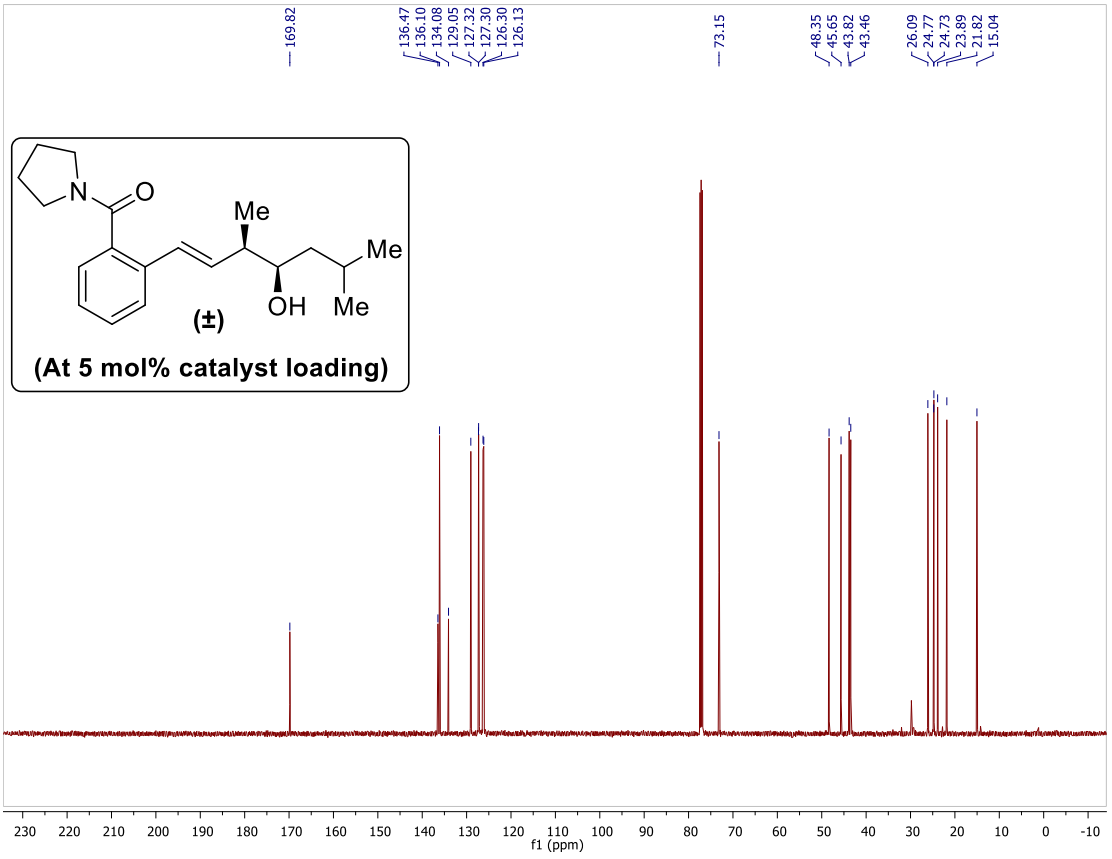
Me
OH
Me
(±)
(At 5 mol% catalyst loading)
f1 (ppm)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(±)
(At 5 mol% catalyst loading)
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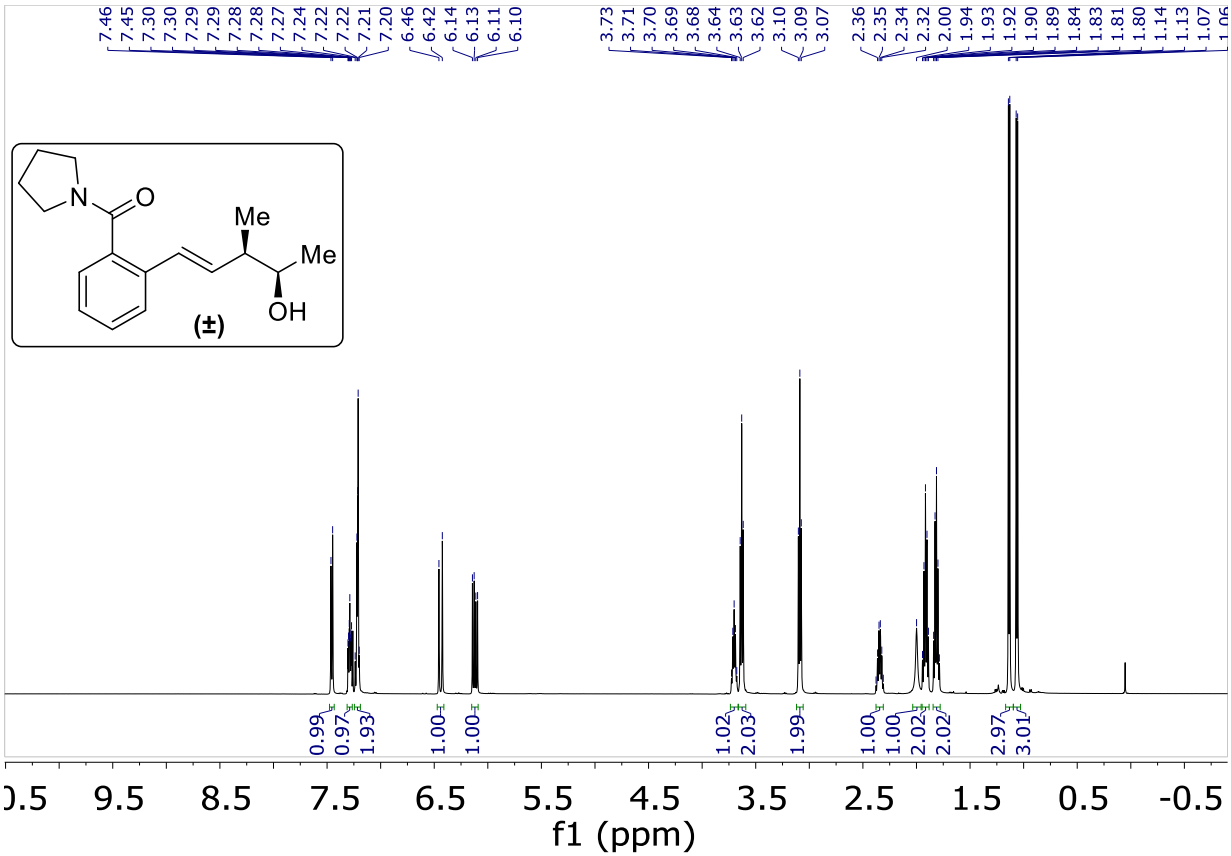
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3.73 3.71 3.70 3.69 3.68 3.64 3.63 3.62 3.10 3.09 3.07
2.36 2.35 2.34 2.32 2.00 1.94 1.93 1.92 1.90 1.89 1.84 1.83 1.81 1.80 1.14 1.13 1.07
N
O
Me
Me
OH
(±)
0.99 0.97 1.93 1.00 1.00 1.02 2.03 1.99 1.00 1.00 2.02 2.02 2.97 3.01
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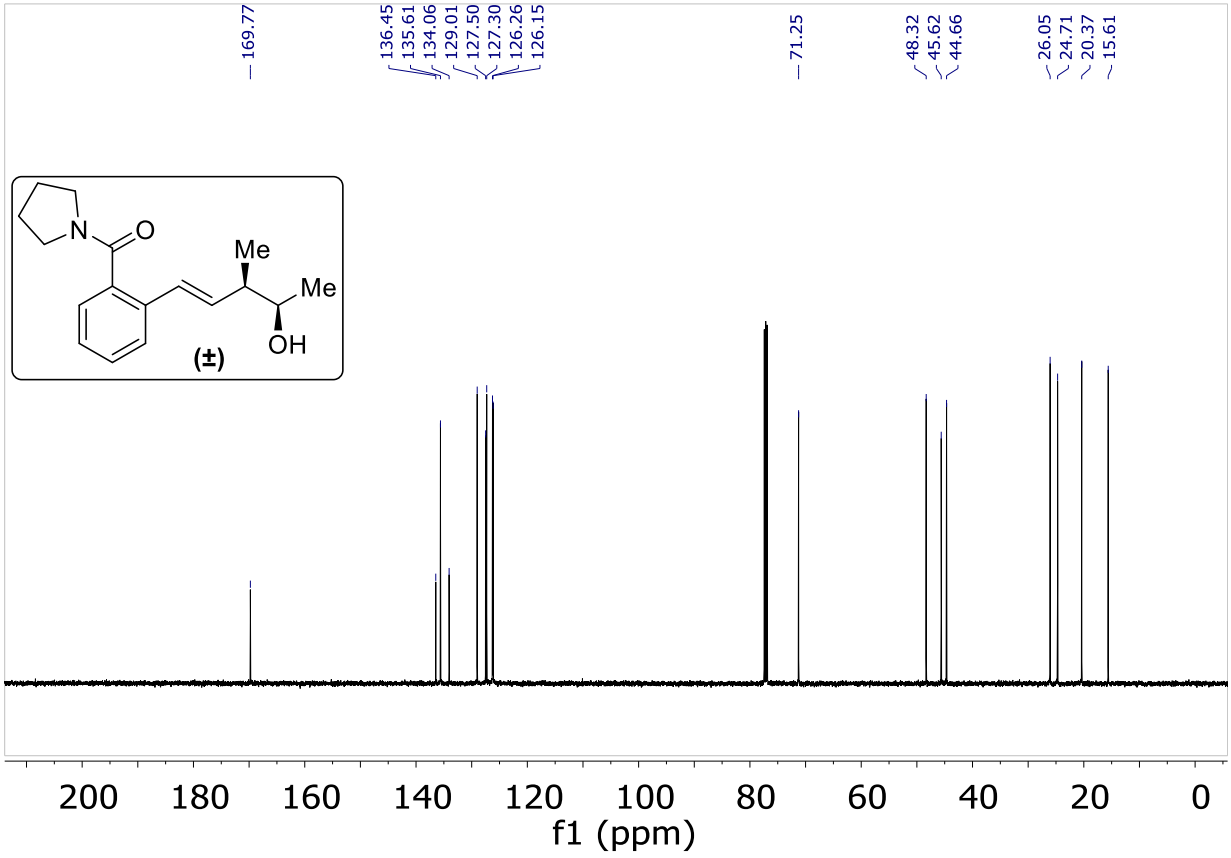
f1 (ppm)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71.25
48.32 45.62 44.66
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O
Me
Me
OH
(±)
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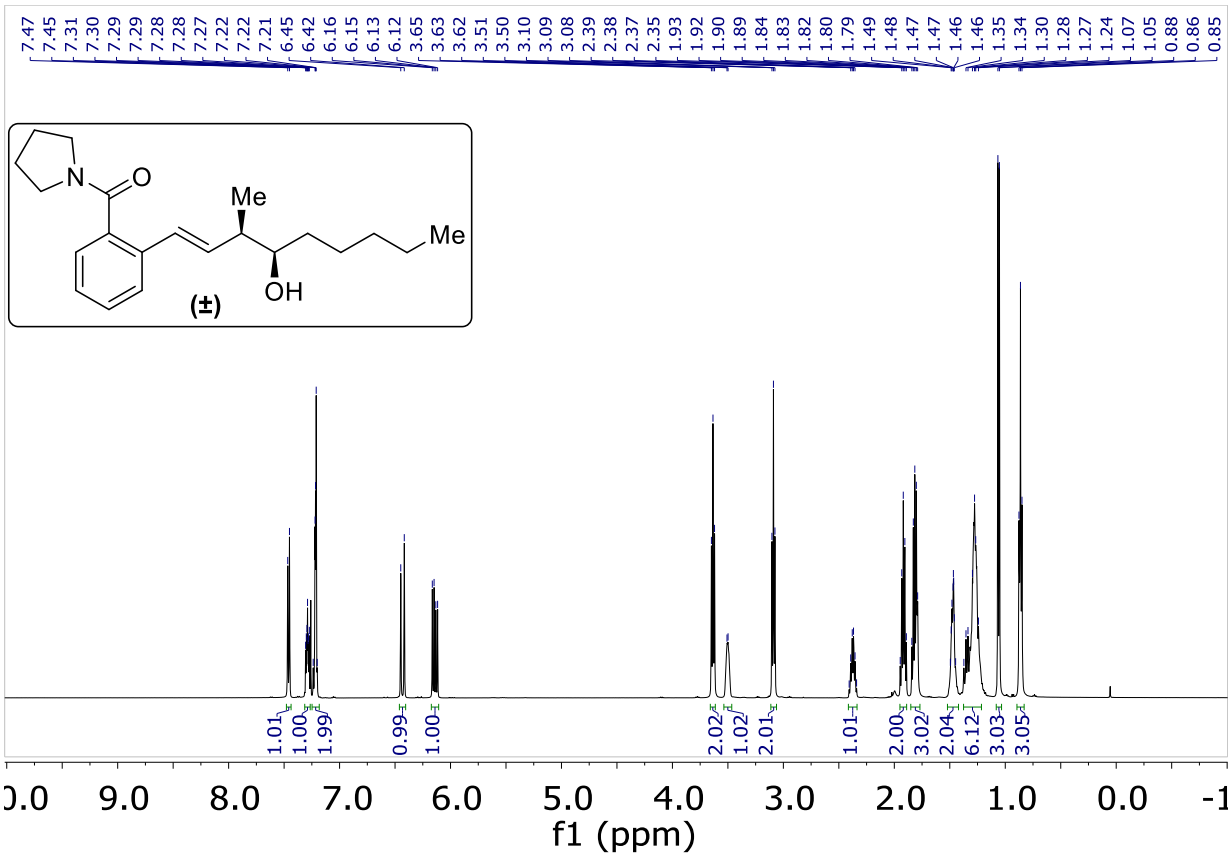
f1 (ppm)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N
O
Me
Me
OH
(±)
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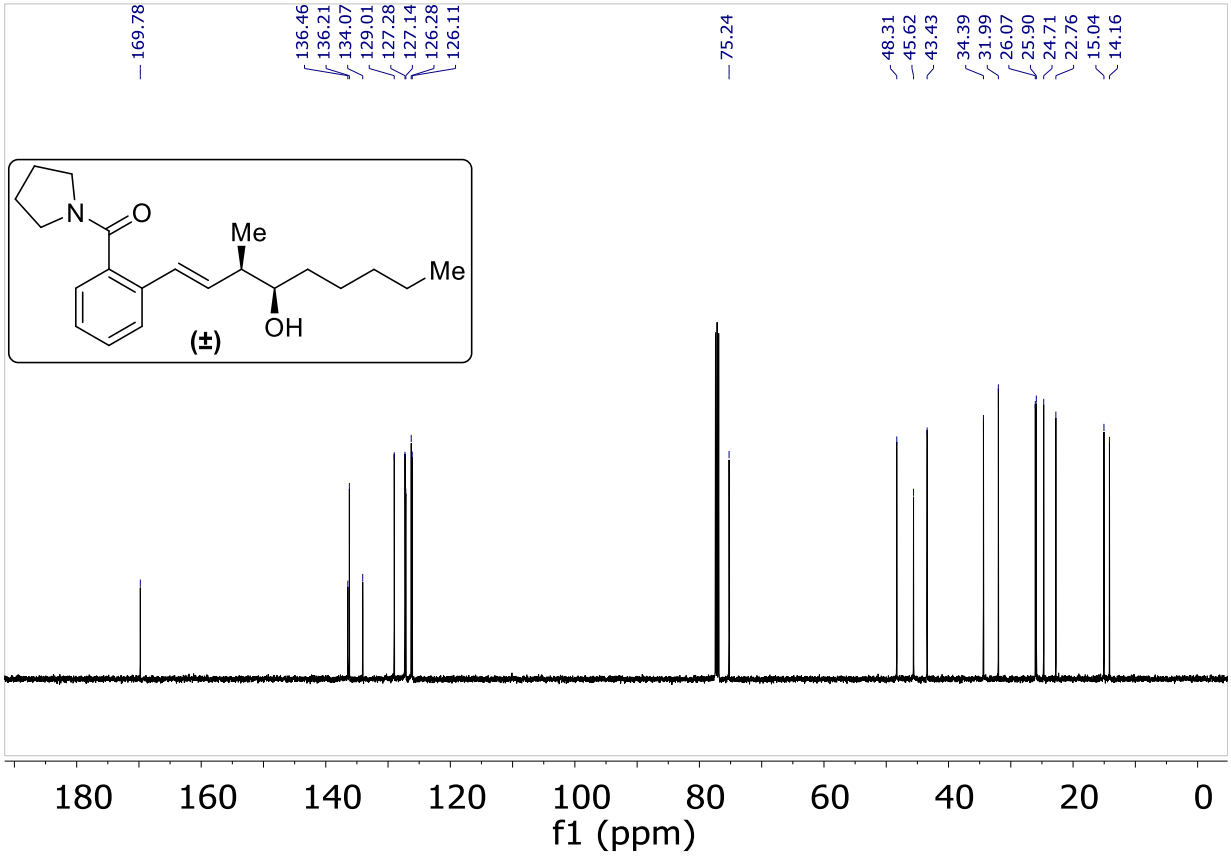
f1 (ppm)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75.24
48.31 45.62 43.43 34.39 31.99 26.07 25.90 24.71 22.76 15.04 14.16
N
O
Me
Me
OH
(±)
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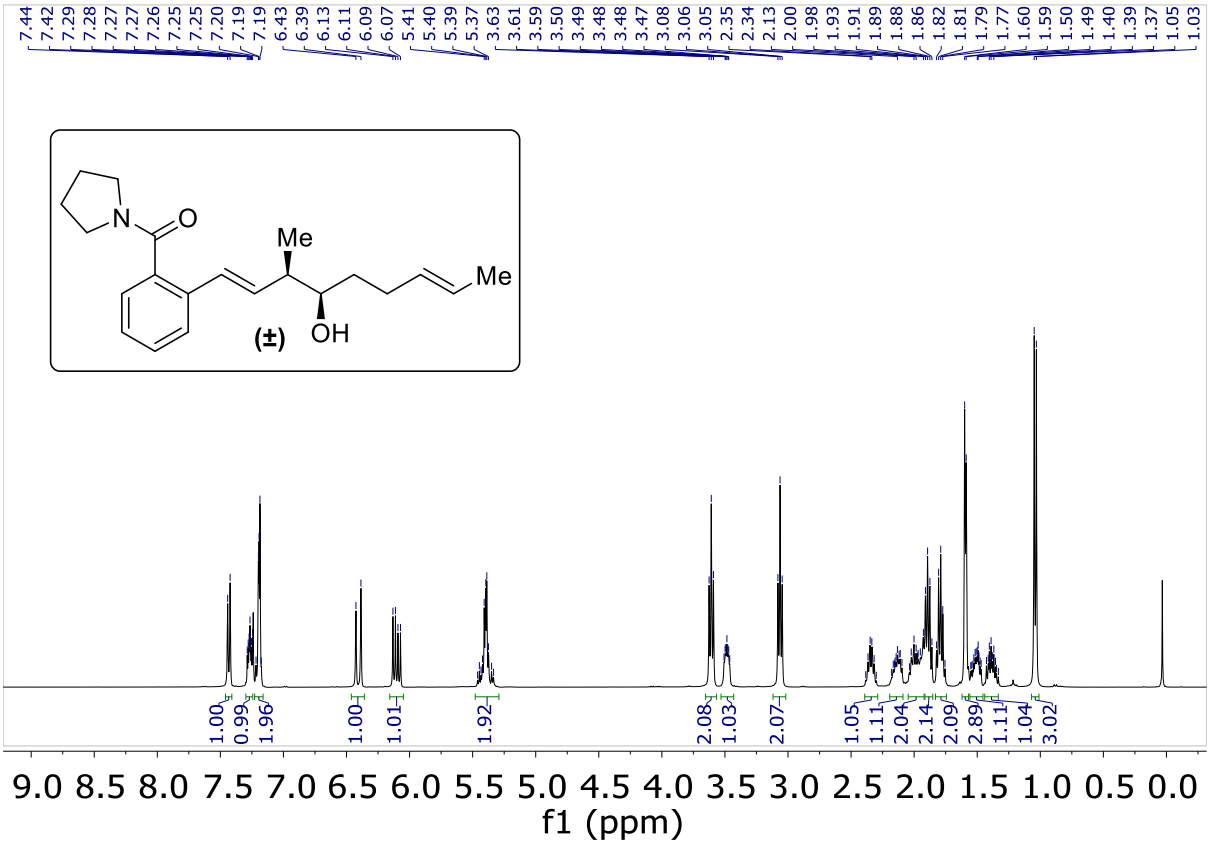
f1 (ppm)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N
O
Me
Me
(±)
OH
1.00 0.99 1.96 1.00 1.01 1.92 2.08 1.03 2.07 1.05 1.11 2.04 2.14 2.09 2.89 1.11 1.04 3.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
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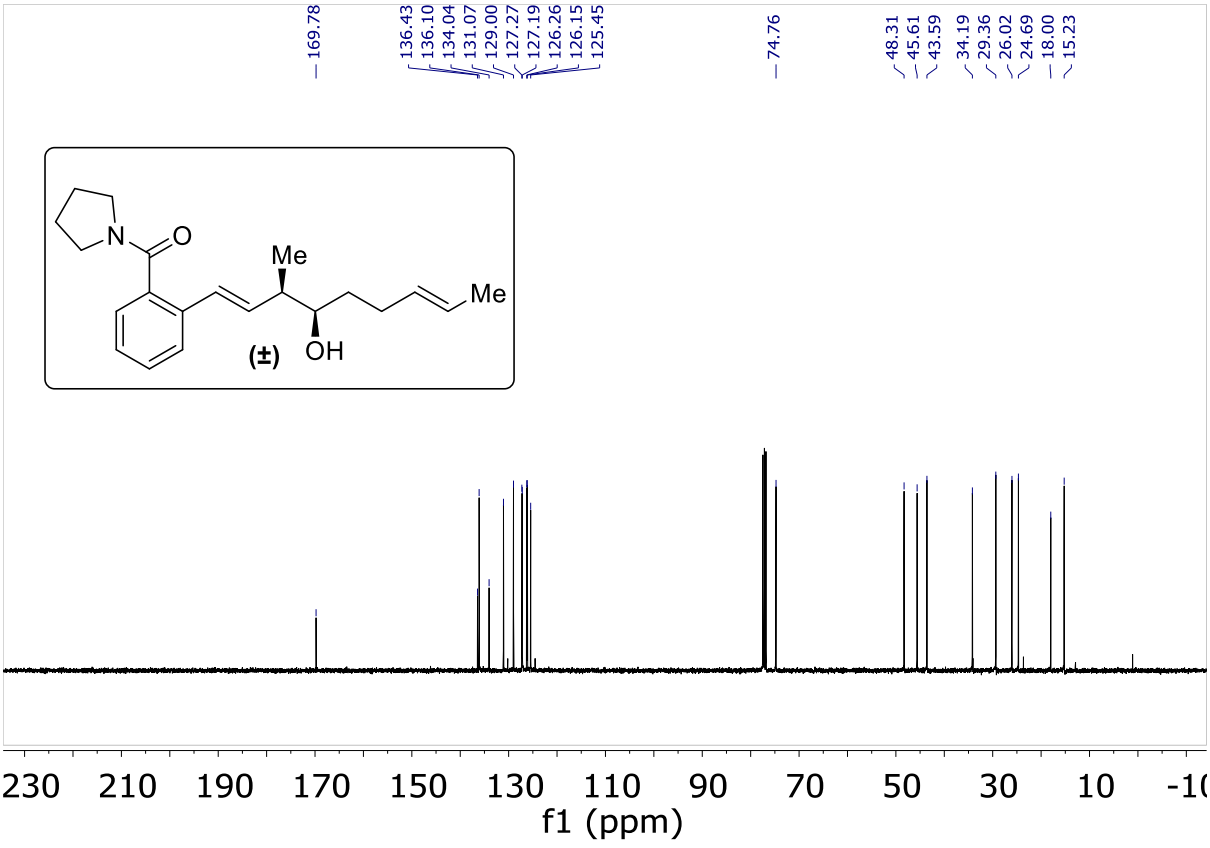
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74.76
48.31 45.61 43.59 34.19 29.36 26.02 24.69 18.00 15.23
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Me
(±)
OH
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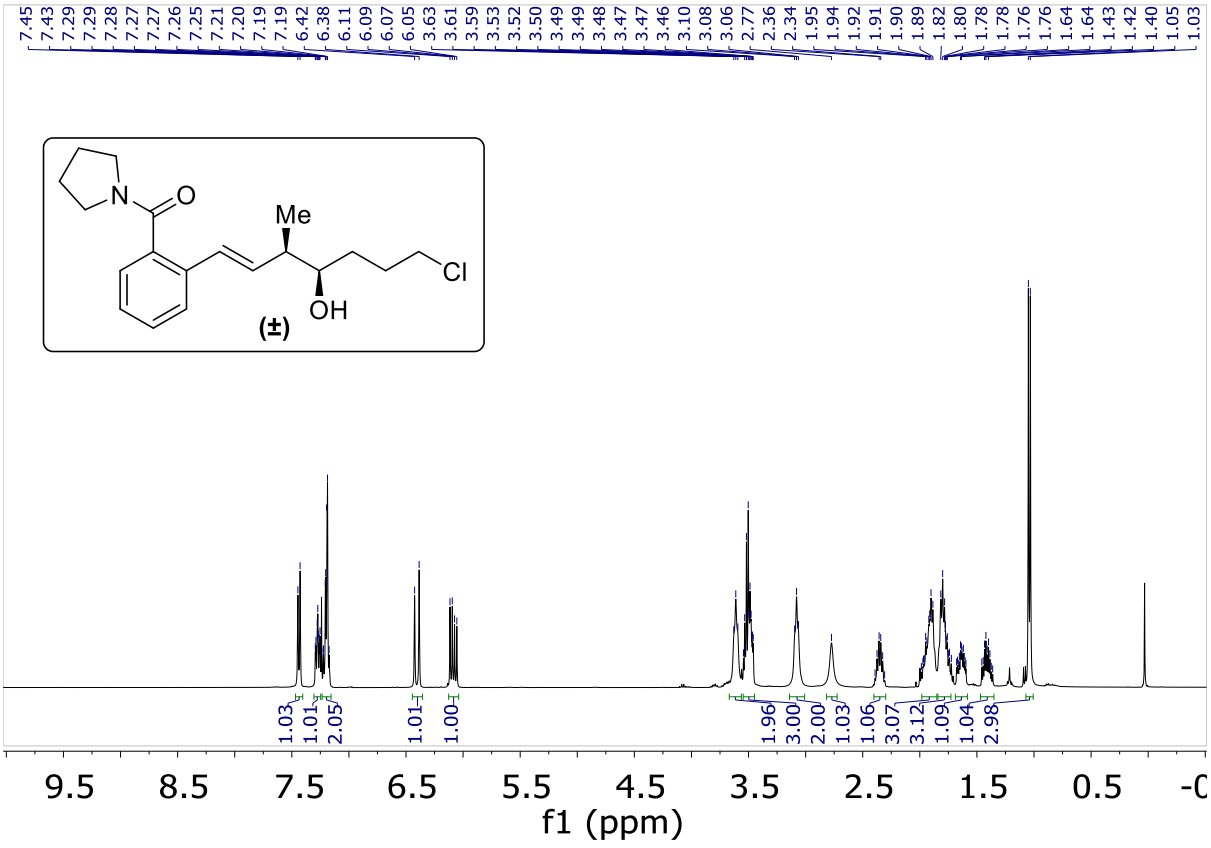
f1 (ppm)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N
O
Me
Cl
OH
(±)
1.03 1.01 2.05 1.01 1.00 1.96 3.00 2.00 1.03 1.06 3.07 3.12 1.09 1.04 2.98
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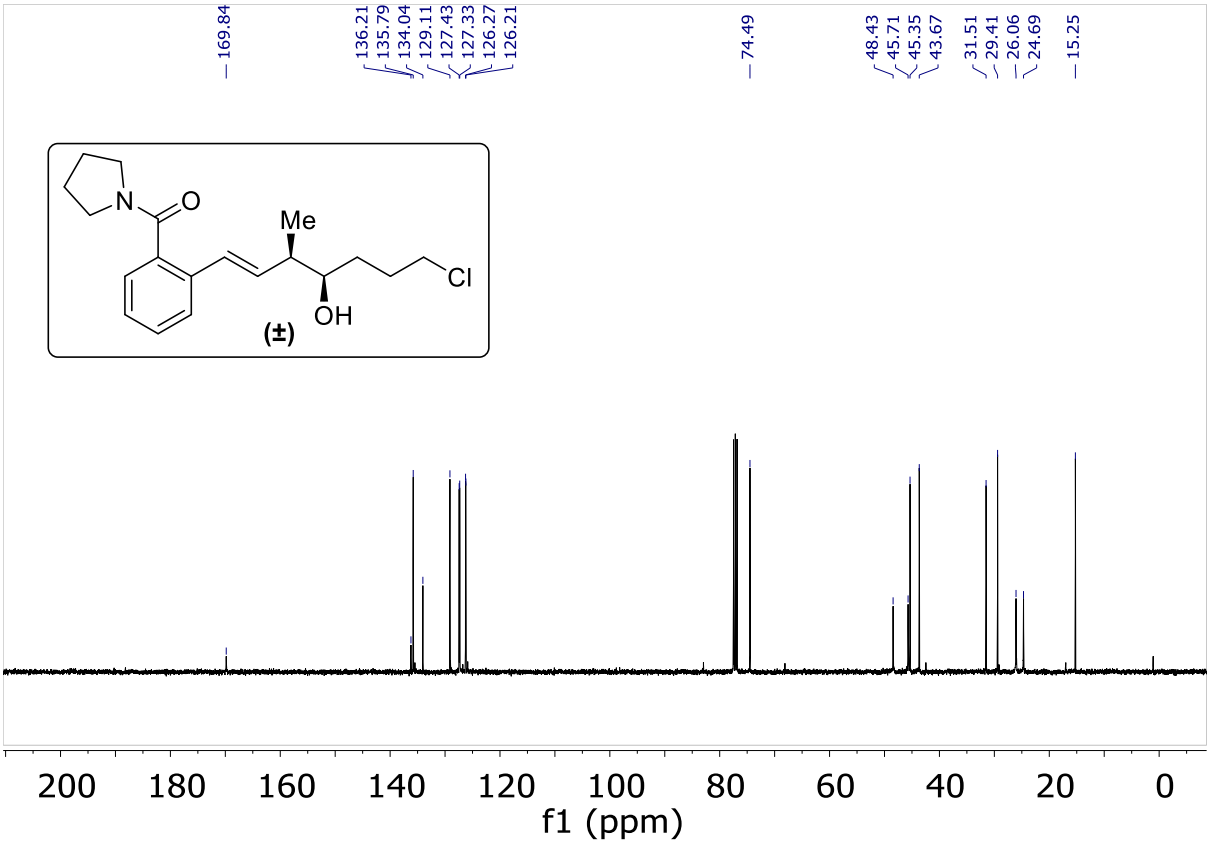
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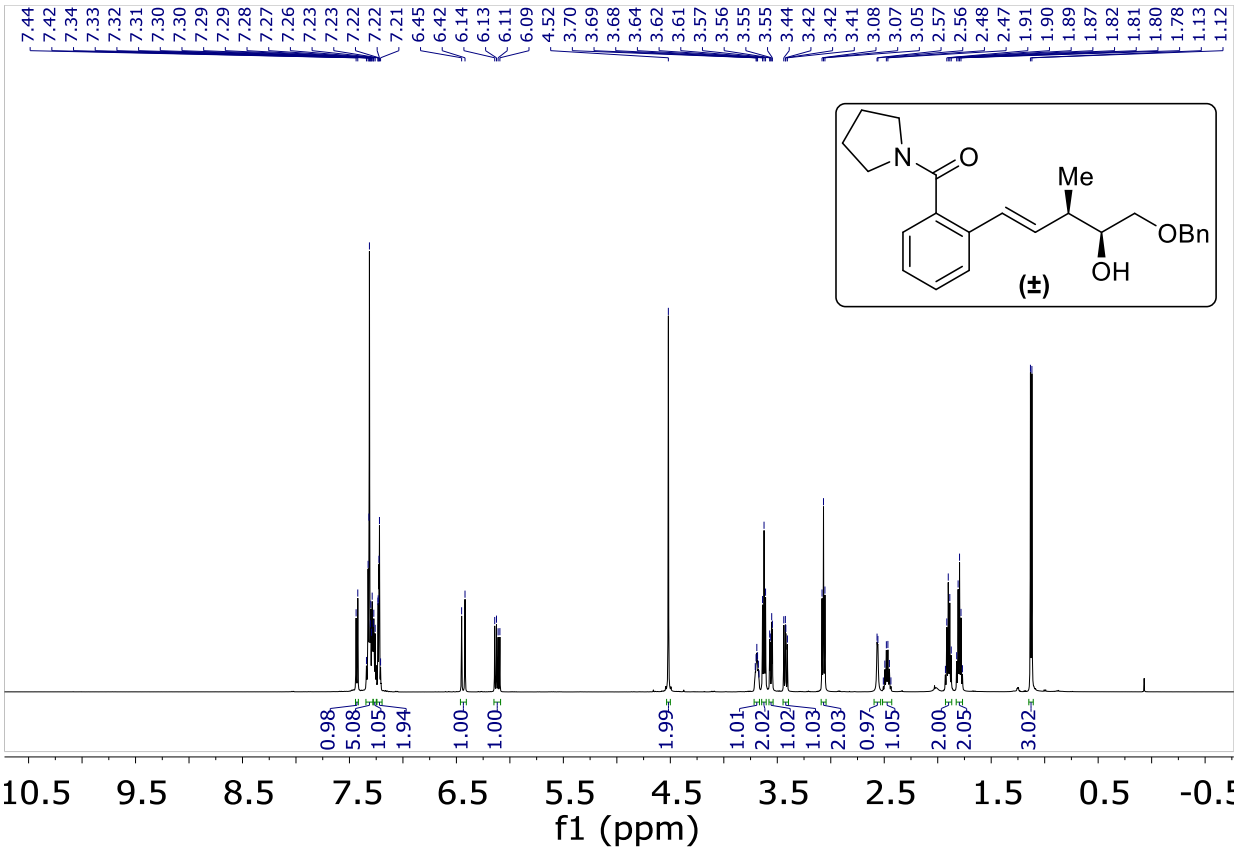
15.25
N
O
Me
Cl
OH
(±)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)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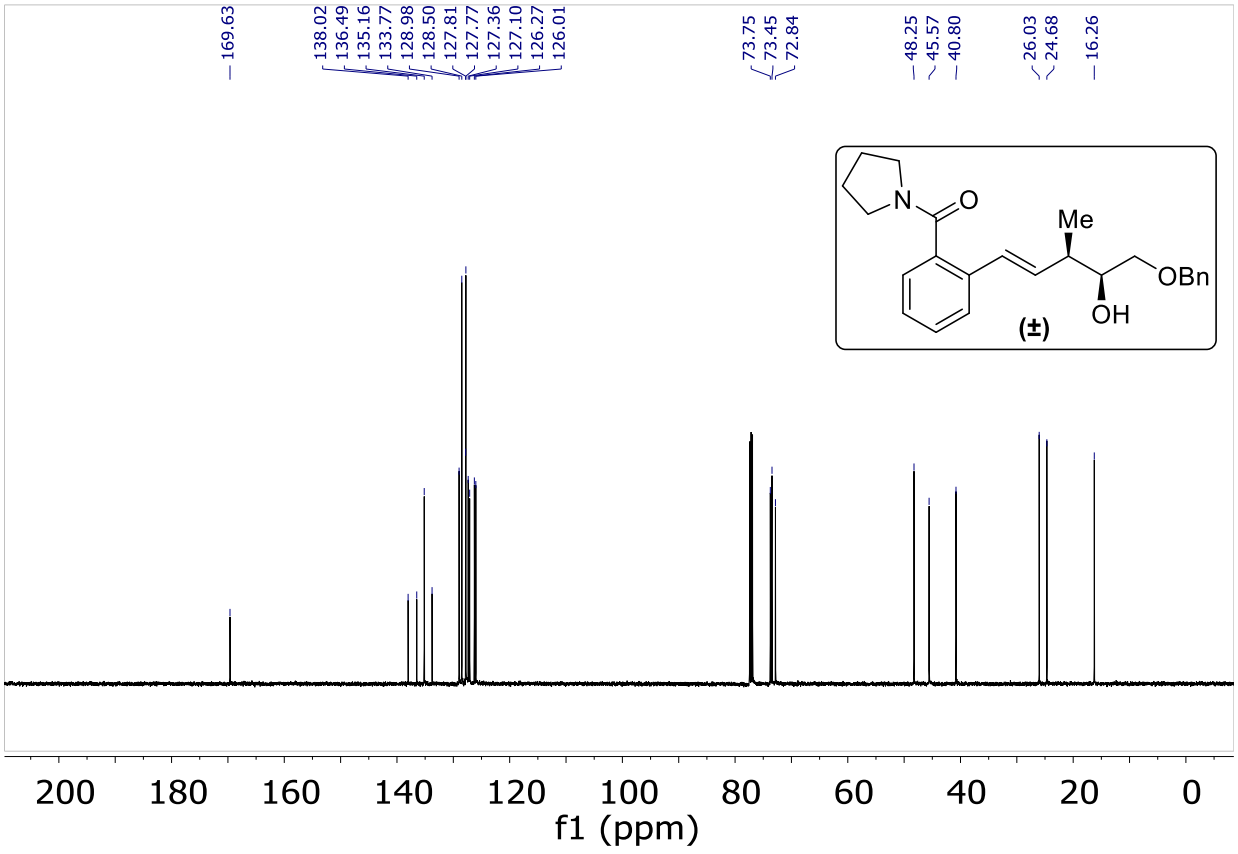
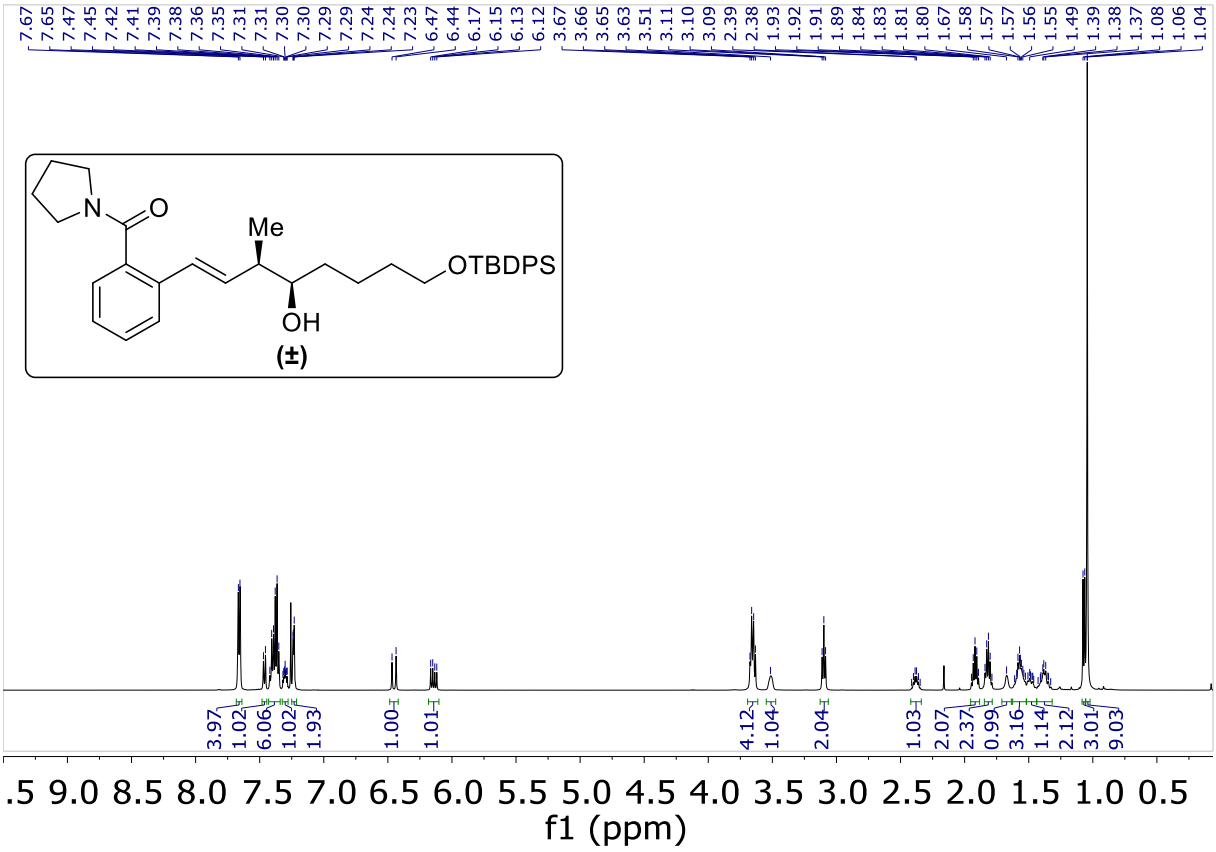
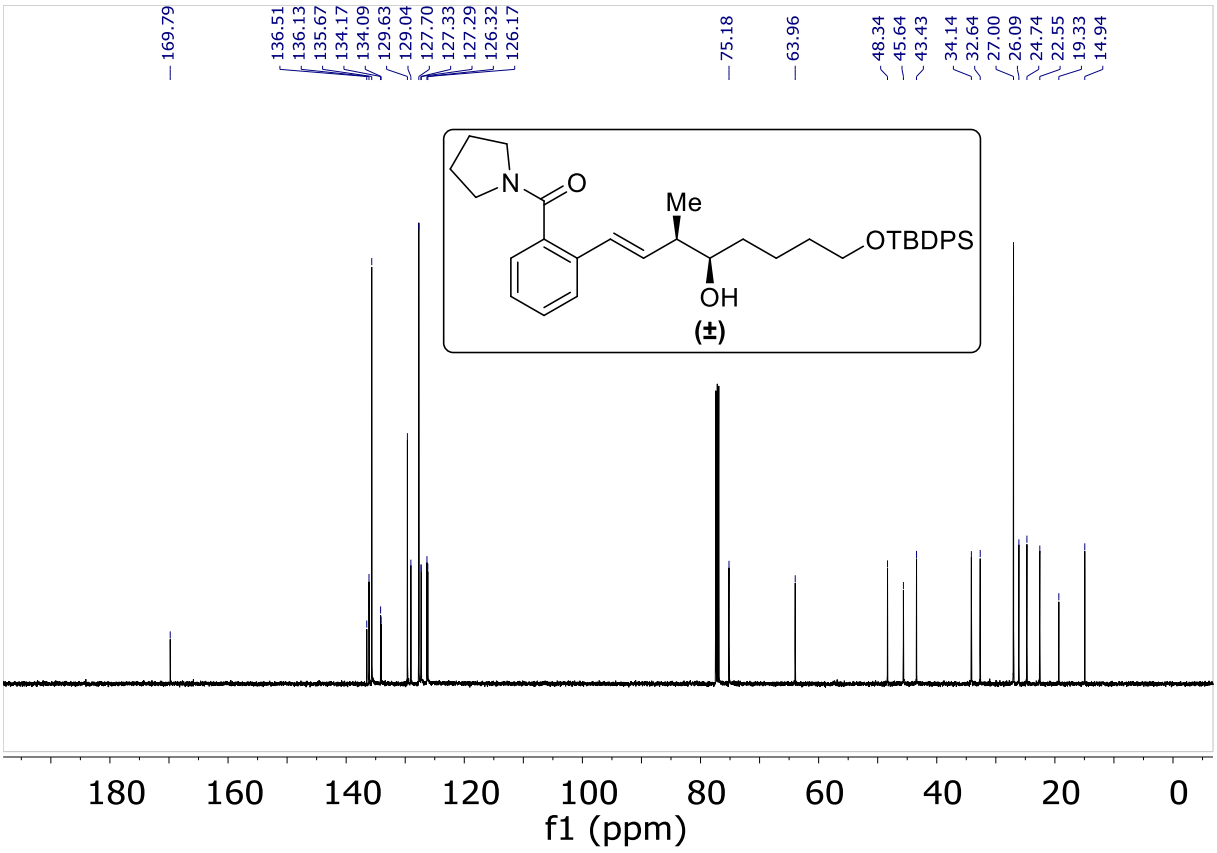
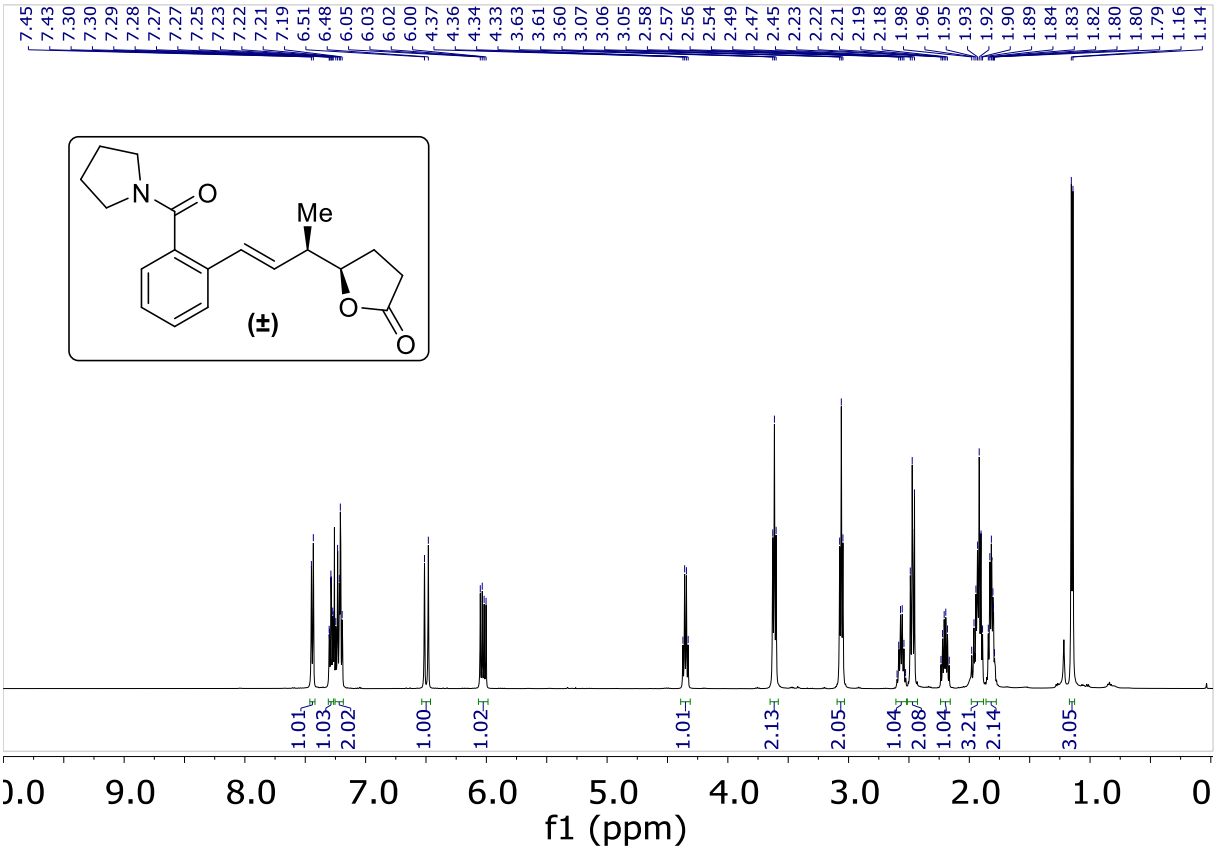
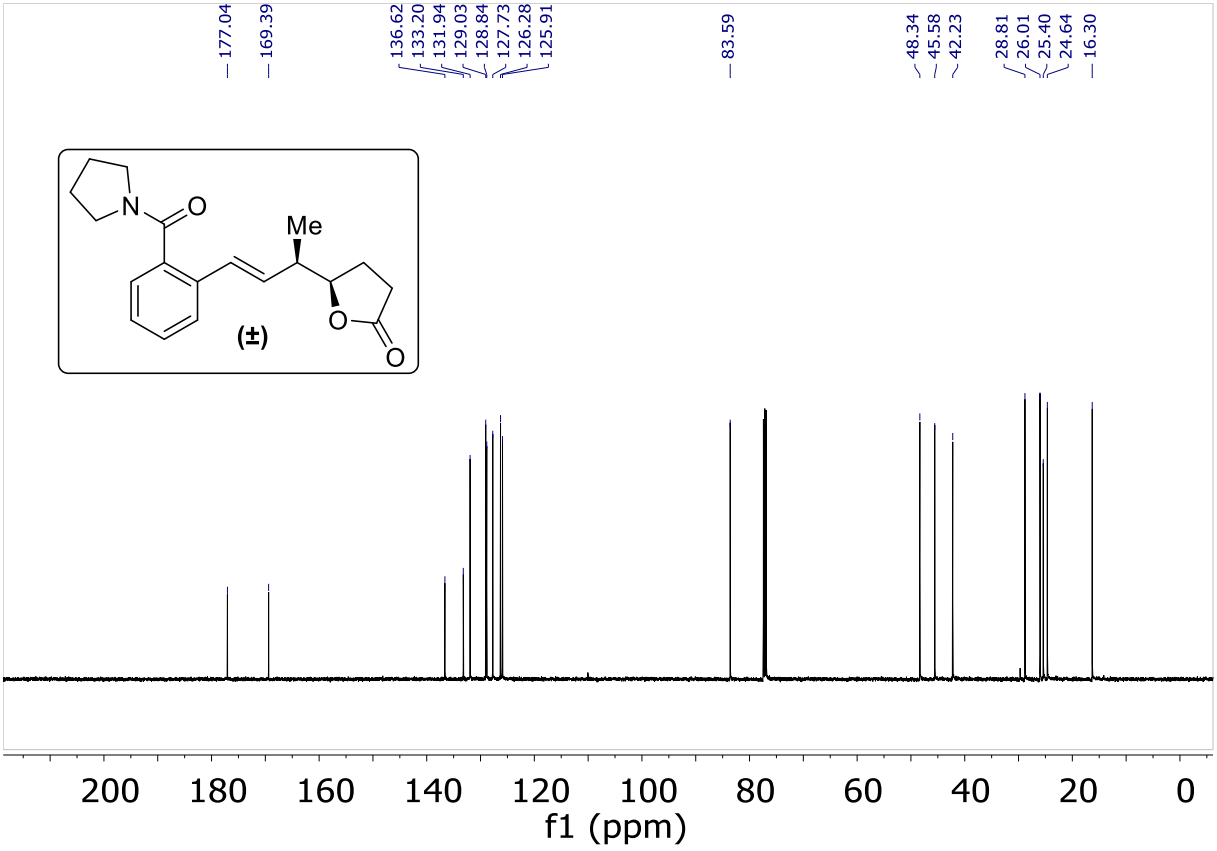
N
O
Me
OBn
OH
(±)
0.98 5.08 1.05 1.94 1.00 1.00 1.99 1.01 2.02 1.02 1.03 2.03 0.97 1.05 2.00 2.05 3.02
10.5 9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0.5
f1 (ppm)

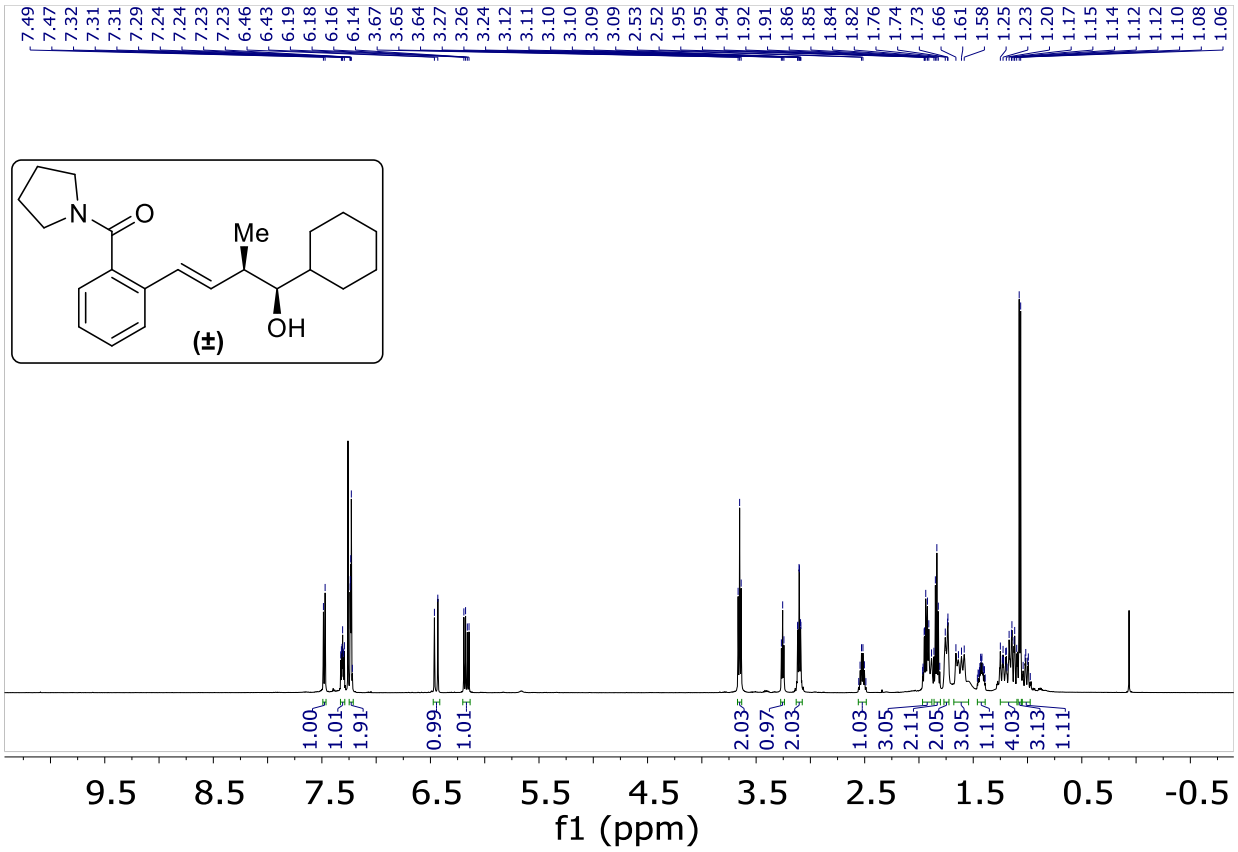

169.63
138.02 136.49 135.16 133.77 128.98 128.50 127.81 127.77 127.36 127.10 126.27 126.01
73.75 73.45 72.84
48.25 45.57 40.80
26.03 24.68
16.26
N
O
Me
OBn
OH
(±)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

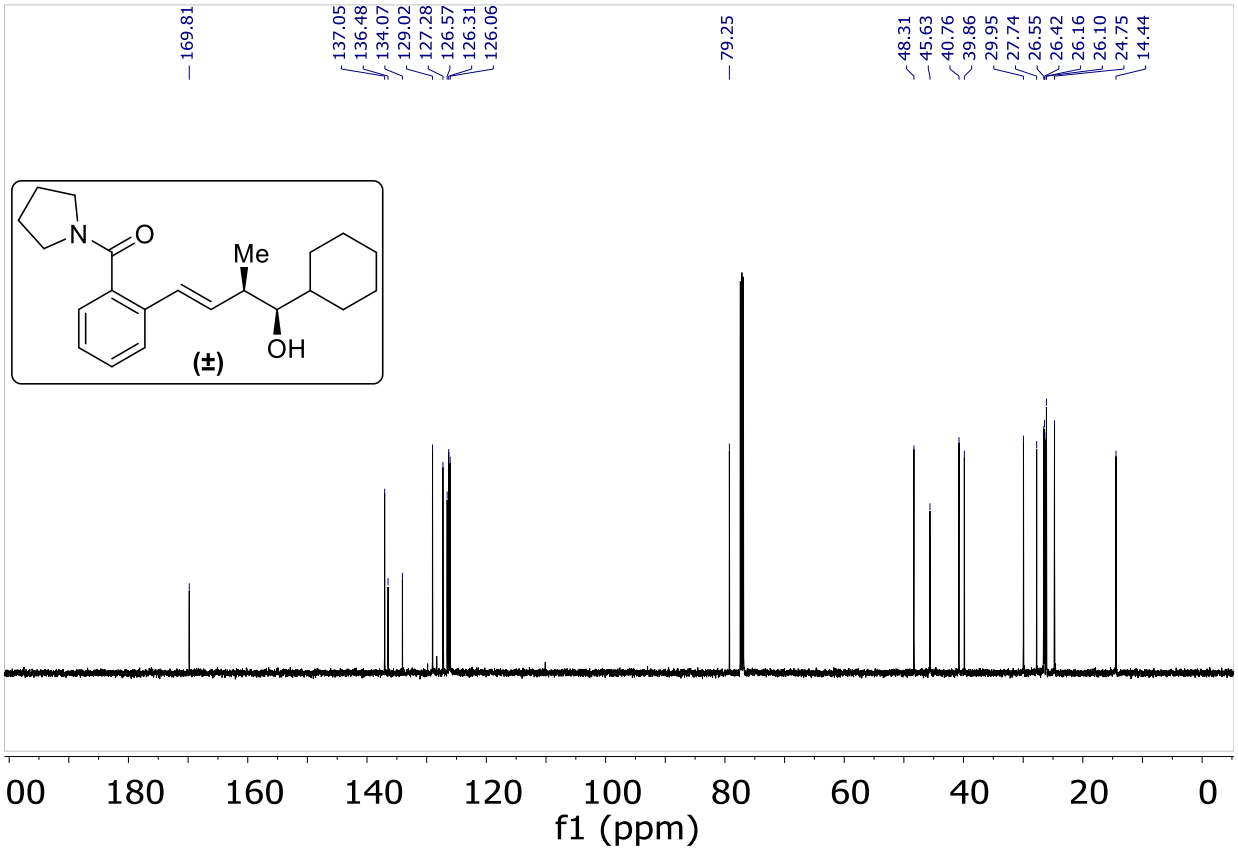

7.67 7.65 7.47 7.45 7.42 7.41 7.39 7.38 7.36 7.35 7.31 7.31 7.30 7.30 7.29 7.29 7.24 7.24 7.23 6.47 6.44 6.17 6.15 6.13 6.12
3.67 3.66 3.65 3.63 3.51 3.11 3.10 3.09 2.39 2.38 1.93 1.92 1.91 1.89 1.84 1.83 1.81 1.80 1.67 1.58 1.57 1.57 1.56 1.55 1.49 1.39 1.38 1.37 1.08 1.06 1.04
N
O
Me
OTBDPS
OH
(±)
3.97 1.02 6.06 1.02 1.93 1.00 1.01 4.12 1.04 2.04 1.03 2.07 2.37 0.99 3.16 1.14 2.12 3.01 9.03
.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

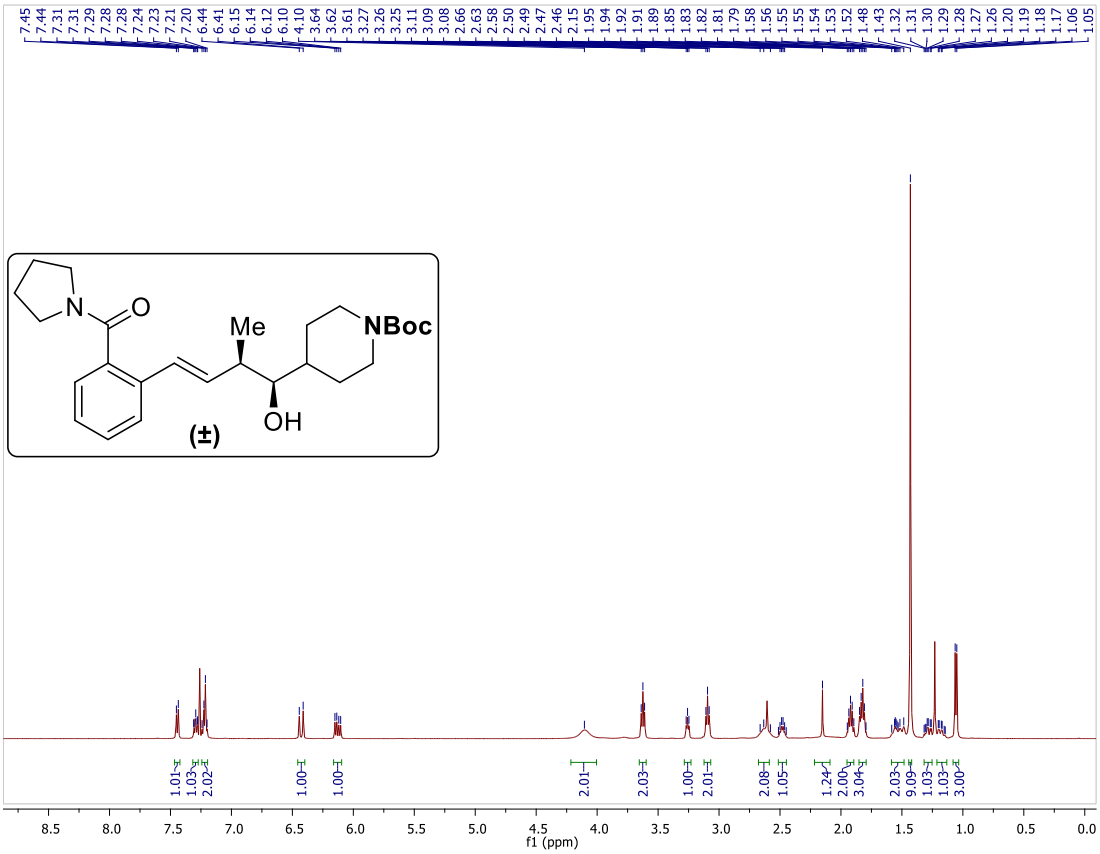

169.79
136.51 136.13 135.67 134.17 134.09 129.63 129.04 127.70 127.33 127.29 126.32 126.17
75.18
63.96
48.34 45.64 43.43 34.14 32.64 27.00 26.09 24.74 22.55 19.33 14.94
N
O
Me
OTBDPS
OH
(±)
180 160 140 120 100 80 60 40 20 0
f1 (ppm)

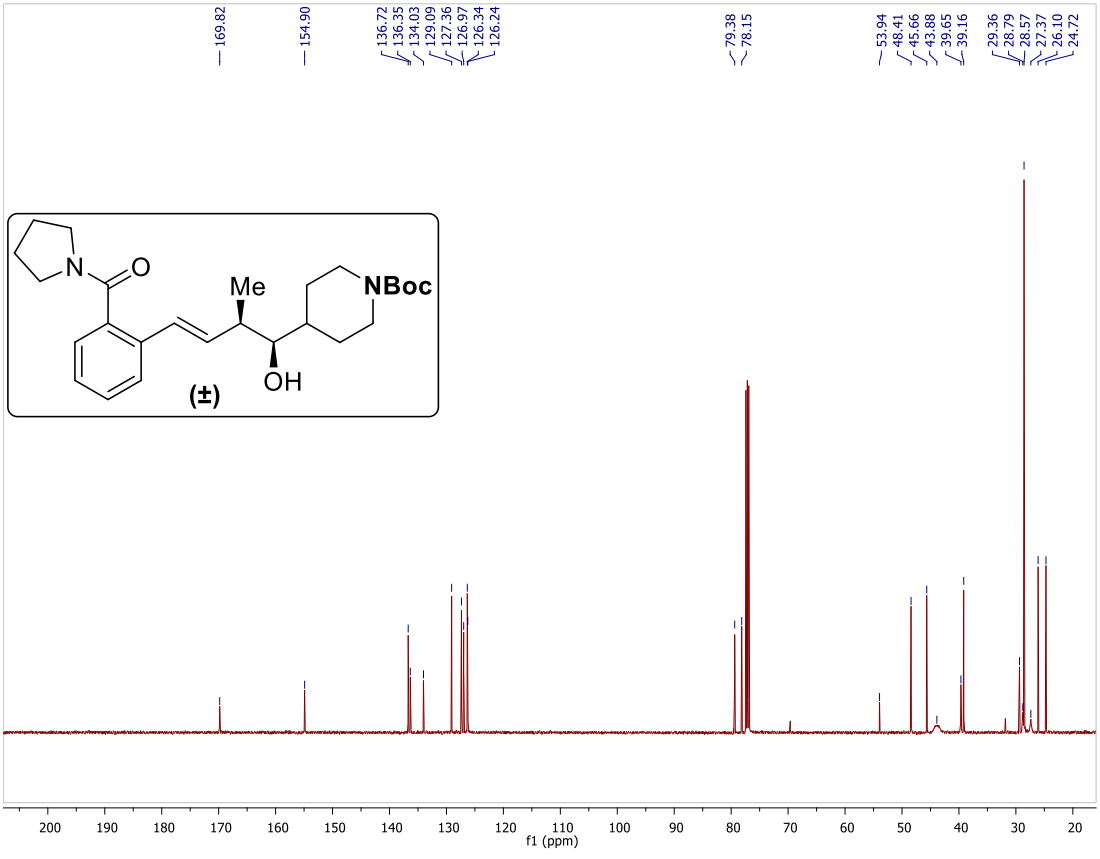

7.45 7.43 7.30 7.30 7.29 7.28 7.27 7.27 7.25 7.23 7.22 7.21 7.19 6.51 6.48 6.05 6.03 6.02 6.00 4.37 4.36 4.34 4.33 3.63 3.61 3.60 3.07 3.06 3.05 2.58 2.57 2.56 2.54 2.49 2.47 2.45 2.23 2.22 2.21 2.19 2.18 1.98 1.96 1.95 1.93 1.92 1.90 1.89 1.84 1.83 1.82 1.80 1.80 1.79 1.16 1.14
N
O
Me
O
O
(±)
1.01 1.03 2.02 1.00 1.02 1.01 2.13 2.05 1.04 2.08 1.04 3.21 2.14 3.05
0.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0
f1 (ppm)

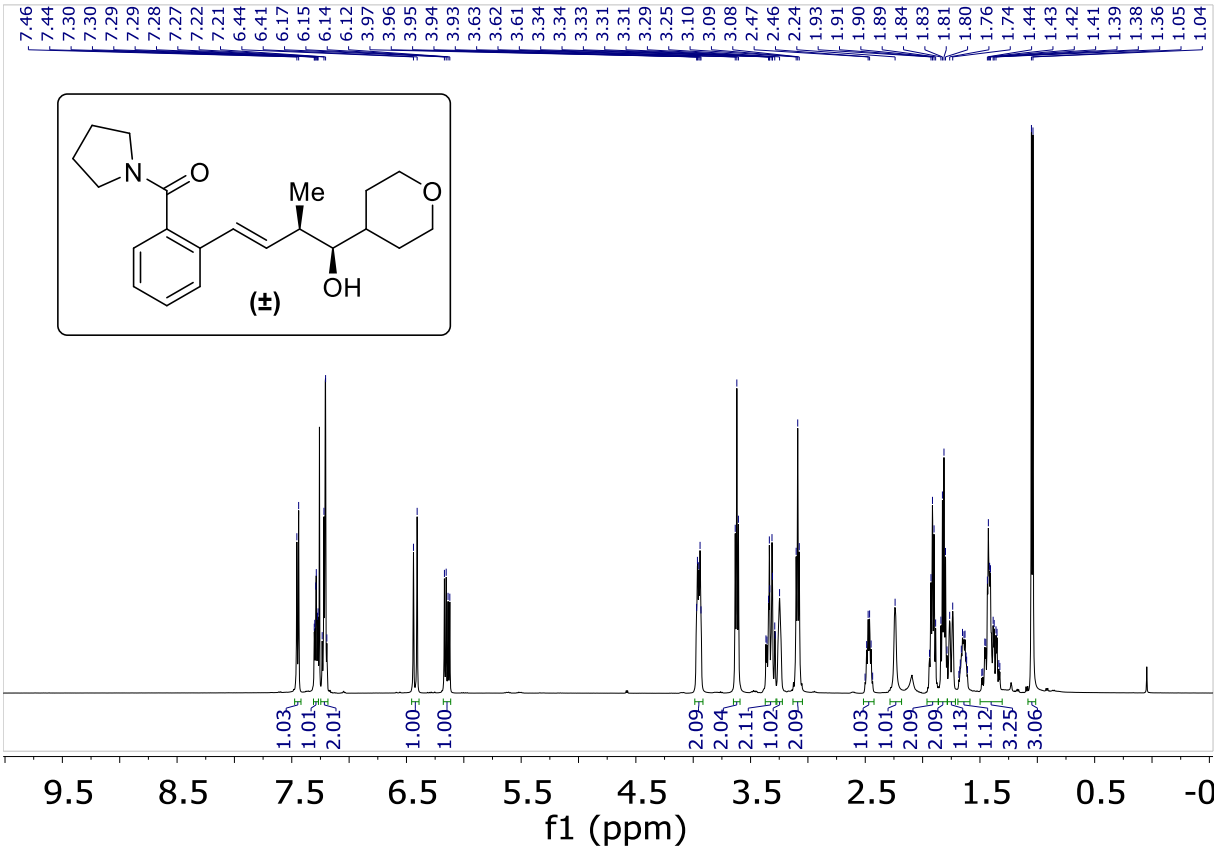

177.04 169.39 136.62 133.20 131.94 129.03 128.84 127.73 126.28 125.91 83.59 48.34 45.58 42.23 28.81 26.01 25.40 24.64 16.30
N
O
Me
O
O
(±)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

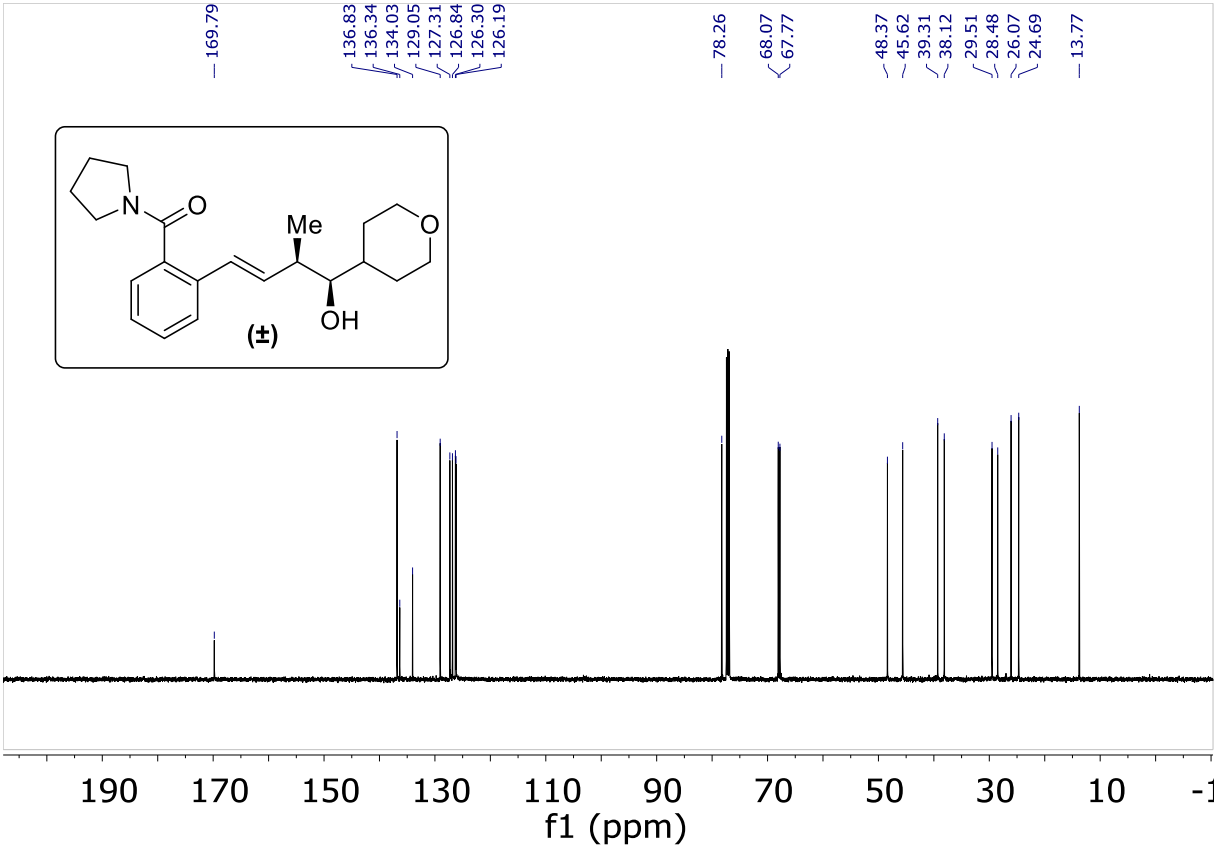

7.49 7.47 7.32 7.31 7.31 7.29 7.24 7.24 7.23 7.23 6.46 6.43 6.19 6.18 6.16 6.14 3.67 3.65 3.64 3.27 3.26 3.24 3.12 3.11 3.10 3.10 3.09 3.09 2.53 2.52 1.95 1.95 1.94 1.92 1.91 1.86 1.85 1.84 1.82 1.76 1.74 1.73 1.66 1.61 1.58 1.25 1.23 1.20 1.17 1.15 1.14 1.12 1.12 1.10 1.08 1.06
N
O
Me
OH
(±)
1.00 1.01 1.91 0.99 1.01 2.03 0.97 2.03 1.03 3.05 2.11 2.05 3.05 1.11 4.03 3.13 1.11
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0.5
f1 (ppm)

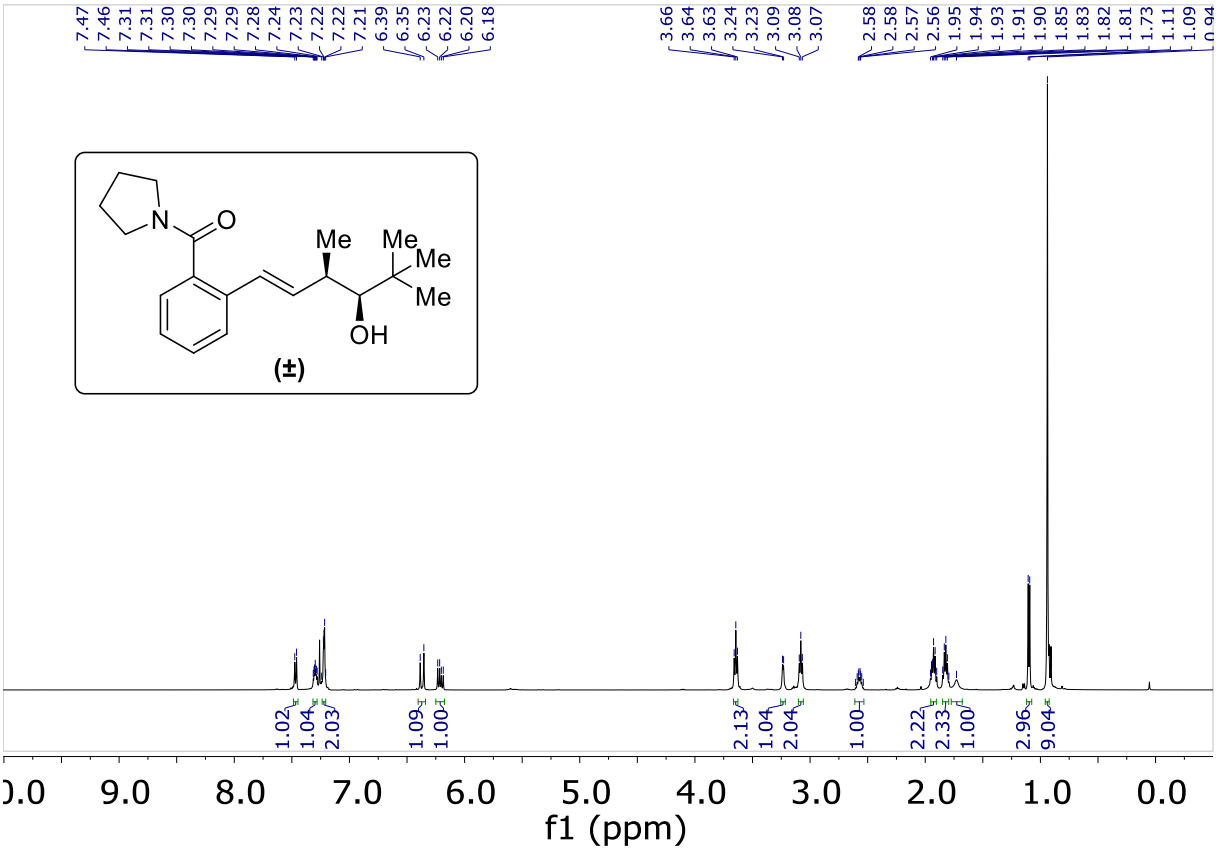

169.81
137.05 136.48 134.07 129.02 127.28 126.57 126.31 126.06
79.25
48.31 45.63 40.76 39.86 29.95 27.74 26.55 26.42 26.16 26.10 24.75 14.44
N
O
Me
OH
(±)
00 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

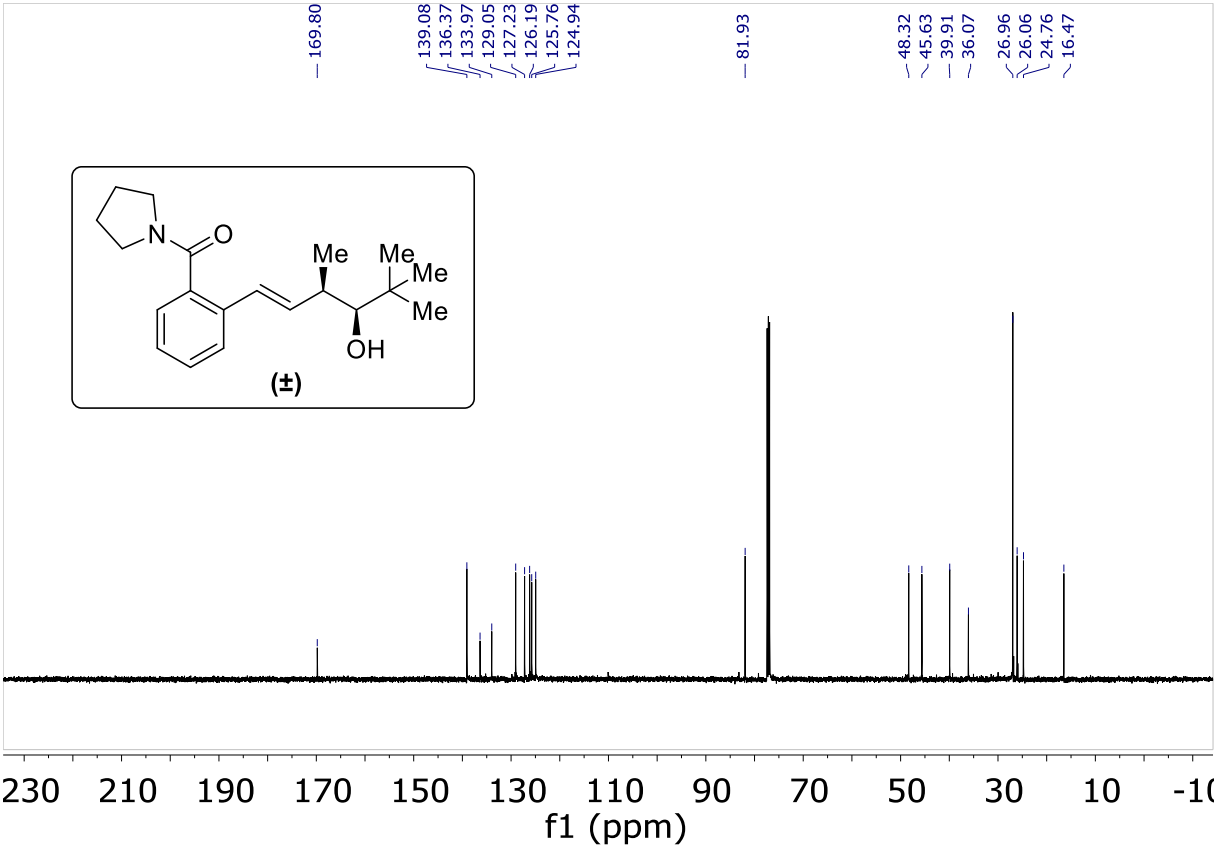

N
O
Me
NBoc
OH
(±)
f1 (ppm)

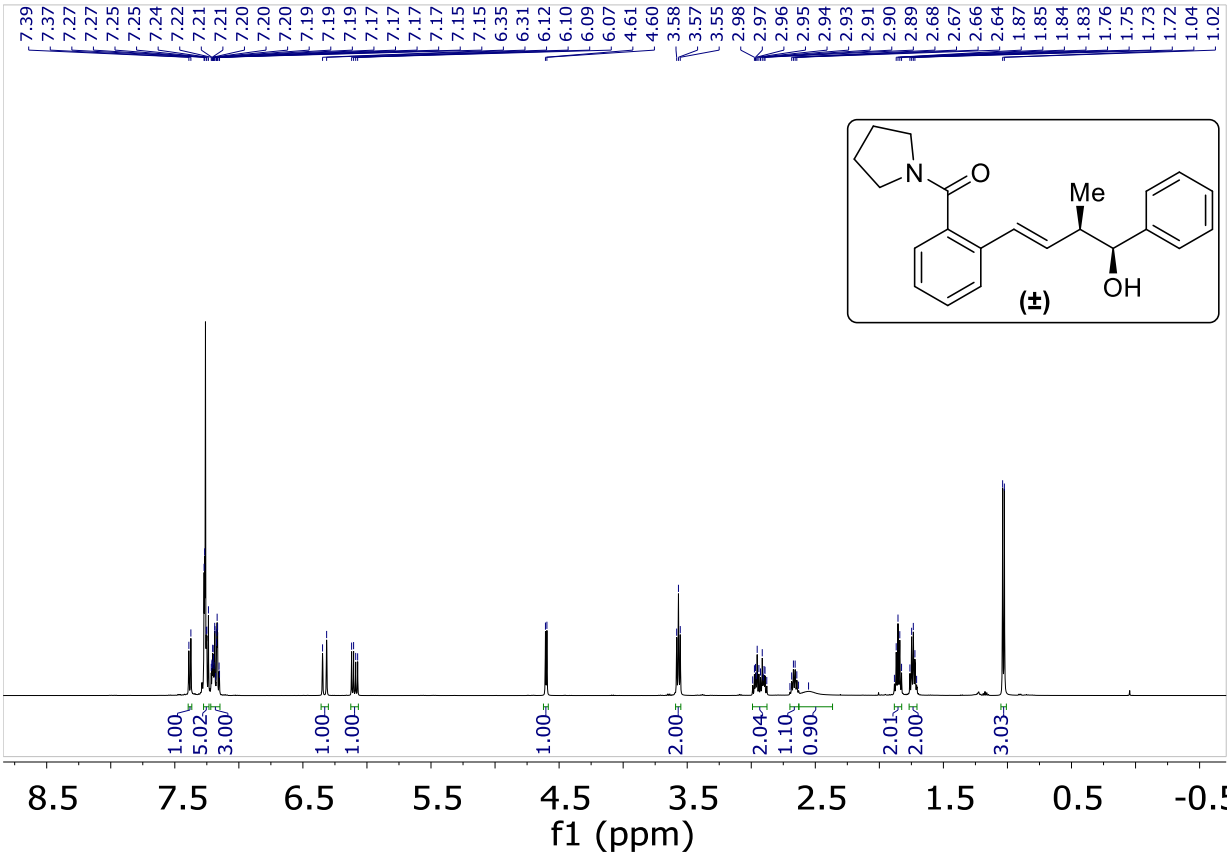

N
O
Me
NBoc
OH
(±)
f1 (ppm)

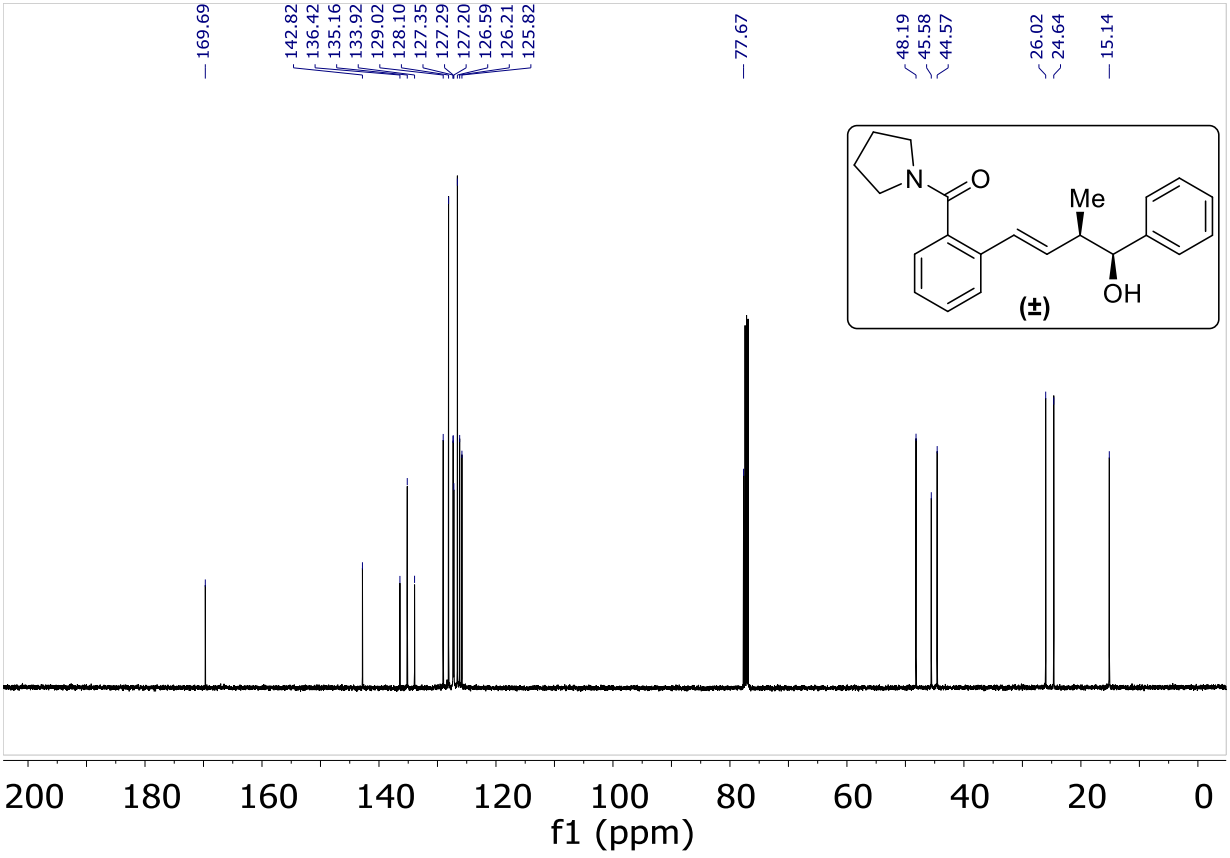

7.46 7.44 7.30 7.30 7.29 7.29 7.28 7.27 7.22 7.21 6.44 6.41 6.17 6.15 6.14 6.12 3.97 3.96 3.95 3.94 3.93 3.63 3.62 3.61 3.34 3.34 3.33 3.31 3.31 3.29 3.25 3.10 3.09 3.08 2.47 2.46 2.24 1.93 1.91 1.90 1.89 1.84 1.83 1.81 1.80 1.76 1.74 1.44 1.43 1.42 1.41 1.39 1.38 1.36 1.05 1.04
N
O
Me
O
OH
(±)
1.03 1.01 2.01 1.00 1.00 2.09 2.04 2.11 1.02 2.09 1.03 1.01 2.09 2.09 1.13 1.12 3.25 3.06
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)

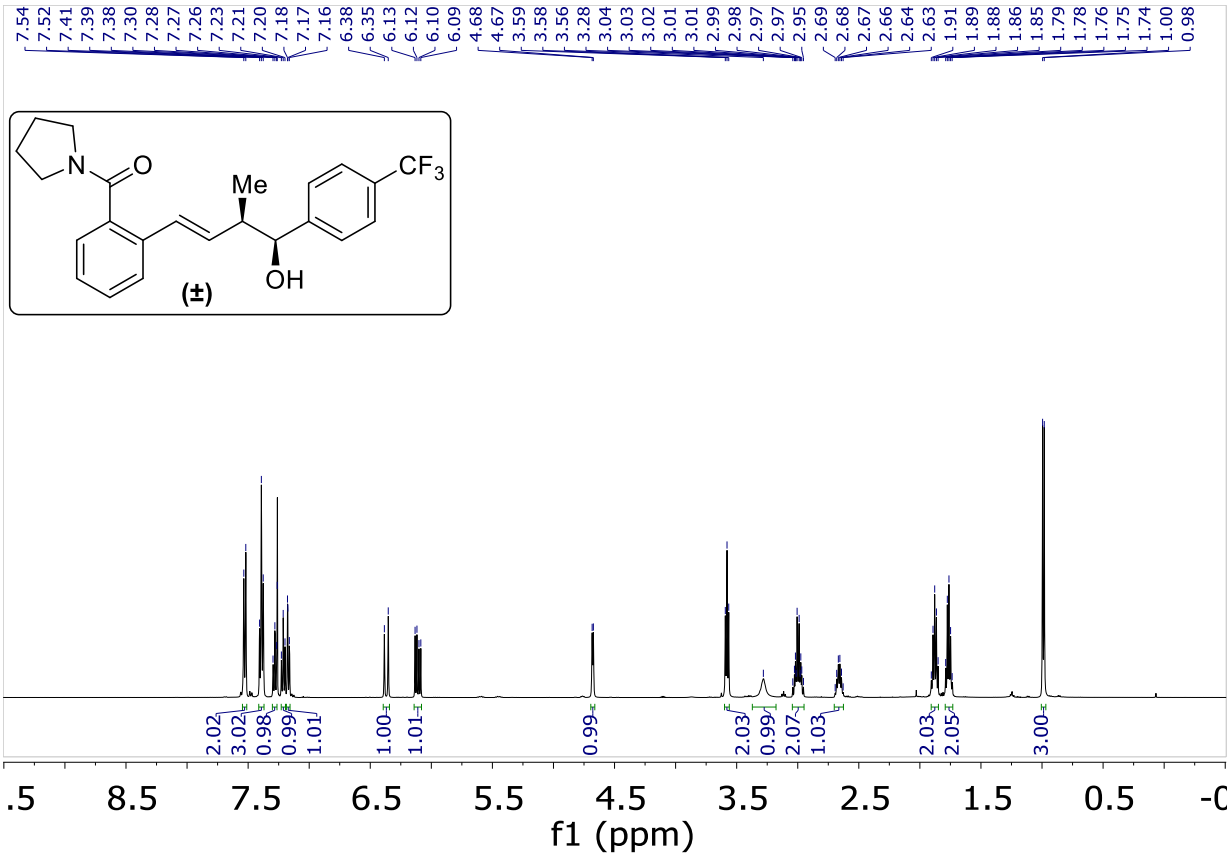

169.79
136.83 136.34 134.03 129.05 127.31 126.84 126.30 126.19
78.26
68.07 67.77
48.37 45.62 39.31 38.12 29.51 28.48 26.07 24.69
13.77
N
O
Me
O
OH
(±)
190 170 150 130 110 90 70 50 30 10 -1
f1 (ppm)

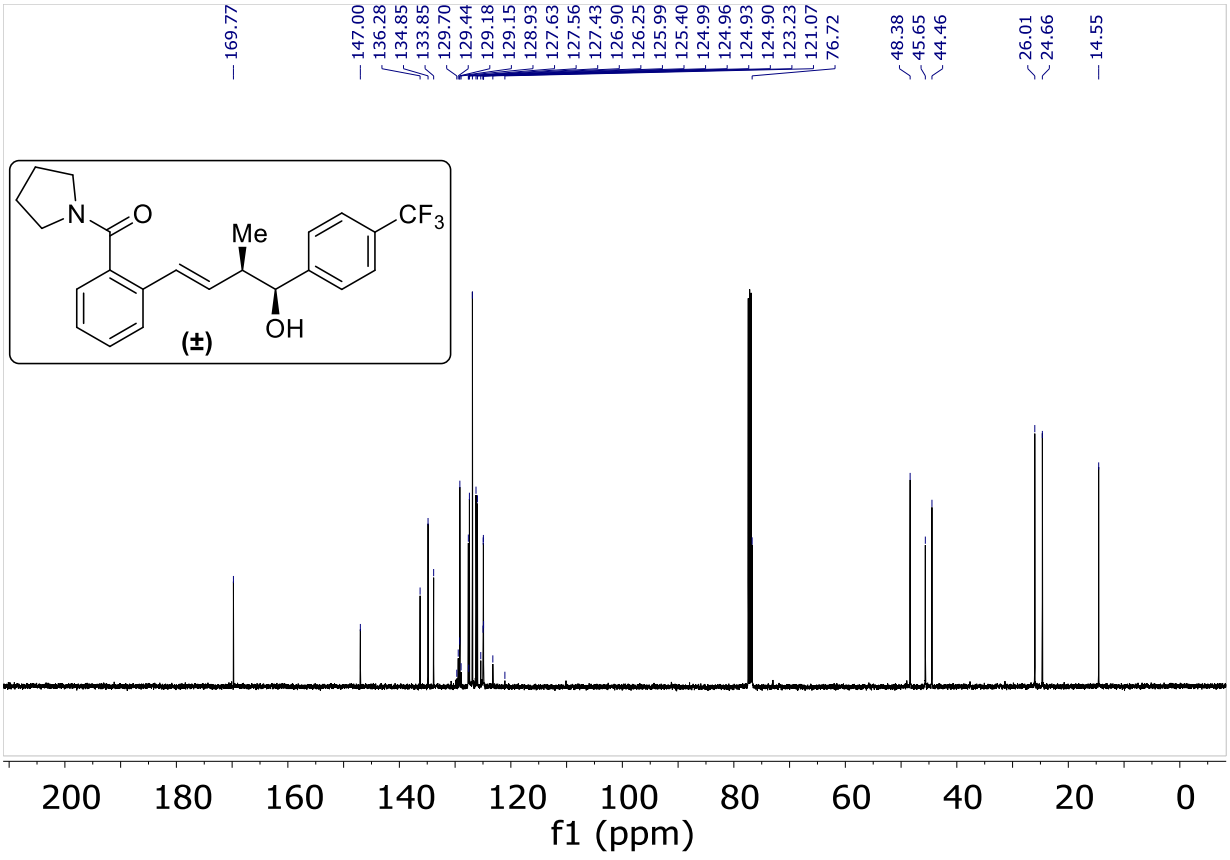

7.47 7.46 7.31 7.31 7.30 7.30 7.29 7.29 7.28 7.24 7.23 7.22 7.22 7.21 6.39 6.35 6.23 6.22 6.20 6.18
3.66 3.64 3.63 3.24 3.23 3.09 3.08 3.07
2.58 2.58 2.57 2.56 1.95 1.94 1.93 1.91 1.90 1.85 1.83 1.82 1.81 1.73 1.11 1.09
N
O
Me
Me
Me
Me
OH
(±)
1.02 1.04 2.03 1.09 1.00 2.13 1.04 2.04 1.00 2.22 2.33 1.00 2.96 9.04
f1 (ppm)

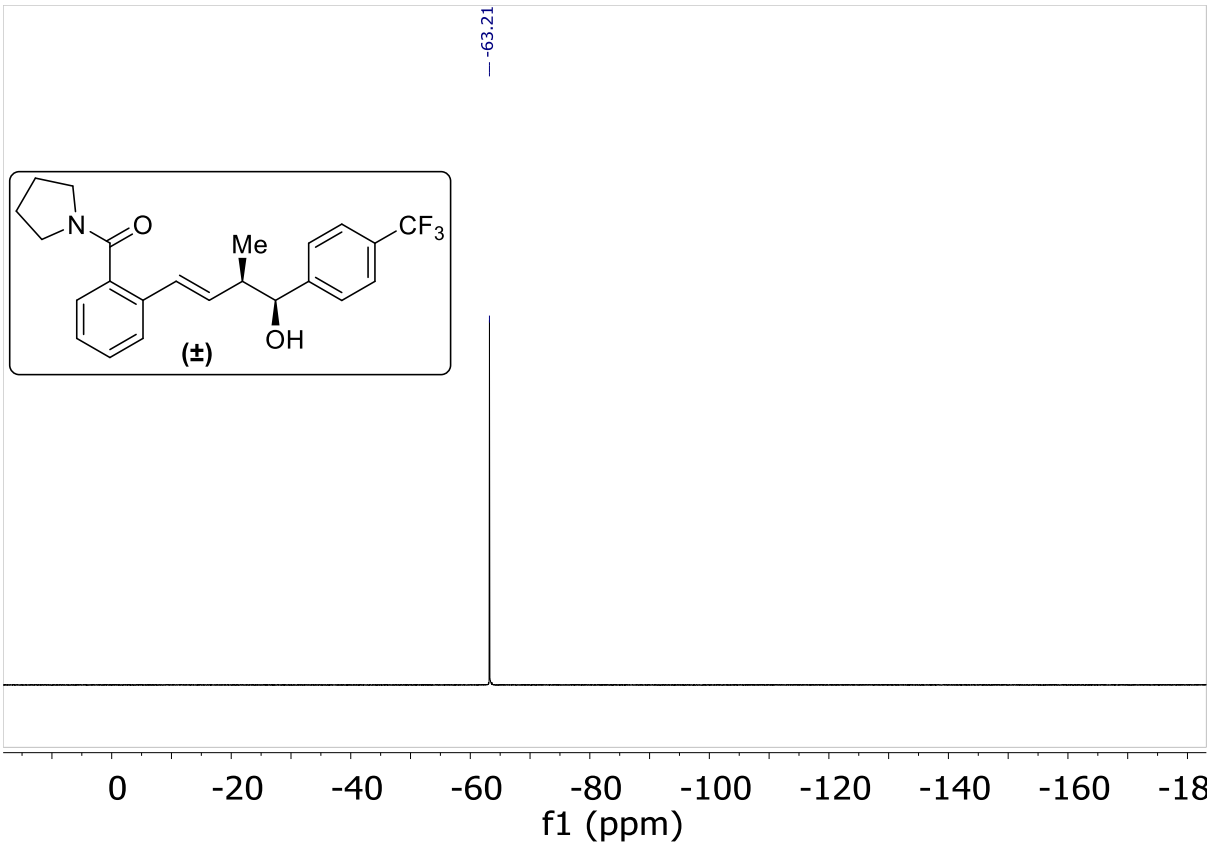

169.80
139.08 136.37 133.97 129.05 127.23 126.19 125.76 124.94
81.93
48.32 45.63 39.91 36.07 26.96 26.06 24.76 16.47
N
O
Me
Me
Me
Me
OH
(±)
f1 (ppm)

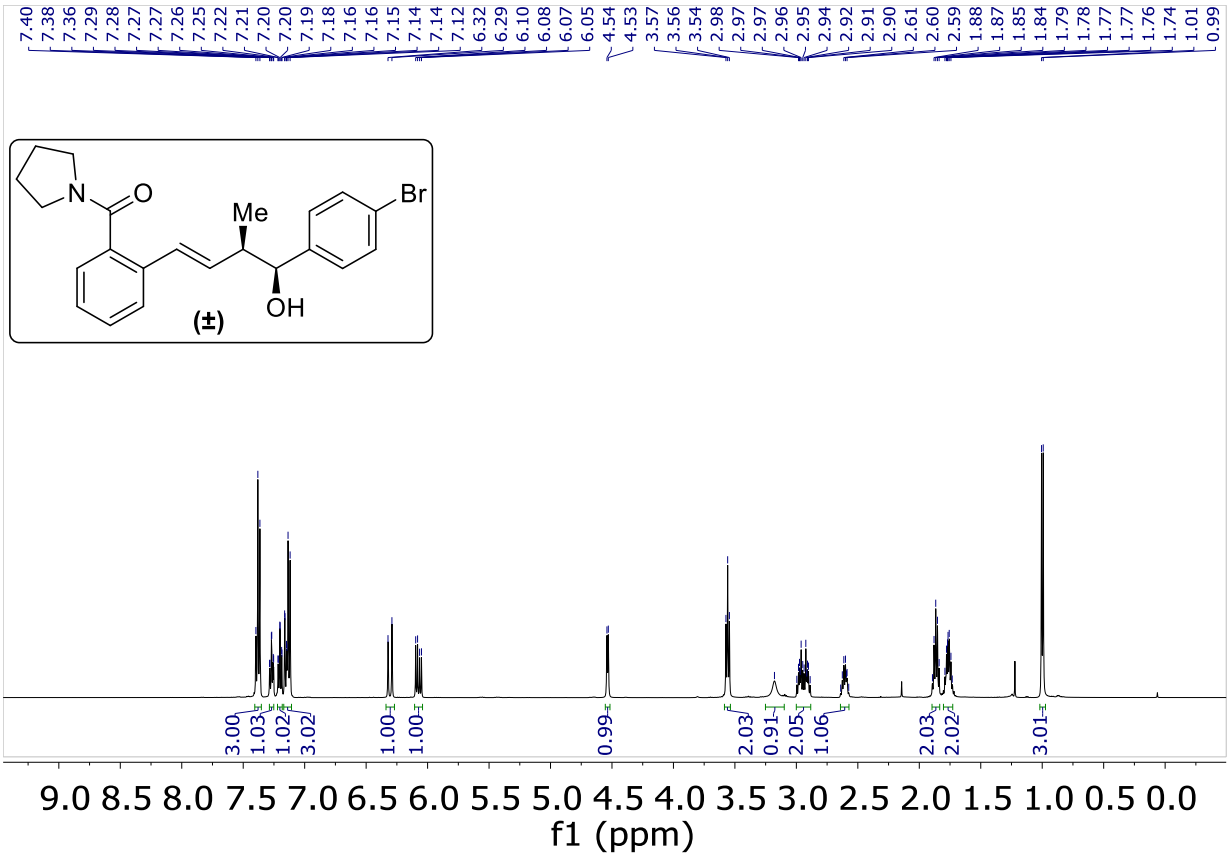

7.39 7.37 7.27 7.27 7.25 7.25 7.24 7.22 7.21 7.21 7.20 7.20 7.20 7.19 7.19 7.19 7.17 7.17 7.17 7.17 7.15 7.15 6.35 6.31 6.12 6.10 6.09 6.07 4.61 4.60 3.58 3.57 3.55 2.98 2.97 2.96 2.95 2.94 2.93 2.91 2.90 2.89 2.68 2.67 2.66 2.64 1.87 1.85 1.84 1.83 1.76 1.75 1.73 1.72 1.04 1.02
N
O
Me
OH
(±)
1.00 5.02 3.00 1.00 1.00 1.00 2.00 2.04 1.10 0.90 2.01 2.00 3.03
8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5
f1 (ppm)

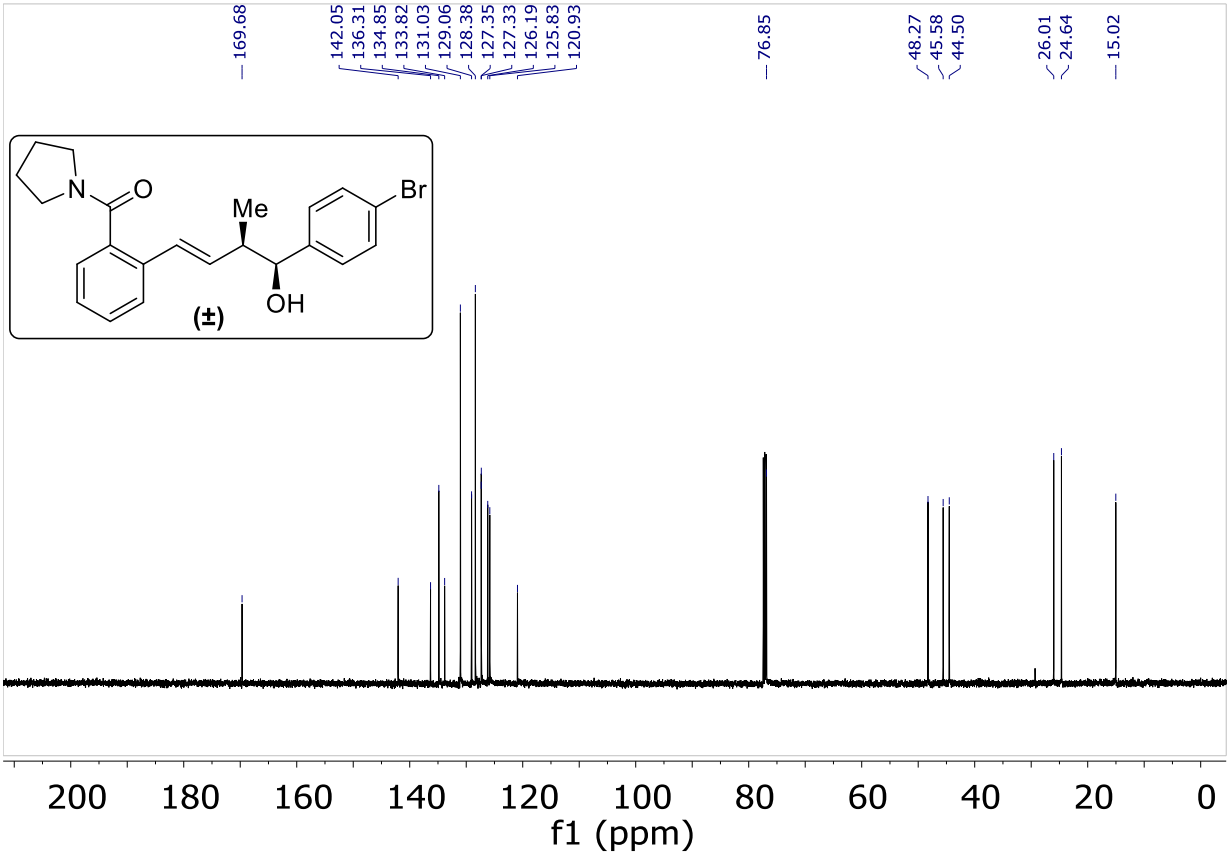

169.69
142.82 136.42 135.16 133.92 129.02 128.10 127.35 127.29 127.20 126.59 126.21 125.82
77.67
48.19 45.58 44.57
26.02 24.64
15.14
N
O
Me
OH
(±)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

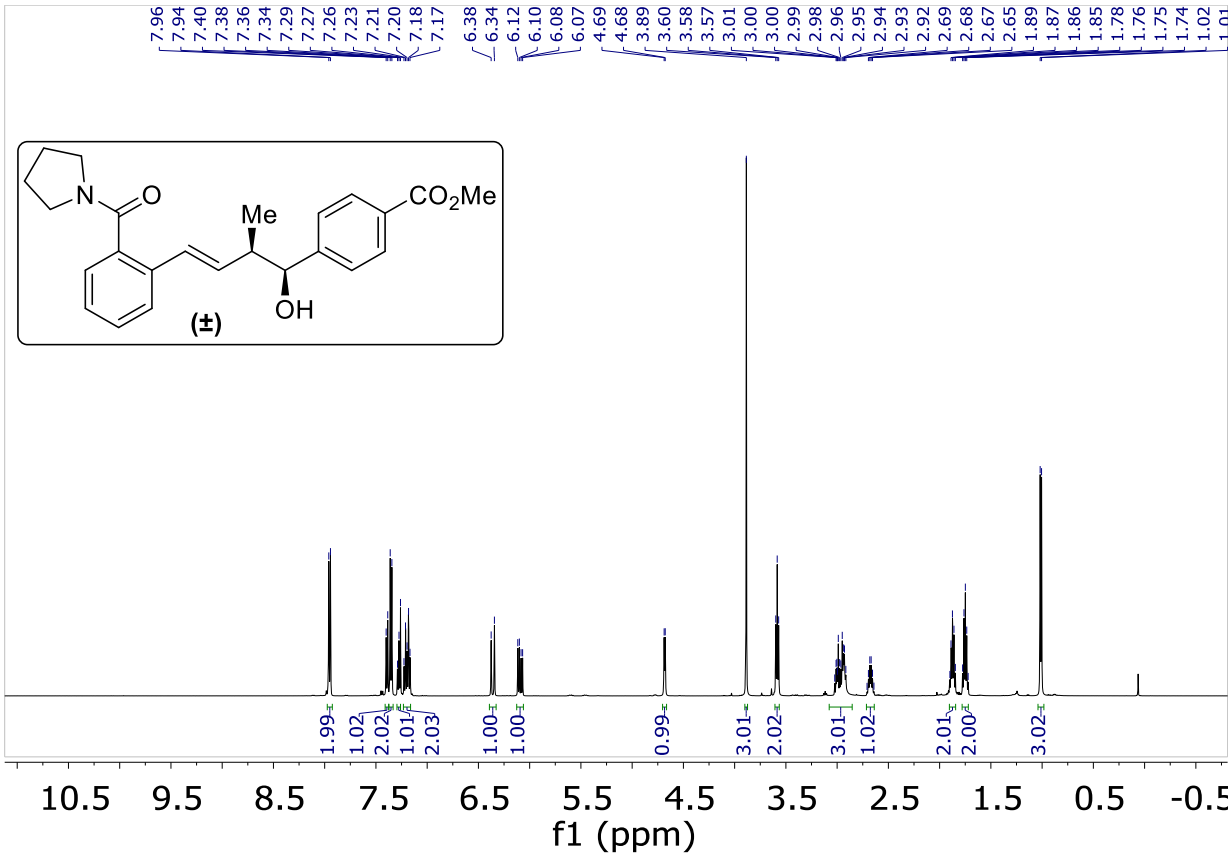

7.54 7.52 7.41 7.39 7.38 7.30 7.28 7.27 7.26 7.23 7.21 7.20 7.18 7.17 7.16 6.38 6.35 6.13 6.12 6.10 6.09 4.68 4.67 3.59 3.58 3.56 3.28 3.04 3.03 3.02 3.01 3.01 2.99 2.98 2.97 2.97 2.95 2.69 2.68 2.67 2.66 2.64 2.63 1.91 1.89 1.88 1.86 1.85 1.79 1.78 1.76 1.75 1.74 1.00 0.98
N
O
Me
CF3
OH
(±)
2.02 3.02 0.98 0.99 1.01 1.00 1.01 0.99 2.03 0.99 2.07 1.03 2.03 2.05 3.00
.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)

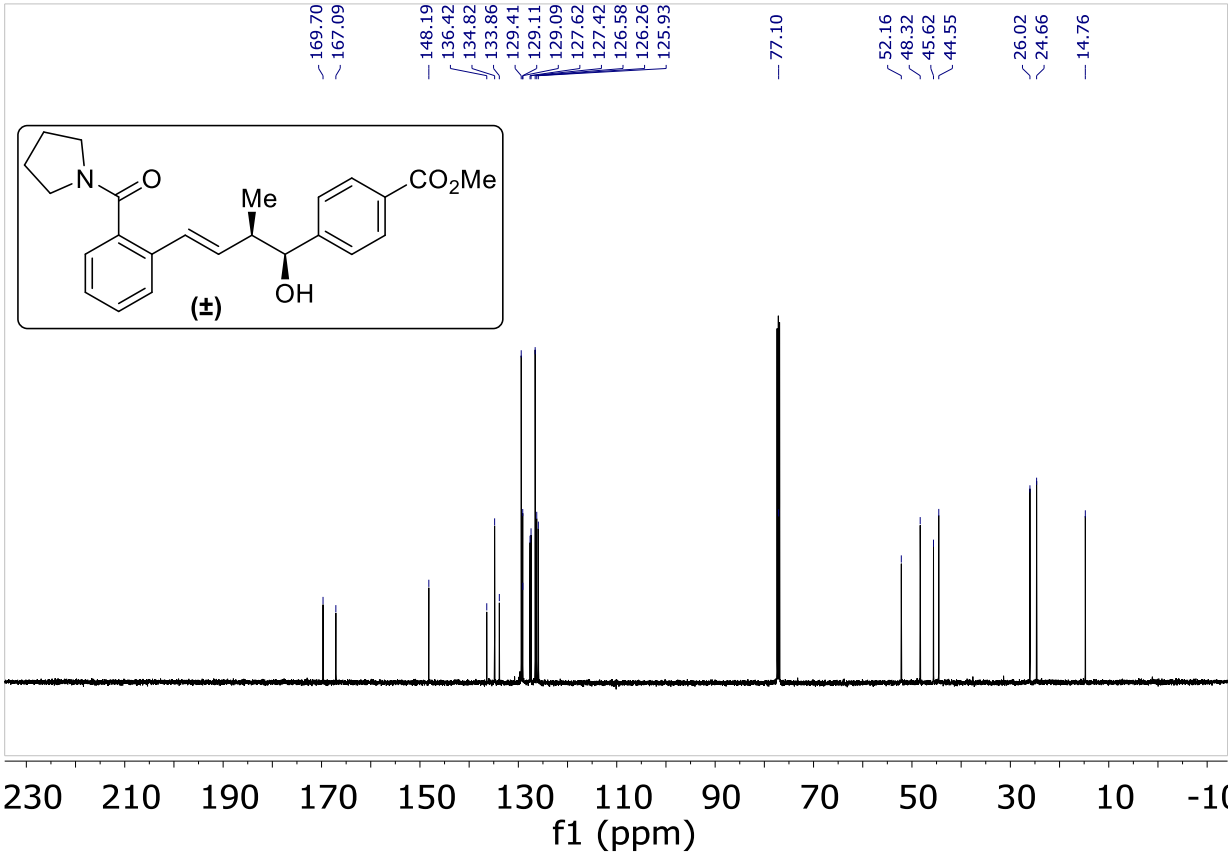

169.77
147.00 136.28 134.85 133.85 129.70 129.44 129.18 129.15 128.93 127.63 127.56 127.43 126.90 126.25 125.99 125.40 124.99 124.96 124.93 124.90 123.23 121.07 76.72
48.38 45.65 44.46
26.01 24.66
14.55
N
O
Me
CF3
OH
(±)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

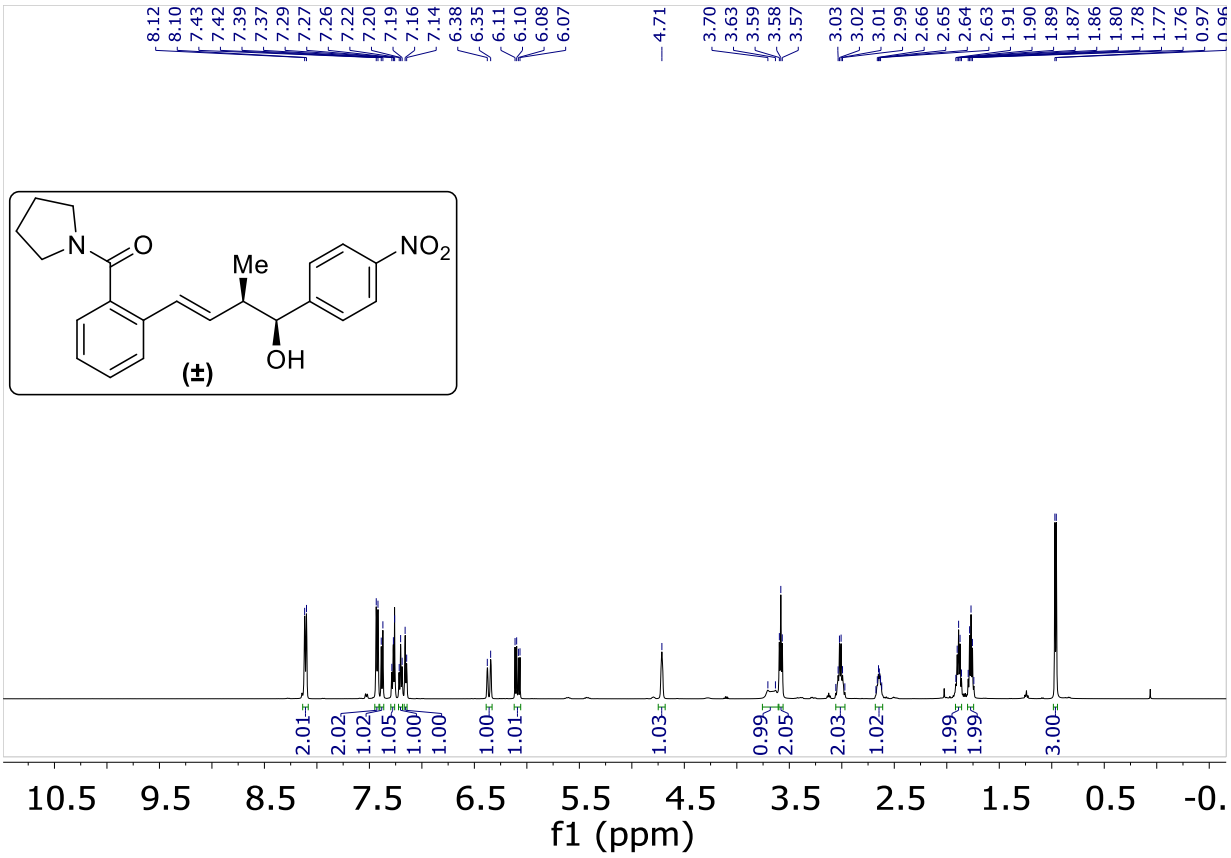

-63.21
N
O
Me
CF3
OH
(±)
0
-20
-40
-60
-80
-100
-120
-140
-160
-18
f1 (ppm)

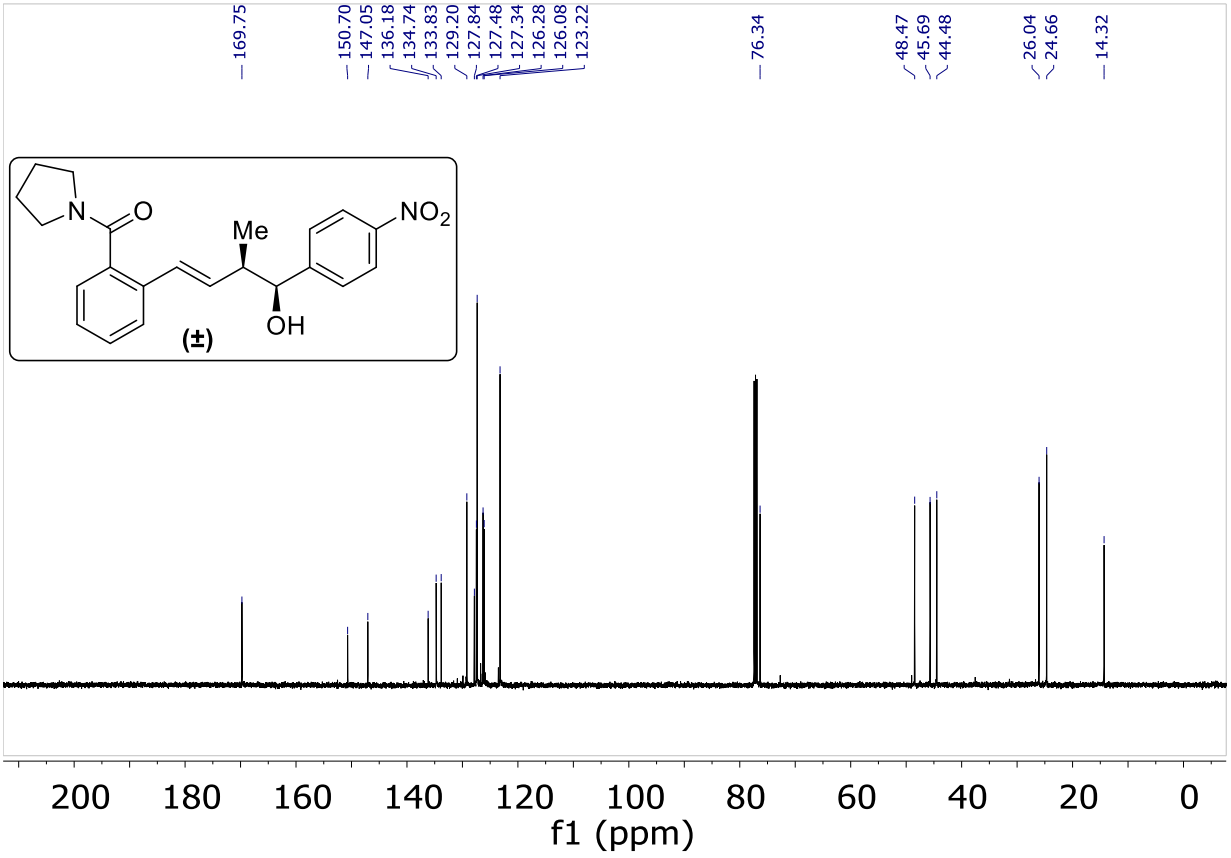

7.40 7.38 7.36 7.29 7.28 7.27 7.27 7.26 7.25 7.22 7.21 7.20 7.20 7.19 7.18 7.16 7.16 7.15 7.14 7.14 7.12 6.32 6.29 6.10 6.08 6.07 6.05 4.54 4.53 3.57 3.56 3.54 2.98 2.97 2.97 2.96 2.95 2.94 2.92 2.91 2.90 2.61 2.60 2.59 1.88 1.87 1.85 1.84 1.79 1.78 1.77 1.77 1.76 1.74 1.01 0.99
N
O
Me
Br
OH
(±)
3.00 1.03 1.02 3.02 1.00 1.00 0.99 2.03 0.91 2.05 1.06 2.03 2.02 3.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

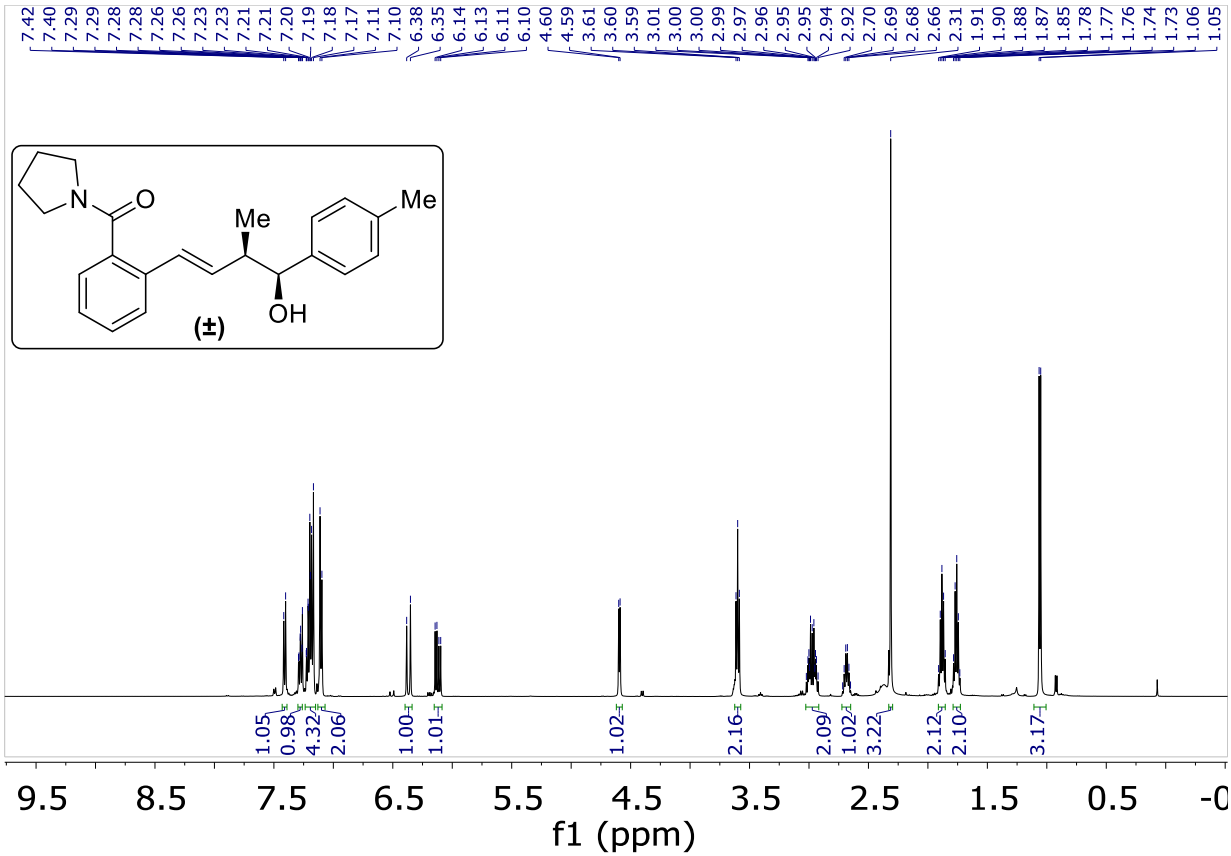

169.68
142.05 136.31 134.85 133.82 131.03 129.06 128.38 127.35 127.33 126.19 125.83 120.93
76.85
48.27 45.58 44.50
26.01 24.64
15.02
N
O
Me
Br
OH
(±)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

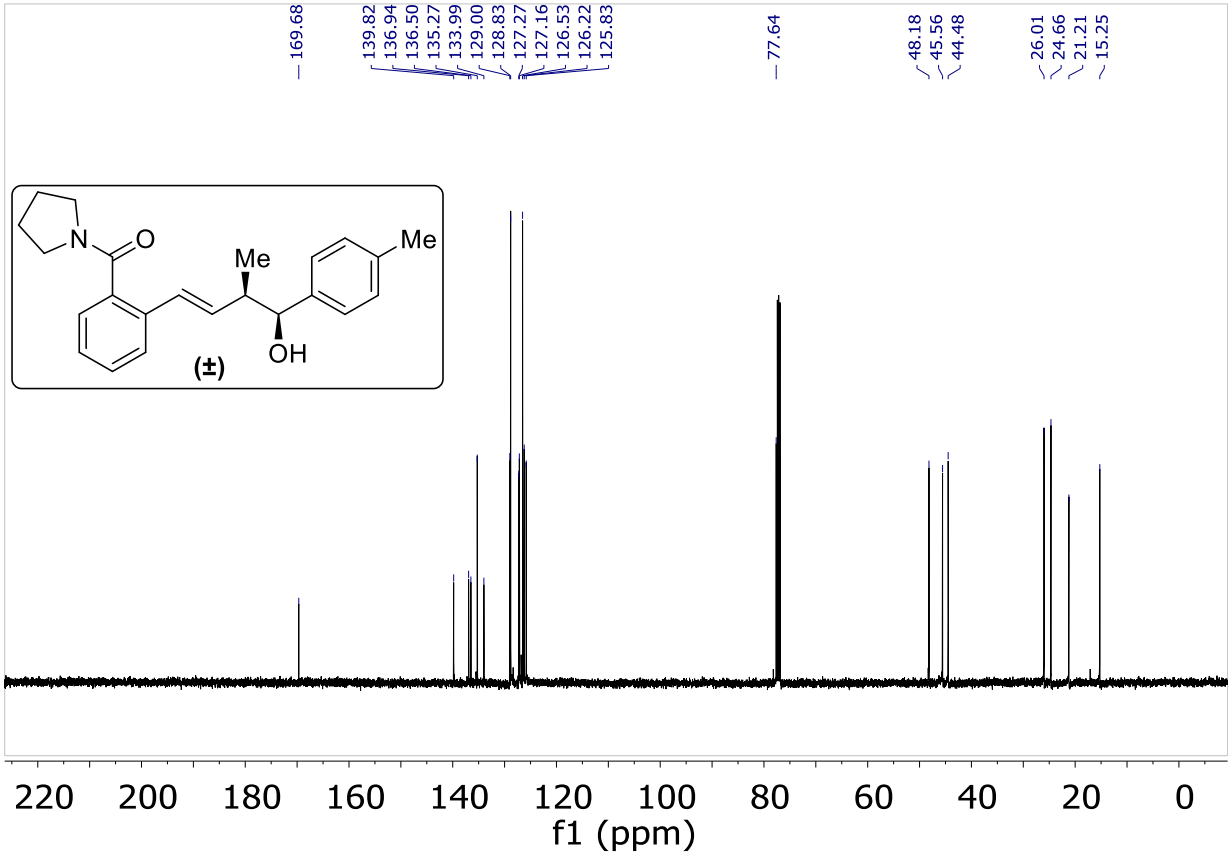

7.96 7.94 7.40 7.38 7.36 7.34 7.29 7.27 7.26 7.23 7.21 7.20 7.18 7.17 6.38 6.34 6.12 6.10 6.08 6.07 4.69 4.68 3.89 3.60 3.58 3.57 3.01 3.00 3.00 2.99 2.98 2.96 2.95 2.94 2.93 2.92 2.69 2.68 2.67 2.65 1.89 1.87 1.86 1.85 1.78 1.76 1.75 1.74 1.02
N O Me CO2Me OH (±)
1.99 1.02 2.02 1.01 2.03 1.00 1.00 0.99 3.01 2.02 3.01 1.02 2.01 2.00 3.02
10.5 9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0.5
f1 (ppm)

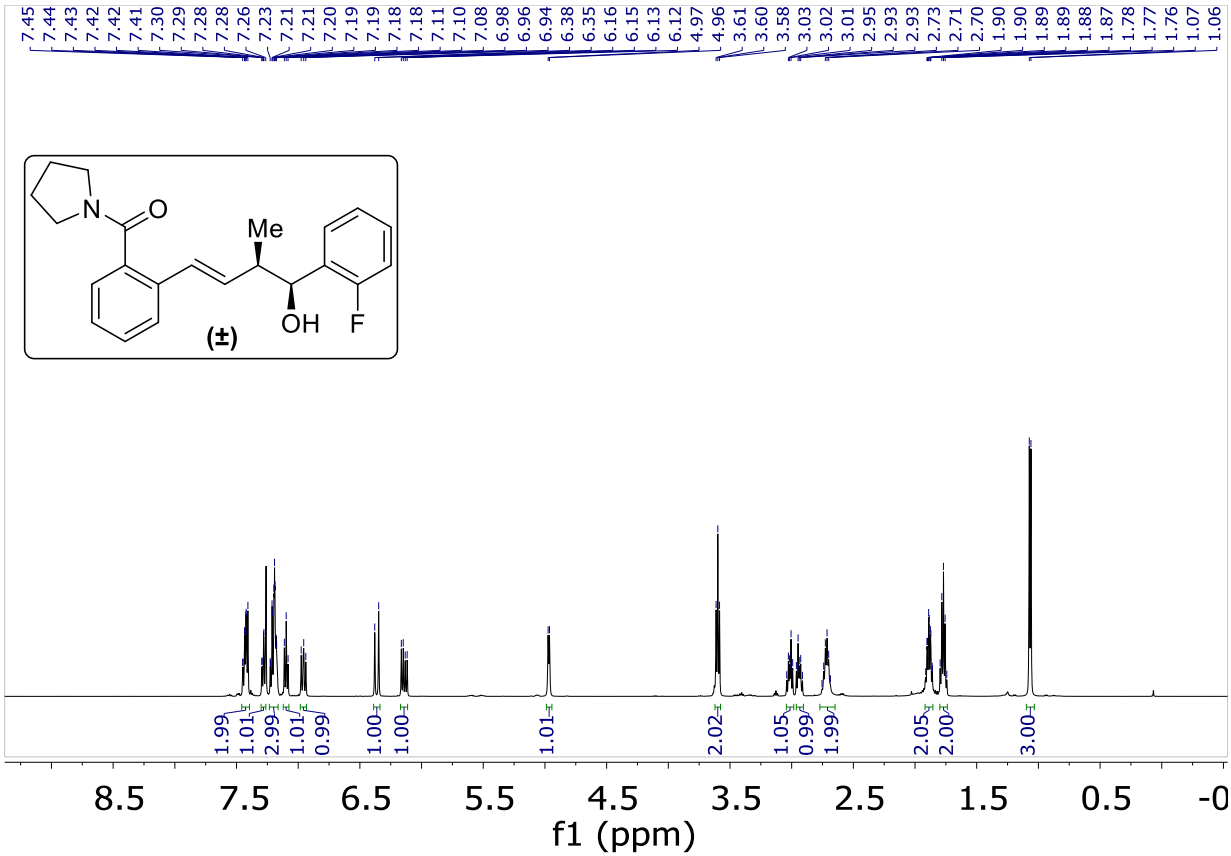

169.70 167.09 148.19 136.42 134.82 133.86 129.41 129.11 129.09 127.62 127.42 126.58 126.26 125.93 77.10 52.16 48.32 45.62 44.55 26.02 24.66 14.76
N O Me CO2Me OH (±)
230 210 190 170 150 130 110 90 70 50 30 10 -10
f1 (ppm)

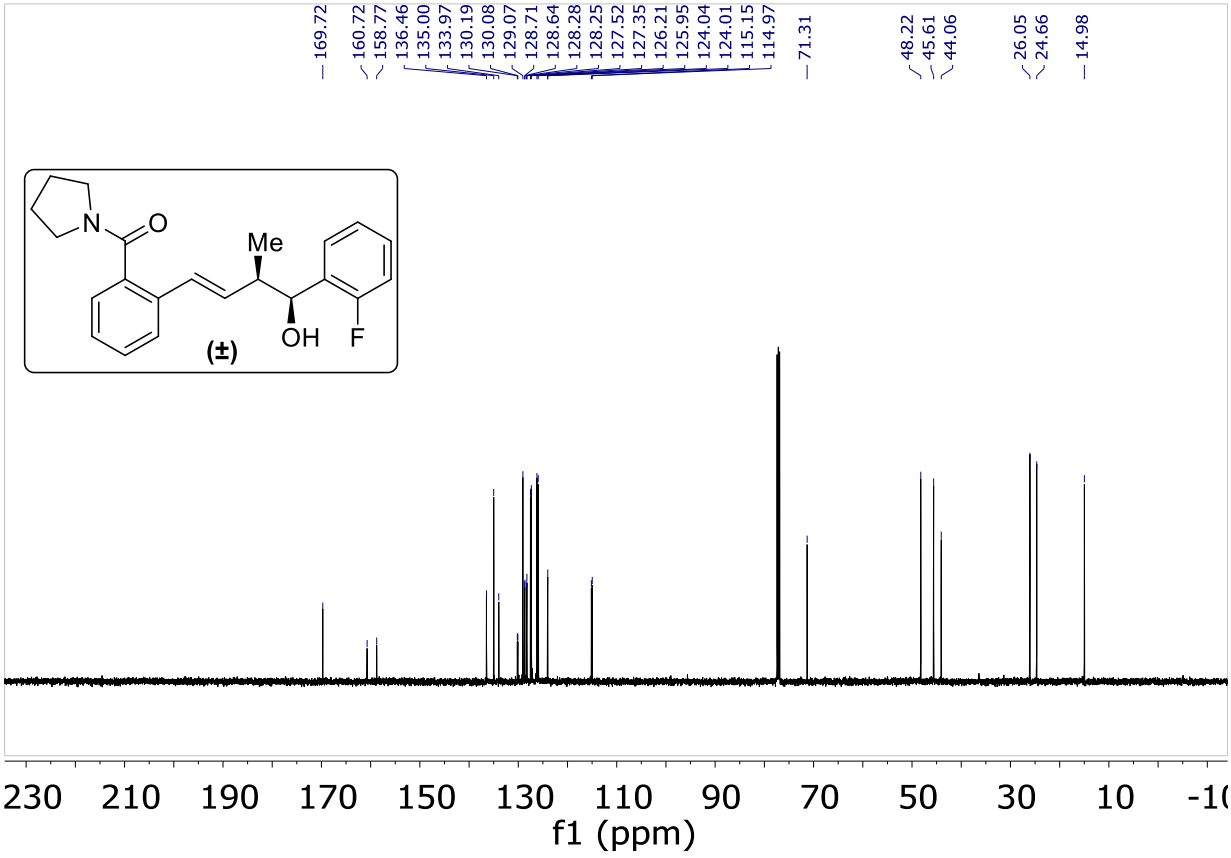

8.12
8.10
7.43
7.42
7.39
7.37
7.29
7.27
7.26
7.22
7.20
7.19
7.16
7.14
6.38
6.35
6.11
6.10
6.08
6.07
4.71
3.70
3.63
3.59
3.58
3.57
3.03
3.02
3.01
2.99
2.66
2.65
2.64
2.63
1.91
1.90
1.89
1.87
1.86
1.80
1.78
1.77
1.76
0.97
N
O
Me
NO2
OH
(±)
2.01
2.02
1.02
1.05
1.00
1.00
1.00
1.01
1.03
0.99
2.05
2.03
1.02
1.99
1.99
3.00
10.5
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.
f1 (ppm)

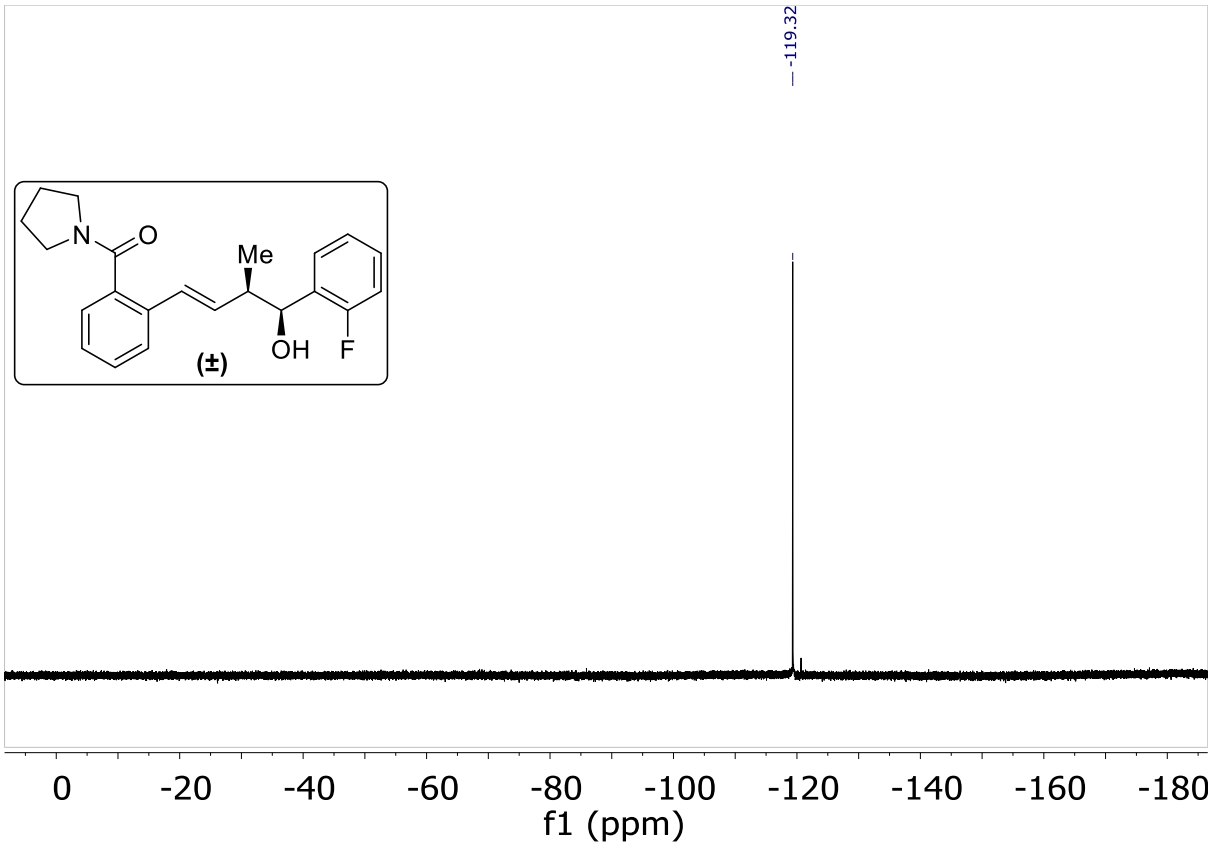

169.75
150.70
147.05
136.18
134.74
133.83
129.20
127.84
127.48
127.34
126.28
126.08
123.22
76.34
48.47
45.69
44.48
26.04
24.66
14.32
N
O
Me
NO2
OH
(±)
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

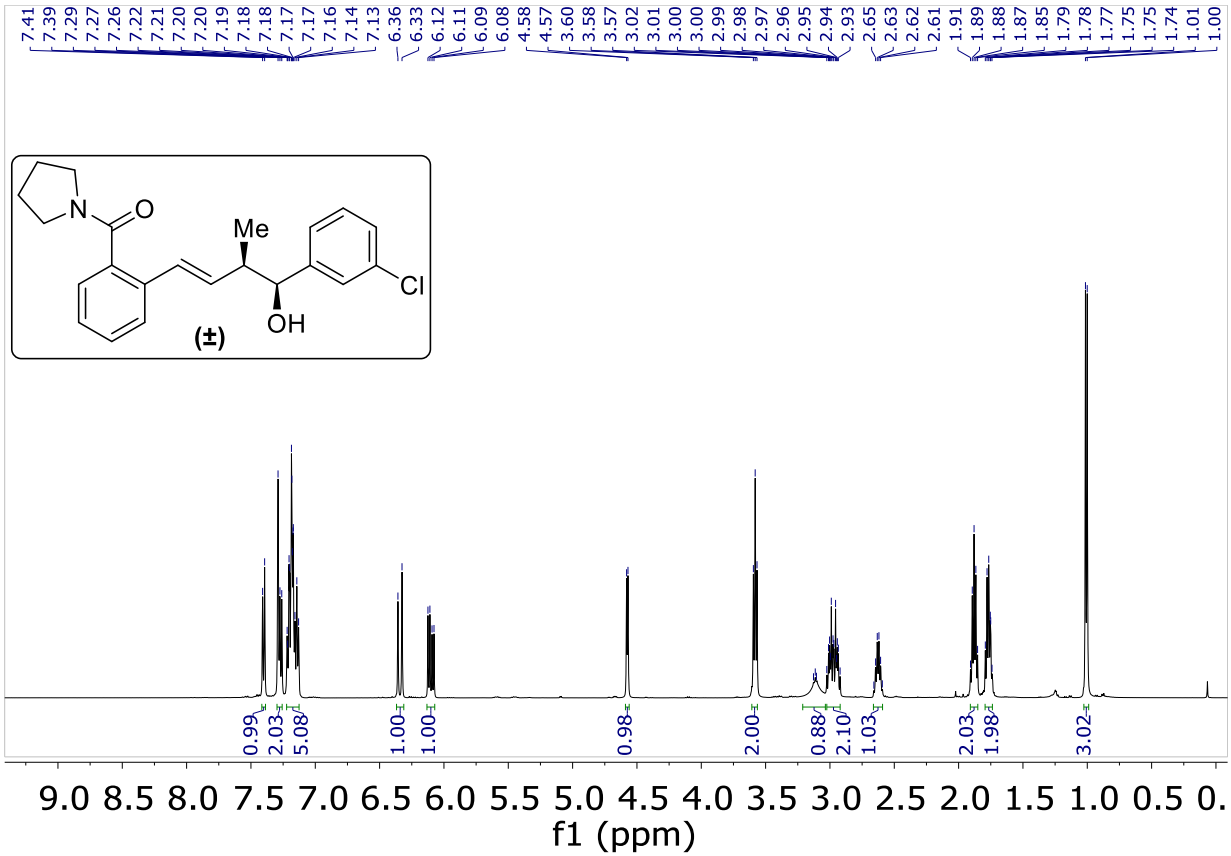

7.42 7.40 7.29 7.29 7.28 7.28 7.26 7.26 7.23 7.23 7.21 7.21 7.20 7.19 7.18 7.17 7.11 7.10 6.38 6.35 6.14 6.13 6.11 6.10 4.60 4.59 3.61 3.60 3.59 3.01 3.00 3.00 2.99 2.97 2.96 2.95 2.95 2.94 2.92 2.70 2.69 2.68 2.66 2.31 1.91 1.90 1.88 1.87 1.85 1.78 1.77 1.76 1.74 1.73 1.06 1.05
N
O
Me
Me
OH
(±)
1.05 0.98 4.32 2.06 1.00 1.01 1.02 2.16 2.09 1.02 3.22 2.12 2.10 3.17
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)

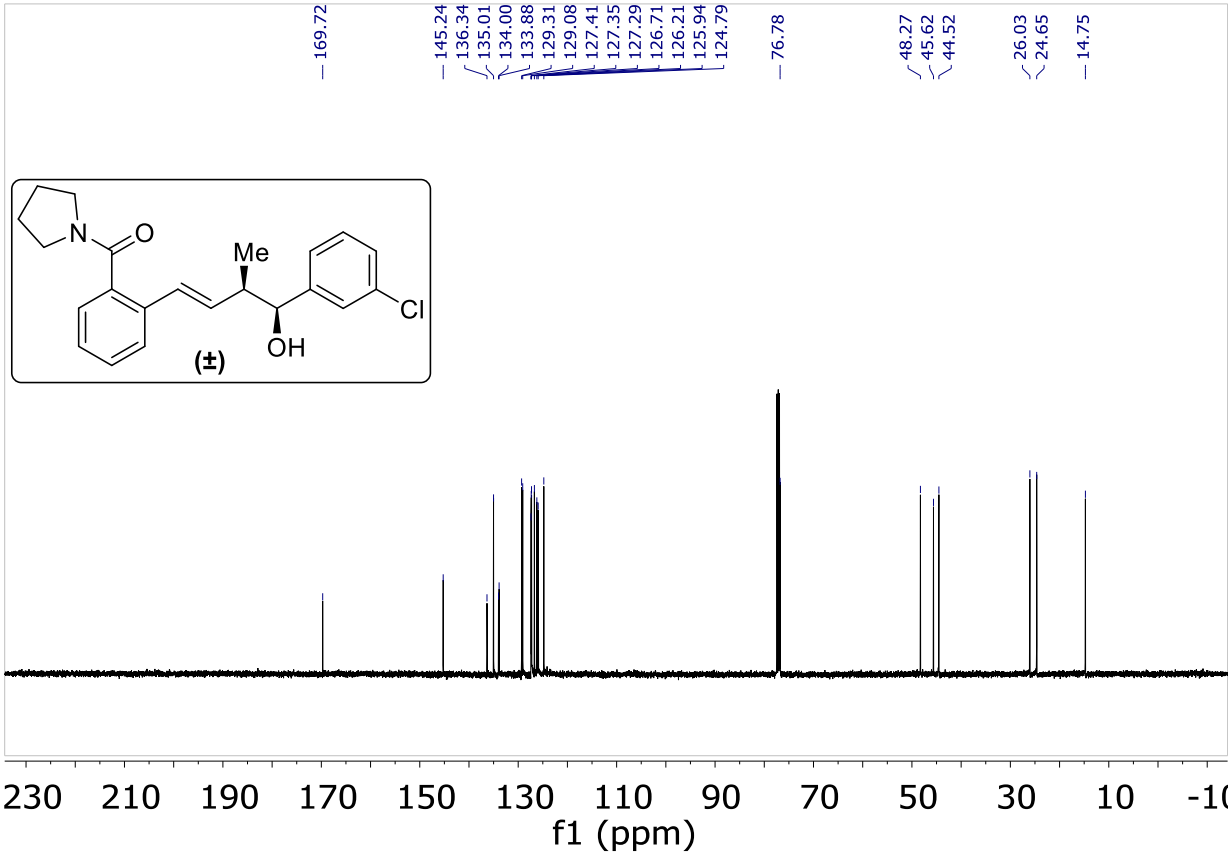

169.68
139.82 136.94 136.50 135.27 133.99 129.00 128.83 127.27 127.16 126.53 126.22 125.83
77.64
48.18 45.56 44.48
26.01 24.66 21.21 15.25
N
O
Me
Me
OH
(±)
220 200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

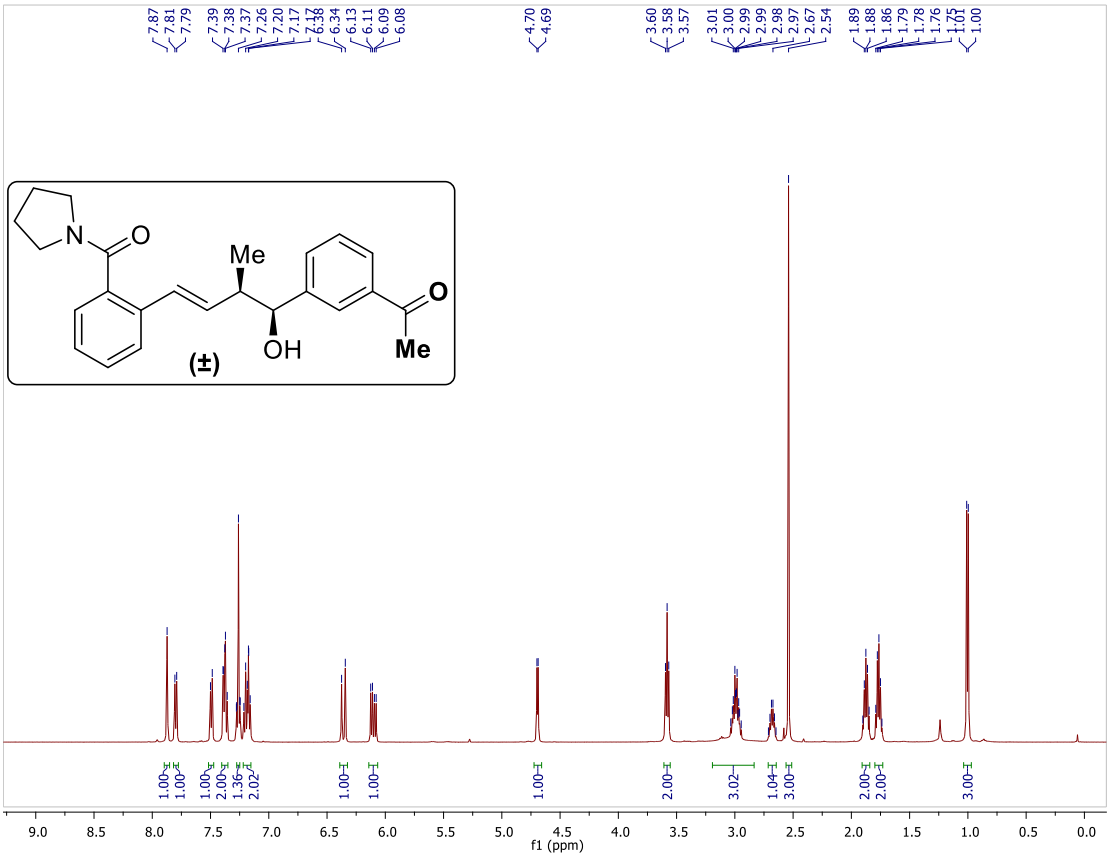

7.45 7.44 7.43 7.42 7.42 7.41 7.30 7.29 7.28 7.28 7.26 7.23 7.21 7.21 7.20 7.19 7.19 7.18 7.18 7.11 7.10 7.08 6.98 6.96 6.94 6.38 6.35 6.16 6.15 6.13 6.12 4.97 4.96 3.61 3.60 3.58 3.03 3.02 3.01 2.95 2.93 2.93 2.73 2.71 2.70 1.90 1.90 1.89 1.89 1.88 1.87 1.78 1.77 1.76 1.07 1.06
N
O
Me
OH
F
(±)
1.99 1.01 2.99 1.01 0.99 1.00 1.00 1.01 2.02 1.05 0.99 1.99 2.05 2.00 3.00
8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)

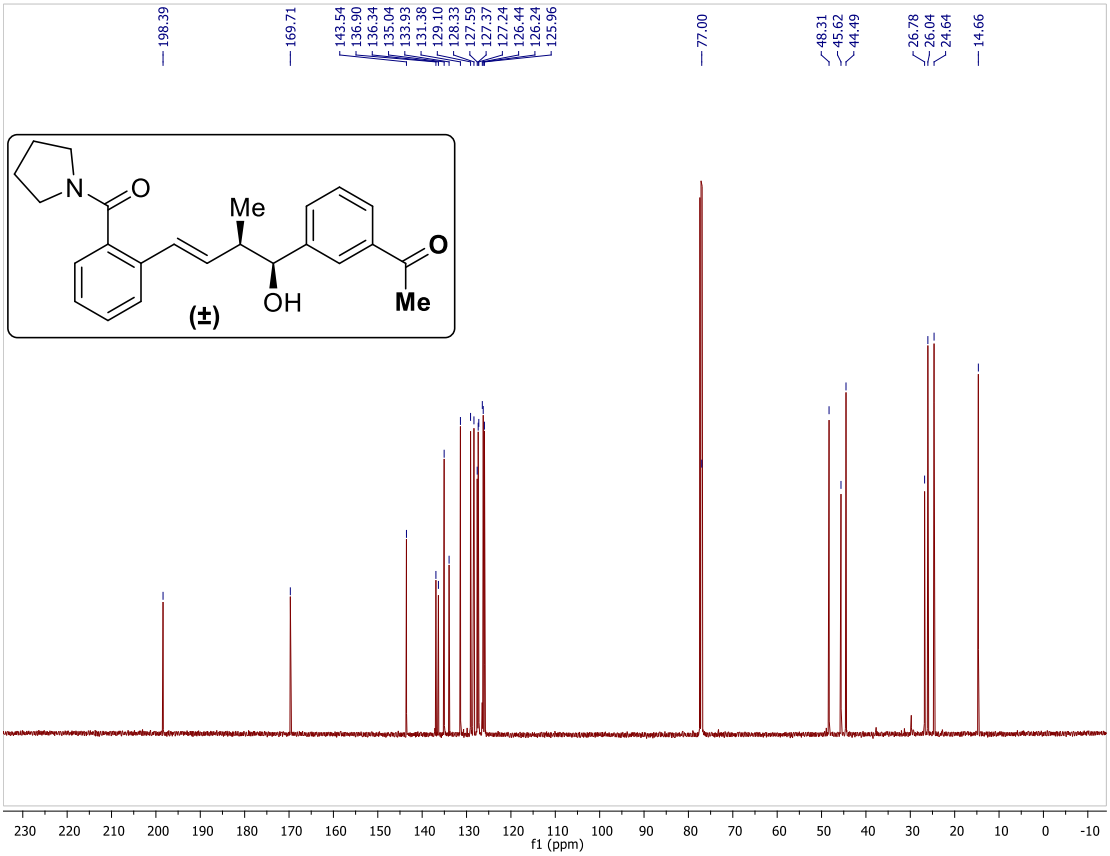

169.72 160.72 158.77 136.46 135.00 133.97 130.19 130.08 129.07 128.71 128.64 128.28 128.25 127.52 127.35 126.21 125.95 124.04 124.01 115.15 114.97 71.31 48.22 45.61 44.06 26.05 24.66 14.98
N
O
Me
OH
F
(±)
230 210 190 170 150 130 110 90 70 50 30 10 -1(
f1 (ppm)

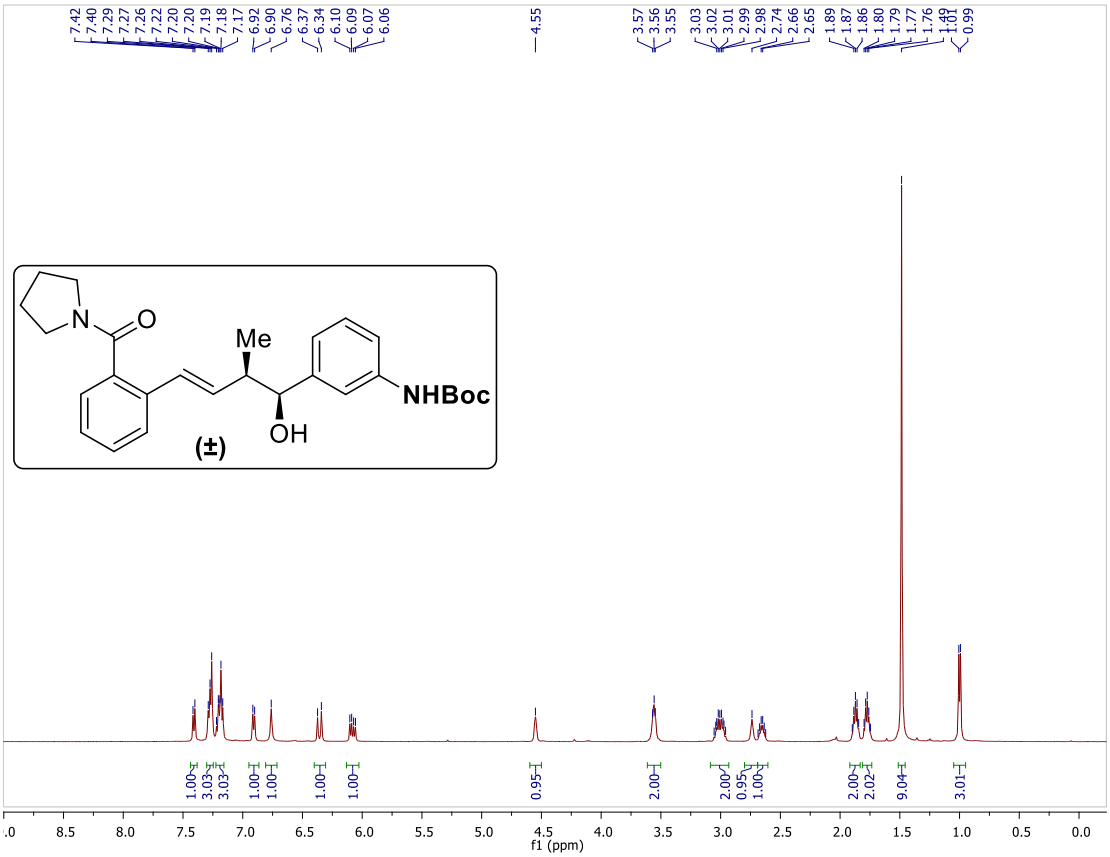

-119.32
N
O
Me
OH
F
(±)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
f1 (ppm)

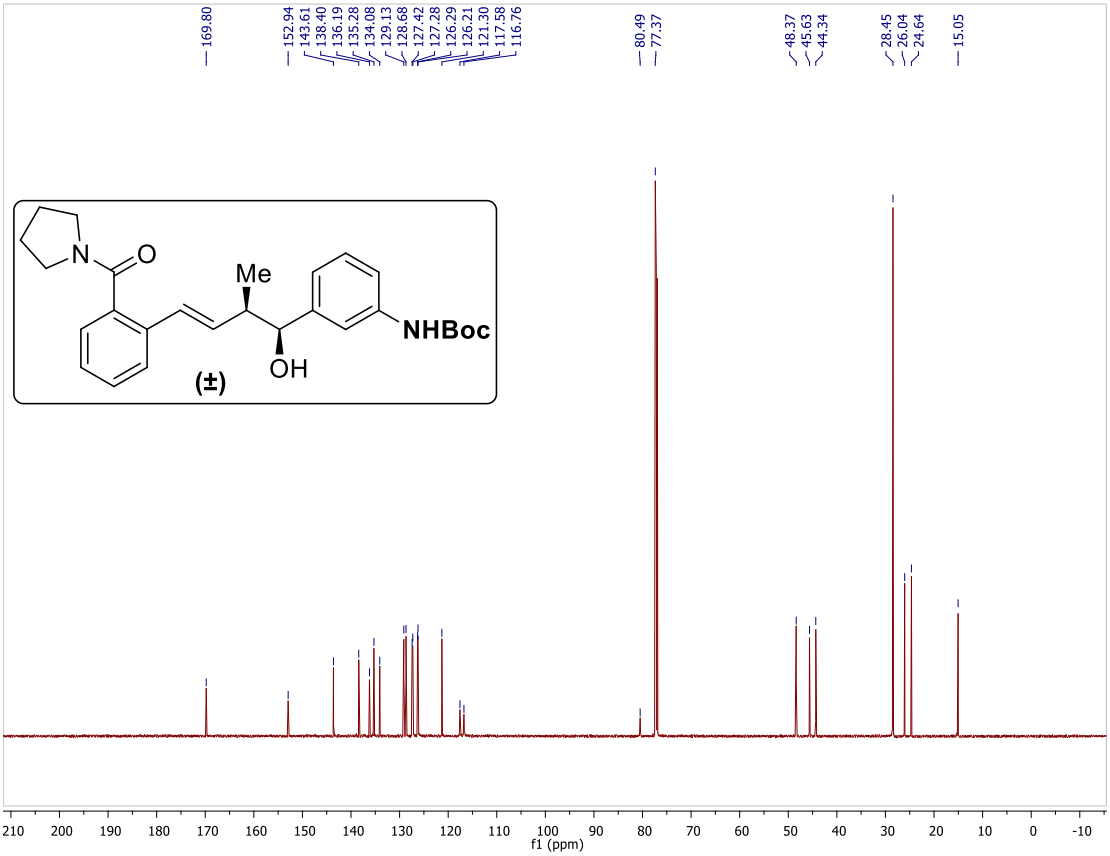

7.41 7.39 7.29 7.27 7.26 7.22 7.21 7.20 7.20 7.19 7.18 7.18 7.17 7.17 7.16 7.14 7.13 6.36 6.33 6.12 6.11 6.09 6.08 4.58 4.57 3.60 3.58 3.57 3.02 3.01 3.00 3.00 2.99 2.98 2.97 2.96 2.95 2.94 2.93 2.65 2.63 2.62 2.61 1.91 1.89 1.88 1.87 1.85 1.79 1.78 1.77 1.75 1.75 1.74 1.01 1.00
N
O
Me
Cl
OH
(±)
0.99 2.03 5.08 1.00 1.00 0.98 2.00 0.88 2.10 1.03 2.03 1.98 3.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.
f1 (ppm)

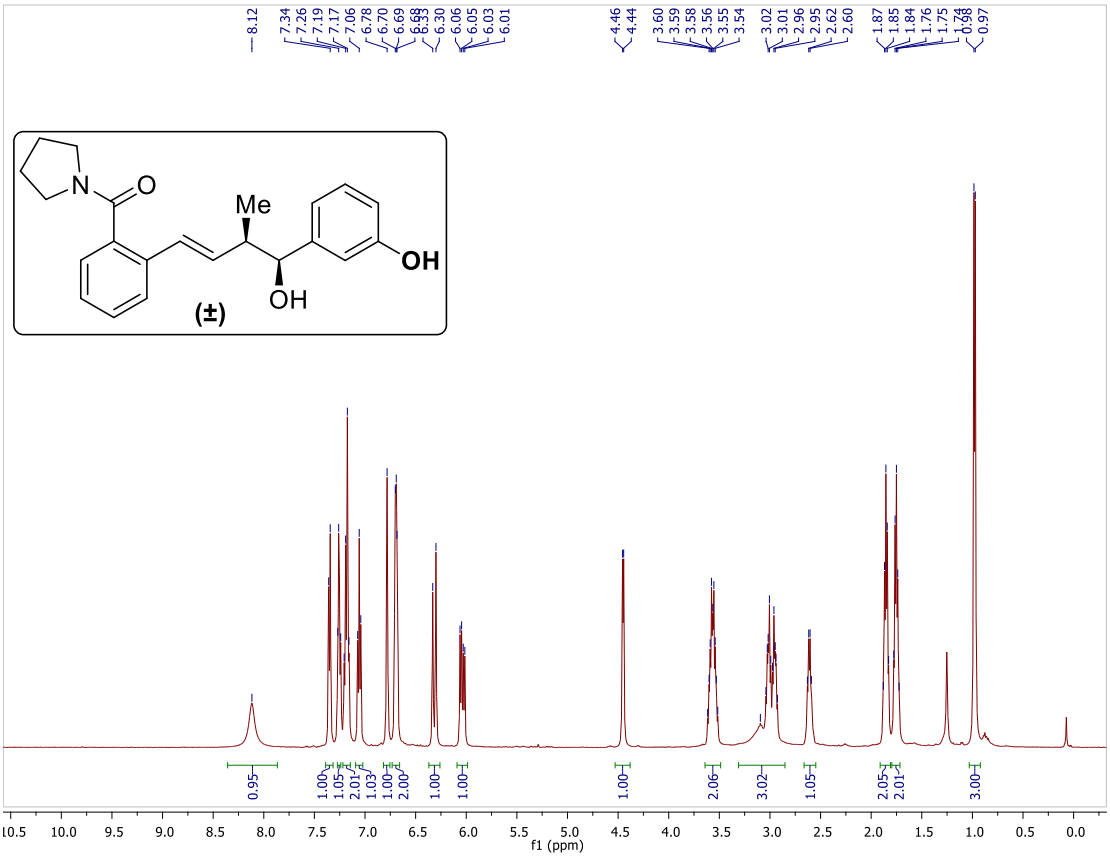

169.72
145.24 136.34 135.01 134.00 133.88 129.31 129.08 127.41 127.35 127.29 126.71 126.21 125.94 124.79
76.78
48.27 45.62 44.52
26.03 24.65
14.75
N
O
Me
Cl
OH
(±)
230 210 190 170 150 130 110 90 70 50 30 10 -1(
f1 (ppm)

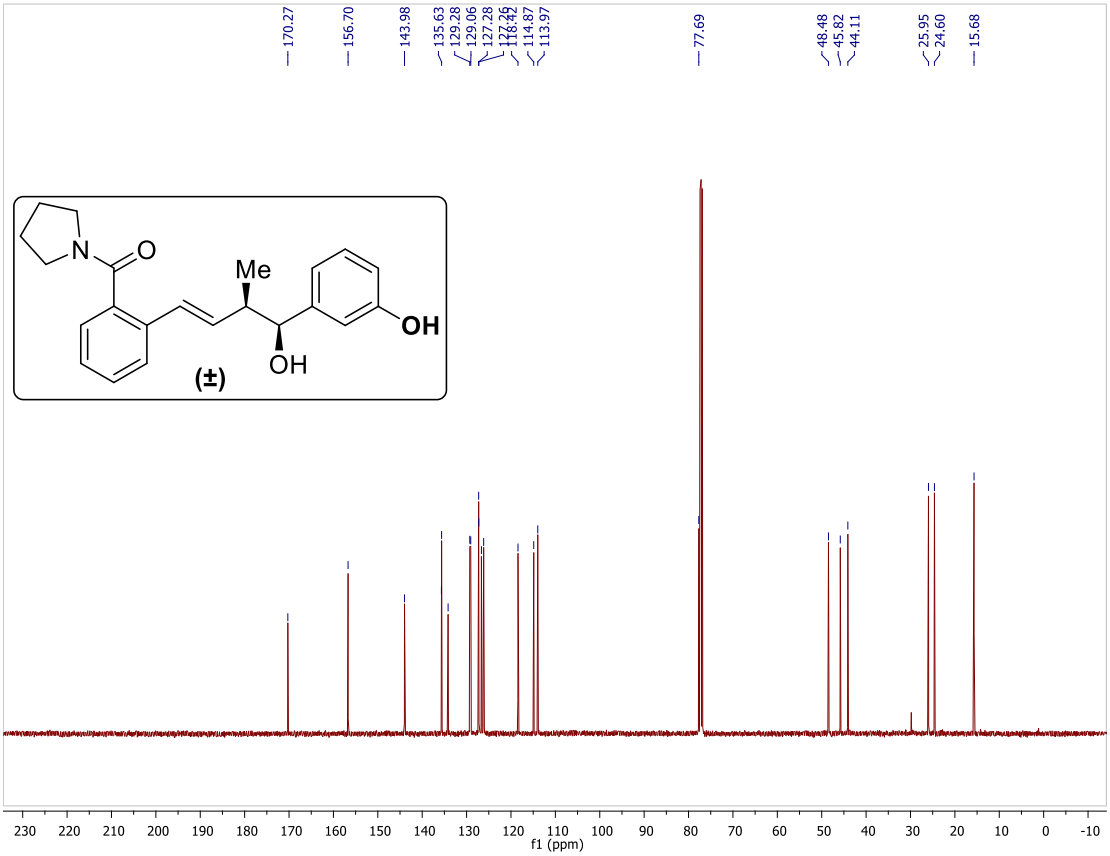

7.87
7.81
7.79
7.39
7.38
7.37
7.26
7.20
7.17
6.38
6.34
6.13
6.11
6.09
6.08
4.70
4.69
3.60
3.58
3.57
3.01
3.00
2.99
2.99
2.98
2.97
2.67
2.54
1.89
1.88
1.86
1.79
1.78
1.76
1.01
1.00
N
O
Me
O
OH
Me
(±)
1.00
1.00
2.00
1.36
2.02
1.00
1.00
1.00
2.00
3.02
1.04
3.00
2.00
2.00
3.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

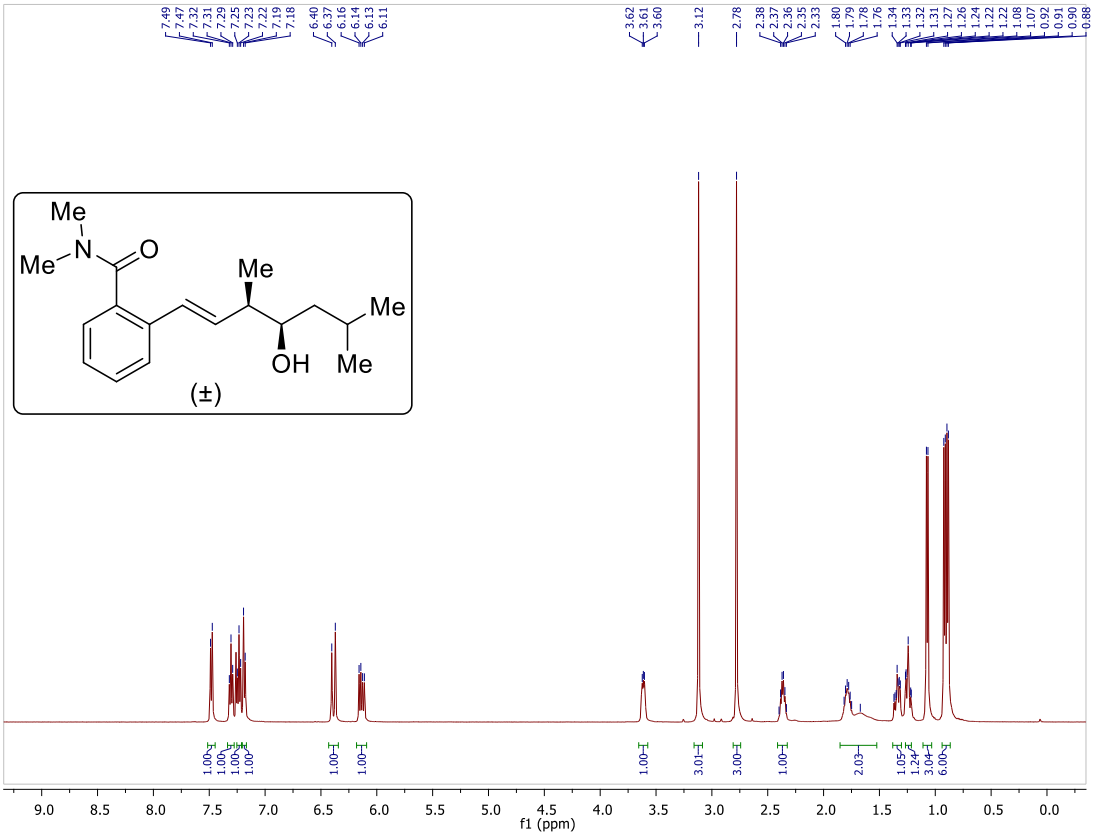

198.39
169.71
143.54
136.90
136.34
135.04
133.93
131.38
129.10
128.33
127.59
127.37
127.24
126.44
126.24
125.96
77.00
48.31
45.62
44.49
26.78
26.04
24.64
14.66
N
O
Me
O
OH
Me
(±)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

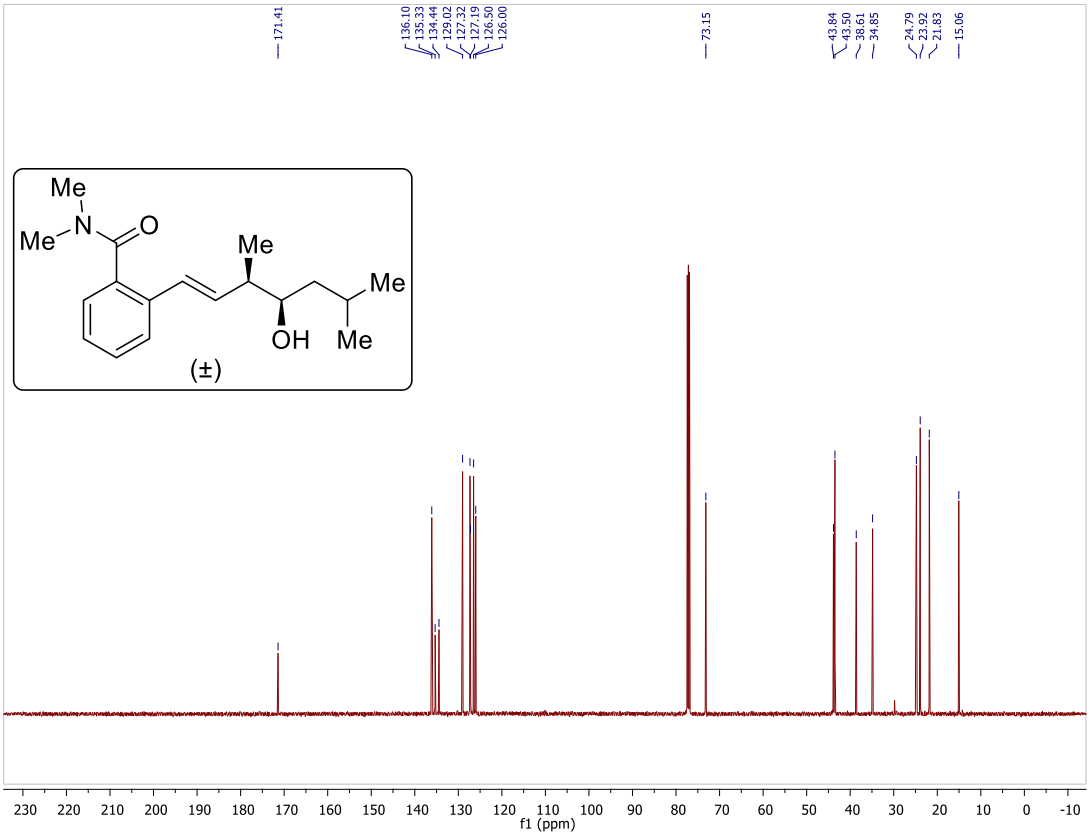

7.42
7.40
7.29
7.27
7.26
7.22
7.20
7.20
7.19
7.18
7.17
6.92
6.90
6.76
6.37
6.34
6.10
6.09
6.07
6.06
4.55
3.57
3.56
3.55
3.03
3.02
3.01
2.99
2.98
2.74
2.66
2.65
1.89
1.87
1.86
1.80
1.79
1.77
1.76
1.49
1.01
0.99
N
O
Me
NHBoc
OH
(±)
1.00
3.03
3.03
1.00
1.00
1.00
1.00
0.95
2.00
2.00
0.95
1.00
2.00
2.02
9.04
3.01
f1 (ppm)

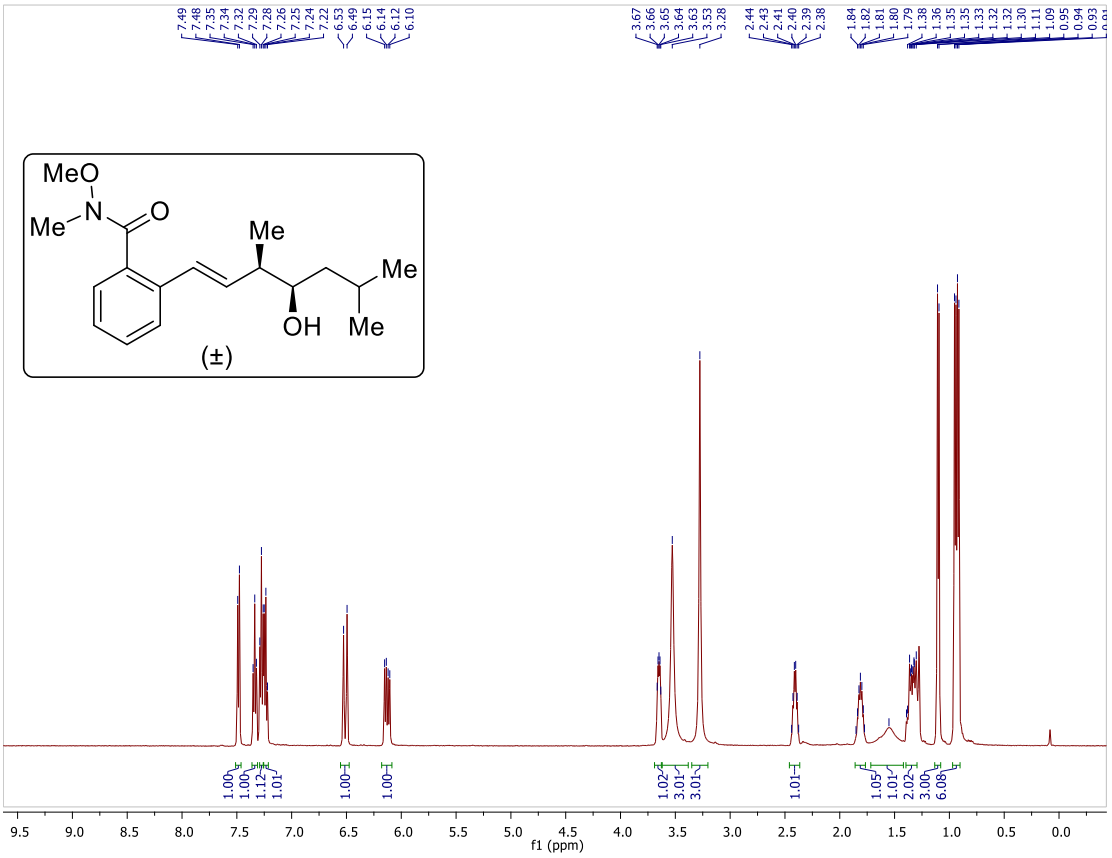

169.80
152.94
143.61
138.40
136.19
135.28
134.08
129.13
128.68
127.42
127.28
126.29
126.21
121.30
117.58
116.76
80.49
77.37
48.37
45.63
44.34
28.45
26.04
24.64
15.05
N
O
Me
NHBoc
OH
(±)
f1 (ppm)

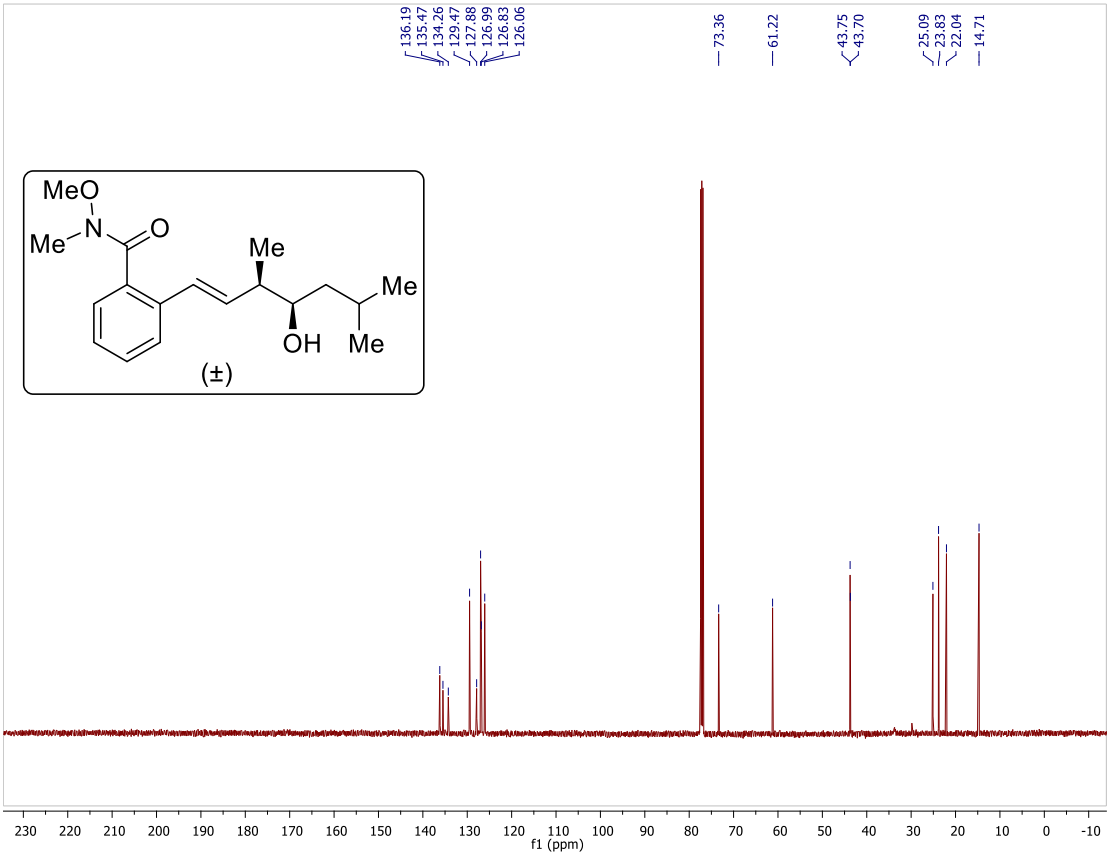

8.12
7.34
7.26
7.19
7.17
7.06
6.78
6.70
6.69
6.30
6.06
6.05
6.03
6.01
4.46
4.44
3.60
3.59
3.58
3.56
3.55
3.54
3.02
3.01
2.96
2.95
2.62
2.60
1.87
1.85
1.84
1.76
1.75
1.74
0.98
0.97
N
O
Me
OH
OH
(±)
0.95
1.00
1.05
2.01
1.03
1.00
2.00
1.00
1.00
1.00
2.06
3.02
1.05
2.05
2.01
3.00
f1 (ppm)

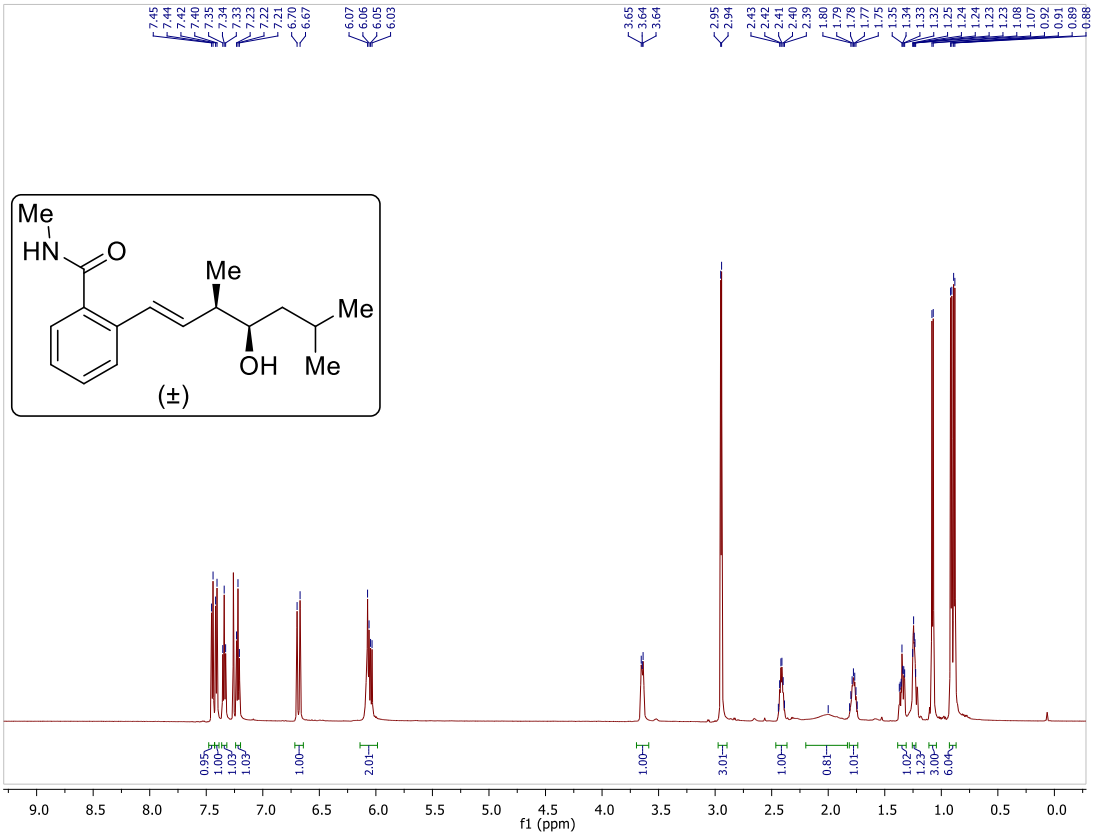

170.27
156.70
143.98
135.63
129.28
129.06
127.28
118.42
114.87
113.97
77.69
48.48
45.82
44.11
25.95
24.60
15.68
N
O
Me
OH
OH
(±)
f1 (ppm)

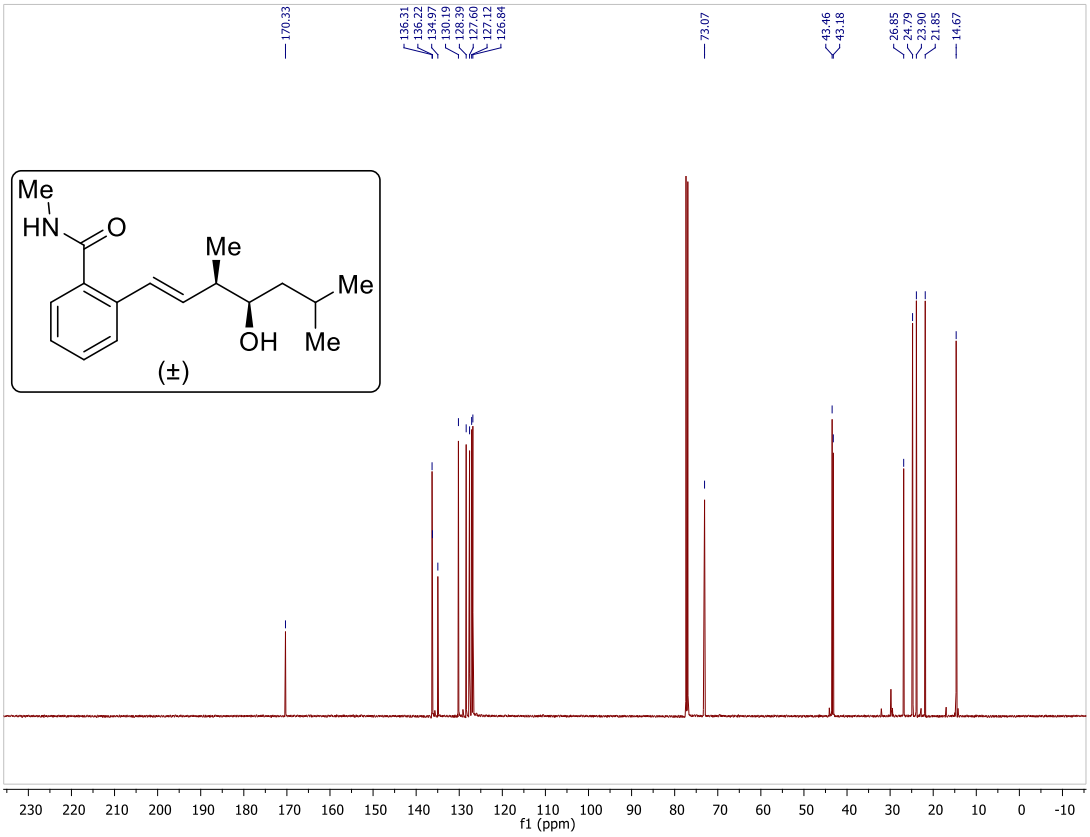

Me
N
Me
O
Me
Me
OH
Me
(±)
f1 (ppm)

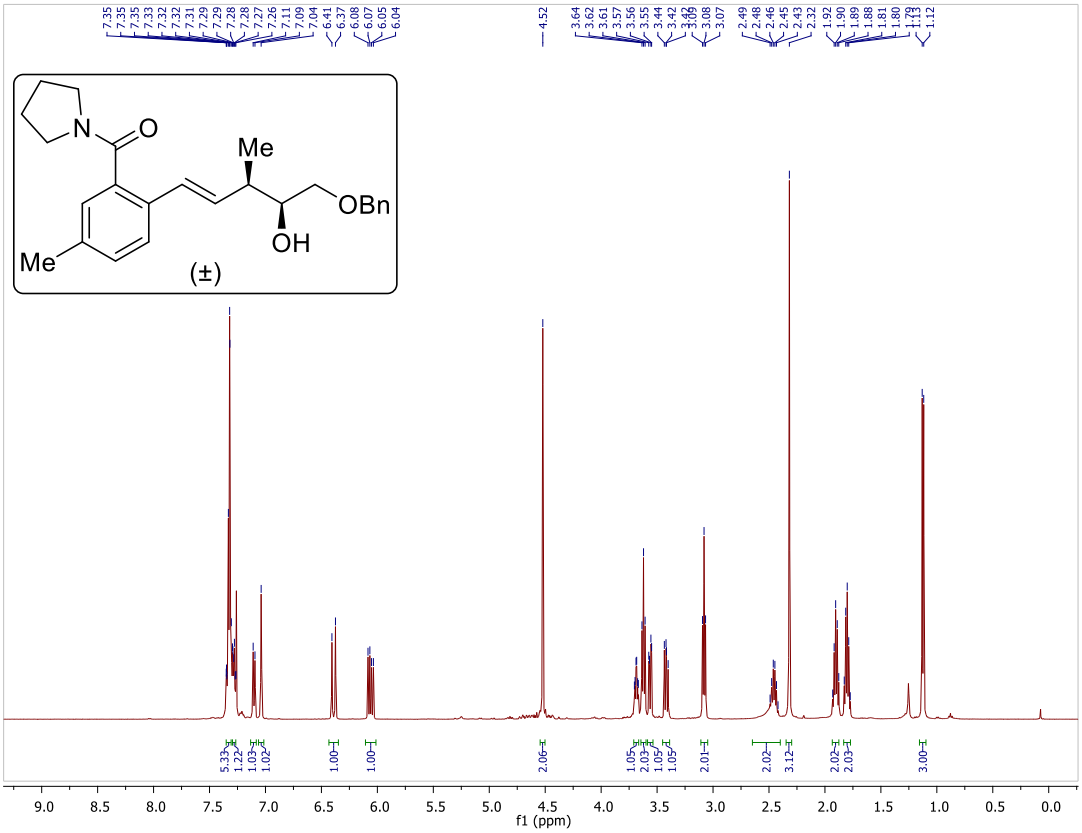

Me
N
Me
O
Me
Me
OH
Me
(±)
f1 (ppm)

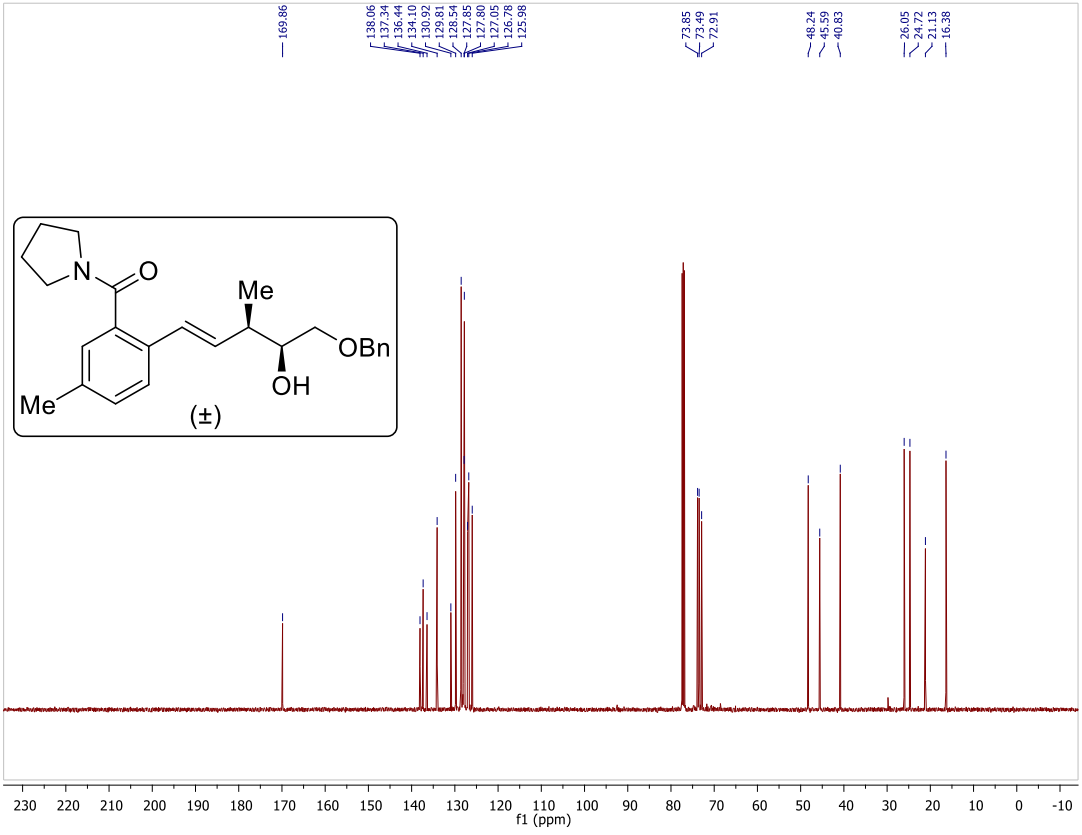

MeO
Me
N
O
Me
Me
OH
Me
(±)
f1 (ppm)

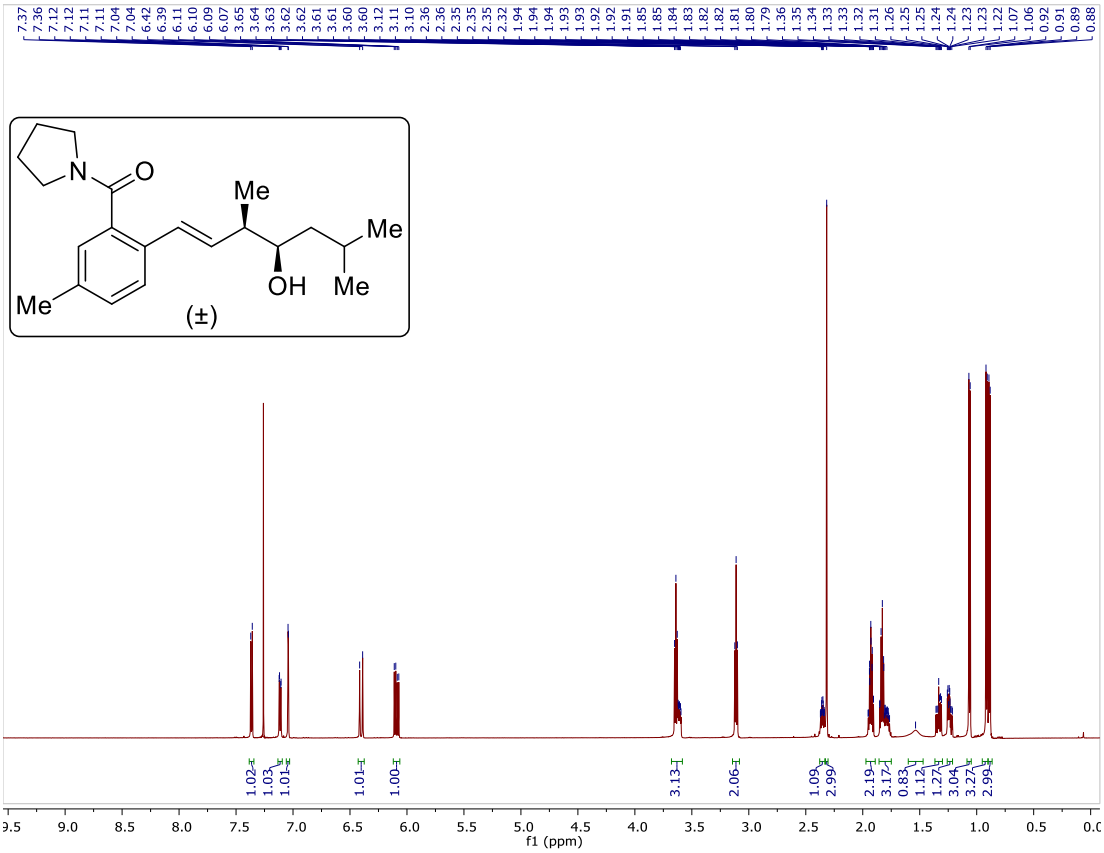

MeO
Me
N
O
Me
Me
OH
Me
(±)
f1 (ppm)

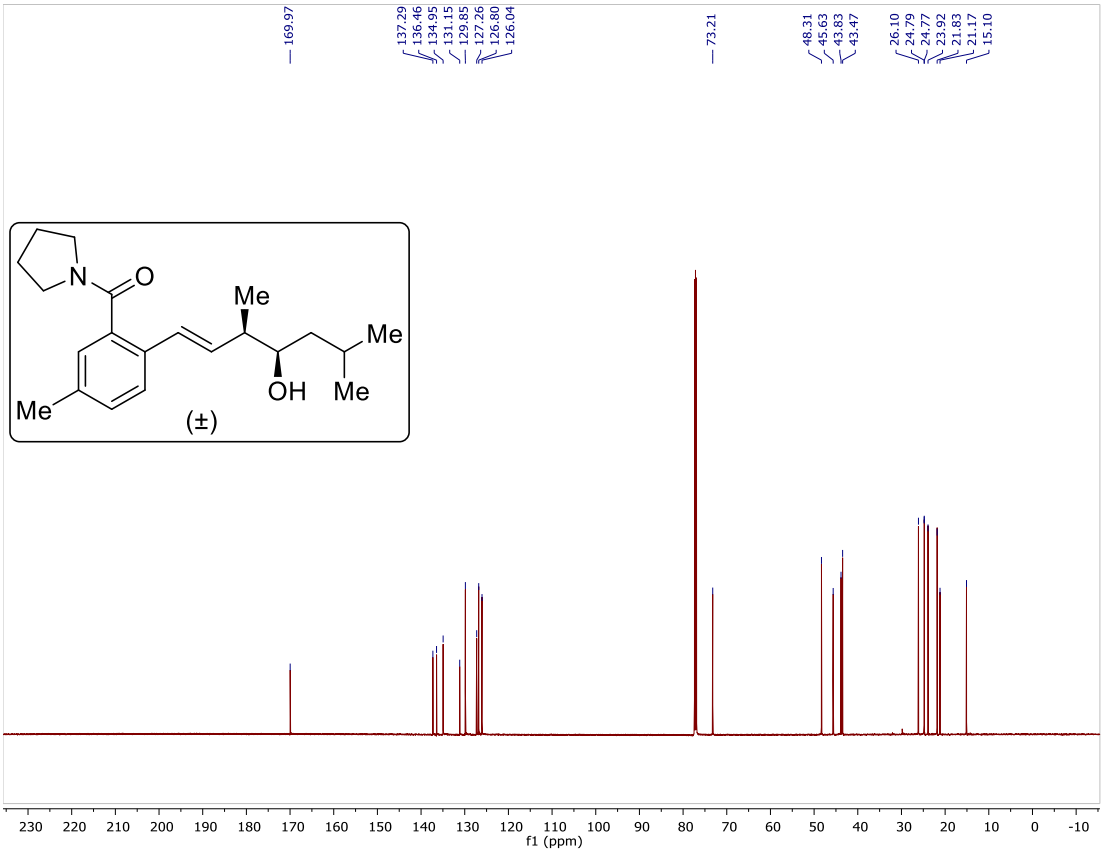

Me
HN
O
Me
Me
OH
Me
(±)
f1 (ppm)

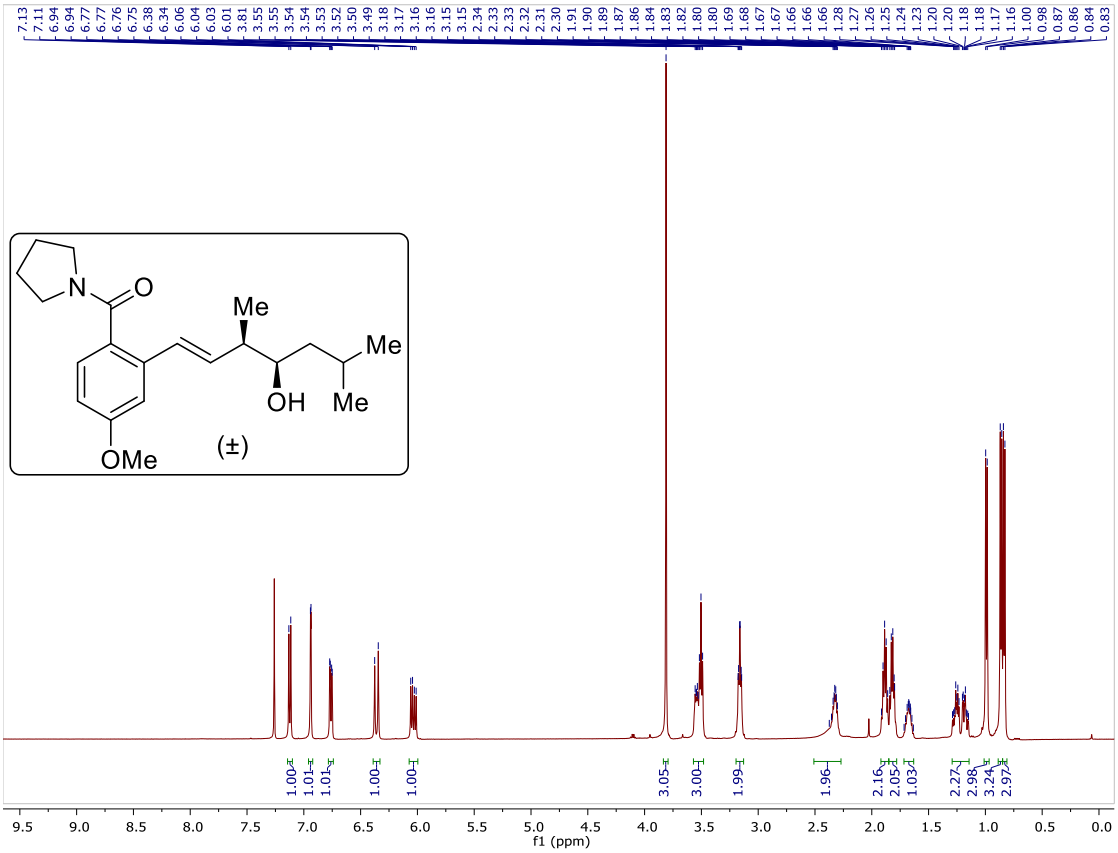

Me
HN
O
Me
Me
OH
Me
(±)
f1 (ppm)

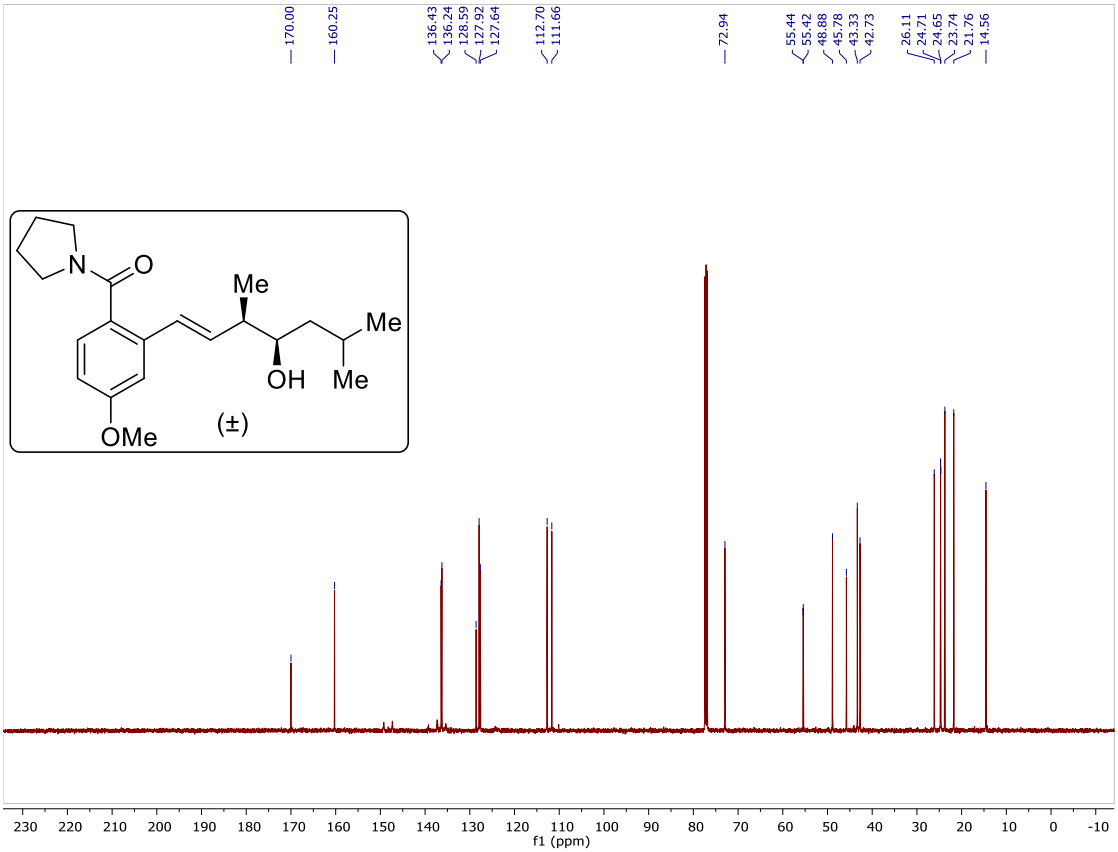

N
O
Me
OBn
OH
Me
(±)
f1 (ppm)

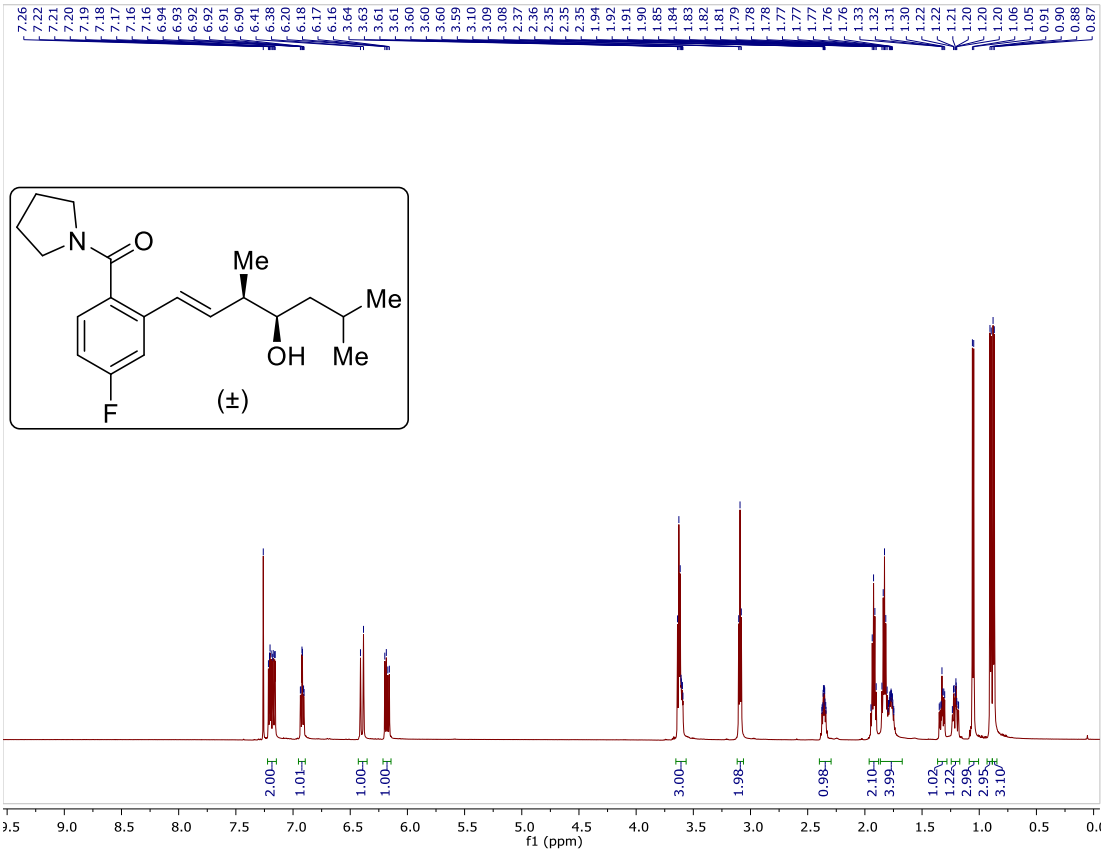

N
O
Me
OBn
OH
Me
(±)
f1 (ppm)

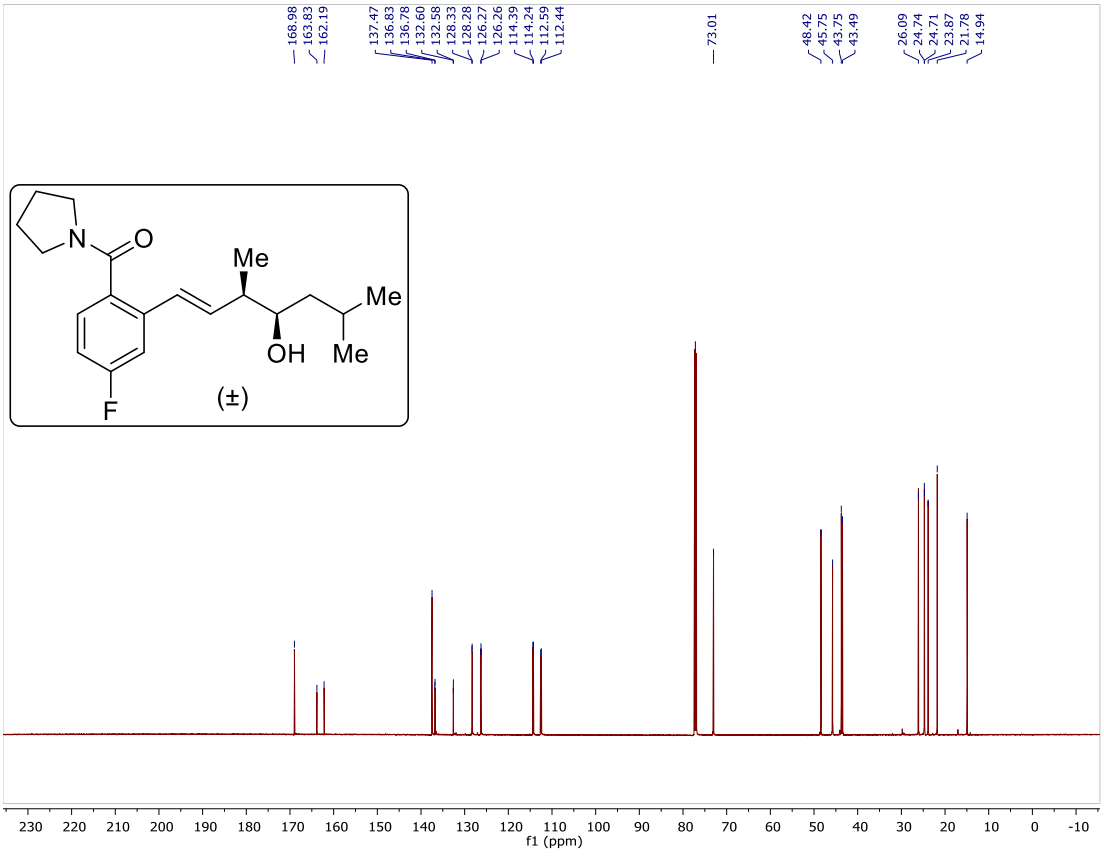

N
O
Me
Me
OH
Me
Me
(±)
f1 (ppm)

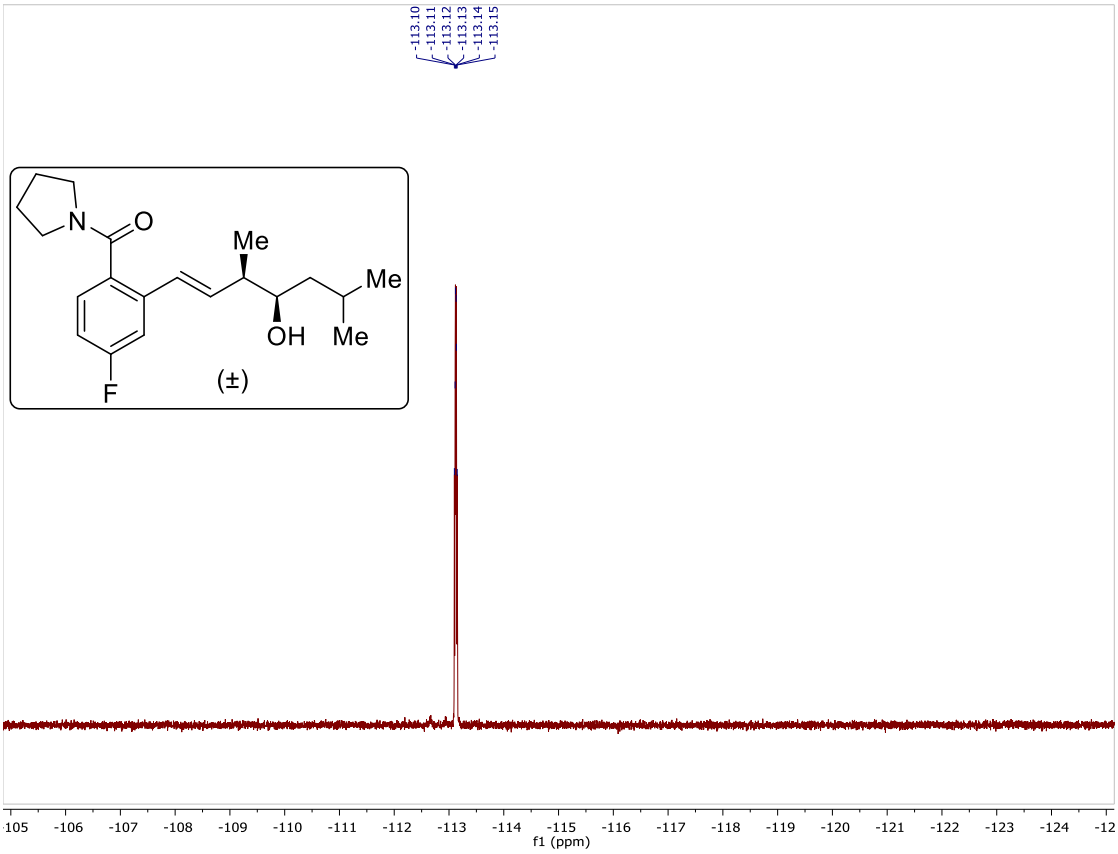

N
O
Me
Me
OH
Me
Me
(±)
f1 (ppm)


N
O
Me
Me
OH
Me
OMe
(±)
f1 (ppm)


N
O
Me
Me
OH
Me
OMe
(±)
f1 (ppm)


7.26 7.22 7.21 7.20 7.19 7.18 7.17 7.16 6.94 6.93 6.92 6.92 6.91 6.90 6.41 6.38 6.20 6.18 6.17 6.16 3.64 3.63 3.61 3.61 3.60 3.60 3.60 3.59 3.10 3.09 3.08 2.37 2.36 2.35 2.35 2.35 1.94 1.92 1.91 1.90 1.85 1.84 1.83 1.82 1.81 1.79 1.78 1.78 1.77 1.77 1.77 1.76 1.76 1.33 1.32 1.31 1.30 1.22 1.22 1.21 1.20 1.20 1.20 1.06 1.05 0.91 0.90 0.88 0.87
N
O
Me
Me
OH
Me
F
(±)
2.00 1.01 1.00 1.00 3.00 1.98 0.98 2.10 3.99 1.02 1.22 2.99 2.95 3.10
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


168.98 163.83 162.19 137.47 136.83 136.78 132.60 132.58 128.33 128.28 126.27 126.26 114.39 114.24 112.59 112.44 73.01 48.42 45.75 43.75 43.49 26.09 24.74 24.71 23.87 21.78 14.94
N
O
Me
Me
OH
Me
F
(±)
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-113.10
-113.11
-113.12
-113.13
-113.14
-113.15
N
O
Me
Me
OH
Me
F
(±)
-105
-106
-107
-108
-109
-110
-111
-112
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-114
-115
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-117
-118
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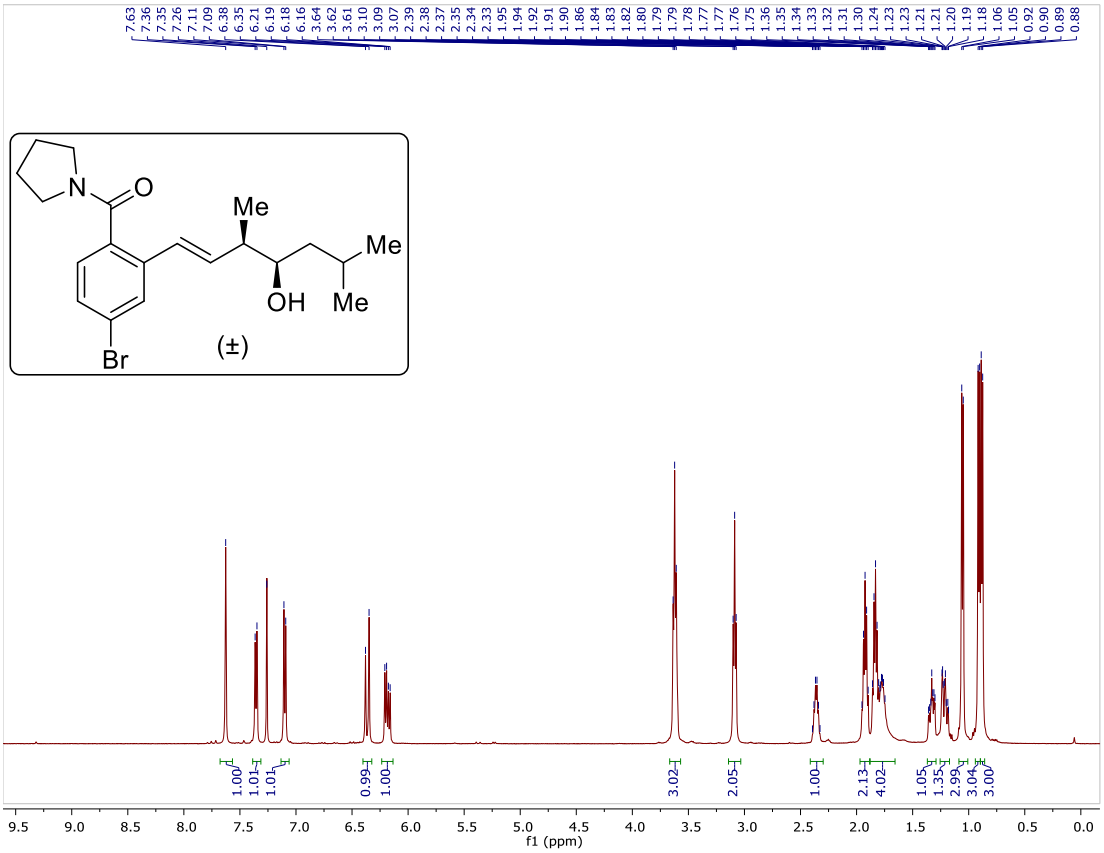
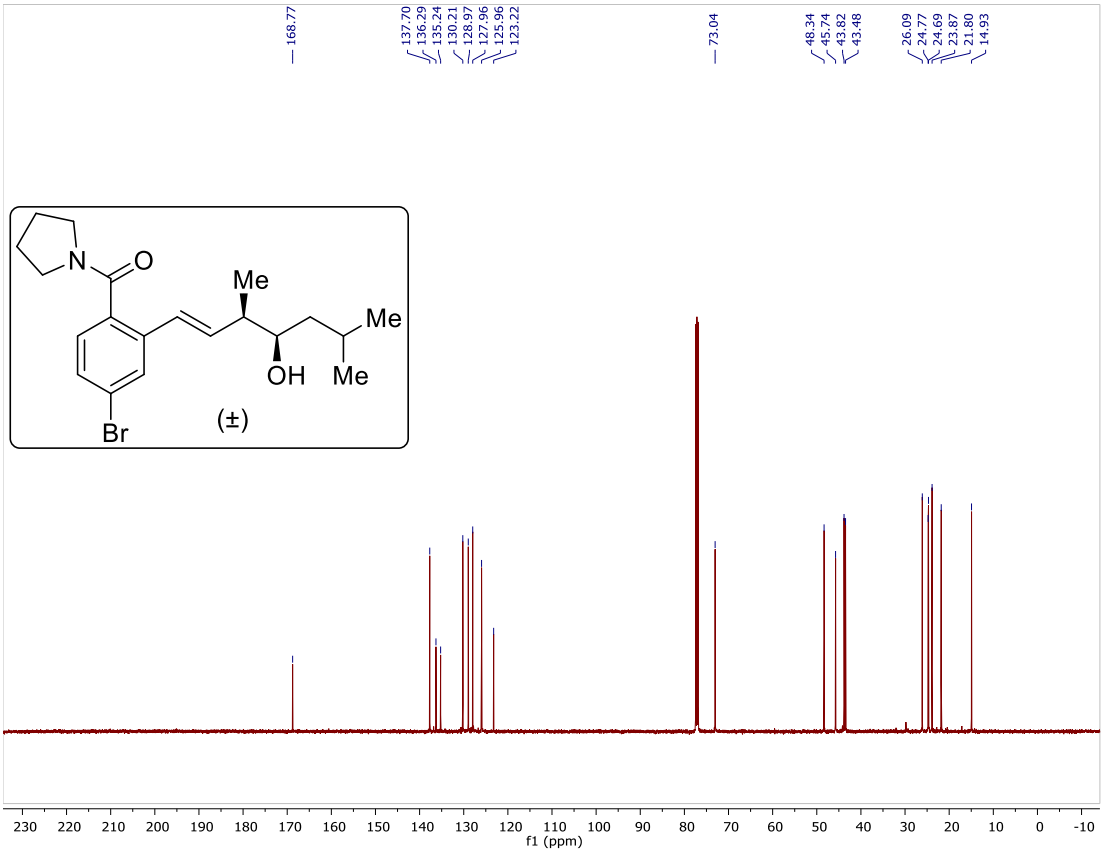
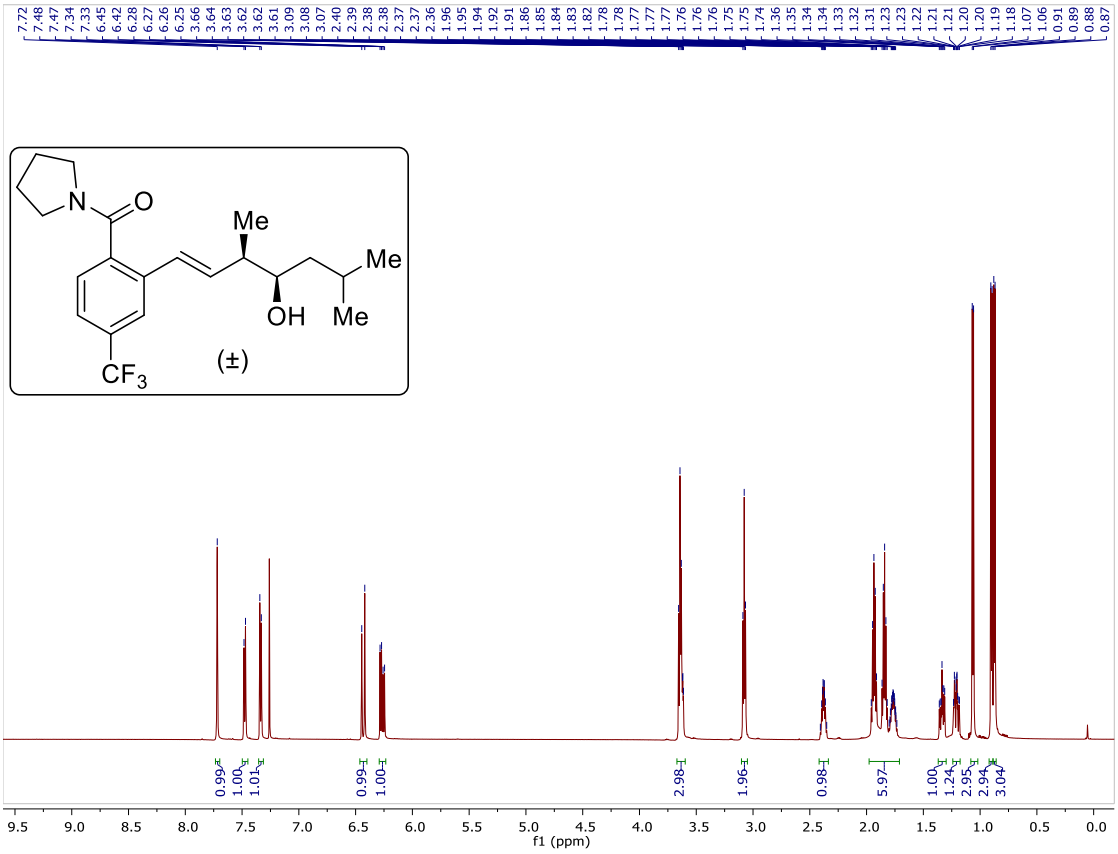
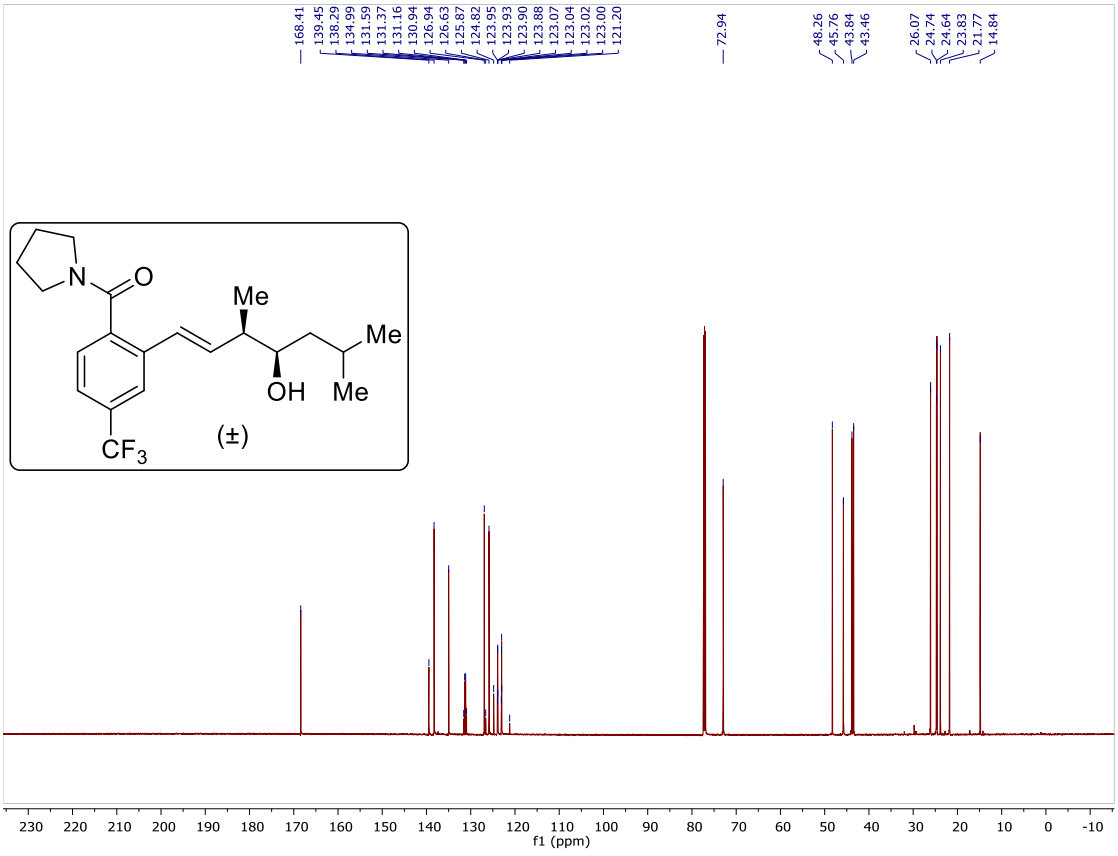
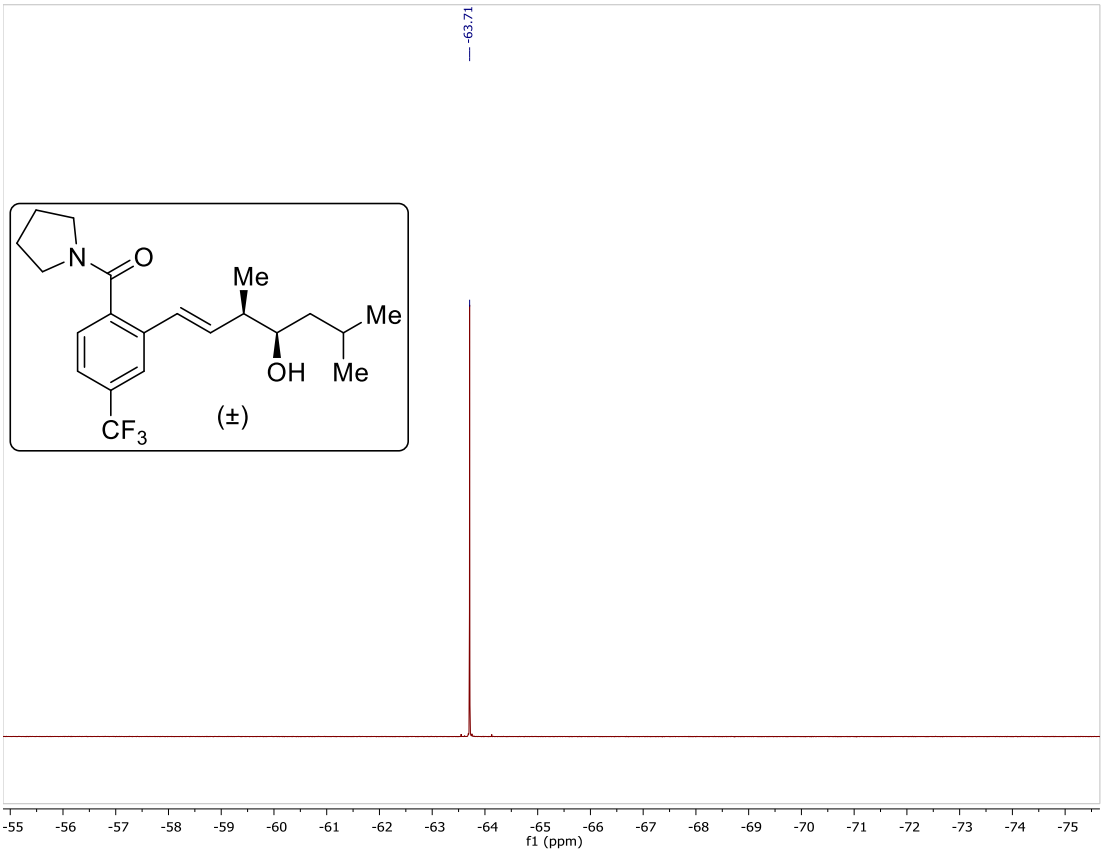
-120
-121
-122
-123
-124
-12
f1 (ppm)

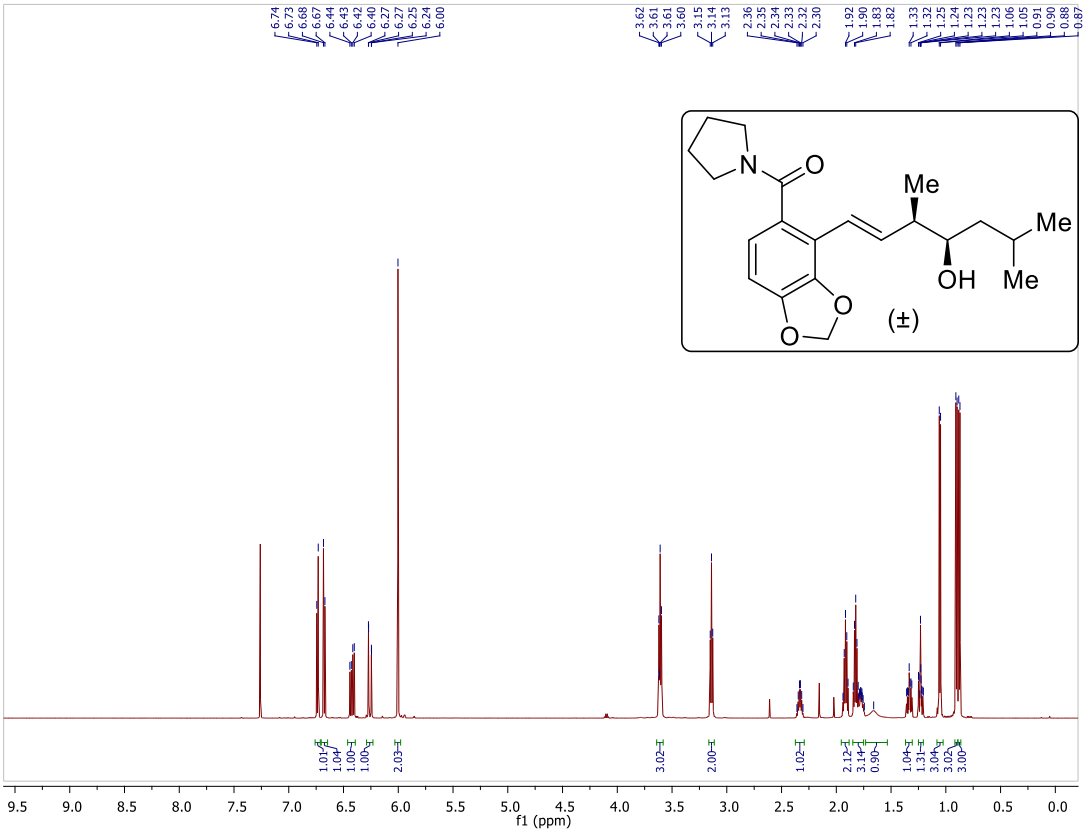

7.63 7.36 7.35 7.26 7.11 7.09 6.38 6.35 6.21 6.19 6.18 6.16 3.64 3.62 3.61 3.10 3.09 3.07 2.39 2.38 2.37 2.35 2.34 2.33 1.95 1.94 1.92 1.91 1.90 1.86 1.84 1.83 1.82 1.80 1.79 1.79 1.78 1.77 1.77 1.76 1.75 1.36 1.35 1.34 1.33 1.32 1.31 1.30 1.24 1.23 1.21 1.21 1.20 1.19 1.18 1.06 1.05 0.92 0.90 0.89 0.88
N
O
Me
Me
OH
Me
Br
(±)
1.00 1.01 1.01 0.99 1.00 3.02 2.05 1.00 2.13 4.02 1.05 1.35 2.99 3.04 3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

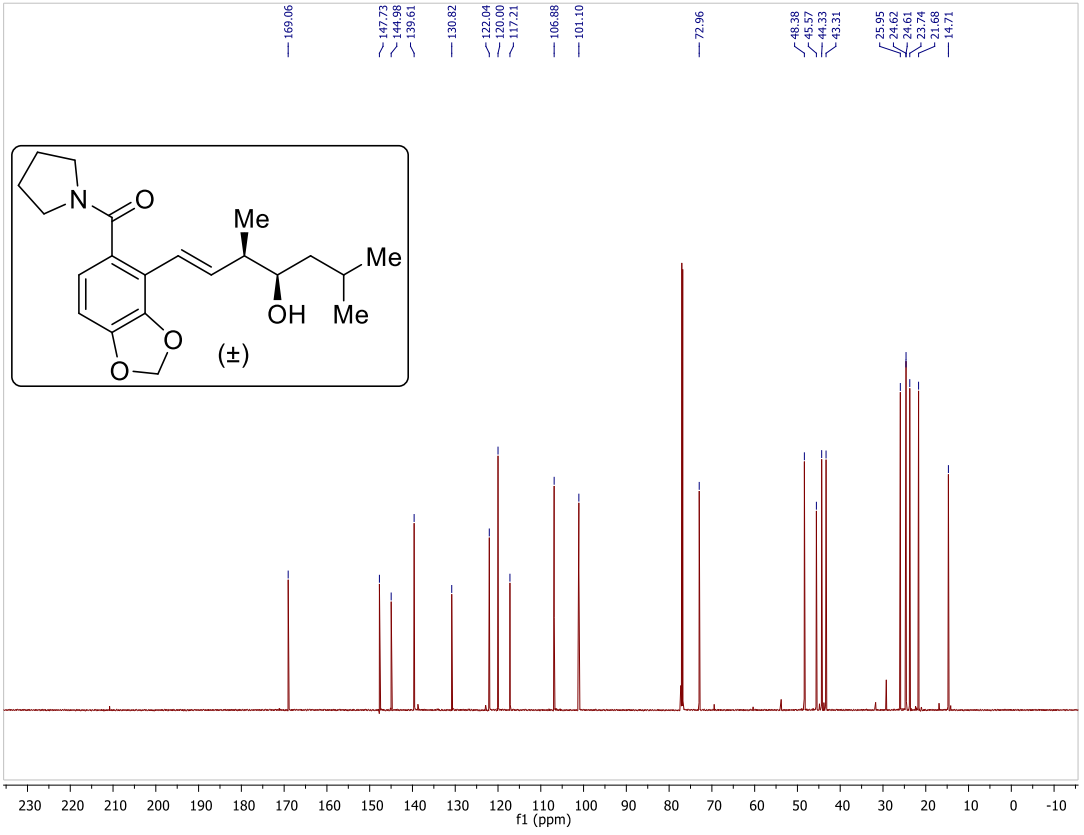

168.77
137.70 136.29 135.24 130.21 128.97 127.96 125.96 123.22
73.04
48.34 45.74 43.82 43.48
26.09 24.77 24.69 23.87 21.80 14.93
N
O
Me
Me
OH
Me
Br
(±)
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

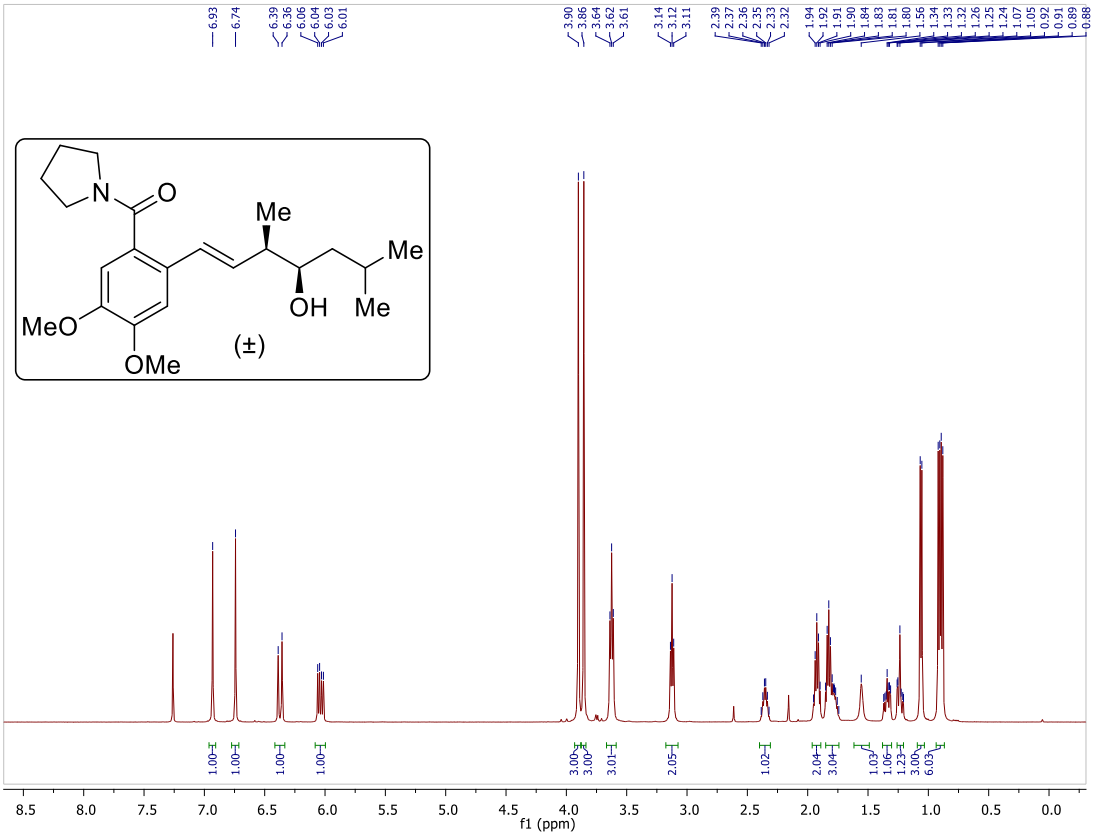

7.72 7.48 7.47 7.34 7.33 6.45 6.42 6.28 6.27 6.26 6.25 3.66 3.64 3.63 3.62 3.62 3.61 3.09 3.08 3.07 2.40 2.39 2.38 2.38 2.37 2.37 2.36 1.96 1.95 1.94 1.92 1.91 1.86 1.85 1.84 1.83 1.82 1.78 1.78 1.77 1.77 1.77 1.76 1.76 1.76 1.75 1.75 1.74 1.36 1.35 1.34 1.34 1.33 1.32 1.31 1.23 1.23 1.22 1.21 1.21 1.20 1.20 1.19 1.18 1.07 1.06 0.91 0.89 0.88 0.87
N
O
Me
Me
OH
Me
CF3
(±)
0.99 1.00 1.01 0.99 1.00 2.98 1.96 0.98 5.97 1.00 1.24 2.95 2.94 3.04
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

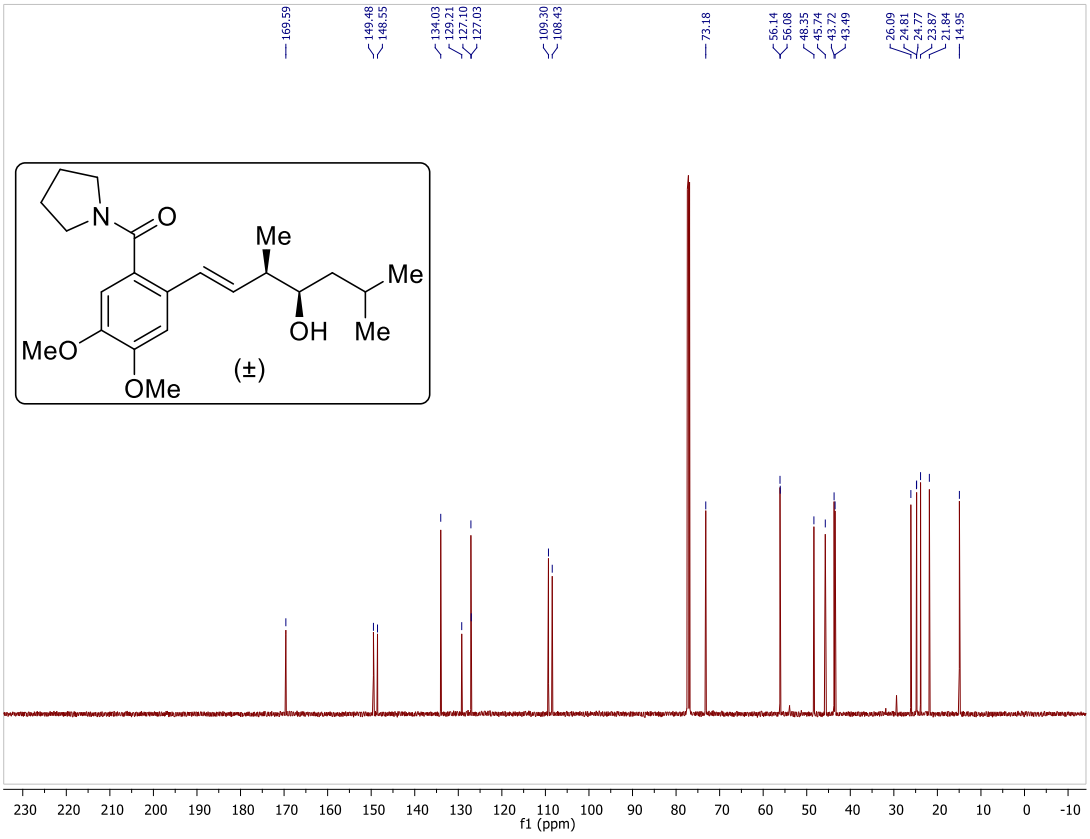

168.41 139.45 138.29 134.99 131.59 131.37 131.16 130.94 126.94 126.63 125.87 124.82 123.95 123.93 123.90 123.88 123.07 123.04 123.02 123.00 121.20
72.94
48.26 45.76 43.84 43.46
26.07 24.74 24.64 23.83 21.77 14.84
N
O
Me
Me
OH
Me
CF3
(±)
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

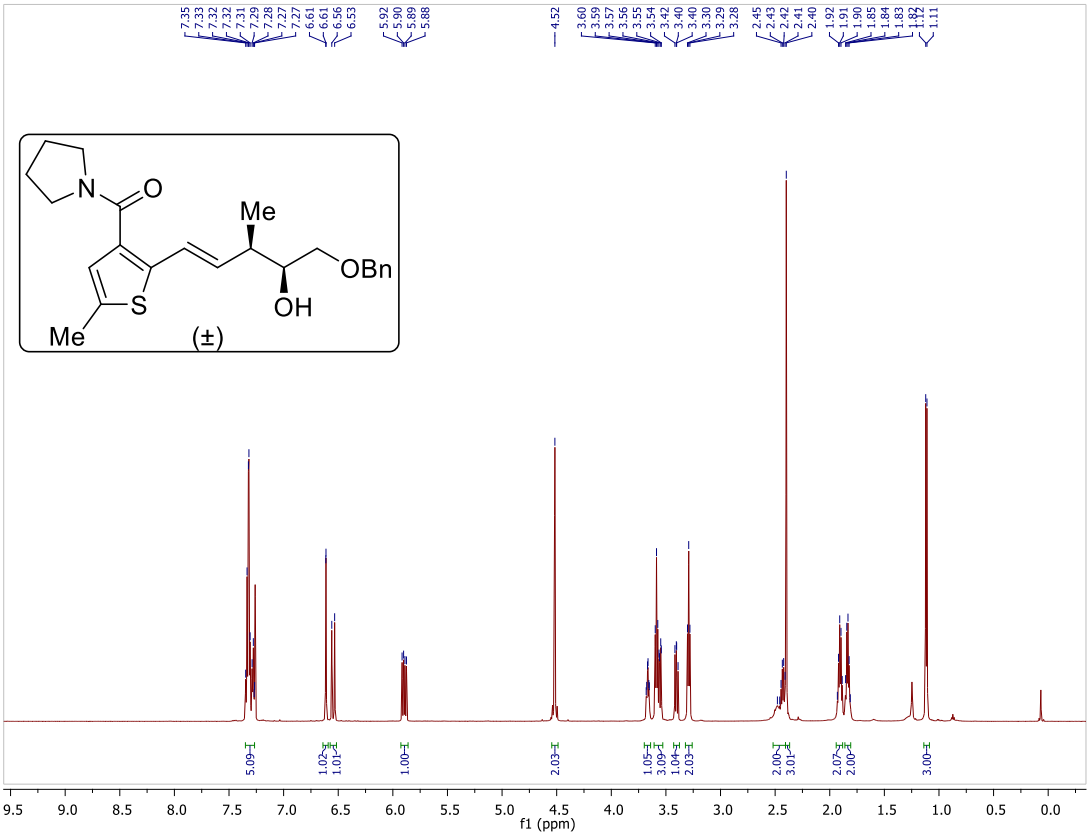

-63.71
N
O
Me
Me
OH
Me
CF3
(±)
-55
-56
-57
-58
-59
-60
-61
-62
-63
-64
-65
-66
-67
-68
-69
-70
-71
-72
-73
-74
-75
f1 (ppm)

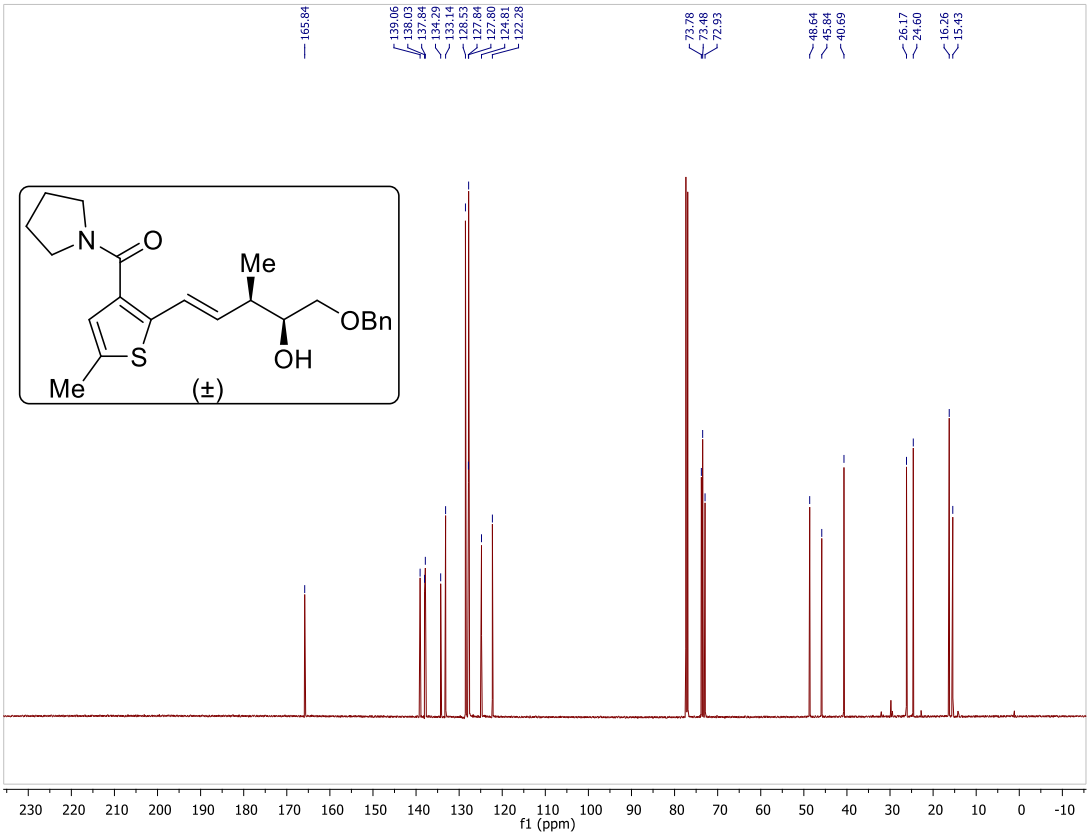

N
O
Me
Me
OH
Me
O
O
(±)
f1 (ppm)

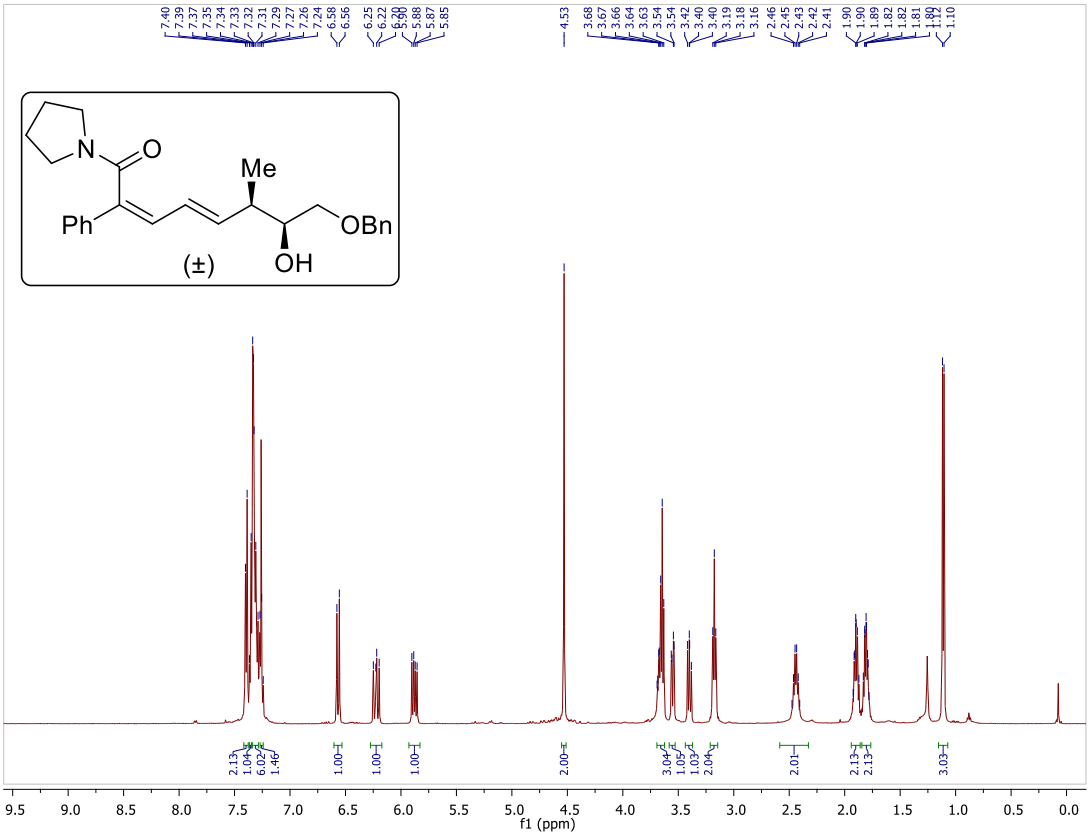

N
O
Me
Me
OH
Me
O
O
(±)
f1 (ppm)

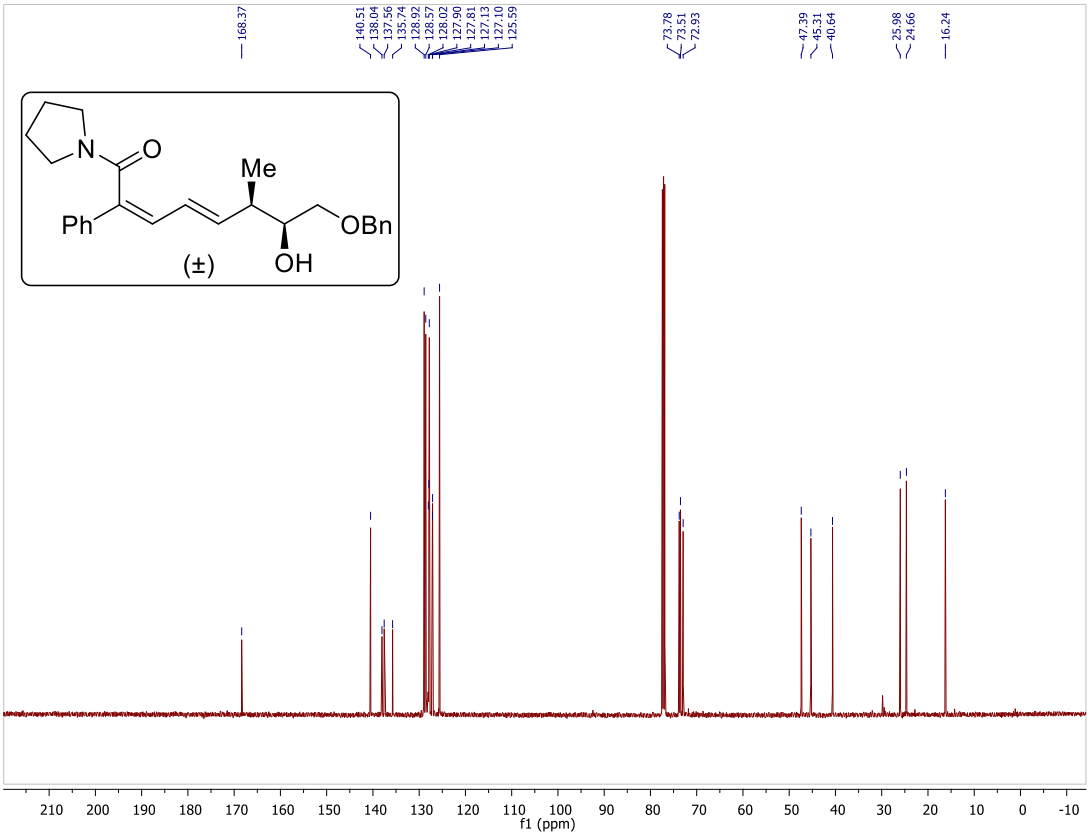

6.93
6.74
6.39
6.36
6.06
6.04
6.03
6.01
3.90
3.86
3.64
3.62
3.61
3.14
3.12
3.11
2.39
2.37
2.36
2.35
2.33
2.32
1.94
1.92
1.91
1.90
1.84
1.83
1.81
1.80
1.56
1.34
1.33
1.32
1.26
1.25
1.24
1.07
1.05
0.92
0.91
0.89
0.88
N
O
Me
Me
OH
Me
MeO
OMe
(±)
1.00
1.00
1.00
1.00
3.00
3.00
3.01
2.05
1.02
2.04
3.04
1.03
1.06
1.23
3.00
6.03
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

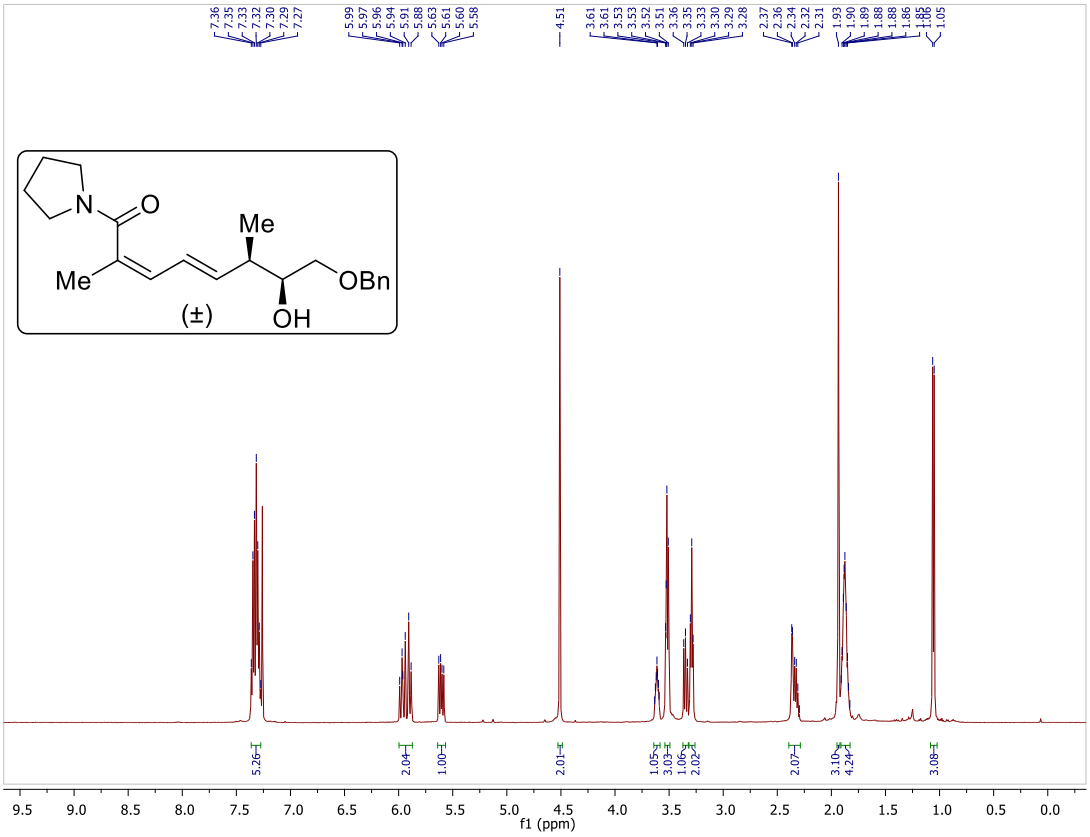

169.59
149.48
148.55
134.03
129.21
127.10
127.03
109.30
108.43
73.18
56.14
56.08
48.35
45.74
43.72
43.49
26.09
24.81
24.77
23.87
21.84
14.95
N
O
Me
Me
OH
Me
MeO
OMe
(±)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

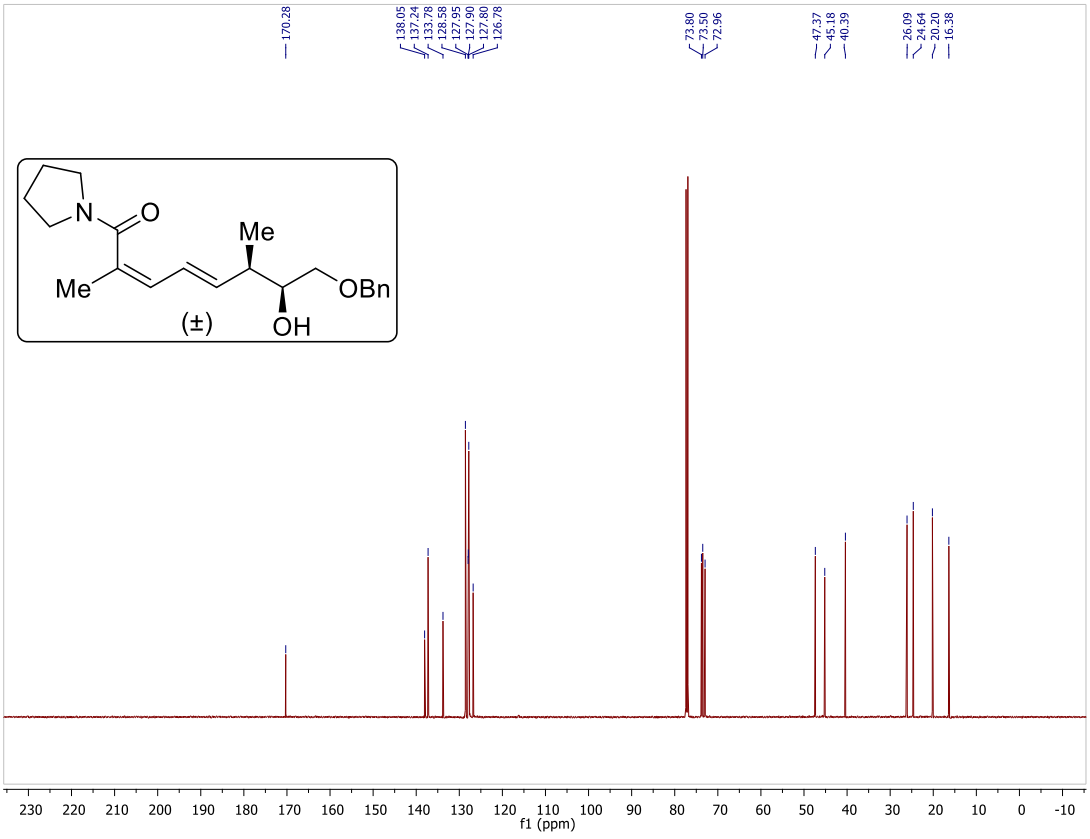

N
O
Me
OBn
S
OH
Me
(±)
f1 (ppm)

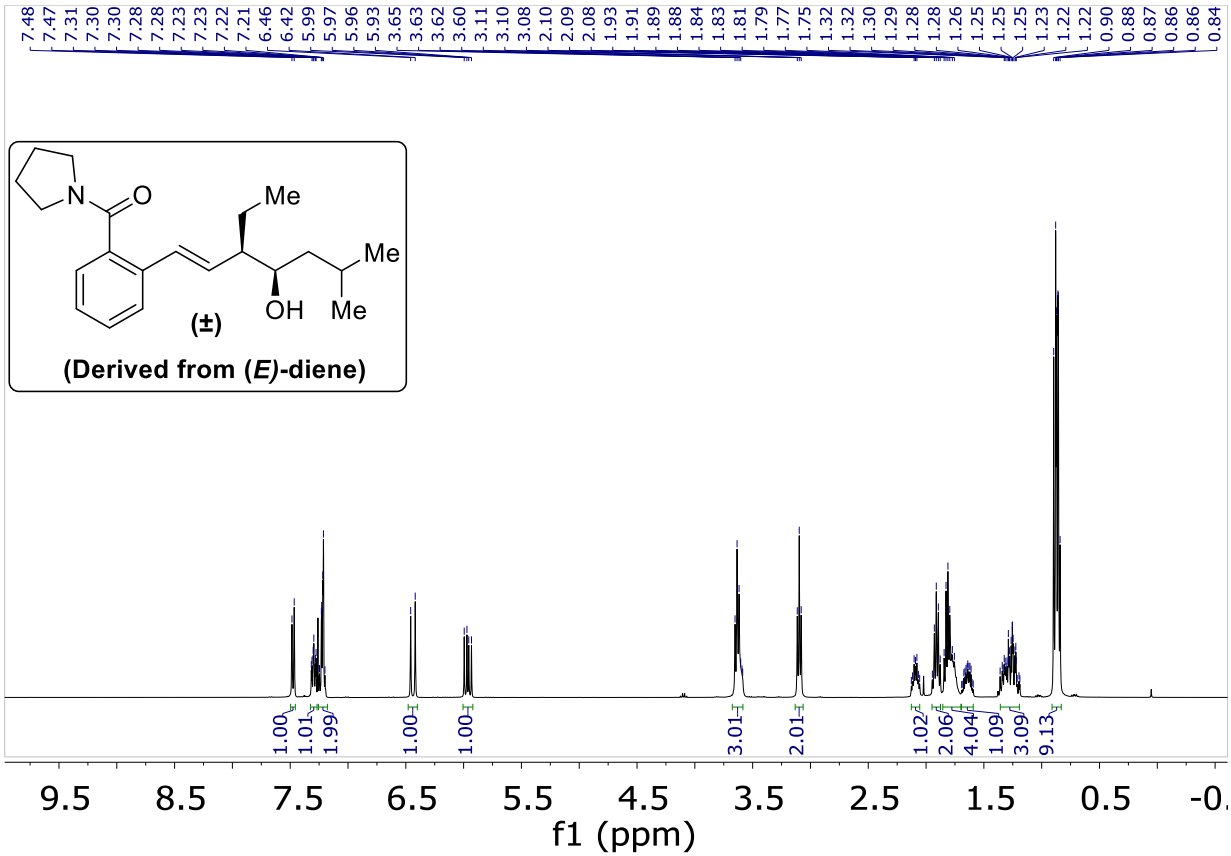

N
O
Me
OBn
S
OH
Me
(±)
f1 (ppm)

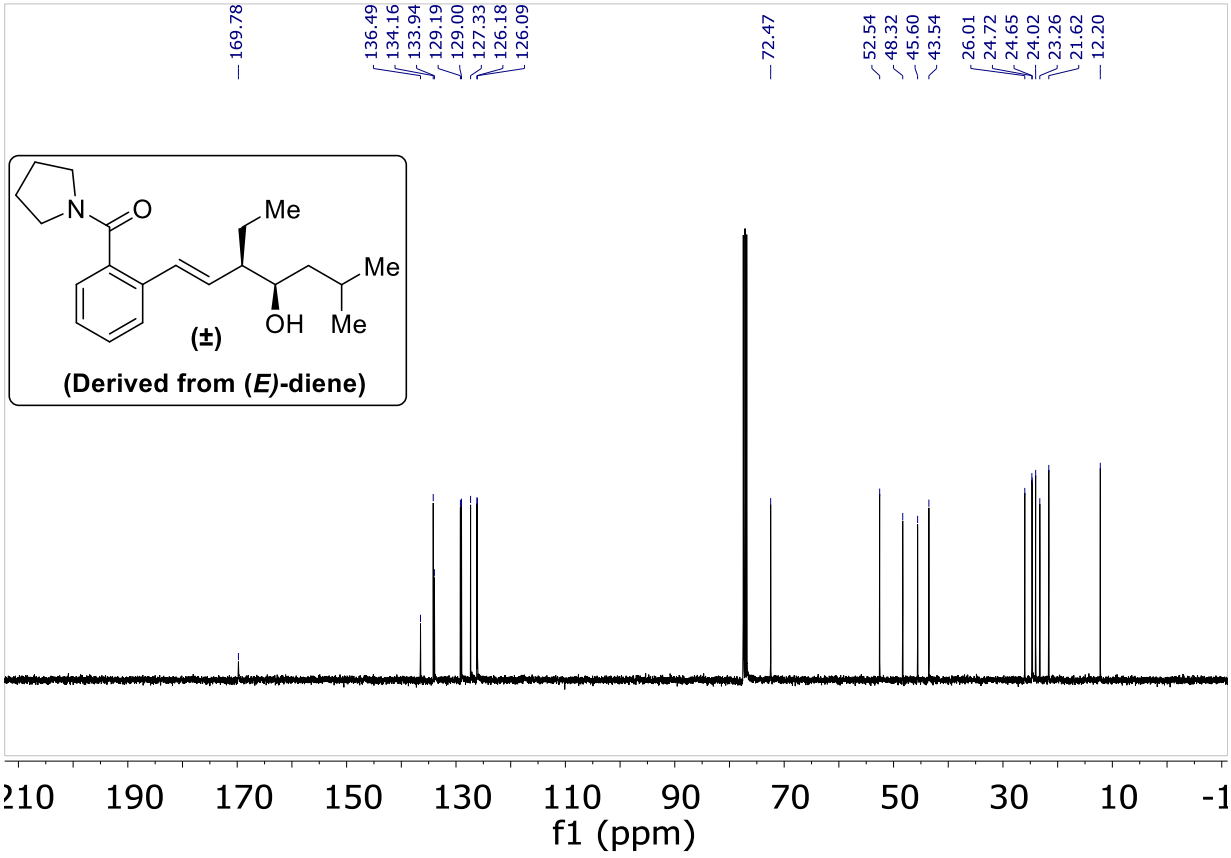

N
O
Me
Ph
OBn
(±)
OH
f1 (ppm)

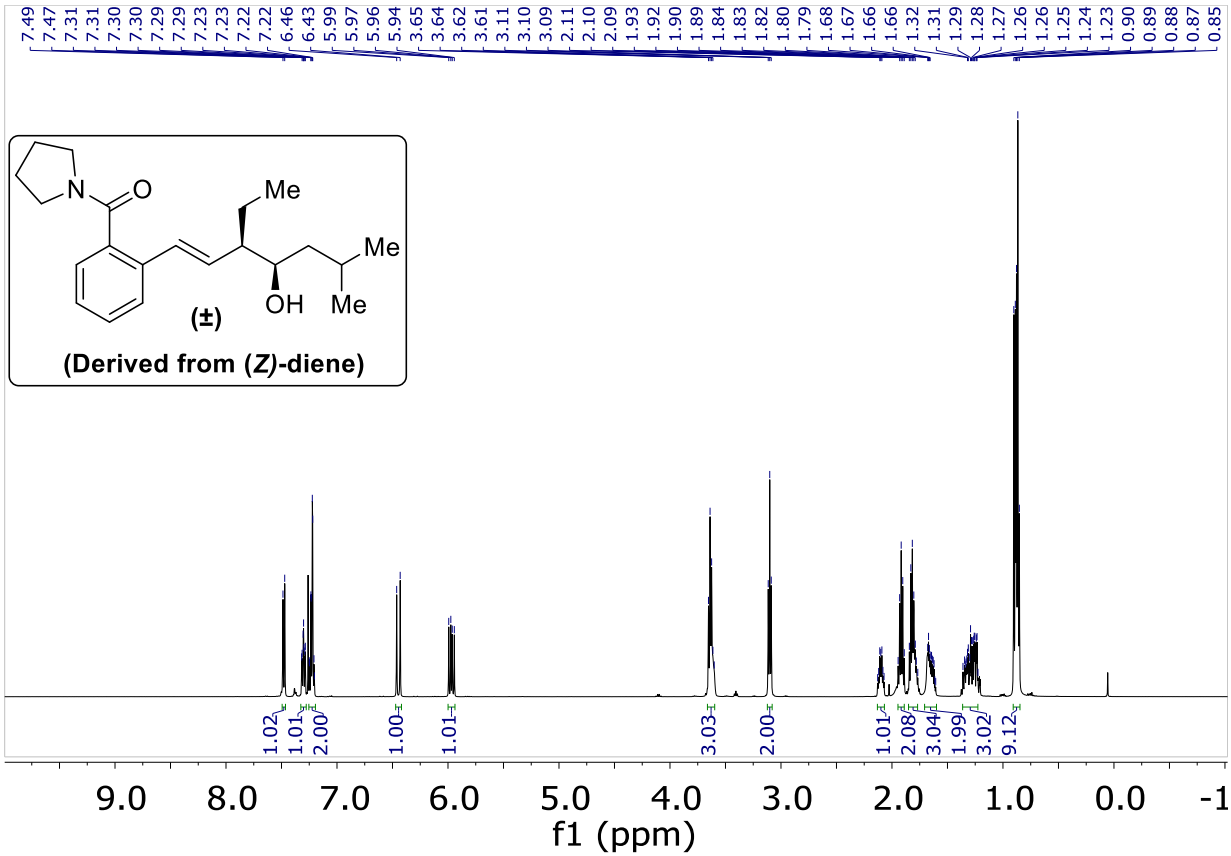

N
O
Me
Ph
OBn
(±)
OH
f1 (ppm)

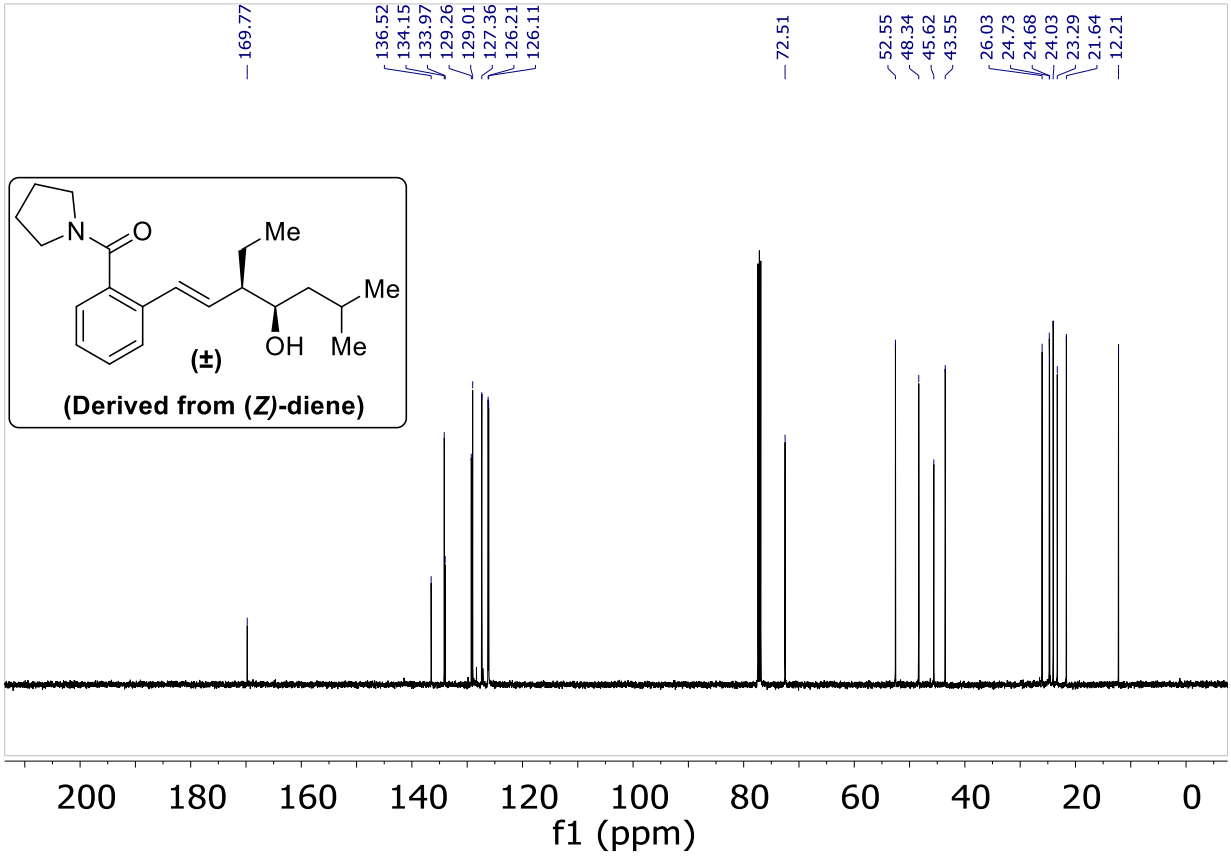

7.36
7.35
7.33
7.32
7.30
7.29
7.27
5.99
5.97
5.96
5.94
5.91
5.88
5.63
5.61
5.60
5.58
4.51
3.61
3.61
3.53
3.53
3.52
3.51
3.36
3.35
3.33
3.30
3.29
3.28
2.37
2.36
2.34
2.32
2.31
1.93
1.90
1.89
1.88
1.88
1.86
1.85
1.06
1.05
N
O
Me
Me
OBn
(±)
OH
5.26
2.04
1.00
2.01
1.05
3.03
1.06
2.02
2.07
3.10
4.24
3.08
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

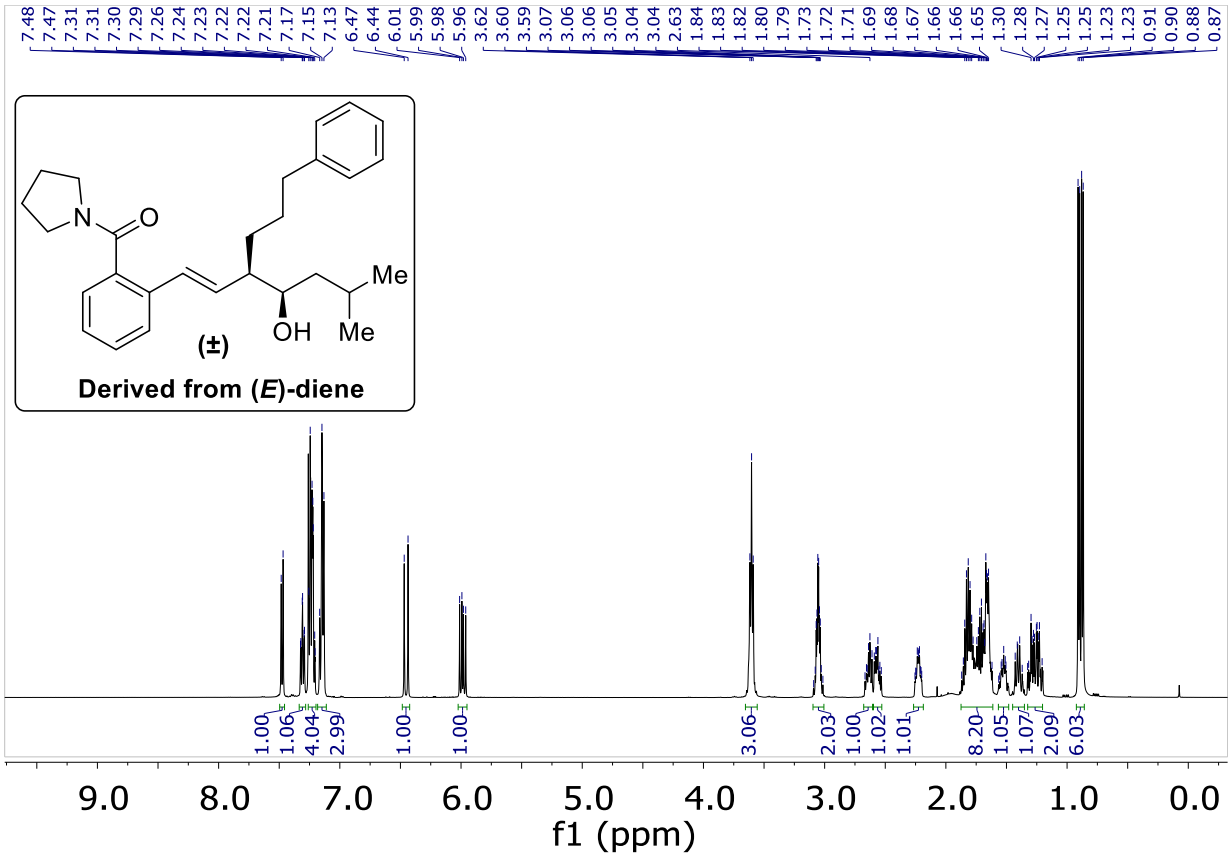

170.28
138.05
137.24
133.78
128.58
127.95
127.90
127.80
126.78
73.80
73.50
72.96
47.37
45.18
40.39
26.09
24.64
20.20
16.38
N
O
Me
Me
OBn
(±)
OH
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

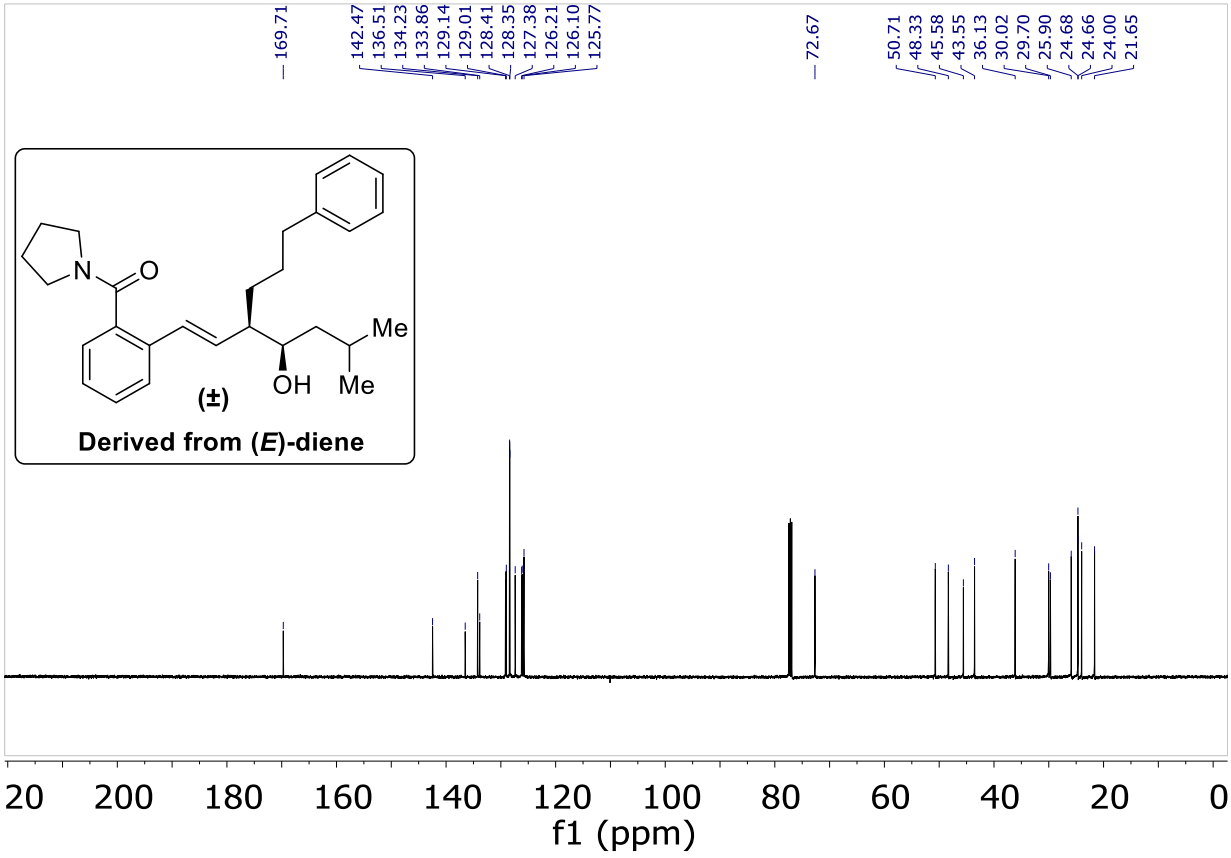

7.48 7.47 7.31 7.30 7.30 7.28 7.28 7.23 7.23 7.22 7.21 6.46 6.42 5.99 5.97 5.96 5.93 3.65 3.63 3.62 3.60 3.11 3.10 3.08 2.10 2.09 2.08 1.93 1.91 1.89 1.88 1.84 1.83 1.81 1.79 1.77 1.75 1.32 1.32 1.30 1.29 1.28 1.28 1.26 1.25 1.25 1.25 1.23 1.22 1.22 0.90 0.88 0.87 0.86 0.86 0.84
N
O
Me
Me
OH
Me
(±)
(Derived from (E)-diene)
1.00 1.01 1.99 1.00 1.00 3.01 2.01 1.02 2.06 4.04 1.09 3.09 9.13
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5
f1 (ppm)

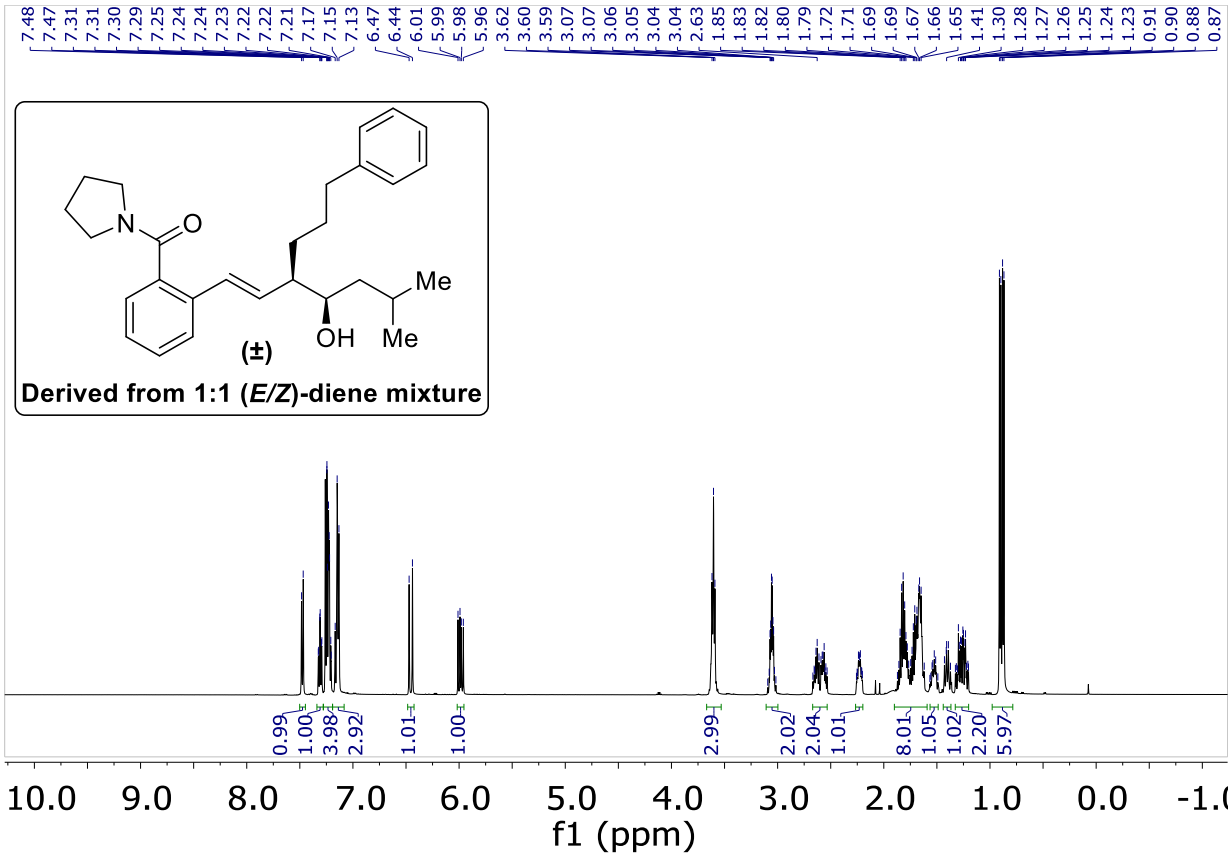

169.78
136.49 134.16 133.94 129.19 129.00 127.33 126.18 126.09
72.47
52.54 48.32 45.60 43.54
26.01 24.72 24.65 24.02 23.26 21.62 12.20
N
O
Me
Me
OH
Me
(±)
(Derived from (E)-diene)
210 190 170 150 130 110 90 70 50 30 10
f1 (ppm)

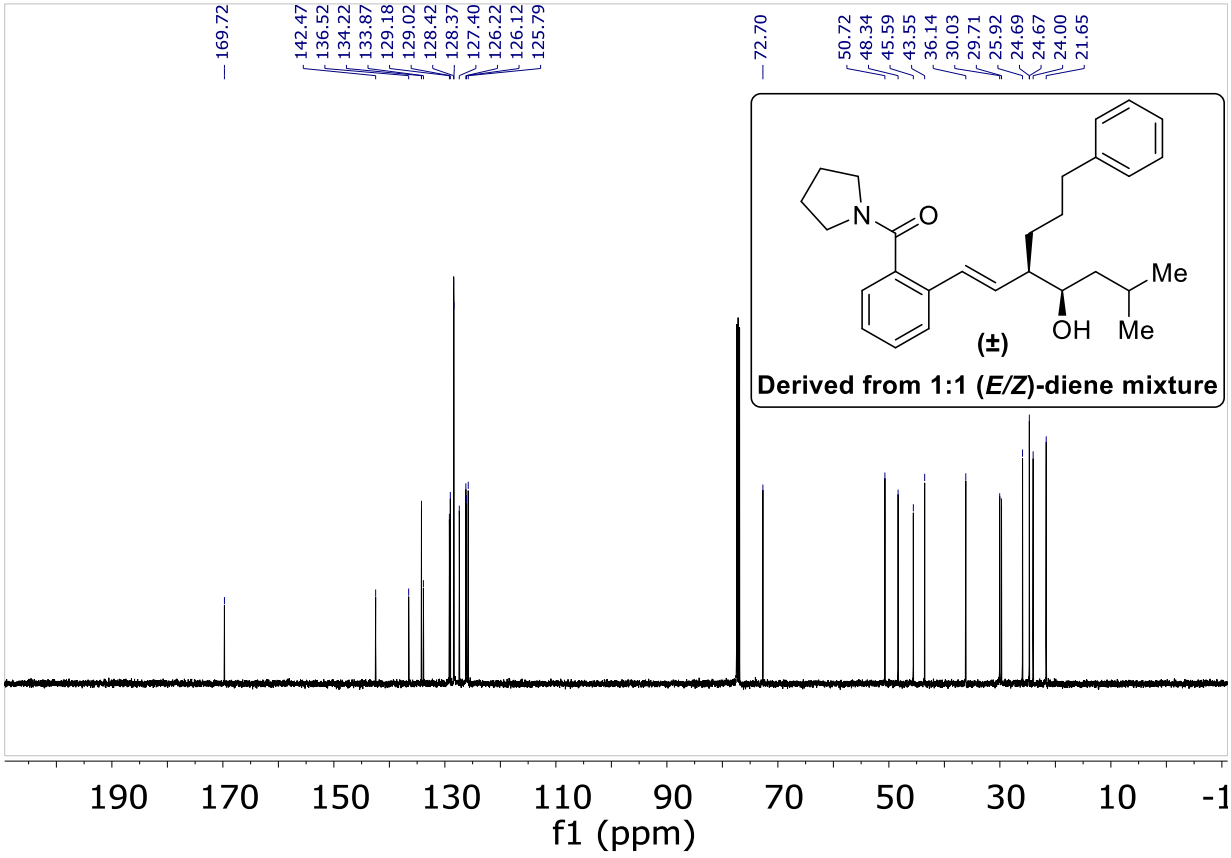

7.49 7.47 7.31 7.31 7.30 7.30 7.29 7.29 7.23 7.23 7.22 7.22 6.46 6.43 5.99 5.97 5.96 5.94 3.65 3.64 3.62 3.61 3.11 3.10 3.09 2.11 2.10 2.09 1.93 1.92 1.90 1.89 1.84 1.83 1.82 1.80 1.79 1.68 1.67 1.66 1.66 1.32 1.31 1.29 1.28 1.27 1.26 1.26 1.25 1.24 1.23 0.90 0.89 0.88 0.87 0.85
N O Me Me OH Me
(±)
(Derived from (Z)-diene)
1.02 1.01 2.00 1.00 1.01 3.03 2.00 1.01 2.08 3.04 1.99 3.02 9.12
9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1
f1 (ppm)

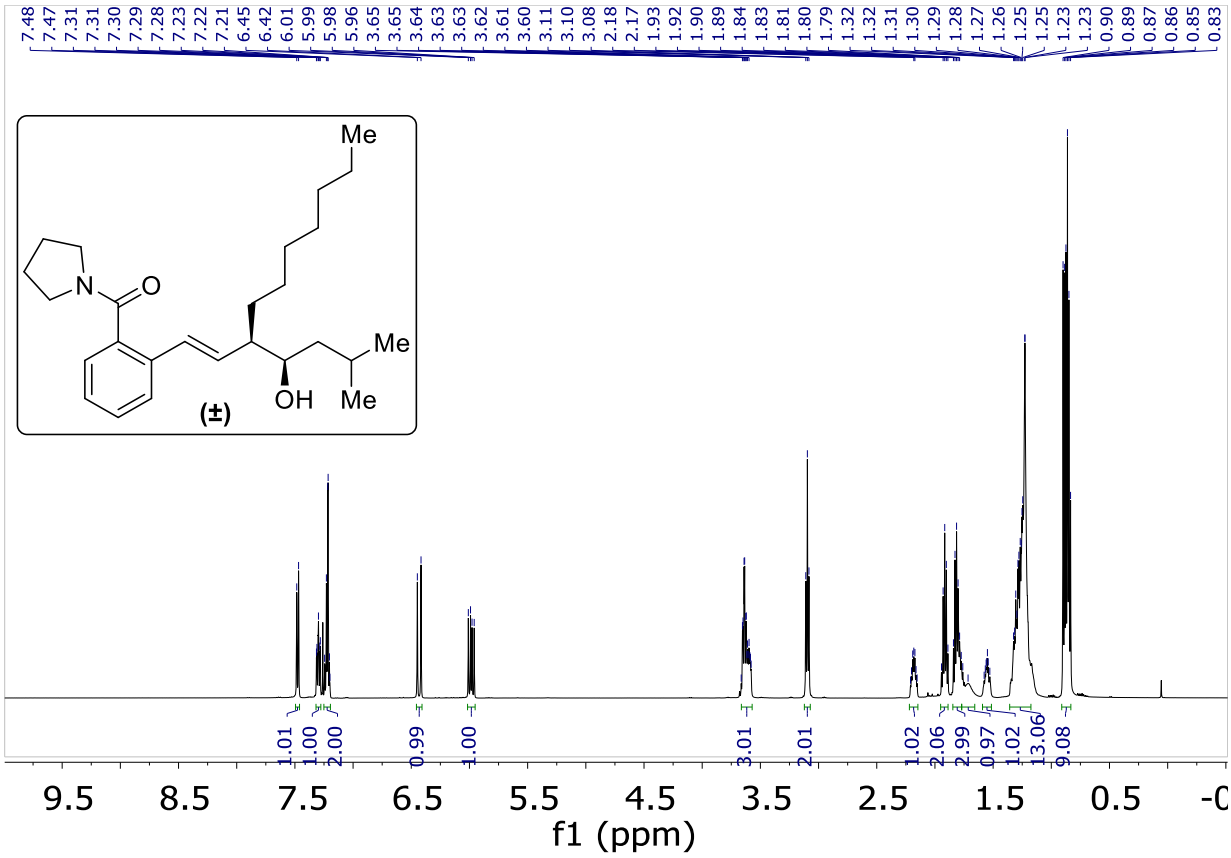

169.77
136.52 134.15 133.97 129.26 129.01 127.36 126.21 126.11
72.51
52.55 48.34 45.62 43.55
26.03 24.73 24.68 24.03 23.29 21.64
12.21
N O Me Me OH Me
(±)
(Derived from (Z)-diene)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

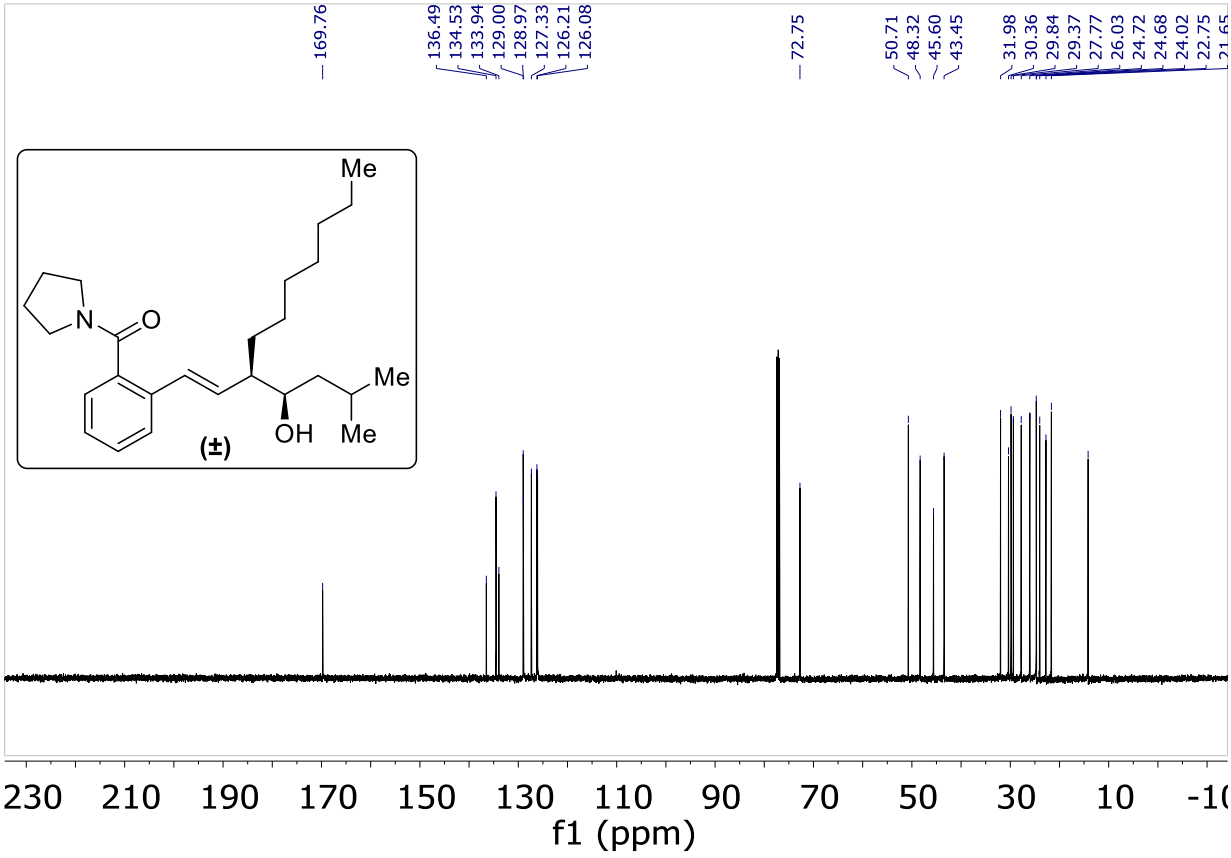

7.48 7.47 7.31 7.31 7.30 7.29 7.26 7.24 7.23 7.22 7.22 7.21 7.17 7.15 7.13 6.47 6.44 6.01 5.99 5.98 5.96 3.62 3.60 3.59 3.07 3.06 3.06 3.05 3.04 3.04 2.63 1.84 1.83 1.82 1.80 1.79 1.73 1.72 1.71 1.69 1.68 1.67 1.66 1.66 1.65 1.30 1.28 1.27 1.25 1.25 1.23 1.23 0.91 0.90 0.88 0.87
N
O
Me
OH
Me
(±)
Derived from (E)-diene
1.00 1.06 4.04 2.99 1.00 1.00 3.06 2.03 1.00 1.02 1.01 8.20 1.05 1.07 2.09 6.03
9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
f1 (ppm)

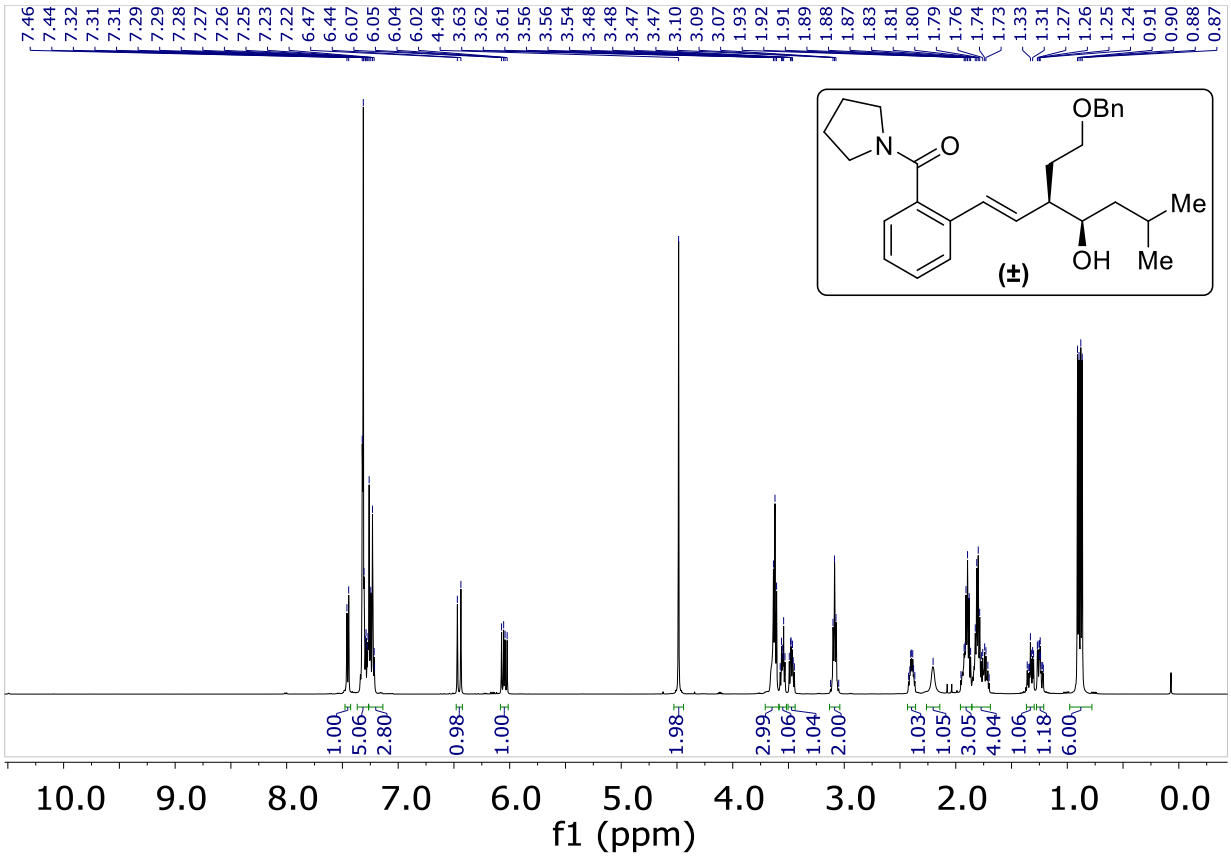

169.71
142.47 136.51 134.23 133.86 129.14 129.01 128.41 128.35 127.38 126.21 126.10 125.77
72.67
50.71 48.33 45.58 43.55 36.13 30.02 29.70 25.90 24.68 24.66 24.00 21.65
N
O
Me
OH
Me
(±)
Derived from (E)-diene
20 200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

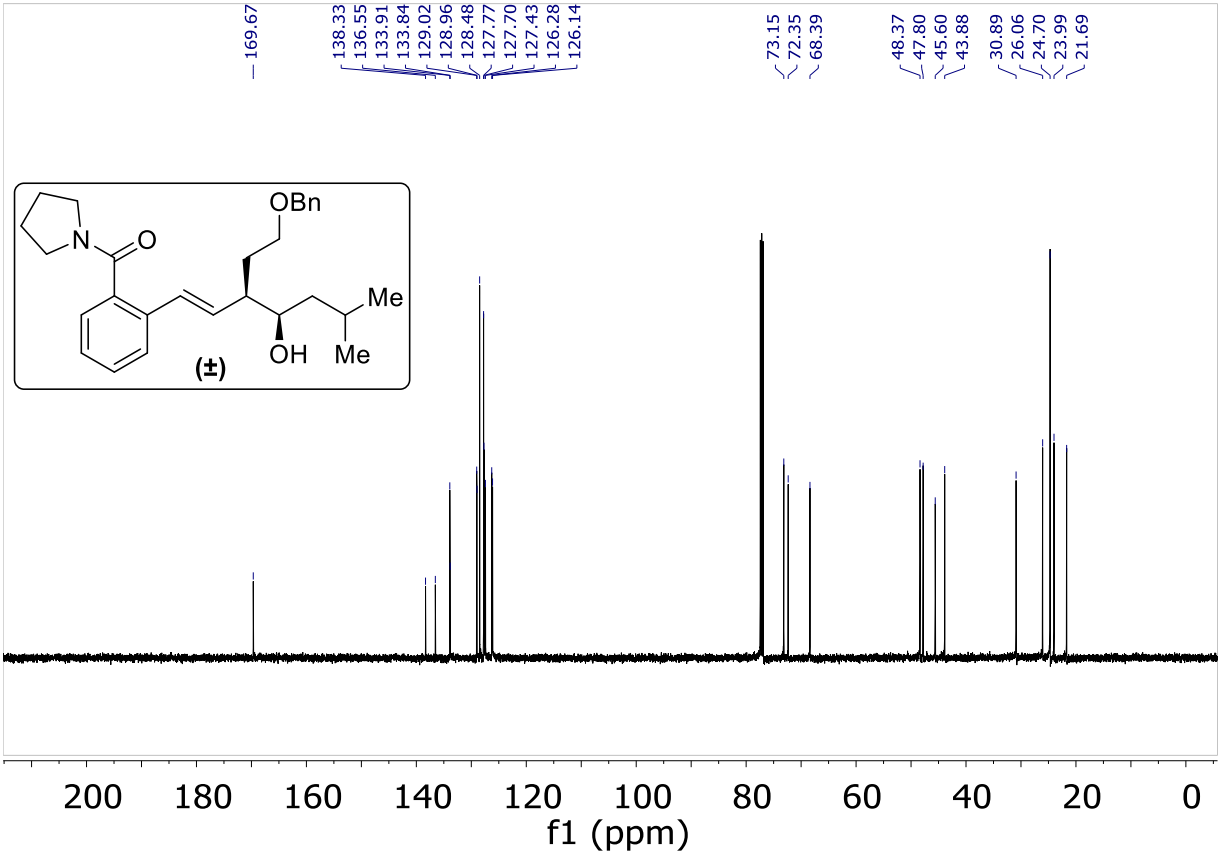

7.48 7.47 7.31 7.31 7.30 7.29 7.25 7.24 7.24 7.23 7.22 7.22 7.21 7.17 7.15 7.13 6.47 6.44 6.01 5.99 5.98 5.96 3.62 3.60 3.59 3.07 3.07 3.06 3.05 3.04 3.04 2.63 1.85 1.83 1.82 1.80 1.79 1.72 1.71 1.69 1.69 1.67 1.66 1.65 1.41 1.30 1.28 1.27 1.26 1.25 1.24 1.23 0.91 0.90 0.88 0.87
N
O
Me
OH
Me
(±)
Derived from 1:1 (E/Z)-diene mixture
0.99 1.00 3.98 2.92 1.01 1.00 2.99 2.02 2.04 1.01 8.01 1.05 1.02 2.20 5.97
10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0
f1 (ppm)

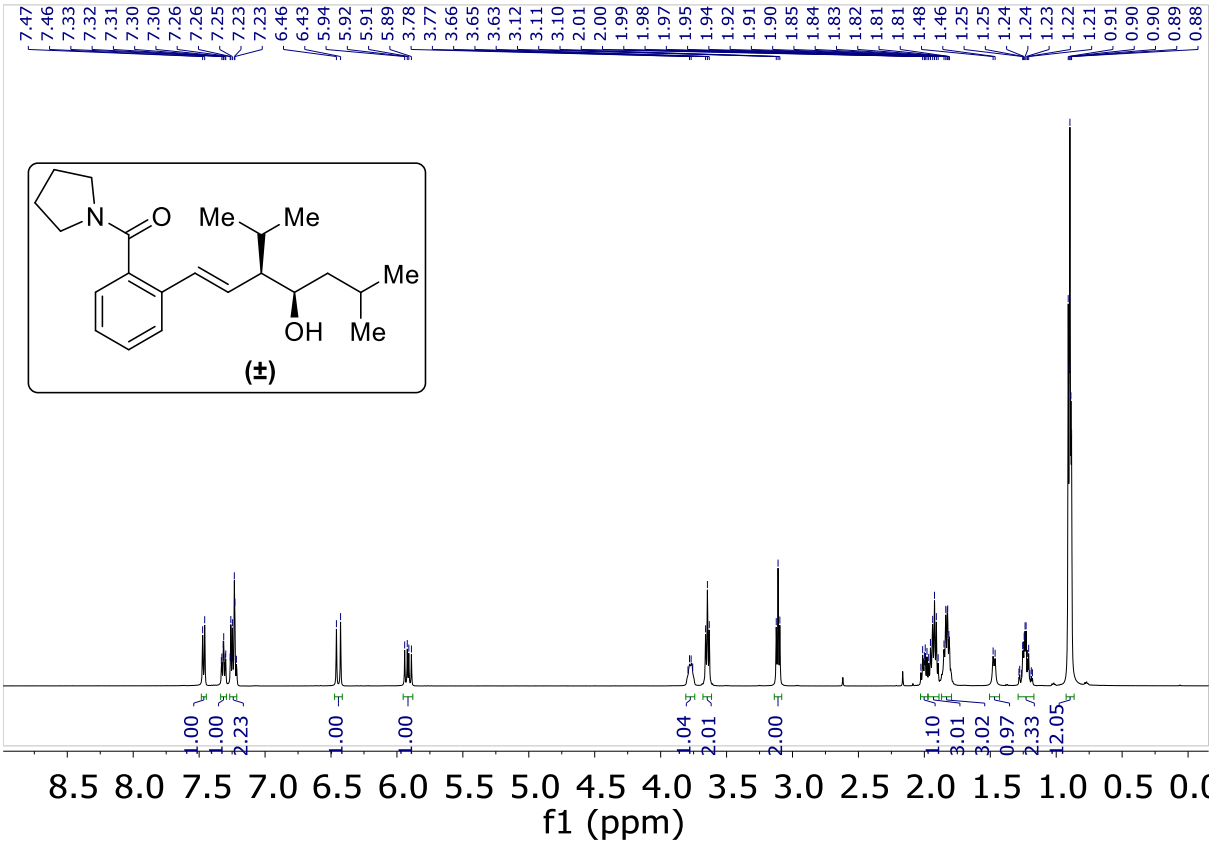

169.72
142.47 136.52 134.22 133.87 129.18 129.02 128.42 128.37 127.40 126.22 126.12 125.79
72.70
50.72 48.34 45.59 43.55 36.14 30.03 29.71 25.92 24.69 24.67 24.00 21.65
N
O
Me
OH
Me
(±)
Derived from 1:1 (E/Z)-diene mixture
190 170 150 130 110 90 70 50 30 10 -1
f1 (ppm)

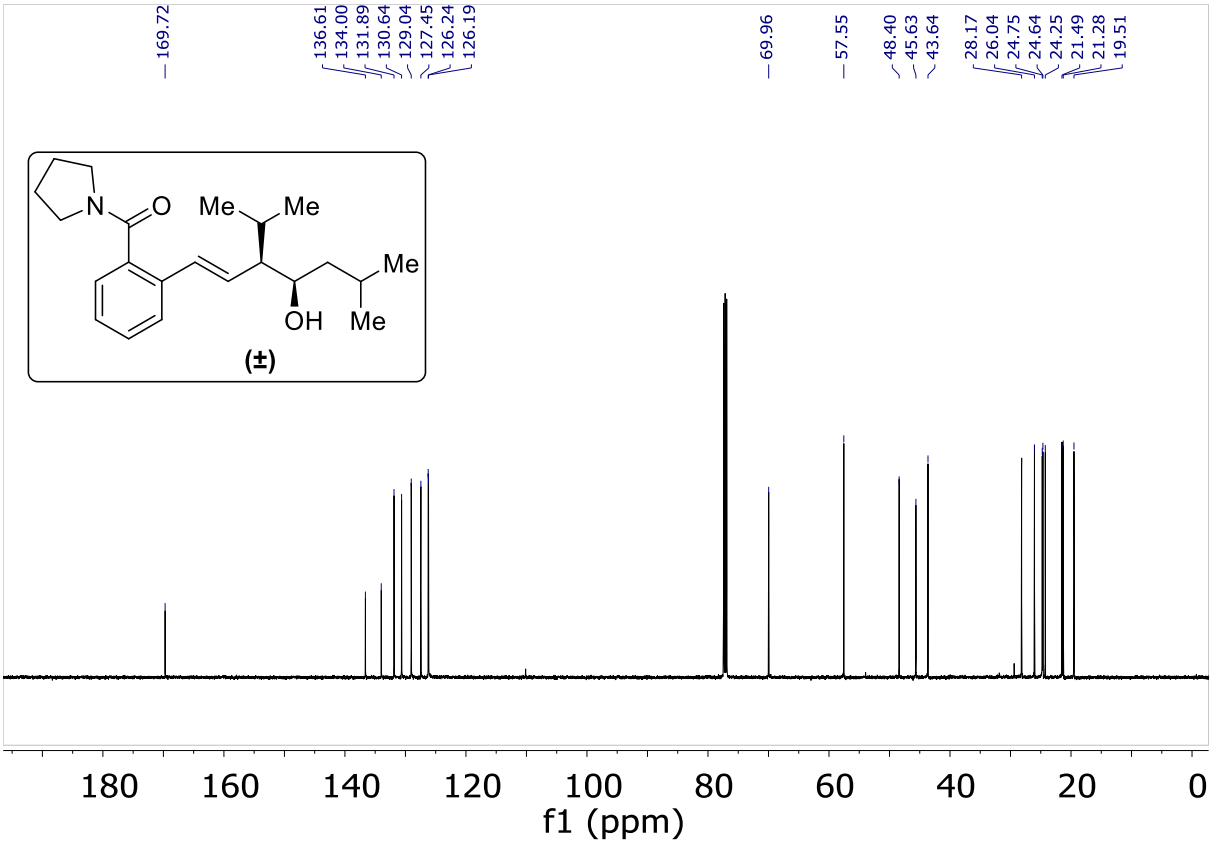

7.48 7.47 7.31 7.31 7.30 7.29 7.28 7.23 7.22 7.21 6.45 6.42 6.01 5.99 5.98 5.96 3.65 3.65 3.64 3.63 3.63 3.62 3.61 3.60 3.11 3.10 3.08 2.18 2.17 1.93 1.92 1.90 1.89 1.84 1.83 1.81 1.80 1.79 1.32 1.32 1.31 1.30 1.29 1.28 1.27 1.26 1.25 1.25 1.23 1.23 0.90 0.89 0.87 0.86 0.85 0.83
Me
N
O
Me
OH
Me
(±)
1.01 1.00 2.00 0.99 1.00 3.01 2.01 1.02 2.06 2.99 0.97 1.02 13.06 9.08
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5
f1 (ppm)

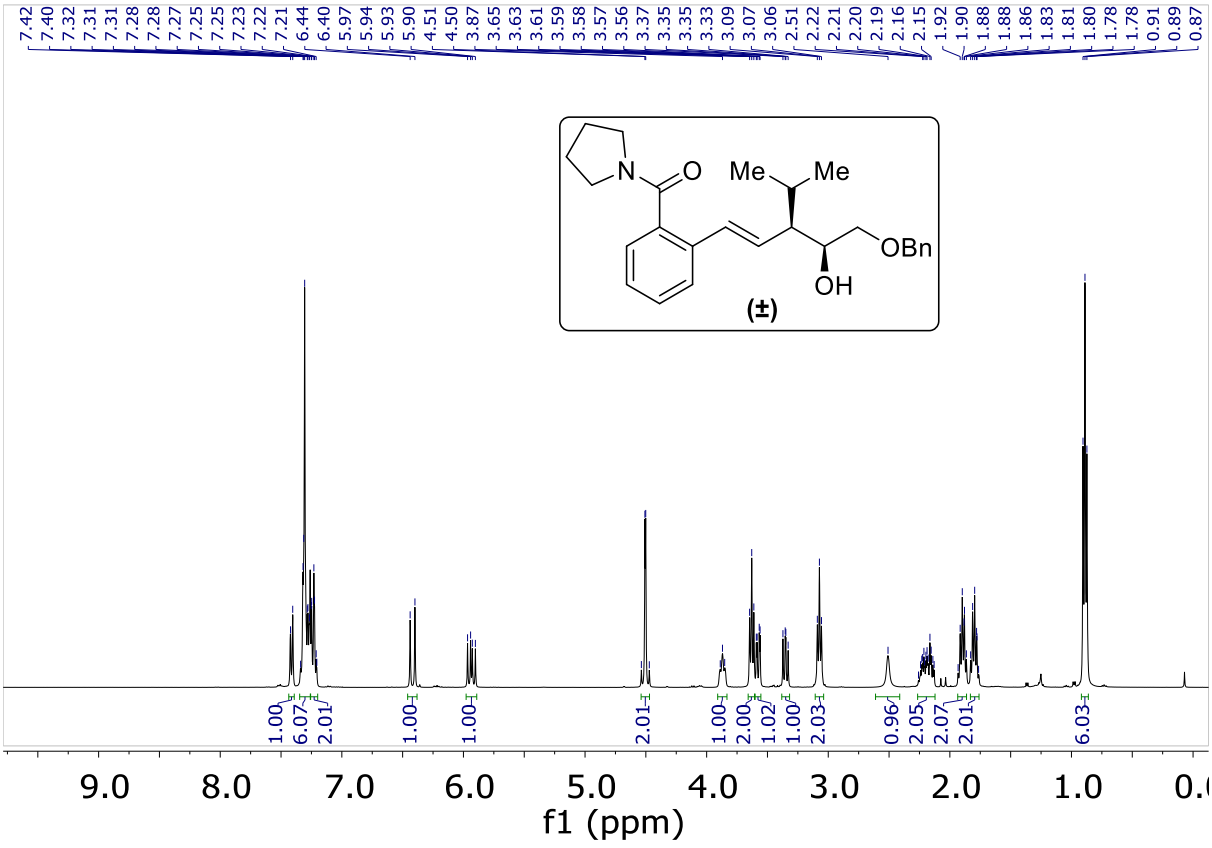

169.76
136.49 134.53 133.94 129.00 128.97 127.33 126.21 126.08
72.75
50.71 48.32 45.60 43.45
31.98 30.36 29.84 29.37 27.77 26.03 24.72 24.68 24.02 22.75
Me
N
O
Me
OH
Me
(±)
230 210 190 170 150 130 110 90 70 50 30 10
f1 (ppm)


7.46 7.44 7.32 7.31 7.31 7.29 7.29 7.28 7.27 7.26 7.25 7.23 7.22 6.47 6.44 6.07 6.05 6.04 6.02 4.49 3.63 3.62 3.61 3.56 3.56 3.54 3.48 3.48 3.47 3.47 3.10 3.09 3.07 1.93 1.92 1.91 1.89 1.88 1.87 1.83 1.81 1.80 1.79 1.76 1.74 1.73 1.33 1.31 1.27 1.26 1.25 1.24 0.91 0.90 0.88 0.87
OBn
N
O
Me
OH
Me
(±)
1.00 5.06 2.80 0.98 1.00 1.98 2.99 1.06 1.04 2.00 1.03 1.05 3.05 4.04 1.06 1.18 6.00
10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
f1 (ppm)


169.67
138.33 136.55 133.91 133.84 129.02 128.96 128.48 127.77 127.70 127.43 126.28 126.14
73.15 72.35 68.39
48.37 47.80 45.60 43.88
30.89 26.06 24.70 23.99 21.69
OBn
N
O
Me
OH
Me
(±)
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)


7.47 7.46 7.33 7.32 7.31 7.30 7.30 7.26 7.26 7.25 7.23 7.23 6.46 6.43 5.94 5.92 5.91 5.89 3.78 3.77 3.66 3.65 3.63 3.12 3.11 3.10 2.01 2.00 1.99 1.98 1.97 1.95 1.94 1.92 1.91 1.90 1.85 1.84 1.83 1.82 1.81 1.81 1.48 1.46 1.25 1.25 1.24 1.24 1.23 1.22 1.21 0.91 0.90 0.90 0.89 0.88
N O Me Me Me OH Me
(±)
1.00 1.00 2.23 1.00 1.00 1.04 2.01 2.00 1.10 3.01 3.02 0.97 2.33 12.05
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


169.72
136.61 134.00 131.89 130.64 129.04 127.45 126.24 126.19
69.96
57.55
48.40 45.63 43.64
28.17 26.04 24.75 24.64 24.25 21.49 21.28 19.51
N O Me Me Me OH Me
(±)
180 160 140 120 100 80 60 40 20 0
f1 (ppm)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N
O
Me
Me
OBn
OH
(±)
1.00 6.07 2.01 1.00 1.00 2.01 1.00 2.00 1.02 1.00 2.03 0.96 2.05 2.07 2.01 6.03
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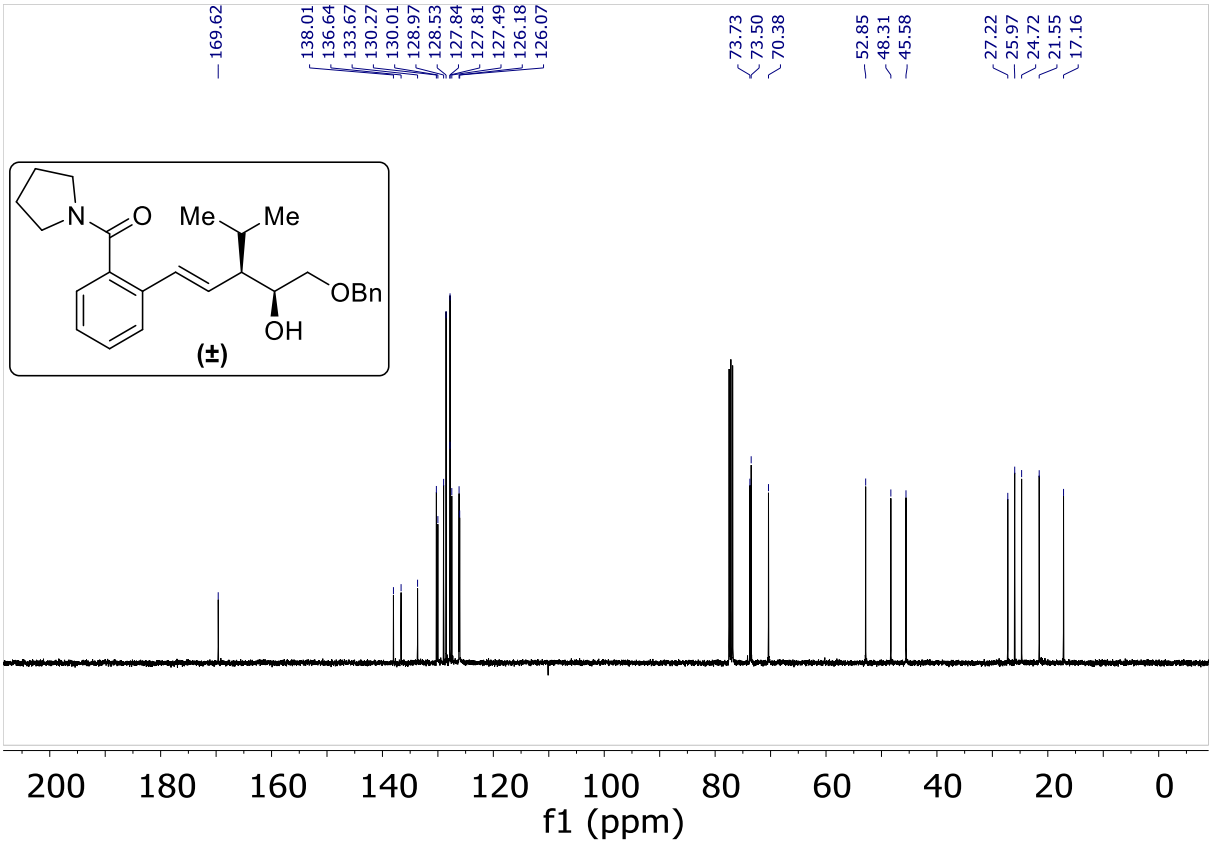
f1 (ppm)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N
O
Me
Me
OBn
OH
(±)
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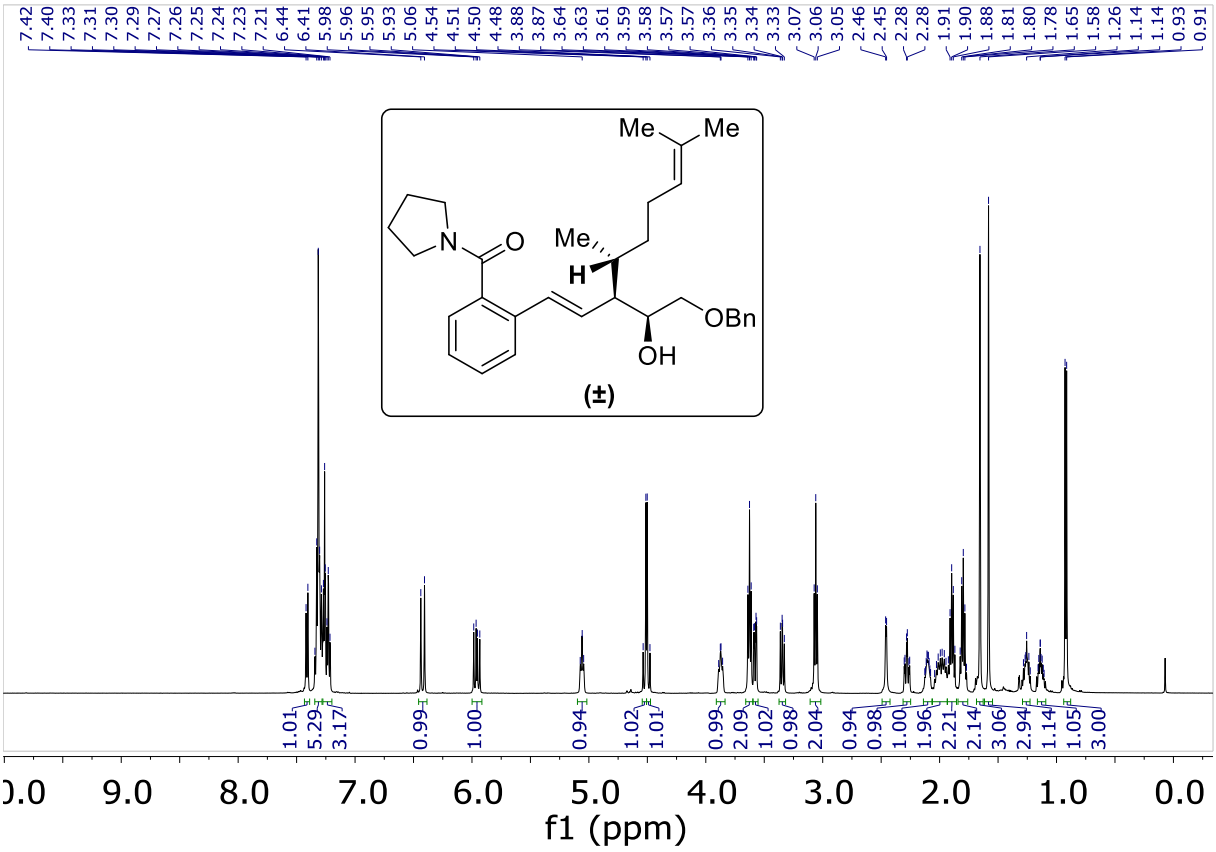
f1 (ppm)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Me
Me
N
O
Me
H
OBn
OH
(±)
1.01 5.29 3.17 0.99 1.00 0.94 1.02 1.01 0.99 2.09 1.02 0.98 2.04 0.94 0.98 1.00 1.96 2.21 2.14 3.06 2.94 1.14 1.05 3.00
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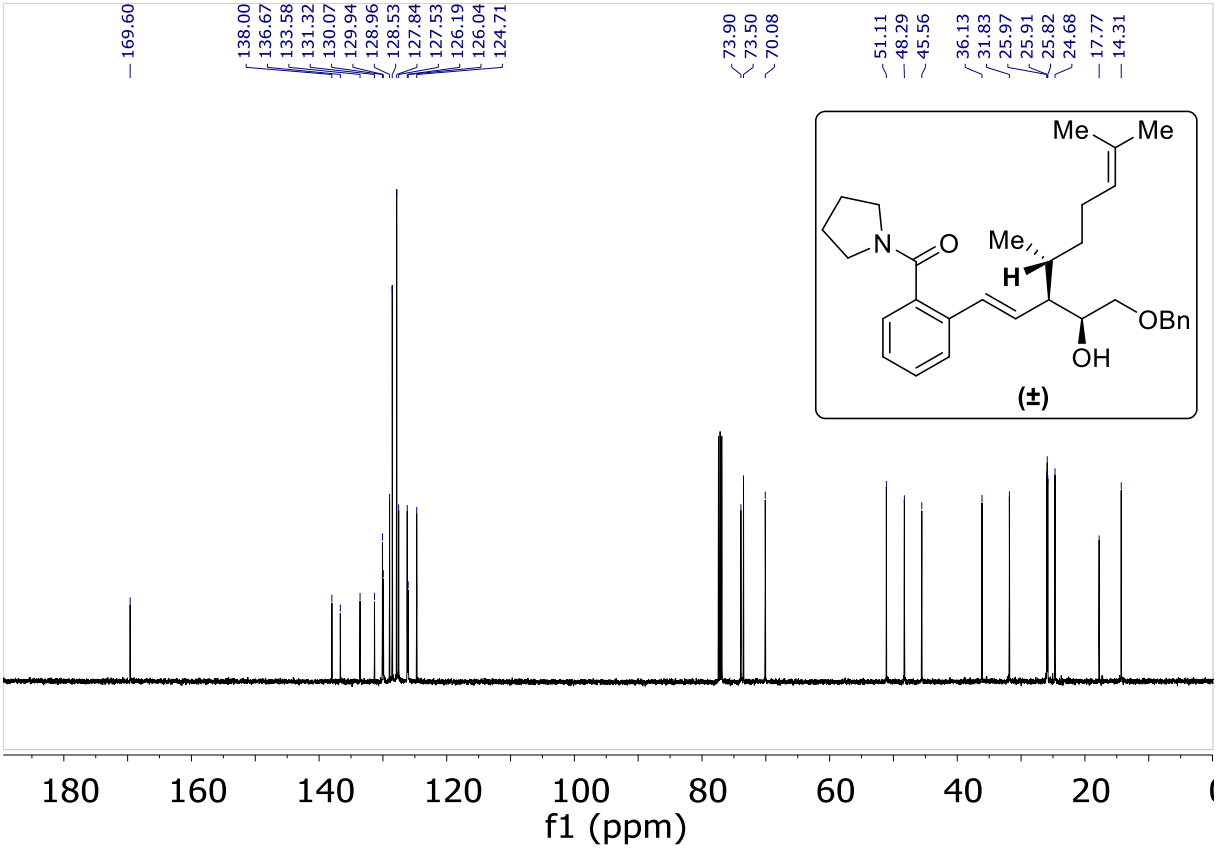
f1 (ppm)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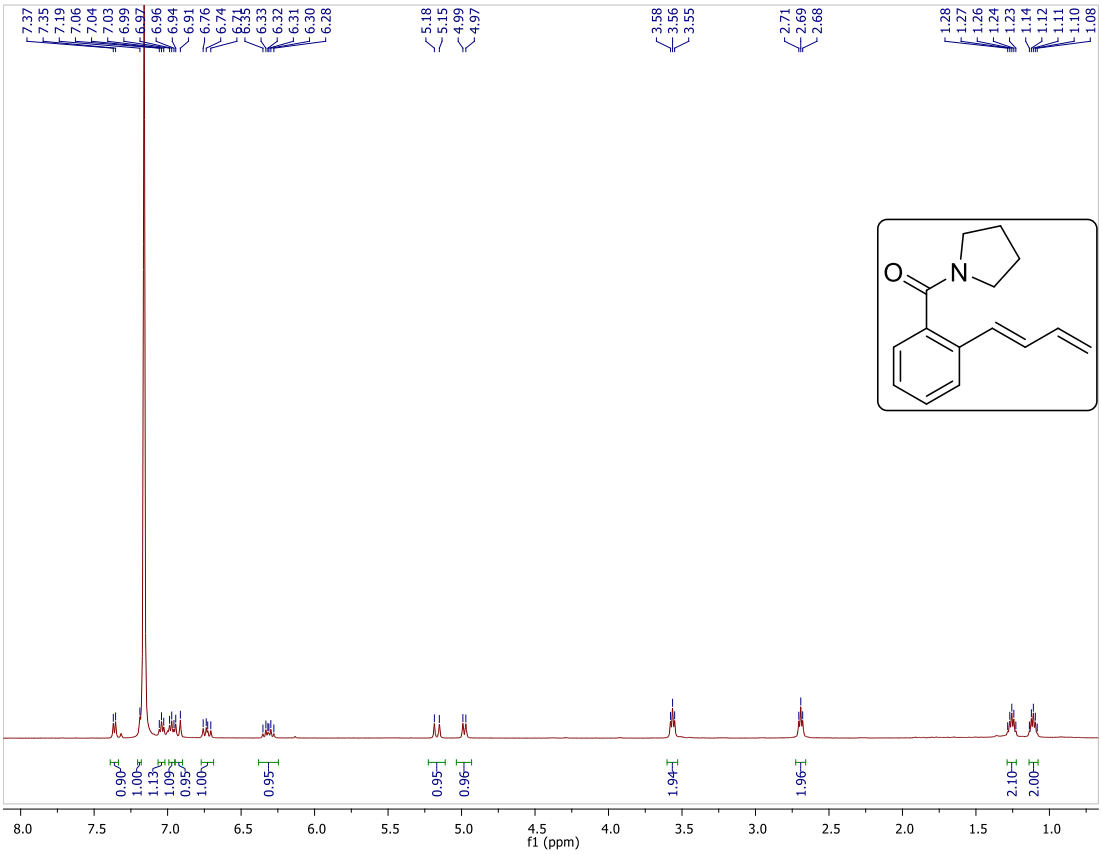
73.90 73.50 70.08
51.11 48.29 45.56 36.13 31.83 25.97 25.91 25.82 24.68 17.77 14.31
Me
Me
N
O
Me
H
OBn
OH
(±)
180 160 140 120 100 80 60 40 20
f1 (ppm)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2.69
2.68
1.28
1.27
1.26
1.24
1.23
1.14
1.12
1.11
1.10
1.08
0.90
1.00
1.13
1.09
0.95
1.00
0.95
0.95
0.96
1.94
1.96
2.10
2.00
O
N
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7.5
7.0
6.5
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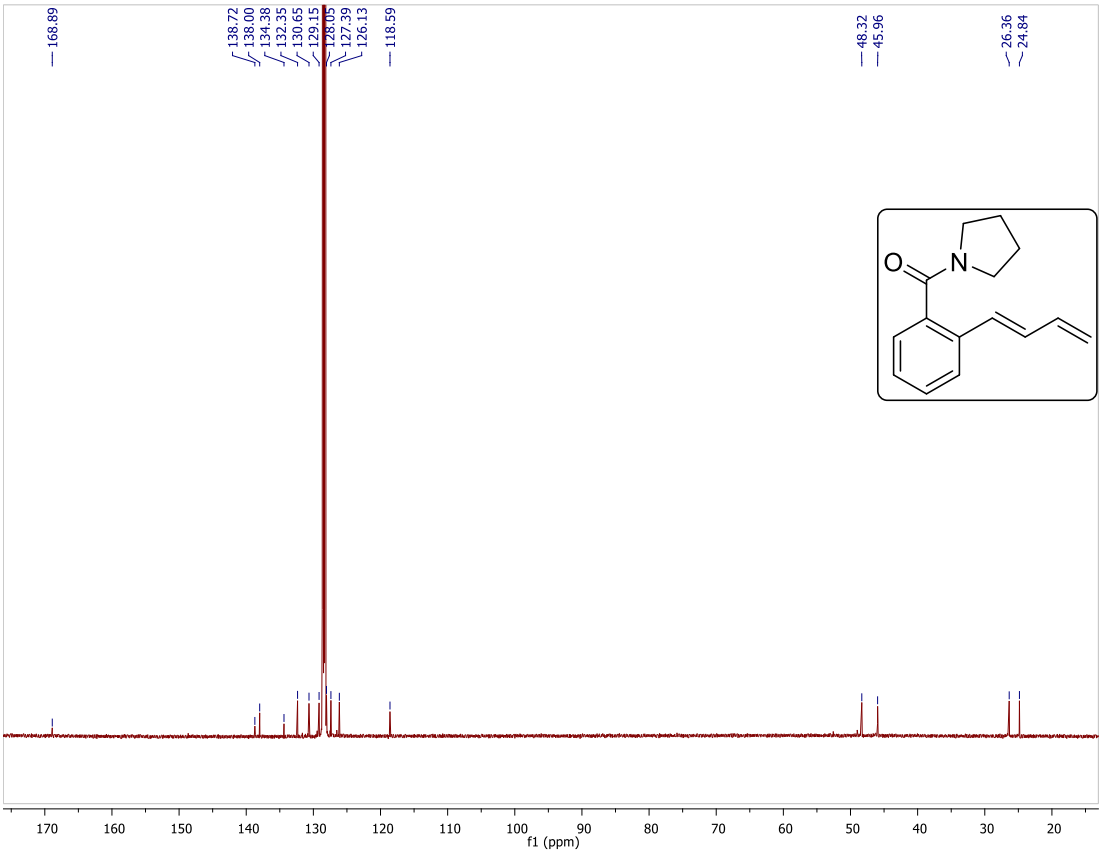
1.0
f1 (ppm)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129.15
128.05
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118.59
48.32
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26.36
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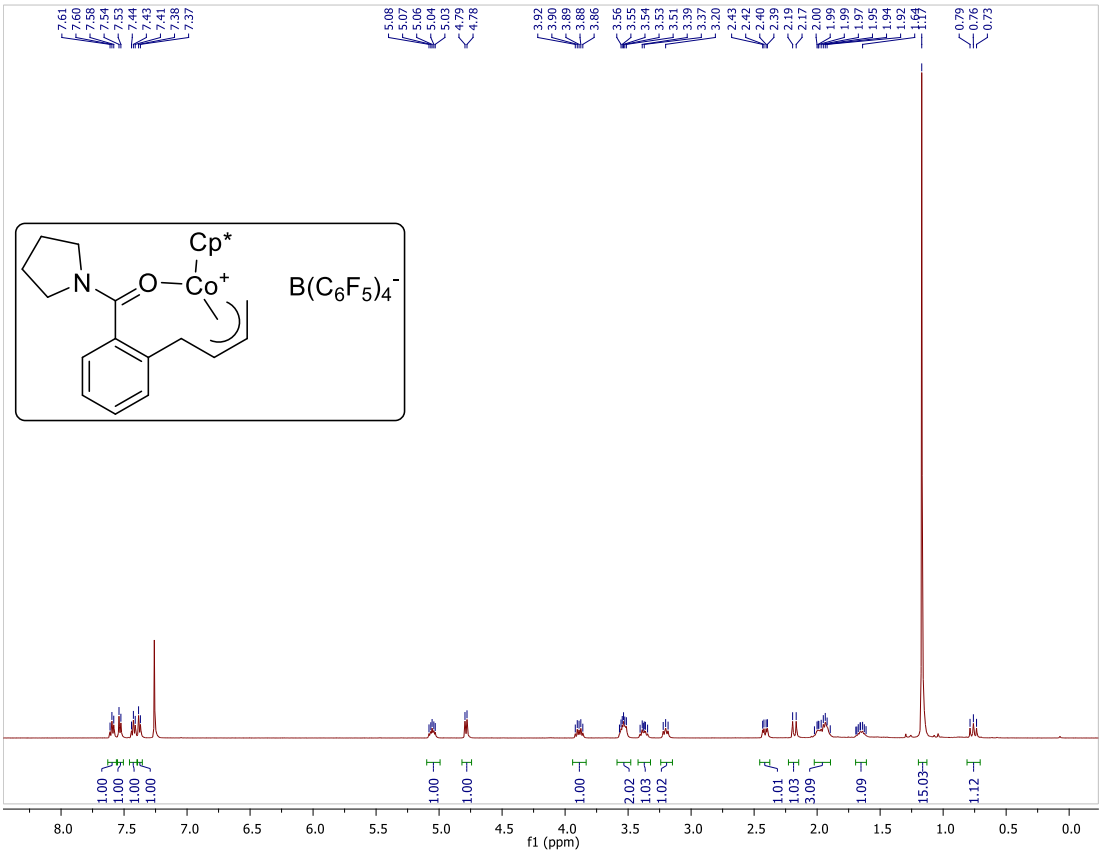
70
60
50
40
30
20
f1 (ppm)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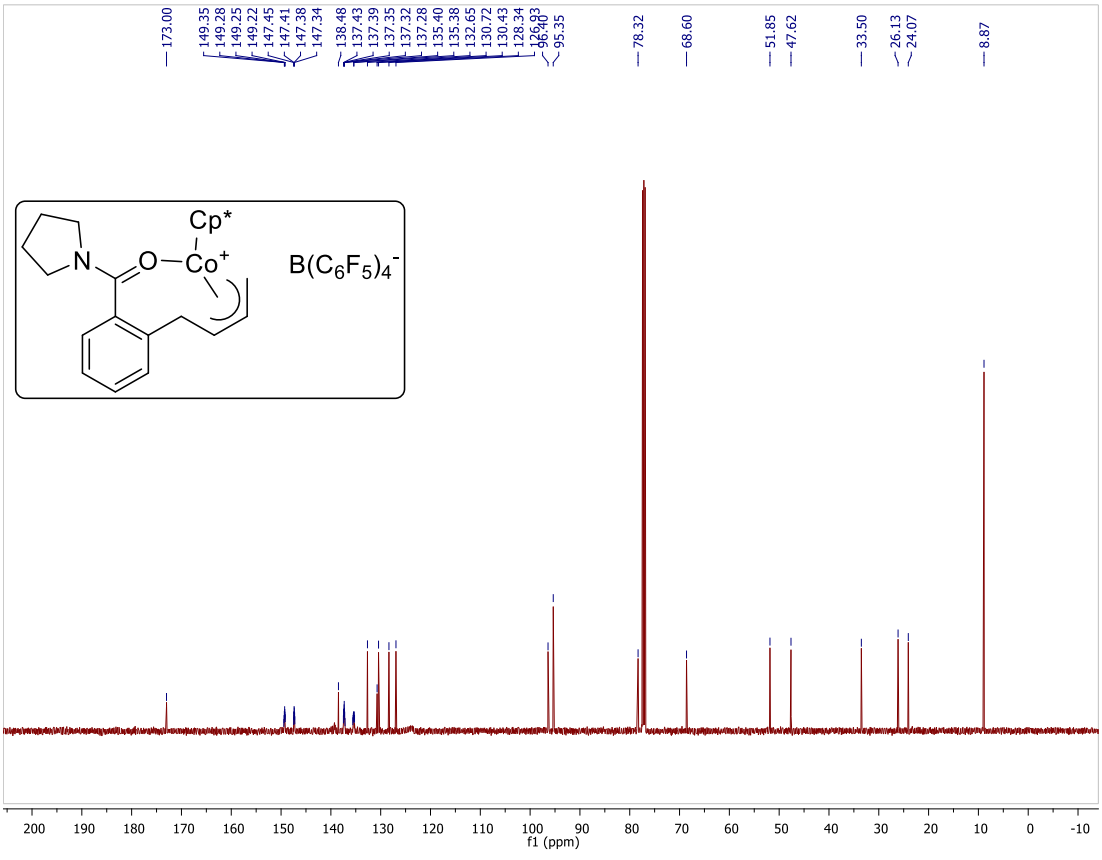
O
Co+
B(C6F5)4-
f1 (ppm)


Cp*
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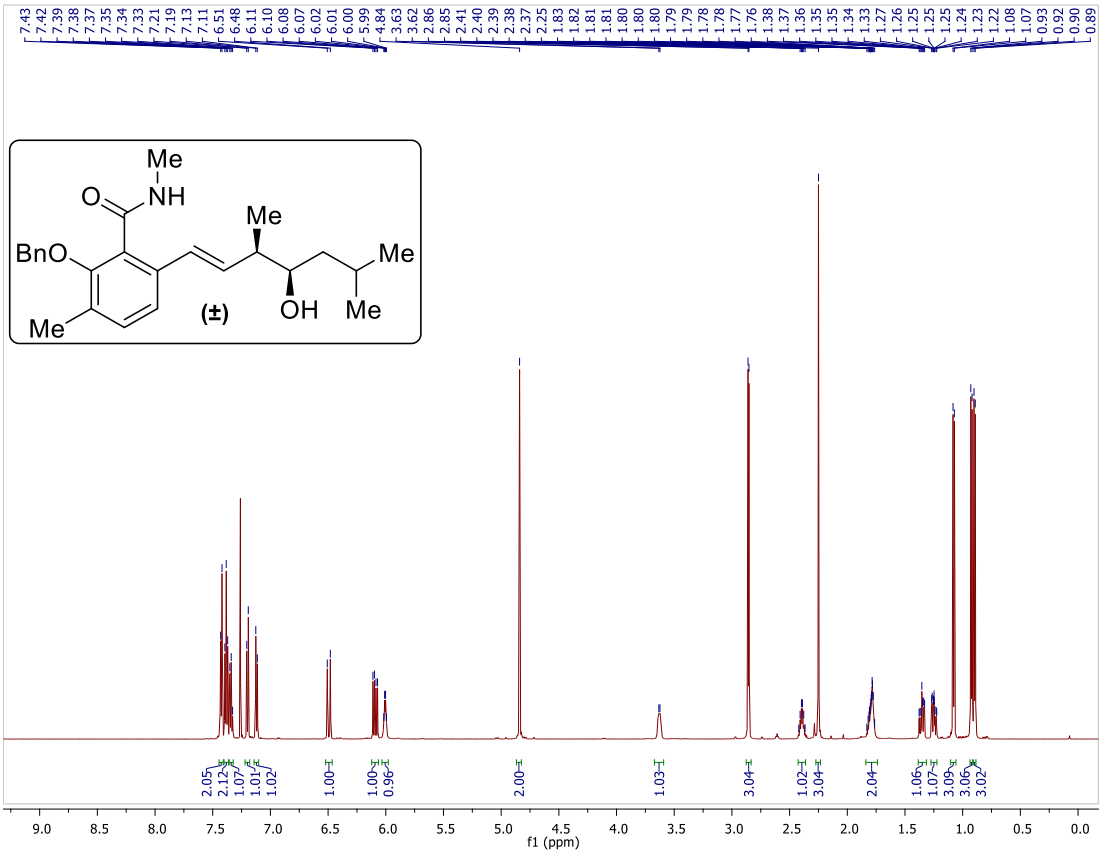
O
Co+
B(C6F5)4-
f1 (ppm)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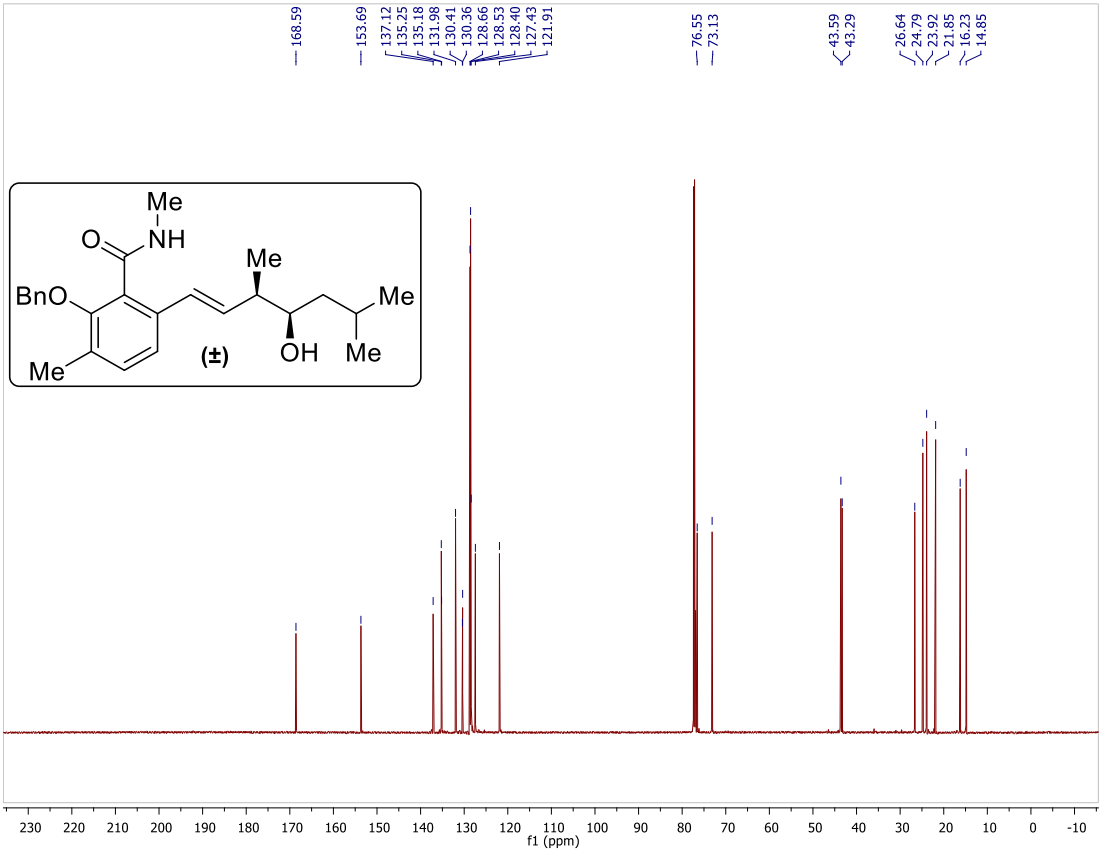
Me
BnO
Me
Me
(±)
OH
Me
f1 (ppm)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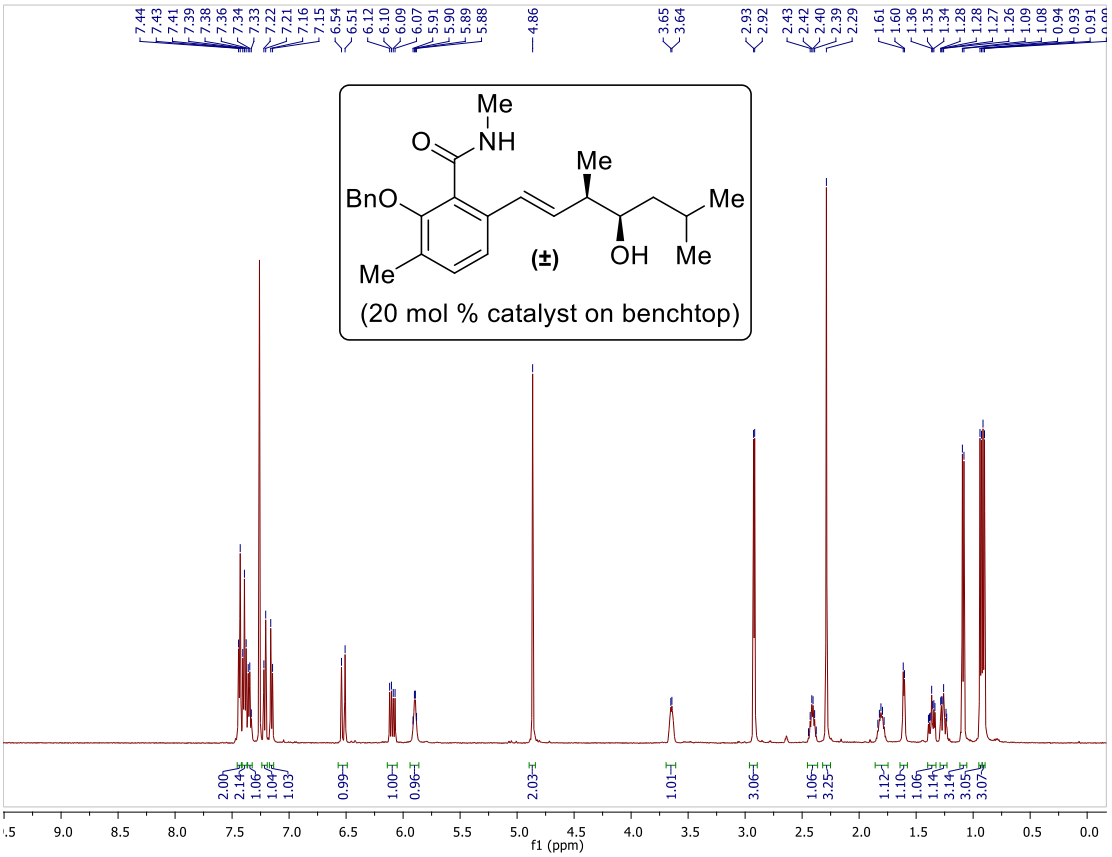
O
NH
Me
BnO
Me
Me
(±)
OH
Me
f1 (ppm)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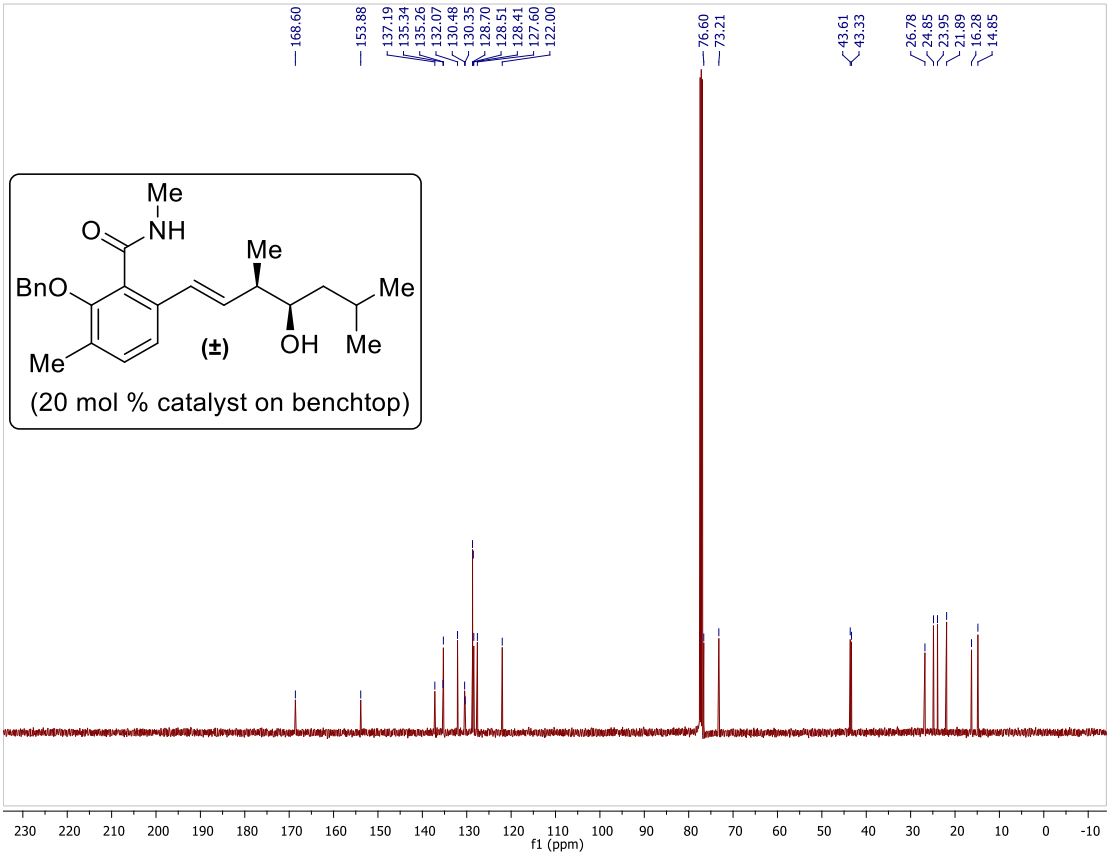
Me
BnO
Me
Me
(±)
OH
Me
Me
(20 mol % catalyst on benchtop)
f1 (ppm)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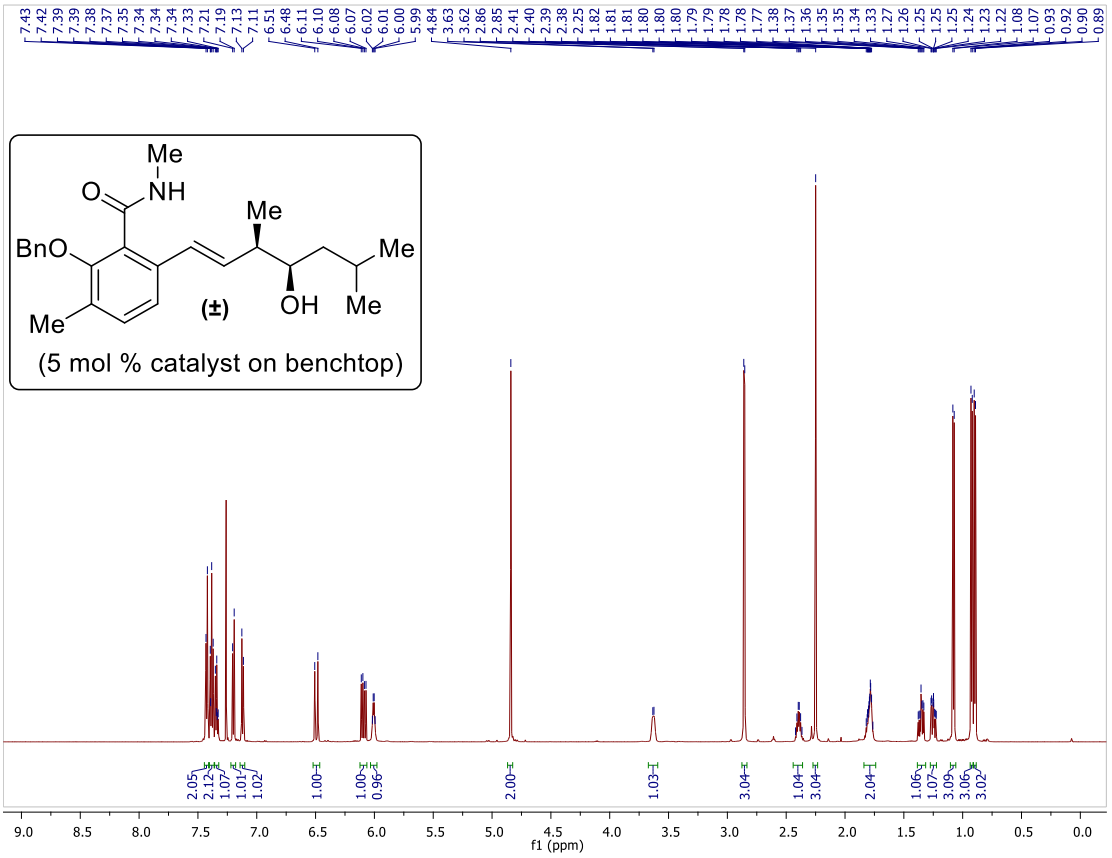
NH
Me
BnO
Me
Me
(±)
OH
Me
(20 mol % catalyst on benchtop)
f1 (ppm)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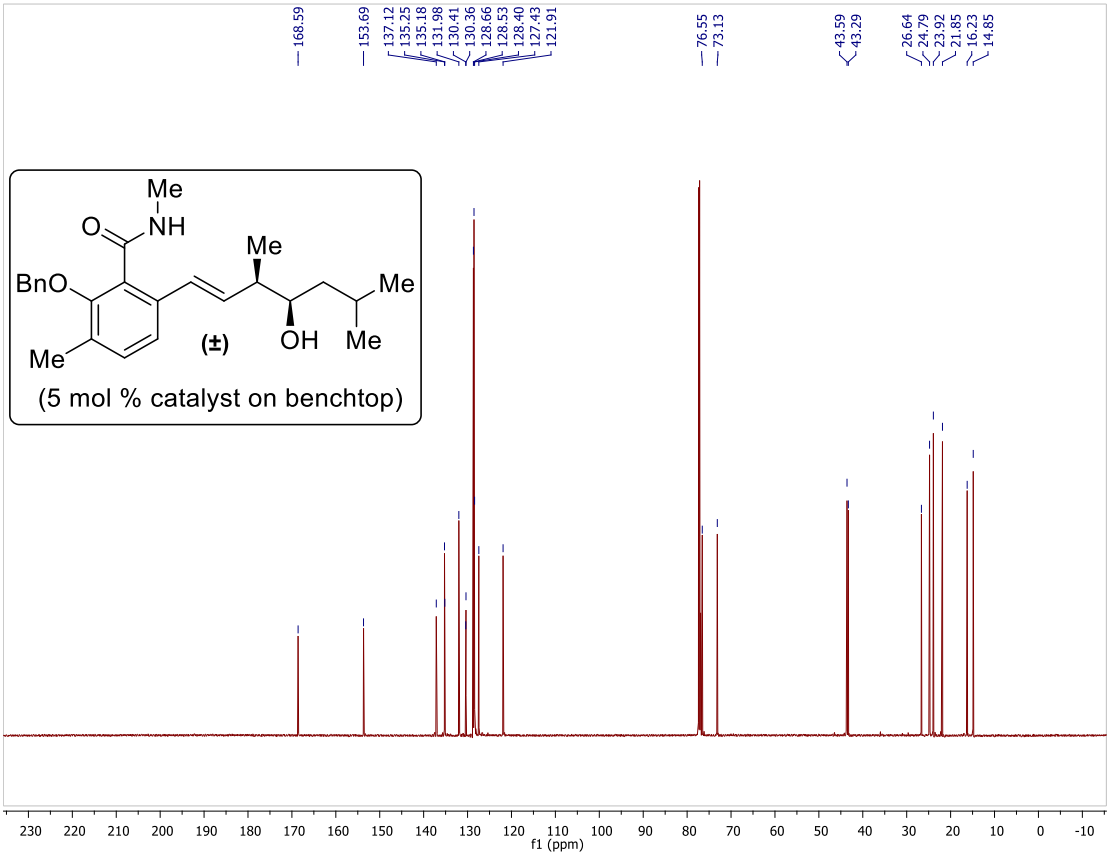
(±)
OH
Me
(5 mol % catalyst on benchtop)
f1 (ppm)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O
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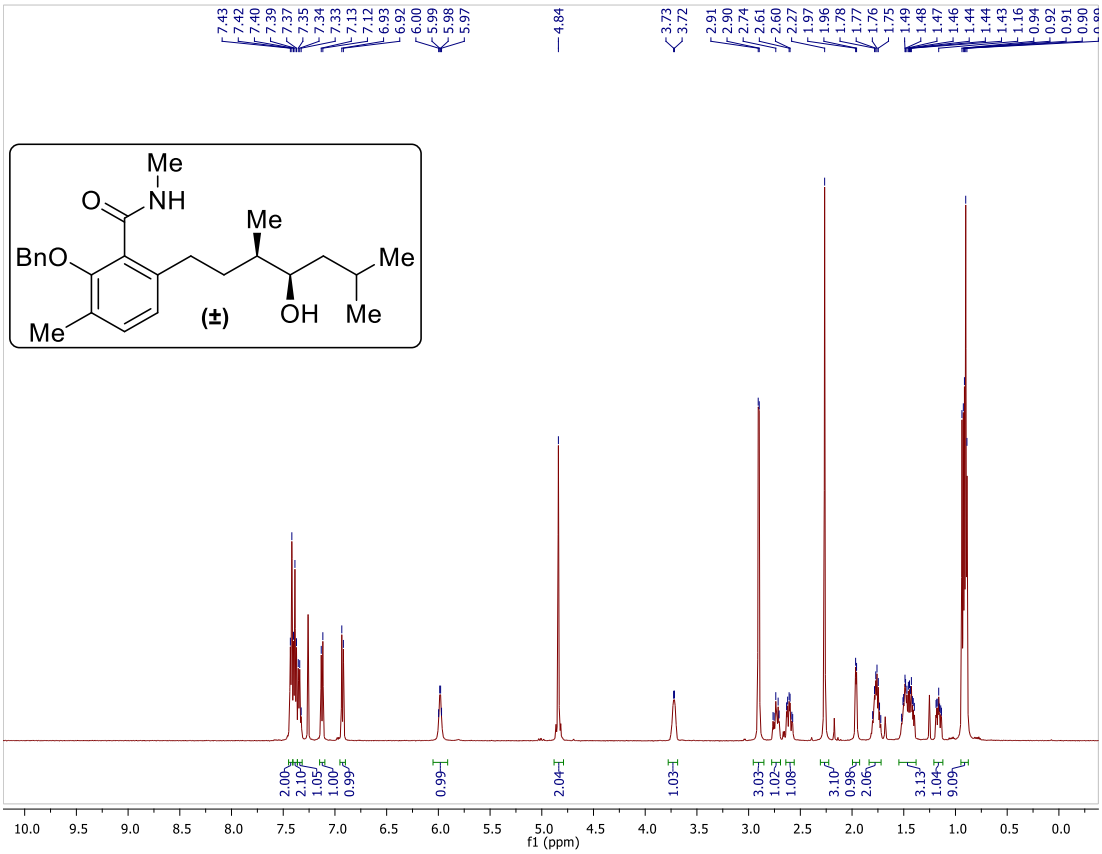
Me
Me
(±)
OH
Me
(5 mol % catalyst on benchtop)
f1 (ppm)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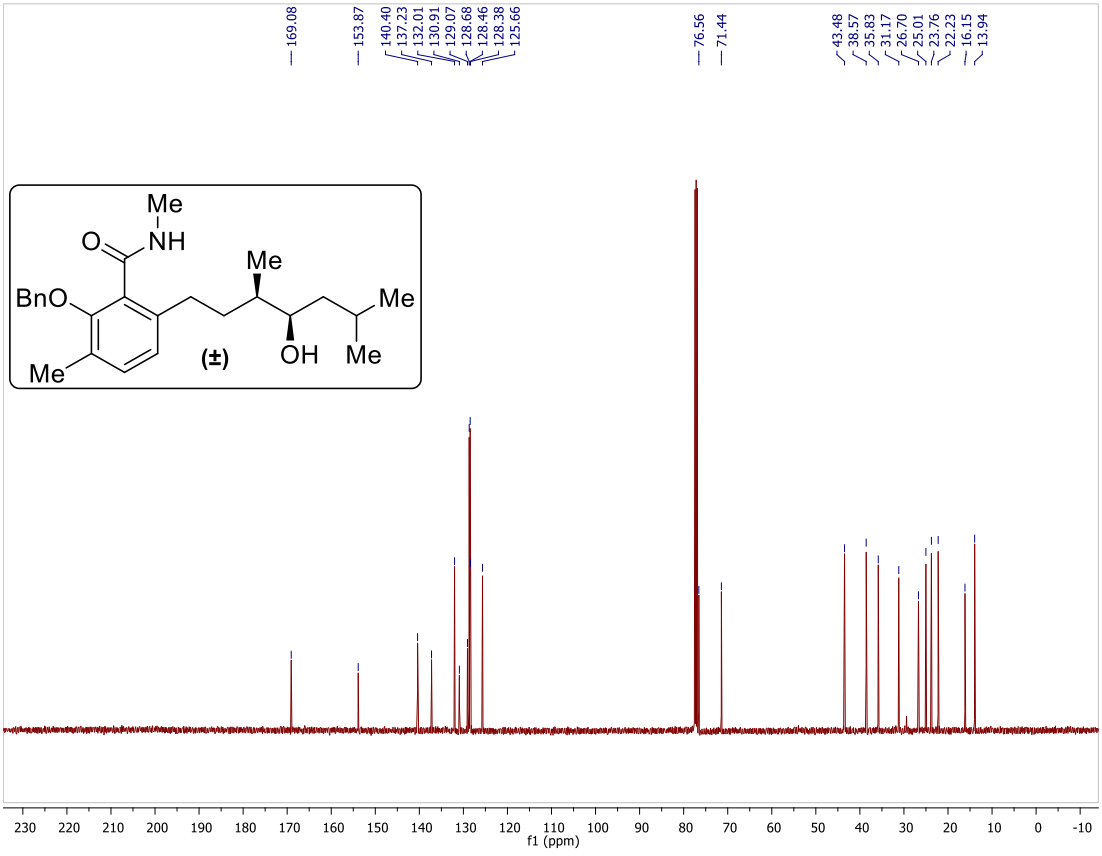
O
Me
BnO
Me
Me
(±)
OH
Me
f1 (ppm)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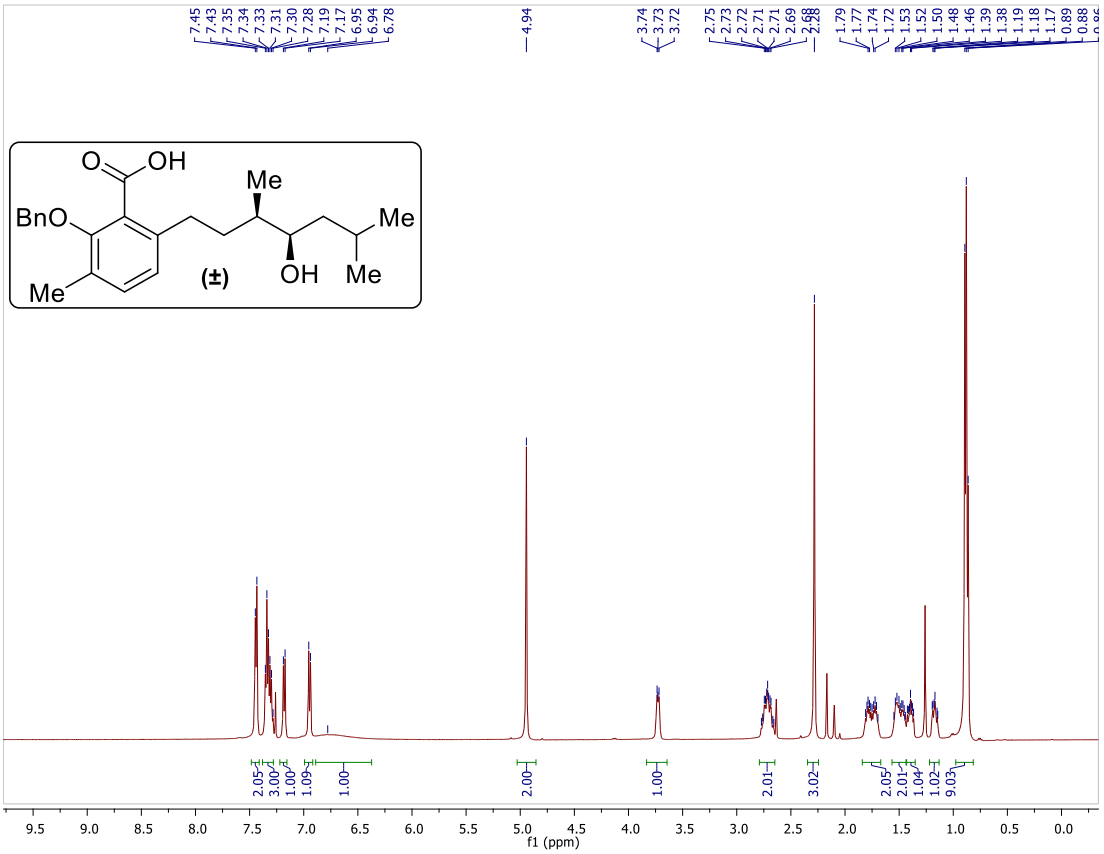
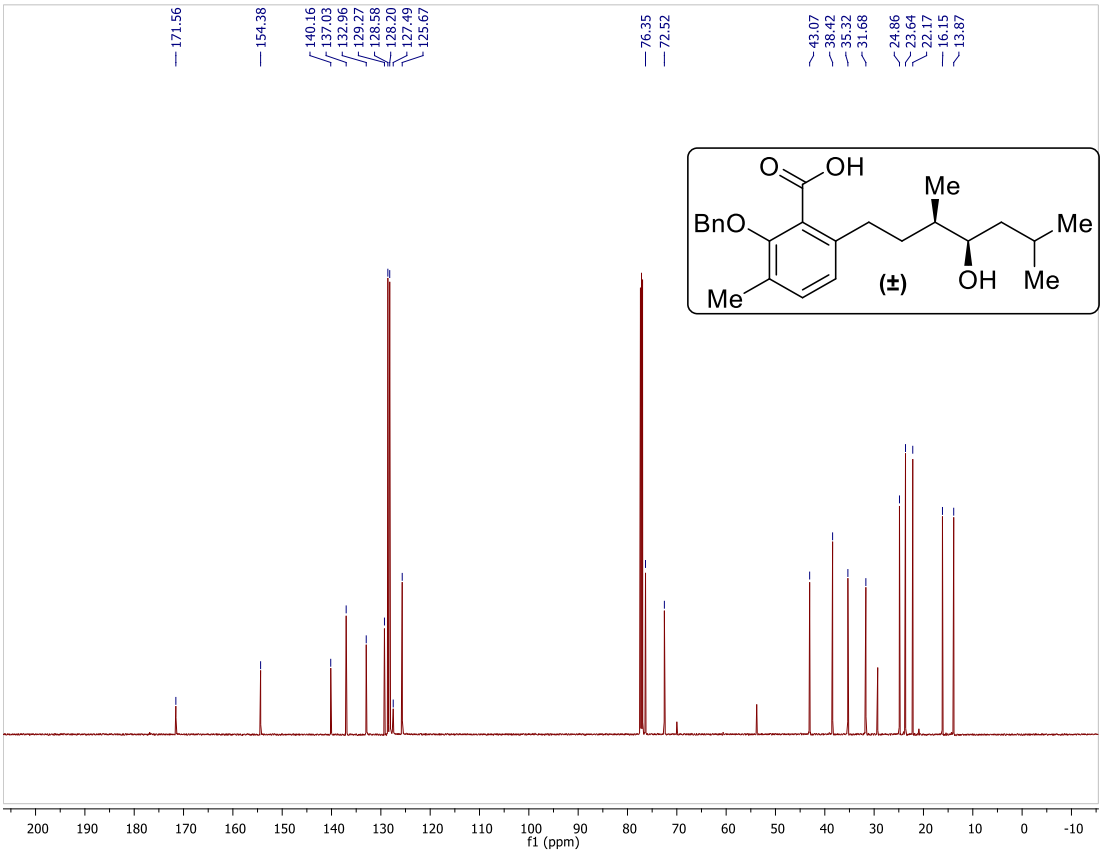
O
Me
BnO
Me
Me
(±)
OH
Me
f1 (ppm)


O
OH
Me
BnO
Me
(±)
OH
Me
Me
f1 (ppm)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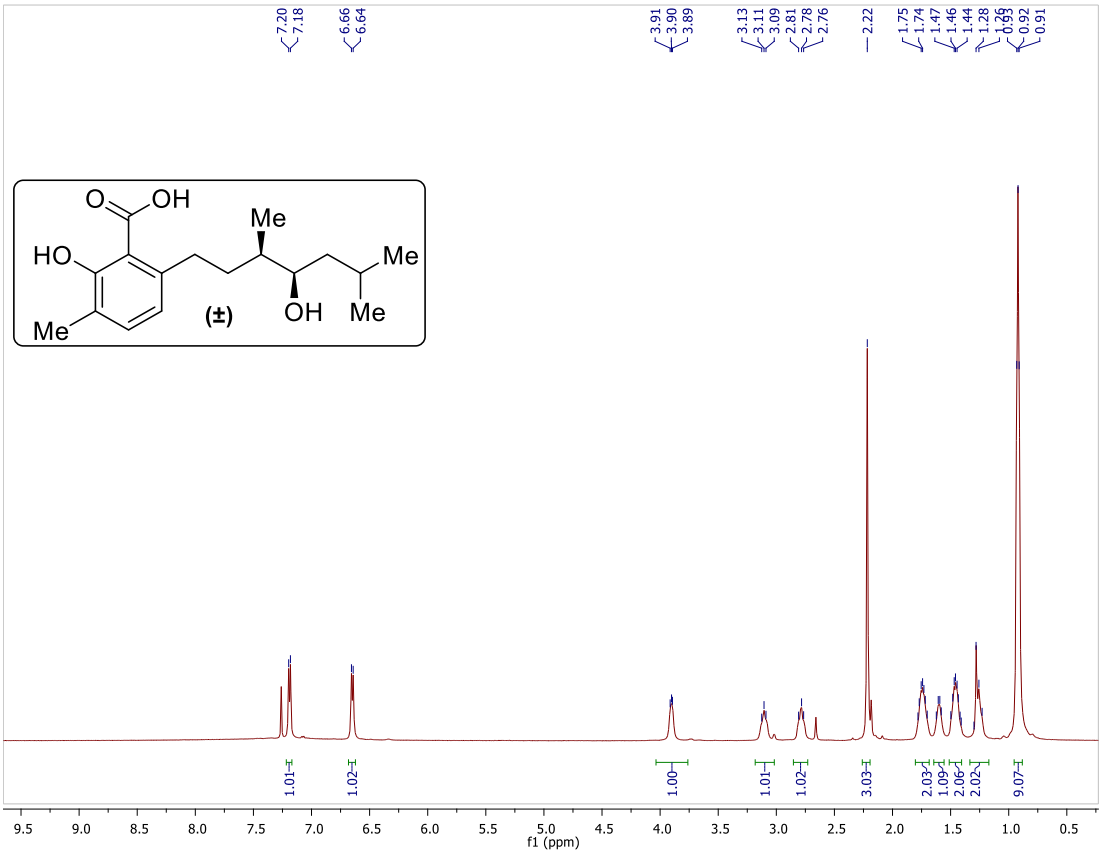
OH
Me
BnO
Me
(±)
OH
Me
Me
f1 (ppm)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6.66
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3.90
3.89
3.13
3.11
3.09
2.81
2.78
2.76
2.22
1.75
1.74
1.47
1.46
1.44
1.28
1.26
0.93
0.92
0.91
O
OH
HO
Me
Me
Me
(±)
OH
Me
Me
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1.02
1.00
1.01
1.02
3.03
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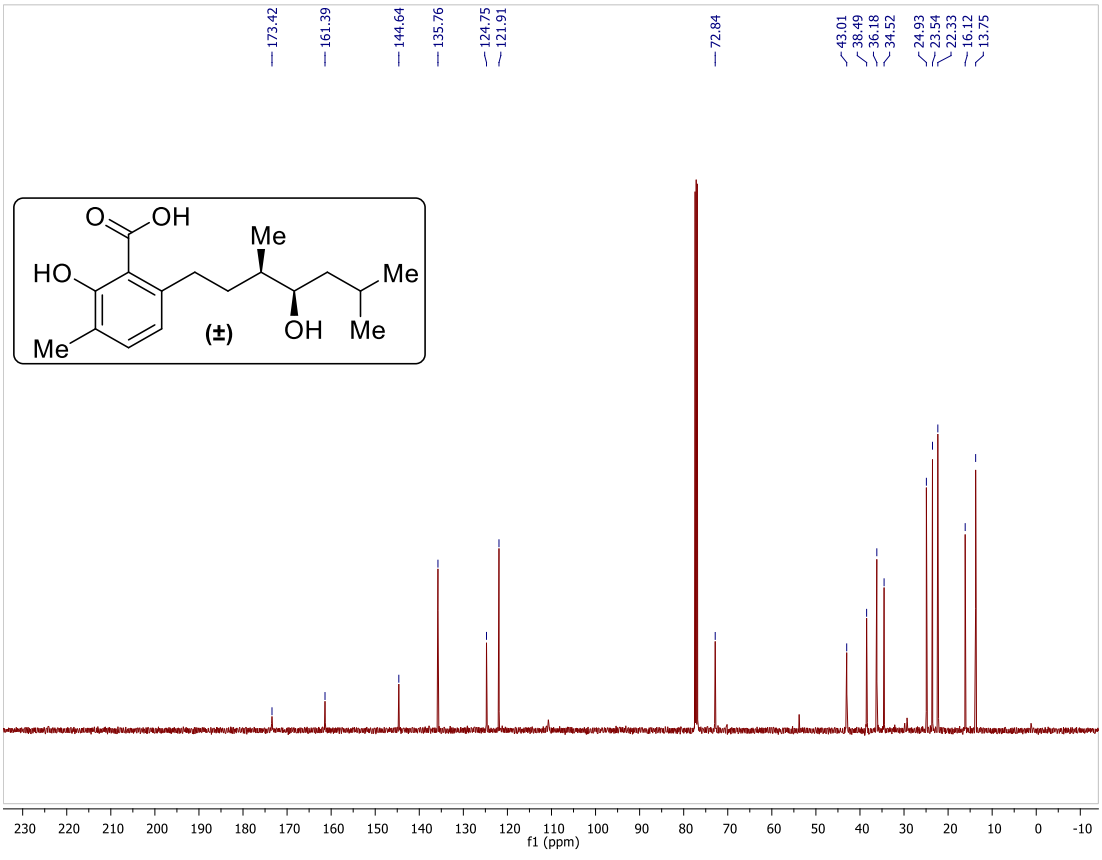
2.06
2.02
9.07
f1 (ppm)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43.01
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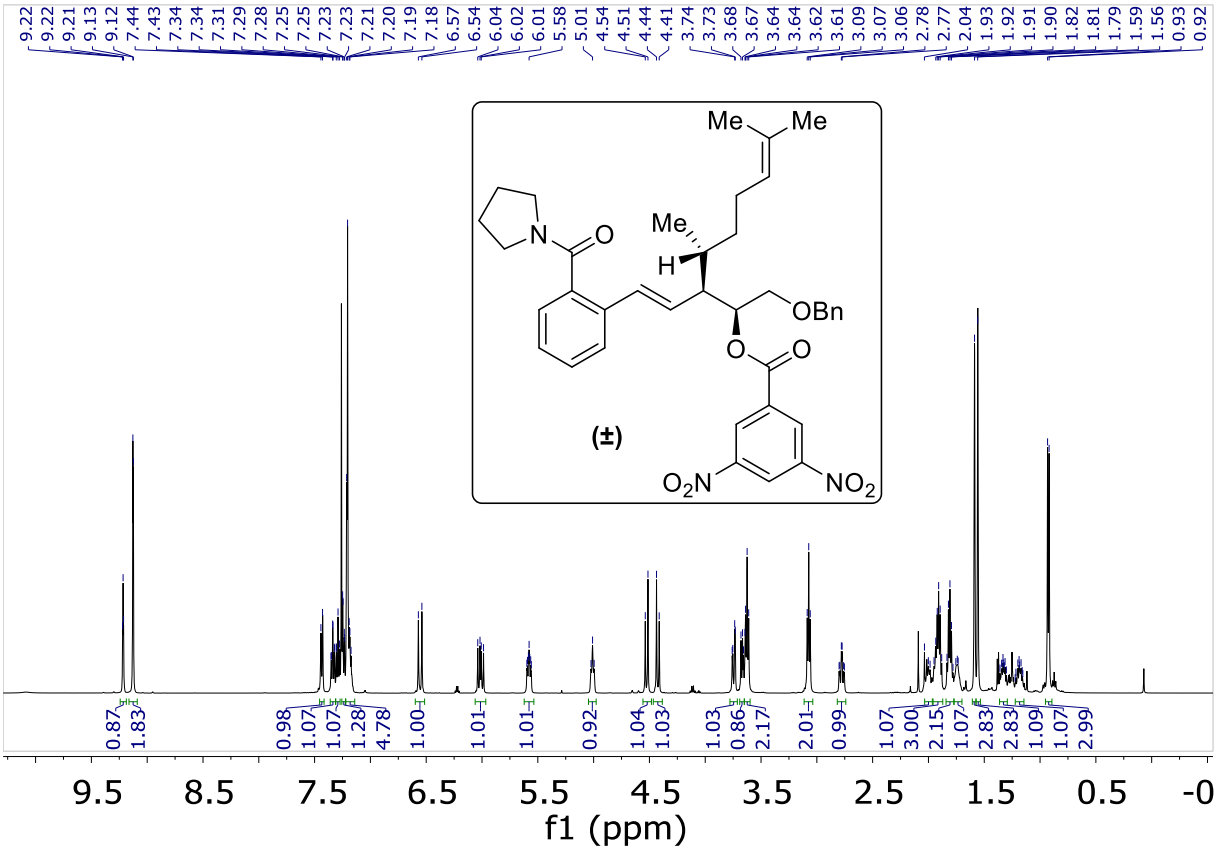
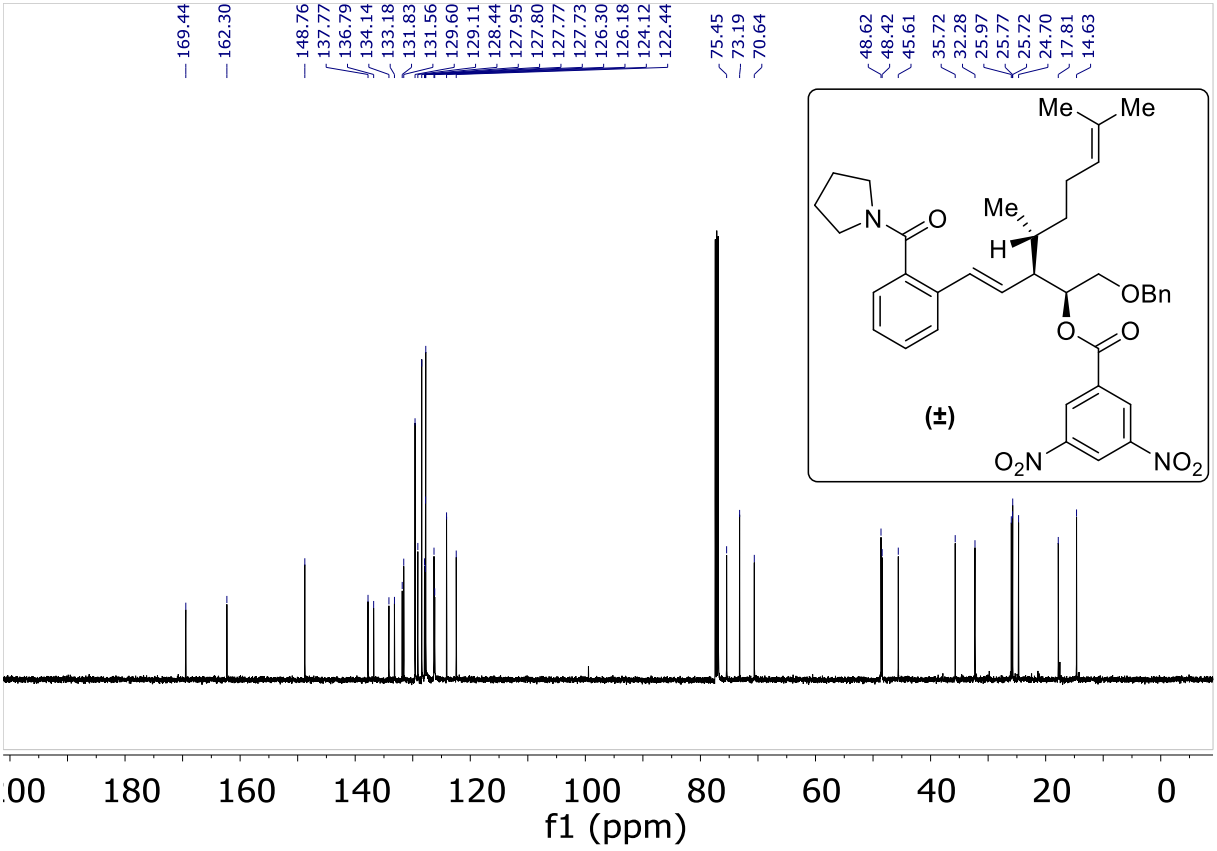
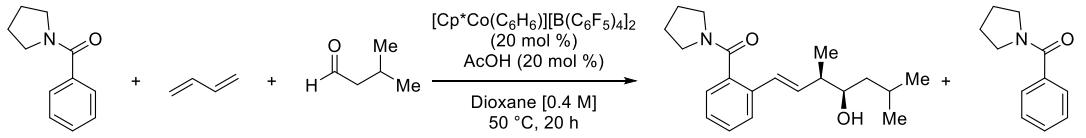
36.18
34.52
24.93
23.54
22.33
16.12
13.75
O
OH
HO
Me
Me
Me
(±)
OH
Me
Me
f1 (ppm)


9.22 9.22 9.21 9.13 9.12 7.44 7.43 7.34 7.34 7.31 7.29 7.28 7.25 7.25 7.23 7.23 7.21 7.20 7.19 7.18 6.57 6.54 6.04 6.02 6.01 5.58 5.01 4.54 4.51 4.44 4.41 3.74 3.73 3.68 3.67 3.64 3.64 3.62 3.61 3.09 3.07 3.06 2.78 2.77 2.04 1.93 1.92 1.91 1.90 1.82 1.81 1.79 1.59 1.56 0.93 0.92
Me
Me
N
O
Me
H
OBn
O
O
(±)
O2N
NO2
0.87 1.83 0.98 1.07 1.07 1.28 4.78 1.00 1.01 1.01 0.92 1.04 1.03 1.03 0.86 2.17 2.01 0.99 1.07 3.00 2.15 1.07 2.83 2.83 1.09 1.07 2.99
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)


169.44 162.30 148.76 137.77 136.79 134.14 133.18 131.83 131.56 129.60 129.11 128.44 127.95 127.80 127.77 127.73 126.30 126.18 124.12 122.44 75.45 73.19 70.64 48.62 48.42 45.61 35.72 32.28 25.97 25.77 25.72 24.70 17.81 14.63
Me
Me
N
O
Me
H
OBn
O
O
(±)
O2N
NO2
00 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

Supplementary Tables:

Supplemtentary Table 2: Optimization of Reaction Conditions



1a **2a** **3a** ***"standard conditions"*** (±)-**4a** **1a**

Entry	Variation from the standard conditions	Yield **4a**	Recovered **1a**
1	None	87% (87%)[c]	11%
2	None[d]	86%	11%
3	No catalyst	0%	100%
4	No AcOH	63%	34%
5	LiOAc (20 mol %) instead of AcOH	38%	60%
6	Performed at 80 °C	80%	18%
7	Performed at 23 °C	11%	88%
8	Performed at [1.0 M]	78%	20%
9	In THF	74%	22%
10	$[Cp^*Co(MeCN_3)][SbF_6]_2$ (20 mol %) as catalyst system	53%	41%
11	$[Cp^*Co(CO)I_2]$ (20 mol %) and $AgSbF_6$ (40 mol %) as catalyst system	65%	19%
12	$[Cp^*RhCl_2]_2$ (10 mol %) and $AgSbF_6$ (40 mol %) as catalyst system	34%	41%
13	$[Cp^*IrCl_2]_2$ (10 mol %) and $AgSbF_6$ (40 mol %) as catalyst system	4%	86%
14	$[RuCl_2(p\text{-cymene})]_2$ (10 mol %) and $AgSbF_6$ (40 mol %) as catalyst system	5%	90%

[a]Conditions: **1a**, (1.0 equiv), **2a** (2.0 equiv), **3a** (3.0 equiv) using above parameters. Butadiene used as a freshly made solution in THF [4 M]. [b]Yields determined by ^1H NMR relative to 1,3,5-trimethoxybenzene external standard. [c]Isolated yield based on a 0.2 mmol scale. [d]Butadiene from a commercial solution in THF [2 M].

Supplementary References:

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