Copper-Catalyzed Intramolecular Alkene Carboetherification: Synthesis of Fused-Ring and Bridged-Ring Tetrahydrofurans

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Supporting Information 1

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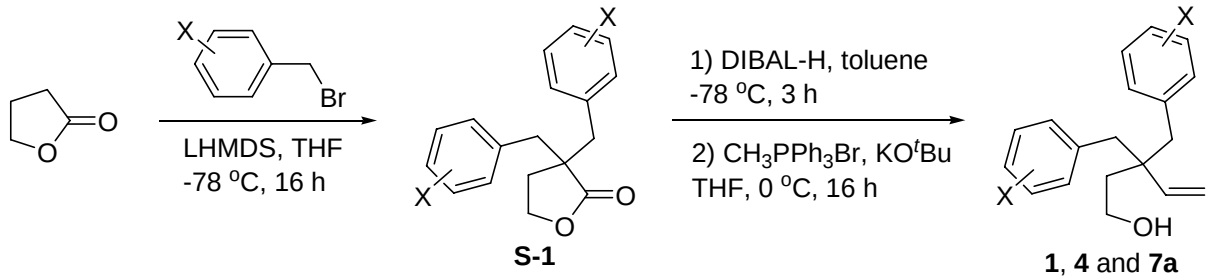
General information:

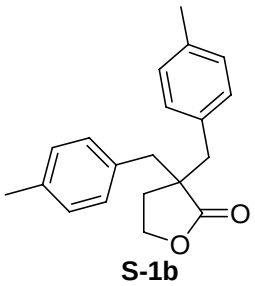
All reactions were performed under an argon atmosphere with stirring. Bisoxazoline ligand 4,5-dihydro-2-(2-(4,5-dihydrooxazol-2-yl)propan-2-yl)oxazole **3** was synthesized using our previous reported procedure.[1] (*R*, *R*)-Ph-Box ligand was purchased from TCI. All other reagents were purchased from Aldrich, Acros or Strem. Solvents were purified using a solvent filtration system. $PhCF_3$ was purchased from Acros and was used without further purification. ^1H NMR spectra were recorded at 300, 400 or 500 MHz using Varian instruments. ^{13}C NMR data were recorded at 75 or 125 MHz. Coupling constants (*J*) are in hertz. Abbreviations used are s = singlet, d = doublet, t = triplet, m = multiplet, ABq = AB quartet and br = broad. IR spectra were taken neat using a Nicolet-Impact 420 FTIR. Wave numbers in cm^{-1} are reported for characteristic peaks. High resolution mass spectra were obtained at SUNY, Buffalo's mass spec. facility on a ThermoFinnigan MAT XL spectrometer. Melting points were obtained on an electrothermal melting point apparatus and are reported uncorrected. X-ray structures were obtained at the X-ray crystallographic facilities at the University of Rochester. Optical rotations were obtained using a Rudolph Autopol I Polarimeter fitted with a micro cell with a 1 dm path length. Enantiomeric excess was determined by high performance liquid chromatography (HPLC) using Chiralpak AD-RH or Regis (*S*, *S*)-Whelk chiral analytical column (UV detection at 254nm) or by Chiral GC using a CP-Chirasil-Dex CB column (25m x 25 mm x 0.25 μm) utilizing a Shimadzu 2010 Gas Chromatograph.

Synthesis of substrates

Substrate **13** was synthesized from reported procedure[2] and the analytical data was consistent with the literature.[3] Substrates **1a**, **1g**, **1h** and **7b** were previous reported.[1] Substrate **10a-c** was synthesized from our previous reported procedure.[1] Substrate **18a**,[4] **20**,[5] **22**,[6] **24a**[6] and **24b**[7] were synthesized from reported procedure and the analytical data was consistent with the literature. Substrates **1b-1f**, **4** and **7a** were synthesized from γ-butyrolactone in 3 steps via our previous reported route:[1]

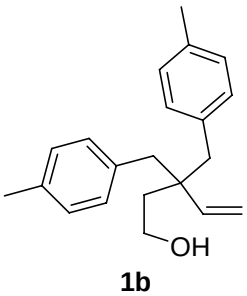


3,3-Bis(4-methylbenzyl)dihydrofuran-2(3*H*)-one (S-1b)



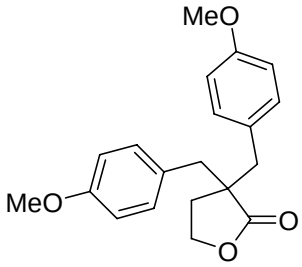
Lactone **S-1b** (1.36 g) was obtained as a white solid (92% yield), mp 169-171 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.09 (s, 8H), 3.38 (t, J = 7.4 Hz, 2H), 2.95 (ABq, J_{AB} = 13.5, Δν = 202.8 Hz, 4H), 2.32 (s, 6H), 2.13 (t, J = 7.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 181.2, 136.6, 133.4, 129.9, 129.2, 65.2, 49.8, 43.3, 29.0, 21.0; IR (neat): 1753, 1512, 1449, 1166, 1029 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{20}H_{23}O_2$: 295.1693, found: 295.1686.

3,3-Bis(4-methylbenzyl)pent-4-en-1-ol (1b)



Alcohol **1b** (0.658 g) was obtained as a clear oil (71% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08 – 7.01 (m, 8H), 5.80 (dd, J = 11.1, 17.8 Hz, 1H), 5.09 (d, J = 11.1 Hz, 1H), 4.90 (d, J = 17.5 Hz, 1H), 3.83 – 3.79 (m, 2H), 2.68 (ABq, J_{AB} = 13.5, Δν = 23.2 Hz, 4H), 2.31 (s, 6H), 1.63 – 1.55 (m, 2H), 1.18 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.0, 135.6, 134.6, 130.8, 128.4, 112.9, 59.7, 43.9, 42.9, 36.8, 21.0; IR (neat): 3298, 2928, 1636, 1514, 1452, 1415, 1042, 912, 811 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{21}H_{26}ONa$: 317.1876, found: 317.1873.

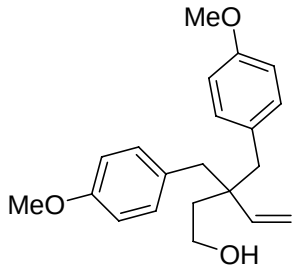
3,3-Bis(4-methoxybenzyl)-dihydrofuran-2(3*H*)-one (S-1c)



S-1c

Lactone **S-1c** (0.939 g) was obtained as a white solid (72% yield), mp 149-151 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.15 (d, J = 8.6 Hz, 4H), 6.86 (d, J = 8.6 Hz, 4H), 3.81 (s, 6H), 3.43 (t, J = 7.4 Hz, 2H), 2.94 (ABq, J_{AB} = 14.0, Δν = 207.8 Hz, 4H), 2.16 (t, J = 7.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 181.2, 158.7, 131.1, 128.5, 113.9, 65.2, 55.2, 50.0, 42.9, 28.9; IR (neat): 1757, 1612, 1513, 1253, 1180, 1166, 1029 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{20}H_{23}O_4$: 327.1591, found: 327.1600.

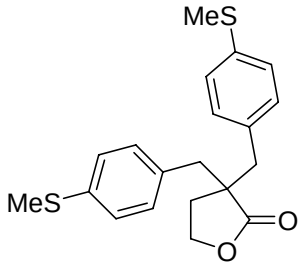
3,3-Bis(4-methoxybenzyl)pent-4-en-1-ol (1c)



1c

Alcohol **1c** (0.718 g) was obtained as a clear oil (84% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08 – 7.03 (m, 4H), 6.82 – 6.78 (m, 4H), 5.79 (dd, J = 11.1, 17.8 Hz, 1H), 5.10 (d, J = 11.1 Hz, 1H), 4.89 (d, J = 17.8 Hz, 1H), 3.84 – 3.77 (m, 8H), 2.65 (ABq, J_{AB} = 13.0, Δν = 22.7 Hz, 4H), 1.61 – 1.56 (m, 2H), 1.24 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.0, 144.9, 131.8, 129.7, 113.1, 113.0, 59.6, 55.1, 43.4, 43.0, 36.7; IR (neat): 3391, 2933, 1611, 1511, 1247, 1178, 1036 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{21}H_{27}O_3$: 327.1955, found: 327.1951.

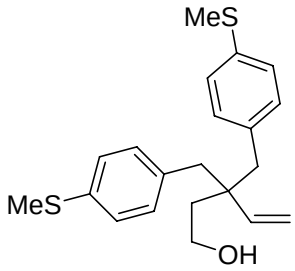
3,3-Bis(4-(methylthio)benzyl)-dihydrofuran-2(3*H*)-one (S-1d)



S-1d

Lactone **S-1d** (2.87 g) was obtained as a white solid (99% yield), mp 156-158 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18 (d, J = 8.2 Hz, 4H), 7.12 (d, J = 8.3 Hz, 4H), 3.43 (t, J = 7.4 Hz, 2H), 2.92 (ABq, J_{AB} = 13.5, Δν = 203.8 Hz, 4H), 2.46 (s, 6H), 2.12 (t, J = 7.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 180.8, 137.2, 133.0, 130.4, 126.5, 65.2, 49.73, 43.1, 28.9, 15.6; IR (neat): 1756, 1493, 1169, 1026, 819 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{20}H_{23}O_2S_2$: 359.1134, found: 359.1130.

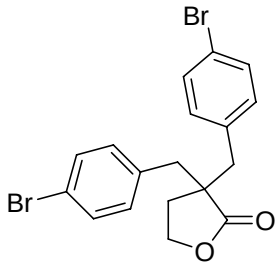
3,3-Bis(4-(methylthio)benzyl)pent-4-en-1-ol (1d)



1d

Alcohol **1d** (2.72 g) was obtained as a clear oil (77% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18 – 7.13 (m, 4H), 7.08 – 7.04 (m, 4H), 5.77 (dd, J = 11.1, 17.8 Hz, 1H), 5.11 (d, J = 11.1 Hz, 1H), 4.90 (d, J = 17.8 Hz, 1H), 3.80 (t, J = 7.0 Hz, 2H), 2.67 (ABq, J_{AB} = 13.5, Δν = 21.8 Hz, 4H), 2.47 (s, 6H), 1.61 – 1.56 (m, 2H), 1.23 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.5, 135.8, 134.5, 131.3, 126.1, 113.3, 59.5, 43.8, 43.0, 36.7, 15.9; IR (neat): 3366, 2920, 1635, 1598, 1494, 1438, 1405, 1095, 1016, 915, 805, 735 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{26}OS_2$: 358.1420, found: 358.1415.

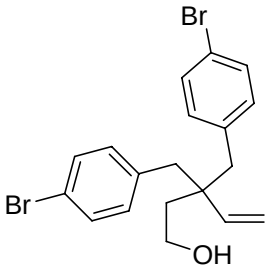
3,3-Bis(4-bromobenzyl)-dihydrofuran-2(3*H*)-one (S-1e)



S-1e

Lactone **S-1e** (3.35 g) was obtained as a white solid (98% yield), mp 157-159 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.40 (m, 4H), 7.11 – 7.05 (m, 4H), 3.46 (t, J = 7.4 Hz, 2H), 2.93 (ABq, J_{AB} = 14.0, Δν = 204.3 Hz, 4H), 2.11 (t, J = 7.4, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 180.4, 135.1, 131.7, 121.4, 65.2, 49.5, 43.0, 28.8; IR (neat): 1756, 1486, 1164, 1071, 1028, 1011 cm^{-1}; HRMS (ESI) calcd for $[M+Na]^+$ $C_{18}H_{16}Br_2O_2Na$: 444.9409, found: 444.9417.

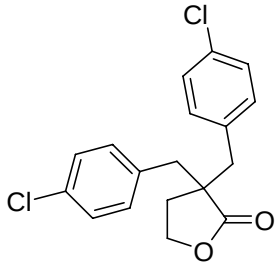
3,3-Bis(4-bromobenzyl)pent-4-en-1-ol (1e)



1e

Alcohol **1e** (2.84 g) was obtained as a clear oil (89% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 – 7.36 (m, 4H), 7.04 – 6.98 (m, 4H), 5.73 (dd, J = 11.1, 17.7 Hz, 1H), 5.13 (d, J = 11.1 Hz, 1H), 4.89 (d, J = 17.8 Hz, 1H), 3.81 (t, J = 5.9 Hz, 2H), 2.66 (ABq, J_{AB} = 14.0, Δν = 19.5 Hz, 4H), 1.60 – 1.54 (m, 2H), 1.26 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.9, 136.5, 132.5, 130.9, 120.3, 113.8, 59.3, 43.7, 42.9, 36.5; IR (neat): 3333, 2936, 1487, 1405, 1073, 1011, 916, 840, 802, 728 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{19}H_{20}Br_2O$: 421.9875, found: 421.9861.

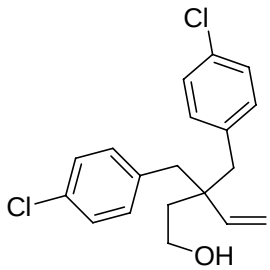
3,3-Bis(4-chlorobenzyl)-dihydrofuran-2(3*H*)-one (S-1f)



S-1f

Lactone **S-1f** (2.68 g) was obtained as a white solid (88% yield), mp 151-153 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.25 (m, 4H), 7.17 – 7.11 (m, 4H), 3.46 (t, J = 7.4 Hz, 2H), 2.94 (ABq, J_{AB} = 14.0, Δν = 205.5 Hz, 4H), 2.12 (t, J = 7.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 180.4, 134.6, 133.3, 131.4, 128.8, 65.2, 49.6, 42.9, 28.8; IR (neat): 1755, 1491, 1166, 1099, 1027, 822 cm^{-1}; HRMS (ESI) calcd for $[M+Na]^+$ $C_{18}H_{16}Cl_2O_2Na$: 357.0420, found: 357.0418.

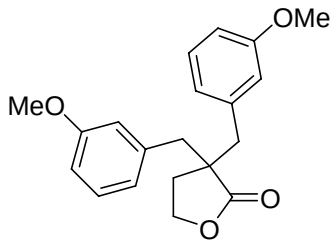
3,3-Bis(4-chlorobenzyl)pent-4-en-1-ol (1f)



1f

Alcohol **1f** (1.86 g) was obtained as a clear oil (87% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.25 – 7.21 (m, 4H), 7.09 – 7.04 (m, 4H), 5.73 (dd, J = 11.1, 17.8 Hz, 1H), 5.13 (d, J = 11.1 Hz, 1H), 4.89 (d, J = 18.0 Hz, 1H), 3.81 (t, J = 7.2 Hz, 2H), 2.68 (ABq, J_{AB} = 13.0, Δν = 19.8 Hz, 4H), 1.59 – 1.54 (m, 2H), 1.26 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.9, 135.9, 132.1, 132.1, 128.0, 113.8, 59.3, 43.7, 42.9, 36.5; IR (neat): 3335, 2936, 1490, 1408, 1092, 1014, 917, 842, 806, 731 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{19}H_{20}Cl_2O$: 334.0886, found: 334.0889.

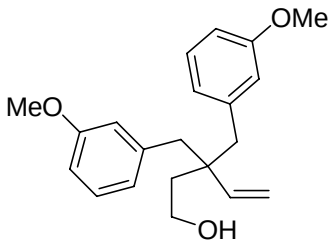
3,3-Bis(3-methoxybenzyl)-dihydrofuran-2(3*H*)-one (S-1i)



S-1i

Lactone **S-1i** (2.61 g) was obtained as a colorless oil (93% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.21 (t, J = 7.9 Hz, 2H), 6.85 – 6.73 (m, 6H), 3.79 (s, 6H), 3.42 (t, J = 7.4 Hz, 2H), 2.96 (ABq, J_{AB} = 14.0, Δν = 206.6 Hz, 4H), 2.16 (t, J = 7.4, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 181.1, 159.6, 138.0, 129.5, 122.4, 115.6, 112.5, 65.3, 55.14, 49.7, 43.8, 29.1; IR (neat): 2918, 2836, 1762, 1601, 1583, 1489, 1264, 1158, 1031, 787, 699 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{20}H_{23}O_4$: 327.1591, found: 327.1588.

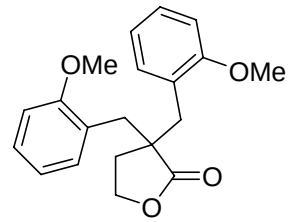
3,3-Bis(3-methoxybenzyl)pent-4-en-1-ol (4)



4

Alcohol **4** (1.71 g) was obtained as a clear oil (88% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.17 (t, J = 7.9 Hz, 2H), 6.79 – 6.68 (m, 6H), 5.83 (dd, J = 11.1, 17.8 Hz, 1H), 5.12 (d, J = 11.1 Hz, 1H), 4.92 (d, J = 17.8 Hz, 1H), 3.85 – 3.74 (m, 8H), 2.71 (ABq, J_{AB} = 14.0, Δν = 22.4 Hz, 4H), 1.67 – 1.60 (m, 2H), 1.39 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.0, 144.9, 139.3, 128.6, 123.4, 116.8, 113.0, 111.3, 59.5, 55.0, 44.4, 42.9, 37.0; IR (neat): 3394, 2942, 1601, 1583, 1489, 1263, 1155, 1044 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{21}H_{27}O_3$: 327.1955, found: 327.1946.

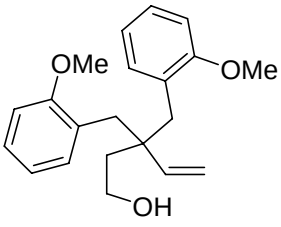
3,3-Bis(2-methoxybenzyl)-dihydrofuran-2(3*H*)-one (S-1j)



S-1j

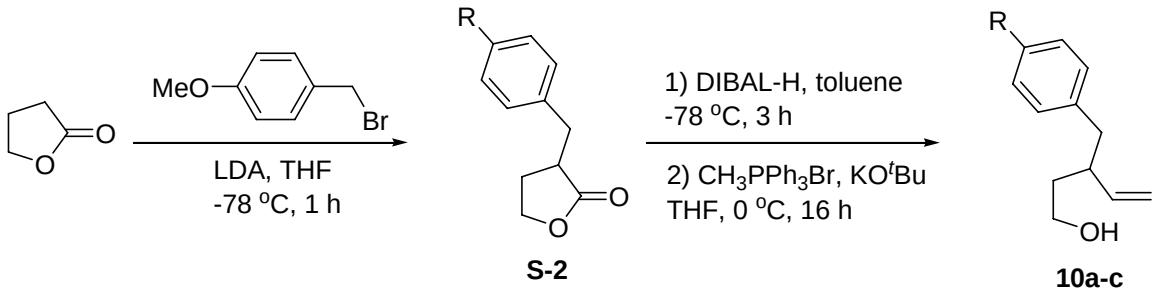
Lactone **S-1j** (2.58 g) was obtained as a colorless oil (99% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.25 – 7.19 (m, 4H), 6.88 (m, J = 4.7, 4H), 3.79 (s, 6H), 3.55 (t, J = 7.2 Hz, 2H), 3.08 (ABq, J_{AB} = 13.0, Δν = 75.1 Hz, 4H), 2.08 (t, J = 7.2 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 181.4, 157.9, 131.9, 128.2, 125.5, 120.6, 110.3, 65.6, 55.1, 49.5, 36.4, 29.4; IR (neat): 2361, 2342, 1762, 1494, 1245, 1027, 755 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{20}H_{23}O_4$: 327.1591, found: 327.1590.

3,3-Bis(2-methoxybenzyl)pent-4-en-1-ol (7a)



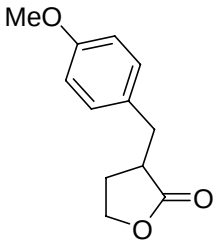
7a

Alcohol **7a** (1.80 g) was obtained as a clear oil (80% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.21 – 7.16 (m, 2H), 7.11 (dd, J = 1.7, 7.8 Hz, 2H), 6.88 – 6.81 (m, 4H), 5.82 (dd, J = 11.5, 17.5 Hz, 1H), 4.98 (dd, J = 11.1 Hz, 1H), 4.84 (dd, J = 17.8 Hz, 1H), 3.88 – 3.73 (m, 8H), 2.82 (ABq, J_{AB} = 13.0, Δν = 11.0 Hz, 4H), 1.63 (t, J = 7.0 Hz, 2H), 1.35 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.0, 145.4, 132.7, 127.3, 126.8, 119.8, 111.39, 110.4, 60.1, 55.1, 44.0, 37.0, 36.8; IR (neat): 3367, 2936, 1599, 1585, 1494, 1462, 1244, 1031, 911, 753 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{21}H_{27}O_3$: 327.1955, found: 327.1954.



S-2 **10a-c**

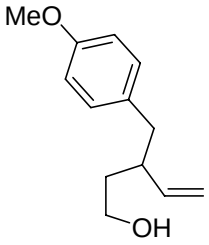
3-(4-Methoxybenzyl)-dihydrofuran-2(3*H*)-one (S-2a)[1]



S-2a

Lactone **S-2a** (4.13 g) was obtained as a colorless oil (83% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.15 – 7.10 (m, 2H), 6.87 – 6.82 (m, 2H), 4.23 – 4.11 (m, 2H), 3.79 (s, 3H), 3.17 (dd, *J* = 4.1, 13.8 Hz, 1H), 2.85 – 2.70 (m, 2H), 2.28 – 2.20 (m, 1H), 2.04 – 1.94 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 178.8, 158.4, 130.3, 129.9, 114.0, 66.5, 55.2, 41.2, 35.1, 27.8; IR (neat): 2914, 2360, 1767, 1612, 1513, 1248, 1150, 1024, 811 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{12}H_{14}O_3$: 206.0937, found: 206.0933.

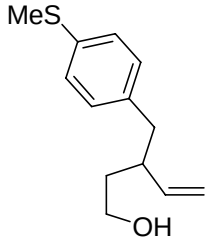
3-(4-Methoxybenzyl)pent-4-en-1-ol (10a)



10a

Alcohol **10a** (2.11 g) was obtained as a clear oil (91% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08 – 7.03 (m, 2H), 6.84 – 6.79 (m, 2H), 5.68 – 5.60 (m, 1H), 5.00 – 4.92 (m, 2H), 3.78 (s, 3H), 3.71 – 3.56 (m, 2H), 2.60 (d, *J* = 7.2 Hz, 2H), 2.47 – 2.38 (m, 1H), 1.74 – 1.67 (m, 1H), 1.54 – 1.45 (m, 1H), 1.29 (t, *J* = 5.3 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 157.8, 142.0, 132.1, 130.1, 115.2, 113.5, 61.2, 55.2, 42.9, 41.1, 36.8; IR (neat): 3361, 2931, 2360, 1613, 1512, 1246, 1178, 1037 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{18}O_2$: 206.1301, found: 206.1299.

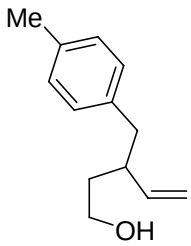
3-(4-(Methylthio)benzyl)pent-4-en-1-ol (10b)



10b

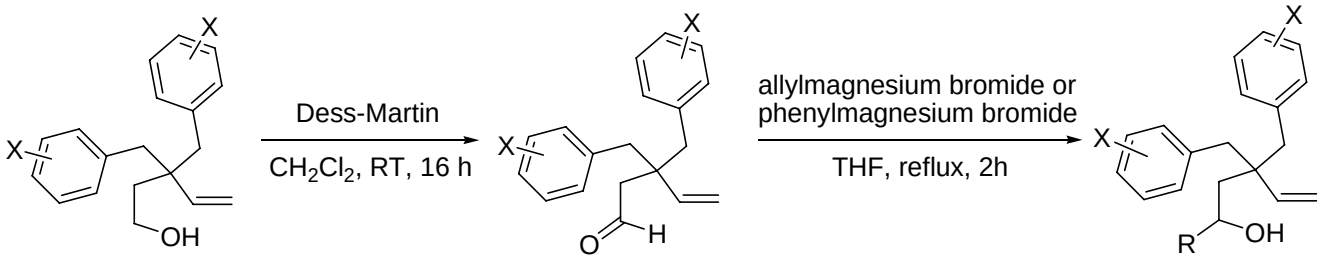
Alcohol **10b** (1.65 g) was obtained as a clear oil (81% yield, 3 steps). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.20-7.14 (m, 2H), 7.07 (d, *J* = 8.2 Hz, 2H), 5.68 – 5.56 (m, 1H), 5.00 – 4.90 (m, 2H), 3.66 – 3.54 (m, 2H), 2.62 (d, *J* = 7.6 Hz, 2H), 2.47 (s, 3H), 2.52 – 2.42 (m, 1H), 1.96 (brs, 1H), 1.76 – 1.61 (m, 1H), 1.58 – 1.40 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 141.73, 137.18, 135.37, 129.81, 126.79, 115.33, 60.88, 42.51, 41.37, 36.78, 16.17; IR (neat): 3321, 3077, 2920, 1633, 1493, 1433, 1411, 1043, 990, 914, 800 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{18}OS$: 222.1073, found: 222.1072.

3-(4-(Methyl)benzyl)pent-4-en-1-ol (10c)



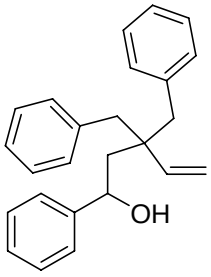
10c

Alcohol **10c** (1.69 g) was obtained as a clear oil (79% yield, 3 steps). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.20-6.96 (m, 4H), 5.69 – 5.59 (m, 1H), 5.12 – 4.85 (m, 2H), 3.71 – 3.55 (m, 2H), 2.64 (d, *J* = 7.2 Hz, 2H), 2.53 – 2.40 (m, 1H), 2.34 (s, 3H), 1.82-1.75 (brs, 1H), 1.76 – 1.66 (m, 1H), 1.57 – 1.45 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 142.08, 136.97, 135.30, 129.17, 128.84, 115.09, 61.06, 42.65, 41.53, 36.81, 21.02; IR (neat): 3314, 2919, 2859, 1637, 1514, 1443, 1415, 1041, 990, 911, 804 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{18}O$: 190.1352, found: 190.1355.



1a or **1f** **S-3** **15a-c**

3,3-Dibenzyl-1-phenylpent-4-en-1-ol (15a)



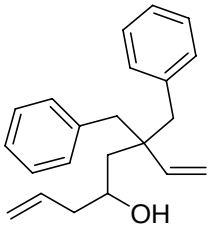
15a

Dess-Martin periodinane (1.44 g, 3.38 mmol, 1.5 equiv) was dissolved in CH_2Cl_2 (40 mL) at 0 °C.[8] A solution of alcohol **1a** (600 mg, 2.25 mmol, 1.0 equiv) in CH_2Cl_2 (20 mL) was added dropwise to the mixture and the reaction was allowed to warm to room temperature and stirred for 16 hours. The reaction mixture was then diluted with Et_2O (80 mL) and washed with saturated $Na_2S_2O_3$ (40 mL), saturated $Na_2S_2O_3$/saturated $NaHCO_3$ (40 mL, 1:1) and brine (40 mL), respectively. The organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to afford the crude aldehyde **S-3a**.

The crude aldehyde **S-3a** (486 mg, 1.84 mmol, 1.0 equiv) was dissolved in THF (15 mL) at room temperature followed by adding phenylmagnesium bromide (2.8 M in Et_2O, 1.0 mL, 2.82 mmol, 1.5 equiv) and the resulting mixture was refluxed for 2 hours. The reaction was quenched with 1 N HCl (15 mL) at 0 °C and extracted with Et_2O (40 + 20 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 90:10 hexanes/EtOAc) to afford 478 mg (76% yield, 2 steps) of **15a** as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 – 7.16 (m, 15H), 5.98 (dd, *J* = 11.1, 17.8 Hz, 1H), 5.19 (dd, *J* = 0.8, 11.1 Hz, 1H), 5.11 – 5.00 (m, 2H), 3.04 – 2.78 (m, 4H), 2.03 (d, *J* = 2.6 Hz, 1H), 1.94 (dd, *J* = 9.5, 14.9 Hz, 1H), 1.70 (dd, *J* = 2.4, 14.9 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.7, 145.6, 138.0, 138.0, 131.3, 131.2, 128.5, 127.7, 127.4, 126.1, 125.8, 113.1, 71.9, 44.8, 43.9, 43.6, 43.5; IR (neat):

3562, 3442, 3927, 2920, 2360, 1601, 1494, 1453, 1063, 1030, 914, 754, 701 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{25}H_{26}O$: 342.1978, found: 342.1981.

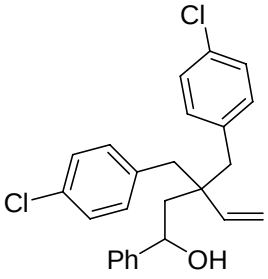
6,6-Dibenzylocta-1,7-dien-4-ol (15b)



15b

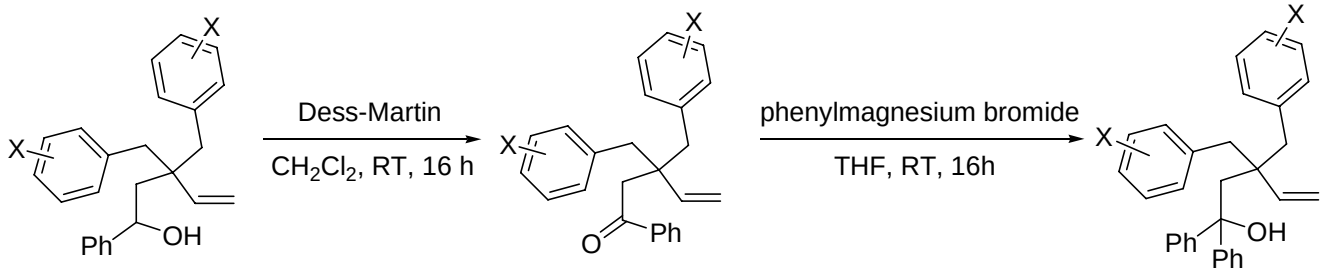
The crude aldehyde **S-3a** was converted to alcohol **15b** using the same procedure as **S-3a** to **15a** except allylmagnesium chloride (1.5 equiv) was the Grignard nucleophile. Alcohol **15b** was obtained 432 mg as a clear oil (69% yield, 2 steps). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.13 (m, 10H), 5.93 (dd, *J* = 11.1, 17.8 Hz, 1H), 5.86 – 5.74 (m, 1H), 5.19 – 5.00 (m, 4H), 4.00 (s, 1H), 2.93 – 2.72 (m, 4H), 2.23 – 2.09 (m, 2H), 1.83 (d, *J* = 3.1 Hz, 1H), 1.62 – 1.54 (m, 1H), 1.48 (dd, *J* = 2.0, 14.8 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.7, 138.0, 137.9, 134.8, 131.2, 131.2, 127.7, 127.7, 126.1, 126.0, 118.1, 112.8, 67.9, 44.7, 43.7, 43.3, 43.2, 41.5; IR (neat): 3572, 3452, 3027, 2933, 1638, 1601, 1494, 1452, 998, 914, 703 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{22}H_{26}O$: 306.1978, found: 306.1983.

3,3-bis(4-Chlorobenzyl)-1-phenylpent-4-en-1-ol (15c)



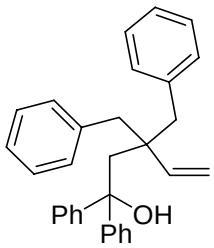
15c

15c was obtained in 74% yield over two steps from **1f** as a colorless oil following procedure of **1a** to **15a**. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 – 7.35 (m, 2H), 7.34 – 7.21 (m, 9H), 7.15 – 7.10 (m, 2H), 5.90 (dd, *J* = 11.1, 17.8 Hz, 1H), 5.23 (dd, *J* = 0.7, 11.1 Hz, 1H), 5.07 – 5.00 (m, 2H), 3.09 (d, *J* = 13.4 Hz, 1H), 2.85 (dt, *J* = 13.4, 22.2 Hz, 3H), 2.00 (d, *J* = 2.6 Hz, 1H), 1.94 (dd, *J* = 9.6, 14.9 Hz, 1H), 1.63 (dd, *J* = 2.4, 14.9 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.69, 144.76, 136.46, 136.33, 132.57, 132.52, 132.08, 132.01, 128.64, 127.91, 127.82, 127.64,125.76, 113.71, 72.04, 43.85, 43.57, 43.55, 42.82; IR (neat): 3433, 3054, 2921, 2845, 1494, 1447, 1400, 1087, 1011, 917, 832, 803, 727, 699 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{25}H_{24}OCl_2$: 410.1199, found: 410.1200.



15a or **15c** **S-4** **15d-e**

3,3-Dibenzyl-1,1-diphenylpent-4-en-1-ol (15d)

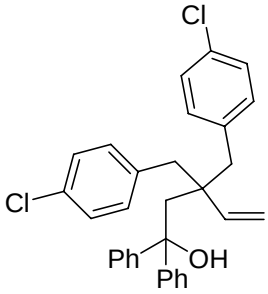


15d

Dess-Martin periodinane (0.478 g, 1.12 mmol, 1.5 equiv) was dissolved in CH_2Cl_2 (16 mL) at 0 ^oC.[8] A solution of alcohol **15a** (256 mg, 0.748 mmol, 1.0 equiv) in CH_2Cl_2 (8 mL) was added dropwise to the mixture and the reaction was allowed to warm to room temperature and stirred for 16 hours. The reaction mixture was then diluted with Et_2O (40 mL) and washed with saturated $Na_2S_2O_3$ (20 mL), saturated $Na_2S_2O_3$/saturated $NaHCO_3$ (20 mL, 1:1) and brine (20 mL), respectively. The organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to afford the crude aldehyde **S-4a**.

The crude ketone **S-4a** (200 mg, 0.588 mmol, 1.0 equiv) was dissolved in THF (4.5 mL) at room temperature followed by addition of phenylmagnesium bromide (2.8 M in Et_2O, 1.05 mL, 2.94 mmol, 5.0 equiv) and the resulting mixture was stirred at room temperature for 12 hours. The reaction was quenched with H_2O (10 mL) at 0 ^oC and extracted with EtOAc (20 mL x 3). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 90:10 hexanes/EtOAc) to afford 200 mg (64% yield, 2 steps) of **15d** as a pale yellow oil. ^1H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.01 (m, 20H), 5.86 (dd, *J* = 11.1, 17.8 Hz, 1H), 5.12 (d, *J* = 17.8 Hz, 1H), 5.01 (d, *J* = 11.2 Hz, 1H), 2.97-2.89 (m, 2H), 2.87-2.81 (m, 2H), 2.65 (s, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.31, 149.15, 146.45, 146.36, 138.13, 131.68, 128.03, 127.89, 126.26, 125.33, 125.22, 112.54, 78.31, 45.75, 45.69, 43.81, 42.88; IR (neat): 3550, 3050, 3026, 2914, 1600, 1493, 1447, 1063, 1031, 916, 756, 701 cm^{-1}; HRMS (ESI) calcd for $[M + Na]^+$ $C_{31}H_{30}O$: 441.2189, found: 441.2178.

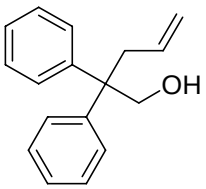
3,3-Bis(4-chlorobenzyl)-1,1-diphenylpent-4-en-1-ol (15e)



15e

15e was obtained in 72% yield over two steps from **15c** as a colorless oil following procedure of **15a** to **15d**. ^1H NMR (500 MHz, $CDCl_3$) δ 7.24 (ddd, *J* = 21.3, 12.2, 4.6 Hz, 12H), 7.16 – 7.10 (m, 6H), 5.70 (dd, *J* = 17.8, 11.1 Hz, 1H), 4.99 (dd, *J* = 37.4, 14.5 Hz, 2H), 2.78 (dt, *J* = 26.2, 13.3 Hz, 4H), 2.53 (s, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 148.78, 145.60, 136.38, 132.77, 132.19, 128.09, 127.92, 126.46, 125.16, 112.85, 78.22, 44.73, 43.73, 42.96; IR (neat): 3565, 2902, 2845, 1490, 1437, 1087, 1002 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{31}H_{28}Cl_2O$: 486.1512, found: 486.1456.

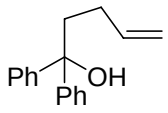
2,2-bis(4-Methylthio)phenyl)pent-4-en-1-ol (18a)[4]



18a

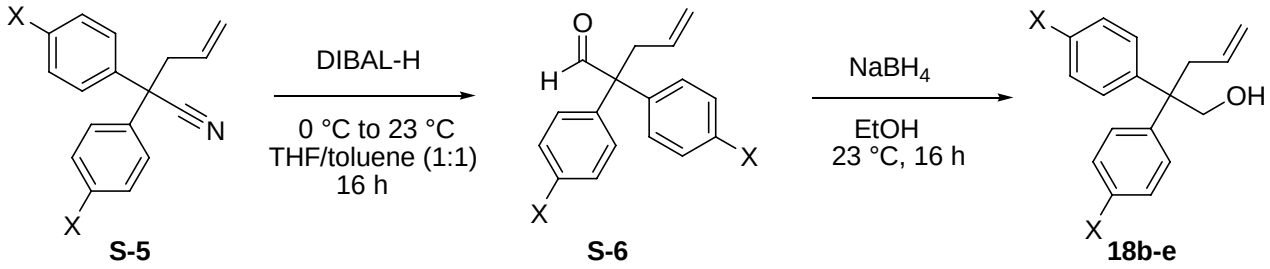
18a (0.3 g, 60% yield) was synthesized according to a published procedure and the analytical data was consistent with the literature.[1] ^1H NMR (300 MHz, $CDCl_3$) δ 7.39-7.16 (m, 10H), 5.62-5.41 (m, 1H), 5.24-5.01 (m, 2H), 4.17 (s, 2H), 3.07-3.01 (m, 2H), 1.55 (brs, 1H).

1,1-Diphenylpent-4-en-1-ol (20)[5]



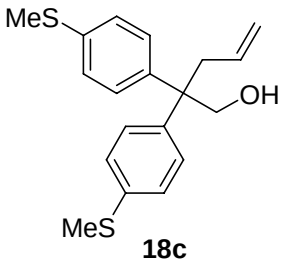
20

20 (0.2 g, 50% yield) was synthesized according to a published procedure[5] and the analytical data was consistent with the literature. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.48-7.44 (m, 4H), 7.38-7.26 (m, 6H), 5.90 (ddt, *J* = 16.9, 10.2, 6.5 Hz, 1H), 5.08 (d, *J* = 17.4 Hz, 1H), 5.00 (d, *J* = 10.0 Hz, 1H), 2.46-2.40 (m, 2H), 2.26 (s, 1H), 2.14-2.07 (m, 2H).



S-5 **S-6** **18b-e**

2,2-Bis(4-(methylthio)phenyl)pent-4-en-1-ol (18c)

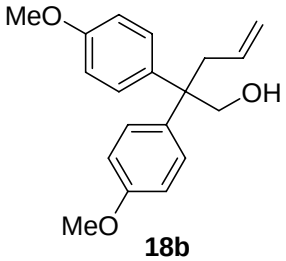


18c

2,2-bis(4(methylthio)phenyl)pent-4-penenitrile **S-5c** (1.0g, 3.51 mmol, 1.00 equiv) was dissolved in a 1:1 mixture of dry THF and toluene (40 mL) in a single-neck round bottom flask equipped with a magnetic stir bar under Ar. The resulting solution was cooled to 0 °C and a solution of DIBAL-H (1.2M, 5.1mL, 2.00equiv) was added dropwise over a period of 10 min and the reaction was left to stir for 16 h at room temperature. 40 mL of 1M HCl was added to the flask and left to stir at room temperature for 1 hour. The organic layer was extracted with Et_2O (3 x 50 mL) and dried over anhydrous Na_2SO_4. The resulting solution was concentrated in vacuo to afford the crude aldehyde **S-6c**.

The crude 2,2-diphenylpent-4-en-1-ol **S-6c** (0.50g, 1.52 mmol, 1.00 equiv) was dissolved in EtOH (20 mL) and $NaBH_4$ (0.20g, 4.57mmol, 3.00 equiv) was added. The reaction mixture was left to stir at room temperature for 16 h and concentrated in vacuo. The crude residue was dissolved in Et_2O (20mL) and 1M HCl (20 mL) was slowly added. The organic layer was separated and the aqueous layer was extracted with Et_2O (3 x 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated in vacuo. The residue was purified by flash column chromatography on SiO_2 (10-40% EtOAc/hexanes, gradient) to afford 0.20 g (50% yield, 2 steps) of **18c** as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.19 (d, *J* = 8.7 Hz, 4H), 7.10 (d, *J* = 8.6 Hz, 4H), 5.48-5.39 (m, 1H), 5.14-4.95 (m, 2H), 4.08 (d, *J* = 6.5 Hz, 2H), 2.91 (d, *J* = 7.0 Hz, 2H), 2.47 (s, 6H), 1.56 (brs, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 141.88, 136.42, 134.26, 128.62, 127.00, 126.69, 126.35, 118.27, 67.85, 50.91, 40.96, 15.86, 15.71; IR (neat): 3424, 2918, 1636, 1594, 1493, 1437, 1397, 1088, 1046, 1014, 958, 911, 810 cm^{-1}; HRMS (ESI) calcd for $[M + Na]^+$ $C_{19}H_{22}OS_2$: 353.1004, found: 353.1012.

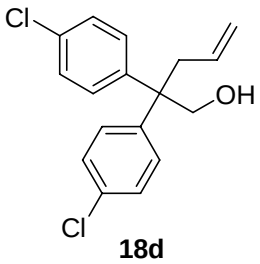
2,2-bis(4-methoxyphenyl)pent-4-en-1-ol (18b)



18b

18b (0.20 g) was obtained as a clear oil (40% yield, 3 steps) using the same procedure as **18c**. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.11 (d, *J* = 8.9 Hz, 4H), 6.84 (d, *J* = 8.9 Hz, 4H), 5.50-5.38 (m, 1H), 5.17-4.94 (m, 2H), 4.07 (s, 2H), 3.79 (s, 6H), 2.91 (d, *J* = 7.0 Hz, 2H), 1.26 (brs, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 157.88, 137.36, 134.74, 129.12, 117.88, 113.52, 68.12, 55.17, 50.32, 41.31; IR (neat): 3484, 2922, 2823, 1608, 1509, 1248, 1181, 1035, 828 cm^{-1}; HRMS (ESI) calcd for $[M + Na]^+$ $C_{19}H_{22}O_3Na$: 321.1461, found: 321.1474.

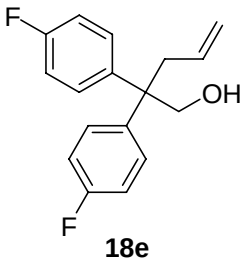
2,2-Bis(4-chlorophenyl)pent-4-en-1-ol (18d)



18d

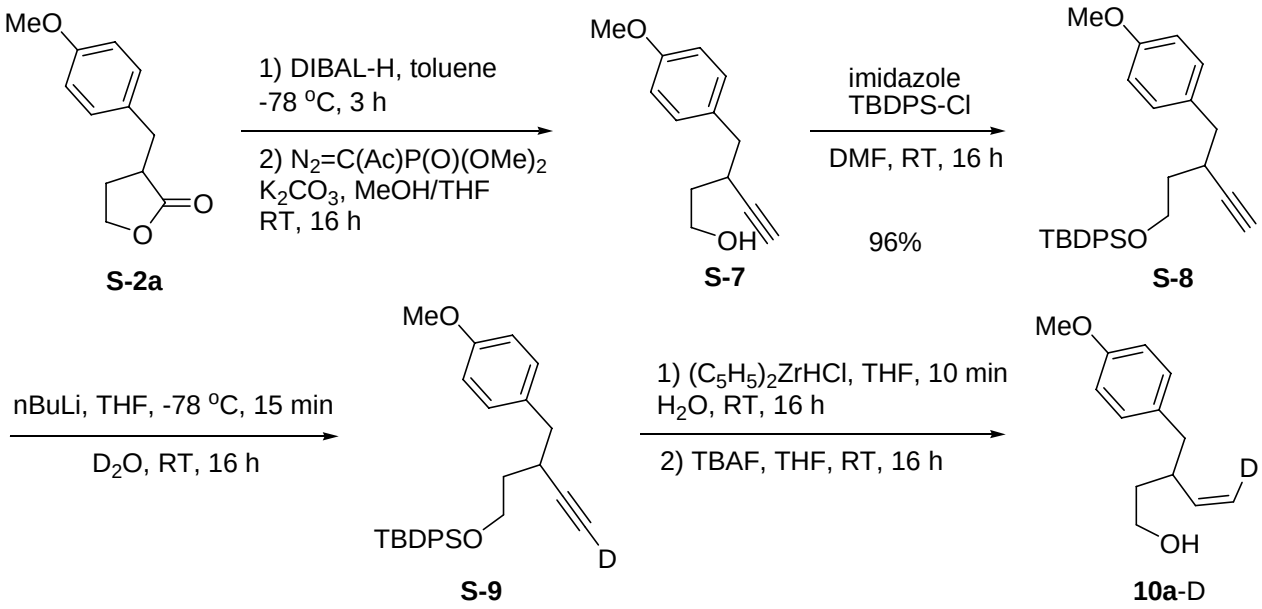
18d (0.80 g) was obtained as a clear oil (31% yield, 3 steps) using the same procedure as **18c**. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.28 (d, *J* = 8.8 Hz, 4H), 7.10 (d, *J* = 8.7 Hz, 4H), 5.50-5.35 (m, 1H), 5.15-4.96 (m, 2H), 4.06 (s, 2H), 2.91-2.80 (m, 2H), 1.36 (brs, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.37, 133.67, 132.47, 129.54, 128.71, 128.42, 127.85, 118.77, 67.66, 50.98, 40.96; IR (neat): 3376, 2941, 2868, 1637, 1597, 1492, 1402, 1094, 1013, 827 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{17}H_{16}OCl_2$: 306.0573, found: 306.0558.

2,2-Bis(4-fluorophenyl)pent-4-en-1-ol (18e)

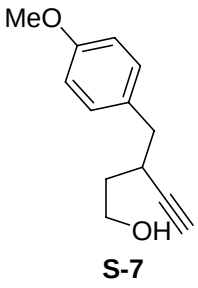


18e

18e (0.50 g) was obtained as a clear oil (33% yield, 3 steps) using the same procedure as **18c**. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.22-7.08 (m, 4H), 7.08-6.92 (m, 4H), 5.48-5.35 (m, 1H), 5.15-4.94 (m, 2H), 4.07 (s, 2H), 2.99-2.81 (m, 2H), 1.41 (brs, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 162.95, 159.59, 140.82, 140.78, 133.95, 129.73, 129.63, 128.21, 128.11, 118.52, 115.48, 115.18, 114.90, 67.92, 50.70, 41.30; IR (neat): 3396, 3064, 2925, 1604, 1508, 1232, 1162, 832 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{17}H_{16}OF_2$: 274.1164, found: 274.1169.



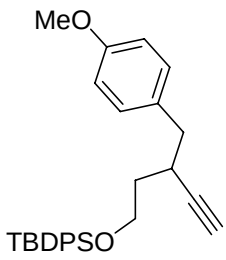
3-(4-Methoxybenzyl)pent-4-yn-1-ol (S-7)



S-7

TsN_3 and N_2=C(Ac)P(O)$(OMe)_2$ were prepared following the reported procedure by Zhao et al.[9] Crude lactol (778 mg, 3.74 mmol, 1.0 equiv) and anhydrous K_2CO_3 (2.07 g, 14.9 mmol, 4.0 equiv) was dissolved in dry MeOH (40 mL) and dry THF (5 mL) under argon at room temperature.[10] N_2=C(Ac)P(O)$(OMe)_2$ (1.00 g, 5.23 mmol, 1.4 equiv) in dry MeOH (5 mL) was added dropwise to the mixture and the reaction was stirred for 16 hours. The solvent was removed under vacuum. The resulting mixture was dissolved in Brine (40 mL) and H_2O (20 mL) and extracted with Et_2O (3 × 60 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 80:20 hexanes/EtOAc) to afford 762 mg (76% yield, 2 steps) of **S-7** as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18 – 7.13 (m, 2H), 6.86 – 6.81 (m, 2H), 3.84 – 3.78 (m, 5H), 2.82 – 2.69 (m, 3H), 2.11 (d, *J* = 1.8 Hz, 1H), 1.82 – 1.73 (m, 1H), 1.71 – 1.60 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.1, 131.0, 130.1, 113.6, 86.6, 70.8, 60.9, 55.2, 40.3, 36.7, 30.4; IR (neat): 3290, 2936, 2360, 2339, 1612, 1513, 1465, 1300, 1247, 1179, 1035, 832 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{16}O_2$: 204.1145, found: 204.1149.

(3-(4-Methoxybenzyl)pent-4-ynyloxy)(*tert*-butyl)diphenylsilane (S-8)

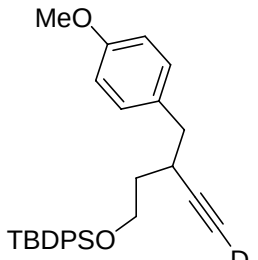


S-8

Alcohol **S-7** (550 mg, 2.70 mmol, 1.0 equiv) and imidazole (366 mg, 5.40 mmol, 2.0 equiv) was dissolved in dry DMF (30 mL) under argon at 0 °C. TBDPS-Cl (890 mg, 0.842 mL, 4.24 mmol, 1.2 equiv) was added dropwise to the mixture and the reaction was allowed to warm to room temperature and stirred for 16 hours. The reaction mixture was then quenched with water (60 mL) at 0 °C and extracted with Et_2O (3 × 60 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 95:5 hexanes/EtOAc) to afford 1.15 g (96% yield)

of **S-8** as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 – 7.61 (m, 4H), 7.44 – 7.33 (m, 6H), 7.17 – 7.12 (m, 2H), 6.86 – 6.81 (m, 2H), 3.88 – 3.76 (m, 5H), 2.95 – 2.87 (m, 1H), 2.78 – 2.69 (m, 2H), 2.02 (d, *J* = 2.4 Hz, 1H), 1.81 – 1.73 (m, 1H), 1.66 – 1.57 (m, 1H), 1.03 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.1, 135.6, 135.5, 133.8, 133.7, 131.4, 130.1, 129.5, 127.6, 127.5, 113.6, 86.9, 70.1, 61.4, 55.2, 40.1, 37.0, 29.9, 26.8, 19.2; IR (neat): 3294, 2932, 2858, 2360, 2339, 1612, 1513, 1247, 1110, 703 cm^{-1}; HRMS (ESI) calcd for $[M+Na]^+$ $C_{29}H_{34}O_2SiNa$: 465.2220, found: 465.2219.

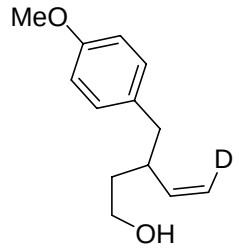
(3-(4-Methoxybenzyl)-5-deuteropent-4-ynyloxy)(tert-butyl)diphenylsilane (S-9)



S-9

Alkyne **S-8** (200 mg, 0.452 mmol, 1.0 equiv) was dissolved in dry THF (15 mL) under argon and cooled to -78 °C. *n*BuLi (1.6 M in hexanes, 0.340 mL, 0.542 mmol, 1.2 equiv) was added dropwise to the mixture and the reaction was allowed to stir for 15 minutes. The reaction mixture was quenched with D_2O (5 mL) then warm to room temperature and stirred for 16 hours. The mixture was diluted with Et_2O (40 mL) and the aqueous layer was removed by pipette. The organic layer were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 95:5 hexanes/EtOAc) to afford 160 mg (80% yield) of **S-9** as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 – 7.60 (m, 4H), 7.44 – 7.33 (m, 6H), 7.14 (d, *J* = 8.5 Hz, 2H), 6.86 – 6.80 (m, 2H), 3.90 – 3.74 (m, 5H), 2.95 – 2.86 (m, 1H), 2.79 – 2.68 (m, 2H), 1.82 – 1.72 (m, 1H), 1.66 – 1.57 (m, 1H), 1.03 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.1, 135.6, 135.5, 133.8, 131.4, 130.2, 129.5, 127.6, 127.6, 113.6, 61.4, 55.2, 40.2, 37.0, 29.9, 26.8, 19.2; IR (neat): 2931, 2588, 2360, 1512, 1247, 1110, 703 cm^{-1}; HRMS (ESI) calcd for $[M+Na]^+$ $C_{29}H_{33}DO_2SiNa$: 466.2283, found: 465.2290.

(*Z*)-3-(4-Methoxybenzyl)-5-deuteropent-4-en-1-ol (10a-D)

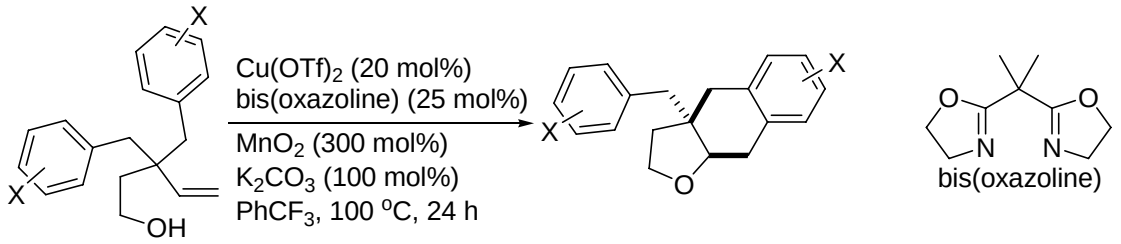


10a-D

Alkyne **S-9** (197 mg, 0.444 mmol, 1.0 equiv) was dissolved in dry THF (10 mL) under argon at room temperature.[11] $(C_5H_5)_2ZrHCl$ (Schwartz's reagent, 229 mg, 0.888 mmol, 2.0 equiv) was added in one portion and the reaction was stirred for 10 minutes. The reaction mixture was quenched with H_2O (2 mL) then stirred for 16 hours. The mixture was diluted with Et_2O (60 mL) and the aqueous layer was removed by pipette. The organic layer were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to afford the crude alkene.

The crude alkene was treated with TBAF·3H_2O (418 mg, 1.33 mmol, 3.0 equiv) in THF (40 mL) at room temperature and stirred for 16 hours. The solvent was removed under vacuum. The residue was purified by flash column chromatography (SiO_2, 60:40 hexanes/EtOAc) to afford 67 mg (73% yield, 2 steps) of **10a**-D as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.09 – 7.02 (m, 2H), 6.84 – 6.78 (m, 2H), 5.63 (ddd, *J* = 2.4, 4.8, 11.1 Hz, 1H), 4.96 (d, *J* = 10.5 Hz, 1H), 3.78 (s, 3H), 3.70 – 3.56 (m, 2H), 2.60 (d, *J* = 7.2 Hz, 2H), 2.47 – 2.38 (m, 1H), 1.74 – 1.66 (m, 1H), 1.54 – 1.45 (m, 1H), 1.36 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 157.7, 141.9, 132.1, 130.1, 114.9 (t, J_{CD} = 23.0 Hz), 113.5, 61.2, 55.2, 42.8, 41.0, 36.7; IR (neat): 3358, 2931, 2360, 1612, 1512, 1464, 1246, 1178, 1037, 807 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{17}DO_2$: 207.1364, found: 207.1370.

General $Cu(OTf)_2$-catalyzed carboetherification procedure (Method A)

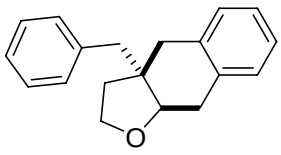


1 **2** **3**

$Cu(OTf)_2$ (20 mol%), bis(oxazoline) **3**[1] (25 mol%) and $PhCF_3$ (0.1 M with respect to substrate) were combined in a pressure tube equipped with a magnetic stir bar under argon. The mixture was stirred at 60 °C for 2 hours then cooled to room temperature. The solution was treated with MnO_2 (3.0 equiv), K_2CO_3 (1.0 equiv) and alcohol substrate (1.0 equiv, 0.0730 – 0.210 mmol scale). The tube was refreshed by argon for 2 minutes, sealed and heated at 100 °C in an oil bath for 24 hours. Filtration of the cooled solution and removal of the solvent *in vacuo* afforded a crude residue. Chromatography on SiO_2 (10 – 20% EtOAc in hexanes) afforded purified product.

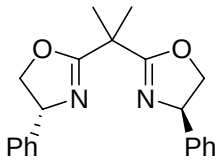
Representative procedure for $Cu(OTf)_2$-catalyzed carboetherification (Method A):

(±)-*cis*-3a-Benzyl-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2a)



2a

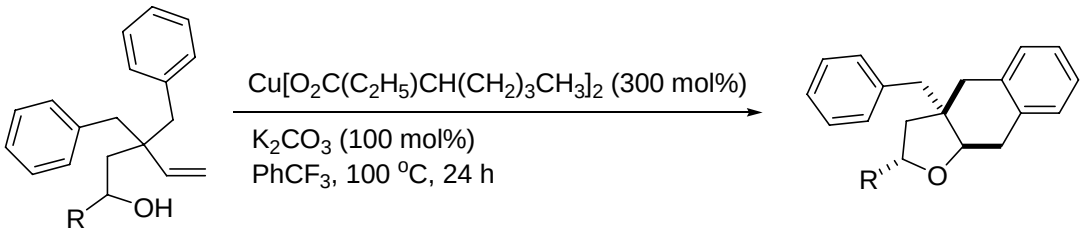
$Cu(OTf)_2$ (13.6 mg, 0.0376 mmol, 20 mol%) and bis(oxazoline) **3**[1] (8.56 mg, 0.0470 mmol, 25 mol%) were put into a 12 mL pressure tube with a stirring bar. $PhCF_3$ (0.6 mL) was syringed into the tube, and the vessel was refreshed with argon for 2 min, sealed and stirred at 60 °C for 2 hours. Upon cooling to room temperature, K_2CO_3 (26.0 mg, 0.188 mmol, 1.0 equiv) and MnO_2 (49.0 mg, 0.564 mmol, 3.0 equiv) were added. Alcohol **1a** (50 mg, 0.188 mmol) was dissolved in $PhCF_3$ (1.0 mL) in a 20 mL vial and the solution was transferred into the reaction tube. The vial was rinsed with $PhCF_3$ (0.28 mL) and the rinse was added to the reaction. The tube was refreshed with argon for 2 minutes, sealed and stirred at 100 °C. After 24 hours, the reaction mixture was cooled to room temperature, diluted with CH_2Cl_2 (3 mL) and vacuum filtered through a pad of silica gel (5 g). The silica gel was further rinsed with EtOAc (3 × 30 mL) and the combined filtrate was concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 90:10 hexanes/EtOAc) to afford 49 mg (98% yield) of **2a** as a clear oil.



(*R*, *R*)-Ph-Box

$Cu(OTf)_2$-catalyzed enantioselective carboetherification (Method B) used the same procedure as **Method A** except 25 mol% of (*R*, *R*)-Ph-Box ligand is used instead of **3**.

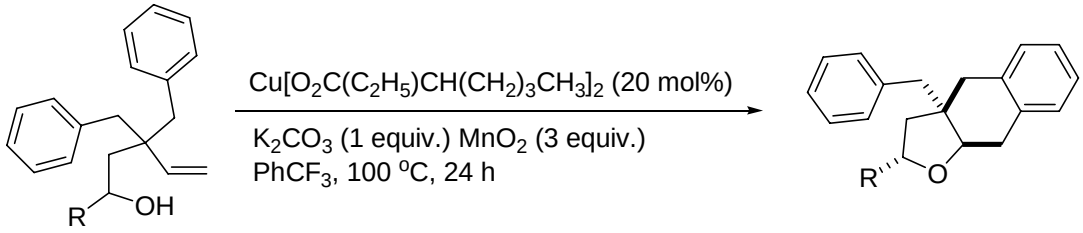
Representative procedure for the $Cu(EH)_2$-promoted carboetherification (Method C):



15 **16**

Copper(II) 2-ethylhexanoate (153 mg, 0.438 mmol, 3.0 equiv.), K_2CO_3 (20.2 mg, 0.146 mmol, 1.0 equiv), alcohol **15a** (50.0 mg, 0.146 mmol) and $PhCF_3$ (1.46 mL) were put into a 12 mL pressure tube with a stirring bar. The tube was refreshed with argon for 2 minutes, sealed and stirred at 100 °C. After 24 hours, the reaction mixture was cooled to room temperature, diluted with CH_2Cl_2 (25 mL), washed with saturated Na_2EDTA solution (15 mL) and 1N NaOH (15 mL), dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 95:5 hexanes/EtOAc) to afford a 12:1 mixture of **16a**:**17a** (43 mg, 86% yield) as a clear oil.

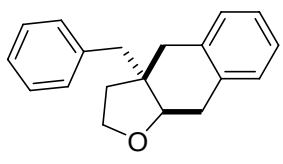
General procedure for the $Cu(EH)_2$-catalyzed carboetherification (Method D):



15 **16**

$Cu(EH)_2$ (13.2 mg, 0.0376 mmol, 20 mol%), K_2CO_3 (26.0 mg, 0.188 mmol, 1.0 equiv), MnO_2 (49.0 mg, 0.564 mmol, 3.0 equiv), alcohol substrate (1 equiv., 0.188 mmol) and $PhCF_3$ (1.6 mL) were put into a 12 mL pressure tube with a stirring bar. The tube was refreshed with argon for 2 minutes, sealed and stirred at 100 °C. After 24 hours, the reaction mixture was cooled to room temperature, filtered through silica gel and concentrated in *vacuo*. The crude residue was purified by flash column chromatography (SiO_2, 10-20% EtOAc in hexanes) to afford purified product.

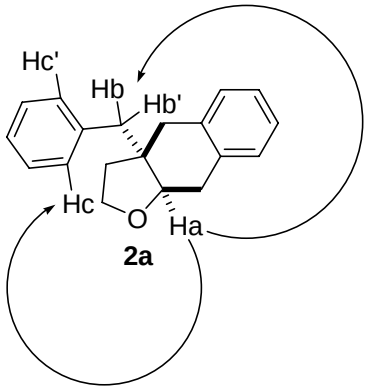
(±)-*cis*-3a-Benzyl-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2a)



2a

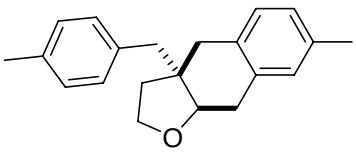
Tetrahydronaphthofuran **2a** (49 mg) was obtained from the catalytic carboetherification (Method A) of **1a** as a clear oil (98% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 – 7.03 (m, 9H), 4.11 (t, J = 4.4 Hz, 1H), 3.68 – 3.55 (m, 2H), 2.88 (dd, J = 4.0, 15.3 Hz, 1H), 2.80 – 2.66 (m, 3H), 2.56 (ABq, J_{AB} = 14.5, $\Delta\nu$ = 65.4 Hz, 2H), 2.04 – 1.96 (m, 1H), 1.49 – 1.40 (m, 1H); ^{13}C NMR (75

MHz, $CDCl_3$) δ 138.3, 136.9, 135.9, 130.5, 128.2, 128.1, 128.0, 126.4, 126.3, 126.2, 83.6, 66.1, 46.9, 45.1, 38.1, 37.6, 34.5; IR (neat): 3025, 2938, 2849, 1492, 1454, 1073, 754, 704 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{19}H_{20}O$: 264.1509, found: 264.1516. The relative stereochemistry of **2a** was assigned by NOE.



2a

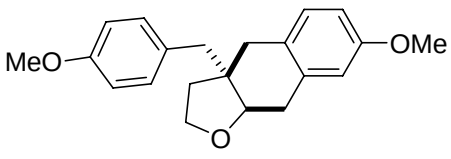
(±)-*cis*-7-Methyl-3a-(4-methylbenzyl)-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2b)



2b

Tetrahydronaphthofuran **2b** (47 mg) was obtained from the catalytic carboetherification (Method A) of **1b** as a clear oil (94% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.15 – 7.07 (m, 4H), 6.99 (s, 1H), 6.95 (d, J = 0.9 Hz, 2H), 4.08 (t, J = 4.3 Hz, 1H), 3.68 – 3.54 (m, 2H), 2.83 (dd, J = 3.9, 15.3 Hz, 1H), 2.76 – 3.54 (m, 3H), 2.51 (ABq, J_{AB} = 14.5, Δν = 66.1 Hz, 2H), 2.34 (s, 3H), 2.30 (s, 3H), 2.01 – 1.94 (m, 1H), 1.47 – 1.38 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 135.9, 135.8, 135.8, 135.2, 133.8, 130.4, 129.0, 128.8, 127.9, 126.8, 83.7, 66.1, 47.0, 44.8, 37.8, 37.5, 34.5, 21.1, 21.0; IR (neat): 3005, 2918, 2858, 1512, 1444, 1219, 1061, 1005, 813 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{24}O$: 292.1822, found: 292.1827. The relative stereochemistry of **2b** was assigned by analogy to **2a**.

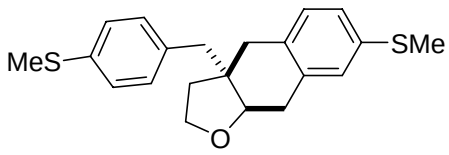
(±)-*cis*-3a-(4-Methoxybenzyl)-7-methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2c)



2c

Tetrahydronaphthofuran **2c** (47 mg) was obtained from the catalytic carboetherification (Method A) of **1c** as a clear oil (94% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.12 (d, J = 8.6 Hz, 2H), 6.97 (d, J = 8.2 Hz, 1H), 6.86 (dd, J = 4.8, 6.7 Hz, 2H), 6.75 (d, J = 2.5 Hz, 1H), 6.69 (dd, J = 2.6, 8.1 Hz, 1H), 4.07 (t, J = 4.3 Hz, 1H), 3.80 (s, 3H), 3.78 (s, 3H), 3.68 – 3.54 (m, 2H), 2.84 (dd, J = 3.9, 15.3 Hz, 1H), 2.77 – 2.60 (m, 3H), 2.48 (ABq, J_{AB} = 14.0, Δν = 58.0 Hz, 2H), 2.00 – 1.92 (m, 1H), 1.48 – 1.40 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.3, 158.2, 137.1, 131.4, 130.4, 129.0, 128.7, 113.8, 113.5, 111.5, 83.4, 66.2, 55.2, 55.2, 47.1, 44.2, 37.5, 37.3, 34.9; IR (neat): 2937, 2908, 2835, 1611, 1511, 1250, 1037, 825 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{24}O_3$: 324.1720, found: 324.1724. The relative stereochemistry of **2c** was assigned by analogy to **2a**.

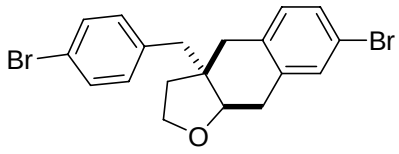
(±)-*cis*-3a-(4-(Methylthio)benzyl)-7-(methylthio)-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2d)



2d

Tetrahydronaphthofuran **2d** (44 mg) was obtained from the catalytic carboetherification (Method A) of **1d** as a clear oil (88% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.24 – 7.19 (m, 2H), 7.15 – 7.03 (m, 4H), 6.98 (d, J = 7.8 Hz, 1H), 4.07 (t, J = 4.3 Hz, 1H), 3.69 – 3.55 (m, 2H), 2.84 (dd, J = 3.9, 15.4 Hz, 1H), 2.77 – 2.40 (m, 11H), 2.00 – 1.93 (m, 1H), 1.49 – 1.40 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 136.6, 136.3, 135.9, 135.1, 134.0, 130.9, 128.5, 126.7, 126.4, 124.8, 83.3, 66.1, 47.0, 44.5, 37.5, 37.5, 34.5, 16.1, 15.9; IR (neat): 2918, 2360, 1600, 1491, 1436, 1092, 1059, 1004, 956, 816 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{24}OS_2$: 356.1263, found: 356.1264. The relative stereochemistry of **2d** was assigned by analogy to **2a**.

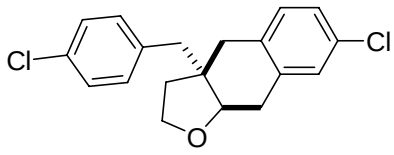
(±)-*cis*-3a-(4-Bromobenzyl)-7-bromo-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2e)



2e

Tetrahydronaphthofuran **2e** (44 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 110 ^{o}C) of **1e** as a clear oil (88% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 – 7.42 (m, 2H), 7.31 (d, J = 1.7 Hz, 1H), 7.28 (dd, J = 2.0, 7.9 Hz, 1H), 7.08 – 7.03 (m, 2H), 6.92 (d, J = 7.9 Hz, 1H), 4.06 (t, J = 4.2 Hz, 1H), 3.69 – 3.56 (m, 2H), 2.85 (dd, J = 3.8, 15.5 Hz, 1H), 2.75 – 2.60 (m, 3H), 2.46 (ABq, J_{AB} = 14.5, Δν = 25.3 Hz, 2H), 1.99 – 1.91 (m, 1H), 1.47 – 1.39 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.1, 136.9, 135.6, 132.0, 131.3, 131.1, 129.6, 129.3, 120.5, 120.1, 82.9, 66.0, 46.7, 44.3, 37.5, 37.4, 34.1; IR (neat): 2939, 2853, 1594, 1485, 1443, 1405, 1073, 1010, 814, 729 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{19}H_{18}Br_2O$: 419.9719, found: 419.9717. The relative stereochemistry of **2e** was assigned by analogy to **2a**.

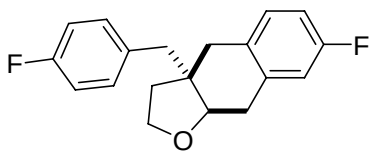
(±)-*cis*-3a-(4-Chlorobenzyl)-7-chloro-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2f)



2f

Tetrahydronaphthofuran **2f** (85 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 ^{o}C) of **1f** as a clear oil (85% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 – 7.30 (m, 2H), 7.22 – 7.12 (m, 4H), 7.01 (d, J = 8.0 Hz, 1H), 4.10 (t, J = 4.2 Hz, 1H), 3.72 – 3.59 (m, 2H), 2.89 (dd, J = 3.8, 15.5 Hz, 1H), 2.78 – 2.66 (m, 3H), 2.52 (ABq, J_{AB} = 15.0, Δν = 29.6 Hz, 2H), 2.03 – 1.95 (m, 1H), 1.52 – 1.43 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 137.7, 136.4, 135.0, 132.4, 132.0, 131. 7, 129.2, 128.3, 128.3, 126.3, 82.9, 66.1, 46.8, 44.3, 37.5, 37.4, 34.2; IR (neat): 2939, 2854, 1599, 1489, 1443, 1409, 1089, 1060, 1014, 820 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{19}H_{18}Cl_2O$: 332.0729, found: 332.0733. The relative stereochemistry of **2f** was assigned by analogy to **2a**.

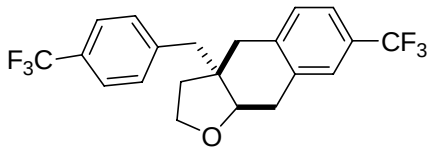
(±)-*cis*-3a-(4-Fluorobenzyl)-7-fluoro-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2g)



2g

Tetrahydronaphthofuran **2g** (36 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **1g** as a clear oil (72% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.19 – 7.12 (m, 2H), 7.05 – 6.96 (m, 3H), 6.92 – 6.80 (m, 2H), 4.08 (t, J = 4.2 Hz, 1H), 3.69 – 3.54 (m, 2H), 2.87 (dd, J = 3.7, 15.5 Hz, 1H), 2.76 – 2.64 (m, 3H), 2.49 (ABq, J_{AB} = 14.5, $\Delta\nu$ = 33.9 Hz, 2H), 2.00 – 1.91 (m, 1H), 1.49 – 1.40 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 161.7 (d, J_{CF} = 243.8 Hz), 161.6 (d, J_{CF} = 242.6 Hz), 137.80 (d, J_{CF} = 7.9 Hz), 133.7 (d, J_{CF} = 3.4 Hz), 132.1 (d, J_{CF} = 2.3 Hz), 131.8 (d, J_{CF} = 6.8 Hz), 129.1 (d, J_{CF} = 8.0 Hz), 115.2 (d, J_{CF} = 20.6 Hz), 115.0 (d, J_{CF} = 20.6 Hz), 112.8 (d, J_{CF} = 21.7 Hz), 83.0, 66.1, 46.9, 44.1, 37.5, 37.3, 34.5; IR (neat): 2940, 2854, 1600, 1509, 1442, 1252, 1222, 1139, 1060, 829 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{19}H_{18}F_2O$: 300.1320, found: 300.1320. The relative stereochemistry of **2g** was assigned by analogy to **2a**.

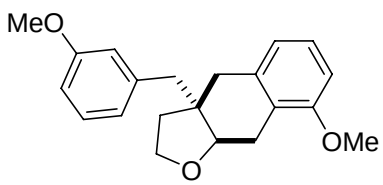
(±)-*cis*-3a-(4-(Trifluoromethyl)benzyl)-7-(trifluoromethyl)-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (2h)



2h

Tetrahydronaphthofuran **2h** (45 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 110 °C) of **1h** as a clear oil (90% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 (d, J = 8.0 Hz, 2H), 7.42 (d, J = 8.4 Hz, 2H), 7.31 (d, J = 8.0 Hz, 2H), 7.16 (d, J = 7.6 Hz, 1H), 4.13 (t, J = 4.2 Hz, 1H), 3.72 – 3.59 (m, 2H), 2.97 (dd, J = 3.7, 15.6 Hz, 1H), 2.86 – 2.73 (m, 3H), 2.59 (ABq, J_{AB} = 14.5, $\Delta\nu$ = 22.3 Hz, 2H), 2.05 – 1.97 (m, 1H), 1.51 – 1.43 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 142.0, 140.6, 136.5, 130.7, 129.2 (d, J_{CF} = 5.3 Hz), 128.7 (d, J_{CF} = 5.0 Hz), 128.3, 126.0 (d, J_{CF} = 8.0 Hz), 125.1 (m), 123.3 (q, J_{CF} = 4.6 Hz), 122.4 (d, J_{CF} = 7.8 Hz), 82.9, 66.0, 46.8, 44.7, 37.8, 37.7, 34.2; IR (neat): 2942, 2862, 1619, 1440, 1420, 1327, 1162, 1120, 1068, 1018, 832 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{28}F_6O$: 400.1256, found: 400.1260. The relative stereochemistry of **2h** was assigned by analogy to **2a**.

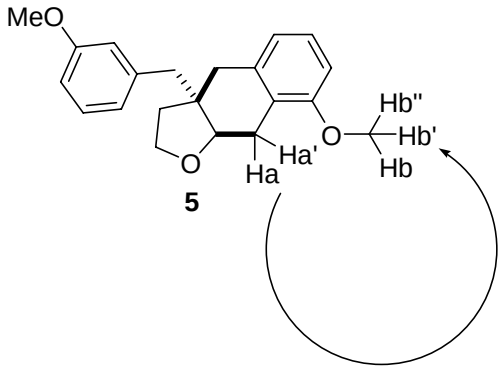
(±)-*cis*-3a-(3-Methoxybenzyl)-8-methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (5)



5

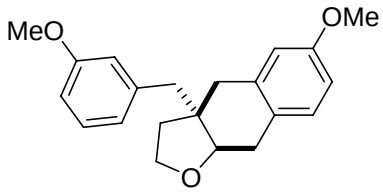
Tetrahydronaphthofurans **5** and **6** (49 mg) were obtained from the catalytic carboetherification (Method A) of **4** [98% yield, **5** : **6** (1.9 : 1)]. They were separated by prep HPLC using EtOAc/hexanes (**5** eluted first). Tetrahydronaphthofuran **5** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.25 – 7.19 (m, 1H), 7.11 (t, J = 7.8 Hz, 1H), 6.82 – 6.68 (m, 5H), 4.02 (dd, J = 3.3, 5.1 Hz, 1H), 3.81 (s, 3H), 3.80 (s, 3H), 3.78 – 3.65 (m, 2H), 3.08 (dd, J = 3.3, 16.7 Hz, 1H), 2.73 (dd, J = 5.2, 16.7 Hz, 1H), 2.67 – 2.60 (m, 2H), 2.53 (ABq, J_{AB} = 15.0, $\Delta\nu$ = 27.7 Hz, 2H), 2.06 – 1.98 (m, 1H), 1.56 – 1.47 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.3, 157.0, 139.9, 137.9, 128.9, 126.4, 123.2, 122.8, 120.8, 116.4, 111.3, 108.1, 82.5, 65.7, 55.3, 55.1, 45.9, 43.8, 37.5, 36.8, 26.1; IR (neat): 2936, 2835, 1588, 1488, 1470, 1454, 1439, 1308, 1262,

1154, 1082, 1062, 1047, 1006, 780, 768, 710 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{24}O_3$: 324.1720, found: 324.1723. The relative stereochemistry of **5** was assigned by analogy to **2a**. The regiochemistry of **5** was assigned by NOE.



5

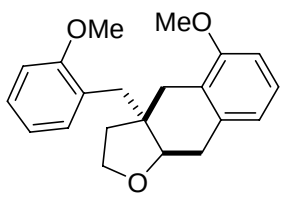
(±)-*cis*-3a-(3-Methoxybenzyl)-6-methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (6)



6

Tetrahydronaphthofuran **6** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.27 – 7.21 (m, 1H), 7.08 (d, J = 8.2 Hz, 1H), 6.81 (dd, J = 2.1, 7.9 Hz, 2H), 6.77 – 6.74 (m, 1H), 6.71 (dd, J = 2.6, 8.2 Hz, 1H), 6.66 (d, J = 2.5 Hz, 1H), 4.08 (t, J = 4.3 Hz, 1H), 3.82 (s, 3H), 3.77 (s, 3H), 3.71 – 3.57 (m, 1H), 2.82 (dd, J = 4.0, 15.3 Hz, 1H), 2.75 – 2.64 (m, 3H), 2.54 (ABq, J_{AB} = 14.5, $\Delta\nu$ = 68.8 Hz, 2H), 2.05 – 1.97 (m, 1H), 1.51 – 1.43 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.3, 158.1, 139.8, 138.2, 129.0, 128.8, 127.8, 123.0, 116.6, 114.1, 111.3, 111.3, 83.7, 66.1, 55.2, 55.1, 46.8, 45.2, 38.4, 37.7, 33.6; IR (neat): 2938, 2834, 1610, 1583, 1500, 1464, 1453, 1435, 1262, 1154, 1062, 1040, 787, 705 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{24}O_3$: 324.1720, found: 324.1721. The relative stereochemistry of **6** was assigned by analogy to **2a**. The regiochemistry of **6** was assigned by analysis of the ^{1}H NMR (two aromatic protons with no vicinal coupling) and process of elimination.

(±)-*cis*-3a-(2-Methoxybenzyl)-5-methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (8a)

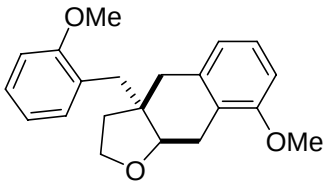


8a

Tetrahydronaphthofurans **8a** and **9a** (48 mg) were obtained from the catalytic carboetherification (Method A) of **7a** [96% yield, **8a** : **9a** (1.3 : 1)]. They were separated by prep HPLC using EtOAc/hexanes (**8a** eluted first). Tetrahydronaphthofuran **8a** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.26 – 7.16 (m, 2H), 7.11 (t, J = 7.8 Hz, 1H), 6.94 – 6.84 (m, 2H), 6.80 (d, J = 7.4 Hz, 1H), 6.73 (d, J = 8.2 Hz, 1H), 4.09 (t, J = 4.0 Hz, 1H), 3.78 (d, J = 7.6 Hz, 6H), 3.69 – 3.54 (m, 2H), 2.93 – 2.84 (m, 2H), 2.81 – 2.67 (m, 3H), 2.57 (d, J = 15.3 Hz, 1H), 2.01 – 1.93 (m, 1H), 1.46 – 1.36 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 157.8, 156.6, 137.2, 132.4, 127.5, 127.0, 126.4, 125.1, 120.8, 120.0, 110.4, 108.0, 82.7, 66.1, 55.3, 55.0, 46.6, 37.7, 37.7, 34.2, 29.9; IR (neat): 2940, 2836, 1589, 1493, 1470, 1440, 1263, 1244, 1070, 1029, 755 cm^{-1}; HRMS (EI) calcd for

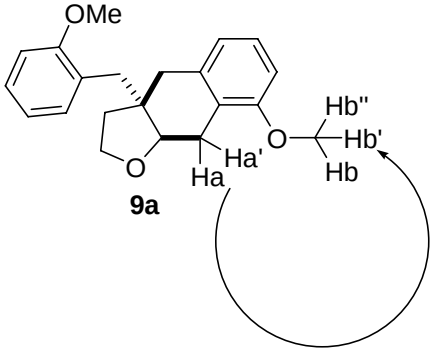
$[M]^+$ $C_{21}H_{24}O_3$: 324.1720, found: 324.1721. The relative stereochemistry of **8a** was assigned by analogy to **2a**. The regiochemistry of **8a** was assigned by process of elimination (it was not **9a**).

(±)-*cis*-3a-(2-Methoxybenzyl)-8-methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (9a)



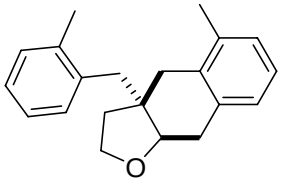
9a

Tetrahydronaphthofuran **9a** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.25 – 7.20 (m, 1H), 7.14 (dd, *J* = 1.7, 7.4 Hz, 1H), 7.09 (t, *J* = 7.9 Hz, 1H), 6.93 – 6.85 (m, 2H), 6.71 (dd, *J* = 7.8, 12.8 Hz, 2H), 4.07 (dd, *J* = 3.1, 4.8 Hz, 1H), 3.81 (s, 3H), 3.78 (s, 3H), 3.72 – 3.60 (m, 2H), 3.14 (dd, *J* = 3.0, 16.5 Hz, 1H), 2.86 (d, *J* = 13.2 Hz, 1H), 2.71 – 2.58 (m, 3H), 2.53 (d, *J* = 14.9 Hz, 1H), 2.02 – 1.96 (m, 1H), 1.47 – 1.39 (m, 1H); ^{13}C NMR (75 MHz, cdcl3) δ 157.8, 157.0, 138.4, 132.3, 127.6, 127.0, 126.2, 123.6, 120.8, 120.03, 110.4, 108.0, 82.5, 65.8, 55.4, 55.0, 46.4, 37.5, 37.1, 37.1, 26.3; IR (neat): 2936, 1588, 1492, 1470, 1244, 1080, 754 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{21}H_{24}O_3$: 324.1720, found: 324.1721. The relative stereochemistry of **9a** was assigned by analogy to **2a**. the regiochemistry of **9a** was assigned by NOE.



9a

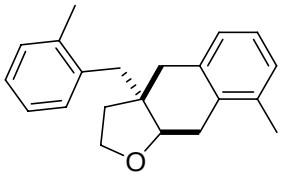
(±)-*cis*-5-Methyl-3a-(2-methylbenzyl)-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (8b)



8b

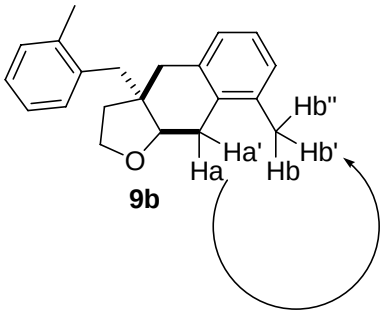
Tetrahydronaphthofurans **8b** and **9b** (47 mg) were obtained from the catalytic carboetherification (Method A) of **7b** [94% yield, **8b** : **9b** (4.5 : 1)]. They were separated by prep HPLC using EtOAc/hexanes (**9b** eluted first). Tetrahydronaphthofuran **8b** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.24 – 7.11 (m, 4H), 7.07 – 6.98 (m, 3H), 4.11 (t, *J* = 4.5 Hz, 1H), 3.70 – 3.58 (m, 2H), 2.93 (dd, *J* = 3.2, 15.9 Hz, 1H), 2.85 – 2.74 (m, 3H), 2.57 (ABq, J_{AB} = 15.0, Δν = 81.1 Hz, 2H), 2.20 (s, 3H), 2.16 (s, 3H), 2.02 – 1.95 (m, 1H), 1.62 – 1.52 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 137.0, 136.8, 135.2, 135.2, 134.9, 130.7, 130.6, 127.8, 126.4, 126.2, 125.8, 125.6, 82.4, 66.0, 47.1, 40.3, 38.3, 34.1, 33.7, 20.3, 19.3; IR (neat): 2940, 2872, 1591, 1471, 1453, 1083, 1065, 1002, 769, 744 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{21}H_{25}O$: 293.1900, found: 293.1892. The relative stereochemistry of **8b** was assigned by analogy to **2a**. The regiochemistry of **8b** was assigned by process of elimination (it was not 9b).

(±)-*cis*-8-Methyl-3a-(2-methylbenzyl)-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (9b)



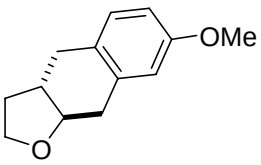
9b

Tetrahydronaphthofuran **9b** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.23 – 7.12 (m, 4H), 7.03 (d, *J* = 4.9 Hz, 2H), 6.91 (t, *J* = 4.4 Hz, 1H), 4.12 – 4.09 (m, 1H), 3.73 – 3.63 (m, 2H), 3.01 (dd, *J* = 3.2, 16.3 Hz, 1H), 2.77 (s, 2H), 2.69 (dd, *J* = 4.8, 16.3 Hz, 1H), 2.62 (s, 2H), 2.30 (s, 3H), 2.26 (s, 3H), 1.99 – 1.91 (m, 1H), 1.60 – 1.52 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 137.0, 136.8, 136.4, 135.7, 133.5, 131.0, 130.7, 128.0, 126.4, 126.2, 125.6, 125.5, 82.8, 65.9, 46.6, 39.9, 38.1, 37.6, 30.0, 20.4, 19.4; IR (neat): 3019, 2940, 2359, 1471, 1064, 1000, 769, 743 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{21}H_{25}O$: 293.1900, found: 293.1892. The relative stereochemistry of **9b** was assigned by analogy to **2a**. The regiochemistry of **9b** was assigned by NOE.



9b

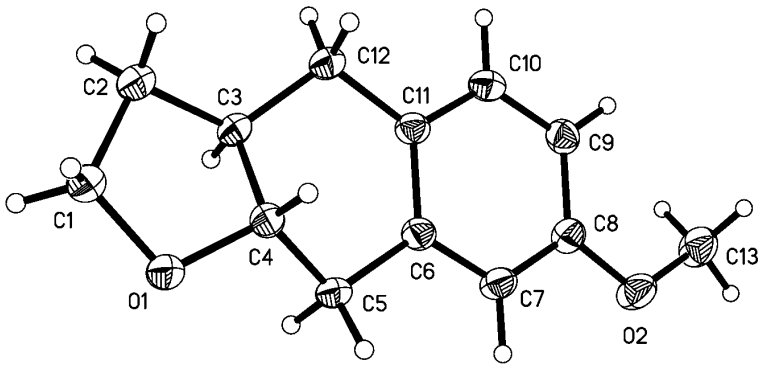
(±)-*trans*-7-Methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (*trans*-11a)



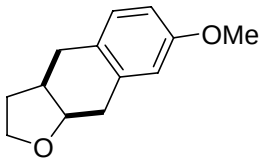
11a

Tetrahydronaphthofurans **11a** and **12a** (78 mg) were obtained from the catalytic carboetherification (Method A, reaction run at 120 ^{o}C) of **10a** [78% yield, **11a** : **12a** (3.2 : 1)]. They were separated by prep HPLC using EtOAc/hexanes (**11a** eluted first). Tetrahydronaphthofuran **11a** was obtained as a white solid, mp 89-91 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.03 (d, *J* = 8.4 Hz, 1H), 6.74 – 6.66 (m, 2H), 4.07 – 4.00 (m, 2H), 3.77 (s, 3H), 3.54 – 3.46 (m, 1H), 3.19 (dd, *J* = 5.3, 15.2 Hz, 1H), 3.07 (dd, *J* = 4.9, 15.7 Hz, 1H), 2.82 (dd, *J* = 11.6, 14.8 Hz, 1H), 2.63 – 2.53 (m, 1H), 2.24 – 2.15 (m, 1H), 1.90 – 1.78 (m, 1H), 1.75 – 1.65 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 157.8, 136.2, 129.9, 128.2, 114.6, 112.5, 80.3, 67.7, 55.2, 42.5, 36.2, 33.5, 31.1; IR (neat): 2958, 2925, 2875, 2840, 1614, 1570, 1498, 1452, 1304, 1259, 1119, 1071, 1028, 982, 921, 911, 857, 821, 799, 671 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{13}H_{17}O_2$: 205.1223, found: 205.1219. The white solid was recrystallized from CH_2Cl_2/hexanes and the relative stereochemistry of **11a** was assigned by X-ray structure.

X-ray crystal structure of 11a



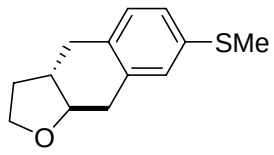
(±)-*cis*-7-Methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (12a)



12a

Tetrahydronaphthofuran **12a** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.02 (d, *J* = 8.1 Hz, 1H), 6.76 (d, *J* = 2.6 Hz, 1H), 6.70 (dd, *J* = 2.6, 8.1 Hz, 1H), 4.29 (dt, *J* = 5.2, 8.7 Hz, 1H), 3.80 – 3.73 (m, 4H), 3.53 (td, *J* = 6.0, 8.9 Hz, 1H), 2.84 (dd, *J* = 5.2, 14.8 Hz, 1H), 2.77 (dd, *J* = 5.2, 14.8 Hz, 1H), 2.71 (dd, *J* = 5.9, 14.2 Hz, 1H), 2.63 – 2.54 (m, 1H), 2.48 (dd, *J* = 6.1, 14.2 Hz, 1H), 2.10 – 2.03 (m, 1H), 1.50 – 1.41 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.3, 137.7, 129.9, 128.2, 113.9, 111.4, 77.8, 67.2, 55.2, 37.8, 35.2, 32.9, 32.6; IR (neat): 2934, 2360, 2341, 1614, 1584, 1504, 1455, 1362, 1254, 1208, 1153, 1038, 825 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{13}H_{17}O_2$: 205.1223, found: 205.1218. The relative stereochemistry of **12a** was assigned by process of elimination (it was not **11a**).

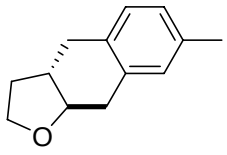
(±)-*trans*-2,3,3a,4,9,9a-hexahydro-7-(methylthio)naphtho[2,3-b]furan (11b)



11b

Tetrahydronaphthofuran **11b** (29 mg) was obtained from the catalytic carboetherification (Method D, reaction run at 140 °C) of **10b** (69% yield, trans: cis=4.6:1). Trans **11b** was separated by prep HPLC using EtOAc/hexanes (trans **11b** eluted first) as a white solid, mp 112-114 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08-7.10 (m, 3H), 4.05 – 4.09 (m, 2H), 3.53 (td, *J* = 10.7, 5.3 Hz, 1H), 3.23 (dd, *J* = 15.2, 5.3 Hz, 1H), 3.13 (dd, *J* = 16.1, 4.9 Hz, 1H), 2.84 (dd, *J* = 15.2, 11.2 Hz, 1H), 2.64 (dd, *J* = 16.2, 12.2 Hz, 1H), 2.49 (s, 3H), 2.30-2.20 (m, 1H), 1.90 – 1.80 (m, 1H), 1.78 – 1.69 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 135.77, 135.63, 133.33, 129.63, 128.54, 125.03, 80.18, 67.65, 42.25, 35.96, 33.91, 31.12, 16.24; IR (neat): 2948, 2911, 2856, 2830, 1591, 1486, 1440, 1378, 1188, 1071, 1031, 980, 820 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{16}OS$: 220.0916, found: 220.0919.

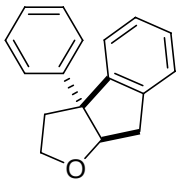
(±)-*trans*-2,3,3a,4,9,9a-hexahydro-7-methylnaphtho[2,3-b]furan (11c)



11c

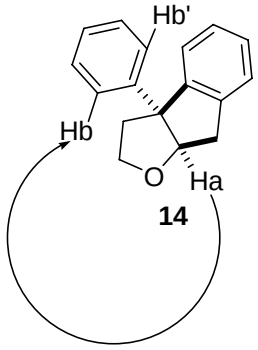
Tetrahydronaphthofuran **11c** (20 mg) was obtained from the catalytic carboetherification (Method D, reaction run at 140 ^{o}C) of **10c** (56% yield, trans: cis=4:1). Trans and cis **11c** were inseparable and were characterized as a mixture of diastereomers; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.13-6.99 (m, 4H), 4.33-4.30 (m, 0.33H), 4.10 – 4.03 (m, 2H), 3.90-3.49 (m, 2H), 3.19 (dd, *J* = 5.3, 15.2 Hz, 1H), 3.07 (dd, *J* = 4.9, 15.7 Hz, 1H), 2.90-2.75 (m, 2H), 2.67-2.50 (m, 2H), 2.36 – 2.30 (m, 4H), 2.10-1.95 (m, 1H), 1.90-1.85 (m, 1H), 1.75-1.65 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 136.52, 135.70, 135.54, 134.83, 133.04, 130.79, 129.06, 128.61, 127.36, 126.94, 80.44, 78.25, 67.61, 67.19, 42.36, 37.70, 35.95, 34.79, 33.98, 33.12, 33.01, 31.19, 21.42, 20.94; IR (neat): 2924, 2868, 1723, 1615, 1500, 1444, 1380, 1325, 1104, 1073, 1036, 980, 803 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{16}O$: 188.1196, found: 188.1199.

(±)-*cis*-3a-Phenyl-3,3a,8,8a-tetrahydro-2*H*-indeno[2,1-*b*]furan (14)



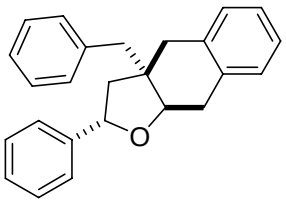
14

Tetrahydroindenofuran **14** (33 mg) was obtained from the catalytic carboetherification (Method A) of **13** as a clear oil (66% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31 – 7.14 (m, 9H), 4.70 (d, *J* = 5.2 Hz, 1H), 4.12 – 4.06 (m, 1H), 3.68 (td, *J* = 6.0, 8.7 Hz, 1H), 3.28 (dd, *J* = 5.3, 17.3 Hz, 1H), 3.09 (d, *J* = 17.3 Hz, 1H), 2.81 – 2.72 (m, 1H), 2.61 – 2.53 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 146.9, 144.6, 142.2, 128.4, 127.5, 127.2, 126.5, 126.3, 125.1, 125.0, 91.3, 68.9, 65.1, 41.3, 39.3; IR (neat): 3021, 2940, 2865, 1598, 1493, 1477, 1456, 1445, 1159, 1066, 756, 719, 699 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{17}H_{17}O$: 237.1274, found: 237.1272. The relative stereochemistry of **14** was assigned by NOE.



14

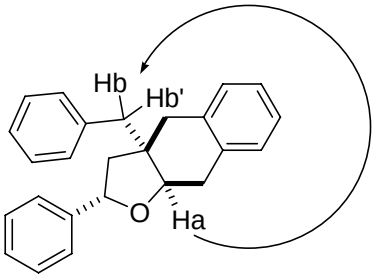
(±)-*trans*-(3a-Benzyl-2-phenyl-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (16a)



16a

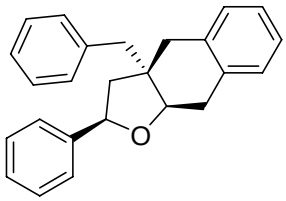
Tetrahydronaphthofurans **16a** and **17a** (49 mg) were obtained from the catalytic carboetherification (Method A) of **15a** [98% yield, **16a** : **17a** (2.6 : 1)]. They were separated by prep HPLC using EtOAc/hexanes (**16a** eluted first). Tetrahydronaphthofuran **16a** was obtained as a white solid, mp 84-86 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 – 7.18 (m, 11H), 7.15 – 7.09 (m, 3H), 4.74 (dd, *J* = 6.0, 9.0 Hz, 1H), 4.44 (t, *J* = 5.0 Hz, 1H), 3.00 (qd, *J* = 5.0, 15.5 Hz, 2H),

2.71 – 2.62 (m, 4H), 2.16 (dd, *J* = 9.1, 12.5 Hz, 1H), 2.02 (dd, *J* = 6.0, 12.5 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 142.9, 138.4, 137.0, 135.6, 130.2, 128.3, 128.3, 128.1, 128.0, 127.2, 126.5, 126.4, 126.3, 125.5, 83.9, 79.6, 48.3, 48.1, 45.4, 37.6, 34.7; IR (neat): 3061, 3026, 2932, 2360, 1721, 1602, 1493, 1452, 1051, 753, 701 cm^{-1}; HRMS (ESI) calcd for $[M+Na]^+$ $C_{25}H_{24}ONa$: 363.1719, found: 363.1714. The relative stereochemistry of **16a** was assigned by NOE and by process of elimination (it was not **17a**). When (*R*, *R*)-Ph-Box and Method B were used, **16a** was obtained as a white solid: $[\alpha]_D^{17}$ = -2.78 º (*c* 0.90, $CHCl_3$). ee = 30%, determined by HPLC analysis [(*S*, *S*)-Whelk, 2% IPA/Hexane, 1.0 mL/min, λ = 254 nm, t(major) = 5.51 min, t(minor) = 6.33 min]



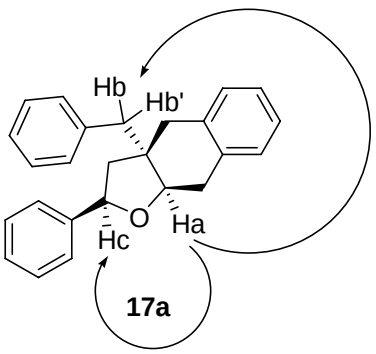
16a

(±)-*cis*-(3a-Benzyl-2-phenyl-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (17a)



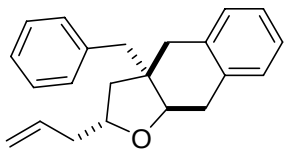
17a

Tetrahydronaphthofuran **17a** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 – 7.11 (m, 11H), 7.06 (d, *J* = 7.2, 1H), 6.88 (dd, *J* = 2.8, 6.7 Hz, 2H), 4.64 (dd, *J* = 5.2, 10.9 Hz, 1H), 4.38 (t, *J* = 3.8 Hz, 1H), 2.99 (dd, *J* = 3.4, 15.0 Hz, 1H), 2.89 (ABq, J_{AB} = 13.5, Δν = 42.7 Hz, 2H), 2.72 (dd, *J* = 4.1, 15.0 Hz, 1H), 2.58 (ABq, J_{AB} = 14.0, Δν = 85.9 Hz, 2H), 2.25 (dd, *J* = 5.2, 12.8 Hz, 1H), 1.39 – 1.31 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 141.4, 138.0, 137.0, 136.5, 130.7, 128.3, 128.2, 128.1, 127.4, 126.5, 126.5, 126.3, 126.0, 84.1, 78.6, 48.1, 46.2, 45.9, 39.1, 35.0; IR (neat): 3342, 3026, 2913, 1492, 1452, 1068, 1027, 755, 701 cm^{-1}; HRMS (ESI) calcd for $[M+Na]^+$ $C_{25}H_{24}ONa$: 363.1719, found: 363.1711. The relative stereochemistry of **17a** was assigned by NOE. When (*R*, *R*)-Ph-Box and Method B were used, **17a** was obtained as a colorless oil: $[\alpha]_D^{17}$ = -22.40 º (*c* 0.50, $CHCl_3$). ee = 67%, determined by HPLC analysis [(*S*, *S*)-Whelk, 2% IPA/Hexane, 1.0 mL/min, λ = 254 nm, t(major) = 5.81 min, t(minor) = 5.27 min]



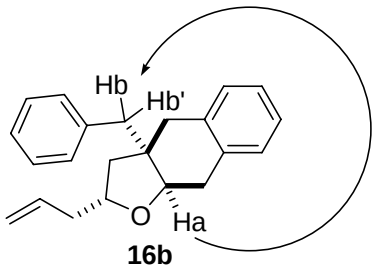
17a

(±)-*trans*-2-Allyl-3a-benzyl-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (16b)



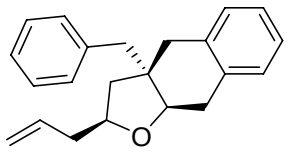
16b

Tetrahydronaphthofurans **16b** and **17b** (49 mg) were obtained from the catalytic carboetherification (Method A) of **15b** [98% yield, **16b** : **17b** (2.5 : 1)]. They were separated by prep HPLC using EtOAc/hexanes (**16b** eluted first). Tetrahydronaphthofuran **16b** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34 – 7.13 (m, 8H), 7.10 – 7.04 (m, 1H), 5.79 – 5.68 (m, 1H), 5.09 – 5.00 (m, 2H), 4.20 (t, J = 5.2 Hz, 1H), 3.81 – 3.72 (m, 1H), 2.91 (d, J = 5.2 Hz, 2H), 2.69 – 2.50 (m, 4H), 2.36 – 2.27 (m, 1H), 2.24 – 2.16 (m, 1H), 1.85 (dd, J = 9.5, 12.4 Hz, 1H), 1.69 (dd, J = 5.6, 12.4 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.6, 137.1, 135.6, 134.7, 130.2, 128.1, 128.1, 127.9, 126.4, 126.3, 126.2, 116.8, 83.0, 77.3, 47.8, 45.4, 44.8, 40.0, 37.5, 34.5; IR (neat): 3065, 3026, 2920, 2360, 2339, 1641, 1603, 1493, 1453, 1073, 997, 914, 753, 703 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{22}H_{25}O$: 305.1900, found: 305.1897. The relative stereochemistry of **16b** was assigned by NOE and by process of elimination (it was not **17b**).



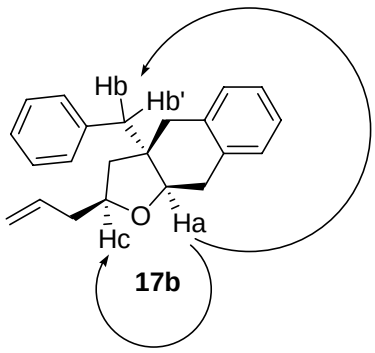
16b

(±)-*cis*-2-Allyl-3a-benzyl-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (17b)



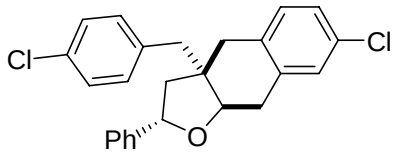
17b

Tetrahydronaphthofuran **17b** was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36 – 7.12 (m, 8H), 7.08 – 7.02 (m, 1H), 5.62 – 5.51 (m, 1H), 4.97 – 4.89 (m, 2H), 4.15 (t, J = 4.3 Hz, 1H), 3.84 – 3.76 (m, 1H), 2.84 (dd, J = 4.0, 15.0 Hz, 1H), 2.78 (d, J = 13.3 Hz, 1H), 2.73 – 2.66 (m, 2H), 2.53 (ABq, J_{AB} = 14.0, Δν = 89.6 Hz, 2H), 2.19 – 2.10 (m, 1H), 2.06 – 1.94 (m, 1H), 1.08 – 1.01 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.2, 137.1, 136.3, 134.5, 130.7, 128.2, 128.1, 128.0, 126.4, 126.3, 126.1, 116.6, 84.0, 76.0, 47.5, 45.7, 42.0, 39.0, 38.9, 35.0; IR (neat): 3025, 2917, 2360, 1492, 1453, 1076, 913, 752, 703 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{22}H_{25}O$: 305.1900, found: 305.1895. The relative stereochemistry of **17b** was assigned by NOE.



17b

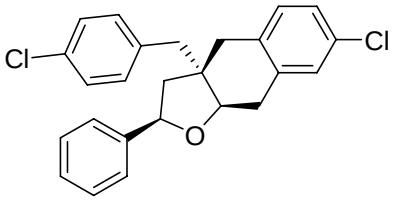
(±)-*trans*-3a-(4-Chlorobenzyl)-7-chloro-2,3,3a,4,9,9a-hexahydro-2-phenylnaphtho[2,3-b]furan (16c)



16c

Tetrahydronaphthofurans **16c** and **17c** (23 mg) were obtained from the catalytic carboetherification (Method A) of **15c** [77% yield, **16c** : **17c** (2.3 : 1)]. They were separated by prep TLC using 10% EtOAc/hexanes. Tetrahydronaphthofuran **16c** was obtained as a white solid, mp 94-96 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.37 – 7.15 (m, 9H), 7.06 – 7.00 (m, 3H), 4.77 (dd, J = 8.7, 6.3 Hz, 1H), 4.41 (t, J = 4.9 Hz, 1H), 2.97 (qd, J = 15.7, 4.8 Hz, 2H), 2.62-2.59 (m, 4H), 2.07 (qd, J = 12.5, 7.5 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 142.63, 137.43, 136.54, 135.17, 132.46, 132.11, 131.38, 129.12, 128.44, 128.36, 128.33, 127.34, 126.48, 125.38, 82.23, 79.51, 48.14, 47.81, 44.47, 36.84, 34.42; IR (neat): 2912, 2820, 1481, 1085, 1048, 1011, 754 cm^{-1}; HRMS (ESI) calcd for $[M]^+$ $C_{25}H_{22}Cl_2O$: 408.1042, found: 408.1050. When (*R*, *R*)-Ph-Box and Method B were used, **16c** was obtained as a white solid: $[\alpha]_D^{17}$ = -2.33 º (*c* 0.25, $CHCl_3$). ee = 32%, determined by HPLC analysis [(*S*, *S*)-Whelk, 2% IPA/Hexane, 1.0 mL/min, λ = 254 nm, t(major) = 6.31 min, t(minor) = 7.17 min]

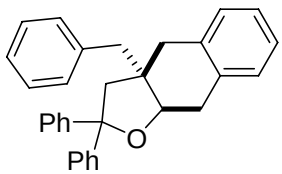
(±)-*cis*-3a-(4-Chlorobenzyl)-7-chloro-2,3,3a,4,9,9a-hexahydro-2-phenylnaphtho[2,3-b]furan (17c)



17c

Tetrahydronaphthofuran **17c** was obtained as a clear oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.32 (d, J = 8.4, 2H), 7.26-7.15 (m, 7H), 6.98 (d, J = 7.9, 1H), 6.91 (dd, J = 6.6, 2.7 Hz, 2H), 4.65 (dd, J = 10.8, 5.1 Hz, 1H), 4.33 (t, J = 3.7 Hz, 1H), 2.98 (dd, J = 15.2, 3.3 Hz, 1H), 2.86 (ABq, J_{AB} = 13.5, Δν = 42.7 Hz, 2H), 2.68 (dd, J = 15.0, 4.1 Hz, 1H), 2.51 (ABq, J_{AB} = 14.0, Δν = 85.9 Hz, 2H), 2.22 (dd, J = 12.8, 5.2 Hz, 1H), 1.38 – 1.30 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 140.88, 138.27, 136.23, 135.12, 132.62, 132.15, 131.86, 129.33, 128.44, 128.28, 127.63, 126.37, 125.89, 83.52, 78.55, 47.88, 46.06, 45.03, 38.43, 34.78; IR (neat): 3023, 2914, 2859, 1491, 1446, 1081, 1053, 1017, 826 cm^{-1}; HRMS (ESI) calcd for $[M]^+$ $C_{25}H_{22}Cl_2O$: 408.1042, found: 408.1053. When (*R*, *R*)-Ph-Box and Method B were used, **17c** was obtained as a colorless oil: $[\alpha]_D^{17}$ = -18.52 º (*c* 0.80, $CHCl_3$). ee = 60%, determined by HPLC analysis [(*S*, *S*)-Whelk, 2% IPA/Hexane, 0.8 mL/min, λ = 254 nm, t(major) = 9.13 min, t(minor) = 8.56 min]

(±)-*cis*-3a-Benzyl-2,3,3a,4,9,9a-hexahydro-2,2-diphenylnaphtho[2,3-b]furan (16d) and (-)-16d

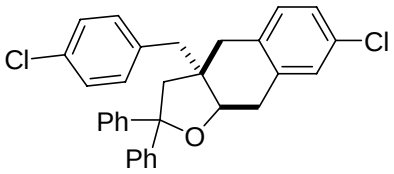


16d

Tetrahydronaphthofuran **16d** (70 mg) was obtained from the catalytic carboetherification (Method A) of **15d** as a clear oil (89% yield). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 – 7.65 (m, 2H), 7.49 (t, J = 7.5 Hz, 2H), 7.41-7.22 (m, 7 H), 7.11 (d, J = 7.3 Hz, 3H), 7.04 (dt, J = 9.1, 2.8 Hz, 3H), 6.74 – 6.70 (m, 2H), 4.41 (d, J = 3.5 Hz, 1H), 3.15 (dd, J = 15.0, 3.2 Hz, 1H), 2.99 (d, J = 13.2 Hz, 1H), 2.75 (dd, J = 15.1, 3.7 Hz, 1H), 2.64 (d, J = 14.1 Hz, 1H), 2.48 (dd, J = 13.8, 4.5 Hz, 2H), 2.40 (d, J = 13.3 Hz, 1H), 2.04 (d, J = 13.2 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 146.43, 144.56, 138.35,

136.92, 136.77, 130.43, 128.43, 128.38, 128.32, 128.01, 127.71, 127.01, 126.80, 126.60, 126.55, 126.30, 126.06, 86.56, 83.11, 51.22, 48.53, 44.85, 39.15, 34.58; IR (neat): 3059, 3024, 2914, 2850, 1597, 1491, 1447, 1043, 757, 702 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{31}H_{28}O$: 416.2135, found: 416.2130. When (*R*, *R*)-Ph-Box and Method B were used, (-)-**16d** was obtained as a colorless oil: $[\alpha]_D^{17} =$ -71.81 º (*c* 0.45, $CHCl_3$). ee = 75%, determined by HPLC analysis [Chiralpak AD-RH, 60:40 CH_3CN/H_2O, 0.75 mL/min, λ = 254 nm, t(major) = 26.71 min, t(minor) = 25.15 min]

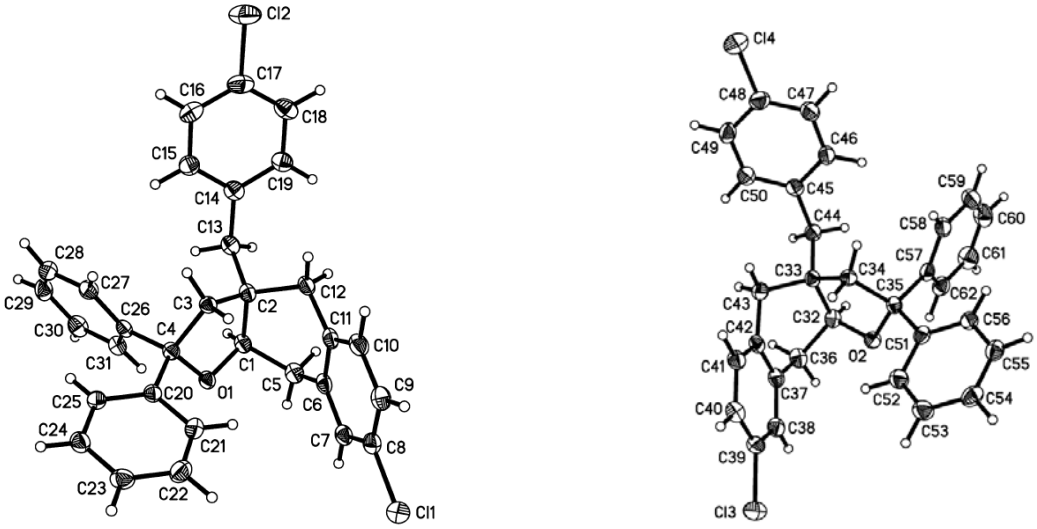
(±)-*cis*-3a-(4-Chlorobenzyl)-7-chloro-2,3,3a,4,9,9a-hexahydro-2,2-diphenylnaphtho[2,3-b]furan (16e) and (-)-16e



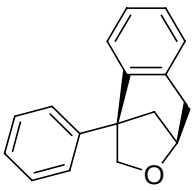
16e

Tetrahydronaphthofuran **16e** (30 mg) was obtained from the catalytic carboetherification (Method A) of **15e** as a white solid (85% yield), mp 116-118 ^oC. ^1H NMR (500 MHz, $CDCl_3$) δ 7.59 (dd, *J* = 8.2, 1.2 Hz, 2H), 7.44 (t, *J* = 7.8 Hz, 2H), 7.34-7.26 (m, 2 H), 7.26-7.21 (m, 2 H), 7.18 (dd, *J* = 7.9, 2.1 Hz, 1H), 7.07-7.04 (m, 3H), 6.98 (dd, *J* = 8.0, 5.2 Hz, 3H), 6.75-6.73 (m, 2 H), 4.34 (t, *J* = 3.6 Hz, 1H), 3.09 (dd, *J* = 15.2, 3.3 Hz, 1H), 2.90 (d, *J* = 13.2 Hz, 1H), 2.67 (dd, *J* = 15.2, 3.8 Hz, 1H), 2.46 (ABq, J_{AB} = 15.0, Δν = 29.6 Hz, 2H), 2.37 (ABq, J_{AB} = 15.0, Δν = 29.6 Hz, 2H), 1.98 (d, *J* = 13.2 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 146.09, 144.44, 138.55, 136.52, 135.06, 132.39, 132.20, 131.60, 129.50, 128.51, 128.46, 128.26, 127.87, 127.15, 126.79, 126.56, 126.36, 125.86, 86.58, 82.44, 50.94, 48.33, 44.02, 38.48, 34.37; IR (neat): 2950, 2943, 2841, 1482, 1446, 1081, 1044, 817, 689 cm^{-1}; HRMS (ESI) calcd for $[M]^+$ $C_{31}H_{26}Cl_2O$: 484.1355, found: 484.1328. When (*R*, *R*)-Ph-Box and Method B were used, (-)-**16e** was obtained as a white solid: $[\alpha]_D^{17} =$ -66.70 º (*c* 1.35, $CHCl_3$). ee could not be determined by either Chiral HPLC or GC. The relative stereochemistry was confirmed by X-ray crystal structure of the racemate.

X-ray crystal structure of 16e



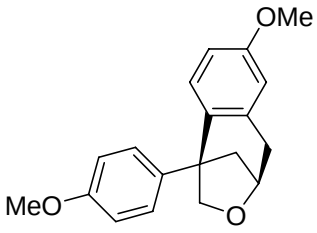
(±)-*cis*-1-Phenyl-1,2,4,5-tetrahydro-1,4-methanobenzo[*d*]oxepine (19a)



19a

Tetrahydrofuran **19a** (42 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **18a** as a white solid (93% yield), mp 139-140 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.50-7.32 (m, 3H), 7.31-7.20 (m, 2H), 7.19-7.13 (m, 2H), 7.00-6.93 (m, 1H), 6.51 (d, *J* = 7.7 Hz, 1H), 4.89-4.77 (m, 1H), 4.40 (d, *J* = 7.0 Hz, 1H), 4.28 (d, *J* = 7.0 Hz, 1H), 3.14 (s, 2H), 2.57 (d, *J* = 11.0 Hz, 1H), 2.39 (dd, *J* = 11.0, 6.3 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.29, 142.20, 133.44, 129.51, 128.16, 126.96, 126.68, 125.89, 125.61, 81.07, 75.43, 51.81, 40.24, 39.41; IR (neat): 3057, 3029, 2928, 2860, 1600, 1485, 1449, 1306, 1076, 1040, 975, 961, 754, 701 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{17}H_{16}O$: 236.1196, found: 236.1201.

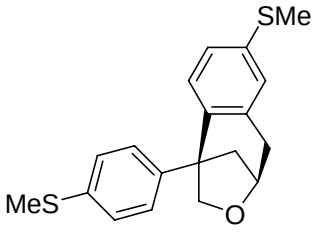
(±)-*cis*-7-Methoxy-1-(4-methoxyphenyl)-1,2,4,5-tetrahydro-1,4-methanobenzo[*d*]oxepine (19b)



19b

Tetrahydrofuran **19b** (51 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **18b** as a white solid (91% yield), mp 117-118 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.16 (d, *J* = 8.5 Hz, 2H), 7.02-6.90 (m, 2H), 6.70 (d, *J* = 2.6 Hz, 1H), 6.58-6.40 (m, 2H), 4.86-4.76 (m, 1H), 4.32 (dd, *J* = 6.8, 0.9 Hz, 1H), 4.22 (d, *J* = 6.9 Hz, 1H), 3.85 (s, 3H), 3.75 (s, 3H), 3.10 (d, *J* = 2.0 Hz, 2H), 2.49 (d, *J* = 10.9 Hz, 1H), 2.33 (dd, *J* = 10.9, 6.3 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.38, 158.23, 138.08, 134.75, 134.45, 129.02, 126.98, 114.43, 111.14, 81.29, 75.43, 55.26, 55.16, 50.55, 40.74, 39.70; IR (neat): 2935, 2866, 2839, 1611, 1574, 1515, 1494, 1464, 1311, 1248, 1182, 1116, 1074, 1039, 978, 826, 803 cm^{-1}; HRMS (ESI) calcd for $[M + H]^+$ $C_{19}H_{20}O_3$: 297.1485, found: 297.1135.

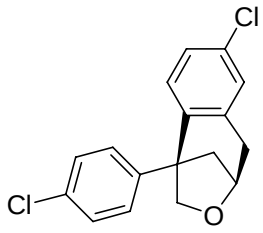
(±)-*cis*-7-(Methylthio)-1-(4-(methylthio)phenyl)-1,2,4,5-tetrahydro-1,4-methanobenzo[*d*]oxepine (19c)



19c

Tetrahydrofuran **19c** (40 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **18c** as a white solid (87% yield), mp 125-126 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.32-7.26 (m, 2H), 7.14 (d, *J* = 8.4 Hz, 2H), 7.04 (d, *J* = 1.9 Hz, 1H), 6.86 (dd, *J* = 8.2, 2.1 Hz, 1H), 6.43 (d, *J* = 8.2 Hz, 1H), 4.85-4.756 (m, 1H), 4.32 (dd, *J* = 7.0, 0.9 Hz, 1H), 4.21 (d, *J* = 7.0 Hz, 1H), 3.08 (s, 2H), 2.52 (s, 3H), 2.49 (d, *J* = 10.9 Hz, 1H), 2.42 (s, 3H), 2.34 (dd, *J* = 10.8, 6.1 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 142.35, 138.74, 137.12, 136.56, 134.18, 128.51, 127.69, 126.40, 124.10, 80.91, 75.31, 51.11, 40.30, 39.30, 15.94, 15.81; IR (neat): 2920, 2848, 1595, 1550, 1496, 1483, 1437, 1305, 1183, 1096, 1064, 1038, 964, 904 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{19}H_{20}OS_2$: 328.0950, found: 328.0953.

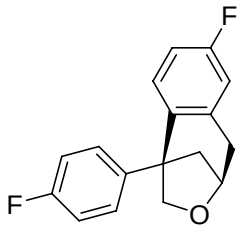
(±)-*cis*-7-Chloro-1-(4-chlorophenyl)-1,2,4,5-tetrahydro-1,4-methanobenzo[*d*]oxepine (19d)



19d

Tetrahydrofuran **19d** (54 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **18d** as a pale yellow oil (93% yield). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.40-7.39 (m, 2H), 7.18-7.12 (m, 3H), 6.92 (dd, *J* = 8.4, 2.3 Hz, 1H), 6.39 (d, *J* = 8.4 Hz, 1H), 4.85-4.75 (m, 1H), 4.31 (dd, *J* = 7.1, 0.9 Hz, 1H), 4.20 (d, *J* = 7.1 Hz, 1H), 3.08 (s, 2H), 2.47 (d, *J* = 11.0 Hz, 1H), 2.33 (dd, *J* = 10.8, 6.6 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.25, 140.13, 135.47, 133.08, 132.51, 129.38, 127.18, 125.80, 80.74, 75.05, 51.12, 40.20, 39.21; IR (neat): 2932, 2859, 1587, 1495, 1474, 1397, 1094, 822 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{17}H_{14}OCl_2$: 304.0416, found: 304.0421.

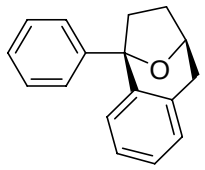
(±)-*cis*-7-Fluoro-1-(4-fluorophenyl)-1,2,4,5-tetrahydro-1,4-methanobenzo[*d*]oxepine (19e)



19e

Tetrahydrofuran **19e** (48 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **18e** as a white solid (92% yield), mp 118-119 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.23-7.04 (m, 4H), 6.84 (dd, *J* = 9.3, 2.7 Hz, 1H), 6.64 (td, *J* = 8.5, 2.8 Hz, 1H), 6.42 (dd, *J* = 8.7, 5.7 Hz, 1H), 4.85-4.75 (m, 1H), 4.31 (dd, *J* = 7.0, 0.9 Hz, 1H), 4.21 (d, *J* = 7.0 Hz, 1H), 3.10 (s, 2H), 2.48 (d, *J* = 11.1 Hz, 1H), 2.34 (dd, *J* = 10.8, 6.1 H2221z, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.40, 163.19, 160.14, 159.94, 137.74, 137.70, 135.81, 135.71, 129.58, 129.47, 127.43, 127.33, 116.07, 115.79, 112.53, 112.26, 81.05, 75.08, 50.87, 40.53, 39.54, 39.52; IR (neat): 2932, 2857, 1609, 1589, 1509, 1490, 1419, 1305, 1239, 1163, 1108, 1071, 1040, 970, 829 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{17}H_{14}OF_2$: 272.1007, found: 272.1011.

(±)-*cis*-5-Phenyl-6,7,8,9-tetrahydro-5H-5,8-epoxybenzo[7]annulene (21) and (-)-21

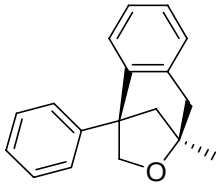


21

Tetrahydrofuran **21** (20 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **20** as a white solid (67% yield), mp 114-116 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.54-7.49 (m, 2H), 7.40-7.32 (m, 3H), 7.11 (dd, *J* = 4.6, 2.1 Hz, 2H), 6.96 (dd, *J* = 8.0, 2.9 Hz, 1H), 6.58 (d, *J* = 7.6 Hz, 1H), 4.91 (t, *J* = 6.4 Hz, 1H), 3.53 (dd, *J* = 16.4, 5.1 Hz, 1H), 2.63 (d, *J* = 16.4 Hz, 1H), 2.54-2.49 (m, 1H), 2.44-2.35 (m, 2H), 1.91-1.83 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.75, 142.70, 131.87, 130.05, 129.21, 128.09, 127.48, 126.71, 125.66, 124.96, 85.45, 74.40, 40.91, 37.19, 29.58; IR (neat): 3041, 2949, 1444, 1306, 1057, 1011, 763, 708 cm^{-1}; HRMS (ESI) calcd for $[M + Na]^+$ $C_{17}H_{16}O$: 259.1093, found: 259.1095. When (*R*, *R*)-Ph-Box and Method B were used, **(-)-21** was obtained as a white solid: $[\alpha]_D^{17}$ = -2.74 ° (*c* 0.30, $CHCl_3$). ee = 50%, determined by HPLC analysis [(*S*, *S*)-Whelk, 2% IPA/Hexane, 0.8 mL/min, λ = 254 nm, t(major) = 6.09 min, t(minor) = 6.65 min]. The absolute stereochemistry of **(-)-21** was tentatively assigned by analogy to similar literature compounds: (+)-

Bruguierol A and (+)-Bruguierol C, having $[\alpha]_D^{25}$ of +14.5 º (*c* 0.007, $CHCl_3$) and +4.2 º (*c* 0.005, MeOH) respectively.[12-13]

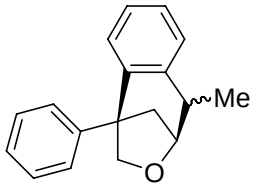
(±)-*cis*-4-Methyl-1-phenyl-1,2,4,5-tetrahydro-1,4-methanobenzo[*d*]oxepine (23)



23

Tetrahydrofuran **23** (41 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **22** as a white solid (87% yield), mp 143-145 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 (t, *J* = 7.7 Hz, 2H), 7.37-7.31 (m, 1H), 7.26-7.21 (m, 2H), 7.16-7.11 (m, 2H), 7.00-6.95 (m, 1H), 6.52 (d, *J* = 7.9 Hz, 1H), 4.35 (dd, *J* = 17.5, 6.9 Hz, 2H), 3.15-3.08 (m, 2H), 2.57 (d, *J* = 11.0 Hz, 1H), 2.21 (d, *J* = 11.0, 1H), 1.56 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ145.00, 142.42, 134.59, 129.17, 128.50, 128.01, 126.94, 126.56, 125.83, 125.58, 81.03, 80.79, 53.73, 46.43, 45.14, 25.93; IR (neat): 3059, 3028, 2965, 2923, 2860, 1600, 1485, 1448, 1376, 1302, 1222, 1157, 1094, 1042, 977, 769, 758, 729, 700 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{18}H_{18}O$: 250.1352, found: 250.1337.

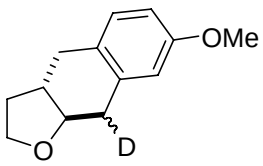
(±)-*cis*-5-Methyl-1-phenyl-1,2,4,5-tetrahydro-1,4-methanobenzo[*d*]oxepine (25a)



25a

Tetrahydrofuran **25a** (38 mg) was obtained from the catalytic carboetherification (Method A, reaction run at 120 °C) of **24a** as a colorless oil (81% yield, 1:1 diastereomer). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.95-7.15 (m, 7H), 6.98 (t, *J* = 7.6 Hz, 1H), 6.51 (ddd, *J* = 7.8, 5.3, 1.3 Hz, 1H), 4.54 (dd, *J* = 6.3, 2.6 Hz, 1H), 4.38-4.25 (m, 2H), 3.21-3.16 (m, 1H), 2.69-2.60 (m, 1H), 2.44 (dd, *J* = 10.9, 6.3 Hz, 0.5H), 2.24 (ddd, *J* = 11.2, 6.4, 0.7, 0.5H), 1.49 (d, *J* = 7.1 Hz, 1.5H), 1.35 (d, *J* = 7.3 Hz, 1.5H); ^{13}C NMR (75 MHz, $CDCl_3$) δ145.13, 144.69, 142.49, 142.16, 139.01, 132.42, 130.07, 129.46, 128.25, 128.21, 128.18, 126.98, 126.94, 126.82, 125.75, 125.61, 80.63, 80.30, 80.04, 79.90, 52.23, 51.91, 42.10, 41.48, 36.17, 20.35, 18.41; IR (neat): 3028, 2951, 2912, 2848, 1649, 1488, 1442, 1274, 1035, 757, 693 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{18}H_{18}O$: 250.1352, found: 250.1361.

(±)-*trans*-9-Deutero-7-methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (11a-D)

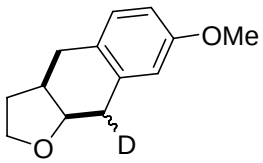


11a-D

Tetrahydronaphthofurans **11a**-D and **12a**-D (50 mg) were obtained from catalytic carboetherification (Method A) of **10a**-D [75% yield, **11a**-D : **12a**-D (1.8 : 1)]. They were separated by prep HPLC using EtOAc/hexanes (**11**-D eluted first). Tetrahydronaphthofuran **11a**-D was obtained as a white solid, mp 92-94 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.03 (d, *J* = 8.4 Hz, 1H), 6.72 (dd, *J* = 2.7, 8.4 Hz, 1H), 6.68 (d, *J* = 2.6 Hz, 1H), 4.04 (dd, *J* = 5.2, 9.2 Hz, 2H), 3.78 (s, 3H), 3.53 – 3.45 (m, 1H), 3.17 (s, 0.5H), 3.08 (dd, *J* = 4.9, 15.7 Hz, 1H), 2.80 (d, *J* = 11.1 Hz, 0.5H), 2.58 (dd, *J* = 12.2, 15.6 Hz, 1H), 2.24 – 2.15 (m, 1H), 1.90 – 1.78 (m, 1H), 1.75 – 1.64 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 157.8, 136.1, 129.9, 128.2, 128.2, 114.6, 114.6, 112.5, 80.3, 80.2, 67.7, 55.2, 42.5, 35.9 (m),

33.5, 31.1; IR (neat): 2925, 2360, 1615, 1572, 1498, 1454, 1289, 1255, 1071, 1026, 814 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{13}H_{16}DO_2$: 206.1286, found: 206.1276.

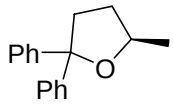
(±)-*cis*-9-Deutero-7-methoxy-2,3,3a,4,9,9a-hexahydronaphtho[2,3-*b*]furan (12a-D)



12a-D

Tetrahydronaphthofuran **12a**-D was obtained as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.02 (d, *J* = 8.1 Hz, 1H), 6.76 (d, *J* = 2.6 Hz, 1H), 6.70 (dd, *J* = 2.7, 8.1 Hz, 1H), 4.31 – 4.25 (m, 1H), 3.81 – 3.73 (m, 4H), 3.57 – 3.49 (m, 1H), 2.82 (s, 0.5H), 2.78 – 2.68 (m, 1.5H), 2.64 – 2.54 (m, 1H), 2.48 (dd, *J* = 5.5, 14.3 Hz, 1H), 2.11 – 2.02 (m, 1H), 1.51 – 1.40 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.3, 137.6, 129.9, 129.9, 128.2, 128.2, 113.9, 111.4, 77.8, 67.2, 55.2, 37.8, 37.7, 34.8 (m), 32.9, 32.7, 32.6; IR (neat): 2962, 2360, 1612, 1583, 1498, 1453, 1260, 1155, 1037, 800 cm^{-1}; HRMS (ESI) calcd for $[M+H]^+$ $C_{13}H_{16}DO_2$: 206.1286, found: 206.1282.

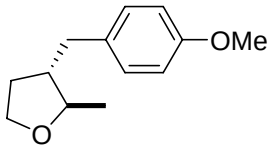
(±)-Tetrahydro-5-methyl-2,2-diphenylfuran (26) and (-)-26[14]



26

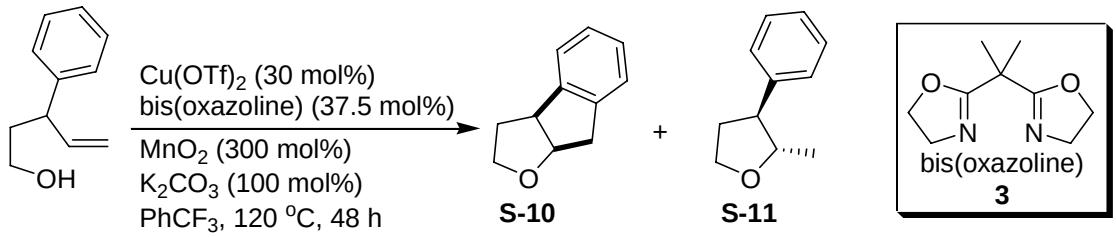
$Cu(OTf)_2$ (9.1 mg, 0.0252 mmol, 20 mol%) and bis(oxazoline) **3**[1] (5.7 mg, 0.0315 mmol, 25 mol%) were put into a 12 mL pressure tube with a stirring bar. $PhCF_3$ (0.6 mL) was syringed into the tube, and the vessel was refreshed with argon for 2 min, sealed and stirred at 60 ^oC for 2 hours. Upon cooling to room temperature, K_2CO_3 (17.4 mg, 0.126 mmol, 1.0 equiv), MnO_2 (32.8 mg, 0.378 mmol, 3.0 equiv) and 1,4-dicyclohexadiene (36 μL, 0.378 mmol, 3.0 equiv.) were added. Alcohol **20** (30 mg, 0.126 mmol, 1.0 equiv.) was dissolved in $PhCF_3$ (0.6 mL) in a 20 mL vial and the solution was transferred into the reaction tube. The vial was rinsed with $PhCF_3$ (0.3 mL) and the rinse was added to the reaction. The tube was refreshed with argon for 2 minutes, sealed and stirred at 100 ^oC. After 24 hours, the reaction mixture was cooled to room temperature, diluted with CH_2Cl_2 (3 mL) and vacuum filtered through a pad of silica gel (5 g). The silica gel was further rinsed with EtOAc (3 × 30 mL) and the combined filtrate was concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 90:10 hexanes/EtOAc) to afford 25 mg (83% yield) of **26** as a white solid. The analytical data was consistent with the literature: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50-7.47 (m, 4H), 7.34-7.20 (m, 6H), 4.31 (dd, *J* = 13.0, 6.6 Hz, 1H), 2.70 (dt, *J* = 12.4, 7.3 Hz, 1H), 2.58 (ddd, *J* = 12.4, 8.0, 6.3 Hz, 1H), 2.07 (dtd, *J* = 13.9, 7.3, 6.5 Hz, 1H), 1.68-1.63 (m, 1H), 1.40 (d, *J* = 5.0 Hz, 3H). When (*R*, *R*)-Ph-Box and Method B were used, (-)-**26** was obtained as a colorless oil: $[\alpha]_D^{17}$ = -4.25 º (*c* 0.50, $CHCl_3$). ee = 76%, determined by GC analysis (CP-Chirasil-Dex CB column) : Tinj = 220 ^{0}C, Tdet = 275 ^{0}C, flow = 2 ml/min, ti = 130 ^{0}C, tf = 220 ^{0}C, rate = 0.5 ^{0}C/min, retention times by using He as carrier gas: tmaj = 40.447, tmin = 40.887.

(±)-*trans*-3-(4-Methoxybenzyl)-tetrahydro-2-methylfuran (27)

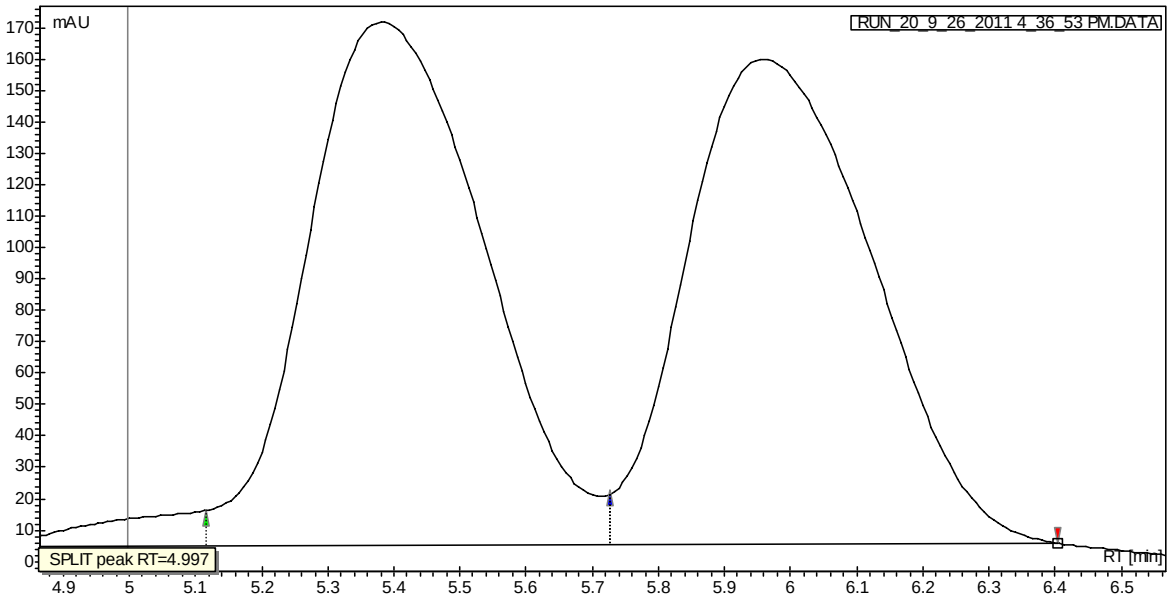


27

$Cu(OTf)_2$ (13.6 mg, 0.0376 mmol, 20 mol%) and bis(oxazoline) **3**[1] (8.56 mg, 0.0470 mmol, 25 mol%) were put into a 12 mL pressure tube with a stirring bar. $PhCF_3$ (0.6 mL) was syringed into the tube, and the vessel was refreshed with argon for 2 min, sealed and stirred at 60 °C for 2 hours. Upon cooling to room temperature, K_2CO_3 (26.0 mg, 0.188 mmol, 1.0 equiv), MnO_2 (49.0 mg, 0.564 mmol, 3.0 equiv) and 1,4-dicyclohexadiene (53 μL, 0.564 mmol, 3.0 equiv.) were added. Alcohol **10a** (39 mg, 0.188 mmol, 1.0 equiv.) was dissolved in $PhCF_3$ (1.0 mL) in a 20 mL vial and the solution was transferred into the reaction tube. The vial was rinsed with $PhCF_3$ (0.28 mL) and the rinse was added to the reaction. The tube was refreshed with argon for 2 minutes, sealed and stirred at 100 °C. After 24 hours, the reaction mixture was cooled to room temperature, diluted with CH_2Cl_2 (3 mL) and vacuum filtered through a pad of silica gel (5 g). The silica gel was further rinsed with EtOAc (3 × 30 mL) and the combined filtrate was concentrated *in vacuo*. The residue was purified by flash column chromatography (SiO_2, 90:10 hexanes/EtOAc) to afford 32 mg (82% yield) of **27** as a clear oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.13 (d, *J* = 8.7 Hz, 2H), 6.87 (d, *J* = 8.6 Hz, 2H), 3.89-3.84 (m, 1H), 3.83 (s, 3H), 3.82-3.81 (m, 1H), 3.65-3.61 (m, 1H), 2.74 (dd, *J* = 13.7, 5.9 Hz, 1H), 2.55 (dd, *J* = 13.7, 5.7 Hz, 1H), 2.04 – 1.96 (m, 2H), 1.67 (t, *J* = 9.9 Hz, 1H), 1.20 (d, *J* = 6.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 157.90, 132.67, 129.61, 113.76, 80.08, 66.55, 55.21. 48.18, 37.91, 32.66, 19.85; IR (neat): 2957, 2927, 2866, 2839, 1611, 1512, 1454, 1299, 1246, 1177, 1034, 804 cm^{-1}; HRMS (EI) calcd for $[M]^+$ $C_{13}H_{18}O_2$: 206.1301, found: 206.1304. The relative stereochemistry of **27** was assigned by analogy to similar literature compounds (O-CH-CH_3 for cis-isomer: 1.05 (d, *J* = 6 Hz, 3H) and O-CH-CH_3 for trans-isomer: 1.15 (d, *J* = 6 Hz, 3H)).[15-16]



Tetrahydroindenofuran **S-10** and tetrahydrofuran **S-11**[4] were obtained from the catalytic carboetherification (Method A, reaction run at 120 °C for 48 h with 30 mol% catalyst loading) of 3-phenylpent-4-en-1-ol as a clear oil. The product is volatile, and the ^{1}H NMR yield is given (64%, 2:1 mixture of **S-10** and **S-11**). Tentative ^{1}H NMR and HRMS of **S-10** are also given: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28 – 7.22 (m, 4H), 4.80 (t, *J* = 6.0 Hz, 1H), 4.08 – 4.05 (m, 1H), 3.87-3.83 (m, 1H), 3.65 (ddd, *J* = 8.6, 4.3, 0.6 Hz, 1H), 3.25 (dd, *J* = 17.4, 5.4 Hz, 1H), 3.12 (d, *J* = 17.4 Hz, 1H), 2.41-2.35 (m, 1H), 2.15-2.10 (m, 1H); HRMS (EI) calcd for $[M]^+$ $C_{11}H_{12}O$: 160.0883, found: 160.0877.



#	Time [min]	Area [%]
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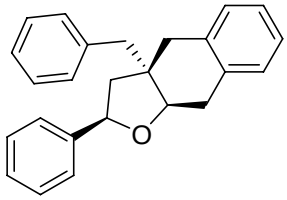
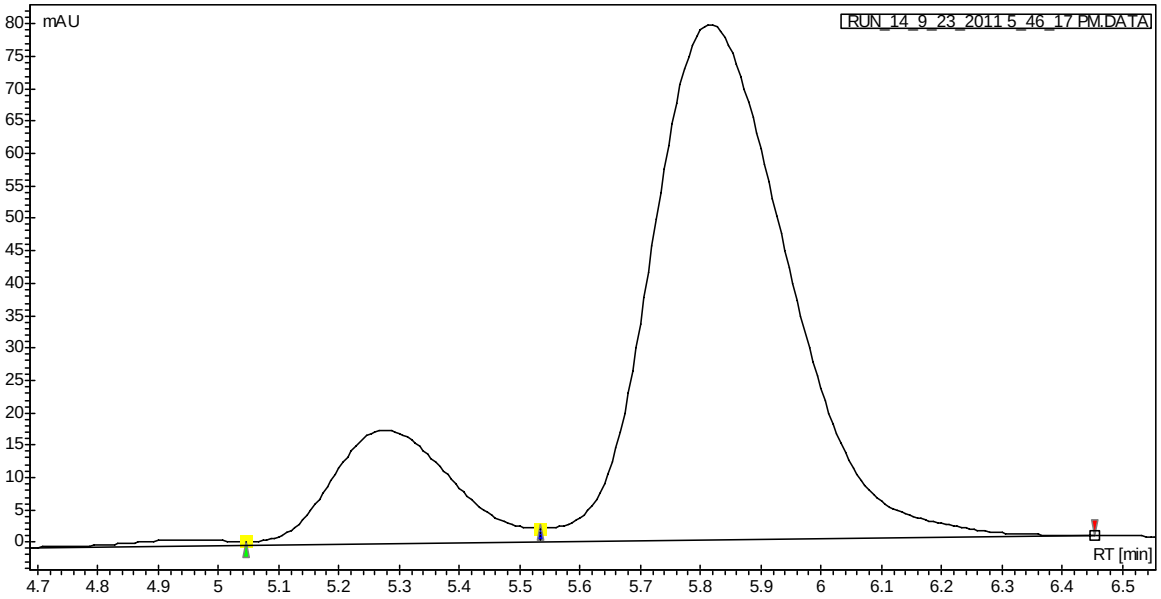
2	5.96	49.621



17a



#	Time [min]	Area [%]
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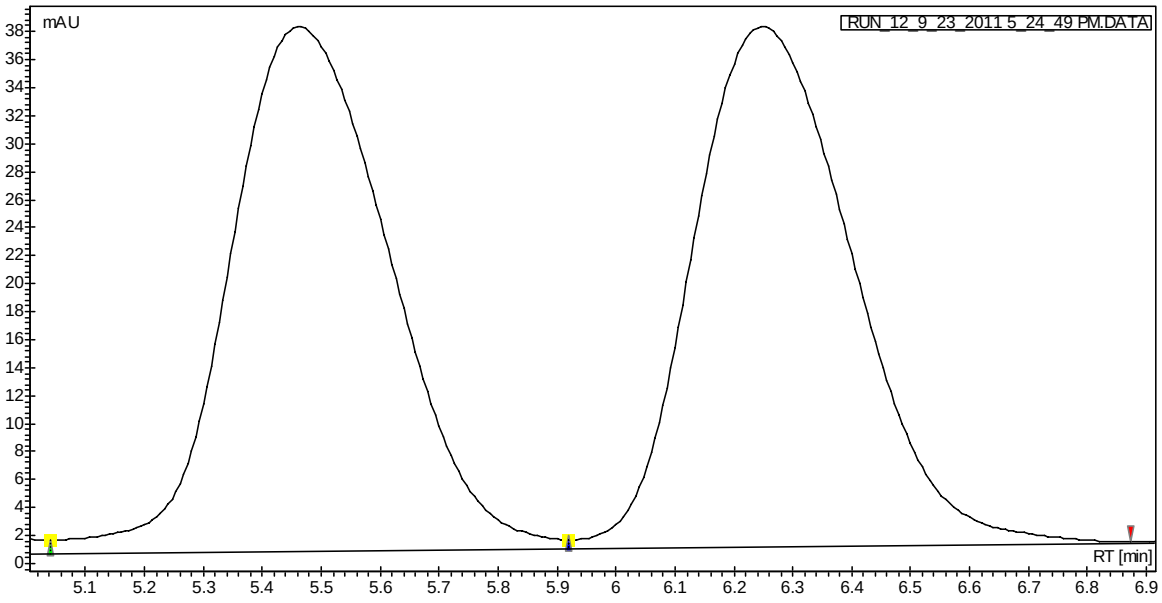
2	5.81	83.727



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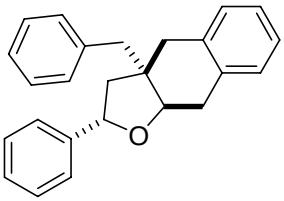
2	6.25	49.722



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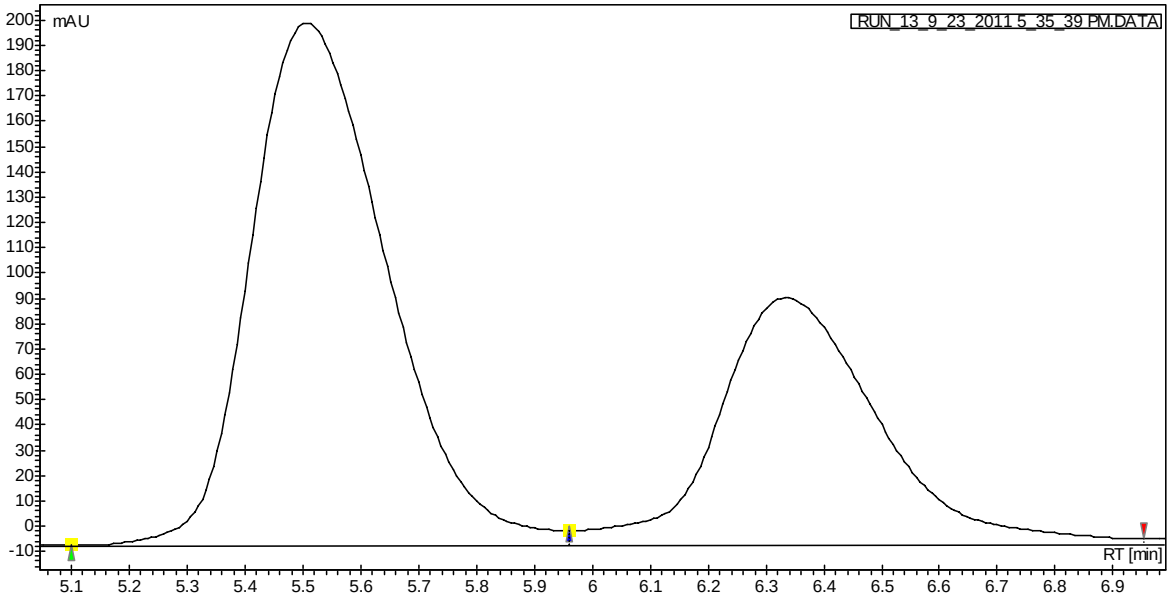

#	Time [min]	Area [%]
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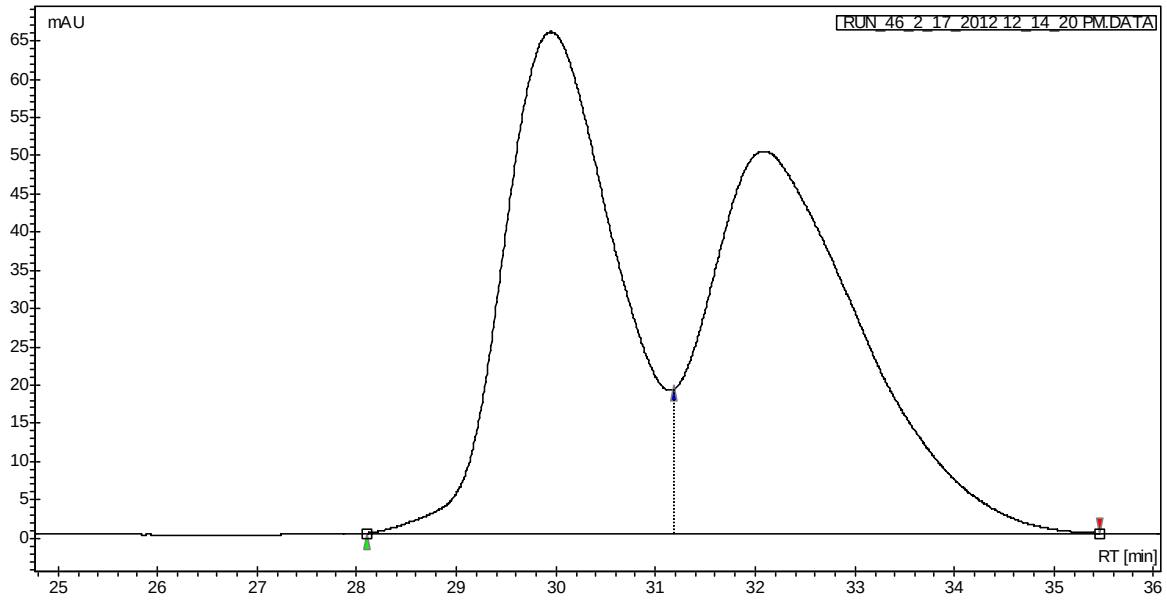
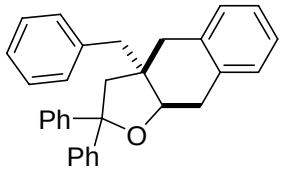
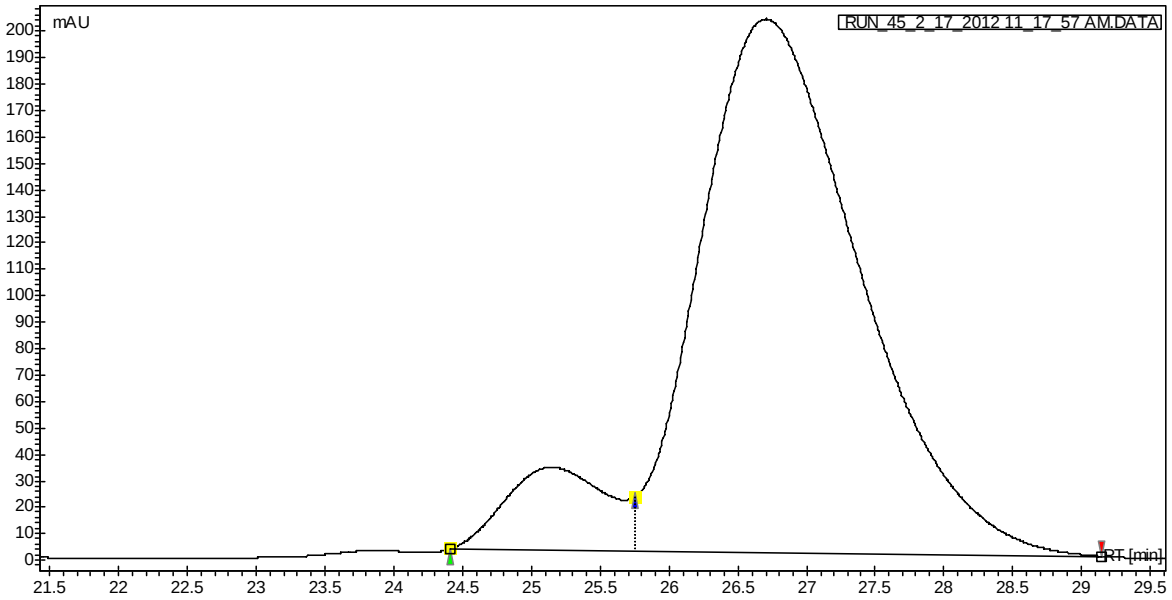


#	Time [min]	Area [%]
1	29.95	49.435
2	32.09	50.565

ee was estimated to be 75% because of incomplete separation.



16d



#	Time [min]	Area [%]
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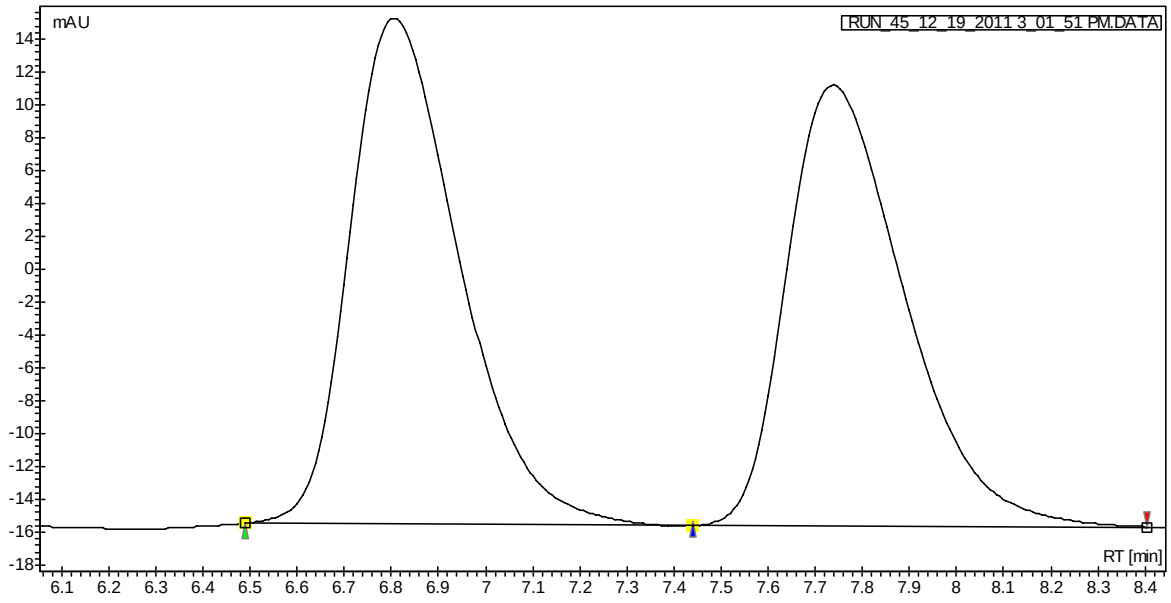
2	26.71	90.924



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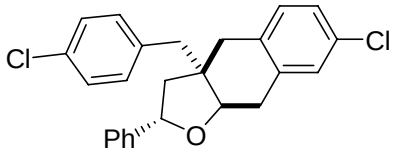
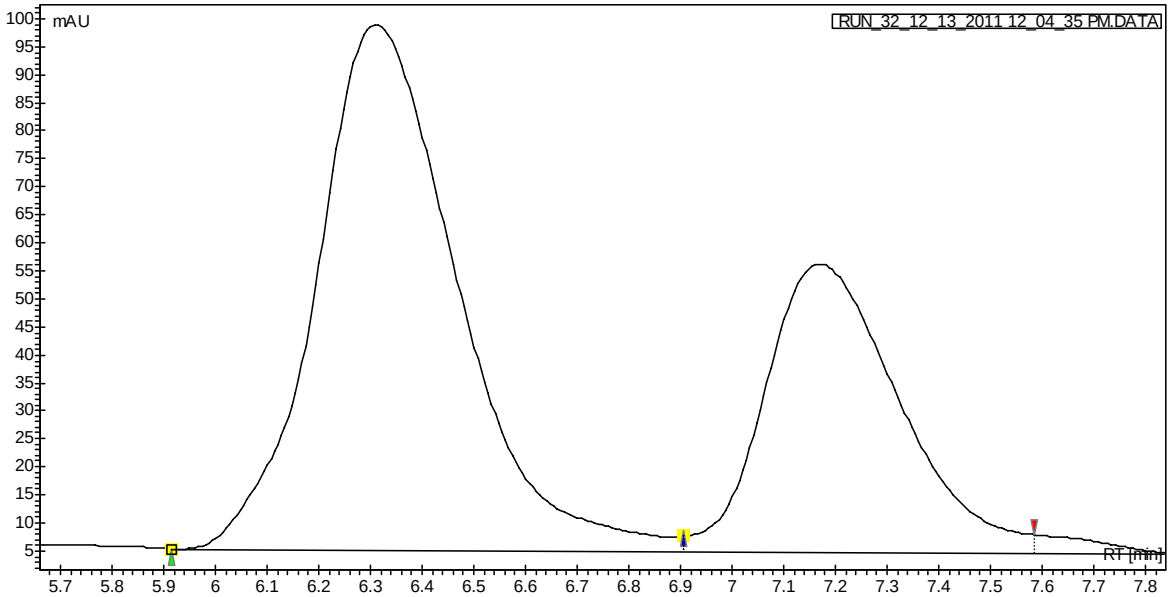
2	7.74	49.490



16c



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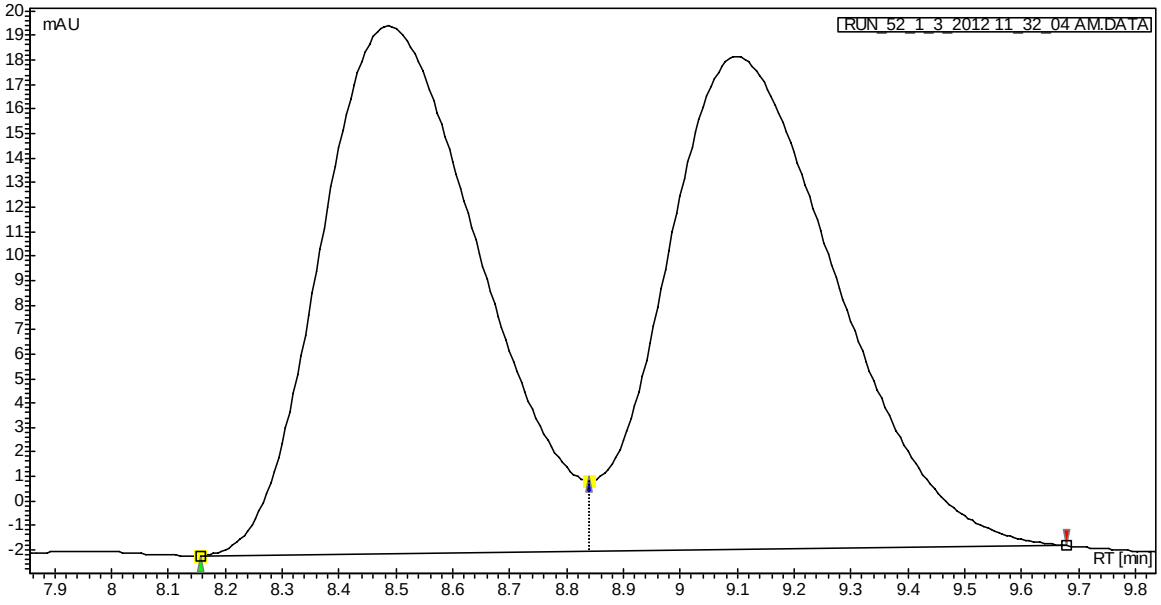

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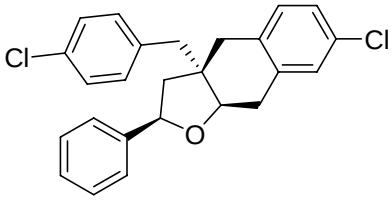
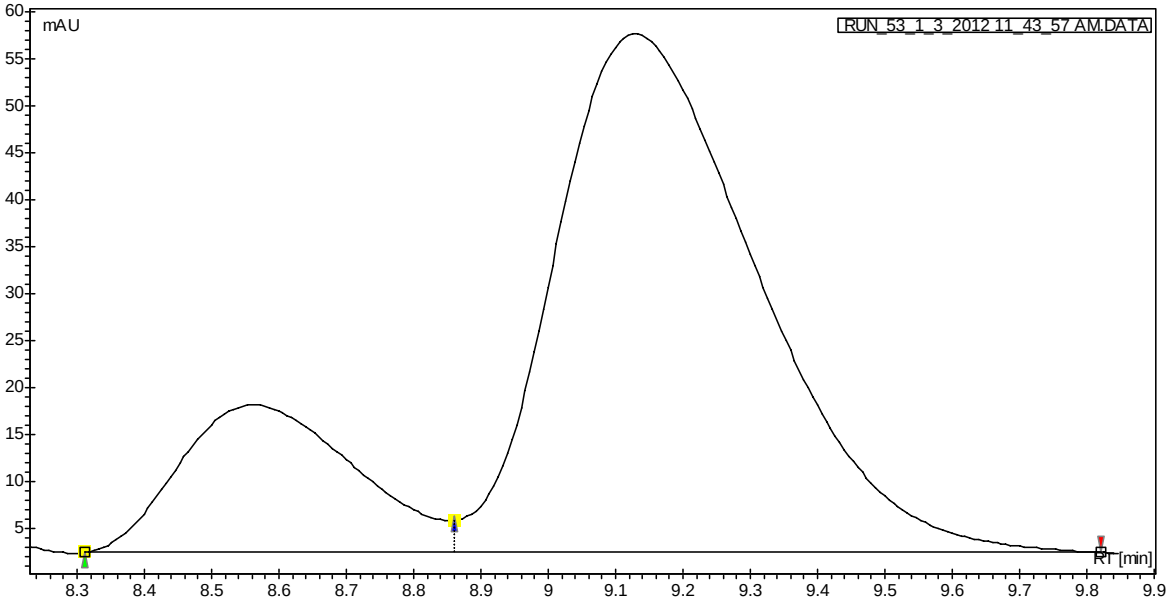


17c



#	Time [min]	Area [%]
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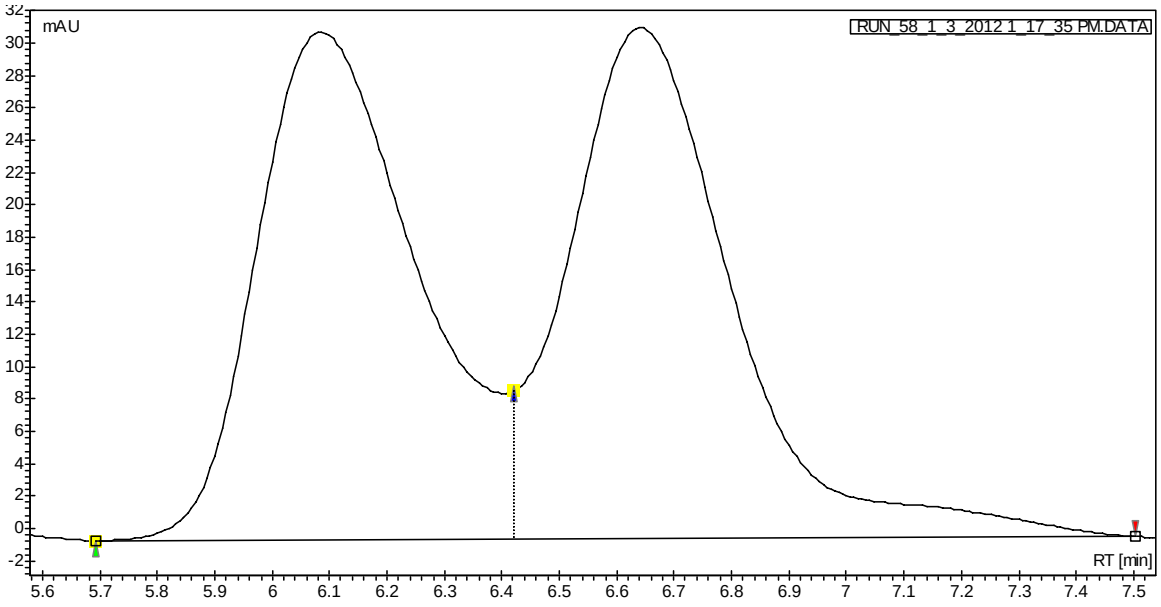
2	9.13	80.142



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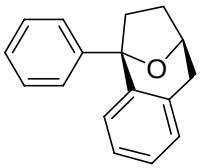
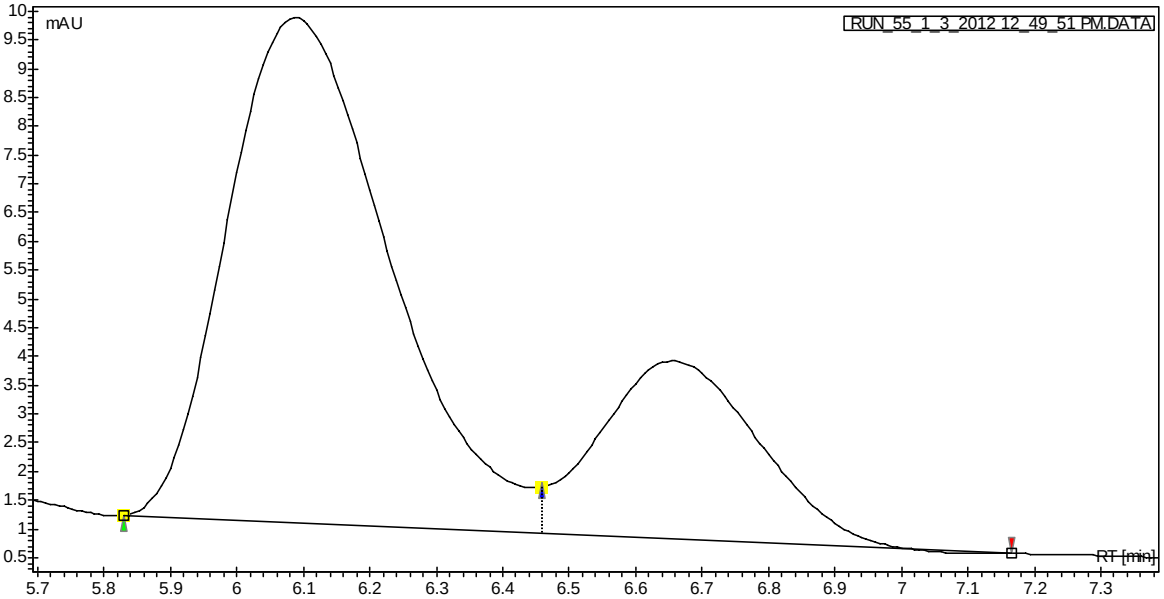
1	6.09	49.437
2	6.64	50.563



21



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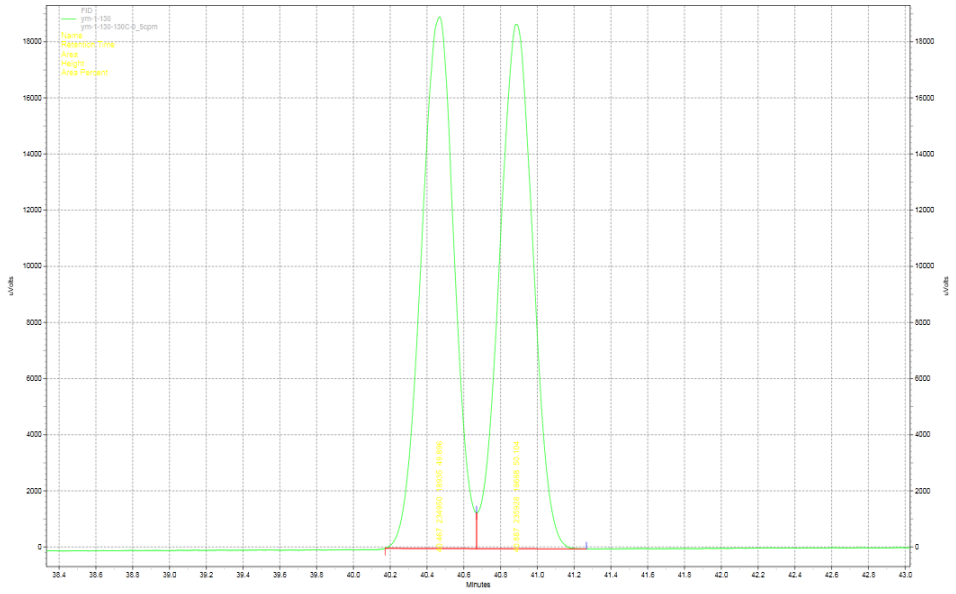
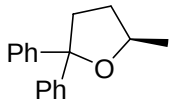
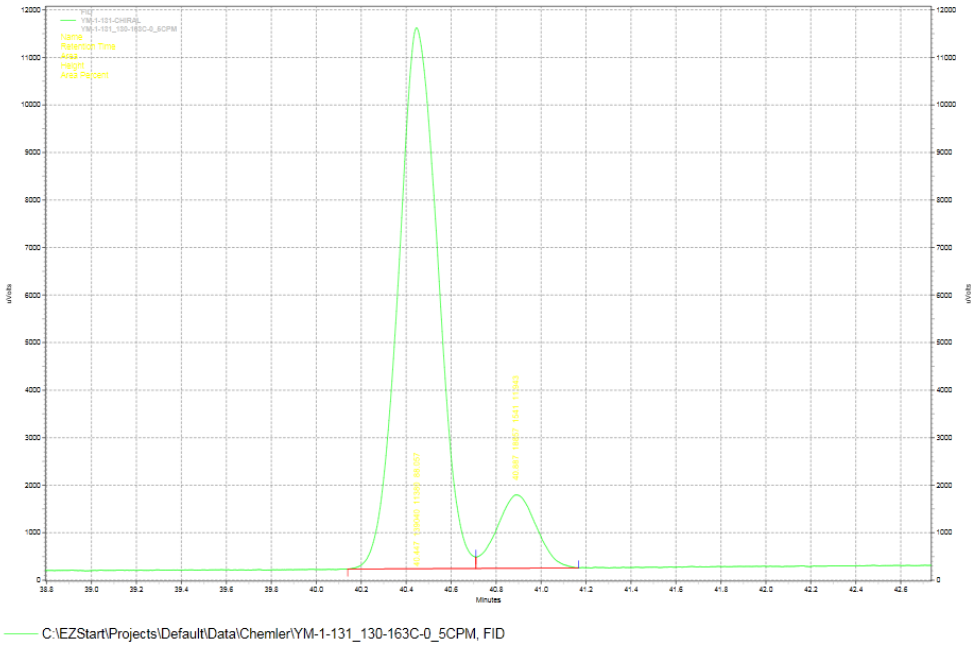
2	6.65	24.538



#	Time [min]	Area [%]
1	40.467	49.90
2	40.887	50.10



26



#	Time [min]	Area [%]
1	40.447	88.06
2	40.887	11.94

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