Electronic Supplementary Information for:

Chiral Lewis acid catalysis in a visible light-triggered cycloaddition/rearrangement cascade

Simone Stegbauer, Christian Jandl, and Thorsten Bach

Table of contents

1. General information S2

2. Analytical methods S4

3. Synthesis of irradiation precursors S6

3.1 Synthesis of standard irradiation precursor S11

3.2 Synthesis of irradiation precursors with variation on olefin linker S15

3.3 Synthesis of irradiation precursors with variation on naphthalene core S58

4. Photocycloaddition/rearrangement reactions of irradiation precursors S83

5. Optimisation of the reaction conditions S120

6. Kinetic resolution during thermal rearrangement S123

7. Qualitative triplet quenching experiments S124

8. NMR spectra of new compounds S125

9. Chiral HPLC traces S177

10. Datasheets of fluorescent light sources S192

11. UV/Vis spectra S194

12. X-ray crystallographic details S195

13. References S203

1. General information

All air and moisture sensitive reactions were carried out in flame-dried glassware under a positive pressure of dry argon (4.8, purity 99.998%) using standard *Schlenk* techniques.

Commercially available chemicals were used without further purification unless otherwise mentioned.

For moisture sensitive reactions, dichloromethane (CH_2Cl_2), diethyl ether (Et_2O) and tetrahydrofuran were dried using a MBSPS 800 *MBraun* solvent purification system. The following columns were used:

Dichloromethane	2 × MB-KOL-A type 2 (aluminium oxide)
Diethylether	1 × MB-KOL-A type 2 (aluminium oxide),
	1 × MB-KOL-M type 2 (3 Å molecular sieve);
Tetrahydrofuran	2 × MB-KOL-M type 2 (3 Å molecular sieve)

The following dry solvents are commercially available and were used without further purification:

Acetonitrile: *Acros Organics*, 99.9% extra dry, over molecular sieves.

Chloroform: *Acros Organics*, 99.9% extra dry, over molecular sieves.

N,*N*-Dimethylformamide: *Acros Organics*, 99.9% extra dry, over molecular sieves.

Ethanol: *Acros Organics*, 99.5% extra dry, absolute.

Toluene: *Acros Organics*, 99.5% extra dry, over molecular sieves.

For photochemical reactions, dry dichloromethane was degassed by four freeze-pump-thaw cycles and stored over activated molecular sieve (4 Å molecular sieve).

Technical solvents for column chromatography (pentane, diethyl ether, ethyl acetate) were used after simple distillation.

Flash column chromatography was performed on silica 60 (*Merck*, 230-400 mesh) with the indicated eluent mixtures.

Photochemical experiments at 366 nm were carried out in flame-dried *Duran* tubes (diameter = 1 cm) in a positive geometry setup (cylindrical array of 16 UV-A lamps, Fluorescent light tube, UV-A, λ_{max} = 366 nm) with the sample placed in the centre of the illumination chamber.

Photochemical experiments using a LED were carried out in a *Schlenk* tube (diameter = 1 cm) with a polished quartz rod as an optical fibre, which was roughened by sandblasting at one end. The roughed end has to be completely submerged in the solvent during the reaction, in order to guarantee optimal and reproducible irradiation conditions.[1] If necessary the *Schlenk* tubes were cooled to −78 °C by using an *Huber* TC100E immersion cooler with ethanol as coolant.

Ice/water (0 °C) or dry ice/ethanol (−78 °C) were used as cooling baths.

2. Analytical methods

Melting points (M.p.) were determined using a *Kofler* heating bar designed by *L. Kofler* (*Reichert*) without correction or using a *Büchi* M-510 melting point apparatus, with range quoted to the nearest whole number.

Thin layer chromatography (TLC) was performed on silica coated glass plates (*Merck*, silica 60 F254) with detection by UV-light ($\lambda = 254$ nm) and/or by staining with a potassium permanganate solution [$KMnO_4$] and/or cerium ammonium molybdate solution [CAM] followed by heat treatment.

> $KMnO_4$-staining solution: potassium permanganate (3.00 g), potassium carbonate (20.0 g) and 5% aqueous sodium hydroxide solution (5.00 mL) in water (300 mL).
>
> CAM-staining solution: cerium sulfate heptahydrate (1.00 g), ammonium molybdate (25.0 g), sulfuric acid (25.0 mL) in water (250 mL).

Infrared spectra (IR) were recorded on a *Perkin Elmer* Frontier Optica+SP10 spectrometer by ATR technique. The signal intensity is assigned using the following abbreviations: s (strong), m (medium), w (weak).

Standard nuclear magnetic resonance spectra were recorded at room temperature either on a *Bruker* AVHD-300, AVHD-400, AVHD-500 or an AV-500 cryo. ^{1}H NMR spectra were calibrated to the residual proton signal of chloroform-d_1 ($\delta = 7.26$ ppm). ^{13}C NMR spectra were referenced to the ^{13}C-D triplet of $CDCl_3$ ($\delta = 77.16$ ppm).[2] Apparent multiplets which occur as a result of coupling constant equality between magnetically non-equivalent protons are marked as virtual (*virt.*). Following abbreviations for single multiplicities were used: *br* – broad, s – singlet, d – doublet, t – triplet, q – quartet, quint – quintet, m – multiplet. Assignment and multiplicity of the ^{13}C NMR signals were determined by two-dimensional NMR experiments (^{1}H-^{1}H COSY, ^{1}H-^{13}C HSQC, ^{1}H-^{13}C HMBC).

Mass Spectroscopy (MS) and High Resolution Mass Spectroscopy (HRMS) was measured on a *Thermo Scientific* DFS-HRMS spectrometer (EI, 70 eV) or on a *Thermo Scientific* LTQ-FT Ultra (ESI).

Analytical High Performance Liquid Chromatography (HPLC) was performed (*Thermo Fisher, Dionex* Ultimate 3000, LPG 3400SD Pump, WPS3000SL Autosampler, DAD 3000 photodiode array detector) using different chiral stationary phases (*Daicel, Chemical Industries*) and UV detection (λ = 215 nm).

UV/Vis Spectroscopy was measured on a *Perkin Elmer* Lambda 35 UV/Vis spectrometer. Spectra were recorded using a *Hellma* precision cell made of quartz *Suprasil* with a pathway of 1 mm. Solvents and concentrations are given for each spectrum.

Specific Rotation was determined using a *Bellingham+Stanley* ADP440+ polarimeter using a 0.5 cm cuvette at λ = 589 nm (Na-D-line) at room temperature. Specific rotation is reported as follows: $[\alpha]_D^T$ in 10^{-1} grad cm^2 g^{-1} (c was defined as g per 100 mL solvent).

3. Synthesis of irradiation precursors

General procedure 1 (GP1): Horner–Wadsworth–Emmons reaction – Synthesis of ethyl alkylideneacetate

In analogy to a modified literature procedure:[3]

Sodium hydride (60 wt% in paraffin oil, 1.10 eq.) was washed with pentane (3 ×) under an argon atmosphere. Residual pentane was removed in vacuo followed by the addition of tetrahydrofuran. The suspension was cooled to 0 °C and triethyl phosphonoacetate (1.15 eq.) was dropwise added while keeping the temperature at 0 °C. The suspension was warmed to room temperature and the reaction mixture was stirred for approximately 30 minutes until no gas evolution was observed. After cooling the ylide solution to 0 °C, liquid ketone (1.00 eq.) was added using a syringe pump (0.15 mL/min.) or solid ketone (1.00 eq.) was solved in tetrahydrofuran and then added dropwise as a solution. The reaction mixture was stirred at 0 °C or at room temperature until full conversion of the starting material was detected by TLC. Subsequently, the mixture was diluted with diethyl ether and water. The layers were separated and the aqueous layer was extracted with diethyl ether (3 ×). The combined organic extract was washed with water (1 ×), brine (1 ×) and it was dried over anhydrous $MgSO_4$. After filtration, the solvent was removed under reduced pressure. The crude product was purified either by column chromatography or by distillation under reduced pressure.

General procedure 2 (GP2): Reduction of ethyl alkylideneacetate with diisobutylaluminium hydride to allylic alcohol

Di*iso*butylaluminium hydride solution (1.0 M in dichloromethane, 2.20 eq.) was added dropwise to a solution of ester (1.00 eq.) in dichloromethane at –78 °C. After full conversion of the starting material which was detected by TLC, the mixture was diluted with

dichloromethane [1.00 × (x mmol of DIBAL-H) mL] at 0 °C to quench the excess of di*iso*butylaluminium hydride. When no further gas evolution was observed, water [0.04 × (x mmol of DIBAL-H) mL], 15% aqueous NaOH solution [0.04 × (x mmol of DIBAL-H) mL] and again water [0.1 × (x mmol of DIBAL-H) mL] was added. After warming the mixture to room temperature it was vigorously stirred at this temperature for 15 minutes and $MgSO_4$ was added. After filtration over Celite and washing with dichloromethane (1 ×), the solvent was removed under reduced pressure. If necessary, the crude product was purified by column chromatography.

General procedure 3 (GP3): Reduction of ethyl alkylideneacetate with lithium aluminium hydride to allylic alcohol

Lithium aluminium hydride powder (2.00 eq.) was suspended in diethyl ether and the mixture was cooled to 0 °C. Ester (1.00 eq.) was dropwise added and the reaction mixture was stirred at 0 °C. After full conversion of the starting material was detected by TLC, the mixture was diluted with diethyl ether at 0 °C to quench the excess of lithium aluminium hydride. When no further gas evolution was observed, water [1.0 × (x g of $LiAlH_4$) mL], 15% aqueous NaOH solution [1.0 × (x g of $LiAlH_4$) mL] and again water [3.0 × (x g of $LiAlH_4$) mL] was added. After warming the mixture to room temperature it was vigorously stirred at this temperature for 15 minutes and $MgSO_4$ was added. After filtration over Celite and washing with diethyl ether (1 ×), the solvent was removed under reduced pressure. If necessary, the crude product was purified by column chromatography.

*General procedure 4 (GP4): Williamson ether synthesis between 1-bromo-2-(bromomethyl)naphthalene (**S1**) and allylic alcohol*

In analogy to a modified literature procedure:[4]

Sodium hydride (60 wt% in paraffin oil, 1.30 eq.) was washed with pentane (3 ×) under an argon atmosphere. Residual pentane was removed in vacuo followed by the addition of tetrahydrofuran. Allylic alcohol (1.20 eq.) was dropwise added and the suspension was stirred at room temperature until no gas evolution was observed. Subsequently, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.00 eq.) was added in small portions and the reaction mixture was stirred at room temperature until all starting material was consumed. The reaction was stopped by the addition of water (1 ×). The mixture was extracted with diethyl ether (3 ×) and the combined organic extracts were washed water (1 x) and with brine (1 ×). After drying the organic extracts over anhydrous $MgSO_4$ and filtration, the solvent was removed under reduced pressure. The crude product was purified by column chromatography.

General procedure 5 (GP5): Formylation reaction to 2-alkenyl-substituted 1-naphthaldehydes

In analogy to a modified literature procedure:[5]

At – 78 °C *n*-butyllithium solution (2.5 M in *n*-hexane, 1.20 eq.) was added to a solution of 1-bromonaphthalene (1.00 eq.) in tetrahydrofuran. After one hour, *N*,*N*-dimethylformamide (5.00 eq.) was added with a syringe pump (0.15 mL/min.) and the reaction mixture was warmed to room temperature. After four hours the reaction was quenched by the addition of saturated aqueous NH_4Cl solution (1 ×) and water (1 ×). The mixture was extracted with diethyl ether (3 ×). The combined organic extracts were washed with brine (1 ×), dried over anhydrous $MgSO_4$, filtered and the solvent was removed under reduced pressure. The crude product was purified by column chromatography.

General procedure 6 (GP6): Vilsmeier-Haack-Arnold type reaction synthesizing 1-bromo-3,4-dihydronaphthalene-2-carbaldehyde derivatives

In analogy to a modified literature procedure:[6]

Phosphorus tribromide (2.5 eq.) was added with a syringe pump (0.25 mL/min.) at 0 °C to a solution of *N*,*N*-dimethylformamide (3.00 eq.) in dichloromethane and the mixture was stirred at 0 °C for 30 minutes. After warming up to room temperature, the mixture was stirred for further 30 minutes at room temperature and cooled down to 0 °C. A solution of α-tetralone derivative (1.00 eq.) in dichloromethane was added to the reaction mixture at 0 C using a syringe pump (2.00 mL/min.). After warming up the reaction mixture to room temperature, it was stirred overnight. The reaction mixture was poured into ice water (300 mL) and solid $NaHCO_3$ was slowly added until no further gas evolution was observed. The layers were separated and the aqueous layer was extracted with dichloromethane (5 ×). The combined organic extracts were washed with cooled water (1 ×), brine (1 ×), dried over anhydrous $MgSO_4$, filtered and the solvent was removed under reduced pressure. The crude product was purified by column chromatography.

General procedure 7 (GP7): Oxidation of 1-Bromo-3,4-dihydronaphthalene-2-carbaldehydes using 2,3-dichloro-5,6-dicyano-p-benzoquinone

In analogy to a modified literature procedure:[7]

1-Bromo-3,4-dihydronaphthalene-2-carbaldehyde derivative (1.00 eq.) was solved in toluene and 2,3-dichloro-5,6-dicyano-*p*-benzoquinone (DDQ, 2.50 eq.) was added. The reaction mixture was stirred at 120 °C until full conversion of the starting material was detected by TLC. If necessary, an addition portion of DDQ was added after a few hours to get the reaction to full conversion of the starting material. The reaction mixture was cooled to room temperature and filtered over Celite and the residue was washed with dichloromethane (100 mL). The solvent

was removed under reduced pressure and the crude product was purified by column chromatography.

General procedure 8 (GP8): Reduction of 1-bromo-2-naphthaldehydes with sodium borohydride

Sodium borohydride (1.50 eq.) was added to a solution of 1-bromo-2-naphthaldehyde derivative (1.00 eq.) in ethanol. After full conversion of the starting material was detected by TLC, the excess of $NaBH_4$ was quenched by the addition of aqueous NH_4Cl solution [10.0 × (x mmol of $NaBH_4$) mL]. The mixture was extracted with dichloromethane (3 ×). The combined organic extracts were dried over anhydrous $MgSO_4$, filtered and the solvent was removed under reduced pressure. The crude product was purified by column chromatography.

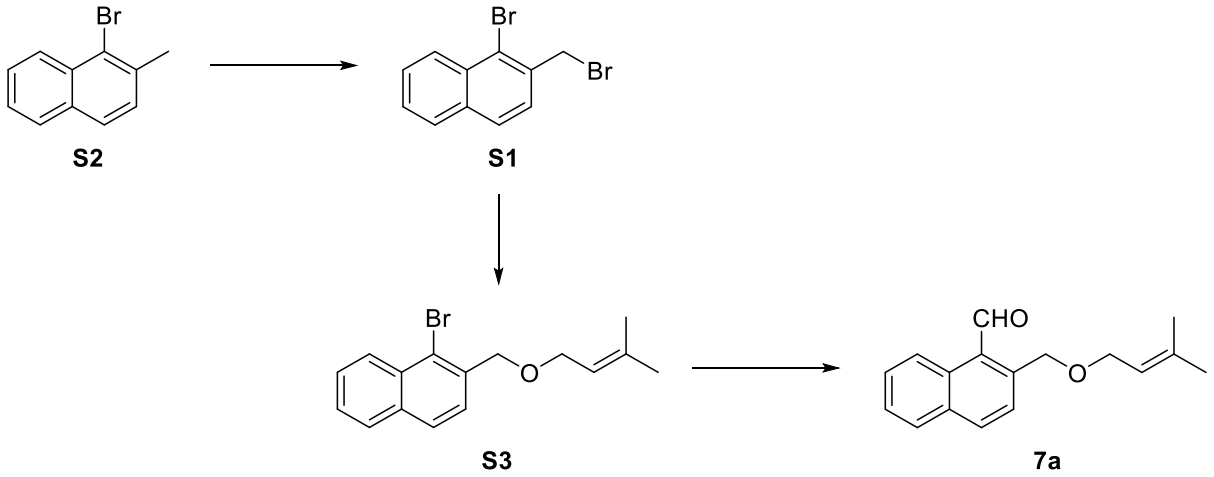
General procedure 9 (GP9): Williamson ether synthesis between (1-bromonaphthalen-2-yl)methanol derivatives and 3,3-dimethylallylbromide.

In analogy to a modified literature procedure:[4]

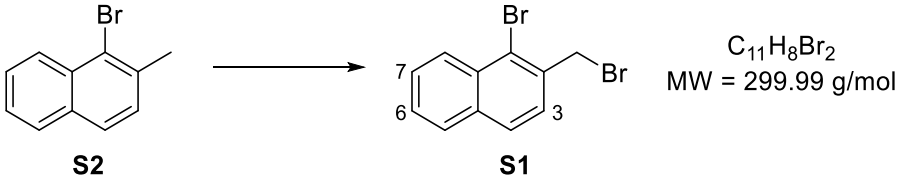
Sodium hydride (60 wt% in paraffin oil, 1.30 eq.) was washed with pentane (3 ×) under an argon atmosphere. Residual pentane was removed in vacuo followed by the addition of tetrahydrofuran. (1-bromonaphthalen-2-yl)methanol derivative (1.00 eq.) was added in portions and the reaction mixture was stirred at room temperature until no gas evolution was observed. Subsequently, 3,3-dimethylallylbromide (2.00 eq.) was dropwise added and the reaction mixture was stirred at room temperature until all starting material was consumed. The reaction was stopped by the addition of water (1 ×). The mixture was extracted with diethyl ether (3 ×) and the combined organic extracts were washed water (1 x) and with brine (1 ×). After drying the organic extracts over anhydrous $MgSO_4$ and filtration, the solvent was removed under reduced pressure. The crude product was purified by column chromatography.

3.1 Synthesis of standard irradiation precursor

Scheme for the synthesis of 2-{[(3'-methylbut-2'-en-1'-yl)oxy]methyl}-1-naphthaldehyde (7a)



1-Bromo-2-(bromomethyl)naphthalene (S1)



N-Bromosuccinimide (5.93 g, 33.3 mmol, 1.05 eq.) and benzoyl peroxide (770 mg, 3.17 mmol, 10 mol%) was added to a solution of 1-bromo-2-methylnaphthalene (**S2**, 7.00 g, 31.7 mmol, 1.00 eq.) in chloroform (90 mL). The mixture was stirred at 85 °C, and after 16 hours, the mixture was cooled to room temperature. An aqueous $NaHCO_3$-solution (50 mL) was slowly added and the layers were separated. The organic layer was washed with brine (1 × 50 mL) and it was dried over anhydrous $MgSO_4$. After filtration, the solvent was removed under reduced pressure. The crude product was purified by column chromatography (silica, P/Et_2O = 100/0 → 100/1 → 50/1) to yield 7.72 g dibromide **S1** (25.7 mmol, 81%) as an off-white solid.

M.p.: 105 °C.

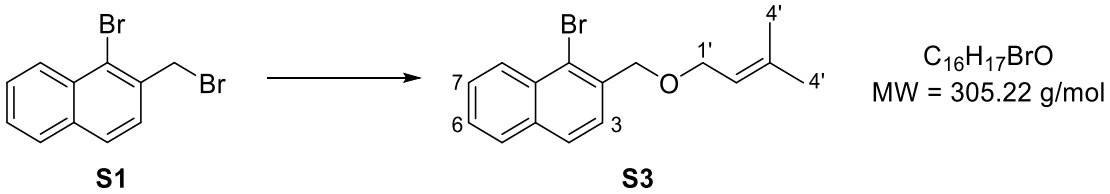
TLC: R_f = 0.35 (P = 1) [UV, $KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 4.87 (s, 2 H, CH_2Br), 7.53 (d, ^3J = 8.3 Hz, 1 H, H-3), 7.55 (ddd, ^3J = 8.0 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.62 (ddd, ^3J = 8.4 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.72 – 7.91 (m, 2 H, H-4, H-5), 8.34 (dd, ^3J = 8.4 Hz, ^4J = 1.2 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 35.0 (t, CH_2Br), 125.1 (s, C-1), 127.4 (d, C_{Ar}), 127.8 (d, C_{Ar}), 127.9 (d, C_{Ar}), 128.0 (d, C_{Ar}), 128.3 (d, C_{Ar}), 128.5 (d, C_{Ar}), 132.7 (s, C-8a), 134.3 (s, C-4a), 135.1 (s, C-2).

The analytical data obtained matched those reported in literature.[8]

1-Bromo-2-{[(3'-methylbut-2'-en-1-yl)oxy]methyl} (S3)



Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 6.00 g, 20.0 mmol, 1.00 eq.) was converted with 3-methylbut-2-en-1-ol (2.06 g, 24.0 mmol, 1.20 eq.) and sodium hydride (1.04 g, 60 wt% in paraffin oil, 26.0 mmol, 1.30 eq.) in tetrahydrofuran (100 mL). After 7.5 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 100/1) gave 5.20 g 1-bromo-2-alkyl-naphthalene **S3** (17.0 mmol, 85%) as a colourless oil.

TLC: R_f = 0.51 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3056 (w, sp^2-CH), 2972 (w, sp^3-CH), 2855 (w, sp^3-CH), 1674 (m, C=C), 1326 (m), 1089 (s, C–O–C), 811 (s, sp^2-CH), 742 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.70 (s, 3 H, H-4'), 1.78 (s, 3 H, H-4'), 4.12 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.83 (s, 2 H, CH_2), 5.47 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.4 Hz, 1 H,

H-2'), 7.51 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.64 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.83 (d, ^3J = 8.5 Hz, 1 H, H-4), 7.84 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.6 Hz, 1 H, H-5), 8.32 (d, ^3J = 8.5 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 26.0 (q, C-4'), 67.3 (t, C-1'), 72.2 (t, CH_2), 121.0 (d, C-2'), 122.6 (s, C-1), 126.2 (d, C-3), 126.5 (d, C-6), 127.1 (d, C-8), 127.5 (d, C-7), 127.8 (d, C-4*), 128.3 (d, C-5*), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.3 (s, C-2), 137.8 (s, C-3').

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 306 (2) [M(^{81}Br)]$^+$, 304 (2) [M(^{79}Br)], 236 (87), 221 (29), 157 (11), 126 (100) $[C_{10}H_6]^+$.

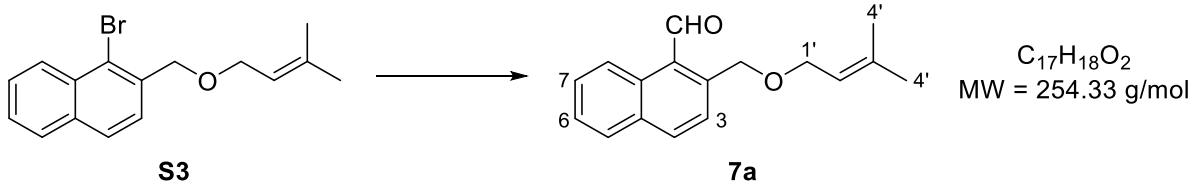
HRMS (EI, 70 eV): calcd for $C_{16}H_{17}O^{79}Br$ [M]$^+$: 304.0457; found: 304.0460.

calcd for $C_{15}{}^{13}CH_{17}O^{79}Br$ [M]$^+$: 305.0491; found: 305.0486.

calcd for $C_{16}H_{17}O^{81}Br$ [M]$^+$: 306.0437; found: 306.0440.

calcd for $C_{15}{}^{13}CH_{17}O^{81}Br$ [M]$^+$: 307.0470; found: 307.0468.

2-{[(3'-Methylbut-2'-en-1'-yl)oxy]methyl}-1-naphthaldehyde (7a)



S3 **7a**

Following GP5, 1-bromo-2-alkyl-naphthalene **S3** (2.37 g, 7.76 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (3.72 mL, 2.5 M in *n*-hexane, 9.31 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (2.98 mL, 2.83 g, 38.78 mmol, 5.00 eq.) in tetrahydrofuran (40 mL). After column chromatography (silica, P/Et_2O = 25/1 → 20/1), 1.69 g aldehyde **7a** (6.64 mmol, 86%) were obtained as a colourless solid.

M.p.: 32 °C.

TLC: R_f = 0.46 (P/Et_2O = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2972 (w, sp^3-CH), 2858 (w, sp^3-CH), 1684 (s, C=O), 1620 (w, C=C), 1377 (m), 1063 (s, C–O–C), 823 (s, sp^2-CH), 756 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.69 (s, 3 H, H-4'), 1.77 (s, 3 H, H-4'), 4.11 (d, ^3J = 6.9 Hz, 2 H, H-1'), 4.99 (s, 2 H, CH_2), 5.41 – 5.45 (m, 1 H, H-2'), 7.55 (ddd, ^3J = 8.1 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.6 Hz, ^3J = 6.9 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.69 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.88 (d, ^3J = 8.1 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.5 Hz, 1 H, H-4), 8.91 (dd, ^3J = 8.6 Hz, ^4J = 1.2 Hz, 1 H, H-8), 10.96 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 26.0 (q, C-4'), 67.3 (t, C-1'), 69.6 (t, CH_2), 120.7 (d, C-2'), 124.6 (d, C-8), 126.5 (d, C-3*), 126.6 (d, C-6*), 128.6 (d, C-5**), 128.8 (m, C-1, C-7**), 131.6 (s, C-8a), 133.4 (s, C-4a), 134.4 (d, C-4), 138.1 (s, C-3'), 142.3 (s, C-2), 193.3 (d, CHO).

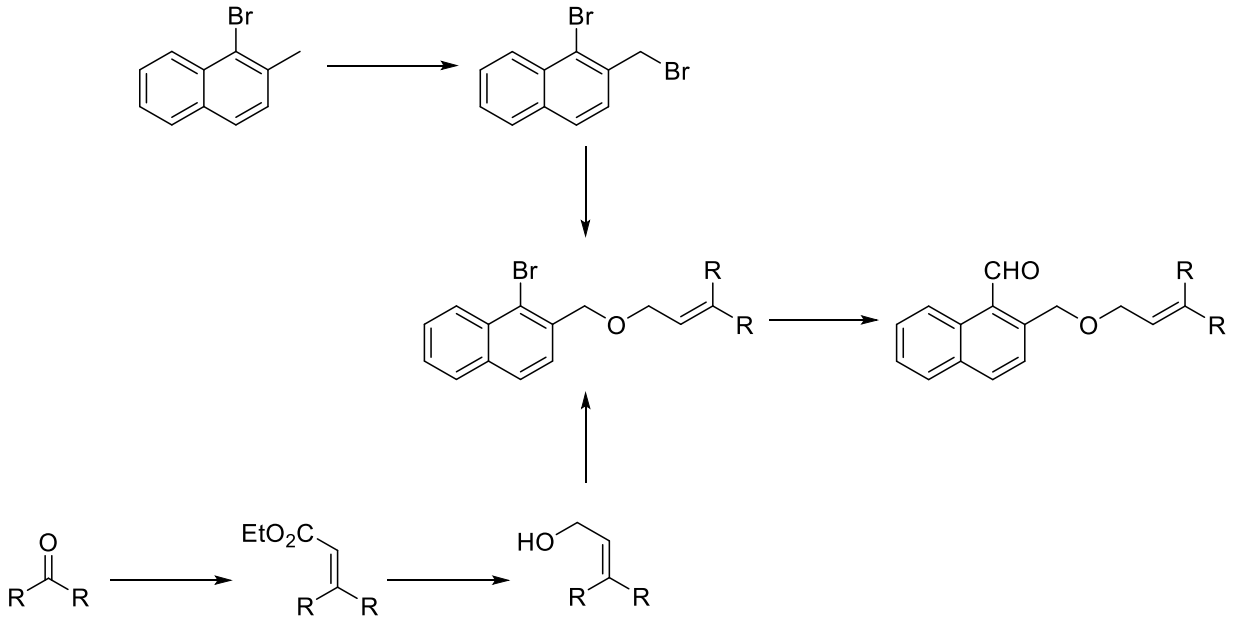
*, ** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 254 (1) $[M]^+$, 185 (89) $[C_{12}H_9O_2]^+$, 168 (100) $[C_{12}H_8O]^+$, 155 (42) $[C_{11}H_7O]^+$, 141 (93) $[C_{11}H_9]^+$, 127 (42) $[C_8H_{15}O]^+$, 41 (55).

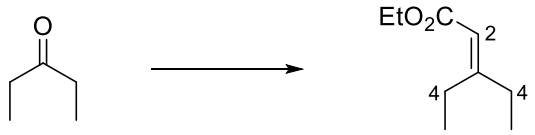
HRMS (EI, 70 eV): calcd for $C_{17}H_{18}O_2$ $[M]^+$: 254.1301; found: 254.1301.

3.2 Synthesis of irradiation precursors with variation on olefin linker

Scheme for the synthesis of 2-{[(alkenyl)oxy]methyl}-1-naphthaldehydes



Ethyl 3-ethylpent-2-enoate (S4)



S5 **S4**

$C_9H_{16}O_2$
MW = 156.23 g/mol

n-Butyllithium solution (17.4 mL, 2.5 M in *n*-hexane, 43.5 mmol, 1.50 eq.) was added dropwise to a solution of triethyl phosphonoacetate (6.91 mL, 7.81 g, 34.8 mmol, 1.20 eq.) in tetrahydrofuran (50 mL) at 0 °C. After a reaction time of 30 minutes, pentan-3-one (**S5,** 2.50 g, 29.0 mmol, 1.00 eq.) was slowly added and the reaction mixture was warmed to room temperature. The reaction was stopped after six hours by the addition of hydrogen chloride solution (200 mL, 1.0 M in water) and diethyl ether (250 mL) was subsequently added. The layers were separated and the aqueous layer was extracted with diethyl ether (2 × 100 mL). The combined organic extracts were washed with water (5 × 400 mL), brine (1 × 100 mL), dried over anhydrous $MgSO_4$, filtered and the solvent was removed under reduced pressure.

Purification of the crude product by distillation under reduced pressure (9 mbar, 58 °C) gave 1.64 g of ester **S4** (10.5 mmol, 36%) as a colourless liquid.

B.p.: 58 °C (9 mbar).

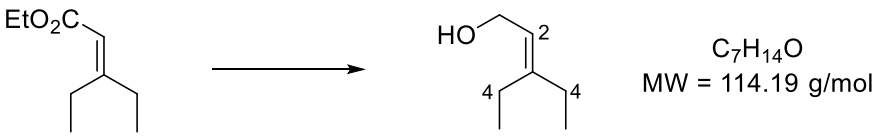
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.07 (t, ^3J = 7.4 Hz, 3 H, H-5), 1.07 (t, ^3J = 7.5 Hz, 3 H, H-5), 1.28 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 2.19 (qd, ^3J = 7.4 Hz, ^4J = 1.3 Hz, 2 H, H-4), 2.62 (q, ^3J = 7.5 Hz, 2 H, H-4), 4.15 (q, ^3J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.60 (t, ^4J = 1.3 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 12.2 (q, C-5), 13.2 (q, C-5), 14.5 (q, $COOCH_2CH_3$), 25.6 (t, C-4), 30.9 (t, C-4), 59.6 (t, $COOCH_2CH_3$), 113.8 (d, C-2), 166.8 (s, $COOCH_2CH_3$*), 167.5 (s, C-3*).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[9]

3-Ethylpent-2-en-1-ol (S6)



S4 **S6**

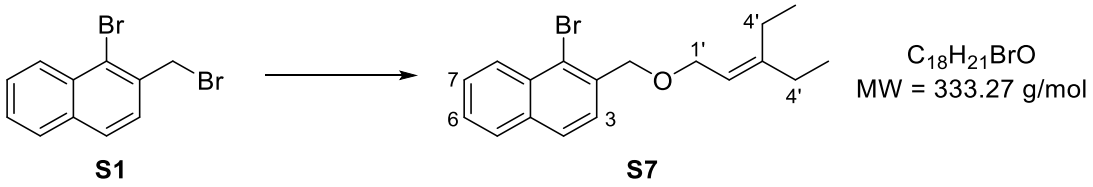
Following GP2, ester **S4** (1.58 g, 10.1 mmol, 1.00 eq.) was converted with di*iso*butylaluminium hydride solution (22.2 mL, 1.0 M in dichloromethane, 22.2 mmol, 2.20 eq.). The reaction was stopped after three hours and 911 mg allylic alcohol **S6** (7.98 mmol, 79%) were obtained as a colourless liquid.

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 0.98 (t, ^3J = 7.6 Hz, 3 H, H-5), 1.02 (d, ^3J = 7.4 Hz, 3 H, H-5), 1.14 (t, ^3J = 4.9 Hz, 1 H, OH), 2.04 – 2.12 (m, 4 H, H-4), 4.16 – 4.18 (m, 2 H, H-1), 5.36 (dddd, ^3J = 7.0 Hz, ^3J = 6.1 Hz, ^4J = 1.5 Hz, ^4J = 0.8 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 12.6 (q, C-5), 13.9 (q, C-5), 23.7 (t, C-4), 29.2 (t, C-4), 59.3 (t, C-1), 121.6 (d, C-2), 147.7 (s, C-3).

The analytical data obtained matched those reported in literature.[10]

1-Bromo-2-{[(3-ethylpent-2-en-1-yl)oxy]methyl}naphthalene (S7)



Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.75 g, 5.83 mmol, 1.00 eq.) was converted with allylic alcohol **S6** (799 mg, 7.00 mmol, 1.20 eq.) and sodium hydride (303 mg, 60 wt% in paraffin oil, 7.58 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After 5.5 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 100/1) gave 1.66 g 1-bromo-2-alkyl-naphthalene **S7** (4.98 mmol, 85%) as a yellowish oil.

TLC: R_f = 0.54 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3057 (w, sp^2-CH), 2965 (m, sp^3-CH), 2873 (m, sp^3-CH), 1690 (w, C=C), 1324 (m), 1096 (s, C–O–C), 812 (s, sp^2-CH), 742 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 0.99 (t, ^3J = 7.6 Hz, 3 H, H-5'), 1.05 (t, ^3J = 7.4 Hz, 3 H, H-5'), 2.01 – 2.17 (m, 4 H, H-4'), 4.17 (d, ^3J = 6.9 Hz, 2 H, H-1'), 4.83 (s, 2 H, CH_2), 5.41 (tt, ^3J = 6.9 Hz, ^4J = 1.5 Hz, 1 H, H-2'), 7.51 (ddd, ^3J = 8.1 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.9 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.65 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.78 – 7.86 (m, 2 H, H-4, H-5), 8.32 (d, ^3J = 8.5 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 12.6 (q, C-5'), 13.7 (q, C-5'), 23.9 (t, C-4'), 29.2 (t, C-4'), 67.1 (t, C-1'), 72.2 (t, CH_2), 118.9 (d, C-2'), 122.6 (s, C-1), 126.2 (d, C-3*),

126.5 (d, C-6*), 127.1 (d, C-8), 127.4 (d, C-7), 127.8 (d, C-4**), 128.3 (d, C-5**), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.4 (s, C-2), 148.5 (s, C-3').

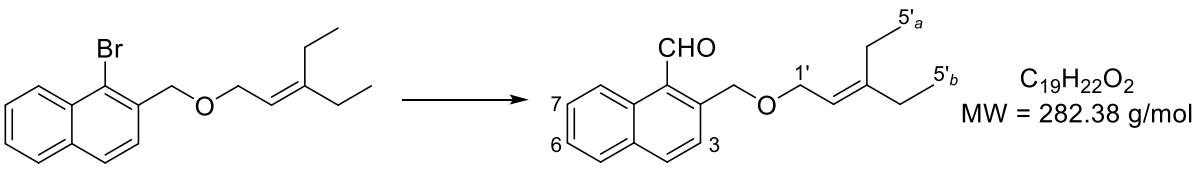
*, ** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 334 (1) $[M(^{81}Br)]^+$, 332 (1) $[M(^{79}Br)]^+$, 236 (42), 207 (13) $[C_{10}H_6{}^{81}Br]^+$, 205 (13) $[C_{10}H_6{}^{79}Br]^+$, 126 (39) $[C_{10}H_6]^+$, 105 (100) $[C_8H_9]^+$, 96 (71).

HRMS (EI, 70 eV): calcd for $C_{18}H_{21}O^{79}Br$ $[M]^+$: 332.0770; found: 332.0765.

calcd for $C_{17}{}^{13}CH_{21}O^{79}Br$ $[M]^+$: 333.0804; found: 333.0802.

2-{[(3-Ethylpent-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7b)



S7 **7b**

Following GP5, 1-bromo-2-alkyl-naphthalene **S7** (1.54 g, 4.61 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (2.21 mL, 2.5 M in *n*-hexane, 5.54 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (1.77 mL, 1.69 g, 23.1 mmol, 5.00 eq.) in tetrahydrofuran (25 mL). After column chromatography (silica, P/EtOAc = 25/1), 815 mg aldehyde **7b** (2.89 mmol, 63%) was obtained as a slightly yellowish oil.

TLC: R_f = 0.66 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3056 (w, sp^2-CH), 2965 (m, sp^3-CH), 2874 (m, sp^3-CH), 1682 (s, C=O), 1621 (w, C=C), 1373 (w), 1060 (s, C–O–C), 822 (s, sp^2-CH), 757 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 0.98 (t, ^3J = 7.6 Hz, 3 H, H-5'$_a$), 1.03 (t, ^3J = 7.4 Hz, 3 H, H-5'$_b$), 2.03 – 2.18 (m, 4 H, H-4'), 4.15 (d, ^3J = 6.9 Hz, 2 H, H-1'), 5.00 (s, 2 H, CH_2), 5.37 (tt, ^3J = 6.9 Hz, ^4J = 1.4 Hz, 1 H, H-2'), 7.54 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.6 Hz, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.70 (d,

^{3}J = 8.4 Hz, 1 H, H-3), 7.88 (d, ^{3}J = 8.1 Hz, 1 H, H-5), 8.05 (d, ^{3}J = 8.4 Hz, 1 H, H-4), 8.91 (dd, ^{3}J = 8.6 Hz, ^{4}J = 1.1 Hz, 1 H, H-8), 10.97 (s, 1 H, CHO).

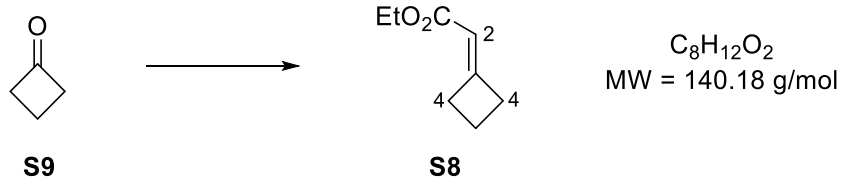
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 12.6 (q, C-5'$_b$), 13.6 (q, C-5'$_a$), 23.9 (t, C-4'), 29.2 (t, C-4'), 67.1 (t, C-1'), 69.7 (t, CH_2), 118.6 (d, C-2'), 124.6 (d, C-8), 126.5 (d, C-3*), 126.6 (d, C-6*), 128.6 (d, C-5**), 128.8 (m, C-1, C-7**), 131.6 (s, C-8a), 133.4 (s, C-4a), 134.4 (d, C-4), 142.4 (s, C-2), 148.8 (s, C-3'), 193.3 (d, CHO).

*, ** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 282 (1) $[M]^+$, 185 (100) $[C_{12}H_9O_2]^+$, 168 (84), 155 (21) $[C_{11}H_7O]^+$, 141 (100) $[C_{11}H_9]^+$, 127 (21) $[C_8H_{15}O]^+$, 97 (3) $[C_7H_{13}]^+$.

HRMS (EI, 70 eV): calcd for $C_{19}H_{22}O_2$ $[M]^+$: 282.1614; found: 282.1608.

Ethyl 2-cyclobutylideneacetate (S8)



S9 **S8**

Following GP1, ketone **S9** (2.50 g, 35.7 mmol, 1.00 eq.) was converted with triethyl phosphonoacetate (8.13 mL, 9.20 g, 41.1 mmol, 1.15 eq.) and sodium hydride (1.57 g, 60 wt% in paraffin oil, 39.2 mmol, 1.10 eq.) in tetrahydrofuran (50 mL). After stirring the reaction mixture for 15 hours at room temperature, the reaction was stopped and the crude product was purified by distillation under reduced pressure (10 mbar, 58 °C). 3.52 g of ester **S8** (25.1 mmol, 70%) were isolated as a colourless liquid.

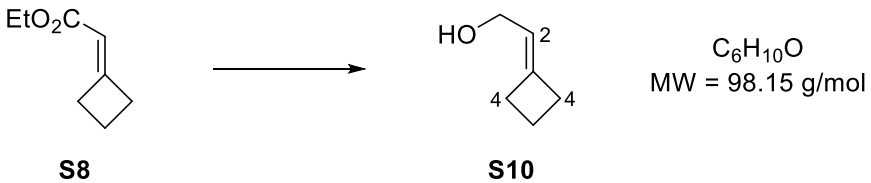
B.p.: 58 °C (10 mbar).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.26 (t, ^{3}J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 2.09 (*virt.* quint, $^{3}J \approx {}^{3}J$ = 7.9 Hz, 2 H, H-5), 2.78 – 2.93 (m, 2 H, H-4), 3.03 – 3.21 (m, 2 H, H-4), 4.14 (q, ^{3}J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.57 (*virt.* quint, $^{4}J \approx {}^{4}J$ = 2.3 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.5 (q, $COOCH_2CH_3$), 17.8 (t, C-5), 32.5 (t, C-4), 33.9 (t, C-4), 59.7 (t, $COOCH_2CH_3$), 112.5 (d, C-2), 166.8 (s, $COOCH_2CH_3$), 167.8 (s, C-3).

The analytical data obtained matched those reported in literature.[11]

2-Cyclobutylideneethan-1-ol (S10)



S8 **S10**

Following GP3, ester **S8** (3.48 g, 24.8 mmol, 1.00 eq.) was converted with lithium aluminium hydride powder (1.88 g, 49.6 mmol, 2.00 eq.). The reaction was stopped after four hours and

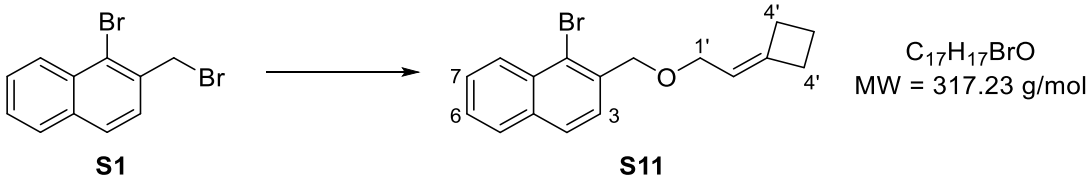
column chromatography (silica, P/Et_2O = 2/1) of the crude material gave 1.73 g allylic alcohol **S10** (17.7 mmol, 71%) as a colourless liquid.

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.19 – 1.21 (m, 1 H, OH), 1.97 (*virt.* quint, $^3J \approx {}^3J$ = 8.0 Hz, 2 H, H-5), 2.62 – 2.85 (m, 4 H, H-4), 4.00 – 4.02 (m, 2 H, H-1), 5.33 (*virt.* tquint, ^3J = 5.7 Hz, $^4J \approx {}^4J$ = 2.3 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 17.3 (q, C-5), 29.3 (t, C-4), 31.3 (t, C-4), 59.7 (t, C-1), 119.2 (d, C-2), 145.6 (s, C-3).

The analytical data obtained matched those reported in literature.[12]

1-Bromo-2-[(2-cyclobutylideneethoxy)methyl]naphthalene (S11)



Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 2.00 g, 6.67 mmol, 1.00 eq.) was converted with allylic alcohol **S10** (785 mg, 8.00 mmol, 1.20 eq.) and sodium hydride (347 mg, 60 wt% in paraffin oil, 8.67 mmol, 1.30 eq.) in tetrahydrofuran (25 mL). After seven hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 100/1) gave 1.15 g 1-bromo-2-alkyl-naphthalene **S11** (3.63 mmol, 54%) as a yellowish oil.

TLC: R_f = 0.34 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3058 (w, sp^2-CH), 2948 (m, sp^3-CH), 2861 (w, sp^3-CH), 1689 (m, C=C), 1325 (m), 1097 (m, C–O–C), 813 (s, sp^2-CH), 745 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.98 (*virt.* quint, $^3J \approx {}^3J$ = 8.0 Hz, 2 H, H-5'), 2.68 – 2.78 (m, 4 H, H-4'), 4.01 (*virt.* dquint, ^3J = 7.1 Hz, $^5J \approx {}^5J$ = 1.1 Hz, 2 H, H-1'), 4.81 (s, 2 H, CH_2), 5.38 (*virt.* tquint, ^3J = 7.1 Hz, $^4J \approx {}^4J$ = 2.3 Hz, 1 H, H-2'), 7.51 (ddd, ^3J = 8.1 Hz,

^3J = 6.9 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.9 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.64 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.4 Hz, 1 H, H-4), 7.82 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.8 Hz, 1 H, H-5), 8.32 (dd, ^3J = 8.5 Hz, ^4J = 1.1 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 17.3 (t, C-5'), 29.7 (t, C-4'), 31.3 (t, C-4'), 67.2 (t, C-1'), 71.9 (t, CH_2), 116.5 (d, C-2'), 122.6 (s, C-1), 126.2 (d, C-3), 126.5 (d, C-6), 127.1 (d, C-8), 127.5 (d, C-7), 127.8 (d, C-4*), 128.3 (d, C-5*), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.4 (s, C-2), 147.0 (s, C-3').

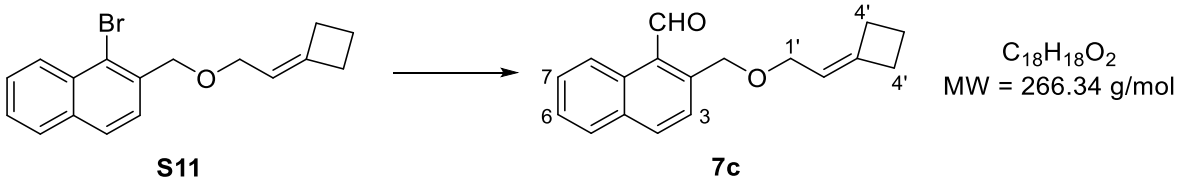
* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 318 (1) [M(^{81}Br)]$^+$, 316 (1) [M(^{79}Br)]$^+$, 236 (22) [$C_{11}H_7{}^{81}BrO]^+$, 234 (22) [$C_{11}H_7{}^{79}BrO]^+$, 207 (5) [$C_{10}H_6{}^{81}Br]^+$, 205 (5) [$C_{10}H_6{}^{79}Br]^+$, 126 (17) [$C_{10}H_6]^+$, 105 (100) [$C_8H_9]^+$, 82 (12).

HRMS (EI, 70 eV): calcd for $C_{17}H_{17}O^{81}Br$ [M]$^+$: 318.0437; found: 318.0450.

calcd for $C_{16}{}^{13}CH_{17}O^{81}Br$ [M]$^+$: 319.0470; found: 319.0480.

2-[(2-Cyclobutylideneethoxy)methyl]-1-naphthaldehyde (7c)



S11 **7c**

Following GP5, 1-bromo-2-alkyl-naphthalene **S11** (1.03 g, 3.26 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (1.56 mL, 2.5 M in *n*-hexane, 3.91 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (1.25 mL, 1.19 g, 16.3 mmol, 5.00 eq.) in tetrahydrofuran (25 mL). After column chromatography (silica, P/EtOAc = 25/1→10/1), 630 mg aldehyde **7c** (2.37 mmol, 73%) was obtained as a slightly yellowish oil.

TLC: R_f = 0.57 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3055 (w, sp^2-CH), 2980 (w, sp^3-CH), 2859 (m, sp^3-CH), 1681 (s, C=O), 1620 (w, C=C), 1368 (w), 1061 (s, C–O–C), 821 (s, sp^2-CH), 736 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.98 (*virt.* quint, $^3J \approx {}^3J$ = 8.0 Hz, 2 H, H-5'), 2.61 – 2.87 (m, 4 H, H-4'), 3.99 (*virt.* dquint, ^3J = 7.1 Hz, $^5J \approx {}^5J$ = 1.2 Hz, 2 H, H-1'), 4.97 (s, 2 H, CH_2), 5.34 (*virt.* tquint, ^3J = 7.1 Hz, $^4J \approx {}^4J$ = 2.3 Hz, 1 H, H-2'), 7.55 (ddd, ^3J = 8.2 Hz, ^3J = 6.8 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.7 Hz, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.69 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.88 (*virt.* dt, ^3J = 8.2 Hz, $^4J \approx {}^4J$ = 1.0 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.5 Hz, 1 H, H-4), 8.90 (dd, ^3J = 8.7 Hz, ^4J = 1.2 Hz, 1 H, H-8), 10.96 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 17.2 (t, C-5'), 29.7 (t, C-4'), 31.3 (t, C-4'), 67.2 (t, C-1'), 69.4 (t, CH_2), 116.2 (d, C-2'), 124.5 (d, C-8), 126.5 (d, C-3*), 126.5 (d, C-6*), 128.6 (d, C-5**), 128.7 (m, C-1, C-7**), 131.5 (s, C-8a), 133.3 (s, C-4a), 134.3 (d, C-4), 142.3 (s, C-2), 147.2 (s, C-3'), 193.2 (d, CHO).

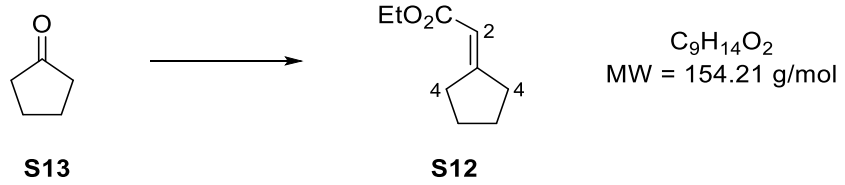
*, ** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 266 (1) $[M]^+$, 185 (100) $[C_{12}H_9O_2]^+$, 168 (94), 155 (15) $[C_{11}H_7O]^+$, 141 (100) $[C_{11}H_9]^+$, 115 (33).

HRMS (EI, 70 eV): calcd for $C_{18}H_{18}O_2$ $[M]^+$: 266.1301; found: 266.1296.

calcd for $C_{17}{}^{13}CH_{18}O_2$ $[M]^+$: 267.1335; found: 267.1337.

Ethyl 2-cyclopentylideneacetate (S12)



S13 **S12**

Ethyl (triphenylphosphoranylidene)acetate (10.0 mL, 11.4 g, 32.7 mmol, 1.10 eq.) was added to a solution of ketone **S13** (2.50 g, 29.7 mmol, 1.00 eq.) in toluene (50 mL). The mixture was heated to 110 °C and stirred at this temperature for twelve hours. Subsequently, the reaction mixture was cooled to room temperature, filtered and the residue was washed with toluene (10 mL). The solvent was removed under reduced pressure and purification of the crude product by column chromatography (silica, P/Et_2O = 30/1) gave 681 mg of ester **S12** (4.42 mmol, 15%) as a colourless liquid.

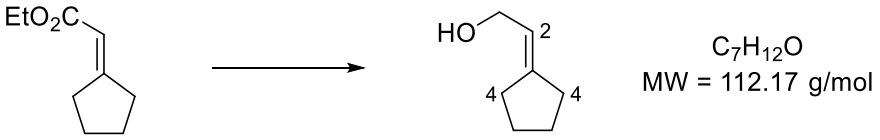
TLC: R_f = 0.72 (P/Et_2O = 10/1) [UV, $KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.27 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 1.66 (*virt.* quint, $^3J \approx {}^3J$ = 7.0 Hz, 2 H, H-5), 1.75 (*virt.* quint, $^3J \approx {}^3J$ = 7.0 Hz, 2 H, H-5), 2.44 (tdt, ^3J = 7.2 Hz, ^4J = 2.0 Hz, ^4J = 1.3 Hz, 1 H, H-4), 2.77 (tdt, ^3J = 7.4 Hz, ^4J = 2.5 Hz, ^4J = 1.3 Hz, 1 H, H-4), 4.15 (q, ^3J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.80 (*virt.* quint, $^4J \approx {}^4J$ = 2.2 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.4 (q, $COOCH_2CH_3$), 25.5 (t, C-5), 26.5 (t, C-5), 32.7 (t, C-4), 36.0 (t, C-4), 59.5 (t, $COOCH_2CH_3$), 111.7 (d, C-2), 167.0 (s, $COOCH_2CH_3$), 169.1 (s, C-3).

The analytical data obtained matched those reported in literature.[11]

2-Cyclopentylideneethan-1-ol (S14)



S12 **S14**

Following GP2, ester **S12** (521 mg, 3.38 mmol, 1.00 eq.) was converted with di*iso*butylaluminium hydride solution (7.43 mL, 1.0 M in dichloromethane, 7.43 mmol, 2.20 eq.). The reaction was stopped after six hours and purification of the crude product by column chromatography (silica, P/Et_2O = 15/1 → 5:1 → 2:1) gave 330 mg of ester **S14** (2.94 mmol, 87%) as a colourless liquid.

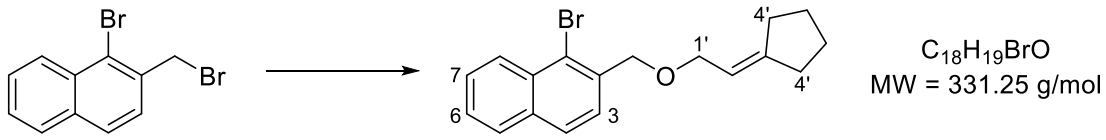
TLC: R_f = 0.10 (P/Et_2O = 10/1) [$KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.15 – 1.17 (m, 1 H, OH), 1.58 – 1.65 (m, 2 H, H-5), 1.65 – 1.73 (m, 2 H, H-5), 2.07 – 2.44 (m, 4 H, H-4), 4.13 (dd, ^3J = 7.2 Hz, ^3J = 3.2 Hz, 2 H, H-1), 5.51 (*virt.* tquint, ^3J = 7.2 Hz, $^4J \approx {}^4J$ = 2.3 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.0 (t, C-5), 26.3 (t, C-5), 28.6 (t, C-4), 33.7 (t, C-4), 61.1 (t, C-1), 119.2 (d, C-2), 147.9 (s, C-3).

The analytical data obtained matched those reported in literature.[13]

1-Bromo-2-[(2-cyclopentylideneethoxy)methyl]naphthalene (S15)



S1 **S15**

Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 723 mg, 2.41 mmol, 1.00 eq.) was converted with allylic alcohol **S14** (324 mg, 2.89 mmol, 1.00 eq.) and sodium hydride (125 mg, 60 wt% in paraffin oil, 3.13 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After 15 hours, the reaction was stopped and purification of the crude product by column chromatography (silica,

P/Et_2O = 100/1 → 50:1) gave 703 mg 1-bromo-2-alkyl-naphthalene **S15** (2.12 mmol, 88%) as a yellowish oil.

TLC: R_f = 0.79 (P/Et_2O = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3057 (w, sp^2-CH), 2952 (m, sp^3-CH), 2866 (m, sp^3-CH), 1689 (m, C=C), 1324 (m), 1102 (s, C–O–C), 813 (s, sp^2-CH), 744 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.59 – 1.66 (m, 2 H, H-5'), 1.66 – 1.72 (m, 2 H, H-5'), 2.19 – 2.29 (m, 2 H, H-4'), 2.30 – 2.34 (m, 2 H, H-4'), 4.12 (*virt.* dquint, ^3J = 7.0 Hz, $^5J \approx {}^5J$ = 1.2 Hz, 2 H, H-1'), 4.83 (s, 2 H, CH_2), 5.56 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 2.3 Hz, 1 H, H-2'), 7.51 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.8 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.65 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.4 Hz, 1 H, H-4), 7.82 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.7 Hz, 1 H, H-5), 8.32 (dd, ^3J = 8.5 Hz, ^4J = 1.1 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.2 (t, C-5'), 26.5 (t, C-5'), 29.0 (t, C-4'), 34.0 (t, C-4'), 68.8 (t, C-1'), 72.1 (t, CH_2), 116.4 (d, C-2'), 122.6 (s, C-1), 126.2 (d, C-3), 126.5 (d, C-6), 127.1 (d, C-8), 127.5 (d, C-7), 127.8 (d, C-4*), 128.3 (d, C-5*), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.4 (s, C-2), 149.3 (s, C-3').

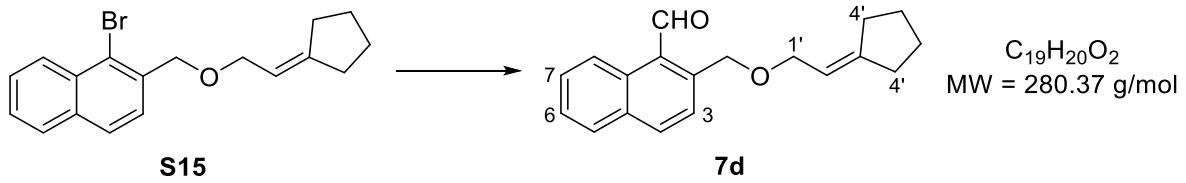
* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 332 (1) $[M(^{81}Br)]^+$, 330 (1) $[M(^{79}Br)]^+$, 234 (100) $[C_{11}H_7{}^{79}BrO]^+$, 207 (20) $[C_{10}H_6{}^{81}Br]^+$, 205 (20) $[C_{10}H_6{}^{79}Br]^+$, 157 (9) $[C_{11}H_9O]^+$, 126 (15) $[C_{10}H_6]^+$.

HRMS (EI, 70 eV): calcd for $C_{18}H_{19}O^{79}Br$ $[M]^+$: 330.0614; found: 330.0608.

calcd for $C_{18}H_{19}O^{81}Br$ $[M]^+$: 332.0593; found: 332.0592.

2-[(2-Cyclopentylideneethoxy)methyl]-1-naphthaldehyde (7d)



Following GP5, 1-bromo-2-alkyl-naphthalene **S15** (658 mg, 1.99 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (953 µL, 2.5 M in *n*-hexane, 2.38 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (770 µL, 727 mg, 9.95 mmol, 5.00 eq.) in tetrahydrofuran (15 mL). After column chromatography (silica, P/EtOAc = 30/1), 452 mg aldehyde **7d** (1.61 mmol, 81%) was obtained as a slightly yellowish oil.

TLC: R_f = 0.84 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3055 (w, sp^2-CH), 2950 (m, sp^3-CH), 2866 (m, sp^3-CH), 1682 (s, C=O), 1621 (w, C=C), 1370 (w), 1061 (s, C–O–C), 822 (s, sp^2-CH), 757 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.59 – 1.66 (m, 2 H, H-5'), 1.69 (*virt.* quint, $^3J \approx {}^3J$ = 6.8 Hz, 2 H, H-5'), 2.22 – 2.26 (m, 2 H, H-4'), 2.29 – 2.33 (m, 2 H, H-4'), 4.10 (*virt.* dquint, ^3J = 6.9 Hz, $^5J \approx {}^5J$ = 1.2 Hz, 2 H, H-1'), 4.99 (s, 2 H, CH_2), 5.53 (*virt.* tquint, ^3J = 6.9 Hz, $^4J \approx {}^4J$ = 2.3 Hz, 1 H, H-2'), 7.54 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.6 Hz, ^3J = 6.8 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.69 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.88 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.8 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.91 (dd, ^3J = 8.6 Hz, ^4J = 1.1 Hz, 1 H, H-8), 10.96 (s, 1 H, CHO).

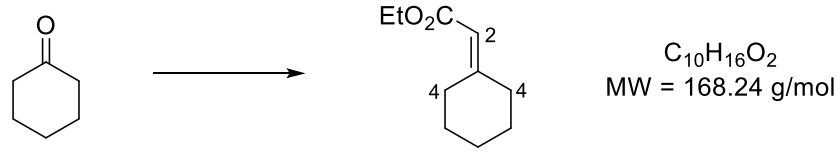
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.2 (t, C-5'), 26.5 (t, C-5'), 29.0 (t, C-4'), 33.9 (t, C-4'), 68.9 (t, C-1'), 69.6 (t, CH_2), 116.1 (d, C-2'), 124.6 (d, C-8), 126.6 (d, C-3*), 126.6 (d, C-6*), 128.6 (d, C-5**), 128.8 (d C-7**), 128.8 (s, C-1), 131.6 (s, C-8a), 133.4 (s, C-4a), 134.4 (d, C-4), 142.4 (s, C-2), 149.6 (s, C-3'), 193.3 (d, CHO).

*, ** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 280 (2) $[M]^+$, 185 (66) $[C_{12}H_9O_2]^+$, 168 (63), 155 (100) $[C_{11}H_7O]^+$, 141 (54) $[C_{11}H_9]^+$, 127 (69).

HRMS (EI, 70 eV): calcd for $C_{19}H_{20}O_2$ $[M]^+$: 280.1458; found: 280.1458.

Ethyl 2-cyclohexylideneacetate (S16)



S17 **S16**

n-Butyllithium solution (11.6 mL, 2.5 M in *n*-hexane, 28.9 mmol, 1.50 eq.) was added dropwise to a solution of triethyl phosphonoacetate (4.58 mL, 5.18 g, 23.1 mmol, 1.20 eq.) in tetrahydrofuran (100 mL) at 0 °C. After a reaction time of 30 minutes, cyclohexanone (**S17**, 1.89 g, 19.3 mmol, 1.00 eq.) was slowly added and the reaction mixture was warmed to room temperature. The reaction was stopped after six hours by the addition of hydrogen chloride solution (80 mL, 2.0 M in water) and dichloromethane (500 mL) was subsequently added. The layers were separated and the aqueous layer was extracted with dichloromethane (2 ×100 mL). The combined organic extracts were washed with water (3 ×200 mL), brine (1 ×100 mL), dried over anhydrous $MgSO_4$, filtered and the solvent was removed under reduced pressure. Purification of the crude product by column chromatography (silica, P/Et_2O = 25/1), gave 2.27 g of ester **S16** (13.5 mmol, 70%) as a colourless liquid.

TLC: R_f = 0.32 (P/Et_2O = 25/1) [UV, $KMnO_4$].

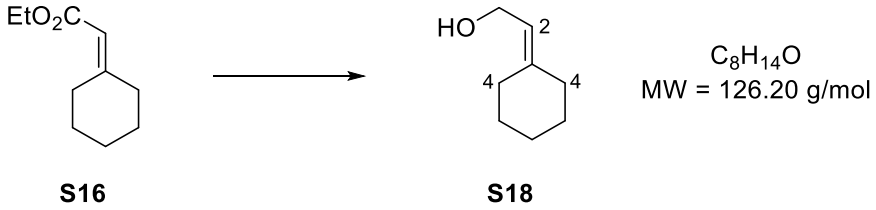
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.27 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 1.57 – 1.66 (m, 6 H, H-5, H-6), 2.17 – 2.20 (m, 2 H, H-4), 2.82 (t, ^3J = 5.8 Hz, 2 H, H-4), 4.14 (q, ^3J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.60 (s, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.5 (q, $COOCH_2CH_3$), 26.4 (t, C-5*), 27.9 (t, C-5*), 28.8 (t, C-6*), 30.0 (t, C-4), 38.1 (t, C-4), 59.6 (t, $COOCH_2CH_3$), 113.1 (d, C-2), 163.7 (s, C-3), 167.0 (s, $COOCH_2CH_3$).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[11]

2-Cyclohexylideneethan-1-ol (S18)



S16 **S18**

Following GP3, ester **S16** (2.24 g, 13.3 mmol, 1.00 eq.) was converted with lithium aluminium hydride powder (1.01 g, 26.6 mmol, 2.00 eq.). The reaction was stopped after two hours and column chromatography (silica, P/Et_2O = 10/1 → 5/1) of the crude material gave 1.61 g allylic alcohol **S18** (12.8 mmol, 96%) as a colourless liquid.

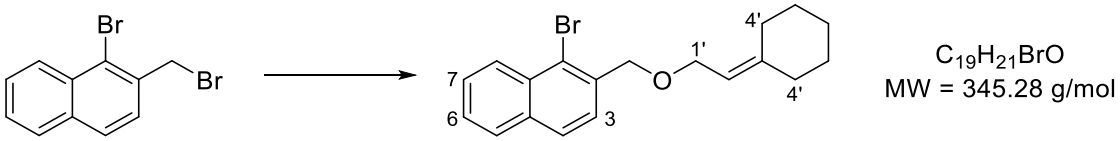
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.13 (t, ^3J = 5.2 Hz, 1 H, OH), 1.45 – 1.57 (m, 6 H, H-5, H-6), 2.11 (t, ^3J = 5.3 Hz, 2 H, H-4), 2.18 (t, ^3J = 5.3 Hz, 2 H, H-4), 4.14 (dd, ^3J = 7.2 Hz, ^3J = 5.2 Hz, 2 H, H-1), 5.36 (tt, ^3J = 7.2 Hz, ^4J = 1.3 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.8 (t, C-5*), 28.0 (t, C-5*), 28.5 (t, C-6*), 29.0 (t, C-4), 37.2 (t, C-4), 58.7 (t, C-1), 120.4 (d, C-2), 144.7 (s, C-3).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[13]

1-Bromo-2-[(2-cyclohexylideneethoxy)methyl]naphthalene (S19)



S1 **S19**

Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.70 g, 5.67 mmol, 1.00 eq.) was converted with allylic alcohol **S18** (858 mg, 6.80 mmol, 1.20 eq.) and sodium hydride (295 mg, 60 wt% in paraffin oil, 7.37 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After six hours, the reaction was stopped and purification of the crude product by column chromatography (silica,

P/Et_2O = 100/1) gave 1.43 g 1-bromo-2-alkyl-naphthalene **S19** (4.14 mmol, 73%) as a colourless oil.

TLC: R_f = 0.48 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3057 (w, sp^2-CH), 2928 (s, sp^3-CH), 2853 (s, sp^3-CH), 1690 (m, C=C), 1324 (m), 1100 (s, C–O–C), 813 (s, sp^2-CH), 744 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.53 – 1.59 (m, 6 H, H-5', H-6'), 2.15 (t, ^3J = 5.5 Hz, 2 H, H-4'), 2.19 (t, ^3J = 5.4 Hz, 2 H, H-4'), 4.14 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.82 (s, 2 H, CH_2), 5.40 (t, ^3J = 7.0 Hz, 1 H, H-2'), 7.51 (ddd, ^3J = 8.1 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.65 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.5 Hz, 1 H, H-4), 7.83 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.6 Hz, 1 H, H-5), 8.32 (dd, ^3J = 8.5 Hz, ^4J = 1.2 Hz, 1 H, H-8).

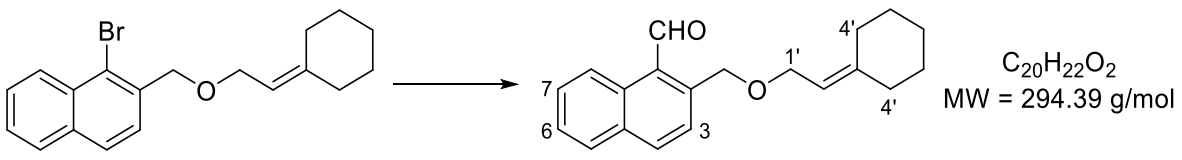
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.9 (t, C-5'*), 28.0 (t, C-5'*), 28.6 (t, C-6'*), 29.2 (t, C-4'), 37.3 (t, C-4'), 66.4 (t, C-1'), 72.0 (t, CH_2), 117.6 (d, C-2'), 122.6 (s, C-1), 126.2 (d, C-3), 126.5 (d, C-6), 127.1 (d, C-8), 127.4 (d, C-7), 127.8 (d, C-4**), 128.3 (d, C-5**), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.4 (s, C-2), 145.8 (s, C-3').

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 306 (5) $[M(^{81}Br)]^+$, 304 (5) $[M(^{79}Br)]^+$, 266 (34), 234 (71) $[C_{11}H_7{}^{79}BrO]^+$, 207 (20) $[C_{10}H_6{}^{81}Br]^+$, 205 (20) $[C_{10}H_6{}^{79}Br]^+$, 157 (25) $[C_{11}H_9O]^+$, 141 (52), 126 (100) $[C_{10}H_6]^+$.

HRMS (EI, 70 eV): calcd for $C_{19}H_{21}O^{79}Br$ $[M]^+$: 344.0770; found: 344.0783.

2-[(2-Cyclohexylideneethoxy)methyl]-1-naphthaldehyde (7e)



S19 **7e**

Following GP5, 1-bromo-2-alkyl-naphthalene **S19** (1.26 g, 3.64 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (1.75 mL, 2.5 M in *n*-hexane, 4.36 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (1.40 mL, 1.33 g, 18.2 mmol, 5.00 eq.) in tetrahydrofuran (25 mL). After column chromatography (silica, P/EtOAc = 25/1), 791 mg aldehyde **7e** (2.67 mmol, 74%) was obtained as a colourless solid.

M.p.: 30 °C.

TLC: R_f = 0.65 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3055 (w, sp^2-CH), 2927 (m, sp^3-CH), 2853 (m, sp^3-CH), 1682 (s, C=O), 1621 (w, C=C), 1376 (w), 1063 (s, C–O–C), 820 (s, sp^2-CH), 755 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.53 – 1.58 (m, 6 H, H-5', H-6'), 2.13 – 2.15 (m, 2 H, H-4'), 2.17 – 2.19 (m, 2 H, H-4'), 4.12 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.98 (s, 2 H, CH_2), 5.36 (tt, ^3J = 7.0 Hz, ^4J = 1.2 Hz, 1 H, H-2'), 7.55 (ddd, ^3J = 8.2 Hz, ^3J = 6.8 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.6 Hz, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.69 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.88 (d, ^3J = 8.2 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.5 Hz, 1 H, H-4), 8.91 (dd, ^3J = 8.6 Hz, ^4J = 1.1 Hz, 1 H, H-8), 10.96 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.8 (t, C-5'*), 27.9 (t, C-5'*), 28.6 (t, C-6'*), 29.2 (t, C-4'), 37.2 (t, C-4'), 66.4 (t, C-1'), 69.4 (t, CH_2), 117.3 (d, C-2'), 124.6 (d, C-8), 126.6 (d, C-3, C-6), 128.6 (d, C-5*), 128.8 (d, C-7*), 128.8 (s, C-1), 131.6 (s, C-8a), 133.4 (s, C-4a), 134.3 (d, C-4), 142.4 (s, C-2), 146.1 (s, C-3'), 193.3 (d, CHO).

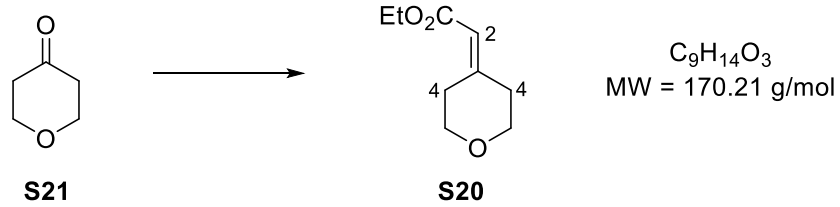
* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 294 (3) $[M]^+$, 185 (100) $[C_{12}H_9O_2]^+$, 168 (82), 155 (15) $[C_{11}H_7O]^+$, 141 (94) $[C_{11}H_9]^+$, 115 (24), 109 (9) $[C_8H_{13}]^+$.

HRMS (EI, 70 eV): calcd for $C_{20}H_{22}O_2$ $[M]^+$: 294.1614; found: 294.1607.

calcd for $C_{19}{}^{13}CH_{22}O_2$ $[M]^+$: 295.1648; found: 295.1651.

Ethyl 2-(tetrahydro-4*H*-pyran-4-ylidene)acetate (S20)



S21 **S20**

Triethyl phosphonoacetate (6.45 mL, 7.28 g, 32.5 mmol, 1.30 eq.) was added to a suspension of potassium carbonate (10.4 g, 75.0 mmol, 3.00 eq.) in DMF (50 mL) at room temperature. After 15 minutes, tetrahydro-4*H*-pyran-4-one (**S21**, 2.50 g, 25.0 mmol, 1.00 eq.) was added, the reaction mixture was heated up to 70 °C and it was stirred at this temperature for 21 hours. The reaction was quenched by the addition of cooled water (150 mL) and the mixture was diluted with diethyl ether (150 mL). Subsequently, the layers were separated and the aqueous layer was extracted with diethyl ether (2 × 100 mL). The combined organic extract was washed with water (200 mL), brine (200 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography (silica, P/Et_2O = 10/1 → 5/1) to yield 1.98 g of ester **S20** (11.6 mmol, 47%) as a colourless oil.

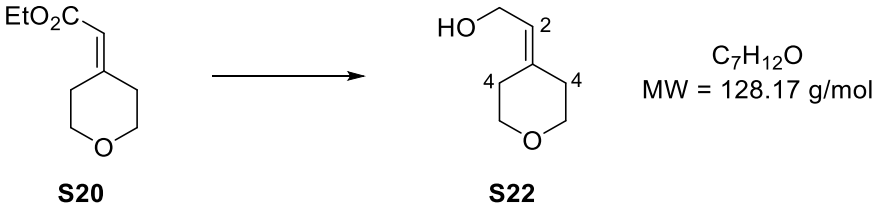
TLC: R_f = 0.43 (P/Et_2O = 10/1) [UV, $KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 287 K): δ [ppm] = 1.27 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 2.33 (td, ^3J = 5.6 Hz, ^4J = 1.2 Hz, 2 H, H-4), 3.01 (td, ^3J = 5.6 Hz, ^4J = 1.2 Hz, 2 H, H-4), 3.74 (t, ^3J = 5.6 Hz, 2 H, H-5), 3.77 (t, ^3J = 5.6 Hz, 2 H, H-5), 4.15 (q, ^3J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.68 (*virt.* quint, $^4J \approx {}^4J$ = 1.2 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.4 (q, $COOCH_2CH_3$), 31.2 (t, C-4), 37.7 (t, C-4), 59.9 (t, $COOCH_2CH_3$), 68.6 (t, C-5), 69.2 (t, C-5), 114.7 (d, C-2), 157.4 (s, C-3), 166.6 (s, $COOCH_2CH_3$).

The analytical data obtained matched those reported in literature.[14]

2-(Tetrahydro-4*H*-pyran-4-ylidene)ethan-1-ol (S22)



S20 **S22**

Following GP2, ester **S20** (1.41 g, 8.28 mmol, 1.00 eq.) was converted with di*iso*butylaluminium hydride solution (18.2 mL, 1.0 M in dichloromethane, 18.2 mmol, 2.20 eq.) in dichloromethane (30 mL) at –78 °C. After four hours, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 10/1 → 3/1 → 1:1). 913 mg homoallylic alcohol **S22** (7.12 mmol, 86%) were obtained as a colourless oil.

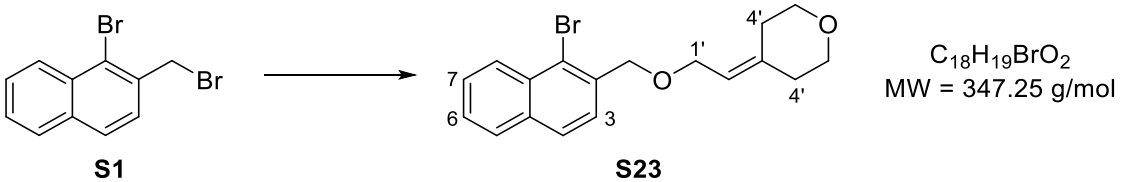
TLC: R_f = 0.21 (P/EtOAc = 4/1) [UV, $KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.27 (t, ^3J = 5.1 Hz, 1 H, OH), 2.25 (td, ^3J = 5.5 Hz, ^4J = 1.3 Hz, 2 H, H-4), 2.33 (td, ^3J = 5.5 Hz, ^4J = 1.3 Hz, 2 H, H-4), 3.67 (t, ^3J = 5.5 Hz, 2 H, H-5), 3.70 (t, ^3J = 5.5 Hz, 2 H, H-5), 4.16 (dd, ^3J = 7.1 Hz, ^3J = 5.1 Hz, 2 H, H-1), 5.47 (*virt.* tquint, ^3J = 7.1 Hz, $^4J \approx {}^4J$ = 1.3 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 30.0 (t, C-4), 36.9 (t, C-4), 58.3 (t, C-1), 68.8 (t, C-5), 69.5 (t, C-5), 122.3 (d, C-2), 138.9 (s, C-3).

The analytical data obtained matched those reported in literature.[14]

4-{2-[(1-Bromonaphthalen-2-yl)methoxy]ethylidene}tetrahydro-2*H*-pyran (S23)



S1 **S23**

Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.75 g, 5.87 mmol, 1.00 eq.) was converted with allylic alcohol **S22** (903 mg, 7.05 mmol, 1.20 eq.) and sodium hydride (305 mg,

60 wt% in paraffin oil, 7.63 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After 15 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 4/1) gave 1.66 g 1-bromo-2-alkyl-naphthalene **S23** (4.78 mmol, 82%) as a yellowish, viscous oil.

TLC: R_f = 0.36 (P/Et_2O = 4/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3056 (w, sp^2-CH), 2957 (m, sp^3-CH), 2844 (m, sp^3-CH), 1502 (w, C=C), 1324 (m), 1098 (s, C–O–C), 814 (s, sp^2-CH), 767 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.28 (t, ^3J = 5.6 Hz, 2 H, H-4'), 2.33 (td, ^3J = 5.6 Hz, ^4J = 1.3 Hz, 2 H, H-4'), 3.68 (t, ^3J = 5.6 Hz, 2 H, H-5'), 3.72 (t, ^3J = 5.6 Hz, 2 H, H-5'), 4.15 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.83 (s, 2 H, CH_2), 5.52 (tt, ^3J = 7.0 Hz, ^4J = 1.3 Hz, 1 H, H-2'), 7.52 (ddd, ^3J = 8.1 Hz, ^3J = 6.9 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.2 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.63 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.4 Hz, 1 H, H-4), 7.83 (*virt.* dt, ^3J = 8.2 Hz, $^4J \approx {}^4J$ = 0.9 Hz, 1 H, H-5), 8.32 (dd, ^3J = 8.6 Hz, ^4J = 1.1 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 30.2 (t, C-4'), 37.0 (t, C-4'), 65.9 (t, C-1'), 68.7 (t, C-5'), 69.5 (t, C-5'), 72.2 (t, CH_2), 119.5 (d, C-2'), 122.7 (s, C-1), 126.2 (d, C-3), 126.6 (d, C-6), 127.1 (d, C-8), 127.5 (d, C-7), 127.8 (d, C-4*), 128.3 (d, C-5*), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.1 (s, C-2), 140.2 (s, C-3').

* assignment is interconvertible.

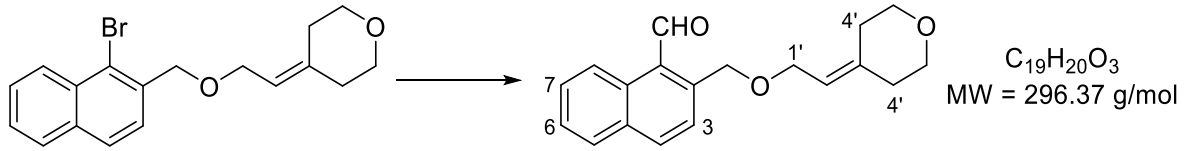
MS (EI, 70 eV): m/z (%) = 348 (7) [M(^{81}Br)]$^+$, 346 (7) [M(^{79}Br)]$^+$, 267 (12), 234 (45), 157 (15) $[C_{11}H_9O]^+$, 141 (93), 105 (100) $[C_8H_9]^+$.

HRMS (EI, 70 eV): calcd for $C_{18}H_{19}O_2{}^{79}Br$ [M]$^+$: 346.0563; found: 346.0563.

calcd for $C_{17}{}^{13}CH_{19}O_2{}^{79}Br$ [M]$^+$: 347.0596; found: 347.0599.

calcd for $C_{18}H_{19}O_2{}^{81}Br$ [M]$^+$: 348.0542; found: 348.0547.

2-{[2-(Tetrahydro-4*H*-pyran-4-ylidene)ethoxy]methyl}-1-naphthaldehyde (7f)



S23 **7f**

Following GP5, 1-bromo-2-alkyl-naphthalene **S23** (1.53 g, 4.41 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (2.12 mL, 2.5 M in *n*-hexane, 5.29 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (1.71 mL, 1.61 g, 22.1 mmol, 5.00 eq.) in tetrahydrofuran (25 mL). After column chromatography (silica, P/EtOAc = 10/1 → 5/1 → 3/1), 929 mg aldehyde **7f** (3.13 mmol, 71%) was obtained as a slightly yellowish oil.

TLC: R_f = 0.29 (P/EtOAc = 4/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3055 (w, sp^2-C), 2956 (w, sp^3-CH), 2846 (w, sp^3-CH), 1680 (s, C=O), 1620 (w, C=C), 1383 (w), 1095 (s, C–O–C), 1059 (s, C–O–C), 823 (s, sp^2-CH), 757 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.27 (t, ^3J = 5.6 Hz, 2 H, H-4'), 2.31 (t, ^3J = 5.6 Hz, 2 H, H-4'), 3.68 (t, ^3J = 5.6 Hz, 2 H, H-5'), 3.71 (t, ^3J = 5.6 Hz, 2 H, H-5'), 4.13 (d, ^3J = 7.0 Hz, 2 H, H-1'), 5.00 (s, 2 H, CH_2), 5.48 (tt, ^3J = 7.0 Hz, ^4J = 1.2 Hz, 1 H, H-2'), 7.55 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.6 Hz, ^3J = 6.8 Hz, ^4J = 1.2 Hz, 1 H, H-7), 7.68 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.89 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.9 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.5 Hz, 1 H, H-4), 8.88 (dd, ^3J = 8.6 Hz, ^4J = 1.1 Hz, 1 H, H-8), 10.97 (s, 1 H, CHO).

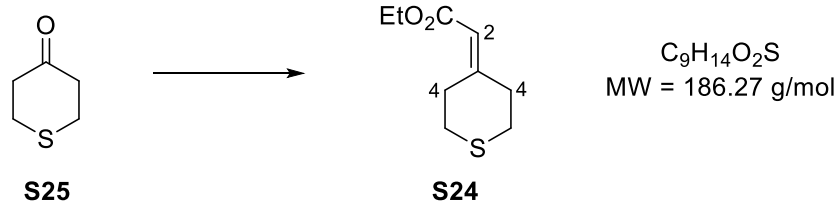
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 30.2 (t, C-4'), 36.9 (t, C-4'), 66.0 (t, C-1'), 68.7 (t, C-5'), 69.5 (t, C-5'), 69.8 (t, CH_2), 119.3 (d, C-2'), 124.4 (d, C-8), 126.4 (d, C-3), 126.6 (d, C-6), 128.7 (d, C-5*), 128.8 (s, C-1), 128.8 (d, C-7*), 131.6 (s, C-8a), 133.4 (s, C-4a), 134.4 (d, C-4), 140.3 (s, C-3'), 142.0 (s, C-2), 193.2 (d, CHO).

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 296 (1) $[M]^+$, 185 (61) $[C_{12}H_9O_2]^+$, 168 (40), 155 (100) $[C_{11}H_7O]^+$, 141 (42) $[C_{11}H_9]^+$, 127 (65), 115 (16).

HRMS (EI, 70 eV): calcd for $C_{19}H_{20}O_3$ $[M]^+$: 296.1407; found: 296.1407.

Ethyl 2-(tetrahydro-4*H*-thiopyran-4-ylidene)acetate (S24)



S25 **S24**

Triethyl phosphonoacetate (5.56 mL, 6.28 g, 28.0 mmol, 1.30 eq.) was added to a suspension of potassium carbonate (8.93 g, 64.7 mmol, 3.00 eq.) in DMF (43 mL) at room temperature. After 15 minutes, tetrahydro-4*H*-thiopyran-4-one (**S25**, 2.50 g, 21.5 mmol, 1.00 eq.) was added, the reaction mixture was heated up to 70 °C and it was stirred at this temperature for 22 hours. The reaction was quenched by the addition of cooled water (150 mL) and the mixture was diluted with diethyl ether (150 mL). Subsequently, the layers were separated and the aqueous layer was extracted with diethyl ether (2 × 100 mL). The combined organic extract was washed with water (200 mL), brine (200 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography (silica, P/EtOAc = 20/1) to yield 2.79 g of ester **S24** (15.0 mmol, 70%) as a colourless oil.

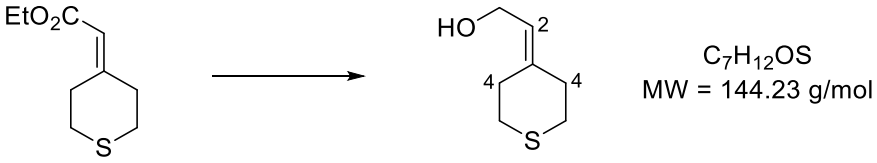
TLC: R_f = 0.67 (P/EtOAc = 10/1) [UV, $KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 287 K): δ [ppm] = 1.26 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 2.40 – 2.63 (m, 2 H, H-4), 2.66 – 2.89 (m, 4 H, H-5), 3.09 – 3.32 (m, 2 H, H-4), 4.13 (q, ^3J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.67 (s, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.4 (q, $COOCH_2CH_3$), 30.6 (t, C-5), 31.2 (t, C-5), 31.7 (t, C-4), 39.4 (t, C-4), 59.9 (t, $COOCH_2CH_3$), 115.9 (d, C-2), 159.4 (s, C-3), 166.4 (s, $COOCH_2CH_3$).

The analytical data obtained matched those reported in literature.[15]

2-(Tetrahydro-4*H*-thiopyran-4-ylidene)ethan-1-ol (S26)



S24 **S26**

Following GP2, ester **S24** (1.81 g, 9.72 mmol, 1.00 eq.) was converted with di*iso*butylaluminium hydride solution (21.4 mL, 1.0 M in dichloromethane, 21.4 mmol, 2.20 eq.) in dichloromethane (30 mL) at –78 °C. After six hours, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 10/1 → 3/1 → 1:1). 1.15 g homoallylic alcohol **S26** (7.97 mmol, 82%) were obtained as an off-white solid.

M.p.: 27 °C.

TLC: R_f = 0.21 (P/EtOAc = 4/1) [UV, $KMnO_4$].

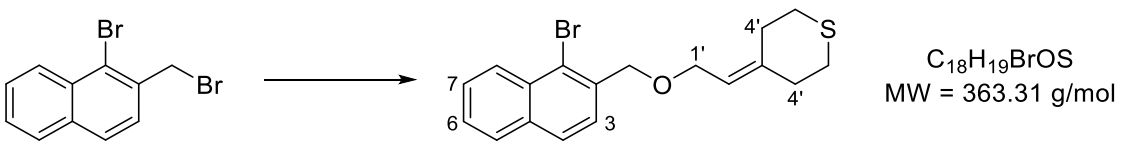
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.15 (t, ^3J = 5.4 Hz, 1 H, OH), 2.36 – 2.52 (m, 2 H, H-4), 2.52 – 2.60 (m, 2 H, H-4), 2.64 – 2.67 (m, 2 H, H-5), 2.67 – 2.72 (m, 2 H, H-5), 4.16 (dd, ^3J = 7.0 Hz, ^3J = 5.4 Hz, 2 H, H-1), 5.46 (tt, ^3J = 7.0 Hz, ^4J = 1.1 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 30.4 (t, C-5), 30.9 (t, C-5*), 31.0 (t, C-4*), 38.8 (t, C-4), 58.2 (t, C-1), 123.7 (d, C-2), 141.1 (s, C-3).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[15]

4-{2-[(1-Bromonaphthalen-2-yl)methoxy]ethylidene}tetrahydro-2*H*-thiopyran (S27)



S1 **S27**

Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.75 g, 5.87 mmol, 1.00 eq.) was converted with allylic alcohol **S26** (1.02 g, 7.05 mmol, 1.20 eq.) and sodium hydride (305 mg, 60 wt% in paraffin oil, 7.63 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After 15 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 4/1) gave 1.58 g 1-bromo-2-alkyl-naphthalene **S27** (4.35 mmol, 74%) as a yellowish, viscous oil.

TLC: R_f = 0.72 (P/Et_2O = 4/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3053 (w, sp^2-CH), 2903 (m, sp^3-CH), 2853 (w, sp^3-CH), 1666 (w, C=C), 1324 (m), 1100 (m), 812 (s, sp^2-CH), 744 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.49 – 2.51 (m, 2 H, H-4'), 2.54 – 2.56 (m, 2 H, H-4'), 2.64 – 2.67 (m, 2 H, H-4'), 2.69 – 2.72 (m, 2 H, H-4'), 4.13 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.82 (s, 2 H, CH_2), 5.51 (tt, ^3J = 7.0 Hz, ^4J = 1.2 Hz, 1 H, H-2'), 7.52 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.58 – 7.61 (m, 1 H, H-7), 7.62 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.5 Hz, 1 H, H-4), 7.83 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.8 Hz, 1 H, H-5), 8.32 (dd, ^3J = 8.5 Hz, ^4J = 1.2 Hz, 1 H, H-8).

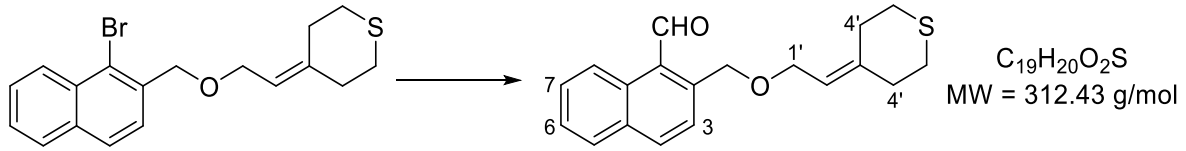
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 30.4 (t, C-5'), 31.1 (t, C-5'*), 31.1 (t, C-4'*), 38.9 (t, C-4'), 65.8 (t, C-1'), 72.3 (t, CH_2), 121.0 (d, C-2'), 122.8 (s, C-1), 126.2 (d, C-3), 126.6 (d, C-6), 127.2 (d, C-8), 127.5 (d, C-7), 127.8 (d, C-4**), 128.3 (d, C-5**), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.0 (s, C-2), 142.2 (s, C-3').

*,** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 364 (1) [M(^{81}Br)]$^+$, 362 (1) [M(^{79}Br)]$^+$, 221 (61), 157 (92) [$C_{11}H_9O$]$^+$, 140 (63), 126 (100) [$C_{10}H_6$]$^+$.

HRMS (EI, 70 eV): calcd for $C_{18}H_{19}O^{81}Br^{32}S$ [M]$^+$: 364.0314; found: 364.0292.

2-{[2-(Tetrahydro-4*H*-thiopyran-4-ylidene)ethoxy]methyl}-1-naphthaldehyde (7g)



S27 **7g**

Following GP5, 1-bromo-2-alkyl-naphthalene **S27** (1.31 g, 3.61 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (1.73 mL, 2.5 M in *n*-hexane, 4.33 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (1.38 mL, 1.32 g, 18.1 mmol, 5.00 eq.) in tetrahydrofuran (25 mL). After column chromatography (silica, P/EtOAc = 20/1 → 10/1), 494 mg aldehyde **7g** (1.58 mmol, 44%) was obtained as an off-white solid.

M.p.: 42 °C.

TLC: R_f = 0.31 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2903 (m, sp^3-CH), 1680 (s, C=O), 1592 (w, C=C), 1426 (m), 1058 (s), 822 (s, sp^2-CH), 757 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.46 – 2.51 (m, 2 H, H-4'), 2.52 – 2.56 (m, 2 H, H-4'), 2.62 – 2.67 (m, 2 H, H-5'), 2.68 – 2.72 (m, 2 H, H-5'), 4.12 (d, ^3J = 6.9 Hz, 2 H, H-1'), 4.99 (s, 2 H, CH_2), 5.47 (tt, ^3J = 6.8 Hz, ^4J = 1.2 Hz, 1 H, H-2'), 7.55 (ddd, ^3J = 8.0 Hz, ^3J = 6.9 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.65 (ddd, ^3J = 8.5 Hz, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.68 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.89 (*virt.* dt, ^3J = 8.3 Hz, $^4J \approx {}^4J$ = 0.8 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.87 (dd, ^3J = 8.7 Hz, ^4J = 1.0 Hz, 1 H, H-8), 10.97 (s, 1 H, CHO).

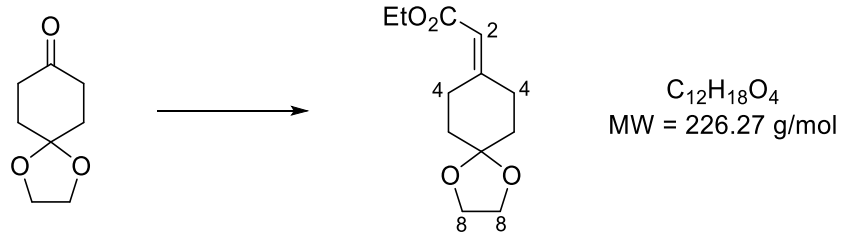
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 30.3 (t, C-5'), 31.0 (t, C-5'*), 31.1 (t, C-4'*), 38.8 (t, C-4'), 65.9 (t, C-1'), 69.9 (t, CH_2), 120.7 (d, C-2'), 124.4 (d, C-8), 126.4 (d, C-3), 126.6 (d, C-6), 128.7 (d, C-5**), 128.7 (s, C-1), 128.8 (d, C-7**), 131.7 (s, C-8a), 133.4 (s, C-4a), 134.4 (d, C-4), 141.9 (s, C-2***), 142.3 (s, C-3'***), 193.1 (d, CHO).

*, **, *** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 312 (1) $[M]^+$, 270 (8), 185 (100) $[C_{12}H_9O_2]^+$, 168 (56), 155 (10) $[C_{11}H_7O]^+$, 141 (56) $[C_{11}H_9]^+$, 115 (22).

HRMS (EI, 70 eV): calcd for $C_{19}H_{20}O_2{}^{32}S$ $[M]^+$: 312.1179; found: 312.1179.

Ethyl 2-(1,4-dioxaspiro[4.5]decan-8-ylidene)acetate (S28)



S29 **S28**

Following GP1, ketone **S29** (3.50 g, 22.4 mmol, 1.00 eq.) was converted with triethyl phosphonoacetate (5.11 mL, 5.78 g, 25.8 mmol, 1.15 eq.) and sodium hydride (986 mg, 60 wt% in paraffin oil, 24.6 mmol, 1.10 eq.) in tetrahydrofuran (60 mL). After stirring the reaction mixture for three hours at room temperature, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 30/1 → 20/1). 2.64 g of ester **S28** (11.7 mmol, 52%) were isolated as a colourless liquid.

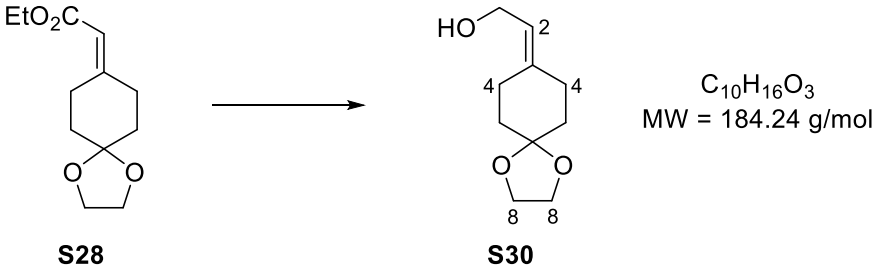
TLC: R_f = 0.48 (P/EtOAc = 10/1) [UV, $KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.28 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 1.70 – 1.84 (m, 4 H, H-5), 2.38 (td, ^3J = 6.7 Hz, ^4J = 1.0 Hz, 2 H, H-4), 3.00 (td, ^3J = 6.6 Hz, ^4J = 1.0 Hz, 2 H, H-4), 3.98 (s, 4 H, H-8), 4.15 (q, ^3J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.66 (s, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.4 (q, $COOCH_2CH_3$), 26.2 (t, C-4), 34.7 (t, C-4), 35.1 (t, C-5), 35.9 (t, C-5), 59.8 (t, $COOCH_2CH_3$), 64.6 (t, C-8), 108.2 (s, C-6), 114.5 (d, C-2), 160.3 (s, C-3), 166.7 (s, $COOCH_2CH_3$).

The analytical data obtained matched those reported in literature.[16]

2-(1,4-Dioxaspiro[4.5]decan-8-ylidene)ethan-1-ol (S30)



S28 **S30**

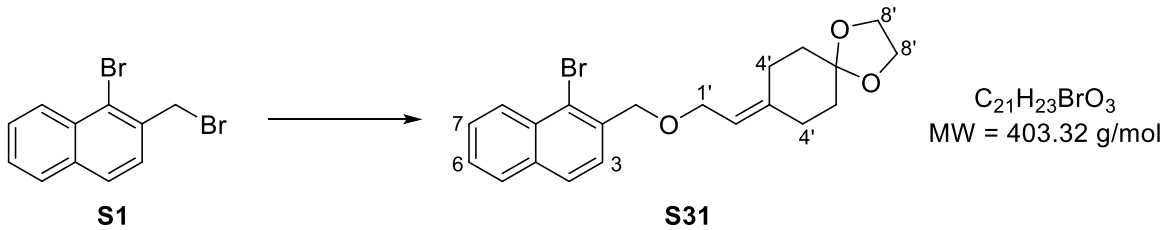
Following GP2, ester **S28** (1.50 g, 6.63 mmol, 1.00 eq.) was converted with di*iso*butylaluminium hydride solution (14.6 mL, 1.0 M in dichloromethane, 14.6 mmol, 2.20 eq.) in dichloromethane (50 mL) at –78 °C. After six hours, the reaction was stopped and 1.05 g of homoallylic alcohol **S30** (5.70 mmol, 86%) were obtained as a colourless oil.

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.14 (td, ^{3}J = 5.5 Hz, ^{4}J = 1.7 Hz, 1 H, OH), 1.65 – 1.75 (m, 4 H, H-5), 2.28 (t, ^{3}J = 6.6 Hz, 2 H, H-4), 2.34 (td, ^{3}J = 6.5 Hz, ^{4}J = 1.2 Hz, 2 H, H-4), 3.97 (s, 4 H, H-8), 4.16 (dd, ^{3}J = 7.1 Hz, ^{3}J = 5.5 Hz, 2 H, H-1), 5.44 (tt, ^{3}J = 7.1 Hz, ^{4}J = 1.2 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 24.9 (t, C-4), 33.2 (t, C-4), 34.8 (t, C-5), 35.9 (t, C-5), 59.2 (t, C-1), 64.1 (t, C-8), 108.5 (s, C-6), 121.8 (d, C-2), 141.2 (s, C-3).

The analytical data obtained matched those reported in literature.[13]

8-{2-[(1-Bromonaphthalen-2-yl)methoxy]ethylidene}-1,4-dioxaspiro[4.5]decane (S31)



S1 **S31**

Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.00 g, 3.33 mmol, 1.00 eq.) was converted with allylic alcohol **S30** (737 mg, 4.00 mmol, 1.20 eq.) and sodium hydride (173 mg, 60 wt% in paraffin oil, 4.33 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After 16 hours, the

reaction was stopped and purification of the crude product by column chromatography (silica, P/EtOAc = 20/1 → 15/1 → 10/1) gave 1.06 g 1-bromo-2-alkyl-naphthalene **S31** (2.63 mmol, 79%) as a colourless, viscous oil.

TLC: R_f = 0.52 (P/EtOAc = 4/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3056 (w, sp^2-CH), 2950 (m, sp^3-CH), 2881 (m, sp^3-CH), 1714 (m, C=C), 1325 (m), 1121 (m, C–O–C), 1090 (s, C–O–C), 814 (s, sp^2-CH), 767 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.68 – 1.75 (m, 4 H, H-5'), 2.30 – 2.35 (m, 4 H, H-4'), 3.97 (s, 4 H, H-8'), 4.14 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.82 (s, 2 H, CH_2), 5.48 (t, ^3J = 7.0 Hz, 1 H, H-2'), 7.51 (ddd, ^3J = 8.2 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.63 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.4 Hz, 1 H, H-4), 7.82 (d, ^3J = 8.2 Hz, 1 H, H-5), 8.31 (d, ^3J = 8.5 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 25.6 (t, C-4), 33.7 (t, C-4), 35.5 (t, C-5), 36.1 (t, C-5), 64.5 (t, C-8), 66.5 (t, C-1'), 72.1 (t, CH_2), 108.8 (s, C-6'), 119.2 (d, C-2'), 122.7 (s, C-1), 126.2 (d, C-3), 126.5 (d, C-6), 127.1 (d, C-8), 127.5 (d, C-7), 127.8 (d, C-4*), 128.3 (d, C-5*), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.2 (s, C-2), 142.7 (s, C-3').

* assignment is interconvertible.

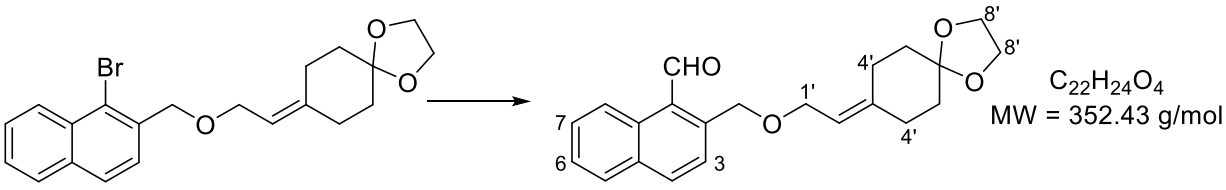
MS (EI, 70 eV): m/z (%) = 404 (1) $[M(^{81}Br)]^+$, 402 (1) $[M(^{79}Br)]^+$, 323 (14), 221 (100) $[C_{13}H_{17}O_3]^+$, 183 (30), 141 (49).

HRMS (EI, 70 eV): calcd for $C_{21}H_{23}O_3{}^{79}Br$ $[M]^+$: 402.0825; found: 402.0815.

calcd for $C_{20}{}^{13}CH_{23}O_3{}^{79}Br$ $[M]^+$: 403.0859; found: 403.0844.

calcd for $C_{21}H_{23}O_3{}^{81}Br$ $[M]^+$: 404.0805; found: 404.0805.

2-{[2-(1,4-Dioxaspiro[4.5]decan-8-ylidene)ethoxy]methyl}-1-naphthaldehyde (7h)



S31 **7h**

Following GP5, 1-bromo-2-alkyl-naphthalene **S31** (641 mg, 1.59 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (829 µL, 2.5 M in *n*-hexane, 1.91 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (611 µL, 580 mg, 7.94 mmol, 5.00 eq.) in tetrahydrofuran (15 mL). After column chromatography (silica, P/EtOAc = 10/1 → 9/1), 429 mg aldehyde **7h** (1.22 mmol, 77%) were obtained as a colourless solid.

M.p.: 43 °C.

TLC: R_f = 0.48 (P/EtOAc = 2/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2951 (m, sp^3-CH), 2882 (m, sp^3-CH), 1683 (s, C=O), 1365 (m), 1080 (s, C–O–C), 824 (s, sp^2-CH), 758 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.68 – 1.74 (m, 4 H, H-5'), 2.29 – 2.34 (m, 4 H, H-4'), 3.97 (s, 4 H, H-8'), 4.13 (d, ^3J = 7.1 Hz, 2 H, H-1'), 4.99 (s, 2 H, CH_2), 5.44 (t, ^3J = 7.1 Hz, 1 H, H-2'), 7.55 (*virt.* t, $^3J \approx {}^3J$ = 7.4 Hz, 1 H, H-6), 7.64 (*virt.* t, $^3J \approx {}^3J$ = 7.4 Hz, 1 H, H-7), 7.68 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.88 (d, ^3J = 8.1 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.89 (d, ^3J = 8.7 Hz, 1 H, H-8), 10.96 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 25.6 (t, C-4), 33.7 (t, C-4), 35.5 (t, C-5), 36.1 (t, C-5), 64.5 (t, C-8), 66.6 (t, C-1'), 69.6 (t, CH_2), 108.8 (s, C-6'), 118.9 (d, C-2'), 124.5 (d, C-8), 126.4 (d, C-3), 126.6 (d, C-6), 128.7 (d, C-5*), 128.8 (m, C-1, C-7*), 131.6 (s, C-8a), 133.4 (s, C-4a), 134.4 (d, C-4), 142.2 (s, C-2), 142.9 (s, C-3'), 193.2 (d, CHO).

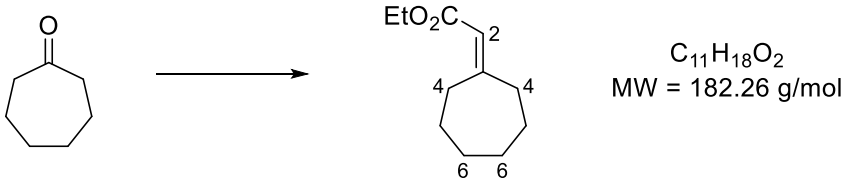
* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 352 (1) $[M]^+$, 185 (73) $[C_{12}H_9O_2]^+$, 169 (100) $[C_{12}H_9O]^+$, 155 (7) $[C_{11}H_7O]^+$, 141 (86) $[C_{11}H_9]^+$, 115 (20).

HRMS (EI, 70 eV): calcd for $C_{22}H_{24}O_4$ $[M]^+$: 352.1669; found: 352.1677.

calcd for $C_{21}{}^{13}CH_{24}O_4$ $[M]^+$: 353.1703; found: 353.1704.

Ethyl 2-cycloheptylideneacetate (S32)



S33 **S32**

Following GP1, ketone **S33** (3.37 g, 30.0 mmol, 1.00 eq.) was converted with triethyl phosphonoacetate (6.84 mL, 7.73 g, 34.5 mmol, 1.15 eq.) and sodium hydride (1.32 g, 60 wt% in paraffin oil, 33.0 mmol, 1.10 eq.) in tetrahydrofuran (100 mL). After stirring the reaction mixture for seven hours at room temperature, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 20/1). 4.25 g of ester **S32** (23.3 mmol, 78%) were isolated as a colourless liquid.

TLC: R_f = 0.64 (P/EtOAc = 20/1) [UV, $KMnO_4$].

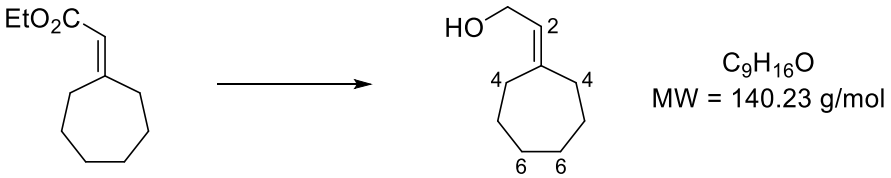
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.27 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2C\mathit{H}_3$), 1.49 – 1.55 (m, 4 H, H-6), 1.58 – 1.76 (m, 4 H, H-5), 2.29 – 2.44 (m, 2 H, H-4), 2.78 – 2.94 (m, 2 H, H-4), 4.12 (q, ^3J = 7.1 Hz, 2 H, $COOC\mathit{H}_2CH_3$), 5.66 (*virt.* quint, $^4J \approx {}^4J$ = 1.3 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.5 (q, $COOCH_2\mathit{C}H_3$), 26.7 (t, C-5), 28.2 (t, C-5), 29.2 (t, C-6), 30.0 (t, C-6), 32.2 (t, C-4), 39.1 (t, C-4), 59.5 (t, $COO\mathit{C}H_2CH_3$), 115.7 (d, C-2), 166.8 (s, C-3*), 166.9 (s, $\mathit{C}OOCH_2CH_3$*).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[17]

2-Cycloheptylideneethan-1-ol (S34)



S32 **S34**

Following GP2, ester **S32** (3.99 g, 21.9 mmol, 1.00 eq.) was converted with di*iso*butylaluminium hydride solution (48.2 mL, 1.0 M in dichloromethane, 48.2 mmol, 2.20 eq.) in dichloromethane (60 mL) at –78 °C. After three hours, the reaction was stopped and 2.94 g of homoallylic alcohol **S34** (21.0 mmol, 96%) were obtained as a colourless oil.

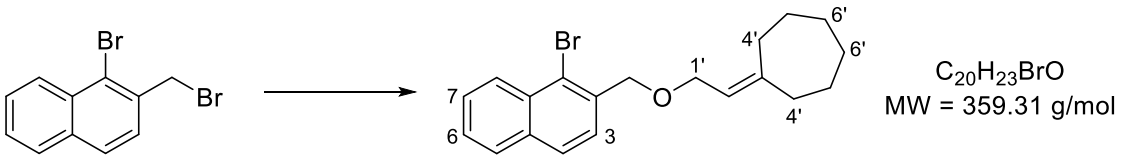
^{1}H NMR (500 MHz, $CDCl_3$, 287 K): δ [ppm] = 1.15 – 1.32 (m, 1 H, OH), 1.46 – 1.53 (m, 4 H, H-6), 1.56 – 1.60 (m, 4 H, H-5), 2.24 (t, ^{3}J = 5.6 Hz, 2 H, H-4), 2.28 (t, ^{3}J = 5.6 Hz, 2 H, H-4), 4.14 (d, ^{3}J = 6.9 Hz, 2 H, H-1), 5.39 (t, ^{3}J = 6.8 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 27.5 (t, C-5), 29.0 (t, C-5*), 29.1 (t, C-6*), 29.9 (t, C-6**), 30.1 (t, C-4**), 37.9 (t, C-4), 59.3 (t, C-1), 123.9 (d, C-2), 145.9 (s, C-3).

*, ** assignment is interconvertible.

The analytical data obtained matched those reported in literature.[17]

1-Bromo-2-[(2-cycloheptylideneethoxy)methyl]naphthalene (S35)



S1 **S35**

Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.75 g, 5.83 mmol, 1.00 eq.) was converted with allylic alcohol **S34** (981 mg, 7.00 mmol, 1.20 eq.) and sodium hydride (303 mg, 60 wt% in paraffin oil, 7.58 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After five hours, the reaction was stopped and purification of the crude product by column chromatography (silica,

P/Et_2O = 100/1) gave 1.61 g 1-bromo-2-alkyl-naphthalene **S35** (4.48 mmol, 77%) as a colourless solid.

M.p.: 39 °C.

TLC: R_f = 0.46 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3057 (w, sp^2-CH), 2920 (s, sp^3-CH), 2850 (m, sp^3-CH), 1689 (w, C=C), 1324 (m), 1099 (m, C–O–C), 812 (s, sp^2-CH), 742 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.50 – 1.65 (m, 4 H, H-6'), 1.55 – 1.65 (m, 4 H, H-5'), 2.27 – 2.31 (m, 4 H, H-4'), 4.14 (d, ^3J = 6.8 Hz, 2 H, H-1'), 4.83 (s, 2 H, CH_2), 5.46 (tt, ^3J = 6.8 Hz, ^4J = 1.3 Hz, 1 H, H-2'), 7.51 (ddd, ^3J = 8.1 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.65 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.5 Hz, 1 H, H-4), 7.82 (*virt.* dt, ^3J = 8.1 Hz, $^4J \approx {}^4J$ = 0.6 Hz, 1 H, H-5), 8.32 (d, ^3J = 8.5 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 27.2 (t, C-5'), 28.9 (t, C-5'*), 29.1 (t, C-6'*), 29.8 (t, C-6'), 30.2 (t, C-4'), 37.8 (t, C-4'), 67.0 (t, C-1'), 72.1 (t, CH_2), 121.1 (d, C-2'), 122.5 (s, C-1), 126.1 (d, C-3), 126.4 (d, C-6), 127.0 (d, C-8), 127.3 (d, C-7), 127.7 (d, C-4**), 128.1 (d, C-5**), 132.2 (s, C-8a), 134.0 (s, C-4a), 136.3 (s, C-2), 146.7 (s, C-3').

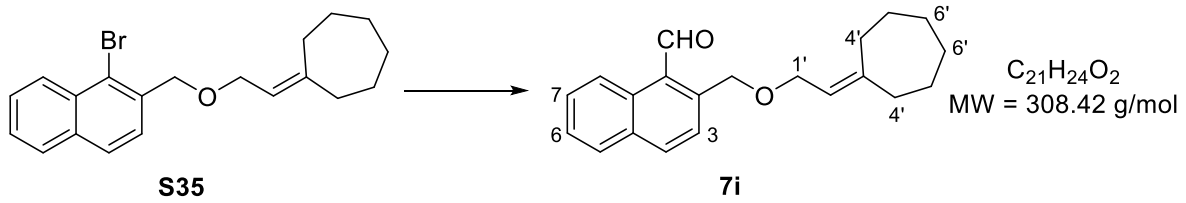
*,** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 360 (2) [M(^{81}Br)]$^+$, 358 (2) [M(^{79}Br)]$^+$, 234 (94), 207 (21) [$C_{10}H_6{}^{81}Br]^+$, 205 (21) [$C_{10}H_6{}^{79}Br]^+$, 157 (22), 126 (89), 105 (100) [$C_8H_9]^+$.

HRMS (EI, 70 eV): calcd for $C_{20}H_{23}O^{79}Br$ [M]$^+$: 358.0927; found: 358.0931.

calcd for $C_{19}{}^{13}CH_{23}O^{79}Br$ [M]$^+$: 359.0960; found: 359.0959.

2-[(2-Cycloheptylideneethoxy)methyl]-1-naphthaldehyde (7i)



S35 **7i**

Following GP5, 1-bromo-2-alkyl-naphthalene **S35** (1.59 g, 4.41 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (2.12 mL, 2.5 M in *n*-hexane, 5.30 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (1.70 mL, 1.61 g, 22.1 mmol, 5.00 eq.) in tetrahydrofuran (25 mL). After column chromatography (silica, P/EtOAc = 25/1), 895 mg aldehyde **7i** (2.90 mmol, 66%) was obtained as a slightly yellowish oil.

TLC: R_f = 0.71 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3056 (w, sp^2-CH), 2921 (s, sp^3-CH), 2852 (m, sp^3-CH), 1683 (s, C=O), 1621 (w, C=C), 1376 (w), 1062 (s, C–O–C), 822 (s, sp^2-CH), 757 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.43 – 1.54 (m, 4 H, H-6'), 1.54 – 1.68 (m, 4 H, H-5'), 2.14 – 2.39 (m, 4 H, H-4'), 4.12 (d, ^3J = 6.8 Hz, 2 H, H-1'), 4.99 (s, 2 H, CH_2), 5.43 (tt, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-2'), 7.54 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.1 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.7 Hz, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.69 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.88 (d, ^3J = 8.1 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.91 (dd, ^3J = 8.7 Hz, ^4J = 1.1 Hz, 1 H, H-8), 10.96 (s, 1 H, CHO).

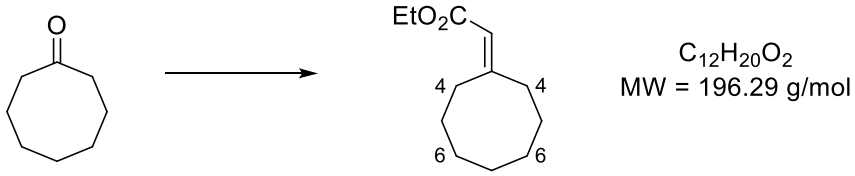
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 27.3 (t, C-5'), 29.0 (t, C-5'*), 29.2 (t, C-6'*), 29.9 (t, C-6'), 30.3 (t, C-4'), 37.9 (t, C-4'), 67.1 (t, C-1'), 69.7 (t, CH_2), 120.9 (d, C-2'), 124.6 (d, C-8), 126.6 (d, C-3), 126.6 (d, C-6), 128.6 (d, C-5**), 128.8 (d, C-7**), 128.8 (s, C-1), 131.6 (s, C-8a), 133.4 (s, C-4a), 134.4 (d, C-4), 142.4 (s, C-2), 147.2 (s, C-3'), 193.3 (d, CHO).

*, ** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 308 (1) $[M]^+$, 185 (100) $[C_{12}H_9O_2]^+$, 170 (94), 168 (64), 155 (12) $[C_{11}H_7O]^+$, 141 (91) $[C_{11}H_9]^+$, 115 (21).

HRMS (EI, 70 eV): calcd for $C_{21}H_{24}O_2$ $[M]^+$: 308.1771; found: 308.1763.

Ethyl 2-cyclooctylideneacetate (S36)



S37 **S36**

Following GP1, ketone **S37** (3.79 g, 30.0 mmol, 1.00 eq.) was converted with triethyl phosphonoacetate (6.84 mL, 7.73 g, 34.5 mmol, 1.15 eq.) and sodium hydride (1.32 g, 60 wt% in paraffin oil, 33.0 mmol, 1.10 eq.) in tetrahydrofuran (100 mL). After stirring the reaction mixture for 18 hours at room temperature, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 20/1). 2.61 g of ester **S36** (13.3 mmol, 44%) were isolated as a colourless liquid.

TLC: R_f = 0.60 (P/EtOAc = 20/1) [UV, $KMnO_4$].

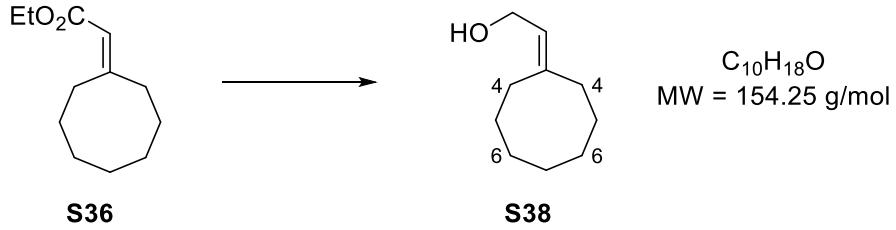
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.27 (t, ^3J = 7.1 Hz, 3 H, $COOCH_2CH_3$), 1.40 – 1.47 (m, 2 H, H-7), 1.47 – 1.59 (m, 4 H, H-6), 1.71 – 1.78 (m, 2 H, H-5), 1.78 – 1.82 (m, 2 H, H-5), 2.24 – 2.36 (m, 2 H, H-4), 2.68 – 2.84 (m, 2 H, H-4), 4.13 (q, ^3J = 7.1 Hz, 2 H, $COOCH_2CH_3$), 5.71 (*virt.* quint, $^4J \approx {}^4J$ = 1.0 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 14.5 (q, $COOCH_2CH_3$), 25.4 (t, C-7*), 25.7 (t, C-5*), 26.6 (t, C-6), 27.8 (t, C-5**), 28.0 (t, C-6**), 30.8 (t, C-4), 38.9 (t, C-4), 59.5 (t, $COOCH_2CH_3$), 115.7 (d, C-2), 166.5 (s, $COOCH_2CH_3$), 168.6 (s, C-3).

*, ** assignment is interconvertible.

The analytical data obtained matched those reported in literature.[13]

2-Cyclooctylideneethan-1-ol (S38)



S36 **S38**

Following GP2, ester **S36** (2.42 g, 12.3 mmol, 1.00 eq.) was converted with di*iso*butylaluminium hydride solution (27.1 mL, 1.0 M in dichloromethane, 27.1 mmol, 2.20 eq.) in dichloromethane (50 mL) at –78 °C. After three hours, the reaction was stopped and 1.77 g of homoallylic alcohol **S38** (11.5 mmol, 93%) were obtained as a colourless oil.

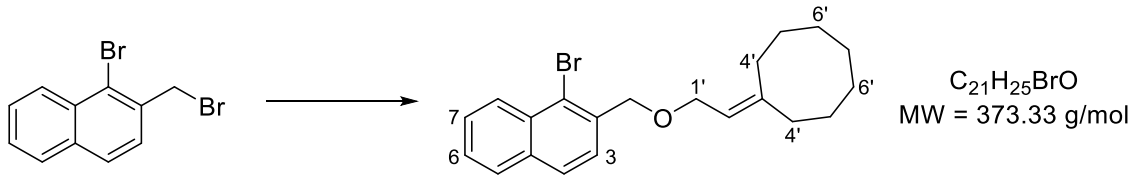
^{1}H NMR (500 MHz, $CDCl_3$, 287 K): δ [ppm] = 1.19 – 1.32 (m, 1 H, OH), 1.47 – 1.53 (m, 6 H, H-6, H-7), 1.57 – 1.62 (m, 2 H, H-5), 1.63 – 1.68 (m, 2 H, H-5), 2.19 (t, ^{3}J = 6.5 Hz, 2 H, H-4), 2.23 (t, ^{3}J = 6.3 Hz, 2 H, H-4), 4.17 (d, ^{3}J = 7.0 Hz, 2 H, H-1), 5.42 (t, ^{3}J = 7.0 Hz, 1 H, H-2).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.0 (t, C-5), 26.1 (t, C-6*), 26.3 (t, C-6*), 27.4 (t, C-7*), 28.2 (t, C-5), 29.2 (t, C-4), 37.8 (t, C-4), 59.5 (t, C-1), 124.0 (d, C-2), 146.1 (s, C-3).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[13]

1-Bromo-2-[(2-cyclooctylideneethoxy)methyl]naphthalene (S39)



S1 **S39**

Following GP4, 1-bromo-2-(bromomethyl)naphthalene (**S1**, 1.75 g, 5.83 mmol, 1.00 eq.) was converted with allylic alcohol **S38** (1.08 g, 7.00 mmol, 1.20 eq.) and sodium hydride (303 mg, 60 wt% in paraffin oil, 7.58 mmol, 1.30 eq.) in tetrahydrofuran (20 mL). After five hours, the

reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 100/1) gave 1.40 g 1-bromo-2-alkyl-naphthalene **S39** (3.75 mmol, 64%) as a colourless solid.

M.p.: 41 °C.

TLC: R_f = 0.49 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3057 (w, sp^2-CH), 2920 (s, sp^3-CH), 2852 (m, sp^3-CH), 1690 (m, C=C), 1324 (m), 1097 (m, C–O–C), 812 (s, sp^2-CH), 742 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.46 – 1.54 (m, 6 H, H-6', H-7'), 1.57 – 1.63 (m, 2 H, H-5'), 1.65 – 1.70 (m, 2 H, H-5'), 2.20 – 2.26 (m, 4 H, H-4'), 4.17 (d, ^3J = 6.7 Hz, 2 H, H-1'), 4.83 (s, 2 H, CH_2), 5.50 (tt, ^3J = 6.7 Hz, ^4J = 1.1 Hz, 1 H, H-2'), 7.51 (ddd, ^3J = 8.0 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.5 Hz, ^3J = 6.9 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.65 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.82 (d, ^3J = 8.4 Hz, 1 H, H-4), 7.82 (*virt.* dt, ^3J = 8.0 Hz, $^4J \approx {}^4J$ = 0.5 Hz, 1 H, H-5), 8.32 (dd, ^3J = 8.5 Hz, ^4J = 1.2 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.1 (t, C-5), 26.2 (t, C-6*), 26.4 (t, C-6*), 27.4 (t, C-7*), 27.8 (t, C-5), 29.4 (t, C-4), 37.8 (t, C-4), 67.3 (t, C-1'), 72.3 (t, CH_2), 121.5 (d, C-2'), 122.5 (s, C-1), 126.2 (d, C-3), 126.5 (d, C-6), 127.1 (d, C-8), 127.4 (d, C-7), 127.8 (d, C-4**), 128.3 (d, C-5**), 132.3 (s, C-8a), 134.1 (s, C-4a), 136.4 (s, C-2), 146.9 (s, C-3').

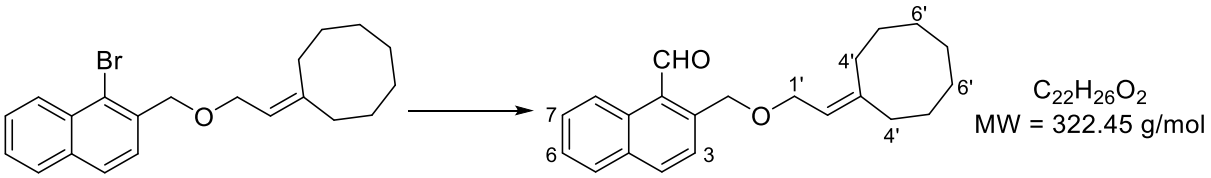
*,** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 374 (1) $[M(^{81}Br)]^+$, 372 (1) $[M(^{79}Br)]^+$, 234 (50), 207 (12) $[C_{10}H_6{}^{81}Br]^+$, 205 (12) $[C_{10}H_6{}^{79}Br]^+$, 136 (48), 126 (53), 105 (100) $[C_8H_9]^+$.

HRMS (EI, 70 eV): calcd for $C_{21}H_{25}O^{79}Br$ $[M]^+$: 372.1083; found: 372.1084.

calcd for $C_{20}{}^{13}CH_{25}O^{79}Br$ $[M]^+$: 373.1117; found: 373.1116.

2-[(2-Cyclooctylideneethoxy)methyl]-1-naphthaldehyde (7j)



S39 **7j**

Following GP5, 1-bromo-2-alkyl-naphthalene **S39** (951 mg, 2.55 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (1.22 mL, 2.5 M in *n*-hexane, 3.06 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (980 µL, 931 mg, 12.7 mmol, 5.00 eq.) in tetrahydrofuran (25 mL). After column chromatography (silica, P/EtOAc = 25/1), 543 mg aldehyde **7j** (1.68 mmol, 66%) was obtained as a colourless solid.

M.p.: 28 °C.

TLC: R_f = 0.67 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3055 (w, sp^2-CH), 2921 (m, sp^3-CH), 2853 (m, sp^3-CH), 1683 (s, C=O), 1621 (w, C=C), 1336 (w), 1061 (s, C–O–C), 821 (s, sp^2-CH), 756 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.47 – 1.52 (m, 6 H, H-6', H-7'), 1.56 – 1.61 (m, 2 H, H-5'), 1.64 – 1.69 (m, 2 H, H-5'), 2.21 – 2.24 (m, 4 H, H-4'), 4.15 (d, ^3J = 6.8 Hz, 2 H, H-1'), 5.00 (s, 2 H, CH_2), 5.46 (t, ^3J = 6.8 Hz, 1 H, H-2'), 7.54 (ddd, ^3J = 8.0 Hz, ^3J = 6.8 Hz, ^4J = 1.2 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.6 Hz, ^3J = 6.8 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.70 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.88 (d, ^3J = 8.0 Hz, 1 H, H-5), 8.05 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.90 (dd, ^3J = 8.6 Hz, ^4J = 1.2 Hz, 1 H, H-8), 10.96 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 26.0 (t, C-5'*), 26.1 (t, C-6'*), 26.3 (t, C-6'*), 27.4 (t, C-7'*), 27.9 (t, C-5'), 29.4 (t, C-4'), 37.7 (t, C-4'), 67.3 (t, C-1'), 69.7 (t, CH_2), 121.2 (d, C-2'), 124.5 (d, C-8), 126.5 (d, C-3**), 126.5 (d, C-6**), 128.6 (d, C-5***), 128.7 (s, C-1), 128.7 (d, C-7***), 131.6 (s, C-8a), 133.3 (s, C-4a), 134.4 (d, C-4), 142.4 (s, C-2), 147.2 (s, C-3'), 193.3 (d, CHO).

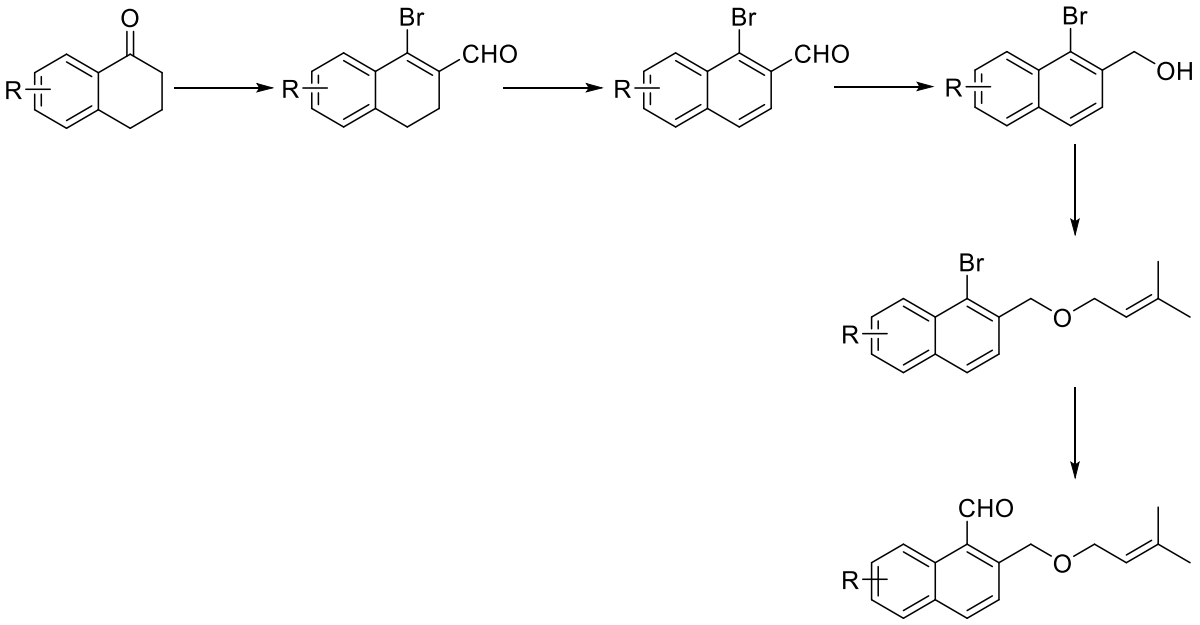
*, **, *** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 322 (1) $[M]^+$, 185 (100) $[C_{12}H_9O_2]^+$, 170 (100) $[C_{12}H_{10}O]^+$, 155 (36) $[C_{11}H_7O]^+$, 141 (88) $[C_{11}H_9]^+$, 127 (27), 115 (21).

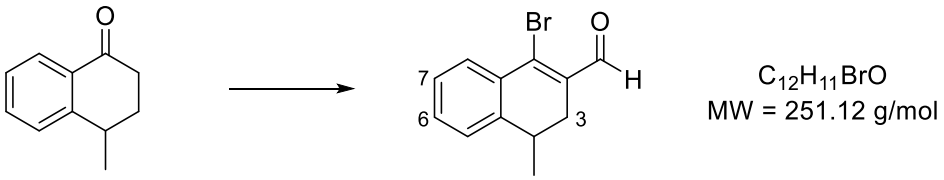
HRMS (EI, 70 eV): calcd for $C_{22}H_{26}O_2$ $[M]^+$: 322.1927; found: 322.1933.

3.3 Synthesis of irradiation precursors with variation on naphthalene core

Scheme for the synthesis of substituted 2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehydes



1-Bromo-4-methyl-3,4-dihydronaphthalene-2-carbaldehyde (S40)



S41 **S40**

Following GP6, a solution of 4-methyl-3,4-dihydronaphthalen-1(2*H*)-one (**S41**, 5.03 g, 31.4 mmol, 1.00 eq.) in dichloromethane (75 mL) was added to a reaction mixture of PBr_3 (7.45 mL, 21.2 g, 78.4 mmol, 2.50 eq.) and *N*,*N*-dimethylformamide (7.29 mL, 6.88 g, 94.1 mmol, 3.00 eq.) in dichloromethane (25 mL). After a reaction time of 14 hours, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 50/1), yielding 3.15 g aldehyde **S40** (12.5 mmol, 40%) as a yellowish oil.

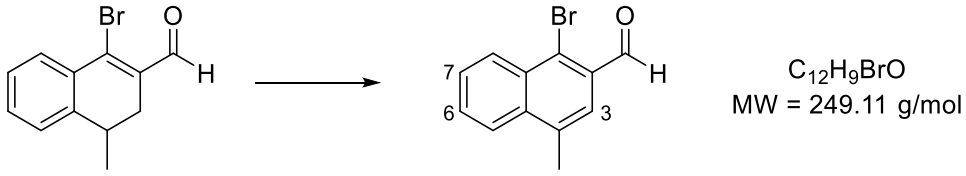
TLC: R_f = 0.83 (P/EtOAc = 10/1) [UV, $KMnO_4$].

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.23 (d, ^3J = 7.0 Hz, 3 H, C-4-CH_3), 2.53 (dd, ^2J = 16.5 Hz, ^3J = 7.3 Hz, 1 H, *H*H-3), 2.68 (dd, ^2J = 16.5 Hz, ^3J = 6.3 Hz, 1 H, H*H*-3), 3.00 (*virt.* sext, $^3J \approx {}^3J \approx {}^3J$ = 6.9 Hz, 1 H, H-4), 7.24 (*virt.* dt, ^3J = 7.5 Hz, $^4J \approx {}^4J$ = 1.1 Hz, 1 H, H-5), 7.34 (*virt.* td, $^3J \approx {}^3J$ = 7.6 Hz, ^4J = 1.4 Hz, 1 H, H-7), 7.40 (*virt.* td, $^3J \approx {}^3J$ = 7.5 Hz, ^4J = 1.4 Hz, 1 H, H-6), 7.92 (dd, ^3J = 7.8 Hz, ^4J = 1.4 Hz, 1 H, H-8), 10.28 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 19.6 (q, C-4-*C*H_3), 30.3 (t, C-3), 31.4 (d, C-4), 126.3 (d, C-5), 127.0 (d, C-6), 129.0 (d, C-8), 131.8 (d, C-7), 132.1 (s, C-8a), 133.2 (s, C-2), 138.4 (s, C-1), 144.0 (s, C-4a), 193.5 (d, CHO).

The analytical data obtained matched those reported in literature.[18]

1-Bromo-4-methyl-2-naphthaldehyde (S42)



S40 **S42**

Following GP7, 3,4-dihydronaphthalene-2-carbaldehyde **S40** (3.14 g, 12.5 mmol, 1.00 eq.) in toluene (100 mL) was oxidized by the addition of DDQ (7.10 g, 31.3 mmol, 2.50 eq.) in one portion. After 16 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 75/1 → 60/1 → 30/1) gave 2.23 g 1-bromo-2-naphthaldehyde **S42** (8.98 mmol, 72%) as an off-white solid.

M.p.: 86 °C.

TLC: R_f = 0.78 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

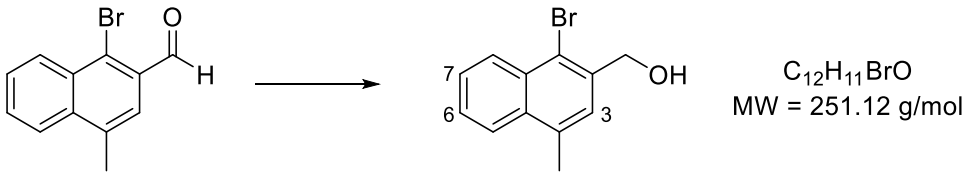
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.69 (d, ^4J = 1.0 Hz, 3 H, C-4-CH_3), 7.67 – 7.74 (m, 2 H, H-6, H-7), 7.78 (s, 1 H, H-3), 8.02 (dd, ^3J = 7.9 Hz, ^4J = 1.5 Hz, 1 H, H-5), 8.55 (dd, ^3J = 8.1 Hz, ^4J = 1.5 Hz, 1 H, H-8), 10.64 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 19.5 (q, C-4-*C*H_3), 124.6 (d, C-3), 125.0 (d, C-5), 128.0 (d, C-6*), 128.9 (d, C-8*), 129.5 (s, C-8a), 129.8 (d, C-7*), 130.9 (s, C-2), 132.1 (s, C-4a), 135.1 (s, C-1), 136.8 (s, C-4), 193.3 (d, CHO).

* assignment is interconvertible.

The compound has been previously reported in the literature.[19]

(1-Bromo-4-methylnaphthalen-2-yl)methanol (S43)



S42 **S43**

Following GP8, 1-bromo-2-naphthaldehyde **S42** (2.21 g, 8.88 mmol, 1.00 eq.) was converted with $NaBH_4$ (504 mg, 13.3 mmol, 1.50 eq.) in ethanol (75 mL). After two hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/EtOAc = 6/1) gave 1.57 g (1-bromonaphthalen-2-yl)methanol **S43** (6.25 mmol, 70%) as a colourless solid.

M.p.: 106 °C.

TLC: R_f = 0.48 (P/EtOAc = 4/1) [UV, $KMnO_4$].

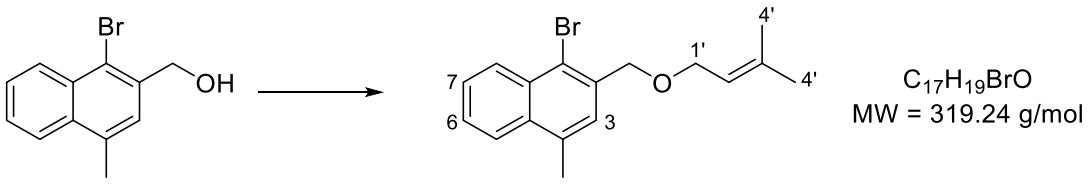
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.06 (t, ^{3}J = 5.9 Hz, 1 H, OH), 2.69 (d, ^{4}J = 1.0 Hz, 3 H, C-4-CH_3), 4.96 (d, ^{3}J = 5.9 Hz, 2 H, CH_2), 7.48 (s, 1 H, H-3), 7.57 (ddd, ^{3}J = 8.2 Hz, ^{3}J = 6.8 Hz, ^{4}J = 1.5 Hz, 1 H, H-6), 7.61 (ddd, ^{3}J = 8.4 Hz, ^{3}J = 6.8 Hz, ^{4}J = 1.5 Hz, 1 H, H-7), 7.98 – 8.00 (m, 1 H, H-5), 8.34 – 8.36 (m, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 19.4 (q, C-4-*C*H_3), 66.0 (t, C-1-*C*H_2), 120.4 (s, C-1), 124.5 (d, C-5), 126.4 (d, C-6), 127.0 (d, C-3*), 127.2 (d, C-7*), 127.6 (d, C-8), 132.1 (s, C-8a), 133.3 (s, C-4a), 134.6 (s, C-4), 137.2 (s, C-2).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[19]

1-Bromo-4-methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S44)



S43 **S44**

Following GP9, (1-bromonaphthalen-2-yl)methanol **S43** (500 mg, 1.99 mmol, 1.00 eq.) was converted with 3,3-dimethylallylbromide (593 mg, 3.98 mmol, 2.00 eq.) and sodium hydride (103 mg, 60 wt% in paraffin oil, 2.59 mmol, 1.30 eq.) in tetrahydrofuran (10 mL). After 15 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 50/1) gave 596 mg 1-bromo-2-alkyl-naphthalene **S44** (1.87 mmol, 94%) as a colourless oil.

TLC: R_f = 0.44 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3070 (w, sp^2-CH), 2972 (w, sp^3-CH), 2866 (w, sp^3-CH), 1686 (m, C=C), 1339 (m), 1090 (s, C–O–C), 885 (m, sp^2-CH), 754 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.70 (s, 3 H, H-4'), 1.79 (s, 3 H, H-4'), 2.68 (d, ^4J = 1.0 Hz, 3 H, C-4-CH_3), 4.12 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.80 (s, 2 H, CH_2), 5.47 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.4 Hz, 1 H, H-2'), 7.49 (s, 1 H, H-3), 7.55 (ddd, ^3J = 8.1 Hz, ^3J = 6.8 Hz, ^4J = 1.5 Hz, 1 H, H-6), 7.59 (ddd, ^3J = 8.4 Hz, ^3J = 6.8 Hz, ^4J = 1.5 Hz, 1 H, H-7), 7.96 – 7.98 (m, 1 H, H-5), 8.35 – 8.37 (m, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 19.5 (q, C-4-*C*H_3), 26.0 (q, C-4'), 67.2 (t, C-1'), 72.2 (t, CH_2), 120.6 (s, C-1), 121.0 (d, C-2'), 124.6 (d, C-5), 126.4 (d, C-6), 127.1 (d, C-3, C-7), 127.8 (d, C-8), 132.2 (s, C-8a), 133.4 (s, C-4a), 134.2 (s, C-4), 135.8 (s, C-2), 137.8 (s, C-3').

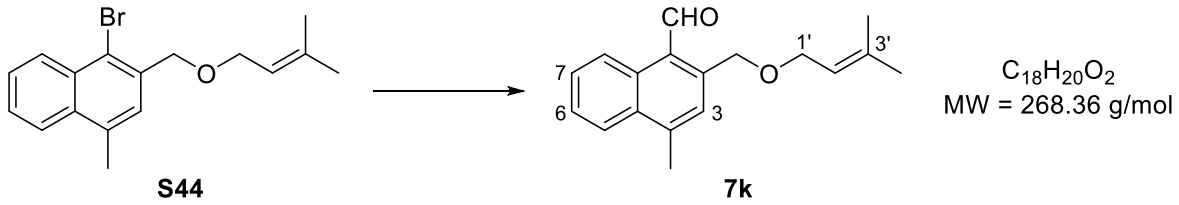
MS (EI, 70 eV): m/z (%) = 320 (3) $[M(^{81}Br)]^+$, 318 (3) $[M(^{79}Br)]^+$, 235 (16), 221 (21), 155 (23), 139 (100) $[C_{11}H_7]^+$, 115 (29).

HRMS (EI, 70 eV): calcd for $C_{17}H_{19}O^{79}Br$ $[M]^+$: 318.0614; found: 318.0612.

calcd for $C_{16}{}^{13}CH_{19}O^{79}Br$ $[M]^+$: 319.0647; found: 319.0642.

calcd for $C_{17}H_{19}O^{81}Br$ $[M]^+$: 320.0593; found: 320.0595.

4-Methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7k)



S44 **7k**

Following GP5, 1-bromo-2-alkyl-naphthalene **S44** (491 mg, 1.54 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (736 µL, 2.5 M in *n*-hexane, 1.84 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (591 µL, 562 mg, 7.68 mmol, 5.00 eq.) in tetrahydrofuran (15 mL). After column chromatography (silica, P/EtOAc = 20/1), 289 mg aldehyde **7k** (1.08 mmol, 70%) was obtained as a yellowish oil.

TLC: R_f = 0.54 (P/EtOAc = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3070 (w, sp^2-CH), 2972 (m, sp^3-CH), 2864 (m, sp^3-CH), 1678 (s, C=O), 1593 (m, C=C), 1377 (w), 1066 (s, C–O–C), 823 (w, sp^2-CH), 755 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.69 (s, 3 H, H-4'), 1.78 (s, 3 H, H-4'), 2.72 (d, ^4J = 0.9 Hz, 3 H, C4-CH_3), 4.11 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.96 (s, 2 H, CH_2), 5.44 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.3 Hz, 1 H, H-2'), 7.56 (s, 1 H, H-3), 7.58 (ddd, ^3J = 8.3 Hz, ^3J = 6.9 Hz, ^4J = 1.4 Hz, 1 H, H-6), 7.64 (ddd, ^3J = 8.6 Hz, ^3J = 6.9 Hz, ^4J = 1.2 Hz, 1 H, H-7), 7.96 (dd, ^3J = 8.3 Hz, ^4J = 1.2 Hz, 1 H, H-5), 8.97 (d, ^3J = 8.6 Hz, 1 H, H-8), 10.93 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 20.5 (q, C-4-*C*H_3), 26.0 (q, C-4'), 67.3 (t, C-1'), 69.5 (t, CH_2), 120.8 (d, C-2'), 124.6 (d, C-5), 125.1 (d, C-8), 126.4 (d, C-6),

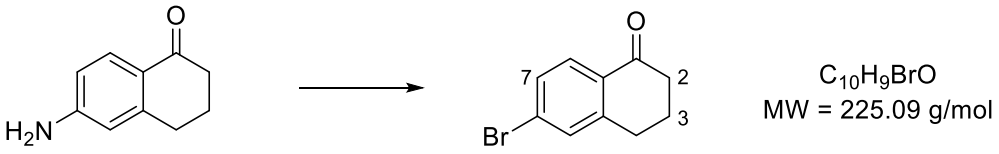
127.2 (s, C-1), 127.6 (d, C-3), 128.4 (d, C-7), 131.8 (s, C-8a), 132.4 (s, C-4a), 138.1 (s, C-3'), 142.0 (s, C-4), 142.2 (s, C-2), 193.0 (d, CHO).

MS (EI, 70 eV): m/z (%) = 268 (2) $[M]^+$, 199 (100) $[C_{13}H_{11}O_2]^+$, 182 (81) $[C_{13}H_{10}O]^+$, 169 (51) $[C_{12}H_{10}O]^+$, 155 (56) $[C_{11}H_7O]^+$, 141 (34) $[C_{11}H_9]^+$, 128 (31), 115 (25).

HRMS (EI, 70 eV): calcd for $C_{18}H_{20}O_2$ $[M]^+$: 268.1458; found: 268.1456.

calcd for $C_{17}{}^{13}CH_{20}O_2$ $[M]^+$: 269.1491; found: 269.1487.

6-Bromo-3,4-dihydronaphthalen-1(2*H*)-one (S45)



S46 **S45**

A solution of sodium nitrate (5.02 g, 72.8 mmol, 1.20 eq.) in water (30 mL) was added dropwise at –5 °C to a solution of 6-amino-3,4-dihydronaphthalen-1(2*H*)-one (**S46**, 9.77 g, 60.6 mmol, 1.00 eq.) in a mixture of hydrobromic acid solution (75 mL, 47% aqueous solution) and water (75 mL). After 30 minutes, a solution of copper(I) bromide (10.4 g, 72.8 mmol, 1.20 eq.) in hydrobromic acid solution (30 mL, 47% aqueous solution) was transferred to the stirred suspension at –5 °C. The resulting mixture was allowed to warm to room temperature and stirred for another one hour. The reaction mixture was extracted with EtOAc (3 × 50 mL) and the combined organic extracts were washed with brine (75 mL). After drying the organic extracts over anhydrous $MgSO_4$ and filtration, the solvent was removed under reduced pressure. Column chromatography (silica, P/EtOAc = 20/1) gave 8.50 g bromide **S45** (37.8 mmol, 62%) as a yellow oil.

TLC: R_f = 0.43 (P/EtOAc = 10/1) [UV, $KMnO_4$].

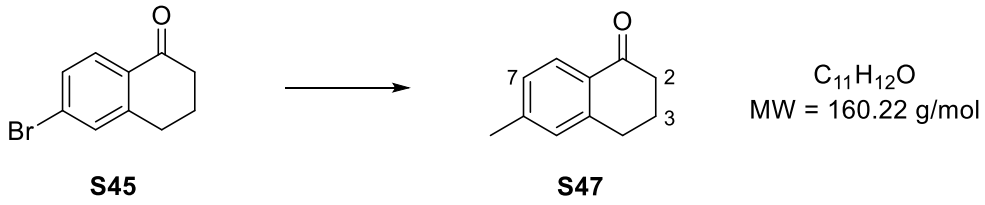
^{1}H NMR (300 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.09 – 2.18 (m, 2 H, H-3), 2.62 – 2.67 (m, 2 H, H-2), 2.94 (t, ^3J = 6.1 Hz, 2 H, H-4), 7.42 – 7.46 (m, 2 H, H-5, H-7), 7.89 (d, ^3J = 8.8 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 23.2 (t, C-3), 29.6 (t, C-4), 39.1 (t, C-2), 128.7 (s, C-6*), 129.1 (d, C-8), 130.3 (d, C-7**), 131.5 (s, C-8a*), 131.8 (d, C-5**), 146.3 (s, C-4a), 197.6 (s, C-1).

*, ** assignment is interconvertible.

The analytical data obtained matched those reported in literature.[20]

6-Methyl-3,4-dihydronaphthalen-1(2*H*)-one (S47)



S45 **S47**

A solution of bromide **S45** (4.25 g, 18.9 mmol, 1.00 eq.), potassium phosphate (16.0 g, 75.5 mmol, 4.00 eq.), methyl boronic acid (1.70 g, 28.3 mmol, 1.50 eq.), triphenylphosphine (495 mg, 1.89 mmol, 10 mol%) and palladium(II) acetate (212 mg, 944 µmol, 5 mol%) in tetrahydrofuran (50 mL) was stirred at reflux for 24 hours. After cooling to room temperature, the mixture was filtered over Celite, the residue was washed with Et_2O (50 mL) and the solvent was evaporated under reduced pressure. Column chromatography (silica, P/EtOAc = 25/1) gave 2.12 g methyl-substituted tetralone **S47** (13.2 mmol, 70%) as a yellowish oil.

TLC: R_f = 0.48 (P/EtOAc = 10/1) [UV, $KMnO_4$].

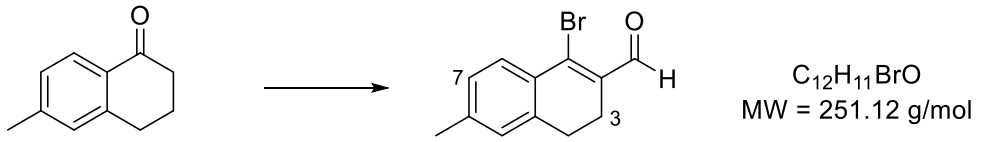
^{1}H NMR (300 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.08 – 2.16 (m, 2 H, H-3), 2.37 (s, 3 H, C-6-CH_3), 2.61 – 2.65 (m, 2 H, H-2), 2.92 (t, ^3J = 6.1 Hz, 2 H, H-4), 7.06 (s, 1 H, H-5), 7.11 (dd, ^3J = 8.0 Hz, ^4J = 1.3 Hz, 1 H, H-7), 7.93 (d, ^3J = 8.0 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.8 (q, C-6-*C*H_3), 23.5 (t, C-3), 29.8 (t, C-4), 39.2 (t, C-2), 127.4 (d, C-8), 127.8 (d, C-7), 129.3 (d, C-5), 130.5 (s, C-8a), 144.4 (s, C-4a*), 144.7 (s, C-6*), 198.4 (s, C-1).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[21]

1-Bromo-6-methyl-3,4-dihydronaphthalene-2-carbaldehyde (S48)



S47 **S48**

Following GP6, a solution of 6-methyl-3,4-dihydronaphthalen-1(2*H*)-one (**S47**, 2.08 g, 13.0 mmol, 1.00 eq.) in dichloromethane (50 mL) was added to a reaction mixture of PBr_3 (3.08 mL, 8.79 g, 32.5 mmol, 2.50 eq.) and *N*,*N*-dimethylformamide (3.02 mL, 2.85 g, 39.0 mmol, 3.00 eq.) in dichloromethane (25 mL). After a reaction time of 18 hours, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 50/1), yielding 1.97 g aldehyde **S48** (7.85 mmol, 60%) as an off-white solid.

M.p.: 54 °C.

TLC: R_f = 0.73 (P/EtOAc = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3009 (w, sp^2-CH), 2947 (w, sp^3-CH), 2853 (m, sp^3-CH), 1664 (s, C=O), 1585 (m, C=C), 1552 (s, C=C), 1256 (s), 819 (m, sp^2-CH), 704 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.38 (s, 3 H, C-6-CH_3), 2.59 – 2.63 (m, 2 H, H-3), 2.78 – 2.83 (m, 2 H, H-4), 7.01 (d, ^4J = 1.8 Hz, 1 H, H-5), 7.14 (dd, ^3J = 8.0 Hz, ^4J = 1.8 Hz, 1 H, H-7), 7.77 (d, ^3J = 8.0 Hz, 1 H, H-8), 10.24 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.6 (q, C-6-*C*H_3), 23.1 (t, C-3), 27.4 (t, C-4), 128.0 (d, C-7), 128.6 (d, C-5), 129.0 (d, C-8), 130.6 (s, C-8a), 133.7 (s, C-2), 139.2 (s, C-1*), 139.5 (s, C-4a*), 142.3 (s, C-6), 193.4 (d, CHO).

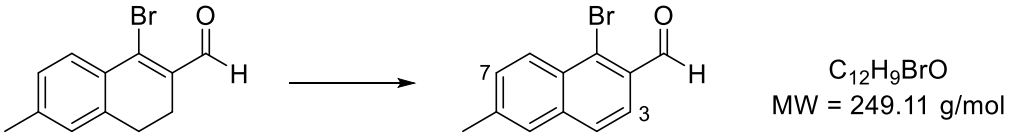
* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 252 (40) [M(^{81}Br)]$^+$, 240 (24), 142 (82), 128 (100) [$C_{10}H_8$]$^+$, 115 (30).

HRMS (EI, 70 eV): calcd for $C_{12}H_{11}O^{81}Br$ [M]$^+$: 251.9967; found: 251.9966.

HRMS (ESI): calcd for $C_{12}H_{12}O^{79}Br$ [M+H]$^+$: 251.0066; found: 251.0071.

1-Bromo-6-methyl-2-naphthaldehyde (S49)



S48 **S49**

Following GP7, 3,4-dihydronaphthalene-2-carbaldehyde **S48** (1.97 g, 7.84 mmol, 1.00 eq.) in toluene (75 mL) was oxidized by the addition of DDQ (4.45 g, 19.6 mmol, 2.50 eq.) in one portion. After 24 hours, an additional portion of DDQ (890 mg, 3.92 mmol, 0.50 eq.) was added. The reaction was stopped after 48 hours and purification of the crude product by column chromatography (silica, P/Et_2O = 75/1 → 50/1 → 30/1) gave 1.21 g 1-bromo-2-naphthaldehyde **S49** (4.86 mmol, 62%) as a yellowish solid.

M.p.: 83 °C.

TLC: R_f = 0.55 (P/Et_2O = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3063 (w, sp^2-CH), 2920 (w, sp^3-CH), 2861 (m, sp^3-CH), 1680 (s, C=O), 1599 (m, C=C), 1554 (w, C=C), 1219 (m), 822 (m, sp^2-CH), 722 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.57 (s, 3 H, C-6-CH_3), 7.51 (dd, ^3J = 8.7 Hz, ^4J = 1.6 Hz, 1 H, H-7), 7.65 (dq, ^4J = 1.6 Hz, ^4J = 0.8 Hz, 1 H, H-5), 7.76 (d, ^3J = 8.5 Hz, 1 H, H-4), 7.90 (d, ^3J = 8.5 Hz, 1 H, H-3), 8.39 (d, ^3J = 8.7 Hz, 1 H, H-8), 10.64 (d, ^4J = 0.9 Hz, 1 H, CHO).

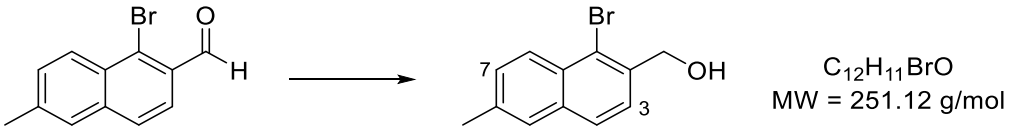
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.9 (q, C-6-*C*H_3), 124.3 (d, C-3), 127.7 (d, C-4*), 127.7 (d, C-5*), 128.1 (d, C-8), 130.5 (s, C-8a), 130.6 (d, C-7), 130.7 (s, C-2), 131.4 (s, C-4a), 137.6 (s, C-1), 140.4 (s, C-6), 193.0 (d, CHO).

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 250 (96) $[M(^{81}Br)]^+$, 249 (100) $[C_{12}H_8{}^{81}BrO]^+$, 248 (98) $[M(^{79}Br)]^+$, 247 (90) $[C_{12}H_8{}^{79}BrO]^+$, 221 (24) $[C_{11}H_8{}^{81}Br]^+$, 219 (25) $[C_{11}H_8{}^{79}Br]^+$, 139 (76) $[C_{11}H_7]^+$, 115 (19).

HRMS (ESI): calcd for $C_{12}H_{10}O^{79}Br$ $[M+H]^+$: 248.9915; found: 248.9915.

(1-Bromo-6-methylnaphthalen-2-yl)methanol (S50)



S49 **S50**

Following GP8, 1-bromo-2-naphthaldehyde **S49** (1.21 g, 4.86 mmol, 1.00 eq.) was converted with $NaBH_4$ (276 mg, 7.29 mmol, 1.50 eq.) in ethanol (50 mL). After two hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/EtOAc = 6/1) gave 696 mg (1-bromonaphthalen-2-yl)methanol **S50** (2.77 mmol, 57%) as a colourless solid.

M.p.: 101 °C.

TLC: R_f = 0.51 (P/EtOAc = 4/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3273 (s, O–H), 2981 (m, sp^3-CH), 2916 (m, sp^3-CH), 1495 (m), 1385 (m), 1064 (s), 808 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.07 (*br* s, ^3J = 4.1 Hz, 1 H, OH), 2.53 (s, 3 H, C-6-CH_3), 4.97 (s, 2 H, CH_2), 7.43 (dd, ^3J = 8.8 Hz, ^4J = 1.8 Hz, 1 H, H-7), 7.57 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.60 (s, 1 H, H-5), 7.74 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.20 (d, ^3J = 8.8 Hz, 1 H, H-8).

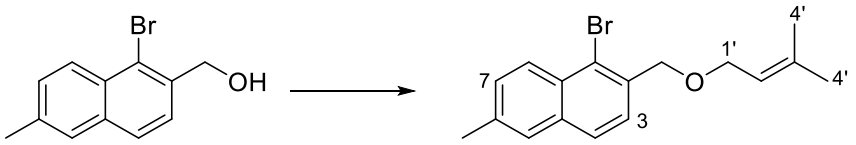
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.6 (q, C-6-*C*H_3), 66.1 (t, C-1-*C*H_2), 122.6 (s, C-1), 126.3 (d, C-3), 126.9 (d, C-4*), 127.2 (d, C-5*), 127.5 (d, C-8*), 129.9 (d, C-7), 130.6 (s, C-8a), 134.4 (s, C-4a), 136.6 (s, C-2**), 136.9 (s, C-6**).

*, ** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 252 (55) $[M(^{81}Br)]^+$, 198 (85), 143 (87), 128 (100) $[C_{10}H_8]^+$, 105 (98) $[C_8H_9]^+$, 91 (57).

HRMS (EI, 70 eV): calcd for $C_{12}H_{11}O^{81}Br$ $[M]^+$: 251.9967; found: 251.9972.

1-Bromo-6-methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S51)



S50 **S51**

Following GP9, (1-bromonaphthalen-2-yl)methanol **S50** (330 mg, 1.31 mmol, 1.00 eq.) was converted with 3,3-dimethylallylbromide (392 mg, 2.63 mmol, 2.00 eq.) and sodium hydride (68.3 mg, 60 wt% in paraffin oil, 1.71 mmol, 1.30 eq.) in tetrahydrofuran (10 mL). After 17.5 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 50/1) gave 336 mg 1-bromo-2-alkyl-naphthalene **S51** (1.05 mmol, 80%) as a yellowish oil.

TLC: R_f = 0.41 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2972 (w, sp^3-CH), 2920 (m, sp^3-CH), 2856 (w, sp^3-CH), 1685 (m, C=C), 1324 (m), 1092 (s, C–O–C), 814 (s, sp^2-CH), 721 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.69 (s, 3 H, H-4'), 1.78 (s, 3 H, H-4'), 2.53 (d, ^4J = 0.9 Hz, 3 H, C-6-CH_3), 4.11 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.80 (s, 2 H, CH_2), 5.46 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.3 Hz, 1 H, H-2'), 7.41 (dd, ^3J = 8.7 Hz, ^4J = 1.8 Hz, 1 H, H-7), 7.59 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.59 (s, 1 H, H-5), 7.72 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.20 (d, ^3J = 8.7 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 21.5 (q, C-6-*C*H_3), 26.0 (q, C-4'), 67.2 (t, C-1'), 72.2 (t, CH_2), 121.0 (d, C-2'), 122.7 (s, C-1), 126.4 (d, C-3*), 127.0 (d, C-4*), 127.1 (d, C-5*), 127.2 (d, C-8*), 129.7 (d, C-7), 130.6 (s, C-8a), 134.3 (s, C-4a), 135.3 (s, C-2), 136.3 (s, C-6), 137.8 (s, C-3').

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 320 (11) [M(^{81}Br)]$^+$, 318 (11) [M(^{79}Br)]$^+$, 235 (75), 221 (5), 155 (100) [$C_{12}H_{11}$]$^+$, 115 (5).

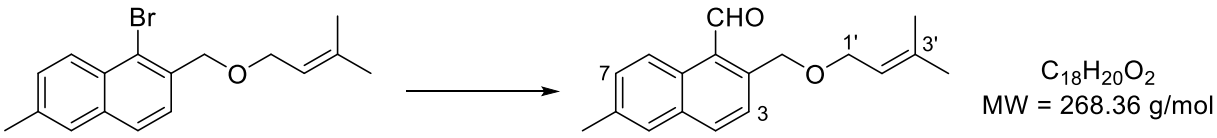
HRMS (EI, 70 eV): calcd for $C_{17}H_{19}O^{79}Br$ $[M]^+$: 318.0614; found: 318.0602.

calcd for $C_{16}{}^{13}CH_{19}O^{79}Br$ $[M]^+$: 319.0647; found: 319.0637.

calcd for $C_{17}H_{19}O^{81}Br$ $[M]^+$: 320.0593; found: 320.0586.

calcd for $C_{16}{}^{13}CH_{19}O^{81}Br$ $[M]^+$: 321.0627; found: 321.0624.

6-Methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7l)



S51 **7l**

Following GP5, 1-bromo-2-alkyl-naphthalene **S51** (298 mg, 933 µmol, 1.00 eq.) was converted with *n*-butyllithium solution (448 µL, 2.5 M in *n*-hexane, 1.12 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (359 µL, 341 mg, 4,66 mmol, 5.00 eq.) in tetrahydrofuran (15 mL). After column chromatography (silica, P/EtOAc = 25/1), 162 mg aldehyde **7l** (604 µmol, 65%) was obtained as a colourless solid.

M.p.: 33 °C.

TLC: R_f = 0.52 (P/EtOAc = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2972 (w, sp^3-CH), 2915 (w, sp^3-CH), 1682 (s, C=O), 1378 (w), 1064 (s, C–O–C), 825 (m, sp^2-CH), 725 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.68 (s, 3 H, H-4'), 1.77 (s, 3 H, H-4'), 2.52 (s, 3 H, C6-CH_3), 4.10 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.96 (s, 2 H, CH_2), 5.42 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.4 Hz, 1 H, H-2'), 7.47 (dd, ^3J = 8.8 Hz, ^4J = 1.9 Hz, 1 H, H-7), 7.63 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.64 (s, 1 H, H-5), 7.96 (d, ^3J = 8.5 Hz, 1 H, H-4), 8.81 (d, ^3J = 8.8 Hz, 1 H, H-8), 10.93 (s, 1 H, CHO).

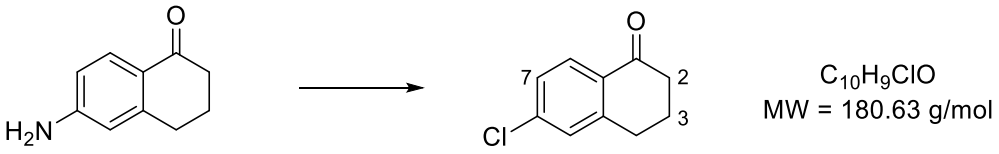
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 21.6 (q, C-6-*C*H_3), 26.0 (q, C-4'), 67.3 (t, C-1'), 69.6 (t, CH_2), 120.7 (d, C-2'), 124.5 (d, C-8), 126.7 (d, C-3), 127.6 (d, C-5),

128.7 (s, C-1), 129.8 (s, C-8a), 131.1 (d, C-7), 133.7 (s, C-4a), 133.8 (d, C-4), 136.4 (s, C-6), 138.1 (s, C-3'), 141.4 (s, C-2), 193.4 (d, CHO).

MS (EI, 70 eV): m/z (%) = 268 (1) $[M]^+$, 199 (92) $[C_{13}H_{11}O_2]^+$, 182 (83) $[C_{13}H_{10}O]^+$, 169 (29) $[C_{12}H_{10}O]^+$, 155 (100) $[C_{11}H_7O]^+$, 141 (26) $[C_{11}H_9]^+$, 128 (40), 115 (17).

HRMS (EI, 70 eV): calcd for $C_{18}H_{20}O_2$ $[M]^+$: 268.1458; found: 268.1450.

6-Chloro-3,4-dihydronaphthalen-1(2*H*)-one (S52)



S46 **S52**

Aminotetralone **S46** (5.28 g, 32.8 mmol, 1.00 eq.) was added at 60 °C to a solution of copper(II) chloride (5.51 g, 41.0 mmol, 1.25 eq.) and *tert*-butyl nitrite (5.42 mL, 4.23 g, 90 wt%, 41.0 mmol, 1.25 eq.) in acetonitrile (50 mL). The reaction mixture was heated at 60°C for 45 minutes, then cooled to room temperature and the reaction was stopped by the addition of hydrogen chloride solution (30 mL, 2.0 M in water) and the mixture was diluted with Et_2O (200 mL). The layers were separated and the aqueous layer was extracted with diethyl ether (3 × 150 mL). The combined organic extract was washed with water (200 mL), brine (200 mL) and it was dried over anhydrous $MgSO_4$. After filtration, the solvent was removed under reduced pressure. Column chromatography (silica, P/EtOAc = 50/1→40/1) of the crude product gave 4.51 g chloro-substituted tetralone **S52** (14.9 mmol, 76%) as a yellow oil.

TLC: R_f = 0.51 (P/EtOAc = 10/1) [UV, $KMnO_4$].

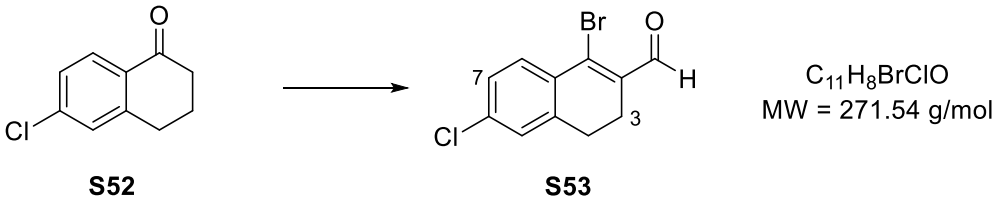
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.12 (*virt.* quint, $^3J \approx {}^3J$ = 6.5 Hz, 2 H, H-3), 2.63 (t, ^3J = 6.7 Hz, 2 H, H-2), 2.92 (t, ^3J = 6.1 Hz, 2 H, H-4), 7.24 – 7.27 (m, 2 H, H-5, H-7), 7.95 (d, ^3J = 8.3 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 23.2 (t, C-3), 29.7 (t, C-4), 39.1 (t, C-2), 127.3 (d, C-7), 128.8 (d, C-5*), 129.0 (d, C-8*), 131.2 (s, C-8a), 139.8 (s, C-6), 146.2 (s, C-4a), 197.4 (s, C-1).

* assignment is interconvertible.

The analytical data obtained matched those reported in literature.[21]

1-Bromo-6-chloro-3,4-dihydronaphthalene-2-carbaldehyde (S53)



S52 **S53**

Following GP6, a solution of 6-chloro-3,4-dihydronaphthalen-1(2*H*)-one (**S52**, 4.38 g, 24.3 mmol, 1.00 eq.) in dichloromethane (90 mL) was added to a reaction mixture of PBr_3 (5.76 mL, 16.4 g, 60.6 mmol, 2.50 eq.) and *N*,*N*-dimethylformamide (5.63 mL, 5.32 g, 72.7 mmol, 3.00 eq.) in dichloromethane (50 mL). After a reaction time of 16 hours, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 50/1), yielding 3.70 g aldehyde **S53** (13.6 mmol, 56%) as an off-white solid.

M.p.: 101 °C.

TLC: R_f = 0.78 (P/EtOAc = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2951 (w, sp^3-CH), 2858 (m, sp^3-CH), 1664 (s, C=O), 1591 (s, C=C), 1549 (s, C=C), 1251 (s), 799 (m, sp^2-CH), 704 (s, sp^2-CH).

^{1}H NMR (300 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.59 – 2.66 (m, 2 H, H-3), 2.80 – 2.85 (m, 2 H, H-4), 7.20 (dt, ^4J = 2.0 Hz, ^4J = 0.9 Hz, 1 H, H-5), 7.31 (dd, ^3J = 8.5 Hz, ^4J = 2.0 Hz, 1 H, H-7), 7.82 (d, ^3J = 8.4 Hz, 1 H, H-8), 10.23 (s, 1 H, CHO).

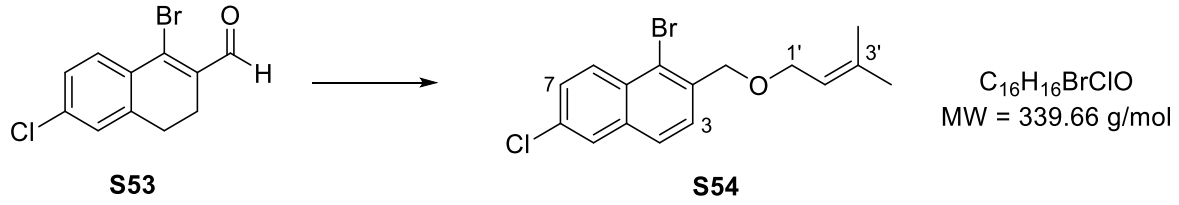
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 22.8 (t, C-3), 27.2 (t, C-4), 127.4 (d, C-7), 127.8 (d, C-5), 130.2 (d, C-8), 131.7 (s, C-8a), 134.7 (s, C-2), 137.4 (s, C-4a*), 137.7 (s, C-6*), 140.7 (s, C-1), 193.1 (d, CHO).

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 274 (6) [M(^{81}Br, ^{37}Cl)]$^+$, 272 (25) [M(^{81}Br, ^{35}Cl)]$^+$, 270 (20) [M(^{79}Br, ^{35}Cl)]$^+$, 237 (22), 162 (50), 128 (100) [$C_{10}H_8$]$^+$.

HRMS (EI, 70 eV): calcd for $C_{11}H_8O^{79}Br^{35}Cl$ [M]$^+$: 269.9442; found: 269.9440.

1-Bromo-6-chloro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S54)



Step 1:

Following GP7, 3,4-dihydronaphthalene-2-carbaldehyde **S53** (3.68 g, 13.6 mmol, 1.00 eq.) in toluene (75 mL) was oxidized by the addition of DDQ (7.69 g, 33.9 mmol, 2.50 eq.) in one portion. After 24 hours, an additional portion of DDQ (7.69 g, 33.9 mmol, 2.50 eq.) was added. The reaction was stopped after 72 hours and the crude product indicated incomplete conversion of the starting material. Purification of the crude product by column chromatography (silica, P/Et_2O = 25/1 → 20/1) gave an inseparable mixture of 1-bromo-2-naphthaldehyde intermediate and starting material **S53** (product:sm = 80/20 according to ^{1}H NMR). The mixture was used in the next step without further purification.

Step 2:

Following GP8, the mixture obtained in the previous step (900 mg, 3.34 mmol, 1.00 eq.) was converted with $NaBH_4$ (189 mg, 5.01 mmol, 1.50 eq.) in ethanol (50 mL). After two hours, the reaction was stopped and the inseparable mixture was used in the next step without further purification.

Step 3:

Following GP9, the mixture obtained in the previous step (545 mg, 3.24 mmol, 1.00 eq.) was converted with 3,3-dimethylallylbromide (966 mg, 6.48 mmol, 2.00 eq.) and sodium hydride (169 mg, 60 wt% in paraffin oil, 4.21 mmol, 1.30 eq.) in tetrahydrofuran (10 mL). After 17 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 60/1) gave 452 mg 1-bromo-2-alkyl-naphthalene **S54**

(1.33 mmol, 24% over three steps starting from 3,4-dihydronaphthalene-2-carbaldehyde **S53**) as a white solid.

M.p.: 38 °C.

TLC: R_f = 0.51 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2974 (w, sp^3-CH), 2913 (w, sp^3-CH), 1691 (m, C=C), 1317 (m), 1083 (s, C–O–C), 813 (m, sp^2-CH), 777 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.69 (s, 3 H, H-4'), 1.78 (s, 3 H, H-4'), 4.12 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.79 (s, 2 H, CH_2), 5.46 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.2 Hz, 1 H, H-2'), 7.51 (dd, ^3J = 9.2 Hz, ^4J = 2.2 Hz, 1 H, H-7), 7.66 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.73 (d, ^3J = 8.5 Hz, 1 H, H-4), 7.81 (d, ^4J = 2.2 Hz, 1 H, H-5), 8.26 (d, ^3J = 9.2 Hz, 1 H, H-8).

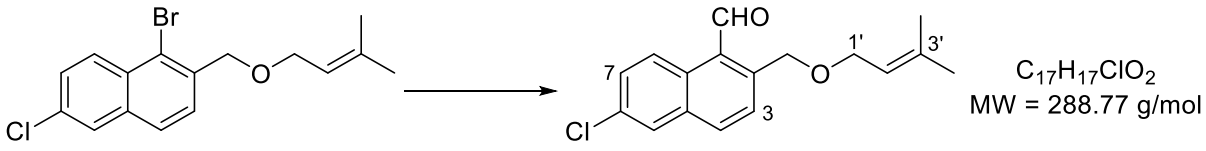
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 26.0 (q, C-4'), 67.4 (t, C-1'), 72.0 (t, CH_2), 120.9 (d, C-2'), 122.5 (s, C-1), 126.8 (d, C-4*), 126.9 (d, C-5*), 127.4 (d, C-3), 128.3 (d, C-7), 129.0 (d, C-8), 130.7 (s, C-8a), 132.5 (s, C-6), 134.6 (s, C-4a), 136.8 (s, C-2), 138.0 (s, C-3').

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 340 (12) [M(^{81}Br^{35}Cl)]$^+$, 267 (44), 255 (100) [$C_{11}H_7{}^{81}Br^{35}Cl]^+$, 253 (70) [$C_{11}H_7{}^{79}Br^{35}Cl]^+$, 139 (71), 126 (16) [$C_{10}H_6]^+$.

HRMS (EI, 70 eV): calcd for $C_{16}H_{16}O^{79}Br^{37}Cl$ [M]$^+$: 340.0038; found: 340.0011.

6-Chloro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7m)



S54 **7m**

Following GP5, 1-bromo-2-alkyl-naphthalene **S54** (435 mg, 1.28 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (616 µL, 2.5 M in *n*-hexane, 1.54 mmol, 1.20 eq.) and

N,*N*-dimethylformamide (493 µL, 469 mg, 6.41 mmol, 5.00 eq.) in tetrahydrofuran (15 mL). After column chromatography (silica, P/EtOAc = 25/1), 267 mg aldehyde **7m** (923 µmol, 72%) were obtained as an off-white solid.

M.p.: 34 °C.

TLC: R_f = 0.60 (P/EtOAc = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2973 (w, sp^3-CH), 2870 (w, sp^3-CH), 1686 (s, C=O), 1617 (w, C=C), 1377 (m), 1063 (m, C–O–C), 823 (m, sp^2-CH).

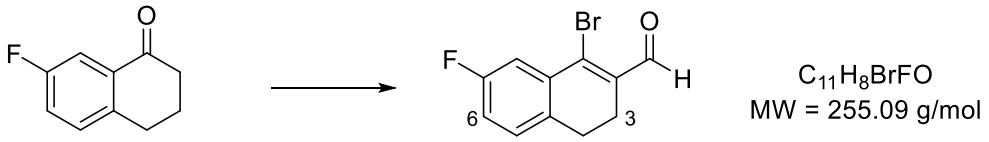
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.68 (s, 3 H, H-4'), 1.77 (s, 3 H, H-4'), 4.10 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.96 (s, 2 H, CH_2), 5.41 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.4 Hz, 1 H, H-2'), 7.57 (dd, ^3J = 9.2 Hz, ^4J = 2.3 Hz, 1 H, H-7), 7.68 (d, ^3J = 8.5 Hz, 1 H, H-3), 7.85 (d, ^4J = 2.3 Hz, 1 H, H-5), 7.95 (d, ^3J = 8.5 Hz, 1 H, H-4), 8.91 (d, ^3J = 9.2 Hz, 1 H, H-8), 10.88 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 26.0 (q, C-4'), 67.4 (t, C-1'), 69.3 (t, CH_2), 120.5 (d, C-2'), 126.8 (d, C-8), 127.1 (d, C-5), 128.0 (d, C-3), 129.0 (s, C-1), 129.6 (m, C-7, C-8a), 132.6 (d, C-4), 133.3 (s, C-6), 134.3 (s, C-4), 138.4 (s, C-3'), 142.6 (s, C-2), 193.0 (d, CHO).

MS (EI, 70 eV): m/z (%) = 219 (79), 204 (72) $[C_{12}H_7{}^{35}ClO]^+$, 202 (100) $[C_{12}H_7{}^{35}ClO]^+$, 189 (28), 175 (86), 139 (81) $[C_{11}H_7]^+$, 128 (28).

HRMS (EI, 70 eV): calcd for $C_{17}H_{17}O_2{}^{35}Cl$ $[M]^+$: 288.0912; found: 288.0896.

1-Bromo-7-fluoro-3,4-dihydronaphthalene-2-carbaldehyde (S55)



S56 **S55**

Following GP6, a solution of 7-fluoro-3,4-dihydronaphthalen-1(*2H*)-one (**S56**, 4.96 g, 30.2 mmol, 1.00 eq.) in dichloromethane (90 mL) was added to a reaction mixture of PBr_3 (7.17 mL, 20.4 g, 75.5 mmol, 2.50 eq.) and *N*,*N*-dimethylformamide (7.01 mL, 6.62 g, 90.6 mmol, 3.00 eq.) in dichloromethane (50 mL). After a reaction time of 17.5 hours, the reaction was stopped and the crude product was purified by column chromatography (silica, P/EtOAc = 40/1), yielding 5.31 g aldehyde **S55** (20.8 mmol, 69%) as a yellow oil.

TLC: R_f = 0.80 (P/EtOAc = 10/1) [UV, $KMnO_4$].

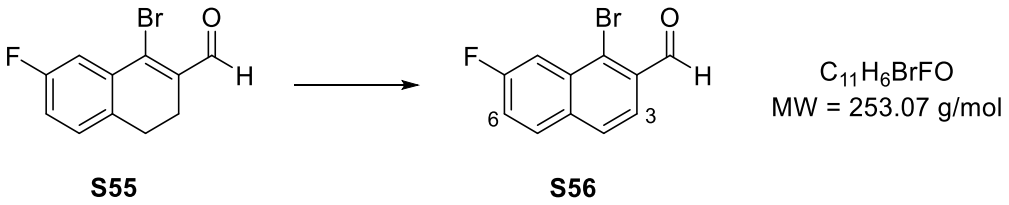
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.61 – 2.64 (m, 2 H, H-3), 2.79 – 2.82 (m, 2 H, H-4), 7.05 (*virt.* td, $^3J \approx {}^3J_{HF}$ = 8.2 Hz, ^4J = 2.6 Hz, 1 H, H-6), 7.17 (ddt, ^3J = 8.4 Hz, $^4J_{HF}$ = 5.6 Hz, ^4J = 1.1 Hz, 1 H, H-5), 7.61 (dd, $^3J_{HF}$ = 9.9 Hz, ^4J = 2.6 Hz, 1 H, H-8), 10.24 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 23.2 (t, C-3), 26.5 (t, C-4), 115.9 (dd, $^2J_{CF}$ = 24.8 Hz, C-8), 117.9 (dd, $^2J_{CF}$ = 21.5 Hz, C-6), 129.1 (dd, $^3J_{CF}$ = 7.8 Hz, C-5), 134.6 (d, $^4J_{CF}$ = 3.2 Hz, C-4a), 135.0 (d, $^3J_{CF}$ = 8.0 Hz, C-8a), 135.5 (s, C-2), 137.4 (d, $^4J_{CF}$ = 2.6 Hz, C-1), 161.9 (d, $^1J_{CF}$ = 244.4 Hz, C-7), 193.2 (d, CHO).

^{19}F NMR (471 MHz, $CDCl_3$, 300 K): δ [ppm] = –114.7 – –114.5 (m, 1 F, C-7-F).

The analytical data obtained matched those reported in literature.[22]

1-Bromo-7-fluoro-2-naphthaldehyde (S56)



S55 **S56**

Following GP7, 3,4-dihydronaphthalene-2-carbaldehyde **S55** (5.07 g, 19.9 mmol, 1.00 eq.) in toluene (75 mL) was oxidized by the addition of DDQ (11.3 g, 49.7 mmol, 2.50 eq.) in one portion. After 24 hours, an additional portion of DDQ (11.3 g, 49.7 mmol, 2.50 eq.) was added. After further 24 hours, TLC analysis indicated still incomplete conversion of the starting material therefore an additional portion of DDQ (2.26 g, 9.94 mmol, 0.50 eq.) was added. The reaction was stopped after three days and purification of the crude product by column chromatography (silica, P/Et_2O = 25/1 → 20/1 → 15/1 → 10/1) gave 752 mg 1-bromo-2-naphthaldehyde **S56** (2.97 mmol, 15%) as an off-white solid.

M.p.: 119 °C.

TLC: R_f = 0.45 (P/Et_2O = 10/1) [UV, $KMnO_4$].

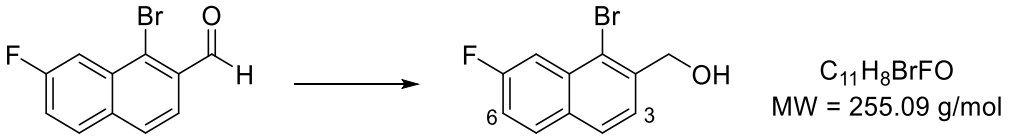
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 7.45 (ddd, $^3J_{HF}$ = 8.9 Hz, ^3J = 7.8 Hz, ^4J = 2.5 Hz, 1 H, H-6), 7.85 – 7.91 (m, 3 H, H-3, H-4, H-5), 8.15 (dd, $^3J_{HF}$ = 10.6 Hz, ^4J = 2.5 Hz, 1 H, H-8), 10.65 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 112.3 (dd, $^2J_{CF}$ = 24.1 Hz, C-8), 120.1 (dd, $^2J_{CF}$ = 25.4 Hz, C-6), 123.7 (dd, $^5J_{CF}$ = 2.6 Hz, C-4), 128.3 (d, C-3), 129.9 (d, $^4J_{CF}$ = 5.8 Hz, C-1), 131.2 (dd, $^3J_{CF}$ = 9.1 Hz, C-5), 132.1 (s, C-2), 133.6 (d, $^3J_{CF}$ = 9.4 Hz, C-8a), 134.1 (s, C-4a), 162.2 (d, $^1J_{CF}$ = 249.3 Hz, C-7), 192.8 (d, CHO).

^{19}F NMR (471 MHz, $CDCl_3$, 300 K): δ [ppm] = –110.1 – –109.9 (m, 1 F, C-7-F).

The analytical data obtained matched those reported in literature.[23]

(1-Bromo-7-fluoronaphthalen-2-yl)methanol (S57)



S56 **S57**

Following GP8, 1-bromo-2-naphthaldehyde **S56** (705 mg, 2.79 mmol, 1.00 eq.) was converted with $NaBH_4$ (158 mg, 4.18 mmol, 1.50 eq.) in ethanol (50 mL). After two hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/EtOAc = 6/1) gave 596 mg (1-bromonaphthalen-2-yl)methanol **S57** (2.34 mmol, 84%) as a colourless solid.

M.p.: 134 °C.

TLC: R_f = 0.54 (P/EtOAc = 4/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3237 (s, O–H), 2922 (m, sp^3-CH), 2852 (w, sp^3-CH), 1510 (m), 1248 (m, C–F), 1072 (m), 834 (s, sp^2-CH).

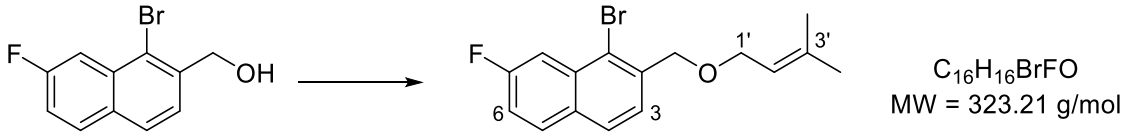
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 2.10 (t, ^3J = 6.3 Hz, 1 H, OH), 4.98 (d, ^3J = 6.3 Hz, 2 H, CH_2), 7.30 (ddd, $^3J_{HF}$ = 9.0 Hz, ^3J = 8.1 Hz, ^4J = 2.5 Hz, 1 H, H-6), 7.61 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.82 – 7.85 (m, 2 H, H-4, H-5), 7.95 (dd, $^3J_{HF}$ = 11.0 Hz, ^4J = 2.5 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 65.9 (t, C-1-*C*H_2), 111.0 (dd, $^2J_{CF}$ = 23.9 Hz, C-8), 117.1 (dd, $^2J_{CF}$ = 25.6 Hz, C-6), 121.3 (d, $^4J_{CF}$ = 5.7 Hz, C-1), 125.3 (d, C-3), 128.0 (d, C-4), 131.0 (dd, $^3J_{CF}$ = 9.2 Hz, C-5), 131.0 (s, C-4a), 133.5 (d, $^3J_{CF}$ = 9.6 Hz, C-8a), 139.0 (s, C-2), 162.0 (d, $^1J_{CF}$ = 247.3 Hz, C-7).

^{19}F NMR (471 MHz, $CDCl_3$, 300 K): δ [ppm] = –111.6 – –111.4 (m, 1 F, C-7-F).

MS (EI, 70 eV): m/z (%) = 256 (49) $[M(^{81}Br)]^+$, 254 (51) $[M(^{79}Br)]^+$, 175 (31) $[C_{11}H_8FO]^+$, 157 (17) $[C_{11}H_9O]^+$, 146 (100) $[C_{10}H_7F]^+$, 127 (26), 88 (9).

1-Bromo-7-fluoro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S58)



S57 **S58**

Following GP9, (1-bromonaphthalen-2-yl)methanol **S57** (574 mg, 2.25 mmol, 1.00 eq.) was converted with 3,3-dimethylallylbromide (670 mg, 4.50 mmol, 2.00 eq.) and sodium hydride (117 mg, 60 wt% in paraffin oil, 2.92 mmol, 1.30 eq.) in tetrahydrofuran (10 mL). After 16 hours, the reaction was stopped and purification of the crude product by column chromatography (silica, P/Et_2O = 60/1) gave 552 mg 1-bromo-2-alkyl-naphthalene **S58** (1.71 mmol, 76%) as a white solid.

M.p.: 42 °C.

TLC: R_f = 0.35 (P/Et_2O = 25/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3068 (w, sp^2-CH), 2973 (w, sp^3-CH), 2856 (w, sp^3-CH), 1632 (m, C=C), 1509 (s), 1208 (m, C–F), 1089 (m, C–O–C), 835 (s, sp^2-CH), 750 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.70 (s, 3 H, H-4'), 1.78 (s, 3 H, H-4'), 4.13 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.80 (s, 2 H, CH_2), 5.46 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.3 Hz, 1 H, H-2'), 7.28 (*virt.* td, $^3J \approx {}^3J_{HF}$ = 8.6 Hz, ^4J = 2.5 Hz, 1 H, H-6), 7.61 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.80 (d, ^3J = 8.4 Hz, 1 H, H-4), 7.82 (d, ^3J = 9.0 Hz, $^4J_{HF}$ = 5.7 Hz, 1 H, H-5), 8.26 (d, $^3J_{HF}$ = 11.2 Hz, ^4J = 2.5 Hz, 1 H, H-8).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 26.0 (q, C-4'), 67.4 (t, C-1'), 72.0 (t, CH_2), 111.1 (dd, $^2J_{CF}$ = 23.9 Hz, C-8), 116.9 (dd, $^2J_{CF}$ = 25.3 Hz, C-6), 120.9 (d, C-2'), 121.4 (d, $^4J_{CF}$ = 5.6 Hz, C-1), 125.5 (d, C-3), 127.6 (d, C-4), 130.8 (dd, $^3J_{CF}$ = 9.1 Hz, C-5), 131.0 (s, C-4a), 133.5 (d, $^3J_{CF}$ = 9.5 Hz, C-8a), 137.6 (s, C-2*), 137.9 (s, C-3'*), 161.9 (d, $^1J_{CF}$ = 246.7 Hz C-7).

^{19}F NMR (471 MHz, $CDCl_3$, 300 K): δ [ppm] = –111.6 – –111.4 (m, 1 F, C-7-F).

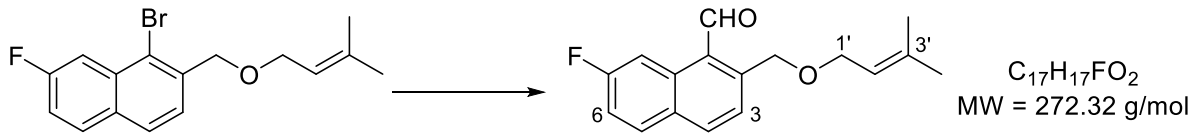
* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 324 (8) [M(^{81}Br)]$^+$, 322 (8) [M(^{79}Br)], 254 (35), 239 (62) [$C_{11}H_7{}^{81}BrF]^+$, 237 (60) [$C_{11}H_7{}^{79}BrF]^+$, 159 (100) [$C_{11}H_8F]^+$.

HRMS (EI, 70 eV): calcd for $C_{16}H_{16}O^{79}BrF$ [M]$^+$: 322.0363; found: 322.0365.

calcd for $C_{15}{}^{13}CH_{16}O^{79}BrF$ [M]$^+$: 323.0397; found: 323.0398.

7-Fluoro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7n)



S58 **7n**

Following GP5, 1-bromo-2-alkyl-naphthalene **S58** (535 mg, 1.66 mmol, 1.00 eq.) was converted with *n*-butyllithium solution (796 µL, 2.5 M in *n*-hexane, 1.99 mmol, 1.20 eq.) and *N*,*N*-dimethylformamide (637 µL, 605 mg, 8.28 mmol, 5.00 eq.) in tetrahydrofuran (15 mL). After column chromatography (silica, P/EtOAc = 25/1), 379 mg aldehyde **7n** (1.39 mmol, 84%) were obtained as a colourless solid.

M.p.: 31 °C.

TLC: R_f = 0.52 (P/EtOAc = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3070 (w, sp^2-CH), 2974 (w, sp^3-CH), 2871 (m, sp^3-CH), 1683 (s, C=O), 1629 (m, C=C), 1372 (w), 1208 (s, C–F), 1090 (m, C–O–C), 843 (s, sp^2-CH), 722 (w, sp^2-CH).

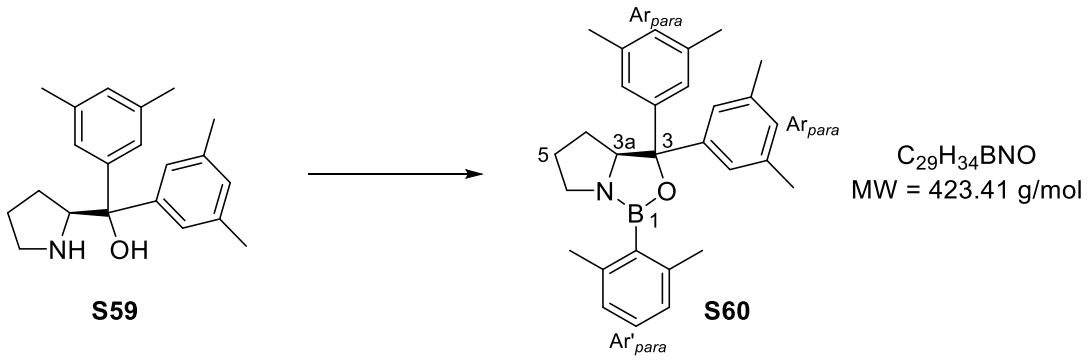
^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.69 (s, 3 H, H-4'), 1.77 (s, 3 H, H-4'), 4.11 (d, ^3J = 7.0 Hz, 2 H, H-1'), 4.98 (s, 2 H, CH_2), 5.42 (*virt.* tquint, ^3J = 7.0 Hz, $^4J \approx {}^4J$ = 1.3 Hz, 1 H, H-2'), 7.33 (ddd, ^3J = 9.0 Hz, $^3J_{HF}$ = 7.9 Hz, ^4J = 2.5 Hz, 1 H, H-6), 7.61 (d, ^3J = 8.4 Hz, 1 H, H-3), 7.87 (dd, ^3J = 9.0 Hz, $^4J_{HF}$ = 6.0 Hz, 1 H, H-5), 8.03 (d, ^3J = 8.4 Hz, 1 H, H-4), 8.73 (d, $^3J_{HF}$ = 12.1 Hz, ^4J = 2.5 Hz, 1 H, H-8), 10.86 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 18.3 (q, C-4'), 26.0 (q, C-4'), 67.4 (t, C-1'), 69.4 (t, CH_2), 109.3 (dd, $^2J_{CF}$ = 24.0 Hz, C-8), 117.1 (dd, $^2J_{CF}$ = 25.7 Hz, C-6), 120.5 (d, C-2'), 126.2 (d, C-3), 128.2 (d, $^2J_{CF}$ = 6.0 Hz, C-1), 130.6 (s, C-4a), 130.8 (dd, $^3J_{CF}$ = 9.4 Hz, C-5), 132.4 (d, $^3J_{CF}$ = 10.5 Hz, C-8a), 134.4 (d, C-4), 138.3 (s, C-3'), 143.8 (s, C-2), 162.9 (d, $^1J_{CF}$ = 247.9 Hz C-7), 192.8 (d, CHO).

^{19}F NMR (471 MHz, $CDCl_3$, 300 K): δ [ppm] = –109.6 – –109.4 (m, 1 F, C-7-F).

4. Photocycloaddition/rearrangement reactions of irradiation precursors

Synthesis of the Oxazaborolidine Catalyst



In analogy to a literature procedure:[24] A *Schlenk* round-bottom flask, equipped with a *Dean-Stark* apparatus was loaded with (*S*)-bis(3,5-dimethylphenyl)(pyrrolidin-2-yl)methanol[25] (**S59**, 18.6 mg, 60 µmol, 1.00 eq.) and (2,6-dimethylphenyl)boronic acid (9.00 mg, 60 µmol, 1.00 eq.). The apparatus was filled with toluene (25 mL) and the solution was refluxed. After four hours toluene (around 20 mL) was removed by distillation and the flask was refilled with toluene (20 mL). This procedure was repeated a second time after further four hours. After 16 hours toluene was distilled off under argon flow. The flask was sealed and the residual solvent was removed under reduced pressure over night. The oxazaborolidine **S60** was obtained as a colourless, viscous oil and used without further purification in the next step. [*Note:* It is necessary to synthesize the oxazaborolidine freshly for every enantioselective photoreaction to avoid decomposition and ensure reproducibility of the results.]

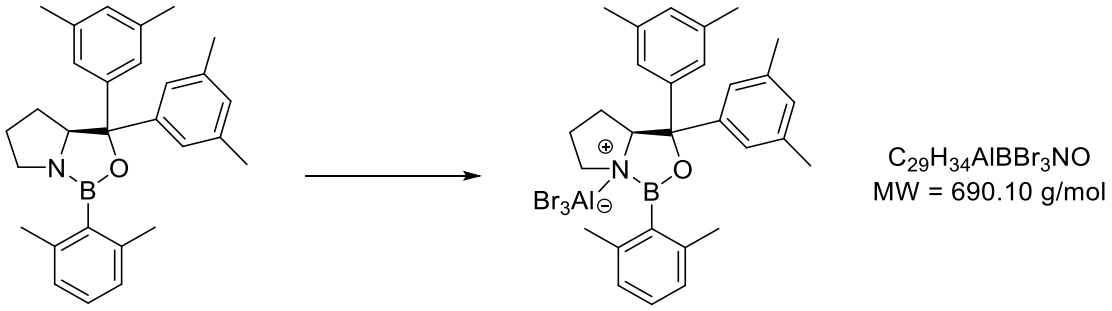
^{1}H NMR (500 MHz, C_6D_6, 300 K): δ [ppm] = 1.09 (*virt.* dq, ^2J = 11.9 Hz, $^3J \approx {}^3J \approx {}^3J$ = 10.1 Hz, 1 H, *H*H-4), 1.42 – 1.47 (m, 1 H, *H*H-5), 1.50 – 1.58 (m, 2 H, H*H*-4, H*H*-5), 2.14 (s, 6 H, Ar-CH_3), 2.17 (s, 6 H, Ar-CH_3), 2.43 (s, 6 H, Ar'-CH_3), 2.83 (ddd, ^2J = 10.8 Hz, ^3J = 9.7 Hz, ^3J = 5.0 Hz, 1 H, *H*H-6), 3.14 (ddd, ^2J = 10.8 Hz, ^3J = 8.8 Hz, ^4J = 5.3 Hz, 1 H, H*H*-6), 4.41 (dd, ^3J = 10.4 Hz, ^3J = 5.2 Hz, 1 H, H-3a), 6.72 – 6.74 (m, 2 H, Ar$_{para}$-H), 7.01 (d, ^3J = 7.7 Hz, 2 H, Ar'$_{meta}$-H), 7.18 (t, ^3J = 7.7 Hz, 1 H, Ar'$_{para}$-H), 7.38 (*br* s, 2 H, Ar$_{ortho}$-H), 7.54 (*br* s, 2 H, Ar$_{ortho}$-H).

^{13}C NMR (126 MHz, C_6D_6, 300 K): δ [ppm] = 21.6 (q, Ar-CH_3), 21.7 (q, Ar-CH_3), 22.6 (q, Ar'-CH_3), 25.5 (t, C-5), 31.2 (t, C-4), 43.4 (t, C-6), 73.0 (d, C-3a), 88.5 (s, C-3), 124.4 (d, Ar_{ortho}-C), 124.5 (d, Ar_{ortho}-C), 126.7 (d, Ar'_{meta}-C), 128.5 (d, Ar_{para}-C), 129.0 (d, Ar'_{para}-C), 129.1 (d, Ar_{para}-C), 134.0 (*br* s, Ar'_{ipso}-C), 137.4 (s, Ar_{meta}-C), 137.6 (s, Ar_{meta}-C), 141.2 (s, Ar'_{ortho}-C), 145.3 (s, Ar_{ipso}-C), 148.8 (s, Ar_{ipso}-C).

^{11}B NMR (128 MHz, C_6D_6, 300 K): δ [ppm] = 33.9 (*br* s, 1 B, NBO).

The analytical data obtained matched those reported in literature.[26]

Activation of the Oxazaborolidine Catalyst



S60 **12d**

In analogy to a literature procedure:[24] Aluminum bromide solution solution (50.0 µL, 1.0 M in dibromomethane, 50.0 µmol, 1.00 eq.) was added to a solution of oxazaborolidine **S60** (60.0 µmol, 1.20 eq.) in dichloromethane (1 mL). The solution was immediately cooled down to – 78 °C. After 5 minutes stirring the purple solution was transferred to the phototube and the *Schlenk* round-bottom flask was washed with dichloromethane (2 × 1 mL).

General Procedure 10 (GP10): Racemic photocycloaddition/rearrangement reaction

The respective 1-naphthaldehyde (100 µmol, 1.00 eq.) was dissolved in dichloromethane (5 mL, c = 20 mM) in a *Schlenk* phototube and the solution was cooled to – 78 °C. Aluminum bromide solution (50.0 µL, 1.0 M in dibromomethane, 50.0 µmol, 50 mol%) was added. The reaction mixture was irradiated at –78 °C using light of λ = 457 nm for 4.5 hours (if not otherwise stated). After warming to 0 °C the mixture was stirred for further 15 minutes (if not otherwise stated) without irradiation at this temperature. The reaction was quenched by the addition of triethylamine (25 µL) followed by warming up the reaction mixture to room temperature and removal of the solvent under reduced pressure. Purification of the crude product by column chromatography gave the rearomatized benzoisochromene as the only product.

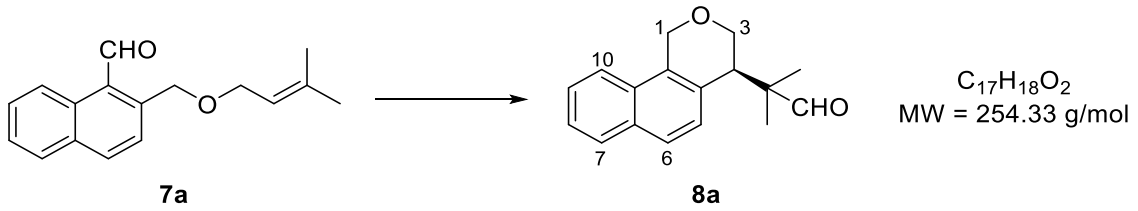
General Procedure 11 (GP11): Enantioselective photocycloaddition/rearrangement reaction

The respective 1-naphthaldehyde (100 µmol, 1.00 eq.) was dissolved in dichloromethane (2 mL) in a *Schlenk* phototube and the solution was cooled to – 78 °C. The activated oxazaborolidine catalyst solution (1.00 mL, 50 µmol, 50 mol%, in dichloromethane) was transferred to the reaction mixture and the vessel was washed with small portions of dichloromethane (2 x 1 mL). The final substrate concentration in the *Schlenk* tube was 20 mM. The *Schlenk* tube was sealed and it was irradiated at –78 °C using light of λ = 457 nm for 4.5 hours (if not otherwise stated). After warming to 0 °C the mixture was stirred for further 30 minutes (if not otherwise stated) without irradiation at this temperature. The reaction was quenched by the addition of triethylamine (25 µL) followed by warming up the reaction mixture to room temperature and removal of the solvent under reduced pressure. Purification of the crude product by column chromatography gave the rearomatized benzoisochromene as the only product.

General Procedure 12 (GP12): Racemic ortho photocycloaddition

The respective 1-naphthaldehyde (100 µmol, 1.00 eq.) was dissolved in dichloromethane (5 mL, c = 20 mM) in a *Duran* phototube. The reaction mixture was irradiated at room temperature using light of λ = 366 nm. The solvent was removed under reduced pressure and the crude product was purified by column chromatography afford the *ortho* photocycloaddition product. [*Note:* The formation of the rearomatized benzoisochromenes was not observed under these conditions.]

(*R*)-2-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8a)



7a **8a**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7a** (25.4 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 10.9 mg of benzoisochromene product *rac*-**8a** (42.8 µmol, 43%) as an off-white solid.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7a** (25.4 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at –78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 22.8 mg of rearomatized benzoisochromene **8a** (89.6 µmol, 90%, 89% *ee*) as a colourless solid.

M.p.: 96 °C.

TLC: R_f = 0.44 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3070 (w, sp^2-CH), 2972 (m, sp^3-CH), 2870 (m, sp^3-CH), 1719 (s, C=O), 1517 (m), 1195 (m, C–O–C), 852 (m, sp^2-CH), 771 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.23 (s, 3 H, CH_3), 1.23 (s, 3 H, CH_3), 2.91 (*virt.* t, $^3J \approx {}^3J$ = 1.4 Hz, 1 H, H-4), 3.81 (dd, ^2J = 11.8 Hz, ^3J = 2.7 Hz, 1 H, *H*H-3), 4.37 (dd, ^2J = 11.8 Hz, ^3J = 1.2 Hz, 1 H, H*H*-3), 5.16 (d, ^2J = 15.7 Hz, 1 H, *H*H-1), 5.32 (d, ^2J = 15.7 Hz,

1 H, H*H*-1), 7.23 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.48 – 7.54 (m, 2 H, H-8, H-9), 7.66 – 7.70 (m, 2 H, H-6, H-7), 7.83 – 7.86 (m, 1 H, H-10), 9.60 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.4 (q, CH_3), 22.1 (q, CH_3), 45.4 (d, C-4), 49.3 [s, *C*$(CH_3)_2$CHO], 65.8 (t, C-3), 66.3 (t, C-1), 121.7 (d, C-7), 126.0 (d, C-9), 126.2 (d, C-6), 126.7 (d, C-8), 128.7 (d, C-5*), 128.8 (d, C-10*), 129.2 (s, C-10a), 130.1 (s, C-6a), 131.0 (s, C-4a), 132.5 (s, C-10b), 205.3 (d, CHO).

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 254 (2) $[M]^+$, 182 (73) $[C_{13}H_{10}O]^+$, 155 (100) $[C_{11}H_{17}O]^+$, 141 (4) $[C_{11}H_9]^+$, 128 (11).

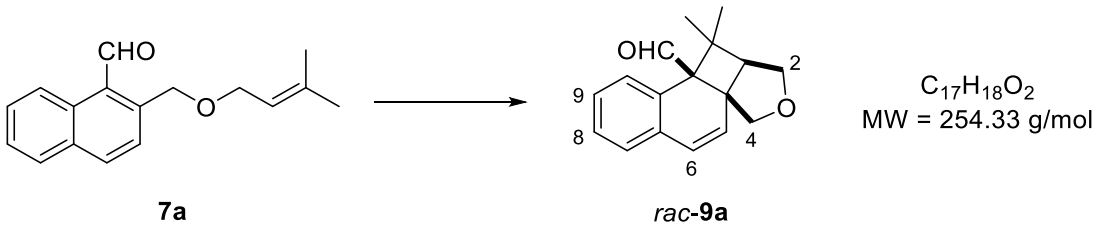
HRMS (EI, 70 eV): calcd for $C_{17}H_{18}O_2$ $[M]^+$: 254.1301; found: 254.1301.

calcd for $C_{16}{}^{13}CH_{18}O_2$ $[M]^+$: 255.1335; found: 255.1324.

Chiral HPLC: t_{R1} = 17.1 min, t_{R2} = 19.1 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +80.5 (c = 3.01, $CHCl_3$) [89% *ee*].

(1a*SR*,4a*SR*,10b*SR*)-1,1-Dimethyl-1a,2-dihydro-4*H*-naphtho[2',1':1,4]cyclobuta[1,2-*c*]furan-10b(1*H*)-carbaldehyde (*rac*-9a)



7a *rac*-**9a**

Racemic *ortho* photocycloaddition

Following General Procedure 12, 1-naphthaldehyde **7a** (25.4 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated for five hours. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 18.2 mg of *ortho* photocycloaddition product *rac*-**9a** (71.6 µmol, 72%) as a yellowish oil.

TLC: R_f = 0.35 (P/EtOAc = 10/1) [UV, $KMnO_4$].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2959 (m, sp^3-CH), 2925 (m, sp^3-CH), 1720 (s, C=O), 1464 (m), 1365 (w), 1113 (s), 1025 (m, C–O–C), 820 (s, sp^2-CH), 749 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 0.90 (s, 3 H, C-1-CH_3), 1.34 (s, 3 H, C-1-CH_3), 2.63 (d, ^3J = 6.2 Hz, 1 H, H-1a), 3.12 (d, ^2J = 10.4 Hz, 1 H, *H*H-4), 3.65 (dd, ^2J = 10.4 Hz, ^3J = 6.2 Hz, 1 H, *H*H-2), 4.21 (d, ^2J = 10.4 Hz, 1 H, H*H*-2), 4.34 (d, ^2J = 10.4 Hz, 1 H, H*H*-4), 5.63 (d, ^3J = 9.8 Hz, 1 H, H-5), 6.37 (d, ^2J = 9.8 Hz, 1 H, H-6), 6.75 (dd, ^3J = 6.8 Hz, ^4J = 2.0 Hz, 1 H, H-10), 7.03 (dd, ^3J = 7.0 Hz, ^4J = 2.0 Hz, 1 H, H-7), 7.09 – 7.24 (m, 2 H, H-8, H-9), 10.24 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 298 K): δ [ppm] = 21.3 (q, C-1-*C*H_3), 30.0 (q, C-1-*C*H_3), 44.4 (s, C-1), 51.0 (s, C-4a), 56.7 (s, C-10b), 60.6 (d, C-1a), 70.5 (t, C-2), 73.5 (t, C-4), 127.0 (d, C-5), 127.7 (d, C-6*), 127.8 (d, C-7*), 128.0 (d, C-8*), 128.0 (d, C-9*), 129.0 (d, C-10), 130.9 (s, C-10a), 132.9 (s, C-6a), 203.2 (d, CHO).

* assignment is interconvertible.

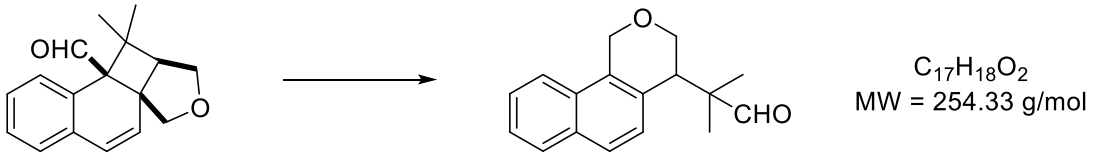
MS (EI, 70 eV): m/z (%) = 254 (5) $[M]^+$, 222 (15), 185 (100) $[C_{12}H_9O_2]^+$, 168 (85), 141 (90) 115 (15).

HRMS (EI, 70 eV): calcd for $C_{17}H_{18}O_2$ $[M]^+$: 254.1301; found: 254.1306.

calcd for $C_{16}{}^{13}CH_{18}O_2$ $[M]^+$: 255.1335; found: 255.1340.

Chiral HPLC: t_{R1} = 18.0 min, t_{R2} = 21.2 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

2-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (*rac*-8a)



rac-**9a** *rac*-**8a**

Thermal Lewis acid catalysed rearrangement

Method A:

Ortho photocycloaddition product *rac*-**9a** (26.4 mg, 104 µmol, 1.00 eq.) was dissolved in dichloromethane (5 mL) and the solution was cooled to 0 °C. Aluminium bromide solution (103 µL, 100 mM in dibromomethane/dichloromethane, 10.4 µmol, 10 mol%) was added and the reaction mixture was stirred at 0 °C. After five hours the Lewis acid was quenched by the addition of triethylamine (25 µL) and the mixture was warmed to room temperature. The solvent was removed under reduced pressure and the crude product was purified by column chromatography (silica, P/EtOAc =20/1) yielding 22.7 mg rearomatized benzoisochromene *rac*-**8a** (89.4 µmol, 86%) as a colourless solid.

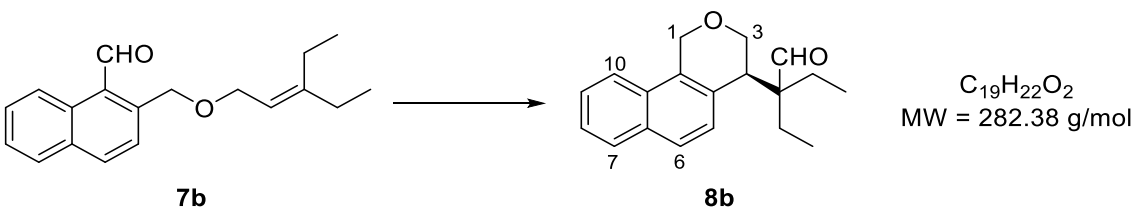
Method B:

Ortho photocycloaddition product *rac*-**9a** (26.4 mg, 104 µmol, 1.00 eq.) was dissolved in dichloromethane (5 mL) and the solution was cooled to 0 °C. Ethyl aluminium dichloride solution (103 µL, 100 mM in hexane/dichloromethane, 10.4 µmol, 10 mol%) was added and the reaction mixture was stirred at 0 °C. After five hours the Lewis acid was quenched by the

addition of triethylamine (25 µL) and the mixture was warmed to room temperature. The solvent was removed under reduced pressure and the crude product was purified by column chromatography (silica, P/EtOAc =20/1) yielding 21.4 mg rearomatized benzoisochromene *rac*-**8a** (84.1 µmol, 81%) as a colourless solid.

The ^{1}H NMR matched to the analytical data reported previously for this compound.

(*R*)-2-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-ethylbutanal (8b)



7b **8b**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7b** (28.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 14.8 mg of benzoisochromene product *rac*-**8b** (52.4 µmol, 52%) as a yellowish oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7b** (28.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 18.4 mg of benzoisochromene product **8b** (65.2 µmol, 65%, 85% *ee*) as a colourless solid.

M.p.: 103 °C.

TLC: R_f = 0.40 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3056 (w, sp^2-CH), 2921 (m, sp^3-CH), 2832 (m, sp^3-CH), 1722 (s, C=O), 1441 (m), 1119 (m, C–O–C), 812 (w, sp^2-CH), 742 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 0.76 (t, ^3J = 7.5 Hz, 3 H, CH_3), 0.95 (t, ^3J = 7.6 Hz, 3 H, CH_3), 1.71 – 1.99 (m, 4 H, CH_2), 2.95 (*br* s, 1 H, H-4), 3.71 (dd, ^2J = 11.6 Hz, ^3J = 2.3 Hz, 1 H, *H*H-3), 4.35 (dd, ^2J = 11.6 Hz, ^3J = 1.1 Hz, 1 H, H*H*-3), 5.18 (d, ^2J = 15.8 Hz, 1 H, *H*H-1), 5.30 (d, ^2J = 15.8 Hz, 1 H, H*H*-1), 7.29 (d, ^3J = 8.5 Hz, 1 H, H-5), 7.46 – 7.55 (m,

2 H, H-8, H-9), 7.59 – 7.67 (m, 1 H, H-7), 7.69 (d, ^{3}J = 8.5 Hz, 1 H, H-6), 7.82 – 7.88 (m, 1 H, H-10), 9.44 (s, 1 H, CHO).

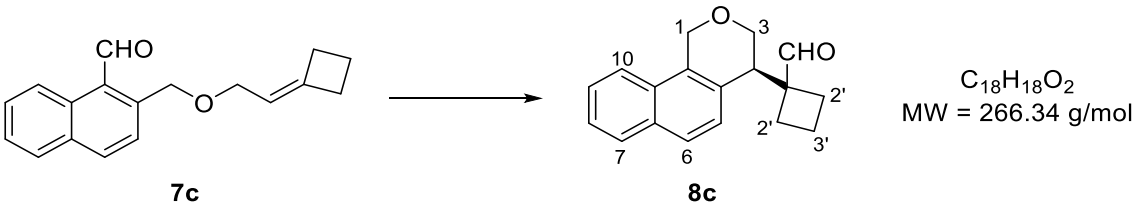
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 7.2 (q, CH_3), 8.3 (q, CH_3), 20.1 (t, CH_2), 22.8 (t, CH_2), 43.4 (d, C-4), 54.1 [s, $C(C_2H_5)_2CHO$], 65.2 (t, C-3), 66.4 (t, C-1), 121.6 (d, C-7), 125.8 (d, C-9), 125.9 (d, C-6), 126.5 (d, C-8), 128.7 (d, C-5*), 129.0 (d, C-10*), 129.0 (s, C-10a), 129.8 (s, C-6a), 130.9 (s, C-4a), 132.4 (s, C-10b), 205.2 (d, CHO).

* assignment is interconvertible.

Chiral HPLC: t_{R1} = 19.2 min, t_{R2} = 20.7 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +90.3 (c = 3.97, $CHCl_3$) [85% *ee*].

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclobutane-1-carbaldehyde (8c)



Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7c** (26.6 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C for 4.5 h after addition of aluminium bromide solution. The mixture was stirred for further 40 minutes at −78 °C in the dark until complete rearrangement following quenching of the Lewis acid by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 2.6 mg of benzoisochromene product *rac*-**8c** (9.7 µmol, 10%) as a colourless oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7c** (26.6 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C for 4.5 h. The mixture was stirred for further two hours at −78 °C in the dark until complete rearrangement following quenching of the Lewis acid by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 21.3 mg of benzoisochromene product **8c** (80.0 µmol, 80%, 85% *ee*) as a colourless solid.

Hint: Warming up the reaction mixture after irradiation to 0 °C led to decomposition of the product. Therefore complete rearrangement was done at−78 °C to minimize decomposition.

M.p.: 144 °C.

TLC: R_f = 0.28 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3059 (w, sp^2-CH), 2956 (m, sp^3-CH), 2855 (w, sp^3-CH), 1713 (s, C=O), 1430 (w), 1112 (m, C–O–C), 818 (m, sp^2-CH), 751 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.83 – 1.90 (m, 2 H, H-3'), 2.02 – 2.08 (m, 1 H, H-2'), 2.22 – 2.28 (m, 1 H, H-2'), 2.47 – 2.53 (m, 1 H, H-2'), 2.56 – 2.62 (m, 1 H, H-2'), 3.15 (*virt.* t, $^{3}J \approx {}^{3}J$ = 1.5 Hz, 1 H, H-4), 3.82 (dd, ^{2}J = 11.5 Hz, ^{3}J = 3.0 Hz, 1 H, *H*H-3), 4.11 (dd, ^{2}J = 11.5 Hz, ^{3}J = 1.4 Hz, 1 H, H*H*-3), 5.12 (d, ^{2}J = 15.6 Hz, 1 H, *H*H-1), 5.31 (d, ^{2}J = 15.6 Hz, 1 H, H*H*-1), 7.34 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.48 – 7.53 (m, 2 H, H-8, H-9), 7.64 – 7.67 (m, 1 H, H-7), 7.71 (dd, ^{3}J = 8.5 Hz, ^{4}J = 1.0 Hz, 1 H, H-6), 7.83 – 7.85 (m, 1 H, H-10), 9.59 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 15.5 (t, C-3'), 26.7 (t, C-2'), 28.6 (t, C-2'), 45.9 (d, C-4), 56.2 (s, C-1'), 65.6 (t, C-3), 66.6 (t, C-1), 121.8 (d, C-7), 126.0 (d, C-9), 126.7 (d, C-6), 127.0 (d, C-8), 127.2 (d, C-5), 128.8 (d, C-10), 129.2 (s, C-10a), 129.6 (s, C-6a), 130.3 (s, C-4a), 132.5 (s, C-10b), 205.2 (d, CHO).

MS (EI, 70 eV): m/z (%) = 266 (8) $[M]^+$, 182 (100) $[C_{13}H_{10}O]^+$, 155 (38) $[C_{11}H_7O]^+$, 141 (6) $[C_{11}H_9]^+$, 128 (9).

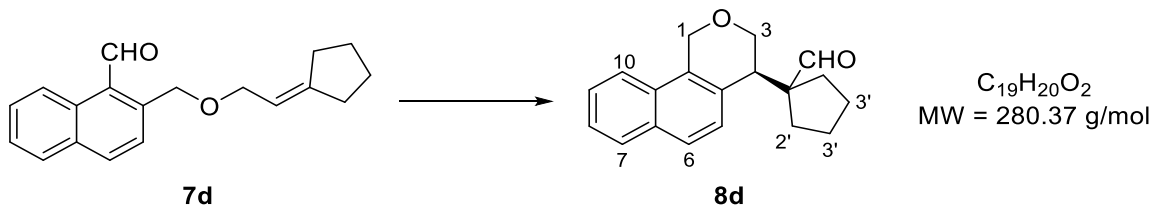
HRMS (EI, 70 eV): calcd for $C_{18}H_{18}O_2$ $[M]^+$: 266.1301; found: 266.1301.

calcd for $C_{17}{}^{13}CH_{18}O_2$ $[M]^+$: 267.1335; found: 267.1341.

Chiral HPLC: t_{R1} = 18.6 min, t_{R2} = 22.3 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +125 (c = 2.46, $CHCl_3$) [85% *ee*].

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclopentane1-carbaldehyde (8d)



Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7d** (28.0 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 8.1 mg of benzoisochromene product *rac*-**8d** (28.8 µmol, 29%) as an off-white solid.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7d** (28.0 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 23.3 mg of benzoisochromene product **8d** (83.1 µmol, 83%, 82% *ee*) as a colourless solid.

M.p.: 105 °C.

TLC: R_f = 0.44 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3058 (w, sp^2-CH), 2963 (m, sp^3-CH), 2868 (m, sp^3-CH), 1716 (s, C=O), 1450 (w), 1118 (m, C–O–C), 819 (m, sp^2-CH), 750 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.34 – 1.40 (m, 1 H, *H*H-3'*), 1.56 – 1.63 (m, 1 H, *H*H-2'), 1.64 – 1.73 (m, 3 H, H-3'), 1.83 – 1.89 (m, 1 H, *H*H-2'), 1.97 – 2.02 (m, 1 H, H*H*-2'), 2.45 – 2.50 (m, 1 H, H*H*-2'), 2.90 (*virt.* t, $^3J \approx {}^3J$ = 1.2 Hz, 1 H, H-4), 3.83 (dd, ^2J = 11.5 Hz, ^3J = 2.6 Hz, 1 H, *H*H-3), 4.26 (dd, ^2J = 11.5 Hz, ^3J = 1.1 Hz, 1 H, H*H*-3), 5.15 (d, ^2J = 15.7 Hz,

1 H, *H*H-1), 5.32 (d, ^{2}J = 15.7 Hz, 1 H, H*H*-1), 7.37 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.48 – 7.53 (m, 2 H, H-8, H-9), 7.64 – 7.66 (m, 1 H, H-7), 7.71 (dd, ^{3}J = 8.5 Hz, 1 H, H-6), 7.84 – 7.86 (m, 1 H, H-10), 9.49 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 24.1 (t, C-3'), 31.3 (t, C-2'), 33.2 (t, C-2'), 47.1 (d, C-4), 61.7 (s, C-1'), 66.4 (t, C-1), 67.2 (t, C-3), 121.7 (d, C-7), 125.9 (d, C-9), 126.4 (d, C-6*), 126.6 (d, C-8*), 127.9 (d, C-5), 128.7 (d, C-10), 129.0 (s, C-10a), 129.5 (s, C-6a), 131.2 (s, C-4a), 132.4 (s, C-10b), 203.5 (d, CHO).

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 280 (3) $[M]^+$, 182 (100) $[C_{13}H_{10}O]^+$, 155 (69) $[C_{11}H_7O]^+$, 141 (4) $[C_{11}H_9]^+$, 128 (8).

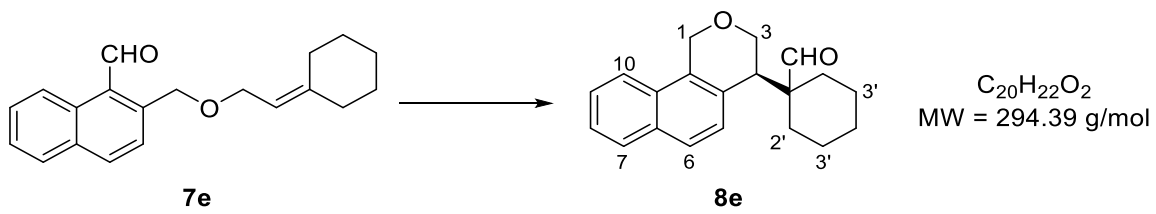
HRMS (EI, 70 eV): calcd for $C_{19}H_{20}O_2$ $[M]^+$: 280.1458; found: 280.1452.

calcd for $C_{18}{}^{13}CH_{20}O_2$ $[M]^+$: 281.1491; found: 281.1492.

Chiral HPLC: t_{R1} = 19.6 min, t_{R2} = 23.1 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +91.4 (c = 2.89, $CHCl_3$) [82% *ee*].

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclohexane-1-carbaldehyde (8e)



7e **8e**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7e** (29.4 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 7.0 mg of benzoisochromene product *rac*-**8e** (23.7 µmol, 24%) as a colourless oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7e** (29.4 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 25.3 mg of benzoisochromene product **8e** (85.8 µmol, 86%, 87% *ee*) as a colourless solid.

M.p.: 164 °C.

TLC: R_f = 0.45 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3058 (w, sp^2-CH), 2929 (s, sp^3-CH), 2854 (m, sp^3-CH), 1718 (s, C=O), 1450 (m), 1117 (m, C–O–C), 819 (m, sp^2-CH), 758 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.14 – 1.26 (m, 2 H, H-3'*), 1.36 – 1.45 (m, 1 H, *H*H-4'*), 1.50 – 1.73 (m, 5 H, H-2', H-3'*, H*H*-4'*), 2.09 – 2.11 (m, 1 H, H*H*-2'), 2.35 – 2.39 (m, 1 H, H*H*-2'), 2.76 (*br* s, 1 H, H-4), 3.71 (dd, ^2J = 11.8 Hz, ^3J = 2.4 Hz, 1 H, *H*H-3), 4.45 (dd, ^2J = 11.8 Hz, ^3J = 1.1 Hz, 1 H, H*H*-3), 5.14 (d, ^2J = 15.7 Hz, 1 H, *H*H-1), 5.27

(d, ^{2}J = 15.7 Hz, 1 H, H*H*-1), 7.25 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.47 – 7.53 (m, 2 H, H-8, H-9), 7.63 – 7.65 (m, 1 H, H-7), 7.67 (dd, ^{3}J = 8.5 Hz, 1 H, H-6), 7.82 – 7.84 (m, 1 H, H-10), 9.58 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 22.9 (t, C-3'**), 23.2 (t, C-4'**), 25.7 (t, C-3'**), 31.3 (t, C-2'), 31.6 (t, C-2'), 48.2 (d, C-4), 52.2 (s, C-1'), 64.7 (t, C-3), 66.2 (t, C-1), 121.8 (d, C-7), 125.9 (d, C-6***), 126.0 (d, C-8***), 126.6 (d, C-9***), 128.8 (d, C-10), 129.0 (d, C-5), 129.2 (s, C-10a), 129.8 (s, C-6a), 130.7 (s, C-4a), 132.6 (s, C-10b), 206.3 (d, CHO).

*, **, *** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 294 (3) $[M]^+$, 182 (84) $[C_{13}H_{10}O]^+$, 155 (100) $[C_{11}H_7O]^+$, 141 (7) $[C_{11}H_9]^+$, 128 (5).

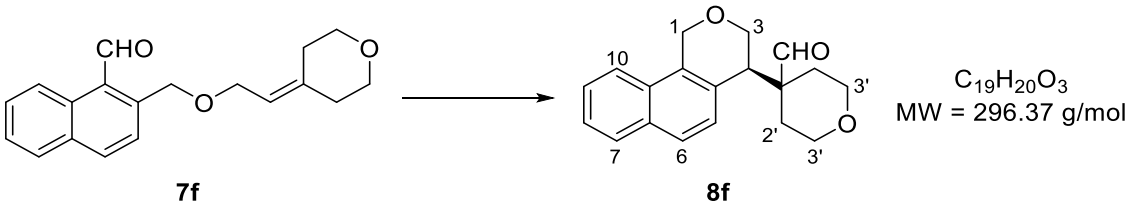
HRMS (EI, 70 eV): calcd for $C_{20}H_{22}O_2$ $[M]^+$: 294.1614; found: 294.1613.

calcd for $C_{19}{}^{13}CH_{22}O_2$ $[M]^+$: 295.1648; found: 295.1648.

Chiral HPLC: t_{R1} = 20.8 min, t_{R2} = 22.8 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +72.8 (c = 3.08, $CHCl_3$) [87% *ee*].

(*R*)-4-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)tetrahydro-2*H*-pyran-4-carbaldehyde (8f)



7f **8f**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7f** (29.6 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C for 14 hours after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 10/1 → 7/1 → 5/1) gave 4.2 mg of benzoisochromene product *rac*-**8f** (14.2 µmol, 14%) as colourless oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7f** (29.6 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C for 16 hours. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc =10/1 → 7/1 → 5/1) gave 23.8 mg of benzoisochromene product **8f** (80.3 µmol, 80%, 83% *ee*) as a colourless solid.

M.p.: 163 °C.

TLC: R_f = 0.16 (P/EtOAc = 4/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2961 (m, sp^3-CH), 2851 (w, sp^3-CH), 1721 (s, C=O), 1441 (w), 1117 (m, C–O–C), 1090 (w, C–O–C), 878 (w), 748 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.86 (*virt.* td, $^2J \approx {}^3J$ = 13.1 Hz, ^3J = 5.3 Hz 1 H, *H*H-2'), 1.95 (*virt.* td, $^2J \approx {}^3J$ = 13.0 Hz, ^3J = 4.8 Hz 1 H, *H*H-2'), 2.06 (*virt.* dq,

^{2}J = 13.1 Hz, $^{3}J \approx {}^{3}J \approx {}^{4}J$ = 2.0 Hz 1 H, H*H*-2'), 2.38 (*virt.* dq, ^{2}J = 13.8 Hz, $^{3}J \approx {}^{3}J \approx {}^{4}J$ = 2.4 Hz 1 H, H*H*-2'), 2.76 (*virt.* dt, ^{3}J = 2.4 Hz, $^{3}J \approx {}^{4}J$ = 1.2 Hz 1 H, H-4), 3.21 (*virt.* td, $^{2}J \approx {}^{3}J$ = 12.2 Hz, ^{3}J = 2.3 Hz 1 H, *H*H-3'), 3.53 (*virt.* td, $^{2}J \approx {}^{3}J$ = 12.3 Hz, ^{3}J = 2.5 Hz 1 H, *H*H-3'), 3.74 (dd, ^{2}J = 11.8 Hz, ^{3}J = 2.4 Hz, 1 H, *H*H-3), 3.82 – 3.86 (m, 1 H, H*H*-3'), 3.95 – 3.99 (m, 1 H, H*H*-3'), 4.43 (dd, ^{2}J = 11.8 Hz, ^{3}J = 1.1 Hz, 1 H, H*H*-3), 5.16 (d, ^{2}J = 15.7 Hz, 1 H, *H*H-1), 5.28 (d, ^{2}J = 15.7 Hz, 1 H, H*H*-1), 7.27 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.48 – 7.65 (m, 2 H, H-8, H-9), 7.64 – 7.65 (m, 1 H, H-7), 7.70 (d, ^{3}J = 8.5 Hz, 1 H, H-6), 7.84 – 7.86 (m, 1 H, H-10), 9.60 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 31.6 (t, C-2'), 32.0 (t, C-2'), 49.3 (d, C-4), 50.0 (s, C-1'), 64.3 (t, C-3), 64.8 (t, C-3'), 65.3 (t, C-3'), 66.3 (t, C-1), 121.8 (d, C-7), 126.2 (m, C-6, C-8*), 126.7 (d, C-9*), 128.7 (d, C-5), 128.8 (d, C-10), 129.2 (s, C-10a), 129.8 (s, C-6a), 130.7 (s, C-4a), 132.6 (s, C-10b), 204.6 (d, CHO).

* assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 296 (2) $[M]^+$, 182 (69) $[C_{13}H_{10}O]^+$, 155 (100) $[C_{11}H_7O]^+$, 128 (6).

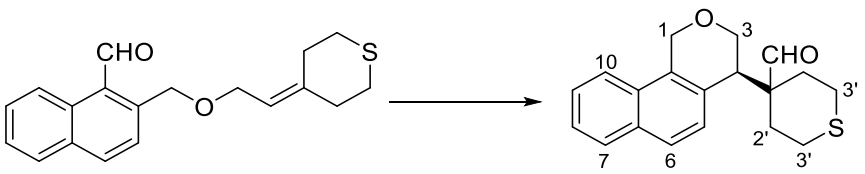
HRMS (EI, 70 eV): calcd for $C_{19}H_{20}O_3$ $[M]^+$: 296.1407; found: 296.1408.

calcd for $C_{18}{}^{13}CH_{20}O_3$ $[M]^+$: 297.1441; found: 297.1447.

Chiral HPLC: t_{R1} = 14.7 min, t_{R2} = 16.5 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +67.8 (c = 2.98, $CHCl_3$) [83% *ee*].

(*R*)-4-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)tetrahydro-2*H*-thiopyran-4-carbaldehyde (8g)



7g **8g**

$C_{19}H_{20}O_2S$
MW = 312.43 g/mol

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7g** (31.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. After warming up to 0 °C, the reaction mixture was stirred at this temperature for 1.5 hours in the dark. TLC analysis showed incomplete rearrangement of the [2+2] photocycloaddition product therefore aluminum bromide solution (50.0 µL, 1.0 M in dibromomethane, 50.0 µmol, 50 mol%) was added and the reaction mixture was warmed to room temperature and stirred for addition 30 minutes in the dark. After TLC analysis showed complete rearrangment of the [2+2] photocycloaddition product, the Lewis acid was quenched by the addition of triethylamine (50 µL). Purification by column chromatography (silica, P/EtOAc = 10/1) gave 11.9 mg of benzoisochromene product *rac*-**8g** (38.1 µmol, 38%) as an off-white solid.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7g** (31.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C for 16 hours and the Lewis acid was quenched at this temperature by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc =15/1 → 10/1) gave 27.1 mg of an inseparable mixture of benzoisochromene product and the corresponding *ortho* photocycloaddition product (ratio 21:79). The mixture was dissolved in dichloromethane (5 mL) and the solution was cooled to

0 °C. Ethyl aluminium dichloride solution (42.4 µL, 1.0 M in hexane, 42.4 µmol, 50 mol%) was added and the reaction mixture was stirred at 0 °C until complete rearrangement. After five hours the Lewis acid was quenched by the addition of triethylamine (25 µL). Purification of the crude product by column chromatography (silica, P/EtOAc =15/1) gave 24.7 mg rearomatized benzoisochromene **8g** (79.2 µmol, 79% over two steps, 96% *ee*) as a colourless solid.

Hint: It was necessary to apply this two-step procedure because warming up the reaction mixture after irradiation lead to incomplete rearrangement (also after prolonged time). Addition of achiral Lewis acid after irradiation lead to decomposition. Therefore this two-step procedure was necessary to get the rearranged benzoisochromene as the only product.

Single crystals were obtained by vapour diffusion using ethyl acetate/dichloromethane (10:1, solvent) and pentane (anti-solvent).

M.p.: 171 °C.

TLC: R_f = 0.75 (P/EtOAc = 2/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3051 (w, sp^2-CH), 2935 (m, sp^3-CH), 2849 (w, sp^3-CH), 1717 (s, C=O), 1441 (w), 1121 (m, C–O–C), 821 (m, sp^2-CH), 741 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.92 – 2.00 (m, 2 H, H-2'), 2.43 (*virt.* ddt, ^2J = 13.8 Hz, ^3J = 4.3 Hz, $^3J \approx {}^4J$ = 1.9 Hz, 1 H, H*H*-2'), 2.51 – 2.61 (m, 3 H, H-3'), 2.70 (*virt.* ddt, ^2J = 13.7 Hz, ^3J = 4.4 Hz, $^3J \approx {}^4J$ = 2.0 Hz, 1 H, H*H*-2'), 2.79 (*br* s, 1 H, H-4), 2.86 (ddd, ^2J = 13.9 Hz, ^3J = 12.4 Hz ^3J = 2.7 Hz 1 H, *H*H-3'), 3.73 (dd, ^2J = 12.0 Hz, ^3J = 2.4 Hz, 1 H, *H*H-3), 4.44 (dd, ^2J = 12.0 Hz, ^3J = 1.1 Hz, 1 H, H*H*-3), 5.16 (d, ^2J = 15.8 Hz, 1 H, *H*H-1), 5.28 (d, ^2J = 15.7 Hz, 1 H, H*H*-1), 7.21 (d, ^3J = 8.5 Hz, 1 H, H-5), 7.48 – 7.55 (m, 2 H, H-8, H-9), 7.62 – 7.67 (m, 1 H, H-7), 7.69 (dd, ^3J = 8.5 Hz, ^4J = 1.0 Hz, 1 H, H-6), 7.79 – 7.95 (m, 1 H, H-10), 9.57 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 25.1 (t, C-3'), 25.4 (t, C-3'), 32.3 (t, C-2'), 32.7 (t, C-2'), 48.4 (d, C-4), 51.4 (s, C-1'), 64.4 (t, C-3), 66.2 (t, C-1), 121.8 (d, C-7), 126.1 (d,

C-6*), 126.2 (d, C-8*), 126.8 (d, C-9*), 128.8 (m, C-5, C-10), 129.2 (s, C-6a**), 129.7 (s, C-10a**), 130.0 (s, C-4a), 132.7 (s, C-10b), 205.2 (d, CHO).

*, ** assignment is interconvertible.

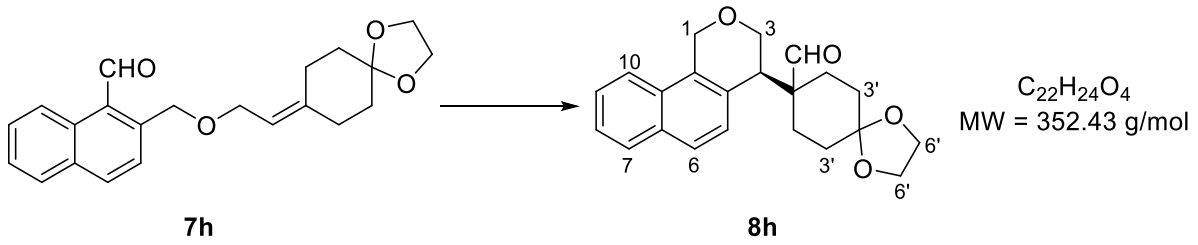
MS (EI, 70 eV): m/z (%) = 283 (5) $[C_{18}H_{19}OS]^+$, 207 (100) $[C_{12}H_{15}OS]^+$, 191 (4), 154 (3), 72 (91), 59 (98).

HRMS (EI, 70 eV): calcd for $C_{19}H_{20}O_2{}^{32}S$ $[M]^+$: 312.1179; found: 312.1179.

Chiral HPLC: t_{R1} = 20.9 min, t_{R2} = 22.6 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +52.9 (c = 5.07, $CHCl_3$) [96% *ee*].

(*R*)-8-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-1,4-dioxaspiro[4.5]decane-8-carbaldehyde (8h)



7h **8h**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7h** (35.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 6/1 → 4/1) gave 23.1 mg of benzoisochromene product *rac*-**8h** (65.5 µmol, 66%) as an off-white solid.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7h** (35.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C for twelve hours. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 5/1 → 4/1) gave 30.9 mg of benzoisochromene product **8h** (87.7 µmol, 88%, 90% *ee*) as a colourless solid.

M.p.: 226 °C.

TLC: R_f = 0.32 (P/EtOAc = 2/1) [UV, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2966 (m, sp^3-CH), 2842 (m, sp^3-CH), 1716 (s, C=O), 1439 (m), 1114 (s, C–O–C), 1096 (s, C–O–C), 881 (m), 752 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.37 (*virt.* td, $^2J \approx {}^3J$ = 13.6 Hz, ^3J = 4.2 Hz, 1 H, *H*H-3'), 1.64 – 1.70 (m, 2 H, H-3'), 1.75 – 1.81 (m, 3 H, H-2', H*H*-3'), 2.15 (*virt.* dq,

^{2}J = 13.8 Hz, $^{3}J \approx {}^{3}J \approx {}^{4}J$ = 3.8 Hz 1 H, H*H*-2'), 2.48 (*virt.* dq, ^{2}J = 13.3 Hz, $^{3}J \approx {}^{3}J \approx {}^{4}J$ = 3.6 Hz 1 H, H*H*-2'), 2.76 (*br* s, 1 H, H-4), 3.73 (dd, ^{2}J = 11.8 Hz, ^{3}J = 2.4 Hz, 1 H, *H*H-3), 3.90 – 3.97 (m, 4 H, H-6'), 4.44 (dd, ^{2}J = 11.7 Hz, ^{3}J = 1.1 Hz, 1 H, H*H*-3), 5.14 (d, ^{2}J = 15.7 Hz, 1 H, *H*H-1), 5.27 (d, ^{2}J = 15.7 Hz, 1 H, H*H*-1), 7.26 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.47 – 7.52 (m, 2 H, H-8, H-9), 7.62 – 7.64 (m, 1 H, H-7), 7.67 (dd, ^{3}J = 8.5 Hz, 1 H, H-6), 7.82 – 7.85 (m, 1 H, H-10), 9.59 (s, 1 H, CHO).

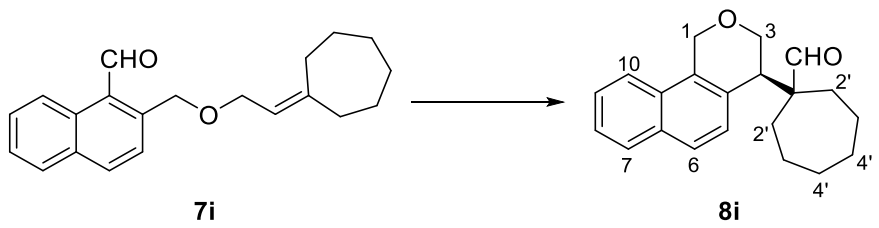
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 28.8 (t, C-2'), 28.9 (t, C-2'), 31.5 (t, C-3'), 31.9 (t, C-3'), 48.4 (d, C-4), 51.3 (s, C-1'), 64.5 (m, C-6'), 64.9 (t, C-3), 66.2 (t, C-1), 108.3 (s, C-4'), 121.8 (d, C-7), 126.0 (d, C-6*), 126.1 (d, C-8*), 126.6 (d, C-9), 128.8 (d, C-10), 128.9 (d, C-5), 129.1 (s, C-6a), 129.7 (s, C-10a), 130.5 (s, C-4a), 132.6 (s, C-10b), 204.8 (d, CHO).

* assignment is interconvertible.

Chiral HPLC: t_{R1} = 18.8 min, t_{R2} = 20.4 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +116 (c = 2.38, $CHCl_3$) [90% *ee*].

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cycloheptane-1-carbaldehyde (8i)



7i **8i**

$C_{21}H_{24}O_2$
MW = 308.42 g/mol

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7i** (30.8 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 6.4 mg of benzoisochromene product *rac*-**8i** (20.8 µmol, 21%) as a yellowish oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7i** (30.8 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 28.1 mg of benzoisochromene product **8i** (91.1 µmol, 91%, 86% *ee*) as a colourless solid.

M.p.: 108 °C.

TLC: R_f = 0.46 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3056 (w, sp^2-CH), 2922 (s, sp^3-CH), 2854 (m, sp^3-CH), 1717 (s, C=O), 1462 (m), 1117 (m, C–O–C), 819 (m, sp^2-CH), 749 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.44 – 1.48 (m, 4 H, H-3'*), 1.59 – 1.71 (m, 6 H, H-2', H-5'*), 1.95 – 2.00 (m, 1 H, H*H*-2'), 2.32 – 2.37 (m, 1 H, H*H*-2'), 2.90 (dd, ^3J = 2.6 Hz, ^3J = 1.3 Hz, 1 H, H-4), 3.76 (dd, ^2J = 11.7 Hz, ^3J = 2.6 Hz, 1 H, *H*H-3), 4.39 (dd, ^2J = 11.7 Hz, ^3J = 1.3 Hz, 1 H, H*H*-3), 5.16 (d, ^2J = 15.7 Hz, 1 H, *H*H-1), 5.31 (d, ^2J = 15.7 Hz,

1 H, H*H*-1), 7.23 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.48 – 7.53 (m, 2 H, H-8, H-9), 7.64 – 7.69 (m, 1 H, H-7), 7.68 (d, ^{3}J = 8.5 Hz, 1 H, H-6), 7.82 – 7.86 (m, 1 H, H-10), 9.50 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 23.2 (t, C-3'**), 23.5 (t, C-3'**), 30.8 (t, C-4'**), 31.2 (t, C-4'**), 31.9 (t, C-2'), 32.2 (t, C-2'), 46.3 (d, C-4), 55.1 (s, C-1'), 65.5 (t, C-3), 66.4 (t, C-1), 121.8 (d, C-7), 126.1 (m, C-6, C-8***), 126.7 (d, C-9***), 128.8 (d, C-10), 128.9 (d, C-5), 129.1 (s, C-10a), 130.0 (s, C-6a), 131.2 (s, C-4a), 132.5 (s, C-10b), 205.1 (d, CHO).

*, **, *** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 308 (2) $[M]^+$, 182 (84) $[C_{13}H_{10}O]^+$, 155 (100) $[C_{11}H_7O]^+$, 141 (8) $[C_{11}H_9]^+$, 128 (7).

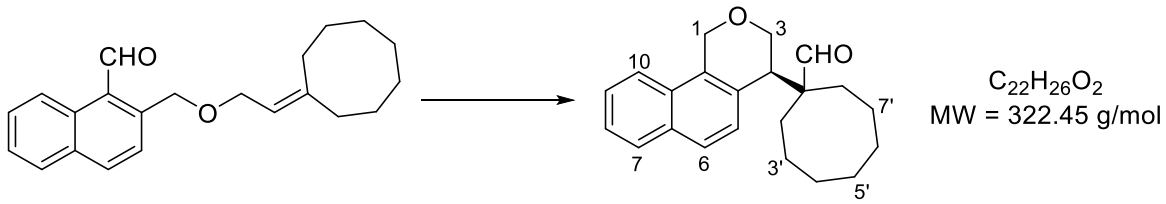
HRMS (EI, 70 eV): calcd for $C_{21}H_{24}O_2$ $[M]^+$: 308.1771; found: 308.1769.

calcd for $C_{20}{}^{13}CH_{24}O_2$ $[M]^+$: 309.1804; found: 309.1802.

Chiral HPLC: t_{R1} = 21.4 min, t_{R2} = 23.6 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +107 (c = 2.47, $CHCl_3$) [86% *ee*].

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclooctane-1-carbaldehyde (8j)



7j **8j**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7j** (32.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 2.2 mg of benzoisochromene product *rac*-**8j** (6.85 µmol, 7%) as a yellowish oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7j** (32.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 27.8 mg of benzoisochromene product **8j** (86.2 µmol, 86%, 90% *ee*) as a colourless solid.

M.p.: 140 °C.

TLC: R_f = 0.42 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3060 (w, sp^2-CH), 2920 (m, sp^3-CH), 2854 (m, sp^3-CH), 1715 (s, C=O), 1473 (w), 1113 (m, C–O–C), 818 (m, sp^2-CH), 749 (s, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.26 – 1.75 (m, 10 H, H-2'*, H-3'*, H-4'*, H-5'*), 1.82 – 1.94 (m, 3 H, *H*H-2', H-3'*), 2.15 – 2.21 (m, 1 H, H*H*-2'), 2.96 (*br* s, 1 H, H-4), 3.72 (dd, ^2J = 11.7 Hz, ^3J = 2.3 Hz, 1 H, *H*H-3), 4.40 (dd, ^2J = 11.7 Hz, ^3J = 1.1 Hz, 1 H, H*H*-3), 5.18 (d, ^2J = 15.8 Hz, 1 H, *H*H-1), 5.29 (d, ^2J = 15.8 Hz, 1 H, H*H*-1), 7.30 (d, ^3J = 8.5 Hz,

1 H, H-5), 7.48 – 7.53 (m, 2 H, H-8, H-9), 7.63 – 7.65 (m, 1 H, H-7), 7.69 (d, ^{3}J = 8.5 Hz, 1 H, H-6), 7.83 – 7.85 (m, 1 H, H-10), 9.41 (s, 1 H, CHO).

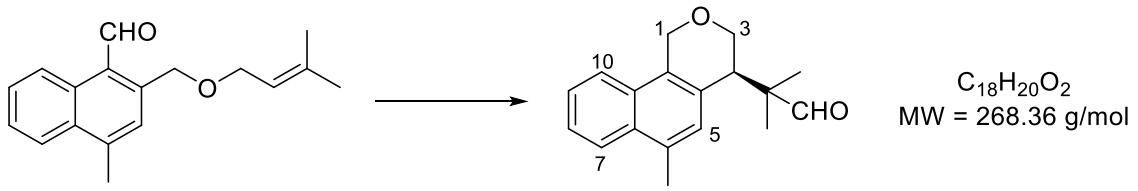
^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 22.6 (t, C-2'**, C-3'**), 25.2 (t, C-2'), 25.6 (t, C-3'**), 27.8 (t, C-4'**), 29.0 (t, C-4'**), 29.5 (t, C-5'**), 44.8 (d, C-4), 54.3 (s, C-1'), 65.5 (t, C-3), 66.6 (t, C-1), 121.7 (d, C-7), 126.0 (m, C-6, C-8***), 126.7 (d, C-9***), 128.8 (d, C-10), 129.0 (d, C-5), 129.1 (s, C-10a), 129.9 (s, C-6a), 131.2 (s, C-4a), 132.5 (s, C-10b), 205.3 (d, CHO).

*, **, *** assignment is interconvertible.

Chiral HPLC: t_{R1} = 22.2 min, t_{R2} = 24.1 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +134 (c = 2.20, $CHCl_3$) [90% *ee*].

(*R*)-2-Methyl-2-(6-methyl-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)propanal (8k)



7k **8k**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7k** (26.8 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 11.0 mg of benzoisochromene product *rac*-**8k** (41.0 µmol, 41%) as a colourless oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7k** (26.8 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 19.3 mg of benzoisochromene product **8k** (71.9 µmol, 72%, 87% *ee*) as a colourless solid.

M.p.: 110 °C.

TLC: R_f = 0.51 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3068 (w, sp^2-CH), 2972 (m, sp^3-CH), 2866 (w, sp^3-CH), 1722 (s, C=O), 1464 (w), 1119 (m, C–O–C), 808 (w, sp^2-CH), 754 (m, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.23 (s, 3 H, CH_3), 1.24 (s, 3 H, CH_3), 2.67 (d, ^4J = 0.6 Hz, 3 H, C-6-CH_3), 2.85 – 2.86 (m, 1 H, H-4), 3.78 (dd, ^2J = 11.8 Hz, ^3J = 2.7 Hz, 1 H, *H*H-3), 4.35 (dd, ^2J = 11.8 Hz, ^3J = 1.2 Hz, 1 H, H*H*-3), 5.14 (d, ^2J = 15.5 Hz, 1 H, *H*H-1), 5.29

(d, ^{2}J = 15.5 Hz, 1 H, H*H*-1), 7.06 (s, 1 H, H-5), 7.50 – 7.56 (m, 2 H, H-8, H-9), 7.65 – 7.67 (m, 1 H, H-7), 8.00 – 8.02 (m, 1 H, H-10), 9.60 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 19.6 (q, C-6-*C*H_3), 21.4 (q, CH_3), 22.2 (q, CH_3), 45.4 (d, C-4), 49.3 [s, *C*$(CH_3)_2$CHO], 65.8 (t, C-3), 66.2 (t, C-1), 122.2 (d, C-7), 125.0 (d, C-10), 125.9 (d, C-8), 126.3 (d, C-9), 128.2 (s, C-6a*), 129.4 (m, C-5, C-10a*), 130.6 (s, C-4a*), 131.9 (s, C-10b), 132.4 (s, C-6), 205.5 (d, CHO).

* assignment is interconvertible.

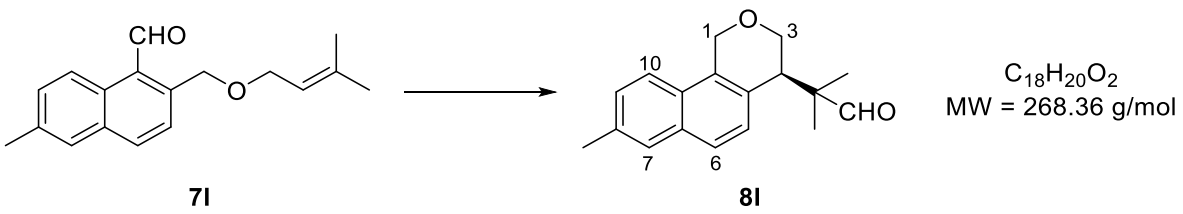
MS (EI, 70 eV): m/z (%) = 268 (4) $[M]^+$, 196 (75) $[C_{14}H_{12}O]^+$, 169 (100) $[C_{12}H_9O]^+$, 153 (18), 141 (5) $[C_{11}H_9]^+$, 128 (7).

HRMS (EI, 70 eV): calcd for $C_{18}H_{20}O_2$ $[M]^+$: 268.1458; found: 268.1461.

Chiral HPLC: t_{R1} = 17.4 min, t_{R2} = 19.9 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +115 (c = 1.73, $CHCl_3$) [87% *ee*].

(*R*)-2-Methyl-2-(8-methyl-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)propanal (8l)



7l **8l**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7l** (26.8 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 13.3 mg of benzoisochromene product *rac*-**8l** (49.5 µmol, 50%) as an off-white solid.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7l** (26.8 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 22.4 mg of benzoisochromene product **8l** (83.4 µmol, 83%, 84% *ee*) as a colourless solid.

M.p.: 90 °C.

TLC: R_f = 0.33 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 2973 (m, sp^3-CH), 2867 (m, sp^3-CH), 1721 (s, C=O), 1463 (w), 1117 (m, C–O–C), 817 (m, sp^2-CH), 763 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 300 K): δ [ppm] = 1.22 (s, 3 H, CH_3), 1.24 (s, 3 H, CH_3), 2.51 (s, 3 H, C-8-CH_3), 2.88 – 2.89 (m, 1 H, H-4), 3.80 (dd, ^2J = 11.7 Hz, ^3J = 2.8 Hz, 1 H, *H*H-3), 4.35 (dd, ^2J = 11.7 Hz, ^3J = 1.2 Hz, 1 H, H*H*-3), 5.14 (d, ^2J = 15.6 Hz, 1 H, *H*H-1), 5.29 (d, ^2J = 15.6 Hz, 1 H, H*H*-1), 7.19 (d, ^3J = 8.6 Hz, 1 H, H-5), 7.35 (dd, ^3J = 8.6 Hz, ^4J = 1.8 Hz,

1 H, H-9), 7.56 (d, ^{3}J = 8.6 Hz, 1 H, H-10), 7.59 (d, ^{3}J = 8.6 Hz, 1 H, H-6), 7.61 (s, 1 H, H-7), 9.59 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.4 (q, C-8-*C*H_3*), 21.7 (q, CH_3*), 22.1 (q, CH_3), 45.4 (d, C-4), 49.3 [s, *C*$(CH_3)_2$CHO], 65.8 (t, C-3), 66.3 (t, C-1), 121.6 (d, C-10), 125.6 (d, C-6), 127.3 (s, C-10a), 127.8 (d, C-7), 128.8 (d, C-5**), 129.4 (d, C-9**), 129.9 (s, C-4a***), 130.0 (s, C-6a***), 132.8 (s, C-10b), 135.7 (s, C-8), 205.4 (d, CHO).

*, **, *** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 268 (6) $[M]^+$, 196 (81) $[C_{15}H_{16}]^+$, 179 (10), 169 (100) $[C_{13}H_{13}]^+$, 153 (21), 128 (5) $[C_7H_{12}O_2]^+$.

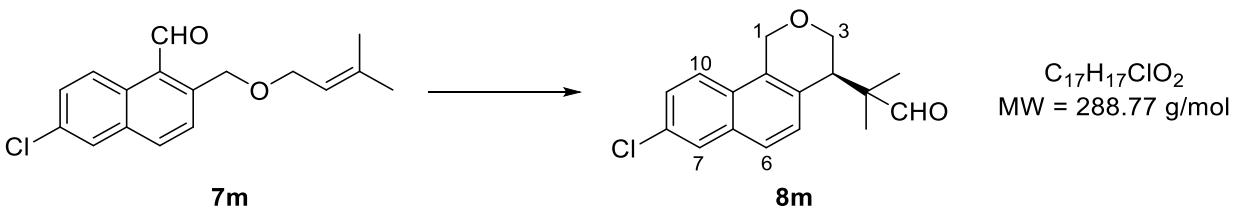
HRMS (EI, 70 eV): calcd for $C_{18}H_{20}O_2$ $[M]^+$: 268.1458; found: 268.1452.

calcd for $C_{17}{}^{13}CH_{20}O_2$ $[M]^+$: 269.1491; found: 269.1492.

Chiral HPLC: t_{R1} = 20.2 min, t_{R2} = 21.8 min, [Daicel, Chiralcel OD-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +77.3 (c = 2.43, $CHCl_3$) [84% *ee*].

(*R*)-2-(8-Chloro-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8m)



Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7m** (28.9 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 12.0 mg of benzoisochromene product *rac*-**8m** (41.6 µmol, 42%) as a yellowish oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7m** (28.9 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 24.3 mg of benzoisochromene product **8m** (84.2 µmol, 84%, 88% *ee*) as a colourless solid.

Single crystals were obtained by slow evaporation of diethyl ether (solvent) at 1 °C.

M.p.: 81 °C.

TLC: R_f = 0.47 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3059 (w, sp^2-CH), 2973 (m, sp^3-CH), 2857 (w, sp^3-CH), 1721 (s, C=O), 1465 (m), 1119 (m, C–O–C), 818 (m, sp^2-CH), 728 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.22 (s, 3 H, CH_3), 1.24 (s, 3 H, CH_3), 2.91 – 2.92 (m, 1 H, H-4), 3.79 (dd, ^2J = 11.8 Hz, ^3J = 2.7 Hz, 1 H, *H*H-3), 4.37 (dd, ^2J = 11.8 Hz, ^3J = 1.2 Hz, 1 H, H*H*-3), 5.12 (d, ^2J = 15.8 Hz, 1 H, *H*H-1), 5.27 (d, ^2J = 15.8 Hz,

1 H, H*H*-1), 7.24 (d, ^{3}J = 8.9 Hz, 1 H, H-5), 7.45 (dd, ^{3}J = 9.0 Hz, ^{4}J = 2.2 Hz, 1 H, H-9), 7.58 – 7.61 (m, 2 H, H-6, H-10), 7.82 (d, ^{4}J = 2.2 Hz, 1 H, H-7), 9.59 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.5 (q, CH_3), 22.1 (q, CH_3), 45.2 (d, C-4), 49.3 [s, *C*$(CH_3)_2$CHO], 65.7 (t, C-3), 66.0 (t, C-1), 123.4 (d, C-6*), 125.4 (d, C-10*), 127.4 (d, C-7**), 127.5 (m, C-9**, C-10a), 129.8 (d, C-5), 130.4 (s, C-6a***), 131.4 (s, C-4a), 131.9 (s, C-8***), 133.3 (s, C-10b***), 205.2 (d, CHO).

*, **, *** assignment is interconvertible.

MS (EI, 70 eV): m/z (%) = 288 (2) $[M(^{35}Cl)]^+$, 218 (29) $[C_{13}H_9{}^{37}Cl]^+$, 216 (84) $[C_{13}H_9{}^{35}Cl]^+$, 191 (55) $[C_{12}H_{10}{}^{37}Cl]^+$, 189 (100) $[C_{12}H_{10}{}^{35}Cl]^+$, 179 (10), 153 (27), 127 (3) $[C_{10}H_7]^+$.

HRMS (EI, 70 eV): calcd for $C_{17}H_{17}O_2{}^{35}Cl$ $[M]^+$: 288.0912; found: 288.0908.

calcd for $C_{16}{}^{13}CH_{17}O_2{}^{35}Cl$ $[M]^+$: 289.0945; found: 289.0940.

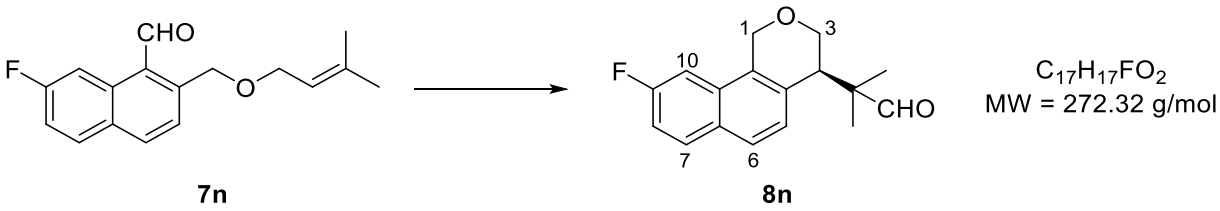
calcd for $C_{17}H_{17}O_2{}^{37}Cl$ $[M]^+$: 290.0882; found: 290.0883.

calcd for $C_{16}{}^{13}CH_{17}O_2{}^{37}Cl$ $[M]^+$: 291.0916; found: 291.0920.

Chiral HPLC: t_{R1} = 19.3 min, t_{R2} = 21.6 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

Specific Rotation: $[\alpha]_D^{25}$ = +45.2 (c = 3.50, $CHCl_3$) [88% *ee*].

(*R*)-2-(9-Fluoro-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8n)



7n **8n**

Racemic photocycloaddition/rearrangement reaction

Following GP10, 1-naphthaldehyde **7n** (27.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane and the solution was irradiated at −78 °C after addition of aluminium bromide solution. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 4.6 mg of benzoisochromene product *rac*-**8n** (16.9 µmol, 17%) as a colourless oil.

Enantioselective photocycloaddition/rearrangement reaction

Following GP11, 1-naphthaldehyde **7n** (27.2 mg, 100 µmol, 1.00 eq.) was dissolved in dichloromethane. The activated oxazaborolidine catalyst solution was transferred to the reaction mixture and the solution was irradiated at −78 °C. Following complete rearrangement at 0 °C, the Lewis acid was quenched by the addition of triethylamine. Purification by column chromatography (silica, P/EtOAc = 20/1) gave 25.2 mg of benzoisochromene product **8n** (92.5 µmol, 93%, 84% *ee*) as a colourless solid.

M.p.: 106 °C.

TLC: R_f = 0.37 (P/EtOAc = 10/1) [UV, $KMnO_4$, CAM].

IR (ATR): $\tilde{\nu}$ [cm^{-1}] = 3069 (w, sp^2-CH), 2973 (m, sp^3-CH), 2870 (m, sp^3-CH), 1720 (s, C=O), 1632 (m, C=C), 1517 (m), 1195 (s, C–F), 1096 (m, C–O–C), 841 (m, sp^2-CH), 715 (w, sp^2-CH).

^{1}H NMR (500 MHz, $CDCl_3$, 298 K): δ [ppm] = 1.22 (s, 3 H, CH_3), 1.24 (s, 3 H, CH_3), 2.92 – 2.93 (m, 1 H, H-4), 3.80 (dd, ^2J = 11.8 Hz, ^3J = 2.7 Hz, 1 H, *H*H-3), 4.37 (dd, ^2J = 11.8 Hz, ^3J = 1.2 Hz, 1 H, H*H*-3), 5.06 (d, ^2J = 15.6 Hz, 1 H, *H*H-1), 5.20 (d, ^2J = 15.6 Hz,

1 H, H*H*-1), 7.19 (d, ^{3}J = 8.5 Hz, 1 H, H-5), 7.20 – 7.29 (m, 2 H, H-8, H-10), 7.67 (dd, ^{3}J = 8.5 Hz, ^{4}J = 1.0 Hz, 1 H, H-6), 7.81 – 7.85 (m, 1 H, H-7), 9.60 (s, 1 H, CHO).

^{13}C NMR (126 MHz, $CDCl_3$, 300 K): δ [ppm] = 21.5 (q, CH_3), 22.1 (q, CH_3), 45.1 (d, C-4), 49.3 [s, *C*$(CH_3)_2$CHO], 65.7 (t, C-3), 66.0 (t, C-1), 105.8 (dd, $^{2}J_{CF}$ = 21.3 Hz, C-8), 116.2 (dd, $^{2}J_{CF}$ = 25.0 Hz, C-10), 126.1 (d, C-6), 128.0 (d, C-5), 129.5 (s, C-6a*), 129.6 (d, J_{CF} = 5.6 Hz, C-10b*), 130.0 (d, $^{3}J_{CF}$ = 8.8 Hz, C-10a), 131.2 (d, $^{3}J_{CF}$ = 9.2 Hz, C-7), 132.2 (s, C-4a), 133.3 (d, $^{1}J_{CF}$ = 246.8 Hz, C-9), 205.2 (d, CHO).

^{19}F NMR (471 MHz, $CDCl_3$, 300 K): δ [ppm] = –112.3 – –112.2 (m, 1 F, C-7-F).

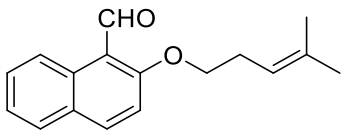
* assignment is interconvertible.

Chiral HPLC: t_{R1} = 16.4 min, t_{R2} = 19.2 min, [Daicel, Chiralcel OJ-RH, 150 x 4,6 mm, 5 µm, 20 °C, 20% MeCN/H_2O (0 min) → 100% MeCN (30 min), 1 mL/min, 215 nm].

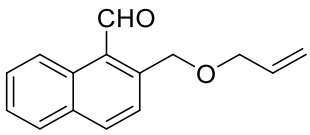
Specific Rotation: $[\alpha]_D^{25}$ = +83.5 (c = 2.83, $CHCl_3$) [84% *ee*].

Unsuccessful substrates:

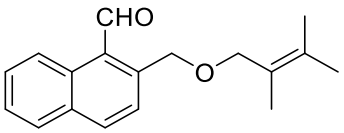
Following, a selection of substrates (**13**) which did not show the desired reactivity under racemic and/or enantioselective photocycloaddition/rearrangement conditions (GP10 and/or GP11) is given. Substrates **13a** – **13d** have no reactivity under standard conditions. ^{1}H NMR experiments of the crude products show no product formation. Only starting material could be re-isolated. Substrate **13e** shows reactivity under standard conditions. However a complex mixture of products was formed and no products was isolated which was structurally related to structure **8** or **9**.



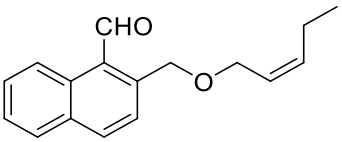
13a



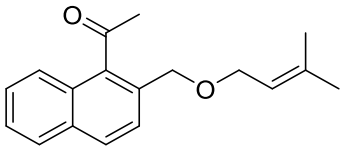
13b



13c



13d



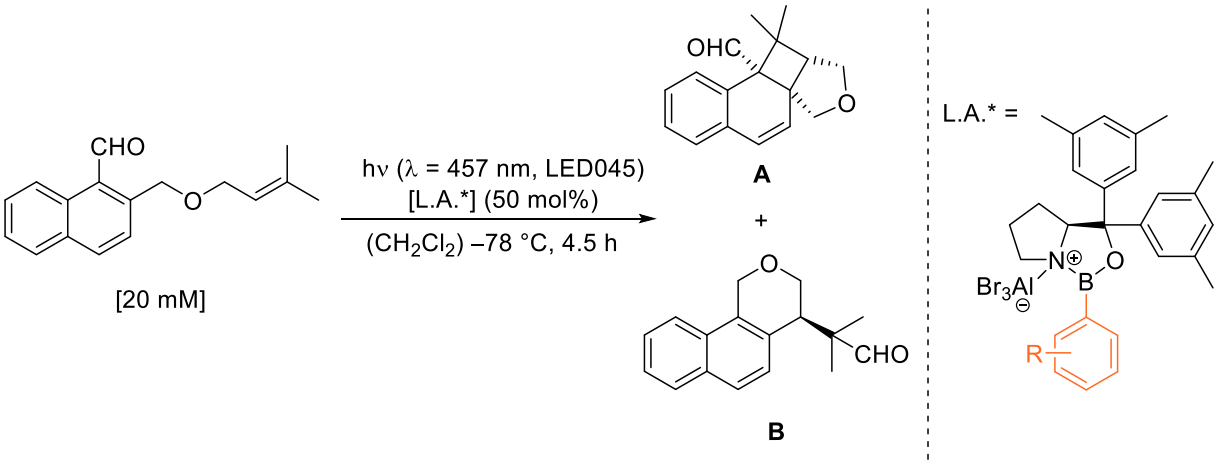
13e

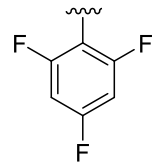
5. Optimisation of the reaction conditions

Optimisation of the chiral Lewis acid:

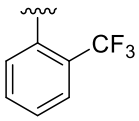
Different Lewis acids were tested to optimize the conversion and yield as well as the enantiophase differentiation.

In a first set of experiments, the influence of the boron substituent of oxazaborolidines was tested.

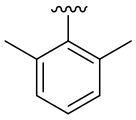




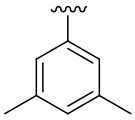
low conversion
(<10%)



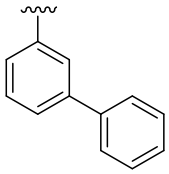
low conversion
(<10%)



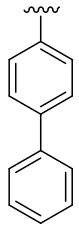
full conversion
88% (**A**:**B** = 23:77)
A: 90% *ee*
B: 89% *ee*



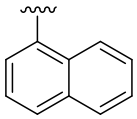
27% rsm
42% (**A**:**B** = 10:90)
A: "94% *ee*"
B: 78% *ee*



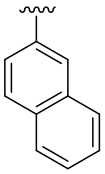
low conversion
(<10%)



61% rsm
23% (**A**:**B** = 10:90)
A: 75% *ee*
B: 70% *ee*

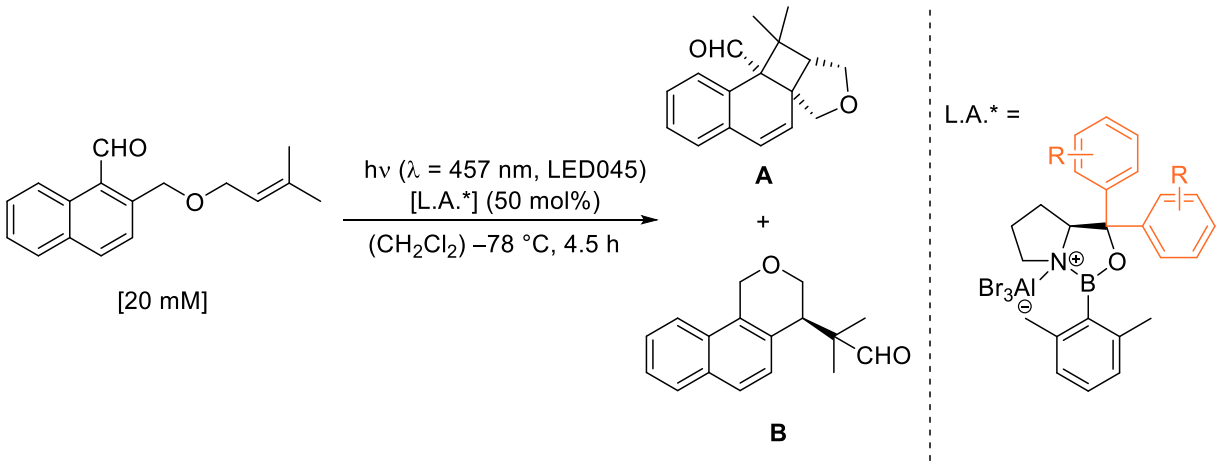


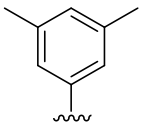
36% rsm
47% (**A**:**B** = 39:61)
A: 96% *ee*
B: 85% *ee*



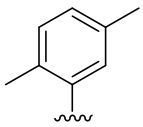
70% rsm
10% (**A**:**B** = 16:86)

In a second experiment, the substituent on the prolinol was optimized.

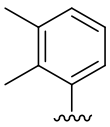




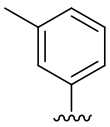
full conversion
88% (**A**:**B** = 23:77)
A: 90% *ee*
B: 89% *ee*



full conversion
91% (**A**:**B** = 21:79)
A: 78% *ee*
B: 79% *ee*

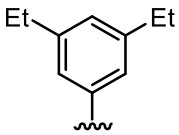


full conversion
86% (**A**:**B** = 24:76)
A: 67% *ee*
B: 65% *ee*

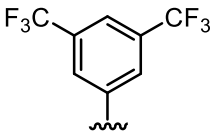


full conversion
92% (only **B**)

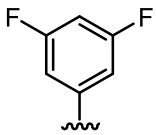
B: 79% *ee*



full conversion
88% (**A**:**B** = 27:73)
A: 76% *ee*
B: 74% *ee*

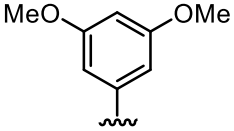


full conversion
92% (**A**:**B** = 45:55)
A: 68% *ee*
B: 54% *ee*

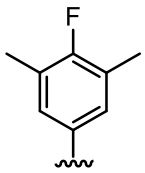


full conversion
87% (only **B**)

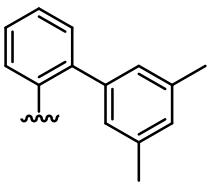
B: 54% *ee*



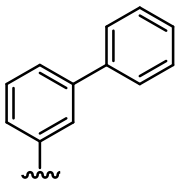
low conversion
crude NMR:
sm:**A**:**B** = 83:7:10



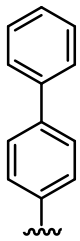
full conversion
94% (**A**:**B** = 29:71)
A: 78% *ee*
B: 80% *ee*



full conversion
90% (**A**:**B** = 24:76)
A: 39% *ee*
B: 37% *ee*

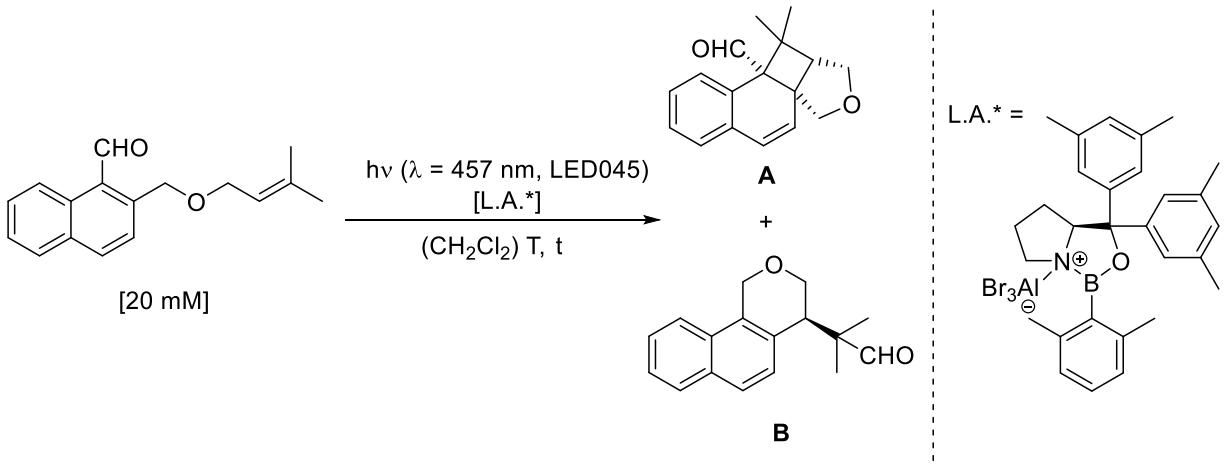


full conversion
84% (**A**:**B** = 41:59)
A: 74% *ee*
B: 73% *ee*



full conversion
92% (**A**:**B** = 31:69)
A: 63% *ee*
B: 65% *ee*

Additional screening experiments:



a) With 50 mol% L.A.*: Irradiation at –78°C for 4.5 hours, then warming to 0 °C for 0.5 hours w/o irradiation – full rearrangement, product **B** as the only product, 88% yield, 89% *ee*.

b) w/o Lewis acid: no product formation after irradiation for 4.5 hours at –78 °C according to crude ^{1}H NMR.

c) Lower catalyst loading (25 mol%): Irradiation at –78°C for 12 hours, then warming to 0 °C for 0.5 hours w/o irradiation – full rearrangement, product **B** as the only product, 86% yield, 83% *ee.*

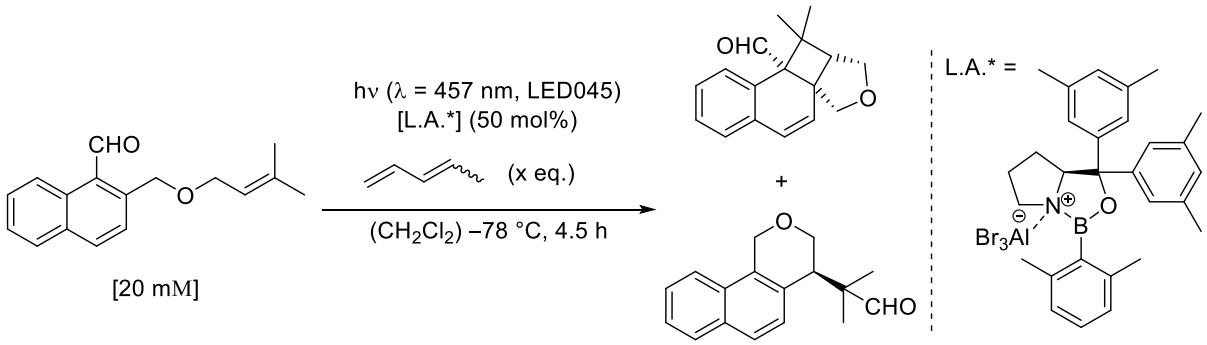
d) Lower catalyst loading (10 mol%): Irradiation at –78°C for 24 hours, then warming to 0 °C for 1.0 hours w/o irradiation – full rearrangement, product **B** as the only product, 79% yield, 73% *ee.*

6. Kinetic resolution during thermal rearrangement

The thermal rearrangement of *ortho* photocycloaddition product *rac*-**9a** to benzoisochromene *rac*-**8a** after addition of chiral Lewis acid **12d** was tested. This experiment was done to check, if kinetic resolution is partially responsible for the observed enantioselectivity.

#	conditions	ratio (9a/8a)	yield (9a+8a)	*ee*(9a), *ee*(8a)
1	–78 °C, 1 h	64/36	90%	3%, –10%
2	–78 °C, 3 h	61/39	86%	3%, –11%
3	–78 °C, 4.5 h	53/47	84%	3%, –7%
4	–78 °C, 4.5 h + 0 °C, 30 min.	0/100	83%	--, 0%

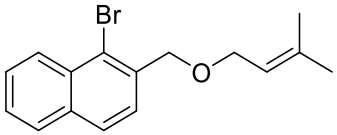
7. Qualitative triplet quenching experiments



#	piperylene (eq.)	yield sm	yield products (ratio ortho product : rearranged Product)	comment
1	5.0	n.d.	0	w/o light, no product formation (crude NMR)
2	0	0	85% (66:34)	--
3	2.5	46%	34% (57:43)	--
4	5.0	55%	23% (69:31)	--

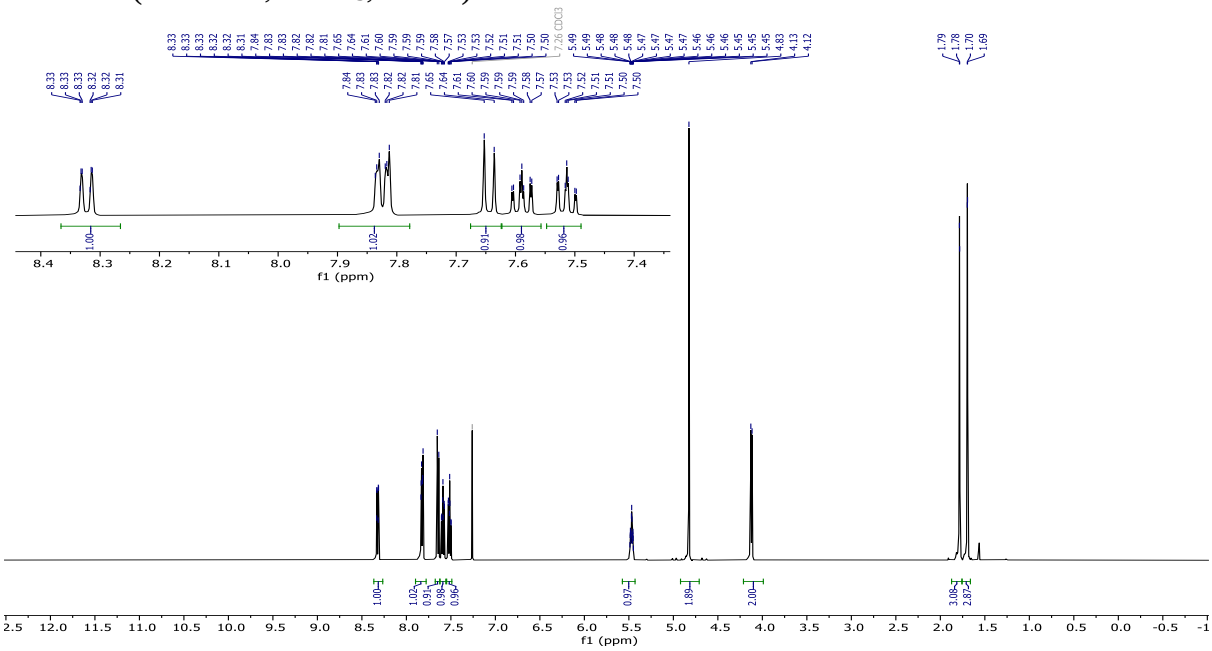
8. NMR spectra of new compounds

1-Bromo-2-{[(3'-methylbut-2'-en-1-yl)oxy]methyl} (S3)

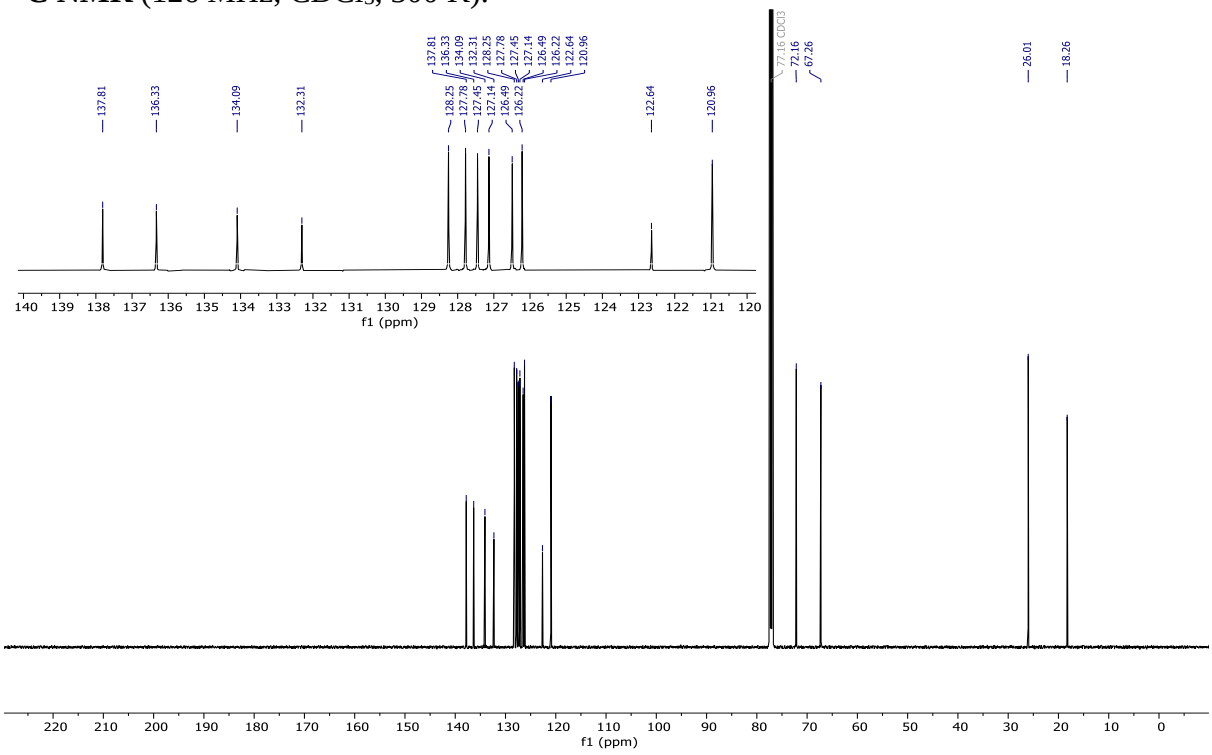


S3

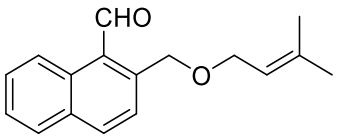
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

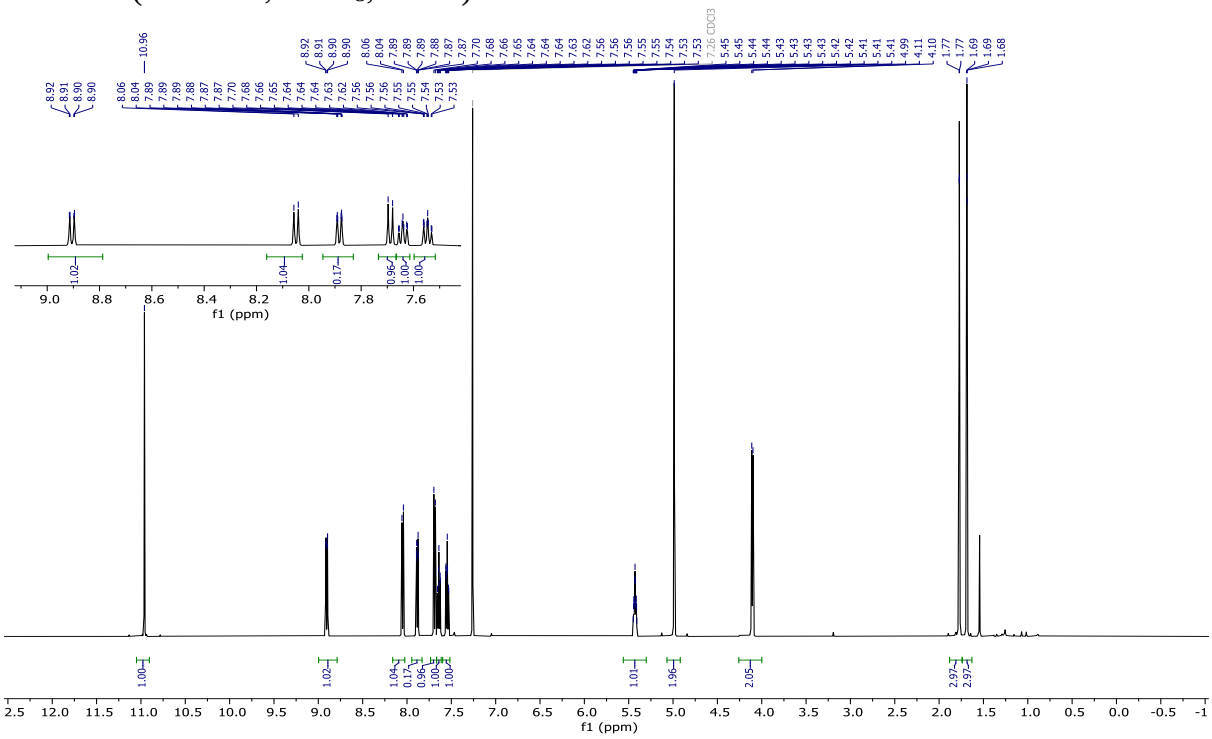


2-{[(3’-Methylbut-2’-en-1’-yl)oxy]methyl}-1-naphthaldehyde (7a)

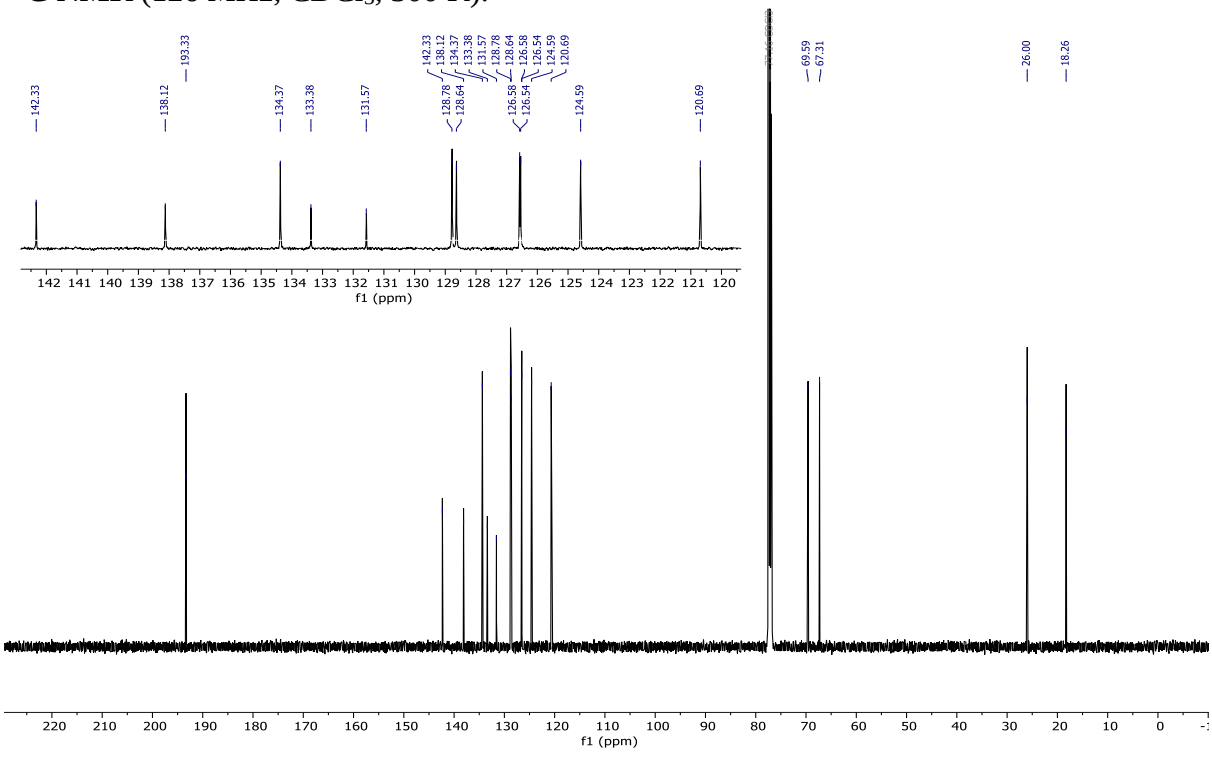


7a

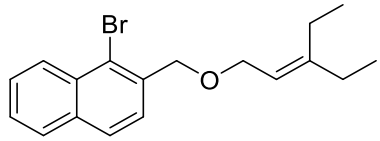
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

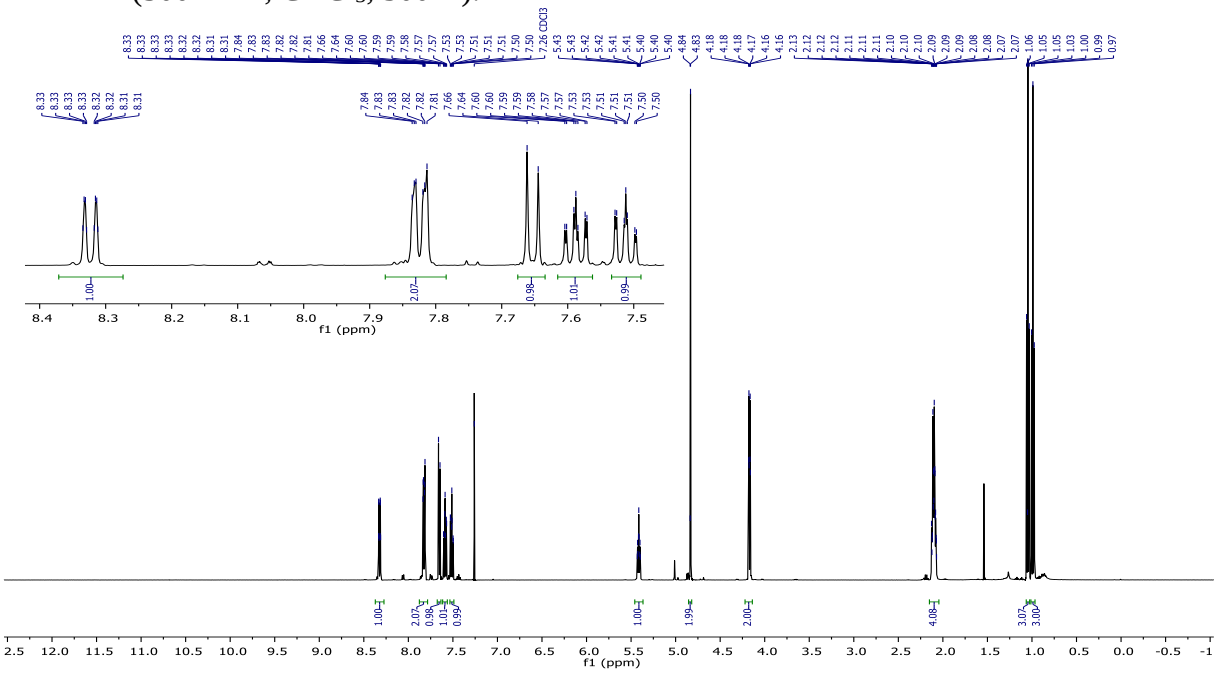


1-Bromo-2-{[(3-ethylpent-2-en-1-yl)oxy]methyl}naphthalene (S7)

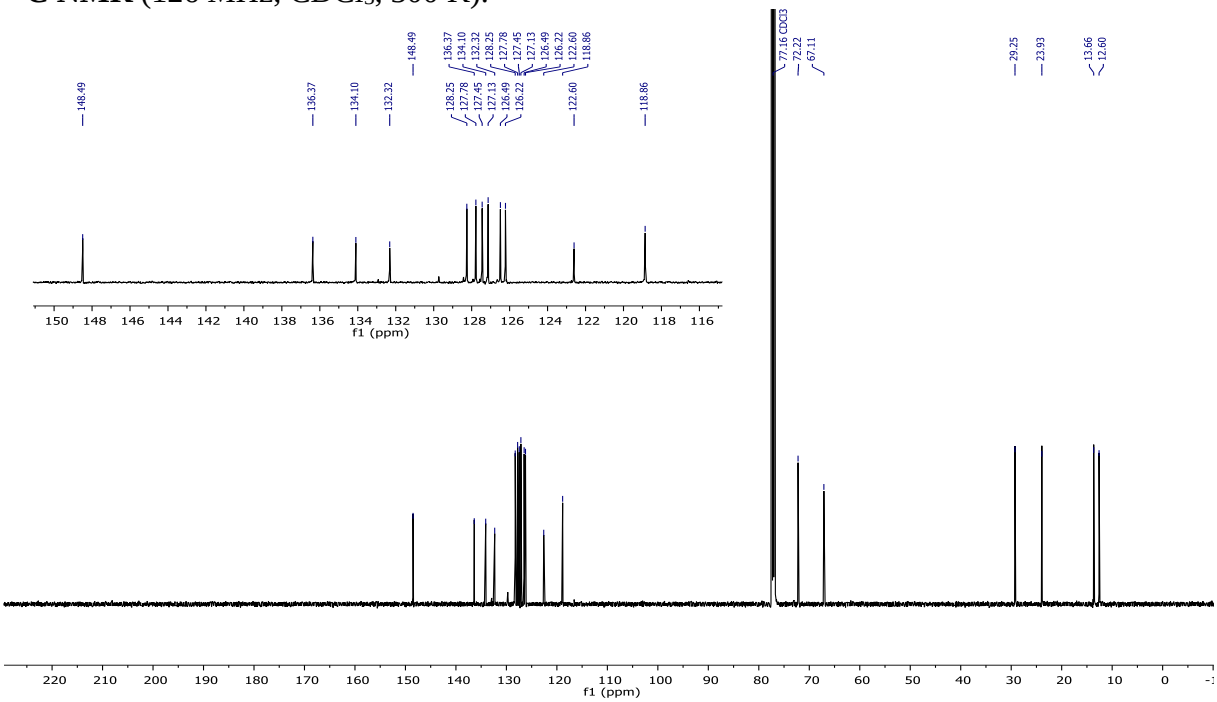


S7

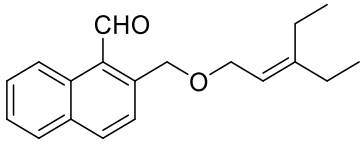
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

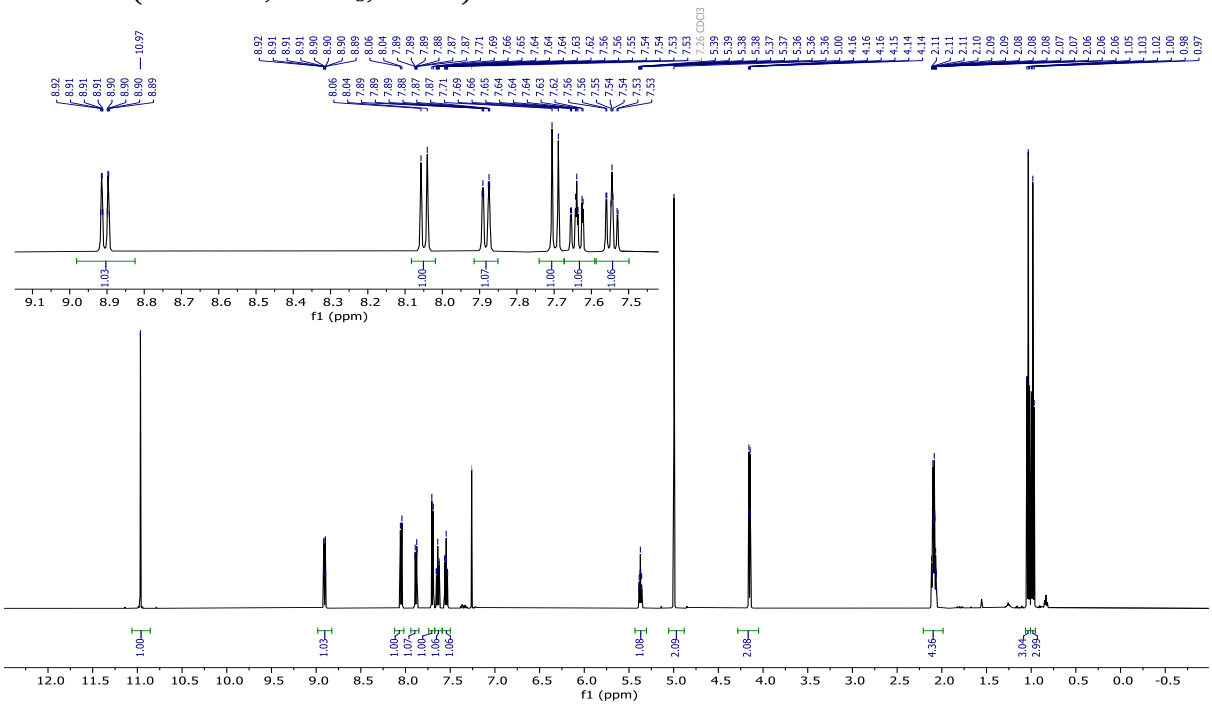


2-{[(3-Ethylpent-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7b)

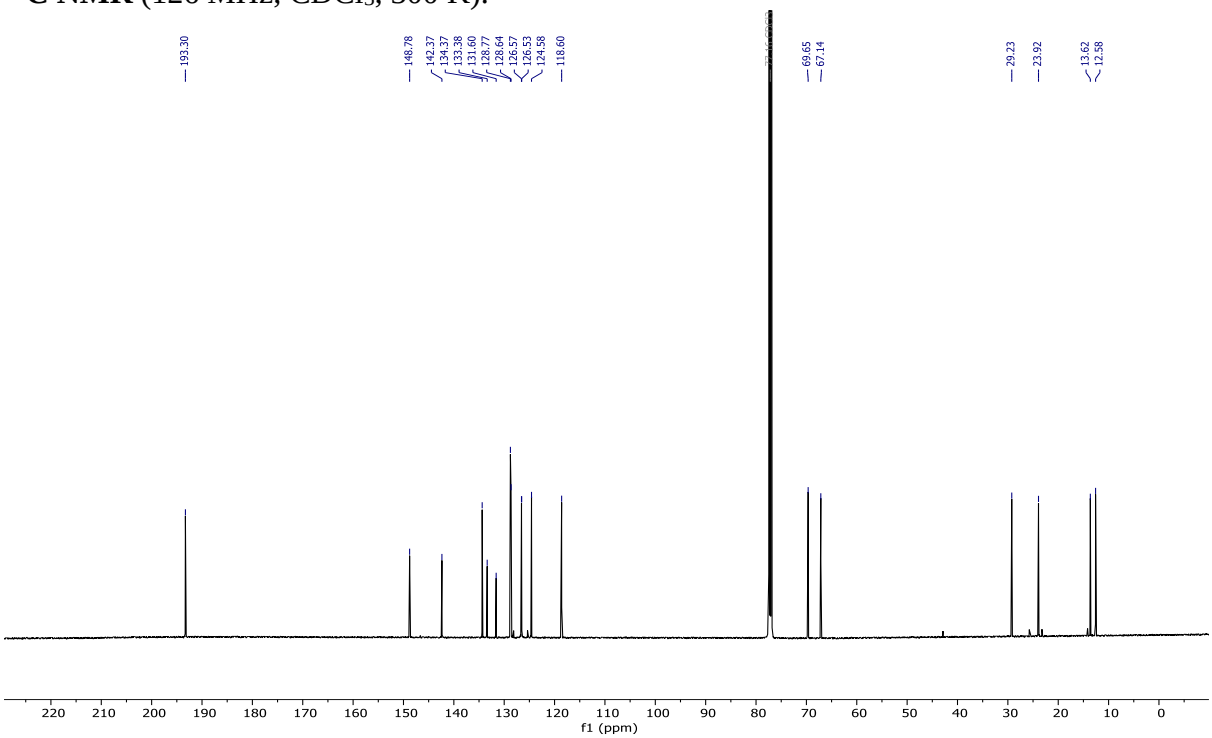


7b

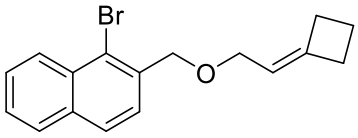
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

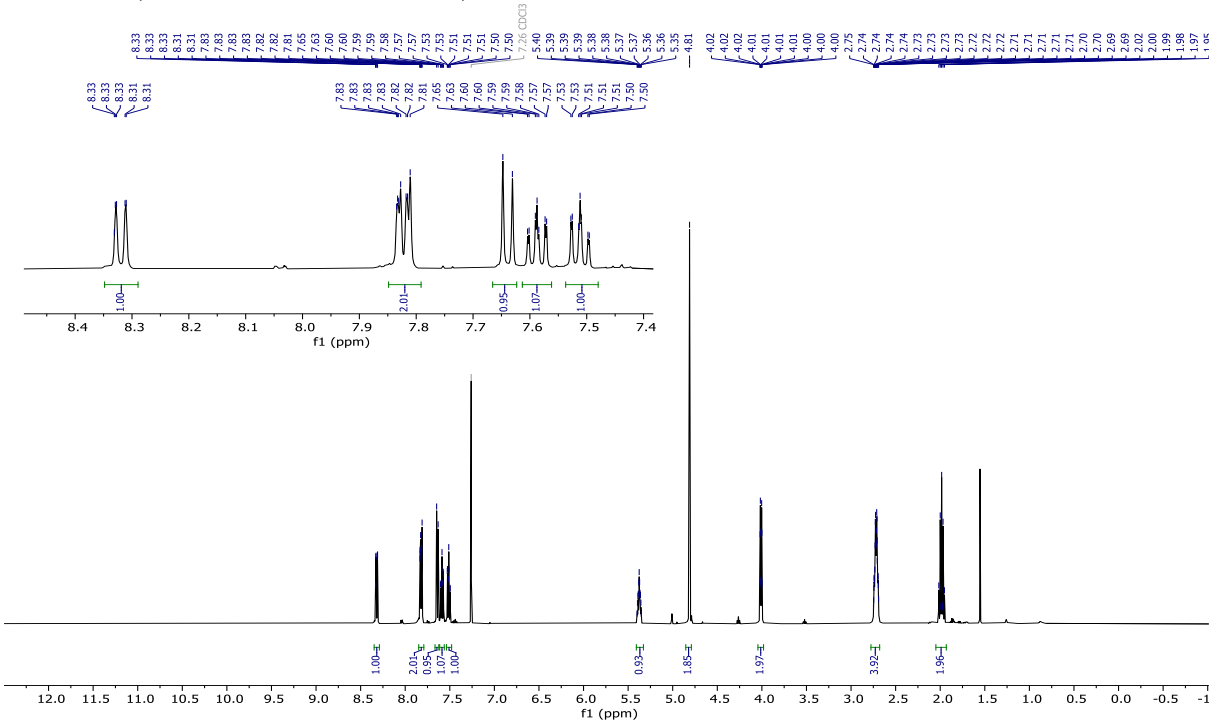


1-Bromo-2-[(2-cyclobutylideneethoxy)methyl]naphthalene (S11)

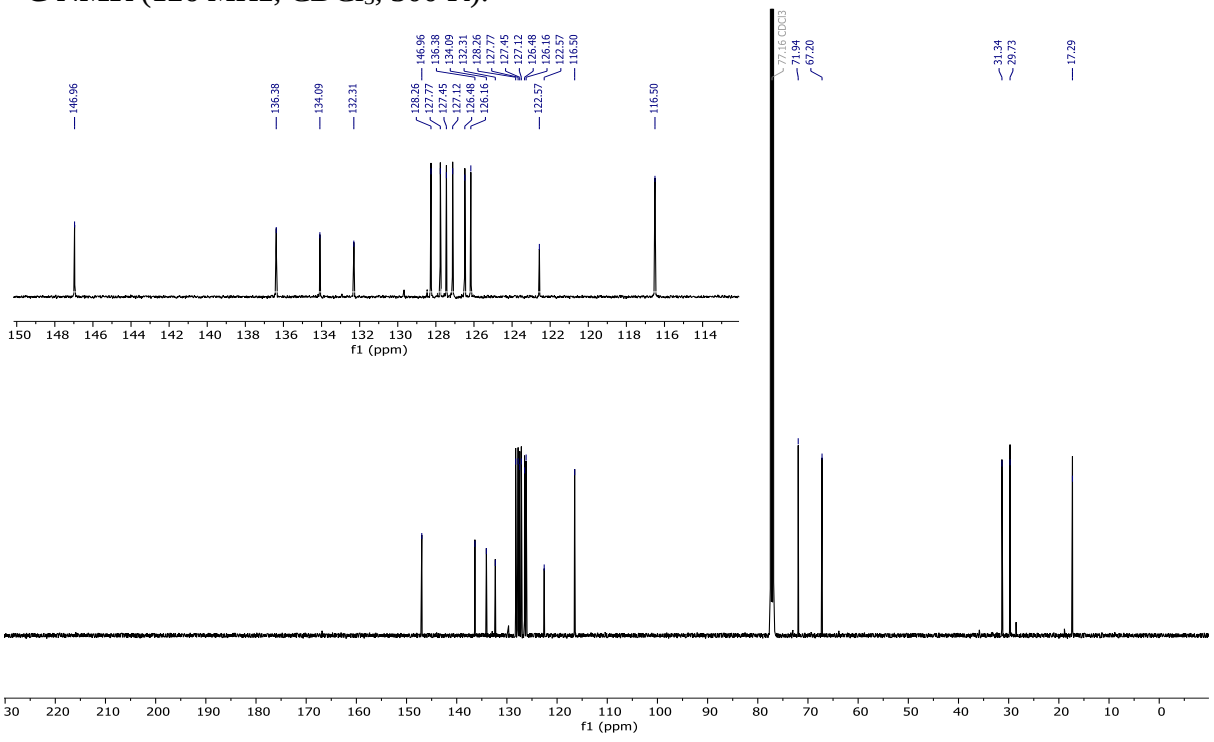


S11

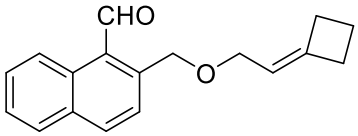
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

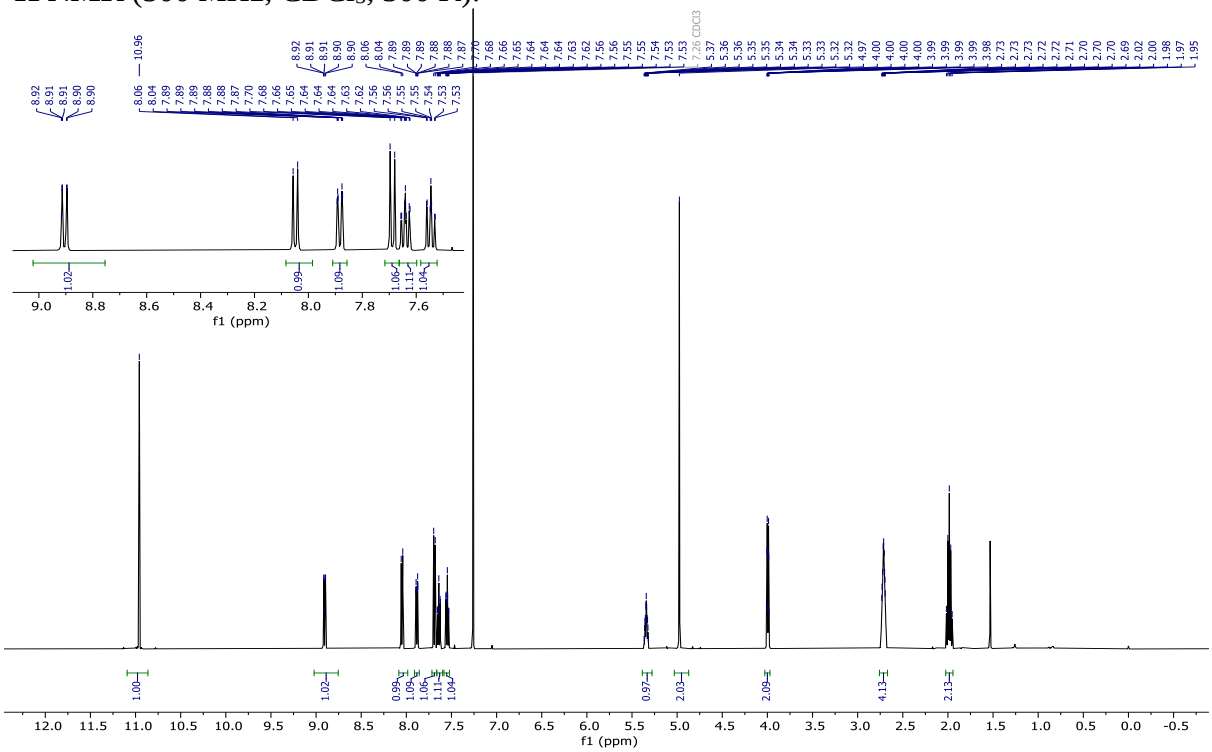


2-[(2-Cyclobutylideneethoxy)methyl]-1-naphthaldehyde (7c)

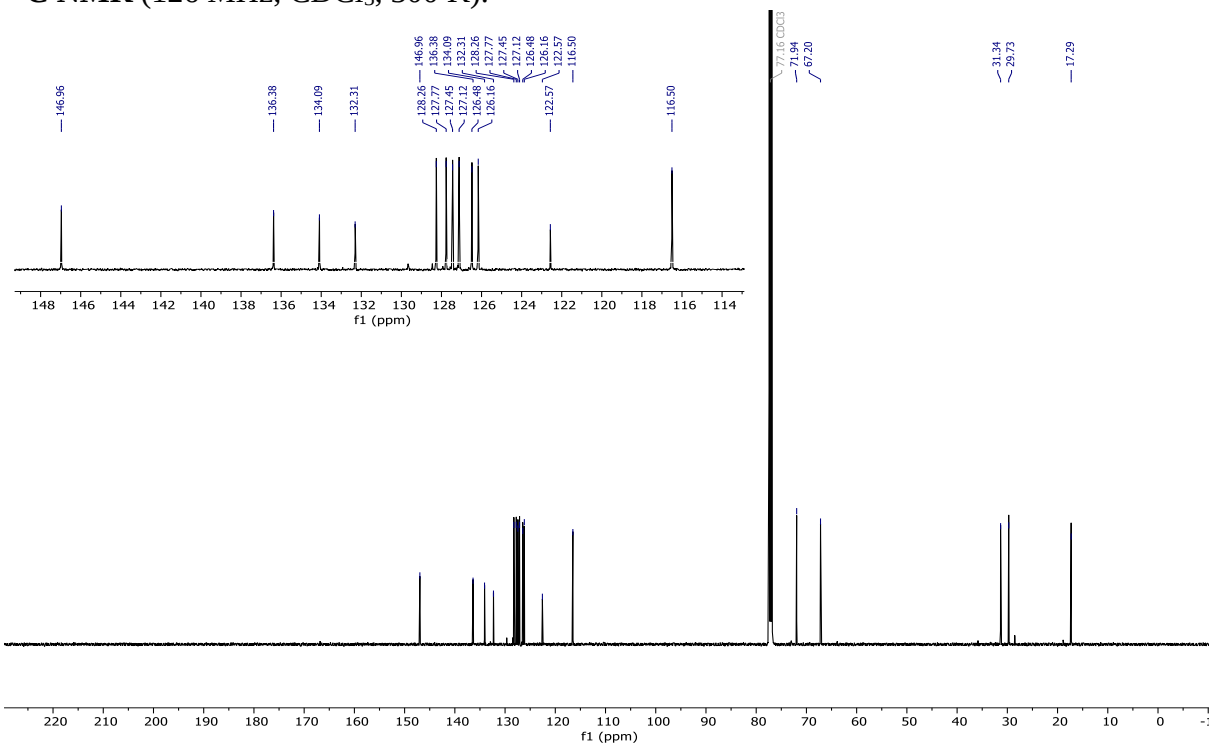


7c

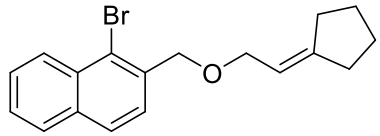
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

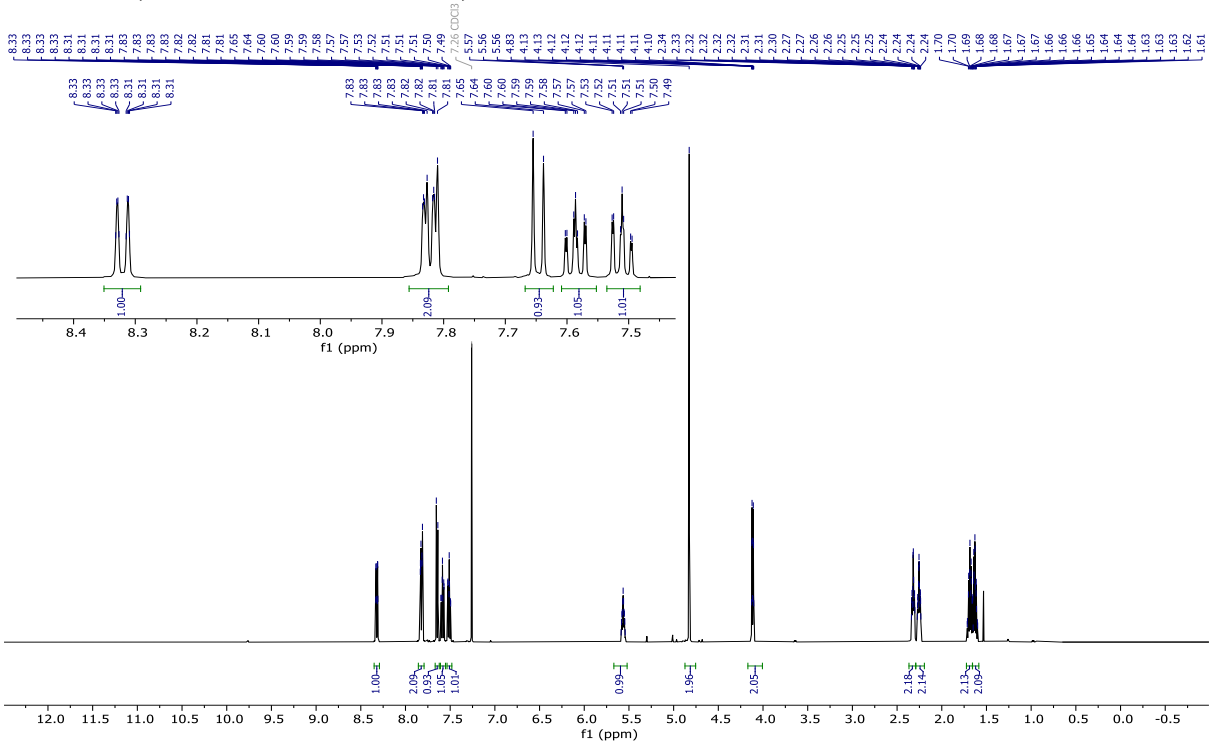


1-Bromo-2-[(2-cyclopentylideneethoxy)methyl]naphthalene (S15)

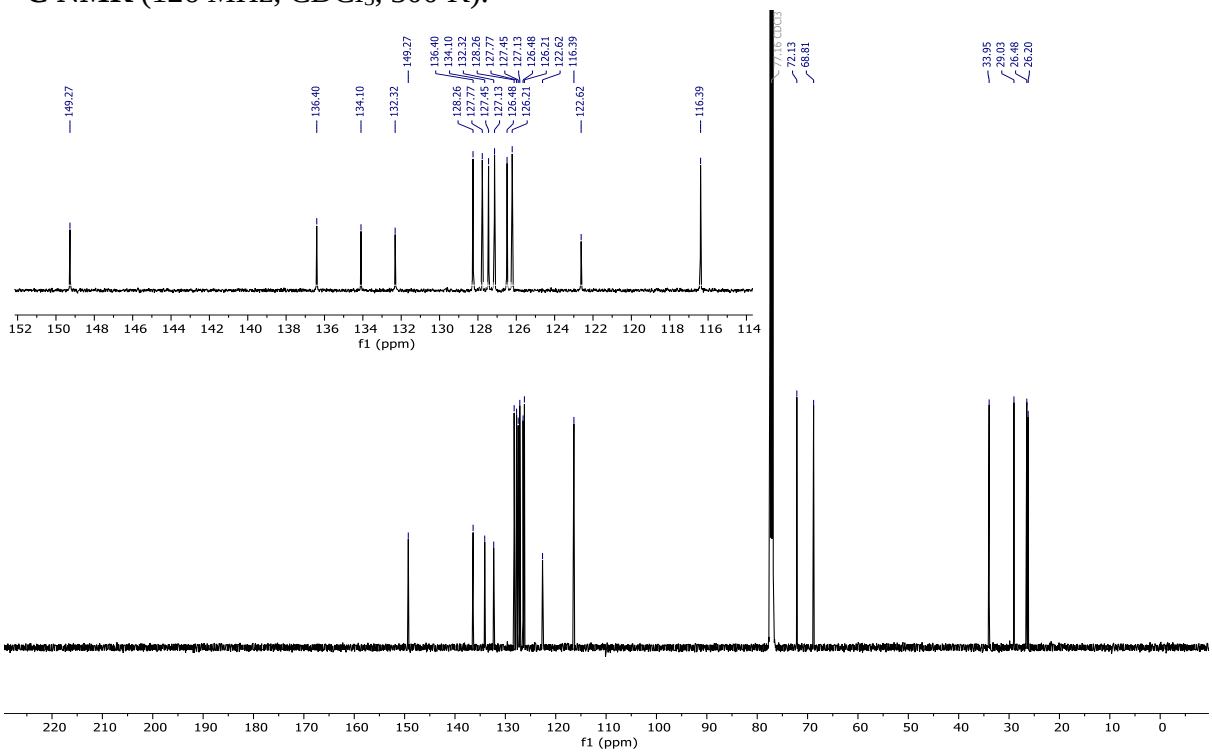


S15

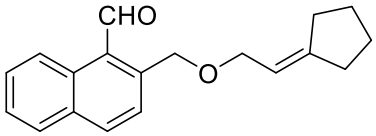
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

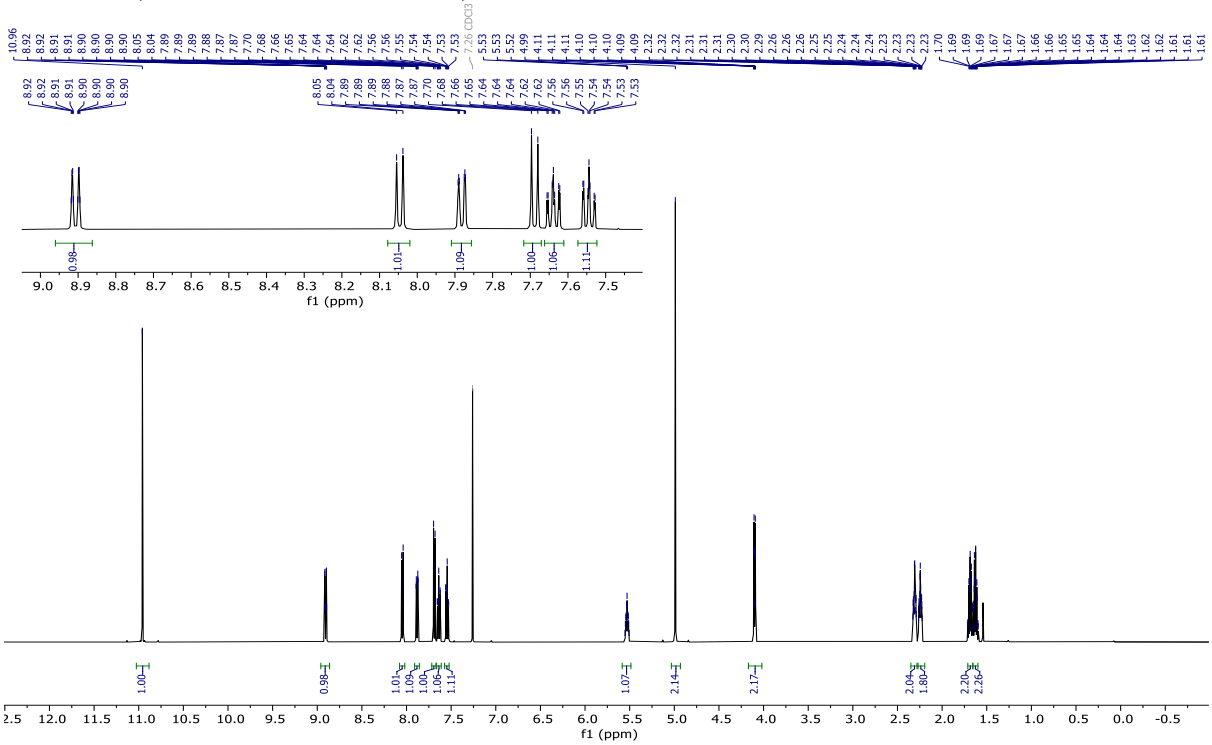


2-[(2-Cyclopentylideneethoxy)methyl]-1-naphthaldehyde (7d)

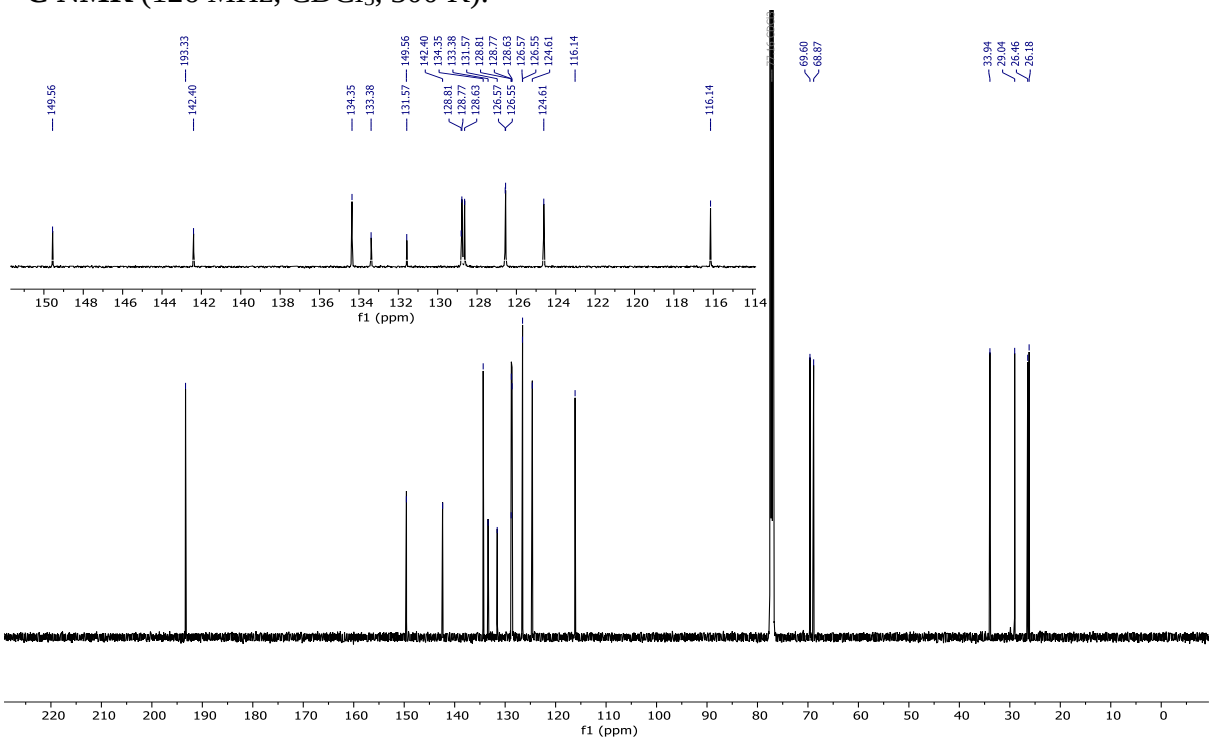


7d

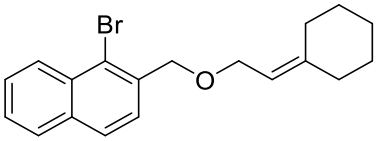
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

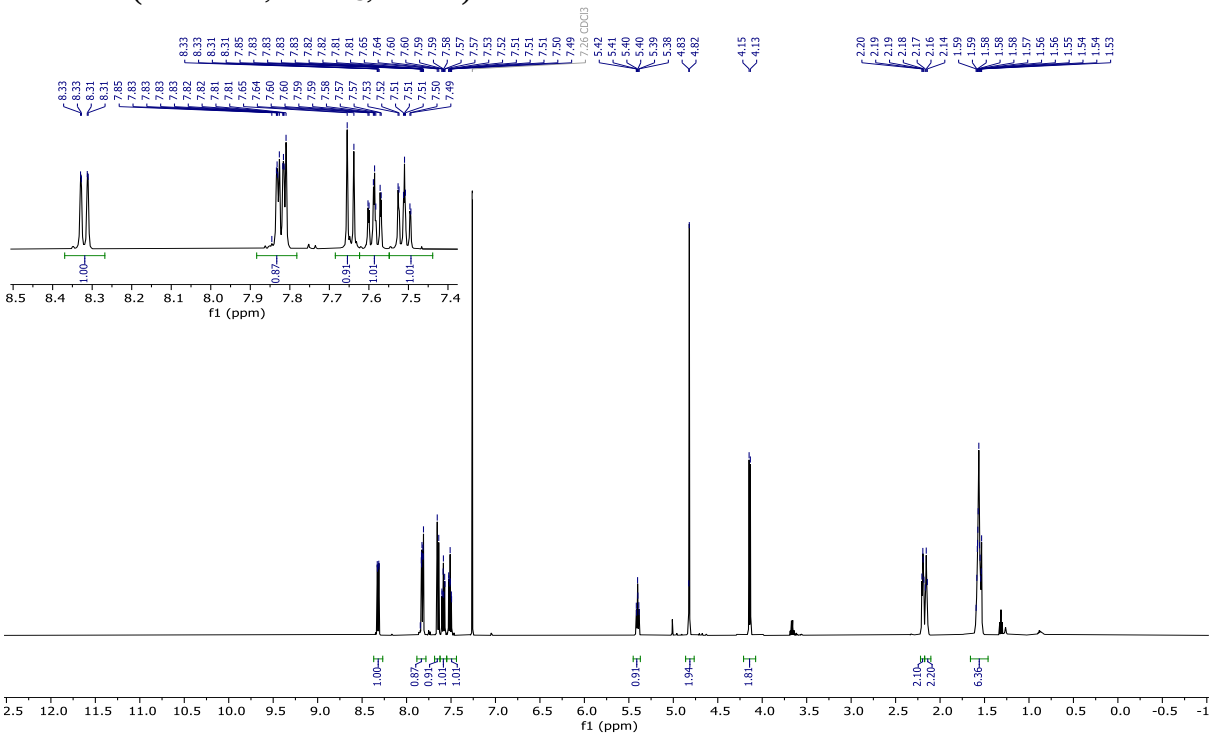


1-Bromo-2-[(2-cyclohexylideneethoxy)methyl]naphthalene (S19)

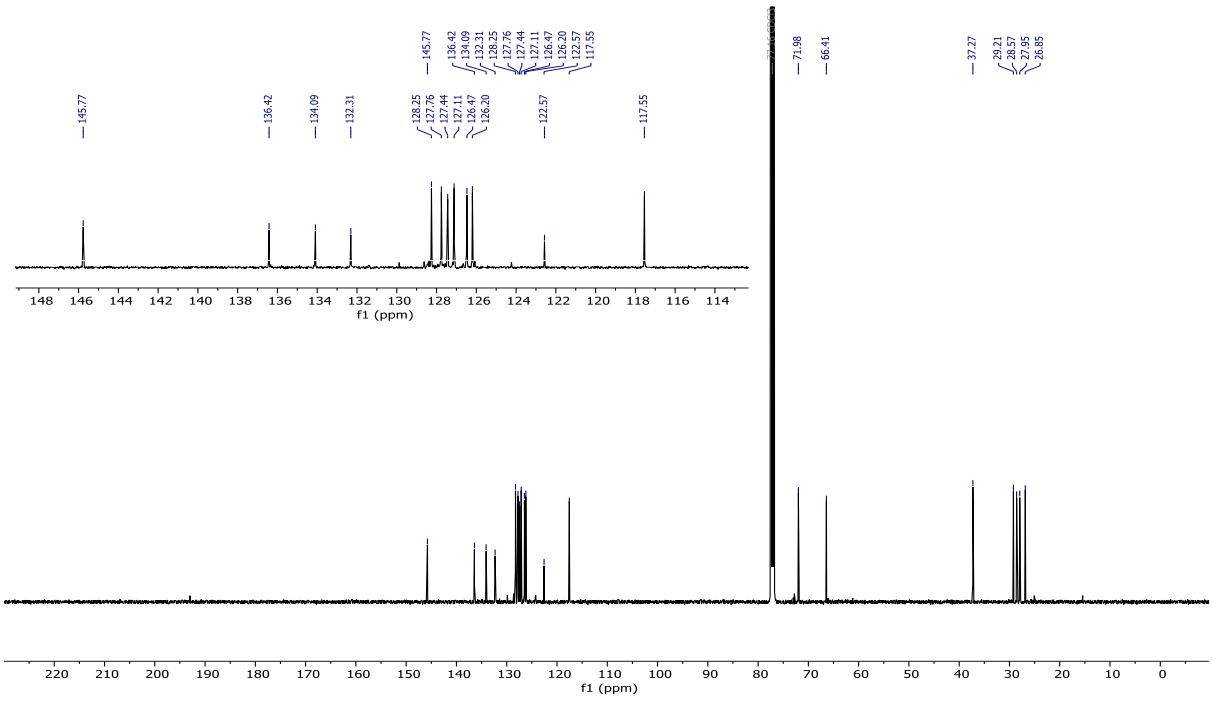


S19

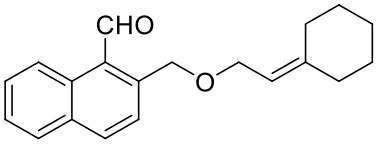
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

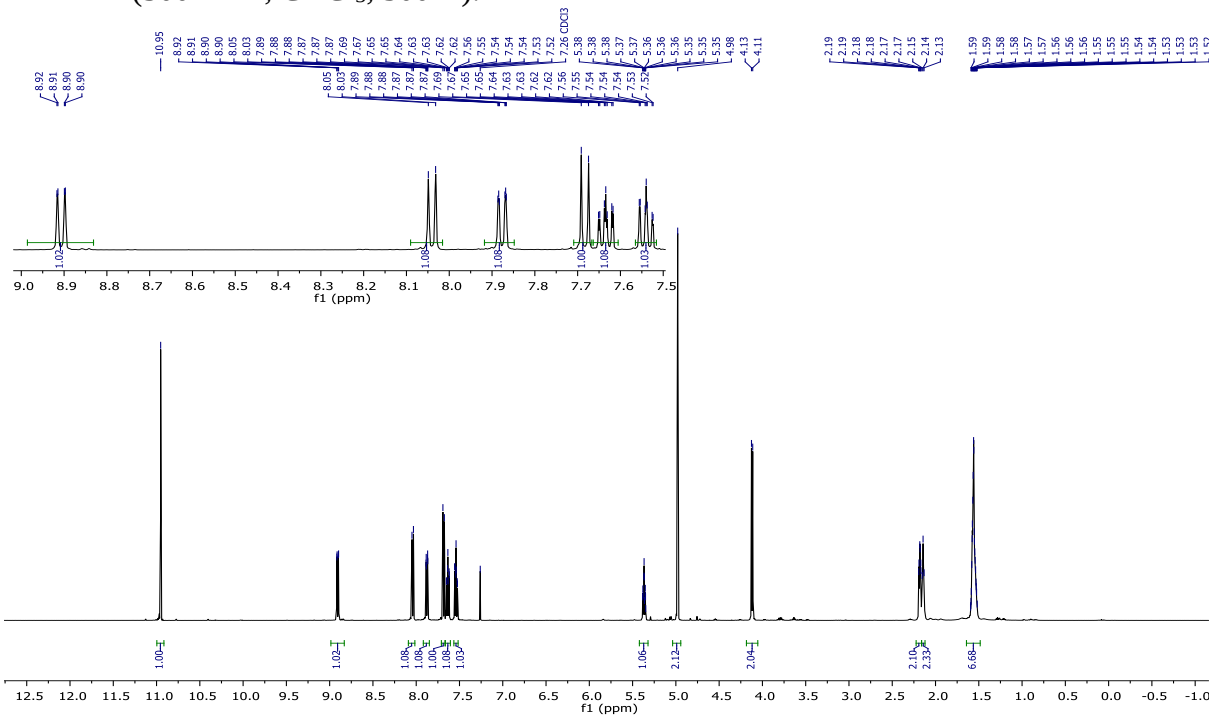


2-[(2-Cyclohexylideneethoxy)methyl]-1-naphthaldehyde (7e)

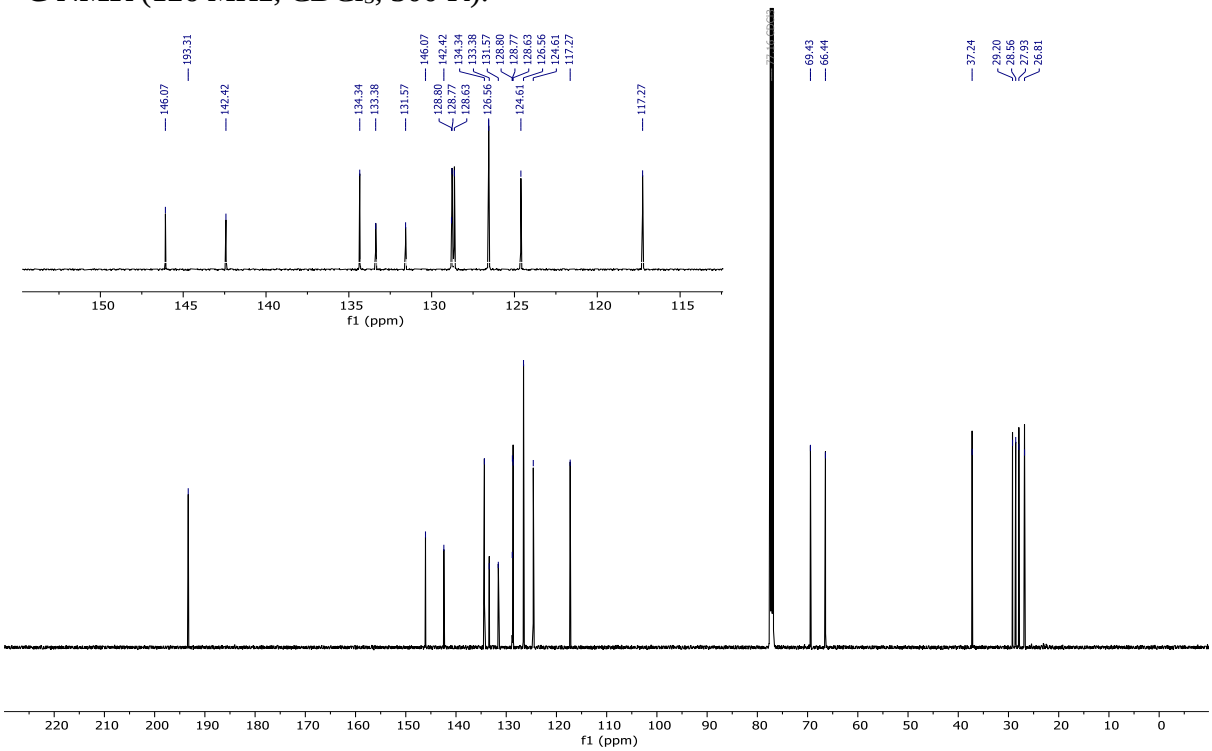


7e

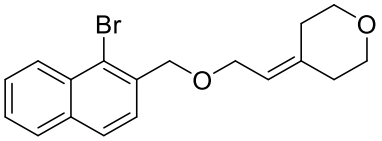
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

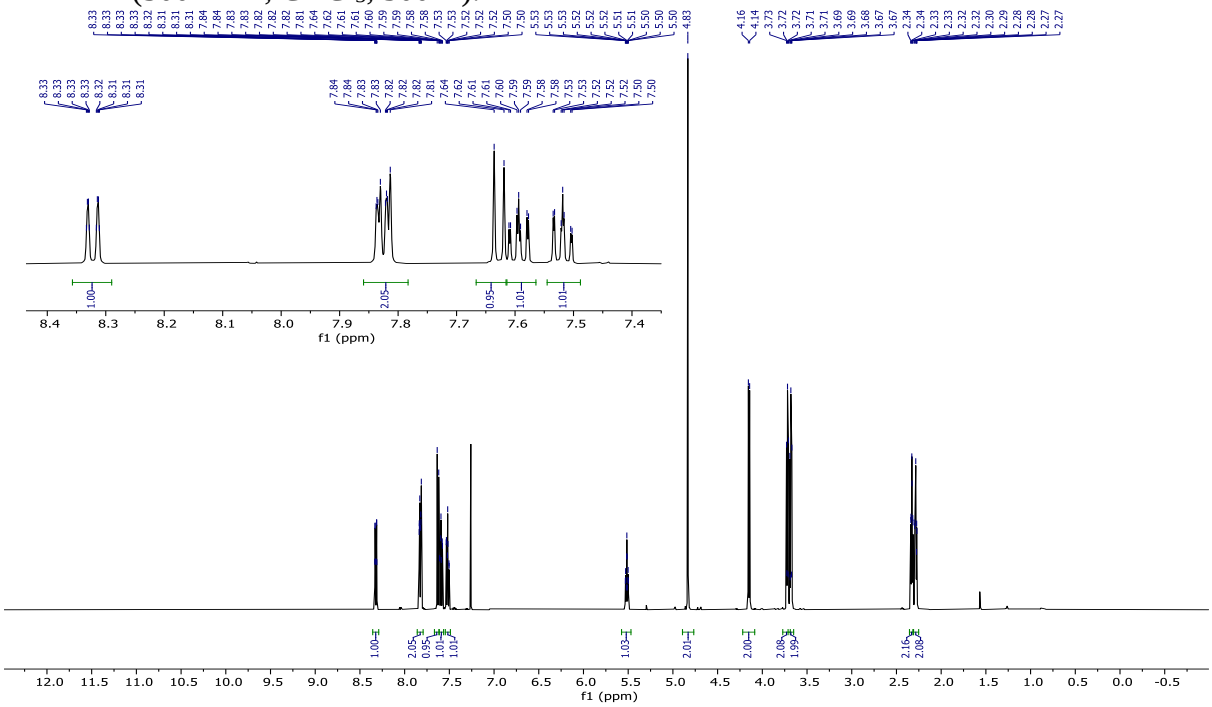


4-{2-[(1-Bromonaphthalen-2-yl)methoxy]ethylidene}tetrahydro-2*H*-pyran (S23)

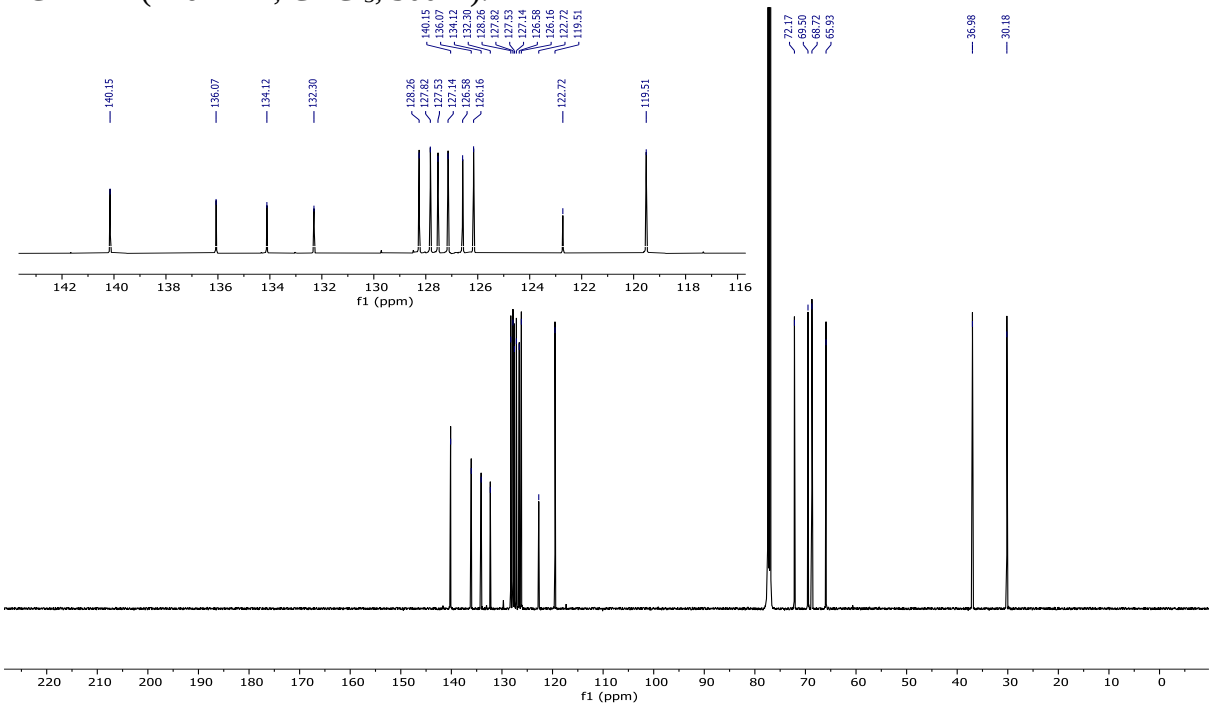


S23

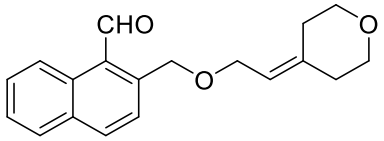
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

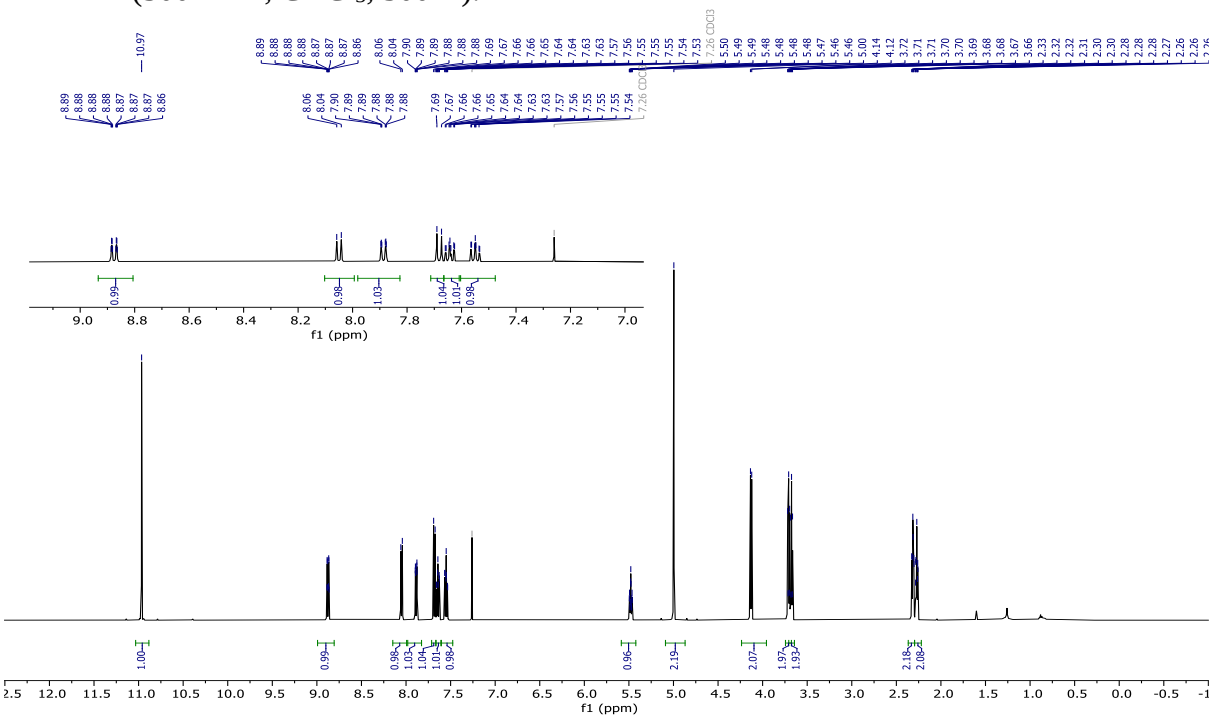


2-{[2-(Tetrahydro-4*H*-pyran-4-ylidene)ethoxy]methyl}-1-naphthaldehyde (7f)

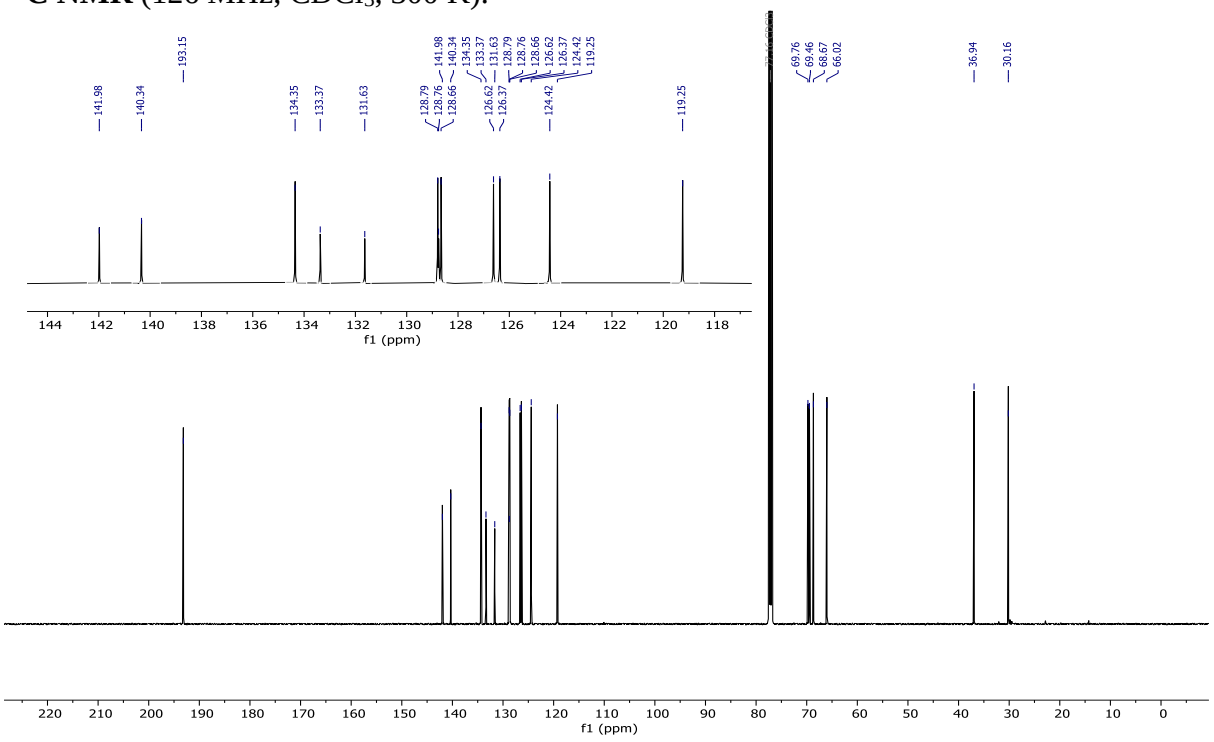


7f

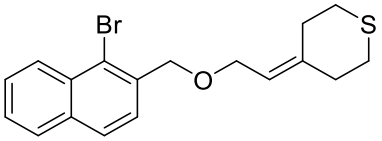
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

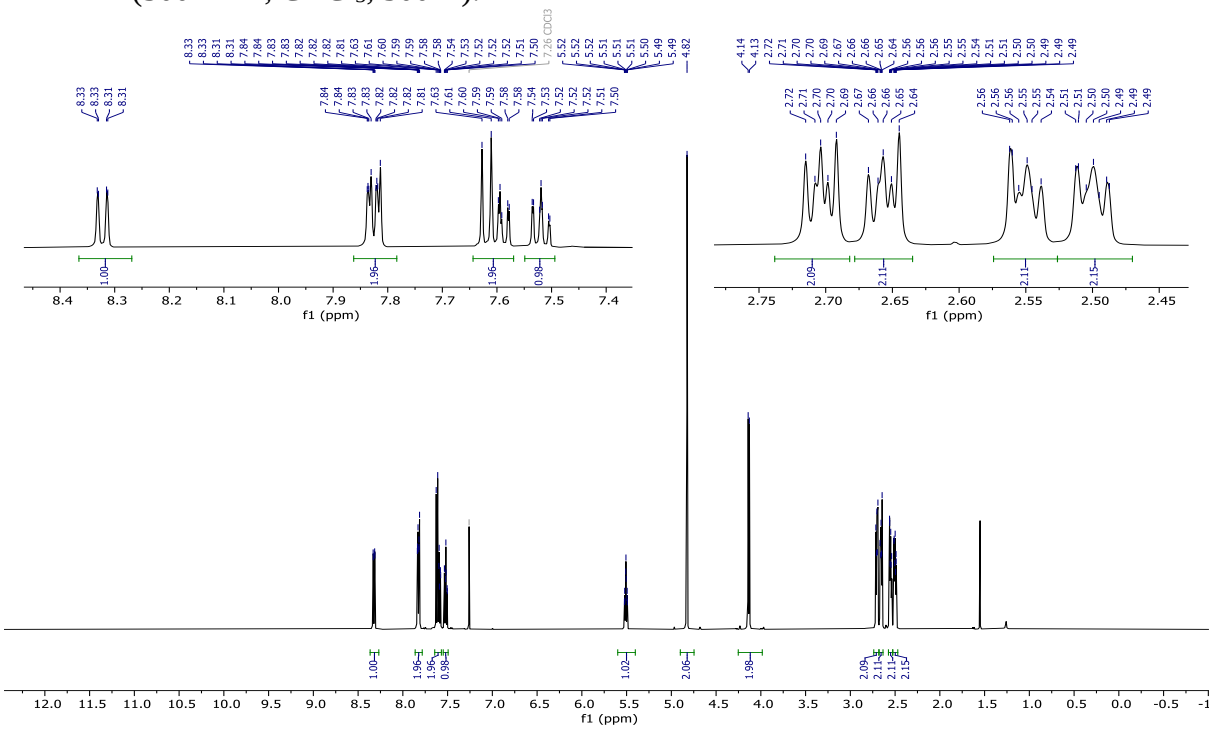


4-{2-[(1-Bromonaphthalen-2-yl)methoxy]ethylidene}tetrahydro-2*H*-thiopyran (S27)

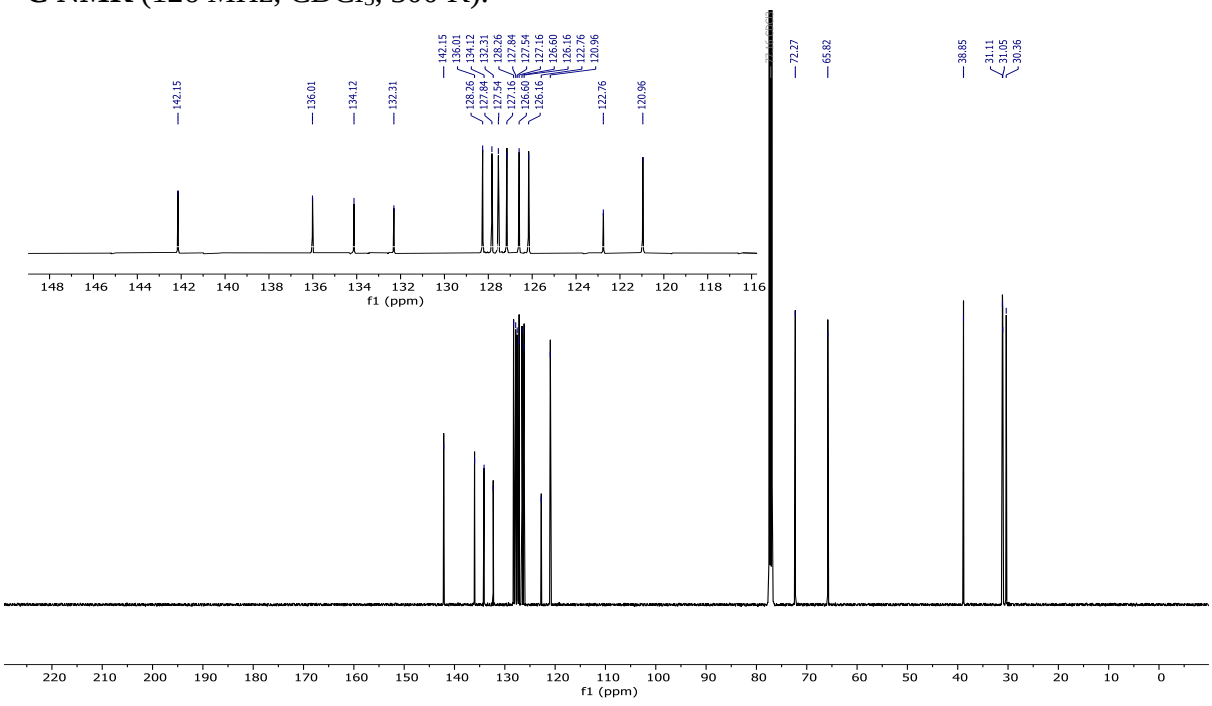


S27

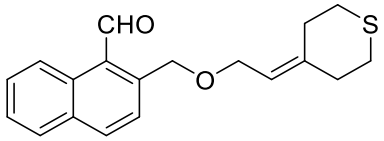
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

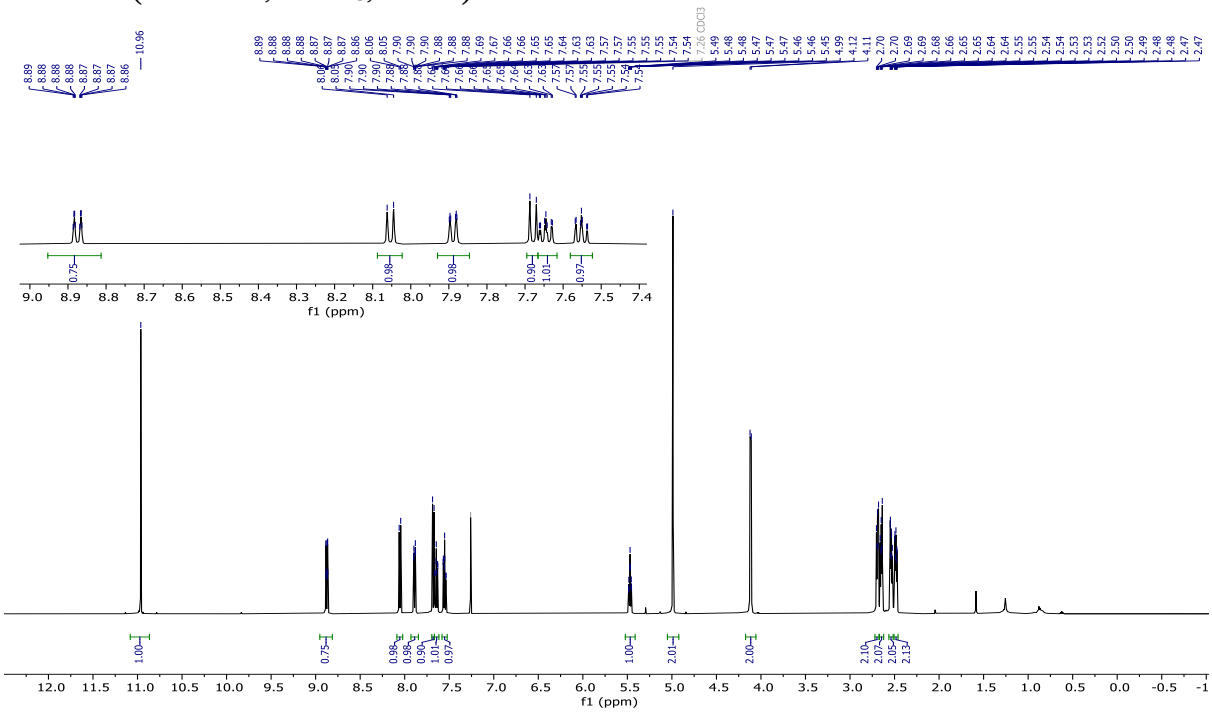


2-{[2-(Tetrahydro-4*H*-thiopyran-4-ylidene)ethoxy]methyl}-1-naphthaldehyde (7g)

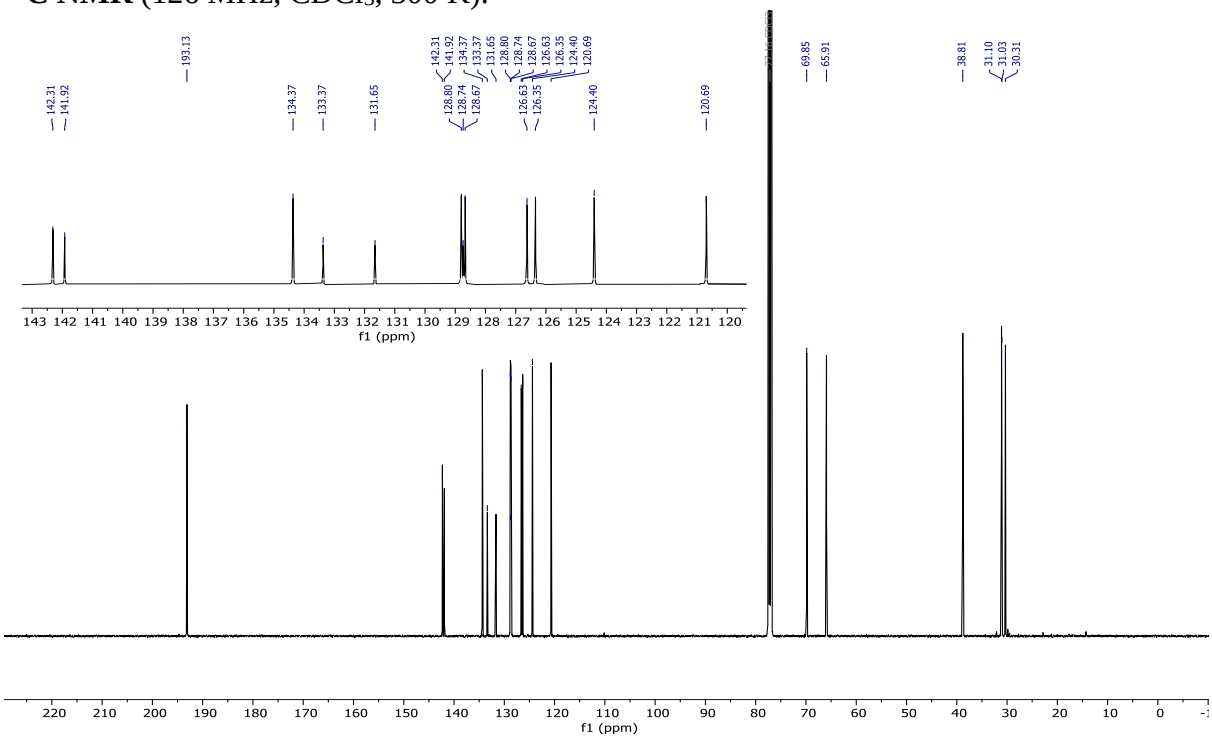


7g

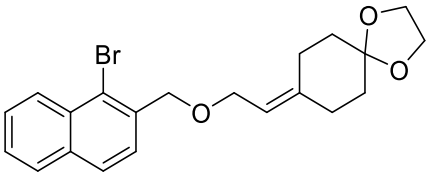
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

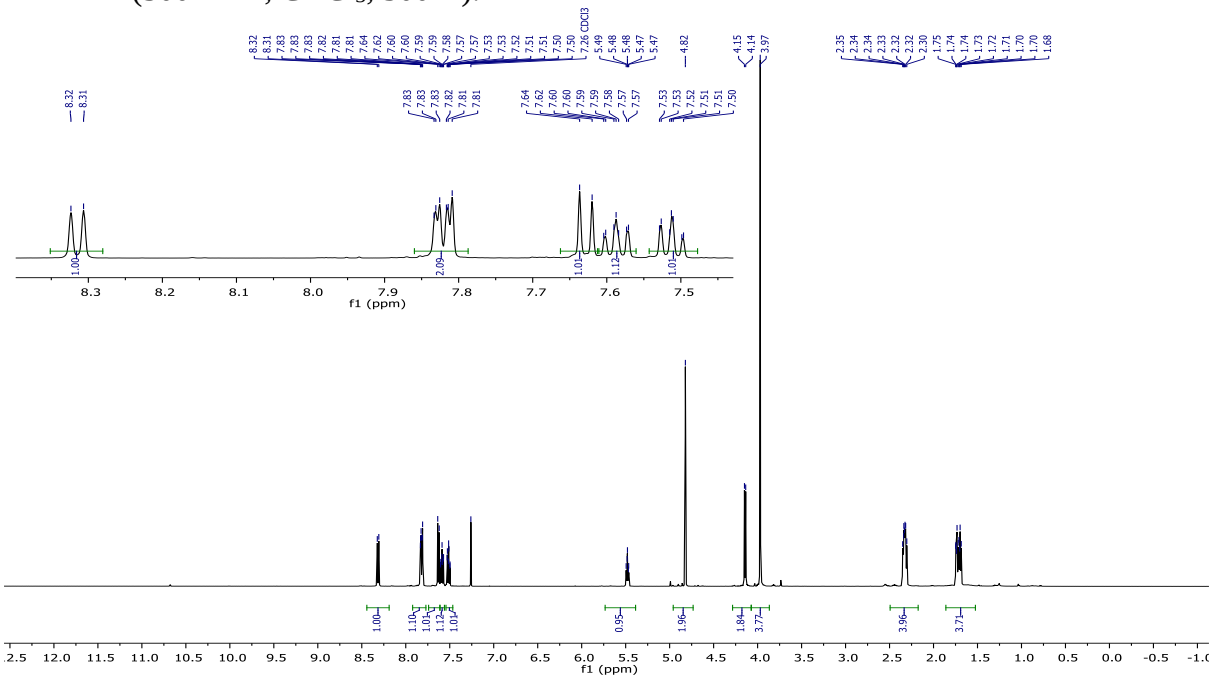


8-{2-[(1-Bromonaphthalen-2-yl)methoxy]ethylidene}-1,4-dioxaspiro[4.5]decane (S31)

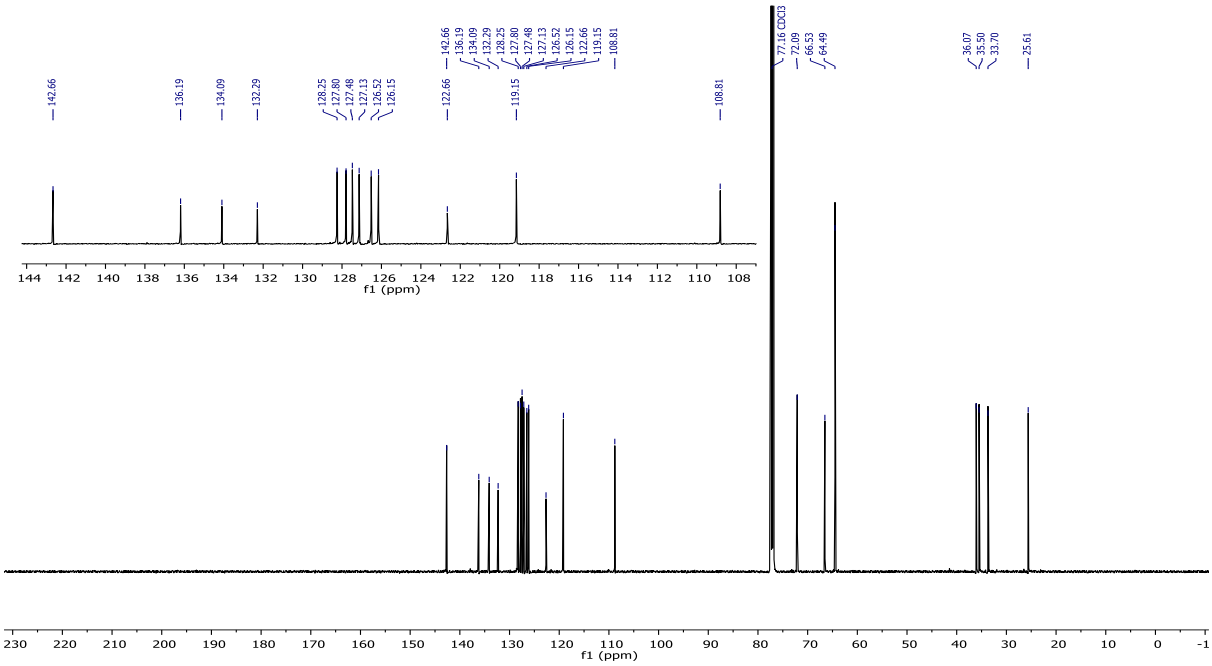


S31

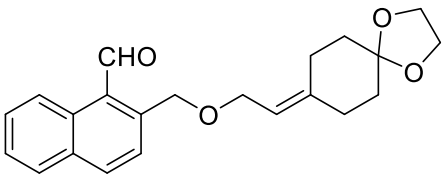
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

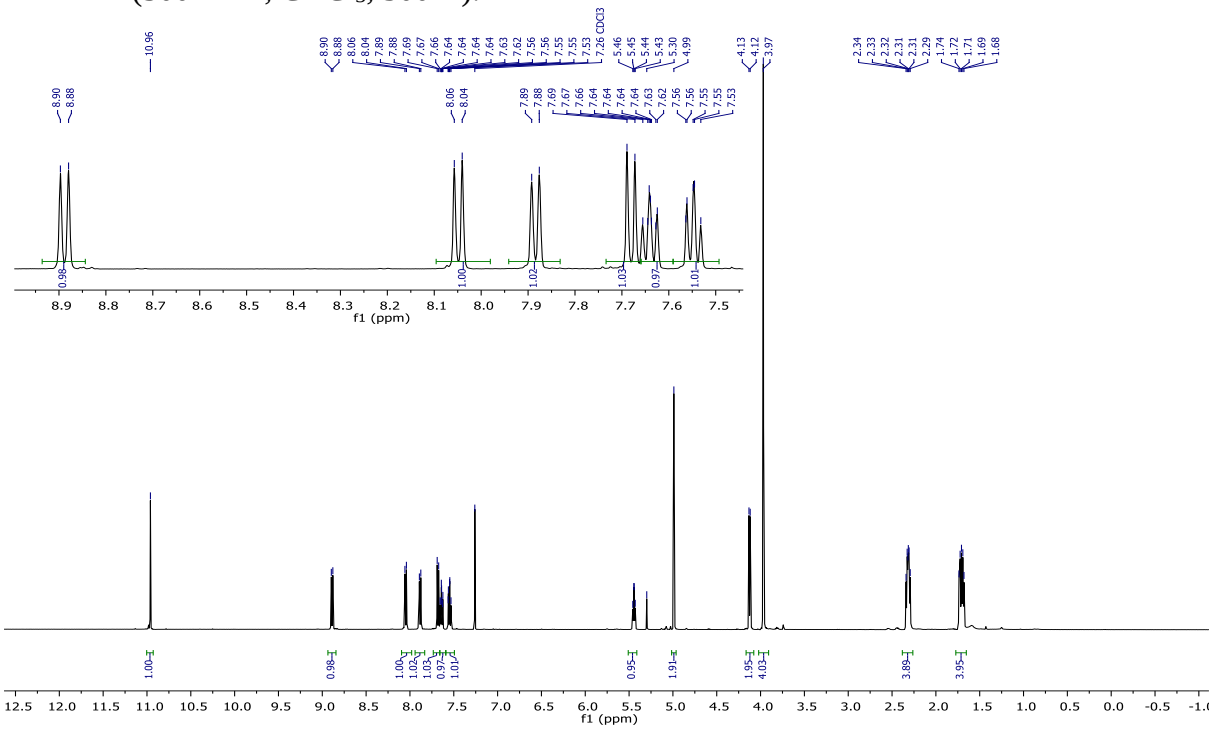


2-{[2-(1,4-Dioxaspiro[4.5]decan-8-ylidene)ethoxy]methyl}-1-naphthaldehyde (7h)

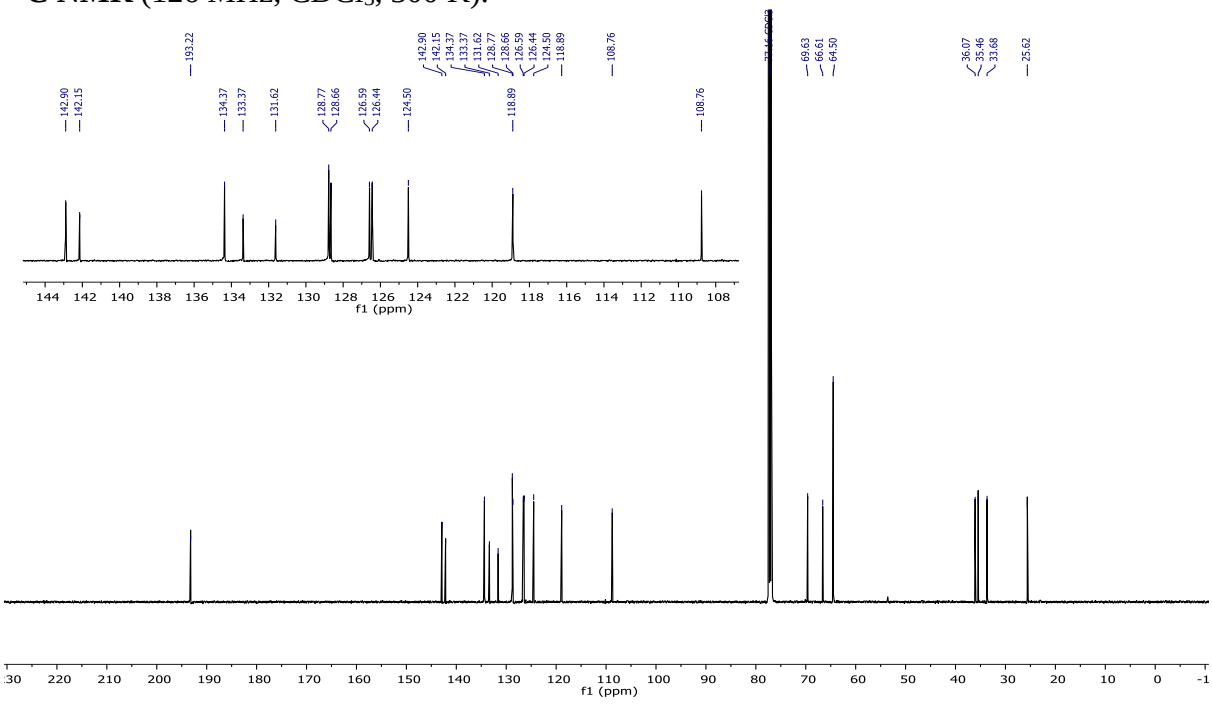


7h

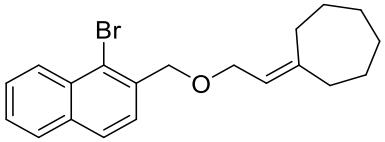
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

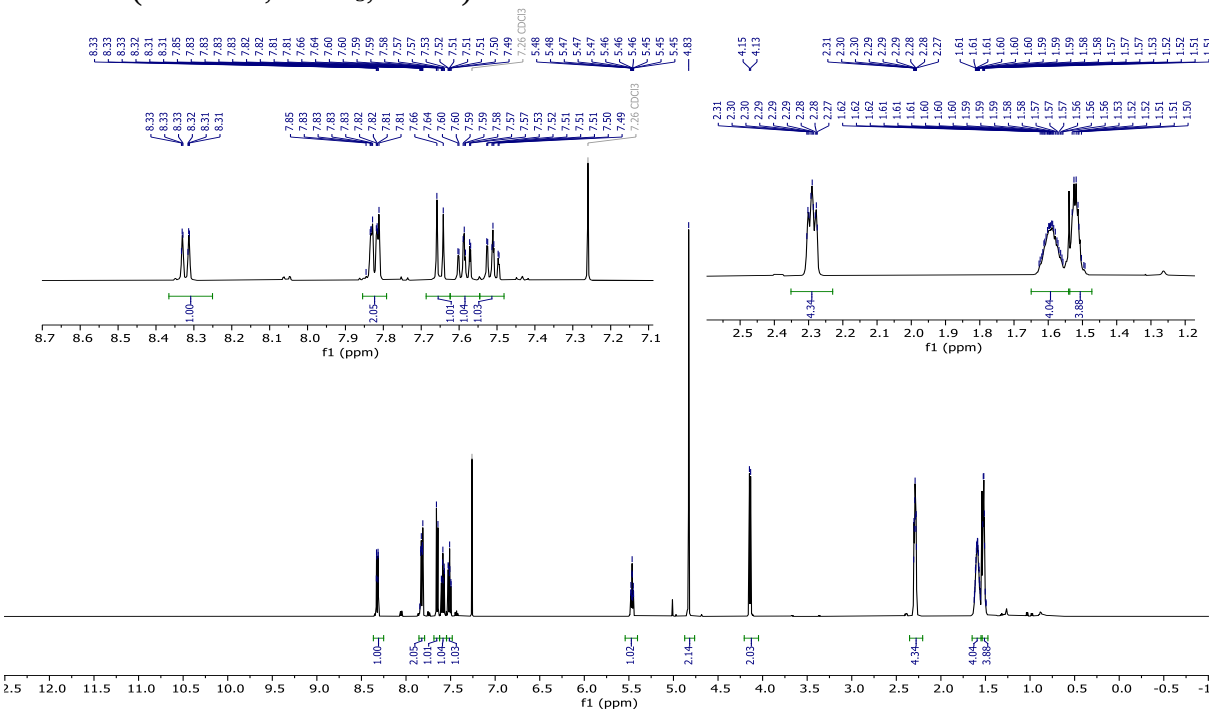


1-Bromo-2-[(2-cycloheptylideneethoxy)methyl]naphthalene (S35)

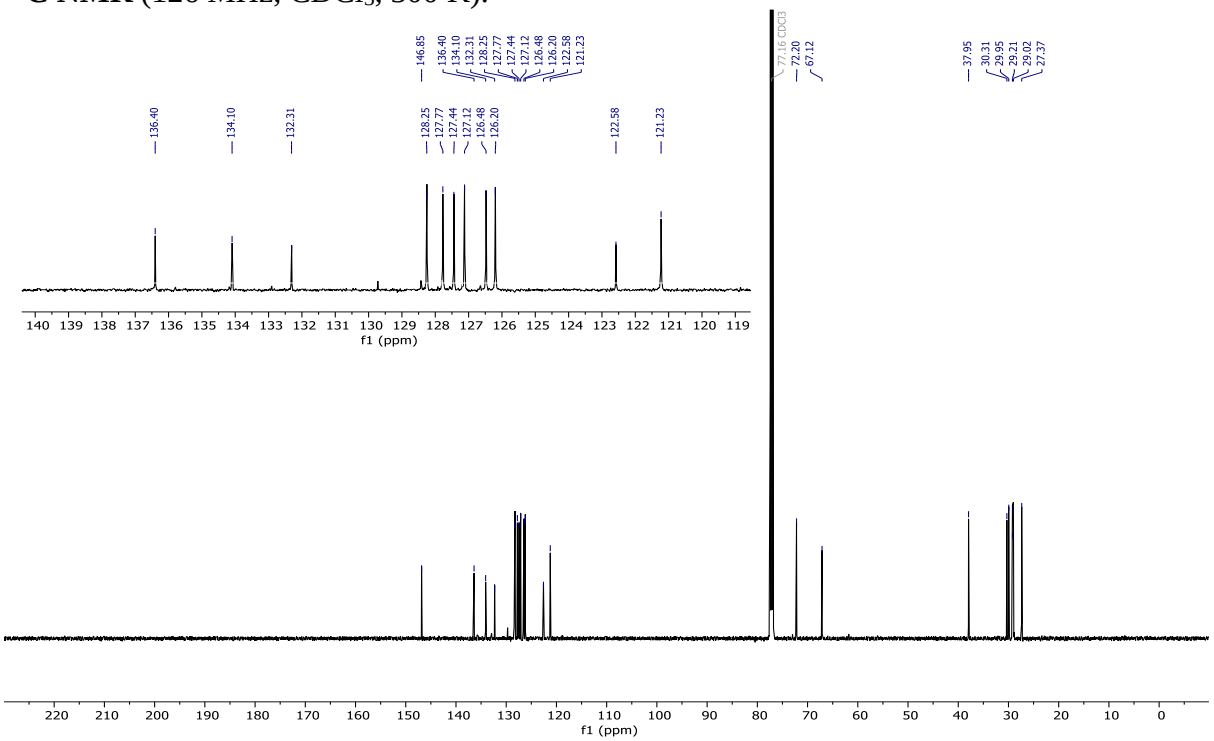


S35

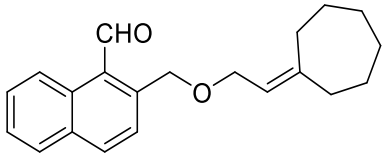
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

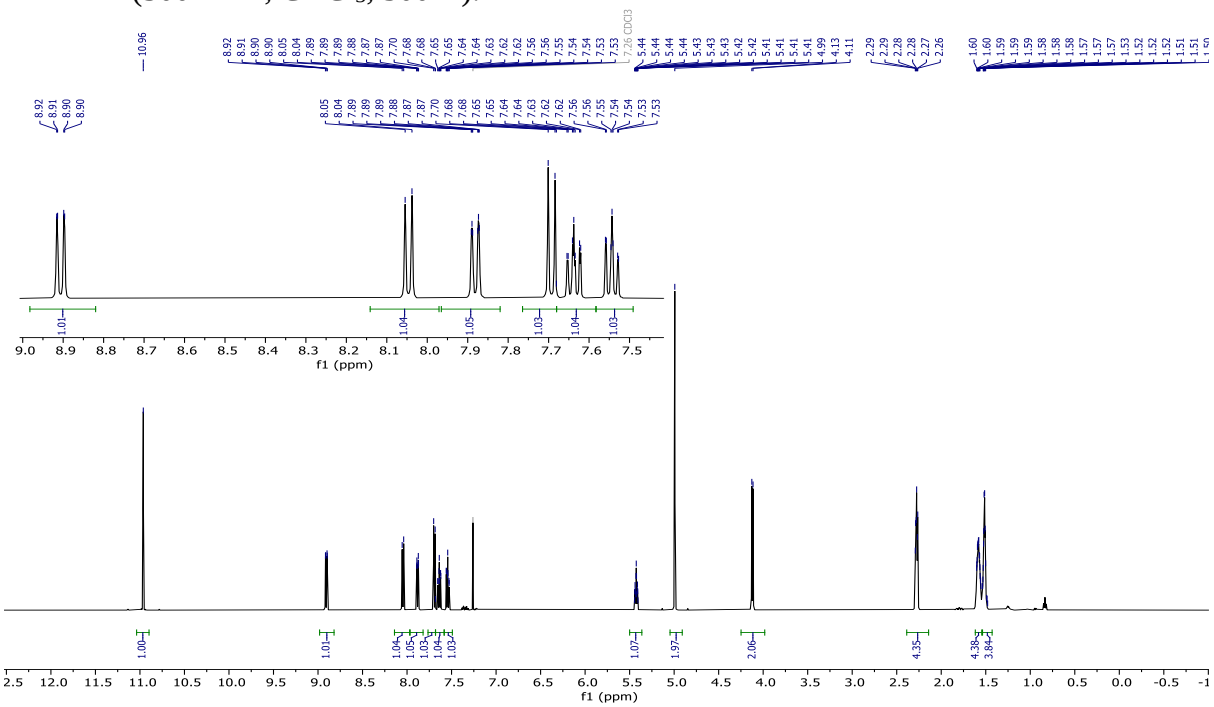


2-[(2-Cycloheptylideneethoxy)methyl]-1-naphthaldehyde (7i)

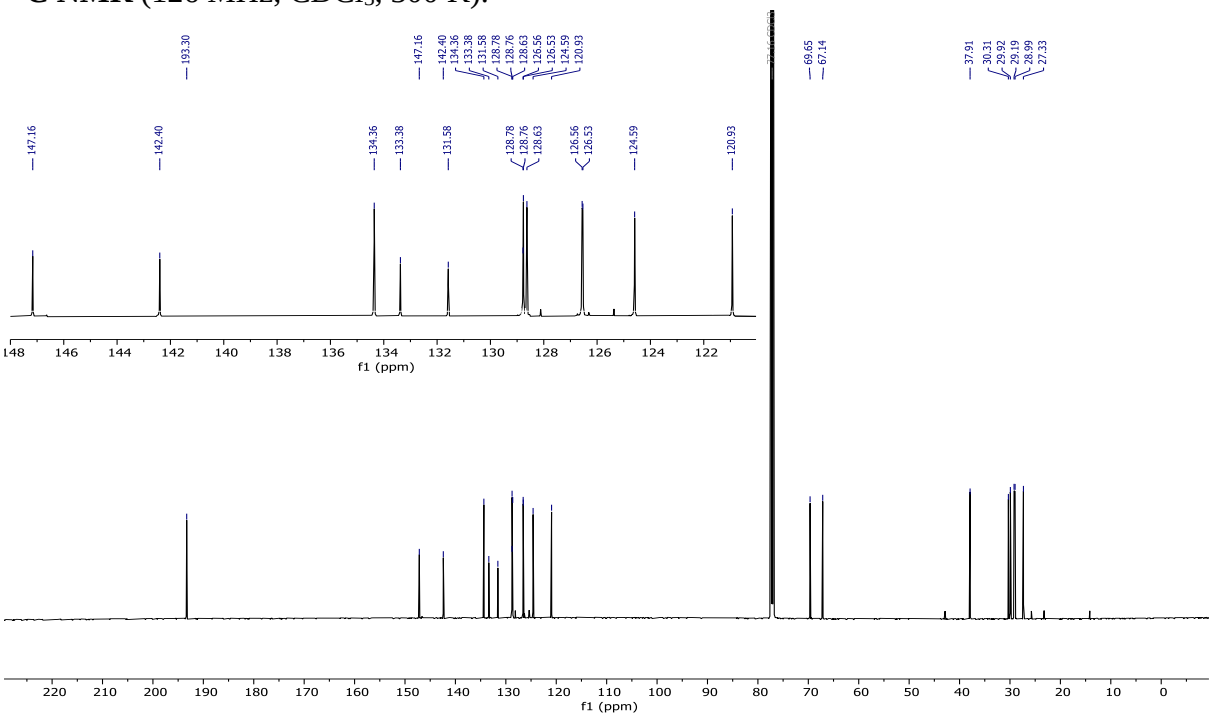


7i

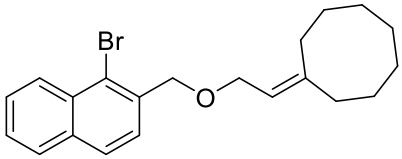
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

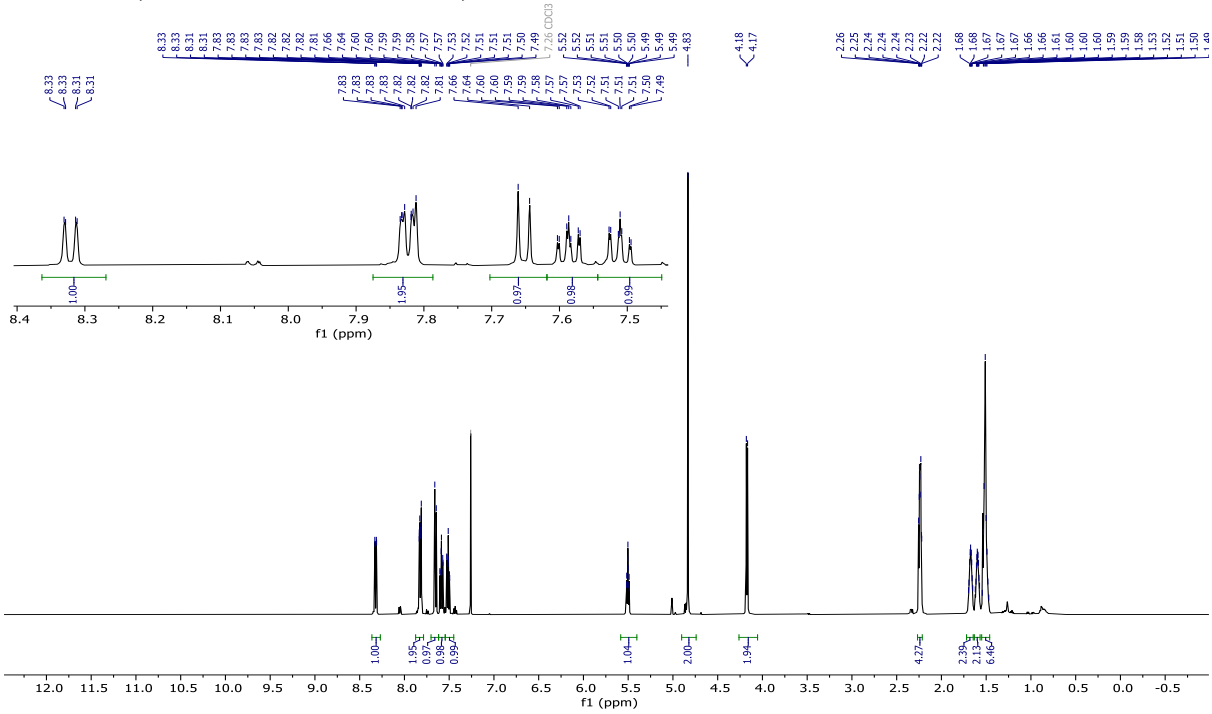


1-Bromo-2-[(2-cyclooctylideneethoxy)methyl]naphthalene (S39)

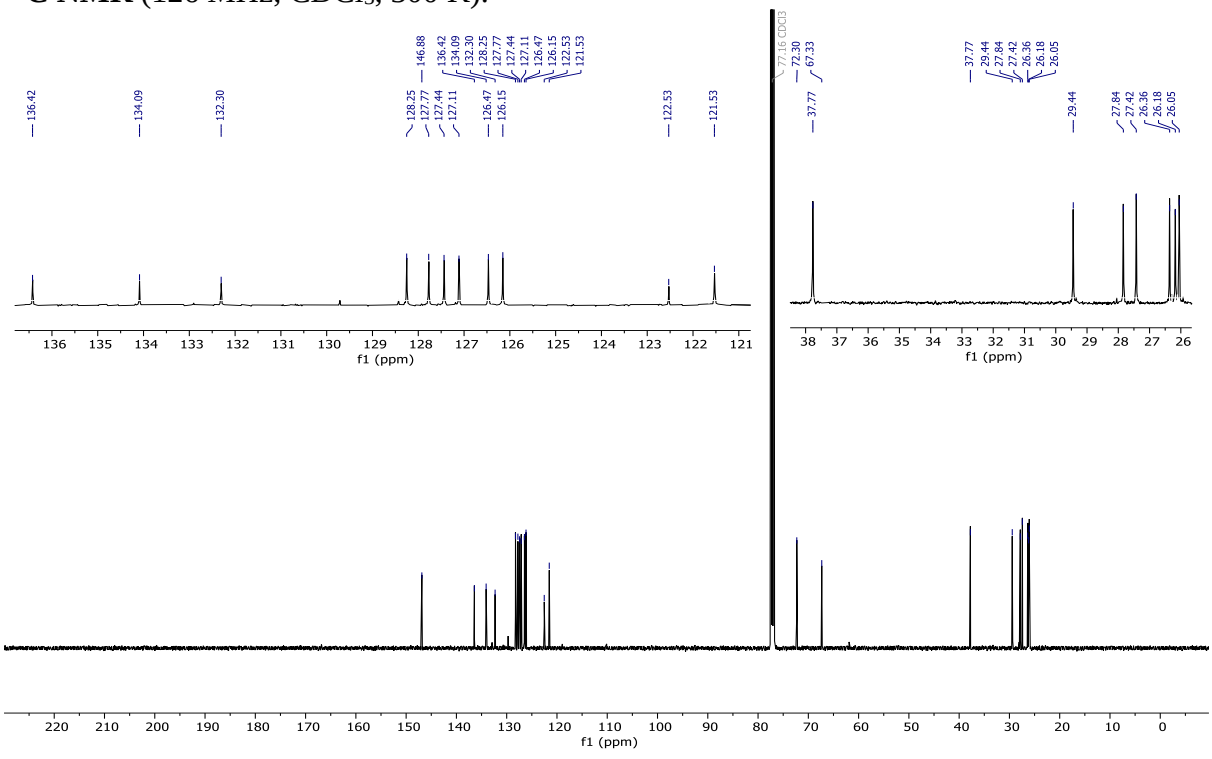


S39

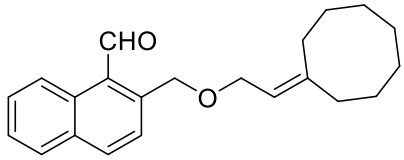
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

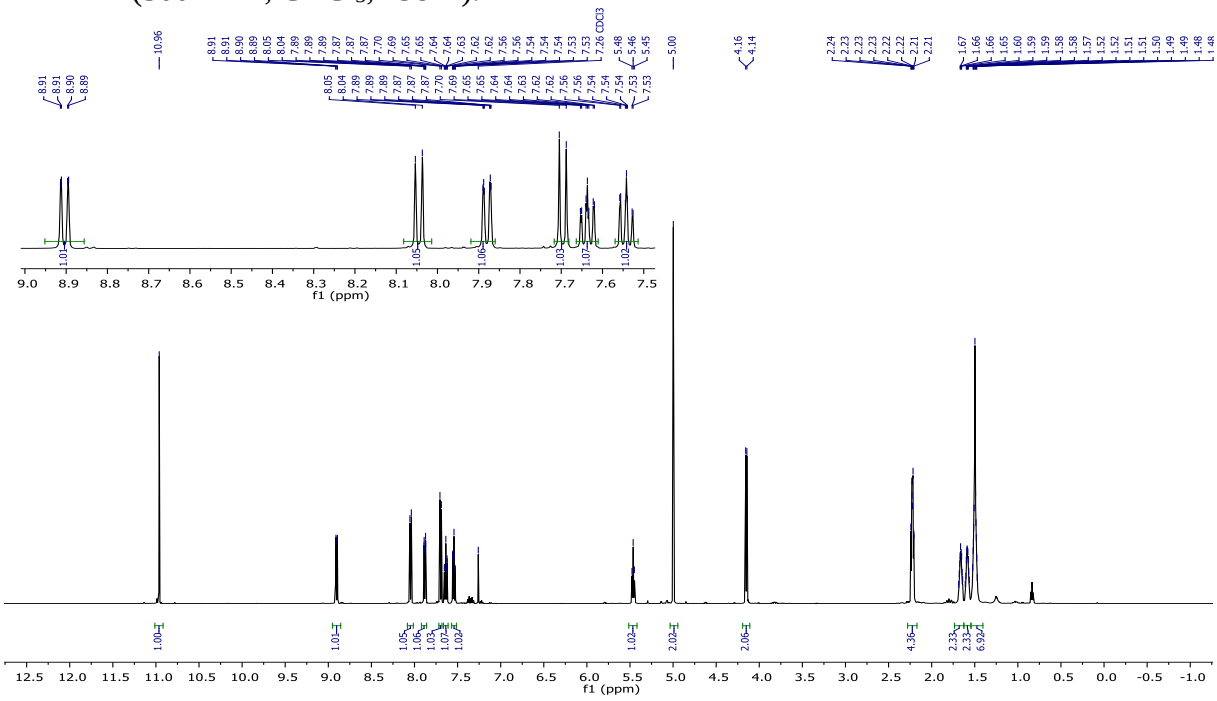


2-[(2-Cyclooctylideneethoxy)methyl]-1-naphthaldehyde (7j)

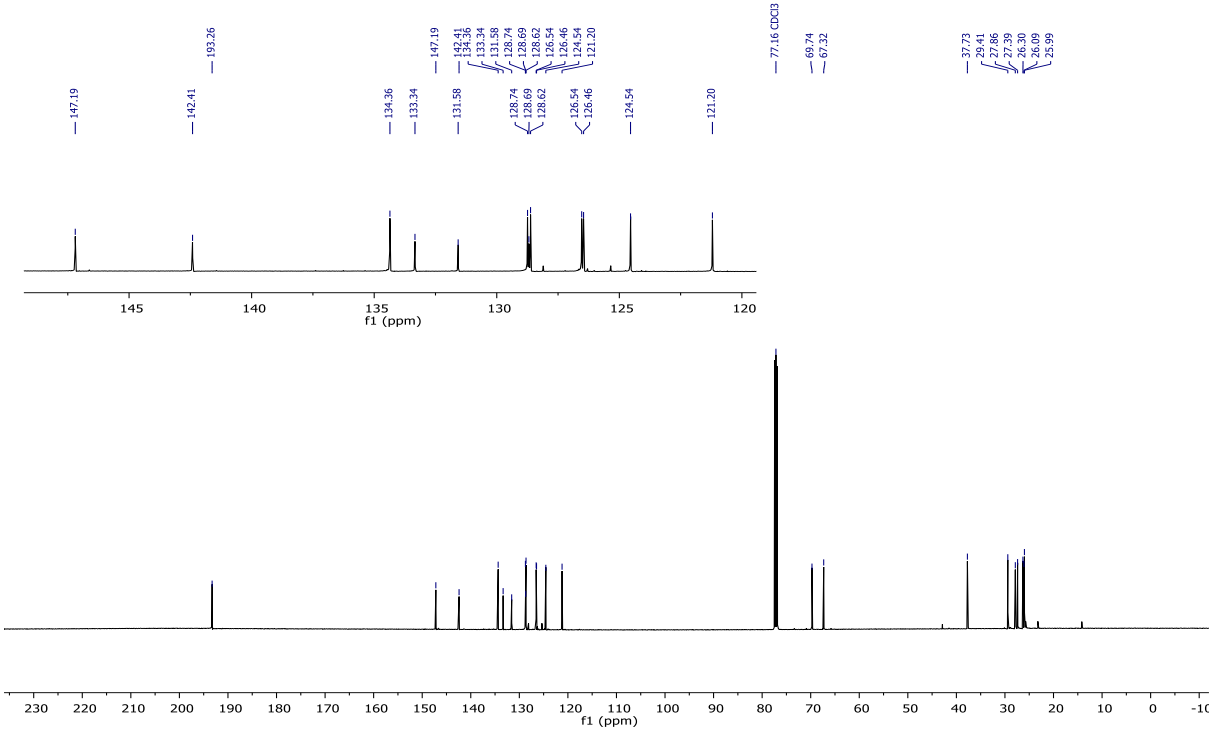


7j

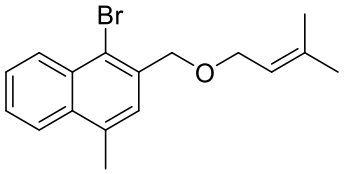
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

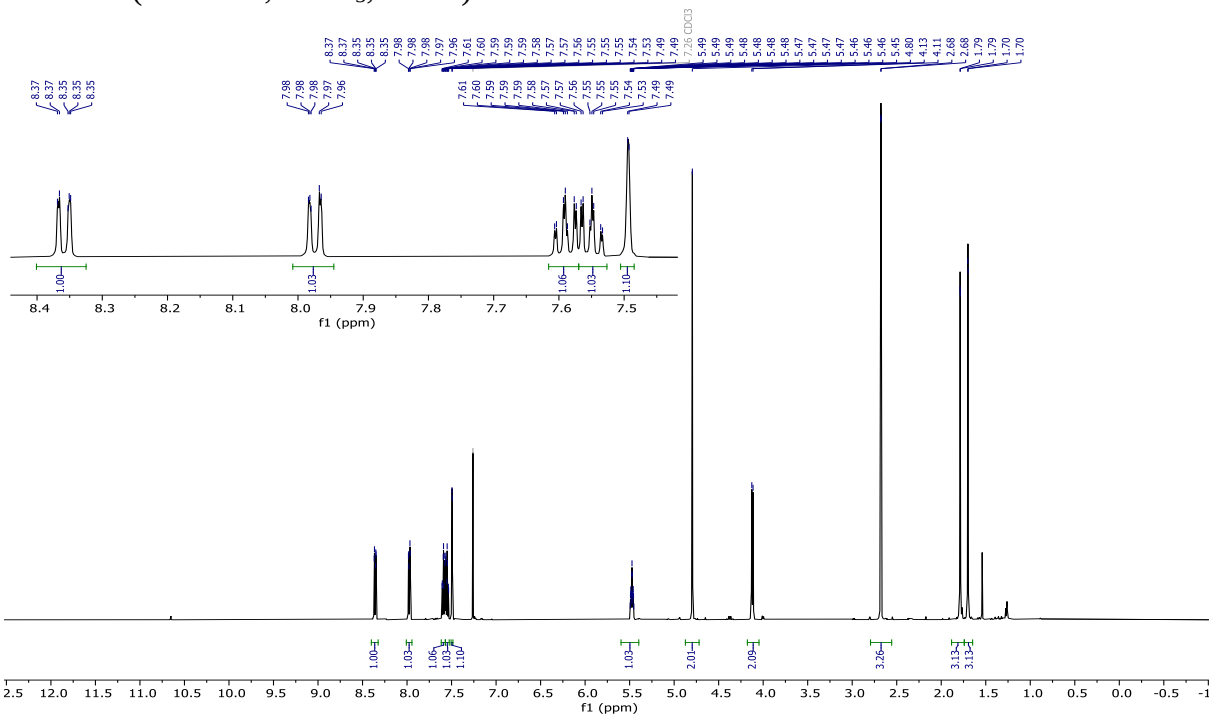


1-Bromo-4-methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S44)

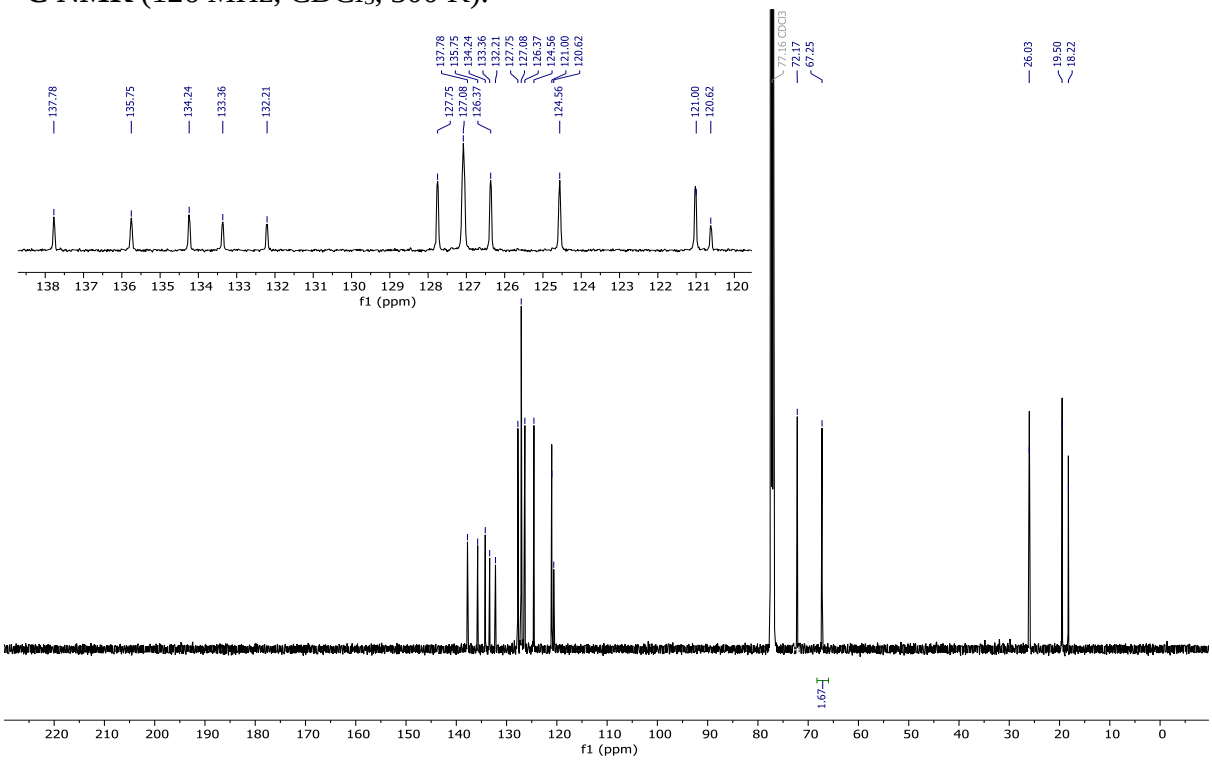


S44

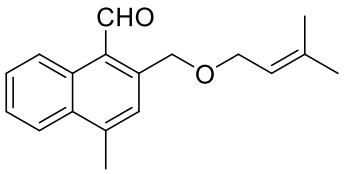
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

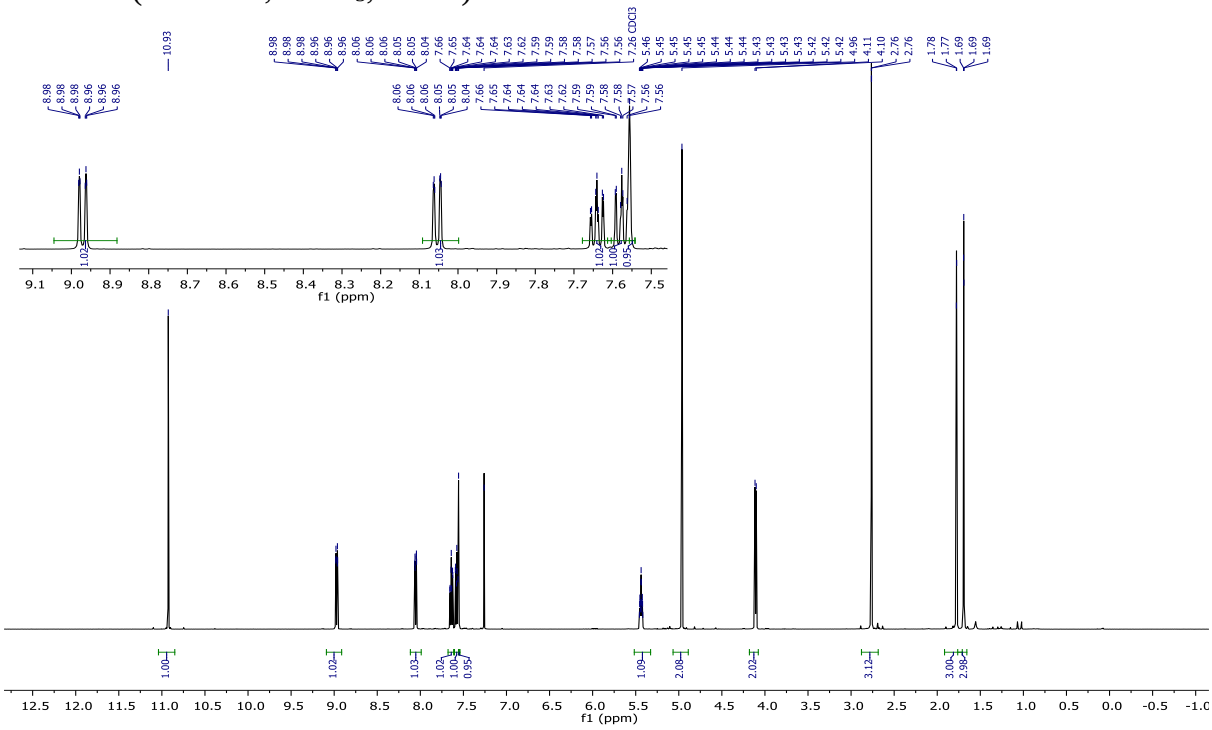


4-Methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7k)

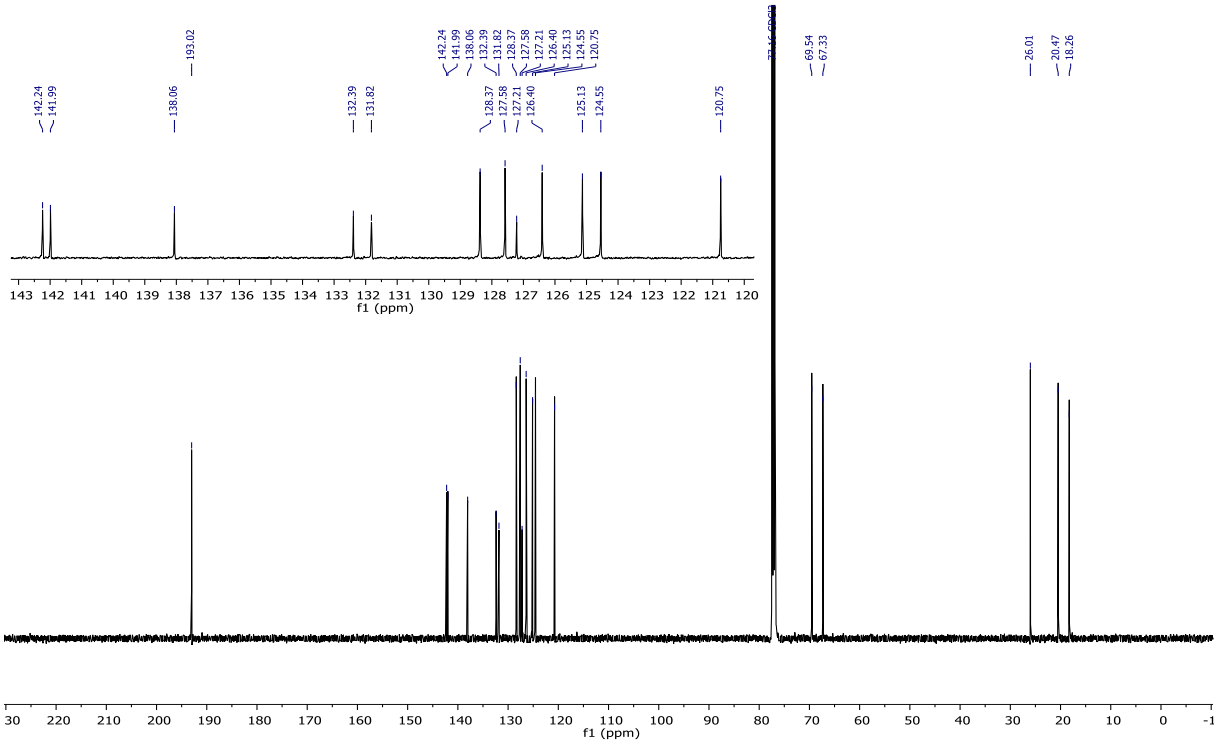


7k

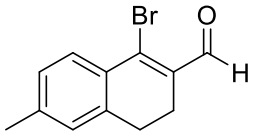
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

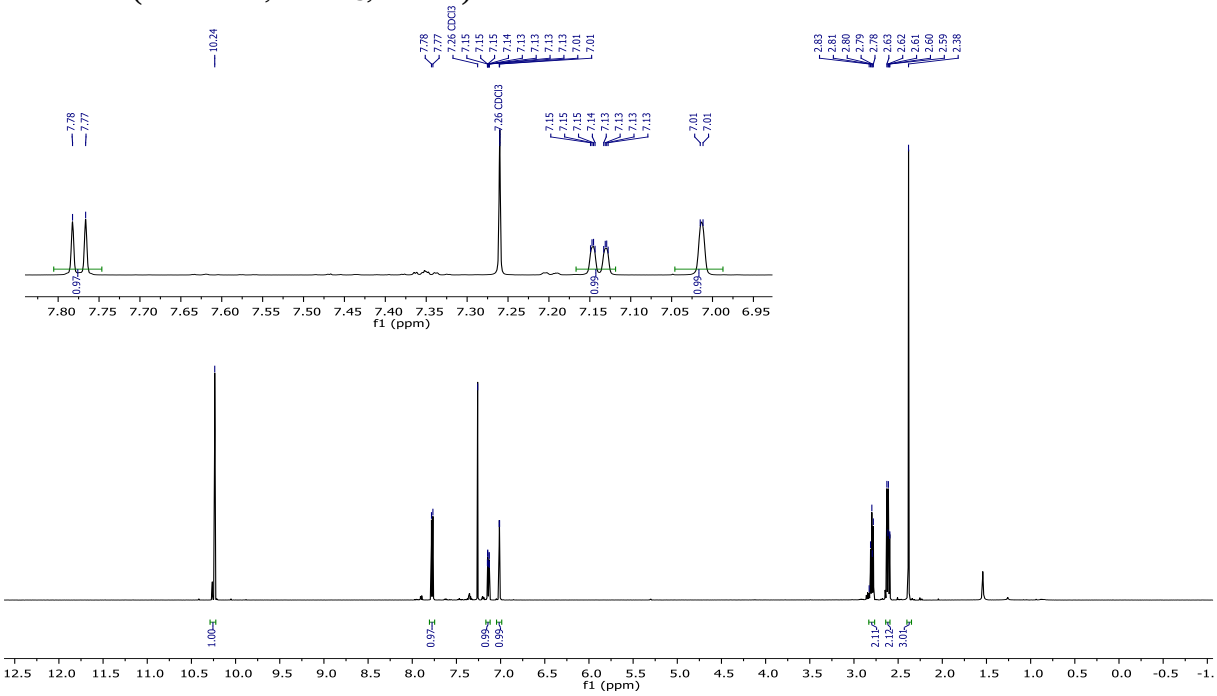


1-Bromo-6-methyl-3,4-dihydronaphthalene-2-carbaldehyde (S48)

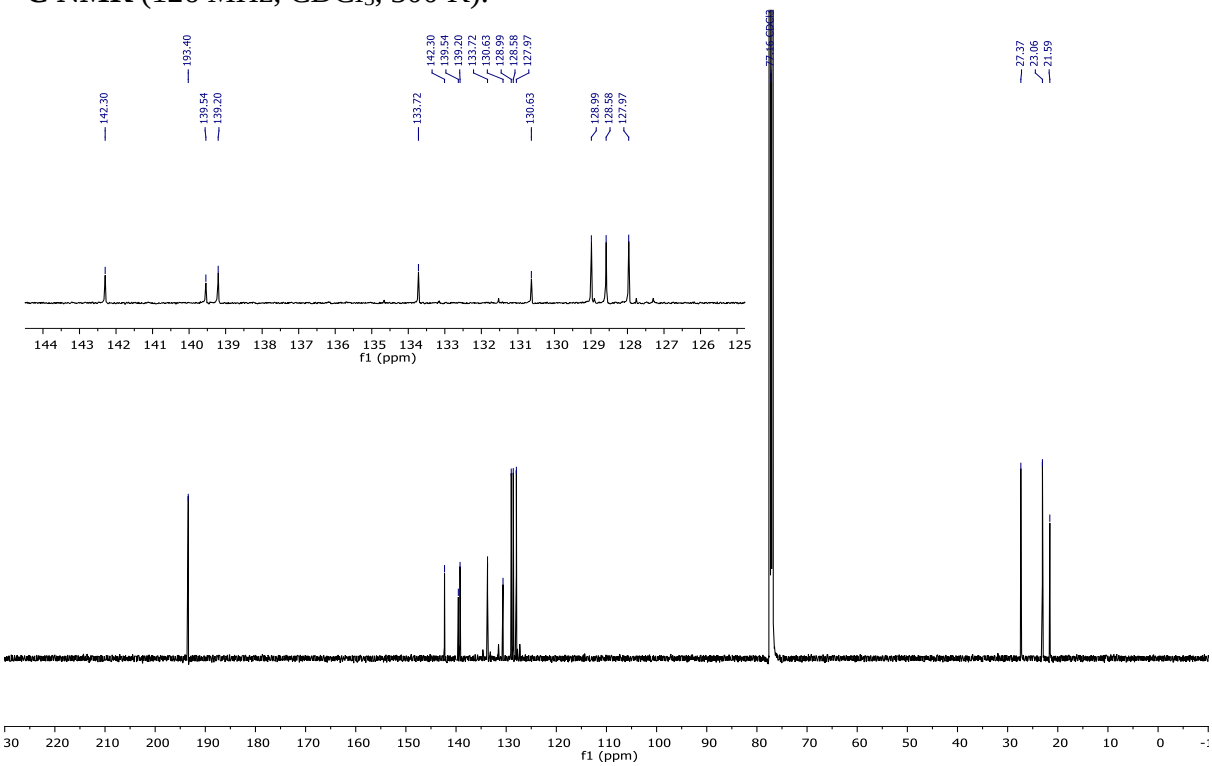


S48

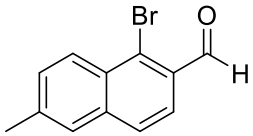
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

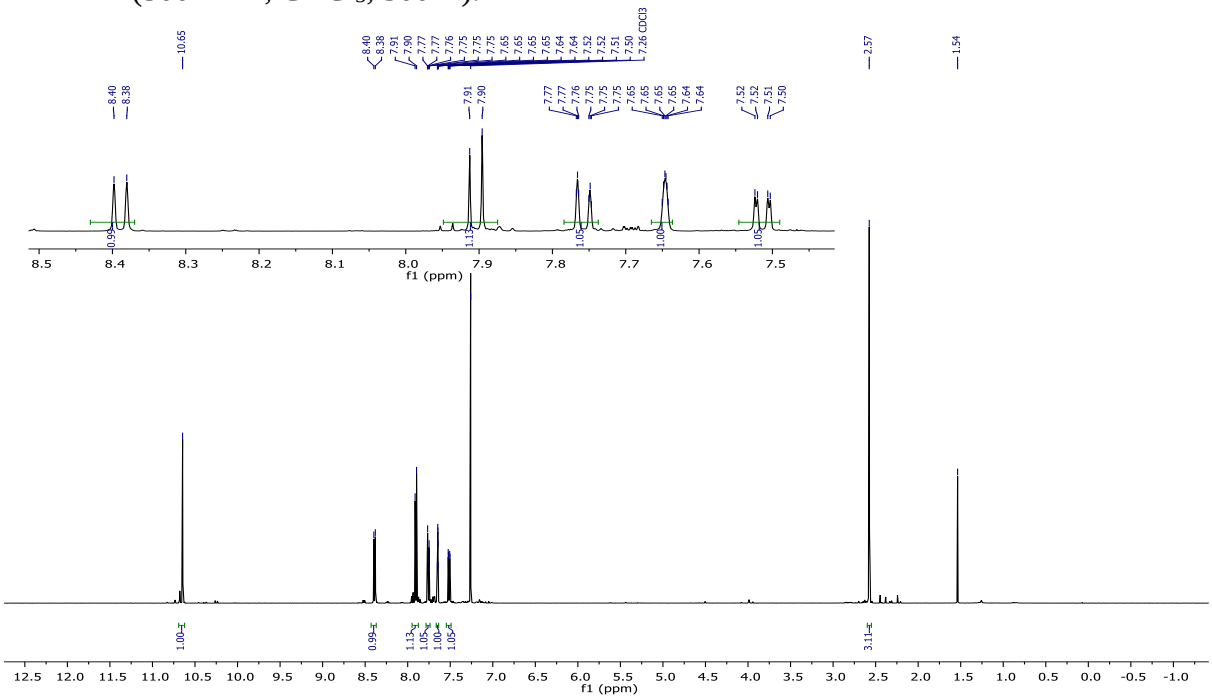


1-Bromo-6-methyl-2-naphthaldehyde (S49)

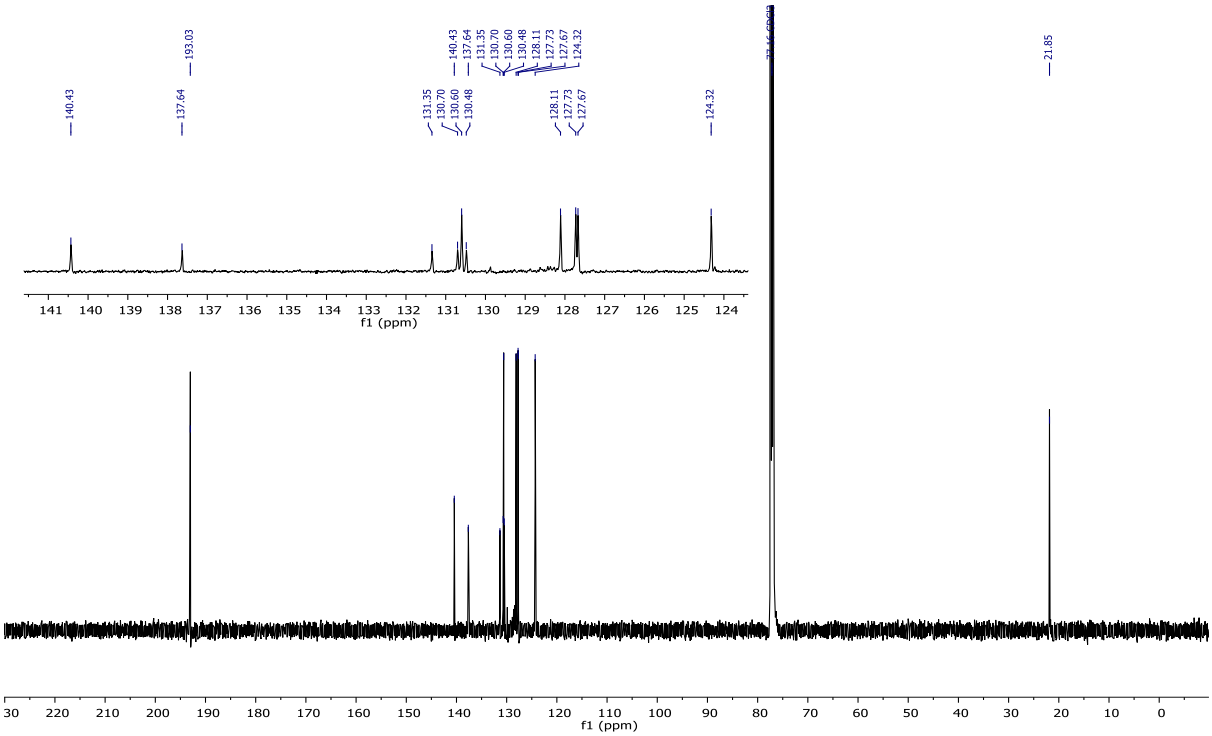


S49

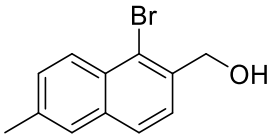
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

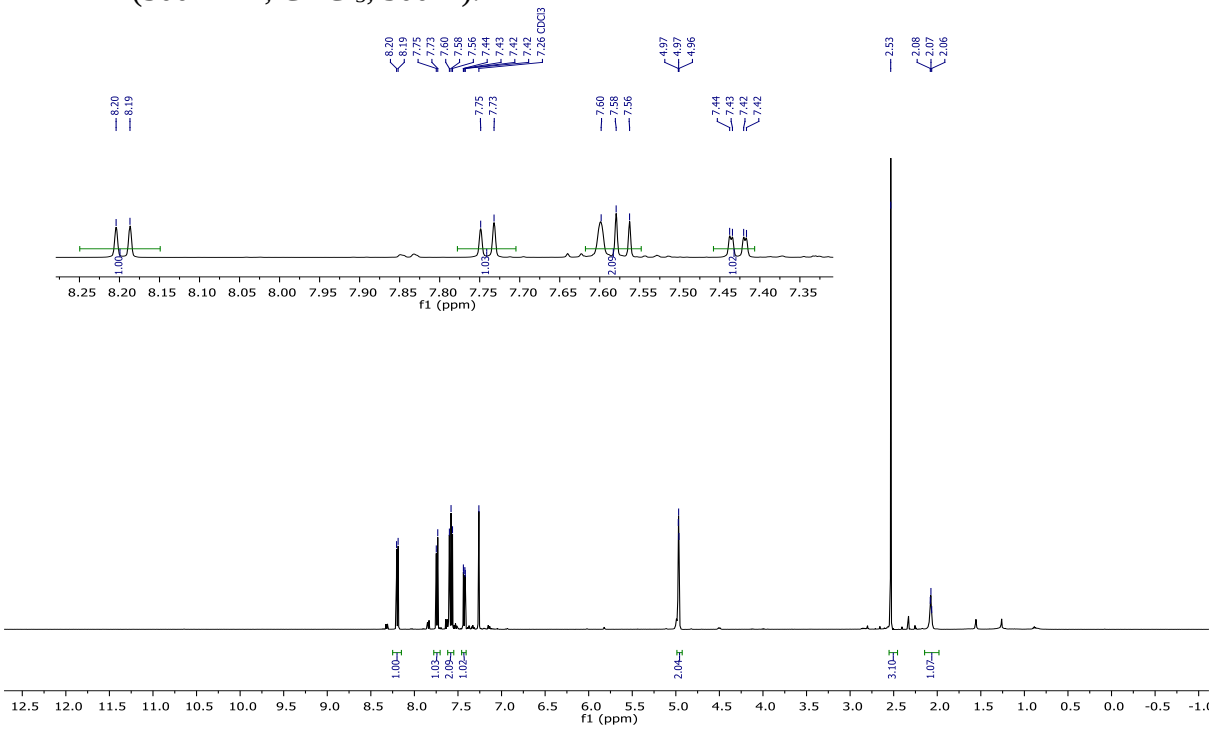


(1-Bromo-6-methylnaphthalen-2-yl)methanol (S50)

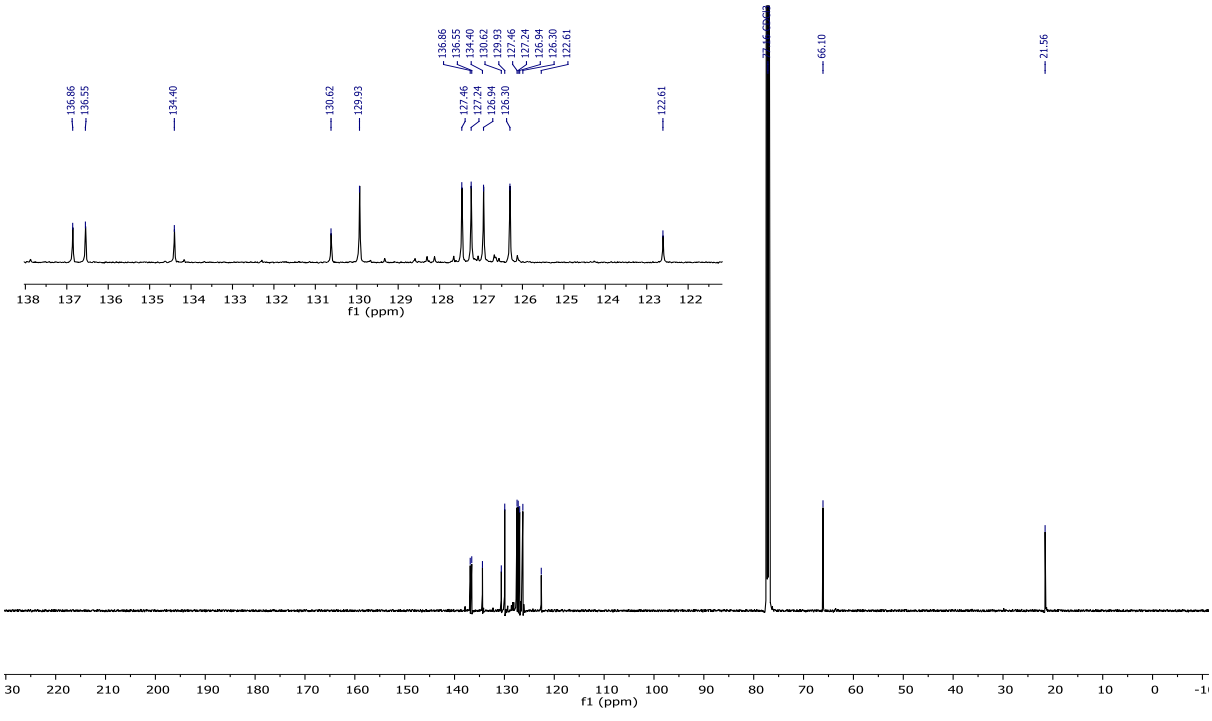


S50

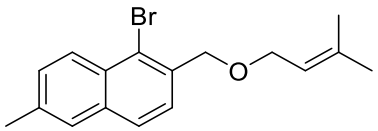
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

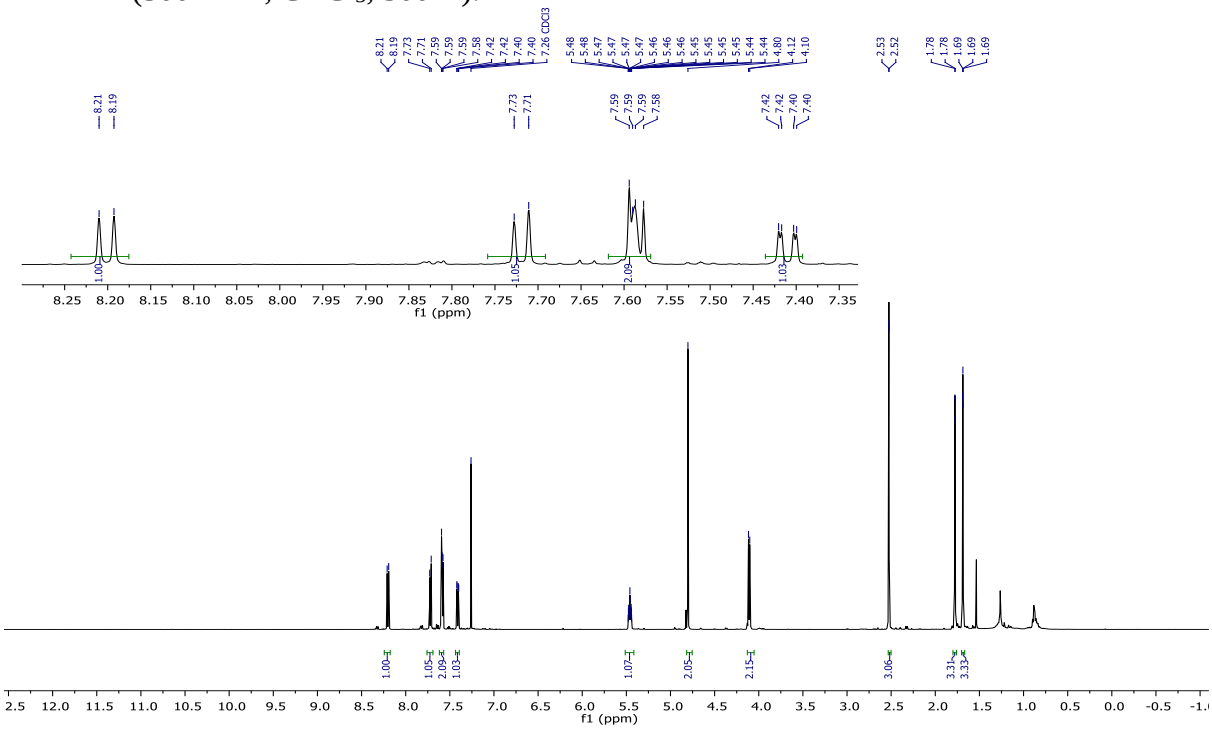


1-Bromo-6-methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S51)

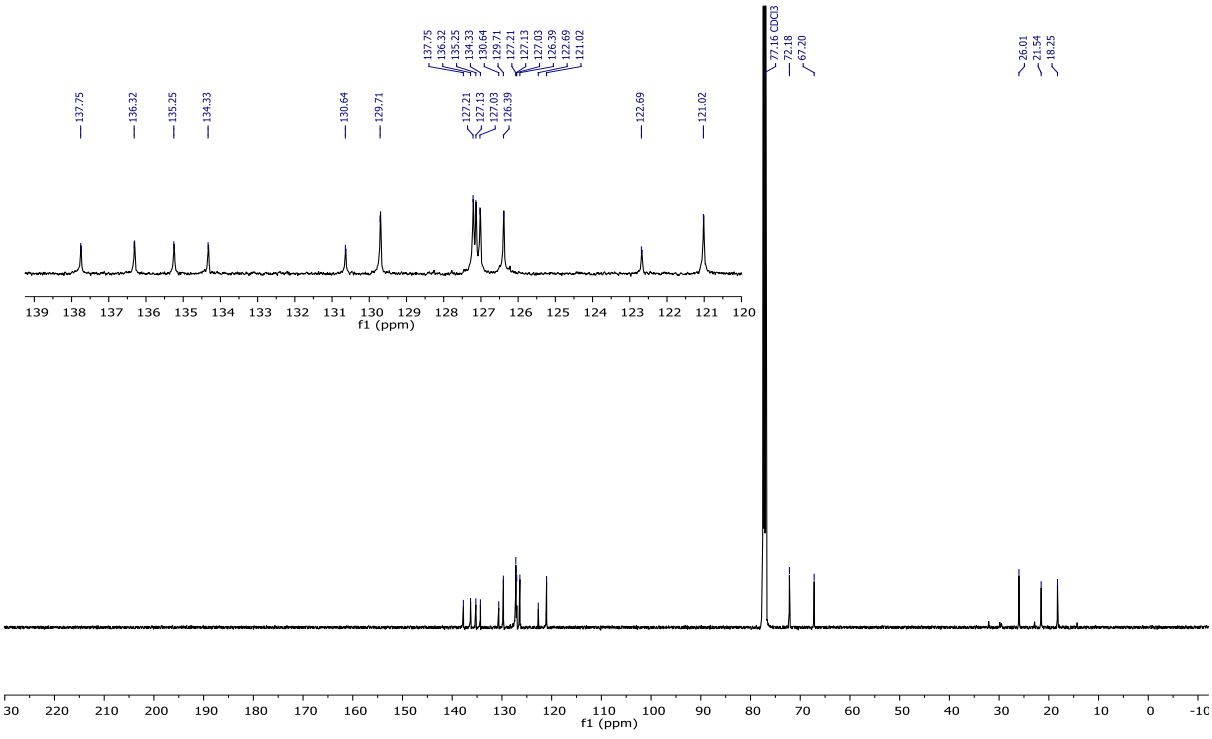


S51

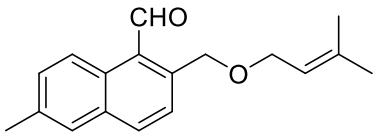
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

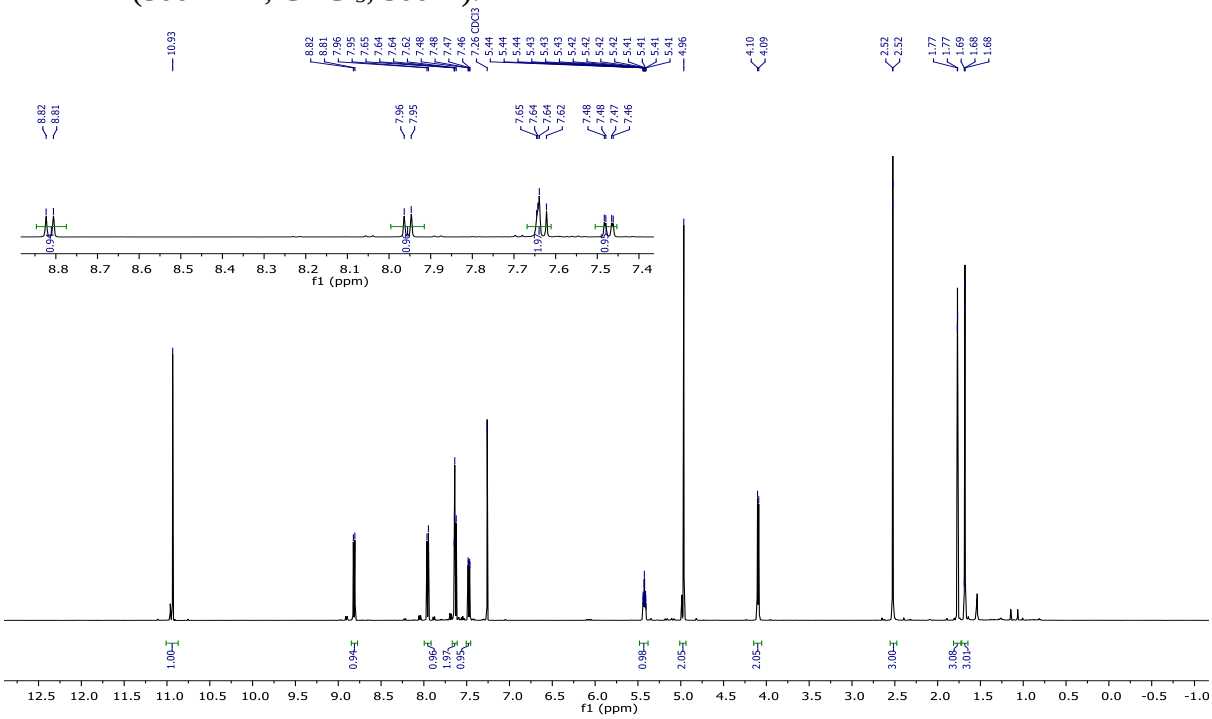


6-Methyl-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7l)

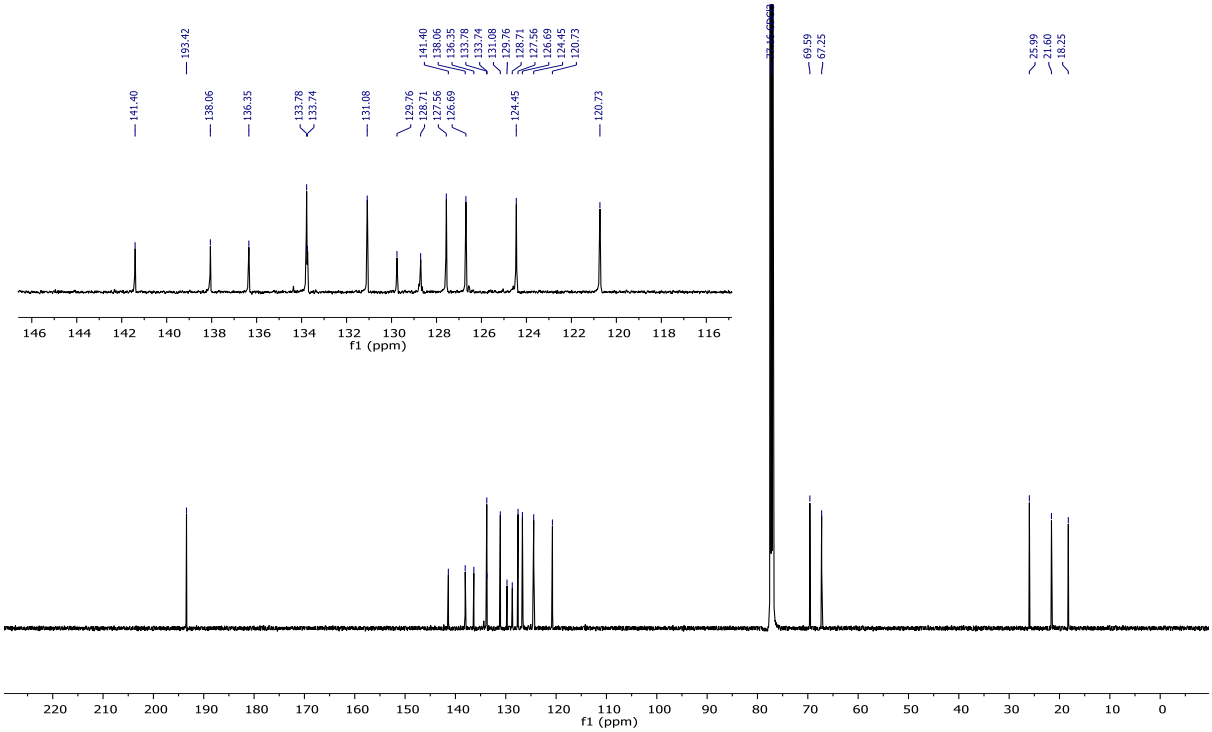


7l

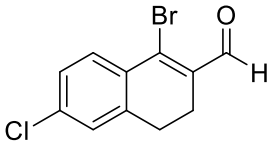
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

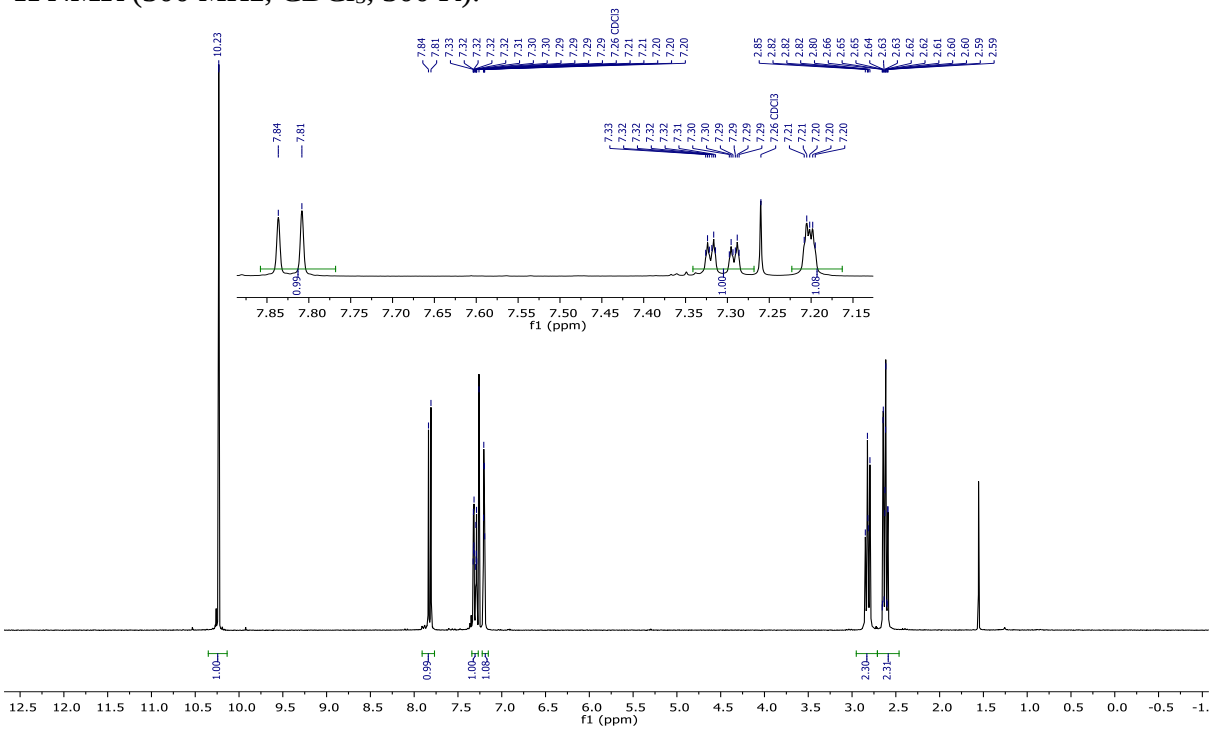


1-Bromo-6-chloro-3,4-dihydronaphthalene-2-carbaldehyde (S53)

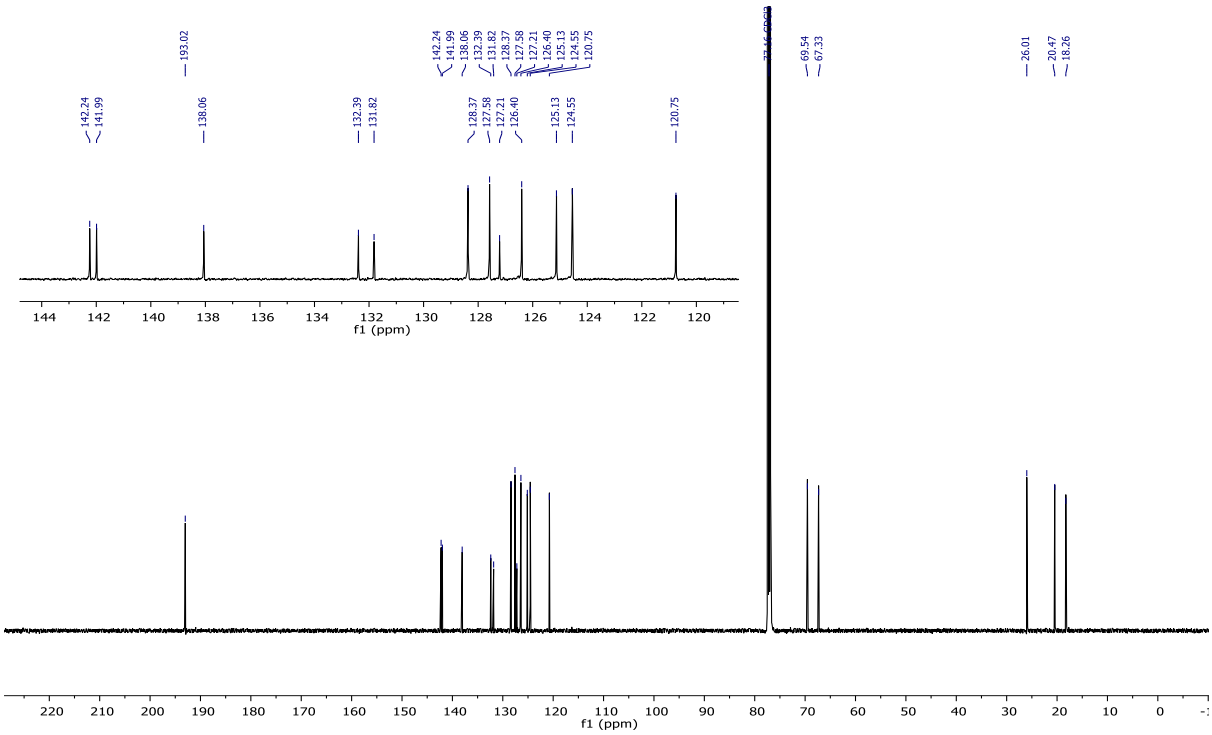


S53

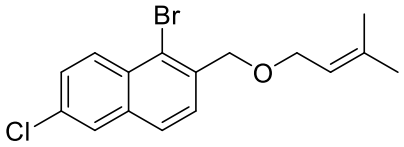
^{1}H NMR (300 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

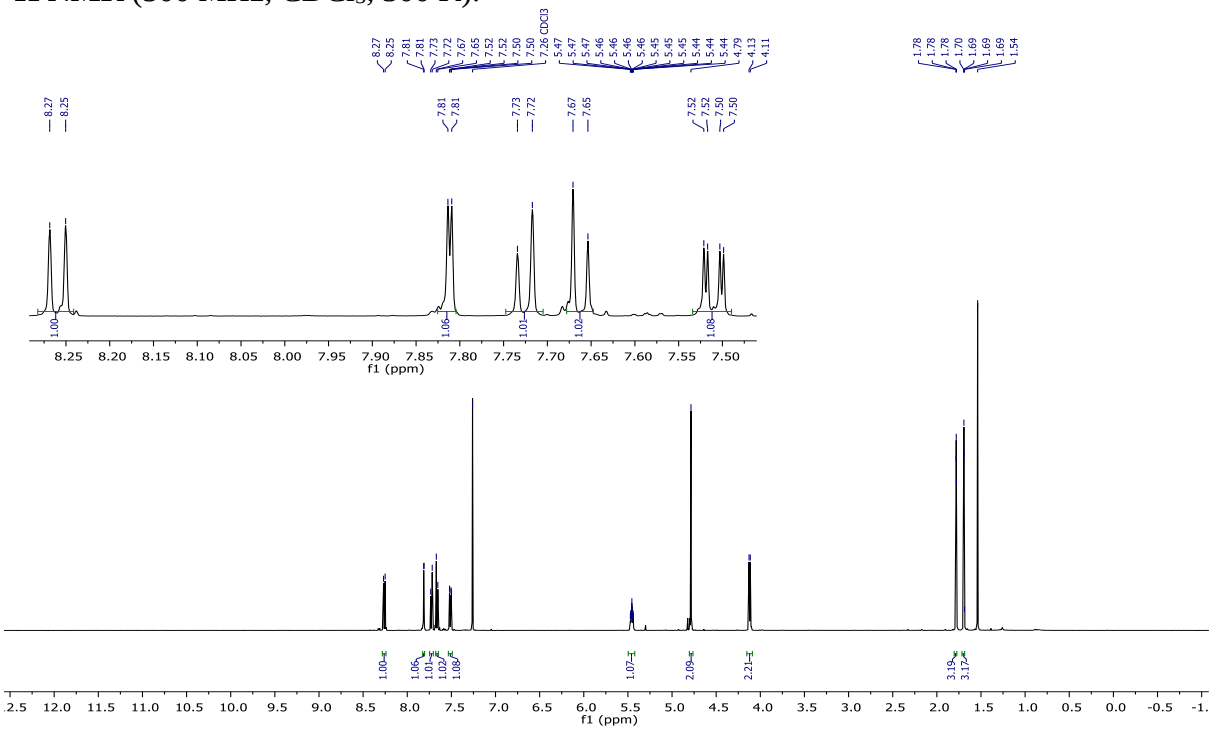


1-Bromo-6-chloro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S54)

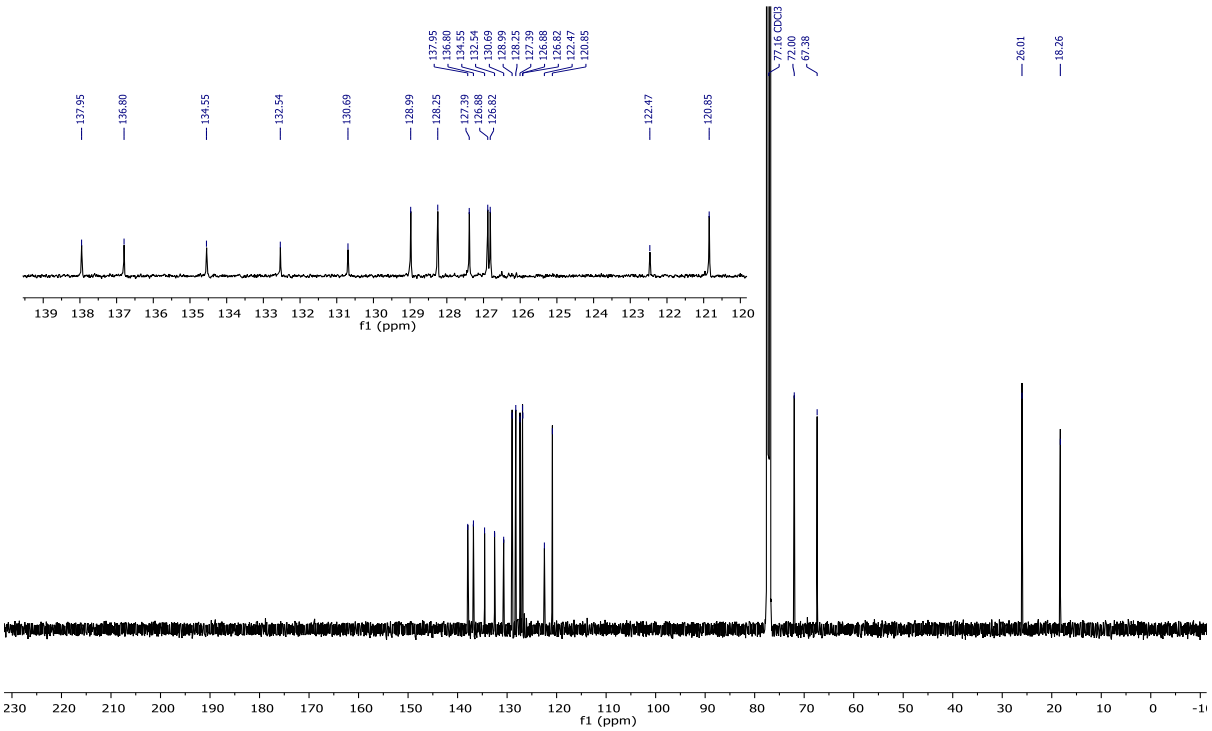


S54

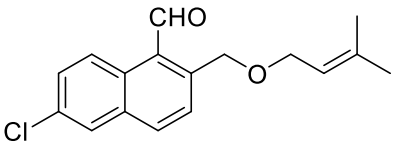
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

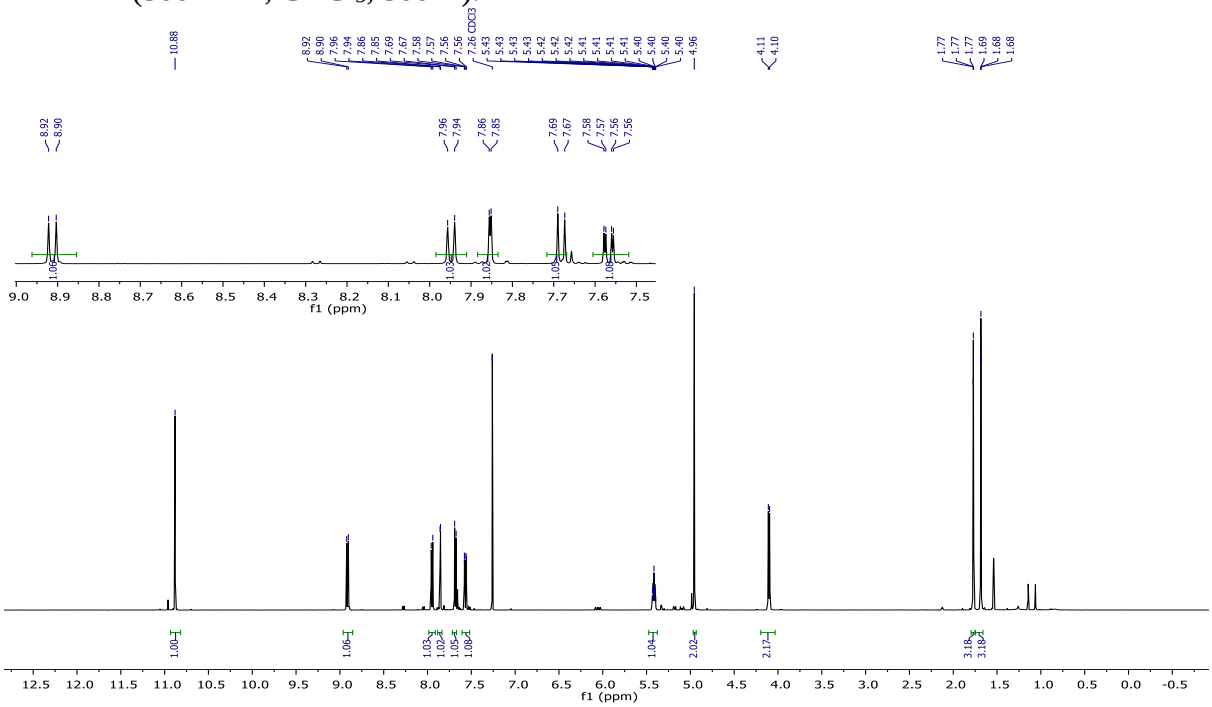


6-Chloro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7m)

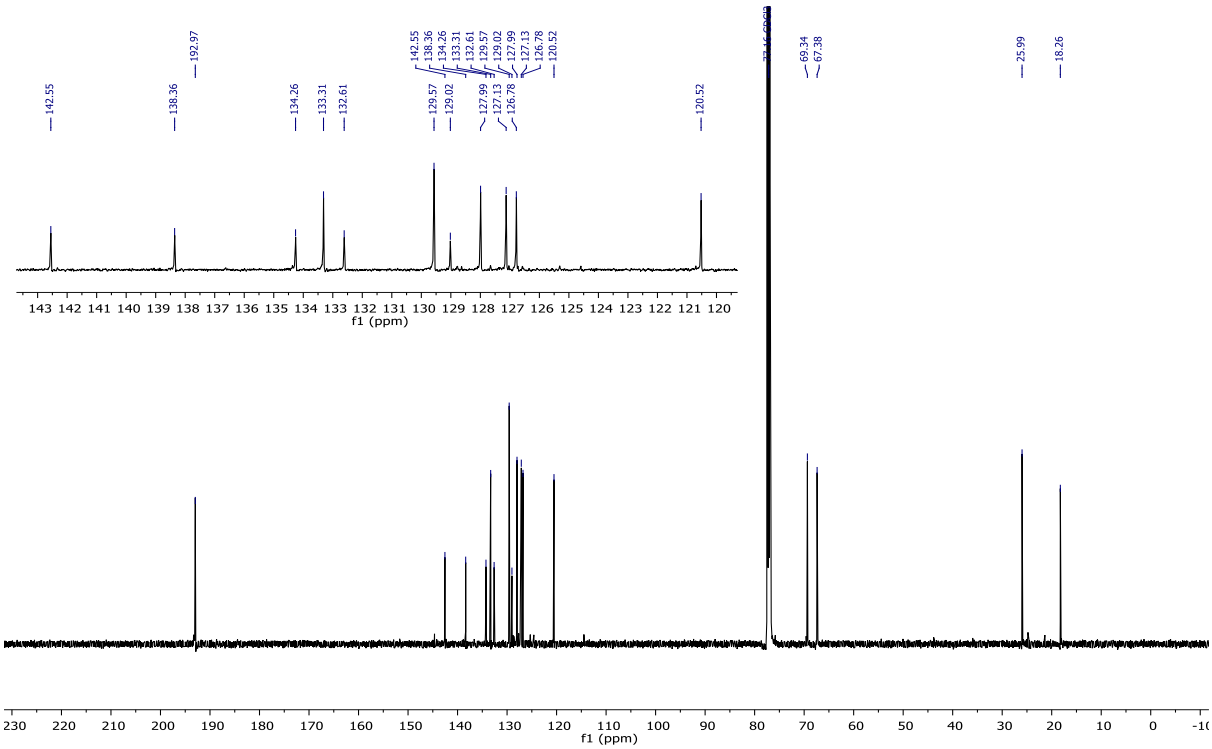


7m

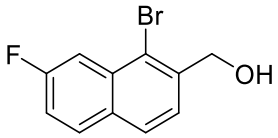
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

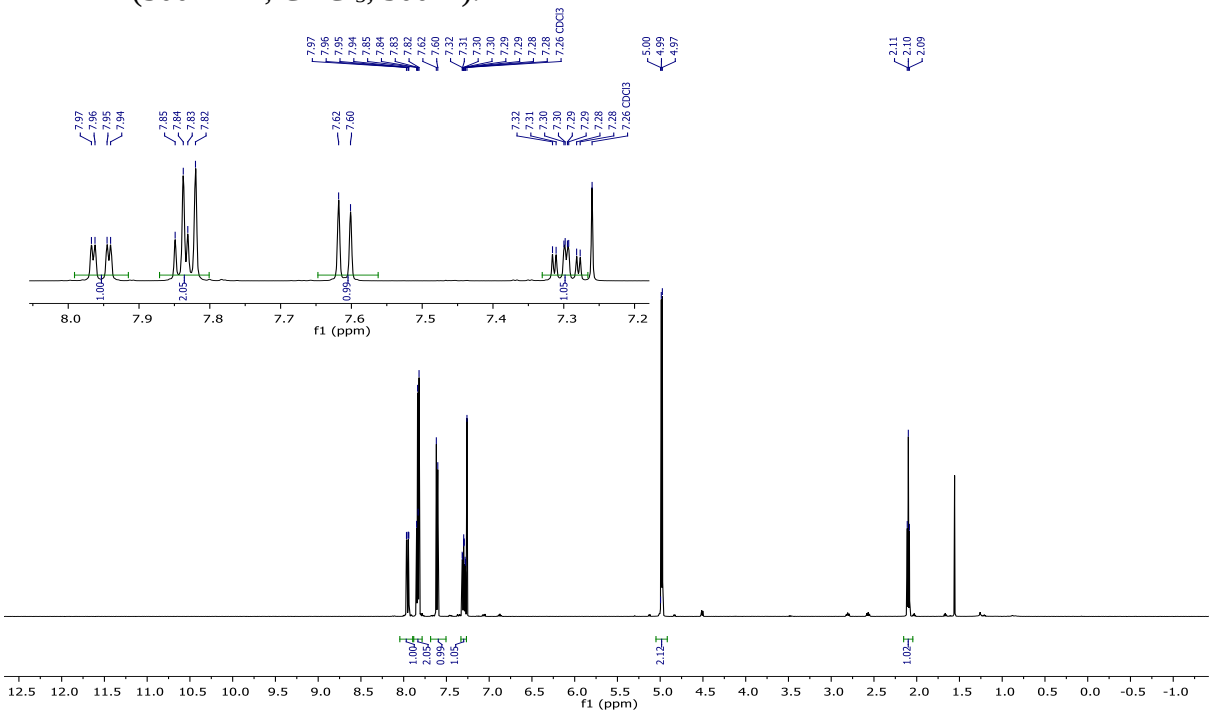


(1-Bromo-7-fluoronaphthalen-2-yl)methanol (S57)

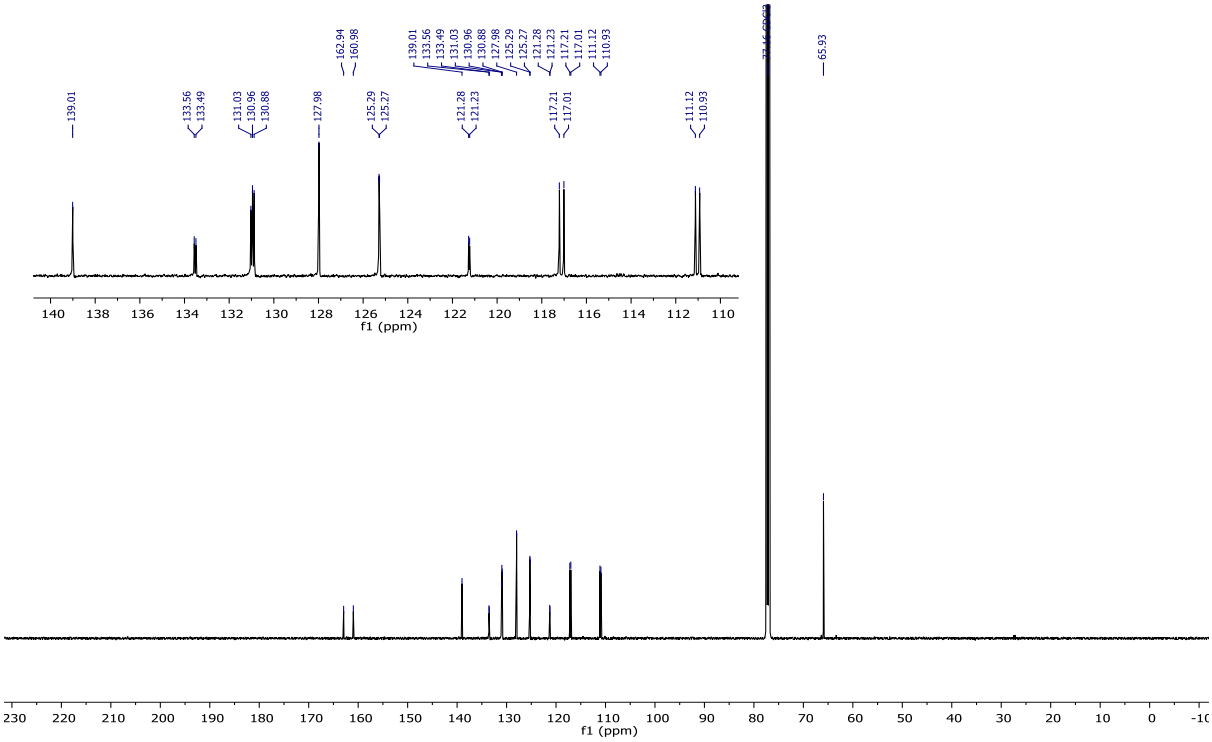


S57

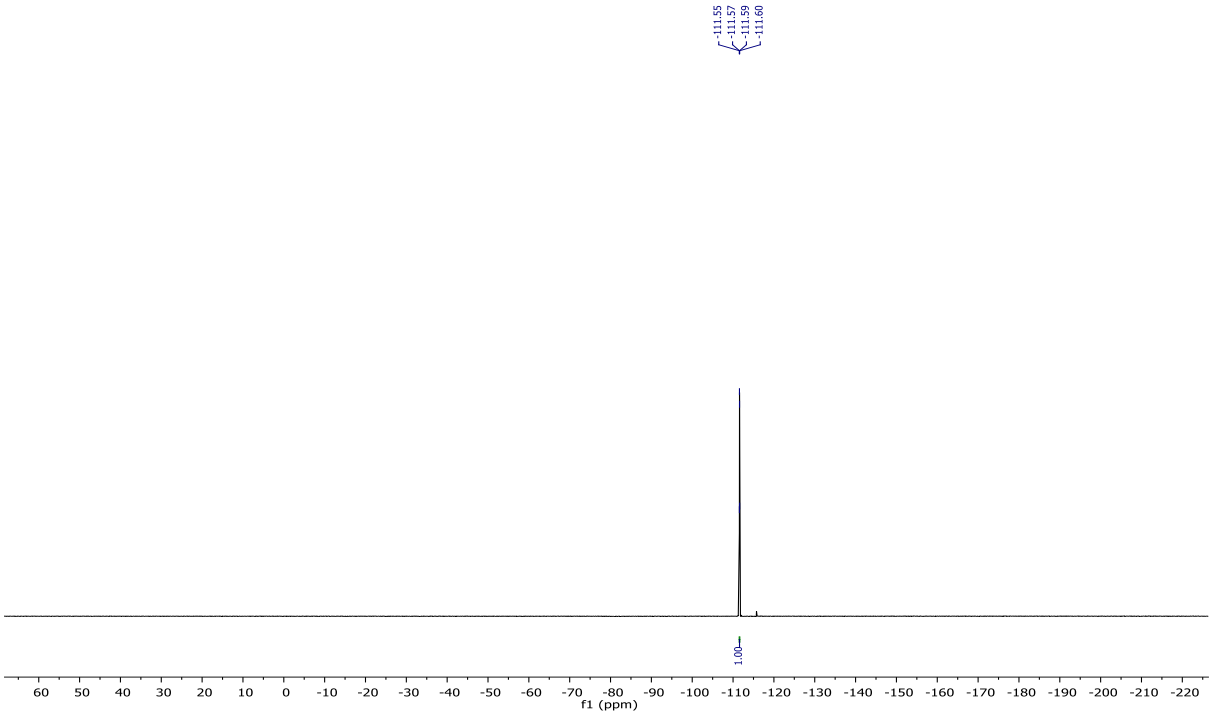
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



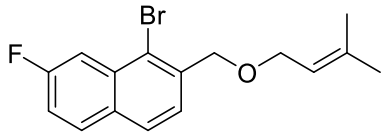
^{13}C NMR (126 MHz, $CDCl_3$, 300 K):



^{19}F NMR (471 MHz, $CDCl_3$, 300 K):

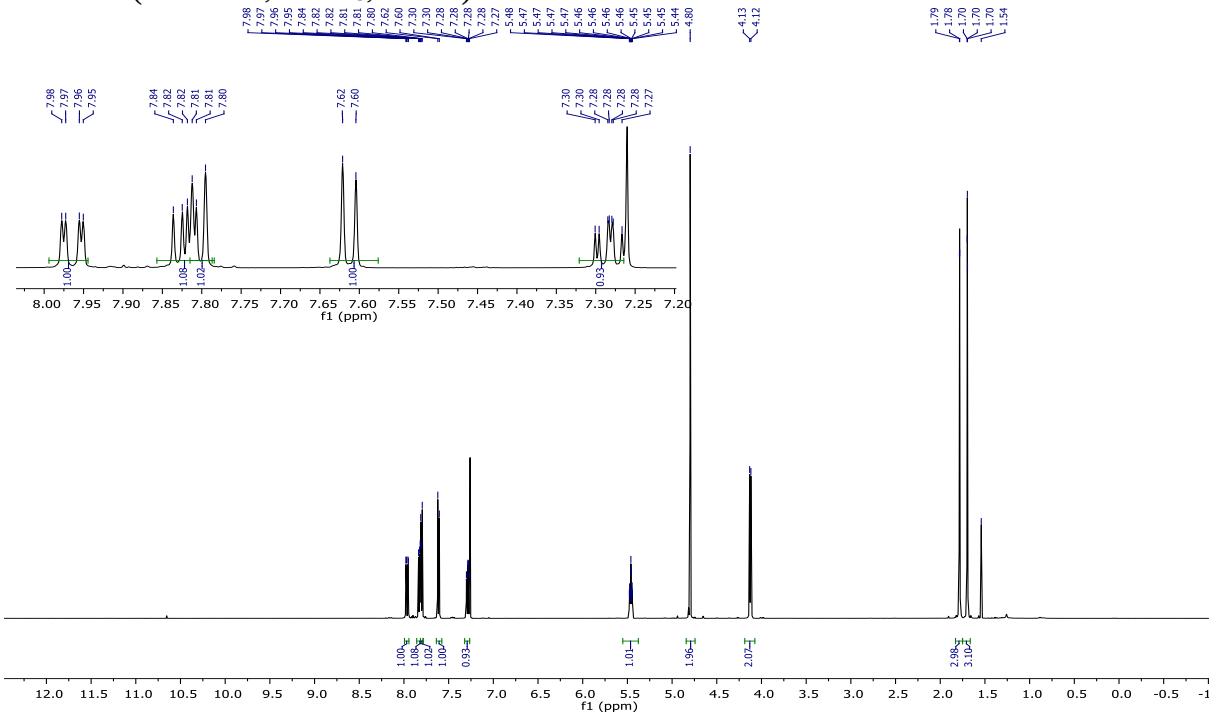


1-Bromo-7-fluoro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}naphthalene (S58)

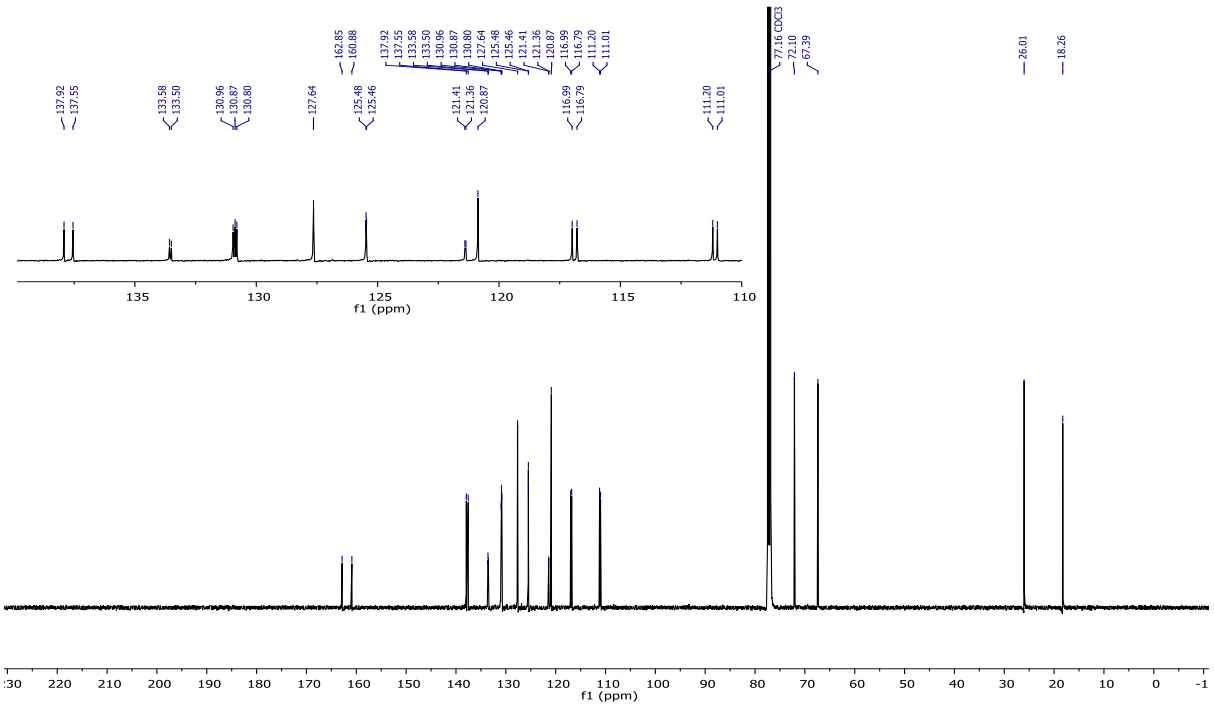


S58

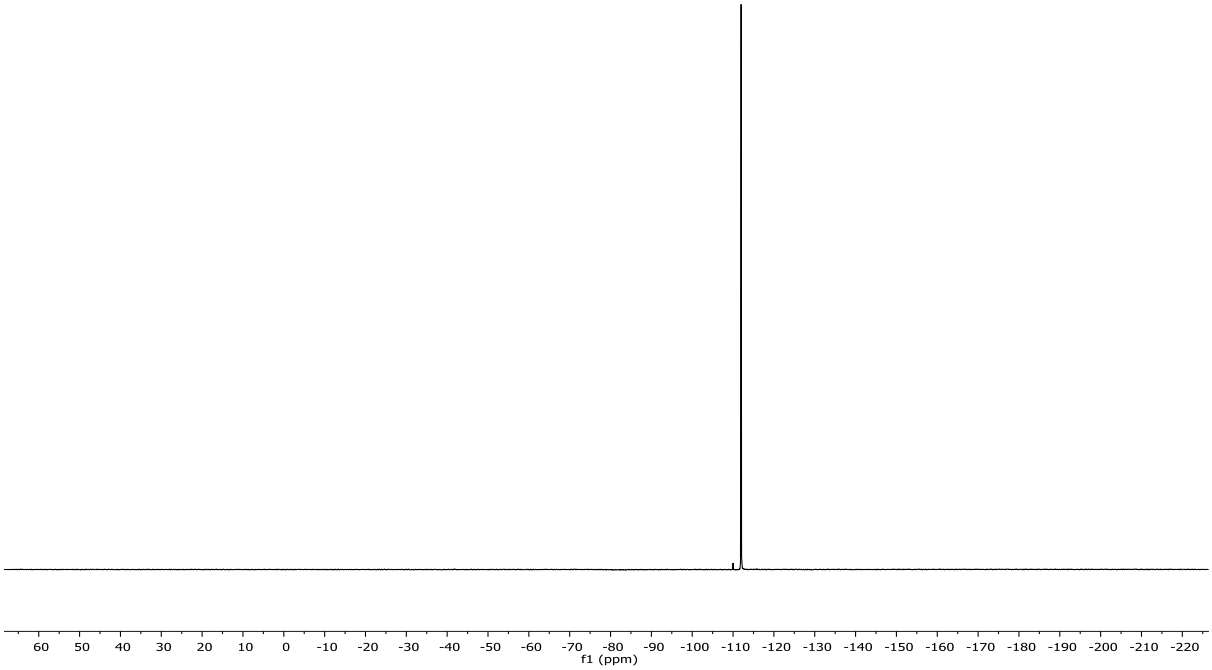
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



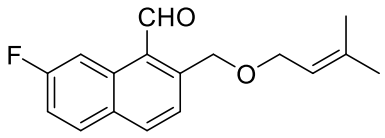
^{13}C NMR (126 MHz, $CDCl_3$, 300 K):



^{19}F NMR (471 MHz, $CDCl_3$, 300 K):

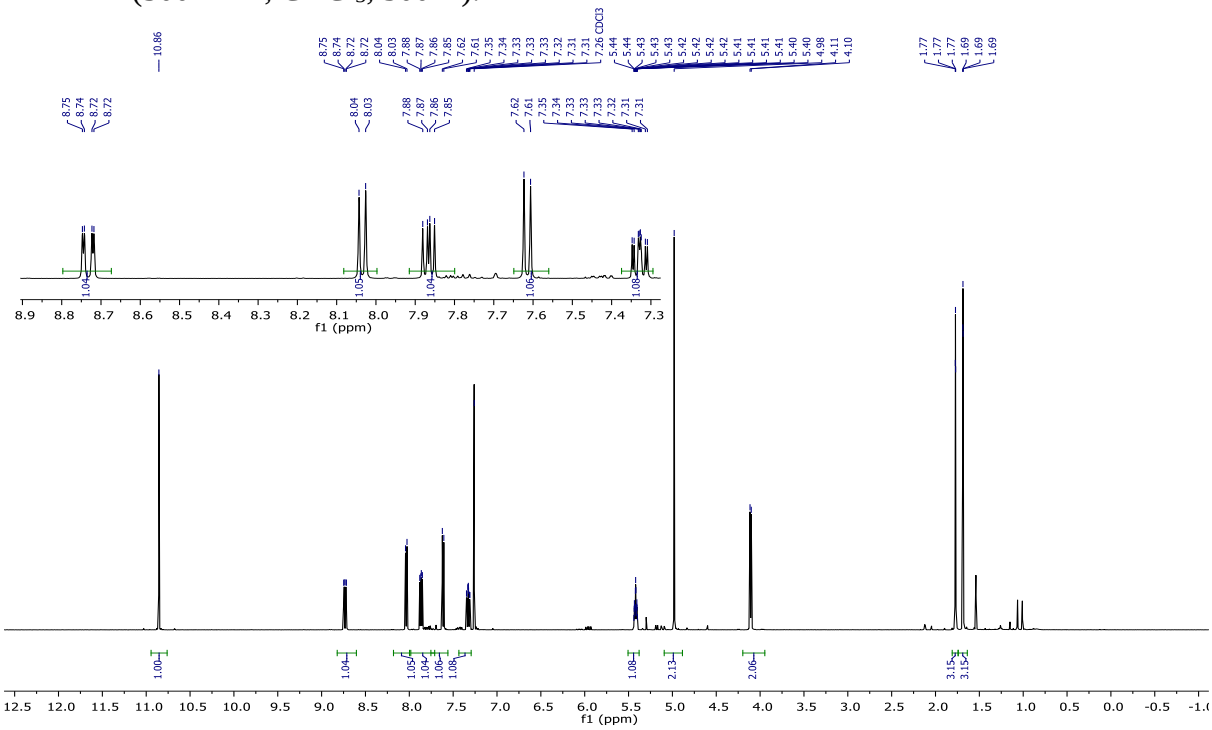


7-Fluoro-2-{[(3-methylbut-2-en-1-yl)oxy]methyl}-1-naphthaldehyde (7n)

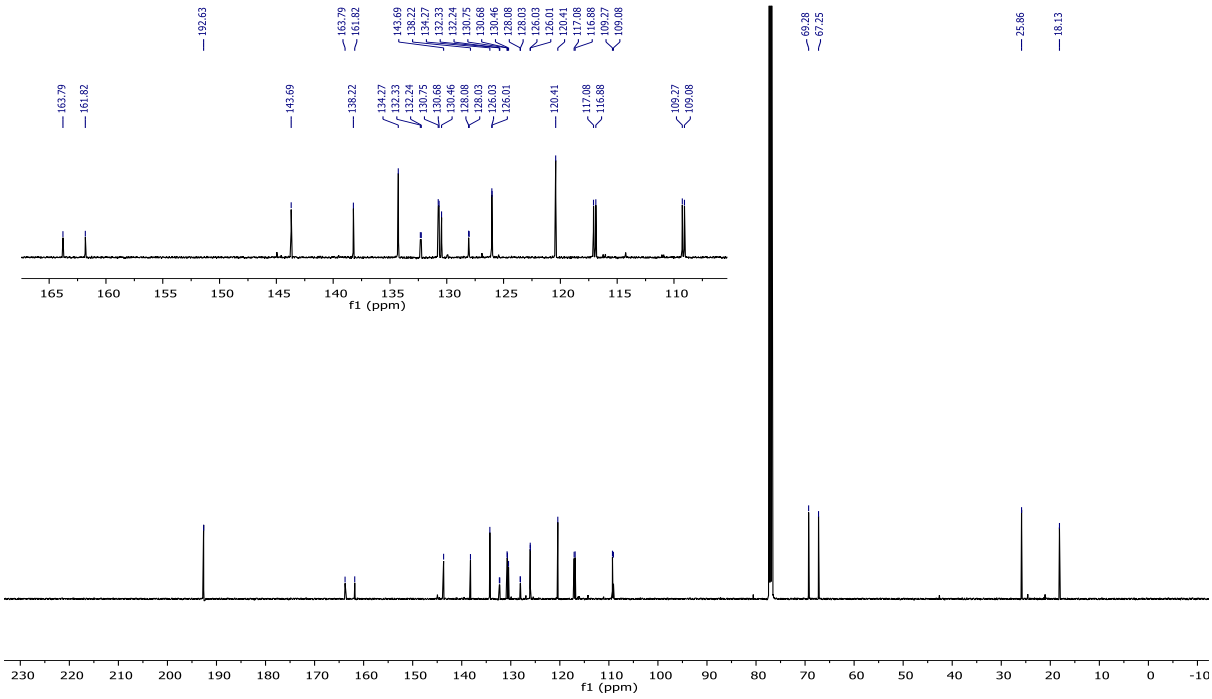


7n

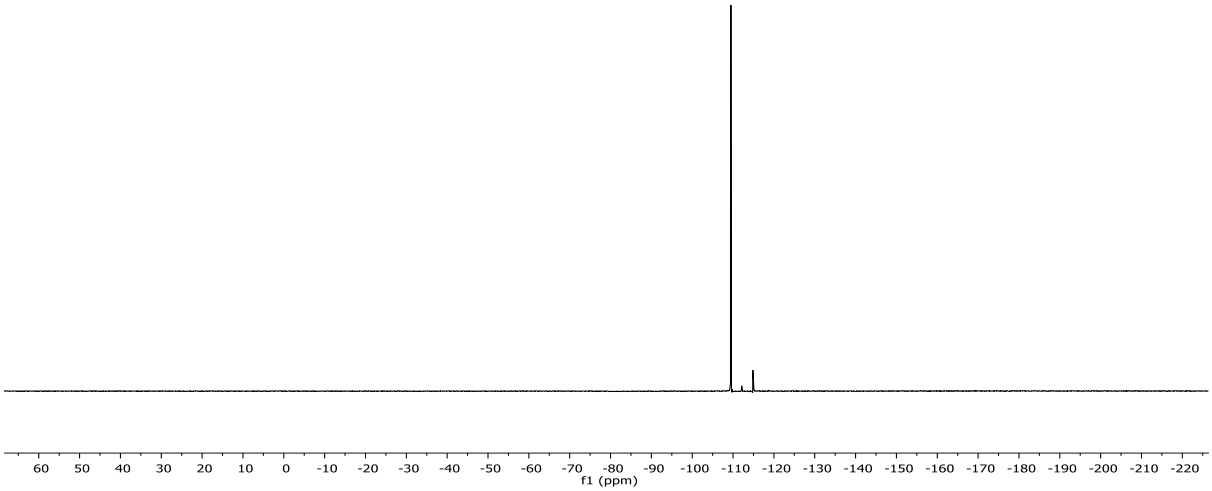
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



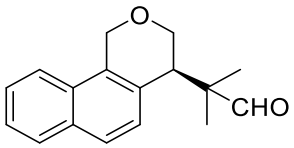
^{13}C NMR (126 MHz, $CDCl_3$, 300 K):



^{19}F NMR (471 MHz, $CDCl_3$, 300 K):

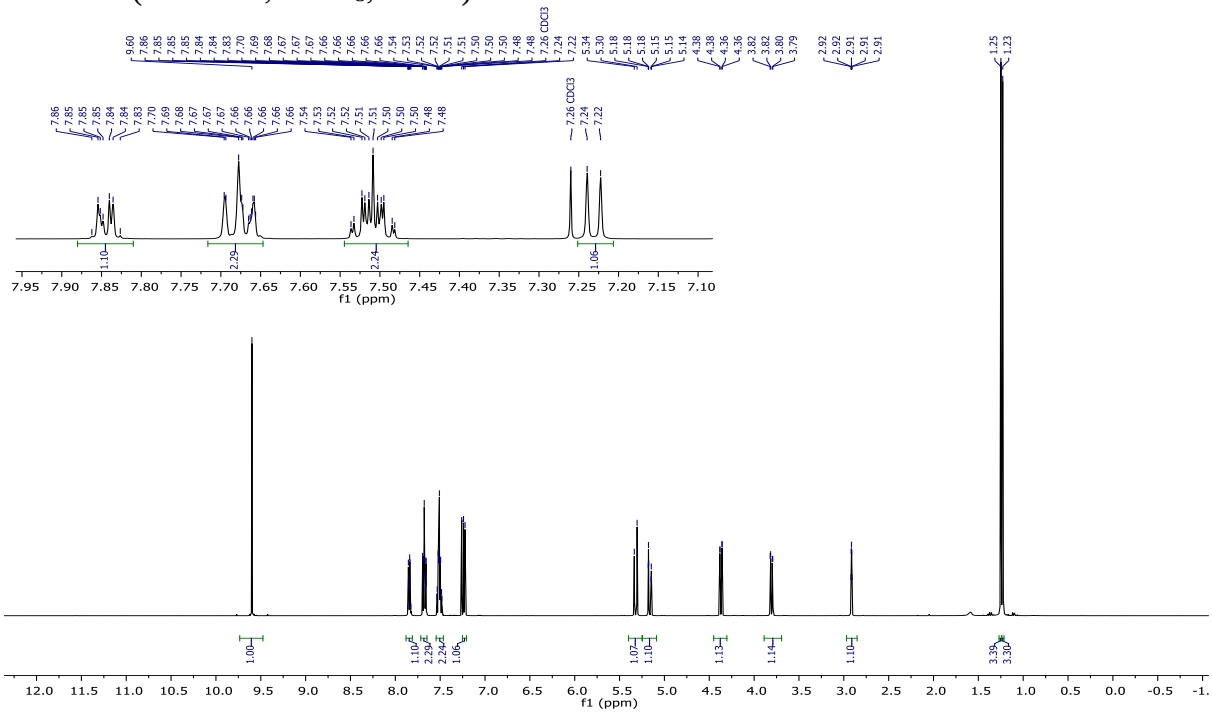


(*R*)-2-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8a)

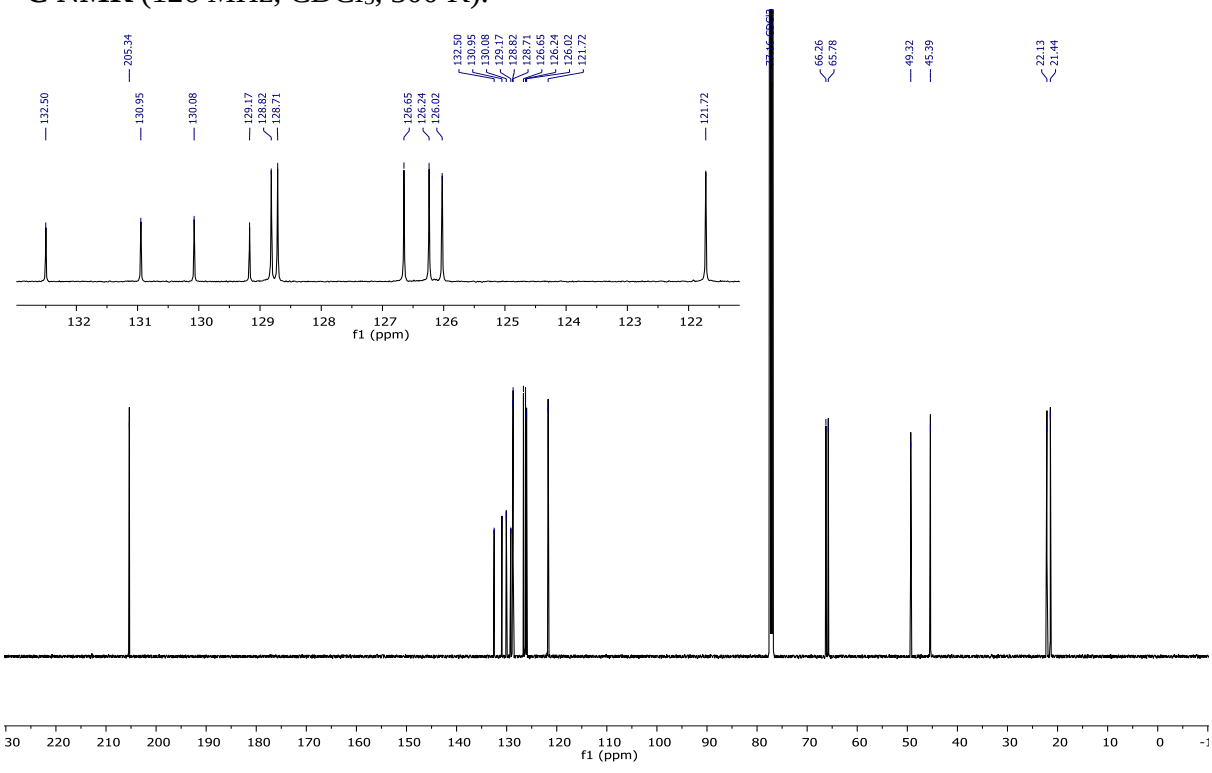


8a

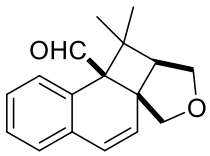
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

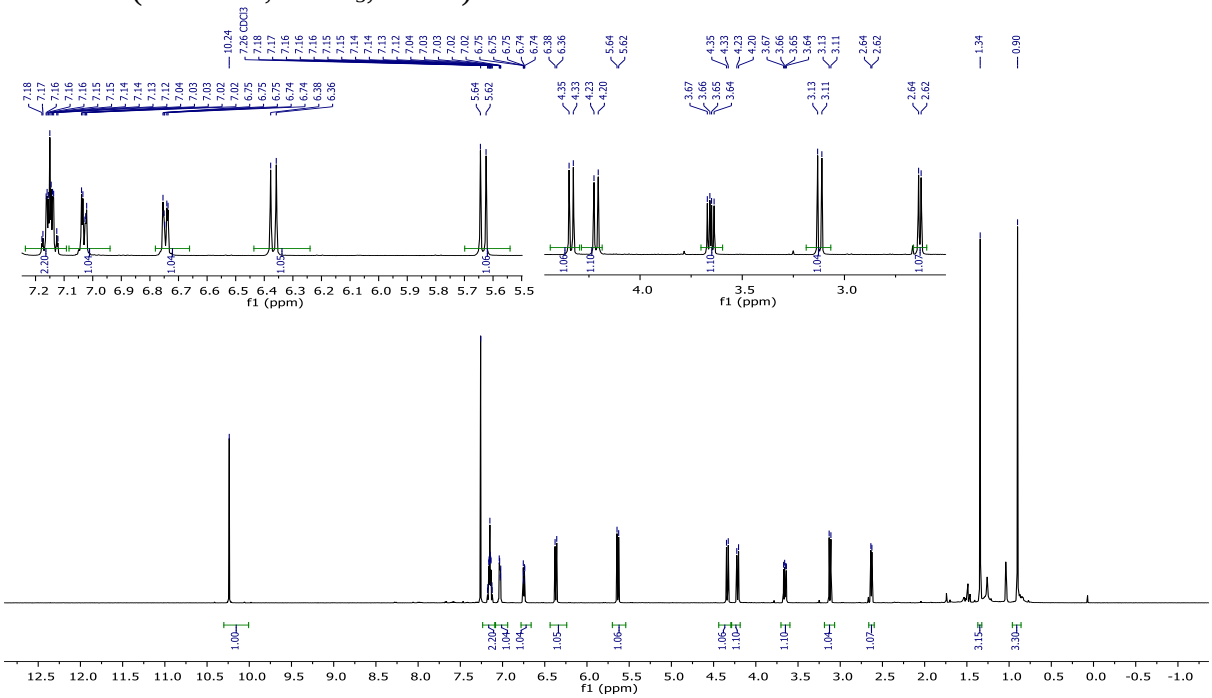


(1a*SR*,4a*SR*,10b*SR*)-1,1-Dimethyl-1a,2-dihydro-4*H*-naphtho[2',1':1,4]cyclobuta[1,2-*c*]furan-10b(1*H*)-carbaldehyde (*rac*-9a)

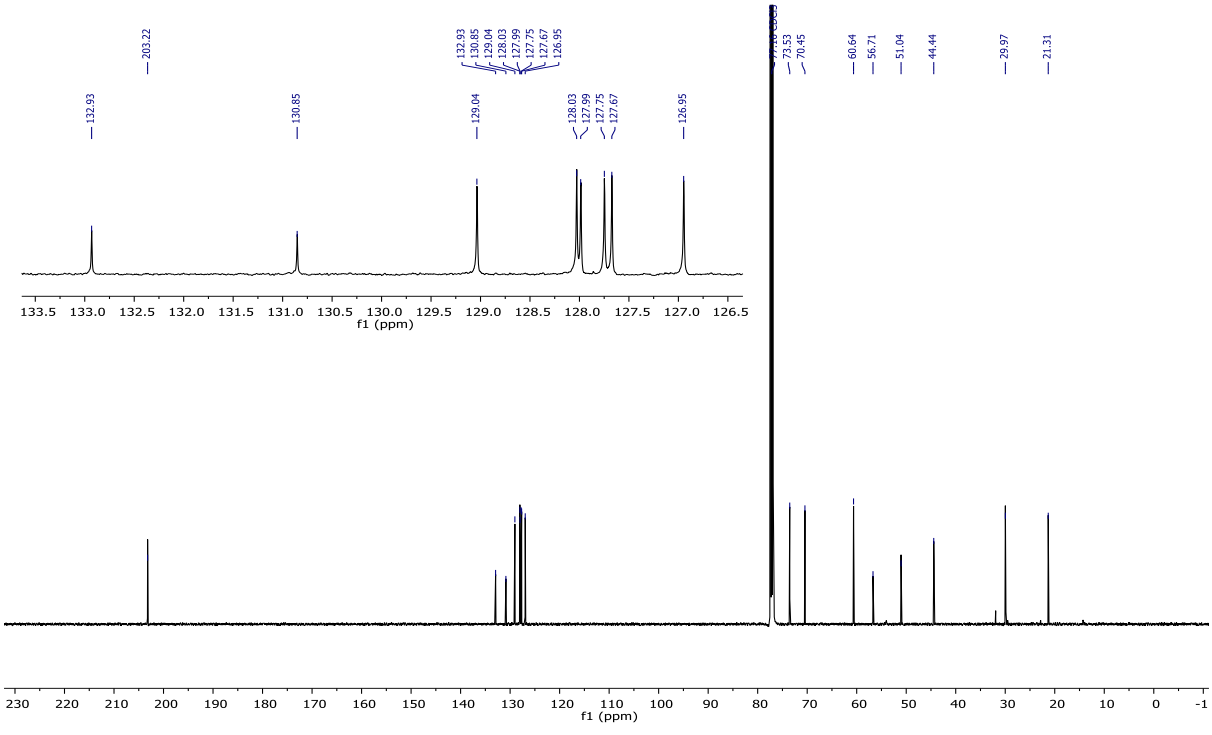


rac-**9a**

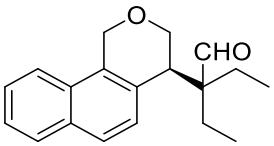
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

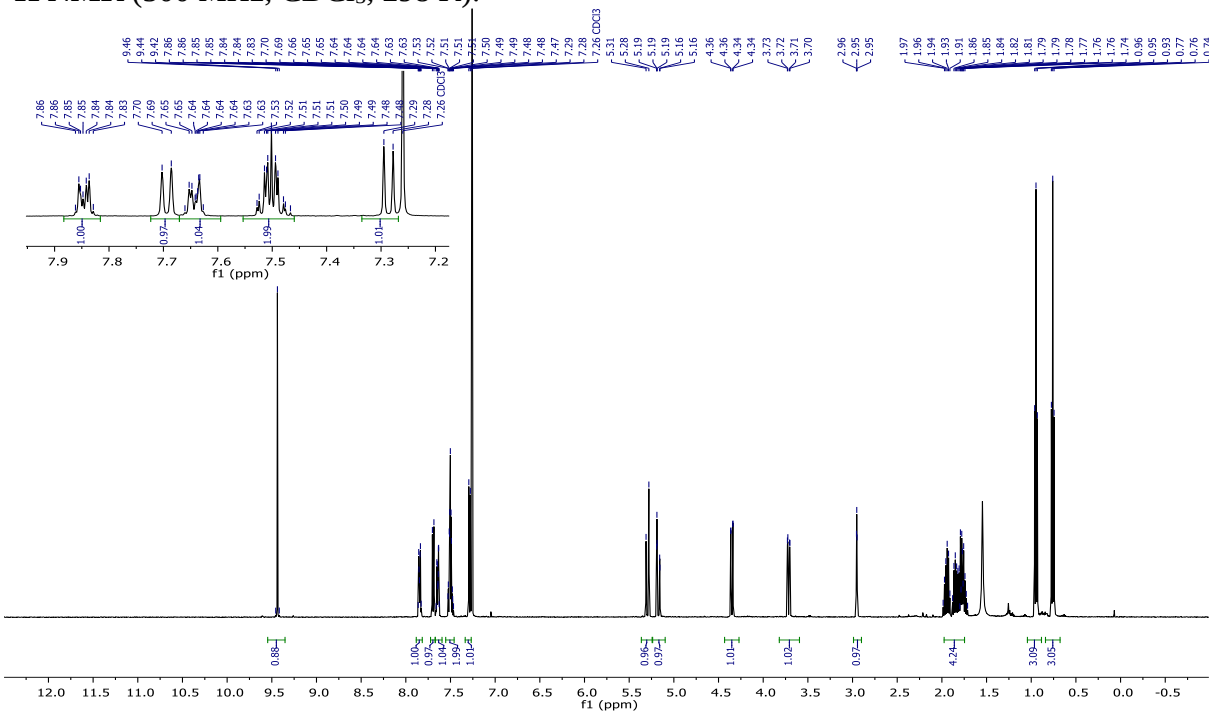


(*R*)-2-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-ethylbutanal (8b)

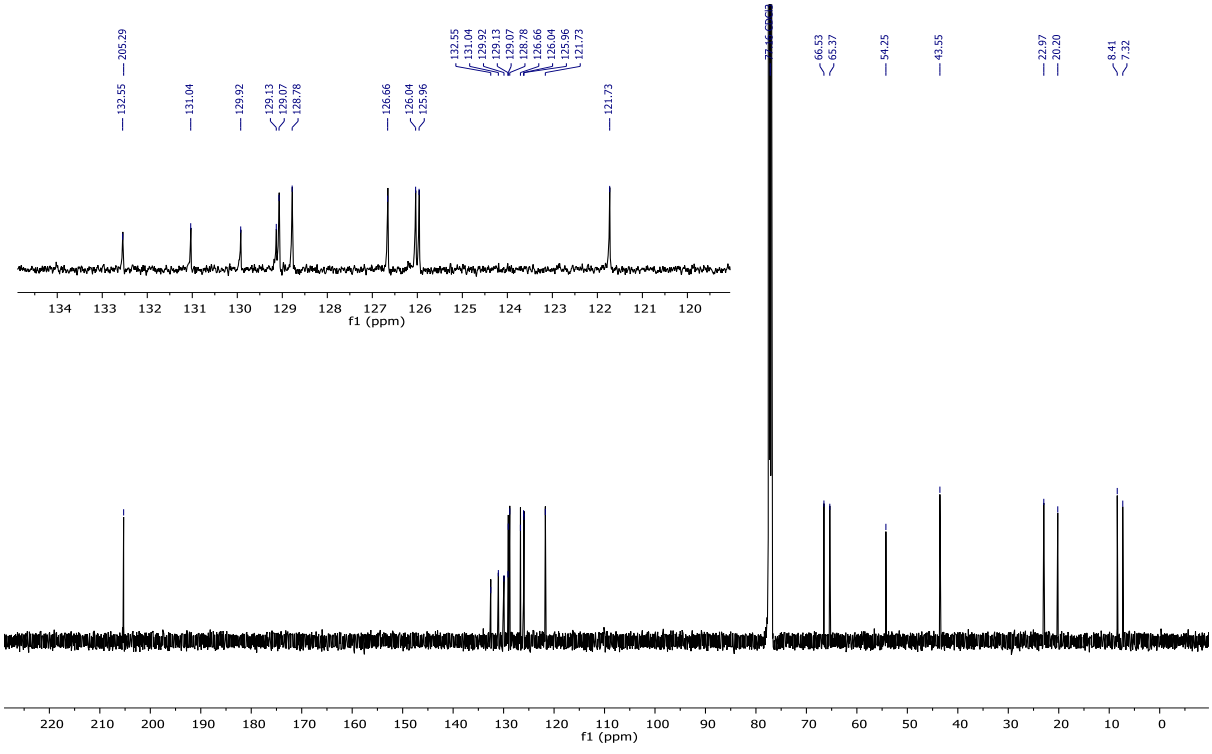


8b

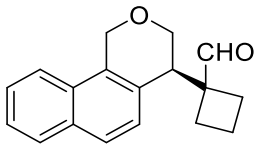
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

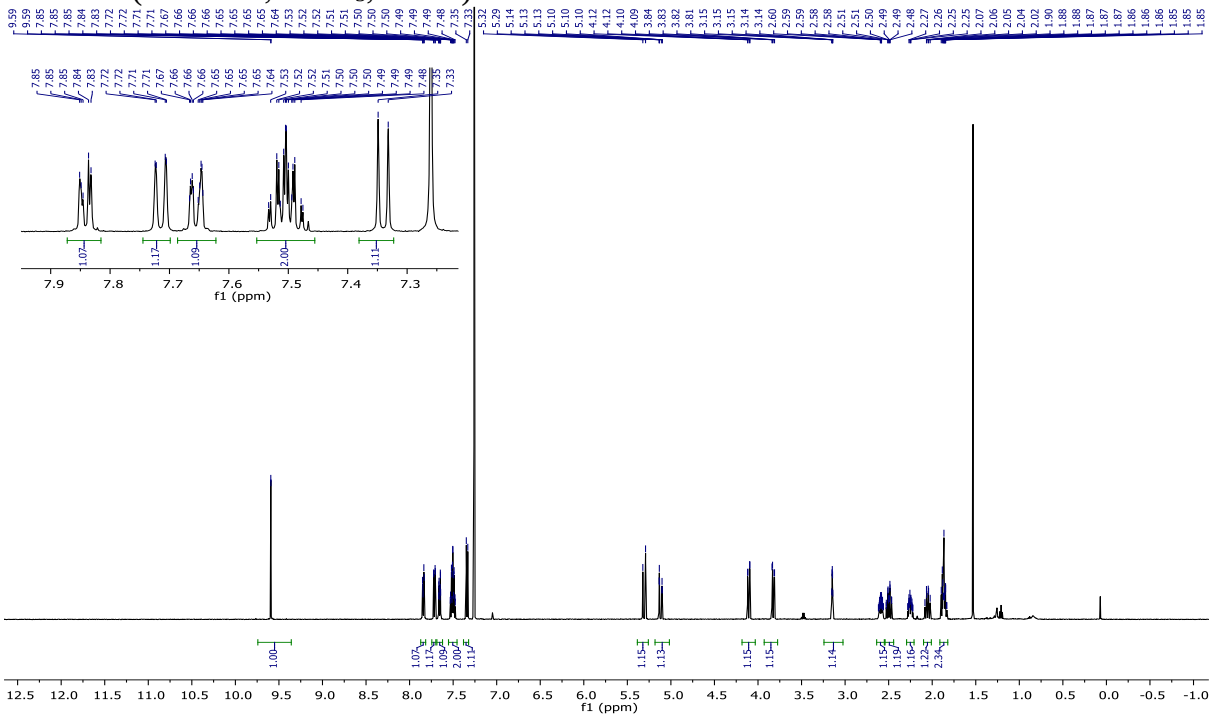


(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclobutane-1-carbaldehyde (8c)

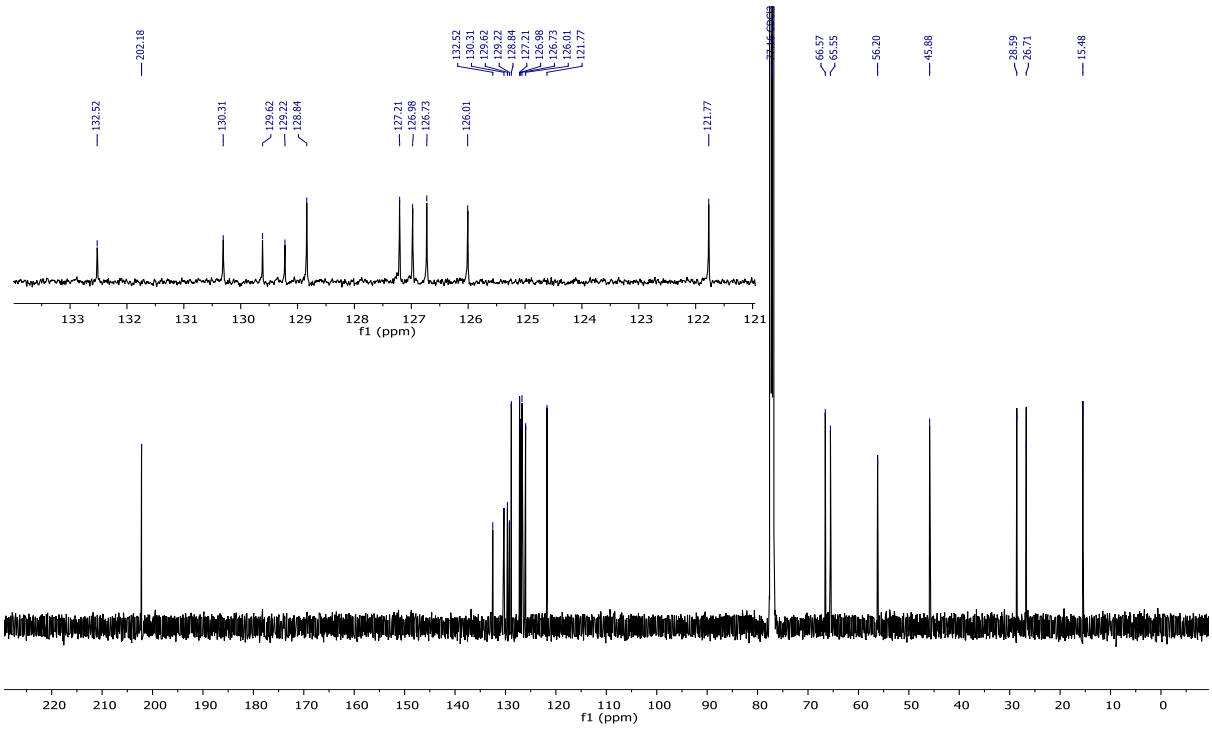


8c

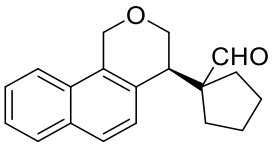
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

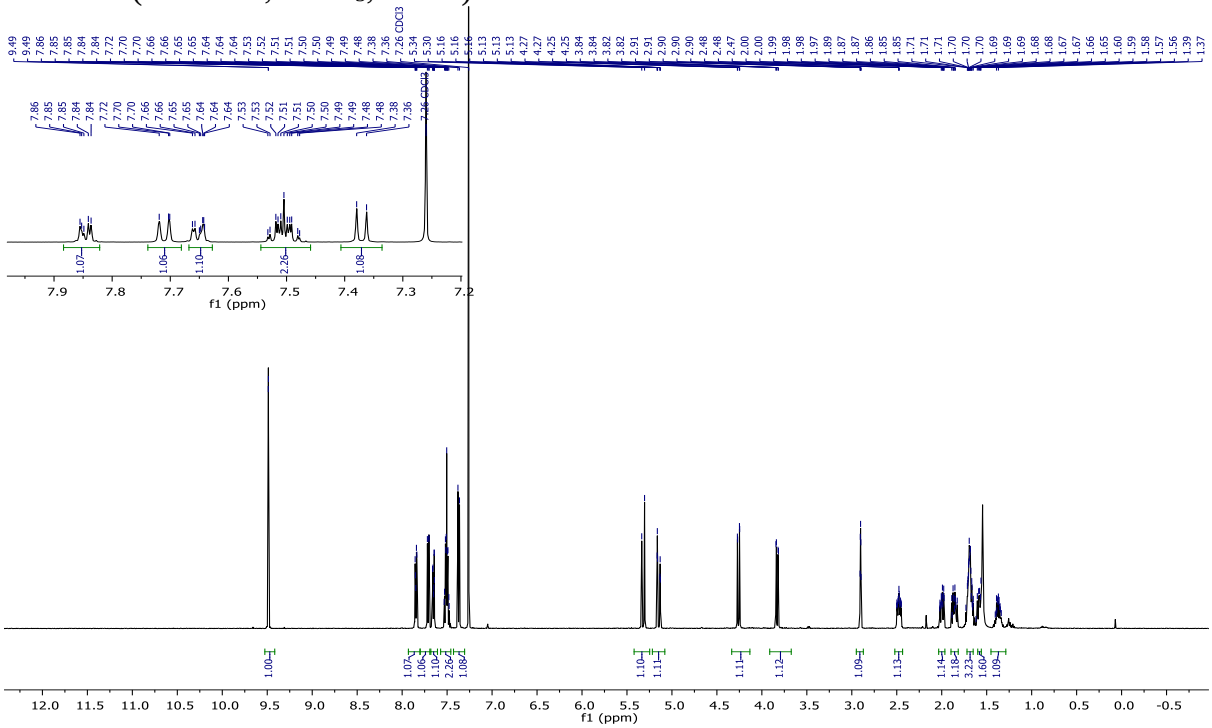


(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclopentane1-carbaldehyde (8d)

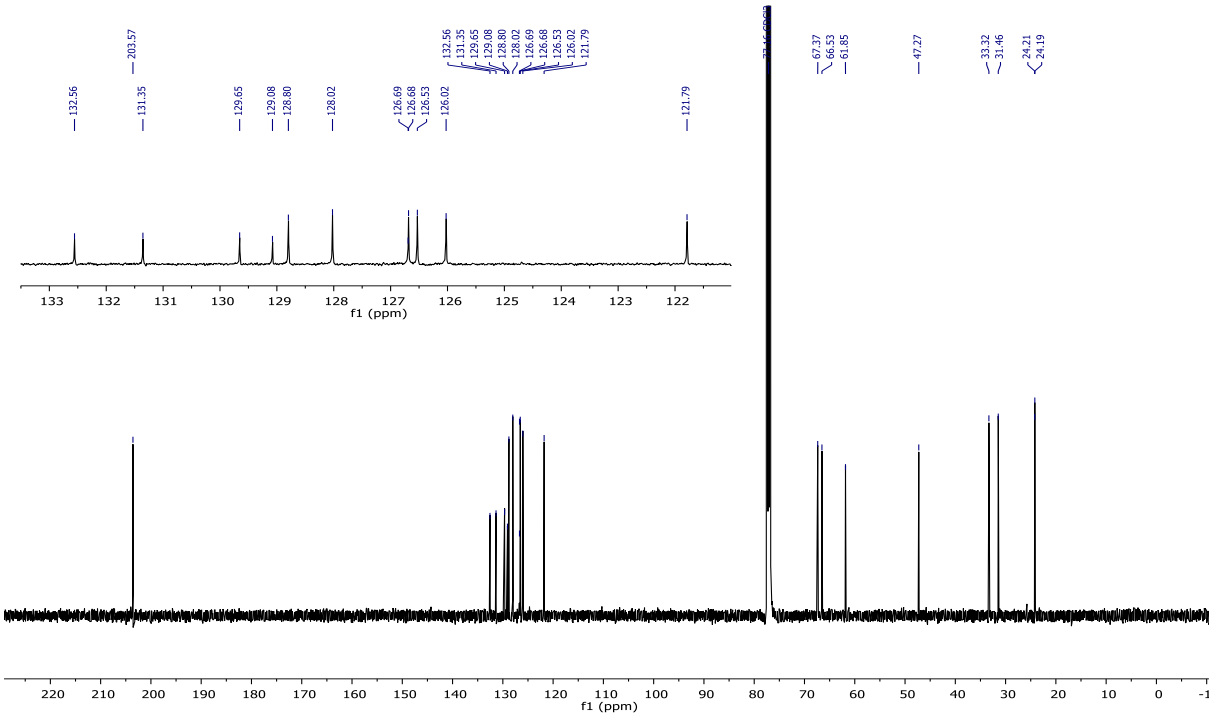


8d

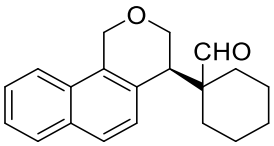
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

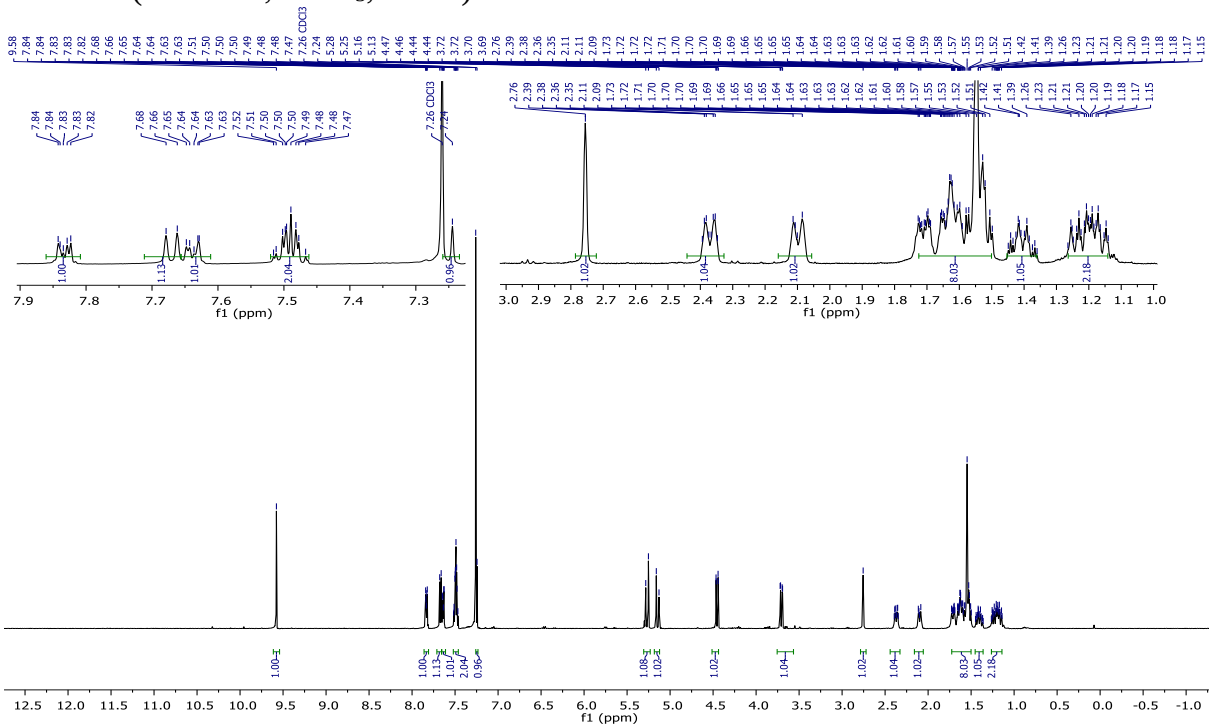


(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclohexane-1-carbaldehyde (8e)

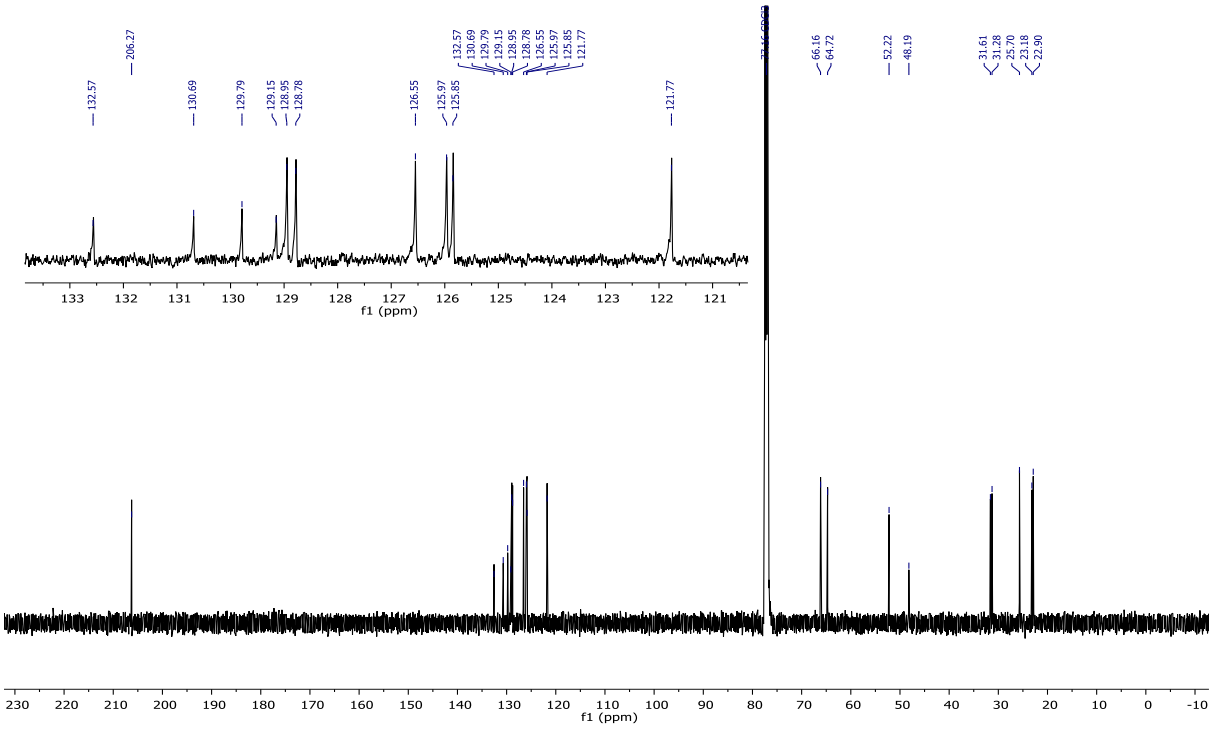


8e

^{1}H NMR (500 MHz, $CDCl_3$, 298 K):

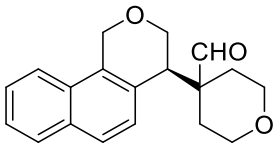


^{13}C NMR (126 MHz, $CDCl_3$, 300 K):



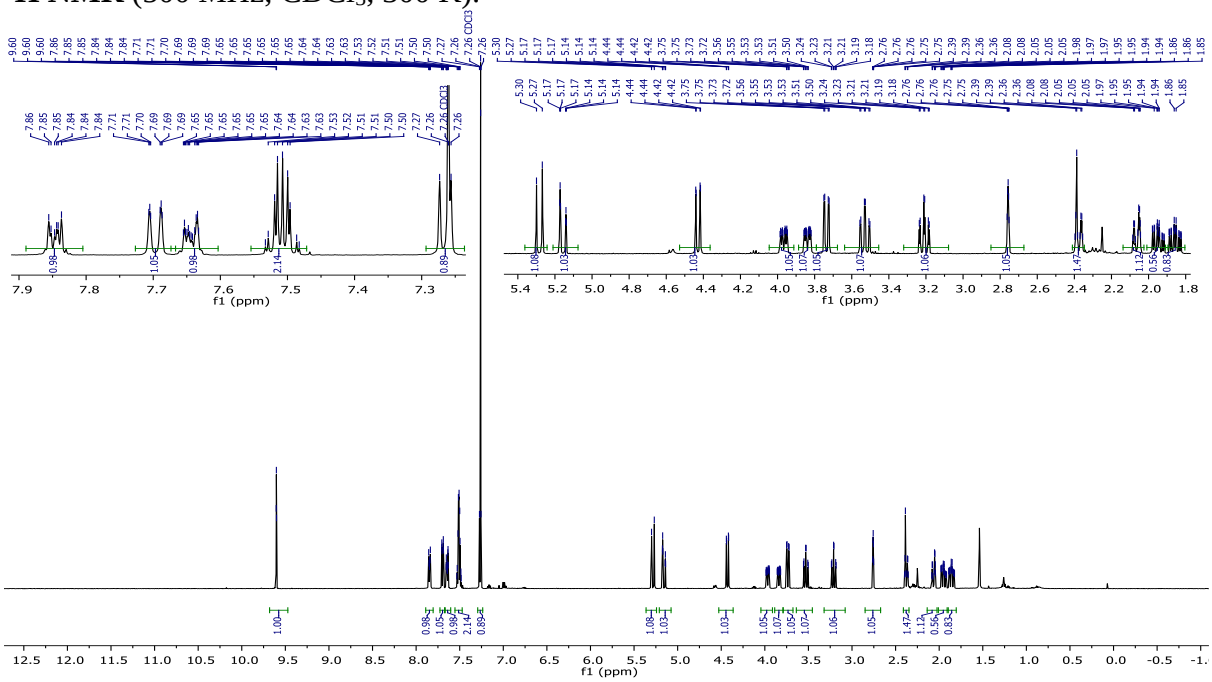
(*R*)-4-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)tetrahydro-2*H*-pyran-4-carbaldehyde

(8f)

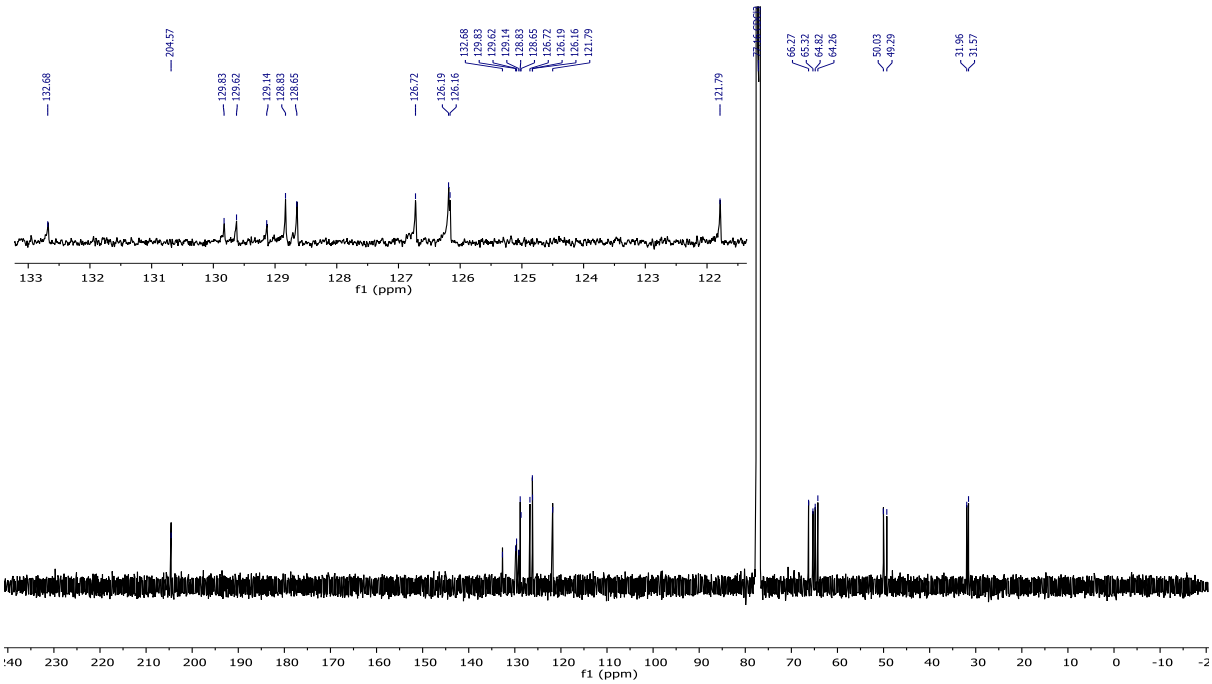


8f

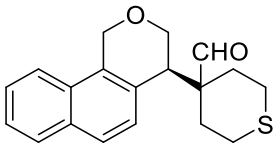
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

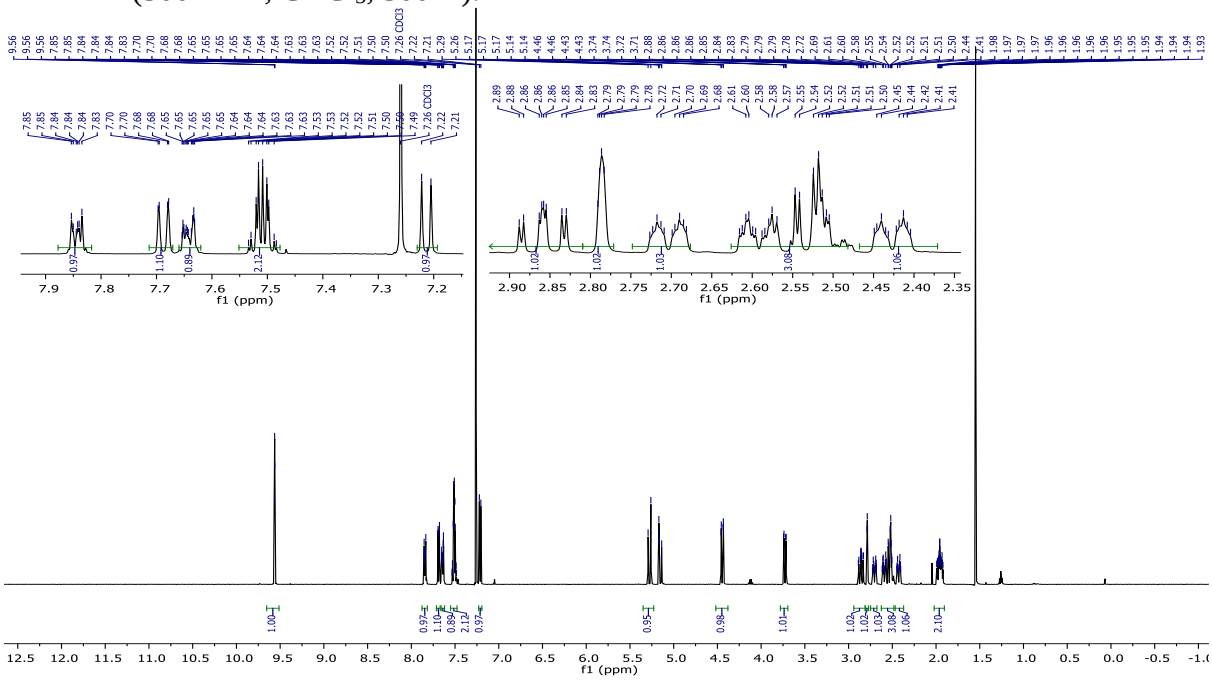


(*R*)-4-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)tetrahydro-2*H*-thiopyran-4-carbaldehyde (8g)

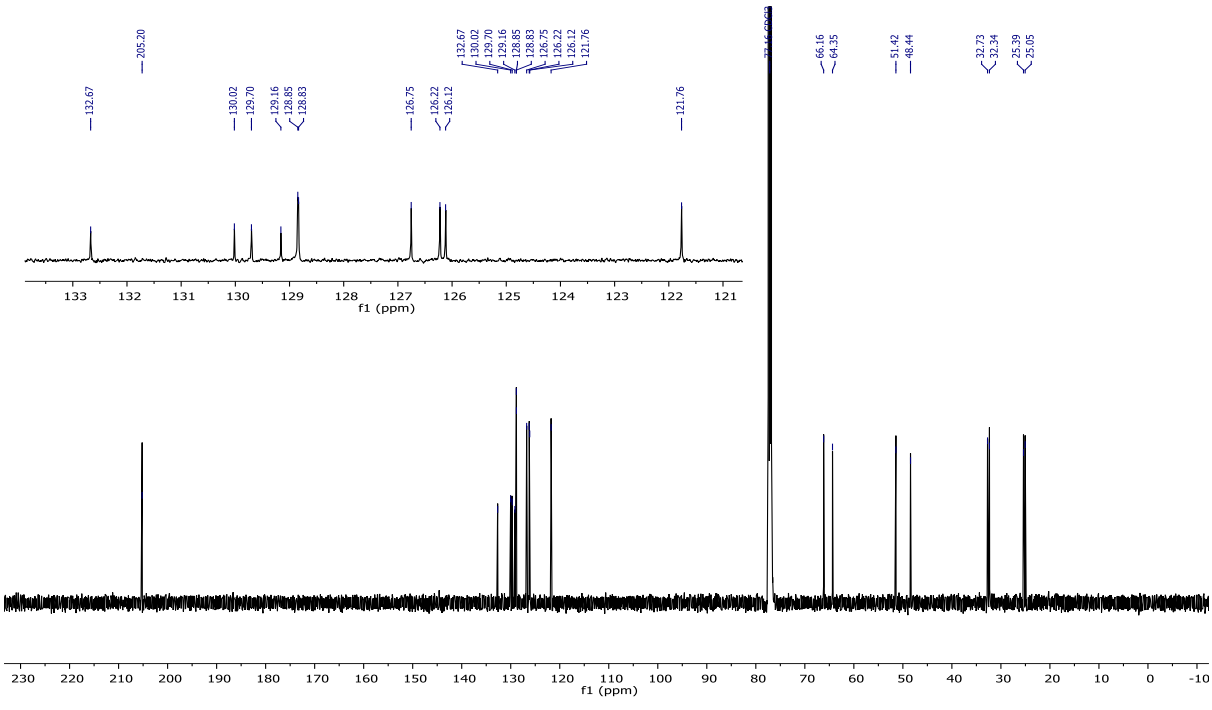


8g

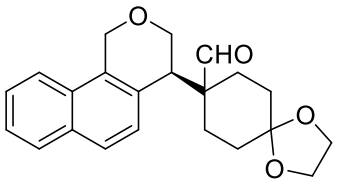
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

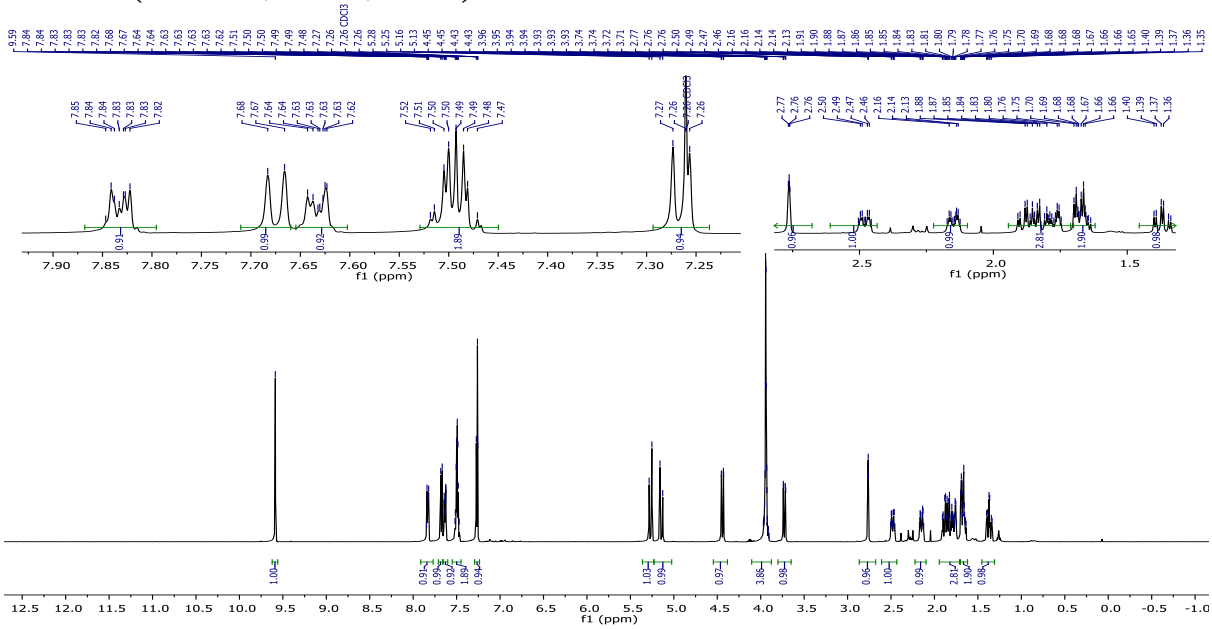


(*R*)-8-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-1,4-dioxaspiro[4.5]decane-8-carbaldehyde (8h)

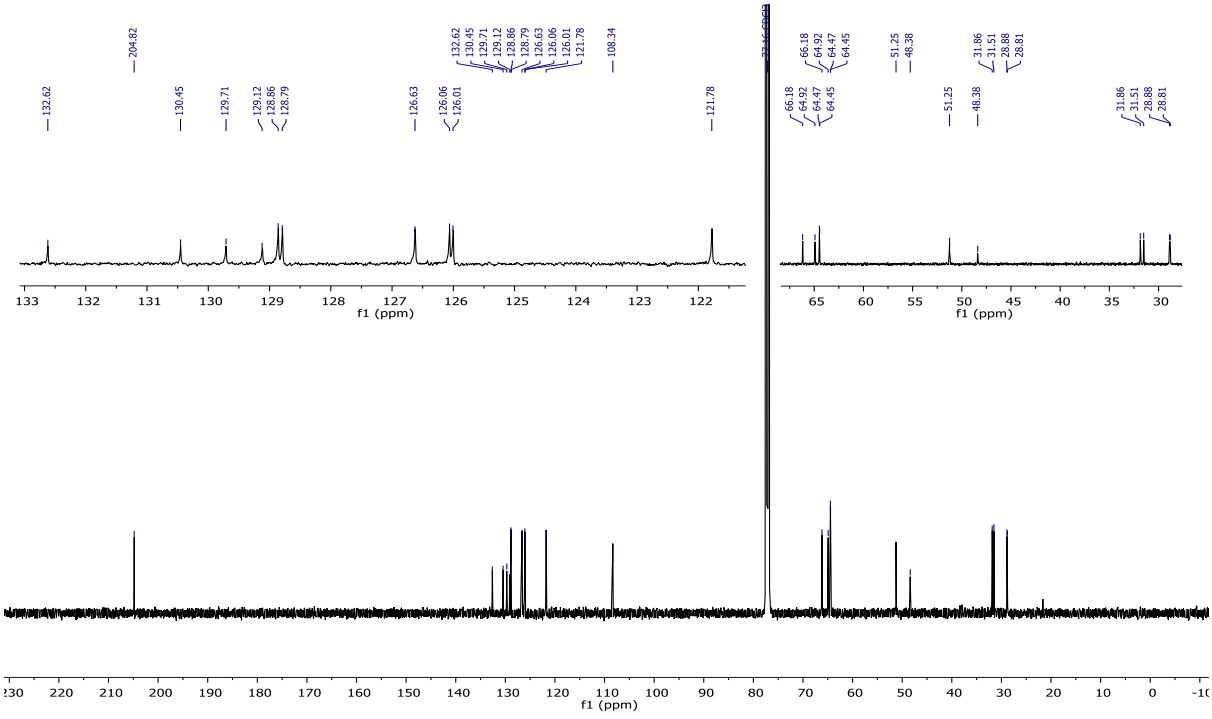


8h

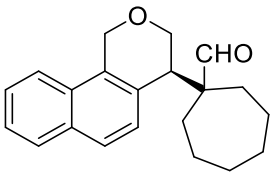
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

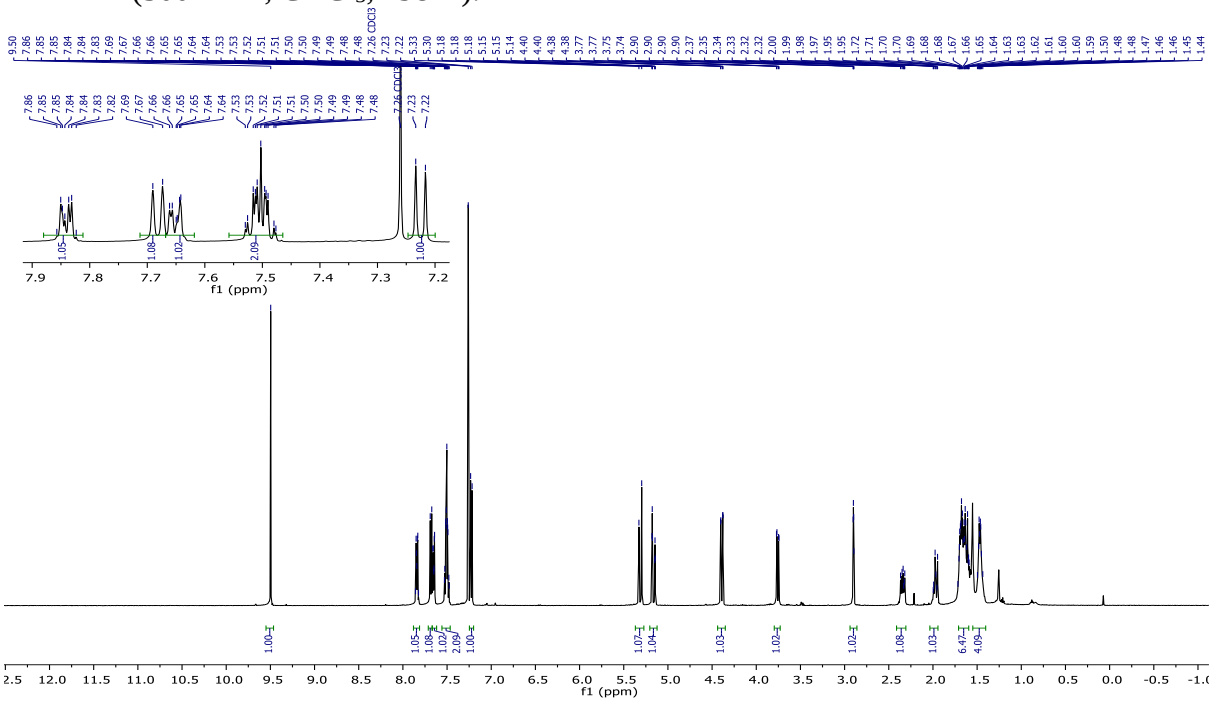


(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cycloheptane-1-carbaldehyde (8i)

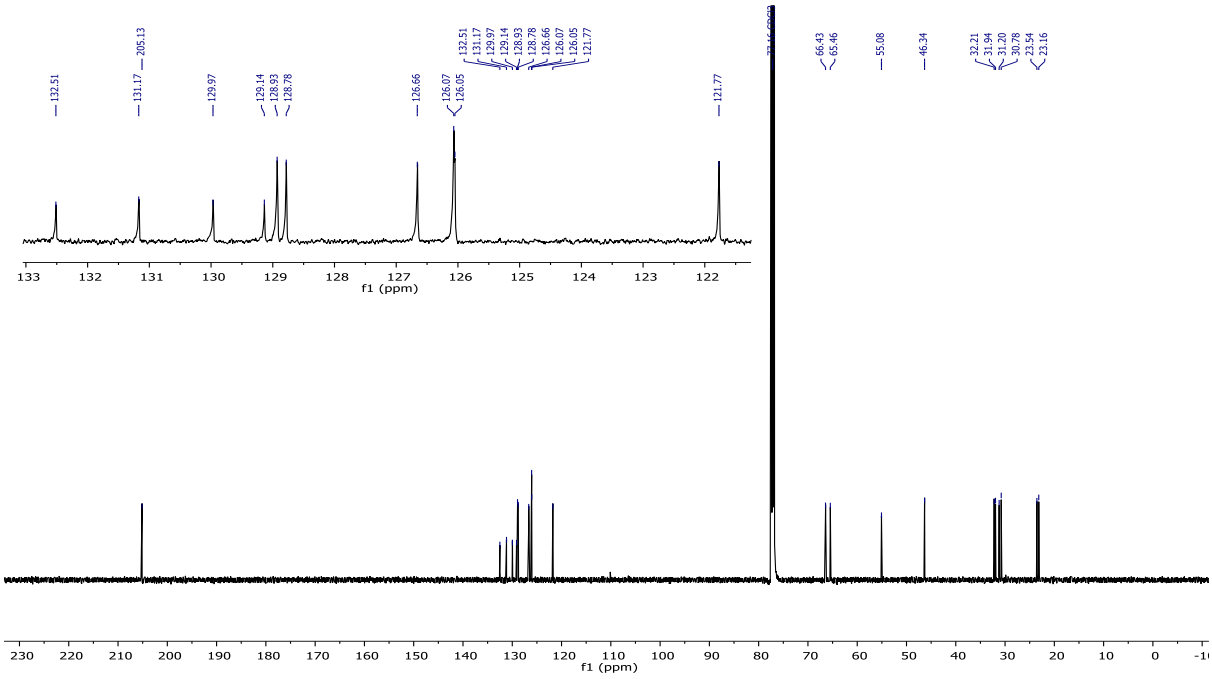


8i

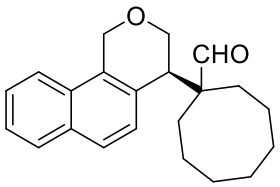
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

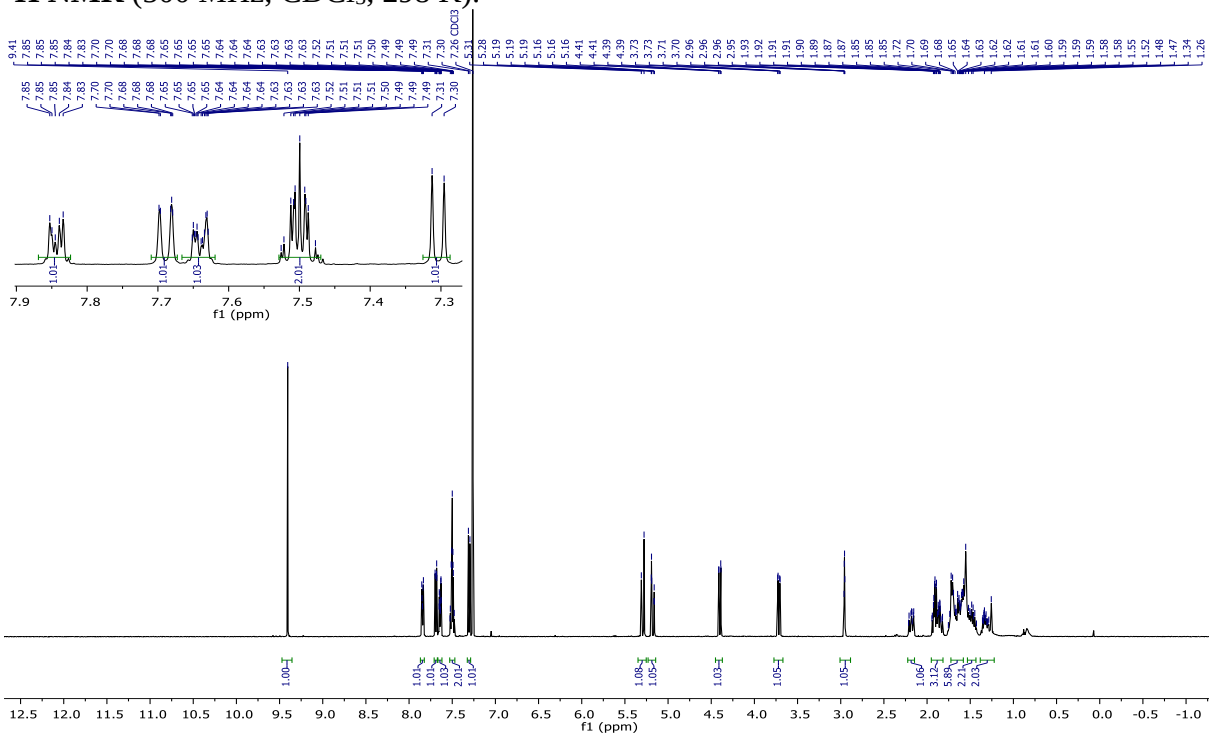


(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclooctane-1-carbaldehyde (8j)

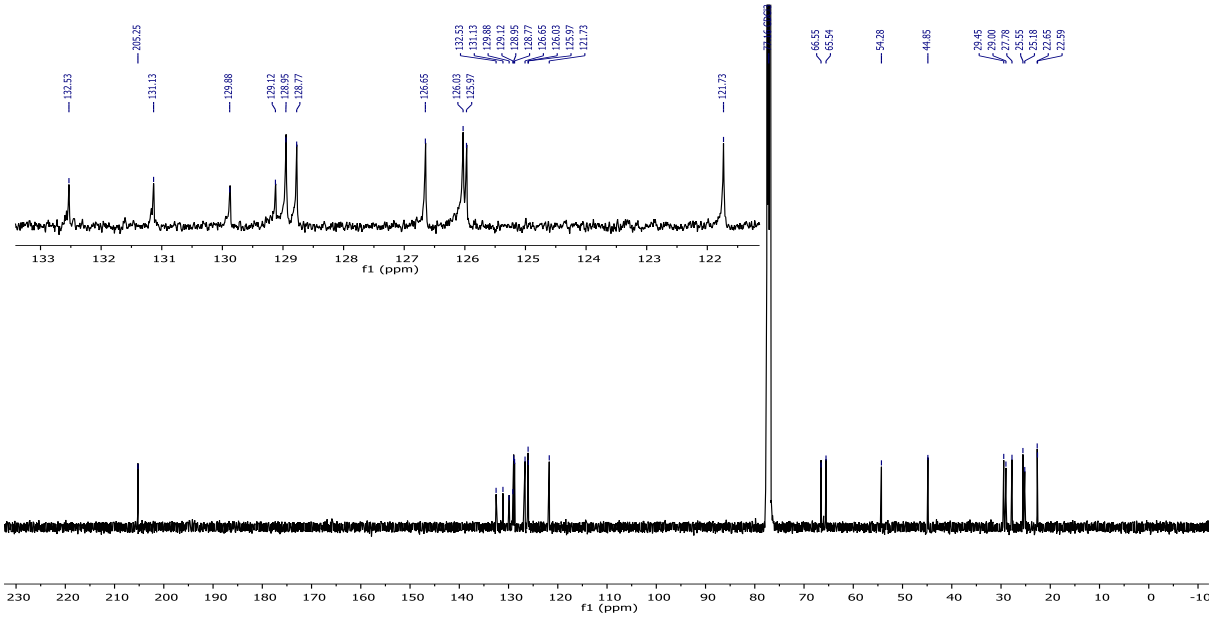


8j

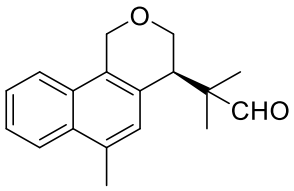
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

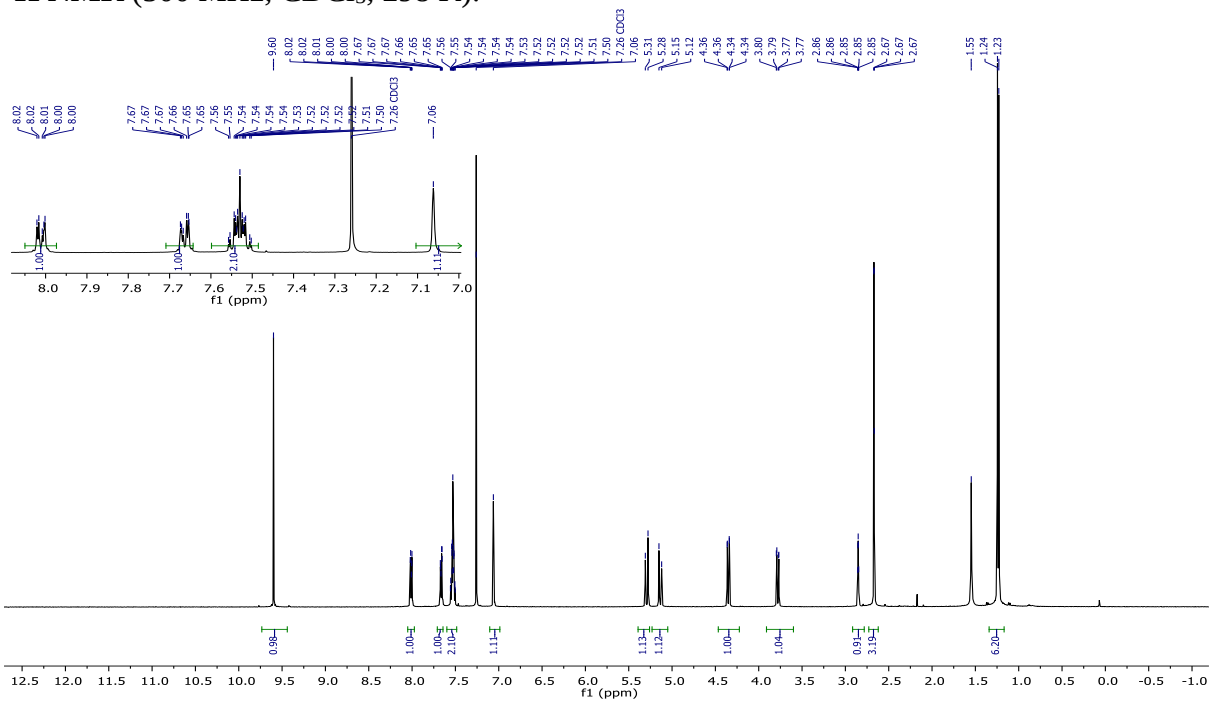


(*R*)-2-Methyl-2-(6-methyl-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)propanal (8k)

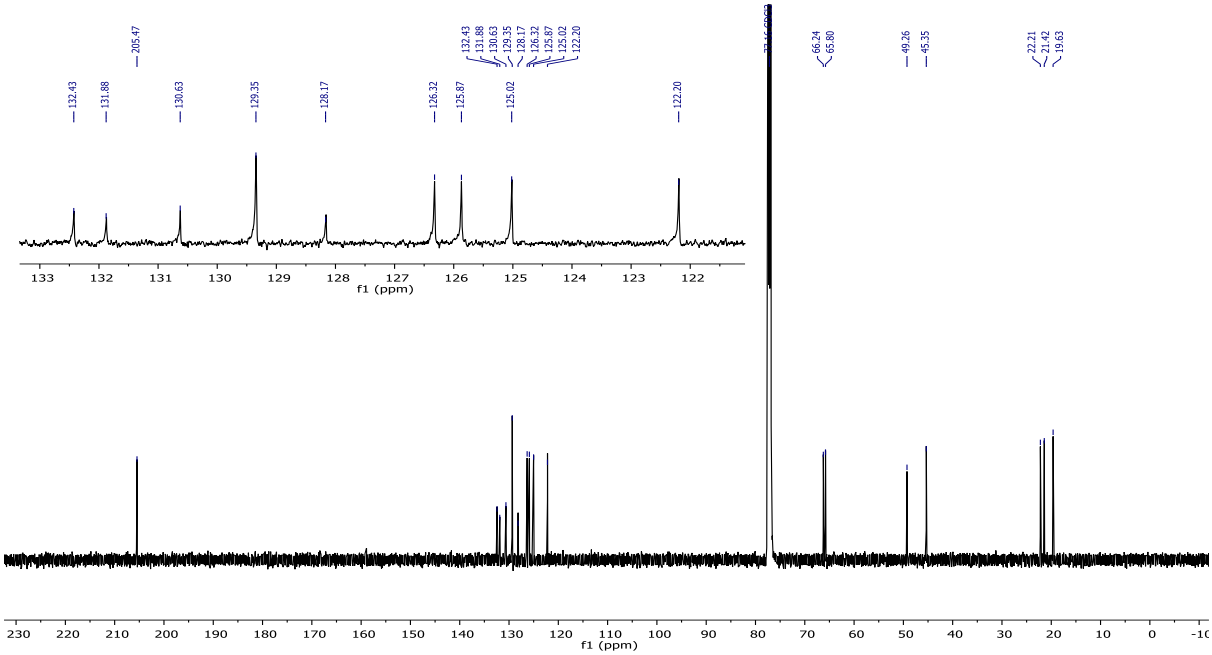


8k

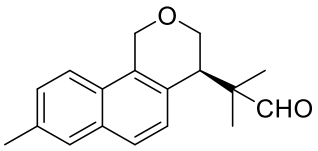
^{1}H NMR (500 MHz, $CDCl_3$, 298 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

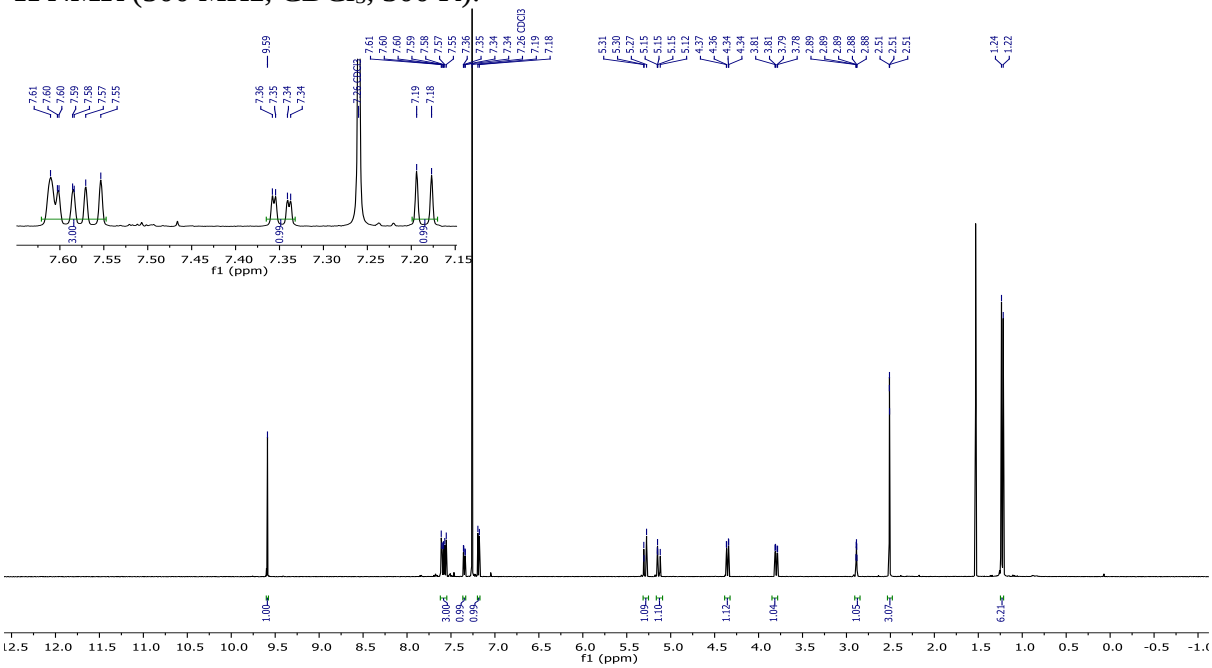


(*R*)-2-Methyl-2-(8-methyl-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)propanal (8l)

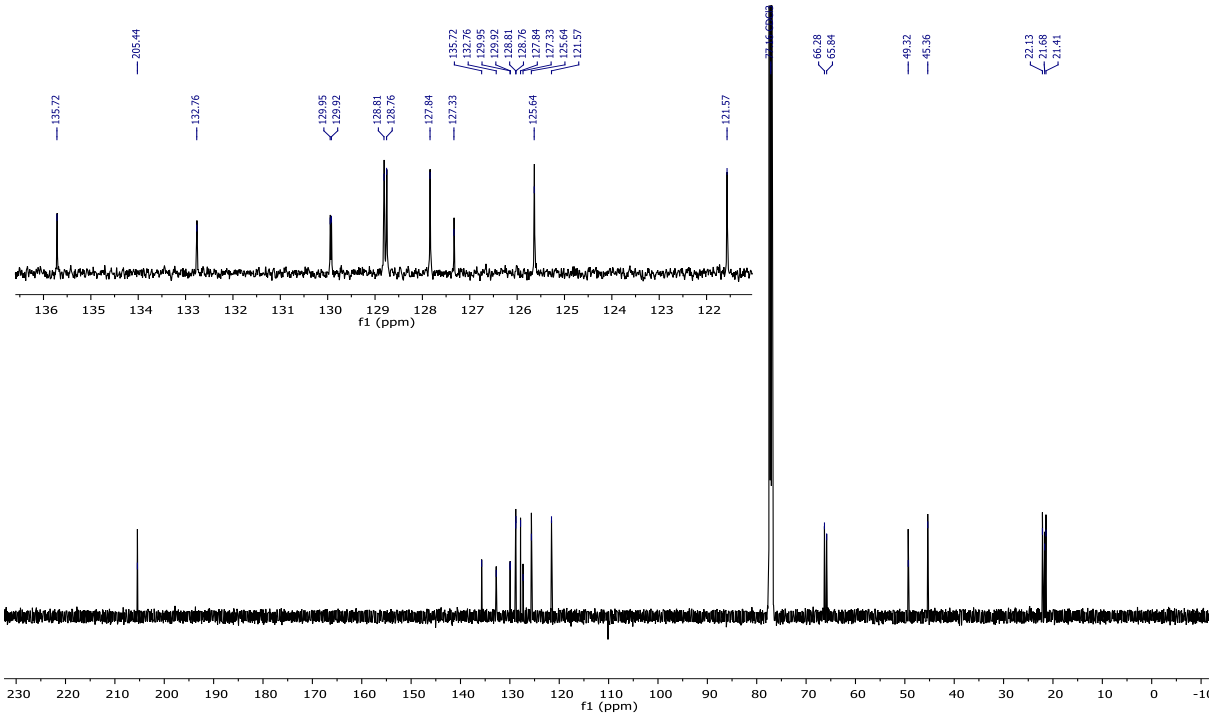


8l

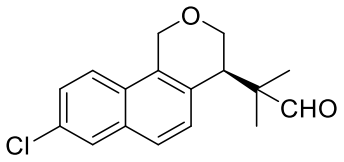
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

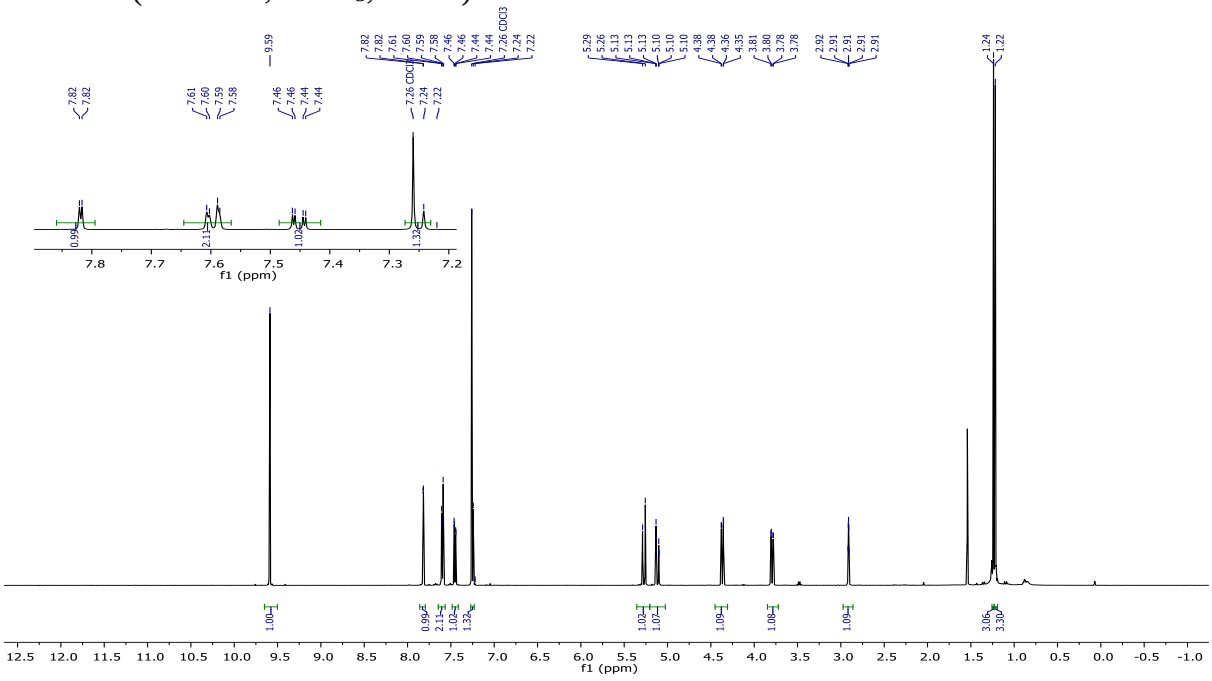


(*R*)-2-(8-Chloro-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8m)

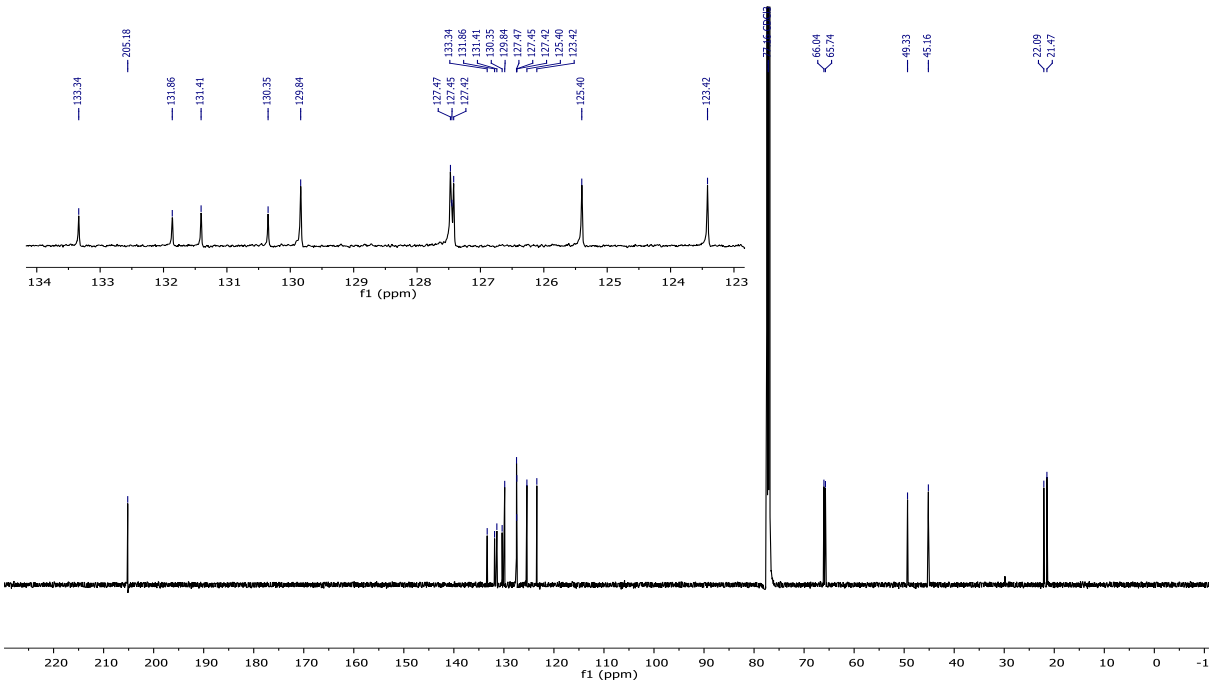


8m

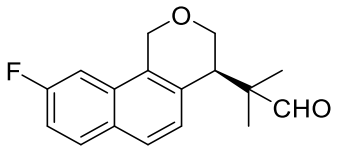
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

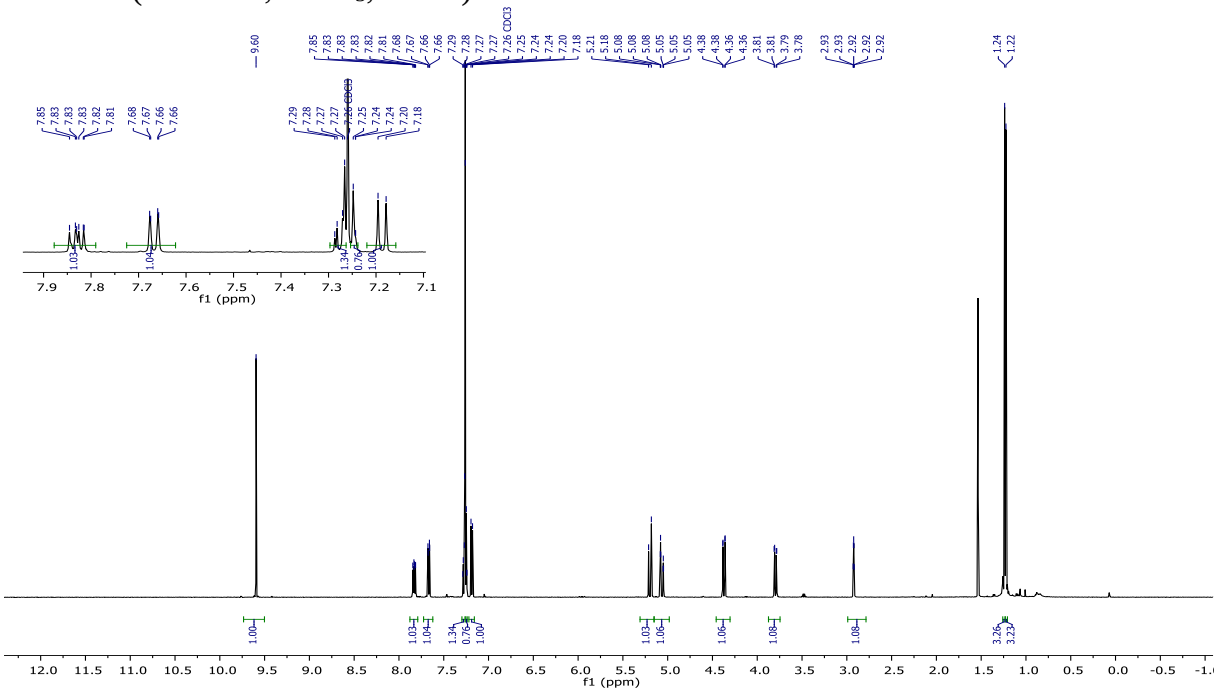


(*R*)-2-(9-Fluoro-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8n)

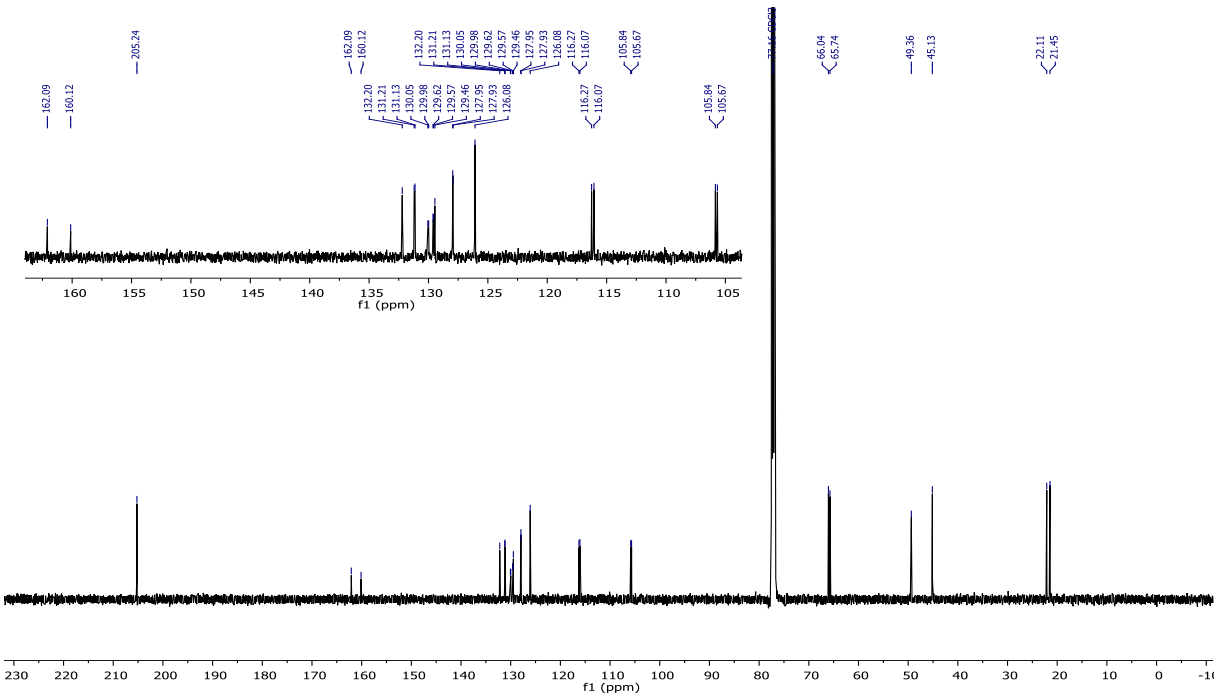


8n

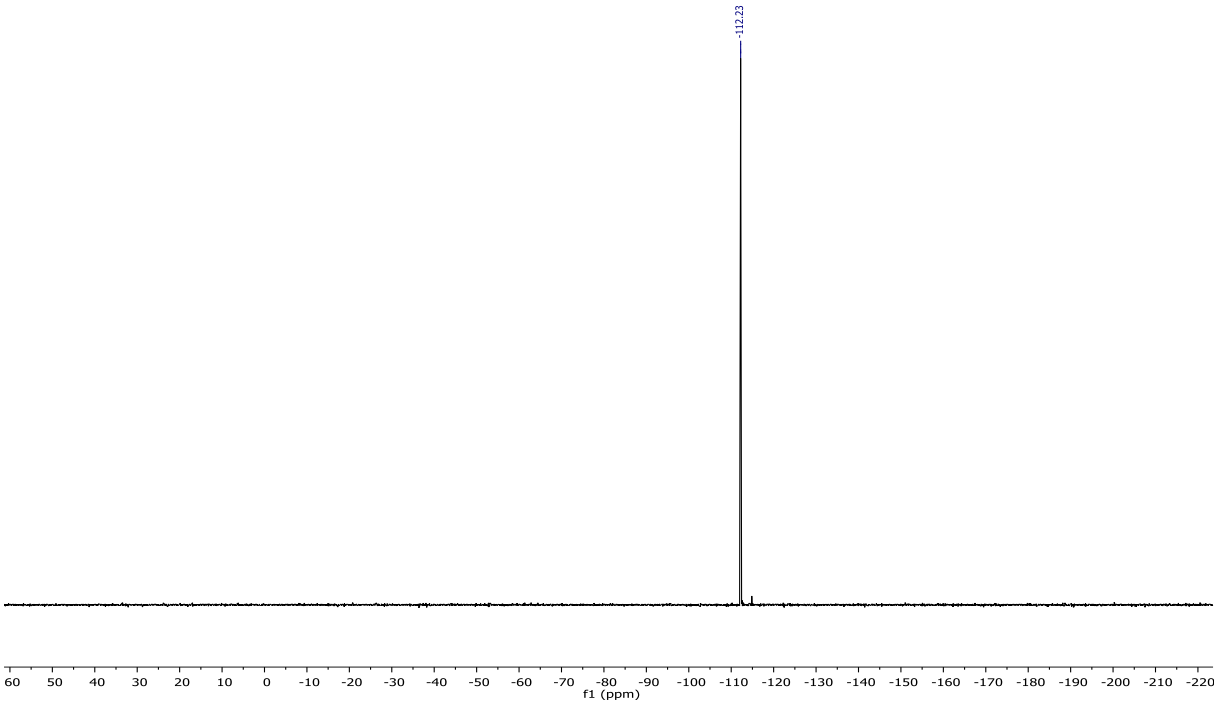
^{1}H NMR (500 MHz, $CDCl_3$, 300 K):



^{13}C NMR (126 MHz, $CDCl_3$, 300 K):

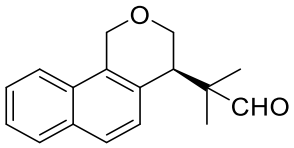


^{19}F NMR (471 MHz, $CDCl_3$, 300 K):



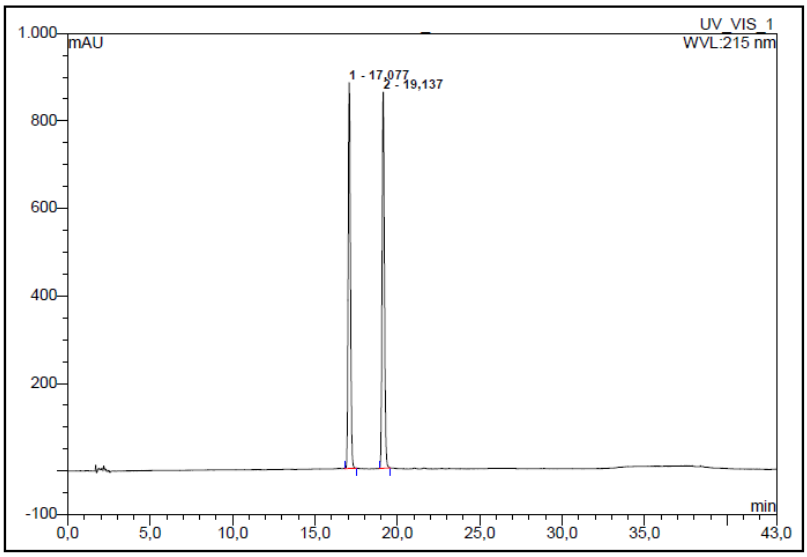
9. Chiral HPLC traces

(*R*)-2-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8a)



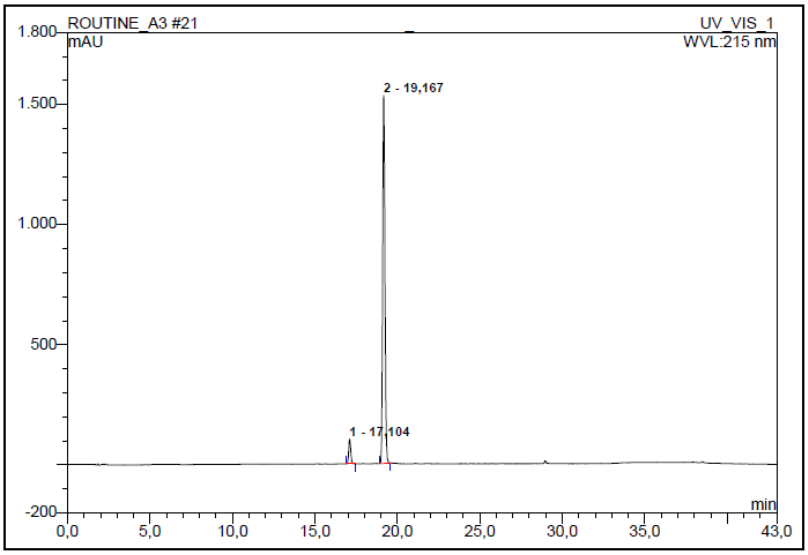
8a

Racemic product:



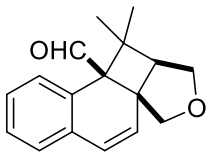
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	17,08	n.a.	882,263	141,369	49,90	n.a.	BMB
2	19,14	n.a.	859,917	141,932	50,10	n.a.	BMB
Total:			1742,179	283,301	100,00	0,000	

Enantioenriched product (89% ee):



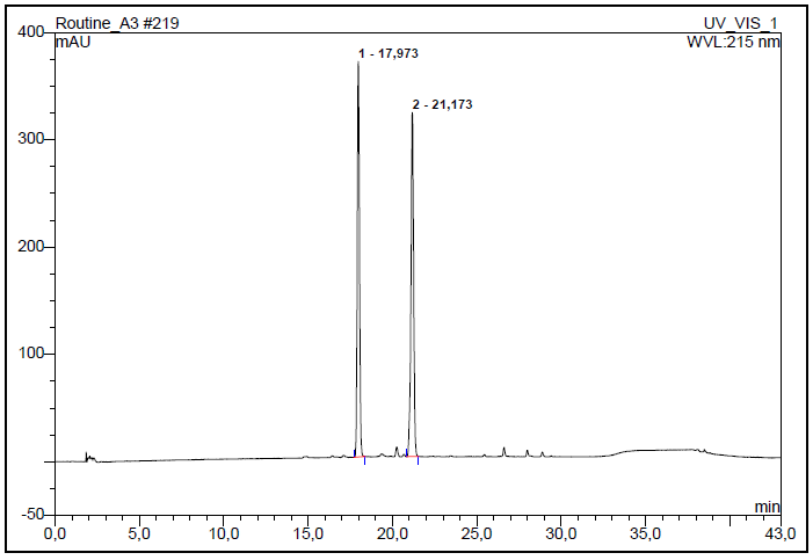
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	17,10	n.a.	102,276	14,901	5,69	n.a.	BMB
2	19,17	n.a.	1531,502	246,751	94,31	n.a.	BMB
Total:			1633,778	261,652	100,00	0,000	

(1a*SR*,4a*SR*,10b*SR*)-1,1-Dimethyl-1a,2-dihydro-4*H*-naphtho[2',1':1,4]cyclobuta[1,2-*c*]furan-10b(1*H*)-carbaldehyde (*rac*-9a)



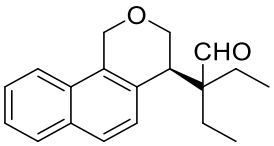
rac-**9a**

Racemic product:



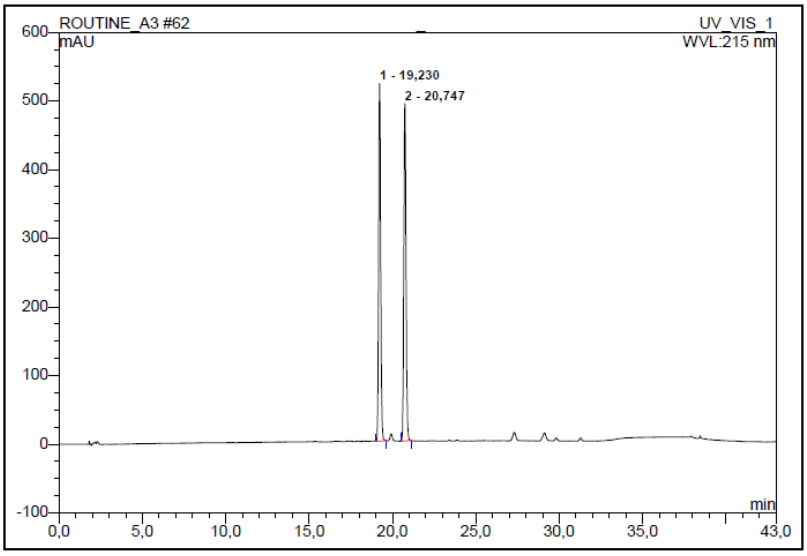
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	17,97	n.a.	368,434	56,107	48,44	n.a.	BMB
2	21,17	n.a.	320,441	59,716	51,56	n.a.	BMB
Total:			688,875	115,823	100,00	0,000	

(*R*)-2-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-ethylbutanal (8b)



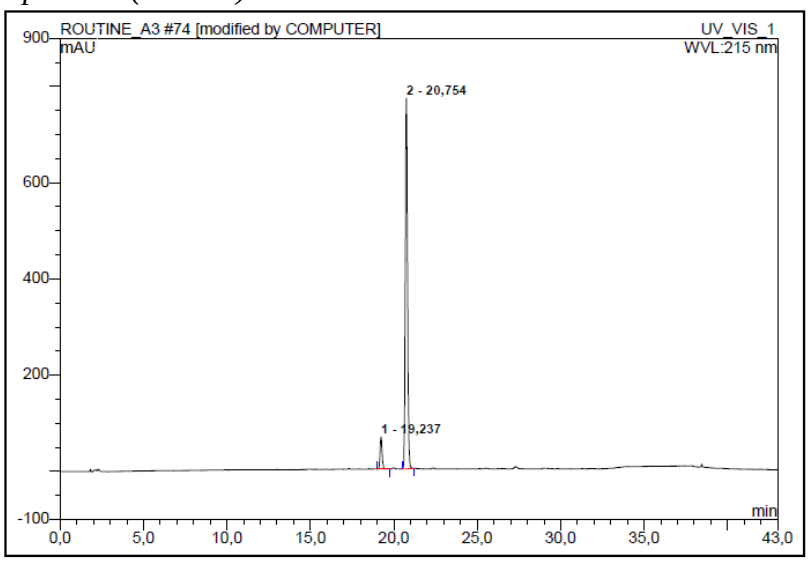
8b

Racemic product:



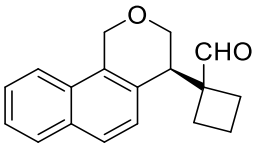
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	19,23	n.a.	520,911	75,026	49,97	n.a.	BMB
2	20,75	n.a.	491,325	75,118	50,03	n.a.	BMB
Total:			1012,235	150,144	100,00	0,000	

Enantioenriched product (85% ee):



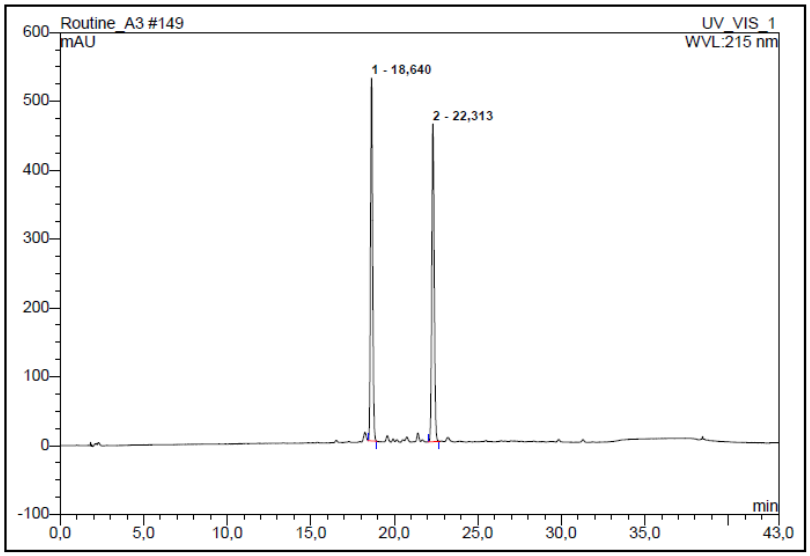
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	19,24	n.a.	66,727	9,546	7,42	n.a.	BMB*
2	20,75	n.a.	770,172	119,135	92,58	n.a.	BMB
Total:			836,898	128,681	100,00	0,000	

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclobutane-1-carbaldehyde (8c)



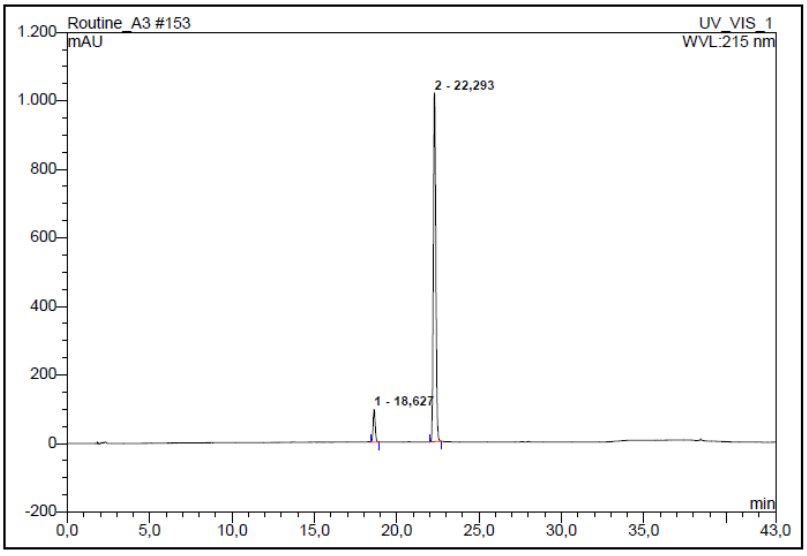
8c

Racemic product:



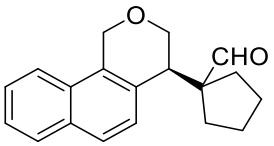
No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	18,64	n.a.		526,907	78,174	49,87	n.a.	BMB
2	22,31	n.a.		461,498	78,595	50,13	n.a.	BMB
Total:				988,406	156,769	100,00	0,000	

Enantioenriched product (85% ee):



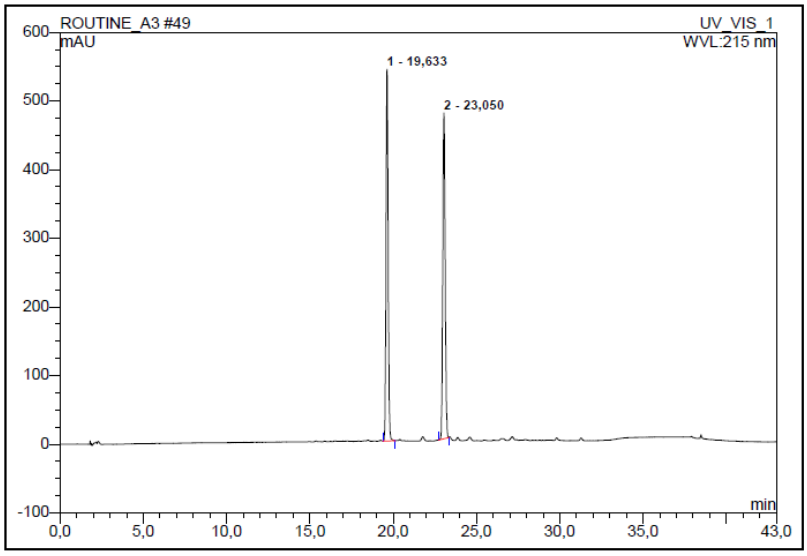
No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	18,63	n.a.		95,136	13,956	7,32	n.a.	BMB
2	22,29	n.a.		1017,549	176,646	92,68	n.a.	BMB
Total:				1112,685	190,602	100,00	0,000	

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclopentane1-carbaldehyde (8d)



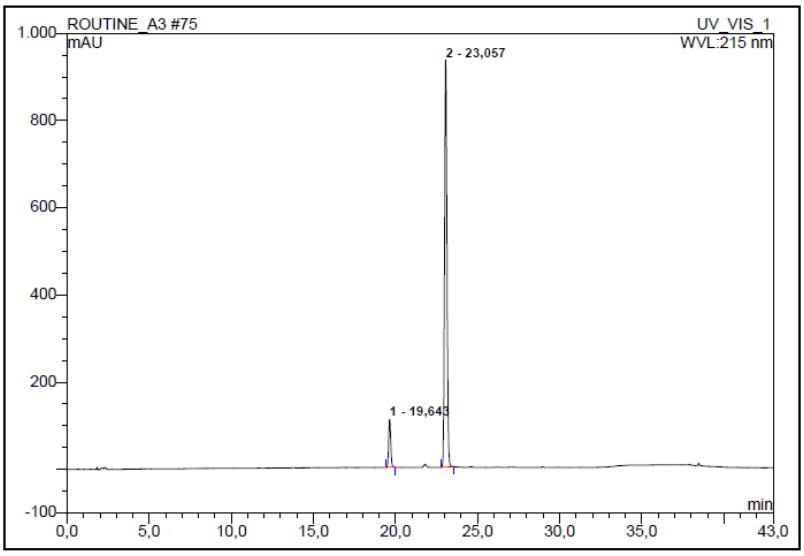
8d

Racemic product:



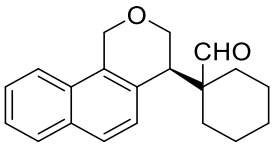
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	19,63	n.a.	541,324	79,592	50,39	n.a.	BMB
2	23,05	n.a.	474,654	78,361	49,61	n.a.	BMB
Total:			1015,977	157,954	100,00	0,000	

Enantioenriched product (82% ee):



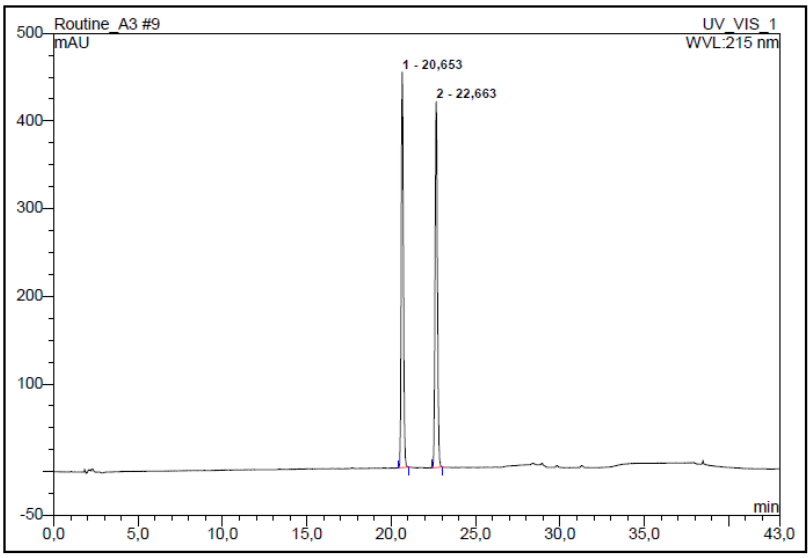
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	19,64	n.a.	109,970	16,001	9,18	n.a.	BMB
2	23,06	n.a.	933,170	158,240	90,82	n.a.	BMB
Total:			1043,140	174,241	100,00	0,000	

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclohexane-1-carbaldehyde (8e)



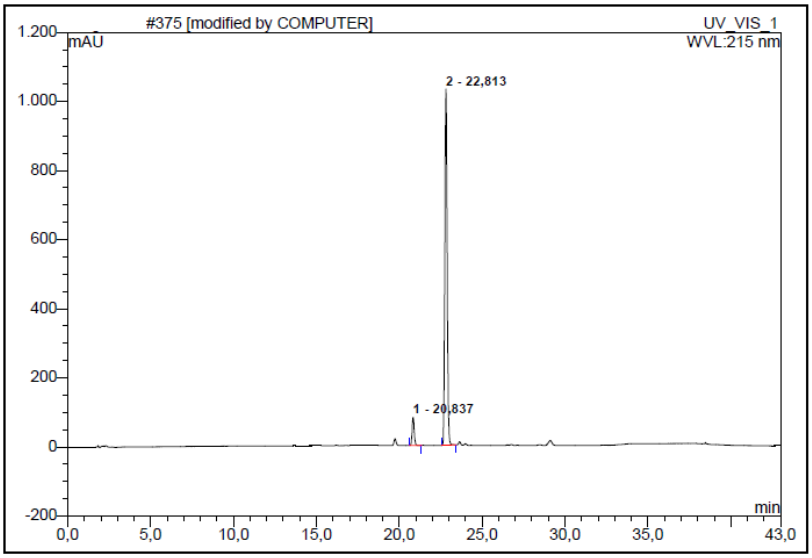
8e

Racemic product:



No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	20,65	n.a.		451,173	67,131	49,88	n.a.	BMB
2	22,66	n.a.		417,453	67,460	50,12	n.a.	BMB
Total:				868,626	134,592	100,00	0,000	

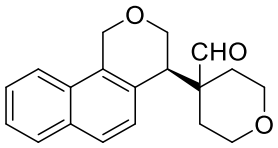
Enantioenriched product (87% ee):



No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	20,84	n.a.		81,295	11,922	6,61	n.a.	BMB*
2	22,81	n.a.		1031,334	168,445	93,39	n.a.	BMB
Total:				1112,629	180,367	100,00	0,000	

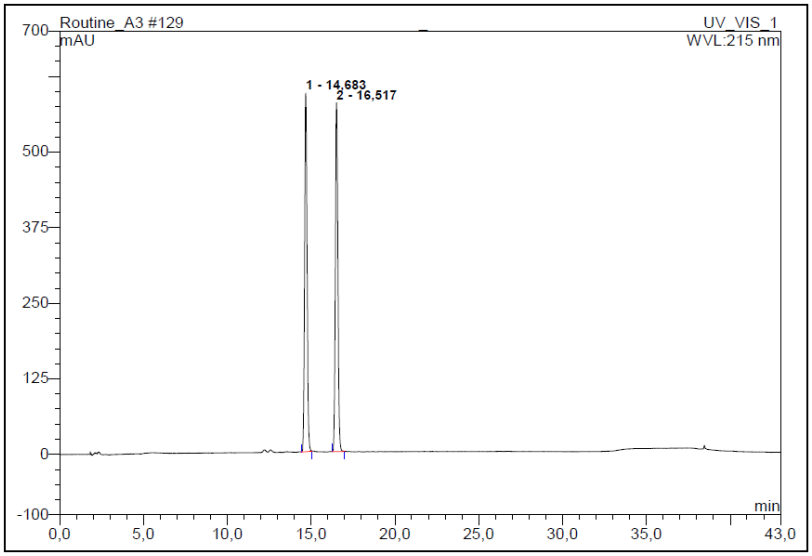
(*R*)-4-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)tetrahydro-2*H*-pyran-4-carbaldehyde

(8f)



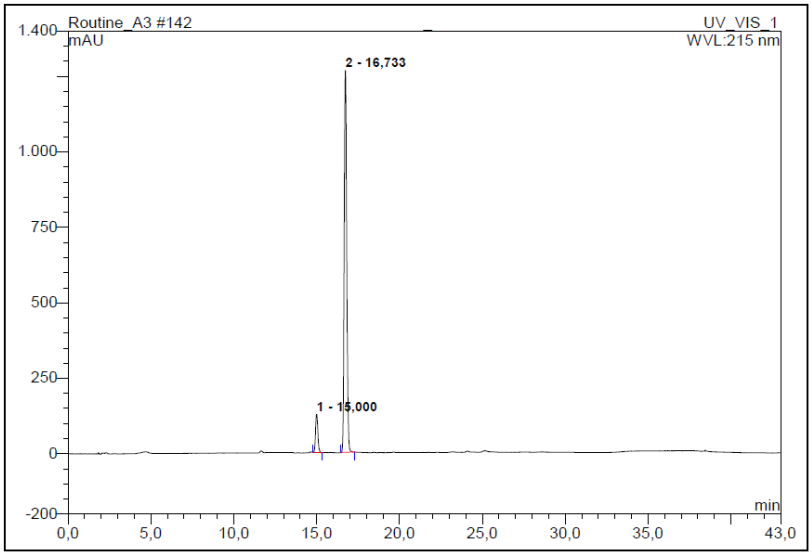
8f

Racemic product:



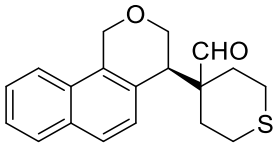
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	14,68	n.a.	592,772	101,301	50,00	n.a.	BMB
2	16,52	n.a.	577,175	101,290	50,00	n.a.	BMB
Total:			1169,948	202,591	100,00	0,000	

Enantioenriched product (83% ee):



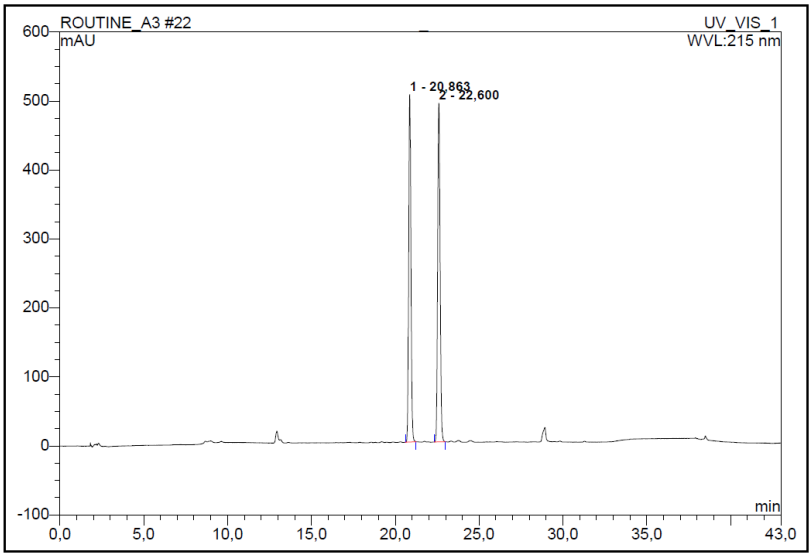
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	15,00	n.a.	126,531	20,624	8,48	n.a.	BMB
2	16,73	n.a.	1264,851	222,649	91,52	n.a.	BMB
Total:			1391,383	243,274	100,00	0,000	

(*R*)-4-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)tetrahydro-2*H*-thiopyran-4-carbaldehyde (8g)



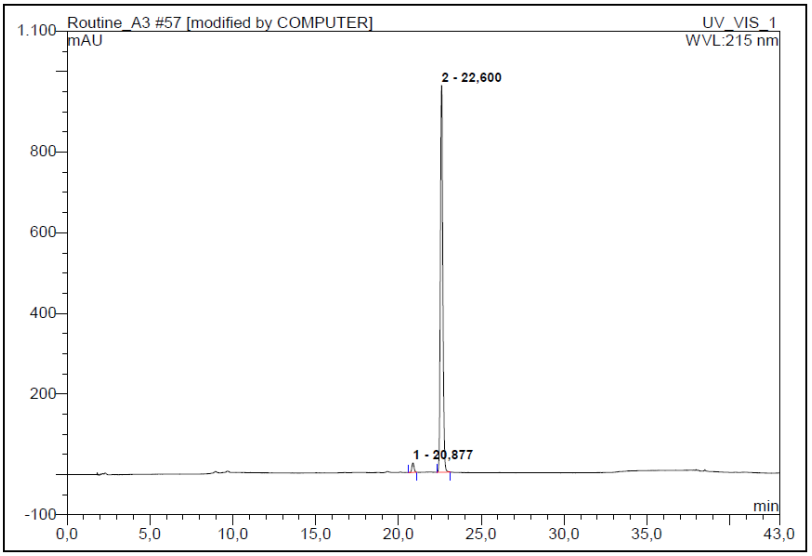
8g

Racemic product:



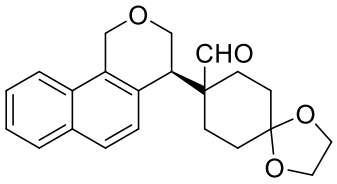
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	20,86	n.a.	503,603	78,486	48,64	n.a.	BMB
2	22,60	n.a.	490,844	82,866	51,36	n.a.	BMB
Total:			994,446	161,352	100,00	0,000	

Enantioenriched product (96% ee):



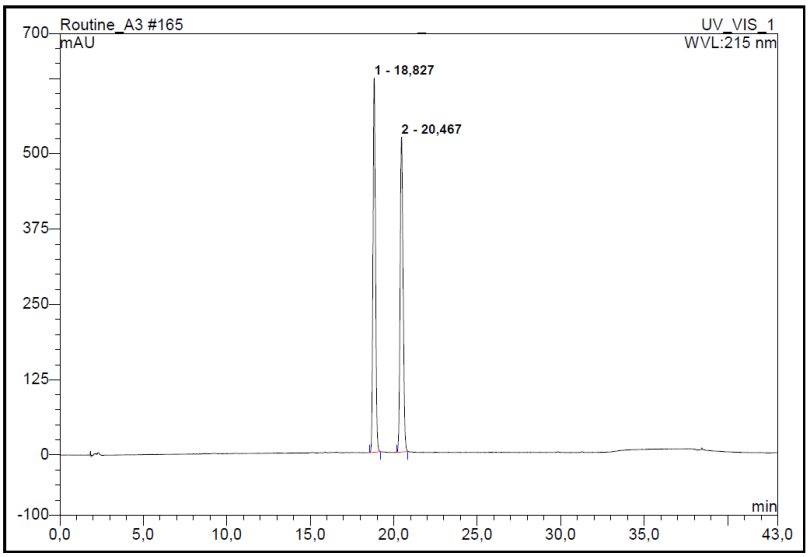
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	20,88	n.a.	23,200	3,499	2,06	n.a.	BMB*
2	22,60	n.a.	959,659	166,255	97,94	n.a.	BMB
Total:			982,859	169,755	100,00	0,000	

(*R*)-8-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)-1,4-dioxaspiro[4.5]decane-8-carbaldehyde (8h)



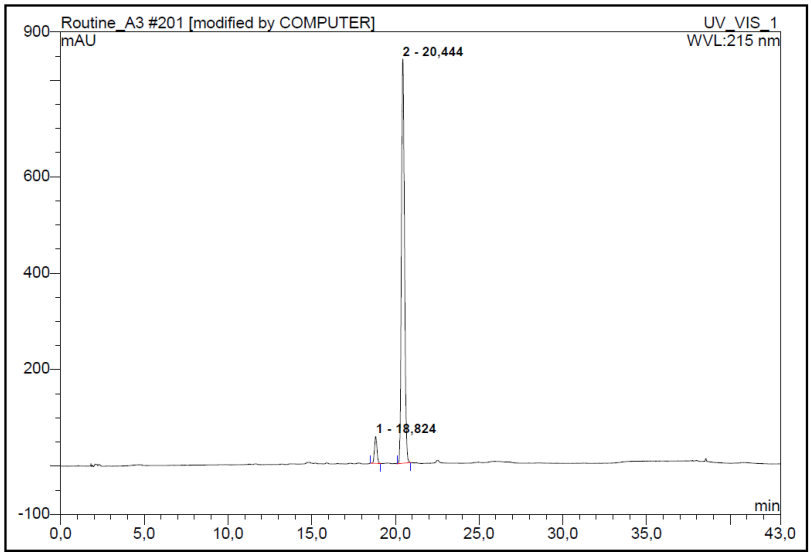
8h

Racemic product:



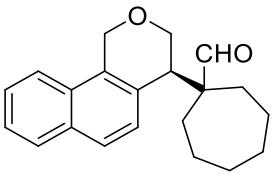
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	18,83	n.a.	621,405	108,468	49,96	n.a.	BMB
2	20,47	n.a.	522,989	108,648	50,04	n.a.	BMB
Total:			1144,393	217,115	100,00	0,000	

Enantioenriched product (90% ee):



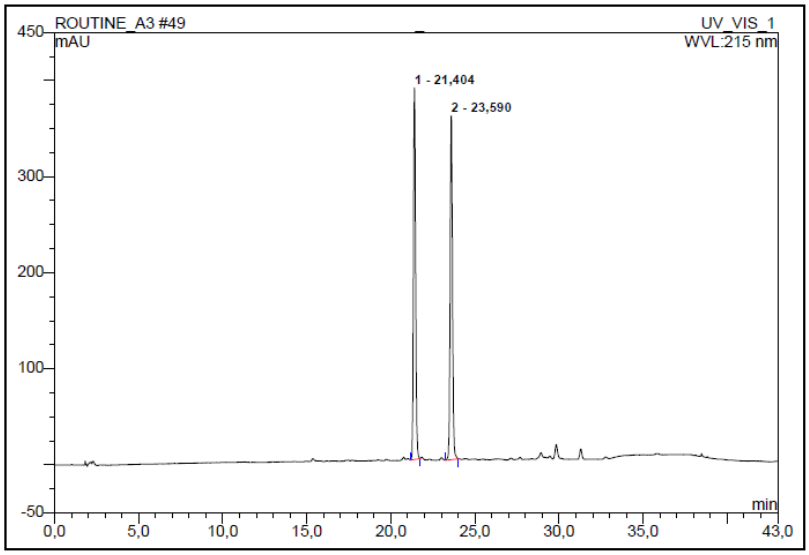
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	18,82	n.a.	55,498	9,441	4,98	n.a.	BMB*
2	20,44	n.a.	837,595	180,062	95,02	n.a.	BMB
Total:			893,093	189,502	100,00	0,000	

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cycloheptane-1-carbaldehyde (8i)



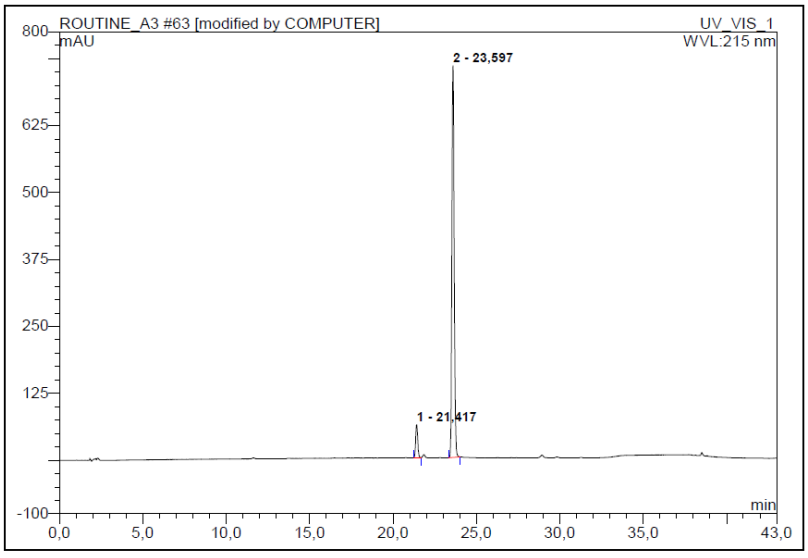
8i

Racemic product:



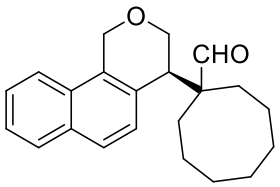
No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	21,40	n.a.		386,754	57,020	49,57	n.a.	BMB
2	23,59	n.a.		357,697	58,002	50,43	n.a.	BMB
Total:				744,451	115,022	100,00	0,000	

Enantioenriched product (86% ee):



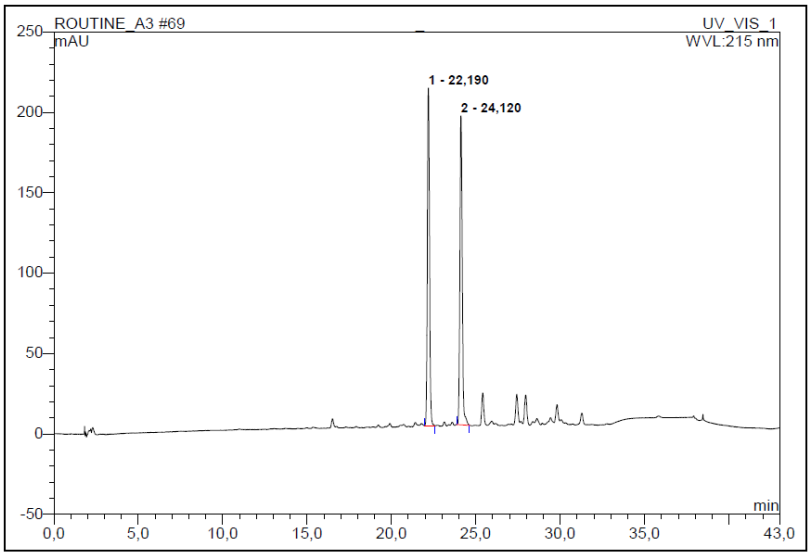
No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	21,42	n.a.		61,785	8,849	7,03	n.a.	BMB*
2	23,60	n.a.		731,759	117,100	92,97	n.a.	BMB
Total:				793,544	125,949	100,00	0,000	

(*R*)-1-(3,4-Dihydro-1*H*-benzo[*h*]isochromen-4-yl)cyclooctane-1-carbaldehyde (8j)



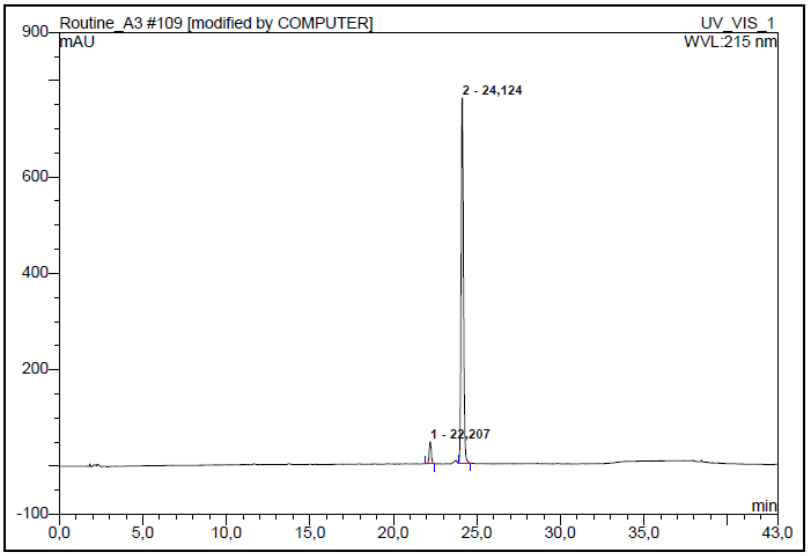
8j

Racemic product:



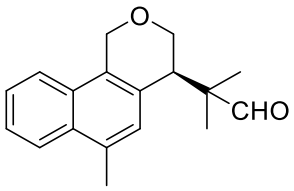
No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	22,19	n.a.		210,150	30,928	49,60	n.a.	BMB
2	24,12	n.a.		192,270	31,426	50,40	n.a.	BMB
Total:				402,420	62,354	100,00	0,000	

Enantioenriched product (90% ee):



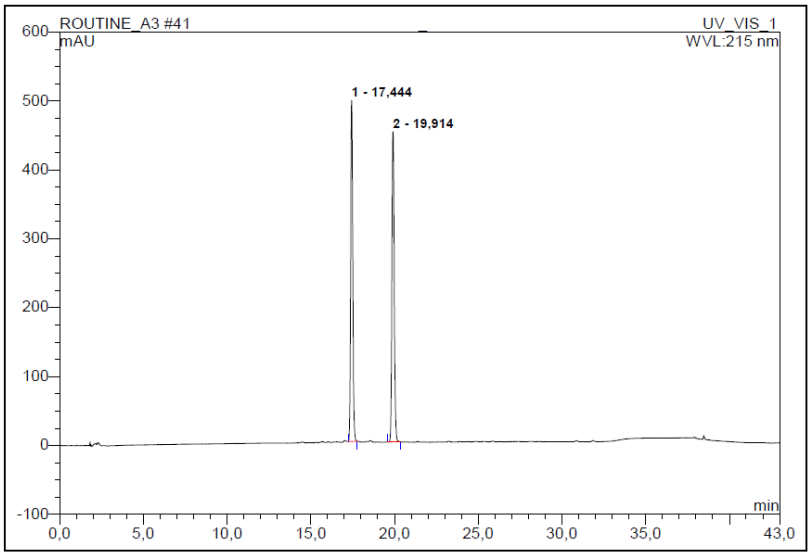
No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	22,21	n.a.		45,635	6,660	5,09	n.a.	BMB*
2	24,12	n.a.		757,958	124,307	94,91	n.a.	BMB
Total:				803,594	130,967	100,00	0,000	

(*R*)-2-Methyl-2-(6-methyl-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)propanal (8k)



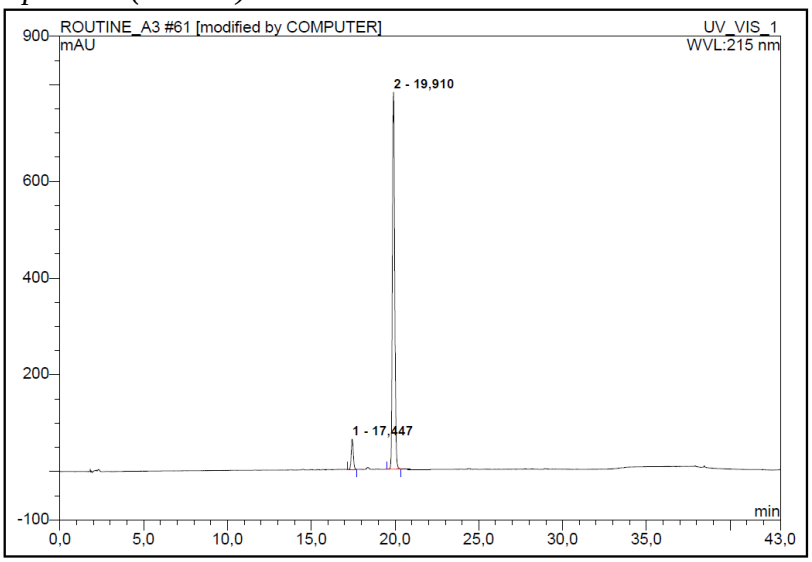
8k

Racemic product:



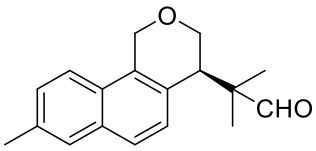
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	17,44	n.a.	494,909	71,163	49,74	n.a.	BMB
2	19,91	n.a.	450,428	71,910	50,26	n.a.	BMB
Total:			945,337	143,073	100,00	0,000	

Enantioenriched product (87% ee):



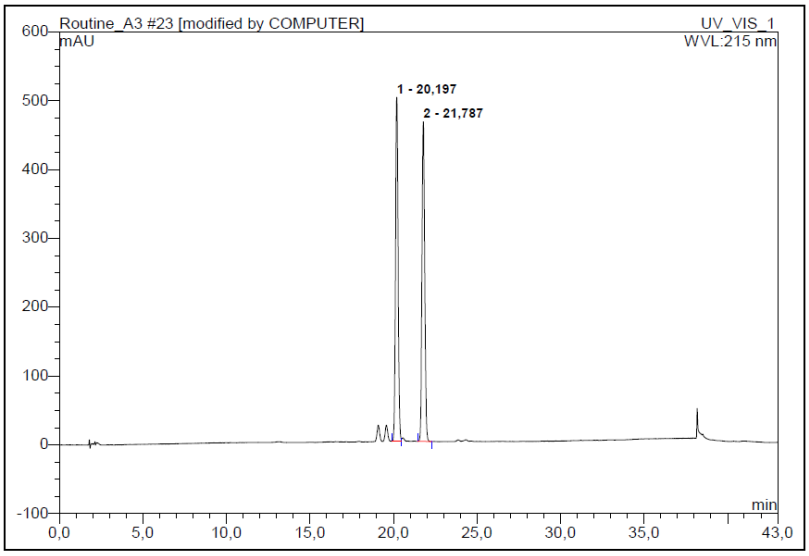
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	17,45	n.a.	62,608	8,910	6,62	n.a.	BMB*
2	19,91	n.a.	779,191	125,658	93,38	n.a.	BMB
Total:			841,799	134,568	100,00	0,000	

(*R*)-2-Methyl-2-(8-methyl-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)propanal (8l)



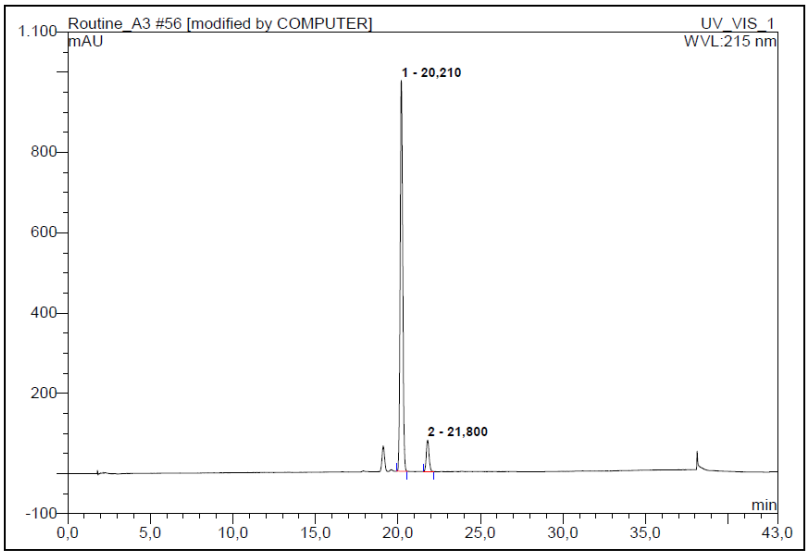
8l

Racemic product:



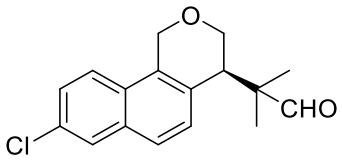
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	20,20	n.a.	499,825	89,908	50,02	n.a.	BM *
2	21,79	n.a.	464,700	89,841	49,98	n.a.	BMB*
Total:			964,525	179,749	100,00	0,000	

Enantioenriched product (84% ee):



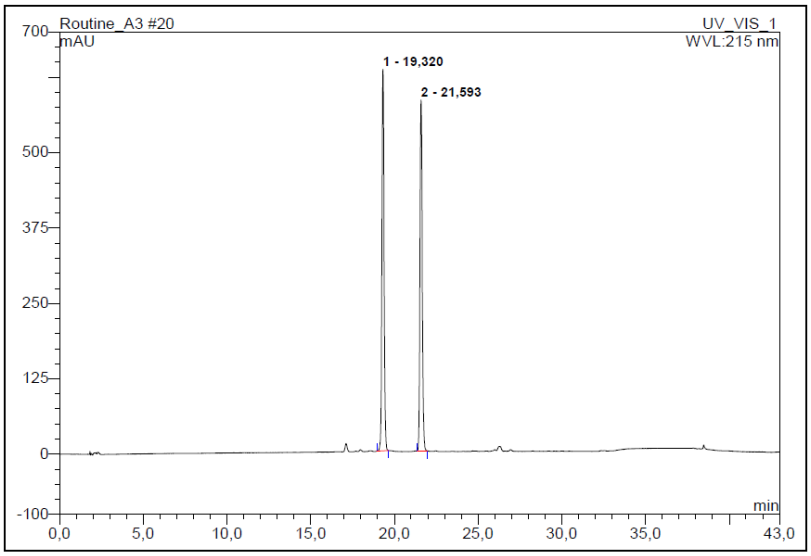
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	20,21	n.a.	973,668	176,211	92,08	n.a.	BMB
2	21,80	n.a.	78,553	15,151	7,92	n.a.	BMB
Total:			1052,221	191,363	100,00	0,000	

(*R*)-2-(8-Chloro-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8m)



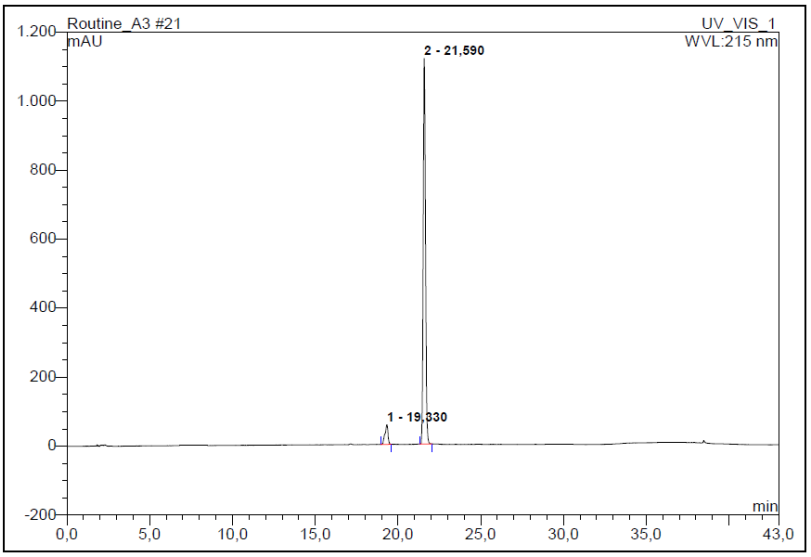
8m

Racemic product:



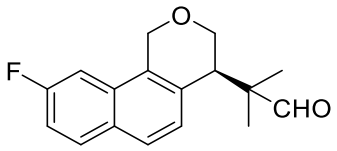
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	19,32	n.a.	632,945	93,931	50,30	n.a.	BMB
2	21,59	n.a.	582,075	92,802	49,70	n.a.	BMB
Total:			1215,020	186,733	100,00	0,000	

Enantioenriched product (88% ee):



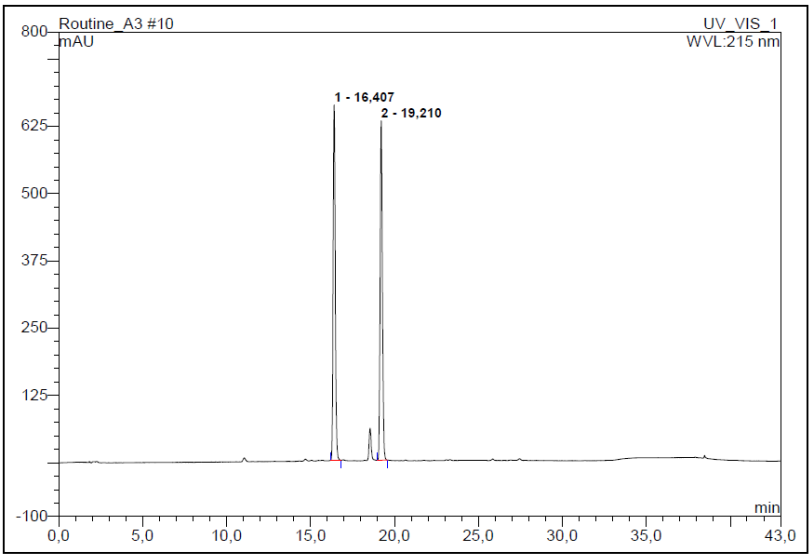
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	19,33	n.a.	57,331	11,964	6,18	n.a.	BMB
2	21,59	n.a.	1117,272	181,682	93,82	n.a.	BMB
Total:			1174,603	193,646	100,00	0,000	

(*R*)-2-(9-Fluoro-3,4-dihydro-1*H*-benzo[*h*]isochromen-4-yl)-2-methylpropanal (8n)



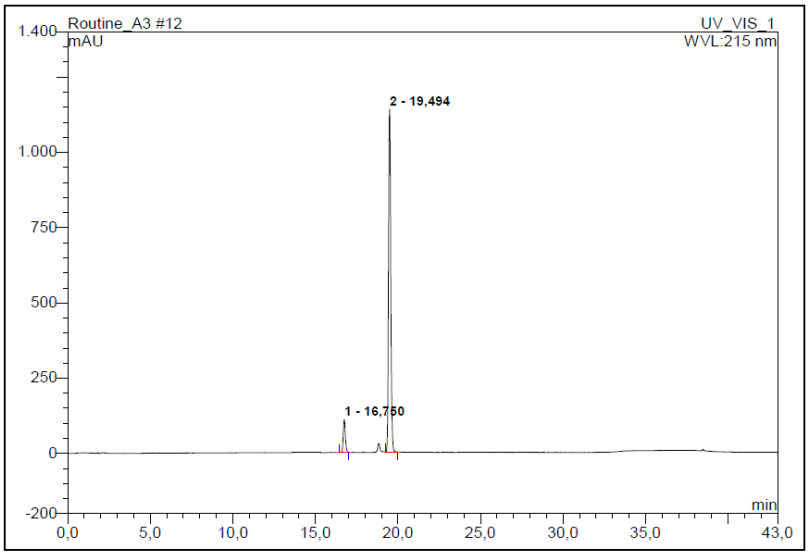
8n

Racemic product:



No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	16,41	n.a.		660,581	98,130	49,63	n.a.	BMB
2	19,21	n.a.		631,035	99,576	50,37	n.a.	BMB
Total:				1291,615	197,706	100,00	0,000	

Enantioenriched product (84% ee):



No.	Ret.Time min		Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	16,75	n.a.		108,961	15,920	8,10	n.a.	BMB
2	19,49	n.a.		1139,131	180,640	91,90	n.a.	BMB
Total:				1248,091	196,560	100,00	0,000	

10. Datasheets of fluorescent light sources

366 nm reactor

Lehrstuhl OC 1 - TUM

200 nm | 250 nm | 300 nm | 350 nm | 400 nm | 450 nm | 500 nm | 550 nm | 600 nm | 650 nm

Datasheet FLT015 — RPR-Set1-UV-A

Basic Information

Type	Fluorescent light tube
Description	Set1 (UV-A)
Manufacturer / Supplier	n/a / Rayonet
Order number / Date of purch.	n/a / n/a
Internal lot / serial number	Set1 / FLT015

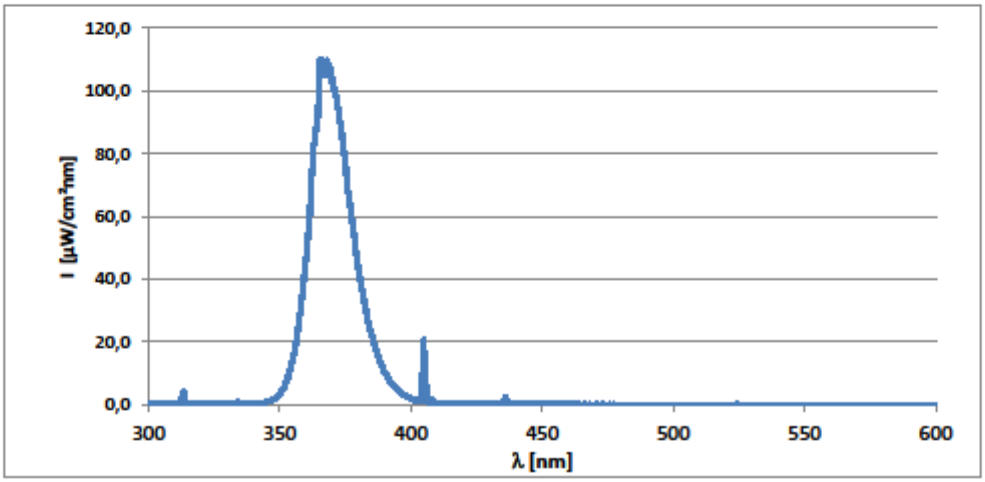
Specification Manufacturer

Type / size	T5 tube, G5 socket
Mechanical specification	16 mm diameter, 288 mm length
Electrical specification	8 W
Wavelength (range, typ.)	350 nm
Spectral width (FWHM)	~ 30 nm
Datasheet	

Characterization

Description of measurement	Measured with Ocean-optics USB4000 spectrometer using a calibrated setup (cosine corrector/fibre). The cosine corrector was placed at 20 mm distance from a single fluorescent tube at half height.	
Measured dominant wavelength / Int.	365 nm	104 µW/mm²nm
Measured spectral width (FWHM)	18 nm	
Integral Reference intensity / range	2194 µW/cm²	300-450 nm

Spectrum



457 nm LED (LED045)

Lehrstuhl OC 1 - TUM

Datasheet LED045 — Av-455-5W

Basic Information

Type	High-Power-LED
Description	Avonec 455-460 nm / 5 W
Manufacturer / Supplier	n/a / Avonec
Order number / Date of purch.	n/a / 07/2016
Internal lot / serial number	2016-07 / LED045

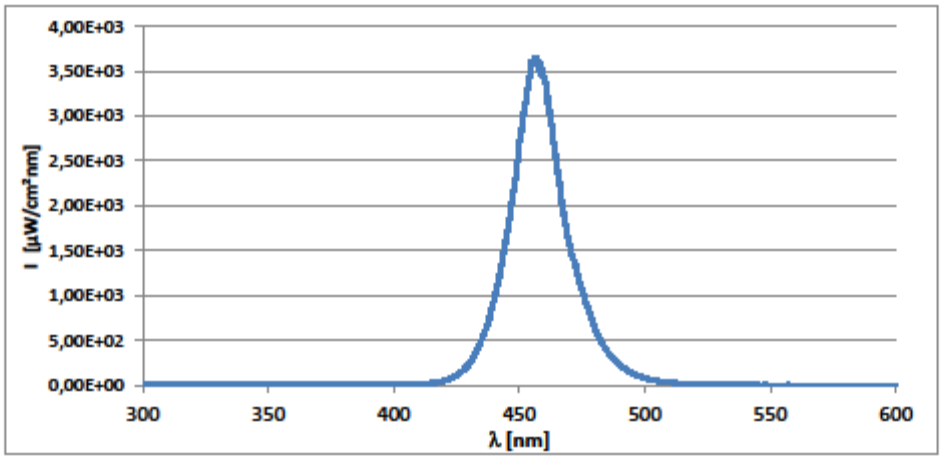
Specification Manufacturer

Type / size	dual emitter / 2 x ca. 1 x 1 mm
Mechanical specification	
Electrical specification	700 mA, UF 6.8 V
Wavelength (range, typ.)	455-460 nm, typ. n/a
Spectral width (FWHM)	n/a
Datasheet	n/a

Characterization

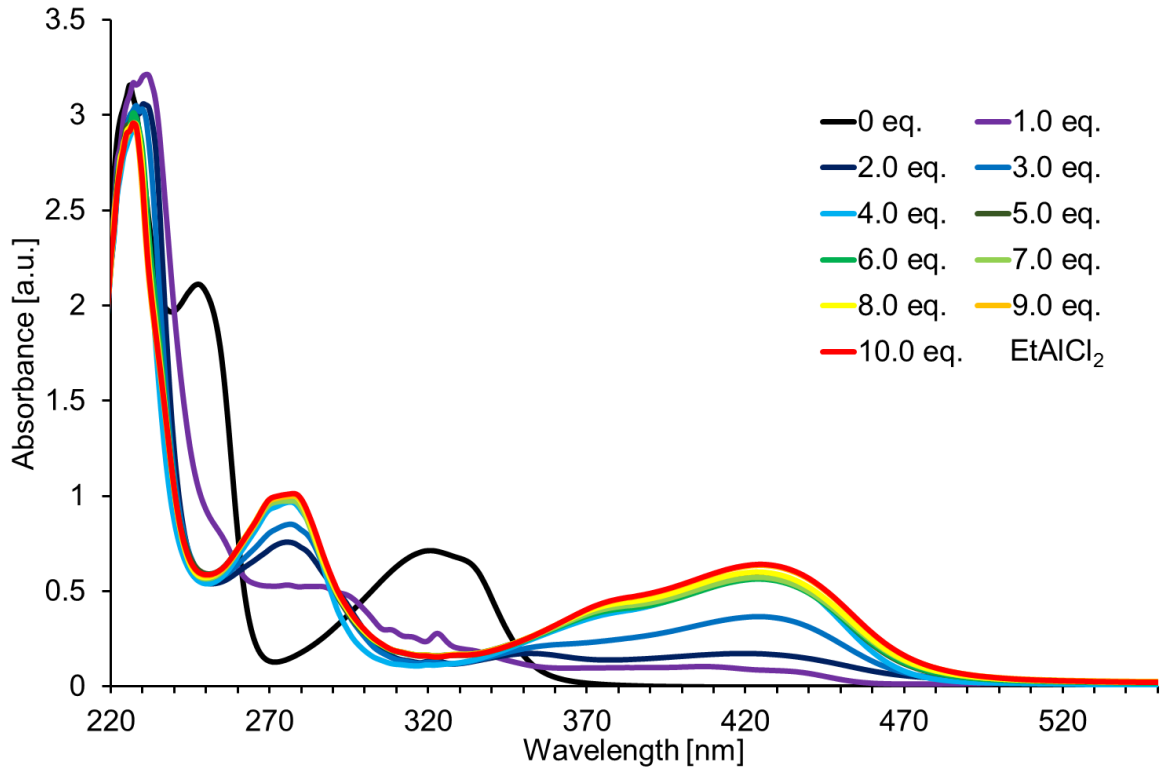
Description of measurement	Measured with Ocean-optics USB4000 spectrometer using a calibrated setup (cosine corrector/fibre). The distance between the emitting surface and the surface of the cosine corrector was 20 mm. The LED was operated at 700 mA on a passive heat-sink at approx. 20 °C
Measured wavelength	457 nm
Measured spectral width	22 nm
Integral Reference intensity	99250 µW/cm² (400-550 nm @ 20 mm distance, 4 mmcosine corr.)

Spectrum



11. UV/Vis spectra

UV/Vis spectrum of 1-naphthaldehyde 7a



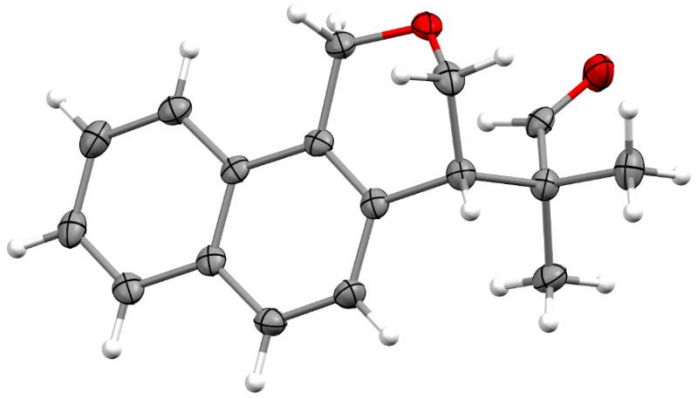
UV/Vis spectrum of 1-naphthaldehyde **7a** in the absence of a Lewis acid (black line) and in the presence of variable equivalents of $EtAlCl_2$ (0.5 eq. – 10.0 eq.) in dichloromethane [c = 1 mM] (measured in a 1.0 mm quartz cuvette). There are three isosbestic points at λ = 259 nm, λ = 297 nm and λ = 354 nm (between 0 eq. – 1.5 eq. L.A.).

12. X-ray crystallographic details

Data were collected on a single crystal x-ray diffractometer equipped with a CPAD detector (Bruker Photon-II), and IMS microsource with MoK_α radiation (λ = 0.71073 Å) and a Helios optic (**8a**, **8g**) or a CMOS detector (Bruker Photon-100), a TXS rotating anode with MoK_α radiation (λ = 0.71073 Å) and a Helios optic (**8m**) using the APEX3 software package.[27] The measurements were performed on single crystals coated with perfluorinated ether. The crystals were fixed on top of a kapton micro sampler and frozen under a stream of cold nitrogen. A matrix scan was used to determine the initial lattice parameters. Reflections were corrected for Lorentz and polarisation effects, scan speed, and background using SAINT.[28] Absorption correction, including odd and even ordered spherical harmonics was performed using SADABS.[28] Space group assignment was based upon systematic absences, E statistics, and successful refinement of the structure. The structures were solved using SHELXT with the aid of successive difference Fourier maps, and were refined against all data using SHELXL in conjunction with SHELXLE.[29-31] Hydrogen atoms (except on heteroatoms) were calculated in ideal positions as follows: Methyl hydrogen atoms were refined as part of rigid rotating groups, with a C–H distance of 0.98 Å and $U_{iso(H)} = 1.5 \cdot U_{eq(C)}$. Non-methyl H atoms were placed in calculated positions and refined using a riding model with methylene, aromatic, and other C–H distances of 0.99 Å, 0.95 Å, and 1.00 Å, respectively, and $U_{iso}(H) = 1.2 \cdot U_{eq}(C)$. Non-hydrogen atoms were refined with anisotropic displacement parameters. Full-matrix least-squares refinements were carried out by minimizing $\Sigma w(F_o^2 \; F_c^2)^2$ with the SHELXL weighting scheme.[29] Neutral atom scattering factors for all atoms and anomalous dispersion corrections for the non-hydrogen atoms were taken from *International Tables for Crystallography*.[32] Images of the crystal structure were generated with Mercury and PLATON.[33] Deposition Numbers 2158145-2158147 contain the supplementary crystallographic data for this paper. These data are provided free of charge by the joint Cambridge Crystallographic Data Centre

and Fachinformationszentrum Karlsruhe Access Structures service www.ccdc.cam.ac.uk/structures.

Compound 8a (CCDC 2158145)



Diffractometer operator C. Jandl
scanspeed 10-60 s per frame
dx 50 mm
2341 frames measured in 8 data sets
phi-scans with delta_phi = 0.5
omega-scans with delta_omega = 0.5
shutterless mode

Crystal data

$C_{17}H_{18}O_2$

M_r = 254.31	D_x = 1.269 Mg m^{-3}
Orthorhombic, $P2_12_12_1$	Melting point: ? K
Hall symbol: P 2ac 2ab	Mo $K\alpha$ radiation, λ = 0.71073 Å
a = 6.4440 (8) Å	Cell parameters from 9898 reflections
b = 8.3645 (11) Å	θ = 2.9–26.3°
c = 24.703 (3) Å	μ = 0.08 mm^{-1}
V = 1331.5 (3) Å^3	T = 100 K
Z = 4	Fragment, colourless
F(000) = 544	0.43 × 0.14 × 0.03 mm

Data collection

Radiation source: IMS microsource	2578 reflections with $I > 2\sigma(I)$
Helios optic monochromator	R_{int} = 0.054
Detector resolution: 16 pixels mm^{-1}	θ_{max} = 26.4°, θ_{min} = 2.6°
phi– and ω–rotation scans	h = −7 8

Absorption correction: multi-scan *SADABS* 2016/2, Bruker

T_{min} = 0.614, T_{max} = 0.745

35906 measured reflections

k = −10 10

l = −30 30

Refinement

Refinement on F^2

Least-squares matrix: full

$R[F^2 > 2\sigma(F^2)]$ = 0.036

$wR(F^2)$ = 0.089

S = 1.11

2734 reflections

175 parameters

0 restraints

0 constraints

Primary atom site location: iterative

Secondary atom site location: difference Fourier map

Hydrogen site location: inferred from neighbouring sites

H-atom parameters constrained

$W = 1/[\Sigma^2(FO^2) + (0.0365P)^2 + 0.4516P]$ WHERE $P = (FO^2 + 2FC^2)/3$

$(\Delta/\sigma)_{max} < 0.001$

$\Delta\rho_{max}$ = 0.18 e Å^{-3}

$\Delta\rho_{min}$ = −0.20 e Å^{-3}

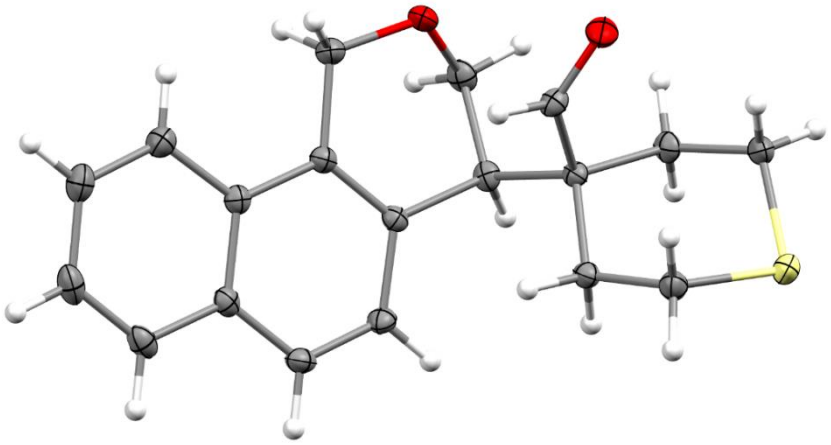
Extinction correction: none

Extinction coefficient: -

Absolute structure: Flack, Parsons[34,35]

Absolute structure parameter: 0.4 (17)

Compound 8g (CCDC 2158147)



Diffractometer operator C. Jandl
scanspeed 3-30 s per frame
dx 40 mm
2419 frames measured in 11 data sets
phi-scans with delta_phi = 0.5
omega-scans with delta_omega = 0.5
shutterless mode

Crystal data

$C_{19}H_{20}O_2S$

M_r = 312.41	D_x = 1.371 Mg m^{-3}
Orthorhombic, $P2_12_12_1$	Melting point: ? K
Hall symbol: P 2ac 2ab	Mo $K\alpha$ radiation, λ = 0.71073 Å
a = 6.4656 (2) Å	Cell parameters from 9069 reflections
b = 13.7036 (5) Å	θ = 2.4–28.3°
c = 17.0877 (7) Å	μ = 0.22 mm^{-1}
V = 1514.00 (10) Å^3	T = 100 K
Z = 4	Fragment, colourless
F(000) = 664	0.17 × 0.14 × 0.10 mm

Data collection

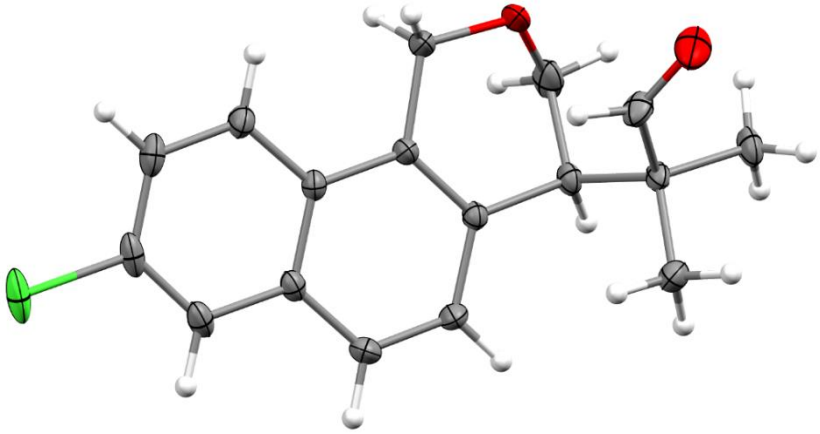
Radiation source: IMS microsource	3533 reflections with $I > 2\sigma(I)$
Helios optic monochromator	R_{int} = 0.043
Detector resolution: 7.5 pixels mm^{-1}	θ_{max} = 27.9°, θ_{min} = 1.9°

phi– and ω–rotation scans	h = −8 8
Absorption correction: multi-scan *SADABS* 2016/2, Bruker	k = −18 18
T_{min} = 0.723, T_{max} = 0.746	l = −22 22
66220 measured reflections	

Refinement

Refinement on F^2	Hydrogen site location: inferred from neighbouring sites
Least-squares matrix: full	H-atom parameters constrained
$R[F^2 > 2\sigma(F^2)]$ = 0.026	$W = 1/[\Sigma^2(FO^2) + (0.0303P)^2 + 0.4484P]$ WHERE $P = (FO^2 + 2FC^2)/3$
$wR(F^2)$ = 0.065	$(\Delta/\sigma)_{max} < 0.001$
S = 1.09	$\Delta\rho_{max}$ = 0.23 e Å^{-3}
3615 reflections	$\Delta\rho_{min}$ = −0.18 e Å^{-3}
199 parameters	Extinction correction: none
0 restraints	Extinction coefficient: -
0 constraints	Absolute structure: Flack, Parsons[34,35]
Primary atom site location: iterative	Absolute structure parameter: 0.031 (15)
Secondary atom site location: difference Fourier map	

Compound 8m (CCDC 2158146)



Diffractometer operator C. Jandl
scanspeed 1-10 s per frame
dx 34 mm
2009 frames measured in 10 data sets
phi-scans with delta_phi = 0.5
omega-scans with delta_omega = 0.5
shutterless mode

Crystal data

$C_{17}H_{17}ClO_2$

M_r = 288.76	D_x = 1.338 Mg m^{-3}
Monoclinic, $P2_1$	Melting point: ? K
Hall symbol: P 2yb	Mo $K\alpha$ radiation, λ = 0.71073 Å
a = 6.0803 (3) Å	Cell parameters from 9872 reflections
b = 8.5188 (4) Å	θ = 2.8–28.4°
c = 13.8407 (6) Å	μ = 0.27 mm^{-1}
β = 90.320 (2)°	T = 123 K
V = 716.89 (6) Å^3	Fragment, colourless
Z = 2	0.28 × 0.20 × 0.10 mm
F(000) = 304	

Data collection

Radiation source: TXS rotating anode	3527 reflections with $I > 2\sigma(I)$
Helios optic monochromator	R_{int} = 0.018

Detector resolution: 16 pixels mm^{-1}

phi– and ω–rotation scans

Absorption correction: multi-scan *SADABS* 2016/2, Bruker

T_{min} = 0.719, T_{max} = 0.746

24577 measured reflections

θ_{max} = 28.4°, θ_{min} = 2.8°

h = −8 8

k = −11 11

l = −18 18

Refinement

Refinement on F^2

Least-squares matrix: full

$R[F^2 > 2\sigma(F^2)]$ = 0.025

$wR(F^2)$ = 0.067

S = 1.05

3555 reflections

183 parameters

1 restraint

0 constraints

Primary atom site location: iterative

Secondary atom site location: difference Fourier map

Hydrogen site location: inferred from neighbouring sites

H-atom parameters constrained

$W = 1/[\Sigma^2(FO^2) + (0.0336P)^2 + 0.1944P]$ WHERE $P = (FO^2 + 2FC^2)/3$

$(\Delta/\sigma)_{max} < 0.001$

$\Delta\rho_{max}$ = 0.23 e $Å^{-3}$

$\Delta\rho_{min}$ = −0.33 e $Å^{-3}$

Extinction correction: none

Extinction coefficient: -

Absolute structure: Flack, Parsons[34,35]

Absolute structure parameter: 0.015 (7)

13. References

1 M. Schuster, M. Knollmueller and P. Gaertner, *Tetrahedron*, 2006, **17**, 2430.

2 G. R. Fulmer, A. J. M. Miller, N. H. Sherden, H. E. Gottlieb, A. Nudelman, B. M. Stoltz, J. E. Bercaw and K. I. Goldberg, *Organometallics*, 2010, **29**, 2176.

3 V. Rawat, P. V. Chouthaiwale, V. B. Chavan, G. Suryavanshi and A. Sudalai, *Tetrahedron Lett.*, 2010, **51**, 6565.

4 Y. Yoshimi, S.-i. Konishi, H. Maeda and K. Mizuno, *Synthesis*, 2001, 1197.

5 G. B. Jones and J. E. Mathews, *Tetrahedron*, 1997, **53**, 14599.

6 (*a*) Z. Arnold and A. Holý, *Collect. Czech. Chem. Commun.*, 1961, **26**, 3059; (*b*) R. M. Coates, P. D. Senter and W. R. Baker, *J. Org. Chem.*, 1982, **47**, 3597.

7 S. Paul, S. Samanta and J. K. Ray, *Tetrahedron Lett.*, 2010, **51**, 5604.

8 K. Sudheendran, C. C. Malakar, J. Conrad and U. Beifuss, *J. Org. Chem.*, 2012, **77**, 10194.

9 M. T. Liu, J. Ho, J. K. Liu, R. Purakait, U. N. Morzan, L. Ahmed, V. S. Batista, H. Matsunami and K. Ryan, *Org. Biomol. Chem.*, 2018, **16**, 2541.

10 L. Xu, Z. Liu, W. Dong, J. Song, M. Miao, J. Xu and H. Ren, *Org. Biomol. Chem.*, 2015, **13**, 6333.

11 P. Szcześniak, M. Pieczykolan and S. Stecko, *J. Org. Chem.*, 2016, **81**, 1057.

12 S. F. Giardina, D. S. Werner, M. Pingle, K. W. Foreman, D. E. Bergstrom, L. D. Arnold and F. Barany, *ACS Med. Chem. Lett.*, 2018, **9**, 827.

13 A. Srikrishna and P. P. Kumar *Tetrahedron*, 2000, **56**, 8189.

14 D. Staveness, T. M. Sodano, K. Li, E. A. Burnham, K. D. Jackson and C. R. J. Stephenson, *Chem.*, 2019, **5**, 215.

15 J. Lei, X. Liu, S. Zhang, S. Jiang, M. Huang, X. Wu and Q. Zhu, *Chem. Eur. J.*, 2015, **21**, 6700.

16 N. Itagaki, M. Kimura, T. Sugahara and Y. Iwabuchi, *Org. Lett.*, 2005, **7**, 4185.

17 R. J. Comito, F. G. Finelli and D. W. C. MacMillan, *J. Am. Chem. Soc.*, 2013, **135**, 9358.

18 R. Jana, I. Chatterjee, S. Samanta and J. K. Ray, *Org. Lett.*, 2008, **10**, 4795.

19 A. K. Adak, A. Mandal, S. K. Manna, S. K. Mondal, A. Jana, D. Ghosh, D. Kundu, S. Samanta and J. K. Ray, *Synth. Commun.*, 2016, **46**, 452.

20 L.-Q. Cui, Z.-L. Dong, K. Liu and C. Zhang, *Org. Lett.*, 2011, **13**, 6488.

21 W.-G. Lee, K. M. Frey, R. Gallardo-Macias, K. A. Spasov, M. Bollini, K. S. Anderson and W. L. Jorgensen, *ACS Med. Chem. Lett.*, 2014, **5**, 1259.

22 K. Knobloch, M. Keller and W. Eberbach, *Eur. J. Org. Chem.*, 2001, 3313.

23 A. Furukawa, T. Arita, T. Fukuzaki, M. Mori, T. Honda, S. Satoh, Y. Matsui, K. Wakabayashi, S. Hayashi, K. Nakamura, K. Araki, M. Kuroha, J. Tanaka, S. Wakimoto, O. Suzuki and J. Ohsumi, *Eur. J. Med. Chem.*, 2012, **54**, 522.

24 R. Brimioulle and T. Bach, *Angew. Chem. Int. Ed.*, 2014, **53**, 12921.

25 S. Poplata and T. Bach, *J. Am. Chem. Soc.*, 2018, **140**, 3228.

26 S. Stegbauer, C. Jandl and T. Bach, *Angew. Chem. Int. Ed.*, 2018, **57**, 14593.

27 *APEX suite of crystallographic software*, APEX 3, Version 2019-1.0, Bruker AXS Inc., Madison, Wisconsin, USA, 2019.

28 *SAINT*, Version 8.40A and *SADABS*, Version 2016/2, Bruker AXS Inc., Madison, Wisconsin, USA, 2016/2019.

29 G. M. Sheldrick, *Acta Crystallogr. Sect. A*, 2015, **71**, 3.

30 G. M. Sheldrick, *Acta Crystallogr. Sect. C*, 2015, **71**, 3.

31 C. B. Hübschle, G. M. Sheldrick and B. Dittrich, *J. Appl. Cryst.*, 2011, **44**, 1281.

32 *International Tables for Crystallography, Vol. C* (Ed.: A. J. Wilson), Kluwer Academic Publishers, Dordrecht, The Netherlands, 1992, Tables 6.1.1.4 (pp. 500-502), 4.2.6.8 (pp. 219-222), and 4.2.4.2 (pp. 193-199).

33 C. F. Macrae, I. J. Bruno, J. A. Chisholm, P. R. Edgington, P. McCabe, E. Pidcock, L. Rodriguez-Monge, R. Taylor, J. van de Streek and P. A. Wood, *J. Appl. Cryst.*, 2008, **41**, 466.

34 H. D. Flack, *Acta Crystallogr. Sect A*, 1983, **39**, 876.

35 S. Parsons, H. D. Flack and T. Wagner, *Acta Crystallogr. Sect B*, 2013, **69**, 249.