Synthesis of Iriomoteolide-1a C12-C23 Fragment via Asymmetric Conjugate Addition and Julia-Kocienski Coupling

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Supporting Information

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General Methods

Experiments involving moisture and/or air sensitive components were performed in oven-dried glassware under a positive pressure of nitrogen using freshly distilled solvents. Commercial grade solvents and reagents were used without further purification with the following exceptions: *t*-BuOMe and CH_2Cl_2 were distilled from calcium hydride. Diethyl ether was distilled from sodium.

Analytical thin layer chromatography (TLC) was performed using Merck 60 F254 precoated silica gel plate (0.2 mm thickness). Subsequent to elution, plates were visualized using UV radiation (254 nm) on Spectoline Model ENF-24061/F 254 nm. Further visualization was possible by staining with basic solution of potassium permanganate or acidic solution of ceric molybdate. Flash chromatography was performed using Merck silica gel 60 with freshly distilled solvents. Columns were typically packed as slurry and equilibrated with the appropriate solvent system prior to use.

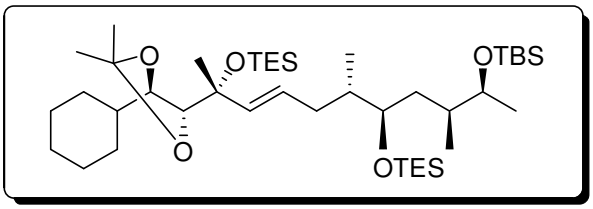
Infrared spectra were recorded on a Bio-Rad FTS 165 FTIR spectrometer. The oil samples were examined under neat conditions. High Resolution Mass Spectrometry (HRMS) spectra were obtained using Finnigan MAT95XP GC/HRMS (Thermo Electron Corporation).

Proton nuclear magnetic resonance spectra (^{1}H NMR) were recorded on a Bruker Avance DPX 300 and Bruker AMX 400 spectrophotometer ($CDCl_3$ as solvent). Chemical shifts for ^{1}H NMR spectra are reported as δ in units of parts per million (ppm) downfield from TMS (δ 0.0) and relative to the signal of chloroform-*d* (δ 7.260, singlet) as the internal standard. Multiplicities were given as: s (singlet); d (doublet); t (triplet); q (quartet); dd (doublets of doublet); ddd (doublets of doublets of doublet); dddd (doublets of doublets of doublets of doublet); dt (doublets of triplet); or m (multiplets). The number of protons (n) for given resonance is indicated by nH. Coupling constants are reported as a *J* value in Hz. Carbon nuclear magnetic resonance spectra (^{13}C NMR) are reported as δ in units of parts per million (ppm) downfield from $SiMe_4$ (δ 0.0) and relative to the signal of chloroform-*d* (δ 77.03, triplet). The proportion of diastereomers and geometric isomers was determined from the integration of ^{1}H NMR and ^{13}C NMR spectra.

Enantioselectivities were determined by capillary GC analysis (Chiraldex G-TA column (30 m x 0.25 mm)), using the flame ionization detector. Optical rotations were measured in $CHCl_3$ on a *Schmidt + Haensdch* polarimeter (Polartronic MH8) with 10.0 mm cell (*c* given in g/100 mL). Absolute configurations of the products were determined by comparison with known compounds.

Experimental Procedures and Characterization Data of Products

(5*R*,9*S*,10*R*,12*S*,13*S*,*E*)-5-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)-3,3-diethyl-5,9,12,13,15,15,16,16-octamethyl-10-(triethylsilyloxy)-4,14-dioxa-3,15-disilaheptadec-6-ene (4a)



To a stirred solution of sulfone **6** (31.1 mg, 0.05 mmol) in anhydrous THF (1 mL) at -78 ^{o}C was added dropwise a solution of KHMDS (0.1 mL, 15% in toluene, 0.06 mmol) in THF over 5 minutes. The blue solution was stirred for 30 minutes during which time the solution became green. A solution of aldehyde **5** (27.8 mg, 0.075 mmol) in THF (0.5 mL) was added dropwise over 5 minutes and the mixture was stirred at -78 ^{o}C for 1 h. The cooling bath was removed and the mixture was stirred at ambient temperature overnight. The solution has changed from dark brown to light yellow. After a night, water was added and continued stirring for 1 h. The reaction was quenched with brine (10 mL) and extracted with Et_2O (10 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 100: 1) to afford the desired *trans*-product as colorless oil (11.0 mg, 29% yield; 48% total yield for the mixture of *E/Z* isomers, 60: 40).

R_f value (hexane/Et_2O 14: 1): 0.52.

$[\alpha]_D^{20}$ = -0.014 (*c* = 1.0, $CHCl_3$).

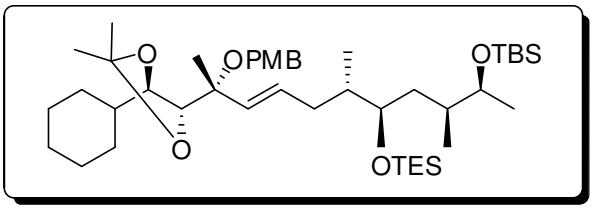
^{1}H NMR (300 MHz, $CDCl_3$): δ 5.73 (d, *J* = 15.6 Hz, 1H), 5.58-5.48 (m, 1H), 3.85-3.80 (m, 2H), 3.72-3.68 (m, 2H), 2.10-1.58 (m, 10H), 1.47-1.44 (m, 2H), 1.38 (s, 6H), 1.29 (s, 3H), 1.19-1.17 (m, 4H), 1.08 (d, 2H), 0.99-0.85 (m, 33H), 0.65-0.58 (m, 12H), 0.04 (s, 3H), 0.03 (s, 3H).

^{13}C NMR (75 MHz, $CDCl_3$): δ 134.9 (CH), 128.3 (CH), 106.3 (C), 83.9 (CH), 83.2 (CH), 77.0 (C), 75.1 (CH), 71.2 (CH), 38.2 (CH), 37.3 (CH_2), 36.2 (CH_2), 35.6 (CH), 34.5 (CH), 31.6 (CH_2), 30.2 (CH_2), 27.3 (CH_3), 26.9 (CH_2), 26.6 (CH_2), 25.9 (CH_2), 25.8 (CH_3), 25.1 (CH_3), 20.8 (CH_3), 18.1 (C), 15.4 (CH_3), 15.0 (CH_3), 7.2 (CH_2), 7.0 (CH_3), 6.8 (CH_2), 5.3 (CH_3), -4.0 (CH_3), -4.8 (CH_3).

FTIR (NaCl, neat): *v* 2955, 1377, 1254, 1065, 1005, 835, 743 cm^{-1}.

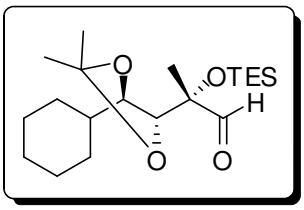
HRMS (ESI) calcd. for $C_{42}H_{87}O_5Si_3$ (M+1) 755.5861, found 755.5818.

(5*S*,6*S*,8*R*)-8-((2*S*,6*R*,*E*)-6-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)-6-(4-methoxybenzyloxy)hept-4-en-2-yl)-10,10-diethyl-2,2,3,3,5,6-hexamethyl-4,9-dioxa-3,10-disiladodecane (4b)



To a stirred solution of sulfone **6** (31.1 mg, 0.05 mmol) in anhydrous THF (1 mL) at -78 ^{o}C was added dropwise a solution of KHMDS (0.1 mL, 15% in toluene, 0.06 mmol) in THF over 5 minutes. The blue solution was stirred for 30 minutes during which time the solution became green. A solution of aldehyde **5** (28.2 mg, 0.075 mmol) in THF (0.5 mL) was added dropwise over 5 minutes and the mixture was stirred at -78 ^{o}C for 1 h. The cooling bath was removed and the mixture was stirred at ambient temperature overnight. The solution has changed from dark brown to light yellow. After a night, water was added and stirring was continued for 1 h. The reaction was quenched with brine (10 mL) and extracted with Et_2O (10 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. From the ^{1}H NMR analysis, the desired product was in trace amount.

(*S*)-2-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)-2-(triethylsilyloxy)propanal (5)



Alkene **12a** (0.369 g, 1.00 mmol) and CH_2Cl_2 (2 mL) were added to a round bottom flask equipped with a magnetic stirrer bar and cooled to -78 ^oC. The reaction mixture was purged with O_2 for a few minutes followed by supplying of O_3. The completion of the reaction was indicated by color changing of the solution (from colorless to blue). After the completion of the reaction, the supply of O_3 was stopped. The reaction mixture was purged with O_2 for a few minutes and quenched with PPh_3 (0.289 g, 1.10 mmol). The reaction was cooled to room temperature and stirred vigorously for 10 min. CH_2Cl_2 was evaporated *in vacuo* and the resulting residue was purified by flash column chromatography (hexane/Et_2O 80: 1) to afford the desired product as colorless oil (0.274 g, 74% yield).

R_f value (hexane/ Et_2O 8: 1): 0.45.

$[\alpha]_D^{20}$ = -0.042 (*c* = 1.06, $CHCl_3$).

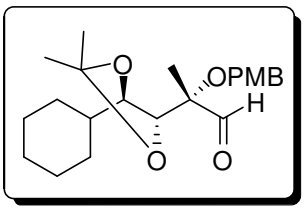
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.80 (s, 1H), 4.00 (d, *J* = 5.2 Hz, 1H), 3.87-3.83 (m, 1H), 2.00-1.92 (m, 3H), 1.70-1.66 (m, 3H), 1.40 (s, 3H), 1.37 (s, 3H), 1.29 (s, 3H), 1.25-1.15 (m, 3H), 0.96 (t, *J* = 7.9 Hz, 9H), 0.98-0.94 (m, 2H), 0.62 (q, *J* = 7.7 Hz, 6H).

^{13}C NMR (75 MHz, $CDCl_3$): δ 202.3 (C), 107.2 (C), 83.2 (CH), 82.9 (CH), 81.7 (C), 36.3 (CH), 31.3 (CH_2), 30.2 (CH_2), 26.5 (CH_2), 25.5 (CH_2), 25.4 (CH_2), 25.0 (CH_3), 21.8 (CH_3), 6.9 (CH_2), 6.4 (CH_3).

FTIR (NaCl, neat): ν 2930, 1736, 1381, 1217, 1049, 745 cm^{-1}.

HRMS (ESI) calcd. for $C_{20}H_{39}O_4Si$ (M+1) 371.2618, found 371.2603.

(*S*)-2-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)-2-(4-methoxybenzyloxy)propanal (5a)

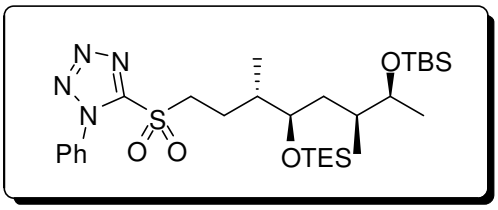


Alkene **12b** (0.375 g, 1.00 mmol) and CH_2Cl_2 (2 mL) were added to a round bottom flask equipped with a magnetic stirrer bar and cooled to -78 ^oC. The reaction mixture was purged with O_2 for a few minutes followed by supplying of O_3. The completion of the reaction was indicated by color changing of the solution (from colorless to blue). After the completion of the reaction, the supply of O_3 was stopped. The reaction mixture was purged with O_2 for a few minutes and quenched with PPh_3 (0.289 g, 1.10 mmol). The reaction was cooled to room temperature and stirred vigorously for 10 min. CH_2Cl_2 was evaporated *in vacuo* and the resulting residue was purified by flash column chromatography (hexane/Et_2O 40: 1) to afford the desired product as colorless oil (0.290 g, 77% yield).

R_f value (hexane/Et_2O 4: 1): 0.34.

^{1}H NMR (400 MHz, $CDCl_3$): δ 9.92 (s, 1H), 7.00 (m, 2H), 6.87 (d, J = 8.2 Hz, 2H), 4.44 (d, J = 10.4 Hz, 1H), 4.32 (d, J = 10.3 Hz, 1H), 4.07 (d, J = 4.88 Hz, 1H), 3.90-3.86 (m, 1H), 3.86 (s, 3H), 2.08-0.84 (m, 20H).

5-((3*S*,4*R*,6*S*,7*S*)-7-(*tert*-butyldimethylsilyloxy)-3,6-dimethyl-4-(triethylsilyloxy)octylsulfonyl)-1-phenyl-1*H*-tetrazole (6)



In a round bottom flask equipped with a rubber septum and a magnetic stirrer bar, sulfone **22** (0.496 g, 1.00 mmol) was dissolved in 2 mL of dry pyridine. DMAP (0.012 g, 0.10 mmol) and TESCl (0.301 g, 2.00 mmol) were added to the reaction mixture and stirred at room temperature. After stirring for 12 h, the reaction was diluted with Et_2O and washed with brine. The organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 10: 1) to afford the desired product as colorless oil (0.605 g, 99% yield).

R_f value (hexane/Et_2O 2: 1): 0.55.

$[\alpha]_D^{20}$ = -0.007 (*c* = 0.9, $CHCl_3$).

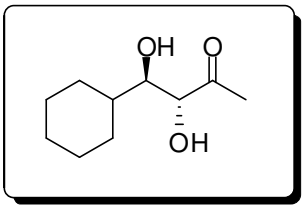
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71-7.68 (m, 2H), 7.62-7.59 (m, 3H), 3.97-3.89 (m, 1H), 3.71-3.64 (m, 3H), 1.99-1.96 (m, 1H), 1.88-1.86 (m, 1H), 1.78-1.77 (m, 1H), 1.64-1.57 (m, 1H), 1.39-1.36 (m, 1H), 1.31-1.25 (m, 1H), 1.07 (d, *J* = 5.6 Hz, 3H), 1.02 (d, *J* = 7.5 Hz, 3H), 0.95 (t, *J* = 7.9 Hz, 9H), 0.86 (s, 9H), 0.85 (d, *J* = 7.5 Hz, 3H), 0.58 (q, *J* = 7.9 Hz, 6H), 0.03 (s, 6H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 153.4 (C), 133.1 (C), 131.3 (CH), 129.6 (CH), 125.0 (CH), 74.5 (CH), 71.6 (CH), 54.4 (CH_2), 37.6 (CH_2), 37.1 (CH), 35.1 (CH_2), 25.8 (CH_3), 22.5 (CH), 20.7 (CH_3), 18.0 (C), 16.2 (CH_3), 14.3 (CH_3), 6.9 (CH_2), 5.1 (CH_3), -4.2 (CH_3), -4.9 (CH_3).

FTIR (NaCl, neat): *v* 2957, 1595, 1499, 1339, 1153, 837, 762 cm^{-1}.

HRMS (ESI) calcd. for $C_{29}H_{55}N_4O_4SSi_2$ (M+1) 611.3483, found 611.3475.

(3*R*,4*R*)-4-cyclohexyl-3,4-dihydroxybutan-2-one (9)



To a mixture of anhydrous DMSO (6 mL) and hydroxyacetone **8** (2 mL) was added the aldehyde **7** (0.112 g, 1.00 mmol) followed by *D*-proline (0.023 g, 20 mol%) respectively, and the resulting homogenous reaction mixture was stirred at room temperature for 60 h. Then, half saturated NH_4Cl solution (10 mL) and ethyl acetate (10 mL) were added with stirring. The layers were separated and the aqueous phase was extracted with ethyl acetate (10 mL x 3). The combined organic layers were dried over anhydrous magnesium sulfate, filtered and concentrated *in vacuo.* The resulting residue was purified by flash column chromatography (hexane/EtOAc 5: 1) to afford the desired product as white solid (0.111 g, 60% yield; dr > 20: 1). The enantiomeric excess was determined by HPLC analysis (chiral Daicel Chiralpak AS, hexane: *i*-PrOH = 85: 15, flow rate 1.0 mL/min., λ = 285 nm: t_R= 7.70 min).

R_f value (hexane/EtOAc 1: 2): 0.45.

$[\alpha]_D^{20}$ = -81.6 (*c* = 1.0, $CHCl_3$) Lit.$[\alpha]_D$ = +83 (*c* = 1.0, $CHCl_3$) of (3*S*,4*S*)-4-cyclohexyl-3,4-dihydroxybutan-2-one.

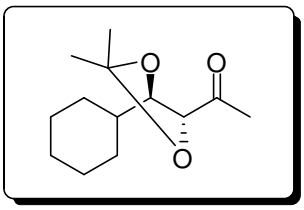
^{1}H NMR (300 MHz, $CDCl_3$): δ 4.23 (d, *J* = 5.4 Hz, 2H), 3.51-3.54 (m, 2H), 2.31 (s, 4H), 1.53-1.93 (m, 6H), 1.04-1.29 (m, 5H).

^{13}C NMR (75 MHz, $CDCl_3$): δ 209.8 (C), 78.3 (CH), 77.6 (CH), 39.8 (CH), 29.7 (CH_2), 27.7 (CH_2), 27.4 (CH_2), 26.2 (CH_3), 26.1 (CH_2), 25.8 (CH_2).

FTIR (KBr, neat): ν 3381, 2920, 2850, 1697 (C=O), 1421, 1359, 1076, 1039, 983 cm^{-1}.

HRMS (ESI) calcd. for $C_{10}H_{19}O_3$ (M+1) 187.1329, found 187.1334.

1-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)ethanone (10)



In a round bottom flask equipped with a rubber septum and a magnetic stirrer bar, diol **9** (0.186 g, 1.00 mmol) was dissolved in CH_2Cl_2 (2 mL) at 25 ^oC. 2-Methoxy-propene (1.041 g, 10.0 mmol) and (1*S*)-(+)-camphor-10-sulfonic acid (0.013 g, 0.05 mmol) were added to the reaction mixture. The reaction mixture was stirred at room temperature for overnight. The reaction mixture was quenched with water (10 mL) and the biphasic reaction mixture was extracted with diethyl ether (10 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 40: 1) to afford the desired product as colorless oil (0.204 g, 90% yield).

R_f value (hexane/Et_2O 8: 1): 0.34.

$[\alpha]_D^{20} = +0.87$ (*c* = 1.2, $CHCl_3$).

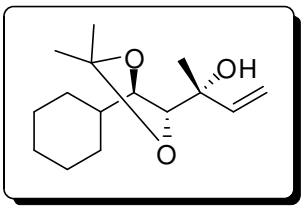
^{1}H NMR (400 MHz, $CDCl_3$): δ 4.32 (d, *J* = 7.6 Hz, 1H), 4.02 (dd, *J* = 8.8, 7.6 Hz, 1H), 2.26 (s, 3H), 1.63-1.87 (m, 5H), 1.60 (s, 3H), 1.34 (s, 3H), 0.92-1.25 (m, 6H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 209.7 (C), 109.4 (C), 82.8 (CH), 82.6 (CH), 37.6 (CH), 29.7 (CH_2), 29.3 (CH_2), 28.4(CH_2), 26.6 (CH_2), 26.2 (CH_2), 25.4 (CH_3), 24.8 (CH_3).

FTIR (KBr, neat): *v* 2927, 2854, 1708 (C=O), 1450, 1355, 1060 cm^{-1}.

HRMS (ESI) calcd. for $C_{13}H_{23}O_3$ (M+1) 227.1650, found 227.1647.

(*R*)-2-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-2-ol (11a)



To an oven-dried two neck round bottom flask equipped with a rubber septum and a magnetic stirrer bar was added magnesium (0.048 g, 2.00 mmol) and one crystal of iodine. Vinylbromide (0.5 mL, 1.0 M solution in THF, 0.50 mmol) was added to the flask and heated the mixture at reflux until the iodine color had disappeared. The vinylbromide solution (1.5 mL, 1.50 mmol) was added dropwise at such a rate that a gentle reflux was maintained. After refluxing for another 3 h, the reaction mixture was cooled to room temperature and immersed into 0 ^{o}C cryobath. Precursor **10** (0.226 g, 1.00 mmol) in THF (1 mL) was added dropwise over 2 h via syringe pump. After stirring at 0 ^{o}C overnight, the reaction mixture was quenched with NH_4Cl solution and the biphasic reaction mixture was extracted with diethyl ether (10 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 40: 1) to afford the desired product **11a** as colorless oil (0.211 g, 83% yield; 92% total yield for the two isomers, dr = 90: 10).

R_f value (hexane/Et_2O 4: 1): 0.25.

$[\alpha]_D^{20}$ = -29.1 (*c* = 1.0, $CHCl_3$).

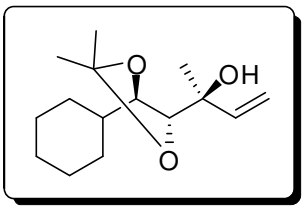
^{1}H NMR (400 MHz, $CDCl_3$): δ 6.05 (dd, *J* = 23.2, 14.4 Hz, 1H), 5.34 (dd, *J* = 23.2, 2.0 Hz, 1H), 5.16 (dd, *J* = 14.4, 2.0 Hz, 1H), 3.95 (d, *J* = 2.0 Hz, 1H), 3.87 (dd, *J* = 12.0, 8.0 Hz, 1H), 2.23 (s, 1H), 1.66-2.04 (m, 5H), 1.50 (s, 3H), 1.34 (s, 3H), 1.33 (s, 3H), 1.23-1.28 (m, 6H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 142.5 (CH), 113.3 (CH_2), 106.7 (C), 82.7 (CH), 82.4 (CH), 74.7 (C), 36.3 (CH), 31.7 (CH_2), 30.3 (CH_2), 28.7 (CH_3), 26.4 (CH_3), 25.7 (CH_2), 25.5 (CH_2), 25.4 (CH_2), 25.0 (CH_3).

FTIR (KBr, neat): *v* 3425, 2989, 2927, 2852, 1651, 1381, 1255, 1033, 758 cm^{-1}.

HRMS (ESI) calcd. for $C_{15}H_{27}O_3$ (M+1) 255.1958, found 255.1960.

(*S*)-2-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-2-ol (11b)



R_f value (hexane/Et_2O 4: 1): 0.33.

$[\alpha]_D^{20}$ = -42.2 (*c* = 1.5, $CHCl_3$).

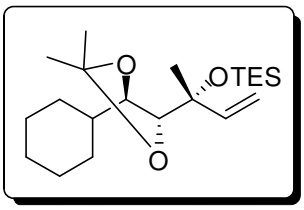
^{1}H NMR (300 MHz, $CDCl_3$): δ 6.01 (dd, *J* = 17.1, 10.8 Hz, 1H), 5.40 (dd, *J* = 17.4, 1.8 Hz, 1H), 5.34 (dd, *J* = 10.5, 1.5 Hz, 1H), 3.90 (d, *J* = 5.4 Hz, 1H), 3.80-3.85 (m, 1H), 2.56 (s, 1H), 1.61-2.07 (m, 5H), 1.37 (s, 3H), 1.32 (s, 6H), 1.20-1.31 (m, 6H).

^{13}C NMR (75 MHz, $CDCl_3$): δ 142.7 (CH), 112.7 (CH_2), 106.8 (C), 82.7 (CH), 81.9 (CH), 75.5 (C), 36.0 (CH), 31.4 (CH_2), 30.2 (CH_2), 27.0 (CH_3), 26.8 (CH_3), 26.3 (CH_2), 25.6 (CH_2), 25.2 (CH_2), 24.8 (CH_3).

FTIR (KBr, neat): *v* 3552, 2893, 2926, 2852, 1614, 1450, 1045 cm^{-1}.

HRMS (ESI) calcd. for $C_{15}H_{27}O_3$ (M+1) 255.1953, found 255.1960.

((*R*)-2-((4*R*,5*R*)-5-cyclohexyl-2,2-dimethyl-1,3-dioxolan-4-yl)but-3-en-2-yloxy)triethylsilane (12a)



In a round bottom flask equipped with a rubber septum and a magnetic stirrer bar, alcohol **11a** (0.254 g, 1.00 mmol) was dissolved in CH_2Cl_2 (2 mL). Then 2,6-lutidine (0.34 mL, 3.00 mmol) followed by TESOTf (0.32 mL, 1.50 mmol) was added to the reaction mixture at -78 ^oC. After stirring at -78 ^oC for 1h, the reaction mixture was quenched with water and the biphasic reaction mixture was extracted with diethyl ether (10 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 10: 1) to afford the desired product as colorless oil (0.361 g, 98% yield).

R_f value (hexane/Et_2O 8: 1): 0.65.

$[\alpha]_D^{20}$ = -0.017 (*c* = 1.0, $CHCl_3$).

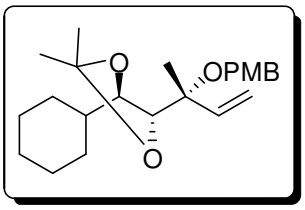
^{1}H NMR (300 MHz, $CDCl_3$): δ 6.16 (dd, *J* = 10.8, 17.4 Hz, 1H), 5.23 (dd, *J* = 1.7, 17.4 Hz, 1H), 5.10 (dd, *J* = 1.7, 10.8 Hz, 1H), 3.89-3.79 (m, 2H), 2.11-1.89 (m, 3H), 1.66-1.63 (m, 3H), 1.42 (s, 3H), 1.40 (s, 3H), 1.30 (s, 3H), 1.22-1.17 (m, 3H), 0.96 (t, *J* = 7.9 Hz, 9H), 0.98-0.93 (m, 2H), 0.62 (q, *J* = 7.9 Hz, 6H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 142.0 (CH), 113.2 (CH_2), 106.4 (C), 83.6 (CH), 83.3 (CH), 77.4 (C), 35.5 (CH), 31.6 (CH_2), 30.3 (CH_2), 26.9 (CH_2), 26.9 (CH_2), 26.6 (CH_2), 25.7 (CH_3), 25.7 (CH_3), 25.1 (CH_3), 7.2 (CH_2), 6.8 (CH_3).

FTIR (NaCl, neat): ν 2922, 1639, 1379, 1368, 1215, 1249, 872, 743 cm^{-1}.

HRMS (ESI) calcd. for $C_{21}H_{41}O_3Si$ (M+1) 369.2825, found 369.2813.

(4*R*,5*R*)-4-cyclohexyl-5-((*R*)-2-(4-methoxybenzyloxy)but-3-en-2-yl)-2,2-dimethyl-1,3-dioxolane (12b)



To an oven-dried round bottom flask equipped with a rubber septum and a magnetic stirrer bar was added sodium hydride (0.080 g, 60% dispersion in oil, 2.00 mmol) and anhydrous DMF (1 mL). The reaction mixture was cooled to 0 ^{o}C. A solution of alcohol **11a** (0.254 g, 1.00 mmol) in DMF (1 mL) was added dropwise and stirred for half an hour at 0 ^{o}C. Subsequently, PMBCl (0.188 g, 1.20 mmol) was introduced and the reaction mixture was allowed to proceed at room temperature for 12 h. The mixture was quenched by pouring the reaction mixture into ice water slowly with stirring. The mixture was then extracted with diethyl ether (10 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 40: 1) to afford the desired product as needle-shaped crystal (0.337 g, 90% yield).

R_f value (hexane/Et_2O 8: 1): 0.32.

$[\alpha]_D^{20}$ = +7.5 (*c* = 1.1, $CHCl_3$).

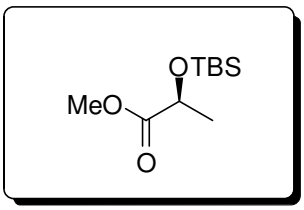
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.22 (d, *J* = 8.4 Hz, 1H), 6.84 (d, *J* = 8.4 Hz, 1H), 6.19 (dd, *J* = 17.6, 5.2 Hz, 1H), 5.35 (ddd, *J* = 24.0, 10.8, 1.2 Hz, 1H), 4.28 (s, 2H), 3.99 (d, *J* = 5.6 Hz, 1H), 3.80-3.82 (m, 4H), 1.48-2.06 (m, 5H), 1.43 (s, 3H), 1.42 (s, 3H), 0.77-1.37 (m, 9H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 158.9 (C), 139.5 (CH), 131.4 (C), 129.4 (CH), 117.8 (CH_2), 113.6 (CH), 106.6 (C), 83.2 (CH), 82.6 (C), 80.1 (CH), 64.3 (CH_2), 55.3 (CH_3), 36.3 (CH), 31.4 (CH_2), 30.5 (CH_2), 26.9 (CH_3), 26.5 (CH_3), 25.8 (CH_2), 25.2 (CH_2), 25.1 (CH_2), 20.1 (CH_3).

FTIR (KBr, neat): *v* 3007, 2927, 2852, 1612, 1857, 1369, 1053, 767 cm^{-1}.

HRMS (ESI) calcd. for $C_{23}H_{35}O_4$ (M+1) 375.2519, found 375.2535.

(*S*)-methyl 2-(*tert*-butyldimethylsilyloxy)propanoate (14)



To a round bottom flask equipped with a rubber septum and a magnetic stirrer bar was added imidazole (0.136 g, 2.00 mmol) and CH_2Cl_2 (2 mL). Then alcohol **13** (0.104 g, 1.00 mmol) was added dropwise and the reaction mixture was cooled to 0 ^oC. *Tert*-butylchlorodimethylsilane (0.226 g, 1.50 mmol) was added slowly and the resulting reaction mixture was stirred overnight at room temperature. The mixture was diluted with CH_2Cl_2 (10 mL), H_2O (10 mL) and extracted with CH_2Cl_2 (20 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/EtOAc 50: 1) to afford the desired product as pale yellow oil (0.216 g, 99% yield).

R_f value (hexane/EtOAc 9: 1): 0.55.

$[\alpha]_D^{20} = -0.029$ (*c* = 1.0, $CHCl_3$).

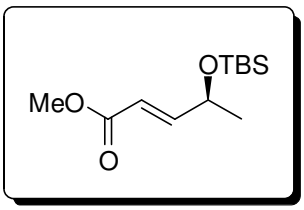
^{1}H NMR (300 MHz, $CDCl_3$): δ 4.32 (q, *J* = 6.7 Hz, 1H), 3.70 (s, 3H), 1.38 (d, *J* = 6.8 Hz, 3H), 0.88 (s, 9H), 0.08 (s, 3H), 0.05 (s, 3H).

^{13}C NMR (75 MHz, $CDCl_3$): δ 174.5 (C), 68.4 (CH), 51.7 (CH_3), 25.6 (CH_3), 21.3 (CH_3), 18.3 (C), -5.0 (CH_3), -5.3 (CH_3).

FTIR (NaCl, neat): *v* 2953, 1759, 1740, 1373, 1362, 1148 cm^{-1}.

HRMS (ESI) calcd. for $C_{10}H_{23}O_3Si$ (M+1) 219.1416, found 219.1419.

(*S*,*E*)-methyl 4-(*tert*-butyldimethylsilyloxy)pent-2-enoate (15)



In a round bottom flask equipped with a rubber septum and a magnetic stirrer bar, the ester **14** (0.218 g, 1.00 mmol) was dissolved in hexane (1.0 mL) and cooled to -78 ^{o}C. DIBAL-H (pre-cooled to -78 ^{o}C, 1.1 mL, 1.0 M in heptane, 1.1 mmol) was added carefully over at least 2 portions. After stirring for another 1 h, MeOH (pre-cooled to -78 ^{o}C, 0.096 g, 3.3 mmol) was added carefully over 2 portions and stirred for a further half an hour until a white suspension was observed. The ylide $MeO_2CCH{=}PPh_3$ (0.669 g, 2.00 mmol) was added in one portion followed by THF (5.0 mL) and the reaction mixture was allowed to warm slowly to room temperature over 30 minutes. The reaction mixture was stirred for another 30 minutes and refluxed for an additional 6 h. After that, the reaction mixture was cooled to room temperature and diluted with Et_2O (5 mL) and saturated potassium sodium tartrate (5 mL). The mixture was stirred until a clear biphasic separation was observed. The aqueous layer was extracted with Et_2O (10 mL x 3). The combined organic extracts were washed with saturated $NaHCO_3$ (15 mL x 2), brine (15 mL x 1) and dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/EtOAc 100: 1) to afford the desired *trans*-product as colorless oil (0.169 g, 69% yield; 88% total yield for the mixture of *E/Z* isomers, *E/Z* = 78: 22).

R_f value (hexane/EtOAc 10: 1): 0.54.

$[\alpha]_D^{20}$ = +0.001 (*c* = 1.0, $CHCl_3$).

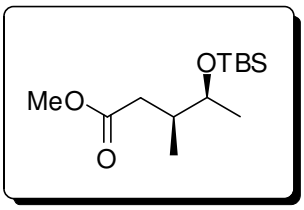
^{1}H NMR (400 MHz, $CDCl_3$): δ 6.93 (dd, *J* = 4, 15.5 Hz, 1H), 5.99 (dd, *J* = 1.4, 15.2 Hz, 1H), 4.46-4.43 (m, 1H), 3.72 (s, 3H), 1.25 (d, *J* = 6.6 Hz, 3H), 0.90 (s, 9H), 0.06 (s, 3H), 0.05 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 167.2 (C), 152.2 (CH), 118.5 (CH), 67.6 (CH), 51.5 (CH_3), 25.8 (CH_3), 23.5 (CH_3), 18.2 (C), -4.9 (CH_3).

FTIR (NaCl, neat): *v* 2930, 1715, 1659, 1368, 1152, 837, 775 cm^{-1}.

HRMS (ESI) calcd. for $C_{12}H_{24}O_3SiNa$ (M+Na) 267.1392, found 267.1394.

(3*S*,4*S*)-methyl 4-(*tert*-butyldimethylsilyloxy)-3-methylpentanoate (16)



In a round bottom flask equipped with a rubber septum and a magnetic stirrer bar, (*R*)-Tol-BINAP (0.020 g, 0.03 mmol) and CuI (0.004 g, 0.02 mmol) were stirred in CH_2Cl_2 (2 mL) for 20 minutes, concentrated in *vacuo* and then stirred in *t*-BuOMe (4 mL) till a bright yellow suspension was observed. The mixture was then cooled to -20 ^oC and MeMgBr (0.83 mL, 3.0 M solution in Et_2O, 2.50 mmol) was added carefully into the reaction mixture. After stirring for 15 minutes, a pre-cooled solution of ester **15** (0.244 g, 1.00 mmol) in *t*-BuOMe (1.2 mL) was added dropwise over 1 h via syringe pump. After stirring at -20 ^oC for another one and an half hour, the reaction mixture was quenched with MeOH (1 mL), and 1 M NH_4Cl solution (4 mL). The aqueous layer was extracted with Et_2O (15 mL x 3) and the combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 90: 1) to afford the desired product as pale yellow oil (0.164 g, 63% yield; 94% *de*).

R_f value (hexane/Et_2O 8: 1): 0.27.

$[\alpha]_D^{20} = +0.012$ (c = 0.65, $CHCl_3$).

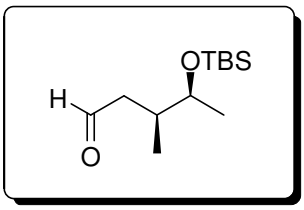
^{1}H NMR (300 MHz, $CDCl_3$): δ 3.79-3.76 (m, 1H), 3.66 (s, 3H), 2.48 (dd, J = 4.7, 14.5 Hz, 1H), 2.13-2.00 (m, 2H), 1.06 (d, J = 6.3 Hz, 3H), 0.88 (d, J = 4.9 Hz, 3H) 0.88 (s, 9H), 0.04 (s, 3H), 0.03 (s, 3H).

^{13}C NMR (75 MHz, $CDCl_3$): δ 174.2 (C), 70.6 (CH), 51.4 (CH_3), 37.3 (CH), 37.2 (CH_2), 25.8 (CH_3), 20.0 (CH_3), 18.1 (C), 14.3 (CH_3), -4.3 (CH_3), -5.0 (CH_3).

FTIR (NaCl, neat): ν 2930, 1742, 1381, 1252, 1038 cm^{-1}.

HRMS (ESI) calcd. for $C_{13}H_{29}O_3Si$ (M+1) 261.1886, found 261.1886.

(3*S*,4*S*)-4-(*tert*-butyldimethylsilyloxy)-3-methylpentanal (17)

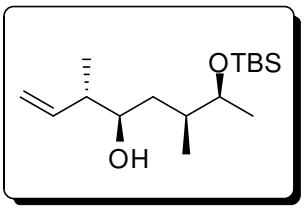


In a round bottom flask equipped with a rubber septum and a magnetic stirrer bar, the ester **16** (0.260 g, 1.00 mmol) was dissolved in hexane (4 mL) and cooled to -78 ^{o}C. DIBAL-H (pre-cooled to -78^{o}C, 1.1 mL, 1.0 M in heptane, 1.10 mmol) was added carefully over at least 2 portions. After stirring for another 1 h, MeOH (pre-cooled to -78 ^{o}C, 0.106 g, 3.30 mmol) was added carefully over 2 portions and stirred for a further 15 minutes till a white suspension was observed. The reaction mixture was then added saturated potassium sodium tartrate solution (5 mL), diluted with Et_2O (5 mL) and warmed to room temperature. The mixture was stirred until a clear biphasic separation was observed. The aqueous layer was extracted with Et_2O (10 mL x 3). The combined organic extracts were washed with saturated $NaHCO_3$ (15 mL x 2), brine (15 mL x 1) and dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 20: 1) to afford the desired product as pale yellow oil (0.200 g, 87% yield).

R_f value (hexane/Et_2O 8: 1): 0.36.

^{1}H NMR (400 MHz, $CDCl_3$): δ 9.76 (m, 1H), 3.80-3.77 (m, 1H), 2.61-2.53 (m, 1H), 2.22-2.17 (m, 2H), 1.06 (d, J = 6.3 Hz, 3H), 0.9 (d, J = 6.5 Hz, 3H), 0.87 (s, 9H), 0.04 (s, 3H), 0.03 (s, 3H).

(3*S*,4*S*,6*S*,7*S*)-7-(*tert*-butyldimethylsilyloxy)-3,6-dimethyloct-1-en-4-ol (18)



To a round bottom flask equipped with a rubber septum and a magnetic stirrer bar was added KO*t*Bu (1.5 mL, 1.0 M in THF, 1.50 mmol), dry THF (8 mL) and was allowed to cool to -78 ^{o}C. *Trans*-2-butene (0.168 g, 3.00 mmol) was condensed from a gas lecture bottle into the mixture at -78 ^{o}C. *n*-Butyllithium (0.94 mL, 1.6 M in hexane, 1.50 mmol) was then added dropwise. After complete addition of *n*-butyllithium, the mixture was stirred at -45 ^{o}C for 15 minutes. The resulting orange solution was re-cooled back to -78 ^{o}C, and to it was added a solution of (-)-methoxydiisopinocampheylborane (0.949 g, 3.00 mmol) in THF (3 mL). The solution became colorless. The reaction mixture was allowed to stir at -78 ^{o}C for 30 minutes followed by addition of boron trifluoride etherate (1.47 mL, 11.0 mmol). After that, a solution of aldehyde **17** in THF (1 mL) was added via a syringe pump over a period of 30 minutes. The mixture was allowed to stir at -78 ^{o}C for 3 h and then treated with with 3 N NaOH solution (3 mL, 9 mmol) and 3 mL of 30% H_2O_2 and the content was stirred for 15 minutes at room temperature. The aqueous layer was extracted with Et_2O (15 mL x 3). The combined organic extracts were washed with brine (20 mL x 1) and dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 40: 1) to afford the desired product as pale yellow oil (0.221 g, 77% yield; 84% *de*).

R_f value (hexane/Et_2O 8: 1): 0.23.

$[\alpha]_D^{20}$ = +0.007 (*c* = 1.0, $CHCl_3$).

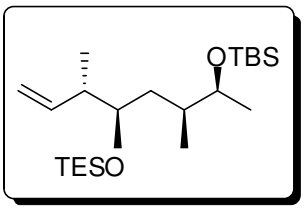
^{1}H NMR (400 MHz, $CDCl_3$): δ 5.86-5.77 (m, 1H), 5.10-5.06 (m, 2H), 3.82-3.80 (m, 1H), 3.59-3.56 (m, 1H), 2.23-2.18 (m, 1H), 2.14 (d, *J* = 4.9 Hz, 1H), 1.81-1.78 (m, 1H), 1.67-1.61 (m, 1H), 1.25-1.20 (m, 1H), 1.08 (d, *J* = 6.2 Hz, 3H), 1.04 (d, *J* = 6.8 Hz, 3H), 0.88 (s, 9H), 0.87 (d, *J* = 4.8 Hz, 3H), 0.06 (s, 3H), 0.05 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 140.5 (CH), 115.6 (CH_2), 73.0 (CH), 71.4 (CH), 43.8 (CH), 37.1 (CH_2), 36.5 (CH), 25.9 (CH_3), 19.2 (CH_3), 18.1 (C), 16.7 (CH_3), 16.4 (CH_3), -4.3 (CH_3), -4.8 (CH_3).

FTIR (NaCl, neat): *v* 3381, 2959, 1639, 1377, 1043, 835, 773 cm^{-1}.

HRMS (ESI) calcd. for $C_{16}H_{35}O_2Si$ (M+1) 287.2406, found 287.2401.

(5*S*,6*S*,8*R*)-8-((*S*)-but-3-en-2-yl)-10,10-diethyl-2,2,3,3,5,6-hexamethyl-4,9-dioxa-3,10-disiladodecane (19)



To a round bottom flask equipped with a rubber septum and a magnetic stirrer bar was added alcohol **18** (0.287 g, 1.00 mmol), dry pyridine (2 mL) and DMAP (0.024 g, 0.20 mmol). TESCl (0.301 g, 2.00 mmol) was then added and the reaction mixture was allowed to stir for 12 h at room temperature. After stirring for 12 h, the reaction mixture was added saturated NH_4Cl solution (10 mL) and diluted with CH_2Cl_2 (10 mL). The mixture was stirred until a clear biphasic separation was observed. Subsequently, the aqueous layer was extracted with CH_2Cl_2 (10 mL x 3). The combined organic extracts were washed with brine (15 mL x 1) and dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 100: 1) to afford the desired product as colorless oil (0.373 g, 93% yield).

R_f value (hexane): 0.25.

$[\alpha]_D^{20}$ = +0.004 (*c* = 1.0, $CHCl_3$).

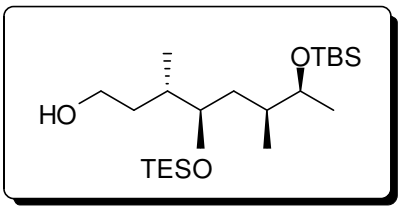
^{1}H NMR (300 MHz, $CDCl_3$): δ 5.89-5.77 (m, 1H), 5.03-4.98 (m, 2H), 3.72-3.65 (m, 2H), 2.35-2.30 (m, 1H), 1.60-1.55 (m, 1H), 1.48-1.45(m, 1H), 1.10-1.20 (m, 1H), 1.08 (d, *J* = 6.2 Hz, 3H), 1.05 (d, *J* = 6.9 Hz, 3H), 0.98 (t, *J* = 7.9 Hz, 9H), 0.90 (s, 9H), 0.87 (d, *J* = 6.8 Hz, 3H), 0.62 (q, *J* = 7.9 Hz, 6H), 0.05 (s, 3H), 0.04 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 140.4 (CH), 114.6 (CH_2), 74.3 (CH), 71.4 (CH), 42.7 (CH), 37.5 (CH_2), 36.9 (CH), 25.9 (CH_3), 21.0 (CH_3), 18.1 (C), 16.3 (CH_3), 14.6 (CH_3), 7.0 (CH_3), 5.3 (CH_2), -4.1 (CH_3), -4.8 (CH_3).

FTIR (NaCl, neat): ν 3073, 2957, 1640, 1379, 1037, 835 cm^{-1}.

HRMS (ESI) calcd. for $C_{22}H_{48}O_2Si_2Na$ (M+Na) 423.3091, found 423.3148.

(3*S*,4*R*,6*S*,7*S*)-7-(*tert*-butyldimethylsilyloxy)-3,6-dimethyl-4-(triethylsilyloxy)octan-1-ol (20)



To a round bottom flask equipped with a rubber septum and a magnetic stirrer bar was added alkene **19** (1.202 g, 3.00 mmol). The flask was cooled to 0 ^{o}C and hydroboration was initiated by dropwise addition of BH_3-THF (1.0 mL, 1.0 M in THF, 1.00 mmol) for 15 minutes. The mixture was stirred at room temperature for 2 h. After stirring for 2 h, the organoborane was dissolved in 5 ml of THF. A solution of 3 N NaOH (1.0 mL, 3.00 mmol) was added followed by the slow addition 1 mL of 30% of hydrogen peroxide aqueous solution. The reaction mixture was heated to 50 ^{o}C for 1 h to ensure completion of the oxidation. The mixture was saturated with potassium carbonate. The two phases were separated and extracted with Et_2O (10 mL x 3). The combined organic extracts were washed with brine (15 mL x 1) and dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 8: 1) to afford the desired product as colorless oil (0.967 g, 77% yield).

R_f value (hexane/Et_2O 2: 1): 0.18.

$[\alpha]_D^{20}$ = -0.005 (*c* = 1.0, $CHCl_3$).

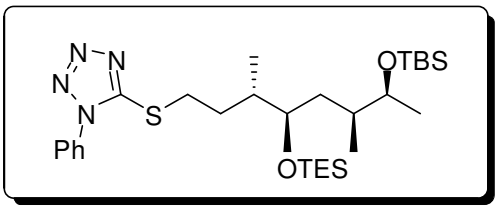
^{1}H NMR (400 MHz, $CDCl_3$): δ 3.71-3.64 (m, 3H), 3.53 (m, 1H), 3.06 (m, 1H), 1.76-1.70 (m, 2H), 1.55-1.48 (m, 1H), 1.38 (m, 1H), 1.29-1.25 (m, 2H), 1.07 (d, *J* = 6.2 Hz, 3H), 0.96 (d, 3H), 0.96 (t, *J* = 8.1 Hz, 9H), 0.88 (s, 9H), 0.84 (d, *J* = 6.7 Hz, 3H), 0.62 (q, *J* = 7.9 Hz, 6H), 0.03 (s, 3H), 0.02 (s, 3H).

^{13}C NMR (75 MHz, $CDCl_3$): δ 74.8 (CH), 71.8 (CH), 59.0 (CH_2), 37.2 (CH_2), 37.1 (CH), 33.4 (CH), 32.7 (CH_2), 25.6 (CH_3), 20.5 (CH_3), 18.1 (C), 16.3 (CH_3), 14.3 (CH_3), 6.9 (CH_3), 5.1 (CH_2), -4.2 (CH_3), -4.8 (CH_3).

FTIR (NaCl, neat): ν 3347, 2957, 1379, 1063 cm^{-1}.

HRMS (ESI) calcd. for $C_{22}H_{51}O_3Si_2$ (M+1) 419.3377, 419.3369.

5-((3*S*,4*R*,6*S*,7*S*)-(*tert*-butyldimethylsilyloxy)-3,6-dimethyl-4-(triethylsilyloxy)octylthio)-1-phenyl-1*H*-tetrazole (21)



In a round bottom flask equipped with a rubber septum and a magnetic stirrer bar, triphenylphosphine (0.393 g, 1.50 mmol) and alcohol **20** (0.419 g, 1.00 mmol) were dissolved in THF (5 mL). DIAD (0.364 g, 1.80 mmol) was next added over 2 minutes at 0 ^{o}C resulting in yellow suspension. Subsequently, a solution of 1-phenyl-1*H*-tetrazole-5-thiol in THF (1 mL) was added over 5 minutes and the reaction mixture was warmed to room temperature. After stirring for 3 h, the reaction was quenched with brine (10 mL) and extracted with Et_2O (10 mL x 3). The combined organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 20: 1) to afford the desired product as colorless oil (0.498 g, 86% yield).

R_f value (hexane/Et_2O 8: 1): 0.21.

$[\alpha]_D^{20} = -0.014$ (c = 1.1, $CHCl_3$).

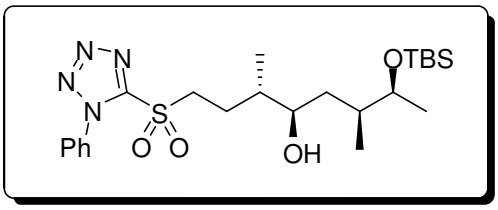
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.57-7.55 (m, 5H), 3.68-3.64 (m, 2H), 3.58-3.52 (m, 1H), 3.34-3.30 (m, 1H), 1.88-1.83 (m, 1H), 1.71-1.65 (m, 2H), 1.58-1.55 (m, 1H), 1.41-1.40 (m, 1H), 1.21-1.17 (m, 1H), 1.03 (d, J = 6.2 Hz, 3H), 0.99 (d, J = 0.66 Hz, 3H), 0.94 (t, J = 7.9 Hz, 9H), 0.85 (s, 9H), 0.84 (d, J = 7.1 Hz, 3H), 0.58 (q, J = 7.9 Hz, 6H), 0.02 (s, 3H), -0.02 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$): δ 154.4 (C), 133.4 (C), 130.0 (CH), 129.7 (CH), 123.8 (CH), 74.7 (CH), 71.4 (CH), 37.2 (CH), 36.6 (CH_2), 36.4 (CH), 31.9 (CH_2), 29.9 (CH_2), 25.9 (CH_3), 20.5 (CH_3), 18.0 (C), 15.7 (CH_3), 14.7 (CH_3), 7.0 (CH_2), 5.2 (CH_3), -4.1 (CH_3), -4.8 (CH_3).

FTIR (NaCl, neat): ν 2955, 1599, 1500, 1383, 1084, 837, 760 cm^{-1}.

HRMS (ESI) calcd. for $C_{29}H_{55}N_4O_2SSi_2$ (M+1) 579.3584, found 579.3567.

(3*S*,4*R*,6*S*,7*S*)-7-(*tert*-butyldimethylsilyloxy)-3,6-dimethyl-1-(1-phenyl-1*H*-tetrazol-5-ylsulfonyl)octan-4-ol (22)



In a round bottom flask equipped with rubber a septum and a magnetic stirrer bar, thiol **21** (0.579 g, 1.00 mmol) was dissolved in EtOH (4 mL). A solution of hexaammonium heptamolybdate tetrahydrate (0.024 g, 0.10 mmol) in 2 mL of 30% hydrogen peroxide was added to the reaction mixture at room temperature and stirred overnight. The reaction was diluted with EtOAc, washed with water and brine. The organic extracts were dried over anhydrous sodium sulfate, filtered and concentrated *in vacuo*. The resulting residue was purified by flash chromatography (hexane/Et_2O 2: 1) to afford the desired product as yellow oil (0.353 g, 71% yield).

R_f value (hexane/EtOAc 2: 1): 0.30.

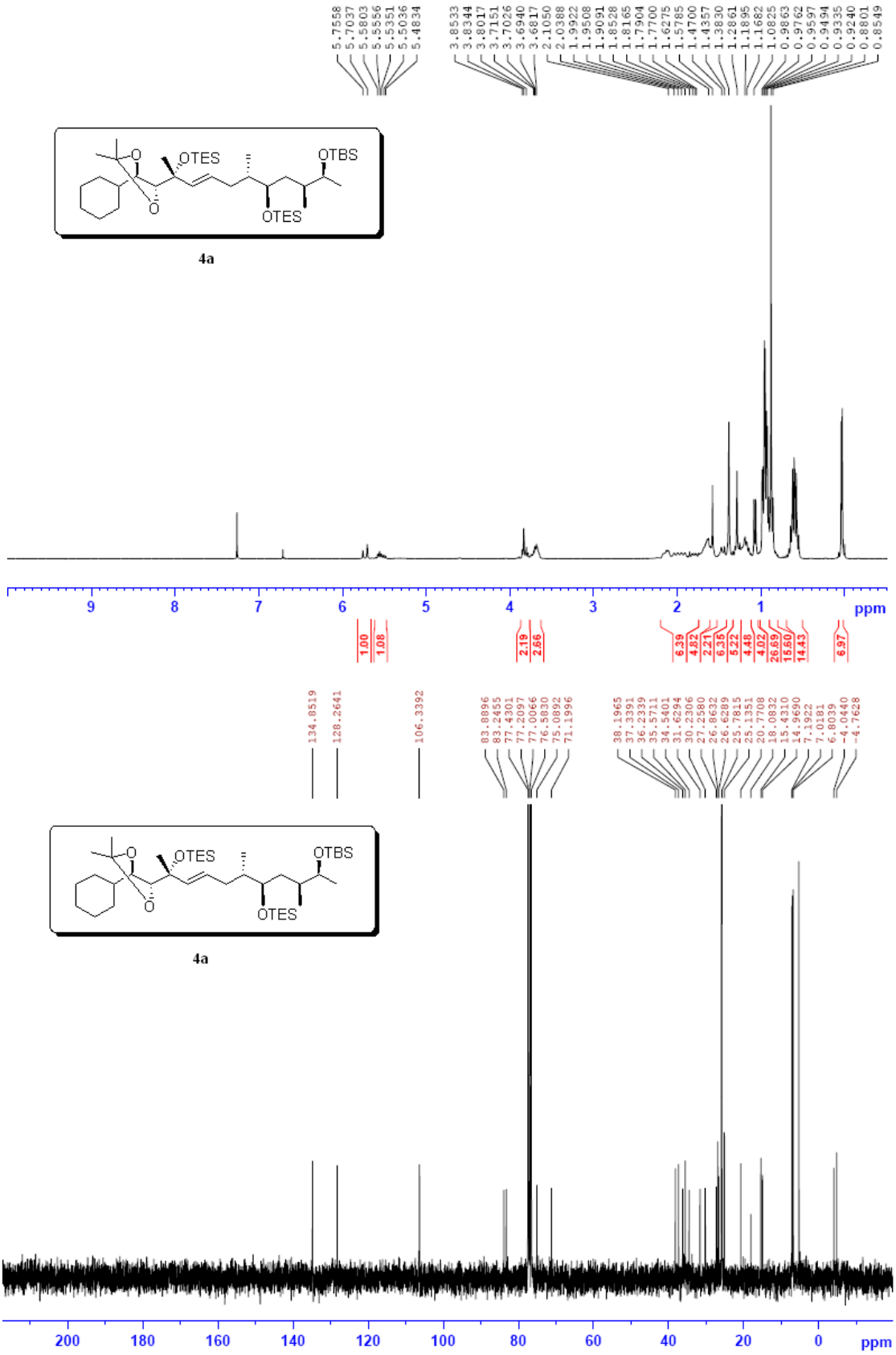
$[\alpha]_D^{20}$ = +0.004 (*c* = 1.0, $CHCl_3$).

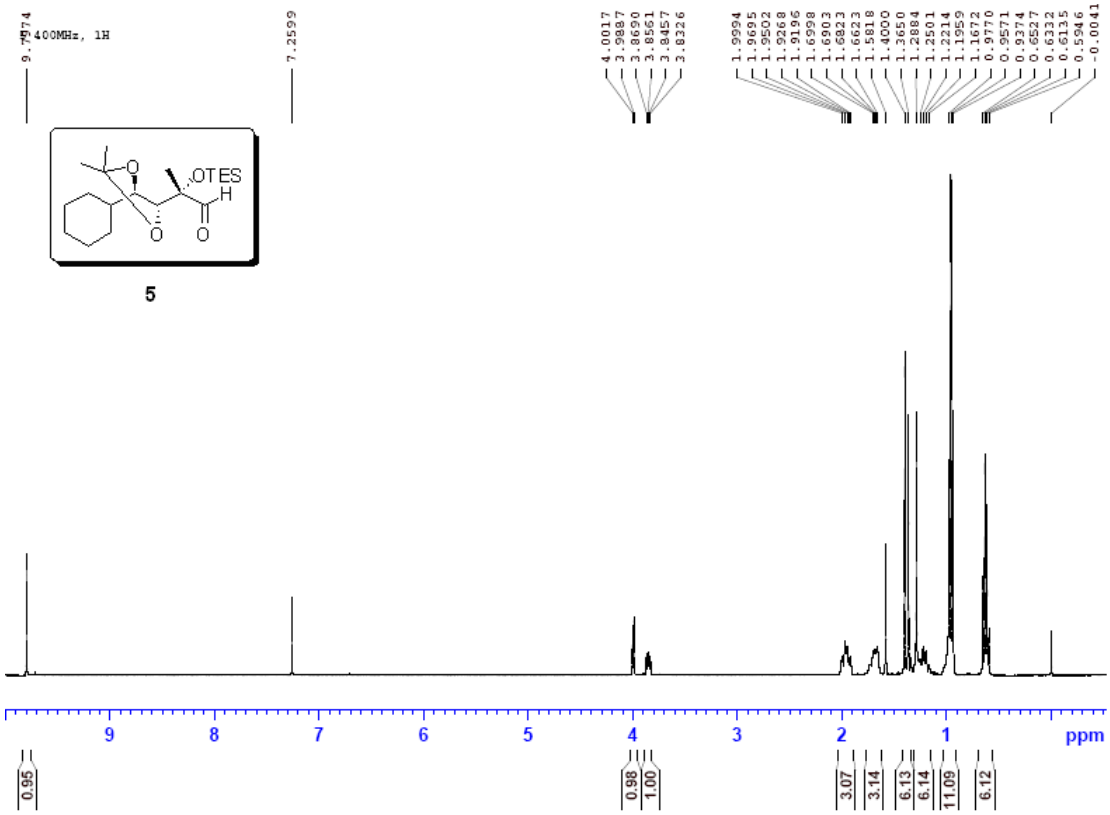
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70-7.68 (m, 2H), 7.63-7.59 (m, 3H), 3.87-3.81 (m, 3H), 3.60-3.55 (m, 1H), 3.14 (d, *J* = 5.4 Hz, 1H), 2.23-2.17 (m, 1H), 1.95-1.86 (m, 2H), 1.70-1.56 (m, 2H), 1.40-1.30 (m, 1H), 1.08 (d, *J* = 6.3 Hz, 3H), 0.97 (d, *J* = 6.8 Hz, 3H), 0.89 (s, 9H), 0.88 (d, *J* = 5.8 Hz, 3H), 0.08 (s, 3H), 0.07 (s, 3H).

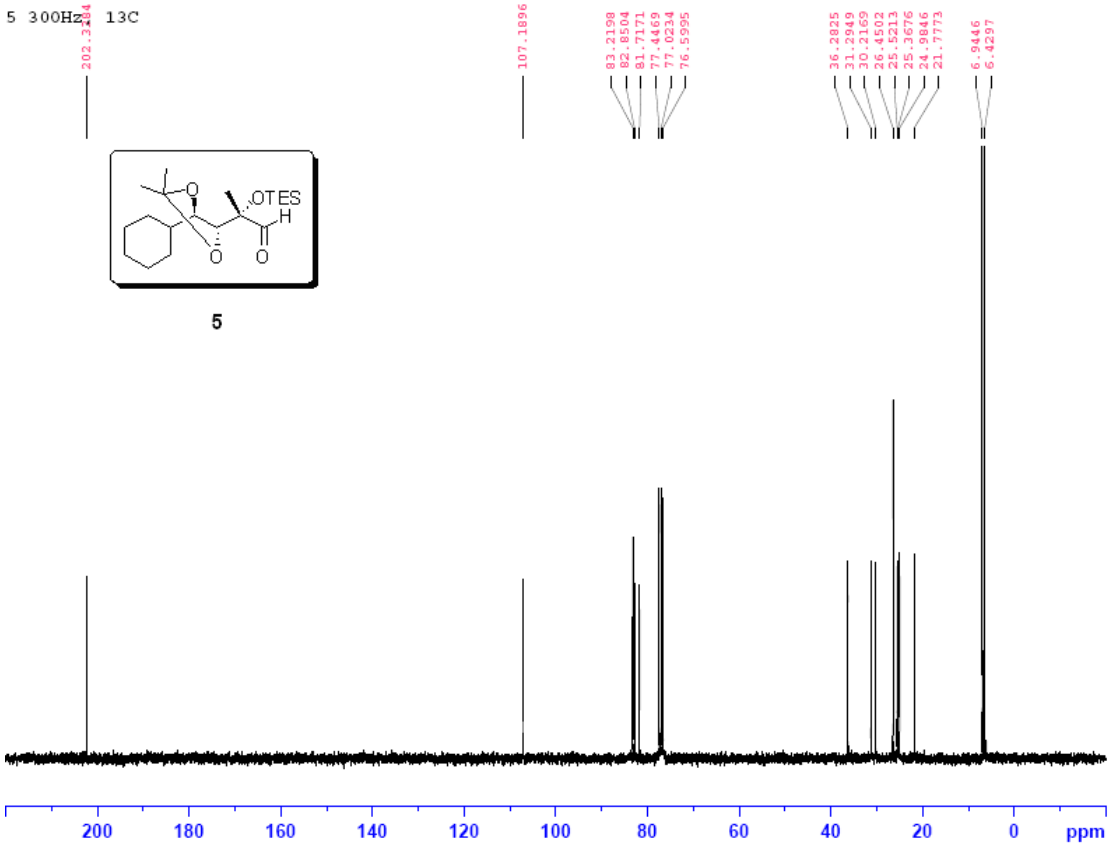
^{13}C NMR (100 MHz, $CDCl_3$): δ 153.5 (C), 133.1 (C), 131.4 (CH), 129.7 (CH), 125.1 (CH), 73.1 (CH), 72.5 (CH), 54.7 (CH_2), 37.7 (CH), 36.9 (CH_2), 35.8 (CH), 25.7 (CH_3), 25.3 (CH_2), 18.3 (CH_3), 18.1 (C), 17.7 (CH_3), 16.1 (CH_3), -4.3 (CH_3), -4.8 (CH_3).

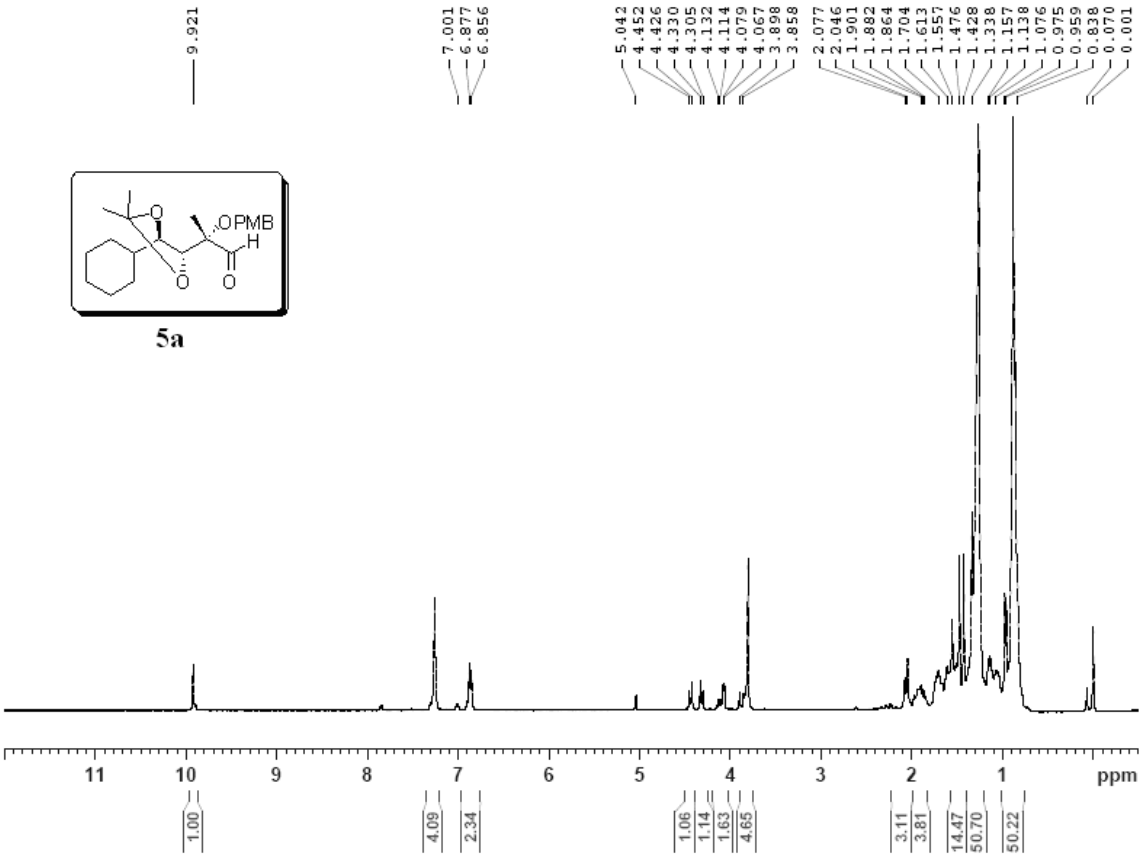
FTIR (NaCl, neat): *v* 3418, 2957, 1595, 1499, 1339, 1152, 835, 773 cm^{-1}.

HRMS (ESI) calcd. for $C_{23}H_{41}N_4O_4Ssi$ (M+1) 496.2618, found 497.2618.

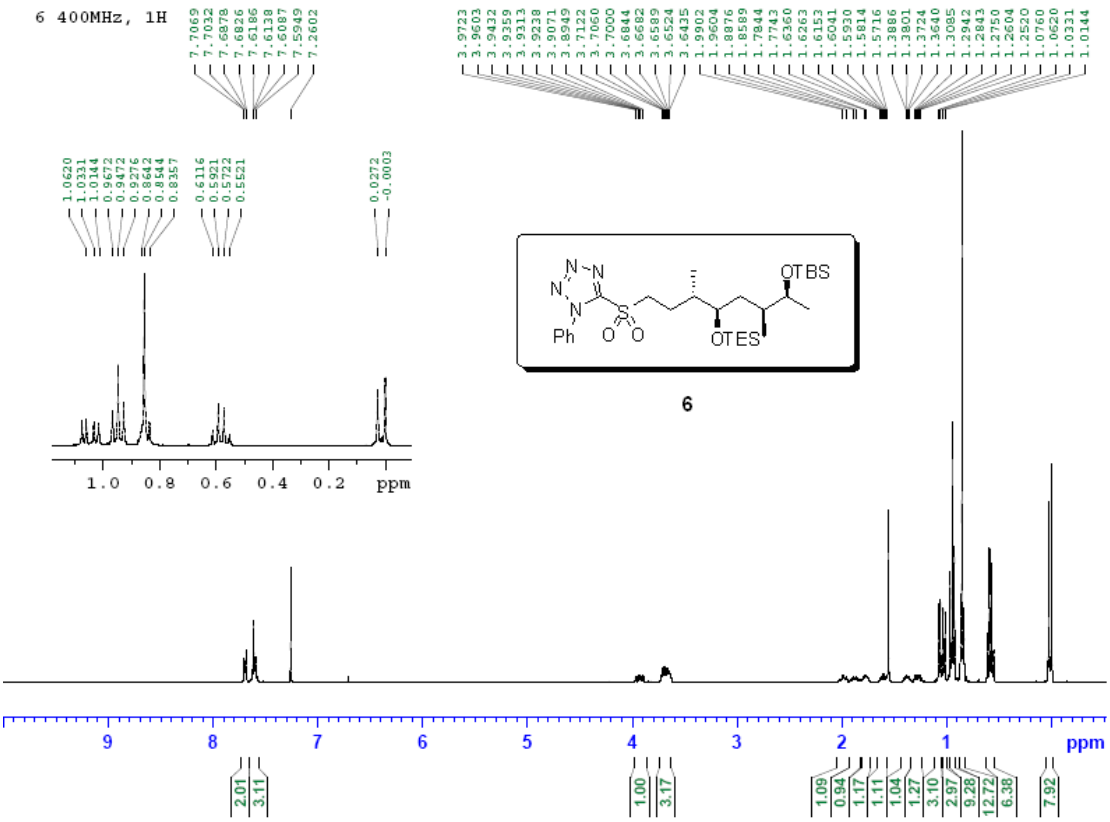

OTES
OTBS
OTES
4a
ppm
OTES
OTBS
OTES
4a
ppm

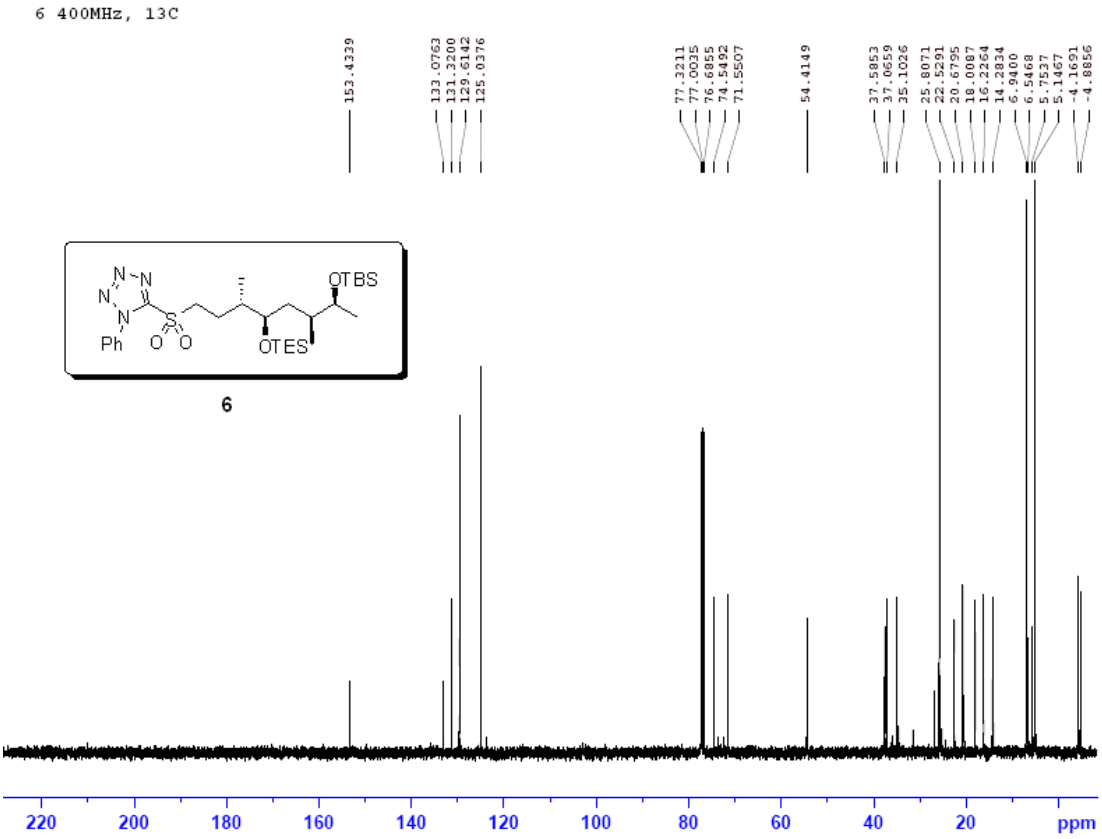

9.7574
400MHz, 1H
7.2599
4.0017
3.9887
3.8690
3.8561
3.8457
3.8326
1.9994
1.9695
1.9502
1.9268
1.9196
1.6998
1.6903
1.6823
1.6623
1.5818
1.4000
1.3650
1.2884
1.2501
1.2214
1.1959
1.1672
0.9770
0.9571
0.9374
0.6527
0.6332
0.6135
0.5946
-0.0041
OTES
H
O
O
O
5
9
8
7
6
5
4
3
2
1
ppm
0.95
0.98
1.00
3.07
3.14
6.13
6.14
11.09
6.12

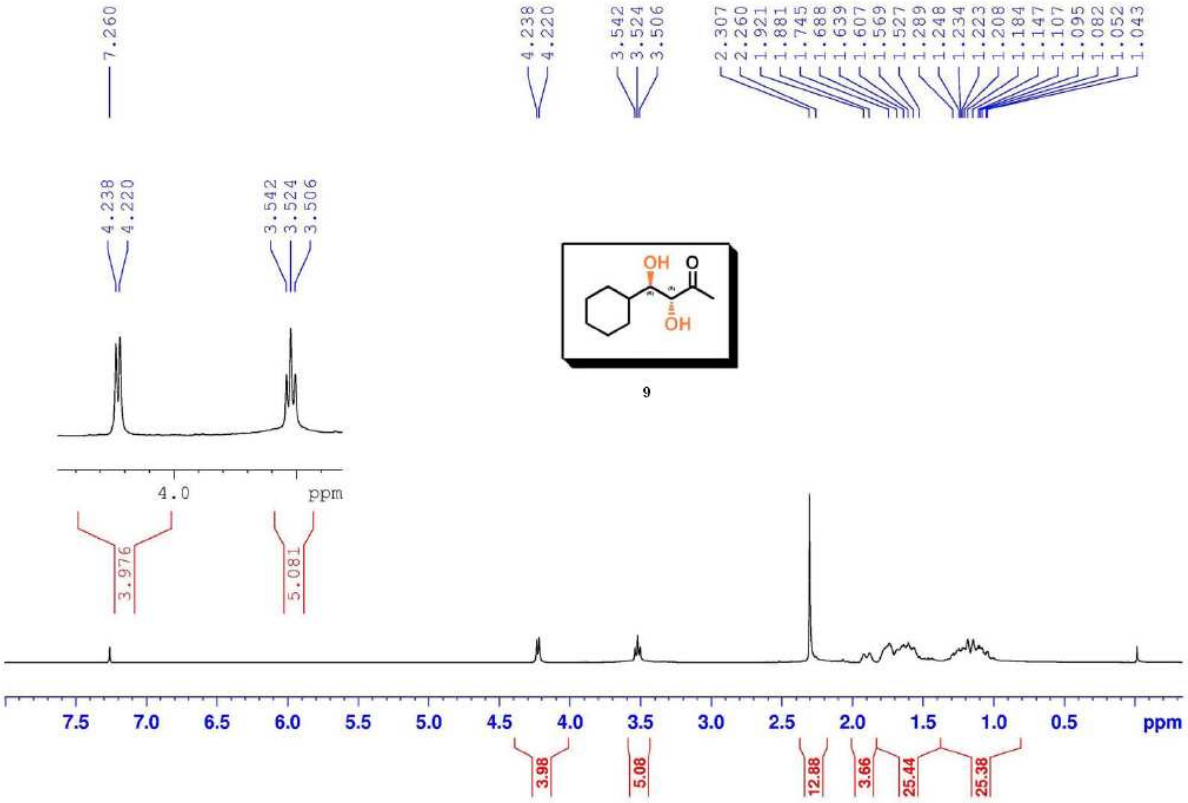

5 300Hz, 13C
202.3284
107.1896
83.2198
82.8504
81.7171
77.4469
77.0234
76.5995
36.2825
31.2949
30.2169
26.4502
25.5213
25.3676
24.9846
21.7773
6.9446
6.4297
OTES
H
O
O
O
5
200
180
160
140
120
100
80
60
40
20
0
ppm

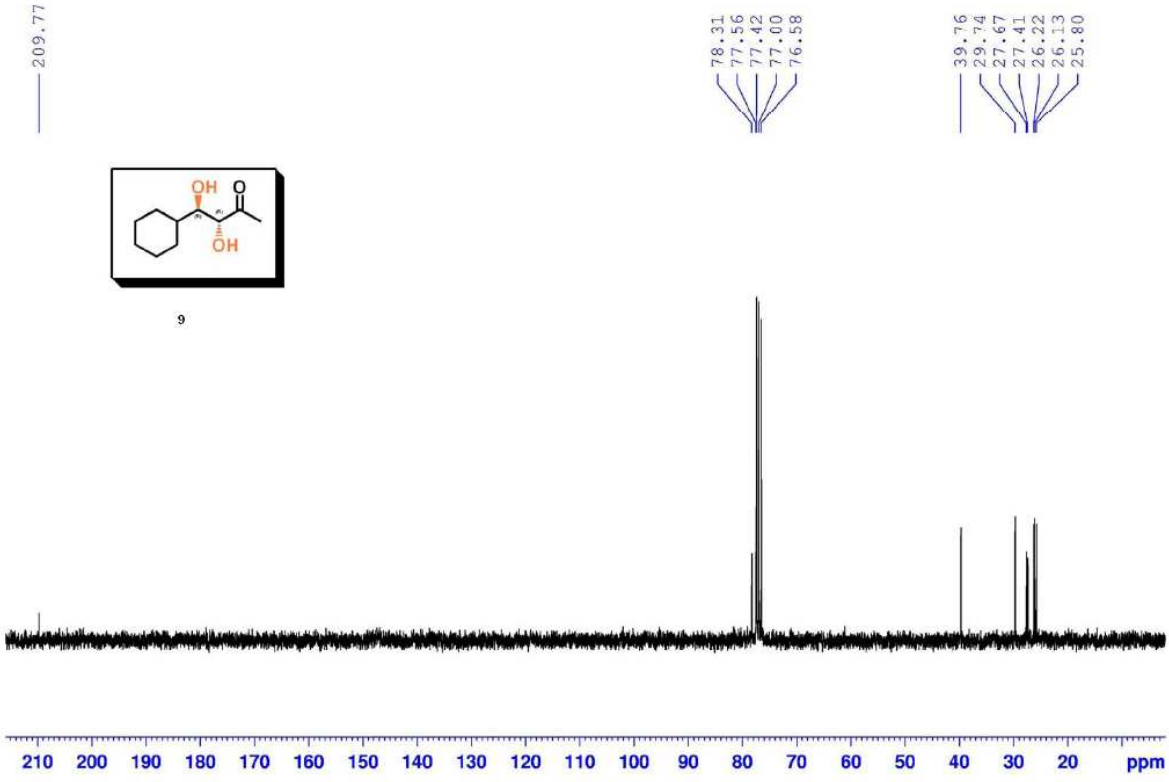

9.921
7.001
6.877
6.856
5.042
4.452
4.426
4.330
4.305
4.132
4.114
4.079
4.067
3.898
3.858
2.077
2.046
1.901
1.882
1.864
1.704
1.613
1.557
1.476
1.428
1.338
1.157
1.138
1.076
0.975
0.959
0.838
0.070
0.001
OPMB
H
O
O
O
11
10
9
8
7
6
5
4
3
2
1
ppm
1.00
4.09
2.34
1.06
1.14
1.63
4.65
3.11
3.81
14.47
50.70
50.22

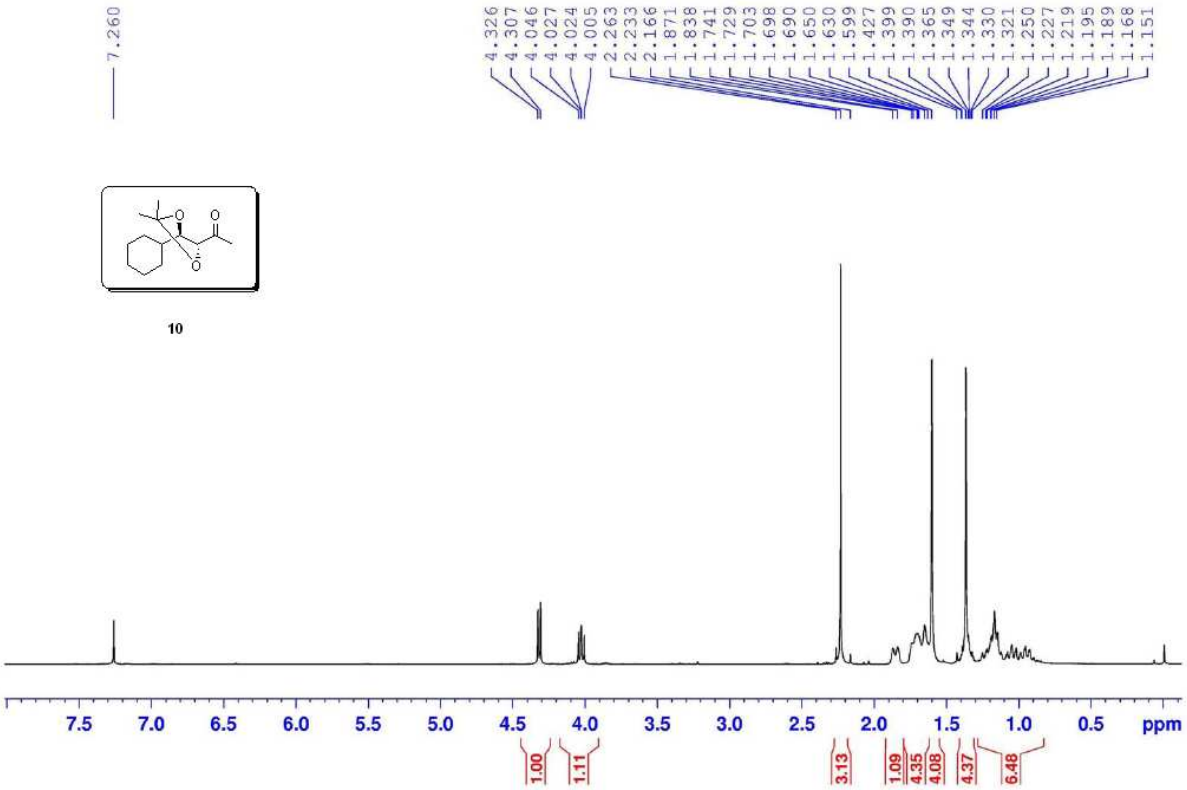
5a

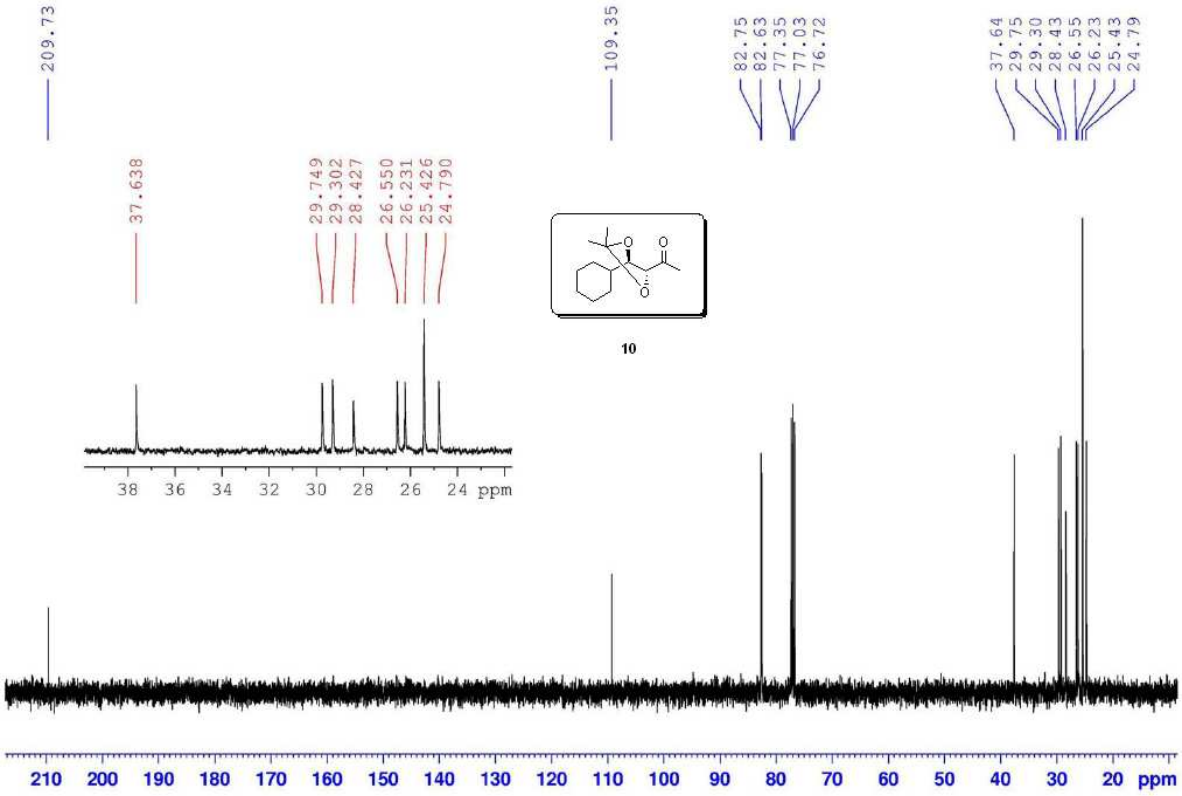

6 400MHz, 1H
6
ppm

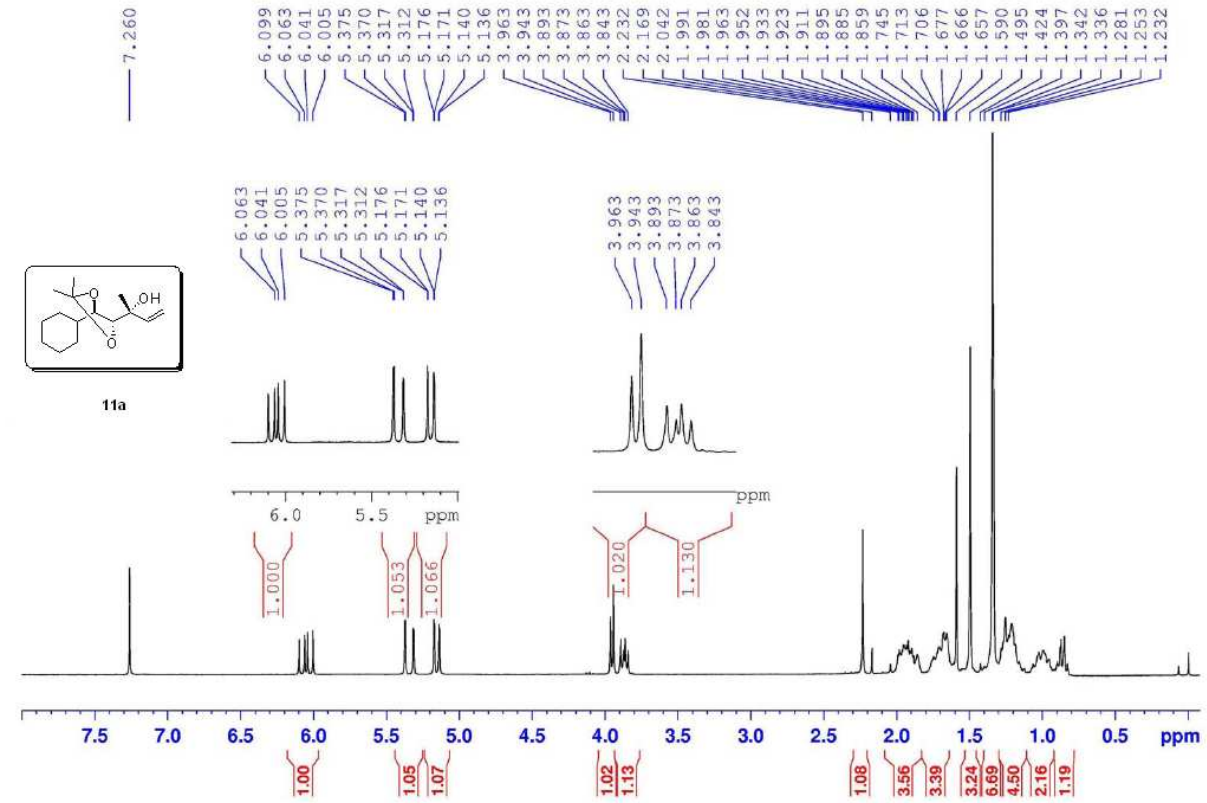

6 400MHz, 13C
6
ppm

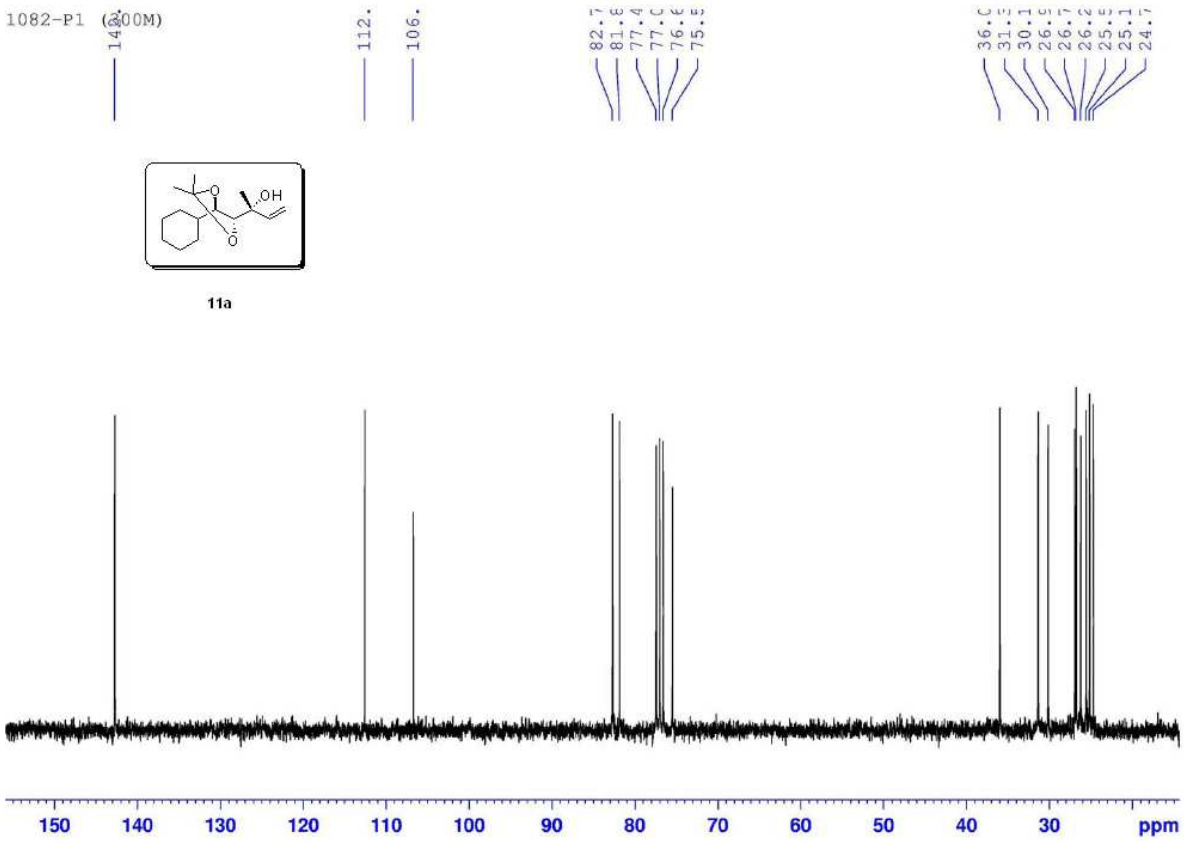

7.260
4.238
4.220
3.542
3.524
3.506
2.307
2.260
1.921
1.881
1.745
1.688
1.639
1.607
1.569
1.527
1.289
1.248
1.234
1.223
1.208
1.184
1.147
1.107
1.095
1.082
1.052
1.043
OH
O
OH
9
4.0
ppm
3.976
5.081
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
3.98
5.08
12.88
3.66
25.44
25.38

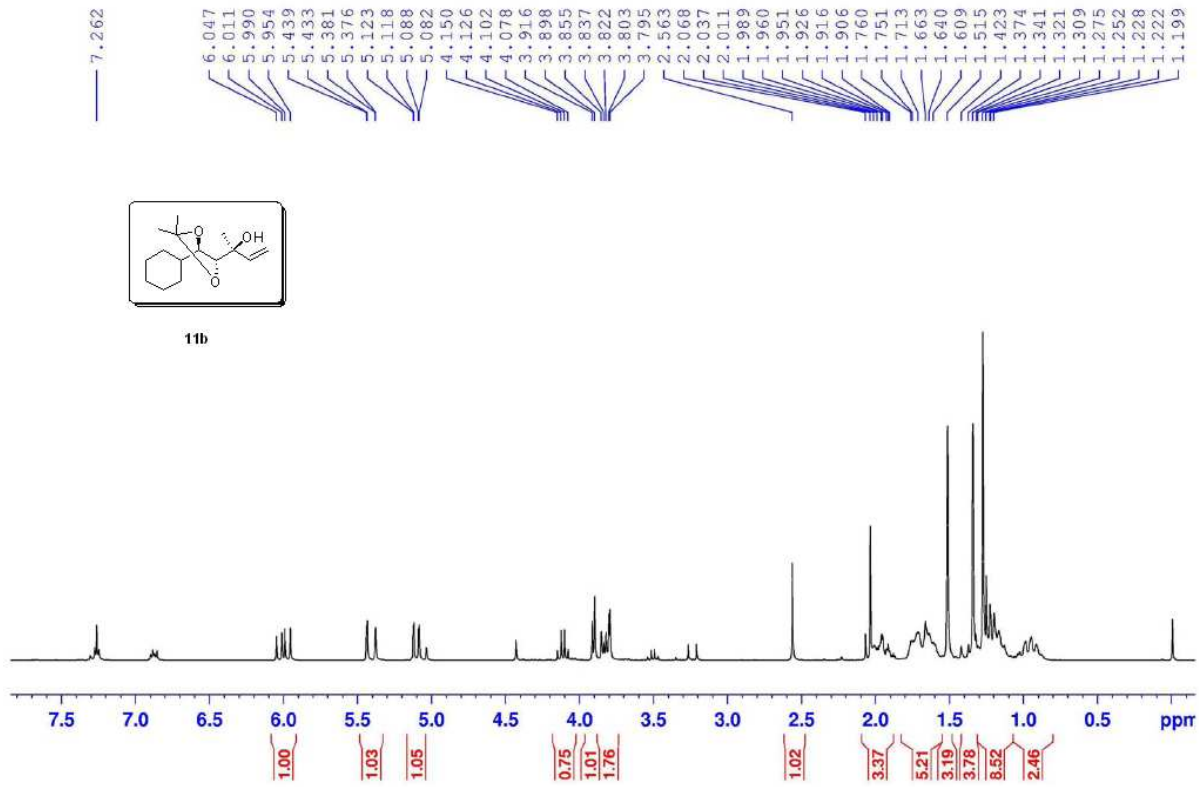

209.77
78.31
77.56
77.42
77.00
76.58
39.76
29.74
27.67
27.41
26.22
26.13
25.80
OH
O
OH
9
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

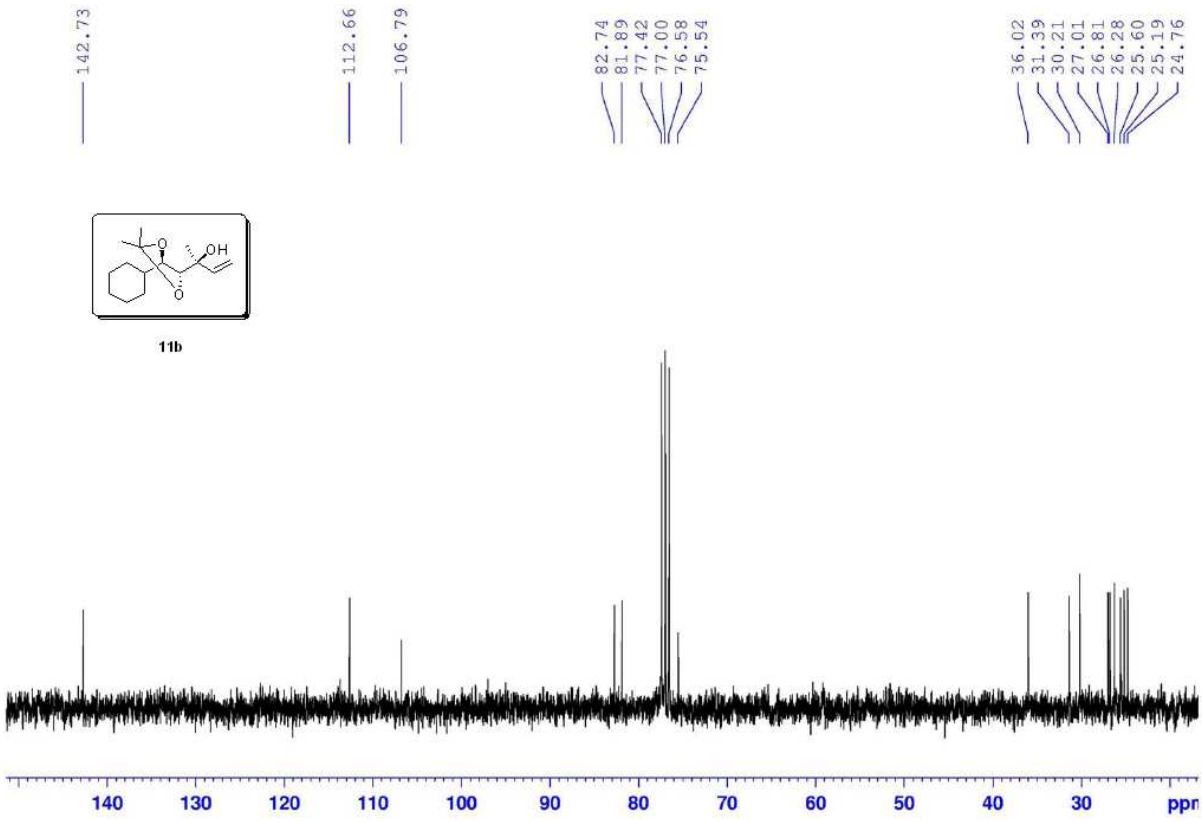

7.260
4.326
4.307
4.046
4.027
4.024
4.005
2.263
2.233
2.166
1.871
1.838
1.741
1.729
1.703
1.698
1.690
1.650
1.630
1.599
1.427
1.399
1.390
1.365
1.349
1.344
1.330
1.321
1.250
1.227
1.219
1.195
1.189
1.168
1.151
10
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.00
1.11
3.13
1.09
4.35
4.08
4.37
6.48


209.73
109.35
82.75
82.63
77.35
77.03
76.72
37.64
29.75
29.30
28.43
26.55
26.23
25.43
24.79
37.638
29.749
29.302
28.427
26.550
26.231
25.426
24.790
10
38 36 34 32 30 28 26 24 ppm
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

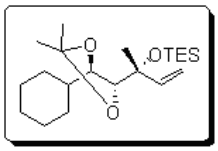

7.260
6.099
6.063
6.041
6.005
5.375
5.370
5.317
5.312
5.176
5.171
5.140
5.136
3.963
3.943
3.893
3.873
3.863
3.843
2.232
2.169
2.042
1.991
1.981
1.963
1.952
1.933
1.923
1.911
1.895
1.885
1.859
1.745
1.713
1.706
1.677
1.666
1.657
1.590
1.495
1.424
1.397
1.342
1.336
1.281
1.253
1.232
OH
O
O
11a
6.0
5.5
ppm
1.000
1.053
1.066
1.020
1.130
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
ppm
1.00
1.05
1.07
1.02
1.13
1.08
3.56
3.39
3.24
6.69
4.50
2.16
1.19


1082-P1 (400M)
112.
106.
82.
81.
77.4
77.
76.
75.
36.
31.
30.1
26.
26.
25.
25.1
24.
OH
O
O
11a
150
140
130
120
110
100
90
80
70
60
50
40
30
ppm


7.262
6.047
6.011
5.990
5.954
5.439
5.433
5.381
5.376
5.123
5.118
5.088
5.082
4.150
4.126
4.102
4.078
4.016
3.898
3.855
3.837
3.822
3.803
3.795
2.563
2.068
2.037
2.011
1.989
1.960
1.951
1.926
1.916
1.906
1.760
1.751
1.713
1.663
1.640
1.609
1.515
1.423
1.374
1.341
1.321
1.309
1.275
1.252
1.228
1.222
1.199
OH
O
O
11b
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
ppm
1.00
1.03
1.05
0.75
1.01
1.76
1.02
3.37
5.21
3.19
3.78
8.52
2.46

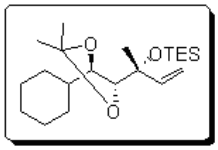

142.73
112.66
106.79
82.74
81.89
77.42
77.00
76.58
75.54
36.02
31.39
30.21
27.01
26.81
26.28
25.60
25.19
24.76
OH
O
O
11b
140
130
120
110
100
90
80
70
60
50
40
30
ppm

12a 300MHz, 1H

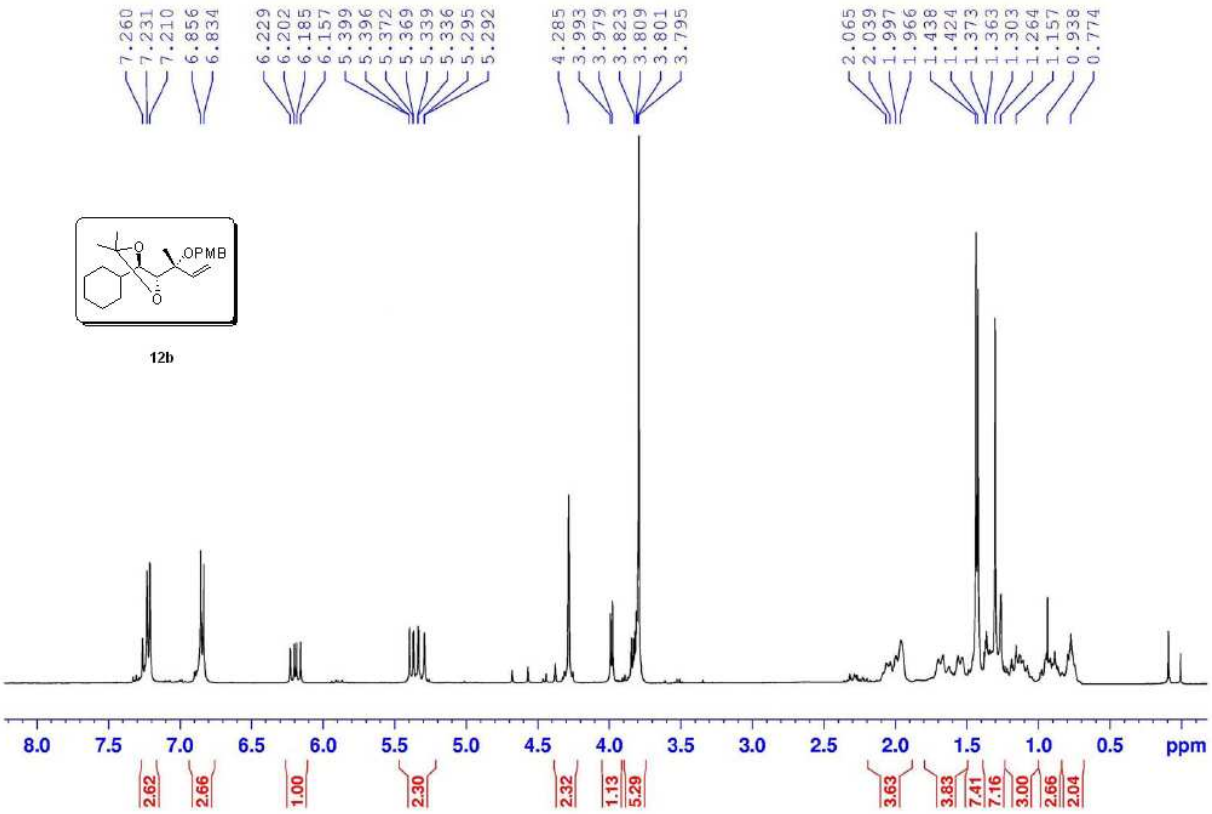


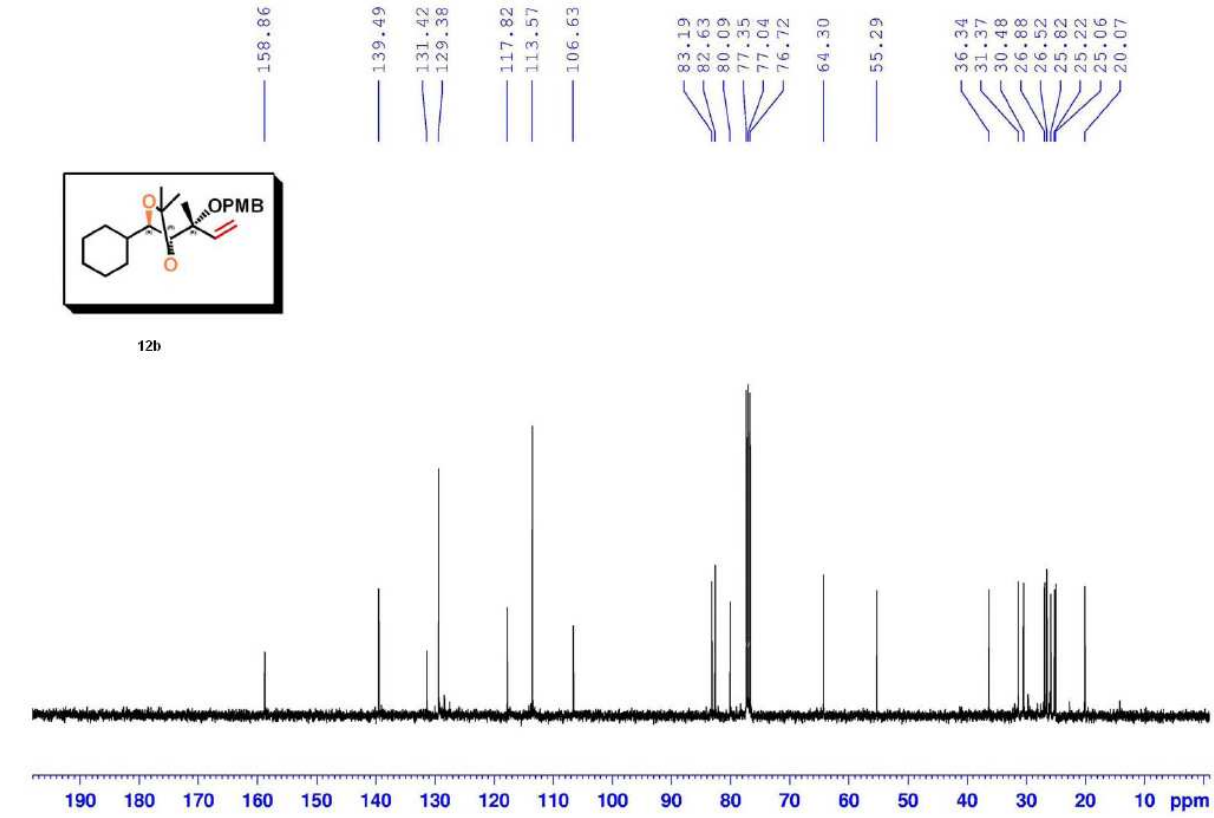
12a

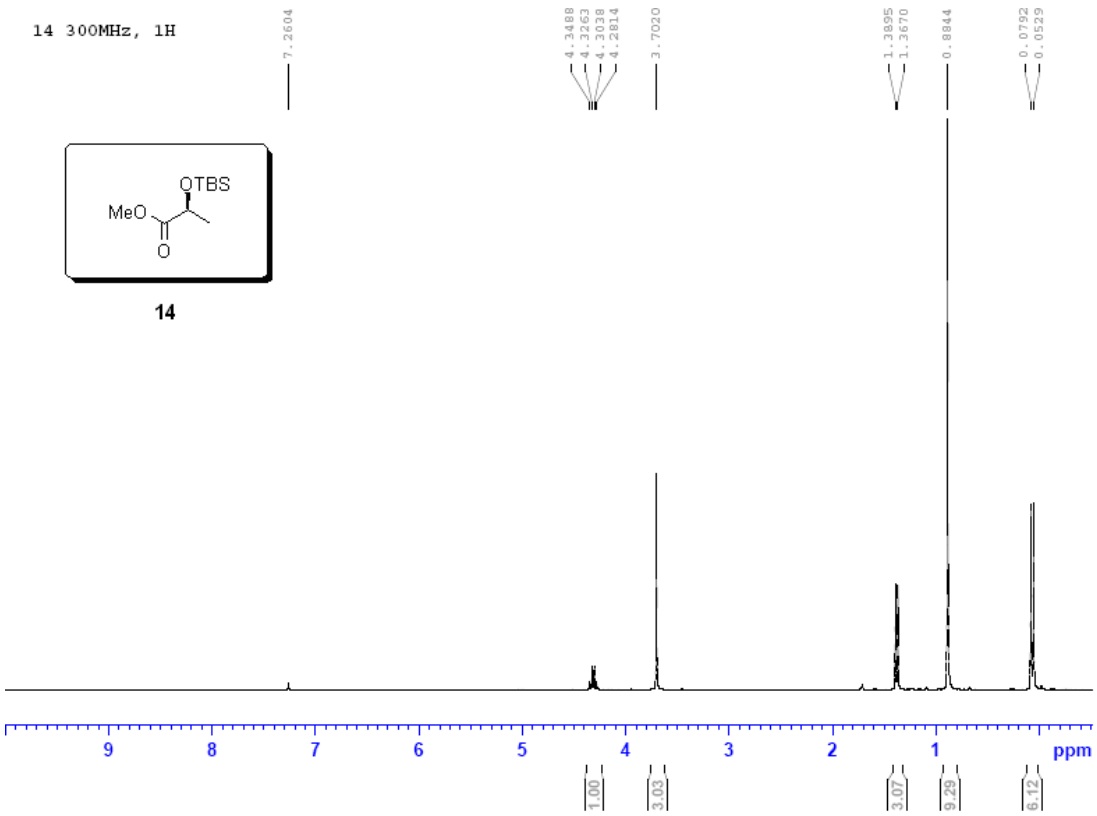
12a 400MHz, 13C

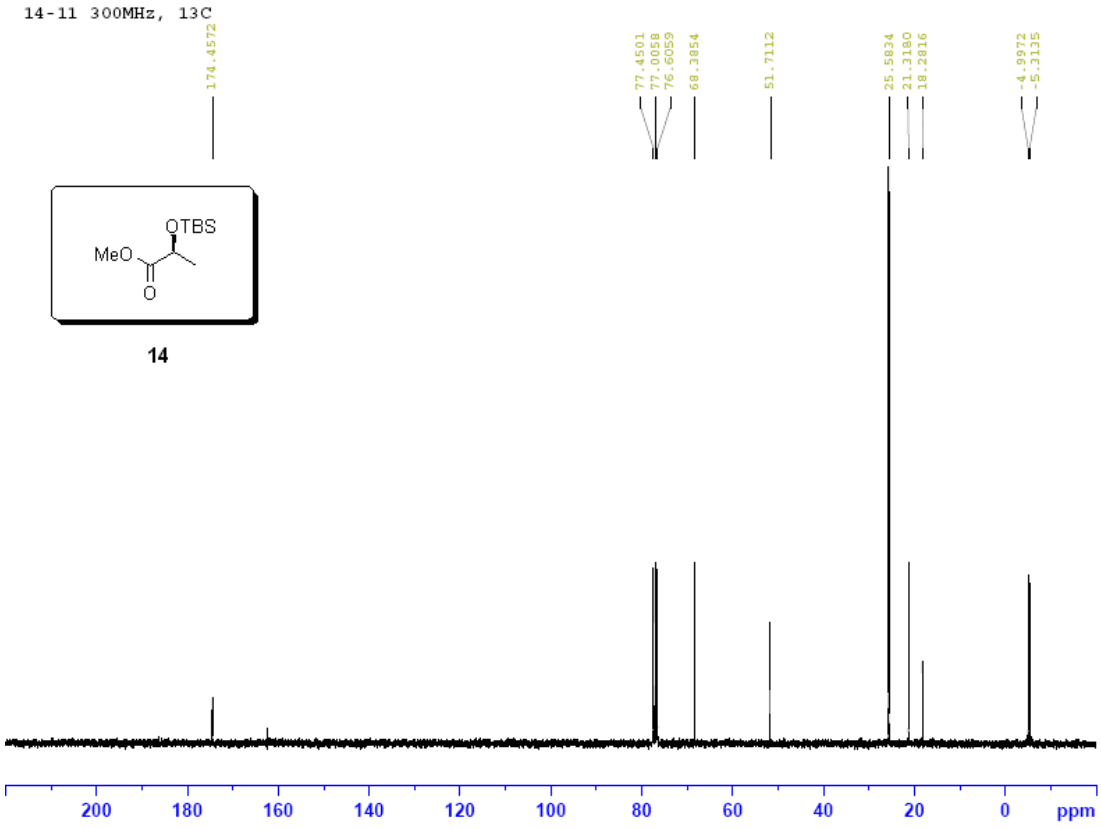


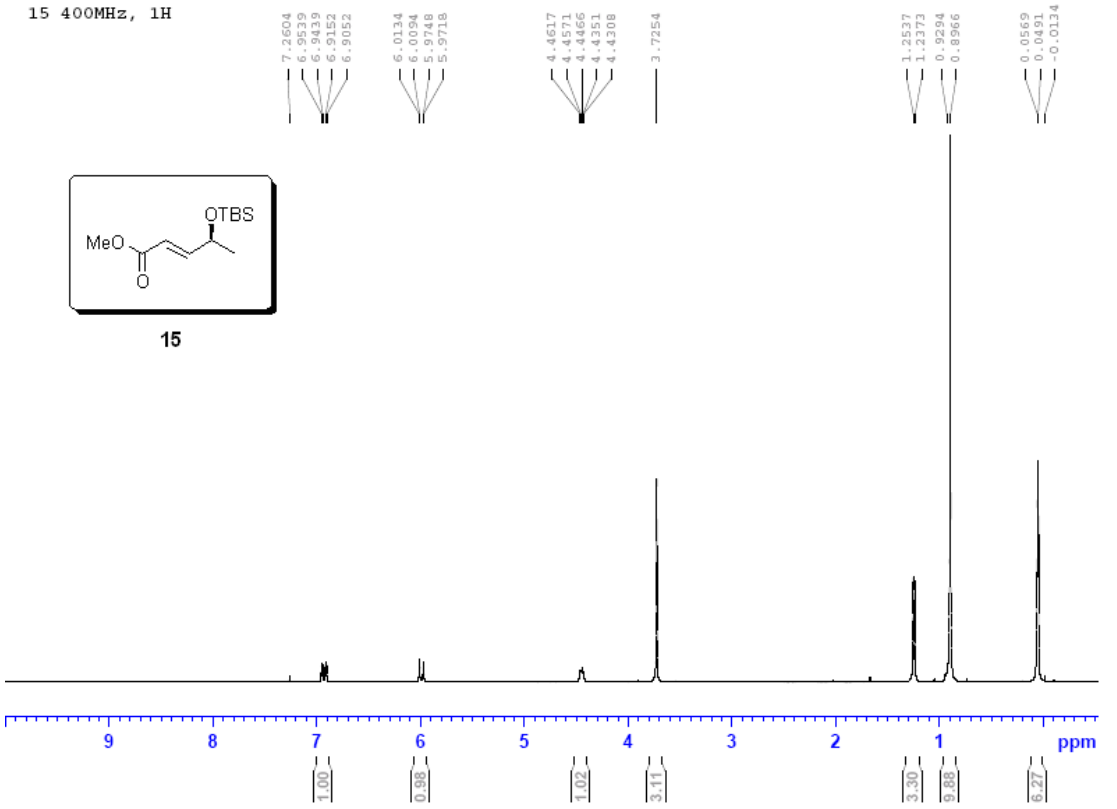
12a

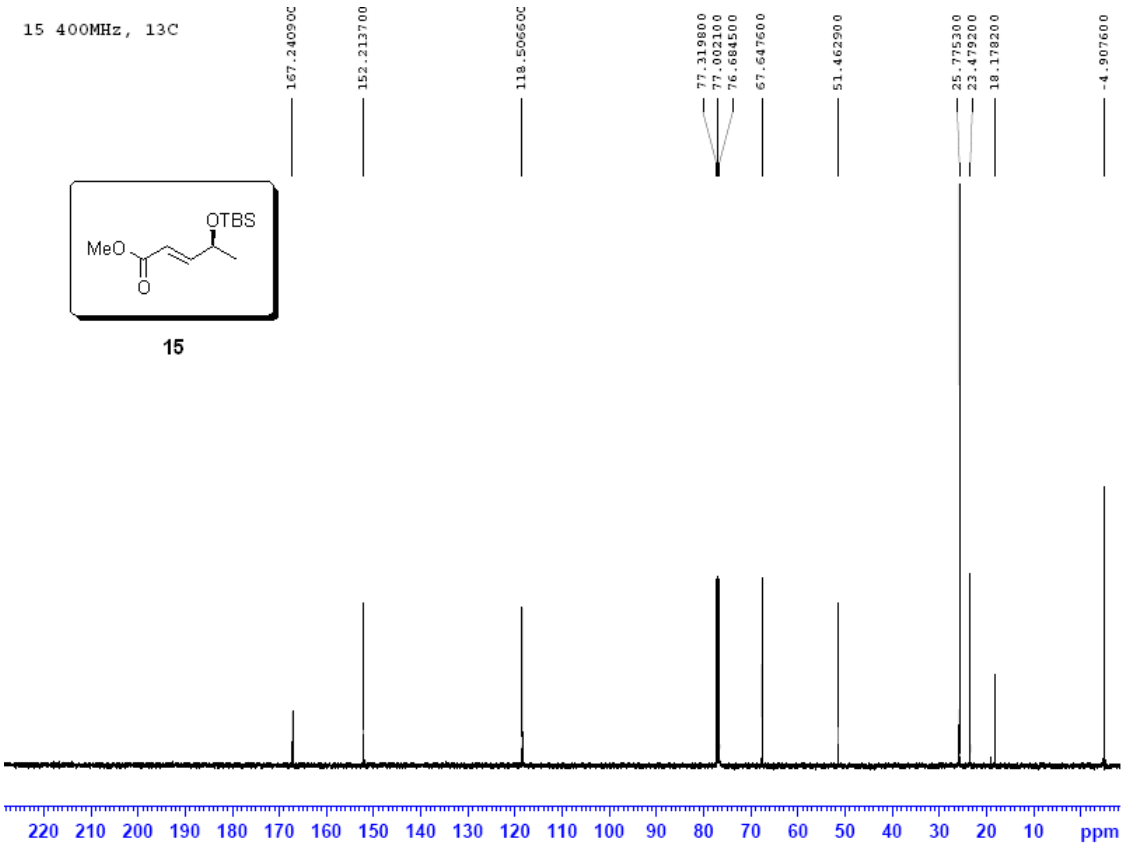

7.260
7.231
7.210
6.856
6.834
6.229
6.202
6.185
6.157
5.399
5.396
5.372
5.369
5.339
5.336
5.295
5.292
4.285
3.993
3.979
3.823
3.809
3.801
3.795
2.065
2.039
1.997
1.966
1.438
1.424
1.373
1.363
1.303
1.264
1.157
0.938
0.774
OPMB
12b
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
2.62
2.66
1.00
2.30
2.32
1.13
5.29
3.63
3.83
7.41
7.16
3.00
2.66
2.04

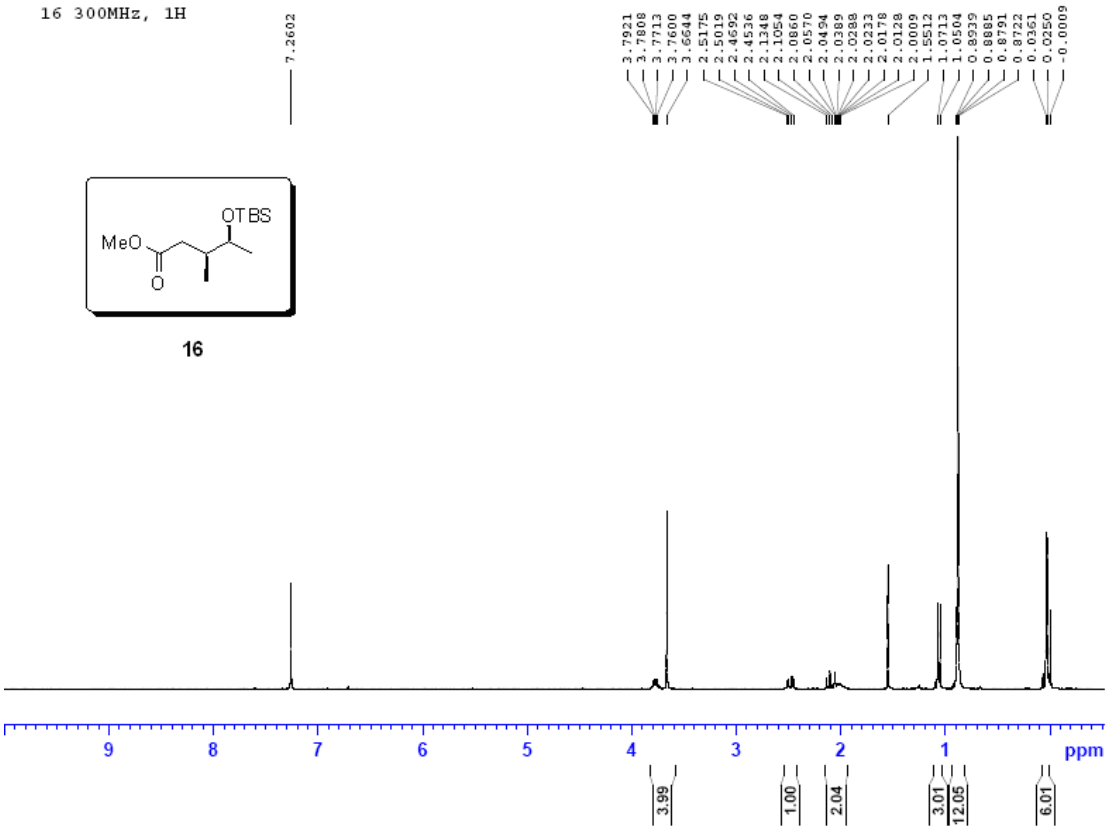

158.86
139.49
131.42
129.38
117.82
113.57
106.63
83.19
82.63
80.09
77.35
77.04
76.72
64.30
55.29
36.34
31.37
30.48
26.88
26.52
25.82
25.22
25.06
20.07
OPMB
12b
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

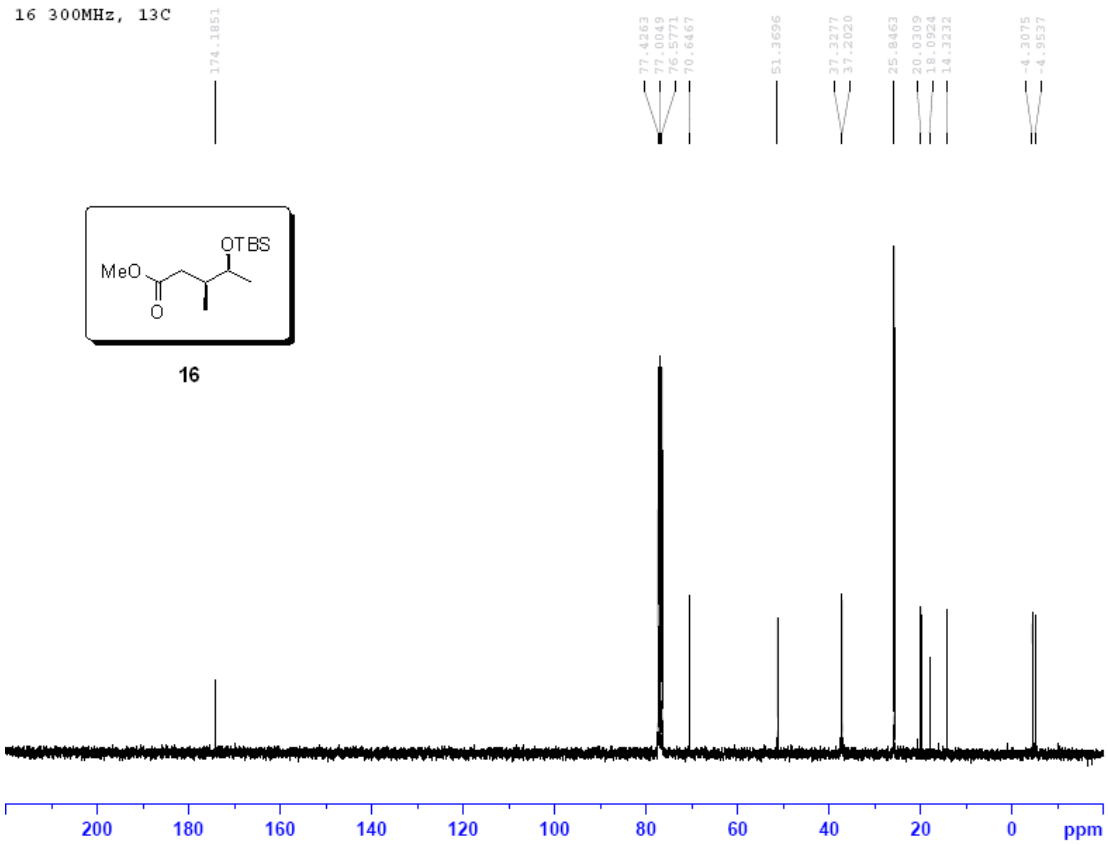

14 300MHz, 1H
7.2604
4.3488
4.3263
4.3038
4.2814
3.7020
1.3895
1.3670
0.8844
0.0792
0.0529
OTBS
MeO
O
14
9
8
7
6
5
4
3
2
1
ppm
1.00
3.03
3.07
9.29
6.12

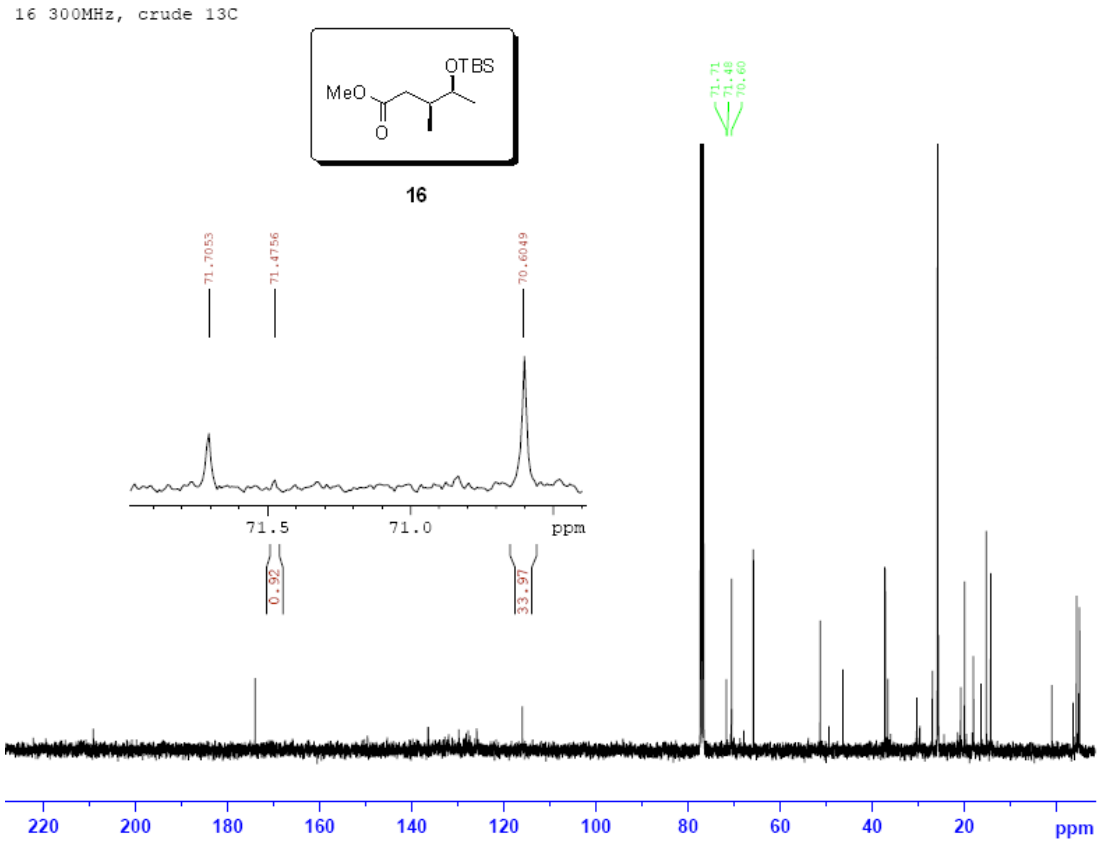

14-11 300MHz, 13C
174.4572
77.4501
77.0058
76.6059
68.3854
51.7112
25.5834
21.3180
18.2816
-4.9972
-5.3135
OTBS
MeO
O
14
200
180
160
140
120
100
80
60
40
20
0
ppm

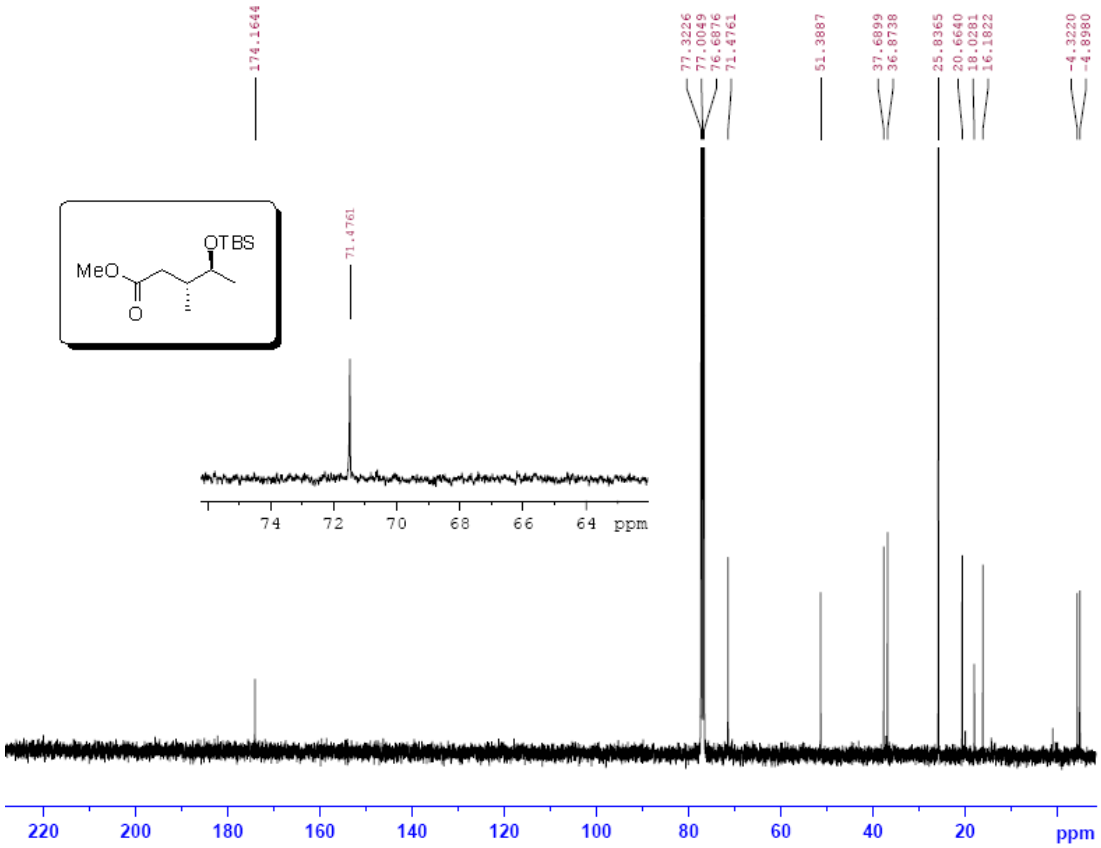

15 400MHz, 1H
7.2604
6.9539
6.9439
6.9152
6.9052
6.0134
6.0094
5.9748
5.9718
4.4617
4.4571
4.4466
4.4351
4.4308
3.7254
1.2537
1.2373
0.9294
0.8966
0.0569
0.0491
-0.0134
OTBS
MeO
O
15
9
8
7
6
5
4
3
2
1
ppm
1.00
0.98
1.02
3.11
3.30
9.88
6.27

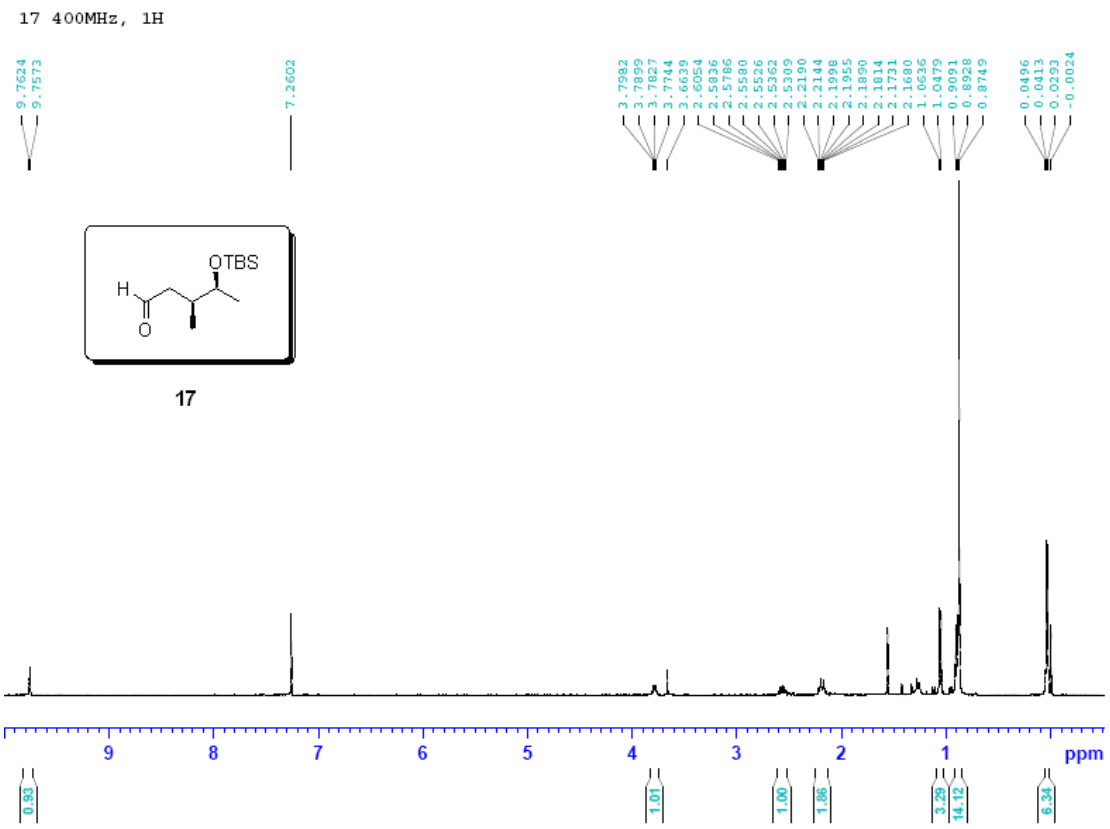

15 400MHz, 13C
167.240900
152.213700
118.506600
77.319800
77.002100
76.684500
67.647600
51.462900
25.775300
23.479200
18.178200
-4.907600
OTBS
MeO
O
15
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

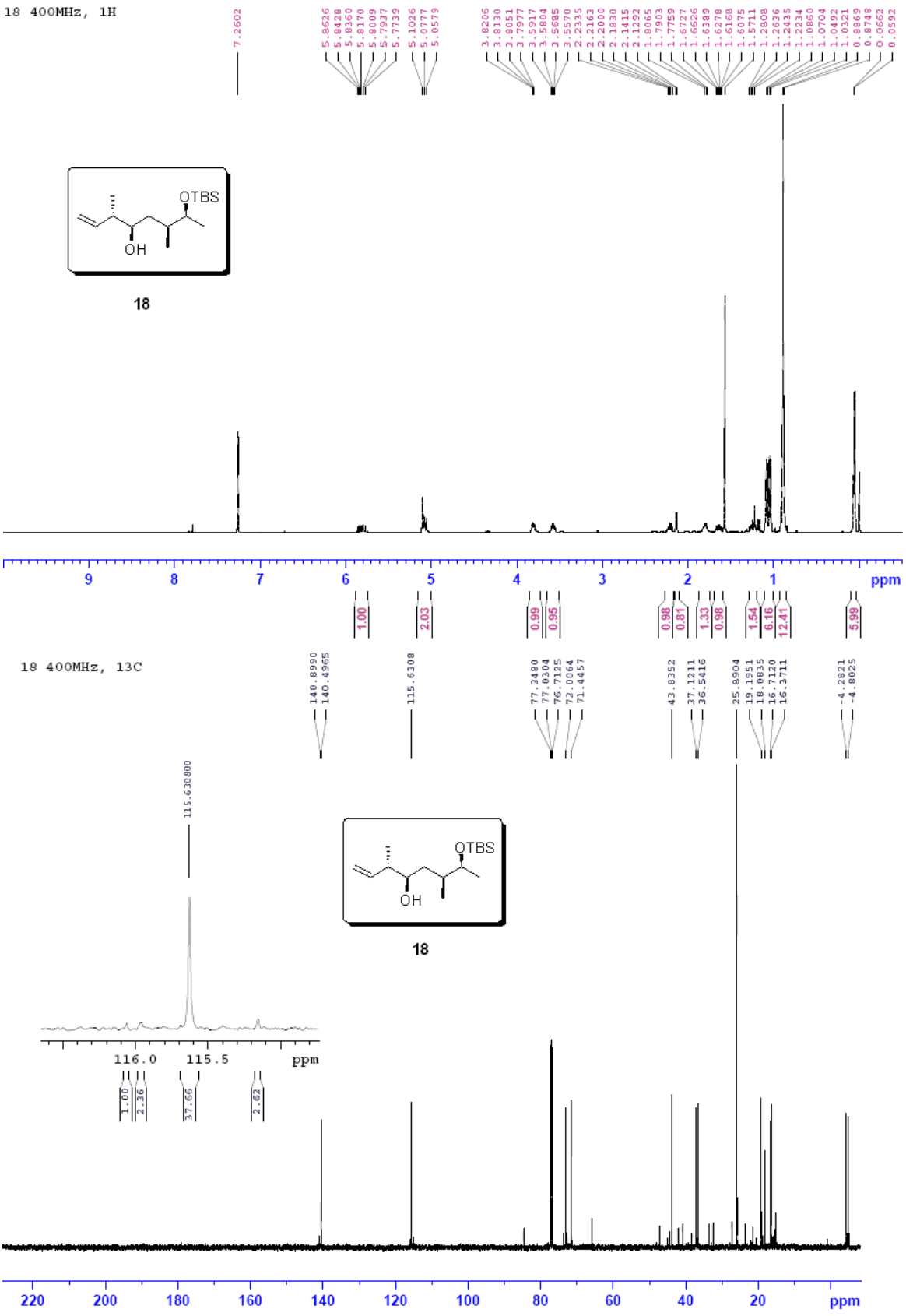

16 300MHz, 1H
7.2602
3.7921
3.7808
3.7713
3.7600
3.6644
2.5175
2.5019
2.4692
2.4536
2.1348
2.1054
2.0860
2.0570
2.0494
2.0389
2.0288
2.0233
2.0178
2.0128
2.0009
1.5512
1.0713
1.0504
0.8939
0.8885
0.8791
0.8722
0.0361
0.0250
-0.0009
MeO
OTBS
O
16
9
8
7
6
5
4
3
2
1
ppm
3.99
1.00
2.04
3.01
12.05
6.01

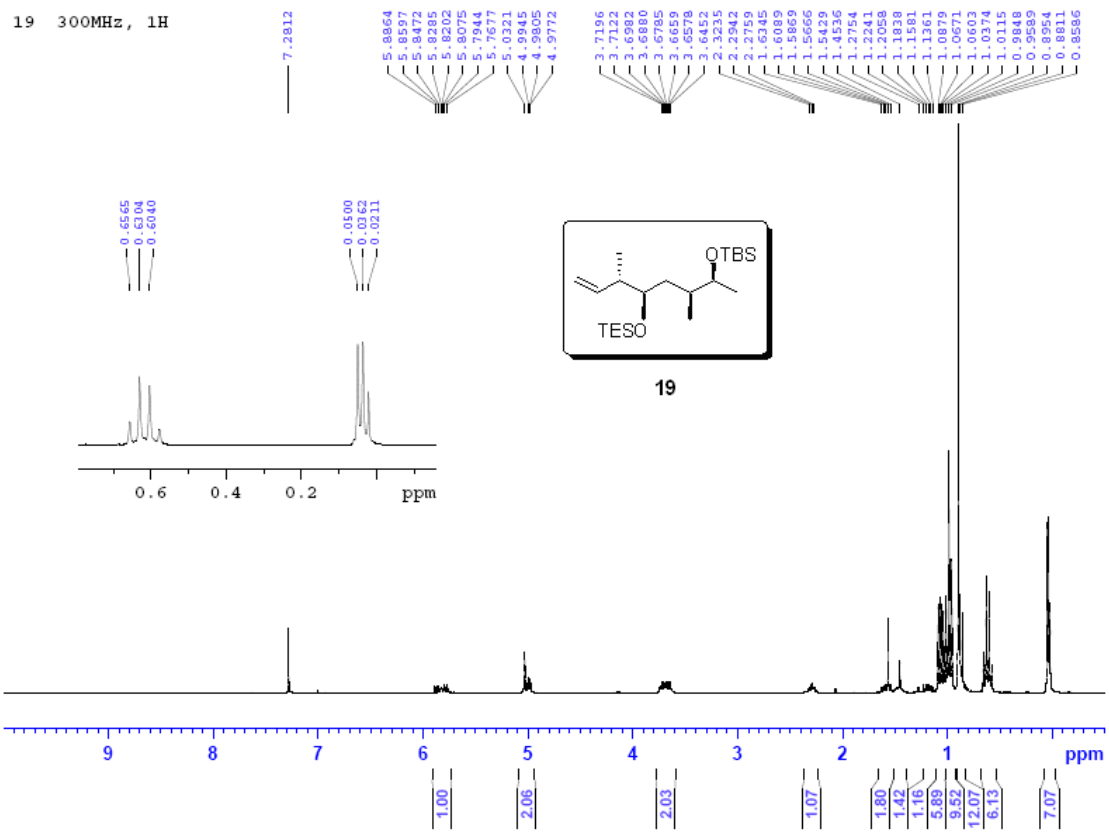

16 300MHz, 13C
174.1851
77.4263
77.0049
76.5771
70.6467
51.3696
37.3277
37.2020
25.8463
20.0309
18.0924
14.3232
-4.3075
-4.9537
MeO
OTBS
O
16
200
180
160
140
120
100
80
60
40
20
0
ppm

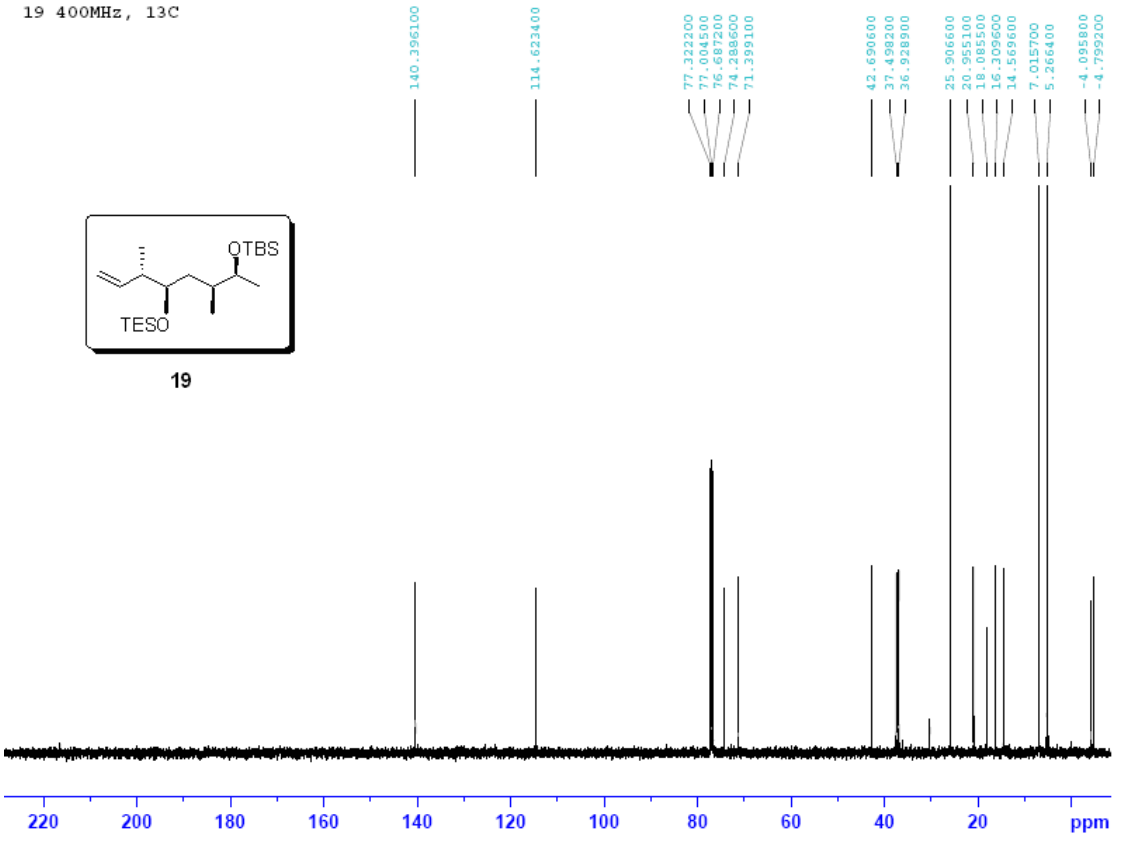

16 300MHz, crude 13C
OTBS
MeO
O
16
71.71
71.48
70.60
71.7053
71.4756
70.6049
71.5
71.0
ppm
0.92
33.97
220
200
180
160
140
120
100
80
60
40
20
ppm

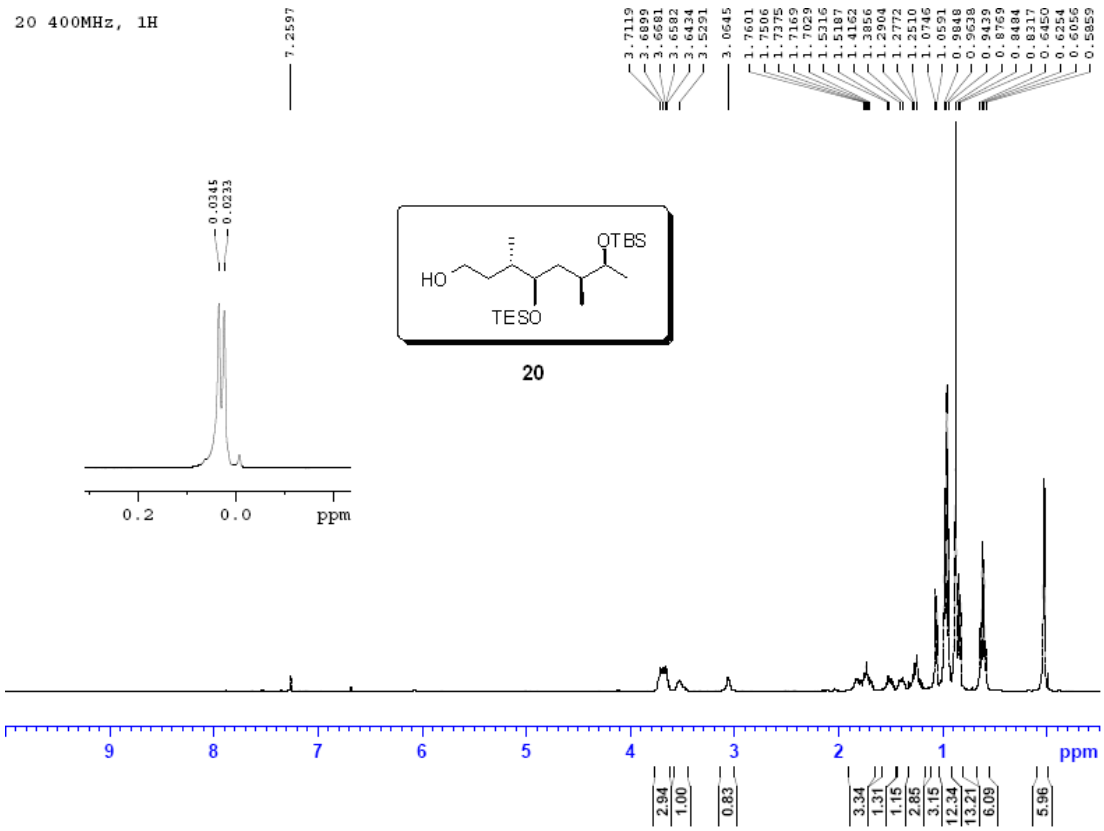

174.1644
77.3226
77.0049
76.6876
71.4761
51.3887
37.6899
36.8738
25.8365
20.6640
18.0281
16.1822
-4.3220
-4.8980
OTBS
MeO
O
71.4761
74
72
70
68
66
64
ppm
220
200
180
160
140
120
100
80
60
40
20
ppm

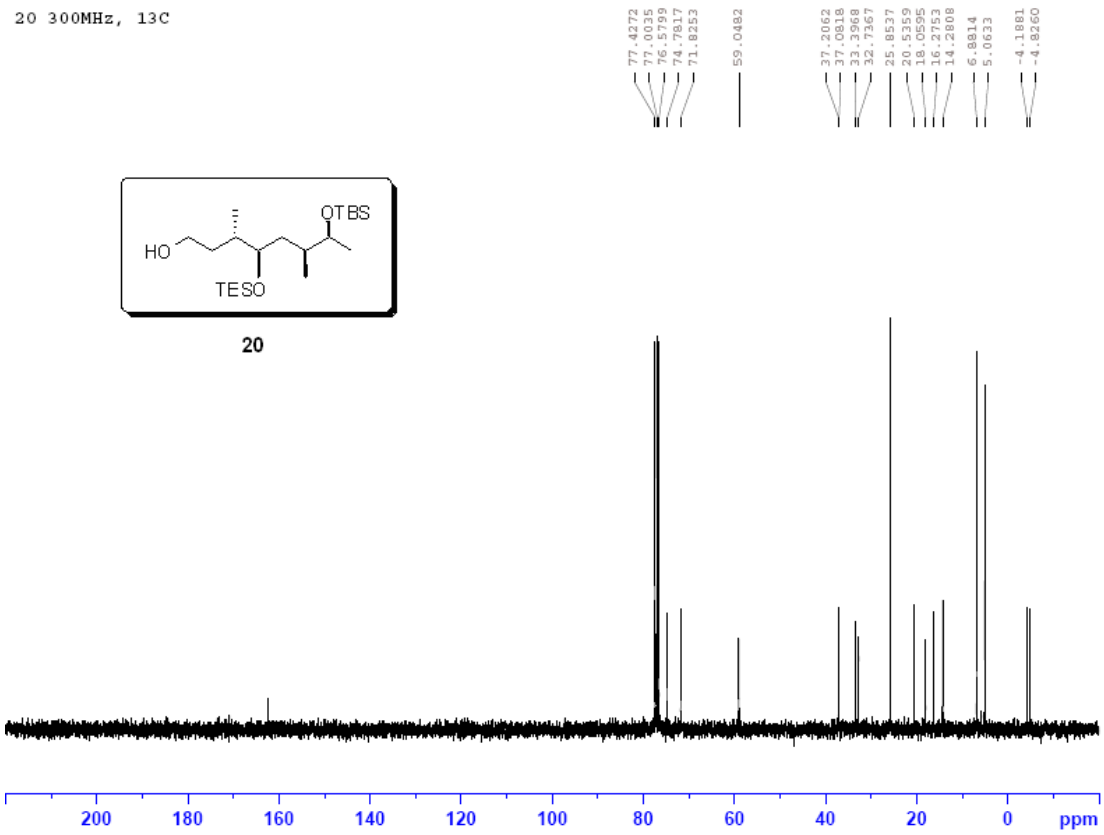

17 400MHz, 1H
9.7624
9.7573
7.2602
3.7982
3.7899
3.7827
3.7744
3.6639
2.6054
2.5836
2.5786
2.5580
2.5526
2.5362
2.5309
2.2190
2.2144
2.1998
2.1955
2.1890
2.1814
2.1731
2.1680
1.0636
1.0479
0.9091
0.8928
0.8749
0.0496
0.0413
0.0293
-0.0024
OTBS
H
O
17
9
8
7
6
5
4
3
2
1
ppm
0.95
1.01
1.00
1.86
3.29
14.12
6.34

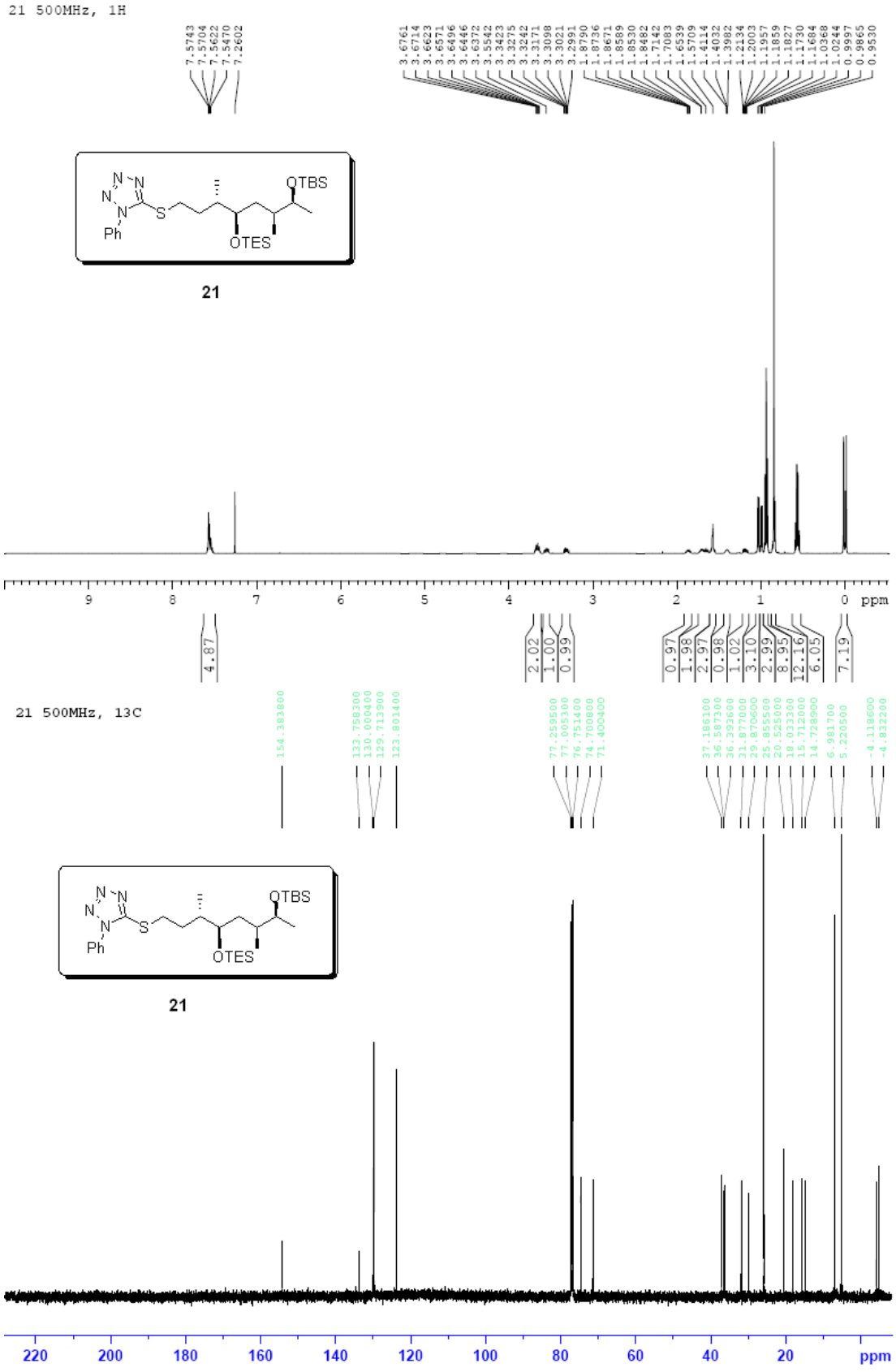

18 400MHz, 1H
OTBS
OH
18
9
8
7
6
5
4
3
2
1
ppm
18 400MHz, 13C
115.630800
116.0
115.5
ppm
220
200
180
160
140
120
100
80
60
40
20
ppm

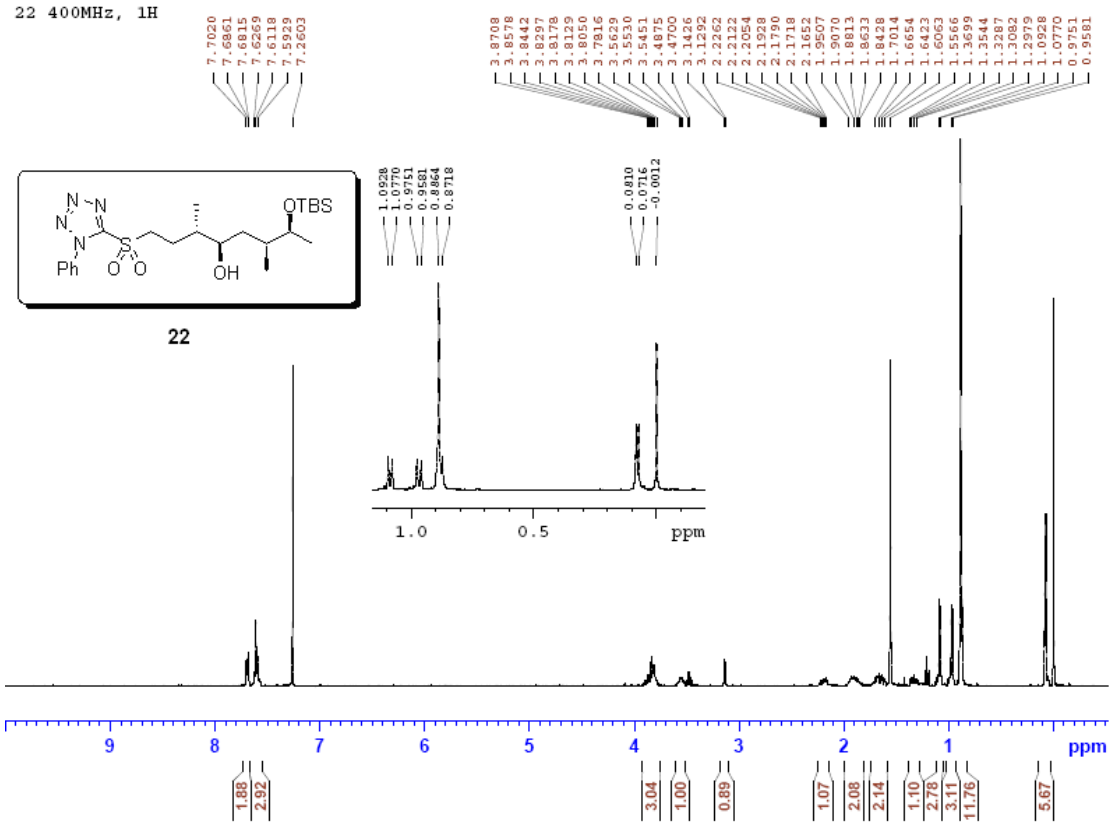

19 300MHz, 1H
OTBS
TESO
19
ppm

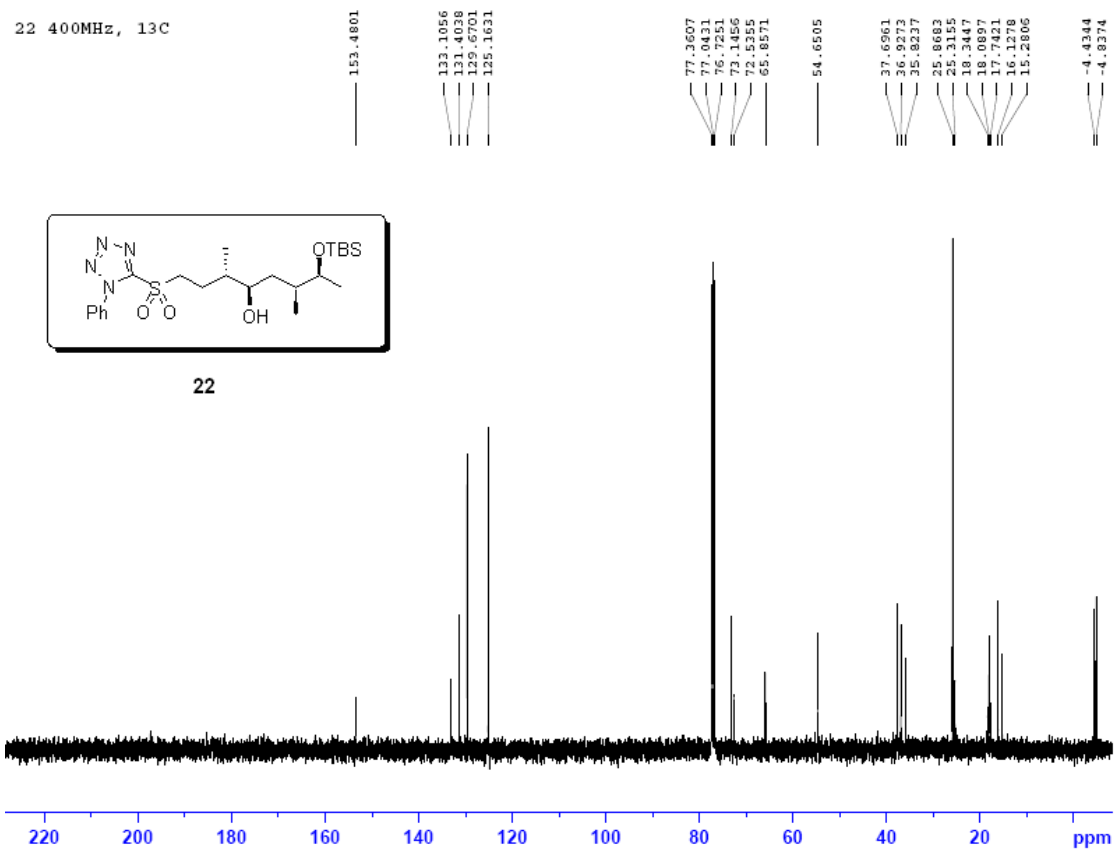

19 400MHz, 13C
OTBS
TESO
19
ppm


20 400MHz, 1H
7.2597
3.7119
3.6899
3.6681
3.6582
3.6434
3.5291
3.0645
1.7601
1.7506
1.7375
1.7169
1.7029
1.5316
1.5187
1.4162
1.3856
1.2904
1.2772
1.2510
1.0746
1.0591
0.9848
0.9638
0.9439
0.8769
0.8484
0.8317
0.6450
0.6254
0.6056
0.5859
0.0345
0.0233
0.2
0.0
ppm
HO
OTBS
TESO
20
9
8
7
6
5
4
3
2
1
ppm
2.94
1.00
0.83
3.34
1.31
1.15
2.85
3.15
12.34
13.21
6.09
5.96


20 300MHz, 13C
77.4272
77.0035
76.5799
74.7817
71.8253
59.0482
37.2062
37.0818
33.3968
32.7367
25.8537
20.5359
18.0595
16.2753
14.2808
6.8814
5.0633
-4.1881
-4.8260
HO
OTBS
TESO
20
200
180
160
140
120
100
80
60
40
20
0
ppm


21 500MHz, 1H
7.5743
7.5704
7.5622
7.5470
7.2602
3.6761
3.6714
3.6623
3.6571
3.6496
3.6446
3.6372
3.5542
3.3423
3.3275
3.3242
3.3171
3.3098
3.3021
3.2991
1.8790
1.8736
1.8671
1.8589
1.8530
1.8482
1.7142
1.7083
1.6539
1.5709
1.4114
1.4032
1.3982
1.2134
1.2003
1.1957
1.1859
1.1827
1.1730
1.1684
1.1368
1.0244
0.9997
0.9865
0.9530
OTBS
OTES
Ph
N
S
21
9
8
7
6
5
4
3
2
1
0
ppm
4.87
2.02
1.00
0.99
0.97
1.98
2.97
0.98
1.02
3.10
2.99
8.95
12.16
6.05
7.19
21 500MHz, 13C
154.383800
133.758300
130.000400
129.713900
123.801400
77.259500
77.005300
76.751400
74.700800
71.400400
37.186100
36.587300
36.393600
31.877000
29.870600
25.855500
20.525000
18.033300
15.712200
14.728900
6.981700
5.220500
-4.118600
-4.832200
OTBS
OTES
Ph
N
S
21
220
200
180
160
140
120
100
80
60
40
20
ppm


22 400MHz, 1H
22
ppm


22 400MHz, 13C
22
ppm