

Desymmetrizations of *meso-tert*-Norbornenols by Rhodium(I)-Catalyzed Enantioselective Retro-allylations

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Supplementary Information

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General Methods:

All reactions were carried out under an atmosphere of nitrogen in oven-dried glassware with magnetic stirring. Tetrahydrofuran (THF) and toluene were purchased from JT Baker and purified by a Cycle-Tainer Solvent Delivery System. Dry chlorobenzene was obtained from Fluka. *o*-Xylene was obtained from ABCR and was dried by filtering through a short column of aluminium oxide. All other reagents were used as obtained unless otherwise noted. Flash Chromatography was performed with Fluka silica gel 60 (0.040-0.063 μm grade). Analytical thin-layer chromatography was performed with commercial glass plates coated with 0.25 mm silica gel (E. Merck, Kieselgel 60 F254). Compounds were visualized by UV-light at 254 nm and by dipping the plates in an ethanolic vanillin/sulfuric acid solution or an aqueous potassium permanganate solution followed by heating. Melting points were obtained on a Büchi B-540 apparatus in open capillary tubes and are uncorrected. Proton nuclear magnetic resonance (^1H -NMR) data were acquired on a Varian VXR 300 (300 MHz) or on a Bruker AV400 (400 MHz) spectrometer. Chemical shifts are reported in delta (δ) units, in parts per million (ppm) relative to the singlet at 7.26 ppm for chloroform-*d*. Splitting patterns are designated as s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. Proton decoupled carbon-13 nuclear magnetic resonance (^{13}C -NMR) data were acquired at 75 MHz on a Varian VXR 300 or at 101 MHz on a Bruker AV400 spectrometer. Chemical shifts are reported in ppm relative to the center line of a triplet at 77.0 ppm for chloroform-*d*. Infrared (IR) data were recorded on a Perkin Elmer, Spectrum 100, FT-IR Spectrometer. Absorbance frequencies are reported in reciprocal centimeters (cm^{-1}). High resolution mass spectra were performed by the MS-service at the Laboratory of Organic Chemistry, ETH Zurich, and are given in *m/z*. Optical rotations were measured on a Jasco P-1000 polarimeter using a 10 cm cell with a Na 589 nm filter. The specific solvents and concentrations (in g/100 mL) are indicated.

Experimental Section

Norbornenols 4 and 15:

The required 7-norbornenone intermediates were prepared according to: R. Snajdrova, I. Braun, T. Bach, K. Mereiter, M. D. Mihovilovic *J. Org. Chem.* **2007**, *72*, 9597-9603.

Syntheses of the 7-norbornenols: To a 0°C cold solution of 7-norbornenone in dry THF (0.2 M) was added phenyl lithium (3.0 equiv., 2 M in dibutyl ether), methyl lithium (3.0 equiv., 1.6 M in diethyl ether), or butyl lithium (3.0 equiv., 1.6 M in hexane). The reaction mixture was stirred for 1 h at 0°C and was quenched with sat. aq. NH₄Cl and extracted with EtOAc. The organic layer was washed with water and brine, dried (MgSO₄) and concentrated *in vacuo*. The required pure *cis*-isomers were isolated by flash chromatography on silica gel. In case of 7-norbornenols **4b-e** and **15b-d**, the aryl lithium species was generated by adding butyl lithium (3.0 equiv., 1.6 M in hexane) to a solution of aryl bromide (3.0 equiv.) in dry THF (0.2 M) at -78°C. After stirring for 1 h, the mixture was warmed to 0°C and 7-norbornenone in dry THF (0.2 M) was added. The reaction mixture was stirred for 1 h at 0°C and was quenched with sat. aq. NH₄Cl. Reaction work-up and purification were performed as described above.

General Method for the Synthesis of Ketones 8:

Norbornenol **4** (0.05 mmol), [{Rh(cod)(OH)}₂] (0.57 mg, 2.50 μmol), Cs₂CO₃ (16.3 mg, 0.05 mmol) and (*S*)-(+)-1-[(*R*)-2-(Diphenylphosphino)ferrocenyl]ethyl-di-*tert*-butylphosphine ((*S*)-**L6**) or (*R*)-(-)-1-[(*S*)-2-(Diphenylphosphino)ferrocenyl]ethyl-di-*tert*-butylphosphine ((*R*)-**L6**) (1.63 mg, 6.00 μmol) were weighed into an oven-dried vial equipped with a magnetic stir bar, capped with a septum and purged with nitrogen. Dry chlorobenzene (0.33 mL) was added. The mixture was degassed with three freeze-pump-thaw cycles and immersed into a preheated oil bath at 115°C. After 12 h, the reaction mixture was cooled to 23°C and directly purified on a silica gel column to give 65–88% yield of ketone **8**.

General Method for the Synthesis of Alcohols 18:

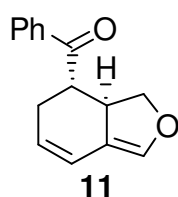
Norbornenol **15** (0.05 mmol), [{Rh(cod)(OH)}₂] (1.14 mg, 5.00 μmol), Cs₂CO₃ (16.3 mg, 0.05 mmol) and (*S*)-(+)-1-[(*R*)-2-(Diphenylphosphino)ferrocenyl]ethyl-di-*tert*-butylphosphine ((*S*)-**L6**) or (*R*)-(-)-1-[(*S*)-2-(Diphenylphosphino)ferrocenyl]ethyl-di-*tert*-butylphosphine ((*R*)-**L6**) (3.26 mg, 12.00 μmol) were weighed into an oven-dried vial equipped with a magnetic stir bar, capped with a septum and purged with nitrogen. Dry chlorobenzene (0.33 mL) was added. The mixture was degassed with three freeze-pump-thaw cycles and immersed into a preheated oil bath at 120°C. After 12 h, the reaction mixture was cooled to 23°C and directly purified on a silica gel column to give 72–76% yield of alcohol **18**.

General Method for the Synthesis of Ketones 20:

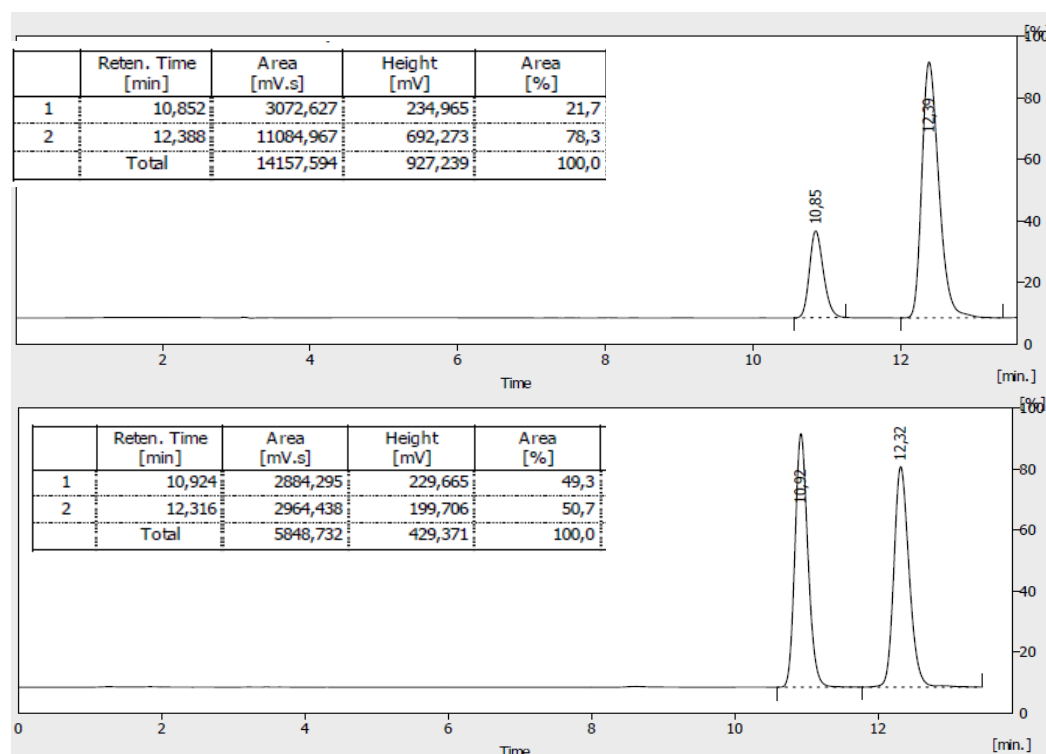
Norbornenol **15** (0.05 mmol), [{Rh(C₂H₄)₂(OAc)}₂] (1.23 mg, 5.00 μmol), powdered Molecular Sieves (4 Å, 20 mg) and (*R*)-(-)-1-[(*S*)-2-(Diphenylphosphino)ferrocenyl]ethyl-di-*tert*-butylphosphine ((*R*)-**L6**) (3.26 mg, 12.00 μmol) were weighed into an oven-dried vial equipped with a magnetic stir bar, capped with a septum and purged with nitrogen. Dry chlorobenzene (0.33 mL) was added. The mixture was degassed with three freeze-pump-thaw cycles and immersed into a preheated oil bath at 120°C. After 12 h, the reaction mixture was cooled to 23°C and directly purified on a silica gel column to give 68–82% yield of ketone **20**.

Synthesis of Ketone 11:

Norbornenol **4a** (11.4 mg, 0.05 mmol), $[\{\text{Rh}(\text{C}_2\text{H}_4)_2(\text{OAc})\}_2]$ (0.62 mg, 2.50 μmol), powdered Molecular Sieves (4 Å, 20 mg) and (*S*)-(+)-1-[(*R*)-2-(Diphenylphosphino)ferrocenyl]ethyldi-tert-butylphosphine ((*S*)-**L6**) (1.63 mg, 6.00 μmol) were weighed into an oven-dried vial equipped with a magnetic stir bar, capped with a septum and purged with nitrogen. Dry chlorobenzene (0.33 mL) was added. The mixture was degassed with three freeze-pump-thaw cycles and immersed into a preheated oil bath at 115°C. After 12 h, the reaction mixture was cooled to 23°C and directly purified on a silica gel column to give ketone **11** (8.7 mg, 77%) as a colorless oil.

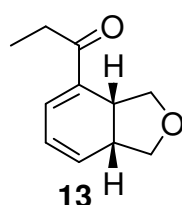


(-)-Phenyl-((3aR,4S)-3,3a,4,5-tetrahydroisobenzofuran-4-yl)-methanone (11): $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.99 – 7.89 (m, 2H), 7.64 – 7.54 (m, 1H), 7.54 – 7.44 (m, 2H), 6.37 (s, 1H), 6.32 (dd, J = 9.5, 2.3 Hz, 1H), 5.66 – 5.54 (m, 1H), 4.75 – 4.63 (m, 1H), 3.75 – 3.59 (m, 3H), 2.63 – 2.47 (m, 1H), 2.39 – 2.24 (m, 1H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 202.4, 140.3, 136.2, 133.4, 128.8, 128.4, 123.9, 119.6, 115.6, 75.4, 47.7, 42.9, 30.6 ppm; **IR (ATR):** $\tilde{\nu}$ = 2928, 2876, 1678, 1597, 1448, 1394, 1448, 1289, 1203, 1172, 1073, 1007, 869, 839, 785, 697, 658 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{15}\text{H}_{14}\text{O}_2]^+$: 226.0989, found: 226.0987; $[\alpha]_{\text{D}}^{20}$ = -15 (c = 0.24, CHCl_3); **R_f**: 0.2 (2 % Et_2O in pentane); HPLC separation (Chiralpak IC, 4.6 x 250 mm; 2.5% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 12.39 min, t_{r} (minor) = 10.85 min), 78:22 *er*.

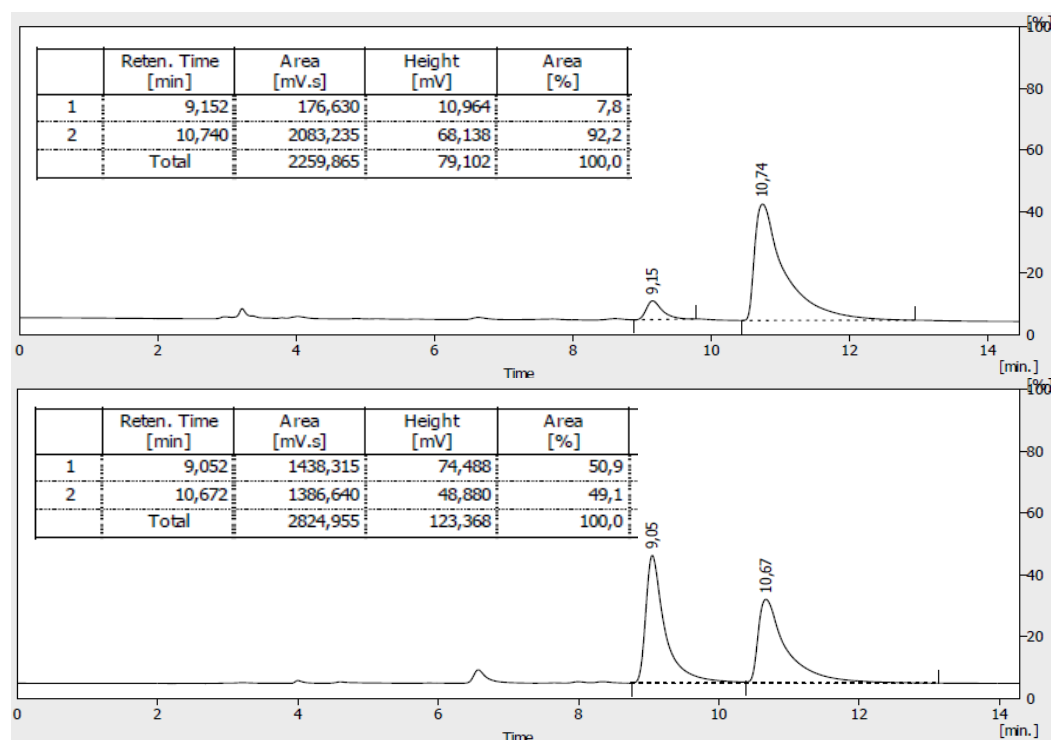


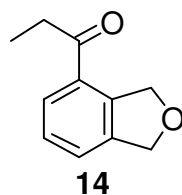
Synthesis of Ketone 13:

Norbornenol **4a** (8.9 mg, 0.05 mmol), $[\{\text{Rh}(\text{cod})(\text{OH})\}_2]$ (0.57 mg, 2.50 μmol), cyclohexene (51 μL , 0.5 mmol) and (*R*)-(+)-1-[(*R*)-2-(Diphenylphosphino)ferrocenyl]ethyldi-*tert*-butylphosphine ((*R*)-**L6**) (1.63 mg, 6.00 μmol) were weighed into an oven-dried vial equipped with a magnetic stir bar, capped with a septum and purged with nitrogen. Dry xylene (0.33 mL) was added. The mixture was degassed with three freeze-pump-thaw cycles and immersed into a preheated oil bath at 115°C. After 12 h, the reaction mixture was cooled to 23°C and directly purified on a silica gel column to give ketone **13** (6.0 mg, 67 %) and aromatic compound **14** (1.7 mg, 19 %) as colorless oils.



(-)-1-((3aR,7aR)-1,3,3a,7a-tetrahydroisobenzofuran-4-yl)propan-1-one (13): $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 6.88 (d, J = 5.7 Hz, 1H), 6.07 (ddd, J = 9.5, 5.7, 2.0 Hz, 1H), 5.99 (dd, J = 9.5, 3.4 Hz, 1H), 4.41 – 4.29 (m, 1H), 4.23 (dd, J = 8.4, 7.3 Hz, 1H), 3.71 (dd, J = 8.4, 4.7 Hz, 1H), 3.38 – 3.27 (m, 2H), 3.21 – 3.11 (m, 1H), 2.75 – 2.65 (m, 2H), 1.11 (t, J = 7.2 Hz, 3H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 201.6, 135.8, 135.1, 130.6, 121.9, 75.5, 75.4, 39.5, 35.6, 30.1, 8.7 ppm; **IR (ATR):** $\tilde{\nu}$ = 2973, 2937, 2856, 1727, 1659, 1573, 1460, 1406, 1378, 1210, 1177, 1073, 1049, 1007, 931, 909, 736 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{11}\text{H}_{14}\text{O}_2]^+$: 178.0989, found: 178.0987; $[\alpha]_{\text{D}}^{20}$ = -43 (c = 0.10, CHCl_3), **R_f**: 0.2 (15 % EtOAc in pentane); HPLC separation (Chiralpak As-H, 4.6 x 250 mm; 10% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 10.74 min, t_{r} (minor) = 9.15 min), 92:8 *er*.

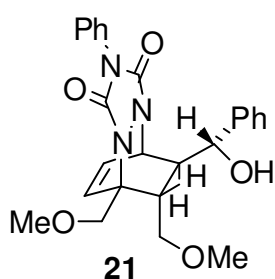




1-(1,3-dihydroisobenzofuran-4-yl)propan-1-one (14): ^1H NMR (300 MHz, CDCl_3) δ = 7.83 (d, J = 6.3 Hz, 1H), 7.47 – 7.36 (m, 2H), 5.46 – 5.39 (m, 2H), 5.15 – 5.07 (m, 2H), 3.02 (q, J = 7.2 Hz, 2H), 1.22 (t, J = 7.2 Hz, 3H) ppm; ^{13}C -NMR (101 MHz, CDCl_3) δ = 201.0, 141.1, 140.9, 131.4, 127.7, 125.3, 75.4, 72.4, 32.1, 8.0 ppm; IR (ATR): $\tilde{\nu}$ = 2974, 2934, 2860, 1675, 1594, 1407, 1378, 1352, 1247, 1169, 1113, 1060, 1035, 903, 875, 777 cm^{-1} ; HRMS (EI) calc'd. for $[\text{C}_{11}\text{H}_{12}\text{O}_2]^+$: 176.0832, found: 176.0830; R_f : 0.3 (10 % EtOAc in pentane).

Synthesis of Diels-Alder adduct 21:

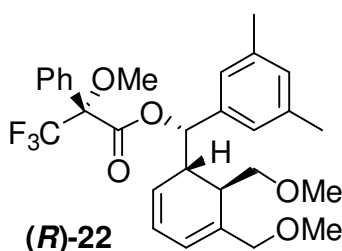
Alcohol **18a** (8.5 mg, 0.03 mmol) and 4-phenyl-3H-1,2,4-triazole-3,5(4H)-dione (21.7 mg, 0.12 mmol) were stirred in toluene (1.5 mL) for 30 min at 23°C. After evaporation of the solvent, the mixture was directly purified on a silica gel column to give Diels-Alder adduct **21** (10.4 mg, 75 %) as a colorless solid.



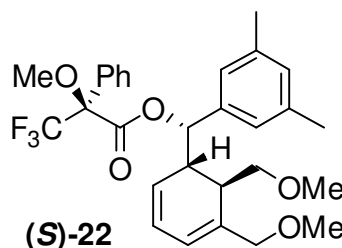
Diels-Alder adduct (21): ^1H -NMR (300 MHz, CDCl_3) δ = 7.49 – 7.28 (m, 10H), 6.36 (dd, J = 8.1, 6.0 Hz, 1H), 6.07 (d, J = 8.1 Hz, 1H), 4.82 – 4.71 (m, 2H), 4.43 – 4.37 (m, 1H), 4.10 (d, J = 3.6 Hz, 1H), 3.79 (d, J = 11.0 Hz, 1H), 3.75 – 3.65 (m, 1H), 3.55 (s, 3H), 3.46 (s, 3H), 3.09 – 2.99 (m, 2H) ppm; ^{13}C -NMR (101 MHz, CDCl_3) δ = 154.9, 153.5, 142.9, 131.3, 130.3, 130.2, 129.1, 128.7, 128.3, 128.1, 126.9, 125.8, 75.5, 72.7, 68.8, 64.6, 59.3, 59.1, 52.0, 47.3, 41.7 ppm; IR (ATR): $\tilde{\nu}$ = 3426, 2983, 2923, 1765, 1611, 1503, 1455, 1405, 1251, 1198, 1115, 1047, 972, 916, 773, 733, 703, 646, 620 cm^{-1} ; HRMS (ESI) calc'd. for $[\text{C}_{25}\text{H}_{28}\text{N}_3\text{O}_5]^+$: 450.2004, found: 450.2005; $[\alpha]_D^{20}$ = -2.5 (c = 0.60, MeOH); R_f : 0.3 (33 % EtOAc in pentane); m.p.: 186–188°C.

(R)- and (S)- α -methoxy- α -trifluoromethyl-phenylacetic acid (MPTA) esters of 18d (22):

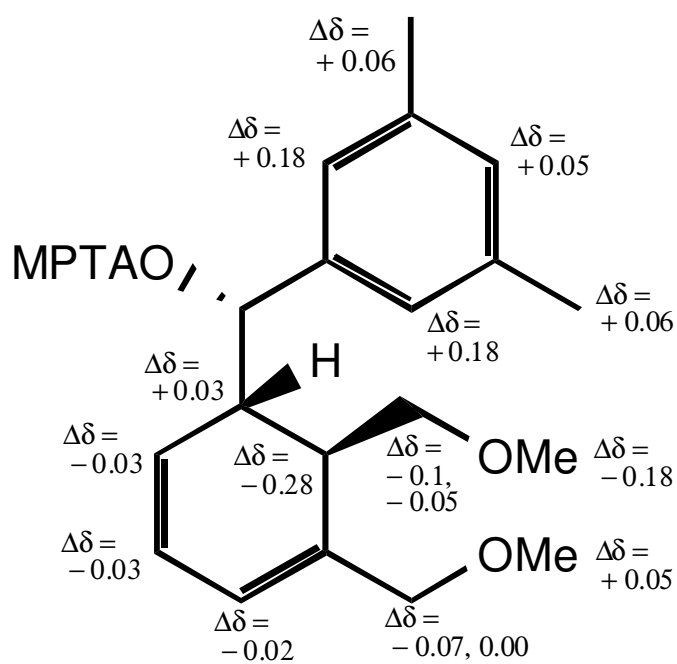
The (R)- and (S)-MPTA esters of **18d** were synthesized from the corresponding acid chlorides, and the absolute configuration of **22** was assigned using the ^1H NMR shift differences $\Delta\delta$ = δ ((R)-**22**) - δ ((S)-**22**) according to: T. R. Hoye, C. S. Jeffrey, F. Shao *Nature Protocols* **2007**, *10*, 2451-2458.



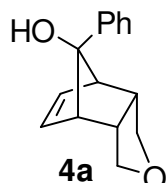
(R)-22: ^1H NMR (300 MHz, CDCl_3) δ = 7.42 – 7.28 (m, 5H), 6.96 – 6.92 (m, 3H), 5.99 – 5.96 (m, 1H), 5.90 (dd, J = 9.4, 5.3 Hz, 1H), 5.60 (d, J = 10.7 Hz, 1H), 4.96 (dd, J = 9.4, 6.1 Hz, 1H), 3.93 (d, J = 13.3 Hz, 1H), 3.80 (d, J = 13.3 Hz, 1H), 3.41 – 3.38 (m, 3H), 3.37 (s, 3H), 3.28 – 3.24 (m, 1H), 3.22 – 3.16 (m, 1H), 3.07 (s, 3H), 2.99 – 2.93 (m, 1H), 2.61 – 2.55 (m, 1H), 2.29 (s, 6H) ppm.



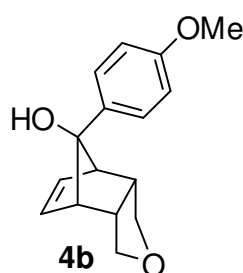
(S)-22: ^1H NMR (300 MHz, CDCl_3) δ = 7.41 – 7.27 (m, 5H), 6.90 – 6.87 (m, 1H), 6.78 – 6.73 (m, 2H), 6.02 – 5.97 (m, 1H), 5.93 (dd, J = 9.3, 5.3 Hz, 1H), 5.54 (d, J = 10.4 Hz, 1H), 4.99 (dd, J = 9.3, 6.3 Hz, 1H), 4.00 (d, J = 12.6 Hz, 1H), 3.80 (d, J = 12.6 Hz, 1H), 3.60 – 3.56 (m, 3H), 3.32 (s, 3H), 3.31 – 3.30 (m, 1H), 3.30 – 3.28 (m, 1H), 3.25 (s, 3H), 2.96 – 2.90 (m, 1H), 2.89 – 2.82 (m, 1H), 2.23 (s, 6H) ppm.



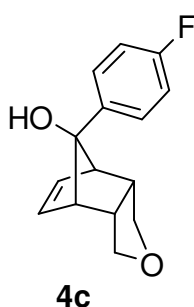
$\Delta\delta = \delta ((R)\text{-}22) - \delta ((S)\text{-}22)$ in ppm



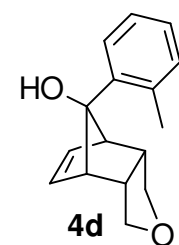
10-Phenyl-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4a): ¹H-NMR (400 MHz, CDCl₃) δ = 7.47 – 7.28 (m, 5H), 6.47 (dd, *J* = 2.1, 2.1 Hz, 2H), 3.52 – 3.46 (m, 4H), 3.44 – 3.39 (m, 2H), 3.14 (s, 1H), 2.81 – 2.67 (m, 2H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 140.2, 134.0, 128.8, 127.9, 126.8, 97.7, 69.6, 53.2, 44.3 ppm; IR (ATR): $\tilde{\nu}$ = 3381, 3069, 2973, 2919, 2858, 1334, 1378, 1235, 1070, 1038, 997, 900, 792, 768, 698, 660 cm⁻¹; HRMS (EI) calc'd. for [C₁₅H₁₆O₂]⁺: 228.1145, found: 228.1145; *R*_f: 0.2 (33 % EtOAc in pentane); m.p.: 164–165 °C; colorless solid.



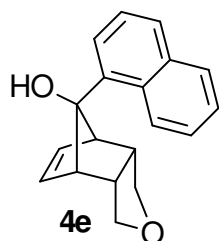
10-(4-Methoxyphenyl)-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4b): ¹H-NMR (400 MHz, CDCl₃) δ = 7.41 – 7.33 (m, 2H), 6.99 – 6.91 (m, 2H), 6.47 (dd, *J* = 2.1, 2.1 Hz, 2H), 3.84 (s, 3H), 3.53 – 3.47 (m, 4H), 3.42 – 3.38 (m, 2H), 3.13 (s, 1H), 2.85 – 2.68 (m, 2H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 159.2, 134.1, 132.4, 128.1, 114.2, 97.3, 69.6, 55.3, 53.4, 44.4 ppm; IR (ATR): $\tilde{\nu}$ = 3425, 3062, 2960, 2858, 1611, 1515, 1464, 1360, 1296, 1250, 1189, 1138, 1100, 1033, 908, 836, 792, 761, 706 cm⁻¹; HRMS (EI) calc'd. for [C₁₆H₁₈O₃]⁺: 258.1251, found: 258.1249; *R*_f: 0.2 (50 % EtOAc in pentane); m.p.: 112–113 °C; colorless solid.



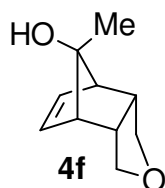
10-(4-Fluorophenyl)-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4c): ¹H-NMR (300 MHz, CDCl₃) δ = 7.46 – 7.34 (m, 2H), 7.14 – 7.02 (m, 2H), 6.46 (dd, *J* = 2.0, 2.0 Hz, 2H), 3.51 – 3.46 (m, 4H), 3.41 – 3.35 (m, 2H), 3.20 (s, 1H), 2.76 – 2.66 (m, 2H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 162.3 (d, *J* = 247 Hz), 136.1 (d, *J* = 3.4 Hz), 134.0, 128.7 (d, *J* = 8.2 Hz), 115.7 (d, *J* = 21.4 Hz), 97.1, 69.6, 53.4, 44.2 ppm; IR (ATR): $\tilde{\nu}$ = 3066, 2962, 2861, 1607, 1514, 1360, 1221, 1185, 1161, 1137, 1099, 1047, 1014, 932, 908, 841, 809, 761, 705 cm⁻¹; HRMS (EI) calc'd. for [C₁₅H₁₅FO₂]⁺: 246.1051, found: 246.1053; *R*_f: 0.2 (50 % EtOAc in pentane); m.p.: 128–129 °C; colorless solid.



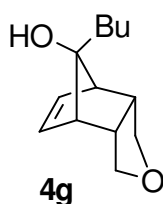
10-(o-tolyl)-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4d): ¹H-NMR (400 MHz, CDCl₃) δ = 7.45 – 7.38 (m, 1H), 7.27 – 7.16 (m, 3H), 6.52 – 6.44 (m, 2H), 3.75 – 3.64 (m, 1H), 3.58 – 3.46 (m, 5H), 3.16 (s, 1H), 3.12 – 3.01 (m, 1H), 2.54 (s, 3H), 2.53 – 2.43 (m, 1H) ppm; ¹³C-NMR δ = 137.7, 137.4, 134.2, 133.5, 132.3, 128.0, 128.0, 125.8, 99.0, 69.8, 54.0, 53.3, 44.1, 43.6, 21.5. ppm; IR (ATR): $\tilde{\nu}$ = 3401, 3061, 2961, 2860, 1643, 1599, 1463, 1349, 1250, 1174, 1099, 1046, 1010, 908, 793, 765, 733, 705, 653 cm⁻¹; HRMS (EI) calc'd. for [C₁₆H₁₈O₂]⁺: 242.1302, found: 242.1303; *R*_f: 0.3 (50 % EtOAc in pentane); colorless oil.



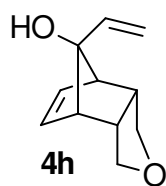
10-(Naphthalen-1yl)-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4e): ¹H-NMR (400 MHz, CDCl₃) δ = 8.49 – 8.39 (m, 1H), 7.93 – 7.81 (m, 2H), 7.62 (dd, *J* = 7.2, 0.9 Hz, 1H), 7.54 – 7.43 (m, 3H), 6.63 – 6.50 (m, 2H), 4.01 – 3.96 (m, 1H), 3.66 – 3.62 (m, 1H), 3.58 – 3.46 (m, 4H), 3.42 – 3.35 (m, 1H), 3.35 – 3.27 (m, 1H), 2.31 – 2.21 (m, 1H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 135.2, 134.7, 134.3, 133.5, 131.5, 129.1, 128.9, 126.1, 125.9, 125.6, 125.5, 124.6, 98.8, 69.8, 69.8, 54.7, 54.3, 43.8, 43.6 ppm; IR (ATR): $\tilde{\nu}$ = 3401, 3050, 2963, 2858, 2237, 1643, 1598, 1508, 1476, 1344, 1253, 1169, 1098, 1045, 998, 908, 804, 780, 730, 705, 646 cm⁻¹; HRMS (EI) calc'd. for [C₁₉H₁₈O₂]⁺: 278.1302, found: 278.1303; *R*_f: 0.3 (50 % EtOAc in pentane); colorless oil.



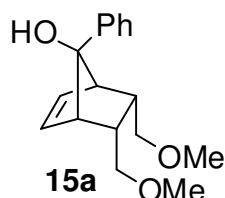
10-Methyl-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4f): ¹H-NMR (400 MHz, CDCl₃) δ = 6.23 (dd, *J* = 1.9, 1.9 Hz, 2H), 3.57 – 3.51 (m, 2H), 3.36 (dd, *J* = 9.0, 2.6 Hz, 2H), 2.94 – 2.88 (m, 3H), 2.62 – 2.55 (m, 2H), 1.29 (s, 3H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 134.4, 94.4, 69.7, 55.0, 44.9, 19.0 ppm; IR (ATR): $\tilde{\nu}$ = 3425, 3060, 2961, 2864, 1720, 1657, 1458, 1349, 1259, 1165, 1091, 1002, 963, 938, 907, 874, 837, 793, 763, 707, 630 cm⁻¹; HRMS (EI) calc'd. for [C₁₀H₁₄O₂]⁺: 166.0983, found: 166.0990; *R*_f: 0.2 (50 % EtOAc in pentane); colorless oil.



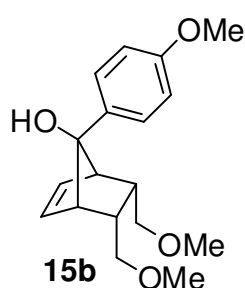
10-Butyl-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4g): ¹H-NMR (400 MHz, CDCl₃) δ = 6.32 (dd, *J* = 2.0, 2.0 Hz, 2H), 3.66 – 3.60 (m, 2H), 3.45 (dd, *J* = 8.9, 2.8 Hz, 2H), 3.02 – 2.93 (m, 2H), 2.93 – 2.88 (m, 1H), 2.79 – 2.72 (m, 2H), 1.73 – 1.66 (m, 2H), 1.45 – 1.33 (m, 4H), 0.95 (t, *J* = 7.1 Hz, 3H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 134.3, 97.1, 69.7, 53.4, 44.7, 31.9, 26.2, 23.3, 14.1 ppm; IR (ATR): $\tilde{\nu}$ = 3444, 3063, 2960, 2928, 2860, 1467, 1351, 1322, 1260, 1161, 1098, 1046, 1013, 910, 794, 764, 733, 705 cm⁻¹; HRMS (EI) calc'd. for [C₁₃H₂₀O₂]⁺: 208.1458, found: 208.1455; *R*_f: 0.25 (33 % EtOAc in pentane); colorless oil.



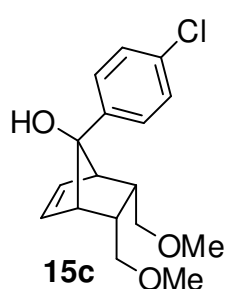
10-Vinyl-4-oxa-tricyclo-[5.2.1.0^{2,6}]-dec-8-en-10-ol (4h): ¹H-NMR (300 MHz, CDCl₃) δ = 6.34 (dd, *J* = 2.0, 2.0 Hz, 2H), 6.16 (dd, *J* = 17.4, 10.9 Hz, 1H), 5.50 (dd, *J* = 17.4, 1.7 Hz, 1H), 5.33 (dd, *J* = 10.9, 1.7 Hz, 1H), 3.64 – 3.57 (m, 2H), 3.48 – 3.44 (m, 2H), 3.01 – 2.94 (m, 2H), 2.94 (s, 1H), 2.89 – 2.85 (m, 2H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 136.6, 133.9, 117.8, 95.5, 69.7, 54.6, 44.5 ppm; IR (ATR): $\tilde{\nu}$ = 3416, 3062, 2960, 2855, 1641, 1419, 1332, 1235, 1177, 1135, 1100, 1042, 1003, 909, 793, 761, 705 cm⁻¹; HRMS (EI) calc'd. for [C₁₁H₁₄O₂]⁺: 178.0989, found: 178.0987; *R*_f: 0.2 (50 % EtOAc in pentane); colorless oil.



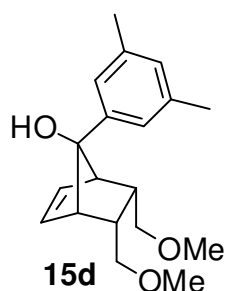
5,6-Bis(methoxymethyl)-7-phenylbicyclo-[2.2.1]-hept-2-en-7-ol (15a): ¹H-NMR (400 MHz, CDCl₃) δ = 7.43 – 7.36 (m, 2H), 7.32 – 7.25 (m, 2H), 7.25 – 7.18 (m, 1H), 6.33 (dd, *J* = 2.0, 2.0 Hz, 2H), 3.35 (dd, *J* = 3.3, 1.7 Hz, 2H), 3.18 (s, 6H), 3.04 – 2.94 (m, 4H), 2.78 (s, 1H), 2.39 – 2.31 (m, 2H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 139.7, 134.2, 128.7, 127.9, 126.8, 94.2, 71.6, 58.7, 53.0, 38.6 ppm; IR (ATR): $\tilde{\nu}$ = 3431, 3059, 2976, 2926, 2873, 1448, 1361, 1245, 1188, 1132, 1099, 1044, 953, 911, 822, 771, 740, 702, 667 cm⁻¹; HRMS (EI) calc'd. for [C₁₇H₂₂O₃]⁺: 274.1564, found: 274.1567; *R*_f: 0.25 (33 % EtOAc in pentane); colorless oil.



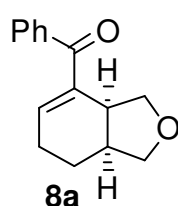
5,6-Bis(methoxymethyl)-7-(4-methoxyphenyl)bicyclo[2.2.1]hept-2-en-7-ol (15b): ¹H-NMR (400 MHz, CDCl₃) δ = 7.45 – 7.37 (m, 2H), 6.95 – 6.87 (m, 2H), 6.41 (dd, *J* = 2.0, 2.0 Hz, 2H), 3.82 (s, 3H), 3.43 – 3.38 (m, 2H), 3.27 (s, 6H), 3.14 – 3.01 (m, 4H), 2.85 (s, 1H), 2.51 – 2.37 (m, 2H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 159.1, 134.3, 132.0, 128.0, 114.1, 93.8, 71.6, 58.7, 55.3, 53.2, 38.4 ppm; IR (ATR): $\tilde{\nu}$ = 2977, 2929, 1611, 1516, 1461, 1361, 1296, 1249, 1181, 1098, 1034, 954, 834, 741, 698, 684, 645 cm⁻¹; HRMS (EI) calc'd. for [C₁₈H₂₄O₄]⁺: 304.1669, found: 304.1668; *R*_f: 0.2 (33 % EtOAc in pentane); colorless oil.



7-(4-chlorophenyl)-5,6-bis(methoxymethyl)bicyclo[2.2.1]hept-2-en-7-ol (15c): $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.43 – 7.29 (m, 4H), 6.39 (dd, J = 1.9, 1.9 Hz, 2H), 3.41 – 3.34 (m, 2H), 3.25 (s, 6H), 3.10 – 2.98 (m, 4H), 2.92 (br s, 1H), 2.42 – 2.30 (m, 2H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 138.3, 134.3, 133.7, 128.9, 128.4, 93.6, 71.4, 58.7, 53.0, 38.3 ppm; **IR (ATR):** $\tilde{\nu}$ = 3453, 3423, 3059, 2926, 2893, 2361, 1492, 1359, 1197, 1095, 1045, 953, 833, 736, 636 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{17}\text{H}_{21}\text{ClO}_3]^+$: 308.1174, found: 308.1175; **R_f**: 0.2 (30 % EtOAc in pentane); colorless oil.

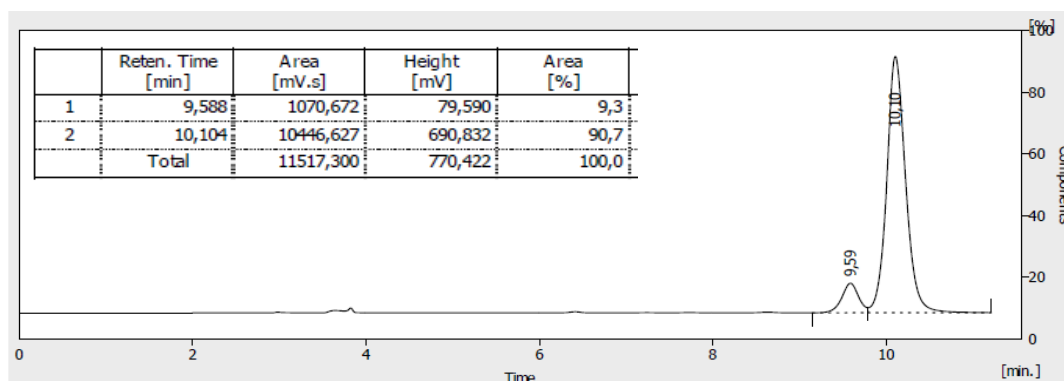


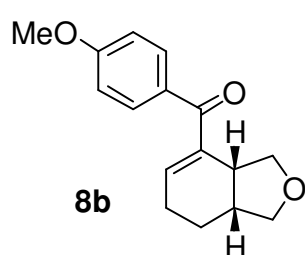
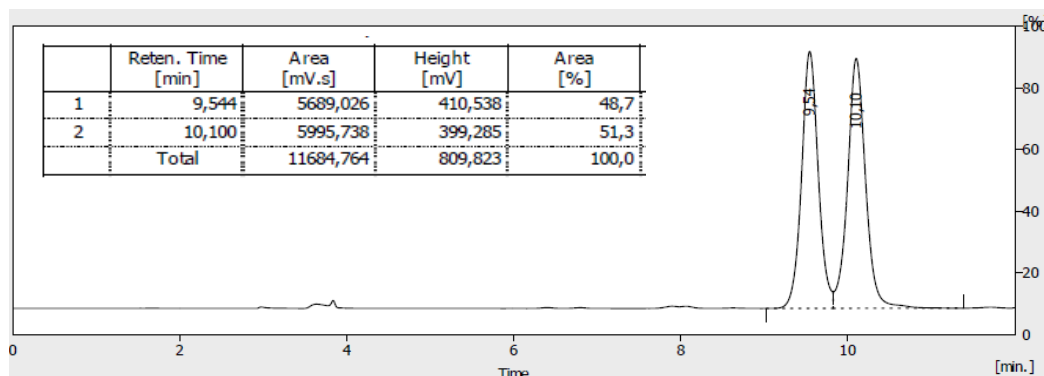
7-(3,5-dimethylphenyl)-5,6-bis(methoxymethyl)bicyclo[2.2.1]hept-2-en-7-ol (15d): $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ = 7.10 – 7.05 (m, 2H), 6.97 – 6.92 (m, 1H), 6.41 (dd, J = 2.0, 2.0 Hz, 2H), 3.44 – 3.39 (m, 2H), 3.28 (s, 6H), 3.14 – 3.04 (m, 4H), 2.85 (s, 1H), 2.51 – 2.44 (m, 2H), 2.33 (s, 6H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 139.6, 138.2, 134.2, 129.6, 124.3, 94.2, 71.7, 58.7, 53.0, 38.4, 21.4 ppm; **IR (ATR):** $\tilde{\nu}$ = 3445, 2921, 2889, 2829, 1606, 1457, 1385, 1272, 1175, 1097, 1052, 957, 853, 734, 622 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{19}\text{H}_{26}\text{O}_3]^+$: 302.1877, found: 302.1876; **R_f**: 0.3 (25 % EtOAc in CH_2Cl_2); **m.p.**: 109–111 $^\circ\text{C}$; colorless solid.



(+)-((3aS,7aS)-1,3,3a,6,7,7a-hexahydroisobenzofuran-4-yl)(phenyl)methanone (8a): (S)-L6 was used; $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.66 – 7.58 (m, 2H), 7.55 – 7.48 (m, 1H), 7.47 – 7.38 (m, 2H), 6.72 (dd, J = 6.0, 2.4 Hz, 1H), 4.30 (dd, J = 8.3, 8.3 Hz, 1H), 4.00 (dd, J = 8.5, 6.2 Hz, 1H), 3.71 (dd, J = 8.5, 3.2 Hz, 1H), 3.56 – 3.46 (m, 1H), 3.40 – 3.27 (m, 1H), 2.47 – 2.20 (m, 3H), 1.84 – 1.70 (m, 1H), 1.69 – 1.51 (m, 1H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 197.9, 144.5, 139.1, 138.6, 131.5, 129.1, 128.1, 73.1, 72.7, 37.8, 36.7, 24.6,

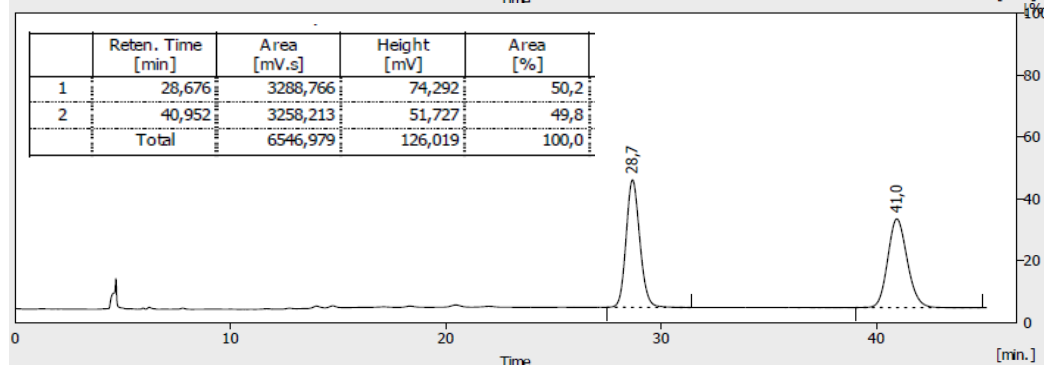
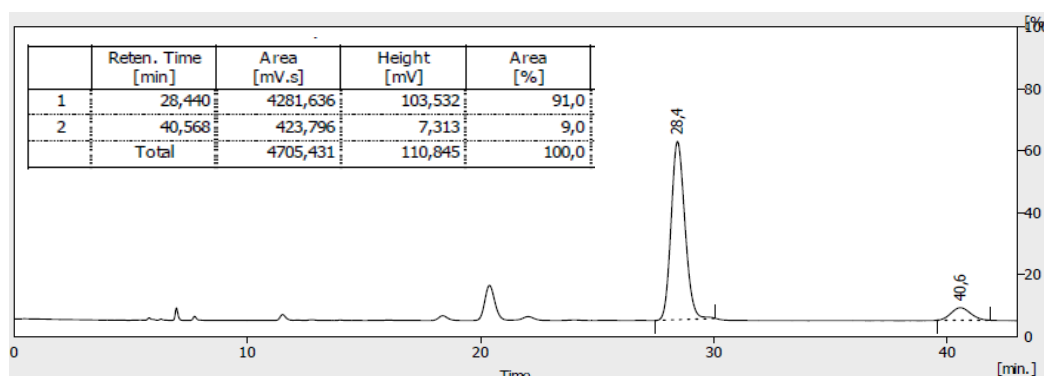
23.0 ppm; **IR (ATR):** $\tilde{\nu}$ = 2928, 2860, 1640, 1597, 1577, 1446, 1425, 1382, 1316, 1266, 1124, 1076, 1058, 1013, 931, 902, 776, 720, 700, 667 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{15}\text{H}_{16}\text{O}_2]^+$: 228.1145, found: 228.1146; $[\alpha]_{\text{D}}^{20}$ = +36 (c = 0.28, CHCl_3); **R_f**: 0.2 (10 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 5% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 10.10 min, t_{r} (minor) = 9.59 min), 91:9 *er*.

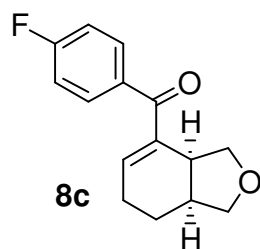




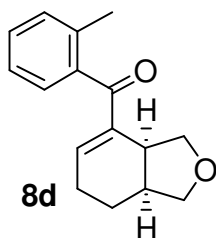
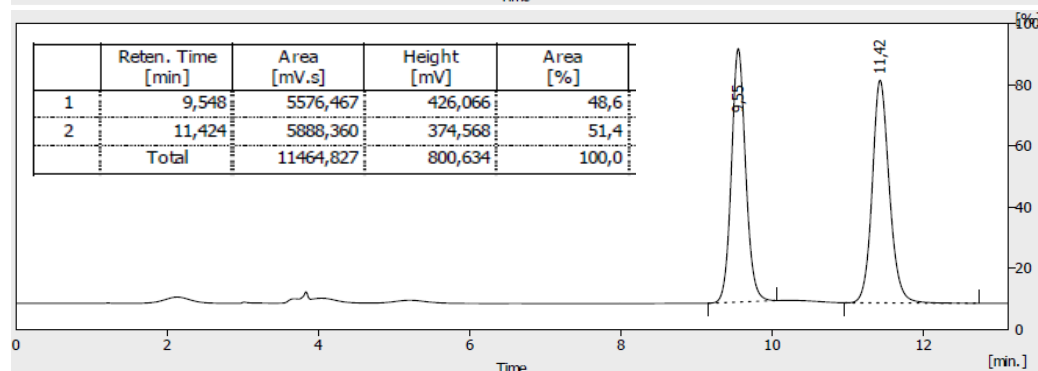
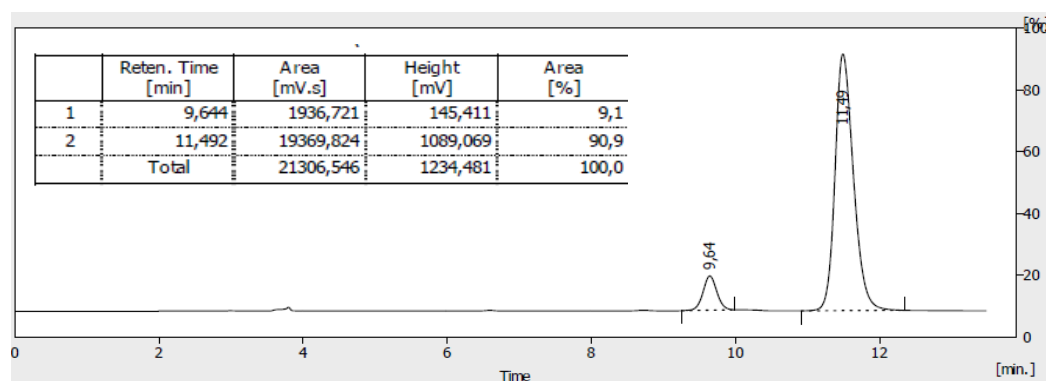
(-)-((3aR,7aR)-1,3,3a,6,7,7a-hexahydroisobenzofuran-4-yl)(4-methoxyphenyl)methanone (8b): (*R*)-**L6** was used; ¹H-NMR (300 MHz, CDCl₃) δ = 7.74 – 7.62 (m, 2H), 6.97 – 6.85 (m, 2H), 6.68 – 6.58 (m, 1H), 4.25 (dd, *J* = 8.3, 8.3 Hz, 1H), 4.00 (dd, *J* = 8.5, 6.3 Hz, 1H), 3.87 (s, 3H), 3.70 (dd, *J* = 8.5, 3.2 Hz, 1H), 3.54 – 3.45 (m, 1H), 3.39 – 3.28 (m, 1H), 2.46 – 2.18 (m, 3H), 1.85 – 1.71 (m, 1H), 1.71 – 1.55 (m, 1H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 196.7, 162.7, 142.2, 138.9, 131.6, 130.9, 113.4, 73.1, 72.7, 55.4, 38.1, 36.7, 24.4, 23.1 ppm; **IR (ATR):** $\tilde{\nu}$ = 2931, 1861, 1635, 1599, 1509, 1462, 1418,

1365, 1308, 1253, 1172, 1057, 1028, 902, 841, 761, 708, 620 cm⁻¹; **HRMS (EI)** calc'd. for [C₁₆H₁₈O₃]⁺: 258.1251, found: 258.1254; [α]_D²⁰ = -52 (*c* = 0.33, CHCl₃); **R_f**: 0.2 (15 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IC, 4.6 x 250 mm; 50% *i*-PrOH / hexane, 0.7 mL/min, 254 nm; t_r (major) = 28.44 min, t_r (minor) = 40.57 min), 91:9 *er*.

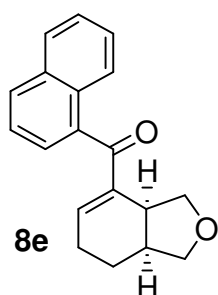




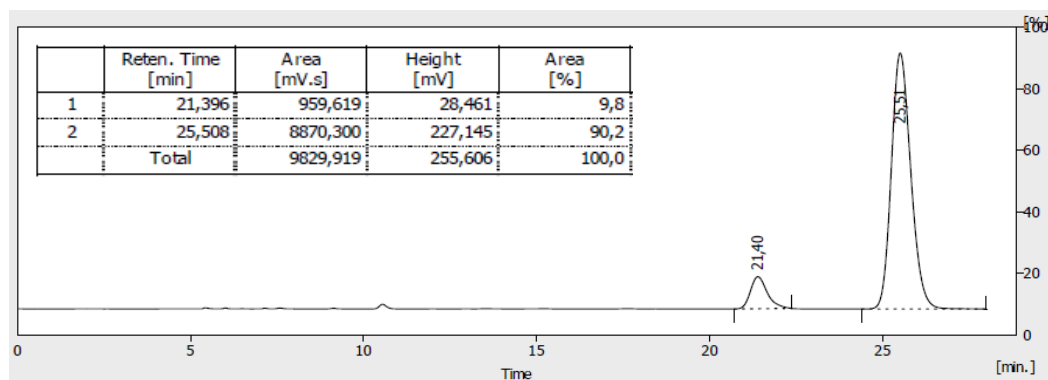
(+)-(4-Fluorophenyl)-((3aR,7aR)-1,3,3a,6,7,7a-hexahydroisobenzofuran-4-yl)-methanone (8c): (S)-L6 was used; ¹H-NMR (300 MHz, CDCl₃) δ = 7.72 – 7.62 (m, 2H), 7.16 – 7.05 (m, 2H), 6.71 – 6.64 (m, 1H), 4.28 (dd, *J* = 8.3, 8.3 Hz, 1H), 4.00 (dd, *J* = 8.5, 6.2 Hz, 1H), 3.70 (dd, *J* = 8.6, 3.2 Hz, 1H), 3.52 – 3.44 (m, 1H), 3.39 – 3.27 (m, 1H), 2.47 – 2.20 (m, 3H), 1.82 – 1.71 (m, 1H), 1.68 – 1.53 (m, 1H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 196.4, 164.8 (d, *J* = 253 Hz), 144.1, 139.0, 134.6 (d, *J* = 3.2 Hz), 131.6 (d, *J* = 8.9 Hz), 115.3 (d, *J* = 21.7 Hz), 73.1, 72.7, 37.9, 36.67, 24.5, 23.0 ppm; **HRMS (EI)** calc'd. for [C₁₅H₁₅FO₂]⁺: 246.1051, found: 246.1054; [α]_D²⁰ = +23 (*c* = 0.28, CHCl₃); **R_f**: 0.2 (10 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 5% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; *t_r* (major) = 11.49 min, *t_r* (minor) = 9.64 min), 91:9 *er*.

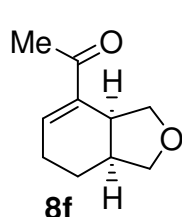
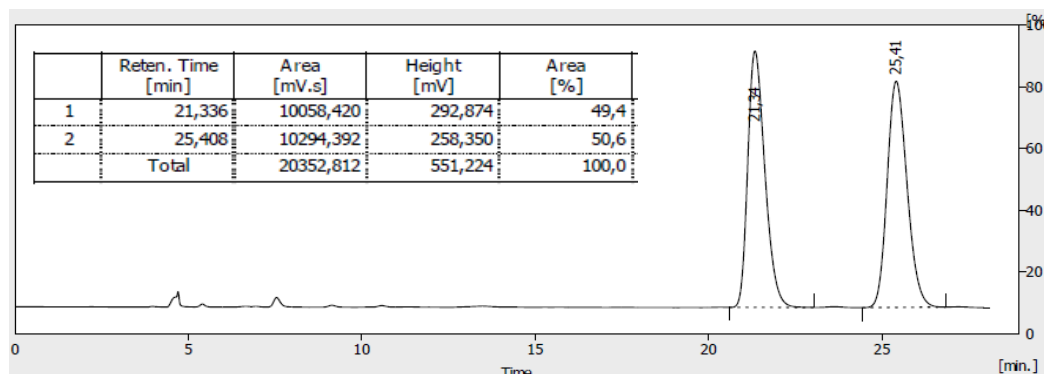


(+)-((3aS,7aS)-1,3,3a,6,7,7a-hexahydroisobenzofuran-4-yl)(o-tolyl)methanone (8d): (S)-L6 was used; ¹H-NMR (400 MHz, CDCl₃) δ = 7.35 – 7.29 (m, 1H), 7.24 – 7.14 (m, 3H), 6.64 – 6.59 (m, 1H), 4.38 (dd, *J* = 8.5, 8.5 Hz, 1H), 4.00 (dd, *J* = 8.5, 6.1 Hz, 1H), 3.76 – 3.66 (m, 1H), 3.58 – 3.47 (m, 1H), 3.39 – 3.24 (m, 1H), 2.46 – 2.38 (m, 1H), 2.36 – 2.17 (m, 2H), 2.26 (s, 3H), 1.82 – 1.70 (m, 1H), 1.61 – 1.51 (m, 1H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 200.1, 146.7, 140.8, 139.3, 135.6, 130.6, 129.4, 127.4, 125.0, 73.1, 72.8, 37.2, 36.7, 24.8, 23.0, 19.5 ppm; **IR (ATR):** $\tilde{\nu}$ = 2929, 2862, 1648, 1452, 1382, 1261, 1139, 1083, 1059, 1014, 903, 739, 658 cm⁻¹; **HRMS (EI)** calc'd. for [C₁₆H₁₈O₂]⁺: 242.1302, found: 242.1305; [α]_D²⁰ = +48 (*c* = 0.28, CHCl₃); **R_f**: 0.3 (10 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IC, 4.6 x 250 mm; 50% *i*-PrOH / hexane, 0.7 mL/min, 254 nm; *t_r* (major) = 30.15 min, *t_r* (minor) = 17.19 min), 88:12 *er*.

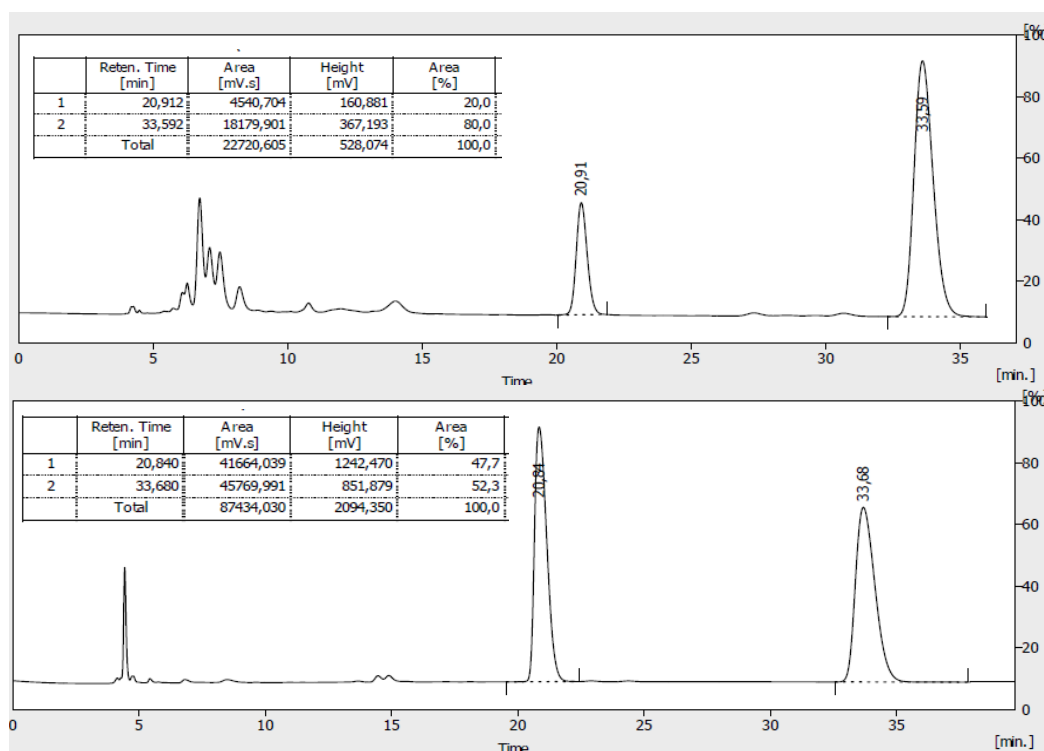


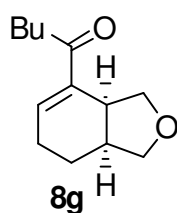
1; **HRMS (EI)** calc'd. for $[C_{19}H_{18}O_2]^+$: 278.1302, found: 278.1304; **[α]_D²⁰** = +23 (*c* = 0.37, $CHCl_3$); **R_f**: 0.2 (15 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IC, 4.6 x 250 mm, 50% *i*-PrOH / hexane, 0.7 mL/min, 254 nm; *t_r* (major) = 25.51 min, *t_r* (minor) = 21.40 min), 90:10 *er*.



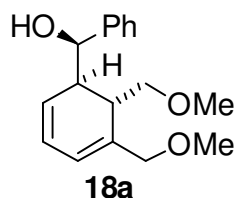
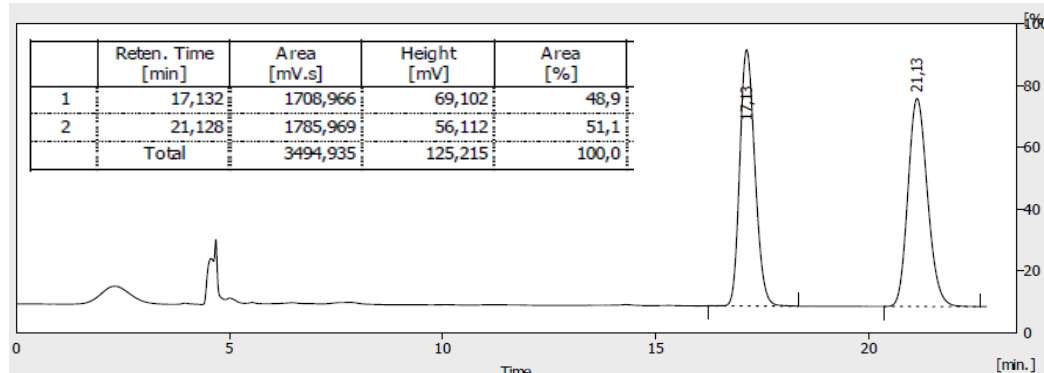
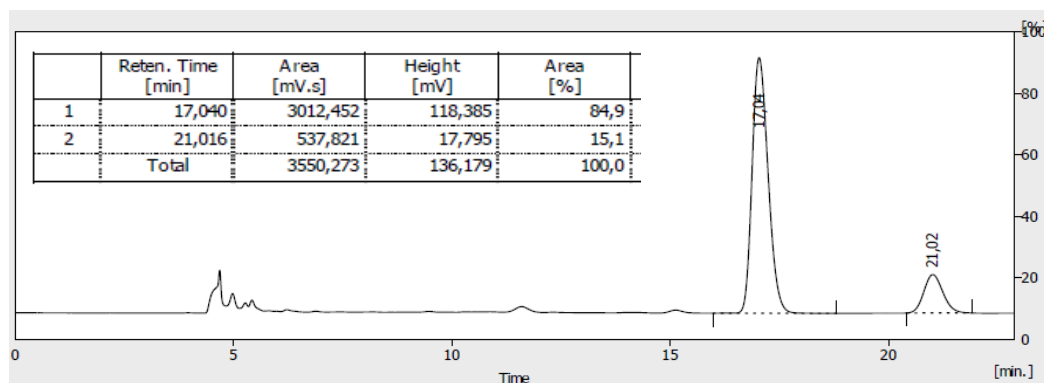


(+)-1-((3aS,7aS)-1,3,3a,6,7,7a-hexahydroisobenzofuran-4-yl)-ethanone (8f): (S)-**L6** was used; $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.01 (dd, J = 6.1, 2.4 Hz, 1H), 4.32 – 4.18 (m, 1H), 3.92 (dd, J = 8.5, 6.0 Hz, 1H), 3.64 (dd, J = 8.5, 2.9 Hz, 1H), 3.37 – 3.27 (m, 1H), 3.17 – 3.02 (m, 1H), 2.37 – 2.18 (m, 3H), 2.30 (s, 3H), 1.78 – 1.64 (m, 1H), 1.57 – 1.45 (m, 1H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 199.1, 141.7, 140.4, 73.1, 72.8, 37.1, 36.7, 25.3, 24.7, 23.0 ppm; **IR (ATR):** $\tilde{\nu}$ = 2956, 2861, 1626, 1474, 1441, 1393, 1275, 1251, 1175, 1097, 1048, 909, 858, 812, 734, 649 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{10}\text{H}_{14}\text{O}_2]^+$: 166.0989, found: 166.0989; $[\alpha]_{\text{D}}^{20}$ = +10 (c = 0.12, CHCl_3); R_f : 0.3 (20 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IC, 4.6 x 250 mm; 50% *i*-PrOH / hexane, 0.75 mL/min, 210 nm; t_r (major) = 33.59 min, t_r (minor) = 20.91 min), 80:20 *er*.

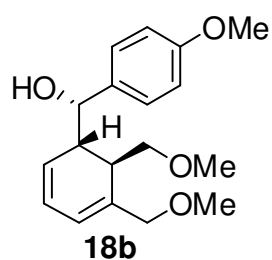
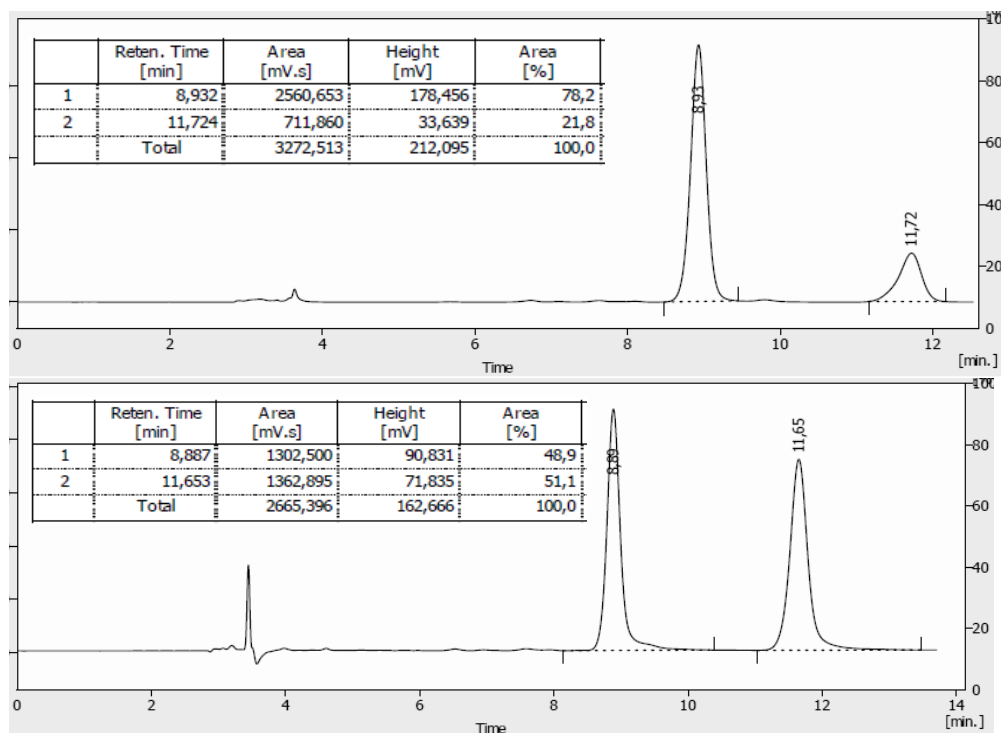




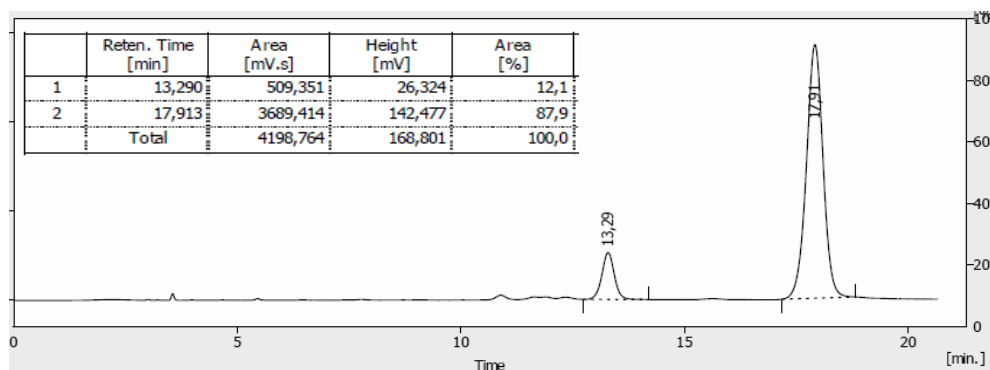
(+)-1-((3aS,7aS)-1,3,3a,6,7,7a-hexahydroisobenzofuran-4-yl)-pentanone (8g): (S)-L6 was used; $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ = 7.06 – 6.99 (m, 1H), 4.26 (dd, J = 8.5, 8.5 Hz, 1H), 3.93 (dd, J = 8.5, 6.0 Hz, 1H), 3.65 (dd, J = 8.5, 2.8 Hz, 1H), 3.36 – 3.27 (m, 1H), 3.17 – 3.04 (m, 1H), 2.68 – 2.60 (m, 2H), 2.37 – 2.18 (m, 3H), 1.75 – 1.66 (m, 1H), 1.63 – 1.47 (m, 3H), 1.37 – 1.30 (m, 2H), 0.92 (t, J = 7.2 Hz, 3H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 201.6, 140.1, 140.0, 73.1, 72.9, 37.3, 36.7, 26.9, 24.7, 23.0, 22.5, 13.9 ppm; **IR (ATR):** $\tilde{\nu}$ = 3053, 2930, 1663, 1451, 1428, 1249, 1186, 1059, 1030, 903, 784, 734 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{13}\text{H}_{20}\text{O}_2]^+$: 208.1458, found: 208.1461; $[\alpha]_{\text{D}}^{20}$ = +1.8 (c = 0.98, CHCl_3); **R_f**: 0.2 (10 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IC, 4.6 x 250 mm; 50% *i*-PrOH / hexane, 0.7 mL/min, 254 nm; t_{r} (major) = 17.04 min, t_{r} (minor) = 21.02 min), 85:15 *er*.

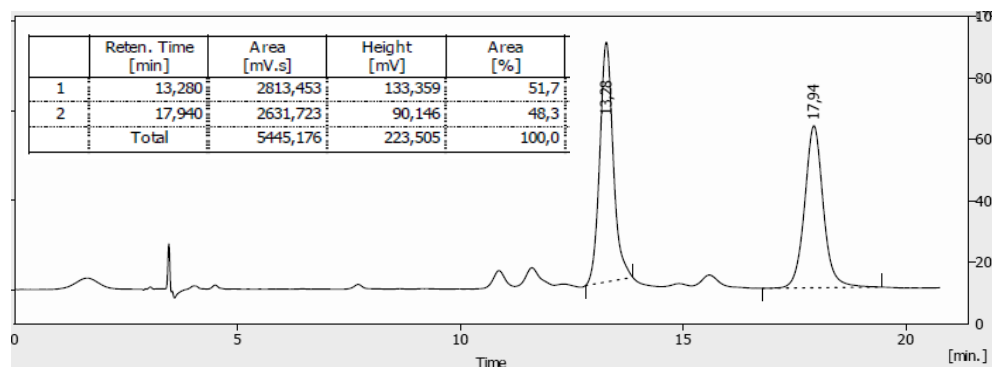


(+)-(R)-((1R,6S)-5,6-bis(methoxymethyl)cyclohexa-2,4-dienyl)-(phenyl)-methanol (18a): (R)-L6 was used; $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.36 – 7.31 (m, 4H), 7.27 – 7.26 (m, 1H), 6.00 – 5.90 (m, 2H), 5.24 – 5.14 (dd, J = 9.0, 6.2 Hz, 1H 1H), 4.46 (dd, J = 8.5, 3.8 Hz, 1H), 4.01 (d, J = 12.5 Hz, 1H), 3.88 (d, J = 12.5 Hz, 1H), 3.39 (s, 3H), 3.37 – 3.27 (m, 2H), 3.25 (s, 3H), 3.02 – 2.96 (m, 1H), 2.70 – 2.64 (m, 1H), 2.18 (d, J = 3.8 Hz, 1H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 143.2, 134.9, 128.2, 127.5, 126.8, 125.8, 124.4, 121.5, 75.3, 73.7, 71.6, 58.3, 58.3, 42.2, 34.6 ppm; **IR (ATR):** $\tilde{\nu}$ = 3432, 3032, 2979, 2923, 2823, 1679, 1453, 1376, 1310, 1196, 1114, 1090, 1039, 961, 913, 765, 726, 701 cm^{-1} ; **HRMS (ESI)** calc'd. for $[\text{C}_{17}\text{H}_{22}\text{NaO}_3]^+$: 297.1461, found: 297.1452; $[\alpha]_{\text{D}}^{20}$ = +65 (c = 0.21, CHCl_3); **R_f**: 0.3 (33 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 10% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 8.93 min, t_{r} (minor) = 11.72 min), 78:22 *er*.

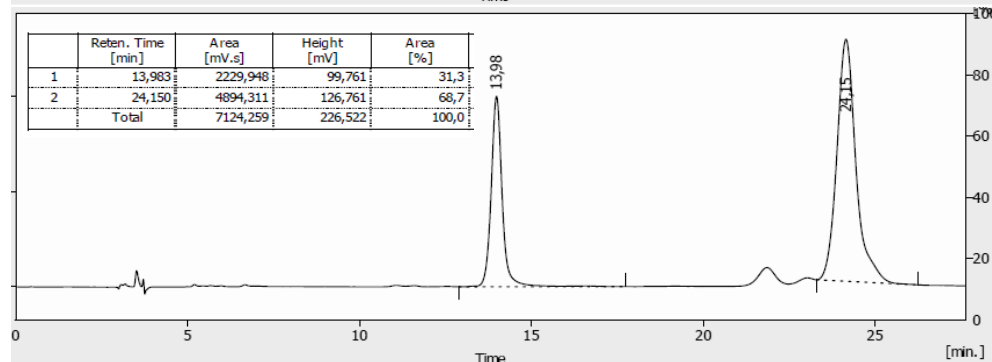
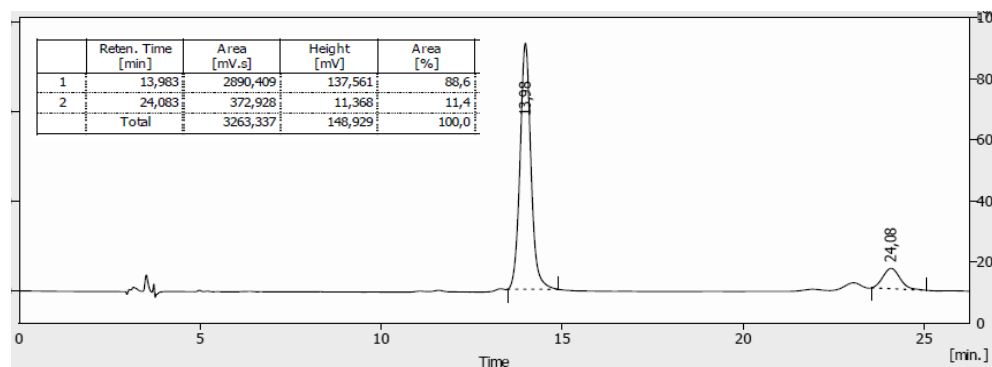


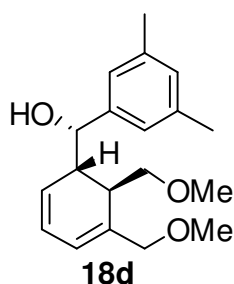
(-)-(S)-((1S,6R)-5,6-bis(methoxymethyl)cyclohexa-2,4-dienyl)-(4-methoxyphenyl)-methanol (18b): (S)-L6 was used; $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.29 – 7.21 (m, 2H), 6.89 – 6.84 (m, 2H), 5.98 – 5.87 (m, 2H), 5.17 (dd, J = 9.1, 6.1 Hz, 1H), 4.40 (dd, J = 8.7, 3.8 Hz, 1H), 4.01 (d, J = 12.5 Hz, 1H), 3.88 (d, J = 12.5 Hz, 1H), 3.80 (s, 3H), 3.38 (s, 3H), 3.38 – 3.27 (m, 2H), 3.27 (s, 3H), 3.03 – 2.97 (m, 1H), 2.70 – 2.59 (m, 1H), 2.14 (d, J = 3.8 Hz, 1H); $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 159.0, 135.5, 134.9, 127.9, 125.9, 124.2, 121.5, 113.6, 75.3, 73.1, 71.7, 58.3, 58.2, 55.3, 42.2, 34.8 ppm; **IR (ATR):** $\tilde{\nu}$ = 3427, 2923, 2834, 1611, 1512, 1459, 1378, 1303, 1246, 1177, 1112, 1034, 959, 836, 735 cm^{-1} ; **HRMS (ESI)** calc'd. for $[\text{C}_{18}\text{H}_{24}\text{NaO}_4]^+$: 327.1567, found: 327.1572; $[\alpha]_{\text{D}}^{20}$ = -165 (c = 0.63, CHCl_3); **R_f**: 0.2 (33 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 10% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 17.91 min, t_{r} (minor) = 13.29 min), 88:12 *er*.



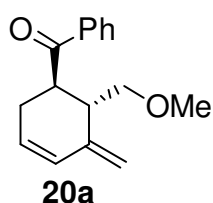
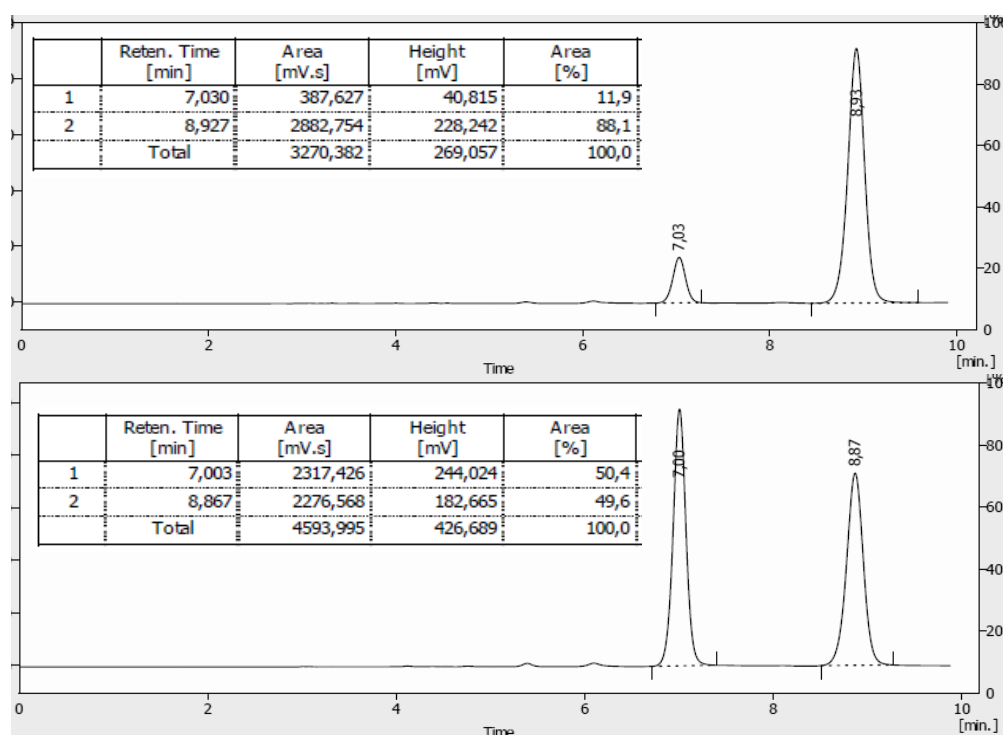


(+)-(R)-((1R,6S)-5,6-bis(methoxymethyl)cyclohexa-2,4-dienyl)-(4-chlorophenyl)-methanol (18c): (*R*)-**L6** was used; ¹H-NMR (300 MHz, CDCl₃) δ = 7.33 – 7.23 (m, 4H), 6.01 – 5.91 (m, 2H), 5.20 (dd, *J* = 9.5, 5.8 Hz, 1H), 4.45 (dd, *J* = 8.4, 3.7 Hz, 1H), 4.00 (d, *J* = 12.2 Hz, 1H), 3.87 (d, *J* = 12.2 Hz, 1H), 3.39 (s, 3H), 3.36 – 3.27 (m, 2H), 3.26 (s, 3H), 3.00 – 2.92 (m, 1H), 2.67 – 2.58 (m, 1H), 2.30 (d, *J* = 3.7 Hz, 1H) ppm; ¹³C-NMR (101 MHz, CDCl₃) δ = 141.7, 135.0, 133.1, 128.3, 128.1, 125.5, 124.7, 121.6, 75.3, 73.2, 71.5, 58.3, 58.3, 42.2, 34.7 ppm; **IR (ATR):** $\tilde{\nu}$ = 3430, 3042, 2982, 2927, 2890, 2821, 1597, 1489, 1449, 1379, 1195, 1114, 1089, 1041, 1014, 915, 841, 732 cm⁻¹; **HRMS (ESI)** calc'd. for [C₁₇H₂₁ClNaO₃]⁺: 331.1071, found: 331.1072; **[α]_D²⁰** = +200 (*c* = 0.40, CHCl₃); **R_f**: 0.3 (33 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 5% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; *t_r* (major) = 13.98 min, *t_r* (minor) = 24.08 min), 89:11 *er*.

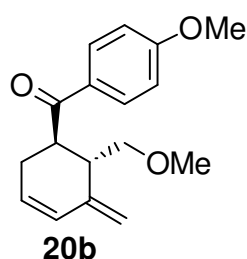
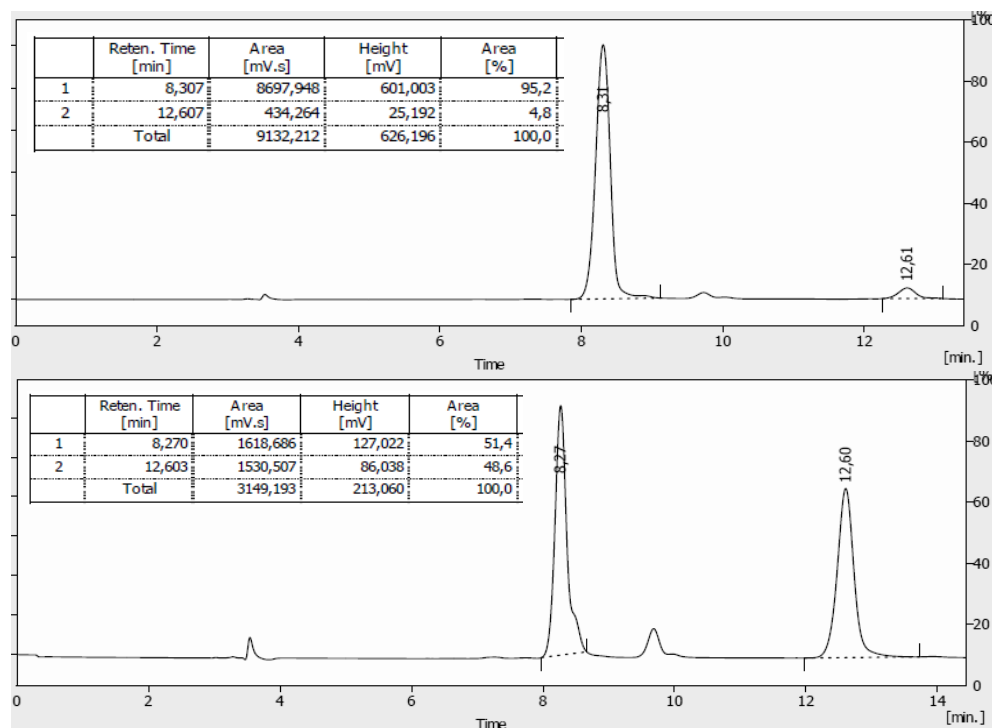




(-)-(R)-((1S,6R)-5,6-bis(methoxymethyl)cyclohexa-2,4-dienyl)-(3,5-dimethylphenyl)-methanol (18d): (*S*)-**L6** was used; $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ = 7.00 – 6.95 (m, 2H), 6.94 – 6.91 (m, 1H), 6.01 – 5.91 (m, 2H), 5.22 (dd, J = 9.3, 6.0 Hz, 1H), 4.39 (dd, J = 8.8, 3.5 Hz, 1H), 4.06 (d, J = 12.6 Hz, 1H), 3.91 (d, J = 12.6 Hz, 1H), 3.41 (s, 3H), 3.39 – 3.31 (m, 2H), 3.30 (s, 3H), 3.08 – 3.00 (m, 1H), 2.74 – 2.66 (m, 1H), 2.33 (s, 6H), 2.17 (d, J = 3.5 Hz, 1H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 143.2, 137.7, 134.8, 129.2, 126.0, 124.6, 124.2, 121.5, 75.3, 73.6, 71.7, 58.3, 58.2, 42.0, 34.7, 21.3 ppm; **IR (ATR):** $\tilde{\nu}$ = 3411, 2920, 1606, 1455, 1378, 1296, 1194, 1111, 1054, 959, 853, 730 cm^{-1} ; **HRMS (ESI)** calc'd. for $[\text{C}_{19}\text{H}_{26}\text{NaO}_3]^+$: 325.1774, found: 325.1774; $[\alpha]_{\text{D}}^{20}$ = -150 (c = 0.43, CHCl_3); **R_f**: 0.3 (33 % EtOAc in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 10% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 8.93 min, t_{r} (minor) = 7.03 min), 88:12 *er*.

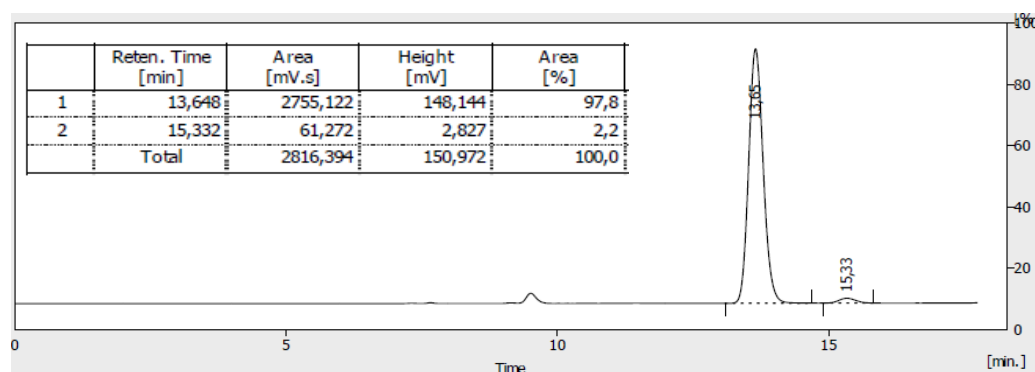


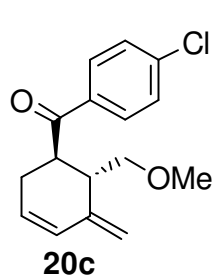
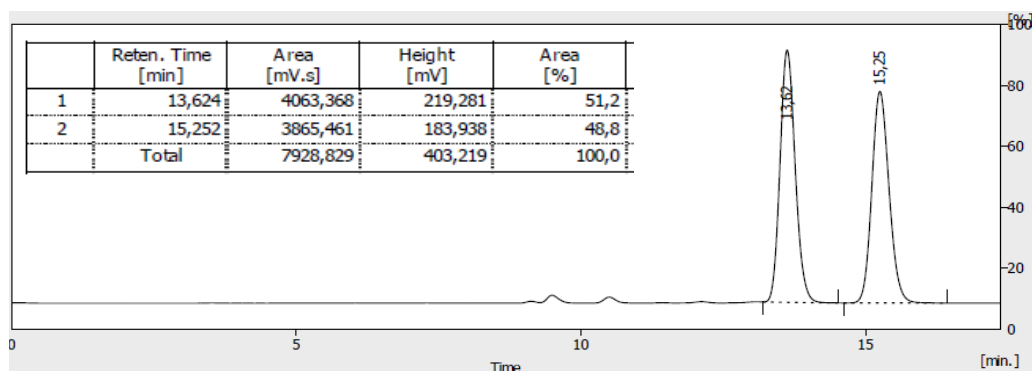
(-)-((1R,6S)-6-(methoxymethyl)-5-methylenecyclohex-3-enyl)-(phenyl)-methanone (20a): $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.99 – 7.91 (m, 2H), 7.59 – 7.50 (m, J = 7.3 Hz, 1H), 7.50 – 7.40 (m, 2H), 6.15 (d, J = 9.9 Hz, 1H), 5.85 – 5.76 (m, 1H), 4.96 (br s, 1H), 4.85 (br s, 1H), 4.01 – 3.95 (m, 1H), 3.58 – 3.51 (m, 1H), 3.40 (dd, J = 9.8, 4.9 Hz, 1H), 3.30 (s, 3H), 3.10 – 3.04 (m, 1H), 2.51 – 2.35 (m, 2H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 202.6, 140.8, 136.5, 132.7, 128.6, 128.4, 127.0, 113.5, 73.8, 58.8, 41.9, 41.5, 25.3, 1.0 ppm; **IR (ATR):** $\tilde{\nu}$ = 3029, 2925, 2360, 1683, 1597, 1448, 1363, 1219, 1196, 1115, 1021, 886, 786, 698 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{16}\text{H}_{18}\text{O}_2]^+$: 242.1302, found: 242.1301; $[\alpha]_{\text{D}}^{20}$ = -4.8 (c = 0.10, CHCl_3); **R_f**: 0.2 (5 % Et_2O in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 1% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 8.31 min, t_{r} (minor) = 12.61 min), 95:5 *er*.



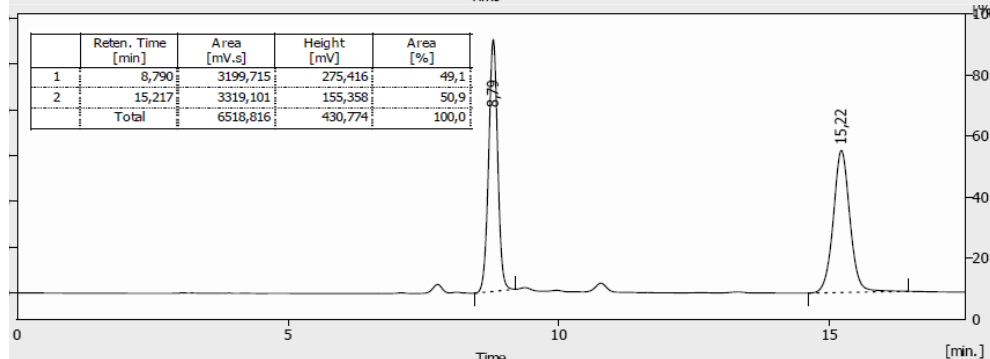
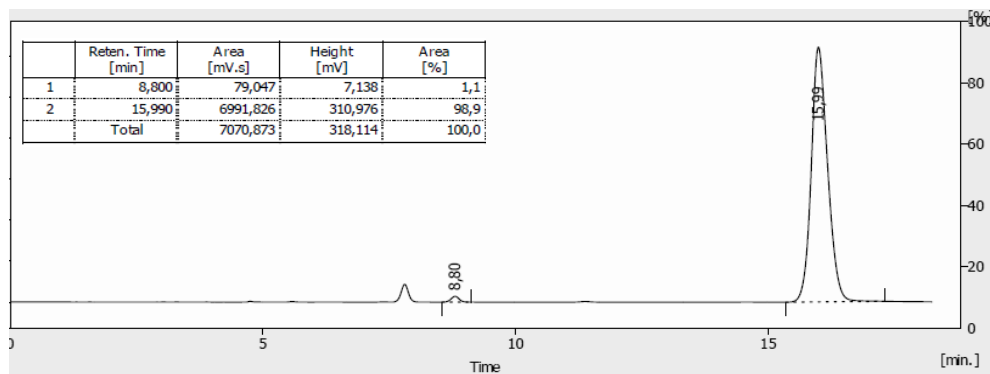
(-)-((1R,6S)-6-(methoxymethyl)-5-methylenecyclohex-3-enyl)-(4-methoxyphenyl)-methanone (20b): $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ 7.99 – 7.92 (m, 2H), 6.98 – 6.91 (m, 2H), 6.16 (d, J = 9.9 Hz, 1H), 5.87 – 5.75 (m, 1H), 4.96 (br s, 1H), 4.87 (br s, 1H), 3.97 – 3.91 (m, 1H), 3.87 (s, 3H), 3.56 (dd, J = 9.7, 7.9 Hz, 1H), 3.39 (dd, J = 9.7, 4.7 Hz, 1H), 3.29 (s, 3H), 3.07 – 2.99 (m, 1H), 2.52 – 2.32 (m, 2H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 201.2, 163.3, 141.1, 130.7, 129.4, 128.6, 127.2, 113.7, 113.3, 73.7, 58.9, 55.4, 42.0, 41.1, 25.8 ppm; **IR (ATR):** $\tilde{\nu}$ = 2925, 1675, 1600, 1511, 1460, 1362, 1311, 1259, 1171, 1116, 1027, 887, 842, 785 cm^{-1} ; **HRMS**

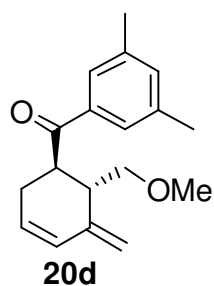
(EI) calc'd. for $[\text{C}_{17}\text{H}_{20}\text{O}_3]^+$: 272.1407, found: 272.1407; $[\alpha]_{\text{D}}^{20}$ = -15 (c = 0.43, CHCl_3); R_f : 0.3 (10 % Et_2O in pentane); colorless oil; HPLC separation (Chiralpak IC, 4.6 x 250 mm; 10% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_r (major) = 13.65 min, t_r (minor) = 15.33 min), 98:2 *er*.





(-)-(4-chlorophenyl)-((SR,6S)-6-(methoxymethyl)-5-methylenecyclohex-3-enyl)-methanone (20c): $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ = 7.93 – 7.87 (m, 2H), 7.46 – 7.40 (m, 2H), 6.15 (d, J = 9.9 Hz, 1H), 5.85 – 5.76 (m, 1H), 4.96 (br s, 1H), 4.85 (br s, 1H), 3.96 – 3.90 (m, 1H), 3.53 (dd, J = 9.7, 8.5 Hz, 1H), 3.40 (dd, J = 9.7, 4.9 Hz, 1H), 3.30 (s, 3H), 3.07 – 2.99 (m, 1H), 2.53 – 2.32 (m, 2H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 201.4, 140.5, 139.1, 134.7, 129.9, 128.9, 128.5, 126.9, 113.6, 73.7, 58.9, 42.0, 41.5, 25.1 ppm; **IR** (ATR): $\tilde{\nu}$ = 2926, 1684, 1589, 1487, 1400, 1362, 1281, 1215, 1115, 1012, 887, 840, 784 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{16}\text{H}_{17}\text{ClO}_2]^+$: 276.0912, found: 276.0915; $[\alpha]_D^{20}$ = -16 (c = 0.19, CHCl_3); R_f : 0.3 (5 % Et_2O in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 1% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_r (major) = 15.99 min, t_r (minor) = 8.80 min, 99:1 *er*.





(-)-(3,5-dimethylphenyl)-((1R,6S)-6-(methoxymethyl)-5-methylenecyclohex-3-enyl)-methanone (20d): $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ = 7.62 – 7.55 (m, 2H), 7.25 – 7.17 (m, 1H), 6.18 (d, J = 9.9 Hz, 1H), 5.86 – 5.77 (m, 1H), 5.00 (br s, 1H), 4.92 (br s, 1H), 3.98 – 3.92 (m, 1H), 3.61 (dd, J = 9.9, 7.7 Hz, 1H), 3.42 (dd, J = 9.9, 4.8 Hz, 1H), 3.32 (s, 3H), 3.11 – 3.03 (m, 1H), 2.58 – 2.40 (m, 2H), 2.37 (s, 6H) ppm; $^{13}\text{C-NMR}$ (101 MHz, CDCl_3) δ = 203.2, 141.2, 138.1, 136.7, 134.4, 128.8, 127.0, 126.2, 113.3, 73.5, 58.7, 41.7, 41.6, 25.9, 21.3 ppm; **IR (ATR):** $\tilde{\nu}$ = 2921, 1681, 1603, 1451, 1380, 1307, 1191, 1117, 987, 884, 776 cm^{-1} ; **HRMS (EI)** calc'd. for $[\text{C}_{18}\text{H}_{22}\text{O}_2]^+$: 270.1615, found: 270.1617; $[\alpha]_{\text{D}}^{20}$ = -34 (c = 0.49, CHCl_3); **R_f**: 0.3 (10 %

Et_2O in pentane); colorless oil; HPLC separation (Chiralpak IA, 4.6 x 250 mm; 1% *i*-PrOH / hexane, 1.0 mL/min, 254 nm; t_{r} (major) = 8.38 min, t_{r} (minor) = 6.56 min), 98:2 *er*.

