Supporting Information

Enantioselective "Clip-Cycle" Synthesis of Di-, Tri- and Spiro- Substituted Tetrahydropyrans.

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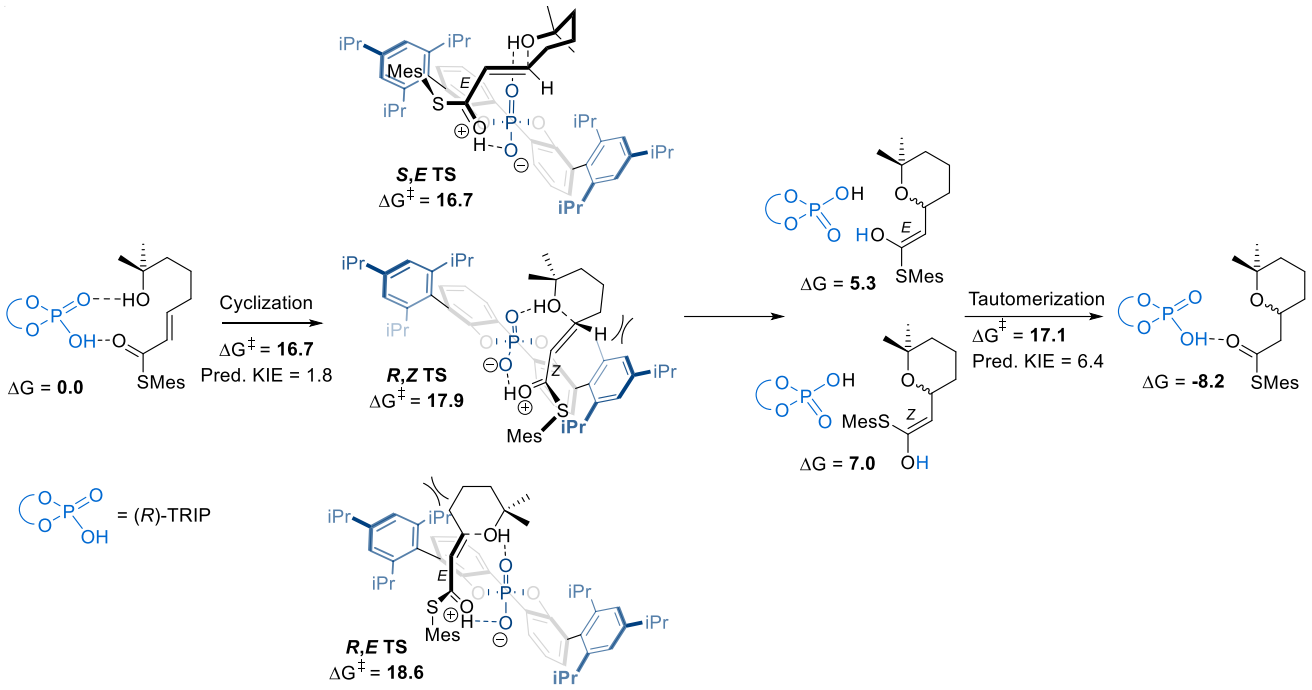
Contents:

Computational methods

All conformational searches were performed using MacroModel (Version 9.9) in the gas phase utilizing the MMFF force field[1] and a mixture of Low Mode following and Monte Carlo search algorithms.[2] Quantum mechanical calculations were carried out using Gaussian16.[3] All DFT calculations were performed using the implicit SMD solvent model.[4] The molecular geometries were optimized at the DFT level of theory using the B3LYP functional[5] with the 6-31G** basis set[6]. Single-point energies were separately calculated using M06-2X functional[7] and def2-TZVP basis set[8]. Frequency calculations were performed on all structures and confirmed to contain no imaginary frequencies or just one imaginary frequency for ground states and transition states, respectively. The free energies were corrected using quasi-harmonic approximation, corrections were done using GoodVibes script.[9] Full set of DFT output files with optimized structures, frequencies and high-level single-point energies can be found at DOI: http://doi.org/10.17639/nott.7156

Computational results



Scheme S1. Cyclization pathways investigated computationally

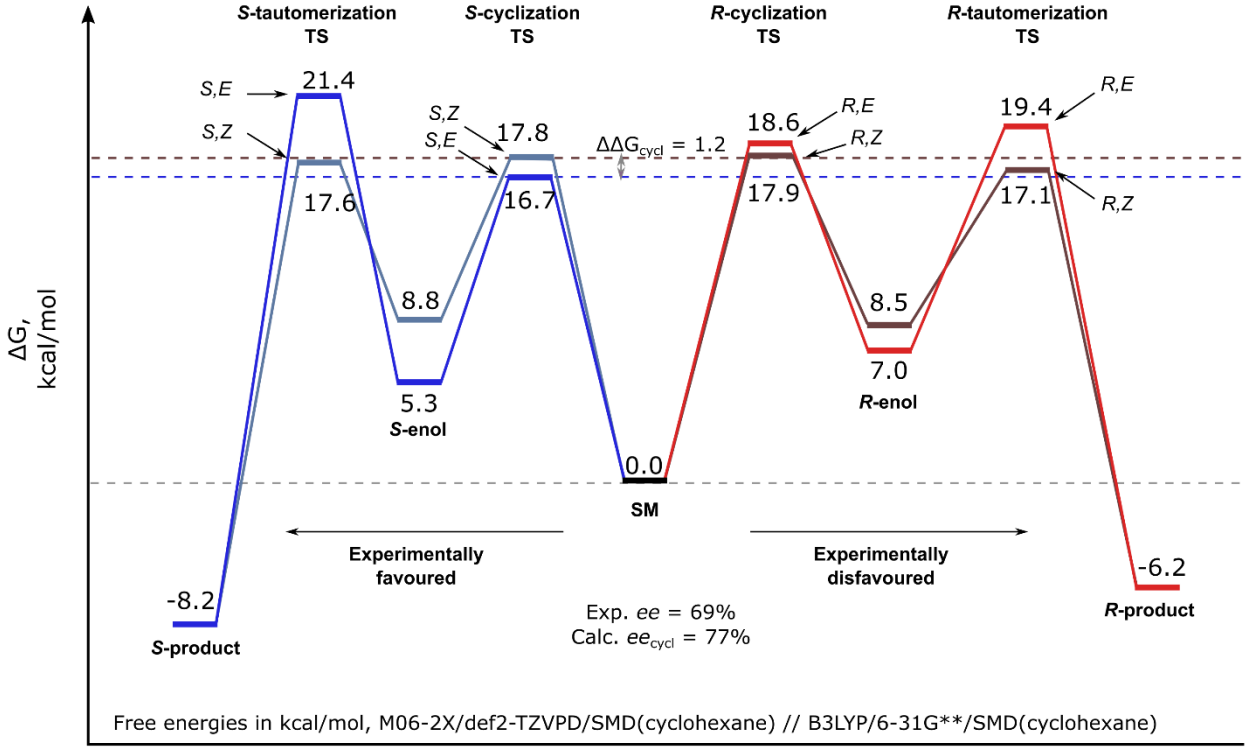


Figure S1. Energy diagram showing the energies of starting complex, cyclization TSs, enol intermediates, tautomerization and product/CPA complexes.

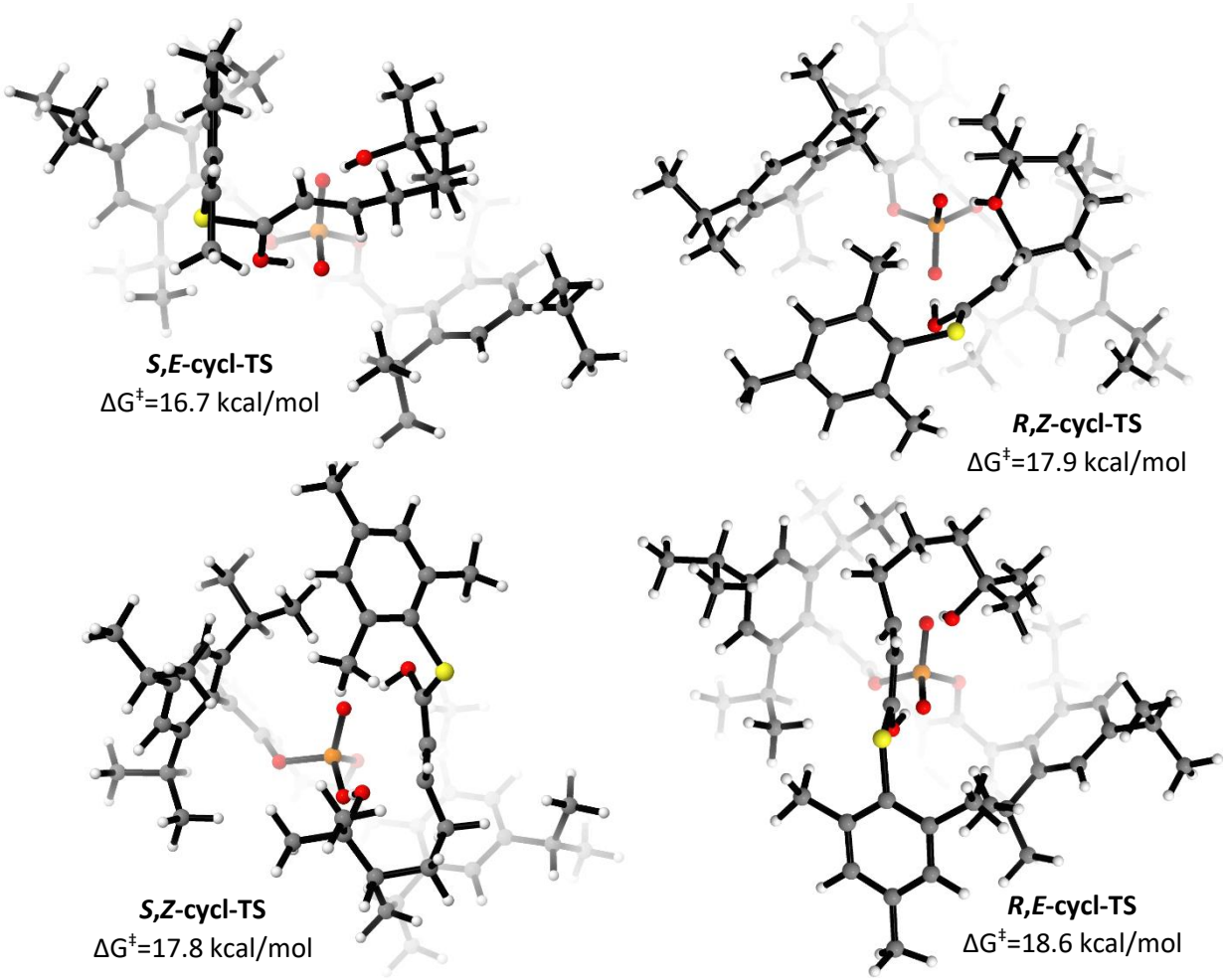


Figure S2. Lowest energy cyclization transition states leading to each of the four possible enol intermediates. Free energies in kcal/mol, calculated with M06-2X/def2-TZVP/SMD(cyclohexane) // B3LYP/6-31G/SMD(cyclohexane).**

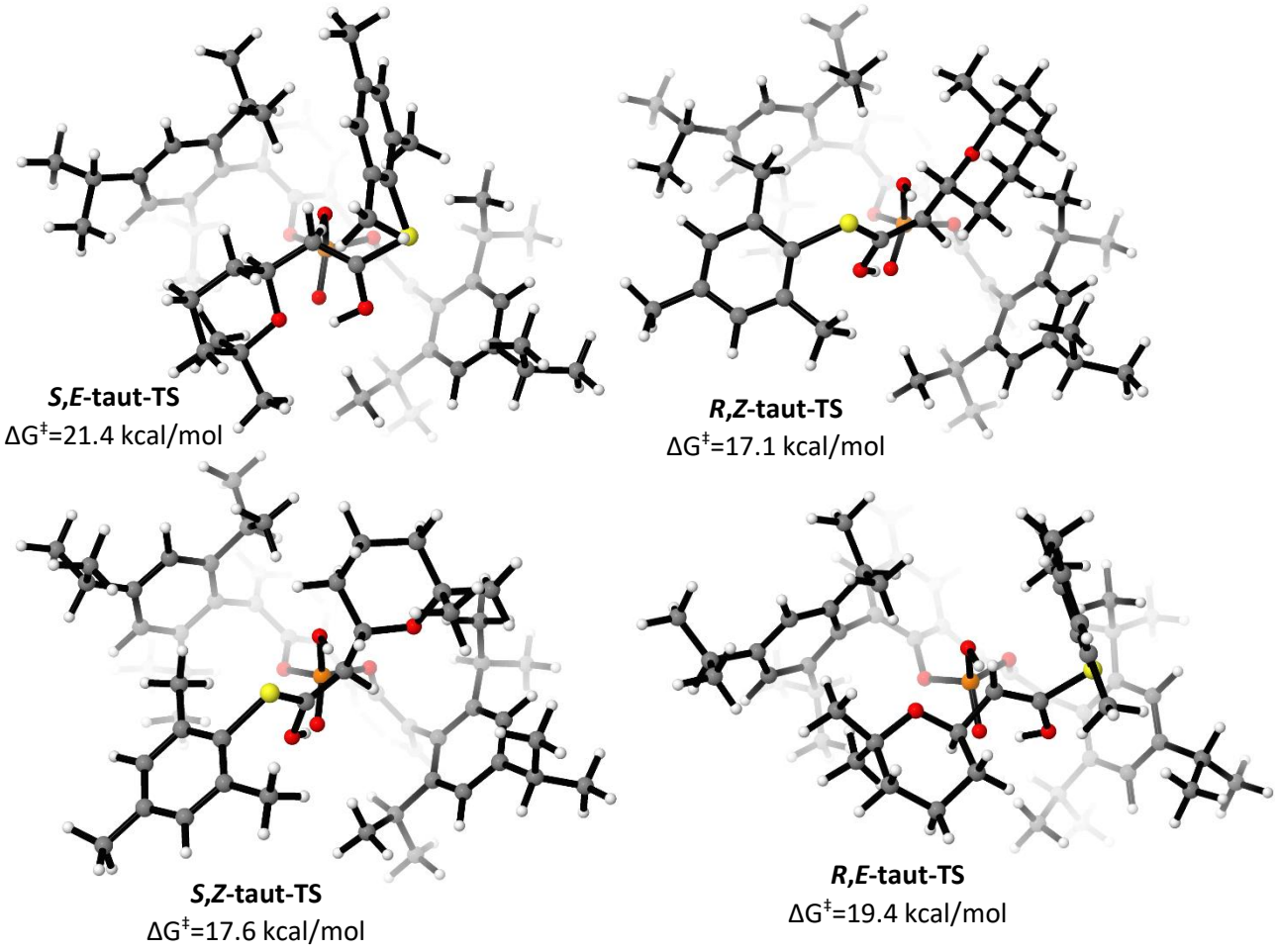


Figure S3. Lowest energy tautomerization transition states for each of the four possible enol intermediates. Free energies in kcal/mol, calculated with M06-2X/def2-TZVP/SMD(cyclohexane) // B3LYP/6-31G/SMD(cyclohexane).**

Computational references

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(3) Gaussian 16, Revision A.01, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Petersson, G. A.; Nakatsuji, H.; Li, X.; Caricato, M.; Marenich, A. V.; Bloino, J.; Janesko, B. G.; Gomperts, R.; Mennucci, B.; Hratchian, H. P.; Ortiz, J. V.; Izmaylov, A. F.; Sonnenberg, J. L.; Williams-Young, D.; Ding, F.; Lipparini, F.; Egidi, F.; Goings, J.; Peng, B.; Petrone, A.; Henderson, T.; Ranasinghe, D.; Zakrzewski, V. G.; Gao, J.; Rega, N.; Zheng, G.; Liang, W.; Hada, M.; Ehara,

M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Throssell, K.; Montgomery, J. A., Jr.; Peralta, J. E.; Ogliaro, F.; Bearpark, M. J.; Heyd, J. J.; Brothers, E. N.; Kudin, K. N.; Staroverov, V. N.; Keith, T. A.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A. P.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Millam, J. M.; Klene, M.; Adamo, C.; Cammi, R.; Ochterski, J. W.; Martin, R. L.; Morokuma, K.; Farkas, O.; Foresman, J. B.; Fox, D. J. Gaussian, Inc., Wallingford CT, 2016.

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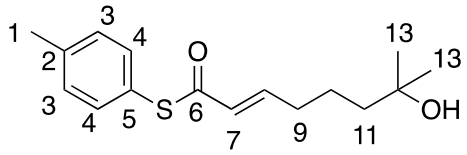
General Experimental

Unless otherwise noted all compounds were bought from commercial suppliers and used without further purification. Where a solvent is described as “dry” it was purified by PureSolv alumina columns from Innovative Technologies. Melting points were determined using a Stuart SMP3 apparatus. Infra-red spectra were acquired on a ThermoNicolet Avatar 370 FT-IR spectrometer. Nuclear magnetic resonance spectra were recorded on a Jeol ECS-400, a Jeol 500 Avance III HD 500 or a Jeol AV500 at ambient temperature. Coupling constants (*J*) are quoted in Hertz. Mass spectrometry was performed by the University of York mass spectrometry service using electron spray ionisation (ESI) technique. Thin layer chromatography was performed on glass-backed plates coated with Merck Silica gel 60 F_{254}. The plates were developed using ultraviolet light, acidic aqueous ceric ammonium molybdate or basic aqueous potassium permanganate. Liquid chromatography was performed using forced flow (flash column) with the solvent systems indicated. The stationary phase was silica gel 60 (220–240 mesh) supplied by Fluorochem or silica gel Merck TLC grade 11695 supplied by Sigma-Aldrich. NMR assignments were made using 2D NMR including COSY, HMBC, HSQC techniques which can be accessed at DOI: 10.15124/8ff9123f-ee1a-4ae2-a60e-7626c989e5a0. All numbering on the structures below is for the benefit of characterization and does not necessarily conform to IUPAC rules.

Experimental Details for the 'Clip-Cycle' Reactions

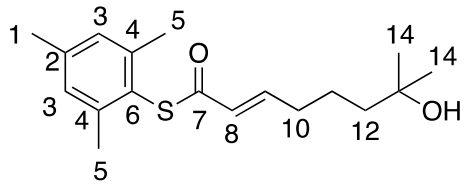
Synthesis of 'Clip-Cycle' Precursors

(*E*)-*S*-*p*-Tolyl 7-hydroxy-7-methyloct-2-enethioate (S1a)



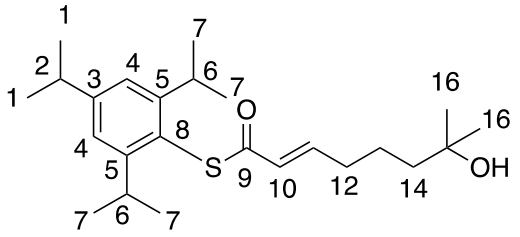
A solution of unsaturated alcohol **1a** (102 mg, 0.80 mmol, 1.0 eq) and thioester **2a** (427 mg, 2.40 mmol, 3.0 eq) were dissolved in dry Et_2O (5 mL) under a nitrogen atmosphere. To this, copper (I) iodide (15.3 mg, 0.08 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (50.2 mg, 0.08 mmol, 10 mol%) were added as solids in a single portion and the mixture was stirred at 40 ^{0}C for 24 hours. The mixture was then concentrated and purified by column chromatography on silica using 10-15 % ethyl acetate in n-hexane to yield **S1a** as a brown oil (193 mg, 87% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31 (2H, d, *J* = 8.0 Hz, H-3), 7.21 (2H, d, *J* = 8.0 Hz, H-4), 6.97 (1H, dt, *J* = 15.6 Hz, 7.0 Hz, H-8), 6.17 (1H, dt, *J* = 15.6 Hz, 1.4 Hz, H-7), 2.36 (3H, s, H-1), 2.27-2.21 (2H, m, H-9), 1.61-1.55 (2H, m, H-11), 1.53-1.46 (2H, m, H-10), 1.22 (6H, s, H-13) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 188.7 (C-6), 146.3 (C-7), 139.7 (C-2), 134.7 (C-4), 130.1 (C-3), 128.2 (C-8), 124.1 (C-5), 70.9 (C-12), 43.3 (C-11), 32.7 (C-9), 29.4 (C-13), 22.9 (C-10), 21.4 (C-1) ppm; IR (film NaCl): ν_{max} 3383, 2964, 2924, 2853, 1687, 1631, 1494, 1464, 1398, 1376, 1284, 1160, 1017, 972, 807 cm^{-1}; HRMS (ESI): m/z calcd for $C_{16}H_{22}NaO_2S^+$ $(M+Na)^+$ 301.1233; found 301.1230.

(*E*)-*S*-Mesityl 7-hydroxy-7-methyloct-2-enethioate (S1b)



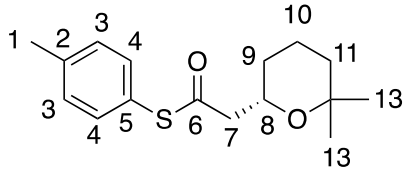
S1b was synthesised using the same procedure as **S1a** with unsaturated alcohol **1a** (76.8 mg, 0.61 mmol, 1.0 eq), thioester **2b** (373 mg, 1.81 mmol, 3.02 eq), copper (I) iodide (11.5 mg, 0.06 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (37.6 mg, 0.06 mmol, 10 mol%) The mixture was purified by column chromatography on silica using 10% ethyl acetate in petroleum ether to yield **S1b** as a brown oil (158 mg, 86% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.00-6.92 (3H, m, H-3, H-9), 6.22 (1H, d, *J* = 15.6 Hz, H-8), 2.32 (6H, s, H-5), 2.31 (3H, s, H-1), 2.28-2.21 (2H, m, H-10), 1.60-1.47 (4H, m, H-11, H-12), 1.22 (6H, s, H-14) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 187.9 (C-7), 145.9 (C-9), 142.8 (C-4), 140.0 (C-2), 129.3 (C-3), 128.3 (C-8), 123.6 (C-6), 71.0 (C-13), 43.4 (C-12), 32.7 (C-10), 29.4 (C-14), 22.9 (C-11), 21.7 (C-5), 21.3 (C-1) ppm; IR (film NaCl): ν_{max} 3412, 2969, 2940, 1684, 1631, 1464, 1375, 1284, 1156,1040, 972, 907, 851, 799, 765, 715 cm^{-1}; HRMS (ESI): m/z calcd for $C_{18}H_{26}NaO_2S^+$ $(M+Na)^+$ 329.1546; found 329.1551.

(*E*)-S-(2,4,6-Triisopropylphenyl) 7-hydroxy-7-methyloct-2-enethioate (S1c)



S1c was synthesised using the same procedure as **S1a** with unsaturated alcohol **1a** (76.8 mg, 0.60 mmol, 1.0 eq), thioester **2c** (373 mg, 1.81 mmol, 3.0 eq), copper (I) iodide (4.2 mg, 0.02 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (13.7 mg, 0.02 mmol, 10 mol%) The mixture was purified by column chromatography on silica using 10% ethyl acetate in n-hexane to yield **S1c** as a brown oil (216 mg, 92% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 6.96 (1H, dt, *J* =17.5 Hz, 6.7 Hz, H-11), 6.23 (1H, d, *J* =17.5 Hz, H-10), 3.39 (2H, sept, *J* = 6.9 Hz, H-6), 2.90 (1H, sept, *J* = 6.9 Hz, H-2), 2.28-2.21 (2H, m, H-12), 1.95-1.55 (2H, m, H-14), 1.53-1.48 (2H, m, H-13), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.23 (6H, s, H-16), 1.17 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 189.0 (C-9), 152.7 (C-5), 151.1 (C-3), 145.7 (C-11), 128.2 (C-10), 122.1 (C-4), 121.6 (C-8), 71.0 (C-15), 43.5 (C-14), 34.5 (C-2), 32.8 (C-12), 32.0 (C-6), 29.4 (C-16), 24.5 (C-13), 24.0 (C-7), 22.9 (C-1) ppm; IR (ATR): ν_{max} 3412, 2969, 2940, 1684, 1631, 1464, 1375, 1284, 1156,1040, 972, 907, 851, 799, 765, 715 cm^{-1}; HRMS (ESI): m/z calcd for $C_{24}H_{38}NaO_2S^+$ $(M+Na)^+$ 413.2485; found 413.2488.

***S*-*p*-*T*olyl-2-(6,6-dimethyltetrahydro-*2H*-pyran-2-yl)ethanethioate (4a)**



Racemic-CSA

To a solution of **S1a** (28.9 mg, 0.10 mmol) in DCE (5 mL), a portion of CSA (73.0 mg, 0.31 mmol, 3 eq) was added and heated under reflux at 80 ^{0}C for 24 hours. The reaction was quenched with Et_3N (1.0 mL), washed with $NaHCO_3$ solution (2 x 5 mL) and brine solution (2 x 5 mL), dried over anhydrous Na_2SO_4 and filtered. The filtrate was concentrated *in vacuo* to give a crude yellow oil. The oil was purified by column chromatography on silica using 5% Et_2O in hexane to yield **4a** as a yellow oil (13.0 mg, 45 % yield).

Asymmetric-(*R*)-TRIP, rt, PhMe

The cyclization precursor **S1a** (23.3 mg, 0.08 mmol) was dissolved in PhMe (4.0 mL). To this, (*R*)-TRIP **3a** (12.7 mg, 0.02 mmol, 20 mol %) was added and stirred at rt under a nitrogen atmosphere for 24 hours. The reaction mixture was quenched by (0.2 ml) of Et_3N then concentrated in *vacuo* and purified by column chromatography on silica using 5% Et_2O in hexane to yield the product as a yellow oil (1.2 mg, 5% yield).

Asymmetric-(*R*)-TRIP, 50 °C, PhMe

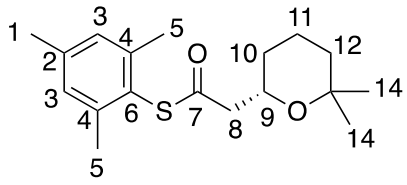
The cyclization precursor **S1a** (16.8 mg, 0.06 mmol) was dissolved in PhMe (3.0 mL). To this, (*R*)-TRIP **3a** (9.2 mg, 0.01 mmol, 20 mol %) was added and stirred at 50 °C under a nitrogen atmosphere for 24 hours. The reaction mixture was quenched by (0.2 ml) of Et_3N then concentrated in *vacuo* and purified by column chromatography on silica using 5% Et_2O in hexane to yield the product as a yellow oil (4.8 mg, 29% yield, 13% ee).

Asymmetric-(*R*)-TRIP, 50 °C, cyclohexane

The cyclization precursor **S1a** (18.5 mg, 0.07 mmol) was dissolved in cyclohexane (3.3 mL). To this, (*R*)-TRIP **3a** (10.1 mg, 0.01 mmol, 20 mol %) was added and stirred at 50 °C under a nitrogen atmosphere for 24 hours. The reaction mixture was quenched by (0.2 ml) of Et_3N then concentrated in *vacuo* and purified by column chromatography on silica using 5% Et_2O in hexane to yield the product as a yellow oil (10.4 mg, 56% yield, 18% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.27 (d, 2H, *J* = 8.1 Hz, H-3), 7.20 (2H, d, *J* = 8.1 Hz, H-4), 4.04 (1H, dddd, *J* =11.5 Hz, 6.6 Hz, 4.1 Hz, 2.7 Hz, H-8), 2.82 (1H, dd, *J* = 14.8 Hz, 6.6 Hz, H-7), 2.64 (1H, dd, *J* = 14.8 Hz, 4.1 Hz, H-7), 2.36 (3H, s, H-1), 1.67-1.61 (3H, m, H-9, H-10), 1.45-1.32 (2H, m, H-11), 1.19 (3H, s, H-13), 1.18 (3H, s, H-13), 1.13 (1H, m, H-10) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.1 (C-6), 139.7 (C-2), 134.5 (C-4), 130.1 (C-3), 124.5 (C-5), 72.4 (C-12), 67.6 (C-8), 50.8 (C-7), 35.9 (C-11), 31.8 (C-13), 31.3 (C-9), 21.9 (C-1), 21.4 (C-13'), 19.9 (C-10) ppm; IR (film NaCl): ν_{max} 2973, 2928, 1707, 1494, 1460, 1379, 1360, 1281, 1213, 1137, 1065, 1043, 974, 900, 867, 806, 746 cm^{-1}; HRMS (ESI): m/z calcd for $C_{16}H_{22}NaO_2S^+$ $(M+Na)^+$ 301.1233; found 301.1227; $[\alpha]_D^{20}$ + 6.1° (c 0.52, $CHCl_3$), for 18% ee.

S-Mesityl 2-(6,6-dimethyltetrahydro-2H-pyran-2-yl)ethanethioate (4b)



Racemic-CSA

4b was synthesised using the same procedure as **4a** with alcohol-thioester **S1b** (18.5 mg, 0.06 mmol) and rac-CSA (41.7 mg, 0.18 mmol, 3 eq.) The crude was purified by column chromatography on silica using 5% Et_2O in hexane to yield **4a** as a yellow oil (14.4 mg, 78 % yield).

Asymmetric-(*R*)-TRIP, 50 °C, PhMe

4b was synthesised using the same procedure as **4a** with alcohol-thioester **S1b** (20.0 mg, 0.07 mmol) and (*R*)-TRIP **3a** (9.91 mg, 0.01 mmol, 20 mol %). The crude was purified by column chromatography on silica using 5% Et_2O in hexane to yield **4b** as a yellow oil (13.4 mg, 66% yield, 60% ee).

Asymmetric-(*R*)-TRIP, 50 °C, cyclohexane

4b was synthesised using the same procedure as **4a** with alcohol-thioester **S1b** (18.7 mg, 0.07 mmol) and (*R*)-TRIP **3a** (9.32 mg, 0.01 mmol, 20 mol %). **4b** yielded as a yellow oil (16.8 mg, 90% yield, 69% ee).

Asymmetric-(*R*)-TRIP, 75 °C, cyclohexane

4b was synthesised using the same procedure as **4a** with alcohol-thioester **S1b** (19.8 mg, 0.07 mmol) and (*R*)-TRIP **3a** (9.81 mg, 0.01 mmol, 20 mol %). **4b** yielded as a yellow oil (17.9 mg, 90% yield, 66% ee).

Asymmetric-(*R*)-TIPSY, 50 °C, cyclohexane

4b was synthesised using the same procedure as **4a** with alcohol-thioester **S1b** (14.6 mg, 0.05 mmol) and (*R*)-TIPSY **3b** (8.6 mg, 0.01 mmol, 20 mol %). **4b** yielded as a yellow oil (3.1 mg, 22% yield, 40% ee).

Asymmetric-(*R*)-anthr, 50 °C, cyclohexane

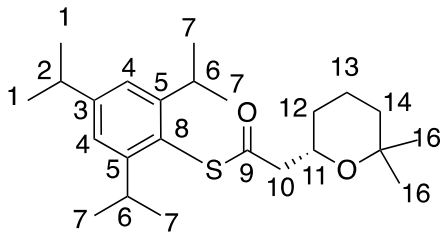
4b was synthesised using the same procedure as **4a** with alcohol-thioester **S1b** (12.5 mg, 0.04 mmol) and (*R*)-anthr **3c** (5.8 mg, 0.01 mmol, 20 mol %). **4b** yielded as a yellow oil (11.9 mg, 95% yield, 21% ee).

Asymmetric-(*R*)-phenanth, 50 °C, cyclohexane

4b was synthesised using the same procedure as **4a** with alcohol-thioester **S1b** (12.5 mg, 0.05 mmol) and (*R*)-phenanth **3d** (5.8 mg, 0.01 mmol, 20 mol %). **4b** yielded as a yellow oil (0.4 mg, 3% yield, 2% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 6.96 (2H, s , H-3), 4.05 (1H, dddd, *J* =11.4 Hz, 7.8 Hz, 5.0 Hz, 2.7 Hz, H-9), 2.78 (1H, dd, *J* = 14.2 Hz, 7.8 Hz, H-8), 2.60 (1H, dd, *J* = 14.2 Hz, 5.0 Hz, H-8), 2.30 (6H, s, H-5), 2.27 (3H, s, H-1), 1.66-1.63 (3H, m, H-10, H-11), 1.55-1.42 (3H, m, H-11, H-12), 1.18 (6H, s, H-14) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 195.4 (C-7), 142.6 (C-2), 139.9 (C-4), 129.2 (C-3), 124.1 (C-6), 72.4 (C-13), 68.2 (C-9), 50.8 (C-8), 35.9 (C-12), 31.8 (C-14), 31.3 (C-14'), 29.8 (C-10), 21.7 (C-5), 21.3 (C-1), 20.0 (C-11) ppm; IR (film NaCl): ν_{max} 2972, 2926, 1702, 1461, 1377, 1364, 1278, 1138, 1063, 1043, 978, 901, 849, 797, 737, 717 cm^{-1}. HRMS (ESI): m/z calcd for $C_{18}H_{26}NaO_2S^+$ $(M+Na)^+$ 329.1546; found 329.1548; $[\alpha]_D^{20}$ + 32.4° (c 0.84, $CHCl_3$), for 66% ee.

(*S*)-S-(2,4,6-Triisopropylphenyl) 2-(6,6-dimethyltetrahydro-2H-pyran-2-yl)ethanethioate (4c)



Racemic-CSA

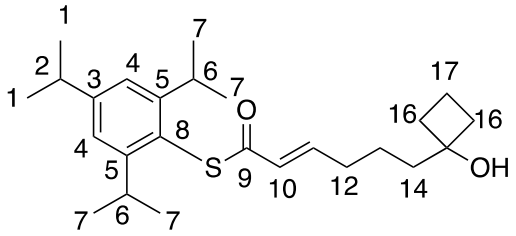
4c was synthesised using the same procedure as **4a** with alcohol-thioester **S1c** (20.3 mg, 0.05 mmol) and rac-CSA (36.3 mg, 0.16 mmol, 3 eq). The crude was purified by column chromatography on silica using 5% Et_2O in hexane to yield **4c** as a yellow oil (18.5 mg, 91% yield).

Asymmetric-(*R*)-TRIP

4c was synthesised using the same procedure as **4a** with alcohol-thioester **S1c** (25.3 mg, 0.07 mmol) and (*R*)-TRIP (9.700 mg, 0.013 mmol, 20 mol %). **4c** yielded as a yellow oil (21.3 mg, 84% yield, 98% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 4.08 (1H, dddd, *J* =11.4 Hz, 8.4 Hz, 4.4 Hz, 2.7 Hz, H-11), 3.42 (2H, sept, *J* = 6.9 Hz, H-6), 2.89 (1H, sept, *J* = 6.9 Hz, H-2), 2.81 (1H, dd, *J* = 14.5 Hz, 8.4 Hz, H-10), 2.63 (1H, dd, *J* = 14.5 Hz, 4.4 Hz, H-10), 1.82-1.63 (2H, m, H-12), 1.61-1.55 (2H, m, H-14), 1.47-1.37 (2H, m, H-13), 1.25 (12H, d, *J* = 6.9 Hz, H-7), 1.19 (3H, s, H-16), 1.16 (6H, d, *J* = 6.9 Hz, H-1), 0.87 (3H, s, H-16') ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.5 (C-9), 152.4 (C-3), 151.0 (C-5), 122.0 (C-8), 122.0 (C-4), 72.2 (C-15), 68.2 (C-11), 50.7 (C-10), 35.8 (C-14), 34.4(C-2), 31.8 (C-16), 31.2 (C-16'), 29.7 (C-7), 24.0 (C-1), 21.7 (C-12), 20.0 (C-13) ppm; IR (ATR): ν_{max} 2924, 2857, 1702, 1459, 1376, 1069, 993, 901, 849, 797, 737, 717 cm^{-1}; HRMS (ESI): m/z calcd for $C_{24}H_{39}O_2S^+$ $(M+H)^+$ 391.2665; found 391.2662; $[\alpha]_D^{20}$ + 65.8° (c 0.96, $CHCl_3$).

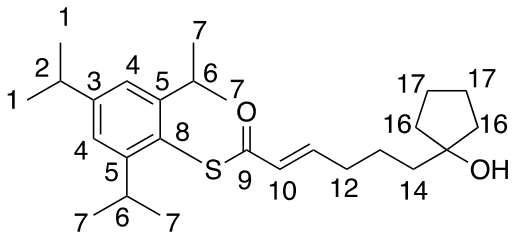
(*E*)-*S*-(2,4,6-Triisopropylphenyl) 6-(1-hydroxycyclobutyl)hex-2-enethioate (S2a)



S2a was synthesised using the same procedure as **S1a** with unsaturated alcohol **1b** (69.2 mg, 0.49 mmol, 1.0 eq), thioester **2c** (305 mg, 1.48 mmol, 3.0 eq), copper (I) iodide (9.00 mg, 0.04 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (29.0 mg, 0.04 mmol, 10 mol%). The mixture was purified by column chromatography on silica using 10% ethyl acetate in n-hexane to yield the product **S2a** as a brown oil (168 mg, 85% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 6.98 (1H, dt, *J* =17.4 Hz, 6.8 Hz, H-11), 6.24 (1H,

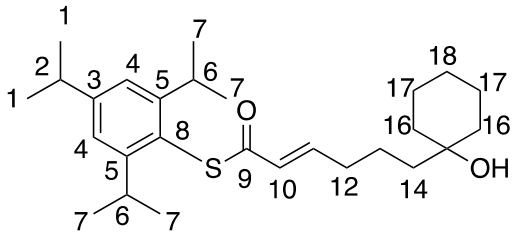
d, *J* =17.4 Hz, H-10), 3.38 (2H, sept, *J* = 6.8 Hz, H-6), 2.88 (1H, sept, *J* = 6.8 Hz, H-2), 2.28-2.23 (2H, m, H-12), 1.81-1.78 (2H, m, H-14), 2.00-1.97 (2H, m, H-16), 1.63-1.59 (3H, m, H-13, H-16), 1.56-1.53 (3H, m, H-13, H-17), 1.26 (6H, d, *J* = 6.8 Hz, H-1) 1.17 (12H, d, *J* = 6.8 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 189.0 (C-9), 152.7 (C-5), 151.1 (C-3), 145.8 (C-11), 128.2 (C-10), 122.1 (C-4), 121.6 (C-8), 75.3 (C-15), 39.0 (C-14), 36.3 (C-16), 34.5 (C-2), 32.6 (C-12), 32.0 (C-6), 24.0 (C-7), 23.6 (C-1), 22.1 (C-13), 12.2 (C-17) ppm; IR (ATR): ν_{max} 3412, 2969, 2940, 1684, 1631, 1464, 1375, 1284, 1156,1040, 972, 907, 851, 799, 765, 715 cm^{-1}; HRMS (ESI): m/z calcd for $C_{25}H_{38}NaO_2S^+$ $(M+Na)^+$ 425.2485; found 425.2491.

(*E*)-*S*-(2,4,6-Triisopropylphenyl) 6-(1-hydroxycyclopentyl)hex-2-enethioate (S2b)



S2b was synthesised using the same procedure as **S1a** with unsaturated alcohol **1c** (71.2 mg, 0.46 mmol, 1.0 eq), thioester **2c** (401 mg, 1.46 mmol, 3.0 eq), copper (I) iodide (6.20 mg, 0.04 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (25.0 mg, 0.04 mmol, 10 mol%). The mixture was purified by column chromatography on silica using 10% ethyl acetate in n-hexane to yield the product **S2b** as a brown oil (155 mg, 81% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 6.96 (1H, dt, *J* =17.5 Hz, 6.8 Hz, H-11), 6.24 (1H, d, *J* =17.5 Hz, H-10), 3.38 (2H, sept, *J* = 6.9 Hz, H-6), 2.87 (1H, sept, *J* = 6.9 Hz, H-2), 2.28-2.23 (2H, m, H-12), 1.81-1.78 (2H, m, H-14), 1.69-1.64 (2H, m, H-16), 1.63-1.60 (4H, m, H-16, H-17), 1.59-1.49 (4H, m, H-13, H-17), 1.25 (6H, d, *J* = 6.9 Hz, H-7) 1.15 (12H, d, *J* = 6.9 Hz, H-1) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 189.0 (C-9), 152.7 (C-5), 151.1 (C-3), 145.8 (C-11), 128.1 (C-10), 122.1 (C-4), 121.6 (C-8), 82.5 (C-15), 41.1 (C-14), 39.8 (C-16), 34.5 (C-2), 32.8 (C-12), 32.1 (C-6), 24.5 (C-1), 24.0 (C-7), 23.8 (C-17), 23.3 (C-13) ppm; IR (ATR): ν_{max} 3412, 2969, 2940, 1684, 1631, 1464, 1375, 1284, 1156,1040, 972, 907, 851, 799, 765, 715 cm^{-1}; HRMS (ESI): m/z calcd for $C_{26}H_{40}NaO_2S^+$ $(M+Na)^+$ 439.2641; found 439.2643.

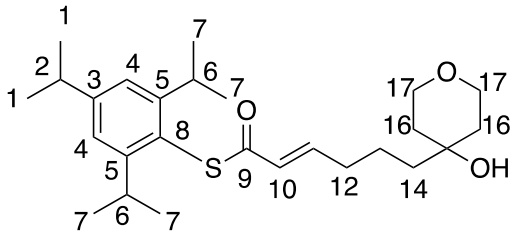
(*E*)-*S*-(2,4,6-Triisopropylphenyl) 6-(1-hydroxycyclohexyl)hex-2-enethioate (S2c)



S2c was synthesised using the same procedure as **S1a** with unsaturated alcohol **1d** (49.8 mg, 0.29 mmol, 1.0 eq), thioester **2c** (256 mg, 0.88 mmol, 3.0 eq), copper (I) iodide (6.00 mg, 0.03 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (14.4 mg, 0.03 mmol, 10 mol%). The mixture was purified by column

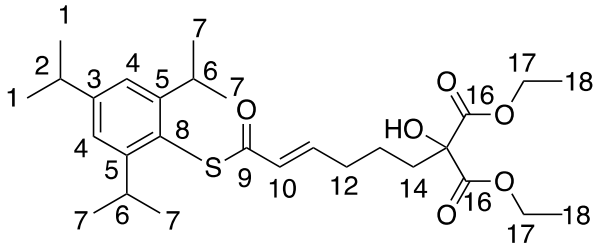
chromatography on silica using 10% ethyl acetate in n-hexane to yield the product **S2c** as a brown oil (107 mg, 86% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 6.97 (1H, dt, *J* =17.5 Hz, 6.8 Hz, H-11), 6.23 (1H, d, *J* =17.5 Hz, H-10), 3.38 (2H, sept, *J* = 6.9 Hz, H-6), 2.89 (1H, sept, *J* = 6.9 Hz, H-2), 2.27-2.16 (2H, m, H-12), 1.62-1.59 (2H, m, H-14), 1.57-1.52 (5H, m, H-13, H-16), 1.50-1.48 (5H, m, H-13, H-17), 1.43-1.41 (2H, m, H-17), 1.25 (6H, d, *J* = 6.9 Hz, H-7) 1.17 (12H, d, *J* = 6.9 Hz, H-1) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 189.0 (C-9), 152.7 (C-5), 151.1 (C-3), 145.9 (C-11), 128.1 (C-10), 122.1 (C-4), 121.6 (C-8), 71.4 (C-15), 37.5 (C-16), 34.5 (C-14), 32.9 (C-2), 32.0 (C-6), 25.9 (C-12), 24.5 (C-18), 24.0 (C-7), 23.6 (C-13), 22.3 (C-1), 21.5 (C-17) ppm; IR (ATR): ν_{max} 3412, 2969, 2940, 1684, 1631, 1464, 1375, 1284, 1156,1040, 972, 907, 851, 799, 765, 715 cm^{-1}; HRMS (ESI): calcd for $C_{27}H_{42}NaO_2S^+$ $(M+Na)^+$ 453.2798; found 453.2807.

(*E*)-*S*-(2,4,6-Triisopropylphenyl) 6-(4-hydroxytetrahydro-2*H*-pyran-4-yl)hex-2-enethioate (S2d)



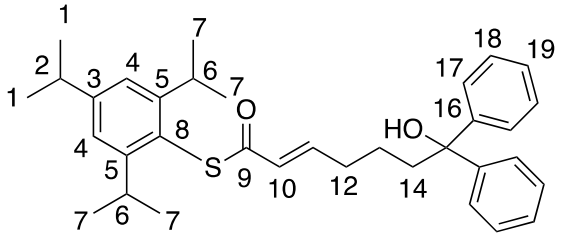
S2d was synthesised using the same procedure as **S1a** with unsaturated alcohol **1e** (76.0 mg, 0.40 mmol, 1.0 eq), thioester **2c** (373 mg, 1.19 mmol, 3.0 eq), copper (I) iodide (25 mg, 0.04 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (7.52 mg, 0.04 mmol, 10 mol%). The mixture was purified by column chromatography on silica using 60% ethyl acetate in n-hexane to yield the product **S2d** as a brown oil (142 mg, 82% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 6.95 (1H, dt, *J* =17.5 Hz, 6.7 Hz, H-11), 6.24 (1H, d, *J* =17.5 Hz, H-10), 3.76-3.73 (4H, m, H-17), 3.38 (2H, sept, *J* = 6.9 Hz, H-6), 2.88 (1H, sept, *J* = 6.9 Hz, H-2), 2.28-2.22 (2H, m, H-12), 1.73-1.60 (2H, m, H-14), 1.59-1.50 (2H, m, H-16), 1.50-1.44 (4H, m, H-13, H-16), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.17 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 188.9 (C-9), 152.6 (C-5), 151.2 (C-3), 145.4 (C-11), 128.3 (C-10), 122.1 (C-4), 121.5 (C-8), 69.0 (C-15), 63.9 (C-16), 43.0 (C-14), 37.7 (C-17), 34.5 (C-2), 32.6 (C-12), 32.1 (C-6), 29.8 (C-13), 24.0 (C-7), 21.1 (C-1) ppm; IR (ATR): ν_{max} 3421, 2959, 2928, 2866, 1698, 1640, 1598, 1459, 1362, 1300, 1238, 1104, 1022, 908, 877, 839, 757, 537 cm^{-1}; HRMS (ESI): m/z calcd for $C_{26}H_{40}NaO_3S^+$ $(M+Na)^+$ 455.2590; found 455.2595.

(*E*)-Diethyl 2-hydroxy-2-(6-oxo-6-((2,4,6-triisopropylphenyl)thio)hex-4-en-1-yl)malonate (S2e)



S2e was synthesised using the same procedure as **S1a** with unsaturated alcohol **1f** (146 mg, 0.57 mmol, 1.0 eq), thioester **2c** (500 mg, 1.72 mmol, 3.0 eq), copper (I) iodide (39.1 mg, 0.06 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (10.4 mg, 0.06 mmol, 10 mol%). The mixture was purified by column chromatography on silica using 30% ethyl acetate in n-hexane to yield the product **S2e** as a brown oil (251 mg, 87% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 6.94 (1H, dt, *J* =17.5 Hz, 6.7 Hz, H-11), 6.23 (1H, d, *J* =17.5 Hz, H-10), 4.29-4.24 (4H, q, *J* = 7.1 Hz, H-17), 3.37 (2H, sept, *J* = 6.9 Hz, H-6), 2.89 (1H, sept, *J* = 6.8 Hz, H-2), 2.29-2.23 (2H, m, H-12), 2.09-2.05 (2H, m, H-14), 1.50-1.42 (2H, m, H-13), 1.28-1.27 (6H, t, *J* = 7.1 Hz H-18), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.17 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 188.8 (C-9), 170.5 (C-16), 152.7 (C-5), 151.1 (C-3), 144.9 (C-11), 128.4 (C-10), 122.1 (C-4), 121.5 (C-8), 78.8 (C-15), 62.7 (C-17), 62.1 (C-14), 34.4 (C-2), 34.1 (C-12), 32.0 (C-6), 24.5 (C-13), 24.0 (C-7), 21.8 (C-1), 14.1 (C-18) ppm; IR (ATR): ν_{max} 3484, 3077, 2932, 1739, 1641, 1445, 1369, 1225, 1132, 1024, 1006, 910, 861, 733, 634 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{42}NaO_6S^+$ $(M+Na)^+$ 529.2594; found 529.2593.

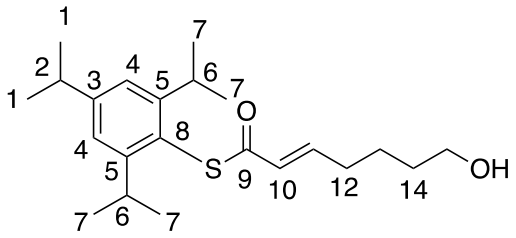
(*E*)-*S*-(2,4,6-Triisopropylphenyl) 7-hydroxy-7,7-diphenylhept-2-enethioate (S2f)



S2f was synthesised using the same procedure as **S1a** with unsaturated alcohol **1g** (174 mg, 0.69 mmol, 1.0 eq), thioester **2c** (600 mg, 2.67 mmol, 3.0 eq), copper (I) iodide (43.0 mg, 0.07 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (131 mg, 0.07 mmol, 10 mol%). The mixture was purified by column chromatography on silica using 20% ethyl acetate in n-hexane to yield the product **S2f** as a brown oil (312 mg, 88% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41-7.38 (4H, m, H-17), 7.33-7.30 (4H, m, H-18), 7.23-7.21 (2H, m, H-19), 7.07 (2H, s, H-4), 6.90 (1H, dt, *J* =17.5 Hz, 6.7 Hz, H-11), 6.17 (1H, d, *J* =17.5 Hz, H-10), 3.38 (2H, sept, *J* = 6.9 Hz, H-6), 2.88 (1H, sept, *J* = 6.9 Hz, H-2), 2.34-2.31 (2H, m, H-12), 2.30-2.21 (2H, m, H-14), 1.55-1.48 (2H, m, H-13), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.16 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 188.9 (C-9), 152.7 (C-5), 151.1 (C-3), 146.9 (C-16), 145.5 (C-11), 128.4 (C-18), 128.3 (C-10), 127.1 (C-19), 126.1

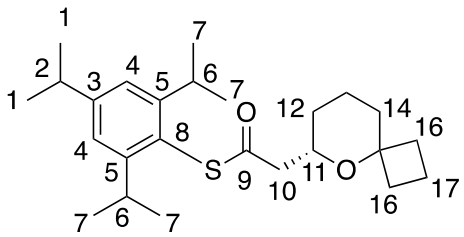
(C-17), 122.1 (C-4), 121.5 (C-8), 78.2 (C-15), 41.5 (C-14), 34.4 (C-2), 32.5 (C-12), 32.0 (C-6), 24.5 (C-1), 24.0 (C-7), 22.4 (C-13) ppm; IR (ATR): ν_{max} 3485, 2960, 2928, 2869, 1674, 16301, 1598, 1461, 1447, 1362, 1169, 1032, 975, 911, 8777, 851, 755, 700, 645 cm^{-1}; HRMS (ESI): m/z calcd for $C_{34}H_{42}NaO_2S^+$ $(M+Na)^+$ 537.2798; found 537.2796.

(*E*)-*S*-(2,4,6-Triisopropylphenyl) 7-hydroxyhept-2-enethioate (S2g)



S2g was synthesised using the same procedure as **S1a** with unsaturated alcohol hex-5-en-1-ol (53.3 mg, 0.53 mmol, 1.0 eq), thioester **2c** (463 mg, 1.59 mmol, 3.0 eq), copper (I) iodide (33.1 mg, 0.05 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (10.1 mg, 0.05 mmol, 10 mol%). The mixture was purified by column chromatography on silica using 20% ethyl acetate in n-hexane to yield the product as a brown oil (184 mg, 96% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 6.95 (1H, dt, *J* =17.5 Hz, 6.7 Hz, H-11), 6.23 (1H, d, *J* =17.5 Hz, H-10), 3.68-3.65 (2H, m, H-15), 3.38 (2H, sept, *J* = 6.9 Hz, H-6), 2.89 (1H, sept, *J* = 6.9 Hz, H-2), 2.33-2.20 (2H, m, H-12), 1.62-156 (4H, m, H-14-H-13), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.17 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 188.9 (C-9), 152.7 (C-5), 151.1 (C-3), 145.5 (C-11), 128.2 (C-10), 122.1 (C-4), 121.6 (C-8), 62.7 (C-15), 34.5 (C-14), 32.3 (C-2), 32.1 (C-6), 24.5 (C-12), 24.3 (C-1), 24.0 (C-7), 23.6 (C-13) ppm; IR (ATR): ν_{max} 3412, 2969, 2940, 1684, 1631, 1464, 1375, 1284, 1156,1040, 972, 907, 851, 799, 765, 715 cm^{-1}; HRMS (ESI): m/z calcd for $C_{22}H_{34}NaO_2S^+$ $(M+Na)^+$ 385.2172; found 385.2172.

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(5-oxaspiro[3.5]nonan-6-yl)ethanethioate (5a)



Racemic-CSA

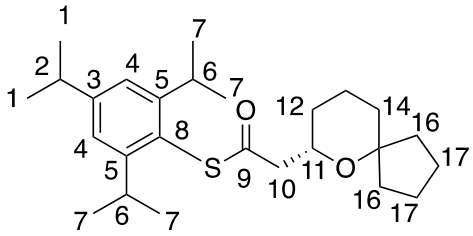
5a was synthesised using the same procedure as **4c** with alcohol-thioester **S2a** (7.94 mg, 0.02 mmol) and rac-CSA (13.9 mg, 0.06 mmol, 3 eq). **5a** yielded as yellow oil (7.62 mg, 97% yield) after column chromatography on silica using 5% Et_2O in hexane.

Asymmetric-(*R*)-TRIP

5a was synthesised using the same procedure as **4c** with alcohol-thioester **S2a** (16.7 mg, 0.06 mmol) and (*R*)-TRIP **3a** (8.80 mg, 0.01 mmol, 20 mol %). **5a** yielded as yellow oil (16.0 mg, 96% yield, 93% ee) after column chromatography on silica using 5% Et_2O in hexane.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.08 (2H, s, H-4), 3.85 (1H, dddd, *J* =11.3 Hz, 8.1 Hz, 4.3 Hz, 2.6 Hz, H-11), 3.44 (2H, sept, *J* = 6.9 Hz, H-6), 2.91-2.83 (2H, m, H-2, H-10), 2.62 (1H, dd, *J* = 14.5 Hz, 4.3 Hz, H-10) 2.10-2.00 (1H, m, H-14), 1.99-1.90 (3H, m, H-14, H-16), 1.79-1.70 (3H, m, H-12, H-13), 1.61-1.52 (4H, m, H-16, H-17), 1.42-1.39 (1H, m, H-12), 1.25 (12H, d, *J* = 6.9 Hz, H-7), 1.18 (6H, d, *J* = 6.9 Hz, H-1) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.4 (C-9), 152.7 (C-3), 151.1 (C-5), 122.7 (C-8), 122.0 (C-4), 77.3 (C-15), 69.4 (C-11), 50.1 (C-10), 34.8 (C-14), 34.4 (C-2), 32.8 (C-12), 31.9 (C-6), 30.8 (C-16), 30.6 (C-16'), 29.7 (C-1), 24.0 (C-7), 20.1 (C-13), 12.6 (C-17) ppm; IR (ATR): ν_{max} 2924, 2859, 1702, 1468, 1376, 1261, 1079, 804 cm^{-1}; HRMS (ESI): m/z calcd for $C_{25}H_{38}NaO_2S^+$ $(M+Na)^+$ 425.2485; found 425.2483; $[\alpha]_D^{20}$ + 39.2° (c 0.38, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl)2-(6-oxaspiro[4.5]decan-7-yl)ethanethioate (5b)



Racemic-CSA

5b was synthesised using the same procedure as **4c** with alcohol-thioester **S2b** (26.0 mg, 0.07 mmol) and rac-CSA (44.1 mg, 0.19 mmol, 3 eq). **5b** yielded as yellow oil (24.2 mg, 93% yield) after column chromatography on silica using 5% Et_2O in hexane.

Asymmetric-(*R*)-TRIP

5b was synthesised using the same procedure as **4c** with alcohol-thioester **S2b** (16.7 mg, 0.06 mmol) and (*R*)-TRIP **3a** (8.80 mg, 0.01 mmol, 20 mol %). **5b** yielded as yellow oil (15.0 mg, 90% yield, 96% ee) after column chromatography on silica using 5% Et_2O in hexane.

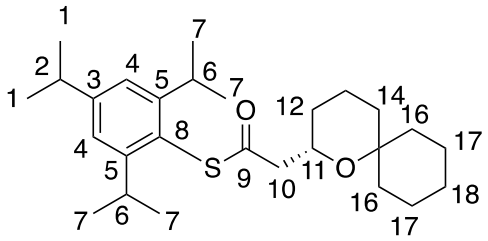
One-pot reaction

A solution of unsaturated alcohol **1c** (30.0 mg, 0.19 mmol, 1.0 eq) and thioester **2a** (170 mg, 0.57 mmol, 3.0 eq) were dissolved in cyclohexane (10 mL) under a nitrogen atmosphere. To this, copper (I) iodide (3.62 mg, 0.02 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (11.9 mg, 0.02 mmol, 10 mol%) were added as solids in a single portion and the mixture was stirred at 50 ^{0}C for 24 hours. The reaction was monitored by TLC and after completion, (*R*)-TRIP **3a** (29 mg, 0.04 mmol, 20 mol %) was added to the reaction

and left to stir for 24 hours. The reaction mixture was quenched by (0.2 ml) of Et_3N then concentrated in *vacuo* and purified by column chromatography on silica using 5% Et_2O in hexane to yield the product as a yellow oil (57.4 mg, 71% yield, 95% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 4.00 (1H, dddd, *J* =11.3 Hz, 8.3 Hz, 4.1 Hz, 2.8 Hz, H-11), 3.38 (2H, sept, *J* = 6.7 Hz, H-6), 3.00-2.72 (2H, m, H-2, H-10), 2.63 (1H, dd, *J* = 14.6 Hz, 4.1 Hz, H-10) 1.89-1.83 (1H, m, H-14), 1.77-1.64 (5H, m, H-14, H-16), 1.62-1.52 (4H, m, H-12, H-17), 1.51-1.41 (4H, m, H-13, H-17), 1.25 (6H, d, *J* = 6.7 Hz, H-1), 1.16 (12H, d, *J* = 6.7 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.4 (C-9), 152.5 (C-3), 151.0 (C-5), 122.1 (C-8), 122.0 (C-4), 84.4 (C-15), 69.2 (C-11), 50.6 (C-10), 41.6 (C-14), 34.7 (C-16), 34.4 (C-16'), 32.7 (C-2), 31.9 (C-6), 31.3 (C-10), 24.5 (C-1), 24.0 (C-7), 24.0 (C-17), 23.3 (C-17'), 21.2 (C-13) ppm; IR (ATR): ν_{max} 2958, 2867, 1699, 1461, 1362, 1091, 973, 906, 876, 731, 650, 471 cm^{-1}; HRMS (ESI): m/z calcd for $C_{26}H_{40}NaO_2S^+$ $(M+Na)^+$ 439.2641; found 439.2643; $[\alpha]_D^{20}$ + 41.7° (c 0.62, $CHCl_3$).

(*S*)-S-(2,4,6-Triisopropyl) 2-(1-oxaspiro[5.5]undecane-2-yl)ethanethioate (5c)



Racemic-CSA

5c was synthesised using the same procedure as **4c** with alcohol-thioester **S2c** (23.1 mg, 0.07 mmol) and rac-CSA (48.7 mg, 0.21 mmol, 3 eq). **5c** yielded as yellow oil (21.9 mg, 95% yield) after column chromatography on silica using 5% Et_2O in hexane.

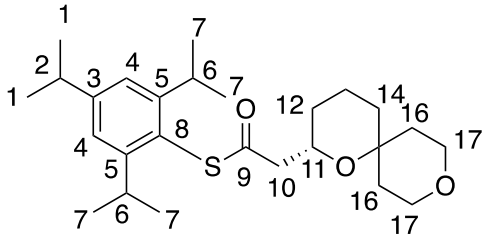
Asymmetric-(*R*)-TRIP

5c was synthesised using the same procedure as **4c** with alcohol-thioester **S2c** (19.9 mg, 0.06 mmol) and (*R*)-TRIP **3a** (8.79 mg, 0.01 mmol, 20 mol %). **5c** yielded as yellow oil (16.5 mg, 83% yield, 60% ee) after column chromatography on silica using 5% Et_2O in hexane.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 4.07 (1H, dddd, *J* =11.5 Hz, 7.9 Hz, 4.6 Hz, 2.7 Hz, H-11), 3.42 (2H, sept, *J* = 7.0 Hz, H-6), 2.94-2.83 (2H, m, H-2, H-10), 2.63 (1H, dd, *J* = 14.6 Hz, 4.6 Hz, H-10) 2.07-2.03 (1H, m, H-14), 1.75-1.64 (2H, m, H-16), 1.63-1.56 (2H, m, H-16), 1.55-1.44 (6H, m, H-14, H-17- H-18), 1.43-1.34 (2H, m, H-12), 1.41-1.35 (3H, m, H-13, H-18), 1.23 (12H, d, *J* = 7.0 Hz, H-7), 1.16 (6H, d, *J* = 7.0 Hz, H-1) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.3 (C-9), 152.5 (C-3), 150.9 (C-5), 122.1 (C-8), 122.0 (C-4), 72.7 (C-15), 66.4 (C-11), 50.8 (C-10), 40.4 (C-14), 35.1 (C-2), 34.4 (C-6), 31.9 (C-16), 31.5 (C-16'), 29.7 (C-12), 26.5 (C-18), 23.9 (C-1), 23.9 (C-7), 21.6 (C-17), 21, 3 (C-17'), 19.2 (C-13).ppm; IR (ATR): ν_{max} 2959, 2931, 2866, 1703, 1687, 1461,

1386, 1070, 987, 876, 746, 653, 473 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{42}NaO_2S^+$ $(M+Na)^+$ 453.2798; found 453.2807; $[\alpha]_D^{20}$ + 11.4° (c 0.75, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(1,9-dioxaspiro[5.5]undecan-2-yl)ethanethioate (5d)



Racemic-CSA

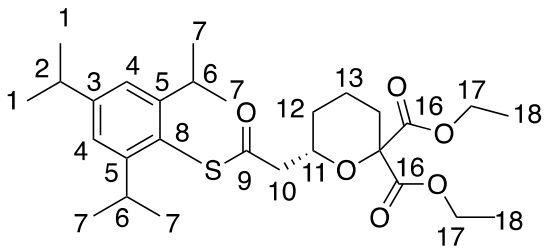
5d was synthesised using the same procedure as **4c** with alcohol-thioester **S2d** (15.9 mg, 0.04 mmol) and rac-CSA (35.6 mg, 0.11 mmol, 3 eq). The reaction mixture was purified by column chromatography on silica using 40% EtOAc in hexane to yield **5d** as a yellow oil (13.7 mg, 86% yield).

Asymmetric-(*R*)-TRIP

5d was synthesised using the same procedure as **4c** with alcohol-thioester **S2d** (18.7 mg, 0.04 mmol) and (*R*)-TRIP (6.52 mg, 0.01 mmol, 20 mol %). %). **5d** yielded as yellow oil (12.9 mg, 69% yield, 99% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.07 (2H, s, H-4), 4.08 (1H, dddd, *J* =11.4 Hz, 8.6 Hz, 4.3 Hz, 2.7 Hz, H-11), 3.81 (1H, ddd, *J* = 11.7 Hz, 4.4 Hz, 4.1 Hz, H-17), 3.65 (1H, ddd, *J* = 11.7 Hz, 4.4 Hz, 2.3 Hz, H-17), 3.63-3.56 (2H, m, H-17), 3.43 (2H, sept, *J* = 6.8 Hz, H-6), 2.93-2.86 (2H, m, H-2, H-10), 2.65 (1H, dd, *J* = 14.5 Hz, 4.3 Hz, H-10), 2.14-2.03 (1H, m, H-14), 1.73-1.60 (5H, m, H-14, H-16), 1.53-1.35 (3H, m, H-12, H-13), 1.34-1.29 (1H, m, H-13), 1.25 (12H, d, *J* = 6.8 Hz, H-7), 1.15 (6H, d, *J* = 6.8 Hz, H-1) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.4 (C-9), 152.2 (C-3), 151.1 (C-5), 122.1 (C-4), 121.8 (C-8), 70.4 (C-15), 66.8 (C-11), 63.3 (C-17), 63.3 (C-17'), 50.5 (C-10), 40.3 (C-16), 35.7 (C-14), 34.4 (C-16'), 32.0 (C-2), 31.3 (C-6), 30.4 (C-12), 24.4 (C-1), 24.0 (C-7), 18.9 (C-13) ppm; IR (ATR): ν_{max} 3421, 2959, 2928, 2866, 1698, 1640, 1598, 1459, 1362, 1300, 1238, 1104, 1022, 908, 877, 839, 757, 537 cm^{-1}; HRMS (ESI): m/z calcd for $C_{26}H_{41}O_3S^+$ $(M+H^+)$ 433.2771; found 433.2783; $[\alpha]_D^{20}$ - 51.2° (c 0.55, $CHCl_3$).

(*S*)-Diethyl 6-(2-oxo-2-((2,4,6-triisopropylphenyl)thio)ethyl)tetrahydro-2*H*-pyran-2,2-dicarboxylate (5e)



Racemic-CSA

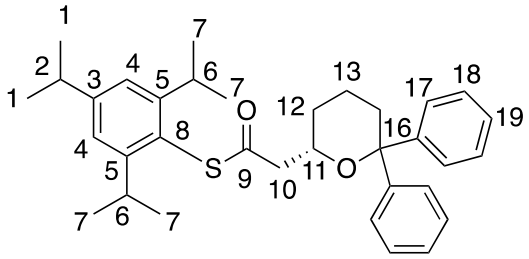
5e was synthesised using the same procedure as **4c** with alcohol-thioester **S2e** (16.8 mg, 0.03 mmol) and rac-CSA (32.1 mg, 0.10 mmol, 3 eq). The reaction mixture was purified by column chromatography on silica using 20% Et_2O in hexane to yield the product as a yellow oil (14.6 mg, 87% yield).

Asymmetric-(*R*)-TRIP

5e was synthesised using the same procedure as **4c** with alcohol-thioester **S2e** (21.6 mg, 0.04 mmol) and (*R*)-TRIP (6.41 mg, 0.01 mmol, 20 mol %). **5e** yielded as yellow oil (12.7 mg, 59% yield, 97% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.05 (2H, s, H-4), 4.23 (4H, q, *J* =7.0 Hz, H-17), 4.06 (1H, dddd, *J* =11.5 Hz, 6.0 Hz, 4.2 Hz, 2.8 Hz, H-11), 3.39 (2H, sept, *J* = 6.9 Hz, H-6), 3.09 (1H, dd, *J* = 14.7 Hz, 6.0 Hz, H-10), 2.89 (1H, sept, *J* = 6.9 Hz, H-2), 2.80 (1H, dd, *J* = 14.7 Hz, 4.2 Hz, H-10), 2.36 (1H, dd, *J* = 11.2 Hz, 2.7 Hz, H-14), 1.77-1.70 (1H, m, H-12), 1.69-1.64 (3H, m, H-12, H-13, H-14), 1.40-1.35 (1H, m, H-14), 1.28 (6H, d, *J* = 6.9 Hz, H-1), 1.22 (6H, t, *J* =7.0 Hz, H-18), 1.15 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 195.1 (C-9), 168.6 (C16), 168.3 (C-16'), 152.4 (C-3), 151.0 (C-5), 122.0 (C-4), 121.8 (C-8), 82.2 (C-15), 71.8 (C-11), 62.0 (C-17), 61.8 (C-17'), 49.7 (C-10), 34.4 (C-14), 31.9 (C-6), 29.7 (C-12), 29.3 (C-2), 23.9 (C-7), 23.9 (C-1), 19.9 (C-13), 14.1 (C-18), 14.0 (C-18) ppm; IR (ATR): ν_{max} 3077, 2932, 1739, 1641, 1445, 1369, 1225, 1132, 1024, 1006, 910, 861, 733, 634 cm^{-1}; HRMS (ESI): m/z calcd for $C_{28}H_{43}O_6S^+$ ($M+H^+$) 507.2775; found 507.2777; $[\alpha]_D^{20}$ - 40.6° (c 0.41, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(6,6-diphenyltetrahydro-2*H*-pyran-2-yl)ethanethioate (5f)



Racemic-CSA

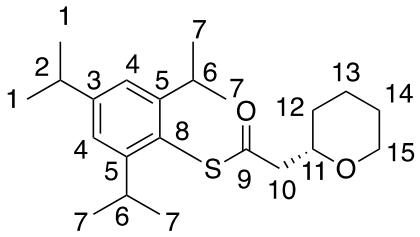
5f was synthesised using the same procedure as **4c** with alcohol-thioester **S2f** (28.9 mg, 0.06 mmol) was and rac-CSA (54.4 mg, 0.17 mmol, 3 eq). The reaction mixture was purified by column chromatography on silica using 30% Et_2O in hexane to yield **5f** as a yellow oil (25.4 mg, 99% yield).

Asymmetric-(*R*)-TRIP

5f was synthesised using the same procedure as **4c** with alcohol-thioester **S2f** (22.3 mg, 0.043 mmol) and (*R*)-TRIP (6.5 mg, 0.086 mmol, 20 mol %). **5f** yielded as yellow oil (14.0 mg, 63% yield, 96% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43-7.40 (4H, m, H-17), 7.32-7.29 (2H, m, H-19), 7.23-7.10 (4H, m, H-18), 7.07 (2H, s, H-4), 4.06 (1H, dddd, *J* =11.6 Hz, 9.1 Hz, 3.5 Hz, 2.7 Hz, H-11), 3.42 (2H, sept, *J* = 6.9 Hz, H-6), 3.12 (1H, dd, *J* = 14.6 Hz, 9.1 Hz, H-10), 2.90 (1H, sept, *J* = 6.9 Hz, H-2), 2.72 (1H, dd, *J* = 14.6 Hz, 3.5 Hz, H-10), 1.81-1.70 (3H, m, H-12, H-14), 1.50-1.41 (3H, m, H-13, H-14), 1.25 (12H, d, *J* = 6.9 Hz, H-7), 1.09 (6H, d, *J* = 6.9 Hz, H-1) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.0 (C-9), 151.0 (C-3), 151.0 (C-5), 149.1 (C-16), 142.4 (C-16'), 128.6 (C-17), 127.9 (C-17'), 127.4 (C-18), 126.8 (C-19), 126.1 (C-19'), 124.8 (C-18'), 122.1 (C-8), 122.0 (C-4), 80.3 (C-15), 68.6 (C-11), 50.5 (C-10), 34.8 (C-14), 34.4 (C-2), 32.0 (C-6), 31.1 (C-12), 29.7 (C-1), 23.9 (C7), 20.4 (C-13) ppm; IR (ATR): ν_{max} 2960, 2936, 2861, 1804, 1670, 1603, 1462, 1380, 1095, 976, 700, 686 cm^{-1}; HRMS (ESI): m/z calcd for $C_{34}H_{42}NaO_2S^+$ $(M+Na)^+$ 537.2798; found 537.2796; $[\alpha]_D^{20}$ - 42.3° (c 0.60, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(tetrahydro-2*H*-pyran-2-yl)ethanethioate (5g)



Racemic-CSA

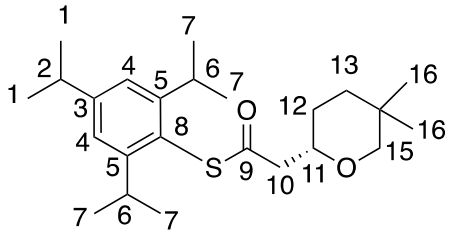
5g was synthesised using the same procedure as **4c** with alcohol-thioester **S2g** (8.51 mg, 0.02 mmol) and rac-CSA (22.7 mg, 0.07 mmol, 3 eq). The reaction mixture was purified by column chromatography on silica using 5% Et_2O in hexane to yield **5g** as a yellow oil (7.57 mg, 89% yield).

Asymmetric-(*R*)-TRIP

5g was synthesised using the same procedure as **4c** with alcohol-thioester **S2g** (10.9 mg, 0.03 mmol) and (*R*)-TRIP (4.53 mg, 0.01 mmol, 20 mol %). **5g** yielded as yellow oil (9.27 mg, 85% yield, 33% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 3.97 (1H, ddd, *J* =10.3 Hz, 4.6 Hz, 2.7 Hz, H-15), 3.80 (1H, dddd, *J* =11.6 Hz, 7.8 Hz, 4.4 Hz, 2.5 Hz, H-11), 3.46-3.40 (3H, m, H-6, H-15), 2.92-2.84 (2H, m, H-2, H-10), 2.67 (1H, dd, *J* = 14.5 Hz, 4.4 Hz, H-10), 1.86-1.81 (1H, m, H-14), 1.67-1.54 (3H, m, H-12, H-14), 1.51-1.34 (2H, m, H-13), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.15 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.3 (C-9), 152.5 (C-3), 151.1 (C-5), 122.1 (C-4), 122.0 (C-8), 75.4 (C-15), 68.7 (C-11), 50.2 (C-10), 34.4 (C-14), 31.9 (C-6), 31.6 (C-2), 29.8 (C-12), 25.7 (C-1), 24.0 (C-7), 23.4 (C-13) ppm; IR (ATR): ν_{max} 2924, 2857, 1702, 1459, 1376, 1069, 993, 901, 849, 797, 737, 717 cm^{-1}; HRMS (ESI): m/z calcd for $C_{22}H_{34}NaO_2S^+$ $(M+Na)^+$ 385.2172; found 385.2172; $[\alpha]_D^{20}$ + 7.23° (c 0.44, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(5,5-dimethyltetrahydro-2*H*-pyran-2-yl)ethanethioate (7a)



The cyclization precursor **S3a** was synthesised using the same procedure as **S1a** with unsaturated alcohol **6a** (82.0 mg, 0.64 mmol, 1.0 eq), thioester **2c** (560 mg, 1.93 mmol, 3.0 eq), copper (I) iodide (12.2 mg, 0.06 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (40.1 mg, 0.06 mmol, 10 mol%). The mixture was then concentrated and used for the cyclization without further purification.

Racemic-CSA

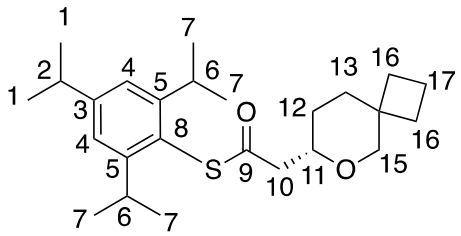
7a was synthesised using the same procedure as **4c** with alcohol-thioester **S3a** (29.2 mg, 0.07 mmol) was and rac-CSA (52.1 mg, 0.23 mmol, 3 eq). The reaction mixture was purified by column chromatography on silica using 5% Et_2O in hexane to yield **7a** as a yellow oil (20.0 mg, 94% yield).

Asymmetric-(*R*)-TRIP

7a was synthesised using the same procedure as **4c** with alcohol-thioester **S3a** (33.3 mg, 0.07 mmol) and (*R*)-TRIP (12.9 mg, 0.017 mmol, 20 mol %). **7a** yielded as yellow oil (28.3 mg, 85% yield, 71% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 3.70 (1H, dddd, *J* =11.6 Hz, 7.8 Hz, 4.1 Hz, 2.6 Hz, H-11), 3.45 (1H, d, *J* = 11.1 Hz, H-15), 3.38 (2H, sept, *J* = 6.9 Hz, H-6), 3.17 (1H, d, *J* = 11.1 Hz, H-15), 2.93-2.85 (2H, m, H-2, H-10), 2.73 (1H, dd, *J* = 14.5 Hz, 4.1 Hz, H-10) 1.58-1.52 (2H, m, H-12), 1.49-1.39 (2H, m, H-13), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.16 (12H, d, *J* = 6.9 Hz, H-7), 1.02 (3H, s, H-16), 0.80 (3H, s, H-16) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.2 (C-9), 152.5 (C-3), 151.1 (C-5), 122.1 (C-4), 122.0 (C-8), 78.5 (C-15), 75.4 (C-11), 49.9 (C-10), 36.7 (C-14), 34.4 (C-2), 32.0 (C-6), 29.9 (C-12), 27.9 (C-13), 27.2 (C-16), 24.4 (C-1), 24.0 (C-7), 23.7 (C-16') ppm; IR (ATR): ν_{max} 2924, 2857, 1702, 1459, 1376, 1069, 993, 901, 849, 797, 737, 717 cm^{-1}; HRMS (ESI): m/z calcd for $C_{24}H_{39}O_2S^+$ $(M+H)^+$ 391.2665; found 391.2662; $[\alpha]_D^{20}$ – 32.14° (c 0.87, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(6-oxaspiro[3.5]nonan-7-yl)ethanethioate (7b)



The cyclization precursor **S3b** was synthesised using the same procedure as **S1a** with unsaturated alcohol **6b** (110 mg, 0.78 mmol, 1.0 eq) , thioester **2c** (684 mg, 2.35 mmol, 3.0 eq), copper (I) iodide (14.9 mg, 0.08 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (50.1 mg, 0.08 mmol, 10 mol%). The mixture was then concentrated and used for the cyclization without further purification.

Racemic-CSA

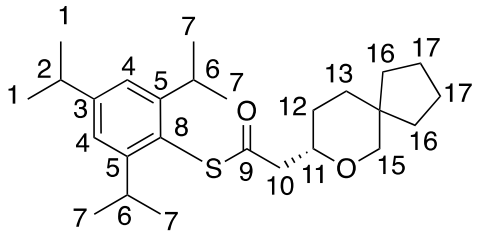
7b was synthesised using the same procedure as **4c** with alcohol-thioester **S3b** (10.3 mg, 0.03 mmol) and rac-CSA (25.2 mg, 0.08 mmol, 3 eq). The reaction mixture was then concentrated in *vacuo* and purified by column chromatography on silica using 5% Et_2O in hexane to yield **7b** as a yellow oil (9.7 mg, 94% yield).

Asymmetric-(*R*)-TRIP

7b was synthesised using the same procedure as **4c** with alcohol-thioester **S3b** (10.5 mg, 0.03 mmol) and (*R*)-TRIP (3.92 mg, 0.02mmol, 20 mol %). **7b** yielded as yellow oil (9.7 mg, 99% yield, 97% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 3.83 (1H, d, *J* = 11.1 Hz, H-15), 3.70 (1H, dddd, *J* =11.7 Hz, 8.5 Hz, 4.7 Hz, 2.6 Hz, H-11), 3.40 (2H, sept, *J* = 6.8 Hz, H-6), 3.23 (1H, d, *J* = 11.1 Hz, H-15), 2.90-2.83 (2H, m, H-2, H-10), 2.67 (1H, dd, *J* = 14.6 Hz, 4.7 Hz, H-10) 2.05-1.99 (1H, m, H-12), 1.90-1.82 (3H, m, H-12, H-16), 1.78-1.72 (1H, m, H-13), 1.62-1.51 (5H, m, H-13, H-16, H-17), 1.25 (6H, d, *J* = 6.8 Hz, H-1), 1.16 (12H, d, *J* = 6.8 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.1 (C-9), 152.4 (C-3), 151.0 (C-5), 122.0 (C-4), 121.9 (C-8), 76.4 (C-15), 74.8 (C-11), 49.7 (C-10), 37.7 (C-14), 35.6 (C-16), 34.4 (C-12), 31.9 (C-12), 30.4 (C-2), 29.0 (C-6), 28.1 (C-13), 23.9 (C-1), 23.9 (C-7), 15.3 (C-17) ppm; IR (ATR): ν_{max} 2924, 2859, 1702, 1468, 1376, 1261, 1079, 804 cm^{-1}; HRMS (ESI): m/z calcd for $C_{25}H_{38}NaO_2S^+$ $(M+Na)^+$ 425.2485; found 425.2483; $[\alpha]_D^{20}$ – 55.23° (c 0.48, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(6-oxaspiro[4.5]decan-7-yl)ethanethioate (7c)



The cyclization precursor **S3c** was synthesised using the same procedure as **S1a** with unsaturated alcohol **6c** (60.0 mg, 0.40 mmol, 1.0 eq), thioester **2c** (399 mg, 1.67 mmol, 3.0 eq), copper (I) iodide (7.40 mg, 0.04 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (24.0 mg, 0.04 mmol, 10 mol%). The mixture was then concentrated and used for the cyclization without further purification.

Racemic-CSA

7c was synthesised using the same procedure as **4c** with alcohol-thioester **S3c** (22.0 mg, 0.05 mmol) and rac-CSA (51.0 mg, 0.16 mmol, 3 eq). The reaction mixture was then concentrated in *vacuo* and purified by column chromatography on silica using 5% Et_2O in hexane to yield **7c** as a yellow oil (21.3 mg, 97% yield).

Asymmetric-(*R*)-TRIP

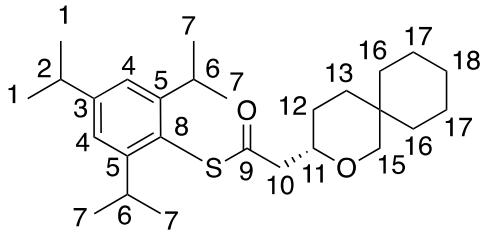
7c was synthesised using the same procedure as **4c** with alcohol-thioester **S3c** (30.9 mg, 0.07 mmol) and (*R*)-TRIP (11.2 mg, 0.02 mmol, 20 mol). **7c** yielded as yellow oil (28.4 mg, 92% yield, 99% ee).

One-pot reaction

7c was synthesised using the same procedure as **5b** with unsaturated alcohol **6c** (30.0 mg, 0.19 mmol, 1.0 eq), thioester **2c** (170 mg, 0.57 mmol, 3.0 eq), copper (I) iodide (3.62 mg, 0.02 mmol, 10 mol%), Hovyeda-Grubbs 2nd generation catalyst (11.9 mg, 0.02 mmol, 10 mol%) and (*R*)-TRIP (29.0 mg, 0.04 mmol, 20 mol). **7c** yielded as yellow oil (57.0 mg, 70% yield, 99% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 3.75 (1H, dddd, *J* =11.2 Hz, 6.9 Hz, 3.7 Hz, 2.5 Hz, H-11), 3.52 (1H, d, *J* = 11.1 Hz, H-15), 3.40 (2H, sept, *J* = 6.9 Hz, H-6), 3.20 (1H, d, *J* = 11.1 Hz, H-15), 2.92-2.85 (2H, m, H-2, H-10), 2.71 (1H, dd, *J* = 14.5 Hz, 3.7 Hz, H-10) 1.87-1.82 (1H, m, H-12), 1.63-1.53 (6H, m, H-12, H-13, H-16,), 1.53-1.43 (2H, m, H-13, H-17), 1.43-1.27 (2H, m, H-13, H-17), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.22-1.199 (1H, m, H-16), 1.16 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.2 (C-9), 152.5 (C-3), 151.1 (C-5), 122.1 (C-4), 122.0 (C-8), 76.6 (C-15), 75.3 (C-11), 49.9 (C-10), 41.9 (C-14), 36.8 (C-16), 36.1 (C-16'), 34.6 (C-12), 34.4 (C-2), 32.0 (C-6), 29.2 (C-13), 25.2 (C-17), 24.8 (C-17'), 24.0 (C-7), 23.7 (C-1) ppm; IR (ATR): ν_{max} 2958, 2867, 1699, 1461, 1362, 1091, 973, 906, 876, 731, 650, 471 cm^{-1}; HRMS (ESI): m/z calcd for $C_{26}H_{40}NaO_2S^+$ $(M+Na)^+$ 439.2641; found 439.2652; $[\alpha]_D^{20}$ – 64.44° (c 0.75, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(2-oxaspiro[5.5]undecan-3-yl)ethanethioate (7d)



The cyclization precursor **S3d** was synthesised using the same procedure as **S1a** with unsaturated alcohol **6d** (83.8 mg, 0.50 mmol, 1.0 eq), thioester **2c** (434 mg, 1.49 mmol, 3.0 eq), copper (I) iodide (9.48 mg, 0.05 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (31.2 mg, 0.05 mmol, 10 mol%). The mixture was then concentrated and used for the cyclization without further purification.

Racemic-CSA

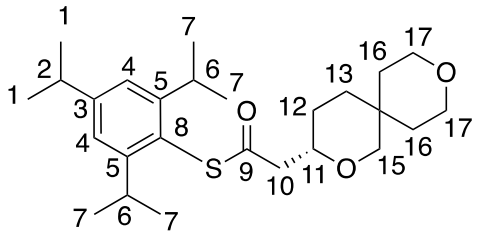
7d was synthesised using the same procedure as **4c** with alcohol-thioester **S3d** (29.8 mg, 0.07 mmol) and rac-CSA (48.0 mg, 0.21 mmol, 3 eq). The reaction mixture was then concentrated in *vacuo* and purified by column chromatography on silica using 5% Et_2O in hexane to yield **7d** as a yellow oil (27.6 mg, 95% yield).

Asymmetric-(*R*)-TRIP

7d was synthesised using the same procedure as **4c** with alcohol-thioester **S3d** (33.0 mg, 0.08 mmol) and (*R*)-TRIP (11.5 mg, 0.02 mmol, 20 mol). **7d** yielded as yellow oil (30.4 mg, 92% yield, 73% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 3.76-3.69 (2H, m, H-11, H-15), 3.40 (2H, sept, *J* = 7.1 Hz, H-6), 3.09 (1H, d, *J* = 11.2 Hz, H-15), 2.93-2.84 (2H, m, H-2, H-10), 2.73 (1H, dd, *J* = 14.7 Hz, 4.6 Hz, H-10) 1.80-1.75 (1H, m, H-12), 1.61-1.53 (2H, m, H-16), 1.52-1.44 (3H, m, H-12, H-16), 1.44-1.38 (4H, m, H-17), 1.34-1.28 (1H, m, H-13), 1.25 (6H, d, *J* = 7.1 Hz, H-1), 1.22-1.19 (1H, m, H-13), 1.16 (12H, d, *J* = 7.1 Hz, H-7), 1.12-1.08 (2H, m, H-18) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.2 (C-9), 152.5 (C-3), 151.1 (C-5), 122.1 (C-4), 122.0 (C-8), 77.0 (C-15), 75.9 (C-11), 49.9 (C-10), 36.6 (C-14), 34.5 (C-2), 34.0 (C-12), 32.1 (C-6), 32.0 (C-16), 31.4 (C-16'), 27.2 (C-17), 26.9 (C-17'), 24.4 (C-1), 24.0 (C-7), 21.6 (C-13), 21.6 (C-18) ppm; IR (ATR): ν_{max} 2959, 2931, 2866, 1703, 1687, 1461, 1386, 1070, 987, 876, 746, 653, 473 cm^{-1}; HRMS (ESI): m/z calcd for $C_{27}H_{42}NaO_2S^+$ $(M+Na)^+$ 453.2798; found 453.2807; $[\alpha]_D^{20}$ – 34.65° (c 1.40, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(2,9-dioxaspiro[5.5]undecan-3-yl)ethanethioate (7e)



The cyclization precursor **S3e** was synthesised using the same procedure as **S1a** with unsaturated alcohol **6e** (42.0 mg, 0.25 mmol, 1.0 eq), thioester **2c** (215 mg, 0.74 mmol, 3.0 eq), copper (I) iodide (4.70 mg, 0.03 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (15.5 mg, 0.03 mmol, 10 mol%). The mixture was then concentrated and used for the cyclization without further purification.

Racemic-CSA

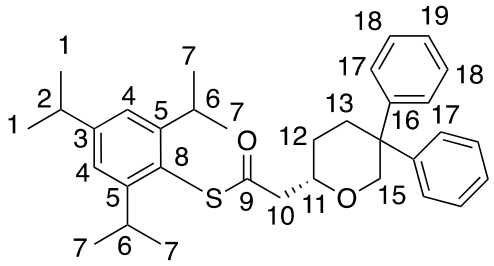
7e was synthesised using the same procedure as **4c** with alcohol-thioester **S3e** (14.3 mg, 0.03 mmol) and rac-CSA (20.9 mg, 0.09 mmol, 3 eq). The reaction mixture was then concentrated in *vacuo* and purified by column chromatography on silica using 40% EtOAc in hexane to yield **7e** as a yellow oil (13.4 mg, 94% yield).

Asymmetric-(*R*)-TRIP

7e was synthesised using the same procedure as **4c** with alcohol-thioester **S3e** (14.3 mg, 0.03 mmol) and (*R*)-TRIP (4.99 mg, 0.07 mmol, 20 mol %). **7e** yielded as yellow oil (13.0 mg, 91% yield, 40% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.06 (2H, s, H-4), 3.88 (1H, d, *J* = 11.4 Hz, H-15), 3.79-3.72 (1H, m, H-11), 3.69-3.65 (2H, m, H-17), 3.64-3.61 (1H, m, H-17), 3.59-3.53 (1H, m, H-17), 3.40 (2H, sept, *J* = 6.8 Hz, H-6), 3.15 (1H, d, *J* = 11.4 Hz, H-15), 2.92-2.86 (2H, m, H-2, H-10), 2.73 (1H, dd, *J* = 14.3 Hz, 4.1 Hz, H-10) 1.89-1.84 (1H, m, H-16), 1.82-1.76 (1H, m, H-16), 1.65-1.58 (2H, m, H-16), 1.57-1.49 (2H, m, H-12), 1.36-1.30 (2H, m, H-13), 1.25 (6H, d, *J* = 6.8 Hz, H-1), 1.16 (12H, d, *J* = 6.8 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.1 (C-9), 152.4 (C-3), 151.2 (C-5), 122.1 (C-4), 121.9 (C-8), 75.9 (C-15), 75.8 (C-11), 64.0 (C-17), 63.4 (C-17'), 49.7 (C-10), 36.0 (C-13), 34.4 (C-2), 34.1 (C-16), 32.0 (C-6), 31.8 (C-16'), 30.2 (C-14), 26.9 (C-12), 24.4 (C-1), 24.0 (C-7) ppm; IR (ATR): ν_{max} 3421, 2959, 2928, 2866, 1698, 1640, 1598, 1459, 1362, 1300, 1238, 1104, 1022, 908, 877, 839, 757, 537 cm^{-1}; HRMS (ESI): m/z calcd for $C_{26}H_{41}O_3S^+$ $(M+H)^+$ 433.2771; found 433.2776; $[\alpha]_D^{20}$ – 9.14° (c 0.57, $CHCl_3$).

(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(5,5-diphenyltetrahydro-2*H*-pyran-2-yl)ethanethioate (7f)



The cyclization precursor **S3f** was synthesised using the same procedure as **S1a** with unsaturated alcohol **6f** (190 mg, 0.75 mmol, 1.0 eq), thioester **2c** (657 mg, 2.26 mmol, 3.0 eq), copper (I) iodide (144 mg, 0.75 mmol, 1.0 eq) and Hovyeda-Grubbs 2nd generation catalyst (47.2 mg, 0.08 mmol, 10 mol%). The mixture was then concentrated and used for the cyclization without further purification.

Racemic-CSA

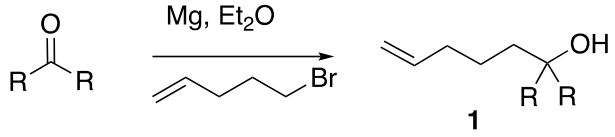
7f was synthesised using the same procedure as **4c** with alcohol-thioester **S3f** (28.9 mg, 0.06 mmol) and rac-CSA (54.4 mg, 0.17 mmol, 3 eq). The reaction mixture was then concentrated in *vacuo* and purified by column chromatography on silica using 20% EtOAc in hexane to yield **7f** as a yellow oil (24.9 mg, 86% yield).

Asymmetric-(*R*)-TRIP

7f was synthesised using the same procedure as **4c** with alcohol-thioester **S3f** (9.51 mg, 0.018 mmol) and (*R*)-TRIP (2.78 mg, 0.003 mmol, 20 mol %). **7f** yielded as yellow oil (6.94 mg, 73% yield, 87% ee).

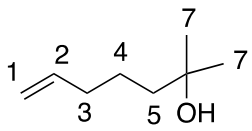
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43-7.31 (2H, m, H-19), 7.309-7.23 (4H, m, H-17), 7.20-7.14 (2H, m, H-18), 7.06 (2H, s, H-4), 4.61 (1H, d, *J* = 11.1 Hz, H-15), 3.95 (1H, dddd, *J* =11.4 Hz, 8.4 Hz, 4.4 Hz, 2.7 Hz, H-11), 3.55 (1H, d, *J* = 11.1 Hz, H-15), 3.46 (2H, sept, *J* = 6.9 Hz, H-6), 2.94-2.85 (2H, m, H-2, H-10), 2.68 (1H, dd, *J* = 14.5 Hz, 4.4 Hz, H-10), 2.51 -2.41 (1H, m, H-12), 1.68-1.51 (2H, m, H-13), 1.25 (6H, d, *J* = 6.9 Hz, H-1), 1.11 (12H, d, *J* = 6.9 Hz, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 196.0 (C-9), 153.0 (C-3), 151.1 (C-5), 146.5 (C-16), 145.7 (C-16'), 129.0 (C-17), 128.3 (C-17'), 128.1 (C-18), 127.0 (C-18'), 126.4 (C-19), 125.8 (C-19'), 122.0 (C-4), 121.8 (C-8), 75.0 (C-15), 75.0 (C-11), 49.7 (C-10), 45.8 (C-14), 34.5 (C-2), 34.4 (C-6), 31.9 (C-12), 29.7 (C-13), 27.7 (C-1), 23.9 (C-7) ppm, IR (ATR): ν_{max} 2960, 2936, 2861, 1804, 1670, 1603, 1462, 1380, 1095, 976, 700, 686 cm^{-1}; HRMS (ESI): m/z calcd for $C_{34}H_{42}NaO_2S^+$ $(M+Na)^+$ 537.2798; found 537.2796; $[\alpha]_D^{20}$ + 21.45° (c 0.32, $CHCl_3$).

2,2-Disubstituted



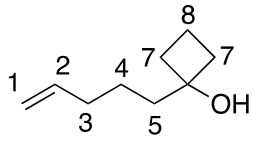
1

2-Methylhept-6-en-2-ol (1a)



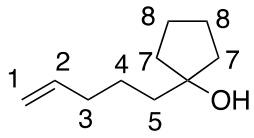
A degassed solution of 5-bromo-1-pentene (5.10 mL, 43.1 mmol) in Et_2O (20 mL) was added 0.3 ml/min, to a mixture of magnesium turnings (1.20 g, 49.4 mmol) in dry Et_2O (40 mL) under a nitrogen atmosphere. The reaction mixture was left to stir at room temperature for two hours. The solution of Grignard reagent was added (5 ml/min) to a solution of dry acetone (3.15 mL, 43.1 mmol) in Et_2O (20 mL). A white precipitate formed within 2 min. The reaction mixture was then quenched with excess saturated aq NH_4Cl solution and the white precipitate was filtered. The organic layer was separated and washed with H_2O, dried over anhydrous Na_2SO_4 and filtered. It was then concentrated *in vacuo* to give a colourless oil. The oil was purified by flash column chromatography on silica with 10% of ethyl acetate in n-hexane to yield **1a** as a colourless oil (1.61 g, 28% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.78 (1H, ddt, *J* = 17.0 Hz, 10.4 Hz, 7.6 Hz, H-2), 5.00 (1H, ddt, *J* = 17.0 Hz, 2.0 Hz, 1.4 Hz, H-1_{trans}), 4.95 (1H, ddt, *J* = 10.4 Hz, 2.0 Hz, 1.4 Hz, H-1_{cis}), 2.03 (2H, dt, *J* = 7.6 Hz, 7.4 Hz, H-3), 1.45-1.43 (4H, m, H-5, H-4), 1.19 (6H, s, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 138.9 (C-2), 114.7 (C-1), 71.1 (C-6), 43.4 (C-5), 34.3 (C-3), 29.3 (C-7), 23.8 (C-4) ppm; IR (ATR): ν_{max} 3369, 3078, 2971, 1641, 1377, 1151, 992, 908, 764 cm^{-1}; HRMS (APCI): m/z calcd for $C_8H_{17}O$ $(M-H)^+$ 129.1274; found 129.1271.

1-(Pent-4-en-1-yl)cyclobutanol (1b)



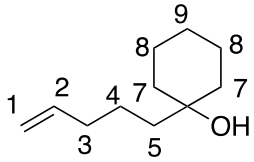
1b was synthesised using the same procedure as **1a** with a solution of cyclobutanone (1.97 mL, 29.7 mmol) in Et_2O (20 mL). The oil was purified by flash column chromatography on silica with 10% of ethyl acetate in n-hexane to yield **1b** as a colourless oil (3.43 g, 81% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.80 (1H, ddt, *J* = 17.1 Hz, 10.4 Hz, 6.6 Hz, H-2), 5.01 (1H, ddt, *J* = 17.1 Hz, 2.0 Hz, 1.4 Hz, H-1_{trans}), 4.94 (1H, ddt, *J* = 10.4 Hz, 2.0 Hz, 1.4 Hz, H-1_{cis}), 2.10-1.94 (6H, m, H-3, H-5, H-7), 1.75-1.67 (1H, m, H-4), 1.59-1.55 (2H, m, H-7), 1.49-1.44 (3H, m, H-4, H-8) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ138.9 (C-2), 114.7 (C-1), 75.3 (C-6), 39.0 (C-5), 36.0 (C-7), 34.1 (C-3), 22.8 (C-4), 12.2 (C-8) ppm ; IR (ATR): ν_{max} 3385, 3076, 2931, 2860, 1641, 1447, 1414, 1354, 1255, 1165, 990, 969, 908 cm^{-1}; HRMS (APCI): m/z calcd for $C_9H_{17}O$ $(M-H)^+$ 141.1274; found 141.1264.

1-(Pent-4-en-1-yl)cyclopentanol (1c)



1c was synthesised using the same procedure as **1a** with a solution of cyclopentanone (3.11 mL, 29.3 mmol) in Et_2O (20 mL). The oil was purified by flash column chromatography on silica with 10% of ethyl acetate in n-hexane to yield **1c** as a colourless oil (3.61 g, 79% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.77 (1H, ddt, *J* = 17.1 Hz, 10.4 Hz, 6.6 Hz, H-2), 4.97 (1H, ddt, *J* = 17.1 Hz, 2.0 Hz, 1.4 Hz, H-1_{trans}), 4.90 (1H, ddt, *J* = 10.4 Hz, 2.0 Hz, 1.4 Hz, H-1_{cis}), 2.03 (2H, dt, *J* = 6.6 Hz, 6.4 Hz, H-3), 1.77-1.74 (2H, m, H-5), 1.61-1.55 (5H, m, H-4, H-7, H-8), 1.51-1.42 (5H, m, H-4, H-7, H-8) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 138.9 (C-2), 114.6 (C-1), 82.5 (C-6), 41.0 (C-5), 39.7 (C-3), 34.3 (C-7), 24.1 (C-4), 23.9 (C-8) ppm; IR (ATR): ν_{max} 3381, 2943, 2871, 1711, 1641, 1283, 1095, 992, 908, 733, 630, 554 cm^{-1}; HRMS (APCI): m/z calcd for $C_{10}H_{19}O$ $(M-H)^+$ 155.14304; found 155.14272.

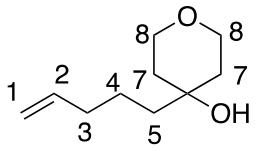
1-(Pent-4-en-1-yl)cyclohexanol (1d)



1d was synthesised using the same procedure as **1a** with a solution of cyclohexanone (3.11 mL, 29.9 mmol) in Et_2O (20 mL). The oil was purified by flash column chromatography on silica with 10% of ethyl acetate in n-hexane to yield **1d** as a colourless oil (4.12 g, 57% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.77 (1H, ddt, *J* = 17.1

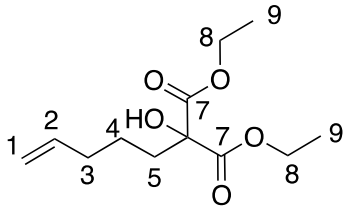
Hz, 10.4 Hz, 6.6 Hz, H-2), 4.98 (1H, ddt, *J* = 17.1 Hz, 2.0 Hz, 1.4 Hz, H-1_{trans}), 4.92 (1H, ddt, *J* = 10.4 Hz, 2.0 Hz, 1.4 Hz, H-1_{cis}), 2.02 (2H, dt, *J* = 6.6 Hz, 6.5 Hz, H-3), 1.59-1.53 (2H, m, H-5), 1.51-1.44 (4H, m, H-7, H-8), 1.43-1.34 (7H, m, H-4, H-7, H-8, H-9), 1.31-1.17 (1H, m, H-9) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 139.0 (C-2), 114.6 (C-1), 71.5 (C-6), 41.9 (C-5), 37.5 (C-7), 34.3 (C-3), 25.9 (C-4), 22.3 (C-8), 22.3 (C-9) ppm; IR (ATR): ν_{max} 3385, 3076, 2931, 2860, 1641, 1447, 1414, 1354, 1255, 1165, 990, 969, 908 cm^{-1}; HRMS (APCI): m/z calcd for $C_{11}H_{21}O$ $(M-H)^+$ 169.1590; found 169.1594.

4-(Pent-4-en-1-yl)tetrahydro-2*H*-pyran-4-ol (1e)



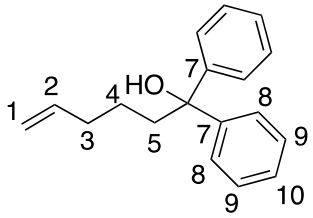
1e was synthesised using the same procedure as **1a** with a solution of tetrahydro-4H-pyran-4-one (3.22 mL, 29.7 mmol) in Et_2O (20 mL). The oil was purified by flash column chromatography on silica with 40% of ethyl acetate in n-hexane to yield **1e** as a colourless oil (3.34 g, 67% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.77 (1H, ddt, *J* = 17.1 Hz, 10.4 Hz, 6.6 Hz, H-2), 4.98 (1H, ddt, *J* = 17.1 Hz, 2.0 Hz, 1.4 Hz, H-1_{trans}), 4.93 (1H, ddt, *J* = 10.4 Hz, 2.0 Hz, 1.4 Hz, H-1_{cis}), 3.75-3.65 (4H, m, H-8), 2.03 (2H, dt, *J* = 6.6 Hz, 6.5 Hz, H-3), 1.89-1.76 (1H, m, H-5), 1.67-1.59 (2H, m, H-7), 1.45-1.41 (5H, m, H-4, H-5, H-7) ppm; ^{13}CNMR (101 MHz, $CDCl_3$): δ 138.6 (C-2), 114.9 (C-1), 68.9 (C-6), 63.9 (C-8), 42.8 (C-5), 37.6 (C-7), 34.1 (C-3), 21.8 (C-4) ppm; IR (ATR): ν_{max} 3414, 3077, 2941, 2866, 2241, 1640, 1417, 1357, 1097, 909, 873, 647, 537 cm^{-1}; HRMS (ESI): m/z calcd for $C_{10}H_{19}O_2$ $(M-H)^+$ 171.1380; found 171.1373.

Diethyl 2-hydroxy-2-(pent-4-en-1-yl)malonate (1f)



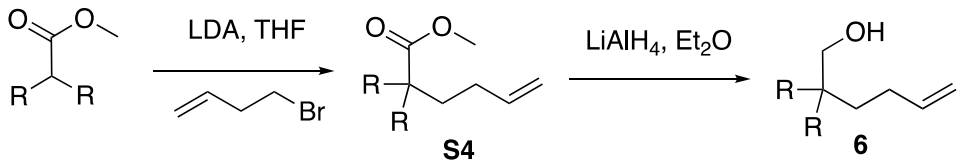
1f was synthesised using the same procedure as **1a** with a solution of diethyl keto malonate (4.21 mL, 29.9 mmol) in Et_2O (20 mL). The oil was purified by flash column chromatography on silica with 20% of ethyl acetate in n-hexane to yield **1f** as a colourless oil (4.51 g, 61% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.75 (1H, ddt, *J* = 17.1 Hz, 10.2 Hz, 7.3 Hz, H-2), 5.00 (1H, ddt, *J* = 17.1 Hz, 2.5 Hz, 1.4 Hz, H-1_{trans}), 4.93 (1H, ddt, *J* = 10.2 Hz, 2.5 Hz, 1.4 Hz, H-1_{cis}), 4.26-4.21 (4H, m, H-8), 2.09-1.98 (4H, m, H-3, H-5), 1.44-1.39 (2H, m, H-4), 1.28-1.24 (6H, t, *J* = 7.1 Hz, H-9) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 170.7 (C-7), 138.2 (C-2), 115.1 (C-1), 79.0 (C-6), 62.5 (C-8), 34.1 (C-5), 33.5 (C-3), 22.4 (C-4), 14.1 (C-9) ppm; IR (ATR): ν_{max} 3493, 2981, 2939, 1736, 1391, 1219, 1196, 1024, 9123, 732, 597 cm^{-1}; HRMS (ESI): m/z calcd for $C_{12}H_{20}NaO_5$ $(M-Na)^+$ 267.1203; found 267.1198.

1,1-Diphenylhex-5-en-1-ol (1g)

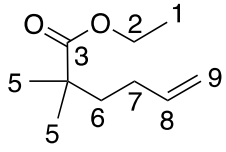


1g was synthesised using the same procedure as **1a** with a solution of benzophenone (5.34 mL, 29.3 mmol) in Et_2O (20 mL). The oil was purified by flash column chromatography on silica with 20% of ethyl acetate in n-hexane to yield **1g** as a colourless oil (5.31 g, 72% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44-7.41 (4H, m, H-8), 7.34-7.30 (4H, m, H-9), 7.26-7.23 (2H, m, H-10), 5.79 (1H, ddt, *J* = 17.1 Hz, 10.2 Hz, 7.3 Hz, H-2), 5.02 (1H, ddt, *J* = 17.1 Hz, 2.5 Hz, 1.4 Hz, H-1_{trans}), 4.99 (1H, ddt, *J* = 10.2 Hz, 2.5 Hz, 1.4 Hz, H-1_{cis}), 2.30 (2H, dt, *J* = 7.3 Hz, 7.1 Hz, H-3), 2.12-2.05 (2H, m, H-5), 1.46-1.37 (2H, m, H-4) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 147.2 (C-7), 138.7 (C-2), 128.3 (C-8), 126.9 (C-10), 126.2 (C-9), 115.0 (C-1), 78.3 (C-6), 41.5 (C-5), 34.1 (C-3), 23.2 (C-4) ppm; IR (ATR): ν_{max} 3469.3, 3061.8, 2947.5, 2980.1, 1640.2, 1598.9, 1493.3, 1446.86, 1162.6, 1058.9, 994.1, 953.6, 907.5, 730.8, 697.5, 604.22 cm^{-1}; HRMS (ESI): m/z calcd for $C_{18}H_{20}NaO^+$ $(M\text{-}Na)^+$ 275.1406; found 275.1412.

3,3-Disubstituted



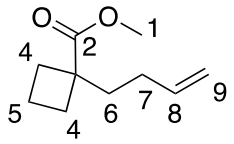
2,2-Dimethyl-hex-5-enoic acid ethyl ester (S4a)



To a solution of diisopropylamine (1.51 ml, 10.8 mmol) in dry THF (5 ml) at -78 °C under N_2 was added n-BuLi (2.5 M in hexanes, 10.8 mmol) and the solution stirred for 45 mins. A solution of ethyl isobutyrate (1.30 ml, 9.91 mmol) in THF (5 ml) was added (1 ml/min) at -78 °C and reaction stirred for 45 mins. 4-Bromo-1-butene (1.00 ml, 9.91 mmol) was added over 1 min at -78 °C and the reaction warmed to room temperature. The reaction was stirred overnight and quenched with 1 M HCl (10 ml). The reaction was partitioned with diethyl ether (30 ml) and aqueous phase extracted with diethyl ether (2 x 30 ml), the organic fractions were combined, washed with saturated brine solution (30 ml), dried with $MgSO_4$, filtered and concentrated *in*

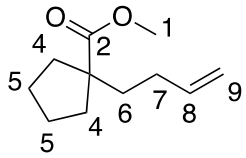
vacuo. The crude residue was purified by flash column chromatography (5% EtOAc/hexane) to afford product as a colorless oil (1.22 g, 70% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.80 (1H, ddt, *J* =16.8 Hz, 9.9 Hz, 6.9 Hz, H-8), 4.99 (1H, ddt, *J* =16.8 Hz, 1.5 Hz, 1.5 Hz, H-9_{trans}), 4.93 (1H, ddt, *J* =9.9, 1.5 Hz, 1.5 Hz, H-9_{cis}), 4.11 (2H, q, *J*=7.6 Hz, H-2), 2.04-1.95 (2H, m, H-7), 1.61-1.59 (2H, m, H-6), 1.25 (3H, t, *J* =7.6 Hz, H-1), 1.16 (6H, s, H-5) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 177.9 (C-3), 138.7 (C-8), 114.5 (C-9), 60.3 (C-2), 42.1 (C-4), 39.9 (C-6), 29.5 (C-7), 25.2 (C-5), 14.3 (C-1) ppm; IR (ATR): ν_{max} 2978, 2938, 1726, 1641, 1473, 1450, 1473, 1386, 1365, 1319, 1280, 1199, 1143, 1094, 1027, 996, 909, 863, 774, 646, 580, 556, 503 cm^{-1}; HRMS (APCI): m/z calcd for $C_{10}H_{19}O_2$ $(M-H)^+$ 171.1380; found 171.1373. Spectroscopical data are in full agreement with those previously reported.[1]

1-But-3-enyl-cyclobutanecarboxylic acid methyl ester (S4b)



S4b was synthesized using the same procedure as **S4a** with diisopropylamine (0.68 ml, 4.82 mmol), n-BuLi (2.5 M in hexanes, 4.82 mmol), methyl cyclobutane carboxylate (0.5 ml, 4.38 mmol) and 4-bromo-1-butene (0.45 ml, 4.38 mmol). The crude residue was purified by flash column chromatography (2% EtOAc/hexane) to afford **S4b** as a colorless oil (285 mg, 66% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.77 (1H, ddt, *J* = 16.8 Hz, 9.9 Hz, 6.1 Hz, H-8), 5.01 (1H, ddt, *J* = 16.8 Hz, 1.5 Hz, 1.5 Hz, H-9_{trans}), 4.94 (1H, ddt, *J* = 9.9 Hz, 1.5 Hz, 1.5 Hz, H-9_{cis}), 3.66 (3H, s, H-1), 2.43-2.32 (2H, m, H-4), 1.99-1.83 (8H, m, H-4, H-5, H-6, H-7) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 177.6 (C-2), 138.3 (C-8), 114.7 (C-9), 51.8 (C-1), 47.5 (C-3), 37.3 (C-6), 30.1 (C-4), 29.4 (C-7), 15.7 (C-5) ppm; IR (ATR): ν_{max} 3077, 2948, 2869, 1731, 1693, 1641, 1434, 1329, 1283, 1244, 1201, 1142, 1112, 994, 911, 806, 692, 637, 458 cm^{-1}; HRMS (APCI): m/z calcd for $C_{10}H_{17}O_2$ $(M-H)^+$ 169.12231; found 169.12218. Spectroscopical data are in full agreement with those previously reported.[1]

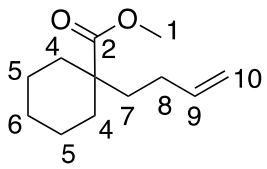
1-But-3-enyl-cyclopentanecarboxylic acid methyl ester (S4c)



S4c was synthesized using the same procedure as **S4a** with diisopropylamine (1.50 ml, 11.0 mmol), n-BuLi (2.5 M in hexanes, 11.0 mmol), methyl cyclopentane carboxylate (1.32 g, 10.1 mmol) and 4-bromo-1-butene (1.00 ml, 10.1 mmol). **S4c** yielded as a colourless oil (1.4 g, 91% yield) after column chromatography (2% EtOAc/hexane). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.74 (1H, ddt, *J* = 16.9 Hz, 10.5 Hz, 6.9 Hz, H-8), 4.98 (1H, ddt, *J* = 16.9 Hz, 1.5 Hz, 1.5 Hz, H-9_{trans}), 4.92 (1H, ddt, *J* = 10.5 Hz, 1.5 Hz, 1.5 Hz, H-9_{cis}), 3.65 (3H, s, H-1), 2.19-2.07 (2H, m, H-4), 1.97-1.91 (2H, m, H-7), 1.70-1.65 (2H, m, H-6), 1.63-1.54 (4H, m, H-5), 1.50-1.45 (2H, m, H-4)

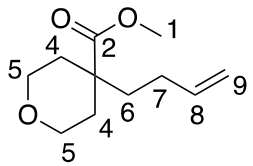
ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 178.3 (C-2), 138.5 (C-8), 114.5 (C-9), 53.9 (C-3), 51.8 (C-1), 38.5 (C-6), 36.1 (C-4), 30.5 (C-7), 25.0 (C-5); IR (ATR): ν_{max} 3078, 2951, 2871, 1730, 1641, 1452, 1339, 1255, 1196, 1162, 994, 910 cm^{-1}. Spectroscopical data are in full agreement with those previously reported.[1]

1-But-3-enyl-cyclohexanecarboxylic acid methyl ester (S4d)



S4d was synthesized using the same procedure as **S4a** with diisopropylamine (1.51 ml, 11.0 mmol), n-BuLi (2.5 M in hexanes, 11.0 mmol), methyl cyclohexane carboxylate (1.50 ml, 10.1 mmol) and 4-bromo-1-butene (1.00 ml, 10.1 mmol). The crude residue was purified by flash column chromatography (2% EtOAc/hexane) to afford **S4d** as a colorless oil (1.61 g, 80% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.76 (1H, ddt, *J* =16.9 Hz, 10.0 Hz, 6.3 Hz, H-9), 4.99 (1H, ddt, *J* =16.9 Hz, 1.5 Hz, 1.5 Hz, H-10_{trans}), 4.93 (1H, ddt, *J* =10.0 Hz, 1.5 Hz, 1.5 Hz, H-10_{cis}), 3.68 (3H, s, H-1), 2.14-2.04 (2H, m, H-4), 2.00-1.99 (2H, m, H-8), 1.65-1.50 (5H, m, H-5, H-6, H-7), 1.40-1.16 (5H, m, H-4, H-5, H-6) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 177.3 (C-2), 138.6 (C-9), 114.5 (C-10), 51.5 (C-1), 46.9 (C-3), 39.8 (C-7), 34.3 (C-4), 28.6 (C-8), 26.0 (C-6), 23.3 (C-5); IR (ATR): ν_{max} 3078, 2930, 2854, 1727, 1641, 1453, 1432, 1364, 1330, 1292, 1275, 1194, 1156, 1134, 1040, 995, 959, 909, 891, 850, 800, 765, 1649, 620, 567, 514 cm^{-1}; HRMS (APCI) calcd for $C_{12}H_{21}O_2$ $(M-H)^+$ 197.153606; found 197.154279. Spectroscopical data are in full agreement with those previously reported.[1]

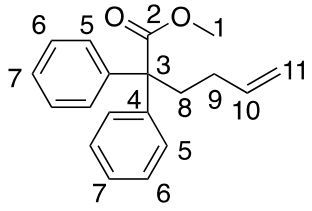
4-But-3-enyl-tetrahydro-pyran-4-carboxylic acid methyl ester (S4e)



S4e was synthesized using the same procedure as **S4a** with diisopropylamine (1.54 ml, 11.0 mmol), n-BuLi (2.5 M in hexanes, 11.0 mmol), methyl tetrahydro-2H-pyran-4-carboxylate (1.54 ml, 10.1 mmol) and 4-bromo-1- butene (1.00 ml, 10.1 mmol). **S4e** yielded as a colourless oil (1.45 g, 73% yield) after column chromatography (10% EtOAc/hexane). ^{1}HNMR (400 MHz, $CDCl_3$): δ 5.75 (1H, ddt, *J* = 16.9, 10.5, 6.4 Hz, H-8), 5.00 (1H, ddt, *J* = 16.9, 1.5 Hz, H-9_{trans}), 4.95 (1H, ddt, *J* = 10.5, 1.5 Hz, H-9_{cis}), 3.83 (2H, ddd, *J* = 11.7, 4.4, 4.1 Hz, H-5), 3.72 (3H, s, H-1), 3.43 (2H, ddd, *J* = 11.7, 2.3 Hz, H-5), 2.10 (2H, ddd, *J* = 13.7, 4.4, 2.3 Hz, H-4), 2.02-1.91 (2H, m, H-7), 1.67-1.59 (2H, m, H-6), 1.52 (2H, ddd, *J* = 13.7, 11.7, 4.1 Hz, H-4) ppm; ^{13}CNMR (101 MHz, $CDCl_3$): δ 176.2 (C-2), 138.0 (C-8), 115.0 (C-9), 65.6 (C-5), 51.9 (C-1), 44.9 (C-3), 40.0 (C-6), 34.3 (C-4), 28.2 (C-7); IR (ATR): ν_{max} 3078, 2954, 2852, 1728, 1641, 1452, 1389, 1337, 1299, 1242, 1210, 1194, 1152, 1108, 1034,

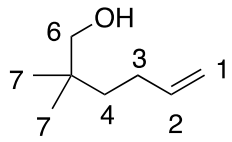
1015, 997, 982, 912, 888, 840, 802, 775, 600, 561, 491, 462 cm^{-1}; HRMS (ESI) calcd for $C_{11}H_{18}NaO_3$ $(M + Na)^+$ 211.1150; found 211.1150. Spectroscopical data are in full agreement with those previously reported.[1]

2,2-Diphenyl-hex-5-enoic acid methyl ester (S4f)



S4f was synthesized using the same procedure as **S4a** with diisopropylamine (1.54 ml, 11.0 mmol), n-BuLi (2.5 M in hexanes, 11.0 mmol), diphenyl methyl acetate (2.24 g, 10.1 mmol) and 4-bromo-1- butene (1.30 ml, 10.1 mmol). **S4f** yielded as a colourless oil (117 mg, 42% yield) after column chromatography (4% EtOAc/hexane). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44-7.41 (4H, m, H-5), 7.34-7.30 (4H, m, H-6), 7.26-7.23 (2H, m, H-7), 5.75 (1H, ddt, *J* = 16.8, 9.9, 6.5 Hz, H-10), 5.01 (1H, ddt, *J* = 16.8, 1.5 Hz, H-11_{trans}), 4.96 (1H, ddt, *J* = 9.9, 1.5 Hz, H-11_{cis}), 3.68 (3H, s, H-1), 2.48-2.44 (2H, m, H-8), 1.83-1.77 (2H, m, H-9) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 174.8 (C-2), 142.8 (C-4), 138.4 (C-10), 129.0 (C-5), 128.0 (C-6), 126.9 (C-7), 114.6 (C-11), 60.3 (C-3), 52.5 (C-1), 37.4 (C-8), 29.8 (C-9) ppm; IR (ATR): ν_{max} 3024, 3060, 2950, 1729, 1640, 1598, 1495, 1445, 1221, 1121, 1063, 1033, 913, 784, 760, 699, 602, 576, 502, 481 cm^{-1}; HRMS (ESI) calcd for $C_{19}H_{21}O_2$ $(M + H)^+$ 281.1528 ; found 281.1536. Spectroscopical data are in full agreement with those previously reported.[1]

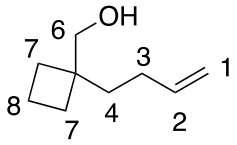
2,2-Dimethylhex-5-en-1-ol (6a)



To a dry round bottom flask, $LiAlH_4$ (431mg, 11.5 mmol) was added, dry Et_2O (5ml) was then added to form a suspension and the flask was cooled to 0 °C. To this mixture, a solution of **S4a** (1.31 g, 7.72 mmol) in dry Et_2O (5ml) was added (1 ml /min). After completion of addition, the reaction was allowed to warm to rt as it was stirred overnight. Upon completion by TLC, the reaction was cooled to 0 °C and was quenched with 0.4 ml of water, 0.4 ml of 15% w/w NaOH solution, and then 1.2 ml of water. The reaction was stirred for 10 min at 0 °C before $MgSO_4$ was added. The resulting white slurry was stirred for 30 min at rt. The white solids were the removed via filtration with Et_2O rinsing. The solution was then concentrated *in vacuo* and yielded the product as colorless oil (883 mg, 89% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.80 (1H, ddt, *J* = 17.1 Hz, 10.4 Hz, 6.6 Hz, H-2), 5.03 (1H, ddt, *J* = 17.1 Hz, 2.0 Hz, 1.4 Hz, H-1_{trans}), 4.95 (1H, ddt, *J* = 10.4 Hz, 2.0 Hz, 1.4 Hz, H-1_{cis}), 3.31 (2H, s, H-6), 2.05-1.98 (2H, m, H-3), 1.35-1.30 (2H, m, H-4), 0.88 (6H, s, H-7) ppm; ^{13}C NMR(101 MHz, $CDCl_3$): δ139.6 (C-2), 114.0 (C-1), 71.6 (C-6), 37.9 (C-5), 35.1 (C-3), 28.4 (C-4), 23.9 (C-7) ppm; IR (ATR): ν_{max}

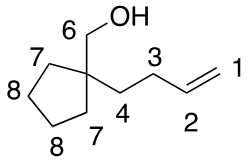
3369, 3078, 2971, 1641, 1377, 1151, 992, 908, 764 cm^{-1}; HRMS (ESI): m/z calcd for $C_8H_{16}O$ $(M-H)^+$ 113.0966; found 113.0958.

(1-(But-3-en-1-yl)cyclobutyl)methanol (6b)



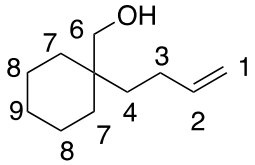
6b was synthesized using the same procedure as **6a** with $LiAlH_4$ (1.10 g, 6.45 mmol) and **S4b** (954 mg, 5.23 mmol). **6b** yielded as a colourless oil (455 mg, 89% yield). ^1H NMR (400 MHz, $CDCl_3$): δ 5.83 (1H, ddt, *J* =16.9 Hz, 10.0 Hz, 6.3 Hz, H-2), 5.01 (1H, ddt, *J* =16.9 Hz, 1.5 Hz, 1.5 Hz, H-1_{trans}), 4.92 (1H, ddt, *J* =10.0 Hz, 1.5 Hz, 1.5 Hz, H-1_{cis}), 3.53 (2H, s, H-6), 2.02-1.84 (2H, m, H-3), 1.82-1.80 (2H, m, H-7), 1.78-1.70 (3H, m, H-4, H-7), 1.68-1.60 (1H, m, H-4), 1.59-1.55 (2H, m, H-8) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 139.4 (C-2), 114.2 (C-1), 67.9 (C-6), 42.9 (C-5), 36.0 (C-3), 28.4 (C-4), 28.3 (C-7), 15.3 (C-8) ppm; IR (ATR): ν_{max} 3343, 2980, 2933, 1641, 1442, 1253, 1168, 994, 955, 908, 633, 553 cm^{-1}; HRMS (APCI): m/z calcd for $C_9H_{17}O$ $(M-H)^+$ 141.1274; found 141.1264.

(1-(But-3-en-1-yl)cyclopentyl)methanol (6c)



6c was synthesized using the same procedure as **6a** with $LiAlH_4$ (294 mg, 7.85 mmol) and **S4c** (954 mg, 5.23 mmol). **6c** yielded as a colourless oil (718 mg, 89% yield). ^1H NMR (400 MHz, $CDCl_3$): δ 5.81 (1H, ddt, *J* =16.9 Hz, 10.0 Hz, 6.3 Hz, H-2), 5.00 (1H, ddt, *J* =16.9 Hz, 1.5 Hz, 1.5 Hz, H-1_{trans}), 4.90 (1H, ddt, *J* =10.0 Hz, 1.5 Hz, 1.5 Hz, H-1_{cis}), 3.37 (2H, s, H-6), 2.04-1.97 (2H, m, H-3), 1.84-1.72 (1H, m, H-4), 1.58-1.52 (3H, m, H-4, H-7), 1.46-1.39 (4H, m, H-7, H-8), 1.39-1.31 (2H, m, H-8) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 139.6 (C-2), 114.1 (C-1), 68.3 (C-6), 47.0 (C-5), 36.4 (C-3), 34.6 (C-7), 29.3 (C-4), 25.4 (C-8) ppm; IR (ATR): ν_{max} 3380.8, 2943.4, 2871.1, 1710.7, 1641.1, 1282.9, 1094.8, 991.7, 907.9, 733 cm^{-1}.

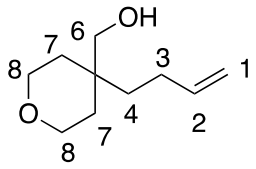
(1-(But-3-en-1-yl)cyclohexyl)methanol (6d)



6d was synthesized using the same procedure as **6a** with $LiAlH_4$ (571 mg, 15.2 mmol) and **S4d** (1.72 mg, 10.2 mmol). **6d** yielded as a colourless oil (139 mg, 61% yield). ^1H NMR (400 MHz, $CDCl_3$): δ 5.81 (1H, ddt, *J* =16.9 Hz, 10.0 Hz, 6.3 Hz, H-2), 5.00 (1H, ddt, *J* =16.9 Hz, 1.5 Hz, 1.5 Hz, H-1_{trans}), 4.96 (1H, ddt, *J* =10.0 Hz, 1.5 Hz,

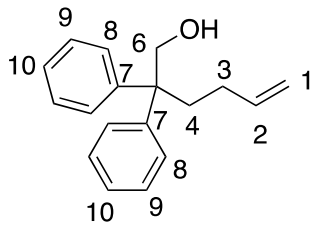
1.5 Hz, H-1_{cis}), 3.40 (2H, s, H-6), 2.00-1.94 (2H, m, H-3), 1.44-1.38 (8H, m, H-7, H-8), 1.37-1.27 (4H, m, H-4, H-9) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 139.8 (C-2), 114.1 (C-1), 68.4 (C-6), 37.1 (C-5), 34.0 (C-3), 32.5 (C-7), 27.6 (C-4), 26.5 (C-9), 21.5 (C-8); IR (ATR): ν_{max} 3338, 3076, 2851, 1960, 1640, 1452, 1033, 906, 848, 632 cm^{-1}; HRMS (APCI) m/z calcd for $C_{11}H_{21}O$ $(M-H)^+$ 169.1587; found 169.1592.

(4-(but-3-en-1-yl)tetrahydro-2*H*-pyran-4-yl)methanol (6e)



6e was synthesized using the same procedure as **6a** with $LiAlH_4$ (513 mg, 13.5 mmol) and **S4e** (1.79 g, 9.03 mmol). **6e** yielded as a colourless oil (1.15 g, 75% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.79 (1H, ddt, *J* =16.9 Hz, 10.0 Hz, 6.3 Hz, H-2), 5.00 (1H, ddt, *J* =16.9 Hz, 1.5 Hz, 1.5 Hz, H-1_{trans}), 4.94 (1H, ddt, *J* =10.0 Hz, 1.5 Hz, 1.5 Hz, H-1_{cis}), 3.65-3.62 (4H, m, H-8), 3.47 (2H, s, H-6), 2.01-1.95 (2H, m, H-3), 1.53-1.45 (4H, m, H-7), 1.42 - 1.37 (2H, m, H-4) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 139.1 (C-2), 114.5 (C-1), 67.0 (C-6), 63.7 (C-8), 35.1 (C-5), 33.7 (C-3), 32.5 (C-7), 27.4 (C-4) ppm; IR (ATR): ν_{max} 3414.2, 3077.2, 2940.9, 2866.23, 2241.3, 1640.9, 1416.6, 1357.3, 1097.5, 909.8730.1, 646.5, 536.5 cm^{-1}; HRMS (APCI): m/z calcd for $C_{10}H_{19}O_2$ $(M-H)^+$ 171.1380; found 171.1371.

2,2-diphenylhex-5-en-1-ol (6f)

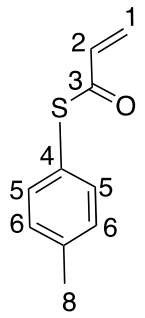


6f was synthesized using the same procedure as **6a** with $LiAlH_4$ (513 mg, 13.5 mmol) and **S4f** (1.79 g, 9.03 mmol) in dry Et_2O (5 ml). **6f** yielded as a colourless oil (1.15 g, 75% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32-7.30 (4H, m, H-8), 7.28-7.24 (2H, m, H-10), 7.22-7.18 (4H, m, H-9), 5.78 (1H, ddt, *J* = 17.1 Hz, 10.2 Hz, 7.3 Hz, H-2), 4.97 (1H, ddt, *J* = 17.1 Hz, 2.5 Hz, 1.4 Hz, H-1_{trans}), 4.92 (1H, ddt, *J* = 10.2 Hz, 2.5 Hz, 1.4 Hz, H-1_{cis}), 4.14 (2H, s, H-6), 2.27-2.23 (2H, m, H-3), 1.83-1.77 (2H, m, H-4) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 145.5 (C-7), 138.9 (C-2), 128.4 (C-8), 128.1 (C-9), 126.5 (C-10), 114.5 (C-1), 68.2 (C-6), 52.0 (C-5), 35.6 (C-3), 28.2 (C-4) ppm; IR (ATR): ν_{max} 3469, 3062, 2948, 2980, 1640, 1599, 1493, 1447, 1163, 1059, 994, 954, 908, 731, 698, 604 cm^{-1}; HRMS (APCI): m/z calcd for $C_{18}H_{20}NaO$ $(M-Na)^+$ 275.1406; found 275.1412.

Synthesis of Thioesters

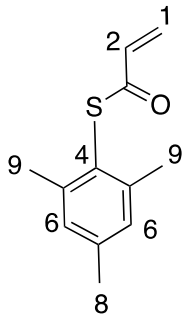
Note: In all cases competing 1,4-addition of the thiol was seen. This product could not be completely removed chromatographically so thioacrylates containing ~35% of the 1,4-addition product were used in the subsequent metathesis reaction.

Thioacrylic acid p-tolyl ester (2a)



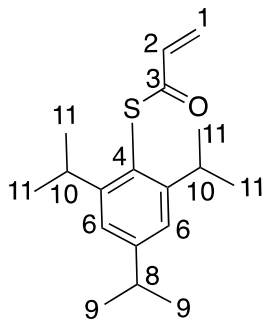
$NaBH_4$ (0.05 g, 1.32 mmol) and p-thiocresol (5.46 g, 44.0 mmol) were added in that order to a solution of NaOH (15% w/w aq. 20 ml) and stirred at room temperature for an hour and then cooled to 0 ^oC before use. In a separate flask, butylated hydroxytoluene (0.145 g, 0.66 mmol) and acryloyl chloride (5.36 ml, 66.0 mmol) were dissolved in cyclohexane (30 ml). To this solution under cooling at 0 ^oC, the borohydride solution was added (1ml/min) and stirred for 30 min. The solution was then heated to 55 ^oC and stirred for an hour. The reaction mixture was extracted with Et_2O (80 ml), washed with $NaHCO_3$ (100 ml) and brine solution (100 ml), and then dried over anhydrous $MgSO_4$. A portion of butylated hydroxytoluene (42.3 mg) was added prior to evaporation to prevent polymerization. **2a** yielded as a pale-yellow oil (5.37 g, 68% yield) after column chromatography (2% Et_2O/hexane). ^1H NMR (400 MHz, $CDCl_3$): δ 7.33 (2H, d, *J* = 8.4 Hz, H-5) 7.24 (2H, d, *J* =8.4 Hz, H-6), 6.45 (1H, dd, *J* =17.5 Hz, 10.0 Hz, H-2), 6.38 (1H, dd, *J* =17.5 Hz, 1.5 Hz, H-1), 5.75 (1H, dd, *J* =10.0 Hz, 1.5 Hz, H-1), 2.39 (3H, s, H-8) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 189.1 (C-3), 139.9 (C-7), 134.7 (C-5), 134.5 (C-2), 130.2 (C-6), 127.4 (C-1), 123.7 (C-4), 21.5 (C-8) ppm; IR (ATR): ν_{max} 3023, 2921, 1681, 1611, 1597, 1493, 1447, 1393, 1304, 1276, 1160, 986, 940, 803, 722, 704, 627, 528, 470 cm^{-1}; HRMS (ESI) m/z calcd for $C_{10}H_{11}OS$ $(M-H)^+$ 179.0536; found 179.0536.

Thioacrylic acid 2,4,6-trimethyl-phenyl ester (2b)



2b was synthesized using the same procedure as **2a** with NaOH (15% w/w aq. 5 ml), $NaBH_4$ (0.015 g, 0.27 mmol), 2,4,6 trimethyl thiophenol (1.36 g, 8.93 mmol), butylated hydroxytoluene (0.030 g, 0.13 mmol) and acryloyl chloride (1.08 ml, 13.34 mmol). **2b** yielded as a pale-yellow oil (1.26 g, 69% yield) after column chromatography (2% Et_2O/hexane). ^1H NMR (400 MHz, $CDCl_3$): δ 6.98 (2H, s, H-6), 6.49 (1H, dd, *J* =17.5 Hz, 10.0 Hz, H-2), 6.40 (1H, dd, *J* =17.5 Hz, 1.2 Hz, H-1), 5.74 (1H, dd, *J* =10.0 Hz, 1.2 Hz, H-1), 2.31 (6H, s, H-9), 2.29 (3H, s, H-8) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 188.3 (C-3), 142.8 (C-4), 140.2 (C-2), 134.7 (C-6), 129.4 (C-7), 127.1 (C-1), 123.1 (C-5), 21.7 (C-9), 21.3 (C-8) ppm; IR (ATR): ν_{max} 2952, 2920, 1681, 1612, 1603, 1463, 1375, 1299, 1160, 1031, 994, 940, 850, 726, 631, 558 cm^{-1}; HRMS (ESI) m/z calcd for $C_{12}H_{15}OS$ $(M-H)^+$ 207.0838; found 207.0838.

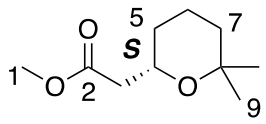
Thioacrylic acid 2,4,6-triisopropyl-phenyl ester (2c)



2c was synthesized using the same procedure as **2a** with NaOH (15% w/w aq. 5 ml), $NaBH_4$ (4.80 mg, 0.131 mmol) and 2,4,6-triisopropylthiophenol (1.00 g, 4.23 mmol), butylated hydroxytoluene (9.33 mg, 0.04 mmol) and acryloyl chloride (1.00 ml, 6.74 mmol). **2c** yielded as a pale-yellow oil (401 mg, 52% yield) after column chromatography (2% Et_2O/hexane). ^1H NMR (400 MHz, $CDCl_3$): δ 7.09 (2H, s, H-6), 6.50 (1H, dd, *J* =17.5 Hz, 10.0 Hz, H-2), 6.38 (1H, dd, *J* =17.5 Hz, 1.2 Hz, H-1), 5.74 (1H, dd, *J* =10.0 Hz, 1.2 Hz, H-1), 3.43-3.38 (2H, sept, *J* =6.9 Hz, H-10), 2.96-2-91 (1H, sept, *J* =6.9 Hz, H-8), 1.25 (6H, d, *J* =6.9 Hz, H-9), 1.18 (12H, d, *J* =6.9 Hz, H-11) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 189.3 (C-3), 152.6 (C-5), 151.2 (C-7), 134.5 (C-1), 126.8 (C-2), 122.1 (C-6), 121.1 (C-4), 34.4 (C-8), 32.0 (C-10), 29.7 (C-10'), 23.9 (C-9), 22.7 (C-11) ppm. IR (ATR): ν_{max} 2952, 2920, 1681, 1612, 1603, 1463, 1375, 1299, 1160, 1031, 994, 940, 850, 726, 631, 558 cm^{-1}. HRMS (ESI) m/z calcd for $C_{18}H_{26}OS$ $(M-H)^+$ 291.1707; found 291.1704.

Determination of the Absolute Stereochemistry

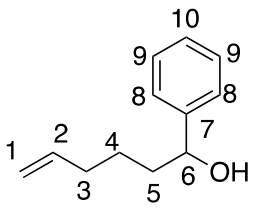
(6,6-Dimethyl-tetrahydro-pyran-2-yl)-acetic acid methyl ester (S6)



To solution of THP thioester **4b** (25.0 mg, 0.09 mmol, 69% ee) in dry MeOH/DCM (1:1, 1 ml) was added AgOTf (67.1 mg, 0.26 mmol) and the reaction was stirred overnight. After completion of the reaction by TLC, the reaction was diluted with Et_2O (5 ml) and filtered through a silica plug followed by Et_2O (3 X 15 ml). The combined filtrate was concentrated in *vacuo* and the crude residue was purified by flash column chromatography 20% EtOAc/hexane to afford **4b** as a pale yellow oil (14.1 mg, 88% yield, 67% ee).[1]H NMR (400 MHz, $CDCl_3$): δ 3.97 (1H, dddd, *J* =11.4 Hz, 7.2 Hz, 4.7 Hz, 2.7 Hz, H-4), 3.65 (3H, s, H-1), 2.47 (1H, dd, *J* =15.1 Hz, 7.2 Hz, H-3), 2.33 (1H, dd, *J* =15.1 Hz, 4.7 Hz, H-3), 1.68-1.60 (3H, m, H-5, H-6), 1.45-1.30 (2H, m, H-7), 1.19 (3H, s, H-9), 1.16 (3H, s, H-9'), 1.13-1.08 (1H, m, H-6) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ 172.2 (C-2), 72.2 (C-8), 67.4 (C-4), 51.6 (C-1), 42.0 (C-3), 36.0 (C-5), 31.8 (C-9), 31.2 (C-7), 21.9 (C-9'), 19.9 (C-6) ppm. IR (ATR): ν_{max} 2974, 2935, 1740, 1435, 1380, 1192 cm^{-1}; ESI-MS: m/z calcd for $C_{10}H_{19}NaO_3^+$ $(M+Na)^+$ 209.1148; found 209.1151. $[\alpha]_D^{20}$ + 26.4° (c 0.71, $CHCl_3$) [lit. $[\alpha]_D^{20}$ - 51.2° (c 0.86, $CHCl_3$) for (*R*) enantiomer[2]].

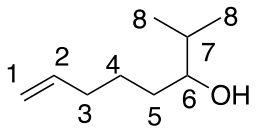
Kinetic Resolution Studies

1-Phenylhex-5-en-1-ol (S7a)



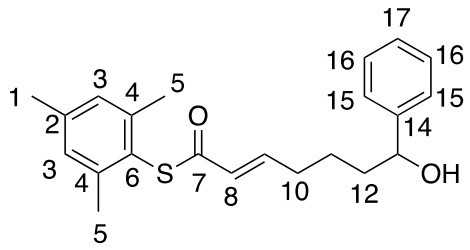
S7a was synthesised using the same procedure as **1a** with a solution of benzaldehyde (1.04 g, 9.84 mmol) in Et_2O (10 mL). The oil was purified by flash column chromatography on silica with 10% of ethyl acetate in n-hexane to yield **S7a** as a colourless oil (0.92 g, 53% yield). ^1H NMR (400 MHz, $CDCl_3$): δ 7.36-7.32 (2H, m, H-8), 7.32-7.28 (2H, m, H-9), 7.27-7.26 (1H, m, H-10), 5.77 (1H, ddt, *J* = 17.0 Hz, 10.3 Hz, 6.9 Hz, H-2), 4.99 (1H, ddt, *J* = 17.0 Hz, 2.5 Hz, 1.4 Hz, H-1), 4.93 (1H, ddt, *J* = 10.3 Hz, 2.5 Hz, 1.4 Hz, H-1), 4.68 (1H, t, *J* = 6.4 Hz, H-6), 2.10-2.04 (2H, m, H-3), 1.85-1.75 (2H, m, H-5), 1.56-1.48 (1H, m, H-4), 1.44-1.33 (1H, m, H-4) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): 144.9 (C-7), 138.7 (C-2), 128.6 (C-9), 127.7 (C-10), 126.0 (C-8), 114.8 (C-1), 74.7 (C-6), 38.6 (C-5), 33.7 (C-3), 25.2 (C-4) ppm; IR (ATR): ν_{max} 3353, 3066, 2977, 2861, 1640, 1493, 1454, 1062, 1027, 993, 909, 761, 699, 550 cm^{-1}; HRMS (ESI): m/z calcd for $C_{12}H_{16}NaO$ $(M-Na)^+$ 199.1093; found 199.1090.

2-Methyloct-7-ene-3-ol (S7b)



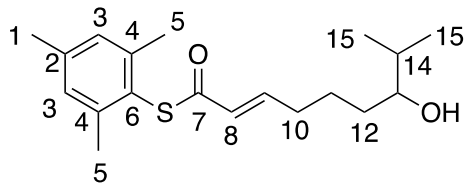
S7b was synthesised using the same procedure as **1a** with a solution of isobutyraldehyde (292 mg, 4.00 mmol) in THF (2 mL). The oil was purified by flash column chromatography on silica with 10% of ethyl acetate in n-hexane to yield **S7b** as a colourless oil (143 mg, 25% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.80 (1H, ddt, *J* = 17.1 Hz, 10.2 Hz, 6.8 Hz, H-2), 5.00 (1H, ddt, *J* = 17.1 Hz, 2.0 Hz, 1.8 Hz, H-1), 4.93 (1H, ddt, *J* = 10.2 Hz, 2.0 Hz, 1.2 Hz, H-1), 3.35 (1H, ddd, *J* = 8.5 Hz, 5.1 Hz, 3.5 Hz, H-6), 2.14-1.98 (2H, m, H-3), 1.69-1.52 (2H, m, H-5), 1.40-1.32 (2H, m, H-4), 0.90 (3H, d, *J* = 4.1 Hz, H-8), 0.89 (3H, d, *J* = 4.1 Hz, H-8) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): 138.9 (C-2), 114.7 (C-1), 76.7 (C-6), 33.9 (C-5), 33.7 (C-3), 33.6 (C-7), 25.4 (C-4), 18.9 (C-8), 17.2 (C-8) ppm; IR (ATR): ν_{max} 3370, 3077, 2958, 2934, 2873, 1698, 1641, 1384, 1367, 1260, 992, 908 cm^{-1}; HRMS (ESI): m/z calcd for $C_9H_{19}O^+$ $(M-H)^+$ 147.1430; found 147.1422.

(*E*)-*S*-Mesityl 7-hydroxy-7-phenylhept-2-enethioate (8a)



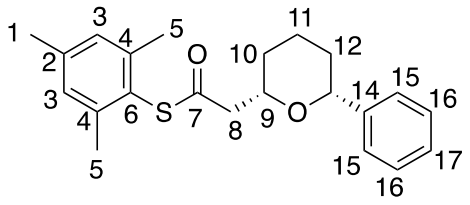
8a was synthesised using the same procedure as **S1a** with unsaturated alcohol **S7a** (60 mg, 0.03 mmol, 1.0 eq), thioester **2b** (175 mg, 0.61 mmol, 3.0 eq), copper (I) iodide (6.00 mg, 0.03 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (16.0 mg, 0.03 mmol, 10 mol%) The mixture was purified by column chromatography on silica using 15% ethyl acetate in n-hexane to yield **8a** as a yellow oil (91 mg, 75% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38-7.34 (2H, m, H-15), 7.34-7.30 (2H, m, H-16), 7.29-7.26 (1H, m, H-17), 6.97 (2H, s, H-3), 6.92 (1H, dt, *J* =15.6 Hz, 6.8 Hz, H-9), 6.18 (1H, d, *J* = 15.6 Hz, H-8), 4.71-4.67 (1H, m, H-13), 2.30 (6H, s, H-5), 2.29 (3H, s, H-1), 2.28-2.21 (2H, m, H-10), 1.60-1.47 (4H, m, H-11, H-12), ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 187.8 (C-7), 145.7 (C-9), 144.6 (C-6), 142.8 (C-4), 140.0 (C-2), 129.3 (C-3), 128.7 (C-16), 128.4 (C-8), 127.9 (C-17), 126.0 (C-15), 123.5 (C-14), 74.5 (C-13), 38.5 (C-12), 32.2 (C-10), 24.3 (C-11), 21.7 (C-5), 21.3 (C-1) ppm; IR (film NaCl): ν_{max} 3425, 3028, 2924, 2856, 1686, 1630, 1453, 1028, 977, 701 cm^{-1}; HRMS (ESI): m/z calcd for $C_{22}H_{26}NaO_2S^+$ $(M+Na)^+$ 377.1546; found 377.1553.

(*E*)-*S*-Mesityl 7-hydroxy-8-methylnon-2-enethioate (8b)



8b was synthesised using the same procedure as **S1a** with unsaturated alcohol **S7b** (131 mg, 0.92 mmol, 1.0 eq), thioester **2b** (590 mg, 2.87 mmol, 3.0 eq), copper (I) iodide (17.6 mg, 0.09 mmol, 10 mol%) and Hovyeda-Grubbs 2nd generation catalyst (57.7 mg, 0.09 mmol, 10 mol%) The mixture was purified by column chromatography on silica using 20% ethyl acetate in n-hexane to yield **8b** as a brown oil (166 mg, 56% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.00 (2H, s, H-3), 6.95 (1H, dt, *J* =15.5 Hz, 6.8 Hz, H-9), 6.22 (1H, d, *J* = 15.5 Hz, H-8), 3.83-3.35 (1H, m, H-13), 2.30 (6H, s, H-5), 2.28 (3H, s, H-1), 2.27-2.23 (2H, m, H-10), 1.73-1.62 (1H, m, H-14), 1.62-1.52 (2H, m, H-12), 1.43-1.23 (2H, m, H-11), 0.92 (3H, d, *J* = 3.7 Hz, H-15), 0.90 (3H, d, *J* = 3.7 Hz, H-15) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 187.9 (C-7), 146.0 (C-9), 142.8 (C-4), 139.9 (C-6), 129.3 (C-3), 128.3 (C-8), 123.6 (C-2), 76.6 (C-13), 33.7 (C-12), 32.4 (C-10), 31.7 (C-14), 24.60 (C-11), 21.7 (C-5), 21.3 (C-1), 18.9 (C-15), 17.18 (C-15') ppm; IR (film NaCl): ν_{max} 3444, 2955, 2929, 2871, 1684, 1630, 1460, 1375, 1298, 1280, 1139, 1033, 982, 850, 801, 715 cm^{-1}; HRMS (ESI): m/z calcd for $C_{19}H_{28}NaO_2S^+$ $(M+Na)^+$ 343.1702; found 343.1704.

***S*-Mesityl 2-(6-phenyltetrahydro-2H-pyran-2-yl)ethanethioate (9a)**



Racemic-CSA

9a was synthesised using the same procedure as **4a** with alcohol-thioester **8a** (20.0 mg, 0.06 mmol) and rac-CSA (39.0 mg, 0.16 mmol, 3 eq.) The crude was purified by column chromatography on silica using 8% EtOAc in hexane to yield **9a** as a colorless oil (16 mg, 80 % yield).

Asymmetric-(*R*)-TRIP, 50 °C, cyclohexane

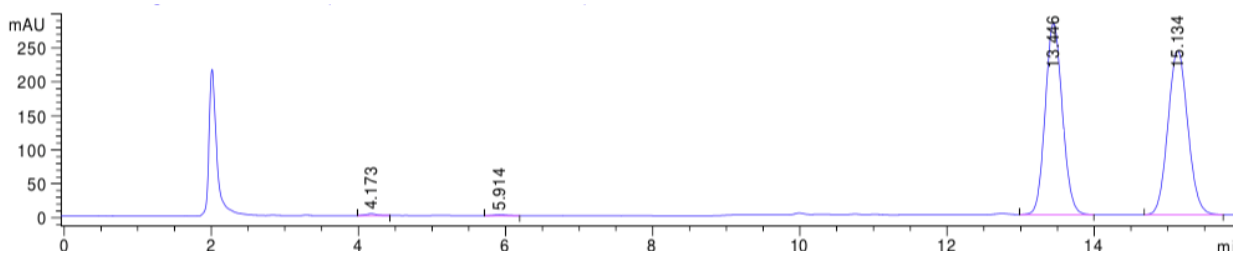
9a was synthesised using the same procedure as **4a** with alcohol-thioester **8a** (40.0 mg, 0.11 mmol) and (*R*)-TRIP **3a** (16.9 mg, 0.02 mmol, 20 mol %). An aliquot (0.25 ml) was taken from the mixture every hour, quenched with (0.05 ml) of triethylamine and passed through a silica plug with (1 ml) of hexane to remove the catalyst. The solution was vacuumed down and dissolved in (0.5 ml) of hexane for HPLC analysis. After 10 hours, the reaction was quenched with (1 ml) of triethylamine and then concentrated and purified using 8% EtOAc in hexane to yield **9a** as a colorless oil (48% conversion, 71% ee).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38-7.34 (2H, m, H-15), 7.34-7.30 (2H, m, H-16), 7.29-7.26 (1H, m, H-17), 6.94 (2H, bs, H-3), 4.41 (1H, dd, *J* = 11.3 Hz, 2.3 Hz, H-13), 4.05 (1H, dddd, *J* =11.3 Hz, 7.6 Hz, 5.3 Hz, 2.0 Hz, H-9), 3.00 (1H, dd, *J* = 14.4 Hz, 7.6 Hz, H-8), 2.78 (1H, dd, *J* = 14.4 Hz, 5.3 Hz, H-8), 2.27 (6H, s, H-5), 2.26 (3H, s, H-1), 2.03-1.83 (2H, m, H-12), 1.79-1.64 (2H, m, H-10), 1.54-1.39 (2H, m, H-11) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 195.2 (C-7), 143.0 (C-2), 142.6 (C-4), 139.9 (C-6), 129.2 (C-3), 128.2 (C-16), 127.2 (C-17), 126.0 (C-15), 124.0 (C-14), 79.8 (C-13), 75.5 (C-9), 50.3 (C-8), 33.1 (C-12), 31.0 (C-14), 29.8 (C-10), 23.9 (C-11), 21.7 (C-5), 21.2 (C-1) ppm; IR (film NaCl): ν_{max} 3028, 2920, 2853, 1700, 1603, 1452, 1088, 1065, 995, 850, 747, 699 cm^{-1}. HRMS (ESI): m/z calcd for $C_{22}H_{26}NaO_2S^+$ $(M+Na)^+$ 377.1546; found 377.1541.

	%Conversion		%ee	
T(h)	**%P**	**%SM**	**%P**	**%SM**
0	0	100	0	0
1	12.7815	87.2185	87.4350	0.3374
2	29.9805	70.0195	85.3644	32.4706
4	42.1505	57.8495	80.7827	69.59798
6	45.3093	54.6908	72.9799	90.7588
8	57.7480	42.2520	67.5487	97.3404

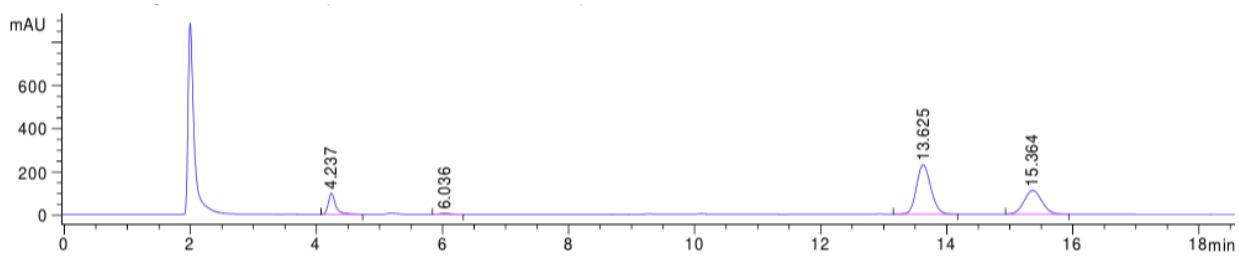
Table 3: Conversion and %ee of Starting Material **9a** and Product **8a**

0 h:



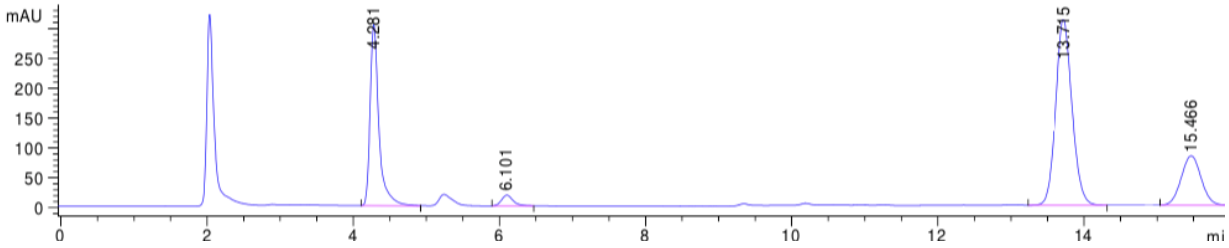
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	4.173	BB	0.1439	25.71851	2.58788	0.2808
2	5.914	BB	0.1669	15.01583	1.33833	0.1639
3	13.446	VB	0.2515	4574.75537	281.63431	49.9456
4	15.134	BB	0.2912	4543.98340	241.89867	49.6097

1 h:



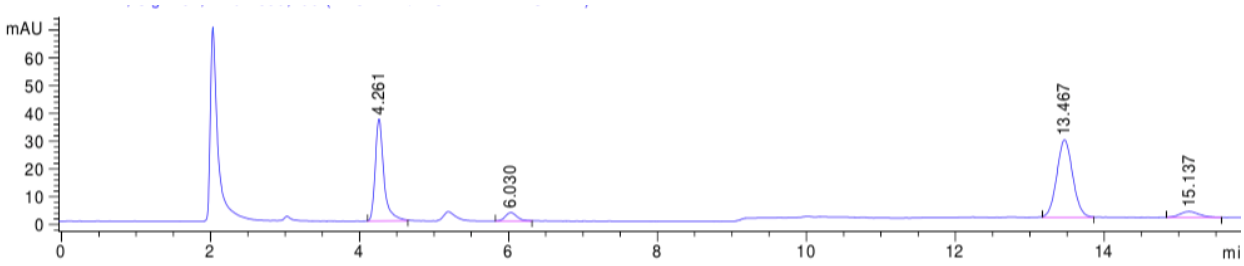
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	4.237	BB	0.1214	798.01410	97.57358	11.9785
2	6.036	BB	0.1636	53.49540	4.97047	0.8030
3	13.625	VB	0.2453	3641.86670	229.32899	54.6658
4	15.364	BB	0.3047	2168.67603	110.61050	32.5527

2 h:



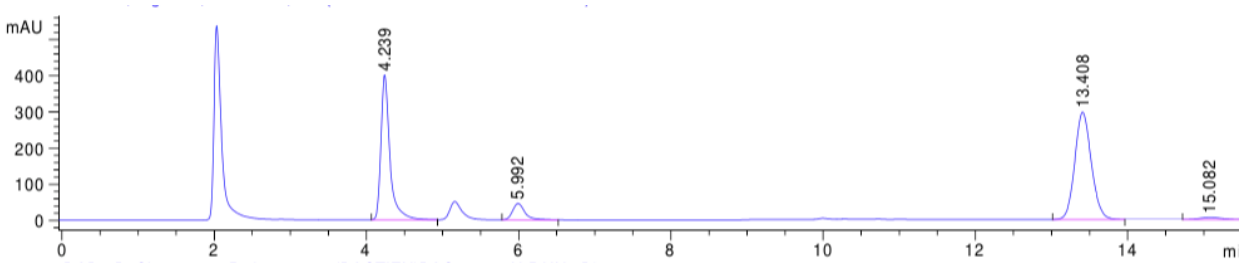
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	4.281	BB	0.1258	2548.53931	304.09341	27.7865
2	6.101	BB	0.1699	201.22401	18.06664	2.1939
3	13.715	VB	0.2367	4835.66162	312.21826	52.7228
4	15.466	BB	0.2965	1586.44092	83.19281	17.2968

4 h:



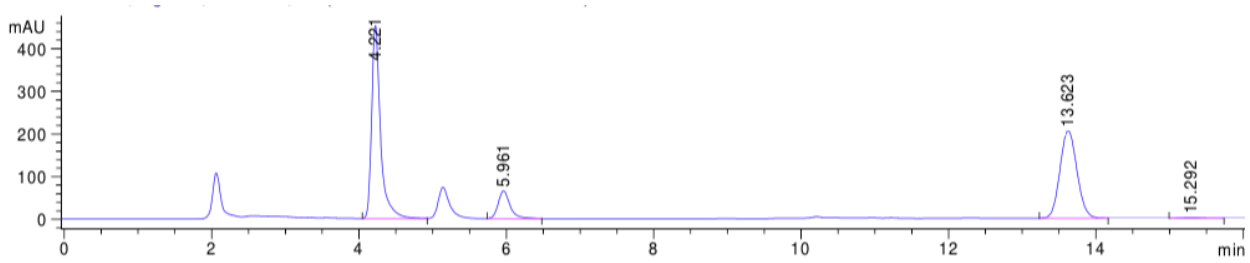
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	4.261	BB	0.1223	297.02185	36.74714	38.0441
2	6.030	BB	0.1675	32.72709	2.99519	4.1919
3	13.467	BB	0.2294	414.37592	27.88330	53.0755
4	15.137	BB	0.2523	36.60488	2.06959	4.6885

6 h:



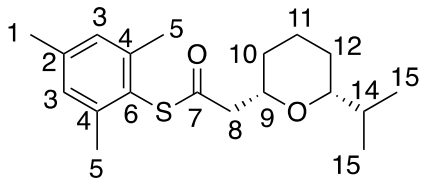
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	4.239	BB	0.1217	3287.93335	400.66153	39.1880
2	5.992	BB	0.1716	513.58417	45.54474	6.1213
3	13.408	BB	0.2316	4472.10254	297.12329	53.3018
4	15.082	BB	0.2919	116.53703	5.91318	1.3890

8 h:



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	4.221	BB	0.1259	3797.96118	452.70950	48.3781
2	5.961	BB	0.1692	735.59698	65.40393	9.3700
3	13.623	BB	0.2505	3291.70166	205.91005	41.9294
4	15.292	BB	0.2280	25.32366	1.43400	0.3226

***S*-Mesityl 2-(6-isopropyltetrahydro-2H-pyran-2-yl)ethanethioate (9b)**



Racemic-CSA

9b was synthesised using the same procedure as **4a** with alcohol-thioester **8b** (19.2 mg, 0.06 mmol) and rac-CSA (41.8 mg, 0.12 mmol, 3 eq.) The crude was purified by column chromatography on silica using 5% EtOAc in hexane to yield **9a** as a yellow oil (10.0 mg, 52 % yield).

Asymmetric-(*R*)-TRIP, 50 °C, cyclohexane

9b was synthesised using the same procedure as **9a** with alcohol-thioester **8b** (40.0 mg, 0.15 mmol) and (*R*)-TRIP **3a** (22.6 mg, 0.03 mmol, 20 mol %). The mixture was purified using 8% EtOAc in hexane to yield **9b** as a yellow oil (53% conversion, 91% ee).

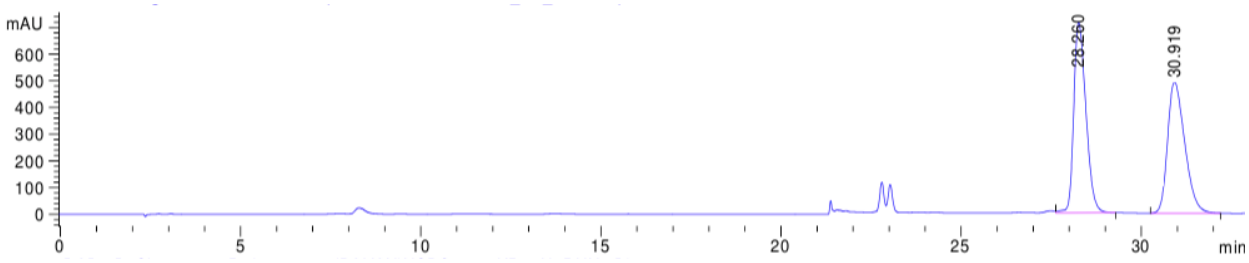
^{1}H NMR (400 MHz, $CDCl_3$): 6.96 (2H, s, H-3), 3.82 (1H, dddd, *J* =11.1 Hz, 8.0 Hz, 4.8 Hz, 1.8 Hz, H-9), 2.97 (1H, ddd, *J* = 11.0 Hz, 6.9 Hz, 1.8 Hz, H-13), 2.88 (1H, dd, *J* = 14.7 Hz, 8.0 Hz, H-8), 2.65 (1H, dd, *J* = 14.7 Hz, 4.8 Hz, H-8), 2.28 (6H, s, H-5), 2.27 (3H, s, H-1), 1.89-1.81 (1H, m, H-14), 1.68-1.45 (6H, m, H-10, H-11, H-12), 0.91 (3H, d, *J* = 6.4 Hz, H-15), 0.85 (3H, d, *J* = 6.4 Hz, H-15) ppm; ^{13}C NMR (101 MHz, $CDCl_3$): δ 195.2 (C-7), 142.6

(C-2), 139.9 (C-4), 129.2 (C-3), 124.1 (C-6), 83.3 (C-13), 74.9 (C-9), 50.5 (C-8), 33.4 (C-14), 31.4 (C-10), 27.9 (C-12), 23.7 (C-11), 21.7 (C-5), 21.2 (C-1), 18.9 (C-15), 18.6 (C-15) ppm; IR (film NaCl): ν_{max} 2925, 2854, 1703, 1464, 1374, 1276, 1088, 849, 744 cm^{-1}. HRMS (ESI): m/z calcd for $C_{19}H_{28}NaO_2S^+$ $(M+Na)^+$ 343.1702; found 343.1707.

	%Conversion		%ee	
T(h)	**%P**	**%SM**	**%P**	**%SM**
0	0	100	0	0
1	13.0853	86.9147	74.1634	17.0246
2	32.0853	67.8207	90.0421	36.5663
4	46.8249	53.1751	93.5681	66.8342
6	52.5505	47.4496	91.4871	85.8996

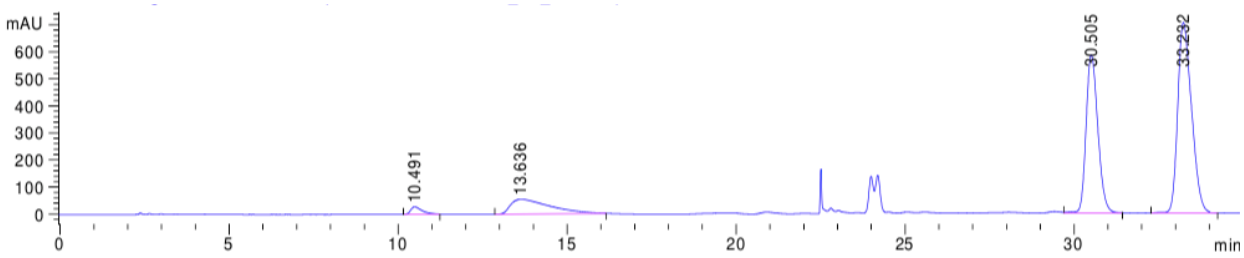
Table 4: Conversion and %ee of Starting Material **9b** and Product **8b**

0 h:



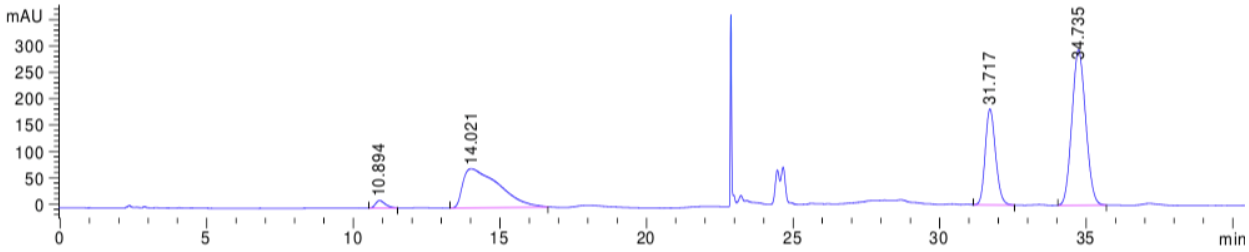
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	28.260	VB	0.3602	1.67622e4	713.22693	50.7166
2	30.919	BB	0.5085	1.62886e4	491.71396	49.2834

1 h:



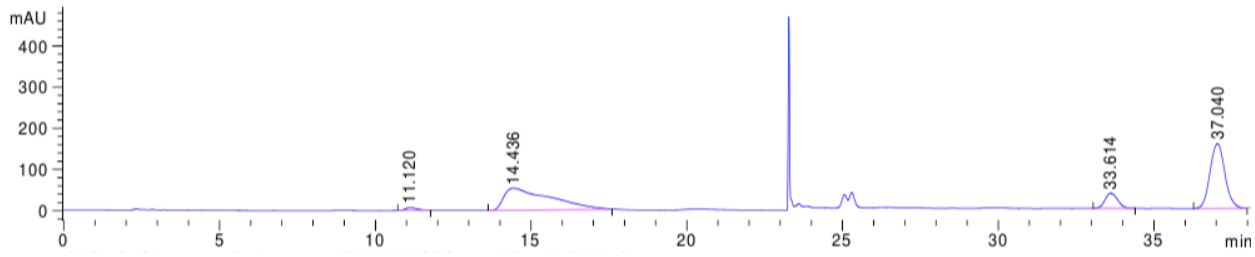
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.491	BB	0.3530	666.02386	28.04716	1.6904
2	13.636	BB	1.0680	4489.70020	54.78961	11.3949
3	30.505	VB	0.3754	1.42075e4	584.90808	36.0589
4	33.232	BB	0.4297	2.00376e4	704.86456	50.8558

2 h:



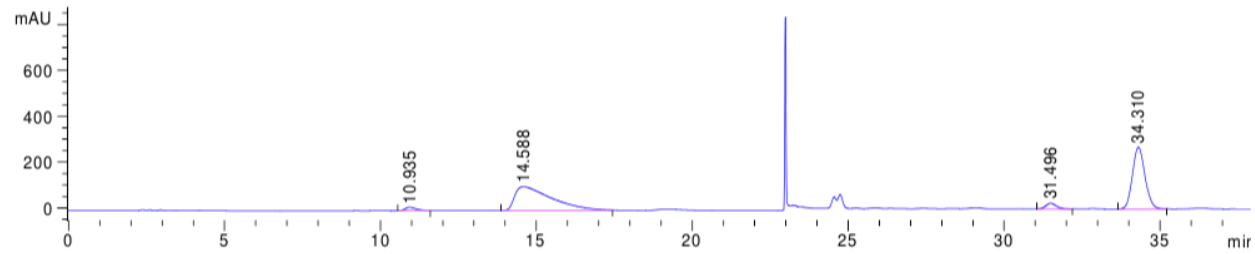
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.894	BB	0.3526	333.86639	14.39450	1.6022
2	14.021	BB	1.1414	6371.66016	74.23270	30.5771
3	31.717	VB	0.3791	4482.38818	182.15936	21.5106
4	34.735	BB	0.5031	9650.10840	295.39673	46.3101

4 h:



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.120	BB	0.3600	184.61282	7.08597	1.5367
2	14.436	BB	1.3597	5555.85498	53.49519	46.2467
3	33.614	BB	0.4454	1040.25244	36.84221	8.6590
4	37.040	BB	0.5299	5232.79102	157.36394	43.5575

6 h:



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.935	BB	0.3689	382.05164	15.21675	2.2368
2	14.588	BB	1.1121	8593.65723	104.64663	50.3137
3	31.496	BB	0.3609	571.37421	24.42403	3.3453
4	34.310	BB	0.4332	7533.07666	270.27985	44.1043

1 C. J. Maddocks, K. Ermanis and P. A. Clarke, *Org. Lett.*, 2020, **22**, 8116–8121.

2 E. Marotta, E. Foresti, T. Marcelli, F. Peri, P. Righi, N. Scardovi and G. Rosini, *Org. Lett.*, 2002, **4**, 4451–4453.

Kinetic Isotope Studies

The deuterated cyclization precursor **S2d$_D$** was synthesized using the same procedure as the protonated **S2d$_H$** and then dissolved in deuterated methanol (CH_3OD) allowing for the H/D exchange, which was confirmed by mass spectrometry.

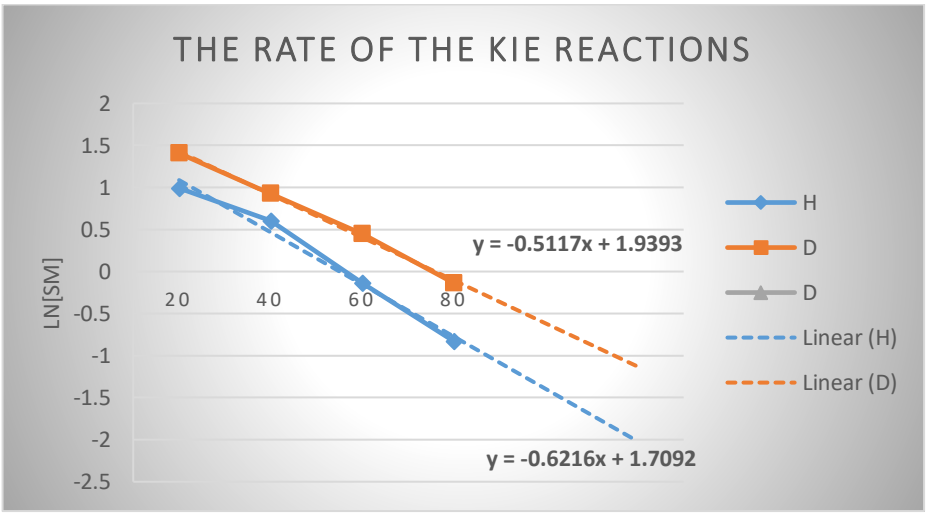
To a solution of alcohol-thioester **S2d$_{H/D}$** (20.0 mg, 0.05 mmol, 1 eq) and unsaturated alcohol **6e** (7.87 mg, 0.05 mmol, 1 eq) in D_{12}-cyclohexane (2.3 ml), (*R*)-TRIP (6.96 mg, 0.01 mmol, 20 mol %) was added and stirred at either 50 °C or room temperature. At regular intervals (20 min and 1 hour for the reaction carried out at 50 °C and room temperature respectively), the mixture was analyzed by ^{1}H NMR to monitor the formation of the products and the consumption of the starting materials over the time.

Time/ min	Conversion %	
	5d$_H$	**5d$_D$**
20	69	53
40	79	71
60	90	82
80	100	90

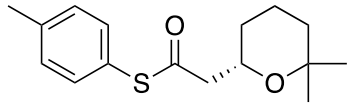
Table 1: Conversion of **Sd$_{H/D}$** over the time at 50 °C.

Time/ h	Conversion %	
	5d$_H$	**5d$_D$**
1	49	49
2	62	60
3	67	66

Table 2: Conversion of **Sd$_{H/D}$** over the time at room temperature.

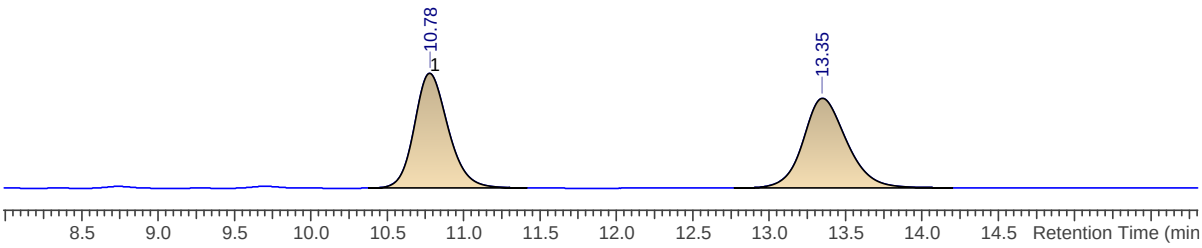


HPLC Data



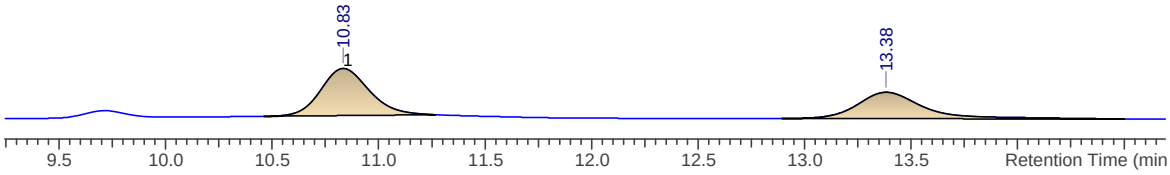
***S*-*p*-*T*olyl-2-(6,6-dimethyltetrahydro-*2H*-pyran-2-yl)ethanethioate (4a)**

HPLC separation conditions: CHIRALPAK AD-H column, hexane/2-propanol (95:5), flow rate: 0.9 ml/min, 25 ^{o}C; tR 10.78 min (major) and 13.35 min (minor).



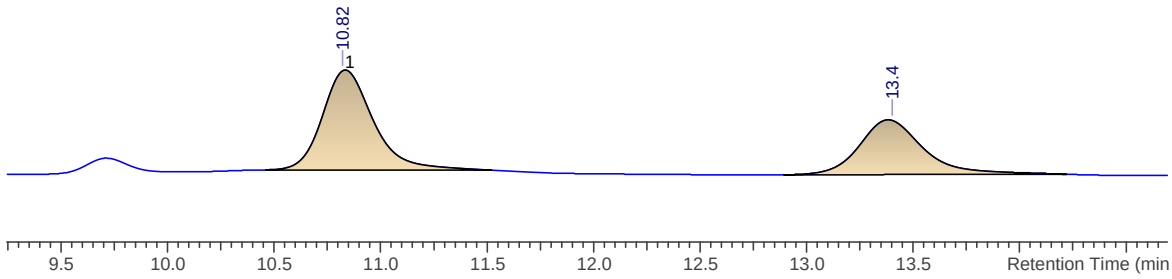
No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	10.78	1761496.375	49.782	0.394
2	13.35	1776920.750	50.218	0.503

(*R*)-TRIP, PhMe, 13% ee

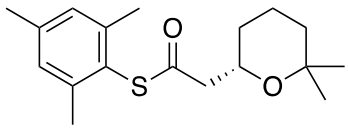


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	10.83	641760.563	56.497	0.409
2	13.38	494162.156	43.503	0.515

(*R*)-TRIP, cyclohexane, 18% ee

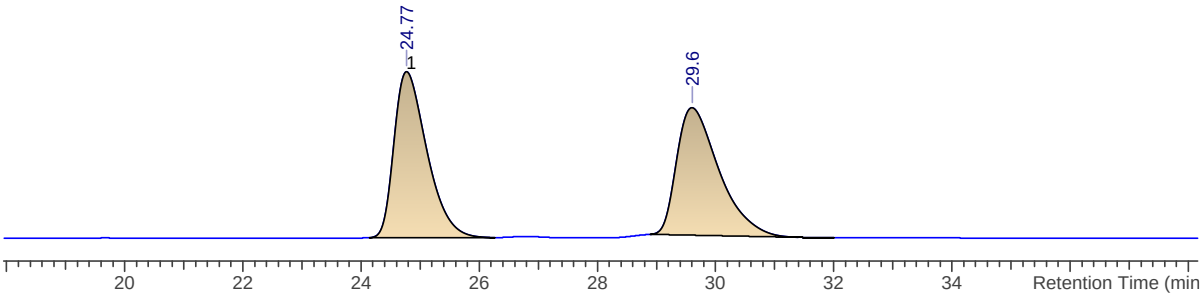


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	10.82	685617.625	59.160	0.418
2	13.40	473311.531	40.840	0.515



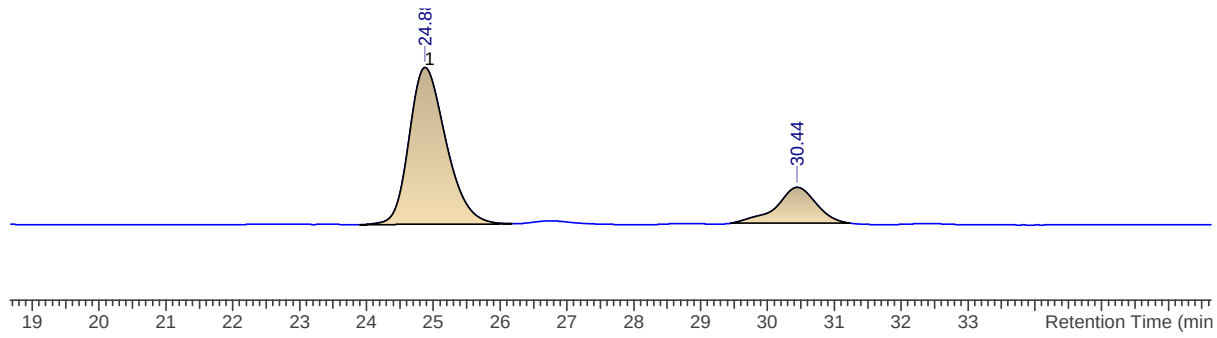
***S*-Mesityl 2-(6,6-dimethyltetrahydro-2H-pyran-2-yl)ethanethioate (4b)**

HPLC separation conditions: CHIRALPAK AD-H column, hexane/2-propanol (98:2), flow rate: 1.0 ml/min, 25 ^{o}C; tR 24.77 min (major) and 29.6 min (minor).



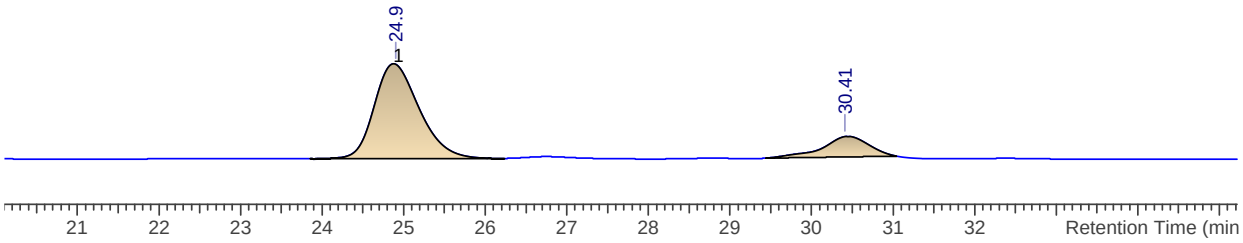
No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	24.77	9083537.000	50.240	1.007
2	29.60	8996811.000	49.760	1.287

(*R*)-TRIP, PhMe, 50 ^{o}C, 60% ee



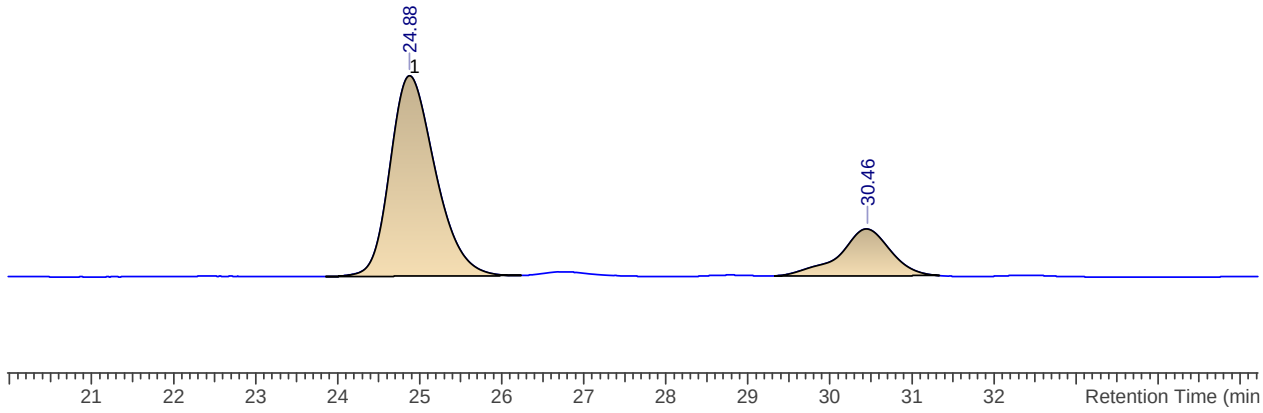
No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	24.88	2385430.250	80.086	0.994
2	30.44	593150.125	19.914	1.012

(*R*)-TRIP, cyclohexane, 75 °C, 66% ee

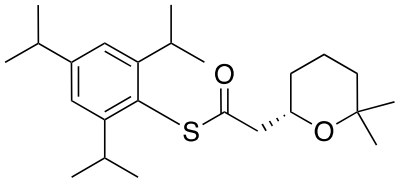


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	24.90	2385430.250	83.245	0.998
2	30.41	480123.563	16.755	0.964

(*R*)-TRIP, cyclohexane, 50 °C, 69% ee

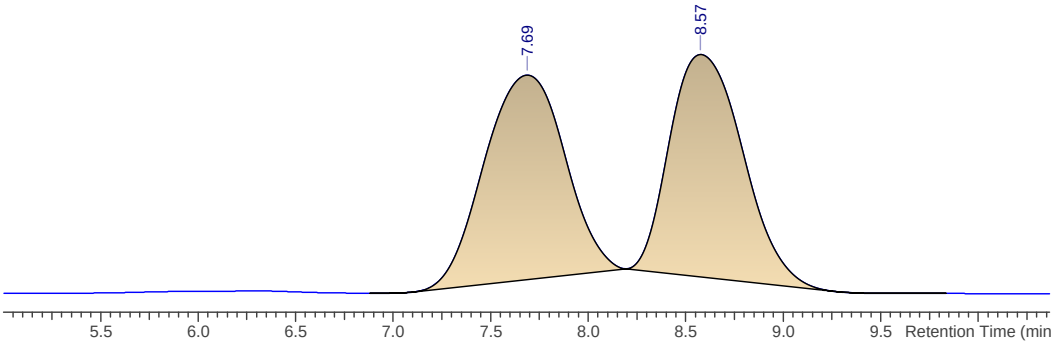


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	24.88	2385499.750	84.625	0.993
2	30.46	433396.469	15.375	0.920

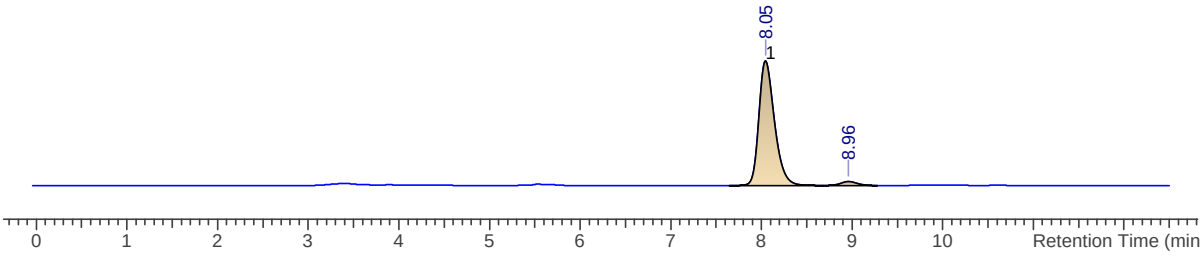


(*S*)-S-(2,4,6-Triisopropylphenyl)2-(6,6-dimethyltetrahydro-2H-pyran-2-yl)ethanethioate (4c)

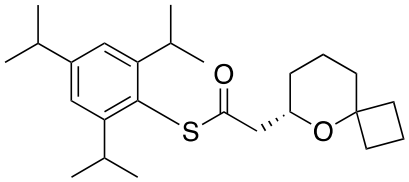
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 6.64 min (major) and 8.57 min (minor), 98% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	7.69	33347516.000	50.272	0.787
2	8.57	32986754.000	49.728	0.706

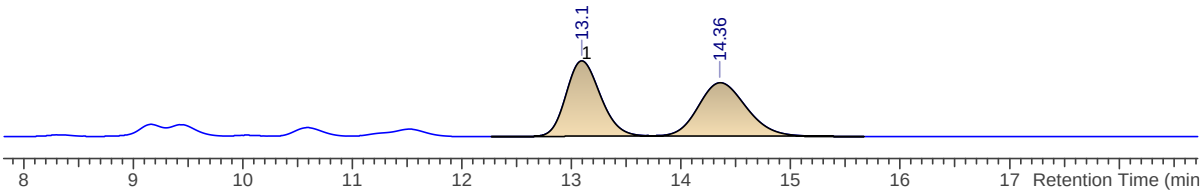


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	8.05	7786344.000	99.037	0.305
2	8.96	75733.797	0.963	0.132

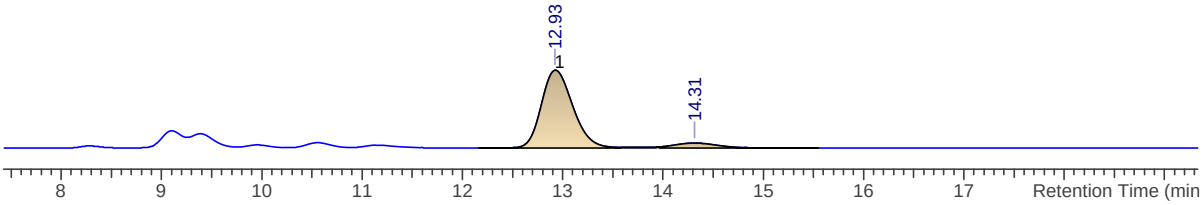


(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(5-oxaspiro[3.5]nonan-6-yl)ethanethioate (5a)

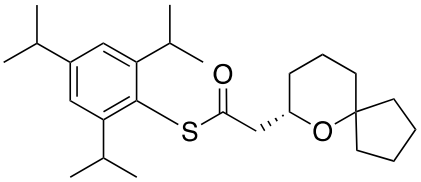
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 12.93 min (major) and 14.31 min (minor), 93% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	13.10	21178112.000	50.201	0.571
2	14.36	21008588.000	49.799	0.799

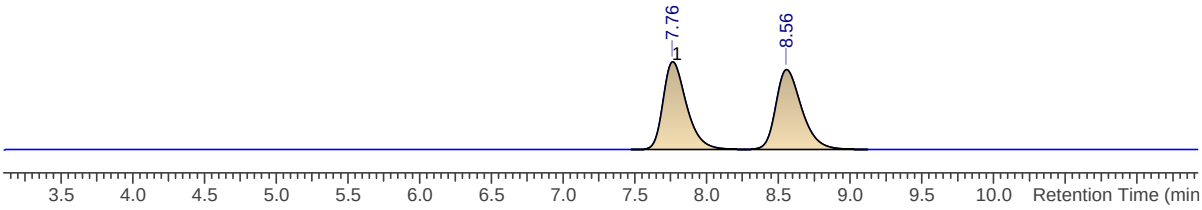


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	12.93	34849340.000	96.445	0.569
2	14.31	1284388.500	3.555	0.588

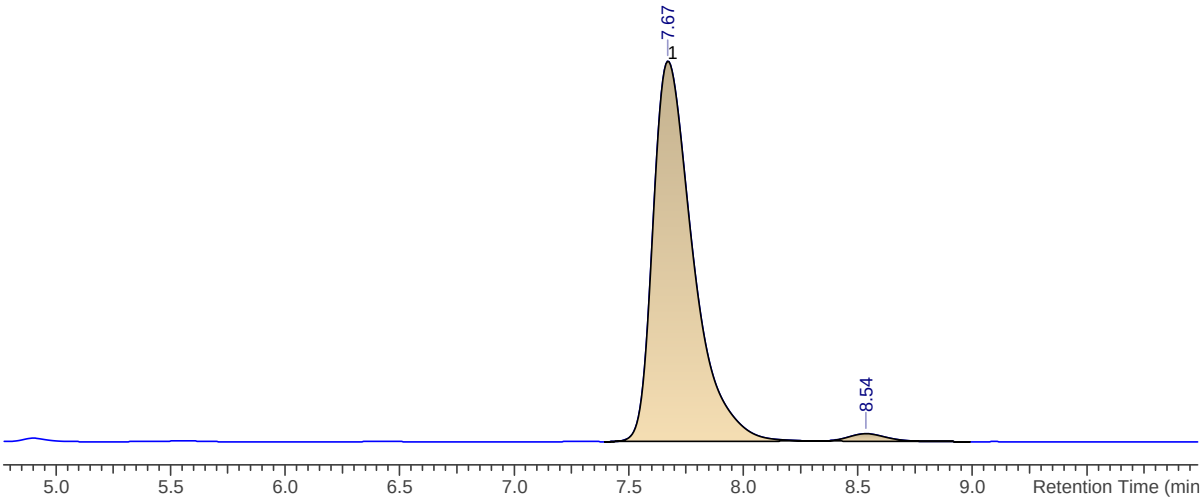


(*S*)-*S*-(2,4,6-Triisopropylphenyl)2-(6-oxaspiro[4.5]decan-7-yl)ethanethioate (5b)

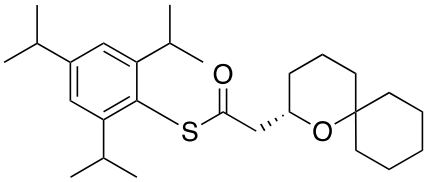
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 7.67 min (major) and 8.54 min (minor), 96% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	7.76	8561297.000	49.962	0.289
2	8.55	8574155.000	50.038	0.320

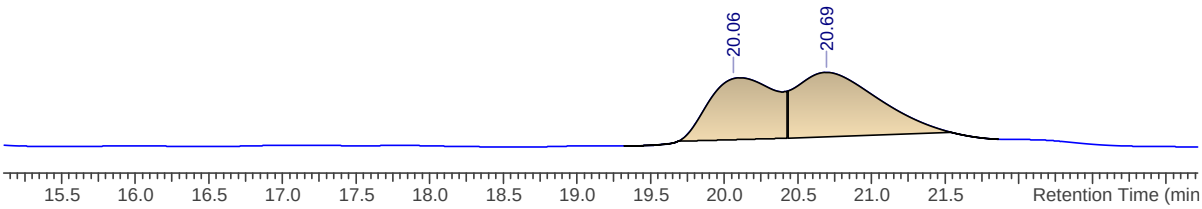


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	7.67	21056412.000	98.199	0.304
2	8.54	386274.000	1.801	0.296

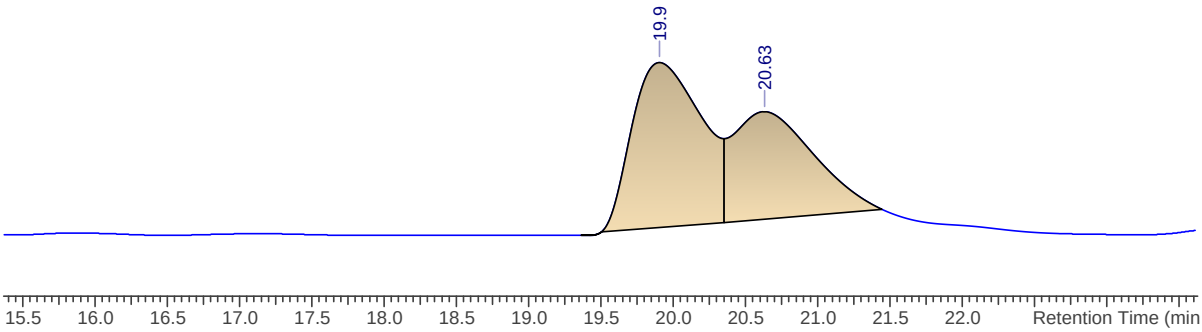


(*S*)-S-(2,4,6-Triisopropyl) 2-(1-oxaspiro[5.5]undecane-2-yl)ethanethioate (5c)

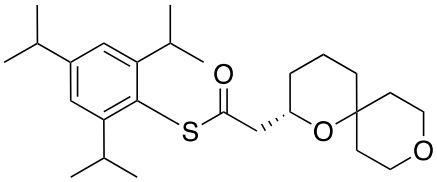
HPLC separation conditions: CHIRALPAK IC column, hexane/2-propanol (100:0), flow rate: 0.6 ml/min, 40 °C; tR 19.9 min (major) and 20.63 min (minor), 60% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	20.06	5220379.500	49.505	0.352
2	20.69	5324767.000	50.495	0.528

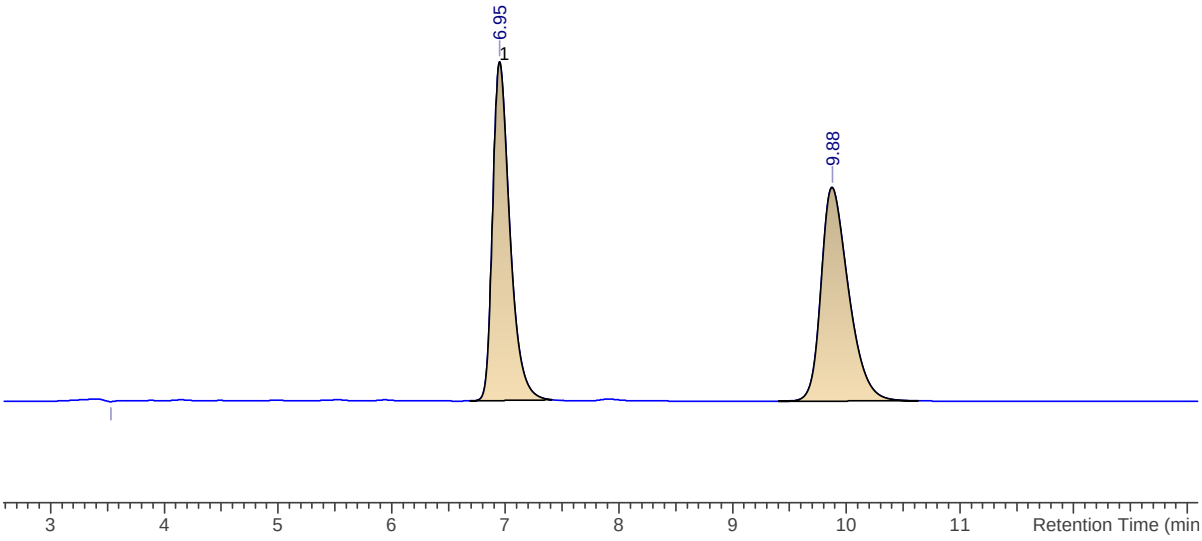


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	19.90	2303106.250	19.967	0.068
2	20.63	9231700.000	80.033	1.229

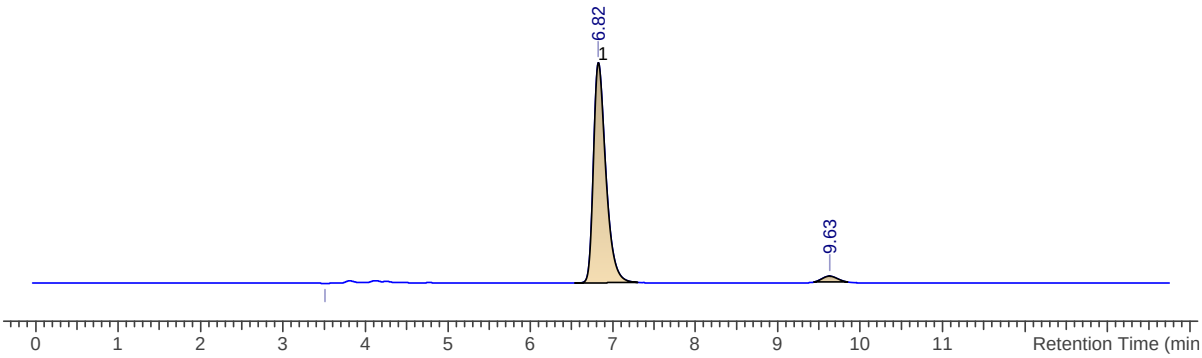


(*S*)-*S*-(2,4,6-Triisopropylphenyl)-2-(1,9-dioxaspiro[5.5]undecan-2-yl)ethanethioate (5d)

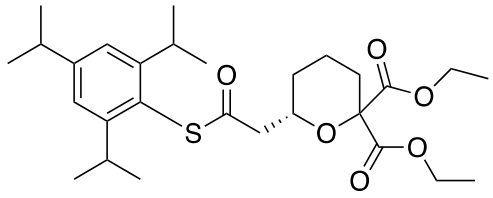
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 6.82 min (major) and 9.63 min (minor), 99% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	6.95	11337981.000	49.887	0.267
2	9.88	11389371.000	50.113	0.430

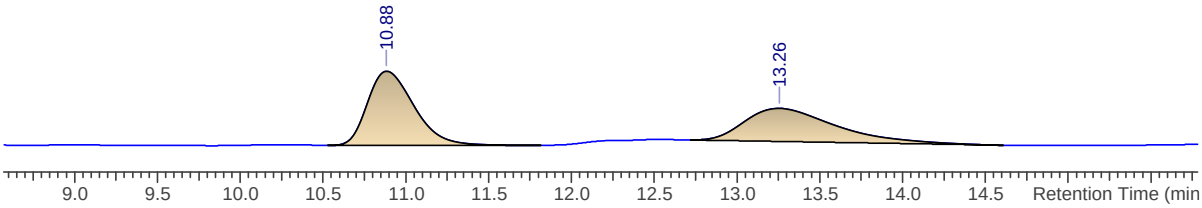


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	6.82	10215860.000	99.288	0.264
2	9.63	73252.609	0.712	0.202

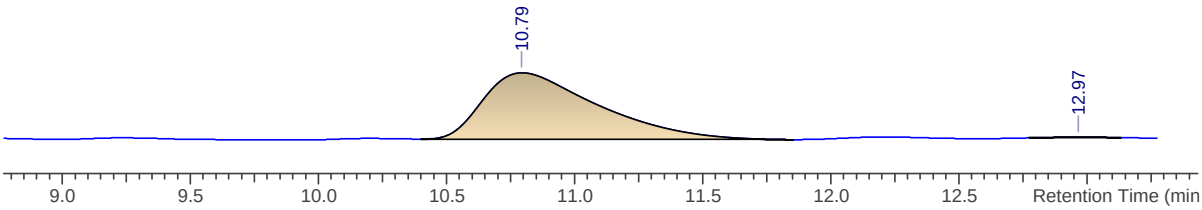


(*S*)-Diethyl-6-(2-oxo-2-((2,4,6-triisopropylphenyl)thio)ethyl)tetrahydro-2*H*-pyran-2,2-dicarboxylate (5e)

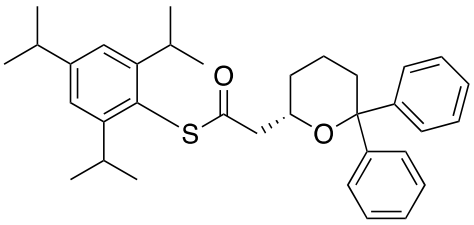
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 10.79 min (major) and 12.97 min (minor), 97% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	10.88	2911815.750	50.103	0.490
2	13.26	2899852.750	49.897	0.985

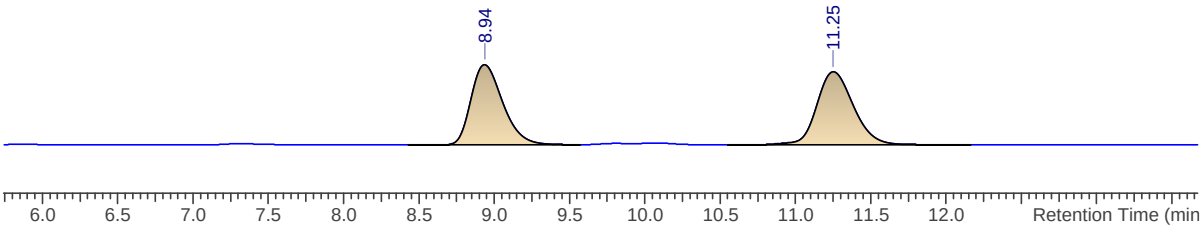


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	10.79	2806635.500	98.734	0.810
2	12.97	36001.199	1.266	0.638

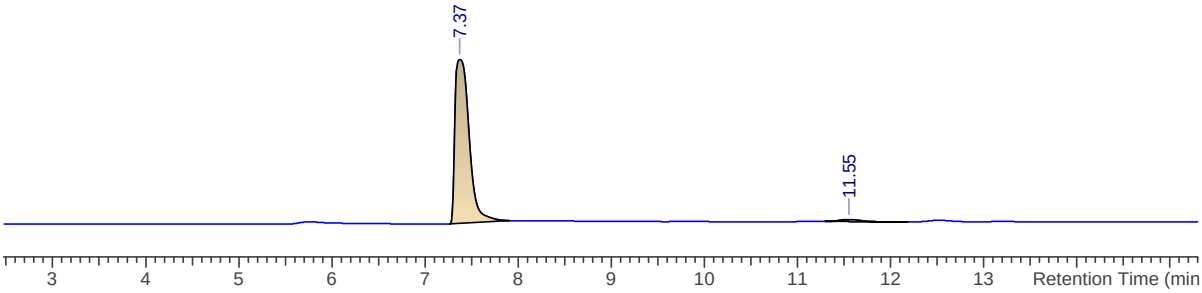


(*S*)-*S*-(2,4,6-Triisopropylphenyl)2-(6,6-diphenyltetrahydro-2*H*-pyran-2-yl)ethanethioate (5f)

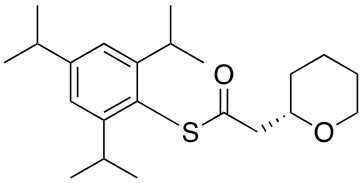
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 7.37 min (major) and 11.55 min (minor), 96% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	8.94	18180564.000	48.688	0.382
2	11.25	19160120.000	51.312	0.436

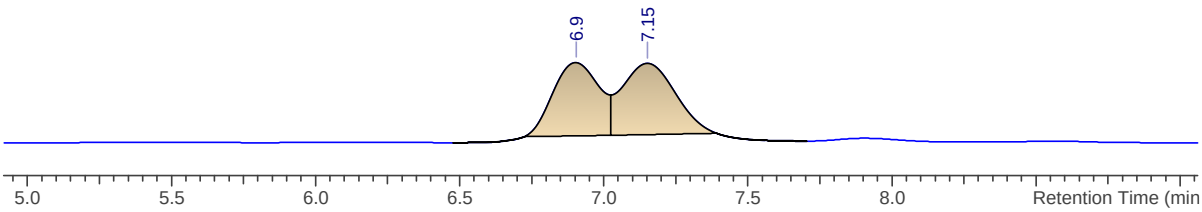


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	7.37	22942132.000	98.099	0.276
2	11.55	444638.813	1.901	0.419

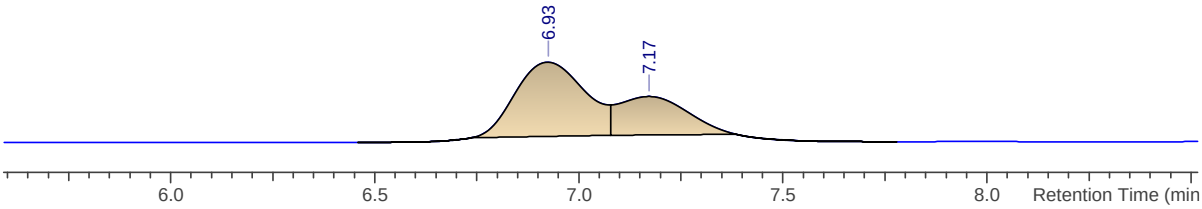


(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(tetrahydro-2*H*-pyran-2-yl)ethanethioate (5g)

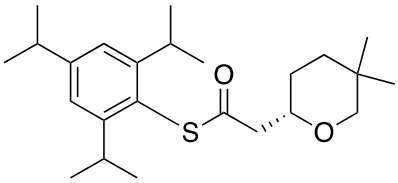
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (100:0), flow rate: 0.6 ml/min, 40 °C; tR 6.93 min (major) and 7.17 min (minor), 33% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	6.90	7088970.000	48.911	0.215
2	7.15	7404771.000	51.089	0.245

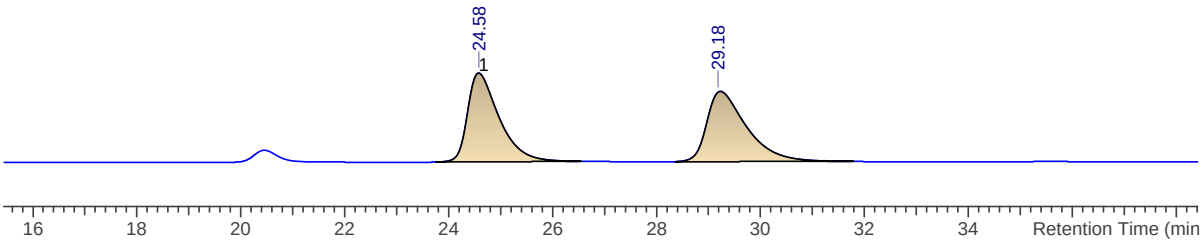


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	6.93	18246696.000	66.289	0.344
2	7.17	9279316.000	33.711	0.201

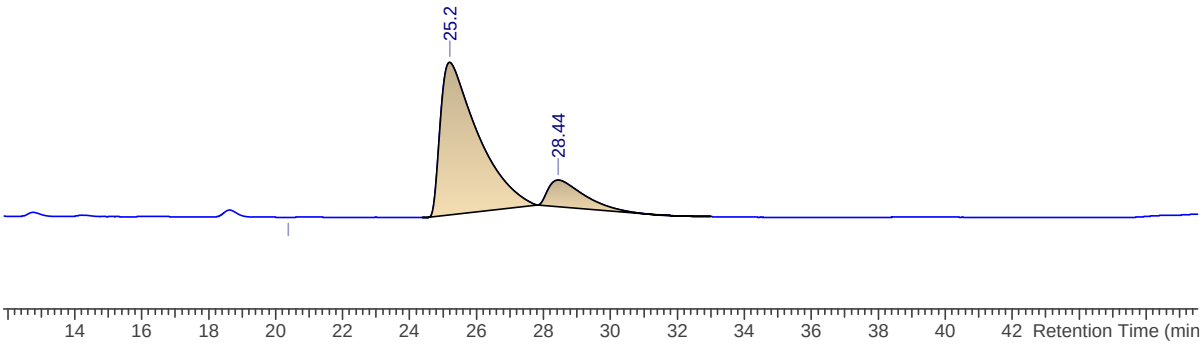


(*S*)-*S*-(2,4,6-Triisopropylphenyl)2-(5,5-dimethyltetrahydro-2*H*-pyran-2-yl)ethanethioate (7a)

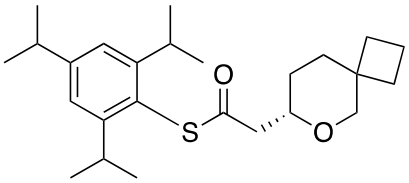
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 25.20 min (major) and 28.44 min (minor), 71% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	24.58	2426636.750	50.089	1.057
2	29.18	2417980.000	49.911	1.341

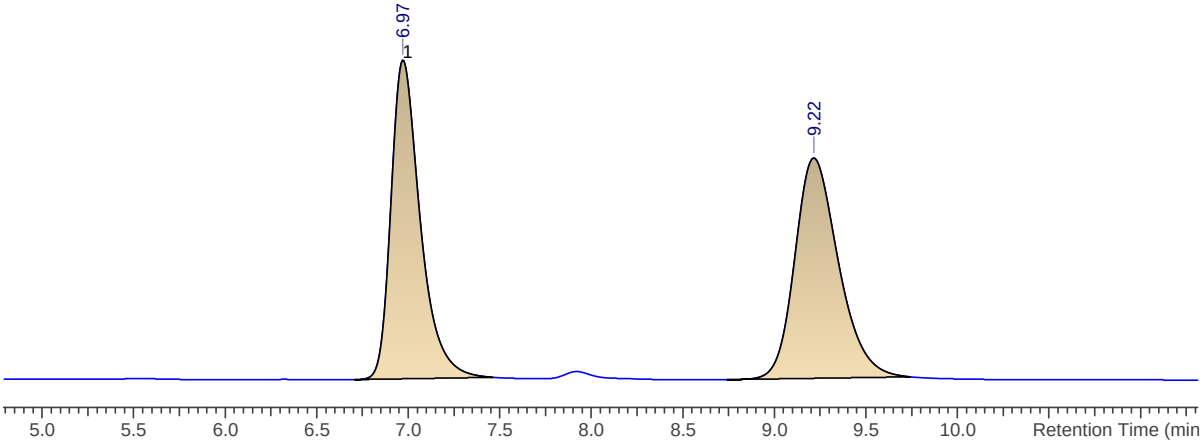


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	25.20	7089395.000	85.629	1.999
2	28.44	1189756.625	14.371	1.882

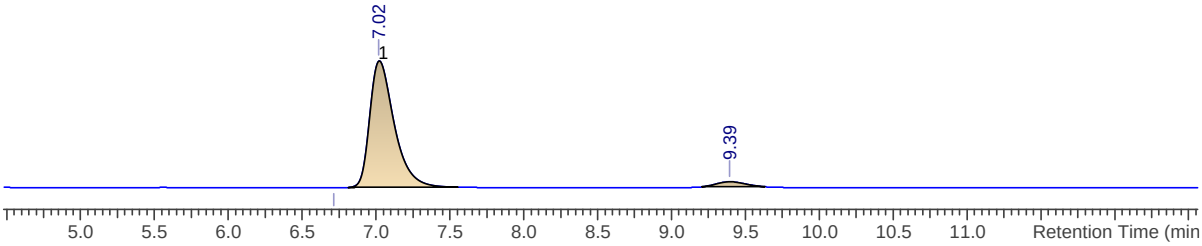


(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(6-oxaspiro[3.5]nonan-7-yl)ethanethioate (7b)

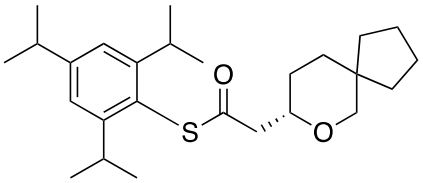
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 7.02 min (major) and 9.39 min (minor), 97% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	6.97	5266314.000	49.232	0.279
2	9.22	5430537.000	50.768	0.427

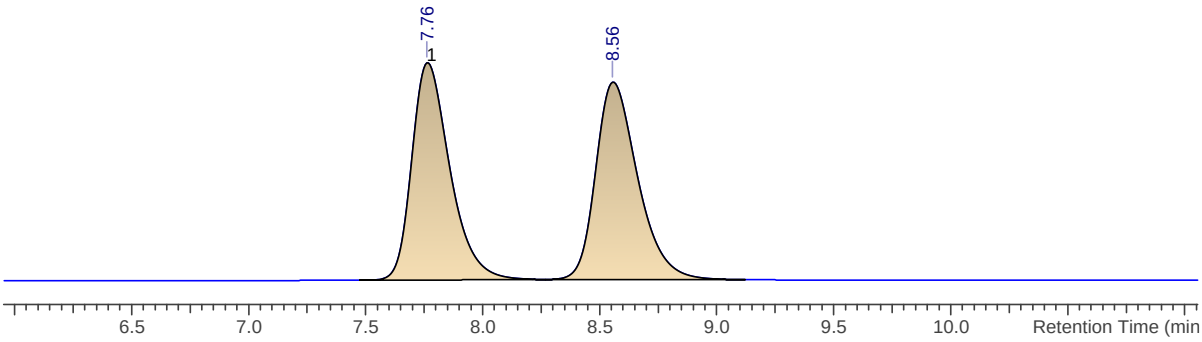


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	7.02	14916656.000	98.607	0.291
2	9.39	210735.641	1.393	0.259

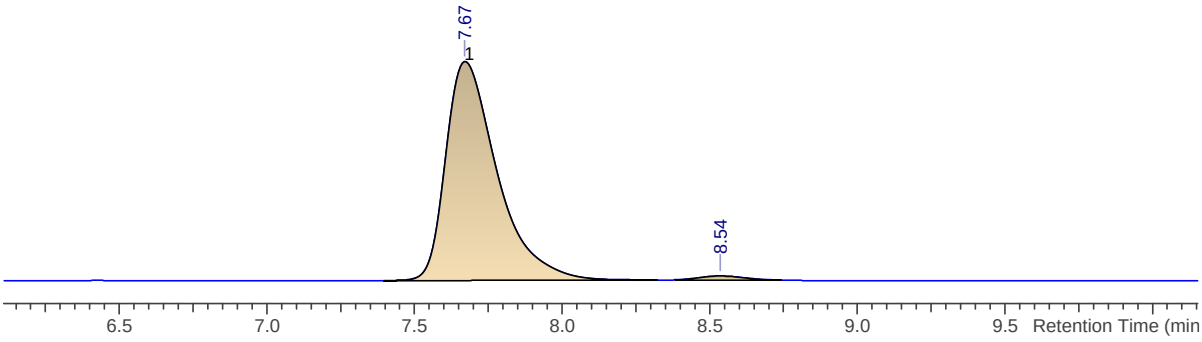


(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(6-oxaspiro[4.5]decan-7-yl)ethanethioate (7c)

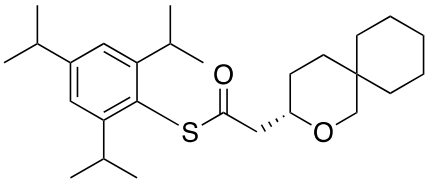
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 7.67 min (major) and 8.54 min (minor), 99% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	7.76	8561297.000	49.962	0.289
2	8.55	8574155.000	50.038	0.320

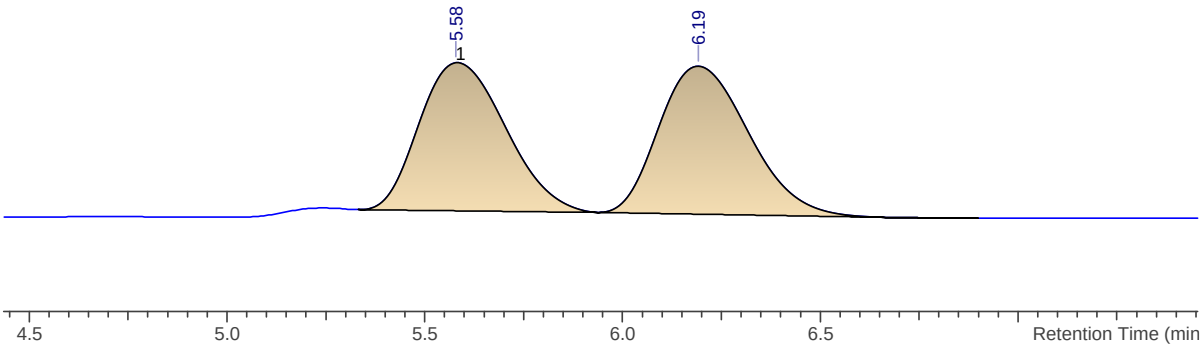


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	7.67	21056412.000	99.399	0.304
2	8.54	127288.211	0.601	0.200

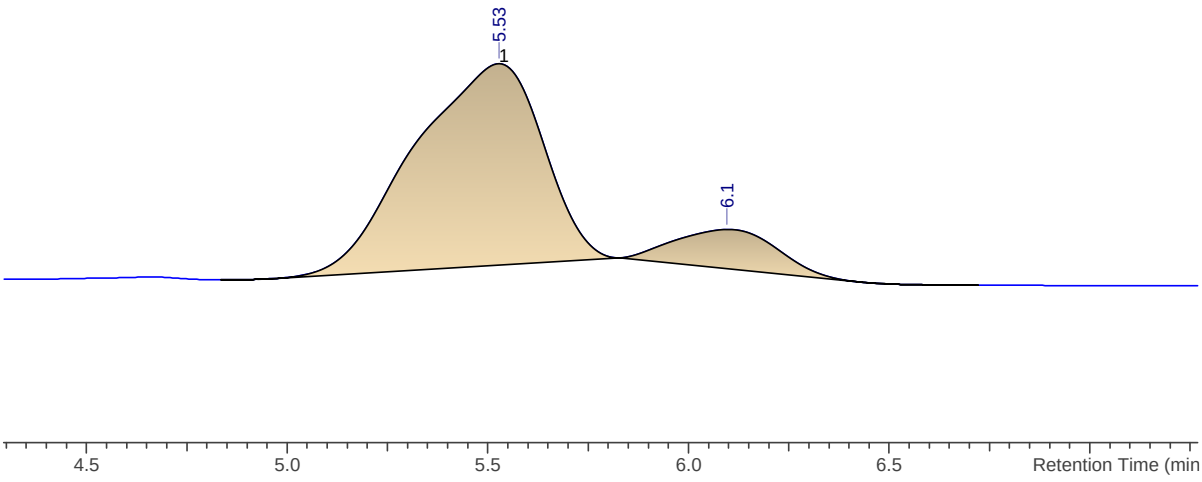


(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(2-oxaspiro[5.5]undecan-3-yl)ethanethioate (7d)

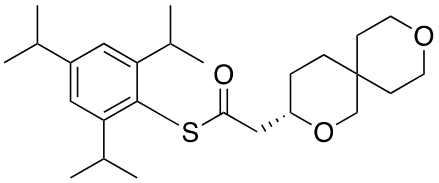
HPLC separation conditions: CHIRALPAK IB column, hexane/2-propanol (100:0), flow rate: 0.6 ml/min, 40 °C; tR 5.53 min (major) and 6.1 min (minor), 73% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	5.58	7373615.500	49.005	0.413
2	6.19	7672967.000	50.995	0.424

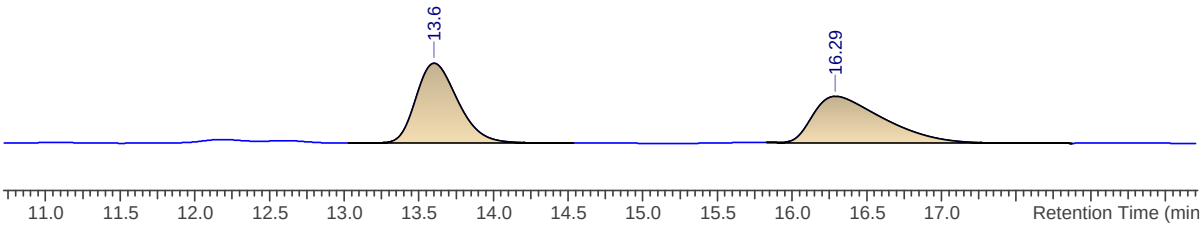


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	5.53	1711052.125	86.592	0.636
2	6.10	264942.563	13.408	0.464

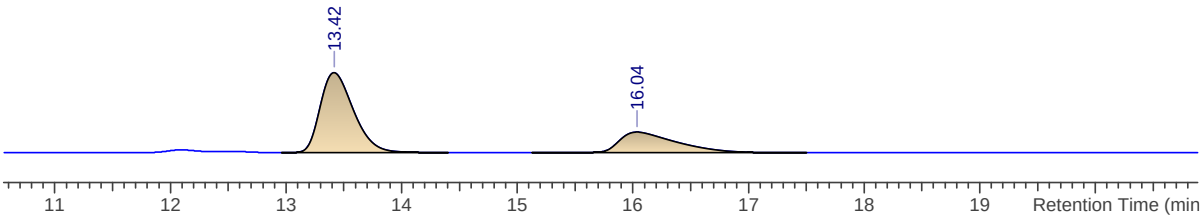


(*S*)-*S*-(2,4,6-Triisopropylphenyl) 2-(2,9-dioxaspiro[5.5]undecan-3-yl)ethanethioate (7e)

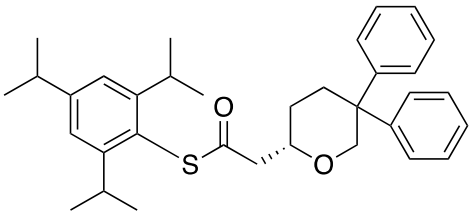
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 13.42 min (major) and 16.04 min (minor), 40% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	13.60	3270212.750	50.766	0.510
2	16.29	3171546.500	49.234	0.862

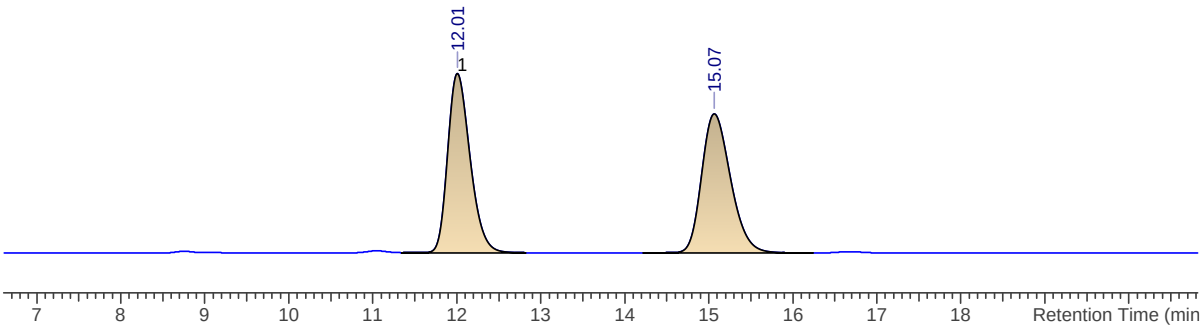


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	13.42	9410043.000	69.551	0.524
2	16.04	4119725.250	30.449	0.885

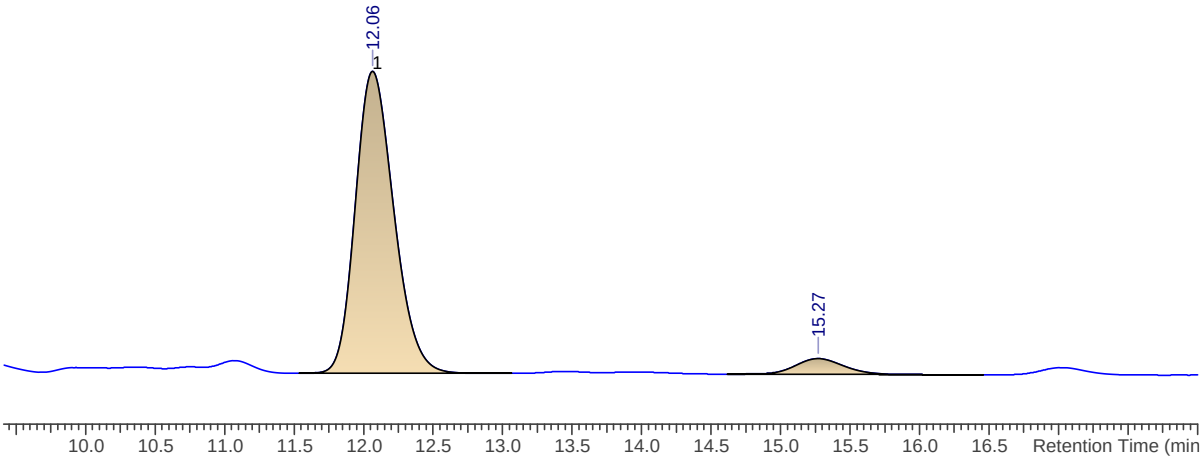


(*S*)-*S*-(2,4,6-Triisopropylphenyl)2-(5,5-diphenyltetrahydro-2*H*-pyran-2-yl)ethanethioate (7f)

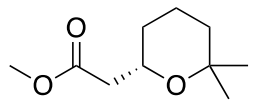
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (99:1), flow rate: 0.6 ml/min, 40 °C; tR 12.06 min (major) and 15.27 min (minor), 87% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	12.01	7751497.500	49.846	0.482
2	15.07	7799358.000	50.154	0.626

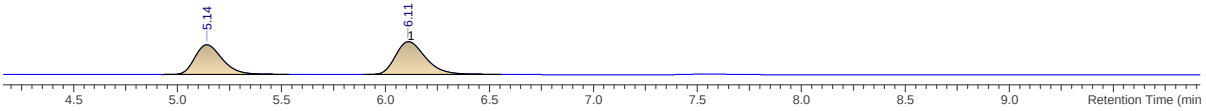


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	12.06	5185279.500	93.809	0.506
2	15.27	342188.531	6.191	0.632

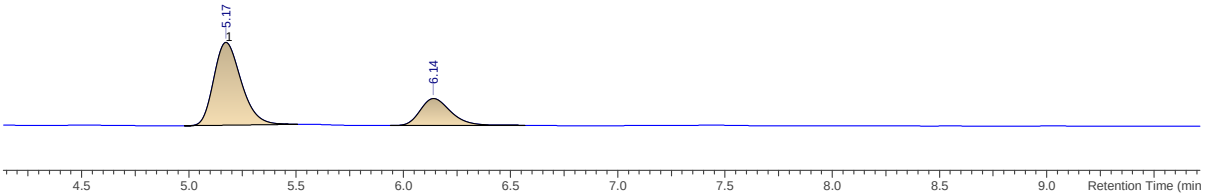


(6,6-Dimethyl-tetrahydro-pyran-2-yl)-acetic acid methyl ester (S6)

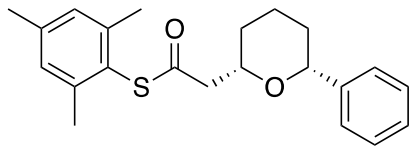
HPLC separation conditions: CHIRALPAK IA column, hexane/2-propanol (95:5), flow rate: 1.0 ml/min, 25 ^{o}C; tR 5.17 min for (S)-enantiomer (major) and 6.14 min for (R)- enantiomer (minor), 66% ee



No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	5.14	6392892.000	49.743	0.233
2	6.11	6458914.500	50.257	0.235

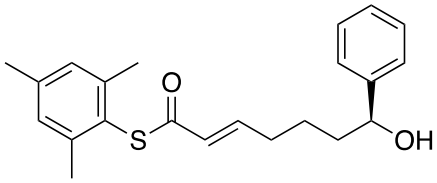


No.	tR	Peak Area (Y units*ms)	Area (%)	Width
1	5.17	1077943.375	83.723	0.231
2	6.14	209571.516	16.277	0.208



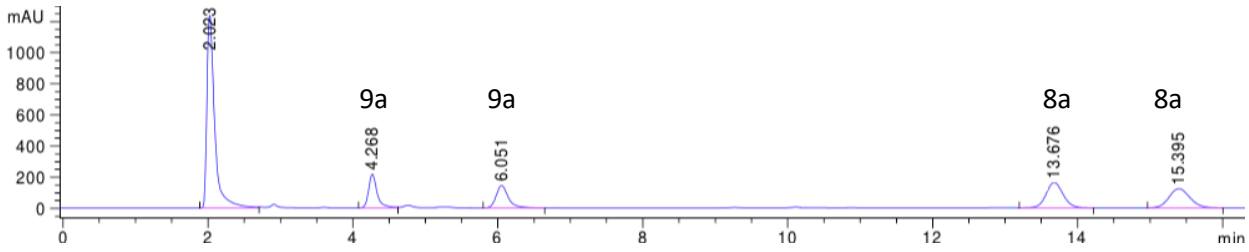
_S_-Mesityl 2-(6-phenyltetrahydro-2H-pyran-2-yl)ethanethioate (9a)

HPLC separation conditions: CHIRALPAK AD-H column, hexane/2-propanol (90:10), flow rate: 1.0 ml/min, 25 ^{o}C for 6.5 min then hexane/2-propanol (80:20); tR 4.22 min (major) and 5.98 min (minor), 68% ee.

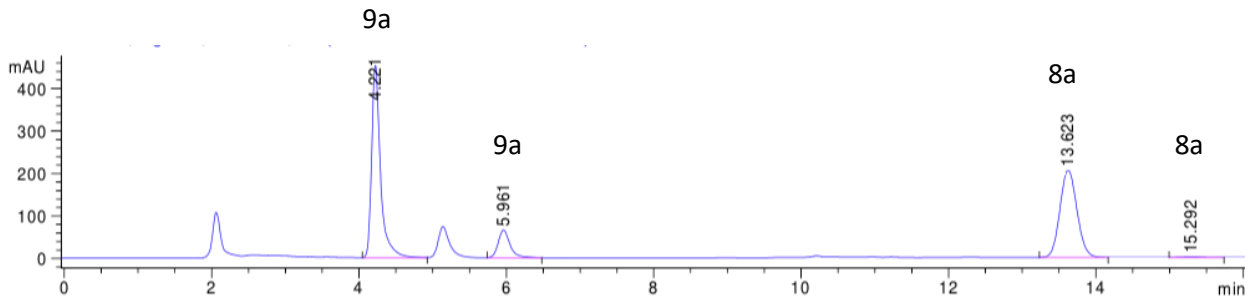


(_E_)-_S_-Mesityl 7-hydroxy-7-phenylhept-2-enethioate (8a)

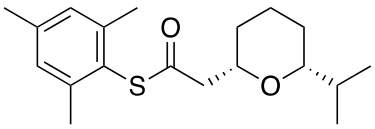
HPLC separation conditions: CHIRALPAK AD-H column, hexane/2-propanol (90:10), flow rate: 1.0 ml/min, 25 ^{o}C for 6.5 min then hexane/2-propanol (80:20); tR 13.62 min (major) and 15.29 min (minor), 97% ee



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	2.023	BB	0.1115	9289.07031	1238.17017	51.9829
2	4.268	BV	0.1241	1787.18799	216.88327	10.0013
3	6.051	BB	0.1773	1696.20862	144.11746	9.4922
4	13.676	VB	0.2513	2643.26660	162.94652	14.7921
5	15.395	BB	0.3103	2453.75293	123.22851	13.7315

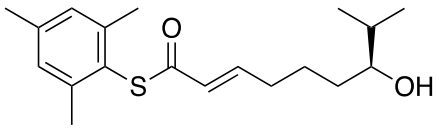


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	4.221	BB	0.1259	3797.96118	452.70950	48.3781
2	5.961	BB	0.1692	735.59698	65.40393	9.3700
3	13.623	BB	0.2505	3291.70166	205.91005	41.9294
4	15.292	BB	0.2280	25.32366	1.43400	0.3226



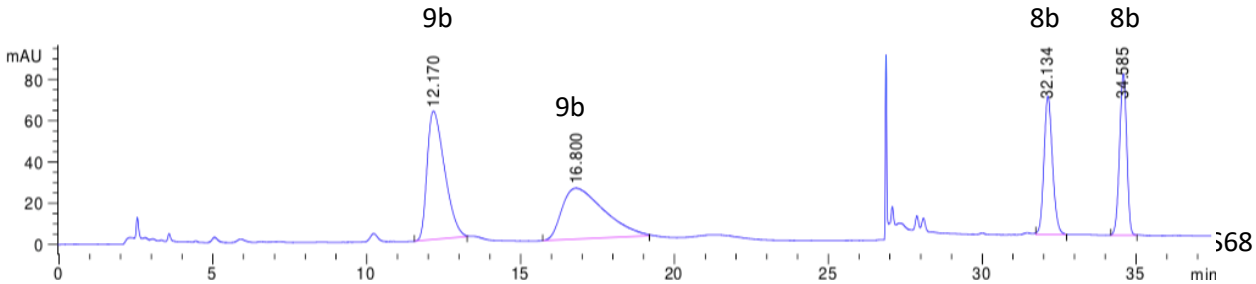
***S*-Mesityl 2-(6-isopropyltetrahydro-2H-pyran-2-yl)ethanethioate (9b)**

HPLC separation conditions: CHIRALPAK AD-H column, hexane/2-propanol (96:4), flow rate: 0.9 ml/min, 25 °C for 15 min then hexane/2-propanol (90:10); tR 14.59 min (major) and 10.94 min (minor), 92% ee.

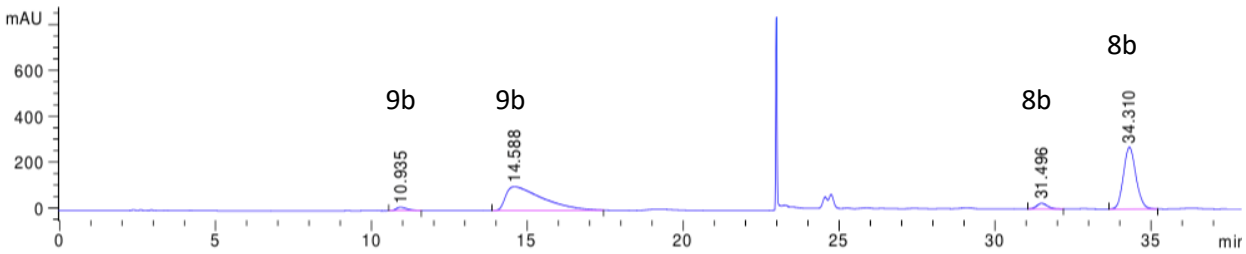


(*E*)-*S*-Mesityl 7-hydroxy-8-methylnon-2-enethioate (8b)

HPLC separation conditions: CHIRALPAK AD-H column, hexane/2-propanol (96:4), flow rate: 0.9 ml/min, 25 °C for 15 min then hexane/2-propanol (90:10); tR 34.31 min (major) and 31.50 min (minor), 85% ee

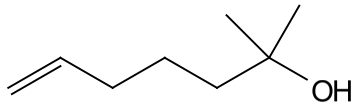


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.170	BB	0.6015	2453.54810	62.29675	33.3278
2	16.800	BB	1.1220	2345.35669	24.74034	31.8582
3	32.134	BB	0.2967	1295.09021	67.23794	17.5919
4	34.585	BB	0.2550	1267.86572	78.25910	17.2221



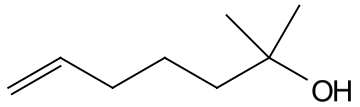
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.935	BB	0.3689	382.05164	15.21675	2.2368
2	14.588	BB	1.1121	8593.65723	104.64663	50.3137
3	31.496	BB	0.3609	571.37421	24.42403	3.3453
4	34.310	BB	0.4332	7533.07666	270.27985	44.1043

Chloroform-d, 400 MHz



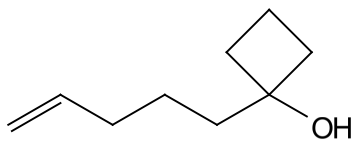
1a

Clororoform-d, 101 MHz



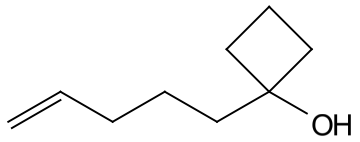
1a

Chloroform-d, 400 MHz



1b

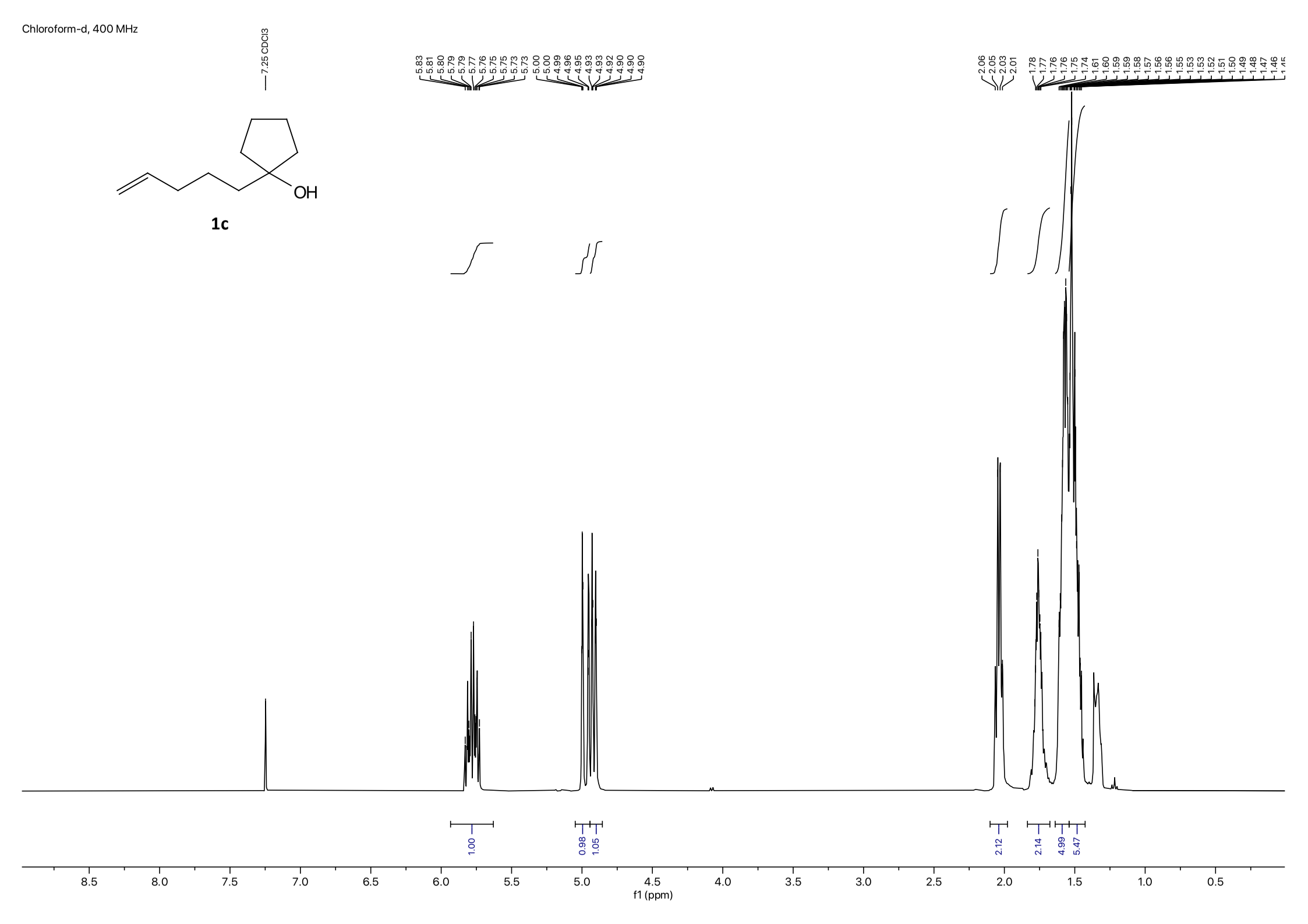
Chloroform-d, 101 MHz



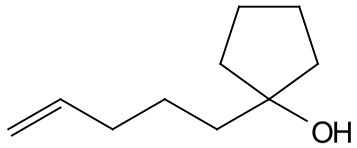
1b

138.91
114.66
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
75.34
38.99
36.01
34.11
22.79
12.20

f1 (ppm)

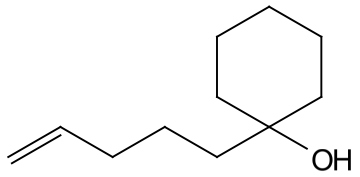

Chloroform-d, 400 MHz
7.25 CDCl3
OH
1c
5.83
5.81
5.80
5.79
5.79
5.77
5.76
5.75
5.75
5.73
5.73
5.00
5.00
4.99
4.96
4.95
4.93
4.93
4.92
4.90
4.90
4.90
2.06
2.05
2.03
2.01
1.78
1.77
1.76
1.76
1.75
1.74
1.61
1.60
1.59
1.59
1.58
1.57
1.56
1.56
1.55
1.53
1.53
1.52
1.51
1.50
1.49
1.48
1.47
1.46
1.00
0.98
1.05
2.12
2.14
4.99
5.47
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

Chloroform-d, 101 MHz



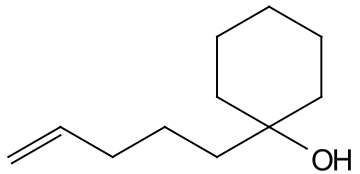
1c

Chloroform-d, 400 MHz



1d

Chloroform-d, 101 MHz

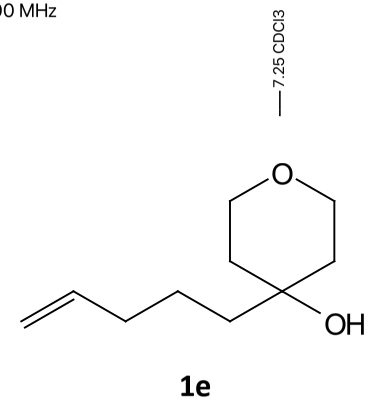


1d

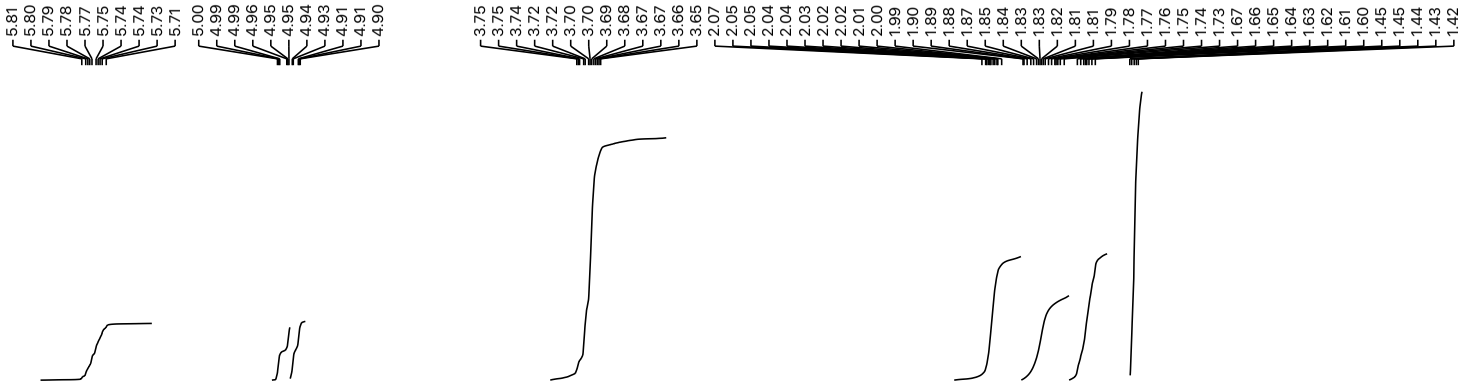
138.97
114.57
77.47 CDCl3
77.15 CDCl3
76.83 CDCl3
71.49
41.89
37.48
34.32
25.92
22.33
22.29

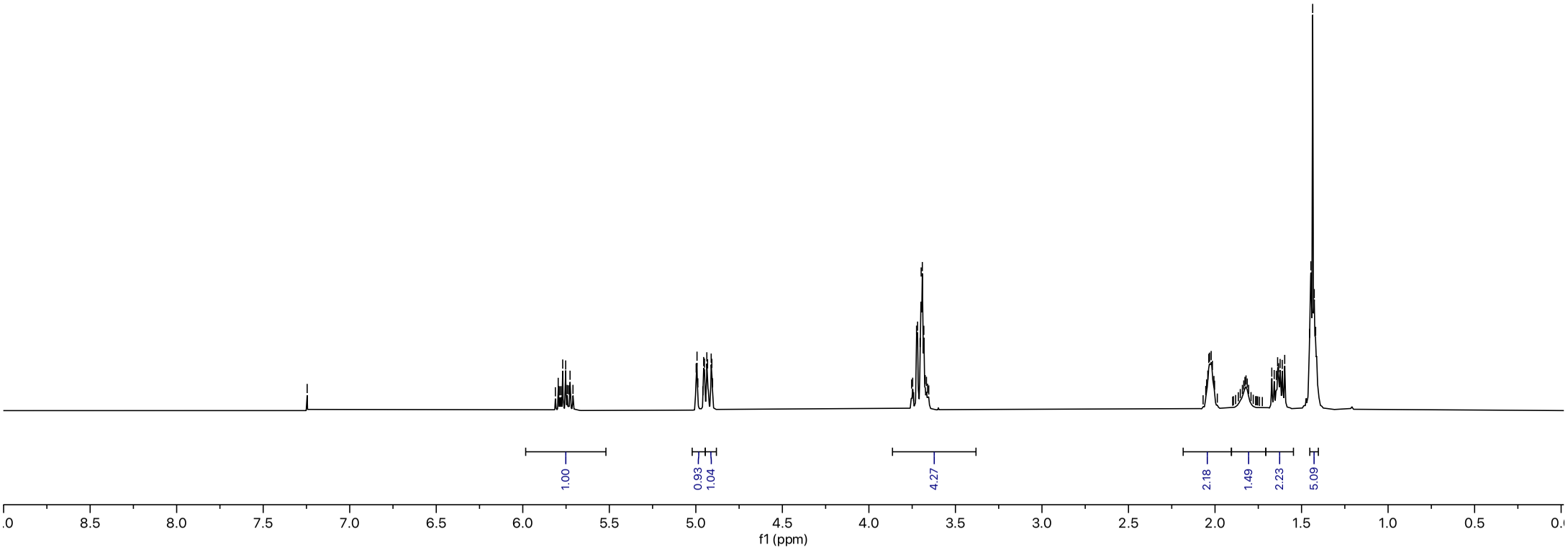
f1 (ppm)

Chloroform-d, 400 MHz

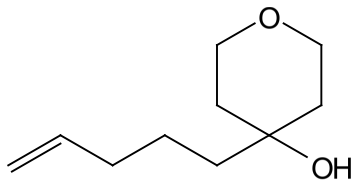


1e





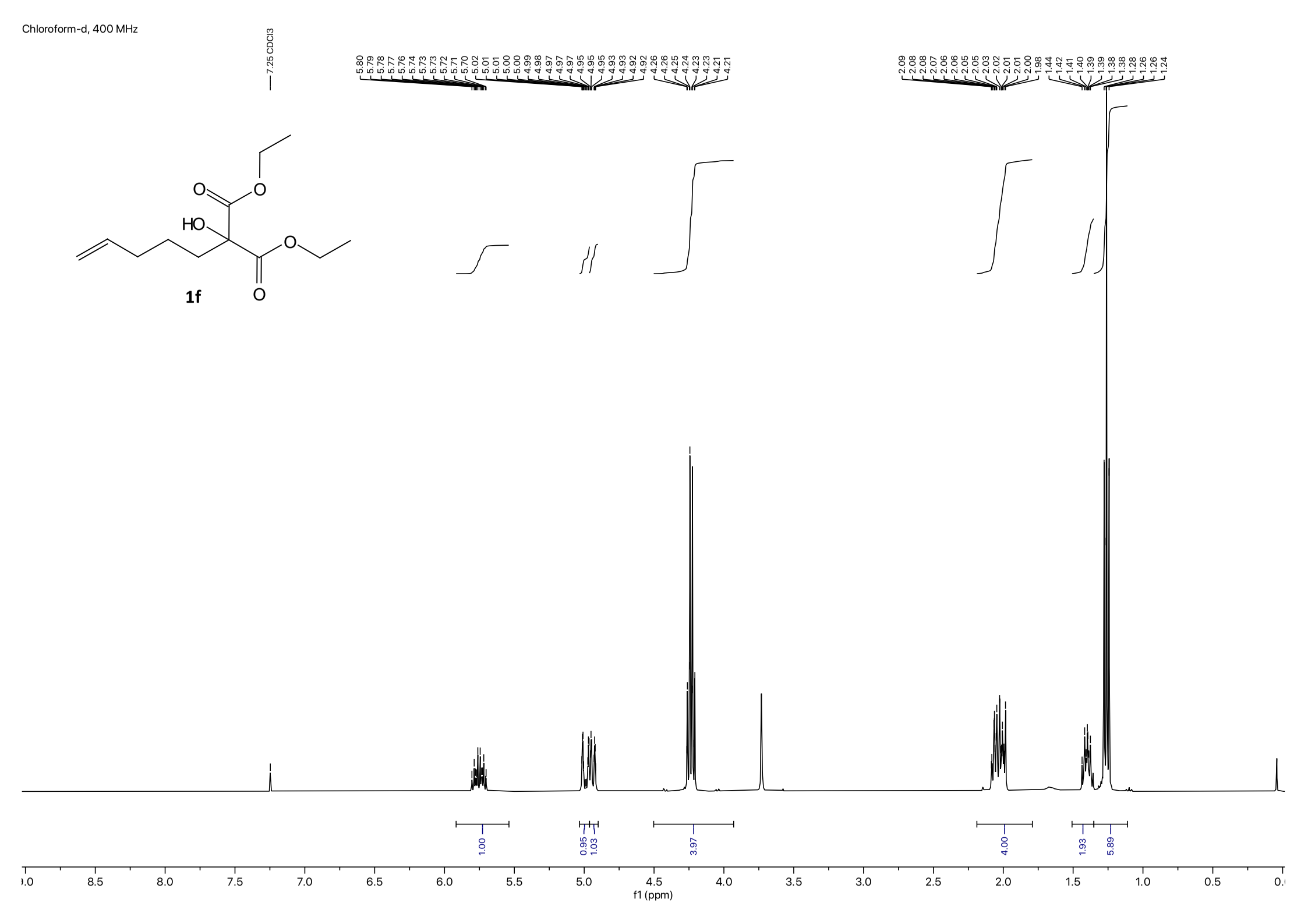
Chloroform-d, 101 MHz



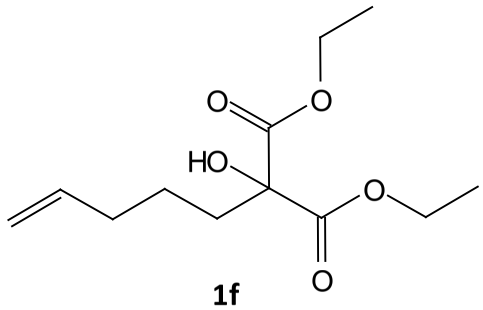
1e

138.61
114.87
77.48 CDCl3
77.16 CDCl3
76.85 CDCl3
68.88
63.92
42.81
37.61
34.08
21.83

f1 (ppm)

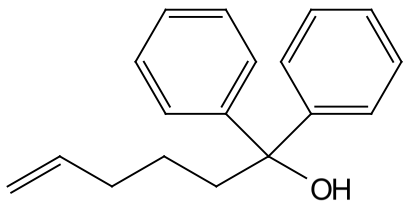

Chloroform-d, 400 MHz
7.25 CDCl3
5.80 5.79 5.78 5.77 5.76 5.74 5.73 5.73 5.72 5.71 5.70 5.02 5.01 5.01 5.00 5.00 4.99 4.98 4.97 4.97 4.97 4.95 4.95 4.93 4.93 4.92 4.92
4.26 4.26 4.25 4.24 4.23 4.23 4.21 4.21
2.09 2.08 2.08 2.07 2.06 2.06 2.05 2.05 2.03 2.02 2.01 2.01 2.00 1.98
1.44 1.42 1.41 1.40 1.39 1.39 1.38 1.38 1.28 1.26 1.26 1.24
HO
O
O
O
O
1f
1.00
0.95
1.03
3.97
4.00
1.93
5.89
f1 (ppm)

Chloroform-d, 101 MHz



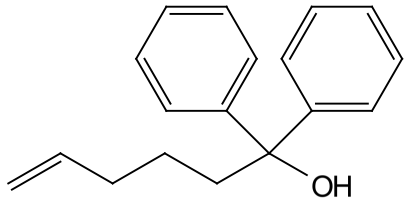
1f

Chloroform-d, 400 MHz



1g

Chloroform-d, 101 MHz



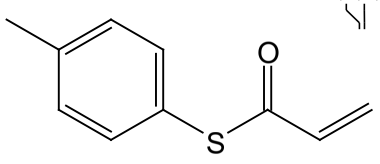
1g

147.21
138.70
128.28
126.93
126.17
114.98
78.33
77.51 CDCl3
77.20 CDCl3
76.88 CDCl3
41.47
34.08
23.15

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

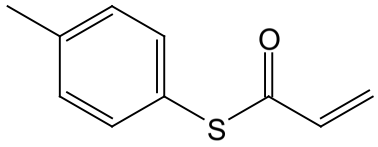
f1 (ppm)

Chloroform-d, 400 MHz

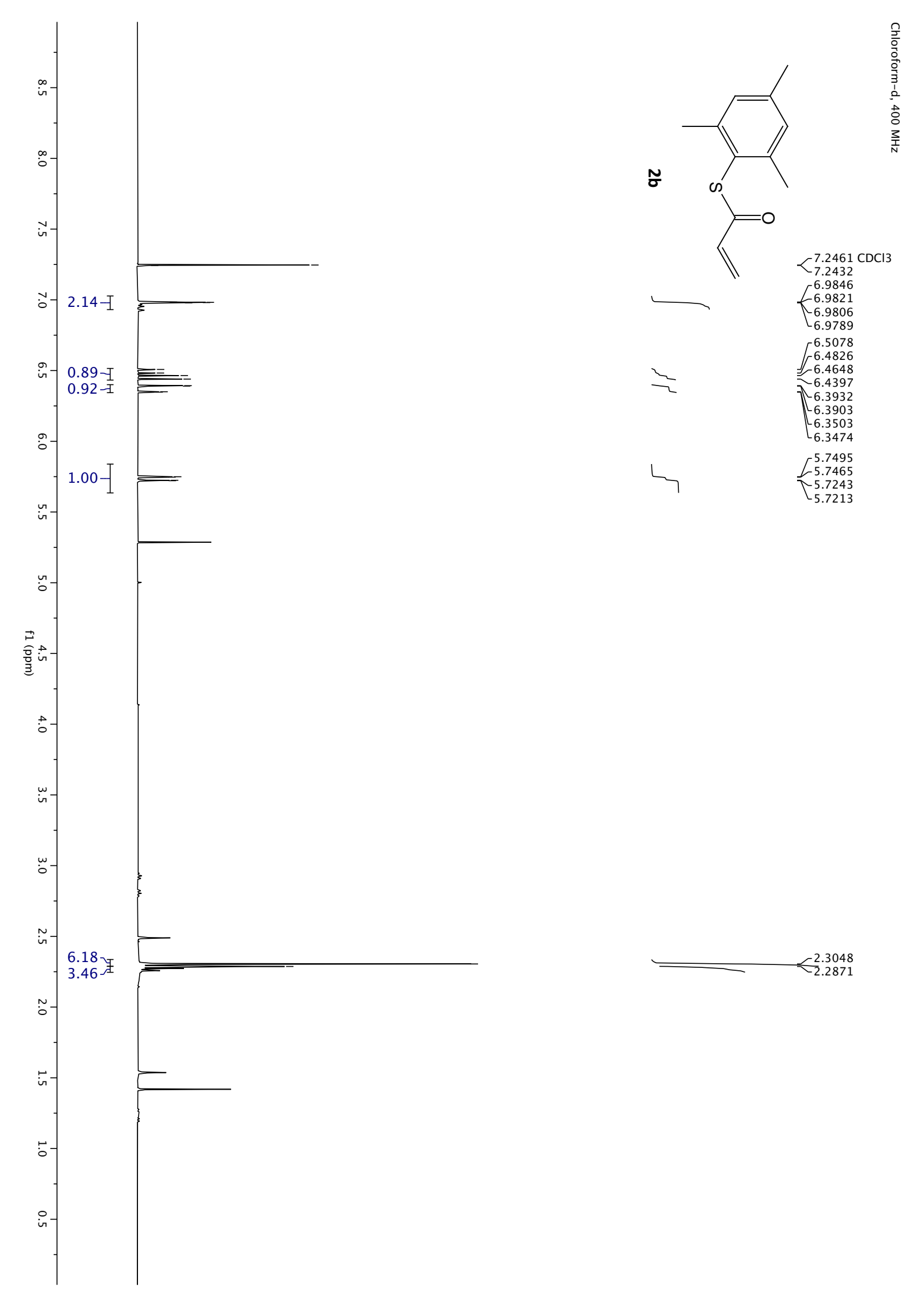


2a

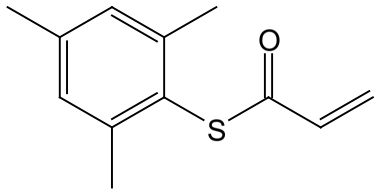
Chloroform-d, 101 MHz



2a

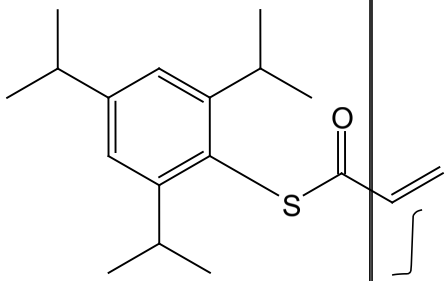

Chloroform-d, 400 MHz
2b
S
O
7.2461 CDCl3
7.2432
6.9846
6.9821
6.9806
6.9789
6.5078
6.4826
6.4648
6.4397
6.3932
6.3903
6.3503
6.3474
5.7495
5.7465
5.7243
5.7213
2.3048
2.2871
2.14
0.89
0.92
1.00
6.18
3.46
f1 (ppm)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5

Chloroform-d, 101 MHz



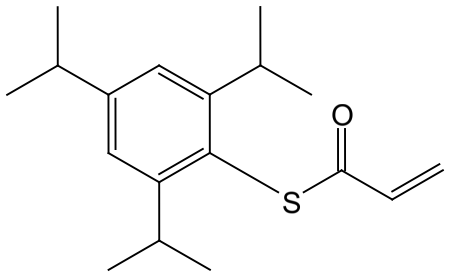
2b

Chloroform-d, 400 MHz



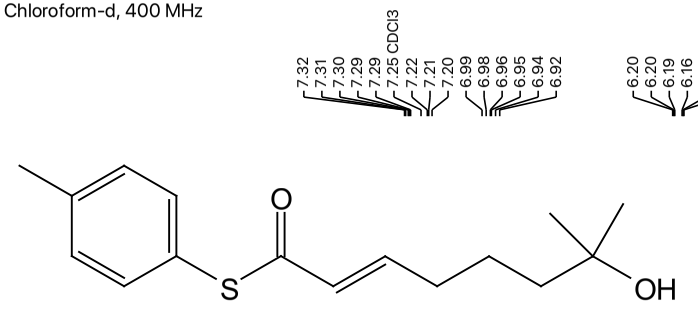
2c

Chloroform-d, 101 MHz



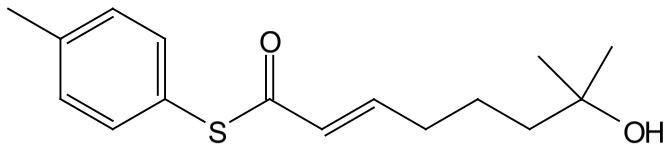
2c

Chloroform-d, 400 MHz

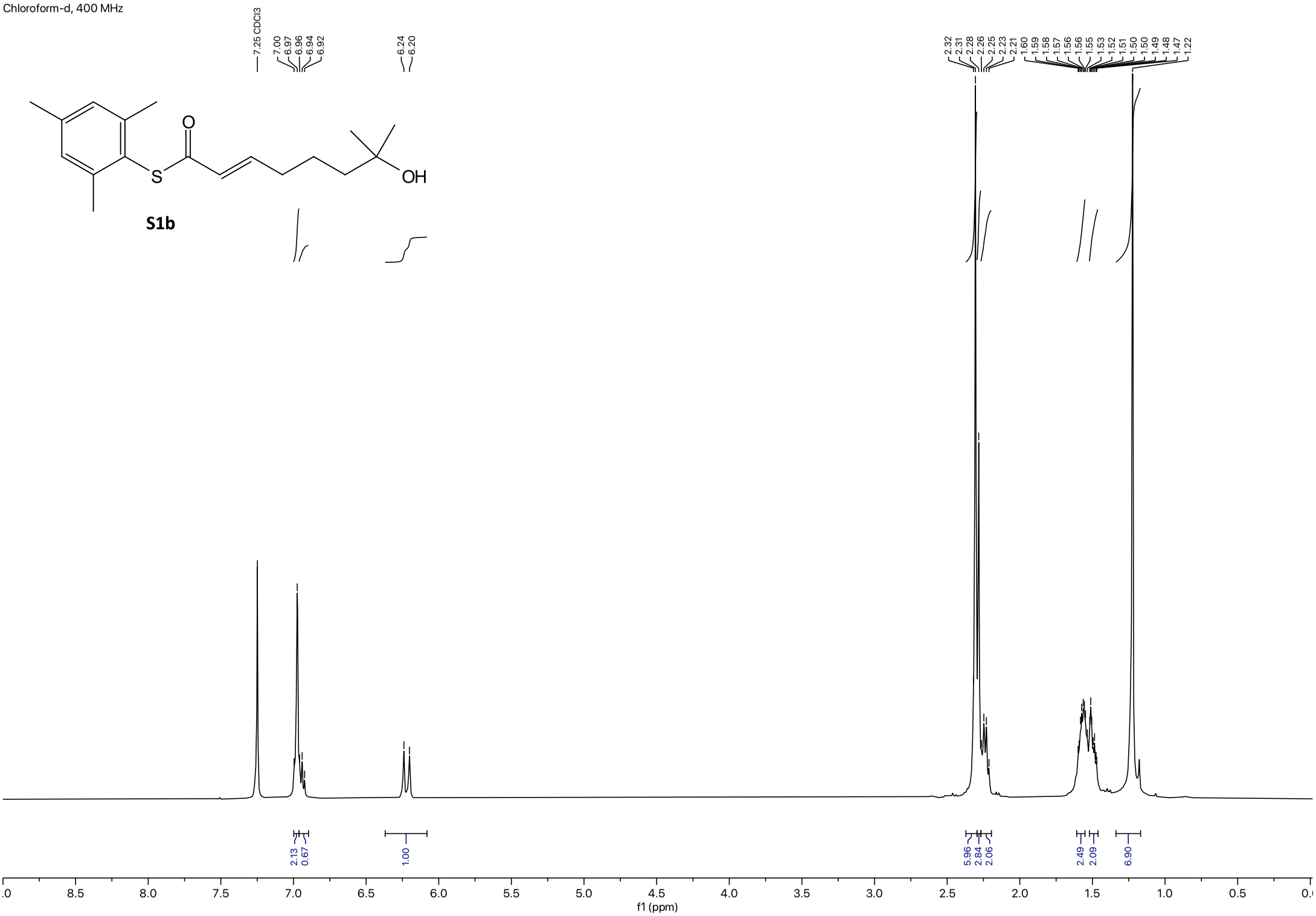


S1a

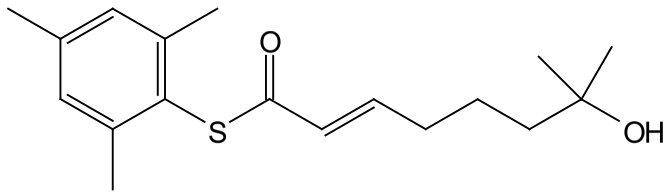
Chloroform-d, 101 MHz



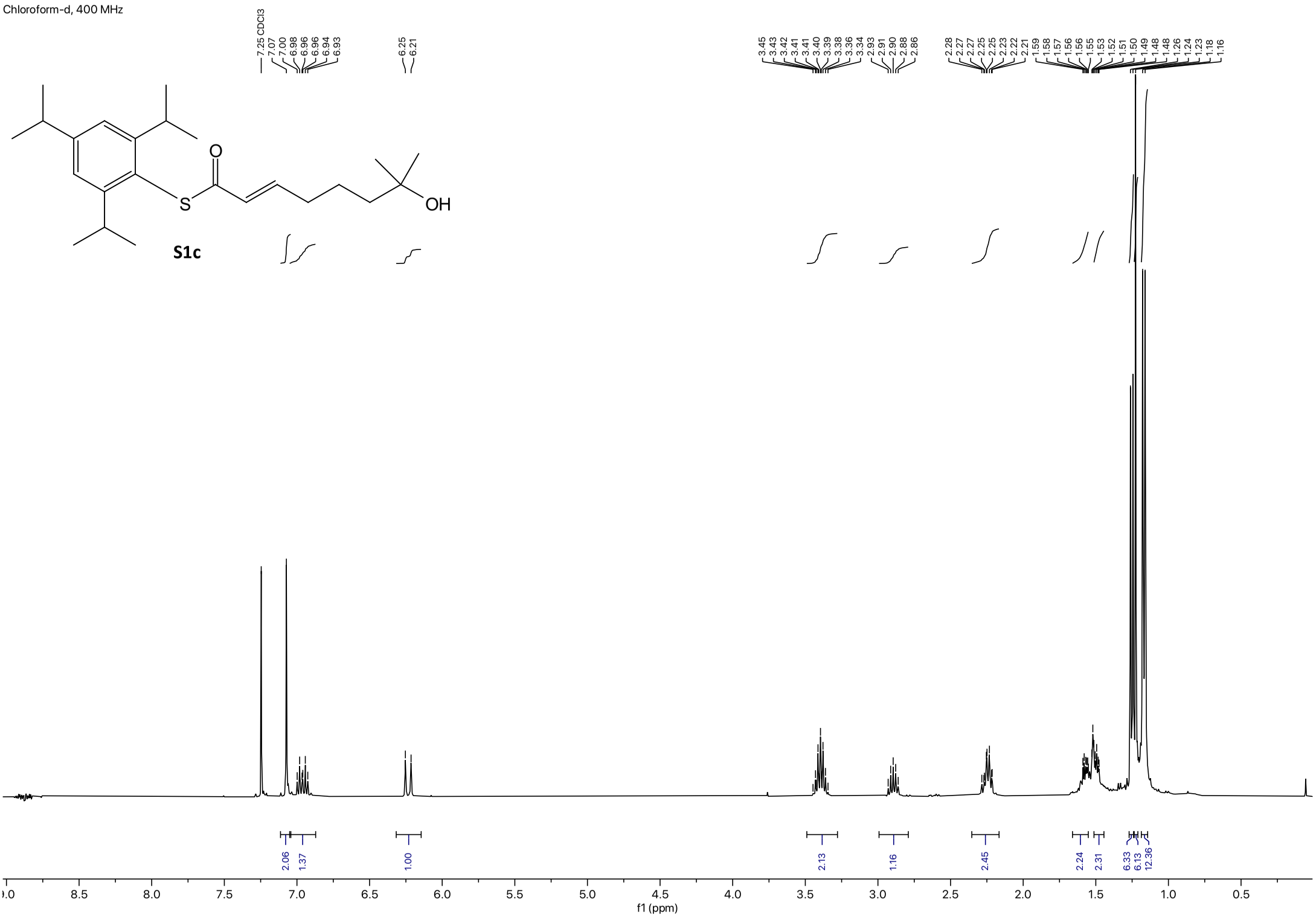
S1a


Chloroform-d, 400 MHz
7.25 CDCl3
7.00
6.97
6.96
6.94
6.92
6.24
6.20
2.32
2.31
2.28
2.26
2.25
2.23
2.21
1.60
1.59
1.58
1.57
1.56
1.56
1.55
1.53
1.52
1.51
1.50
1.50
1.49
1.48
1.47
1.22
O
S
OH
S1b
2.13
0.67
1.00
5.96
2.84
2.06
2.49
2.09
6.90
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

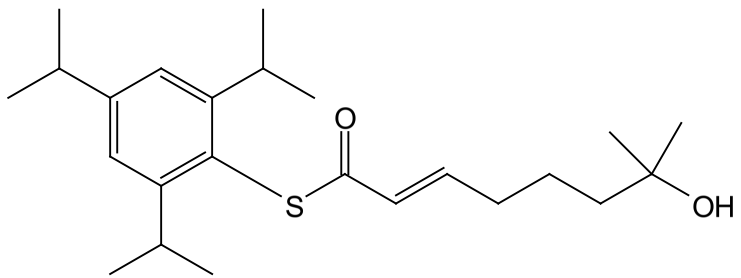
Chloroform-d, 101 MHz



S1b


Chloroform-d, 400 MHz
7.25 CDCl3
7.07
7.00
6.98
6.96
6.96
6.94
6.93
6.25
6.21
3.45
3.43
3.42
3.41
3.41
3.40
3.39
3.38
3.36
3.34
2.93
2.91
2.90
2.88
2.86
2.28
2.27
2.27
2.25
2.25
2.23
2.22
2.21
1.59
1.58
1.57
1.56
1.56
1.55
1.53
1.52
1.51
1.50
1.49
1.48
1.26
1.24
1.23
1.18
1.16
O
S
OH
S1c
2.06
1.37
1.00
2.13
1.16
2.45
2.24
2.31
6.33
6.13
12.36
f1 (ppm)

Chloroform-d, 101 MHz

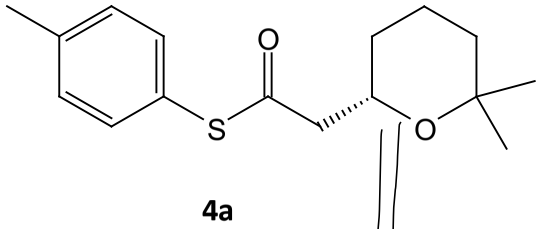


S1c

188.96
152.67
151.11
145.67
128.16
122.10
121.57
77.44 CDCl3
77.12 CDCl3
76.80 CDCl3
70.97
43.45
34.45
32.76
32.04
29.40
24.48
23.97
22.92

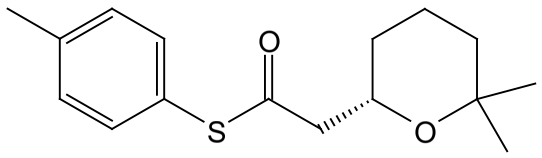
f1 (ppm)

Chloroform-d, 400 MHz



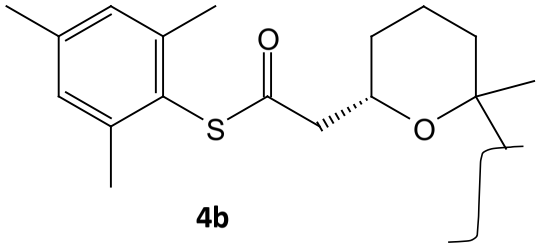
4a

Chloroform-d,101 MHz



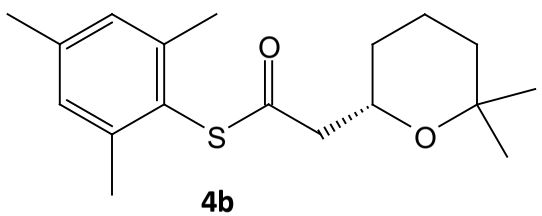
4a

Chloroform-d, 400 MHz



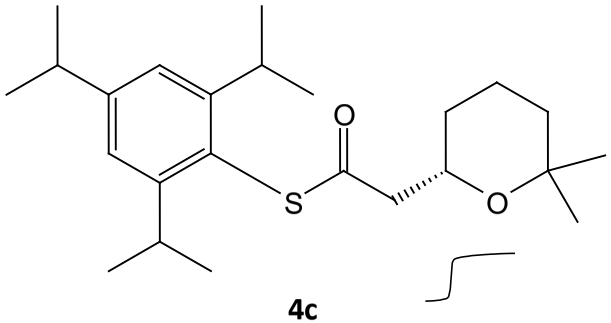
4b

Chloroform-d, 101 MHz



4b

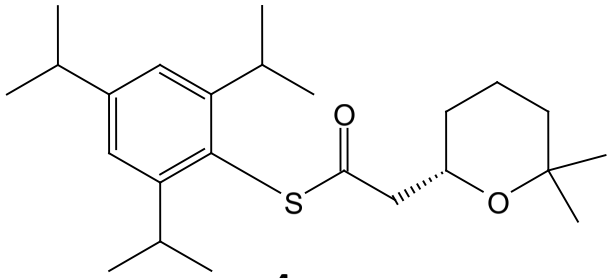
Chloroform-d, 400 MHz



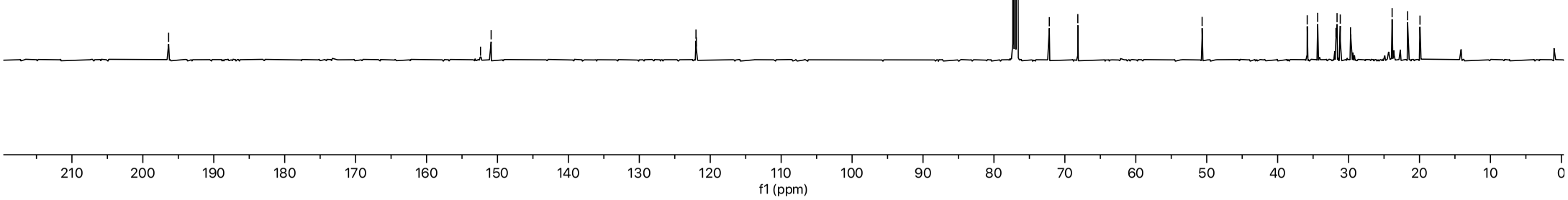
4c

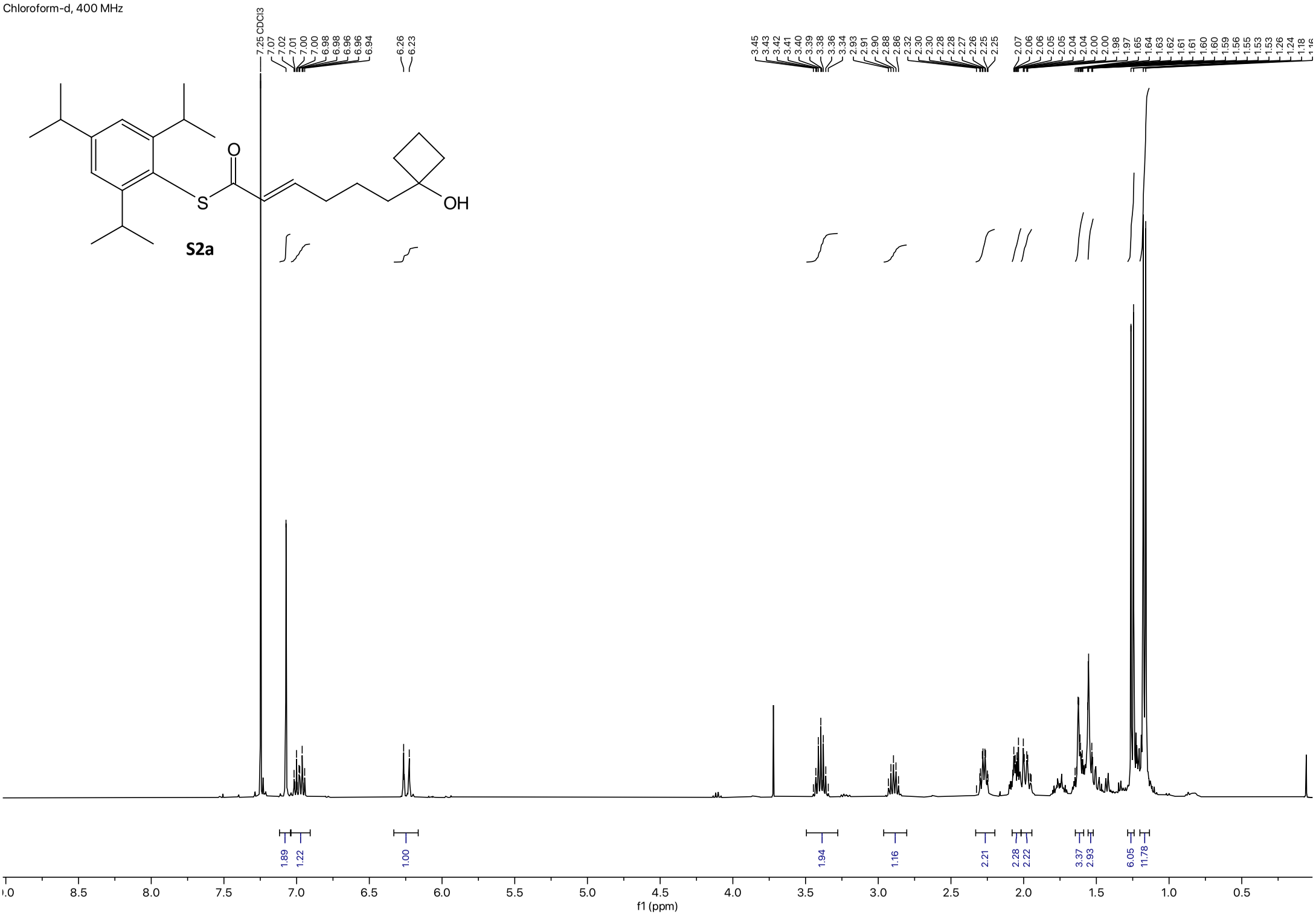
Chloroform-d, 101 MHz

196.36
152.39
150.89
122.01
121.96
77.28 CDCl3
77.02 CDCl3
76.77 CDCl3
72.19
68.17
50.65
35.83
34.36
31.78
31.62
31.17
29.73
23.86
21.68
19.93

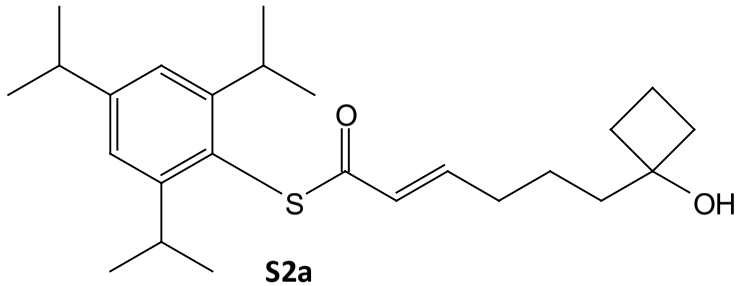


4c




Chloroform-d, 400 MHz
7.25 CDCl3
7.07
7.02
7.01
7.00
7.00
6.98
6.98
6.96
6.96
6.94
6.26
6.23
3.45
3.43
3.42
3.41
3.40
3.39
3.38
3.36
3.34
2.93
2.91
2.90
2.88
2.86
2.32
2.30
2.28
2.28
2.27
2.26
2.25
2.25
2.07
2.06
2.06
2.05
2.05
2.04
2.04
2.00
2.00
1.98
1.97
1.65
1.64
1.63
1.62
1.61
1.61
1.60
1.60
1.59
1.56
1.55
1.53
1.53
1.26
1.24
1.18
O
S
OH
S2a
1.89
1.22
1.00
1.94
1.16
2.21
2.28
2.22
3.37
2.93
6.05
11.78
f1 (ppm)

Chloroform-d, 101 MHz

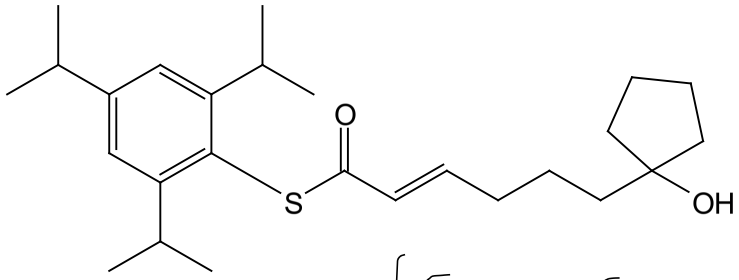


S2a

188.96
152.67
151.10
145.78
128.17
122.09
121.59
77.44 CDCl3
77.11 CDCl3
76.80 CDCl3
75.32
39.00
36.25
34.45
32.63
32.04
23.97
23.61
22.10
12.18

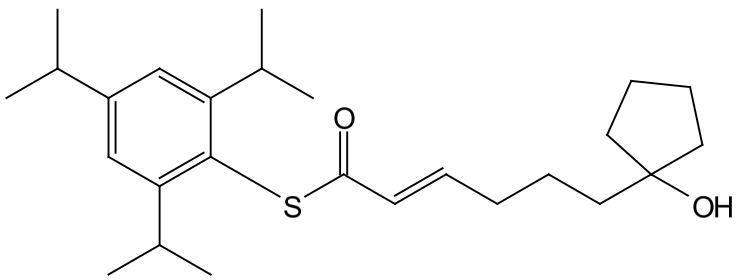
f1 (ppm)

Chloroform-d, 400 MHz



S2b

Chloroform-d, 101 Mhz

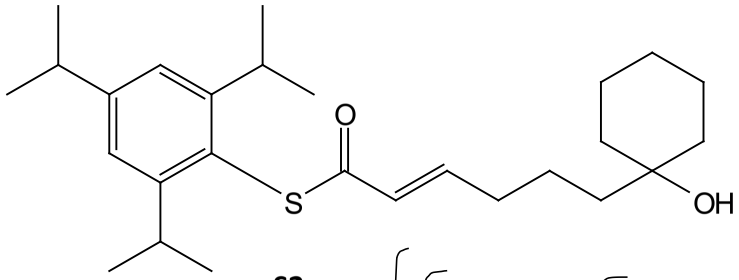


S2b

188.96
152.67
151.10
145.80
128.14
122.10
121.58
82.49
77.44 CDCl3
77.12 CDCl3
76.80 CDCl3
41.12
39.84
34.45
32.84
32.05
24.47
23.97
23.84
23.33

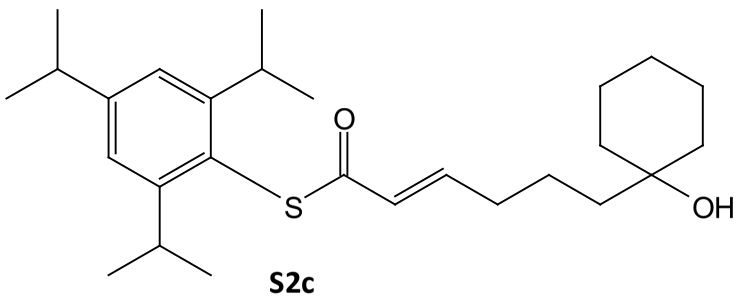
f1 (ppm)

Chloroform-d, 400 MHz



S2c

Chloroform-d, 101 MHz

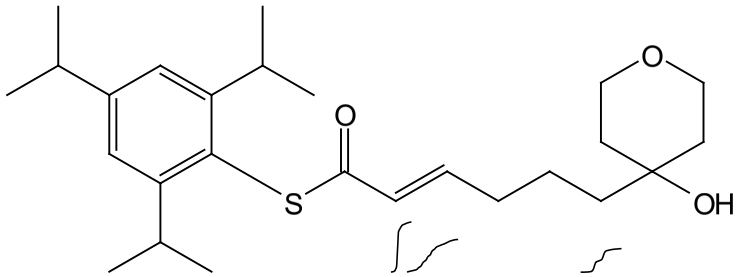


S2c

188.98
152.66
151.09
145.89
128.11
122.09
121.59
77.44 CDCl3
77.12 CDCl3
76.80 CDCl3
71.44
37.50
34.45
32.86
32.04
25.87
24.46
23.98
23.62
22.30
21.56

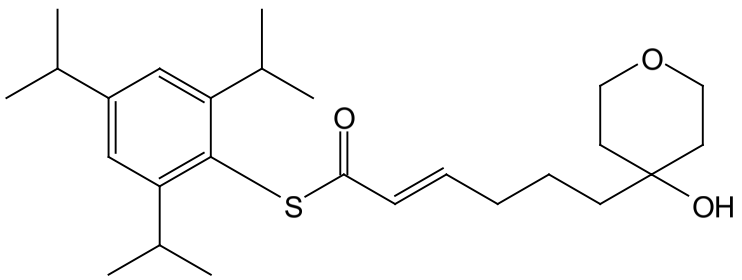
f1 (ppm)

Chloroform-d, 400 MHz



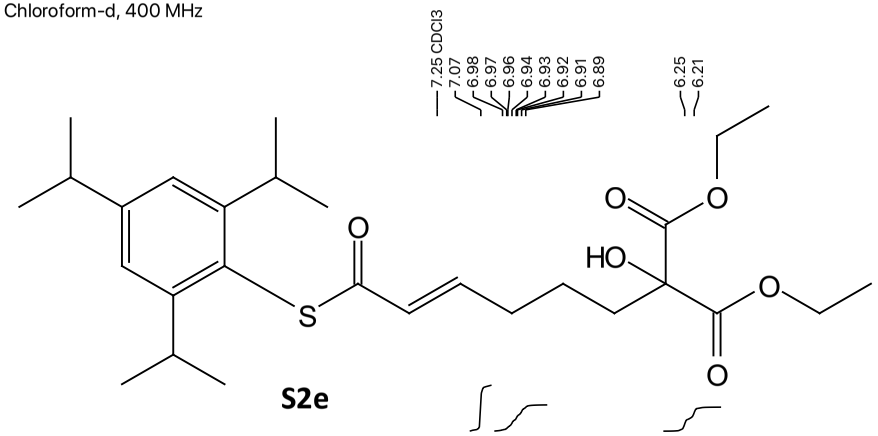
S2d

Chloroform-d, 101 MHz



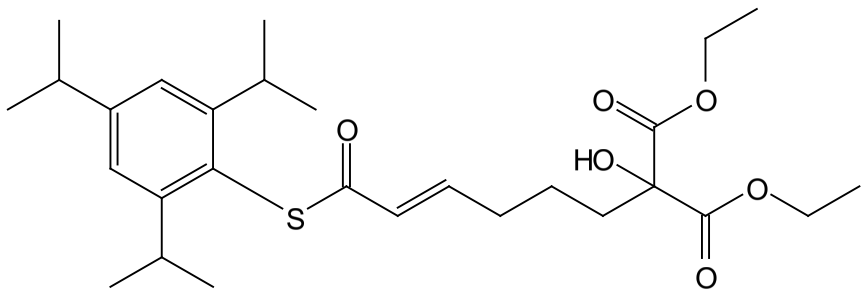
S2d

Chloroform-d, 400 MHz



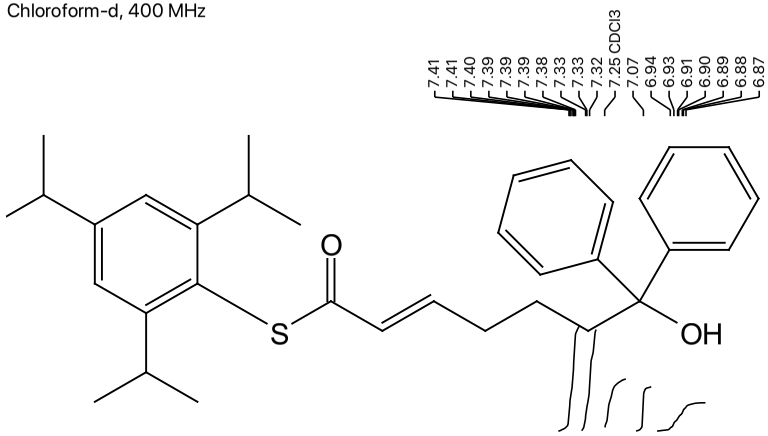
S2e

Chloroform-d, 101 MHz



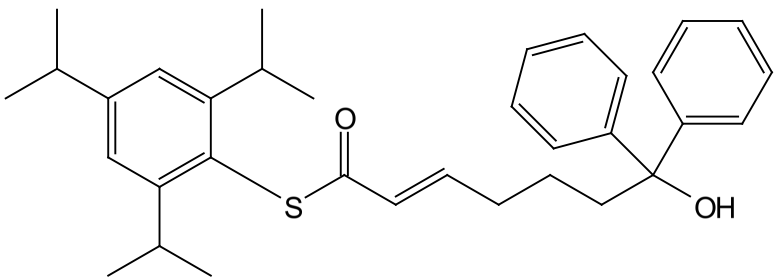
S2e

Chloroform-d, 400 MHz



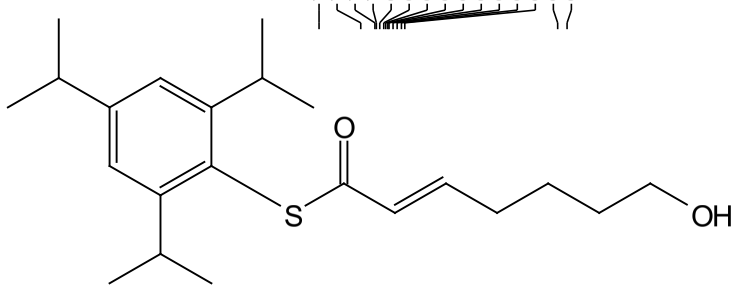
S2f

Chloroform-d, 101 MHz



S2f

Chloroform-d, 400 MHz



S2g

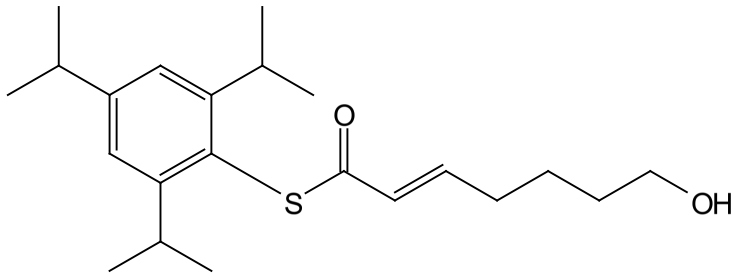
7.25 CDCl3
7.07
7.01
7.01
6.99
6.98
6.97
6.96
6.96
6.94
6.92
6.90
6.89
6.25
6.21

3.68
3.67
3.65
3.44
3.43
3.41
3.39
3.37
3.36
3.34
2.93
2.91
2.90
2.88
2.86
2.33
2.31
2.30
2.29
2.28
2.27
2.26
2.26
2.24
2.24
2.20
1.62
1.61
1.61
1.60
1.58
1.57
1.57
1.56
1.26
1.24
1.18
1.16

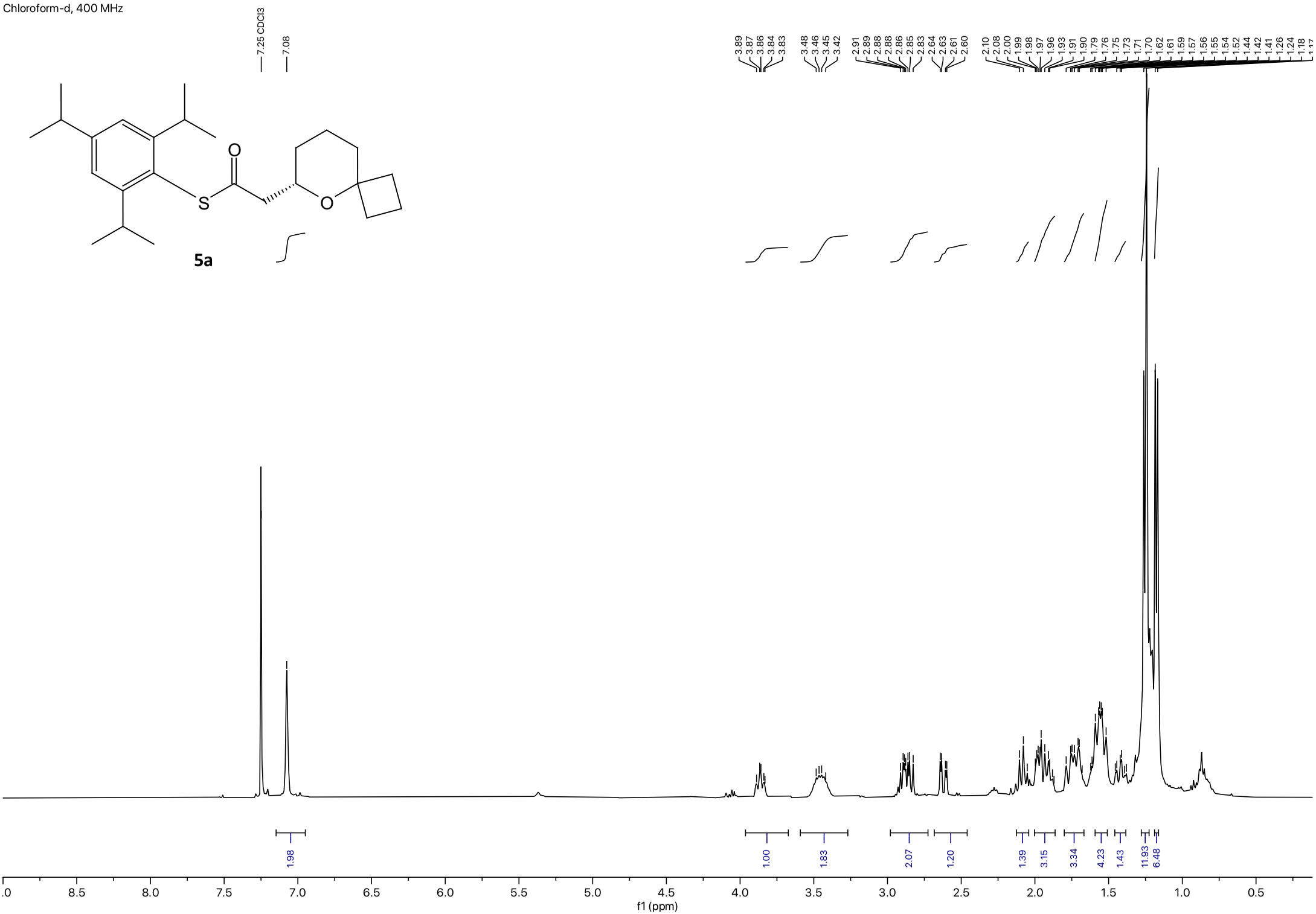
1.97
1.07
1.00
2.38
2.10
1.01
2.09
4.67
6.42
12.18

8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

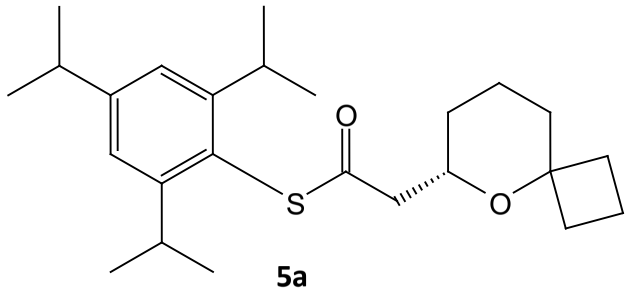
Chloroform-d, 101 MHz



S2g

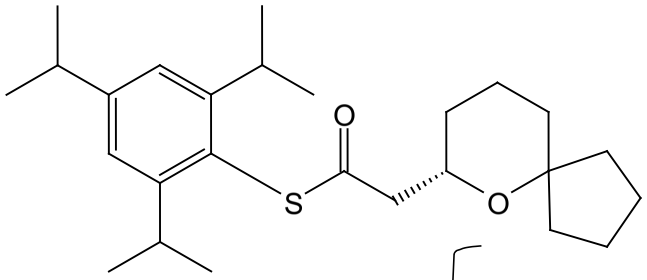

Chloroform-d, 400 MHz
7.25 CDCl3
7.08
3.89
3.87
3.86
3.84
3.83
3.48
3.46
3.45
3.42
2.91
2.89
2.88
2.88
2.86
2.85
2.83
2.64
2.63
2.61
2.60
2.10
2.08
2.00
1.99
1.98
1.97
1.96
1.93
1.91
1.90
1.79
1.76
1.75
1.73
1.71
1.70
1.62
1.61
1.59
1.57
1.56
1.55
1.54
1.52
1.44
1.42
1.41
1.26
1.24
1.18
O
S
O
5a
1.98
1.00
1.83
2.07
1.20
1.39
3.15
3.34
4.23
1.43
11.93
6.48
f1 (ppm)

Chloroform-d, 101 MHz



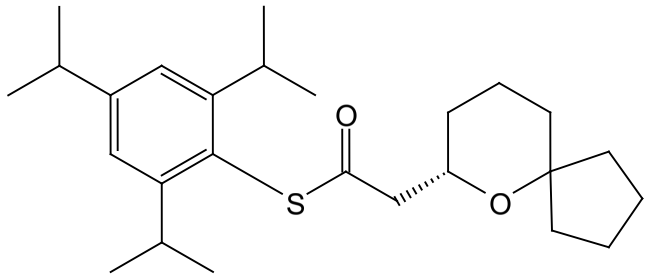
5a

Chloroform-d, MHz



5b

Chloroform-d, 101 MHz

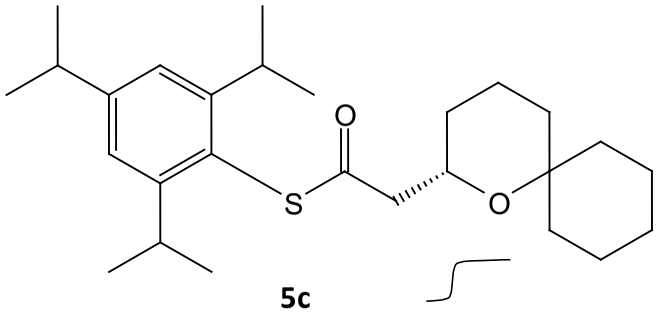


5b

196.41
152.47
150.99
122.05
122.03
84.36
77.44 CDCl3
76.81 CDCl3
69.23
50.61
41.60
34.73
34.44
32.65
31.92
31.32
24.54
23.99
23.96
23.33
21.23

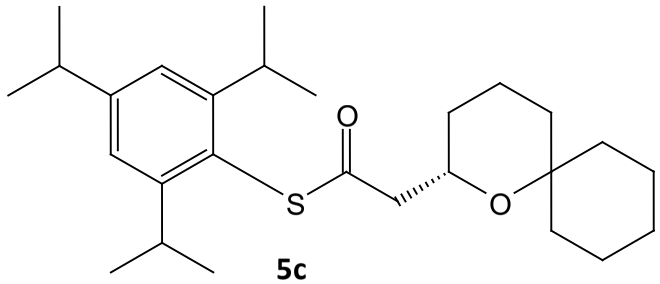
f1 (ppm)

Chloroform-d, 400 MHz



5c

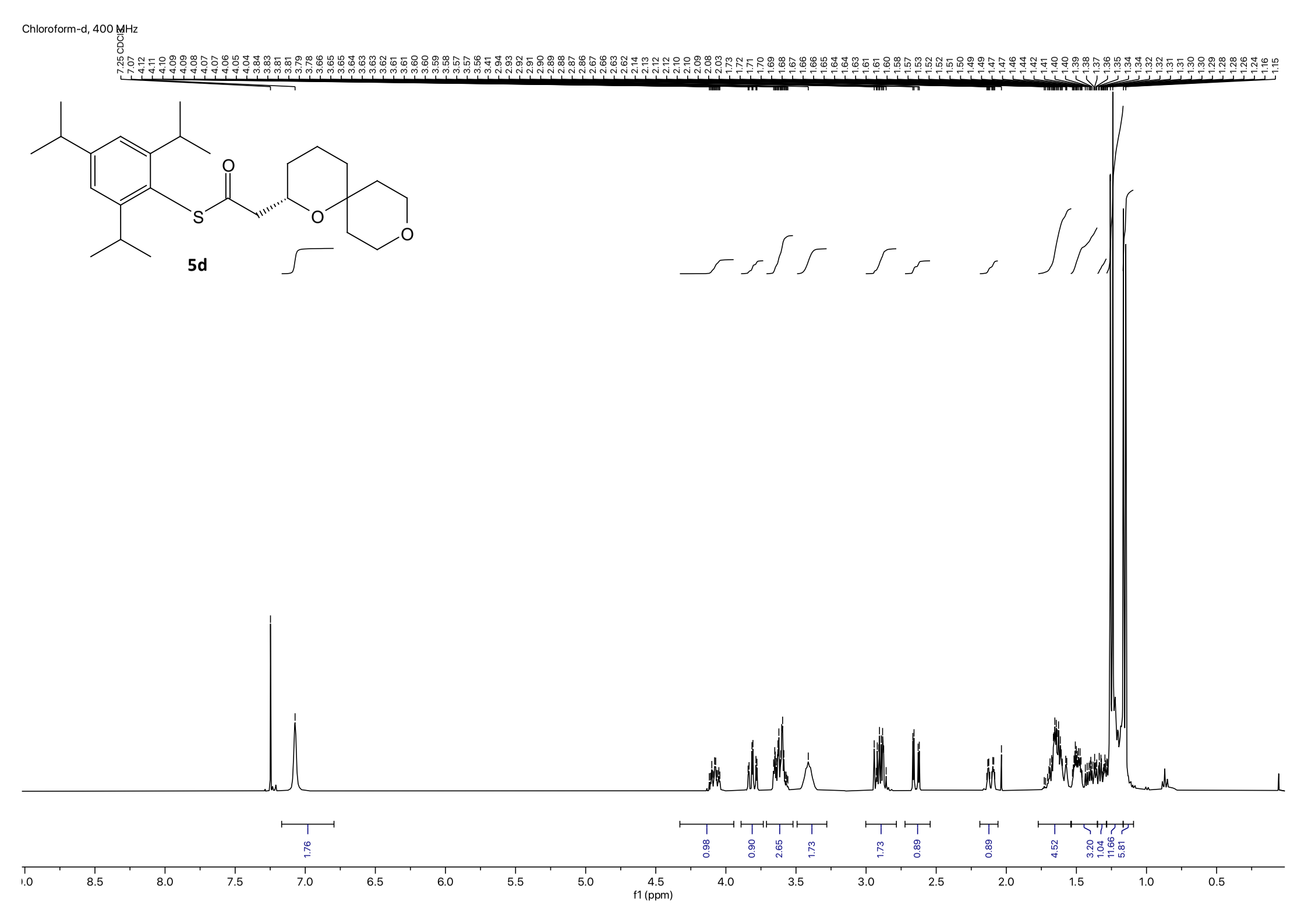
Chloroform-d, 101 MHz



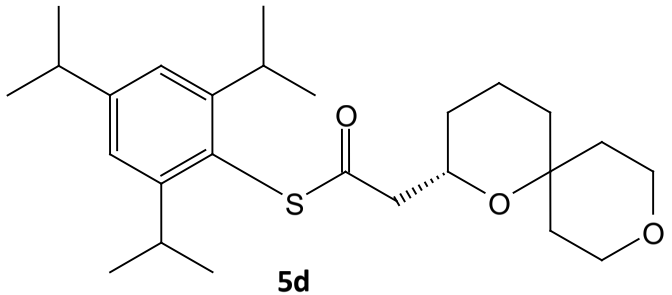
5c

196.29
152.52
150.89
122.05
121.95
77.27 CDCl3
76.77 CDCl3
72.74
66.45
50.77
40.44
35.13
34.35
31.88
31.52
29.74
26.46
23.88
23.87
21.59
21.28
19.17

f1 (ppm)


Chloroform-d, 400 MHz
7.25 CDCl3
7.07
4.12
4.11
4.10
4.09
4.09
4.08
4.07
4.07
4.06
4.05
4.04
3.84
3.83
3.81
3.81
3.79
3.78
3.66
3.65
3.65
3.64
3.63
3.63
3.62
3.61
3.61
3.60
3.60
3.59
3.58
3.57
3.57
3.56
3.41
2.94
2.93
2.92
2.91
2.90
2.89
2.88
2.87
2.86
2.67
2.66
2.63
2.62
2.14
2.13
2.12
2.12
2.10
2.10
2.09
2.08
2.03
1.73
1.72
1.71
1.70
1.69
1.68
1.67
1.66
1.66
1.65
1.64
1.64
1.63
1.61
1.61
1.60
1.58
1.57
1.53
1.52
1.52
1.51
1.50
1.49
1.49
1.47
1.47
1.46
1.44
1.42
1.41
1.40
1.40
1.39
1.38
1.37
1.36
1.35
1.34
1.34
1.32
1.31
1.31
1.30
1.30
1.29
1.28
1.28
1.26
1.24
1.16
1.15
O
S
O
O
O
5d
1.76
0.98
0.90
2.65
1.73
1.73
0.89
0.89
4.52
3.20
1.04
11.66
5.81
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

Choroform-d, 101 MHz

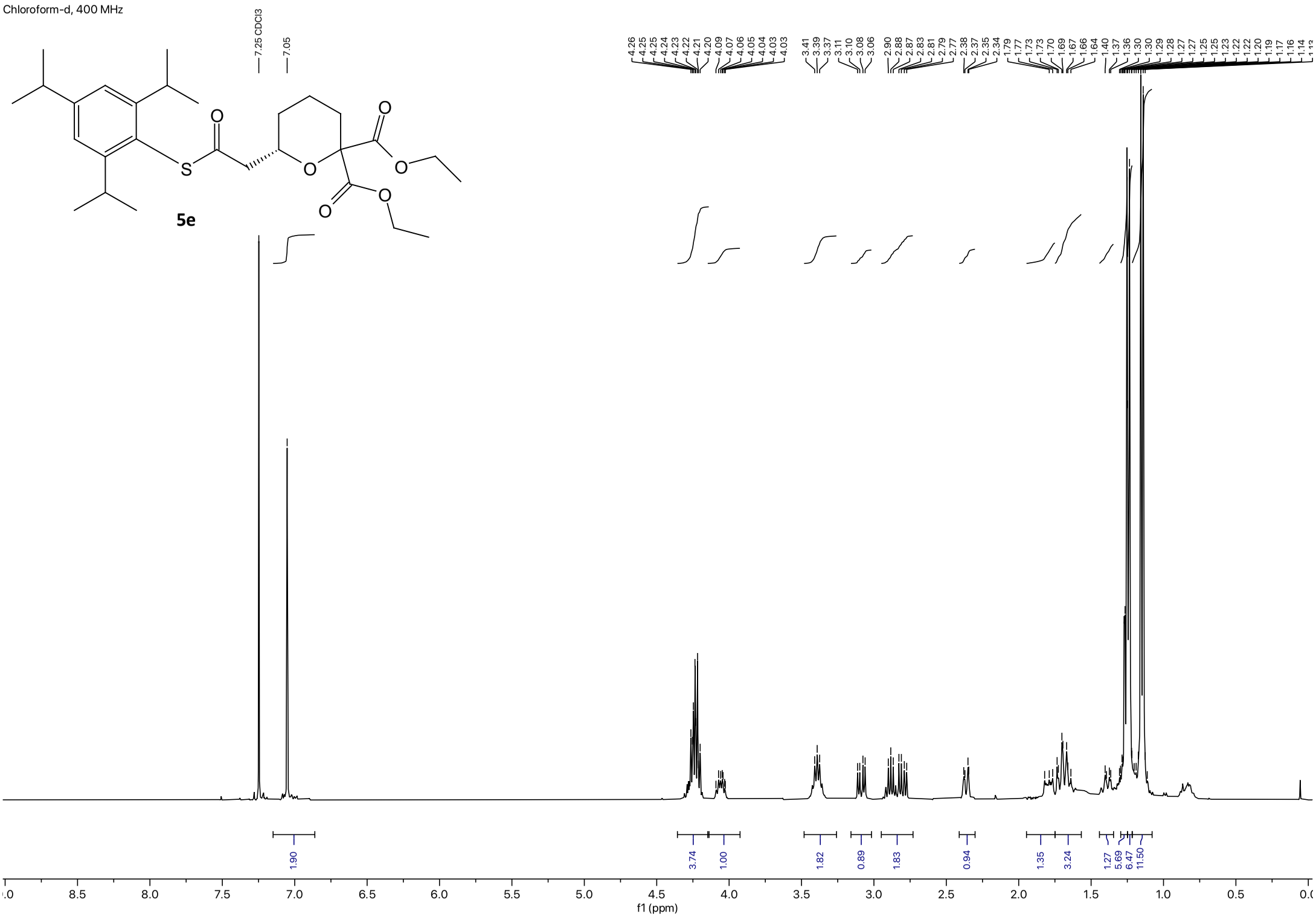


5d

196.36
152.17
151.14
122.10
121.84
77.44 CDCl3
77.12 CDCl3
76.80 CDCl3
70.44
66.75
63.32
63.27
50.47
40.25
35.66
34.44
32.03
31.31
30.44
24.36
23.95
18.88

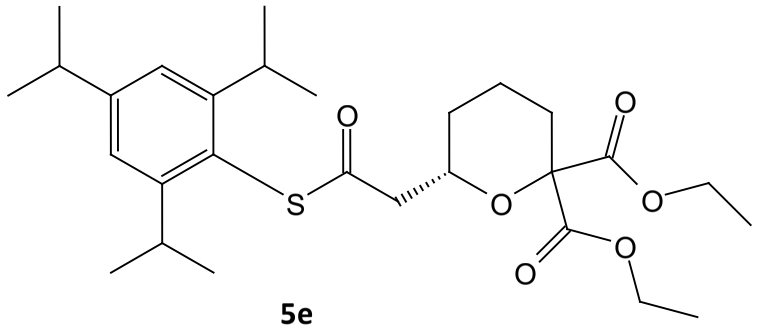
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

f1 (ppm)


Chloroform-d, 400 MHz
7.25 CDCl3
7.05
5e
4.26 4.25 4.25 4.24 4.23 4.22 4.21 4.20 4.09 4.07 4.06 4.05 4.04 4.03 4.03
3.41 3.39 3.37 3.11 3.10 3.08 3.06
2.90 2.88 2.87 2.83 2.81 2.79 2.77
2.38 2.37 2.35 2.34
1.79 1.77 1.73 1.73 1.70 1.69 1.67 1.66 1.64 1.40 1.37 1.36 1.30 1.30 1.29 1.28 1.27 1.27 1.25 1.25 1.23 1.22 1.22 1.20 1.19 1.17 1.16 1.14
1.90
3.74
1.00
1.82
0.89
1.83
0.94
1.35
3.24
1.27
5.69
6.47
11.50
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

Chloroform-d, 101 MHz

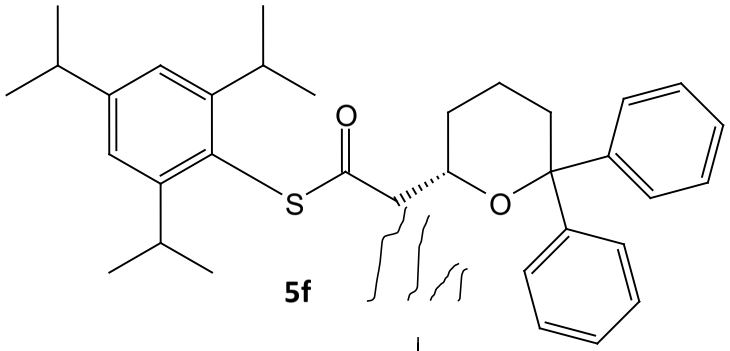
195.14
168.62
168.30
152.44
151.04
121.95
121.75
82.17
77.28 CDCl3
76.77 CDCl3
71.77
61.98
61.80
49.74
34.36
31.86
29.74
29.33
23.89
23.85
19.85
14.12
14.04



5e

f1 (ppm)

Chloroform-d, 400 MHz



5f

7.43 7.42 7.42 7.40 7.40 7.32 7.32 7.31 7.29 7.25 CDCl3 7.23 7.21 7.19 7.17 7.16 7.14 7.12 7.10 7.07

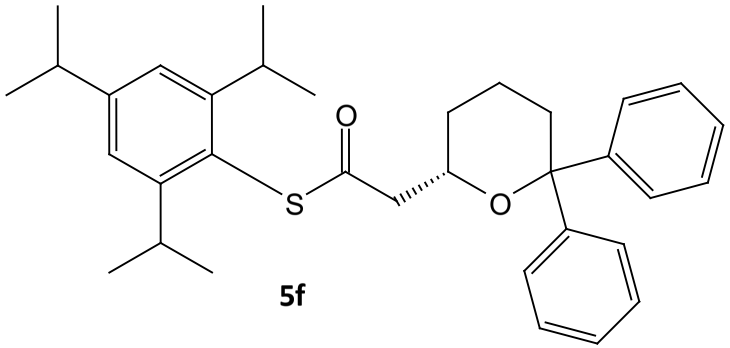
4.10 4.09 4.08 4.08 4.07 4.06 4.06 4.05 4.04 4.03 3.48 3.15 3.13 3.11 3.09 2.91 2.90 2.88 2.77 2.75 2.74 2.71 2.70 1.81 1.80 1.78 1.77 1.77 1.76 1.75 1.73 1.72 1.70 1.50 1.49 1.47 1.46 1.44 1.43 1.41 1.40 1.27 1.26 1.25 1.24 1.22 1.16 1.16 1.14 1.12 1.11 1.09

4.04 3.68 1.62 1.39 1.00 1.42 0.75 0.76 1.54 2.99 2.94 12.36 6.38

9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5

f1 (ppm)

Chloroform-d, 101 MHz

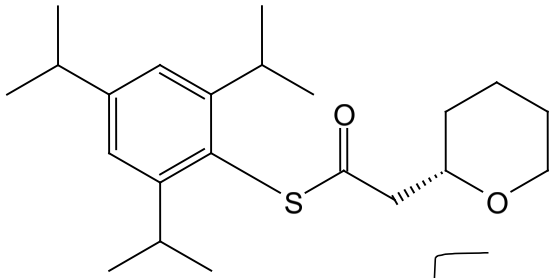


5f

196.01
151.02
151.01
149.05
142.43
128.58
127.93
127.44
126.77
126.14
124.77
122.05
121.98
80.26
77.28 CDCl3
77.02 CDCl3
76.77 CDCl3
68.62
50.51
34.82
34.36
31.95
31.06
29.72
23.88
20.35

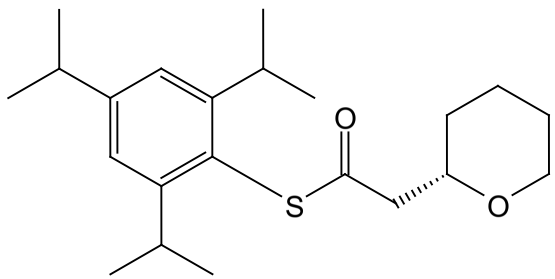
f1 (ppm)

Chloroform-d, 400 MHz



5g

Chloroform-d, 101 MHz

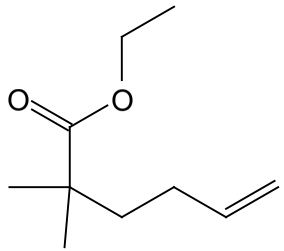


5g

196.30
152.50
151.09
122.08
122.00
77.44 CDCl3
77.12 CDCl3
76.80 CDCl3
75.43
68.72
50.23
34.44
31.94
31.56
29.81
25.73
23.97
23.43

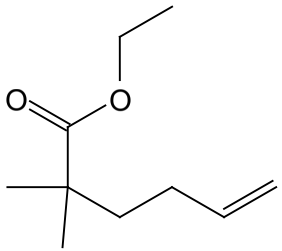
f1 (ppm)

Chloroform-d, 400 MHz



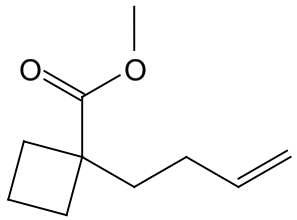
S4a

Chloroform-d, 101 MHz



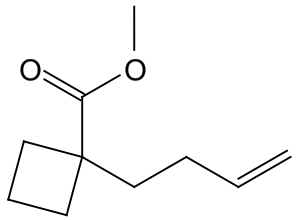
S4a

Chloroform-d, 400 MHz



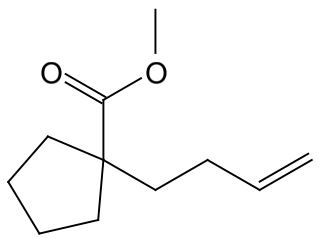
S4b

Chloroform-d, 101 MHz



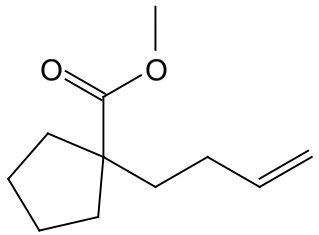
S4b

Chloroform-d, 400 MHz



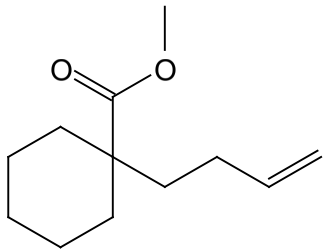
S4c

Chloroform-d, 101 MHz



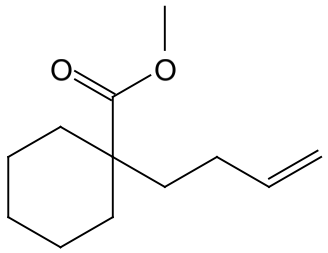
S4c

Chloroform-d, 400 MHz



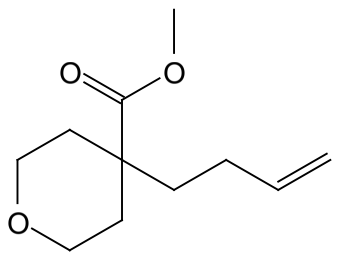
S4d

Chloroform-d, 101 MHz



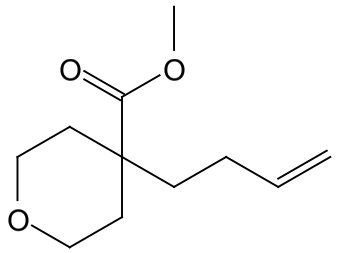
S4d

Clorform-d, 400 MHz



S4e

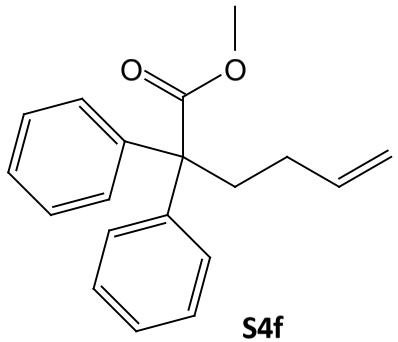
Clorform-d, 101 MHz



S4e

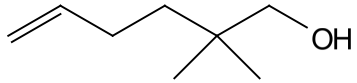
Chloroform-d, 400 MHz
S4f
O
O
7.32
7.30
7.30
7.28
7.27
7.25 CDCl3
7.25
7.23
7.22
5.82
5.80
5.79
5.79
5.78
5.76
5.75
5.74
5.74
5.72
4.99
4.98
4.98
4.94
4.93
4.93
4.90
3.68
2.48
2.47
2.46
2.45
2.44
1.83
1.82
1.81
1.81
1.80
1.79
1.77
10.85
1.00
2.06
3.19
2.14
2.11
f1 (ppm)
0.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5

Chloroform-d, 101 MHz



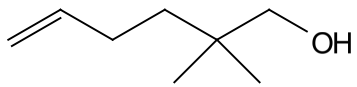
S4f

Chloroform-d, 400 MHz



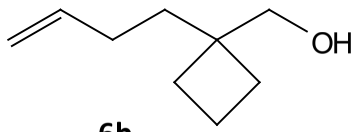
6a

Chloroform-d, 101 MHz



6a

Chloroform-d, 400 MHz



6b

7.25 CDCl3

5.87 5.86 5.85 5.84 5.83 5.81 5.80 5.80 5.79 5.77

5.04 5.03 4.99 4.98 4.93 4.91 4.90

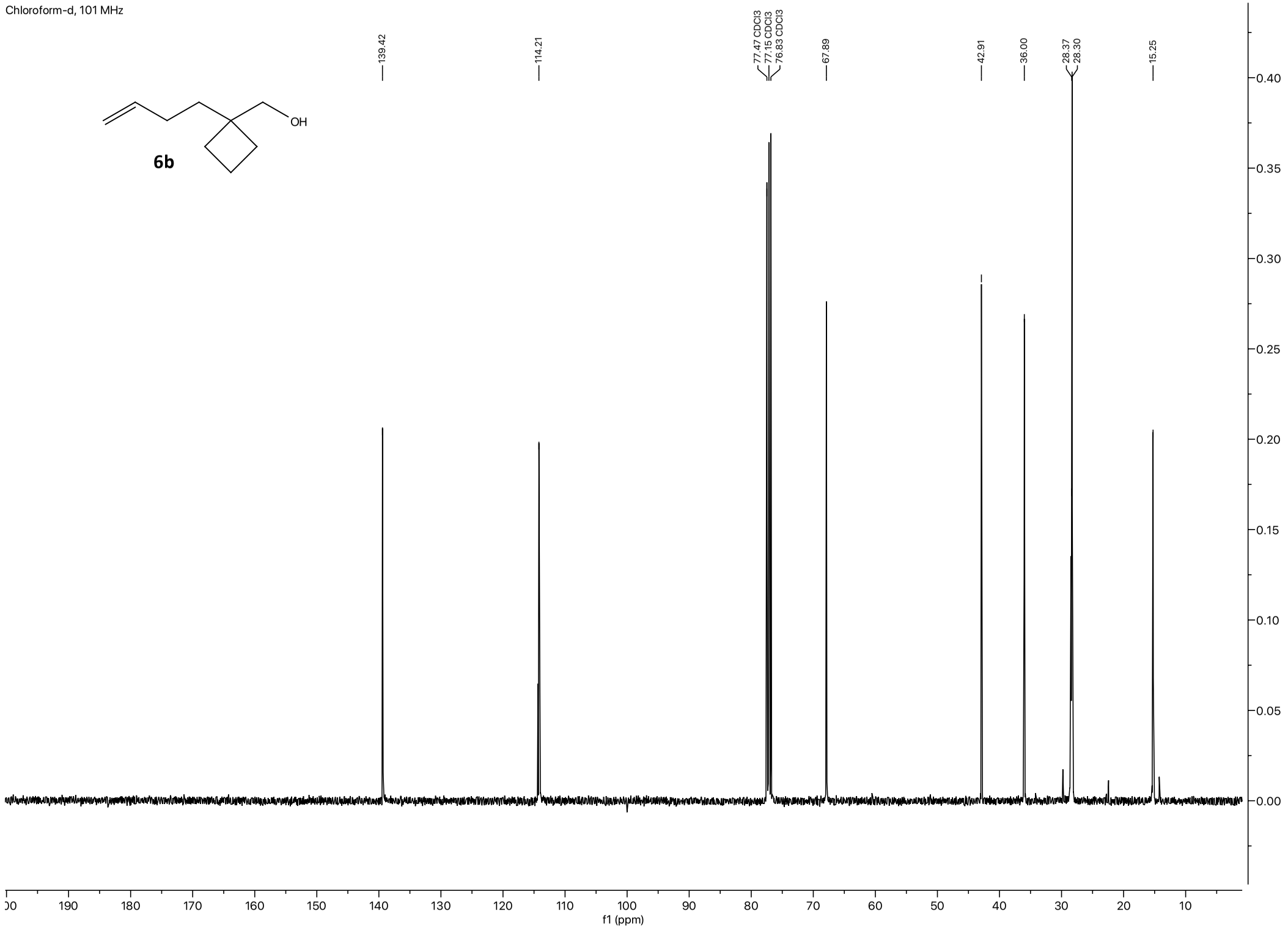
3.53

2.02 2.00 1.99 1.97 1.96 1.95 1.88 1.86 1.86 1.84 1.82 1.81 1.80 1.78 1.77 1.75 1.74 1.72 1.72 1.70 1.68 1.60 1.59 1.58 1.57 1.56 1.55

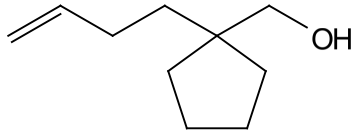
1.00 1.02 0.96 2.03 2.06 2.17 2.98 1.41 1.87

8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0

f1 (ppm)

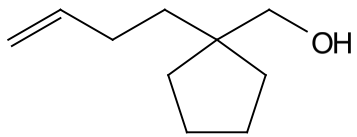

Chloroform-d, 101 MHz
139.42
114.21
77.47 CDCl3
77.15 CDCl3
76.83 CDCl3
67.89
42.91
36.00
28.37
28.30
15.25
OH
6b
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

Chloroform-d, 400 MHz

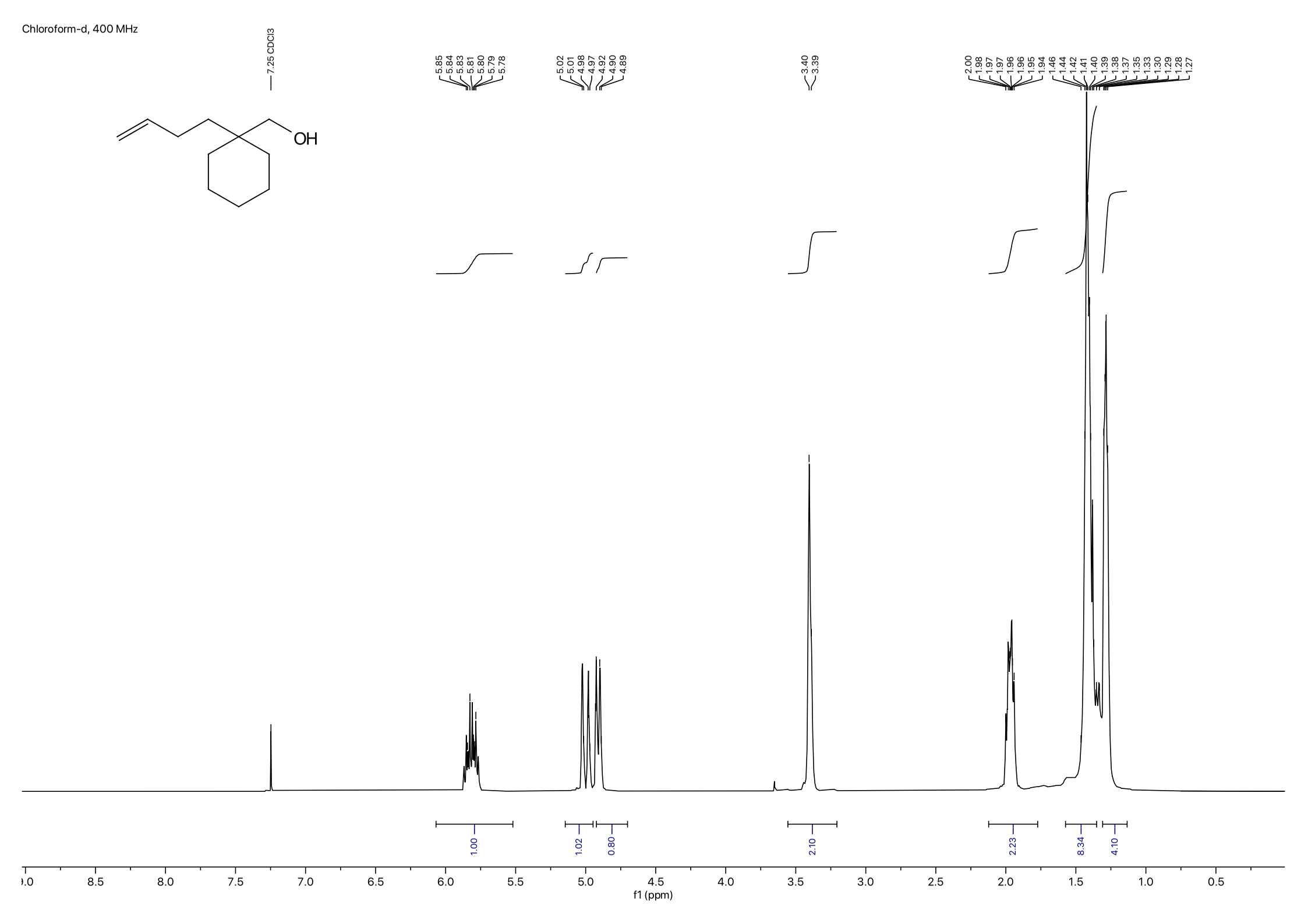


6c

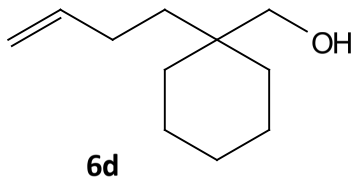
Chloroform-d, 101 MHz



6c


Chloroform-d, 400 MHz
7.25 CDCl3
5.85
5.84
5.83
5.81
5.80
5.79
5.78
5.02
5.01
4.98
4.97
4.92
4.90
4.89
3.40
3.39
2.00
1.98
1.97
1.97
1.96
1.96
1.95
1.94
1.46
1.44
1.42
1.41
1.40
1.39
1.38
1.37
1.35
1.33
1.30
1.29
1.28
1.27
OH
1.00
1.02
0.80
2.10
2.23
8.34
4.10
f1 (ppm)

Chloroform-d, 101 MHz

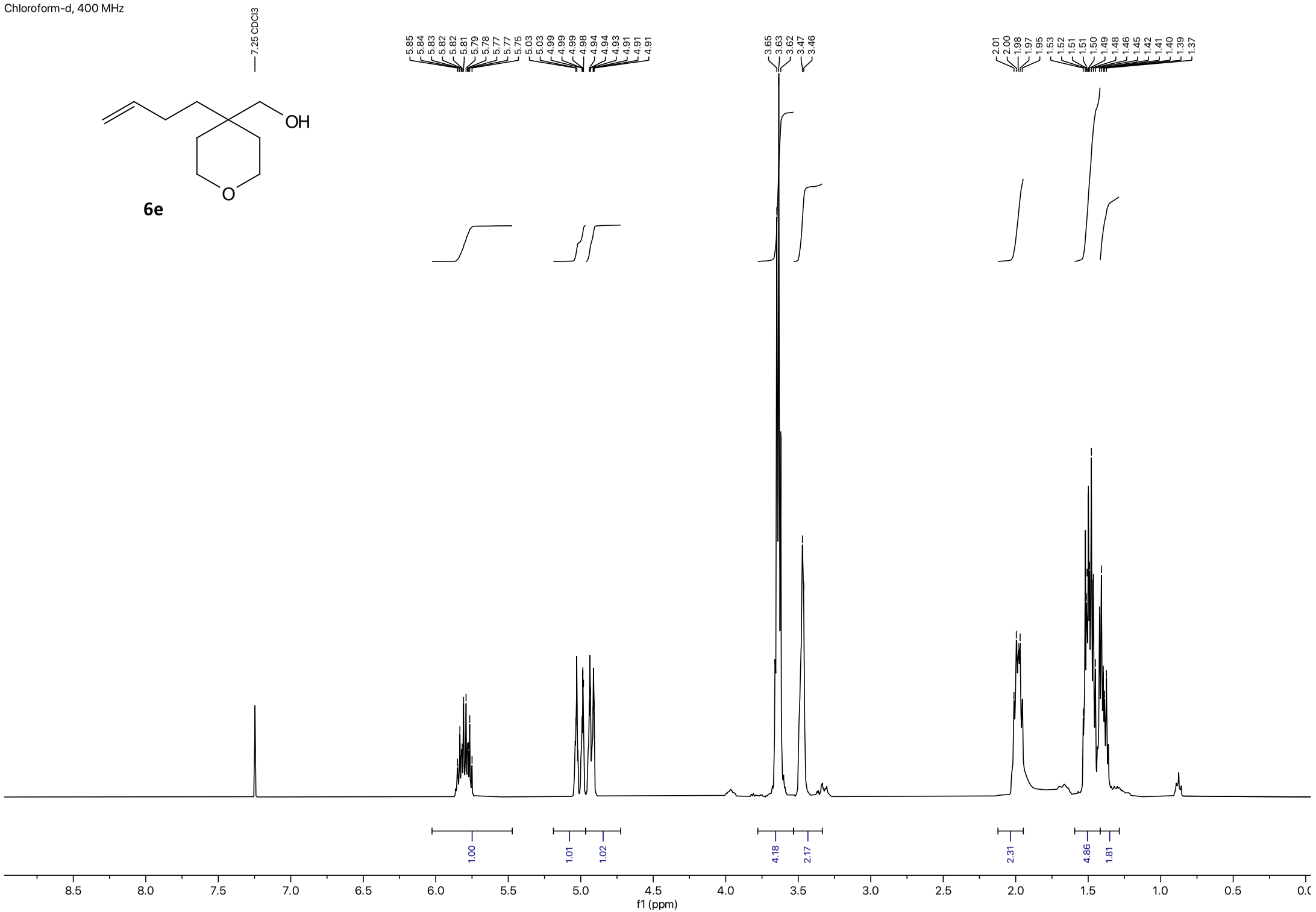


6d

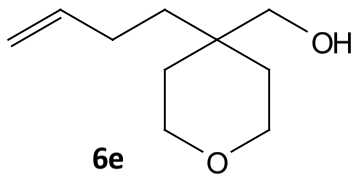
139.76
114.10
77.45 CDCl3
77.13 CDCl3
76.81 CDCl3
68.39
37.07
34.01
32.50
27.61
26.48
21.54

190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10

f1 (ppm)

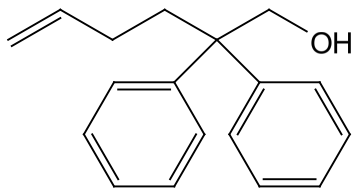

Chloroform-d, 400 MHz
7.25 CDCl3
5.85
5.84
5.83
5.82
5.82
5.81
5.79
5.78
5.77
5.77
5.75
5.03
5.03
4.99
4.99
4.99
4.98
4.94
4.94
4.93
4.91
4.91
4.91
3.65
3.63
3.62
3.47
3.46
2.01
2.00
1.98
1.97
1.95
1.53
1.52
1.51
1.51
1.50
1.49
1.48
1.46
1.45
1.42
1.41
1.40
1.39
1.37
OH
O
6e
1.00
1.01
1.02
4.18
2.17
2.31
4.86
1.81
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

Chloroform-d, 101 MHz



6e

Chloroform-d, 400 MHz



6f

7.32
7.30
7.28
7.25 CDCl3
7.24
7.22
7.21
7.20
7.18
5.83
5.81
5.80
5.80
5.79
5.77
5.76
5.75
5.75
5.73
4.99
4.98
4.95
4.94
4.93
4.93
4.92
4.90
4.90
4.14
2.27
2.26
2.25
2.24
2.23
1.83
1.82
1.81
1.81
1.79
1.77

4.10
1.62
4.26
1.00
0.66
1.37
2.07
2.06
2.03

9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5

f1 (ppm)

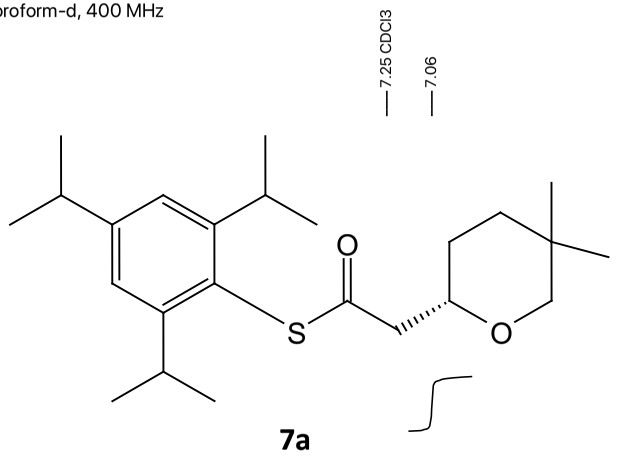
Chloroform-d, 101 MHz

6f

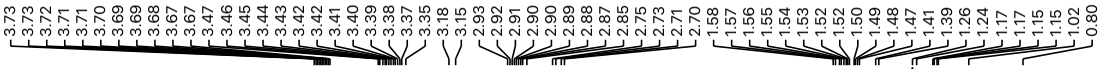
145.54
138.87
128.35
128.10
126.48
114.52
77.49 CDCl3
77.17 CDCl3
76.86 CDCl3
68.17
52.02
43.57
35.57
28.82

f1 (ppm)

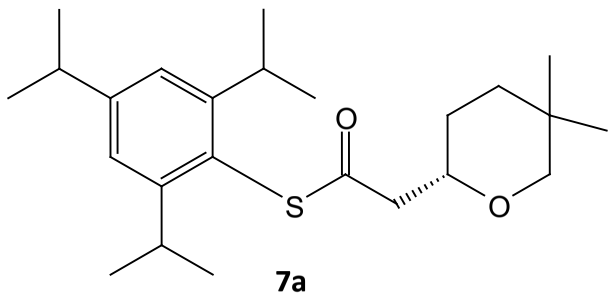
Chloroform-d, 400 MHz



7a



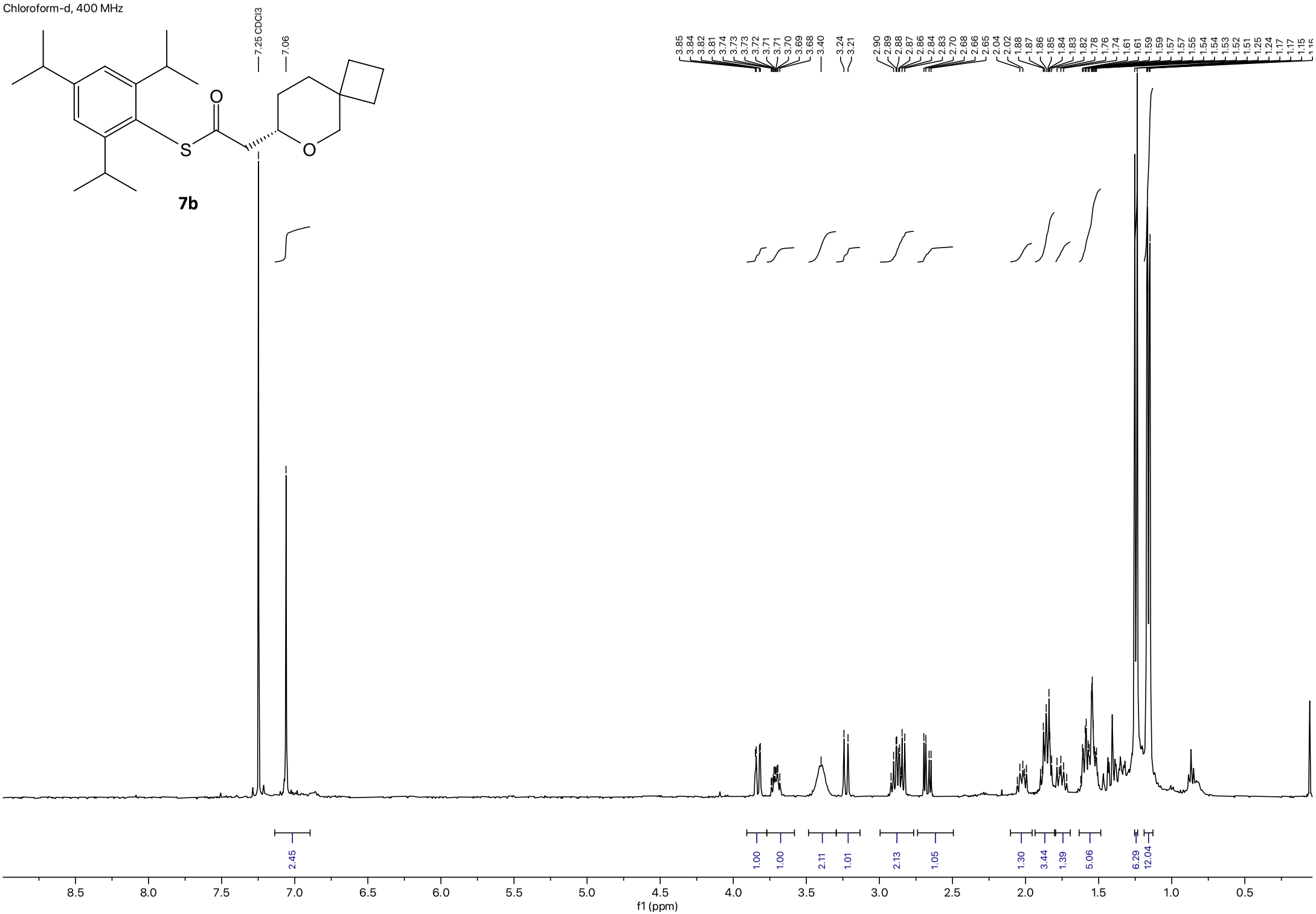
Chloroform-d, 101 MHz



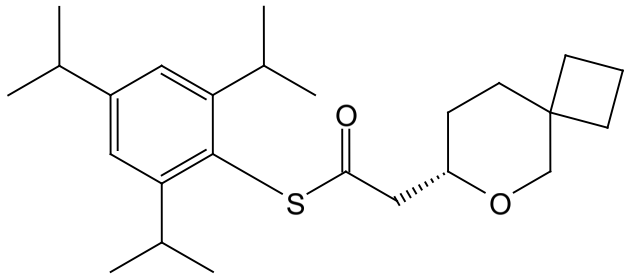
7a

196.22
152.45
151.09
122.07
121.97
78.50
77.42 CDCl3
76.79 CDCl3
75.42
49.85
36.72
34.43
31.95
29.88
27.91
27.22
24.42
23.95
23.69

f1 (ppm)


Chloroform-d, 400 MHz
7.25 CDCl3
7.06
O
S
O
7b
3.85 3.84 3.82 3.81 3.74 3.73 3.73 3.72 3.71 3.71 3.70 3.69 3.68 3.40 3.24 3.21
2.90 2.89 2.88 2.87 2.86 2.84 2.83 2.70 2.68 2.66 2.65 2.04 2.02 1.88 1.87 1.86 1.85 1.84 1.83 1.82 1.78 1.76 1.74 1.61 1.61 1.59 1.59 1.57 1.57 1.55 1.54 1.54 1.53 1.52 1.51 1.25 1.24 1.17 1.17 1.15
2.45
1.00 1.00 2.11 1.01 2.13 1.05 1.30 3.44 1.39 5.06 6.29 12.04
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

Chloroform-d, 101 MHz

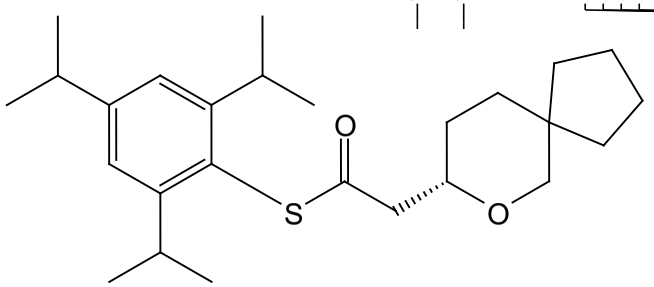


7b

196.11
152.36
151.01
121.98
121.90
77.28 CDCl3
77.02 CDCl3
76.77 CDCl3
76.37
74.83
49.72
37.73
35.58
34.36
31.87
30.42
29.00
28.11
23.87
23.86
15.31

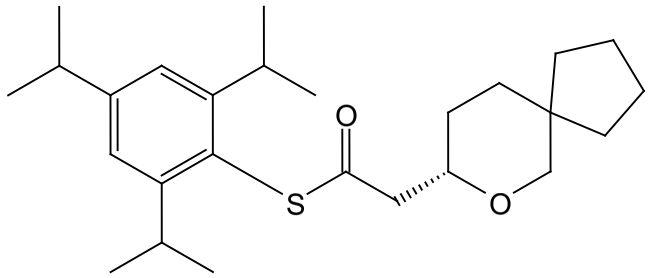
f1 (ppm)

Chloroform-d, 400 MHz



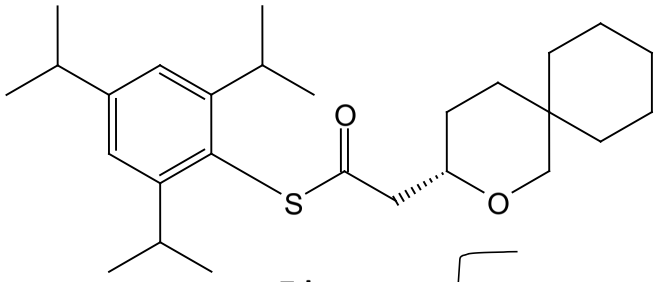
7c

Chloroform-d, 101 MHz



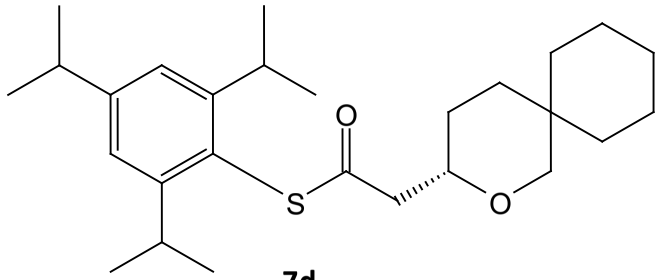
7c

Chloroform-d, 400 MHz



7d

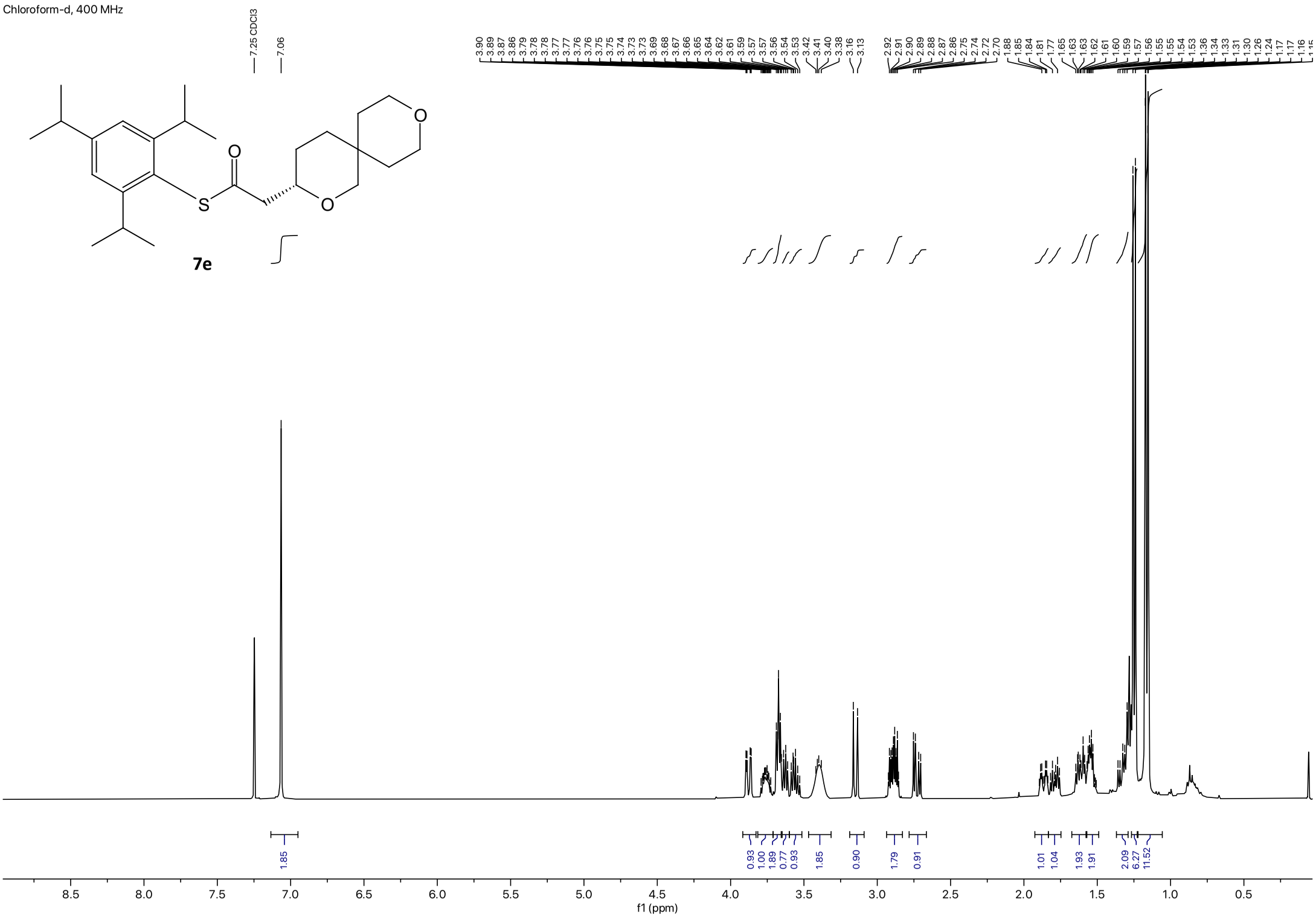
Chloroform-d, 101 MHz



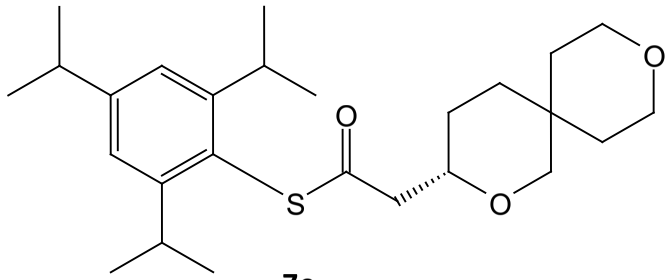
7d

196.19
152.47
151.08
122.07
121.98
77.44 CDCl3
77.12 CDCl3
76.99
76.81 CDCl3
75.87
49.90
36.59
34.45
32.08
31.97
31.36
27.22
26.89
24.42
23.97
23.65
21.64
21.55

f1 (ppm)


Chloroform-d, 400 MHz
7.25 CDCl3
7.06
7e
f1 (ppm)

Chloroform-d, 101 MHz

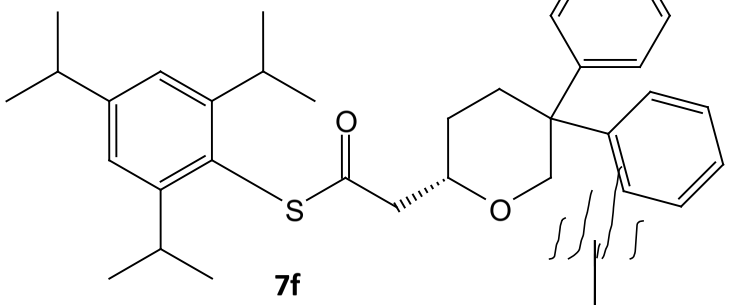


7e

196.06
152.44
151.17
122.11
121.85
77.45 CDCl3
77.12 CDCl3
76.81 CDCl3
75.85
75.82
63.99
63.36
49.69
35.97
34.44
34.08
31.97
31.76
30.15
26.89
24.41
23.96

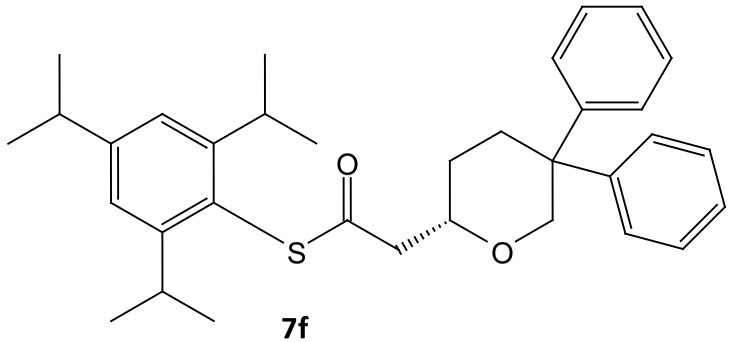
f1 (ppm)

Chloroform-d, 400 MHz



7f

Chloroform-d, 101 MHz



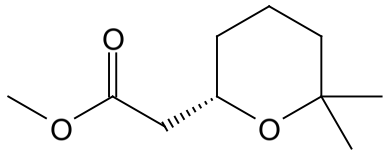
7f

196.00
152.98
151.07
146.46
145.69
128.95
128.32
128.05
126.98
126.36
125.76
122.00
121.78
77.28 CDCl3
77.02 CDCl3
76.77 CDCl3
75.03
75.02
49.67
45.80
34.54
34.36
31.89
29.72
27.71
23.87

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

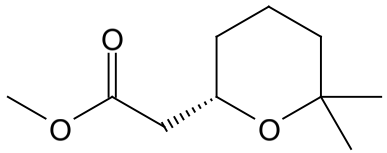
f1 (ppm)

Chloroform-d, 400 MHz



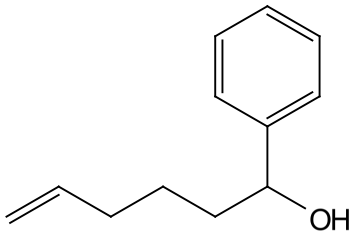
S6

Chloroform-d, 101 MHz



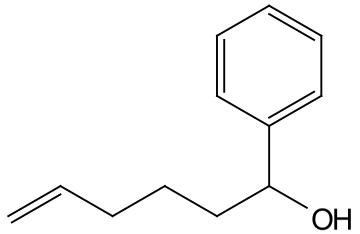
S6

Chloroform-d, 400 MHz



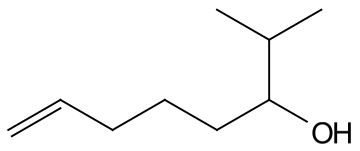
S7a

Chloroform-d, 101 MHz



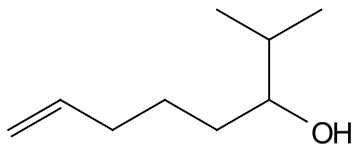
S7a

Chloroform-d, 400 MHz



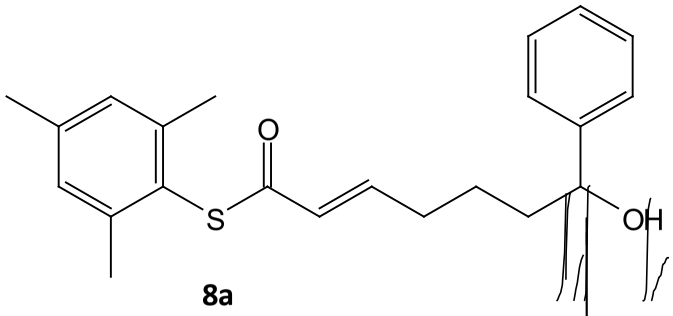
S7b

Chloroform-d, 101 MHz



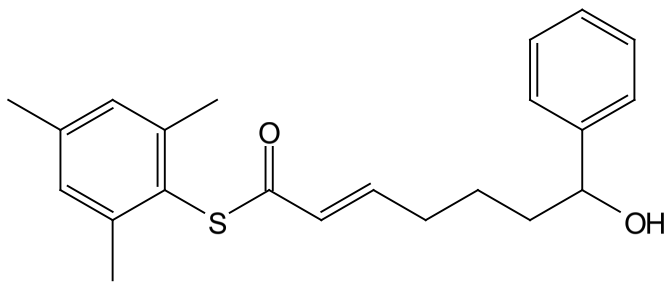
S7b

Chloroform-d, 400 MHz

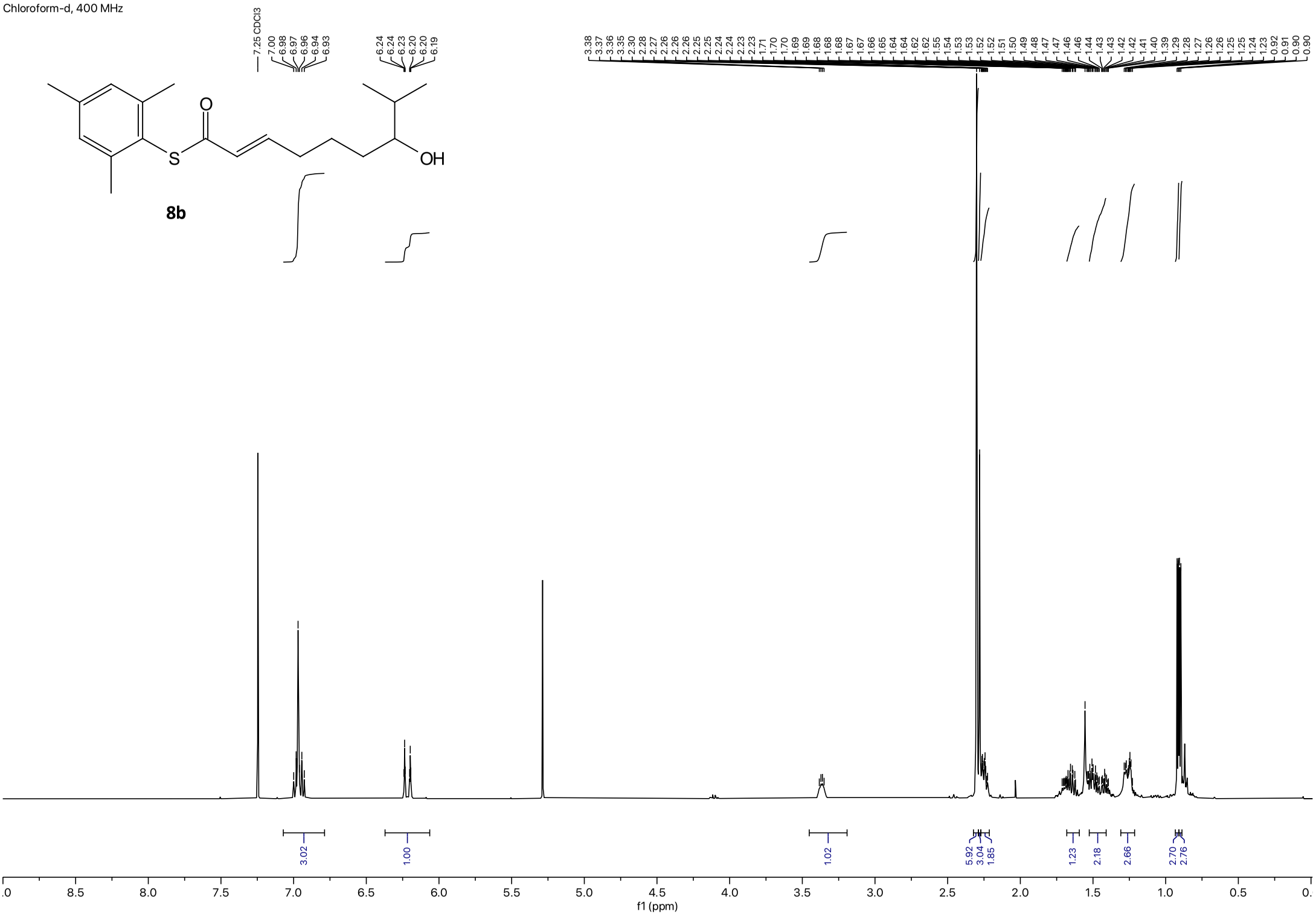


8a

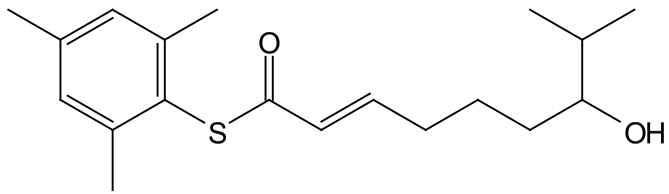
Chloroform-d, 101 MHz



8a


Chloroform-d, 400 MHz
7.25 CDCl3
7.00
6.98
6.97
6.96
6.94
6.93
6.24
6.24
6.23
6.20
6.20
6.19
3.38
3.37
3.36
3.35
2.30
2.28
2.27
2.26
2.26
2.26
2.25
2.25
2.24
2.24
2.23
2.23
1.71
1.70
1.70
1.69
1.69
1.68
1.68
1.68
1.67
1.67
1.66
1.65
1.64
1.64
1.62
1.62
1.55
1.54
1.53
1.53
1.52
1.52
1.51
1.50
1.49
1.48
1.47
1.47
1.46
1.46
1.44
1.43
1.43
1.42
1.42
1.41
1.40
1.39
1.29
1.28
1.27
1.26
1.26
1.25
1.25
1.24
1.23
0.92
0.91
0.90
0.90
O
S
OH
8b
3.02
1.00
1.02
5.92
3.04
1.85
1.23
2.18
2.66
2.70
2.76
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

Chloroform-d, 101 MHz



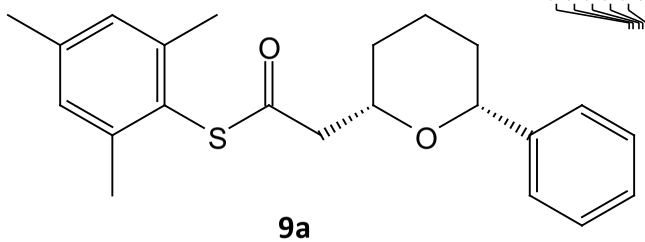
8b

187.86
145.98
142.79
139.94
129.28
128.27
123.56
77.43 CDCl3
77.11 CDCl3
76.79 CDCl3
76.55
33.68
32.37
31.69
24.60
21.72
21.25
18.92
17.18

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

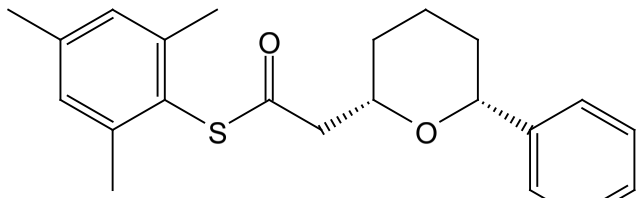
f1 (ppm)

Chloroform-d, 400 Hz



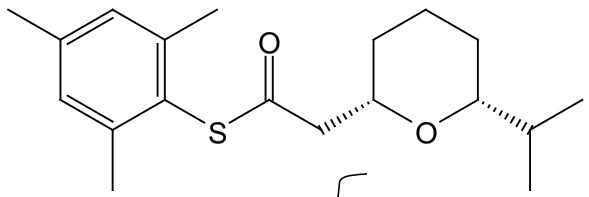
9a

Chloroform-d, 101 Hz



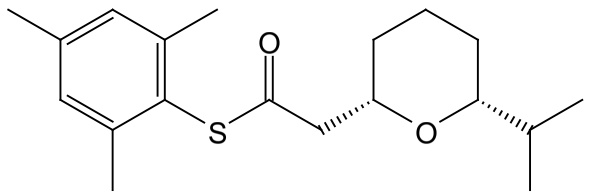
9a

Chloroform-d, 400 MHz



9b

Chloroform-d, 101 MHz



9b

195.16
142.57
139.89
129.23
124.05
83.30
77.43 CDCl3
77.11 CDCl3
76.79 CDCl3
74.88
50.48
33.39
31.43
27.93
23.66
21.71
21.24
18.89
18.62

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

f1 (ppm)