Supporting Information

Ruthenium Catalyzed Diastereo- and Enantioselective Coupling of Propargyl Ethers with Alcohols: Siloxy-Crotylation *via* Hydride Shift Enabled Conversion of Alkynes to π-Allyls

Tao Liang, Wandi Zhang, Te-Yu Chen, Khoa D. Nguyen and Michael J. Krische*****

University of Texas at Austin, Department of Chemistry,
Austin, TX 78712, USA

Table of Contents:

I. General Information:

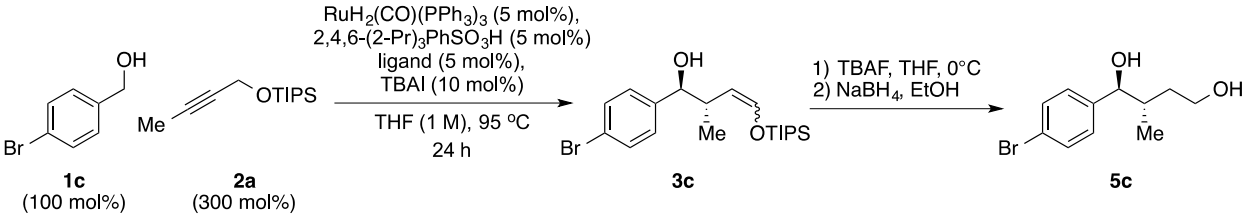
All reactions were run under an atmosphere of argon, unless otherwise indicated. Resealable pressure tubes (13x100 mm) were purchased from Fischer Scientific (catalog number 14–959–35C) and were flame dried followed by cooling in a desiccator or under a stream of argon prior to use. Tetrahydrofuran (THF) was dried over sodium metal, benzophenone, and distilled immediately prior to use. $RuH_2(CO)(PPh_3)_3$ and all ligands were used as received from Strem Chemicals Inc. Alcohols were purified by distillation or recrystallization immediately prior to use. Preparative column chromatography was employing Silicycle silica gel (40-63 μm). Analytical thin-layer chromatography (TLC) was carried out using 0.25 mm commercial silica gel plates (Dynamic Absorbents F_{254}). Visualization was accomplished with UV light followed by dipping in Seebach's stain solution then heating. Purification of reactions was carried out by flash chromatography using Silicycle silica gel (40–63 μm). Specific optical rotations were recorded on an Atago AP-300 automatic polarimeter at the sodium line (589.3 nm) in $CHCl_3$. Solution concentrations are given in the units of 10^{-2} g mL^{-1}.

II. Spectroscopy, Spectrometry, and Data Collection:

Infrared spectra were recorded on a Perkin-Elmer 1600 spectrometer. Low-resolution mass spectra (LRMS) were obtained on a Karatos MS9 and are reported as m/z (relative intensity). Accurate masses are reported for the molecular ion (M+H, M+Na), or a suitable fragment ion. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded with a Varian Gemini (400 MHz) spectrometer. Chemical shifts are reported in delta (δ) units, parts per million (ppm) downfield from tetramethylsilane or ppm relative to the center of the singlet at 7.26 ppm for deuteriochloroform. Data reported as multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet). Integration and coupling constants were reported in Hertz (Hz). Carbon-13 nuclear magnetic resonance (^{13}C NMR) spectra were recorded with a Varian Gemini (100 MHz) spectrometer and were routinely run with broadband decoupling. Chemical shifts are reported in delta (δ) units, ppm relative to the center of the triplet at 77.16 ppm for deuteriochloroform.

III. Experimental Details and Spectral Data

A. Key optimization experiments



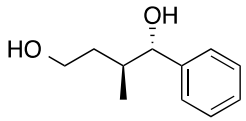
Entry	Ligand	**3c** Z:E	Z ee %, E ee %	**5c** Yield **%**	**5c** ee %
1	dppf	1.3:1		29	-
2	(*R*)-BINAP	2:1		17	93
3	(*R*)-SEGPHOS	2:1		13	96
4	SL-J009-1	3:1	87, 94	70	88
5	SL-J002-1	2.3:1		49	77
6	SL-J003-1	3:1		90	66
7[a,b]	SL-J009-1	3:1	90, 96	77	92
8[a,c]	SL-J009-1	3:1		72	90

[a]7.5 mol% 2,4,6-(2-Pr)$_3$PhSO$_3$H. [b]85°C. [c]75°C.

B. General Procedure for the Couplings of Alcohols 2a-2o and Alkyne 1a-1c

To a resealable pressure tube (ca. 13 x 100) was added $H_2Ru(CO)(PPh_3)_3$ (9.2 mg, 0.010 mmol, 5 mol%), SL-J009-1 ligand (5.6 mg, 0.010 mmol, 5 mol%), Bu_4NI (7.4 mg, 0.020 mmol, 10 mol%) and 2,4,6-tri(2-propyl)phenylsulfonic acid (4.2 mg, 0.015 mmol, 7.5 mol%). At this stage solid alcohol coupling partners (0.20 mmol, 100 mol%) were added. The tube was then sealed with a rubber septum and purged with argon. THF (0.20 mL, 1 M concentration with respect to alcohols) was then added. At this stage, liquid alcohol coupling partners (0.20 mmol, 100 mol%) were added. 2-propylalcohol (31 µL, 0.40 mmol, 200 mol%) was then added. Alkyne 1a (0.60 mmol, 300 mol%) was added *via* syringe and the rubber septum was quickly replaced with a screw cap. The mixture was then heated at 85 °C for the time stated. After cooling to room temperature, the mixture was passed through a short silica pad, washed the pad with EA, and concentrated *in vacuo*. The residue was dissolved in THF (2.0 mL) and TBAF (1.0 M in THF, 0.2 mL) was added at 0ºC. The mixture was stirred at r.t for 30 min, then $NaBH_4$ (14.8 mg, 0.4 mmol), EtOH (1.0 mL) were added. After 1 h, the reaction was quenched by NH_4Cl (aq), and extracted by EA. Organic layer was washed by water, brine, dried over Na_2SO_4, and concentrated *in vacuo*. The residue was subjected to flash column chromatography (SiO_2, eluent Hexanes:EA = 2:1) to afford the corresponding crotylation products.

(1*S*,2*S*)-2-methyl-1-phenylbutane-1,4-diol (5a).



The residue was subjected to flash column chromatography for purification to furnish the title compound (37.8 mg, 70%, *dr* = >20:1) as a white solid.

R_f=0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38 – 7.24 (m, 5H), 4.41 (d, J = 7.6 Hz, 1H), 3.83 – 3.74 (m, 1H), 3.71 – 3.61 (m, 1H), 2.68 (m, 2H), 2.00 (d, J = 6.0 Hz, 1H), 1.86 – 1.75 (m, 1H), 1.67 – 1.55 (m, 1H), 0.78 (d, J = 6.9 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 143.75, 128.46, 127.70, 126.79, 79.40, 61.10, 38.54, 36.34, 17.48.

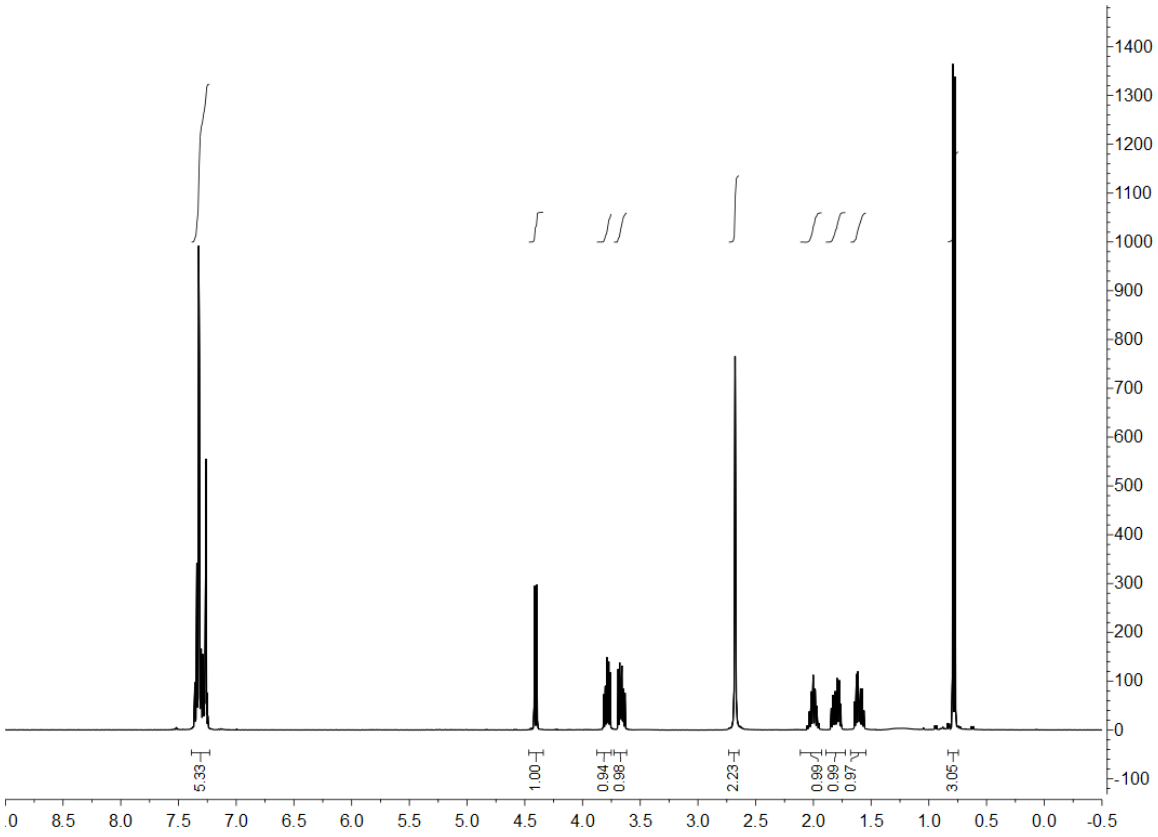
LRMS (CI) Calcd. for $C_{11}H_{16}NaO_2$ $[M+Na]^+$: 203, Found: 203.

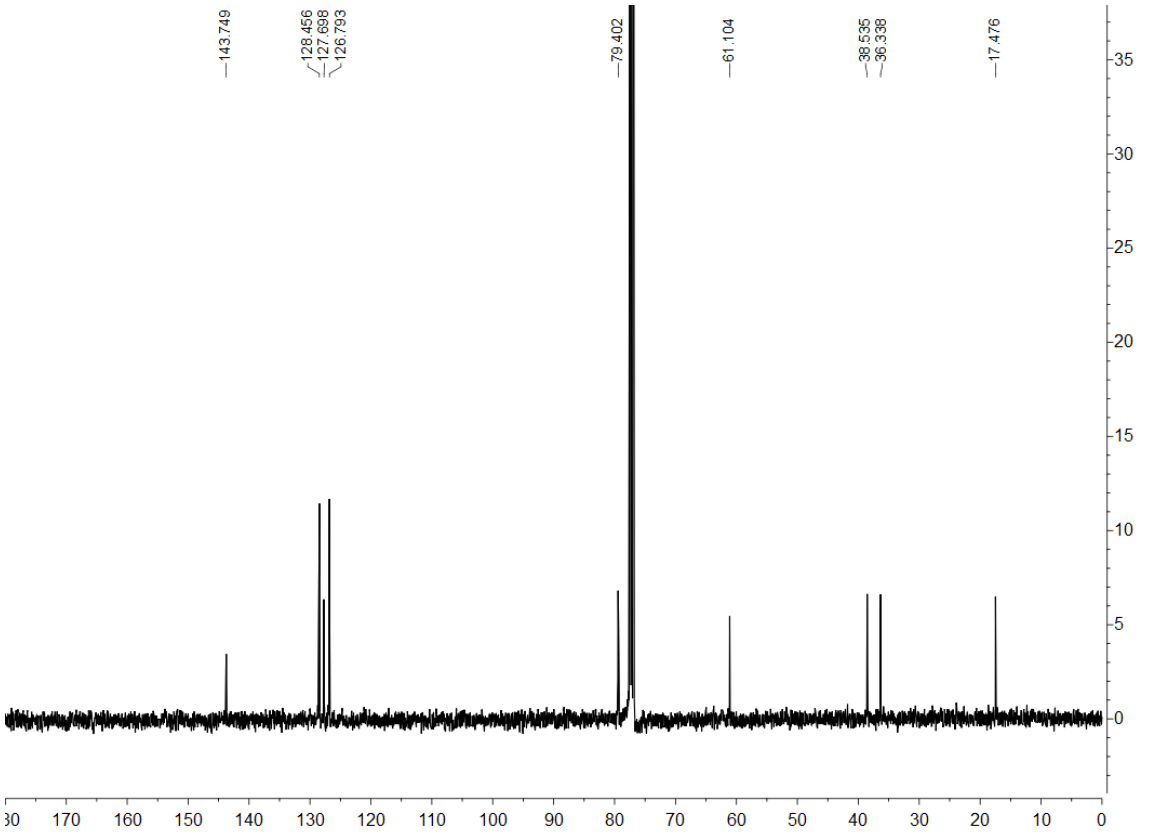
FTIR (neat): 3355, 3288, 2874, 1456, 1052, 1021, 1000, 768, 700 cm^{-1}.

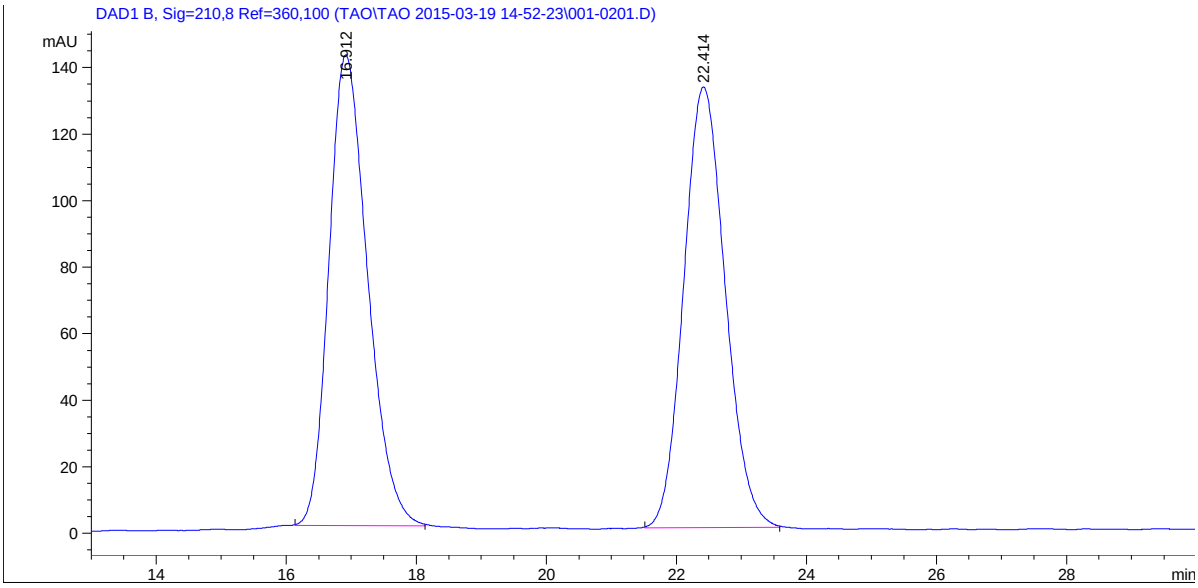
HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 91%.

$[\alpha]^{25}_D$ = - 41.3 (c = 0.75, $CHCl_3$)

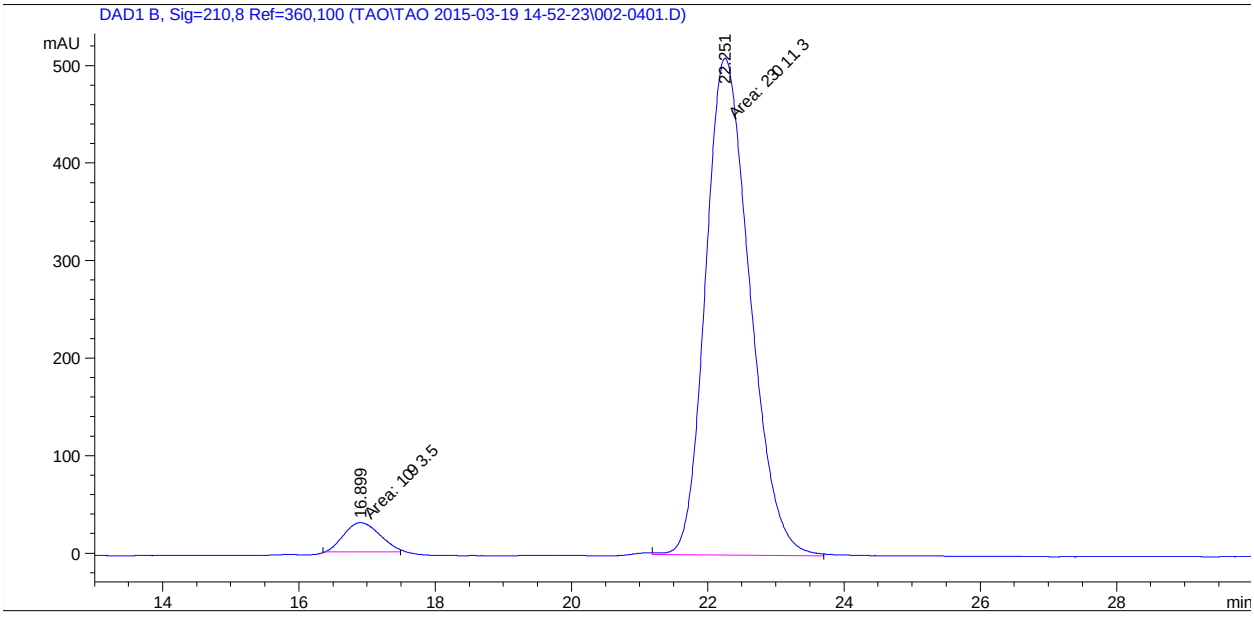
M.P. 91.3-92.3 °C


5.33
1.00
0.94
0.98
2.23
0.99
0.99
0.97
3.05


143.749
128.456
127.698
126.793
79.402
61.104
38.535
36.338
17.476

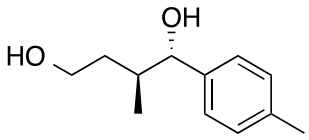


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.912	BB	0.6339	5844.65186	141.50946	49.8516
2	22.414	BB	0.6877	5879.45801	132.49396	50.1484



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.899	MM	0.6081	1093.50195	29.96907	4.5364
2	22.251	MM	0.7528	2.30113e4	509.44580	95.4636

(1*S*,2*S*)-2-methyl-1-(*p*-tolyl)butane-1,4-diol (5b).



The residue was subjected to flash column chromatography for purification to furnish the title compound (24.8mg, 64%, *dr* = >20:1) as a white solid.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.21 (d, J = 8.1 Hz, 2H), 7.15 (d, J = 7.9 Hz, 2H), 4.39 (d, J = 7.6 Hz, 1H), 3.86 – 3.76 (m, 1H), 3.74 – 3.61 (m, 1H), 2.34 (s, 3H), 2.26 (s, 2H), 1.99 (d, J = 6.4 Hz, 1H), 1.88 – 1.76 (m, 1H), 1.67 – 1.55 (m, 1H), 0.78 (d, J = 7.0 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 140.77, 137.42, 129.18, 126.71, 79.34, 61.27, 38.43, 36.52, 21.26, 17.49.

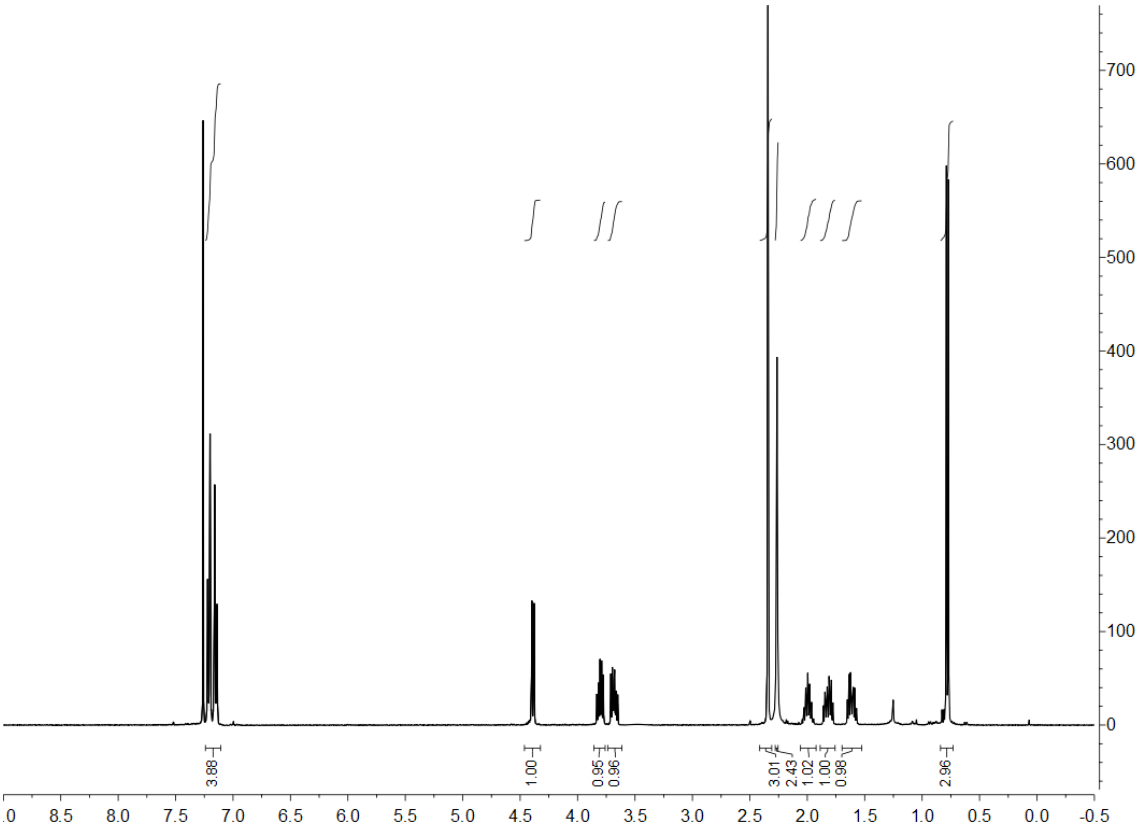
LRMS (CI) Calcd. for $C_{12}H_{18}NaO_2$ $[M+Na]^+$: 217, Found: 217.

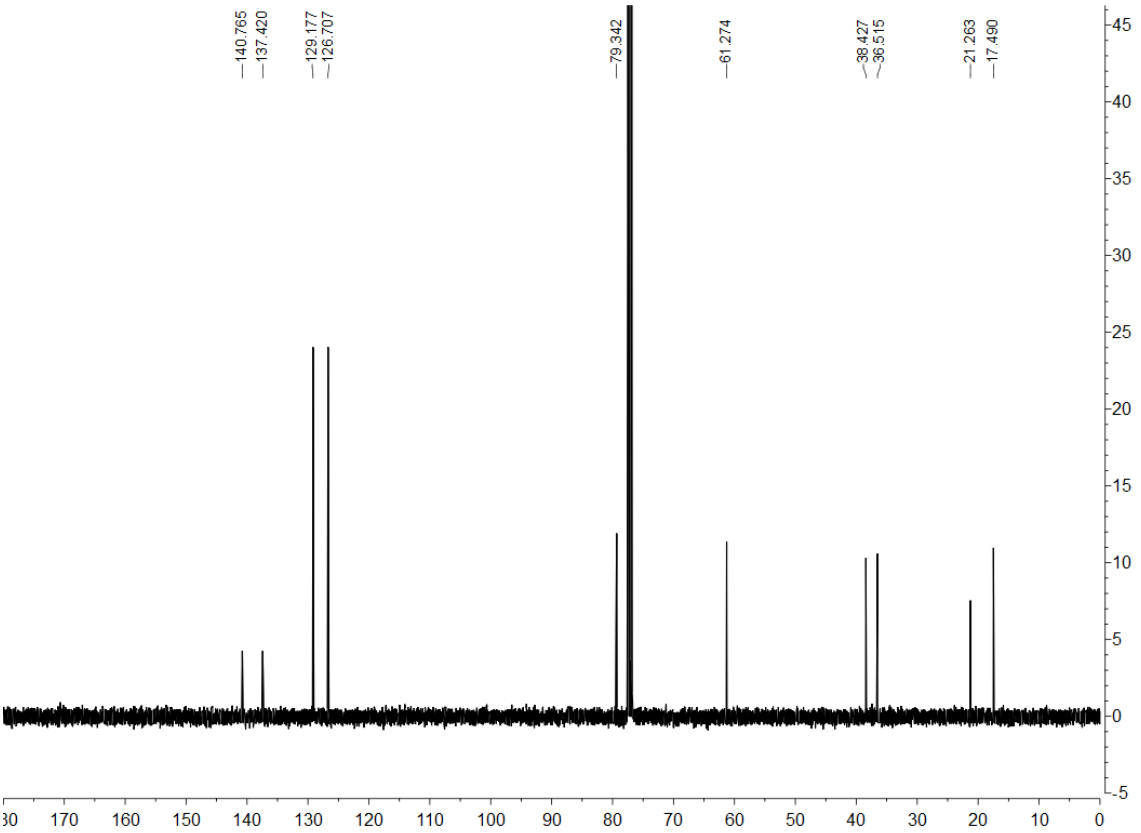
FTIR (neat): 3314, 3016, 2970, 1739, 1365, 1229, 1217cm^{-1}.

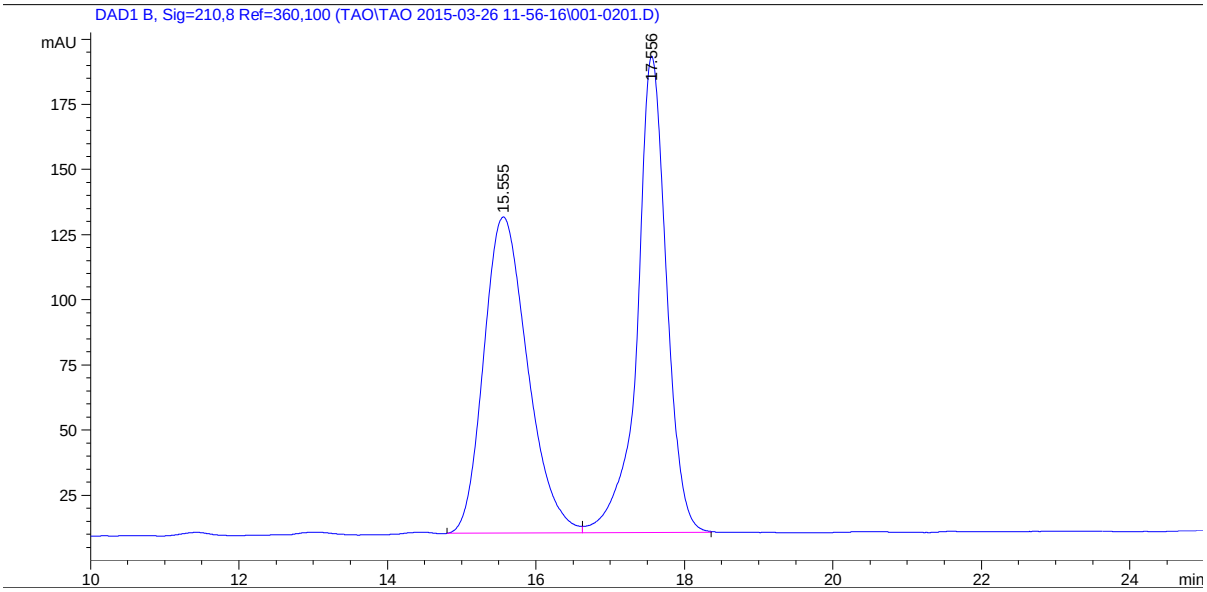
HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 93%.

$[\alpha]^{25}_D$ = - 51.8 (c = 0.65, $CHCl_3$)

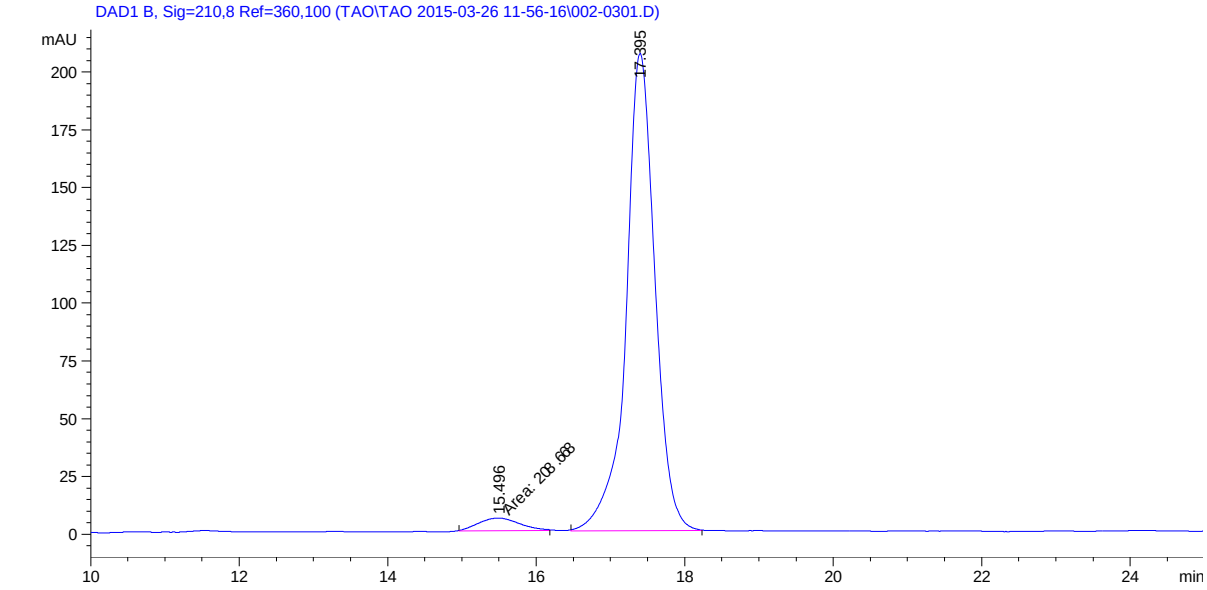
M.P. 117-118.6 °C


3.88
1.00
0.95
0.96
3.01
2.43
1.02
1.00
0.98
2.96


140.765
137.420
129.177
126.707
79.342
61.274
38.427
36.515
21.263
17.490

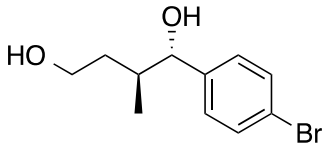


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.555	BV	0.6318	4969.22900	121.32995	49.7294
2	17.556	VB	0.4167	5023.30176	182.76692	50.2706



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.496	MM	0.6357	208.66779	5.47067	3.5911
2	17.395	BB	0.4124	5601.99072	206.54958	96.4089

(1*S*,2*S*)-1-(4-bromophenyl)-2-methylbutane-1,4-diol (5c).



The residue was subjected to flash column chromatography for purification to furnish the title compound (39.8 mg, 76%, *dr* = >20:1) as a white solid.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, Methanol-d_4): δ 7.47 (d, J = 8.5 Hz, 2H), 7.25 (d, J = 8.2 Hz, 2H), 4.40 (d, J = 6.5 Hz, 1H), 3.69 – 3.61 (m, 1H), 3.59 – 3.51 (m, 1H), 1.97 – 1.78 (m, 2H), 1.39 – 1.26 (m, 1H), 0.81 (d, J = 6.8 Hz, 3H).

^{13}C NMR (100 MHz, Methanol-d_4): δ 144.57, 132.02, 129.74, 121.62, 78.81, 61.13, 38.41, 36.07, 16.54.

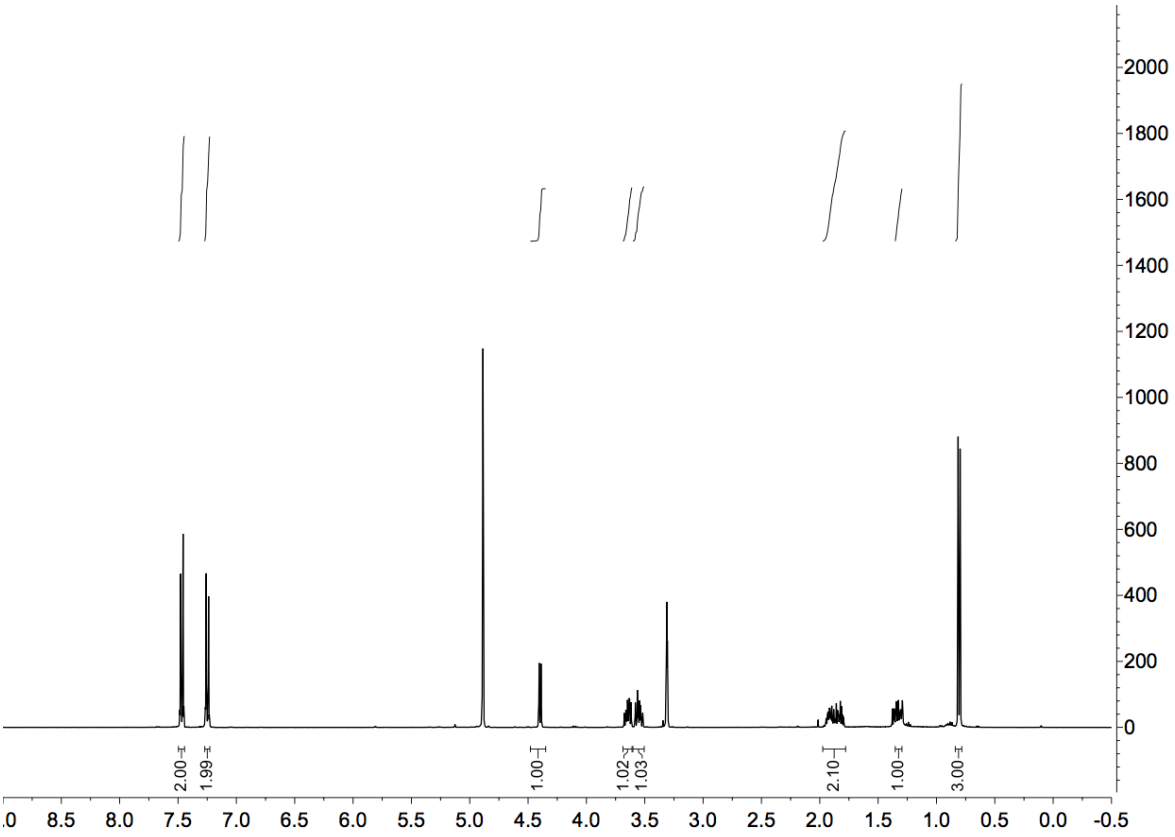
LRMS (CI) Calcd. for $C_{11}H_{15}BrNaO_2$ $[M+Na]^+$: 281, Found: 281.

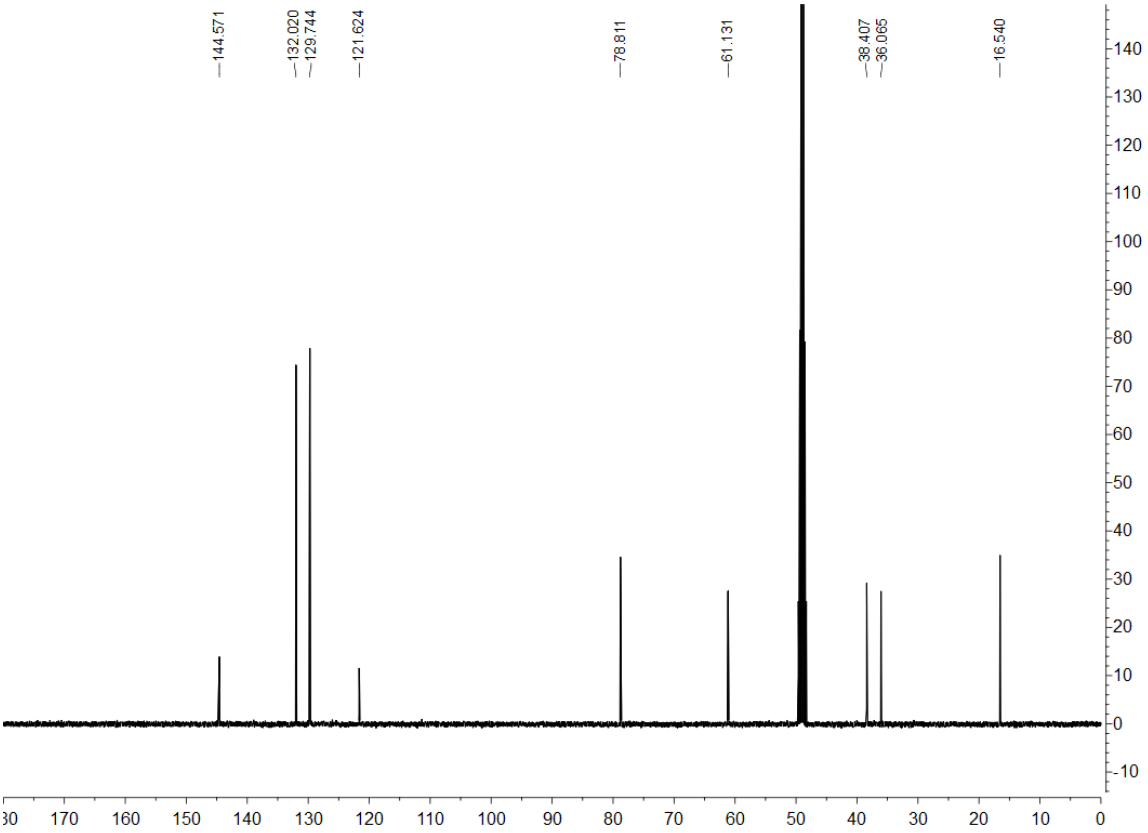
FTIR (neat): 2959, 2929, 2856, 1484, 1050, 1011, 825 cm^{-1}.

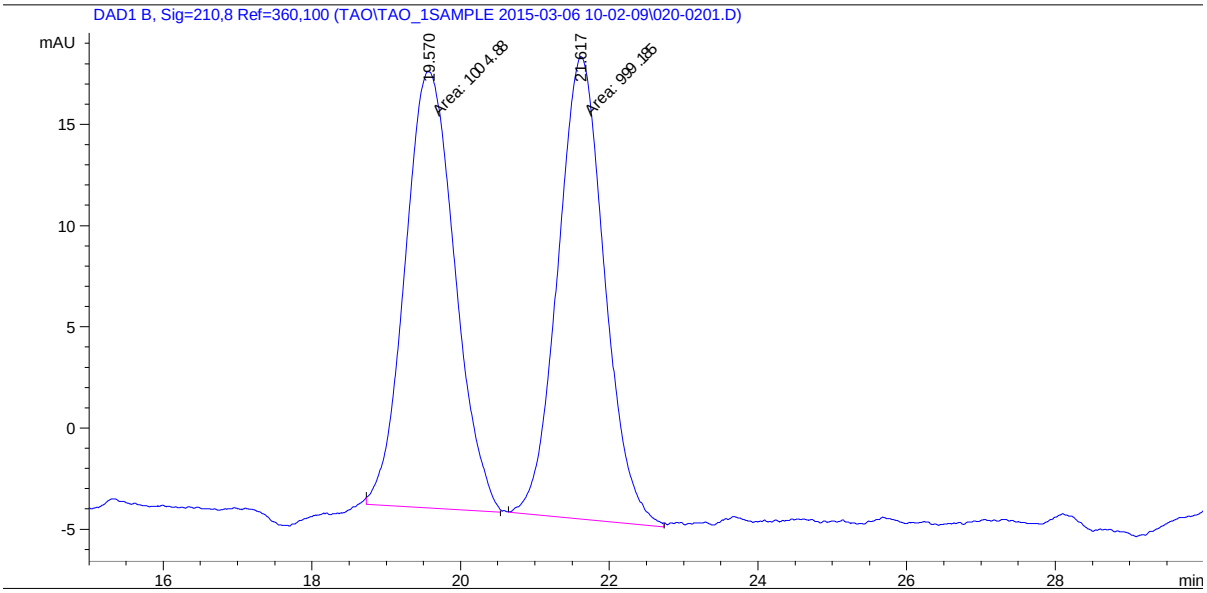
HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 92%.

$[\alpha]^{25}_D$ = - 6.4 (c = 0.7, $CHCl_3$)

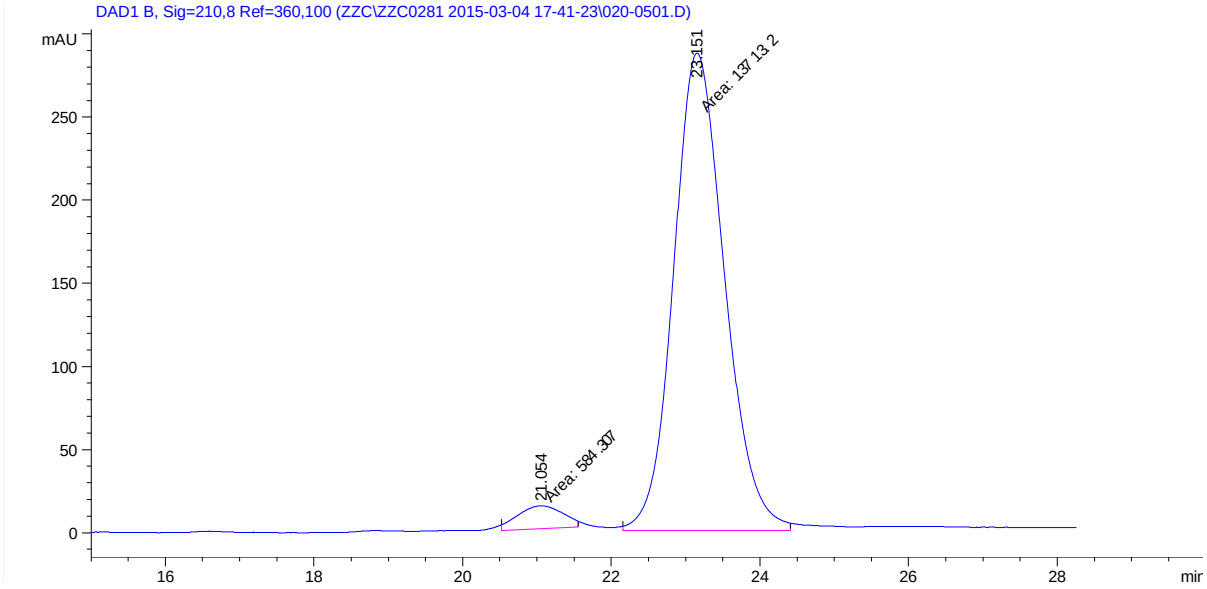
M.P. 146.1-147.4 °C


2.00
1.99
1.00
1.02
1.03
2.10
1.00
3.00


144.571
132.020
129.744
121.624
78.811
61.131
38.407
36.065
16.540

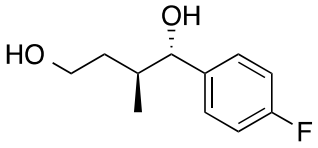


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.570	MM	0.7770	1004.88214	21.55487	50.1421
2	21.617	MM	0.7291	999.18536	22.84135	49.8579



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	21.054	MM	0.7062	584.30731	13.79014	4.0868
2	23.151	MM	0.7959	1.37132e4	287.16132	95.9132

(1*S*,2*S*)-1-(4-fluorophenyl)-2-methylbutane-1,4-diol (5d).



The residue was subjected to flash column chromatography for purification to furnish the title compound (27.7 mg, 75%, *dr* = >20:1) as a white solid.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32 – 7.26 (m, 2H), 7.06 – 6.99 (m, 2H), 4.41 (d, *J* = 7.5 Hz, 1H), 3.81 (ddd, *J* = 10.6, 6.3, 5.1 Hz, 1H), 3.68 (ddd, *J* = 10.7, 7.8, 4.8 Hz, 1H), 2.03 – 1.91 (m, 1H), 1.85 – 1.75 (m, 1H), 1.65 – 1.56 (m, 1H), 0.78 (d, *J* = 6.9 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 163.37, 160.93, 139.40, 139.37, 128.22, 128.14, 115.21, 115.00, 78.56, 60.91, 38.49, 36.03, 17.20.

^{19}F NMR (100 MHz, $CDCl_3$): δ -115.17.

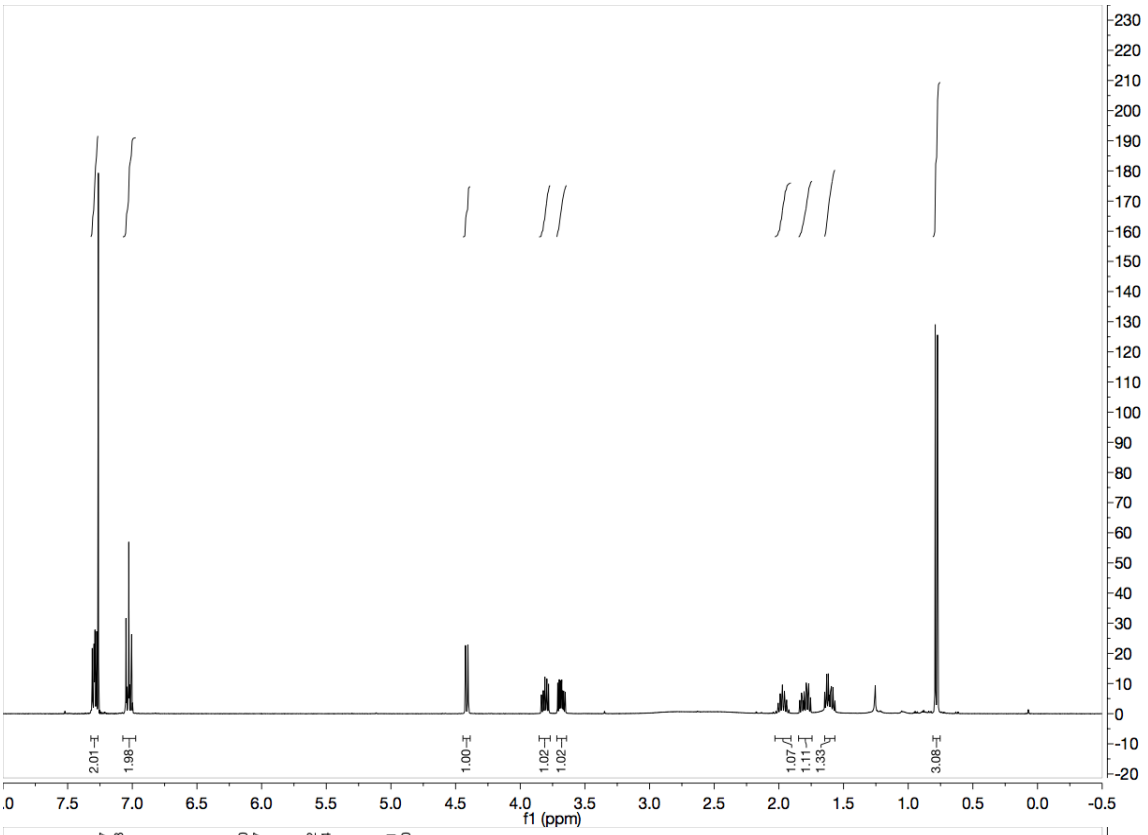
LRMS (CI) Calcd. for $C_{11}H_{15}FNaO_2$ $[M+Na]^+$: 221, Found: 221.

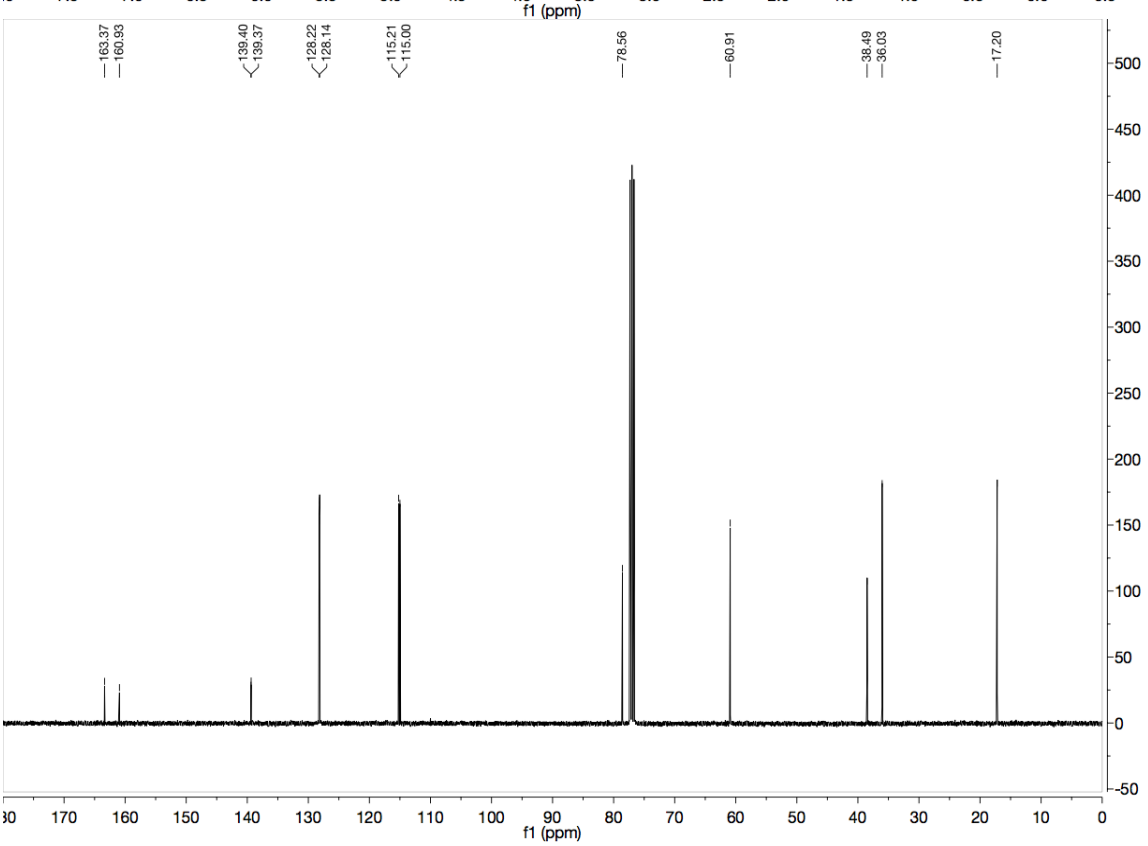
FTIR (neat): 3336, 1604, 1509, 1222, 1056, 1033, 1013, 836 cm^{-1}.

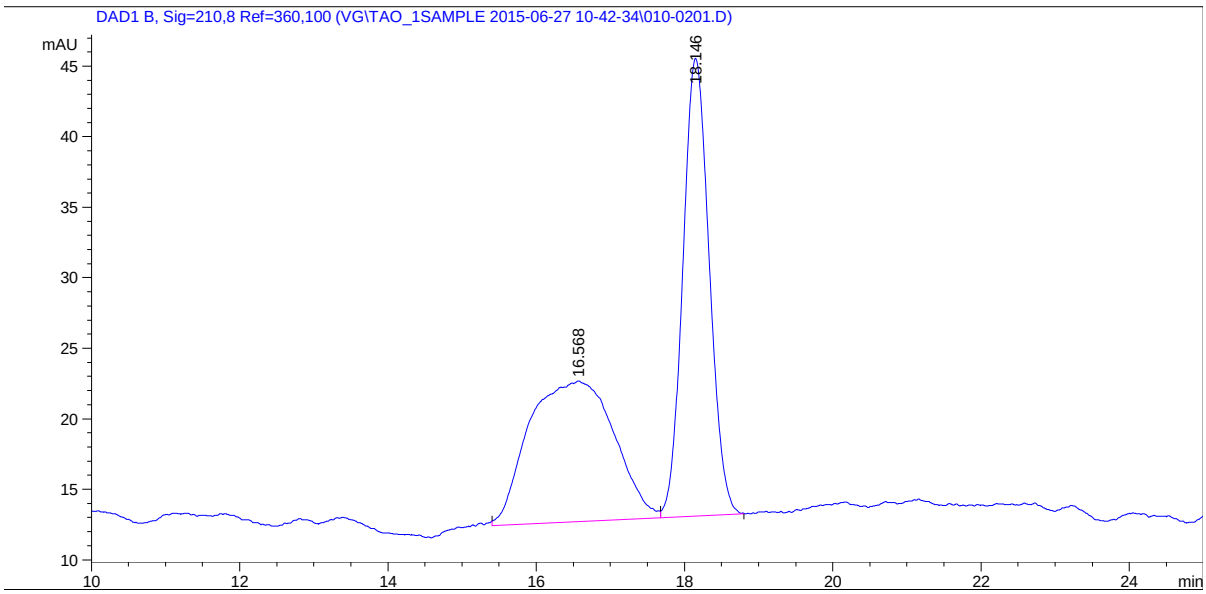
HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 92%.

$[\alpha]^{25}_D$ = + 10.0 (c = 0.32, $CHCl_3$)

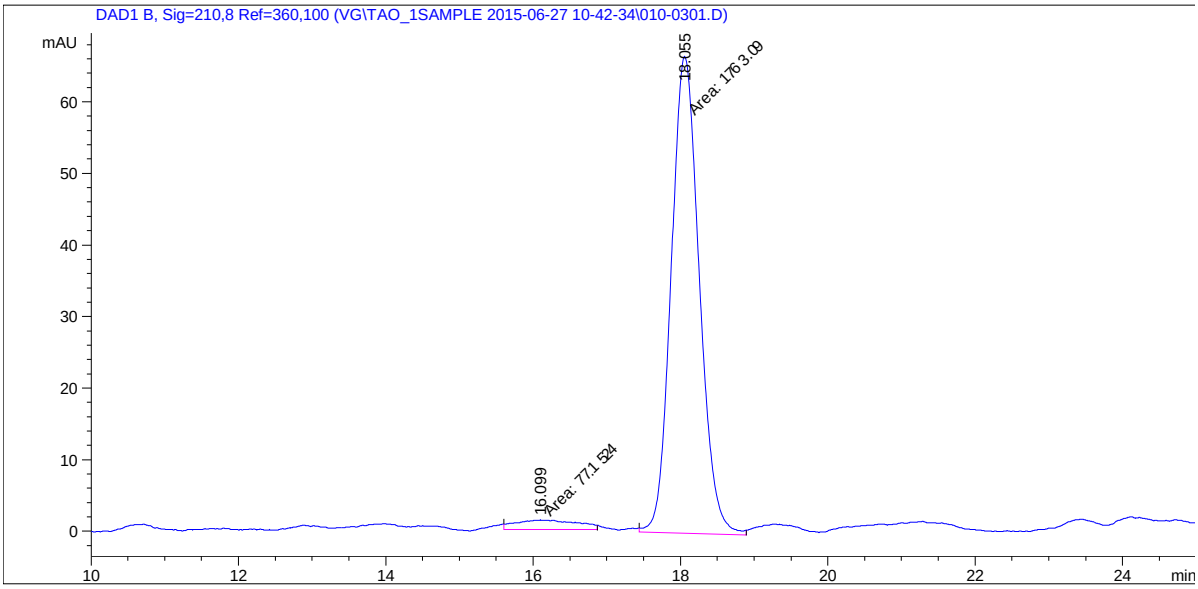
M.P. 114.7-115.9 °C


2.01
1.98
1.00
1.02
1.02
1.07
1.11
1.33
3.08
f1 (ppm)


163.37
160.93
139.40
139.37
128.22
128.14
115.21
115.00
78.56
60.91
38.49
36.03
17.20
f1 (ppm)

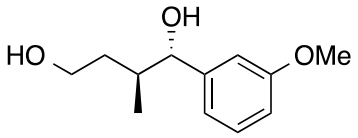


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.568	BV	0.9456	794.74628	9.95268	49.6548
2	18.146	VB	0.3818	805.79523	32.44131	50.3452



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.099	MM	0.9821	77.15244	1.30927	4.1925
2	18.055	MM	0.4412	1763.08777	66.59743	95.8075

(1*S*,2*S*)-1-(3-methoxyphenyl)-2-methylbutane-1,4-diol (5e).



The residue was subjected to flash column chromatography for purification to furnish the title compound (31.5 mg, 75%, *dr* = >20:1) as a colorless oil.

R_f= 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24 (t, *J* = 8.1 Hz, 1H), 6.90 – 6.86 (m, 2H), 6.83 – 6.78 (m, 1H), 4.35 (d, *J* = 7.6 Hz, 1H), 3.79 (s, 3H), 3.78 – 3.72 (m, 1H), 3.68 – 3.59 (m, 1H), 3.01 – 2.87 (m, 2H), 1.97 (p, *J* = 6.5 Hz, 1H), 1.83 – 1.72 (m, 1H), 1.65 – 1.53 (m, 1H), 0.78 (d, *J* = 6.9 Hz, 3H).

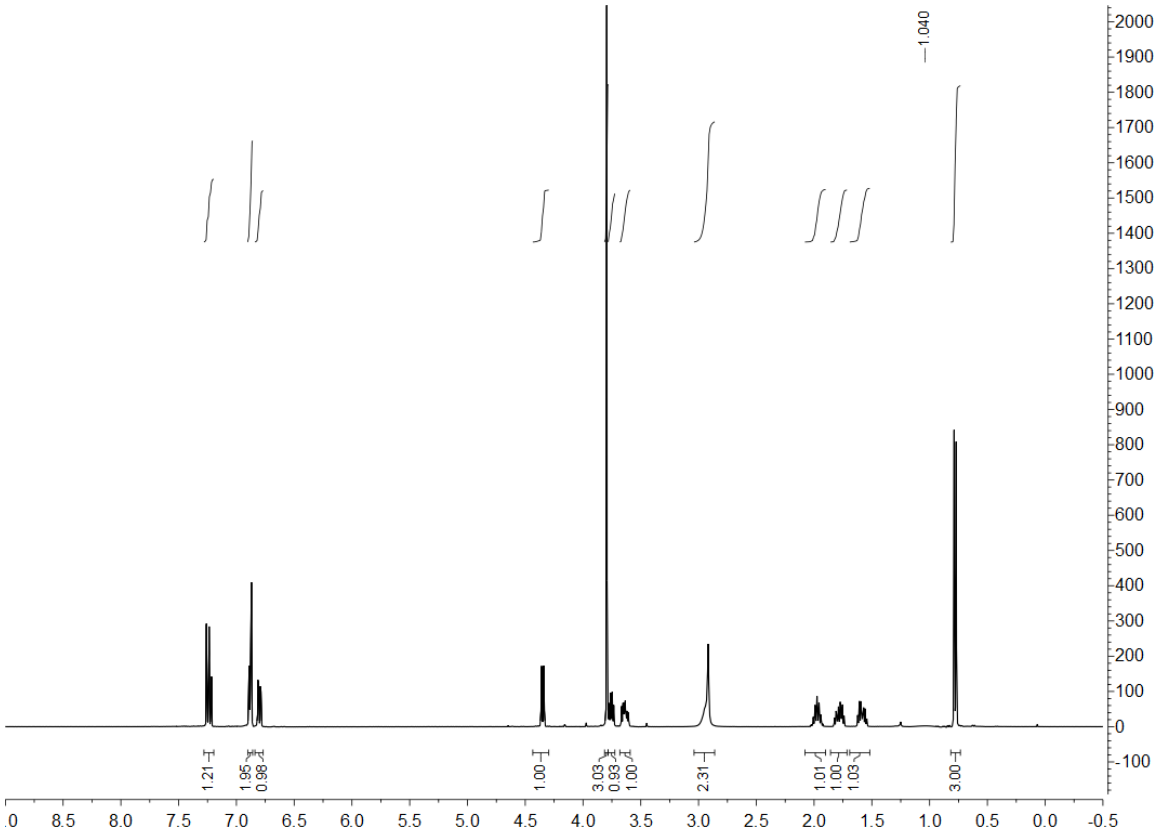
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.71, 145.53, 129.39, 119.23, 112.99, 112.30, 79.26, 60.99, 55.34, 38.50, 36.32, 17.50.

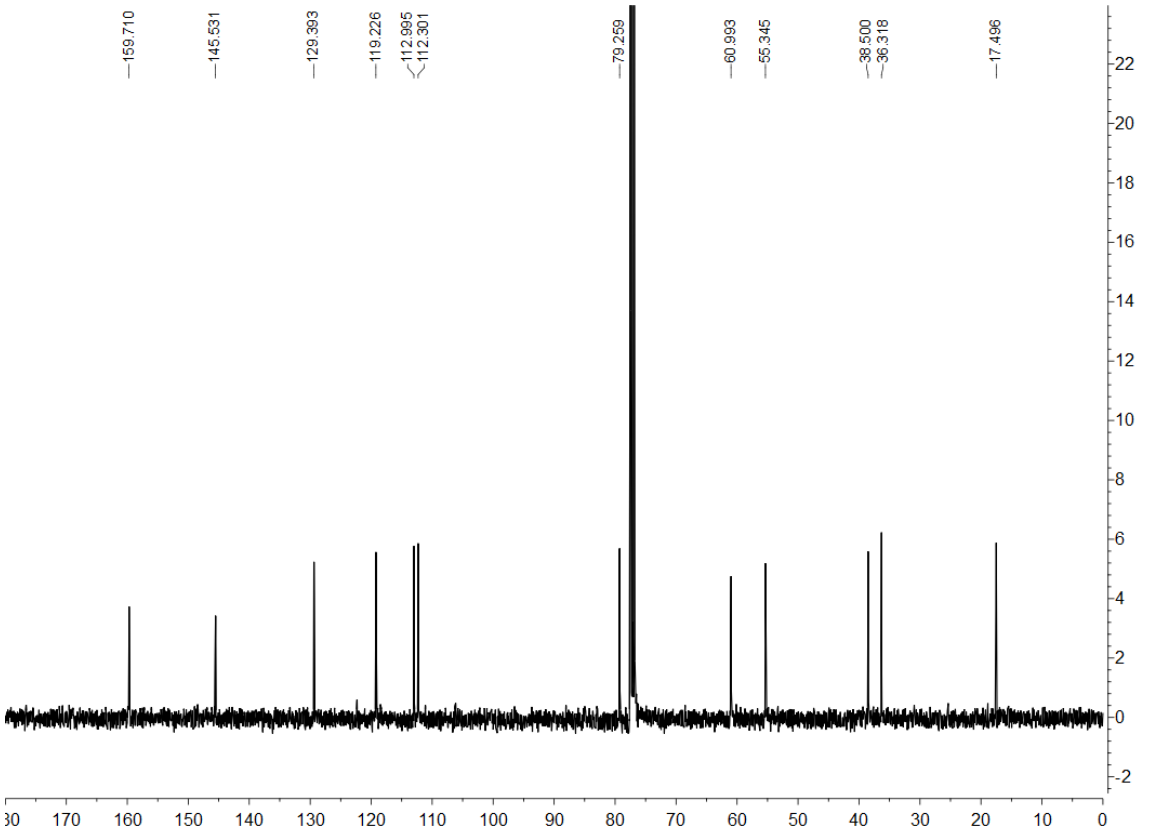
LRMS (CI) Calcd. for $C_{12}H_{18}NaO_3$ $[M+Na]^+$: 233, Found: 233.

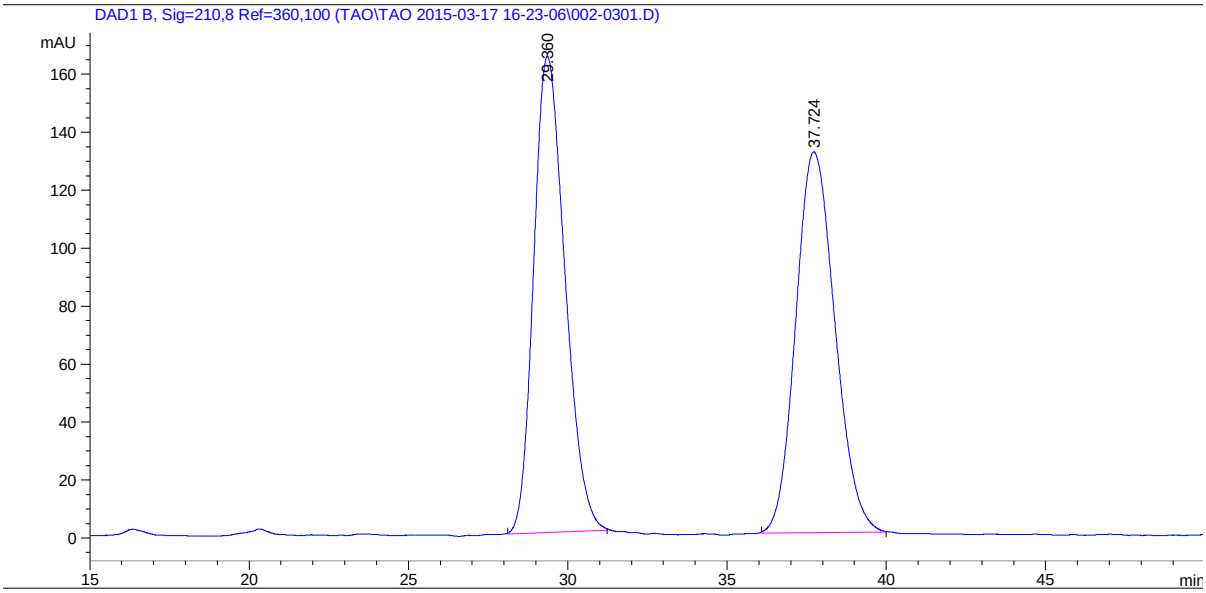
FTIR (neat): 3448, 3016, 2970,1739, 1435, 1366, 1229, 1216 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 92%.

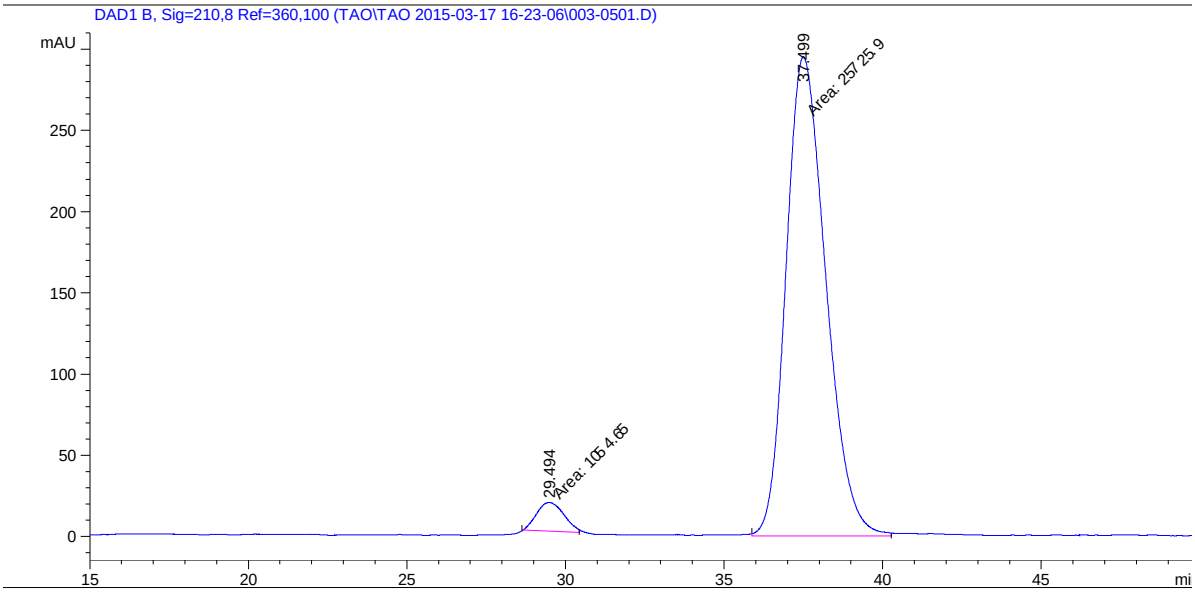
$[\alpha]^{25}_D$ = - 29.0 (c = 0.76, $CHCl_3$)


1.040
1.21
1.95
0.98
1.00
3.03
0.93
1.00
2.31
1.01
1.00
1.03
3.00


159.710
145.531
129.393
119.226
112.995
112.301
79.259
60.993
55.345
38.500
36.318
17.496

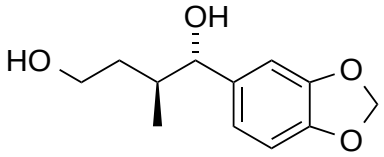


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.360	BB	1.0488	1.12134e4	164.18495	49.8926
2	37.724	BB	1.2898	1.12617e4	131.41185	50.1074



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.494	MM	0.9963	1054.65125	17.64229	3.9381
2	37.499	MM	1.4534	2.57259e4	295.01712	96.0619

(1*S*,2*S*)-1-(benzo[*d*][1,3]dioxol-5-yl)-2-methylbutane-1,4-diol (5f).



The residue was subjected to flash column chromatography for purification to furnish the title compound (23.7 mg, 63%, *dr* = >20:1) as a white solid.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 6.84 (s, 1H), 6.76 (d, *J* = 1.0 Hz, 2H), 5.95 (s, 2H), 4.32 (d, *J* = 7.8 Hz, 1H), 3.84 – 3.76 (m, 1H), 3.72 – 3.64 (m, 1H), 2.61 (s, 2H), 1.94 (hept, *J* = 6.7 Hz, 1H), 1.85 – 1.76 (m, 1H), 1.65 – 1.57 (m, 1H), 0.77 (d, *J* = 6.9 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 147.71, 146.90, 137.73, 120.11, 107.90, 106.88, 100.96, 79.17, 61.07, 38.48, 36.41, 17.38.

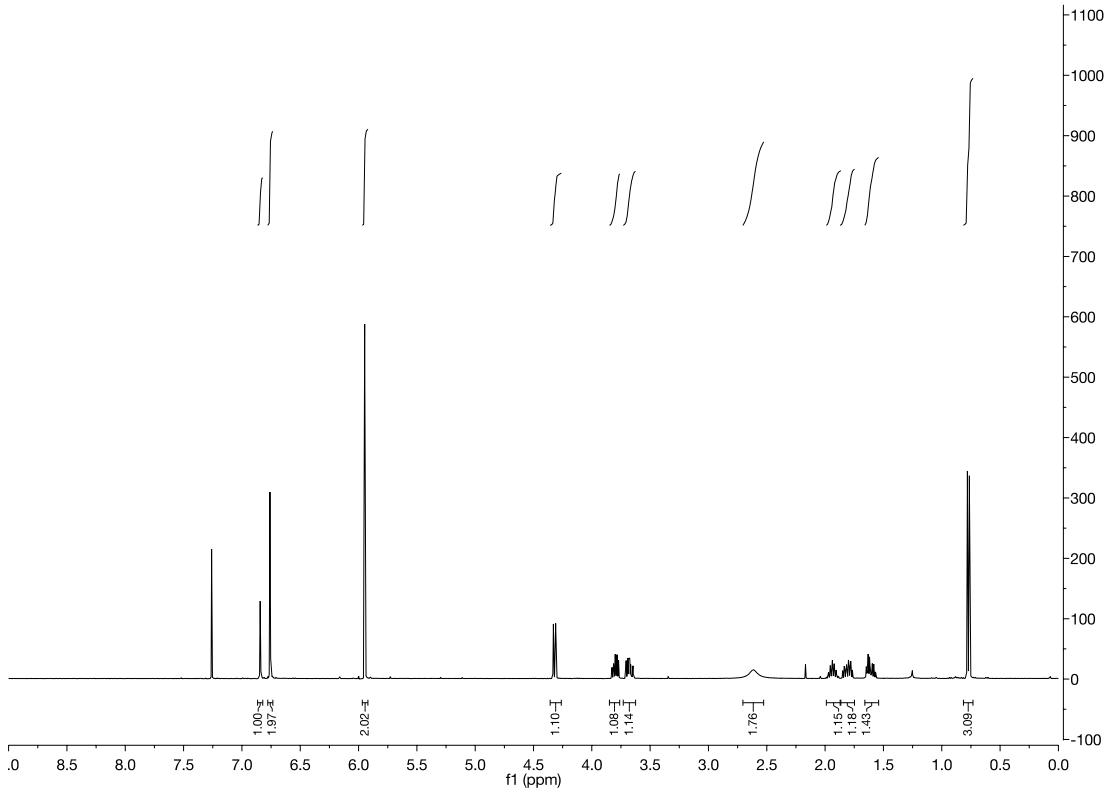
LRMS (CI) Calcd. for $C_{12}H_{16}NaO_4$ $[M+Na]^+$: 247, Found: 247.

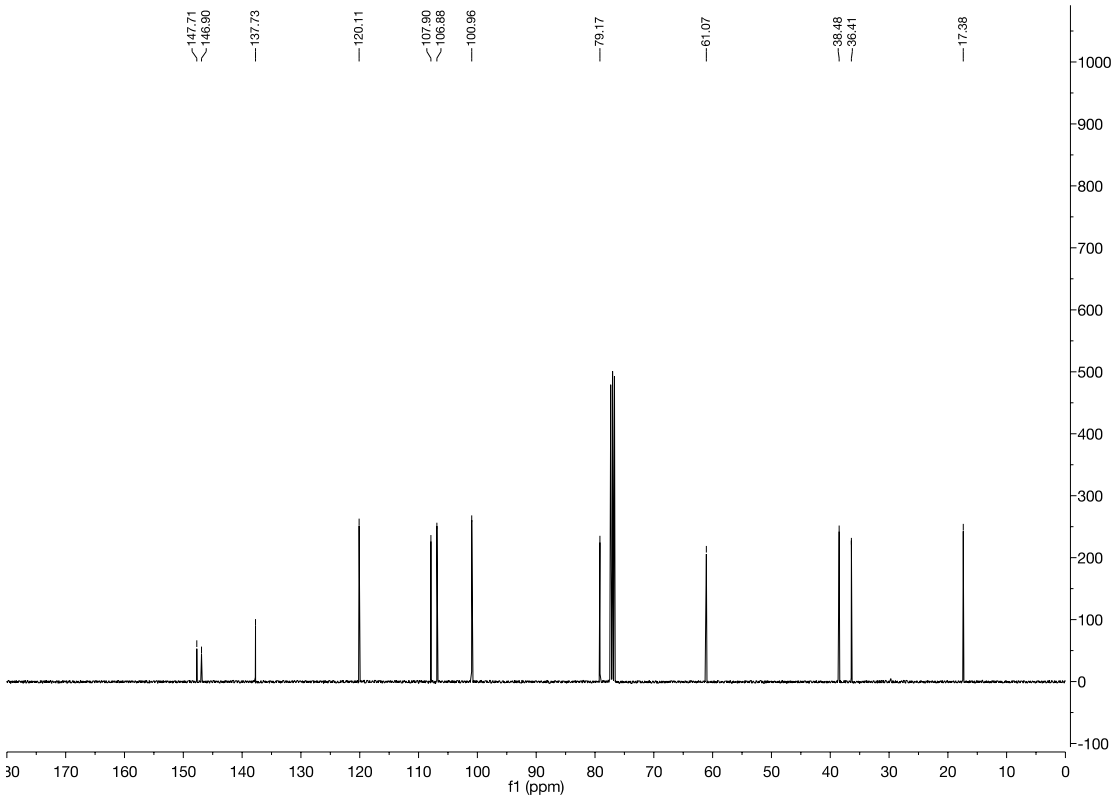
FTIR (neat): 3323, 2890, 1488,1246, 1037, 1006, 932, 823 cm^{-1}.

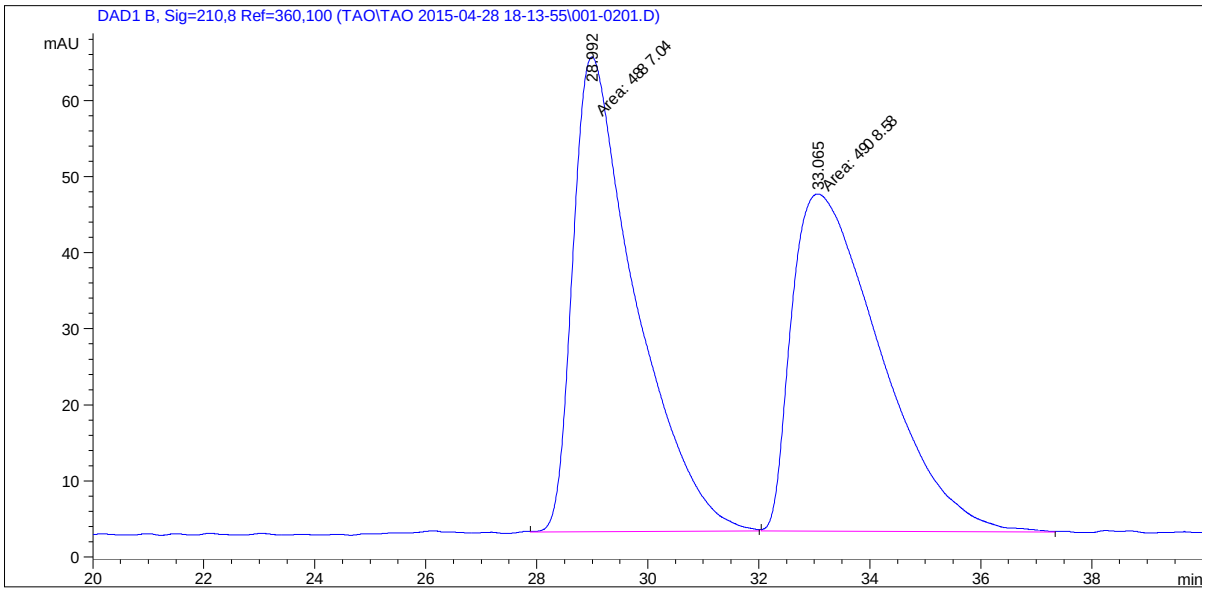
HPLC (Chiralcel AS-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 94%.

$[\alpha]^{25}_D$ = - 58.7 (c = 0.48, $CHCl_3$)

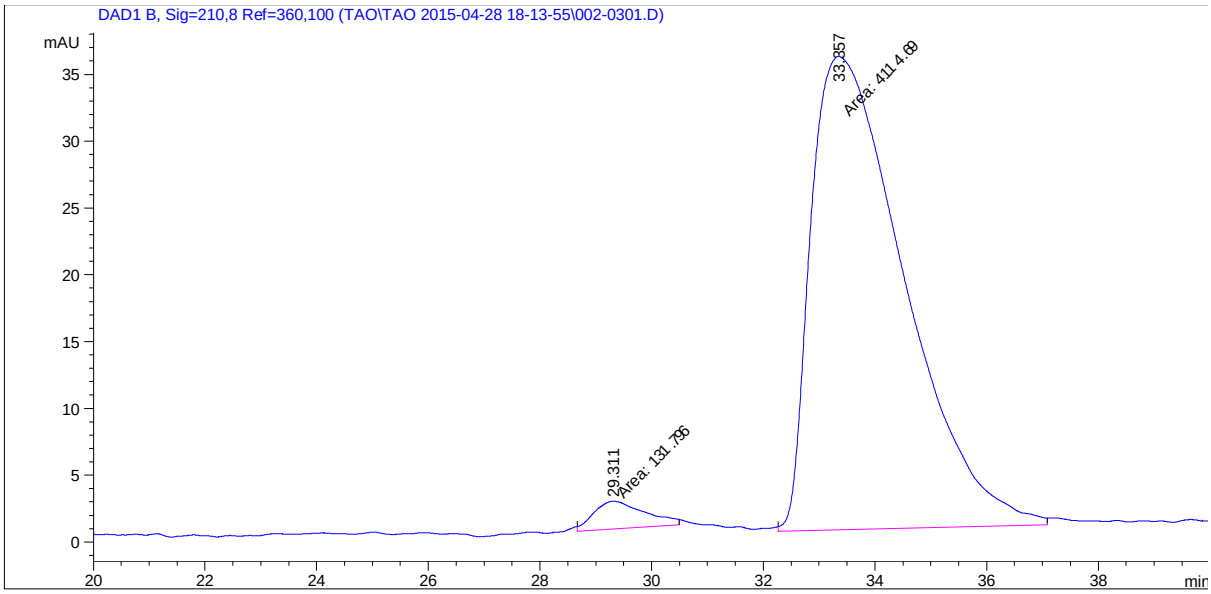
M.P. 97.3-98.6 °C


1.00
1.97
2.02
1.10
1.08
1.14
1.76
1.15
1.18
1.43
3.09
f1 (ppm)


147.71
146.90
137.73
120.11
107.90
106.88
100.96
79.17
61.07
38.48
38.41
17.38
f1 (ppm)

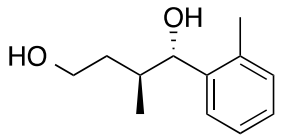


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	28.992	MM	1.3066	4887.03564	62.33603	49.8900
2	33.065	MM	1.8481	4908.57764	44.26786	50.1100



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.311	MM	1.0546	131.79645	2.08292	3.1037
2	33.357	MM	1.9357	4114.68604	35.42754	96.8963

(1*S*,2*S*)-2-methyl-1-(o-tolyl)butane-1,4-diol (5g)



The residue was subjected to flash column chromatography for purification to furnish the title compound (23.6 mg, 61%, *dr* = >20:1) as a white solid.

R_f = 0.4 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42 (dd, *J* = 7.6, 1.5 Hz, 1H), 7.22 (td, *J* = 7.3, 1.8 Hz, 1H), 7.16 (td, *J* = 7.3, 1.5 Hz, 1H), 7.13 (dd, *J* = 7.5, 1.8 Hz, 1H), 4.69 (d, *J* = 7.8 Hz, 1H), 3.84 – 3.73 (m, 1H), 3.66 (ddd, *J* = 10.8, 7.9, 4.7 Hz, 1H), 2.86 (s, 2H), 2.34 (s, 3H), 2.02 (hept, *J* = 7.0 Hz, 1H), 1.90 – 1.76 (m, 1H), 1.74 – 1.61 (m, 1H), 0.81 (d, *J* = 7.0 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 141.99, 135.06, 130.37, 127.18, 126.30, 126.22, 75.18, 61.06, 38.02, 36.22, 19.49, 17.40.

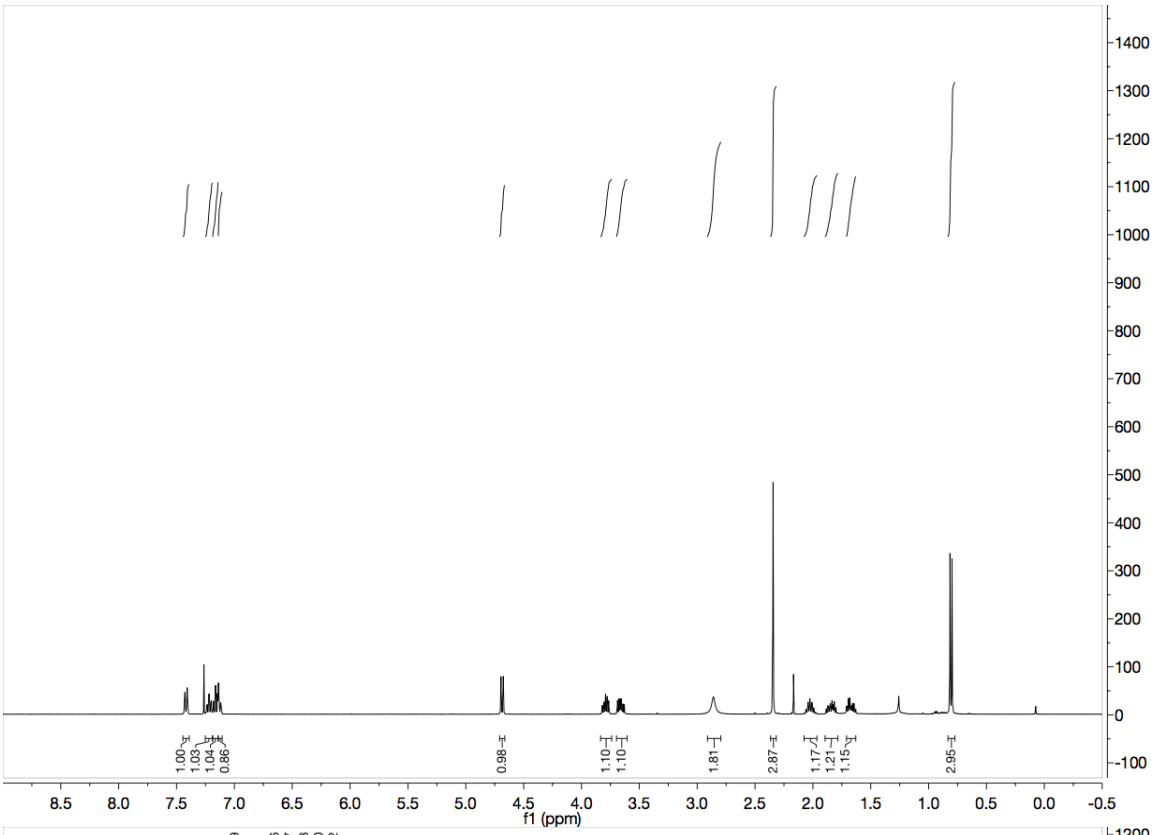
LRMS (CI) Calcd. for $C_{12}H_{18}NaO_2$ $[M+Na]^+$: 217, Found: 217.

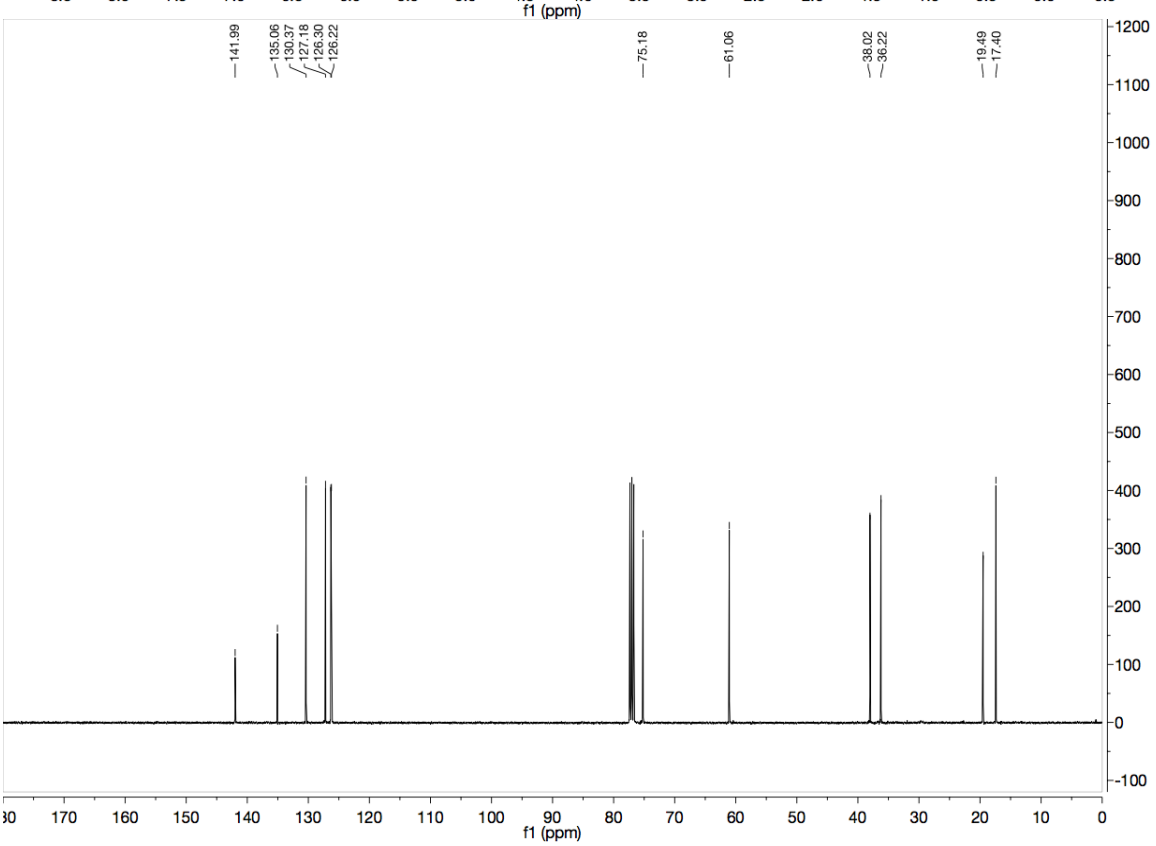
FTIR (neat): 2958, 2923, 1460, 1378, 1054, 1012, 756, 729 cm^{-1}.

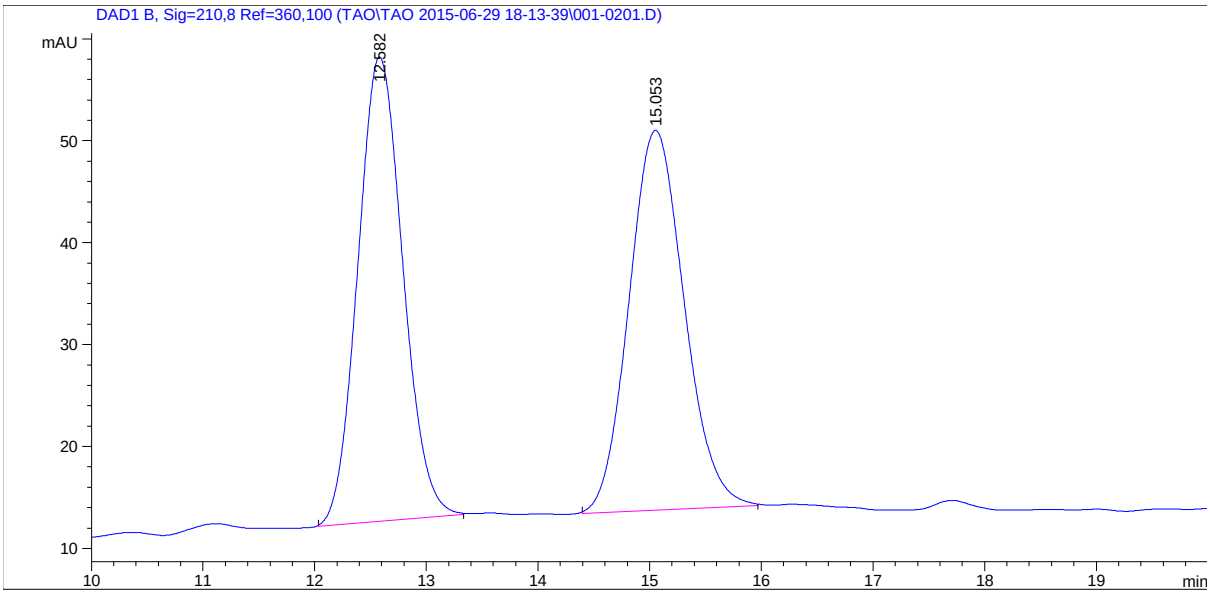
HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 87%.

$[\alpha]^{25}_D$ = - 37.9 (c = 0.44, $CHCl_3$)

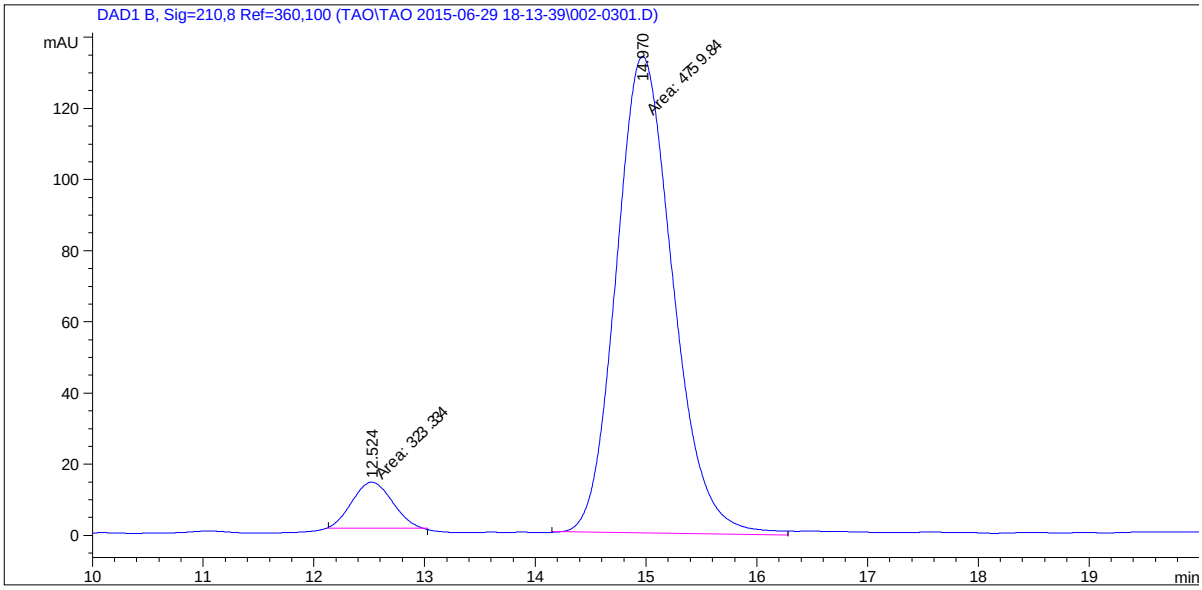
M.P. 84.6-86.7 °C


1.00
1.03
1.04
0.86
0.98
1.10
1.10
1.81
2.87
1.17
1.21
1.15
2.95
f1 (ppm)


141.99
135.06
130.37
127.18
126.30
126.22
75.18
61.06
38.02
36.22
19.49
17.40
f1 (ppm)

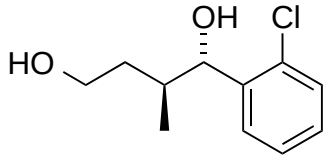


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.582	BB	0.4370	1277.60510	45.58098	49.9202
2	15.053	BB	0.5332	1281.68738	37.27221	50.0798



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.524	MM	0.4181	323.33398	12.88840	6.3609
2	14.970	MM	0.5924	4759.83838	133.90485	93.6391

(1*S*,2*S*)-1-(2-chlorophenyl)-2-methylbutane-1,4-diol (5h).



The residue was subjected to flash column chromatography for purification to furnish the title compound (29.1 mg, 68%, *dr* = >20:1) as a colorless oil.

R_f= 0.5 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.52 (dd, *J* = 7.7, 1.7 Hz, 1H), 7.32 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.28 (dd, *J* = 7.6, 1.3 Hz, 1H), 7.19 (dd, *J* = 7.7, 1.8 Hz, 1H), 4.95 (d, *J* = 6.8 Hz, 1H), 3.83 – 3.74 (m, 1H), 3.68 – 3.58 (m, 1H), 3.26 (bs, 1H), 2.69 (bs, 1H), 2.09 (hept, *J* = 6.5 Hz, 1H), 1.83 – 1.69 (m, 1H), 1.68 – 1.56 (m, 1H), 0.90 (d, *J* = 7.0 Hz, 3H).

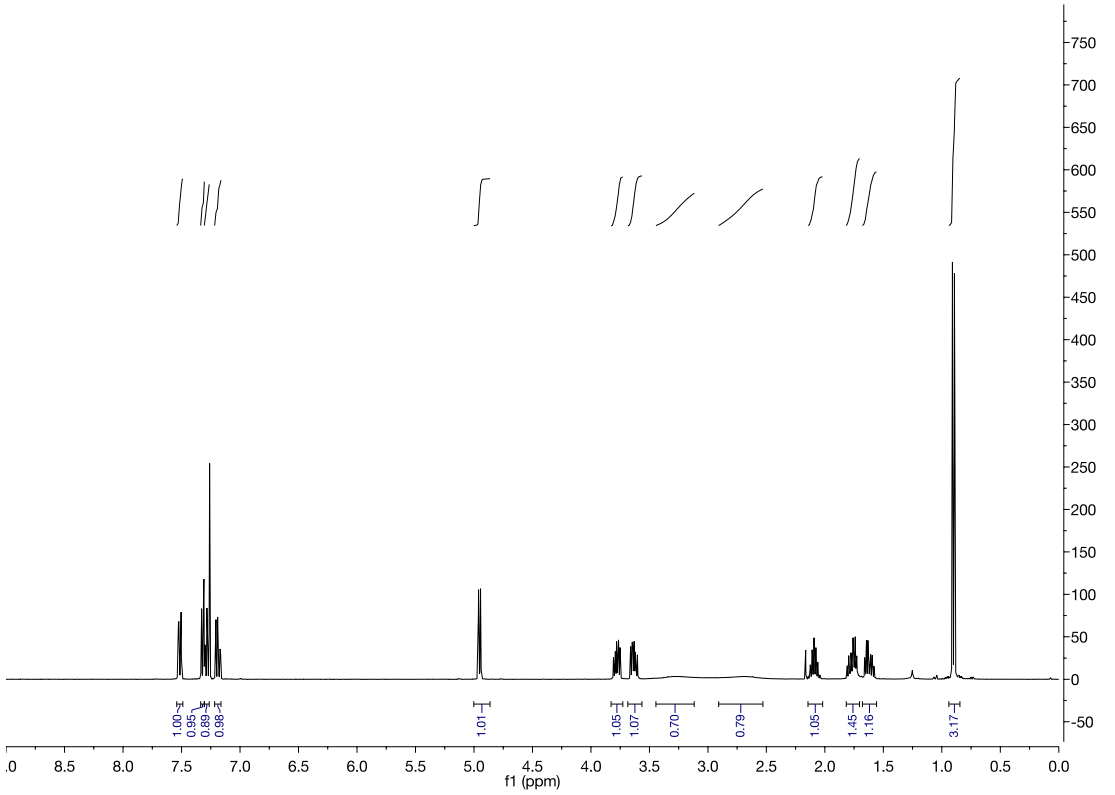
^{13}C NMR (100 MHz, $CDCl_3$): δ 141.23, 132.45, 129.33, 128.38, 128.19, 126.95, 74.73, 60.67, 37.38, 35.01, 16.92.

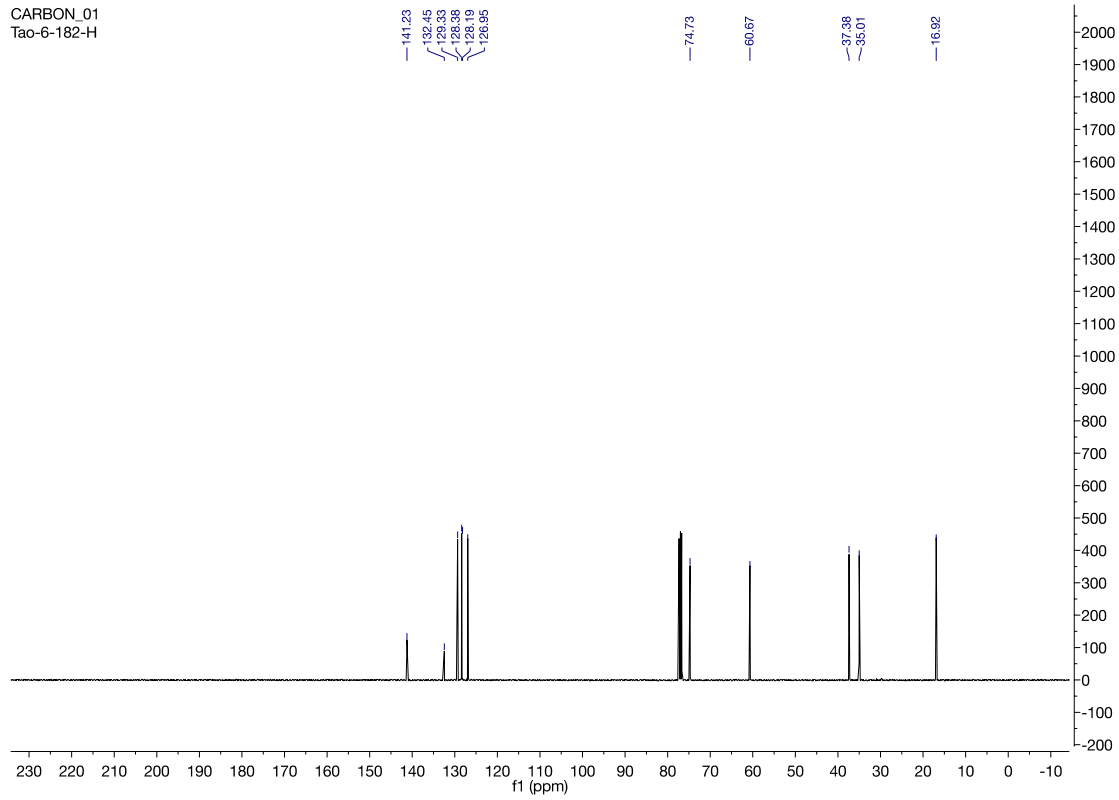
LRMS (CI) Calcd. for $C_{11}H_{15}NaClO_2$ $[M+Na]^+$: 237, Found: 237.

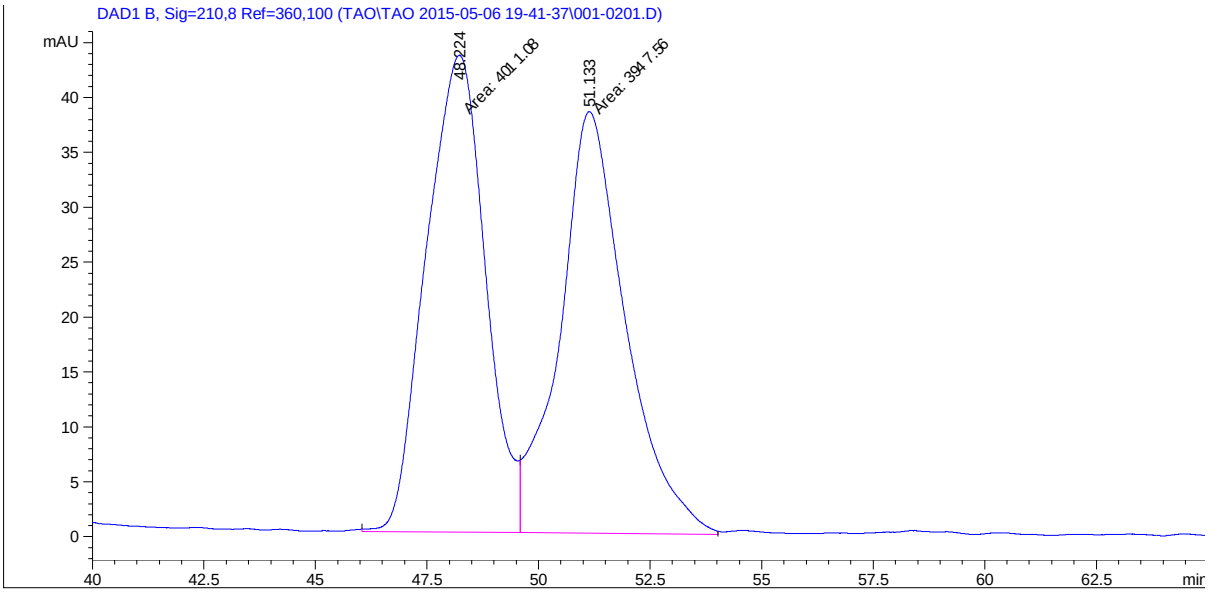
FTIR (neat): 3315, 2958, 2922,2850, 1438, 1049, 1023, 735 cm^{-1}.

HPLC (Chiralcel AS-H/AS-H column, hexanes:*i*-PrOH = 95:5, 0.5 mL/min, 210 nm), ee = 91%.

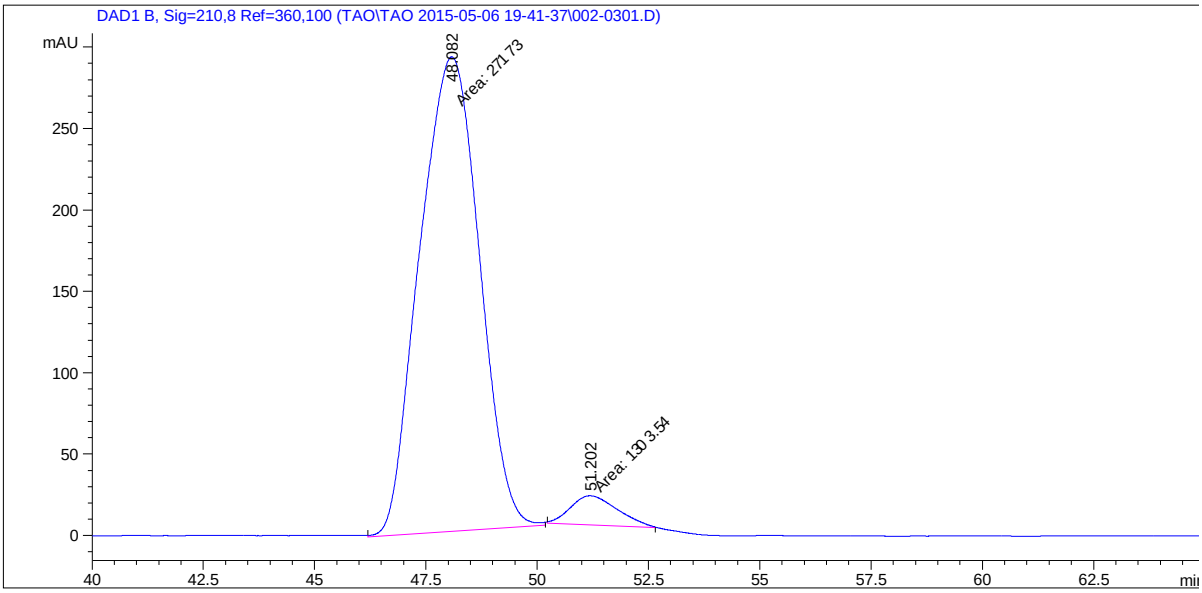
$[\alpha]^{25}_D$ = - 19.2 (c = 0.53, $CHCl_3$)


1.00
0.95
0.89
0.98
1.01
1.05
1.07
0.70
0.79
1.05
1.45
1.16
3.17
f1 (ppm)


CARBON_01
Tao-6-182-H
141.23
132.45
129.33
128.38
128.19
126.95
74.73
60.67
37.38
35.01
16.92
f1 (ppm)

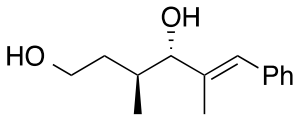


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	48.224	MF	1.5389	4011.08301	43.44012	50.3991
2	51.133	FM	1.7133	3947.55981	38.40157	49.6009



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	48.082	MM	1.5540	2.71730e4	291.42899	95.4224
2	51.202	MM	1.2196	1303.53503	17.81412	4.5776

(3*S*,4*S*,*E*)-3,5-dimethyl-6-phenylhex-5-ene-1,4-diol (5i).



The residue was subjected to flash column chromatography for purification to furnish the title compound (29.7 mg, 72%, *dr* = >20:1) as a colorless liquid.

R_f= 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36 – 7.31 (m, 2H), 7.30 – 7.27 (m, 2H), 7.27 – 7.18 (m, 1H), 6.47 (s, 1H), 3.88 (d, *J* = 8.3 Hz, 1H), 3.85 – 3.78 (m, 1H), 3.69 (ddd, *J* = 10.8, 8.1, 4.5 Hz, 1H), 2.76 (s, 2H), 1.97 – 1.88 (m, 1H), 1.87 (d, *J* = 1.4 Hz, 3H), 1.86 – 1.79 (m, 1H), 1.68 – 1.58 (m, 1H), 0.90 (d, *J* = 6.8 Hz, 3H).

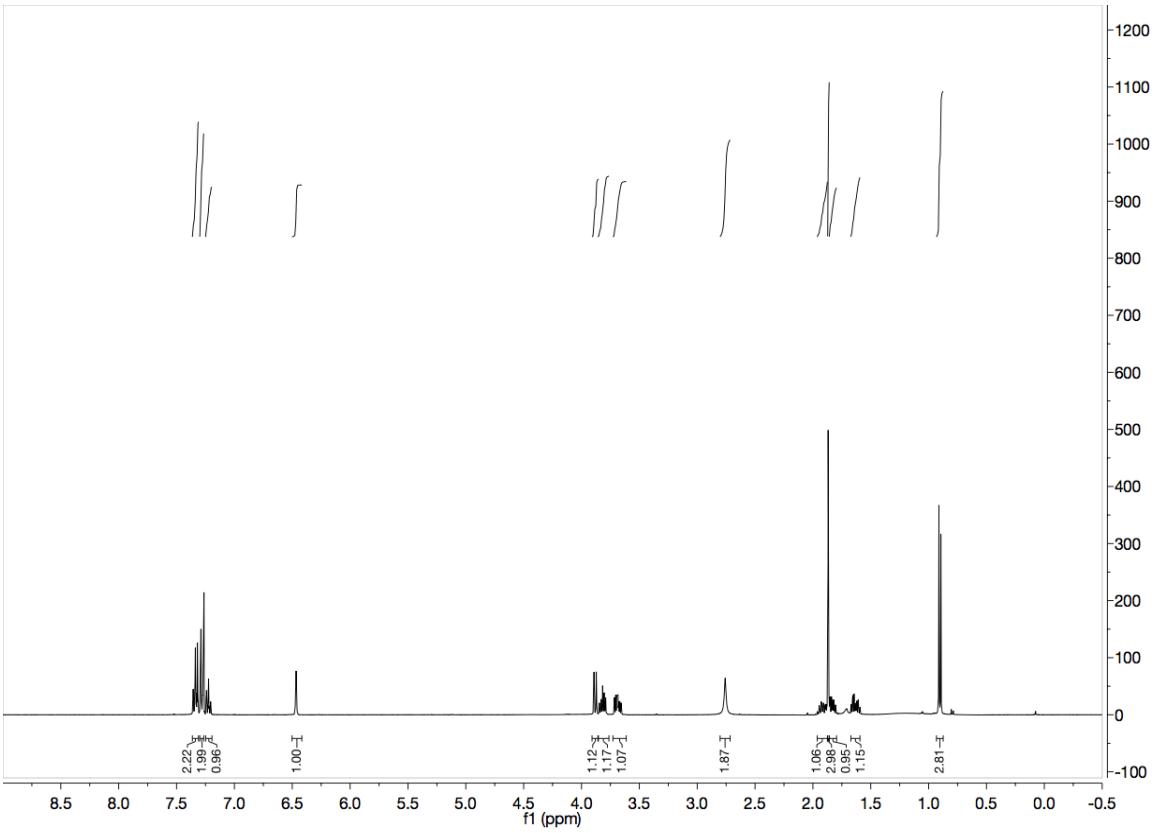
^{13}C NMR (100 MHz, $CDCl_3$): δ 139.37, 137.42, 128.97, 128.12, 127.52, 126.51, 83.42, 61.24, 36.78, 34.64, 17.82, 12.98.

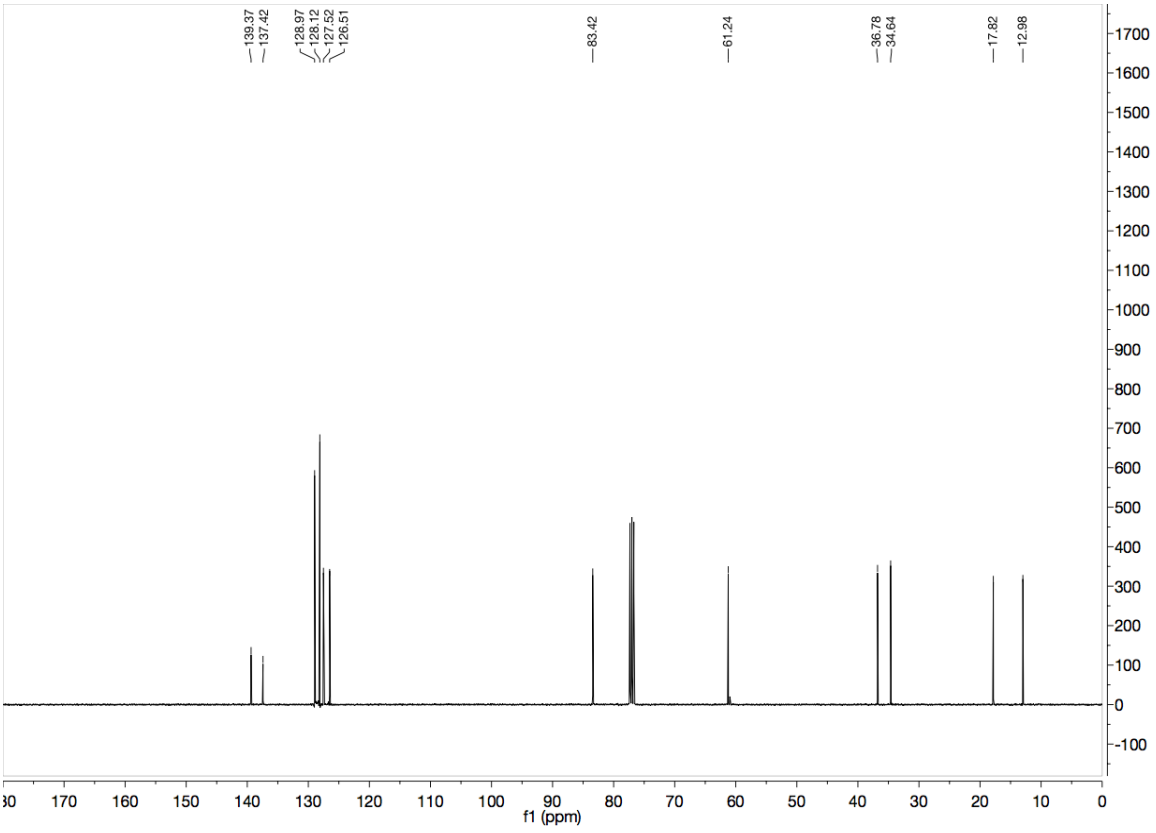
LRMS (CI) Calcd. for $C_{14}H_{20}NaO_2$ $[M+Na]^+$: 243, Found: 243.

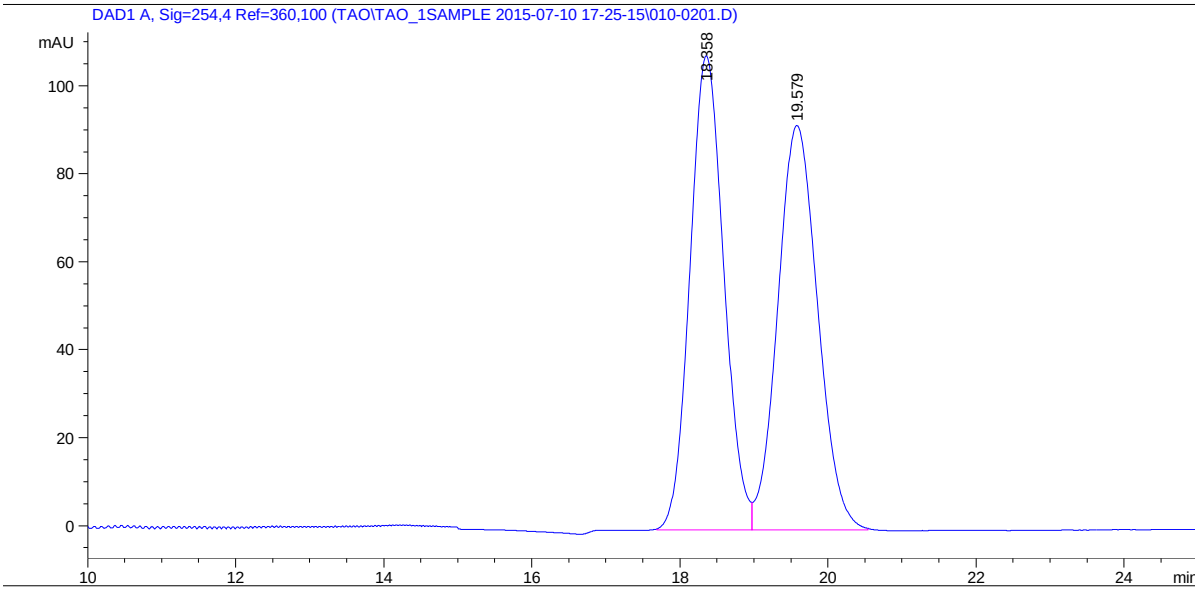
FTIR (neat): 2959, 2923, 1147, 1378, 1057, 1008, 750, 699 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:05, 1 mL/min, 254 nm), ee = 90%.

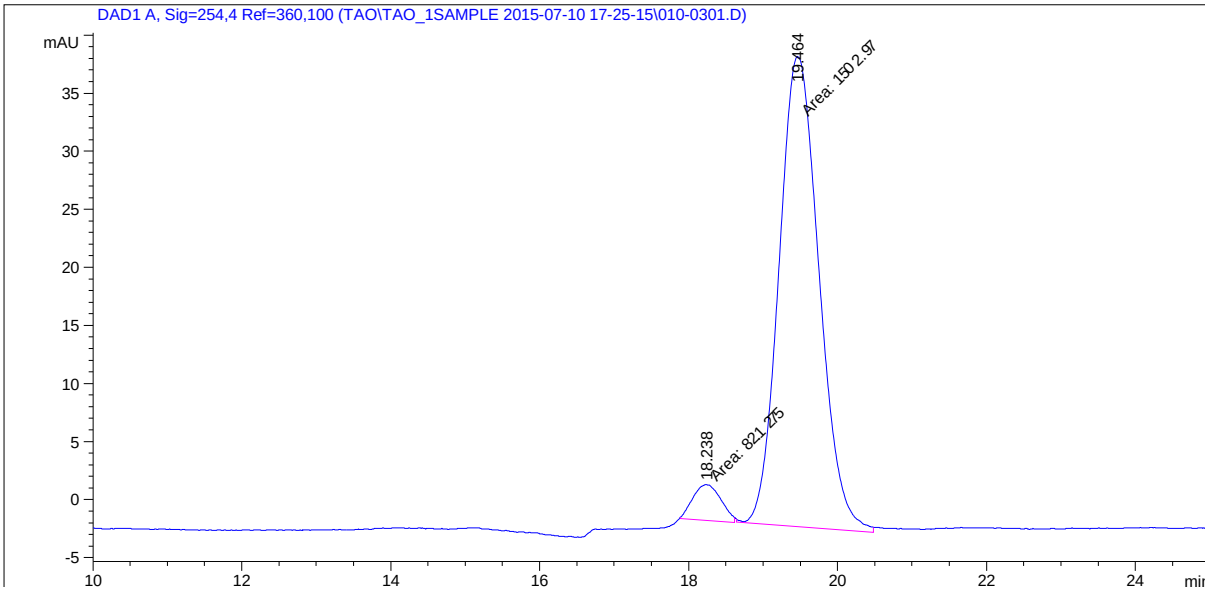
$[\alpha]^{25}_D$ = + 42.4 (c = 0.11, $CHCl_3$)


2.22
1.99
0.96
1.00
1.12
1.17
1.07
1.87
1.06
2.98
0.95
1.15
2.81
f1 (ppm)


139.37
137.42
128.97
128.12
127.52
126.51
83.42
61.24
36.78
34.64
17.82
12.98
f1 (ppm)

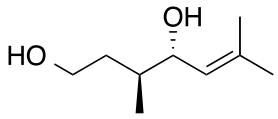


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	18.358	BV	0.5027	3442.22559	107.74624	49.9694
2	19.579	VB	0.5774	3446.44556	91.92495	50.0306



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	18.238	MM	0.4430	82.12747	3.08987	5.1812
2	19.464	MM	0.6189	1502.96655	40.47425	94.8188

(3*S*,4*S*)-3,6-dimethylhept-5-ene-1,4-diol (5j).



The residue was subjected to flash column chromatography for purification to furnish the title compound (23.1 mg, 73%, *dr* = >20:1) as a colorless oil.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 5.19 (dp, *J* = 9.0, 1.4 Hz, 1H), 4.12 (dd, *J* = 9.0, 7.2 Hz, 1H), 3.83 – 3.71 (m, 1H), 3.69 – 3.57 (m, 1H), 2.40 (s, 2H), 1.79 – 1.65 (m, 8H), 1.62 – 1.51 (m, 1H), 0.86 (d, *J* = 6.7 Hz, 3H).

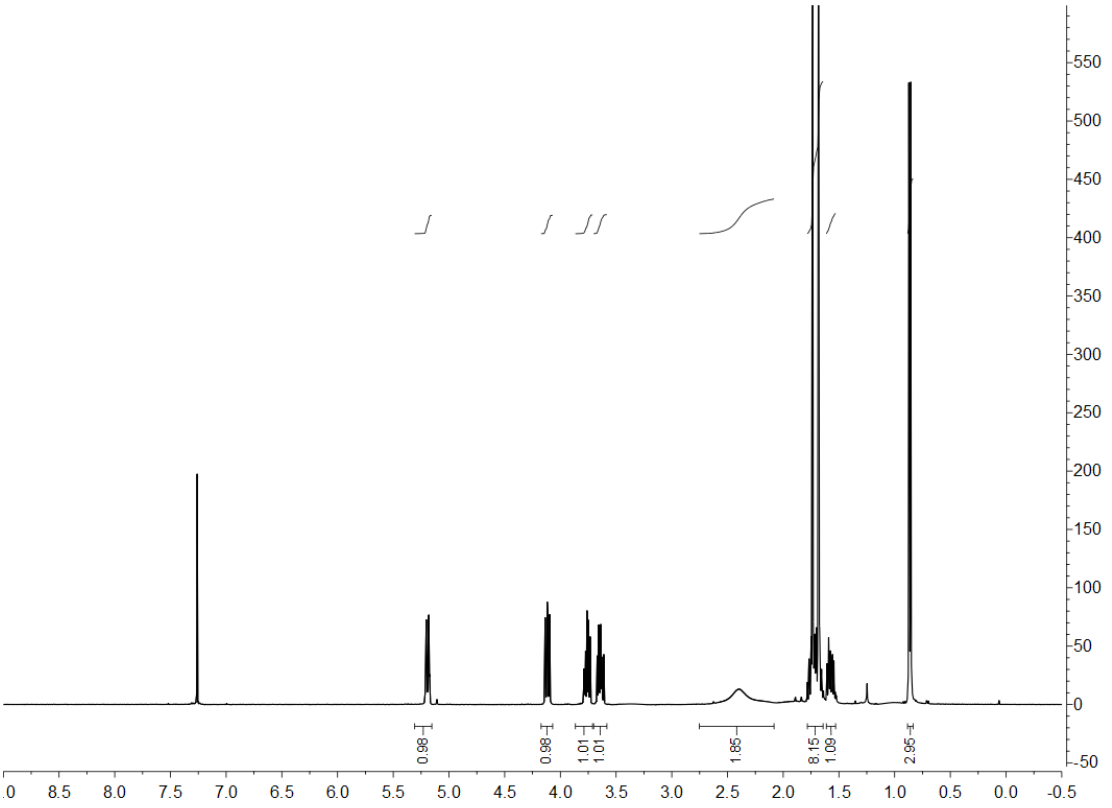
^{13}C NMR (100 MHz, $CDCl_3$): δ 136.01, 126.76, 73.00, 61.23, 37.63, 36.76, 26.04, 18.52, 16.66.

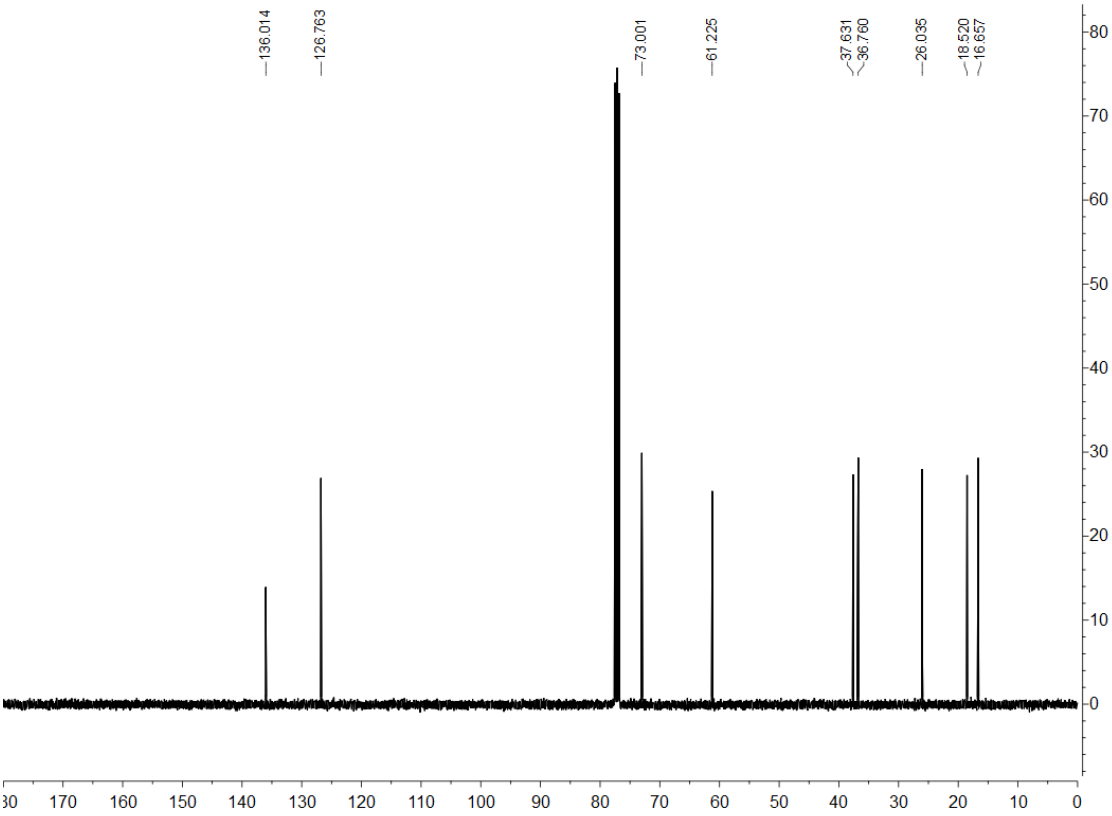
LRMS (CI) Calcd. for $C_9H_{18}NaO_2$ $[M+Na]^+$: 181, Found: 181.

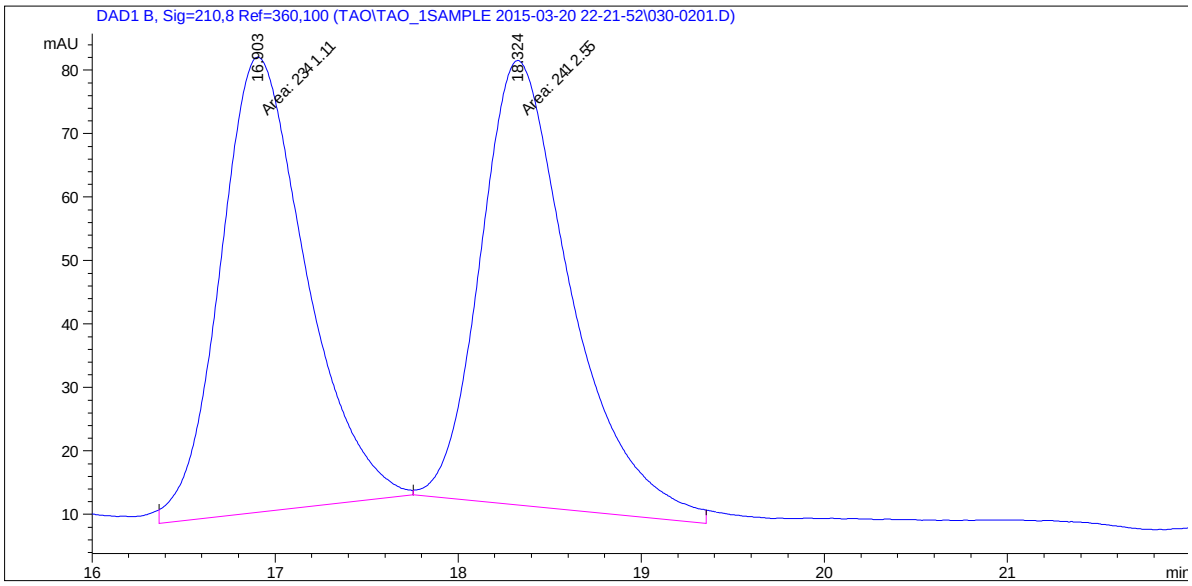
FTIR (neat): 3016, 2970, 1739, 1366, 1229, 1217 cm^{-1}.

HPLC (Chiralcel AD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 94%.

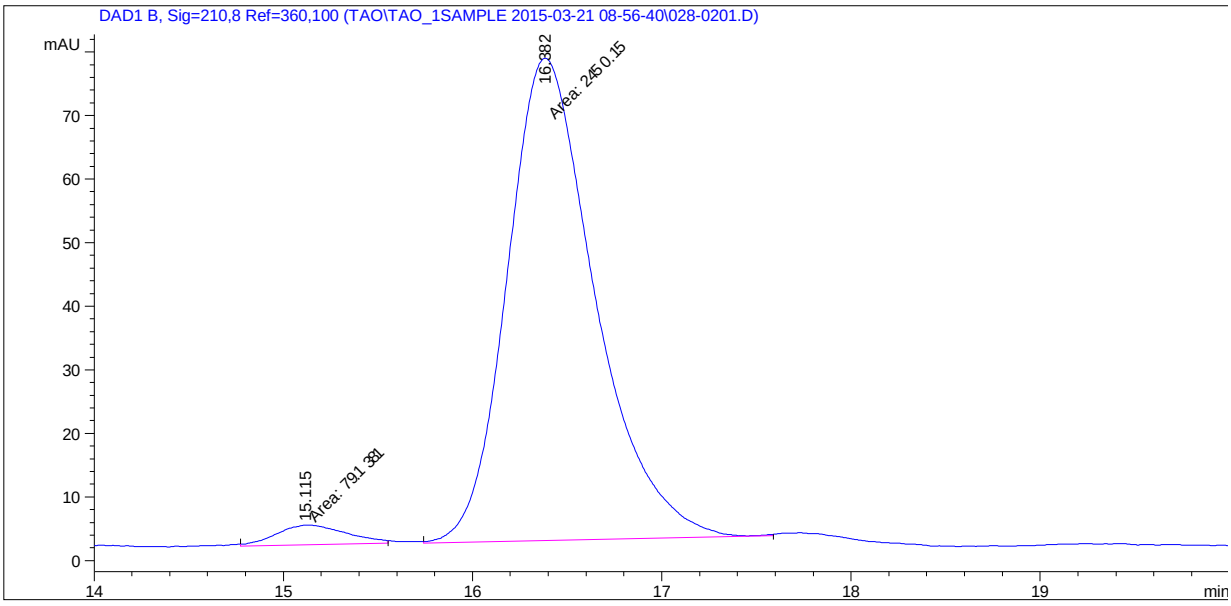
$[\alpha]^{25}_D$ = + 3.8 (c = 0.61, $CHCl_3$)


0.98
0.98
1.01
1.01
1.85
8.15
1.09
2.95


136.014
126.763
73.001
61.225
37.631
36.760
26.035
18.520
16.657

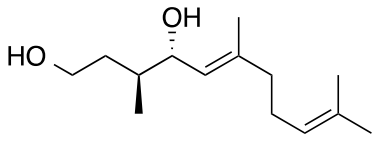


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.903	MM	0.5440	2341.11060	71.72882	49.2486
2	18.324	MM	0.5742	2412.55249	70.02545	50.7514



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.115	MM	0.4262	79.13813	3.09482	3.1289
2	16.382	MM	0.5384	2450.14819	75.85360	96.8711

(3*S*,4*S*,*E*)-3,6,10-trimethylundeca-5,9-diene-1,4-diol (5k).



The residue was subjected to flash column chromatography for purification to furnish the title compound (42.3 mg, 72%, *dr* = >20:1) as a colorless oil.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 5.19 (dq, *J* = 9.1, 1.3 Hz, 1H), 5.10 – 5.03 (m, 1H), 4.13 (dd, *J* = 9.0, 7.3 Hz, 1H), 3.76 (ddd, *J* = 11.0, 6.1, 5.0 Hz, 1H), 3.70 – 3.60 (m, 1H), 2.14 – 2.00 (m, 4H), 1.81 – 1.69 (m, 2H), 1.68 – 1.66 (m, 6H), 1.60 (s, 3H), 1.58 – 1.54 (m, 1H), 0.86 (d, *J* = 6.7 Hz, 3H).

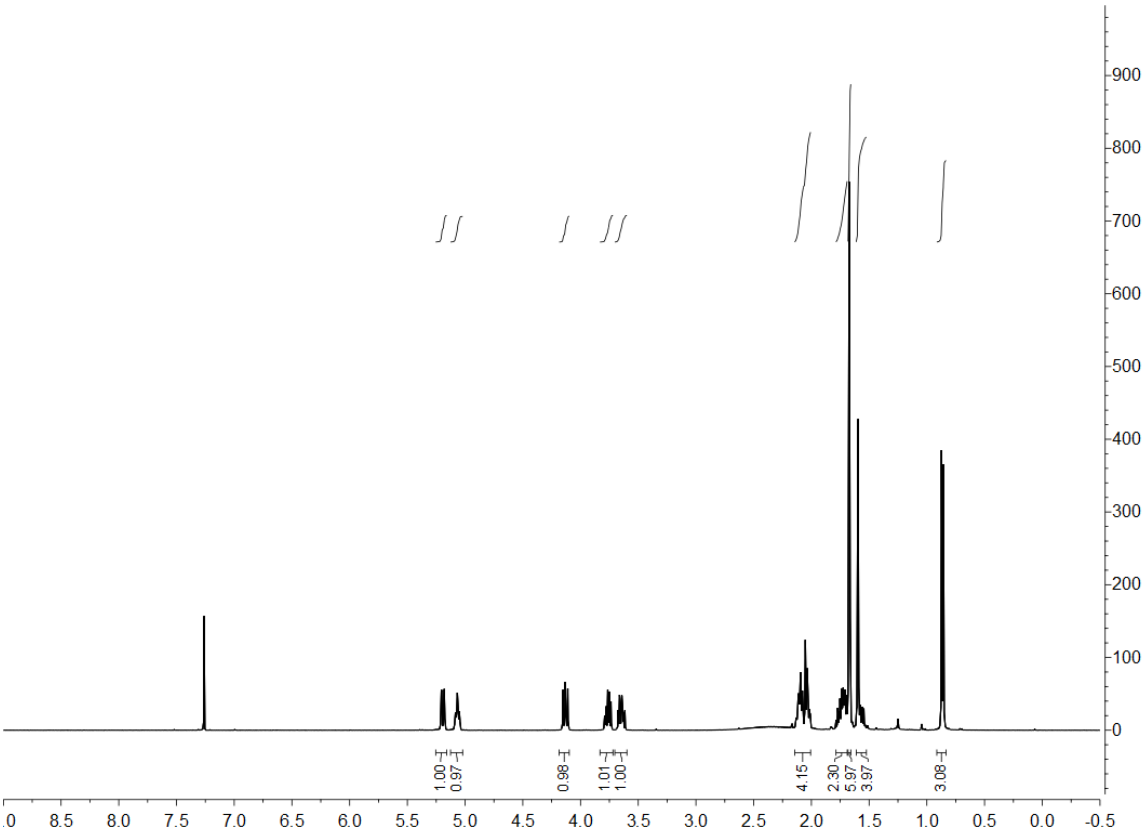
^{13}C NMR (100 MHz, $CDCl_3$): δ 139.39, 131.85, 126.69, 124.07, 72.92, 61.27, 39.86, 37.69, 36.85, 26.48, 25.83, 17.84, 16.86, 16.62.

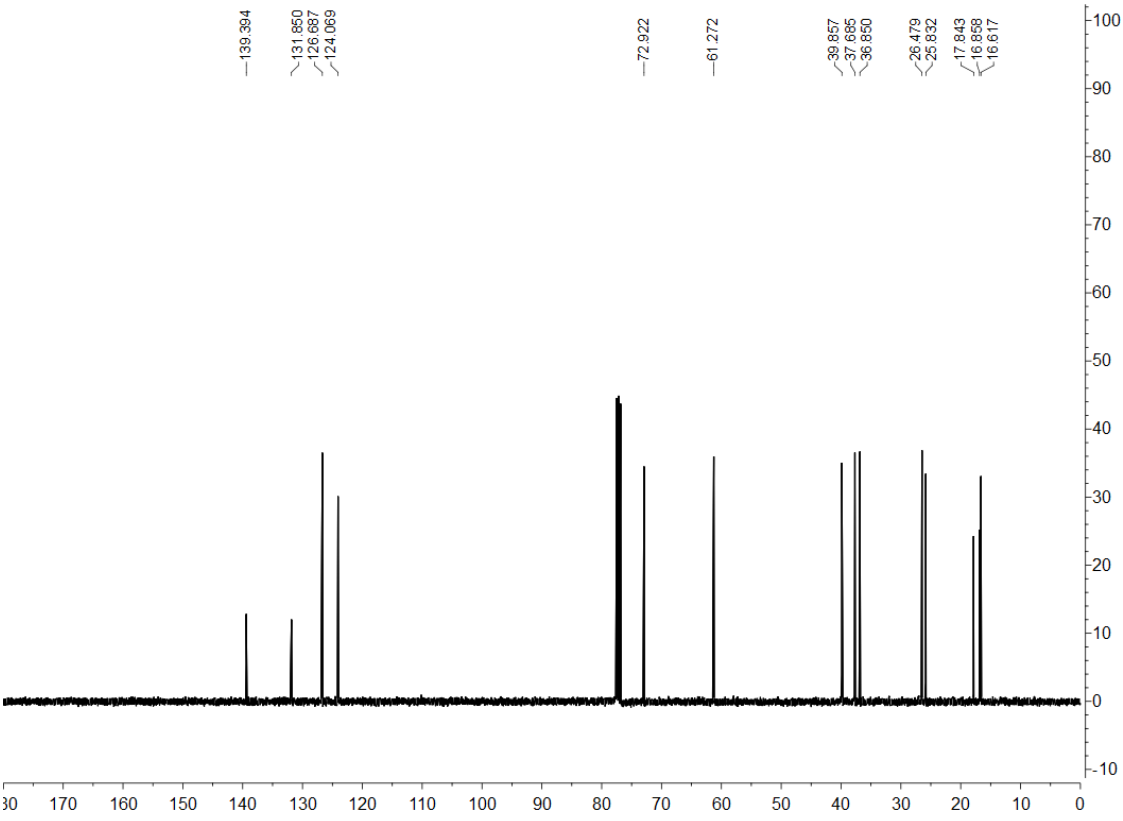
LRMS (CI) Calcd. for $C_{14}H_{26}NaO_2$ $[M+Na]^+$: 249, Found: 249.

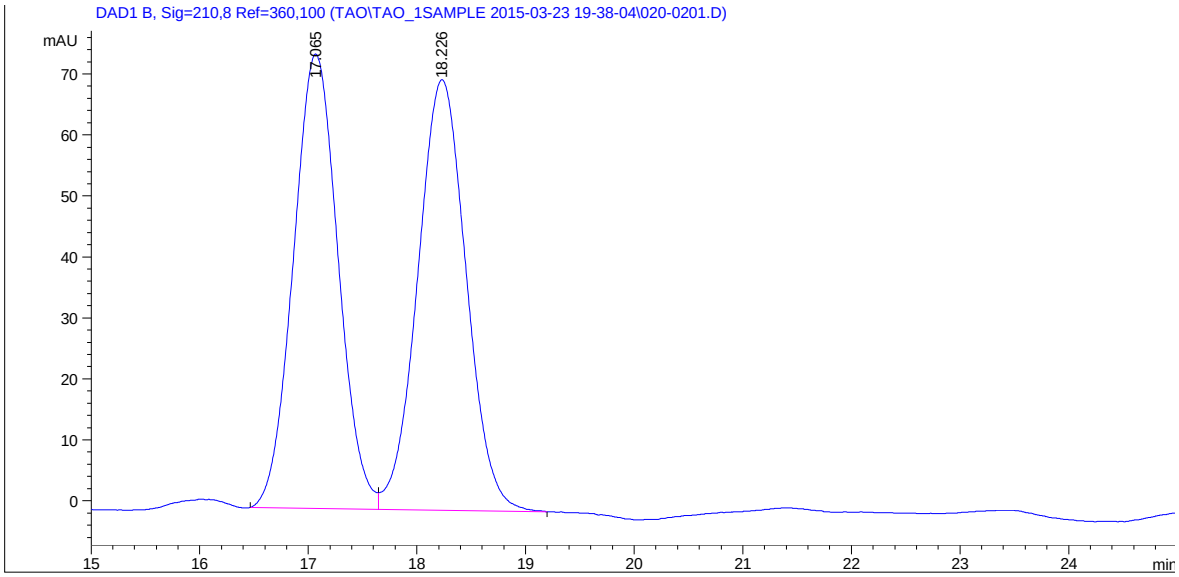
FTIR (neat): 2970, 1739, 1448, 1366, 1229, 1217 cm^{-1}.

HPLC (Chiralcel OD-H column/OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 96%.

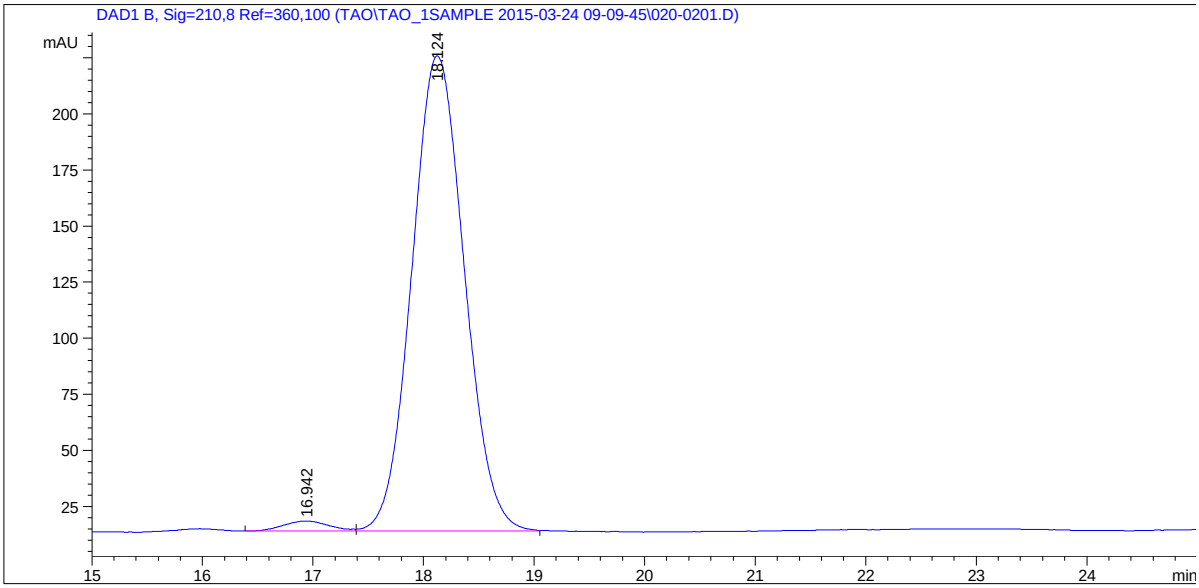
$[\alpha]^{25}_D$ = - 6.8(c = 0.54, $CHCl_3$)


1.00
0.97
0.98
1.01
1.00
4.15
2.30
5.97
3.97
3.08


139.394
131.850
126.687
124.069
72.922
61.272
39.857
37.685
36.850
26.479
25.832
17.843
16.858
16.617

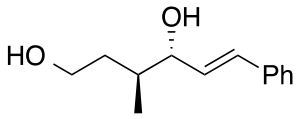


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	17.065	BV	0.4444	2136.06885	74.53375	49.3446
2	18.226	VB	0.4783	2192.80786	70.60277	50.6554



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	16.942	BV	0.3495	126.60713	4.42887	1.7824
2	18.124	VB	0.5183	6976.73682	211.78230	98.2176

(3*S*,4*S*,*E*)-3-methyl-6-phenylhex-5-ene-1,4-diol (5l).



The residue was subjected to flash column chromatography for purification to furnish the title compound (29.7 mg, 72%, *dr* = >20:1) as a white solid.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41 – 7.20 (m, 5H), 6.57 (d, *J* = 15.9 Hz, 1H), 6.22 (dd, *J* = 15.9, 7.1 Hz, 1H), 4.08 (t, *J* = 6.9 Hz, 1H), 3.83 – 3.75 (m, 1H), 3.71 – 3.63 (m, 1H), 2.59 (s, 2H), 1.91 – 1.71 (m, 2H), 1.68 – 1.55 (m, 1H), 0.97 (d, *J* = 6.9 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 136.81, 131.54, 131.15, 128.71, 127.80, 126.59, 60.87, 37.18, 36.17, 16.79.

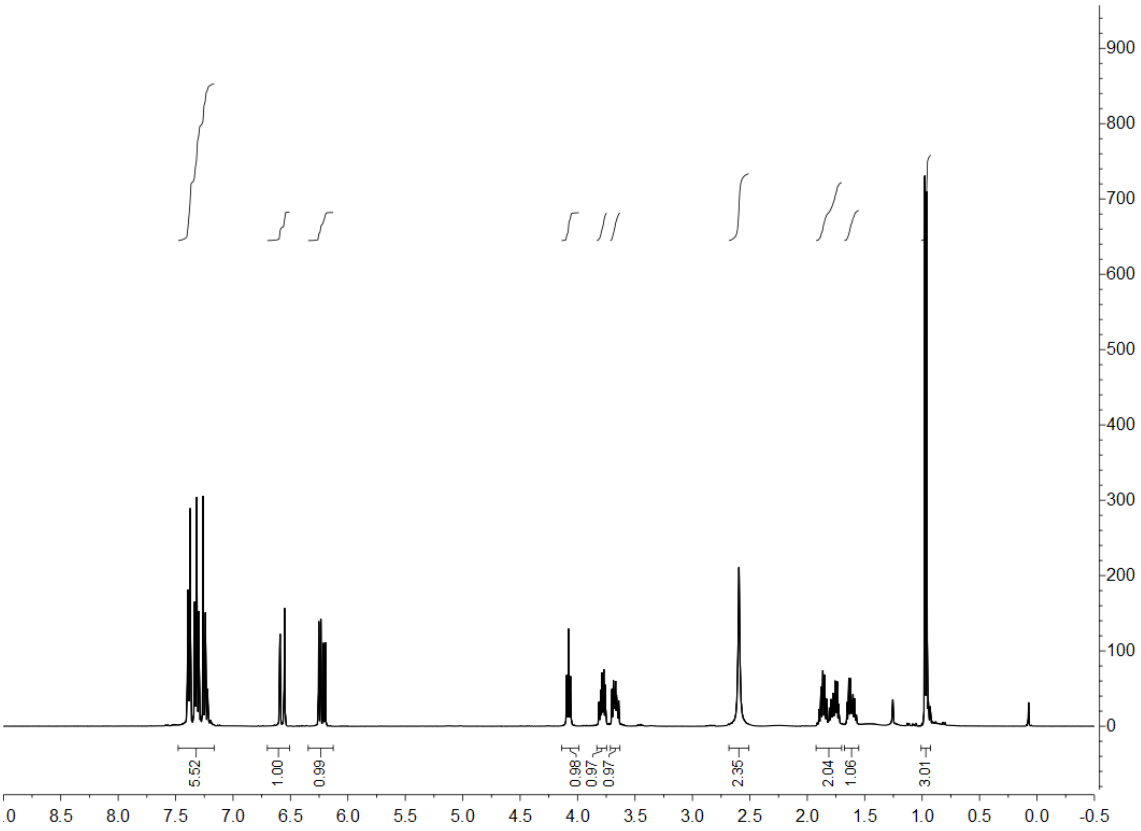
LRMS (CI) Calcd. for $C_{13}H_{18}NaO_2$ $[M+Na]^+$: 229, Found: 229.

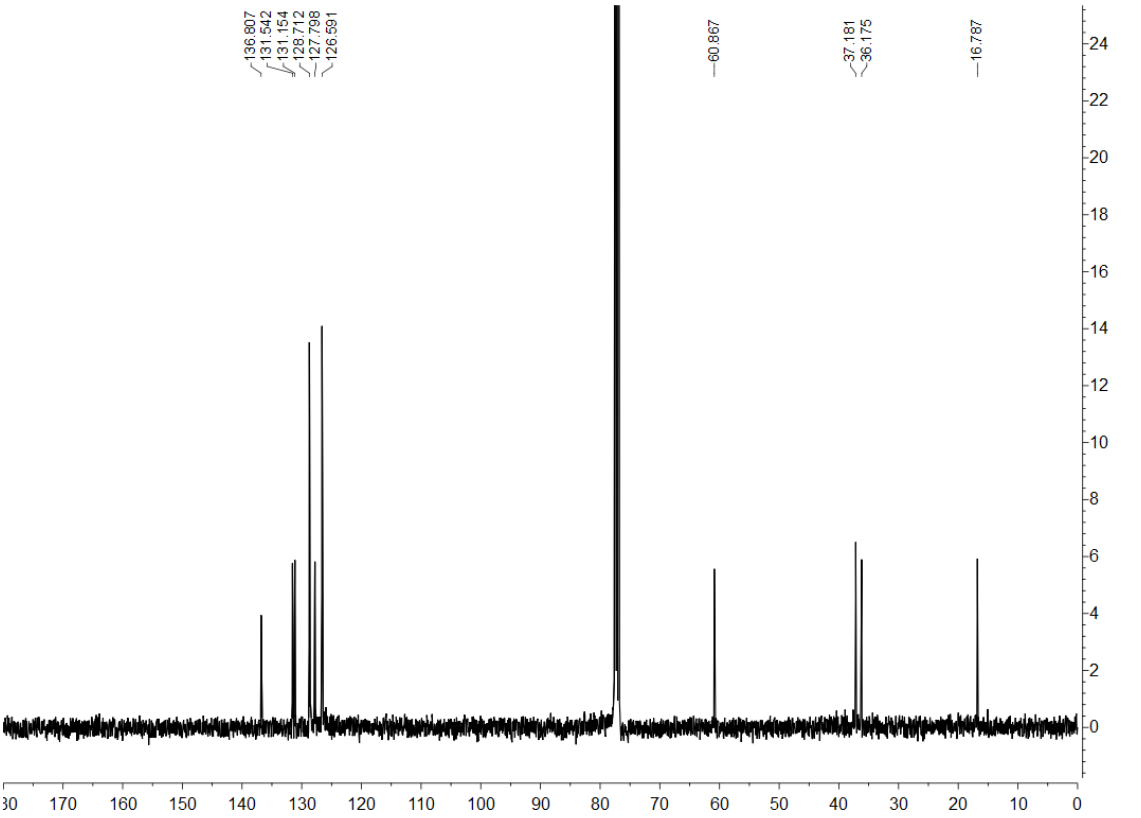
FTIR (neat): 3260, 3025, 2970, 2944, 1739, 1449, 1366, 1228, 1217, 1011, 970, 693 cm^{-1}.

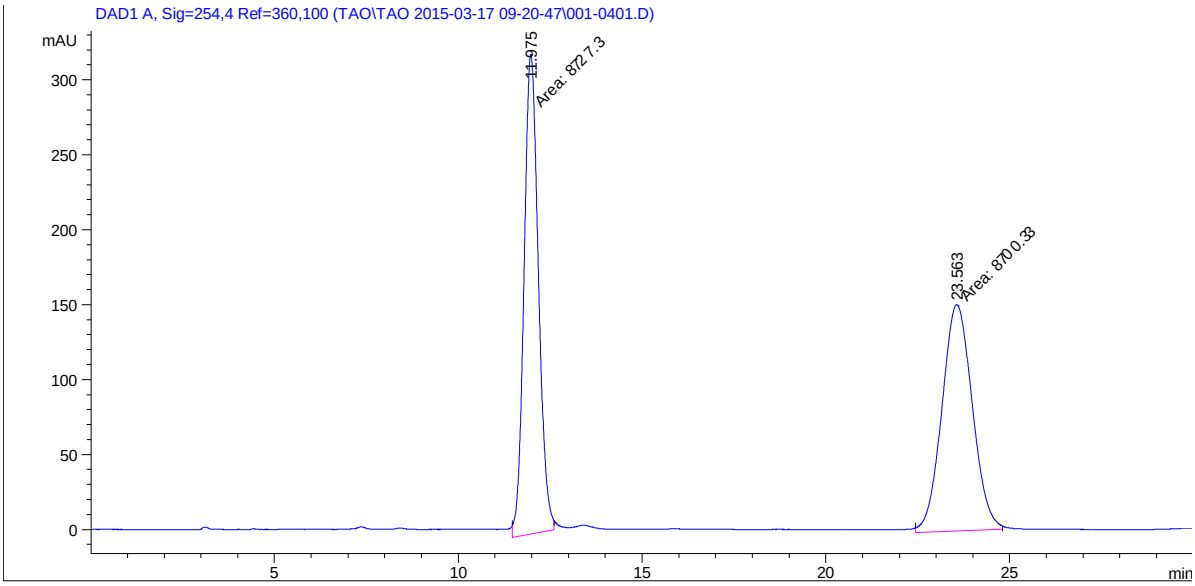
HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 90:10, 1 mL/min, 254 nm), ee = 93%.

$[\alpha]^{25}_D$ = + 8.2 (c = 0.65, $CHCl_3$)

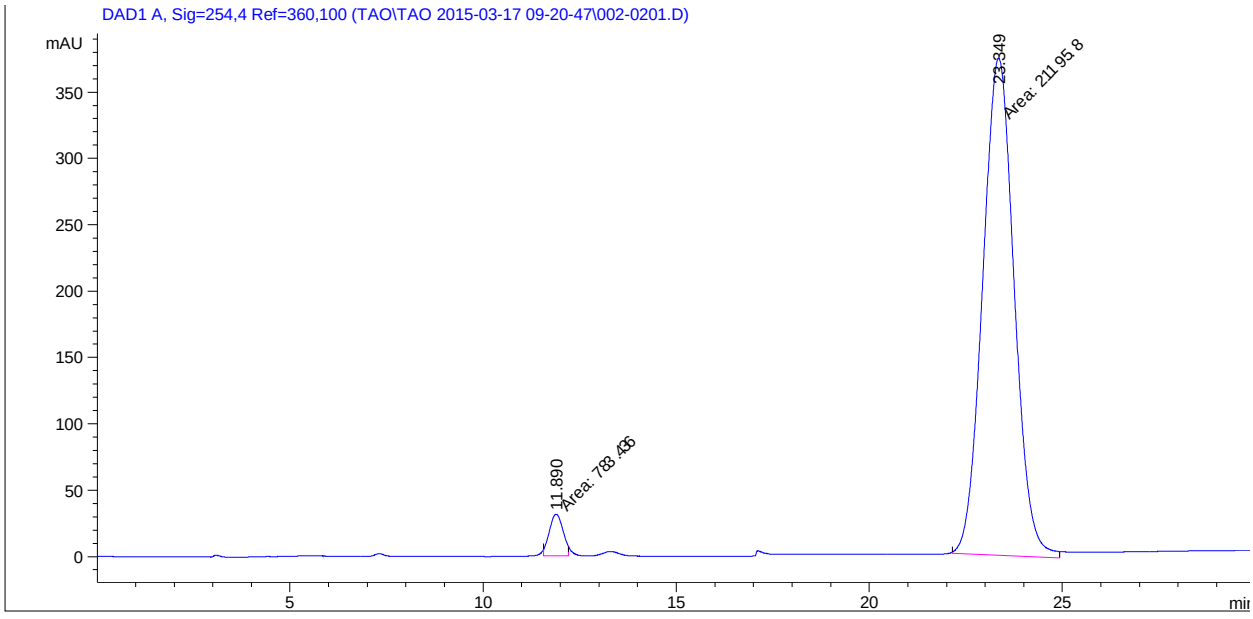
M.P. 84.5-86 ºC


5.52
1.00
0.99
0.98
0.97
0.97
2.35
2.04
1.06
3.01


136.807
131.542
131.154
128.712
127.798
126.591
60.867
37.181
36.175
16.787

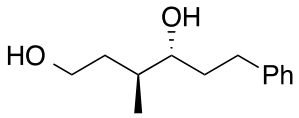


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.975	MM	0.4547	8727.30273	319.92133	50.0774
2	23.563	MM	0.9592	8700.32813	151.16803	49.9226



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.890	MM	0.4136	783.43585	31.57117	3.5644
2	23.349	MM	0.9433	2.11958e4	374.49902	96.4356

(3*S*,4*R*)-3-methyl-6-phenylhexane-1,4-diol (5m).



The residue was subjected to flash column chromatography for purification to furnish the title compound (14.5 mg, 0.1 mmol scale, 70%, *dr* = >20:1) as a colorless oil.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31 – 7.26 (m, 2H), 7.24 – 7.15 (m, 3H), 3.76 (ddd, *J* = 10.6, 6.6, 5.0 Hz, 1H), 3.63 (ddd, *J* = 10.6, 7.0, 5.0 Hz, 1H), 3.52 – 3.40 (m, 1H), 2.85 (ddd, *J* = 13.7, 9.9, 5.5 Hz, 1H), 2.72 – 2.56 (m, 3H), 1.92 – 1.51 (m, 5H), 0.95 (d, *J* = 6.8 Hz, 3H).

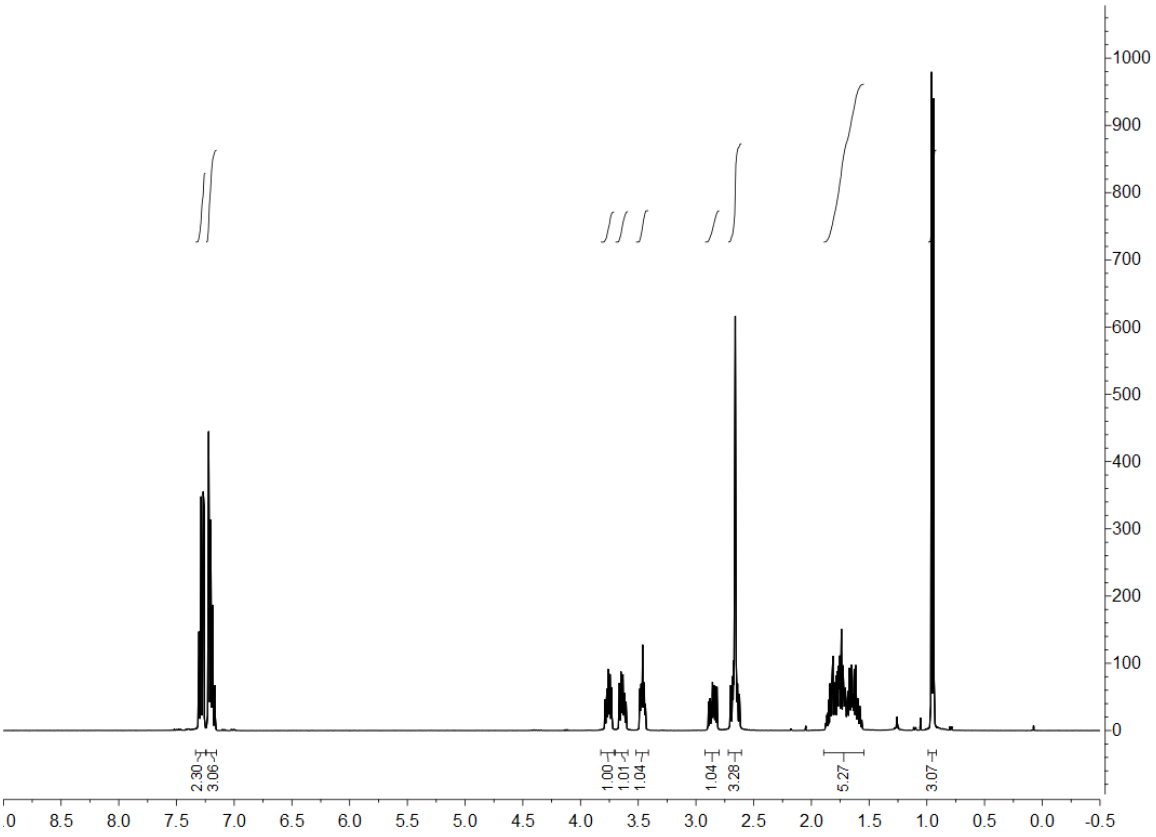
^{13}C NMR (100 MHz, $CDCl_3$): δ 142.40, 128.57, 128.53, 125.93, 75.34, 60.50, 36.76, 36.39, 35.34, 32.45, 16.62.

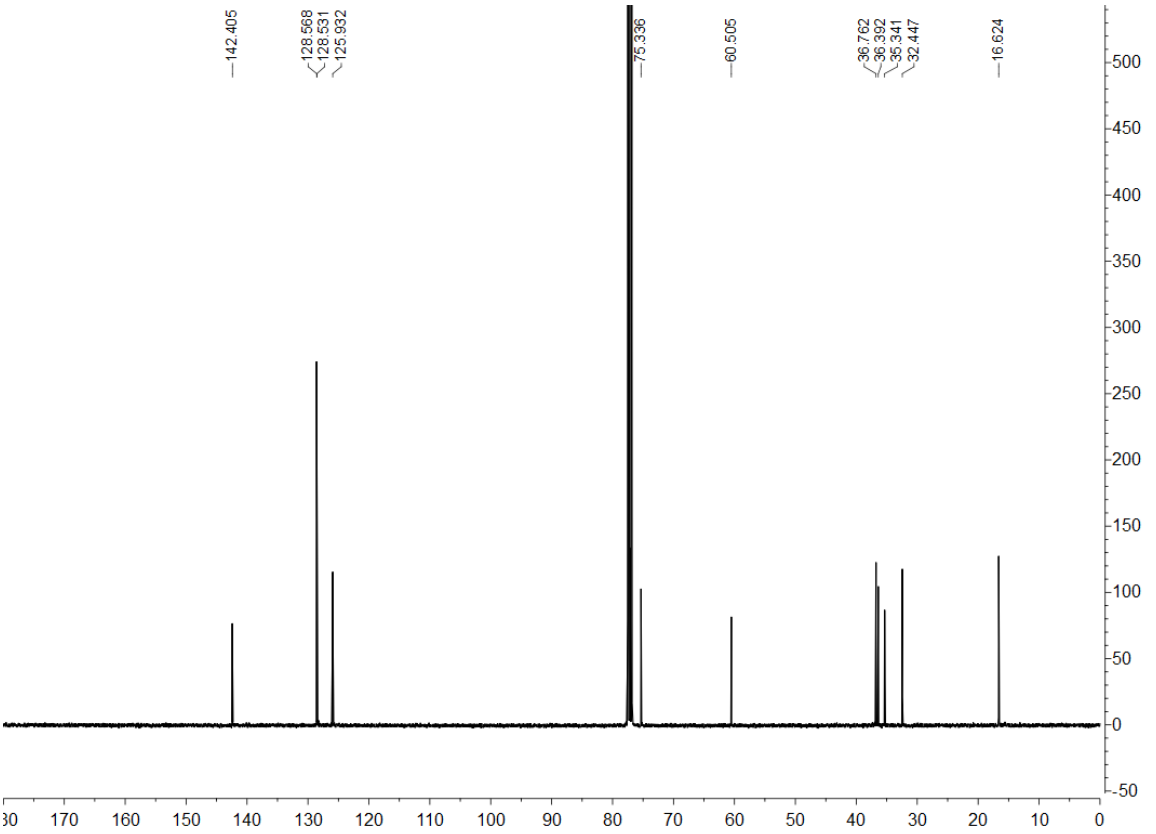
LRMS (CI) Calcd. for $C_{13}H_{20}NaO_2$ $[M+Na]^+$: 231, Found: 231.

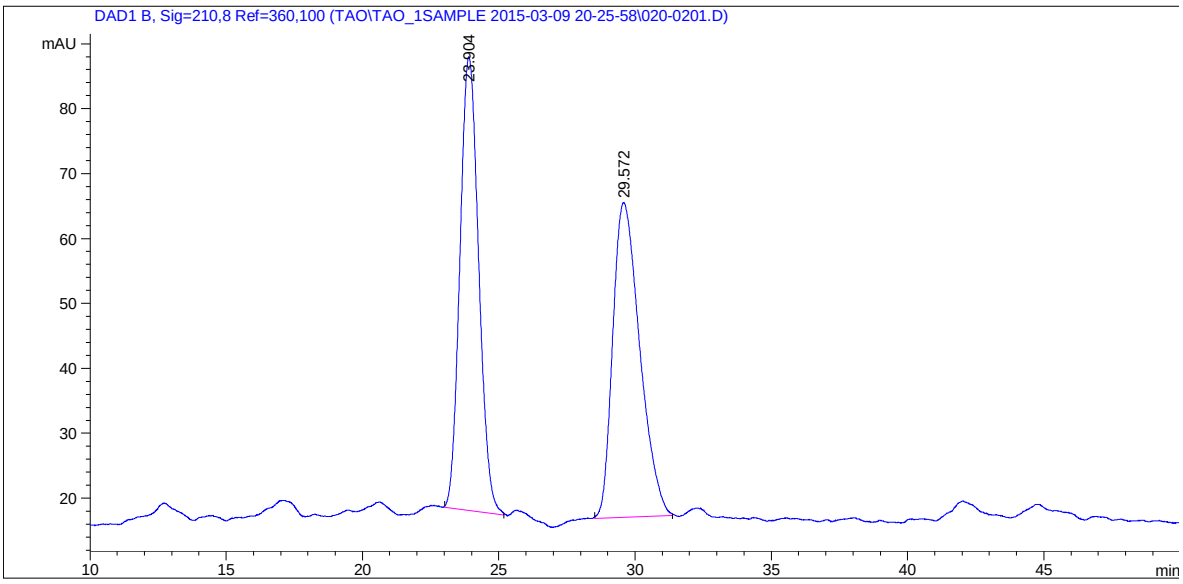
FTIR (neat): 3026, 2970, 2946, 1739, 1454, 1366, 1229, 1217, 1052, 698 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1.0 mL/min, 210 nm), ee = 90%.

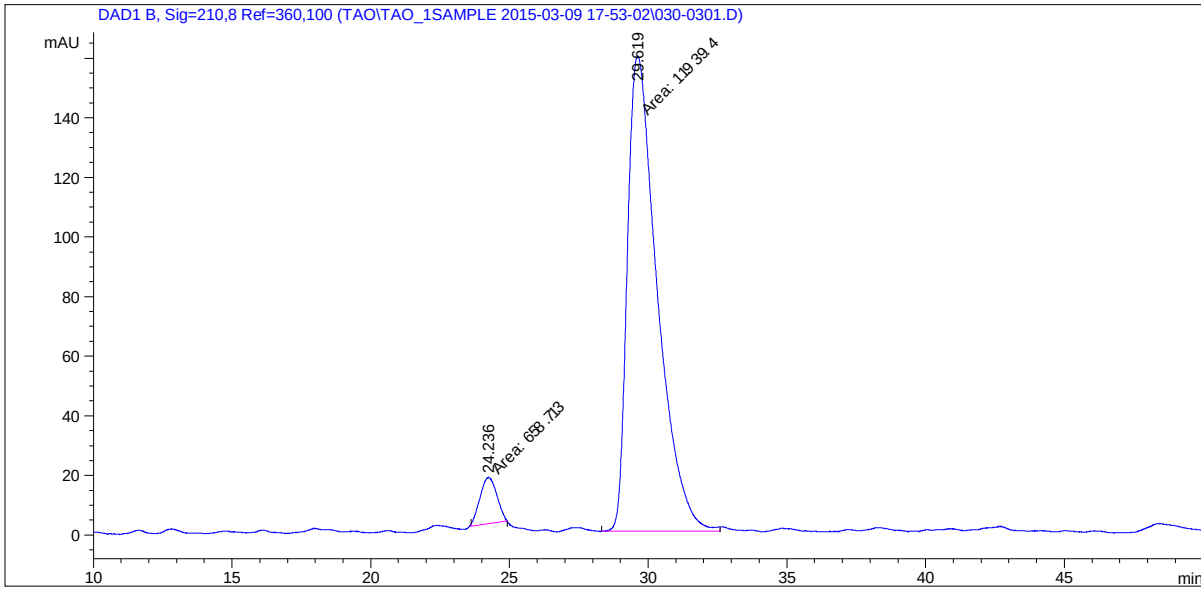
$[\alpha]^{25}_D$ = + 17.8 (c = 0.73, $CHCl_3$)


2.30
3.06
1.00
1.01
1.04
1.04
3.28
5.27
3.07


142.405
128.568
128.531
125.932
75.336
60.505
36.762
36.392
35.341
32.447
16.624

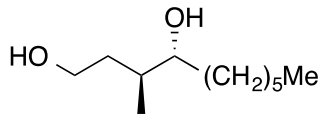


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.904	BB	0.6953	3334.83179	69.80979	50.0286
2	29.572	BB	0.8201	3331.01636	48.44849	49.9714



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.236	MM	0.7041	658.71326	15.59339	5.2287
2	29.619	MM	1.2478	1.19394e4	159.47311	94.7713

(3*S*,4*R*)-3-methyldecane-1,4-diol (5n).



The residue was subjected to flash column chromatography for purification to furnish the title compound (30.5 mg, 81%, *dr* = >20:1) as a colorless oil.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 3.75 (ddd, *J* = 11.3, 6.7, 4.9 Hz, 1H), 3.62 (ddd, *J* = 10.7, 7.0, 5.0 Hz, 1H), 3.44 – 3.35 (m, 1H), 2.73 (s, 2H), 1.75 – 1.17 (m, 14H), 0.93 (d, *J* = 6.7 Hz, 3H), 0.90 – 0.85 (m, 3H).

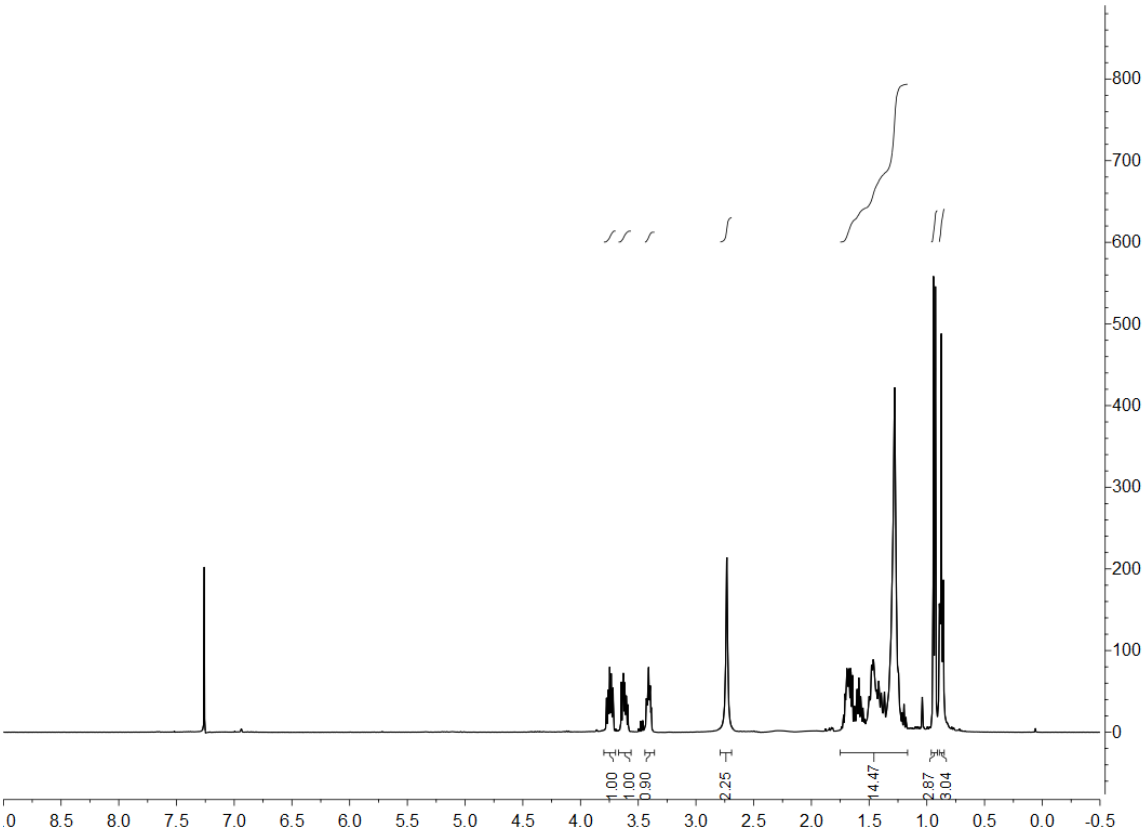
^{13}C NMR (100 MHz, $CDCl_3$): δ 76.03, 60.54, 36.53, 35.36, 34.59, 32.00, 29.55, 25.97, 22.78, 16.73, 14.23.

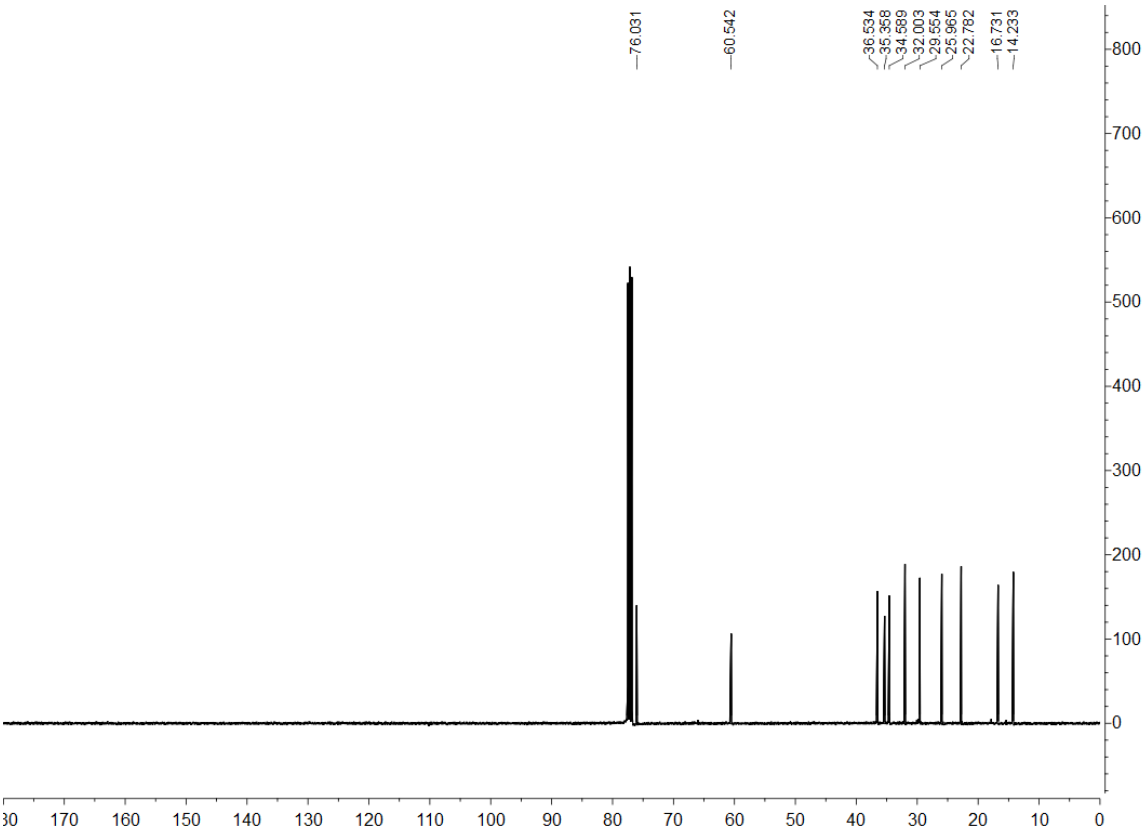
LRMS (CI) Calcd. for $C_{11}H_{24}NaO_2$ $[M+Na]^+$: 211, Found: 211.

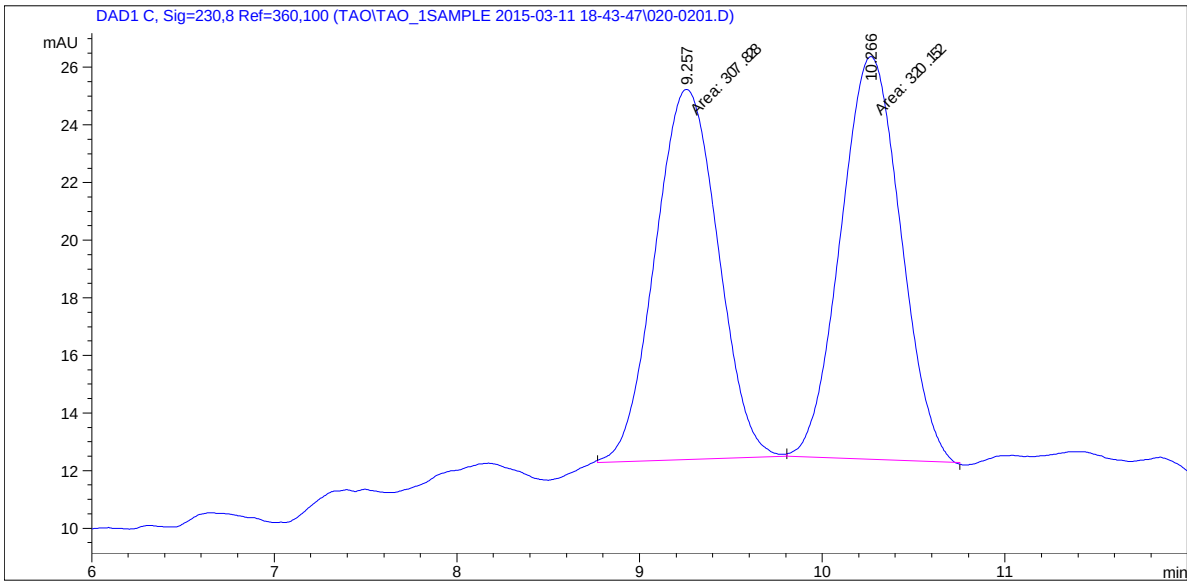
FTIR (neat): 2970, 2928, 1739, 1456, 1366, 1229, 1217 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 230 nm), ee = 90%.

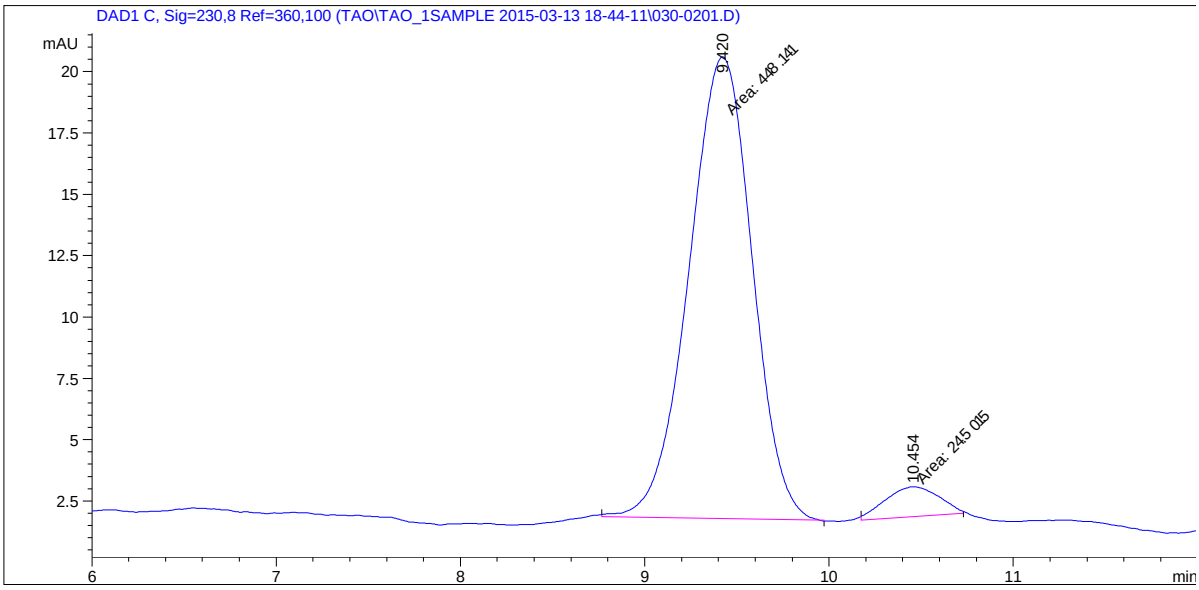
$[\alpha]^{25}_D$ = -2.1 (c = 0.62, $CHCl_3$)


1.00
1.00
0.90
2.25
14.47
2.87
3.04


76.031
60.542
36.534
35.358
34.589
32.003
29.554
25.965
22.782
16.731
14.233

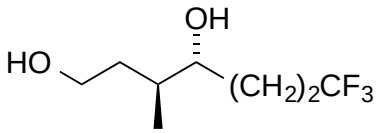


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.257	MM	0.3991	307.82849	12.85460	49.0188
2	10.266	MM	0.3816	320.15195	13.98154	50.9812



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.420	MM	0.3969	448.14063	18.81815	94.8160
2	10.454	MM	0.3367	24.50155	1.21290	5.1840

(3*S*,4*R*)-7,7,7-trifluoro-3-methylheptane-1,4-diol (5o).



The residue was subjected to flash column chromatography for purification to furnish the title compound (26.8 mg, 67%, *dr* = >20:1) as a colorless oil.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 3.86 – 3.75 (m, 1H), 3.73 – 3.63 (m, 1H), 3.43 (ddd, *J* = 9.3, 6.1, 3.0 Hz, 1H), 2.54 (s, 2H), 2.47 – 2.27 (m, 1H), 2.25 – 2.03 (m, 1H), 1.84 – 1.55 (m, 5H), 0.97 (d, *J* = 6.7 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 74.47, 60.40, 37.10, 35.29, 31.12, 30.83, 30.55, 30.26, 27.02, 26.99, 16.60.

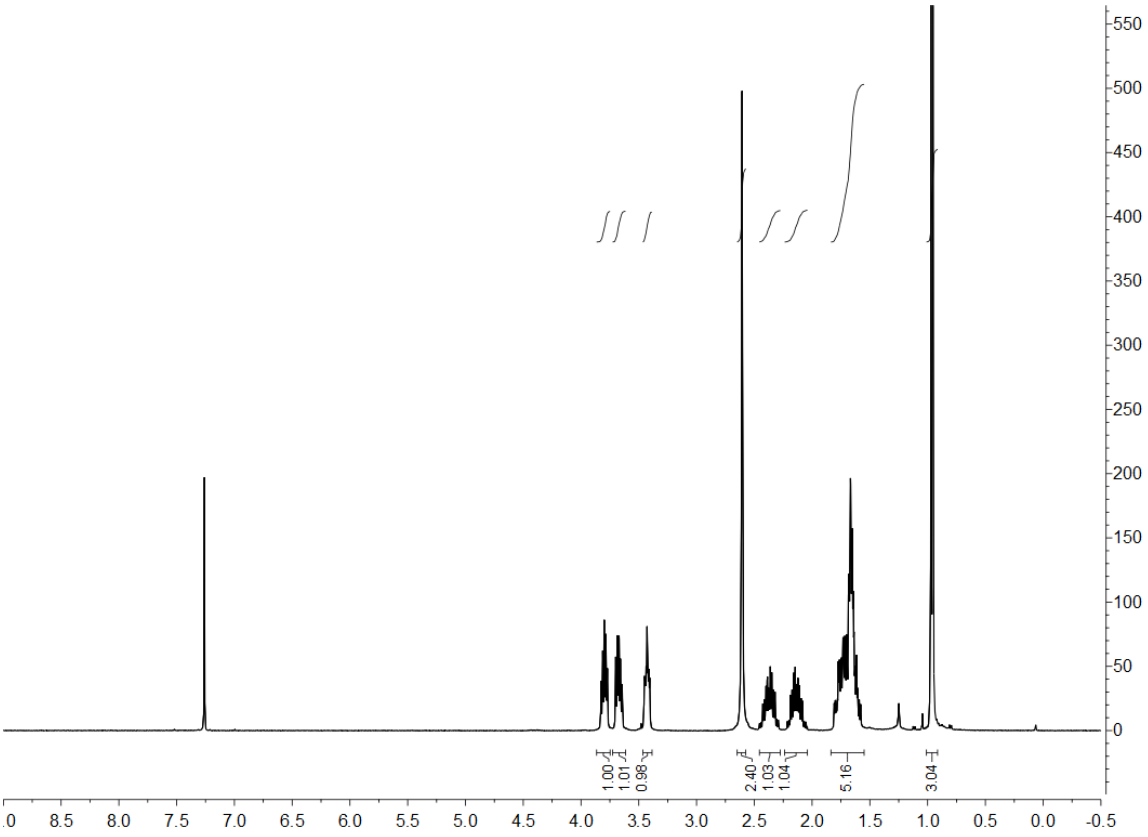
^{19}F NMR (378 MHz, $CDCl_3$): δ 66.34.

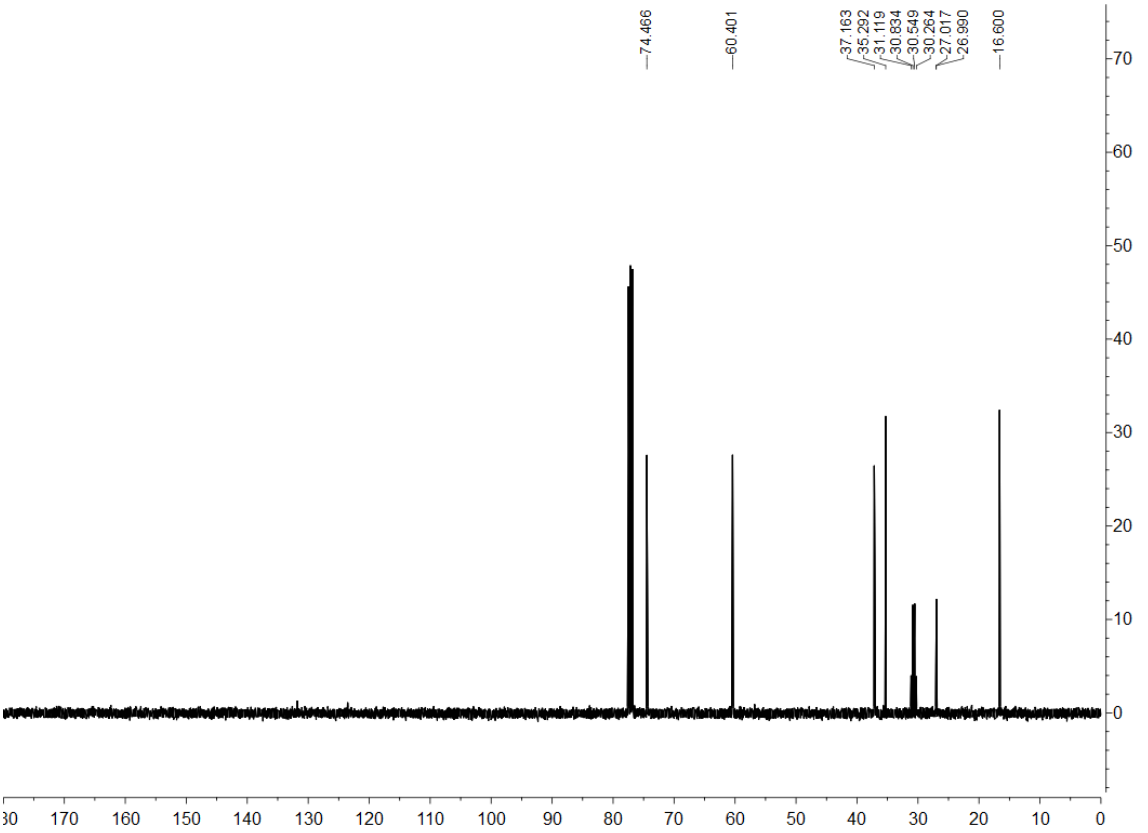
LRMS (CI) Calcd. for $C_8H_{15}NaF_3O_2$ $[M+Na]^+$: 223, Found: 223.

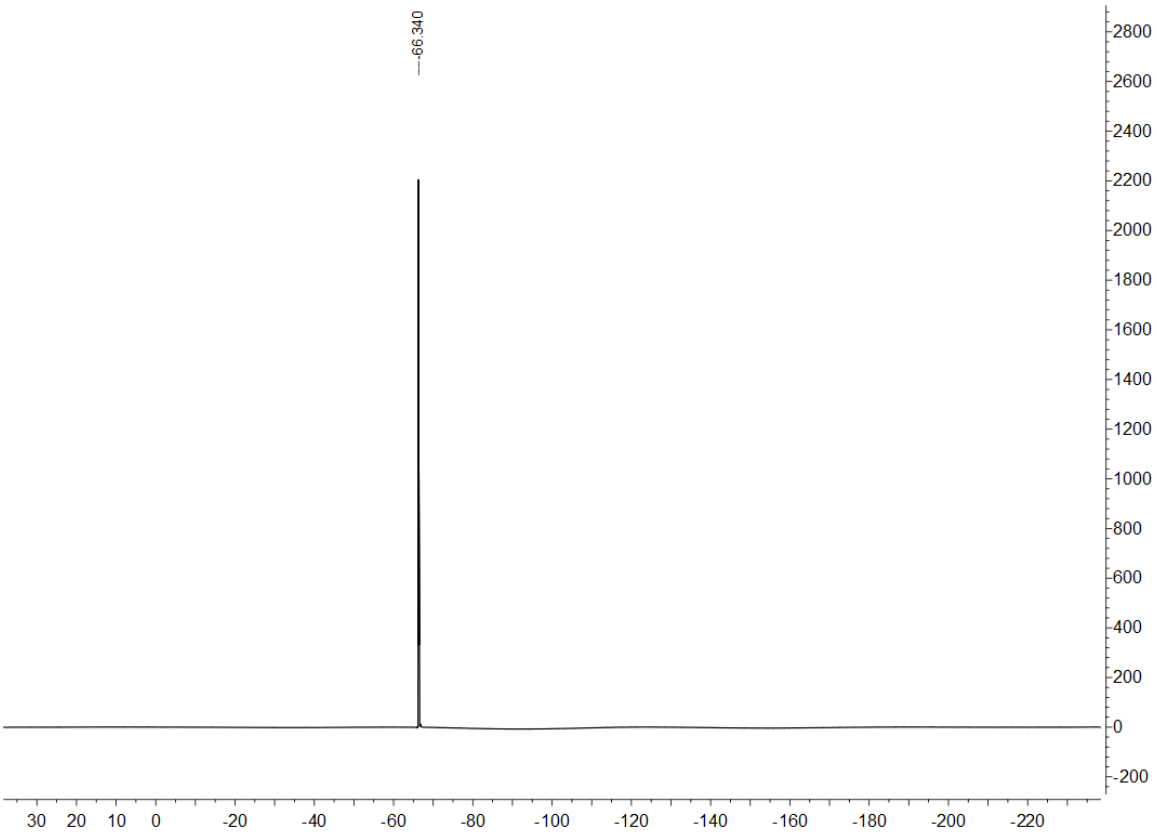
FTIR (neat): 2970, 1739, 1366, 1252, 1229, 1217, 1138, 1031 cm^{-1}.

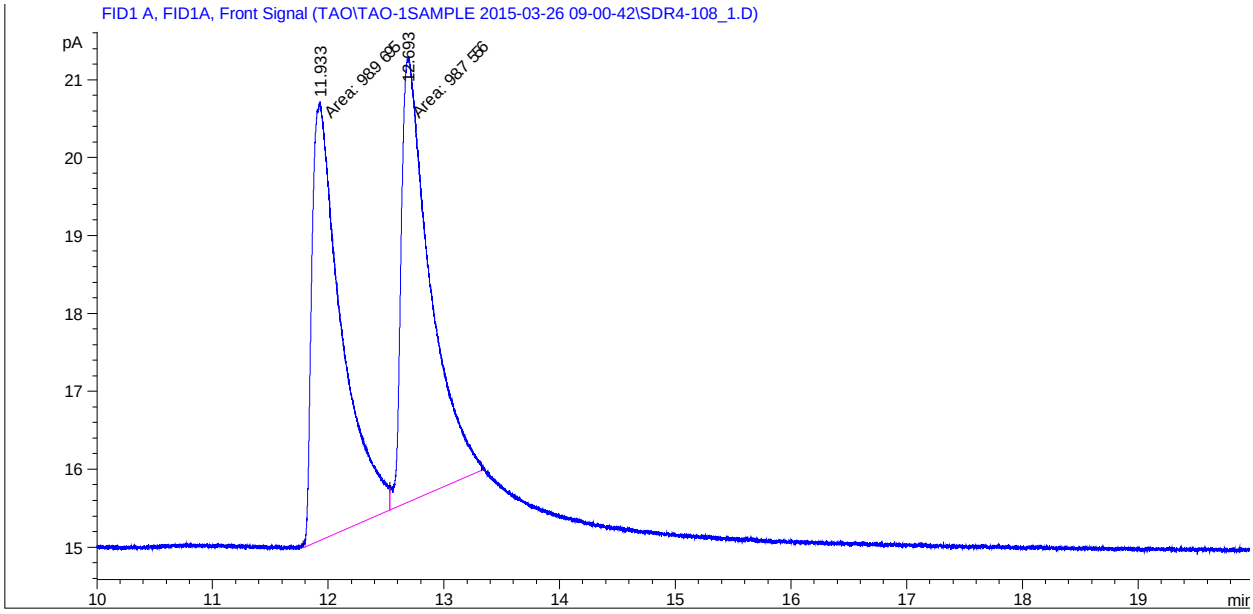
GC (cyclosil-B: Initial temperature: 110℃, rate: 1℃ /min, End temperature: 150℃), ee = 90%.

$[\alpha]^{25}_D$ = -4.7 (c = 0.63, $CHCl_3$)

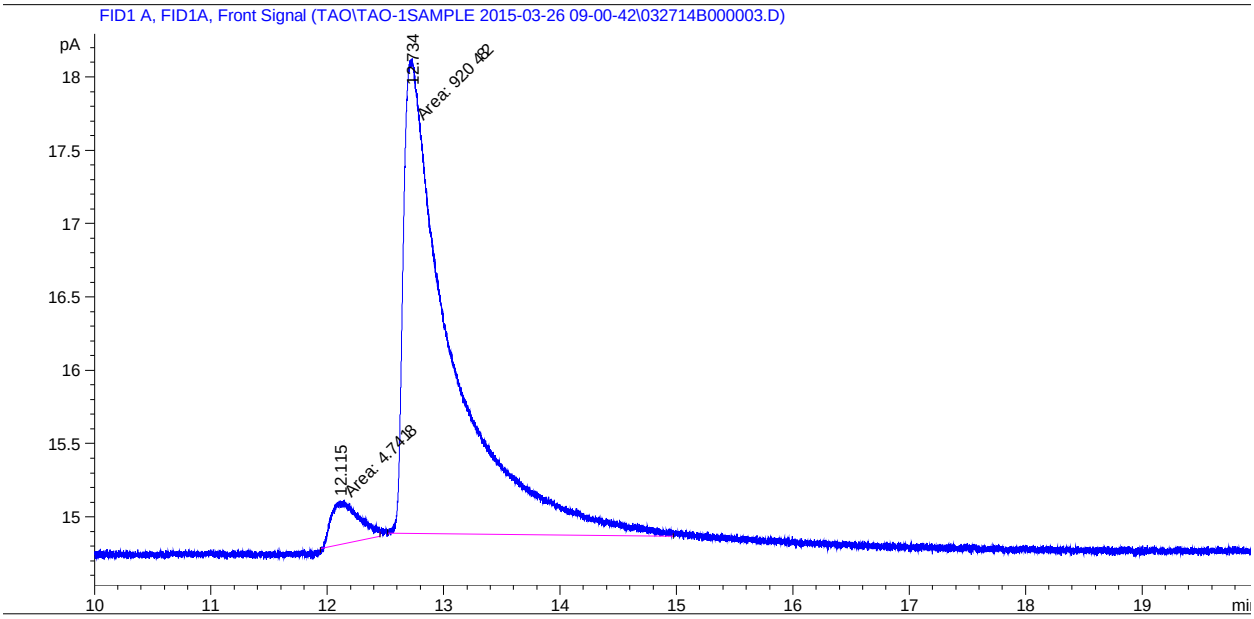

1.00
1.01
0.98
2.40
1.03
1.04
5.16
3.04


74.466
60.401
37.163
35.292
31.119
30.834
30.549
30.264
27.017
26.990
16.600



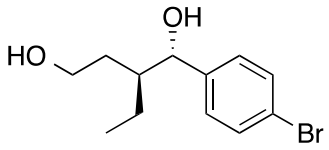


Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	11.933	MF	0.2926	98.96948	5.63673	50.05408
2	12.693	FM	0.2884	98.75562	5.70641	49.94592



Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	12.115	MM	0.2619	4.74180	3.01749e-1	4.89906
2	12.734	MM	0.4743	92.04816	3.23429	95.10094

(1*S*,2*S*)-1-(4-bromophenyl)-2-ethylbutane-1,4-diol (5p).



The residue was subjected to flash column chromatography for purification to furnish the title compound (34.3 mg, 63%, *dr* = >20:1) as a white solid.

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.46 (d, *J* = 8.4 Hz, 2H), 7.20 (d, *J* = 8.1 Hz, 2H), 4.54 (d, *J* = 6.5 Hz, 1H), 3.74 (ddd, *J* = 10.6, 6.8, 4.7 Hz, 1H), 3.58 (ddd, *J* = 10.6, 6.8, 4.7 Hz, 1H), 3.35 (s, 1H), 1.78 – 1.60 (m, 3H), 1.40 – 1.14 (m, 3H), 0.88 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 143.08, 131.35, 128.20, 121.01, 76.00, 60.69, 45.26, 31.68, 23.66, 11.43.

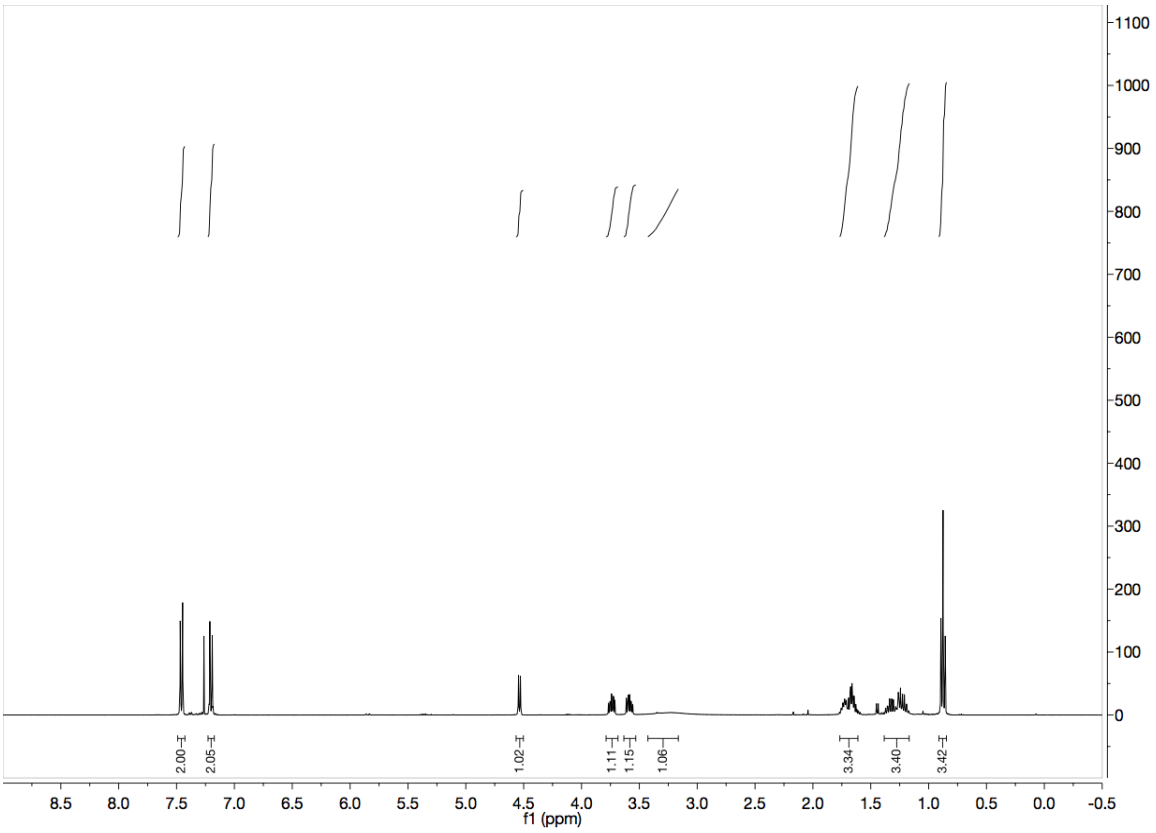
LRMS (CI) Calcd. for $C_{12}H_{17}BrNaO_2$ $[M+Na]^+$: 295, Found: 295.

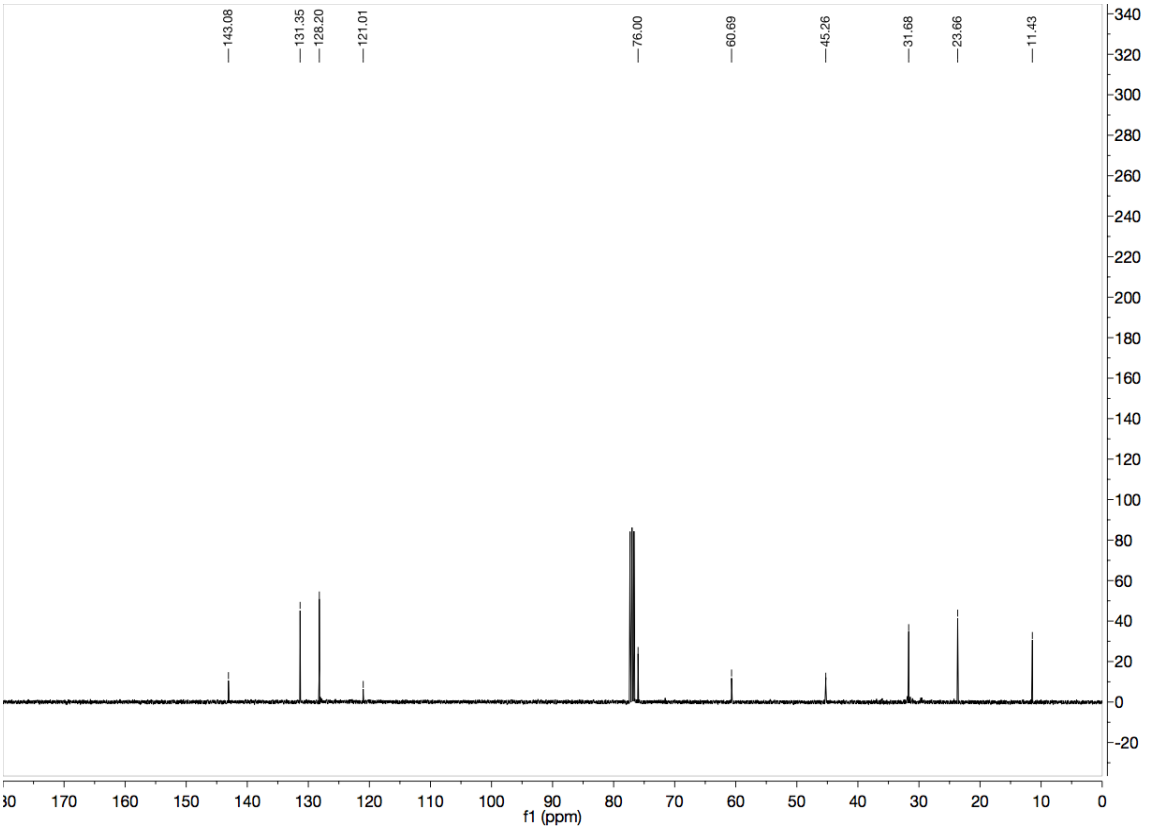
FTIR (neat): 3299, 2886, 1070, 1057, 1008, 838, 686, 669 cm^{-1}.

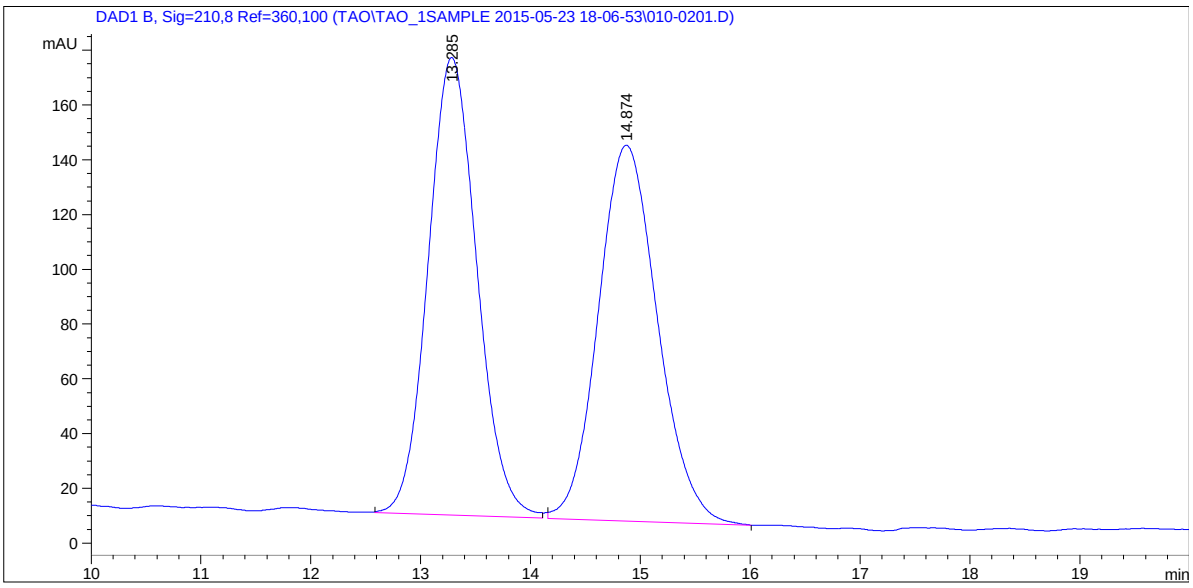
HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 230 nm), ee = 96%.

$[\alpha]^{25}_D$ = -30.0 (c = 0.45, $CHCl_3$)

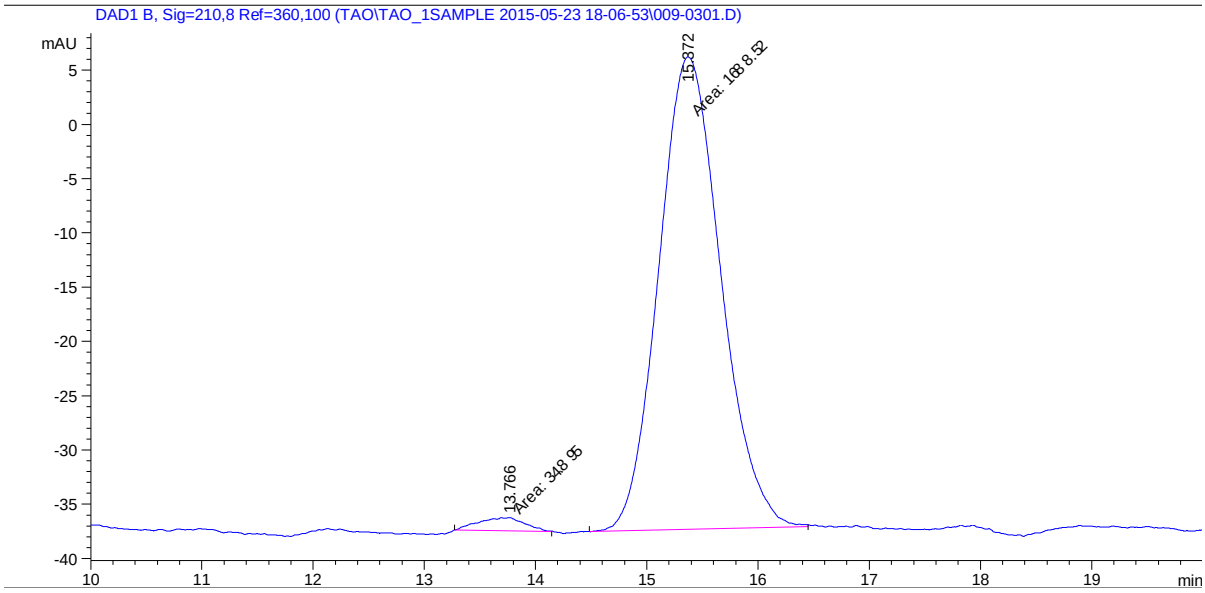
M.P. 134.9-135.9 ºC


2.00
2.05
1.02
1.11
1.15
1.06
3.34
3.40
3.42
f1 (ppm)


143.08
131.35
128.20
121.01
76.00
60.69
45.26
31.68
23.66
11.43
f1 (ppm)

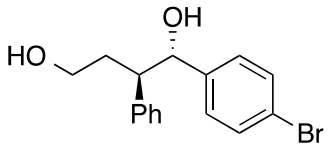


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.285	BB	0.4783	5161.87988	167.12447	50.0902
2	14.874	BB	0.5751	5143.28369	137.27925	49.9098



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.766	MM	0.4741	34.89495	1.22664	2.0248
2	15.372	MM	0.6464	1688.51941	43.53523	97.9752

(1*S*,2*R*)-1-(4-bromophenyl)-2-phenylbutane-1,4-diol (5q).



The residue was subjected to flash column chromatography for purification to furnish the title compound (41 mg, 64%, *dr* = >20:1).

R_f = 0.3 (50% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, Methanol-d_4) δ 7.22 – 7.14 (m, 2H), 7.09 – 7.02 (m, 2H), 7.01 – 6.96 (m, 1H), 6.95 – 6.89 (m, 4H), 4.58 (d, *J* = 8.1 Hz, 1H), 3.30 (ddd, *J* = 10.6, 8.0, 4.5 Hz, 1H), 3.26 – 3.15 (m, 3H), 2.87 (ddd, *J* = 11.5, 8.1, 3.7 Hz, 1H), 2.33 – 2.17 (m, 1H), 1.93 – 1.75 (m, 1H).

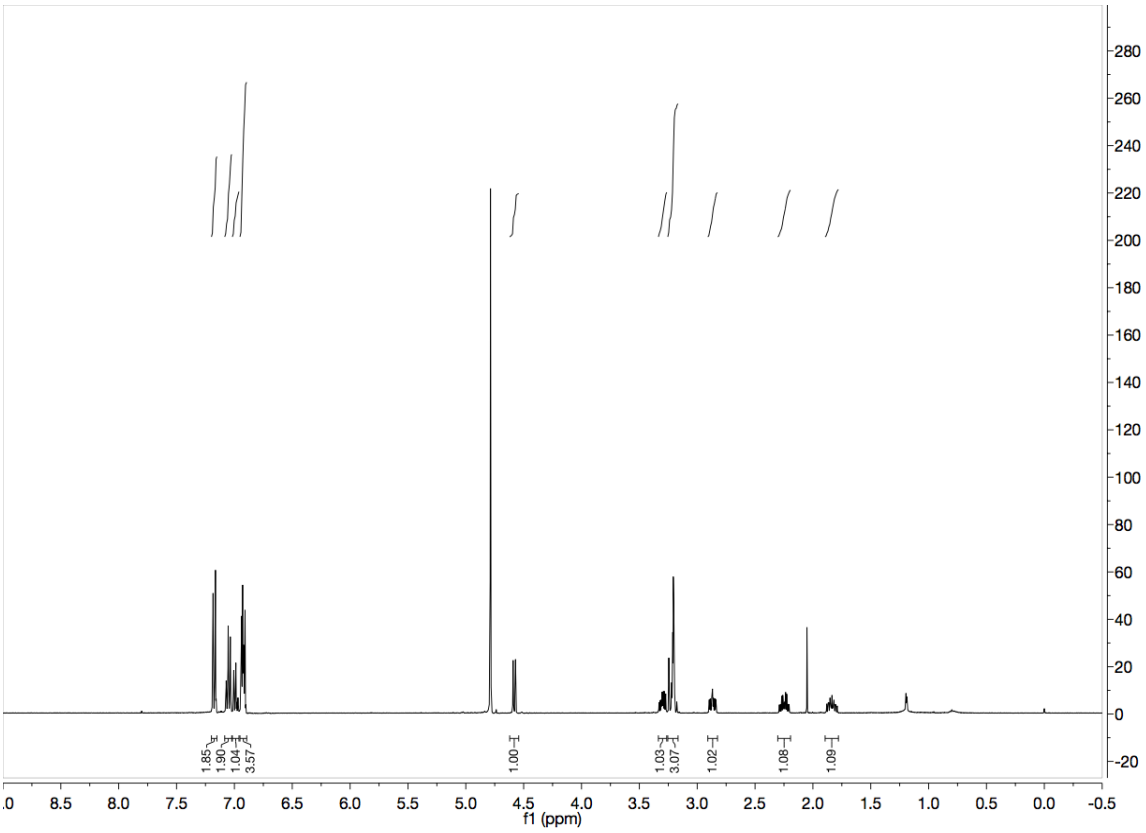
^{13}C NMR (100 MHz, Methanol-d_4): δ 144.57, 142.79, 131.71, 129.89, 129.84, 129.12, 127.39, 121.47, 78.79, 61.27, 51.78, 35.43.

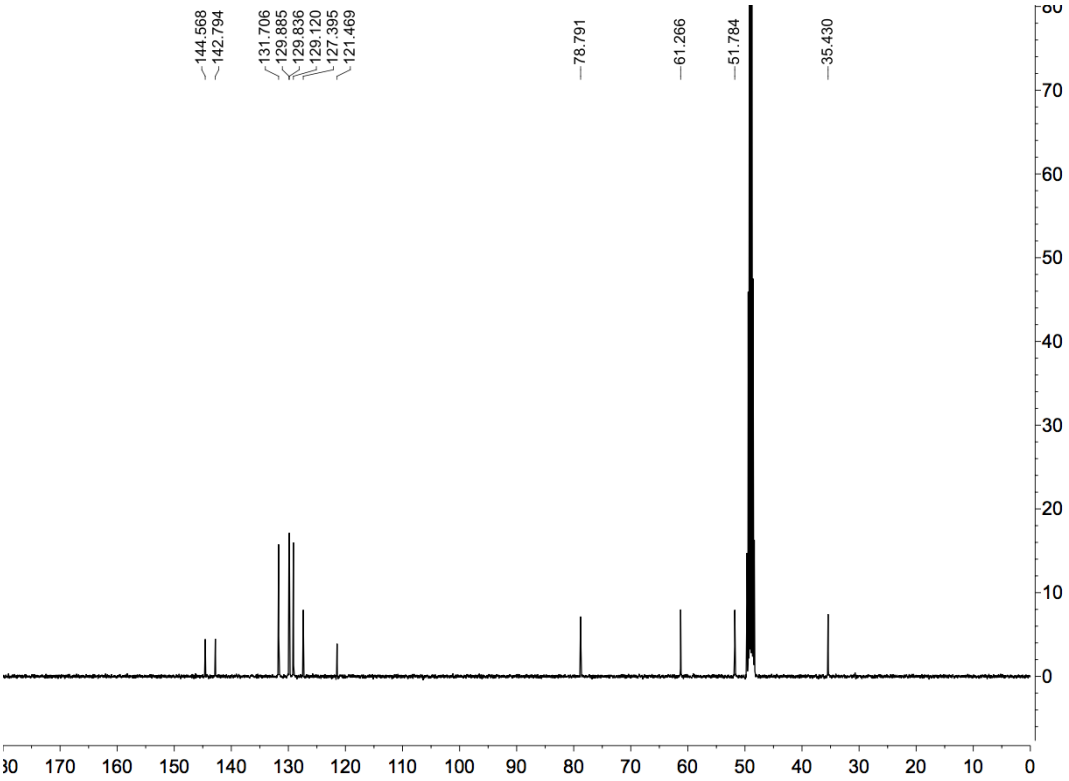
LRMS (CI) Calcd. for $C_{16}H_{17}BrNaO_2$ $[M+Na]^+$: 343, Found: 343.

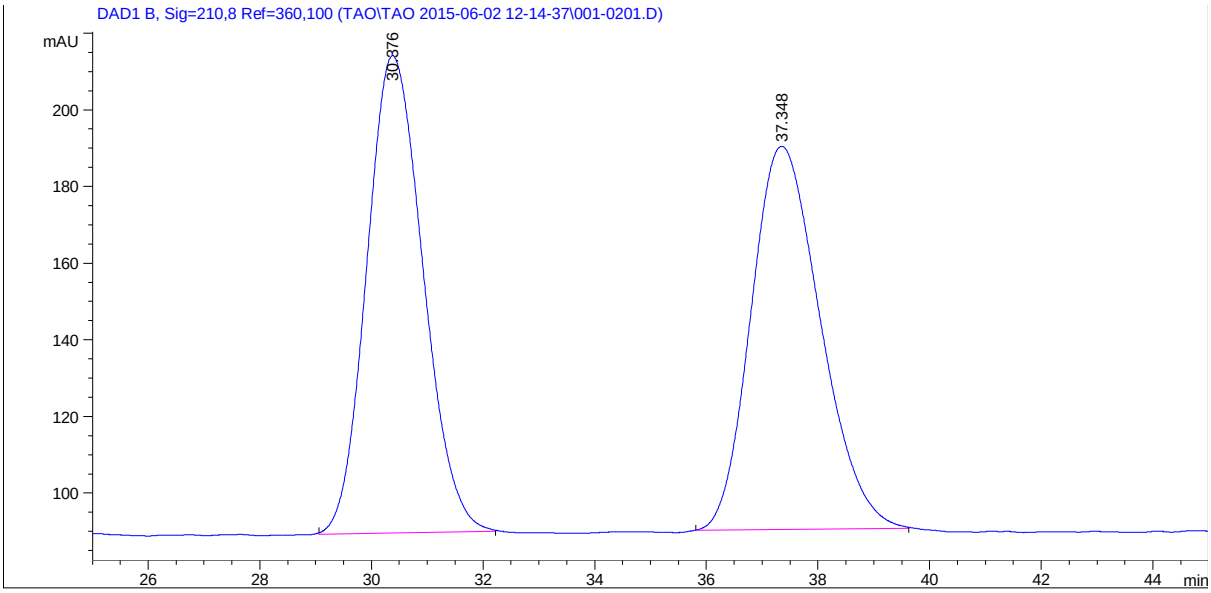
FTIR (neat): 2362, 1486, 1070, 1037, 1008, 818, 756, 700 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 90%.

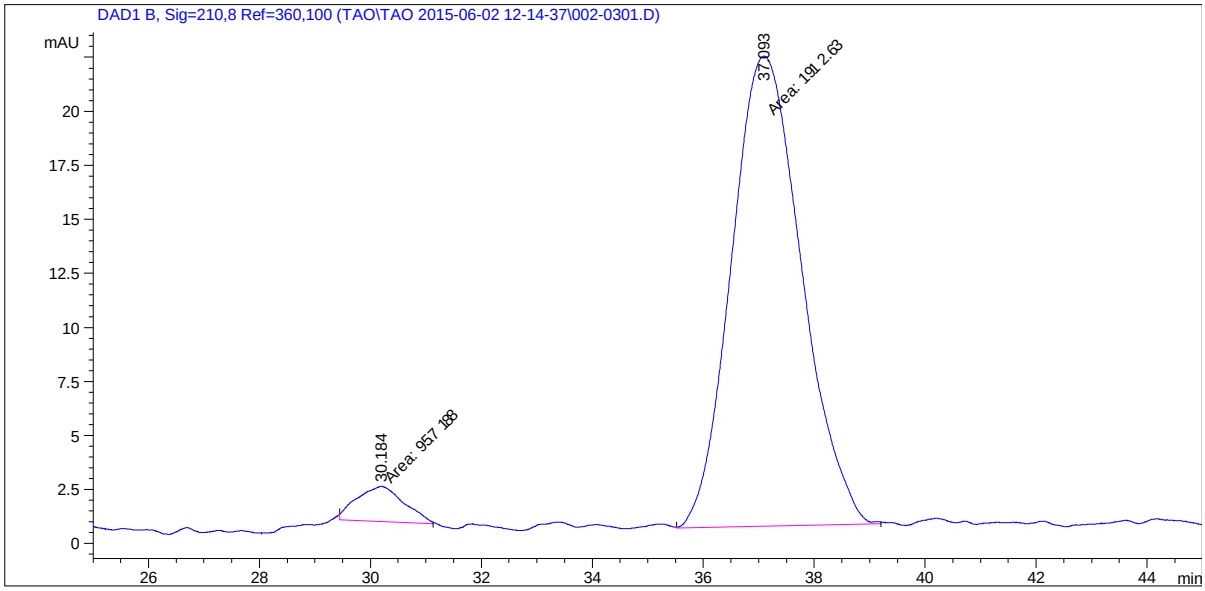
$[\alpha]^{25}_D$ = -1.3 (c = 1.0, Methanol)


1.85
1.90
1.04
3.57
1.00
1.03
3.07
1.02
1.08
1.09
f1 (ppm)


144.568
142.794
131.706
129.885
129.836
129.120
127.395
121.469
78.791
61.266
51.784
35.430



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.376	BB	1.0911	8726.72266	124.59850	50.2329
2	37.348	BB	1.3323	8645.80469	100.04136	49.7671

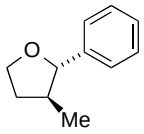


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.184	MM	0.9871	95.71881	1.61612	4.7660
2	37.093	MM	1.4656	1912.62830	21.75019	95.2340

C. General Procedure for Conversion of Alcohols 5a, 5c, 5e, 5f, 5k and 5m to *trans*-2,3-disubstituted furans 6a, 6c, 6e, 6f, 6k and 6m

To a solution of alcohol in pyridine (0.4 M) at 0 °C was added TsCl (1.5 eq) in one portion. The mixture was stirred at 0 °C for 5 hours and was allowed to warm to room temperature overnight. Once TLC indicated no alcohol left, pyridine was removed by vacuo and the residue was subjected to flash column chromatography (Alumina, basic, 60-325 Mesh, eluent Hexanes:EA = 20:1) to afford the corresponding disubstituted furan products.

(2*S*,3*S*)-3-methyl-2-phenyltetrahydrofuran (6a).



The residue was subjected to flash column chromatography for purification to furnish the title compound (81%, *dr* = >20:1) as a colorless liquid.

R_f = 0.7 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.21 (m, 5H), 4.28 (d, *J* = 8.3 Hz, 1H), 4.10 (td, *J* = 8.3, 7.0 Hz, 1H), 4.03 (td, *J* = 8.4, 4.2 Hz, 1H), 2.27 – 2.15 (m, 1H), 2.15 – 1.99 (m, 1H), 1.71 (dq, *J* = 12.0, 8.5 Hz, 1H), 1.08 (d, *J* = 6.6 Hz, 3H).

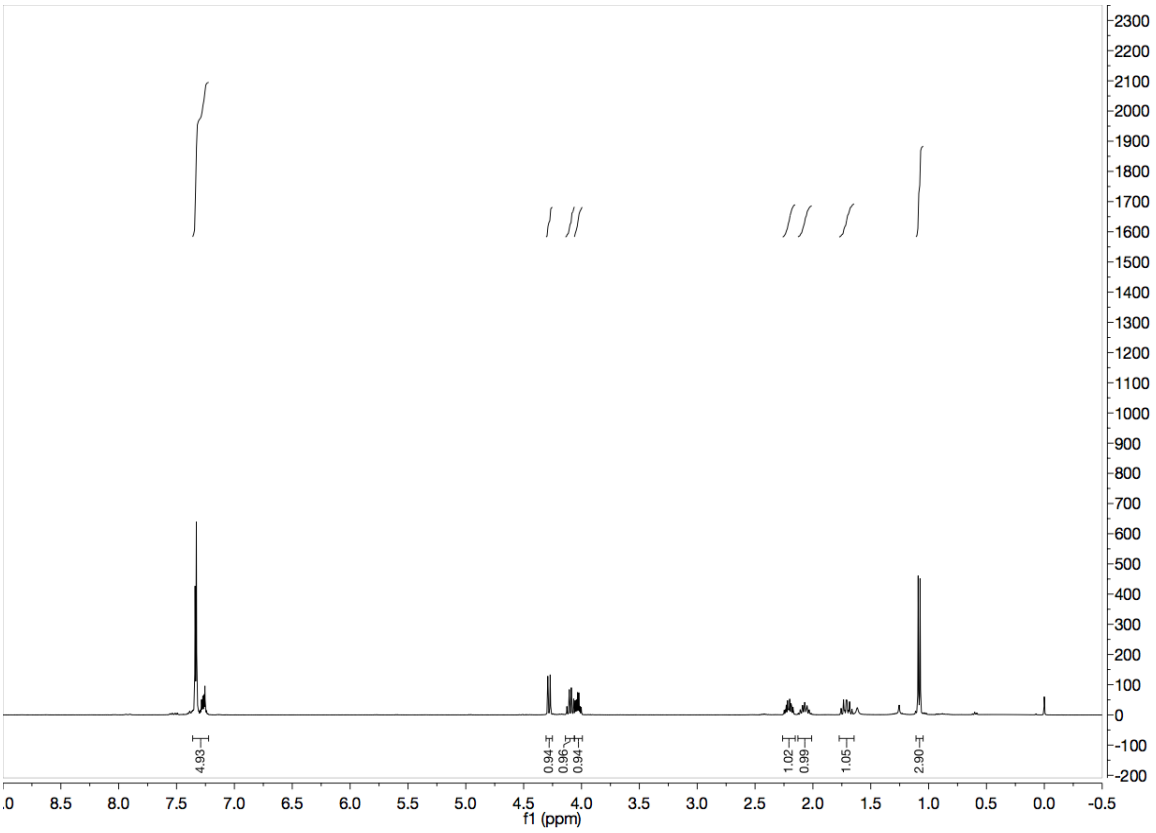
^{13}C NMR (100 MHz, $CDCl_3$): δ 142.21, 128.27, 127.40, 126.08, 87.91, 67.90, 42.87, 34.95, 16.38.

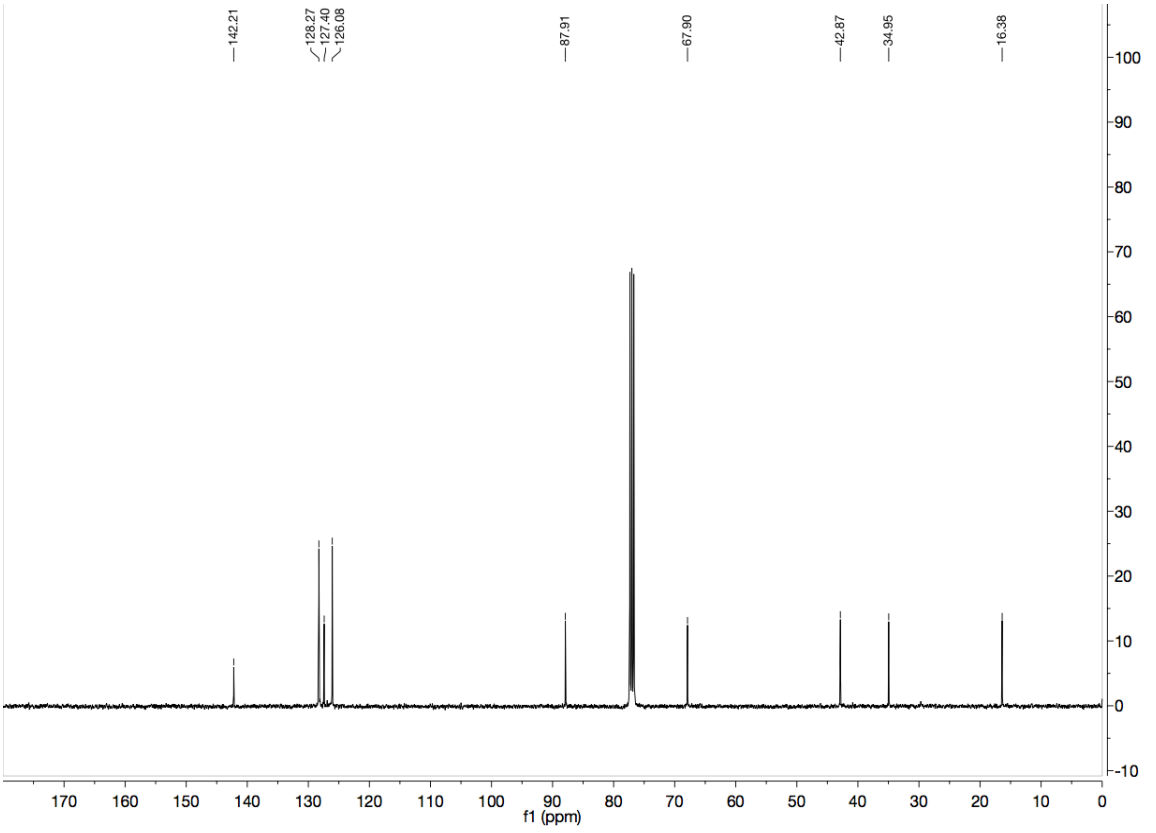
LRMS (CI) Calcd. for $C_{11}H_{15}O$ $[M+H]^+$: 163, Found: 163.

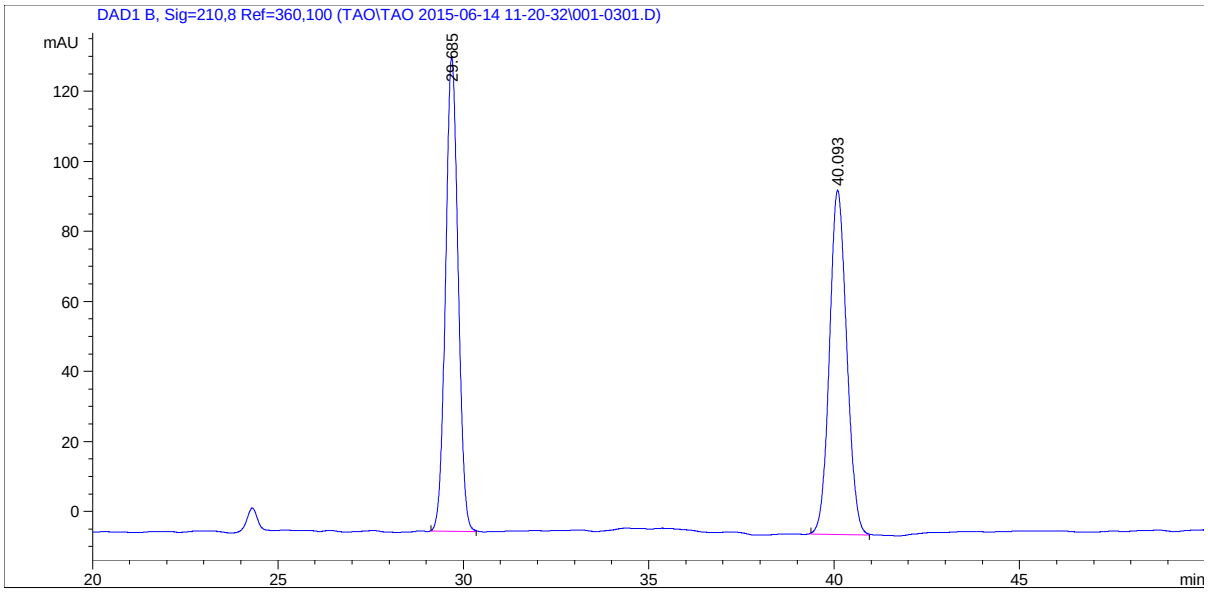
FTIR (neat): 1453, 1097, 1044, 1026, 995, 926, 751, 699 cm^{-1}.

HPLC (Chiralcel OJ-H/OJ-H column, hexanes:*i*-PrOH = 99:1, 1 mL/min, 210 nm), ee = 91%.

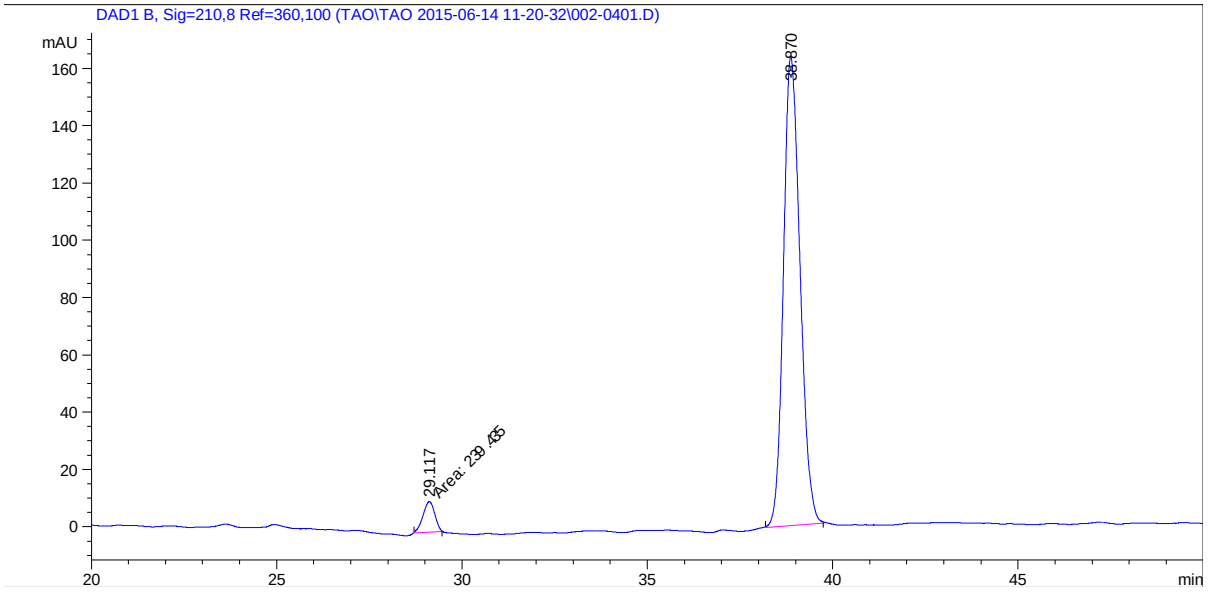
$[\alpha]^{25}_D$ = -9.7 (c = 0.52, $CHCl_3$)


4.93
0.94
0.96
0.94
1.02
0.99
1.05
2.90
f1 (ppm)


142.21
128.27
127.40
126.08
87.91
67.90
42.87
34.95
16.38
f1 (ppm)

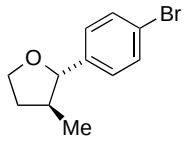


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.685	BB	0.3669	3197.04639	135.66116	50.0370
2	40.093	BB	0.5027	3192.31348	98.35523	49.9630



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.117	MM	0.3720	239.43546	10.72619	4.4972
2	38.870	BB	0.4801	5084.62305	163.82202	95.5028

(2*S*,3*S*)-2-(4-bromophenyl)-3-methyltetrahydrofuran (6c).



The residue was subjected to flash column chromatography for purification to furnish the title compound (78%, *dr* = >20:1) as a colorless liquid.

R_f= 0.7 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.44 (m, 2H), 7.23 – 7.19 (m, 2H), 4.24 (d, *J* = 8.2 Hz, 1H), 4.08 (td, *J* = 8.3, 7.0 Hz, 1H), 4.02 (td, *J* = 8.4, 4.3 Hz, 1H), 2.25 – 2.16 (m, 1H), 2.07 – 1.94 (m, 1H), 1.77 – 1.66 (m, 1H), 1.07 (d, *J* = 6.6 Hz, 3H).

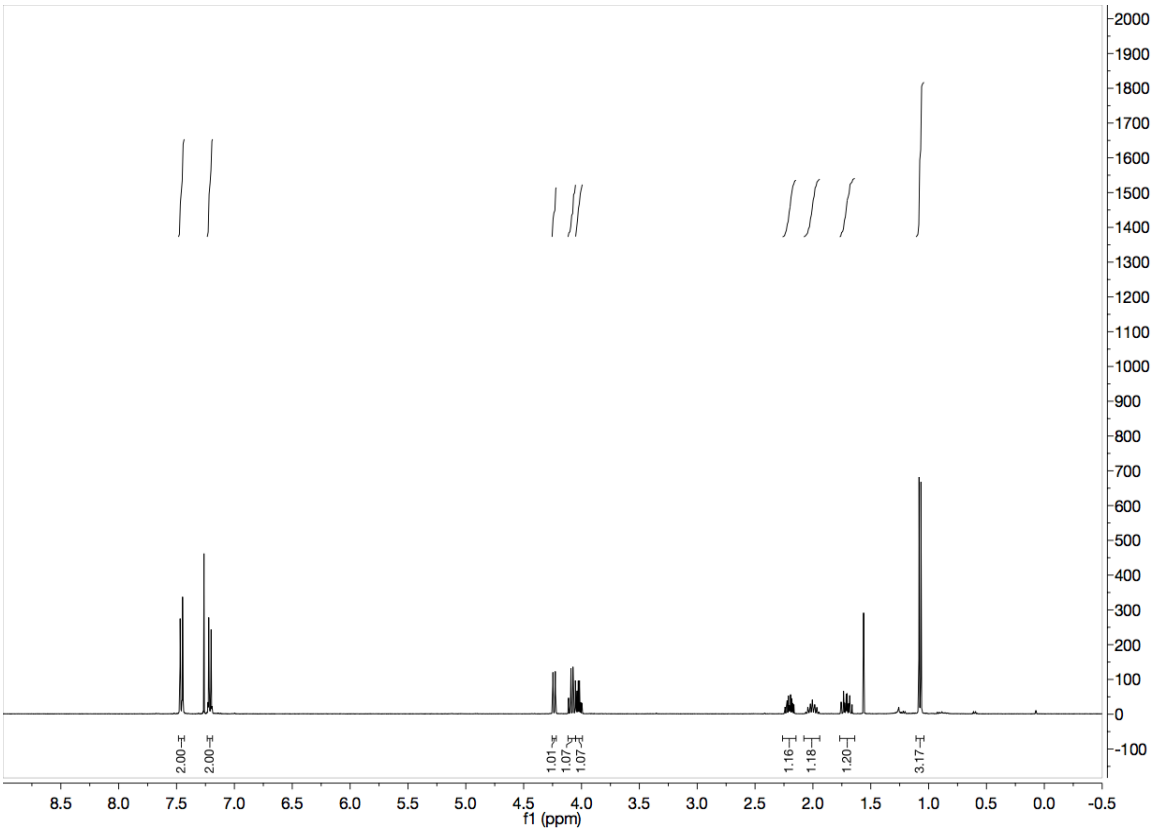
^{13}C NMR (100 MHz, $CDCl_3$): δ 141.35, 131.36, 127.74, 121.11, 87.21, 67.92, 43.02, 34.85, 16.25.

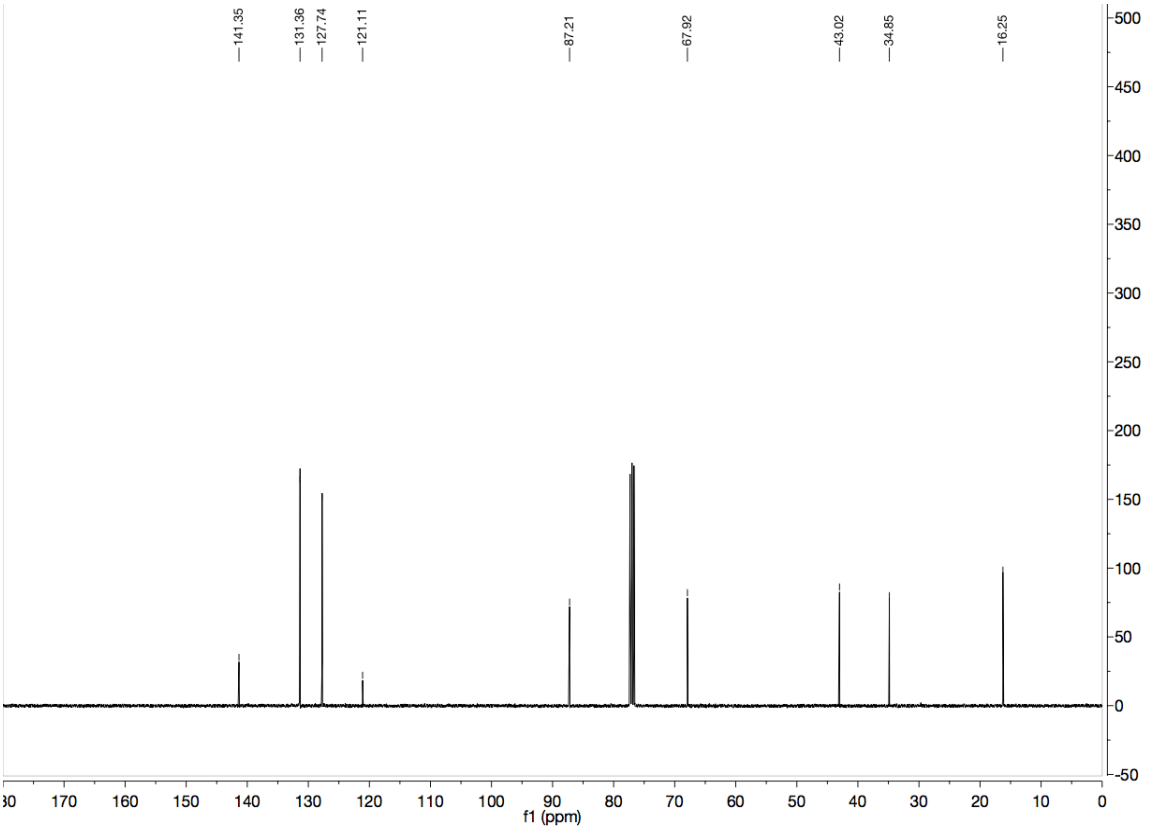
LRMS (CI) Calcd. for $C_{11}H_{14}BrO$ $[M+H]^+$: 241, Found: 241.

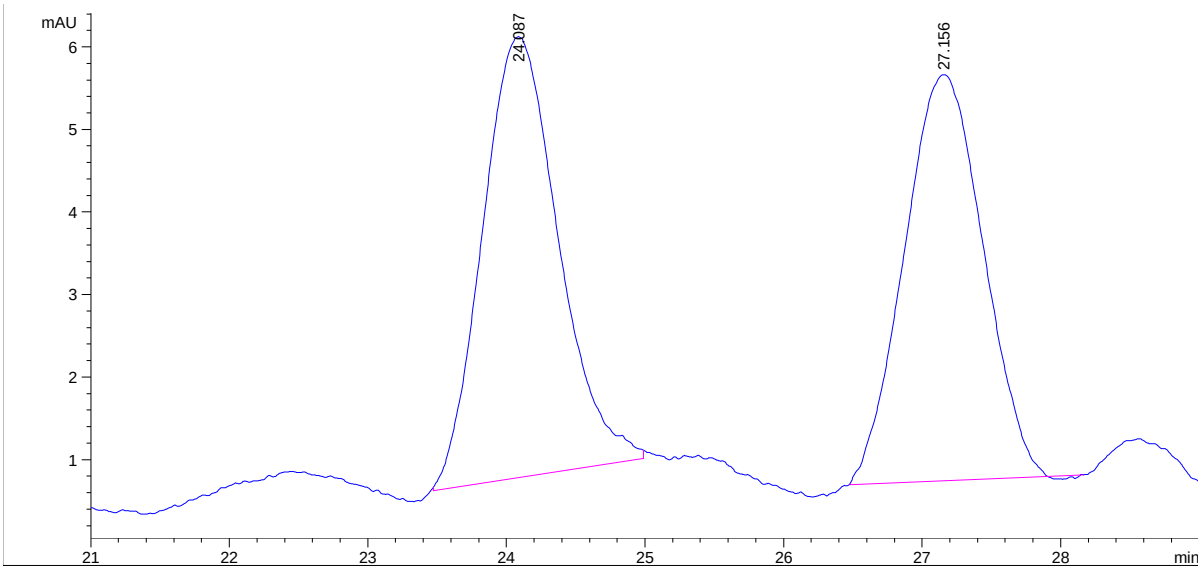
FTIR (neat): 2960, 2871, 1486, 1069, 1046, 1010, 819, 800 cm^{-1}.

HPLC (Chiralcel AD-H/AD-H column, hexanes:*i*-PrOH = 99:1, 0.5 mL/min, 210 nm), ee = 92%.

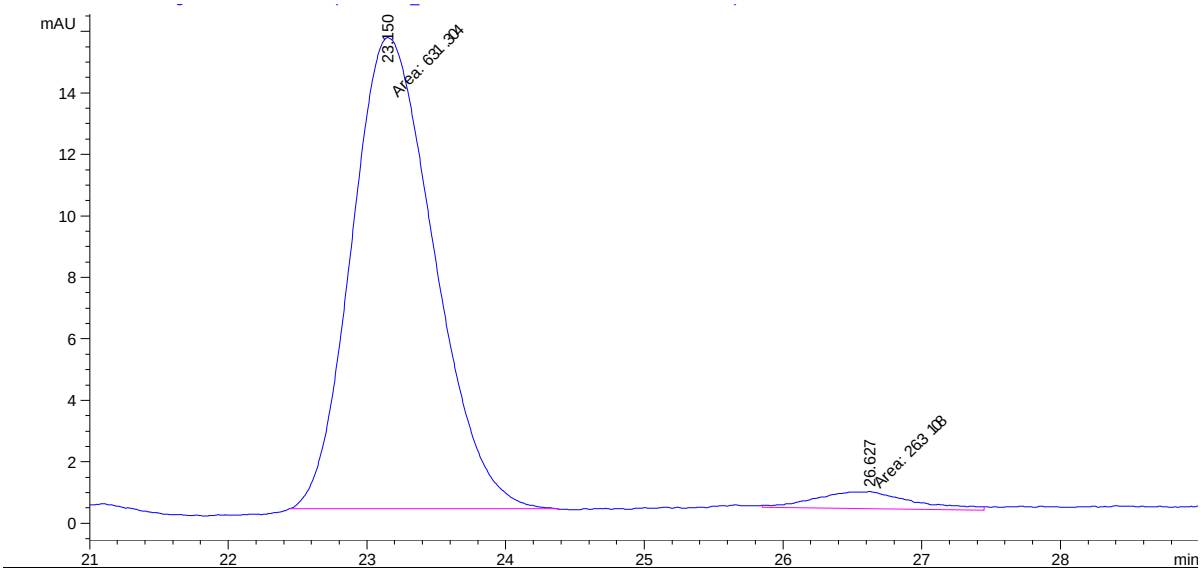
$[\alpha]^{25}_D$ = -1.8 (c = 1.15, $CHCl_3$)


2.00
2.00
1.01
1.07
1.07
1.16
1.18
1.20
3.17
f1 (ppm)


141.35
131.36
127.74
121.11
87.21
67.92
43.02
34.85
16.25
f1 (ppm)

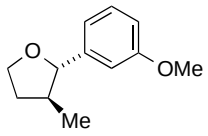


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.081	BB	0.5451	592.29285	15.95542	49.1568
2	27.161	MM	0.6626	612.61224	15.40874	50.8432



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.150	MM	0.6870	631.30402	15.31611	95.9991
2	26.627	MM	0.7998	26.31081	5.48276e-1	4.0009

(2*S*,3*S*)-2-(3-methoxyphenyl)-3-methyltetrahydrofuran (6e).



The residue was subjected to flash column chromatography for purification to furnish the title compound (80%, *dr* = >20:1) as a colorless liquid.

R_f = 0.7 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 – 7.23 (m, 1H), 6.93 – 6.89 (m, 2H), 6.83 – 6.79 (m, 1H), 4.27 (d, *J* = 8.1 Hz, 1H), 4.09 (td, *J* = 8.2, 7.0 Hz, 1H), 4.03 (td, *J* = 8.4, 4.3 Hz, 1H), 3.82 (s, 3H), 2.25 – 2.15 (m, 1H), 2.13 – 2.01 (m, 1H), 1.76 – 1.64 (m, 1H), 1.10 (d, *J* = 6.6 Hz, 3H).

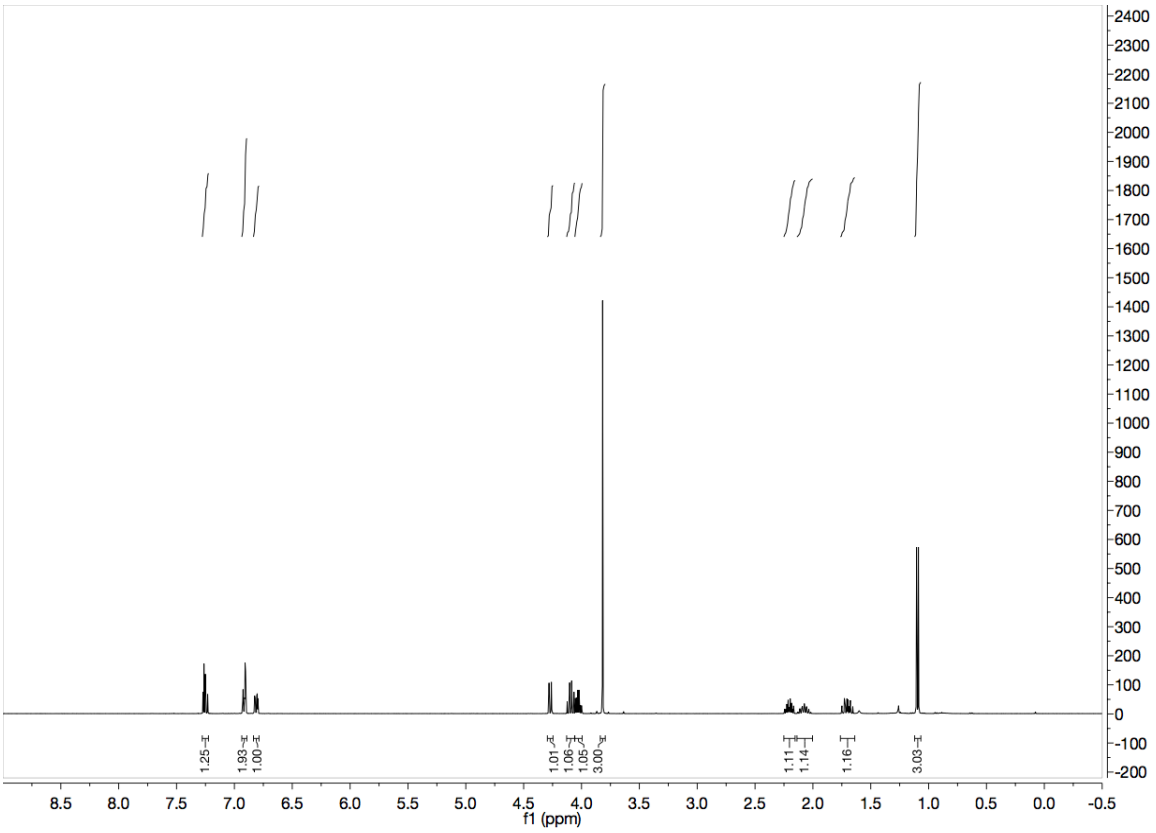
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.66, 144.03, 129.24, 118.43, 112.85, 111.45, 87.75, 67.90, 55.19, 42.79, 34.91, 16.53.

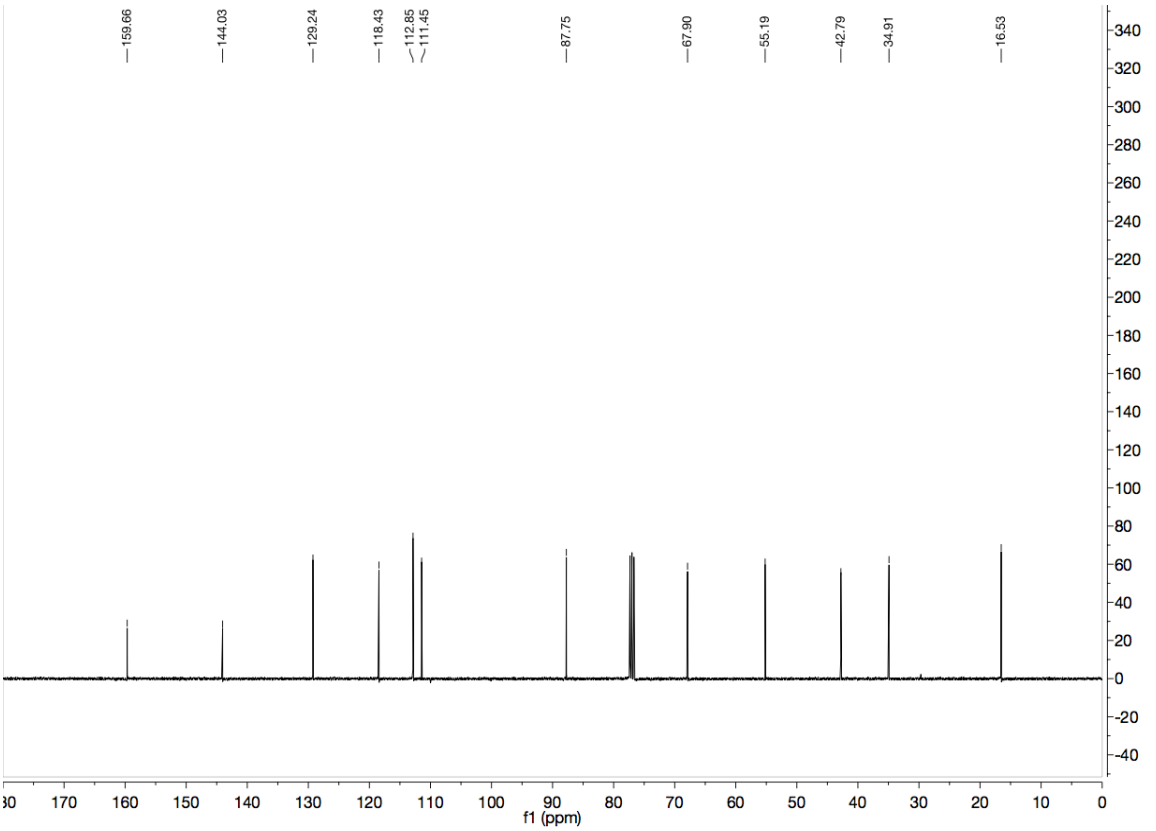
LRMS (ESI) Calcd. for $C_{12}H_{17}O_2$ $[M+H]^+$: 193, Found: 193.

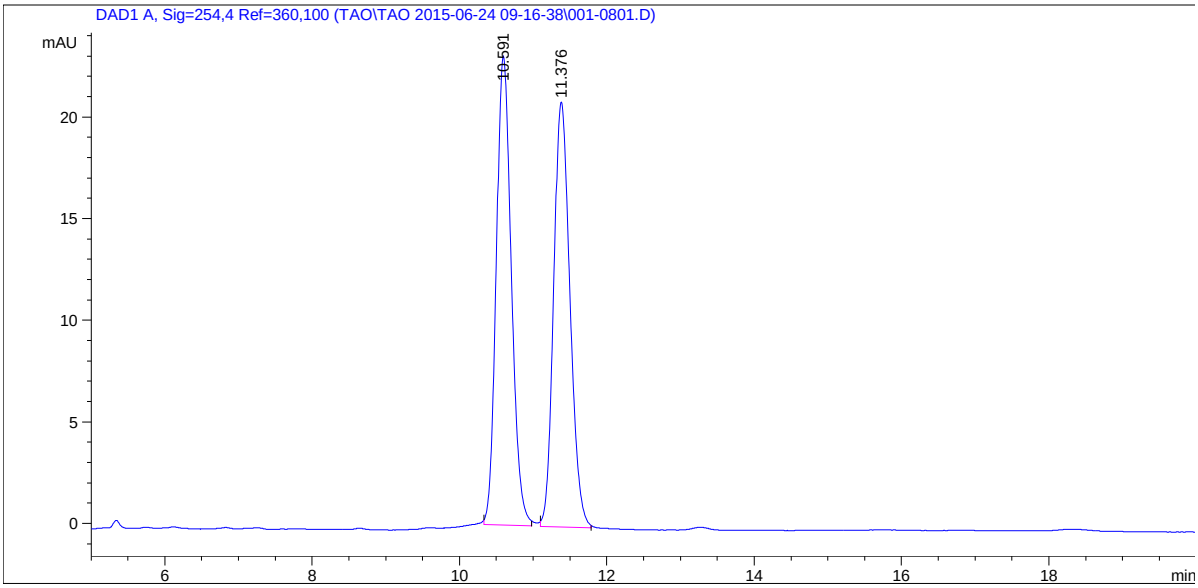
FTIR (neat): 1602, 1585, 1488, 1455, 1267, 1158, 1040, 782 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 99:1, 1 mL/min, 210 nm), ee = 92%.

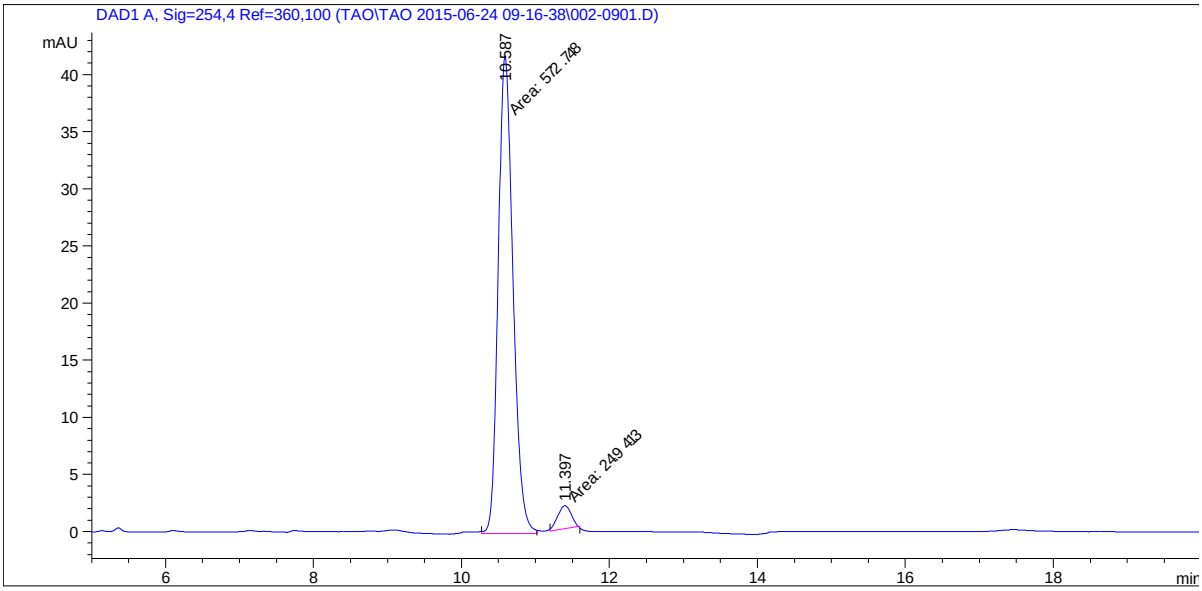
$[\alpha]^{25}_D$ = +1.9 (c = 0.52, $CHCl_3$)


1.25
1.93
1.00
1.01
1.06
1.05
3.00
1.11
1.14
1.16
3.03
f1 (ppm)


159.66
144.03
129.24
118.43
112.85
111.45
87.75
67.90
55.19
42.79
34.91
16.53
f1 (ppm)

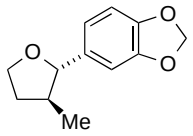


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.591	BB	0.2184	324.96088	23.06670	50.5531
2	11.376	BB	0.2353	317.84952	20.91154	49.4469



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.587	MM	0.2284	572.74780	41.79500	95.8270
2	11.397	MM	0.2063	24.94130	2.01465	4.1730

5-((2*S*,3*S*)-3-methyltetrahydrofuran-2-yl)benzo[*d*][1,3]dioxole (6f).



The residue was subjected to flash column chromatography for purification to furnish the title compound (82%, *dr* = >20:1) as a colorless liquid.

R_f = 0.7 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.86 – 6.84 (m, 1H), 6.80 – 6.75 (m, 2H), 5.94 (s, 2H), 4.18 (d, *J* = 8.4 Hz, 1H), 4.06 (td, *J* = 8.3, 7.0 Hz, 1H), 3.99 (td, *J* = 8.4, 4.2 Hz, 1H), 2.25 – 2.15 (m, 1H), 2.08 – 1.94 (m, 1H), 1.75 – 1.62 (m, 1H), 1.05 (d, *J* = 6.6 Hz, 3H).

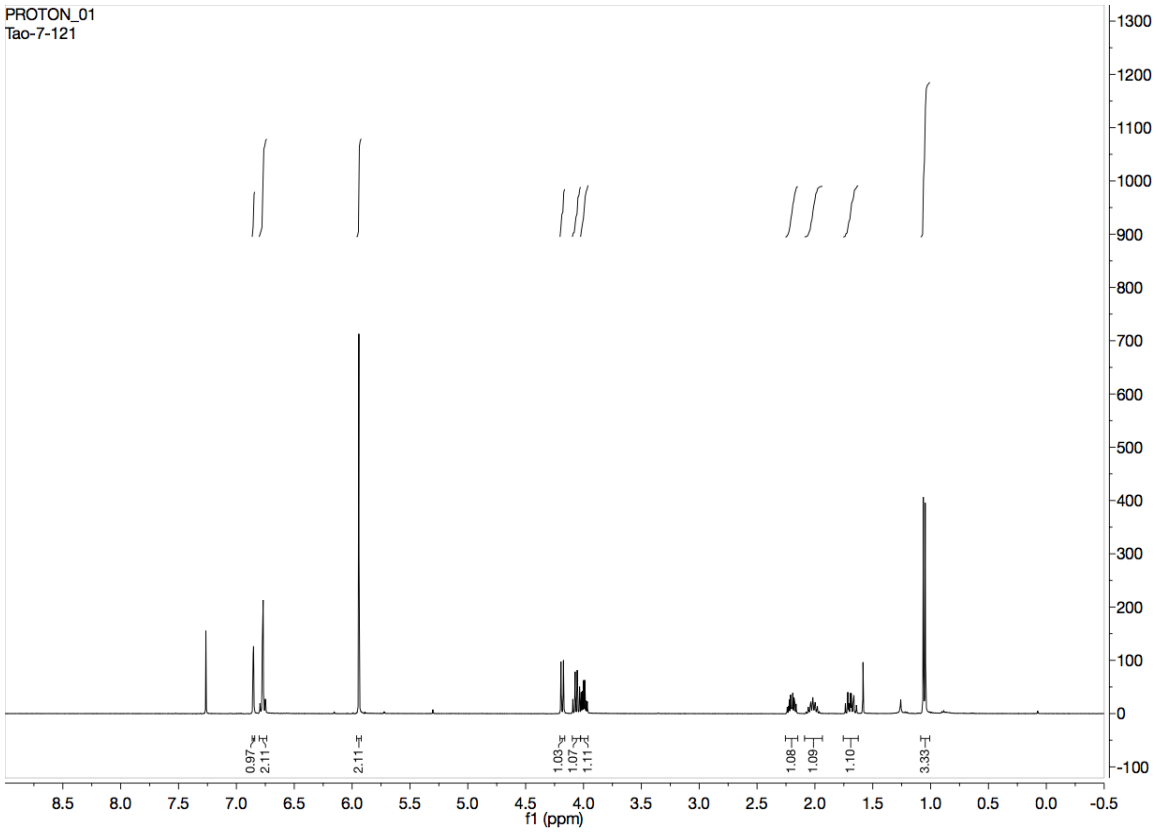
^{13}C NMR (100 MHz, $CDCl_3$): δ 147.70, 146.89, 136.04, 119.65, 107.91, 106.52, 100.89, 87.85, 67.73, 42.73, 34.87, 16.22.

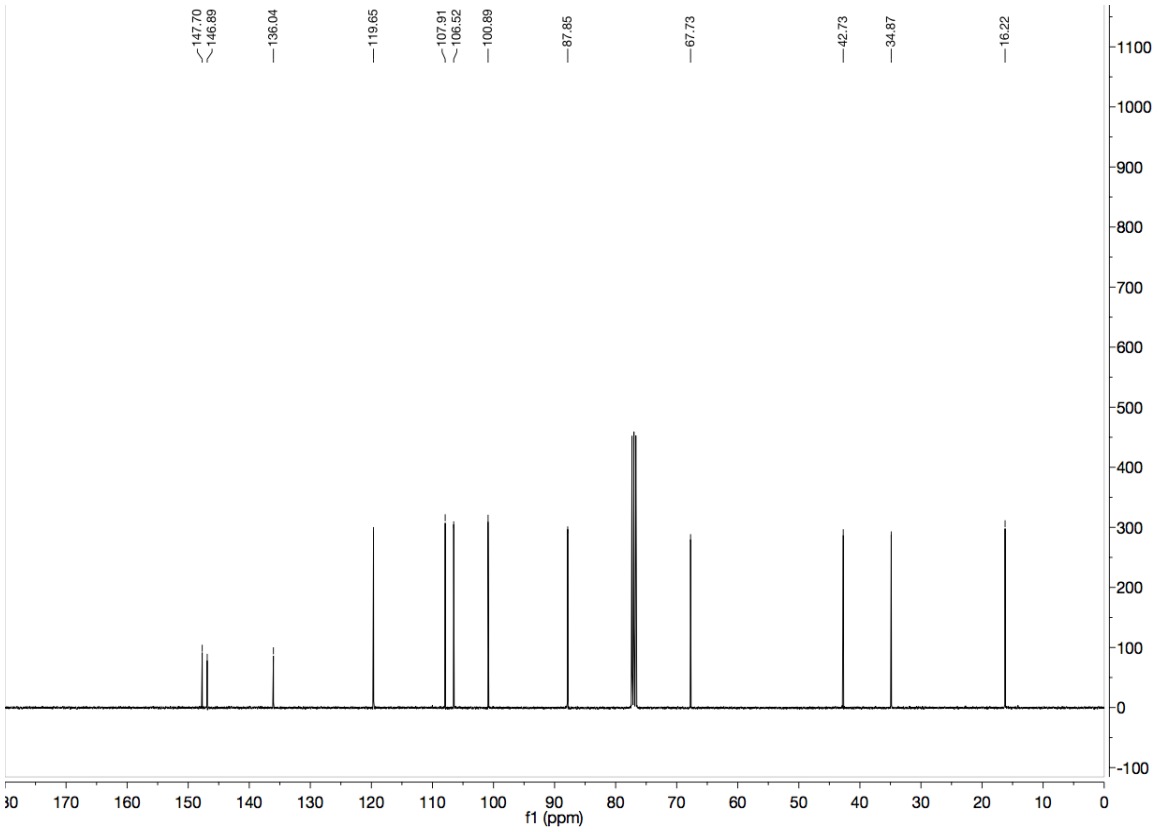
LRMS (ESI) Calcd. for $C_{12}H_{15}O_3$ $[M+H]^+$: 207, Found: 207.

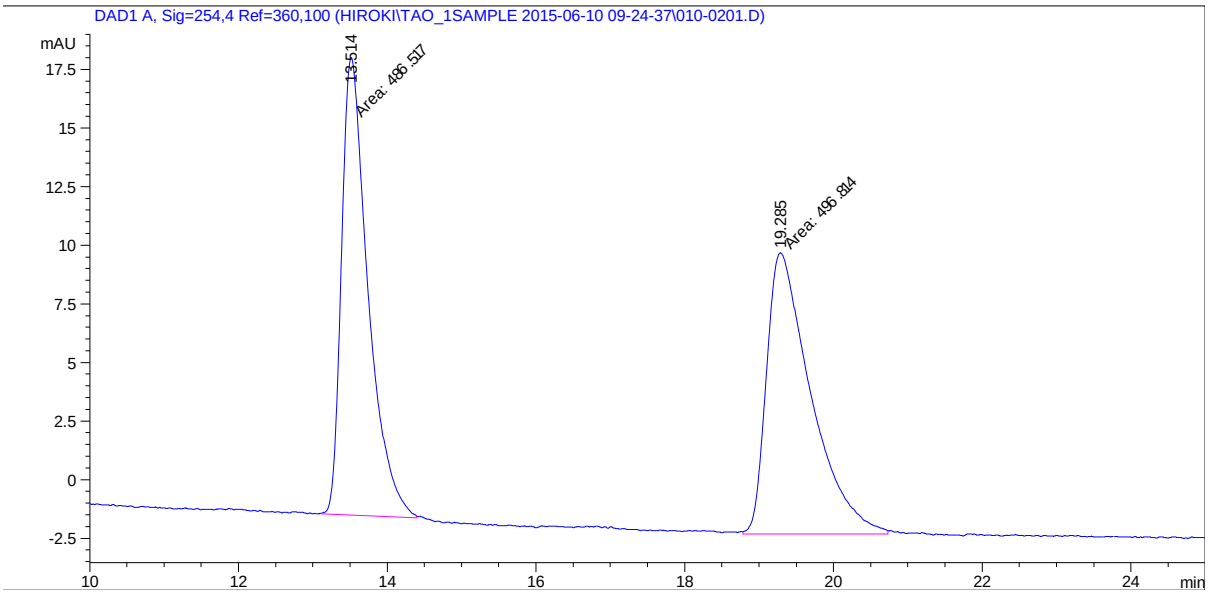
FTIR (neat): 1504, 1487, 1243, 1096, 1036, 934, 808, 784 cm^{-1}.

HPLC (Chiralcel AD-H column, hexanes:*i*-PrOH = 99:1, 1 mL/min, 254 nm), ee = 92%.

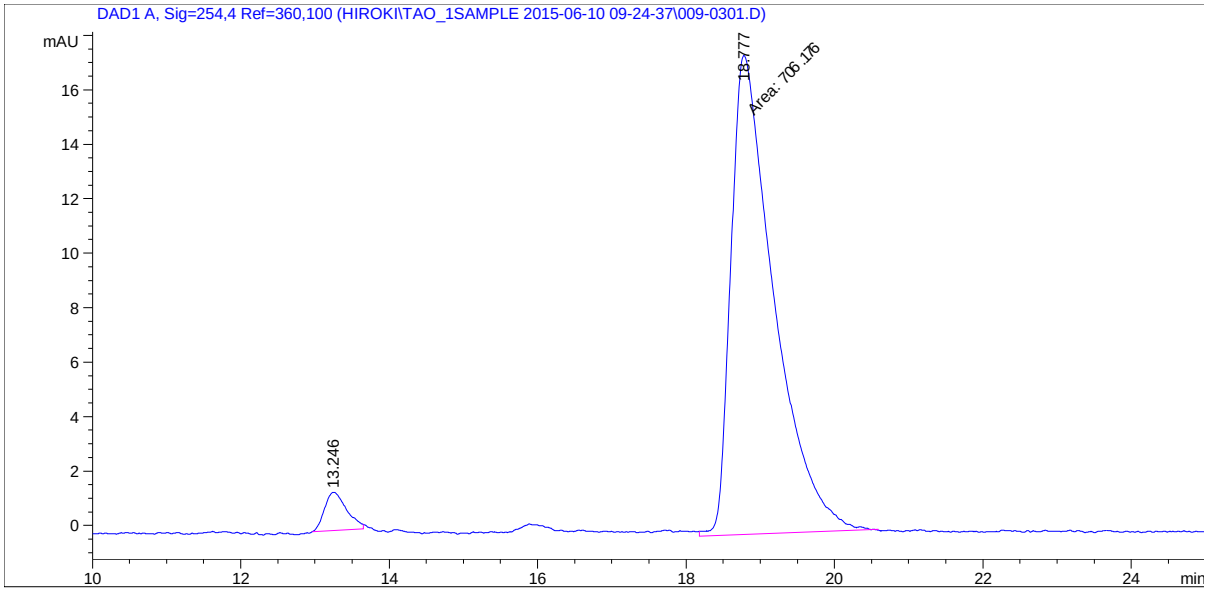
$[\alpha]^{25}_D$ = +5.2 (c = 0.58, $CHCl_3$)


PROTON_01
Tao-7-121
0.97
2.11
2.11
1.03
1.07
1.11
1.08
1.09
1.10
3.33
f1 (ppm)


147.70
146.89
136.04
119.65
107.91
106.52
100.89
87.85
67.73
42.73
34.87
16.22
f1 (ppm)

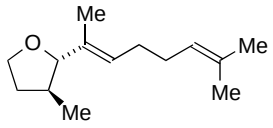


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.514	MM	0.4154	486.51660	19.51870	49.4764
2	19.285	MM	0.6902	496.81357	11.99724	50.5236



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	13.246	BB	0.2576	28.69911	1.39728	3.9053
2	18.777	MM	0.6696	706.17615	17.57615	96.0947

(2*S*,3*S*)-3-methyl-2-((*E*)-7-methylocta-2,6-dien-2-yl)tetrahydrofuran (6k).



The residue was subjected to flash column chromatography for purification to furnish the title compound (77%, *dr* = >20:1) as a colorless liquid.

R_f= 0.7 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.15 (dq, *J* = 8.8, 1.3 Hz, 1H), 5.12 – 5.06 (m, 1H), 4.00 (t, *J* = 8.7 Hz, 1H), 3.93 – 3.81 (m, 2H), 2.16 – 2.07 (m, 3H), 2.07 – 2.00 (m, 2H), 1.91 – 1.77 (m, 1H), 1.70 (d, *J* = 1.4 Hz, 3H), 1.68 (d, *J* = 1.3 Hz, 3H), 1.62 – 1.53 (m, 4H), 0.99 (d, *J* = 6.6 Hz, 3H).

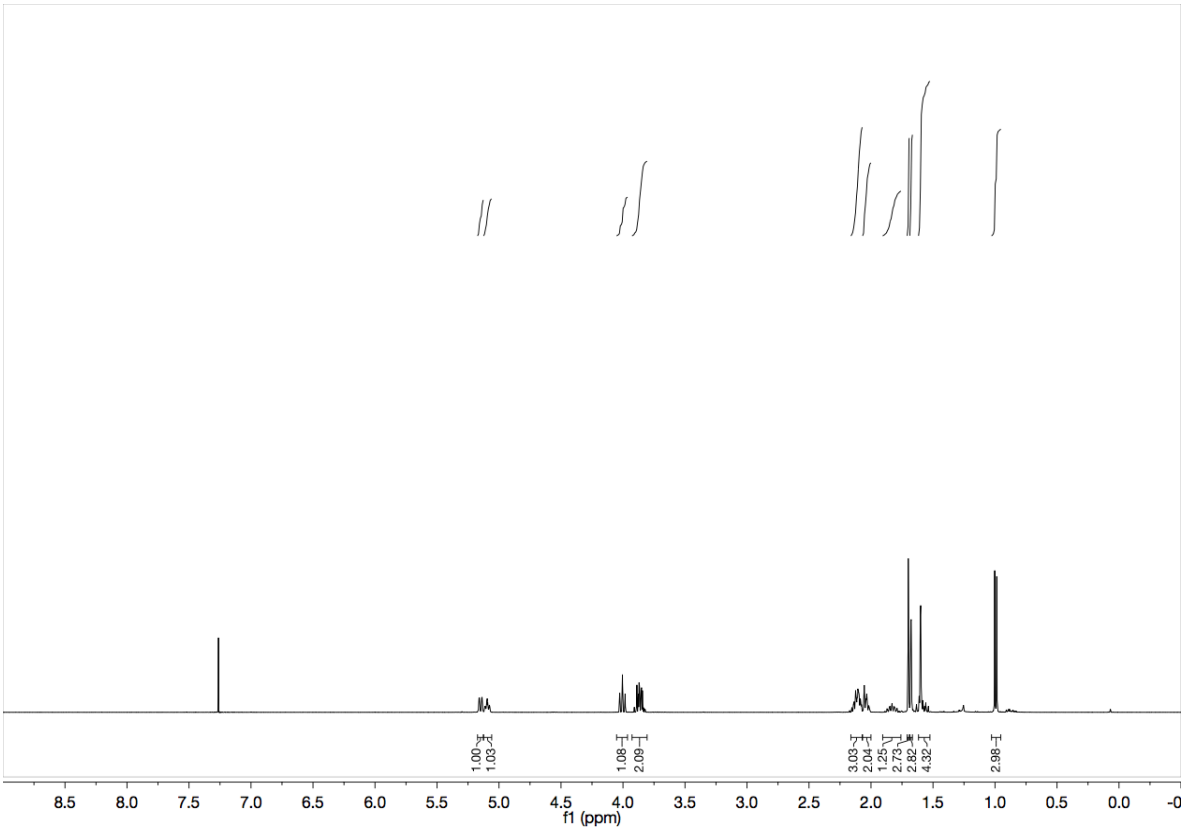
^{13}C NMR (100 MHz, $CDCl_3$): δ 140.32, 131.50, 124.60, 124.04, 82.24, 66.96, 40.71, 39.76, 34.78, 26.43, 25.65, 17.66, 16.75, 15.90.

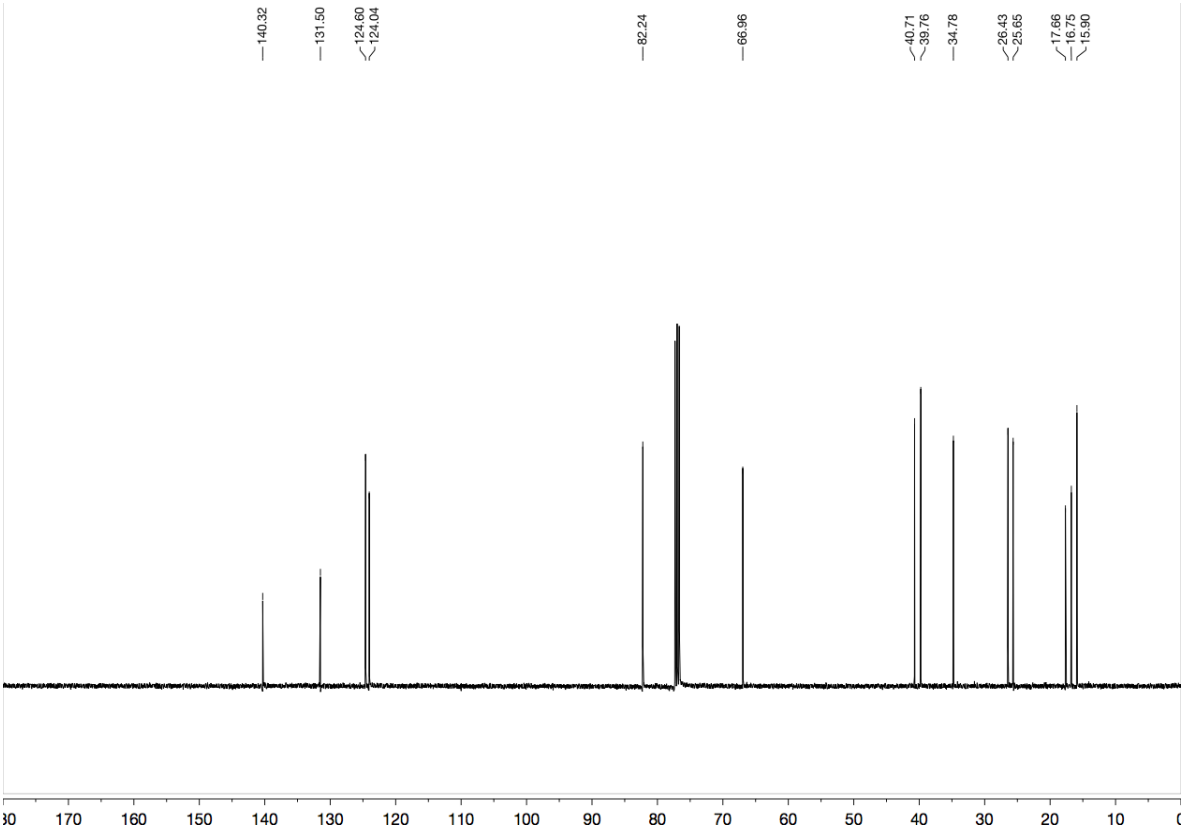
LRMS (ESI) Calcd. for $C_{14}H_{25}O$ $[M+H]^+$: 209, Found: 209.

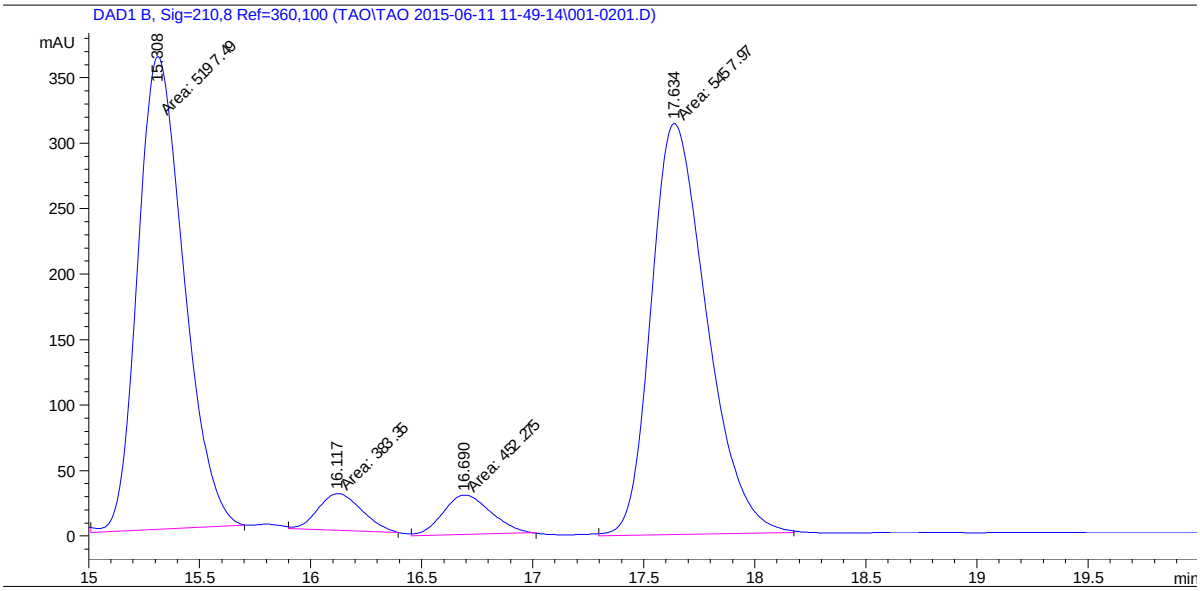
FTIR (neat): 2958, 2926, 2871, 1452, 1376, 1101, 1032, 987, 913 cm^{-1}.

HPLC (Chiralcel AD-H/AD-H column, hexanes:*i*-PrOH = 99:1, 0.5 mL/min, 254 nm), ee = 96%.

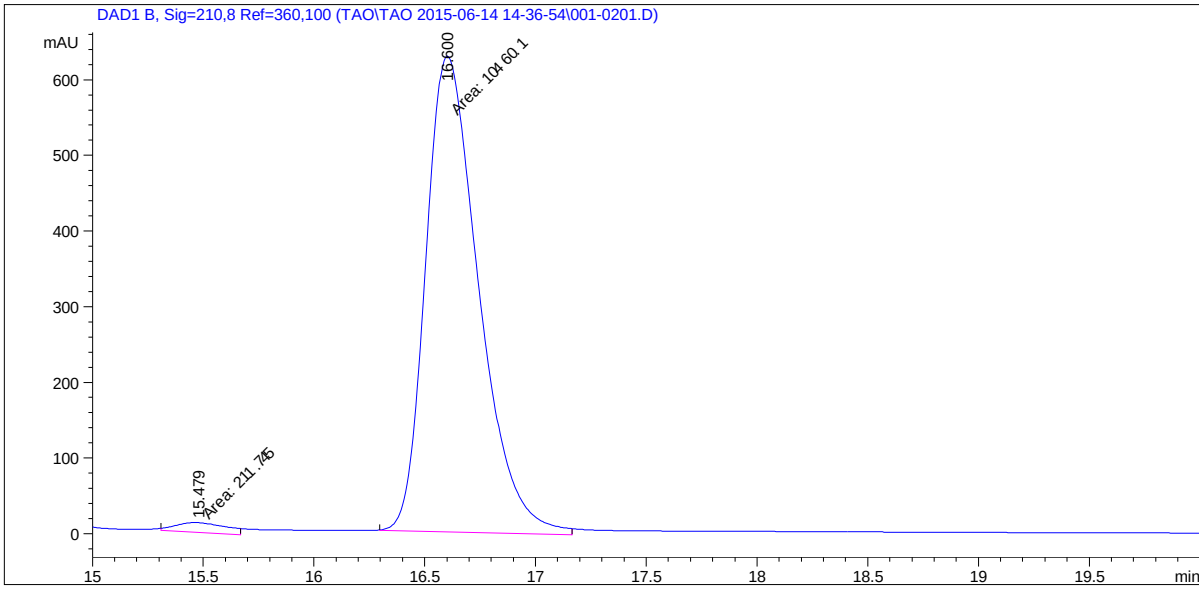
$[\alpha]^{25}_D$ = +3.9 (c = 0.30, $CHCl_3$)


1.00
1.03
1.08
2.09
3.03
2.04
1.25
2.73
2.82
4.32
2.98
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)


140.32
131.50
124.60
124.04
82.24
66.96
40.71
39.76
34.78
26.43
25.65
17.66
16.75
15.90
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10

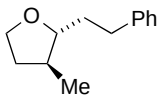


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.308	MM	0.2399	5197.48584	361.13022	45.2306
2	16.117	MM	0.2279	383.35046	28.03022	3.3361



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.479	MM	0.2695	211.74541	13.09471	1.9842
2	16.600	MM	0.2771	1.04601e4	629.16864	98.0158

(2*R*,3*S*)-3-methyl-2-phenethyltetrahydrofuran (6m).



The residue was subjected to flash column chromatography for purification to furnish the title compound (72%, *dr* = >20:1) as a colorless liquid.

R_f= 0.7 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 – 7.26 (m, 2H), 7.24 – 7.16 (m, 3H), 3.90 – 3.80 (m, 2H), 3.34 (td, *J* = 8.2, 3.5 Hz, 1H), 2.85 (ddd, *J* = 13.7, 10.8, 5.1 Hz, 1H), 2.67 (ddd, *J* = 13.7, 10.5, 6.2 Hz, 1H), 2.15 – 2.04 (m, 1H), 1.92 – 1.69 (m, 3H), 1.59 – 1.48 (m, 1H), 1.03 (d, *J* = 6.7 Hz, 3H).

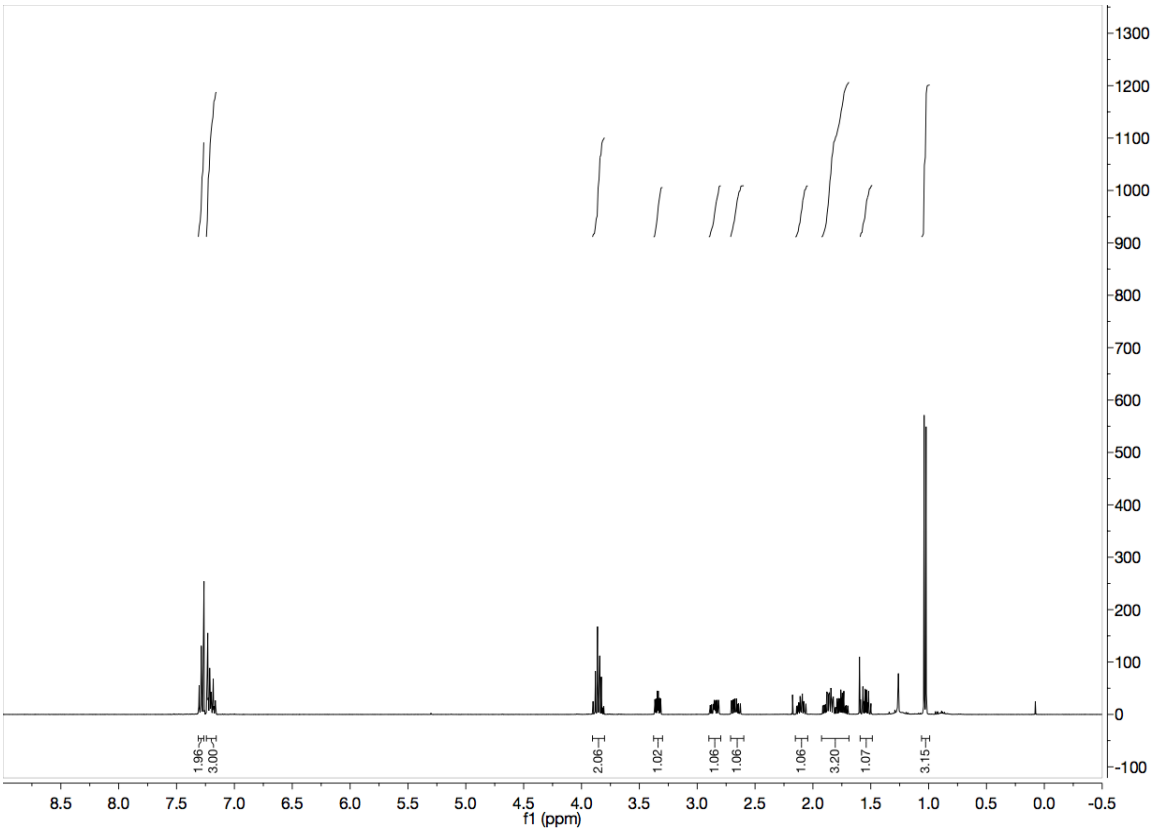
^{13}C NMR (100 MHz, $CDCl_3$): δ 142.43, 128.38, 128.29, 125.66, 85.24, 66.74, 39.05, 36.23, 34.72, 32.84, 17.23.

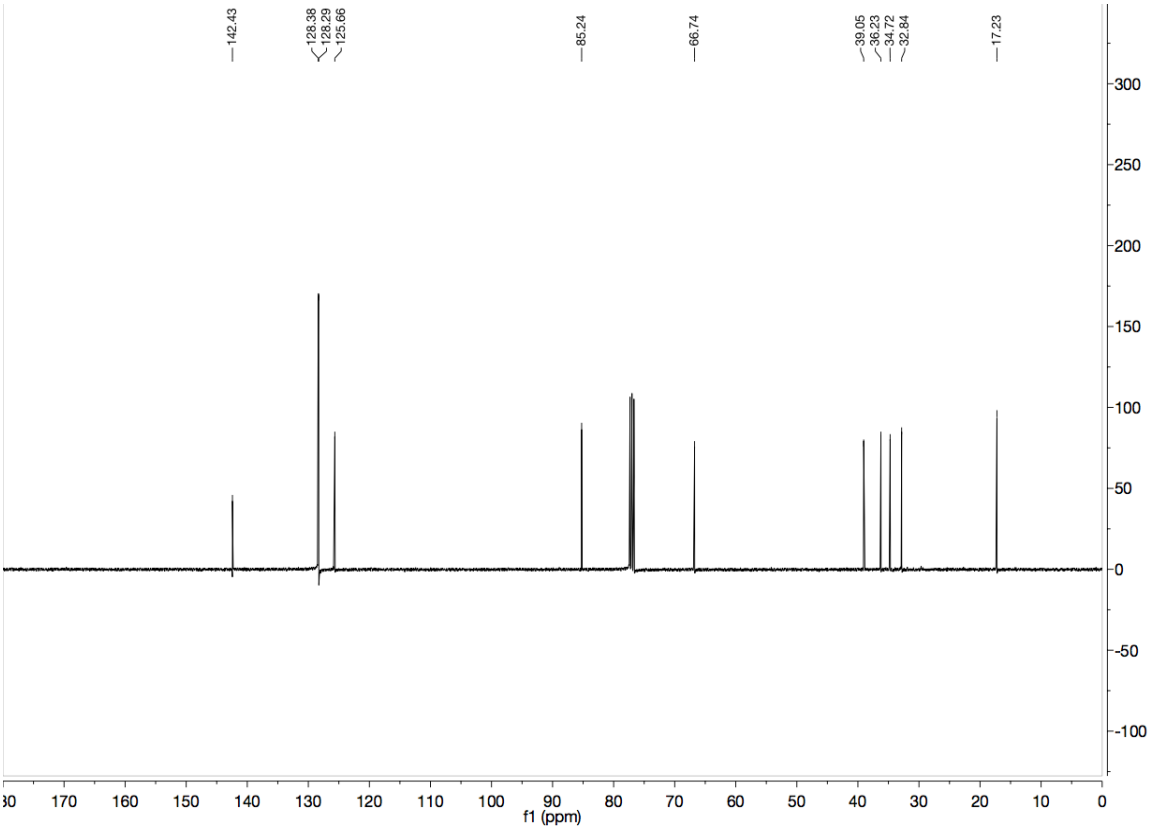
LRMS (ESI) Calcd. for $C_{13}H_{19}O$ $[M+H]^+$: 191, Found: 191.

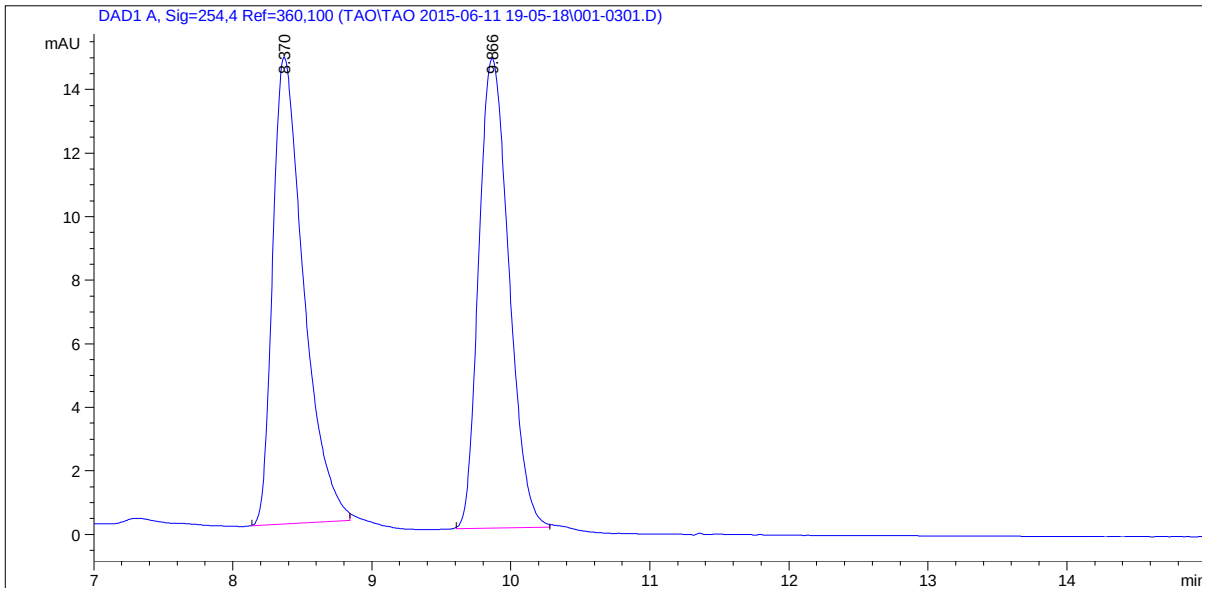
FTIR (neat): 2957, 2927, 1454, 1106, 1039, 1013, 745, 699 cm^{-1}.

HPLC (Chiralcel AD-H column, hexanes:*i*-PrOH = 99:1, 0.5 mL/min, 254 nm), ee = 90%.

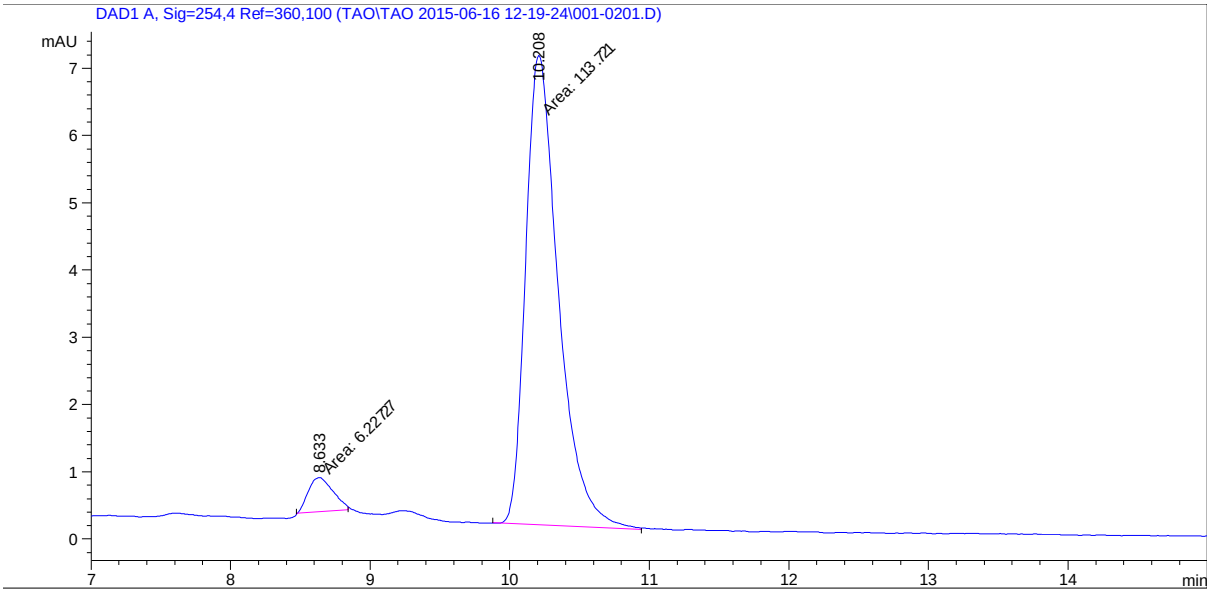
$[\alpha]^{25}_D$ = +39.2 (c = 0.31, $CHCl_3$)


1.96
3.00
2.06
1.02
1.06
1.06
1.06
3.20
1.07
3.15
f1 (ppm)


142.43
128.38
128.29
125.66
85.24
66.74
39.05
36.23
34.72
32.84
17.23
f1 (ppm)



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.370	BB	0.2329	227.55005	14.67808	50.5338
2	9.866	BB	0.2376	222.74254	14.79539	49.4662

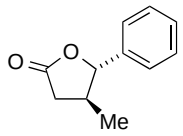


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.633	MM	0.2052	6.22727	5.05894e-1	5.1916
2	10.208	MM	0.2717	113.72086	6.97588	94.8084

D. **General Procedure for Conversion of Alcohols 2a, 2l, 2p to *trans*-4,5-disubstituted lactones 7a, 7l and 7p**

To a resealable pressure tube (ca. 13 x 100) was added $H_2Ru(CO)(PPh_3)_3$ (9.2 mg, 0.010 mmol, 5 mol%), SL-J009-1 ligand (5.6 mg, 0.010 mmol, 5 mol%), Bu_4NI (7.4 mg, 0.020 mmol, 10 mol%) and 2,4,6-tri(2-propyl)phenylsulfonic acid (4.2 mg, 0.015 mmol, 7.5 mol%). At this stage solid alcohol coupling partners (0.20 mmol, 100 mol%) were added. The tube was then sealed with a rubber septum and purged with argon. THF (0.20 mL, 1 M concentration with respect to alcohols) was then added. At this stage, liquid alcohol coupling partners (0.20 mmol, 100 mol%) were added. 2-propylalcohol (31 μL, 0.40 mmol, 200 mol%) was then added. Alkyne 1a (0.60 mmol, 300 mol%) was added *via* syringe and the rubber septum was quickly replaced with a screw cap. The mixture was then heated at 85 °C for the time stated. After cooling to room temperature, the mixture was passed through a short silica pad, washed the pad with EA, and concentrated *in vacuo*. The residue was dissolved in THF (2.0 mL) and TBAF (1.0 M in THF, 0.2 mL) was added at 0ºC. The mixture was stirred at r.t for 30 min, and then quenched by water, extracted by DCM (3 x 1 mL). The organic layer was washed by brine, dried over Na_2SO_4. The organic solvent was evaporated down to 2 mL and 4 Å MS (100 mg), NaOAc (8.2 mg, 0.10 mmol) and PCC (129 mg, 0.60 mmol) were added, and the mixture was stirred at room temperature for 24 hours. The solvent was removed by *vacuo*, and the residue was subjected to flash column chromatography (SiO_2, eluent Hexanes:EA = 5:1) to afford the corresponding lactone products.

(4*S*,5*S*)-4-methyl-5-phenyldihydrofuran-2(3*H*)-one (7a).



The residue was subjected to flash column chromatography for purification to furnish the title compound (70%, *dr* = >20:1) as a colorless liquid.

R_f= 0.2 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.31 (m, 5H), 4.94 (d, *J* = 8.3 Hz, 1H), 2.79 (dd, *J* = 16.9, 7.7 Hz, 1H), 2.55 – 2.42 (m, 1H), 2.34 (dd, *J* = 16.9, 10.5 Hz, 1H), 1.19 (d, *J* = 6.6 Hz, 3H).

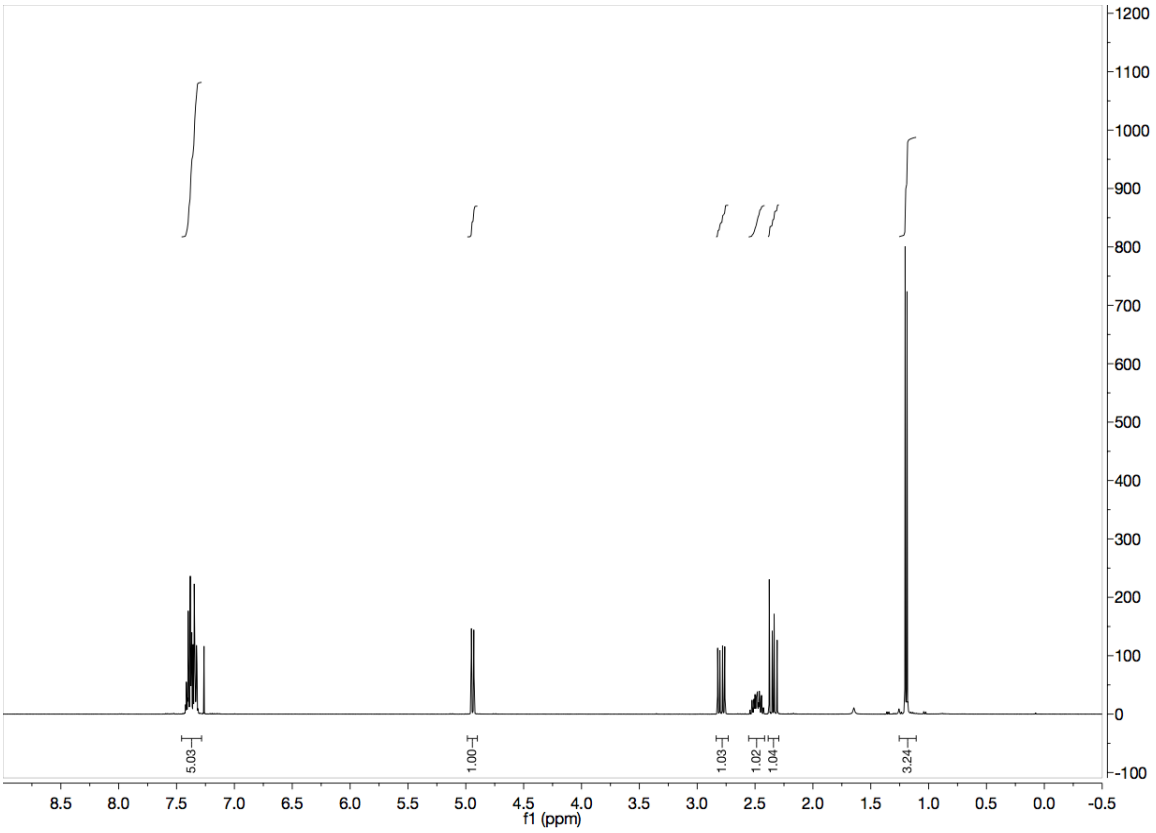
^{13}C NMR (100 MHz, $CDCl_3$): δ 176.07, 137.93, 128.69, 125.90, 88.13, 39.81, 37.21, 16.49.

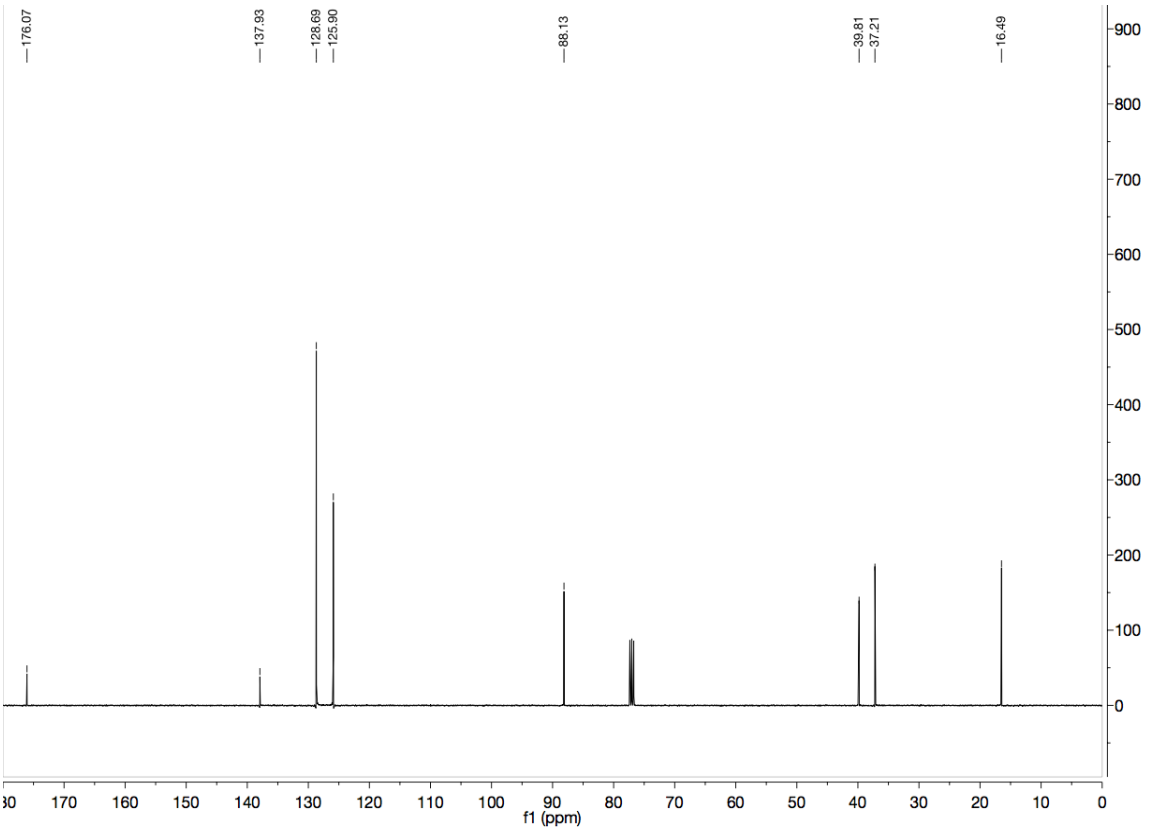
LRMS (ESI) Calcd. for $C_{11}H_{13}O_2$ $[M+H]^+$: 177, Found: 177.

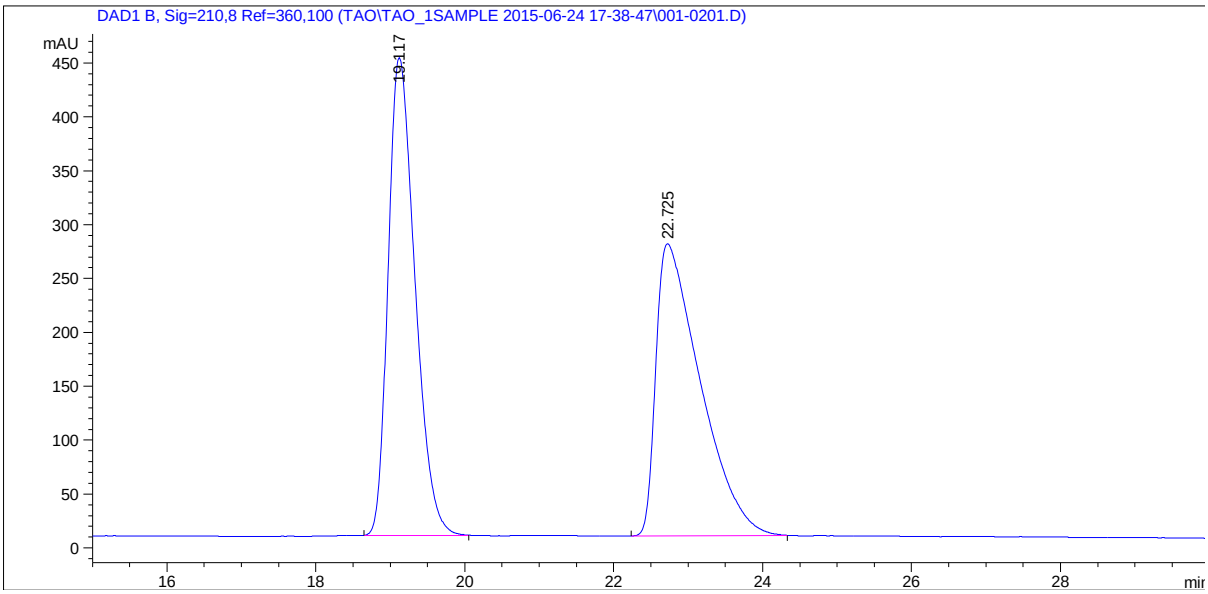
FTIR (neat): 1778, 1278, 1210, 1140, 998, 946, 756, 699 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 91%.

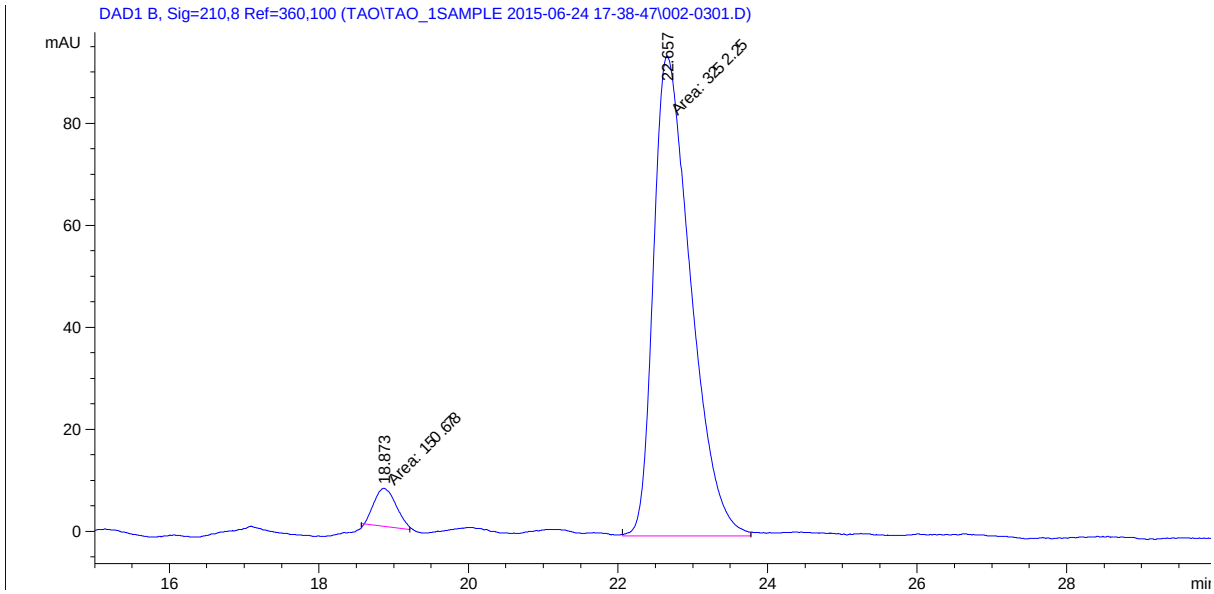
$[\alpha]^{25}_D$ = +1.1 (c = 0.9, $CHCl_3$)


5.03
1.00
1.03
1.02
1.04
3.24
f1 (ppm)


176.07
137.93
128.69
125.90
88.13
39.81
37.21
16.49
f1 (ppm)

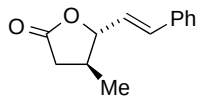


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	19.117	BB	0.3870	1.11370e4	443.40332	49.8286
2	22.725	BB	0.5887	1.12136e4	271.02835	50.1714



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	18.873	MM	0.3384	150.67789	7.42006	4.4279
2	22.657	MM	0.5766	3252.25488	94.00772	95.5721

(4*S*,5*S*)-4-methyl-5-((*E*)-styryl)dihydrofuran-2(3*H*)-one (7l).



The residue was subjected to flash column chromatography for purification to furnish the title compound (76%, *dr* = >20:1) as a colorless liquid.

R_f= 0.2 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.27 (m, 5H), 6.70 (d, *J* = 16.3 Hz, 1H), 6.17 (dd, *J* = 15.9, 7.2 Hz, 1H), 4.58 (ddd, *J* = 8.1, 7.2, 1.1 Hz, 1H), 2.74 (dd, *J* = 16.9, 7.7 Hz, 1H), 2.46 – 2.33 (m, 1H), 2.27 (dd, *J* = 16.9, 10.2 Hz, 1H), 1.20 (d, *J* = 6.6 Hz, 3H).

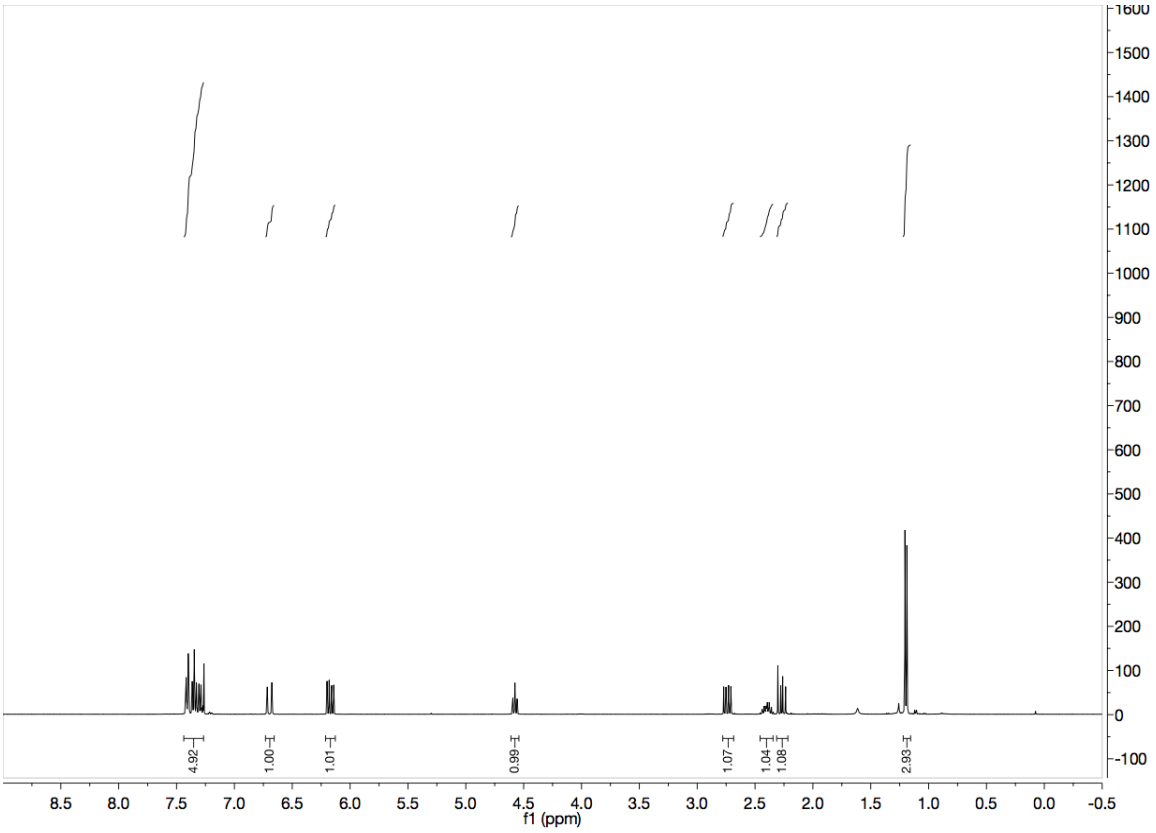
^{13}C NMR (100 MHz, $CDCl_3$): δ 176.07, 135.62, 133.88, 128.70, 128.42, 126.73, 125.18, 87.46, 37.32, 36.78, 16.50.

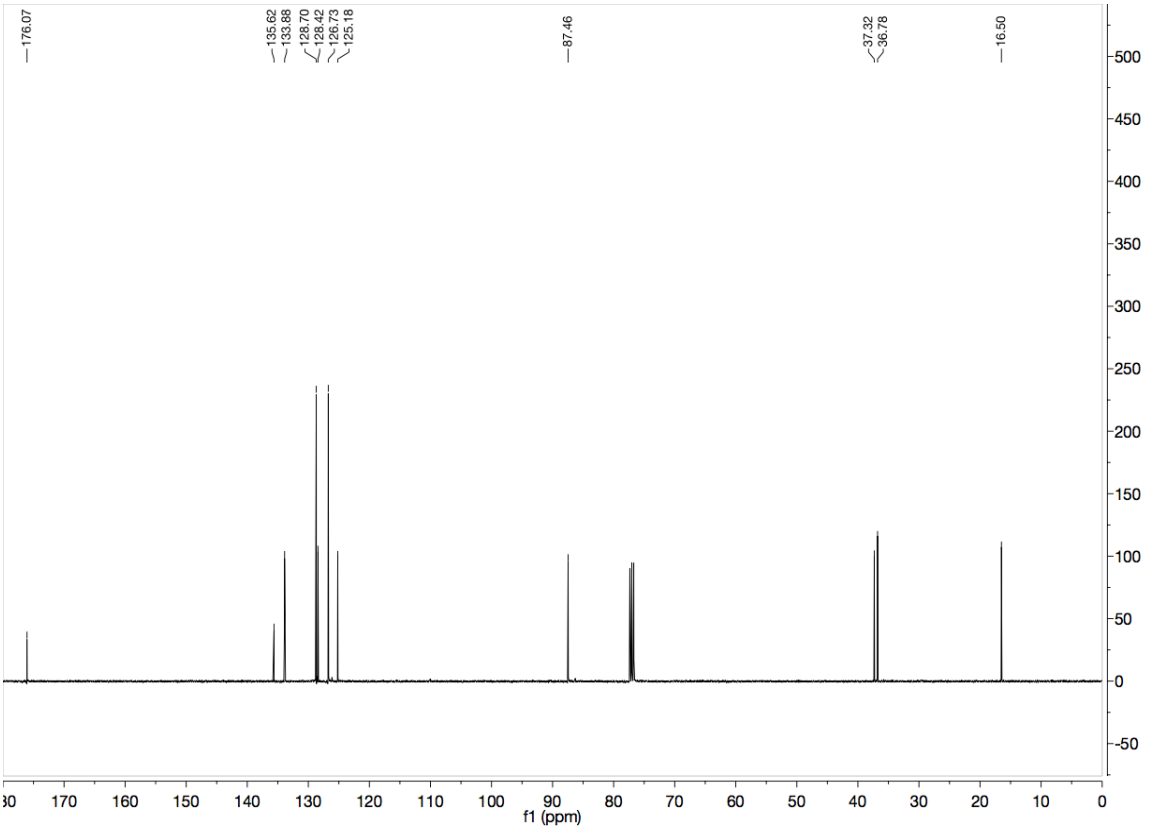
LRMS (ESI) Calcd. for $C_{13}H_{15}O_2$ $[M+H]^+$: 203, Found: 203.

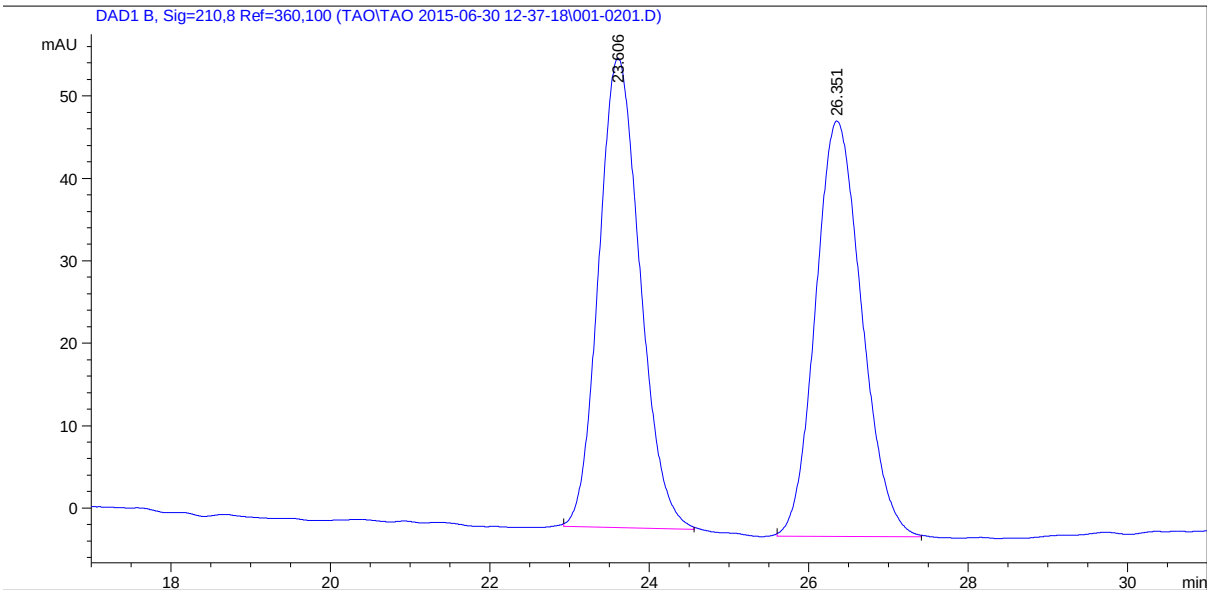
FTIR (neat): 1775, 1209, 1156, 986, 968, 939, 750, 693 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 93%.

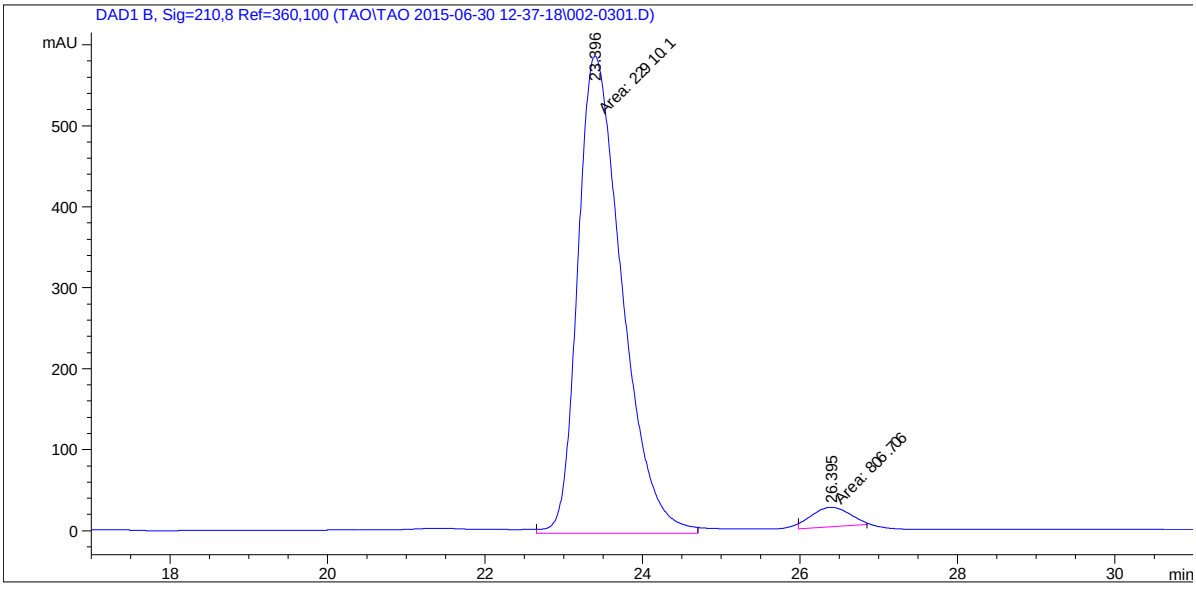
$[\alpha]^{25}_D$ = +47.5 (c = 0.4, $CHCl_3$)


4.92
1.00
1.01
0.99
1.07
1.04
1.08
2.93
f1 (ppm)


176.07
135.62
133.88
128.70
128.42
126.73
125.18
87.46
37.32
36.78
16.50
f1 (ppm)

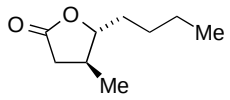


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.606	BB	0.5565	2052.90649	56.96287	50.3022
2	26.351	BB	0.6218	2028.24023	50.36858	49.6978



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.396	MM	0.6482	2.29101e4	589.07062	96.5986
2	26.395	MM	0.5590	806.70642	24.05120	3.4014

(4*S*,5*R*)-5-butyl-4-methyldihydrofuran-2(3*H*)-one (7p).



The residue was subjected to flash column chromatography for purification to furnish the title compound (72%, *dr* = >20:1) as a colorless liquid.

R_f= 0.2 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 4.00 (td, *J* = 8.0, 4.1 Hz, 1H), 2.72 – 2.60 (m, 1H), 2.26 – 2.13 (m, 2H), 1.72 – 1.56 (m, 2H), 1.55 – 1.44 (m, 1H), 1.42 – 1.30 (m, 3H), 1.13 (d, *J* = 6.4 Hz, 3H), 0.91 (t, *J* = 7.1 Hz, 3H).

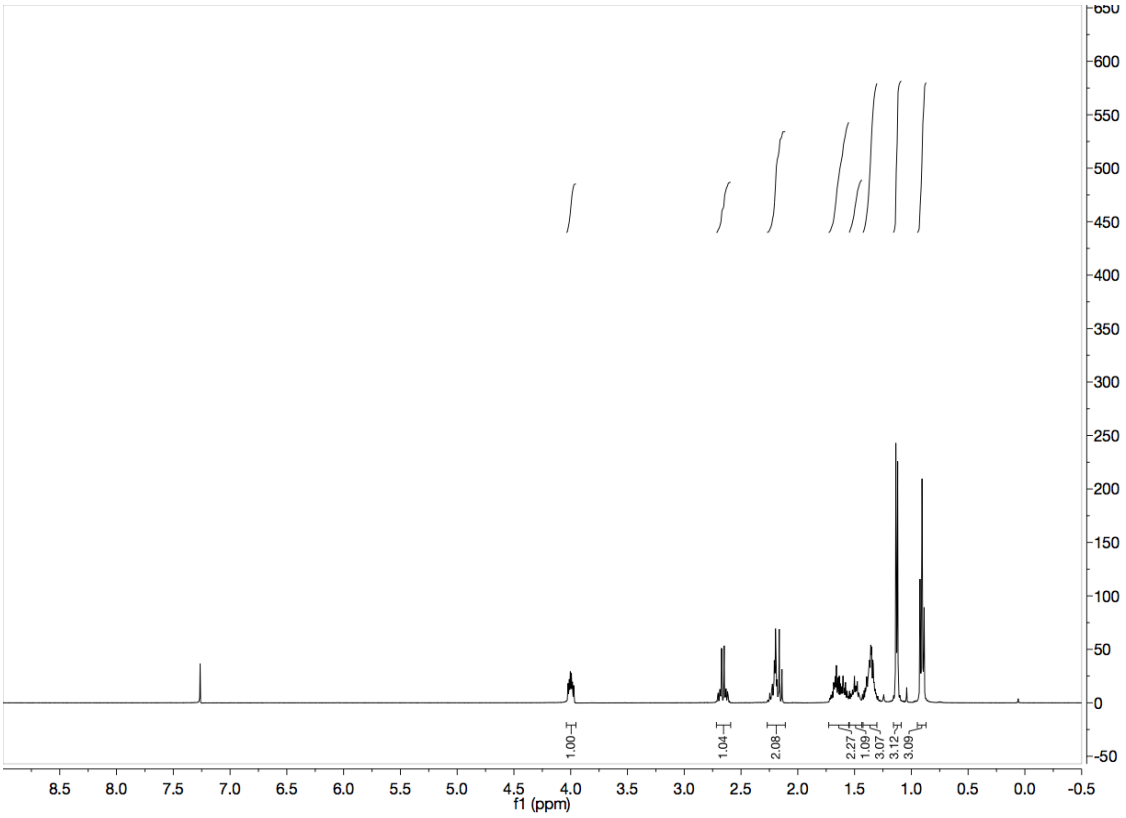
^{13}C NMR (100 MHz, $CDCl_3$): δ 176.59, 87.44, 37.11, 36.06, 33.68, 27.83, 22.46, 17.47, 13.88.

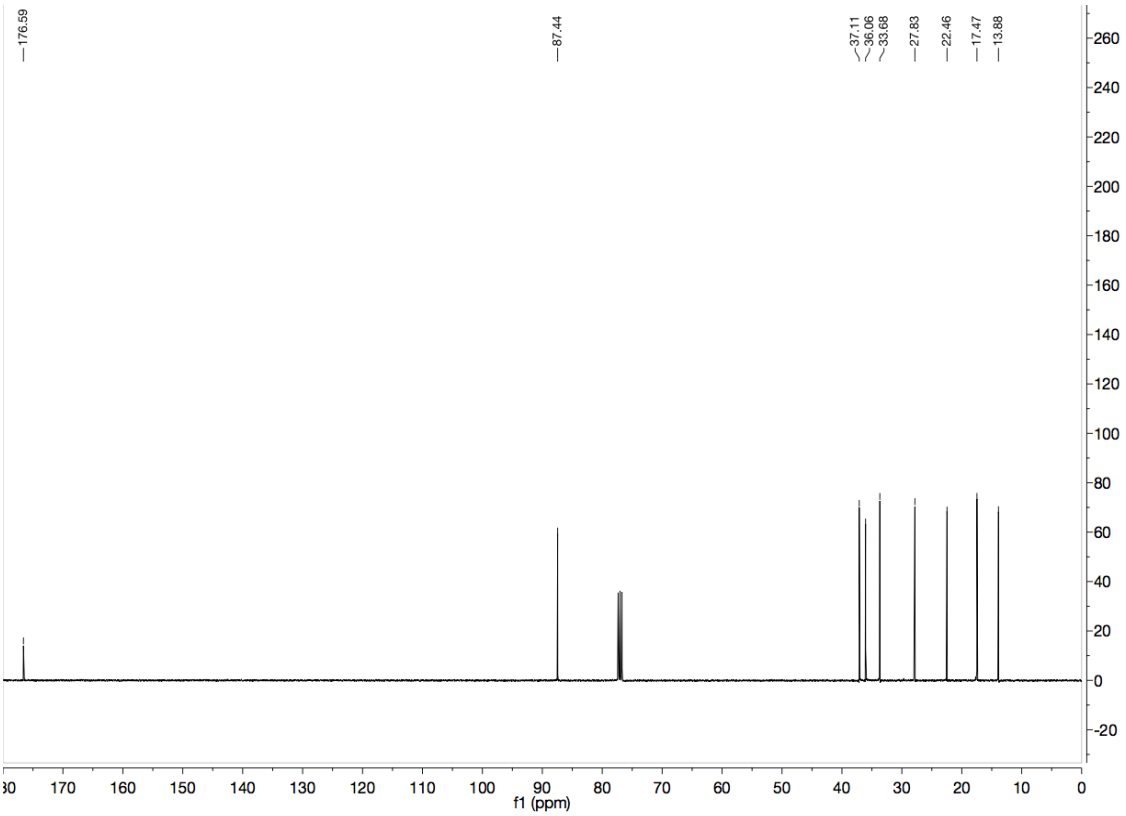
LRMS (ESI) Calcd. for $C_9H_{17}O_2$ $[M+H]^+$: 157, Found: 157.

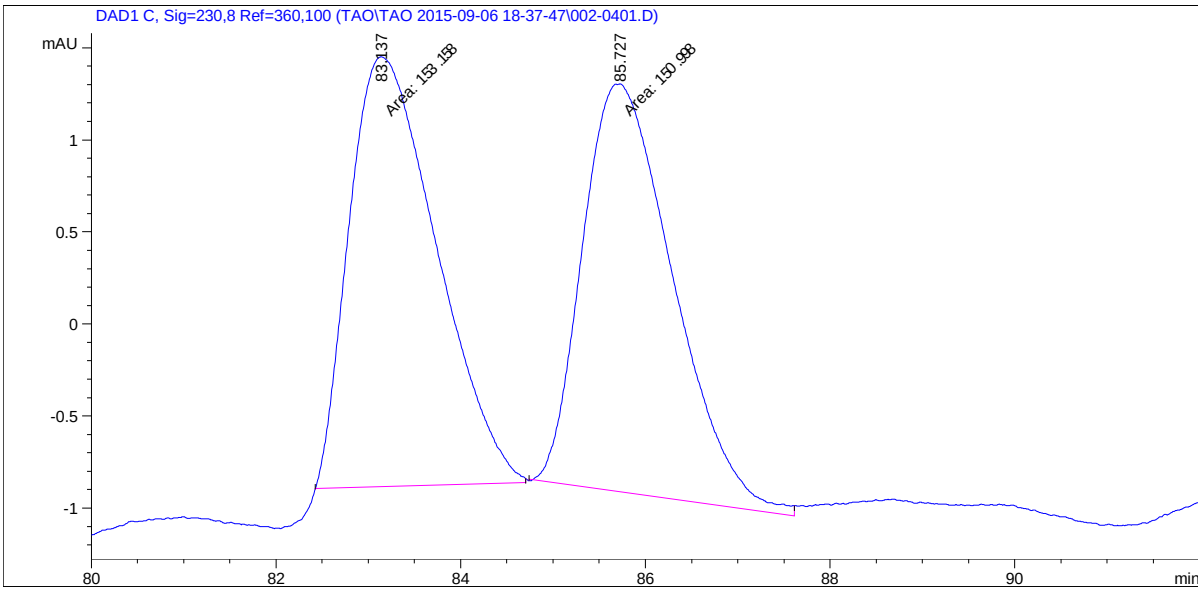
FTIR (neat): 1775, 1210, 1170, 1124, 1077, 984, 942, 926 cm^{-1}.

HPLC (Chiralcel OD-H/OD-H/OD-H column, hexanes:*i*-PrOH = 99:1, 0.5 mL/min, 230 nm), ee = 90%.

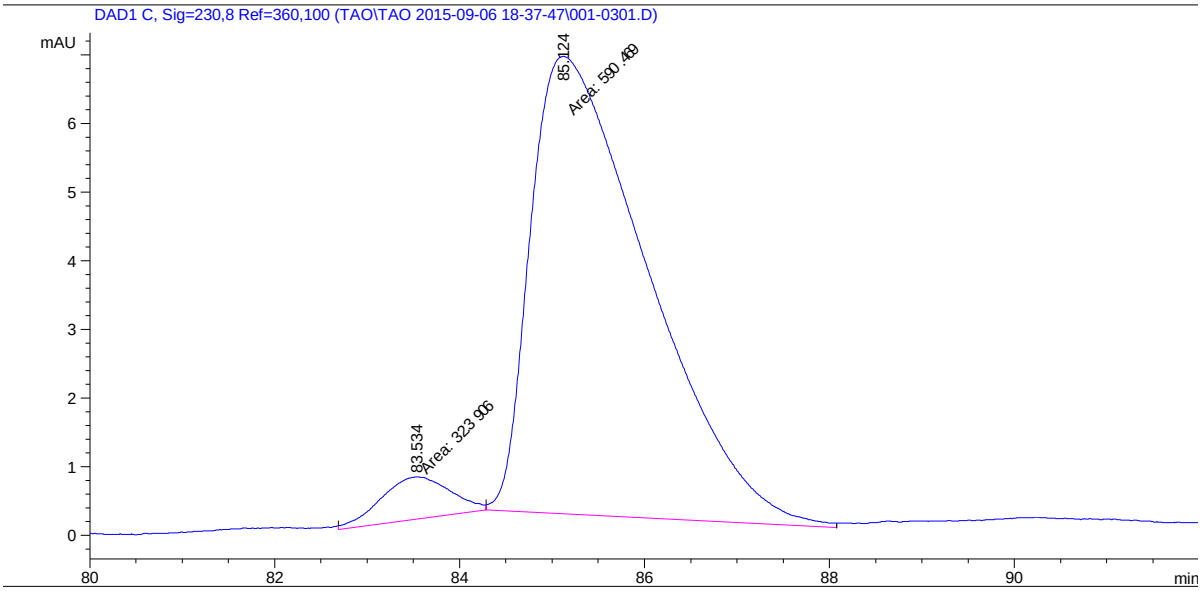
$[\alpha]^{25}_D$ = +59.6 (c = 0.71, $CHCl_3$)


1.00
1.04
2.08
2.27
1.09
3.07
3.12
3.09
f1 (ppm)


176.59
87.44
37.11
36.06
33.68
27.83
22.46
17.47
13.88
f1 (ppm)



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	83.137	MM	1.0936	153.15843	2.33419	50.3552
2	85.727	MM	1.1356	150.99785	2.21610	49.6448

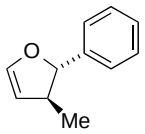


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	83.534	MM	0.6246	32.39059	6.15862e-1	5.2003
2	85.124	MM	1.4763	590.46930	6.66621	94.7997

E. Formation of trans-4,5-disubstituted-2,3-dehydrofuran 8a

To a resealable pressure tube (ca. 13 x 100) was added $H_2Ru(CO)(PPh_3)_3$ (9.2 mg, 0.010 mmol, 5 mol%), SL-J009-1 ligand (5.6 mg, 0.010 mmol, 5 mol%), Bu_4NI (7.4 mg, 0.020 mmol, 10 mol%) and 2,4,6-tri(2-propyl)phenylsulfonic acid (4.2 mg, 0.015 mmol, 7.5 mol%). THF (0.20 mL, 1 M concentration with respect to alcohols) was then added, followed by benzyl alcohol (0.20 mmol, 100 mol%), 2-propylalcohol (31 μL, 0.40 mmol, 200 mol%). Alkyne 1a (0.60 mmol, 300 mol%) was added *via* syringe and the rubber septum was quickly replaced with a screw cap. The mixture was then heated at 85 °C for 48 hours. After cooling to room temperature, the mixture was passed through a short silica pad, washed the pad with EA, and concentrated *in vacuo*. The residue was dissolved in THF (2.0 mL) and TBAF (1.0 M in THF, 0.2 mL) was added at 0ºC. The mixture was stirred at r.t for 30 min, and then quenched by water, extracted by DCM (3 x 1 mL). The organic layer was washed by brine, dried over Na_2SO_4. The organic solvent was evaporated and THF (2 mL) was added, followed by MsCl (45.6 mg, 0.4 mmol) and triethyl amine (121 mg, 1.2 mmol). The mixture was refluxed for 1 hour and then quenched by NH_4Cl, extracted by ether (3 x 1 mL). The organic layer was washed by water, brine, dried over Na_2SO_4. The solvent was removed by *vacuo*, and the residue was subjected to flash column chromatography (SiO_2, eluent Pentane:Et_2O = 9:1) to afford the dehydrofuran 8a (61%, *dr* = >20:1) as colorless liquid.

(2*S*,3*S*)-3-methyl-2-phenyl-2,3-dihydrofuran (8a).



R_f = 0.3 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.27 (m, 5H), 6.45 (dd, *J* = 2.8, 2.1 Hz, 1H), 4.97 – 4.90 (m, 2H), 3.04 – 2.90 (m, 1H), 1.23 (d, *J* = 6.7 Hz, 3H).

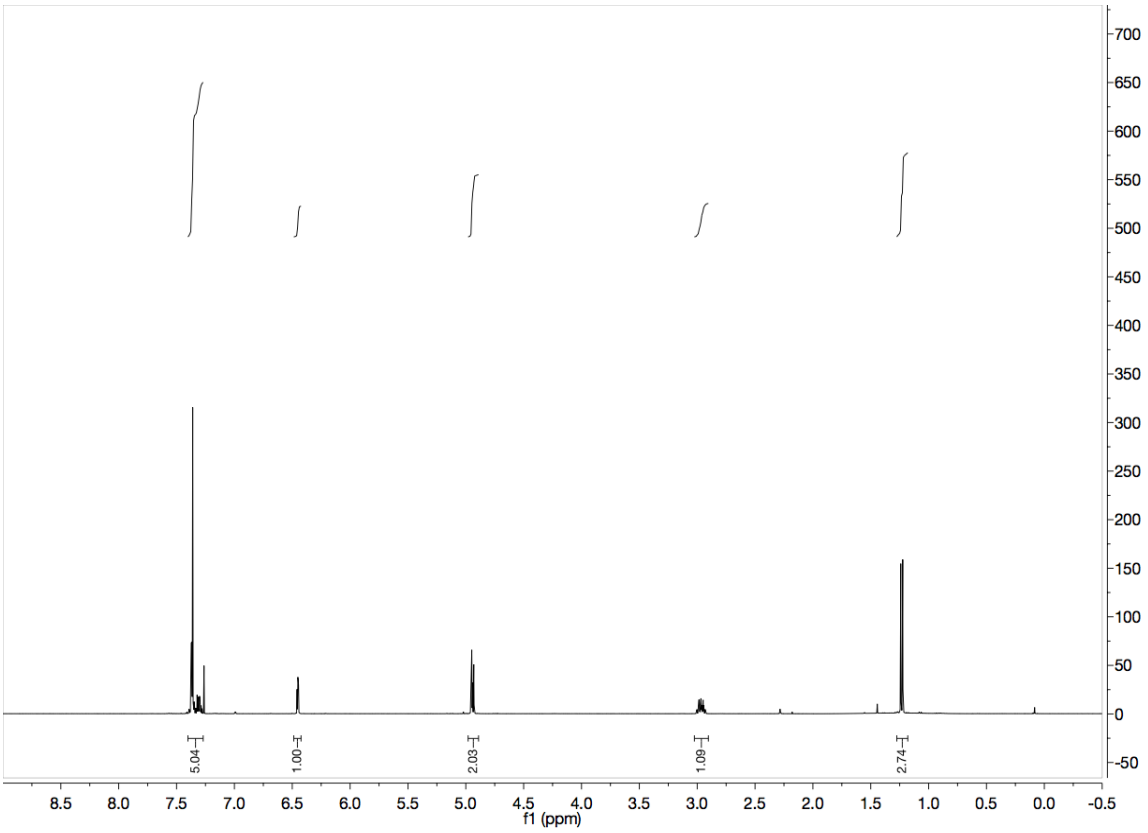
^{13}C NMR (100 MHz, $CDCl_3$): δ 144.74, 142.41, 128.51, 127.70, 125.46, 105.78, 90.15, 45.93, 20.78.

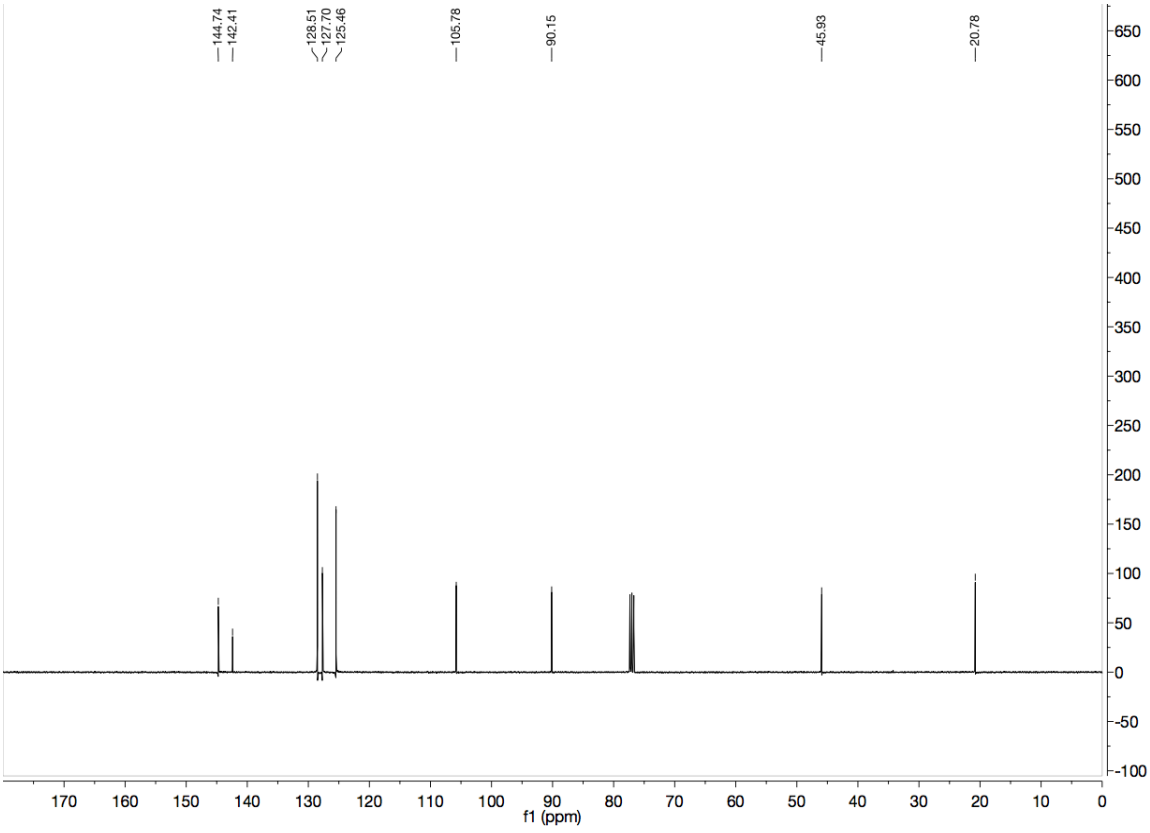
LRMS (ESI) Calcd. for $C_{11}H_{13}O$ $[M+H]^+$: 161, Found: 161.

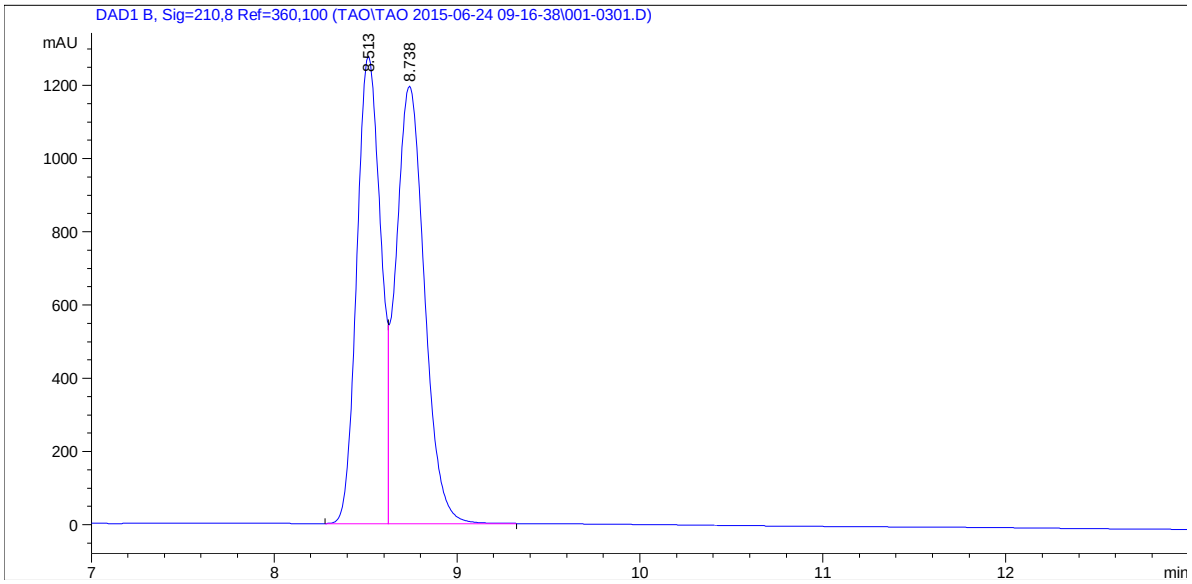
FTIR (neat): 2359, 2341, 1140, 1095, 1011, 721, 697, 669 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 99:1, 0.5 mL/min, 210 nm), ee = 91%.

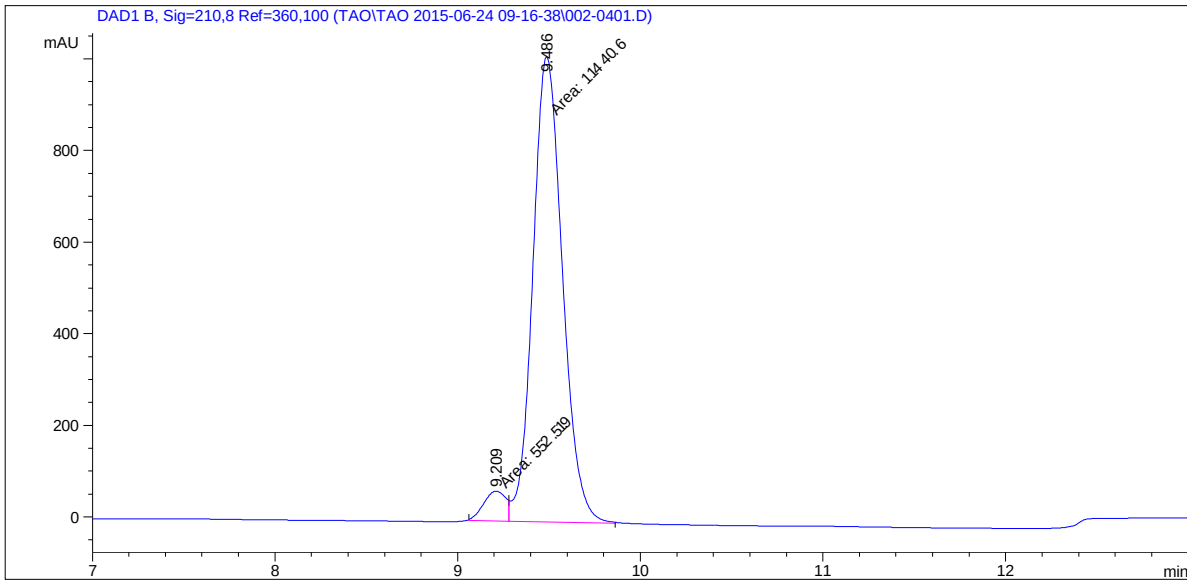
$[\alpha]^{25}_D$ = +171.4 (c = 0.34, $CHCl_3$)


5.04
1.00
2.03
1.09
2.74
f1 (ppm)


144.74
142.41
128.51
127.70
125.46
105.78
90.15
45.93
20.78
f1 (ppm)



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.513	BV	0.1425	1.16507e4	1276.80237	47.5093
2	8.738	VB	0.1637	1.28723e4	1194.92786	52.4907

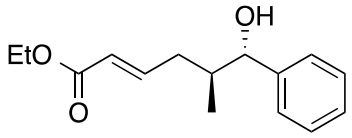


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.209	MF	0.1417	552.51855	64.98923	4.6070
2	9.486	FM	0.1877	1.14406e4	1016.07440	95.3930

F. Formation of 9a

To a resealable pressure tube (ca. 13 x 100) was added $H_2Ru(CO)(PPh_3)_3$ (9.2 mg, 0.010 mmol, 5 mol%), SL-J009-1 ligand (5.6 mg, 0.010 mmol, 5 mol%), Bu_4NI (7.4 mg, 0.020 mmol, 10 mol%) and 2,4,6-tri(2-propyl)phenylsulfonic acid (4.2 mg, 0.015 mmol, 7.5 mol%). THF (0.20 mL, 1 M concentration with respect to alcohols) was then added, followed by benzyl alcohol (0.20 mmol, 100 mol%), 2-propylalcohol (31 μL, 0.40 mmol, 200 mol%). Alkyne 1a (0.60 mmol, 300 mol%) was added *via* syringe and the rubber septum was quickly replaced with a screw cap. The mixture was then heated at 85 °C for 48 hours. After cooling to room temperature, the mixture was passed through a short silica pad, washed the pad with EA, and concentrated *in vacuo*. The residue was dissolved in THF (4.0 mL, 0.05 M) and TBAF (1.0 M in THF, 0.2 mL) was added at 0ºC. The mixture was stirred at r.t for 30 min, and then (Carbethoxymethylene)triphenylphosphorane (208 mg, 0.6 mmol) was added. The mixture was stirred at room temperature for 36 hours. The solvent was removed by *vacuo*, and the residue was subjected to flash column chromatography (SiO_2, eluent Hexanes:EA = 6:1) to afford 9a (71%, *dr* = >20:1, *E/Z* = >20:1) as colorless liquid.

Ethyl (5*S*,6*S*,*E*)-6-hydroxy-5-methyl-6-phenylhex-2-enoate (9a).



R_f = 0.2 (20% EtOAc/Hexanes).

Spectral data is reported for the major isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.27 (m, 5H), 6.97 (ddd, *J* = 15.6, 8.4, 6.6 Hz, 1H), 5.85 (dd, *J* = 15.6, 1.7 Hz, 1H), 4.43 (d, *J* = 7.3 Hz, 1H), 4.18 (q, *J* = 7.1 Hz, 2H), 2.61 – 2.51 (m, 1H), 2.15 (ddd, *J* = 14.2, 8.6, 1.3 Hz, 1H), 2.06 – 1.95 (m, 2H), 1.28 (t, *J* = 7.1 Hz, 3H), 0.77 (d, *J* = 6.8 Hz, 3H).

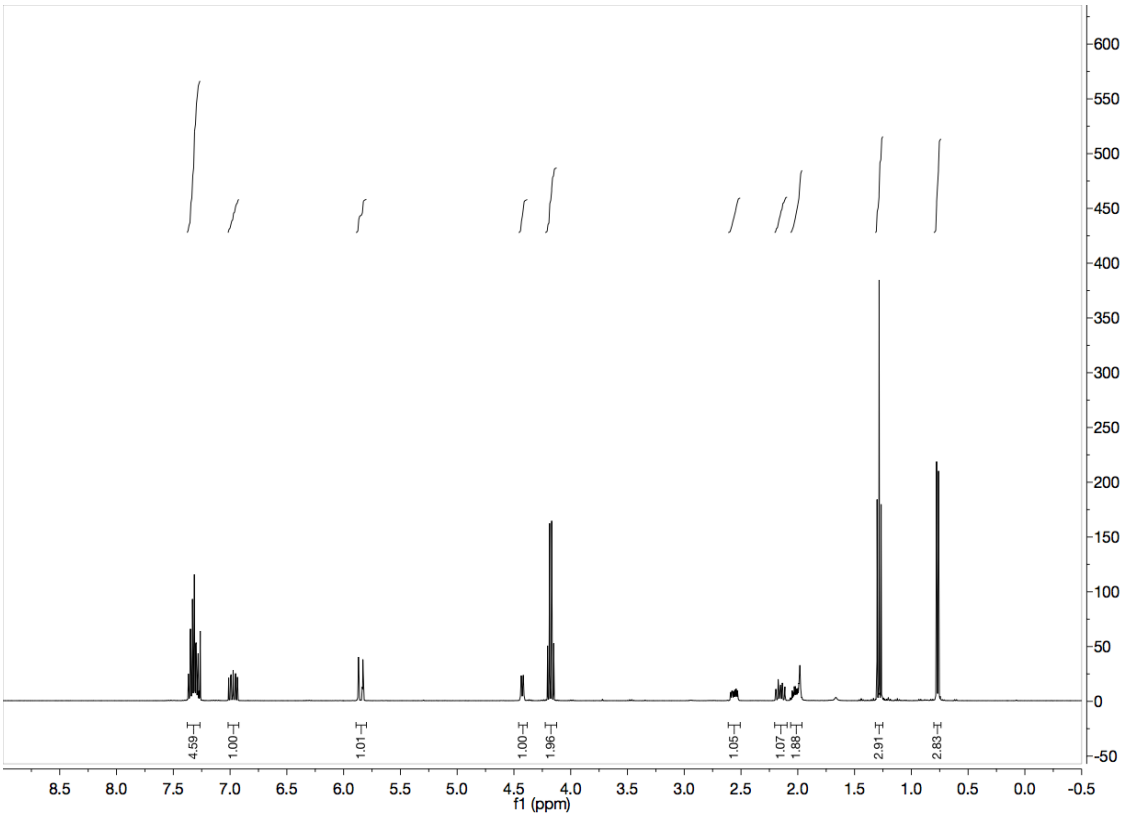
^{13}C NMR (100 MHz, $CDCl_3$): δ 166.58, 147.83, 143.08, 128.38, 128.36, 127.73, 126.56, 122.80, 78.34, 60.17, 39.68, 35.13, 15.98, 14.27.

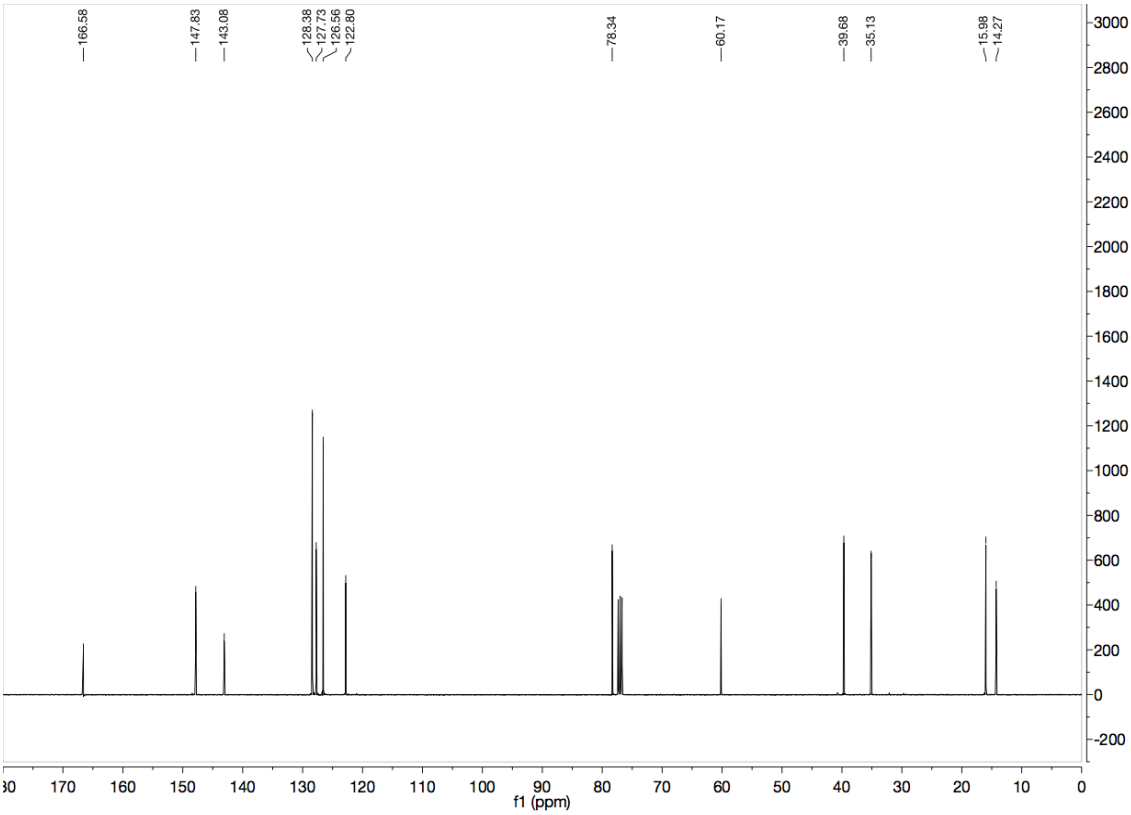
LRMS (ESI) Calcd. for $C_{15}H_{21}O_3$ $[M+H]^+$: 249, Found: 249.

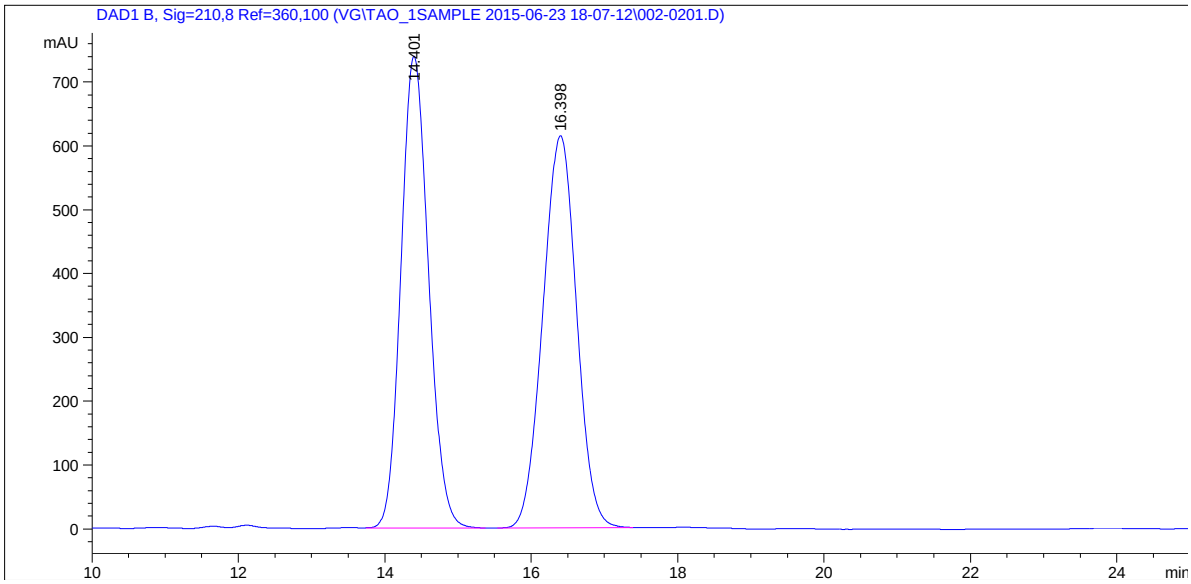
FTIR (neat): 1699, 1651, 1311, 1270, 1172, 1041, 982, 762, 701 cm^{-1}.

HPLC (Chiralcel OD-H column, hexanes:*i*-PrOH = 95:5, 1 mL/min, 210 nm), ee = 91%.

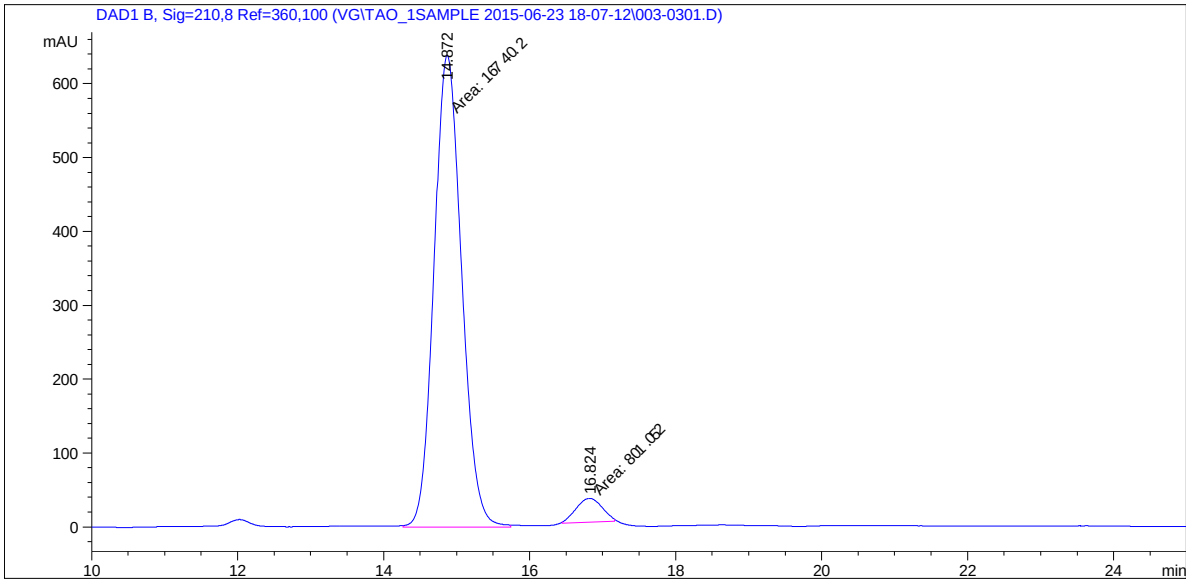
$[\alpha]^{25}_D$ = -11.3 (c = 1.2, $CHCl_3$)


4.59
1.00
1.01
1.00
1.96
1.05
1.07
1.88
2.91
2.83
f1 (ppm)


166.58
147.83
143.08
128.38
127.73
126.56
122.80
78.34
60.17
39.68
35.13
15.98
14.27
f1 (ppm)



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.401	BB	0.4108	1.94268e4	738.85236	49.7849
2	16.398	BB	0.5020	1.95947e4	614.55487	50.2151



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.872	MM	0.4368	1.67402e4	638.75323	95.4333
2	16.824	MM	0.4139	801.05170	32.25486	4.5667

G. Crystallographic Material for Coupling product 5c

X-ray Experimental for $C_{11}H_{15}O_2Br$ (5c)

Crystals grew as clusters of clear, colorless prisms by slow evaporation from Ethyl Acetate and DCM. The data crystal was cut from a larger crystal and had approximate dimensions; 0.38 x 0.27 x 0.08 mm. The data were collected at -140 °C on a Nonius Kappa CCD diffractometer using a Bruker AXS Apex II detector and a graphite monochromator with MoKα radiation (λ = 0.71073Å). Reduced temperatures were maintained by use of an Oxford Cryosystems 600 low-temperature device. A total of 1011 frames of data were collected using ω and φ-scans with a scan range of 2° and a counting time of 48 seconds per frame. Details of crystal data, data collection and structure refinement are listed in Table 1. Data reduction were performed using SAINT V8.27B.[1] The structure was solved by direct methods using SUPERFLIP[2] and refined by full-matrix least-squares on F2 with anisotropic displacement parameters for the non-H atoms using SHELXL-2013.[3] Structure analysis was aided by use of the programs PLATON98[4] and WinGX.[5] The hydrogen atoms bound to carbon atoms were calculated in idealized positions. The hydrogen atoms on the hydroxyl oxygen atoms were observed in a ΔF map and refined with isotropic displacement parameters. The absolute structure was determined by the method of Flack.[6] The Flack x parameter refined to 0.006(9). This assignment was confirmed by use of the Hooft y-parameter[7], which refined to 0.013(5).

The function, $\Sigma w(|Fo|2 - |Fc|2)2$, was minimized, where $w = 1/[(\sigma(Fo))2 + (0.0221*P)2]$ and $P = (|Fo|2 + 2|Fc|2)/3$. $R_w(F^2)$ refined to 0.0506, with R(F) equal to 0.0271 and a goodness of fit, S, = 1.01. Definitions used for calculating R(F),$R_w(F^2)$ and the goodness of fit, S, are given below.[8] The data were checked for secondary extinction but no correction was necessary. Neutral atom scattering factors and values used to calculate the linear absorption coefficient are from the International Tables for X-ray Crystallography (1992).[9] All figures were generated using SHELXTL/PC.[5] Tables of positional and thermal parameters, bond lengths and angles, torsion angles and figures are found elsewhere.

Table 1. Crystal data and structure refinement for 5c.

Empirical formula	C11 H15 Br O2	
Formula weight	259.14	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	monoclinic	
Space group	P 21	
Unit cell dimensions	a = 5.7323(12) Å	α= 90°.
	b = 7.920(2) Å	β= 98.524(6)°.
	c = 12.149(2) Å	γ = 90°.
Volume	545.5(2) Å3	
Z	2	
Density (calculated)	1.578 Mg/m^3	
Absorption coefficient	3.740 mm^{-1}	
F(000)	264	
Crystal size	0.384 x 0.272 x 0.084 mm	
Theta range for data collection	3.081 to 33.184°.	
Index ranges	-8<=h<=8, -12<=k<=12, -17<=l<=18	
Reflections collected	24040	
Independent reflections	3850 [R(int) = 0.0432]	
Completeness to theta = 25.242°	99.6 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	1.00 and 0.700	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3850 / 1 / 137	
Goodness-of-fit on F2	1.006	
Final R indices [I>2sigma(I)]	R1 = 0.0271, wR2 = 0.0487	
R indices (all data)	R1 = 0.0366, wR2 = 0.0506	
Absolute structure parameter	0.006(9)	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.666 and -0.452 $e.Å^{-3}$	

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters (Å^{2}x 10^3) for 3m. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
C1	8039(4)	5546(3)	3656(2)	14(1)
C2	8445(4)	4948(3)	2624(2)	15(1)
C3	6838(4)	3832(3)	2054(2)	14(1)
C4	4841(4)	3314(3)	2492(2)	12(1)
C5	4472(4)	3944(3)	3523(2)	14(1)
C6	6072(4)	5061(3)	4110(2)	15(1)
C7	3115(3)	2064(5)	1870(1)	13(1)
C8	4239(4)	335(3)	1754(2)	14(1)
C9	2425(4)	-909(3)	1157(2)	14(1)
C10	3389(4)	-2686(3)	1082(2)	16(1)
C11	5293(6)	-338(3)	2897(2)	33(1)
O1	2288(3)	2826(2)	807(1)	18(1)
O2	1669(3)	-3674(2)	387(1)	19(1)
Br1	10228(1)	7057(1)	4472(1)	21(1)

Table 3. Bond lengths [Å] and angles [°] for 5c.

C1-C6	1.382(3)
C1-C2	1.391(3)
C1-Br1	1.903(2)
C2-C3	1.386(3)
C2-H2	0.95
C3-C4	1.394(3)
C3-H3	0.95
C4-C5	1.393(3)
C4-C7	1.519(3)
C5-C6	1.392(3)
C5-H5	0.95
C6-H6	0.95
C7-O1	1.441(3)
C7-C8	1.529(4)
C7-H7	1.00
C8-C11	1.526(3)
C8-C9	1.534(3)
C8-H8	1.00
C9-C10	1.520(3)
C9-H9A	0.99
C9-H9B	0.99
C10-O2	1.432(3)
C10-H10A	0.99
C10-H10B	0.99
C11-H11A	0.98
C11-H11B	0.98
C11-H11C	0.98
O1-H1O	0.81(3)
O2-H5O	0.78(3)
C6-C1-C2	121.36(19)
C6-C1-Br1	118.75(16)
C2-C1-Br1	119.89(17)
C3-C2-C1	118.7(2)

C3-C2-H2	120.7
C1-C2-H2	120.7
C2-C3-C4	121.31(19)
C2-C3-H3	119.3
C4-C3-H3	119.3
C5-C4-C3	118.72(19)
C5-C4-C7	120.38(19)
C3-C4-C7	120.89(17)
C6-C5-C4	120.8(2)
C6-C5-H5	119.6
C4-C5-H5	119.6
C1-C6-C5	119.1(2)
C1-C6-H6	120.4
C5-C6-H6	120.4
O1-C7-C4	106.0(2)
O1-C7-C8	112.30(18)
C4-C7-C8	112.18(17)
O1-C7-H7	108.7
C4-C7-H7	108.7
C8-C7-H7	108.7
C11-C8-C7	110.12(17)
C11-C8-C9	110.78(18)
C7-C8-C9	110.71(17)
C11-C8-H8	108.4
C7-C8-H8	108.4
C9-C8-H8	108.4
C10-C9-C8	113.33(17)
C10-C9-H9A	108.9
C8-C9-H9A	108.9
C10-C9-H9B	108.9
C8-C9-H9B	108.9
H9A-C9-H9B	107.7
O2-C10-C9	108.45(17)
O2-C10-H10A	110.0
C9-C10-H10A	110.0

O2-C10-H10B	110.0
C9-C10-H10B	110.0
H10A-C10-H10B	108.4
C8-C11-H11A	109.5
C8-C11-H11B	109.5
H11A-C11-H11B	109.5
C8-C11-H11C	109.5
H11A-C11-H11C	109.5
H11B-C11-H11C	109.5
C7-O1-H1O	110(2)
C10-O2-H5O	111(2)

Table 4. Anisotropic displacement parameters ($Å^2 x\ 10^3$) for 5c. The anisotropic displacement factor exponent takes the form: $-2p^2[\ h^2\ a^{*2}U^{11} + ... + 2\ h\ k\ a^*\ b^*\ U^{12}\ ]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
C1	12(1)	9(1)	17(1)	-2(1)	-6(1)	0(1)
C2	11(1)	16(1)	18(1)	0(1)	1(1)	0(1)
C3	17(1)	13(1)	12(1)	-3(1)	2(1)	2(1)
C4	11(1)	9(1)	14(1)	0(1)	-2(1)	2(1)
C5	14(1)	12(1)	16(1)	1(1)	2(1)	1(1)
C6	16(1)	16(1)	11(1)	-2(1)	0(1)	3(1)
C7	13(1)	11(1)	14(1)	-2(1)	-2(1)	-2(1)
C8	15(1)	9(1)	15(1)	0(1)	-4(1)	1(1)
C9	15(1)	10(1)	17(1)	-2(1)	-3(1)	0(1)
C10	15(1)	14(2)	19(1)	0(1)	-4(1)	-1(1)
C11	51(2)	14(1)	26(1)	1(1)	-23(1)	-2(1)
O1	20(1)	10(1)	20(1)	3(1)	-11(1)	-2(1)
O2	21(1)	7(1)	25(1)	-2(1)	-9(1)	0(1)
Br1	16(1)	18(1)	26(1)	-8(1)	-6(1)	-2(1)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2$x 10^3) for 5c.

	x	y	z	U(eq)
H2	9796	5298	2317	18
H3	7103	3412	1351	17
H5	3113	3607	3829	17
H6	5813	5484	4814	18
H7	1748	1925	2287	16
H8	5541	470	1297	16
H9A	1043	-950	1558	17
H9B	1876	-487	396	17
H10A	4880	-2653	762	20
H10B	3718	-3194	1833	20
H11A	4023	-570	3334	50
H11B	6367	506	3283	50
H11C	6164	-1381	2807	50
H1O	1210(50)	2280(50)	490(20)	33(8)
H5O	1900(60)	-4640(40)	480(30)	32(9)

Table 6. Torsion angles [°] for 5c.

C6-C1-C2-C3	-0.6(3)
Br1-C1-C2-C3	179.19(16)
C1-C2-C3-C4	0.3(3)
C2-C3-C4-C5	0.1(3)
C2-C3-C4-C7	-178.8(2)
C3-C4-C5-C6	-0.4(3)
C7-C4-C5-C6	178.6(2)
C2-C1-C6-C5	0.3(3)
Br1-C1-C6-C5	-179.43(16)
C4-C5-C6-C1	0.2(3)
C5-C4-C7-O1	122.3(2)
C3-C4-C7-O1	-58.8(3)
C5-C4-C7-C8	-114.8(2)
C3-C4-C7-C8	64.1(3)
O1-C7-C8-C11	174.6(2)
C4-C7-C8-C11	55.3(3)
O1-C7-C8-C9	-62.6(2)
C4-C7-C8-C9	178.12(17)
C11-C8-C9-C10	-53.8(3)
C7-C8-C9-C10	-176.23(19)
C8-C9-C10-O2	-172.37(17)

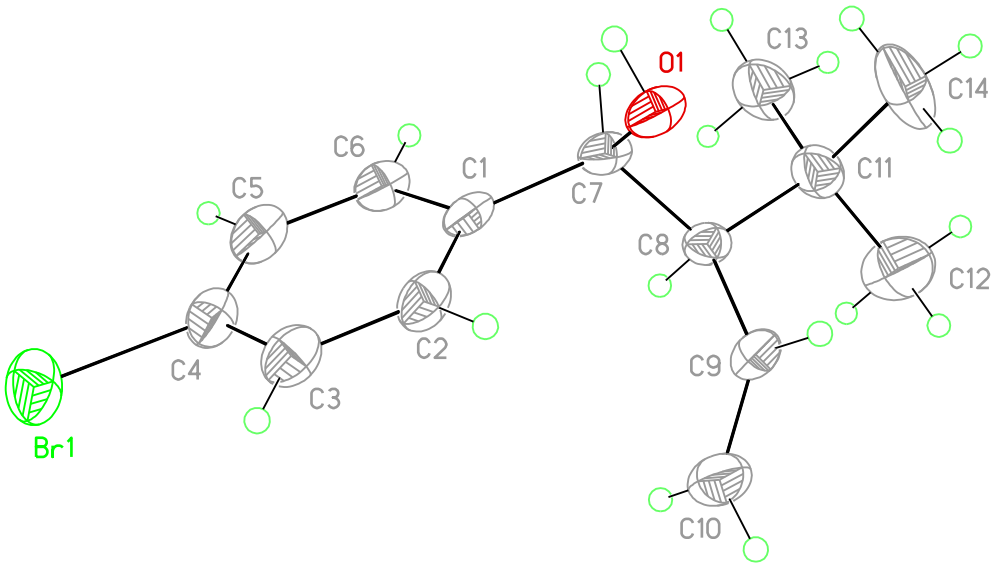
Table 7. Hydrogen bonds for 5c [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
O1-H1O...O2#1	0.81(3)	1.98(3)	2.772(2)	170(4)
O2-H5O...O1#2	0.78(3)	2.05(3)	2.832(2)	175(3)

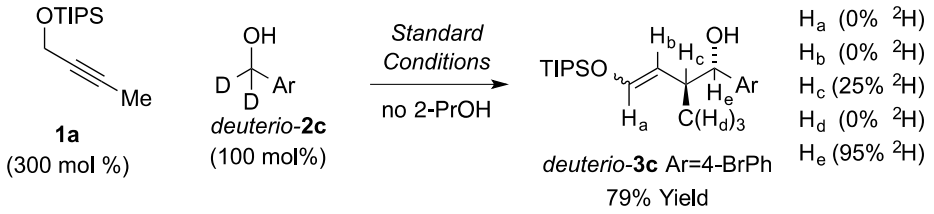
Symmetry transformations used to generate equivalent atoms:

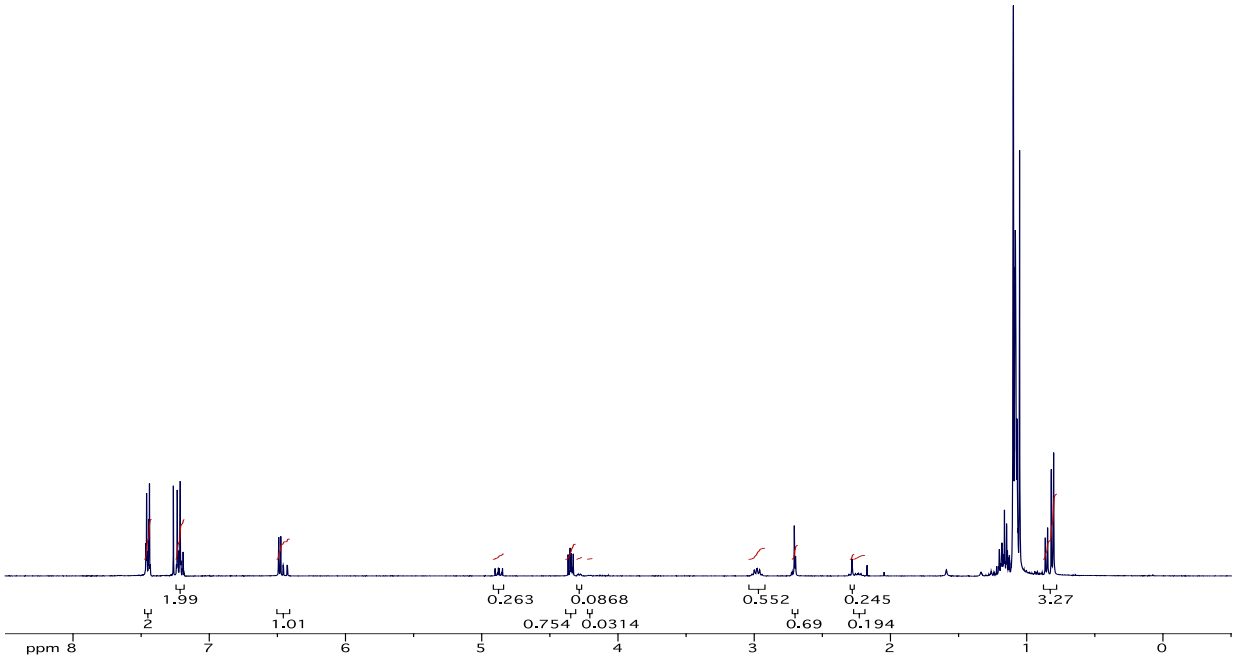
#1 -x,y+1/2,-z #2 x,y-1,z

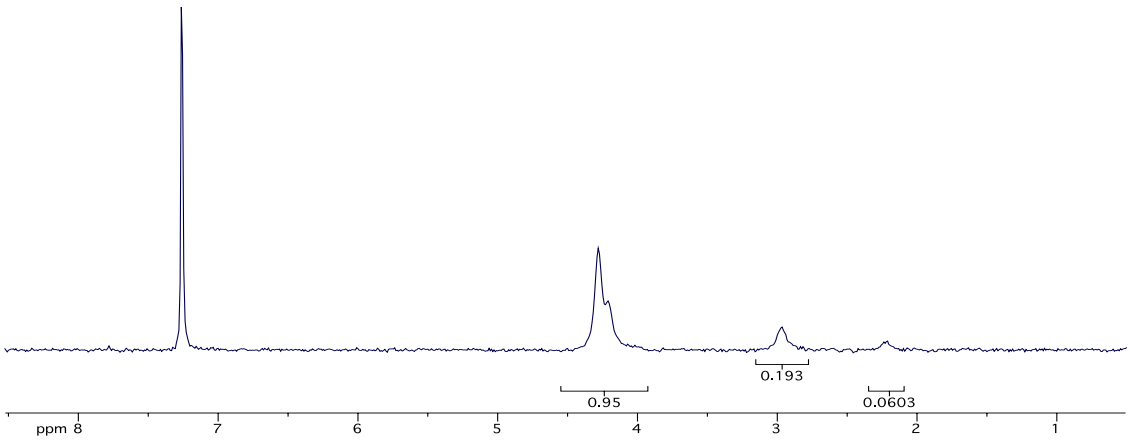
Figure 1. View of **5c** showing the atom labeling scheme. Displacement ellipsoids are scaled to the 50% probability level.

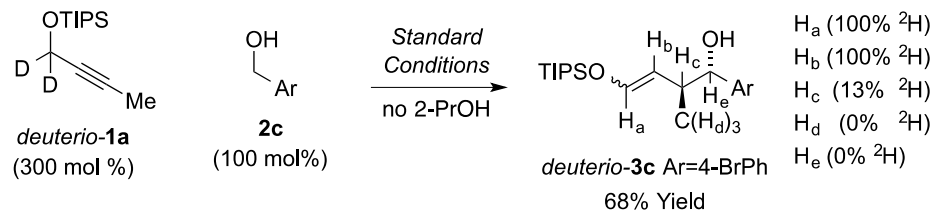


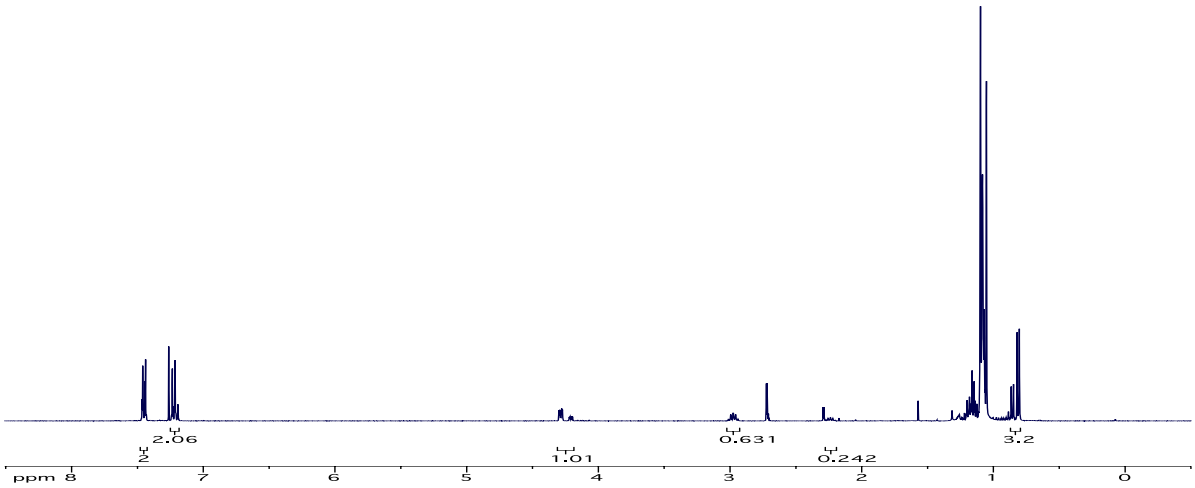
H. Isotopic Labeling Studies

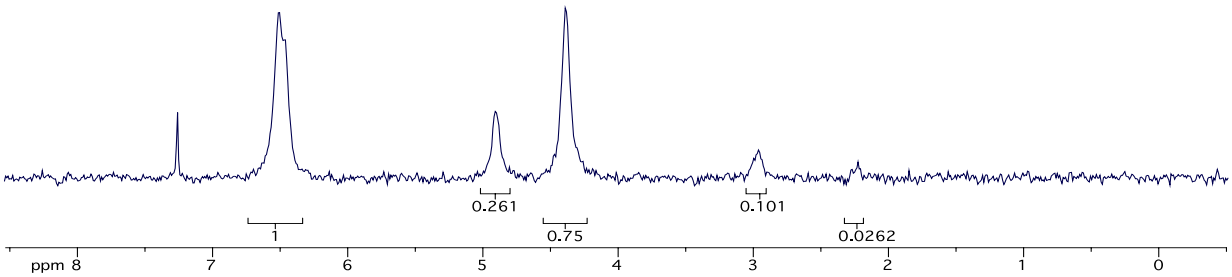







OTIPS
D
D
Me
deuterio-1a
(300 mol %)
OH
Ar
2c
(100 mol%)
Standard
Conditions
no 2-PrOH
TIPSO
Hb
Hc
OH
He
Ar
Ha
C(Hd)3
deuterio-3c Ar=4-BrPh
68% Yield
Ha (100% 2H)
Hb (100% 2H)
Hc (13% 2H)
Hd (0% 2H)
He (0% 2H)


2.06
1.01
0.631
0.242
3.2
ppm 8
7
6
5
4
3
2
1
0


0.261
0.101
1
0.75
0.0262
ppm 8
7
6
5
4
3
2
1
0

Reference:

1. SAINT V8.27B Bruker AXS Inc, (2012), Madison, WI.

2. Palatinus, L.; Chapuis, G. *J. Appl. Cryst.* **2007**, *40*, 786.

3. Sheldrick, G. M. SHELXL-2013. Program for the Refinement of Crystal Structures. *Acta Cryst A.* **2008**, *64*, 112.

4. Spek, A. L. (1998). PLATON, A Multipurpose Crystallographic Tool. Utrecht University, The Netherlands.

5. Farrugia, L. J. WinGX 1.64. An Integrated System of Windows Programs for the Solution, Refinement and Analysis of Single Crystal X-ray Diffraction Data. *J. Appl. Cryst.* **1999**, *32*. 837.

6. Flack, H. D. *Acta Cryst A.* **1983**, *39*, 876.

7. Hooft, R. W. W.; Straver, L. H.; Spek, A. L. *J. Appl. Cryst*. **2008**, *41*, 96.

8. $R_w(F^2) = \{\Sigma w(|F_o|^2 - |F_c|^2)^2/\Sigma w(|F_o|)^4\}^{1/2}$ where w is the weight given each reflection. $R(F) = \Sigma(|F_o| - |F_c|)/\Sigma|F_o|\}$ for reflections with $F_o > 4(\sigma(F_o))$. $S = [\Sigma w(|F_o|^2 - |F_c|^2)^2/(n - p)]^{1/2}$, where n is the number of reflections and p is the number of refined parameters.

9. International Tables for X-ray Crystallography (1992). Vol. C, Tables 4.2.6.8 and 6.1.1.4, A. J. C. Wilson, editor, Boston: Kluwer Academic Press.