Benzannulated 6,5-Spiroketals from Donor-Acceptor Cyclopropanes

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Supporting Information

Contents

Experimental

General

^{1}H NMR spectra were recorded at either 400 MHz on a Varian 400-MR NMR system or at 500 MHz on a Varian 500 MHz AR premium shielded spectrometer. All spectra were recorded from samples in $CDCl_3$ at 25 °C in 5 mm NMR tubes. Chemical shifts are reported relative to the residual chloroform singlet at δ 7.26 ppm. Resonances were assigned as follows: chemical shift (multiplicity, coupling constant(s), number of protons, and assigned proton). Multiplicity abbreviations are reported by the conventions: s (singlet), br s (broad singlet), d (doublet), dd (doublet of doublets), dt (doublet of triplets), dq (doublet of quartets), t (triplet), td (triplet of doublets), q (quartet), m (multiplet). ^{13}C NMR spectra were recorded at either 100 MHz on a Varian 400-MR NMR system or at 125 MHz on a Varian 500 MHz AR premium shielded spectrometer. Chemical shifts have been reported relative to the $CDCl_3$ triplet at δ 77.00 ppm. Infrared spectra were recorded on a Bruker Optics Alpha ATR FT-IR spectrometer. High resolution mass-spectra (HRMS) were recorded on a Bruker microTOF_Q mass spectrometer using an electrospray ionisation (ESI) source in either the positive or negative modes.

Materials and Methods: Thin layer chromatography (tlc) was performed on ALUGRAM® aluminium-backed UV254 silica gel 60 (0.20 mm) plates. Compounds were visualized by UV light at 254 nm and by dipping the plates with 10% w/w phosphomolybdic acid in ethanol. Column chromatography was performed using silica gel (200-400 mesh). Preparative layer chromatography with UV254 was performed on Analtech glass-baked UV254 silica gel (2.0 mm) plates. Dichloromethane (DCM), Diethyl ether (Et_2O), Methanol (MeOH), Ethanol (EtOH), Tetrahydrofuran (THF) were dried using a PURE SOLV MD-6 solvent purification system. All other solvents and reagents were used as received.

X-ray Crystallography

Crystals were attached with Paratone N oil to a CryoLoop supported in a copper mounting pin, then quenched in a cold nitrogen stream. Data were collected at 100 K using Cu-K_α radiation (micro-source, mirror monochromated) using an Agilent SuperNova diffractometer with Atlas detector. The data processing was undertaken within the CrysAlisPro software;[1] combined Gaussian and multiscan scaling absorption corrections were applied to the data.[1] The

structures were solved by direct methods with SHELXT-2014, and extended and refined with SHELXL-2014.[2] The non-hydrogen atoms were modelled with anisotropic displacement parameters and a riding atom model with group displacement parameters used for the hydrogen atoms. The ethyl group of the ester in **8aii** is disordered and has been modelled over two sites of equal occupancy (C17-C18 and C17'-C18'). The asymmetric units of **8ai** and **17bi** contain two molecules with the same configuration; all crystal structures are racemic mixtures. Details of each structure including structure refinement parameters and CCDC numbers are included in Table S1. The crystal data can be obtained free of charge from The Cambridge Crystallographic Data Centre via https://www.ccdc.cam.ac.uk.

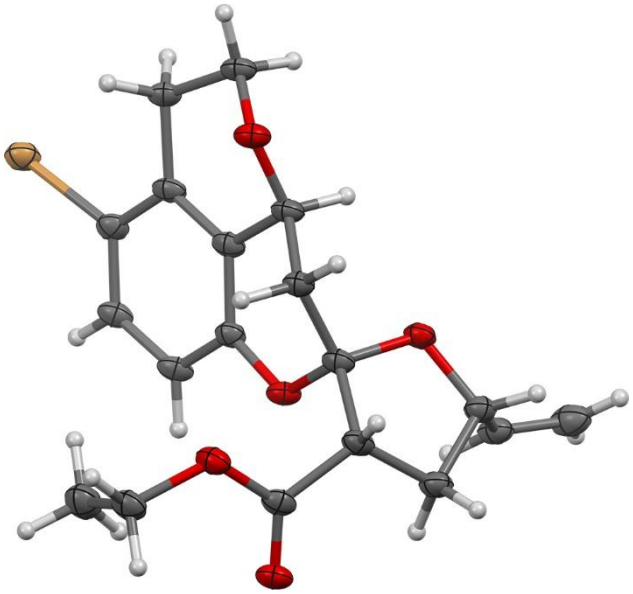
Table S1. X-ray crystallography data and structure refinement parameters.

	8ai	**8aii**	**8ni**
CCDC No.	**1901377**	**1901378**	**1901379**
Formula	$C_{19}H_{23}BrO_5$	$C_{19}H_{23}BrO_5$	$C_{18}H_{21}BrO_5$
M	411.28	411.28	381.26
T (K)	100	100	100
Crystal system	orthorhombic	monoclinic	monoclinic
Space group	*P*na2$_1$ (#33)	*P*2$_1$/*n* (#14)	*P*2$_1$/*n* (#14)
a (Å)	26.5160(4)	9.9282(3)	8.72560(10)
b (Å)	9.77050(10)	13.4521(6)	14.8633(2)
c (Å)	14.2775(2)	14.3693(5)	13.4801(2)
α (°)	90	90	90
β (°)	90	100.845(3)	90.348(2)
γ (°)	90	90	90
V (Å^3)	3698.94(9)	1884.82(12)	1748.22(4)
Z [*Z'*]	8 [2]	4	4
Crystal description	colourless irregular	colourless irregular	colourless block
Crystal size (mm^3)	0.25 × 0.17 ×0.15	0.29 × 0.23 ×0.10	0.15 × 0.14 × 0.08
μ (mm^{-1})	3.254	3.192	3.352
$2\vartheta_{max}$, $2\vartheta_{full}$ (°)	149.56, 134.00	150.40, 134.00	148.55, 134.00
$N_{measured\ refl}$	12633	18103	13591
$N_{independent\ refl}$ [R_{int}]	6568 [0.0241]	3812 [0.0432]	3507 [0.0227]
$N_{observed\ refl}$ [$I > 2\sigma(I)$]	6434	3470	3325
$N_{parameters}$	457	242	210
$N_{restraints}$	1	3	0
R [$I > 2\sigma(I)$]	0.0322	0.0620	0.0217
wR [all data]	0.0747	0.1838	0.0548
GOF	1.030	1.152	1.031
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.585, –0.393	1.718, –1.169	0.368, –0.216

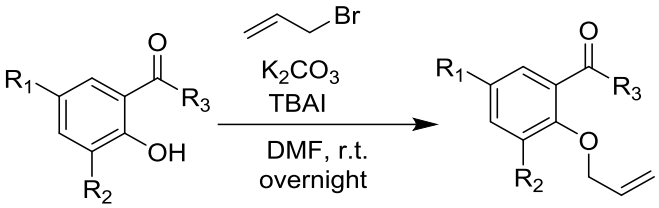
Table S1 (continued). X-ray crystallography data and structure refinement parameters.

	8nii	**17bi**	**17bii**
CCDC No.	**1901380**	**1901381**	**1901382**
Formula	$C_{18}H_{21}BrO_4$	$C_{19}H_{21}BrO_5$	$C_{18}H_{21}BrO_4$
M	381.26	409.27	409.27
T (K)	100	100	100
Crystal system	monoclinic	monoclinic	triclinic
Space group	$P2_1/n$ (#14)	$P2_1/n$ (#14)	$P\bar{1}$ (#2)
a (Å)	8.53780(10)	11.08110(10)	9.0999(11)
b (Å)	15.5361(2)	15.7953(2)	9.3672(11)
c (Å)	13.0440(2)	20.0472(2)	10.7852(13)
α (°)	90	90	74.335(11)
β (°)	93.691(2)	92.1470(10)	81.282(10)
γ (°)	90	90	88.775(10)
V (Å^3)	1726.62(4)	3506.38(6)	874.78(19)
Z [Z']	4	8 [2]	2
Crystal description	colourless irregular	colourless irregular	colourless block
Crystal size (mm^3)	0.38 × 0.25 ×0.09	0.33 × 0.23 ×0.08	0.19 × 0.14 × 0.02
μ (mm^{-1})	3.393	3.432	3.439
$2\vartheta_{max}$, $2\vartheta_{full}$ (°)	148.56, 134.00	148.66, 134.00	150.33, 134.00
$N_{measured\ refl}$	15546	25728	5670
$N_{independent\ refl}$ [R_{int}]	3465 [0.0221]	7020 [0.0272]	3434 [0.0388]
$N_{observed\ refl}$ [$I > 2\sigma(I)$]	3402	6725	2966
$N_{parameters}$	210	453	227
$N_{restraints}$	0	0	0
R [$I > 2\sigma(I)$]	0.0239	0.0243	0.0562
wR [all data]	0.0619	0.0636	0.1597
GOF	1.086	1.032	1.060
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.328, –0.471	0.360, –0.393	1.483, –1.196

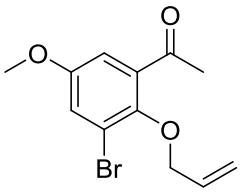
Figure S1. ORTEP diagram of the asymmetric unit of **17bii** with 40% probability ellipsoids.



General Procedure 1: Synthesis of 2-allyloxybenzaldehyde and 2-allyloxyacetophenone derivatives



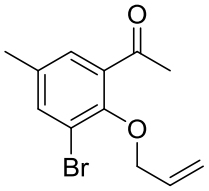
To a solution of 2-hydroxybenzaldehyde or 2-hydroxyacetophenone derivatives (1 eq) in DMF (1 mmol/mL) at room temperature was added K_2CO_3 (2.3 eq), TBAI (0.1 eq) and allyl bromide (1.2 eq) with stirring for 20 hours. Then the reaction was quenched with water at room temperature and extracted with Et_2O (x3). The combined organic layer was washed with water (x3) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo* to give the desired 2-allyloxybenzaldehyde or 2-allyloxyacetophenone.



1-(2-Allyloxy-3-bromo-5-methoxy-phenyl)-ethanone

Following **general procedure 1**: 3-bromo-2-hydroxy-5-methyoxyacetophenone (882 mg, 3.6 mmol), K_2CO_3 (1.15 g, 8.3 mmol), allyl bromide (0.38 mL, 4.3 mmol) and TBAI (111 mg, 0.3 mmol) were combined in DMF (5 mL) to provide the title compound (968 mg, 98%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.25 (d, J =3.2 Hz, 1H), 7.05 (d, J = 3.2 Hz, 1H), 6.12-6.02 (m, 1H), 5.40 (d, J = 17.2 Hz, 1H), 5.29 (d, J = 10.4 Hz, 1H), 4.41 (d, J = 5.6 Hz, 2H), 3.79 (s, 3H), 2.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 199.8, 156.0, 148.2, 135.5, 132.7, 122.9, 118.9, 118.9, 113.0, 76.1, 55.9, 30.7; FTIR (ATR / cm^{-1}): 2938, 2838, 1683, 1596, 1462, 1412, 1356, 1238, 1207, 1042, 977, 928, 863, 776; HRMS-ESI calculated for $C_{12}H_{13}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 306.9940; found: 306.9949.

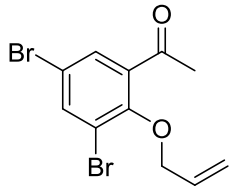


1-(2-Allyloxy-3-bromo-5-methyl-phenyl)-ethanone

Following **general procedure 1**: 3-bromo-2-hydroxy-5-methylacetophenone (916 mg, 4 mmol), K_2CO_3 (1.5 g, 10.6 mmol), allyl bromide (0.48 mL, 5.5 mmol) and TBAI (85 mg, 0.23 mmol) were combined in DMF (5 mL) to provide the title compound (1.08 g, 99%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.51 (d, J = 2 Hz, 1H), 7.31 (d, J = 2 Hz, 1H), 6.13-6.03 (m, 1H), 5.40 (d, J = 17.2 Hz, 1H), 5.28 (d, J = 10.4 Hz, 1H), 4.44 (d, J = 6 Hz, 2H), 2.61 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 200.2, 152.1, 137.3, 135.5, 135.3, 132.6, 129.2, 119.0, 118.2, 75.9, 30.7, 20.4; FTIR (ATR / cm^{-1}): 2954, 2918, 2851, 1733, 1460,

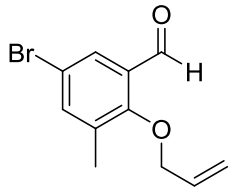
1376, 1240, 1183, 983, 804; HRMS-ESI calculated for $C_{12}H_{13}{}^{79}BrO_2Na^+$ $[M+Na]^+$: 290.9991; found: 290.9974.



1-(2-Allyloxy-3,5-dibromo-phenyl)-ethanone

Following **general procedure 1**: 3,5-dibromo-2-hydroxyacetophenone (1.07 g, 3.6 mmol), K_2CO_3 (1.16 g, 8.4 mmol), allyl bromide (0.38 mL, 4.4 mmol) and TBAI (67 mg, 0.18 mmol) were combined in DMF (4 mL) to provide the crude residue. The crude residue was purified by flash chromatography (1:20 EtOAc/40−60 Pet. Ether) to afford the title compound (1.07 g, 89 %) as a yellow oil.

^{1}H NMR (500 MHz, $CDCl_3$), δ (ppm): 7.82 (d, J =2.5 Hz, 1H), 7.63 (d, J = 2.5 Hz, 1H), 6.09-6.02 (m, 1H), 5.40 (d, J = 17 Hz, 1H), 5.30 (d, J = 10 Hz, 1H), 4.46 (d, J = 6 Hz, 2H), 2.60 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$), δ (ppm): 198.4, 153.6, 138.8, 136.7, 132.1, 131.6, 119.6, 119.5, 117.6, 76.1, 30.6; FTIR (ATR / cm^{-1}): 2984, 2931, 1688, 1434, 1415, 1387, 1267, 1233, 1180, 974, 929, 870, 706; HRMS-ESI calculated for $C_{11}H_{10}{}^{79}Br_2O_2Na^+$ $[M+Na]^+$: 354.8940; found: 354.8933.



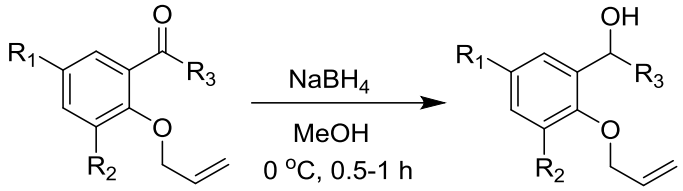
2-Allyloxy-5-bromo-3-methyl-benzaldehyde

Following **general procedure 1**: 5-bromo-2-hydroxy-3-methyl benzaldehyde, K_2CO_3 (945 mg, 6.9 mmol), allyl bromide (0.32 mL, 3.6 mmol) and TBAI (55.4 mg, 0.15 mmol) were combined in DMF (2 mL) to provide the title compound (765 mg, 98%) as a yellow solid.

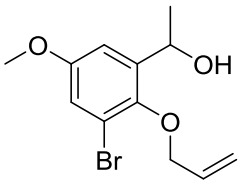
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 10.27 (s, 1H), 7.77 (d, J = 2.4 Hz, 1H), 7.55 (dd, J = 2.4, 0.8 Hz, 1H), 6.11-6.01 (m, 1H), 5.40 (dq, J = 17.2, 1.6 Hz, 1H), 5.31 (dq, J = 10.4, 1.2 Hz, 1H), 4.44 (dt, J = 6, 1.2 Hz, 2H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm):

188.9, 159.3, 139.7, 135.0, 132.2, 130.7, 128.8, 119.1, 117.5, 76.6, 15.7; FTIR (ATR / cm^{-1}): 2922, 2864, 1683, 1573, 1460, 1423, 1390, 1226, 1196, 978, 923, 874, 747; HRMS-ESI calculated for $C_{11}H_{11}{}^{79}BrO_2Na^+$ $[M+Na]^+$: 276.9835; found: 276.9818; m.p. = 44.2 °C-45.7 °C.

General Procedure 2a: Synthesis of 1-bromomethyl or 1-bromoethyl benzene derivatives



To a solution of 2-allyloxybenzaldehyde or 2-allyloxyacetophenone derivatives (1 eq) in MeOH (0.5 mmol/mL) at 0 °C was added $NaBH_4$ (1.1 eq) slowly. After the completion of the reaction (0.5-1 h), saturated NH_4Cl solution was added slowly at 0 °C and then the reaction mixture was allowed to warm to room temperature and extracted with Et_2O (x3). The combined organic layer was washed with water (x3) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo* to give the desired alcohol.

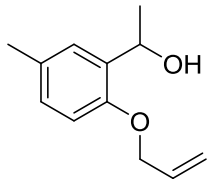


2-Allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methoxy-benzene

Following **general procedure 2a**: 1-(2-allyloxy-3-bromo-5-methoxy-phenyl)-ethanone (1.11 g, 3.9 mmol), $NaBH_4$ (163 mg, 4.3 mmol) were combined in MeOH (8 mL) to provide the alcohol 1-(2-allyloxy-3-bromo-5-methoxy-phenyl)-ethanol (1.12 g, 98%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.01 (d, J =2.8 Hz, 1H), 6.97 (d, J = 3.2 Hz, 1H), 6.17-6.07 (m, 1H), 5.43 (dq, J = 17.6, 1.6 Hz, 1H), 5.30 (dd, J = 10.4, 1.6 Hz, 1H), 5.16 (q, J = 6.4 Hz, 1H), 4.51-4.43 (m, 2H), 3.78 (s, 3H), 2.17 (br s, 1H), 1.48 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 156.5, 146.5, 141.2, 133.3, 118.1, 117.4, 117.3, 111.2, 74.8, 65.4,

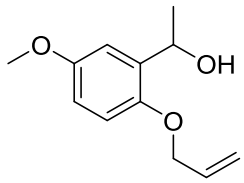
55.8, 23.9; FTIR (ATR / cm^{-1}): 3379, 2973, 2933, 2837, 1467, 1434, 1203, 1130, 1046, 982, 929, 780; HRMS-ESI calculated for $C_{12}H_{15}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 309.0097; found: 309.0093.



1-Allyloxy-2-(1-bromo-ethyl)-4-methyl-benzene

Following **general procedure 2a**: 2-(2-propen-1-yloxy)-5-methylacetophenone (951 mg, 5 mmol), $NaBH_4$ (208 mg, 5.5 mmol) were combined in MeOH (10 mL) to provide the alcohol 1-(2-allyloxy-5-methyl-phenyl)-ethanol (961 mg, 99%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.15 (s, 1H), 7.01 (dd, J = 8, 2 Hz, 1H), 6.77 (d, J = 8.4 Hz, 1H), 6.11-6.01 (m, 1H), 5.41 (dd, J = 17.2, 2.4 Hz, 1H), 5.29 (dd, J = 10.8, 1.6 Hz, 1H), 5.10 (q, J = 6.4 Hz, 1H), 4.56 (d, J = 4.8 Hz, 2H), 2.64 (br s, 1H), 2.30 (s, 3H), 1.52 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 153.4, 133.4, 133.2, 130.2, 128.4, 126.9, 117.4, 111.7, 68.9, 66.7, 23.0, 20.6; FTIR (ATR / cm^{-1}): 3383, 2972, 2923, 2866, 1497, 1454, 1240, 1073, 1022, 997, 925, 802; HRMS-ESI calculated for $C_{12}H_{16}O_2Na^+$ $[M+Na]^+$: 215.1043; found: 215.1025.

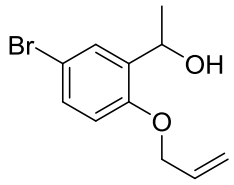


1-Allyloxy-2-(1-bromo-ethyl)-4-methoxy-benzene

Following **general procedure 2a**: 2-(2-propen-1-yloxy)-5-methoxyacetophenone (825 mg, 4 mmol), $NaBH_4$ (170 mg, 4.4 mmol) were combined in MeOH (8 mL) to provide alcohol 1-(2-allyloxy-5-methoxy-phenyl)-ethanol (832 mg, 99%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.95 (d, J = 2.8 Hz, 1H), 6.81-6.72 (m, 2H), 6.10-6.01 (m, 1H), 5.41 (d, J = 17.2 Hz, 1H), 5.29 (d, J = 10.4 Hz, 1H), 5.11 (q, J = 6.4 Hz,1H), 4.54 (d, J = 4.8 Hz, 2H), 3.78 (s, 3H), 2.63 (br s, 1H), 1.51 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 153.9, 149.6, 135.1, 133.3, 117.4, 112.9, 112.4, 112.3, 69.4, 66.5, 55.7, 23.0;

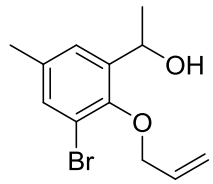
FTIR (ATR / cm^{-1}): 3413, 2970, 2929, 2835, 1492, 1456, 1274, 1204, 1160, 1072, 1019, 924, 874, 800; HRMS-ESI calculated for $C_{12}H_{16}O_3Na^+$ $[M+Na]^+$: 231.0992; found: 231.0986.



1-Allyloxy-4-bromo-2-(1-bromo-ethyl)-benzene

Following **general procedure 2a**: 2-(2-propen-1-yloxy)-5-bromoacetophenone (949 mg, 3.72 mmol), $NaBH_4$ (455 mg, 4.1 mmol) were combined in MeOH (8 mL) to provide the alcohol 1-(2-allyloxy-5-bromo-phenyl)-ethanol (956 mg, 99%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.50 (d, J = 2.4 Hz, 1H), 7.31 (dd, J = 8.8, 2.8 Hz, 1H), 6.73 (d, J = 8.4 Hz, 1H), 6.08-5.99 (m, 1H), 5.40 (dq, J = 17.2, 1.6 Hz, 1H), 5.31 (dq, J = 10.8, 1.2 Hz, 1H), 5.11 (q, J = 6.4 Hz, 1H), 4.56 (dt, J = 5.2, 1.6 Hz, 2H), 2.43 (br s, 1H), 1.49 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 154.4, 136.1, 132.6, 130.7, 129.1, 117.9, 113.4, 113.3, 69.0, 65.8, 23.0; FTIR (ATR / cm^{-1}): 3374, 2974, 2869, 1483, 1452, 1233, 1181, 1072, 995, 905, 803; HRMS-ESI calculated for $C_{11}H_{13}{}^{79}BrO_2Na^+$ $[M+Na]^+$: 278.9991; found: 279.0009.

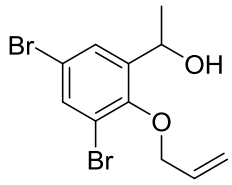


2-Allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methyl-benzene

Following **general procedure 2a**: 1-(2-allyloxy-3-bromo-5-methyl-phenyl)-ethanone (1.08 g, 4 mmol), $NaBH_4$ (170 mg, 4.4 mmol) were combined in MeOH (8 mL) to provide the alcohol 1-(2-allyloxy-3-bromo-5-methyl-phenyl)-ethanol (1.08 g, 98%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.29 (s, 1H), 7.20 (s, 1H), 6.18-6.08 (m, 1H), 5.44 (d, J = 17.2 Hz, 1H), 5.30 (d, J = 10.4 Hz, 1H), 5.17 (q, J = 6.4 Hz, 1H), 4.50 (d, J = 5.6 Hz, 2H), 2.30 (s, 3H), 1.48 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 150.5, 140.2, 135.7, 133.3, 132.9, 126.2, 118.2, 116.8, 74.7, 65.3, 23.9, 20.7; FTIR (ATR / cm^{-1}): 3365, 2974,

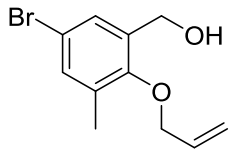
2925, 2867, 1465, 1267, 1221, 1130, 1076, 981, 926, 857, 777; HRMS-ESI calculated for $C_{12}H_{15}{}^{79}BrO_2Na^+$ $[M+Na]^+$: 293.0148; found: 293.0123



2-Allyloxy-1,5-dibromo-3-(1-bromo-ethyl)-benzene

Following **general procedure 2a**: 1-(2-allyloxy-3,5-dibromo-phenyl)-ethanone (1.07 g, 3.2 mmol), $NaBH_4$ (133 mg, 3.5 mmol) were combined in MeOH (7 mL) to provide the alcohol 1-(2-allyloxy-3,5-dibromo-phenyl)-ethanol (1.08 g, 99%) as a yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$), δ (ppm): 7.61 (d, J = 2.5 Hz, 1H), 7.55 (d, J = 2 Hz, 1H), 6.14-6.06 (m, 1H), 5.43 (d, J =17.5Hz, 1H), 5.31 (d, J = 10.5 Hz, 1H), 5.14 (q, J = 5.2 Hz, 1H), 4.54-4.45 (m, 2H), 2.08 (br s, 1H), 1.46 (d, J = 6.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$), δ (ppm): 152.0, 142.5, 134.7, 132.8, 128.9, 118.6, 118.1, 117.8, 74.7, 65.0, 24.0; FTIR (ATR / cm^{-1}): 3347, 2976, 2928, 1555, 1437, 1418, 1370, 1215, 1150, 977, 916, 860, 709; HRMS-ESI calculated for $C_{11}H_{12}{}^{79}Br_2O_2Na^+$ $[M+Na]^+$: 356.9096; found: 356.9095; m.p.= 54.5 ^{o}C-55.8 ^{o}C.



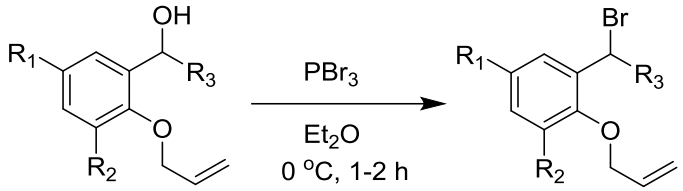
(2-Allyloxy-5-bromo-3-methyl-phenyl)-methanol

Following **general procedure 2a**: 2-allyloxy-3-bromo-benzaldehyde (765 mg, 3 mmol), and $NaBH_4$ (125 mg, 3.3 mmol) were combined in MeOH (6 mL) to provide (2-allyloxy-5-bromo-3-methyl-phenyl)-methanol (771 mg, 99%) as a yellow solid.

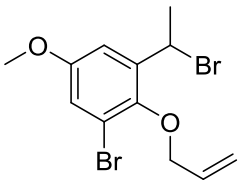
^{1}H NMR (500 MHz, $CDCl_3$), δ (ppm): 7.33 (s, 1H), 7.25 (s, 1H), 6.10-6.03 (m, 1H), 5.41 (d, J = 17 Hz, 1H), 5.28 (d, J = 10.5 Hz, 1H), 4.64 (s, 2H), 4.33 (dd, J = 5.5, 1.5 Hz, 2H), 2.30 (br s, 1H), 2.26 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$), δ (ppm): 154.3, 136.0, 133.4, 133.3, 129.3, 117.9, 116.9, 74.2, 60.7, 16.1; FTIR (ATR / cm^{-1}): 3285, 2919, 2864, 1447, 1407, 1357, 1228,

1192, 1049, 979, 919, 865; HRMS-ESI calculated for $C_{11}H_{13}{}^{79}BrO_2Na^+$ $[M+Na]^+$: 278.9991; found: 278.9987; m.p. = 55.3 ºC-56.7 ºC.

General Procedure 2b: Synthesis of 1-bromomethyl or 1-bromoethyl benzene derivatives



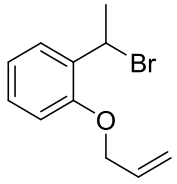
To a solution of the alcohol derivatives (1 eq) in Et_2O (0.5 mmol/mL) at 0 ºC was added PBr_3 (1.1 eq) slowly. After the completion of the reaction (1-2 h), saturated $NaHCO_3$ solution was added slowly at 0 ºC and then the reaction mixture was allowed to warm to room temperature and extracted with Et_2O (x3). The combined organic layer was washed with saturated $NaHCO_3$ (x2), water (x3) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo* to give the desired 1-bromomethyl or 1-bromoethyl benzene derivatives.



2-Allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methoxy-benzene

Following **general procedure 2b**: 1-(2-allyloxy-3-bromo-5-methoxy-phenyl)-ethanol (1119 mg, 3.9 mmol), PBr_3 (0.4 ml, 4.3 mmol) were combined in Et_2O (8 mL) to provide the title compound (875 mg, 64%) as a brown oil.

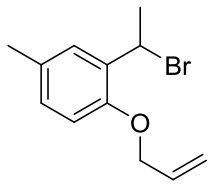
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.04 (s, 2H), 6.21-6.11 (m, 1H), 5.60 (q, J = 7.2 Hz, 1H), 5.48 (d, J = 17.2 Hz, 1H), 5.32 (d, J = 10.4 Hz, 1H), 4.58-4.49 (m, 2H), 3.80 (s, 3H), 1.97 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 156.4, 146.0, 138.9, 133.2, 118.5, 118.4, 117.7, 112.8, 74.5, 55.8, 42.1, 26.6; FTIR (ATR / cm^{-1}): 2928, 2836, 1467, 1332, 1212, 1036, 978, 920, 846, 787.



1-Allyloxy-2-(1-bromo-ethyl)-benzene

Following **general procedure 2b**: 2-(2-propen-1-yloxy)methylacetophenone (1.06 g, 6 mmol), $NaBH_4$ (250 mg, 6.6 mmol) were combined in MeOH (12 mL) to provide 1-(2-allyloxy-phenyl)-ethanol as a colourless oil without further purification. This alcohol compound, PBr_3 (0.62 ml, 6.6 mmol) were combined in Et_2O (12 mL) to provide the title compound (1.44 g, 99%) as a brown oil.

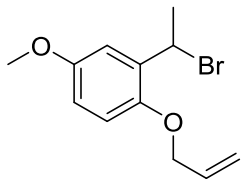
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.53 (dd, J = 8, 2 Hz, 1H), 7.27-7.23 (m, 1H), 6.98 (t, J = 7.4 Hz, 1H), 6.85 (d, J = 8 Hz, 1H), 6.14-6.04 (m, 1H), 5.75 (q, J = 6.8 Hz, 1H), 5.47 (dq, J = 17.2, 1.6 Hz, 1H), 5.30 (dq, J = 10.8, 1.6 Hz, 1H), 4.63-4.59 (m, 2H), 2.04 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 154.9, 133.0, 131.6, 129.4, 127.3, 121.0, 117.4, 112.2, 69.0, 43.2, 25.6; FTIR (ATR / cm^{-1}): 2955, 2916, 2850, 1457, 1377, 1237, 1024, 892, 751.



1-Allyloxy-2-(1-bromo-ethyl)-4-methyl-benzene

Following **general procedure 2b**: 1-(2-allyloxy-5-methyl-phenyl)-ethanol (961 mg, 5 mmol), PBr_3 (0.51 ml, 5.5 mmol) were combined in Et_2O (10 mL) to provide the title compound (1.25 g, 98%) as a yellow oil.

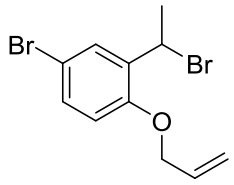
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.32 (d, J = 2 Hz, 1H), 7.04 (dd, J = 8.4, 2.4 Hz, 1H), 6.75 (d, J = 8.4 Hz, 1H), 6.12-6.03 (m, 1H), 5.73 (q, J = 7.2 Hz, 1H), 5.45 (dq, J = 17.2, 1.6 Hz, 1H), 5.29 (dq, J = 10.4, 1.2 Hz, 1H), 4.63-4.53 (m, 2H), 2.30 (s, 3H), 2.03 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 152.8, 133.3, 131.3, 130.3, 129.8, 127.8, 117.2, 112.3, 69.2, 43.4, 25.7, 20.6; FTIR (ATR / cm^{-1}): 2961, 2922, 2865, 1479, 1455, 1236, 1119, 1023, 995, 923, 802.



1-Allyloxy-2-(1-bromo-ethyl)-4-methoxy-benzene

Following **general procedure 2b**: 1-(2-allyloxy-5-methoxy-phenyl)-ethanol (832 mg, 4 mmol), PBr_3 (0.41 ml, 4.4 mmol) were combined in Et_2O (8 mL) to provide the title compound (890 mg, 82%) as a yellow oil.

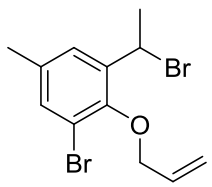
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.08 (d, J = 2.4 Hz, 1H), 6.81-6.77 (m, 2H), 6.12-6.03 (m, 1H), 5.70 (q, J = 6.8 Hz, 1H), 5.44 (dq, J = 17.2, 1.6 Hz, 1H), 5.29 (dq, J = 10.8, 1.2 Hz, 1H), 4.61-4.50 (m, 2H), 3.79 (s, 3H), 2.01 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 153.9, 149.0, 133.4, 132.8, 117.3, 114.0, 113.8, 113.2, 69.9, 55.7, 43.0, 25.7; FTIR (ATR / cm^{-1}): 2932, 2834, 1495, 1461, 1279, 1209, 1038, 924, 871, 800.



1-Allyloxy-4-bromo-2-(1-bromo-ethyl)-benzene

Following **general procedure 2b**: 1-(2-allyloxy-5-bromo-phenyl)-ethanol (956 mg, 3.7 mmol), PBr_3 (0.39 ml, 4.1 mmol) were combined in Et_2O (8 mL) to provide the title compound (1080 mg, 90%) as a brown oil.

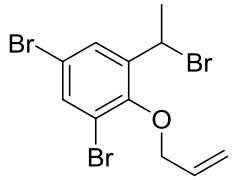
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.61 (d, J = 2.4 Hz, 1H), 7.33 (dd, J = 8.8, 2.8 Hz, 1H), 6.73 (d, J = 8.8 Hz, 1H), 6.10-6.01 (m, 1H), 5.62 (q, J = 7.2 Hz, 1H), 5.45 (dq, J = 17.6, 1.6 Hz, 1H), 5.31 (dq, J = 10.4, 1.6 Hz, 1H), 4.60-4.57 (m, 2H), 2.00 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 153.9, 133.8, 132.5, 132.0, 130.3, 117.8, 113.9, 113.2, 69.3, 41.6, 25.5; FTIR (ATR / cm^{-1}): 2978, 2922, 2865, 1483, 1455, 1245, 1129, 993, 926, 804.



2-Allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methyl-benzene

Following **general procedure 2b**: 1-(2-allyloxy-3-bromo-5-methyl-phenyl)-ethanol (1.08 g, 4 mmol), PBr_3 (0.41 ml, 4.4 mmol) were combined in Et_2O (8 mL) to provide the title compound (922 mg, 69%) as a brown oil.

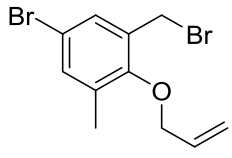
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.31 (s, 2H), 6.22-6.12 (m, 1H), 5.62 (q, J = 7.2 Hz, 1H), 5.49 (d, J = 17.2 Hz, 1H), 5.32 (d, J = 10.4 Hz, 1H), 4.60-4.52 (m, 2H), 2.32 (s, 3H), 1.98 (d, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 150.0, 138.2, 135.8, 133.9, 133.1, 127.7, 118.4, 117.1, 74.4, 42.2, 26.6, 20.7; FTIR (ATR / cm^{-1}): 2954, 2917, 2850, 1465, 1377, 1217, 1196, 1033, 987, 858, 720.



2-Allyloxy-1,5-dibromo-3-(1-bromo-ethyl)-benzene

Following **general procedure 2b**: 1-(2-allyloxy-3-bromo-5-methoxy-phenyl)-ethanol (1.08 g, 3.2 mmol), PBr_3 (0.3 ml, 3.5 mmol) were combined in Et_2O (7 mL) to provide the title compound (702 mg, 55%) as a brown oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.63 (s, 2H), 6.19-6.10 (m, 1H), 5.57-5.52 (m, 1H), 5.48 (d, J = 17.2 Hz, 1H), 5.34 (d, J = 10.4 Hz, 1H), 4.61-4.53 (m, 2H), 1.97 (d, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 151.6, 140.4, 135.6, 132.6, 130.4, 118.9, 118.4, 117.7, 74.5, 40.7, 26.4; FTIR (ATR / cm^{-1}):2925, 2865, 1443, 1418, 1324, 1252, 1196, 1090, 972, 931, 860, 710.

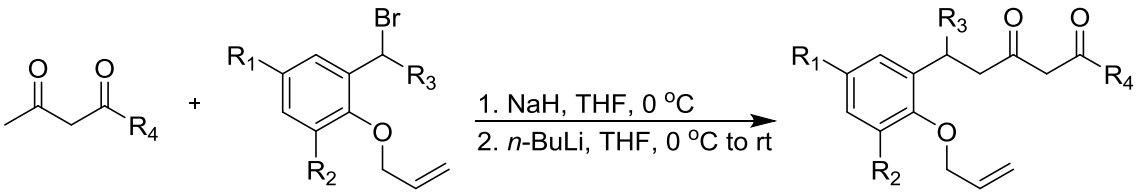


2-Allyloxy-5-bromo-1-bromomethyl-3-methyl-benzene

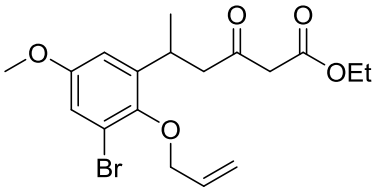
Following **general procedure 2b**: (2-allyloxy-5-bromo-3-methyl-phenyl)-methanol (771 mg, 3 mmol), PBr_3 (0.31 ml, 3.3 mmol) were combined in Et_2O (6 mL) to provide the title compound (644 mg, 67%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.35 (d, J = 3 Hz, 1H), 7.25 (s, 1H), 6.16-6.06 (m, 1H), 5.46 (d, J = 17.2 Hz, 1H), 5.30 (d, J = 10.4 Hz, 1H), 4.48 (s, 2H), 4.44 (dd, J = 5.6, 0.8 Hz, 2H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 154.7, 134.4, 134.0, 133.7, 133.2, 131.5, 117.8, 116.6, 73.9, 27.2, 16.3; FTIR (ATR / cm^{-1}): 2924, 2885, 1467, 1423, 1376, 1221, 1196, 979, 932, 861, 769.

General Procedure 3: Synthesis of 1,3-diketone derivatives



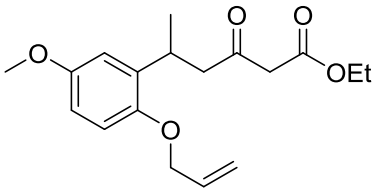
To a solution of NaH in THF (0.3mmol/mL) at 0 °C was added ethyl acetoacetate or 1,3-diketone derivatives (1 eq) dropwise. The reaction mixture was stirred for 10 minutes, at which time *n*-BuLi in hexane (1.1 eq) was added dropwise. After a further 10 minutes stirring at 0 °C, a solution of 1-bromomethyl or 1-bromoethyl benzene derivatives (1.3-1.5 eq) in THF (2.5 mmol/mL) was added quickly to the reaction mixture and this mixture was allowed to warm to room temperature for an additional 30 minutes stirring. After this time, the reaction was quenched with 3.5 M HCl and extracted with Et_2O (x3). The combined organic layer was washed with saturated $NaHCO_3$ (x3) water (x3) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo*. The crude residue was purified by chromatography.



5-(2-Allyloxy-3-bromo-5-methoxy-phenyl)-3-oxo-hexanoic acid ethyl ester (10a)

Following **general procedure 3**: to a solution of NaH (45 mg, 1.1 mmol) in THF (4 mL) was added ethyl acetoacetate (0.13 mL, 0.99 mmol) followed by *n*-BuLi in hexane (1.0 mL, 1.1 M) and 2-allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methyl-benzene (1.28 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:10 EtOAc/40−60 Pet. Ether) to afford the title compound (299 mg, 76%) as a yellow oil.

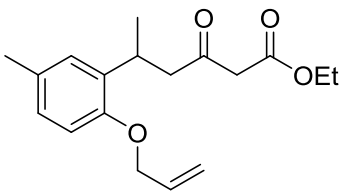
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.93 (d, J = 3.2 Hz, 1H), 6.66 (d, J = 2.8 Hz, 1H), 6.19-6.09 (m, 1H), 5.44 (d, J = 17.2 Hz, 1H), 5.27 (d, J = 10.4 Hz, 1H), 4.53-4.39 (m, 2H), 4.17 (q, J = 7.2 Hz, 2H), 3.75 (s, 3H), 3.73-3.67 (q, J = 6.8 Hz, 1H), 3.39 (d, J = 2.4 Hz, 2H), 2.87 (dd, J = 17.2, 6 Hz, 1H), 2.72 (dd, J = 17.2, 8 Hz, 1H), 1.28-1.21 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 201.1, 167.0, 156.3, 147.1, 141.6, 133.5, 117.9, 117.8, 115.6, 112.4, 74.6, 61.4, 55.7, 50.2, 49.5, 28.7, 21.1, 14.1; FTIR (ATR / cm^{-1}): 2972, 2935, 1741, 1715, 1601, 1467, 1437, 1420, 1312, 1206, 1024, 984, 931, 785; HRMS-ESI calculated for $C_{18}H_{23}{}^{79}BrO_5Na^+$ $[M+Na]^+$: 421.0621; found: 421.0649.



5-(2-Allyloxy-5-methoxy-phenyl)-3-oxo-hexanoic acid ethyl ester (10b)

Following **general procedure 3**: to a solution of NaH (60 mg, 1.46 mmol) in THF (5 mL) was added ethyl acetoacetate (0.17 mL, 1.33 mmol) followed by *n*-BuLi in hexane (1.5 mL, 1 M) and 1-allyloxy-2-(1-bromo-ethyl)-4-methoxy-benzene (1.73 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:10 EtOAc/40−60 Pet. Ether) to afford the title compound (214 mg, 50%) as a pale yellow oil.

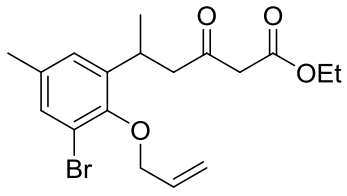
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.78-6.74 (m, 2H), 6.68-6.65 (m, 1H), 6.10-6.00 (m, 1H), 5.42-5.37 (m, 1H), 5.27-5.24 (m, 1H), 4.51-4.48 (m, 2H), 4.17 (q, J = 6.8 Hz, 2H), 3.75 (s, 3H), 3.72-3.66 (q, J = 6.8 Hz, 1H), 3.38 (d, J = 2.4 Hz, 2H), 2.89 (dd, J = 16.4, 5.6 Hz, 1H), 2.72 (dd, J = 16.4, 8.4 Hz, 1H), 1.27-1.24 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 201.9, 167.1, 153.8, 149.9, 135.4, 133.6, 116.9, 113.8, 113.0, 110.8, 69.5, 61.2, 55.6, 50.0, 49.4, 29.2, 19.9, 14.0; FTIR (ATR / cm^{-1}): 2966, 2935, 1741, 1714, 1647, 1497, 1459, 1424, 1367, 1210, 1024, 927, 799; HRMS-ESI calculated for $C_{18}H_{24}O_5Na^+$ $[M+Na]^+$: 343.1516; found: 343.1546.



5-(2-Allyloxy-5-methyl-phenyl)-3-oxo-hexanoic acid ethyl ester (10c)

Following **general procedure 3**: to a solution of NaH (34 mg, 0.85 mmol) in THF (3 mL) was added ethyl acetoacetate (0.1 mL, 0.77 mmol) followed by *n*-BuLi in hexane (0.85 mL, 1 M) and 1-allyloxy-2-(1-bromo-ethyl)-4-methyl-benzene (1.0 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:20 Et_2O/40−60 Pet. Ether) to afford the title compound (200 mg, 85%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.96-6.94 (m, 2H), 6.73 (d, J = 7.6 Hz, 1H), 6.11-6.01 (m, 1H), 5.40 (dq, J = 17.2, 1.6 Hz, 1H), 5.26 (dq, J = 10.4, 2.0 Hz, 1H), 4.52 (dt, J = 5.2, 1.6 Hz, 2H), 4.17 (q, J = 6.8 Hz, 2H), 3.71-3.66 (q, J = 6.8 Hz, 1H), 3.38 (d, J = 2.4 Hz, 2H), 2.89 (dd, J = 16, 5.2 Hz, 1H), 2.74 (dd, J = 16.4, 8.4 Hz, 1H), 2.27 (s, 3H), 1.28-1.24 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 202.1, 167.2, 153.6, 133.6, 133.6, 130.0, 127.9, 127.5, 117.0, 111.9, 68.9, 61.2, 50.1, 49.4, 29.2, 20.6, 19.9, 14.1; FTIR (ATR / cm^{-1}): 2975, 2926, 1741, 1715, 1647, 1499, 1457, 1413, 1366, 1229, 1153, 1025, 997, 927, 804; HRMS-ESI calculated for $C_{18}H_{24}O_4Na^+$ $[M+Na]^+$: 327.1567; found: 327.1556.

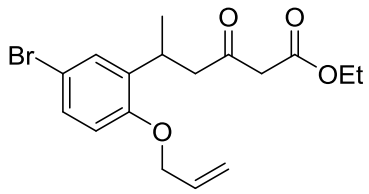


5-(2-Allyloxy-3-bromo-5-methyl-phenyl)-3-oxo-hexanoic acid ethyl ester (10d)

Following **general procedure 3**: to a solution of NaH (85 mg, 2.12 mmol) in THF (6 mL) was added ethyl acetoacetate (0.24 mL, 1.92 mmol) followed by *n*-BuLi in hexane (1.63 mL, 1.3 M) and 2-allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methyl-benzene (2.5 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:15 Et_2O/40−60 Pet. Ether) to afford the title compound (420 mg, 57%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.22 (s, 1H), 6.91 (s, 1H), 6.19-6.10 (m, 1H), 5.44 (d, J = 17.2 Hz, 1H), 5.28 (d, J = 10.8 Hz, 1H), 4.55-4.41 (m, 2H), 4.17 (q, J = 7.2 Hz, 2H), 3.73-3.68 (q, J = 6.8 Hz, 1H), 3.39 (d, J = 3.2 Hz, 2H), 2.86 (dd, J = 17.2, 6 Hz, 1H), 2.73 (dd, J = 17.2, 8.4 Hz, 1H), 2.27 (s, 3H), 1.28-1.21 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 201.2, 167.0, 150.9, 140.6, 135.3, 133.5, 131.8, 126.6, 117.9, 117.4, 74.4, 61.3, 50.4, 49.5, 28.4, 21.2, 20.7, 14.1; FTIR (ATR / cm^{-1}): 2976, 2928, 1741, 1715, 1646, 1465, 1419, 1367, 1314,

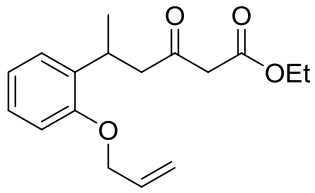
1227, 1027, 984, 931, 855, 782; HRMS-ESI calculated for $C_{18}H_{23}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 405.0672; found: 405.0657.



5-(2-Allyloxy-5-bromo-phenyl)-3-oxo-hexanoic acid ethyl ester (10e)

Following **general procedure 3**: to a solution of NaH (95 mg, 2.37 mmol) in THF (7 mL) was added ethyl acetoacetate (0.27 mL, 2.15 mmol) followed by *n*-BuLi in hexane (1.32 mL, 1.8 M) and 1-allyloxy-2-(1-bromo-ethyl)-4-methoxy-benzene (2.8 mmol) to give a crude residue. The crude residue was purified by flash chromatography to afford the title compound (685 mg, 86%) as a colourless oil.

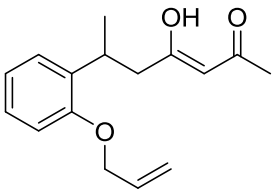
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.26-6.23 (m, 2H), 6.70 (d, J = 9.2 Hz, 1H),6.08-5.98 (m, 1H), 5.40 (dq, J = 17.6, 1.6 Hz, 1H), 5.28 (dq, J = 10.4, 1.6 Hz, 1H), 4.53 (dt, J = 5.2, 1.6 Hz, 2H), 4.18 (q, J = 7.2 Hz, 2H), 3.73-3.65 (m, 1H), 3.39 (s, 2H), 2.89 (dd, J = 16.8, 5.6 Hz, 1H), 2.73 (dd, J = 16.8, 8.4 Hz, 1H), 1.28-1.24 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 201.4, 167.1, 154.8, 136.4, 130.1, 129.8, 117.5, 113.6, 113.2, 69.0, 61.3, 49.6, 49.5, 28.8, 19.7, 14.1; FTIR (ATR / cm^{-1}): 2977, 2932, 1739, 1714, 1485, 1455, 1407, 1366, 1235, 1020, 996, 928, 804; HRMS-ESI calculated for $C_{17}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 391.0515; found: 391.0532.



5-(2-Allyloxy-phenyl)-3-oxo-hexanoic acid ethyl ester (10f)

Following **general procedure 3**: to a solution of NaH (45 mg, 1.1 mmol) in THF (4 mL) was added ethyl acetoacetate (0.13 mL, 1.0 mmol) followed by *n*-BuLi in hexane (1.1 mL, 1 M) and 1-allyloxy-2-(1-bromo-ethyl)-benzene (1.3 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:20 EtOAc/40−60 Pet. Ether) to afford the title compound (177 mg, 61%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.18-7.14 (m, 2H), 6.92 (t, J = 7.6 Hz, 1H), 6.84 (d, J = 8.4 Hz, 1H), 6.12-6.02 (m, 1H), 5.42 (dq, J = 17.2, 1.6 Hz, 1H), 5.28 (dq, J = 10.4, 1.6 Hz, 1H), 4.56 (dt, J = 5.2, 1.6 Hz, 2H), 4.17 (q, J = 7.2 Hz, 2H), 3.75-3.70 (m, 1H), 3.38 (d, J = 2.0 Hz, 2H), 2.91 (dd, J = 16.4, 5.6 Hz, 1H), 2.75 (dd, J = 16.4, 8.4 Hz, 1H), 1.29-1.24 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 202.1, 167.2, 155.7, 133.9, 133.4, 127.2, 127.1, 120.8, 117.1, 111.8, 68.8, 61.3, 50.0, 49.5, 29.1, 19.9, 14.1; FTIR (ATR / cm^{-1}): 2977, 2932, 1741, 1714, 1647, 1491, 1450, 1412, 1367, 1234, 1022, 929, 752; HRMS-ESI calculated for $C_{17}H_{22}O_4Na^+$ $[M+Na]^+$: 313.1410; found: 313.1406.



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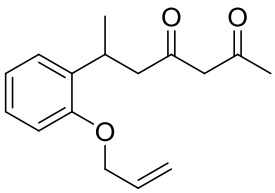
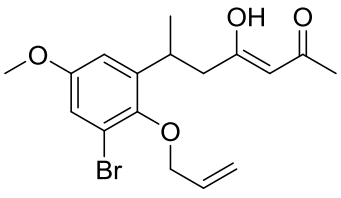


(enol/diketone: 6/1)

6-(2-Allyloxy-phenyl)-heptane-2,4-dione (10g)

Following **general procedure 3**: to a solution of NaH (102 mg, 2.54 mmol) in THF (7 mL) was added acetylacetone (0.24 mL, 2.3 mmol) followed by *n*-BuLi in hexane (2.3 mL, 1.1 M) and 1-allyloxy-2-(1-bromo-ethyl)-benzene (3 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:30 Et_2O/40−60 Pet. Ether) to afford the title compound (299 mg, 50%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.19-7.15 (m, 2H), 6.93 (t, J = 7.6 Hz, 1H), 6.85 (d, J = 8 Hz, 1H), 6.13-6.04 (m, 1H), 5.48-5.39 (m, 1.85H), 5.31-5.27 (m, 1H), 4.57-4.55 (m, 2H), 3.71-3.66 (m, 1H), 3.50 (s, 0.27H), 2.91 (dd, J = 16, 6 Hz, 0.14H), 2.70 (dd, J = 13.6, 5.6 Hz, 1.15H), 2.43-2.38 (m, 1H), 2.15 (s, 0.38H), 2.02 (s, 2.3H), 1.29 (d, J = 6.8 Hz, 2.9H), 1.25 (d, J = 6.8 Hz, 0.5H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm):192.7, 191.6, 155.8, 134.2, 133.4, 127.3, 127.1, 126.9, 120.9, 120.8, 117.2, 116.9, 111.8, 111.7, 100.5, 68.8, 68.7, 58.1, 50.6, 45.5, 45.5, 45.3, 30.5, 29.2, 25.1, 20.0, 19.9, 19.8; FTIR (ATR / cm^{-1}): 2966, 2926, 2872, 1703, 1598, 1490, 1450, 1423, 1358, 1236, 1121 1018, 996, 927, 750; HRMS-ESI calculated for $C_{16}H_{20}O_3Na^+$ $[M+Na]^+$: 283.1305; found: 283.1327.



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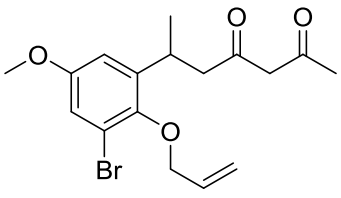
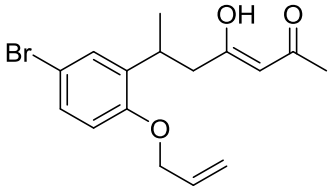


(enol/diketone: 6/1)

6-(2-Allyloxy-3-bromo-5-methoxy-phenyl)-heptane-2,4-dione (10h)

Following **general procedure 3**: to a solution of NaH (84 mg, 2.1 mmol) in THF (7 mL) was added acetylacetone (0.2 mL, 1.9 mmol) followed by *n*-BuLi in hexane (1.2 mL, 1.8 M) and 2-allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methoxy-benzene (2.47 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:20 EtOAc/40−60 Pet. Ether) to afford the title compound (649 mg, 92%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.94 (d, J = 3.2 Hz, 1H), 6.68 (d, J = 2.8 Hz, 1H), 6.21-6.11 (m, 1H), 5.48-5.43 (m, 1.84H), 5.29 (d, J = 10.4 Hz, 1H), 4.48-4.38 (m, 2H), 3.76 (s, 3H), 3.67-3.62 (q, 1H), 3.52 (s, 0.3H), 2.83 (dd, J = 16.8, 6 Hz, 0.15H), 2.68 (dd, J = 17.2, 8 Hz, 0.15H), 2.60 (dd, J = 14.4, 6 Hz, 1H), 2.40-2.34 (m, 1H), 2.18 (s, 0.4H), 2.03 (s, 2.6H), 1.23-1.21 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 202.5, 191.8, 191.6, 156.3, 147.2, 141.7, 133.5, 118.0, 117.9, 117.8, 115.7, 115.6, 112.4, 112.3, 105.1, 100.6, 74.6, 58.0, 55.7, 51.0, 47.7, 45.8, 30.9, 30.3, 28.7, 25.0, 21.2; FTIR (ATR / cm^{-1}): 2966, 2837, 1705, 1599, 1466, 1435, 1344, 1205, 1052, 982, 923, 782; HRMS-ESI calculated for $C_{17}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 391.0515; found: 391.0516.



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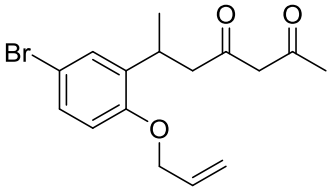


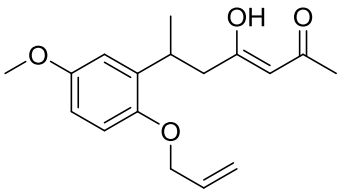
(enol/diketone: 6/1)

6-(2-Allyloxy-5-bromo-phenyl)-heptane-2,4-dione (10i)

Following **general procedure 3**: to a solution of NaH (113 mg, 2.8 mmol) in THF (8 mL) was added acetylacetone (0.26 mL, 2.8 mmol) followed by *n*-BuLi in hexane (1.58 mL, 1.8 M) and 1-allyloxy-4-bromo-2-(1-bromo-ethyl)-benzene (3.34 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:30 Et_2O/40−60 Pet. Ether) to afford the title compound (726 mg, 76%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.26-7.24 (m, 2H), 6.71 (d, J = 9.2 Hz, 1H), 6.09-5.99 (m, 1H), 5.45-5.41 (m, 1.85H), 5.31-5.27 (m, 1H), 4.52 (dt, J = 4.8, 1.6 Hz, 2H), 3.67-3.62 (m, 1H), 3.52 (s, 0.3H), 2.86 (dd, J = 16.8, 5.6 Hz, 0.15H), 2.64 (dd, J = 14.4, 6 Hz, 1.15H), 2.40-2.34 (m, 1H), 2.18 (s, 0.4H), 2.03 (s, 2.6H), 1.26-1.23 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 202.8, 201.9, 192.1, 191.6, 154.8, 154.8, 136.7, 136.3, 132.9, 132.8, 130.1, 129.9,

129.9, 129.8, 117.5, 117.3, 113.6, 113.5, 113.2, 113.1, 100.5, 69.0, 69.0, 58.2, 50.3, 45.1, 30.8, 30.3, 28.8, 25.1, 19.8, 19.7; FTIR (ATR / cm^{-1}): 2967, 2926, 2874, 1705, 1600, 1484, 1453, 1422, 1350, 1238, 1129, 1018, 995, 927, 803; HRMS-ESI calculated for $C_{16}H_{19}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 361.0410; found: 361.0394.



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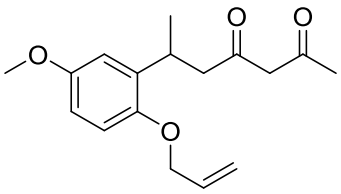
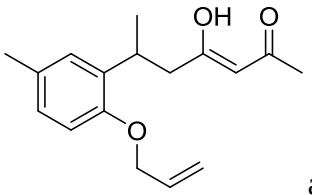


(enol/diketone: 6/1)

6-(2-Allyloxy-5-methoxy-phenyl)-heptane-2,4-dione (10j)

Following **general procedure 3**: to a solution of NaH (85 mg, 2.1 mmol) in THF (6 mL) was added acetylacetone (0.2 mL, 1.9 mmol) followed by *n*-BuLi in hexane (1.2 mL, 1.8 M) and 1-allyloxy-2-(1-bromo-ethyl)-4-methoxy-benzene (2.5 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:20 Et_2O/40−60 Pet. Ether) to afford the title compound (251 mg, 45%) as a yellow oil.

^1H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.79-6.75 (m, 2H), 6.69-6.66 (m, 1H), 6.11-6.02 (m, 1H), 5.46-5.41 (m, 1.8H), 5.28-5.25 (m, 1H), 4.50 (d, J = 5.2 Hz, 2H), 3.76 (s, 3H), 3.67-3.62 (m, 1H), 3.51 (s, 0.3H), 2.88 (dd, J = 16.4, 6 Hz, 0.15H), 2.67 (dd, J = 14.4, 6 Hz, 1.15H), 2.41-2.35 (m, 1H), 2.16 (s, 0.4H), 2.02 (s, 2.6H), 1.26 (d, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 210.6, 203.4, 192.6, 191.6, 153.8, 150.0, 135.8, 135.3, 133.7, 116.8, 113.8, 113.7, 113.1, 113.0, 111.0, 110.8, 100.5, 69.6, 58.1, 55.6, 50.7, 45.3, 30.6, 25.1, 20.1, 19.9; FTIR (ATR / cm^{-1}): 2961, 2835, 1704, 1601, 1495, 1456, 1424, 1356, 1208, 1023, 996, 922, 795; HRMS-ESI calculated for $C_{17}H_{22}O_4Na^+$ $[M+Na]^+$: 313.1410; found: 313.1408.



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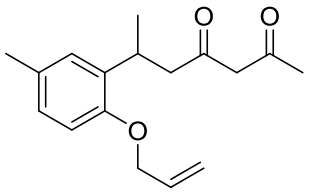


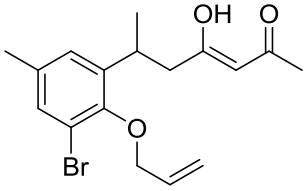
(enol/diketone: 6/1)

6-(2-Allyloxy-5-methyl-phenyl)-heptane-2,4-dione (10k)

Following **general procedure 3**: to a solution of NaH (83 mg, 2.1 mmol) in THF (6 mL) was added acetylacetone (0.19 mL, 1.8 mmol) followed by *n*-BuLi in hexane (1.72 mL, 1.2 M) and

1-allyloxy-4-bromo-2-(1-bromo-ethyl)-benzene (2.42 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:20 Et_2O/40−60 Pet. Ether) to afford the title compound (354 mg, 72%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.97-6.94 (m, 2H), 6.74 (d, J = 8 Hz, 1H), 6.12-6.02 (m, 1H), 5.47-5.42 (m, 1.85H), 5.29-5.26 (m, 1H), 4.53 (dt, J = 4.8, 1.6 Hz, 2H), 3.66-3.61 (m, 1H), 3.50 (s, 0.25H), 2.89 (dd, J = 16, 6 Hz, 0.15H), 2.69 (dd, J = 14.4, 6 Hz, 1.15H), 2.42-2.36 (m, 1H), 2.28 (s, 2.6H), 2.27 (s, 0.4H), 2.15 (s, 0.4H), 2.03 (s, 2.6H), 1.27 (d, J = 6.8 Hz, 2.6H), 1.24 (d, J = 6.8 Hz, 0.4H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 203.6, 202.2, 192.8, 191.6, 153.7, 153.6, 134.0, 133.6, 133.5, 133.5, 130.0, 129.9, 127.9, 127.7, 127.5, 127.4, 117.0, 116.8, 111.9, 111.8, 100.5, 68.9, 58.1, 50.7, 45.4, 30.7, 30.5, 29.2, 25.1, 20.7, 20.6, 20.1, 19.9; FTIR (ATR / cm^{-1}): 2965, 2923, 2870, 1704, 1604, 1498, 1454, 1422, 1357, 1240, 1128, 1023, 995, 922, 803; HRMS-ESI calculated for $C_{17}H_{22}O_3Na^+$ $[M+Na]^+$: 297.1461; found: 297.1467.



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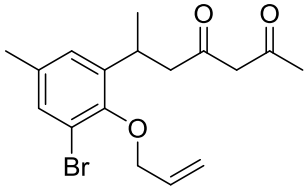
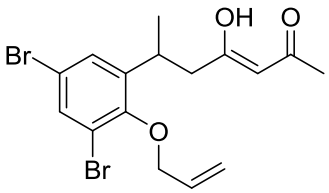


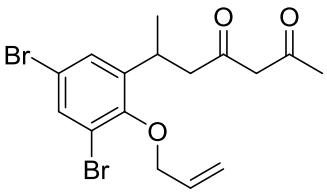
(enol/diketone: 8/1)

6-(2-Allyloxy-3-bromo-5-methyl-phenyl)-heptane-2,4-dione (10l)

Following **general procedure 3**: to a solution of NaH (57 mg, 1.42 mmol) in THF (4 mL) was added acetylacetone (0.13 mL, 1.29 mmol) followed by *n*-BuLi in hexane (1.3 mL, 1.1 M) and 2-allyloxy-1-bromo-3-(1-bromo-ethyl)-5-methyl-benzene (1.68 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:30 Et_2O/40−60 Pet. Ether) to afford the title compound (353 mg, 77%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.23 (d, J = 1.2 Hz, 1H), 6.93 (d, J = 2 Hz, 1H), 6.22-6.12 (m, 1H), 5.47 (s, 0.9H), 5.46 (dq, J = 17.2, 1.6 Hz, 1H), 5.30 (dq, J = 10, 1.6 Hz, 1H), 4.50-4.40 (m, 2H), 3.67-3.62 (m, 1H), 3.52 (s, 0.2H), 2.82 (dd, J = 17.2, 6.4 Hz, 0.15H), 2.69 (dd, J = 16.8, 8 Hz, 0.15H), 2.60 (dd, J = 14.4, 6 Hz, 1H), 2.41-2.35 (m, 1H), 2.28 (s, 3H), 2.17 (s, 0.3H), 2.03 (s, 2.6H), 1.24-1.21 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 202.6, 191.9, 191.6, 151.0, 140.8, 140.5, 135.3, 133.5, 131.8, 126.7, 117.9, 117.3, 100.5, 74.5, 58.1, 46.1, 45.9, 30.1, 28.5, 25.0, 21.3, 20.7; FTIR (ATR / cm^{-1}): 2967, 2924, 2870, 1702, 1601, 1456, 1421, 1357, 1271, 1063, 983, 925, 854, 817, 781; HRMS-ESI calculated for $C_{17}H_{21}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 375.0566; found: 375.0558.



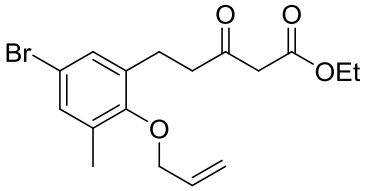
and


(enol/diketone: 8/1)

6-(2-Allyloxy-3,5-dibromo-phenyl)-heptane-2,4-dione (10m)

Following **general procedure 3**: to a solution of NaH (48 mg, 1.2 mmol) in THF (4 mL) was added acetylacetone (0.11 mL, 1.1mmol) followed by *n*-BuLi in hexane (1.1 mL, 1.1 M) and 2-allyloxy-1,5-dibromo-3-(1-bromo-ethyl)-benzene (1.4 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:30 Et_2O/40−60 Pet. Ether) to afford the title compound (293 mg, 64%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.26 (d, J = 2.4 Hz, 1H), 6.96 (d, J = 2.8 Hz, 1H), 5.91-5.81 (m, 1H), 5.20-5.18 (m, 0.5H), 5.16 (s, 0.95H), 5.15-5.14 (m, 0.5H), 5.02 (d, J = 10.4 Hz, 1H), 4.23-4.13 (m, 2H), 3.40-3.34 (m, 1H), 3.25 (s, 0.24H), 2.54 (dd, J = 17.6, 6 Hz, 0.13H), 2.42 (dd, J = 17.6, 8 Hz, 0.13H), 2.29 (dd, J = 14.8, 6.8 Hz, 1H), 2.10 (dd, J = 14.8, 7.6 Hz,1H), 1.91 (s, 0.3H), 1.75 (s, 2.7H), 0.94 (d, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 191.6, 191.3, 152.7, 143.2, 133.7, 133.7, 133.0, 129.2, 129.1, 118.6, 118.4, 117.5, 117.5, 100.6, 74.6, 74.5, 58.1, 50.7, 45.6, 30.9, 30.1, 28.4, 25.0, 21.2, 21.2; FTIR (ATR / cm^{-1}): 2966, 2925, 2869, 1706, 1600, 1439, 1419, 1339, 1216, 1146, 979, 858, 708; HRMS-ESI calculated for $C_{16}H_{18}{}^{79}Br_2O_3Na^+$ $[M+Na]^+$: 438.9515; found: 438.9512.

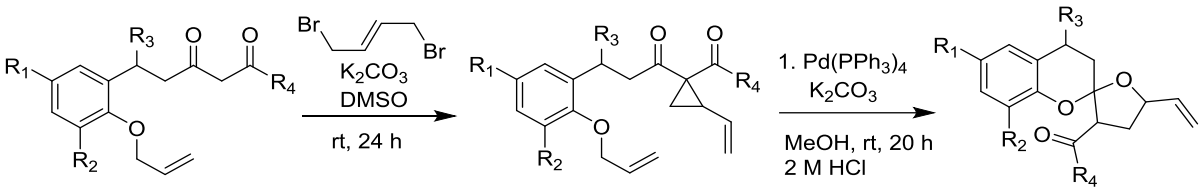


5-(2-Allyloxy-5-bromo-3-methyl-phenyl)-3-oxo-pentanoic acid ethyl ester (10n)

Following **general procedure 3**: to a solution of NaH (75 mg, 1.9 mmol) in THF (5 mL) was added ethyl acetoacetate (0.16 mL, 1.28 mmol) followed by *n*-BuLi in hexane (1.44 mL, 1.3 M) and 2-allyloxy-5-bromo-1-bromomethyl-3-methyl-benzene (1.7 mmol) to give a crude residue. The crude residue was purified by flash chromatography (1:20 EtOAc/40−60 Pet. Ether) to afford the title compound (401 mg, 85%) as a pale yellow oil.

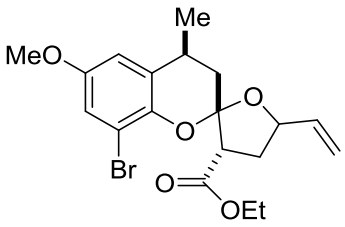
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.14 (dd, J = 19.6, 3.2 Hz, 2H), 6.11-6.01 (m, 1H), 5.40 (d, J = 17.2, 1H), 5.26 (d, J = 10.4, 1H), 4.28 (d, J = 5.6, 2H), 4.19 (q, J = 7.2 Hz, 2H), 3.43 (s, 2H), 2.86 (s, 4H), 2.24 (s, 3H), 1.27 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 201.7, 167.0, 154.8, 135.8, 133.6, 133.5, 132.2, 130.4, 117.6, 116.7, 73.8, 61.4, 49.3, 43.3, 24.1, 16.3, 14.1; FTIR (ATR / cm^{-1}): 2981, 2931, 1740, 1715, 1647, 1467, 1417, 1367, 1315, 1195, 1098, 986, 928, 860, 655; HRMS-ESI calculated for $C_{17}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 391.0515; found: 391.0479.

General Procedure 4: Synthesis of benzannulated 6,5-spiroketals



To a solution of 1,3-diketone derivatives (1.0 eq) in DMSO (0.6 mmol/mL) was added K_2CO_3 (3.2 eq) and *trans*-1,4-dibromo-2-butene (1.2 eq) with stirring at room temperature for 24 hours. After this time the reaction was quenched with water and extracted with Et_2O (x3). The combined organic layer was washed with water (x3) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo*. The crude residue was used for the next step without further purification.

To a solution of crude vinyl cyclopropane (1.0 eq) in degassed EtOH or MeOH (0.1 mmol/mL) was added $Pd(PPh_3)_4$ (0.05 eq) with stirring for 10 minutes followed by the addition of K_2CO_3 (3.0 eq) with stirring for a further 16 hours under the nitrogen atmosphere. The reaction was quenched with 2 M HCl and extracted with DCM (x3). The combined organic layer was washed with water (x1) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo*. The crude residue was purified by flash chromatography or preparative thin layer chromatography.

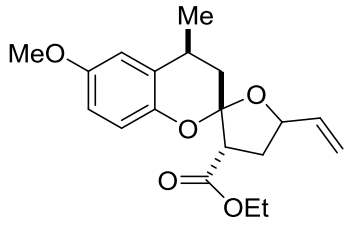


8-Bromo-6-methoxy-4-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-carboxylic acid ethyl ester (8a)

Following **general procedure 4**: 5-(2-allyloxy-3-bromo-5-methoxy-phenyl)-3-oxo-hexanoic acid ethyl ester **10a** (367 mg, 0.92 mmol), K_2CO_3 (407 mg, 2.94 mmol) and *trans*-1,4-dibromo-2-butene (241 mg, 1.1 mmol) were combined in DMSO (2 mL) to provide the crude vinyl cyclopropane compound which was not stable during flash chromatography purification. Five major diagnostic peaks for this vinyl cyclopropane are shown in the crude ^{1}H NMR data. ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 2.66-2.57 (m, 1H), 1.84-1.80 (m, 0.5H), 1.73-1.67 (m, 0.5H), 1.53-1.47 (m, 0.5H), 1.37-1.33 (m, 0.5H). This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (55 mg, 0.046 mmol) and K_2CO_3 (388 mg, 2.8 mmol) were combined in EtOH (9 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:40−1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (298 mg, 79%, dr: 1:1).

8a$_i$ (yellow solid, 150 mg, 40%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.92 (d, J = 2.8 Hz, 1H), 6.76 (d, J = 2.8 Hz, 1H), 5.88-5.79 (m, 1H), 5.26 (d, J = 17.2 Hz, 1H), 5.12 (d, J = 10.4 Hz, 1H), 4.79-4.74 (m, 1H), 4.24-4.15 (m, 2H), 3.73 (s, 3H), 3.26-3.19 (m, 1H), 3.11-2.99 (m, 2H), 2.21 (t, J = 13.2 Hz, 1H), 2.08 (dd, J = 13.2, 5.6 Hz, 1H), 2.00-1.94 (m, 1H), 1.35 (d, J = 6.8 Hz, 3H), 1.23 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 169.1, 153.6, 142.8, 137.7, 129.3, 116.1, 116.1, 112.0, 111.2, 106.2, 78.6, 61.0, 55.9, 52.7, 38.1, 32.2, 26.8, 19.3, 14.2; FTIR (ATR / cm^{-1}): 2960, 2932, 1734, 1608, 1568, 1464, 1435, 1369, 1301, 1204, 1106, 1043, 974, 908, 855, 796; HRMS-ESI calculated for $C_{19}H_{23}{}^{79}BrO_5Na^+$ $[M+Na]^+$: 433.0621; found: 433.0631; m.p. = 74.9 ºC-76.3 ºC.

8a$_{ii}$ (yellow solid, 148 mg, 39%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.93 (d, J = 3.2 Hz, 1H), 6.75 (d, J = 2.8 Hz, 1H), 5.93-5.85 (m, 1H), 5.10 (d, J = 17.2 Hz, 1H), 5.03 (d, J = 10 Hz, 1H), 4.58-4.52 (m, 1H), 4.22-4.17 (m, 2H), 3.74 (s, 3H), 3.25-3.15 (m, 1H), 3.07-3.02 (m, 1H), 2.78-2.69 (m, 1H), 2.48-2.41 (m, 1H), 2.22 (t, J = 13.2 Hz, 1H), 2.01 (dd, J = 13.6, 6 Hz, 1H), 1.34 (d, J = 6.8 Hz, 3H), 1.24 (t, J = 7 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.7, 153.5, 142.7, 139.4, 129.3, 116.2, 116.0, 112.0, 111.1, 105.7, 80.6, 61.0, 55.8, 53.8, 37.7, 32.6, 26.8, 19.4, 14.2; FTIR (ATR / cm^{-1}): 2960, 2931, 1730, 1608, 1568, 1463, 1369, 1303, 1202, 1039, 962, 907, 863, 796; HRMS-ESI calculated for $C_{19}H_{23}{}^{79}BrO_5Na^+$ $[M+Na]^+$: 433.0621; found: 433.0633; m.p. = 75.6 ºC-76.9 ºC.

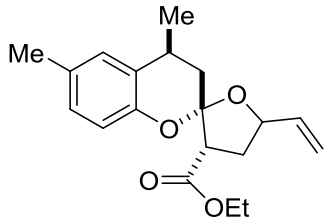


6-Methoxy-4-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'carboxylic acid ethyl ester (8b)

Following **general procedure 4**: 5-(2-allyloxy-5-methoxy-phenyl)-3-oxo-hexanoic acid ethyl ester **10b** (100 mg, 0.32 mmol), K_2CO_3 (146 mg, 1.1 mmol) and *trans*-1,4-dibromo-2-butene (84 mg, 0.4 mmol) were combined in DMSO (1 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (19 mg, 0.016 mmol) and K_2CO_3 (133 mg, 0.96 mmol) were combined in EtOH (5 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:40−1:10 Et_2O/40−60 Pet. Ether) and preparative layer chromatography plate (1:3 DCM/40−60 Pet. Ether) to afford the title compound (80 mg, 76%).

8b$_i$ (pale yellow oil, 40 mg, 38%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.79 (d, J = 2.4 Hz, 1H), 6.71-6.66 (m, 2H), 5.87-5.79 (m, 1H), 5.24 (d, J = 17.2 Hz, 1H), 5.11 (d, J = 9.6 Hz, 1H), 4.77-4.71 (m, 1H), 4.20-4.13 (m, 2H), 3.75 (s, 3H), 3.25-3.19 (m, 1H), 3.06 (t, J = 9.2 Hz, 1H), 2.98-2.91 (m, 1H), 2.17 (t, J = 13 Hz, 1H), 2.06 (dd, J = 13.2, 6 Hz, 1H), 1.98-1.91 (m, 1H), 1.36 (d, J = 7.2 Hz, 3H), 1.20 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 169.4, 153.8, 145.9, 138.0, 127.9, 117.4, 115.9, 112.6, 111.9, 105.6, 78.3, 60.9, 55.7, 52.7, 38.5, 32.2, 26.4, 19.3, 14.2; FTIR (ATR / cm^{-1}): 2959, 2933, 1736, 1492, 1424, 1369, 1262, 1203, 1040, 979, 902, 808; HRMS-ESI calculated for $C_{19}H_{24}O_5Na^+$ $[M+Na]^+$: 355.1516; found: 355.1525.

8b$_{ii}$ (pale yellow oil, 40 mg, 38%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.78 (d, J = 2.4 Hz, 1H), 6.69-6.66 (m, 2H), 5.88-5.79 (m, 1H), 5.09 (d, J = 17.2 Hz, 1H), 5.00 (d, J = 10 Hz, 1H), 4.56-4.50 (m, 1H), 4.19-4.14 (m, 2H), 3.75 (s, 3H), 3.22-3.16 (m, 1H), 3.05-3.00 (m, 1H), 2.66-2.57 (m, 1H), 2.43-2.36 (m, 1H), 2.18 (t, J = 13 Hz, 1H), 2.00 (dd, J = 13.2, 5.6 Hz, 1H), 1.35 (d, J = 7.2 Hz, 3H), 1.21 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.9, 153.7, 145.9, 139.5, 127.9, 117.3, 115.8, 112.6, 111.9, 105.1, 80.1, 60.9, 55.7, 53.8, 38.3, 32.7, 26.4, 19.4, 14.2; FTIR (ATR / cm^{-1}): 2959, 2931, 1736, 1492, 1423, 1370, 1261, 1201, 1038, 963, 901, 812; HRMS-ESI calculated for $C_{19}H_{24}O_5Na^+$ $[M+Na]^+$: 355.1516; found: 355.1527.



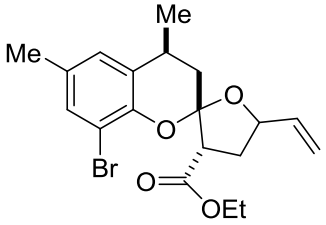
4,6-Dimethyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-carboxylic acid ethyl ester (8c)

Following **general procedure 4**: 5-(2-allyloxy-5-methyl-phenyl)-3-oxo-hexanoic acid ethyl ester **10c** (180 mg, 0.59 mmol), K_2CO_3 (265 mg, 1.92 mmol) and *trans*-1,4-dibromo-2-butene (155 mg, 0.71 mmol) were combined in DMSO (1.5 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (35 mg, 0.03 mmol) and K_2CO_3 (249 mg, 1.8 mmol) were combined in EtOH (6 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:60−1:20 Et_2O/40−60 Pet. Ether) and preparative layer chromatography plate (1:5 DCM/40−60 Pet. Ether) to afford the title compound (92 mg, 50%).

8c$_i$ (pale yellow oil, 48 mg, 26%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.04 (s, 1H), 6.89 (d, J = 8.4 Hz, 1H), 6.65 (d, J = 8 Hz, 1H), 5.89-5.80 (m, 1H), 5.09 (d, J = 17.2 Hz, 1H), 5.00 (d, J = 10.8 Hz, 1H), 4.56-4.51 (m, 1H), 4.19-4.14 (m, 2H), 3.22-3.15 (m, 1H), 3.06-3.01 (m, 1H), 2.67-2.59 (m, 1H), 2.44-2.37 (m, 1H), 2.27 (s, 3H), 2.19 (t, J = 13.2 Hz, 1H), 2.00 (dd, J = 13.2, 5.6 Hz, 1H), 1.36 (d, J = 6.8 Hz, 3H), 1.21 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.9, 149.6, 139.5, 129.8, 127.7, 126.8, 126.8, 116.6, 115.8, 105.1, 80.1, 60.8, 53.9, 38.4, 32.7, 26.0, 20.7, 19.3, 14.2; FTIR (ATR / cm^{-1}): 2959, 2929, 1737, 1494, 1458, 1369, 1209, 1172, 1089, 963, 925, 898, 815; HRMS-ESI calculated for $C_{19}H_{24}O_4Na^+$ $[M+Na]^+$: 339.1567; found: 339.1561.

8c$_{ii}$ (pale yellow oil, 44 mg, 24%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.04 (s, 1H), 6.89 (d, J = 8.8 Hz, 1H), 6.66 (d, J = 8 Hz, 1H), 5.87-5.79 (m, 1H), 5.23 (d, J = 17.2 Hz, 1H), 5.10 (d, J = 10.4 Hz, 1H), 4.77-4.72 (m, 1H), 4.19-4.13 (m, 2H), 3.24-3.18 (m, 1H), 3.06 (t, J = 9.2 Hz, 1H), 2.99-2.91 (m, 1H), 2.27 (s, 3H), 2.17 (t, J = 13.2 Hz, 1H), 2.06 (dd, J = 13.2, 6 Hz, 1H), 1.98-1.91 (m, 1H), 1.36 (d, J = 6.8 Hz, 3H), 1.20 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 169.4, 149.6, 138.0, 130.0, 127.8, 126.8, 126.8, 116.7, 115.9, 105.6, 78.3, 60.8, 52.7, 38.6, 32.2, 26.0, 20.7, 19.3, 14.2; FTIR (ATR / cm^{-1}): 2960, 2928, 1738, 1494, 1459,

1368, 1215, 1169, 1100, 978, 925, 899, 813; HRMS-ESI calculated for $C_{19}H_{24}O_4Na^+$ $[M+Na]^+$: 339.1567; found: 339.1538.



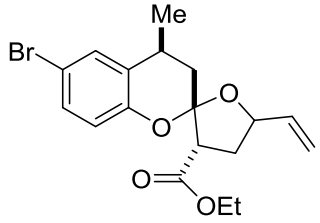
8-Bromo-4,6-dimethyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-carboxylic acid ethyl ester (8d)

Following **general procedure 4**: 5-(2-allyloxy-3-bromo-5-methyl-phenyl)-3-oxo-hexanoic acid ethyl ester **10d** (295 mg, 0.77 mmol), K_2CO_3 (340 mg, 2.46 mmol) and *trans*-1,4-dibromo-2-butene (202 mg, 0.92 mmol) were combined in DMSO (1.5 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (45 mg, 0.039 mmol) and K_2CO_3 (321 mg, 2.3 mmol) were combined in EtOH (7 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:60−1:20 Et_2O/40−60 Pet. Ether) and preparative layer chromatography plate (1:5 DCM/40−60 Pet. Ether) to afford the title compound (189 mg, 60%).

8d$_i$ (yellow solid, 109 mg, 35%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.16 (s, 1H), 6.97 (s, 1H), 5.94-5.85 (m, 1H), 5.10 (d, J = 17.6 Hz, 1H), 5.03 (d, J = 10.8 Hz, 1H), 4.59-4.53 (m, 1H), 4.22-4.16 (m, 2H), 3.23-3.16 (m, 1H), 3.07-3.02 (m, 1H), 2.79-2.70 (m, 1H), 2.48-2.41 (m, 1H), 2.26-2.19 (m, 4H), 2.01 (dd, J = 13.2, 5.6 Hz, 1H), 1.35 (d, J = 6.8 Hz, 3H), 1.24 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.7, 146.1, 139.4, 131.2, 130.8, 128.4, 126.2, 116.2, 111.0, 105.7, 80.6, 61.0, 53.9, 37.8, 32.6, 26.4, 20.4, 19.4, 14.2; FTIR (ATR / cm^{-1}): 2960, 2926, 1729, 1457, 1367, 1231, 1208, 1169, 1037, 991, 907, 854, 757; HRMS-ESI calculated for $C_{19}H_{23}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 417.0672; found: 417.0682; m.p. = 63.3 ºC-64.7 ºC.

8d$_{ii}$ (yellow oil, 80 mg, 25%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.16 (s, 1H), 6.98 (s, 1H), 5.88-5.79 (m, 1H), 5.26 (d, J = 17.2 Hz, 1H), 5.12 (d, J = 10.4 Hz, 1H), 4.79-4.74 (m, 1H), 4.24-4.15 (m, 2H), 3.25-3.19 (m, 1H), 3.11-2.99 (m, 2H), 2.24 (s, 3H), 2.20 (d, J = 12.8 Hz, 1H), 2.08 (dd, J = 13.2, 5.6 Hz, 1H), 2.01-1.94 (m, 1H), 1.36 (d, J = 6.8 Hz, 3H), 1.23 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 169.1, 146.2, 137.7, 131.3, 130.9, 128.4, 126.2, 116.1, 111.0, 106.3, 78.6, 61.0, 52.7, 38.2, 32.2, 26.4, 20.4, 19.3, 14.2; FTIR (ATR /

cm^{-1}): 2961, 2930, 1739, 1458, 1367, 1264, 1231, 1166, 1107, 975, 908, 854, 752; HRMS-ESI calculated for $C_{19}H_{23}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 417.0672; found: 417.0692.



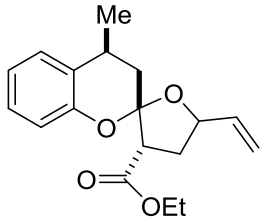
6-Bromo-4-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-carboxylic acid ethyl ester (8e)

Following **general procedure 4**: 5-(2-allyloxy-5-bromo-phenyl)-3-oxo-hexanoic acid ethyl ester **10e** (243.7 mg, 0.66 mmol), K_2CO_3 (292 mg, 2.1 mmol) and *trans*-1,4-dibromo-2-butene (173 mg, 0.79 mmol) were combined in DMSO (1.5 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (38 mg, 0.033 mmol) and K_2CO_3 (278 mg, 2 mmol) were combined in EtOH (7 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:70−1:10 Et_2O/40−60 Pet. Ether) and preparative layer chromatography plate (1:30 Et_2O/40−60 Pet. Ether) to afford the title compound (170 mg, 68%).

8e$_i$ (yellow solid, 100 mg, 40%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.33 (s, 1H), 7.17 (dd, J = 8.8, 2.4 Hz, 1H), 6.62 (d, J = 8.8 Hz, 1H), 5.85-5.76 (m, 1H), 5.10 (d, J = 16.8 Hz, 1H), 5.01 (d, J = 10 Hz, 1H), 4.57-4.51 (m, 1H), 4.19-4.14 (m, 2H), 3.23-3.17 (m, 1H), 3.07-3.02 (m, 1H), 2.64-2.56 (m, 1H), 2.45-2.38 (m, 1H), 2.17 (t, J = 13.2 Hz, 1H), 2.00 (dd, J = 13.2, 5.6 Hz, 1H), 1.35 (d, J = 6.8 Hz, 3H), 1.20 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.6, 151.0, 139.1, 130.1, 129.5, 129.3, 118.6, 116.0, 113.1, 105.3, 80.2, 60.9, 53.7, 37.8, 32.6, 26.1, 19.1, 14.2; FTIR (ATR / cm^{-1}): 2961, 2929, 1736, 1476, 1401, 1370, 1261, 1187, 1085, 962, 917, 892, 814; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 403.0515; found: 403.0518; m.p. = 89.2 ºC-90.6 ºC.

8e$_{ii}$ (yellow oil, 70 mg, 28%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.34 (s, 1H), 7.18 (dd, J = 8.8, 2.4 Hz, 1H), 6.64 (d, J = 8.8 Hz, 1H), 5.86-5.78 (m, 1H), 5.25 (d, J = 17.2 Hz, 1H), 5.12 (d, J = 10.4 Hz, 1H), 4.76-4.71 (m, 1H), 4.21-4.12 (m, 2H), 3.25-3.19 (m, 1H), 3.08 (t, J = 9.2 Hz, 1H), 2.98-2.91 (m, 1H), 2.16 (t, J = 13.2 Hz, 1H), 2.07 (dd, J = 13.6, 6 Hz, 1H), 2.00-1.93 (m, 1H), 1.36 (d, J = 7.2 Hz, 3H), 1.19 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ

(ppm): 169.1, 151.0, 137.7, 130.1, 129.5, 129.3, 118.7, 116.1, 113.2, 105.8, 78.5, 60.9, 52.5, 38.1, 32.1, 26.1, 19.1, 14.2; FTIR (ATR / cm^{-1}): 2963, 2932, 1738, 1477, 1402, 1369, 1183, 1083, 967, 916, 891, 813; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 403.0515; found: 403.0523.



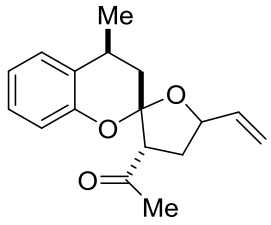
4-Methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-carboxylic acid ethyl ester (8f)

Following **general procedure 4**: 5-(2-allyloxy-phenyl)-3-oxo-hexanoic acid ethyl ester **10f** (140 mg, 0.48 mmol), K_2CO_3 (213 mg, 1.54 mmol) and *trans*-1,4-dibromo-2-butene (126 mg, 0.58 mmol) were combined in DMSO (1 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (28 mg, 0.024 mmol) and K_2CO_3 (200 mg, 1.44 mmol) were combined in EtOH (6 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:40−1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (99 mg, 68%).

8f$_i$ (yellow oil, 54 mg, 37%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.24 (d, J = 7.6 Hz, 1H), 7.09 (t, J = 7.8 Hz, 1H), 6.91 (t, J = 7.4 Hz, 1H), 6.76 (d, J = 8 Hz, 1H), 5.88-5.80 (m, 1H), 5.25 (d, J = 17.2 Hz, 1H), 5.12 (d, J = 10 Hz, 1H), 4.79-4.74 (m, 1H), 4.20-4.14 (m, 2H), 3.28-3.22 (m, 1H), 3.08 (t, J = 9.2 Hz, 1H), 3.01-2.93 (m, 1H), 2.20 (t, J = 13 Hz, 1H), 2.08 (dd, J = 13.2, 5.6 Hz, 1H), 2.00-1.93 (m, 1H), 1.38 (d, J = 6.8 Hz, 3H), 1.20 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 169.3, 151.8, 137.9, 127.2, 127.2, 126.4, 120.9, 116.9, 115.9, 105.7, 78.4, 60.9, 52.7, 38.6, 32.2, 26.0, 19.2, 14.2; FTIR (ATR / cm^{-1}): 2961, 2931, 1737, 1610, 1580, 1487, 1448, 1369, 1217, 1138, 1019, 978, 890, 753; HRMS-ESI calculated for $C_{18}H_{22}O_4Na^+$ $[M+Na]^+$: 325.1410; found: 325.1439.

8f$_{ii}$ (yellow oil, 45 mg, 31%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.24 (d, J = 8 Hz, 1H), 7.09 (t, J = 7.6 Hz, 1H), 6.90 (t, J = 7.4 Hz, 1H), 6.75 (d, J = 8 Hz, 1H), 5.89-5.80 (m, 1H), 5.10 (d, J = 17.2 Hz, 1H), 5.01 (d, J = 10.4 Hz, 1H), 4.58-4.52 (m, 1H), 4.20-4.14 (m, 2H), 3.25-3.19 (m, 1H), 3.07-3.02 (m, 1H), 2.68-2.60 (m, 1H), 2.45-2.38 (m, 1H), 2.21 (t, J = 13.2

Hz, 1H), 2.02 (dd, *J* = 13.2, 5.6 Hz, 1H), 1.37 (d, *J* = 7.2 Hz, 3H), 1.21 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.8, 151.8, 139.5, 139.4, 127.2, 127.1, 126.3, 120.7, 116.9, 115.9, 105.2, 80.2, 60.9, 53.9, 38.3, 32.7, 26.0, 19.2, 14.2; FTIR (ATR / cm^{-1}): 2961, 2931, 1736, 1609, 1580, 1486, 1449, 1369, 1211, 1140, 962, 890, 753; HRMS-ESI calculated for $C_{18}H_{22}O_4Na^+$ $[M+Na]^+$: 325.1410; found: 325.1434.



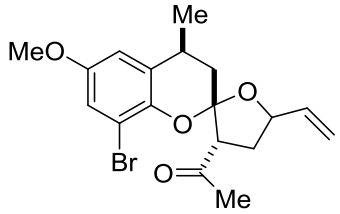
1-(4-Methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-yl)ethan-1-one (8g)

Following **general procedure 4**: 6-(2-allyloxy-phenyl)-heptane-2,4-dione **10g** (275 mg, 1.05 mmol), K_2CO_3 (469 mg, 3.39 mmol) and *trans*-1,4-dibromo-2-butene (284 mg, 1.3 mmol) were combined in DMSO (2 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (60 mg, 0.053 mmol) and K_2CO_3 (435 mg, 3.15 mmol) were combined in MeOH (10 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:40−1:20 Et_2O/40−60 Pet. Ether) to afford the title compound (129 mg, 45%).

8g$_i$ (yellow oil, 69 mg, 24%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.25 (d, *J* = 7.6 Hz, 1H), 7.10 (t, *J* = 7.8 Hz, 1H), 6.93 (t, *J* = 7.4 Hz, 1H), 6.75 (d, *J* = 8.4 Hz, 1H), 5.87-5.79 (m, 1H), 5.25 (d, *J* = 17.2 Hz, 1H), 5.12 (d, *J* = 10 Hz, 1H), 4.76-4.71 (m, 1H), 3.31-3.25 (m, 1H), 3.13 (t, *J* = 8.4 Hz, 1H), 2.96-2.89 (m, 1H), 2.26 (s, 3H), 2.18 (dd, *J* = 13.2, 5.6 Hz, 1H), 2.06 (t, *J* = 12.8 Hz, 1H), 1.93-1.86 (m, 1H), 1.39 (d, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 203.7, 151.5, 137.6, 127.3, 127.0, 126.5, 121.1, 116.9, 116.2, 105.6, 78.7, 60.1, 39.4, 32.5, 29.9, 26.0, 19.1; FTIR (ATR / cm^{-1}): 2959, 2928, 2874, 1713, 1580, 1486, 1447, 1356, 1274, 1214, 1136, 1033, 962, 922, 888, 754; HRMS-ESI calculated for $C_{17}H_{20}O_3Na^+$ $[M+Na]^+$: 295.1305; found: 295.1317.

8g$_{ii}$ (yellow oil, 60 mg, 21%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.24 (d, *J* = 7.6 Hz, 1H), 7.09 (t, *J* = 7.6 Hz, 1H), 6.92 (t, *J* = 7.4 Hz, 1H), 6.73 (d, *J* = 8 Hz, 1H), 5.90-5.81 (m, 1H), 5.12 (d, *J* = 16.8 Hz, 1H), 5.02 (d, *J* = 10 Hz, 1H), 4.58-4.52 (m, 1H), 3.27-3.21 (m, 1H), 3.03-2.98 (m, 1H), 2.65-2.56 (m, 1H), 2.45-2.39 (m, 1H), 2.28 (s, 3H), 2.10-1.99 (m, 2H), 1.37 (d,

J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 204.3, 151.5, 139.2, 127.3, 127.1, 126.5, 121.0, 116.8, 116.0, 105.3, 80.2, 61.2, 38.5, 33.4, 29.9, 26.0, 19.2; FTIR (ATR / cm^{-1}): 2960, 2928, 1708, 1580, 1487, 1449, 1357, 1274, 1214, 1026, 959, 923, 886, 753; HRMS-ESI calculated for $C_{17}H_{20}O_3Na^+$ $[M+Na]^+$: 295.1305; found: 295.1301.



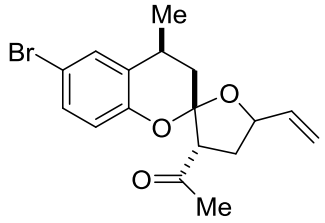
1-(8-Bromo-6-methoxy-4-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-yl)ethan-1-one (8h)

Following **general procedure 4**: 6-(2-allyloxy-3-bromo-5-methoxy-phenyl)-heptane-2,4-dione **10h** (332 mg, 0.9 mmol), K_2CO_3 (398 mg, 2.88 mmol) and *trans*-1,4-dibromo-2-butene (236 mg, 1.08 mmol) were combined in DMSO (1.5 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (52 mg, 0.045 mmol) and K_2CO_3 (373 mg, 2.7 mmol) were combined in MeOH (8 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:20−1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (200 mg, 58%).

8h$_i$ (brown oil, 103 mg, 30%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.93 (d, J = 2.8 Hz, 1H), 6.76 (d, J = 2.4 Hz, 1H), 5.87-5.78 (m, 1H), 5.26 (d, J = 16.8 Hz, 1H), 5.13 (d, J = 10.4 Hz, 1H), 4.83-4.75 (m, 1H), 3.73 (s, 3H), 3.29-3.20 (m, 1H), 3.06-2.95 (m, 2H), 2.37 (s, 3H), 2.13 (dd, J = 13.2, 6 Hz, 1H), 2.06-1.94 (m, 2H), 1.35 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 204.8, 153.8, 142.4, 137.4, 129.2, 116.2, 116.1, 112.1, 111.3, 106.5, 78.9, 59.7, 55.9, 38.4, 32.8, 30.0, 26.8, 19.4; FTIR (ATR / cm^{-1}): 2960, 2933, 1705, 1608, 1569, 1465, 1435, 1357, 1302, 1205, 1107, 1043, 961, 906, 882, 797; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 403.0515; found: 403.0520.

8h$_{ii}$ (brown oil, 97 mg, 28%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.93 (d, J = 2.8 Hz, 1H), 6.75 (d, J = 2.8 Hz, 1H), 5.94-5.85 (m, 1H), 5.11 (d, J = 17.6 Hz, 1H), 5.05 (d, J = 10 Hz, 1H), 4.60-4.54 (m, 1H), 3.74 (s, 3H), 3.25-3.16 (m, 1H), 2.94-2.89 (m, 1H), 2.75-2.67 (m, 1H), 2.54-2.47 (m, 1H), 2.42 (s, 3H), 2.05-1.94 (m, 2H), 1.33 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz,

$CDCl_3$), δ (ppm): 205.7, 153.7, 142.3, 139.1, 129.3, 116.4, 116.1, 112.2, 111.2, 106.1, 80.8, 60.9, 55.8, 37.4, 33.8, 30.0, 26.8, 19.5; FTIR (ATR / cm^{-1}): 2960, 2933, 1703, 1608, 1464, 1435, 1358, 1303, 1202, 1104, 1034, 987, 958, 881, 795; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 403.0515; found: 403.0507.



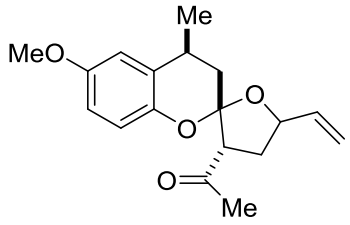
1-(6-Bromo-4-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-yl)ethan-1-one (8i)

Following **general procedure 4**: 6-(2-allyloxy-5-bromo-phenyl)-heptane-2,4-dione **10i** (305 mg, 0.9 mmol), K_2CO_3 (398 mg, 2.88 mmol) and *trans*-1,4-dibromo-2-butene (236 mg, 1.08 mmol) were combined in DMSO (2 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (52 mg, 0.045 mmol) and K_2CO_3 (373 mg, 2.7 mmol) were combined in MeOH (8 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:30−1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (186 mg, 59%).

8i$_i$ (yellow oil, 97 mg, 31%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.33 (s, 1H), 7.18 (dd, J = 8.8, 2.4 Hz, 1H), 6.61 (d, J = 8.8 Hz, 1H), 5.85-5.77 (m, 1H), 5.11 (d, J = 16.8 Hz, 1H), 5.03 (d, J = 10.4 Hz, 1H), 4.57-4.51 (m, 1H), 3.27-3.17 (m, 1H), 3.03-2.98 (m, 1H), 2.62-2.53 (m, 1H), 2.46-2.39 (m, 1H), 2.27 (s, 3H), 2.08-1.97 (m, 2H), 1.35 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 204.0, 150.7, 138.9, 130.2, 129.5, 129.4, 118.6, 116.2, 113.4, 105.4, 80.2, 60.9, 38.1, 33.3, 29.9, 26.1, 19.1; FTIR (ATR / cm^{-1}): 2963, 2931, 1711, 1478, 1403, 1357, 1263, 1221, 1122, 1030, 960, 890, 816; HRMS-ESI calculated for $C_{17}H_{19}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 373.0410; found: 373.0413.

8i$_{ii}$ (yellow oil, 89 mg, 28%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.34 (s, 1H), 7.19 (dd, J = 8.4, 2.4 Hz, 1H), 6.63 (d, J = 10.4 Hz, 1H), 5.86-5.77 (m, 1H), 5.25 (d, J = 16.8 Hz, 1H), 5.13 (d, J = 10.4 Hz, 1H), 4.73-4.68 (m, 1H), 3.30-3.21 (m, 1H), 3.14-3.10 (m, 1H), 2.94-2.87 (m, 1H), 2.24 (s, 3H), 2.16 (dd, J = 13.2, 5.6 Hz, 1H), 2.03 (t, J = 12.8 Hz, 1H), 1.93-1.86 (m, 1H), 1.37 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 203.3, 150.7, 137.4,

130.2, 129.5, 129.3, 118.7, 116.3, 113.5, 105.7, 78.8, 59.9, 39.0, 32.4, 29.9, 26.1, 19.1; FTIR (ATR / cm^{-1}): 2962, 2930, 1715, 1477, 1402, 1357, 1262, 1216, 1120, 1036, 962, 924, 890, 816; HRMS-ESI calculated for $C_{17}H_{19}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 373.0410; found: 373.0402.



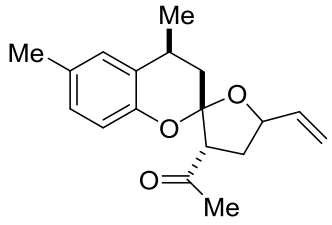
1-(6-Methoxy-4-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-yl)ethan-1-one (8j)

Following **general procedure 4**: 6-(2-allyloxy-5-methoxy-phenyl)-heptane-2,4-dione **10j** (213 mg, 0.73 mmol), K_2CO_3 (192 mg, 2.37 mmol) and *trans*-1,4-dibromo-2-butene (192 mg, 0.88 mmol) were combined in DMSO (1.5 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (42 mg, 0.036 mmol) and K_2CO_3 (303 mg, 2.19 mmol) were combined in MeOH (7 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:30−1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (127 mg, 58%).

8j$_i$ (yellow oil, 66 mg, 30%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.80 (s, 1H), 6.68 (s, 2H), 5.87-5.78 (m, 1H), 5.24 (d, J = 17.2 Hz, 1H), 5.11 (d, J = 10.4 Hz, 1H), 4.73-4.68 (m, 1H), 3.75 (s, 3H), 3.31-3.20 (m, 1H), 3.14-3.09 (m, 1H), 2.94-2.88 (m, 1H), 2.25 (s, 3H), 2.16 (dd, J = 12.8, 5.6 Hz, 1H), 2.04 (t, J = 12.8 Hz, 1H), 1.91-1.84 (m, 1H), 1.37 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 203.7, 154.0, 145.6, 137.7, 127.7, 117.4, 116.1, 112.7, 112.0, 105.5, 78.6, 60.1, 55.7, 39.4, 32.5, 29.9, 26.3, 19.2; FTIR (ATR / cm^{-1}): 2959, 2932, 1714, 1493, 1424, 1357, 1269, 1206, 1139, 1037, 965, 900, 811; HRMS-ESI calculated for $C_{18}H_{22}O_4Na^+$ $[M+Na]^+$: 325.1410; found: 325.1429.

8j$_{ii}$ (yellow oil, 61 mg, 28%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 6.78 (s, 1H), 6.66 (s, 2H), 5.89-5.80 (m, 1H), 5.11 (d, J = 17.2 Hz, 1H), 5.02 (d, J = 10.4 Hz, 1H), 4.56-4.50 (m, 1H), 3.75 (s, 3H), 3.26-3.16 (m, 1H), 3.02-2.97 (m, 1H), 2.63-2.54 (m, 1H), 2.44-2.37 (m, 1H), 2.28 (s, 3H), 2.08-1.97 (m, 2H), 1.35 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 204.4, 153.9, 145.6, 139.3, 127.8, 117.3, 115.9, 112.7, 112.0, 105.2, 80.1, 61.2, 55.7, 38.5, 33.4,

29.9, 26.3, 19.3; FTIR (ATR / cm^{-1}): 2958, 2932, 1710, 1492, 1423, 1357, 1269, 1201, 1138, 1034, 961, 898, 807; HRMS-ESI calculated for $C_{18}H_{22}O_4Na^+$ $[M+Na]^+$: 325.1410; found: 325.1422.



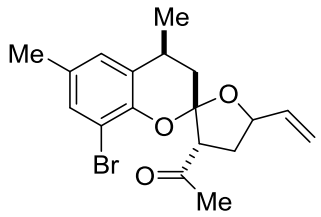
1-(4,6-Dimethyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-yl)ethan-1-one (8k)

Following **general procedure 4**: 6-(2-allyloxy-5-methyl-phenyl)-heptane-2,4-dione **10k** (342 mg, 1.25 mmol), K_2CO_3 (553 mg, 4 mmol) and *trans*-1,4-dibromo-2-butene (328 mg, 1.5 mmol) were combined in DMSO (2 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (72 mg, 0.062 mmol) and K_2CO_3 (517 mg, 3.74 mmol) were combined in MeOH (10 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:40−1:20 Et_2O/40−60 Pet. Ether) to afford the title compound (178 mg, 51%).

8k$_i$ (yellow oil, 112 mg, 32%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.05 (s, 1H), 6.91 (d, J = 8 Hz, 1H), 6.65 (d, J = 8 Hz, 1H), 5.86-5.78 (m, 1H), 5.24 (d, J = 17.2 Hz, 1H), 5.11 (d, J = 10.4 Hz, 1H), 4.74-4.69 (m, 1H), 3.28-3.21 (m, 1H), 3.14-3.09 (m, 1H), 2.95-2.88 (m, 1H), 2.27 (s, 3H), 2.24 (s, 3H), 2.16 (dd, J = 12.8, 5.6 Hz, 1H), 2.04 (t, J = 13.2 Hz, 1H), 1.91-1.84 (m, 1H), 1.37 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 203.7, 149.3, 137.7, 130.3, 127.9, 126.9, 126.6, 116.7, 116.1, 105.5, 78.6, 60.1, 39.5, 32.4, 29.9, 26.0, 20.7, 19.2; FTIR (ATR / cm^{-1}): 2959, 2926, 1713, 1493, 1456, 1356, 1213, 1168, 1034, 982, 962, 896, 815; HRMS-ESI calculated for $C_{18}H_{22}O_3Na^+$ $[M+Na]^+$: 309.1461; found: 309.1438.

8k$_{ii}$ (yellow oil, 66 mg, 19%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.04 (s, 1H), 6.90 (d, J = 8.4 Hz, 1H), 6.63 (d, J = 8.4 Hz, 1H), 5.89-5.81 (m, 1H), 5.11 (d, J = 17.2 Hz, 1H), 5.02 (d, J = 10 Hz, 1H), 4.56-4.51 (m, 1H), 3.24-3.17 (m, 1H), 3.02-2.97 (m, 1H), 2.64-2.55 (m, 1H), 2.44-2.37 (m, 1H), 2.28 (s, 3H), 2.27 (s, 3H), 2.08-1.97 (m, 2H), 1.36 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 204.4, 149.3, 139.3, 130.1, 127.8, 126.9, 126.7, 116.5, 115.9, 105.2, 80.1, 61.2, 38.6, 33.4, 29.8, 26.0, 20.7, 19.2; FTIR (ATR / cm^{-1}): 2958, 2925,

1709, 1493, 1455, 1423, 1356, 1209, 1172, 1029, 987, 961, 895, 814; HRMS-ESI calculated for $C_{18}H_{22}O_3Na^+$ $[M+Na]^+$: 309.1461; found: 309.1448.



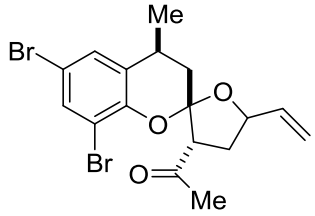
1-(8-Bromo-4,6-dimethyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-yl)ethan-1-one (8l)

Following **general procedure 4**: 6-(2-allyloxy-3-bromo-5-methyl-phenyl)-heptane-2,4-dione **10l** (279 mg, 0.79 mmol), K_2CO_3 (350 mg, 2.53 mmol) and *trans*-1,4-dibromo-2-butene (220 mg, 0.95 mmol) were combined in DMSO (1.5 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (46 mg, 0.04 mmol) and K_2CO_3 (332 mg, 2.4 mmol) were combined in MeOH (8 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:40−1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (146 mg, 52%).

8l$_i$ (yellow oil, 73 mg, 26%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.17 (s, 1H), 6.98 (s, 1H), 5.87-5.78 (m, 1H), 5.26 (d, J = 17.2 Hz, 1H), 5.13 (d, J = 10.8 Hz, 1H), 4.83-4.75 (m, 1H), 3.29-3.19 (m, 1H), 3.06-2.96 (m, 1H), 2.37 (s, 3H), 2.24 (s, 3H), 2.13 (dd, J = 13.2, 6 Hz, 1H), 2.06-1.95 (m, 2H), 1.35 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 204.8, 145.9, 137.5, 131.3, 131.3, 128.4, 126.4, 116.2, 111.1, 106.6, 78.9, 59.7, 38.5, 32.8, 30.0, 26.4, 20.4, 19.4; FTIR (ATR / cm^{-1}): 2960, 2926, 1706, 1565, 1458, 1356, 1230, 1108, 1037, 959, 905, 880, 853, 793, 731; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 387.0566; found: 387.0584.

8l$_{ii}$ (yellow solid, 73 mg, 26%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.16 (s, 1H), 6.97 (s, 1H), 5.94-5.86 (m, 1H), 5.11 (d, J = 16.8 Hz, 1H), 5.05 (d, J = 10 Hz, 1H), 4.60-4.54 (m, 1H), 3.24-3.14 (m, 1H), 2.94-2.89 (m, 1H), 2.76-2.67 (m, 1H), 2.54-2.47 (m, 1H), 2.42 (s, 3H), 2.24 (s, 3H), 2.05-1.94 (m, 2H), 1.33 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 205.7, 145.8, 139.2, 131.2, 131.2, 128.5, 126.5, 116.4, 111.0, 106.2, 80.8, 60.9, 37.5, 33.8, 30.0, 26.4, 20.4, 19.5; FTIR (ATR / cm^{-1}): 2960, 2926, 1704, 1573, 1459, 1357, 1229, 1169, 1121,

957, 905, 882, 853, 793, 732; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 387.0566; found: 387.0571; m.p. = 70.3 ºC-71.4 ºC.

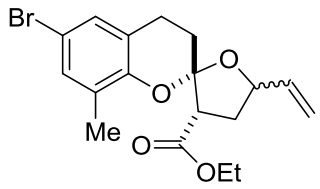


1-(6,8-Dibromo-4-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-yl)ethan-1-one (8m)

Following **general procedure 4**: 6-(2-allyloxy-3,5-dibromo-phenyl)-heptane-2,4-dione **10m** (162 mg, 0.39 mmol), K_2CO_3 (171 mg, 1.24 mmol) and *trans*-1,4-dibromo-2-butene (102 mg, 0.46 mmol) were combined in DMSO (1 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (23 mg, 0.02 mmol) and K_2CO_3 (161 mg, 1.16 mmol) were combined in MeOH (5 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:30−1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (73 mg, 44%).

8m$_i$ (yellow oil, 50 mg, 30%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.48 (s, 1H), 7.29 (s, 1H), 5.86-5.78 (m, 1H), 5.26 (d, J = 17.2 Hz, 1H), 5.14 (d, J = 10.4 Hz, 1H), 4.81-4.74 (m, 1H), 3.31-3.21 (m, 1H), 3.07-2.95 (m, 2H), 2.36 (s, 3H), 2.13 (dd, J = 13.6, 6 Hz, 1H), 2.07-1.97 (m, 2H), 1.36 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 204.3, 147.6, 137.2, 133.1, 130.6, 128.9, 116.4, 113.3, 112.3, 106.9, 79.1, 59.5, 38.0, 32.7, 30.0, 26.6, 19.2; FTIR (ATR / cm^{-1}): 2960, 2926, 1704, 1556, 1439, 1356, 1225, 1120, 1037, 959, 925, 888, 731; HRMS-ESI calculated for $C_{17}H_{18}{}^{79}Br_2O_3Na^+$ $[M+Na]^+$: 450.9515; found: 450.9537.

8m$_{ii}$ (yellow oil, 23 mg, 14%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.47 (s, 1H), 7.28 (s, 1H), 5.90-5.81 (m, 1H), 5.11 (d, J = 17.2 Hz, 1H), 5.06 (d, J = 10.4 Hz, 1H), 4.61-4.55 (m, 1H), 3.27-3.17 (m, 1H), 2.95-2.90 (m, 1H), 2.75-2.65 (m, 1H), 2.55-2.48 (m, 1H), 2.40 (s, 3H), 2.02-1.98 (m, 2H), 1.33 (d, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 205.3, 147.5, 138.8, 133.0, 130.7, 128.9, 116.7, 113.1, 112.2, 106.5, 80.9, 60.7, 37.1, 33.7, 30.1, 26.6, 19.3; FTIR (ATR / cm^{-1}): 2964, 2930, 1704, 1571, 1439, 1358, 1226, 1186, 1123, 1034, 956, 926, 887, 740; HRMS-ESI calculated for $C_{17}H_{18}{}^{79}Br_2O_3Na^+$ $[M+Na]^+$: 450.9515; found: 450.9527.

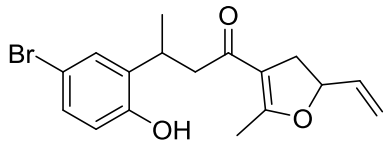


6-Bromo-8-methyl-5'-vinyl-4',5'-dihydro-3'*H*-spiro[chromane-2,2'-furan]-3'-carboxylic acid ethyl ester (8n)

Following **general procedure 4**: 5-(2-allyloxy-5-bromo-3-methyl-phenyl)-3-oxo-pentanoic acid ethyl ester **10n** (369.3 mg, 1 mmol), K_2CO_3 (442 mg, 3.2 mmol) and *trans*-1,4-dibromo-2-butene (257 mg, 1.2 mmol) were combined in DMSO (2 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (58 mg, 0.05 mmol) and K_2CO_3 (415 mg, 3 mmol) were combined in EtOH (10 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:40−1:10 Et_2O/40−60 Pet. Ether) and preparative layer chromatography plate (1:4 DCM/40−60 Pet. Ether) to afford the title compound (270 mg, 70%).

8n$_i$ (yellow solid, 120 mg, 31%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.05 (d, J = 10.4 Hz, 2H), 5.88-5.79 (m, 1H), 5.25 (d, J = 16.8 Hz, 1H), 5.13 (d, J = 10.8 Hz, 1H), 4.76-4.71 (m, 1H), 4.17-4.11 (m, 2H), 3.14-3.03 (m, 2H), 3.01-2.94 (m, 1H), 2.69 (dd, J =16.4, 4.8 Hz, 1H), 2.43-2.35 (m, 1H), 2.11-2.06 (m, 4H), 2.02-1.94 (m, 1H), 1.19 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 169.2, 149.3, 137.7, 130.9, 129.0, 128.4, 123.4, 116.0, 112.3, 105.7, 78.5, 60.9, 52.8, 32.4, 29.2, 22.2, 15.4, 14.1; FTIR (ATR / cm^{-1}): 2925, 1739, 1466, 1368, 1341, 1191, 1061, 987, 952, 859; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 403.0515; found: 403.0509; yellow solid, m.p. = 83.3 ºC-84.9 ºC.

8n$_{ii}$ (yellow solid, 150 mg, 39%) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.05 (d, J = 10.4 Hz, 2H), 5.84-5.75 (m, 1H), 5.08 (d, J = 17.2 Hz, 1H), 5.00 (d, J = 10.4 Hz, 1H), 4.60-4.54 (m, 1H), 4.18-4.12 (m, 2H), 3.10-3.02 (m, 2H), 2.71-2.62 (m, 2H), 2.48-2.36 (m, 2H), 2.07 (s, 3H), 2.04-1.99 (m, 1H), 1.20 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.7, 149.3, 139.2, 130.8, 128.9, 128.3, 123.4, 115.6, 112.1, 105.1, 80.0, 60.9, 53.9, 32.9, 28.8, 22.1, 15.5, 14.1; FTIR (ATR / cm^{-1}): 2979, 2923, 1736, 1466, 1368, 1261, 1188, 1127, 1010, 986, 932, 858, 802; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 403.0515; found: 403.0511; m.p. = 77.3 ºC-78.6 ºC.

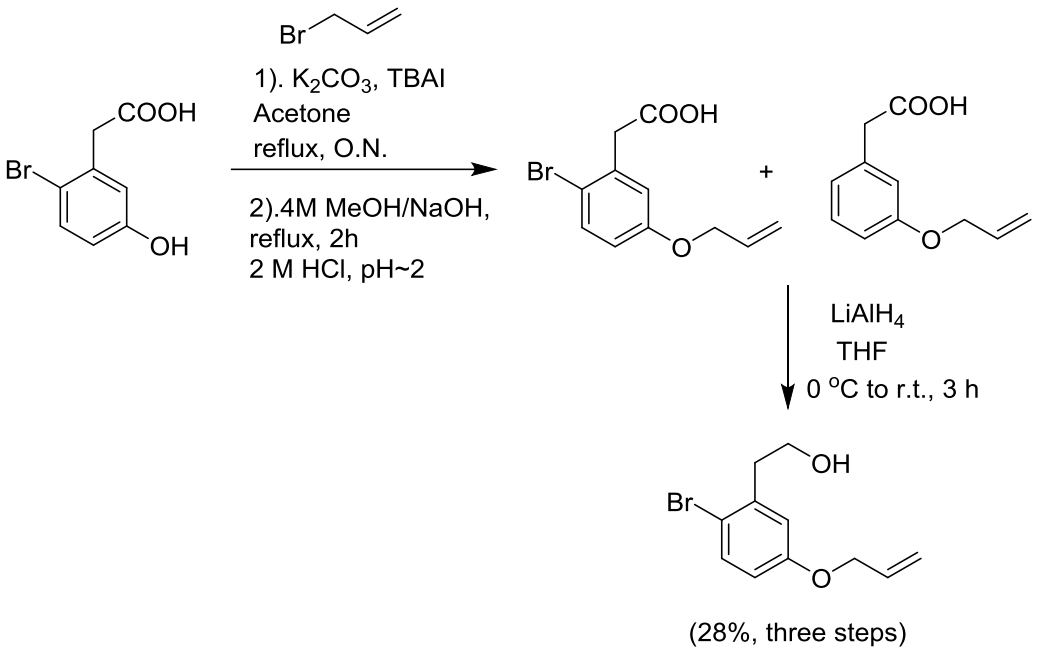


3-(5-Bromo-2-hydroxyphenyl)-1-(2-methyl-5-vinyl-4,5-dihydrofuran-3-yl)butan-1-one (13iB)

Following **general procedure 4**: 6-(2-allyloxy-5-bromo-phenyl)-heptane-2,4-dione **10i** (197 mg, 0.58 mmol), K_2CO_3 (256 mg, 1.86 mmol) and *trans*-1,4-dibromo-2-butene (158 mg, 0.7 mmol) were combined in DMSO (1 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (21.0 mg, 0.018 mmol) and K_2CO_3 (153 mg, 1.11 mmol) were combined in MeOH (3 mL) with stirring for 30 min to provide a crude residue. The crude residue was purified by flash chromatography (1:2 DCM/40−60 Pet. Ether) to afford the **13iB** (98 mg, 49%, two steps).

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 9.04 (s, 1H), 7.23-7.22 (m, 1H), 7.19-7.16 (m, 1H), 6.81 (d, J = 8.8 Hz, 1H), 5.93-5.83 (m, 1H), 5.32-5.20 (m, 2H), 5.09-5.02 (m, 1H), 3.65-3.57 (m, 1H), 3.10-3.04 (m, 1H), 2.76-2.73 (m, 2H), 2.71-2.64 (m, 1H), 2.23 (d, J = 1.2 Hz, 3H), 1.32 (d, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 197.5, 170.8, 153.5, 136.2, 136.2, 135.9, 135.9, 130.2, 129.1, 129.1, 120.3, 117.4, 117.3, 112.9, 110.2, 110.1, 83.4, 83.3, 51.7, 51.7, 35.5, 25.6, 25.6, 21.6, 21.6, 15.5; FTIR (ATR / cm^{-1}): 3252, 2929, 1649, 1576, 1481, 1227, 958, 816, 750; HRMS-ESI calculated for $C_{17}H_{19}{}^{79}BrO_3Na^+$ $[M+Na]^+$: 373.0410; found: 373.0391.

Synthesis of the tetracyclic core of berkelic acid

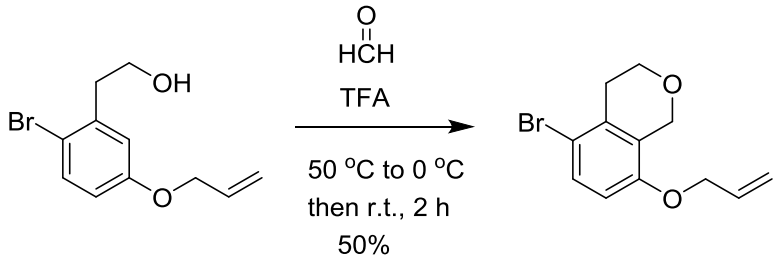


2-(5-Allyloxy-2-bromo-phenyl)-ethanol

To a solution of 2-bromo-5-hydroxybenzeneacetic acid (1.23 g, 5.8 mmol) and allyl bromide (1.77 mL, 20.3 mmol) in 40 mL acetone was added K_2CO_3. This reaction mixture was stirred under reflux for 12 hours. The solid was filtered out and acetone was evaporated *in vacuo*. To this residue was added 10 mL 4 M NaOH in MeOH. This mixture was heated under reflux for 2 hours. After it was cooled down, the pH value of the mixture was adjusted to 1 with 2 M HCl. The resulting solution was extracted with EtOAc (x3). The combined organic layer was washed with water (x1) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo* to provide a mixture of 2-bromo-5- allyloxybenzeneacetic acid and 3- allyloxybenzeneacetic acid (1.56 g).

To a suspension of $LiAlH_4$ (460 mg, 11.5 mmol) in THF (25 mL) at 0 ^oC was added a solution of a mixture of 2-bromo-5-allyloxybenzeneacetic acid and 3-allyloxybenzeneacetic acid (1.56 g) in 3 mL THF with stirring for 30 minutes. The reaction mixture was warmed to room temperature with further stirring for 2 hours. After this time the reaction was slowly quenched with H_2O followed by addition of 4 M HCl to form a suspension which was redissolved with more H_2O and the resulting solution was extracted with Et_2O (x3). The combined organic layer was washed with water (x1) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo*. The crude residue was purified by flash chromatography (1:10 EtoAc/40−60 Pet. Ether) to provide the title compound (418 mg, 28%, three steps) as a yellow oil.

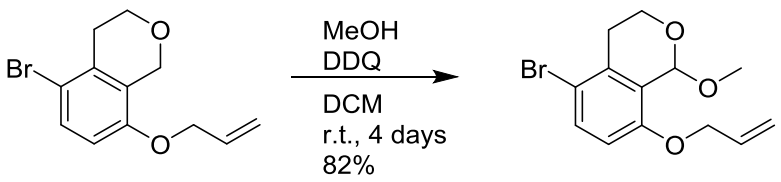
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.43 (d, J = 8.8 Hz, 1H), 6.86 (d, J = 3.2 Hz, 1H), 7.05 (dd, J = 7.6, 2 Hz, 1H), 6.69 (dd, J = 8.8, 2.8 Hz, 1H), 6.08-5.98 (m, 1H), 5.43-5.37 (m, 1H), 5.31-5.27 (m, 1H), 4.51 (dt, J = 5.2, 1.6 Hz, 2H), 3.88 (t, J = 6.4 Hz, 2H), 2.98 (t, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 157.9, 138.8, 133.4, 132.9, 117.9, 117.8, 115.2, 114.6, 69.0, 62.1, 39.5; FTIR (ATR / cm^{-1}): 3340, 2877, 1593, 1470, 1234, 1032, 924, 800; HRMS-ESI calculated for $C_{11}H_{13}{}^{79}BrO_2K^+$ $[M+K]^+$: 294.9731; found: 294.9768.



8-Allyloxy-5-bromo-isochroman

Paraformaldehyde (35 mg, 1.1 mmol) and TFA (0.3 mL) were added into a round bottom flask and stirred at 50 °C for 0.5 hour to provide a clear solution and then cooled to 0 °C. To the resulting mixture was added neat 2-(5-allyloxy-2-bromo-phenyl)-ethanol (229 mg, 0.89 mmol) with stirring for 1 hour before warmed up to room temperature with further stirring for 2 hours. After this time, TFA was removed under reduced pressure. The residue was added to 1 mL ice water and extracted with Et_2O (×3). The combined organic extracts were washed with $NaHCO_3$ (sat. ×1), water (×1) and brine (×1), dried, and reduced *in vacuo*. The crude residue was purified by flash chromatography (1:50 Et_2O/40−60 Pet. Ether) to provide the title compound (118 mg, 50%) as a yellow oil.

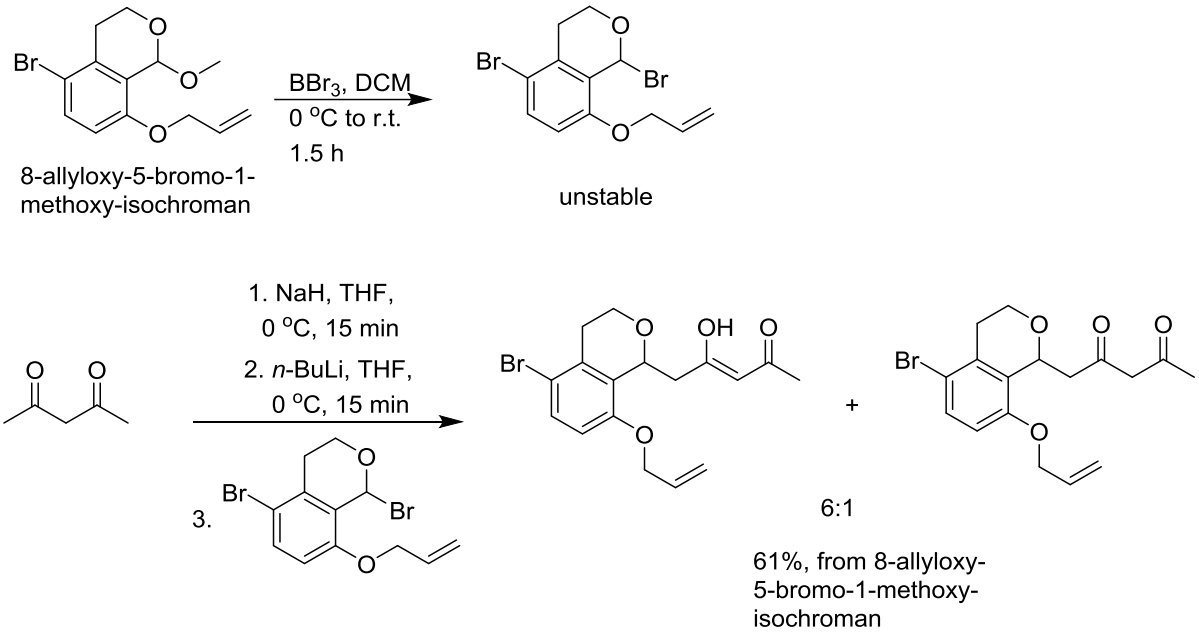
^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.35 (d, J = 8.8 Hz, 1H), 6.59 (d, J = 8.8 Hz, 1H), 6.05-5.96 (m, 1H), 5.41-5.35 (m, 1H), 5.29-5.26 (m, 1H), 4.73 (s, 2H), 4.51 (dt, J = 5.2, 1.6 Hz, 2H), 3.94 (t, J = 6.0 Hz, 2H), 2.98 (t, J = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 153.5, 134.2, 132.8, 130.1, 126.6, 117.4, 115.7, 110.1, 68.7, 64.7, 64.2, 29.2; FTIR (ATR / cm^{-1}): 1578, 1445, 1283, 972, 796.



8-Allyloxy-5-bromo-1-methoxy-isochroman

To a solution of DDQ (331 mg, 1.43 mmol) in DCM (6 mL) at room temperature was added 8-allyloxy-5-bromo-isochroman (294 mg, 1.1 mmol) and MeOH (60 uL, 1.43 mmol). The dark green mixture was stirred under a nitrogen atmosphere at room temperature for four days. The reaction mixture was quenched with $NaHCO_3$ (sat.) and the mixture was filtered through celite pad which was then extracted with DCM (x3). The combined organic layer was washed with saturated $NaHCO_3$ (x1), water (x1) and brine (x1), dried over Na_2SO_4 and reduced *in vacuo*. The crude residue was purified by flash chromatography (1:30 EtOAc/40−60 Pet. Ether) to provide the title compound (270 mg, 82%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.43 (d, J = 8.8 Hz, 1H), 6.65 (d, J = 8.8 Hz, 1H), 6.08-5.98 (m, 1H), 5.56 (s, 1H), 5.45-5.39 (m, 1H), 5.30-5.27 (m, 1H), 4.62-4.47 (m, 2H), 4.22-4.15 (m, 1H), 3.96-3.91 (m, 1H), 3.55 (s, 3H), 2.85-2.76 (m, 1H), 2.70-2.65 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 155.0, 134.8, 132.9, 132.2, 125.7, 117.3, 115.4, 111.4, 94.1, 69.1, 56.6, 55.6, 28.6; FTIR (ATR / cm^{-1}): 2914, 1581, 1457, 1051, 957, 798; HRMS-ESI calculated for $C_{13}H_{15}{}^{79}BrO_2Na^+$ $[M+Na]^+$: 321.0097; found: 321.0081.



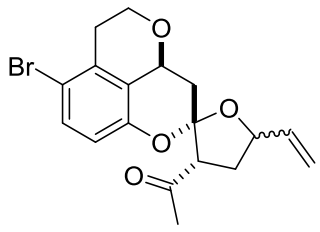
5-(8-Allyloxy-5-bromo-isochroman-1-yl)-4-hydroxy-pent-3-en-2-one

8-Allyloxy-5-bromo-1-methoxy-isochroman (237 mg, 0.79 mmol) was added to a 25 mL flame-dried round bottom flask under nitrogen atmosphere and this round bottom flask was dried under high vaccum for another half an hour and then charged with nitrogen and anhydrous

DCM. This solution was cooled to 0 ºC and BBr_3 was added dropwise with stirring until a yellow precipitate was observed (about 10 minutes) and then warmed to room temperature with further stirring for 1.5 hours, which led to the fresh unstable 8-(allyloxy)-1,5-dibromoisochromane. The solvent of this reaction was removed under high vaccum at 0 ºC and then charged with nitrogen.

In the next step, following **general procedure 3**: to a solution of NaH (29 mg, 0.73 mmol) in THF (3 mL) was added acetylacetone (68 uL, 0.66 mmol) followed by *n*-BuLi in hexane (0.48 mL, 1.5M) and a solution of fresh 8-(allyloxy)-1,5-dibromoisochromane in 1 mL THF to give a crude residue. The crude residue was purified by flash chromatography (1:20 EtOAc/40−60 Pet. Ether) to afford the title compound (147 mg, 61% from 8-allyloxy-5-bromo-1-methoxy-isochroman) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.40 (d, J = 8.8 Hz, 1H), 6.63 (d, J = 8.8 Hz, 1.2H), 6.06-5.97 (m, 1H), 5.60 (s, 0.95H), 5.45-5.35 (m, 2.2H), 5.31-5.28 (m, 1.1H), 4.55-4.51 (m, 2.2H), 5.49-5.43 (m, 2H), 4.57-4.56 (m, 2H), 4.05-3.99 (m, 1H), 3.98-3.94 (m, 0.17H), 3.89-3.84 (m, 1H), 3.83-3.80 (m, 0.17H), 3.67 (s, 0.3H), 3.17 (dd, J = 14.8, 2.8 Hz, 0.17H), 3.05 (dd, J = 14.8, 2.8 Hz, 1H), 2.96-2.89 (m, 0.17H), 2.84-2.81 (m, 0.17H), 2.80-2.74 (m, 2H), 2.72-2.70 (m, 0.17H), 2.67-2.61 (m, 1H), 2.25 (s, 0.5H), 2.07 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 192.0, 190.8, 153.5, 134.8, 134.7, 132.5, 130.9, 130.8, 128.3, 117.8, 117.6, 116.0, 116.0, 110.8, 110.7, 100.6, 69.3, 68.9, 68.8, 68.5, 60.1, 59.7, 58.3, 47.3, 41.9, 30.7, 29.4, 29.4, 24.8; FTIR (ATR / cm^{-1}): 3091, 2942, 1622, 1600, 1249, 1036, 914, 776; HRMS-ESI calculated for $C_{17}H_{19}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 389.0359; found: 389.0346; m.p. = 64.6 ºC-65.8 ºC.



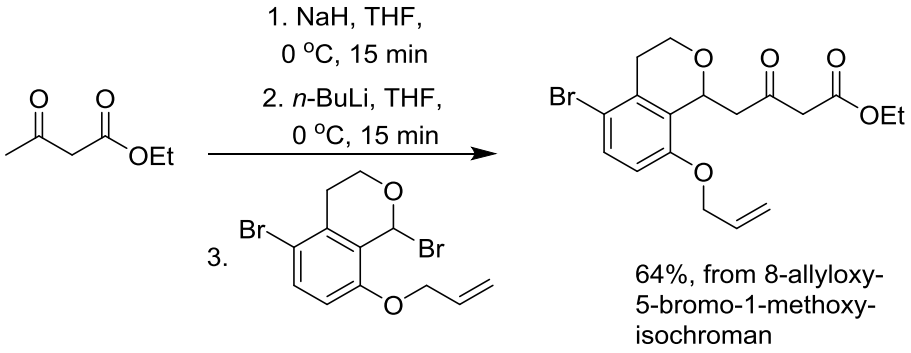
1-(7'-Bromo-5-vinyl-3',3a',4,5,5',6'-hexahydro-3*H*-spiro[furan-2,2'-pyrano[2,3,4-*de*]chromen]-3-yl)ethan-1-one (17a)

Following **general procedure 4**: 5-(8-allyloxy-5-bromo-isochroman-1-yl)-4-hydroxy-pent-3-en-2-one **16a** (135 mg, 0.37 mmol), K_2CO_3 (164 mg, 1.18 mmol) and *trans*-1,4-dibromo-2-butene (96 mg, 0.44 mmol) were combined in DMSO (1 mL) to provide the crude vinyl

cyclopropane compound which was used for the next step without further purification. This crude vinyl cyclopropane, $Pd(PPh_3)_4$ (21.0 mg, 0.018 mmol) and K_2CO_3 (153 mg, 1.11 mmol) were combined in MeOH (5 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:20-1:10 EtOAc/40−60 Pet. Ether) to afford the title compound (79 mg, 56%).

17a$_i$ (yellow oil, 35 mg) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.31 (d, J = 8.8 Hz, 1H), 6.53 (d, J = 8.8 Hz, 1H), 5.88-5.80 (m, 1H), 5.29 (dt, J = 17.2, 1.6 Hz, 1H), 5.16 (dt, J = 10.4, 1.2 Hz, 1H), 4.85 (dd, J = 12.0, 5.2 Hz, 1H), 4.79-4.73 (m, 1H), 4.37-4.31 (m, 1H), 4.00-3.93 (m, 1H), 3.23-3.18 (m, 1H), 2.97-2.87 (m, 2H), 2.73 (dd, J = 17.6, 4.8 Hz, 1H), 2.52-2.47 (m, 1H), 2.35-2.29 (m, 1H), 2.19 (s, 3H), 1.93-1.85 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 202.3, 149.3, 137.2, 132.5, 131.7, 123.2, 116.5, 115.6, 115.4, 106.7, 79.3, 68.0, 65.6, 59.9, 36.3, 31.9, 29.9, 29.1; FTIR (ATR / cm^{-1}): 2927, 2857, 1716, 1579, 1454, 1339, 1256, 1087, 1047, 908, 811; HRMS-ESI calculated for $C_{18}H_{19}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 401.0359; found: 401.0334.

17a$_{ii}$ (yellow oil, 44 mg) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.30 (d, J = 6.8 Hz, 1H), 6.51 (d, J = 8.8 Hz, 1H), 5.91-5.82 (m, 1H), 5.18 (d, J = 17.2 Hz, 1H), 5.08 (d, J = 10.4 Hz, 1H), 4.83 (dd, J = 12.0, 5.6 Hz, 1H), 4.61-4.55 (m, 1H), 4.35-4.30 (m, 1H), 3.99-3.92 (m, 1H), 3.11-3.06 (m, 1H), 2.96-2.87 (m, 1H), 2.72 (dd, J = 17.6, 4.8 Hz, 1H), 2.60-2.52 (m, 1H), 2.44-2.37 (m, 2H), 2.33-2.27 (m, 1H), 2.22 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 202.9, 149.3, 138.8, 132.4, 131.6, 123.3, 116.6, 115.5, 115.3, 106.4, 80.6, 68.1, 65.6, 61.0, 35.7, 32.7, 29.8, 29.1; FTIR (ATR / cm^{-1}): 2925, 2858, 1712, 1579, 1453, 1338, 1256, 1087, 901, 810; HRMS-ESI calculated for $C_{18}H_{19}{}^{79}BrO_4Na^+$ $[M+Na]^+$: 401.0359; found: 401.0340.



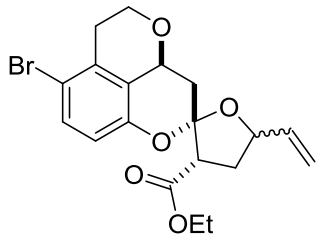
Ethyl 4-(8-(allyloxy)-5-bromoisochroman-1-yl)-3-oxobutanoate

8-Allyloxy-5-bromo-1-methoxy-isochroman (425 mg, 1.42 mmol) was added to a 25 mL flame-dried round bottom flask under nitrogen atmosphere and this round bottom flask was

dried under high vaccum for another half an hour and then charged with nitrogen and anhydrous DCM. This solution was cooled to 0 ºC and BBr_3 was added dropwise with stirring until a yellow precipitate was observed (about 10 minutes) and then warmed to room temperature with further stirring for 1.5 hours, which led to the fresh unstable 8-(allyloxy)-1,5-dibromoisochromane. The solvent of this reaction was removed under high vaccum at 0 ºC and then charged with nitrogen.

In the next step, following **general procedure 3**: to a solution of NaH (53 mg, 1.32 mmol) in THF (5 mL) was added acetylacetone (150 uL, 1.18 mmol) followed by *n*-BuLi in hexane (0.9 mL, 1.45M) and a solution of fresh 8-(allyloxy)-1,5-dibromoisochromane in 1 mL THF to give a crude residue. The crude residue was purified by flash chromatography (1:20 EtOAc/40−60 Pet. Ether) to afford the title compound (300 mg, 64% from 8-allyloxy-5-bromo-1-methoxy-isochroman) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.38 (d, J = 8.8 Hz, 1H), 6.61 (d, J = 8.8 Hz, 1H), 6.04-5.95 (m, 1H), 5.42-5.38 (m, 1H), 5.30-5.26 (m, 1H), 4.53-4.51 (m, 2H), 4.19 (q, J = 7.2 Hz, 2H), 4.00-3.94 (m, 1H), 3.84-3.79 (m, 1H), 3.54 (d, J = 2.4 Hz, 2H), 3.19 (dd, J = 16.0, 3.2 1H), 2.97 (dd, J = 15.6, 9.6 Hz, 1H), 2.77-2.73 (m, 2H), 1.27 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 200.8, 167.1, 153.4, 134.8, 132.4, 130.8, 127.8, 117.7, 116.0, 110.7, 68.9, 68.4, 61.2, 60.0, 49.6, 46.6, 29.4, 14.1; FTIR (ATR / cm^{-1}): 3080, 2932, 1737, 1714, 1250, 1038, 924, 799; HRMS-ESI calculated for $C_{18}H_{21}{}^{79}BrO_5Na^+$ $[M+Na]^+$: 419.0465; found: 419.0433; m.p. = 48.0 ºC-49.5 ºC.



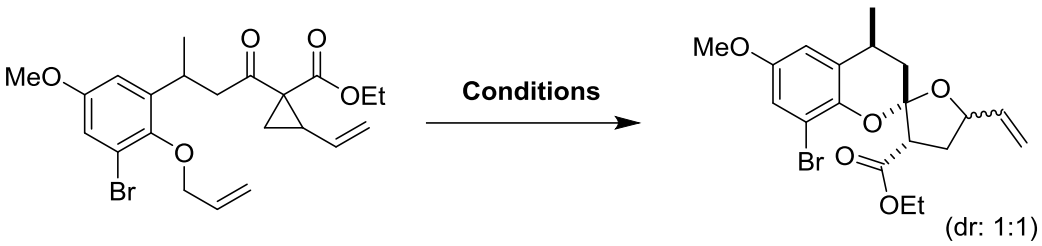
Ethyl 7'-bromo-5-vinyl-3',3a',4,5,5',6'-hexahydro-3*H*-spiro[furan-2,2'-pyrano[2,3,4-*de*]chromene]-3-carboxylate (17b)

Following **general procedure 4**: ethyl 4-(8-(allyloxy)-5-bromoisochroman-1-yl)-3-oxobutanoate **16b** (254 mg, 0.63 mmol), K_2CO_3 (283 mg, 2.05 mmol) and *trans*-1,4-dibromo-2-butene (165 mg, 0.77 mmol) were combined in DMSO (1.5 mL) to provide the crude vinyl cyclopropane compound which was used for the next step without further purification. This

crude vinyl cyclopropane, $Pd(PPh_3)_4$ (37 mg, 0.032 mmol) and K_2CO_3 (265 mg, 1.92 mmol) were combined in EtOH (6 mL) to provide a crude residue. The crude residue was purified by flash chromatography (1:20-1:10 Et_2O/40−60 Pet. Ether) to afford the title compound (135 mg, 52%).

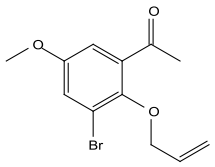
17b$_i$ (yellow oil, 60 mg) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.29 (d, J = 8.8 Hz, 1H), 6.53 (d, J = 8.8 Hz, 1H), 5.89-5.80 (m, 1H), 5.28 (dt, J = 17.2, 1.2 Hz, 1H), 5.15 (dt, J = 10.4, 1.2 Hz, 1H), 4.84-4.78 (m, 2H), 4.36-4.31 (m, 1H), 4.17-4.07 (m, 2H), 3.99-3.92 (m, 1H), 3.15 (t, J = 8.8 Hz, 1H), 2.99-2.88 (m, 2H), 2.72 (dd, J = 17.6, 4.8 Hz, 1H), 2.48-2.37 (m, 2H), 2.02-1.94 (m, 1H), 1.13 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.7, 149.6, 137.5, 132.3, 131.5, 123.4, 116.2, 115.3, 115.3, 106.9, 79.0, 68.1, 65.6, 61.0, 52.6, 35.6, 31.6, 29.1, 14.2; FTIR (ATR / cm^{-1}): 2917, 2850, 1740, 1454, 1256, 1089, 1015, 908, 812; HRMS-ESI calculated for $C_{19}H_{21}{}^{79}BrO_5Na^+$ $[M+Na]^+$: 431.0465; found: 431.0467.

17b$_{ii}$ (yellow oil, 75 mg) ^{1}H NMR (400 MHz, $CDCl_3$), δ (ppm): 7.29 (d, J = 8.4 Hz, 1H), 6.52 (d, J = 8.8 Hz, 1H), 5.91-5.82 (m, 1H), 5.17 (d, J = 17.2 Hz, 1H), 5.07 (d, J = 10.0 Hz, 1H), 4.80 (dd, J = 12.4, 5.2 Hz, 1H), 4.62-4.56 (m, 1H), 4.35-4.31 (m, 1H), 4.17-4.08 (m, 2H), 3.98-3.91 (m, 1H), 3.14-3.09 (m, 1H), 2.96-2.87 (m, 1H), 2.71 (dd, J = 17.6, 4.8 Hz, 1H), 2.62-2.54 (m, 1H), 2.48-2.38 (m, 2H), 2.32 (dd, J = 12.4, 5.6 Hz, 1H), 1.14 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$), δ (ppm): 168.0, 149.2, 138.6, 131.9, 131.2, 123.1, 116.2, 115.0, 114.9, 106.1, 80.4, 67.8, 65.3, 60.7, 53.6, 35.1, 31.9, 28.8, 13.9; FTIR (ATR / cm^{-1}): 2918, 2850, 1739, 1454, 1260, 1088, 1010, 904, 808; HRMS-ESI calculated for $C_{19}H_{21}{}^{79}BrO_5Na^+$ $[M+Na]^+$: 431.0465; found: 431.0463.

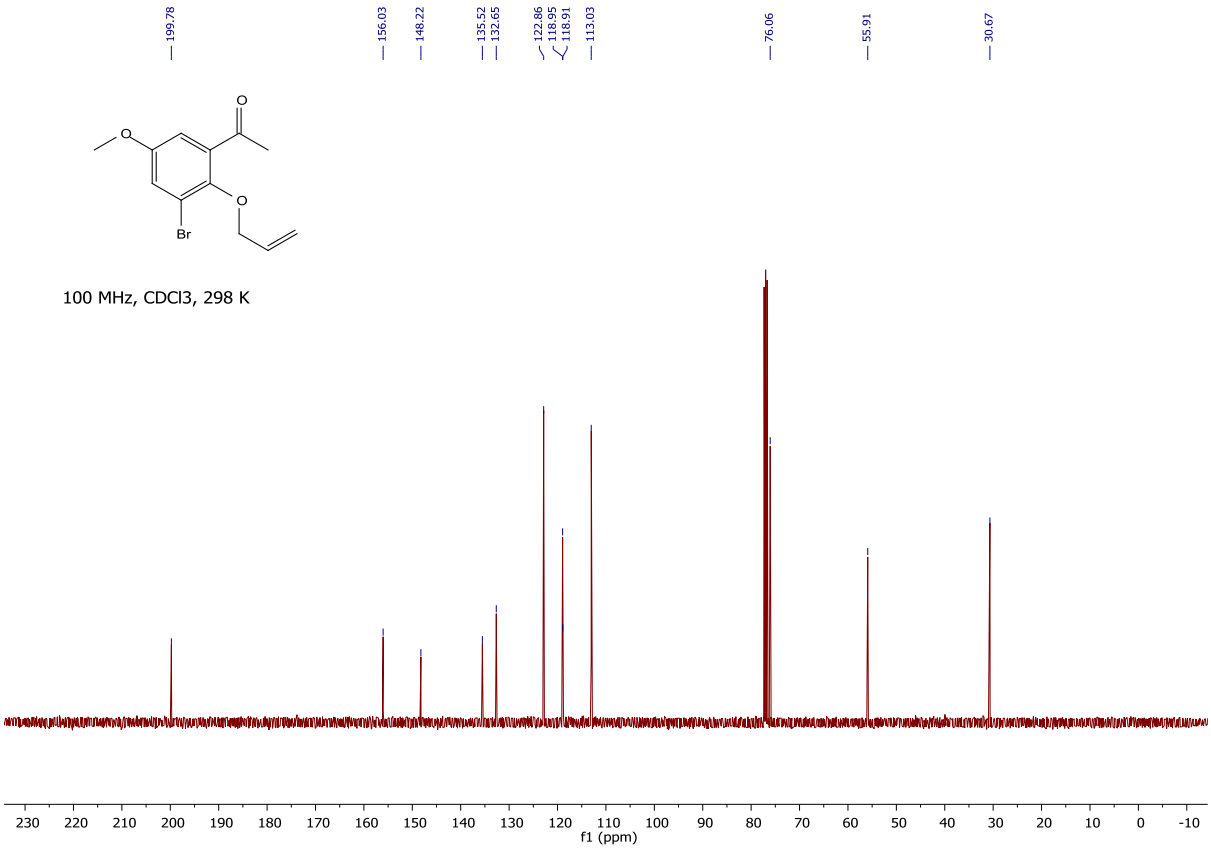


Entry	Solvent	Catalyst	Time (h)	Yield (%)
1	**EtOH**	**5 mol% $Pd(PPh_3)_4$**	**16**	**79**
2	EtOH	10 mol% $Pd(PPh_3)_4$	16	80
3	EtOH	2.5 mol% $Pd(PPh_3)_4$	16	35
4	EtOH	2.5 mol% $Pd(PPh_3)_4$	48	47
5	EtOH	5 mol% $Pd_2(dba)_3$, PPh_3	16	52
6	THF	5 mol% $Pd(PPh_3)_4$	16	61

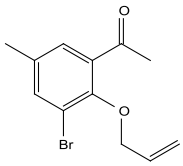
Copies of ^{1}H NMR and ^{13}C NMR spectra



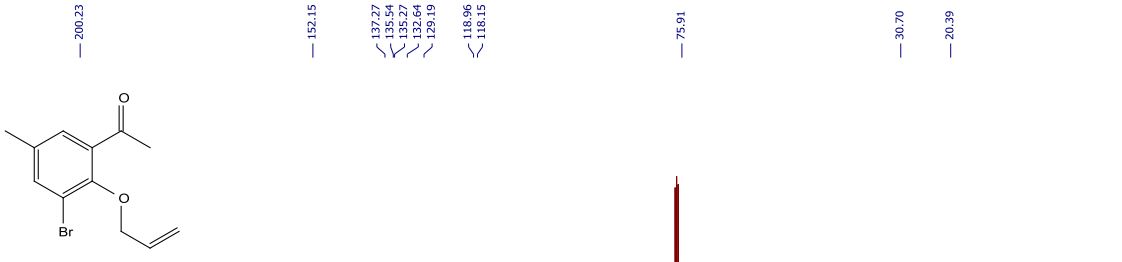
400 MHz, CDCl3, 298 K



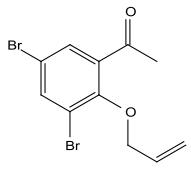
100 MHz, CDCl3, 298 K



400 MHz, CDCl3, 298 K

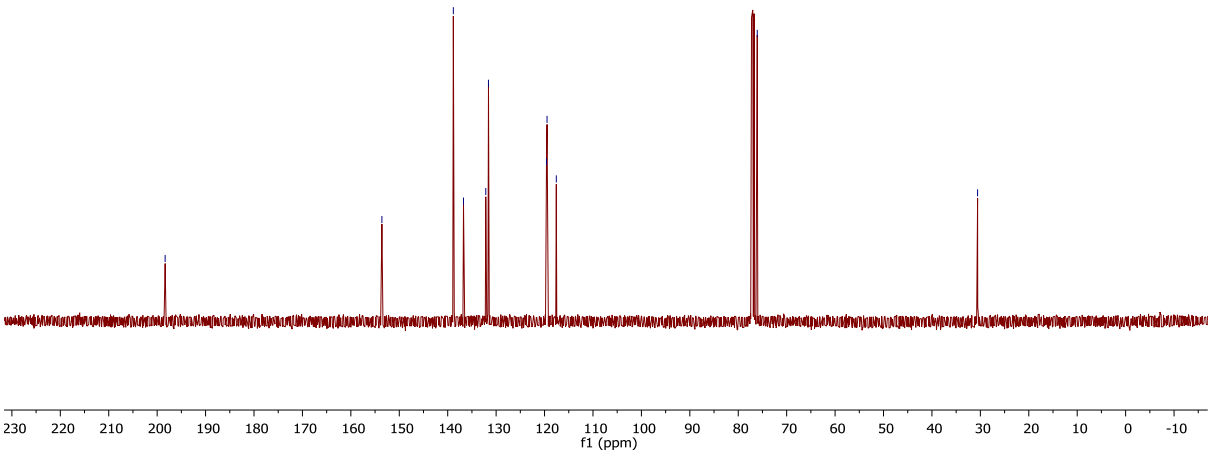


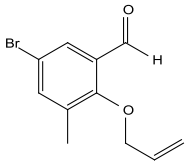
100 MHz, CDCl3, 298 K



500 MHz, CDCl3, 298 K

125 MHz, CDCl3, 298 K





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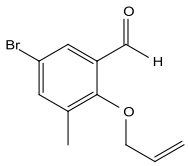
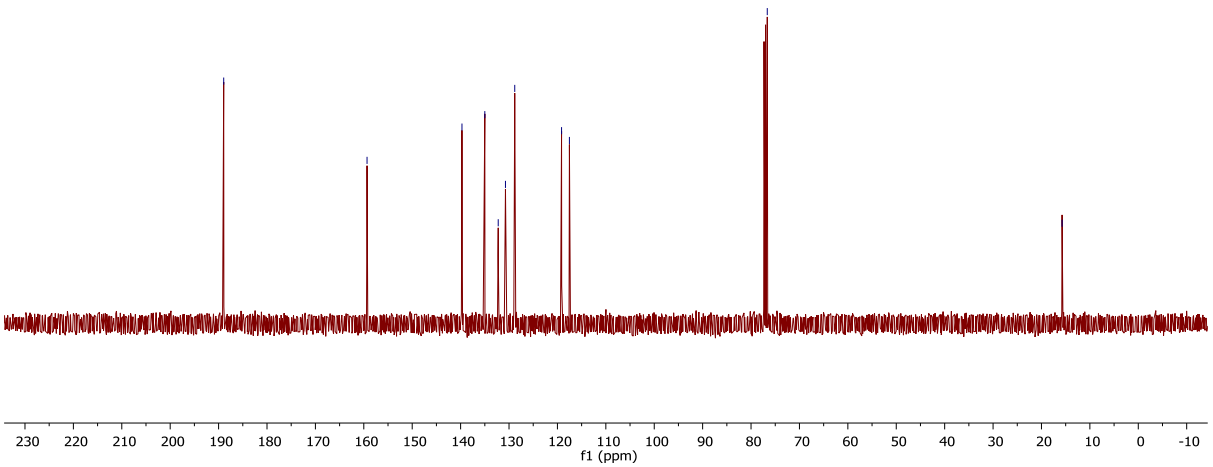
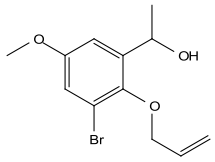
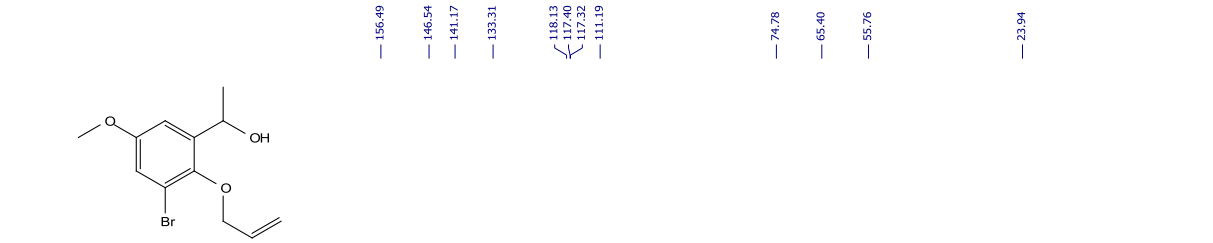


100 MHz, CDCl3, 298 K

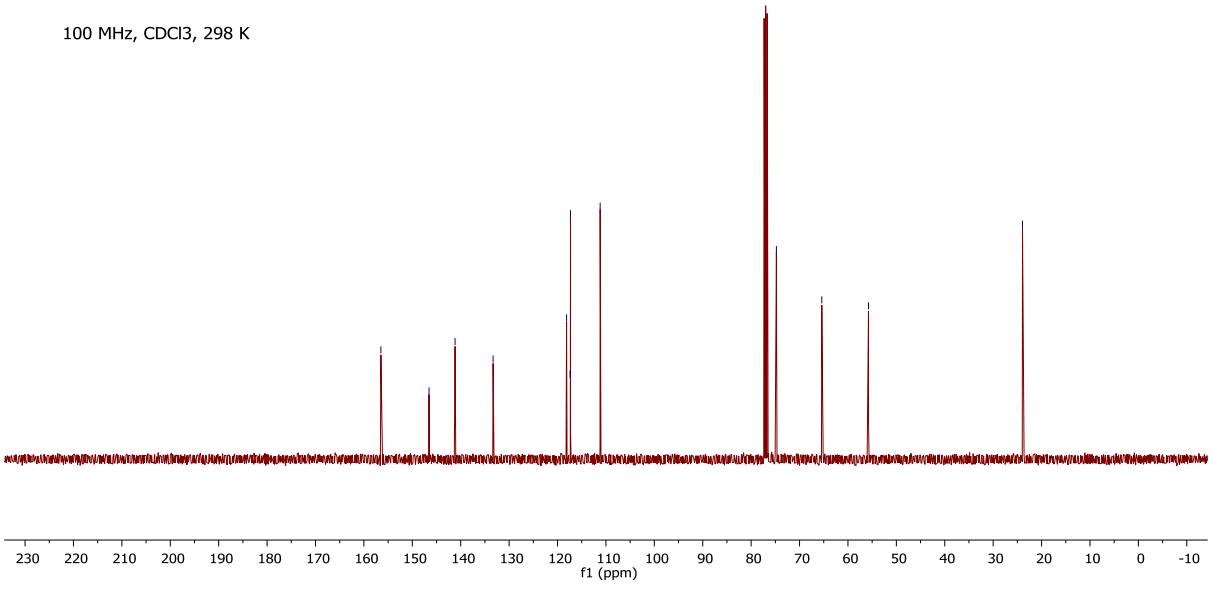


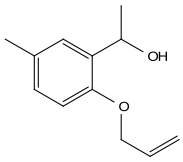


400 MHz, CDCl3, 298 K

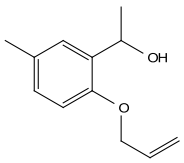


100 MHz, CDCl3, 298 K

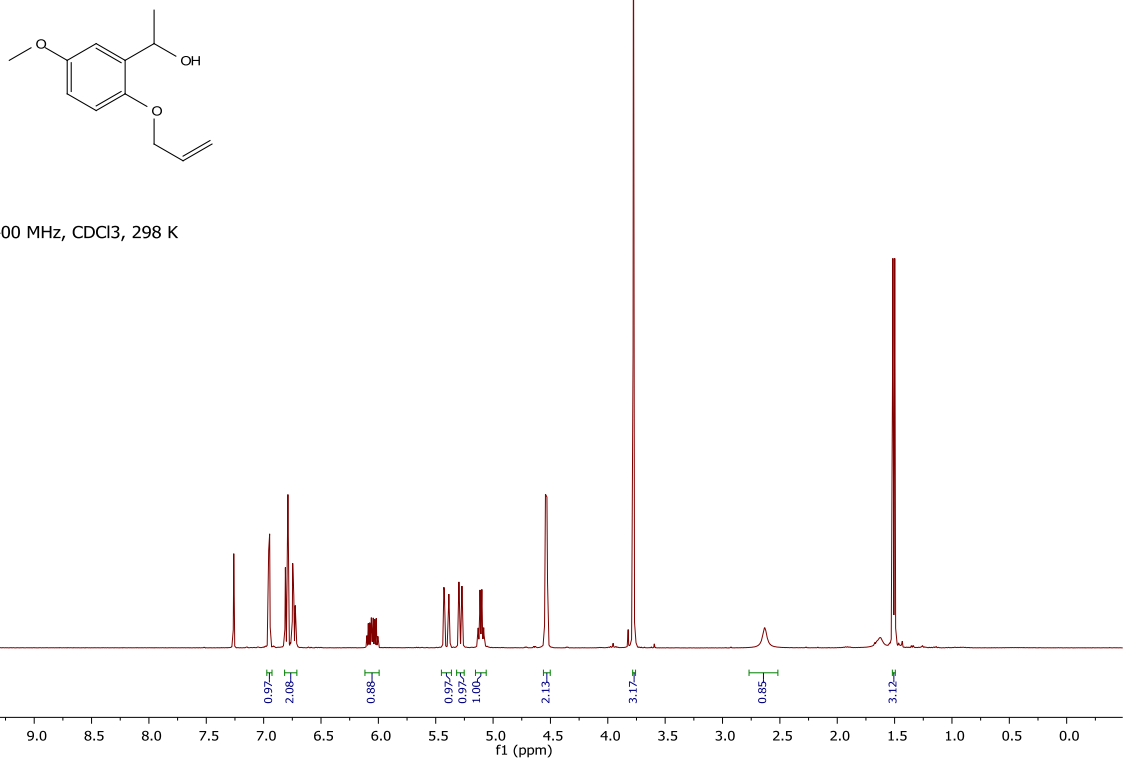


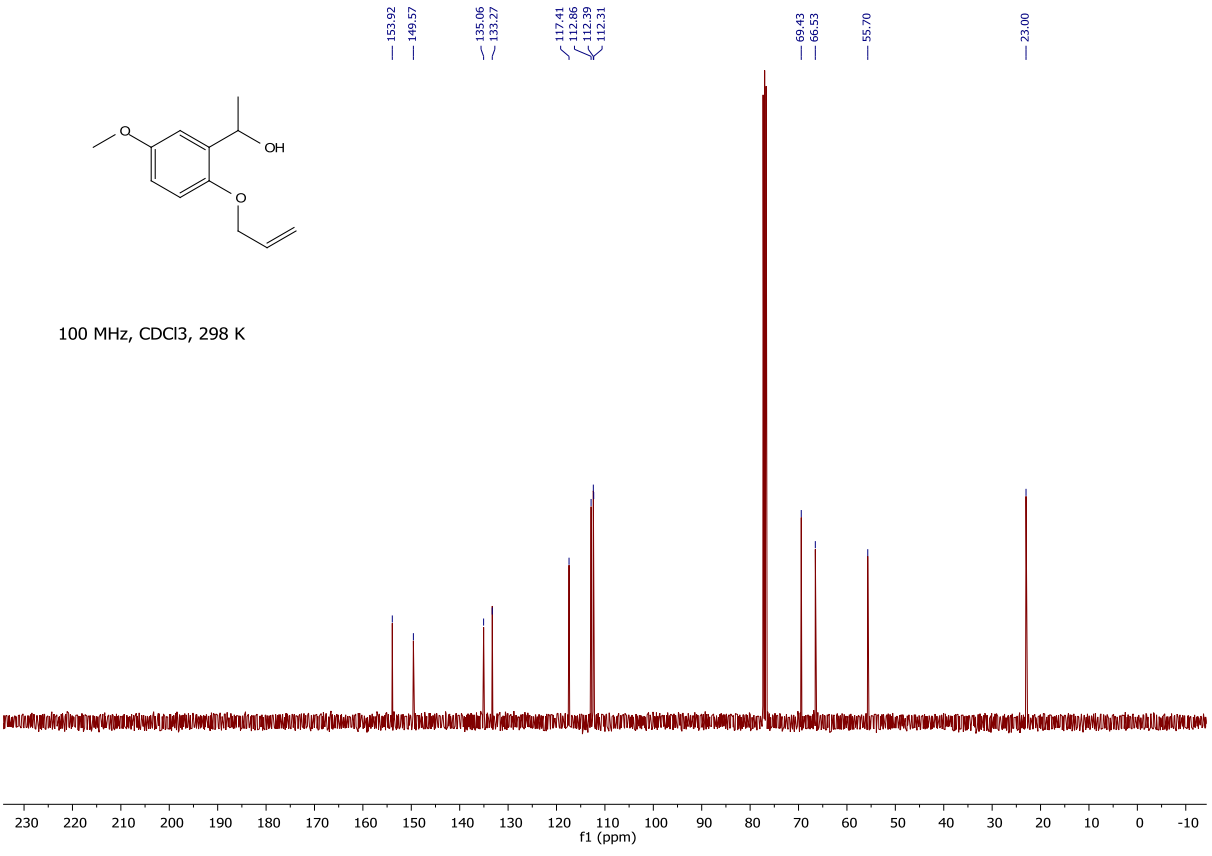


400 MHz, CDCl3, 298 K



100 MHz, CDCl3, 298 K


O
OH
O
400 MHz, CDCl3, 298 K
0.97
2.08
0.68
0.97
0.97
1.00
2.13
3.17
0.85
3.12
f1 (ppm)


153.92
149.57
135.06
133.27
117.41
112.86
112.39
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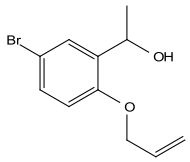
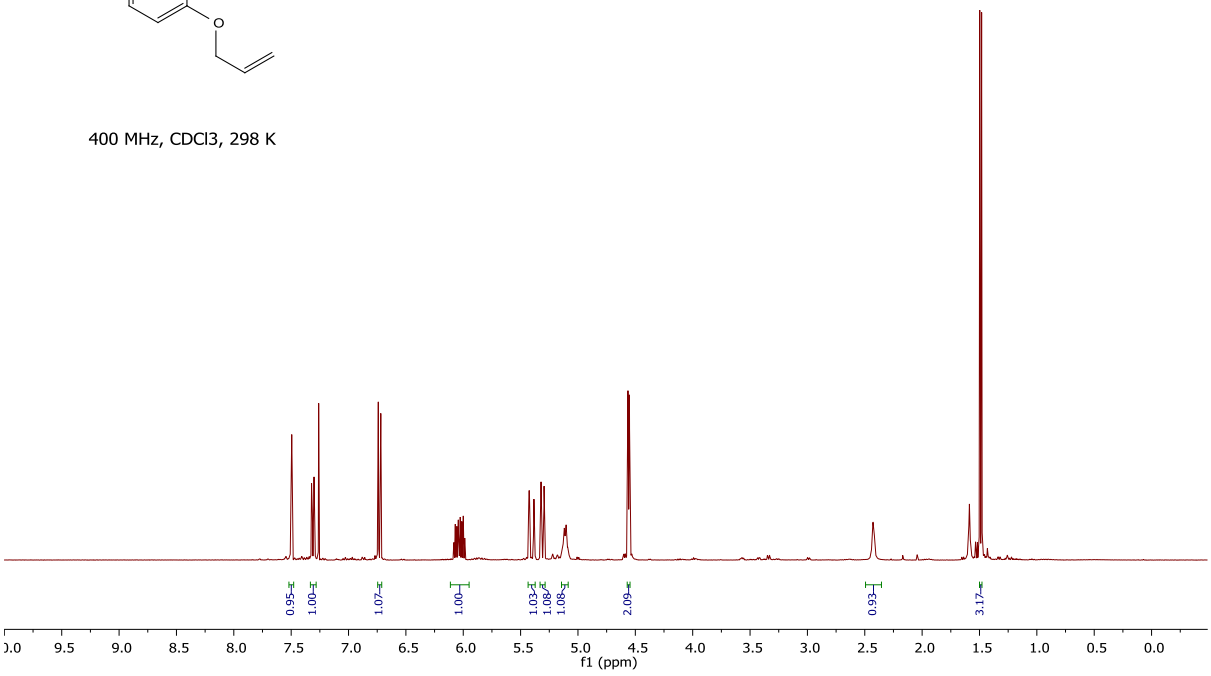
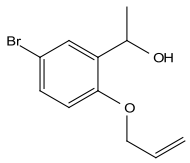
69.43
66.53
55.70
23.00
O
OH
O
100 MHz, CDCl3, 298 K
f1 (ppm)

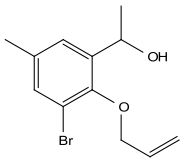


400 MHz, CDCl3, 298 K

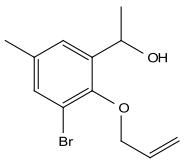




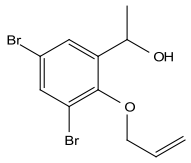
100 MHz, CDCl3, 298 K



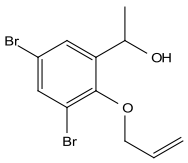
400 MHz, CDCl3, 298 K



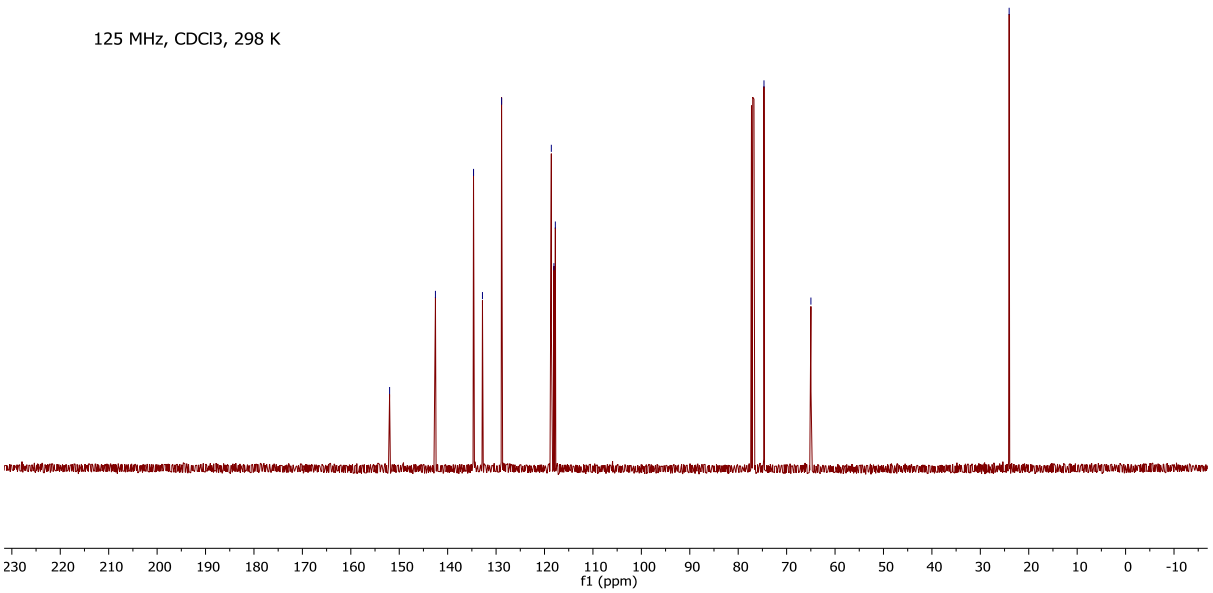
100 MHz, CDCl3, 298 K

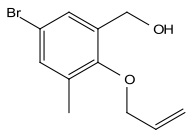


500 MHz, CDCl3, 298 K

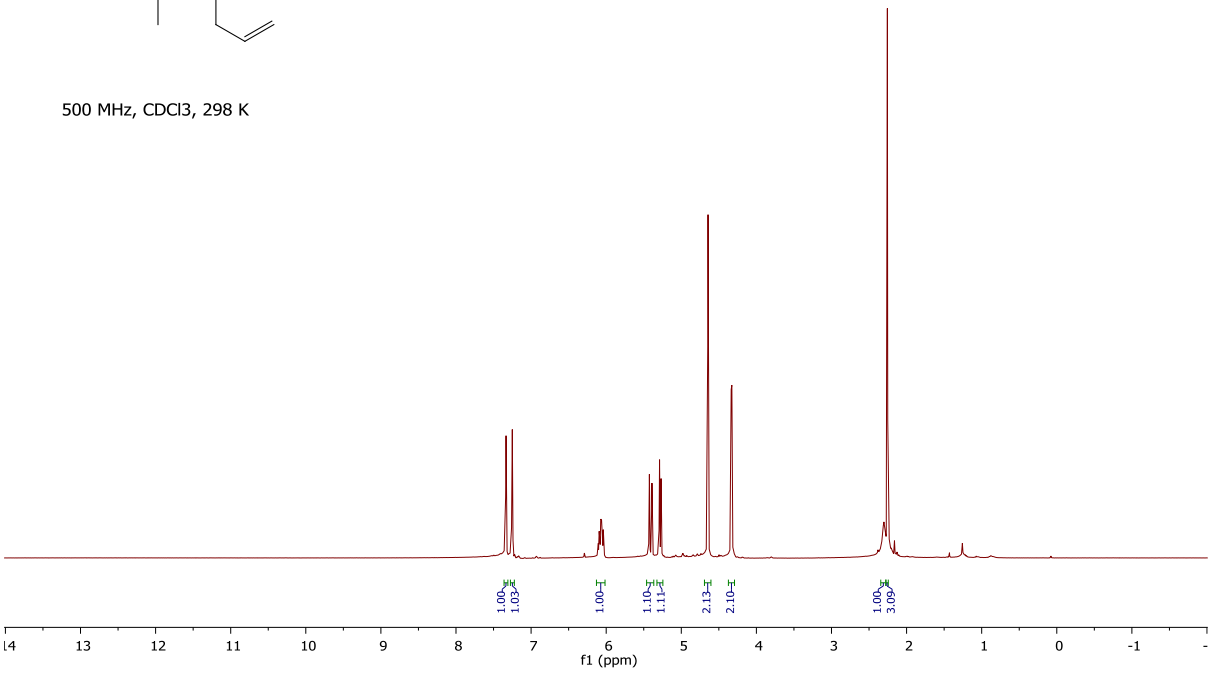


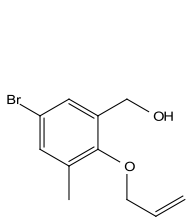
125 MHz, CDCl3, 298 K



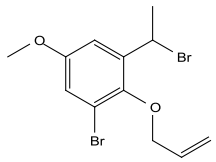


500 MHz, CDCl3, 298 K

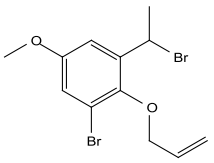




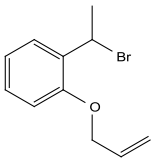
125 MHz, CDCl3, 298 K



400 MHz, CDCl3, 298 K



100 MHz, CDCl3, 298 K



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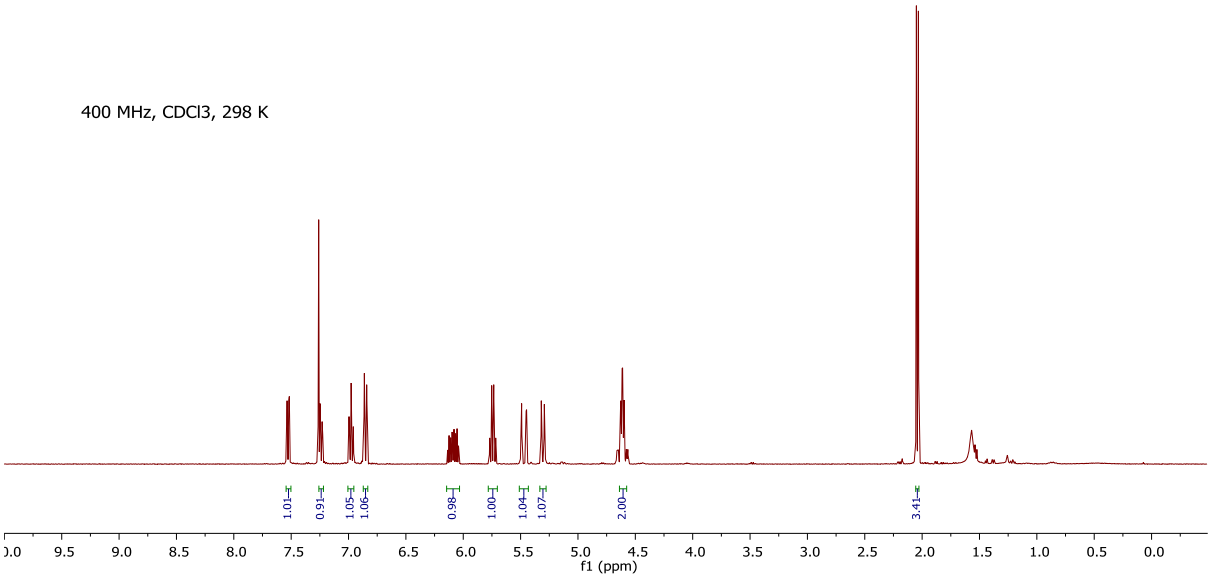
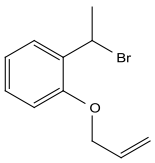
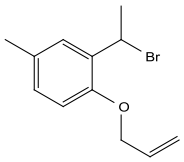
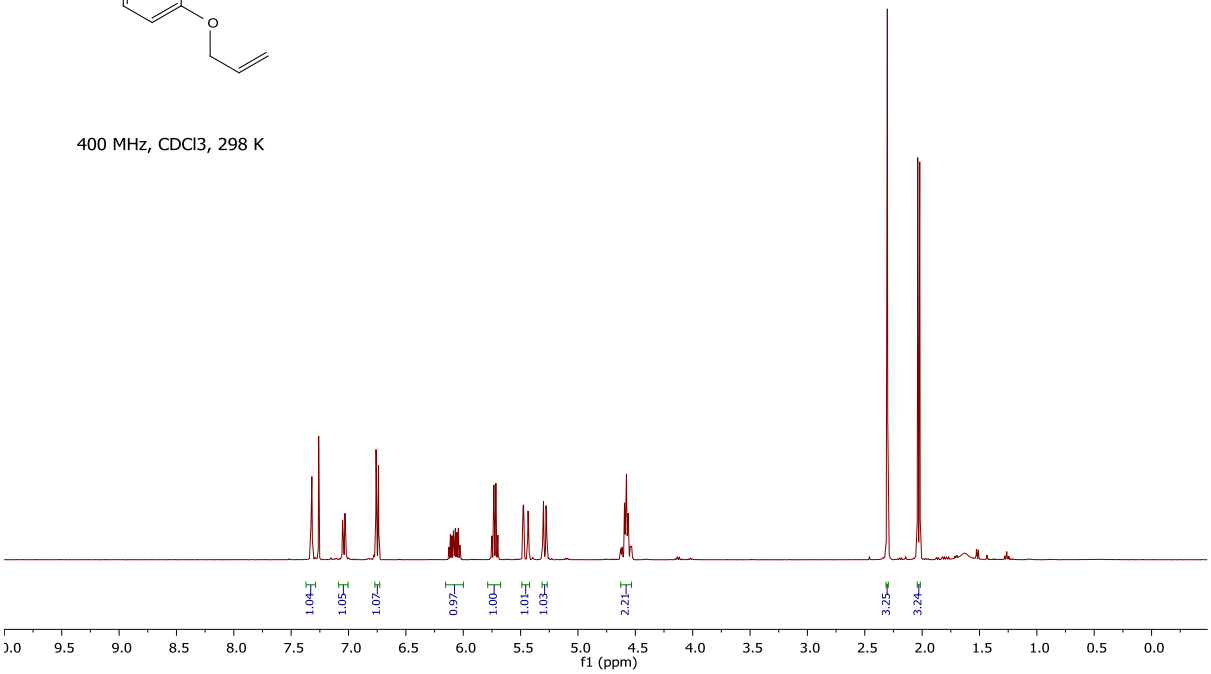


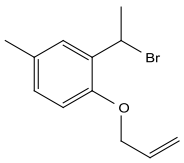


100 MHz, CDCl3, 298 K

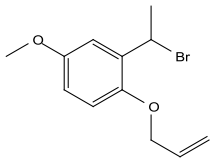


400 MHz, CDCl3, 298 K

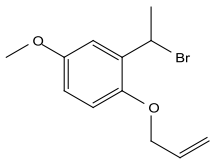




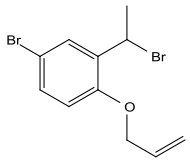
100 MHz, CDCl3, 298 K



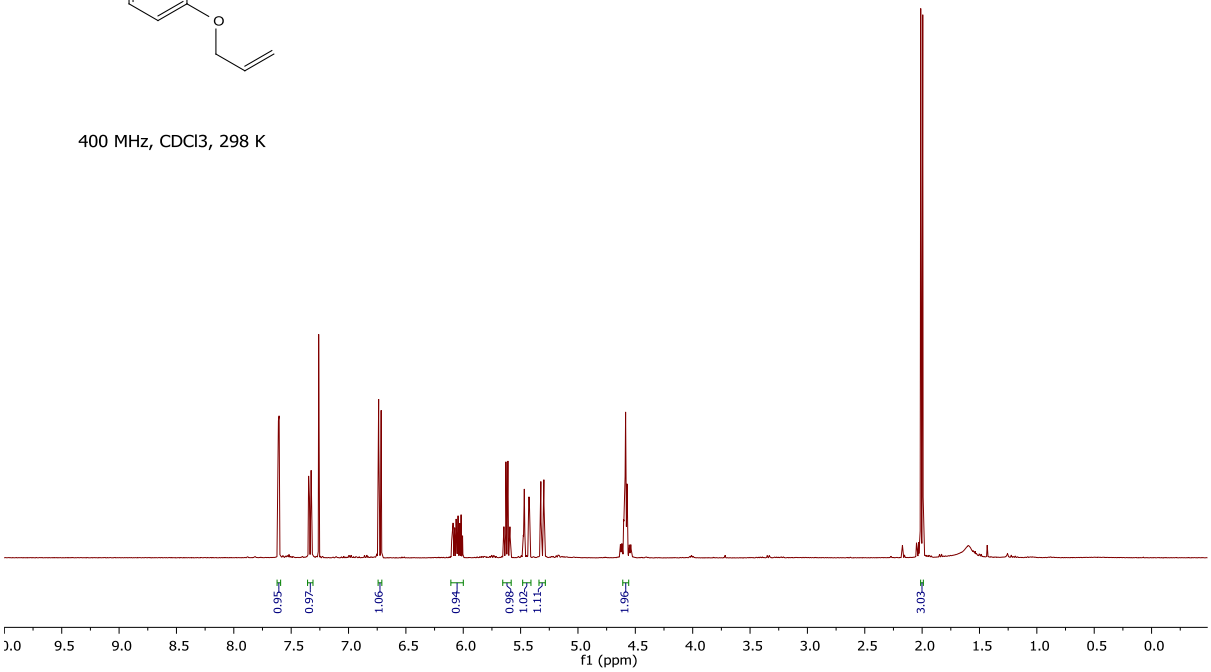
400 MHz, CDCl3, 298 K

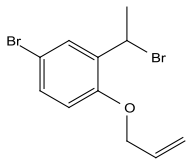


100 MHz, CDCl3, 298 K

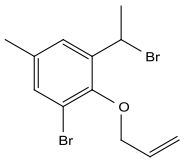


400 MHz, CDCl3, 298 K

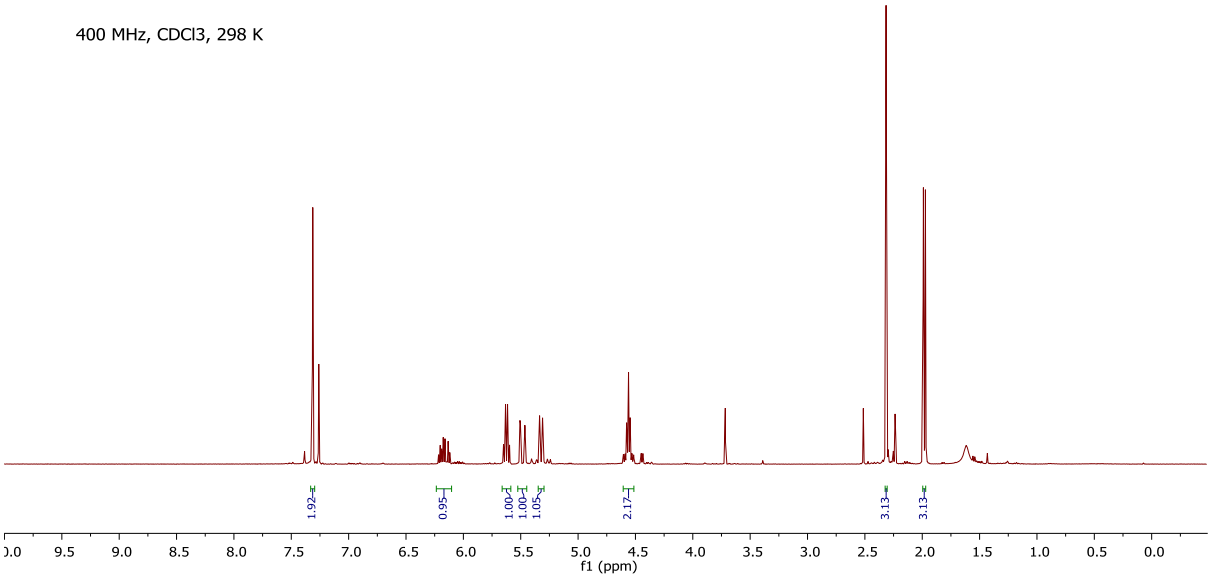


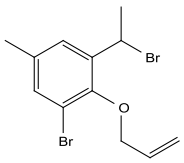


100 MHz, CDCl3, 298 K

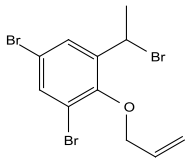


400 MHz, CDCl3, 298 K

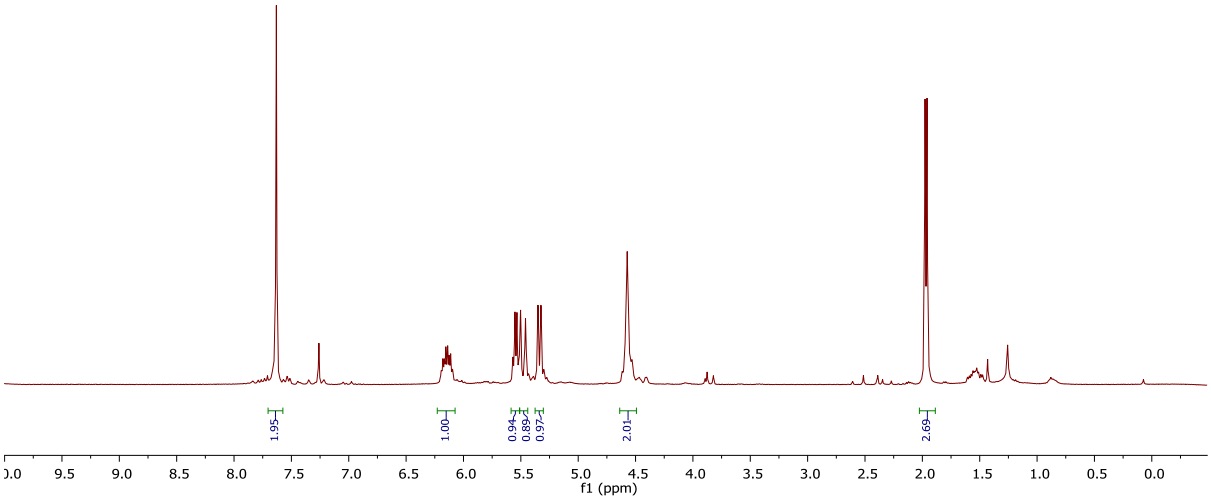


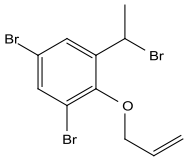


100 MHz, CDCl3, 298 K



400 MHz, CDCl3, 298 K





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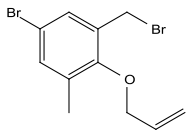
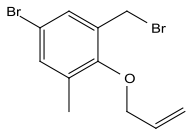
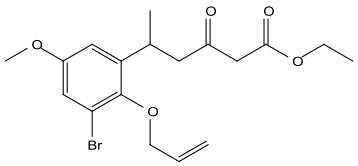


400 MHz, CDCl3, 298 K

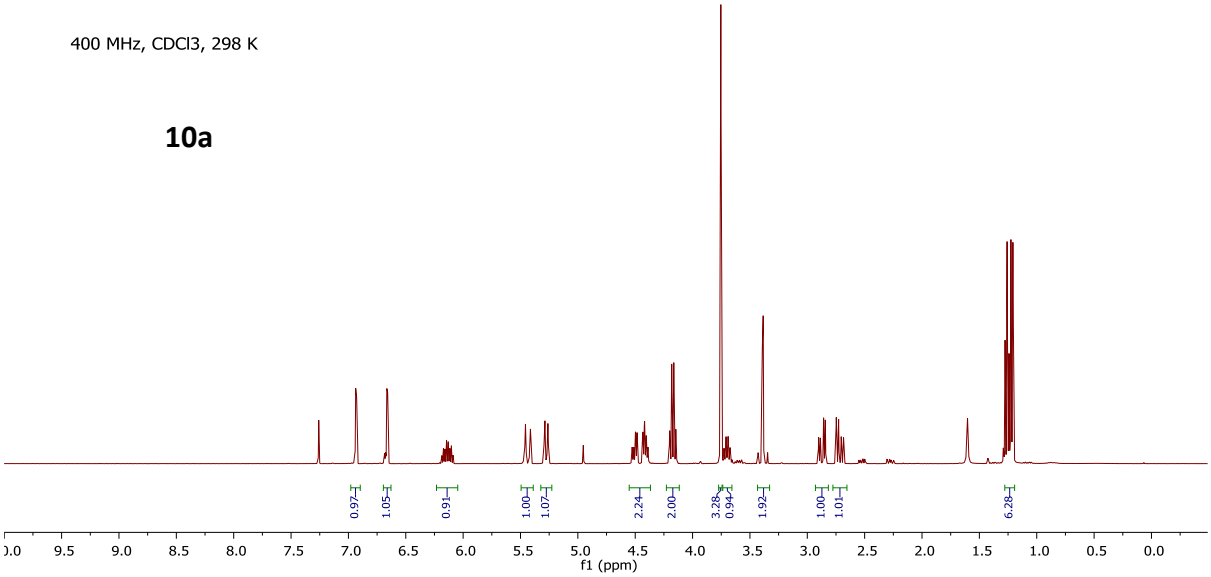


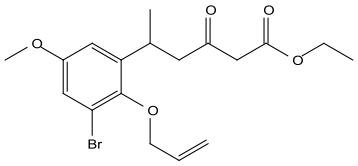
100 MHz, CDCl3, 298 K



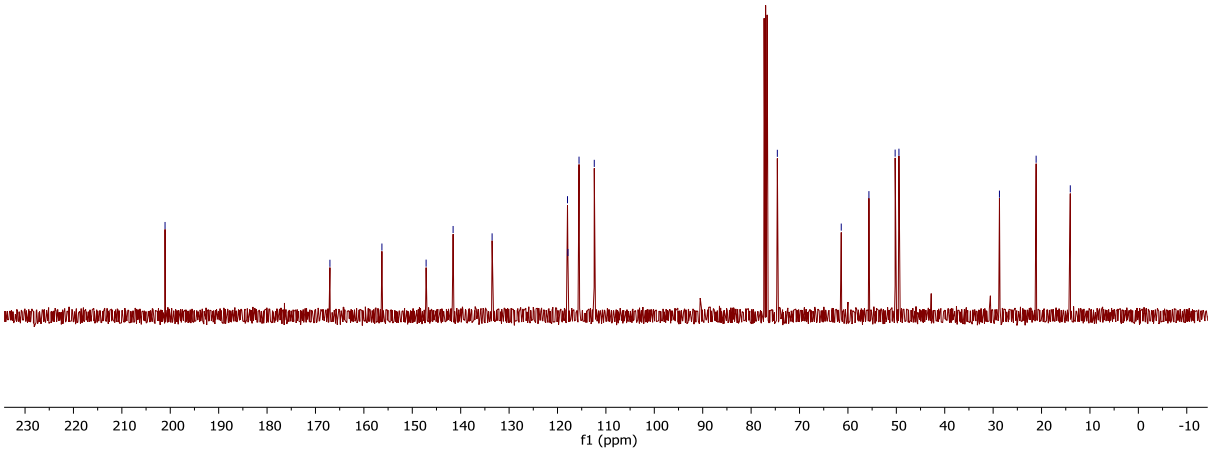
400 MHz, CDCl3, 298 K

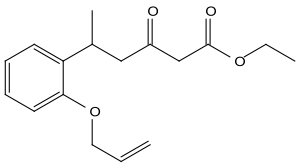
10a





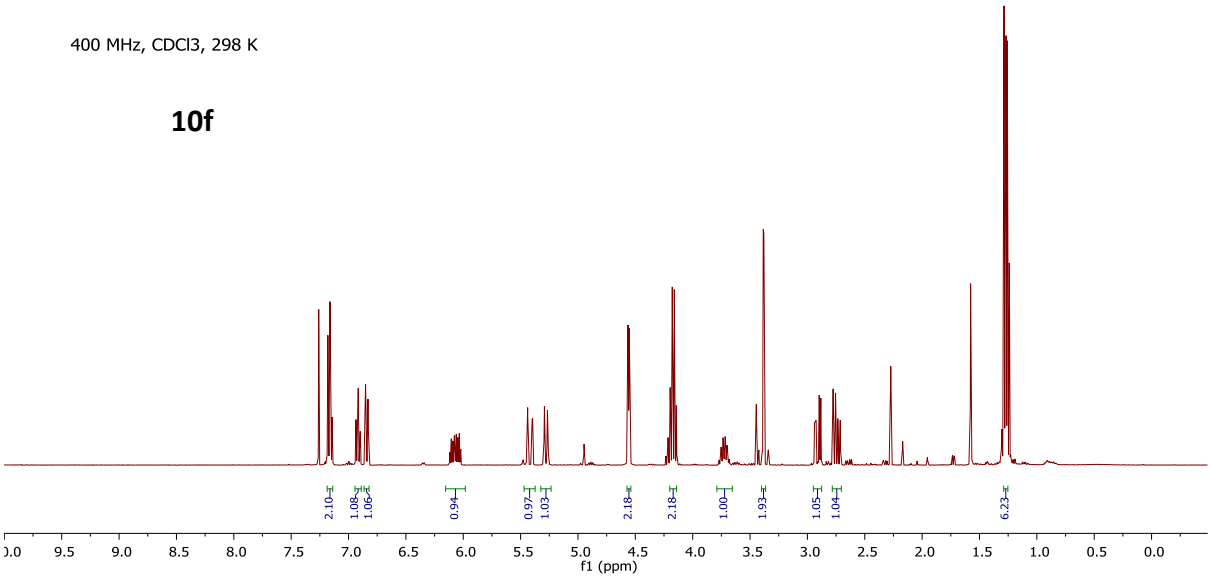
100 MHz, CDCl3, 298 K

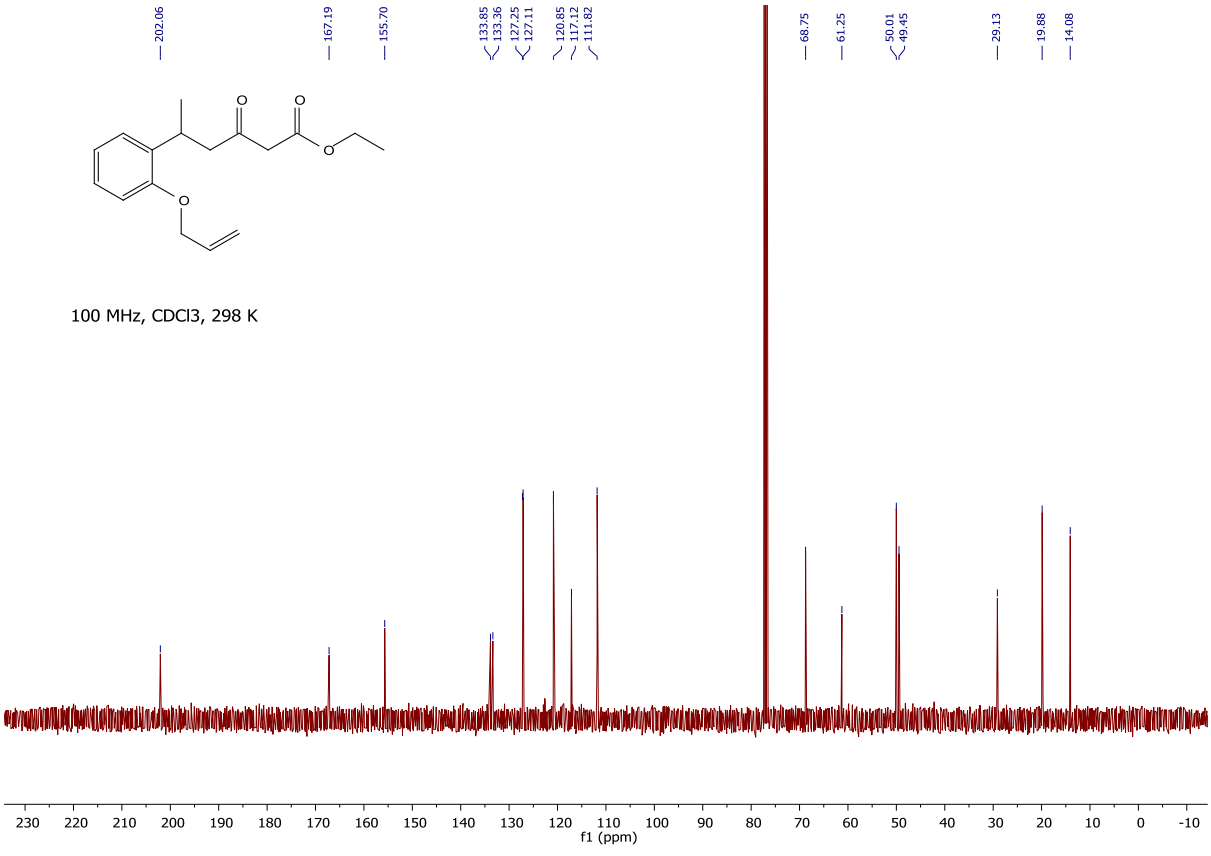




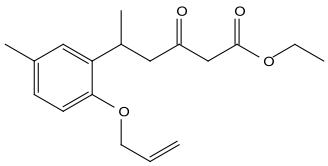
400 MHz, CDCl3, 298 K

10f



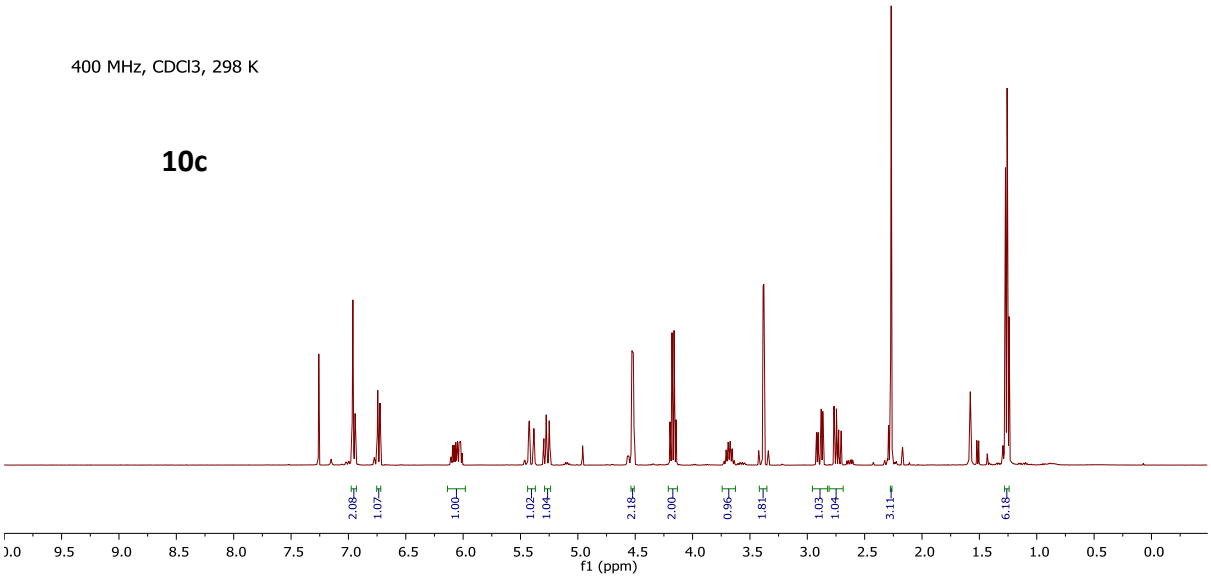


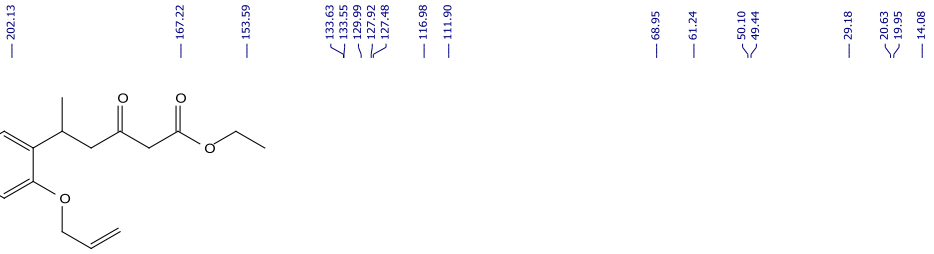
100 MHz, CDCl3, 298 K



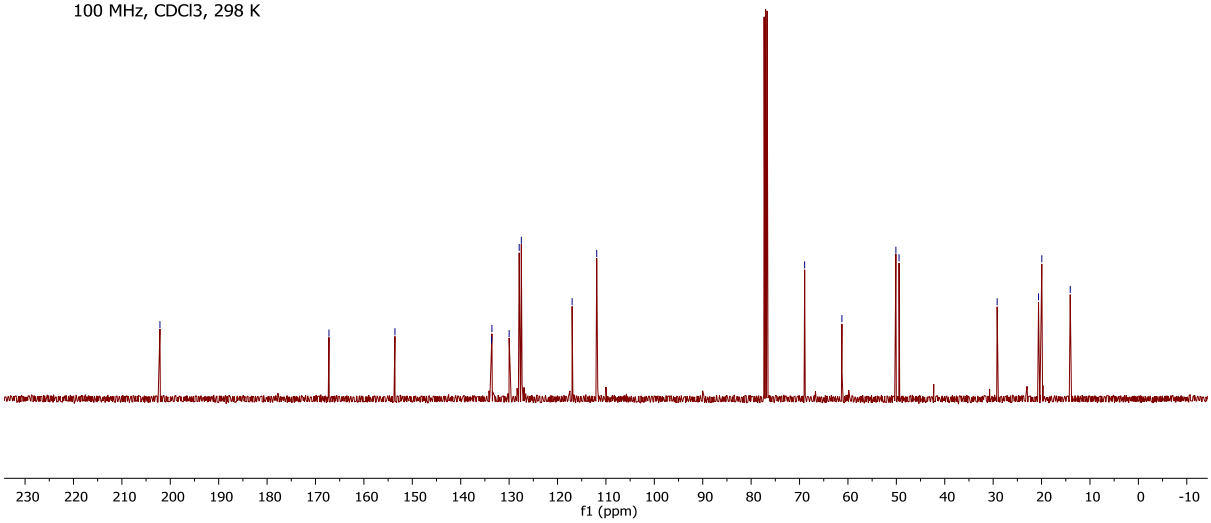
400 MHz, CDCl3, 298 K

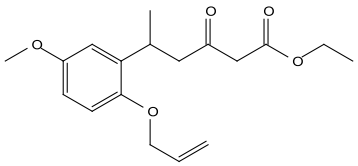
10c





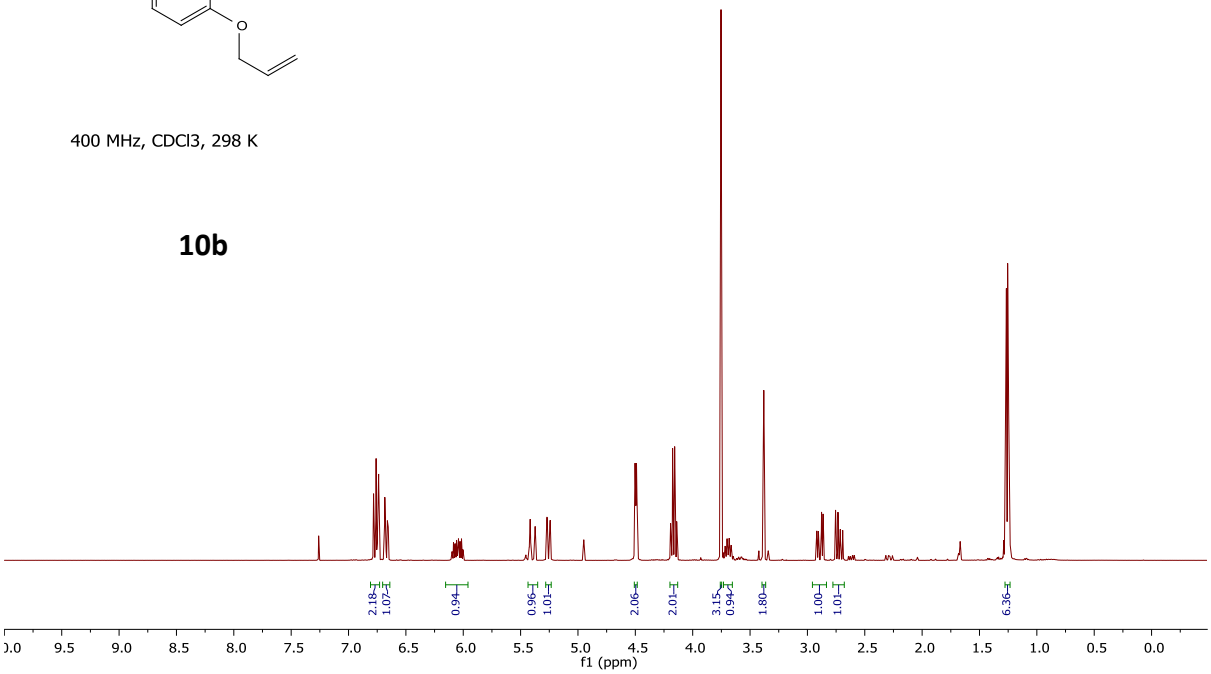
100 MHz, CDCl3, 298 K

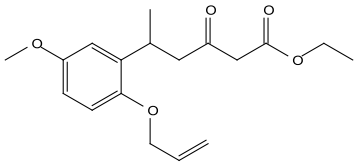




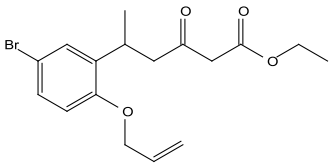
400 MHz, CDCl3, 298 K

10b



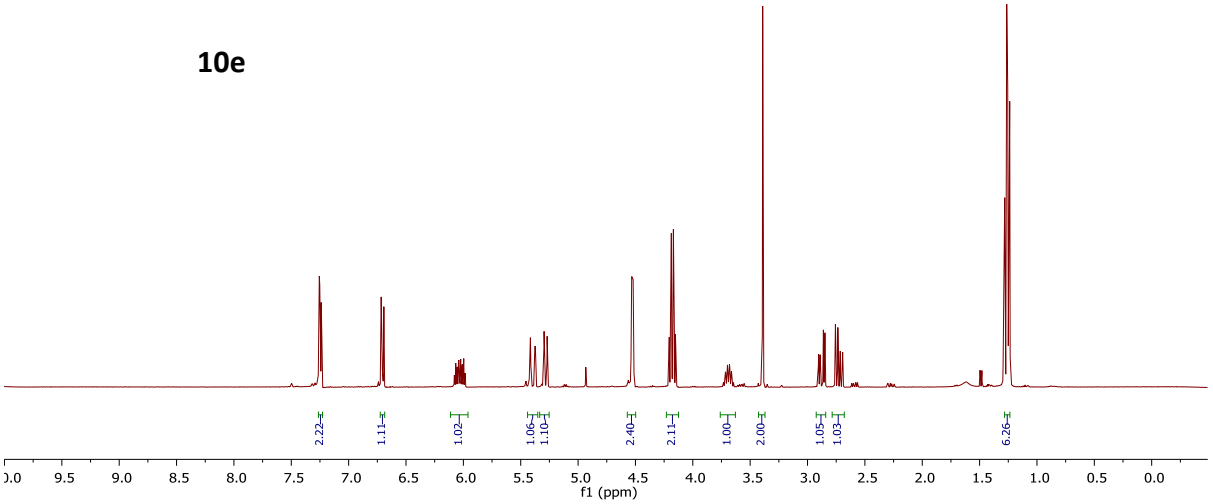


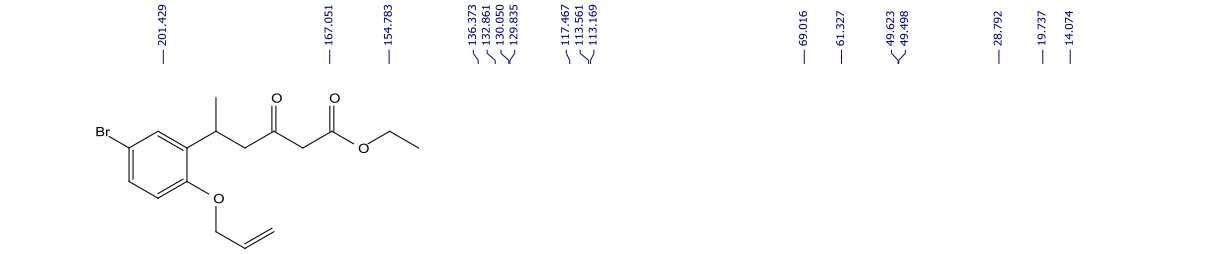
100 MHz, CDCl3, 298 K



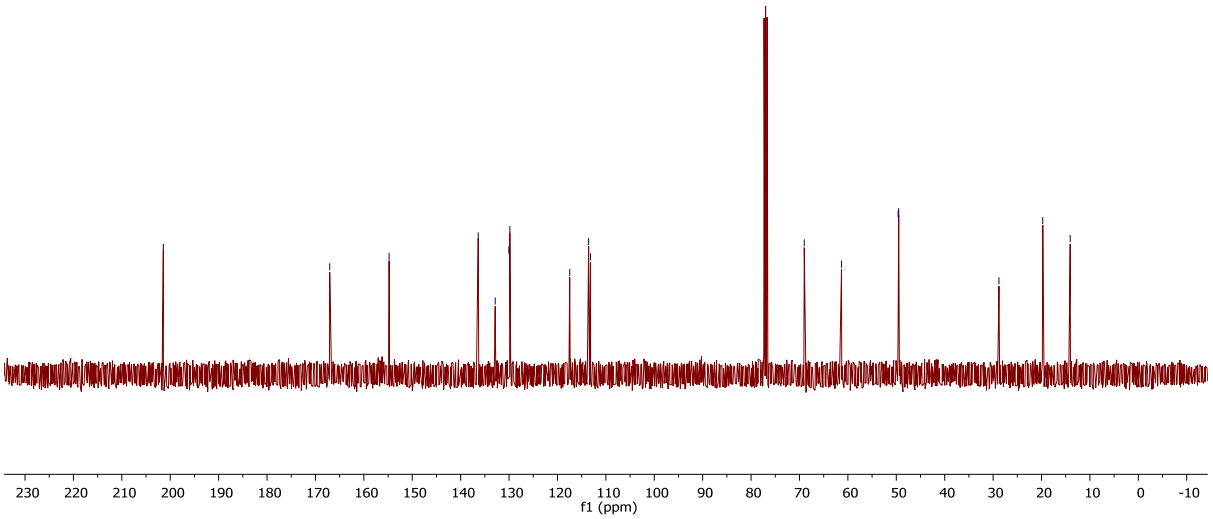
400 MHz, CDCl3, 298 K

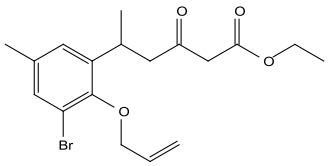
10e





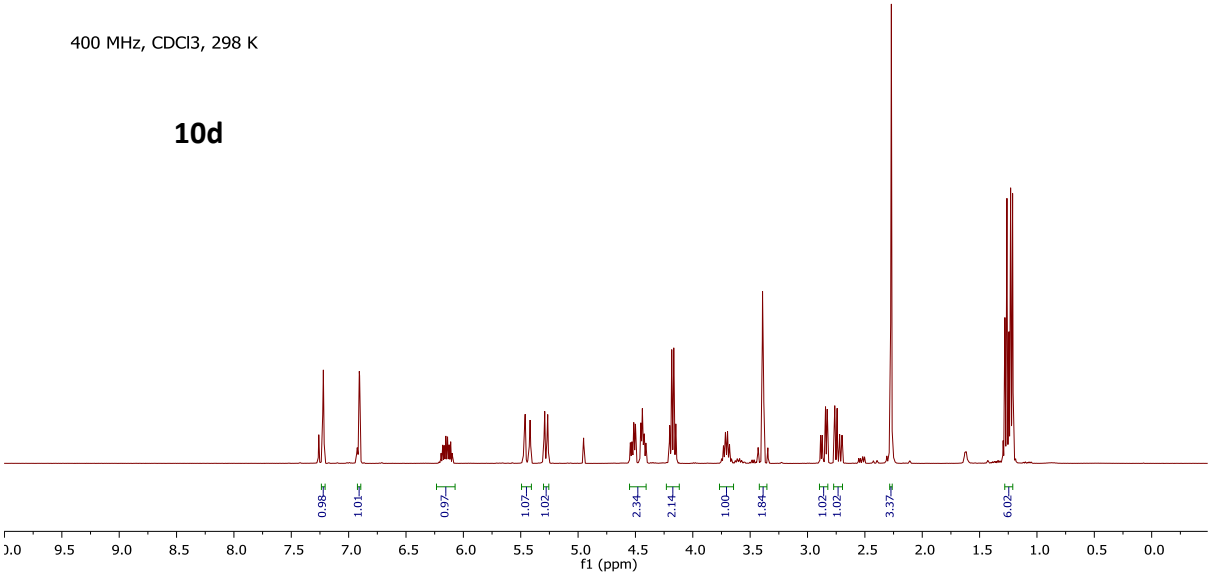
100 MHz, CDCl3, 298 K

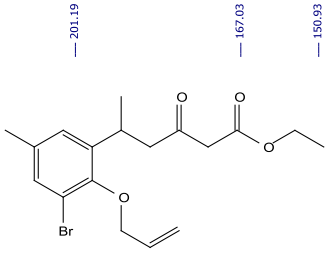




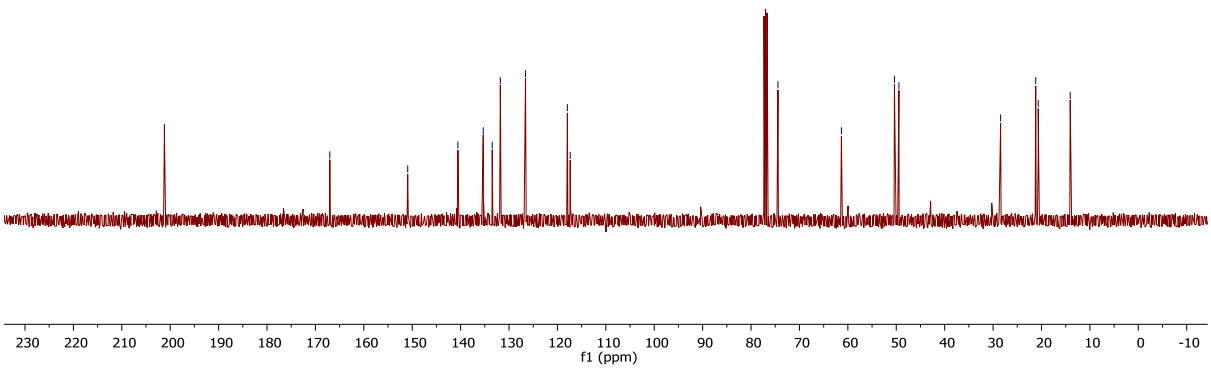
400 MHz, CDCl3, 298 K

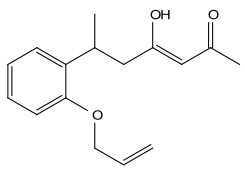
10d



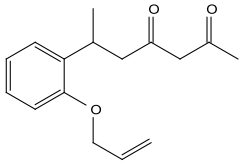


100 MHz, CDCl3, 298 K





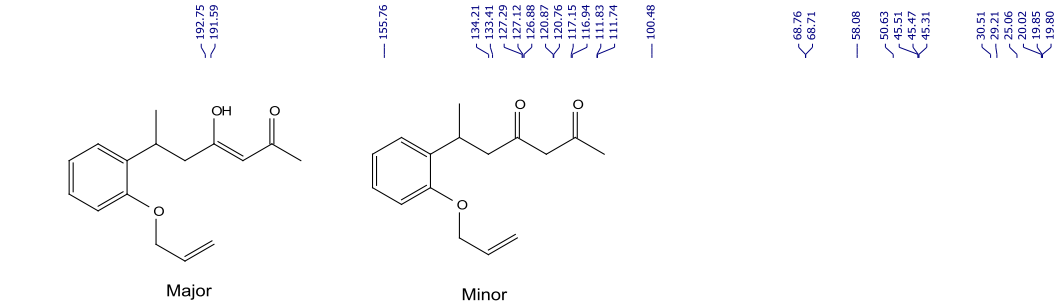
Major



Minor

400 MHz, CDCl3, 298 K

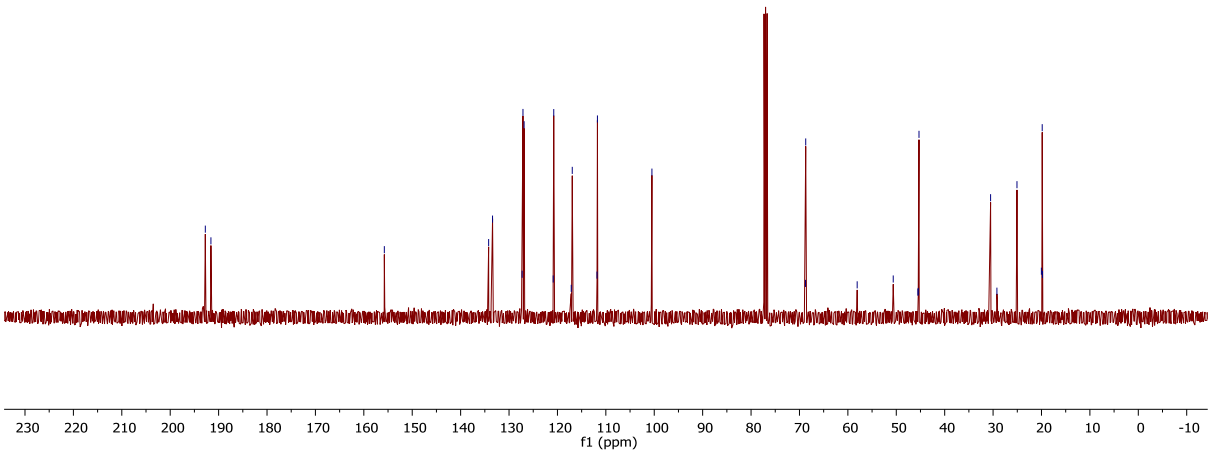
10g

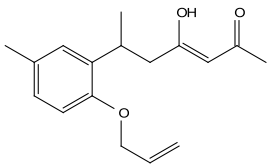


Major

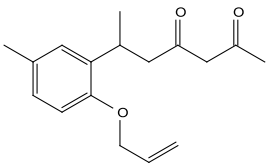
Minor

100 MHz, CDCl3, 298 K





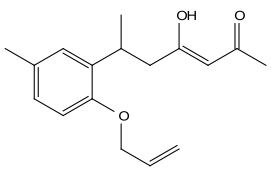
Major



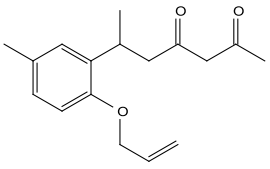
Minor

400 MHz, CDCl3, 298 K

10k

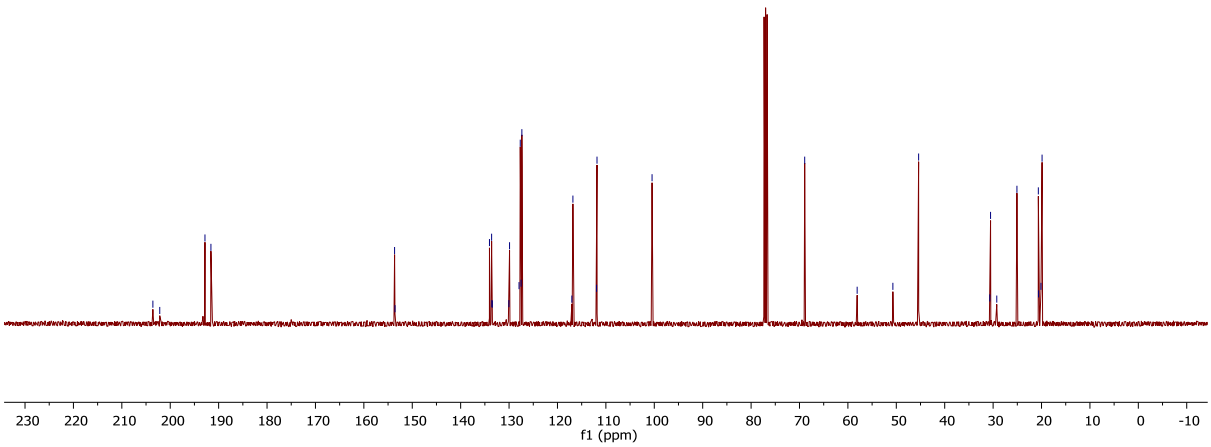


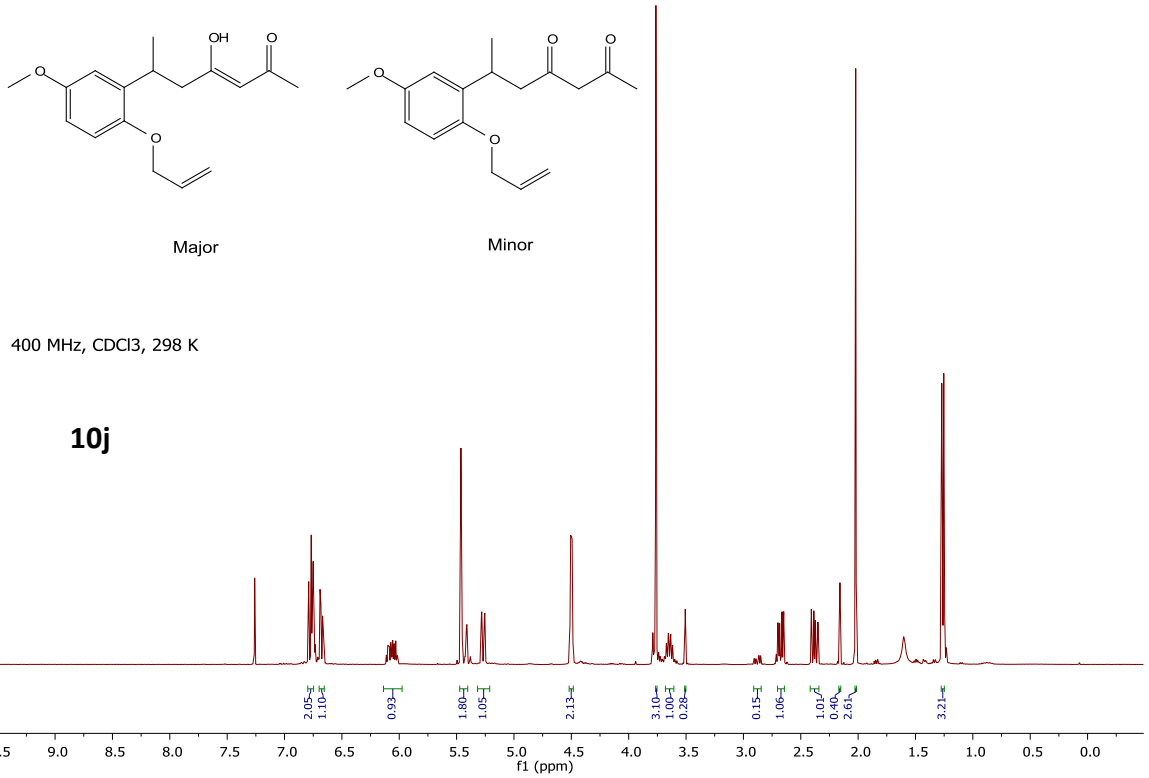
Major

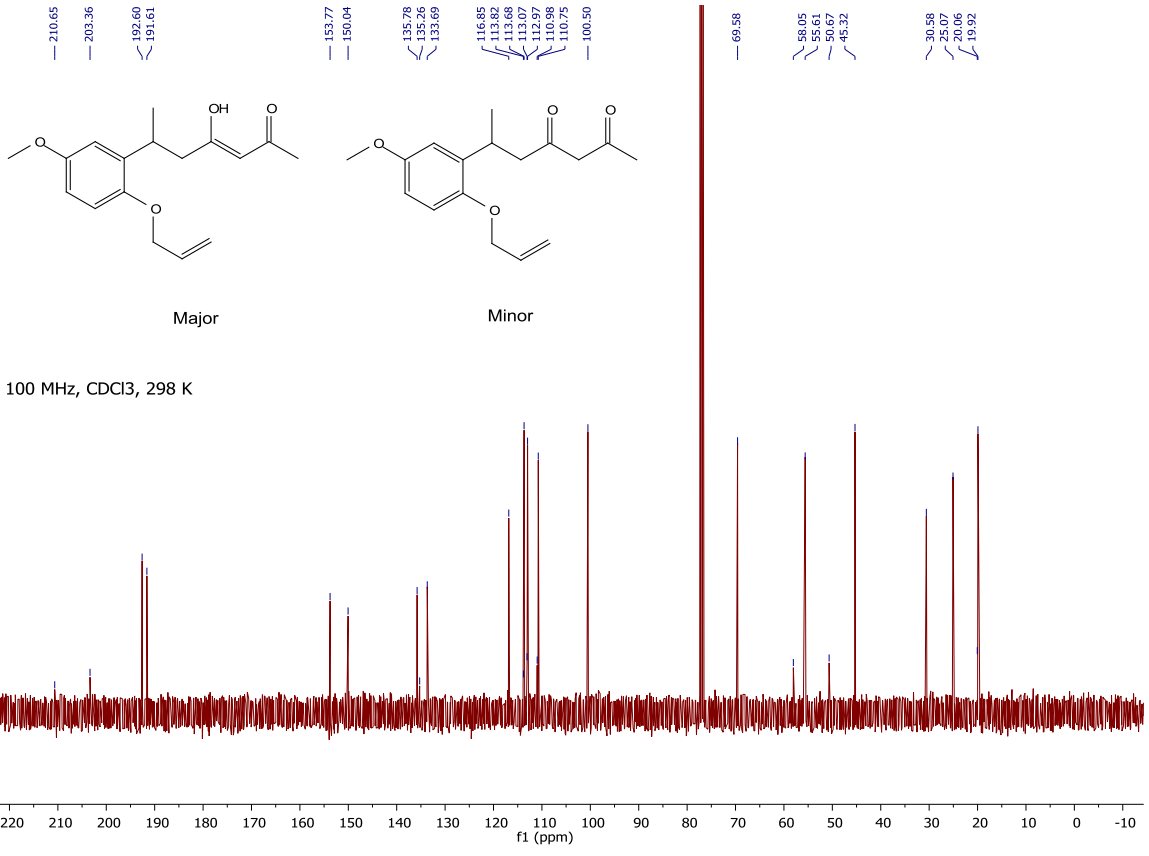


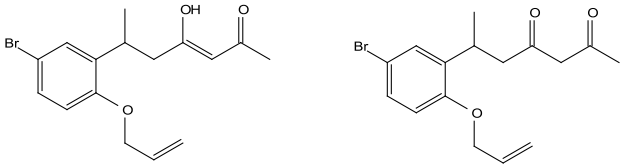
Minor

100 MHz, CDCl3, 298 K




OH
O
O
O
O
O
O
O
Major
Minor
400 MHz, CDCl3, 298 K
10j
2.05
1.10
0.93
1.80
1.05
2.13
3.10
1.00
0.28
0.15
1.06
1.01
0.40
2.61
3.21
f1 (ppm)


210.65
203.36
192.60
191.61
153.77
150.04
135.78
135.26
133.69
116.85
113.82
113.68
113.07
112.97
110.98
110.75
100.50
69.58
58.05
55.61
50.67
45.32
30.58
25.07
20.06
19.92
OH
O
O
O
O
O
O
Major
Minor
100 MHz, CDCl3, 298 K
f1 (ppm)

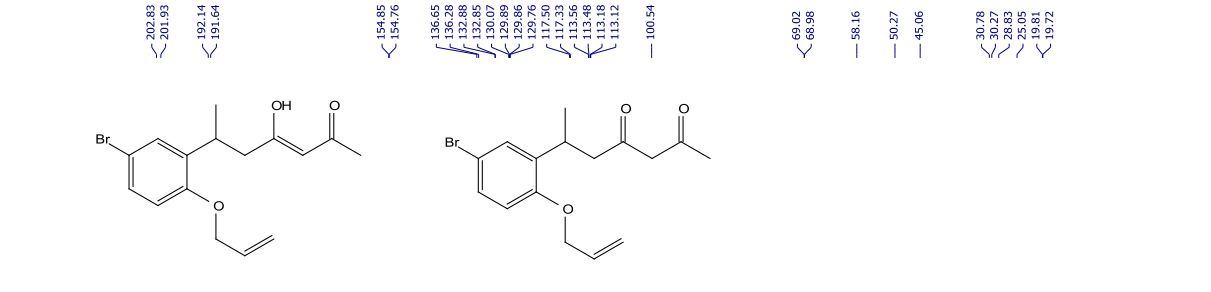


Major

Minor

400 MHz, CDCl3, 298 K

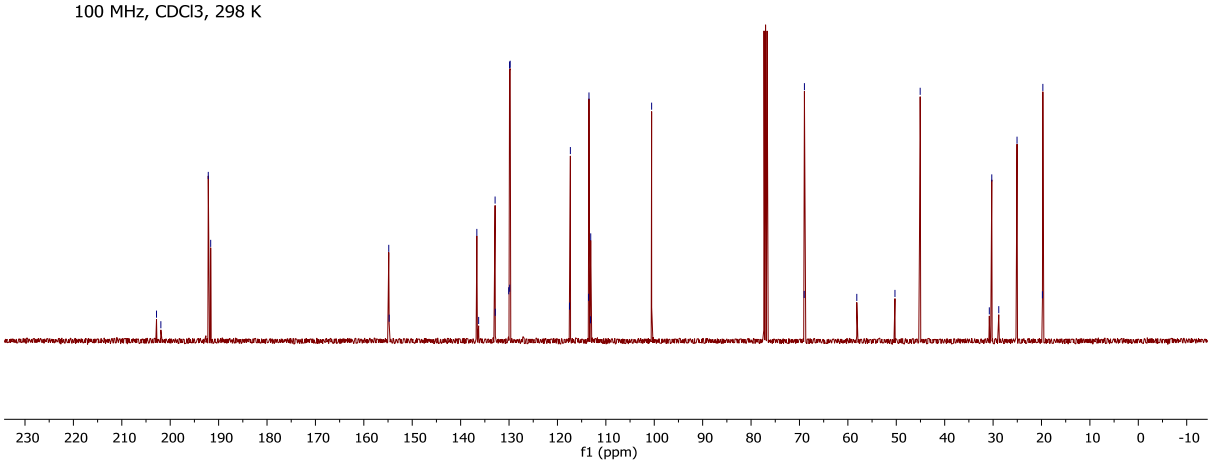
10i

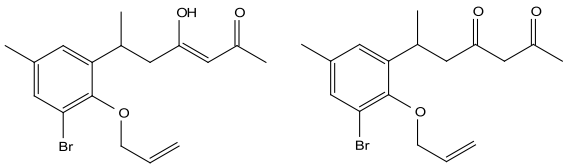


Major

Minor

100 MHz, CDCl3, 298 K



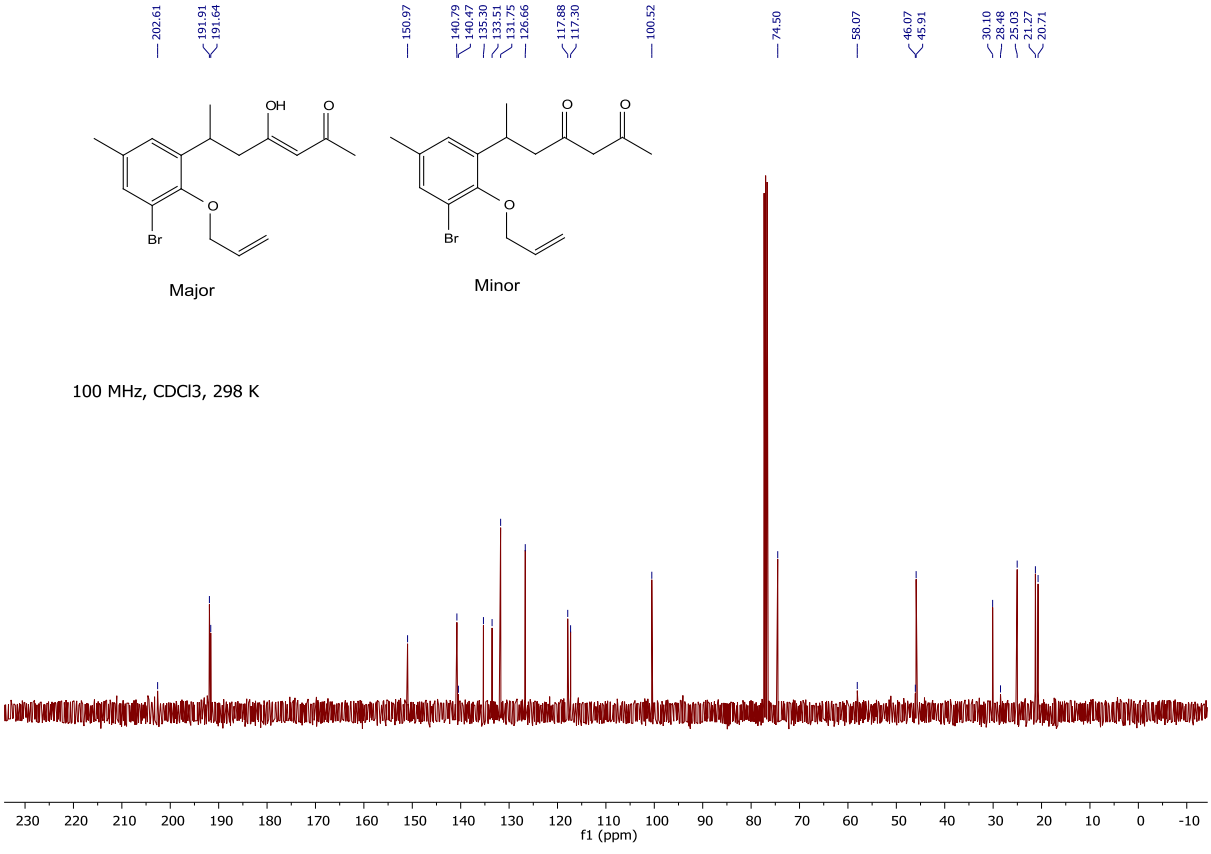


Major

Minor

400 MHz, CDCl3, 298 K

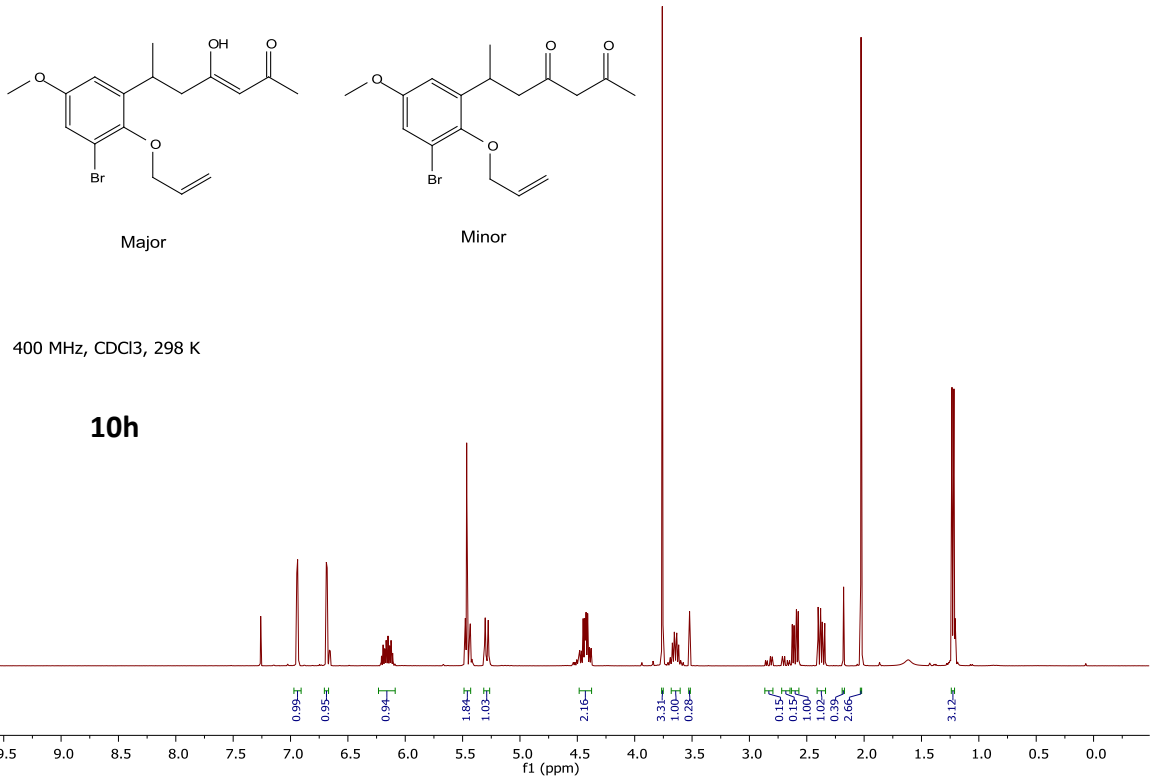
10l

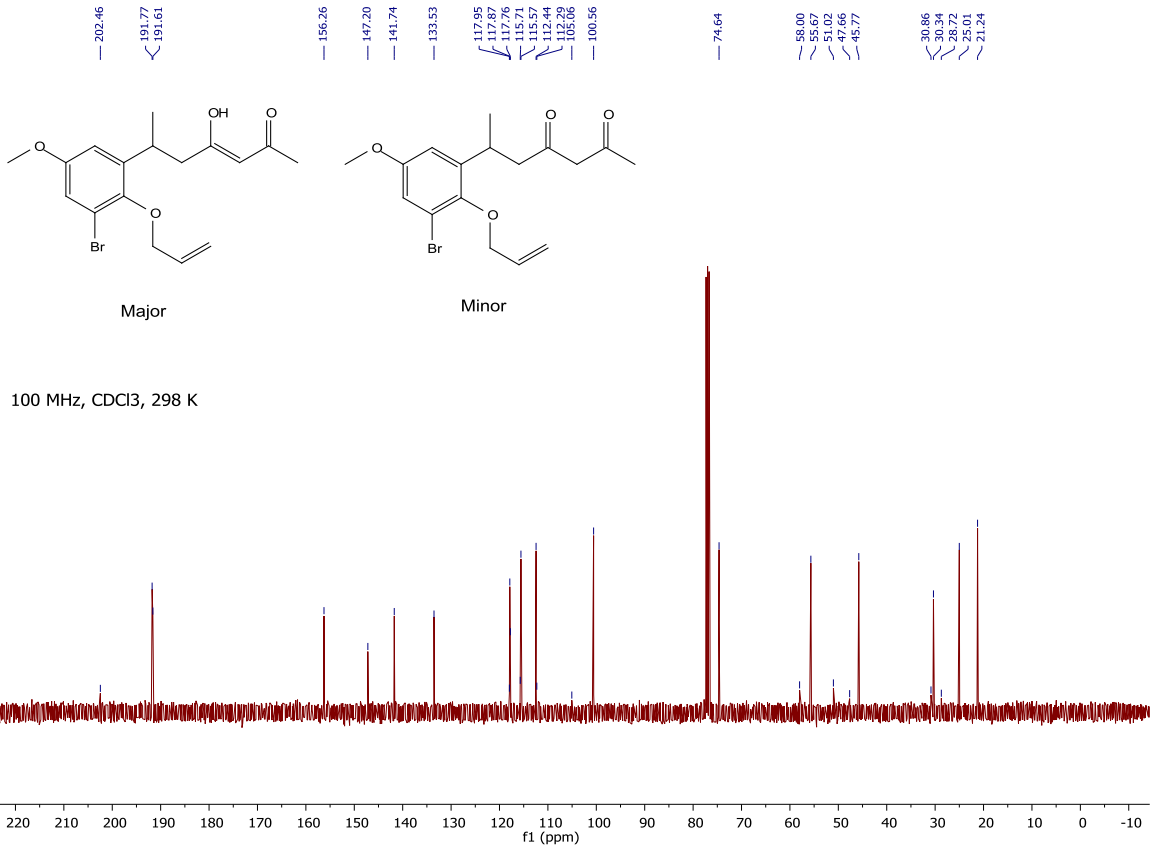


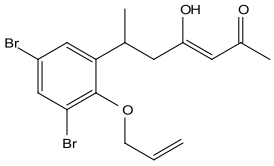
Major

Minor

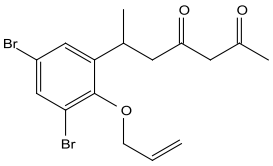
100 MHz, CDCl3, 298 K


OH
O
O
Br
Major
O
O
O
Br
Minor
400 MHz, CDCl3, 298 K
10h
0.99
0.95
0.94
1.84
1.03
2.16
3.31
1.00
0.28
0.15
0.15
1.00
1.02
0.39
2.66
3.12
f1 (ppm)


202.46
191.77
191.61
156.26
147.20
141.74
133.53
117.95
117.87
117.76
115.71
115.57
112.44
112.29
105.06
100.56
74.64
58.00
55.67
51.02
47.66
45.77
30.86
30.34
28.72
25.01
21.24
OH
O
O
Br
Major
O
O
O
Br
Minor
100 MHz, CDCl3, 298 K
f1 (ppm)



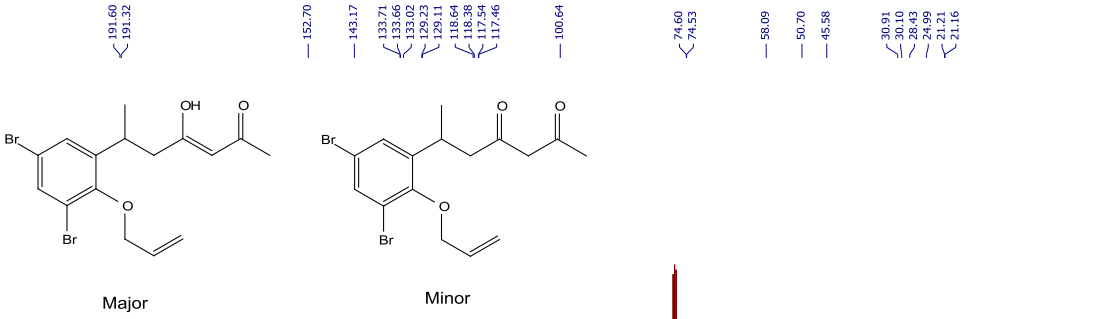
Major



Minor

400 MHz, CDCl3, 298 K

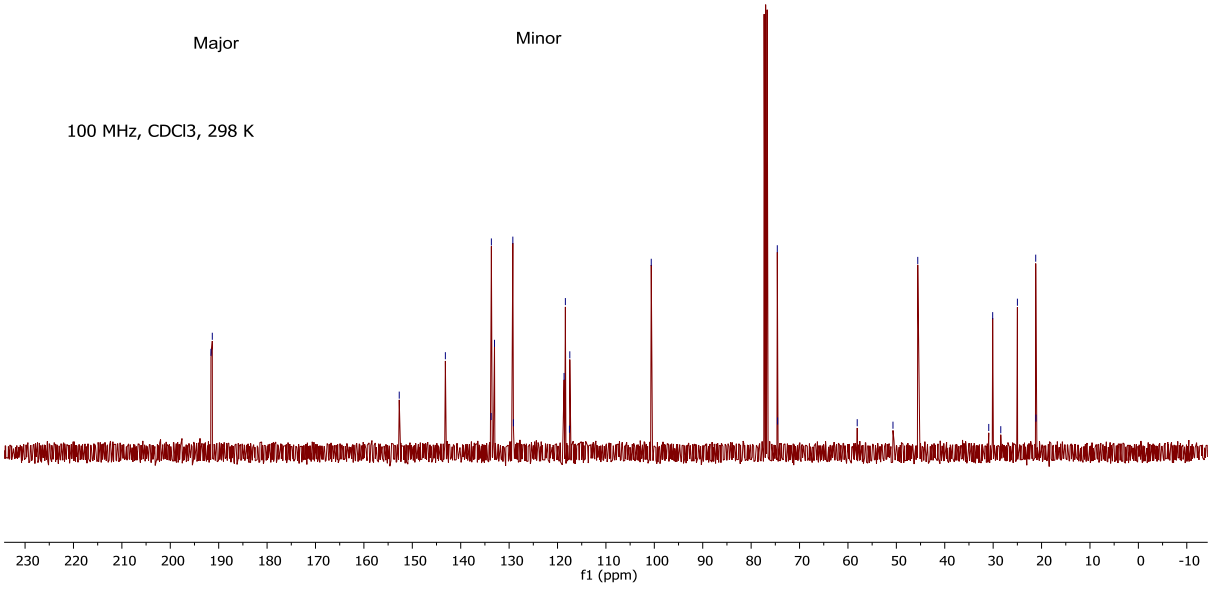
10m

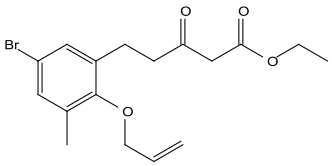


Major

Minor

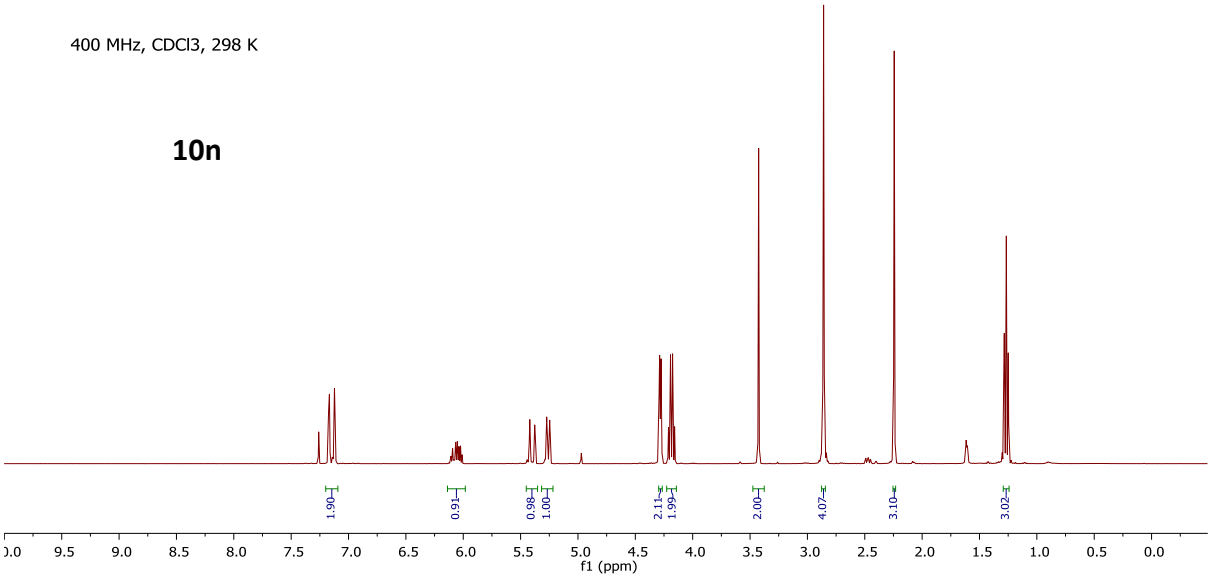
100 MHz, CDCl3, 298 K

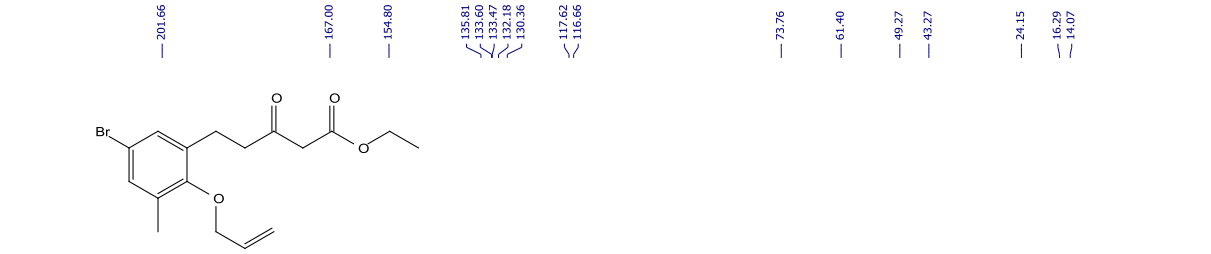




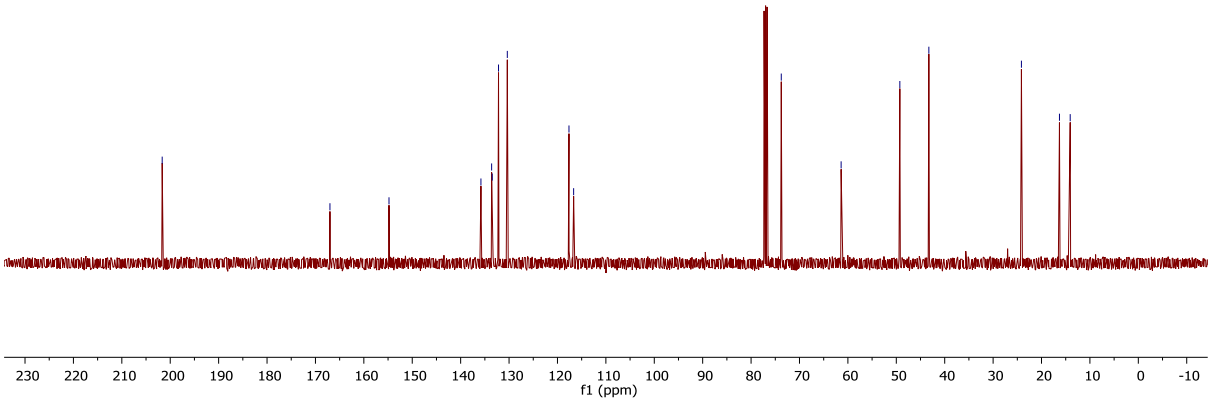
400 MHz, CDCl3, 298 K

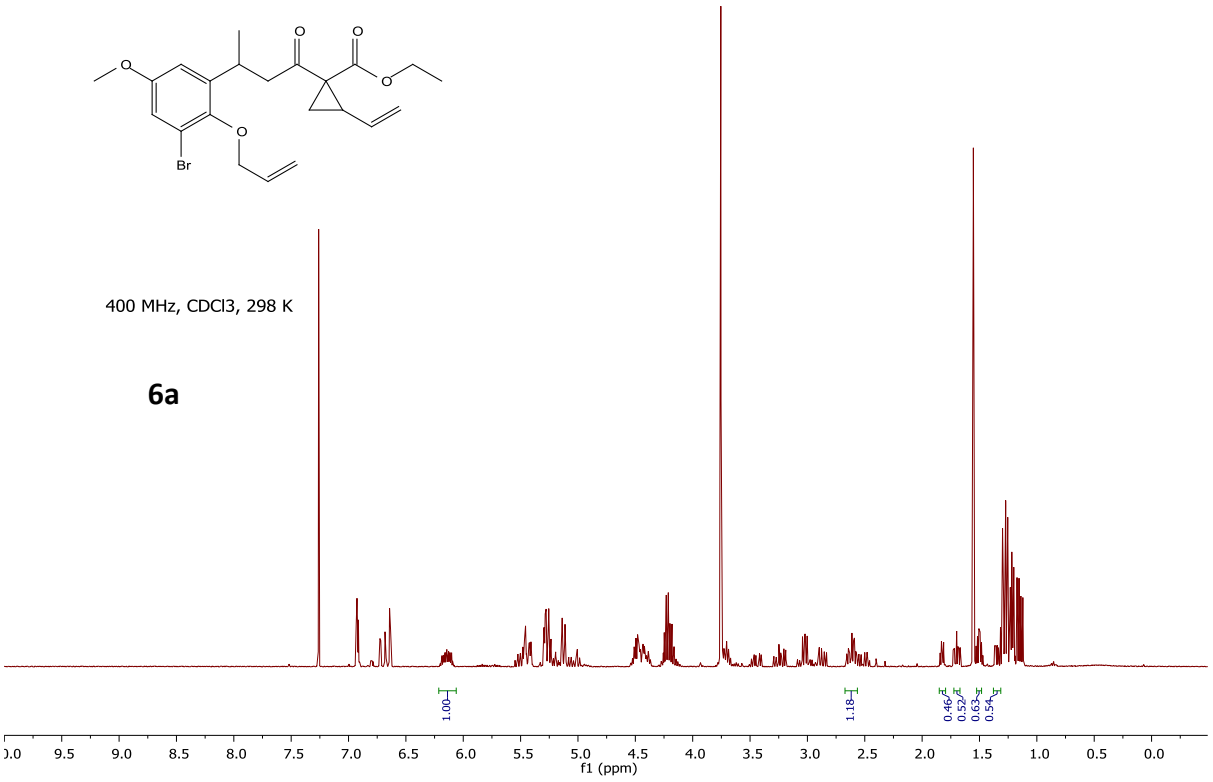
10n

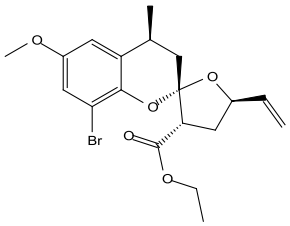




100 MHz, CDCl3, 298 K

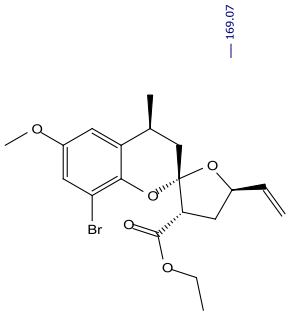



400 MHz, CDCl3, 298 K
6a
1.00
1.18
0.46
0.52
0.63
0.54
f1 (ppm)

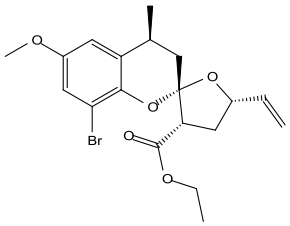


400 MHz, CDCl3, 298 K

8a$_i$

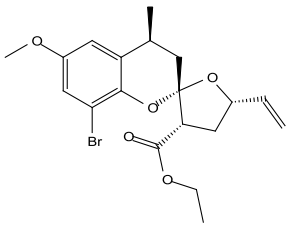


100 MHz, CDCl3, 298 K

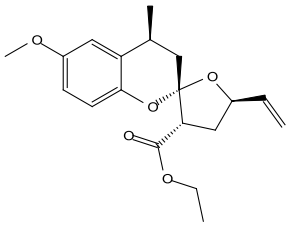


400 MHz, CDCl3, 298 K

8a$_{ii}$

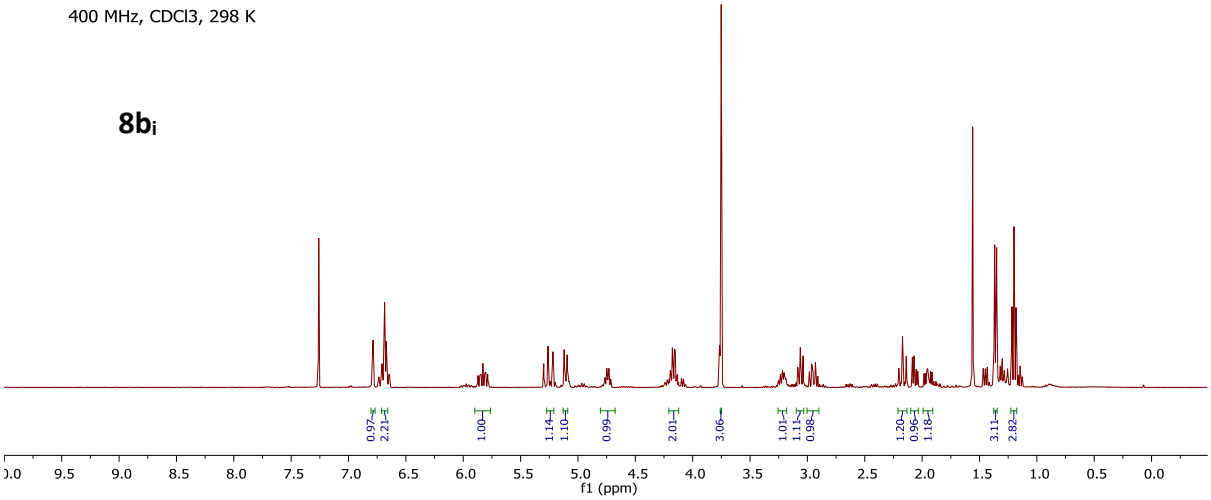


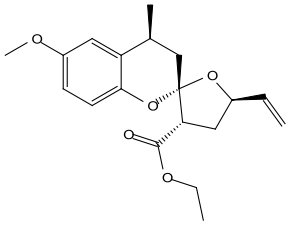
100 MHz, CDCl3, 298 K



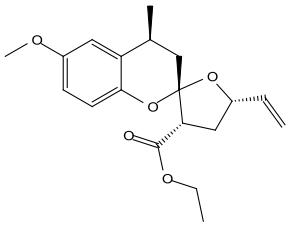
400 MHz, CDCl3, 298 K

8b$_i$



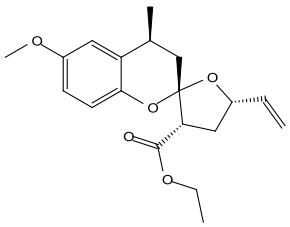


100 MHz, CDCl3, 298 K

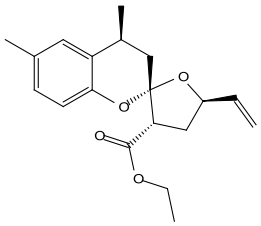


400 MHz, CDCl3, 298 K

8b$_{ii}$

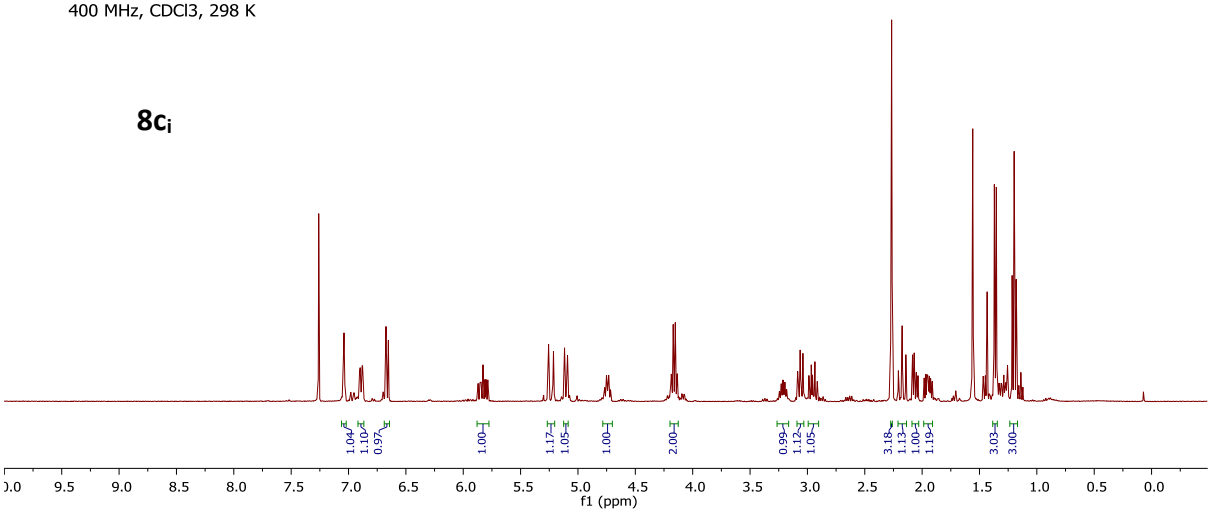


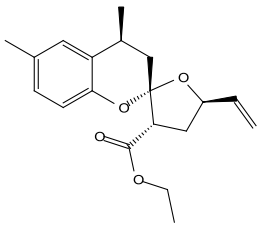
100 MHz, CDCl3, 298 K



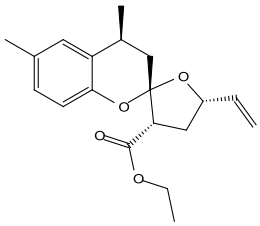
400 MHz, CDCl3, 298 K

8c$_i$



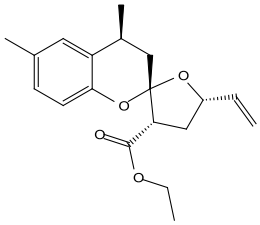


100 MHz, CDCl3, 298 K

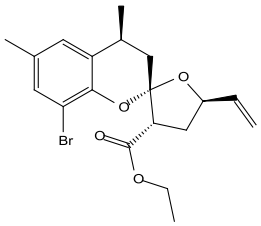


400 MHz, CDCl3, 298 K

8c$_{ii}$

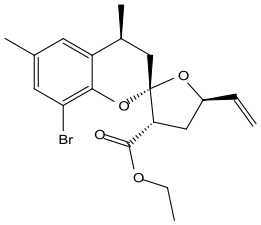


100 MHz, CDCl3, 298 K

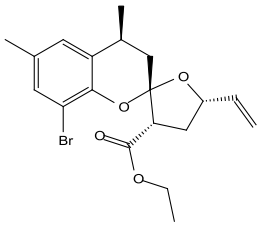


400 MHz, CDCl3, 298 K

8d$_i$

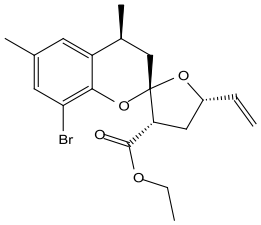


100 MHz, CDCl3, 298 K

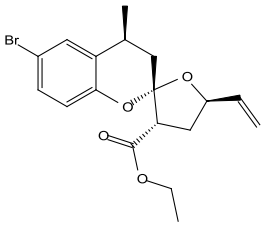


400 MHz, CDCl3, 298 K

8d$_{ii}$

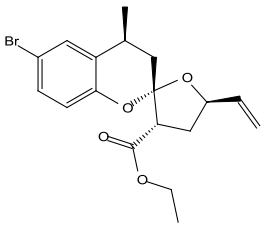


100 MHz, CDCl3, 298 K

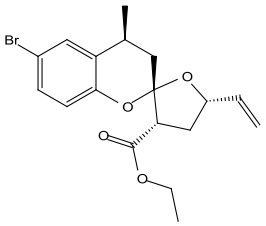


400 MHz, CDCl3, 298 K

8e$_i$

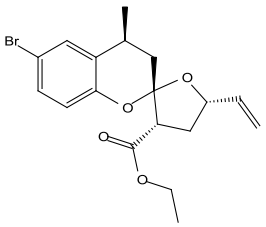


100 MHz, CDCl3, 298 K

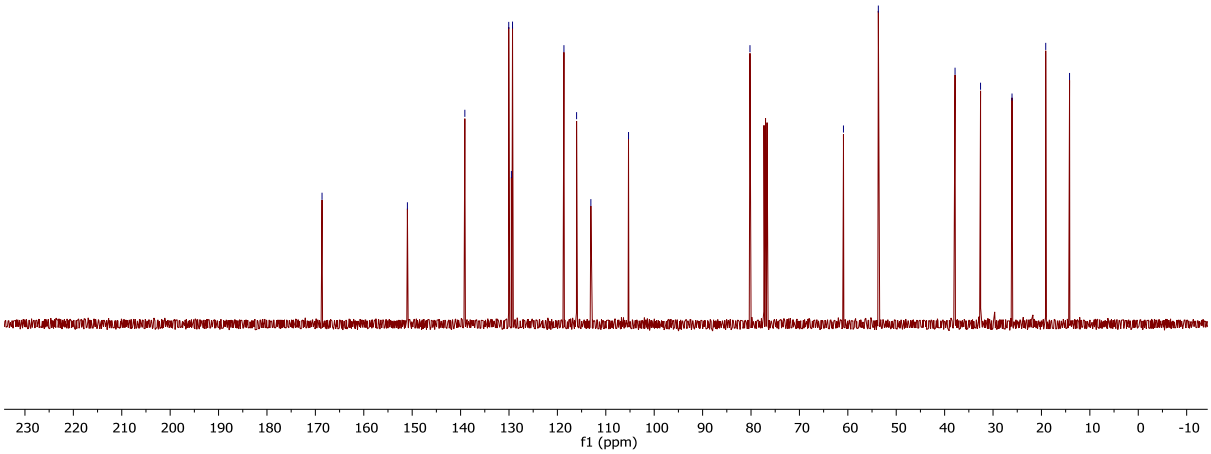


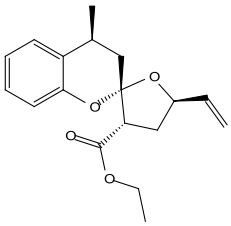
400 MHz, CDCl3, 298 K

8e$_{ii}$



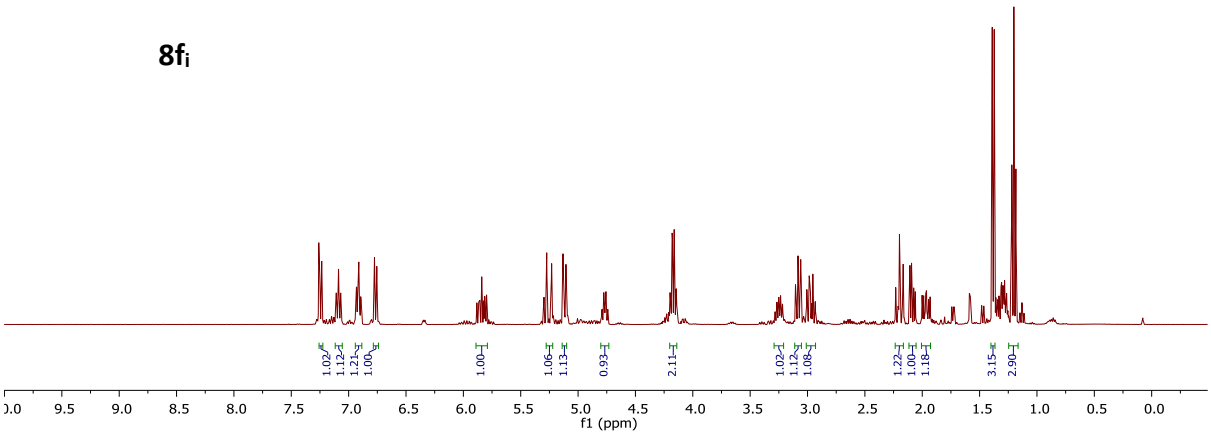
100 MHz, CDCl3, 298 K

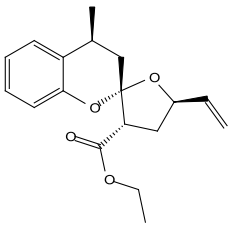




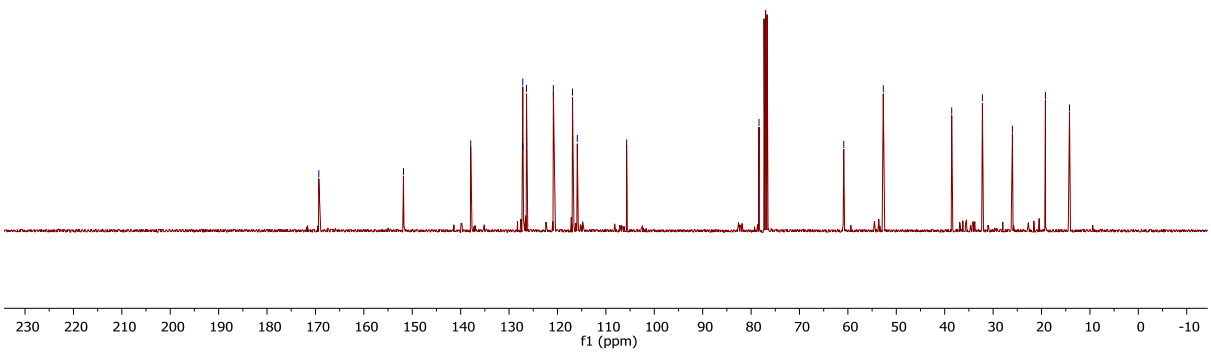
400 MHz, CDCl3, 298 K

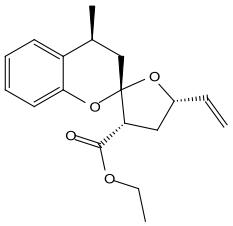
8f$_i$





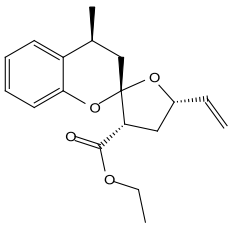
100 MHz, CDCl3, 298 K



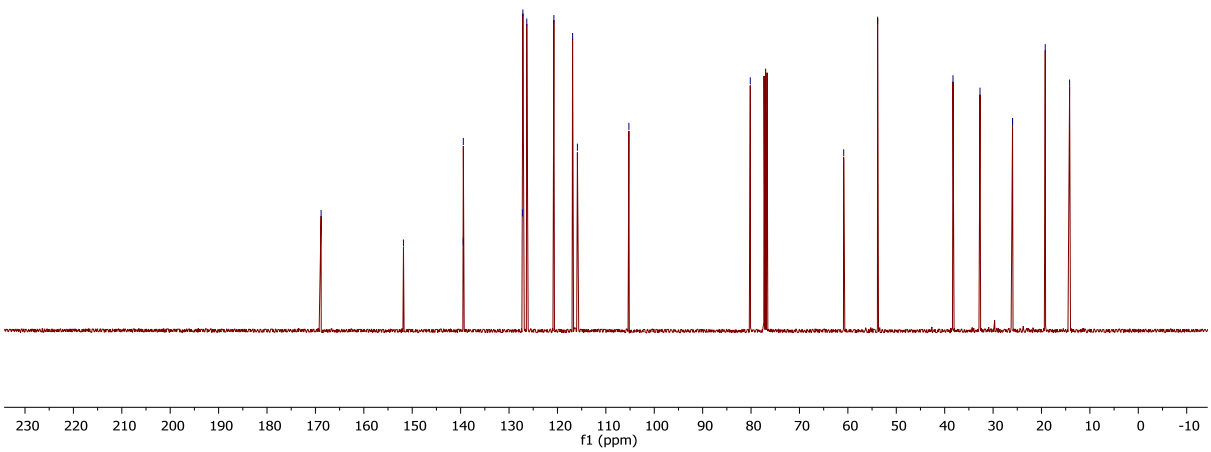


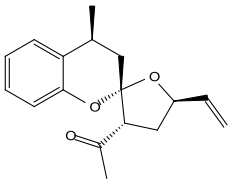
400 MHz, CDCl3, 298 K

8f$_{ii}$



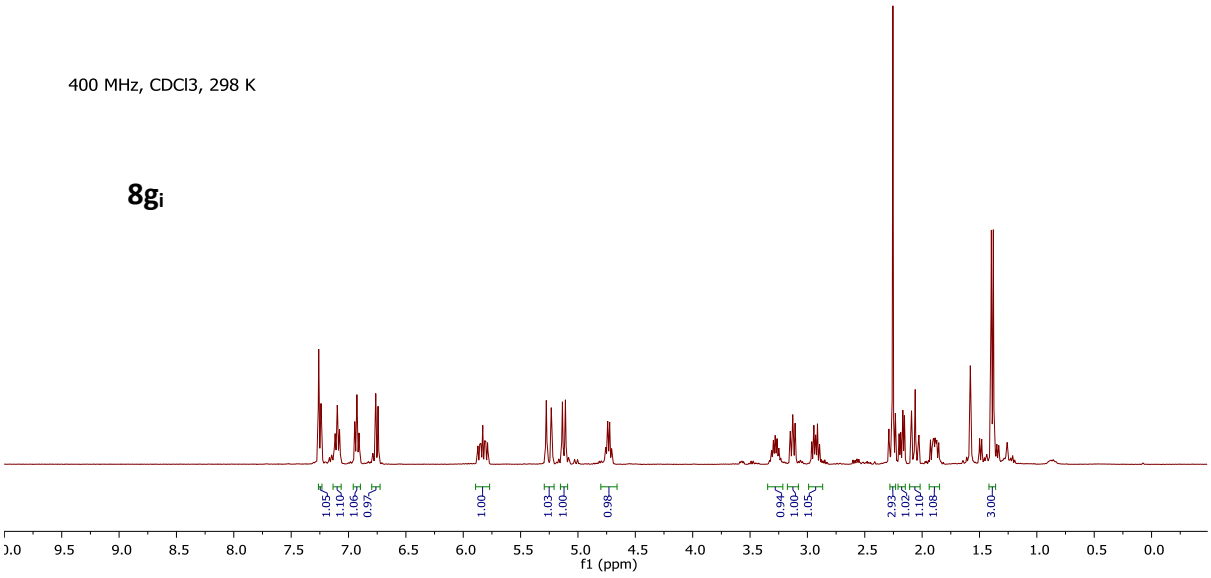
100 MHz, CDCl3, 298 K

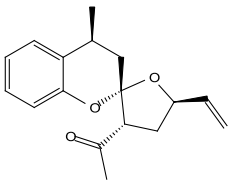




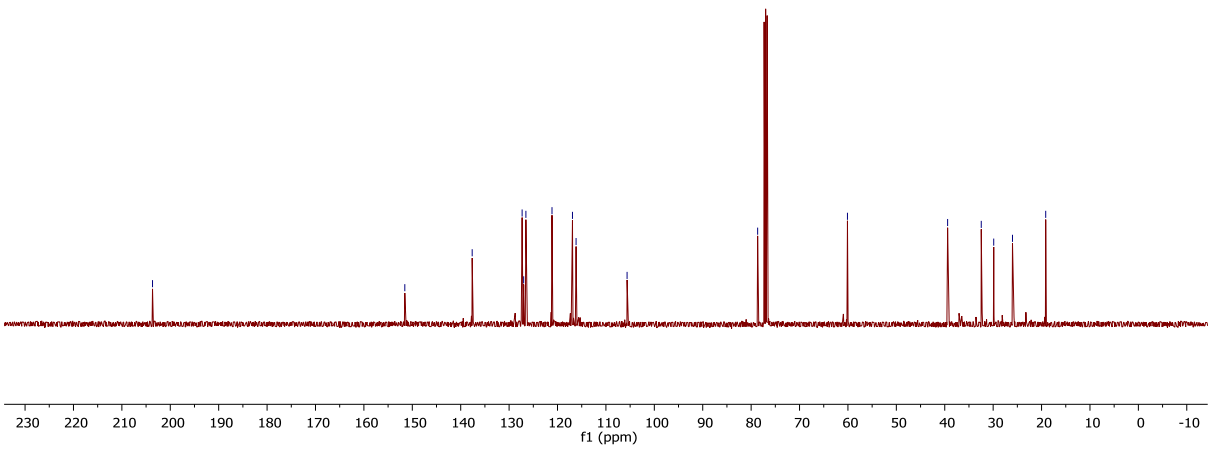
400 MHz, CDCl3, 298 K

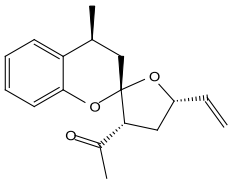
8g$_i$





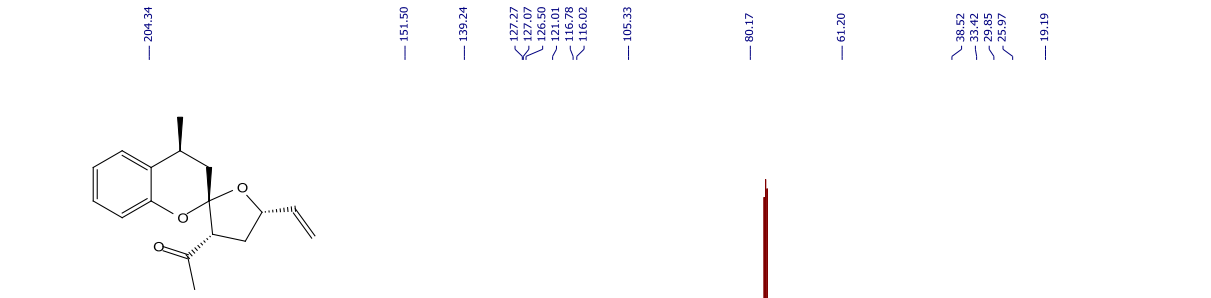
100 MHz, CDCl3, 298 K



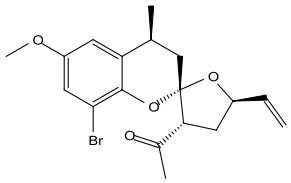


400 MHz, CDCl3, 298 K

8g$_{ii}$

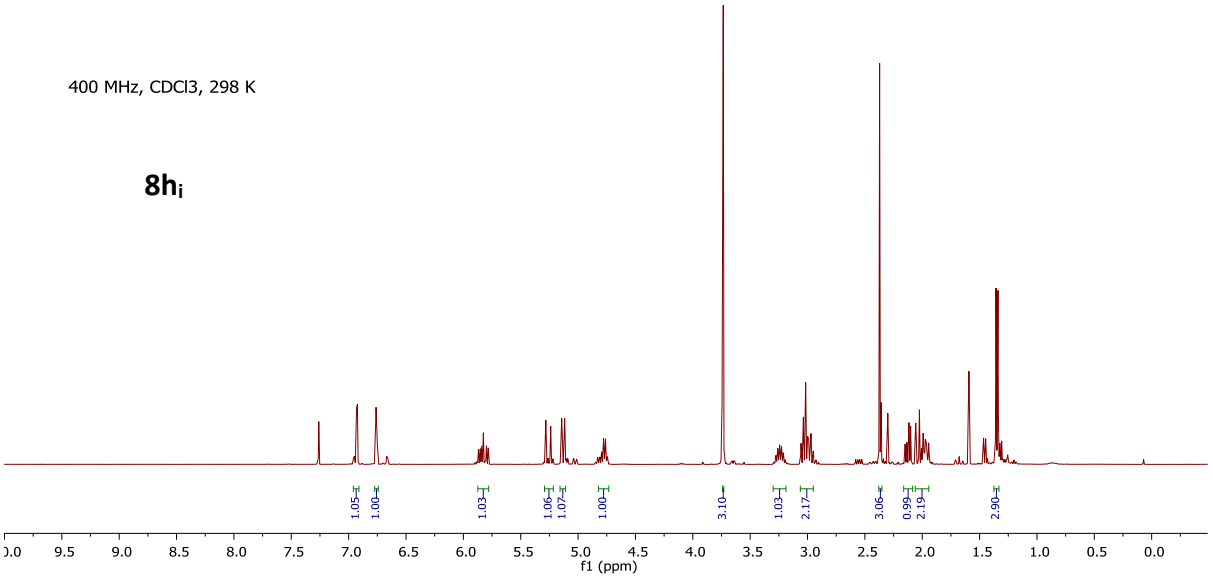


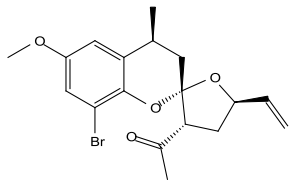
100 MHz, CDCl3, 298 K



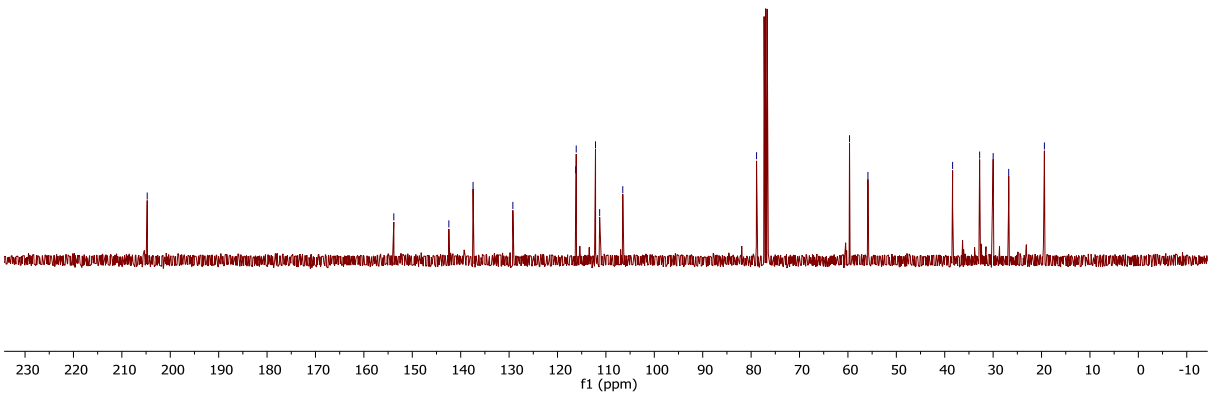
400 MHz, CDCl3, 298 K

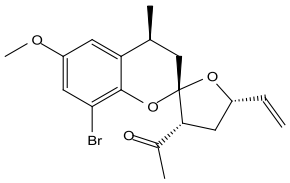
8h$_i$





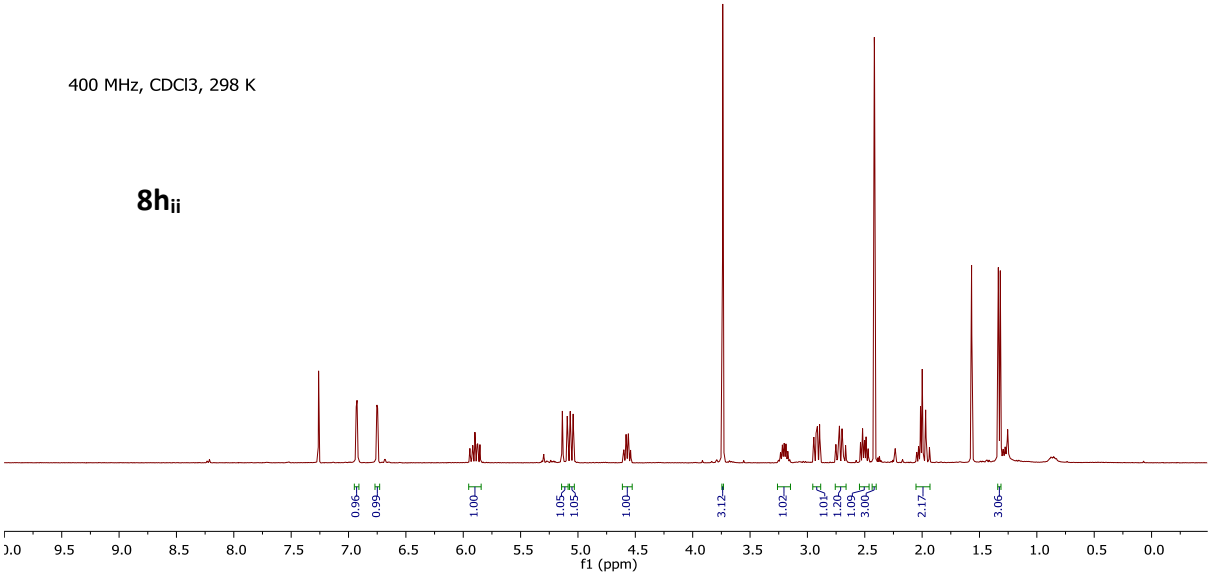
100 MHz, CDCl3, 298 K

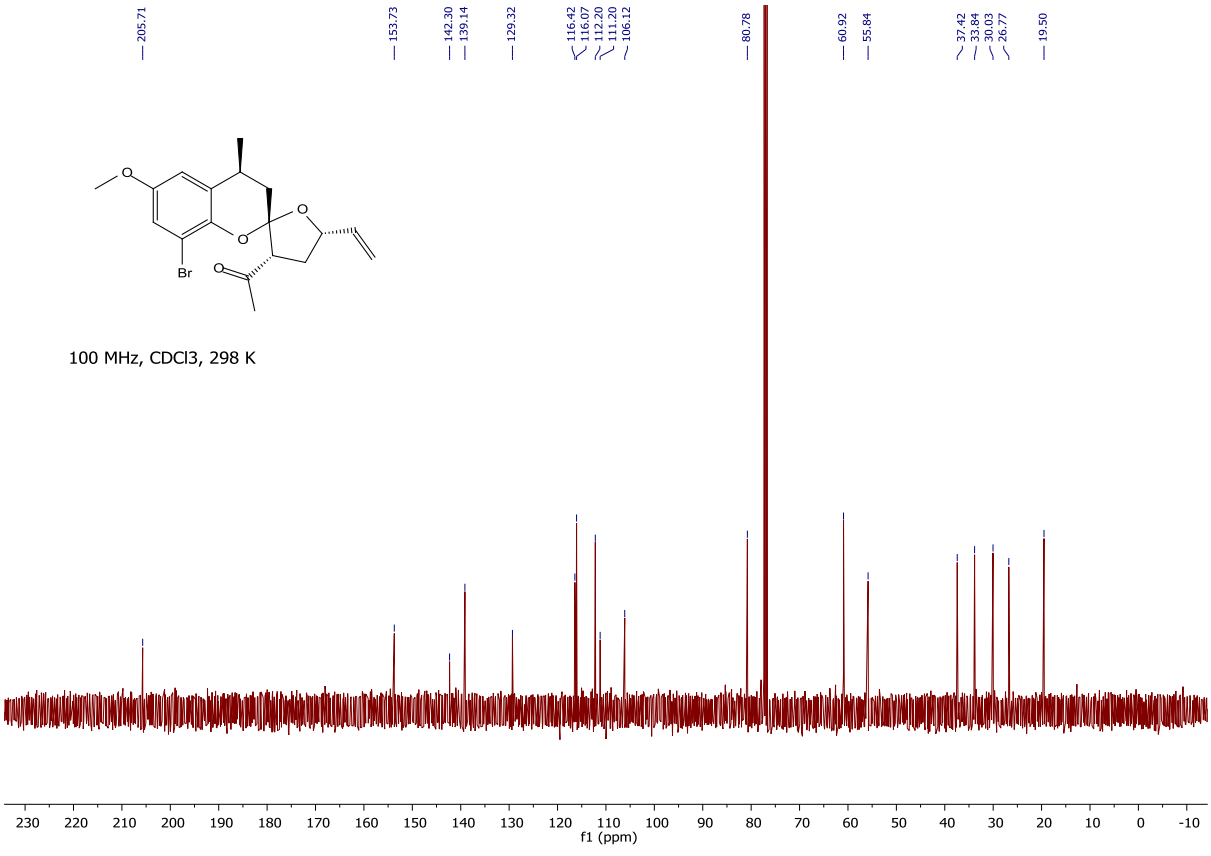




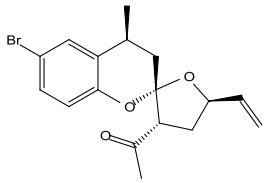
400 MHz, CDCl3, 298 K

8h$_{ii}$



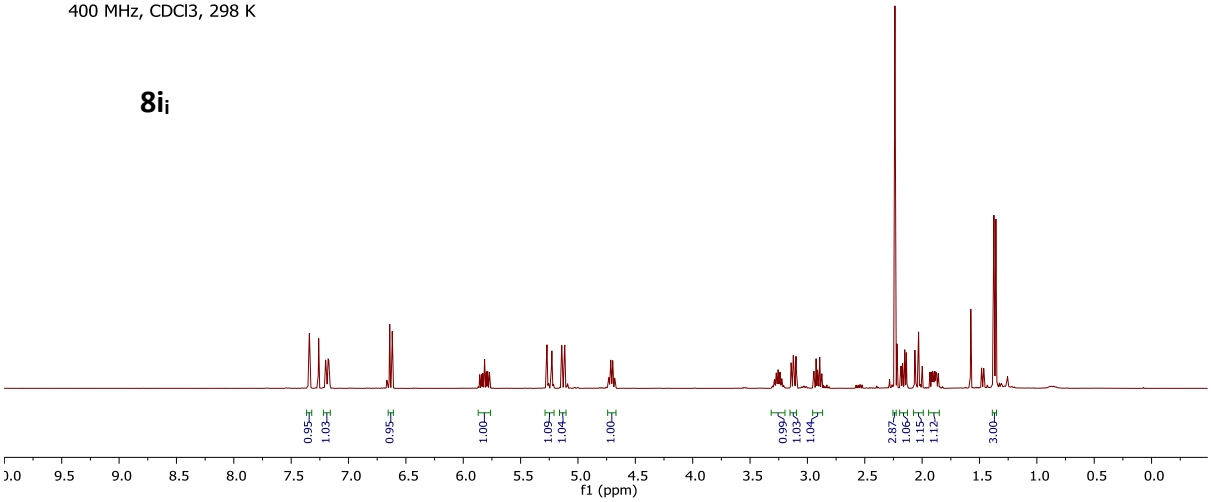


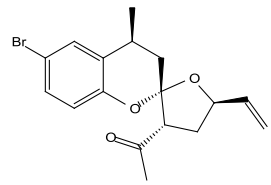
100 MHz, CDCl3, 298 K



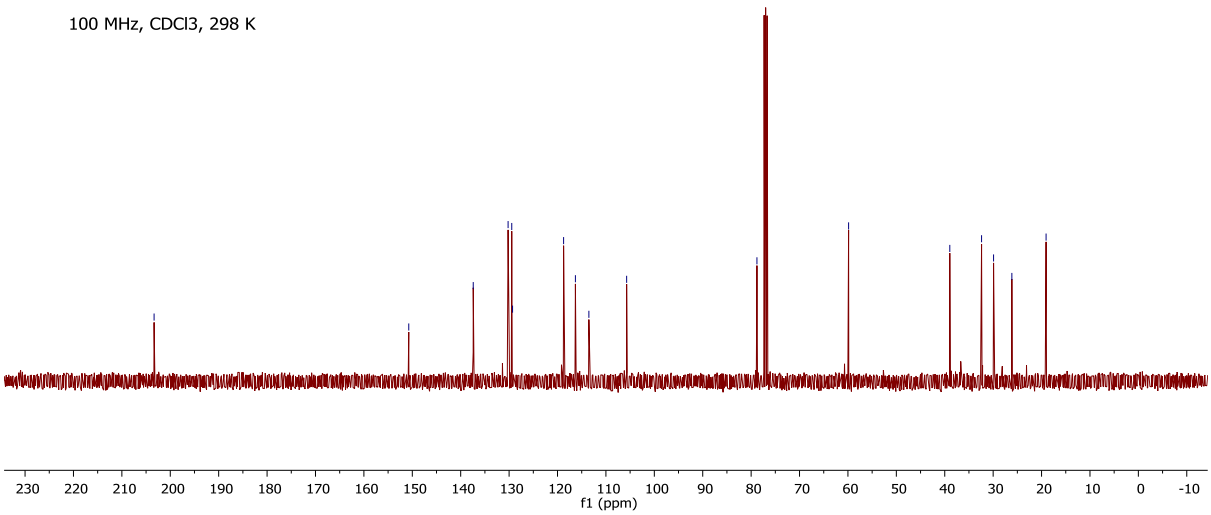
400 MHz, CDCl3, 298 K

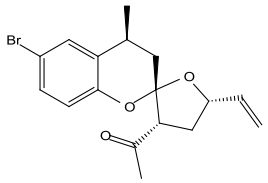
8i$_i$





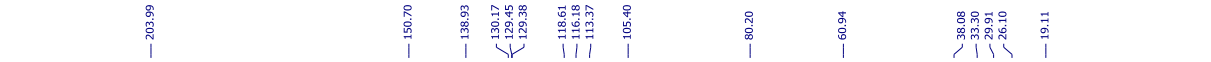
100 MHz, CDCl3, 298 K

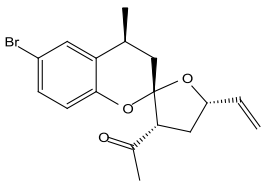




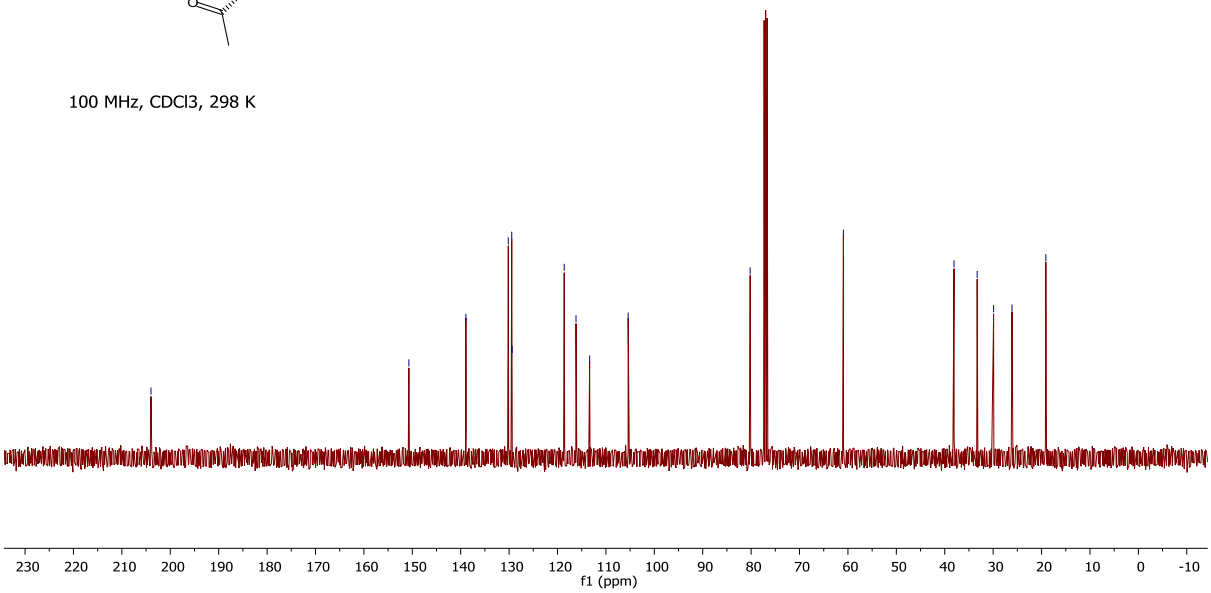
400 MHz, CDCl3, 298 K

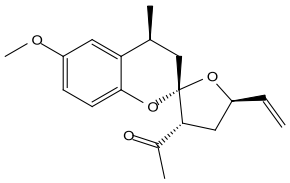
8i$_{ii}$





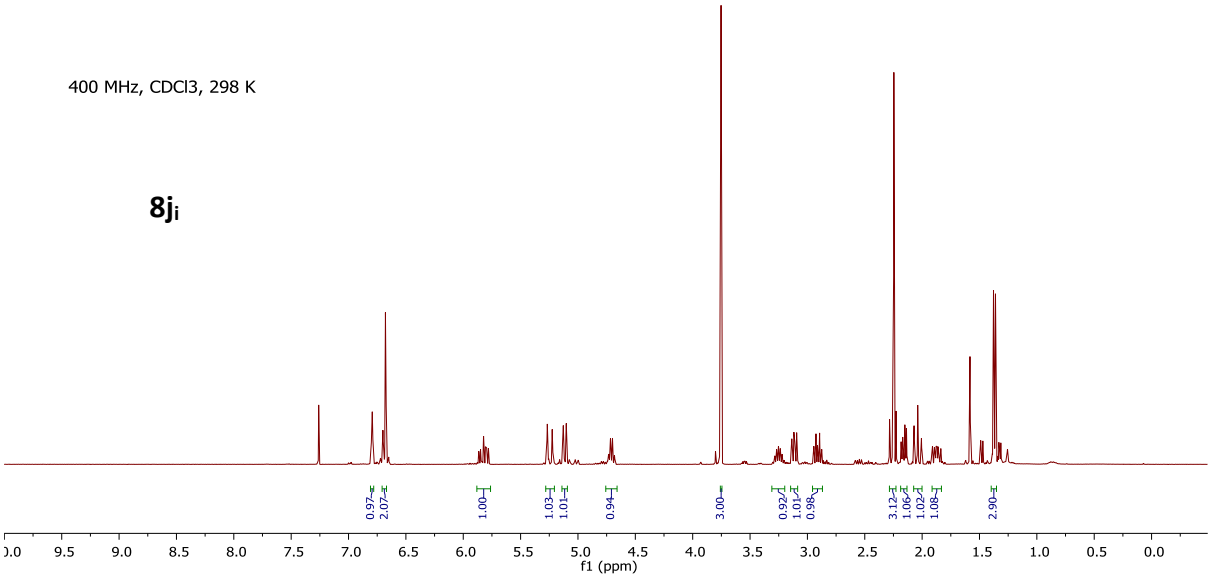
100 MHz, CDCl3, 298 K

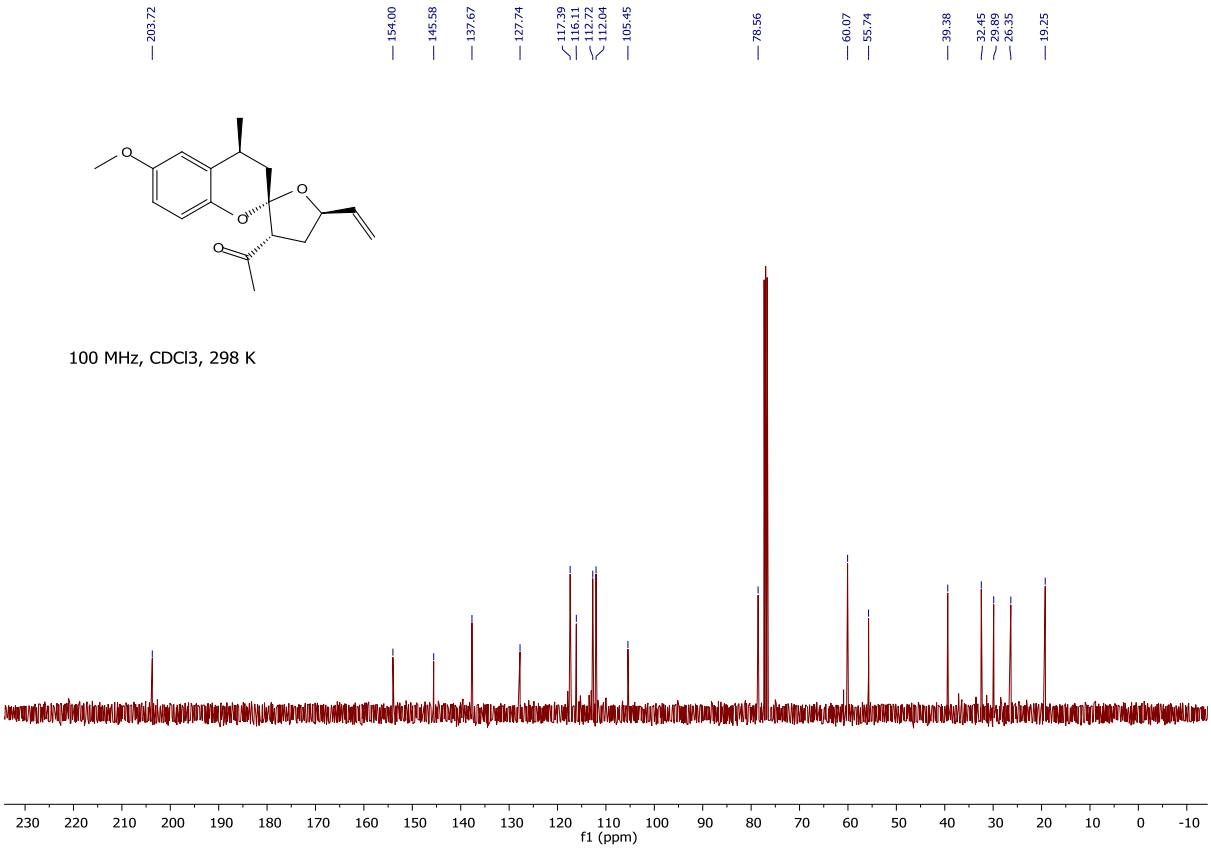




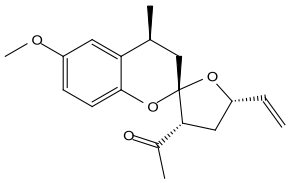
400 MHz, CDCl3, 298 K

8j$_i$



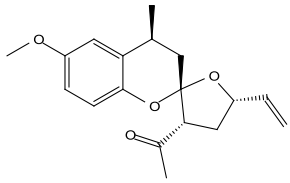


100 MHz, CDCl3, 298 K

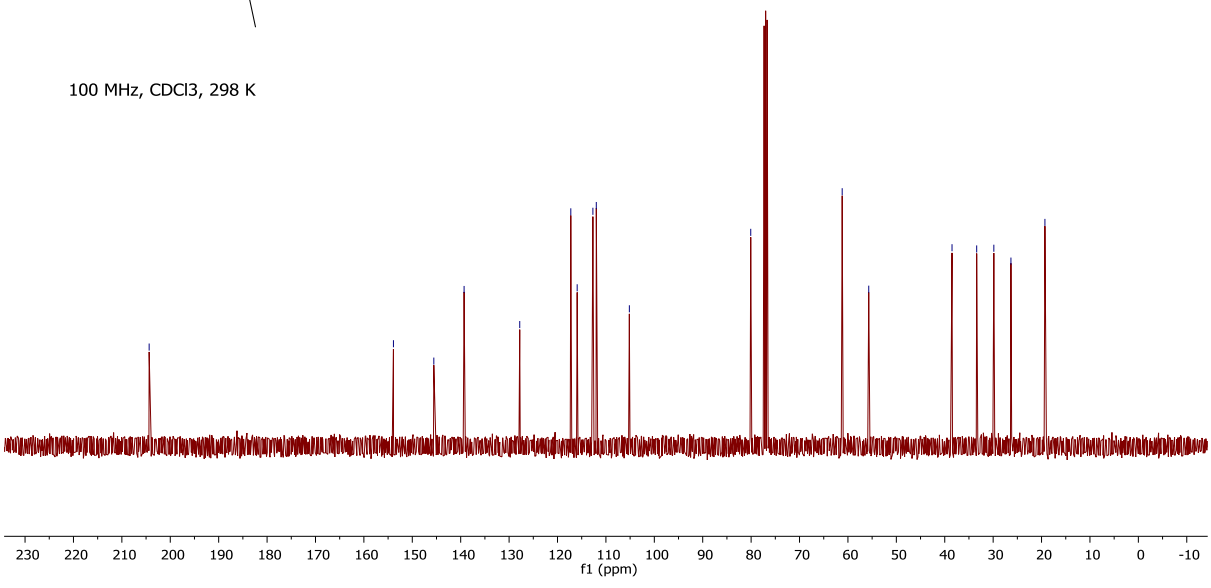


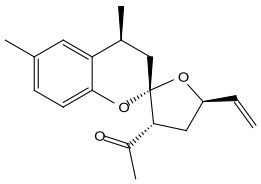
400 MHz, CDCl3, 298 K

8j$_{ii}$



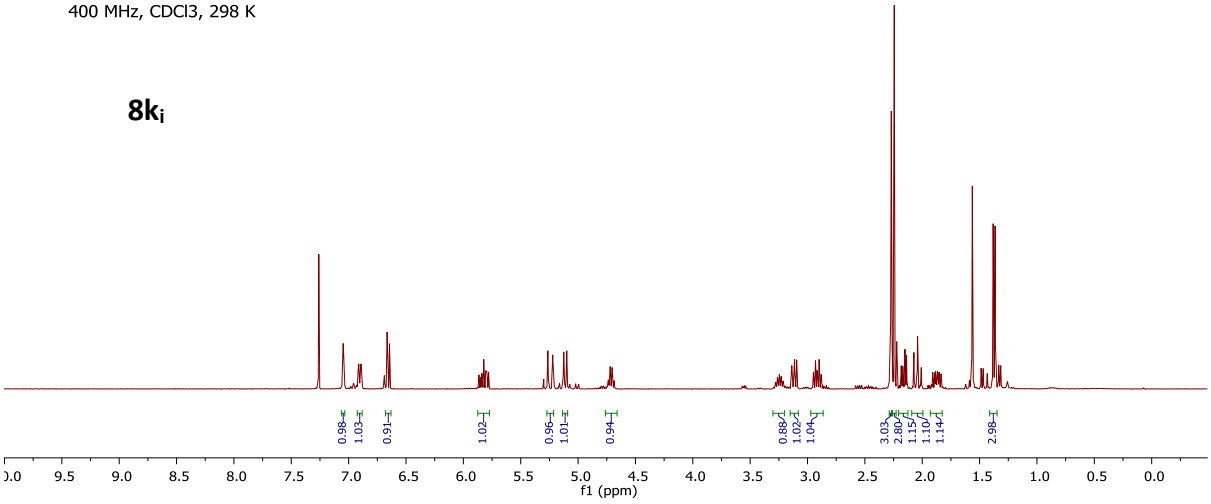
100 MHz, CDCl3, 298 K

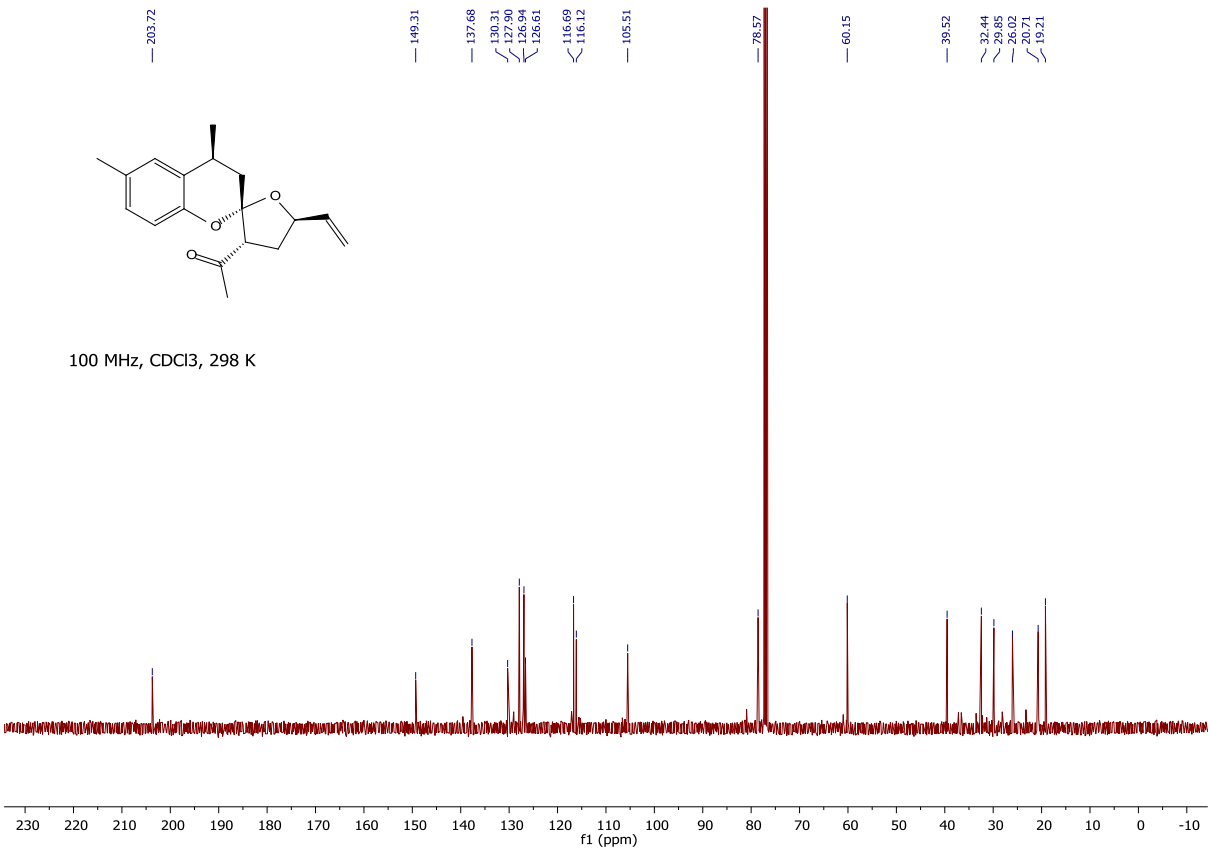




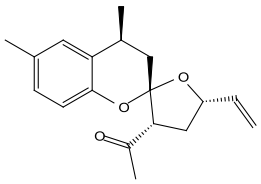
400 MHz, CDCl3, 298 K

8k$_i$



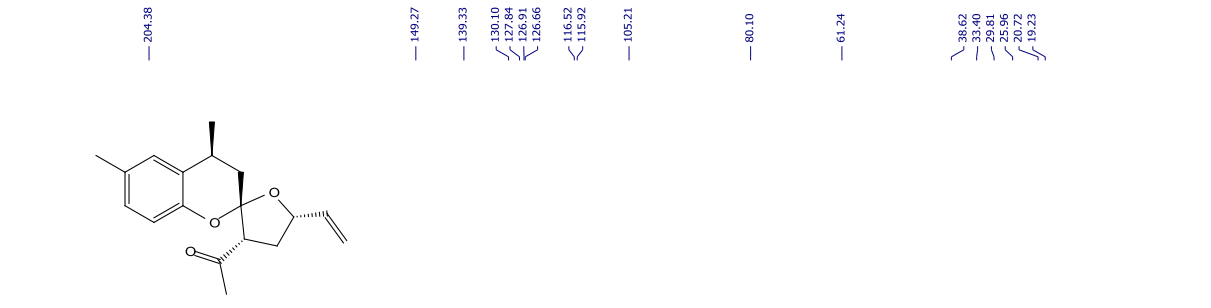


100 MHz, CDCl3, 298 K

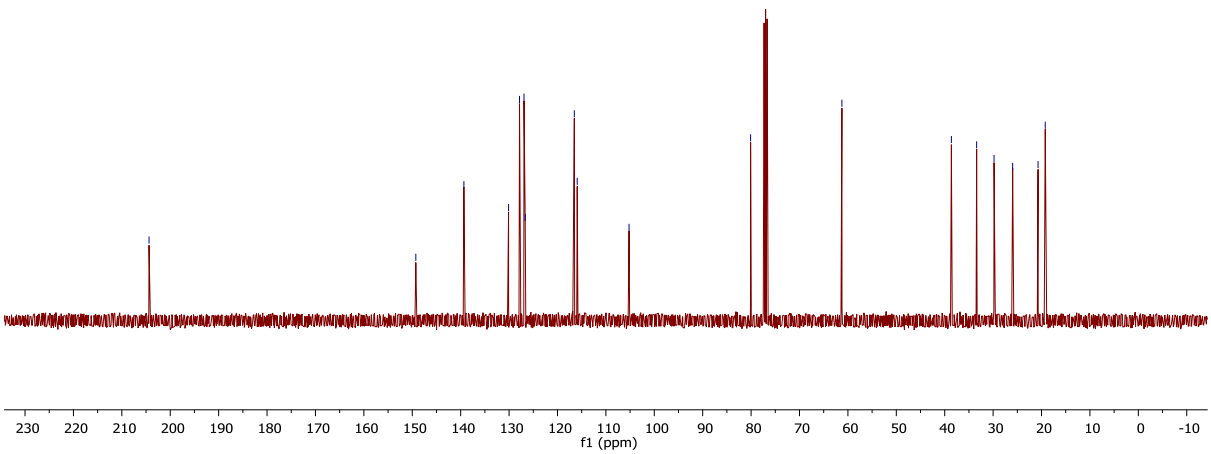


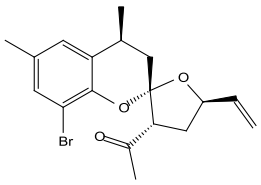
400 MHz, CDCl3, 298 K

8k$_{ii}$



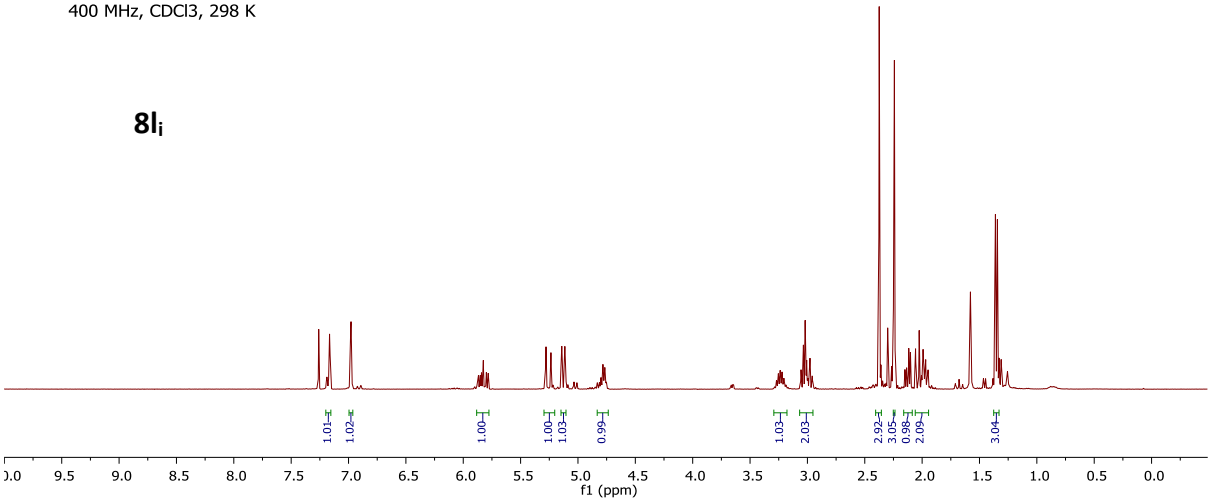
100 MHz, CDCl3, 298 K

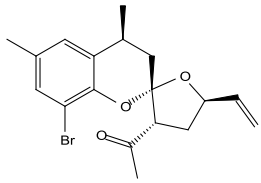




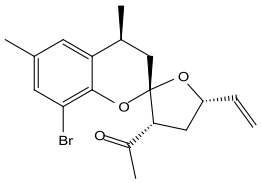
400 MHz, CDCl3, 298 K

8l$_i$



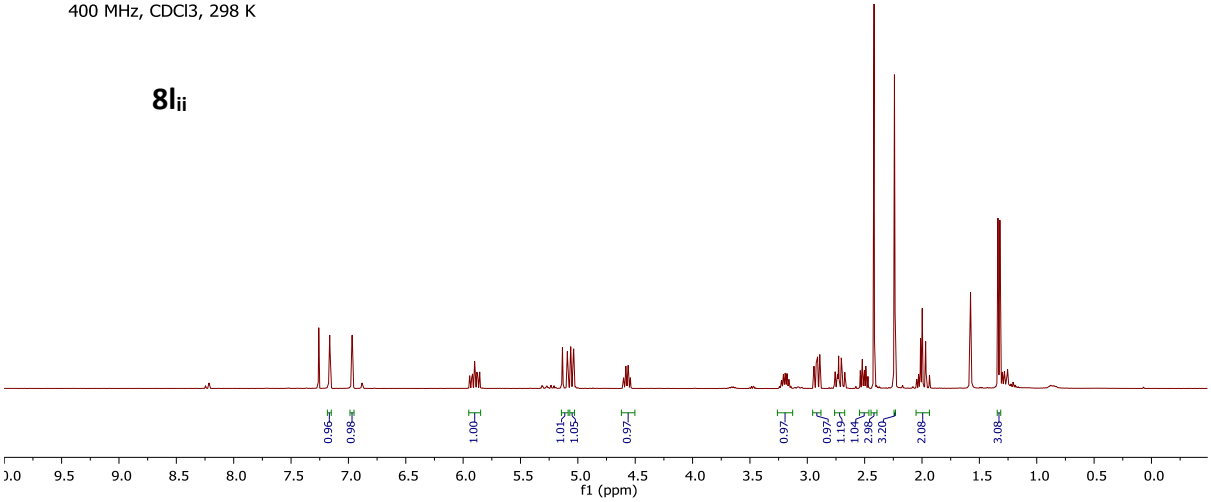


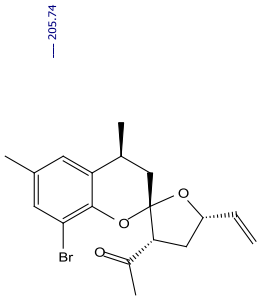
100 MHz, CDCl3, 298 K



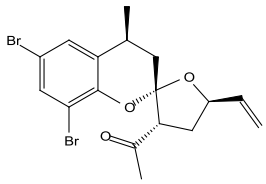
400 MHz, CDCl3, 298 K

8l$_{ii}$



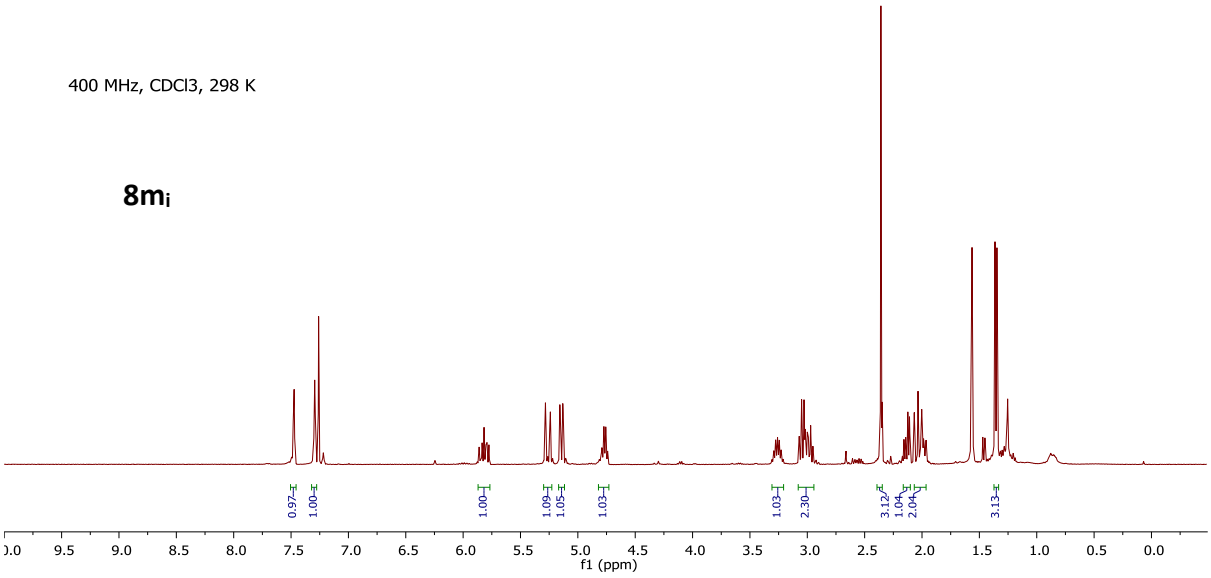


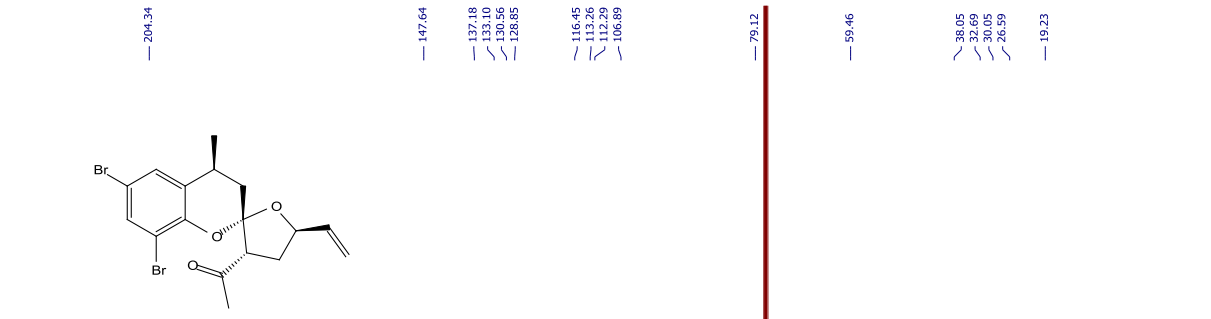
100 MHz, CDCl3, 298 K



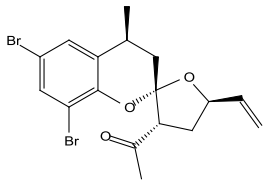
400 MHz, CDCl3, 298 K

8m$_i$



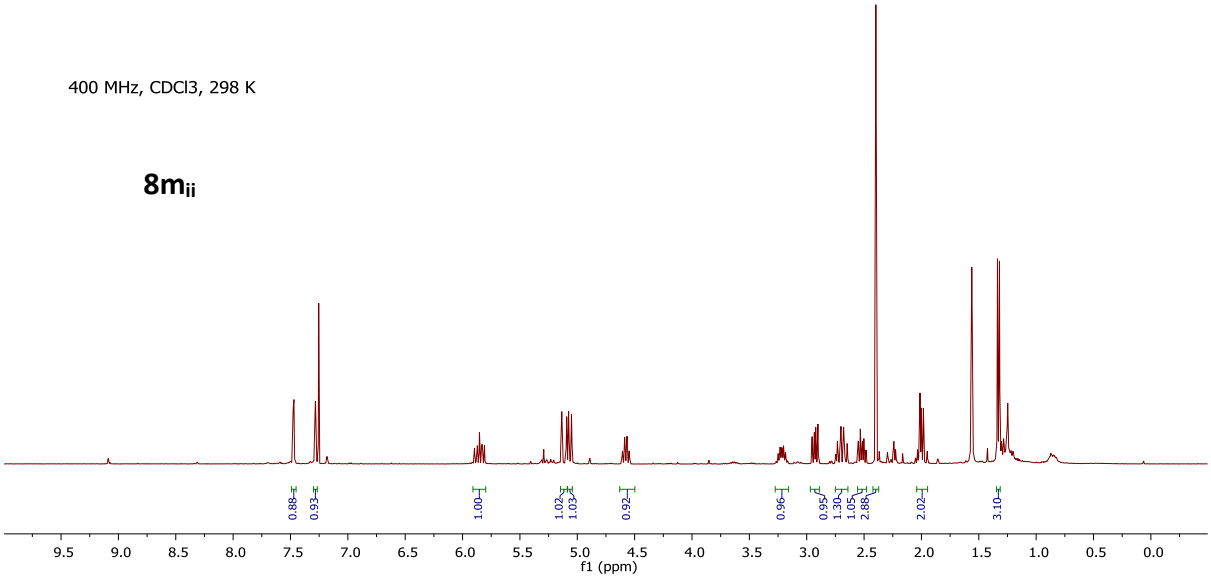


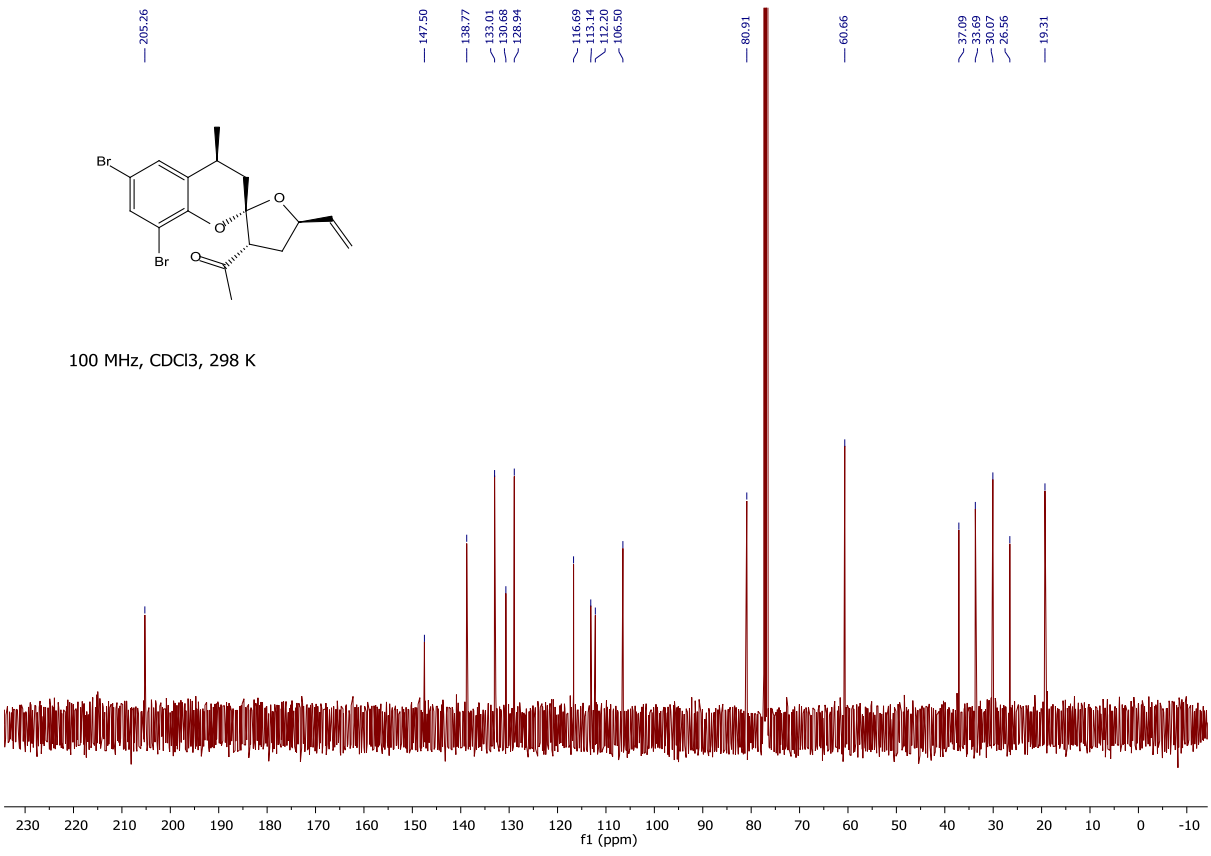
100 MHz, CDCl3, 298 K



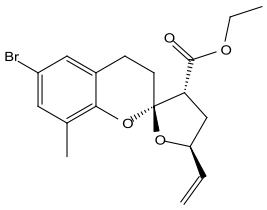
400 MHz, CDCl3, 298 K

8m$_{ii}$



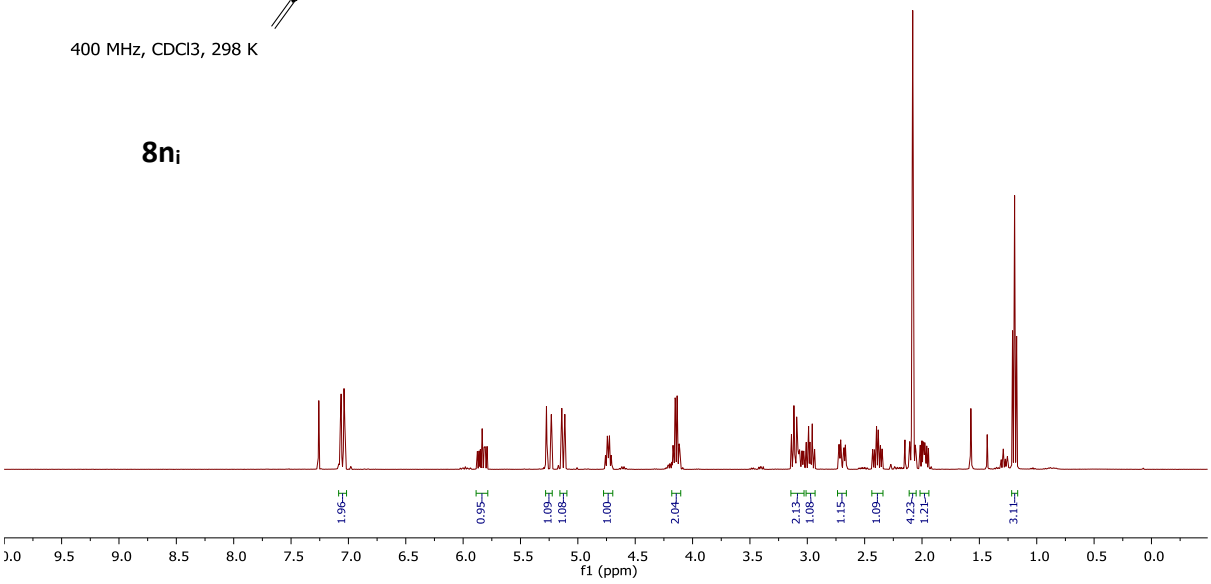


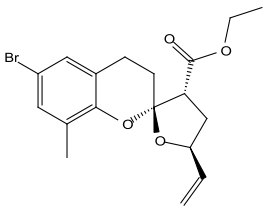
100 MHz, CDCl3, 298 K



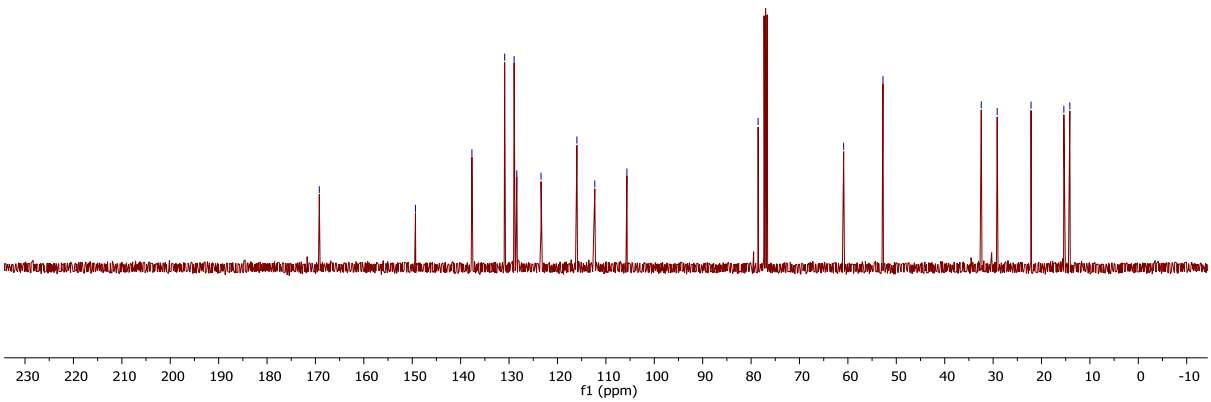
400 MHz, CDCl3, 298 K

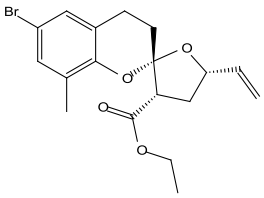
8n$_i$





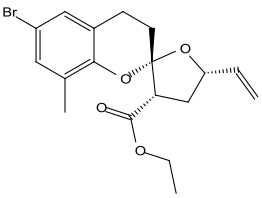
100 MHz, CDCl3, 298 K



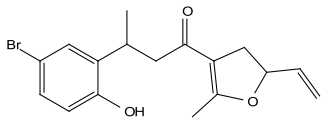


400 MHz, CDCl3, 298 K

8n$_{ii}$

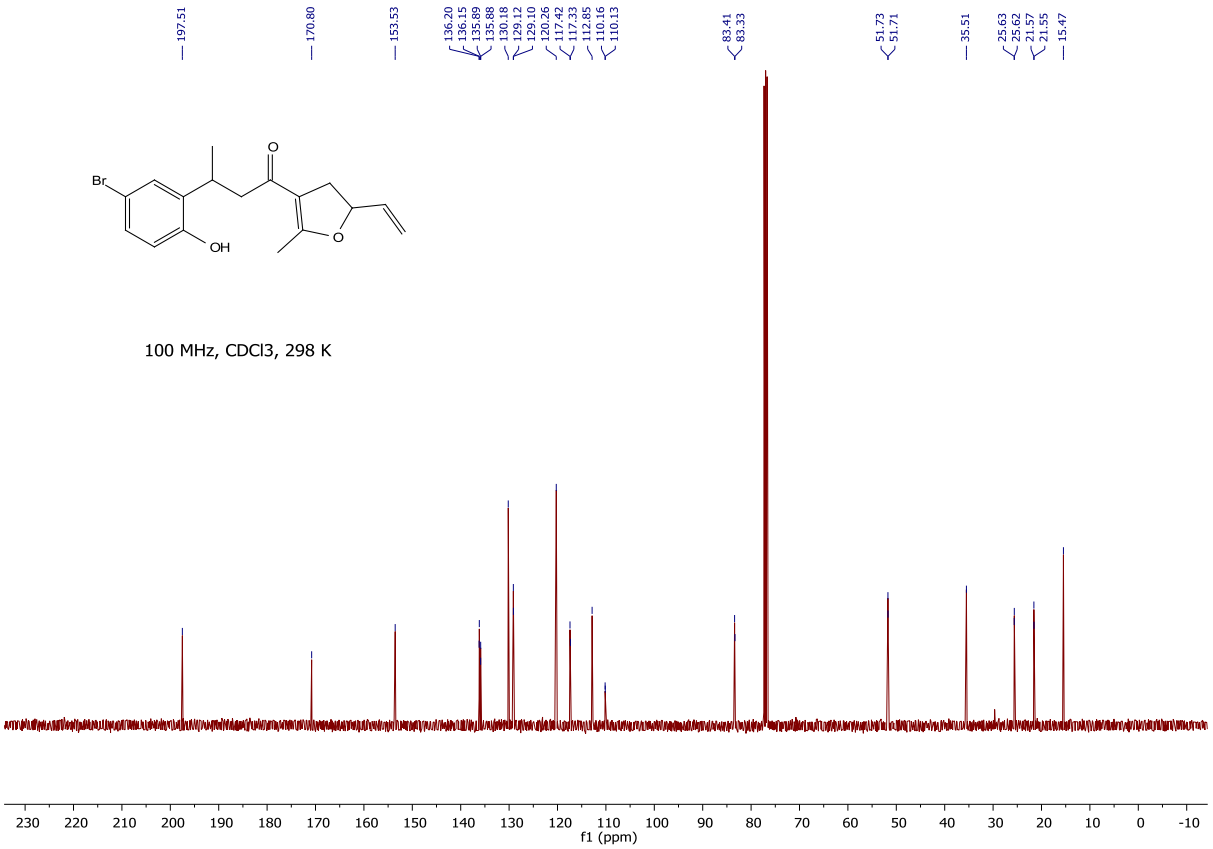


100 MHz, CDCl3, 298 K

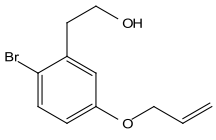


13iB

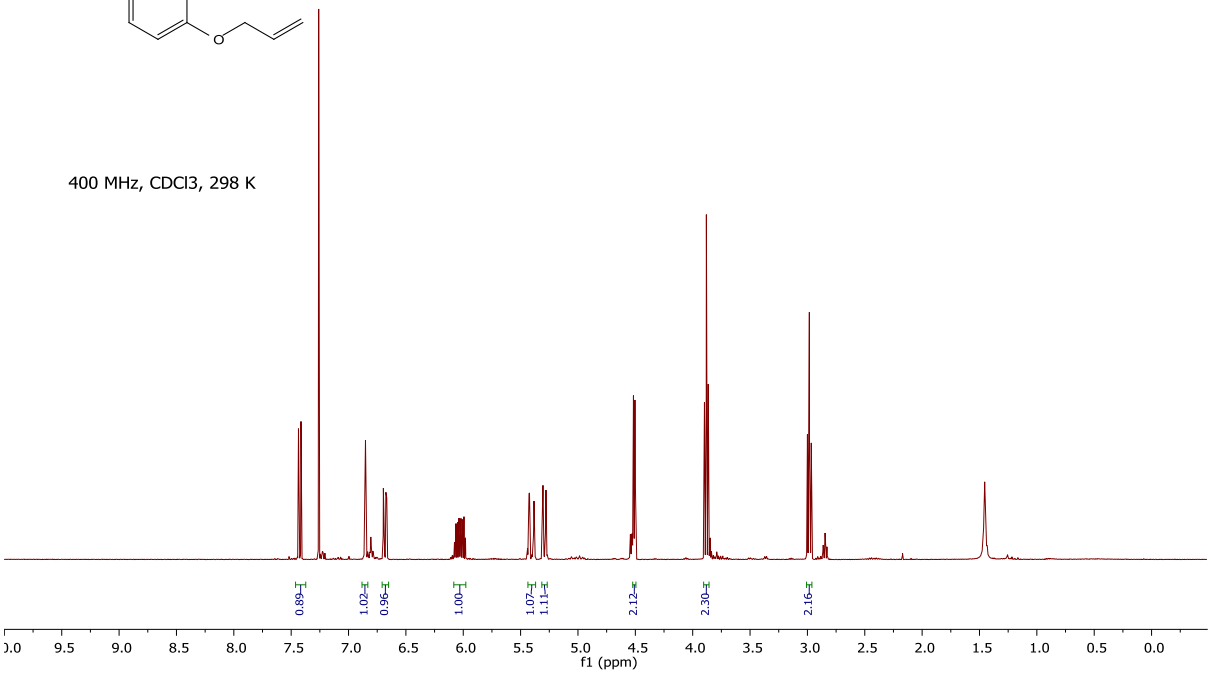
400 MHz, CDCl3, 298 K

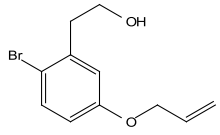


100 MHz, CDCl3, 298 K

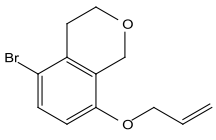


400 MHz, CDCl3, 298 K

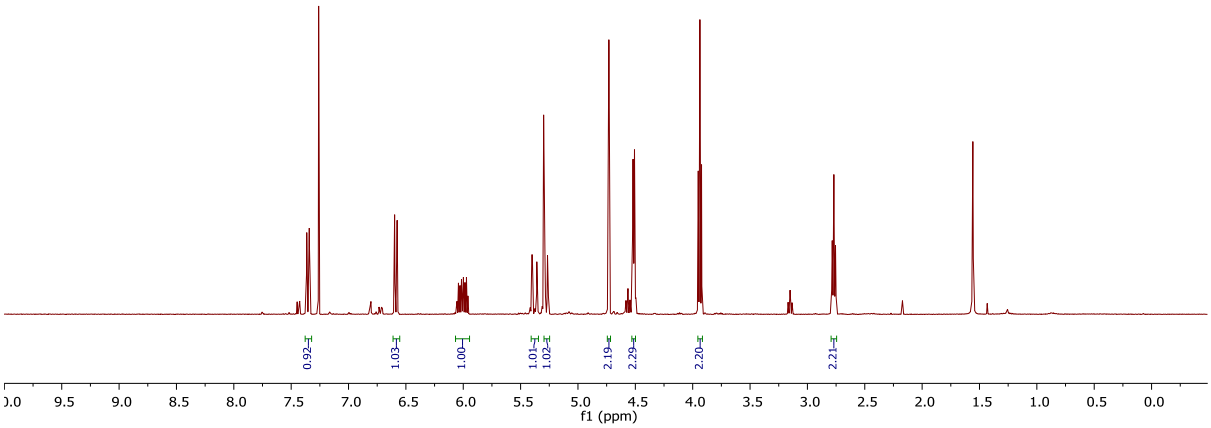


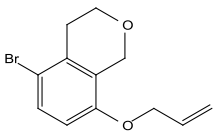


100 MHz, CDCl3, 298 K

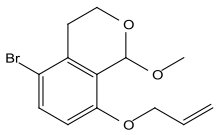


400 MHz, CDCl3, 298 K





100 MHz, CDCl3, 298 K



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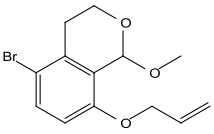
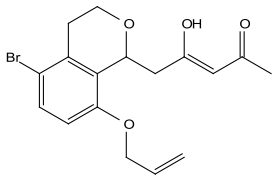
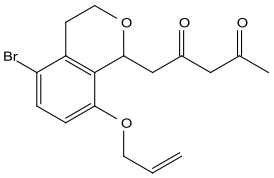


100 MHz, CDCl3, 298 K



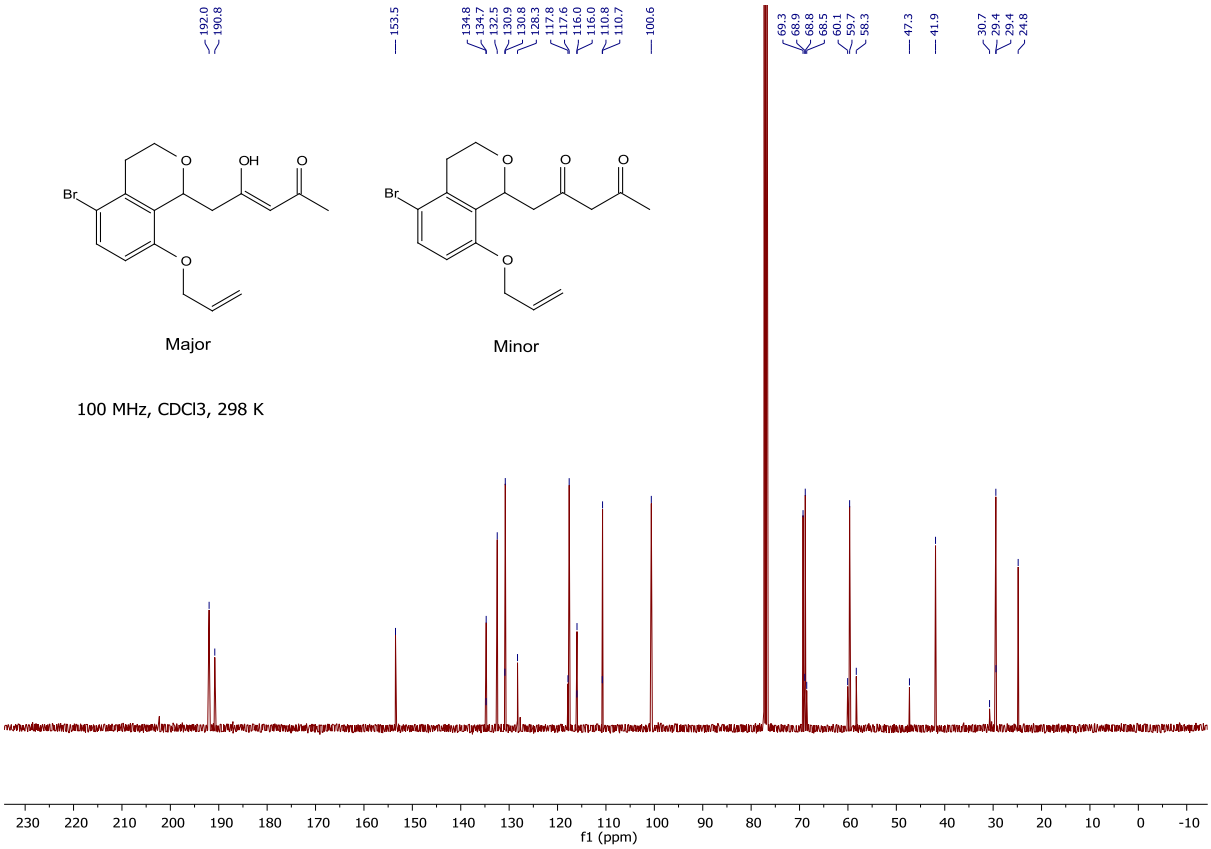
major



minor

400 MHz, CDCl3, 298 K

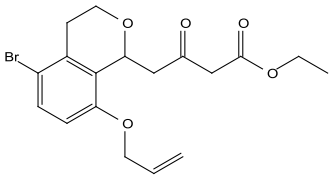
16a



Major

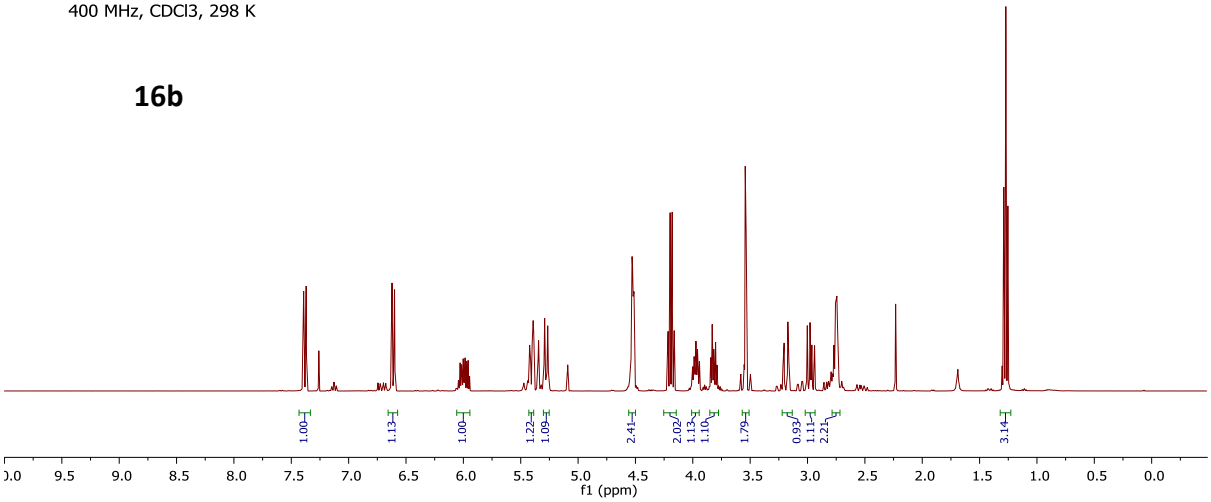
Minor

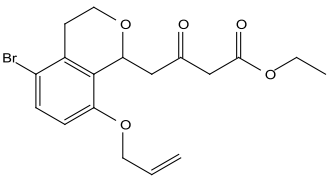
100 MHz, CDCl3, 298 K



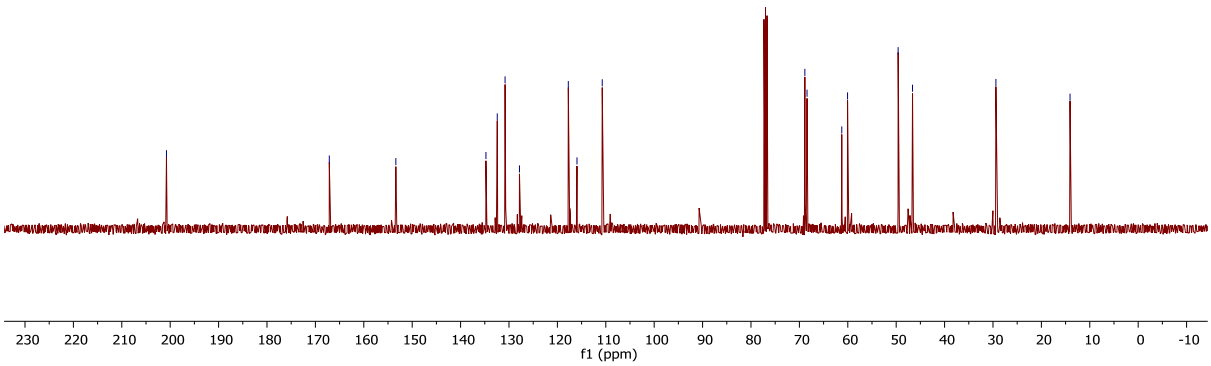
400 MHz, CDCl3, 298 K

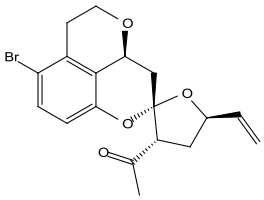
16b





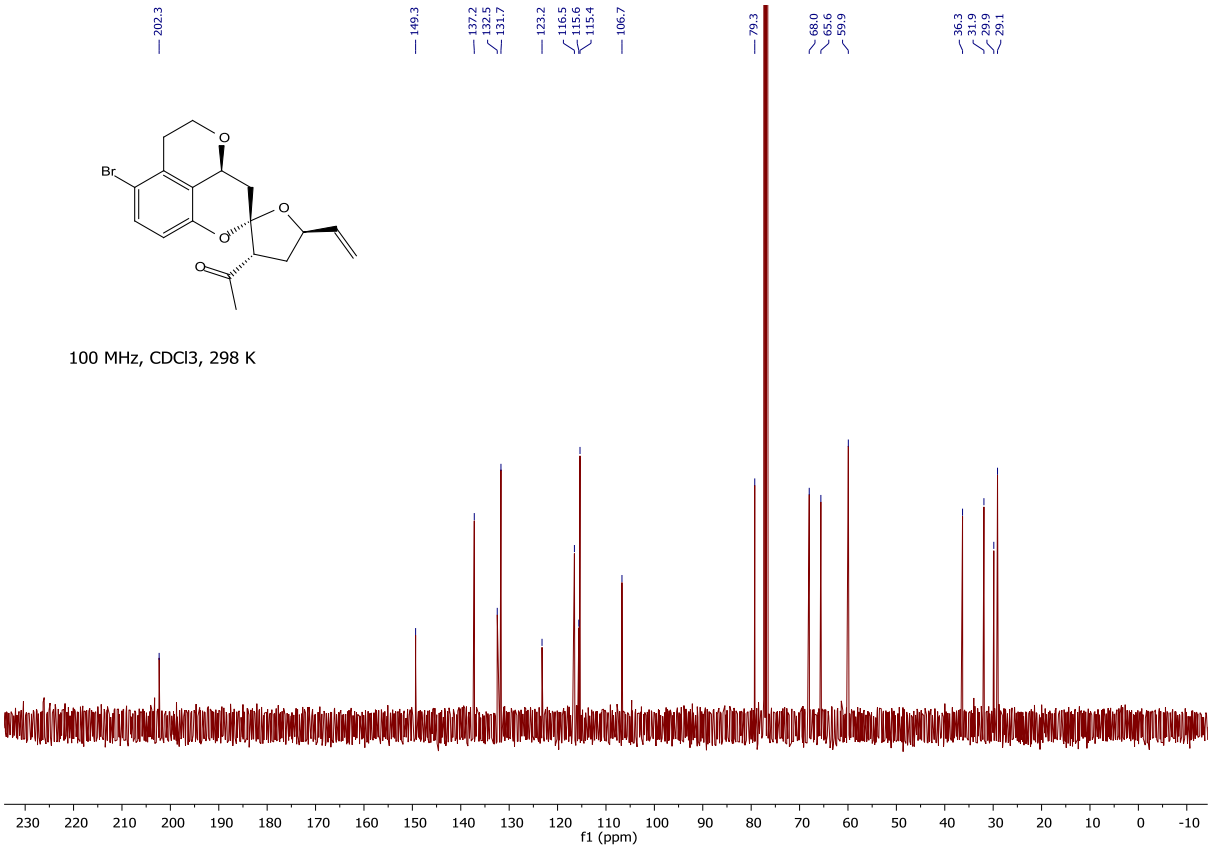
100 MHz, CDCl3, 298 K



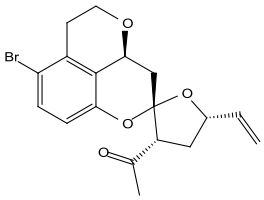


400 MHz, CDCl3, 298 K

17a$_i$

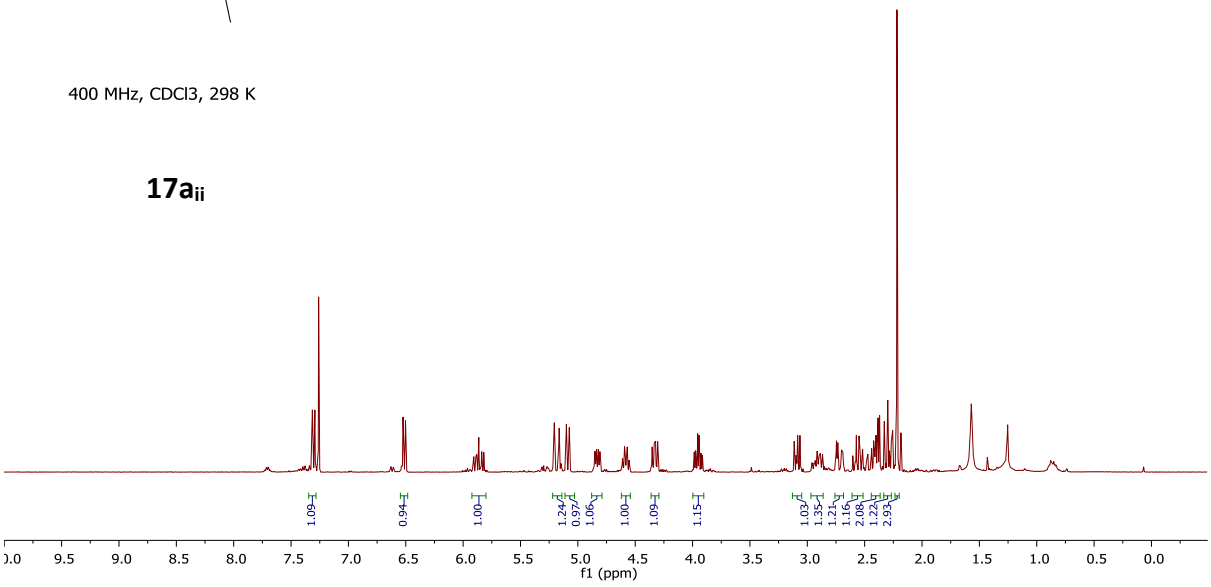


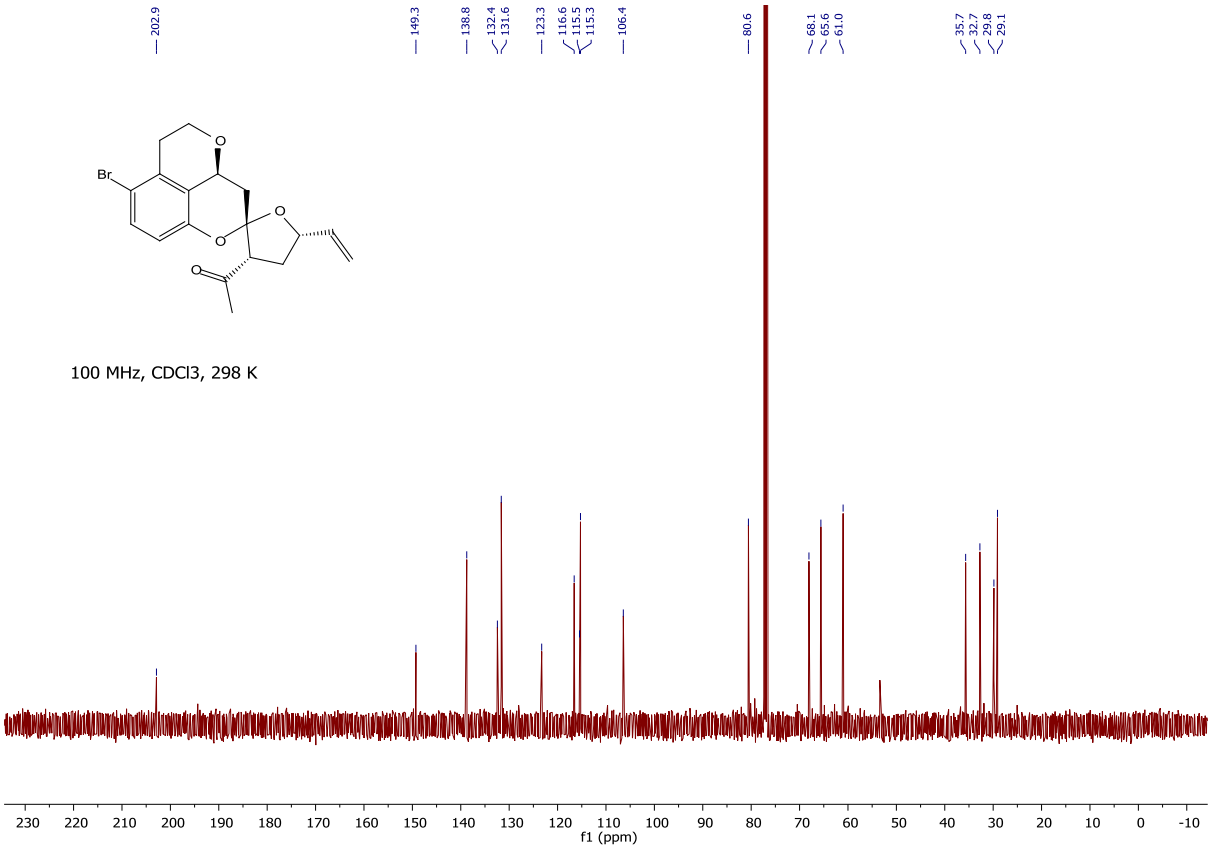
100 MHz, CDCl3, 298 K



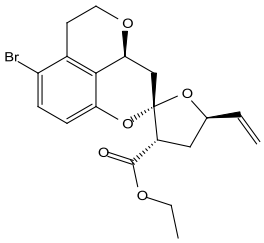
400 MHz, CDCl3, 298 K

17a$_{ii}$



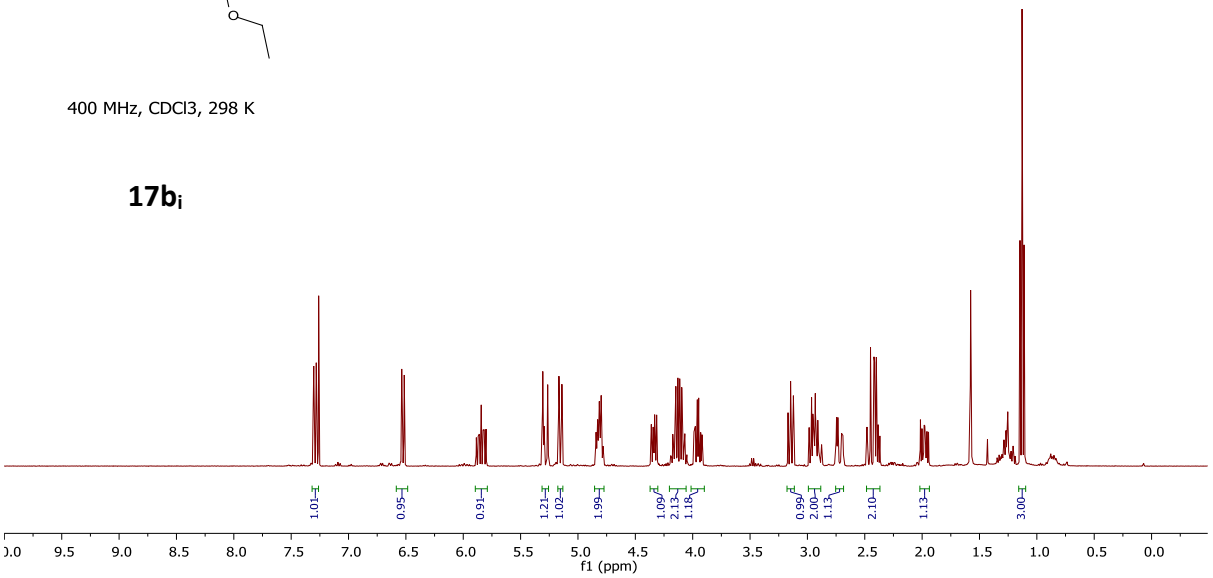


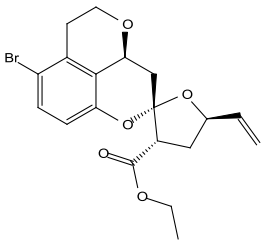
100 MHz, CDCl3, 298 K



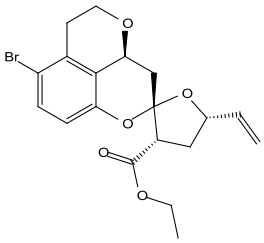
400 MHz, CDCl3, 298 K

17b$_i$



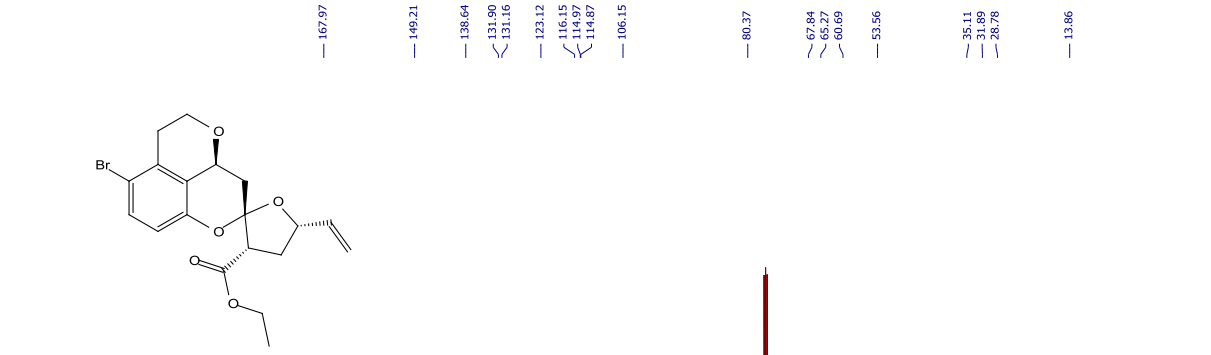


100 MHz, CDCl3, 298 K

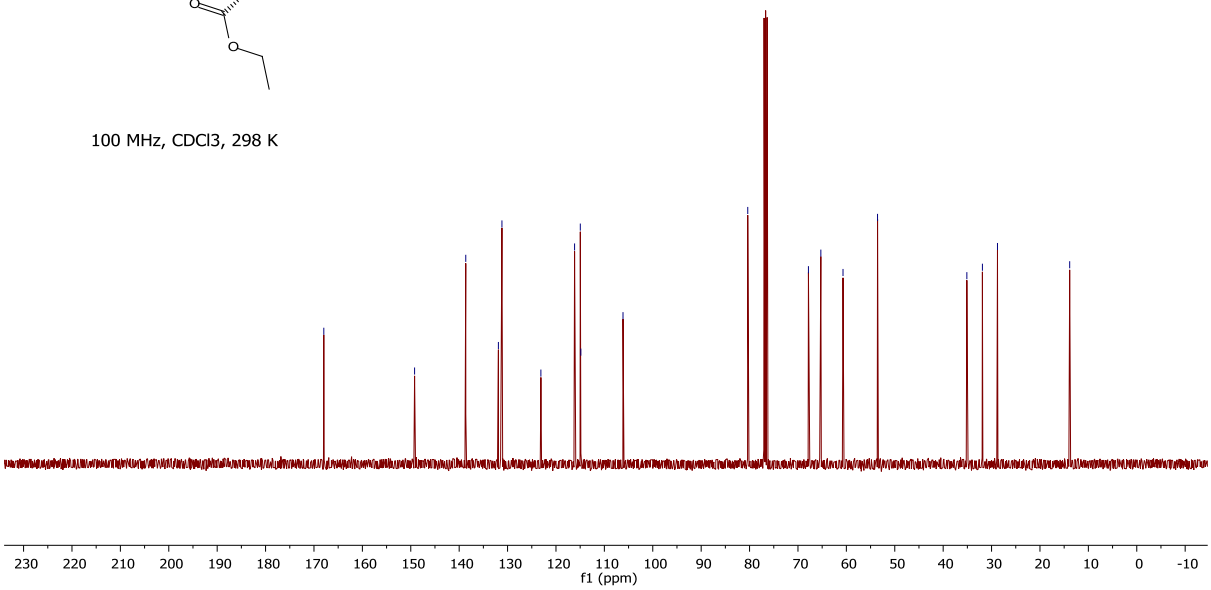


400 MHz, CDCl3, 298 K

17b$_{ii}$



100 MHz, CDCl3, 298 K



1. *CrysAlisPro Software System*, Version 1.171.38.46; Rigaku Oxford Diffraction: Oxford, UK, 2015.
2. (a) Sheldrick, G. M. *SHELX-2014*, Göttingen, Germany, 2014; (b) Sheldrick, G. M., A short history of SHELX. *Acta Crystallogr., Sect. A: Found. Crystallogr.* **2008,** *64*, 112-122.