Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry.

Supporting information

Development and Use of a General Route to Brassinolide, Its Biosynthetic Precursors, Metabolites and Analogues

Alaksiej L. Hurski, Yuri V. Ermolovich, Vladimir N. Zhabinskii*, and Vladimir A. Khripach

Institute of Bioorganic Chemistry, National Academy of Sciences of Belarus, Kuprevich st., 5/2, 220141 Minsk, Belarus.

*Corresponding Author: vz@iboch.bas-net.by (V.N.Z.)

Contents

General remarks S2

Procedures and spectroscopic analytical data S2

References S19

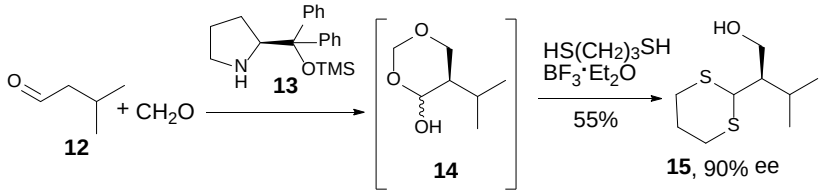
^{1}HNMR and ^{13}CNMR spectra of compounds **1-11, 15, 17-18, 20, 22, 26-32, 34-39, 43, 45-46, 48-49, 52-59** S21

Experimental section

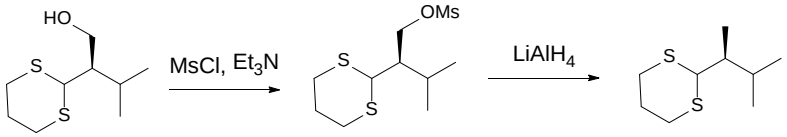
General remarks

All reactions that required anhydrous conditions were carried out under a positive argon flow with appropriately dried glassware, reagents and solvents. Petroleum ether (PE) used had a boiling range of 60−90 °C. Reactions were monitored by TLC on silica gel GF_{254} plates. Column chromatography was performed through silica gel (200−300 mesh). One and two-dimensional nuclear magnetic resonance (NMR) spectra were obtained using a Bruker AVANCE 500 spectrometer. All spectra were taken in $CDCl_3$. Chemical shift values are given in ppm and coupling constants (J) in Hz. ^{1}H spectra were referenced to $CHCl_3$ at 7.26 ppm and ^{13}C spectra were referenced to $CDCl_3$ at 77.00 ppm. Multiplicity was indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), dd (doublet of doublet), ddd (doublet of doublet of doublets), qdd (quartet of doublet of doublet). High resolution mass spectra were recorded on a LTQ Orbitrap mass spectrometer coupled to an Accela HPLC System (HPLC column: Hypersyl GOLD, 50 mm × 1 mm, 1.9 μm). Reagents were used as obtained from Aldrich, Acros Chimica, Fluka or Merck. If necessary, solvents were distilled and dried before use by standard methods.[1] Epibrassinolide from the ordinary commercial sources is very expensive (>$100 per 10 mg). The same compound is produced and applied as an active ingredient of a widely used in Russia and Belarus agrochemical Epin[2] and its price is much more reasonable (about $200 per 1 g with epibrassinolide content > 85%). It can be bought at http://iboch.bas-net.by or http://www.mikonik.com.

Procedures and spectroscopic analytical data



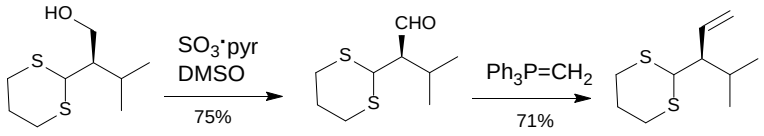
(*R*)-2-(1,3-Dithian-2-yl)-3-methylbutan-1-ol (15). Solid phosphate buffer (pH 7, 1.62 g), formalin (7.5 mL, 100 mmol), and isovaleraldehyde (**12**) (2.97 ml, 27.1 mmol) were added sequentially to a stirred solution of diphenylprolinol ether **13**[3] (2.7 g, 8.29 mmol) in toluene (55 mL). The mixture was stirred overnight, and the organic layer was separated and concentrated under reduced pressure (water bath temperature: < 30 °C). 1,3-Propanedithiol (6.95 mL, 69 mmol) and CH_2Cl_2 (50 mL) were added to the residue and the resulting solution was cooled to 0 °C. $BF_3{\cdot}Et_2O$ (7.5 mL, 61 mmol) was added to the reaction mixture dropwise over 5 min, and the solution was stirred at the same temperature for 2 h, warmed to rt, cooled to 0 °C and quenched with 20% aqueous NaOH (150 mL). The aqueous layer was separated and extracted with CH_2Cl_2 (50 mL × 3). The combined organic layers were washed with 20% aqueous NaOH (50 mL × 3), water (50 mL) and brine (50 mL), then dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/EtOAc = 9/1 – 4/1) to give alcohol **15** (3.12 g, 55%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.37 (d, *J* = 4.8 Hz, 1H), 3.88 (dd, *J* = 12.1, 3.3 Hz, 1H), 3.80 (dd, *J* = 12.1, 6.0 Hz, 1H), 2.91 (dd, *J* = 18.8, 7.1 Hz, 1H), 2.80 – 2.87 (m, 3H), 2.01 – 2.14 (m, 3H), 1.80 – 1.92 (m, 1H), 1.59 – 1.66 (m, 1H), 1.02 (d, *J* = 6.8 Hz, 3H), 0.95 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 61.5, 51.8, 50.5, 31.3, 30.9, 26.9, 26.2, 21.5, 19.7. $[\alpha]_D^{20}$ = +1.9 (c 2.2, $CHCl_3$). IR (film): 3449, 2950, 2898, 1468, 1367. HRMS (ESI): calcd for $C_9H_{19}OS_2$ $[M+H]^+$ 207.0872, found 207.0872. The enantiomeric purity of **15** was determined by ^{1}H NMR of its Mosher ester (prepared from (*R*)-MTPA-Cl)[4] by integration of the signals of thioacetal protons at 4.17 and 4.21 ppm (S-C*H*-S). It was determined to be 90% *ee*.



15 **37** **8**, 88% from **15**

(*S*)-2-(3-Methylbutan-2-yl)-1,3-dithiane (8). *(a). (R)-2-(1,3-Dithian-2-yl)-3-methylbutyl methanesulfonate (**37**).* MsCl (0.84 mL, 10.9 mmol) was added to a stirred solution of alcohol **15** (1.87 g, 9.06 mmol) and Et_3N (2.3 mL, 16.5 mmol) in Et_2O (40 ml) at 0 °C. The mixture was stirred for 15 min and quenched with aqueous $NaHCO_3$ (40 mL). The aqueous layer was separated and extracted with Et_2O (15 mL × 3). The combined organic layers were washed with brine (50 mL), dried over Na_2SO_4 and concentrated under reduced pressure to give 2.6 g (101%) of crude mesylate **37** as an oil. ^{1}H NMR (500 MHz, $CDCl_3$4.43 (dd, *J* = 10.2, 5.1 Hz, 1H), 4.32 – 4.40 (m, 2H), 3.07 (s, 3H), 2.79 – 2.99 (m, 4H), 2.05 – 2.21 (m, 2H), 1.78 – 1.94 (m, 2H), 1.06 (d, *J* = 6.8 Hz, 3H), 1.00 (d, *J* = 6.8 Hz, 3H) . ^{13}C NMR (125 MHz, $CDCl_3$): δ 68.4, 49.7, 49.1, 37.3, 31.2, 31.0, 27.3, 26.0, 21.5, 19.5. HRMS (ESI): calcd for $C_{10}H_{21}O_3S_3$ $[M+H]^+$ 285.0647, found 285.0640.

*(b). (S)-2-(3-Methylbutan-2-yl)-1,3-dithiane (**8**).* A solution of crude mesylate **37** (2.6 g) in Et_2O (10 mL) was added at 0 °C to a stirred suspension of $LiAlH_4$ (0.69 g, 18.2 mmol) in Et_2O (30 mL). The reaction mixture was warmed to room temperature, stirred for 2 h, cooled to 0 °C, quenched with water (2.6 mL) and filtered. The precipitate was washed thoroughly with Et_2O (15 mL × 3) and the filtrate was evaporated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/Et_2O = 40/1 – 9/1) to give dithiane **8** (1.51 g, 88%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.18 (d, *J* = 5.6 Hz, 1H), 2.88 – 2.97 (m, 1H), 2.81 – 2.87 (m, 3H), 2.06 – 2.13 (m, 1H), 1.77 – 1.96 (m, 2H), 1.52 – 1.64 (m, 1H), 1.04 (d, *J* = 6.9 Hz, 3H), 0.96 (d, *J* = 6.7 Hz, 3H), 0.87 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 53.9, 44.4, 31.2, 30.7, 29.7, 26.3, 21.3, 18.7, 13.1. $[\alpha]_D^{20}$ = +17.3 (c 2.2, $CHCl_3$). IR (film): 2964, 2904, 1462, 1421, 1377. HRMS (APCI): calcd for $C_9H_{19}S_2$ $[M+H]^+$ 189.0766, found 189.0761.

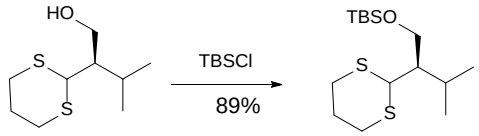


15 **38** **10**

(*R*)-2-(4-methylpent-1-en-3-yl)-1,3-dithiane (10). *(a). (R)-2-(1,3-dithian-2-yl)-3-methylbutanal (**38**).* SO_3·pyr (0.77g, 5.38 mmol) was added to a stirred solution of **15** (0.5 g, 0.24 mmol) and Et_3N (1.7 mL, 12.2 mmol) in a mixture of DMSO (7.5 mL) and CH_2Cl_2 (24 mL) at 0 ^{o}C. The resulting solution was stirred at the same temperature for 1 h and quenched with aqueous $NaHCO_3$ (25 mL). The aqueous layer was separated and extracted with CH_2Cl_2 (5 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/Et_2O = 40/1 – 2/1) to give aldehyde **38** (0.37 g, 75%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 9.67 (d, *J* = 4.5 Hz, 1H), 4.37 (d, *J* = 7.4 Hz, 1H), 2.77 – 2.92 (m, 4H), 2.37 (td, *J* = 7.1, 4.5 Hz, 1H), 2.31 (dq, *J* = 13.6, 6.8 Hz, 1H), 2.05 – 2.14 (m, 1H), 1.82 – 1.96 (m, 1H), 1.06 (d, *J* = 6.7 Hz, 3H), 0.95 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 202.0, 61.1, 45.0, 29.9, 29.6, 26.9, 25.6, 20.8, 18.7. $[\alpha]_D^{20}$ = +19.0 (c 0.55, $CHCl_3$). IR (film): 2960, 2902, 1722, 1465, 1390. HRMS (ESI): calcd for $C_9H_{17}OS_2$ $[M+H]^+$ 205.0715, found 205.0715.

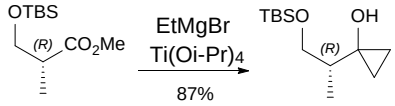
*(b). (R)-2-(4-methylpent-1-en-3-yl)-1,3-dithiane (**10**).* A 2.5M solution of *n*-BuLi (1.45 mL, 3.63 mmol) was added at 0 °C to a suspension of Ph_3PCH_3Br (1.42 g, 3.98 mmol) in THF (10 mL) and the mixture was stirred for 30 min. A solution of aldehyde **38** (0.37 g, 1.81 mmol) in THF (3.6 mL) was added at 0 °C to a solution of the ylide. The reaction mixture was stirred for 30 min, diluted with Et_2O (20 mL) and quenched with water (20 mL). The aqueous layer was separated and extracted with Et_2O (5 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column

chromatography on SiO_2 (PE/EtOAc = 9/1 – 3/1) to give compound **10** (0.26 g, 71%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): 5.64 (dt, *J* = 16.9, 9.9 Hz, 1H), 5.18 (dd, *J* = 10.1, 1.9 Hz, 1H), 5.07 (dd, *J* = 16.9, 1.6 Hz, 1H), 4.22 (d, *J* = 6.4 Hz, 1H), 2.79 – 2.95 (m, 4H), 1.96 – 2.14 (m, 3H), 1.77 – 1.90 (m, 1H), 0.95 (d, *J* = 6.5 Hz, 3H), 0.85 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 135.9, 118.6, 55.9, 51.0, 31.0, 30.8, 28.0, 26.2, 20.9, 19.0. $[\alpha]_D^{20}$ = +5.0 (c 1.0, $CHCl_3$). IR (film): 3080, 2661, 2929, 2898, 1641, 1463, 1388. HRMS (ESI): calcd for $C_{10}H_{19}S_2$ $[M+H]^+$ 203.0923, found 203.0919.



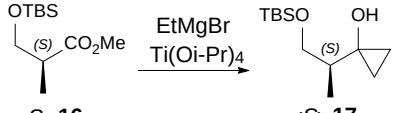
15 **11**

(*R*)-(2-(1,3-dithian-2-yl)-3-methylbutoxy)(*tert*-butyl)dimethylsilane (11). TBSCl (0.75 g, 4.98 mmol) was added at 0 °C to a solution of alcohol **15** (0.86 g, 4.17 mmol) and imidazole (0.43 g, 6.32 mmol) in DMF (4 mL). The reaction mixture was left overnight at room temperature, diluted with Et_2O (10 mL) and quenched with water (20 mL). The aqueous layer was separated and extracted with Et_2O (10 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/Et_2O = 40/1 – 10/1) to give silyl ether **11** (1.16 g, 89%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.39 (d, *J* = 4.9 Hz, 1H), 3.79 (dd, *J* = 10.0, 5.0 Hz, 1H), 3.76 (dd, *J* = 10.0, 4.6 Hz, 1H), 2.76 – 2.96 (m, 4H), 2.04 – 2.13 (m, 2H), 1.80 – 1.90 (m, 1H), 1.65 (p, *J* = 5.2 Hz, 1H), 1.03 (d, *J* = 6.9 Hz, 3H), 0.97 (d, *J* = 6.8 Hz, 3H), 0.90 (s, 9H), 0.07 (s, 6H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 60.8, 51.8, 50.9, 31.6, 31.5, 27.5, 26.5, 25.9 (× 3), 22.1, 19.8, 18.2, -5.39, -5.44. $[\alpha]_D^{20}$ = -3.3 (c 0.75, $CHCl_3$). IR (film): 2952, 2932, 1470, 1255, 1095. HRMS (ESI): calcd for $C_{15}H_{33}OS_2Si$ $[M+H]^+$ 321.1737, found 321.1734.



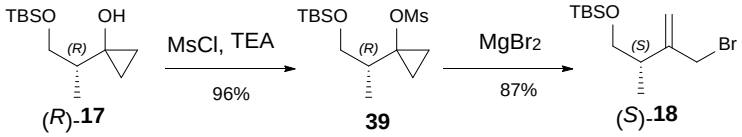
(*R*)-**16** (*R*)-**17**

(*R*)-1-(1-[(*tert*-Butyldimethylsilyl)oxy]propan-2-yl)cyclopropanol ((*R*)-17). A solution of EtMgBr, prepared from Mg (3.02 g, 0.124 mol) and EtBr (9.4 mL, 0.123 mol) in THF (125 mL), was added over 1 h at room temperature to a stirred solution of ester **(*R*)-16** (5.85 g, 25 mmol) and Ti(O*i*-Pr)$_4$ (7.5 mL, 25 mmol) in THF (30 mL). The reaction mixture was stirred for 5 min, cooled to 0 °C, quenched with aqueous NH_4Cl (15 mL) and filtered through a pad of Celite. The precipitate was washed thoroughly with EtOAc (50 mL × 3) and the filtrate was evaporated under reduced pressure to give cyclopropanol **(*R*)-17** (5.02 g, 87%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 3.92 (dd, *J* = 9.6, 3.9 Hz, 1H), 3.69 (dd, *J* = 9.6, 5.0 Hz, 1H), 3.65 (s, 1H), 1.34 – 1.42 (m, 1H), 1.03 (d, *J* = 7.1 Hz, 3H), 0.90 – 0.92 (m, 9H), 0.72 – 0.79 (m, 1H), 0.68 (ddd, *J* = 10.8, 6.0, 5.1 Hz, 1H), 0.48 (ddd, *J* = 10.8, 6.2, 4.8 Hz, 1H), 0.34 – 0.41 (m, 1H), 0.089 (s, 3H), 0.091 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 68.4, 59.6, 40.6, 25.8 (× 3), 18.1, 13.1, 12.8, 11.2, -5.59, -5.63. $[\alpha]_D^{20}$ = -4.0 (c 1.1, $CHCl_3$). IR (film): 3442, 3087, 2959, 2934, 2862, 1469, 1255, 1084. HRMS (APCI): calcd for $C_{12}H_{27}O_2Si$ $[M+H]^+$ 231.1775, found 231.1771.



(*S*)-**16** (*S*)-**17**

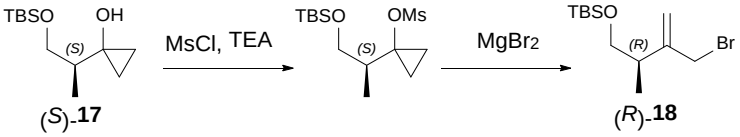
(*S*)-17 was prepared from **(*S*)-16** following the same procedure. $[\alpha]_D^{20}$ = +4.1 (c 1.0, $CHCl_3$).



(*R*)-**17** **39** (*S*)-**18**

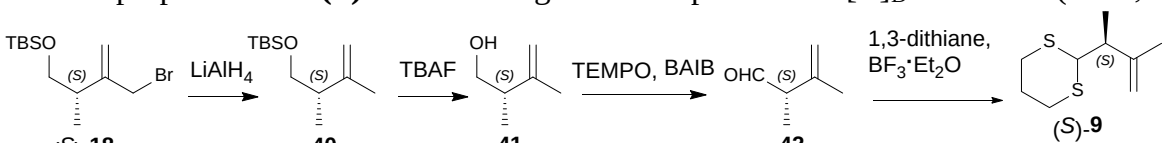
(*S*)-(3-(Bromomethyl)-2-methylbut-3-enyloxy)(*tert*-butyl)dimethylsilane ((*S*)-18). *(a). (R)-1-(1-[(tert-Butyldimethylsilyl)oxy]propan-2-yl)cyclopropanol methane-sulfonate (**39**).* MsCl (2.2 mL, 28 mmol) was added over 5 min at 0 °C to a stirred solution of cyclopropanol **(*R*)-17** (5.02 g, 22 mmol) and Et_3N (6.07 mL, 44 mmol) in Et_2O (60 mL). The mixture was stirred for 10 min and quenched with aqueous $NaHCO_3$ (60 mL). The aqueous layer was separated and extracted with Et_2O (20 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure to give mesylate **39** (6.42 g, 96%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 3.72 (dd, *J* = 10.1, 5.4 Hz, 1H), 3.56 (dd, *J* = 10.2, 6.3 Hz, 1H), 2.97 (s, 3H), 2.02 – 2.11 (m, 1H), 1.24 (m, 2H), 0.99 (d, *J* = 7.0 Hz, 3H), 0.86 – 0.91 (m, 10H), 0.77 – 0.83 (m, 1H), 0.04 (s, 6H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 69.2, 64.8, 40.5, 39.8, 25.8 (× 3), 18.2, 13.3, 10.2, 9.2, -5.5 (× 2). $[\alpha]_D^{20}$ = +1.0 (c 0.5, $CHCl_3$). IR (film): 3095, 2955, 2931, 2860, 1469, 1349, 1258, 1171, 1089. HRMS (APCI): calcd for $C_{13}H_{29}O_4SSi$ $[M+H]^+$ 309.1550, found 309.1537.

*(b). (S)-(3-(Bromomethyl)-2-methylbut-3-enyloxy)(tert-butyl)dimethylsilane (**(S)-18**).* A solution of mesylate **39** (6.42 g, 20 mmol) in Et_2O (40 mL) was added to a solution of $MgBr_2$, prepared from Mg (3 g, 123 mmol) and 1,2-dibromoethane (13 mL, 150 mmol) in Et_2O (125 mL). The teaction mixture was stirred at rt for 4 h, cooled to 0 °C and quenched with water (100 mL). The aqueous layer was separated and extracted with Et_2O (50 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/Et_2O = 40/1 – 20/1) to give bromide **(*S*)-18** (5.29 g, 87%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.24 (d, *J* = 0.6 Hz, 1H), 5.01 (s, 1H), 4.07 (dd, *J* = 10.0, 0.6 Hz, 1H), 4.02 (d, *J* = 10.0 Hz, 1H), 3.60 (dd, *J* = 9.7, 6.1 Hz, 1H), 3.54 (dd, *J* = 9.7, 6.6 Hz, 1H), 2.56 (h, *J* = 6.4 Hz, 1H), 1.11 (d, *J* = 7.0 Hz, 3H), 0.87 – 0.89 (m, 9H), 0.042 (s, 3H), 0.037 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 148.5, 114.9, 67.9, 39.2, 37.4, 25.9 (× 3), 18.3, 16.7, -5.4 (× 2). $[\alpha]_D^{20}$ = -30.0 (c 1.4, $CHCl_3$). IR (film): 2959, 2931, 2859, 1640, 1477, 1257, 1097. HRMS (APCI): calcd for $C_{12}H_{26}BrOSi$ $[M+H]^+$ 293.0931, found 293.0924.



(*S*)-**17** (*R*)-**18**

(*R*)-18 was prepared from **(*S*)-17** following the same procedure. $[\alpha]_D^{20}$ = +29.0 (c 1.3, $CHCl_3$).



(*S*)-**18** **40** **41** **42** (*S*)-**9**

41% from (*S*)-**18**

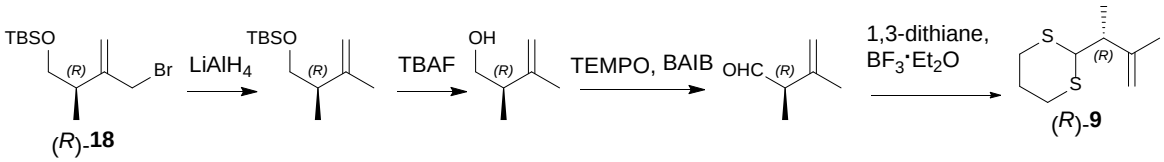
(*S*)-2-(3-Methylbut-3-en-2-yl)-1,3-dithiane ((*S*)-9). *(a). (S)-tert-Butyl(2,3-dimethylbut-3-enyloxy)dimethyl-silane (**40**).* A solution of bromide **(*S*)-18** (2.58 g, 8.80 mmol) in Et_2O (10 mL) was added over 5 min at 0 °C to a stirred suspension of $LiAlH_4$ (0.59 g, 15.5 mmol) in Et_2O (15 mL). The reaction mixture was warmed to room temperature, stirred for 1 h, cooled to 0 °C, quenched with H_2O (2.2 mL) and filtered. The filter cake was washed with Et_2O (5 mL × 3). The filtrate was evaporated under atmospheric pressure to give approximately 3 mL of a solution of crude **40** in Et_2O, which was used for the next step without further purification.

*(b). (S)-2,3-Dimethylbut-3-en-1-ol (**41**).* Crude **40** from the previous step was diluted with THF (4 mL), and then 1M solution of TBAF in THF (12 mL) was added. The resulting mixture was kept at room temperature for 2 h, diluted with Et_2O (50 mL) and washed with a saturated aqueous solution of NH_4Cl (10 mL × 3), water (10 mL) and brine (10 mL). The organic layer was dried over Na_2SO_4 and concentrated under atmospheric pressure to give approximately 3 ml of a solution of crude **41** in THF, which was directly subjected to the next reaction step.

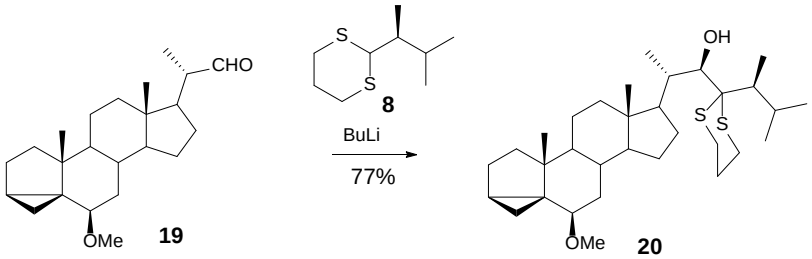
*(c). (S)-2,3-Dimethylbut-3-enal (**42**).* Crude **41** from the previous step was diluted with CH_2Cl_2 (8 mL), and then TEMPO (12 mg, 0.077 mmol) and $PhI(OAc)_2$ (3.14 g, 9.75 mmol) were sequentially added to the obtained solution. The reaction mixture was stirred at room temperature for 2 h and quenched with saturated aqueous $Na_2S_2O_3$ (4 mL). The aqueous layer was separated

and extracted with CH_2Cl_2 (2 mL × 3). The combined organic layers were washed with water (3 ml), aqueous $NaHCO_3$ (2 mL × 3), dried over $MgSO_4$ and filtered. The filter cake was washed with CH_2Cl_2 (2 mL × 2) to give a solution of **42** which was immediately used in the next step.

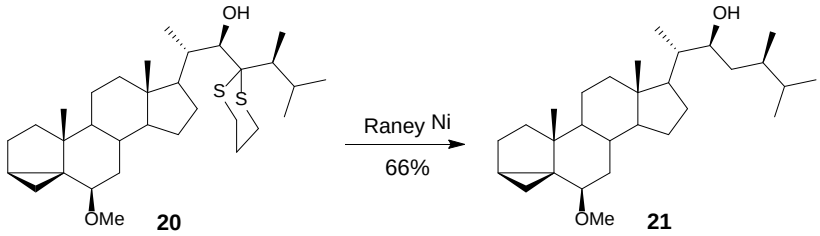
*(d). (S)-2-(3-Methylbut-3-en-2-yl)-1,3-dithiane (**(S)-9**).* The above filtrate containing aldehyde **42** was cooled to -78 °C, and 1,3-propanedithiol (1.74 mL, 17.1 mmol) followed by $BF_3{\cdot}Et_2O$ (1.9 mL, 15.6 mmol) were added. The reaction mixture was warmed to 0 °C and quenched with 20% aqueous NaOH (20 mL). The aqueous layer was separated and extracted with CH_2Cl_2 (10 mL × 3). The combined organic layers were washed with water (10 mL), brine (10 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by column chromatography on Al_2O_3 (PE/Et_2O = 40/1 – 10/1) to give dithiane **(*S*)-9** (0.69 g, 41% over 4 steps) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.84 (d, *J* = 1.1 Hz, 2H), 4.06 (d, *J* = 8.5 Hz, 1H), 2.79 – 2.90 (m, 4H), 2.52 (dq, *J* = 14.0, 7.0 Hz, 1H), 2.05 – 2.13 (m, 1H), 1.82 (qdd, *J* = 8.1, 7.5, 4.3 Hz, 1H), 1.74 (t, *J* = 0.9 Hz, 3H), 1.22 (d, *J* = 7.0 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 145.9, 112.9, 51.7, 46.0, 30.9, 30.6, 25.9, 19.0, 17.0. $[\alpha]_D^{20}$ = +12.0 (c 0.85, $CHCl_3$). IR (film): 3070, 2970, 2934, 2896, 1649, 1449, 1378. HRMS (APCI): calcd for $C_9H_{17}S_2$ $[M+H]^+$ 189.0766, found 189.0761.



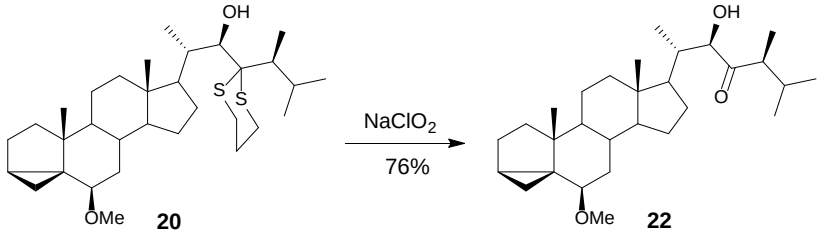
(*R*)-9 was prepared from **(*R*)-18** following the same procedure. $[\alpha]_D^{20}$ = -11.1 (c 1.0, $CHCl_3$).



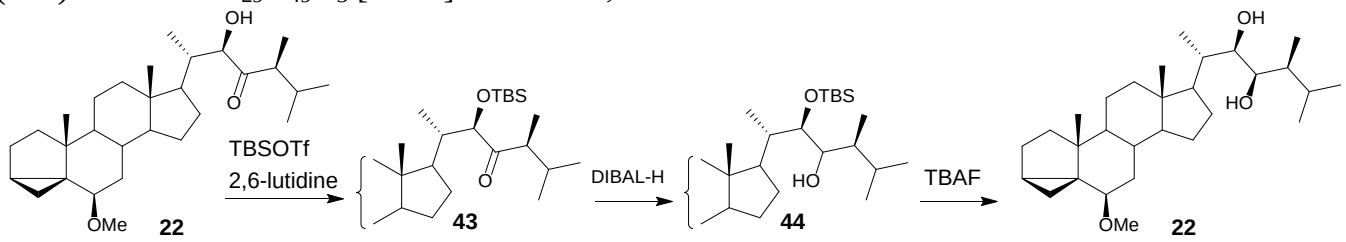
(22*R*)-22-Hydroxy-6β-methoxy-23,23-(trimethylene-dithio)-3α,5-cyclo-5α-campestane (20). 1.9 M solution of *n*-BuLi (1.76 mL, 3.34 mmol) was added at room temperature to a solution of dithiane **8** (0.53 g, 2.78 mmol) in THF (9 mL). The mixture was stirred for 15 min and cooled to -78 °C. A solution of aldehyde **19**[5] (0.48 g, 1.39 mmol) in THF (1.5 mL) was added to the reaction mixture. The solution was stirred at -78 °C for 2 min, quenched with saturated aqueous NH_4Cl (10 mL), and warmed to room temperature. The aqueous layer was separated and extracted with Et_2O (5 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/Et_2O = 40/1 – 2/1) to give alcohol **20** (0.57 g, 77%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.06 (s, 1H), 3.32 (s, 3H), 2.97 (ddd, *J* = 13.9, 9.5, 4.0 Hz, 1H), 2.74 – 2.83 (m, 2H), 2.62 – 2.74 (m, 3H), 2.53 – 2.62 (m, 1H), 2.16 – 2.27 (m, 1H), 2.07 – 0.69 (m, 22H), 1.10 (d, *J* = 6.7 Hz, 3H), 1.08 (d, *J* = 7.0 Hz, 3H), 1.02 (s, 3H), 0.99 (d, *J* = 6.7 Hz, 3H), 0.91 (d, *J* = 6.9 Hz, 3H), 0.77 (s, 3H), 0.61 – 0.66 (m, 1H), 0.43 (dd, *J* = 7.8, 5.1 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 82.4, 75.2, 65.5, 56.6, 56.5, 55.0, 47.9, 44.1, 43.3, 43.0, 40.4, 37.1, 35.2, 35.1, 33.3, 30.6, 28.6, 28.4, 27.0, 25.9, 24.9, 24.3, 24.1, 24.1, 22.8, 21.4, 19.3, 18.1, 14.3, 13.1, 12.0, 9.9. $[\alpha]_D^{20}$ = +23.8 (c 2.0, $CHCl_3$). IR (KBr): 3456, 3060, 2946, 2872, 1463, 1383, 1103. HRMS (APCI): calcd for $C_{32}H_{54}NaO_2S_2$ $[M+Na]^+$ 557.3457, found 557.3452.



(22*S*)-22-Hydroxy-6β-methoxy-3α,5-cyclo-5α-campestane (21). Freshly prepared Raney-Ni (W-7) (200 mg) was added to a solution of compound **20** (30 mg, 0.056 mmol) in EtOH (3 mL). The resulting suspension was stirred under a hydrogen atmosphere for 12 h and then the liquid was decanted. The catalyst was washed with EtOH (5 mL × 3) and the combined organic phases were evaporated under reduced pressure. The residue was purified by column chromatography on silica gel (PE/EtOAc = 4/1 – 2/1) to give alcohol **21** (16 mg, 66%) as an oil. The spectroscopic data of **21** were entirely consistent with those previously reported.[6]



(22*R*)-22-Hydroxy-6β-methoxy-3α,5-cyclo-5α-campestan-23-one (22). A solution of NaH_2PO_4 (14 mg, 0.117 mmol) in H_2O (0.3 mL) and 80% solid $NaClO_2$ (38 mg, 0.42 mmol) were sequentially added at 0 °C to a stirred solution of compound **20** (30 mg, 0.056 mmol) and 2-methyl-2-butene (0.059 mL, 0.56 mmol) in EtOH (3 mL). The reaction mixture was stirred for 5 min and quenched with aqueous saturated $Na_2S_2O_3$ (0.5 mL). The solvents were evaporated and the residue was diluted with EtOAc (10 mL) and water (5 mL). The aqueous layer was separated and extracted with EtOAc (5 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/Et_2O = 4/1 – 2/1) to give ketone **22** (19 mg, 76%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.32 (d, *J* = 4.4 Hz, 1H), 3.33 (s, 3H), 3.29 – 3.32 (m, 1H), 2.78 (s, 1H), 2.45 (p, *J* = 7.2 Hz, 1H), 2.05 (dt, *J* = 13.6, 8.0 Hz, 2H), 1.83 – 1.94 (m, 3H), 1.31 – 1.81 (m, 11H), 1.09 – 1.28 (m, 5H), 1.07 (d, *J* = 7.2 Hz, 3H), 1.02 (s, 3H), 0.93 (d, *J* = 6.8 Hz, 3H), 0.88 (d, *J* = 6.7 Hz, 3H), 0.77 (s, 3H), 0.72 (d, *J* = 6.6 Hz, 3H), 0.63 – 0.67 (m, 1H), 0.44 (dd, *J* = 7.9, 5.1 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 216.3, 82.4, 77.3, 56.6, 56.4, 52.6, 48.1, 47.9, 43.4, 42.6, 40.0, 38.2, 35.1 (×2), 33.3, 30.6, 28.7, 28.4, 24.9, 24.0, 22.7, 21.5, 21.4, 19.3, 19.0, 15.2, 13.1, 12.5, 12.2. $[\alpha]_D^{20}$ = -29.1 (c 1.1, $CHCl_3$). IR (KBr): 3476, 3058, 2931, 1703, 1459, 1382, 1098. HRMS (ESI): calcd for $C_{29}H_{49}O_3$ $[M+H]^+$ 445.3676, found 445.3666.

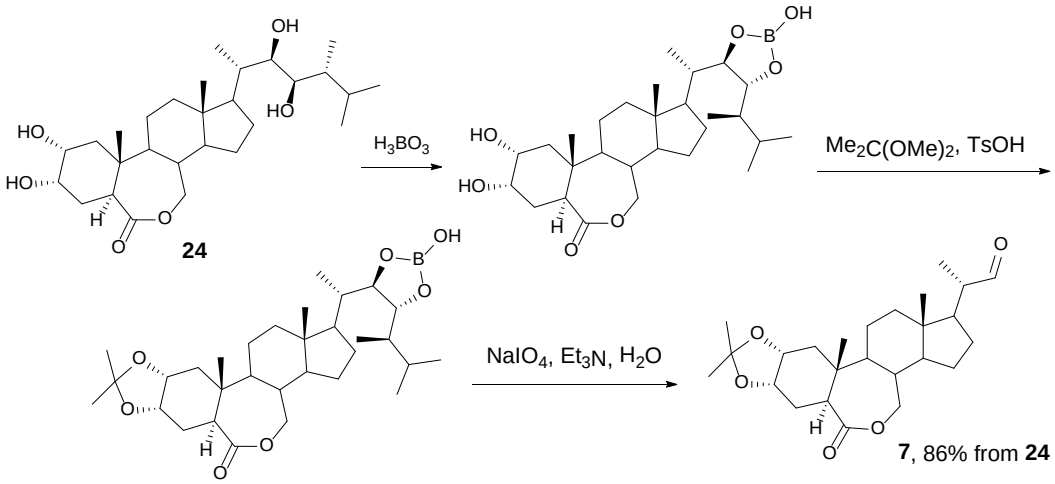


(22*R*,23*R*)-6β-Methoxy-3α,5-cyclo-5α-campestan-22,23-diol (23). *(a). (22R)-22-[(tert-Butyldimethylsilyl)oxy]-6β-methoxy-3α,5-cyclo-5α-campestan-23-one (**43**).* TBSOTf (0.122 ml, 0.53 mmol) was added at 0 °C to a stirred solution of alcohol **22** (0.12 g, 0.27 mmol) and 2,6-lutidine (0.156 mL, 1.34 mmol) in CH_2Cl_2 (1.2 mL). The reaction mixture was stirred for 30 min at the same temperature and quenched with saturated aqueous $NaHCO_3$ (2 mL). The aqueous layer was separated and extracted with EtOAc (3 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column

chromatography on SiO_2 (PE/Et_2O = 9/2 – 3/1) to give TBS ether **43** (0.14 g, 93%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.31 (s, 1H), 3.34 (s, 3H), 2.79 (t, *J* = 2.7 Hz, 1H), 2.37 (dq, *J* = 14.3, 7.1 Hz, 1H), 1.83 – 1.99 (m, 5H), 1.05 – 1.81 (m, 16H), 1.02 (s, 3H), 1.01 (d, *J* = 7.1 Hz, 3H), 0.92 (s, 9H), 0.91 (d, *J* = 8.5 Hz, 3H), 0.82 (d, *J* = 6.6 Hz, 3H), 0.79 (d, *J* = 6.6 Hz, 3H), 0.75 (s, 3H), 0.64 – 0.67 (m, 1H), 0.44 (dd, *J* = 7.9, 5.1 Hz, 1H), 0.05 (s, 3H), -0.02 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 214.6, 82.4, 79.2, 56.8, 56.6, 52.5, 48.5, 47.9, 43.4, 42.6, 40.1, 38.5, 35.1(×2), 33.3, 30.6, 29.1, 28.7, 25.9(×3), 24.9, 24.1, 22.7, 21.5, 21.4, 19.4, 19.2, 18.5, 15.9, 13.1, 12.9, 12.0, -4.2, -5.0. $[\alpha]_D^{20}$ = -18 (c 1, $CHCl_3$). IR (KBr): 2949, 1726, 1468, 1382, 1264, 1063. HRMS (ESI): calcd for $C_{35}H_{63}O_3Si$ $[M+H]^+$ 559.4541, found 559.4539.

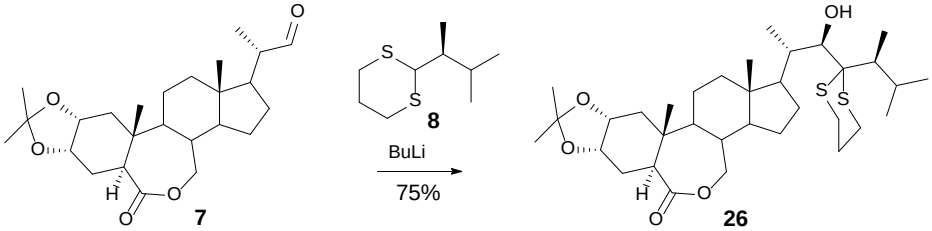
*(b). (22R)-22-[(tert-Butyldimethylsilyl)oxy]-23-hydroxy-6β-methoxy-3α,5-cyclo-5α-campestane (**44**).* A 1 M solution of DIBAL-H in toluene (0.2 mL, 0.2 mmol) was added to a stirred solution of ketone **43** (22 mg, 0.039 mmol) in toluene (1 mL) at -78 °C. The mixture was stirred at the same temperature for 15 min and quenched with MeOH (0.2 mL). Saturated aqueous solution of Na-K-tartrate (2 mL) and EtOAc (2 mL) were added to the mixture and the resulting mixture was stirred at room temperature for 1 h. The aqueous layer was separated and extracted with EtOAc (2 mL × 3). The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4 and concentrated under reduced pressure to give crude **44** (22 mg), which was used directly in the next step without further purification.

*(c). (22R,23R)-6β-Methoxy-3α,5-cyclo-5α-campestan-22,23-diol (**23**).* Crude **44** (22 mg) was diluted with THF (0.5 mL) and a 1 M solution of TBAF in THF (0.2 mL, 0.2 mmol) was added. The mixture was stirred at room temperature for 1 h, diluted with EtOAc (10 mL) and washed with a concentrated aqueous solution of NH_4Cl (2 mL). The organic layer was separated, washed with brine (2 mL), dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/EtOAc = 9/1 – 7/3) to give *syn*-diol **23** (16 mg, 91%) as an oil. The physical and spectroscopic data of **23** were entirely consistent with those previously reported.[7]

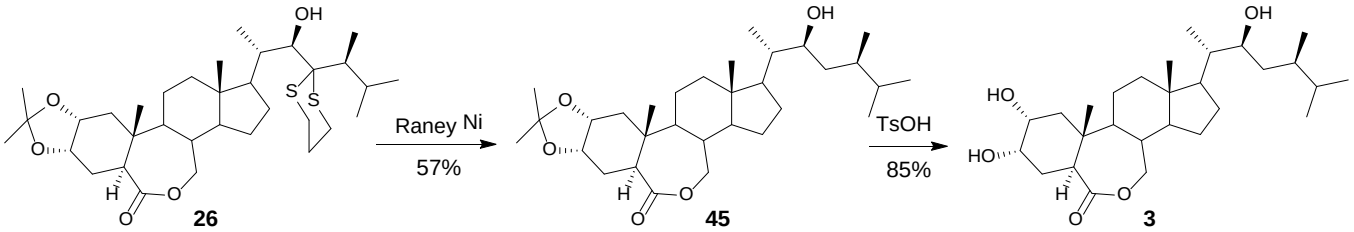


(20*S*)-20-Formyl-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-pregnan-6-one (7). Boric acid (513 mg, 8.27 mmol) was added to a stirred solution of epibrassinolide (**24**) (3.63 g, 7.56 mmol) in THF (90 mL) at 23 °C. One hour later the resulting solution of boronic ester was treated with 2,2-dimethoxypropane (9.35 mL, 76.3 mmol) and TsOH·H_2O (287 mg, 1.51 mmol). The mixture was stirred for 1.5 h, then triethylamine (3.15 mL, 22.6 mmol), water (30 mL) and $NaIO_4$ (4.84 g, 22.6 mmol) were added successively. After stirring for 18 h at 23 °C, the reaction mixture was diluted with H_2O (150 mL) and EtOAc (50 mL). The organic layer was separated, and the water phase was extracted with EtOAc (50 mL × 2). The combined organic phases were dried over Na_2SO_4 and concentrated *in vacuo*. The residue was chromatographed on silica gel (PE/EtOAc = 3/1) to give 2.72 g (86%) of aldehyde **7** as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 9.55 (d, *J* = 3.0 Hz, 1H), 4.31 – 4.40 (m, 2H), 4.04 – 4.12 (m, 2H), 3.27 (dd, *J* = 10.6, 4.0 Hz, 1H), 2.26 – 2.40 (m, 2H), 1.60 – 1.96 (m, 8H), 1.48 – 1.58 (m, 4H), 1.15 – 1.45 (m, 8H),

1.07 – 1.13 (m, 4H), 0.87 (s, 3H), 0.74 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 204.5, 176.5, 107.5, 73.0, 72.4, 71.0, 54.6, 51.2, 50.7, 49.3, 43.6, 40.1, 39.3, 39.3, 35.9, 33.4, 27.6, 27.0, 26.5, 24.9, 23.6, 22.8, 19.6, 13.3, 12.4. $[\alpha]_D^{20}$ = +19.9° (*c* = 1.1; $CHCl_3$). IR (film): 2945, 2708, 1738, 1727, 1460, 1380, 1314, 1261, 1207, 1180, 1061, 753. HRMS (APCI): calcd for $C_{25}H_{39}O_5$ $[M+H]^+$ 419.2792, found: 419.2786.



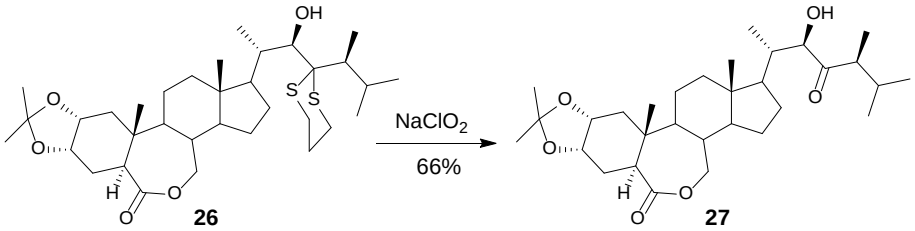
(22*R*)-22-Hydroxy-2α,3α-isopropylidenedioxy-23,23-(trimethylenedithio)-B-homo-7-oxa-5α-campestan-6-one (26). The title compound (4.17 g) was prepared in 75% yield as a foam from aldehyde **7** and dithiane **8** as described above for the preparation of compound **20**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.31 – 4.41 (m, 2H), 4.14 – 4.04 (m, 2H), 4.02 (d, *J* = 4.0 Hz, 1H), 3.28 (dd, *J* = 10.3, 4.1 Hz, 1H), 2.87 – 3.01 (m, 1H), 2.73 – 2.81 (m, 1H), 2.69 (dt, *J* = 12.6, 5.1 Hz, 3H), 2.57 (dt, *J* = 12.6, 6.3 Hz, 1H), 2.31 (dd, *J* = 15.6, 3.2 Hz, 1H), 2.16 – 2.25 (m, 1H), 1.05 – 2.07 (m, 18H), 1.51 (s, 3H), 1.31 (s, 3H), 1.09 (d, *J* = 6.6 Hz, 3H), 1.07 (d, *J* = 7.1 Hz, 3H), 0.98 (d, *J* = 6.7 Hz, 3H), 0.90 (d, *J* = 6.8 Hz, 3H), 0.87 (s, 3H), 0.76 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.6, 107.6, 75.0, 73.0, 72.4, 71.2, 65.4, 54.6, 54.6, 51.9, 44.1, 43.3, 40.2, 39.8, 39.4, 37.0, 35.9, 33.5, 28.3(×2), 27.6, 27.0, 26.5, 25.9, 24.5, 24.3, 24.0, 23.6, 23.0, 19.6, 18.1, 14.2, 11.9, 9.9. $[\alpha]_D^{20}$ = +23 (c 1, $CHCl_3$). IR (KBr): 3450, 2944, 1724, 1466, 1387, 1064. HRMS (APCI): calcd for $C_{34}H_{57}O_5S_2$ $[M+H]^+$ 609.3647, found 609.3624.



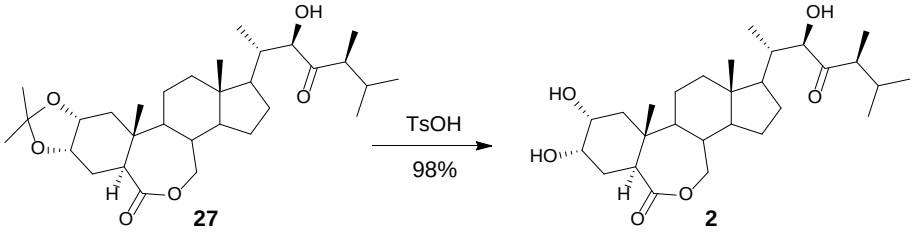
(22*S*)-2α,3α,22-Trihydroxy-B-homo-7-oxa-5α-campestan-6-one (3). *(a). (22S)-22-Hydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6-one (**45**).* The title compound (79 mg) was prepared in 57% yield as white crystals from dithiane **26** as described above for the preparation of compound **21**. Mp: 226-228 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.31 – 4.40 (m, 2H), 4.02 – 4.14 (m, 2H), 3.74 (t, *J* = 6.4 Hz, 1H), 3.28 (dd, *J* = 10.4, 4.1 Hz, 1H), 2.31 (dd, *J* = 15.7, 3.4 Hz, 1H), 2.04 – 1.89 (m, 2H), 1.86 – 1.68 (m, 5H), 1.68 – 1.16 (m, 13H), 1.50 (s, 3H), 1.30 (s, 3H), 1.10 (dd, *J* = 15.7, 2.0 Hz, 1H), 0.89-0.84 (m, 9H), 0.81 (d, *J* = 6.7 Hz, 3H), 0.79 (d, *J* = 6.8 Hz, 3H), 0.71 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.6, 107.5, 73.0, 72.4, 71.4, 71.2, 54.6, 52.3, 51.8, 43.0, 40.1, 39.7, 39.36, 39.33, 39.27, 35.9, 35.3, 33.4, 32.0, 27.7, 27.6, 26.5, 24.5, 23.6, 22.9, 19.9, 19.6, 17.8, 15.7, 12.1, 11.1. $[\alpha]_D^{20}$ = +26.3 (c 1.5, $CHCl_3$). IR (KBr): 3498, 2952, 1744, 1466, 1383, 1055. HRMS (APCI): calcd for $C_{31}H_{53}O_5$ $[M+H]^+$ 505.3888, found 505.3867.

*(b). (22S)-2α,3α,22-Trihydroxy-B-homo-7-oxa-5α-campestan-6-one (**3**).* $TsOH{\cdot}H_2O$ (10 mg, 0.26 mmol) was added to a solution of compound **45** (14 mg, 0.028 mmol) in a mixture of MeOH (3 mL), THF (3 mL) and H_2O (0.6 mL). The resulting solution was stirred at room temperature for 48 h and quenched with aqueous $NaHCO_3$. The solvents were evaporated under reduced pressure and the residue was diluted with $CHCl_3$ (10 mL) and water (5 mL). The aqueous layer was separated and extracted with $CHCl_3$ (3 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 ($CHCl_3$–MeOH 40:1-9:1) to give compound **3** (11 mg, 85%) as white crystals. Mp: 246-248 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.06 – 4.12 (m, 2H), 3.99 – 4.05 (m,

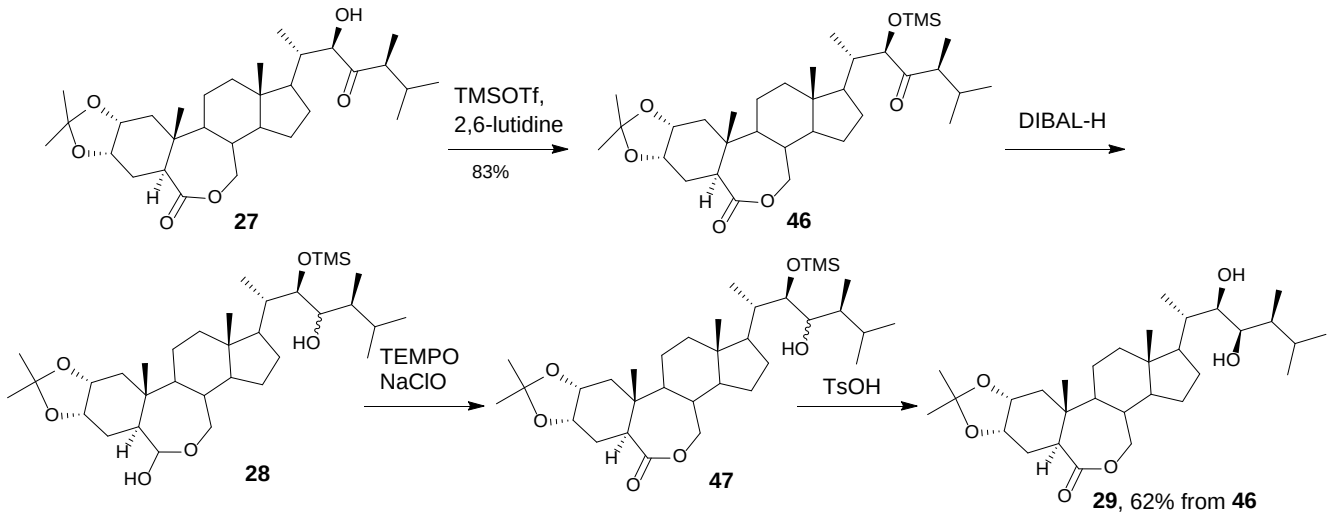
1H), 3.74 (t, *J* = 6.6 Hz, 1H), 3.67 – 3.72 (m, 1H), 3.11 (dd, *J* = 12.2, 4.4 Hz, 1H), 2.45 (br. s, 1H), 2.20 (br. s, 1H), 2.17 – 2.07 (m, 1H), 2.01 – 1.90 (m, 3H), 1.86 (dd, *J* = 12.7, 4.6 Hz, 1H), 1.79 – 1.11 (m, 19H), 0.91 (s, 3H), 0.87 (d, *J* = 6.6 Hz, 3H), 0.82 (d, *J* = 6.7 Hz, 3H), 0.80 (d, *J* = 6.9 Hz, 3H), 0.70 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.4, 71.5, 70.5, 68.1, 68.0, 58.2, 52.4, 51.3, 42.5, 41.4, 40.9, 39.6, 39.4, 39.3, 39.2, 38.3, 35.3, 32.0, 31.0, 27.6, 24.7, 22.2, 20.0, 17.8, 15.8, 15.5, 11.7, 11.1. $[\alpha]_D^{20}$ = -44.3 (c 0.7, $CHCl_3$). IR (KBr): 3436, 2955, 1737, 1468, 1382. HRMS (APCI): calcd for $C_{28}H_{49}O_5$ $[M+H]^+$ 465.3575, found 465.3556.



(22*R*)-22-Hydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6,23-dione (27). The title compound (1.06 g) was prepared in 66% yield as white crystals from dithiane **26** as described above for the preparation of compound **22**. Mp: 189-191 °C. ^{1}H NMR (500 MHz, $CDCl_3$): 4.32 – 4.41 (m, 2H), 4.29 (d, *J* = 4.6 Hz, 1H), 4.04 – 4.16 (m, 2H), 3.32 (d, *J* = 5.6 Hz, 1H), 3.29 (dd, *J* = 10.8, 3.7 Hz, 1H), 2.42 (p, *J* = 7.2 Hz, 1H), 2.31 (dd, *J* = 15.7, 3.5 Hz, 1H), 1.98 – 2.13 (m, 2H), 1.59 – 1.96 (m, 10H), 1.51 (s, 3H), 1.49 – 1.20 (m, 5H), 1.30 (s, 3H), 1.06 (d, *J* = 7.2 Hz, 3H), 0.92 (d, *J* = 6.8 Hz, 3H), 0.88 (s, 3H), 0.87 (d, *J* = 6.3 Hz, 3H), 0.76 (s, 3H), 0.72 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 216.0, 176.6, 107.6, 77.1, 73.0, 72.4, 71.1, 54.6, 52.3, 51.9, 48.1, 42.9, 40.1, 39.5, 39.4, 38.2, 35.9, 33.4, 28.7, 28.2, 27.5, 26.5, 24.4, 23.6, 22.9, 21.5, 19.6, 19.0, 15.1, 12.4, 12.1. $[\alpha]_D^{20}$ = -22.9 (c 1.7, $CHCl_3$). IR (KBr): 3450, 2963, 1744, 1715, 1466, 1378, 1180. HRMS (APCI): calcd for $C_{31}H_{51}O_6$ $[M+H]^+$ 519.3680, found 519.3655.



(22*R*)-2α,3α,22-Trihydroxy-B-homo-7-oxa-5α-campestan-6,23-dione (2) /cryptolide (2)/. $TsOH \cdot H_2O$ (50 mg, 0.26 mmol) was added to a solution of compound **27** (100 mg, 0.198 mmol) in a mixture of MeOH (10 mL), THF (10 mL) and H_2O (2 mL). The resulting solution was stirred at room temperature for 48 h and quenched with aqueous $NaHCO_3$. The solvents were evaporated under reduced pressure and the residue was diluted with $CHCl_3$ (10 mL) and water (5 mL). The aqueous layer was separated and extracted with $CHCl_3$ (3 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 ($CHCl_3$–MeOH 40:1-9:1) to give cryptolide **2** (90 mg, 98%) as white crystals. Mp: 238-240 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.29 (d, *J* = 5.2 Hz, 1H), 4.09 (d, *J* = 5.1 Hz, 2H), 4.01 (s, 1H), 3.69 (d, *J* = 9.9 Hz, 1H), 3.40 (d, *J* = 5.4 Hz, 1H), 3.12 (dd, *J* = 12.0, 4.0 Hz, 1H), 2.20 – 2.59 (m, 3H), 1.12 – 2.19 (m, 18H), 1.06 (d, *J* = 7.2 Hz, 3H), 0.92 (d, *J* = 6.9 Hz, 3H), 0.90 (s, 3H), 0.86 (d, *J* = 6.7 Hz, 3H), 0.74 (s, 3H), 0.71 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 216.0, 176.4, 77.1, 70.4, 68.0, 68.0, 58.0, 52.3, 51.3, 48.1, 42.4, 41.4, 40.8, 39.3, 39.2, 38.3, 38.1, 31.0, 28.7, 28.0, 24.6, 22.1, 21.5, 19.0, 15.4, 15.1, 12.4, 11.7. $[\alpha]_D^{20}$ = -23.6 (c 1.1, $CHCl_3$). IR (KBr): 3439, 2962, 2937, 1728, 1706, 1469, 1391. HRMS (APCI): calcd for $C_{28}H_{47}O_6$ $[M+H]^+$ 479.3367, found 479.3353.

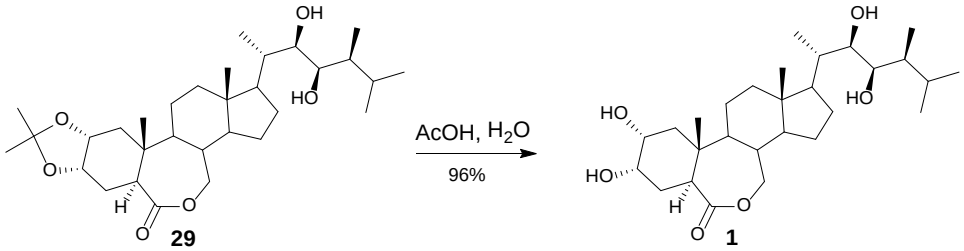


(22*R*,23*R*)-22,23-Dihydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6-one (29). *(a). (22R)-22-[(Trimethylsilyl)oxy]-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6,23-dione (**46**).* TMSOTf (0.81 mL, 4.47 mmol) was added at 0 °C to a stirred solution of alcohol **27** (1.54 g, 2.97 mmol) and 2,6-lutidine (0.69 mL, 5.96 mmol) in CH_2Cl_2 (20 mL). The reaction mixture was stirred for 30 min at the same temperature and quenched with aqueous $NaHCO_3$ (20 mL). The aqueous layer was separated and extracted with CH_2Cl_2 (7 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/Et_2O = 9/2 – 3/1) to give TMS ether **46** (1.45 g, 83%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.33 – 4.40 (m, 2H), 4.21 (s, 1H), 4.04 – 4.15 (m, 2H), 3.29 (dd, *J* = 9.9, 4.6 Hz, 1H), 2.44 – 2.54 (m, 1H), 2.31 (dd, *J* = 15.7, 3.4 Hz, 1H), 2.02 – 1.15 (m, 13H), 1.53 (s, 3H), 1.31 (s, 3H), 1.12 (dd, *J* = 15.7, 1.9 Hz, 1H), 0.99 (d, *J* = 7.1 Hz, 3H), 0.89 (d, *J* = 6.3 Hz, 6H), 0.88 (s, 3H), 0.84 (d, *J* = 6.6 Hz, 3H), 0.78 (d, *J* = 6.7 Hz, 3H), 0.74 (s, 3H), 0.12 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 215.5, 176.6, 107.6, 79.8, 73.1, 72.4, 71.1, 54.6, 52.1, 51.9, 48.0, 43.0, 40.2, 39.5, 39.4, 38.7, 36.0, 33.5, 29.1, 28.3, 27.7, 26.6, 24.6, 23.7, 22.9, 21.6, 19.6, 18.9, 14.7, 13.1, 12.0, 0.4 (×3). $[\alpha]_D^{20}$ = -4.6 (c 1.3, $CHCl_3$). IR (KBr): 2959, 1741, 1717, 1468, 1384, 1254, 1067. HRMS (APCI): calcd for $C_{34}H_{59}O_6Si$ $[M+H]^+$ 591.4075, found 591.4047.

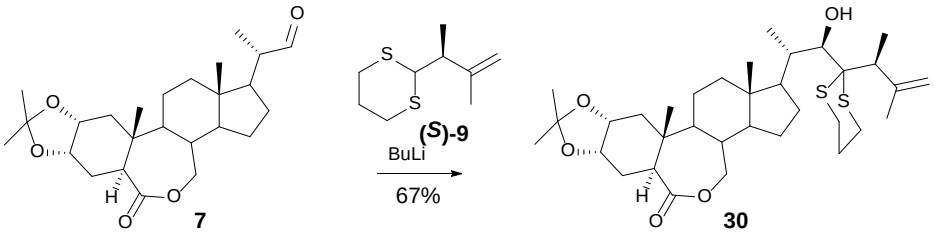
*(b). (22R)-22-[(Trimethylsilyl)oxy]-6,23-dihydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestane (**28**).* A 1 M solution of DIBAL-H in toluene (7.6 mL, 7.6 mmol) was added to a stirred solution of **46** (1.08 g, 1.83 mmol) in toluene (38 mL) at -78 °C. The mixture was stirred at the same temperature for 15 min and quenched with MeOH (2 mL). A saturated aqueous solution of Na-K-tartrate (40 mL) and EtOAc (40 mL) were added to the mixture and the resulting mixture was stirred at room temperature for 1 h. The aqueous layer was separated and extracted with EtOAc (10 mL × 3). The combined organic layers were washed with brine (20 mL), dried over Na_2SO_4 and concentrated under reduced pressure to give an inseparable mixture (70:30, based on ^{1}H NMR spectrum) of diastereomeric at C-23 alcohols **28** (1.2 g) which were taken on to the next reaction without further purification.

*(c). (22R)-22-[(Trimethylsilyl)oxy]-23-hydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6-one (**47**).* A solution of KBr (22 mg, 0.18 mmol) in a phosphate buffer (9.6 mL, pH 7) was added to a solution of crude lactol **28** (1.2 g) and TEMPO (85 mg, 0.54 mmol) in CH_2Cl_2 (50 mL). A mixture of a 10% solution of NaClO (4.5 mL, 6.04 mmol) and brine (4.5 mL) was added to the vigorously stirred mixture over 40 min at 0 °C. The reaction mixture was stirred for 30 min and quenched with $Na_2S_2O_3$ (20 mL). The aqueous layer was separated and extracted with $CHCl_3$ (15 mL × 3). The combined organic layers were washed with water (20 mL), dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/EtOAc = 9/1 – 3/1) to give **47** as an oil (1.02 g, an inseparable mixture of 23-alcohols).

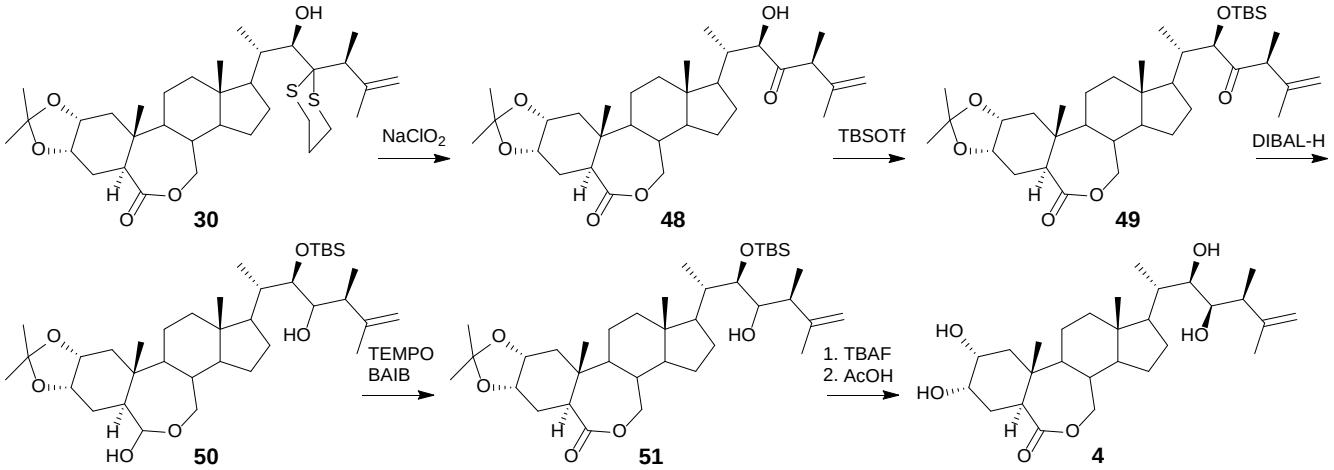
*(d). (22R,23R)-22,23-Dihydroxy-2α,3α-isopropylidene-dioxy-B-homo-7-oxa-5α-campestan-6-one (**29**).* PPTS (50 mg, 0.26 mmol) was added to a solution of **47** (1.02 g) in MeOH (20 mL). The reaction mixture was stirred at room temperature for 10 min, quenched with Et_3N (0.1 mL) and evaporated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/EtOAc = 4/1 – 1/1) to give diol **29** (0.59 g, 62% over 3 steps) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.33 – 4.41 (m, 2H), 4.11 (dd, *J* = 12.9, 2.8 Hz, 1H), 4.07 (dd, *J* = 12.7, 9.5 Hz, 1H), 3.71 (d, *J* = 8.0 Hz, 1H), 3.54 (d, *J* = 8.3 Hz, 1H), 3.29 (dd, *J* = 10.6, 4.1 Hz, 1H), 2.31 (dd, *J* = 15.7, 3.6 Hz, 1H), 2.10 (br. s, 1H), 2.02 – 1.93 (m, 2H), 1.90 (br. s, 1H), 1.86 – 1.16 (m, 15H), 1.51 (s, 3H), 1.31 (s, 3H), 1.10 (dd, *J* = 15.7, 2.3 Hz, 1H), 0.96 (d, *J* = 6.7 Hz, 3H), 0.94 (d, *J* = 6.7 Hz, 3H), 0.89 (d, *J* = 6.7 Hz, 3H), 0.88 (s, 3H), 0.84 (d, *J* = 6.9 Hz, 3H), 0.72 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.6, 107.6, 74.6, 73.5, 73.0, 72.4, 71.2, 54.6, 52.2, 51.8, 42.9, 40.2, 40.0, 39.8, 39.4, 36.8, 35.9, 33.5, 30.7, 27.7, 27.6, 26.5, 24.4, 23.6, 23.0, 20.8, 20.7, 19.6, 12.1, 11.8, 10.1. $[\alpha]_D^{20}$ = +25.0 (c 1.0, $CHCl_3$). IR (KBr): 3445, 2946, 1737, 1467, 1381, 1065. HRMS (APCI): calcd for $C_{31}H_{53}O_6$ $[M+H]^+$ 521.3837, found 521.3840.



(22*R*,23*R*)-2α,3α,22,23-Tetrahydroxy-B-homo-7-oxa-5α-campestan-6-one (1) /brassinolide (1)/. A solution of acetonide **29** (0.68 g, 1.31 mmol) in a mixture of AcOH (20 mL) and H_2O (4 mL) was heated at 60 °C for 1 h. The solvents were evaporated under reduced pressure. The residue was purified by column chromatography on SiO_2 ($CHCl_3$/*i*-PrOH = 10/1 – 4/1) to give brassinolide (0.60 g, 96%) as white crystals. Mp: 273-278 °C, lit.[8] 273-278 °C, lit.[9] 278-281 °C. Spectral data (^{1}H and ^{13}C NMR) are identical with those reported.[10]



(22*R*)-22-Hydroxy-2α,3α-isopropylidenedioxy-23,23-(trimethylenedithio)-B-homo-7-oxa-5α-campest-25-en-6-one (30). The title compound (144 mg) was prepared in 67% yield as a foam from aldehyde **7** and dithiane **(*S*)-9** as described above for the preparation of compound **20**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.91 (d, *J* = 1.0 Hz, 1H), 4.83 – 4.84 (m, 1H), 4.32 – 4.39 (m, 2H), 3.99 – 4.15 (m, 2H), 3.90 (d, *J* = 4.6 Hz, 1H), 3.27 (dd, *J* = 10.2, 4.3 Hz, 1H), 2.86 – 3.00 (m, 2H), 2.64 – 2.78 (m, 4H), 2.30 (dd, *J* = 15.8, 3.7 Hz, 1H), 2.25 (dd, *J* = 11.6, 5.0 Hz, 1H), 2.10 – 1.07 (m, 17H),1.96 (s, 3H), 1.50 (s, 3H), 1.30 (s, 3H), 1.24 (t, *J* = 5.7 Hz, 3H), 1.14 (d, *J* = 6.6 Hz, 3H), 0.86 (s, 3H), 0.76 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.6, 148.3, 114.4, 107.5, 74.0, 73.0, 72.4, 71.1, 61.7, 54.9, 54.6, 51.8, 45.6, 43.2, 40.1, 39.8, 39.3, 37.1, 35.9, 33.5, 28.5, 27.5, 27.1, 26.6, 26.4, 24.6, 24.0, 23.6, 22.9, 21.9, 19.6, 16.4, 14.5, 11.9. $[\alpha]_D^{20}$ = +19 (c 0.9, $CHCl_3$). IR (KBr): 3464, 3074, 2943, 1736, 1638, 1461, 1385, 1070. HRMS (APCI): calcd for $C_{34}H_{55}O_5S_2$ $[M+H]^+$ 607.3485, found 607.3464.



(22*R*,23*R*)-2α,3α,22,23-Tetrahydroxy-B-homo-7-oxa-5α-campest-25-en-6-one (4). *(a). (22R)-22-Hydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campest-25-en-6,23-dione (**48**).* The title compound (1.06 g) was prepared in 66% yield as an oil from dithiane **30** as described above for the preparation of compound **22**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.88 – 4.90 (m, 1H), 4.85 (s, 1H), 4.31 – 4.38 (m, 2H), 4.24 (dd, *J* = 5.0, 1.2 Hz, 1H), 4.02 – 4.13 (m, 2H), 3.41 (q, *J* = 7.0 Hz, 1H), 3.24 – 3.29 (m, 2H), 2.29 (dd, *J* = 15.7, 3.6 Hz, 1H), 2.11 – 1.02 (m, 16H), 1.73 (s, 3H), 1.49 (s, 3H), 1.29 (s, 3H), 1.22 (d, *J* = 7.1 Hz, 3H), 0.86 (d, *J* = 3.4 Hz, 3H), 0.73 (s, 3H), 0.66 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 213.1, 176.5, 143.2, 113.7, 107.5, 78.9, 73.0, 72.4, 71.1, 54.5, 52.1, 51.8, 49.5, 42.8, 40.1, 39.4, 39.4, 38.4, 35.8, 33.4, 28.1, 27.5, 26.4, 24.4, 23.5, 22.8, 20.1, 19.6, 16.8, 12.7, 12.0. $[\alpha]_D^{20}$ = +26 (c 1.0, $CHCl_3$). IR (CCl_4): 3491, 3078, 2941, 1742, 1709, 1640, 1453, 1381, 1046. HRMS (APCI): calcd for $C_{31}H_{49}O_6$ $[M+H]^+$ 517.3524, found 517.3502.

*(b). (22R)-22-[(tert-Butyldimethylsilyl)oxy]-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campest-25-en-6-one (**49**).* The title compound (74 mg) was prepared in 80% yield as an oil from hydroxy ketone **48** as described above for the preparation of compound **43**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.85 (s, 1H), 4.81 (s, 1H), 4.32 – 4.39 (m, 2H), 4.28 (s, 1H), 4.05 – 4.15 (m, 2H), 3.34 (q, *J* = 6.9 Hz, 1H), 3.28 (dd, *J* = 9.4, 5.2 Hz, 1H), 2.29 (dd, *J* = 15.7, 3.3 Hz, 1H), 2.00 – 1.09 (m, 16H), 1.70 (s, 3H), 1.53 (s, 3H), 1.31 (s, 3H), 1.18 (d, *J* = 7.0 Hz, 3H), 0.91 (s, 9H), 0.87 (s, 3H), 0.73 (d, *J* = 6.7 Hz, 3H), 0.71 (s, 3H), 0.05 (s, 3H), -0.04 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 211.2, 176.5, 143.8, 112.9, 107.6, 80.4, 73.0, 72.4, 71.1, 54.5, 52.1, 52.0, 49.5, 42.9, 40.2, 39.5, 39.4, 39.0, 36.0, 33.6, 28.3, 27.7, 26.6, 25.9 (×3), 24.6, 23.7, 22.8, 20.3, 19.5, 18.4, 17.1, 12.8, 11.9, -4.3, -5.2. $[\alpha]_D^{20}$ = +24 (c 1.0, $CHCl_3$). IR (film): 3073, 2956, 1743, 1724, 1647, 1467, 1381, 1257, 1068. HRMS (APCI): calcd for $C_{37}H_{63}O_6Si$ $[M+H]^+$ 631.4388, found 631.4360.

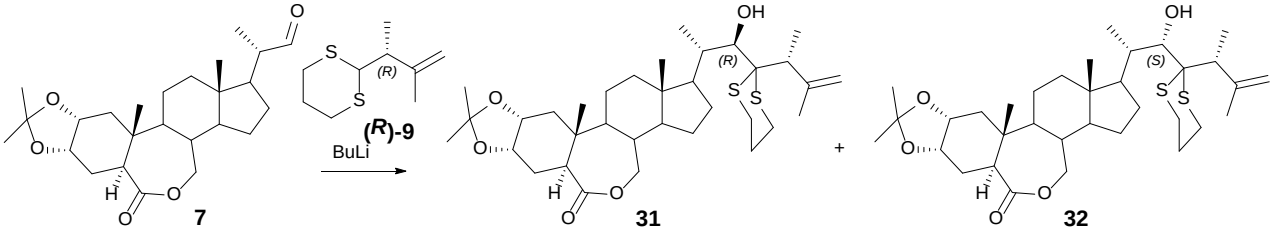
*(c). (22R)-22-[(tert-Butyldimethylsilyl)oxy]-6α,23-dihydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campest-25-ene (**50**).* A 1 M solution of DIBAL-H in toluene (0.2 mL, 0.2 mmol) was added to a stirred solution of ketone **49** (21 mg, 0.033 mmol) in toluene (1 mL) at -78 °C. The mixture was stirred at the same temperature for 15 min and quenched with MeOH (0.2 mL). A saturated aqueous solution of Na-K-tartrate (2 mL) and EtOAc (2 mL) were added to the mixture and the resulting mixture was stirred at room temperature for 1 h. The aqueous layer was separated and extracted with EtOAc (1 mL × 3). The combined organic layers were washed with brine (1 mL), dried over Na_2SO_4 and concentrated under reduced pressure to give lactol **50** used in the next step without further purification.

*(d). (22R)-22-[(tert-Butyldimethylsilyl)oxy]-23-hydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campest-25-en-6-one (**51**).* BAIB (43 mg, 0.13 mmol) and TEMPO (20 mg, 0.13 mmol) were added to the crude **50** in CH_2Cl_2 (1 mL). The reaction mixture was stirred for 4 h and quenched with an aqueous saturated solutions of $Na_2S_2O_3$ (2 mL) and $NaHCO_3$ (2 mL). The aqueous layer was separated and extracted with EtOAc (5 mL × 3). The combined organic layers were washed with water (2 mL), dried over Na_2SO_4 and concentrated under reduced pressure. The

residue was purified by column chromatography on SiO_2 (PE/Et_2O = 9/1 – 3/1) to give **51** (20 mg, 95%, an inseparable mixture of 23-alcohols) as an oil, which was carried on for the next step without further purification.

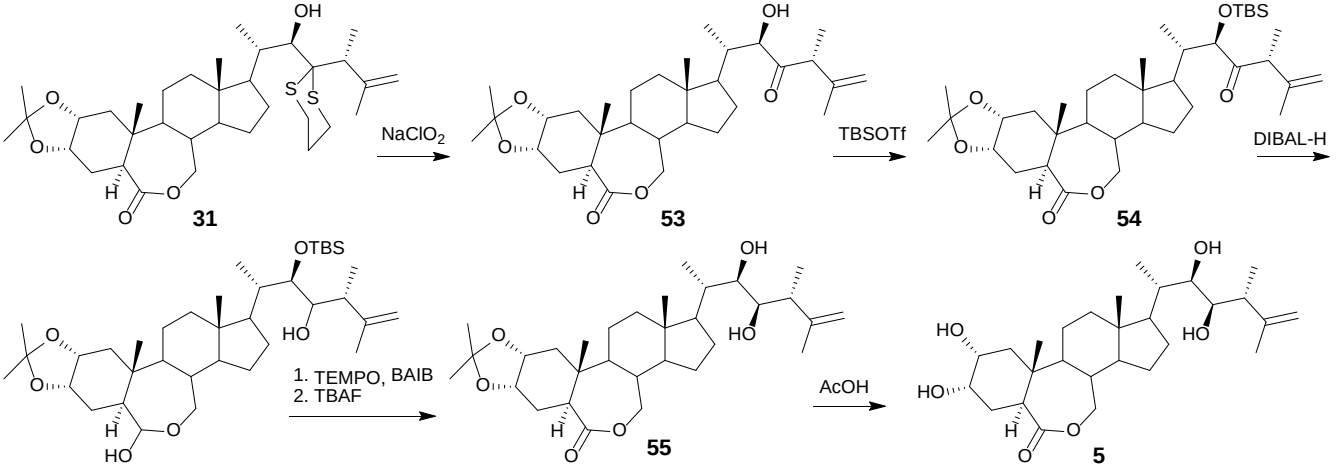
*(e). (22R,23R)-22,23-Dihydroxy-2α,3α-isopropylidene-dioxy-B-homo-7-oxa-5α-campest-25-en-6-one (**52**).* 1 M solution of TBAF in THF (0.2 ml, 0.2 mmol) was added to a solution of crude **51** (20 mg, 0.031 mmol). The mixture was stirred at room temperature for 1 h, diluted with EtOAc (10 mL) and washed with a saturated aqueous solution of NH_4Cl (2 mL). The organic layer was separated, washed with water (2 mL), brine (2 mL), dried over Na_2SO_4 and concentrated under reduced pressure. The residue was analyzed by ^1H NMR to determine the diastereoselectivity of the reaction (92:8) and purified by column chromatography on SiO_2 (PE/EtOAc = 9/1 – 7/3) to give compound **52** (14 mg, 82%) as an oil. ^1H NMR (500 MHz, $CDCl_3$): δ 4.94 (s, 1H), 4.81 (s, 1H), 4.33 – 4.40 (m, 2H), 4.04 – 4.14 (m, 2H), 3.55 – 3.62 (s, 2H), 3.29 (dd, *J* = 10.6, 4.0 Hz, 1H), 2.31 (dd, *J* = 15.7, 3.6 Hz, 1H), 2.24 (dd, *J* = 13.1, 6.2 Hz, 1H), 2.05 – 1.18 (m, 15H), 1.78 (s, 3H), 1.51 (s, 3H), 1.31 (s, 3H), 1.10 (dd, *J* = 15.7, 2.2 Hz, 1H), 1.00 (d, *J* = 7.0 Hz, 3H), 0.96 (d, *J* = 6.7 Hz, 3H), 0.87 (s, 3H), 0.72 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.7, 147.7, 111.8, 107.6, 73.5, 73.0, 72.8, 72.4, 71.2, 54.6, 52.1, 51.8, 42.9, 41.7, 40.2, 39.8, 39.4, 37.4, 35.9, 33.5, 27.7, 27.5, 26.5, 24.4, 23.6, 23.0, 22.2, 19.6, 12.1, 12.0, 11.6. $[\alpha]_D^{20}$ = +31 (c 0.55, $CHCl_3$). IR (film): 3469, 3073, 2943, 1734, 1644, 1455, 1381, 1068. HRMS (APCI): calcd for $C_{31}H_{51}O_6$ $[M+H]^+$ 519.3680, found 519.3663.

*(f). (22R,23R)-2α,3α,22,23-Tetrahydroxy-B-homo-7-oxa-5α-campest-25-en-6-one (**4**).* The title compound (32 mg) was prepared in 91% yield as white crystals from acetonide **52** as described above for the preparation of brassinolide (**1**). Mp: 255-257 °C. ^1H NMR (500 MHz, $CDCl_3$): δ 4.95 (s, 1H), 4.81 (s, 1H), 4.04 – 4.13 (m, 2H), 4.02 (s, 1H), 3.71 (ddd, *J* = 12.7, 7.7, 5.4 Hz, 1H), 3.60 (s, 2H), 3.12 (dd, *J* = 12.3, 4.3 Hz, 1H), 1.81 – 2.31 (m, 10H), 1.79 (s, 3H), 1.15 – 1.77 (m, 12H), 1.00 (d, *J* = 7.0 Hz, 3H), 0.96 (d, *J* = 6.7 Hz, 3H), 0.92 (s, 3H), 0.71 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.2, 147.7, 111.8, 73.5, 72.9, 70.4, 68.1, 68.1, 58.2, 52.2, 51.3, 42.4, 41.8, 41.5, 40.9, 39.6, 39.2, 38.3, 37.5, 31.0, 27.6, 24.7, 22.3, 22.2, 15.5, 12.1, 11.7, 11.6. $[\alpha]_D^{20}$ = +33 (c 0.55, $CHCl_3$). IR (KBr): 3432, 3086, 2965, 2940, 1709, 1647, 1458, 1378. HRMS (APCI): calcd for $C_{28}H_{47}O_6$ $[M+H]^+$ 479.3367, found 479.3347.



(22*R*)-22-Hydroxy-2α,3α-isopropylidenedioxy-23,23-(trimethylenedithio)-B-homo-7-oxa-5α-ergost-25-en-6-one (31) and (22*S*)-22-hydroxy-2α,3α-isopropylidenedioxy-23,23-(trimethylenedithio)-B-homo-7-oxa-5α-ergost-25-en-6-one (32). The title compounds were prepared as a mixture of C-22 isomers from aldehyde **7** and dithiane **(*R*)-9** as described above for the preparation of compound **20**. The crude oil mixture was separated by flash chromatography on SiO_2 (PE/ EtOAc = 9/1 – 6/4) to give the less polar compound **32** (87 mg, 35%) as a foam and the more polar compound **31** (103 mg, 41%) as a foam. Data for **31**: ^1H NMR (500 MHz, $CDCl_3$): δ 4.84 (s, 1H), 4.80 (s, 1H), 4.33 – 4.41 (m, 2H), 4.04 – 4.14 (m, 2H), 4.02 (d, *J* = 2.2 Hz, 1H), 3.29 (dd, *J* = 10.3, 4.3 Hz, 1H), 2.89 – 2.97 (m, 2H), 2.79 – 2.88 (m, 2H), 2.65 (dt, *J* = 8.6, 4.1 Hz, 1H), 2.59 (dt, *J* = 14.0, 4.1 Hz, 1H), 2.32 (dd, *J* = 15.7, 3.4 Hz, 1H), 2.27 (dd, *J* = 11.8, 5.1 Hz, 1H), 2.13 – 1.06 (m, 17H), 1.96 (s, 3H), 1.52 (s, 3H), 1.32 (d, *J* = 7.0 Hz, 3H), 1.31 (s, 3H), 1.09 (d, *J* = 6.7 Hz, 3H), 0.88 (s, 3H), 0.79 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.6, 147.7, 114.4, 107.6, 73.8, 73.1, 72.5, 71.2, 61.8, 55.4, 54.6, 52.0, 47.1, 43.5, 40.2, 39.9, 39.4, 36.3, 35.9, 33.5, 28.1, 27.6, 27.2, 26.5, 25.7, 24.7, 24.2, 23.6, 23.0, 21.2, 19.6, 16.8, 14.7, 11.9. $[\alpha]_D^{20}$ = +15.5 (c 2.1, $CHCl_3$). IR (KBr): 3435, 3079, 2943, 1737, 1458, 1387, 1078. HRMS (ESI): calcd

for $C_{34}H_{55}O_5S_2$ $[M+H]^+$ 607.3485, found 607.3496. Data for **32**: ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.91 (d, *J* = 1.1 Hz, 1H), 4.86 – 4.87 (m, 1H), 4.33 – 4.39 (m, 2H), 4.12 (dd, *J* = 12.8, 2.2 Hz, 1H), 4.07 (dd, *J* = 12.5, 9.9 Hz, 1H), 3.84 – 3.87 (m, 1H), 3.28 (dd, *J* = 10.4, 4.2 Hz, 1H), 3.01 (dd, *J* = 9.9, 3.9 Hz, 1H), 2.94 – 2.99 (m, 2H), 2.89 (d, *J* = 3.8 Hz, 1H), 2.75 – 2.86 (m, 2H), 2.67 (ddd, *J* = 14.2, 6.5, 3.9 Hz, 1H), 2.31 (dd, *J* = 15.7, 3.4 Hz, 1H), 2.21 – 1.17 (m, 16H), 1.95 (s, 3H), 1.51 (s, 3H), 1.34 (d, *J* = 7.1 Hz, 3H), 1.31 (s, 3H), 1.27 (d, *J* = 6.8 Hz, 3H), 1.10 (dd, *J* = 15.7, 2.0 Hz, 1H), 0.87 (s, 3H), 0.77 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.7, 148.3, 114.5, 107.5, 77.8, 73.0, 72.4, 71.2, 62.0, 54.6, 52.7, 51.7, 45.8, 44.0, 40.1, 39.8, 39.7, 39.2, 35.9, 33.5, 29.3, 27.6, 27.6, 26.5, 26.3, 25.1, 24.1, 23.6, 23.0, 22.1, 20.1, 19.6, 17.1, 12.3. $[\alpha]_D^{20}$ = +28 (c 1.0, $CHCl_3$). IR (KBr): 3445, 3073, 2943, 1757, 1455, 1381, 1065. HRMS (ESI): calcd for $C_{34}H_{55}O_5S_2$ $[M+H]^+$ 607.3485, found 607.3495.



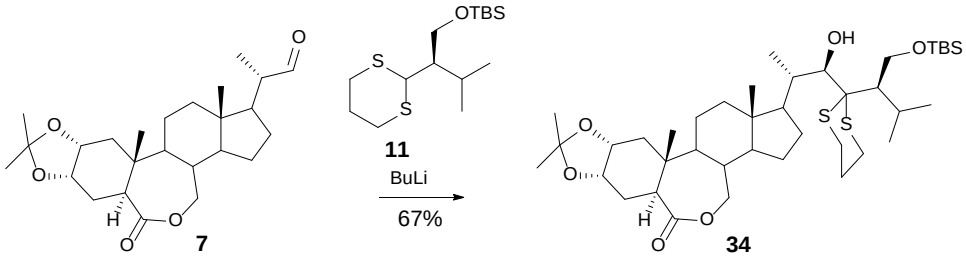
(22*R*,23*R*)-2α,3α,22,23-Tetrahydroxy-B-homo-7-oxa-5α-ergost-25-en-6-one (5). *(a). (22R)-22-Hydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-ergost-25-en-6,23-dione (**53**).* The title compound (132 mg) was prepared in 57% yield as an oil from compound **31** as described above for the preparation of compound **22,** except a 3:7 mixture of THF and EtOH was used as a solvent. ^{1}H NMR (500 MHz, $CDCl_3$): 4.93 (t, *J* = 1.3 Hz, 1H), 4.90 (s, 1H), 4.32 – 4.39 (m, 3H), 4.04 – 4.13 (m, 2H), 3.46 (q, *J* = 6.8 Hz, 1H), 3.32 (d, *J* = 5.2 Hz, 1H), 3.28 (dd, *J* = 10.8, 3.9 Hz, 1H), 2.30 (dd, *J* = 15.7, 3.6 Hz, 1H), 2.06 – 1.16 (m, 15H), 1.64 (s, 3H), 1.50 (s, 3H), 1.30 (s, 3H), 1.19 (d, *J* = 6.8 Hz, 3H), 1.09 (dd, *J* = 15.8, 2.1 Hz, 1H), 0.87 (s, 3H), 0.75 (s, 3H), 0.69 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 212.8, 176.6, 143.9, 114.9, 107.6, 76.9, 73.0, 72.4, 71.1, 54.6, 52.0, 51.8, 49.6, 42.8, 40.1, 39.5, 39.4, 39.0, 35.9, 33.4, 27.8, 27.5, 26.4, 24.4, 23.6, 22.9, 19.6, 19.2, 14.2, 12.5, 12.2. $[\alpha]_D^{20}$ = -130 (c 0.52, $CHCl_3$). IR (KBr): 3444, 3083, 2939, 1748, 1712, 1637, 1456, 1384, 1056. HRMS (ESI): calcd for $C_{31}H_{49}O_6$ $[M+H]^+$ 517.3524, found 517.3527.

*(b). (22R)-22-[(tert-Butyldimethylsilyl)oxy]-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-ergost-25-en-6-one (**54**).* The title compound (67 mg) was prepared in 82% yield as an oil from hydroxy ketone **53** as described above for the preparation of compound **43**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.89 (m, 1H), 4.88 (s, 1H), 4.43 (s, 1H), 4.32 – 4.40 (m, 2H), 4.04 – 4.13 (m, 2H), 3.41 (q, *J* = 6.8 Hz, 1H), 3.28 (dd, *J* = 9.4, 5.2 Hz, 1H), 2.99 (s, 1H), 2.29 (dd, *J* = 15.7, 3.5 Hz, 1H), 1.99 – 1.03 (m, 15H), 1.66 (s, 3H), 1.52 (s, 3H), 1.31 (s, 3H), 1.12 (d, *J* = 6.8 Hz, 3H), 0.90 (s, 9H), 0.88 (s, 3H), 0.75 (d, *J* = 6.5 Hz, 3H), 0.75 (s, 3H), 0.02 (s, 3H), -0.08 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 210.1, 176.6, 144.4, 114.3, 107.6, 78.3, 73.0, 72.4, 71.1, 54.5, 52.1, 52.0, 49.9, 42.8, 40.1, 39.6 (×2), 39.4, 36.0, 33.6, 28.1, 27.6, 26.6, 25.9 (×3), 24.6, 23.6, 22.8, 19.5, 19.1, 18.5, 14.6, 12.6, 12.0, -4.3, -5.2. $[\alpha]_D^{20}$ = -114 (c 0.5, $CHCl_3$). IR (KBr): 3076, 2953, 1746, 1723, 1643, 1467, 1374, 1258, 1068. HRMS (ESI): calcd for $C_{37}H_{63}O_6Si$ $[M+H]^+$ 631.4388, found 631.4399.

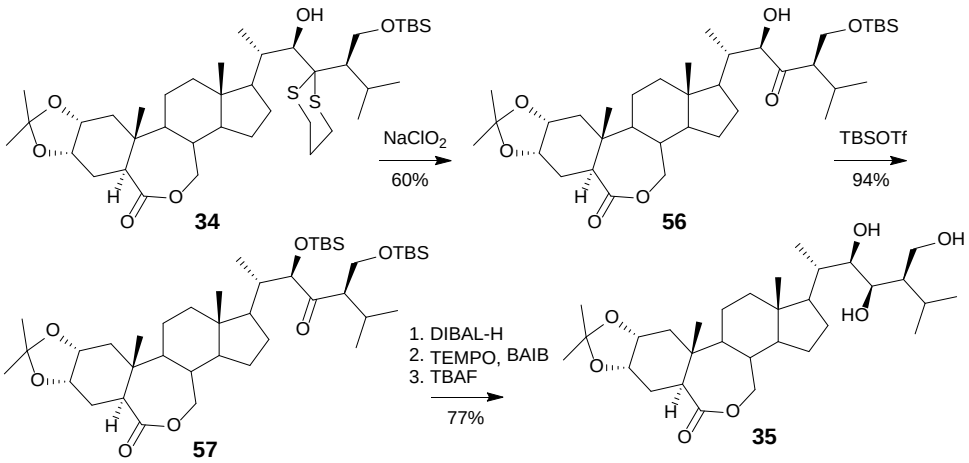
*(c). (22R,23R)-22,23-Dihydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-ergost-25-en-6-one (**55**).* The title compound (12 mg) was prepared in 86% yield from silylated hydroxyketone

54 as an oil as described above for the preparation of compound **52** from **50**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.91 (td, *J* = 2.9, 1.4 Hz, 1H), 4.82 (d, *J* = 1.1 Hz, 1H), 4.32 – 4.41 (m, 2H), 4.03 – 4.15 (m, 2H), 3.56 – 3.60 (m, 1H), 3.34 – 3.38 (m, 1H), 3.28 (dd, *J* = 10.5, 4.1 Hz, 1H), 2.38 (p, *J* = 6.9 Hz, 1H), 2.31 (dd, *J* = 15.7, 3.7 Hz, 1H), 2.14 (d, *J* = 3.1 Hz, 1H), 2.04 – 1.05 (m, 17H), 1.73 (s, 3H), 1.51 (s, 3H), 1.31 (s, 3H), 1.08 (d, *J* = 7.0 Hz, 3H), 0.97 (d, *J* = 6.6 Hz, 3H), 0.87 (s, 3H), 0.71 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.7, 146.8, 114.0, 107.6, 74.9, 73.0, 72.4, 72.2, 71.2, 54.6, 52.6, 51.8, 44.5, 43.0, 40.5, 40.2, 39.7, 39.4, 35.9, 33.5, 27.7, 27.6, 26.5, 24.5, 23.6, 23.0, 19.6 (×2), 16.2, 12.4, 12.0. $[\alpha]_D^{20}$ = +16 (c 0.5, $CHCl_3$). IR (KBr): 3457, 3073, 2925, 1734, 1638, 1467, 1384, 1065. HRMS (APCI) $C_{31}H_{51}O_6$ $[M+H]^+$ 519.3680, found 519.3685.

*(d). (22R,23R)-2α,3α,22,23-Tetrahydroxy-B-homo-7-oxa-5α-ergost-25-en-6-one (**5**).* The title compound (67 mg) was prepared in 85% yield as white crystals from acetonide **55** as described above for the preparation of brassinolide (**1**) from **52**. Mp: 234-236 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.91 (m, 1H), 4.82 (s, 1H), 4.04 – 4.13 (m, 2H), 4.01 (s, 1H), 3.70 (d, *J* = 11.1 Hz, 1H), 3.58 (s, 1H), 3.36 (s, 1H), 3.12 (dd, *J* = 12.2, 4.3 Hz, 1H), 2.48 – 1.12 (m, 22H), 1.73 (s, 3H), 1.08 (d, *J* = 6.9 Hz, 3H), 0.97 (d, *J* = 6.4 Hz, 3H), 0.91 (s, 3H), 0.70 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.3, 146.8, 114.0, 75.0, 72.2, 70.5, 68.1, 68.1, 58.1, 52.7, 51.2, 44.5, 42.5, 41.5, 40.9, 40.5, 39.6, 39.2, 38.3, 31.0, 27.5, 24.8, 22.2, 19.6, 16.2, 15.5, 12.4, 11.7. $[\alpha]_D^{20}$ = +24 (c 0.28, MeOH). IR (KBr): 3429, 3074, 2946, 1715, 1638, 1461, 1381. HRMS (APCI) $C_{28}H_{47}O_6$ $[M+H]^+$ 479.3367, found 479.3367.



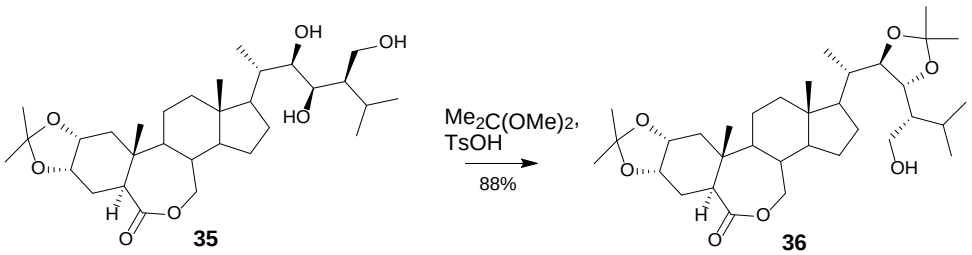
(22*R*)-28-[(*tert*-Butyldimethylsilyl)oxy]-22-hydroxy-2α,3α-isopropylidenedioxy-23,23-(trimethylenedithio)-B-homo-7-oxa-5α-campestan-6-one (34). The title compound (750 mg) was prepared in 66% yield as a foam from aldehyde **7** and dithiane **11** as described above for the preparation of compound **20**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.31 – 4.39 (m, 2H), 3.97 – 4.13 (m, 4H), 3.84 (d, *J* = 6.1 Hz, 1H), 3.27 (dd, *J* = 9.9, 4.8 Hz, 1H), 3.21 (d, *J* = 6.2 Hz, 1H), 2.76 – 2.85 (m, 2H), 2.64 – 2.73 (m, 2H), 2.55 – 2.61 (m, 1H), 2.29 (dd, *J* = 15.6, 3.5 Hz, 1H), 2.25 – 2.14 (m, 2H), 2.07 – 0.98 (m, 17H), 1.50 (s, 3H), 1.30 (s, 3H), 1.12 (d, *J* = 6.5 Hz, 3H), 1.11 (d, *J* = 6.9 Hz, 3H), 1.07 (d, *J* = 7.0 Hz, 3H), 0.84 – 0.92 (m, 12H), 0.76 (s, 3H), 0.08 (s, 3H), 0.07 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.6, 107.5, 77.2, 73.0, 72.4, 71.2, 64.4, 61.3, 54.5, 54.2, 51.8, 51.7, 43.2, 40.1, 39.7, 39.3, 37.8, 35.9, 33.5, 28.5, 28.2, 27.6, 26.9, 26.8, 26.5, 26.1 (× 3), 25.8, 24.6, 24.2, 23.6, 22.9, 19.6 (× 2), 18.1, 14.9, 12.0, -5.5, -5.6. $[\alpha]_D^{20}$ = +30.5 (c 1, $CHCl_3$). IR (KBr): 3438, 2956, 1730, 1475, 1381, 1256, 1065. HRMS (ESI) $C_{40}H_{71}O_6S_2Si$ $[M+H]^+$ 739.4456, found 739.4469.



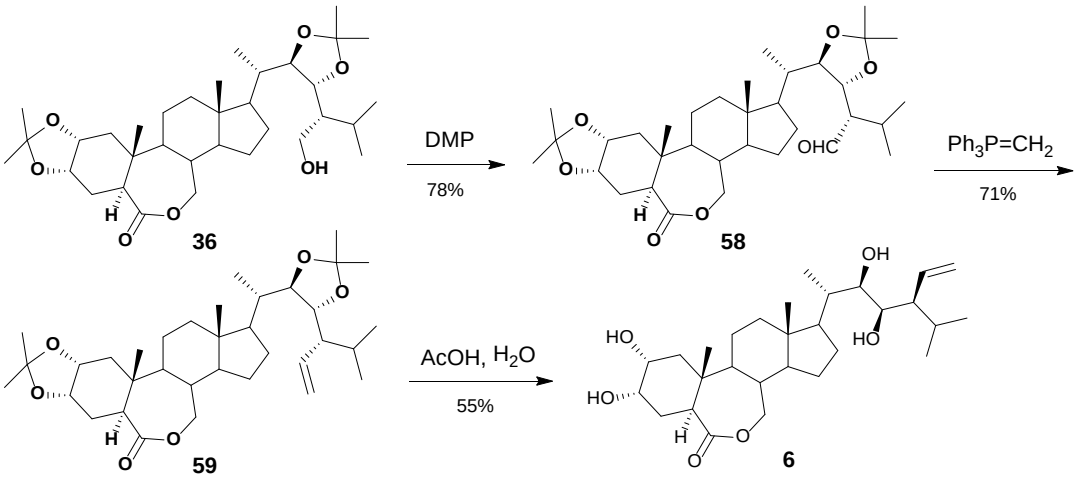
(22*R*,23*R*)-22,23,28-Trihydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6-one (35). *(a). (22R)-28-[(tert-Butyldimethylsilyl)oxy]-22-hydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6,22-dione (**56**).* The title compound (350 mg) was prepared in 60% yield as an oil from dithiane **34** as described above for the preparation of compound **22**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.31 – 4.40 (m, 2H), 4.25 (d, *J* = 4.4 Hz, 1H), 4.03 – 4.14 (m, 2H), 3.79 (dd, *J* = 9.3, 4.6 Hz, 1H), 3.64 (t, *J* = 9.3 Hz, 1H), 3.32 (d, *J* = 5.3 Hz, 1H), 3.28 (dd, *J* = 10.6, 4.0 Hz, 1H), 2.71 (td, *J* = 8.8, 4.7 Hz, 1H), 2.29 (dd, *J* = 15.7, 3.6 Hz, 1H), 2.07-1.16 (m, 16H) 1.49 (s, 3H), 1.29 (s, 3H), 1.09 (dd, *J* = 15.8, 2.2 Hz, 1H), 0.93 (d, *J* = 6.8 Hz, 3H), 0.86 (s, 3H), 0.857 (d, *J* = 6.7 Hz, 3H), 0.83 (s, 9H), 0.75 (s, 3H), 0.72 (d, *J* = 6.6 Hz, 3H), -0.01 (s, 3H), -0.03 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 216.0, 176.6, 107.6, 80.7, 73.0, 72.4, 71.1, 64.5, 55.9, 54.6, 52.5, 51.9, 42.9, 40.1, 39.4, 39.3, 36.8, 35.8, 33.4, 28.3, 27.5, 26.8, 26.4, 25.7 (×3), 24.4, 23.6, 22.9, 21.7, 19.9, 19.6, 18.1, 12.9, 12.0, -5.8, -5.8. $[\alpha]_D^{20}$ = -25 (c 1.0, $CHCl_3$). IR (film): 3471, 2952, 1742, 1707, 1471, 1385, 1258, 1061. HRMS (ESI) $C_{37}H_{65}O_7Si$ $[M+H]^+$ 649.4494, found 649.4504.

*(b). (22R)-22,28-Bis[(tert-butyldimethylsilyl)oxy]-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6,22-dione (**57**).* The title compound (284 mg) was prepared in 94% yield as an oil from compound **56** as described above for the preparation of compound **43**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.34 – 4.40 (m, 2H), 4.33 (s, 1H), 4.05 – 4.15 (m, 2H), 3.73 (dd, *J* = 9.7, 4.0 Hz, 1H), 3.66 (dd, *J* = 9.6, 8.7 Hz, 1H), 3.29 (dd, *J* = 9.3, 5.3 Hz, 1H), 2.49 – 2.55 (m, 1H), 2.30 (dd, *J* = 15.7, 3.5 Hz, 1H), 2.00 – 1.02 (m, 20H) 1.53 (s, 3H), 1.31 (s, 3H), 0.93 (d, *J* = 6.9 Hz, 3H), 0.91 (s, 9H), 0.88 (s, 3H), 0.87 (s, 9H), 0.85 (d, *J* = 5.8 Hz, 3H), 0.78 (d, *J* = 6.5 Hz, 3H), 0.75 (s, 3H), 0.07 (s, 3H), 0.04 (s, 3H), 0.03 (s, 3H), -0.04 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 213.4, 176.6, 107.6, 82.0, 73.0, 72.4, 71.1, 64.2, 56.4, 54.6, 52.4, 52.1, 42.9, 40.2, 39.6, 39.4, 37.7, 36.0, 33.6, 28.5, 27.7, 26.8, 26.6, 26.0 (×6), 24.6, 23.7, 22.8, 21.7, 19.8, 19.5, 18.5, 18.4, 13.3, 11.9, -4.0, -4.9, -5.3, -5.5. $[\alpha]_D^{20}$ = -38 (c 1.25, $CHCl_3$). IR (film): 2956, 1743, 1726, 1474, 1385, 1254, 1067. HRMS (ESI) $C_{43}H_{79}O_7Si_2$ $[M+H]^+$ 763.5359, found 763.5374.

*(c). (22R,23R)-22,23,28-Trihydroxy-2α,3α-isopropylidenedioxy-B-homo-7-oxa-5α-campestan-6-one (**35**).* The title compound (48 mg) was prepared in 77% yield as an oil from silylated hydroxyketone **57** as described above for the preparation of compound **52** from **49**. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.33 – 4.40 (m, 2H), 4.03 – 4.15 (m, 2H), 3.77 – 3.93 (m, 3H), 3.72 (d, *J* = 7.1 Hz, 1H), 3.34 (br.s, 1H), 3.28 (dd, *J* = 10.5, 3.9 Hz, 1H), 2.71 (br.s, 2H), 2.31 (dd, *J* = 15.7, 3.4 Hz, 1H), 2.16 – 0.94 (m, 18H), 1.51 (s, 3H), 1.30 (s, 3H), 1.02 (d, *J* = 6.3 Hz, 3H), 1.01 (d, *J* = 6.4 Hz, 3H), 0.91 (d, *J* = 6.7 Hz, 3H), 0.87 (s, 3H), 0.71 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.8, 107.6, 74.6, 74.1, 73.0, 72.4, 71.2, 61.2, 54.6, 52.2, 51.8, 46.7, 42.9, 40.2, 39.7, 39.3, 37.8, 35.9, 33.4, 27.8, 27.5, 26.5, 26.1, 24.4, 23.6, 22.9, 21.0, 20.6, 19.6, 12.0, 11.8. $[\alpha]_D^{20}$ = +18.5 (c 1, $CHCl_3$). IR (film): 3446, 2942, 1723, 1473, 1388, 1101. HRMS (APCI) $C_{31}H_{53}O_7$ $[M+H]^+$ 537.3786, found 537.3789.



(22*R*,23*R*)-28-Hydroxy-2α,3α:22,23-bis(isopropylidenedioxy)-B-homo-7-oxa-5α-campestan-6-one (36). $TsOH \cdot H_2O$ (2 mg, 0.01 mmol) was added to a solution of triol **35** (19 mg, 0.035 mmol) and 2,2-dimethoxypropane (0.009 mL, 0.073 mmol) in acetone (1 mL). The reaction mixture was kept for 30 min at room temperature, quenched with Et_3N (0.02 mL) and evaporated. The residue was purified by column chromatography on SiO_2 (PE/EtOAc = 9/1 – 3/1) to give alcohol **36** (18 mg, 89%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 4.32 – 4.41 (m, 2H), 4.02 – 4.14 (m, 2H), 3.98 (dd, *J* = 8.6, 4.7 Hz, 1H), 3.92 (d, *J* = 8.3 Hz, 1H), 3.73 – 3.84 (m, 2H), 3.28 (dd, *J* = 10.8, 3.6 Hz, 1H), 2.92 (br.s, 1H), 2.31 (dd, *J* = 15.6, 3.5 Hz, 1H), 2.06 – 1.16 (m, 17H), 1.50 (s, 3H), 1.39 (s, 3H), 1.36 (s, 3H), 1.31 (s, 3H), 1.10 (dd, *J* = 15.8, 2.2 Hz, 1H), 1.02 (d, *J* = 6.8 Hz, 3H), 0.98 (d, *J* = 6.6 Hz, 3H), 0.92 (t, *J* = 5.7 Hz, 3H), 0.87 (s, 3H), 0.70 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.6, 107.9, 107.6, 81.0, 79.0, 73.0, 72.4, 71.1, 61.4, 54.6, 53.1, 51.7, 47.5, 43.0, 40.1, 39.6, 39.3, 35.9, 35.9, 33.4, 27.8, 27.5, 27.2, 27.1, 27.0, 26.4, 24.4, 23.6, 22.9, 21.2, 19.7, 19.1, 12.4, 11.9. $[\alpha]_D^{20}$ = +40 (c 0.45, $CHCl_3$). IR (KBr): 3472, 2939, 1741, 1467, 1383, 1067. HRMS (APCI) $C_{34}H_{57}O_7$ $[M+H]^+$ 577.4099, found 577.4106.



(22*R*,23*R*)-2α,3α,22,23-Tetrahydroxy-B-homo-7-oxa-5α-stigmast-28-en-6-one (6). *(a). (22R,23R,24R)-24-Formyl-2α,3α:22,23-bis(isopropylidenedioxy)-B-homo-7-oxa-5α-cholestan-6-one (**58**).* A 15% solution of DMP in CH_2Cl_2 (0.71 mL, 0.25 mmol) was added at room temperature to a stirred solution of alcohol **36** (73 mg, 0.127 mmol) in CH_2Cl_2 (4 mL). The reaction mixture was stirred at room temperature for 30 min and quenched with saturated aqueous $Na_2S_2O_3$ (3 mL). The aqueous layer was separated and extracted with CH_2Cl_2 (3 mL × 3). The combined organic layers were washed with water (3 mL), aqueous $NaHCO_3$ (3 mL × 2), dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/EtOAc = 9/1 – 3/1) to give aldehyde **58** (57 mg, 78%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 9.73 (d, *J* = 4.8 Hz, 1H), 4.31 – 4.40 (m, 2H), 4.10 – 4.02 (m, 3H), 3.77 (d, *J* = 9.0 Hz, 1H), 3.27 (dd, *J* = 10.8, 3.7 Hz, 1H), 2.31 (dd, *J* = 15.6, 3.5 Hz, 1H), 2.23 (dq, *J* = 13.6, 6.8 Hz, 1H), 2.01 – 1.17 (m, 15H), 1.49 (s, 3H), 1.35 (s, 3H), 1.30 (s, 3H), 1.29 (s, 3H), 1.09 (dd, *J* = 15.8, 2.0 Hz, 1H), 1.05 (d, *J* = 6.7 Hz, 3H), 0.96 (d, *J* = 6.7 Hz, 6H), 0.92 (dd, *J* = 7.5, 3.5 Hz, 1H), 0.87 (s, 3H), 0.71 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 205.2, 176.6, 108.2, 107.5, 80.0, 75.4, 73.0, 72.4, 71.1, 58.3, 54.6, 53.1, 51.7, 43.1, 40.2, 39.6, 39.3, 35.9, 35.0, 33.4, 27.7, 27.5, 26.9, 26.8, 26.6, 26.4, 24.4, 23.6, 22.9, 20.5, 20.4, 19.6, 12.4, 11.9. $[\alpha]_D^{20}$ = +42 (c 1,

$CHCl_3$). IR (film): 2946, 1733, 1467, 1383, 1067. HRMS (ESI) $C_{34}H_{55}O_7$ $[M+H]^+$ 575.3942, found 575.3951.

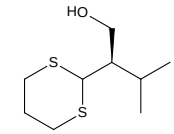
*(b). (22R,23R)-2α,3α:22,23-Bis(isopropylidenedioxy)-B-homo-7-oxa-5α-stigmast-28-en-6-one (**59**).* A 2.5M solution of *n*-BuLi (0.2 mL, 0.5 mmol) was added at 0 °C to a suspension of Ph_3PCH_3Br (196 mg, 0.55 mmol) in THF (1 mL) and the mixture was stirred for 30 min. A solution of aldehyde **58** (21 mg, 0.037 mmol) in THF (1 mL) was added at 0 °C to the solution of ylide, the reaction mixture was stirred for 30 min, diluted with Et_2O (5 mL) and quenched with water (5 mL). The aqueous layer was separated and extracted with EtOAc (3 mL × 3). The combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on SiO_2 (PE/EtOAc = 9/1 – 3/1) to give compound **59** (15 mg, 71%) as an oil. ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.78 (dt, *J* = 17.3, 10.0 Hz, 1H), 5.15 (dd, *J* = 10.3, 2.2 Hz, 1H), 4.94 (dd, *J* = 17.3, 2.2 Hz, 1H), 4.32 – 4.41 (m, 2H), 4.11 (dd, *J* = 12.7, 2.6 Hz, 1H), 4.06 (dd, *J* = 12.7, 9.6 Hz, 1H), 3.88 (dd, *J* = 8.9, 2.4 Hz, 1H), 3.77 (d, *J* = 8.9 Hz, 1H), 3.28 (dd, *J* = 10.8, 3.8 Hz, 1H), 2.32 (dd, *J* = 15.7, 3.6 Hz, 1H), 2.03 – 1.16 (m, 17H), 1.50 (s, 3H), 1.35 (s, 3H), 1.31 (s, 6H), 1.10 (dd, *J* = 15.7, 2.2 Hz, 1H), 0.97 (d, *J* = 6.6 Hz, 3H), 0.96 (d, *J* = 6.6 Hz, 3H), 0.88 (d, *J* = 7.0 Hz, 3H), 0.88 (s, 3H), 0.71 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.7, 136.8, 117.5, 107.6, 107.5, 79.8, 77.0, 73.1, 72.5, 71.2, 54.7, 53.3, 52.0, 51.7, 43.1, 40.2, 39.5, 39.4, 35.9, 35.0, 33.4, 29.8, 27.8, 27.5, 27.2, 27.0, 26.4, 24.4, 23.6, 23.0, 21.0, 20.5, 19.7, 12.5, 11.9. $[\alpha]_D^{20}$ = +22 (c 0.75, $CHCl_3$). IR (film): 3074, 2943, 1736, 1464, 1383, 1061. HRMS (ESI) $C_{35}H_{57}O_6$ $[M+H]^+$ 573.4150, found 573.4159.

*(c). (22R,23R)-2α,3α,22,23-Tetrahydroxy-B-homo-7-oxa-5α-stigmast-28-en-6-one (**6**).* A solution of diacetonide **59** (36 mg, 0.026 mmol) in a mixture of AcOH (2 mL) and H_2O (0.4 mL) was heated at 100 °C for 1 h. The solvents were evaporated under reduced pressure. The residue was purified by column chromatography on SiO_2 ($CHCl_3$/*i*-PrOH = 20/1 – 4/1) to give tetraol **6** (17 mg, 55%) as white crystals. Mp: 268-271 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 5.75 (dt, *J* = 17.4, 10.1 Hz, 1H), 5.18 (dd, *J* = 10.3, 2.1 Hz, 1H), 4.99 (dd, *J* = 17.4, 2.0 Hz, 1H), 4.06 – 4.12 (m, 2H), 4.02 (s, 1H), 3.69 – 3.77 (m, 2H), 3.47 (d, *J* = 7.7 Hz, 1H), 3.11 (dd, *J* = 12.2, 4.5 Hz, 1H), 2.20 – 1.12 (m, 23H), 0.99 (d, *J* = 6.6 Hz, 3H), 0.92 (s, 3H), 0.90 (d, *J* = 6.9 Hz, 3H), 0.88 (d, *J* = 6.9 Hz, 3H), 0.70 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.2, 136.6, 117.9, 74.7, 72.3, 70.4, 68.1, 68.0, 58.2, 53.1, 52.4, 51.3, 42.4, 41.5, 40.9, 39.7, 39.2, 38.3, 36.1, 31.0, 28.0, 27.1, 24.7, 22.3, 21.1, 20.7, 15.5, 13.0, 11.9. $[\alpha]_D^{20}$ = +19 (c 0.35, $CHCl_3$). IR (KBr): 3445, 3076, 2928, 1730, 1467, 1390. HRMS (ESI) $C_{29}H_{49}O_6$ $[M+H]^+$ 493.3524, found 493.3523.

References

1. W. L. E. Armarego and C. L. L. Chai, *Purification of Laboratory Chemicals*, 6th edn., Butterworth-Heinemann, 2009.
2. V. A. Khripach, V. N. Zhabinskii and N. B. Khripach, in *Brassinosteroids*, eds. S.Hayat and A.Ahmad, Kluwer Academic Publishers, Dordrecht, 2003, pp. 189-230.
3. R. K. Boeckman and J. R. Miller, *Org. Lett.*, 2009, **11**, 4544-4547.
4. T. R. Hoye, C. S. Jeffrey and F. Shao, *Nature Protocols*, 2007, **2**, 2451-2458.
5. G. D. Anderson, T. J. Powers, C. Djerassi, J. Fayos and J. Clardy, *J. Am. Chem. Soc.*, 1975, **97**, 388-394.
6. A. L. Hurski, V. N. Zhabinskii and V. A. Khripach, *Steroids*, 2012, **77**, 780-790.
7. K. Mori, M. Sakakibara, Y. Ichikawa, H. Ueda, K. Okada, T. Umemura, G. Yabuta, S. Kuwahara, M. Kondo, M. Minobe and A. Sogabe, *Tetrahedron*, 1982, **38**, 2099-2109.
8. M. Ishiguro, S. Takatsuto, M. Morisaki and N. Ikekawa, *J. Chem. Soc.-Chem. Commun.*, 1980, 962-964.
9. M. J. Thompson, N. B. Mandava, W. J. Meudt, W. R. Lusby and D. W. Spaulding, *Steroids*, 1981, **38**, 567-580.

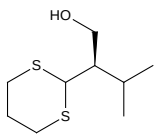
10. (a) A. Porzel, V. Marquardt, G. Adam, G. Massiot and D. Zeigan, *Magn. Reson. Chem.*, 1992, **30**, 651-657; (b) H. Suzuki, S. K. Kim, N. Takahashi and T. Yokota, *Phytochemistry*, 1993, **33**, 1361-1367.


HO
S
S

15

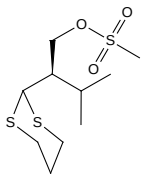
1.00
1.00
1.01
4.06
3.23
1.06
1.02
3.13
3.08
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

S.


HO
S
S

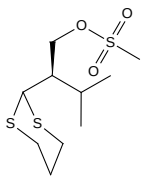
15

61.46
51.84
50.48
31.26
30.91
26.89
26.19
21.48
19.71
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


O
O
S
O
S
S

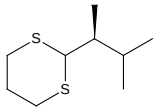
37

1.00
1.98
2.97
4.05
2.02
2.02
3.00
3.07
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


O
O
S
O
S
S

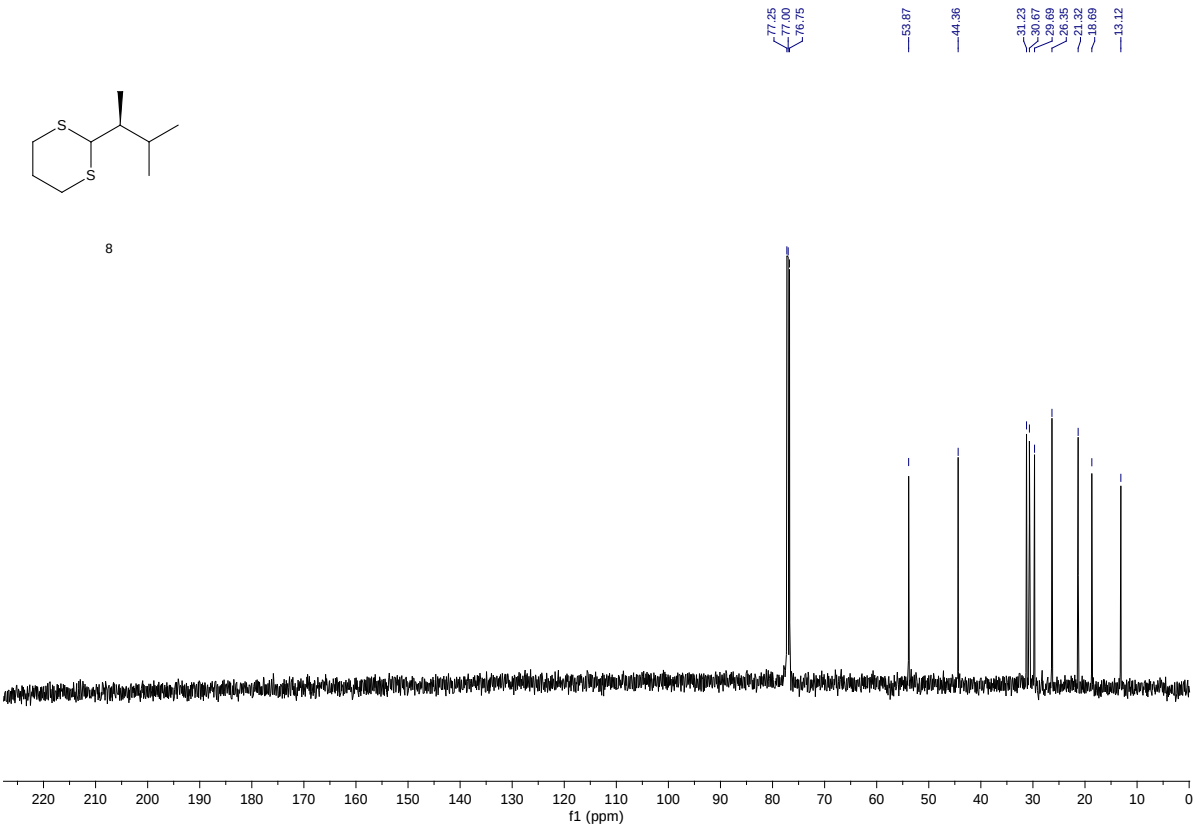
37

68.39
49.71
49.10
37.33
31.19
30.99
27.34
26.05
21.55
19.49
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


S
S

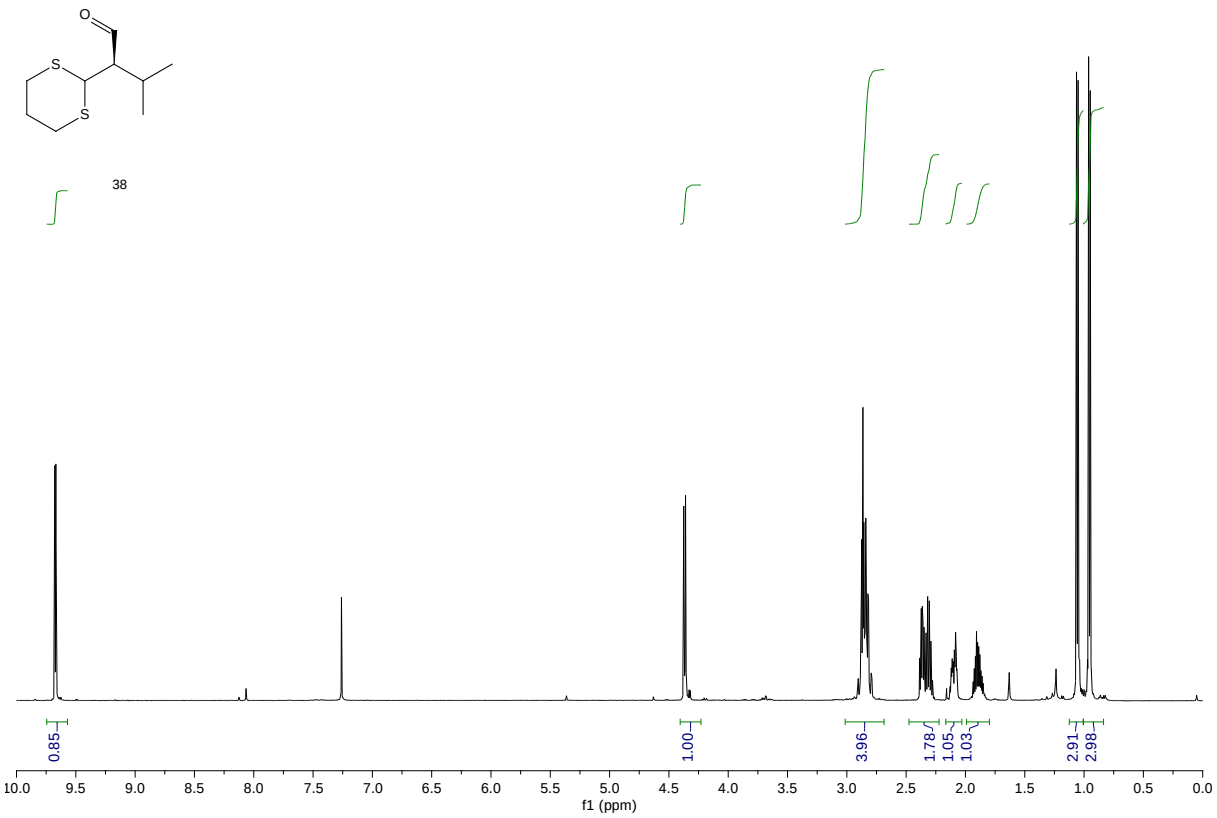
8

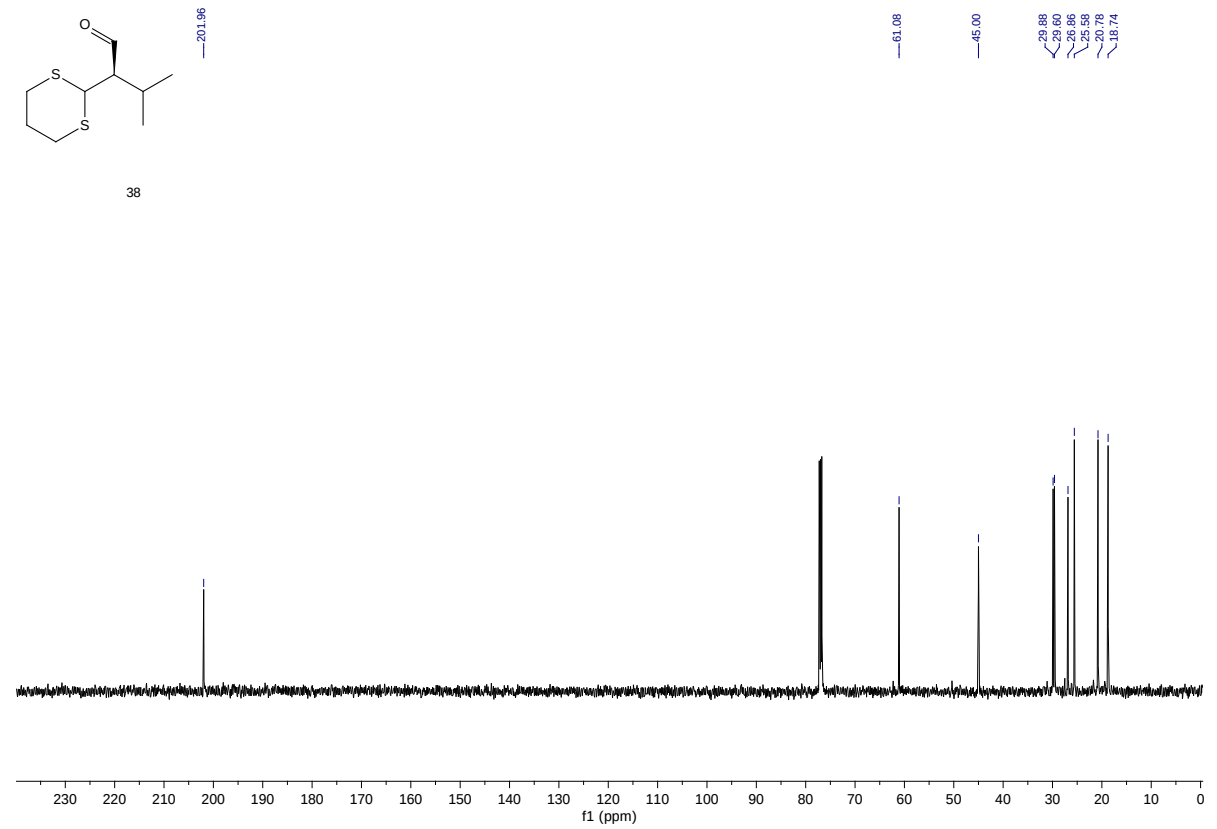
1.00
1.14
3.03
1.06
2.08
1.13
3.13
3.11
3.31
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

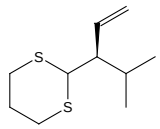

77.25
77.00
76.75
53.87
44.36
31.23
30.67
29.69
26.35
21.32
18.69
13.12
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

S
S

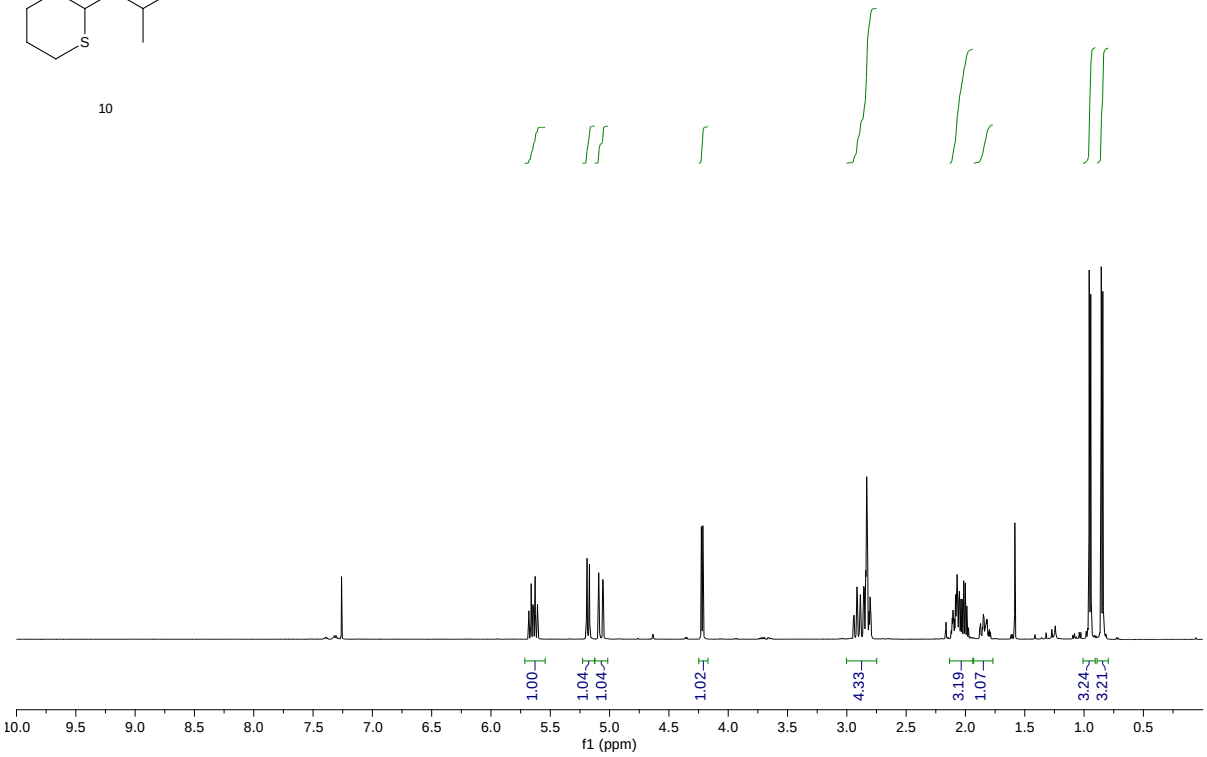
8

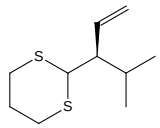

O
S
S
38
0.85
1.00
3.96
1.78
1.05
1.03
2.91
2.98
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


O
S
S
38
201.96
61.08
45.00
29.88
29.60
26.86
25.58
20.78
18.74
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


S
S

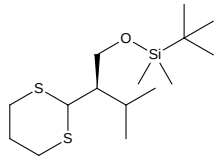
10


1.00
1.04
1.04
1.02
4.33
3.19
1.07
3.24
3.21
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


S
S

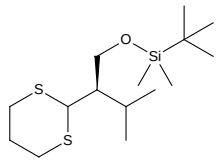
10

135.94
118.61
55.86
50.98
30.98
30.84
28.00
26.21
20.94
18.97
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


O
Si
S
S

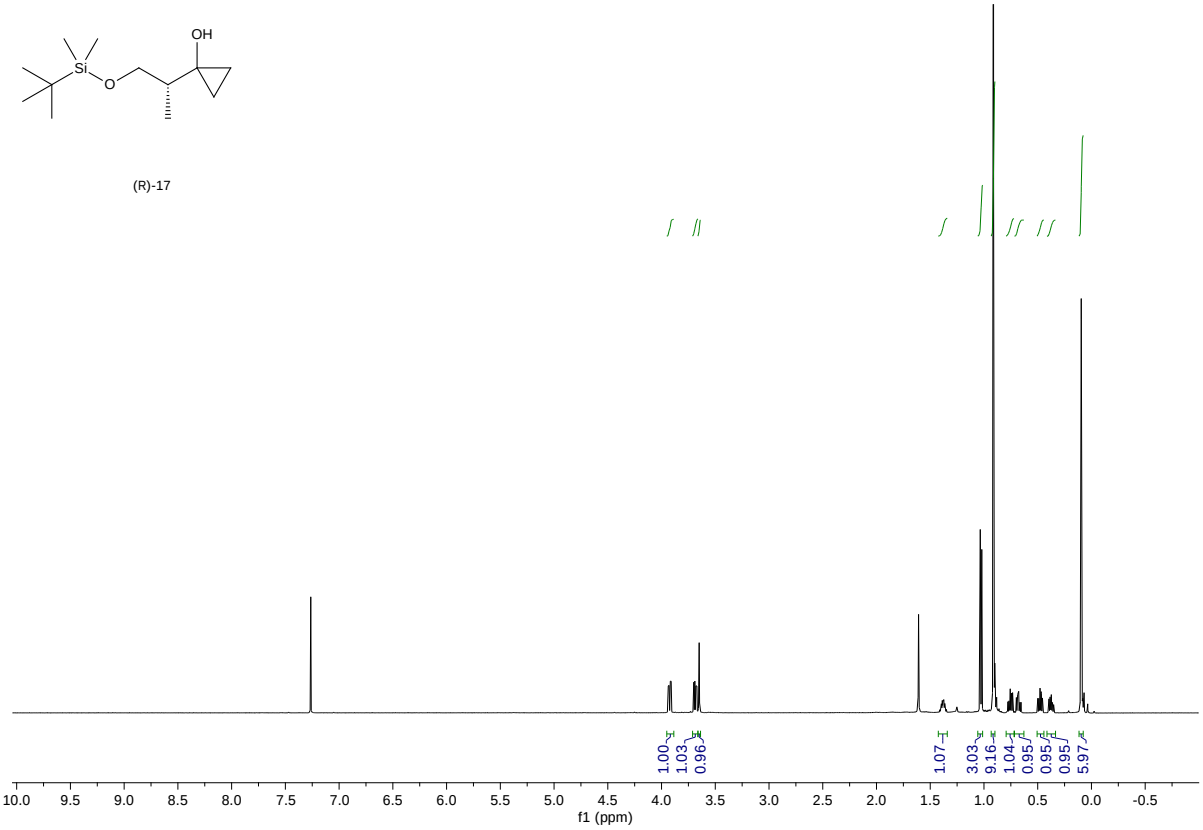
11

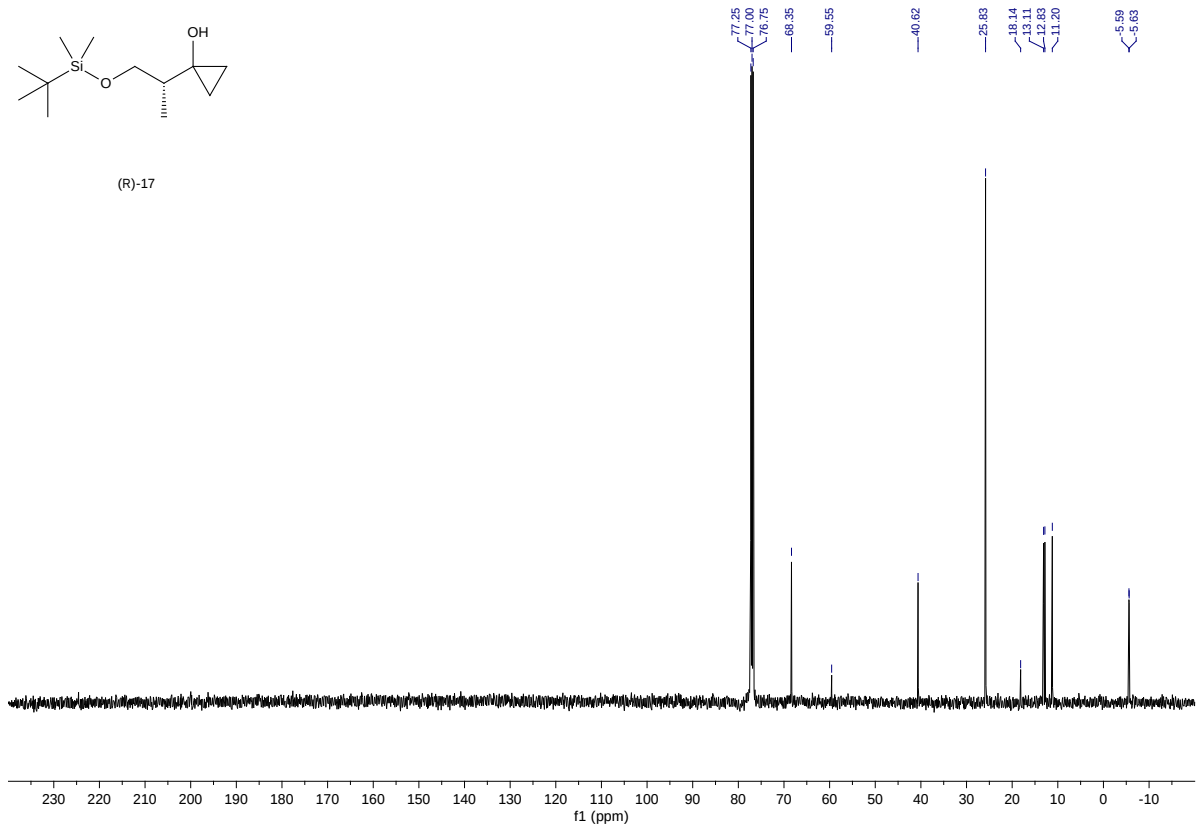
1.00
2.04
4.17
2.06
1.05
1.02
3.28
3.23
9.43
6.23
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

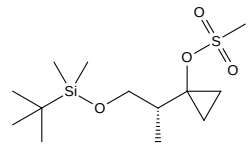

O
Si
S
S

11

60.80
51.81
50.93
31.56
31.49
27.50
26.51
25.90
22.14
19.77
18.19
-5.38
-5.44
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

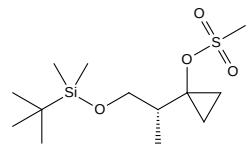

OH
Si
O
(R)-17
1.00
1.03
0.96
1.07
3.03
9.16
1.04
0.95
0.95
0.95
5.97
f1 (ppm)


OH
Si
O
(R)-17
77.25
77.00
76.75
68.35
59.55
40.62
25.83
18.14
13.11
12.83
11.20
-5.59
-5.63
f1 (ppm)



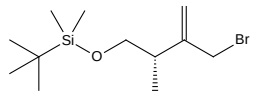
39

1.00
1.01
2.97
0.98
2.12
3.06
10.38
1.17
6.07
f1 (ppm)



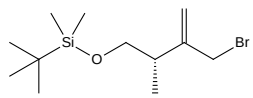
39

77.25
77.00
76.75
69.19
64.76
40.48
39.84
25.83
18.18
13.34
10.16
9.21
-5.53
f1 (ppm)


Si
O
Br

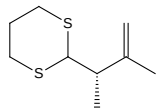
(S)-18

1.00
0.98
0.99
1.09
0.99
1.01
0.94
3.00
9.52
6.02
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

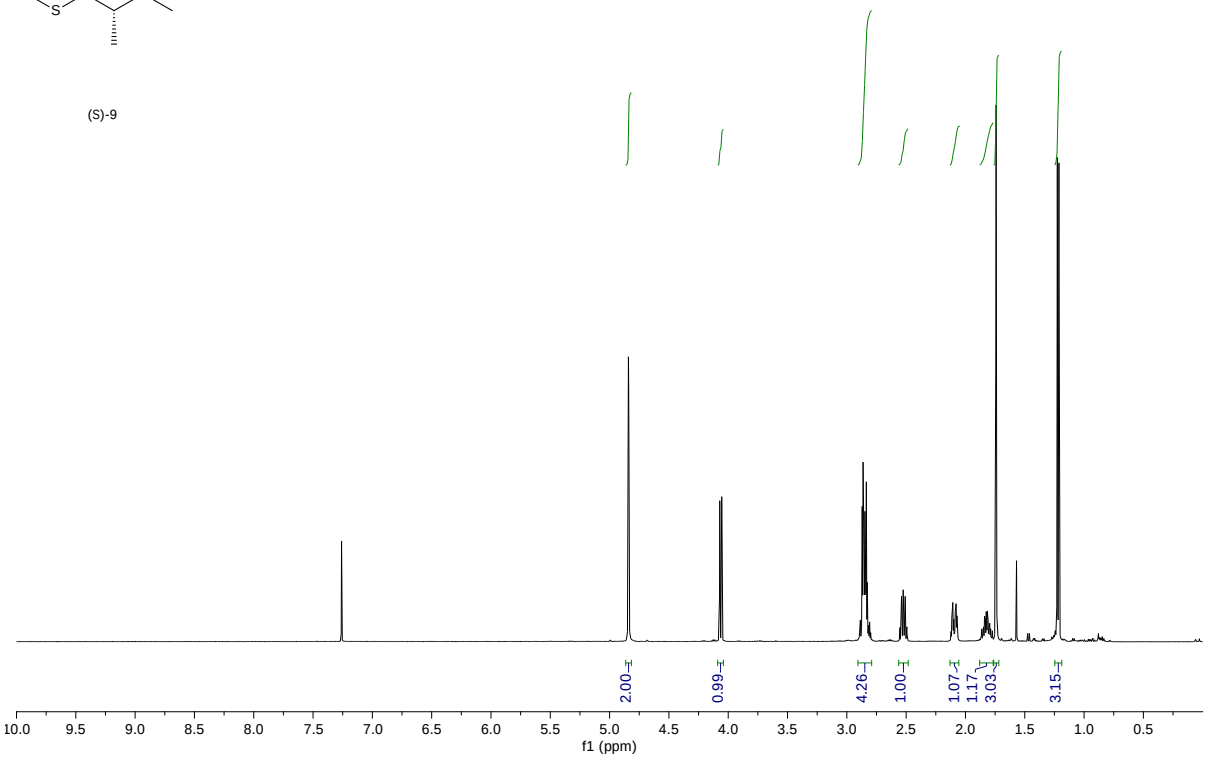

Si
O
Br

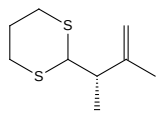
(S)-18

148.50
114.86
67.87
39.17
37.44
25.88
18.26
16.65
-5.43
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



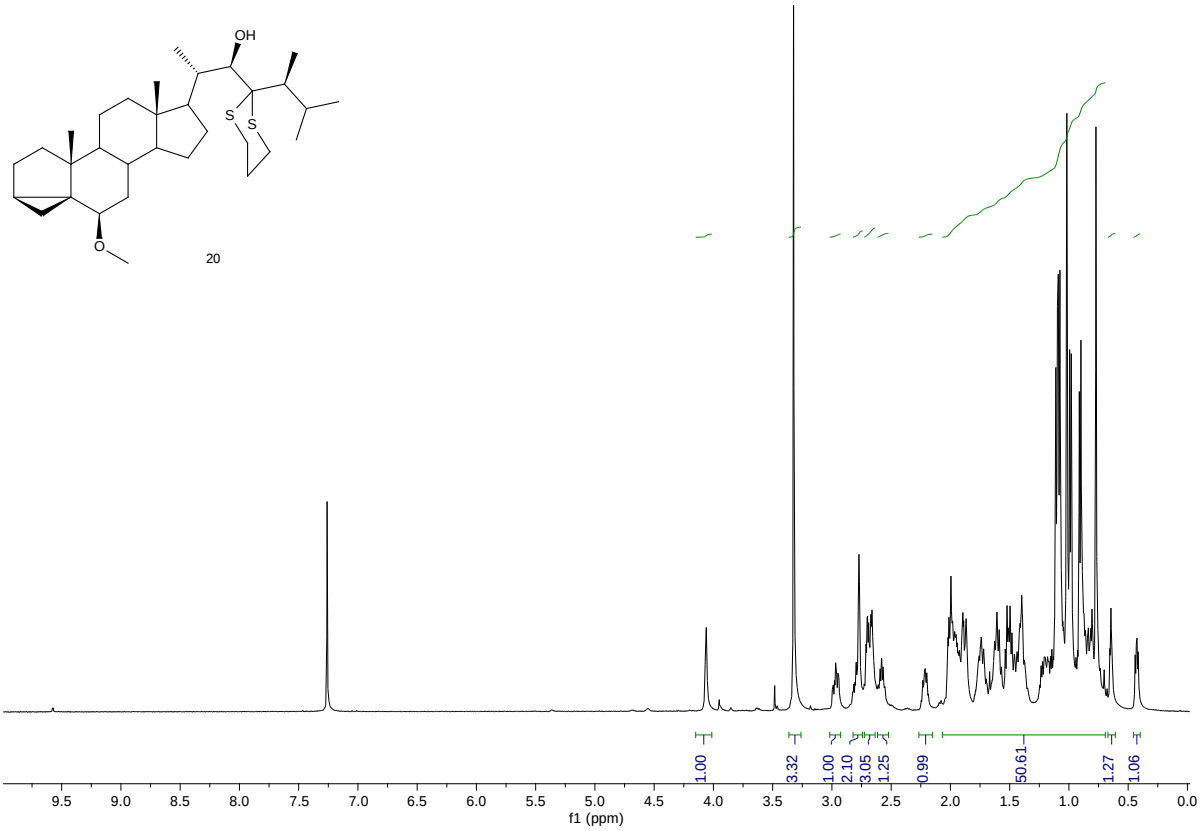
(S)-9

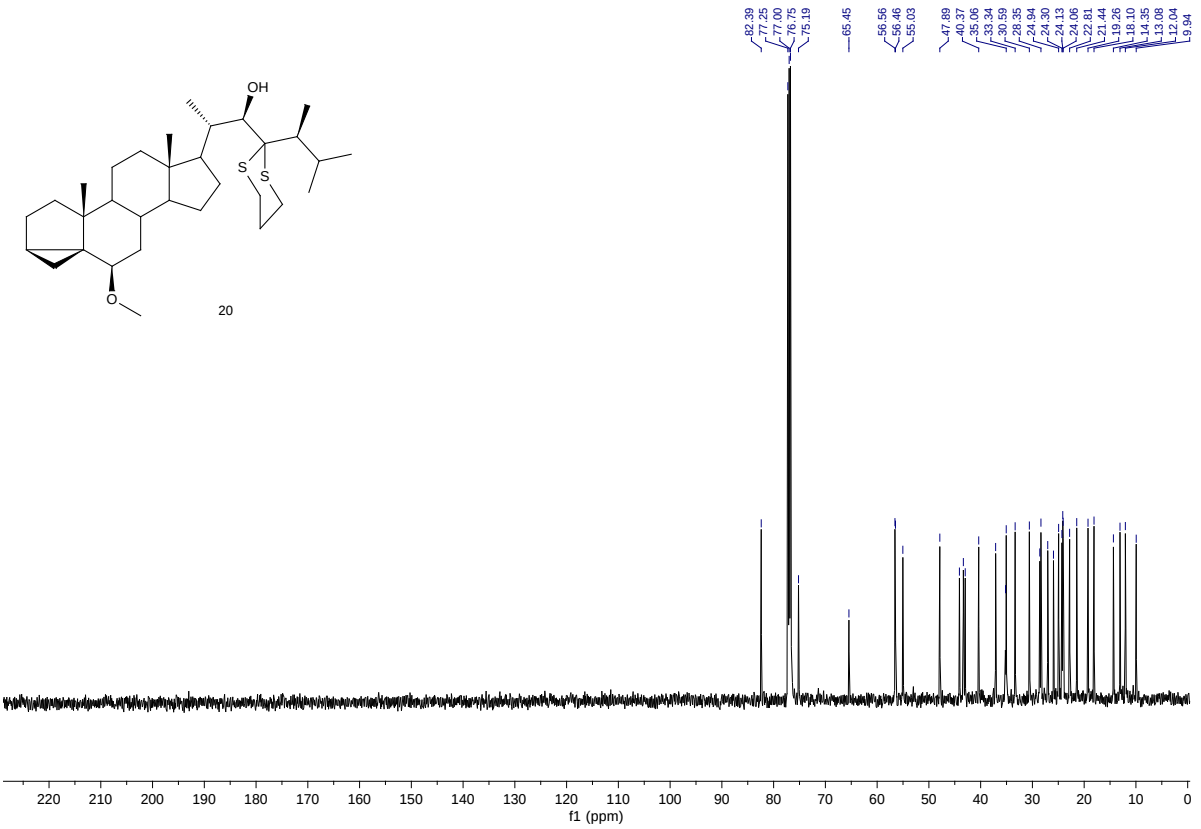

2.00
0.99
4.26
1.00
1.07
1.17
3.03
3.15
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

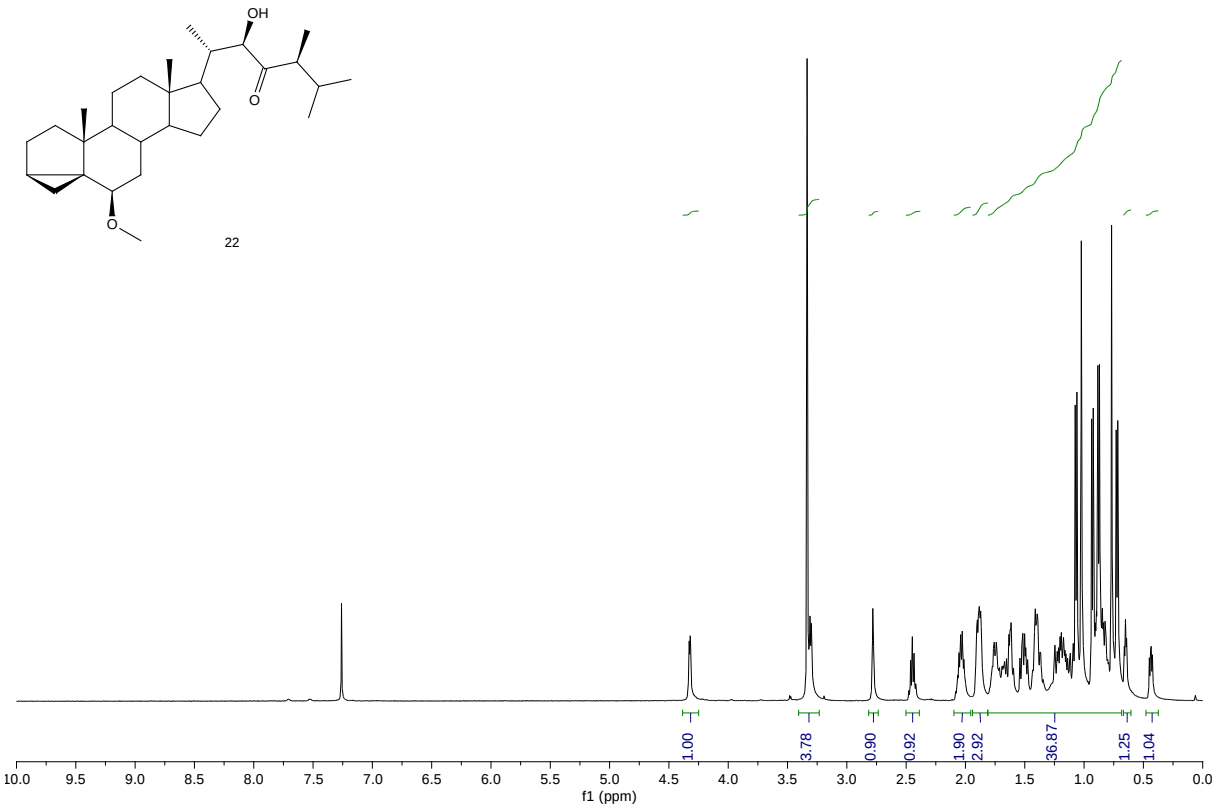


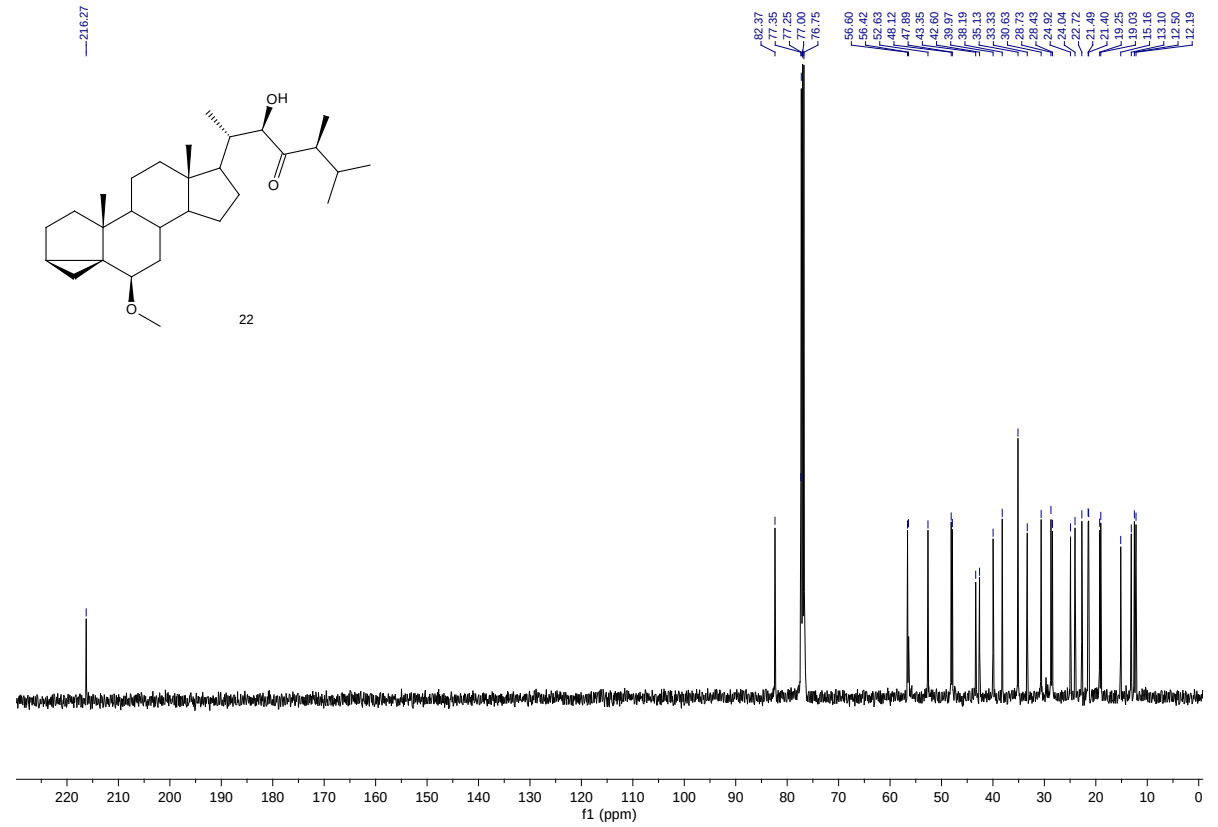
(S)-9

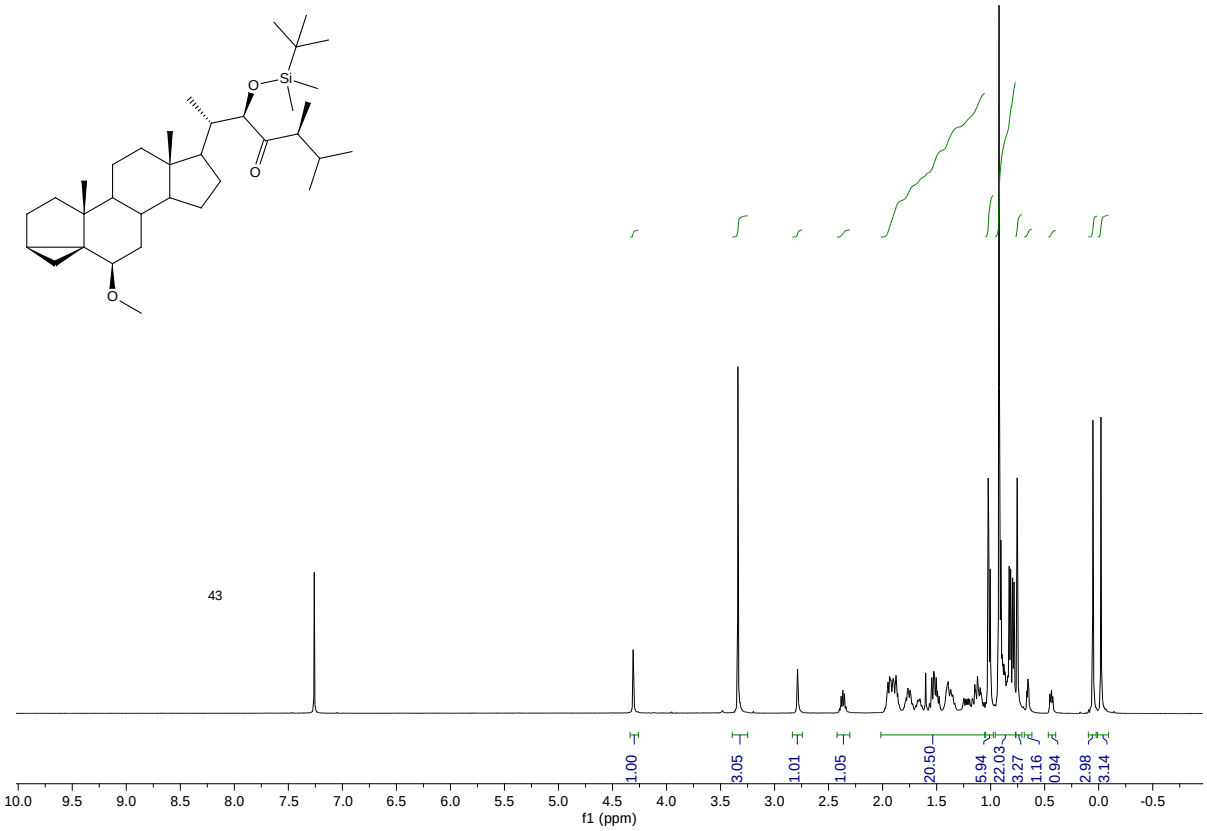
145.92
112.86
77.25
77.00
76.75
51.72
46.03
30.90
30.56
25.91
19.03
17.02
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

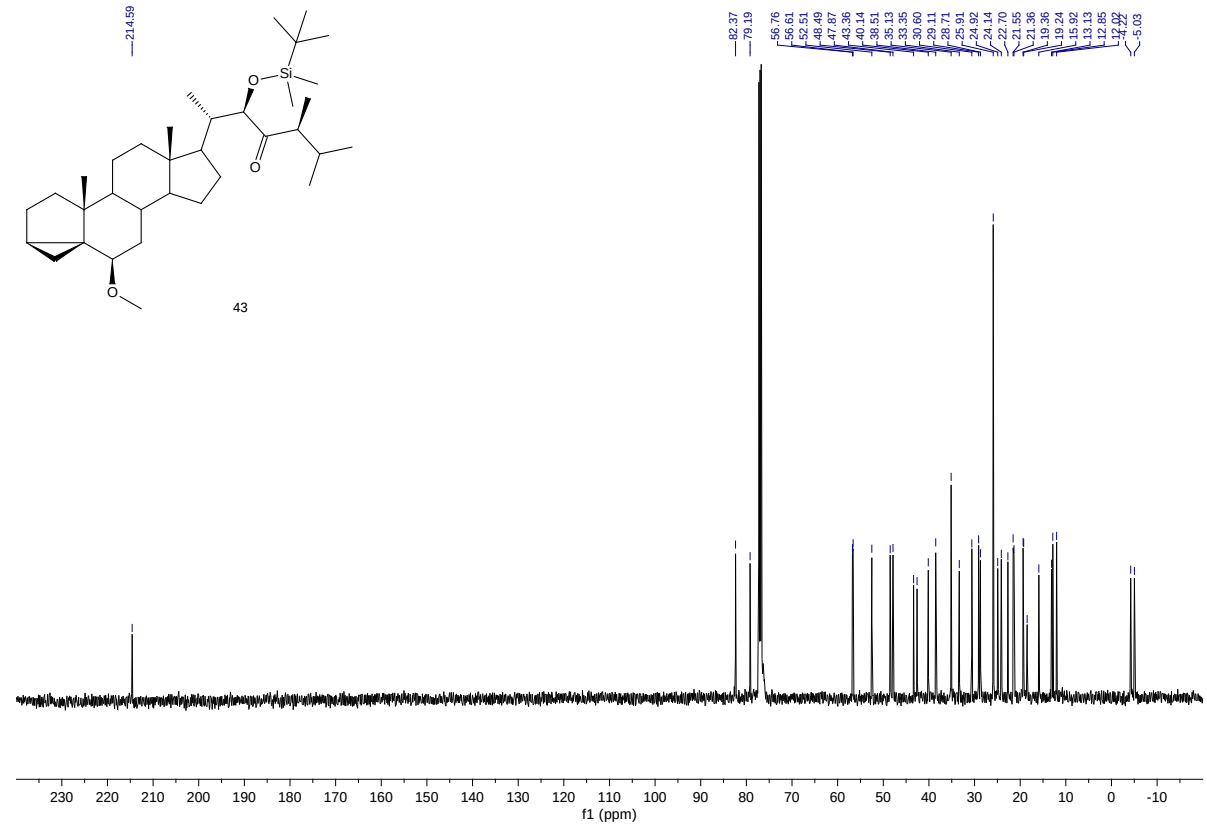

OH
S
S
O
20
1.00
3.32
1.00
2.10
3.05
1.25
0.99
50.61
1.27
1.06
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

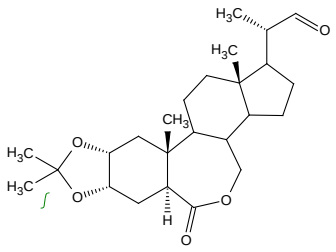

82.39
77.25
77.00
76.75
75.19
65.45
56.56
56.46
55.03
47.89
40.37
35.06
33.34
30.59
28.35
24.94
24.30
24.13
24.06
22.81
21.44
19.26
18.10
14.35
13.08
12.04
9.94
OH
S
S
O
20
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


OH
O
O
22
1.00
3.78
0.90
0.92
1.90
2.92
36.87
1.25
1.04
f1 (ppm)


216.27
82.37
77.35
77.25
77.00
76.75
56.60
56.42
52.63
48.12
47.89
43.35
42.60
39.97
38.19
35.13
33.33
30.63
28.73
28.43
24.92
24.04
22.72
21.49
21.40
19.25
19.03
15.16
13.10
12.50
12.19
OH
O
O
22
f1 (ppm)


O
Si
O
O
43
1.00
3.05
1.01
1.05
20.50
5.94
22.03
3.27
1.16
0.94
2.98
3.14
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

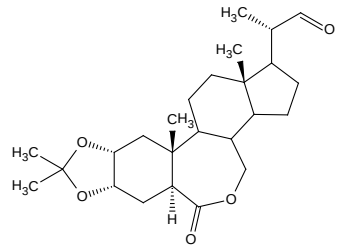

214.59
82.37
79.19
56.76
56.61
52.51
48.49
47.87
43.36
40.14
38.51
35.13
33.35
30.60
29.11
28.71
25.91
24.92
24.14
22.70
21.55
21.36
19.36
19.24
15.92
13.13
12.85
12.02
4.22
-5.03
O
Si
O
O
43
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


H3C
O
H3C
CH3
H3C
O
H3C
O
O
H
O

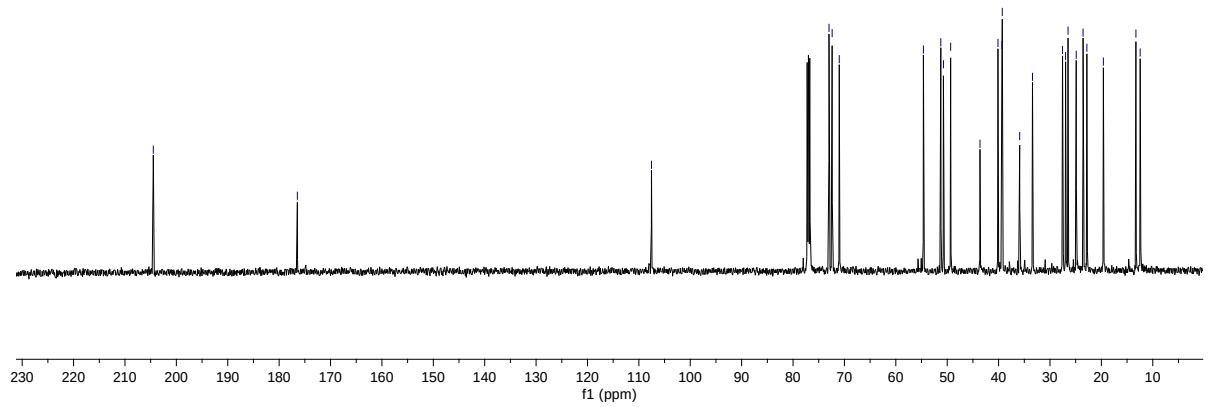
7

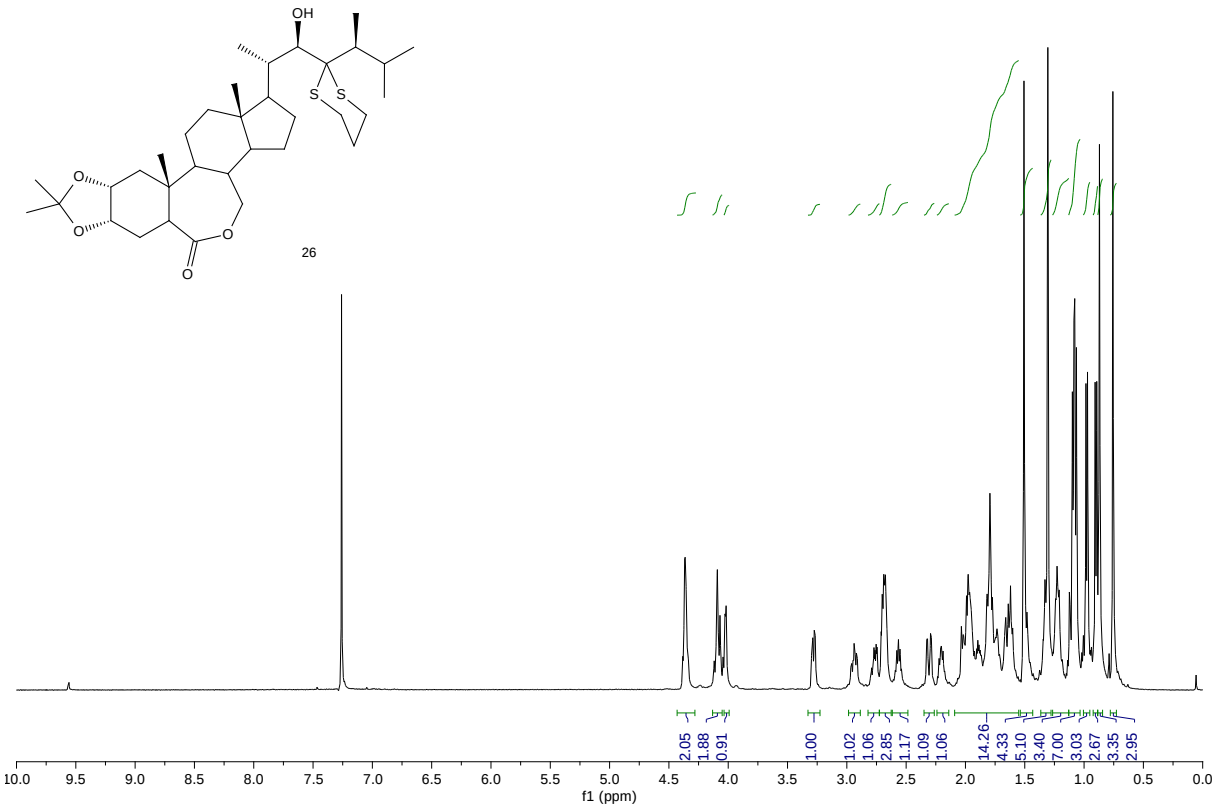
0.97
2.07
2.00
1.00
2.06
9.66
4.20
9.45
3.99
3.05
3.03
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

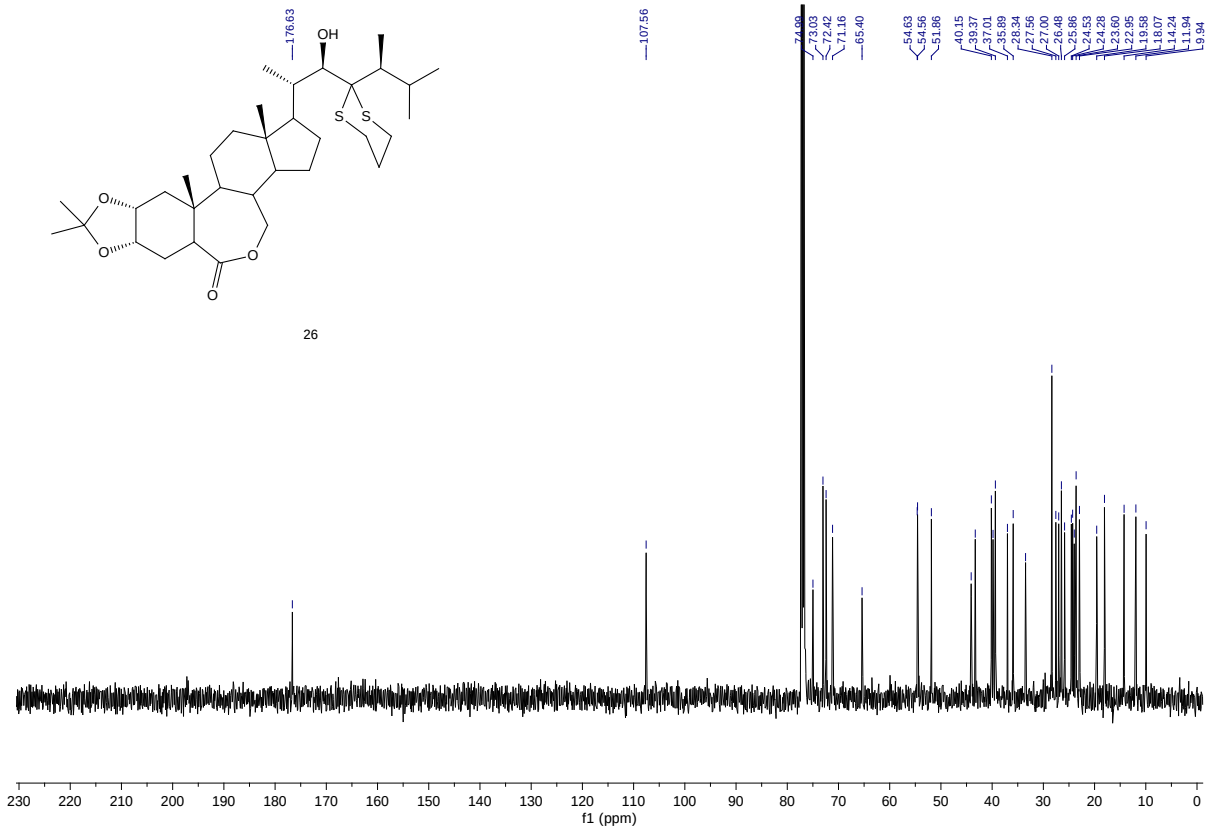

204.49
176.46
107.55
73.00
72.39
71.00
54.63
51.24
50.73
49.33
40.12
39.35
39.28
35.90
33.41
27.56
26.49
24.89
23.56
12.45

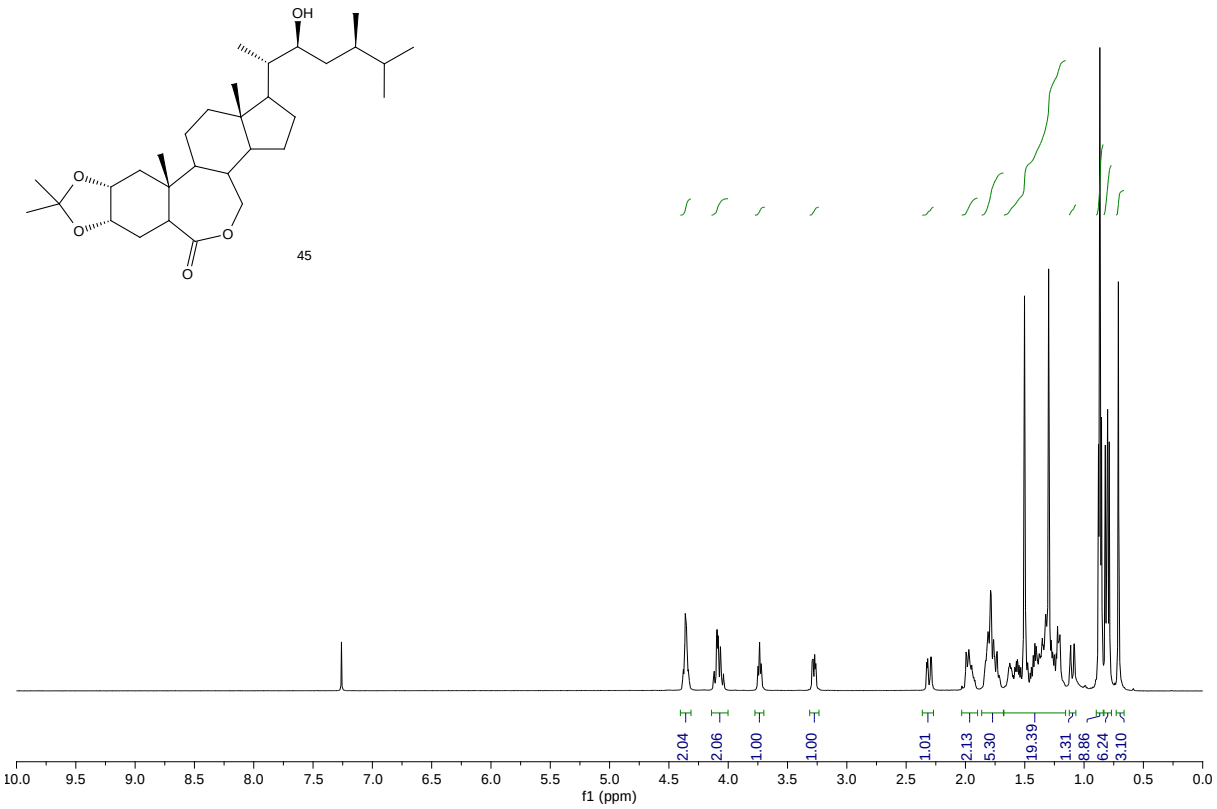

H3C
O
H3C
CH3
H3C
O
O
H
O

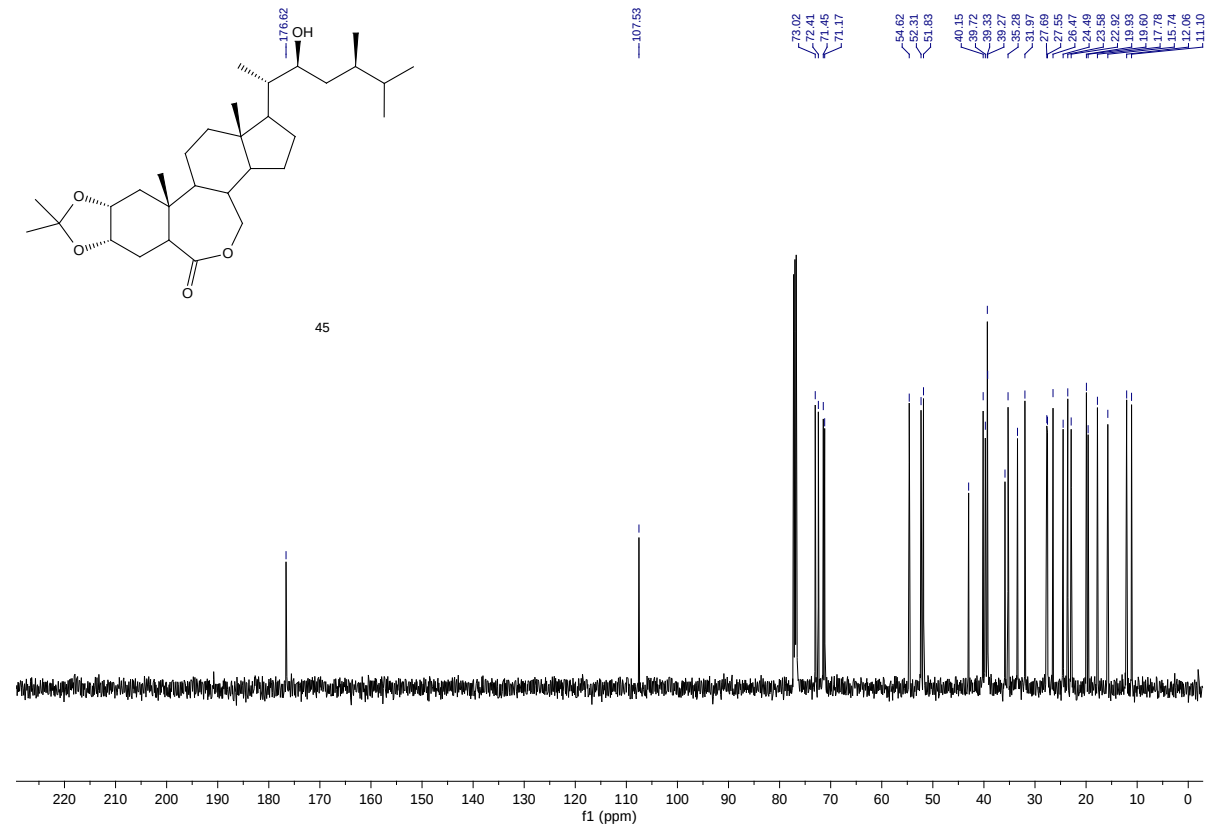
7

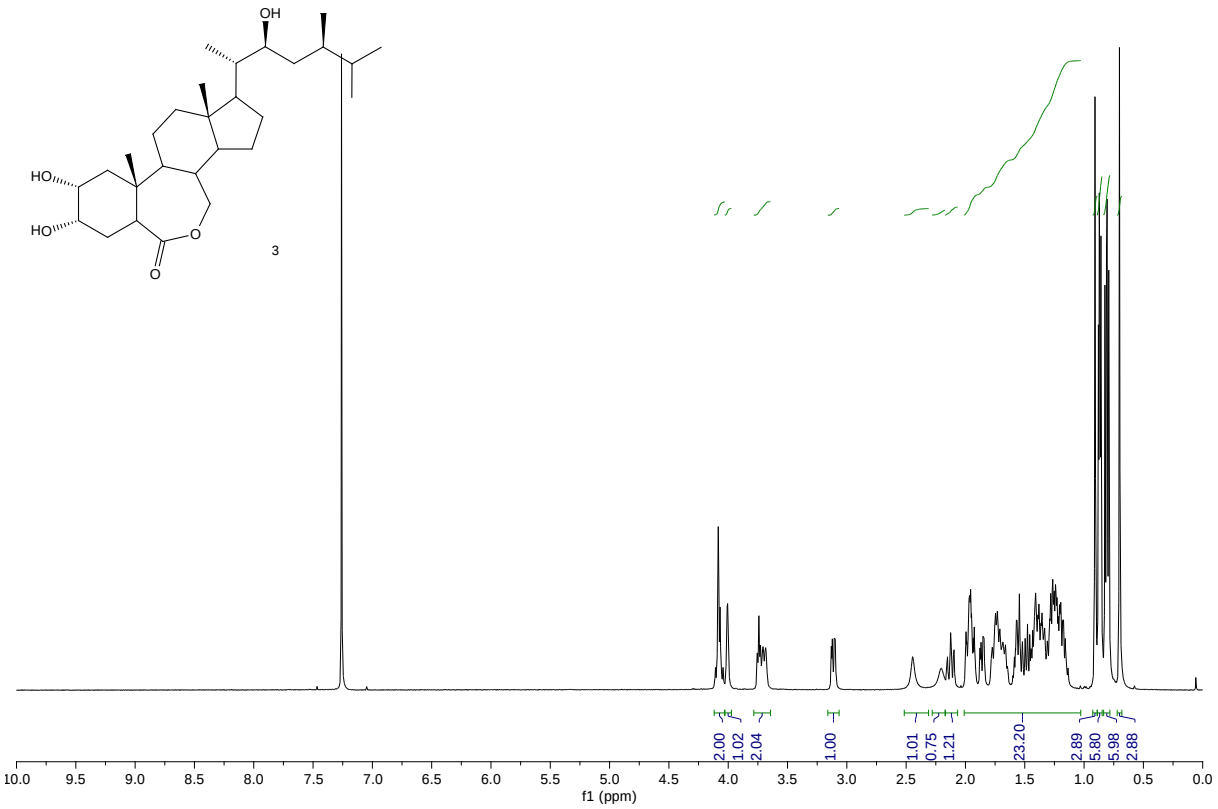

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

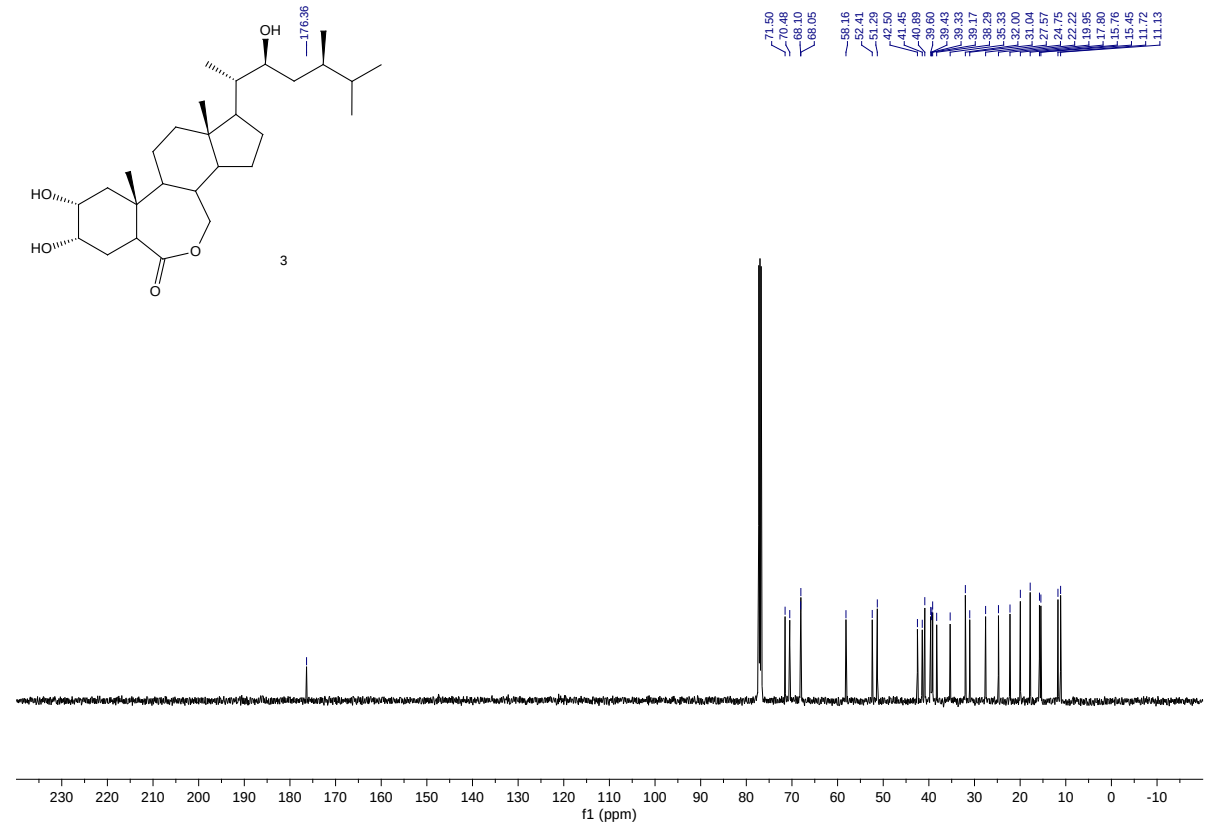

OH
S
S
O
O
O
O
O
26
2.05
1.88
0.91
1.00
1.02
1.06
2.85
1.17
1.09
1.06
14.26
4.33
5.10
3.40
7.00
3.03
2.67
3.35
2.95
f1 (ppm)

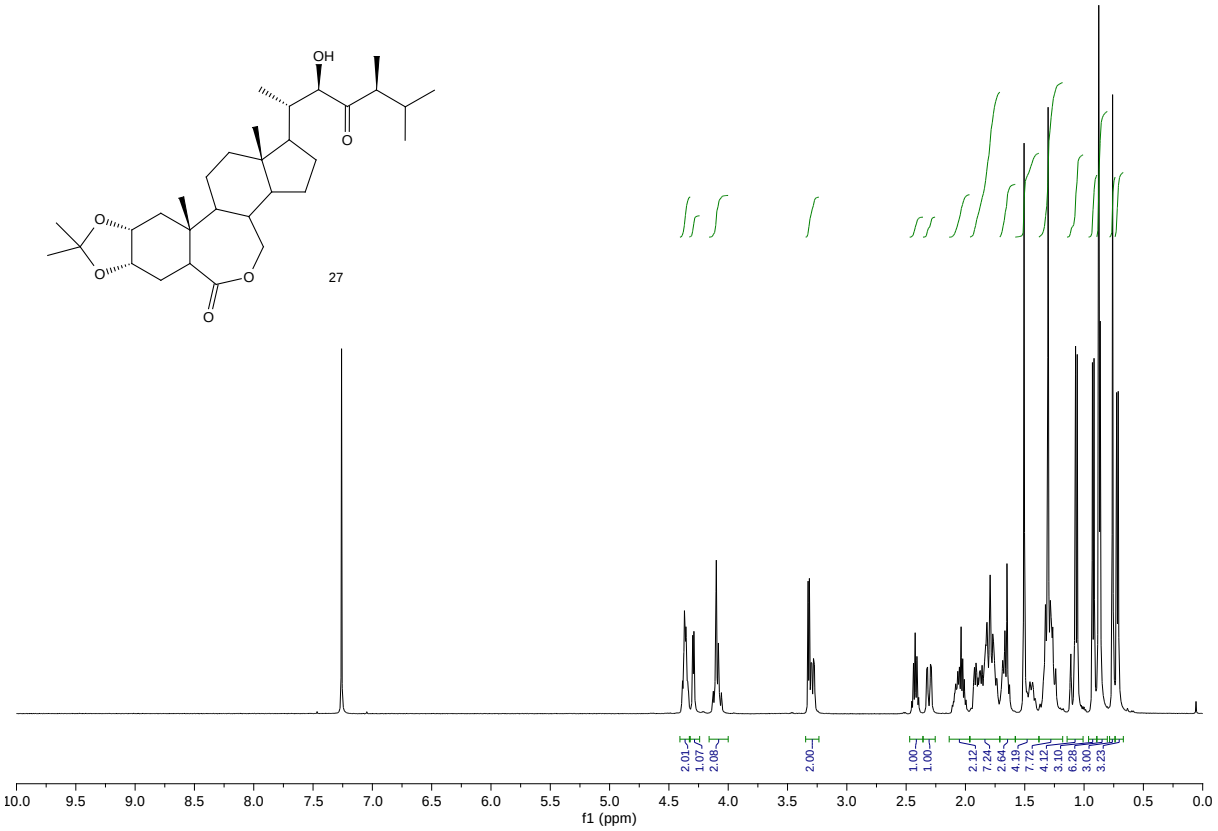

176.63
107.56
74.99
73.03
72.42
71.16
65.40
54.63
54.56
51.86
40.15
39.37
37.01
35.89
28.34
27.56
27.00
26.48
25.86
24.53
24.28
23.60
22.95
19.58
18.07
14.24
11.94
9.94
OH
S
S
O
O
O
O
O
26
f1 (ppm)

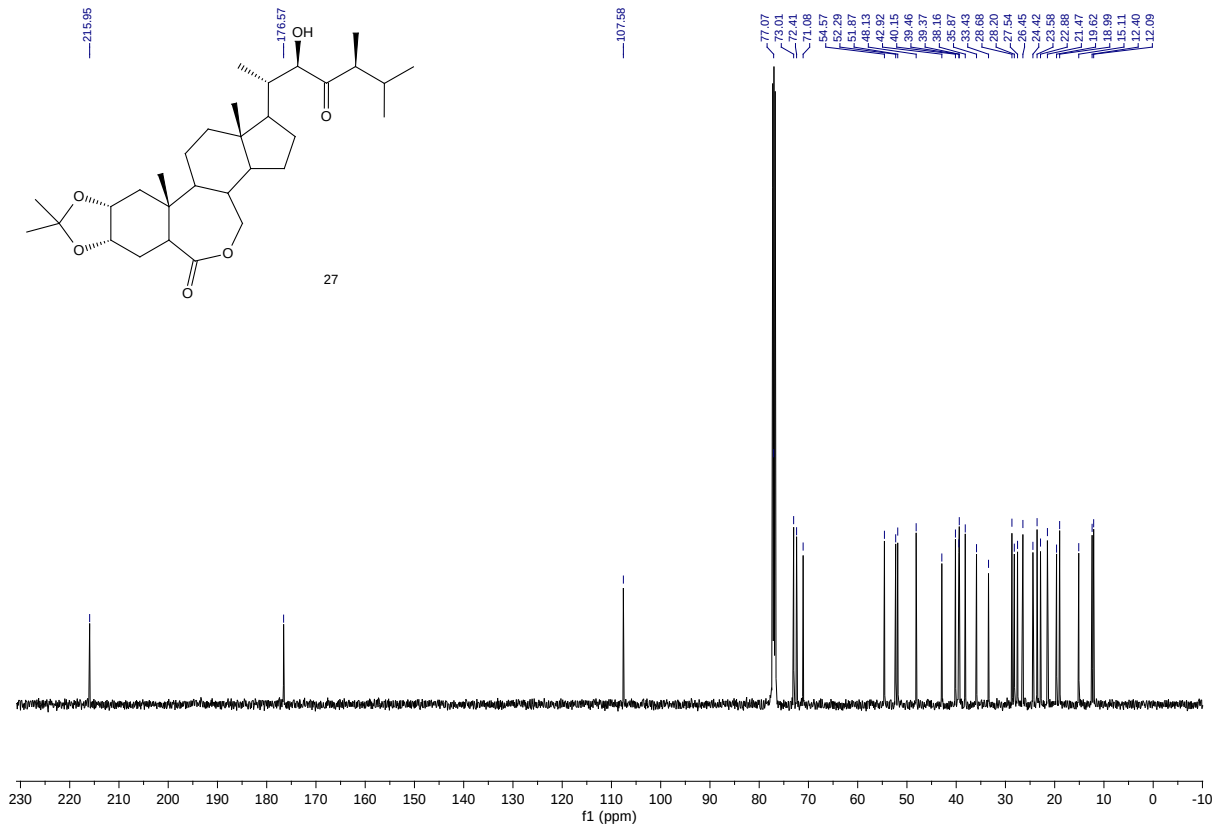

OH
O
O
O
O
45
2.04
2.06
1.00
1.00
1.01
2.13
5.30
19.39
1.31
8.86
6.24
3.10
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

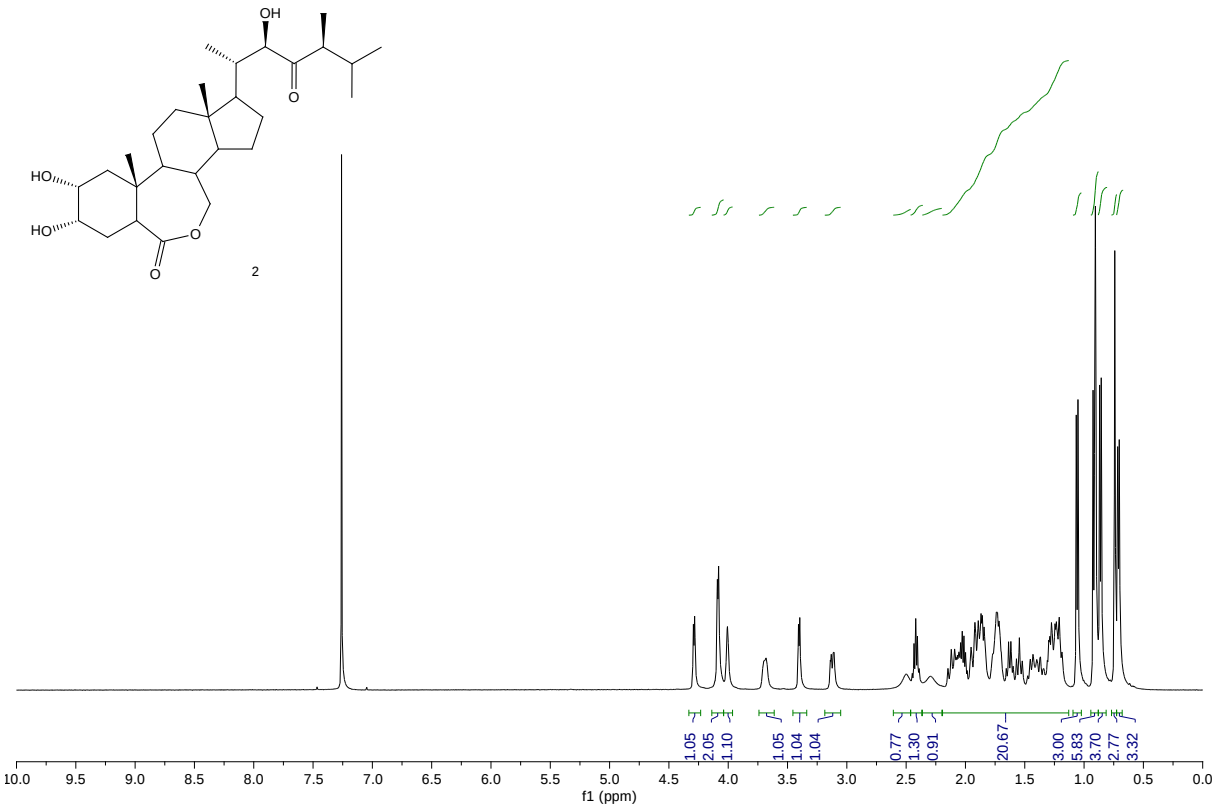

176.62
OH
107.53
73.02
72.41
71.45
71.17
54.62
52.31
51.83
40.15
39.72
39.33
39.27
35.28
31.97
27.69
27.55
26.47
24.49
23.58
22.92
19.93
19.60
17.78
15.74
12.06
11.10
O
O
O
O
45
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

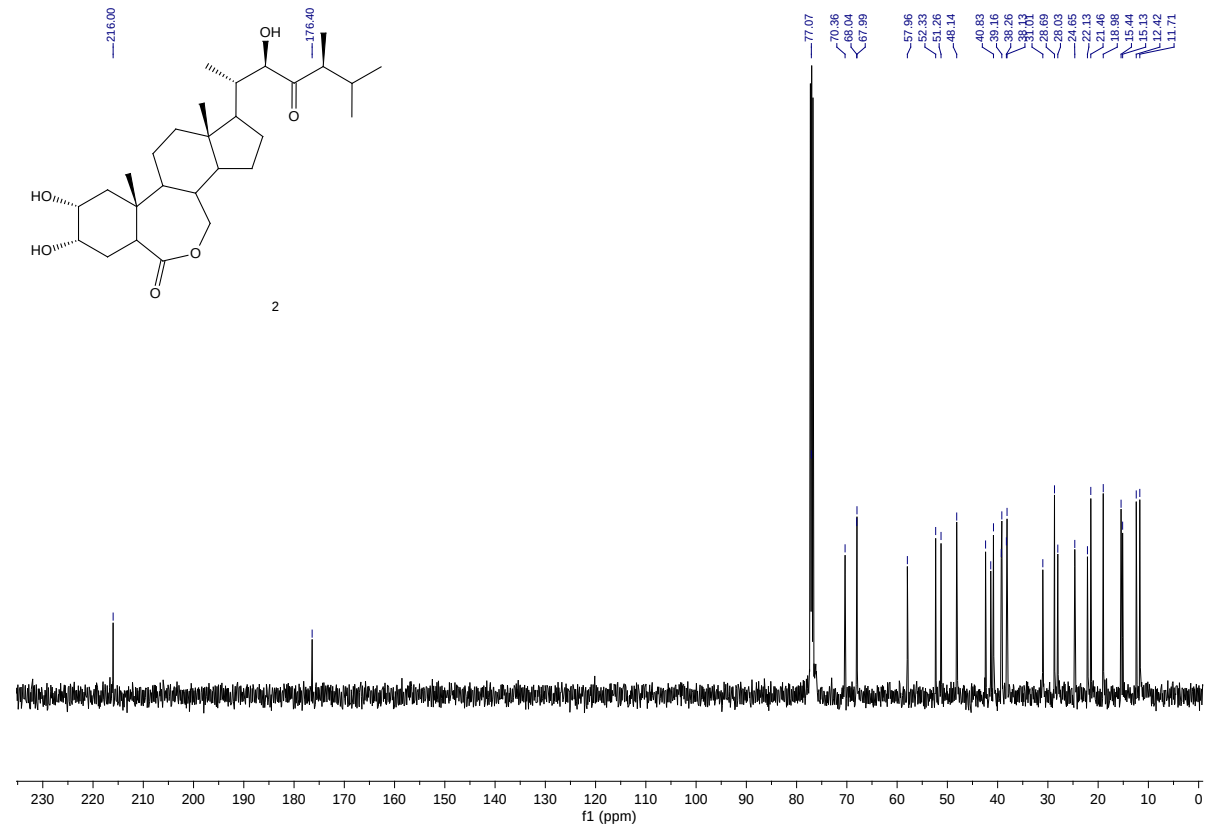

OH
HO
HO
O
O
3
2.00
1.02
2.04
1.00
1.01
0.75
1.21
23.20
2.89
5.80
5.98
2.88
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

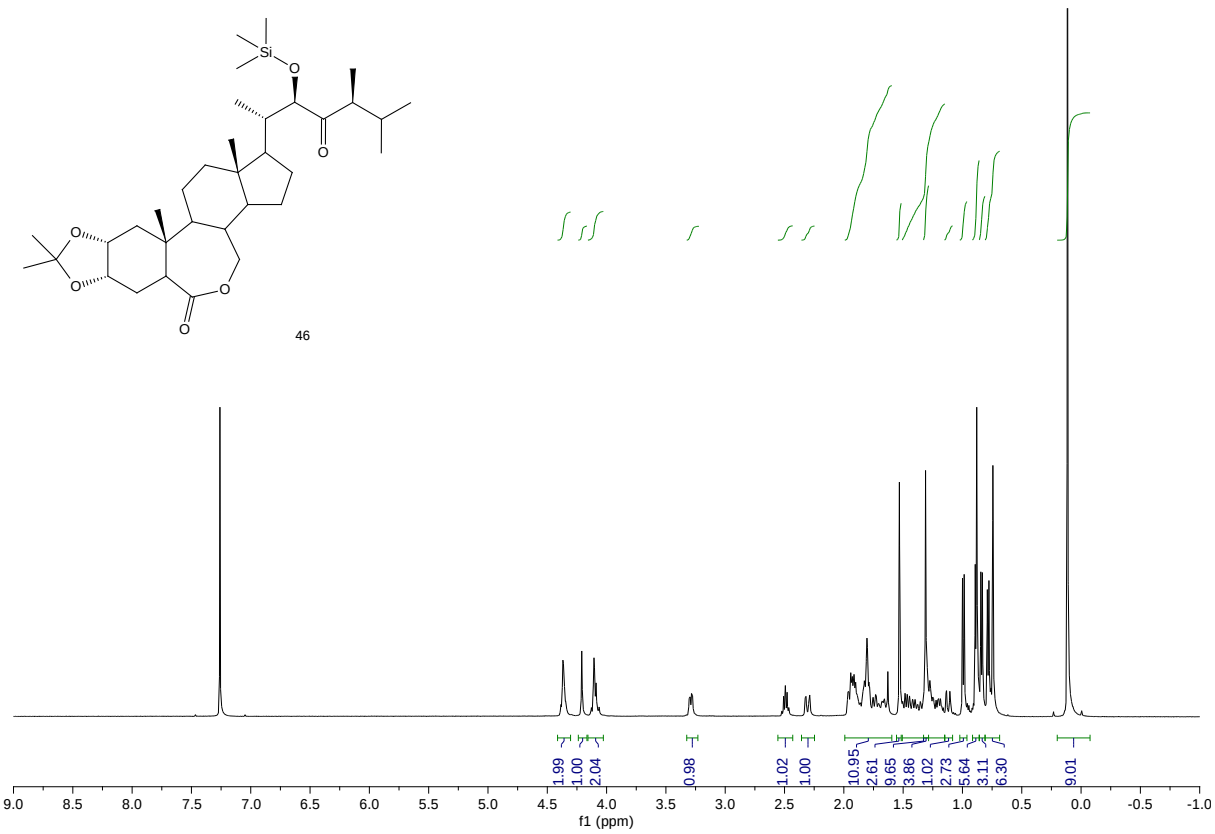

176.36
OH
HO
HO
O
O
3
71.50
70.48
68.10
68.05
58.16
52.41
51.29
42.50
41.45
40.89
39.60
39.43
39.33
39.17
38.29
35.33
32.00
31.04
27.57
24.75
22.22
19.95
17.80
15.76
15.45
11.72
11.13
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

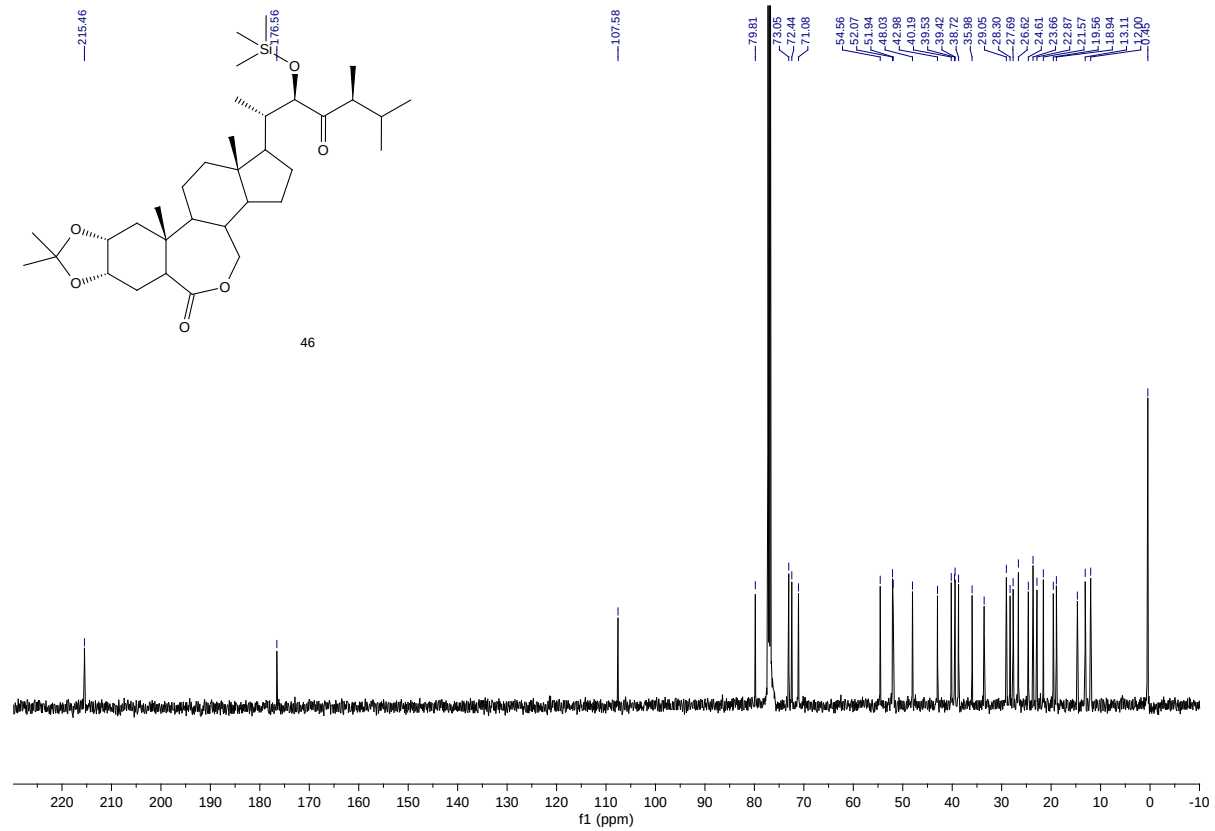

OH
O
O
O
O
O
27
2.01
1.07
2.08
2.00
1.00
1.00
2.12
7.24
2.64
4.19
7.72
4.12
3.10
6.28
3.00
3.23
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

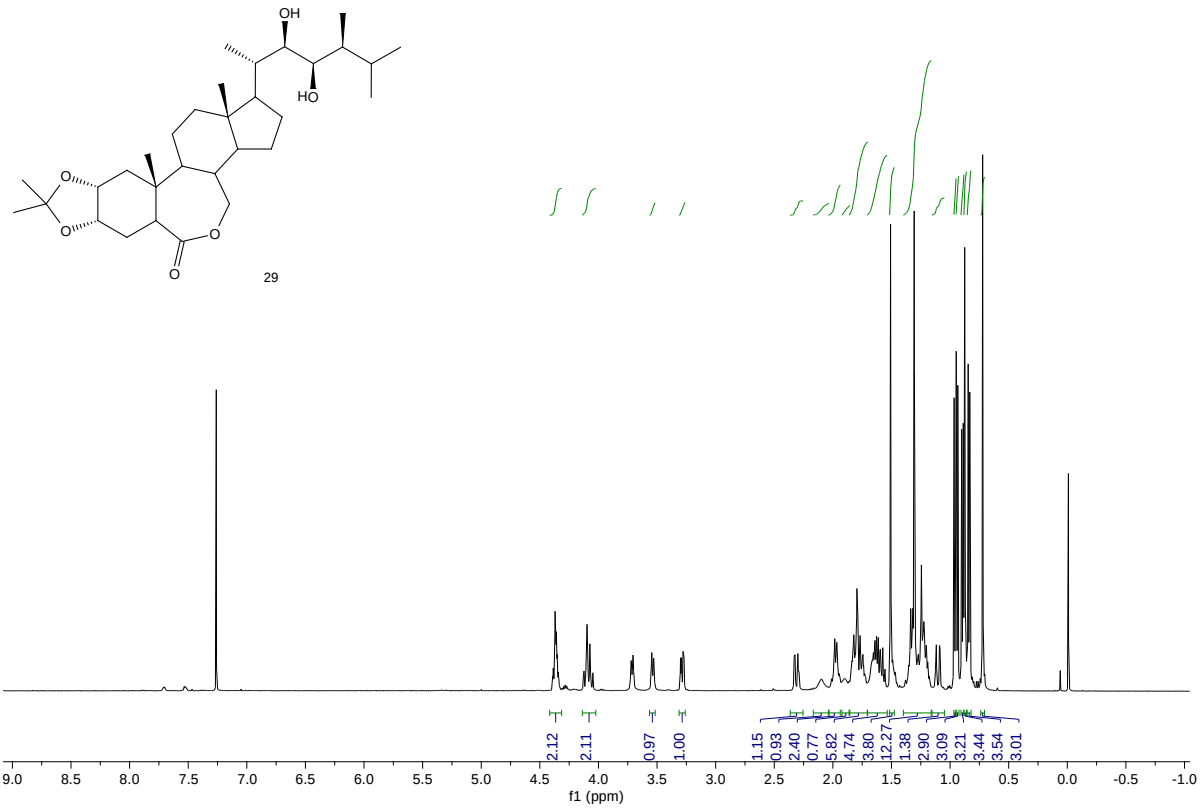

215.95
176.57
OH
O
O
O
O
O
27
107.58
77.07
73.01
72.41
71.08
54.57
52.29
51.87
48.13
42.92
40.15
39.46
39.37
38.16
35.87
33.43
28.68
28.20
27.54
26.45
24.42
23.58
22.88
21.47
19.62
18.99
15.11
12.40
12.09
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

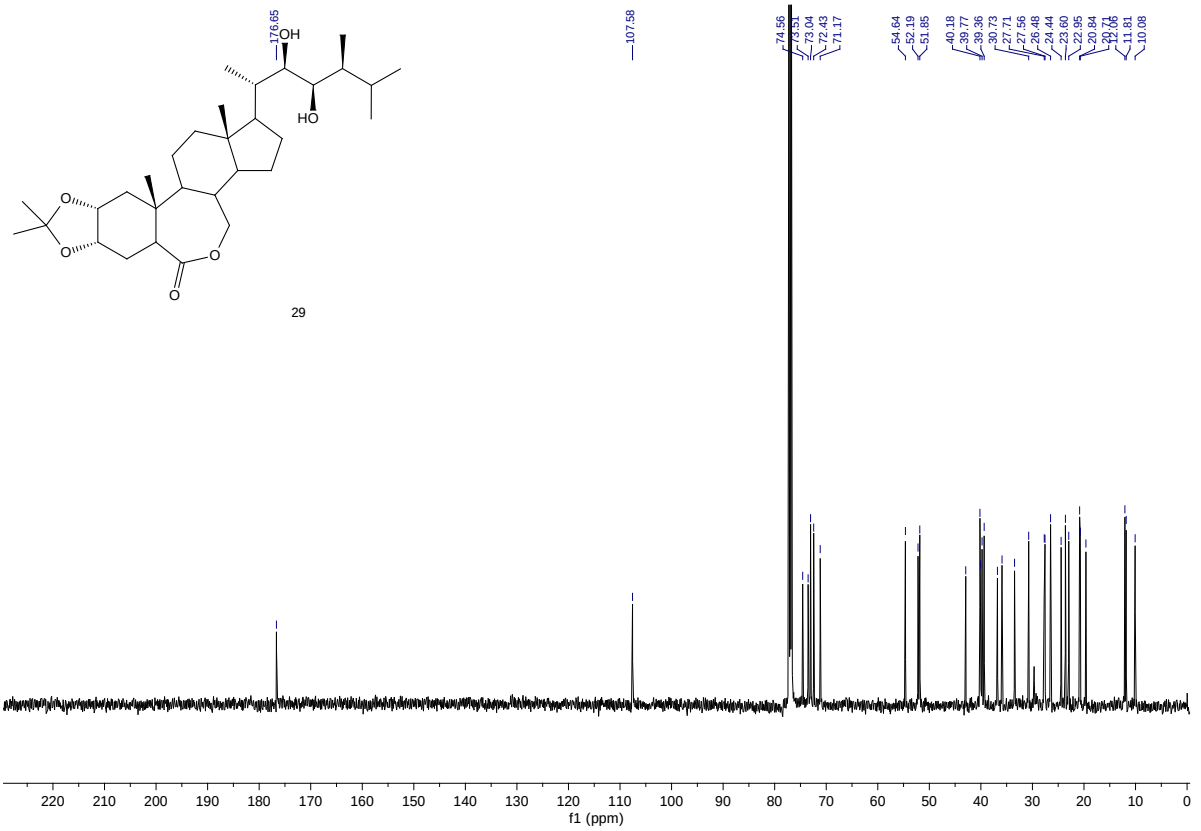

OH
O
HO
HO
O
O
2
1.05
2.05
1.10
1.05
1.04
1.04
0.77
1.30
0.91
20.67
3.00
5.83
3.70
2.77
3.32
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

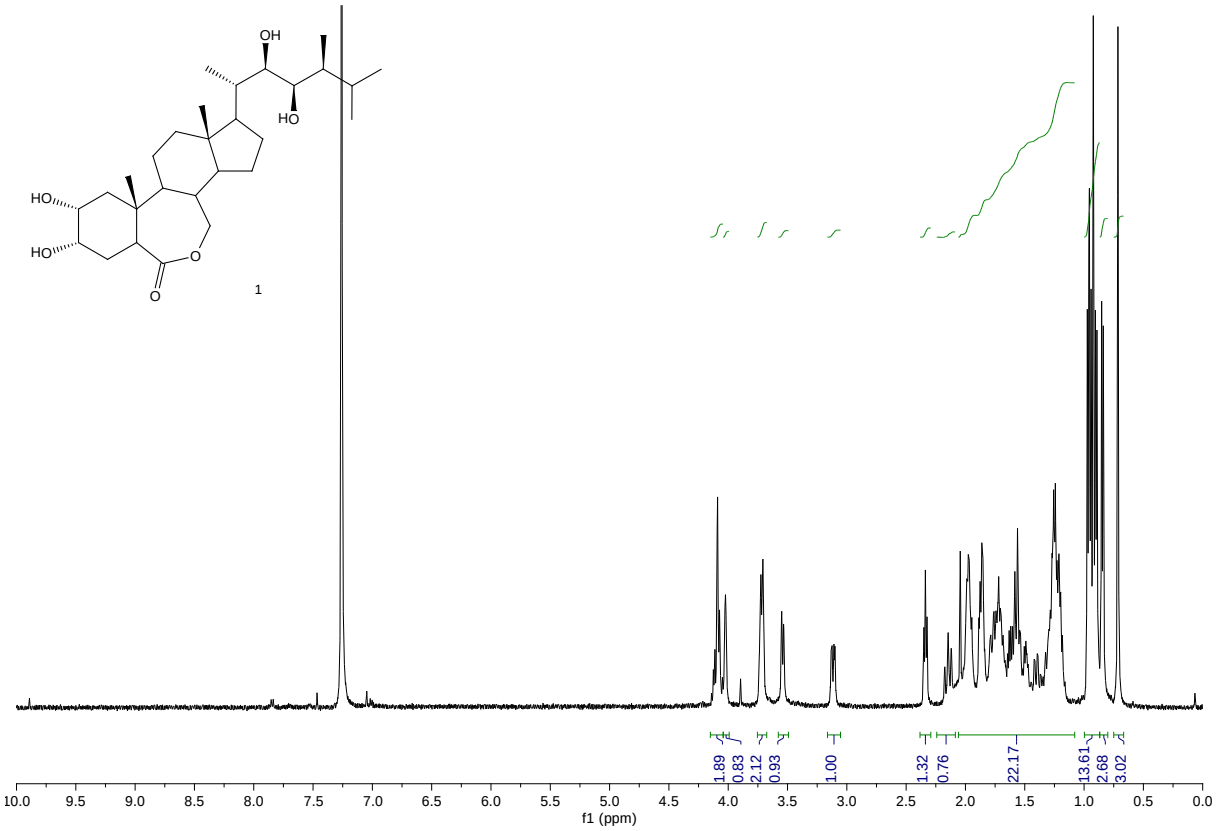

216.00
176.40
OH
O
HO
HO
O
O
2
77.07
70.36
68.04
67.99
57.96
52.33
51.26
48.14
40.83
39.16
38.26
38.13
37.01
28.69
28.03
24.65
22.13
21.46
18.98
15.44
15.13
12.42
11.71
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

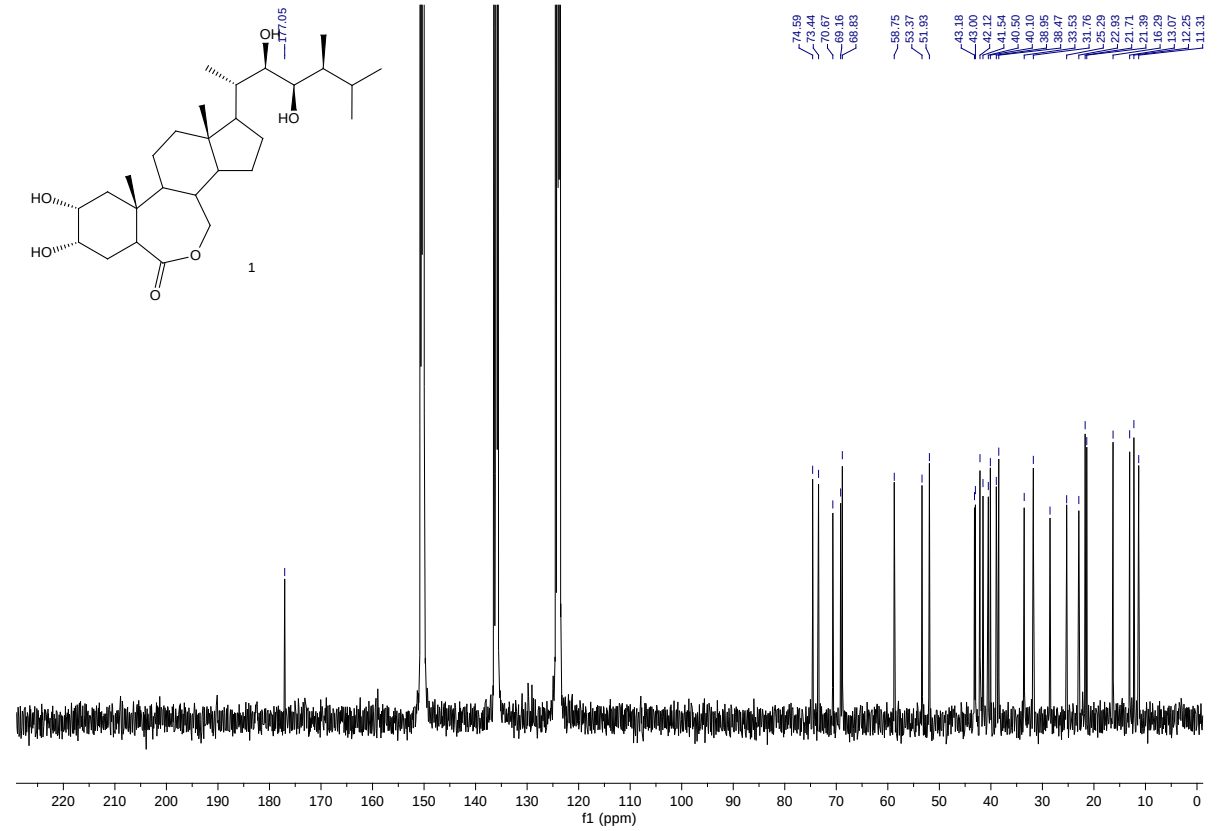

46
1.99
1.00
2.04
0.98
1.02
1.00
10.95
2.61
9.65
3.86
1.02
2.73
5.64
3.11
6.30
9.01
f1 (ppm)

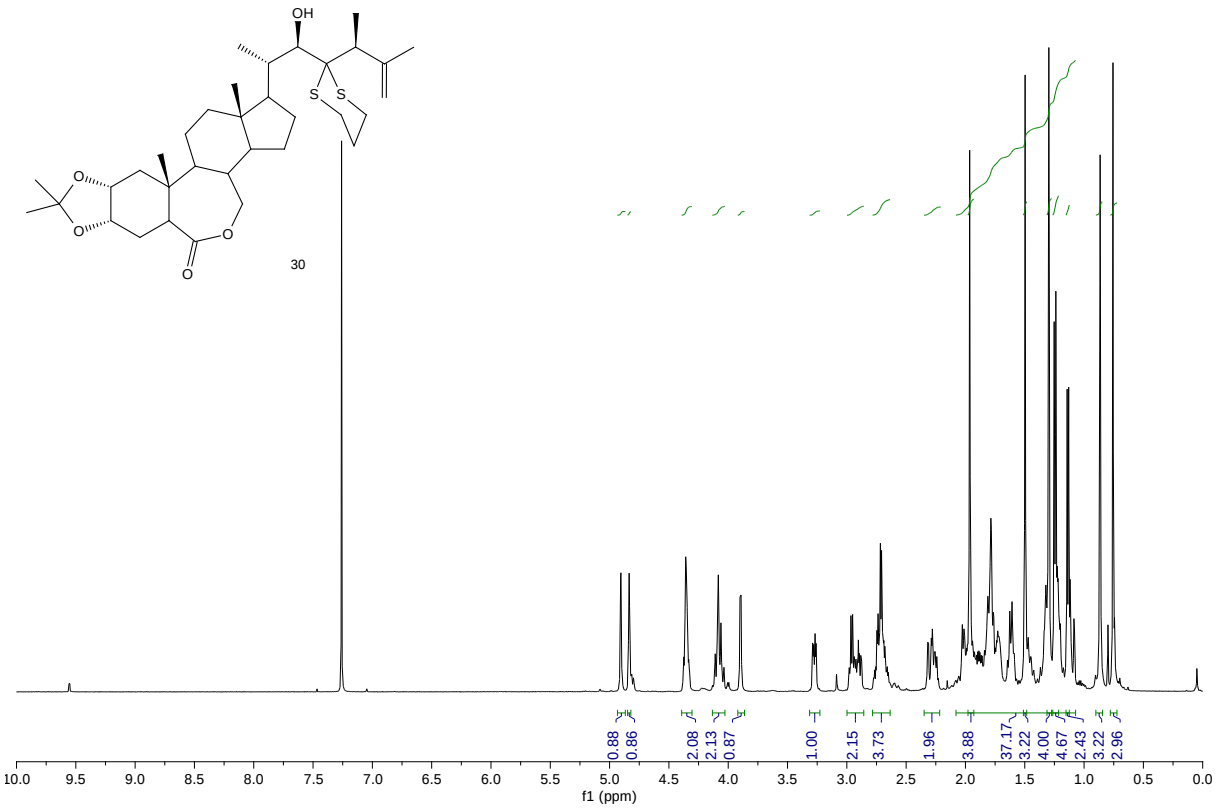

215.46
176.56
107.58
79.81
73.05
72.44
71.08
54.56
52.07
51.94
48.03
42.98
40.19
39.53
39.42
38.72
35.98
29.05
28.30
27.69
26.62
24.61
23.66
22.87
21.57
19.56
18.94
13.11
12.00
10.45
46
f1 (ppm)

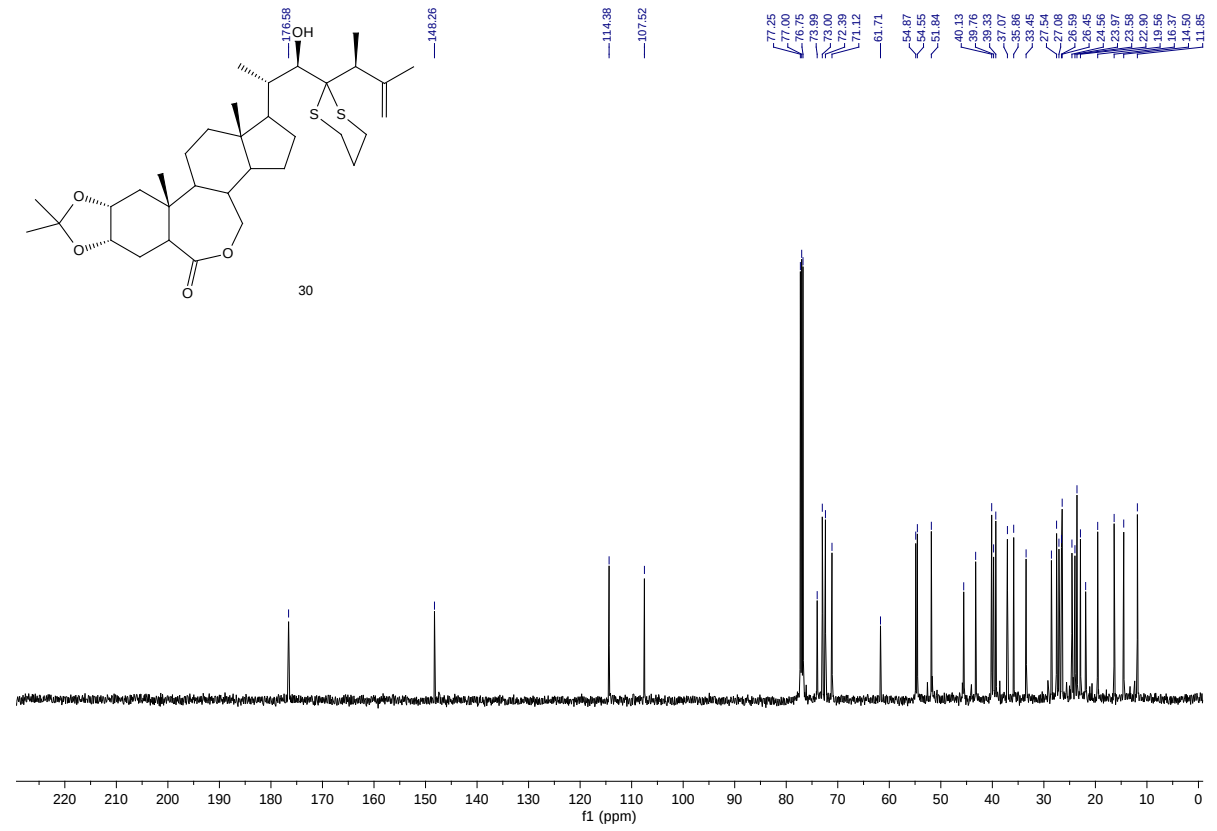

OH
HO
O
O
O
O
29
2.12
2.11
0.97
1.00
1.15
0.93
2.40
0.77
5.82
4.74
3.80
12.27
1.38
2.90
3.09
3.21
3.44
3.54
3.01
f1 (ppm)

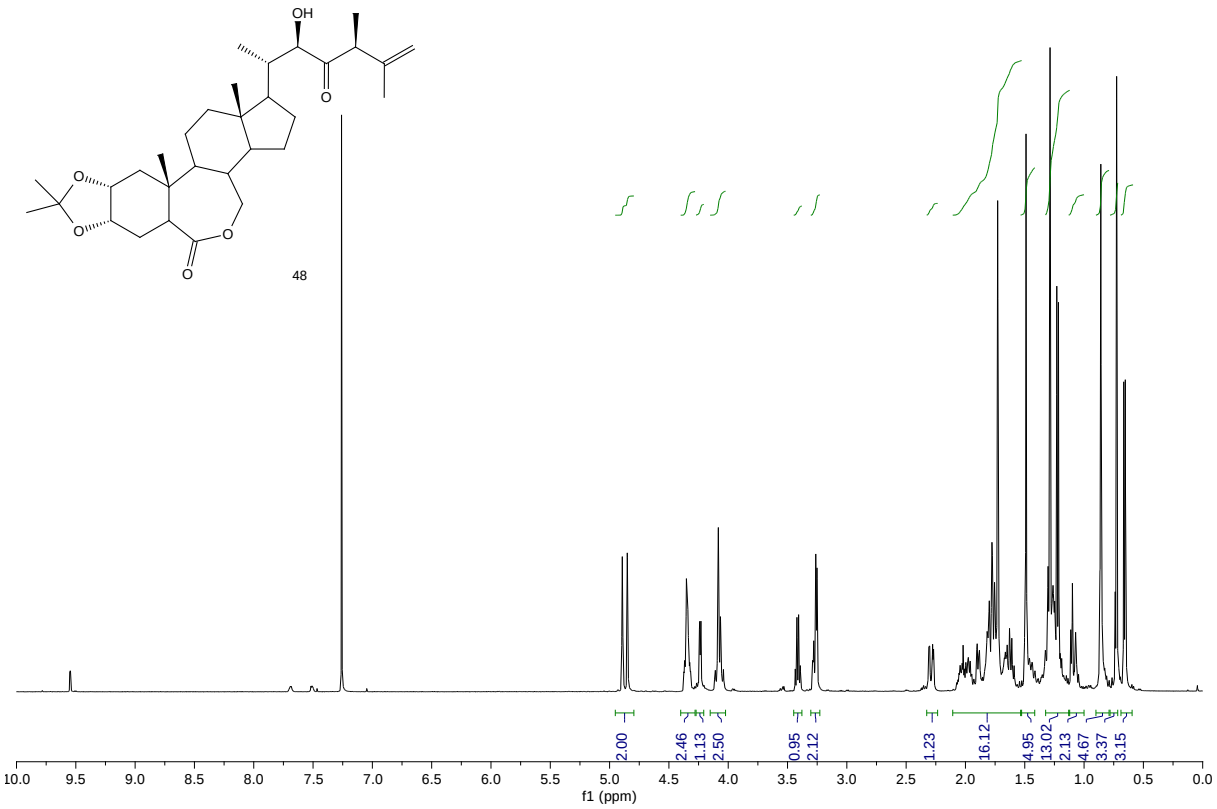

176.65
OH
HO
O
O
O
O
29
107.58
74.56
73.51
73.04
72.43
71.17
54.64
52.19
51.85
40.18
39.77
39.36
30.73
27.71
27.56
26.48
24.44
23.60
22.95
20.84
20.71
12.08
11.81
10.08
f1 (ppm)

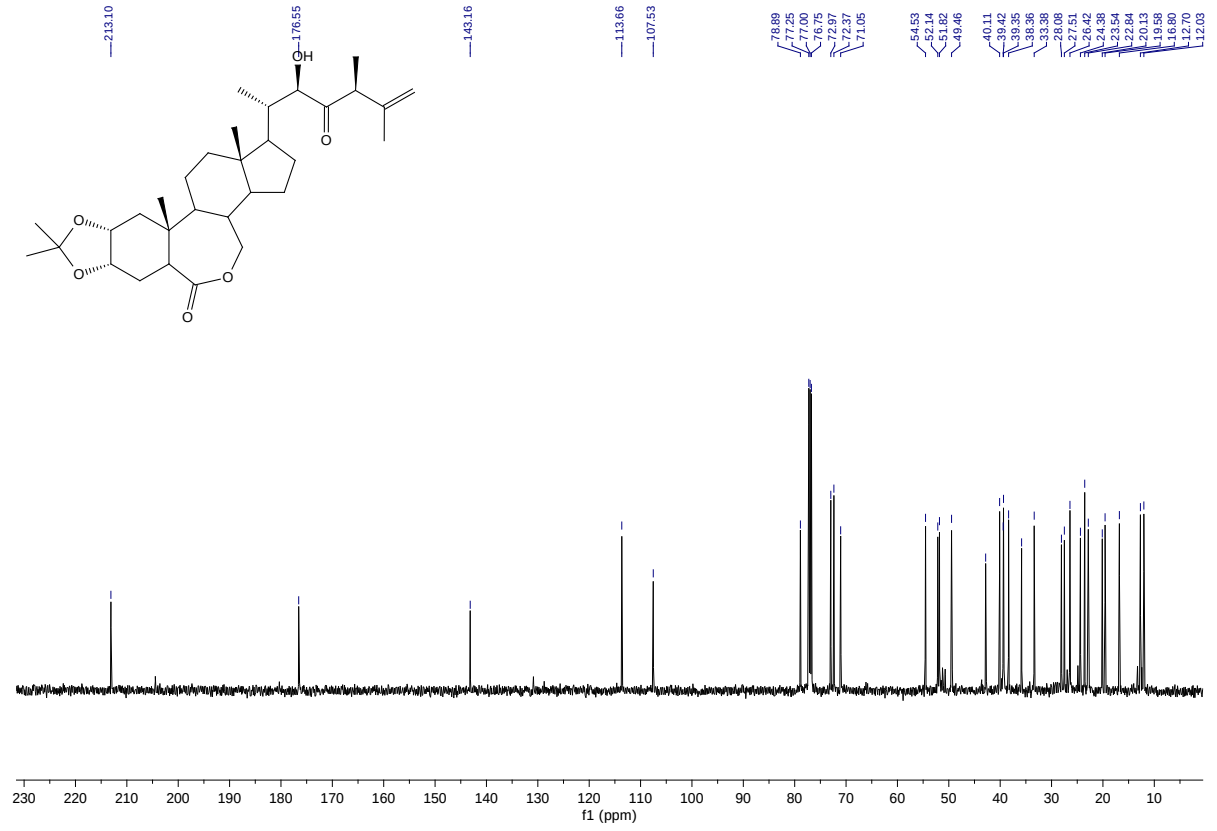

OH
HO
HO
HO
O
O
1
1.89
0.83
2.12
0.93
1.00
1.32
0.76
22.17
13.61
2.68
3.02
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

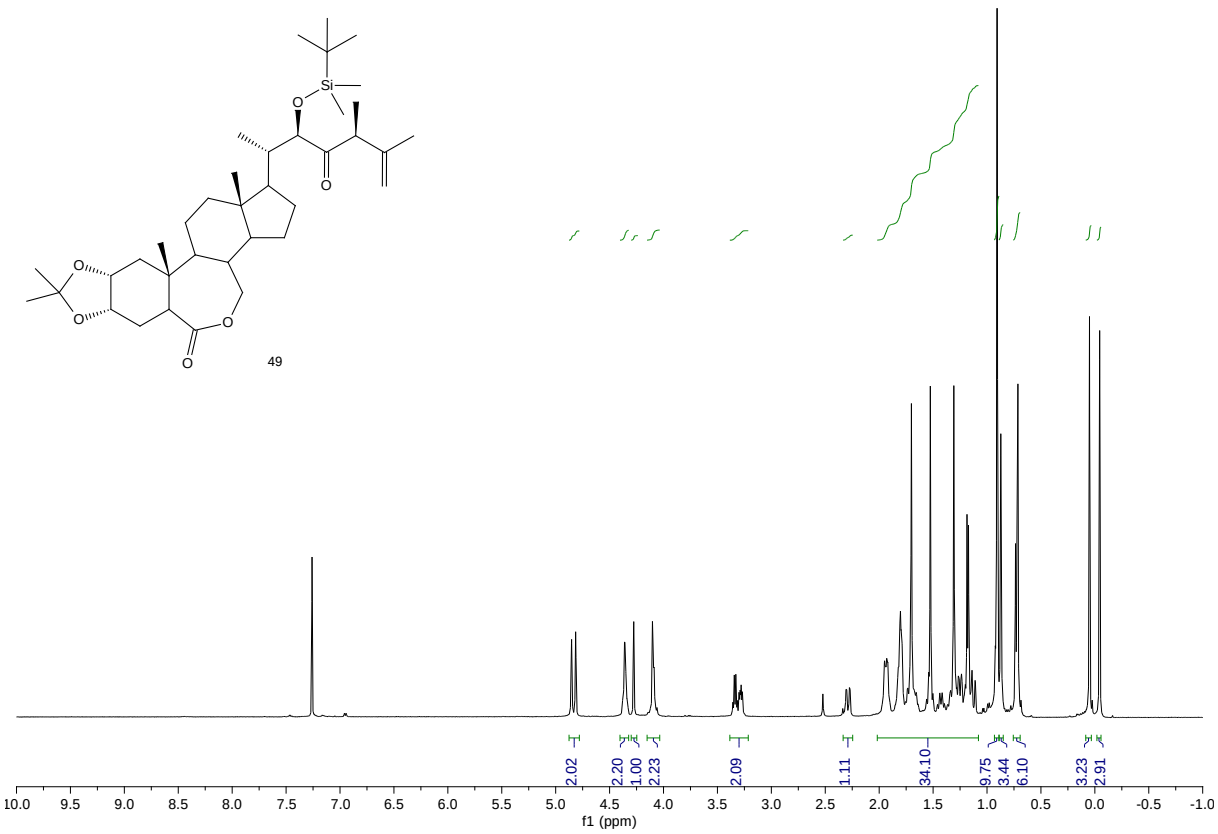

177.05
OH
HO
HO
HO
O
O
1
74.59
73.44
70.67
69.16
68.83
58.75
53.37
51.93
43.18
43.00
42.12
41.54
40.50
40.10
38.95
38.47
33.53
31.76
25.29
22.93
21.71
21.39
16.29
13.07
12.25
11.31
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

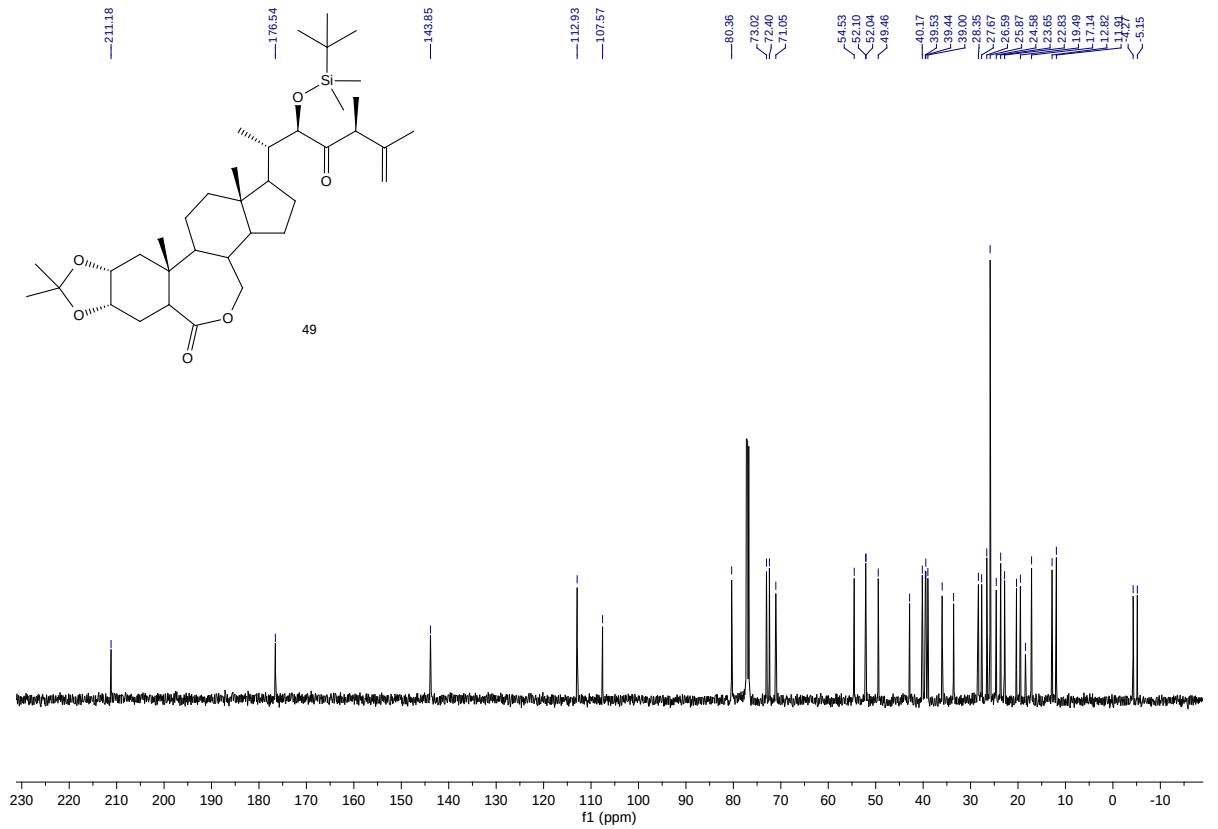

OH
S
S
O
O
O
O
O
30
0.88
0.86
2.08
2.13
0.87
1.00
2.15
3.73
1.96
3.88
37.17
3.22
4.00
4.67
2.43
3.22
2.96
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

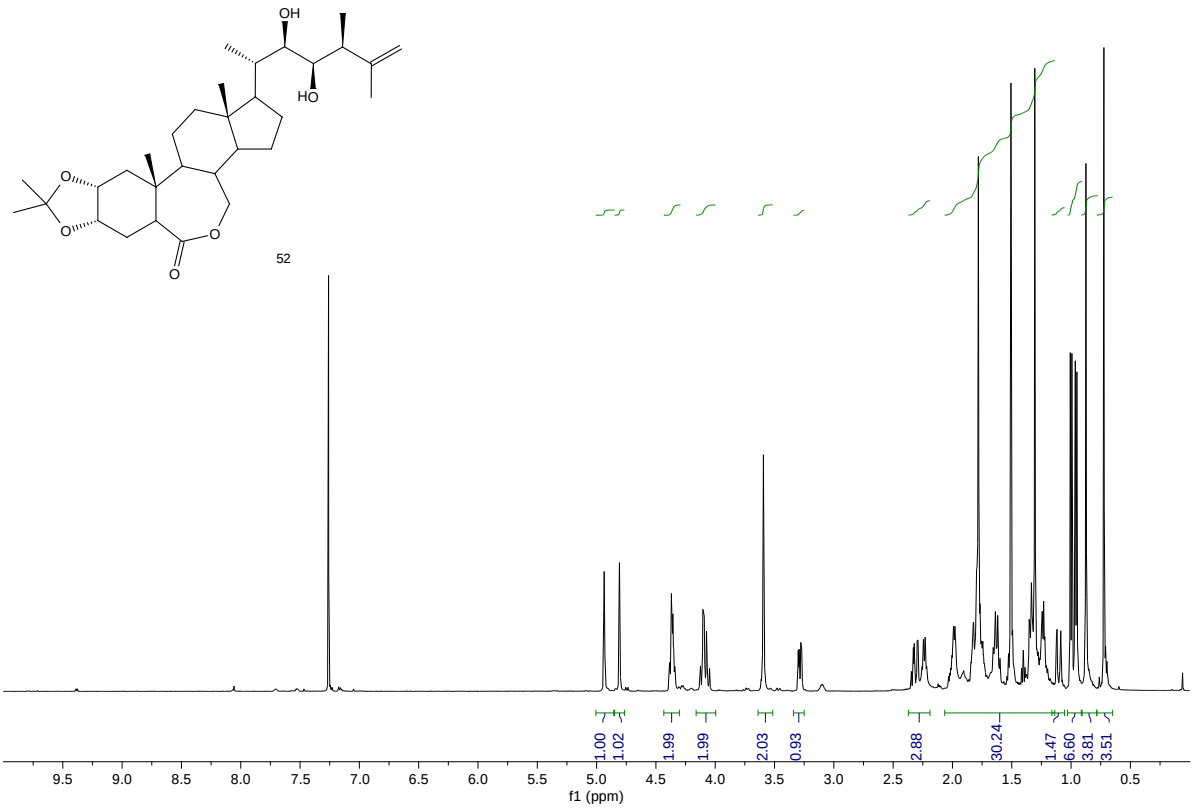

176.58
148.26
114.38
107.52
77.25
77.00
76.75
73.99
73.00
72.39
71.12
61.71
54.87
54.55
51.84
40.13
39.76
39.33
37.07
35.86
33.45
27.54
27.08
26.59
26.45
24.56
23.97
23.58
22.90
19.56
16.37
14.50
11.85
OH
S
S
O
O
O
O
O
30
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

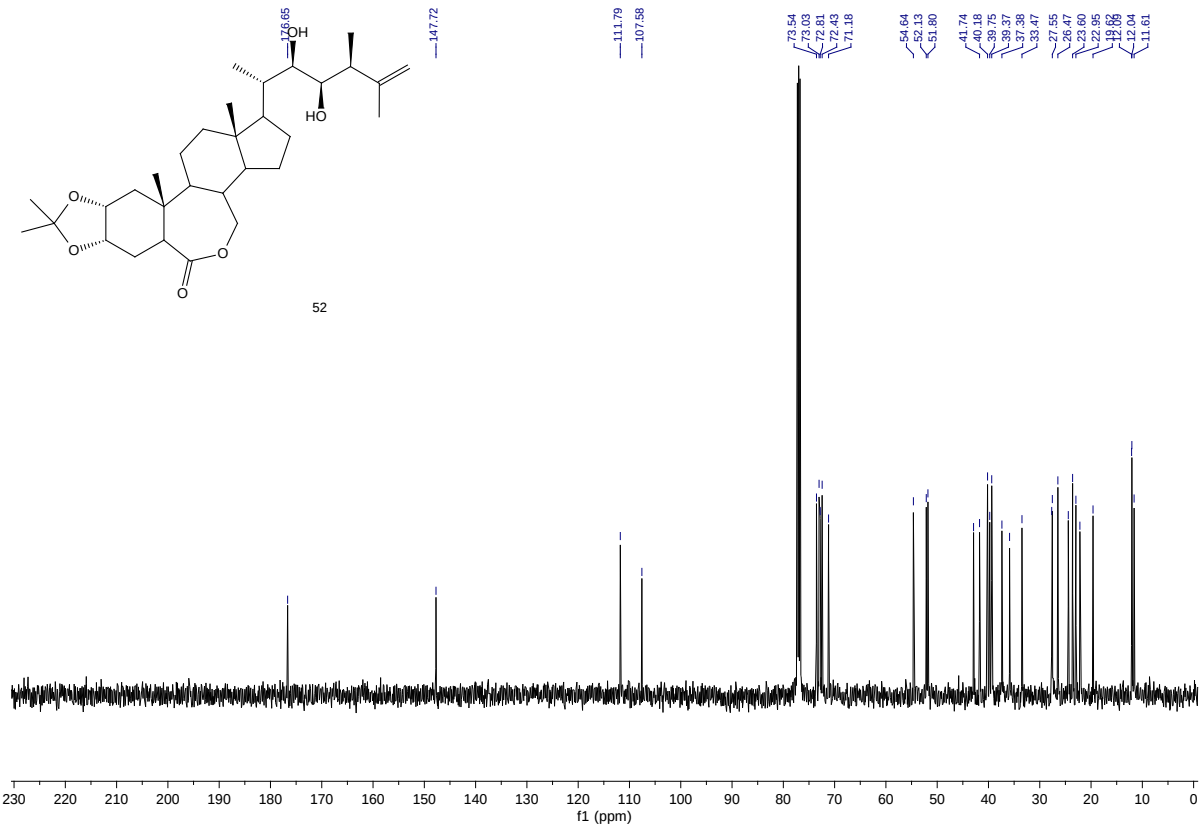

OH
O
O
O
O
O
48
2.00
2.46
1.13
2.50
0.95
2.12
1.23
16.12
4.95
13.02
2.13
4.67
3.37
3.15
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

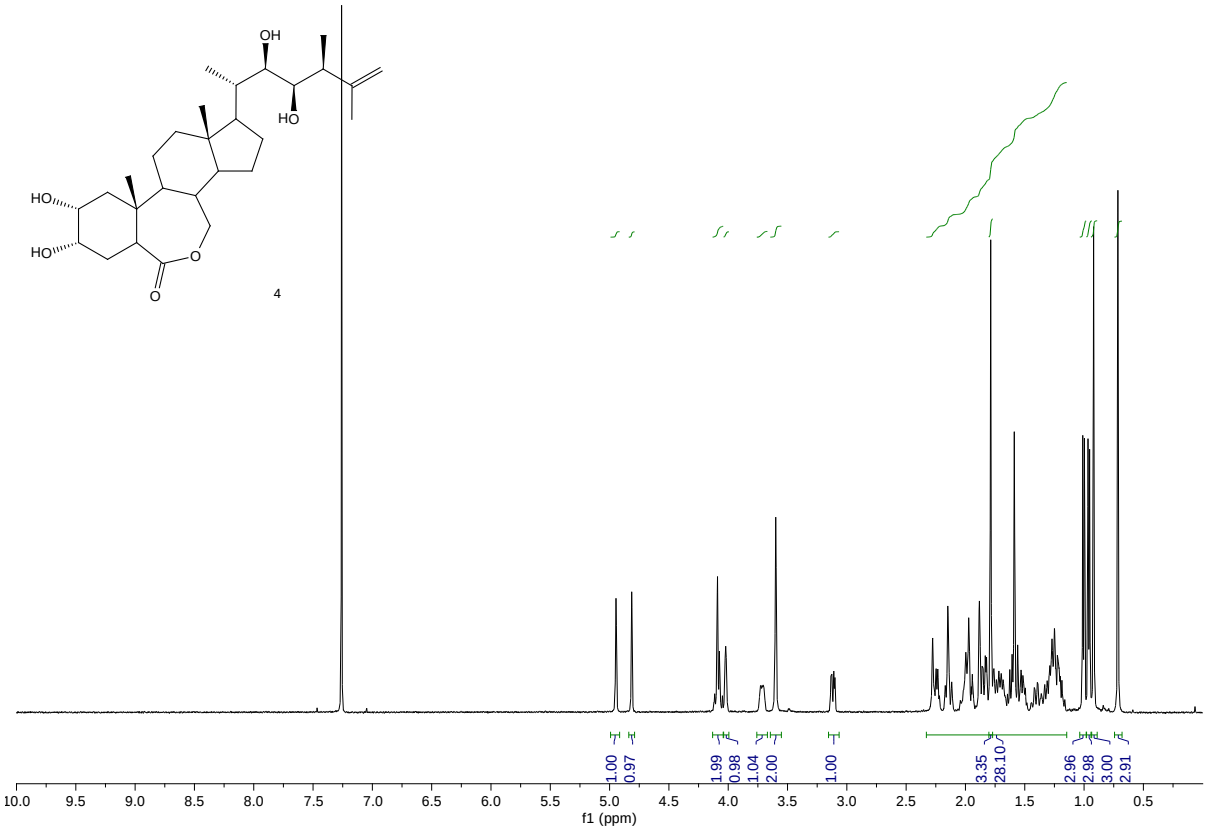

213.10
176.55
143.16
113.66
107.53
78.89
77.25
77.00
76.75
72.97
72.37
71.05
54.53
52.14
51.82
49.46
40.11
39.42
39.35
38.36
33.38
28.08
27.51
26.42
24.38
23.54
22.84
20.13
19.58
16.80
12.70
12.03
OH
O
O
O
O
O
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

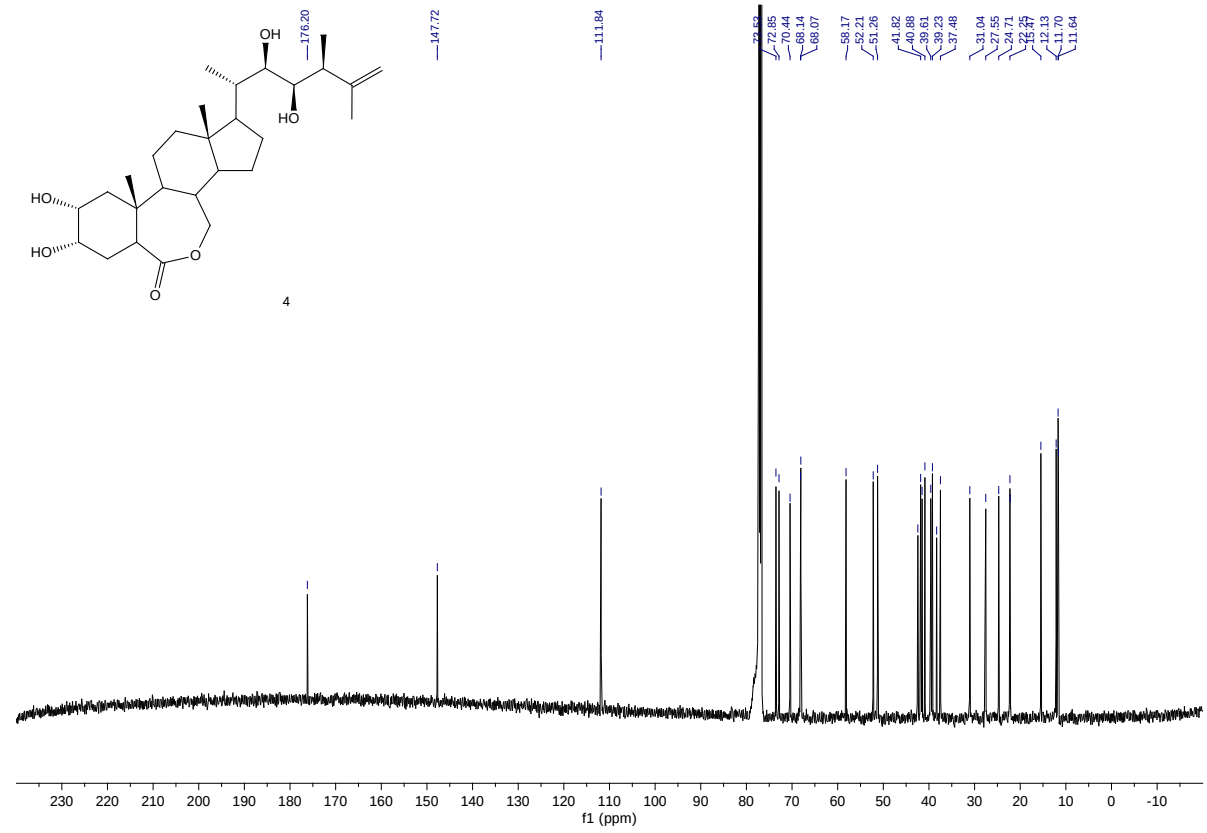

Si
O
O
O
O
O
O
O
49
2.02
2.20
1.00
2.23
2.09
1.11
34.10
9.75
3.44
6.10
3.23
2.91
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

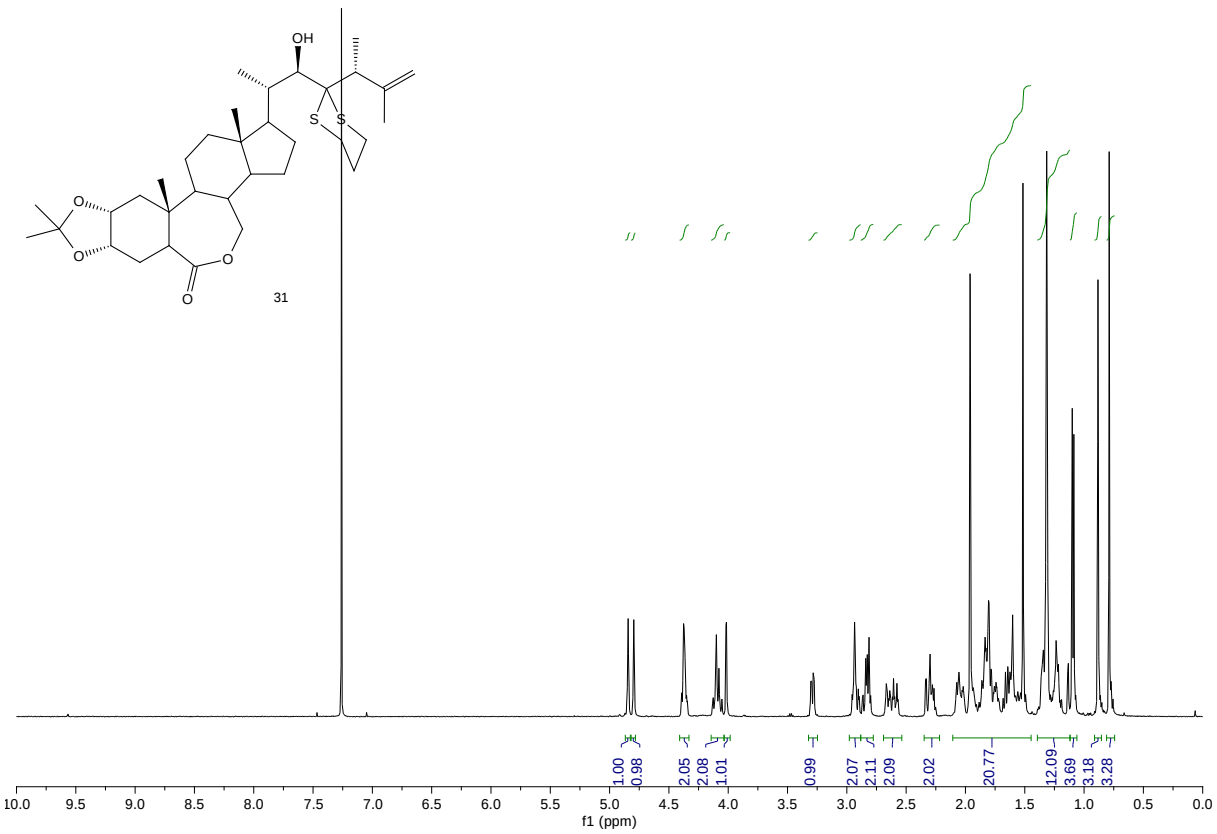

211.18
176.54
143.85
112.93
107.57
80.36
73.02
72.40
71.05
54.53
52.10
52.04
49.46
40.17
39.53
39.44
39.00
28.35
27.67
26.59
25.87
24.58
23.65
22.83
19.49
17.14
12.82
11.91
4.27
-5.15
Si
O
O
O
O
O
O
O
49
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

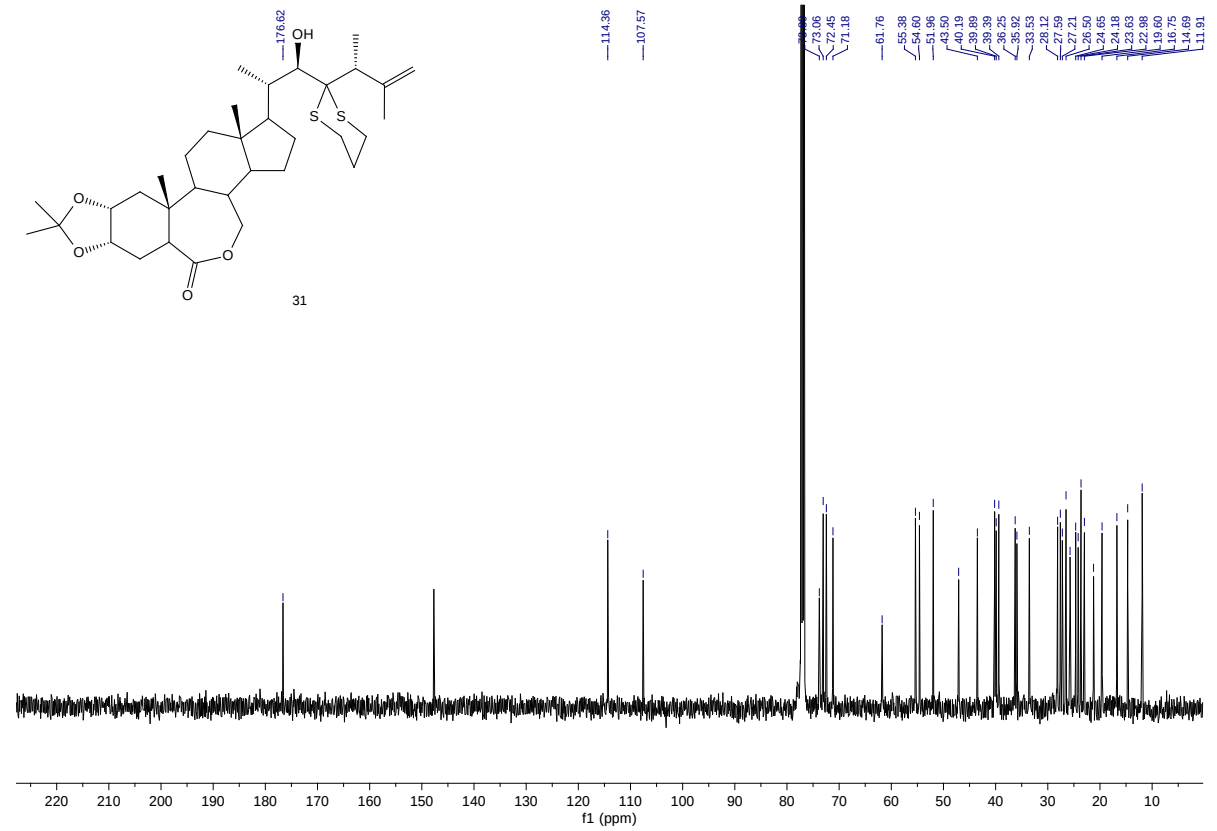

OH
HO
O
O
O
O
52
1.00
1.02
1.99
1.99
2.03
0.93
2.88
30.24
1.47
6.60
3.81
3.51
f1 (ppm)

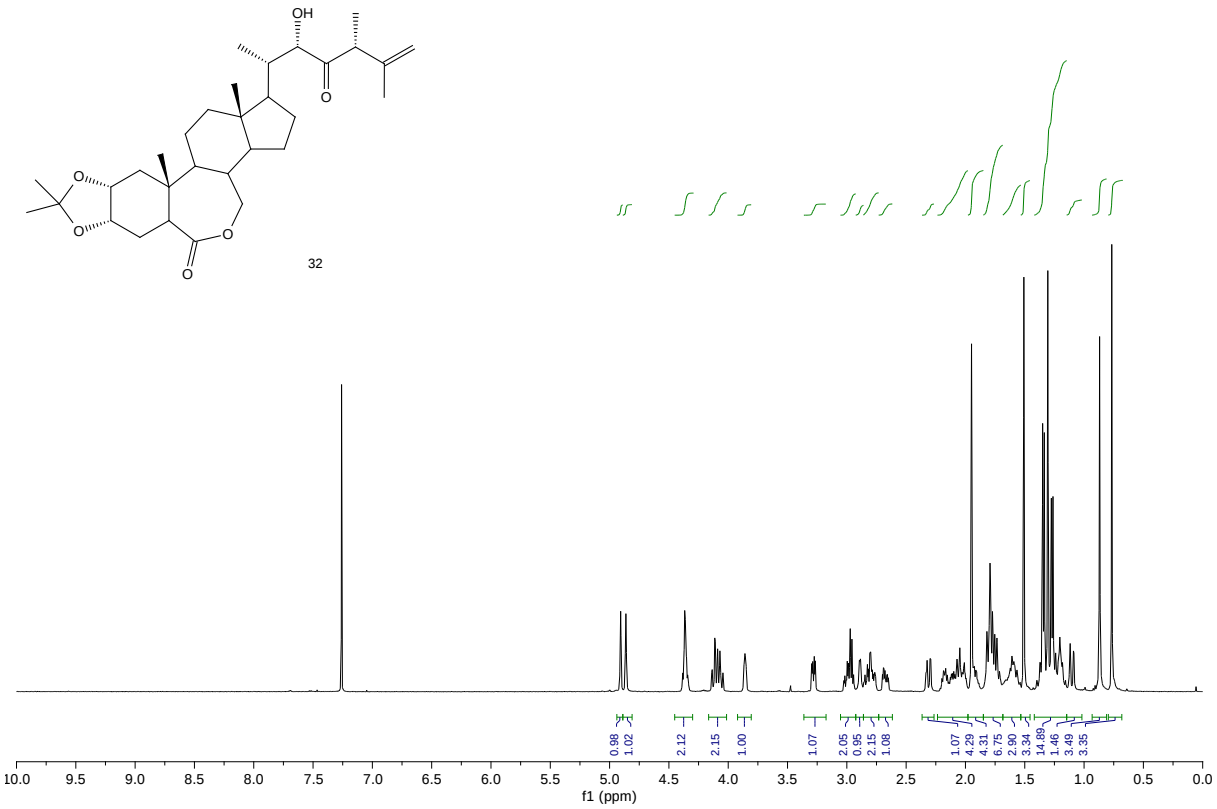

176.65
147.72
111.79
107.58
73.54
73.03
72.81
72.43
71.18
54.64
52.13
51.80
41.74
40.18
39.75
39.37
37.38
33.47
27.55
26.47
23.60
22.95
12.04
11.61
OH
HO
O
O
O
O
52
f1 (ppm)

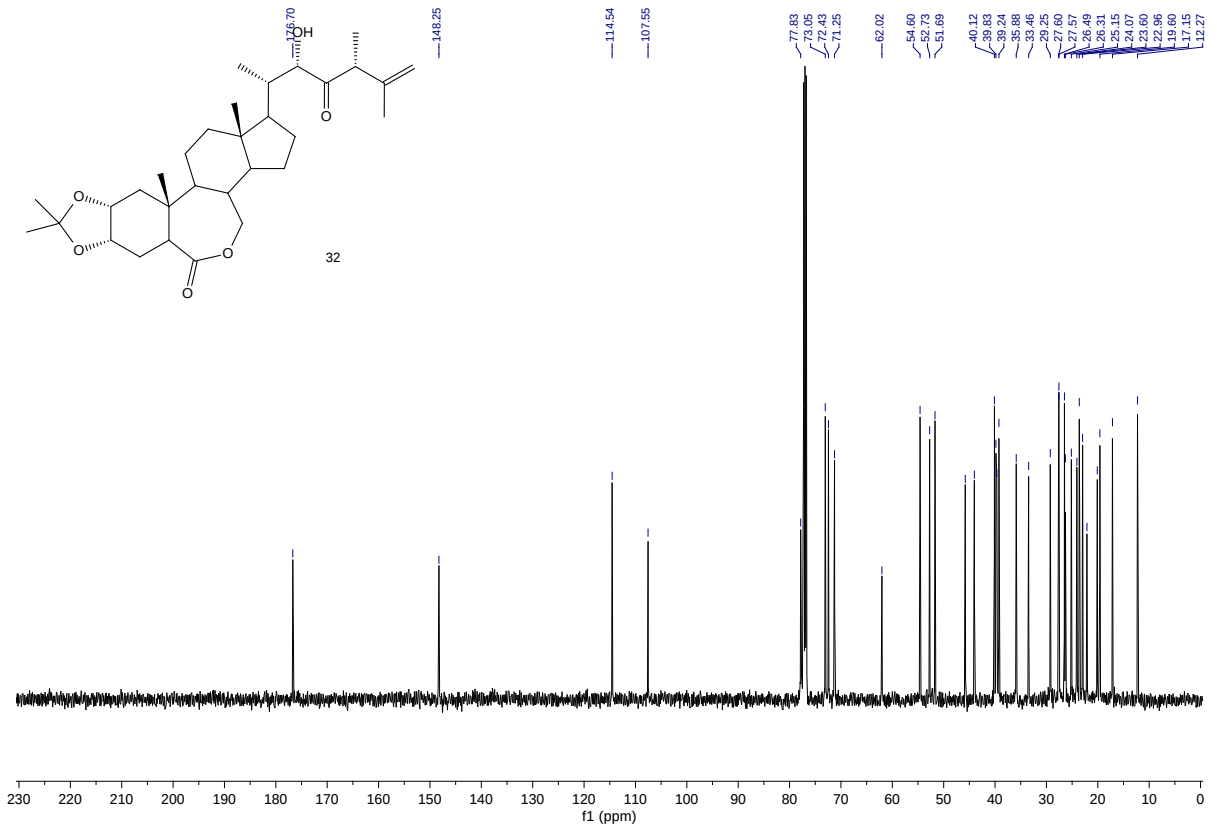

OH
HO
HO
HO
O
O
4
1.00
0.97
1.99
0.98
1.04
2.00
1.00
3.35
28.10
2.96
2.98
3.00
2.91
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

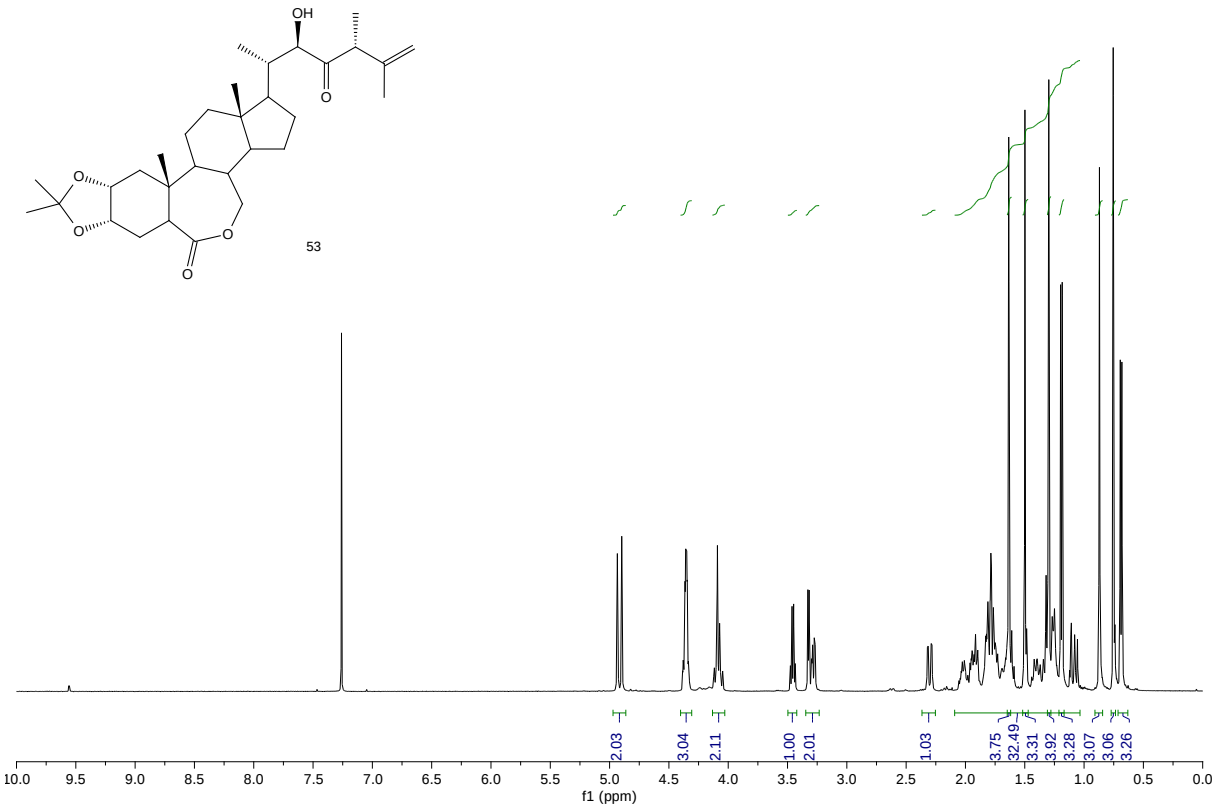

OH
HO
HO
HO
O
O
4
176.20
147.72
111.84
72.85
70.44
68.14
68.07
58.17
52.21
51.26
41.82
40.88
39.61
39.23
37.48
31.04
27.55
24.71
12.13
11.70
11.64
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

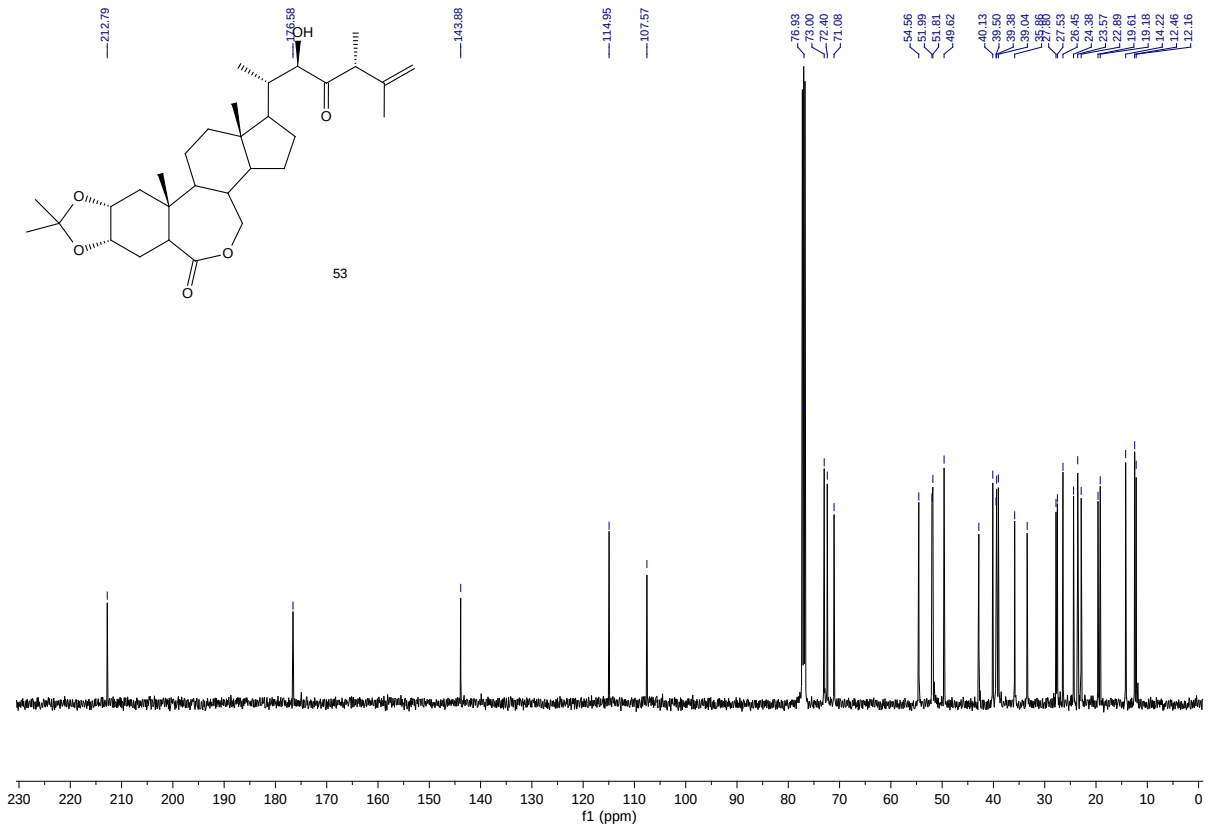

OH
S
S
O
O
O
O
O
31
1.00
0.98
2.05
2.08
1.01
0.99
2.07
2.11
2.09
2.02
20.77
12.09
3.69
3.18
3.28
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

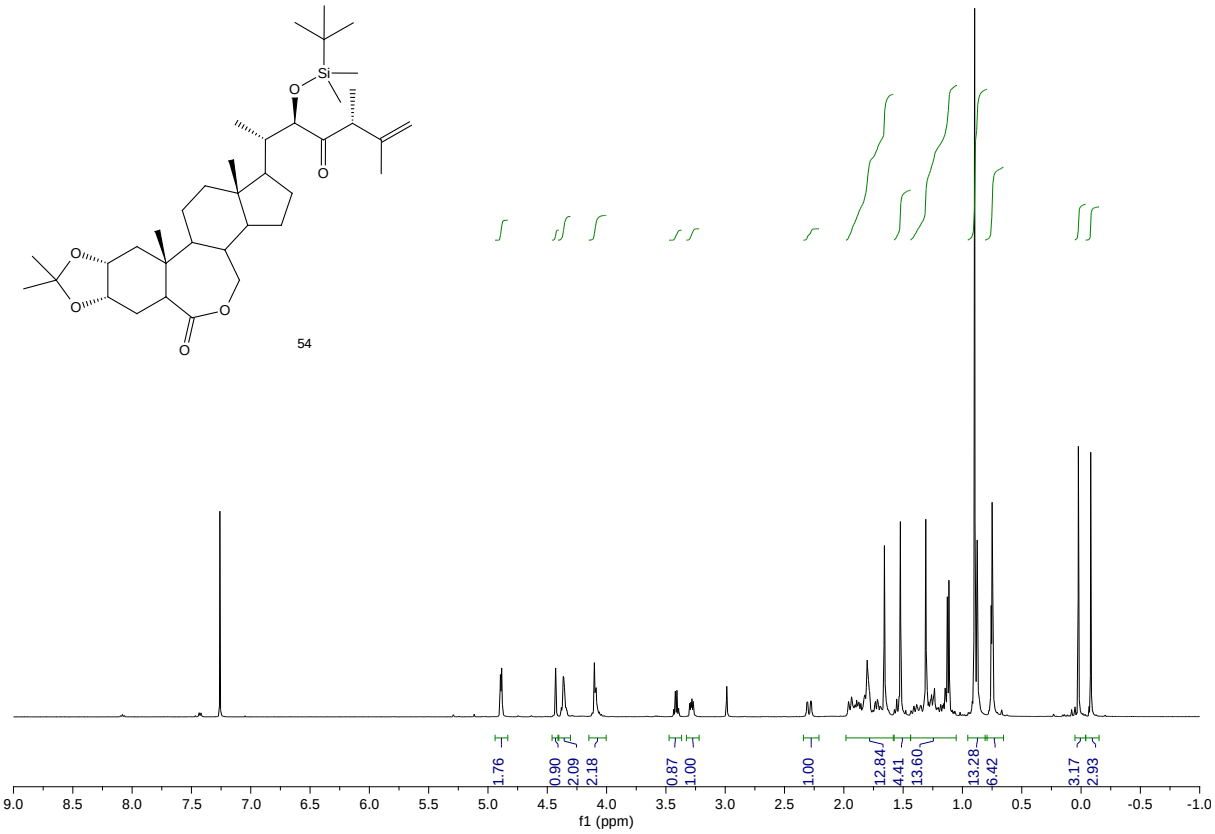

176.62
OH
S
S
O
O
O
O
O
31
114.36
107.57
73.06
72.45
71.18
61.76
55.38
54.60
51.96
43.50
40.19
39.89
39.39
36.25
35.92
33.53
28.12
27.59
27.21
26.50
24.65
24.18
23.63
22.98
19.60
16.75
14.69
11.91
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

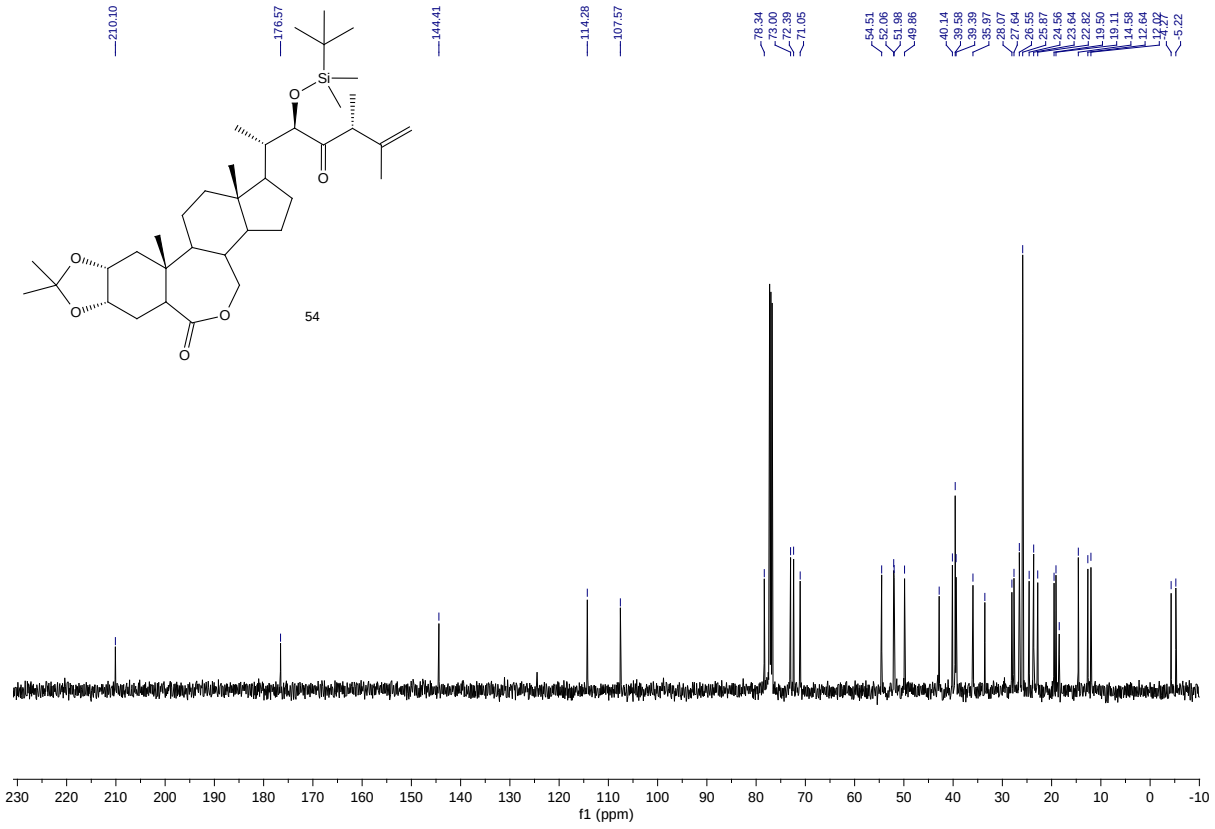

OH
O
O
O
O
O
32
0.98
1.02
2.12
2.15
1.00
1.07
2.05
0.95
2.15
1.08
1.07
4.29
4.31
6.75
2.90
3.34
14.69
1.46
3.49
3.35
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

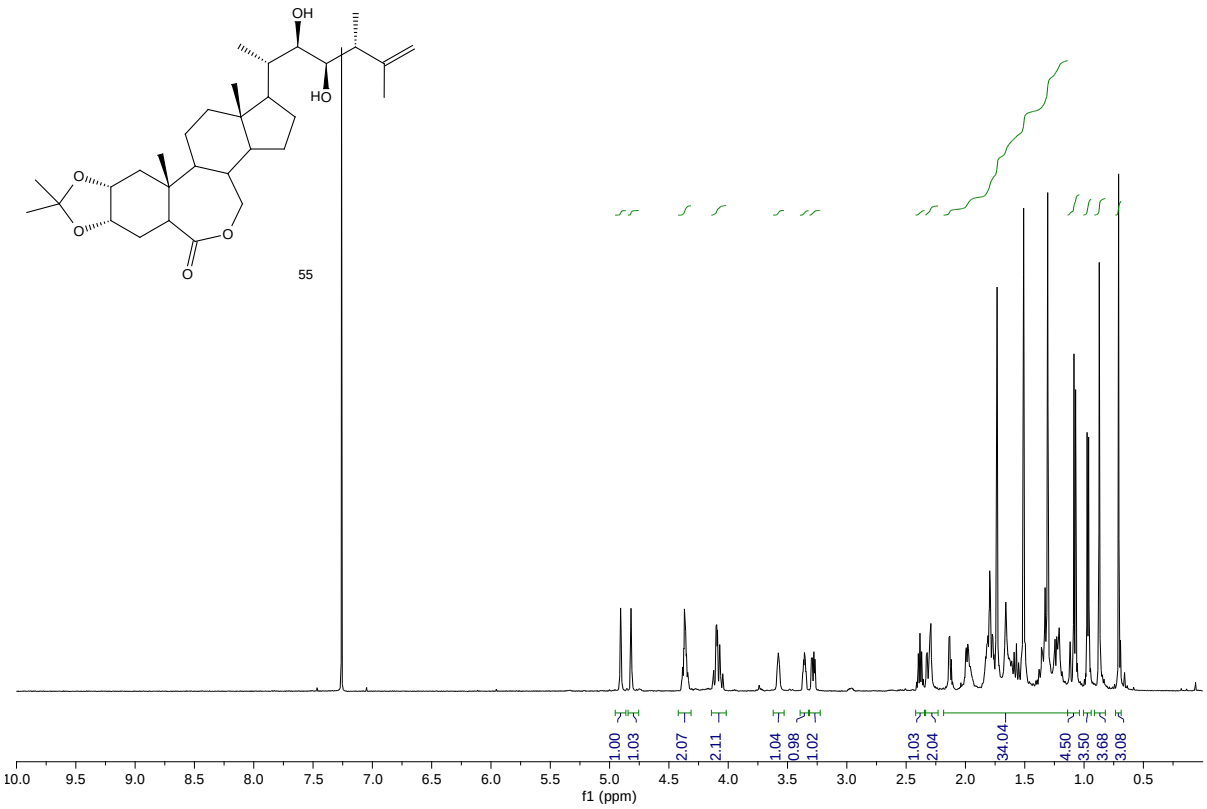

176.70
148.25
114.54
107.55
77.83
73.05
72.43
71.25
62.02
54.60
52.73
51.69
40.12
39.83
39.24
35.88
33.46
29.25
27.60
27.57
26.49
26.31
25.15
24.07
23.60
22.96
19.60
17.15
12.27
OH
O
O
O
O
O
32
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

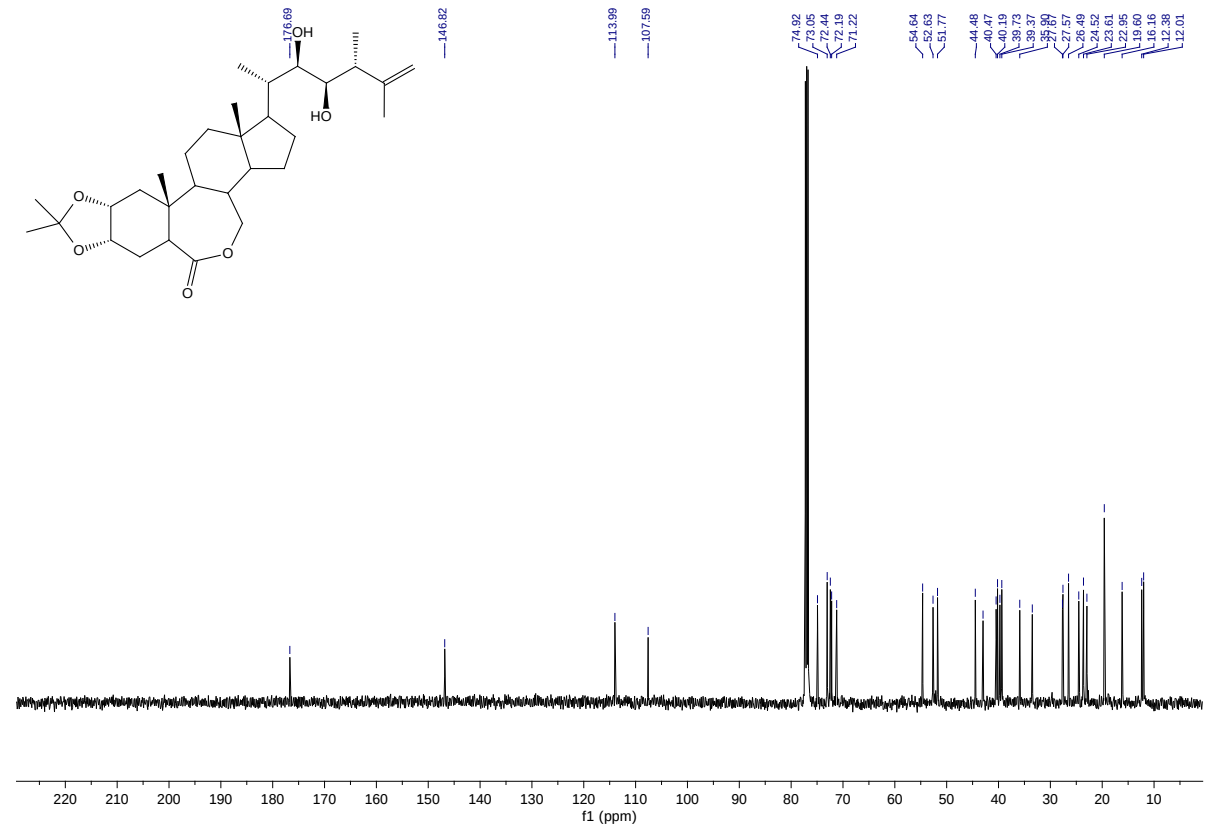

OH
O
O
O
O
O
53
2.03
3.04
2.11
1.00
2.01
1.03
3.75
32.49
3.31
3.92
3.28
3.07
3.06
3.26
f1 (ppm)

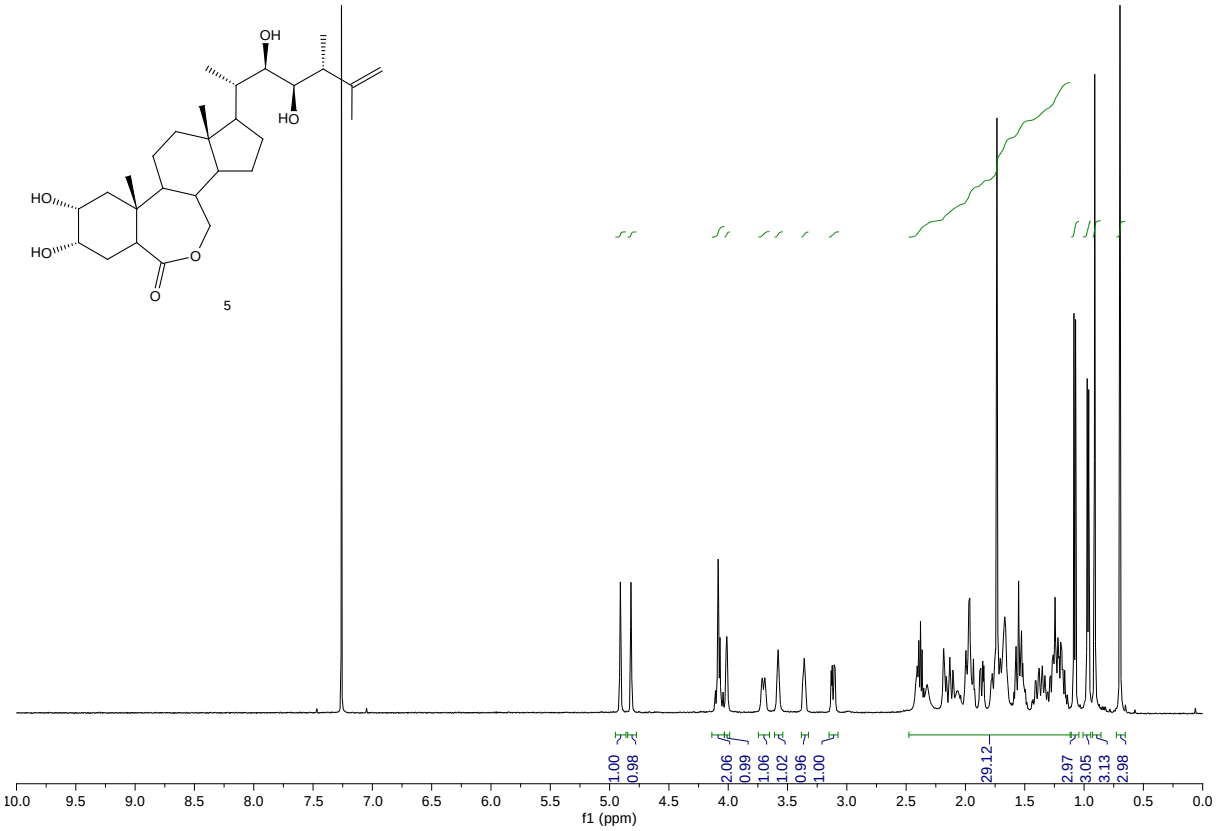

212.79
176.58
143.88
114.95
107.57
76.93
73.00
72.40
71.08
54.56
51.99
51.81
49.62
40.13
39.50
39.38
39.04
27.53
26.45
24.38
23.57
22.89
19.61
19.18
14.22
12.46
12.16
OH
O
O
O
O
O
53
f1 (ppm)

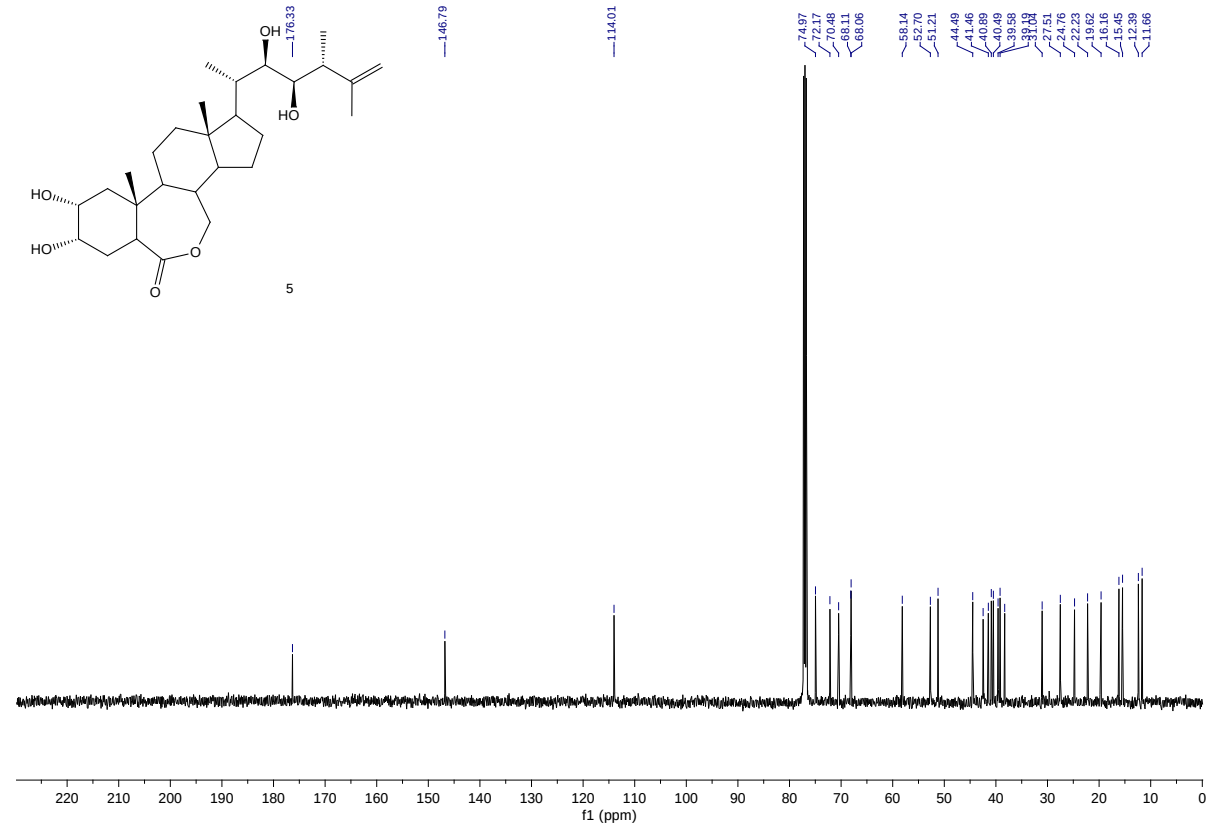

54
1.76
0.90
2.09
2.18
0.87
1.00
1.00
12.84
4.41
13.60
13.28
6.42
3.17
2.93
f1 (ppm)

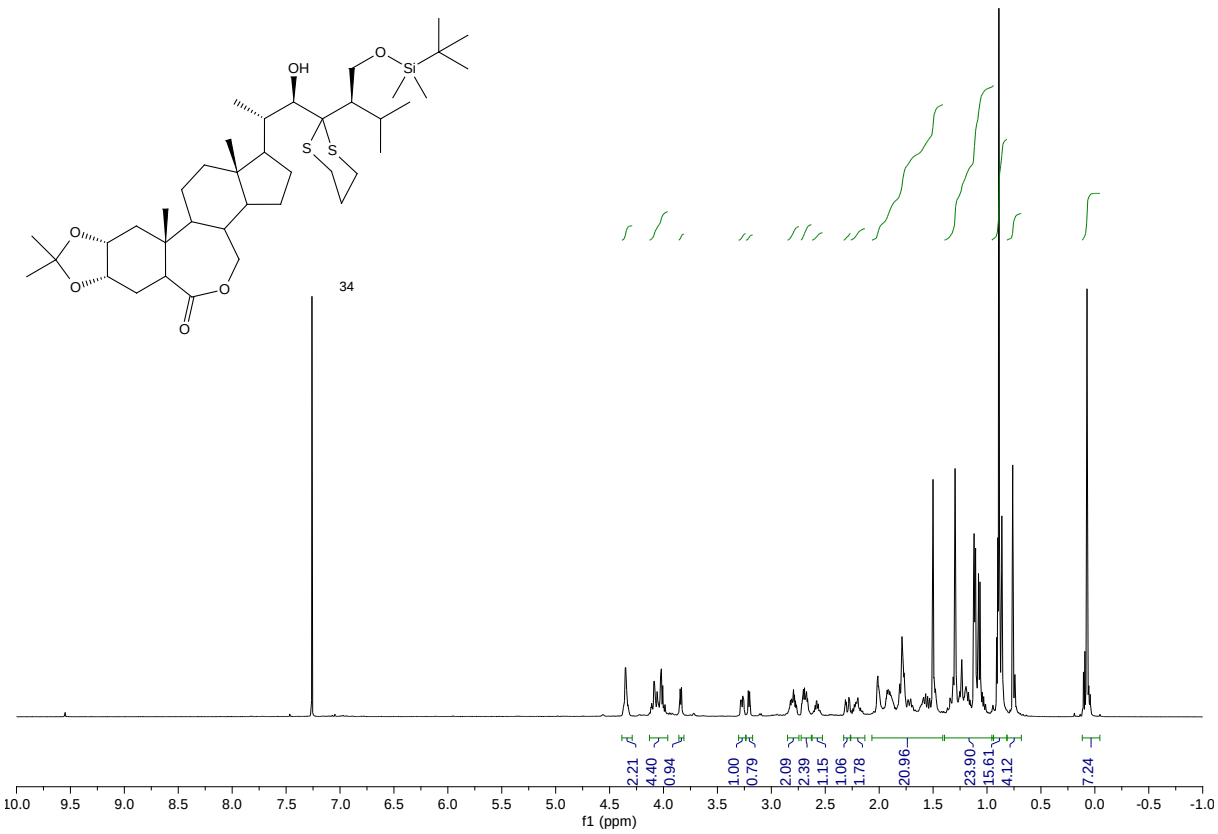

210.10
176.57
144.41
114.28
107.57
78.34
73.00
72.39
71.05
54.51
52.06
51.98
49.86
40.14
39.58
39.39
35.97
28.07
27.64
26.55
25.87
24.56
23.64
22.82
19.50
19.11
14.58
12.64
54
f1 (ppm)

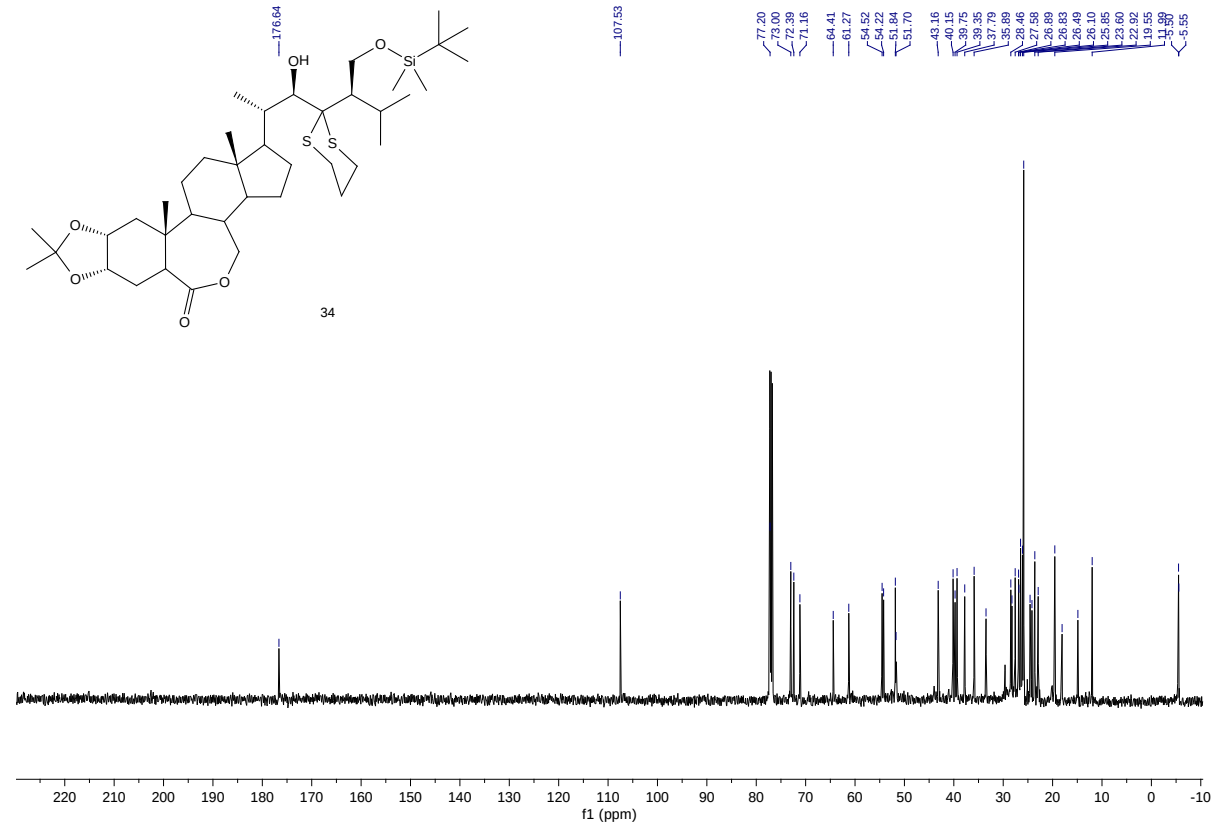

OH
HO
O
O
O
O
55
1.00
1.03
2.07
2.11
1.04
0.98
1.02
1.03
2.04
34.04
4.50
3.50
3.68
3.08
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

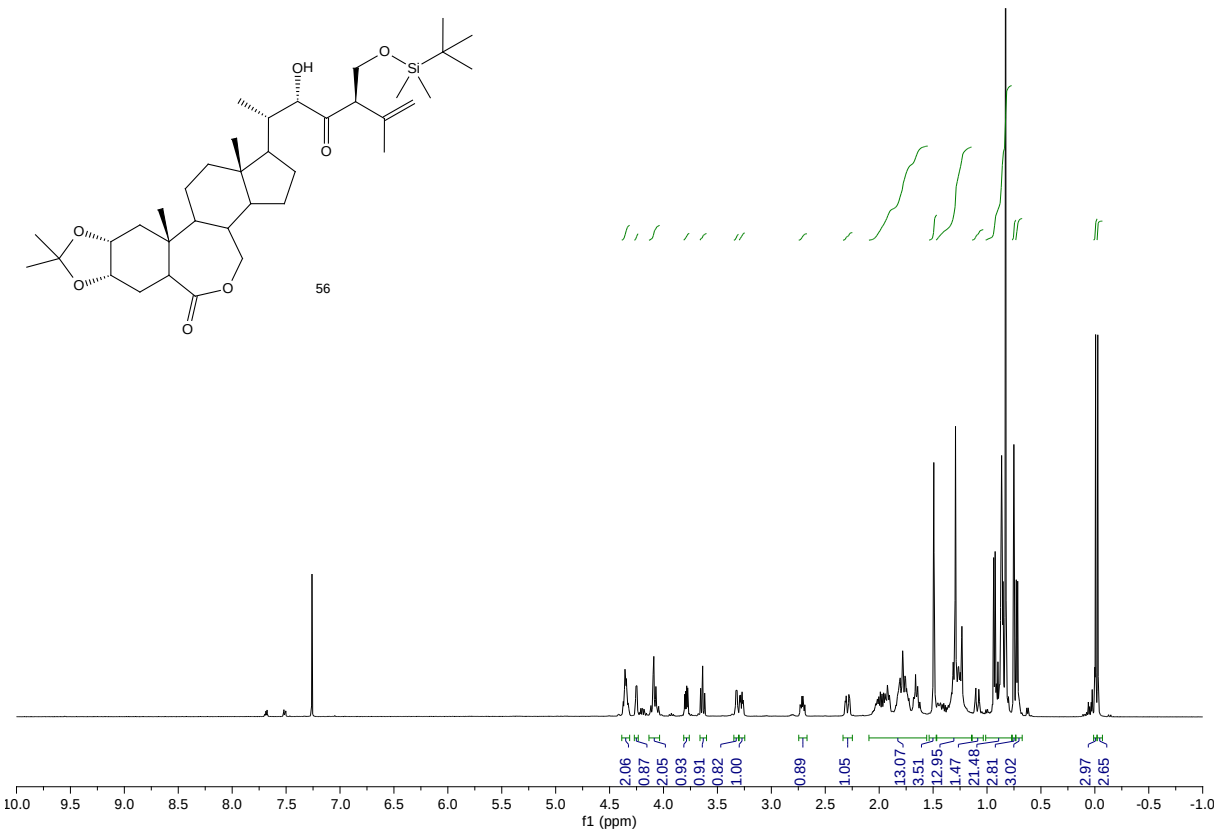

176.69
146.82
113.99
107.59
74.92
73.05
72.44
72.19
71.22
54.64
52.63
51.77
44.48
40.47
40.19
39.73
39.37
27.57
26.49
24.52
23.61
22.95
19.60
16.16
12.38
12.01
OH
HO
O
O
O
O
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

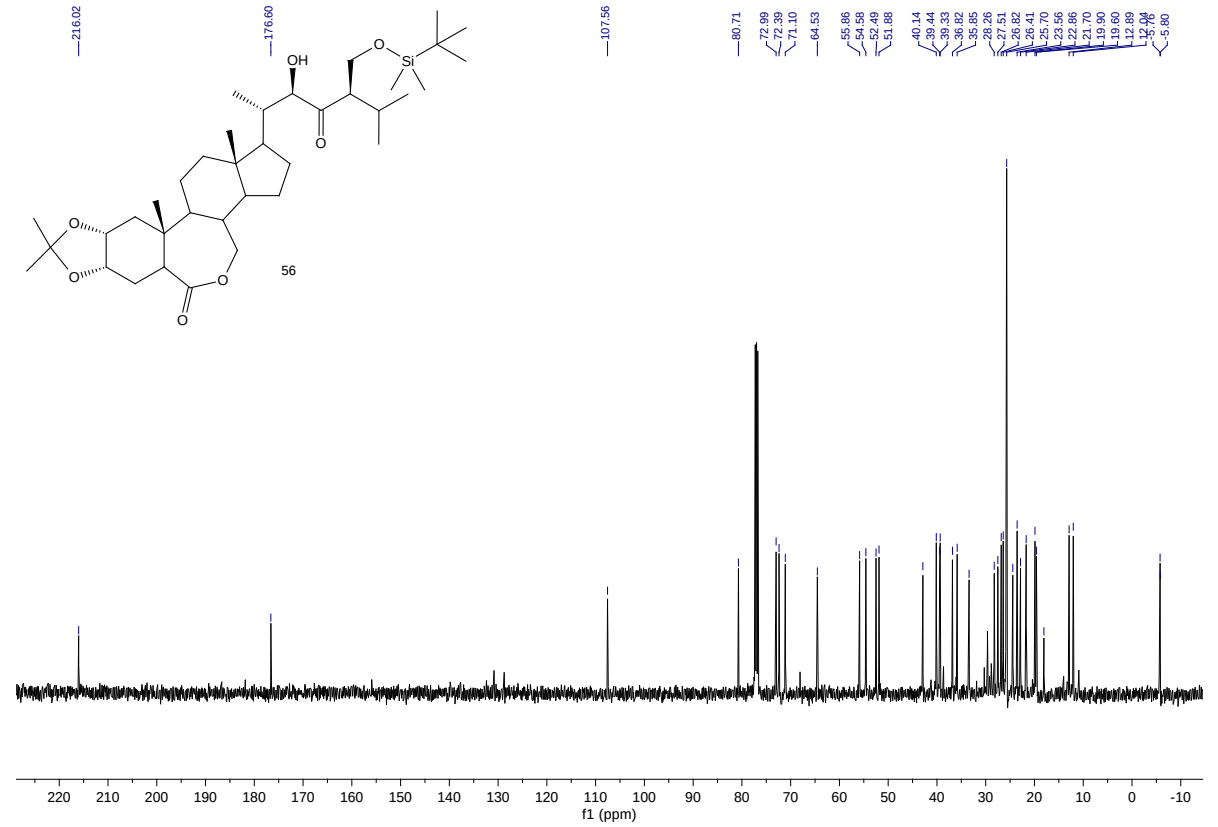

OH
HO
HO
HO
O
O
5
1.00
0.98
2.06
0.99
1.06
1.02
0.96
1.00
29.12
2.97
3.05
3.13
2.98
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

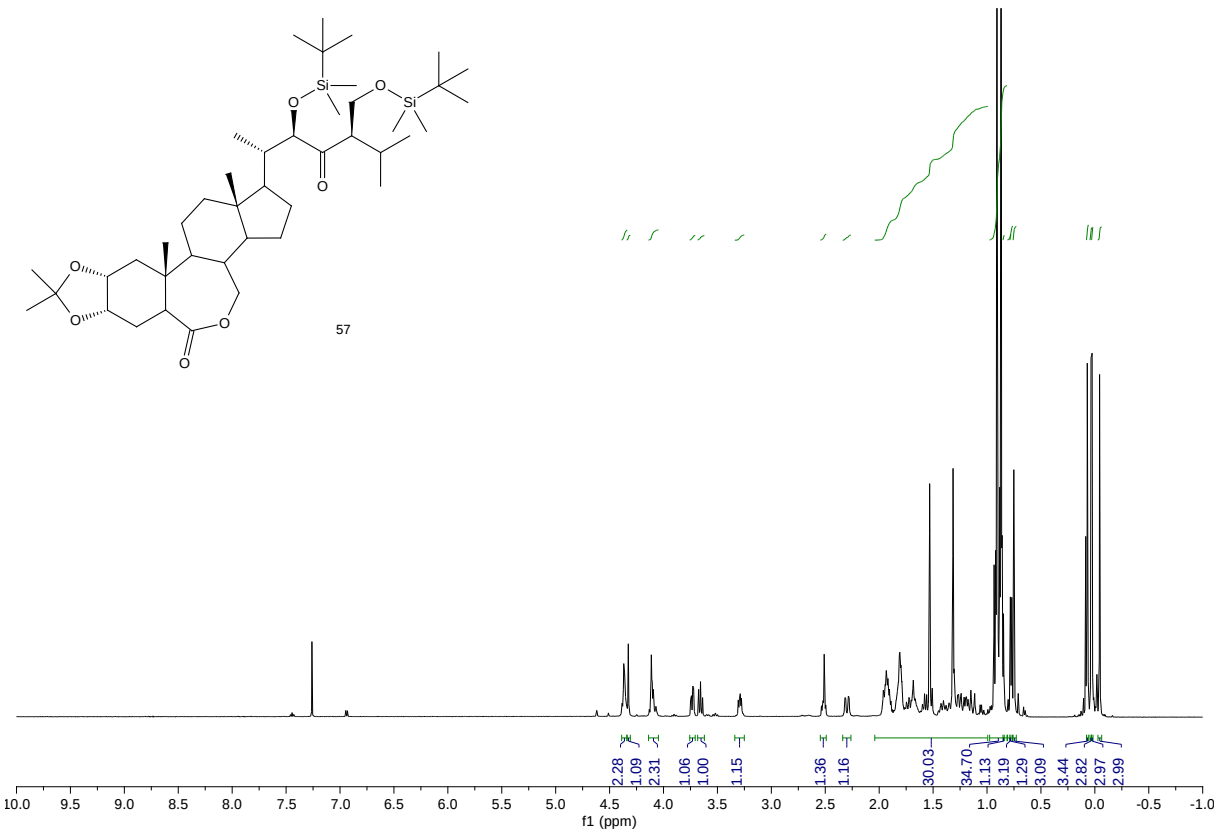

OH
HO
HO
HO
O
O
5
176.33
146.79
114.01
74.97
72.17
70.48
68.11
68.06
58.14
52.70
51.21
44.49
41.46
40.89
40.49
39.58
37.03
27.51
24.76
22.23
19.62
16.16
15.45
12.39
11.66
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

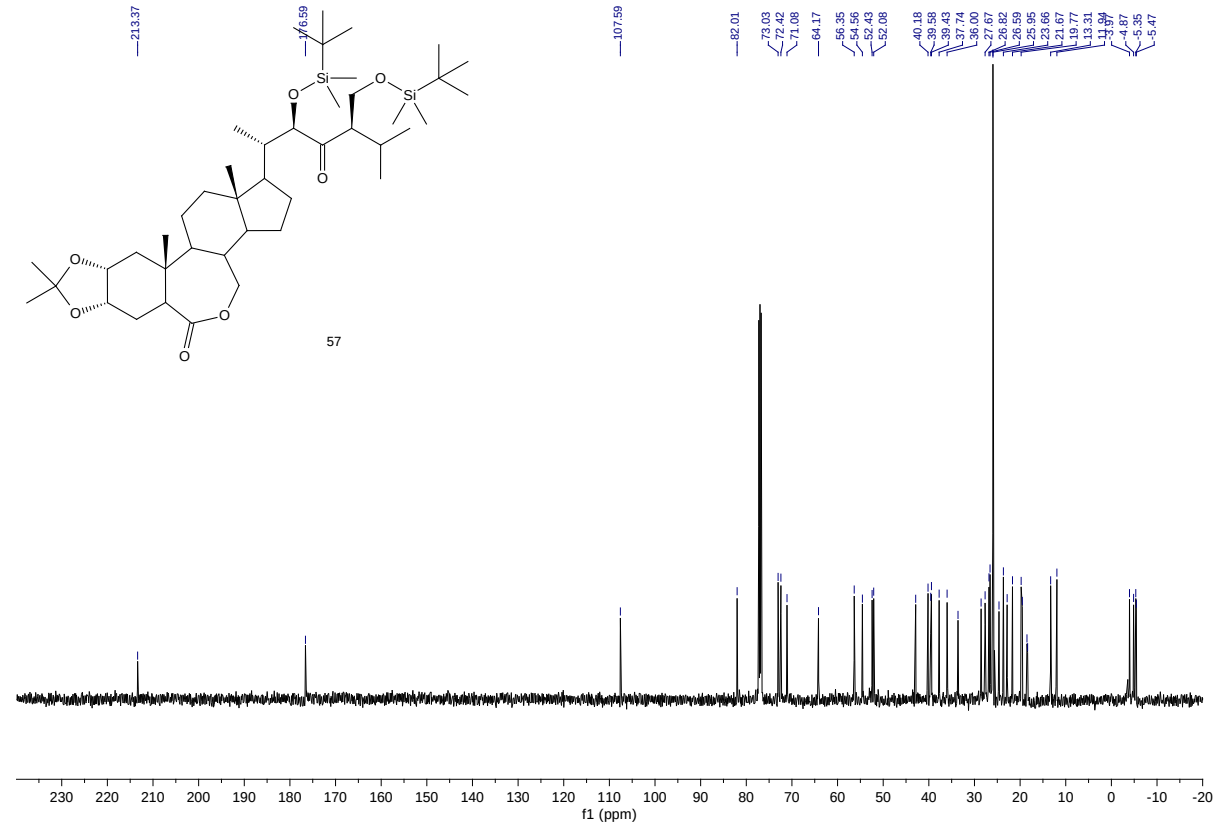

OH
O
Si
S
S
O
O
O
O
34
2.21
4.40
0.94
1.00
0.79
2.09
2.39
1.15
1.06
1.78
20.96
23.90
15.61
4.12
7.24
f1 (ppm)

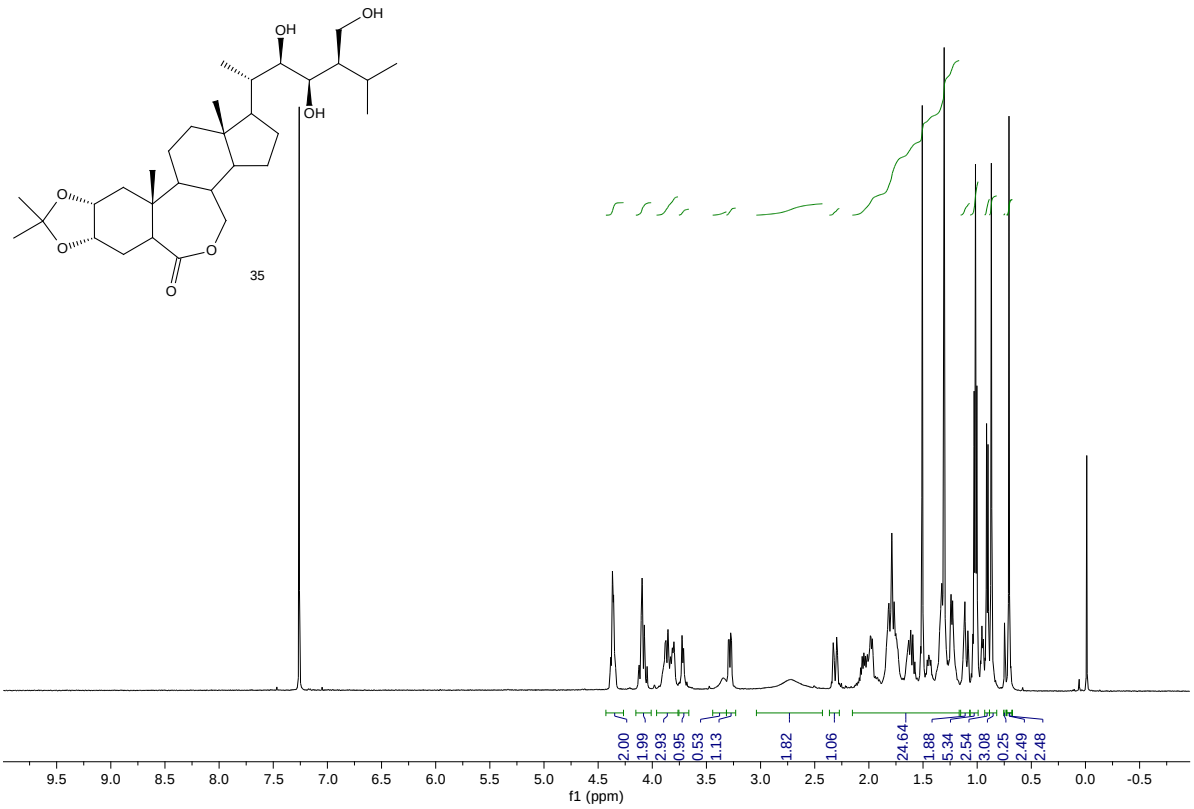

176.64
107.53
77.20
73.00
72.39
71.16
64.41
61.27
54.52
54.22
51.84
51.70
43.16
40.15
39.75
39.35
37.79
35.89
28.46
27.58
26.89
26.83
26.49
26.10
25.85
23.60
22.92
19.55
11.99
5.55
OH
O
Si
S
S
O
O
O
O
34
f1 (ppm)

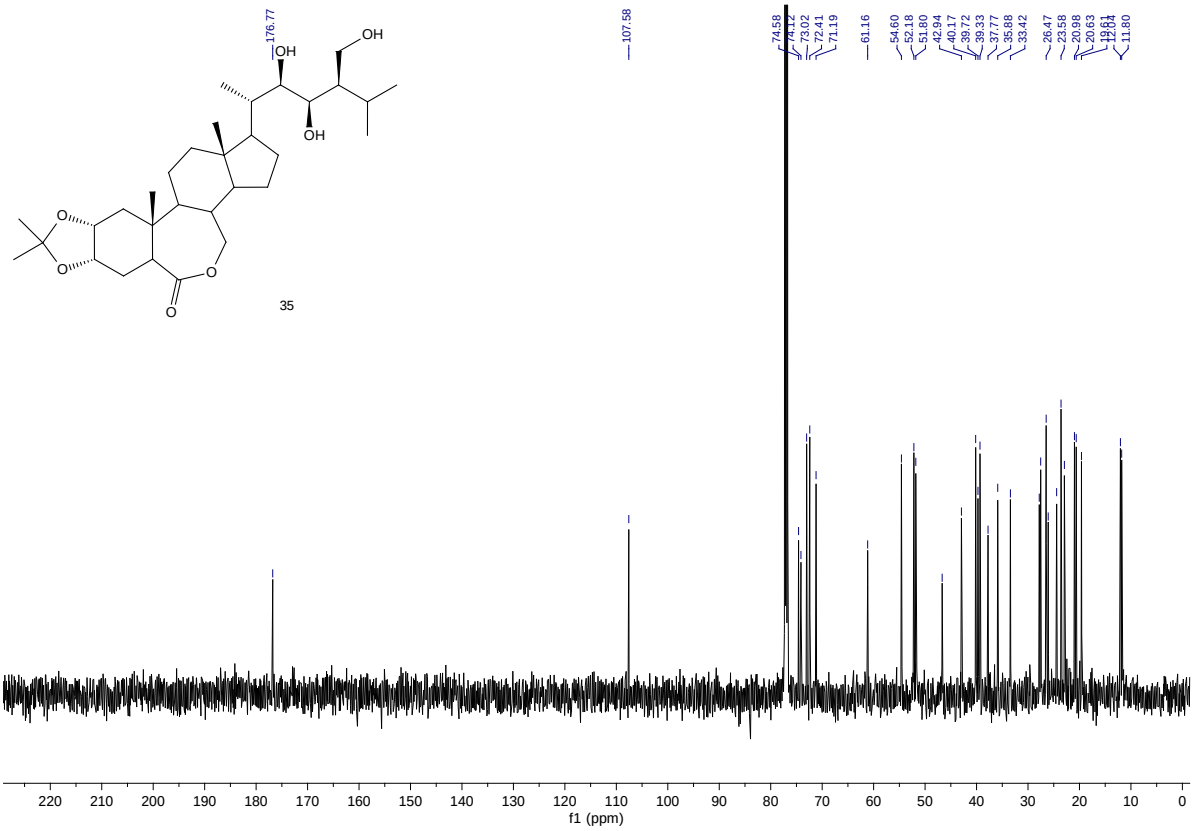

OH
O
Si
O
O
O
O
O
56
2.06
0.87
2.05
0.93
0.91
0.82
1.00
0.89
1.05
13.07
3.51
12.95
1.47
21.48
2.81
3.02
2.97
2.65
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)

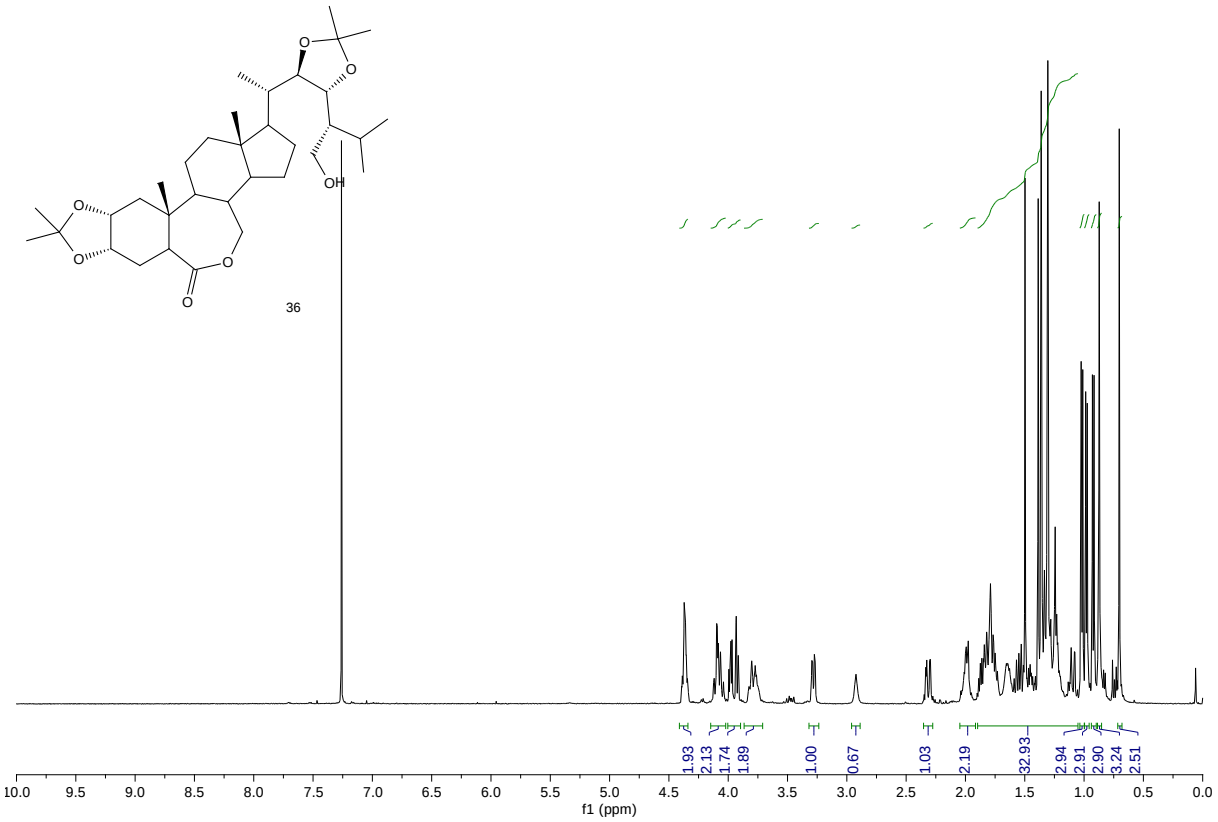

216.02
176.60
107.56
80.71
72.99
72.39
71.10
64.53
55.86
54.58
52.49
51.88
40.14
39.44
39.33
36.82
35.85
28.26
27.51
26.82
26.41
25.70
23.56
22.86
21.70
19.90
19.60
12.89
12.04
5.76
-5.80
OH
O
Si
O
O
O
O
O
56
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

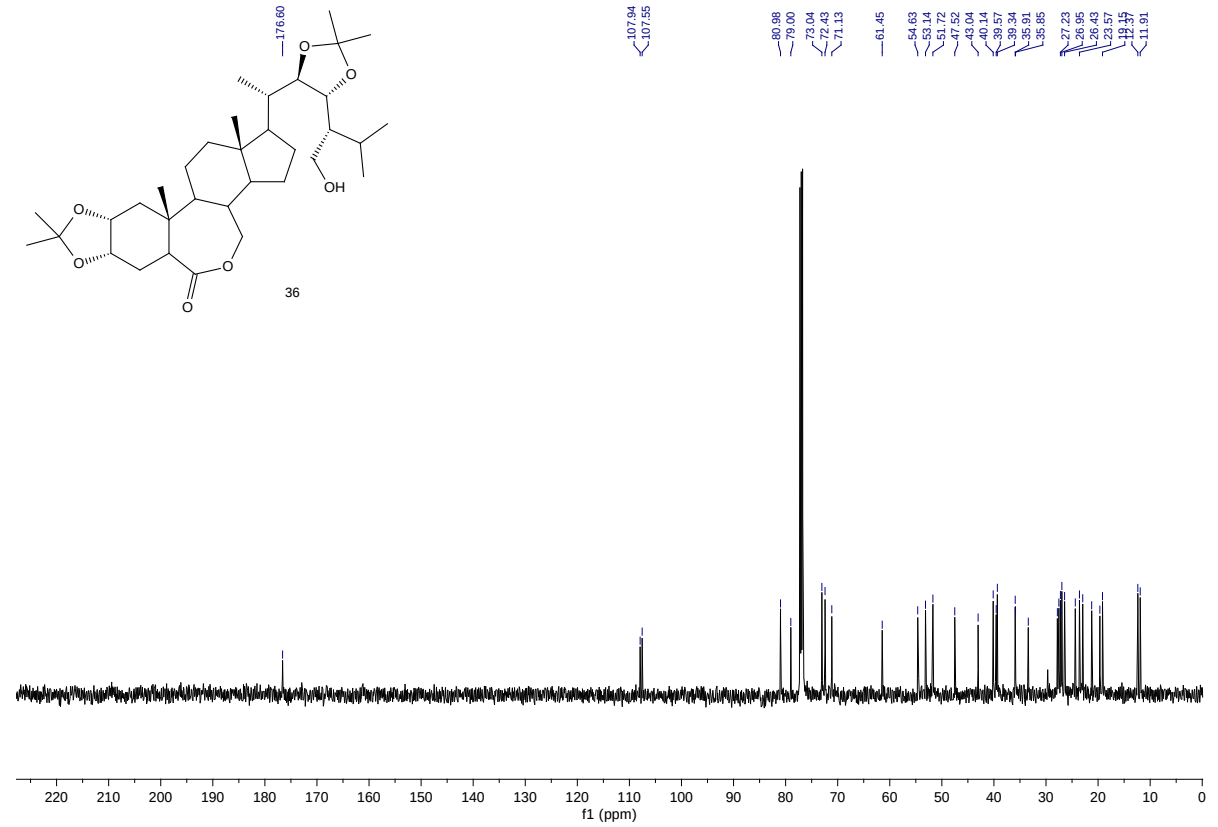

57
2.28
1.09
2.31
1.06
1.00
1.15
1.36
1.16
30.03
34.70
1.13
3.19
1.29
3.09
3.44
2.82
2.97
2.99
f1 (ppm)

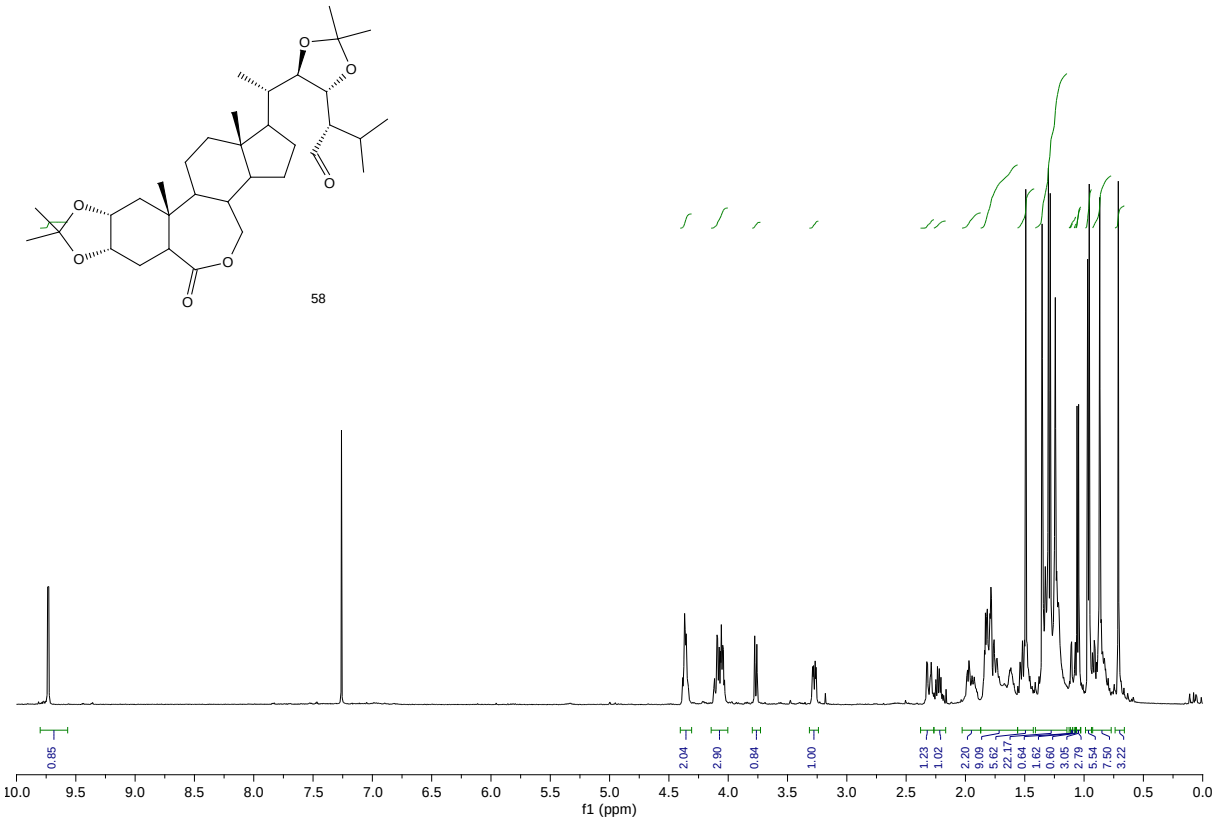

213.37
176.59
107.59
82.01
73.03
72.42
71.08
64.17
56.35
54.56
52.43
52.08
40.18
39.58
39.43
37.74
36.00
27.67
26.82
26.59
25.95
23.66
21.67
19.77
13.31
11.94
3.97
-4.67
-5.35
-5.47
57
f1 (ppm)

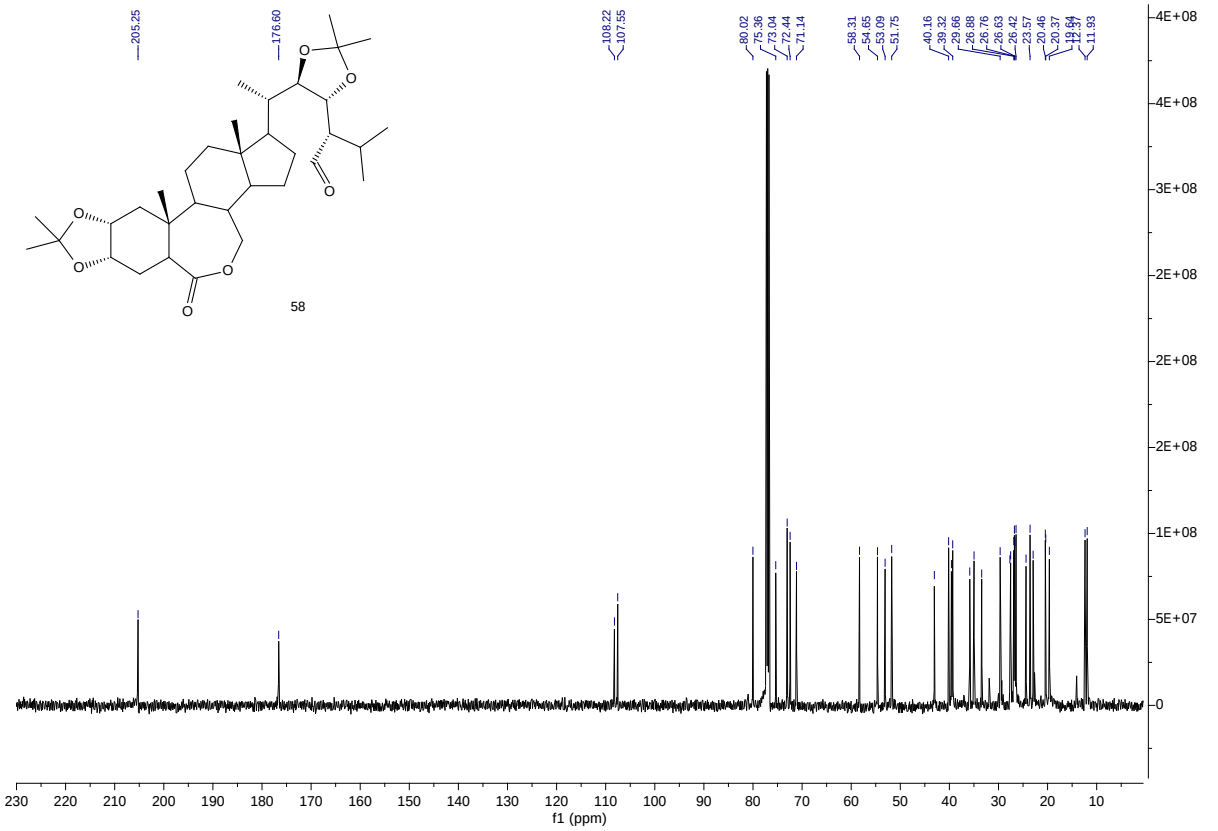

OH
OH
OH
O
O
O
O
35
2.00
1.99
2.93
0.95
0.53
1.13
1.82
1.06
24.64
1.88
5.34
2.54
3.08
0.25
2.49
2.48
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

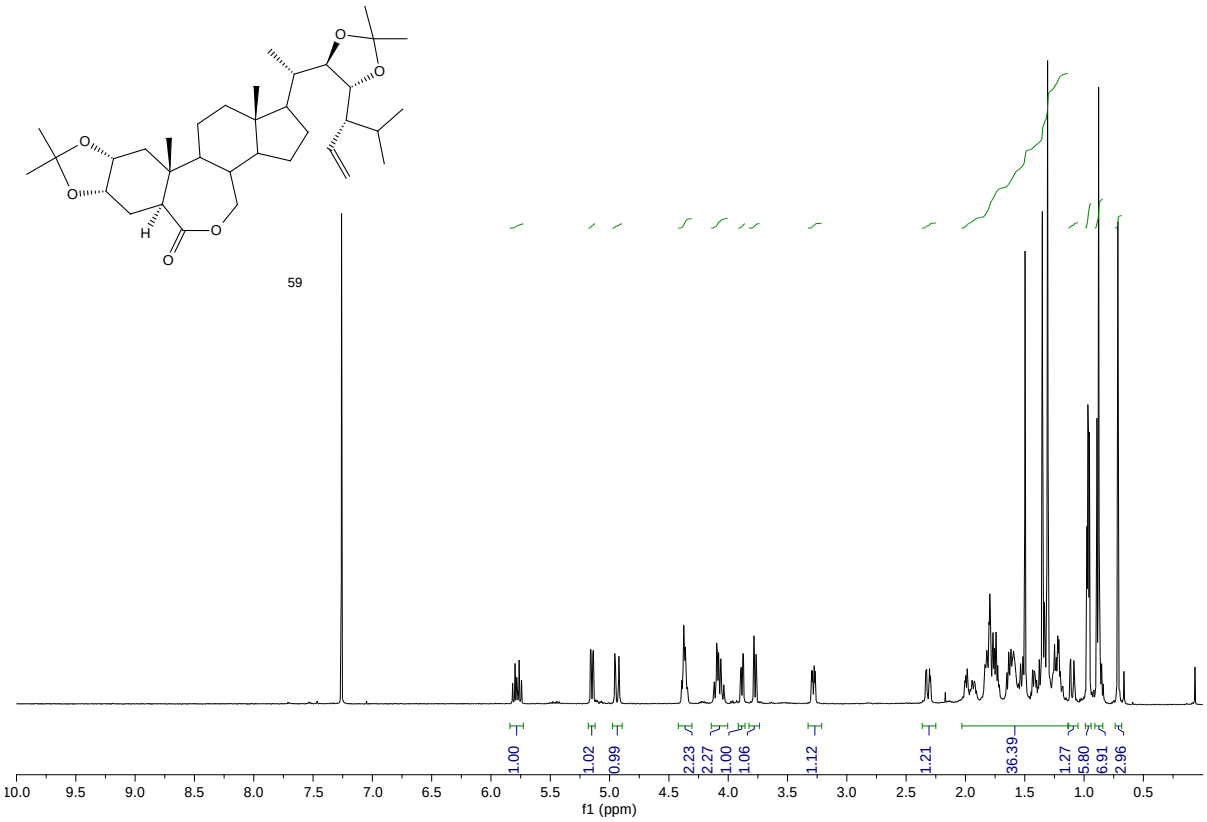

176.77
OH
OH
OH
O
O
O
O
35
107.58
74.58
74.12
73.02
72.41
71.19
61.16
54.60
52.18
51.80
42.94
40.17
39.72
39.33
37.77
35.88
33.42
26.47
23.58
20.98
20.63
19.61
12.04
11.80
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

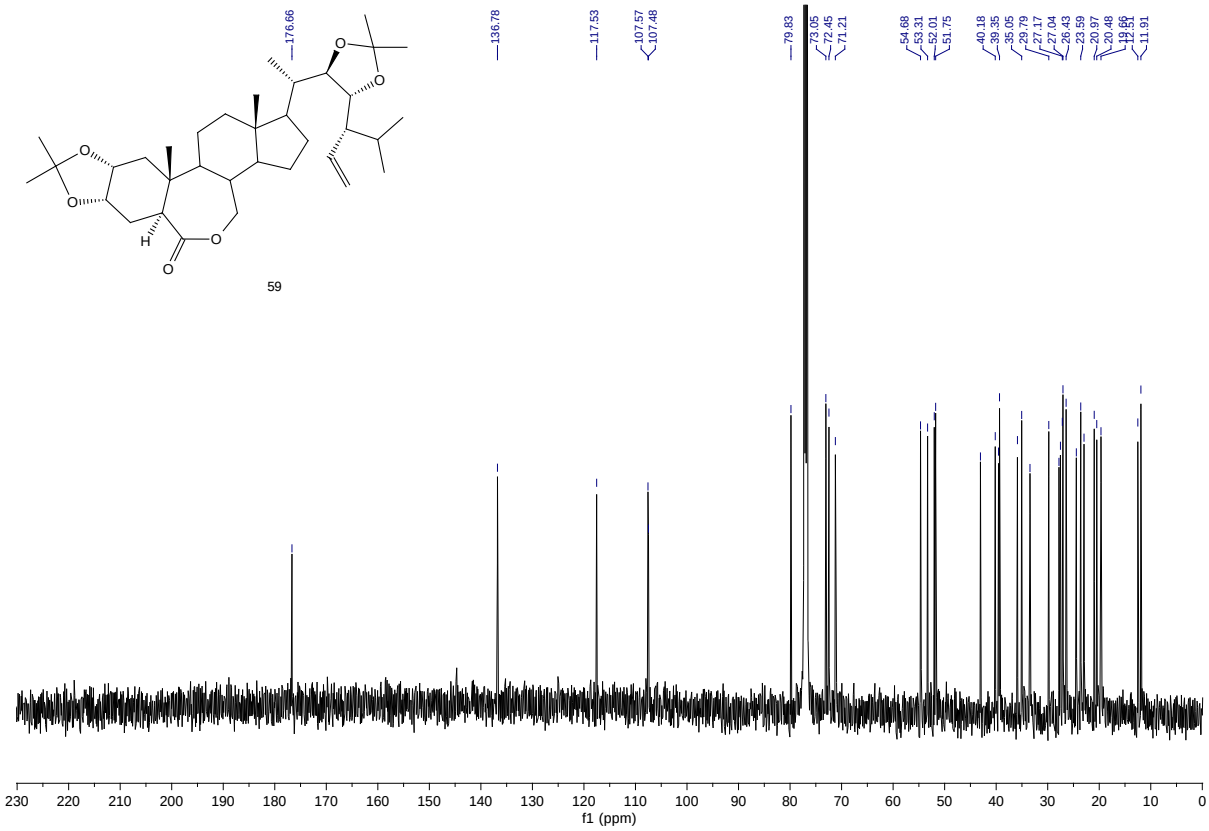

OH
O
O
O
O
O
O
36
1.93
2.13
1.74
1.89
1.00
0.67
1.03
2.19
32.93
2.94
2.91
2.90
3.24
2.51
f1 (ppm)

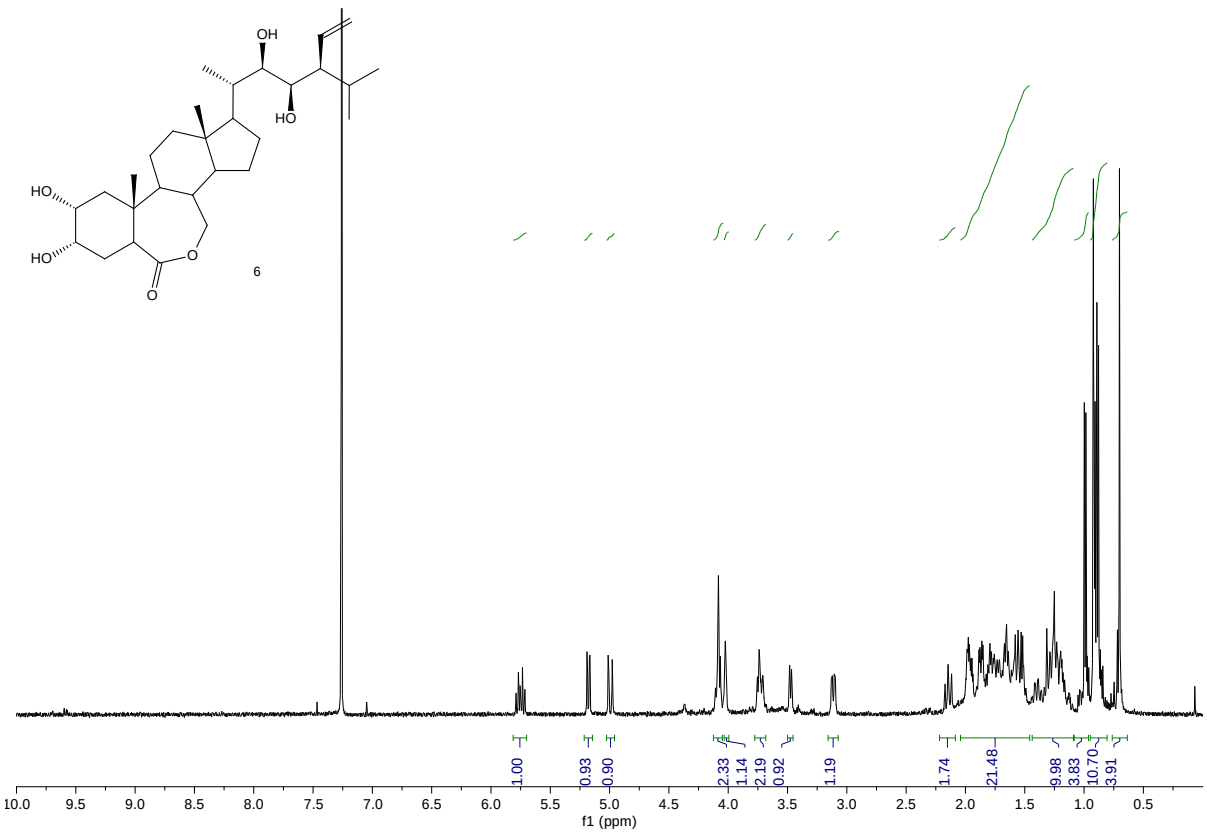

176.60
107.94
107.55
80.98
79.00
73.04
72.43
71.13
61.45
54.63
53.14
51.72
47.52
43.04
40.14
39.57
39.34
35.91
35.85
27.23
26.95
26.43
23.57
12.15
12.07
11.91
OH
O
O
O
O
O
O
36
f1 (ppm)

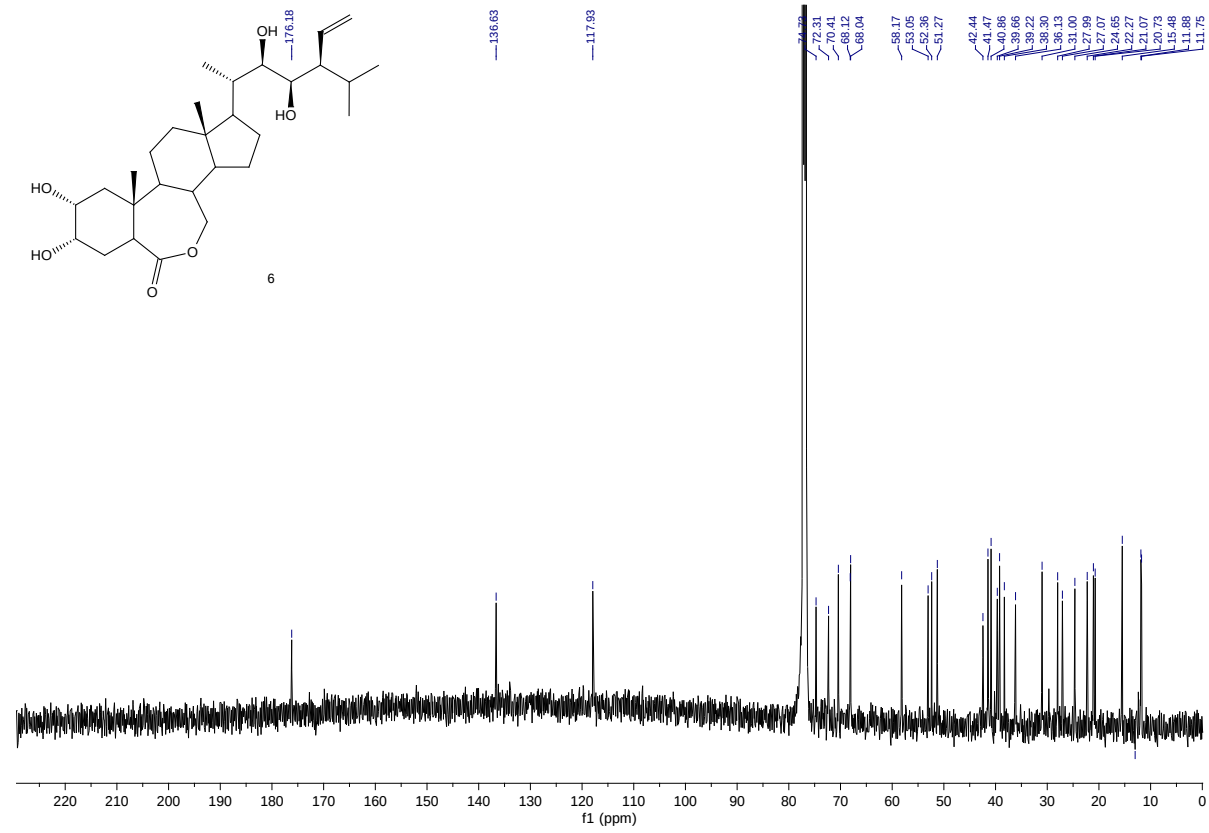

58
0.85
2.04
2.90
0.84
1.00
1.23
1.02
2.20
9.09
5.62
22.17
0.64
1.62
0.60
3.05
2.79
5.54
7.50
3.22
f1 (ppm)


205.25
176.60
108.22
107.55
80.02
75.36
73.04
72.44
71.14
58.31
54.65
53.09
51.75
40.16
39.32
29.66
26.88
26.76
26.63
26.42
23.57
20.46
20.37
12.54
12.37
11.93
58
f1 (ppm)


59
1.00
1.02
0.99
2.23
2.27
1.00
1.06
1.12
1.21
36.39
1.27
5.80
6.91
2.96
f1 (ppm)


59
176.66
136.78
117.53
107.57
107.48
79.83
73.05
72.45
71.21
54.68
53.31
52.01
51.75
40.18
39.35
35.05
29.79
29.17
27.04
26.43
23.59
20.97
20.48
19.66
19.50
11.91
f1 (ppm)


OH
HO
HO
HO
O
O
6
1.00
0.93
0.90
2.33
1.14
2.19
0.92
1.19
1.74
21.48
9.98
3.83
10.70
3.91
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


OH
HO
HO
HO
O
O
6
176.18
136.63
117.93
74.22
72.31
70.41
68.12
68.04
58.17
53.05
52.36
51.27
42.44
41.47
40.86
39.66
39.22
38.30
36.13
31.00
27.99
27.07
24.65
22.27
21.07
20.73
15.48
11.88
11.75
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)