Iridium-Catalyzed Enantioselective Polyene Cyclization

Michael A. Schafroth, David Sarlah, Simon Krautwald and Erick M. Carreira*

Laboratorium für Organische Chemie, ETH Hönggerberg, Wolfgang-Pauli-Strasse 10, CH-8093 Zürich, Switzerland

E-mail: carreira@org.chem.ethz.ch

Supporting Information

General Methods:

Unless otherwise noted, all reactions were performed in oven dried glassware under argon. Commercially available chemicals were used as received unless noted otherwise.
^{1}H-NMR spectra were recorded on a Bruker Ultrashield 400 MHz in the indicated deuterated solvent. The data is being reported as (s = singlet, d = doublet, t = triplet, m = multiplet or unresolved, br = broad signal, coupling constant(s) in Hz, integration). ^{13}C-NMR spectra were recorded with 1H-decoupling on a Bruker Ultrashield 100 MHz spectrometer in the indicated deuterated solvent. ^{31}P-NMR spectra were recorded with ^{1}H-decoupling on a Bruker Ultrashield 161 MHz spectrometer in the indicated deuterated solvent. Infrared spectra were recorded neat on a Varian 800 FT-IR Scimilar Series spectrophotometer. Optical rotations were measured on a JASCO DIP-1000 digital polarimeter in 10 cm, 1 mL cells, the concentration in g/100 mL and the solvent is given in parentheses. SFC analyses were carried out on a Jasco SFC system with Daicel columns with supercritical CO_2 and MeOH as co-eluent.

High resolution mass spectrometric measurements were performed by the mass spectrometry service of the Laboratorium für Organische Chemie at the ETH Zürich on a VG-TRIBRID spectrometer (EI-MS), Varian IonSpec spectrometer (ESI-MS) or IonSpec Ultima Fourier Transform Mass Spectrometer (MALDI-MS) and are reported as (*m*/*z*).

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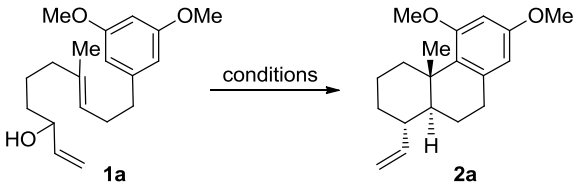
Synthesis of the Phosphoramidite Ligand (*R*)-L1[1]

A Schlenk flask under argon was charged with (*R*)-BINOL (10.0 g, 34.9 mmol, 1.00 equiv). PCl_3 (45.8 mL, 524 mmol, 15.0 equiv) and a catalytic amount of *N*,*N*-Dimethylformamide (81.0 µl, 1.05 mmol, 0.03 equiv) were added and the reaction mixture was heated at 50 °C during 30 min. The initially heterogeneous mixture turned into a homogenous solution. After cooling to 23 °C, the excess PCl_3 was evaporated into a cold-finger-trap *in vacuo* and quenched with saturated aqueous $NaHCO_3$, 1 mL toluene was added and remaining PCl_3 was azeotropically removed. The resulting phosphorchloridite (air-and moisture-sensitive!) was redissolved in THF (200 mL). In a separate Schlenk flask under argon, the iminostilbene (7.44 g, 38.5 mmol, 1.1 equiv) was dissolved in THF (200 mL) and deprotonated at –78 °C by slow addition of *n*-BuLi (21.6 mL, 1.05 equiv, 1.6 M solution in hexanes). The resulting deep blue solution was stirred at –78 °C for 1 hour before the phosphorchloridite solution was slowly added via cannula. The resulting mixture was stirred at –78 °C, then warmed to 23 °C and continued to stir during 10 h. After completion of the reaction, as determined by TLC, the solvents were evaporated in vacuo. Purification of the residue by flash chromatography (SiO_2; Hexanes/Toluene 2:1) yielded the desired product as a white powder (10.8 g, 61 %). Keep under inert atmosphere, in the dark, for long-term storage.

^{1}H-NMR (400 MHz; $CDCl_3$) δ = 7.99 (d, J = 8.8 Hz, 1H), 7.91 (d, J = 8.2 Hz, 1H), 7.76 (d, J = 8.1 Hz, 1H), 7.62 (d, J = 8.8 Hz, 1H), 7.45 – 7.34 (m, 3H), 7.30–7.15 (m, 9H), 7.12 – 7.09 (m, 1H), 7.01 – 6.90 (m, 3H), 6.85 (d, J = 8.8 Hz, 1H), 6.53 (td, J = 7.7, 1.5 Hz, 1H); ^{13}C NMR (100 MHz; $CDCl_3$) δ = 149.95, 149.86, 148.7, 143.1, 142.5, 136.5, 135.2, 132.9, 132.2, 131.53, 131.44, 131.34, 130.31, 130.20, 129.16, 129.07, 129.05, 129.00, 128.97, 128.90, 128.55, 128.40, 128.30, 127.9, 127.1, 126.80, 126.70, 126.15, 126.04, 125.6, 124.8, 124.3, 122.1, 121.5; ^{31}P NMR (161 MHz; $CDCl_3$) δ = 137.88 (s).

[1] C. Defieber, M. A. Ariger, P. Moriel, E. M. Carreira*, Angew. Chem.* **2007**, *119*, 3200–3204*; Angew. Chem. Int. Ed.* **2007**, *46*, 3139–3143.

Optimization studies



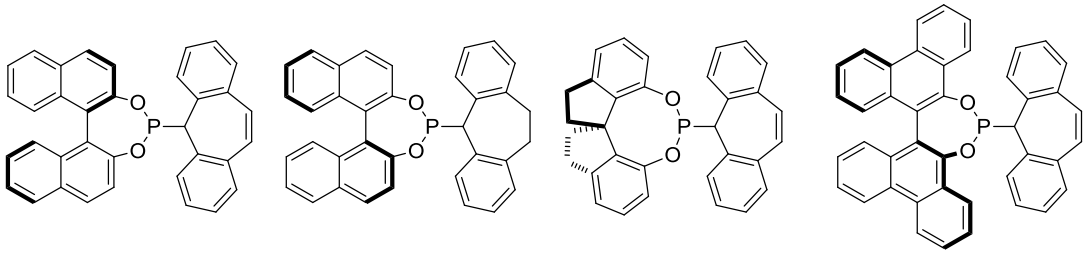
1a **2a**

Effect of phosphoramidate ligand

Standard procedure: Substrate **1a** (0.25 mmol, 1.0 equiv), $[\{Ir(cod)Cl\}_2]$ (4 mol%), **L*** (16 mol%), $(BuO)_2P(O)OH$ (50 mol%), DCE (1.5 mL), 50 °C, 24h.

Table S1

Entry	Ligand **L***	Yield (%)	e.e. (%)
1	(*R*)-L1	49	74
2	(*S*)-L2	n.r.	-
3	(*R*)-L3	37	21
4	(*S*)-L4	23	-16



(*R*)-L1 (*S*)-L2 (*R*)-L3 (*S*)-L4

Effect of promoter

Standard procedure: Substrate **1a** (0.25 mmol, 1.0 equiv), [{Ir(cod)Cl}$_2$] (4 mol%), **(*R*)-L1** (16 mol%), promoter, DCE (1.5 mL), 25 °C, 24h.

Table S2

Entry	Promoter (mol%)	Yield (%)	e.e. (%)
1	$(BuO)_2P(O)OH$ (50)	42	89
2	TFA (20)	53	64
3	TfOH (20)	12	81
4	C_6H_5COOH (50)	37	73
5	p-$NO_2C_6H_4COOH$ (50)	40	75
6	CCl_3COOH (50)	39	68
7	HCOOH (50)	n.r.	-
8	CH_3COOH (50)	28	85
9	$Bi(OTf)_3$ (10)	71	96
10	$Sc(OTf)_3$ (10)	91	80
11	$In(OTf)_3$ (10)	84	88
12	$Yb(OTf)_3$ (10)	79	94
13	$Zn(OTf)_2$ (10)	72	>99.5
14	$Zn(OTf)_2$ (20)	90	>99.5
15	$Zn(OTf)_2$ (50)	83	99

Effect of temperature

Standard procedure: Substrate **1a** (0.25 mmol, 1.0 equiv), [{Ir(cod)Cl}$_2$] (4 mol%), **(*R*)-L1** (16 mol%), $Bi(OTf)_3$ (10 mol%), DCE (1.5 mL), temperature, 24h.

Table S3

Entry	Temperature (°C)	Yield (%)	e.e. (%)
1	4	64	96
2	25	71	89
3	50	75	54

Effect of solvent

Standard procedure: Substrate **1a** (0.25 mmol, 1.0 equiv), [{Ir(cod)Cl}$_2$] (4 mol%), **(*R*)-L1** (16 mol%), Zn(OTf)$_2$ (10 mol%), solvent (1.5 mL), 25 °C, 24h.

Table S4

Entry	Solvent	Yield (%)	e.e. (%)
1	DCE	90	>99.5
2	1,4-Dioxane	8	>99.5
3	DMF	n.r.	-
4	Benzene	28	94
5	MeCN	18	99
6	THF	14	99.5

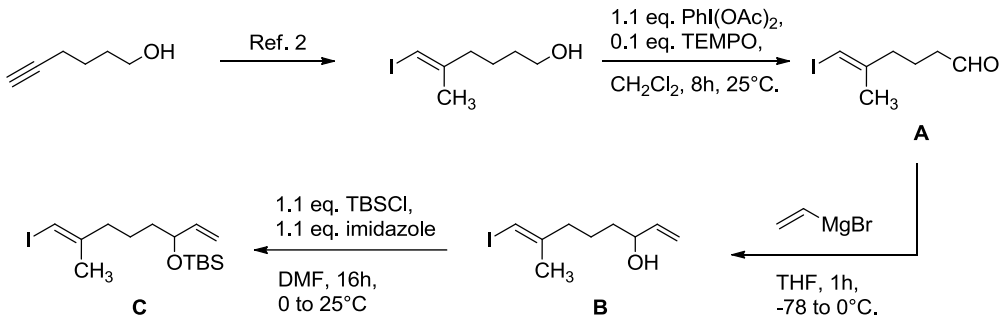
Effect of concentration

Standard procedure: Substrate **1a** (0.25 mmol, 1.0 equiv), [{Ir(cod)Cl}$_2$] (4 mol%), **(*R*)-L1** (16 mol%), Zn(OTf)$_2$ (10 mol%), DCE, 25 °C, 24h.

Table S5

Entry	Concentration (M)	Yield (%)	e.e. (%)
1	0.08	59	>99.5
2	0.17	72	>99.5
3	0.25	61	>99.5

Synthesis and Characterization of Starting Materials



Synthesis of (*E*)-6-iodo-5-methylhex-5-enal (A)

To a solution of (*E*)-6-iodo-5-methylhex-5-en-1-ol[2] (7.20 g, 30.0 mmol, 1.0 equiv) in CH_2Cl_2 (150 mL) was added TEMPO (0.47 g, 3.0 mmol, 0.1 equiv) followed by $PhI(OAc)_2$ (9.66 g, 33.0 mmol, 1.1 equiv) and the reaction mixture was stirred at room temperature for 8h. Upon consumption of the starting material (TLC, 20% ether in hexanes) the reaction was quenched by addition of saturated aqueous $Na_2S_2O_3$ and saturated aqueous $NaHCO_3$ solution (1:1, 200 mL). The aqueous layer was separated and extracted with diethyl ether (3 × 100 mL). The combined organic layers were dried over $MgSO_4$, concentrated under reduced pressure and purified by flash chromatography (SiO_2; hexanes/diethyl ether 5:1) to give the title compound as a colorless oil (5.92 g, 83 %).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.76 (t, *J* = 1.5 Hz, 1H), 5.91 (h, *J* = 1.2 Hz, 1H), 2.42 (td, *J* = 7.4, 1.5 Hz, 2H), 2.24 (td, *J* = 7.4, 1.2 Hz, 2H), 1.82 (d, *J* = 1.0 Hz, 3H), 1.81 – (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 201.9, 147.0, 75.7, 43.0, 38.7, 23.7, 20.0; IR (ν_{max}/cm^{-1}): 3056, 2938, 2818, 2721, 2285, 1723, 1276, 1142, 913, 747, 630; EI-MS calcd for $C_7H_{11}IO$ (M^+) 237.9855; found 237.9855.

Synthesis of (*E*)-8-iodo-7-methylocta-1,7-dien-3-ol (B)

To a solution of **A** (5.10 g, 21.4 mmol, 1.0 equiv) in THF (140 mL) was added vinylmagnesium bromide (1.0 M in THF, 22.5 mL, 22.5 mmol, 1.05 equiv) at −78 °C. The reaction mixture was allowed to warm to 0 °C and was quenched by slow addition of saturated aqueous NH_4Cl (100 mL). The aqueous layer was separated from the organic phase and further extracted with diethyl ether (3 ×

[2] R. K. Thalji and W. R. Roush, *J. Am. Chem. Soc.*, **2005**, *127*, 16778–16779

100 mL). The combined organic layers were dried over $MgSO_4$, concentrated under reduced pressure and purified by flash chromatography (SiO_2; hexanes/diethyl ether 6:1) to give the title compound as a colorless oil (4.81 g, 84 %).

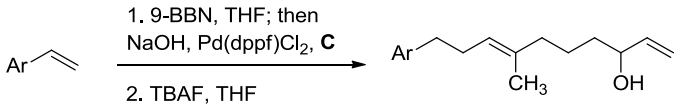
^{1}H NMR (400 MHz, $CDCl_3$) δ = 5.92 – 5.78 (m, 2H), 5.22 (dt, *J* = 17.2, 1.4 Hz, 1H), 5.12 (dt, *J* = 10.4, 1.4 Hz, 1H), 4.17 – 4.00 (m, 1H), 2.29 – 2.19 (m, 2H), 1.83 (d, *J* = 1.1 Hz, 3H), 1.65 – 1.39 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 147.9, 141.1, 115.0, 74.9, 73.1, 39.5, 36.3, 23.9, 23.5; IR (ν_{max}/cm^{-1}): 3366, 2937, 2824, 2286, 1429, 1274, 1141, 990, 913, 747, 630.

Synthesis of (*E*)-*tert*-butyl((8-iodo-7-methylocta-1,7-dien-3-yl)oxy)dimethylsilane (C)

To a solution of **B** (4.75 g, 17.8 mmol, 1.0 equiv) in DMF (40 mL) was added imidazole (1.35 g, 19.8 mmol, 1.1 equiv) followed by TBSCl (3.00 g, 19.8 mmol, 1.1 equiv) at 0 °C. The reaction mixture was allowed to warm to room temperature and was further stirred for 16 h. Upon consumption of the starting material (TLC, hexanes/diethyl ether 4:1) the reaction mixture was diluted with saturated aqueous NH_4Cl solution (200 mL) and extracted with diethyl ether (3 × 100 mL). The combined organic layers were washed with LiCl solution (5% aqueous, 100 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by flash chromatography (SiO_2; hexanes) to give the title compound as a colorless oil (5.75 g, 84 %).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 5.86 (q, *J* = 1.2 Hz, 1H), 5.77 (ddd, *J* = 17.2, 10.4, 6.0 Hz, 1H), 5.13 (dt, *J* = 17.2, 1.7 Hz, 1H), 5.03 (ddd, *J* = 10.4, 1.7, 1.2 Hz, 1H), 4.09 (tdd, *J* = 6.0, 4.3, 1.5 Hz, 1H), 2.25 – 2.15 (m, 2H), 1.81 (d, *J* = 1.1 Hz, 3H), 1.57 – 1.39 (m, 4H), 0.90 (s, 9H), 0.05 (s, 3H), 0.03 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 148.1, 141.7, 113.9, 74.7, 73.6, 39.6, 37.41, 26.0, 23.9, 23.2, 18.4, -4.2, -4.7; IR (ν_{max}/cm^{-1}): 2928, 2856, 1643, 1471, 1461, 1360, 1250, 1123, 1082, 1027, 1005.

Synthesis of Polyene Substrates

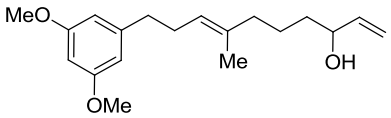


General Procedure A

To a solution of the corresponding vinylarene (4.0 mmol, 2.0 equiv) in THF (2.5 mL) was slowly added a solution of 9-BBN (0.5 M in THF, 8.0 mL, 4.0 mmol, 2.0 equiv) at 0 °C. The resulting mixture was allowed to warm to room temperature and stirred for 16 h. Upon consumption of the starting material (TLC, hexanes/diethyl ether mixture), the reaction mixture was cooled to 0 °C and aqueous NaOH (3 M, 5 mL) was added, followed by $Pd(dppf)Cl_2 \cdot CH_2Cl_2$ (0.16 g, 0.2 mmol, 0.1 equiv) and **C** (0.76 g, 2.0 mmol, 1.0 equiv). The resulting dark-red solution was stirred at 4 °C for 16 h. Saturated aqueous NH_4Cl (50 mL) was added, the organic phase separated and the aqueous layer extracted with EtOAc (3 × 30 mL). The combined organic layers were washed with brine, dried over $MgSO_4$ and concentrated under reduced pressure. The residue was quickly passed through a short pad of silica with 5% diethyl ether in hexanes.[3] The solvent was removed under reduced pressure, the yellowish residue was re-dissolved in THF (10 mL) and a solution of TBAF (1.0 M in THF, 4 mL, 4.0 mmol, 2.0 equiv) was added at 0 °C. The reaction mixture was allowed to warm to room temperature and stirred for 4 to 8 h. Upon consumption of all starting material (TLC, hexanes/EtOAc mixture) the solvent was removed under reduced pressure and the residue was dissolved in diethyl ether (50 mL). The organic phase was washed with water (50 mL) and the aqueous phase extracted with ether (2 × 50 mL). The combined organic layers were dried over $MgSO_4$, concentrated under reduced pressure and purified by flash chromatography (hexanes/EtOAc mixture as eluent) to give the corresponding allylic alcohol as a colorless oil.

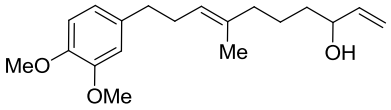
[3] The coupling-product was isolated as a mixture with the corresponding vinylarene. The mixture was used directly for deprotection of the allylic alcohol.

(*E*)-10-(3,5-dimethoxyphenyl)-7-methyldeca-1,7-dien-3-ol (1a)



The title compound was prepared following general procedure A from 3,5-dimethoxystyrene[4] in 74 % yield.
^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.36 (d, *J* = 2.3 Hz, 2H), 6.30 (t, *J* = 2.3 Hz, 1H), 5.85 (ddd, *J* = 17.0, 10.4, 6.2 Hz, 1H), 5.25 – 5.14 (m, 2H), 5.10 (dt, *J* = 10.4, 1.3 Hz, 1H), 4.12 – 4.04 (m, 1H), 3.78 (s, 6H), 2.58 (dd, *J* = 8.7, 6.7 Hz, 2H), 2.30 (q, *J* = 7.5 Hz, 2H), 2.05 – 1.93 (m, 2H), 1.59 – 1.36 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 160.8, 145.0, 141.4, 135.7, 124.1, 114.7, 106.8, 97.8, 73.3, 55.4, 39.6, 36.7, 36.5, 29.8, 23.6, 16.0; IR (ν_{max}/cm^{-1}): 3383, 2934, 2837, 1595, 1460, 1427, 1347, 1313, 1292, 1204, 1149, 1067; ESI-MS calcd for $C_{19}H_{29}O_3$ (MH^+) 305.2111; found 305.2112.

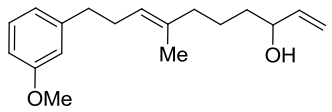
(*E*)-10-(3,4-dimethoxyphenyl)-7-methyldeca-1,7-dien-3-ol (1b)



The title compound was prepared following general procedure A from 3,4-dimethoxystyrene in 84 % yield.
^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.81 – 6.77 (m, 1H), 6.75 – 6.67 (m, 2H), 5.85 (ddd, *J* = 17.2, 10.5, 6.2 Hz, 1H), 5.28 – 5.13 (m, 2H), 5.10 (dt, *J* = 10.5, 1.4 Hz, 1H), 4.09 (qt, *J* = 5.1, 1.3 Hz, 1H), 3.87 (s, 3H), 3.85 (s, 3H), 2.61 – 2.55 (m, 2H), 2.28 (q, *J* = 7.4 Hz, 2H), 2.03 – 1.94 (m, 2H), 1.55 (d, *J* = 1.4 Hz, 3H), 1.52 – 1.37 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 148.8, 147.2, 141.4, 135.6, 135.2, 124.1, 120.4, 114.7, 112.0, 111.3, 73.3, 56.1, 56.0, 39.6, 36.6, 35.8, 30.2, 23.7, 16.0; IR (ν_{max}/cm^{-1}): 3512, 2934, 2835, 1590, 1515, 1464, 1262, 1235, 1154; ESI-MS calcd for $C_{19}H_{29}O_3$ (MH^+) 305.2111; found 305.2110.

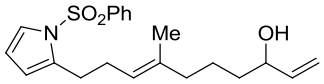
[4] Nicolaou, K. C. et. al. *Chem. Eur. J.*, **1999**, *5*, 2602–2621.

(*E*)-10-(3-methoxyphenyl)-7-methyldeca-1,7-dien-3-ol (1c)



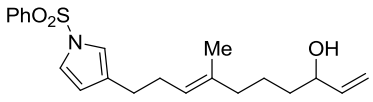
The title compound was prepared following general procedure A from 3-methoxystyrene in 75 % yield.
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.22 – 7.15 (m, 1H), 6.82 – 6.70 (m, 3H), 5.85 (ddd, *J* = 17.2, 10.4, 6.2 Hz, 1H), 5.25 – 5.14 (m, 2H), 5.10 (dt, *J* = 10.4, 1.4 Hz, 1H), 4.13 – 4.04 (br, 1H), 3.80 (s, 3H), 2.62 (dd, *J* = 8.7, 6.7 Hz, 2H), 2.30 (q, *J* = 7.5 Hz, 2H), 2.03 – 1.95 (m, 2H), 1.62 – 1.34 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 159.7, 144.2, 141.4, 135.7, 129.3, 124.1, 121.1, 114.7, 114.5, 111.0, 73.3, 55.3, 39.6, 36.7, 36.3, 29.9, 23.6, 15.9; IR (ν_{max}/cm^{-1}): 3381, 3090, 3035, 2935, 1814, 1601, 1584, 1478, 1437, 1260, 1152, 1035; ESI-MS calcd for $C_{18}H_{26}NaO_2$ (MNa^+) 297.1825; found 297.1826.

(*E*)-7-methyl-10-(1-(phenylsulfonyl)-1*H*-pyrrol-2-yl)deca-1,7-dien-3-ol (1d)



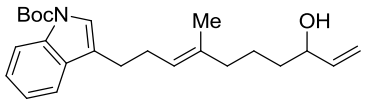
The title compound was prepared following general procedure A from 1-(phenylsulfonyl)-2-vinyl-1*H*-pyrrole in 79 % yield.
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.89 – 7.79 (m, 2H), 7.64 – 7.54 (m, 1H), 7.54 – 7.41 (m, 2H), 7.07 (dd, *J* = 3.2, 2.2 Hz, 1H), 6.92 – 6.88 (m, 1H), 6.16 (dd, *J* = 3.2, 1.6 Hz, 1H), 5.86 (ddd, *J* = 17.2, 10.4, 6.2 Hz, 1H), 5.22 (dt, *J* = 17.2, 1.4 Hz, 1H), 5.14 – 5.04 (m, 2H), 4.15 – 4.06 (br, 1H), 2.45 – 2.35 (m, 2H), 2.26 – 2.11 (m, 2H), 1.96 (m, 2H), 1.54 – 1.33 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 141.4, 139.4, 135.8, 133.7, 129.9, 129.4, 126.8, 123.9, 121.0, 117.5, 115.1, 114.7, 73.3, 39.6, 36.7, 28.5, 27.1, 23.7, 16.0; IR (ν_{max}/cm^{-1}): 3411, 2930, 1448, 1368, 1174, 1102, 1060, 913, 774, 729; Maldi-MS calcd for $C_{21}H_{28}NO_3S$ (MH^+) 374.1784; found 374.1784.

(*E*)-7-methyl-10-(1-(phenylsulfonyl)-1*H*-pyrrol-3-yl)deca-1,7-dien-3-ol (1e)



The title compound was prepared following general procedure A from 1-(phenylsulfonyl)-3-vinyl-1*H*-pyrrole[5] in 78 % yield.
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.80 – 7.75 (m, 2H), 7.64 – 7.59 (m, 1H), 7.56 – 7.49 (m, 2H), 7.32 (ddd, *J* = 3.3, 1.7, 0.5 Hz, 1H), 6.23 (t, *J* = 3.3 Hz, 1H), 6.05 – 6.00 (m, 1H), 5.89 (ddd, *J* = 17.2, 10.4, 6.2 Hz, 1H), 5.25 (dt, *J* = 17.2, 1.4 Hz, 1H), 5.17 – 5.07 (m, 2H), 4.15 – 4.06 (br, 1H), 2.75 – 2.67 (m, 2H), 2.32 – 2.22 (m, 2H), 2.05 – 1.96 (m, 2H), 1.63 – 1.32 (m, 8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 141.4, 139.4, 135.8, 133.7, 129.9, 129.4, 126.8, 123.9, 121.0, 117.5, 115.1, 114.7, 73.3, 39.6, 36.7, 28.5, 27.1, 23.7, 16.0; IR (ν_{max}/cm^{-1}): 3389, 2930, 2855, 1448, 1364, 1176, 913, 744, 686, 631; Maldi-MS calcd for $C_{21}H_{28}NO_3S$ (MH^+) 374.1784; found 374.1785.

(*E*)-*tert*-butyl 3-(8-hydroxy-4-methyldeca-3,9-dien-1-yl)-1*H*-indole-1-carboxylate (1f)

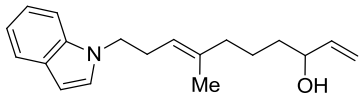


The title compound was prepared following general procedure A from *tert*-butyl 3-vinyl-1*H*-indole-1-carboxylate[5] in 71 % yield.
^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.13 (d, *J* = 7.7 Hz, 1H), 7.56 (ddd, *J* = 7.7, 1.4, 0.7 Hz, 1H), 7.39 (s, 1H), 7.33 (ddd, *J* = 8.3, 7.2, 1.3 Hz, 1H), 7.26 (ddd, *J* = 7.7, 7.2, 1.1 Hz, 1H), 5.88 (ddd, *J* = 17.2, 10.4, 6.2 Hz, 1H), 5.30 – 5.20 (m, 2H), 5.13 (ddd, *J* = 10.4, 1.6, 1.2 Hz, 1H), 4.12 (q, *J* = 6.3 Hz, 1H), 2.79 – 2.67 (m, 2H), 2.43 (m, 2H), 2.10 – 1.98 (m, 2H), 1.70 (s, 9H), 1.66 – 1.60 (m, 3H), 1.57 – 1.28 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 141.3, 135.7, 124.19, 124.17, 122.4 122.3, 121.1, 119.0, 115.2, 114.6, 73.2, 54.0, 39.5, 36.6, 29.2, 28.3, 27.6, 25.1, 23.5, 20.8, 15.9, 14.1; IR (ν_{max}/cm^{-1}): 3441, 2932, 2859, 2050, 1731, 1454, 1379,

[5] Xiao, D.; Ketcha, D. M. *J. Het. Chem.* **1995**, *32*, 499–503.

1308, 1256, 1157, 1084; ESI-MS calcd for $C_{24}H_{33}NNaO_3$ (MNa^+) 406.2353; found 4062347.

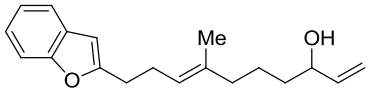
(*E*)-10-(1*H*-indol-1-yl)-7-methyldeca-1,7-dien-3-ol (1g)



The title compound was prepared following general procedure A from *N*-vinylindole[6] in 68 % yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.63 (dt, *J* = 7.9, 1.0 Hz, 1H), 7.36 (dd, *J* = 8.3, 1.0 Hz, 1H), 7.20 (ddd, *J* = 8.3, 7.0, 1.2 Hz, 1H), 7.12 – 7.06 (m, 2H), 6.47 (dd, *J* = 3.3, 0.8 Hz, 1H), 5.84 (ddd, *J* = 17.0, 10.4, 6.2 Hz, 1H), 5.22 (dt, *J* = 17.2, 1.4 Hz, 1H), 5.17 – 5.08 (m, 2H), 4.16 – 4.02 (m, 3H), 2.52 (q, *J* = 7.2 Hz, 2H), 2.01 – 1.92 (m, 2H), 1.51 – 1.33 (m, 7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 141.3, 138.3, 136.1, 128.7, 127.9, 121.4, 121.0, 120.4, 119.3, 114.8, 109.5, 101.0, 73.3, 46.4, 39.5, 36.6, 29.1, 23.5, 15.9; IR (ν_{max}/cm^{-1}): 3364, 2932, 2834, 1612, 1510, 1462, 1399, 1335, 1314, 1255, 1240, 1203, 1163, 1122, 1065, 1012; ESI-MS calcd for $C_{19}H_{25}NNaO$ (MNa^+) 306.1828; found 306.1824.

(*E*)-10-(benzofuran-2-yl)-7-methyldeca-1,7-dien-3-ol (1h)



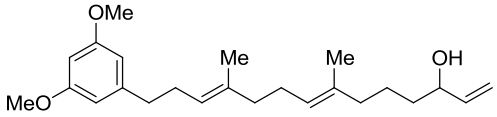
The title compound was prepared following general procedure A from 2-vinylbenzofuran[7] in 84 % yield.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.53 – 7.48 (m, 1H), 7.46 – 7.42 (m, 1H), 7.27 – 7.16 (m, 2H), 6.40 (d, *J* = 1.0 Hz, 1H), 5.85 (ddd, *J* = 17.2, 10.4, 6.2 Hz, 1H), 5.26 – 5.19 (m, 2H), 5.12 (ddd, *J* = 10.4, 1.2 Hz, 1H), 4.22 – 4.02 (m, 1H), 2.91 – 2.76 (m, 2H), 2.52 – 2.41 (m, 2H), 2.06 – 1.98 (m, 2H), 1.65 – 1.59 (m, 4H), 1.52 – 1.40 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 159.2, 154.7, 141.2, 136.3, 129.0, 123.2, 123.1, 122.4, 120.2, 114.6, 110.7, 102.0, 73.2, 39.4, 36.5, 28.7,

[6] D. Bogdal, K. Jaskot, *Syn. Comm.* **2000**, *30*, 3341–3352.
[7] Marrocchi, A.; Minuti, L.; Taticchi, A.; Scheeren, H. W. *Tetrahedron* **2001**, *57*, 4959–4965.

26.2, 23.4, 15.8; IR (v_{max}/cm^{-1}): 3366, 2930, 2831, 1455, 1253, 1168, 913, 744, 631; ESI-MS calcd for $C_{19}H_{24}NaO_2$ (MNa^+) 307.1669; found 307.1671.

(7*E*,11*E*)-14-(3,5-dimethoxyphenyl)-7,11-dimethyltetradeca-1,7,11-trien-3-ol (1i)



The title compound was prepared following general procedure A from (*E*)-1,3-dimethoxy-5-(4-methylhexa-3,5-dien-1-yl)benzene[8] in 64 % yield.
^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.40 – 6.38 (m, 2H), 6.33 (t, *J* = 2.3 Hz, 1H), 5.98 – 5.81 (m, 1H), 5.30 – 5.18 (m, 2H), 5.18 – 5.10 (m, 2H), 4.17 – 4.08 (br, 1H), 3.81 (s, 6H), 2.60 (dd, *J* = 9.2, 6.6 Hz, 2H), 2.39 – 2.28 (m, 2H), 2.15 – 2.05 (m, 2H), 2.06 – 1.97 (m, 5H), 1.61 (dd, *J* = 1.5, 0.7 Hz, 6H), 1.57 – 1.46 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 160.7, 144.9, 141.3, 135.8, 134.8, 124.5, 123.6, 114.6, 106.5, 97.7, 73.2, 55.3, 39.7, 39.5, 36.6, 36.5, 29.7, 26.6, 23.6, 16.1, 15.8; IR (v_{max}/cm^{-1}): 3376, 2935, 2838, 1596, 1459, 1293, 1205, 1152, 1068, 912, 742, 630; ESI-MS calcd for $C_{24}H_{37}O_3$ (MH^+) 373.2737; found 373.2735.

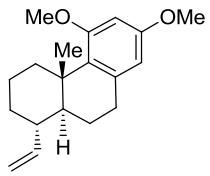
[8] Ota, K.; Kurokawa, T.; Kawashima, E.; Miyaoka, H. *Tetrahedron* **2009**, *65*, 8668-8676.

General Procedure B

Polyene Cyclizations of Allylic Alcohols

$[Ir(cod)_2Cl]_2$ (13.4 mg, 20.0 µmol, 0.04 equiv) and ligand **(*R*)-L** (40.8 mg, 80.0 µmol, 0.16 equiv) were placed in a screw capped vial (5.0 mL) or flask with a magnetic stir bar. Commercial grade 1,2-dichloroethane (3 mL) was added and the reaction vessel was quickly purged with nitrogen, closed and stirred vigorously for 15 mins during which the solution turned dark red. Allylic alcohol (0.5 mmol, 1.0 equiv) and $Zn(OTf)_2$ (36.4 mg, 0.1 mmol, 0.2 equiv) were added to the reaction mixture resulting in an orange solution. The reaction was stirred at room temperature for 24 h. The solvent was removed under reduced pressure and the residue was purified by flash chromatography (SiO_2; hexanes/CH_2Cl_2 mixture as the eluent) to afford the product.

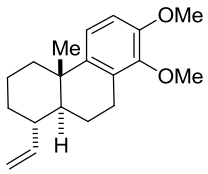
(1*S*,4a*S*,10a*S*)-5,7-dimethoxy-4a-methyl-1-vinyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (2a)



Following general procedure B on a double scale by using (*E*)-10-(3,5-dimethoxyphenyl)-7-methyldeca-1,7-dien-3-ol (**1a**, 1 mmol) afforded the title compound as a colorless oil in 90 % yield. The enantiomeric excess was found to be >99.5% (OJ-H; flow: 1.50 mL/min; 14.41 min (major), 16.85 min (minor); 99% CO_2, 1% MeOH at 100 bar, 40 ˚C).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.29 (d, *J* = 2.6 Hz, 1H), 6.20 (d, *J* = 2.5 Hz, 1H), 5.60 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 5.04 – 4.92 (m, 2H), 3.76 (d, *J* = 1.5 Hz, 6H), 3.11 – 3.01 (m, 1H), 2.86 – 2.67 (m, 2H), 2.18 (tdd, *J* = 11.9, 9.2, 3.8 Hz, 1H), 1.83 – 1.56 (m, 4H), 1.43 – 1.11 (m, 7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 160.1, 158.0, 144.5, 139.3, 128.7, 113.9, 105.1, 97.7, 55.2, 55.2, 49.6, 42.9, 38.2, 35.9, 34.4, 32.8, 22.1, 21.8, 17.9; IR (ν_{max}/cm^{-1}): 3047, 2932, 2834, 1477, 1297, 1159, 673, 630; MALDI-MS calcd for $C_{19}H_{26}O_2$ (M^+) 286.1927; found 286.1927; $[\alpha]_D^{25}$ = +149.6 (c = 1.0, $CHCl_3$).

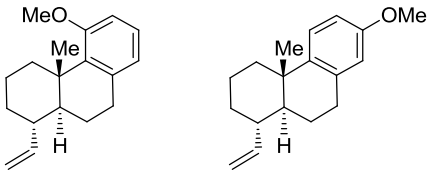
(1*S*,4a*S*,10a*S*)-7,8-dimethoxy-4a-methyl-1-vinyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (2b)



Following general procedure B by using (*E*)-10-(3,4-dimethoxyphenyl)-7-methyldeca-1,7-dien-3-ol (**1b**) afforded the title compound as a colorless oil in 71 % yield. The enantiomeric ratio was found to be >99.5% (OJ-H; flow: 1.50 mL/min; 27.88 min (minor), 33.84 min (major); 99% CO_2, 1% MeOH at 100 bar, 40 ˚C)**.**

^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.80 (s, 1H), 6.54 (s, 1H), 5.60 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 5.08 – 4.96 (m, 2H), 3.84 (d, *J* = 8.9 Hz, 6H), 2.82 – 2.67 (m, 2H), 2.21 (dq, *J* = 12.6, 2.9 Hz, 1H), 2.07 (tdd, *J* = 12.4, 8.9, 3.6 Hz, 1H), 1.92 – 1.81 (m, 1H), 1.79 – 1.66 (m, 3H), 1.55 – 1.17 (m, 4H), 1.13 (d, *J* = 0.7 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 147.1, 147.0, 143.9, 140.3, 127.9, 114.2, 111.8, 108.4, 56.2, 55.9, 46.5, 43.4, 38.2, 36.9, 34.0, 29.4, 22.9, 22.6, 21.8; IR (ν_{max}/cm^{-1}): 3061, 2927, 2848, 1508, 1465, 1256, 1152, 764, 630; ESI-MS calcd for $C_{19}H_{27}O_2$ (MH^+) 287.2006; found 287.2009; $[\alpha]_D^{25}$ = +118.6 (c = 0.5, $CHCl_3$).

(1*S*,4a*S*,10a*S*)-5-methoxy-4a-methyl-1-vinyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (2c') and (1*S*,4a*S*,10a*S*)-7-methoxy-4a-methyl-1-vinyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (2c)



2c' **2c**

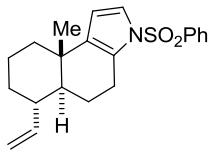
Following general procedure B by using (*E*)-10-(3-methoxyphenyl)-7-methyldeca-1,7-dien-3-ol (**1c**) afforded the title compounds **2c'** and **2c** in a 1:2 ratio and 69 % overall yield. Separation of resulting regioisomers proved difficult by using normal

silica, however $AgNO_3$–impregnated SiO_2 partially resolve the mixture. The enantiomeric excess was found to be >99.5% for **2c** (OJ-H; flow: 2.00 mL/min; 11.41 min (major), 13.44 min (minor); 99% CO_2, 1% MeOH at 100 bar, 25 ˚C); and 99% for **2c'** (OJ-H; flow: 2.00 mL/min; 6.77 min (major), 7.18 min (minor); 100% CO_2 at 100 bar, 25 ˚C).

2c': ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.05 (t, *J* = 7.9 Hz, 1H), 6.72 (s, 1H), 6.70 (s, 1H), 5.61 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 5.06 – 4.92 (m, 2H), 3.79 (s, 3H), 3.17 – 3.01 (m, 1H), 2.91 – 2.67 (m, 2H), 2.19 (tdd, *J* = 12.1, 9.2, 3.8 Hz, 1H), 1.85 – 1.58 (m, 4H), 1.46 – 1.11 (m, 7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 159.2, 144.5, 138.7, 135.9, 126.2, 122.5, 114.0, 109.3, 55.2, 49.4, 42.9, 38.7, 35.6, 34.4, 32.3, 22.1, 21.8, 17.7; IR (ν_{max}/cm^{-1}): 3107, 3036, 2818, 1478, 1314, 1281, 1123, 681, 673, 630; MALDI-MS calcd for $C_{18}H_{24}O$ (M^+) 256.1822; found 256.1822; $[\alpha]_D^{25}$ = +113.9 (c = 2.0, $CHCl_3$).

2c: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.23 (d, *J* = 8.8 Hz, 1H), 6.73 (dd, *J* = 8.8, 2.8, 1H), 6.65 – 6.58 (m, 1H), 5.62 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 5.07 – 4.97 (m, 2H), 3.79 (s, 3H), 2.88 – 2.81 (m, 2H), 2.30 – 2.22 (m, 1H), 2.15 – 2.03 (m, 1H), 1.93 – 1.84 (m, 1H), 1.79 – 1.68 (m, 3H), 1.56 – 1.17 (m, 4H), 1.13 (d, *J* = 0.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 157.3, 144.0, 140.7, 137.1, 125.9, 114.2, 113.7, 111.9, 55.3, 46.4, 43.5, 38.1, 36.6, 34.0, 30.0, 23.0, 22.5, 21.8; IR (ν_{max}/cm^{-1}): 3109, 3036, 2816, 1478, 1321, 1277, 1165, 681, 673, 631; MALDI-MS calcd for $C_{18}H_{24}O$ (M^+) 256.1822; found 256.1822; $[\alpha]_D^{25}$ = +132.3 (c = 2.0, $CHCl_3$).

(5a*S*,6*S*,9a*S*)-9a-methyl-3-(phenylsulfonyl)-6-vinyl-4,5,5a,6,7,8,9,9a-octahydro-3*H*-benzo[*e*]indole (2d)

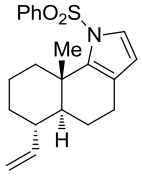


Following general procedure B by using (*E*)-7-methyl-10-(1-(phenylsulfonyl)-1*H*-pyrrol-2-yl)deca-1,7-dien-3-ol (**1d**) afforded the title compound as a colorless oil in 90 % yield. The enantiomeric ratio was found to be >99.5% (OJ-H; flow: 2.00

mL/min; 9.83 min (major), 10.98 min (minor); 98% CO_2, 2% MeOH at 100 bar, 25 ˚C)**.**

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.60 – 7.53 (m, 3H), 7.50 – 7.43 (m, 2H), 7.29 (d, *J* = 3.5 Hz, 1H), 6.05 (d, *J* = 3.5 Hz, 1H), 5.52 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 5.01 – 4.87 (m, 2H), 2.74 – 2.61 (m, 1H), 2.47 – 2.41 (m, 2H), 2.15 – 2.02 (m, 1H), 1.80 – 1.71 (m, 1H), 1.66 – 1.52 (m, 2H), 1.45 – 1.13 (m, 6H), 1.13 – 0.93 (m, 1H), 0.79 – 0.61 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 144.0, 141.4, 140.8, 133.2, 129.2, 126.1, 125.7, 125.2, 114.2, 112.0, 50.1, 42.3, 38.0, 36.0, 34.0, 24.9, 22.1, 21.1, 18.9; IR (ν_{max}/cm^{-1}): 3727, 3626, 3090, 3035, 1812, 1478, 1363, 1173, 1034; ESI-MS calcd for $C_{21}H_{26}NO_2S$ (MH^+) 356.1679; found 356.1685; $[\alpha]_D^{25}$ = +69.9 (c = 2.0, $CHCl_3$).

(5a*S*,6*S*,9a*S*)-9a-methyl-1-(phenylsulfonyl)-6-vinyl-4,5,5a,6,7,8,9,9a-octahydro-1*H*-benzo[*g*]indole (2e)

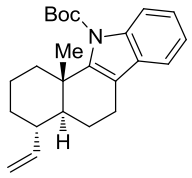


Following general procedure B by using (*E*)-7-methyl-10-(1-(phenylsulfonyl)-1*H*-pyrrol-3-yl)deca-1,7-dien-3-ol (**1e**) afforded the title compound as a colorless oil in 93 % yield. The enantiomeric ratio was found to be >99.5% (OJ-H; flow: 2.00 mL/min; 12.65 min (major), 13.27 min (minor); 98% CO_2, 2% MeOH at 100 bar, 25 ˚C)**.**

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.79 – 7.72 (m, 2H), 7.59 (ddt, *J* = 8.3, 6.7, 1.3 Hz, 1H), 7.53 – 7.47 (m, 2H), 7.16 (dt, *J* = 3.4, 0.9 Hz, 1H), 6.13 (d, *J* = 3.4 Hz, 1H), 5.52 (ddd, *J* = 17.0, 10.2, 8.9 Hz, 1H), 4.99 – 4.92 (m, 2H), 2.87 – 2.76 (m, 1H), 2.47 (dddd, *J* = 17.2, 11.4, 7.1, 1.2 Hz, 1H), 2.00 (tdd, *J* = 12.0, 8.8, 3.8 Hz, 1H), 1.93 – 1.49 (m, 5H), 1.47 – 1.07 (m, 4H), 1.05 – 0.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 143.7, 139.7, 135.5, 133.6, 129.4, 127.7, 126.9, 121.2, 114.31, 109.0, 46.9, 42.2, 37.6, 34.2, 34.2, 23.7, 22.2, 21.7, 21.1; IR (ν_{max}/cm^{-1}): 3725,

3625, 2928, 2848, 1478, 1369, 1184, 1135; ESI-MS calcd for $C_{21}H_{26}NO_2S$ (MH^+) 356.1679; found 356.1684; $[\alpha]_D^{25}$ = +92.6 (c = 2.0, $CHCl_3$).

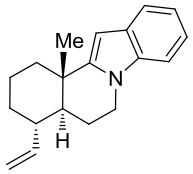
(4*S*,4a*S*,11b*S*)-*tert*-butyl 11b-methyl-4-vinyl-2,3,4,4a,5,6-hexahydro-1*H*-benzo[*a*]carbazole-11(11b*H*)-carboxylate (2f)



Following general procedure B by using (*E*)-*tert*-butyl 3-(8-hydroxy-4-methyldeca-3,9-dien-1-yl)-1*H*-indole-1-carboxylate (**1f**) afforded the title compound as a colorless oil in 86 % yield. The enantiomeric ratio was found to be >99.5% (OJ-H; flow: 2.00 mL/min; 7.71 min (major), 8.24 min (minor); 99.5% CO_2, 0.5% MeOH at 100 bar, 25 ˚C)**.**

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.87 (ddd, *J* = 8.3, 1.2, 0.7 Hz, 1H), 7.38 (ddd, *J* = 7.3, 1.6, 0.7 Hz, 1H), 7.26 – 7.14 (m, 2H), 5.61 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 5.07 – 4.97 (m, 2H), 2.76 – 2.54 (m, 3H), 2.29 – 2.16 (m, 1H), 1.94 (ddt, *J* = 15.1, 6.8, 1.6 Hz, 1H), 1.80 – 1.50 (m, 15H), 1.47 – 1.12 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 151.6, 145.1, 144.1, 136.9, 129.4, 123.6, 122.1, 118.0, 116.8, 114.6, 114.2, 83.6, 50.9, 42.6, 37.7, 34.3, 34.2, 28.4, 22.1, 21.6, 21.1, 18.3; IR (ν_{max}/cm^{-1}): 3069, 2976, 2927, 2862, 1731, 1478, 1454, 1368, 1356, 1310, 1250, 1223, 1153, 1117; ESI-MS calcd for $C_{24}H_{31}NNaO_2$ (MNa^+) 388.2247; found 388.2244; $[\alpha]_D^{25}$ = +182.6 (c = 2.0, $CHCl_3$).

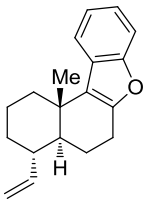
(4*S*,4a*S*,12b*S*)-12b-methyl-4-vinyl-1,2,3,4,4a,5,6,12b-octahydroindolo[2,1-*a*]isoquinoline (2g)



Following general procedure B by using (*E*)-10-(1*H*-indol-1-yl)-7-methyldeca-1,7-dien-3-ol (**1g**) afforded the title compound as a white foam in 71 % yield. The enantiomeric excess was found to be 99% (IB; flow: 2.00 mL/min; 8.03 min (minor), 9.03 min (major); 95% CO_2, 5% MeOH at 100 bar, 25 ˚C).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.54 (dt, *J* = 7.6, 0.9 Hz, 1H), 7.27 – 7.23 (m, 1H), 7.14 (ddd, *J* = 8.2, 7.0, 1.3 Hz, 1H), 7.08 (ddd, *J* = 8.2, 7.1, 1.2 Hz, 1H), 6.21 (s, 1H), 5.61 (ddd, *J* = 17.0, 10.1, 8.8 Hz, 1H), 5.12 – 4.99 (m, 2H), 4.30 (ddd, *J* = 11.9, 7.0, 1.3 Hz, 1H), 3.83 (td, *J* = 11.9, 6.5 Hz, 1H), 2.24 – 2.05 (m, 4H), 1.96 – 1.62 (m, 5H), 1.53 – 1.45 (m, 1H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 149.2, 143.0, 136.3, 128.6, 120.4 120.0, 119.7, 115.1, 108.9, 94.3, 44.4, 42.6, 42.4, 37.6, 35.2, 33.7, 22.7, 22.4, 21.0; IR (ν_{max}/cm^{-1}): 3090, 3035, 2912, 2818, 1478, 1321, 1124, 681, 673, 630; MALDI-MS calcd for $C_{19}H_{23}N$ (M^+) 265.1825; found 265.1825; $[\alpha]_D^{25}$ = +100.4 (c = 2.0, $CHCl_3$).

(4*S*,4a*S*,11c*S*)-11c-methyl-4-vinyl-1,2,3,4,4a,5,6,11c-octahydronaphtho[2,1-*b*]benzofuran (2h)

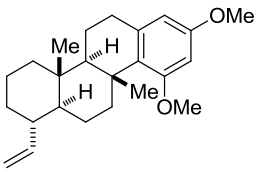


Following general procedure B by using (*E*)-10-(benzofuran-2-yl)-7-methyldeca-1,7-dien-3-ol (**1h**) afforded the title compound as a colorless oil in 89 % yield. The enantiomeric ratio was found to be 99.5% (IB; flow: 2.00 mL/min; 6.86 min (minor), 7.43 min (major); 98% CO_2, 2% MeOH at 100 bar, 25 ˚C)**.**

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.61 – 7.54 (m, 1H), 7.45 – 7.35 (m, 1H), 7.22 – 7.09 (m, 2H), 5.62 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 5.07 – 4.99 (m, 2H), 2.77 –

2.70 (m, 2H), 2.54 – 2.46 (m, 1H), 2.23 – 2.10 (m, 1H), 2.04 – 1.95 (m, 1H), 1.83 – 1.63 (m, 3H), 1.62 – 1.50 (m, 2H), 1.43 (ddd, *J* = 13.0, 11.1, 2.2 Hz, 1H), 1.27 (s, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ = 154.9, 153.0, 143.7, 127.5, 123.1, 122.6, 122.0, 120.2, 114.4, 111.1, 48.4, 42.2, 37.1, 35.5, 34.3, 24.3, 22.2, 21.1, 20.0; IR (v_{max}/cm^{-1}): 3071, 3035, 2929, 1478, 1451, 1182, 674, 630; ESI-MS calcd for $C_{19}H_{23}O$ (MH^+) 267.1743; found 267.1746; $[\alpha]_D^{25}$ = +98.6 (c = 5.0, $CHCl_3$).

(1*S*,4a*S*,4b*R*,10b*R*,12a*S*)-8,10-dimethoxy-4a,10b-dimethyl-1-vinyl-1,2,3,4,4a,4b,5,6,10b,11,12,12a-dodecahydrochrysene (2i)



Following general procedure B by using (7*E*,11*E*)-14-(3,5-dimethoxyphenyl)-7,11-dimethyltetradeca-1,7,11-trien-3-ol (**1i**) afforded the title compound as a white solid in 43 % yield and a mixture of mono- and dicyclized product **2i'** in 30 % yield. The enantiomeric excess was found to be 99.5% (OJ-H; flow: 2.00 mL/min; 16.49 min (major), 18.19 min (minor); 99.5% CO_2, 0.5% MeOH at 100 bar, 25 ˚C).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.28 (d, *J* = 2.6 Hz,1H), 6.20 (d, *J* = 2.4 Hz, 1H), 5.54 (ddd, *J* = 17.1, 10.1, 8.9 Hz, 1H), 4.98 – 4.84 (m, 2H), 3.76 (s, 3H), 3.74 (s, 3H), 3.10 (dt, *J* = 12.9, 2.8 Hz, 1H), 2.87 – 2.75 (m, 2H), 1.96 – 1.78 (m, 3H), 1.73 – 1.47 (m, 5H), 1.35 – 1.07 (m, 7H), 1.00 – 0.80 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 159.8, 157.9, 144.5, 138.9, 130.8, 113.4, 104.9, 97.8, 56.3, 55.2, 55.2, 51.8, 42.6, 39.8, 39.1, 37.8, 37.5, 34.1, 33.8, 23.2, 21.2, 21.0, 18.1, 14.4; IR (v_{max}/cm^{-1}): 3079, 2986, 2964, 2929, 2841, 1615, 1575, 1473, 1463, 1449, 1291, 1220, 1159, 1097; MALDI-MS calcd for $C_{24}H_{35}O_2$ (MH^+) 355.2632; found 355.2632; m.p. [°C] = 154.5 – 155.5; $[\alpha]_D^{25}$ = -31.6 (c = 1.0, $CHCl_3$).

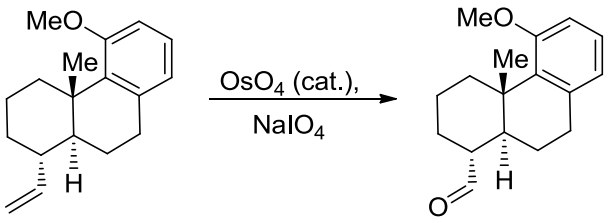
Procedure for cyclization of 2i' to 2i

To a solution of **2i'** (35 mg, 1.0 mmol, 1.0 equiv) in DCE (4 mL) was added TFA (38 μl, 0.50 mmol, 5.0 equiv) and the reaction mixture was stirred for 24h at 60 °C. The solvent was removed under reduced pressure and the residue was

purified by flash chromatography (SiO_2; Hexanes/CH_2Cl_2 5:1) to give the product **2i** as a white solid in 75 % yield and 99.5% ee.

Determination of Absolute Stereochemistry

Determination of the absolute stereochemistry of (1*S*,4a*S*,10a*S*)-5-methoxy-4a-methyl-1-vinyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene by correlation of 2c' to (1*R*,4a*S*,10a*S*)-5-methoxy-4a-methyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene-1-carbaldehyde



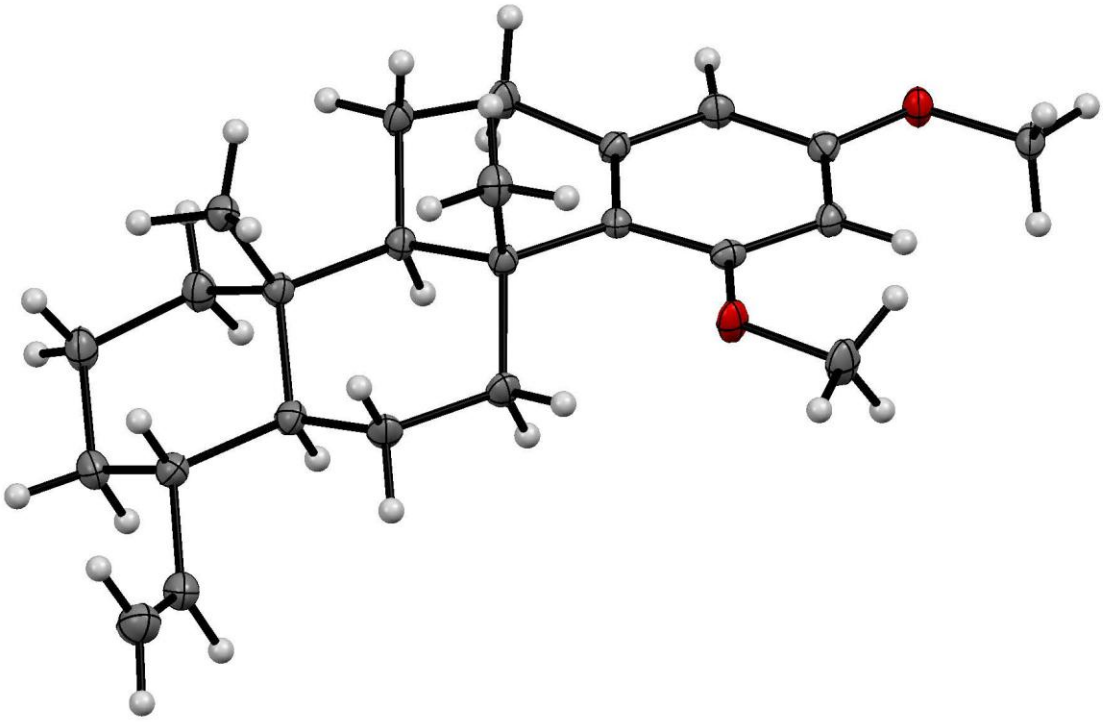
Sodium metaperiodate (25.0 mg, 0.12 mmol, 3.0 equiv) and osmium(VIII) oxide (4.0 % solution in water, 6.0 µL, 0.8 µmol, 0.02 equiv) were added at 0 °C to a solution of (1*S*,4a*S*,10a*S*)-5-methoxy-4a-methyl-1-vinyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene (175 mg, 0.80 mmol, 1.0 equiv) in acetone/water 3:1 (0.5 mL). After 1 h, the reaction mixture was allowed to reach room temperature, and was then partitioned between ethyl acetate and water. The organic layer was washed with brine, dried ($MgSO_4$), and evaporated under reduced pressure. The residue was purified by flash chromatography (SiO_2, hexanes/EtOAc 5:1) to provide (1*R*,4a*S*,10a*S*)-5-methoxy-4a-methyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene-1-carbaldehyde. $[\alpha]_D^{28}$ = +106.5 (c = 0.5, $CHCl_3$); reported[9] rotation for (1*S*,4a*R*,10a*R*)-5-methoxy-4a-methyl-1,2,3,4,4a,9,10,10a-octahydrophenanthrene-1-carbaldehyde $[\alpha]_D^{20}$ = –70.8 (c = 0.53, $CHCl_3$, 88% ee).

[9] Rendler, S.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2010**, *132*, 5027-5029.

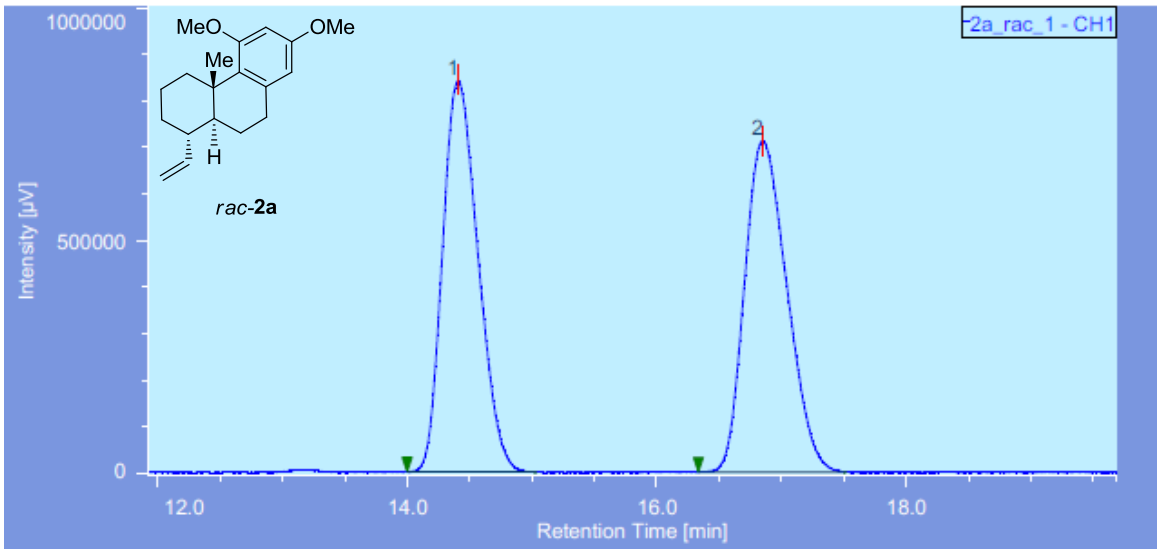
X-ray Structure of 2i

Single crystals of **2i** suitable for X-ray crystallographic analysis were obtained by a single recrystallization at room temperature using slow diffusion of MeOH into a solution of **2i** in CH_2Cl_2. X-ray crystal structure analysis of **2i**: formula $C_{24}H_{34}O_2$, M = 354.51, colorless crystals 0.090 x 0.260 x 0.320 mm, monoclinic, space group C121, a = 13.0071(7) Å, b = 6.7819(4) Å, c = 22.0380(15) Å, β = 93.132(2)°, V = 1941.1(2) $Å^3$, $d_{cacl.}$ = 1.213 $g \cdot cm^{-3}$, I = 0.075 mm^{-1}. See provided cif-file for further details.

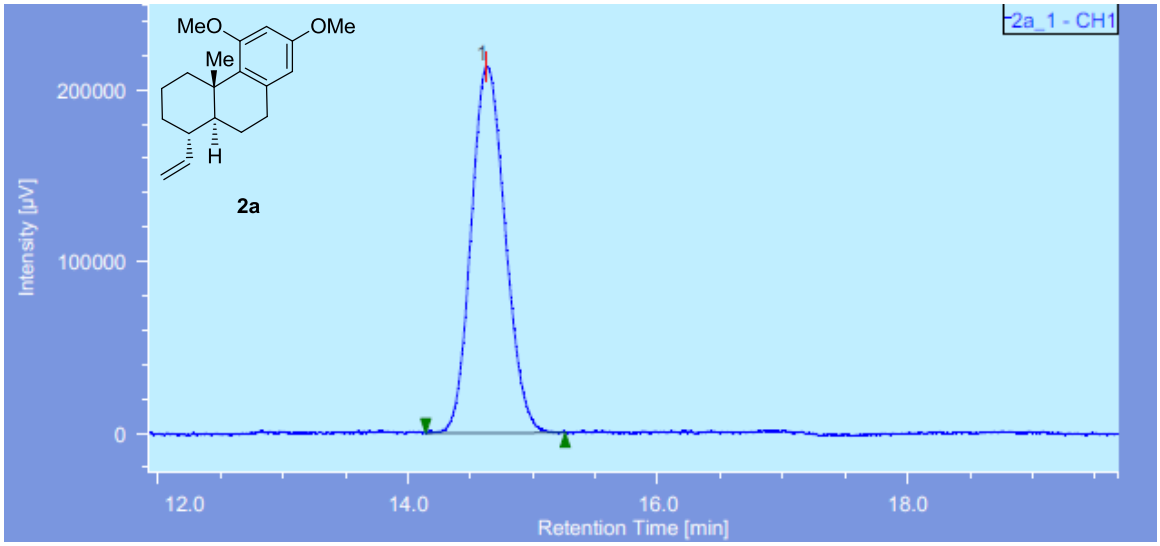
Figure S1. X-ray structure of 2i



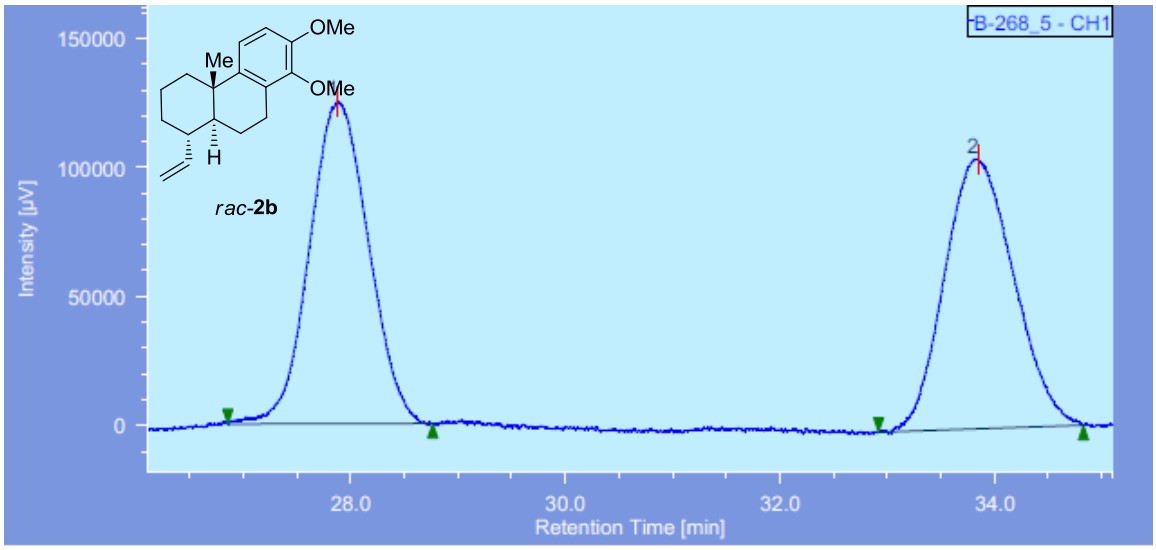
SFC traces of racemic and enantioenriched products



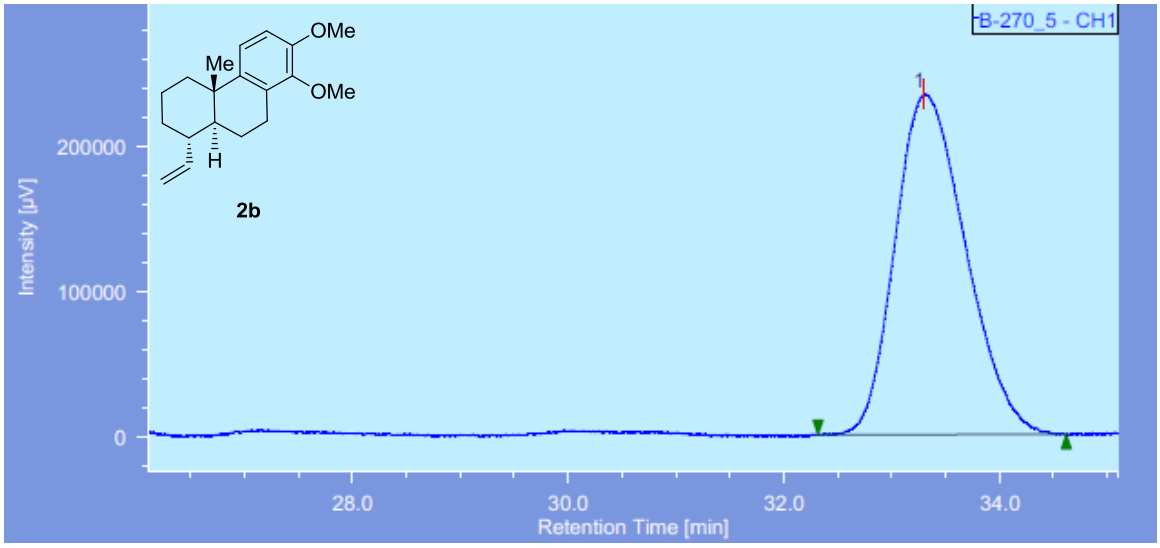
#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	1	14.408	16642962	840238	49.891	54.159	N/A	11739	4.190	1.229	
2	Unknown	1	16.850	16715579	711198	50.109	45.841	N/A	11209	N/A	1.244	



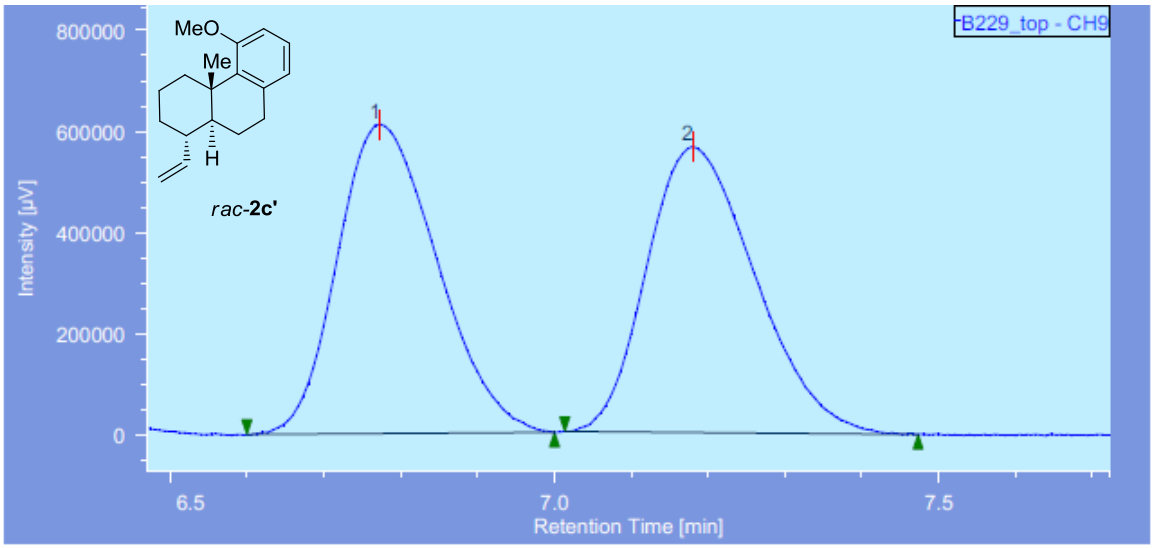
#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor
1	Unknown	1	14.633	4050259	213222	100.000	100.000	N/A	13532	N/A	1.126



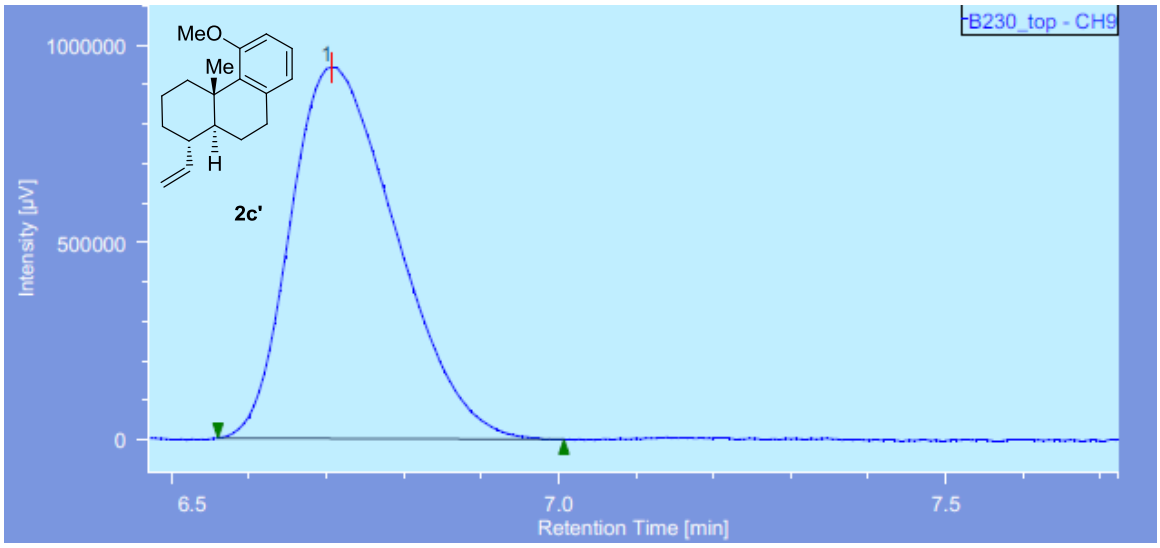
#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	1	27.883	4764766	124768	50.462	54.396	N/A	12027	5.369	1.039	
2	Unknown	1	33.842	4677576	104603	49.538	45.604	N/A	12546	N/A	1.115	



#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor
1	Unknown	1	33.300	10675693	234819	100.000	100.000	N/A	12053	N/A	1.261



#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	9	6.773	5501396	610832	49.907	51.963	N/A	12547	1.617	1.230	
2	Unknown	9	7.180	5521952	564683	50.093	48.037	N/A	11961	N/A	1.265	



#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor
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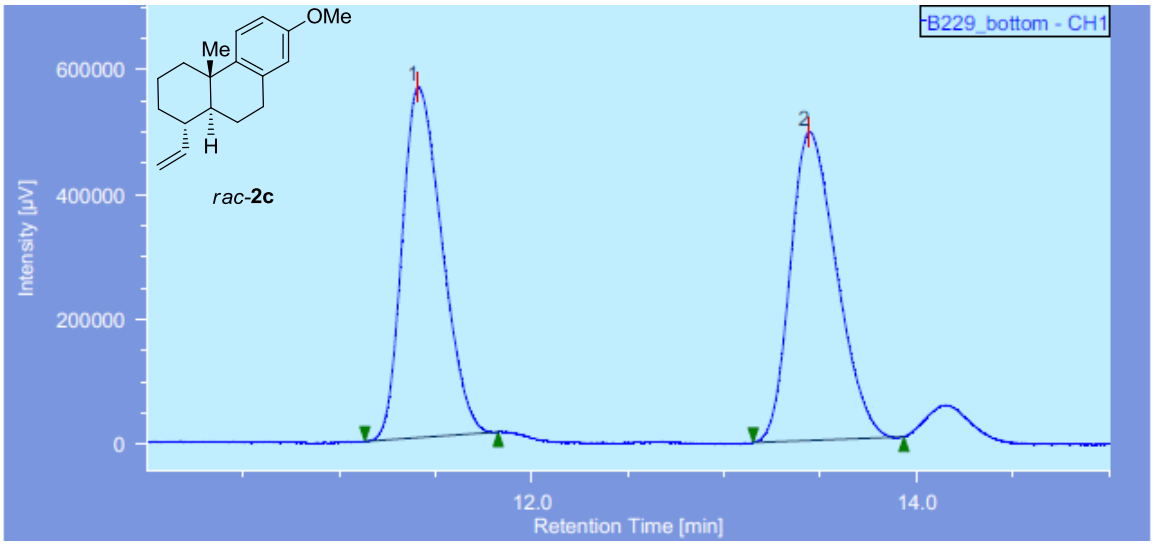
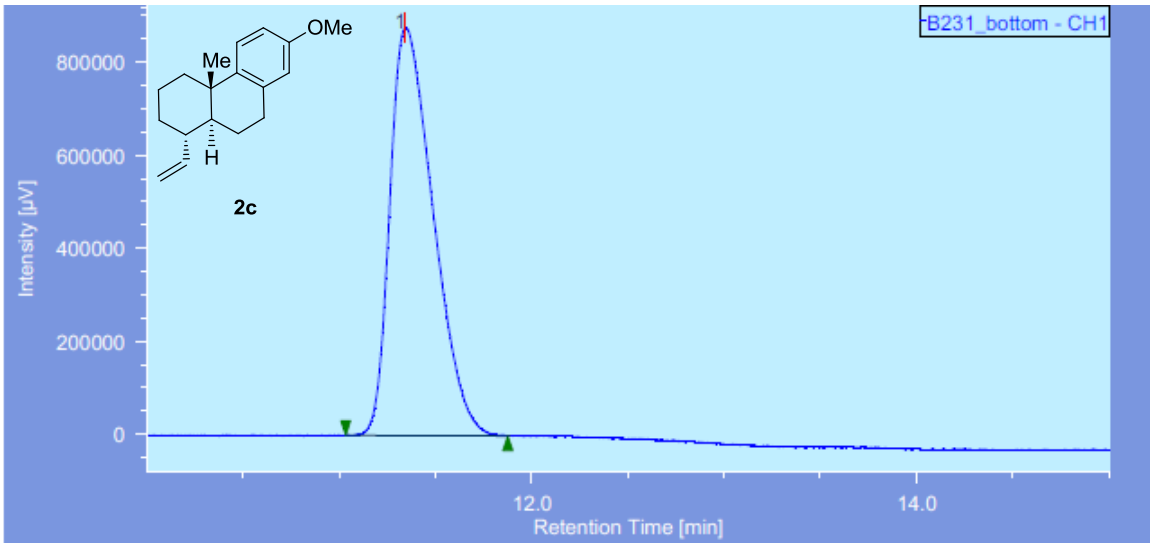
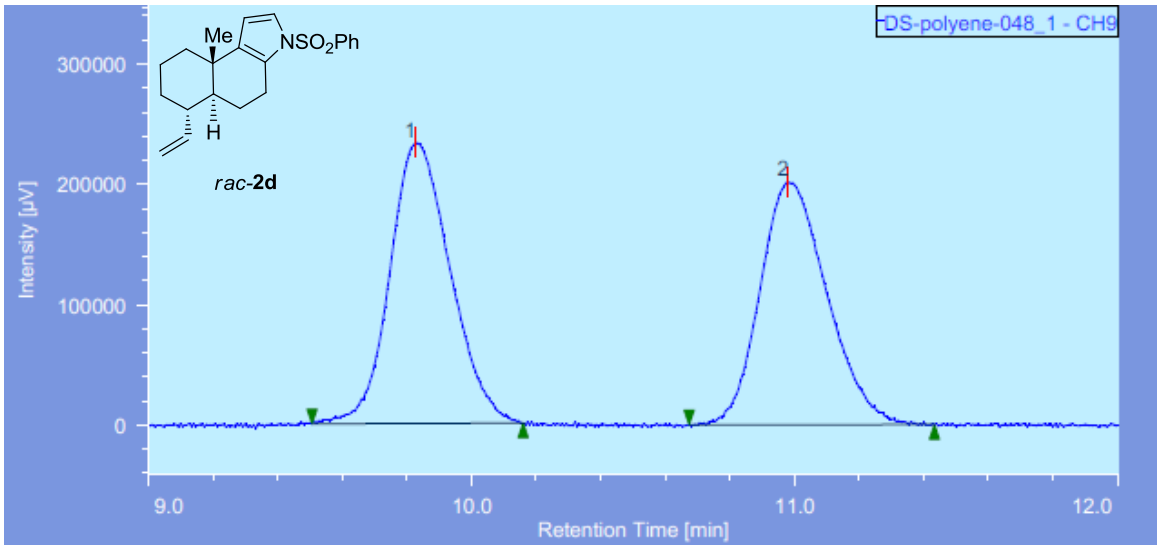


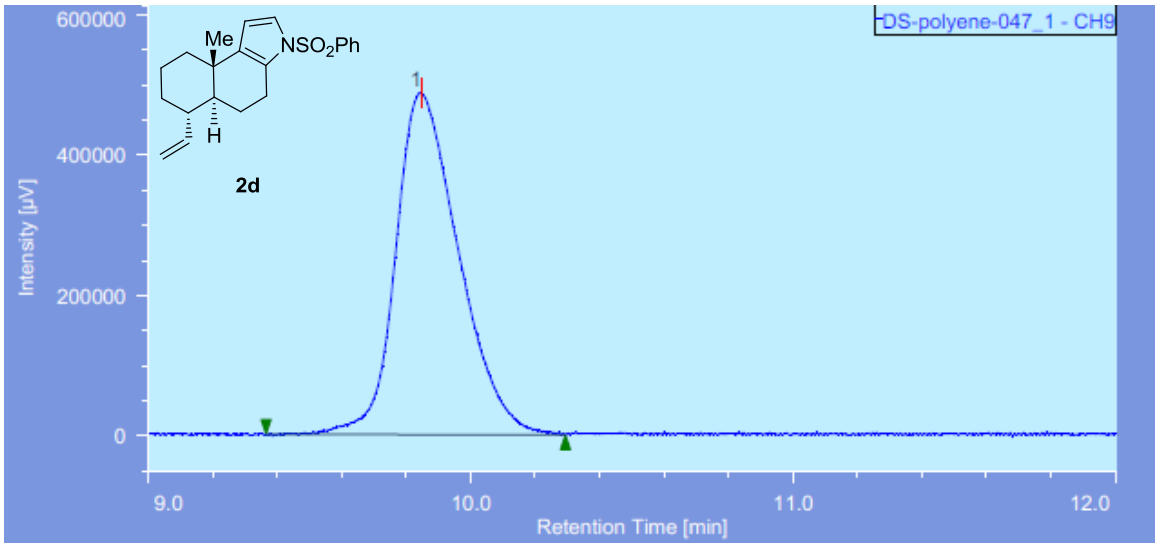
#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	1	11.408	8043617	560681	49.344	53.203	N/A	14075	4.901	1.310	
2	Unknown	1	13.442	8257559	493177	50.656	46.797	N/A	14448	N/A	1.286	



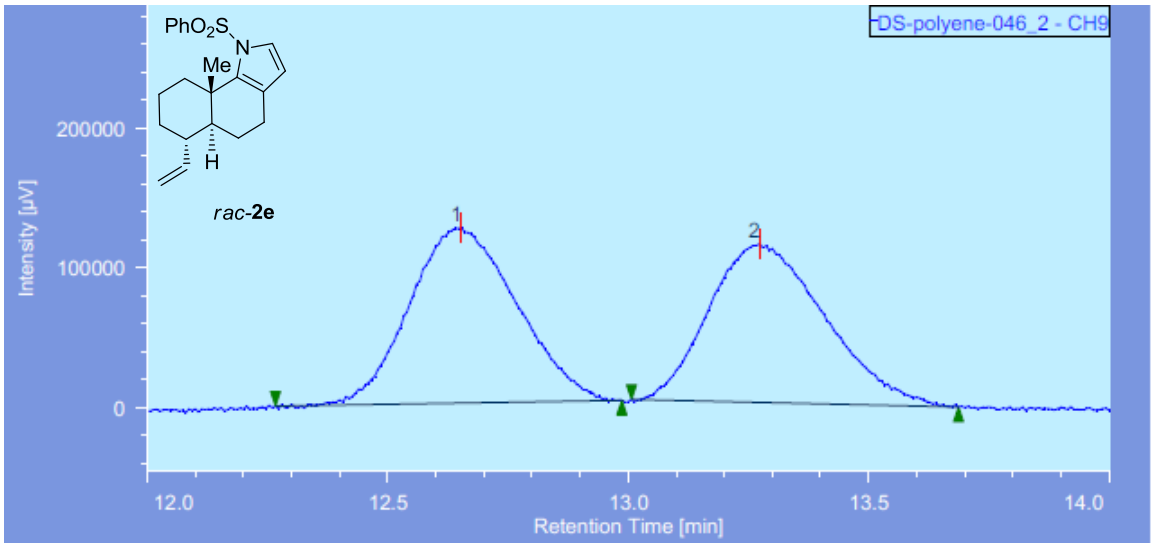
#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor
1	Unknown	1	11.342	13684873	876110	100.000	100.000	N/A	11831	N/A	1.526



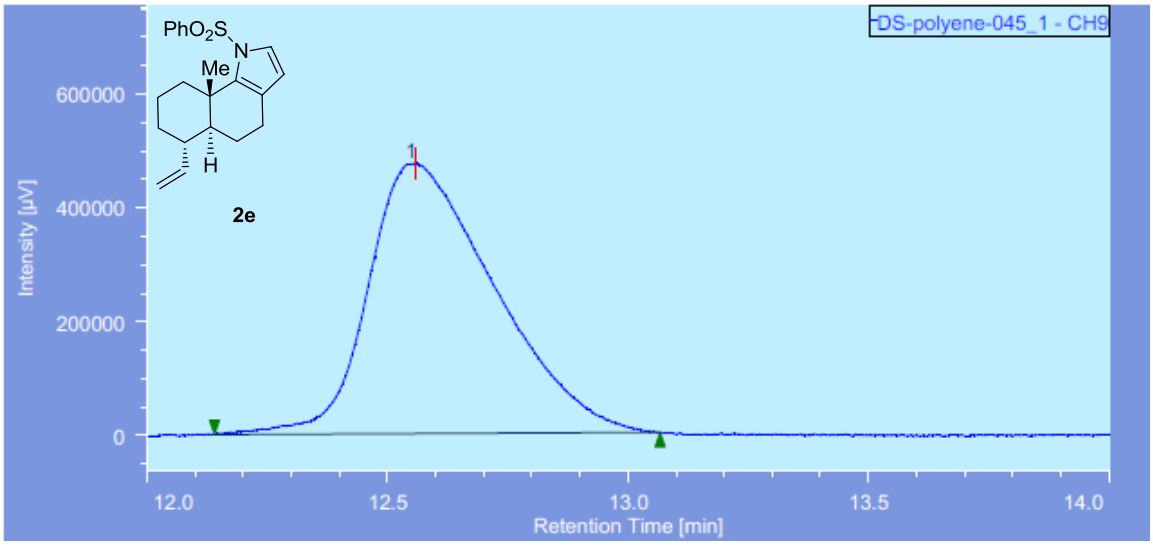
#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	9	9.827	3030887	232991	51.064	53.635	N/A	13388	3.212	1.177	
2	Unknown	9	10.980	2904594	201413	48.936	46.365	N/A	13341	N/A	1.251	



#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor
1	Unknown	9	9.847	6610054	486880	100.000	100.000	N/A	12762	N/A	1.279



#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	9	12.653	1944327	125740	50.683	52.549	N/A	14318	1.423	1.089	
2	Unknown	9	13.273	1891909	113542	49.317	47.451	N/A	13881	N/A	1.267	



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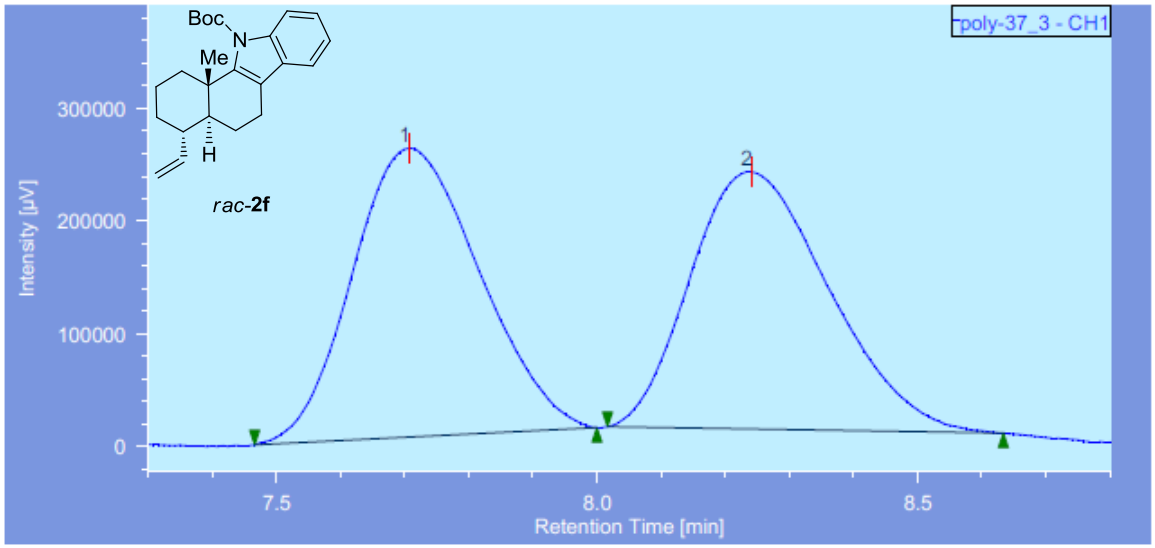
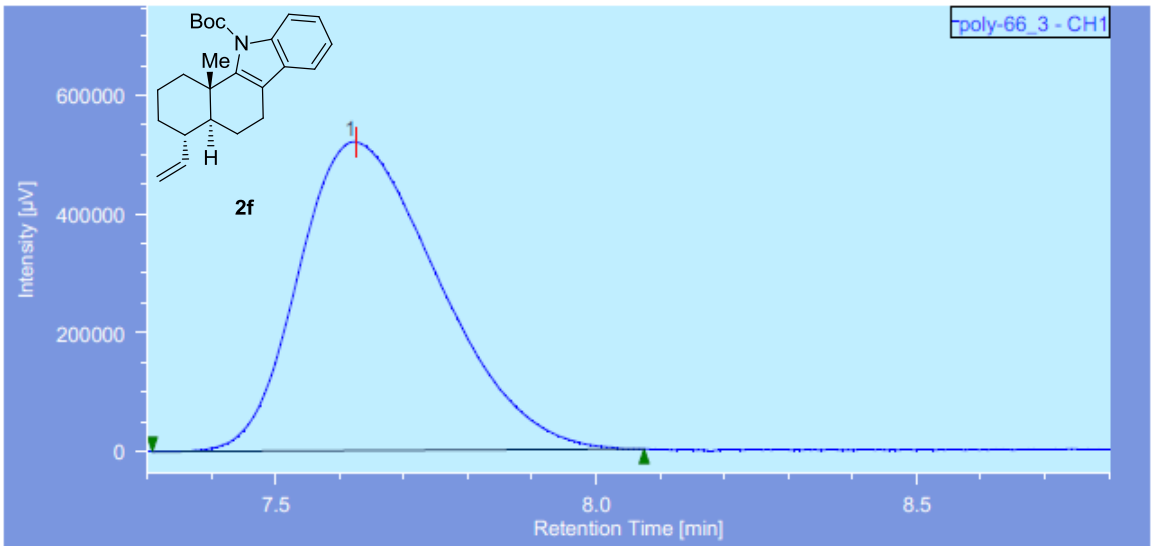


#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	1	7.708	3517761	256159	50.712	52.925	N/A	6882	1.378	1.142	
2	Unknown	1	8.242	3418938	227844	49.288	47.075	N/A	6632	N/A	1.240	



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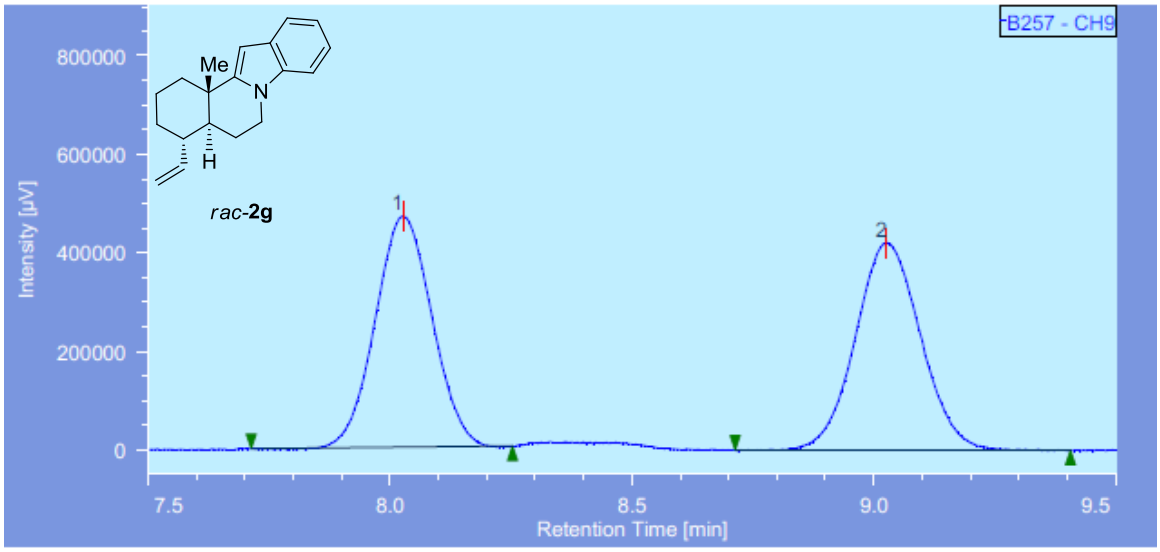
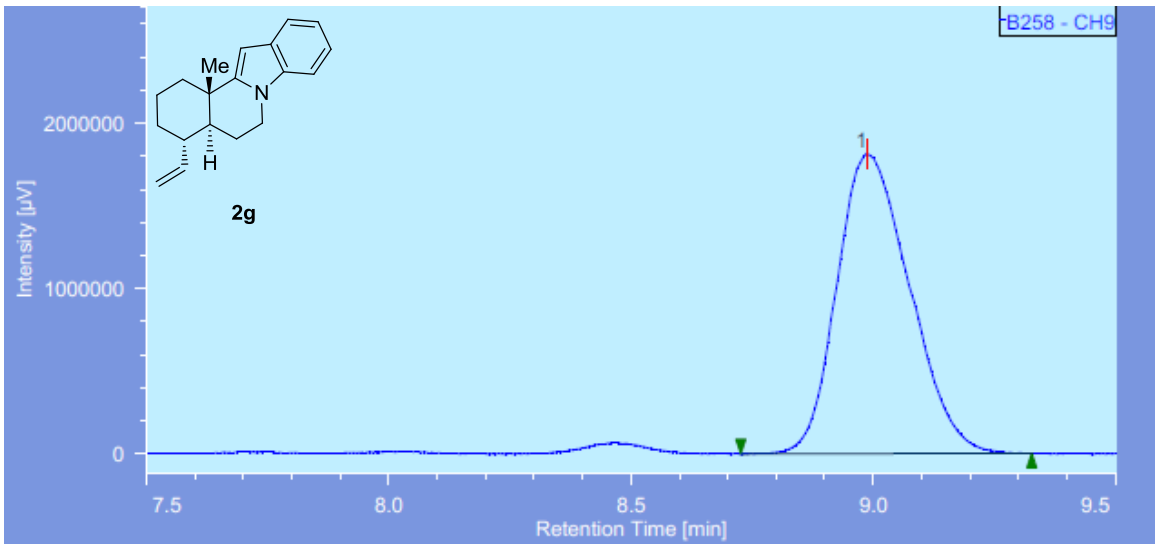


#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	9	8.027	3812775	468410	49.181	52.679	N/A	22002	4.333	1.032	
2	Unknown	9	9.027	3939820	420760	50.819	47.321	N/A	21487	N/A	1.049	



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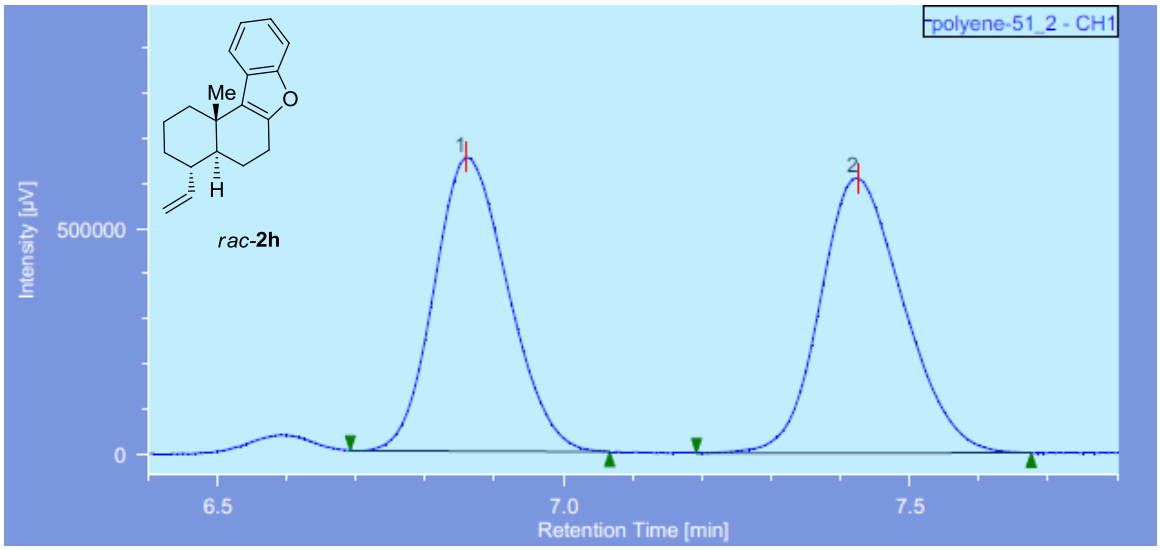
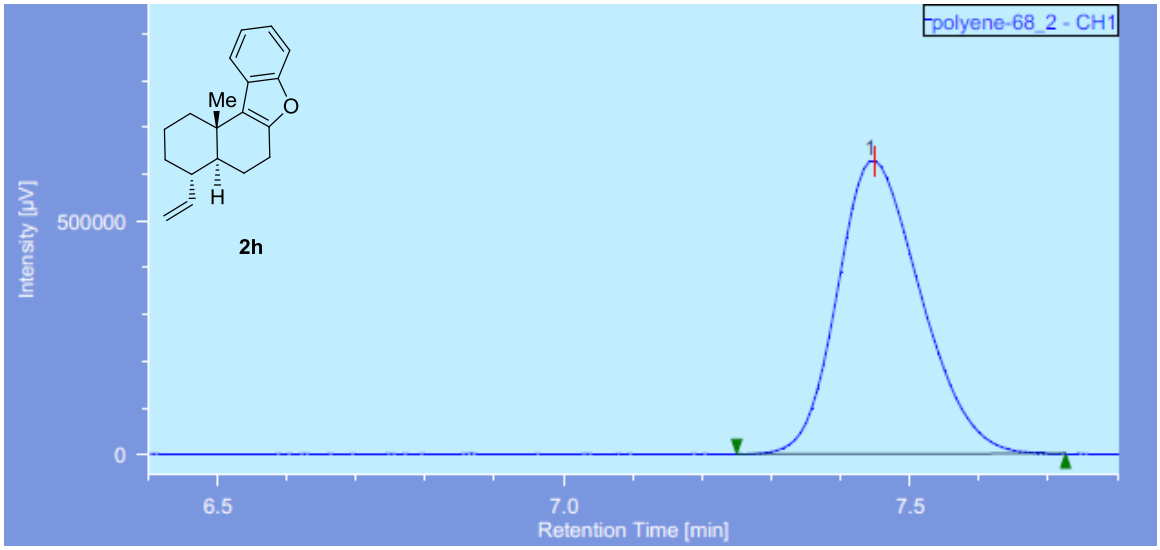


#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	1	6.858	4812327	650068	48.552	51.633	N/A	19431	2.728	1.183	
2	Unknown	1	7.425	5099302	608937	51.448	48.367	N/A	18253	N/A	1.154	



#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor
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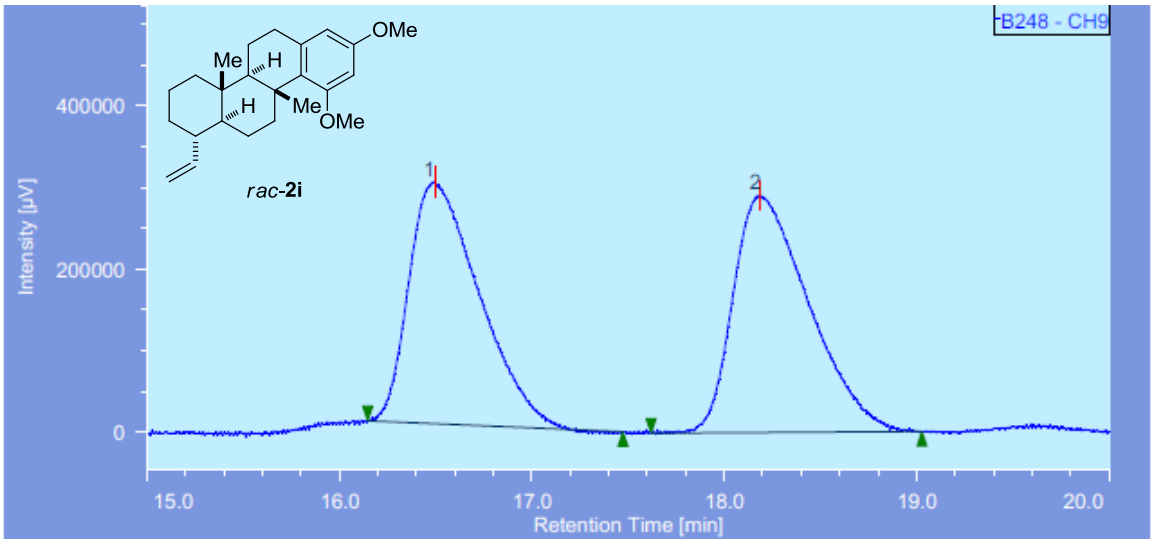
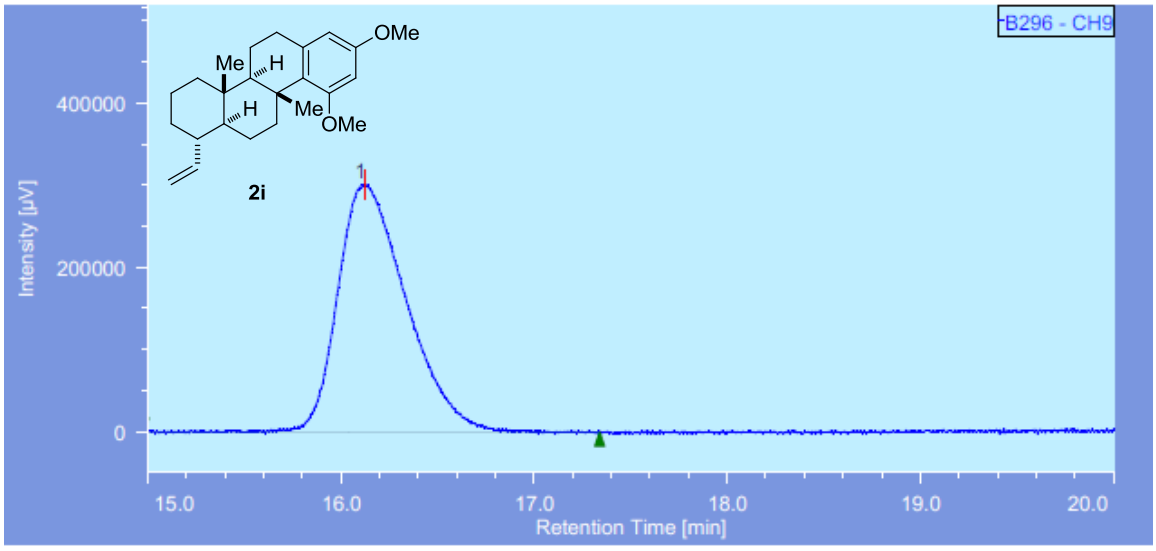
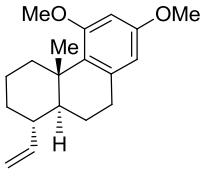


#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor	Warning
1	Unknown	9	16.493	7509364	295946	48.592	50.396	N/A	9405	2.414	1.558	
2	Unknown	9	18.187	7944571	291297	51.408	49.604	N/A	10030	N/A	1.531	



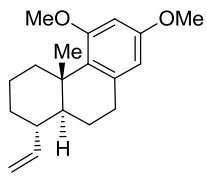
#	Peak Name	CH	tR [min]	Area [µV·sec]	Height [µV]	Area%	Height%	Quantity	NTP	Resolution	Symmetry Factor
1	Unknown	9	16.127	7460288	301169	100.000	100.000	N/A	9916	N/A	1.393

^{1}H-NMR and ^{13}C-NMR Spectra of Products



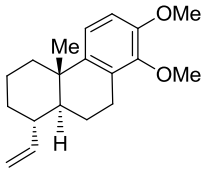
2a

^{1}H-NMR: 400 MHz, $CDCl_3$



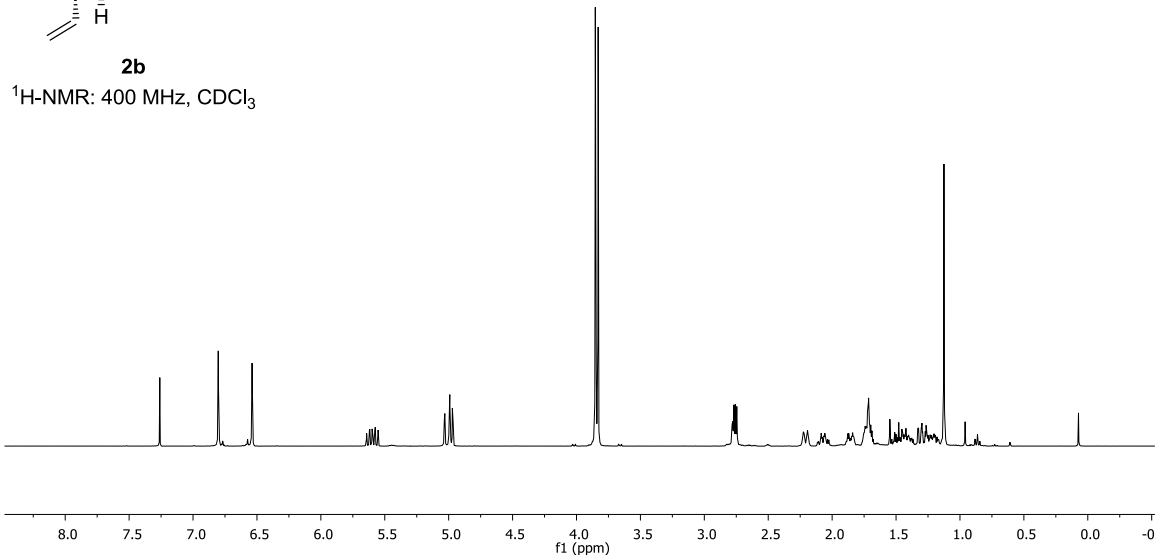
2a

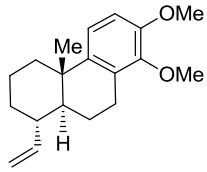
^{13}C-NMR: 100 MHz, $CDCl_3$



2b

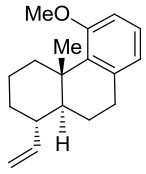
^{1}H-NMR: 400 MHz, $CDCl_3$





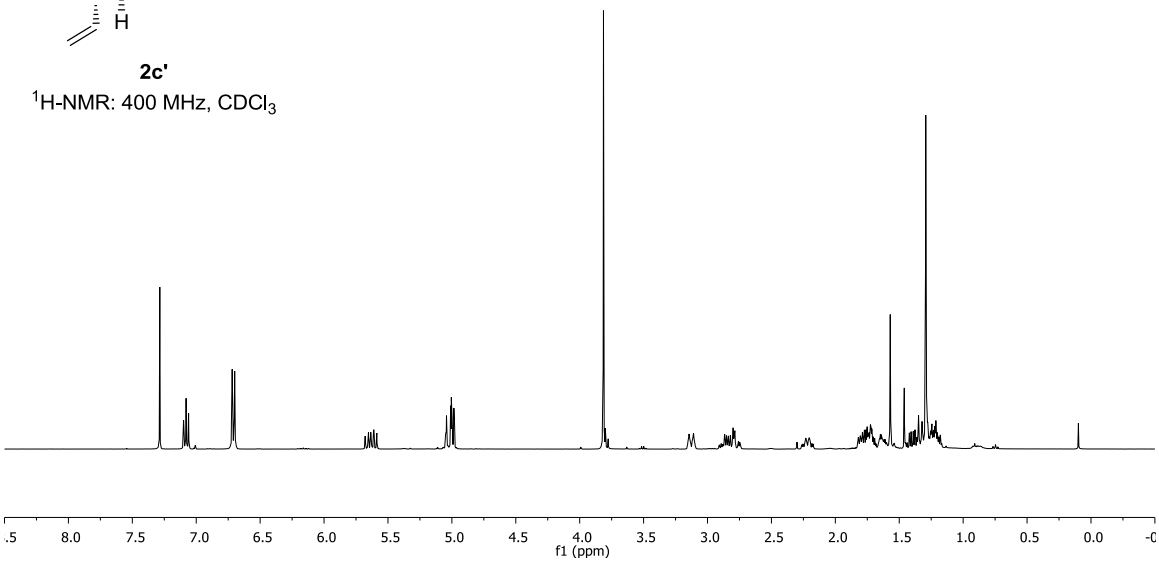
2b

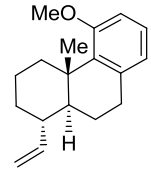
^{13}C-NMR: 100 MHz, $CDCl_3$



2c'

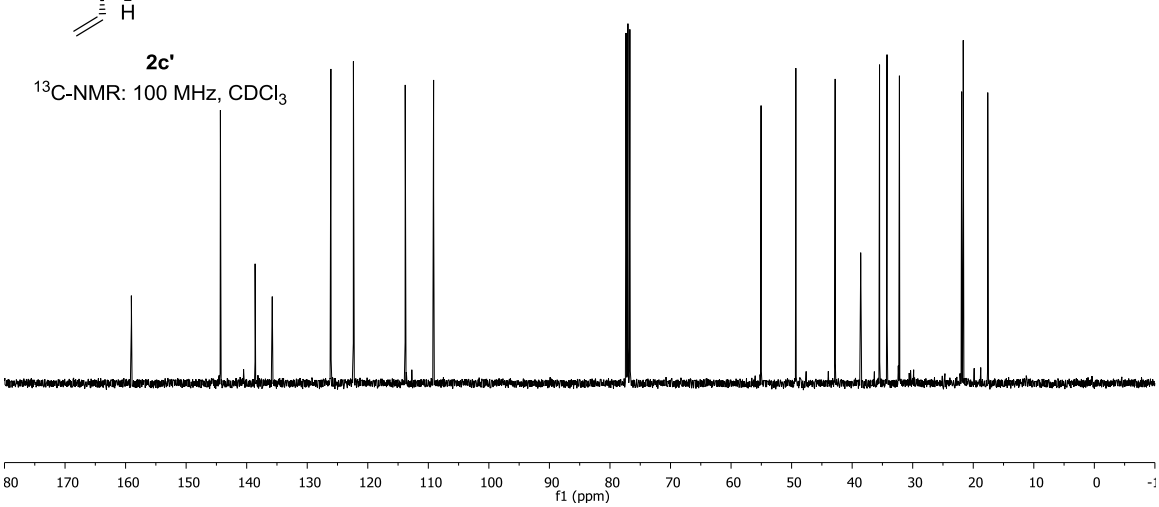
^{1}H-NMR: 400 MHz, $CDCl_3$

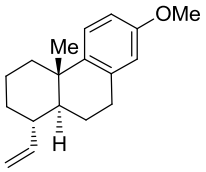




2c'

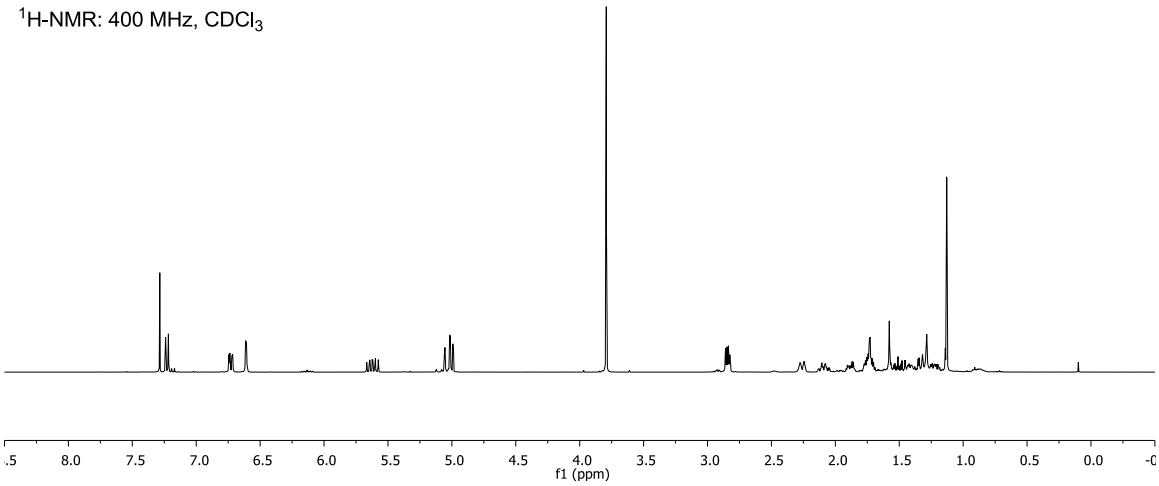
^{13}C-NMR: 100 MHz, $CDCl_3$

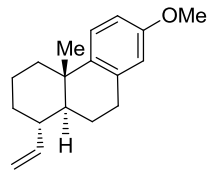




2c

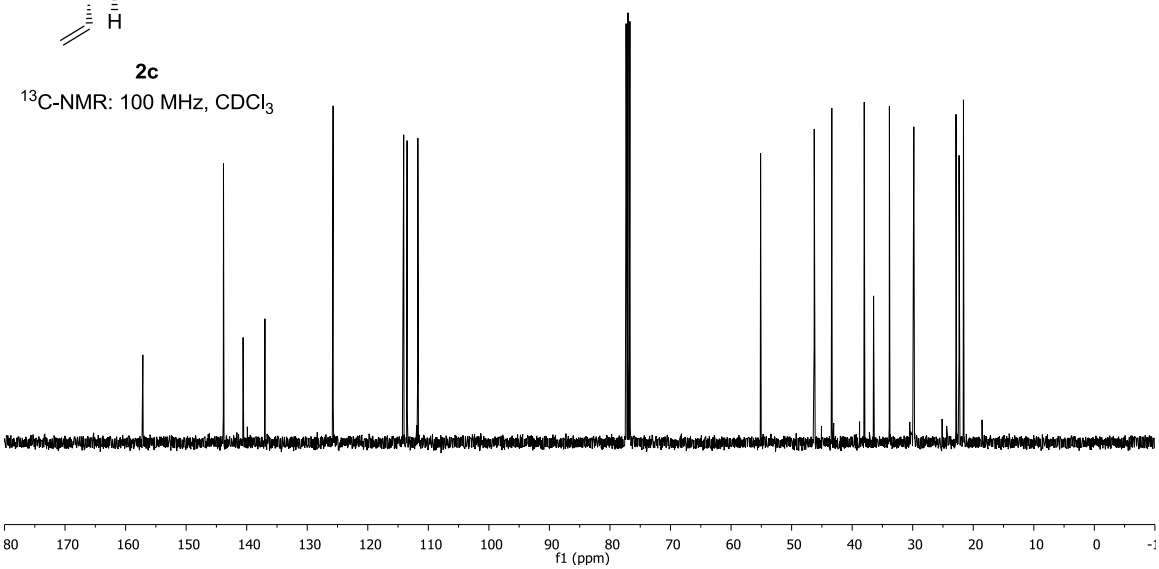
^{1}H-NMR: 400 MHz, $CDCl_3$

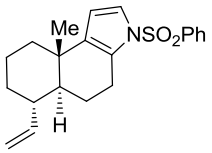




2c

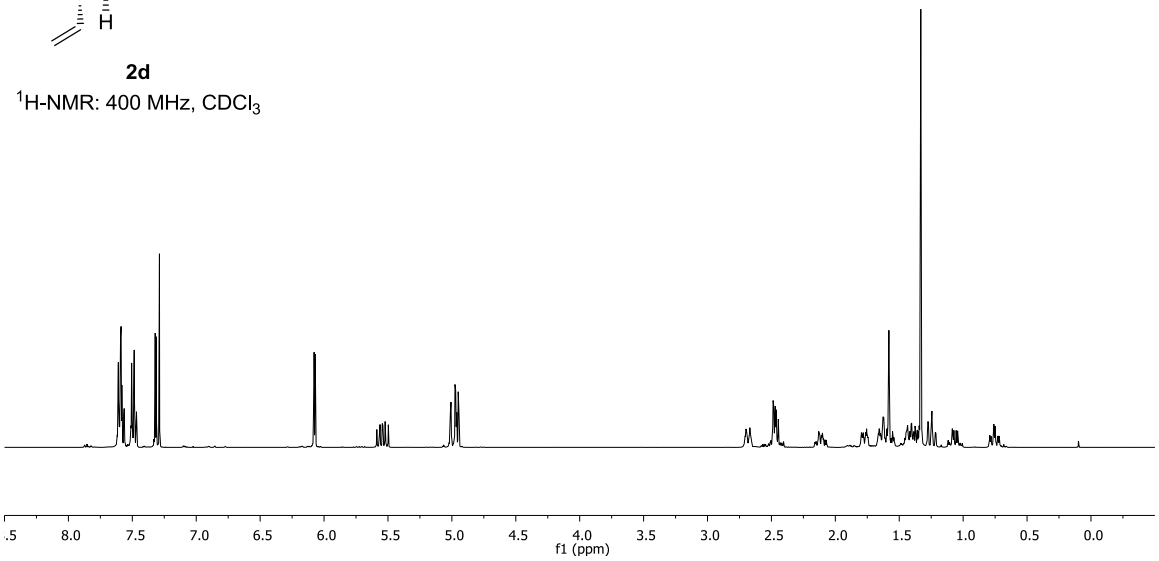
^{13}C-NMR: 100 MHz, $CDCl_3$

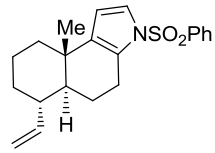




2d

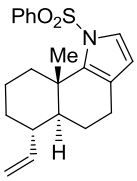
^{1}H-NMR: 400 MHz, $CDCl_3$





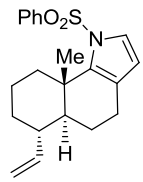
2d

^{13}C-NMR: 100 MHz, $CDCl_3$



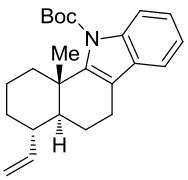
2e

^{1}H-NMR: 400 MHz, $CDCl_3$



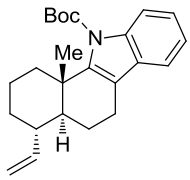
2e

^{13}C-NMR: 100 MHz, $CDCl_3$



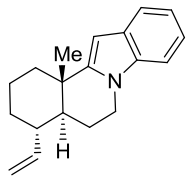
2f

^{1}H-NMR: 400 MHz, $CDCl_3$



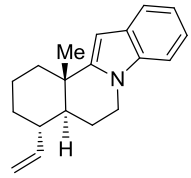
2f

^{13}C-NMR: 100 MHz, $CDCl_3$



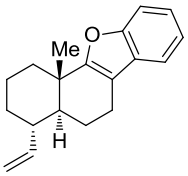
2g

^{1}H-NMR: 400 MHz, $CDCl_3$



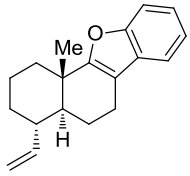
2g

^{13}C-NMR: 100 MHz, $CDCl_3$



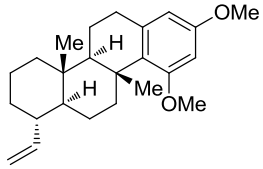
2h

^{1}H-NMR: 400 MHz, $CDCl_3$



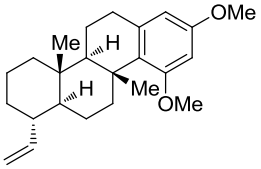
2h

^{13}C-NMR: 100 MHz, $CDCl_3$



2i

^{1}H-NMR: 400 MHz, $CDCl_3$



2i

^{13}C-NMR: 100 MHz, $CDCl_3$