Supporting Information.

An unexpected directing effect in the asymmetric transfer hydrogenation of α,α-disubstituted ketones.

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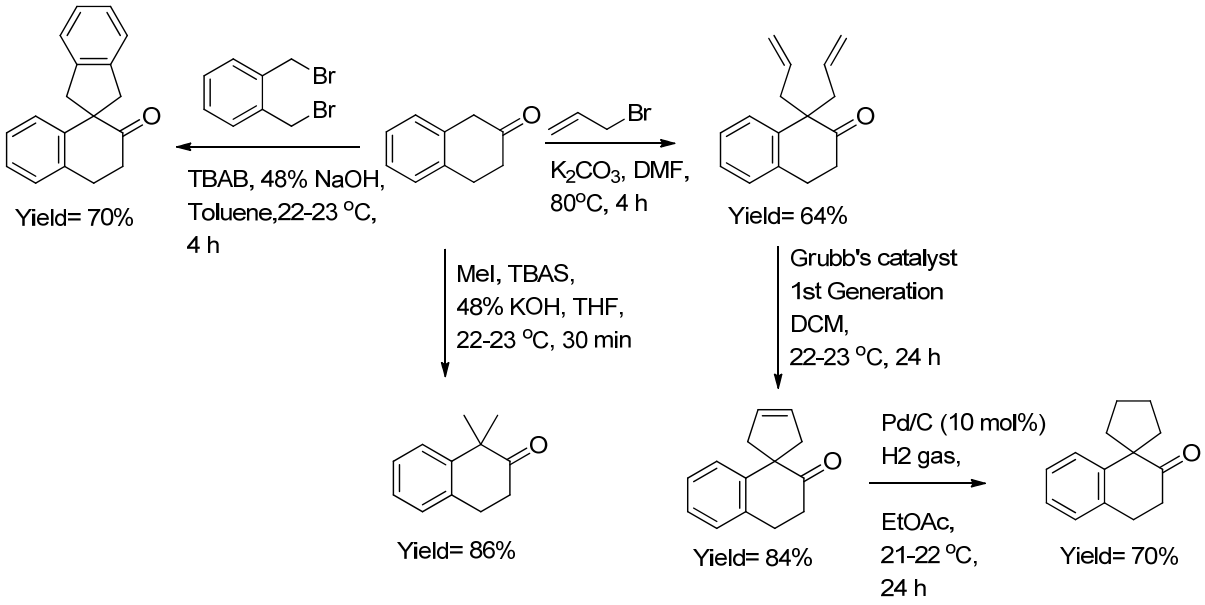
1) Experimental procedures and characterisation data.

General Experimental:

All the air sensitive reactions were carried out in Argon atmosphere. NMR spectra were recorded on a Bruker DPX-300 (300 MHz) or a Bruker DPX-400 (400 MHz). All chemical shifts are reported in ppm downfield from TMS (Me_4Si). Coupling constants (*J*) are reported in Hz. Multiplicity in ^{1}H-NMR is reported as singlet (s), doublet (d), double doublet (dd), double triplet (dt), broad singlet (br s), broad doublet (br d),and multiplet (m). Mass spectra were recorded on an Esquire 2000. High resolution mass spectra were recorded on Bruker Micro ToF. Infrared spectra were recorded on PerkinElmer spectrum100. The optical rotations were measured on Optical Activity Ltd. AA-1000 Polarimeter. The Chiral HPLC measurements were carried out on HPLC consisting of a Gilson 811B Dynamic Mixer, a Gilson 805 Monometer Module, a Gilson 305 Piston Pump, Merck-Hitachi L-4000 UV detector linked to HEWLETT PACKARD 3396 Series II integrator with CHIRAL PAK IA/IB column (0.46 cm x 25 cm). The chiral GC measurements were done on HEWLETT PACKARD 5890 linked to HEWLETT PACKARD HP3396A integrator or PERKIN-ELMER 8500 chromatography linked to PC running DataApex Clarity software with Chrompak CP-Chirasil Dex Cβ column. Melting points were determined on a Stuart scientific melting point apparatus and are uncorrected. Purification of compounds was done by using flash column chromatography using silica gel of mesh size 230-400.

Synthesis of β-tetralone derivatives 5b-5e:



1,1-Dimethyl-3,4-dihydronaphthalen-2(1H)-one 5b (SRC 538).

This is a known compound and the method is based on a reported synthesis.[1]

To a mixture of β- tetralone (0.750 g, 5.136 mmol), TBAS (0.278 g, 0.822 mmol, 0.16 eq) and methyl iodide (0.959 mL, 15.408 mmol, 3.0 eq) in THF (3 mL) was rapidly added 50% KOH solution in H_2O (5 mL). The reaction mixture became warm and turned blue. The reaction mixture was stirred for 30 min during which time the colour changed from blue to green and finally light brown. The reaction mixture was poured into water (20 mL) and extracted with diethyl ether (2 x 25 mL). The combined organic layer was washed with sat. NH_4Cl soln (2 x 25 mL), dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane: ethyl acetate (96:4) to give 1,1-dimethyl-3,4-dihydronaphthalen-2(1H)-one **5b** as a white solid (0.775 g, 4.454 mmol, 86%). ν_{max} 2972, 2933, 1709, 1488, 1449, 1380, 1244, 1091, 1042, 758, 742 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.37-7.34 (1H, m, -CH of -C_6H_4-), 7.30-7.23 (1H, m, -CH of -C_6H_4-), 7.20-7.18 (2H, m, -CH of -C_6H_4-), 3.10 (2H, t, *J* 6.7, -CH_2-C_6H_4-), 2.69 (2H, d, *J* 6.7, -CH_2-CO-), 1.44 (6H, br s, -C(CH_3)$_2$-); δc (300 MHz, $CDCl_3$) 214.76, 143.52, 135.15, 128.13, 127.10, 126.37, 126.13, 47.76, 37.20, 28.59, 26.89(2C); m/z ESI-MS $[M+Na]^+$ 175.2; HRMS found 175.1118 ($C_{12}H_{14}O$+H requires 175.1117, error = -0.6 ppm).

1,1-Di(prop-2-en-1-yl)-3,4-dihydronaphthalen-2(1H)-one (SRC 520).

This is a known compound[2] and method is used same as for ethyl 2-acetyl-2-allylpent-4-enoate.[3]

To a mixture of K_2CO_3 (1.44 g, 10.397 mmol, 3.04 eq) in DMF (15 mL) was added β-tetralone (0.500 g, 3.420 mmol) under an inert atmosphere and the resulting mixture was stirred at 21-22 ^oC for 10 min. To this, a solution of allyl bromide (0.734 mL, 8.482 mmol, 2.48 eq) in DMF (5 mL) was added dropwise. The resulting mixture was heated to 80 ^oC for 4 h. The reaction mixture was cooled to rt, diluted with water (25 mL) and extracted with diethyl ether (3 x 25 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using n-pentane: diethyl ether (97:3) to give 1,1-di(prop-2-en-1-yl)-3,4-dihydronaphthalen-2(1H)-one as a colourless oil (0.500 g, 2.212 mmol, 64%). ν_{max} 3076, 2909, 1710, 1639, 1489, 1444, 1416, 1226, 1167, 997, 916, 760, 737 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.35-7.28 (2H,

m, 2 -CH of -C_6H_4-), 7.22-7.14 (2H, m, 2 -CH of -C_6H_4-), 5.44-5.30 (2H, m, 2 x -CH_2-C*H*=CH_2), 4.95-4.85 (4H, m, 2 x -CH_2-CH=C*H*$_2$), 2.96 (2H, t, *J* 6.0, -C*H*$_2$-C_6H_4-), 2.78 (2H, d, *J* 12.0, 8.0, 2 x -C*H*H-CH=CH_2), 2.54 (2H, t, *J* 6.0, -C*H*$_2$CO-), 2.52-2.47 (2H, m, 2 x -CH*H*-CH=CH_2), δc (300 MHz, $CDCl_3$) 139.12, 136.97, 133.34(2C), 128.00, 126.98, 126.87, 126.34, 118.28(2C), 55.98, 45.06(2C), 40.28, 27.83; m/z ESI-MS $[M+H]^+$ 227.2; HRMS found 249.1248 ($C_{16}H_{18}ONa$ requires 249.1250, error = 0.7 ppm).

3',4'-Dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-one 5d (SRC 523).

This is a novel compound and the method is used is same as for spiro[4,5]dec-2-ene-6,10-dione.

To a solution of 1,1-diallyl-3,4-dihydronaphthalen-2(1H)-one (0.400 g, 1.770 mmol) in dry DCM (80 mL) was added Grubb's Catalyst 1st generation (72.8 mg, 5 mol%) under an inert atmosphere and the resulting mixture was stirred for 24 h at 22-23 ^oC. The colour of the reaction changed from purple to brown. The reaction mixture was concentrated on a rotary evaporator to give a crude residue. The crude compound was purified by column chromatography using n-pentane: diethyl ether (95:5) to give 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-one **5d** as a colourless oil (0.295 g, 1.489 mmol, 84%). ν_{max} 3055, 2916, 2846, 1709, 1488, 1451, 1346, 1234, 1140, 1048, 972, 788, 754, 666 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.27-7.21 (2H, m, 2 -CH of -C_6H_4-), 7.19-7.13 (2H, m, 2 -CH of -C_6H_4-), 5.71 (2H, m, -C*H*=C*H*-), 3.22-3.15 (2H, m, -C*H*H-CH=CH-C*H*H-), 3.10 (2H, t, *J* 7.5, -C*H*$_2$-C_6H_4-), 2.73 (2H, t, *J* 7.5, -C*H*$_2$CO-), 2.68-2.59 (2H, m, -CH*H*-CH=CH-CH*H*-); δc (300 MHz, $CDCl_3$) 212.91, 144.78, 134.59, 128.04(2C), 127.67, 127.37, 126.32, 126.14, 46.83(2C), 37.63, 28.90; m/z ESI-MS $[M+Na]^+$ 221.2; HRMS found 221.0935 ($C_{14}H_{14}ONa$ requires 221.0937, error = 0.8 ppm).

3',4'-Dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-one 5c (SRC 529).

This is a known compound[4] and the method used is same as for spiro[4,5]decane-6,10-dione.

A solution of 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-one **5d** (0.198 g, 1.000 mmol) in dry ethyl acetate (20 mL) containing added Pd/C (10 % on carbon) (100 mg) was stirred under atmospheric pressure of hydrogen at 21-22 ^oC for 24 h. The reaction

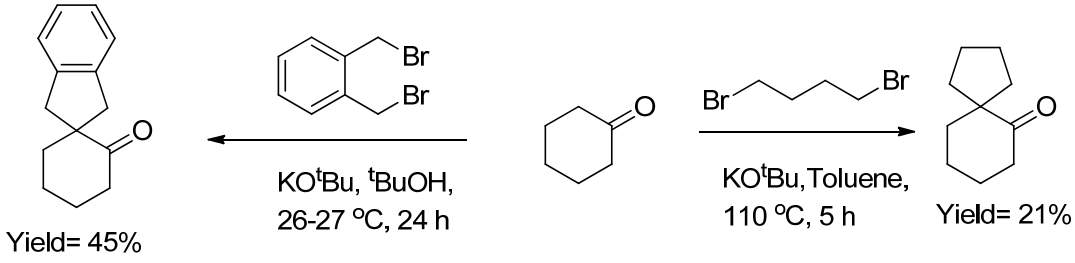
mixture was filtered through celite and the filtrate was concentrated on a rotary evaporator to give a crude residue. The crude compound was purified by column chromatography using n-pentane: diethyl ether (95.5:4.5) to give 3',4'-dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-one **5c** as a colourless oil (0.140 g, 0.700 mmol, 70%). ν_{max} 2950, 2867, 1706, 1487, 1449, 1346, 1236, 1045, 936, 754, 742 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.29-7.20 (2H, m, -CH of -C_6H_4-), 7.18-7.14 (2H, m, -CH of -C_6H_4-), 3.09 (2H, t, *J* 6.5, -CH_2-CH_2CO), 2.69 (2H, t, *J* 6.5, -CH_2-CH_2CO-), 2.39-2.29 (2H, m, -CH*H*CH_2CH_2CH*H*-), 1.93-1.81 (6H, m, -C*H*HCH_2CH_2C*H*H-); δc (300 MHz, $CDCl_3$) 213.75, 143.83, 135.90, 127.85, 126.96, 126.14(2C), 59.25, 38.35(2C), 37.18, 28.77, 26.63(2C); m/z ESI-MS $[M+Na]^+$ 223.1; HRMS found 223.1094 ($C_{14}H_{16}ONa$ requires 223.1093, error = -0.2 ppm).

1,3,3',4'-Tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-one 5e (SRC 519).

This is a novel compound.

To a mixture of TBAB (27.7 mg, 0.0855 mmol, 0.05 eq) in 48% NaOH solution (1.1 mL) was added solution of α,α'-dibromo xylene (0.451 g, 1.710 mmol) in toluene (2.5 mL). To this, a solution of β-tetralone (0.250 g, 1.710 mmol) in toluene (0.5 mL) was added dropwise during which the temperature increased from 22 ^oC to 38-40 ^oC. The reaction mixture was stirred at 22-23 ^oC for 4 h. The residue was diluted with water (20 mL) and extracted with toluene (2 x 25 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using n-pentane: diethyl ether (88:12) to give 1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-one **5e** as a white solid (0.300 g, 1.210 mmol, 70%). Mp 128-130 ^oC; ν_{max} 3019, 2953, 2893, 1699, 1485, 1452, 1233, 1146, 1017, 760, 750, 743 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.21-7.14 (6H, m, 4 -CH of -C_6H_4-, 2 -CH of -C_6H_4-), 7.13-7.08 (2H, m, 2-CH of -C_6H_4-), 3.79 (2H, d, *J* 16.5, -C*H*H-C_6H_4-C*H*H-), 3.21 (2H, d, *J* 16.5, -CH*H*-C_6H_4-CH*H*-), 3.18 (2H, t, *J* 6.0, -CH_2-CH_2CO-), 2.77 (2H, t, *J* 6.0, -CH_2CO-); δc (300 MHz, $CDCl_3$) 212.47, 142.97, 140.73 (2C), 135.31, 128.00, 127.72, 126.93(2C), 126.65, 125.95, 124.17(2C), 58.93, 44.84(2C), 37.30, 28.62; m/z ESI-MS $[M+Na]^+$ 271.1; HRMS found 249.1275 ($C_{18}H_{16}O$ +H requires 249.1274, error = -0.3 ppm).

Synthesis of cyclohexanone derivatives 8 and 9:



Spiro[4,5]decane-6-one 8 (SRC 452).

This is a known compound and the method is based on a reported synthesis.[5]

To a mixture of KO^{t}Bu (2.54 g, 22.62 mmol, 2.22 eq) in dry toluene (20 mL) was added cyclohexanone (1.0 g, 10.189 mmol) under an inert atmosphere. The mixture was stirred at 20-21 ^{o}C for 1 h. To this mixture, 1,4-dibromobutane (1.216 mL, 10.189 mmol, 1.0 eq) was added dropwise. The resulting mixture was stirred at 110-111 ^{o}C for 5 h. The reaction mixture was cooled to rt, diluted with water (10 mL) and HCl (15%, 20 mL). The mixture was extracted with diethyl ether (3 x 25 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give crude oil. The oil was purified by column chromatography using n-pentane: diethyl ether (98:2) to give spiro[4,5]decane-6-one **8** as colourless oil (0.330 g, 2.171 mmol, 21%). ν_{max} 2934, 2863, 1703, 1443, 1345, 1311, 1126, 954 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 2.42-2.38 (2H, m, -C*H*$_2$CO-), 2.10-2.02 (2H, m, -CH$_2$-C-C*H*$_2$-), 1.86-1.78 (2H, m, -C*H*$_2$-CH$_2$CO-), 1.72-1.70 (4H, m, -C*H*$_2$-C*H*$_2$-CH$_2$-CH$_2$CO-), 1.63-1.54 (4H, m, -C*H*$_2$-C*H*$_2$-), 1.44-1.35 (2H, m, -C*H*$_2$-C-CH$_2$-); δc (300 MHz, $CDCl_3$) 214.71, 56.82, 39.92, 39.43, 35.42(2C), 27.32, 25.22(2C), 22.82; m/z ESI-MS $[M+Na]^+$ 175.0; HRMS found 175.1099 ($C_{10}H_{16}ONa$ requires 175.1093, error = -3.4 ppm).

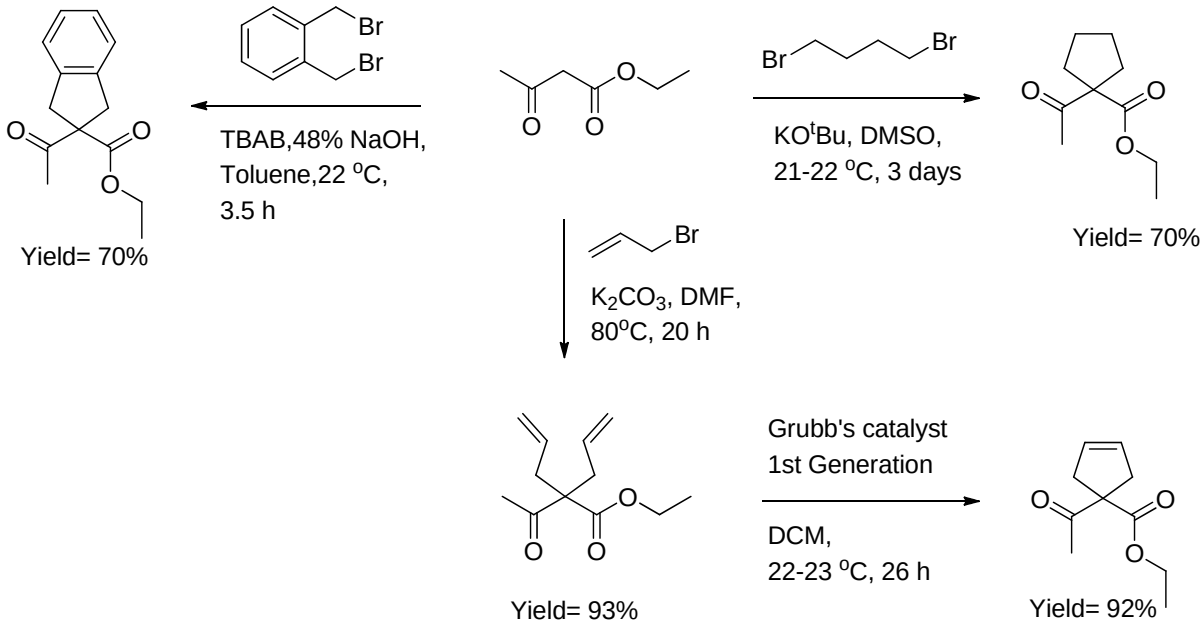
1',3'- Dihydro-2H-spiro[cyclohexane-1,2'-inden]-2-one 9 (SRC 480).

This is a known compound.[6]

To a mixture of KO^{t}Bu (1.27 g, 11.308 mmol, 2.22 eq) in dry ^{t}BuOH (12.5 mL) was added cyclohexanone (0.500 g, 5.094 mmol) under an inert atmosphere. The mixture was stirred at 26-27 ^{o}C for 10-15 min. To this mixture, α,α'-dibromo xylene (1.34 g, 5.094 mmol, 1.0 eq) was added and resulting mixture was stirred at 26-27 ^{o}C for 24 h. The reaction mixture was concentrated on a rotary evaporator to give residue. The residue was diluted with water (10

mL) and 15% HCl (10 mL). The mixture was extracted with DCM (3 x 50 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane: ethyl acetate (95:5) to give 1',3'- dihydro-2H-spiro[cyclohexane-1,2'-inden]-2-one **9** as colourless oil (0.460 g, 2.300 mmol, 45%). ν_{max} 3023, 2930, 2860, 1700, 1485, 1444, 1428, 1337, 1311, 1220, 1127, 744, 727 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.18-7.12 (4H, m, -CH of -C_6H_4-), 3.46 (2H, d, *J* 12.0, -C*H*H-C_6H_4-C*H*H-), 2.82 (2H, d, *J* 12.0, -CH*H*-C_6H_4-CH*H*-), 2.49 (2H, t, *J* 6.0, -CH_2CO), 1.92-1.89 (2H, m, -CH_2-CH_2CO), 1.87-1.84 (2H, m, -CH_2-CH_2-CH_2CO), 1.83-1.76 (2H, m, -CH_2-CH_2-CH_2-CH_2CO); δc (300 MHz, $CDCl_3$) 212.93, 140.84, 126.50, 124.84, 57.22, 41.31, 39.53, 39.13, 27.48, 22.21; m/z ESI-MS $[M+Na]^+$ 223.2; HRMS found 223.1091 ($C_{10}H_{16}ONa$ requires 223.1093, error = 0.9 ppm).

Synthesis of ethyl acetoacetate derivatives 13a-c:



Ethyl 1-acetylcyclopentanecarboxylate 13a (SRC 471).

This is a known compound and the method is based on a reported synthesis.[7]

To a mixture of KO^{t}Bu (2.65 g, 19.210 mmol, 2.5 eq) in DMSO (15 mL) was added ethyl acetoacetate (1.0 g, 7.684 mmol) under an inert atmosphere. The mixture was stirred at 21-22 °C for 10 min. 1,4-Dibromobutane (0.918 mL, 7.684 mmol, 1.0 eq) was then added dropwise. The resulting mixture was stirred at 21-22 °C for 3 days. The reaction mixture was poured

into ice-cold water and extracted with ethyl acetate (3 x 30 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane: ethyl acetate (95:5) to give ethyl 1-acetylcyclopentanecarboxylate **13a** as colourless oil (1.0 g, 5.434 mmol, 70%). ν_{max} 2959, 2874, 1739, 1711, 1623, 1446, 1356, 1240, 1147, 1097, 1052, 1026, 857 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 4.23-4.16 (2H, q, *J* 7.0, -OC*H*$_2$CH$_3$), 2.16 (3H, s, -COC*H*$_3$), 2.13-2.08 (4H, m, -C*H*$_2$-C-C*H*$_2$-), 1.71-1.60 (4H, m, -C*H*$_2$-C*H*$_2$-), 1.26 (3H, t, *J* 7.0, -OCH$_2$C*H*$_3$); δc (300 MHz, $CDCl_3$) 61.31, 32.96(2C), 26.04, 25.64(2C), 14.02; m/z ESI-MS $[M+Na]^+$ 207.2; HRMS found 207.0992 ($C_{10}H_{16}O_3Na$ requires 207.0992, error = -0.4 ppm).

Ethyl 2-acetyl-2-(prop-2-en-1-yl)pent-4-enoate (SRC 482).

This is a known compound and the method is based on a reported synthesis.[3]

To a mixture of K_2CO_3 (3.22 g, 23.359 mmol, 3.04 eq) in DMF (10 mL) was added ethyl acetoacetate (1.0 g, 7.684 mmol) under an inert atmosphere. The resulting mixture was stirred at 21-22 ^oC for 10 min. To this, a solution of allyl bromide (1.649 mL, 19.056 mmol, 2.48 eq) in DMF (5 mL) was added dropwise. The resulting mixture was heated to 80 ^oC for 20 h. The reaction mixture was cooled to rt, diluted with water (20 mL) and extracted with diethyl ether (3 x 20 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane: ethyl acetate (92:8) to give ethyl 2-acetyl-2-(prop-2-en-1-yl)pent-4-enoate as a colourless oil (1.5 g, 7.142 mmol, 93%). ν_{max} 3079 2981, 1740, 1715, 1641, 1442, 1356, 1278, 1207, 1179, 1138, 1017, 994, 918, 855 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 5.67-5.53 (2H, m, 2 x -CH$_2$-C*H*=CH$_2$), 5.14-5.08 (4H, m, 2 x -CH$_2$-CH=C*H*$_2$), 4.24-4.17 (2H, q, *J* 7.0, -OC*H*$_2$CH$_3$), 2.69-2.54 (4H, m, (-C*H*$_2$-CH=CH$_2$)$_2$), 2.14 (3H, s, -COC*H*$_3$), 1.27 (3H, t, *J* 7.0, -OCH$_2$C*H*$_3$); δc (300 MHz, $CDCl_3$) 132.16(2C), 119.15(2C), 63.20, 61.38, 35.92(2C), 26.91, 14.10; m/z ESI-MS $[M+Na]^+$ 233.2; HRMS found 233.1153 ($C_{12}H_{18}O_3Na$ requires 233.1148, error = -2.0 ppm).

Ethyl 1-acetylcyclopent-3-ene-1-carboxylate 13b (SRC 487).

The method is based on a reported synthesis.[3] This is a known compound.[8]

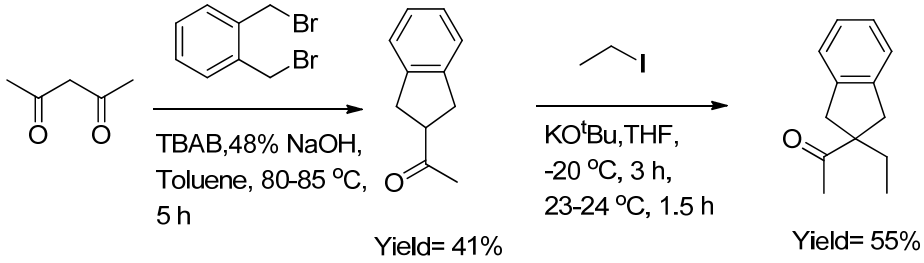
To a solution of ethyl 2-acetyl-2-(prop-2-en-1-yl)pent-4-enoate (0.250 g, 1.190 mmol) in dry DCM (60 mL) was added Grubb's Catalyst 1st generation (49 mg, 5 mol%) under an inert atmosphere and the resulting mixture was stirred for 24 h at 22-23 ^{o}C. The colour of the reaction changed from purple to brown. The reaction mixture was concentrated on a rotary evaporator to give crude residue. The crude compound was purified by column chromatography using n-pentane: diethyl ether (94:6) to give ethyl 1-acetylcyclopent-3-ene-1-carboxylate **13b** as a colourless oil (0.200 g, 1.099 mmol, 92%). ν_{max} 3063, 2983, 1713, 1445, 1357, 1260, 1230, 1153, 1096, 1071, 1017 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 5.59 (2H, br m, -C*H*=C*H*-), 4.25-4.18 (2H, q, *J* 7.0, -OC*H*$_2$CH$_3$), 2.94 (4H, br s, -C*H*$_2$-CH=CH-C*H*$_2$-), 2.19 (3H, s, -COC*H*$_3$), 1.27 (3H, t, *J* 7.0, -OCH$_2$C*H*$_3$); δc (300 MHz, $CDCl_3$) 127.71, 61.60, 39.22, 25.91, 14.00; m/z ESI-MS $[M+Na]^+$ 205.1; HRMS found 205.0837 ($C_{10}H_{14}O_3Na$ requires 205.0835, error = -1.2 ppm).

Ethyl 2-acetyl-2,3-dihydro-1H-indene-2-carboxylate 13c (SRC 472).

This is a known compound and the method is used same as for on a reported synthesis.[9]

To a mixture of TBAB (31 mg, 0.0958 mmol, 0.05 eq) in 48% NaOH solution (1.1 mL) was added solution of α,α'-dibromo xylene (0.500g, 1.894 mmol) in toluene (2.5 mL). To this solution of ethyl acetoacetate (0.240 mL, 1.894 mmol, 1.0 eq) in toluene (0.5 mL) was added dropwise and during addition the temperature increased from 22 ^{o}C to 38-40 ^{o}C. The reaction mixture was stirred at 22 ^{o}C for 3.5 h. The residue was diluted with water (20 mL) and extracted with toluene (2 x 25 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane: ethyl acetate (95:5) to give ethyl 2-acetyl-2,3-dihydro-1H-indene-2-carboxylate **13c** as a colourless oil (0.310 g, 1.336 mmol, 70%). ν_{max} 2981, 1710, 1486, 1460, 1336, 1269, 1233, 1150, 1072, 1017, 858, 743 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.17-7.14 (4H, m, -CH of -C$_6$*H*$_4$-), 4.25-4.18 (2H, q, *J* 7.0, -OC*H*$_2$CH$_3$), 3.53-3.46 (4H, m, -C*H*$_2$-C$_6$H$_4$-C*H*$_2$-), 2.23 (3H, s, -COC*H*$_3$), 1.26 (3H, t, *J* 7.0, -OCH$_2$C*H*$_3$); δc (300 MHz, $CDCl_3$) 140.21(2C), 127.35(2C), 124.67(2C), 62.21, 38.38(2C), 26.50, 14.42; m/z ESI-MS $[M+Na]^+$ 255.1; HRMS found 225.0997 ($C_{14}H_{16}O_3Na$ requires 225.0992, error = -2.0 ppm).

Synthesis of 1-(2-Ethyl-2,3-Dihydro-1H-inden-2-yl)ethanone 13d:



1-(2,3-Dihydro-1H-inden-2-yl)ethanone (SRC 681).

This is a known compound and the method is used same as for on a reported synthesis.[10]

To a mixture of TBAB (0.161 g, 0.50 mmol, 0.05 eq) in 48% NaOH solution (5 mL) was added solution of α,α'-dibromo xylene (2.640 g, 10.0 mmol) in toluene (6 mL). To this solution of acetylacetone (1.0 g, 10.0 mmol, 1.0 eq) in toluene (6 mL) was added dropwise and during addition the temperature increased from 22 °C to 38-40 °C. The reaction mixture was heated to 80-85 °C for 5 h. The reaction mixture was cooled to room temperature, diluted with water (20 mL) and extracted with toluene (2 x 35 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane: ethyl acetate (93:7) to give 1-(2,3-dihydro-1H-inden-2-yl)ethanone as a colourless oil (0.600 g, 3.75 mmol, 41%). ν_{max} 3022, 2939, 2849, 1708, 1484, 1459, 1359, 1199, 1163, 745 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.22-7.14 (4H, m, -CH of -C_6H_4-), 3.50-3.38 (1H, m, -C*H*$COCH_3$), 3.19 (2H, d, *J* 7.5, -C*H*H-C_6H_4-C*H*H-), 3.21 (2H, d, *J* 7.5, -CH*H*-C_6H_4-CH*H*-), 2.24 (3H, s, -$COCH_3$); δc (300 MHz, $CDCl_3$) 209.30, 141.43(2C), 126.61(2C), 124.39(2C), 51.86, 34.94(2C), 28.47; m/z ESI-MS $[M+Na]^+$ 183.1; HRMS found 183.0785 ($C_{11}H_{12}ONa$ requires 183.0780, error = -2.8 ppm).

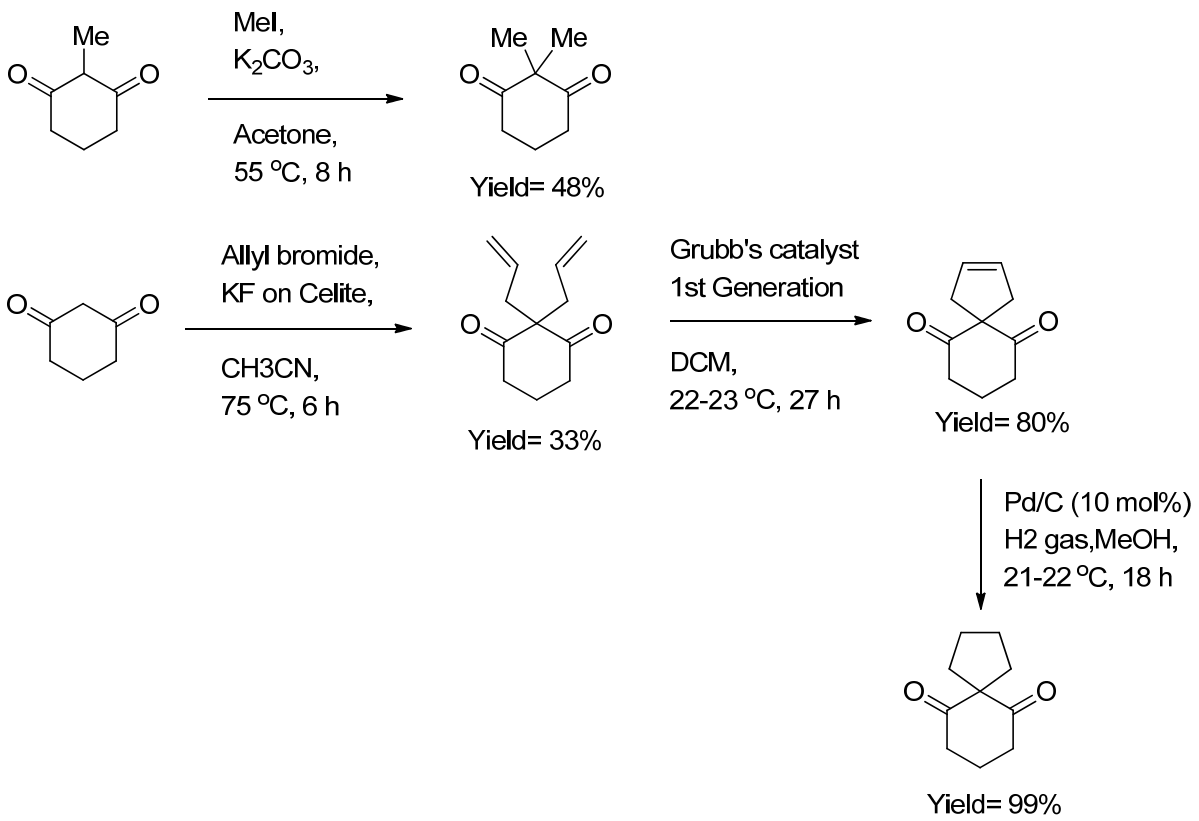
1-(2-Ethyl-2,3-dihydro-1H-inden-2-yl)ethanone 13d (SRC 682).

This is a known compound and the method is based on a reported synthesis.[10]

To a mixture of KO^{t}Bu (0.522 g, 4.657 mmol, 1.50 eq) in THF (15 mL) was added 1-(2,3-dihydro-1H-inden-2-yl)ethanone (0.500 g, 3.125 mmol) under an inert atmosphere. The resulting mixture was stirred at 21-22 °C for 10 min and cooled to -20 °C. To this, ethyl iodide (0.275mL, 3.438 mmol, 1.10 eq) was added drop wise. The resulting mixture was stirred at -20 °C for 3 h and warmed to room temperature. The reaction mixture was stirred at

room temperature for 1.5 h. The reaction mixture was diluted with water (20 mL) and extracted with ethyl acetate (3 x 50 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane: ethyl acetate (92:8) to give 1-(2-ethyl-2,3-dihydro-1H-inden-2-yl)ethanone **13d** as a colourless oil (0.325 g, 1.728 mmol, 55%). ν_{max} 3023, 2964, 2931, 1701, 1484, 1459, 1355, 1218, 1135, 783, 743, 722 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.19-7.12 (4H, m, -CH of -C_6H_4-), 3.37 (2H, d, *J* 16.5, -C*H*H-C_6H_4-C*H*H-), 2.85 (2H, d, *J* 16.5, -CH*H*-C_6H_4-CH*H*-), 2.19 (3H, s, -COCH_3), 1.80 (2H, q, *J* 7.5, -CH_2CH$_3$), 0.83 (3H, t, *J* 7.5, -CH_2CH_3); δc (300 MHz, $CDCl_3$) 141.20(2C), 126.51(2C), 124.53 (2C), 60.81, 40.28(2C), 30.82, 25.80, 9.56; m/z ESI-MS $[M+Na]^+$ 211.1; HRMS found 211.1153 ($C_{13}H_{16}ONa$ requires 211.1094, error = -0.1 ppm).

Synthesis of cyclohexane-1,3-dione derivatives 15a-c:



2,2-Dimethylcyclohexane-1,3-dione 15a.

This is a known compound and the method is based on a reported synthesis.[11]

Methyl iodide (1.23 mL, 19.8 mmol) was added to a stirred mixture of K_2CO_3 (2.18 g, 15.57 mmol) and 2-methylcyclohexane-1,3-dione (1.00 g, 7.92 mmol) in acetone (6 mL) and heated to reflux for 8 h. The acetone was removed under vacuum, CH_2Cl_2 was added, evaporated. CH_2Cl_2 was added, washed with water, the aqueous layer was washed with CH_2Cl_2, the organics were combined. 2 M HCl (5 mL) was added, stirred for 4 hours at rt. CH_2Cl_2 was removed *in vacuo*. Toluene and 2 M HCl (5 mL) were added and then stirred for 2 hours. Phases were separated, and the aqueous phase washed with toluene. The organics were combined, washed with brine, dried anhydrous $MgSO_4$, filtered and then evaporated to give **15a** as a yellow oil. Purified by column chromatography on silica gel (Hexane/EtOAc, 49:1 – 2:1) to give a clear oil (0.540 g, 3.857 mmol, 48%). ν_{max}(film): 2965, 1724, 1687, 1425, 1028, 844 cm^{-1}; δ_H (400 MHz, $CDCl_3$): 2.69 (4H, t, *J* 6.8, 2 x CH_2), 1.95 (2H, quintet, *J* 6.8, CH_2), 1.31 (6H, s, 2 x CH_3); δ_C (100 MHz, $CDCl_3$): δ 210.4, 61.6, 37.3, 22.1, 18.0.

2,2-Di(prop-2-en-1-yl)cyclohexane-1,3-dione.

This is a known compound and the method is based on a reported synthesis.[12]

KF was added to a mixture of celite stirred in H_2O then stirred for 40 mins. The celite was filtered off then dried in a desiccator overnight. The KF-celite (1.77 g) was added to a mixture of cyclohexane-1,3-dione (500 mg, 4.46 mmol) and allyl bromide (1.16 mL, 13.38 mmol) in CH_3CN (15 mL). The mixture was heated at 75°C for 6 hours. The reaction mixture was filtered under vacuum, washed with acetonitrile (2 x 15 mL) and the solvent evaporated to give an crude product as a yellow oil. Purification by column chromatography (Hexane/EtOAc, 49:1 – 4:1) gave the product 2,2-di(prop-2-en-1-yl)cyclohexane-1,3-dione as a colourless oil (286 mg, 1.48 mmol, 33%). ($[M+Na]^+$);. ν_{max}(film): 3029, 1692, 1723, 1692, 1210, 998, 919 cm^{-1}; δ_H (300 MHz, $CDCl_3$): 5.60-5.46 (2H, m, =CH-), 5.04-4.98 (4H, m, $=CH_2$), 2.55-2.48 (8H, s, 4 x $-CH_2-$), 1.94-1.85 (2H, m, $-CH_2-$); δ_C (100 MHz, $CDCl_3$): 132.5, 119.4, 68.3, 40.9, 40.0, 16.4; *m/z* (ESI+) 215.0 (M+Na). HRMS Found 215.1039 ($[M+Na]^+$) ($C_{12}H_{16}O_2Na$ requires 215.1043 ($[M+Na]^+$)).

Spiro[4,5]dec-2-ene-6,10-dione 15c (SRC 408).

This is a known compound and the method is based on a reported synthesis.[12a]

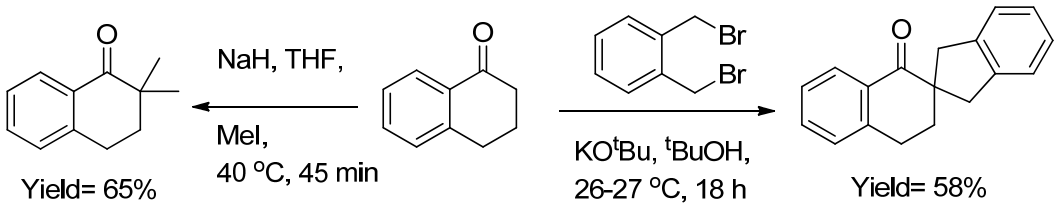
To a solution of 2,2-di(prop-2-en-1-yl)cyclohexane-1,3-dione (0.300 g, 1.562 mmol) in dry DCM (18 mL) was added Grubb's Catalyst 1st generation (66 mg, 5.15 mol%) under an inert atmosphere. The solution was stirred at 22-23 °C for 27 h. during which time the colour of the reaction changed from purple to brown. The reaction mixture was concentrated on a rotary evaporator to give a crude residue. The crude compound was purified by column chromatography using hexane: ethyl acetate (92:8) to give spiro[4,5]dec-2-ene-6,10-dione **15c** as white solid (0.207 g, 1.262 mmol, 80%). Mp 58-60 °C; ν_{max} 3053, 2913, 1723, 1687, 1434, 1340, 1320, 1262, 1114, 1011, 912 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 5.54 (2H, m, -C*H*=C*H*), 2.87 (4H, m, -CH_2-CH=CH-CH_2-), 2.72 (4H, br t, *J* 7.5, -CH_2-CO-), 2.04-1.95 (2H, m, -CH_2-); δc (75 MHz, $CDCl_3$) 207.03, 127.02, 39.08, 37.54, 17.48; m/z ESI-MS $[M+Na]^+$ 187.2; HRMS found 187.0721 ($C_{10}H_{12}O_2Na$ requires 187.0730, error = 4.4 ppm).

Spiro[4,5]decane-6,10-dione 15b (SRC 409/SRC 490).

This is a known compound.[13]

A solution of spiro[4,5]dec-2-ene-6,10-dione (0.100 g, 0.610 mmol) in dry methanol (10 mL) containing Pd/C (10 % on carbon) (65 mg) under atmospheric pressure of hydrogen at 21-22 °C was stirred for 18 h. The reaction mixture was filtered through celite and filtrate was concentrated on a rotary evaporator to give a crude residue. The crude compound was purified by column chromatography using hexane: ethyl acetate (90:10) to give spiro[4,5]decane-6,10-dione **15b** as a colourless oil (0.100 g, 0.602 mmol, 99%). ν_{max} 2954, 2870, 1722, 1689, 1448, 1314, 1273, 1031 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 2.67 (4H, t, *J* 6.0, -CH_2CO-), 2.08-2.03 (4H, m,-C(C*H*)$_2$-), 2.00-1.93 (2H, m, -CH_2-CH_2CO-), 1.69-1.65 (4H, m,-CH_2-CH_2-); δc (75 MHz, $CDCl_3$) 208.62,72.49, 37.91, 33.17, 26.42, 17.70.

Synthesis of α-tetralone derivative 17a-b:



2,2-Dimethyl-3,4-dihydronaphthalen-1(2H)-one (SRC 670).

This is a known compound and the method is based on a reported synthesis.[14]

To a suspension of NaH (0.957 g, 23.94 mmol, 3.54 eq) into THF (25 mL) was added solution of α-tetralone (1.0 g, 6.840 mmol) in THF (2.5 mL). The reaction mixture was stirred for 15 min. To this, iodomethane (1.49 mL, 23.94 mmol, 3.54 eq) was added drop wise. The resulting mixture was stirred at 40 ^{o}C for 45 min. The reaction mixture was cooled to room temperature and then in ice cold water. The reaction mixture was quenched by slow addition of water. The mixture was diluted with water (50 mL) and extracted with ethyl acetate (2 x 50 mL). The combined organic layer was washed with water, brine soln, dried over anhydrous Na_2SO_4, filtered and evaporated to give a crude oil. The oil was purified by column chromatography using hexane:ethyl acetate (90:10) to give 2,2-dimethyl-3,4-dihydronaphthalen-1(2H)-one as an oil (0.780 g, 4.483 mmol, 65 %). δ_H (300 MHz, $CDCl_3$) 8.04 (1H, dd, *J* 1.3, 7.0, -CH of -C_6H_4-), 7.45 (1H, dt, *J* 1.5, 7.3 -CH of -C_6H_4-), 7.30 (1H, t, *J* 7.5, -CH of -C_6H_4-), 7.22 (1H, d, *J* 8.1, -CH of -C_6H_4-), 2.98 (2H, t, *J* 6.4, -CH_2-C_6H_4-), 1.98 (2H, d, *J* 6.4, -CH_2CO-), 1.22 (6H, br s, -C(CH_3)$_2$-); δc (300 MHz, $CDCl_3$) 143.35, 132.95, 131.37, 128.63, 127.93, 126.54, 41.56, 36.55, 25.65, 24.31(2C).

1,3,3',4'-Tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-one 17 (SRC 546 a).

This is a known compound[15] and the method used is same as for 1',3'- Dihydro-2H-spiro[cyclohexane-1,2'-inden]-2-one.[6]

To a mixture of KO^{t}Bu (0.426 g, 3.80 mmol, 2.22 eq) in dry ^{t}BuOH (10 mL) was added α-tetralone (0.250 g, 1.710 mmol) under an inert atmosphere and the resulting solution was stirred at 26-27 ^{o}C for 10-15 min. To this mixture, α,α'-dibromo xylene (0.451 g, 1.710 mmol, 1.0 eq) was added and resulting mixture was stirred at 26-27 ^{o}C for 18 h. The reaction mixture was concentrated on a rotary evaporator to give a residue. The residue was diluted with water (10 mL) and 15% HCl (10 mL). The mixture was extracted with DCM (3 x 50 mL). The combined organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated to give a crude residue. The oil was purified by column chromatography using hexane: ethyl acetate (94:6) to give 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-one **17** as a white solid (0.250 g, 1.008 mmol, 58%). Mp 88-90 ^{o}C; ν_{max} 3346, 3071, 2921, 2842, 1764, 1668, 1599, 1486, 1455, 1427, 1231, 1226, 1155, 906, 749, 739, 715 cm^{-1}; δ_H (300

MHz, $CDCl_3$) 8.05 (1H, dd, *J* 6.0, 1.2, -CH of -C_6H_4-), 7.48 (1H, dt, *J* 6.0, 1.2, -CH of -C_6H_4-), 7.32 (1H, t, *J* 3.0, -CH of -C_6H_4-), 7.25 (1H, t, *J* 3.0, -CH of -C_6H_4-), 7.20-7.15 (4H, m, -CH of -C_6H_4-), 3.49 (2H, d, *J* 12.0, -C*H*H-C_6H_4-C*H*H-), 3.08 (2H, t, *J* 4.5, -CH_2-CH_2-C_6H_4-), 2.97 (2H, d, *J* 12.0, -CH*H*-C_6H_4-CH*H*-), 2.22 (2H, t, *J* 4.5, -CH_2-CO); δc (300 MHz, $CDCl_3$) 143.30, 141.10(2C), 133.22, 131.59, 128.68, 128.18, 126.71, 126.59(2C), 124.57(2C), 53.50, 41.31(2C), 33.86, 26.08; m/z ESI-MS $[M+Na]^+$ 271.1; HRMS found 271.1093 ($C_{18}H_{16}ONa$ requires 271.1093, error = -0.1 ppm).

Asymmetric transfer hydrogenation:

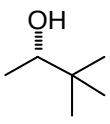
General procedure for asymmetric transfer hydrogenation of 1,3-diketone derivatives:

A mixture of catalyst (2 mol%) in FA:TEA (5:2) (0.3 mL) was stirred at 28 ^oC under an inert atmosphere in a Schlenk tube. To this, ketone (0.3 mmol) was added and the resulting mixture was stirred at 28 ^oC for 21-91 h under an inert atmosphere. The completion of reaction was confirmed by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to EtOAc. The filtrate was concentrated to give a crude alcohol. The crude compound was purified by flash column chromatography.

General procedure for asymmetric transfer hydrogenation of ketone derivatives:

A mixture of catalyst (1 mol%) in FA:TEA (5:2) (0.15 mL) was stirred at 28 ^oC under an inert atmosphere in a Schlenk tube. To this, ketone (0.3 mmol) was added and stirred at 28-45 ^oC for 9-47 h under an inert atmosphere. The completion of reaction was confirmed by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to EtOAc. The filtrate was concentrated to give a crude alcohol. The crude compound was purified by flash column chromatography.

(*S*)-3,3-Dimethylbutan-3-ol (SRC 543/544/645).

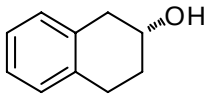


This compound is known and fully characterized.[16]

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (6.2 mg, 0.010 mmol, 1 mol%) in FA:TEA (5:2) (0.500 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 3,3-dimethylbutan-3-one (0.100 g, 1.00 mmol) was added and stirred at 30 ^{o}C for 24 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give 3,3-dimethylbutan-3-ol as colourless oil (0.055 g, 0.539 mmol, 56%). $[\alpha]_D^{22}$ = +2.1 (*c* 0.750 in $CHCl_3$) [lit. value $[\alpha]_D$ = +31.0 (*c* 1.0 in $CHCl_3$) 60% ee (*S*)][17]; δ_H (300 MHz, $CDCl_3$) 3.51-3.43 (1H, m, -C*H*OH-), 1.40 (1H, d, *J* 4.0, -CHO*H*-), 1.12 (3H, d, *J* 6.0, -CHOH-CH_3), 0.89 (6H, s, -C(CH_3)$_3$); δc (75 MHz, $CDCl_3$) 75.63, 34.87, 25.38(3C), 17.86; the enantiomeric excess was determined by Chiral GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 70 ^{o}C, Injection temperature 220 ^{o}C, Detection temperature 220 ^{o}C, Gas Helium, Pressure 15 psi) R_t (min) = 19.513 min (minor enantiomer *R*), 20.237 min (major enantiomer *S*), %ee = 10% (*S*).

The racemic standard was prepared by $NaBH_4$ reduction.

(*R*)-β-Tetralol 6a (SRC 521).

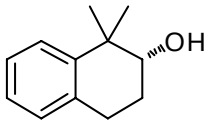


This is a known compound.[17]

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (2.1 mg, 0.00342 mmol, 1 mol%) in FA:TEA (5:2) (0.171 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, β-tetralone (0.050 g, 0.342 mmol) was added and the solution was stirred at 28 ^{o}C for 30 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.050 g). The crude compound was purified by flash column chromatography to give pure alcohol **6a** as a light brown oil (0.045 g, 0.304 mmol, 88%). $[\alpha]_D^{23}$ = +52.7 (*c* 0.370 in $CHCl_3$) [lit. value $[\alpha]_D^{23}$ = -51.4 (*c* 0.70 in $CHCl_3$) 82% ee (*S*)][17]; ν_{max} 3338, 3018, 2925, 2842, 1495, 1452, 1437, 1360, 1290, 1231, 1111, 1037, 962, 741 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.14-7.06 (4H, m, -CH of -C$_6H_4$-), 4.20-4.11 (1H, m, -C*H*OH), 3.12-3.06 (1H, dd, *J* 15.0, 3.0, -C$_6$H$_4$-

CH*H*CHOH), 3.01-2.84 (2H, m, -C*H*$_2$-C$_6$H$_4$-), 2.81-2.73 (1H, dd, *J* 18.0, 6.0, -C$_6$H$_4$-C*H*$_2$CHOH), 2.11-2.01 (1H, m, -C*H*HCHOH), 1.88-1.76 (1H, m, -CH*H*CHOH), 1.71 (1H, br s, -O*H*); δc (75 MHz, $CDCl_3$) 135.62, 134.20, 129.50, 128.58, 125.96, 125.84, 67.23, 38.38, 31.47, 26.95; m/z ESI-MS $[M+Na]^+$ 171.2; HRMS found 171.0777 ($C_{10}H_{12}ONa$ requires 171.0780, error = 2.1 ppm); the enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 95:5, 0.50mL/min, 254 nM, 19^{o}C) Rt (min) = 17.390 (minor enantiomer, *S*), 18.791 min (major enantiomer, *R*), %ee= 88%.
The racemic standard was prepared by $NaBH_4$ reduction.

(*R*) 1,1-Dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol 6b (SRC 539).



The racemic compound is known.[18]

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (1.8 mg, 0.00287 mmol, 1 mol%) in FA:TEA (5:2) (0.150 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 1,1-dimethyl-3,4-dihydronaphthalen-2(1H)-one (0.050 g, 0.287 mmol) was added and the solution stirred at 28 ^{o}C for 9 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.050 g). The crude compound was purified by flash column chromatography to give pure alcohol **6b** as a colourless oil (0.045 g, 0.255 mmol, 89%). $[\alpha]_D^{21}$ = +23.48 (*c* 0.445 in $CHCl_3$); ν_{max} 3370, 2967, 2937, 1489, 1446, 1383, 1361, 1286, 1038, 758, 727 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.36-7.33 (1H, m, -C*H* of -C$_6$H$_4$-,), 7.20-7.05 (3H, m, -C*H* of -C$_6$H$_4$-), 3.77 (1H, dd, *J* 9.0, 3.0, -C*H*OH-), 3.01-2.80 (2H, m, C$_6$H$_4$-C*H*$_2$-), 2.13 (1H, br s, -O*H*), 2.08-1.87 (2H, m, -C*H*$_2$-CHOH-), 1.34 (3H, s, -CH_3), 1.29 (3H, br s, -CH_3); δc (75 MHz, $CDCl_3$) 144.17, 134.46, 128.71, 126.85, 126.16, 125.66, 75.60, 39.08, 28.93, 26.98, 26.78, 24.98; m/z ESI-MS $[M+Na]^+$ 199.2; HRMS found 199.1089 ($C_{12}H_{16}ONa$ requires 199.1093, error = 2.2 ppm); the enantiomeric excess by using Chiral GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 150 ^{o}C, Injection temperature 220 ^{o}C, Detection temperature 220 ^{o}C, Gas Hydrogen, Pressure 15 psi) R_t (min) = 28.643 min (minor enantiomer), 28.820 min (major enantiomer), %ee = 94%.

The racemic standard was prepared by $NaBH_4$ reduction.

Mosher's ester of (*R*) 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol 6b (SRC 676).

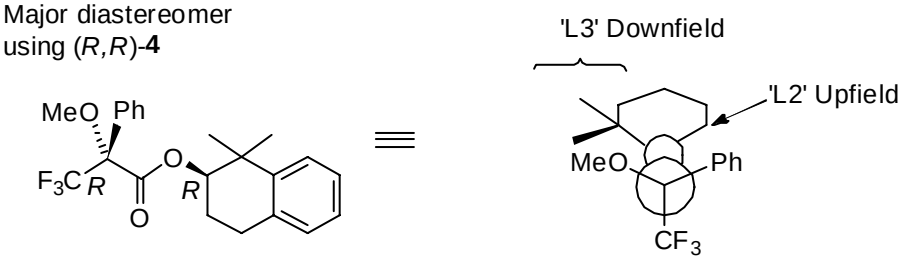
To a solution of 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol (5 mg, 0.0284 mmol) in dry DCM (2 mL) was added TEA (0.008 mL, 0.057 mmol, 2.0 eq) and DMAP (1 mg). The solution was added (*S*)-(+)-MTPA-Cl (0.0066 mL, 0.0355 mmol, 1.25 eq) at 0 ^{o}C. The resulting solution was stirred at room temperature for 18 h. The completion of the reaction was checked by TLC. The reaction mixture was concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (90:10) to give the product as an oil (6 mg). The compound was analyzed by ^{1}H-NMR.

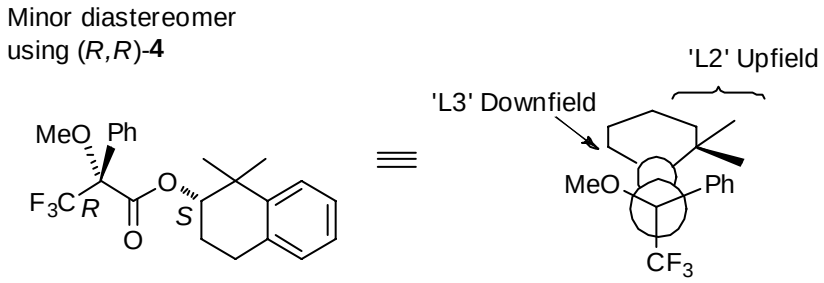
Mosher's ester of racemic 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol (SRC 678)

The compound was prepared similarly as described for Mosher's ester of (*R*) 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol.

Mosher's method[19]:

We used the (*S*)-(+)-MTPA-Cl (derived from the (*R*)-acid) which gives the (*R*)-configuration ester. The two diastereoisomers which can form are shown below. [19] The Mosher model predicts that these isomers will adopt the conformations shown below:





Using the notation from Mosher's paper,[19] the protons at positions 'L3' will be downfield of those at position 'L2'. The major enantiomer from the reduction reaction gave the *R,R*-Mosher ester. In order to compare the relative positions of the key peaks, the racemic alcohol was reacted with (*S*)-(+)-MTPA-Cl to give a mixture of *R,R* and *R,S* isomers for comparison.

1H NMR (key peaks) of Mosher's ester of alcohol from (1*R*,2*R*) 3C-teth-Ru complex

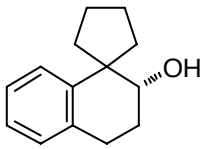
L2= 2.17-1.97 (2H, m, -C*H*$_2$-CHOH-); L3= 1.33 (3H, s, -CH$_3$), 1.26 (3H, br s, -CH$_3$),

1H NMR (key peaks) of other diastereoisomer of Mosher's ester of racemic alcohol

L3= 2.21-2.06 (2H, m, -C*H*$_2$-CHOH-); L2= 1.27 (3H, s, -CH$_3$), 1.19 (3H, br s, -CH$_3$),

The relative positions of the L2 and L3 peaks indicates that the *R*-alcohol was formed predominantly. The spectra are shown in the spectroscopy section.

(*R*)-3',4'-Dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-ol 6c (SRC 558).

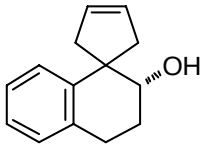


The racemic compound is known.[8]

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (3.1 mg, 0.005 mmol, 1 mol%) in FA:TEA (5:2) (0.250 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 3',4'-dihydro-spiro[cyclopentane-1,1'-[2H]-naphthalene]-2'-one (0.100 g, 0.500 mmol) was added and the solution was stirred at 28 ^{o}C for 18 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **6c** as white solid (0.090 g, 0.445 mmol, 89%). Mp 72-74 ^{o}C; $[\alpha]_D^{21}$ = -34.66 (*c* 0.225 in $CHCl_3$); ν_{max} 3348, 3055, 3022, 2954, 2937, 2871, 1574, 1488, 1426, 1295, 1187, 1067, 945, 756, 709 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.27-7.24 (1H, m, -CH of -C$_6$H$_4$-), 7.18-7.04 (3H, m, -CH of -C$_6$H$_4$-), 3.80 (1H, dd, *J* 9.0, 3.0, -C*H*OH), 3.06-2.95 (1H, m, -C*H*H-C$_6$H$_4$-), 2.85-2.77 (1H, m, -CH*H*-C$_6$H$_4$-), 2.16-1.78 (10H, m, -C*H*$_2$-CHOH and-(C*H*$_2$)$_4$-), 1.55 (1H, br s, -O*H*); δc (75 MHz, $CDCl_3$) 144.87, 134.65, 128.54, 127.50, 126.27, 125.46, 74.38, 51.14, 41.83, 37.10, 27.53, 27.22, 26.67, 25.57; m/z ESI-MS $[M+Na]^+$ 225.2; HRMS found 225.1250 ($C_{14}H_{18}ONa$ requires 225.1250, error = -0.4 ppm); The enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 98:2, 0.50mL/min, 254 nM, 12^{o}C) Rt (min) = 30.979 (minor enantiomer), 33.814 min (major enantiomer), %ee= 99%.

The racemic standard was prepared by $NaBH_4$ reduction.

(*R*) 3',4'-Dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol 6d (SRC 550).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (3.13 mg, 0.00505 mmol, 1 mol%) in FA:TEA (5:2) (0.250 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-one (0.100 g, 0.505 mmol) was added and the solution was stirred at 28 ^{o}C for 20 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **6d** as a white solid (0.090 g, 0.450 mmol, 89%). Mp 84-86 ^{o}C; $[\alpha]_D^{21}$ = +38.8 (*c* 0.350 in $CHCl_3$); ν_{max} 3347, 3062, 2937, 2851, 1624, 1488, 14532, 1426, 1344, 1283, 1243, 1185, 1085, 1059, 946, 936, 923, 754, 732, 702, 668 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.27-7.24 (1H, m, -CH of -C_6H_4-), 7.17-7.03 (3H, m, -CH of -C_6H_4-), 5.79 (2H, m, -C*H*=C*H*-), 3.90 (1H, dd, *J* 9.0, 3.0, -C*H*OH), 3.02-2.76 (3H, m, -CH_2-C_6H_4- and -C*H*H-CH=CH-CH_2-), 2.73-2.67 (2H, m, -CHH-CH=CH-CH_2-), 2.48-2.39 (1H, m, -CH_2-CH=CH-CH*H*-), 2.04-1.84 (2H, m, -CH_2-CHOH-), 1.67 (1H, br s, -O*H*); δc (75 MHz, $CDCl_3$) 145.70, 133.71, 130.17, 129.37, 128.38, 126.77, 126.70, 125.74, 75.05, 49.51, 48.38, 44.28, 27.92, 27.00; m/z ESI-MS $[M+Na]^+$ 223.2; HRMS found 223.1088 ($C_{14}H_{16}ONa$ requires 223.1093, error = 2.5 ppm); the enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 98:2, 0.50mL/min, 254 nM, 15^{o}C) Rt (min) = 30.385 (minor enantiomer), 34.728 min (major enantiomer), %ee= 99%.
The racemic standard was prepared by $NaBH_4$ reduction.

Mosher's ester of (*R*) 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol 6d (SRC 565).

To a solution of (*R*) 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol (10 mg, 0.050 mmol) in dry DCM (2 mL) was added TEA (0.014 mL, 0.100 mmol, 2.0 eq) and

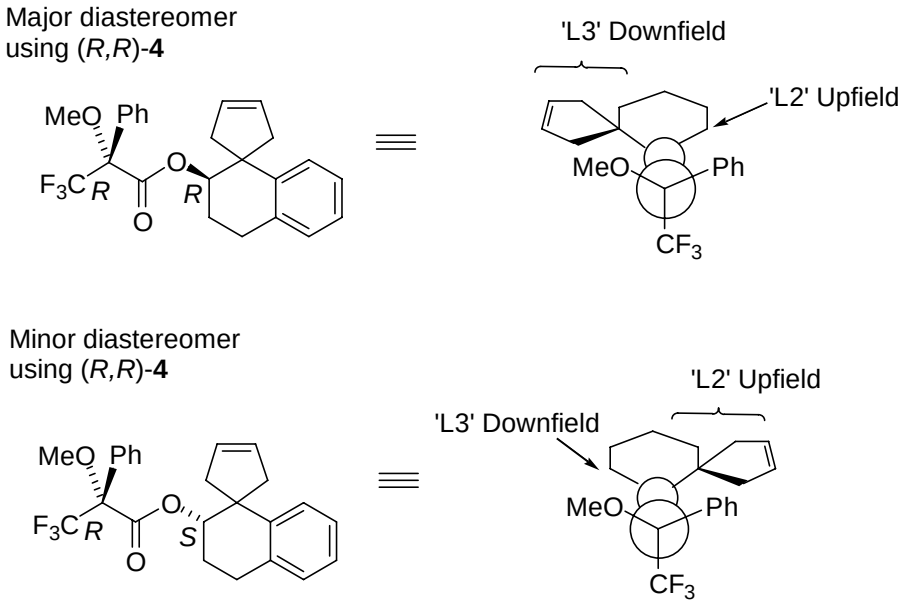
DMAP (1 mg). The solution was added (*S*)-(+)-MTPA-Cl (0.014 mL, 0.075 mmol, 1.5 eq) at 0 ^{o}C. The resulting solution was stirred at rt for 18 h. The completion of the reaction was checked by TLC. The reaction mixture was concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (95:5) to give the product as an oil (8 mg). The compound was analyzed by 1H-NMR.

Mosher's ester of racemic 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol (SRC 566)

The compound was prepared similarly as described for Mosher's ester of (*R*) 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol.

Mosher's method[19]:

We used the (*S*)-(+)-MTPA-Cl (derived from the (*R*)-acid) which gives the (*R*)-configuration ester. The two diastereoisomers which can form are shown below.[19] The Mosher model predicts that these isomers will adopt the conformations shown below:



Using the notation from Mosher's paper,[19] the protons at positions 'L3' will be downfield of those at position 'L2'. The major enantiomer from the reduction reaction gave the *R,R*-Mosher ester. In order to compare the relative positions of the key peaks, the racemic alcohol was reacted with (*S*)-(+)-MTPA-Cl to give a mixture of *R,R* and *R,S* isomers for comparison.

1H NMR (key peaks) of Mosher's ester of alcohol from (1*R*,2*R*) 3C-teth-Ru complex

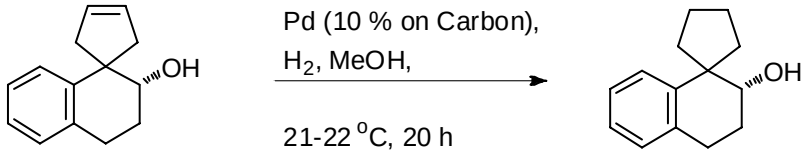
L2= 2.11-1.93 (2H, m, -C*H*$_2$-CHOH-); L3= 2.73-2.67 (2H, m, -CHH-CH=CH-C*H*$_2$-),

1H NMR (key peaks) of other diastereoisomer of Mosher's ester of racemic alcohol

L3= 2.17-2.09 (2H, m, -CH_2-CHOH-); L2= 2.61-2.58 (2H, m, -CHH-CH=CH-CH_2-),

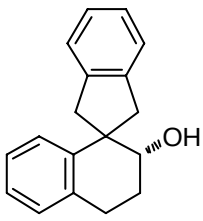
The relative positions of the L2 and L3 peaks indicates that the *R*-alcohol was formed predominantly. The spectra are shown in the spectroscopy section.

(*R*) 3',4'-Dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-ol 6c by Pd/C hydrogenation of 6d (SRC 560) to confirm that both were of the same configuration.



A solution of (*R*) 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol (99% ee) **6d** (0.010 g, 0.05 mmol) in dry methanol (2 mL) containing added Pd/C (10 % on carbon) (5 mg) under atmospheric pressure of hydrogen at 21-22 ^{o}C, was stirred for 20 h. The reaction mixture was filtered through celite and the filtrate was concentrated on a rotary evaporator to give (*R*) 3',4'-Dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-ol **6c** (0.010 g, 0.049 mmol, 99%). The enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 98:2, 0.50mL/min, 254 nM, 12^{o}C) Rt (min) = 30.979 (minor enantiomer), 34.079 min (major enantiomer), %ee= 99%.

(*R*)-1,3,3',4'-Tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-ol 6e (SRC 549).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (2.5 mg, 0.00403 mmol, 1 mol%) in FA:TEA (5:2) (0.200 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube.

To this, 1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-one (0.100 g, 0.403 mmol) was added and the solution was stirred at 30 ^{o}C for 24 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **6e** as white solid (0.090 g, 0.360 mmol, 89%). Mp 90-92 ^{o}C; $[\alpha]_D^{21}$ = -40.71 (*c* 0.350 in $CHCl_3$); ν_{max} 3570, 2934, 2872, 2832, 1486, 1455, 1216, 1110, 1079, 995, 759, 751, 729 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.23-7.18 (4H, m, 4 -CH of -C_6H_4-), 7.10-7.05 (2H, m, 2-CH of -C_6H_4-), 7.03-6.97 (2H, m, 2-CH of -C_6H_4-), 4.06-3.96 (1H, m, -C*H*OH), 3.58 (1H, d, *J* 18.0, -C*H*H-C_6H_4-CHH-), 3.31 (1H, d, *J* 15.0, -CH_2-C_6H_4-C*H*H-), 3.16 (1H, d, *J* 15.0, -CHH-C_6H_4-CH*H*-), 3.11 (1H, d, *J* 18.0, -CH*H*-C_6H_4-CH_2), 3.08-3.00 (1H, m, -C*H*H-C_6H_4-), 2.95-2.84 (1H, m, -CH*H*-C_6H_4-), 2.14-1.95 (2H, m, -CH_2CHOH-), 1.64 (1H, br d, -OH); δc (75 MHz, $CDCl_3$) 144.19, 142.87, 142.06, 133.85, 128.70, 126.67, 126.52(2C), 126.47, 126.03, 124.38, 124.33, 74.37, 50.85, 47.36, 43.61, 27.67, 26.08; m/z ESI-MS $[M+Na]^+$ 273.2; HRMS found 273.1252 ($C_{18}H_{18}ONa$ requires 273.1250, error = -1.1 p); the enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 98:2, 0.50mL/min, 254 nM, 23^{o}C) Rt (min) = 52.365 (minor enantiomer), 54.326 min (major enantiomer), %ee= 99%.

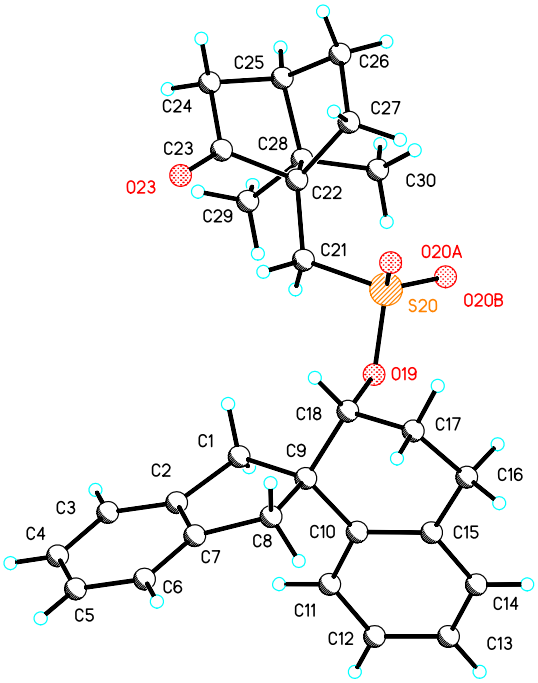
The racemic standard was prepared by $NaBH_4$ reduction.

(1*S*)-(+)-10 camphorsulfonyl ester derivative 7 of 1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-ol 6e (SRC 553).

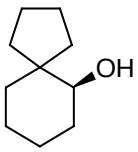
To a solution of 1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-ol **6e** (50 mg, 0.200 mmol) in dry DCM (4 mL) was added TEA (0.055 mL, 0.400 mmol, 2.0 eq) and DMAP (0.5 mg, 0.02 eq). To the solution was added (*S*)-(+)-10-camphorsulfonyl chloride (0.075 g, 0.300 mmol, 1.5 eq) at 0 ^{o}C. The resulting solution was stirred at rt overnight. The completion of reaction was checked by TLC. The reaction mixture was diluted with water (10 mL) followed by extraction with DCM (2 x 10 mL). The combined organic layers were washed with 1 M HCl (2 x 10 mL), sat. NaHCO3 (2 x 10 mL) and brine (10 mL). The organic layer was dried over anhydrous Na_2SO_4, filtered and concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (90:10) to give compound **7** as a colourless oil (0.060 g, 0.129 mmol, 64%). The oil converted into a solid on standing. The solid was recrystallized from n-

pentane: diethyl ether to give crystals for X-ray analysis. Mp 126-128 ^{o}C; $[\alpha]_D^{26}$ = + 5.93 (*c* 0.295 in $CHCl_3$); ν_{max} 2967, 2909, 1746, 1488, 1351, 1361, 1712, 1059, 905, 888, 828, 745 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.24-7.17 (4H, m, 4 -CH of -C_6H_4-), 7.10-7.07 (2H, m, 2-CH of -C_6H_4-), 7.03-6.98 (2H, m, 2-CH of -C_6H_4-), 5.16 (1H, dd, *J* 6.0, 3.0, -C*H*OH), 3.56 (1H, d, *J* 12.0, -C*H*H-C_6H_4-CHH-), 3.53 (1H, d, *J* 9.0, -SO_2-C*H*H-), 3.35 (1H, d, *J* 12.0, -CHH-C_6H_4-C*H*H-), 3.22 (1H, d, *J* 12.0, -CHH-C_6H_4-CH*H*-), 3.19 (1H, d, *J* 12.0, -CH*H*-C_6H_4-CHH-), 3.15-3.07 (1H, m, -C*H*H-C_6H_4-), 2.99-2.94 (1H, m, -CH*H*-C_6H_4-), 2.93 (1H, d, *J* 9.0, -SO_2-CH*H*-), 2.43-2.17 (4H, m, -C*H*$_2$CHOSO_2-, Cam -CH_2), 2.05 (1H, t, *J* 3.0, Cam -CH_2), 1.99-1.90 (1H, m, Cam -CH_2), 1.87 (1H, d, *J* 12.0, Cam -CH_2), 1.51-1.44 (1H, m, Cam -CH_2), 1.34-1.28 (1H, m, Cam -CH_2), 1.03 (3H, s, Cam -CH_3), 0.82 (3H, s, Cam -CH_3); δc (75 MHz, $CDCl_3$) 214.13, 143.15, 142.24, 141.14, 133.28, 128.61, 126.87, 126.71, 126.65, 126.33, 125.91, 124.48, 124.49, 84.89, 57.92, 49.72, 48.36, 47.80, 47.68, 44.81, 42.70, 42.38, 26.81, 26.34, 25.98, 24.74, 19.80, 19.65; m/z ESI-MS $[M+Na]^+$ 487.0; HRMS found 487.1933 ($C_{28}H_{32}O_4SNa$ requires 487.1914, error = -3.6 ppm).

X-ray crystalographic data for (R)-7 **('RS7')**; CCDC no. 817154, $C_{28}H_{32}O_4S$, M = 464.60, Orthorhombic, space group P2(1)2(1)2(1), a = 7.43712(9), b = 8.62914(9), c = 36.4793(4) Å , α = 90˚, β = 90˚, γ = 90˚, U = 2341.09(5) Å^3 (by least squares refinement on 26920 reflection positions), T =100(2) K, λ = 1.54184 Å, Z = 4, D(cal) = 1.318 Mg/m^3, F(000) = 992. mu(MoK-α) = 1.491 mm^{-1}. Crystal character: colourless block. Crystal dimensions 0.20 x 0.16 x 0.08 mm. Further details are given in the SI.



(*S*)-Spiro[4,5]decane-6-ol 10 (SRC 485) .



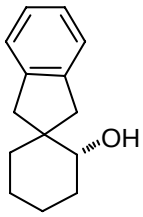
The racemic compound is known.[20]

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (4.08 mg, 0.0066 mmol, 1 mol%) in FA:TEA (5:2) (0.329 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, spiro[4,5]decane-6-one (0.100 g, 0.658 mmol) was added and stirred at 28 ^{o}C for 22 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **10** as a white solid (0.095 g, 0.616 mmol, 93%). Mp 32-34 ^{o}C; $[\alpha]_D^{26}$ = -14.1 (*c* 0.500 in $CHCl_3$);ν_{max} 3284, 2927, 2857, 1447, 1342, 1139, 1065, 1050, 981, 892, 729 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 3.45-3.42 (1H, m, -C*H*OH-), 1.75-1.15 (17H, m, 16H of -CH_2-, 1H of -OH); δc (75 MHz, $CDCl_3$) 75.75, 36.82,

35.75, 31.81, 25.78, 25.47, 22.93, 22.52; m/z ESI-MS $[M+Na]^+$ 177.2; HRMS found 177.1255 ($C_{10}H_{18}ONa$ requires 177.1250, error = -2.6 ppm); the enantiomeric excess was determined by Chiral GC for acetate derivative GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 115 ^oC, Injection temperature 220 ^oC, Detection temperature 220 ^oC, Gas Hydrogen, Pressure 15 psi) R_t (min) = 39.067 min (minor enantiomer), 40.613 min (major enantiomer), %ee = 71%.

$NaBH_4$ reduction failed in an attempt to prepare racemic standard. The opposite enantiomer was prepared by using (1*S*,2*S*) 3C-teth-Ru complex for the GC comparison.

(*R*) 1',3'-Dihydrospiro[cyclohexane-1,2'-inden]-2-ol 11 (SRC 497).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (3.1 mg, 0.005 mmol, 1 mol%) in FA:TEA (5:2) (0.250 mL) was stirred at 28 ^oC under an inert atmosphere in a Schlenk tube. To this, 1',3'- dihydro-2H-spiro[cyclohexane-1,2'-inden]-2-one (0.100 g, 0.500 mmol) was added and the solution was stirred at 28 ^oC for 22 h under an inert atmosphere. The completion of the reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **11** as a colourless oil (0.095 g, 0.570 mmol, 94%). $[\alpha]_D^{26}$ = -6.4 (*c* 0.250 in $CHCl_3$); ν_{max} 3391, 3021, 2926, 2857, 1697, 1484, 1448, 1300, 1222, 1060, 1029, 751, 729 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.19-7.10 (4H, m, -CH of -C_6H_4-), 3.65-3.62 (1H, m, -C*H*OH-), 3.12 (1H, d, *J* 18.0, -C*H*H-C_6H_4-CHH-), 3.07 (1H, d, *J* 15.0, - CHH-C_6H_4-C*H*H-), 2.71 (1H, d, *J* 18.0, -CH*H*-C_6H_4-CHH-), 2.66 (1H, d, *J* 15.0, -CHH-C_6H_4- CH*H*-), 1.83-1.66 (3H, m, -CH_2-), 1.57-1.25 (6H, m, -CH_2-, -O*H*); δc (75 MHz, $CDCl_3$) 142.66, 142.17, 126.14, 126.08, 124.76, 124.59, 75.27, 48.38, 43.35, 38.47, 35.22, 31.55, 23.01, 22.18; m/z ESI-MS $[M+Na]^+$ 225.2; HRMS found 225.1250 ($C_{14}H_{18}ONa$

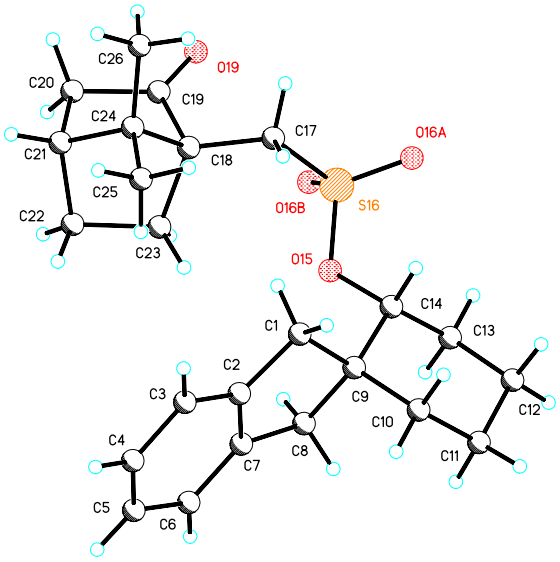
requires 225.1250, error = -0.4 ppm); the enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 90:10, 0.50mL/min, 254 nM, 24^{o}C) Rt (min) = 14.014 (major enantiomer), 15.715 min (minor enantiomer), %ee= 93%.
The racemic standard was prepared by $LiAlH_4$ reduction.

(1*S*)-(+)-10 camphorsulfonyl ester derivative 12 of 1',3'-dihydrospiro[cyclohexane-1,2'-inden]-2-ol, (SRC 503/510)

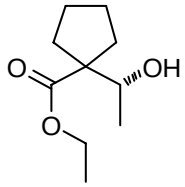
To a solution of 1',3'-dihydro-spiro[cyclohexane-1,2'-inden]-2-ol **11** (100 mg, 0.495 mmol) in dry DCM (5 mL) was added TEA (0.172 mL, 1.238 mmol, 2.5 eq) and DMAP (1.2 mg, 0.02 eq). To the solution was added (*S*)-(+)-10-camphorsulfonyl chloride (0.186 g, 0.742 mmol, 1.5 eq) at 0 ^{o}C. The resulting solution was stirred at rt overnight. The completion of the reaction was checked by TLC. The reaction mixture was diluted with water (15 mL) followed by extraction with DCM (2 x 15 mL). The combined organic layers were washed with 1 M HCl (2 x 10 mL), sat. $NaHCO_3$ (2 x 10 mL) and brine (10 mL). The organic layer was dried over anhydrous. Na_2SO_4, filtered and concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (84:16) to give compound **12** as an oil (0.100 g, 0.240 mmol, 48%). The oil converted into a solid on standing. The solid was recrystallized from n-pentane: diethyl ether to give crystals for X-ray analysis. Mp 118-120 ^{o}C; $[\alpha]_D^{21}$ = + 15.51 (*c* 0.290 in $CHCl_3$); ν_{max} 2945, 1741, 1486, 1393, 1347, 1280, 1165, 941, 900, 872, 736 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.18-7.08 (4H, m, -CH of -C_6H_4-), 3.65-3.62 (1H, dd, *J* 9.0, 3.0, -C*H*OH-), 3.49 (1H, d, *J* 15.0, -SO_2-C*H*H-), 3.14 (1H, d, *J* 15.0, -C*H*H-C_6H_4-CHH-), 3.10 (1H, d, *J* 18.0, - CHH-C_6H_4-CH*H*-), 2.86 (1H, d, *J* 15.0, -SO_2-CH*H*-), 2.77 (1H, d, *J* 18.0, -CHH-C_6H_4-CH*H*-), 2.75 (1H, d, *J* 15.0, -CH*H*-C_6H_4- CHH-), 2.44-2.31 (2H, m, Cam -CH_2), 2.07 (1H, t, *J* 4.5, Cam -CH_2), 2.02-1.83 (4H, m, -C*H*$_2$-$CHOSO_2$-, Cam -CH_2), 1.80-1.70 (2H, m, -C*H*$_2$-CH_2-$CHOSO_2$-), 1.55-1.30 (6H, m, 4H of -C-C*H*$_2$-C*H*$_2$-, 2H of Cam -CH_2), 1.05 (3H, s, Cam -CH_3), 0.8 (3H, s, Cam -CH_3); δc (75 MHz, $CDCl_3$) 214.27, 141.84, 141.46, 126.28, 124.64, 86.29, 57.93, 48.29, 47.82, 47.52, 43.27, 42.69, 42.43, 39.80, 35.30, 29.88, 26.85, 24.77, 22.70, 21.65, 19.86, 19.66; m/z ESI-MS $[M+Na]^+$ 439.1; HRMS found 439.1923 ($C_{24}H_{32}O_4SNa$ requires 439.1914, error = -2.2 ppm).

X-ray crystallographic data for (*R*)-**12 ('RS5')**; CCDC no. 817152, $C_{24}H_{32}O_4S$, M = 416.56, Monoclinic, space group P2(1), a = 9.9752(2), b = 10.52392(16), c = 11.2107(2) Å , α = 90˚, β

= 116.107(3)˚, γ = 90˚, U = 1056.81(3) Å^3 (by least squares refinement on 14569 reflection positions), T =100(2) K, λ = 0.71073 Å, Z = 2, D(cal) = 1.309 Mg/m^3, F(000) = 448. mu(MoK-α) = 0.181 mm^{-1}. Crystal character: colourless block. Crystal dimensions 0.50 x 0.30 x 0.30 mm. Full details are given in the cif file.



(*R*) Ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a (SRC 483).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (3.4 mg, 0.00543 mmol, 1 mol%) in FA:TEA (5:2) (0.270 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, ethyl 1-acetylcyclopentanecarboxylate (0.100 g, 0.543 mmol) was added and the solution was stirred at 30 ^{o}C for 47 h under an inert atmosphere. The completion of the reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography

to give pure alcohol **14a** as a colourless oil (0.095 g, 0.510 mmol, 94%). $[\alpha]_D^{28}$ = +6.2 (*c* 0.335 in $CHCl_3$); ν_{max} 3448, 2956, 2873, 1711, 1622, 1449, 1369, 1264, 1233, 1172, 1094, 1025, 897 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 4.19 (2H, q, *J* 7.0, -OC*H*$_2$CH$_3$), 3.77-3.71 (1H, m, -C*H*OH), 2.92 (1H, br s, -OH), 2.17-2.08 (1H, m, -C*H*$_2$-), 2.00-1.95 (1H, m, -C*H*$_2$-), 1.92-1.80 (1H, m, -C*H*$_2$-), 1.73-1.59 (4H, m, -C*H*$_2$-CH$_2$-,), 1.52-1.42 (1H, m, -C*H*$_2$-), 1.28 (3H, t, *J* 7.0, -OCH$_2$C*H*$_3$), 1.16 (3H, d, *J* 6.0, -C*H*$_3$); δc (75 MHz, $CDCl_3$) 72.63, 60.67, 34.27, 32.79, 26.02, 25.59, 19.49, 14.19; m/z ESI-MS $[M+Na]^+$ 209.2; HRMS found 209.1152 ($C_{10}H_{18}O_3Na$ requires 209.1148, error = -1.7 ppm); the enantiomeric excess by using Chiral GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 140 ^oC, Injection temperature 220 ^oC, Detection temperature 220 ^oC, Gas Hydrogen, Pressure 15 psi) R_t (min) = 12.903 min (minor enantiomer), 13.263 min (major enantiomer), %ee = 61%.

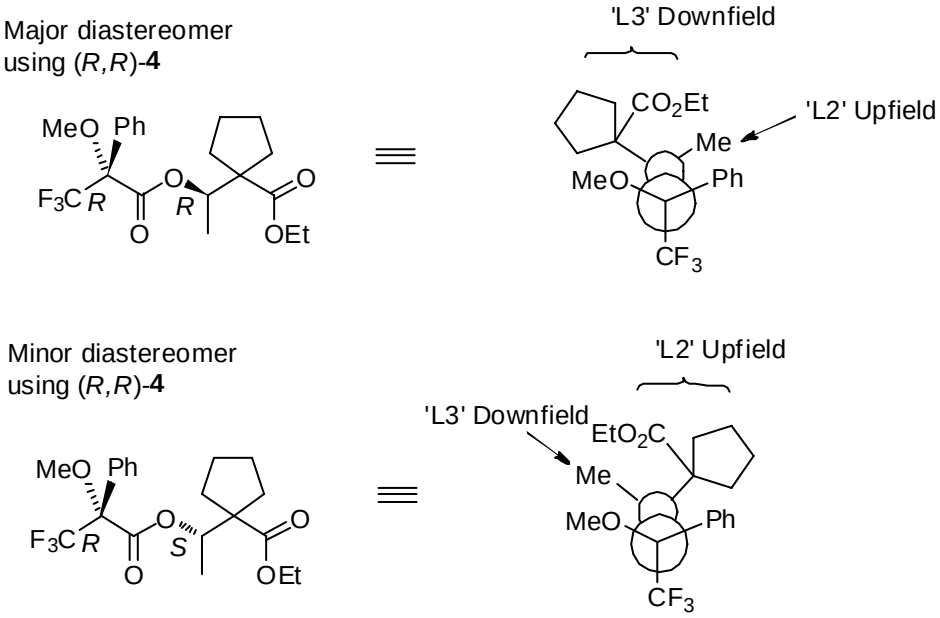
$NaBH_4$ reduction failed in an attempt to prepare a racemic standard. The enantiomer was prepared by using (1*S*,2*S*) 3C-teth-Ru complex.

Mosher's ester of ethyl (*R*) 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a (SRC 678).
To a solution of ehyl (*R*) 1-(1-hydroxyethyl)cyclopentanecarboxylate (5 mg, 0.0268 mmol) in dry DCM (2 mL) was added TEA (0.0075 mL, 0.0536 mmol, 2.0 eq) and DMAP (1 mg). The solution was added (*S*)-(+)-MTPA-Cl (0.0063 mL, 0.0034 mmol, 1.25 eq) at 0 ^oC. The resulting solution was stirred at room temperature for 18 h. The completion of the reaction was checked by TLC. The reaction mixture was concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane:ethyl acetate (90:10) to give the product as an oil (5 mg). The compound was analyzed by ^{1}H-NMR.

Mosher's ester of ethyl (*S*) 1-(1-hydroxyethyl)cyclopentanecarboxylate (SRC 679).
The compound was prepared similarly as described for Mosher's ester of ehyl (*R*) 1-(1-hydroxyethyl)cyclopentanecarboxylate.

Mosher's method[19]:

We used the (*S*)-(+)-MTPA-Cl (derived from the (*R*)-acid) which gives the (*R*)-configuration ester. The two diastereoisomers which can form are shown below.[19] The Mosher model predicts that these isomers will adopt the conformations shown below:



Using the notation from Mosher's paper,[19] the protons at positions 'L3' will be downfield of those at position 'L2'. The major enantiomer from the reduction reaction gave the (*R*,*R*)-Mosher ester. In order to compare the relative positions of the key peaks, the (*S*) alcohol was reacted with (*S*)-(+)-MTPA-Cl to give a mixture of *R*,*R* and *R*,*S* isomers for comparison.

1H NMR (key peaks) of Mosher's ester of alcohol from (1*R*,2*R*) 3C-teth-Ru complex

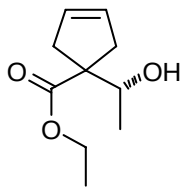
L2= 1.24 (3H, d, *J* 6.0, -C*H*$_3$); L3=1.63-1.55 (8H, m, -(CH$_2$)$_4$-)

1H NMR (key peaks) of Mosher's ester of alcohol from (1*S*,2*S*) 3C-teth-Ru complex

L3= 1.31 (3H, d, *J* 6.0, -C*H*$_3$); L2=1.60-1.49 (8H, m, -(CH$_2$)$_4$-)

The relative positions of the L2 and L3 peaks indicates that the *R*-alcohol was formed predominantly. The spectra are shown in the spectroscopy section.

(*R*)-Ethyl 1-(1-hydroxyethyl)cyclopent-3-ene-1-carboxylate 14b (SRC 491).

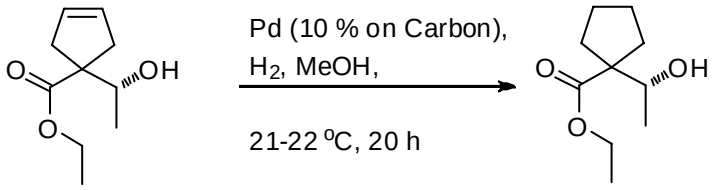


This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (1.7 mg, 0.00275 mmol, 1 mol%) in FA:TEA (5:2) (0.138 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, ethyl 1-acetylcyclopent-3-ene-1-carboxylate (0.050 g, 0.275 mmol) was added and the solution was stirred at 28 ^{o}C for 30 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.050 g). The crude compound was purified by flash column chromatography to give pure alcohol **14b** as a colourless oil (0.045 g, 0.244 mmol, 89%). $[\alpha]_D^{26}$ = +31.27 (*c* 0.275 in $CHCl_3$); ν_{max} 3447, 2979, 2934, 1713, 1446, 1368, 1264, 1210, 1094, 1041, 947, 906, 672 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 5.68-5.63 (1H, m, -C*H*=CH-), 5.61-5.56 (1H, m, -CH=C*H*-), 4.20 (2H, q, *J* 7.0, -OC*H*$_2$CH$_3$), 3.95 (1H, m, -C*H*OH), 2.89-2.71 (3H, m, -C*H*H-CH=CH-C*H*$_2$-), 2.60-2.45 (2H, m, -CH*H*-, -O*H*), 1.28 (3H, t, *J* 7.0, -OCH$_2$C*H*$_3$), 1.12 (3H, d, *J* 6.0, -C*H*$_3$); δc (75 MHz, $CDCl_3$) 177.36, 129.16, 128.00, 71.47, 60.95, 56.81, 40.45, 38.35, 18.05, 14.16; m/z ESI-MS $[M+Na]^+$ 207.1; HRMS found 207.0993 ($C_{10}H_{16}O_3Na$ requires 207.0992, error = -0.6 ppm); The enantiomeric excess by using Chiral GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 115 ^{o}C, Injection temperature 220 ^{o}C, Detection temperature 220 ^{o}C, Gas Hydrogen, Pressure 15 psi) R_t (min) = 25.412 min (minor enantiomer), 26.335 min (major enantiomer), %ee = 92%.

$NaBH_4$ reduction failed in an attempt to prepare a racemic standard. The enantiomer was prepared by using (1*S*,2*S*) 3C-teth-Ru complex. The products were combined to produce a racemic standard.

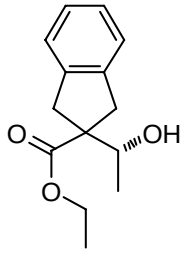
(*R*)-Ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a by Pd/C hydrogenation of 14b (SRC 500) to confirm that both were of same configuration (*R*).



A solution of ethyl 1-(1-hydroxyethyl)cyclopent-3-ene-1-carboxylate (92% ee) **14b** (0.025 g, 0.136 mmol) in dry methanol (2 mL) containing Pd/C (10 % on carbon) (14.48 mg) under atmospheric pressure of hydrogen at 21-22 ^{o}C was stirred for 20 h. The reaction mixture was

filtered through celite and the filtrate was concentrated on a rotary evaporator to give ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate **14a** (0.023 g, 0.123 mmol, 91%). The enantiomeric excess was established by using Chiral GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 140 ^{o}C, Injection temperature 220 ^{o}C, Detection temperature 220 ^{o}C, Gas Hydrogen, Pressure 15 psi) R_t (min) = 12.717 min (minor enantiomer), 12.923 min (major enantiomer), %ee = 92%.

(*R*)-Ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate 14c (SRC 496).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (2.7 mg, 0.00431 mmol, 1 mol%) in FA:TEA (5:2) (0.216 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, ethyl 2-acetyl-2,3-dihydro-1H-indene-2-carboxylate (0.100 g, 0.431 mmol) was added and stirred at 28 ^{o}C for 17 h under an inert atmosphere. The completion of the reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **14c** as a colourless oil (0.095 g, 0.406 mmol, 94%). $[\alpha]_D^{26}$ = +21.8 (*c* 0.415 in $CHCl_3$); ν_{max} 3450, 2958, 1715, 1486, 1460, 1368, 1282, 1201, 1178, 1095, 1043, 902, 740 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.20-7.13 (4H, m, -C*H* of -C_6H_4-), 4.20 (2H, q, *J* 7.2, -O$CH_2$$CH_3$), 4.02-3.95 (1H, m, -C*H*OH), 3.47 (1H, d, *J* 18, -C*H*H-C_6H_4-CH_2-), 3.39 (1H, d, *J* 16.5, -CH_2-C_6H_4-C*H*H-), 3.20 (1H, d, *J* 18, -CH_2-C_6H_4-CH*H*-), 3.05 (1H, d, *J* 16.5, - CH*H*-C_6H_4-CH_2-), 2.79 (1H, d, *J* 6.0, -O*H*), 1.25 (3H, t, *J* 7.2, -OCH_2CH_3), 1.11 (3H, d, *J* 6.0, -CH_3); δc (75 MHz, $CDCl_3$) 141.61, 140.70, 126.65, 126.59, 124.27, 124.11, 71.73, 61.14, 58.43, 40.27, 38.24, 18.70, 14.15; m/z ESI-MS $[M+Na]^+$ 257.2; HRMS found 257.1152 ($C_{14}H_{18}O_3Na$ requires 257.1148, error = -1.4 ppm); the enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 95:5, 0.50mL/min,

254 nM, 26^{o}C) Rt (min) = 21.654 (major enantiomer), 23.337 min (minor enantiomer), %ee= 90%.

The racemic standard was prepared by $NaBH_4$ reduction.

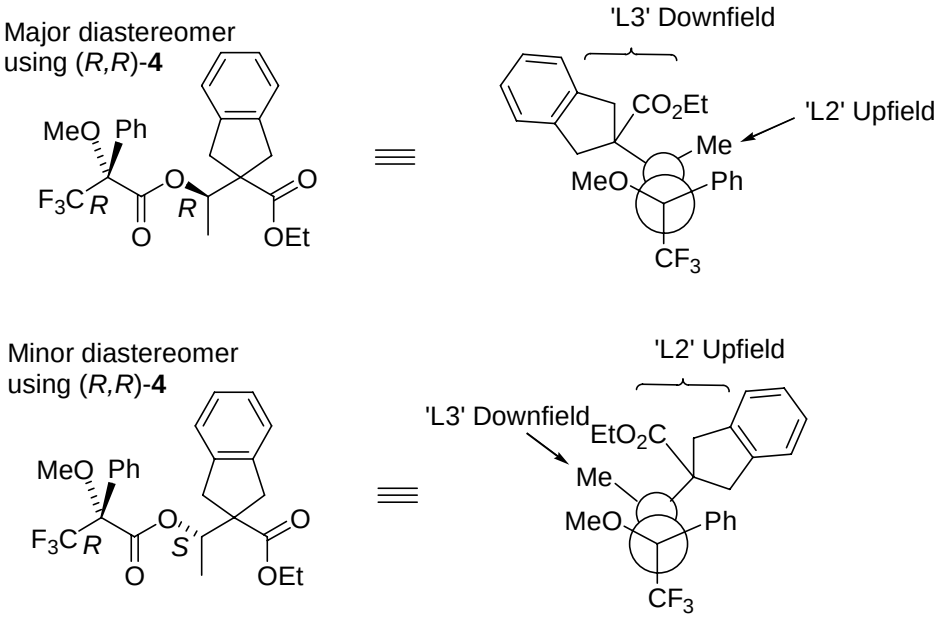
Mosher's ester of ethyl (*R*)-2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate (SRC 509).

To a solution of ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate **14c** (39 mg, 0.167 mmol) in dry DCM (2 mL) was added TEA (0.046 mL, 0.334 mmol, 2.0 eq) and DMAP (2.0 mg, 0.1 eq). The solution was added (*S*)-(+)-MTPA-Cl (0.046 mL, 0.250 mmol, 1.5 eq) at 0 ^{o}C. The resulting solution was stirred at rt for 5 h. The completion of reaction was checked by TLC. The reaction mixture was concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (95:5) to give an oil (50 mg, 0.111 mmol, 66%). $[\alpha]_D^{21}$ = + 48.03 (*c* 0.305 in $CHCl_3$); ν_{max} 2985, 1739, 1488, 1451, 1385, 1238, 1150, 1121, 1014, 858, 741, 715 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.48-7.46 (2H, m, -CH of -C_6H_5), 7.39-7.32 (3H, m, -CH of -C_6H_5), 7.14-7.12 (4H, m, -CH of -C_6H_4-), 5.67-5.60 (1H, q, *J* 7.0, -C*H*OCO-), 4.19-4.04 (2H, m, -COOC*H*$_2$CH$_3$), 3.58 (1H, d, *J* 18.0, -C*H*H-C_6H_4-CHH-), 3.47 (3H, d, -OCH3), 3.43 (1H,d, *J* 15.0, -CHH-C_6H_4-C*H*H-), 3.10 (1H, d, *J* 18.0, -CHH-C_6H_4-CH*H*-), 3.03 (1H, d, *J* 15.0, -CH*H*-C_6H_4-CHH-), 1.20 (3H, t, *J* 9, -COOCH$_2$C*H*$_3$), 1.16 (3H, d, *J* 6.0, -OCHC*H*$_3$), δc (75 MHz, $CDCl_3$) 129.54, 128.34(2C), 127.39(2C), 126.86, 126.77, 124.16, 124.11, 76.61, 61.38, 57.04, 55.28, 39.33, 38.10, 15.27, 13.96; m/z ESI-MS $[M+Na]^+$ 473.1; HRMS found 473.1561 ($C_{24}H_{25}F_3O_5Na$ requires 473.1546, error = -3.1 ppm).

Mosher's ester of ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate (SRC 513) racemic sample.

The compound was prepared as described for Mosher's ester of ethyl (*R*)-2-(1-hydroxyethyl)-2,3-dihydr-1H-indene-2-carboxylate.

We used the (*S*)-(+)-MTPA-Cl (derived from the (*R*)-acid) which gives the (*R*)-configuration ester. The two diastereoisomers which can form are shown below. [19] The Mosher model predicts that these isomers will adopt the conformations shown below:



Using the notation from Mosher's paper,[19] the protons at positions 'L3' will be downfield of those at position 'L2'. The major enantiomer from the reduction reaction gave the (*R*,*R*)-Mosher ester. In order to compare the relative positions of the key peaks, the racemic alcohol was reacted with (*S*)-(+)-MTPA-Cl to give a mixture of *R,R* and *R,S* isomers for comparison.

1H NMR (key peaks) of Mosher's ester of alcohol from (1*R*,2*R*) 3C-teth-Ru complex

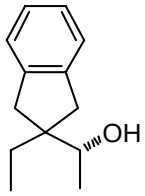
L2= 1.16 (3H, d, *J* 6.0, -C*H*$_3$); L3=3.58 (1H, d, *J* 18.0, -C*H*H-C$_6$H$_4$-CHH-), 3.43 (1H,d, *J* 15.0, -CH$_2$-C$_6$H$_4$-C*H*H-), 3.10 (1H, d, *J* 18.0, -CH$_2$-C$_6$H$_4$-CH*H*-), 3.03 (1H, d, *J* 15.0, -CH*H*-C$_6$H$_4$-CH$_2$-),

1H NMR (key peaks) of other diastereoisomer from Mosher's ester of racemic alcohol.

L3= 1.26 (3H, d, *J* 6.0, -C*H*$_3$); L2=3.54 (1H, d, *J* 18.0, -C*H*H-C$_6$H$_4$-CHH-), 3.38 (1H, d, *J* 15.0, -CH$_2$-C$_6$H$_4$-C*H*H-), 3.06 (1H, d, *J* 15.0, -CH$_2$-C$_6$H$_4$-CH*H*-), 2.99 (1H, d, *J* 15.0, - C*H*H-C$_6$H$_4$-CH$_2$-).

The relative positions of the L2 and L3 peaks indicates that the *R*-alcohol was formed predominantly. The spectra are shown in the spectroscopy section.

(*R*) 1-(2-Ethyl-2,3-dihydro-1H-indene-2-yl)ethanol 14d (SRC 683).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (3.3 mg, 0.00532 mmol, 1 mol%) in FA:TEA (5:2) (0.266 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 1-(2-ethyl-2,3-dihydro-1H-inden-2-yl)ethanone (0.100 g, 0.532 mmol) was added and stirred at 28 ^{o}C for 24 h under an inert atmosphere. The completion of the reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol as a colourless oil (0.090 g, 0.473 mmol, 89%). $[\alpha]_D^{28}$ = -3.18 (*c* 0.550 in $CHCl_3$); ν_{max} 3391, 3021, 2965, 2918, 1587, 1484, 1459, 1377, 1301, 1066, 982, 894, 788, 740 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.16-7.09 (4H, m, -C*H* of -C_6H_4-), 3.87 (1H, q, *J* 6.0, -C*H*OH), 3.04 (1H, d, *J* 18.0, -C*H*H-C_6H_4-CH_2-), 2.98 (1H, d, *J* 18.0, -CH_2-C_6H_4-C*H*H-), 2.73 (1H, d, *J* 18.0, -CH_2-C_6H_4-CH*H*-), 2.69 (1H, d, *J* 18.0, - CH*H*-C_6H_4-CH_2-), 1.70-1.58 (1H, m, -C*H*HCH$_3$), 1.55-1.43 (1H, m, -CH*H*CH$_3$), 1.39 (1H, br s, -O*H*), 1.13 (3H, d, *J* 6.0, -C*H*$_3$), 0.83 (3H, t, *J* 7.5, -CH_2C*H*$_3$); δc (75 MHz, $CDCl_3$) 142.98, 142.78, 126.13(2C), 124.32, 124.21, 72.56, 50.50, 39.99 (2C), 29.65, 18.63, 8.82; m/z ESI-MS $[M+Na]^+$ 213.1; HRMS found 253.1258 ($C_{13}H_{18}ONa$ requires 213.1250, error = -4.0 ppm); the enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 95:5, 0.50 mL/min, 254 nM, 26^{o}C) Rt (min) = 14.769 (major enantiomer), 16.783 min (minor enantiomer), %ee= 73%.

The racemic standard was prepared by $NaBH_4$ reduction.

Mosher's ester of (*R*) 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol 14d (SRC 689).

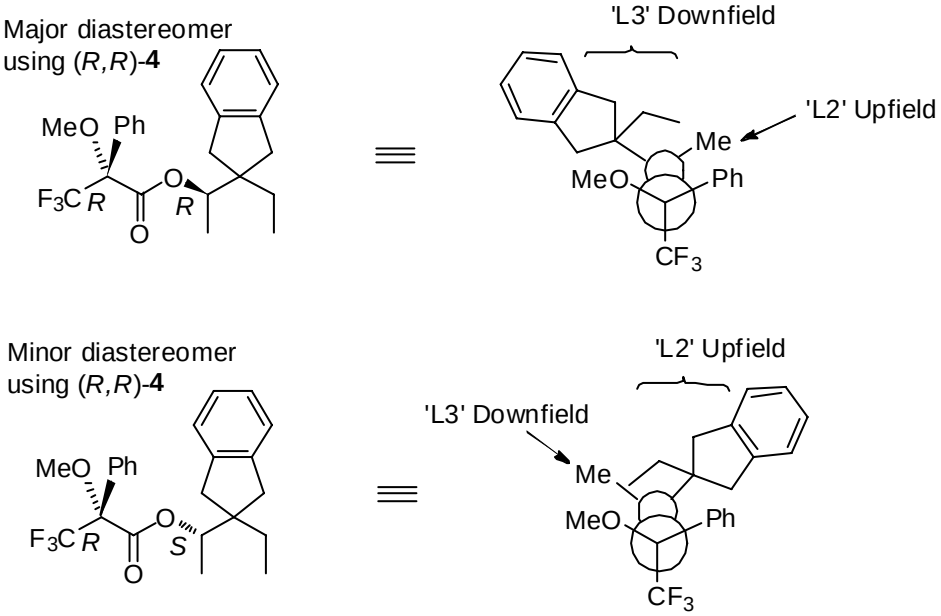
To a solution of (*R*) 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol (5mg, 0.0263 mmol) in dry DCM (1 mL) was added TEA (0.0073 mL, 0.0526 mmol, 2.0 eq) and DMAP (1 mg). The solution was added (*S*)-(+)-MTPA-Cl (0.0062 mL, 0.0329 mmol, 1.25 eq) at 0 ^{o}C. The resulting solution was stirred at room temperature for 18 h. The completion of the reaction

was checked by TLC. The reaction mixture was concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (90:10) to give the product as an oil (6 mg). The compound was analyzed by ^{1}H-NMR.

Mosher's ester of 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol (SRC 690) racemic sample.

The compound was prepared as described for Mosher's ester of ethyl (*R*) 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol.

We used the (*S*)-(+)-MTPA-Cl (derived from the (*R*)-acid) which gives the (*R*)-configuration ester. The two diastereoisomers which can form are shown below. [19] The Mosher model predicts that these isomers will adopt the conformations shown below:



Using the notation from Mosher's paper,[19] the protons at positions 'L3' will be downfield of those at position 'L2'. The major enantiomer from the reduction reaction gave the (*R*,*R*)-Mosher ester. In order to compare the relative positions of the key peaks, the racemic alcohol was reacted with (*S*)-(+)-MTPA-Cl to give a mixture of *R*,*R* and *R*,*S* isomers for comparison.

1H NMR (key peaks) of Mosher's ester of alcohol from (1*R*,2*R*) 3C-teth-Ru complex

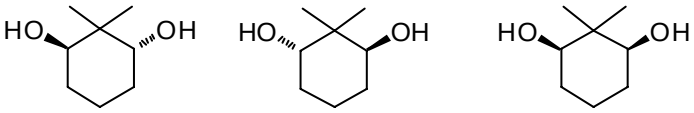
L2= 1.22 (3H, d, *J* 6.0, -C*H*$_3$); L3=2.94 (1H, d, *J* 12.0, -C*H*H-C$_6$H$_4$-CH$_2$-), 2.92 (1H,d, *J* 12.0, -CH$_2$-C$_6$H$_4$-C*H*H-), 2.74 (1H, d, *J* 12.0, -CH$_2$-C$_6$H$_4$-CH*H*-), 2.72 (1H, d, *J* 12.0, -CH*H*-C$_6$H$_4$-CH$_2$-).

1H NMR (key peaks) of other diastereoisomer from Mosher's ester of racemic alcohol.

L3= 1.28 (3H, d, *J* 6.0, -C*H*$_3$); L2=2.92 (1H, d, *J* 12.0, -C*H*H-C$_6$H$_4$-CH$_2$-), 2.92 (1H,d, *J* 12.0, -CH$_2$-C$_6$H$_4$-C*H*H-), 2.84 (1H, d, *J* 12.0, -CH$_2$-C$_6$H$_4$-CH*H*-), 2.66 (1H, d, *J* 12.0, -CH*H*-C$_6$H$_4$-CH$_2$-).

The relative positions of the L2 and L3 peaks indicates that the *R*-alcohol was formed predominantly. The spectra are shown in the spectroscopy section.

Synthesis of 2,2-dimethylcyclohexane-1,3-diol 16a.



(*R*,*R*) (*S*,*S*) (*R*,*S*)

Trans diastereomer *Cis* diastereomer

Asymmetric: A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (7.56 mg, 0.0122 mmol, 2 mol%) in FA:TEA (5:2) (0.610 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 2,2-dimethylcyclohexane-1,3-dione **15a** (0.100 g, 0.713 mmol) was added and stirred at 28 ^{o}C for 7 h under an inert atmosphere. The completion of reaction was checked by TLC. Column chromatography on silica (hexane/EtOAc, 49:1 - 1:1) achieved partial separation of the diastereomeric mixture to give the least polar (*cis*) diastereomer of **16a** as a white solid (31 mg), the more polar (*trans*) diastereomer of **16a** as a colourless oil (35 mg) (combined yield: 66 mg, 64%). Enantiomeric excess and conversion were established by GC analysis (Chrompac cyclodextrin-β-236M-19, T = 180°C, P = 15 psi, He, **15a** 9.54 mins, *trans*-**16a** 13.03 mins, *cis*-**16a** 13.34 mins)

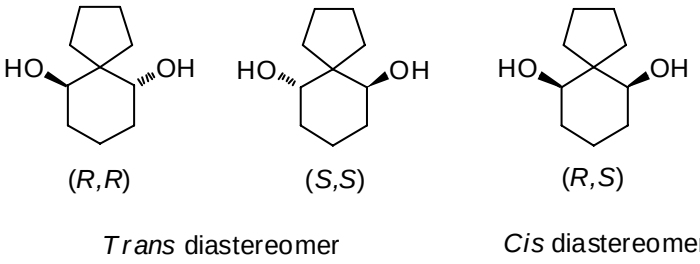
Cis-Diastereomer of **16a**: Mp (°C): 102-104; HRMS: calc. for C$_8$H$_{16}$O$_2$Na: 167.1043 ([M+Na]$^+$). Found 167.1043. IR: ν_{max}(film): 3321, 2933, 1447, 1073, 1011, 981 cm^{-1}; δ_H (400 MHz, CDCl$_3$): 3.43-3.39 (2H, m, 2 x -C*H*OH), 2.07 (1H, br s, -O*H*), 2.06 (1H, br s, -O*H*), 1.86-1.79 (1H, m, -C*H*H-), 1.78-1.72 (2H, m, 2 x C*H*HCHOH), 1.59-1.50 (2H, m, 2 x CH*H*CHOH), 1.38-1.30 (1H, m, -CH*H*), 1.03 (3H, s, CH$_3$), 1.00 (3H, s, CH$_3$); δ_C (100 MHz, CDCl$_3$): 76.3, 29.2, 24.6, 17.1; MS: *m/z* (ESI+) 167.0 ([M+Na]$^+$); Data is consistent with that reported in the literature.[21]

Trans-Diastereomer of **16a**: $[\alpha]_D^{22}$ -35.1° (*c* = 0.5, CHCl$_3$); IR: ν_{max}(solid): 3357, 2934, 1362, 1072 cm^{-1}; δ_H (400 MHz, CDCl$_3$): 3.68 (2H, br s, 2 x -CH), 1.78-1.71 (2H, m, -CH$_2$), 1.68-

1.62 (2H, m, -CH_2), 1.55-1.47 (2H, m, -CH_2), 1.30 (2H, s, -OH), 1.00 (6H, s, 2 x -CH_3); δ_C (100 MHz, $CDCl_3$): 76.3, 29.4, 24.6, 17.1. Data is consistent with that reported in the literature.[22]

Racemic: The diketone (150 mg, 1.07 mmol) was stirred in NaOH (0.5 M, 5 mL), $NaBH_4$ (41 mg, 1.07 mmol) was added, the solution was heated to 50°C until no starting ketone was left for 22 h. After cooling K_2CO_3 was added, then washed with CH_2Cl_2 (3 x 10 mL), filtered, evaporated, to give a crude white solid. Column chromatography on silica (hexane/EtOAc, 49:1-1:1) achieved partial separation of the diastereomeric mixture to give the least polar (*cis*) diastereomer of **16a** as a white solid (45 mg), the more polar (*trans*) diastereomer of **16a** as a colourless oil (18 mg), and the remaining diastereomeric mixture (2 mg) as a white solid (combined yield: 65 mg, 42%).

(*R,R*)-Spiro[4,5]decane-6,10-diol 16b (SRC 588).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (7.5 mg, 0.0120 mmol, 2 mol%) in FA:TEA (5:2) (0.602 mL) was stirred at 28 ^oC under an inert atmosphere in a Schlenk tube. To this, spiro[4,5]decane-6,10-dione (0.100 g, 0.602 mmol) was added and stirred at 45 ^oC for 36 h under an inert atmosphere. The completion of the reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure *cis* diastereomer of **16b** as white solid (0.055 g, 0.323 mmol, 53%) and *trans* diastereomer of **16b** as white solid (0.025 g, 0.147 mmol, 24%). The ratio of *cis:trans* from crude ^{1}H-NMR (before separation) was 65: 35. The diastereomeric ratio and enantiomeric excess were determined by Chiral GC for acetate derivative; GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 140 ^oC, Injection temperature 220 ^oC, Detection temperature 220 ^oC, Gas

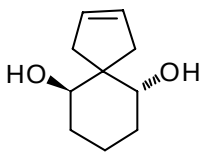
Hydrogen, Pressure 15 psi) R_t (min) = 64.537 min (minor enantiomer, *trans*), 67.033 min (major enantiomer, *trans*), 68.363 min (*cis* diastereomer), dr = 65.5: 34.5 (*cis*:*trans*) %ee = 99%. GC quoted is of mixture prior to separation of *cis* and *trans* isomers. The ee of the *trans* isomer after separation was unchanged.

Cis diastereomer of **16b**: Mp 94-95 ^oC; ν_{max} 3276, 2953, 2928, 2862, 1449, 1349, 1334, 1025, 1009, 955, 900 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 3.56 (2H, br s, -C*H*OH), 2.79 (2H, br s, -O*H*), 2.00-1.88 (1H, m, $-CH_2-CHH-CH_2-$), 1.81 (2H, t, *J* 7.5, $-CH_2-(CH_2)_2-CH_2-$), 1.73-1.66 (4H, m, $-CH_2-CH_2-CH_2-$), 1.64-1.55 (4H, m, $-CH_2-(CH_2)_2-CH_2-$), 1.42 (2H, t, *J* 7.5, $-CH_2-(CH_2)_2-CH_2-$), 1.38-1.32 (1H, m, $-CH_2-CHH-CH_2-$), δc (75 MHz, $CDCl_3$) 75.28(2C), 34.69, 32.33, 30.02(2C), 25.94, 25.44, 14.47; m/z ESI-MS $[M+Na]^+$ 193.1; HRMS found 193.1201 ($C_{10}H_{18}O_2Na$ requires 193.1199, error = -1.2 ppm);

Trans diastereomer of **16b**:Mp 114-115 ^oC; $[\alpha]_D^{26}$ = -56.3 (*c* 0.175 in $CHCl_3$); ν_{max} 3327, 2939, 2865, 1443, 1392, 1273, 1050, 980, 957, 891, 878 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 3.75 (2H, dd, *J* 9.0, 3.0, -C*H*OH), 1.80-1.41 (16H, m, 14H of $-CH_2-$, 2H of -O*H*); δc (75 MHz, $CDCl_3$) 73.68(2C), 31.73, 30.66(2C), 26.79(2C), 18.66(2C); m/z ESI-MS $[M+Na]^+$ 193.1; HRMS found 193.1199 ($C_{10}H_{18}O_2Na$ requires 193.1199, error = 0.0 ppm); the enantiomeric excess was determined by Chiral GC for acetate derivative GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 140 ^oC, Injection temperature 220 ^oC, Detection temperature 220 ^oC, Gas Hydrogen, Pressure 15 psi) R_t (min) = 65.230 min (minor enantiomer), 69.927 min (major enantiomer), %ee = 99%.

The racemic standard was prepared by $NaBH_4$ reduction. The retention times of the peaks in the GC of the diacetates of the crude product correlated with those of the *cis* and *trans* products after separation.

(*R*,*R*)-Spiro[4,5]dec-2-ene-6,10-diol 16c (SRC 403/SRC 514).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (7.56 mg, 0.0122 mmol, 2 mol%) in FA:TEA (5:2) (0.610 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, spiro[4,5]dec-2-ene-6,10-dione (0.100 g, 0.610 mmol) was added and the mixture was stirred at 28 ^{o}C for 21 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **16c** as a white solid (0.080 g, 0.476 mmol, 78%). Mp 98-100 ^{o}C; $[\alpha]_D^{20}$ = -63.0 (*c* 0.197 in $CHCl_3$); ν_{max} 3331, 2940, 2919, 2852, 1455, 1404, 1288, 1257, 1093, 1062, 1049, 959, 689 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 5.67 (2H, m, -C*H*=C*H*-), 3.83 (1H, d, *J* 2.4, -C*H*OH), 3.82 (1H, d, *J* 3.0, -C*H*OH), 2.60 (2H, d, *J* 15.0, -C*H*H-CH=CH-C*H*H-), 2.20 (2H, d, *J* 15.0, -CH*H*-CH=CH-CH*H*-), 1.72-1.50 (8H, m, -(CH_2)$_3$-2 x -O*H*); δc (75 MHz, $CDCl_3$) 129.66, 73.95, 38.89, 30.14, 18.47; m/z ESI-MS $[M+Na]^+$ 191.1; HRMS found 191.1039 ($C_{10}H_{16}O_2Na$ requires 191.1043, error = 1.7 ppm); the enantiomeric excess was determined by Chiral GC of the acetate derivative (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 150 ^{o}C, Injection temperature 220 ^{o}C, Detection temperature 220 ^{o}C, Gas Hydrogen, Pressure 15 psi) R_t (min) = 39.133 min (minor enantiomer), 40.447 min (major enantiomer), %ee = 99%.

$NaBH_4$ reduction did not work in an attempt to prepare a racemic standard. The enantiomer was prepared by using (1*S*,2*S*) 3C-teth-Ru complex **4**.

Mosher's method[19]**:**

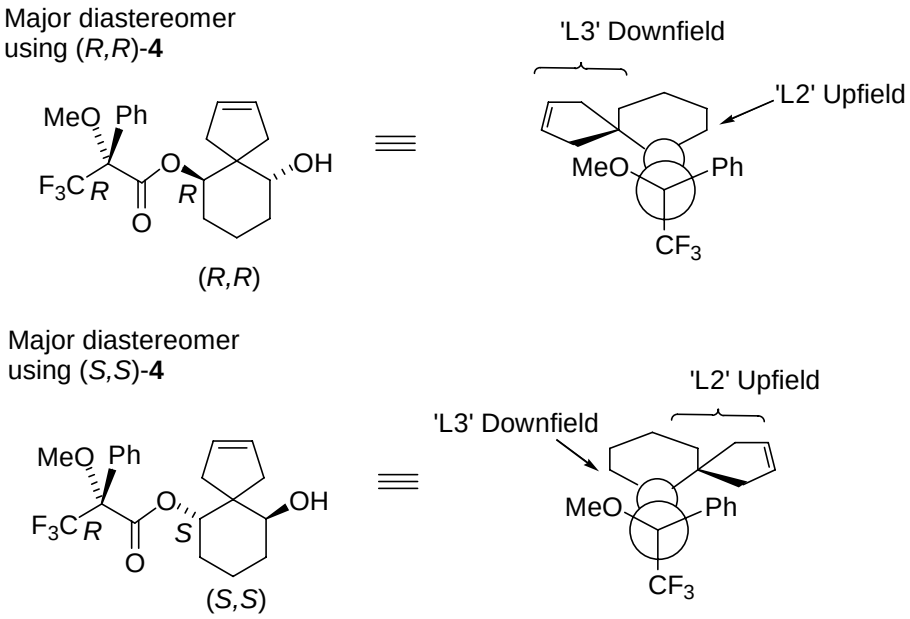
Mosher's ester of (*R,R*)-spiro[4,5]dec-2-ene-6,10-diol 16c (SRC 575).

To a solution of (*R,R*)-spiro[4,5]dec-2-ene-6,10-diol (5 mg, 0.0298 mmol) in dry DCM (2 mL) was added TEA (0.014mL, 0.1044 mmol, 3.5 eq) and DMAP (1.0 mg). To the solution was added (*S*)-(+)-MTPA-Cl (0.014 mL, 0.0745 mmol, 2.5 eq) at 0 ^{o}C. The resulting solution was stirred at rt for 18 h. The completion of reaction was checked by TLC. The reaction mixture was concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (95:5) to give mono ester compound **16c** as an oil (7 mg). The compound was analyzed by 1H-NMR.

Mosher's ester of (*S,S*)-spiro[4,5]dec-2-ene-6,10-diol 16c (SRC 576).

The compound was prepared similarly as described for Mosher's ester of (*R,R*)-spiro[4,5]dec-2-ene-6,10-diol.

We used the (*S*)-(+)-MTPA-Cl (derived from the (*R*)-acid) which gives the (*R*)-configuration ester. The two diastereoisomers which can form are shown below (only one ester is formed).[19] The Mosher model predicts that these isomers will adopt the conformations shown below:



Using the notation from Mosher's paper,[19] the protons at positions 'L3' will be downfield of those at position 'L2'. The major enantiomer from the reduction reaction gave the *R*,*R*-Mosher ester. In order to compare the relative positions of the key peaks, the (*S*,*S*) alcohol was reacted with (*S*)-(+)-MTPA-Cl to give a mixture of *R*,*R* and *R*,*S* isomers for comparison.

1H NMR (key peaks) of Mosher's ester of alcohol from (1*R*,2*R*) 3C-teth-Ru complex (SRC 575)

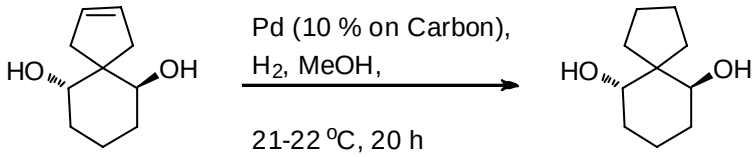
L2= 1.75-1.34 (6H, m, -(CH_2)$_3$-, -OH); L3=2.67-2.59 (1H, m, -C*H*H-CH=CH-CHH-), 2.43-2.22 (2H, d, *J* 15.6, -CHH-CH=CH-CH_2-), 2.13-2.04 (1H, m, -CH*H*-CH=CH-CHH-)

1H NMR (key peaks) of Mosher's ester of alcohol from (1*S*,2*S*) 3C-teth-Ru complex (SRC 576)

L3= 1.79-1.47 (6H, m, -(CH_2)$_3$-); L2=2.64-2.56 (1H, m, -C*H*H-CH=CH-CHH-), 2.38-2.16 (2H, d, *J* 15.6, -CHH-CH=CH-CH_2-), 2.09-2.01 (1H, m, -CH*H*-CH=CH-CHH-)

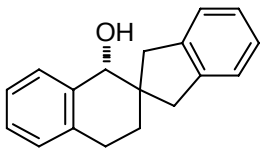
The relative positions of the L2 and L3 peaks indicates that the *R*-alcohol was formed predominantly. The spectra are shown in the spectroscopy section.

(*S,S*)-Spiro[4,5]decane-6,10-diol 16b by Pd/C hydrogenation of (*S,S*)-spiro[4,5]dec-2-ene-6,10-diol 16c confirm that both were of same configuration.



A solution of (*S,S*)-spiro[4,5]dec-2-ene-6,10-diol (99% ee) **16b** (10 mg, 0.060 mmol) in dry methanol (2 mL) containing Pd/C (10 % on carbon) (6.39 mg) under atmospheric pressure of hydrogen at 21-22 ^{o}C was stirred for 22 h. The reaction mixture was filtered through celite and the filtrate was concentrated on a rotary evaporator to give (*S,S*)-spiro[4,5]decane-6,10-diol **16c** (9 mg, 0.053 mmol, 88%). the enantiomeric excess was determined by Chiral GC for acetate derivative GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 140 ^{o}C, Injection temperature 220 ^{o}C, Detection temperature 220 ^{o}C, Gas Hydrogen, Pressure 15 psi) R_t (min) = 64.553 min (major enantiomer), 66.880 min (minor enantiomer), %ee = 99%.

(*R*)-1,3,3',4'-Tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol 18 (SRC 551).



This is a novel compound.

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (2.5 mg, 0.00403 mmol, 1 mol%) in FA:TEA (5:2) (0.200 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-one (0.100 g, 0.403 mmol) was added and the solution was stirred at 45 ^{o}C for 24 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol **18** as white solid (0.085 g, 0.340 mmol, 84%). Mp 74-75 ^{o}C; $[\alpha]_D^{16}$ = +30.94 (*c* 0.265 in $CHCl_3$); ν_{max} 3565, 3020, 2903, 2841, 1484, 1450, 1382, 1262, 1176, 1103, 1031, 1008, 938, 794, 773, 736 cm^{-1}; δ_H (300 MHz, $CDCl_3$) 7.35-

7.32 (1H, m, -CH of -C_6H_4-), 7.27-7.11 (7H, m, -CH of -C_6H_4-), 4.43 (1H, d, *J* 6.0, -C*H*OH-), 3.31 (1H, d, *J* 15.0, -C*H*H-C_6H_4-CHH-), 2.93-2.89 (2H, m, -CH_2-CH_2-C_6H_4-), 2.83 (1H, d, *J* 15.0, -CHH-C_6H_4-C*H*H-), 2.78 (1H, d, *J* 15.0, -CHH-C_6H_4-CH*H*-), 2.68 (1H, d, *J* 15.0, -CH*H*-C_6H_4-CHH-), 2.22-2.12 (1H, m, -CH_2-C-), 1.80-1.72 (1H, m, -CH_2-C-), 1.66 (1H, br d, -OH); δc (75 MHz, $CDCl_3$) 142.38, 142.04, 137.89, 136.06, 129.95, 129.10, 127.93, 126.35, 126.25, 126.20, 124.86, 124.67, 74.40, 46.98, 41.36, 40.67, 28.15, 26.30; m/z ESI-MS $[M+Na]^+$ 273.1; HRMS found 273.1254 ($C_{18}H_{18}ONa$ requires 273.1250, error = -1.6 ppm); the enantiomeric excess was determined by Chiral HPLC (ChiralPak IA Column: 0.46 cm x 25 cm, hexane:IPA 90:10, 0.50mL/min, 254 nM, 12^oC) Rt (min) = 16.401 (major enantiomer), 22.026 min (minor enantiomer), %ee= 99%.

The racemic standard was prepared by $NaBH_4$ reduction.

Mosher's ester of (*R*) 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol 18a (SRC 625).

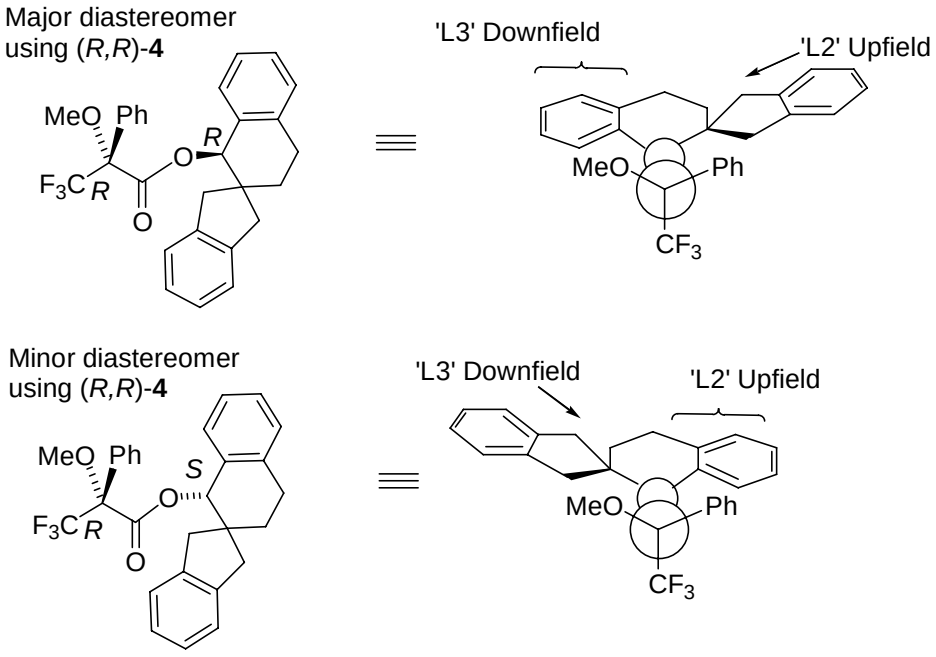
To a solution of 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol (12 mg, 0.048 mmol) into dry DCM (2 mL) was added TEA (0.017 mL, 0.120 mmol, 2.5 eq) and DMAP (1 mg). The solution was added (*S*)-(+)-MTPA-Cl (0.014 mL, 0.072 mmol, 1.5 eq) at 0 ^oC. The resulting solution was stirred at rt for 1.5 h. The completion of reaction was checked by TLC. The reaction mixture was concentrated on a rotary evaporator to get oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (95:5) to give the product as oil (8 mg). The compound was analyzed by 1H-NMR.

Mosher's ester of racemic 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol (SRC 624).

The compound was prepared similarly as described for Mosher's ester of (*R*) 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol.

Mosher's method[19]:

We used the (*S*)-(+)-MTPA-Cl (derived from the (*R*)-acid) which gives the (*R*)-configuration ester. The two diastereoisomers which can form are shown below.[19] The Mosher model predicts that these isomers will adopt the conformations shown below:



Using the notation from Mosher's paper,[19] the protons at positions 'L3' will be downfield of those at position 'L2'. The major enantiomer from the reduction reaction gave the *R,R*-Mosher ester. In order to compare the relative positions of the key peaks, the racemic alcohol was reacted with (*S*)-(+)-MTPA-Cl to give a mixture of *R,R* and *R,S* isomers for comparison.

1H NMR (key peaks) of Mosher's ester of alcohol from (1*R*,2*R*) 3C-teth-Ru complex.

L2= 2.96 (1H, d, *J* 15.0, -C*H*H-C_6H_4-CHH-), 2.83 (1H, d, *J* 15.0, -CHH-C_6H_4-C*H*H-), 2.65 (1H, d, *J* 15.0, -CHH-C_6H_4-CH*H*-), 2.58 (1H, d, *J* 15.0, CH*H*-C_6H_4-CHH-); L3= Ph

1H NMR (key peaks) of other diastereoisomer of Mosher's ester of racemic alcohol.

L3= 3.10 (1H, d, *J* 18.0, -C*H*H-C_6H_4-CHH-), 2.81 (1H, d, *J* 15.0, -CHH-C_6H_4-C*H*H-), 2.75 (1H, d, *J* 15.0, -CHH-C_6H_4-CH*H*-), 2.69 (1H, d, *J* 15.0, CH*H*-C_6H_4-CHH-); L3= Ph

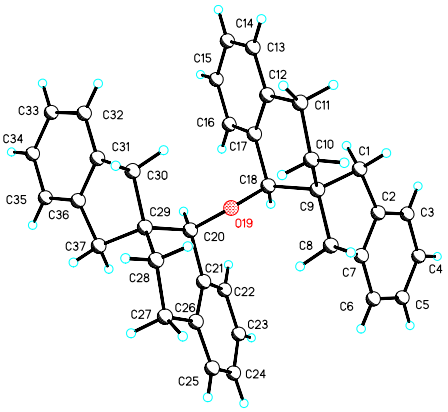
The relative positions of the L2 and L3 peaks indicates that the *R*-alcohol was formed predominantly. The spectra are shown in the spectroscopy section.

Attempted synthesis of (1S)-(+)-10 camphorsulfonyl ester derivative of 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol 18a (SRC 555).

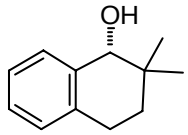
Resulted in ether linked product:

To a solution of 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol (50 mg, 0.200 mmol) in dry DCM (4 mL) was added TEA (0.055 mL, 0.400 mmol, 2.0 eq) and DMAP (0.5 mg, 0.02 eq). To the solution was added (*S*)-(+)-10-camphorsulfonyl chloride (0.075 g, 0.300 mmol, 1.5 eq) at 0 ^{o}C. The resulting solution was stirred at rt overnight. The completion of reaction was checked by TLC. The reaction mixture was diluted with water (10 mL) followed by extraction with DCM (2 x 10 mL). The combined organic layers were washed with 1 M HCl (2 x 10 mL), sat. NaHCO3 (2 x 10 mL) and brine (10 mL). The organic layer was dried over anhydrous Na_2SO_4, filtered and concentrated on a rotary evaporator to give an oil. The oil was purified by flash column chromatography using hexane: ethyl acetate (90:10) to give a product as colourless oil (0.028 g, 0.058 mmol, 58%). The oil converted into a solid on standing. The solid was recrystallized from n-pentane: diethyl ether to give crystals for X-ray analysis. δ_H (300 MHz, $CDCl_3$) 7.24-7.18 (6H, m, 6 -CH of -C_6H_4-), 7.08-7.98 (8H, m, 8-CH of -C_6H_4-), 6.88-6.68 (2H, m, 2-CH of -C_6H_4-), 4.17 (2H, s, -C*H*O-), 3.02-2.83 (4H, m, 2 x -C*H*$_2$-C_6H_4), 2.60-2.33 (8H, d, 2 x -C*H*$_2$-C_6H_4-C*H*$_2$-), 2.32-2.22 (2H, m, 2 x-C_6H_4-CH_2-C*H*H-), 1.63-1.52 (2H, m, 2 x-C_6H_4-CH_2-CH*H*-).

X-ray crystallographic data: **(RS6 – α-tetralone dimer)**; CCDC no. 817153, $C_{36}H_{34}O$, M = 482.63, Monoclinic, space group P2(1)/n, 10.3318(3), b = 18.3947(5), c = 14.2896(4) Å , α = 90˚, β = 108.039(3)˚, γ = 90˚, U = 2582.24(12) Å^3 (by least squares refinement on 13397 reflection positions), T =100(2) K, λ = 1.54184 Å, Z = 4, D(cal) = 1.241 Mg/m^3, F(000) = 1032. mu(MoK-α) = 0.552 mm^{-1}. Crystal character: colourless block. Crystal dimensions 0.30 x 0.20 x 0.12 mm. Note that as this molecule is in the centrosymmetric space group P2(1)/n, it must be racemic; the space group contains two *RR*- and two *SS*- configuration molecules. Further details are given in the cif file.



(*R*)-2,2-Dimethyl-1,2,3,4-tetrahydronaphthalen-1-ol 18b (SRC 680).

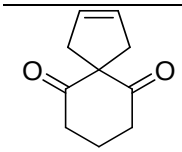
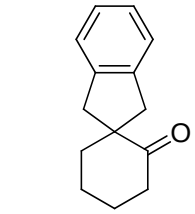
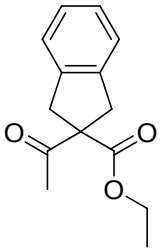
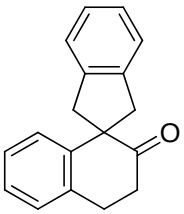
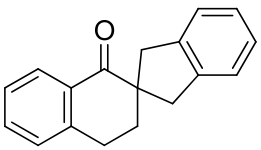


This compound is known.[23]

A mixture of catalyst (1*R*,2*R*) 3C-teth-Ru complex (3.56 mg, 0.00575 mmol, 1 mol%) in FA:TEA (5:2) (0.287 mL) was stirred at 28 ^{o}C under an inert atmosphere in a Schlenk tube. To this, 2,2-dimethyl-3,4-dihydronaphthalen-1(2H)-one (0.100 g, 0.575 mmol) was added and the solution stirred at 45 ^{o}C for 49 h under an inert atmosphere. The completion of reaction was checked by TLC. The reaction mixture was filtered through a short column of silica using hexane: ethyl acetate (1:1) to ethyl acetate. The filtrate was concentrated to give a crude alcohol (0.100 g). The crude compound was purified by flash column chromatography to give pure alcohol as a colourless oil (0.090 g, 0.511 mmol, 89%). $[\alpha]_D^{30}$ = -20.2 (*c* 1.125 in $CHCl_3$) [lit. value $[\alpha]_D^{22}$ = -23.5 (*c* 3.37 in $CHCl_3$) (*R*)][24]; δ_H (300 MHz, $CDCl_3$) 7.47-7.41 (1H, m, -C*H* of -C_6H_4-,), 7.22-7.17 (2H, m, -C*H* of -C_6H_4-), 7.13-7.08 (1H, m, -C*H* of -C_6H_4-), 4.26 (1H, d, *J* 6.0, -C*H*OH-), 2.89-2.70 (2H, m, C_6H_4-CH_2-), 1.86-1.77 (1H, m, C_6H_4-CH_2-C*H*H-), 1.61-1.49 (2H, m, -O*H,* C_6H_4-CH_2-CH*H*-), 1.00 (3H, s, -CH_3), 0.98 (3H, s, -CH_3); δc (75 MHz, $CDCl_3$) 138.45, 135.87, 128.80, 128.73, 127.32, 126.12, 76.63, 33.83, 31.92, 25.93, 25.59, 22.53; m/z ESI-MS $[M+Na]^+$ 199.1; the enantiomeric excess by using Chiral GC (Chrompak CP-Chirasil Dex Cβ Column, Oven temperature 140 ^{o}C, Injection temperature 220 ^{o}C, Detection temperature 220 ^{o}C, Gas Hydrogen, Pressure 15 psi) R_t (min) = 29.423 min (major enantiomer), 29.917 min (minor enantiomer), %ee = 98%.

The racemic standard was prepared by $NaBH_4$ reduction.

Asymmetric transfer hydrogenation of selected compounds using catalyst (*R*,*R*)-**1** (arene = p-cymene). These were completed under the conditions shown below. The times are given for full conversion to product.

Compound	Catalyst mol%	Temp	Time	%ee
	4mol%	30 ^{o}C	7 days (15% mono)	92% (*R*)
	1 mol%	28 ^{o}C	48h	94% (*R*)
	1 mol%	28 ^{o}C +60 ^{o}C	24 h + 5h	91% (*R*)
	1 mol%	28 ^{o}C	24 h	99% (*R*)
	1 mol%	45 ^{o}C	48 h	No reaction

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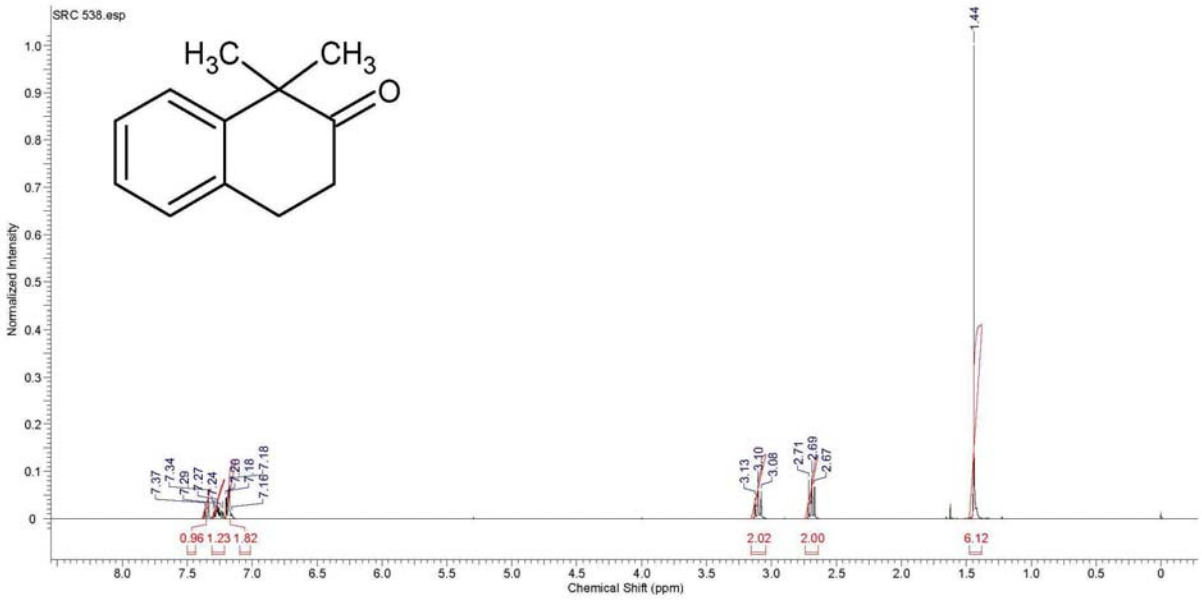
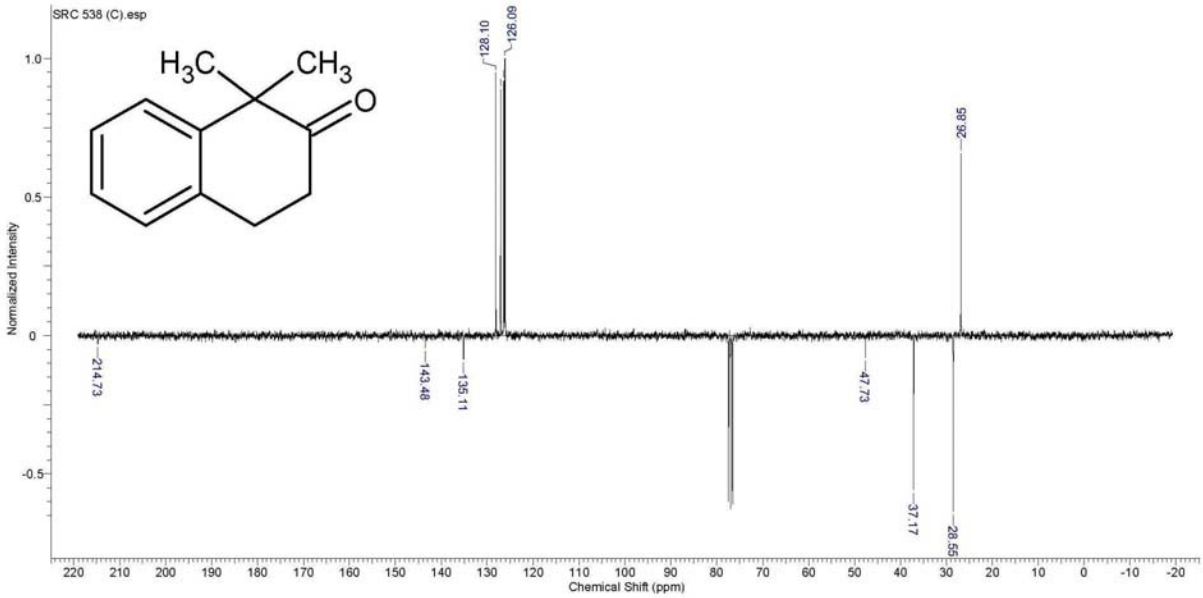
2) Spectroscopic data, and details of ee determination.

[1]H-NMR of 1,1-dimethyl-3,4-dihydronaphthalen-2(1H)-one 5b.



[13]C-NMR of 1,1-dimethyl-3,4-dihydronaphthalen-2(1H)-one 5b.



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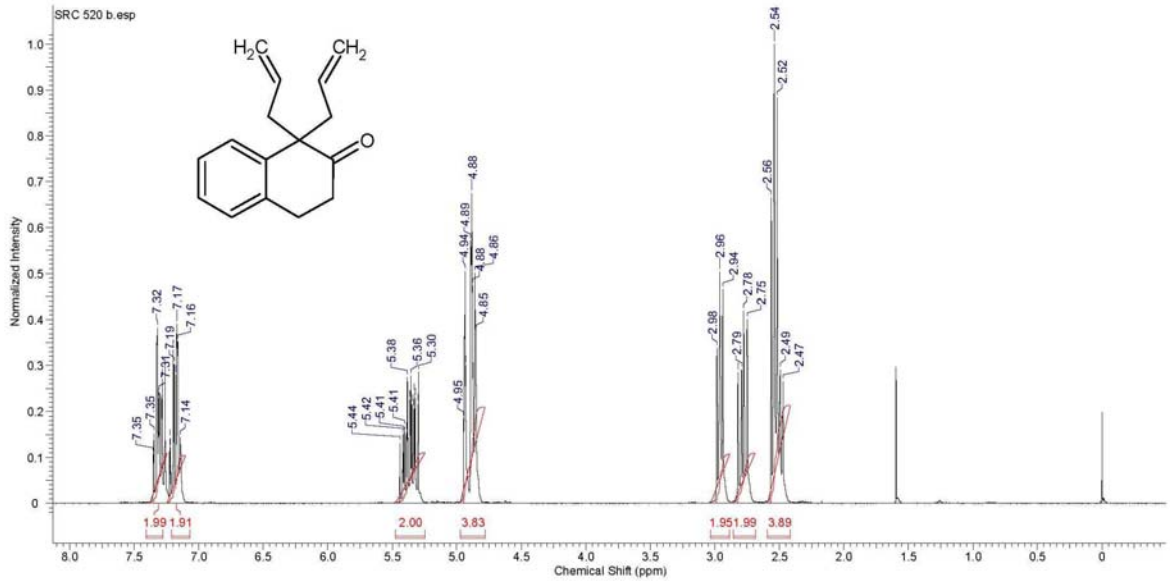

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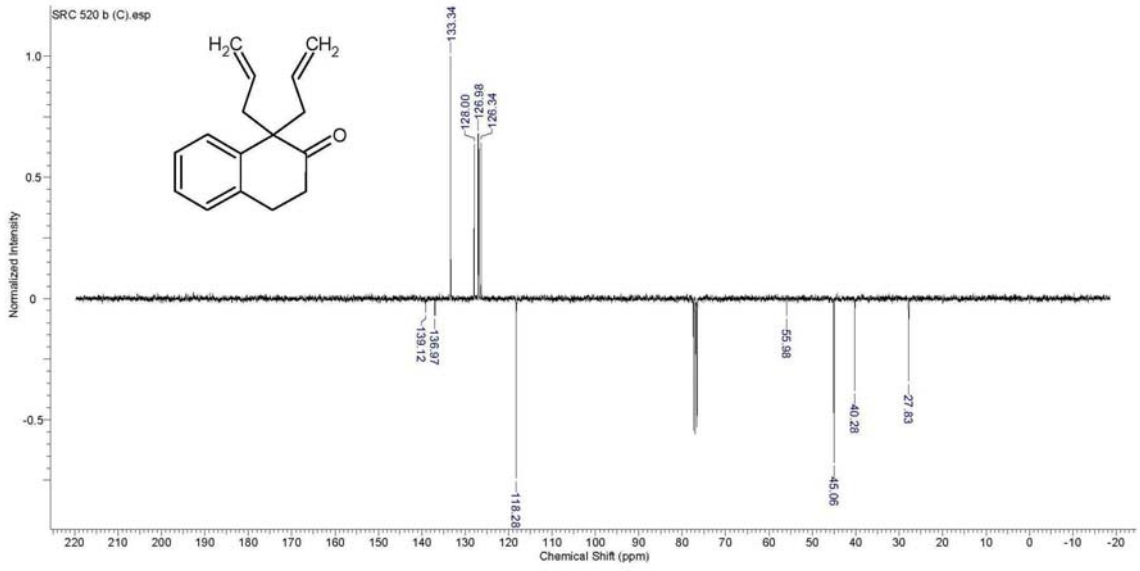
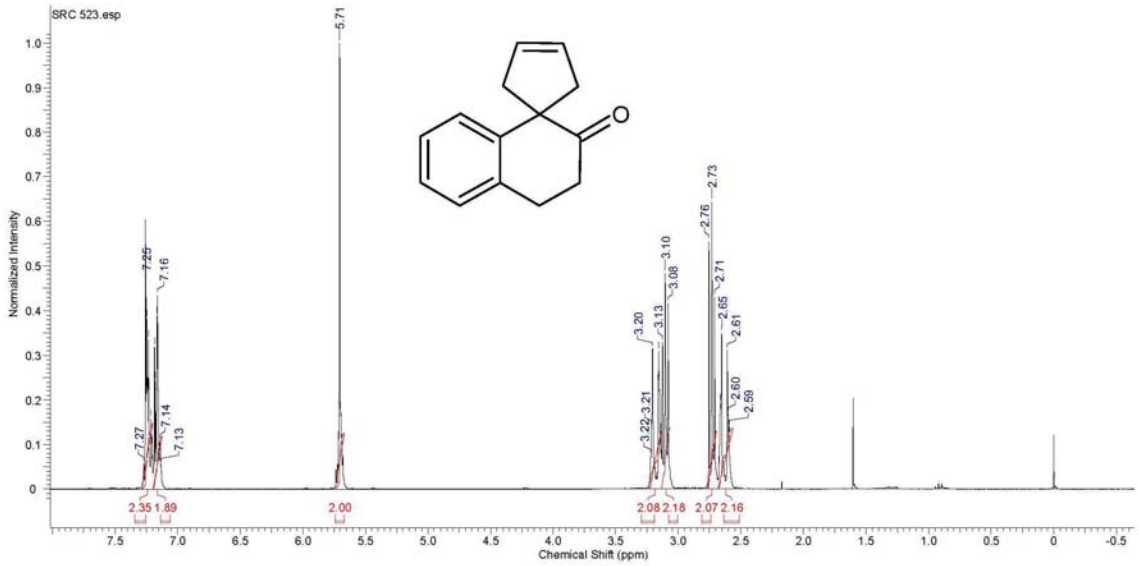
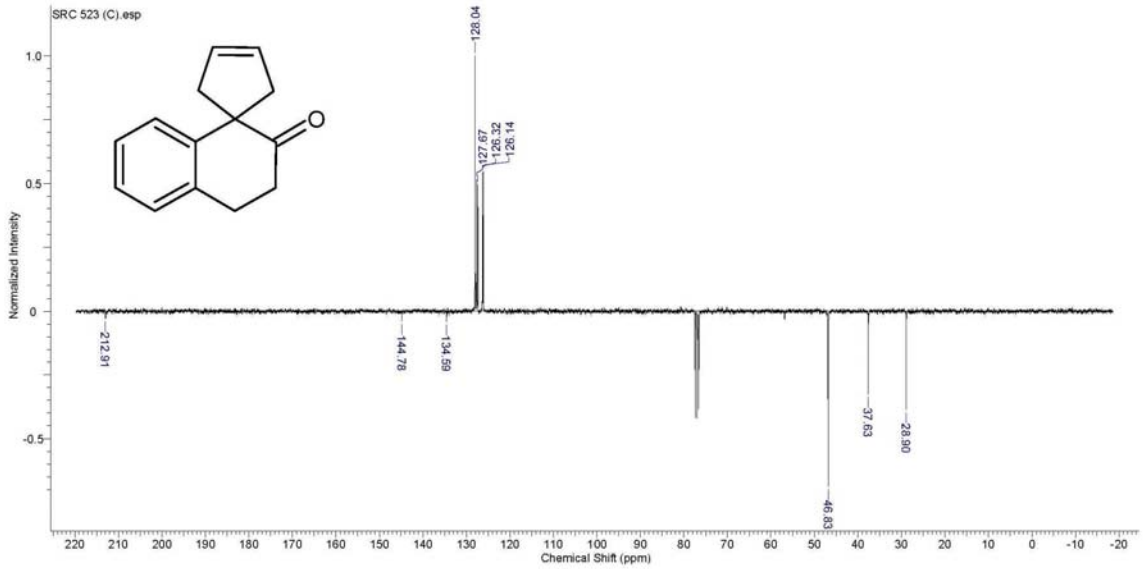


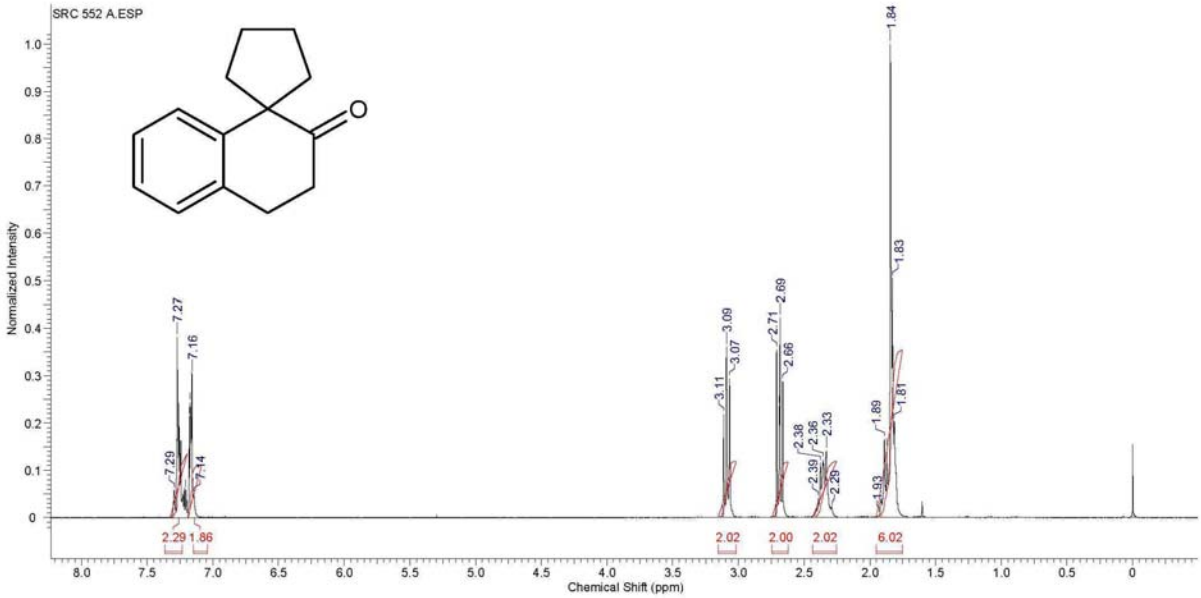
[1]H-NMR of 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-one 5d.



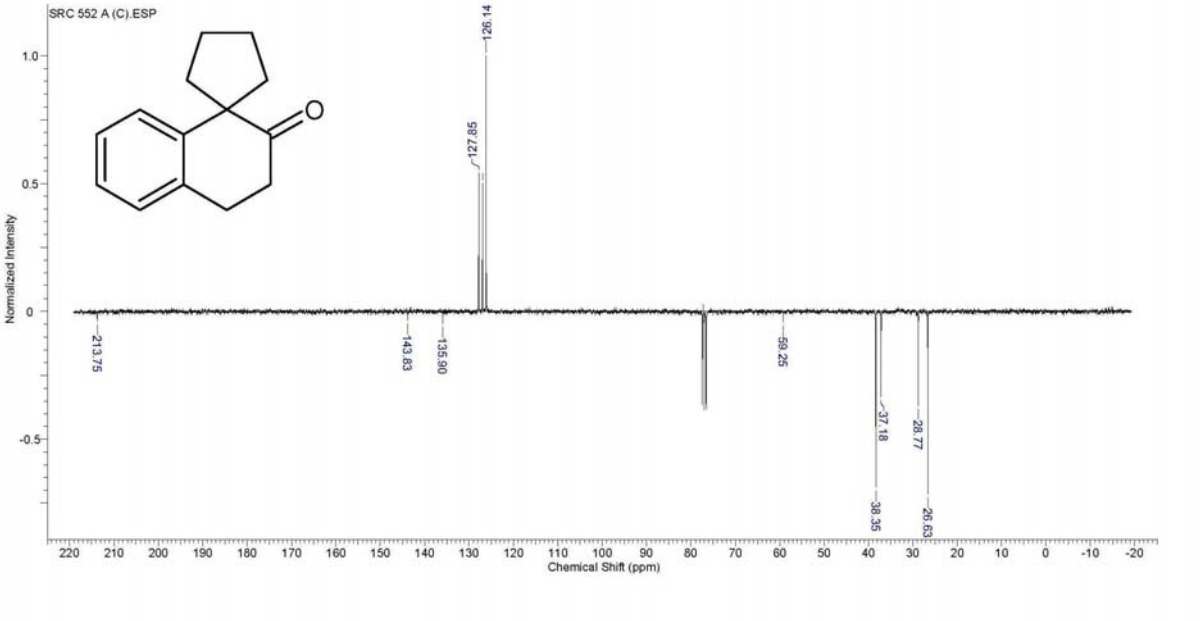
[13]C-NMR of 3',4'-Dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-one 5d.



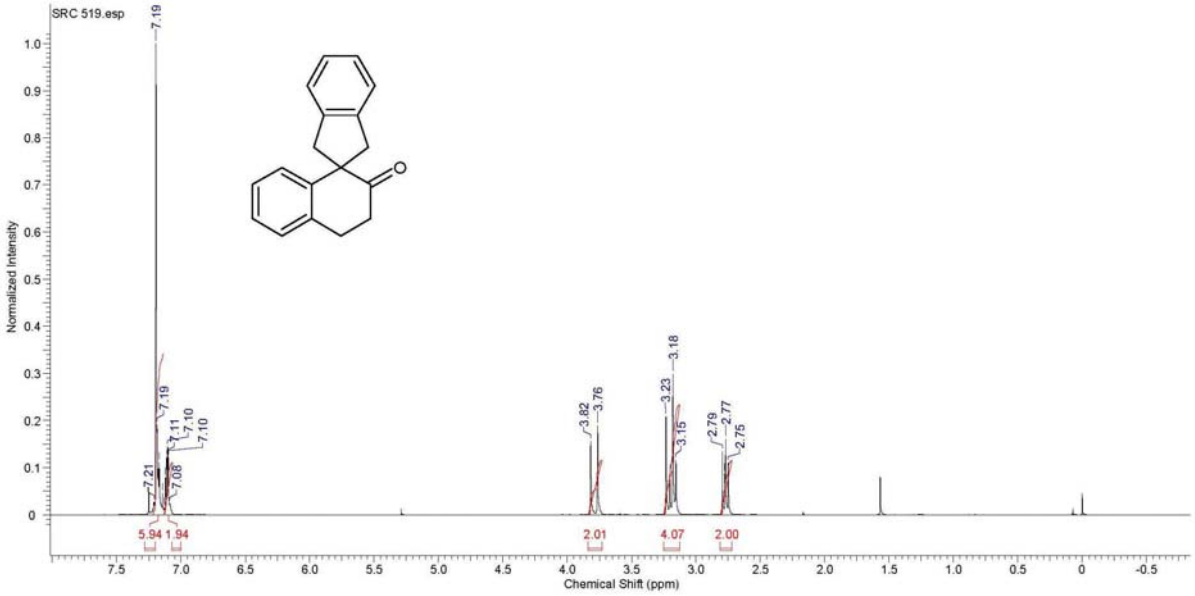
^{1}H-NMR of 3',4'-dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-one 5c.



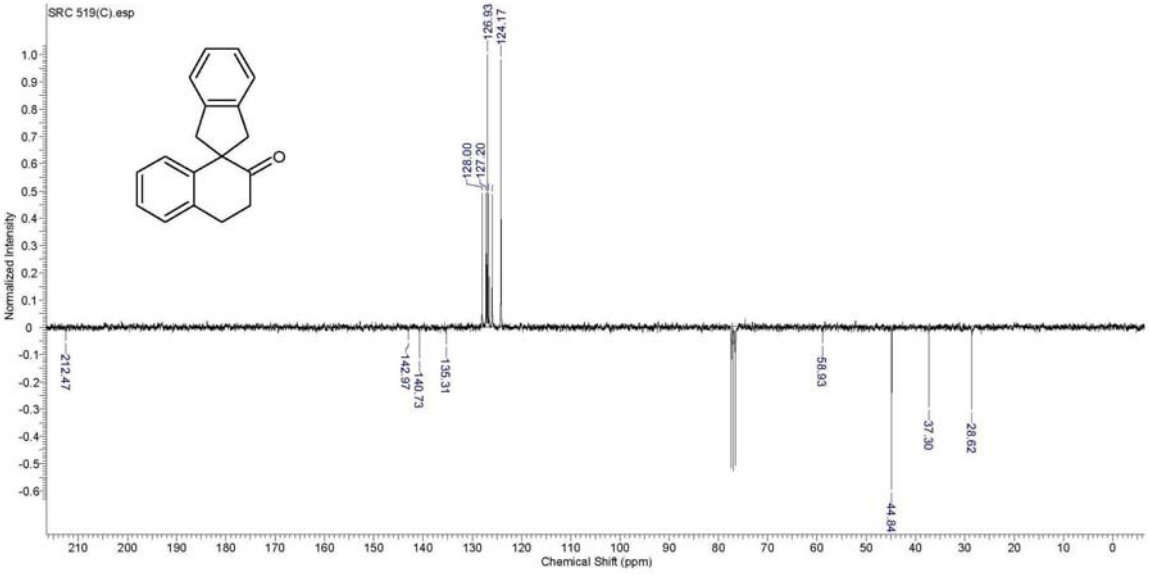
^{13}C-NMR of 3',4'-dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-one 5c.



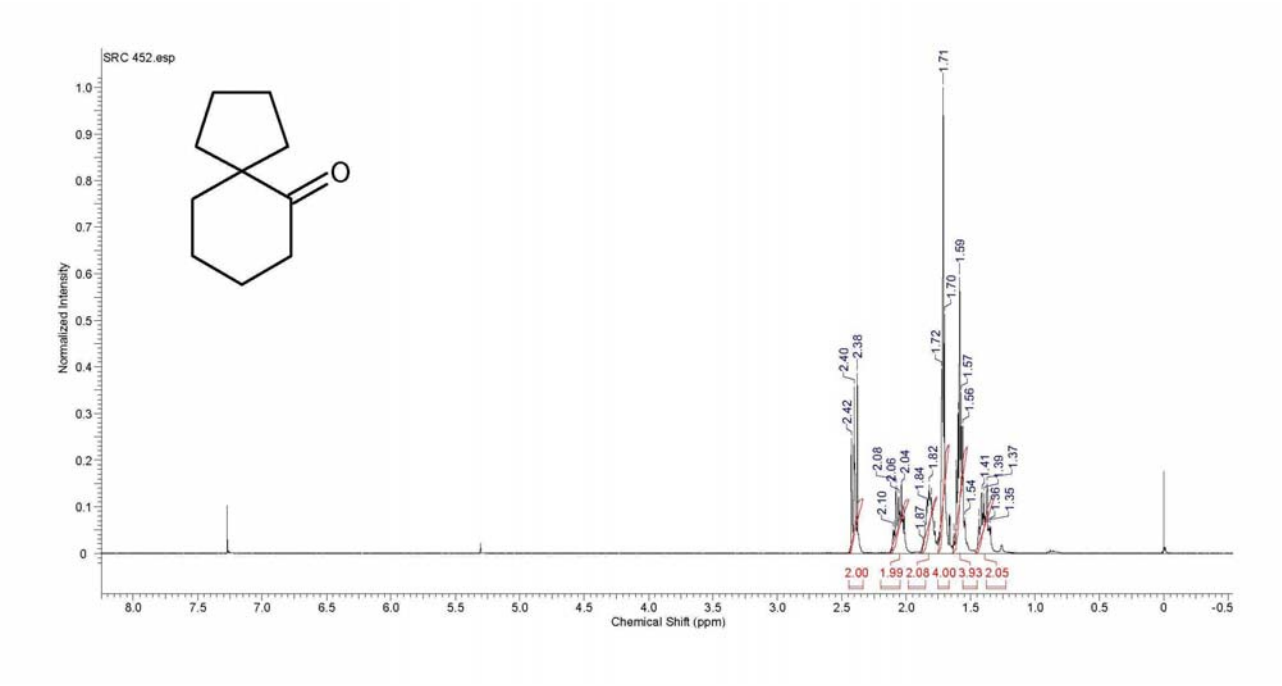
[1]H-NMR of 1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-one 5e.



[13]C-NMR of 1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-one 5e.



[1]H-NMR of spiro[4,5]decane-6-one 8.



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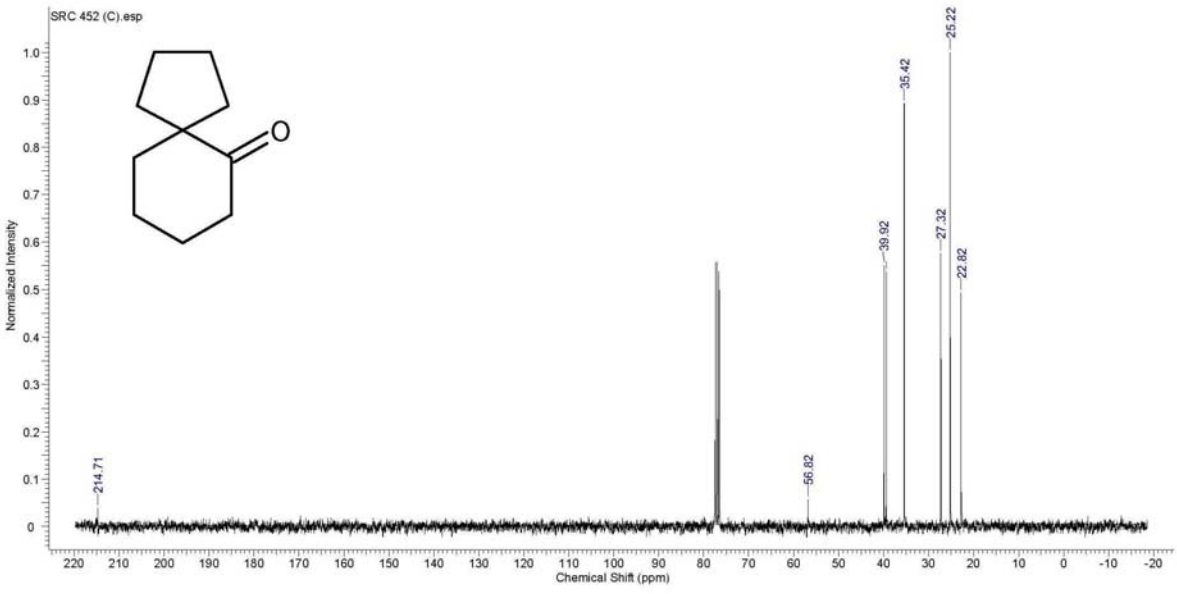

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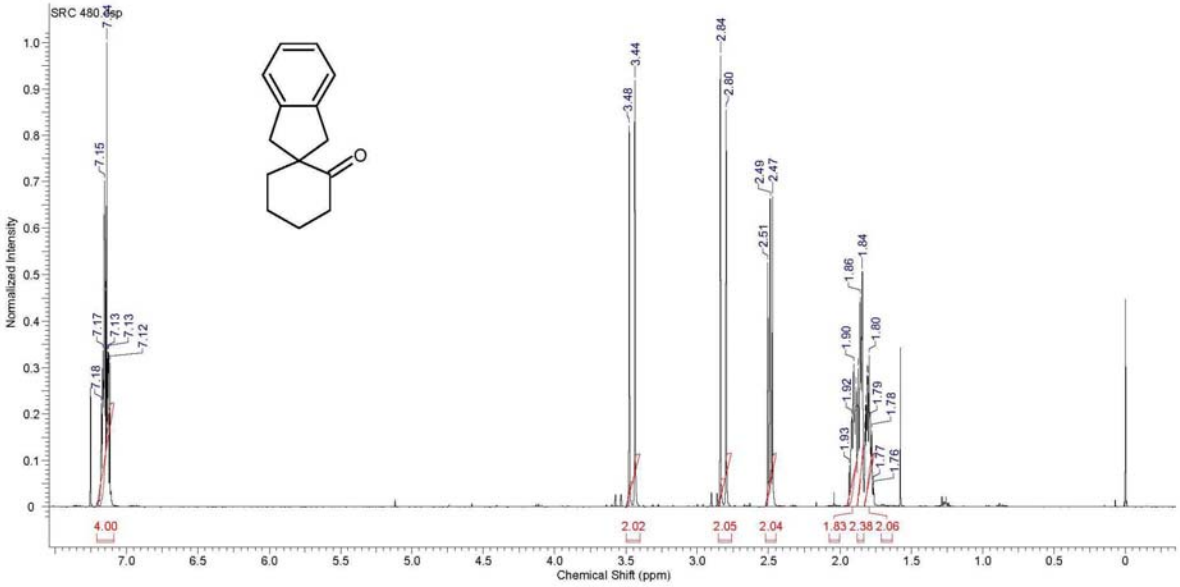
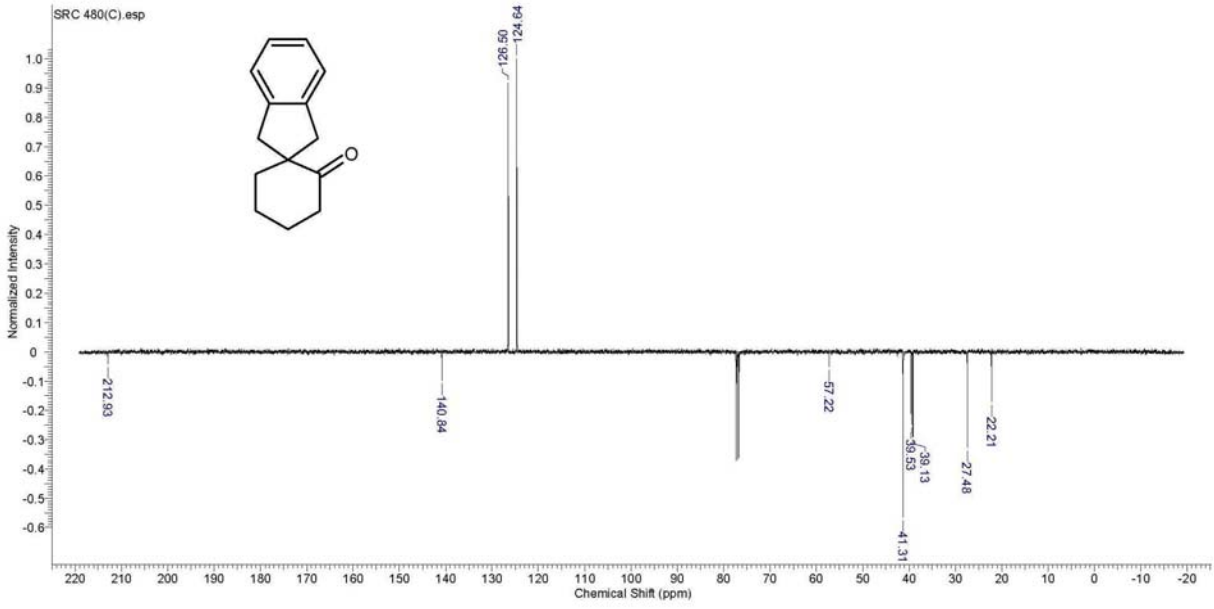
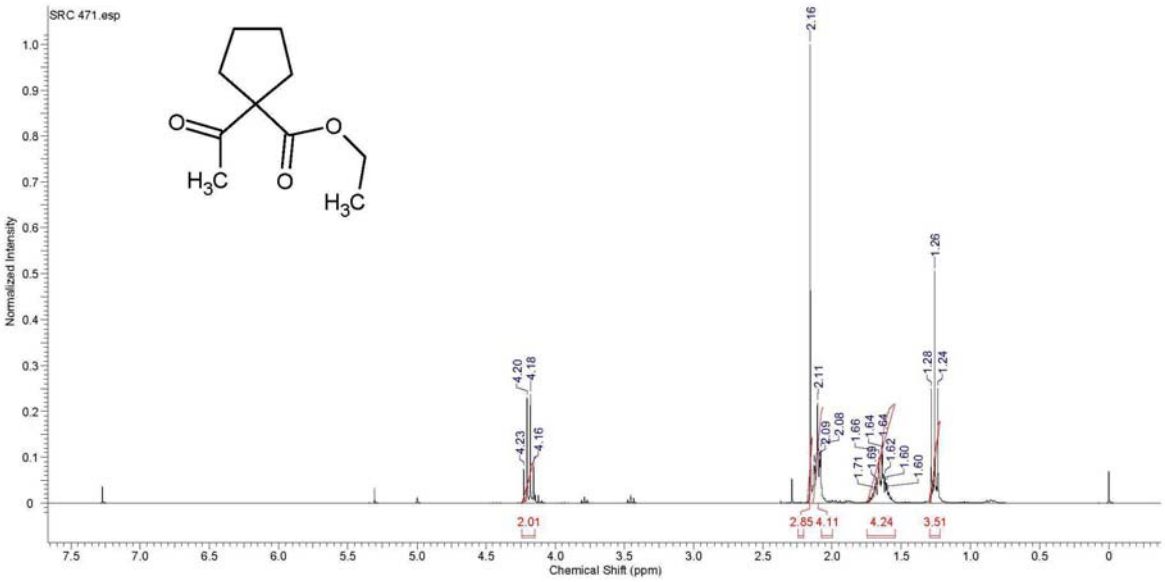


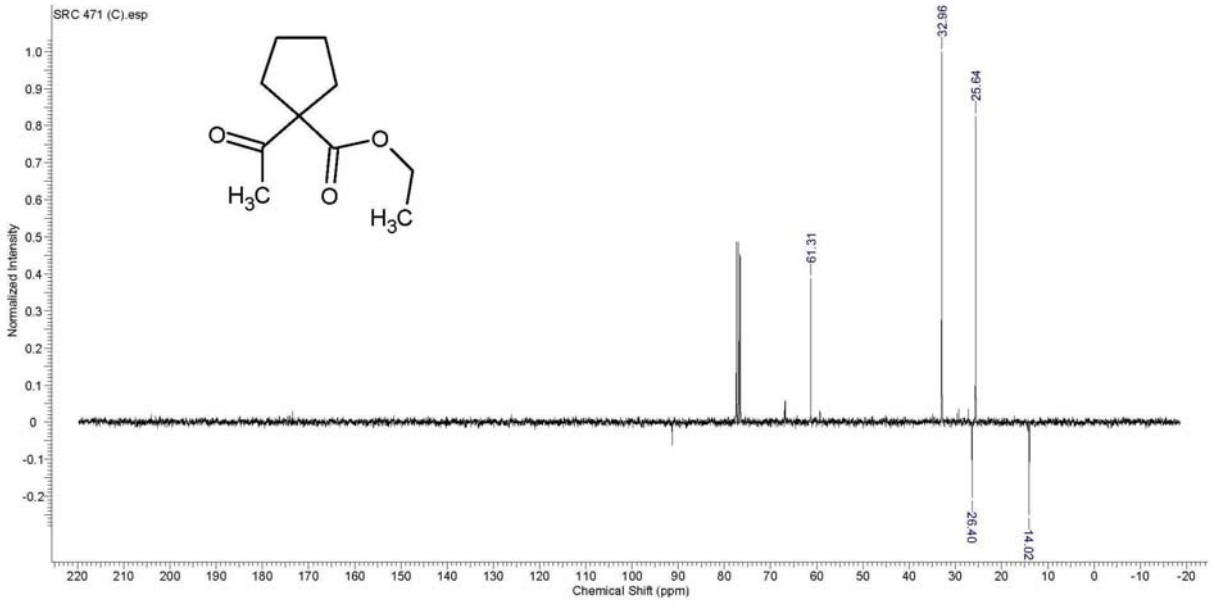
^{13}C-NMR of 1',3'-dihydro-2H-spiro[cyclohexane-1,2'-inden]-2-one 9.



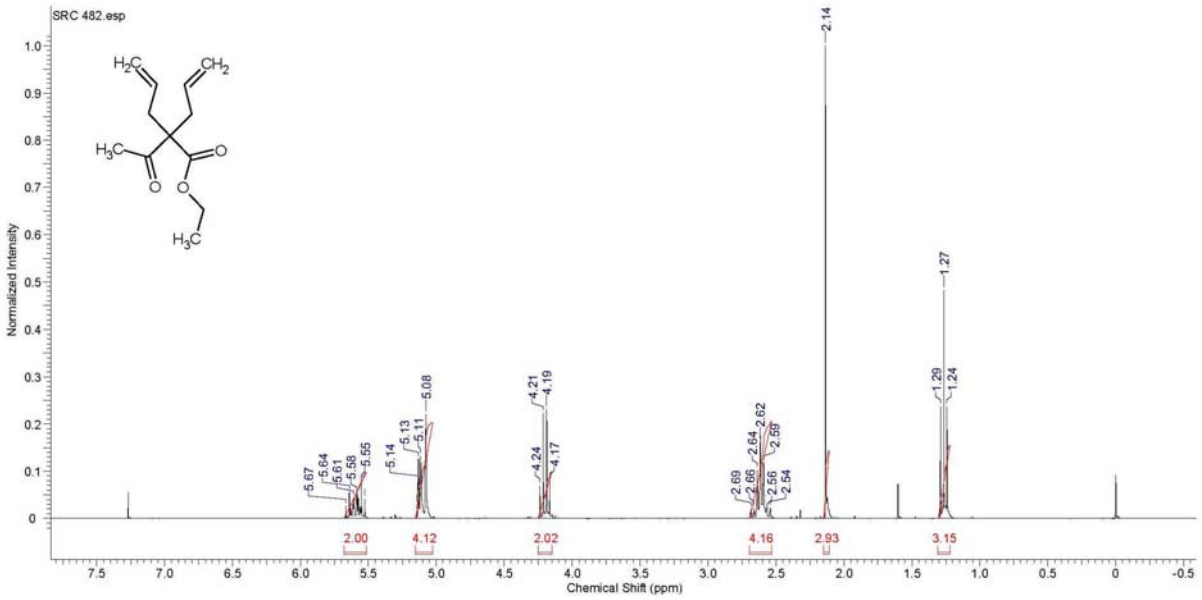
[1]H-NMR of ethyl 1-acetylcyclopentanecarboxylate 13a.



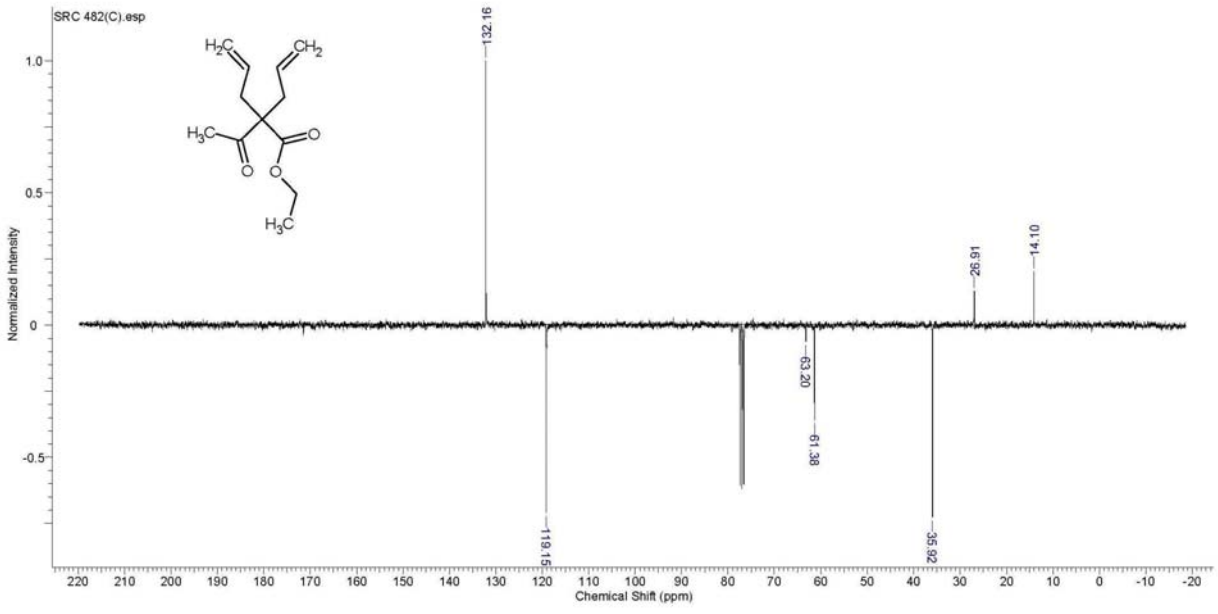
[13]C-NMR of ethyl 1-acetylcyclopentanecarboxylate 13a.



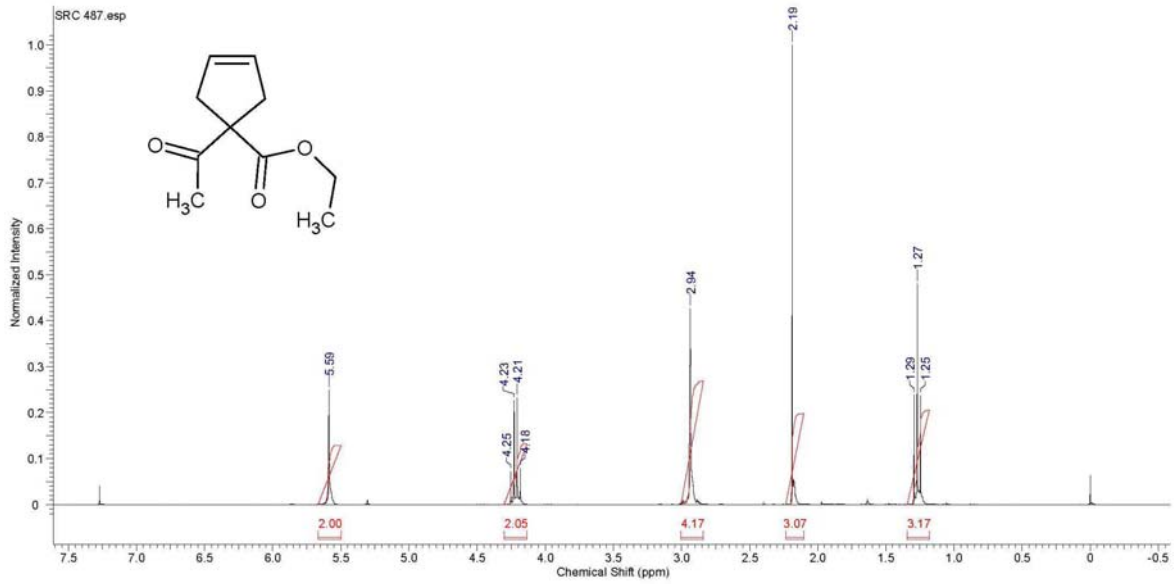
[1]H-NMR of ethyl 2-acetyl-2-(prop-2-en-1-yl)pent-4-enoate.



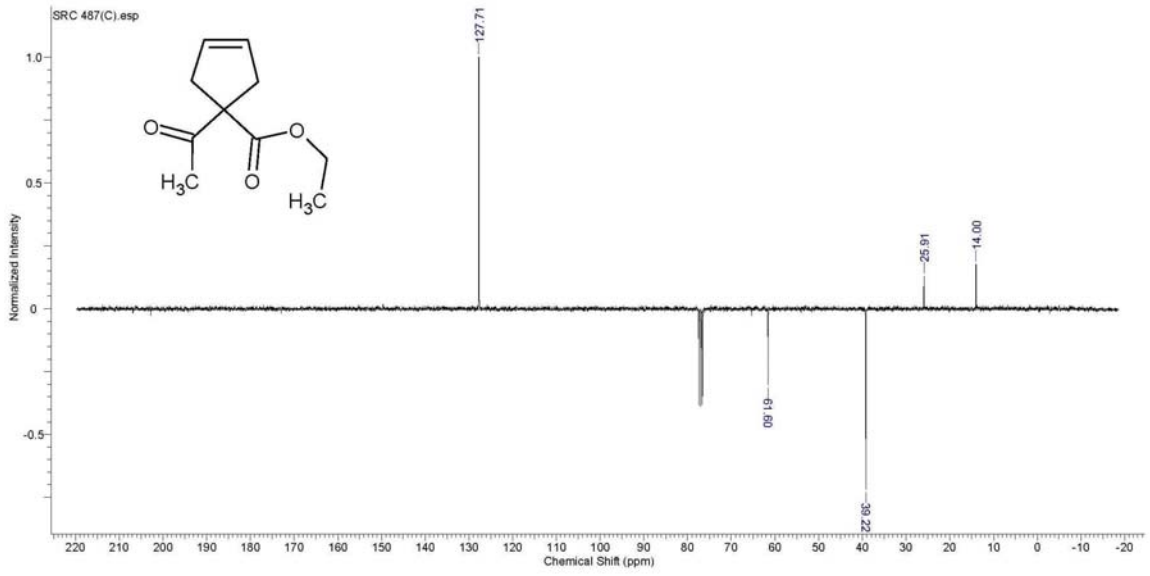
[13]C-NMR of ethyl 2-acetyl-2-(prop-2-en-1-yl)pent-4-enoate.



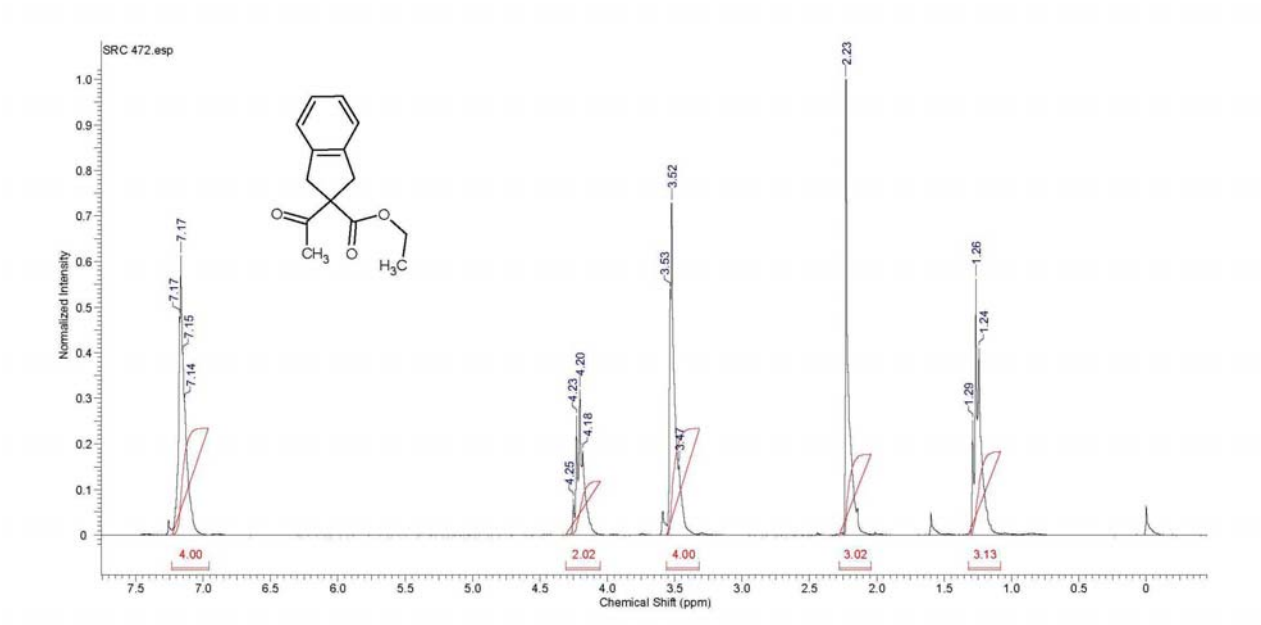
[1]H-NMR of ethyl 1-acetylcyclopent-3-ene-1-carboxylate 13b.



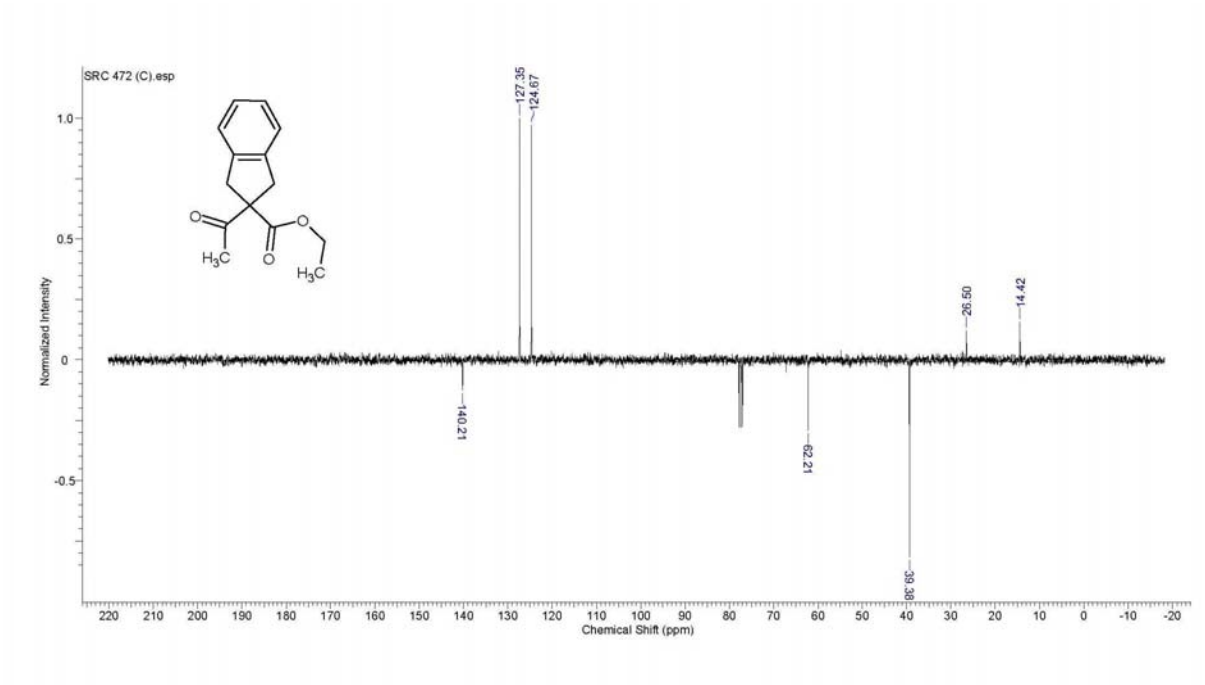
[13]C-NMR of ethyl 1-acetylcyclopent-3-ene-1-carboxylate 13b.



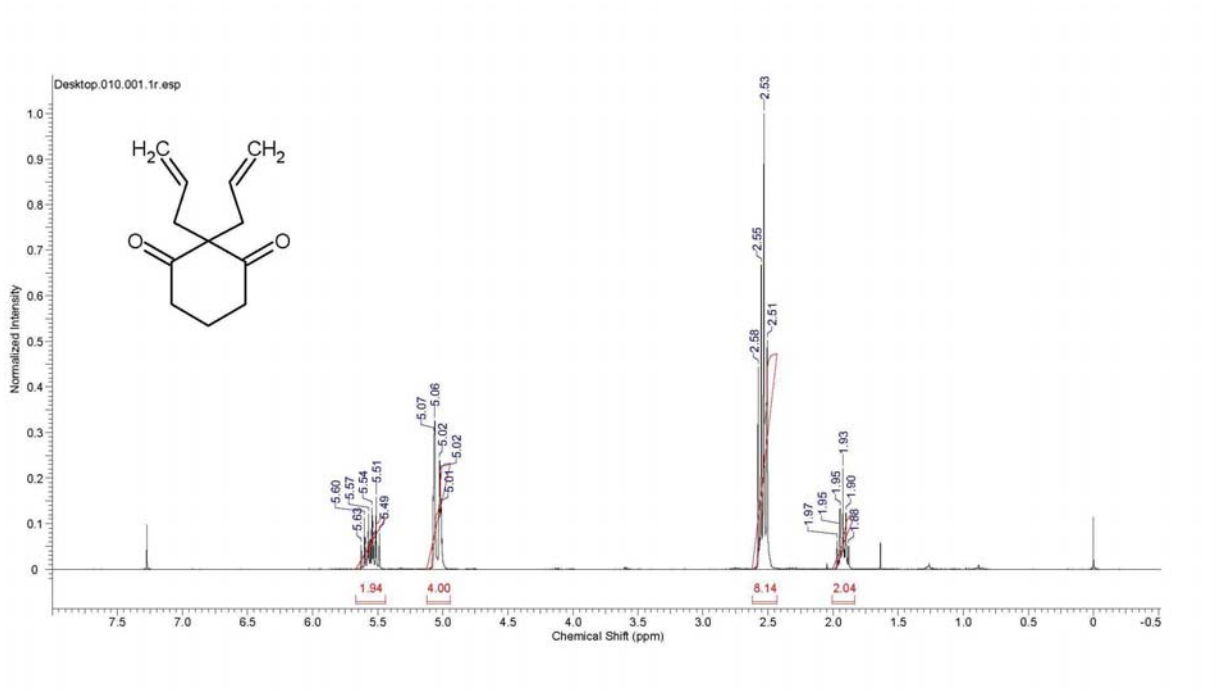
[1]H-NMR of ethyl 2-acetyl-2,3-dihydro-1H-indene-2-carboxylate 13c.



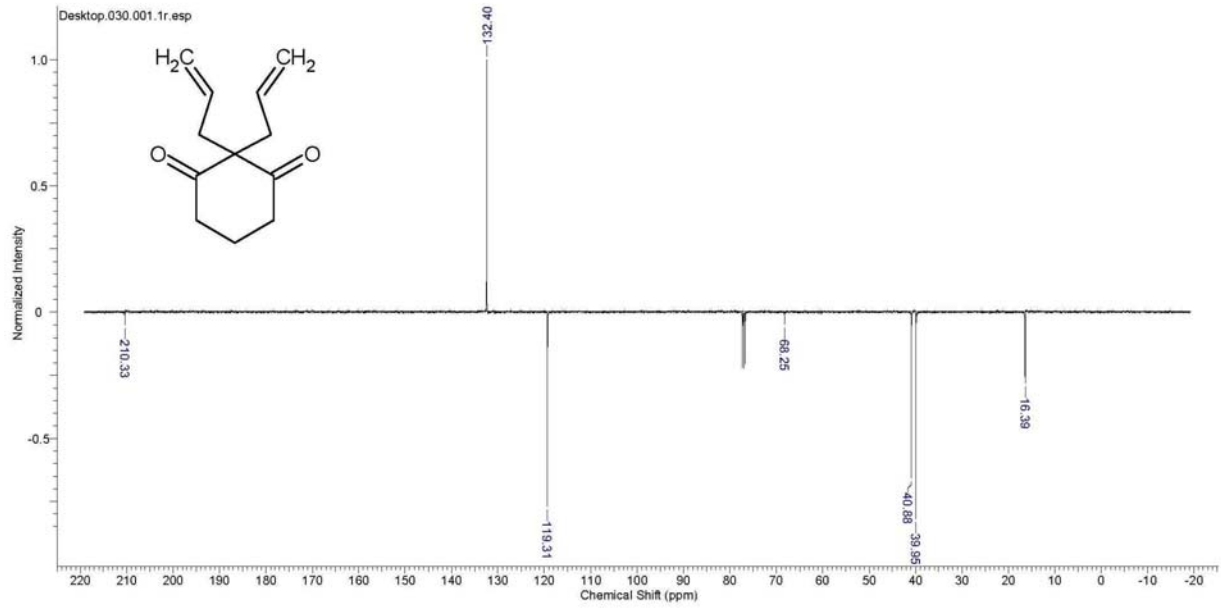
[13]C-NMR of ethyl 2-acetyl-2,3-dihydro-1H-indene-2-carboxylate 13c.



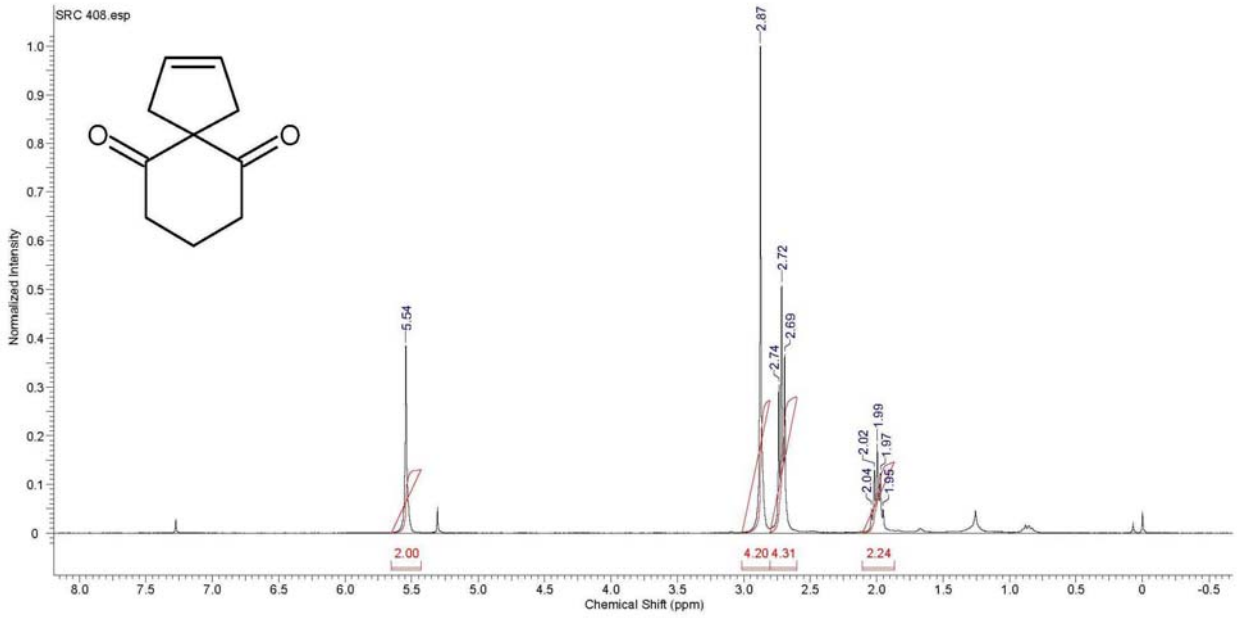
[1]H-NMR of 2,2-di(prop-2-en-1-yl)cyclohexane-1,3-dione.



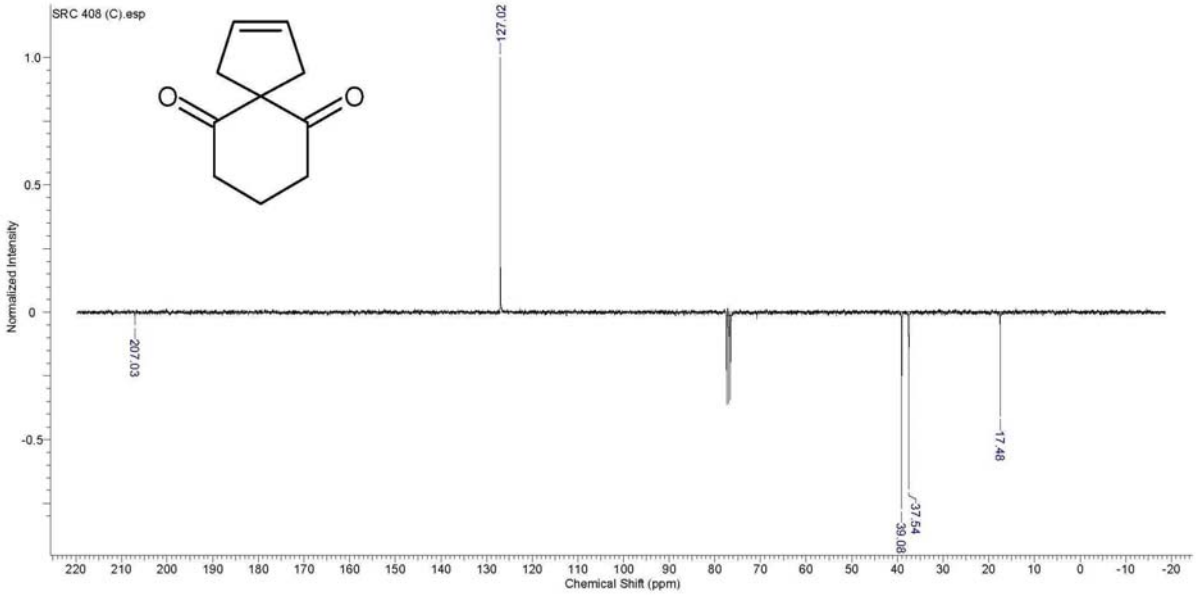
[13]C-NMR of 2,2-di(prop-2-en-1-yl)cyclohexane-1,3-dione.



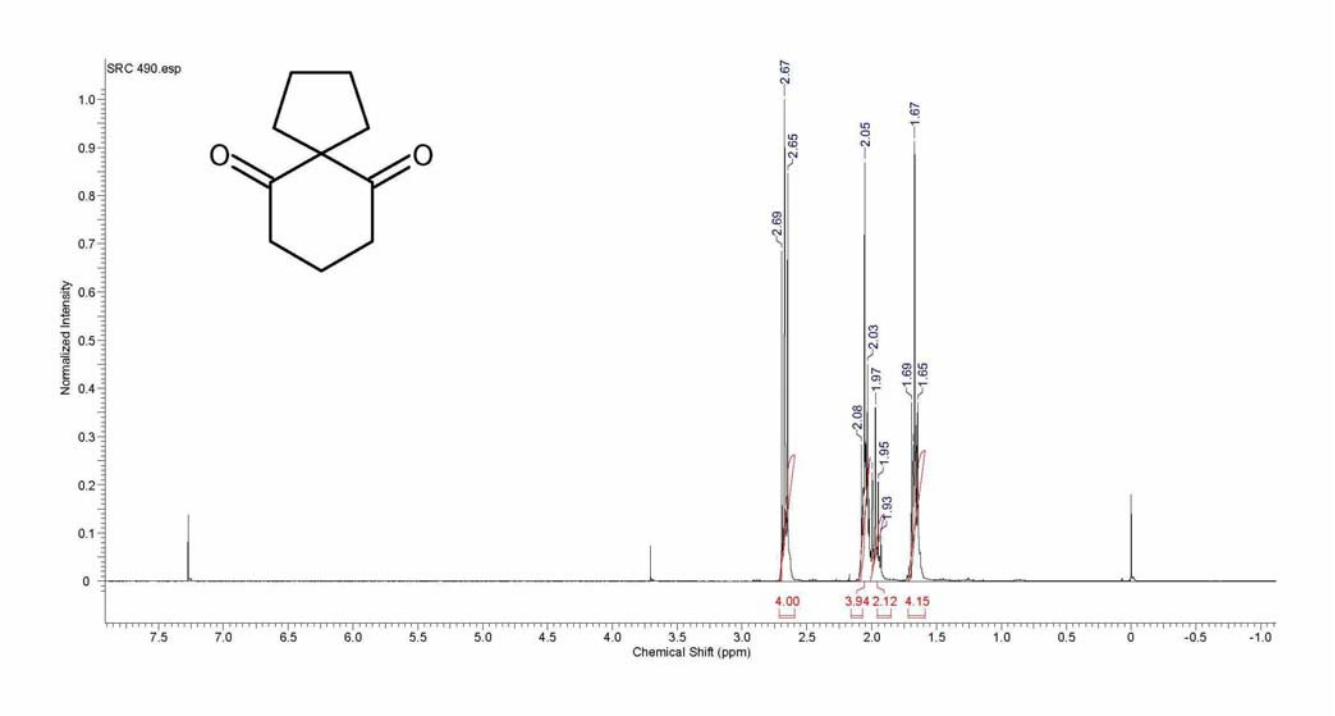
[1]H-NMR of spiro[4,5]dec-2-ene-6,10-dione 15c.



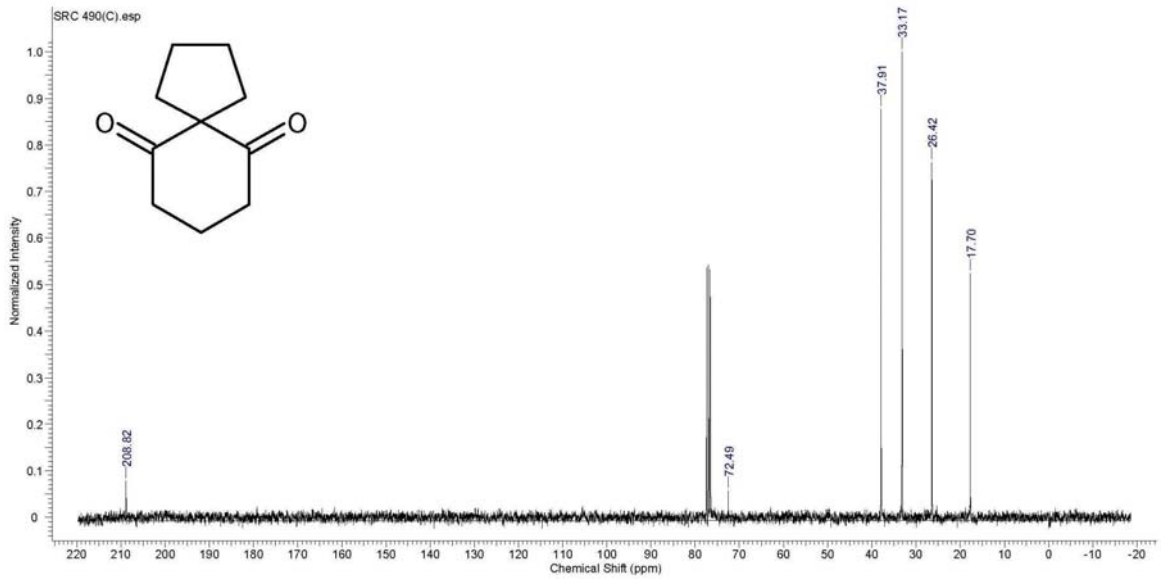
[13]C-NMR of spiro[4,5]dec-2-ene-6,10-dione 15c.



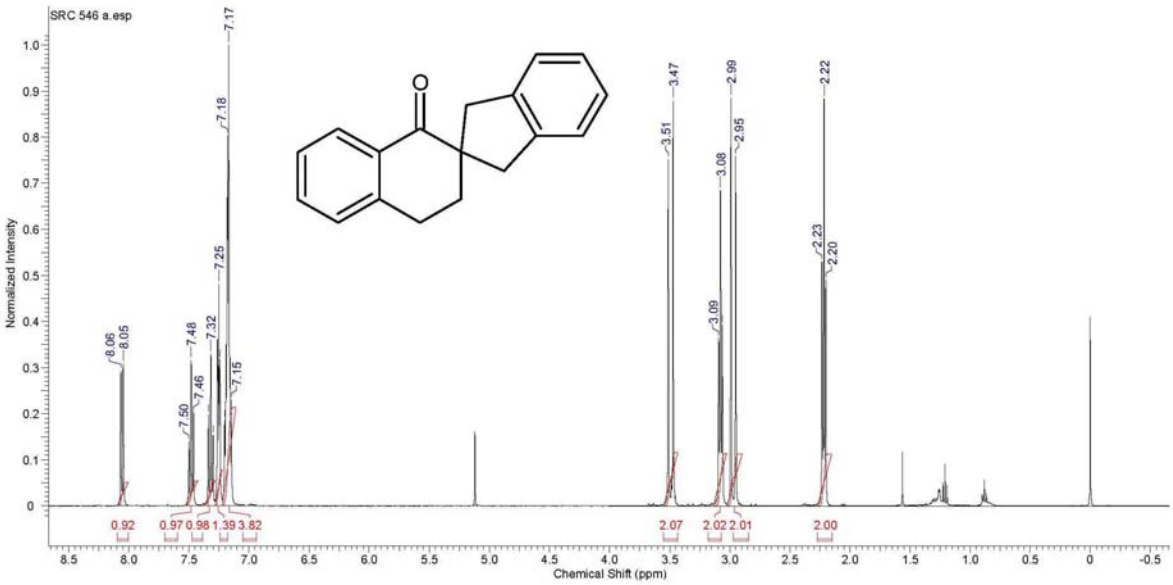
[1]H-NMR of spiro[4,5]decane-6,10-dione 15b.



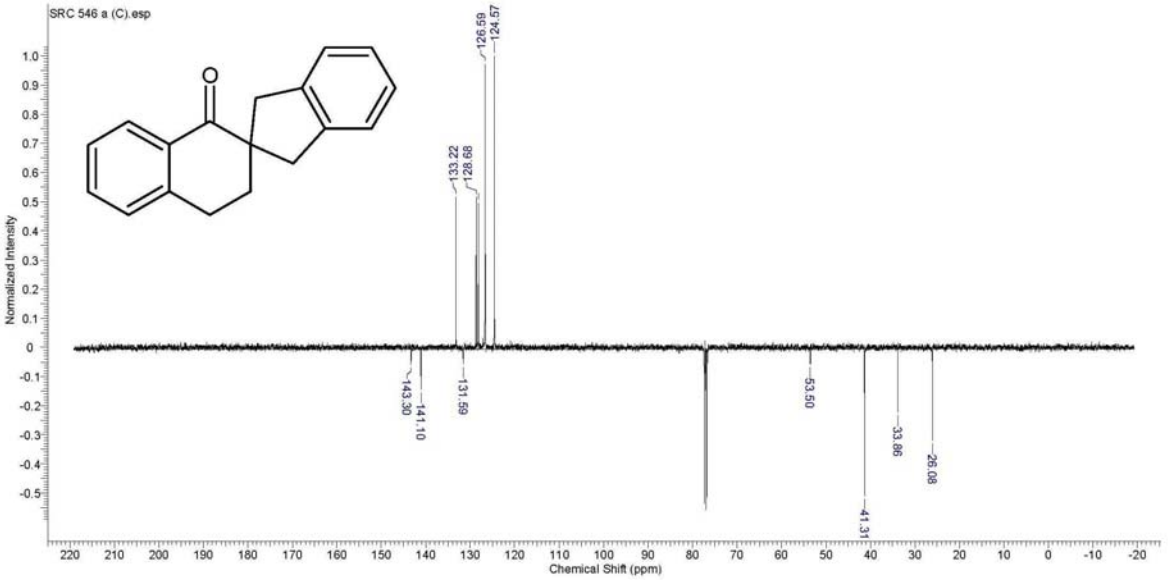
[13]C-NMR of spiro[4,5]decane-6,10-dione 15b.



^{1}H-NMR of 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-one 17a.

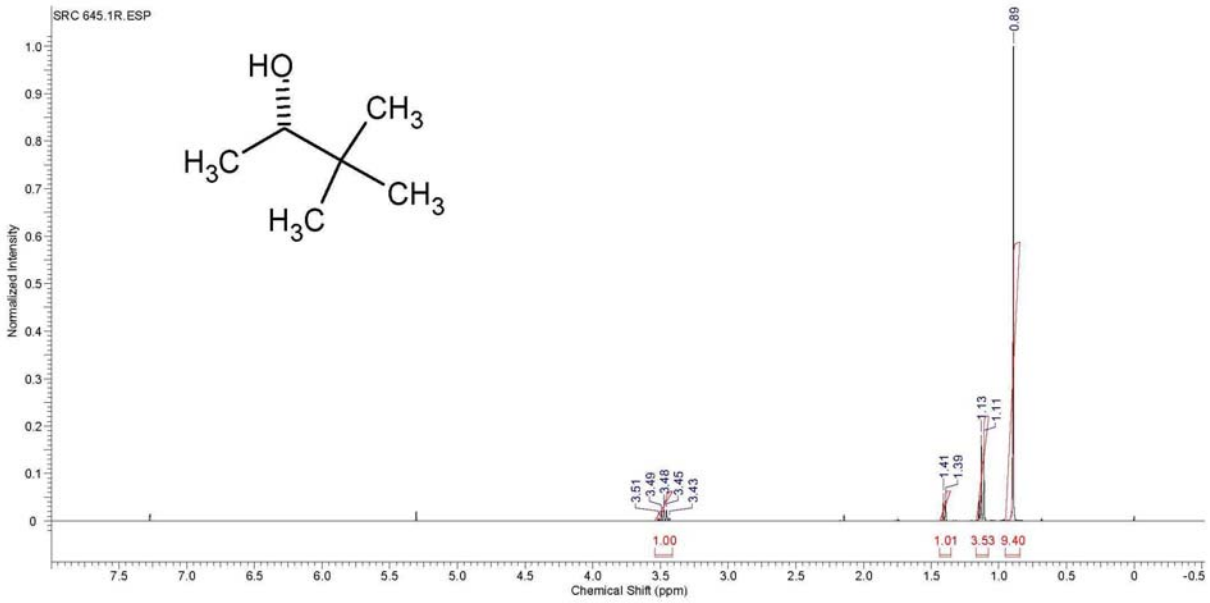


^{13}C-NMR of 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-one 17a.

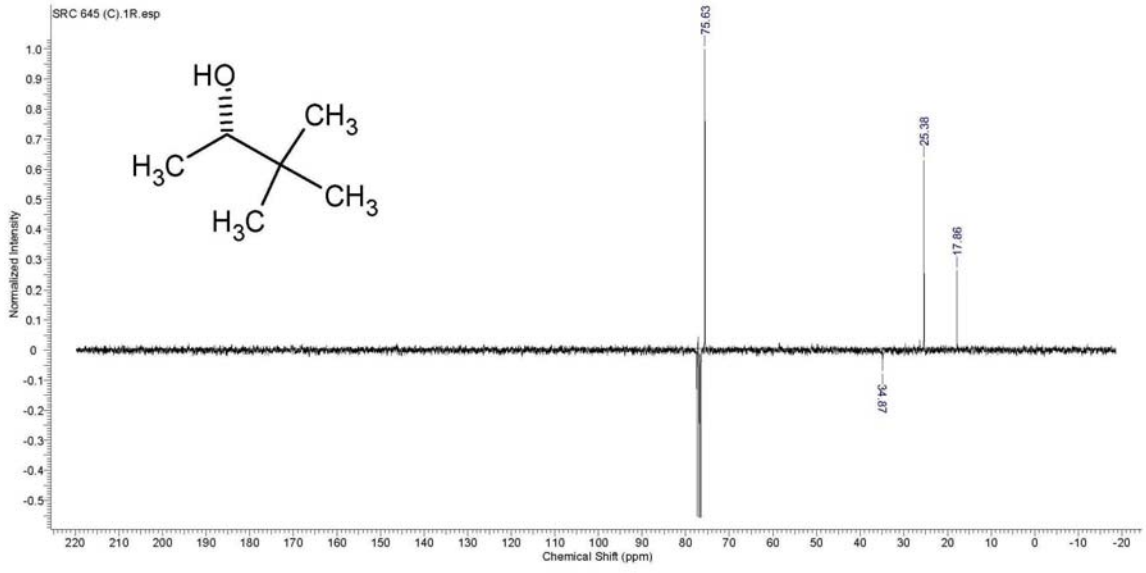


Asymmetric transfer hydrogenation:

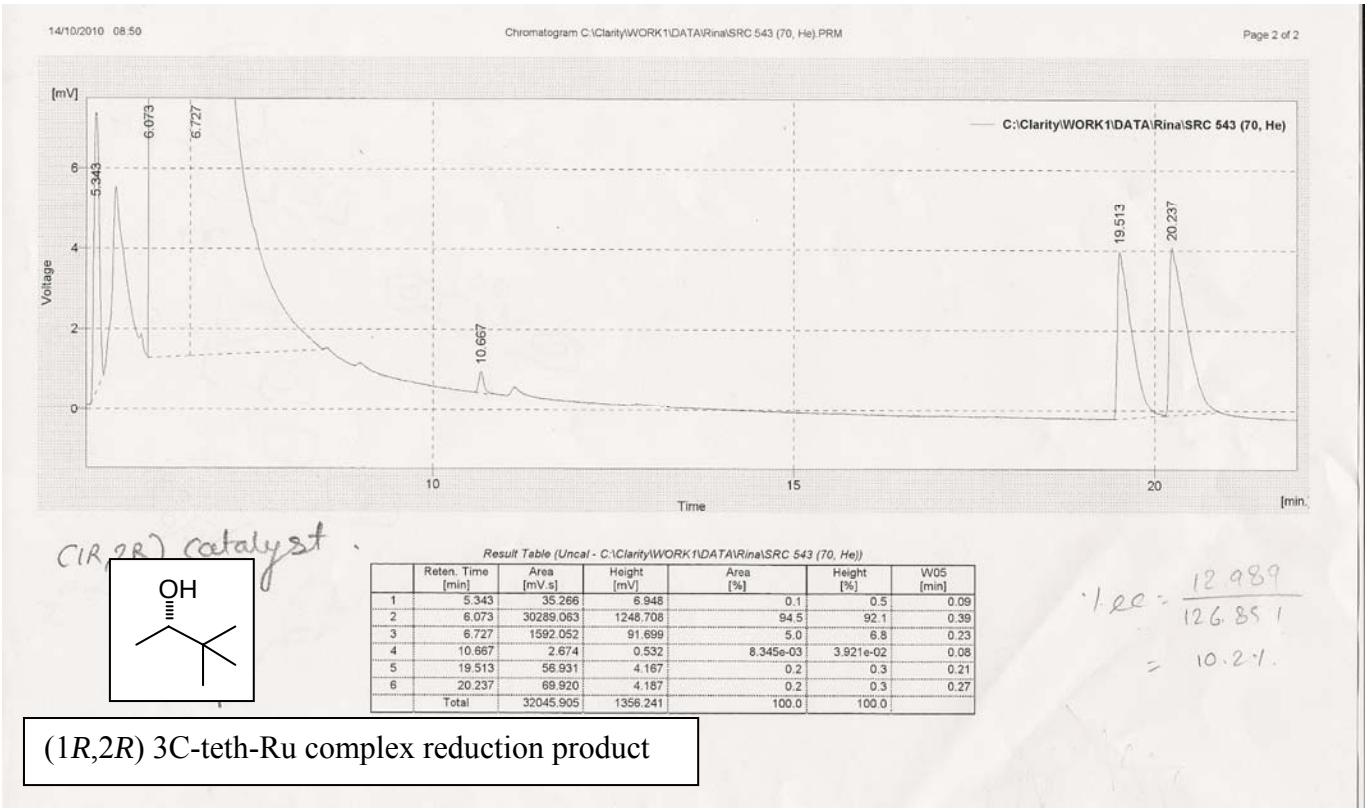
^{1}H-NMR of (*S*)-3,3-dimethylbutan-3-ol.



^{13}C-NMR of (*S*)-3,3-dimethylbutan-3-ol.



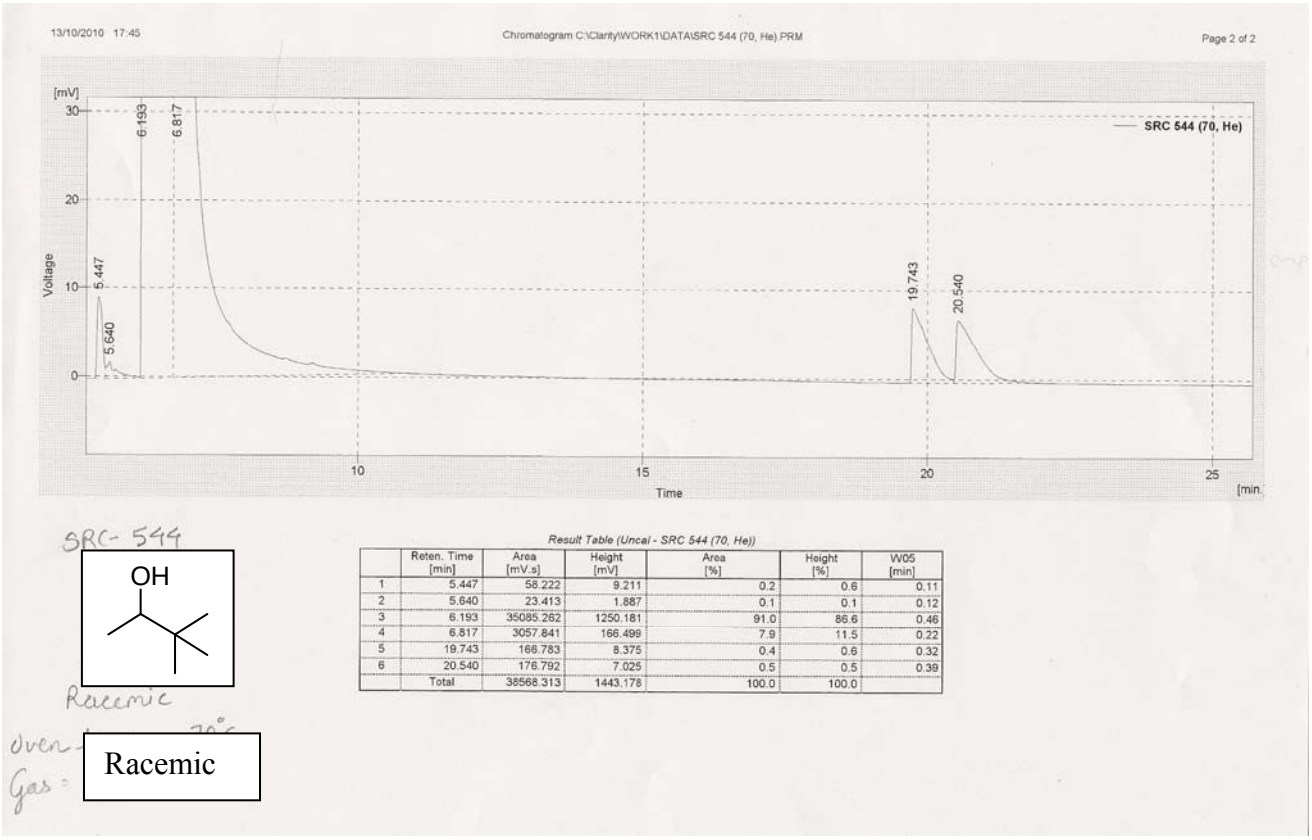
GC of (*S*)-3,3-dimethylbutan-3-ol.



	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	5.343	35.266	6.948	0.1	0.5	0.09
2	6.073	30289.063	1248.708	94.5	92.1	0.39
3	6.727	1592.052	91.699	5.0	6.8	0.23
4	10.667	2.674	0.532	8.345e-03	3.921e-02	0.08
5	19.513	56.931	4.167	0.2	0.3	0.21
6	20.237	69.920	4.187	0.2	0.3	0.27
	Total	32045.905	1356.241	100.0	100.0	

(1*R*,2*R*) 3C-teth-Ru complex reduction product

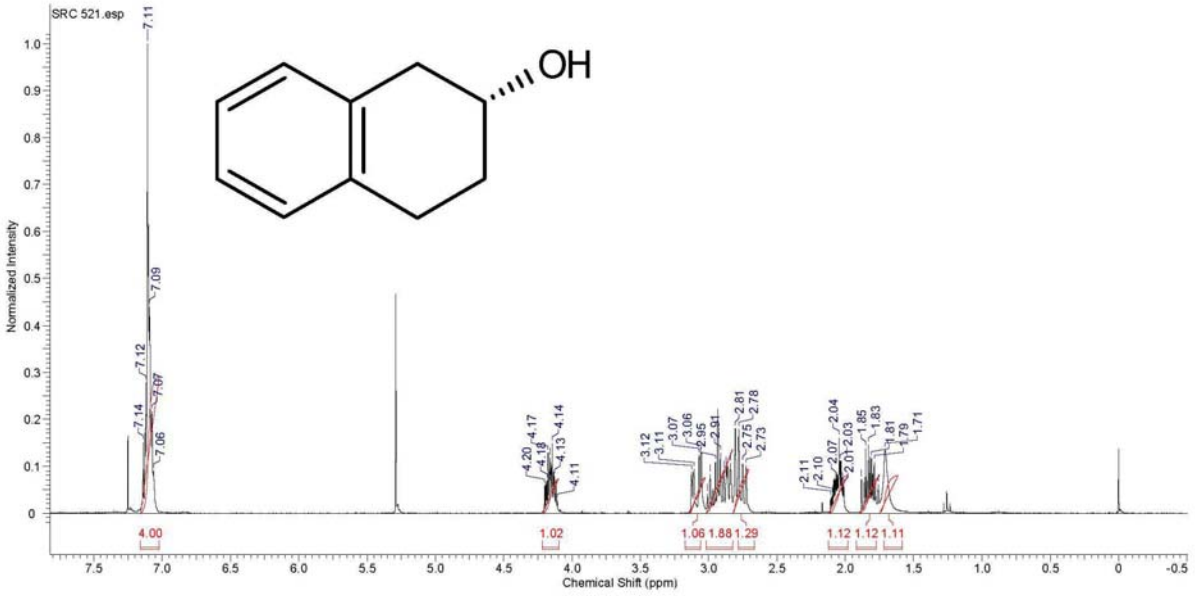
GC of 3,3-dimethylbutan-3-ol.



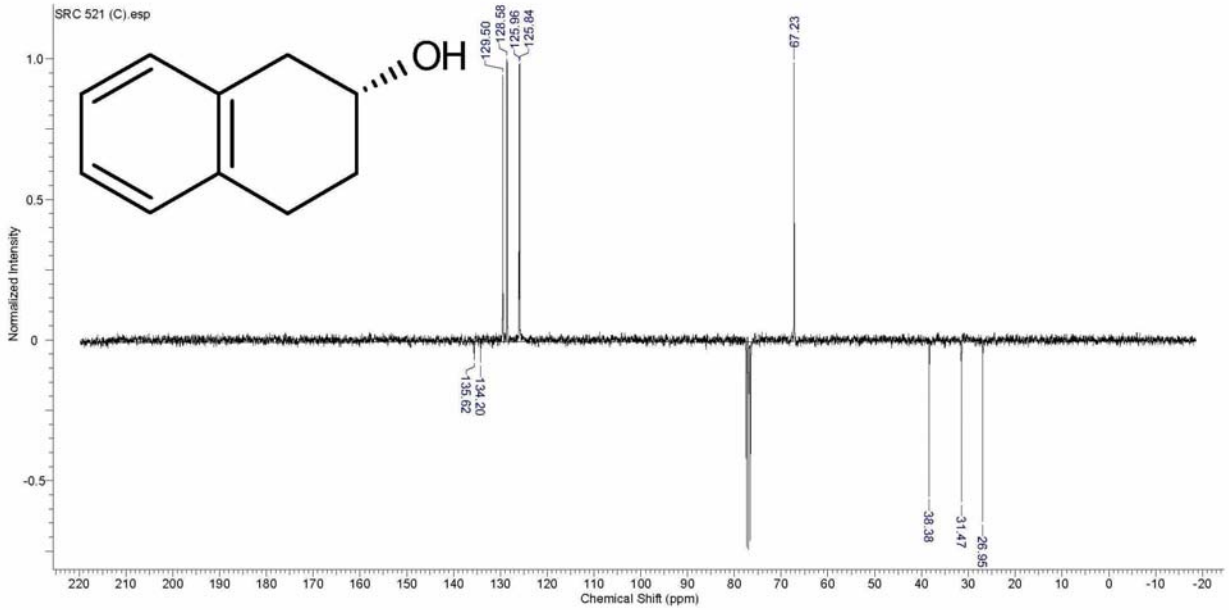
	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	5.447	58.222	9.211	0.2	0.6	0.11
2	5.640	23.413	1.887	0.1	0.1	0.12
3	6.193	35085.262	1250.181	91.0	86.6	0.46
4	6.817	3057.841	166.499	7.9	11.5	0.22
5	19.743	166.783	8.375	0.4	0.6	0.32
6	20.540	176.792	7.025	0.5	0.5	0.39
	Total	38568.313	1443.178	100.0	100.0	

Racemic

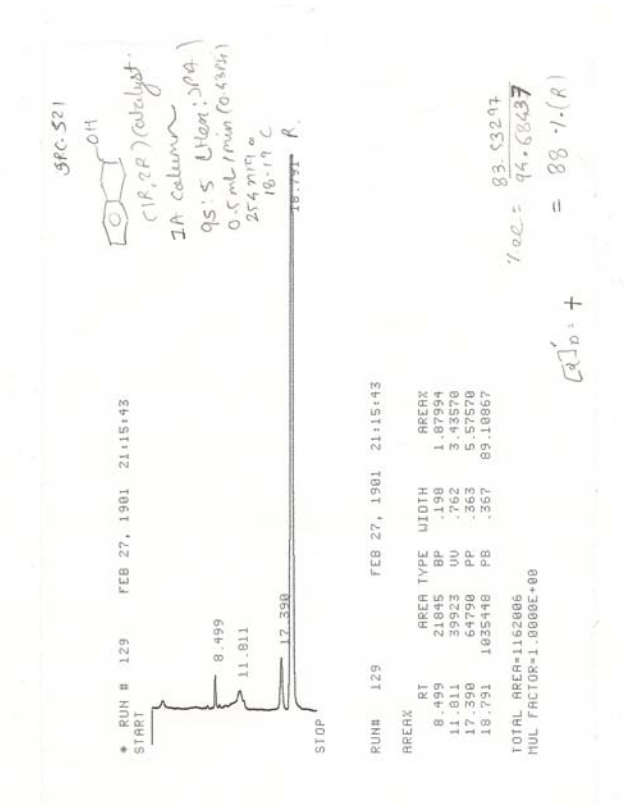
^{1}H-NMR of (*R*)-β-tetralol 6a.

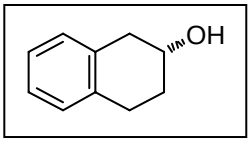


^{13}C-NMR of (*R*)-β-tetralol 6a.



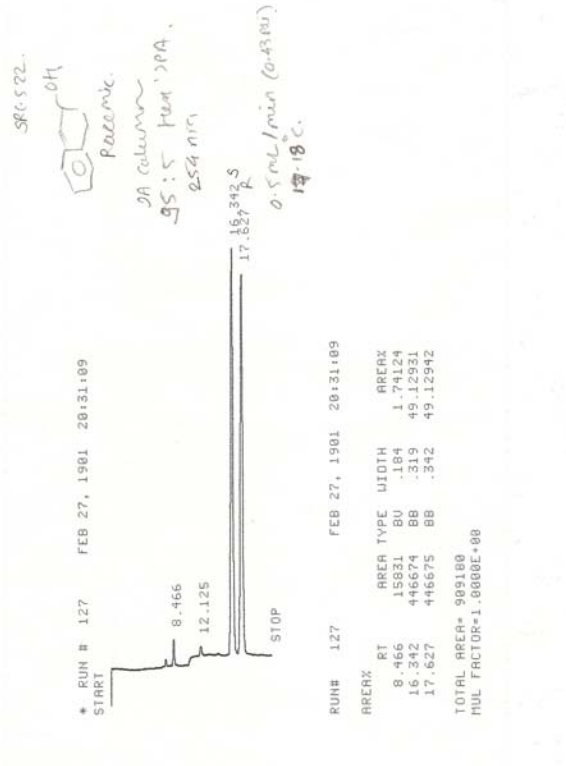
HPLC of (*R*)-β-tetralol 6a.

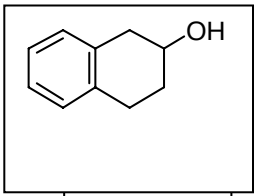




(1*R*,2*R*) 3C-teth-Ru complex reduction product

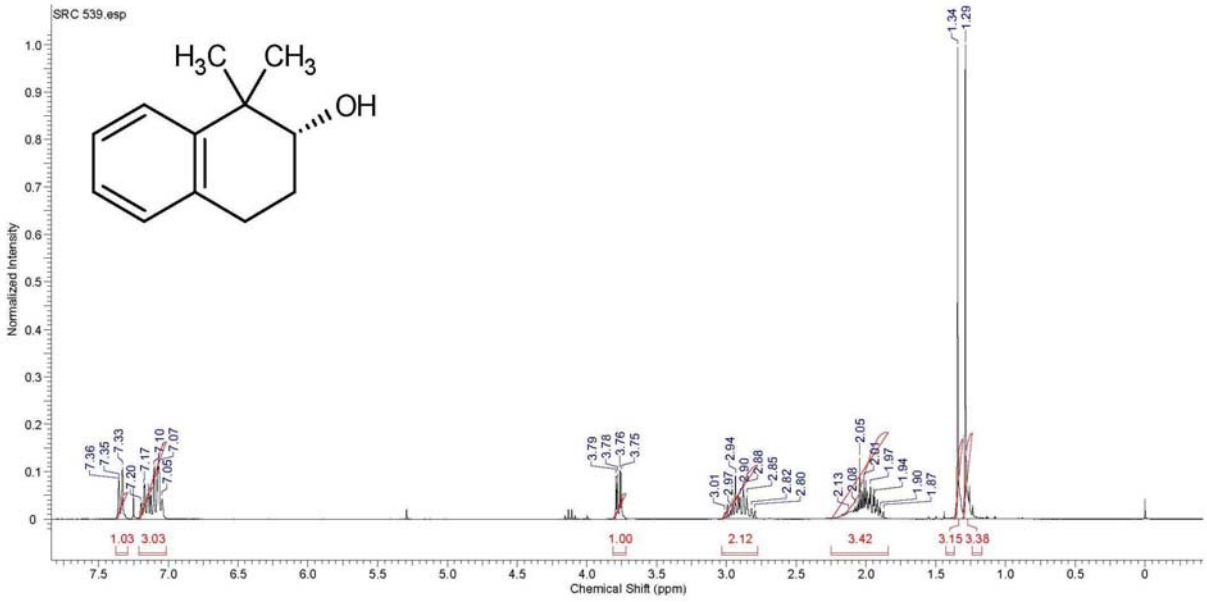
HPLC of racemic β-tetralol.



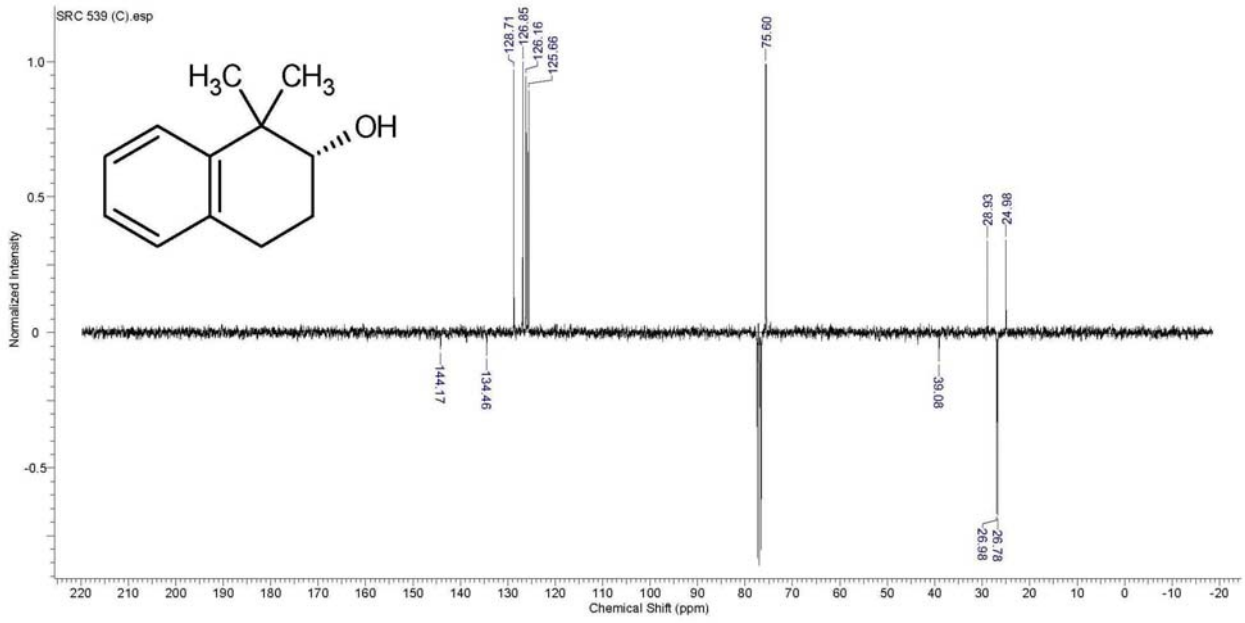


Racemic

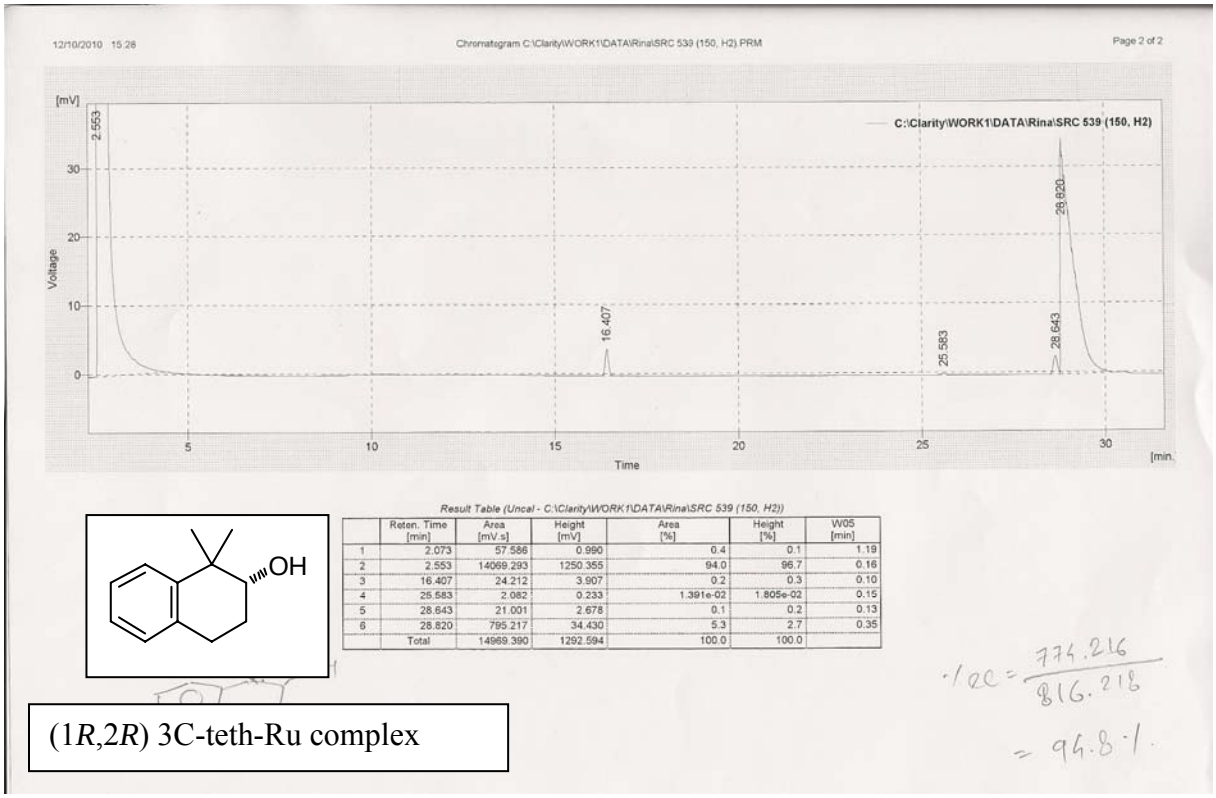
[1]H-NMR of (*R*) 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol 6b.



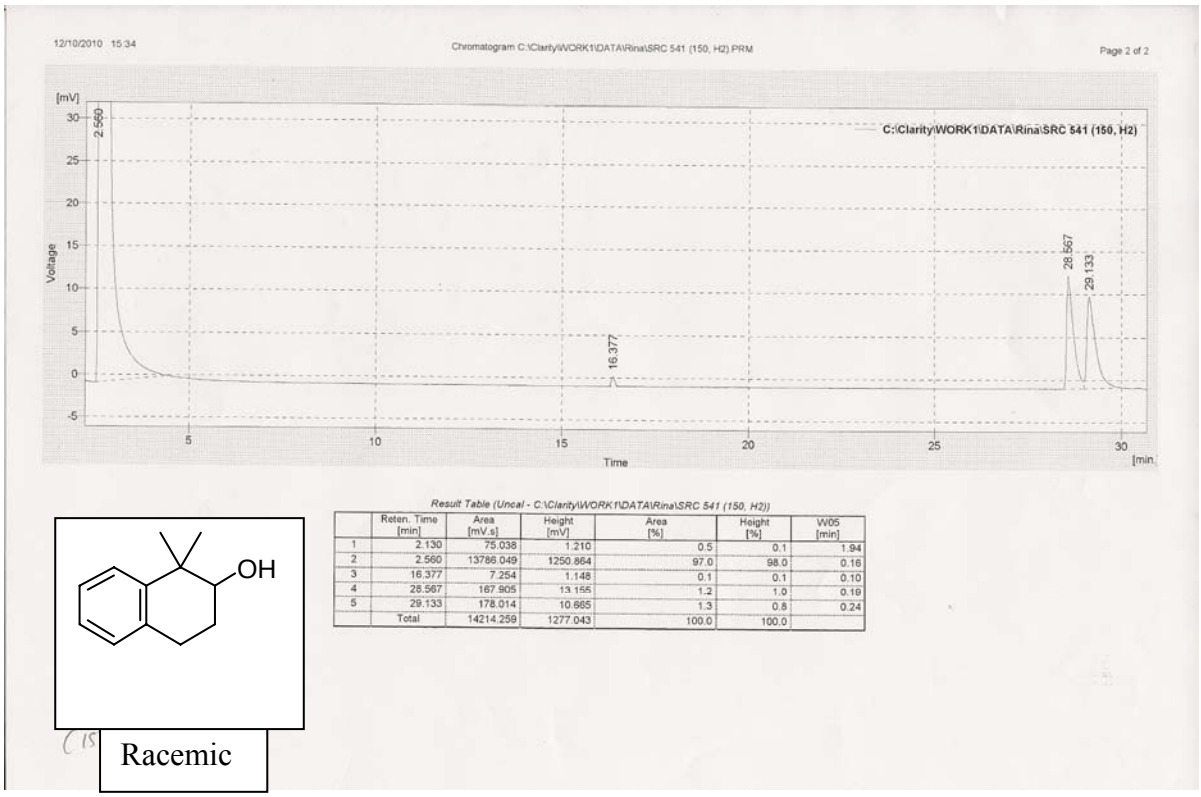
[13]C-NMR of (*R*) 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol 6b.



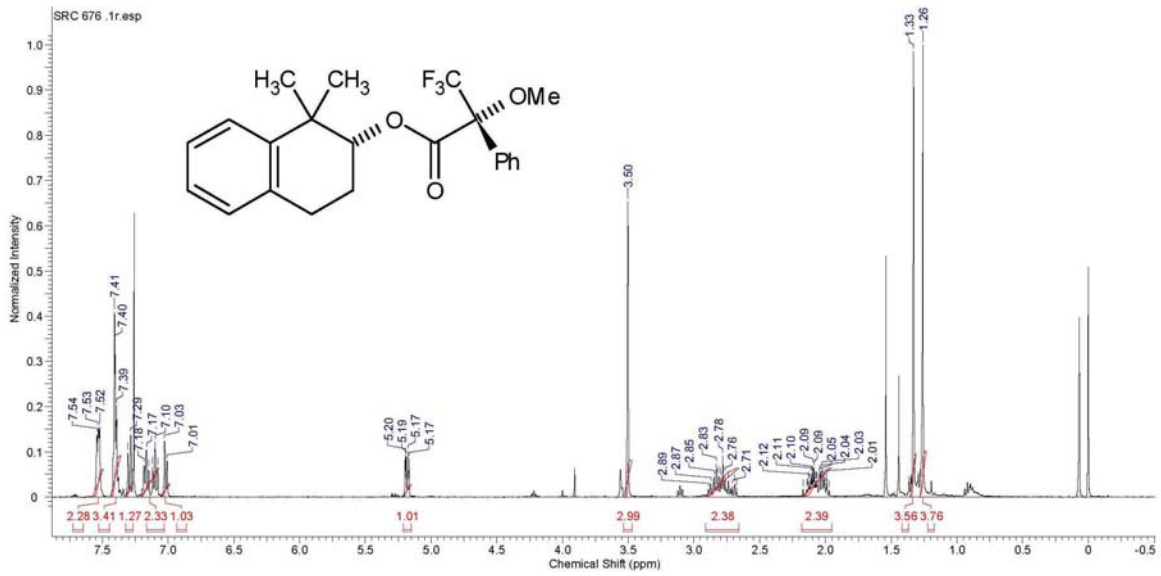
GC of (*R*) 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol 6b.



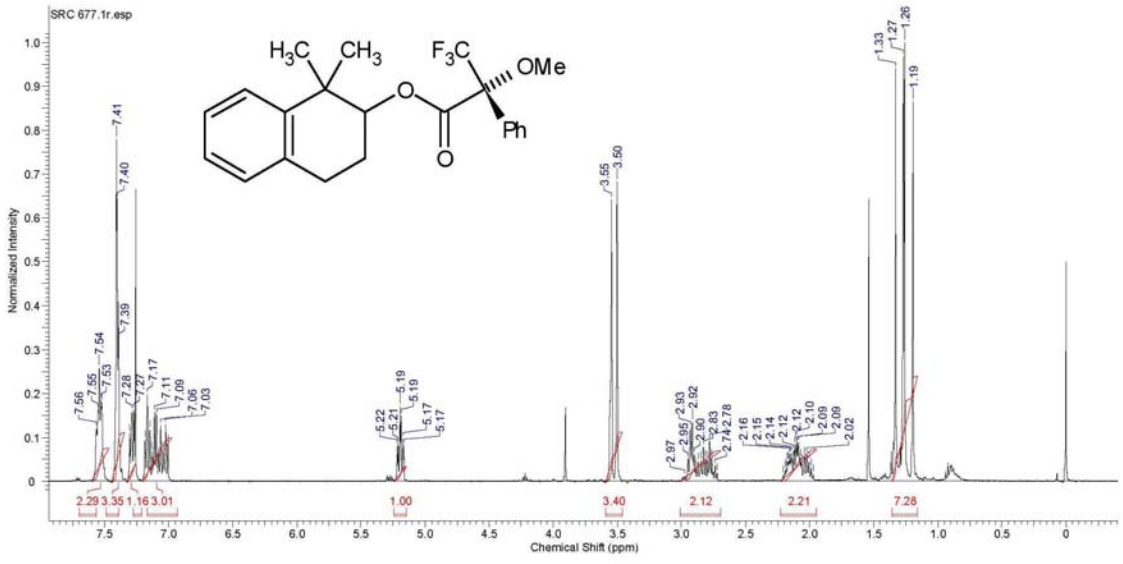
GC of racemic 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol.



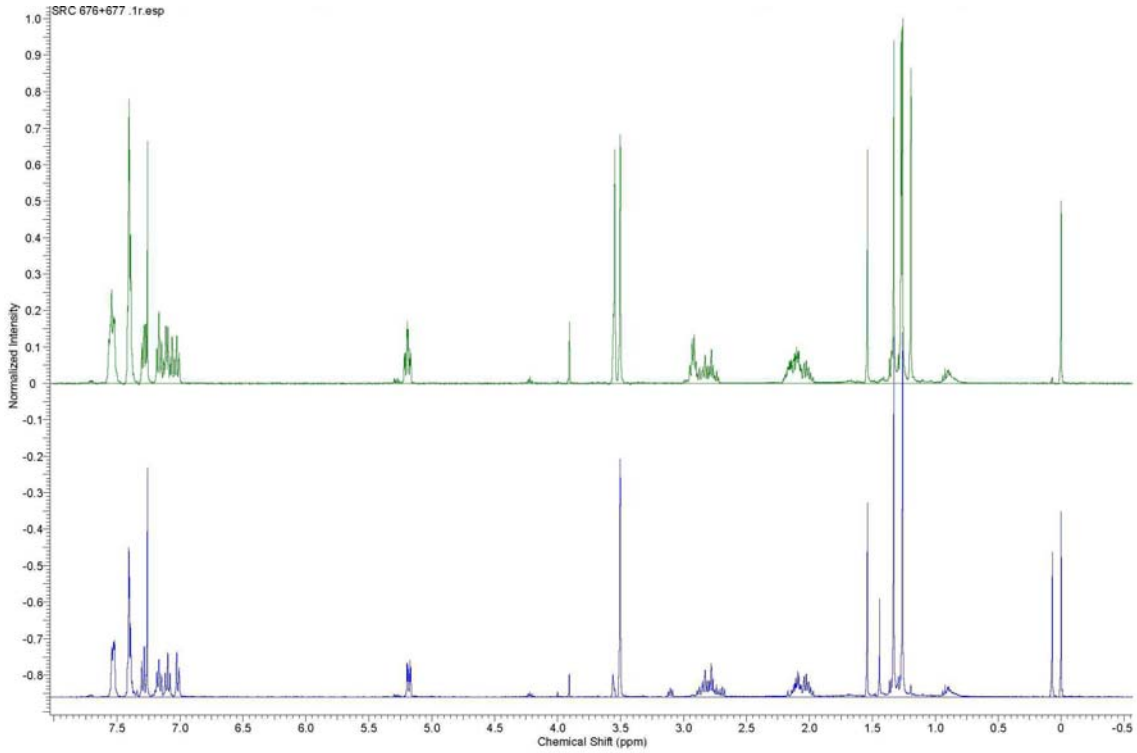
^{1}H-NMR of Mosher's ester of (*R*) 1,1-Dimethyl-3,4-dihydronaphthalen-2-ol 6b.



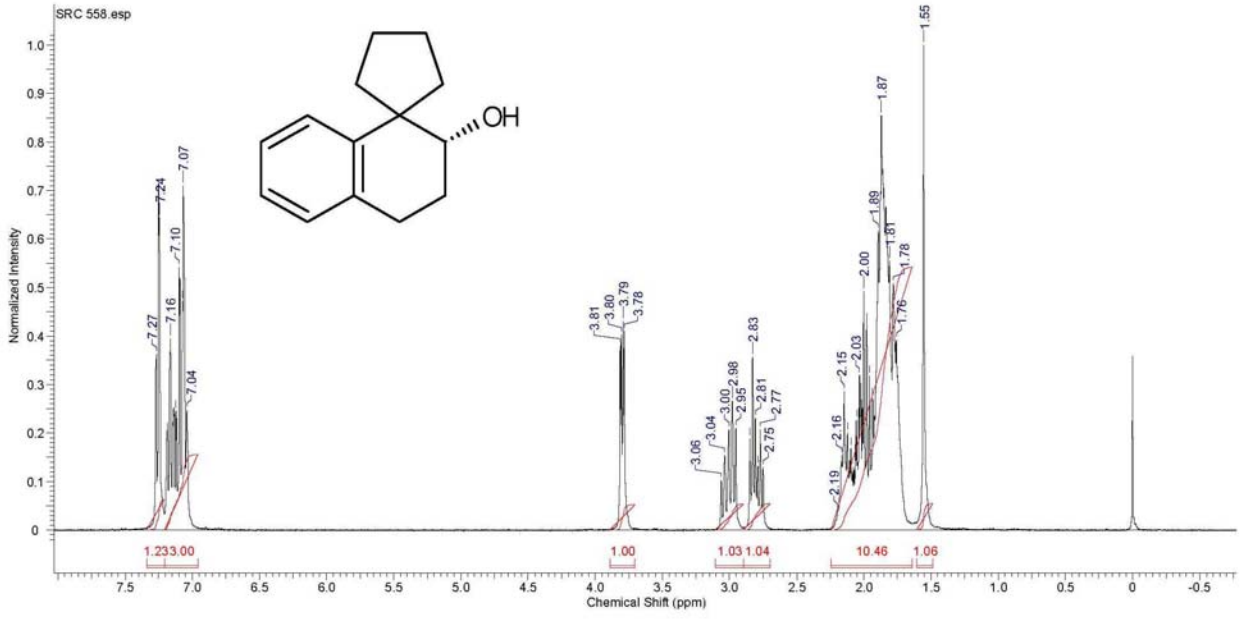
^{1}H-NMR of Mosher's ester of racemic 1,1-dimethyl-1,2,3,4-tetrahydronaphthalen-2-ol.



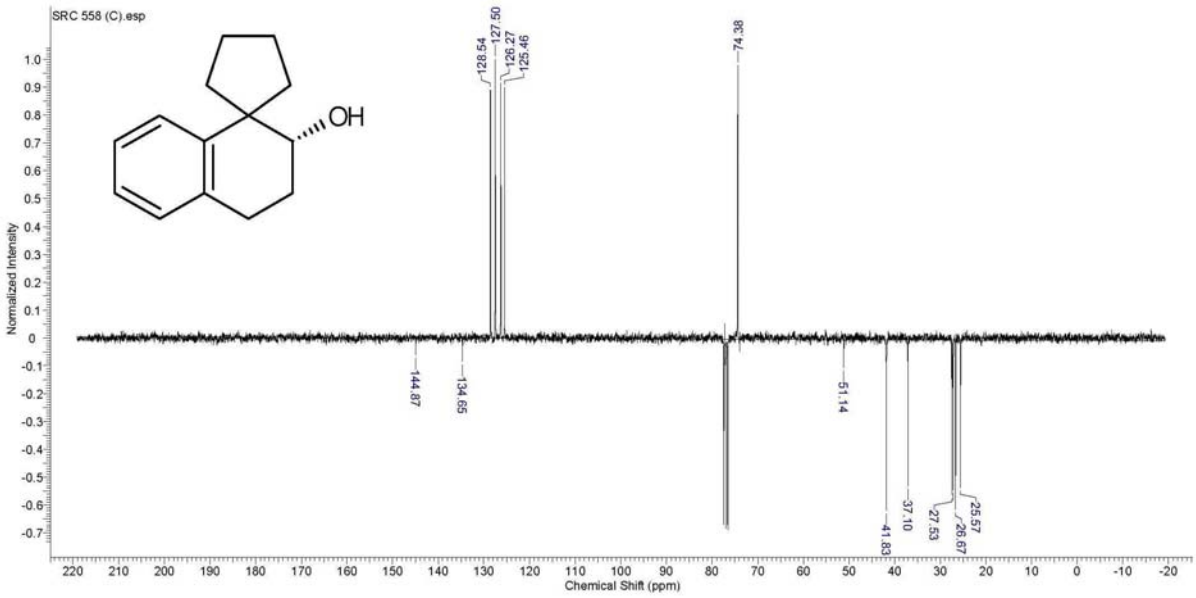
^{1}H-NMR Overlay of asymmetric and racemic Mosher esters.



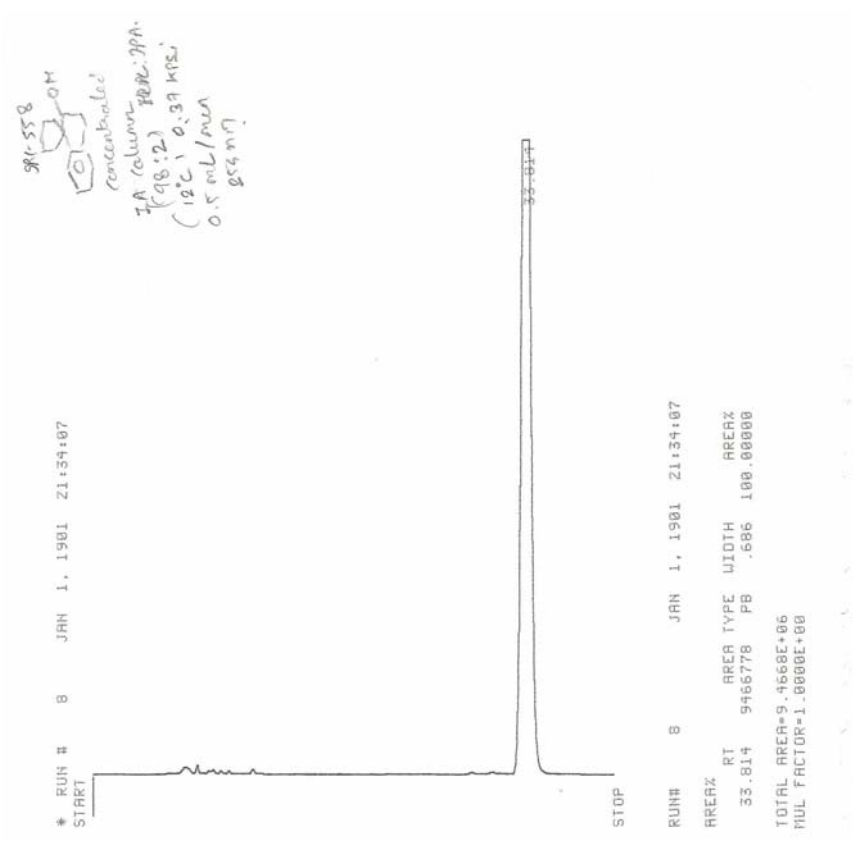
^{1}H-NMR of (*R*)-3',4'-dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-ol 6c.

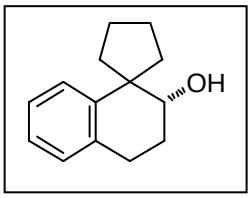


^{13}C-NMR of (*R*)-3',4'-dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-ol 6c.



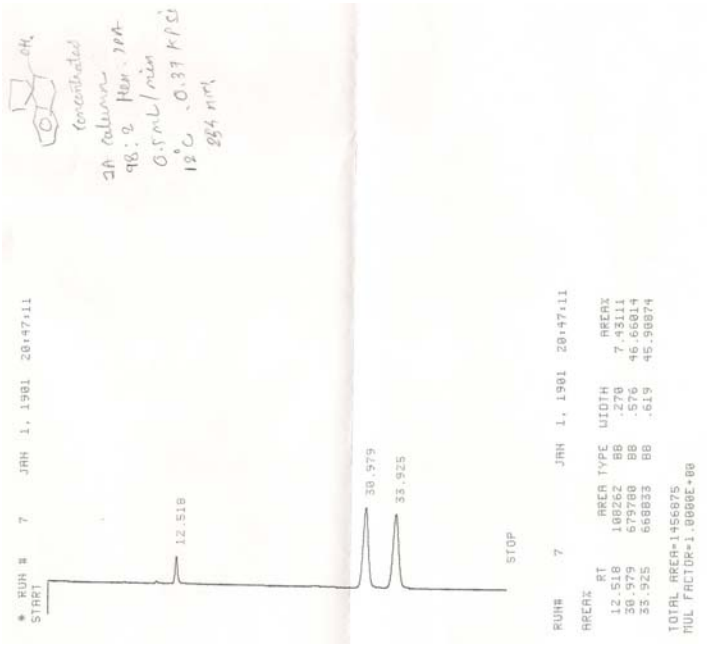
HPLC of (*R*)-3',4'-dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-ol 6c.

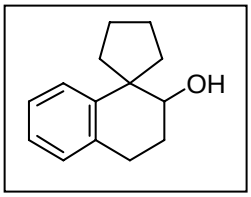




(1*R*,2*R*) 3C-teth-Ru complex reduction product

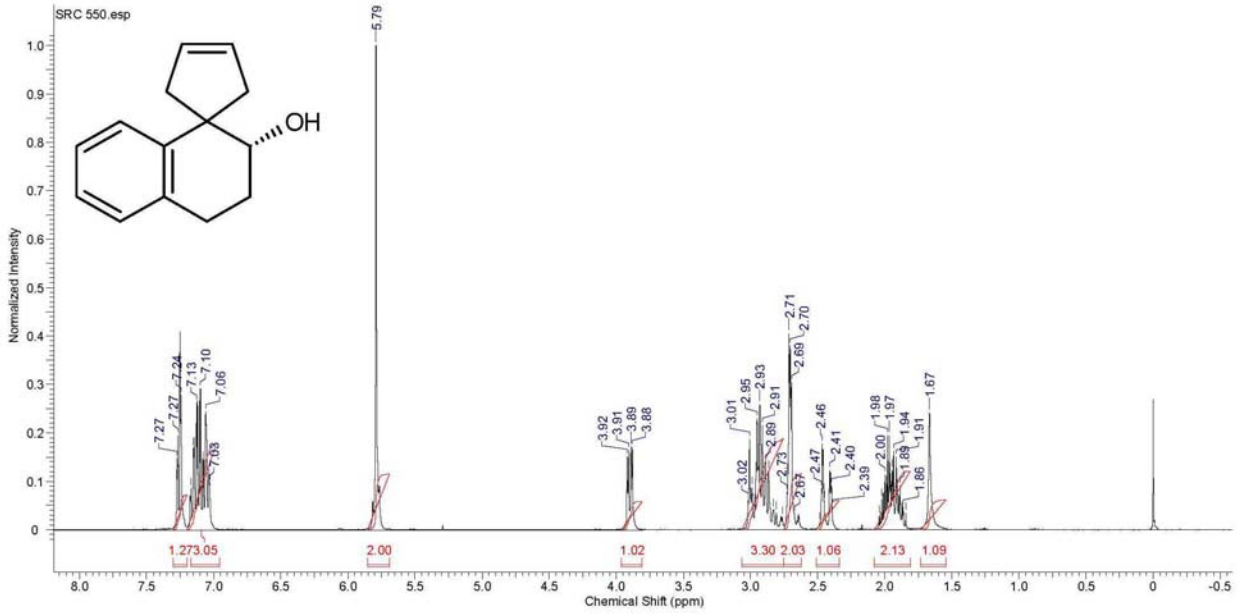
HPLC of racemic 3',4'-dihydro-2'H-spiro[cyclopentane-1,1'-naphthalene]-2'-ol.



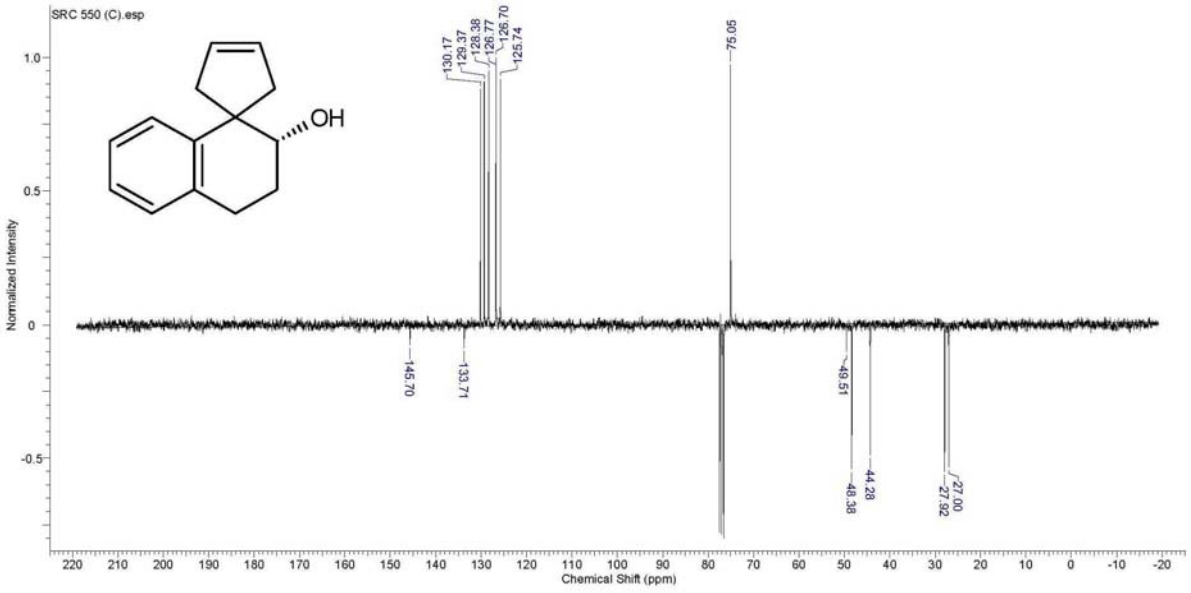


Racemic

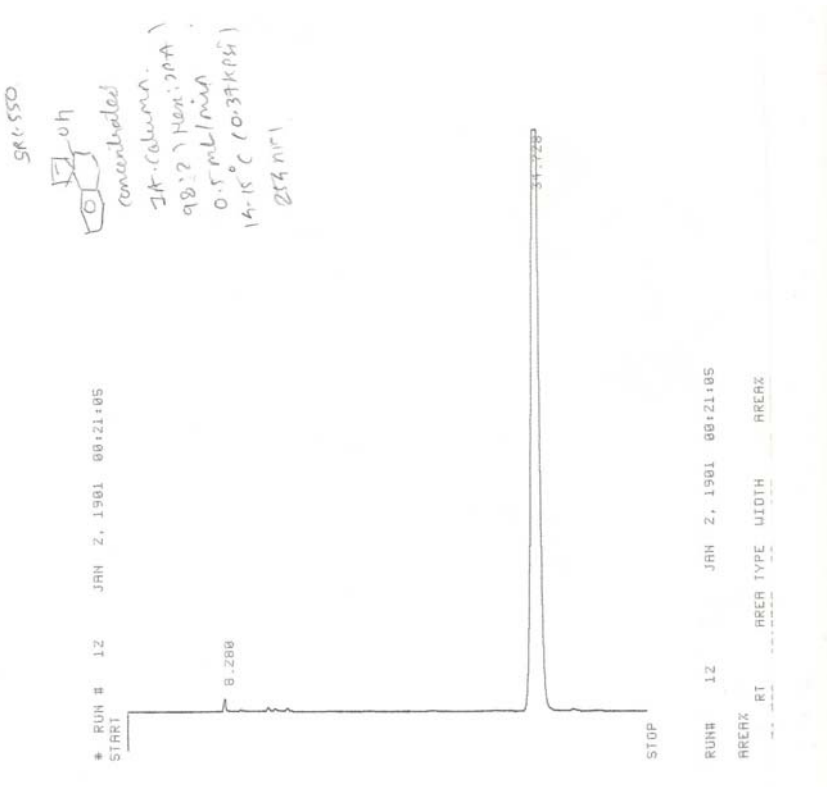
^{1}H-NMR of (*R*) 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol 6d.

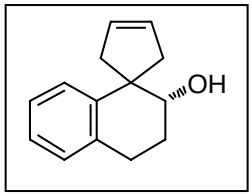


^{13}C-NMR of (*R*) 3',4'-dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol 6d.



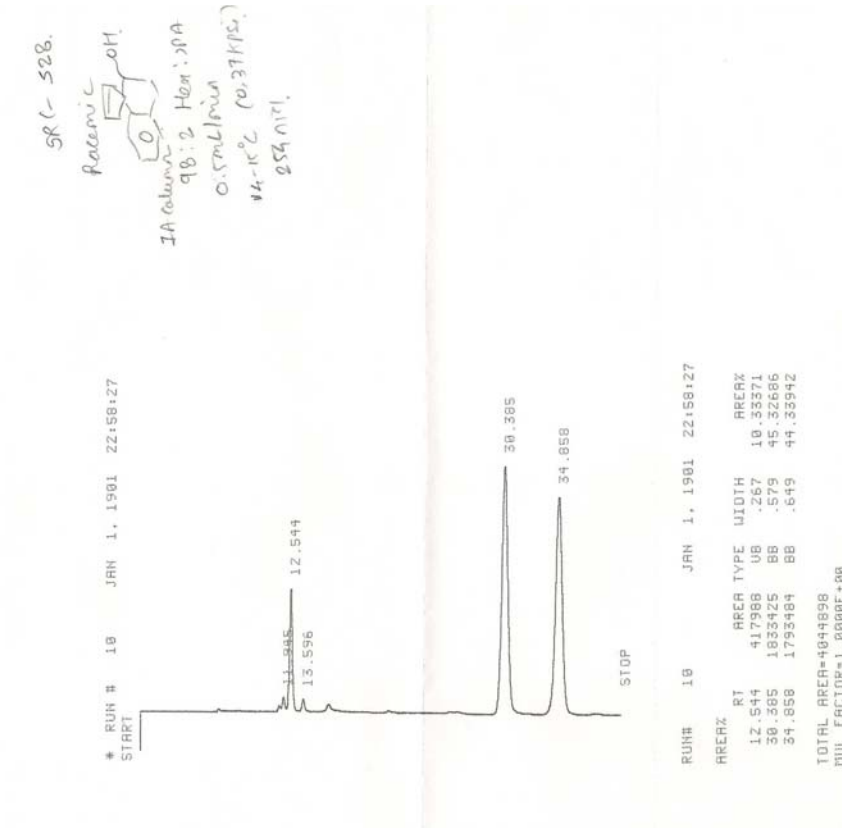
HPLC of (*R*) 3',4'-Dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol 6d.

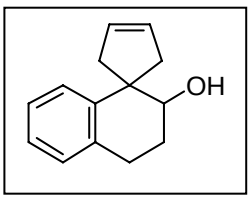




(1*R*,2*R*) 3C-teth-Ru complex reduction product

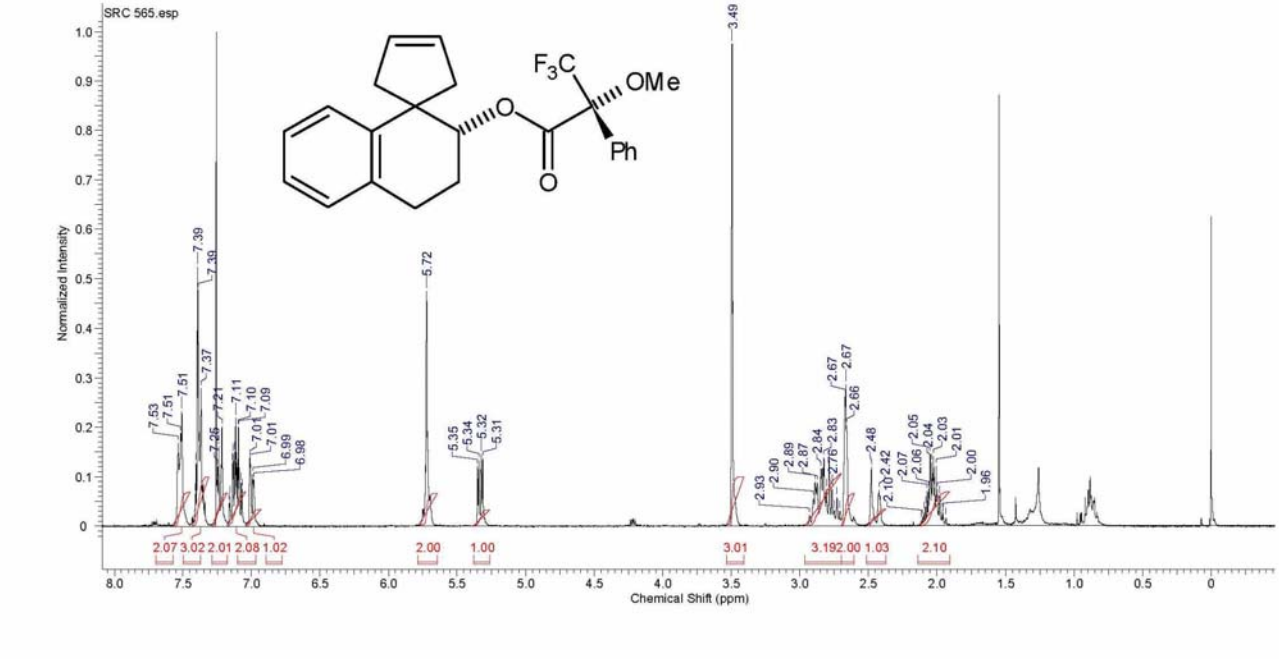
HPLC of racemic 3',4'-Dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol 6d.



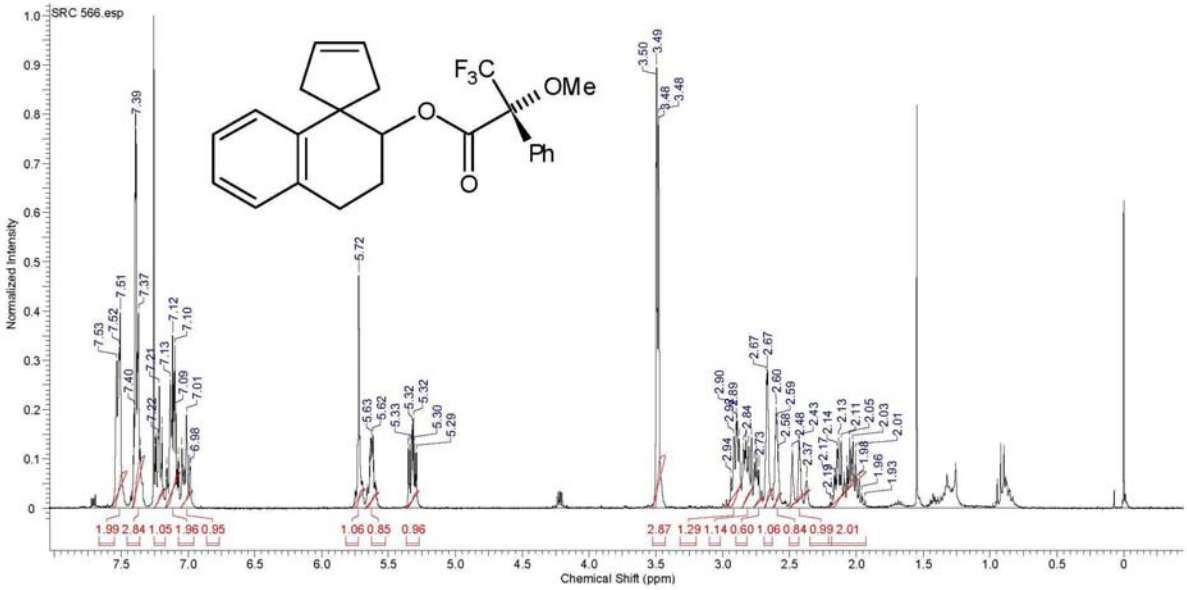


Racemic

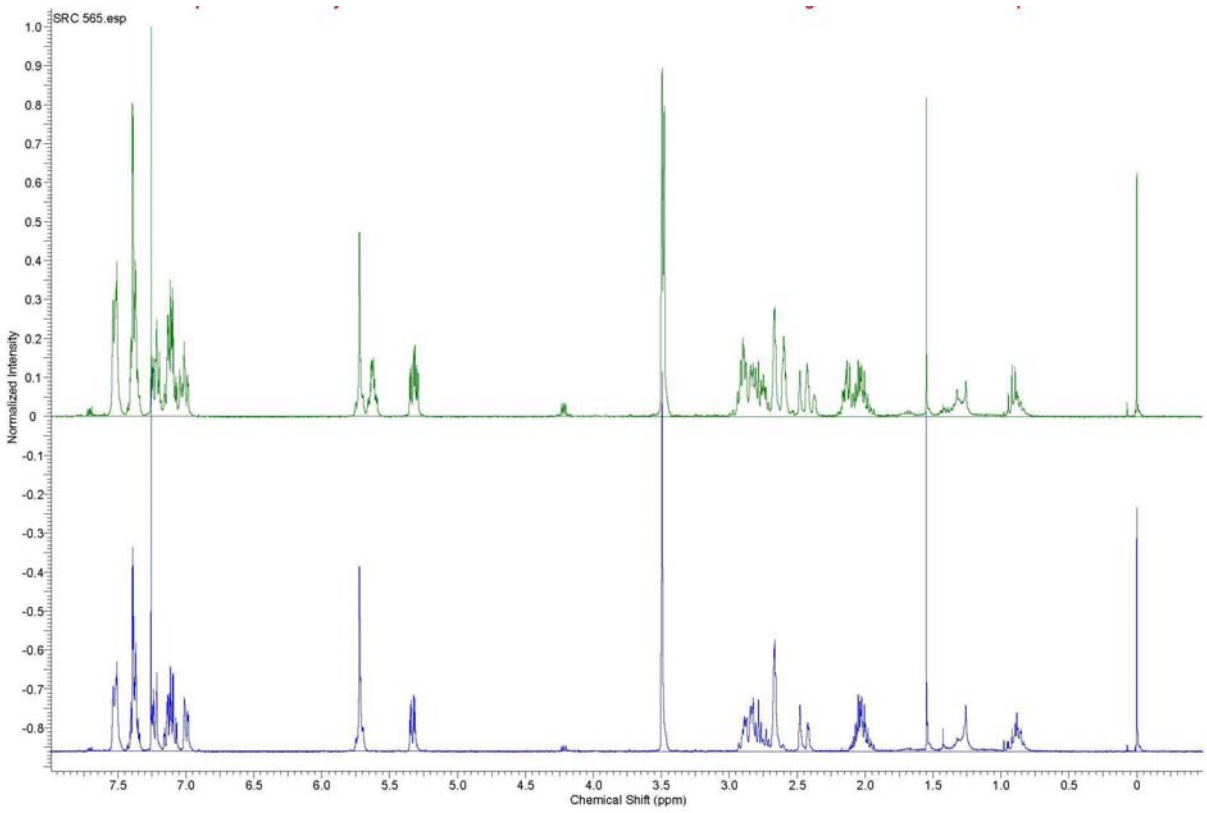
1H-NMR of Mosher's ester of (*R*) 3',4'-Dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol 6d.



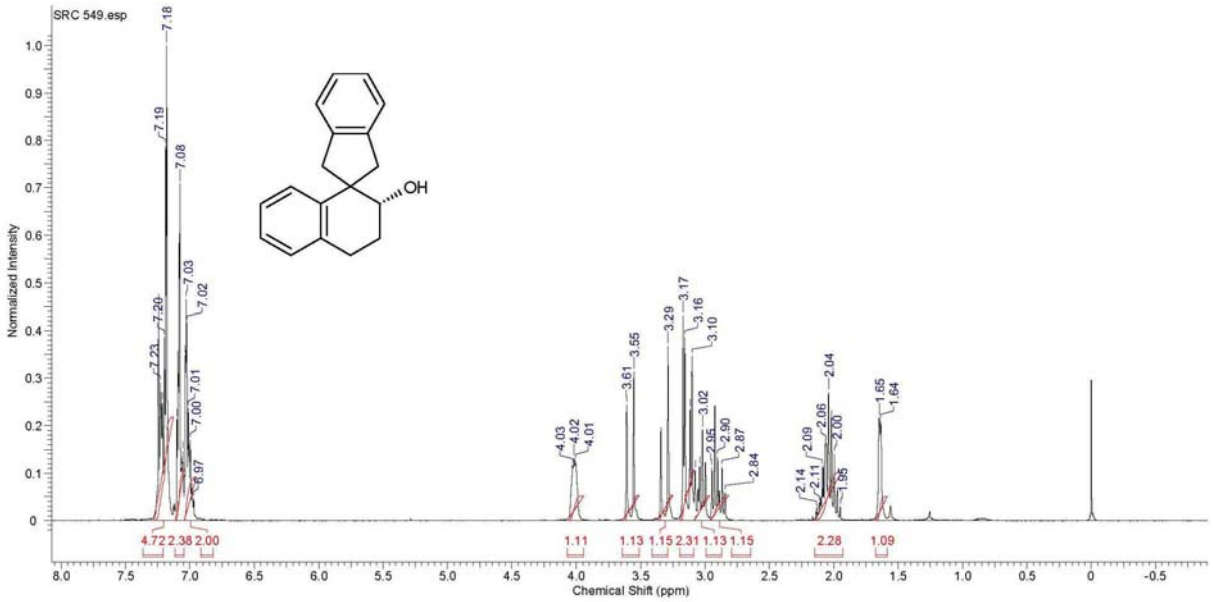
1H-NMR of Mosher's ester of racemic 3',4'-Dihydro-2'H-spiro[cyclopent-3-ene-1,1'-naphthalene]-2'-ol.



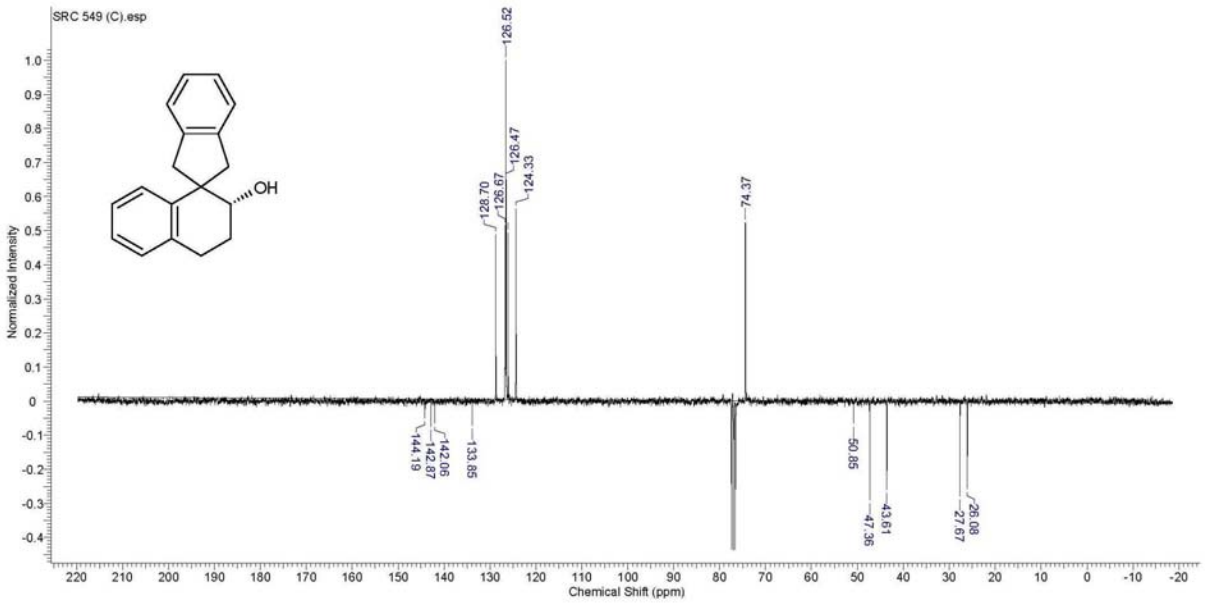
1H-NMR overlay of asymmetric and racemic Mosher esters.



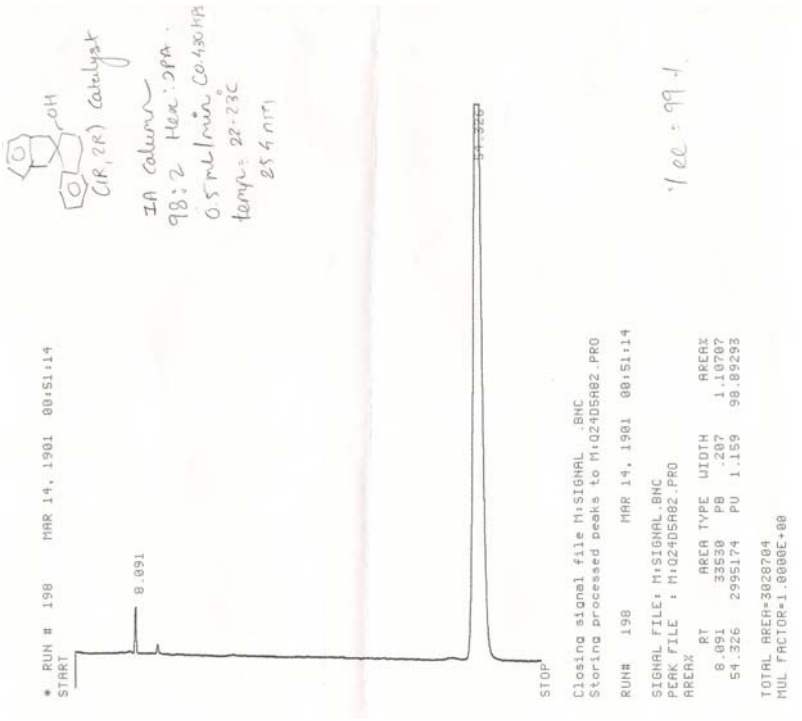
[1]H-NMR of (*R*)-1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-ol 6e.

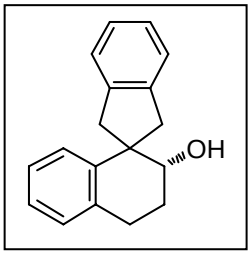


[13]C-NMR of (*R*)-1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-ol 6e.



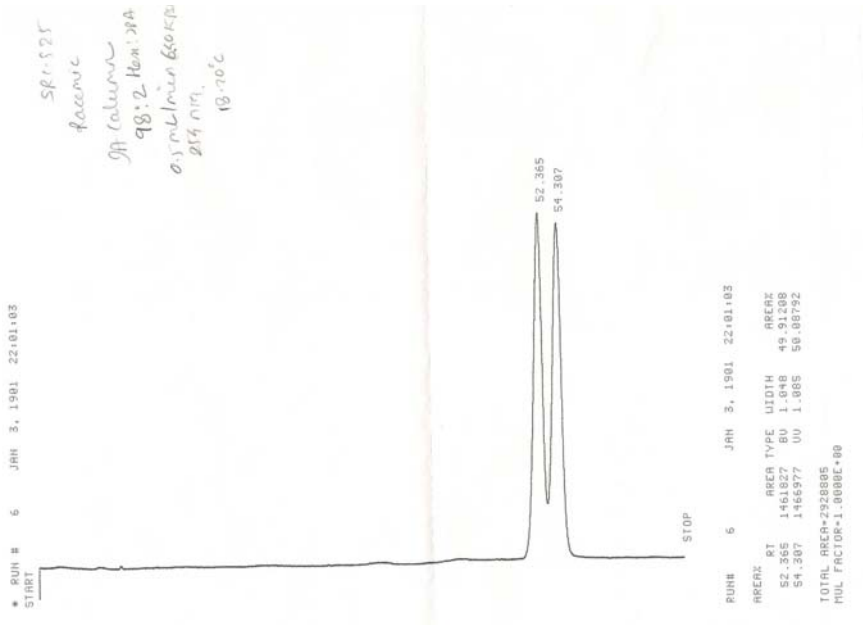
HPLC of (*R*)-1,3,3’,4’-tetrahydro-spiro[2H-indene-1,2’-[2H]-naphthalene]-2’-ol 6e.

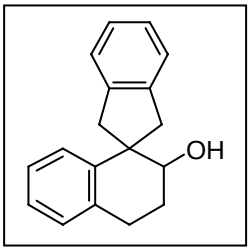




(1*R*,2*R*) 3C-teth-Ru complex reduction product

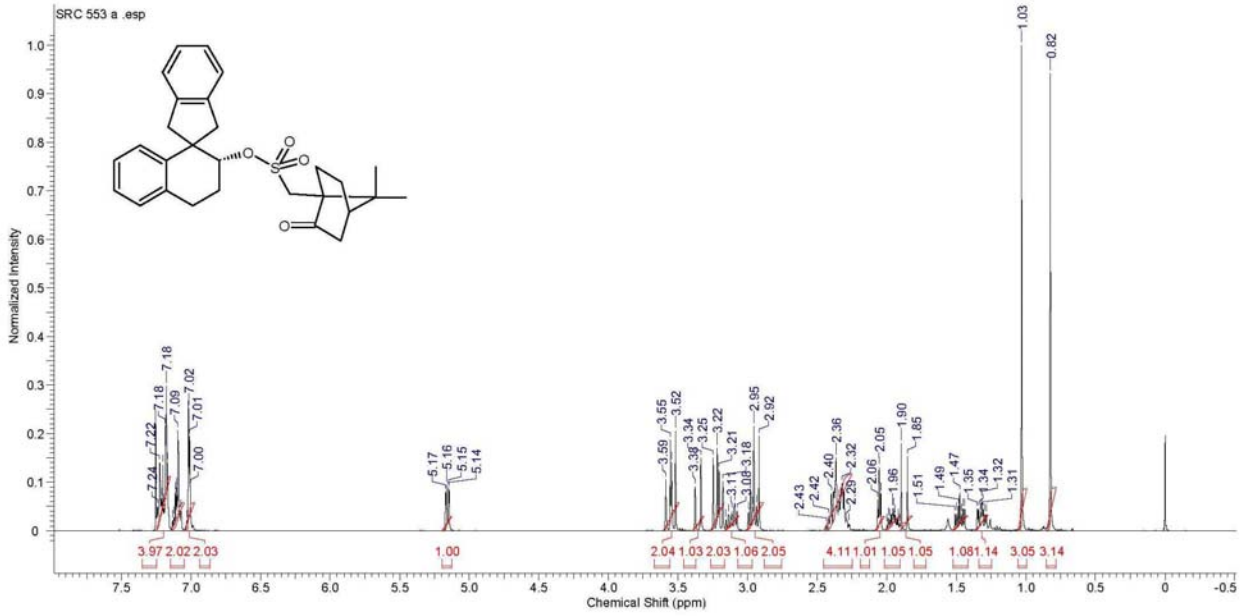
HPLC of racemic 1,3,3’,4’-tetrahydro-spiro[2H-indene-1,2’-[2H]-naphthalene]-2’-ol.



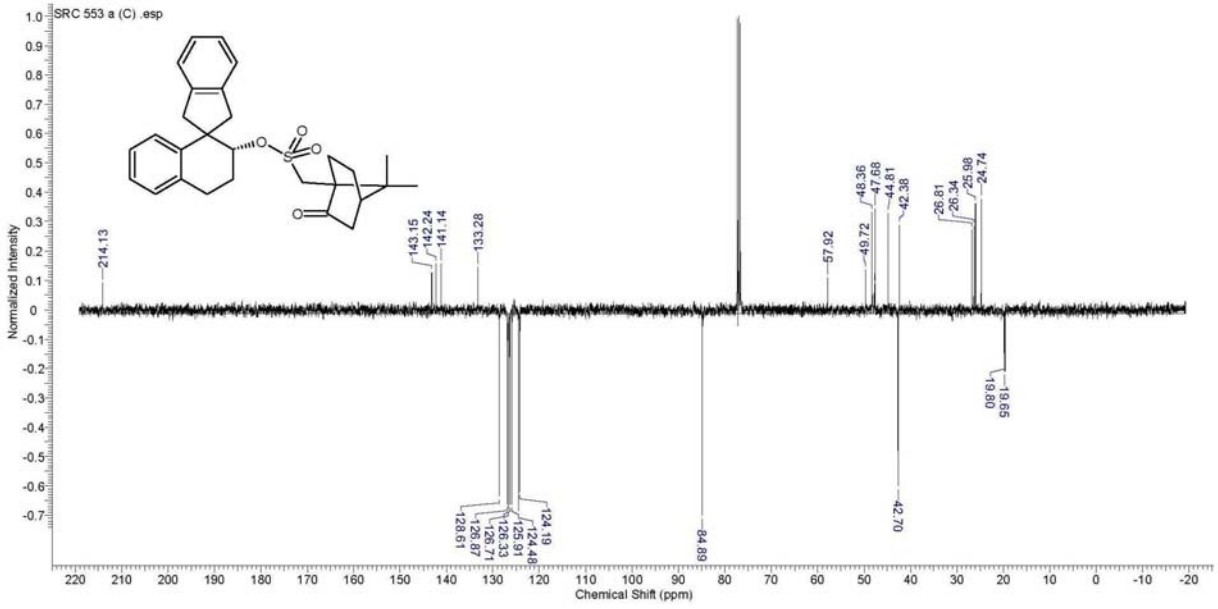


Racemic

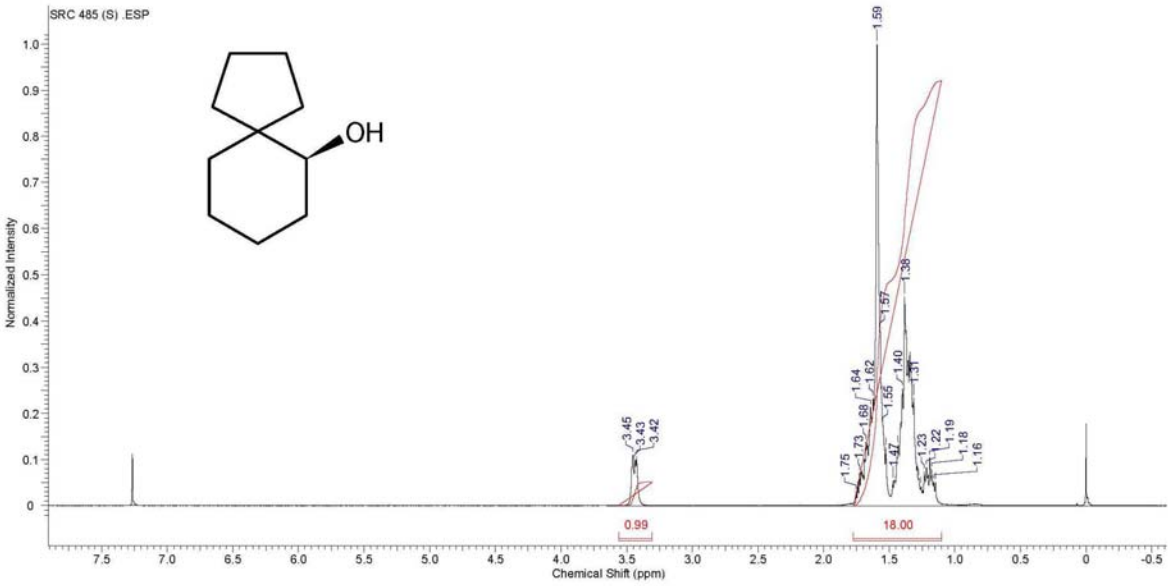
^{1}H-NMR of (1*S*)-(+)-10 camphorsulfonyl ester derivative 7 of (*R*)-1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-ol 6e.



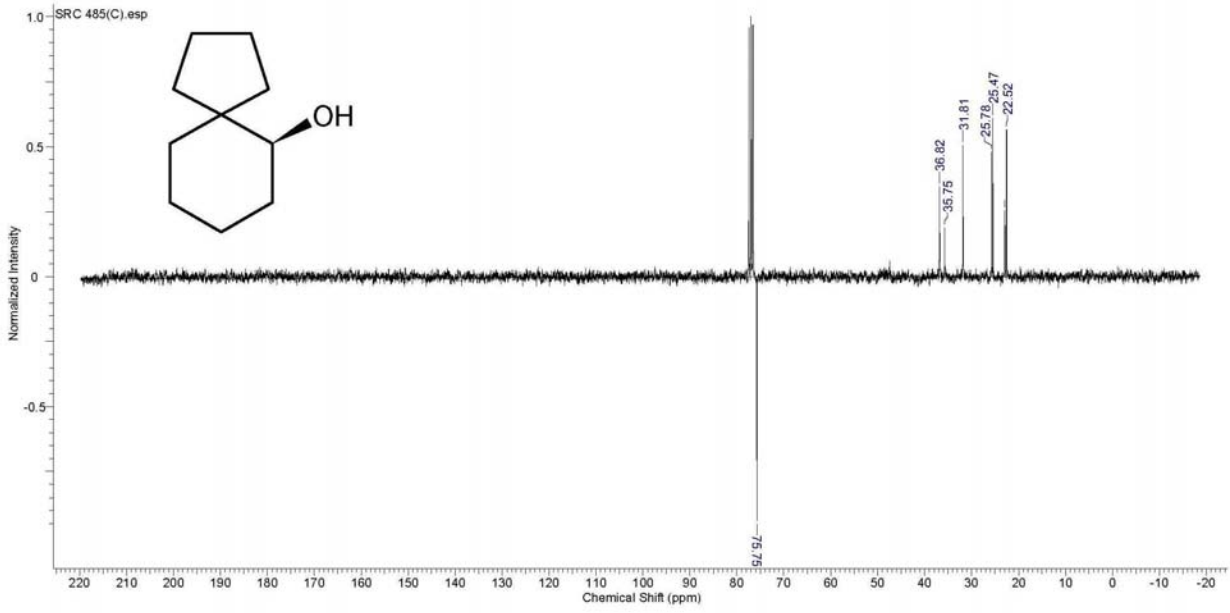
^{13}C-NMR of (1*S*)-(+)-10 camphorsulfonyl ester derivative 7 of (*R*)-1,3,3',4'-tetrahydro-spiro[2H-indene-1,2'-[2H]-naphthalene]-2'-ol 6e.



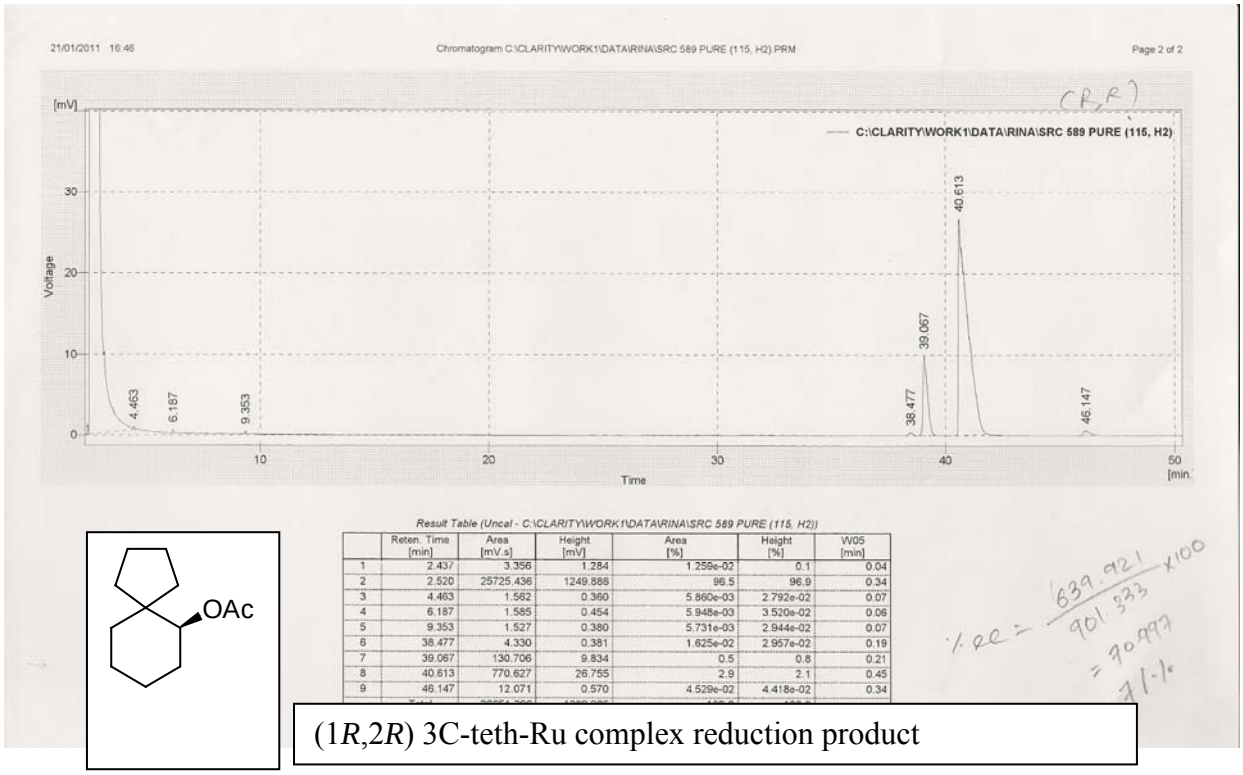
[1]H-NMR of (*S*) spiro[4,5]decane-6-one 10.



[13]C-NMR of (*S*) spiro[4,5]decane-6-one 10.



GC of acetate derivative of (*S*) spiro[4,5]decane-6-one 10.

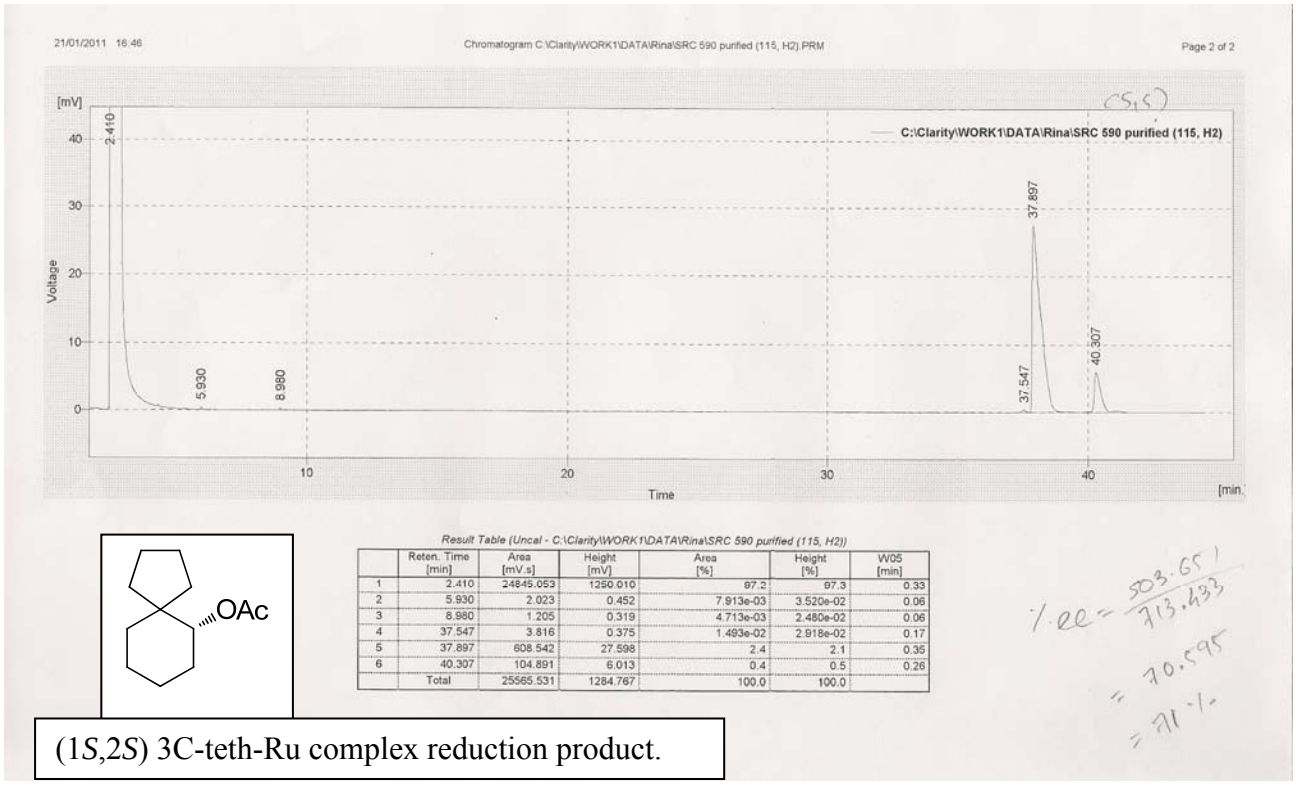


Result Table (Uncal - C:\CLARITY\WORK1\DATA\RINA\SRC 589 PURE (115, H2))

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.437	3.356	1.284	1.259e-02	0.1	0.04
2	2.520	25725.436	1249.886	96.5	96.9	0.34
3	4.463	1.562	0.360	5.860e-03	2.792e-02	0.07
4	6.187	1.585	0.454	5.948e-03	3.520e-02	0.06
5	9.353	1.527	0.380	5.731e-03	2.944e-02	0.07
6	38.477	4.330	0.381	1.625e-02	2.957e-02	0.19
7	39.067	130.706	9.834	0.5	0.8	0.21
8	40.613	770.627	26.755	2.9	2.1	0.45
9	46.147	12.071	0.570	4.529e-02	4.418e-02	0.34

(1*R*,2*R*) 3C-teth-Ru complex reduction product

GC of acetate derivative of (*R*) spiro[4,5]decane-6-one.

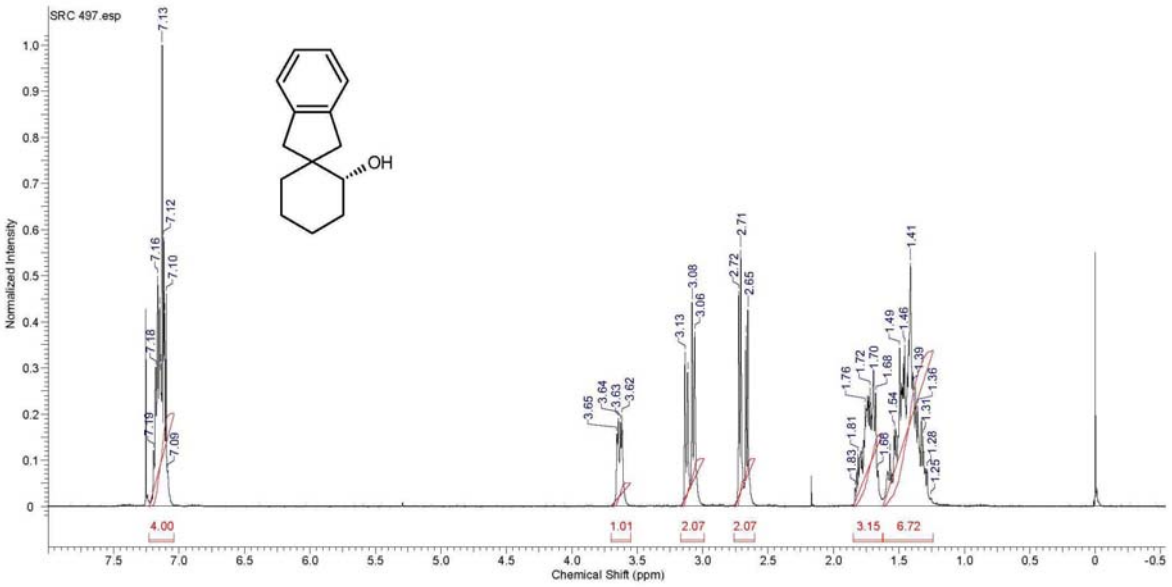


Result Table (Uncal - C:\Clarity\WORK1\DATA\Rina\SRC 590 purified (115, H2))

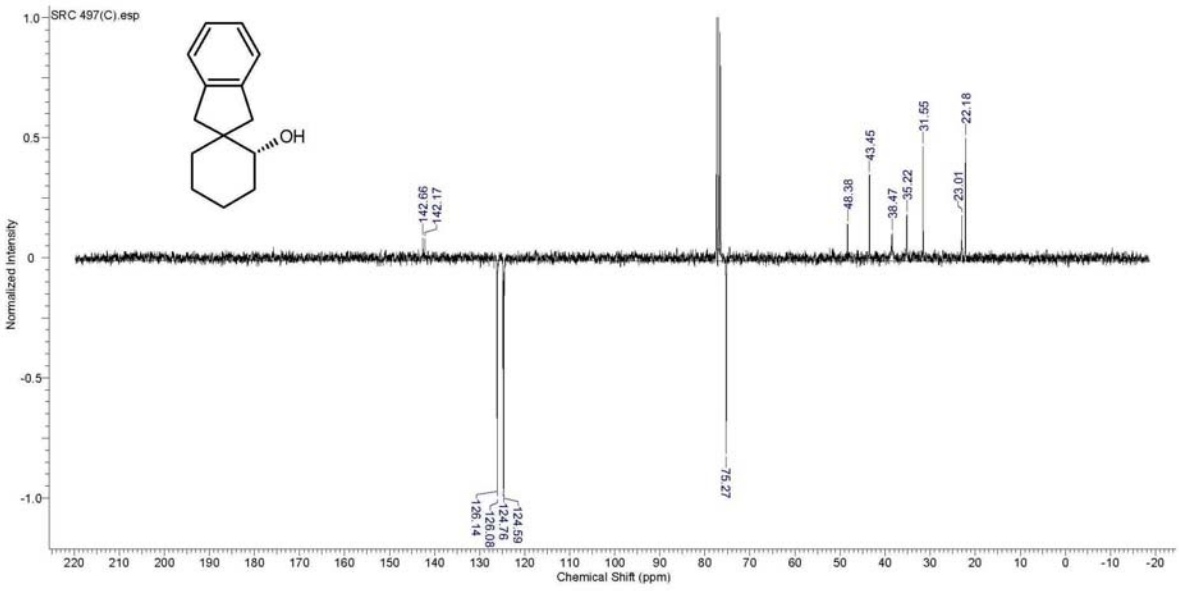
	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.410	24845.053	1250.010	97.2	97.3	0.33
2	5.930	2.023	0.452	7.913e-03	3.520e-02	0.06
3	8.980	1.205	0.319	4.713e-03	2.480e-02	0.06
4	37.547	3.816	0.375	1.493e-02	2.918e-02	0.17
5	37.897	608.542	27.598	2.4	2.1	0.35
6	40.307	104.891	6.013	0.4	0.5	0.26
	Total	25565.531	1284.767	100.0	100.0	

(1*S*,2*S*) 3C-teth-Ru complex reduction product.

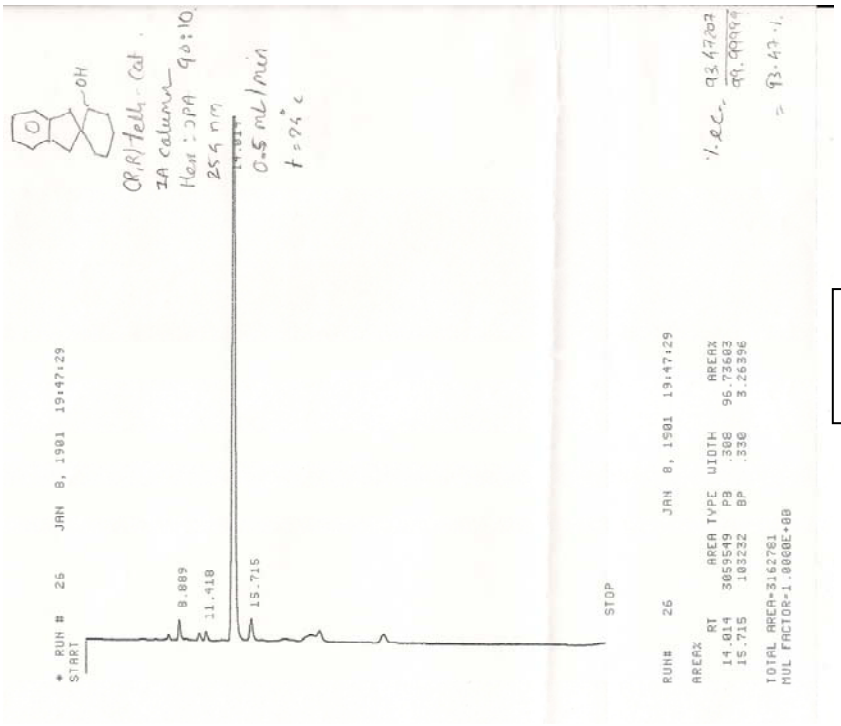
[1]H-NMR of (*R*) 1',3'-Dihydrospiro[cyclohexane-1,2'-inden]-2-ol 11.

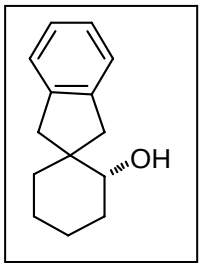


[13]C-NMR of (*R*) 1',3'-Dihydrospiro[cyclohexane-1,2'-inden]-2-ol 11.



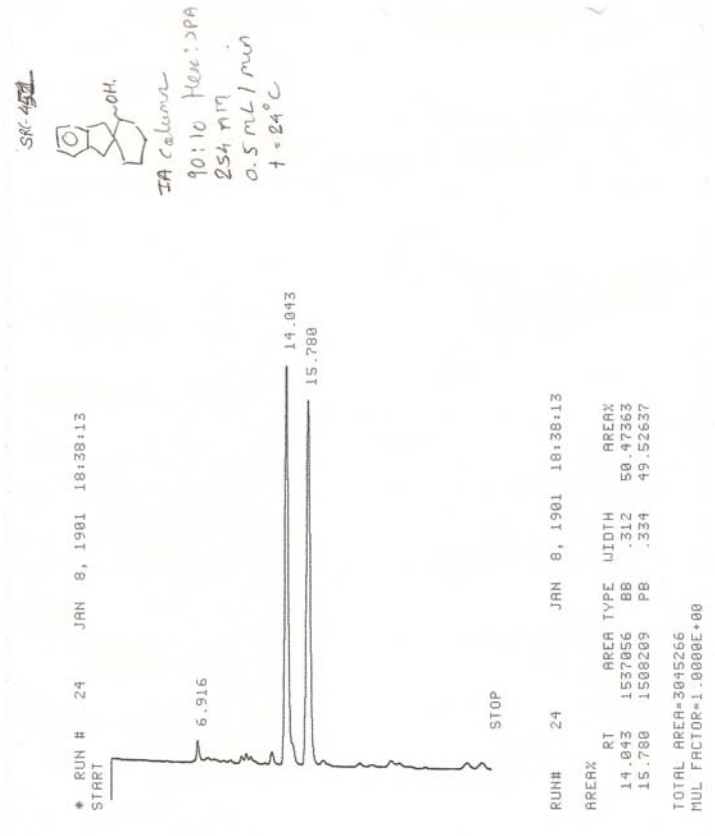
HPLC of (*R*) 1',3'-Dihydrospiro[cyclohexane-1,2'-inden]-2-ol 11.

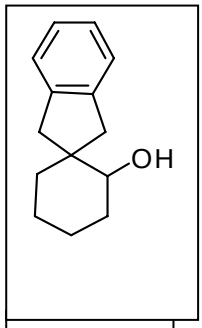




(1*R*,2*R*) 3C-teth-Ru complex reduction product

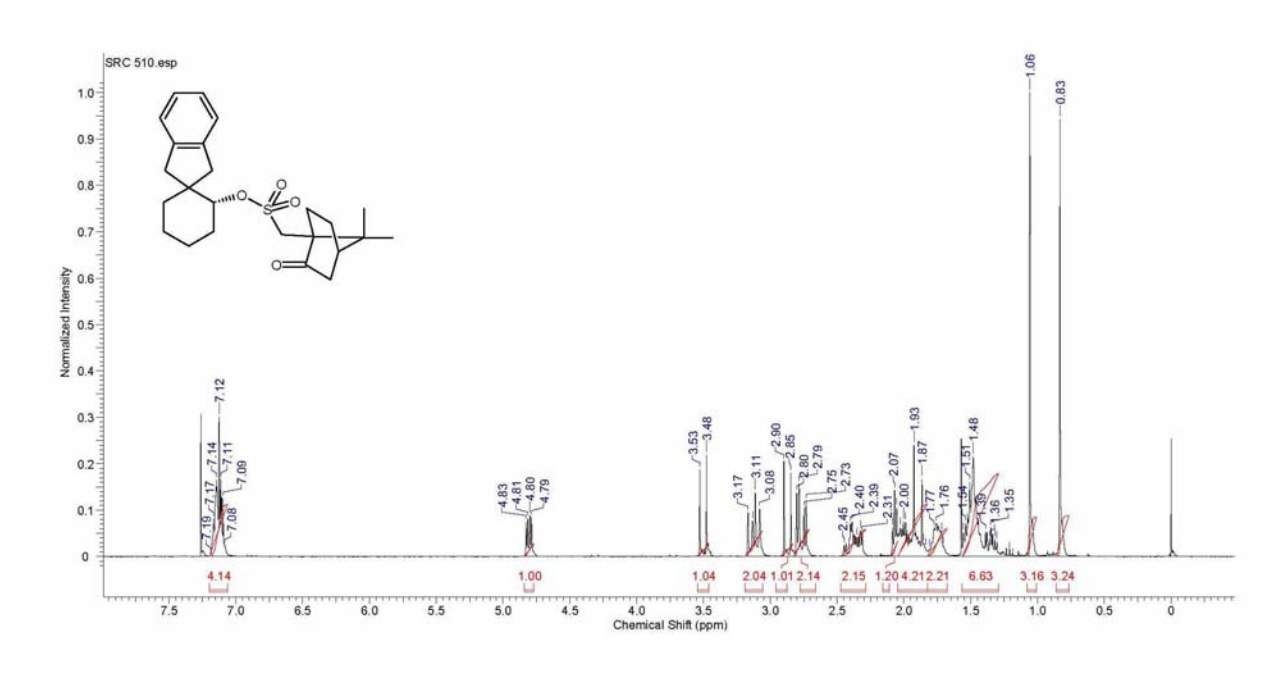
HPLC of racemic 1',3'-dihydrospiro[cyclohexane-1,2'-inden]-2-ol.



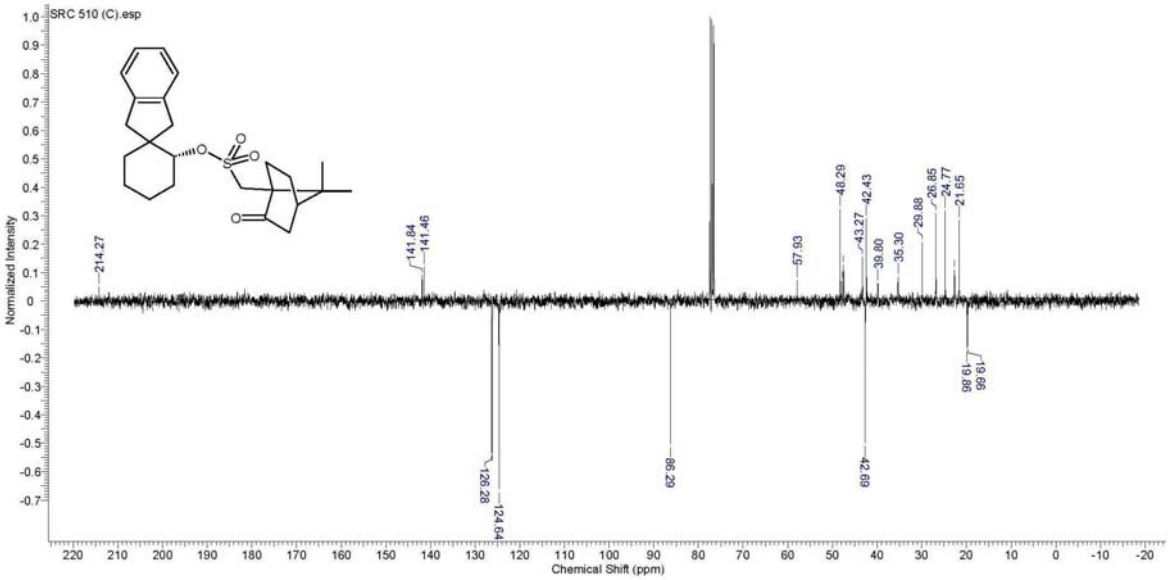


Racemic

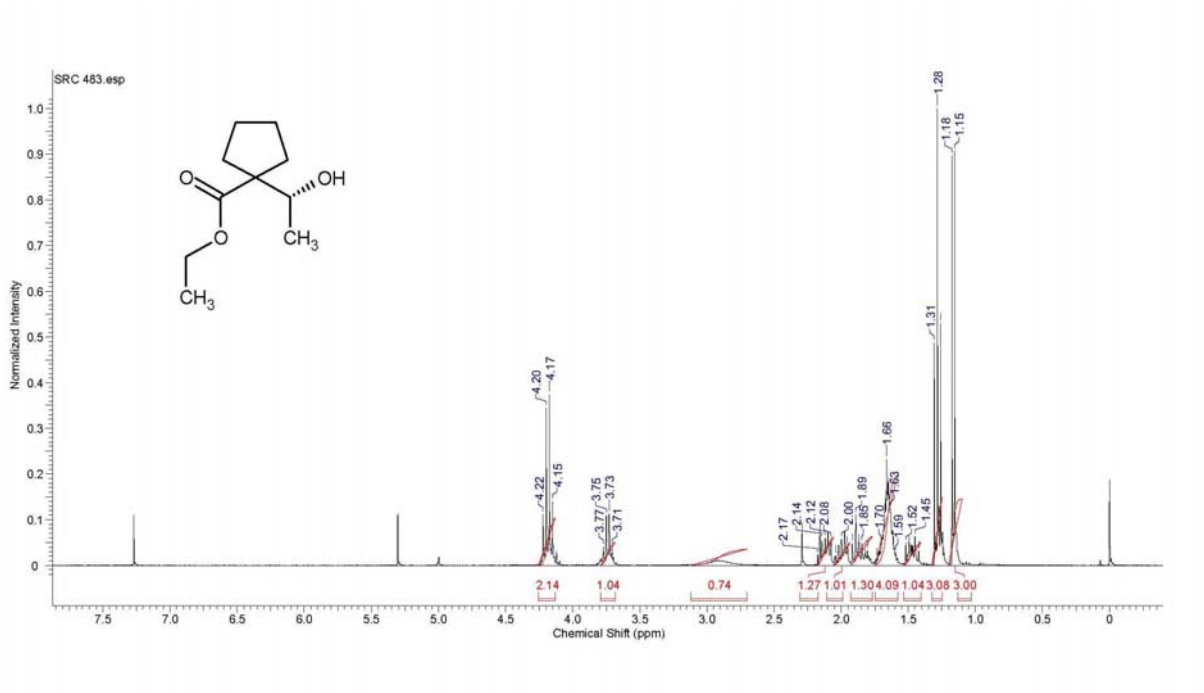
^{1}H-NMR of (1*S*)-(+)-10 camphorsulfonyl ester derivative 12 of 1',3'-dihydrospiro[cyclohexane-1,2'-inden]-2-ol 11.



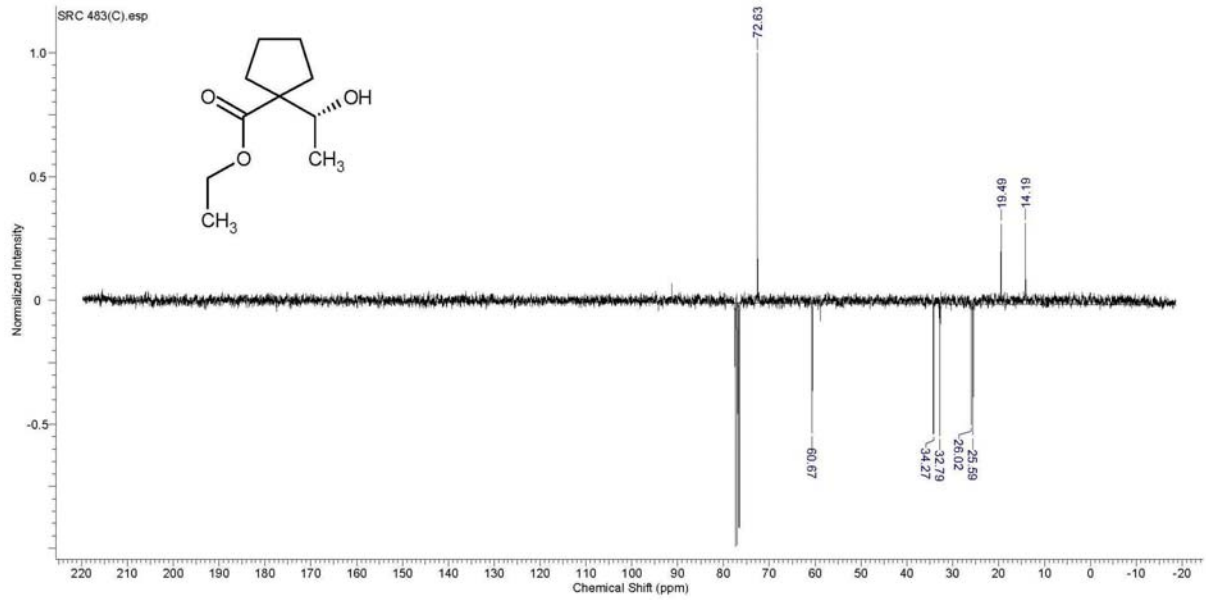
^{13}C-NMR of (1*S*)-(+)-10 camphorsulfonyl ester derivative 12 of 1',3'-dihydrospiro[cyclohexane-1,2'-inden]-2-ol 11.



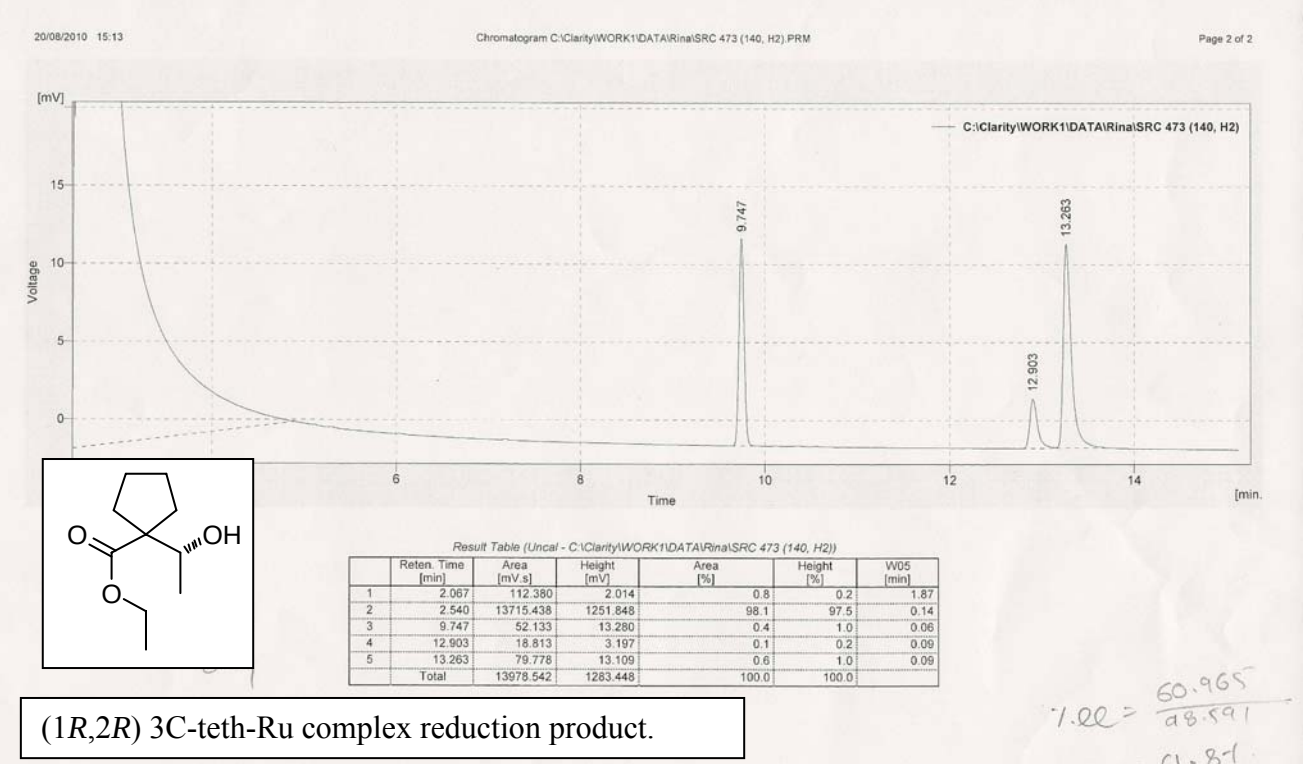
^{1}H-NMR of (*R*) ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a.



^{13}C-NMR of (*R*) ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a.



GC of (*R*) ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a.

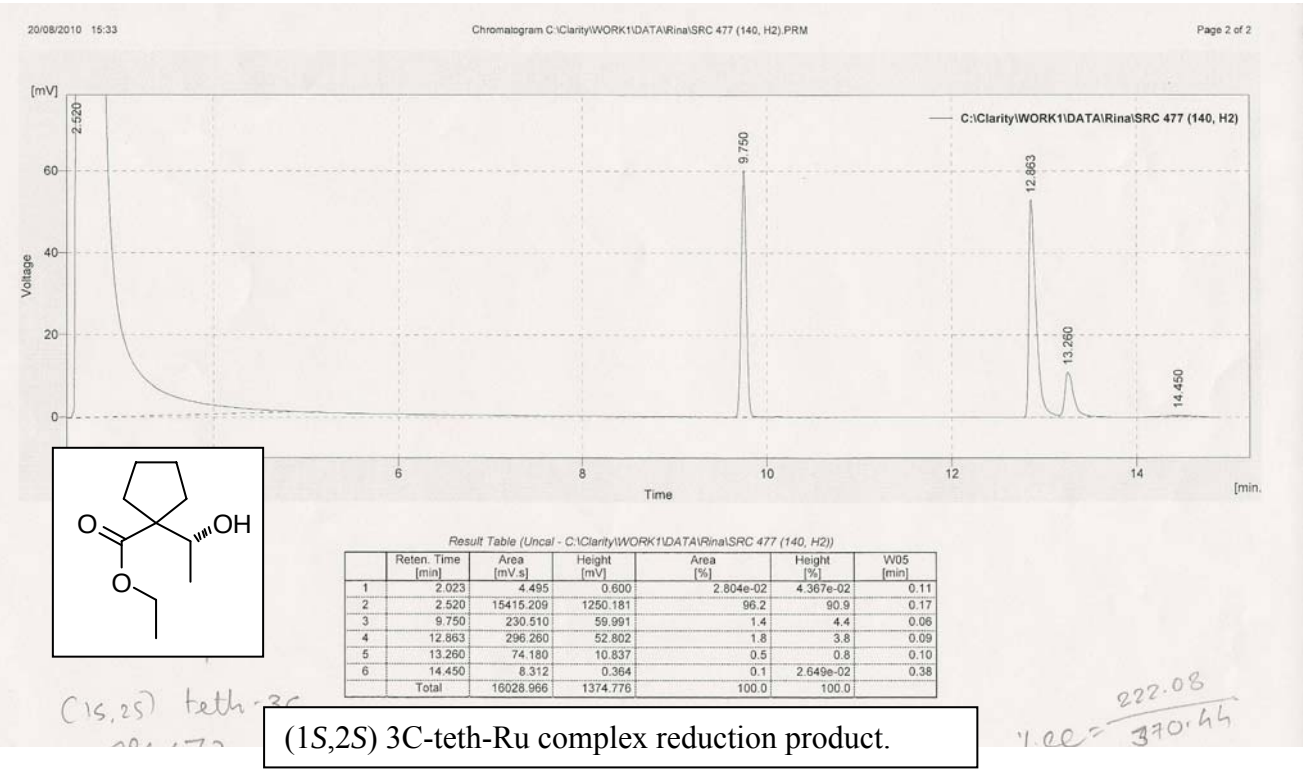


Result Table (Uncal - C:\Clarity\WORK1\DATA\Rina\SRC 473 (140, H2))

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.067	112.380	2.014	0.8	0.2	1.87
2	2.540	13715.438	1251.848	98.1	97.5	0.14
3	9.747	52.133	13.280	0.4	1.0	0.06
4	12.903	18.813	3.197	0.1	0.2	0.09
5	13.263	79.778	13.109	0.6	1.0	0.09
	Total	13978.542	1283.448	100.0	100.0	

(1*R*,2*R*) 3C-teth-Ru complex reduction product.

GC of (*S*) ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a.

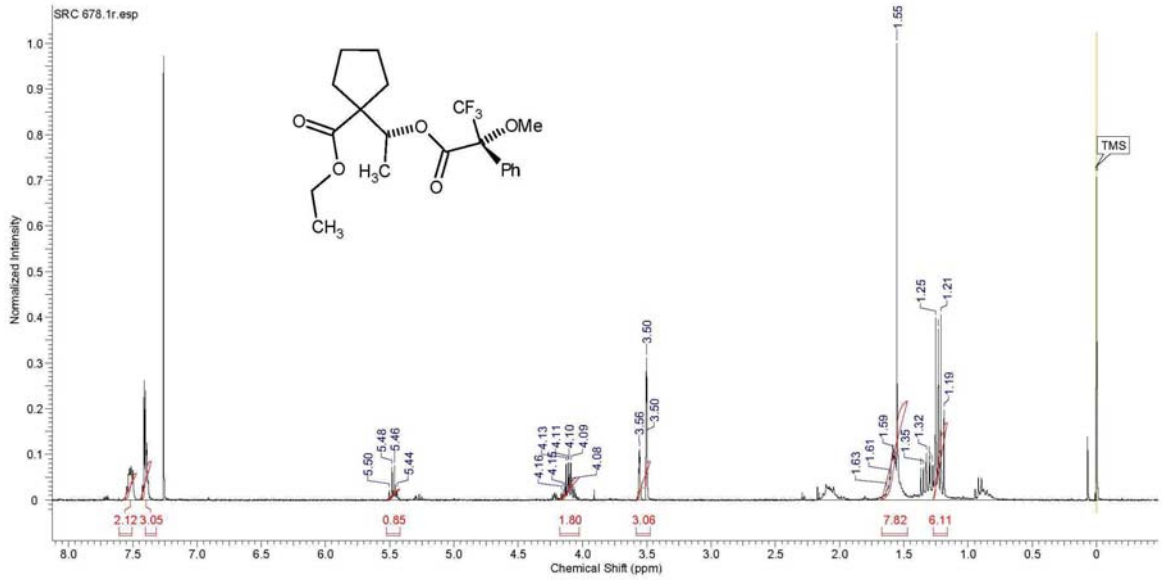


Result Table (Uncal - C:\Clarity\WORK1\DATA\Rina\SRC 477 (140, H2))

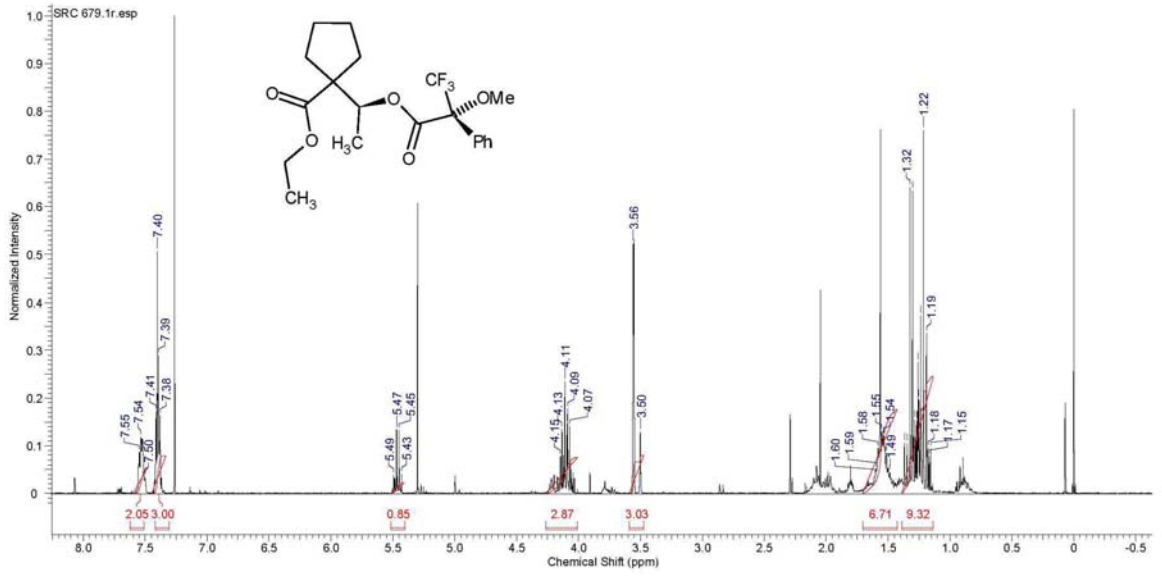
	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.023	4.495	0.600	2.804e-02	4.367e-02	0.11
2	2.520	15415.209	1250.181	96.2	90.9	0.17
3	9.750	230.510	59.991	1.4	4.4	0.06
4	12.863	296.260	52.802	1.8	3.8	0.09
5	13.260	74.180	10.837	0.5	0.8	0.10
6	14.450	8.312	0.364	0.1	2.649e-02	0.38
	Total	16028.966	1374.776	100.0	100.0	

(1*S*,2*S*) 3C-teth-Ru complex reduction product.

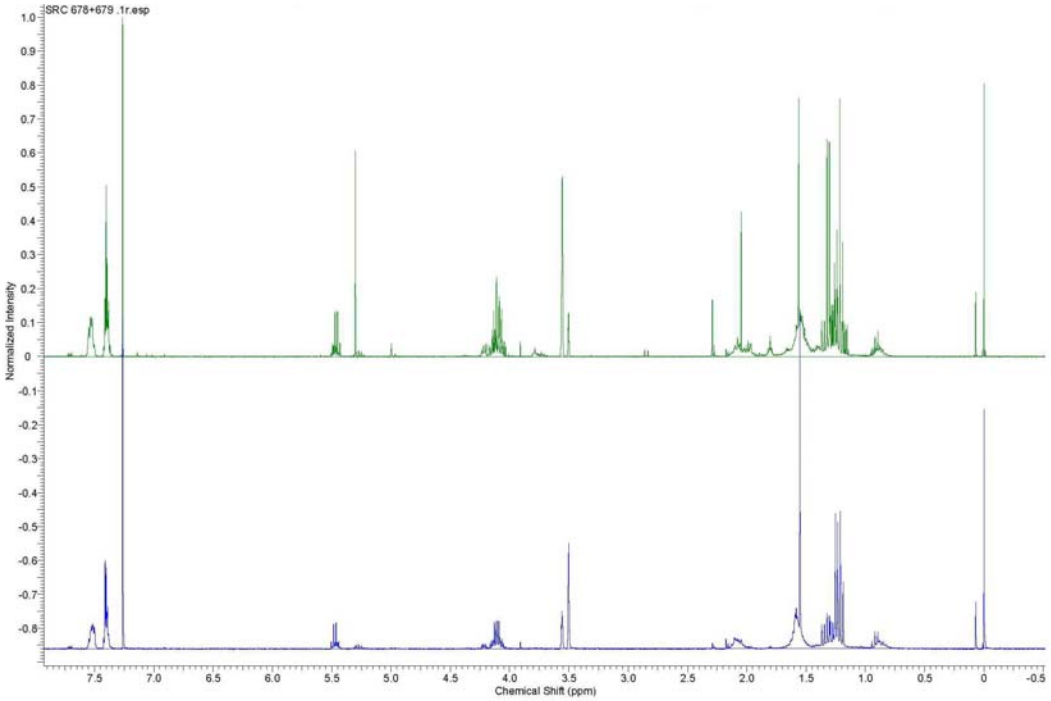
^{1}H-NMR of Mosher's ester of ethyl (*R*) 1-(1-hydroxyethyl)cyclopentanecarboxylate 14a.



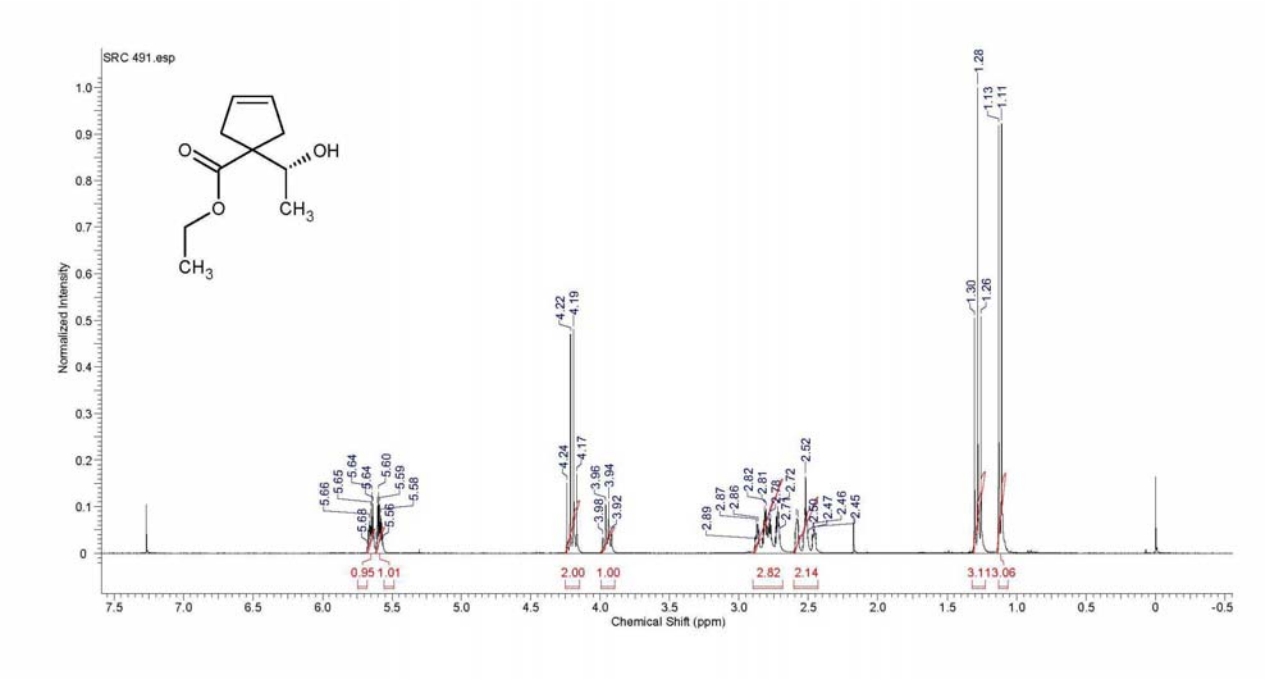
^{1}H-NMR of Mosher's ester of (*S*) ethyl 1-(1-hydroxyethyl)cyclopentanecarboxylate



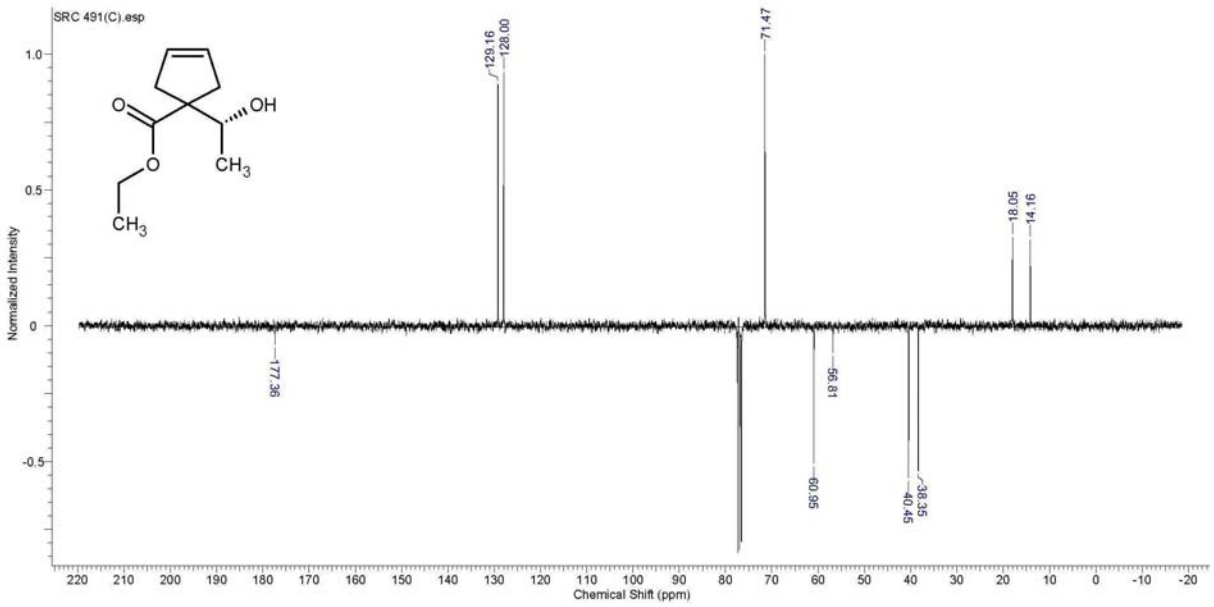
^{1}H-NMR Overlay of asymmetric and racemic Mosher esters.



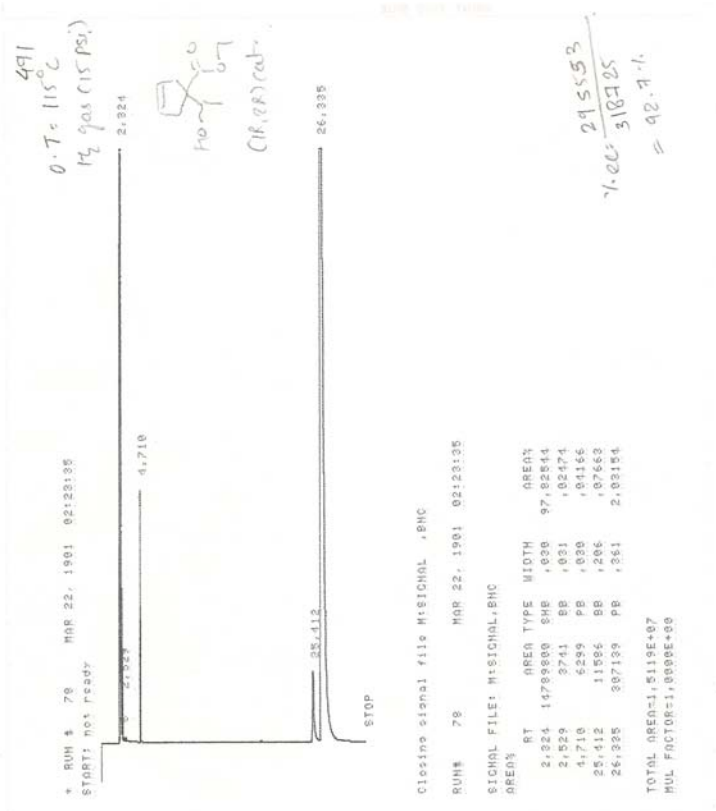
^{1}H-NMR of (*R*) ethyl 1-(1-hydroxyethyl)cyclopent-3-ene-1-carboxylate 14b.

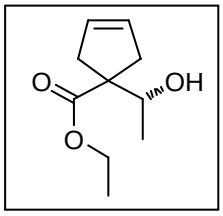


^{13}C-NMR of (*R*) ethyl 1-(1-hydroxyethyl)cyclopent-3-ene-1-carboxylate 14b.



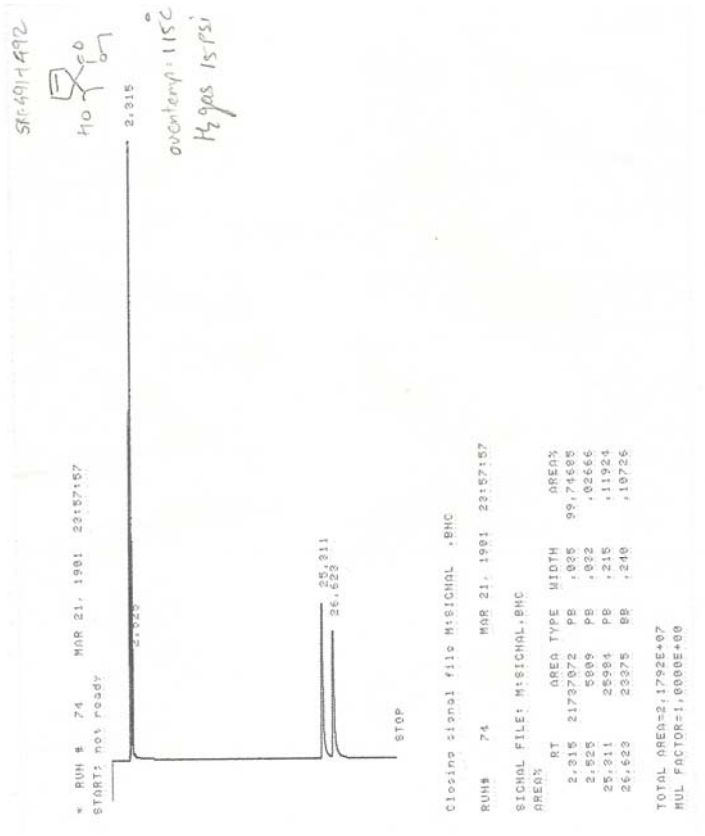
GC of (*R*) ethyl 1-(1-hydroxyethyl)cyclopent-3-ene-1-carboxylate 14b.

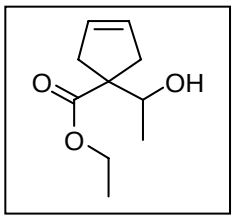




(1*R*,2*R*) 3C-teth-Ru complex reduction product

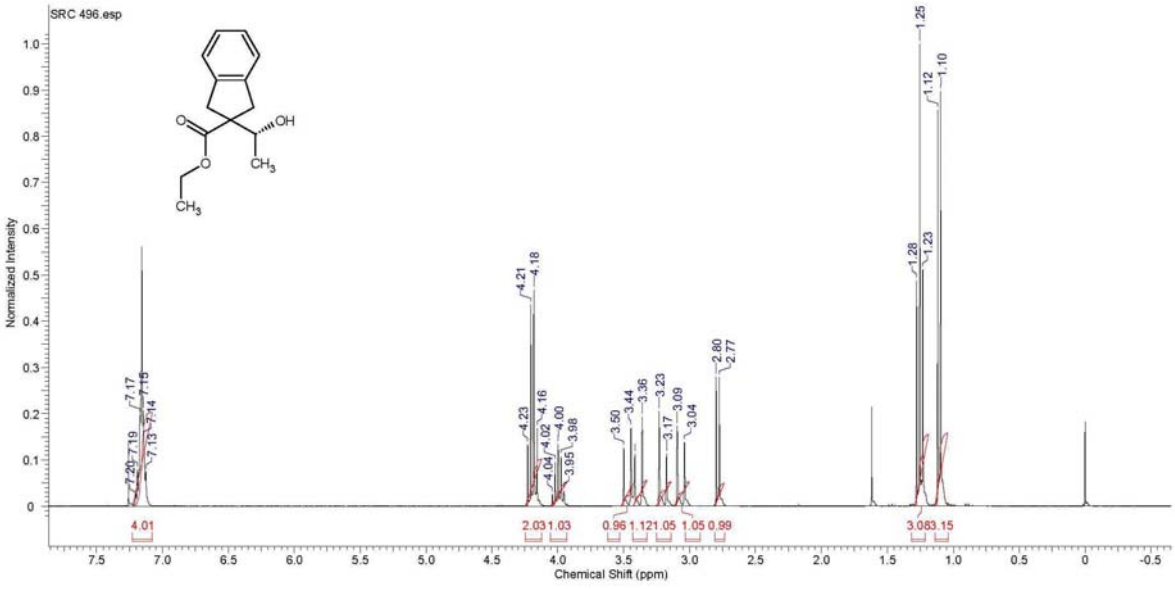
GC of racemic ethyl 1-(1-hydroxyethyl)cyclopent-3-ene-1-carboxylate.



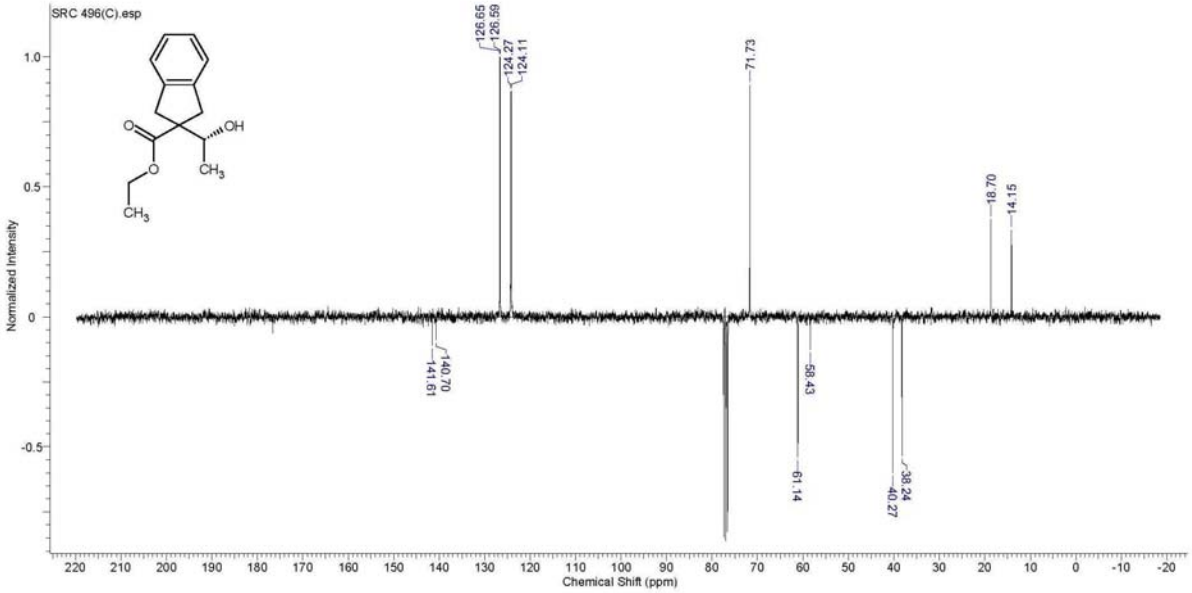


Racemic

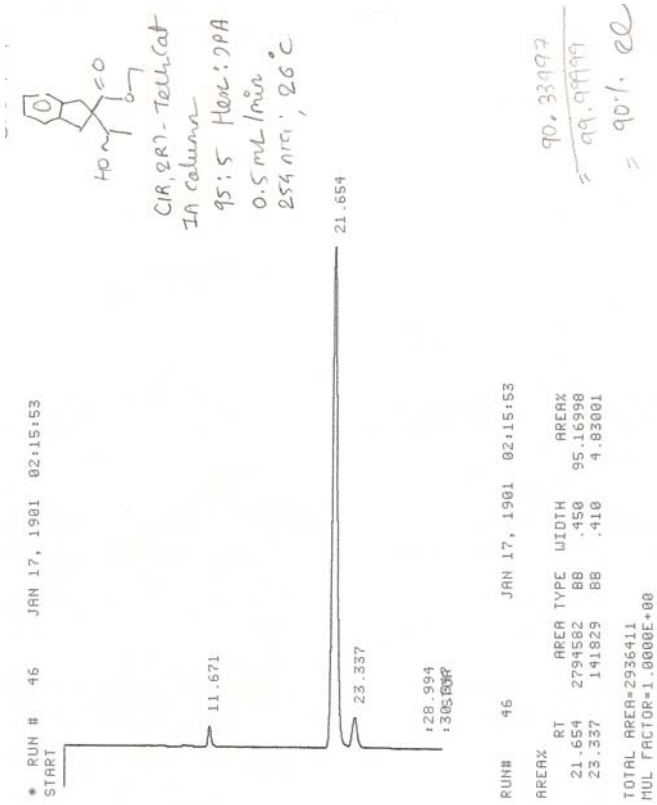
^{1}H-NMR of (*R*) ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate 14c.

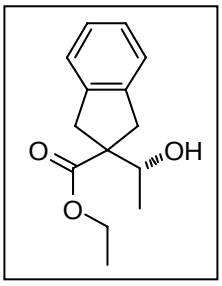


^{13}C-NMR of (*R*) ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate 14c.



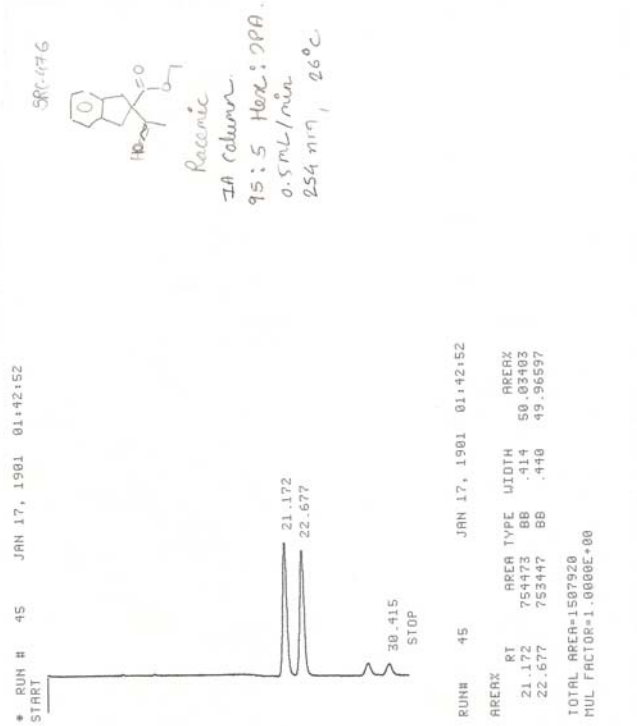
HPLC of (*R*) Ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate 14c.

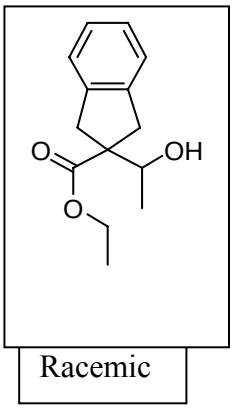




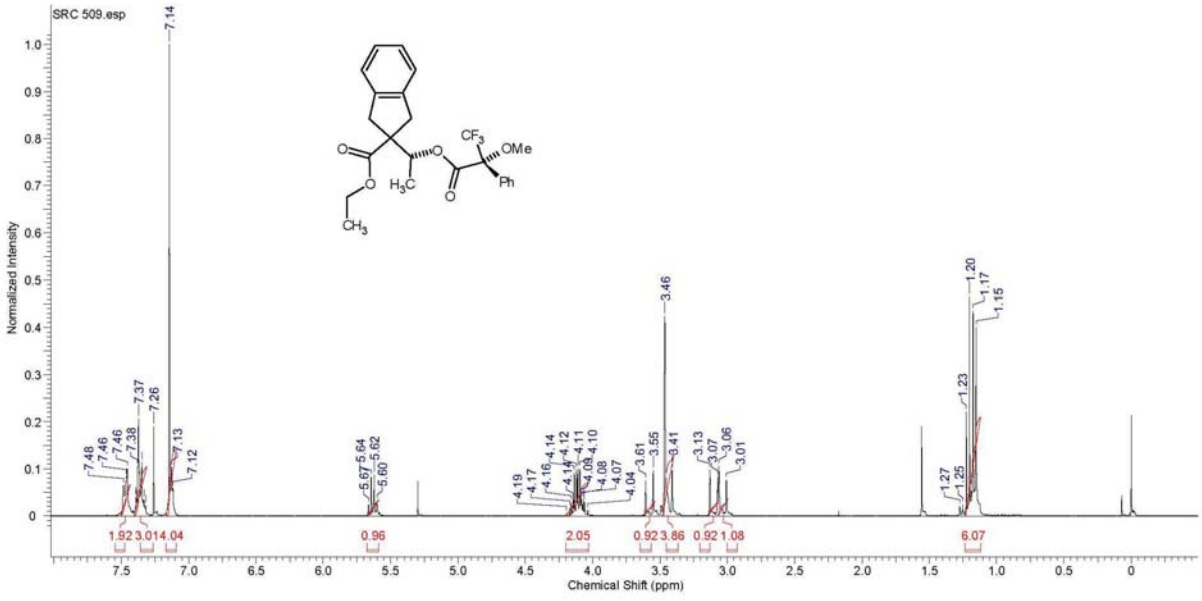
(1*R*,2*R*) 3C-teth-Ru complex reduction product

HPLC of racemic ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate 14c.

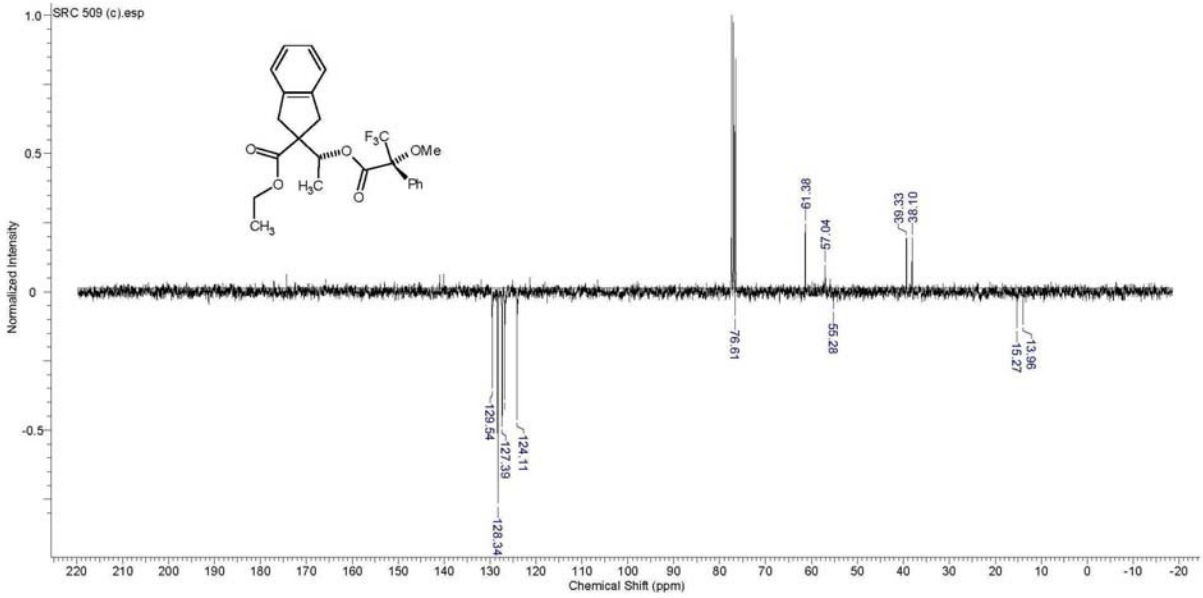




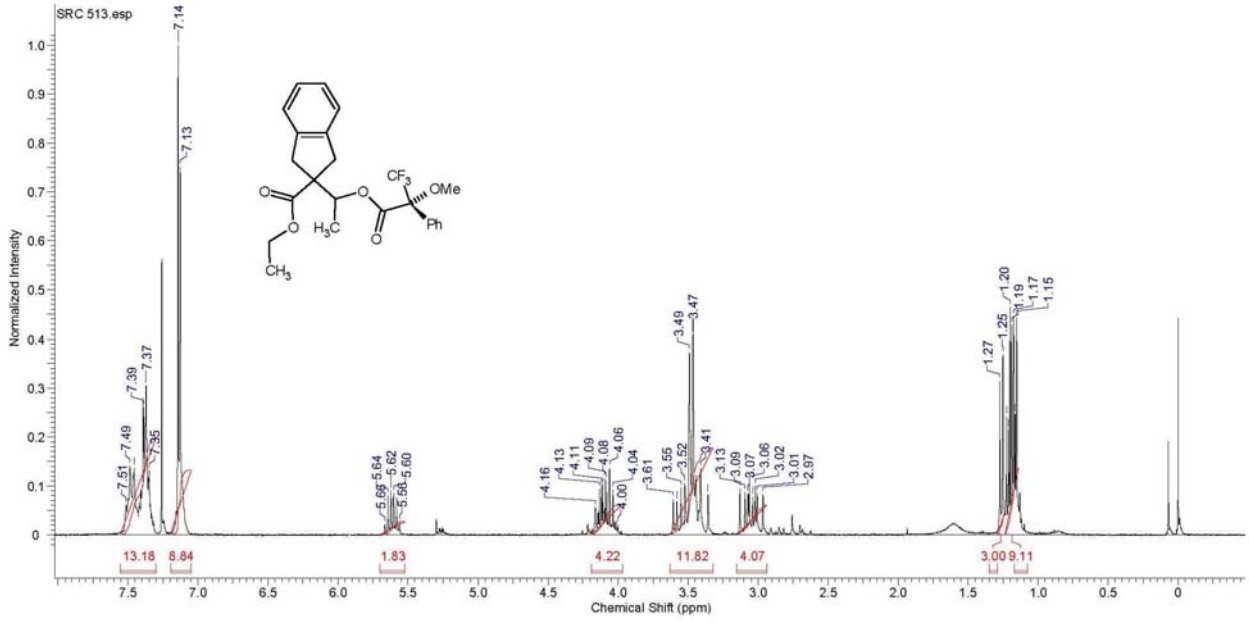
^{1}H-NMR of Mosher's ester of (*R*) ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate 14c.



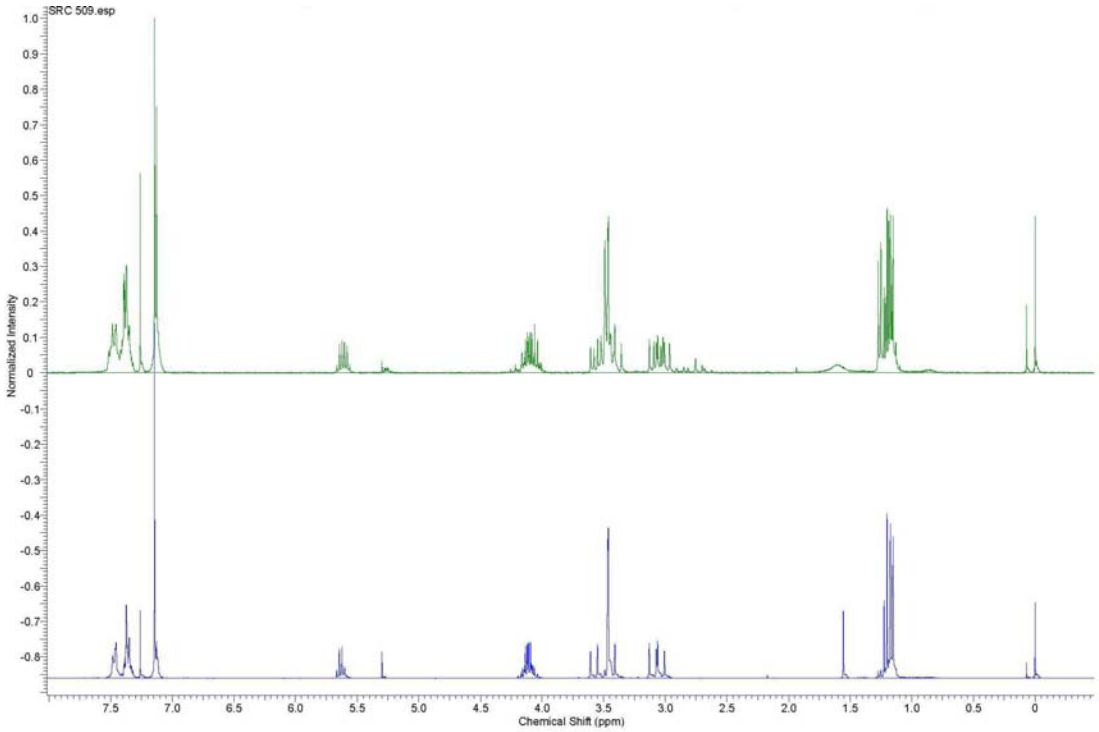
^{13}C-NMR of Mosher's ester of (*R*) ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate 14c.



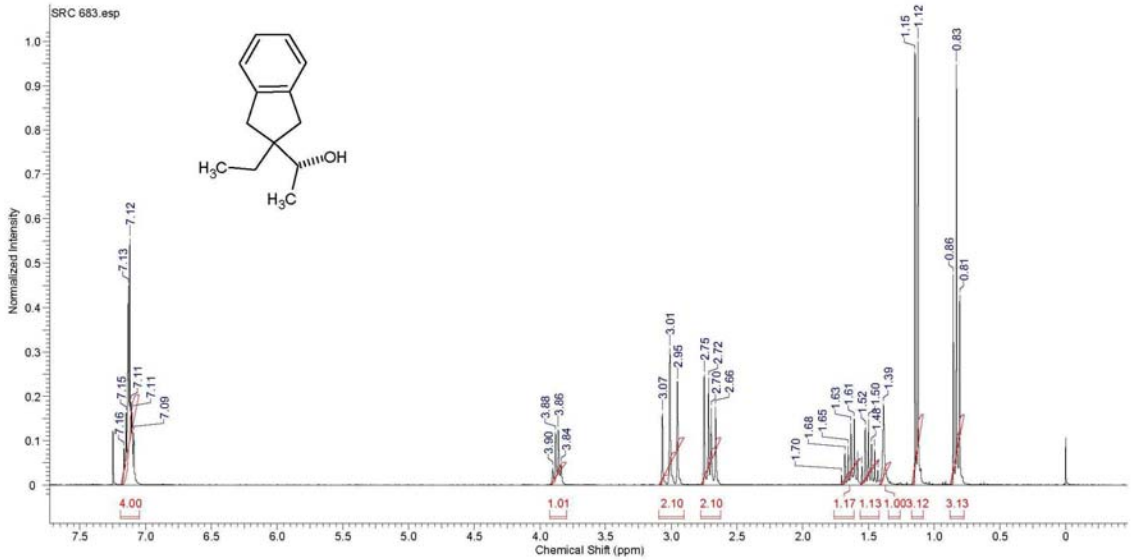
^{1}H-NMR of Mosher's ester of racemic ethyl 2-(1-hydroxyethyl)-2,3-dihydro-1H-indene-2-carboxylate.



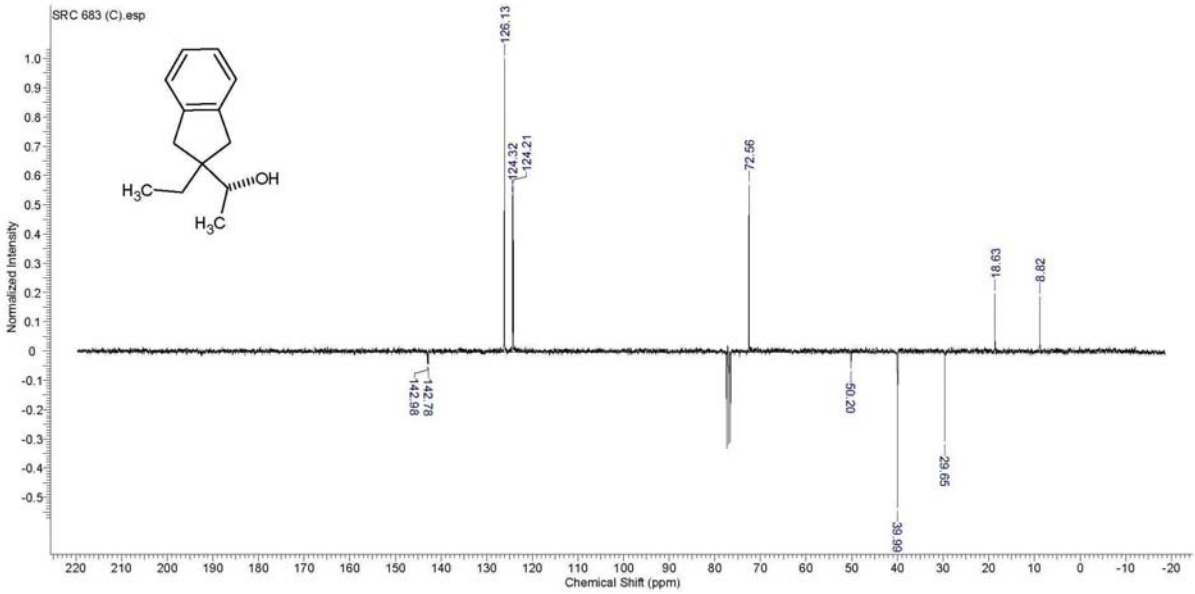
1H-NMR Overlay of asymmetric and racemic Mosher esters.



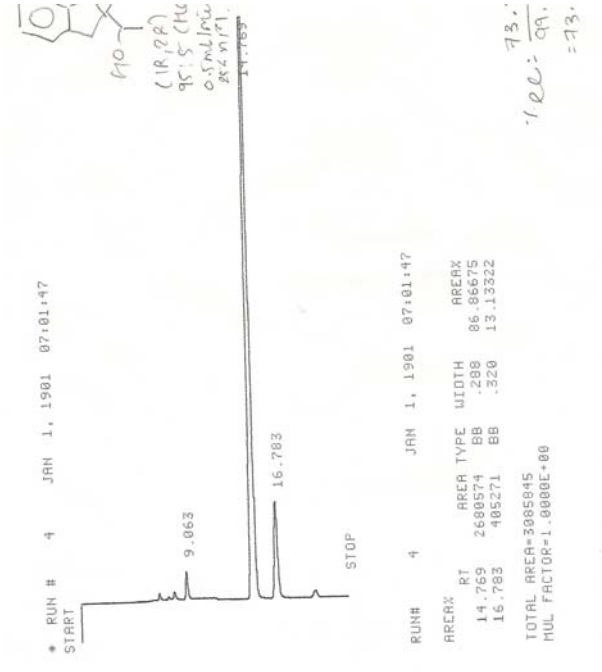
^{1}H-NMR of (*R*) 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol 14d.

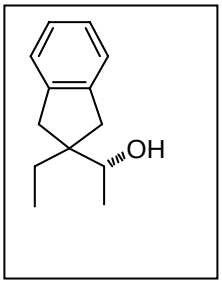


^{13}C-NMR of (*R*) 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol 14d.



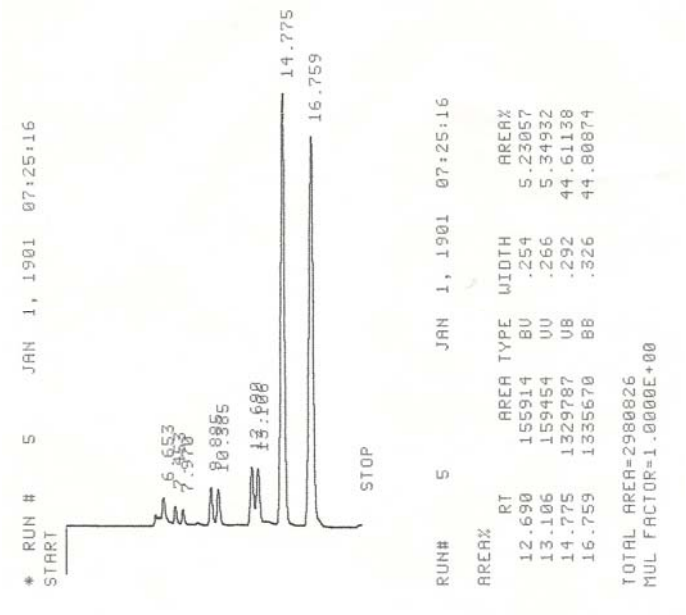
HPLC of (*R*) 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol 14d.

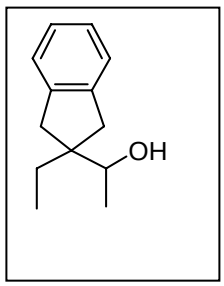




(1*R*,2*R*) 3C-teth-Ru complex reduction product

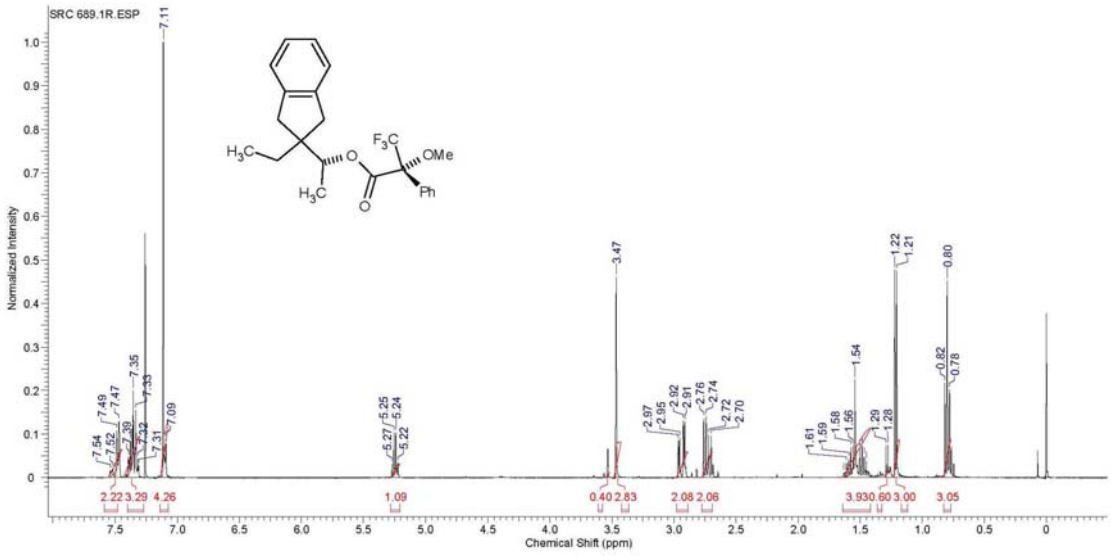
HPLC of racemic 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol.



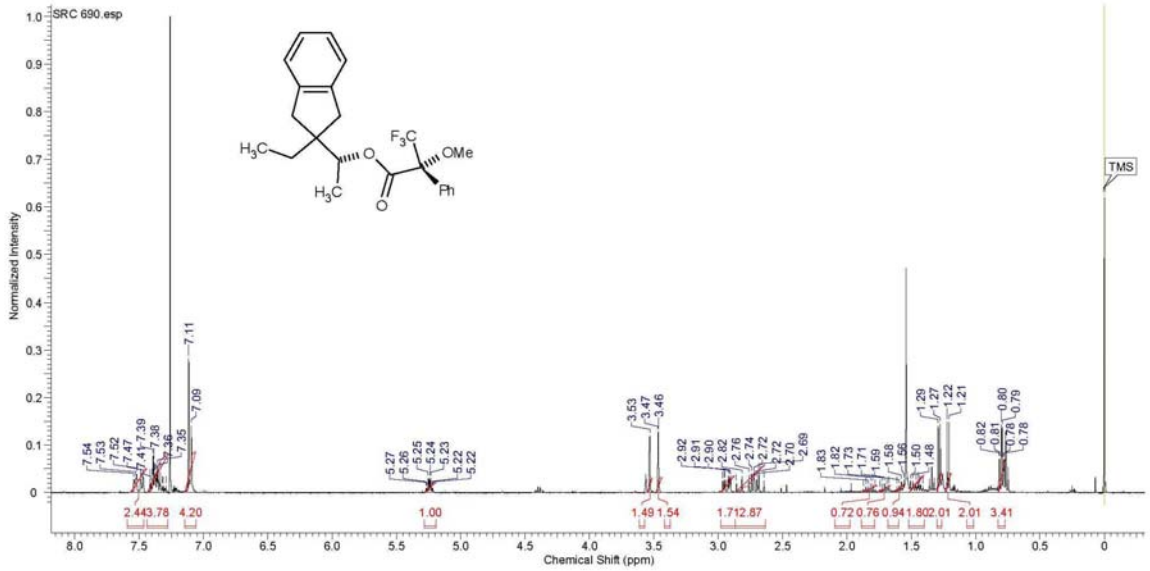


Racemic

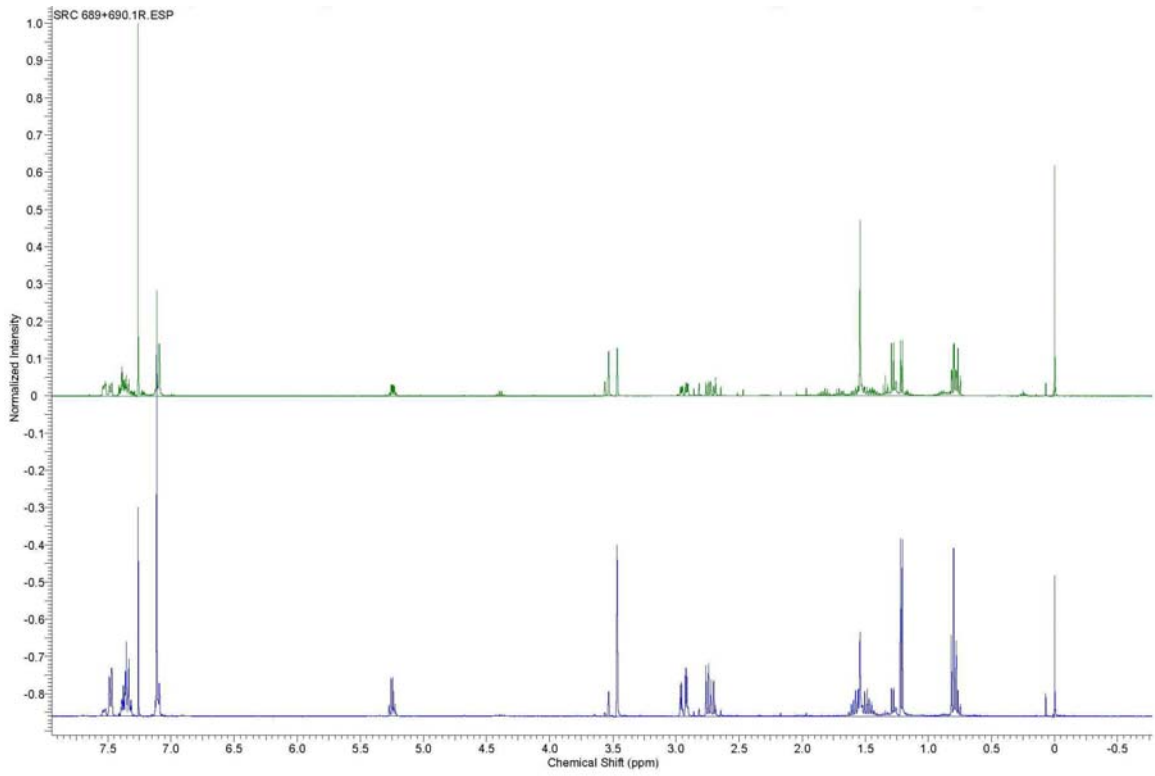
^{1}H-NMR of Mosher's ester of (*R*) 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol 14d.



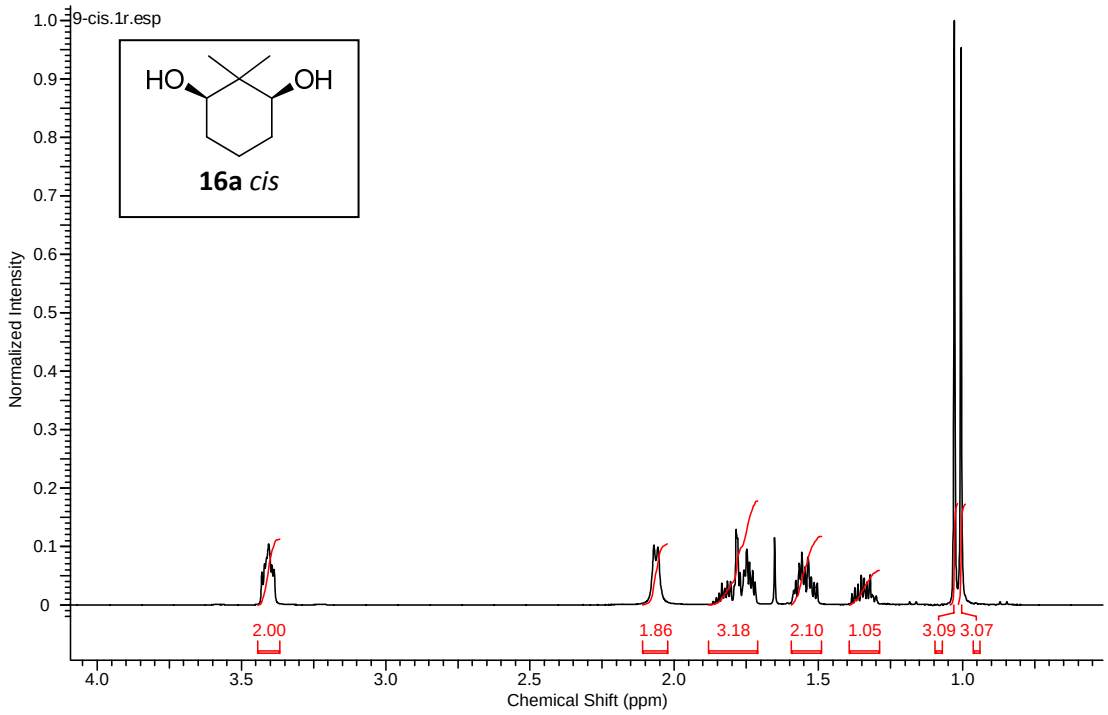
^{1}H-NMR of Mosher's ester of racemic 1-(2-ethyl-2,3-dihydro-1H-indene-2-yl)ethanol.



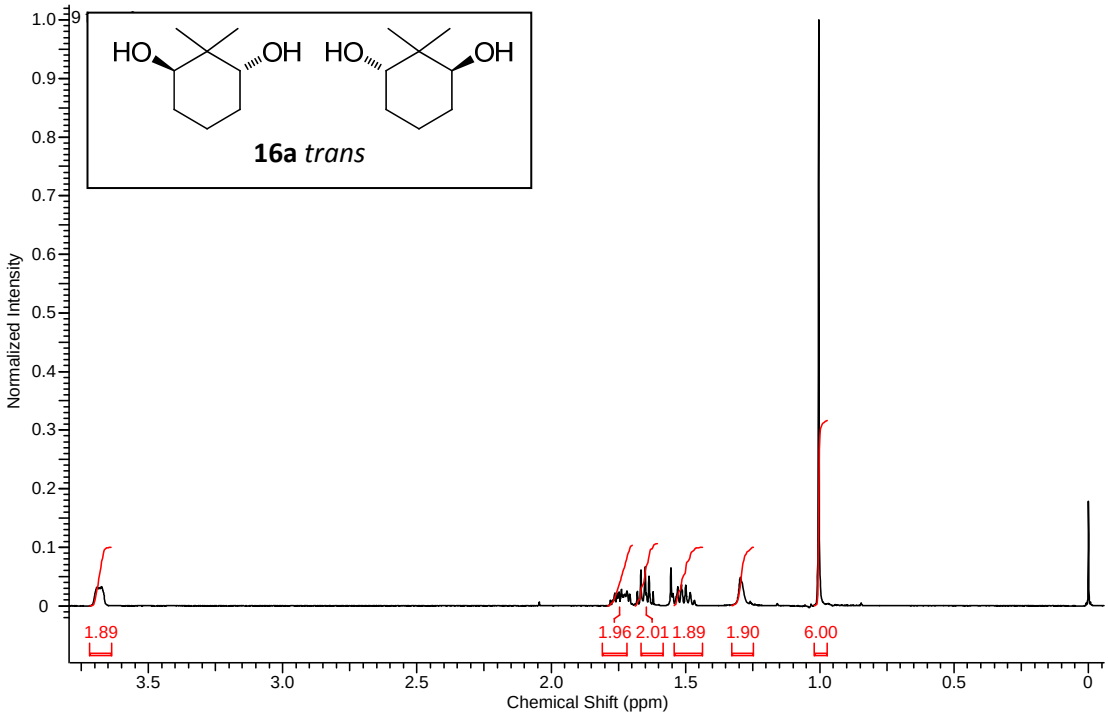
1H-NMR Overlay of asymmetric and racemic Mosher esters.



^{1}H-NMR of *cis*-2,2-dimethylcyclohexane-1,3-diol 16a.



^{1}H-NMR of *trans*-2,2-dimethylcyclohexane-1,3-diol 16a.



Enantiomeric excess determination of diol 16a; this was non-trivial and is explained below:

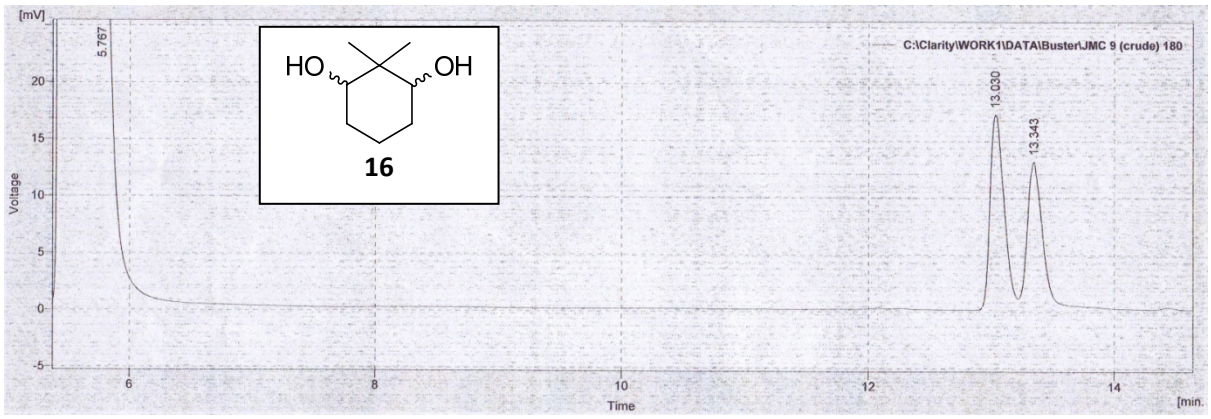
The racemic reduction was attempted using $NaBH_4$ in 0.5 M NaOH. The reaction was monitored by TLC and ^{1}H NMR, after 16 h the reaction was worked up. In the crude product it was possible to detect the cis and trans compounds which were separated by chromatography.

In the ^{1}H NMR of the *cis* product the two methyl hydrogens are seen as 2 singlets, as they are no longer equivalent due to the alcohol groups being on one side, and so the environments for the methyl groups are different.

In the ^{1}H NMR of the *trans* product, **16a**, the two methyl hydrogens are seen as a singlet as they are equivalent. The peak at 3.7 ppm is shifted from 3.4 ppm in the *cis* product.

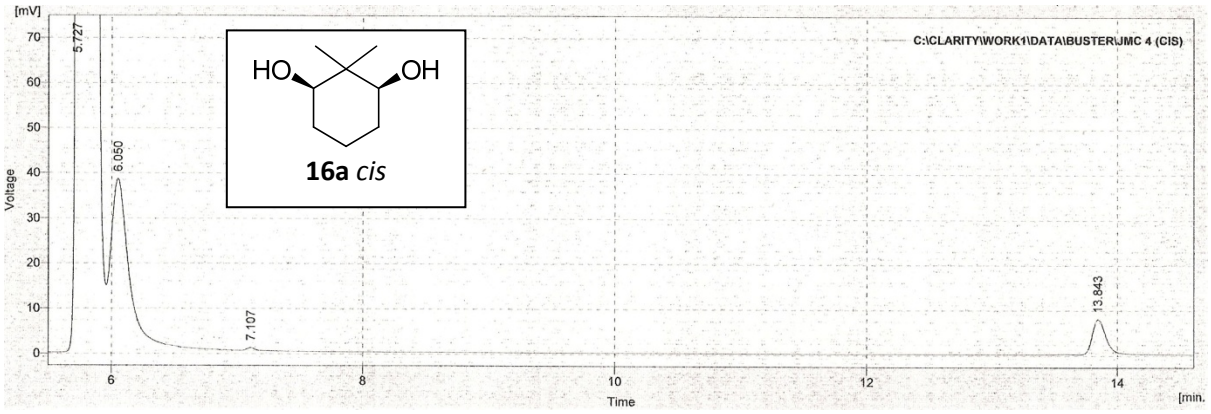
The asymmetric reduction with (R,R) tethered Ru (II) catalyst (2 mol%) with FA/TEA conditions at 28°C. After 7 h both carbonyls had been reduced, as detected by mass spectroscopy.

Chiral Gas Chromatography (GC) was used to assess the ee; it was first attempted at 180^{o}C for analysis of compound **16a**.



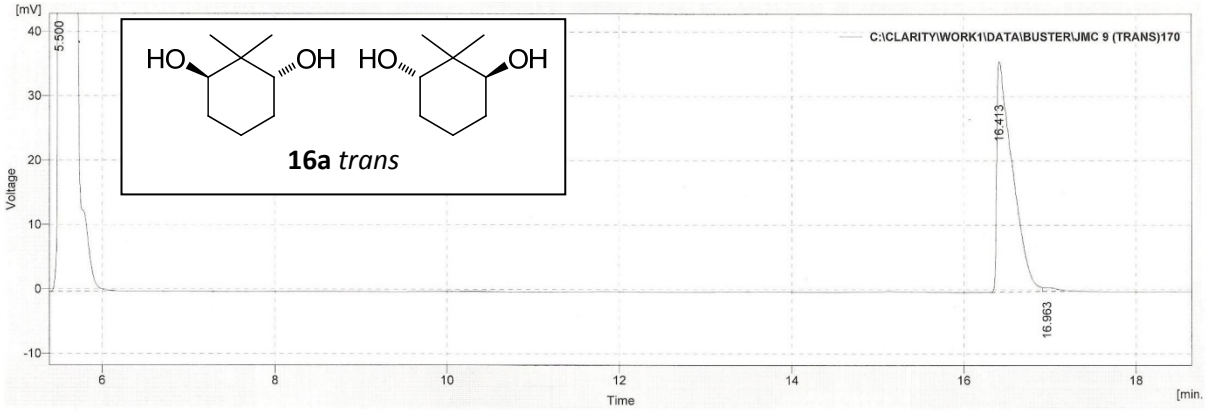
GC analysis of the crude asymmetric reduction product **16** at 180°C to give the diastereomer ratio.

With the crude racemic material at a column temperature of 180°C, there were two peaks, the first eluted at 13.0 mins and the second at 13.3 mins. The material was then purified to separate the two diastereomers to assign the peaks to each diastereomer.



GC analysis of the purified reduced *cis* product **16a** at 180°C.

The GC analysis of the purified *cis* product saw **16a** eluted after 13.8 mins, which would correspond with the second peak in the crude mixture.



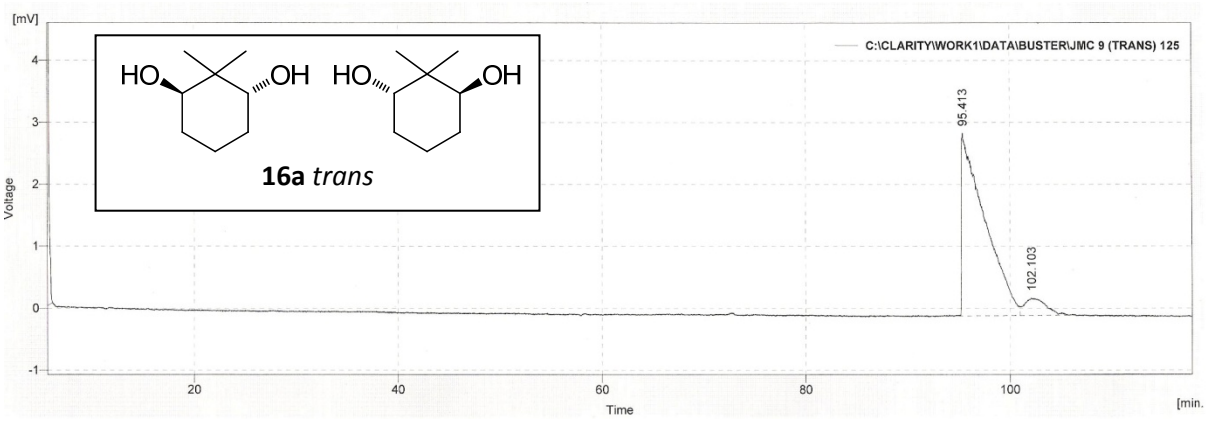
Result Table (Uncal - C:\CLARITY\WORK1\DATA\BUSTER\JMC 9 (TRANS)170)

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	5.500	14607.277	1250.386	97.0	97.2	0.19
2	16.413	452.084	35.766	3.0	2.8	0.20
3	16.963	6.737	0.592	4.472e-02	4.604e-02	0.19
	Total	15066.098	1286.744	100.0	100.0	

GC analysis of the purified *trans* compound, **16a,** at 170°C with area of peaks.

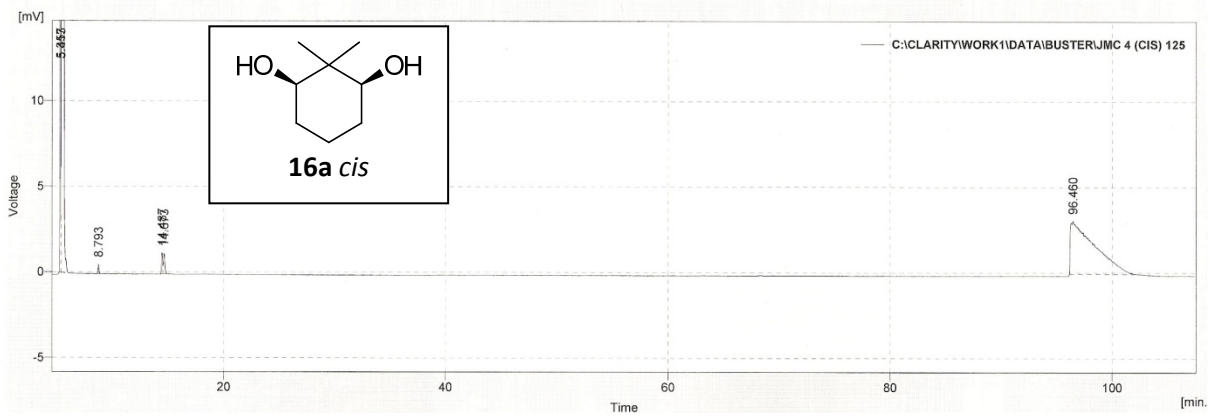
The purified asymmetrically reduced compound of the *trans* **16a**, was analysed at a GC column temperature of 170°C at which the major peak was eluted after 16.4 mins, which would correspond to the first peak in the crude asymmetric sample. The GC spectrum also shows a small peak eluted after 16.9 mins. This corresponds with the *cis* product. The ratio of the *cis* product within the *trans* material was calculated at 67:1 (*trans*:*cis*), In the calculation for the enantiomeric excess, this is taken into account. After the assignment of the peaks in the GC spectra at 180°C, it is possible to calculate the diastereomeric ratio (dr) with the crude asymmetric sample. The areas of the peaks were measured and the diastereomeric ratio of **16a** (*cis*) and **16a** (*trans*) in the crude material was established as 45:55 (*cis:trans*).

The temperature of the GC column was lowered to attempt to separate the enantiomers and diastereomers to work out the ee of the *trans* product.



GC analysis of the purified *trans* asymmetrically reduced product at 125°C.

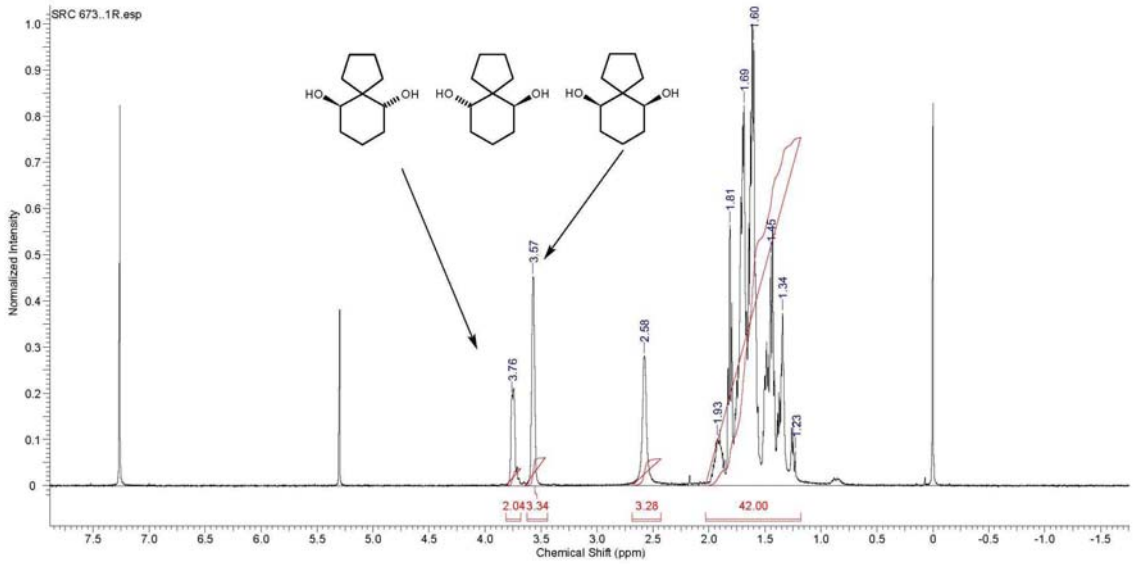
To improve separation of the two enantiomers the purified asymmetric *trans* material was eluted at a column temperature of 125°C; the first peak eluted after 95.4 mins, the second enantiomer peak was eluted after 102.1 mins. Only two peaks were seen in the GC analysis, this means that the *cis* material started to overlap with one enantiomer of the *trans* material.



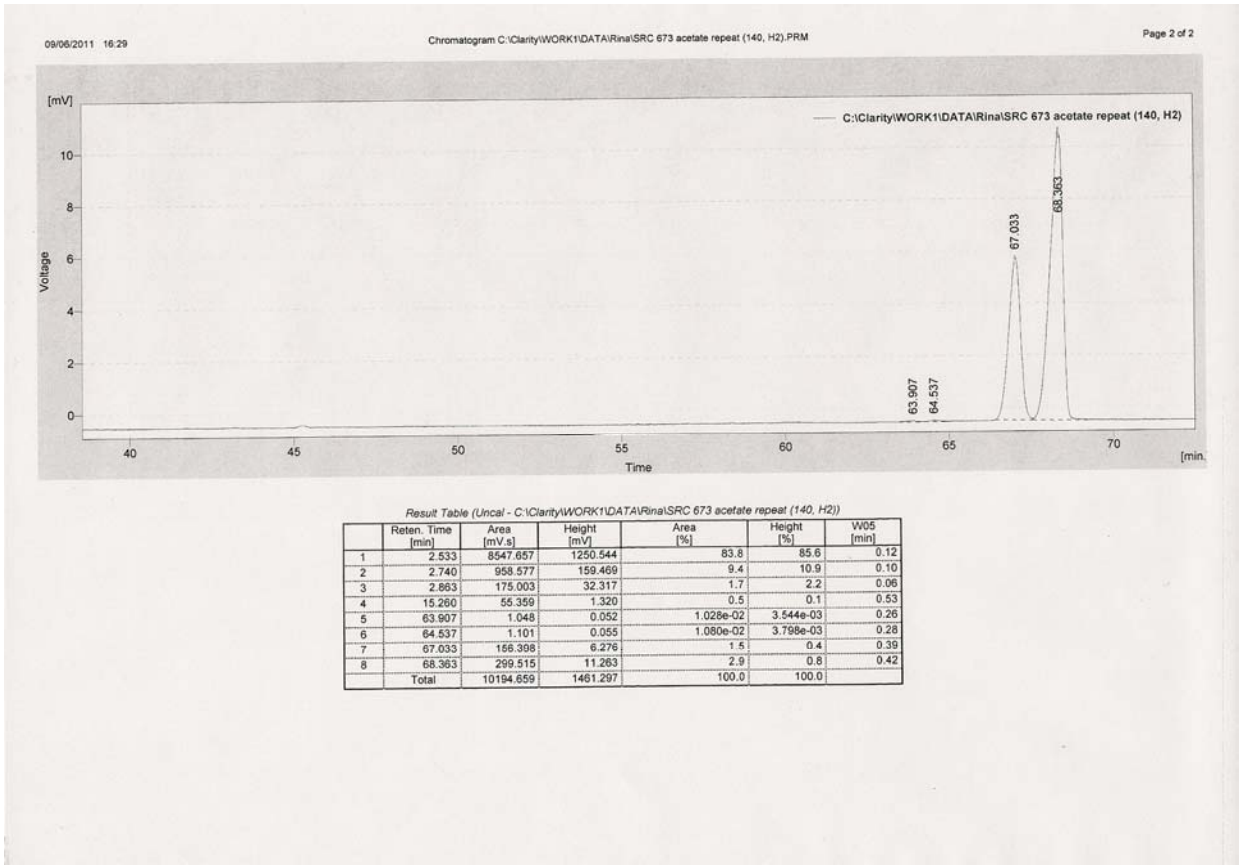
GC analysis of the purified *cis* reduced product, **16-a** at 125°C.

At this temperature it was found that the *cis* product was eluted after 96.4 mins. At a column temperature of 125°C the *cis* product was co-eluted with the major *trans* enantiomer - this was taken into account in the calculation of the ee of the *trans* material which was determined to be 83% (*R*,*R*) on the basis of analogy with **16b** and **16c**.

[1]H-NMR of crude *cis* and *trans* isomers of spiro[4,5]decane-6,10-diol 16b.



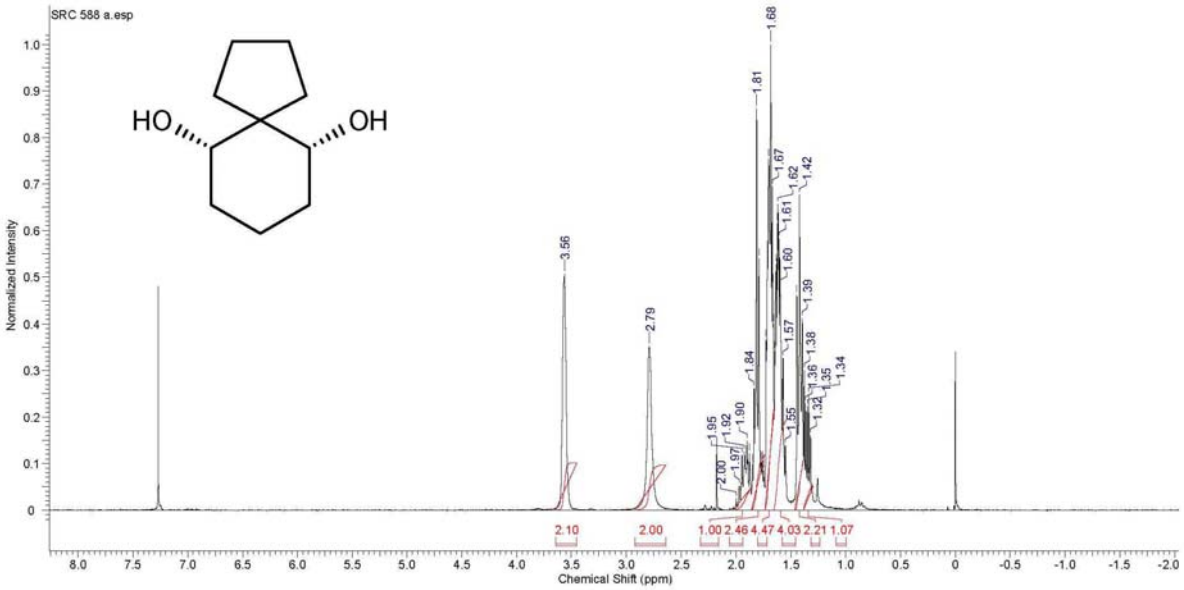
GC of acetate derivative of crude *cis* and *trans* isomers of spiro[4,5]decane-6,10-diol 16b.



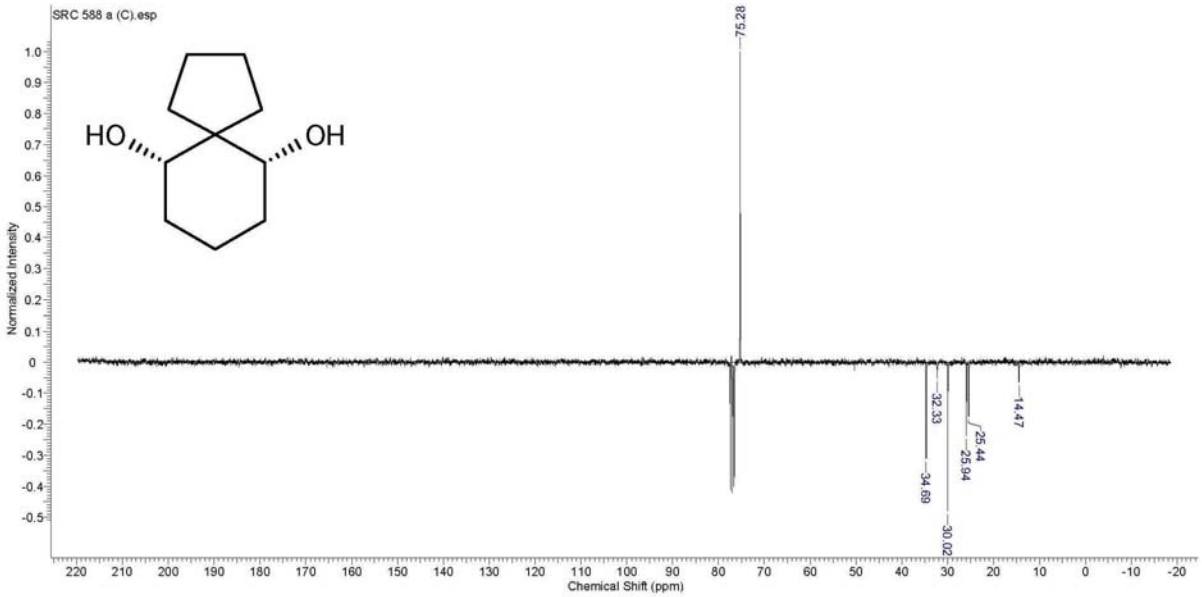
Result Table (Uncal - C:\Clarity\WORK1\DATA\Rina\SRC 673 acetate repeat (140, H2))

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.533	8547.657	1250.544	83.8	85.6	0.12
2	2.740	958.577	159.469	9.4	10.9	0.10
3	2.863	175.003	32.317	1.7	2.2	0.06
4	15.260	55.359	1.320	0.5	0.1	0.53
5	63.907	1.048	0.052	1.028e-02	3.544e-03	0.26
6	64.537	1.101	0.055	1.080e-02	3.798e-03	0.28
7	67.033	156.398	6.276	1.5	0.4	0.39
8	68.363	299.515	11.263	2.9	0.8	0.42
	Total	10194.659	1461.297	100.0	100.0	

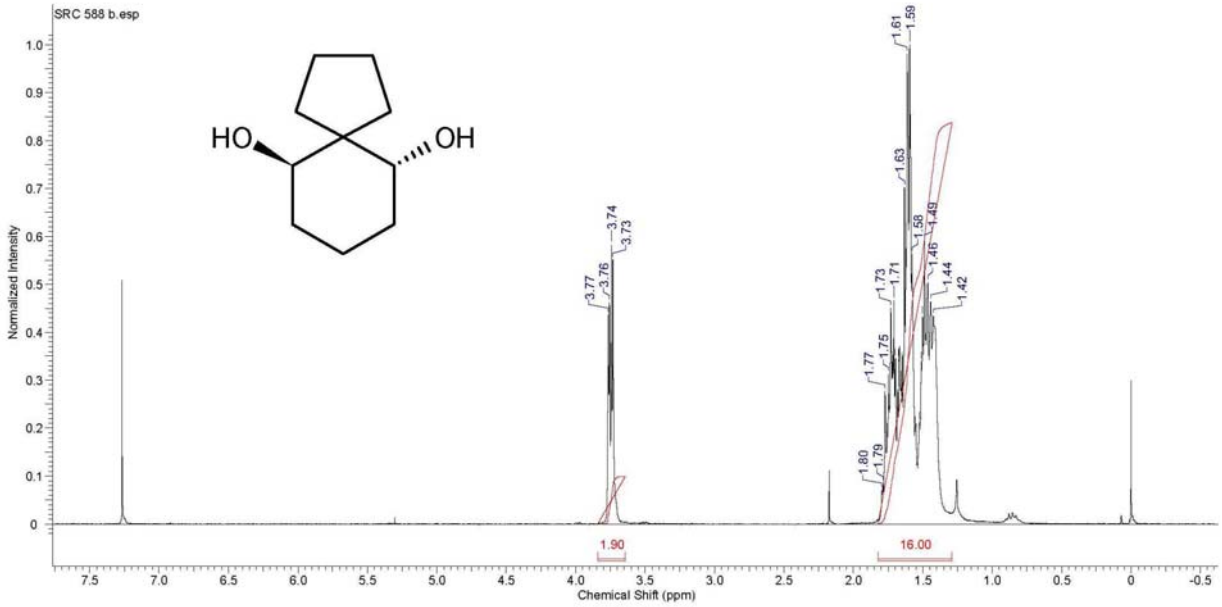
[1]H-NMR of *cis* spiro[4,5]decane-6,10-diol 16b.



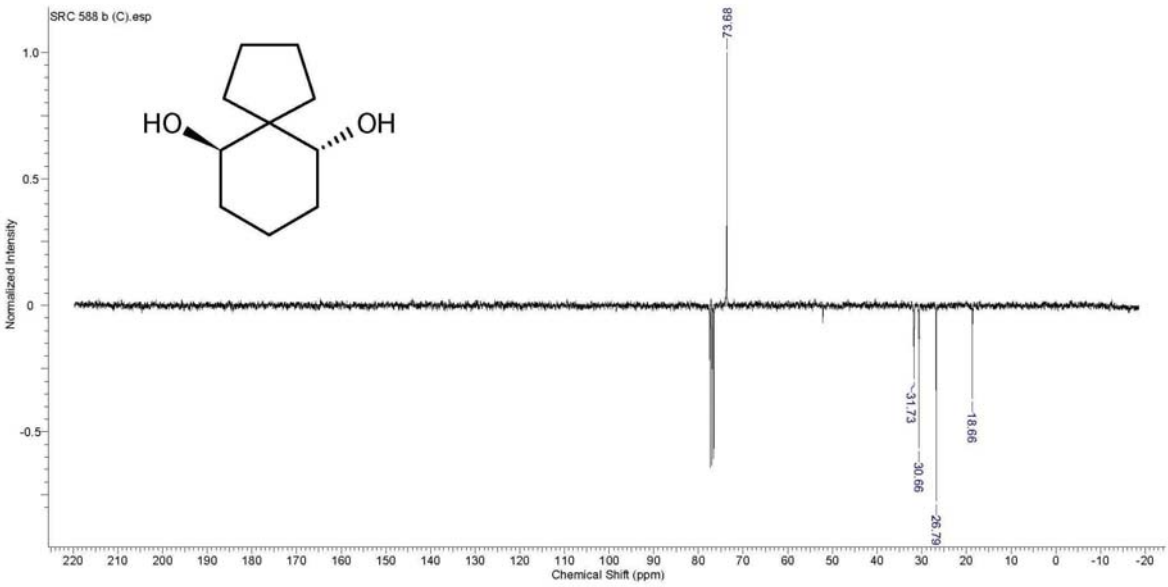
[13]C-NMR of *cis* spiro[4,5]decane-6,10-diol 16b.



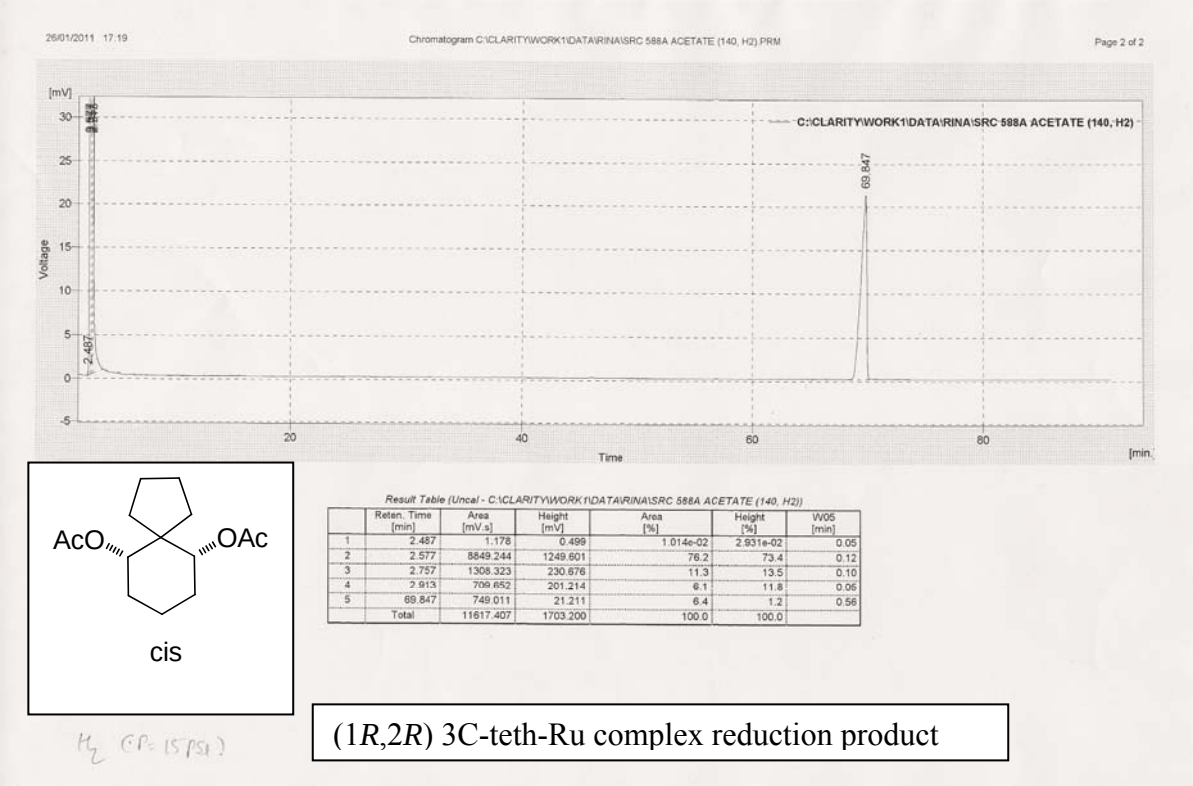
^{1}H-NMR of *trans*-(*R,R*) spiro[4,5]decane-6,10-diol 16b.



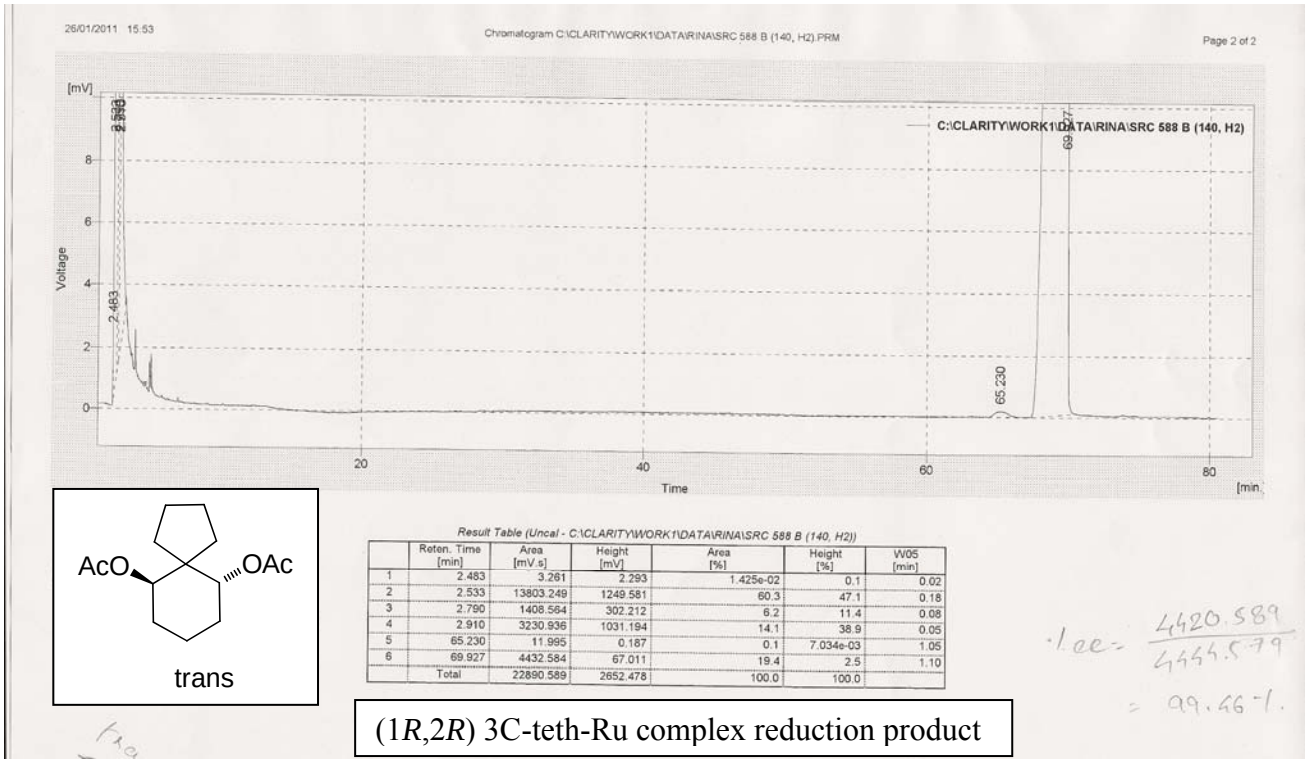
^{13}C-NMR of *trans*-(*R,R*) spiro[4,5]decane-6,10-diol 16b.



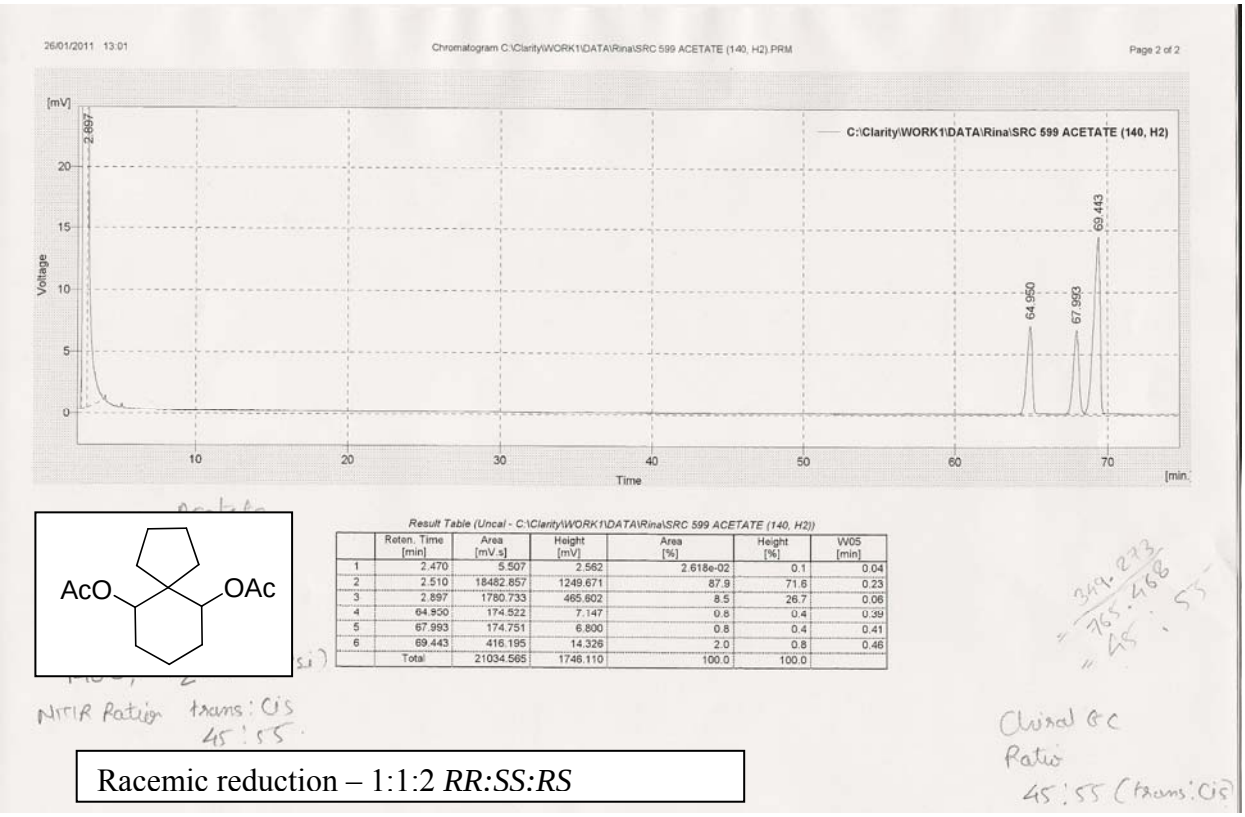
GC of acetate derivative of *cis* spiro[4,5]decane-6,10-diol.



GC of acetate derivatives of *trans*-(*R,R*) spiro[4,5]decane-6,10-diol 16b.

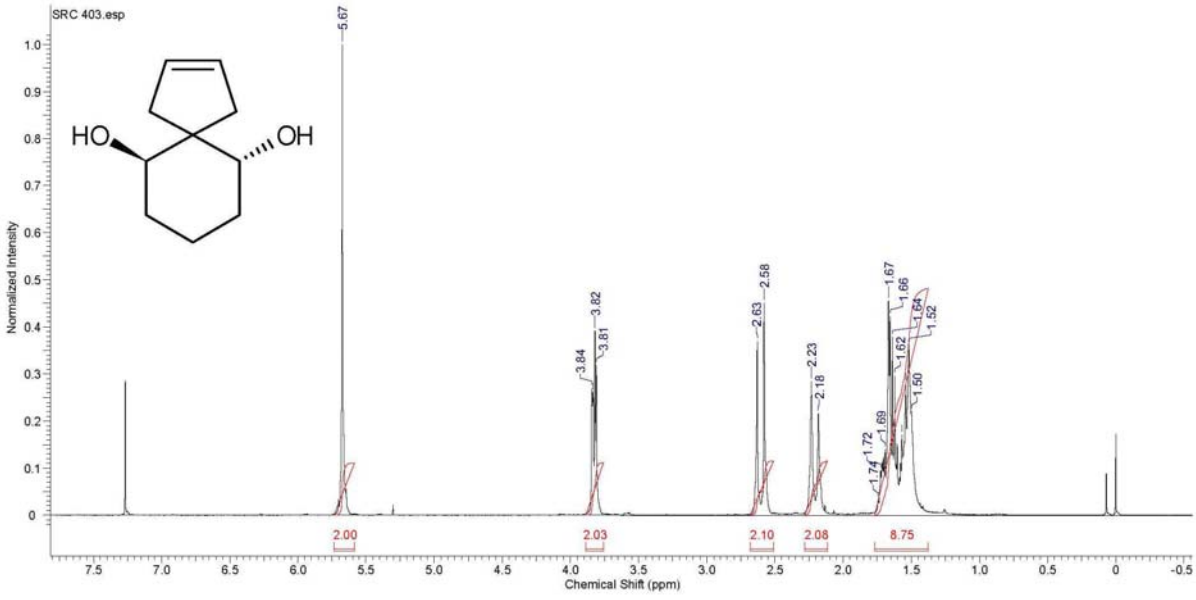


GC of acetate derivative of racemic spiro[4,5]decane-6,10-diol.

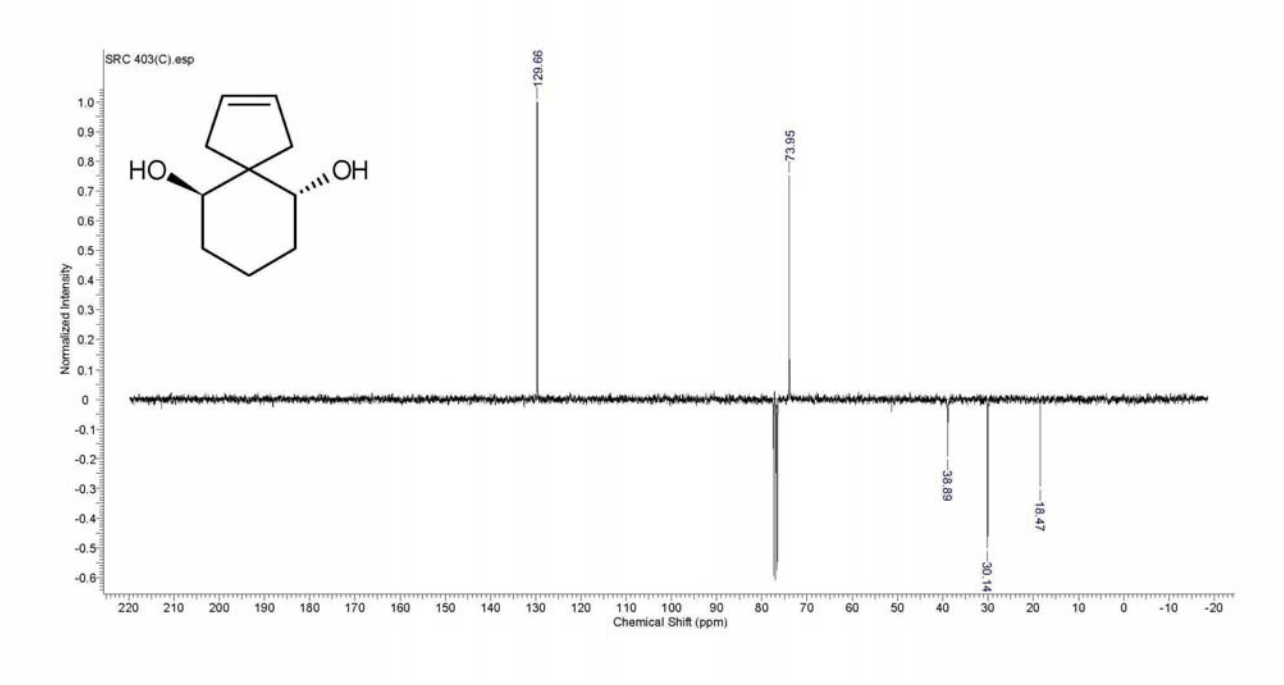


Racemic reduction – 1:1:2 *RR:SS:RS*

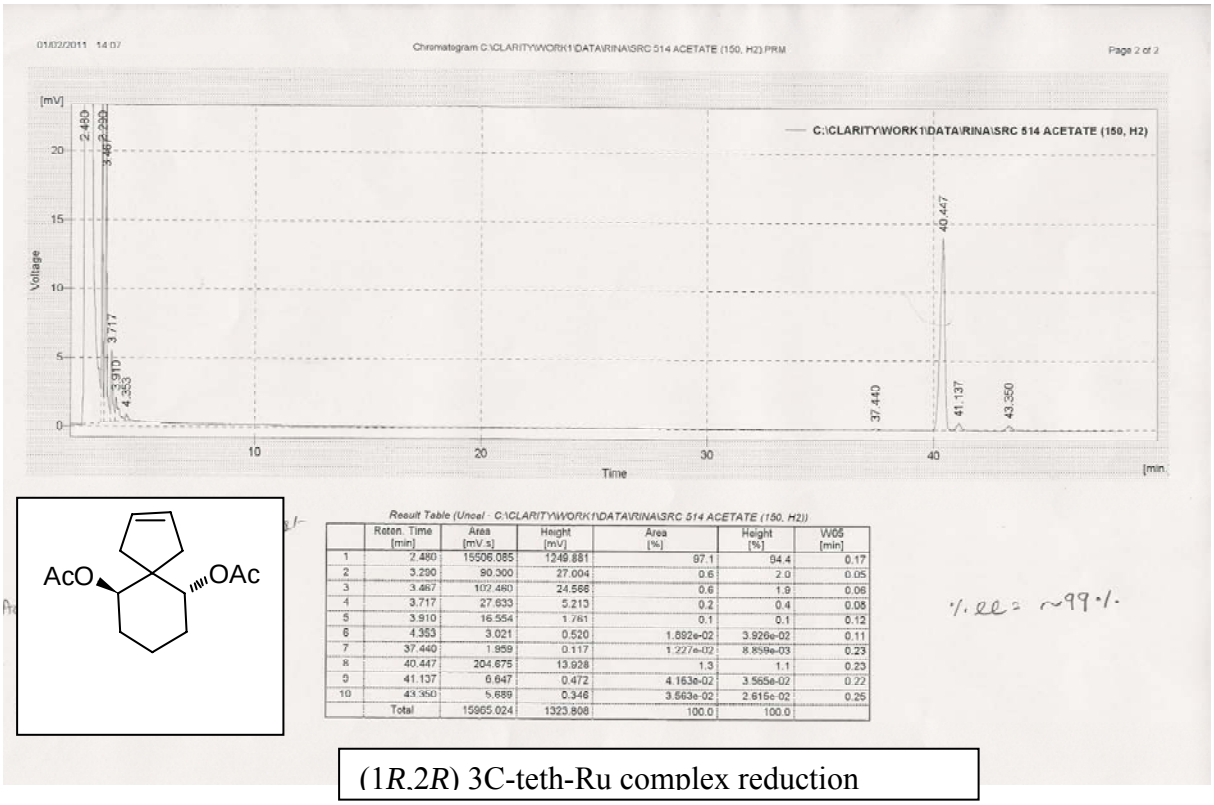
^{1}H-NMR of (*R,R*) spiro[4,5]dec-2-ene-6,10-diol 16c.



^{13}C-NMR of (*R,R*) spiro[4,5]dec-2-ene-6,10-diol 16c.



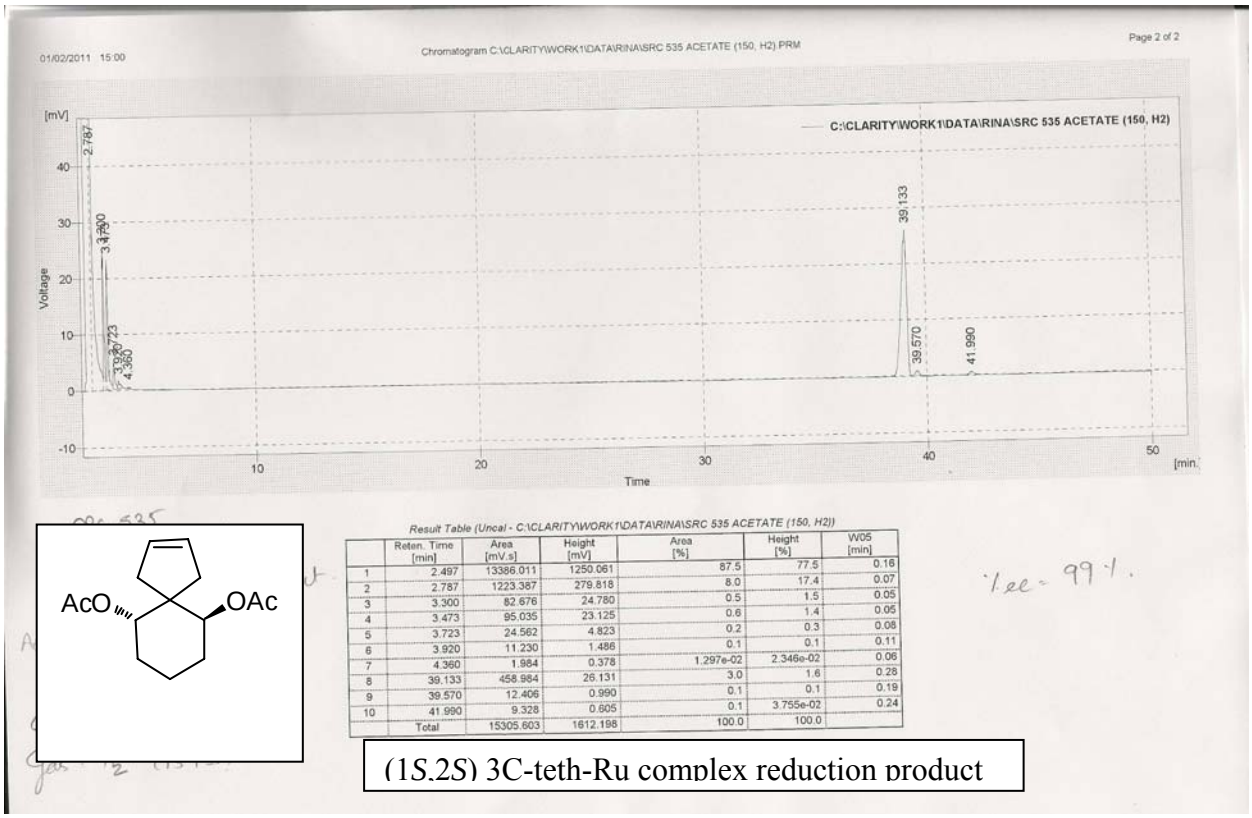
GC of acetate derivative of (*R,R*) spiro[4,5]dec-2-ene-6,10-diol 16c.



	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.480	15506.085	1249.881	97.1	94.4	0.17
2	3.290	90.300	27.004	0.6	2.0	0.05
3	3.467	102.480	24.566	0.6	1.9	0.06
4	3.717	27.933	5.215	0.2	0.4	0.08
5	3.910	16.554	1.761	0.1	0.1	0.12
6	4.353	3.021	0.520	1.892e-02	3.926e-02	0.11
7	37.440	1.959	0.117	1.227e-02	8.859e-03	0.23
8	40.447	204.675	13.928	1.3	1.1	0.23
9	41.137	6.647	0.472	4.163e-02	3.565e-02	0.22
10	43.350	5.689	0.346	3.563e-02	2.615e-02	0.25
	Total	15965.024	1323.808	100.0	100.0	

(1*R*,2*R*) 3C-teth-Ru complex reduction

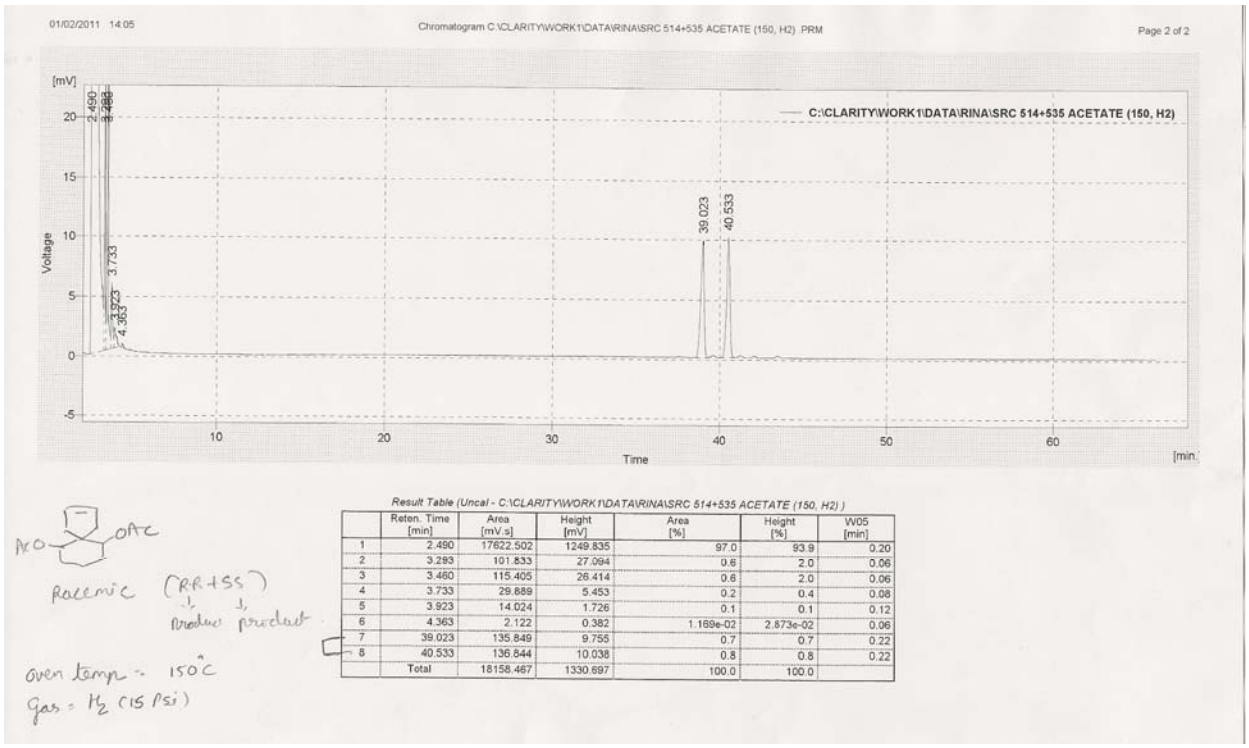
GC of acetate derivative of (*S,S*) spiro[4,5]dec-2-ene-6,10-diol 16c.



Result Table (Uncal - C:\CLARITY\WORK1\DATA\RINA\SRC 535 ACETATE (150, H2))

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.497	13386.011	1250.061	87.5	77.5	0.16
2	2.787	1223.387	279.818	8.0	17.4	0.07
3	3.300	82.676	24.780	0.5	1.5	0.05
4	3.473	95.035	23.125	0.6	1.4	0.05
5	3.723	24.562	4.823	0.2	0.3	0.08
6	3.920	11.230	1.486	0.1	0.1	0.11
7	4.360	1.984	0.378	1.297e-02	2.346e-02	0.06
8	39.133	458.984	26.131	3.0	1.6	0.28
9	39.570	12.406	0.990	0.1	0.1	0.19
10	41.990	9.328	0.605	0.1	3.755e-02	0.24
	Total	15305.603	1612.198	100.0	100.0	

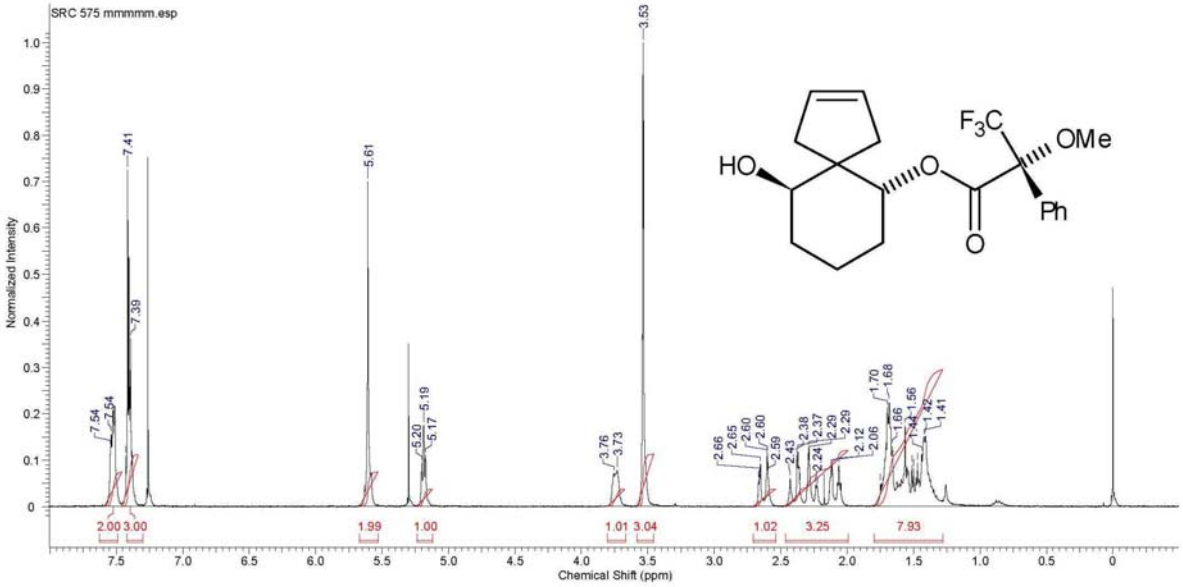
GC of acetate derivative of racemic spiro[4,5]dec-2-ene-6,10-diol.



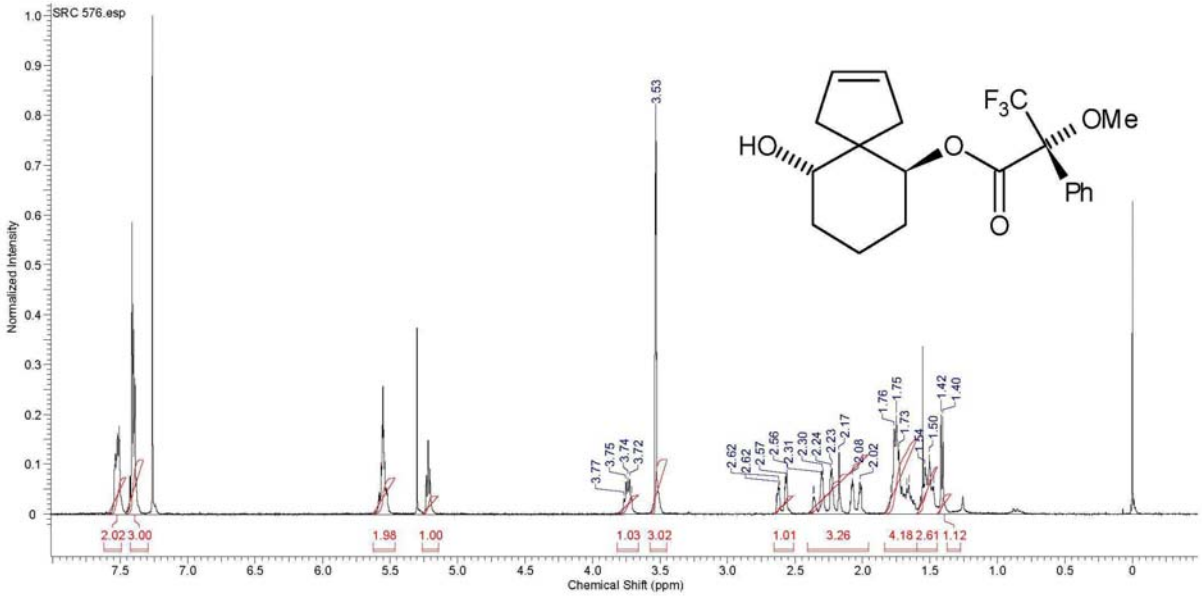
Result Table (Uncal - C:\CLARITY\WORK1\DATA\RINA\SRC 514+535 ACETATE (150, H2))

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.490	17622.502	1249.835	97.0	93.9	0.20
2	3.293	101.833	27.094	0.6	2.0	0.06
3	3.460	115.405	26.414	0.6	2.0	0.06
4	3.733	29.889	5.453	0.2	0.4	0.08
5	3.923	14.024	1.726	0.1	0.1	0.12
6	4.363	2.122	0.382	1.169e-02	2.873e-02	0.06
7	39.023	135.849	9.755	0.7	0.7	0.22
8	40.533	136.844	10.038	0.8	0.8	0.22
	Total	18158.467	1330.697	100.0	100.0	

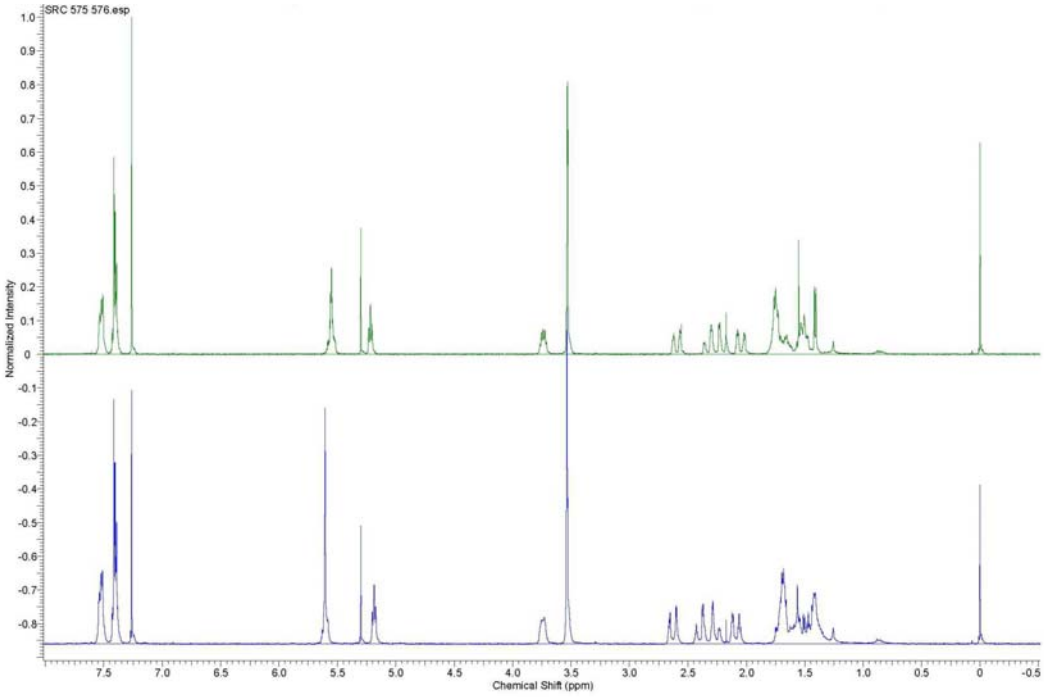
^{1}H-NMR of Mosher's ester of (*R*,*R*) spiro[4,5]dec-2-ene-6,10-diol 16c.



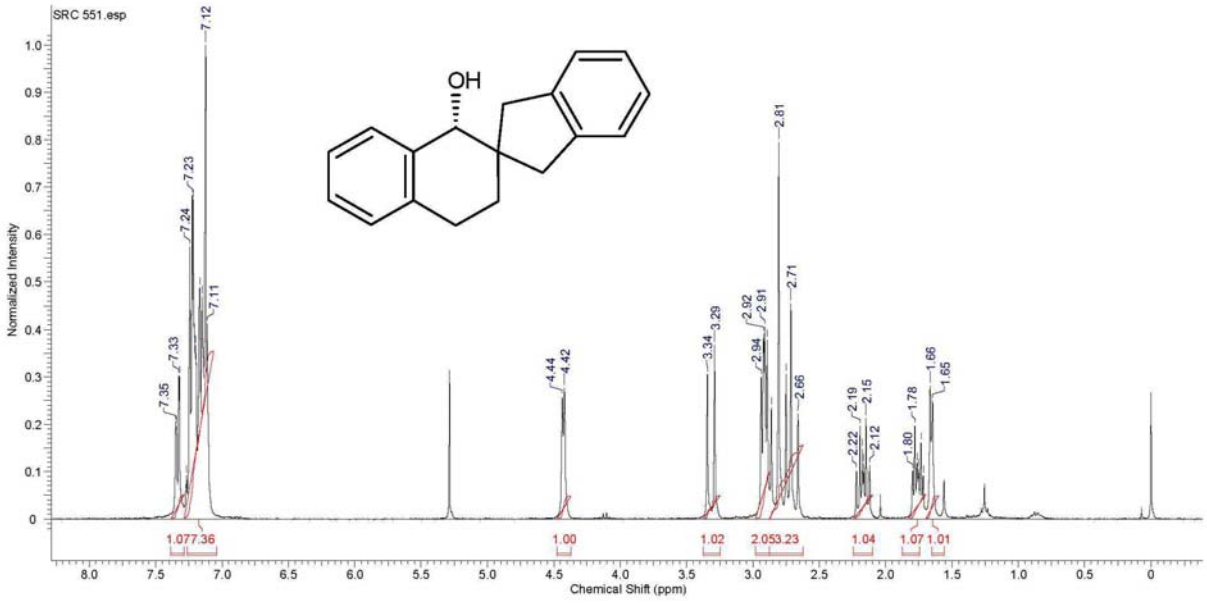
^{1}H-NMR of Mosher's ester of (*S*,*S*) spiro[4,5]dec-2-ene-6,10-diol 16c.



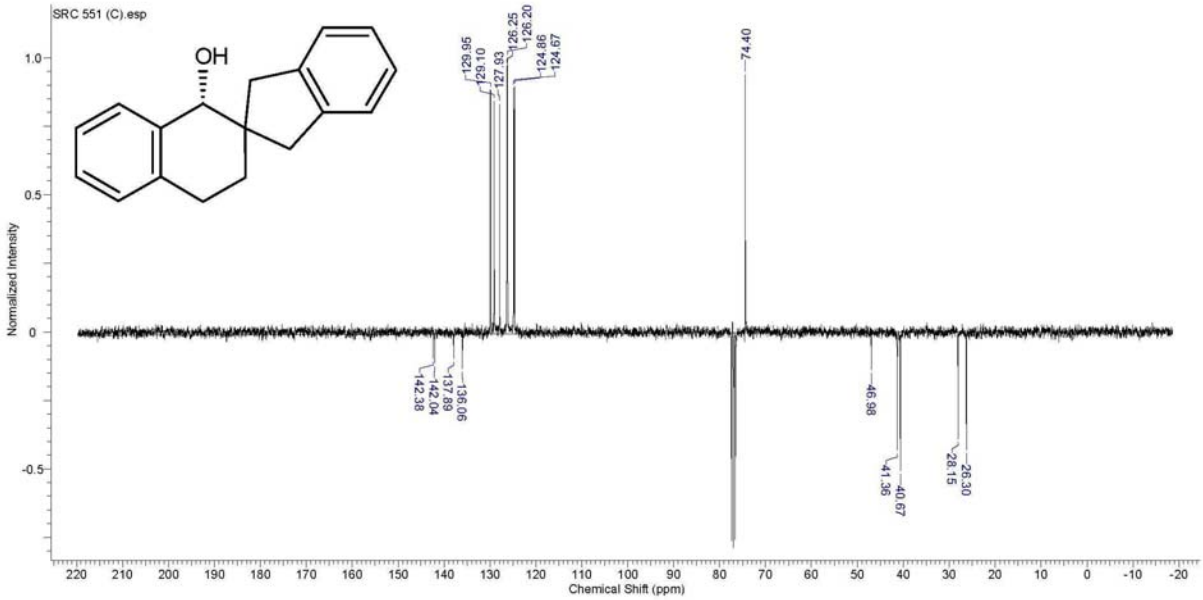
^{1}H-NMR Overlay of both Mosher esters:



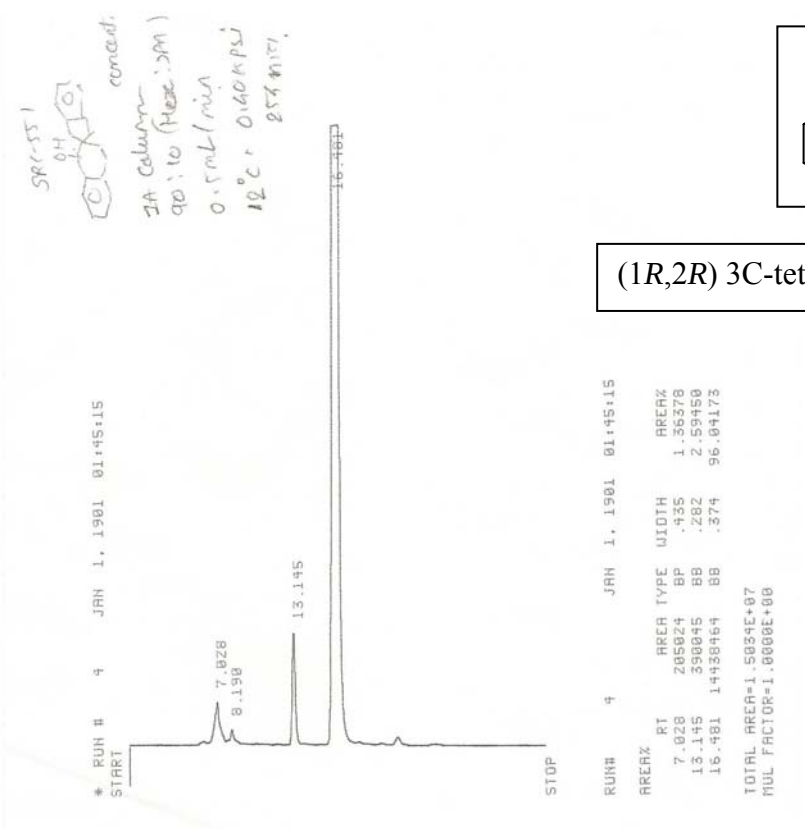
^{1}H-NMR of (*R*)-1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol 18a.

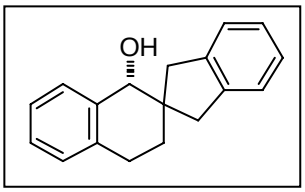


^{13}C-NMR of (*R*)-1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol 18a.



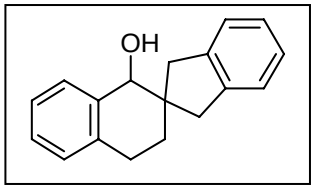
HPLC of (*R*)-1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol 18a.

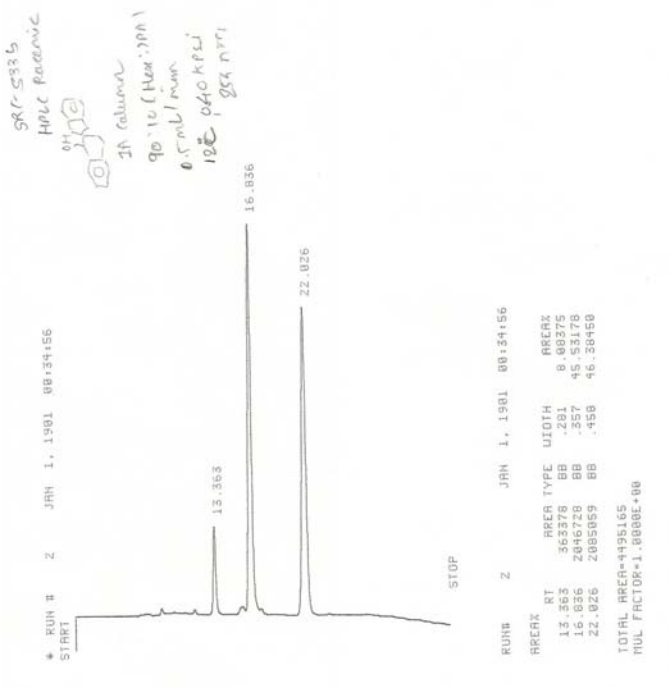




(1*R*,2*R*) 3C-teth-Ru complex reduction product

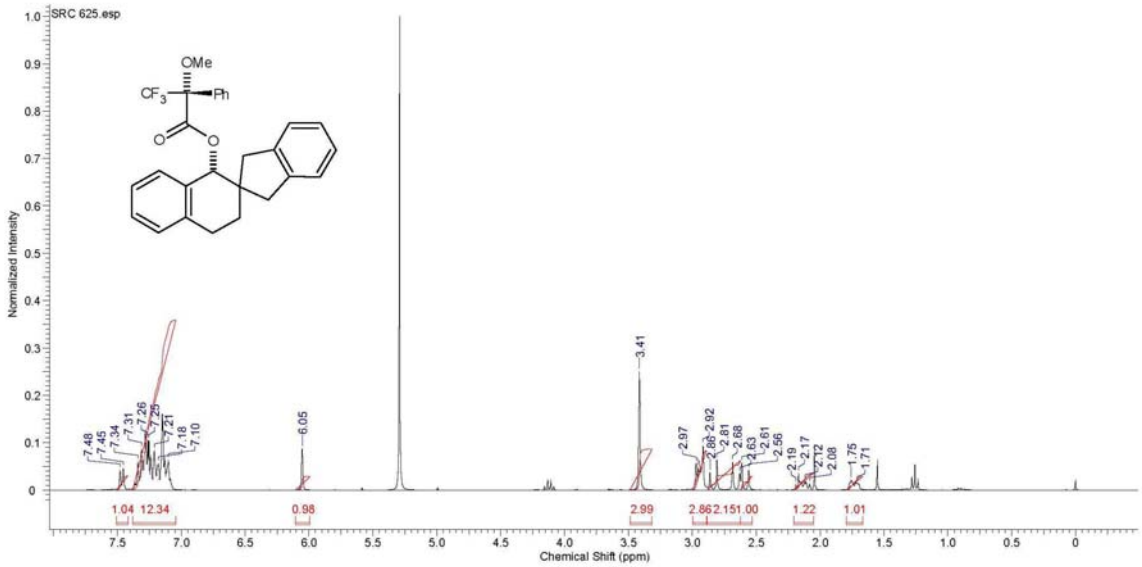
HPLC of racemic 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol.



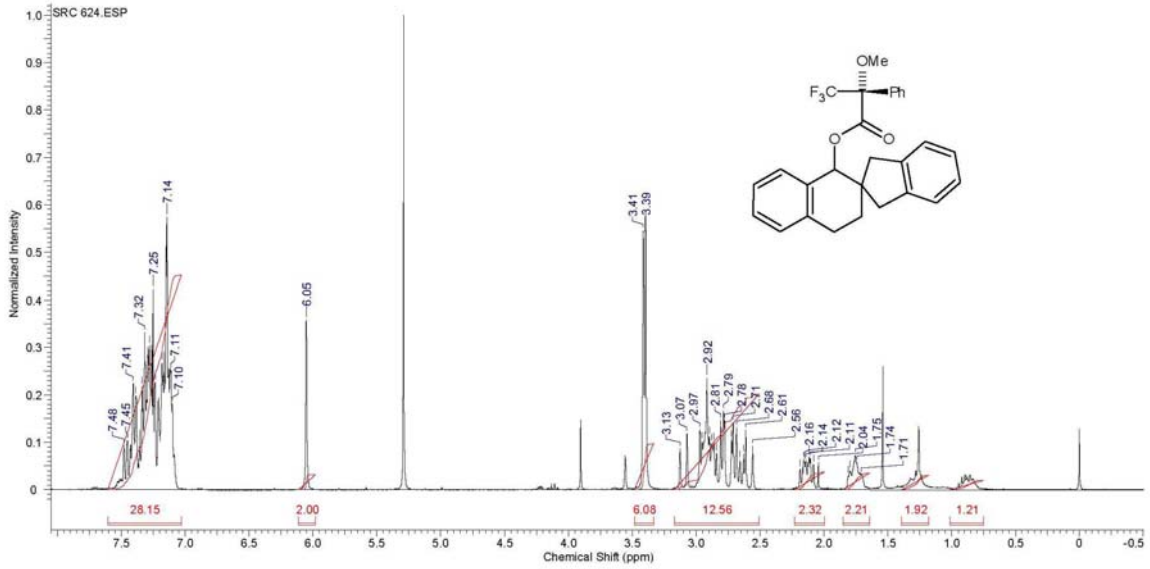


Racemic

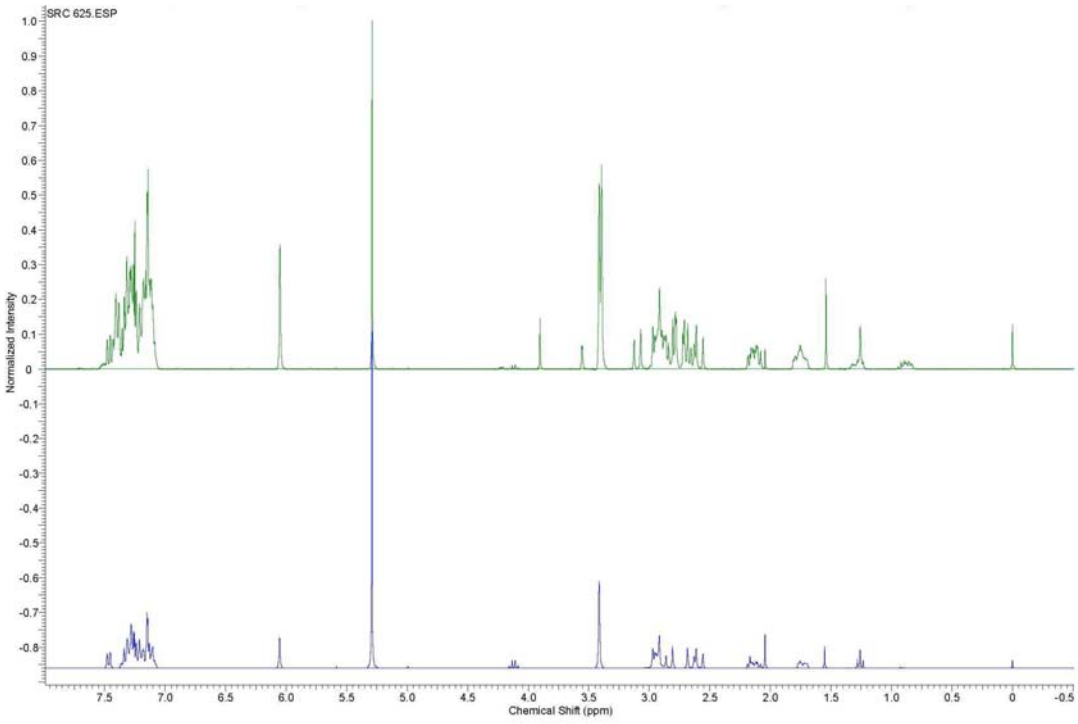
^{1}H-NMR of Mosher's ester of (*R*) 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol 18a.



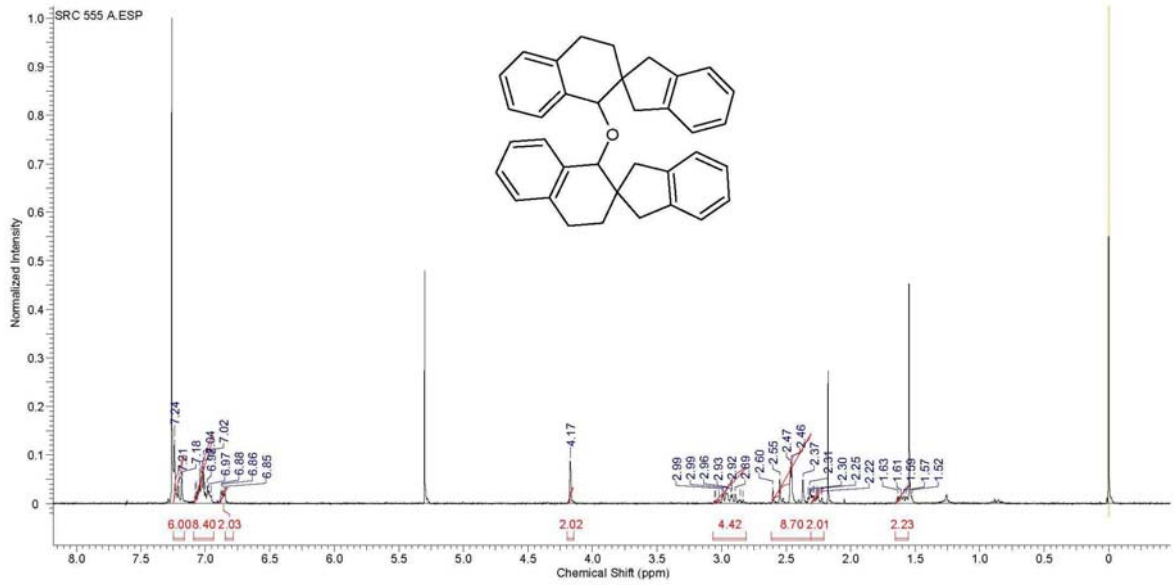
^{1}H-NMR of Mosher's ester of 1,3,3',4'-tetrahydro-spiro[2H-indene-2,2'-[2H]-naphthalene]-1'-ol.



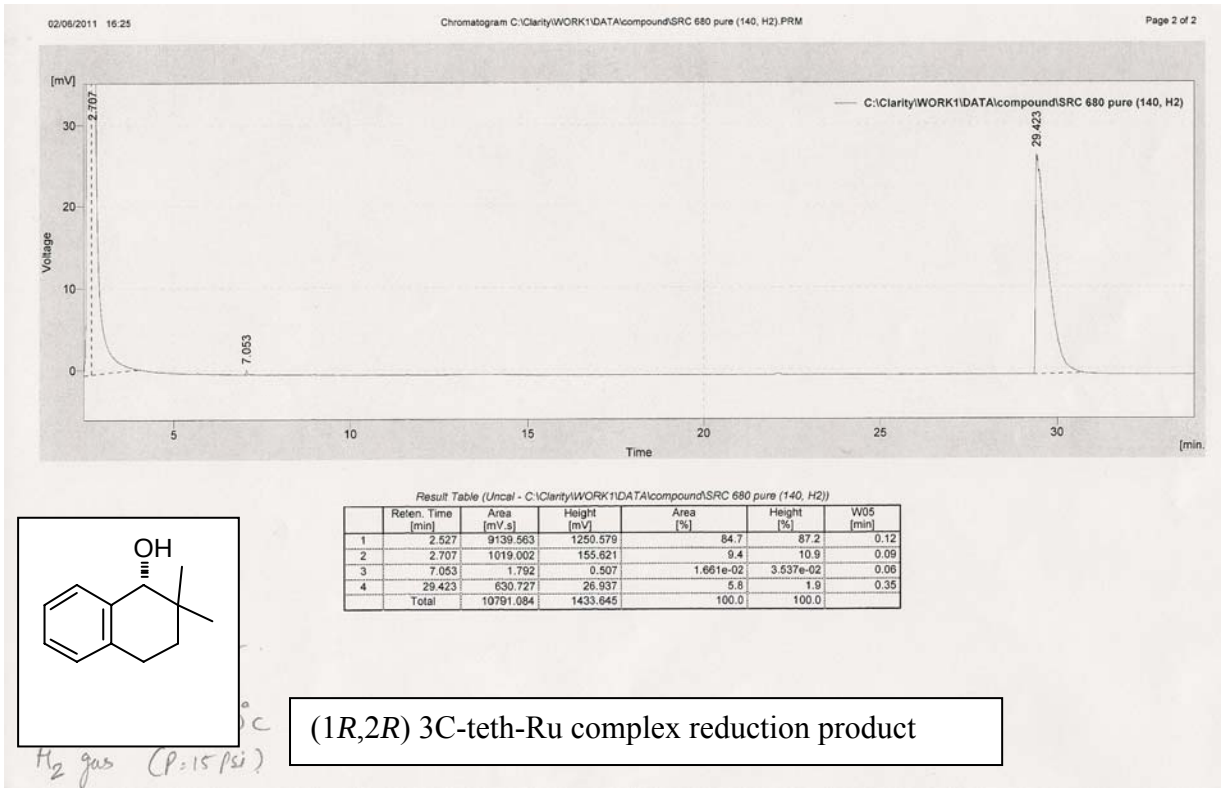
^{1}H-NMR Overlay of Asymmetric and racemic Mosher ester products.



^{1}H-NMR of ether linked product (SRC 555).



GC of (*R*)-2,2-dimethyl-1,2,3,4-tetrahydronaphthalen-1-ol 18b.

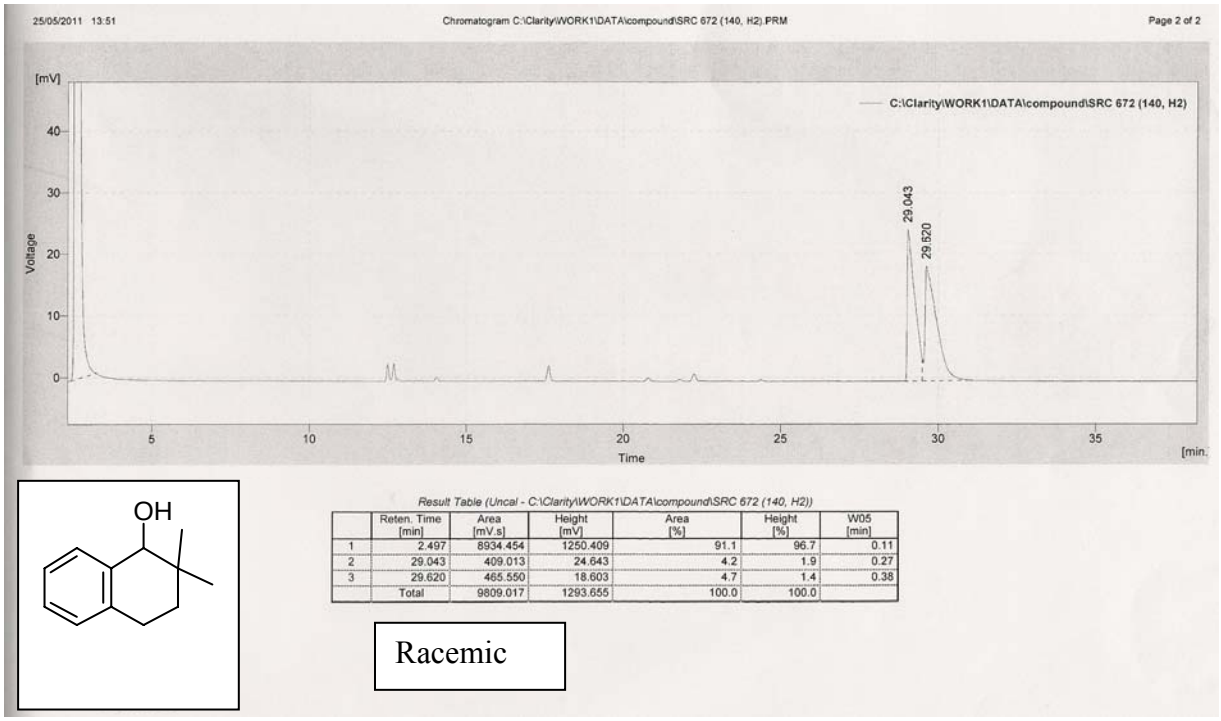


Result Table (Uncal - C:\Clarity\WORK1\DATA\compound\SRC 680 pure (140, H2))

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.527	9139.563	1250.579	84.7	87.2	0.12
2	2.707	1019.002	155.621	9.4	10.9	0.09
3	7.053	1.792	0.507	1.661e-02	3.537e-02	0.06
4	29.423	630.727	26.937	5.8	1.9	0.35
	Total	10791.084	1433.645	100.0	100.0	

(1*R*,2*R*) 3C-teth-Ru complex reduction product

GC of racemic 2,2-dimethyl-1,2,3,4-tetrahydronaphthalen-1-ol.



Result Table (Uncal - C:\Clarity\WORK1\DATA\compound\SRC 672 (140, H2))

	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.497	8934.454	1250.409	91.1	96.7	0.11
2	29.043	409.013	24.643	4.2	1.9	0.27
3	29.620	465.550	18.603	4.7	1.4	0.38
	Total	9809.017	1293.655	100.0	100.0	

Racemic