# Nazarov Cyclization Initiated by Peracid Oxidation. The Total Synthesis of (±)-Rocaglamide

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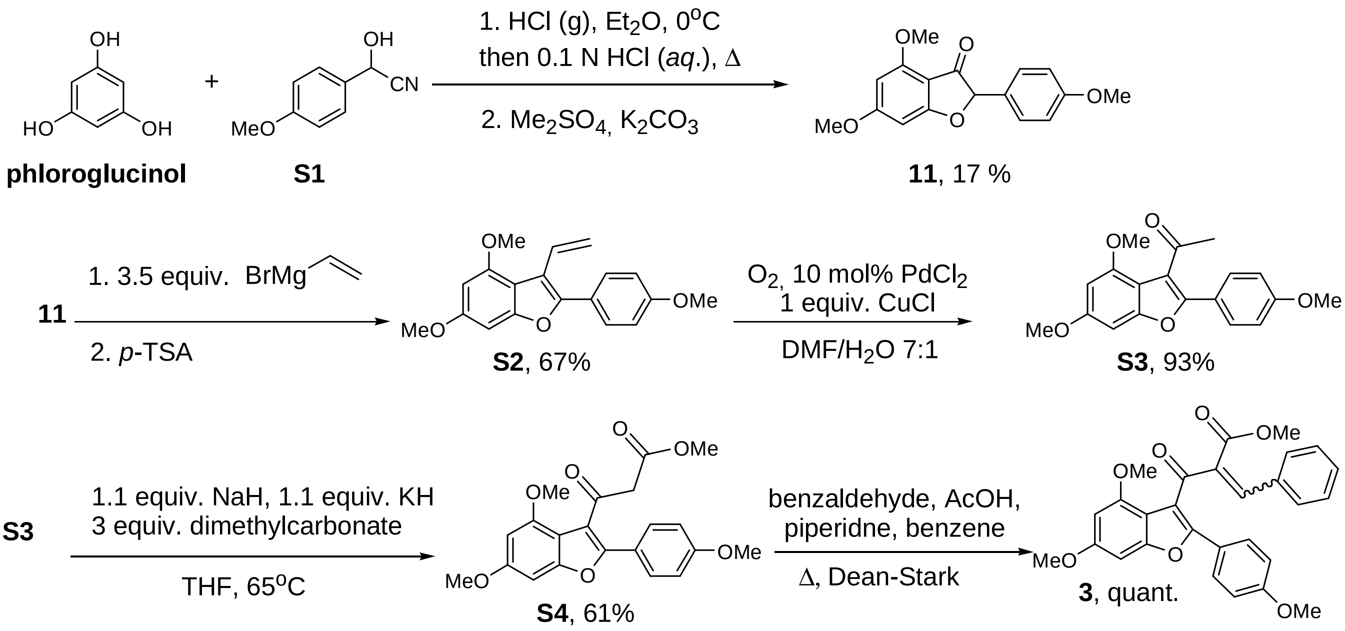
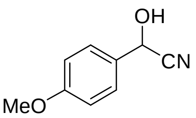
## 1. General Informations

Unless otherwise noted, all reactions were carried out under an atmosphere of argon in oven-dried glassware with magnetic stirring. TCL (Thin-Layer-Chromatography) visualization was done with UV light and/or potassium permanganate, *p*-anisaldehyde or ceric ammonium molybdate stains followed by heating. Column chromatography was performed on EM Science silicagel 60 (230-400 mesh). Chloroform-*d* and Methanol-$d_4$ were purchased from Cambridge Isotope. Diethyl ether ($Et_2O$), dichloromethane, tetrahydrofuran (THF) and toluene were purchased from Fisher and dispensed using the Glass Contour solvent purification system.

$^1$H NMR, $^{13}$C NMR and $^{19}$F NMR were collected on a 400 MHz or a 500 MHz Avance spectrometer at ambient temperature. Chemical shift $\delta$ was reported in unit of parts per million (ppm) downfield from tetramethylsilane; data are reported as s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, b = broad and dd = doublet of doublets, with coupling constants given in Hz. High resolution mass spectra were done on a ThermoFinnigan MAT 95XL at the Chemistry Instrumentation Center of the University of Buffalo. Melting points were measured on a Thomas Hoover capillary melting point apparatus and were uncorrected. Infrared (IR) spectra were recorded on a 8400S Shimadzu FTIR spectrometer.

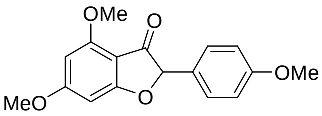
## 2.Synthesis of substrate 3





2-Hydroxy-2-(4-methoxyphenyl)acetonitrile (**S1**)

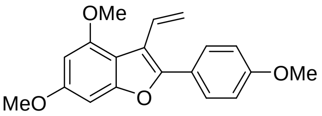
Potassium cyanide (57.4 g, 881 mmol) was added to a stirring mixture of distilled water (200 mL) and EtOAc (230 mL). Once dissolved, sodium bisulfite ($NaHSO_3$, 91.7 g, 881 mmol) was added and stirring continued. *Note: The order of addition is important, addition of KCN to a solution of* $NaHSO_3$ *results in a violent reaction.* To this mixture, freshly distilled *p*-anisaldehyde was added (17.9 mL, 147 mmol), the flask was then sealed with an outlet and stirred vigorously for 20h. The reaction was poured into 300 mL distilled water, washed with distilled water (3 x 200 mL), then brine. The organic layer was dried over $MgSO_4$ and concentrated. The residue was dissolved in 150 mL of toluene and ~30 mL hexane were added with swirling. The solution was allowed to stand, whereupon crystallization occured. The product was filtered, washed with hexane and dried *in vacuo* to give the desired cyanhydrin **S1** (23.7g, 99%) $^1$H NMR (400 MHz, $CDCl_3$) δ 2.74 (d, *J* = 7.0 Hz, 1H), 3.84 (s, 3H), 4.48 (d, *J* = 7.0Hz, 1H), 6.96 (d, *J* = 9.0 Hz, 2H), 7.46 (d, *J* = 9.0 Hz, 2H).



4,6-Dimethoxy-2-(4-methoxyphenyl)benzofuran-3(2H)-one (**11**)

To a 3-necked flask containing dry $Et_2O$ (440 mL) the previous cyanohydrin (26.6 g, 163 mmol) and phloroglucinol (20.6 g, 163 mmol, dried *in vacuo* 1h @ 35 in. Hg, 100°C) were added. The flask was cooled to 0°C with mechanical stirring. Dry HCl (g) was bubbled through slowly for 1h. After ~30 min a precipitate developed which could range in appearance from orange and sticky to off-white and free flowing. Once a full hour of gas flow had elapsed, the gas was stopped, the precipitate was scraped from the walls of the reaction vessel and the flask refrigerated for 3 days. Once removed from the cold, the supernatant was vacuum suctioned from the flask, and replaced with fresh $Et_2O$. The precipitate was triturated in this same manner several times with $Et_2O$ (3 x 300 mL). To remove the residual ether that could not be removed by vacuum suctioning, the flask was connected to a vacuum pump directly and warmed until the precipitate was freely flowing. At this point the trituration with ether was repeated followed by and additional evacuation on a pump. The resulting powder was then dissolved in 0.1 M HCl (*aq.*) (356 mL) and heated to 112°C with a reflux condenser in place. The solution was refluxed for ~3 h, at which time a precipitate formed. The reaction was cooled, the precipitate was filtered, washed with distilled water and dried *in vacuo* overnight to yield the di-phenolic benzofuranone (11.25 g, 25%) $^1H$ NMR (500 MHz, $CD_3OD$) $\delta$. 3.79 (s, 3H), 5.45 (s, 1H), 5.94 (d, $J$ = 2.0 Hz, 1H), 6.03 (d, $J$ = 2.0 Hz, 1H), 6.93 (d, $J$ = 9.0 Hz, 2H), 7.23 (d, $J$ = 9.0 Hz, 2H). Once dry, the product of the above reaction was dissolved in degassed acetone (300 mL, degassed by five vacuum/argon cycles under stirring). This solution was cannulated to a suspension of dimethyl sulfate (23.5 mL, 248 mmol) and potassium carbonate (34.3 g, 248 mmol) in 150 mL of degassed acetone and the mixture was refluxed under argon for 30 min. After this time, methanol (200 mL) was added and the mixture was filtered and concentrated. The resulting solid was filtered, washed with 100 mL of methanol and dried *in vacuo* overnight to give **11** (8.60 g, 69%) as a clear brown powder.

$^1H$ NMR (500 MHz, $CDCl_3$) $\delta$ 3.79 (s, 3H), 3.89 (s, 3H), 3.90 (s, 3H), 5.43 (s, 1H), 6.04 (d, $J$ = 2.0 Hz, 1H), 6.22 (d, $J$ = 2.0 Hz, 1H), 6.89 (d, $J$ = 9.0 Hz, 2H), 7.31 (d, $J$ = 9.0 Hz, 2H).

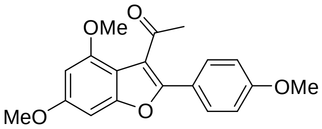


4,6-Dimethoxy-2-(4-methoxyphenyl)-3-vinylbenzofuran (**S2**)

To a stirring solution of benzofuranone **11** (10.34 g, 34.4 mmol) in dry THF (300 mL) under argon at room temperature, vinyl magnesium bromide (100 mL, 1M in THF, 100 mmol) was added rapidly *via* cannula. The reaction was stirred ~15 min., until no starting material remained as judged by TLC. The reaction was quenched with a saturated (satd.) aqueous (aq.) solution of $NH_4Cl$ and made slightly acidic by the addition of 1N HCl (*aq.*). The mixture was poured into distilled water /EtOAc (100 mL/250 mL) and extracted. The aqueous phase was extracted with EtOAc (100 mL) and the combined organic extracts were washed successively with distilled water and brine. The organic layer was dried over $MgSO_4$, filtered and concentrated. The crude material was re-dissolved in toluene (200 mL) and *p*-TSA (5 mg) was added. The reaction was stirred briefly (no more than 7 min.), until most material was converted to the least polar product by TLC ($R_f$ ~0.8, 80:20 hexane/EtOAc, blue under UV). The reaction was filtered over a silica plug (EtOAc) and concentrated. The resulting residue was submitted to flash column chromatography (75:25 hexane/EtOAc) to give the desired vinylbenzofurane **S2** (7.11 g, 67%) as a white solid.

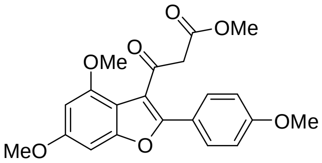
*Pre-stirring the ketone at rt for 2 h with 1.5 equivalents of anhydrous $CeCl_3$, allowed to decrease the amount of Grignard reagent to 1.5 equivalents, but did not increase the yield of the reaction.*

IR (neat) $cm^{-1}$ 2997, 2953, 2938, 2905, 2835, 1618, 1591, 1501, 1250, 1148, 1113, 1103 $^1H$ NMR (500 MHz, $CDCl_3$) δ 3.86 (s, 6H), 3.91 (s, 3H), 5.40 (dd, $J$ = 11.5 Hz, 2.0 Hz, 1H), 5.99 (dd, $J$ = 17.5 Hz, 2.0 Hz, 1H), 6.35 (d, $J$ = 2.0Hz, 1H), 6.65 (d, $J$ = 2.0 Hz, 1H), 6.97 (m, 3H), 7.70 (d, $J$ = 8.5 Hz, 2H) $^{13}C$ NMR (125 MHz, $CDCl_3$) δ 55.3, 55.4, 55.7, 88.0, 94.5, 111.6, 114.0, 114.3, 118.3, 123.9, 127.7, 129.2, 150.7, 154.6, 156.1, 158.9, 159.5 HRMS: (M+) calculated for $C_{19}H_{18}O_4$: 310.1200, observed 310.1196.



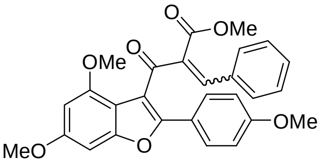
1-(4,6-Dimethoxy-2-(4-methoxyphenyl)benzofuran-3-yl)methylketone (**S3**)

In a round bottom flask, the previous vinyl benzofuran (139 mg, 0.447 mmol) was dissolved in 10 mL of a (7:1) mixture of DMF and distilled water. To this solution, $PdCl_2$ (7.9 mg, 0.0447mmol) and CuCl (49 mg, 0.0492 mmol) were added. The reaction was placed under an oxygen atmosphere and warmed to 65°C. After 4 h at this temperature the reaction was cooled, filtered over celite (EtOAc), and poured into water. The aqueous layer was extracted with EtOAc (3 x 25 mL) and the combined organic extracts were washed with distilled water, brine and then dried over $MgSO_4$. After filtration, the filtrate was concentrated and the resulting residue was submitted to flash column chromatography (80:20 hexane/EtOAc) to give the desired methyl ketone **S3** (135 mg, 93%). IR (neat) $cm^{-1}$ 3012, 2961, 2947, 2838, 1689, 1608, 1501, 1463, 1453, 1414, 1251, 1217, 1148, 1110 $^1H$ NMR (400 MHz, $CDCl_3$) δ 2.57 (s, 3H), 3.76 (s, 3H), 3.77 (s, 3H), 3.81 (s, 3H), 6.30 (d, $J$ = 1.6 Hz, 1H), 6.60 (d, $J$ = 1.6 Hz, 1H), 6.89 (d, $J$ = 8.8 Hz, 2H), 7.72 (d, $J$ = 8.8 Hz, 2H) $^{13}C$ NMR (100 MHz, $CDCl_3$) δ 32.3, 55.2, 55.5, 55.6, 88.0, 94.8, 110.6, 113.9, 117.1, 122.4, 128.7, 151.6, 153.3, 155.2, 159.6, 160.3, 199.8 HRMS: (M+H) calculated for $C_{19}H_{19}O_5$: 327.1227, observed 327.1230.



Methyl 3-(4,6-dimethoxy-2-(4-methoxyphenyl)benzofuran-3-yl)-3-oxopropanoate (**S4**)

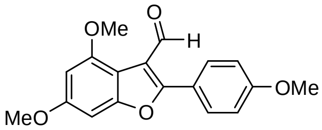
In a 2-neck round bottom flask fitted with a Liebig condenser, NaH (60% in mineral oil, 195 mg, 4.88 mmol) and KH (30% in mineral oil, 653 mg, 4.88 mmol) were washed first with hexane (3 mL), then with dry THF (3 mL) under argon. The hydride reagents were suspended in dry THF (50 mL), dimethyl carbonate (1.12 mL, 13.3 mmol) was added *via* syringe and the flask was warmed to 65°C. Once at that temperature, ketone **S3** (1.45 g, 4.44 mmol), dissolved in dry THF (15 mL), was added slowly. The reaction was refluxed until the starting ketone was consumed, cooled to room temperature and quenched with satd. $NH_4Cl$ (*aq*). The reaction was made acidic by the addition of 1N HCl (*aq.*) and poured into distilled water (100 mL). The aqueous phase was extracted with EtOAc (2 x 30 mL), the combined organic extracts were washed with distilled water, brine and then dried over $MgSO_4$. Filtration of the organic phase, followed by concentration and chromatography (silica gel, 85:15 hexane/EtOAc) gave **S4** (1.13 g, 66%). IR (neat) $cm^{-1}$ 3010, 2955, 2838, 1738, 1667, 1608, 1501 $^1H$-NMR (400 MHz, $CDCl_3$) δ 3.66 (s, 3H), 3.85 (s, 3H), 3.86 (s, 3H), 3.91 (s, 3H), 4.04 (s, 2H), 6.38 (d, *J* = 2.0 Hz, 1H), 6.68 (d, *J* = 2.0 Hz, 1H), 6.96 (d, *J* = 8.8 Hz, 2H), 7.84 (d, *J* = 8.8 Hz, 2H) $^{13}C$-NMR (100 MHz, $CDCl_3$) δ 50.2, 52.1, 55.3, 55.7, 88.1, 95.0, 110.0, 113.9, 115.8, 122.0, 129.2, 153.1, 153.8, 155.2, 159.7, 160.6, 168.0, 193.1.



Interrupted Nazarov substrate (**3**)

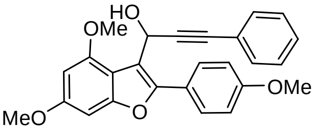
β-Ketoester **S4** (1.13 g, 2.93 mmol) was dissolved in benzene (20 mL). To the solution, glacial acetic acid (0.08 mL, 1.32 mmol), piperidine (0.03 mL, 0.29 mmol), and benzaldehyde (0.31 mL, 3.08 mmol) were added. The flask was fitted with a Dean-Stark trap and Liebig condenser and the reaction was heated to 110°C. Once the reaction finished (as determined by TLC) the flask was cooled, the reaction was poured into distilled water (50 mL), diluted with EtOAc (50 ml) and extracted (2 x 25 mL). The organic extract was washed with 1N HCl, satd. $NaHCO_3$, and brine. The organic layer was dried over $Na_2SO_4$, filtered and concentrated. The resulting residue was subjected to flash chromatography (80:20 hexane/EtOAc) to yield **6** (1.24 g, 89%) as a 1 : 3.3 mixture of E/Z isomers. IR (neat) $cm^{-1}$ 3006, 2949, 2837, 1729, 1651, 1615, 1502 $^1H$-NMR (400 MHz, $CDCl_3$) δ 3.78 (s, 3H, *E*), 3.80 (s, 3H, *E* + *Z*), 3.82 (s, 3H, *Z*), 3.86 (s, 3H, *E*), 3.87 (s, 3H, *Z*), 3.89 (s, 3H, *E*), 3.90 (s, 3H, *Z*) 6.31 (m, 1H, *E* + *Z*), 6.50 (d, *J* = 2.0 Hz, 1H, *E*), 6.70 (d, *J* = 2.0 Hz, 1H, *Z*), 6.95 (m, 3H, *Z* + 2H, *E*), 7.12 (m, 1H, *E*), 7.34 (m, 4H, *Z* + 3H, *E*), 7.37 (s, 1H, *Z*), 7.74 (d, *J* = 9.2 Hz, 2H, *Z*), 7.79 (s, 1H, *E*), 7.90 (d, *J* = 8.8 Hz, 2H, *E*) $^{13}C$-NMR (100 MHz, $CDCl_3$) major isomer δ 52.6, 55.3, 55.7, 55.8, 87.9, 94.9, 112.4, 114.2, 122.1, 128.1, 128.8, 129.4, 130.7, 131.2, 133.1, 136.1, 144.4, 152.3, 153.6, 155.1, 159.7, 160.2, 167.7, 191.1 HRMS: (M+H) calculated for $C_{28}H_{25}O_7$: 473.1595, observed 473.1596.

## 3. Synthesis of rocaglates



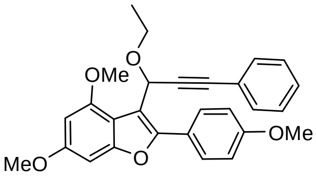
4,6-Dimethoxy-2-(4-methoxyphenyl)benzofuran-3-carboxaldehyde (**12**)

To a stirring solution of vinyl benzofuran (**S2**) (5.0 g, 16.1 mmol) in acetone (240 mL), tBuOH (35 mL) and distilled water (12 mL) were added and the reaction vessel was flushed with argon. To this solution N-methylmorpholine-N-oxide (3.6 g, 20.5 mmol) was added followed by $OsO_4$ (2.4 mL of a 4% solution in $H_2O$, 0.4 mmol). The reaction was stirred at room temperature for ~3 h, until the starting material was consumed. The reaction was concentrated to an oil *via* rotary evaporation and then diluted with THF (410 mL) and distilled water (150 mL). To this solution, sodium periodate (7.5 g, 35.0 mmol) was added. The reaction was stirred until the intermediary diol was converted to aldehyde **12**. Upon completion the reaction was poured into a saturated sodium thiosulfate solution (*aq.*) and extracted with EtOAc (2 x 200 mL). The organic extracts were combined and washed several times with additional sodium thiosulfate until the aqueous layer stopped developing a pink coloration. The organic extract was washed with distilled water, brine and then dried over $MgSO_4$. The organic phase was filtered and concentrated to yield the desired aldehyde **12** (5.05 g, quantitative) which was used without further purification. IR (neat) cm$^{-1}$ 3003, 2966, 2941, 2910, 2887, 2835, 1674, 1622, 1597, 1539, 1497, 1350, 1313, 1250, 1150, 1107) $^1$H-NMR (400 MHz, $CDCl_3$) $\delta$ 3.88 (s, 3H), 3.89 (s, 3H), 3.95 (s, 3H), 6.43 (d, $J$ = 2.0 Hz,1H), 6.69 (d, $J$ = 2.0 Hz,1H), 7.01 (d, $J$ = 8.8 Hz, 2H), 8.22 (d, $J$ = 8.8 Hz, 2H), 10.59 (s, 1H) ) $^{13}$C-NMR (100 MHz, $CDCl_3$) $\delta$ 55.4, 55.7, 55.8, 88.0, 95.5, 110.6, 113.8, 116.2, 121.9, 130.3, 154.6, 155.3, 158.4, 159.6, 161.5, 187.5; HRMS: (M+H) calculated for $C_{18}H_{17}O_5$: 313.1071, observed 313.1078; mp = 145°C–149°C.



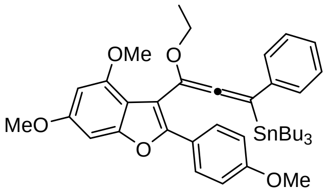
1-[4,6-Dimethoxy-2-(4-methoxy-phenyl)-benzofuran-3-yl]-3-phenyl-prop-2-yn-1-ol

Phenyl acetylene (2.7 mL, 24.6 mmol) was dissolved in 80 mL dry THF and cooled to -78ºC. To this solution, *n*-BuLi (11 mL of a 1.9M solution in hexane, 20.9 mmol) was added dropwise under argon. The solution was allowed to stir for 10 min. after which a solution of aldehyde **12** (5.05 g, 16.1 mmol) in dry THF (120 mL) was added *via* cannula. The reaction was allowed to warm to r.t. and quenched with $NH_4Cl$ (*aq.*). The mixture was poured into distilled water and the aqueous phase was made neutral by the addition of 1N HCl (*aq.*). The mixture was extracted EtOAc (2 x 200 mL) and the combined organic extracts were washed with brine. The organic layer was dried over $Na_2SO_4$ and concentrated. Precipitation in methyl-*t*-butyl ether afforded the desired propargylic alcohol. (5.20 g, 78%) IR (neat) $cm^{-1}$ 3474, 3003, 2935, 2836, 1621, 1597, 1501, 125&, 1146, 1111; $^1$H-NMR (400 MHz, $CDCl_3$) δ 3.87 (s, 6H), 4.06 (s, 3H), 4.63 (d, *J* = 9.2 Hz, 1H), 5.85 (d, *J* = 9.2 Hz, 1H), 6.45 (d, *J* = 1.6 Hz, 1H), 6.73 (d, *J* = 1.6 Hz, 1H), 7.03 (d, *J* = 6.8 Hz, 2H), 7.28 (m, 3H), 7.40 (m, 2H), 7.63 (d, *J* = 6.8 Hz, 2H) $^{13}$C-NMR (125 MHz, $CDCl_3$) δ 55.4, 55.9, 56.2, 57.6, 84.5, 89.1, 89.4, 95.0, 111.2, 114.3, 115.6, 122.8, 122.9, 128.2, 128.3, 129.3, 131.7, 149.7, 152.3, 156.2, 159.3, 160.0 HRMS: (M) calculated for $C_{28}H_{26}O_5$: 414.1462, observed 414.1471; mp = 119°C–121°C.



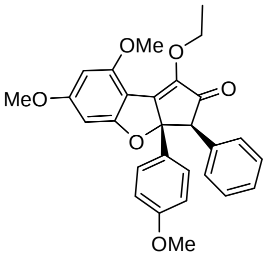
3-(1-ethoxy-3-phenylprop-2-ynyl)-4,6-dimethoxy-2-(4-methoxyphenyl)benzofuran (**13a**)

The resulting alcohol (3.7 g, 9 mmol) was dissolved in 60 mL of dry THF and KH (0.74 g, 18.5 mmol, from the 30% suspension in mineral oil which was washed 3 times with hexanes) was added. The reaction was stirred for ~5 min. until steady gas evolution was observed. At this point, ethyl iodide (2.22 mL, 27.8 mmol) is added and the reaction stirred until the intermediary propargyl alcohol is consumed. The excess KH is quenched by the addition of $NH_4Cl$ (*aq.*) and the mixture is poured into distilled water and made neutral by the addition of 1N HCl (*aq.*). The mixture was extracted with EtOAc (2 x 100 mL) and the combined organic extracts were washed successively with brine and distilled water . The organic layer was dried over $Na_2SO_4$ and concentrated. The resulting residue was subjected to flash column chromatography (80:20 hexane/EtOAc) to afford propargyl ether **13a** (2.57 g, 64%) IR (neat) cm$^{-1}$ 2969, 2936, 2907, 2878, 2836, 1622, 1611, 1592, 1501, 1490, 1296, 1252, 1215, 1149, 1110, 1060, 1029 $^1$H-NMR (500 MHz, $CDCl_3$) δ 1.31 (t, *J* = 6.5 Hz, 3H), 3.70 (m, 1H), 3.86 (s, 6H), 3.91 (m, 1H), 3.94 (s, 3H), 6.29 (s, 1H), 6.36 (d, *J* = 1.5 Hz, 1H), 6.67 (d, *J* = 1.5 Hz, 1H), 7.00 (d, *J* = 7.2 Hz, 2H), 7.10 (m, 2H), 7.20 (m, 3H), 8.03 (d, *J* = 9.0 Hz, 2H) $^{13}$C-NMR (125 MHz, $CDCl_3$) δ 15.3, 55.4, 55.5, 55.8, 63.2, 64.0, 84.8, 87.5, 88.1, 94.6, 112.2, 112.6, 113.5, 122.9, 123.5, 128.0, 128.1, 130.0, 131.7, 152.7, 154.4, 155.3, 158.9, 159.8 HRMS: (M+Na) calculated for $C_{28}H_{26}O_5Na$: 465.1672, observed 465.1666; mp = 98°C–100°C.



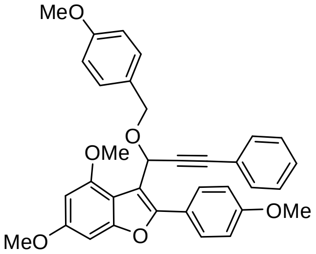
Stannyl allene (**14a**)

Propargyl ether **13a** (1.00 g, 2.26 mmol) was dissolved in 20 ml of dry $Et_2O$ and cooled to –40$^o$C under argon. To this solution *t*-BuLi (1.46 mL, 1.7M solution in hexanes, 2.49 mmol) was added dropwise. With the addition of the base the reaction color progressed from light yellow to a deep brown. Upon completion of addition the reaction was allowed to stir for 5 min and then tri-butyl tin chloride (0.74 mL, 2.71 mmol) was added and the reaction was allowed to warm to room temperature. Upon the addition of the stannyl chloride the color of the reaction bleached back to yellow and eventually a white ppt. developed. The magnetic stir bar was removed and the reaction was concentrated and the residue was taken up in hexanes and immediately subjected to flash column chromatography (90:10 hexanes/EtOAc on silica deactivated with $Et_3N$) to afford stannyl allene **14a** (1.57 g 95%). This material was used without delay in subsequent reactions.



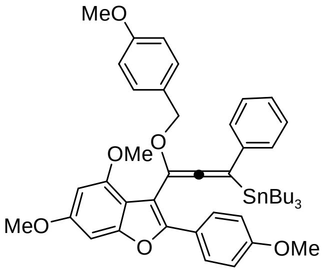
Nazarov product (**15a**)

Stannyl allene **14a** (1.55 g, 1.95 mmol) was dissolved in 20 mL of DMF and *m*-CPBA (1.66 g of 77% *m*-CPBA, 7.41 mmol w/r/t *m*-CPBA) were added all at once. The flask was flushed with argon and stirred. After ~3 h and additional 1 equiv. of *m*-CPBA was added and the reaction was stirred until the starting allene was consumed (an additional 3 h). At this time the reaction was poured into a solution of sodium thiosulfate in water, and extracted EtOAc (2 x 50 mL). The organic extracts were washed with satd. $NaHCO_3$ (*aq.*) twice, distilled water and finally brine. The organic phase was dried over $MgSO_4$, filtered and concentrated to give an orange residue. This was subjected to flash column chromatography (85:15 hexane/EtOAc). *Note:fractions containing the desired product appear orange/blue under UV light.* This material was concentrated, re-dissolved in the minimum amount of $Et_2O$ and allowed to stand. After a few moments a precipitate developed and the $Et_2O$ suspension is briefly refrigerated. After refrigeration the precipitate is filtered to yield the pure Nazarov product **15a** as a yellow powder (0.45 g, 50%). $^1$H-NMR (400 MHz, $CDCl_3$) δ 1.45 (t, *J* = 5.6 Hz, 3H), 3.67 (s, 3H), 3.80 (s, 3H), 3.09 (s, 3H), 4.12 (m, 1H), 4.53 (m, 1H), 5.57 (s, 1H), 6.04 (d, *J* = 1.2 Hz, 1H), 6.18 (d, *J* = 1.2 Hz, 1H), 6.59 (d, *J* = 7.2 Hz, 2H), 6.88 (m, 2H), 7.11 (m, 5H) $^{13}$C-NMR (100 MHz, $CDCl_3$) δ 15.8, 55.1, 55.8, 55.9, 66.5, 68.4, 89.7, 93.0, 98.2, 104.7, 113.0, 127.0, 127.4, 127.8, 130.0, 132.0, 134.3, 144.9, 149.9, 157.8, 159.1, 165.6, 166.1, 198.4; HRMS: (M+Na) calculated for $C_{28}H_{26}O_6Na$: 481.1622, observed 481.1610; mp = 131°C–135°C.



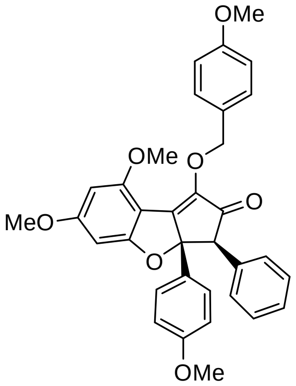
3-(1-(4-methoxybenzyloxy)-3-phenylprop-2-ynyl)-4,6-dimethoxy-2-(4-methoxyphenyl) benzofuran (**13b**)

The propargyl alcohol was prepared in the same method as used for ethyl propargyl ether **13a**. To form the *p*-methoxy benzyl propargyl ether, KH (0.77g, 19.3 mmol) was added to a flask and washed once with hexane under argon. To this flask, 100 mL of dry THF was added followed by the propargyl alcohol (5.00 g, 12.1 mmol). To the stirring solution, sodium iodide (3.62 g, 24.1 mmol) and *p*-methoxybenzyl chloride (3.28 mL, 24.1 mmol) were added and the reaction was warmed to 45°C. The solution was stirred at this temperature until the starting material was consumed, as determined by TLC (~2 h). Once complete the reaction was quenched with ammonium chloride and made slightly acidic by the addition of 1 N HCl (*aq*). The reaction was poured into distilled water and extracted with EtOAc (2 x 150 mL). The combined organic extracts were washed with distilled water and brine. The organic phase was dried over $MgSO_4$, filtered and concentrated. The resulting residue was subjected to flash column chromatography (67:33 Hex/$Et_2O$). The combined product containing fractions were poured into a separatory funnel and washed four times with 1N NaOH (*aq*) to remove excess *p*-methoxy benzyl alcohol. The organic phase was again dried over $MgSO_4$, filtered and concentrated to yield the *p*-methoxybenzyl propargyl ether **13b** (6.19 g, 96%) as a thick yellow oil IR (neat) $cm^{-1}$ 3002, 2956, 2936, 2906, 2834, 1611, 1507, 1464, 1249, 1149, 1113 $^1H$ NMR (400 MHz, $CDCl_3$) δ 3.86 (s, 6H), 3.90 (s, 3H), 3.91 (s, 3H), 4.75 (d, *J* = 11.6 Hz, 1H), 4.83 (d, *J* = 11.6 Hz, 1H), 6.28 (s, 1H), 6.35 (d, *J* = 2.0 Hz, 1H), 6.68 (d, *J* = 2.0 Hz, 1H), 6.89 (d, *J* = 8.4 Hz, 2H), 6.99 (d, *J* = 8.8 Hz, 2H), 7.17-7.27 (m, 5H), 7.36 (d, *J* = 8.8 Hz, 2H), 8.01 (d, *J* = 8.4 Hz, 2H) $^{13}C$ NMR (100 MHz, $CDCl_3$) δ 55.3, 55.35, 55.4, 55.8, 62.3, 69.9, 87.2, 88.0, 94.6, 112.0, 112.4, 113.5, 113.7, 114.0, 122.9, 123.4, 128.1, 128.2, 128.7, 130.0, 130.1, 131.7, 152.8, 154.4, 155.4, 158.9, 159.2, 159.8. HRMS: (M) calculated for $C_{34}H_{30}O_6$: 534.2037, observed 534.2051



(3-(4-methoxybenzyloxy)-3-(4,6-dimethoxy-2-(4-methoxyphenyl)benzofuran-3-yl)-1-phenylpropa-1,2-dienyl)tributylstannane (**14b**)

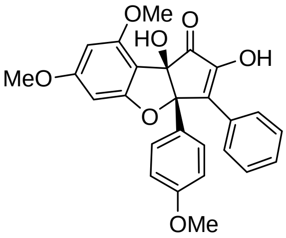
Propargyl ether **13b** (2.6 g, 4.9 mmol) was dissolved in 70 ml of dry $Et_2O$ and cooled to –40°C under argon. To this solution *t*-BuLi (3.0 mL, 1.7M solution in hexanes, 5.1 mmol) was added dropwise. With the addition of the base the reaction color progressed from light yellow to a deep brown. The reaction was allowed to stir for 5 min and then tri-butyl tin chloride (1.5 mL, 5.6 mmol) was added. Upon the addition of the stannyl chloride the color of the reaction bleached back to yellow and eventually a white precipitate developed. The reaction was allowed to warm up to rt, the magnetic stir bar was removed and the reaction was concentrated and the residue was taken up in hexanes and immediately subjected to flash column chromatography (75:25 hexanes/EtOAc) to afford stannyl allene **14b** (3.8 g 94%). This material was used without delay in subsequent reactions. IR (neat) $cm^{-1}$ 3002, 2952, 2921, 2836, 1917, 1612, 1506, 1464, 1247, 1146, 1109 $^1H$ NMR (500 MHz, $CDCl_3$) 0.80 (t, *J* = 7.0 Hz, 9H), 1.15-1.25 (m, 12H), 1.35-1.45 (m, 6H), 3.83 (s, 3H), 3.85 (s, 6H), 3.89 (s, 3H), 4.83 (d, *J* = 11.0 Hz, 1H), 4.89 (d, *J* = 11.0 Hz, 1H), 6.36 (d, *J* = 2.0 Hz, 1H), 6.67 (d, *J* = 2.0 Hz, 1H), 6.79 (d, *J* = 9.0 Hz, 2H), 6.88 (d, *J* = 8.5 Hz, 2H), 7.09 (m, 2H), 7.18-7.25 (m, 3H), 7.38 (d, *J* = 8.5 Hz, 2H), 7.77 (d, *J* = 9.0 Hz, 2H) $^{13}C$ NMR (125 MHz, $CDCl_3$) δ 11.6, 27.2, 29.0, 46.2, 55.2, 55.3, 55.7, 70.2, 87.8, 94.3, 109.1, 113.0, 113.7, 116.5, 123.2, 123.5, 126.3, 128.1, 128.2, 128.9, 129.5, 130.1, 130.3, 140.4, 150.8, 154.2, 155.8, 158.9, 159.1, 159.4, 200.1. HRMS: (M) calculated for $C_{34}H_{30}O_6$: 534.2037, observed 534.2051



Nazarov product **15b**

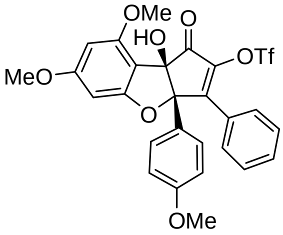
Stannyl allene **14a** (3.8 g, 4.6 mmol) was dissolved in 150 mL of DMF and *m*-CPBA (4.5 g of 77% *m*-CPBA, 18.4 mmol w/r/t *m*-CPBA) were added all at once. The flask was flushed with argon and stirred. After ~3 h and additional 1 equiv. of *m*-CPBA was added and the reaction was stirred until the starting allene was consumed (an additional 3 h). At this time the reaction was poured in distilled water, and extracted EtOAc (2 x 200 mL). The organic extracts were washed with distilled water twice, a 10 % solution of sodium thiosulfate and finally brine. The organic phase was dried over $MgSO_4$, filtered and concentrated to give an orange residue. This was subjected to flash column chromatography (80:20 hexane/EtOAc). *Note:fractions containing the desired product appear orange/blue under UV light.* This material was concentrated, re-dissolved in the minimum amount of $Et_2O$ and allowed to stand. After a few moments a precipitate developed and the $Et_2O$ suspension is briefly refrigerated. After refrigeration the precipitate is filtered to yield the pure Nazarov product **15b** as a yellow powder (0.96 g, 38%).

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.64 (s, 3H), 3.77 (s, 3H), 3.84 (s, 3H), 3.89 (s, 3H), 4.52 (s, 1H), 5.38 (d, *J* = 11.7 Hz, 1H), 5.64 (d, *J* = 11.7 Hz, 1H), 6.04 (d, *J* = 2.0 Hz, 1H), 6.15 (d, *J* = 2.0 Hz, 1H), 6.48 (d, *J* = 8.8 Hz, 2H), 6.78 (d, *J* = 8.4 Hz, 2H), 6.82 (m, 2H), 6.95 (d, *J* = 8.8 Hz, 2H), 7.10 (m, 2H), 7.51 (d, *J* = 8.4 Hz, 2H) $^{13}$C NMR (100 MHz, $CDCl_3$) δ 55.0, 55.27, 55.8, 55.8, 66.6, 72.6, 89.6, 93.0, 98.3, 112.8, 113.8, 127.0, 127.4, 127.8, 128.6, 129.7, 130.0, 130.3, 131.7, 134.4, 143.9, 151.3, 157.8, 159.0, 159.6, 165.6, 166.3, 198.6 HRMS; (M+H) calculated for $C_{34}H_{31}O_7$: 551.2064, observed 551.2064; mp = 135°C–139°C.



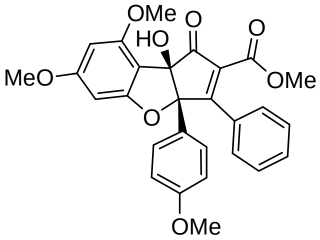
Cyclopentyl enol **18**

Nazarov product **15b** (264 mg, 0.48 mmol) was dissolved in 5 mL of DCM. To this solution 1 mL of distilled water  was added followed by DDQ (489 mg, 2.16 mmol). The reaction was stirred at room temperature for 12 h. Upon completion the reaction was poured into distilled water  and extracted with EtOAc (2 x 20 mL). The organic layer was washed exhaustively with distilled water  to remove the excess DDQ. The organic layer was then washed with brine, dried over $MgSO_{4,}$ filtered and concentrated. The resulting residue was subjected to flash column chromatography (60:40 EtOAc/Hex) to yield **16** (158 mg, 71%) as a white solid. IR (neat) $cm^{-1}$ 3432, 3315, 1710, 1598, 1512, 1500, 1393 $^1H$ NMR (400 MHz, $CDCl_3$) δ 2.88 (broad s, 1H), 3.77 (s, 3H), 3.78 (s, 3H), 3.82 (s, 3H), 6.06 (d, *J* = 1.2 Hz, 1H), 6.16 (d, *J* = 1.2 Hz, 1H), 6.88 (d, *J* = 6.8 Hz, 2H), 7.29-7.37 (m, 5H), 7.99 (d, *J* = 5.6 Hz, 2H) $^{13}C$ NMR (100 MHz, $CDCl_3$) δ 55.2, 55.6, 55.7, 83.9, 88.8, 92.7, 98.0, 105.0, 113.9, 127.9, 128.3, 129.3, 130.7, 131.2, 132.9, 148.3, 158.7, 159.7, 161.7, 164.4, 195.6. HRMS: (M+Na) calculated for $C_{26}H_{22}O_7Na$: 469.1258, observed 465.1265; mp = 95°C–100°C.



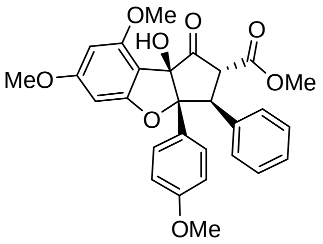
Enol triflate **19**

Cyclopentyl enol **18** (105 mg, 0.235 mmol) was dissolved in 4 mL of dry THF and cooled to $0^oC$ under argon. To this solution freshly prepared KHMDS (0.59 mL of a 1 M solution in THF, 0.59 mmol) was added dropwise. The solution was stirred for 3 min where upon Commins' reagent (168 mg, 0.47 mmol) was added slowly in 1 mL of dry THF. The reaction was stirred at $0^oC$ for 30 min and then poured into water (20 mL). The aqueous layer was extracted with EtOAc (3 x 25 mL) and the combined organic extracts were washed with brine. The organic layer was dried over $MgSO_4$, filtered and concentrated. The resulting residue was subjected to flash column chromatography (60:40 Hexane/EtOAc) to yield the desired enol triflate **19** (112 mg, 83%) as a yellow solid. IR (neat) cm$^{-1}$ 3445, 2940, 2843, 1740, 1624, 1597, 1512, 1427, 1215 $^{1}$H NMR (400 MHz, $CDCl_3$) δ 3.03 (s, 1H), 3.76 (s, 3H), 3.82 (s, 3H), 3.83 (s, 3H), 6.08 (d, *J* = 2.0Hz, 1H), 6.13 (d, *J* = 2.0 Hz, 1H), 6.95 (d, *J* = 8.8 Hz, 2H), 7.33-7.43 (m, 5H), 7.58 (d, *J* = 8.8 Hz, 2H) $^{13}$C NMR (100 MHz, $CDCl_3$) δ 55.3, 55.7, 55.8, 84.6, 88.9, 93.1, 97.1, 105.2, 114.3, 126.0, 127.6, 128.2, 128.8, 130.4, 131.8, 142.5, 152.7, 158.7, 160.1, 161.1, 164.7, 191.2 HRMS: (M+Na) calculated for $C_{27}H_{21}O_9F_3SNa$: 601.0751, observed 601.0734; mp = 179°C–183°C.



α,.β-Unsaturated ester **20**

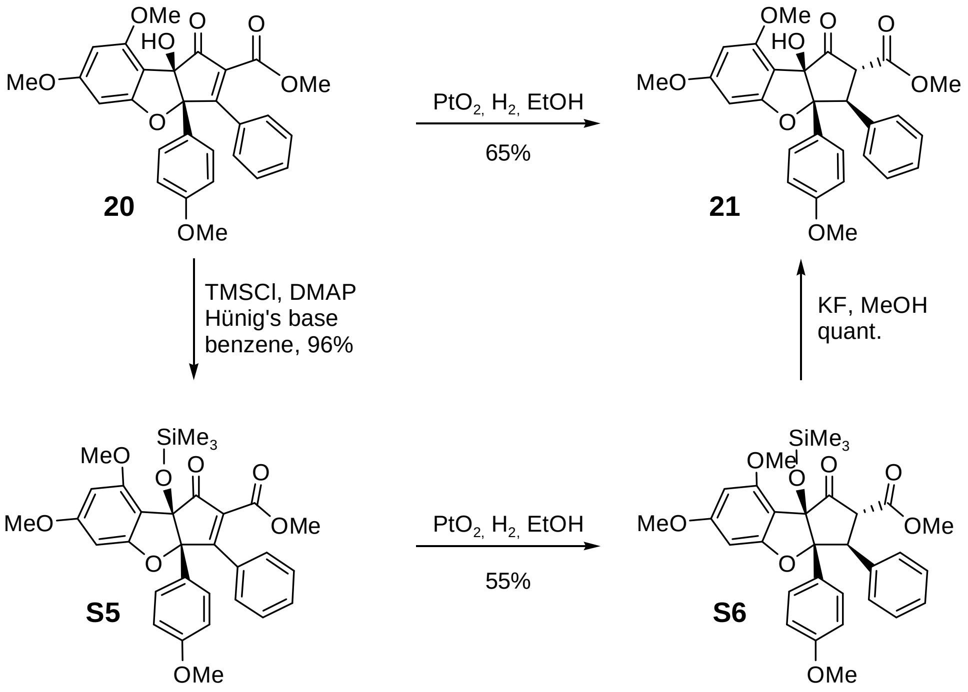
The enol triflate **19** (112 mg, 0.194 mmol) was dissolved in 4 mL of dry THF. The solution was saturated with CO for 5 min. whereupon $Pd(PPh_3)_4$ (56 mg, 0.048 mmol), MeOH (0.62 mL, 15.5 mmol), and Hünig’s base (0.135 mL, 0.776 mmol) were added. The reaction was warmed to 65$^{o}$C for 6 h. Upon consumption of the starting material the reaction was poured into distilled water and extracted with EtOAc (3 x 20 mL). The organic extract was washed with water and then brine. The organic layer was dried over $MgSO_4$, filtered and concentrated. The resulting residue was subjected to flash column chromatography (50:50 Hexane/EtOAc) to yield the desired ester, **20** (69 mg, 79%) as a white solid. IR (neat) cm$^{-1}$ 3445, 2955, 2843, 1740, 1613, 1219, 1150 $^{1}$H NMR (400 MHz, $CDCl_3$) δ 3.24 (s, 1H), 3.77 (s, 3H), 3.79 (s, 3H), 3.81 (s, 3H), 3.82 (s, 3H), 6.08 (d, J=2.0Hz, 1H), 6.13 (d, J=2.0Hz, 1H), 6.93 (d, J=8.8Hz, 2H), 7.29-7.38 (m, 7H) $^{13}$C NMR (100 MHz, $CDCl_3$) δ 52.5, 55.2, 55.6, 55.6, 86.9, 88.6, 92.8, 98.5, 105.8, 114.1, 125.8, 127.5, 128.3, 129.4, 130.9, 131.6, 133.0, 158.5, 159.8, 160.9, 164.1, 164.2, 166.1, 196.2. HRMS: (M) calculated for $C_{28}H_{24}O_8$: 488.1466, observed 488.1482; mp = 189°C–191°C.



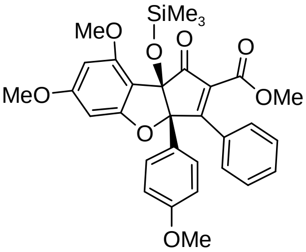
β-ketoester **21**

α, β-unsaturated ester **20** (52 mg, 0.11 mmol) was dissolved in 10 mL of absolute ethanol, platinum oxide (10 mg) was added and the solution was saturated with $H_2$ for 10 min and stirred at room temperature for 3 h. Upon consumption of the starting material the reaction was filtered over celite and the filtrate concentrated. The resulting residue was subjected to flash column chromatography (50:50 Hexane/EtOAc) to yield the desired hydrogenation product **21** (33 mg, 65%).

*Note: purifcation of the desired compound proved troublesome and the hydrogenation showed poor reproducibility. Hydrogenation of the corresponding silylated compound (see below) turned out to be more reliable and title compound* ***21*** *was therefore alternatively obtained by desilylation of the resultant β-ketoester.*

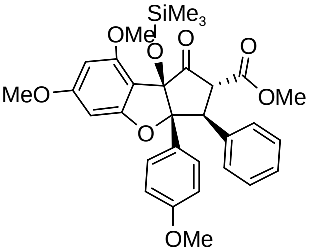


Silylated cyclopenta β-ketoester **S6** (50 mg, 0.09 mmol) was dissolved in 3 mL of dry MeOH. To this solution potassium fluoride (100 mg, 1.7 mmol) was added. The reaction was stirred at rt for 6 h after which the starting material was consumed. The methanol solution was poured into saturated ammonium chloride solution and extracted twice with EtOAc (2 x 25 mL). The combined organic extracts were washed with distilled water and brine and then dried over $MgSO_4$. The organic phase was filtered and concentrated to yield the desired compound **21** (45 mg, quantitative) which was used without further purification. The compound was obtained as a 1:1 to 3:1 mixture of the keto- and the enolic forms $^1$H NMR (400 MHz, $CDCl_3$) δ 3.59 (s, 3H, enol), 3.65 (s, 3H, enol), 3.66 (s, 3H, ketone), 3.71 (s, 3H, ketone), 3.79 (s, 3H, enol), 3.81 (s, 3H, ketone), 3.83 (s, 3H, enol), 3.86 (s, 3H, ketone), 3.88 (d, $J$ = 13.2 Hz, 1H, ketone), 4.24 (d, $J$ = 13.2 Hz, 1H, ketone), 4.48 (s, 1H, enol), 6.05 (d, $J$ = 2.0 Hz, 1H, enol), 6.11 (d, $J$ = 2.0 Hz, 1H, ketone), 6.19 (d, $J$ = 2.0 Hz, 1H, enol), 6.35 (d, $J$ = 2.0 Hz, 1H, ketone), 6.53 (d, $J$ = 9.2 Hz, 2H, enol), 6.68 (d, $J$ = 9.2 Hz, 2H, ketone), 6.93 (m, 3H), 7.01 (d, $J$ = 9.2 Hz, 2H, enol), 7.08 (m, 3H), 10.60 (s, 1H, enol). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 51.5, 51.9, 52.9, 54.9, 55.1, 55.6, 55.7, 56.4, 56.9, 88.5, 88.9, 89.1, 89.9, 92.4, 92.9, 99.3, 100.7, 102.3, 105.8, 106.1, 112.0, 113.2, 125.4, 126.6, 127.0, 127.2, 127.7, 127.9, 128.0, 129.0, 129.1, 135.4, 138.9, 158.1, 158.5, 158.6, 158.9, 160.8, 161.0, 163.6, 165.0, 167.3, 170.1, 172.0, 203.4. HRMS: (M+Na) calculated for $C_{28}H_{26}O_8Na$: 513.1520, observed 513.1524



Trimethyl silyl ether **S5**

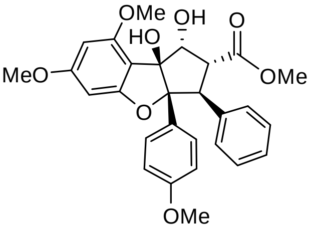
α,β-unsaturated ester **20** (69 mg, 0.153 mmol) was dissolved in 3 mL of benzene. To this solution, Hünig's base (0.080 mL, 0.0459 mmol) and DMAP (2 mg, 0.0153 mmol) were added. Chlorotrimethyl silane (0.039 mL, 0.306 mmol) was added and the reaction was stirred at rt for 30 min. Upon consumption of the starting material the reaction was filtered over a plug of silica (EtOAc) and the filtrate concentrated to yield the trimethyl silyl ether **S5** (83 mg, 96%). IR (neat) cm$^{-1}$ 2959, 2932, 2917, 2847, 1740, 1597, 1427, 1219 $^1$H NMR (400 MHz, $CDCl_3$) δ -.03 (s, 9H), 3.75 (s, 3H), 3.78 (s, 3H), 3.80 (s, 3H), 3.82 (s, 3H), 6.06 (d, *J* = 2.0Hz, 1H), 6.11 (d, *J* = 2.0Hz, 1H), 6.91 (d, *J* = 9.2 Hz, 2H), 7.23-7.27 (m, 4H), 7.32-7.34 (m, 3H) $^{13}$C NMR (100 MHz, $CDCl_3$) δ 1.0, 52.3, 55.1, 55.3, 55.5, 88.5, 89.2, 92.5, 99.1, 106.6, 113.6, 126.9, 128.2, 128.3, 129.1, 130.3, 131.7, 133.5, 158.7, 159.7, 161.0, 164.3, 164.5, 194.6. HRMS: (M) calculated for $C_{31}H_{32}O_8Si$: 560.1861, observed 560.1874.



Silylated cyclopenta β-ketoester **S6**

Silylated α,β-unsaturated ester **S5** (76 mg, 0.11 mmol) was dissolved in 15 mL of absolute ethanol, platinum oxide (10 mg) was added and the solution was saturated with $H_2$ for 10 min and stirred at room temperature for 6 h. Upon consumption of the starting material the reaction was filtered over celite and the filtrate concentrated. The resulting residue was subjected to flash column chromatography (80:20 Hexane/EtOAc) to yield the desired hydrogenation product **S6** (42 mg, 55%).

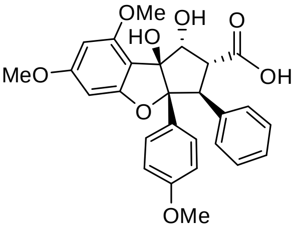
$^1$H NMR (500 MHz, $CDCl_3$) δ – 0.38 (s, 9H), 3.62 (s, 3H), 3.72 (s, 3H), 3.79 (s, 3H), 3.87 (s, 3H), 3.94 (d, *J* = 13.5 Hz, 1H), 4.08 (d, *J* = 13.5 Hz, 1H), 6.08 (d, *J* = 2.0 Hz, 1H), 6.32 (d, *J* = 2.0 Hz, 1H), 6.64 (d, *J* = 8.5 Hz, 2H), 6.80 (m, 2H), 6.92 (d, *J* = 8.5 Hz, 2H), 7.08 (m, 3H) $^{13}$C NMR (125 MHz, $CDCl_3$) δ 0.6, 51.3, 52.7, 55.1, 55.3, 55.6, 56.4, 58.4, 89.6, 92.6, 99.7, 105.7, 112.6, 126.4, 127.0, 127.8, 128.0, 128.5, 135.8, 158.7, 159.4, 161.4, 165.1, 167.7, 201.2. HRMS: (M+Na) calculated for $C_{31}H_{34}O_8SiNa$: 585.1915, observed 585.1941; mp = 155°C–158°C



Aglafolin **2**

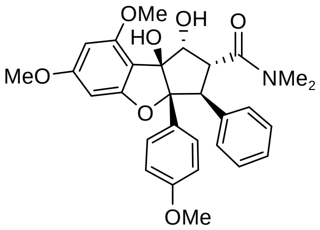
Sodium borohydride (80 mg 2.1 mmol) was slowly and carefully added in 3 mL of glacial acetic acid. After 30 min of stirring the resulting solution was added to a solution of of β-ketoester **20** (25 mg, 0.05

mmol) in 1 mL of dry acetonitrile. The reaction was stirred at rt for 15 h, poured into water and extracted with EtOAc (3x10 mL). The combined organic layers were washed with distilled water (10 mL) and brine and then dried over $MgSO_4$. The organic phase was filtered and concentrated and the resulting residue was subjected to flash column chromatography (80:20 EtOAc/Hex) to yield aglafolin **2** (14 mg, 56%) as a single stereoisomer. IR (neat) $cm^{-1}$ 3483, 3005, 2951, 2839, 1744, 1601, 1501, 1439, 1250 $^1H$ NMR (400 MHz, $CDCl_3$) δ 3.62 (s, 1H), 3.63 (s, 3H), 3.75 (s, 3H), 3.82 (s, 3H), 3.86 (s, 3H), 3.88 (dd, *J* = 14.4, 6.4 Hz, 1H), 4.28 (d, *J* = 14.4 Hz, 1H), 5.01 (dd, *J* = 6.8, 1.2 Hz, 1H), 6.10 (d, *J* = 1.6 Hz, 1H), 6.26 (d, *J* = 1.6 Hz, 1H), 6.65 (d, *J* = 9.2 Hz, 2H), 6.85 (m, 2H), 7.04 (m, 3H), 7.09 (d, *J* = 9.2 Hz, 2H) $^{13}C$ NMR (100 MHz, $CDCl_3$) δ 50.4, 51.9, 55.0, 55.1, 55.6, 55.7, 79.5, 89.5, 92.6, 93.7, 101.9, 107.7, 112.7, 126.5, 127.7, 127.8, 128.3, 128.9, 136.9, 157.0, 158.7, 160.9, 164.1, 170.5. HRMS: (M+Na) calculated for $C_{28}H_{28}O_8Na$: 515.1676, observed 515.1701; mp = 89°C–91°C.



Rocaglic acid

Aglafolin (14 mg, 0.028 mmol) was dissolved in 6 mL of a 5:1 mixture of tetrahydrofuran and distilled water. Lithium hydroxide (10mg, 0.42 mmol) was added and the reaction was stirred at rt for 12h. The mixture was diluted with 20 mL of dichloromethane and washed with 10 mL of 1N HCl, the organic layer was extracted with dichloromethane (2 x 5 mL), dried over $MgSO_4$, filtered and concentrated to yield rocaglic acid (11 mg, 82%) which was used without further purification. IR (neat) $cm^{-1}$ 3600-3200, 2923, 2853, 1715, 1610, 1513, 1453 $^1H$ NMR (400 MHz, $CDCl_3$) δ 3.72 (s, 3H), 3.88 (s, 3H), 3.89 (s, 3H), 4.07 (dd, *J* = 14.0, 6.4 Hz, 1H), 4.28 (d, *J* = 15.2 Hz, 1H), 5.06 (d, *J* = 6.4, Hz, 1H), 6.12 (d, *J* = 2.0 Hz, 1H), 6.29 (d, *J* = 2.0 Hz, 1H), 6.68 (d, *J* = 8.8, 2H), 6.89 (m, 2H), 7.07 (m, 3H), 7.10 (d, *J* = 8.8 Hz, 2H); $^{13}C$ NMR (100 MHz, $CDCl_3$) δ 50.1, 54.9, 55.0, 55.7, 55.8, 79.3, 89.4, 92.6, 93.6, 101.8, 107.5, 112.7, 126.2, 126.6, 127.7, 127.8, 128.9, 136.8, 156.8, 158.6, 160.8, 164.1, 174.0.



Rocaglamide **1**

Rocaglic acid (11 mg, 0.023 mmol) was dissolved in 4 mL of dry dichloromethane. Dicyclohexylcarbodiimide (12 mg, 0.058 mmol), 4-dimethylaminopyridine (19 mg, 0.15 mmol) and dimethylamine hydrochloride (6 mg, 0.07 mmol) were added and the reaction was stirred at rt for 15 h. The reaction was quenched with 1N HCl and extracted with dichloromethane (2x10 mL). The combined organic layers were washed with distilled water, brine and then dried over $MgSO_4$. The organic phase was filtered and concentrated and the resulting residue was subjected to flash column chromatography (EtOAc) to yield rocaglamide **1** as a white solid (7 mg, 60%). Eventually rocaglamide can be recrystalized from dichloromethane/hexanes to give translucid crystals. IR (neat) $cm^{-1}$ 3500-3250, 2935, 2838, 1620, 1512, 1496 $^1H$ NMR (400 MHz, $CDCl_3$) δ 1.81 (s, 1H), 2.95 (s, 3H), 3.33 (s, 3H), 3.72 (s, 3H), 3.85 (s, 3H), 3.87 (s, 3H), 4.03 (bs, 1H), 4.07 (dd, *J* = 13.4, 6.4 Hz, 1H), 4.57 (d, *J* = 13.4Hz, 1H), 4.94 (dd, *J* = 6.4, 2.0 Hz, 1H), 6.12 (d, *J* = 2.0 Hz, 1H), 6.29 (d, *J* = 2.0 Hz, 1H), 6.69 (dd, *J* = 6.8, 2.4 Hz, 2H), 6.88 (m, 2H), 7.04 (m, 3H), 7.12 (dd, *J* = 6.8, 2.0 Hz, 2H); $^{13}C$ NMR (100 MHz, $CDCl_3$) δ 35.7, 37.0, 47.7, 55.0, 55.6, 56.0, 78.5, 89.2, 92.5, 94.0, 101.7, 107.6, 112.7, 126.2, 127.1, 127.6, 127.7, 128.8, 137.6, 157.2, 158.6, 161.0, 163.9, 169.5. HRMS: (M+Na) calculated for $C_{29}H_{31}O_7NNa$: 528.1993, observed 528.1981; mp = 119°C–121°C.

These data are in accordance with those reported by Li, H. S.; Fu, B.; Wang, M. A.; Li, N.; Liu, W. J.; Xie, Z. Q.; Ma, Y. Q.; Qin, Z. H. *Eur. J. Org. Chem.* **2008**, 1753.

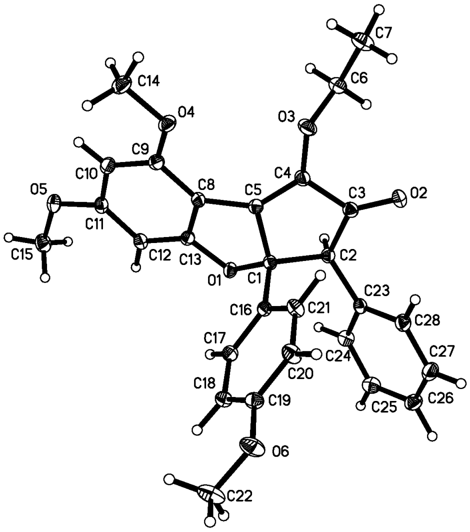
REFERENCE NUMBER: frojm03

# CRYSTAL STRUCTURE REPORT

$C_{28}H_{26}O_{6}$

Report prepared for:
J. Malona, Prof. A. Frontier

March 04, 2007



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## Data collection

A crystal ($0.28 \times 0.14 \times 0.04$ mm$^3$) was placed onto the tip of a 0.1 mm diameter glass capillary tube or fiber and mounted on a Bruker SMART APEX II CCD Platform diffractometer for a data collection at 100.0(1) K.[1] A preliminary set of cell constants and an orientation matrix were calculated from 216 reflections harvested from three sets of 20 frames. These initial sets of frames were oriented such that orthogonal wedges of reciprocal space were surveyed. The data collection was carried out using MoK$\alpha$ radiation (graphite monochromator) with a frame time of 60 seconds and a detector distance of 5.02 cm. A randomly oriented region of reciprocal space was surveyed: four major sections of frames were collected with 0.50° steps in $\omega$ at four different $\phi$ settings and a detector position of -33° in $2\theta$. The intensity data were corrected for absorption.[2] Final cell constants were calculated from the xyz centroids of 3978 strong reflections from the actual data collection after integration.[3] See Table 1 for additional crystal and refinement information.

## Structure solution and refinement

The structure was solved using SIR97[4] and refined using SHELXL-97.[5] The space group $P2_1/c$ was determined based on systematic absences and intensity statistics. A direct-methods solution was calculated which provided most non-hydrogen atoms from the E-map. Full-matrix least squares / difference Fourier cycles were performed which located the remaining non-hydrogen atoms. All non-hydrogen atoms were refined with anisotropic displacement parameters. All hydrogen atoms were found from the difference Fourier map and refined independently from the carbon atoms with individual isotropic displacement parameters. The final full matrix least squares refinement converged to $R1 = 0.0452$ ($F^2$, $I > 2\sigma(I)$) and $wR2 = 0.1189$ ($F^2$, all data).

## Structure description

The structure is the one suggested. All atoms lie on general positions.

Data collection, structure solution, and structure refinement were conducted at the X-ray Crystallographic Facility, B51 Hutchison Hall, Department of Chemistry, University of Rochester. All publications arising from this report MUST either 1) include William W. Brennessel as a coauthor or 2) acknowledge William W. Brennessel and the X-ray Crystallographic Facility of the Department of Chemistry at the University of Rochester.

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[1] APEX2 V2.1-0, Bruker Analytical X-ray Systems, Madison, WI (2006).

[2] SADABS 2004/1, An empirical correction for absorption anisotropy, R. Blessing, *Acta Cryst.* **A51**, 33-38 (1995).

[3] SAINT V7.34A, Bruker Analytical X-ray Systems, Madison, WI (2006).

[4] SIR97, A new tool for crystal structure determination and refinement, A. Altomare, M. C. Burla, M. Camalli, G. L. Cascarano, C. Giacovazzo, A. Guagliardi, A. G. G. Moliterni, G. Polidori, R. Spagna. *J. Appl. Cryst.* **32**, 115-119 (1999).

[5] SHELXTL V6.14, Bruker Analytical X-ray Systems, Madison, WI (2000).

Some equations of interest:

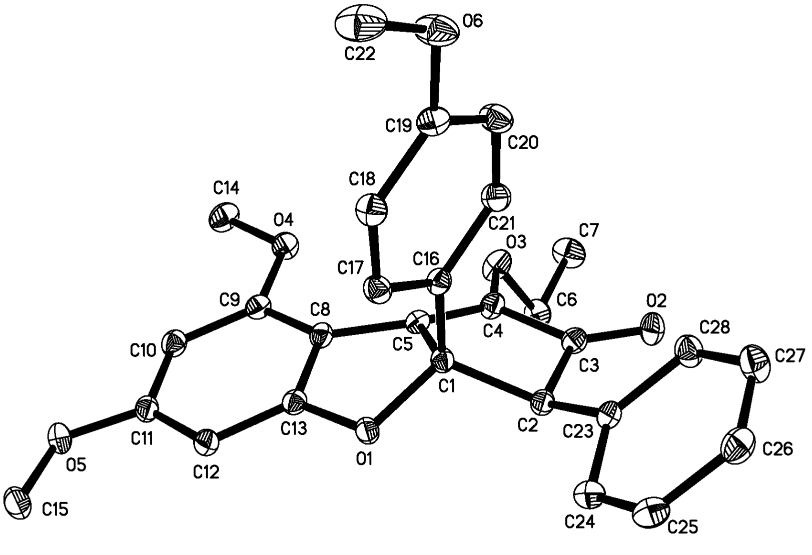
$$R_{\mathrm{int}} = \Sigma|F_o^2 - \langle F_o^2\rangle| \,/\, \Sigma|F_o^2|$$

$$R_1 = \Sigma||F_o|-|F_c|| \,/\, \Sigma|F_o|$$

$$wR2 = [\Sigma[w(F_o^2-F_c^2)^2] \,/\, \Sigma[w(F_o^2)^2]]^{1/2}$$

$$\text{where } w = q \,/\, [\sigma^2(F_o^2) + (a{*}P)^2 + b{*}P + d + e{*}\sin(\theta)]$$

$$\text{GooF} = S = [\Sigma[w(F_o^2-F_c^2)^2] \,/\, (n-p)]^{1/2}$$



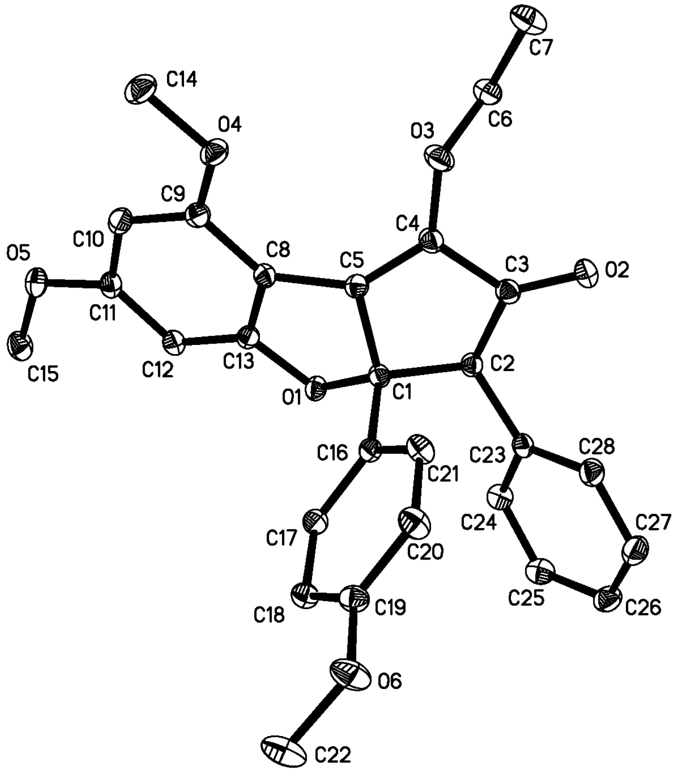

C7
C14
O4
O3
C6
C9
C4
C10
O5
C8
C5
C3
O2
C11
C12
C13
C2
C15
O1
C1
C16
C21
C23
C28
C24
C17
C20
C27
C18
C19
C25
C26
O6
C22

Table 1. Crystal data and structure refinement for frojm03.

| | | |
|---|---|---|
| Identification code | frojm03 | |
| Empirical formula | C28 H26 O6 | |
| Formula weight | 458.49 | |
| Temperature | 100.0(1) K | |
| Wavelength | 0.71073 Å | |
| Crystal system | Monoclinic | |
| Space group | $P2_1/c$ | |
| Unit cell dimensions | $a$ = 10.8038(10) Å | $\alpha$ = 90° |
| | $b$ = 23.985(2) Å | $\beta$ = 102.021(1)° |
| | $c$ = 8.7832(8) Å | $\gamma$ = 90° |
| Volume | 2226.0(4) $Å^3$ | |
| $Z$ | 4 | |
| Density (calculated) | 1.368 $Mg/m^3$ | |
| Absorption coefficient | 0.096 $mm^{-1}$ | |
| $F$(000) | 968 | |
| Crystal color, morphology | colorless, plate | |
| Crystal size | 0.28 x 0.14 x 0.04 $mm^3$ | |
| Theta range for data collection | 1.70 to 32.57° | |
| Index ranges | $-16 \leq h \leq 16, -36 \leq k \leq 36, -13 \leq l \leq 13$ | |
| Reflections collected | 40008 | |
| Independent reflections | 8035 [$R$(int) = 0.0537] | |
| Observed reflections | 5715 | |
| Completeness to theta = 32.57° | 99.2% | |
| Absorption correction | Multi-scan | |
| Max. and min. transmission | 0.9962 and 0.9737 | |
| Refinement method | Full-matrix least-squares on $F^2$ | |
| Data / restraints / parameters | 8035 / 0 / 411 | |
| Goodness-of-fit on $F^2$ | 1.021 | |
| Final $R$ indices [$I$>2sigma($I$)] | $R1$ = 0.0452, $wR2$ = 0.1044 | |
| $R$ indices (all data) | $R1$ = 0.0731, $wR2$ = 0.1189 | |
| Largest diff. peak and hole | 0.438 and -0.250 e.$Å^{-3}$ | |

Table 2. Atomic coordinates (x $10^4$) and equivalent isotropic displacement parameters (Å$^2$x $10^3$ ) for frojm03. $U_{eq}$ is defined as one third of the trace of the orthogonalized $U_{ij}$ tensor.

| | x | y | z | $U_{eq}$ |
|---|---|---|---|---|
| O1 | 6762(1) | 909(1) | 7706(1) | 14(1) |
| O2 | 7343(1) | 2844(1) | 9028(1) | 19(1) |
| O3 | 5086(1) | 2417(1) | 10028(1) | 20(1) |
| O4 | 3571(1) | 1247(1) | 10459(1) | 18(1) |
| O5 | 3310(1) | -399(1) | 7408(1) | 19(1) |
| O6 | 10830(1) | 618(1) | 14012(1) | 24(1) |
| C1 | 7164(1) | 1369(1) | 8784(1) | 12(1) |
| C2 | 7603(1) | 1897(1) | 8036(1) | 13(1) |
| C3 | 7017(1) | 2357(1) | 8891(1) | 15(1) |
| C4 | 5928(1) | 2108(1) | 9433(1) | 15(1) |
| C5 | 5951(1) | 1549(1) | 9256(1) | 13(1) |
| C6 | 4463(1) | 2862(1) | 9029(2) | 19(1) |
| C7 | 4071(1) | 3297(1) | 10064(2) | 24(1) |
| C8 | 5152(1) | 1061(1) | 9048(1) | 13(1) |
| C9 | 4012(1) | 903(1) | 9461(1) | 15(1) |
| C10 | 3429(1) | 412(1) | 8864(1) | 16(1) |
| C11 | 3978(1) | 72(1) | 7881(1) | 15(1) |
| C12 | 5110(1) | 213(1) | 7450(1) | 15(1) |
| C13 | 5663(1) | 707(1) | 8067(1) | 13(1) |
| C14 | 2445(1) | 1074(1) | 10951(2) | 22(1) |
| C15 | 3857(1) | -801(1) | 6537(2) | 21(1) |
| C16 | 8143(1) | 1153(1) | 10164(1) | 13(1) |
| C17 | 8654(1) | 623(1) | 10167(1) | 14(1) |
| C18 | 9551(1) | 423(1) | 11428(1) | 16(1) |
| C19 | 9954(1) | 766(1) | 12710(1) | 16(1) |
| C20 | 9458(1) | 1303(1) | 12719(1) | 19(1) |
| C21 | 8561(1) | 1491(1) | 11466(1) | 17(1) |
| C22 | 11301(2) | 60(1) | 14096(2) | 27(1) |
| C23 | 8995(1) | 1928(1) | 8015(1) | 14(1) |
| C24 | 9450(1) | 1587(1) | 6960(1) | 17(1) |
| C25 | 10732(1) | 1573(1) | 6930(1) | 19(1) |

| | | | | |
|---|---|---|---|---|
| C26 | 11573(1) | 1911(1) | 7935(2) | 20(1) |
| C27 | 11133(1) | 2254(1) | 8982(2) | 21(1) |
| C28 | 9853(1) | 2259(1) | 9033(1) | 18(1) |

Table 3. Bond lengths [Å] and angles [°] for frojm03.

| | | | |
|---|---|---|---|
| O(1)-C(13) | 1.3785(13) | C(14)-H(14A) | 0.997(16) |
| O(1)-C(1) | 1.4599(13) | C(14)-H(14B) | 1.004(17) |
| O(2)-C(3) | 1.2190(14) | C(14)-H(14C) | 0.988(17) |
| O(3)-C(4) | 1.3602(14) | C(15)-H(15A) | 0.961(18) |
| O(3)-C(6) | 1.4537(15) | C(15)-H(15B) | 0.993(17) |
| O(4)-C(9) | 1.3596(14) | C(15)-H(15C) | 0.996(16) |
| O(4)-C(14) | 1.4349(14) | C(16)-C(17) | 1.3841(15) |
| O(5)-C(11) | 1.3579(14) | C(16)-C(21) | 1.3978(16) |
| O(5)-C(15) | 1.4320(15) | C(17)-C(18) | 1.3957(16) |
| O(6)-C(19) | 1.3715(14) | C(17)-H(17) | 0.987(15) |
| O(6)-C(22) | 1.4277(16) | C(18)-C(19) | 1.3883(16) |
| C(1)-C(5) | 1.5177(15) | C(18)-H(18) | 0.994(16) |
| C(1)-C(16) | 1.5243(15) | C(19)-C(20) | 1.3951(17) |
| C(1)-C(2) | 1.5479(15) | C(20)-C(21) | 1.3810(17) |
| C(2)-C(23) | 1.5094(15) | C(20)-H(20) | 0.980(16) |
| C(2)-C(3) | 1.5418(16) | C(21)-H(21) | 0.975(15) |
| C(2)-H(2) | 0.993(15) | C(22)-H(22A) | 0.952(19) |
| C(3)-C(4) | 1.4841(16) | C(22)-H(22B) | 0.992(18) |
| C(4)-C(5) | 1.3494(16) | C(22)-H(22C) | 1.010(19) |
| C(5)-C(8) | 1.4430(15) | C(23)-C(28) | 1.3944(16) |
| C(6)-C(7) | 1.5017(18) | C(23)-C(24) | 1.3997(16) |
| C(6)-H(6A) | 1.001(17) | C(24)-C(25) | 1.3906(17) |
| C(6)-H(6B) | 0.997(15) | C(24)-H(24) | 0.973(16) |
| C(7)-H(7A) | 0.987(18) | C(25)-C(26) | 1.3886(18) |
| C(7)-H(7B) | 0.947(19) | C(25)-H(25) | 0.982(16) |
| C(7)-H(7C) | 1.006(19) | C(26)-C(27) | 1.3879(18) |
| C(8)-C(13) | 1.4019(15) | C(26)-H(26) | 0.997(17) |
| C(8)-C(9) | 1.4063(15) | C(27)-C(28) | 1.3931(17) |
| C(9)-C(10) | 1.3874(16) | C(27)-H(27) | 0.954(18) |
| C(10)-C(11) | 1.4043(17) | C(28)-H(28) | 0.970(16) |
| C(10)-H(10) | 0.924(15) | C(13)-O(1)-C(1) | 105.63(8) |
| C(11)-C(12) | 1.3962(16) | C(4)-O(3)-C(6) | 115.59(9) |
| C(12)-C(13) | 1.3852(16) | C(9)-O(4)-C(14) | 116.87(9) |
| C(12)-H(12) | 0.991(16) | C(11)-O(5)-C(15) | 118.12(9) |

| | |
|---|---|
| C(19)-O(6)-C(22) | 117.57(10) |
| O(1)-C(1)-C(5) | 103.63(8) |
| O(1)-C(1)-C(16) | 108.81(8) |
| C(5)-C(1)-C(16) | 112.08(9) |
| O(1)-C(1)-C(2) | 114.83(9) |
| C(5)-C(1)-C(2) | 103.93(8) |
| C(16)-C(1)-C(2) | 113.11(9) |
| C(23)-C(2)-C(3) | 118.85(9) |
| C(23)-C(2)-C(1) | 116.03(9) |
| C(3)-C(2)-C(1) | 100.72(8) |
| C(23)-C(2)-H(2) | 108.9(9) |
| C(3)-C(2)-H(2) | 104.3(9) |
| C(1)-C(2)-H(2) | 106.9(9) |
| O(2)-C(3)-C(4) | 125.90(10) |
| O(2)-C(3)-C(2) | 126.46(10) |
| C(4)-C(3)-C(2) | 107.54(9) |
| C(5)-C(4)-O(3) | 128.03(10) |
| C(5)-C(4)-C(3) | 109.19(10) |
| O(3)-C(4)-C(3) | 122.77(10) |
| C(4)-C(5)-C(8) | 142.68(11) |
| C(4)-C(5)-C(1) | 110.60(9) |
| C(8)-C(5)-C(1) | 105.17(9) |
| O(3)-C(6)-C(7) | 107.37(10) |
| O(3)-C(6)-H(6A) | 107.3(9) |
| C(7)-C(6)-H(6A) | 111.0(9) |
| O(3)-C(6)-H(6B) | 109.5(8) |
| C(7)-C(6)-H(6B) | 112.8(8) |
| H(6A)-C(6)-H(6B) | 108.7(12) |
| C(6)-C(7)-H(7A) | 110.7(10) |
| C(6)-C(7)-H(7B) | 109.6(11) |
| H(7A)-C(7)-H(7B) | 110.6(15) |
| C(6)-C(7)-H(7C) | 110.6(11) |
| H(7A)-C(7)-H(7C) | 106.1(15) |
| H(7B)-C(7)-H(7C) | 109.2(15) |
| C(13)-C(8)-C(9) | 118.29(10) |
| C(13)-C(8)-C(5) | 105.50(9) |
| C(9)-C(8)-C(5) | 135.90(10) |
| O(4)-C(9)-C(10) | 124.51(10) |
| O(4)-C(9)-C(8) | 116.54(10) |
| C(10)-C(9)-C(8) | 118.94(10) |
| C(9)-C(10)-C(11) | 120.62(11) |
| C(9)-C(10)-H(10) | 122.0(9) |
| C(11)-C(10)-H(10) | 117.3(9) |
| O(5)-C(11)-C(12) | 123.95(10) |
| O(5)-C(11)-C(10) | 113.94(10) |
| C(12)-C(11)-C(10) | 122.10(10) |
| C(13)-C(12)-C(11) | 115.62(10) |
| C(13)-C(12)-H(12) | 122.2(9) |
| C(11)-C(12)-H(12) | 122.2(9) |
| O(1)-C(13)-C(12) | 122.09(10) |
| O(1)-C(13)-C(8) | 113.44(9) |
| C(12)-C(13)-C(8) | 124.42(10) |
| O(4)-C(14)-H(14A) | 104.4(9) |
| O(4)-C(14)-H(14B) | 111.0(10) |
| H(14A)-C(14)-H(14B) | 110.2(13) |
| O(4)-C(14)-H(14C) | 111.8(9) |
| H(14A)-C(14)-H(14C) | 108.7(13) |
| H(14B)-C(14)-H(14C) | 110.6(13) |
| O(5)-C(15)-H(15A) | 106.5(10) |
| O(5)-C(15)-H(15B) | 109.8(9) |
| H(15A)-C(15)-H(15B) | 108.7(14) |
| O(5)-C(15)-H(15C) | 110.5(9) |
| H(15A)-C(15)-H(15C) | 111.9(14) |
| H(15B)-C(15)-H(15C) | 109.4(13) |
| C(17)-C(16)-C(21) | 118.00(10) |
| C(17)-C(16)-C(1) | 121.59(10) |
| C(21)-C(16)-C(1) | 120.41(10) |
| C(16)-C(17)-C(18) | 121.83(10) |
| C(16)-C(17)-H(17) | 119.9(9) |
| C(18)-C(17)-H(17) | 118.3(9) |
| C(19)-C(18)-C(17) | 119.25(11) |
| C(19)-C(18)-H(18) | 120.5(9) |

|  |  |  |  |
|---|---|---|---|
| C(17)-C(18)-H(18) | 120.2(9) | C(28)-C(23)-C(2) | 123.42(10) |
| O(6)-C(19)-C(18) | 124.63(11) | C(24)-C(23)-C(2) | 117.93(10) |
| O(6)-C(19)-C(20) | 115.73(10) | C(25)-C(24)-C(23) | 121.00(11) |
| C(18)-C(19)-C(20) | 119.64(11) | C(25)-C(24)-H(24) | 119.5(9) |
| C(21)-C(20)-C(19) | 120.21(11) | C(23)-C(24)-H(24) | 119.5(9) |
| C(21)-C(20)-H(20) | 120.0(9) | C(26)-C(25)-C(24) | 119.76(11) |
| C(19)-C(20)-H(20) | 119.8(9) | C(26)-C(25)-H(25) | 120.2(9) |
| C(20)-C(21)-C(16) | 121.06(11) | C(24)-C(25)-H(25) | 120.1(9) |
| C(20)-C(21)-H(21) | 118.7(9) | C(27)-C(26)-C(25) | 119.82(11) |
| C(16)-C(21)-H(21) | 120.2(9) | C(27)-C(26)-H(26) | 119.7(10) |
| O(6)-C(22)-H(22A) | 106.3(11) | C(25)-C(26)-H(26) | 120.5(10) |
| O(6)-C(22)-H(22B) | 111.0(10) | C(26)-C(27)-C(28) | 120.41(12) |
| H(22A)-C(22)-H(22B) | 111.5(15) | C(26)-C(27)-H(27) | 120.4(10) |
| O(6)-C(22)-H(22C) | 112.8(10) | C(28)-C(27)-H(27) | 119.2(10) |
| H(22A)-C(22)-H(22C) | 108.4(15) | C(27)-C(28)-C(23) | 120.39(11) |
| H(22B)-C(22)-H(22C) | 106.9(14) | C(27)-C(28)-H(28) | 119.7(10) |
| C(28)-C(23)-C(24) | 118.60(11) | C(23)-C(28)-H(28) | 119.9(10) |

Table 4. Anisotropic displacement parameters (Å$^2$x 10$^3$) for frojm03. The anisotropic displacement factor exponent takes the form: $-2\pi^2$[ $h^2$ $a^{*2}U_{11}$ + ... + 2 h k a* b* $U_{12}$ ]

| | $U_{11}$ | $U_{22}$ | $U_{33}$ | $U_{23}$ | $U_{13}$ | $U_{12}$ |
|---|---|---|---|---|---|---|
| O1 | 14(1) | 13(1) | 15(1) | -2(1) | 4(1) | -2(1) |
| O2 | 21(1) | 12(1) | 24(1) | 1(1) | 6(1) | -1(1) |
| O3 | 24(1) | 14(1) | 26(1) | 3(1) | 14(1) | 6(1) |
| O4 | 16(1) | 20(1) | 19(1) | -2(1) | 8(1) | -1(1) |
| O5 | 19(1) | 15(1) | 22(1) | -2(1) | 4(1) | -6(1) |
| O6 | 29(1) | 22(1) | 16(1) | 0(1) | -3(1) | 8(1) |
| C1 | 14(1) | 11(1) | 13(1) | 0(1) | 3(1) | -1(1) |
| C2 | 14(1) | 12(1) | 14(1) | 0(1) | 4(1) | -1(1) |
| C3 | 15(1) | 14(1) | 15(1) | 1(1) | 3(1) | 1(1) |
| C4 | 17(1) | 13(1) | 17(1) | 1(1) | 7(1) | 1(1) |
| C5 | 13(1) | 14(1) | 12(1) | 1(1) | 4(1) | 0(1) |
| C6 | 18(1) | 16(1) | 22(1) | -1(1) | 4(1) | 2(1) |
| C7 | 27(1) | 20(1) | 26(1) | -3(1) | 5(1) | 8(1) |
| C8 | 14(1) | 12(1) | 14(1) | 2(1) | 2(1) | 0(1) |
| C9 | 14(1) | 16(1) | 14(1) | 2(1) | 3(1) | 1(1) |
| C10 | 14(1) | 17(1) | 17(1) | 2(1) | 3(1) | -2(1) |
| C11 | 16(1) | 14(1) | 14(1) | 2(1) | 0(1) | -2(1) |
| C12 | 17(1) | 13(1) | 15(1) | 1(1) | 2(1) | -1(1) |
| C13 | 12(1) | 14(1) | 13(1) | 2(1) | 2(1) | -1(1) |
| C14 | 17(1) | 27(1) | 23(1) | 2(1) | 10(1) | 0(1) |
| C15 | 24(1) | 16(1) | 22(1) | -3(1) | 2(1) | -3(1) |
| C16 | 13(1) | 13(1) | 14(1) | 1(1) | 4(1) | 0(1) |
| C17 | 15(1) | 14(1) | 15(1) | -2(1) | 4(1) | 0(1) |
| C18 | 16(1) | 15(1) | 18(1) | -1(1) | 4(1) | 2(1) |
| C19 | 16(1) | 18(1) | 14(1) | 2(1) | 3(1) | 2(1) |
| C20 | 24(1) | 16(1) | 15(1) | -2(1) | 2(1) | 2(1) |
| C21 | 22(1) | 13(1) | 16(1) | 0(1) | 4(1) | 2(1) |
| C22 | 33(1) | 26(1) | 20(1) | 3(1) | 1(1) | 14(1) |
| C23 | 15(1) | 12(1) | 14(1) | 2(1) | 4(1) | -1(1) |
| C24 | 18(1) | 18(1) | 14(1) | -1(1) | 4(1) | 0(1) |
| C25 | 20(1) | 22(1) | 16(1) | 1(1) | 7(1) | 3(1) |

| | | | | | | |
|---|---|---|---|---|---|---|
| C26 | 15(1) | 23(1) | 22(1) | 3(1) | 6(1) | 0(1) |
| C27 | 17(1) | 20(1) | 25(1) | -4(1) | 4(1) | -4(1) |
| C28 | 18(1) | 15(1) | 21(1) | -3(1) | 6(1) | -1(1) |

Table 5. Hydrogen coordinates (x 10 $^4$) and isotropic displacement parameters (Å$^2$ x 10$^3$) for frojm03.

| | x | y | z | U(eq) |
|---|---|---|---|---|
| H2 | 7109(15) | 1914(6) | 6948(18) | 21(4) |
| H6A | 3708(16) | 2695(7) | 8319(19) | 28(4) |
| H6B | 5049(14) | 3010(6) | 8388(17) | 16(3) |
| H7A | 3536(17) | 3584(7) | 9440(20) | 36(5) |
| H7B | 4799(18) | 3462(8) | 10690(20) | 39(5) |
| H7C | 3539(18) | 3127(8) | 10760(20) | 42(5) |
| H10 | 2685(14) | 288(6) | 9113(17) | 20(4) |
| H12 | 5497(15) | -25(6) | 6754(19) | 23(4) |
| H14A | 2263(15) | 1384(7) | 11630(18) | 23(4) |
| H14B | 2591(16) | 717(7) | 11560(20) | 30(4) |
| H14C | 1721(16) | 1035(7) | 10062(19) | 25(4) |
| H15A | 3297(17) | -1117(7) | 6390(20) | 32(4) |
| H15B | 4695(16) | -920(6) | 7144(19) | 25(4) |
| H15C | 3961(15) | -639(7) | 5526(19) | 23(4) |
| H17 | 8390(14) | 378(6) | 9256(17) | 17(4) |
| H18 | 9871(15) | 35(7) | 11423(18) | 23(4) |
| H20 | 9752(15) | 1548(7) | 13613(18) | 23(4) |
| H21 | 8201(14) | 1861(6) | 11519(17) | 17(4) |
| H22A | 11789(18) | 13(7) | 15120(20) | 40(5) |
| H22B | 11816(16) | -6(7) | 13300(20) | 32(4) |
| H22C | 10604(17) | -229(8) | 13920(20) | 35(5) |
| H24 | 8860(15) | 1357(6) | 6234(18) | 21(4) |
| H25 | 11039(15) | 1328(7) | 6193(18) | 24(4) |
| H26 | 12493(16) | 1906(7) | 7924(19) | 30(4) |
| H27 | 11707(16) | 2482(7) | 9690(20) | 32(5) |
| H28 | 9557(15) | 2498(7) | 9773(19) | 24(4) |

Table 6. Torsion angles [°] for frojm03.

| | | | |
|---|---|---|---|
| C13-O1-C1-C5 | -23.12(10) | C14-O4-C9-C10 | 1.91(16) |
| C13-O1-C1-C16 | 96.30(10) | C14-O4-C9-C8 | -176.78(10) |
| C13-O1-C1-C2 | -135.78(9) | C13-C8-C9-O4 | 177.67(10) |
| O1-C1-C2-C23 | -90.47(11) | C5-C8-C9-O4 | -9.79(19) |
| C5-C1-C2-C23 | 157.05(9) | C13-C8-C9-C10 | -1.10(16) |
| C16-C1-C2-C23 | 35.25(13) | C5-C8-C9-C10 | 171.45(12) |
| O1-C1-C2-C3 | 139.82(9) | O4-C9-C10-C11 | -177.71(10) |
| C5-C1-C2-C3 | 27.34(10) | C8-C9-C10-C11 | 0.96(17) |
| C16-C1-C2-C3 | -94.46(10) | C15-O5-C11-C12 | 6.21(16) |
| C23-C2-C3-O2 | 31.70(17) | C15-O5-C11-C10 | -173.60(10) |
| C1-C2-C3-O2 | 159.58(11) | C9-C10-C11-O5 | 179.06(10) |
| C23-C2-C3-C4 | -151.82(10) | C9-C10-C11-C12 | -0.75(17) |
| C1-C2-C3-C4 | -23.93(11) | O5-C11-C12-C13 | -179.14(10) |
| C6-O3-C4-C5 | -125.23(13) | C10-C11-C12-C13 | 0.65(16) |
| C6-O3-C4-C3 | 55.94(15) | C1-O1-C13-C12 | -169.68(10) |
| O2-C3-C4-C5 | -172.50(12) | C1-O1-C13-C8 | 12.87(12) |
| C2-C3-C4-C5 | 10.99(13) | C11-C12-C13-O1 | -178.00(10) |
| O2-C3-C4-O3 | 6.53(19) | C11-C12-C13-C8 | -0.84(16) |
| C2-C3-C4-O3 | -169.98(10) | C9-C8-C13-O1 | 178.47(9) |
| O3-C4-C5-C8 | 26.3(2) | C5-C8-C13-O1 | 3.84(13) |
| C3-C4-C5-C8 | -154.76(15) | C9-C8-C13-C12 | 1.09(17) |
| O3-C4-C5-C1 | -171.15(11) | C5-C8-C13-C12 | -173.53(11) |
| C3-C4-C5-C1 | 7.81(13) | O1-C1-C16-C17 | 9.05(14) |
| O1-C1-C5-C4 | -143.58(9) | C5-C1-C16-C17 | 123.06(11) |
| C16-C1-C5-C4 | 99.26(11) | C2-C1-C16-C17 | -119.84(11) |
| C2-C1-C5-C4 | -23.22(12) | O1-C1-C16-C21 | -171.56(10) |
| O1-C1-C5-C8 | 25.57(10) | C5-C1-C16-C21 | -57.55(13) |
| C16-C1-C5-C8 | -91.58(10) | C2-C1-C16-C21 | 59.55(13) |
| C2-C1-C5-C8 | 145.94(9) | C21-C16-C17-C18 | 0.60(17) |
| C4-O3-C6-C7 | -154.76(11) | C1-C16-C17-C18 | 180.00(10) |
| C4-C5-C8-C13 | 144.90(16) | C16-C17-C18-C19 | -0.65(17) |
| C1-C5-C8-C13 | -18.22(11) | C22-O6-C19-C18 | -4.11(18) |
| C4-C5-C8-C9 | -28.3(3) | C22-O6-C19-C20 | 175.97(12) |
| C1-C5-C8-C9 | 168.59(13) | C17-C18-C19-O6 | -179.87(11) |

|  |  |  |  |
|---|---|---|---|
| C17-C18-C19-C20 | 0.04(17) | C1-C2-C23-C24 | 73.79(13) |
| O6-C19-C20-C21 | -179.48(11) | C28-C23-C24-C25 | 0.57(17) |
| C18-C19-C20-C21 | 0.59(18) | C2-C23-C24-C25 | -176.82(10) |
| C19-C20-C21-C16 | -0.65(19) | C23-C24-C25-C26 | -1.54(18) |
| C17-C16-C21-C20 | 0.05(17) | C24-C25-C26-C27 | 1.17(18) |
| C1-C16-C21-C20 | -179.36(11) | C25-C26-C27-C28 | 0.13(19) |
| C3-C2-C23-C28 | 16.89(16) | C26-C27-C28-C23 | -1.11(19) |
| C1-C2-C23-C28 | -103.46(12) | C24-C23-C28-C27 | 0.75(17) |
| C3-C2-C23-C24 | -165.86(10) | C2-C23-C28-C27 | 177.98(11) |

REFERENCE NUMBER: frojm09

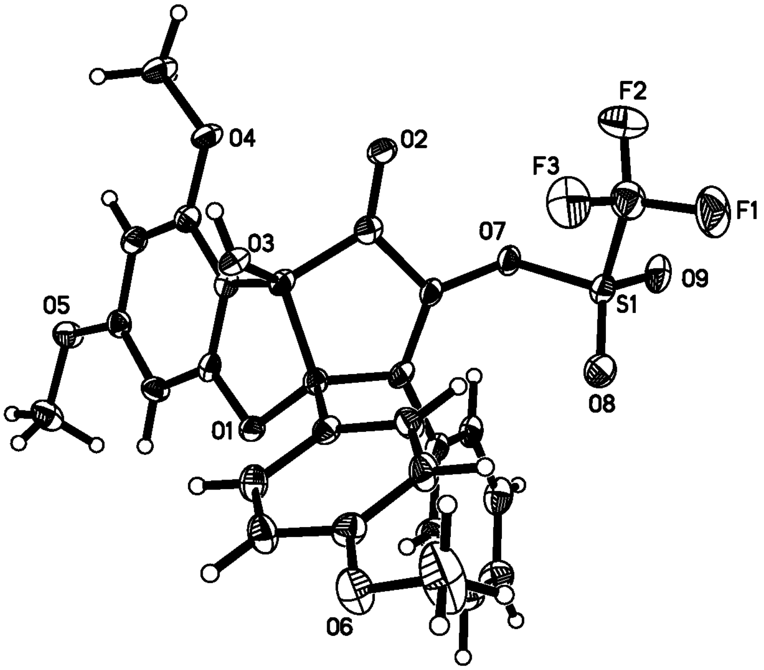
# CRYSTAL STRUCTURE REPORT

$C_{27} H_{21} F_3 O_9 S$

Report prepared for:

J. Malona, Prof. A. Frontier

September 10, 2008



William W. Brennessel

X-ray Crystallographic Facility

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120 Trustee Road

Rochester, NY 14627

## Data collection

A crystal (0.24 x 0.06 x 0.05 $mm^3$) was placed onto the tip of a 0.1 mm diameter glass capillary tube or fiber and mounted on a Bruker SMART APEX II CCD Platform diffractometer for a data collection at 100.0(1) K.[1] A preliminary set of cell constants and an orientation matrix were calculated from reflections harvested from three orthogonal wedges of reciprocal space. The full data collection was carried out using MoK$\alpha$ radiation (graphite monochromator) with a frame time of 60 seconds and a detector distance of 3.99 cm. A randomly oriented region of reciprocal space was surveyed: three major sections of frames were collected with 0.50° steps in $\omega$ at three different $\phi$ settings and a detector position of -38° in $2\theta$. The intensity data were corrected for absorption.[2] Final cell constants were calculated from the xyz centroids of 2737 strong reflections from the actual data collection after integration.[3] See Table 1 for additional crystal and refinement information.

## Structure solution and refinement

The structure was solved using SIR97[4] and refined using SHELXL-97.[5] The space group *P*-1 was determined based on the lack of systematic absences and intensity statistics. A direct-methods solution was calculated which provided most non-hydrogen atoms from the E-map. Full-matrix least squares / difference Fourier cycles were performed which located the remaining non-hydrogen atoms. All non-hydrogen atoms were refined with anisotropic displacement parameters. The hydroxyl hydrogen atom was found from the difference Fourier map and refined independently from O3, with an individual isotropic displacement parameter. All other hydrogen atoms were placed in ideal positions and refined as riding atoms with relative isotropic displacement parameters. The final full matrix least squares refinement converged to $R1 = 0.0583$ ($F^2$, $I > 2\sigma(I)$) and $wR2 = 0.1494$ ($F^2$, all data).

## Structure description

The structure is the one suggested with all atoms in general positions. The molecules are ordered in pairs through bi-directional hydrogen bonding (see diagram and Table 7).

Unless noted otherwise all structural diagrams containing thermal displacement ellipsoids are drawn at the 50 % probability level.

Data collection, structure solution, and structure refinement were conducted at the X-ray Crystallographic Facility, B51 Hutchison Hall, Department of Chemistry, University of Rochester. All publications arising from this report MUST either 1) include William W. Brennessel as a coauthor or 2) acknowledge William W. Brennessel and the X-ray Crystallographic Facility of the Department of Chemistry at the University of Rochester.

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[1] *APEX2*, version 2.2-0; Bruker AXS: Madison, WI, 2007.

[2] Sheldrick, G. M. *SADABS*, version 2007/4; University of Göttingen: Göttingen, Germany, 2007.

[3] *SAINT*, version 7.46A; Bruker AXS: Madison, WI, 2007.

[4] Altomare, A.; Burla, M. C.; Camalli, M.; Cascarano, G. L.; Giacovazzo, C.; Guagliardi, A.; Moliterni, A. G. G.; Polidori, G.; Spagna, R. *SIR97: A new program for solving and refining crystal structures*; Istituto di Cristallografia, CNR: Bari, Italy, 1999.

[5] Sheldrick, G. M. *Acta. Cryst.* **2008**, *A64*, 112-122.

Some equations of interest:

$$R_{\mathrm{int}} = \Sigma|F_o^2 - \langle F_o^2\rangle| \;/\; \Sigma|F_o^2|$$

$$R1 = \Sigma||F_o|-|F_c|| \;/\; \Sigma|F_o|$$

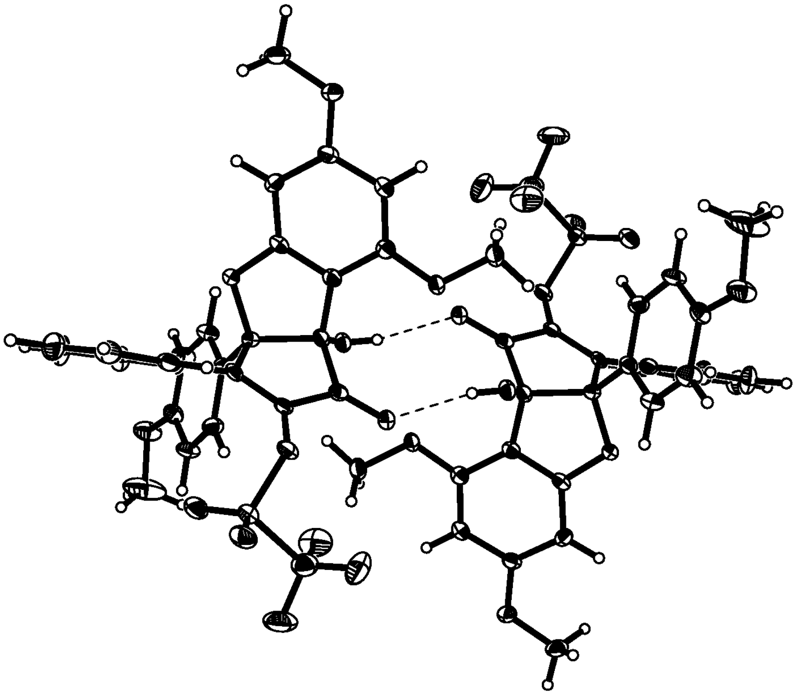
$$wR2 = [\Sigma[w(F_o^2-F_c^2)^2] \;/\; \Sigma[w(F_o^2)^2]]^{1/2}$$

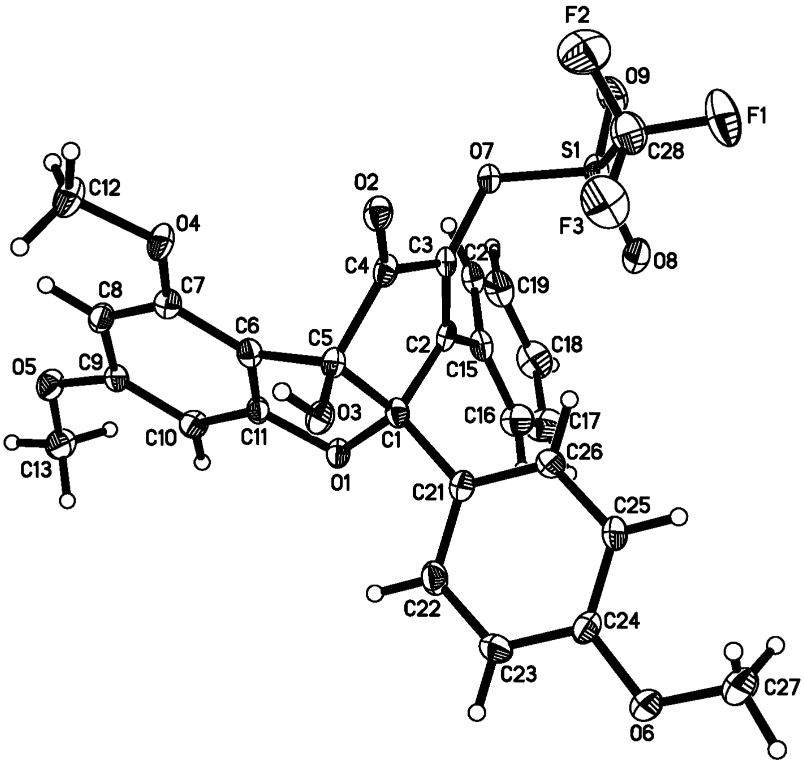
where $w = 1 / [\sigma^2(F_o^2) + (aP)^2 + bP]$ and

$$P = 1/3 \max(0, F_o^2) + 2/3\, F_c^2$$

$$\mathrm{GOF} = S = [\Sigma[w(F_o^2-F_c^2)^2] \;/\; (m-n)]^{1/2}$$

where $m$ = number of reflections and $n$ = number of parameters

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F1
S1
C28
O7
O2
C12
O4
F3
O8
C3
C20
C4
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C7
C6
C5
C2
C18
C15
O5
C9
O3
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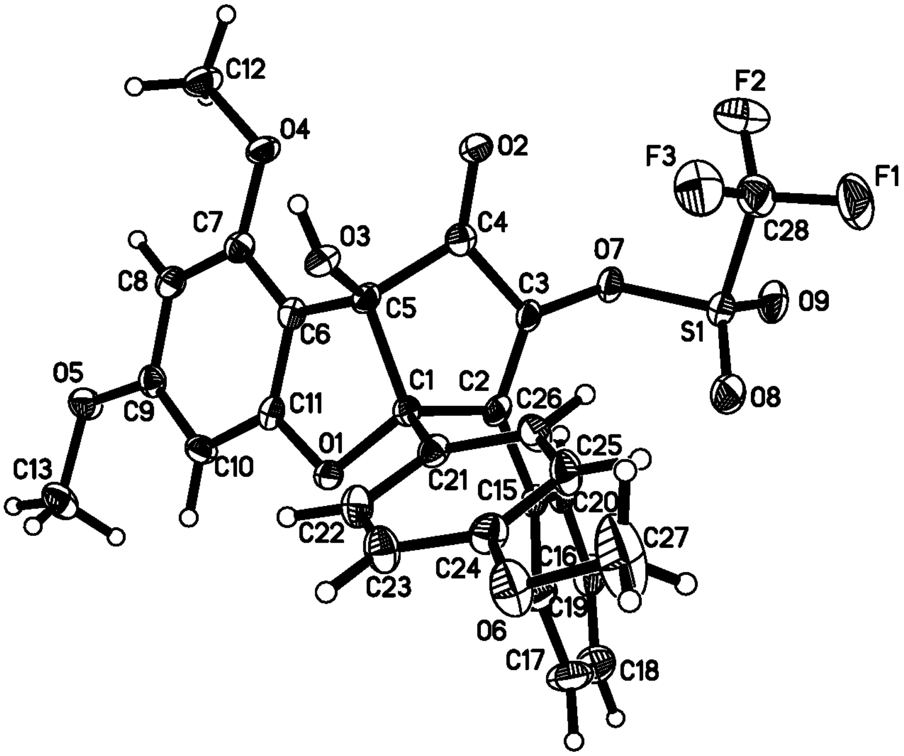
O1
C21
C25
C22
C24
C23
C27
O6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F2
O4
O2
F3
F1
C28
C7
O3
C4
O7
C8
C5
C3
S1
O9
C6
O5
C1
C2
C26
O8
C9
C11
C25
C13
C10
O1
C21
C15
C20
C22
C27
C24
C16
C23
O6
C19
C17
C18

Table 1. Crystal data and structure refinement for frojm09.

| | | |
|---|---|---|
| Identification code | frojm09 | |
| Empirical formula | C27 H21 F3 O9 S | |
| Formula weight | 578.50 | |
| Temperature | 100.0(1) K | |
| Wavelength | 0.71073 Å | |
| Crystal system | Triclinic | |
| Space group | *P*-1 | |
| Unit cell dimensions | $a$ = 9.0885(14) Å | $\alpha$ = 85.558(3)° |
| | $b$ = 9.8939(15) Å | $\beta$ = 79.432(3)° |
| | $c$ = 14.454(2) Å | $\gamma$ = 77.598(3)° |
| Volume | 1246.9(3) $\text{Å}^3$ | |
| $Z$ | 2 | |
| Density (calculated) | 1.541 $\text{Mg/m}^3$ | |
| Absorption coefficient | 0.209 $\text{mm}^{-1}$ | |
| $F$(000) | 596 | |
| Crystal color, morphology | pale yellow, needle | |
| Crystal size | 0.24 x 0.06 x 0.05 $\text{mm}^3$ | |
| Theta range for data collection | 1.43 to 29.57° | |
| Index ranges | $-12 \le h \le 12, -13 \le k \le 13, -20 \le l \le 20$ | |
| Reflections collected | 14383 | |
| Independent reflections | 6890 [$R$(int) = 0.0779] | |
| Observed reflections | 3660 | |
| Completeness to theta = 29.57° | 98.4% | |
| Absorption correction | Multi-scan | |
| Max. and min. transmission | 0.9896 and 0.9516 | |
| Refinement method | Full-matrix least-squares on $F^2$ | |
| Data / restraints / parameters | 6890 / 0 / 368 | |
| Goodness-of-fit on $F^2$ | 0.960 | |
| Final $R$ indices [$I$>2sigma($I$)] | $R$1 = 0.0583, $wR$2 = 0.1123 | |
| $R$ indices (all data) | $R$1 = 0.1319, $wR$2 = 0.1494 | |
| Largest diff. peak and hole | 0.350 and -0.387 $\text{e.Å}^{-3}$ | |

Table 2. Atomic coordinates (x $10^4$) and equivalent isotropic displacement parameters ($Å^2$x $10^3$ ) for frojm09. $U_{eq}$ is defined as one third of the trace of the orthogonalized $U_{ij}$ tensor.

| | x | y | z | $U_{eq}$ |
|---|---|---|---|---|
| S1 | -1740(1) | 1645(1) | 8999(1) | 20(1) |
| F1 | -2749(3) | -519(2) | 9697(1) | 46(1) |
| F2 | -3735(2) | 452(2) | 8512(2) | 43(1) |
| F3 | -1444(3) | -754(2) | 8300(2) | 41(1) |
| O1 | 3249(2) | 2510(2) | 6111(1) | 17(1) |
| O2 | -1165(2) | 662(2) | 6299(1) | 19(1) |
| O3 | 2034(2) | 17(2) | 5390(1) | 18(1) |
| O4 | -564(2) | 2447(2) | 4403(1) | 20(1) |
| O5 | 2428(2) | 5886(2) | 3564(1) | 22(1) |
| O6 | 6467(2) | -3073(2) | 7842(2) | 30(1) |
| O7 | -1564(2) | 2270(2) | 7957(1) | 19(1) |
| O8 | -312(3) | 1197(2) | 9291(2) | 29(1) |
| O9 | -2964(2) | 2571(2) | 9513(1) | 26(1) |
| C1 | 2355(3) | 1526(3) | 6575(2) | 16(1) |
| C2 | 1157(3) | 2238(3) | 7365(2) | 16(1) |
| C3 | -186(3) | 1917(3) | 7322(2) | 16(1) |
| C4 | -165(3) | 1195(3) | 6470(2) | 17(1) |
| C5 | 1370(3) | 1250(3) | 5852(2) | 16(1) |
| C6 | 1377(3) | 2538(3) | 5236(2) | 16(1) |
| C7 | 566(3) | 3091(3) | 4517(2) | 17(1) |
| C8 | 949(3) | 4216(3) | 3977(2) | 18(1) |
| C9 | 2145(3) | 4791(3) | 4150(2) | 18(1) |
| C10 | 2966(3) | 4266(3) | 4864(2) | 18(1) |
| C11 | 2526(3) | 3148(3) | 5389(2) | 16(1) |
| C12 | -1274(4) | 2846(3) | 3591(2) | 25(1) |
| C13 | 3696(4) | 6464(3) | 3669(2) | 26(1) |
| C15 | 1510(3) | 3136(3) | 8016(2) | 18(1) |
| C16 | 2903(4) | 2855(3) | 8325(2) | 25(1) |
| C17 | 3225(4) | 3739(4) | 8922(2) | 32(1) |
| C18 | 2173(4) | 4935(4) | 9190(2) | 33(1) |
| C19 | 793(4) | 5244(3) | 8869(2) | 27(1) |

|  |  |  |  |  |
|---|---|---|---|---|
| C20 | 446(4) | 4343(3) | 8294(2) | 21(1) |
| C21 | 3418(3) | 275(3) | 6919(2) | 16(1) |
| C22 | 4920(3) | -87(3) | 6461(2) | 21(1) |
| C23 | 5895(4) | -1222(3) | 6786(2) | 24(1) |
| C24 | 5388(3) | -2019(3) | 7554(2) | 21(1) |
| C25 | 3887(3) | -1694(3) | 8002(2) | 23(1) |
| C26 | 2913(3) | -541(3) | 7677(2) | 20(1) |
| C27 | 5930(5) | -4019(4) | 8537(3) | 59(1) |
| C28 | -2469(4) | 102(4) | 8864(2) | 30(1) |

Table 3. Bond lengths [Å] and angles [°] for frojm09.

| | |
|---|---|
| S(1)-O(8) | 1.408(2) |
| S(1)-O(9) | 1.412(2) |
| S(1)-O(7) | 1.577(2) |
| S(1)-C(28) | 1.826(3) |
| F(1)-C(28) | 1.317(4) |
| F(2)-C(28) | 1.311(4) |
| F(3)-C(28) | 1.319(4) |
| O(1)-C(11) | 1.375(3) |
| O(1)-C(1) | 1.448(3) |
| O(2)-C(4) | 1.213(3) |
| O(3)-C(5) | 1.401(3) |
| O(3)-H(3) | 0.79(4) |
| O(4)-C(7) | 1.359(3) |
| O(4)-C(12) | 1.431(3) |
| O(5)-C(9) | 1.362(3) |
| O(5)-C(13) | 1.427(4) |
| O(6)-C(24) | 1.366(4) |
| O(6)-C(27) | 1.412(4) |
| O(7)-C(3) | 1.404(3) |
| C(1)-C(21) | 1.510(4) |
| C(1)-C(2) | 1.525(4) |
| C(1)-C(5) | 1.569(4) |
| C(2)-C(3) | 1.339(4) |
| C(2)-C(15) | 1.462(4) |
| C(3)-C(4) | 1.466(4) |
| C(4)-C(5) | 1.522(4) |
| C(5)-C(6) | 1.497(4) |
| C(6)-C(11) | 1.371(4) |
| C(6)-C(7) | 1.394(4) |
| C(7)-C(8) | 1.380(4) |
| C(8)-C(9) | 1.398(4) |
| C(8)-H(8) | 0.9500 |
| C(9)-C(10) | 1.387(4) |
| C(10)-C(11) | 1.380(4) |
| C(10)-H(10) | 0.9500 |
| C(12)-H(12A) | 0.9800 |
| C(12)-H(12B) | 0.9800 |
| C(12)-H(12C) | 0.9800 |
| C(13)-H(13A) | 0.9800 |
| C(13)-H(13B) | 0.9800 |
| C(13)-H(13C) | 0.9800 |
| C(15)-C(16) | 1.385(4) |
| C(15)-C(20) | 1.400(4) |
| C(16)-C(17) | 1.383(4) |
| C(16)-H(16) | 0.9500 |
| C(17)-C(18) | 1.384(5) |
| C(17)-H(17) | 0.9500 |
| C(18)-C(19) | 1.382(5) |
| C(18)-H(18) | 0.9500 |
| C(19)-C(20) | 1.384(4) |
| C(19)-H(19) | 0.9500 |
| C(20)-H(20) | 0.9500 |
| C(21)-C(26) | 1.379(4) |
| C(21)-C(22) | 1.387(4) |
| C(22)-C(23) | 1.382(4) |
| C(22)-H(22) | 0.9500 |
| C(23)-C(24) | 1.379(4) |
| C(23)-H(23) | 0.9500 |
| C(24)-C(25) | 1.379(4) |
| C(25)-C(26) | 1.393(4) |
| C(25)-H(25) | 0.9500 |
| C(26)-H(26) | 0.9500 |
| C(27)-H(27D) | 0.9800 |
| C(27)-H(27A) | 0.9800 |
| C(27)-H(27B) | 0.9800 |
| O(8)-S(1)-O(9) | 122.88(14) |
| O(8)-S(1)-O(7) | 111.65(12) |
| O(9)-S(1)-O(7) | 105.38(12) |

| | | | |
|---|---|---|---|
| O(8)-S(1)-C(28) | 107.38(16) | C(7)-C(8)-C(9) | 120.0(3) |
| O(9)-S(1)-C(28) | 106.30(15) | C(7)-C(8)-H(8) | 120.0 |
| O(7)-S(1)-C(28) | 101.00(13) | C(9)-C(8)-H(8) | 120.0 |
| C(11)-O(1)-C(1) | 106.6(2) | O(5)-C(9)-C(10) | 123.6(3) |
| C(5)-O(3)-H(3) | 110(3) | O(5)-C(9)-C(8) | 114.7(2) |
| C(7)-O(4)-C(12) | 117.6(2) | C(10)-C(9)-C(8) | 121.7(3) |
| C(9)-O(5)-C(13) | 117.2(2) | C(11)-C(10)-C(9) | 115.9(3) |
| C(24)-O(6)-C(27) | 116.4(3) | C(11)-C(10)-H(10) | 122.1 |
| C(3)-O(7)-S(1) | 121.14(17) | C(9)-C(10)-H(10) | 122.1 |
| O(1)-C(1)-C(21) | 109.0(2) | C(6)-C(11)-O(1) | 113.2(2) |
| O(1)-C(1)-C(2) | 108.9(2) | C(6)-C(11)-C(10) | 124.5(3) |
| C(21)-C(1)-C(2) | 113.0(2) | O(1)-C(11)-C(10) | 122.3(3) |
| O(1)-C(1)-C(5) | 106.2(2) | O(4)-C(12)-H(12A) | 109.5 |
| C(21)-C(1)-C(5) | 116.1(2) | O(4)-C(12)-H(12B) | 109.5 |
| C(2)-C(1)-C(5) | 103.1(2) | H(12A)-C(12)-H(12B) | 109.5 |
| C(3)-C(2)-C(15) | 128.9(3) | O(4)-C(12)-H(12C) | 109.5 |
| C(3)-C(2)-C(1) | 108.5(2) | H(12A)-C(12)-H(12C) | 109.5 |
| C(15)-C(2)-C(1) | 122.6(3) | H(12B)-C(12)-H(12C) | 109.5 |
| C(2)-C(3)-O(7) | 127.3(3) | O(5)-C(13)-H(13A) | 109.5 |
| C(2)-C(3)-C(4) | 113.3(3) | O(5)-C(13)-H(13B) | 109.5 |
| O(7)-C(3)-C(4) | 119.3(2) | H(13A)-C(13)-H(13B) | 109.5 |
| O(2)-C(4)-C(3) | 126.9(3) | O(5)-C(13)-H(13C) | 109.5 |
| O(2)-C(4)-C(5) | 127.5(3) | H(13A)-C(13)-H(13C) | 109.5 |
| C(3)-C(4)-C(5) | 105.6(2) | H(13B)-C(13)-H(13C) | 109.5 |
| O(3)-C(5)-C(6) | 114.7(2) | C(16)-C(15)-C(20) | 119.2(3) |
| O(3)-C(5)-C(4) | 112.7(2) | C(16)-C(15)-C(2) | 121.5(3) |
| C(6)-C(5)-C(4) | 114.2(2) | C(20)-C(15)-C(2) | 119.2(3) |
| O(3)-C(5)-C(1) | 111.2(2) | C(17)-C(16)-C(15) | 120.4(3) |
| C(6)-C(5)-C(1) | 99.6(2) | C(17)-C(16)-H(16) | 119.8 |
| C(4)-C(5)-C(1) | 102.8(2) | C(15)-C(16)-H(16) | 119.8 |
| C(11)-C(6)-C(7) | 118.4(3) | C(16)-C(17)-C(18) | 120.1(3) |
| C(11)-C(6)-C(5) | 109.2(2) | C(16)-C(17)-H(17) | 120.0 |
| C(7)-C(6)-C(5) | 131.9(3) | C(18)-C(17)-H(17) | 120.0 |
| O(4)-C(7)-C(8) | 124.8(3) | C(19)-C(18)-C(17) | 120.1(3) |
| O(4)-C(7)-C(6) | 115.7(3) | C(19)-C(18)-H(18) | 120.0 |
| C(8)-C(7)-C(6) | 119.4(3) | C(17)-C(18)-H(18) | 120.0 |

| | | | |
|---|---|---|---|
| C(18)-C(19)-C(20) | 120.1(3) | C(24)-C(25)-C(26) | 119.1(3) |
| C(18)-C(19)-H(19) | 119.9 | C(24)-C(25)-H(25) | 120.5 |
| C(20)-C(19)-H(19) | 119.9 | C(26)-C(25)-H(25) | 120.5 |
| C(19)-C(20)-C(15) | 120.1(3) | C(21)-C(26)-C(25) | 121.4(3) |
| C(19)-C(20)-H(20) | 120.0 | C(21)-C(26)-H(26) | 119.3 |
| C(15)-C(20)-H(20) | 120.0 | C(25)-C(26)-H(26) | 119.3 |
| C(26)-C(21)-C(22) | 118.8(3) | O(6)-C(27)-H(27D) | 109.5 |
| C(26)-C(21)-C(1) | 121.0(3) | O(6)-C(27)-H(27A) | 109.5 |
| C(22)-C(21)-C(1) | 120.2(2) | H(27D)-C(27)-H(27A) | 109.5 |
| C(23)-C(22)-C(21) | 120.0(3) | O(6)-C(27)-H(27B) | 109.5 |
| C(23)-C(22)-H(22) | 120.0 | H(27D)-C(27)-H(27B) | 109.5 |
| C(21)-C(22)-H(22) | 120.0 | H(27A)-C(27)-H(27B) | 109.5 |
| C(24)-C(23)-C(22) | 120.7(3) | F(2)-C(28)-F(1) | 109.3(3) |
| C(24)-C(23)-H(23) | 119.6 | F(2)-C(28)-F(3) | 109.5(3) |
| C(22)-C(23)-H(23) | 119.6 | F(1)-C(28)-F(3) | 109.2(3) |
| O(6)-C(24)-C(25) | 124.3(3) | F(2)-C(28)-S(1) | 110.0(2) |
| O(6)-C(24)-C(23) | 115.8(3) | F(1)-C(28)-S(1) | 108.8(2) |
| C(25)-C(24)-C(23) | 119.9(3) | F(3)-C(28)-S(1) | 110.0(2) |

Table 4. Anisotropic displacement parameters ($Å^2$x $10^3$) for frojm09. The anisotropic displacement factor exponent takes the form: $-2\pi^2$[ $h^2$ $a^{*2}U_{11}$ + ... + 2 h k a* b* $U_{12}$ ]

| | $U_{11}$ | $U_{22}$ | $U_{33}$ | $U_{23}$ | $U_{13}$ | $U_{12}$ |
|---|---|---|---|---|---|---|
| S1 | 23(1) | 23(1) | 14(1) | 2(1) | -4(1) | -7(1) |
| F1 | 63(2) | 42(1) | 34(1) | 12(1) | 0(1) | -27(1) |
| F2 | 39(1) | 44(1) | 55(1) | -5(1) | -16(1) | -20(1) |
| F3 | 54(1) | 24(1) | 43(1) | -7(1) | 2(1) | -8(1) |
| O1 | 19(1) | 19(1) | 14(1) | 3(1) | -5(1) | -7(1) |
| O2 | 23(1) | 22(1) | 16(1) | 1(1) | -7(1) | -9(1) |
| O3 | 22(1) | 16(1) | 16(1) | -1(1) | -7(1) | -4(1) |
| O4 | 27(1) | 21(1) | 17(1) | 4(1) | -11(1) | -11(1) |
| O5 | 23(1) | 23(1) | 23(1) | 8(1) | -7(1) | -10(1) |
| O6 | 23(1) | 28(1) | 31(1) | 11(1) | 0(1) | 4(1) |
| O7 | 19(1) | 23(1) | 12(1) | 3(1) | -2(1) | -2(1) |
| O8 | 26(1) | 38(1) | 23(1) | 11(1) | -9(1) | -8(1) |
| O9 | 32(1) | 28(1) | 17(1) | -4(1) | 3(1) | -5(1) |
| C1 | 19(2) | 17(2) | 13(1) | 2(1) | -3(1) | -7(1) |
| C2 | 21(2) | 15(1) | 12(1) | 4(1) | -7(1) | -3(1) |
| C3 | 20(2) | 16(1) | 11(1) | 3(1) | -3(1) | -4(1) |
| C4 | 22(2) | 14(1) | 16(1) | 5(1) | -6(1) | -5(1) |
| C5 | 20(2) | 17(2) | 12(1) | 1(1) | -5(1) | -5(1) |
| C6 | 19(2) | 16(2) | 13(1) | 0(1) | -2(1) | -4(1) |
| C7 | 19(2) | 15(1) | 16(1) | -1(1) | -3(1) | -3(1) |
| C8 | 20(2) | 19(2) | 16(1) | 1(1) | -5(1) | -2(1) |
| C9 | 18(2) | 19(2) | 15(1) | 3(1) | -2(1) | -3(1) |
| C10 | 17(2) | 18(2) | 21(2) | 1(1) | -4(1) | -7(1) |
| C11 | 18(2) | 16(2) | 11(1) | 0(1) | -2(1) | 0(1) |
| C12 | 31(2) | 24(2) | 24(2) | 4(1) | -15(1) | -10(1) |
| C13 | 22(2) | 26(2) | 31(2) | 12(1) | -5(1) | -9(1) |
| C15 | 24(2) | 18(2) | 12(1) | 0(1) | -2(1) | -8(1) |
| C16 | 26(2) | 28(2) | 24(2) | -6(1) | -6(1) | -5(1) |
| C17 | 26(2) | 42(2) | 33(2) | -10(2) | -13(2) | -9(2) |
| C18 | 40(2) | 34(2) | 28(2) | -9(2) | -5(2) | -16(2) |
| C19 | 38(2) | 20(2) | 21(2) | -4(1) | 1(1) | -7(2) |

| | | | | | | |
|---|---|---|---|---|---|---|
| C20 | 27(2) | 20(2) | 14(1) | 3(1) | -1(1) | -7(1) |
| C21 | 21(2) | 14(1) | 15(1) | 1(1) | -5(1) | -4(1) |
| C22 | 26(2) | 20(2) | 17(1) | 4(1) | -1(1) | -5(1) |
| C23 | 20(2) | 24(2) | 23(2) | 0(1) | 3(1) | 0(1) |
| C24 | 22(2) | 20(2) | 20(1) | 4(1) | -7(1) | -1(1) |
| C25 | 24(2) | 22(2) | 19(2) | 9(1) | -1(1) | -4(1) |
| C26 | 16(2) | 23(2) | 21(2) | 4(1) | -2(1) | -5(1) |
| C27 | 38(2) | 52(3) | 60(3) | 38(2) | 8(2) | 17(2) |
| C28 | 36(2) | 26(2) | 29(2) | 2(2) | -3(2) | -11(2) |

Table 5. Hydrogen coordinates (x 10 $^{4}$) and isotropic displacement parameters (Å$^{2}$ x 10$^{3}$) for frojm09.

| | x | y | z | U(eq) |
|---|---|---|---|---|
| H3 | 1560(40) | -80(40) | 5000(30) | 42(12) |
| H8 | 399 | 4601 | 3487 | 22 |
| H10 | 3780 | 4652 | 4985 | 22 |
| H12A | -2049 | 2295 | 3585 | 37 |
| H12B | -499 | 2686 | 3021 | 37 |
| H12C | -1762 | 3831 | 3612 | 37 |
| H13A | 3785 | 7234 | 3208 | 39 |
| H13B | 4636 | 5751 | 3566 | 39 |
| H13C | 3537 | 6804 | 4307 | 39 |
| H16 | 3642 | 2050 | 8126 | 30 |
| H17 | 4170 | 3524 | 9148 | 39 |
| H18 | 2400 | 5545 | 9595 | 39 |
| H19 | 81 | 6075 | 9043 | 32 |
| H20 | -515 | 4545 | 8088 | 25 |
| H22 | 5278 | 446 | 5925 | 26 |
| H23 | 6927 | -1456 | 6475 | 29 |
| H25 | 3523 | -2249 | 8524 | 27 |
| H26 | 1879 | -312 | 7985 | 24 |
| H27D | 6786 | -4762 | 8657 | 88 |
| H27A | 5163 | -4416 | 8316 | 88 |
| H27B | 5467 | -3536 | 9119 | 88 |

Table 6. Torsion angles [°] for frojm09.

| | | | |
|---|---|---|---|
| O8-S1-O7-C3 | 22.7(2) | O1-C1-C5-C4 | -139.8(2) |
| O9-S1-O7-C3 | 158.4(2) | C21-C1-C5-C4 | 98.9(3) |
| C28-S1-O7-C3 | -91.2(2) | C2-C1-C5-C4 | -25.3(3) |
| C11-O1-C1-C21 | 145.8(2) | O3-C5-C6-C11 | -101.9(3) |
| C11-O1-C1-C2 | -90.4(2) | C4-C5-C6-C11 | 125.7(3) |
| C11-O1-C1-C5 | 20.0(3) | C1-C5-C6-C11 | 16.9(3) |
| O1-C1-C2-C3 | 134.4(2) | O3-C5-C6-C7 | 70.7(4) |
| C21-C1-C2-C3 | -104.3(3) | C4-C5-C6-C7 | -61.6(4) |
| C5-C1-C2-C3 | 21.9(3) | C1-C5-C6-C7 | -170.4(3) |
| O1-C1-C2-C15 | -44.2(3) | C12-O4-C7-C8 | 8.5(4) |
| C21-C1-C2-C15 | 77.1(3) | C12-O4-C7-C6 | -171.0(3) |
| C5-C1-C2-C15 | -156.7(2) | C11-C6-C7-O4 | -179.7(2) |
| C15-C2-C3-O7 | -6.6(5) | C5-C6-C7-O4 | 8.2(5) |
| C1-C2-C3-O7 | 175.0(2) | C11-C6-C7-C8 | 0.7(4) |
| C15-C2-C3-C4 | 169.2(3) | C5-C6-C7-C8 | -171.4(3) |
| C1-C2-C3-C4 | -9.2(3) | O4-C7-C8-C9 | -179.3(3) |
| S1-O7-C3-C2 | -67.1(4) | C6-C7-C8-C9 | 0.2(4) |
| S1-O7-C3-C4 | 117.3(2) | C13-O5-C9-C10 | 3.5(4) |
| C2-C3-C4-O2 | 171.8(3) | C13-O5-C9-C8 | -176.3(3) |
| O7-C3-C4-O2 | -12.1(4) | C7-C8-C9-O5 | 179.3(3) |
| C2-C3-C4-C5 | -8.0(3) | C7-C8-C9-C10 | -0.6(4) |
| O7-C3-C4-C5 | 168.2(2) | O5-C9-C10-C11 | -179.8(3) |
| O2-C4-C5-O3 | -39.2(4) | C8-C9-C10-C11 | 0.0(4) |
| C3-C4-C5-O3 | 140.6(2) | C7-C6-C11-O1 | -179.7(2) |
| O2-C4-C5-C6 | 94.1(4) | C5-C6-C11-O1 | -5.9(3) |
| C3-C4-C5-C6 | -86.2(3) | C7-C6-C11-C10 | -1.4(4) |
| O2-C4-C5-C1 | -159.1(3) | C5-C6-C11-C10 | 172.4(3) |
| C3-C4-C5-C1 | 20.7(3) | C1-O1-C11-C6 | -9.5(3) |
| O1-C1-C5-O3 | 99.3(2) | C1-O1-C11-C10 | 172.2(3) |
| C21-C1-C5-O3 | -22.0(3) | C9-C10-C11-C6 | 1.0(4) |
| C2-C1-C5-O3 | -146.2(2) | C9-C10-C11-O1 | 179.1(3) |
| O1-C1-C5-C6 | -22.1(3) | C3-C2-C15-C16 | 145.6(3) |
| C21-C1-C5-C6 | -143.4(2) | C1-C2-C15-C16 | -36.2(4) |
| C2-C1-C5-C6 | 92.4(2) | C3-C2-C15-C20 | -37.7(4) |

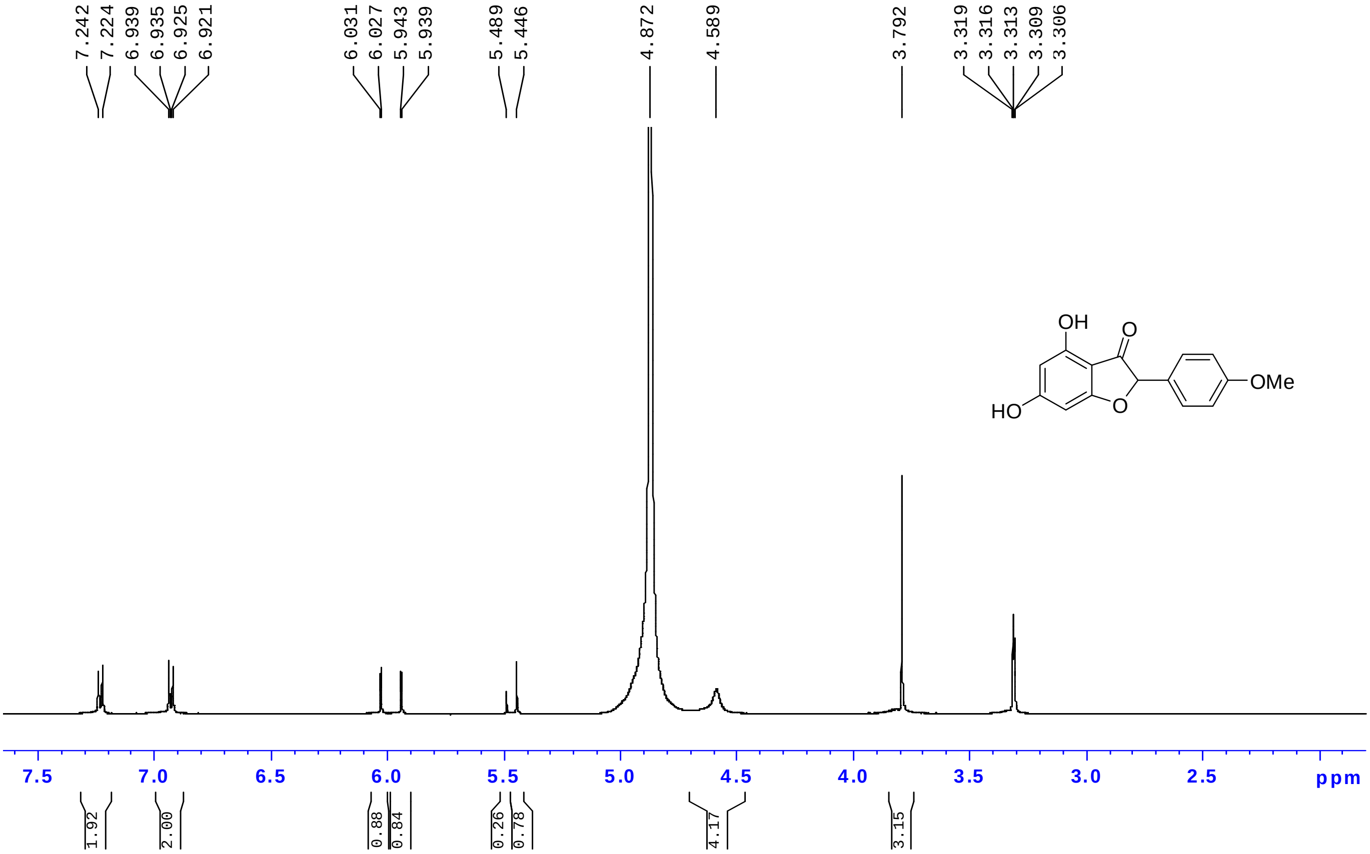
| | | | |
|---|---|---|---|
| C1-C2-C15-C20 | 140.5(3) | C27-O6-C24-C25 | 11.5(5) |
| C20-C15-C16-C17 | 1.6(5) | C27-O6-C24-C23 | -171.1(3) |
| C2-C15-C16-C17 | 178.4(3) | C22-C23-C24-O6 | -176.9(3) |
| C15-C16-C17-C18 | -2.0(5) | C22-C23-C24-C25 | 0.7(5) |
| C16-C17-C18-C19 | 0.6(5) | O6-C24-C25-C26 | 176.0(3) |
| C17-C18-C19-C20 | 1.3(5) | C23-C24-C25-C26 | -1.3(5) |
| C18-C19-C20-C15 | -1.7(4) | C22-C21-C26-C25 | 1.4(4) |
| C16-C15-C20-C19 | 0.2(4) | C1-C21-C26-C25 | -179.7(3) |
| C2-C15-C20-C19 | -176.6(3) | C24-C25-C26-C21 | 0.2(5) |
| O1-C1-C21-C26 | 153.8(3) | O8-S1-C28-F2 | -174.4(2) |
| C2-C1-C21-C26 | 32.5(4) | O9-S1-C28-F2 | 52.4(3) |
| C5-C1-C21-C26 | -86.4(3) | O7-S1-C28-F2 | -57.4(2) |
| O1-C1-C21-C22 | -27.4(4) | O8-S1-C28-F1 | 65.8(3) |
| C2-C1-C21-C22 | -148.6(3) | O9-S1-C28-F1 | -67.4(3) |
| C5-C1-C21-C22 | 92.5(3) | O7-S1-C28-F1 | -177.1(2) |
| C26-C21-C22-C23 | -2.0(4) | O8-S1-C28-F3 | -53.7(3) |
| C1-C21-C22-C23 | 179.1(3) | O9-S1-C28-F3 | 173.1(2) |
| C21-C22-C23-C24 | 1.0(5) | O7-S1-C28-F3 | 63.3(2) |

Table 7. Hydrogen bonds and close contacts for frojm09 [Å and °].

| D-H...A | d(D-H) | d(H...A) | d(D...A) | <(DHA) |
|---|---|---|---|---|
| O3-H3...O2#1 | 0.79(4) | 2.13(4) | 2.868(3) | 157(4) |

Symmetry transformations used to generate equivalent atoms:

#1 -x,-y,-z+1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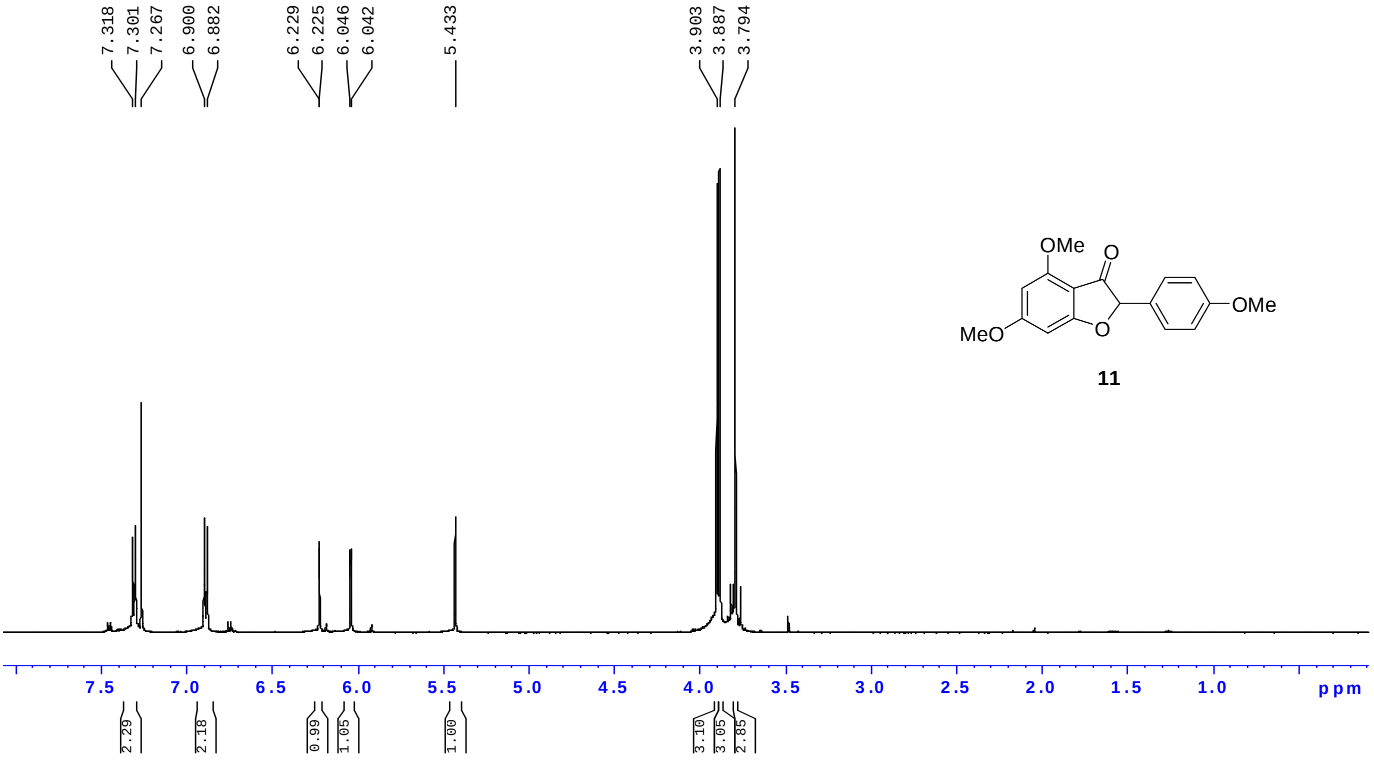
6.935
6.925
6.921
6.031
6.027
5.943
5.939
5.489
5.446
4.872
4.589
3.792
3.319
3.316
3.313
3.309
3.306
OH
O
HO
O
OMe
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
ppm
1.92
2.00
0.88
0.84
0.26
0.78
4.17
3.15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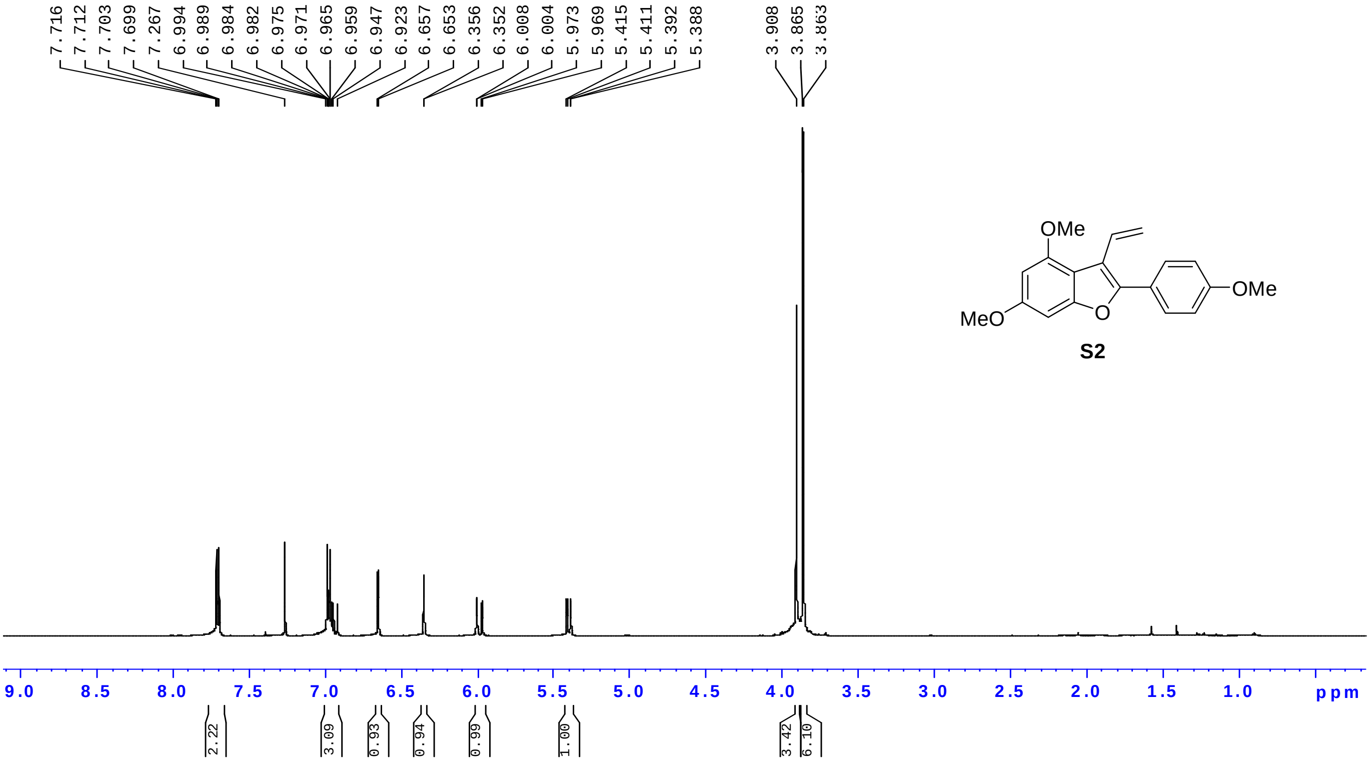
7.301
7.267
6.900
6.882
6.229
6.225
6.046
6.042
5.433
3.903
3.887
3.794
OMe
O
MeO
O
OMe
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm
2.29
2.18
0.99
1.05
1.00
3.10
3.05
2.85

**11**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7.703
7.699
7.267
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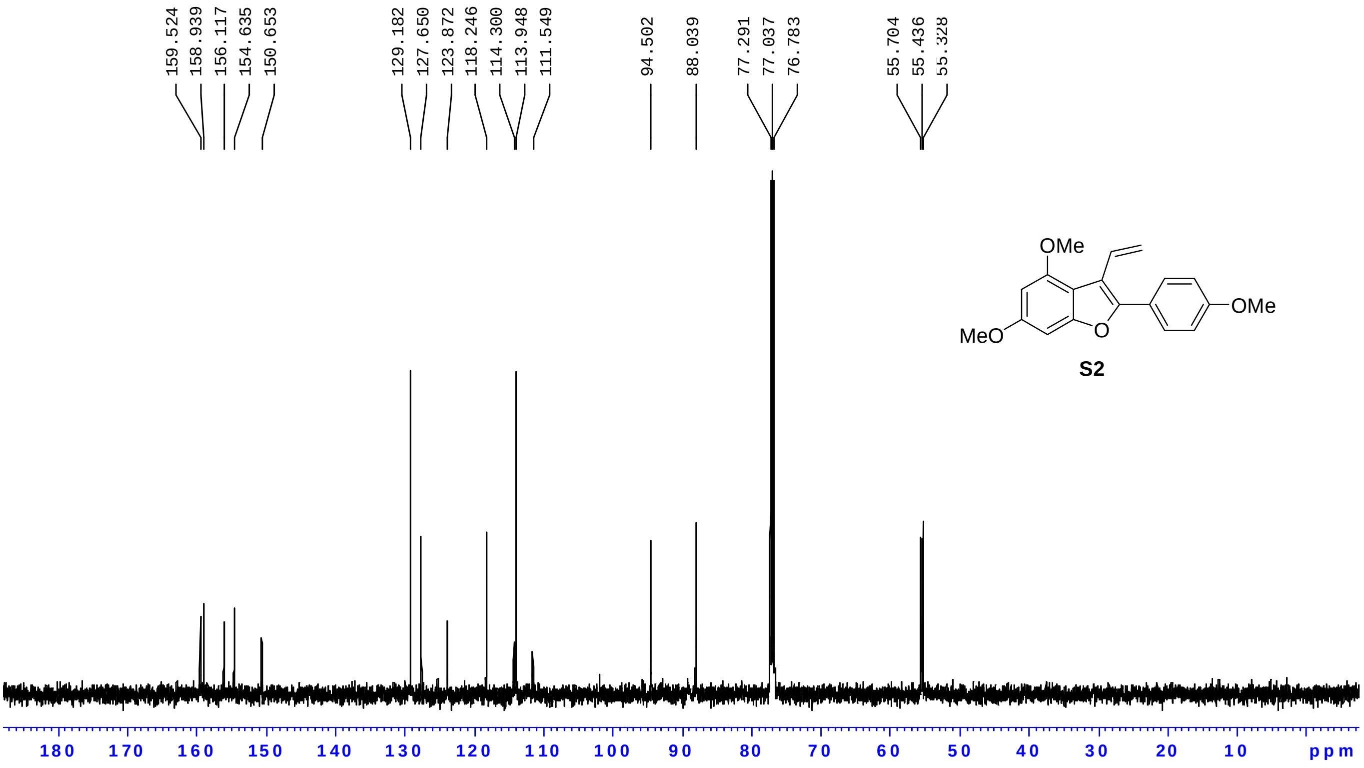
6.989
6.984
6.982
6.975
6.971
6.965
6.959
6.947
6.923
6.657
6.653
6.356
6.352
6.008
6.004
5.973
5.969
5.415
5.411
5.392
5.388
3.908
3.865
3.863
OMe
OMe
MeO
O
S2
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm
2.22
3.09
0.93
0.94
0.99
1.00
3.42
6.10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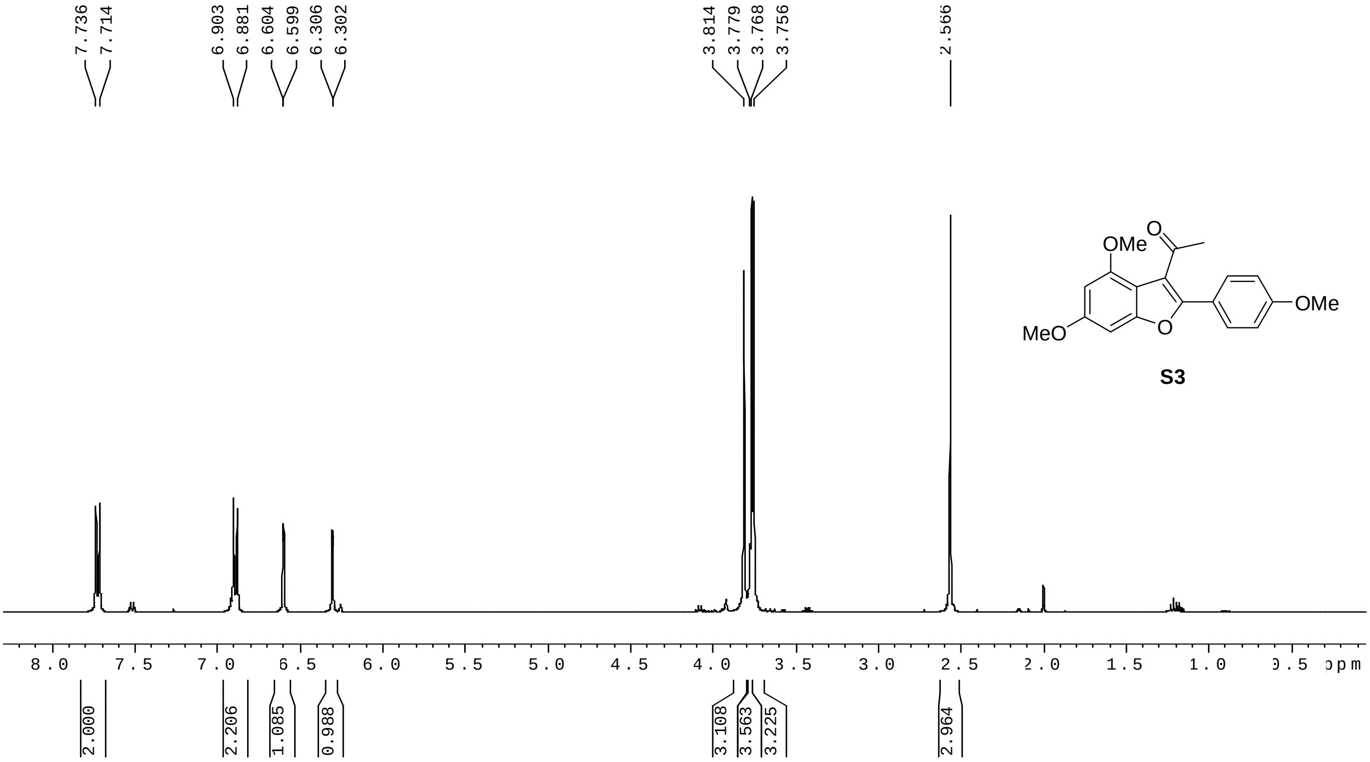
158.939
156.117
154.635
150.653
129.182
127.650
123.872
118.246
114.300
113.948
111.549
94.502
88.039
77.291
77.037
76.783
55.704
55.436
55.328
OMe
OMe
MeO
O
S2
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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6.903
6.881
6.604
6.599
6.306
6.302
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3.779
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3.756
2.566
OMe
O
MeO
O
OMe
S3
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
ppm
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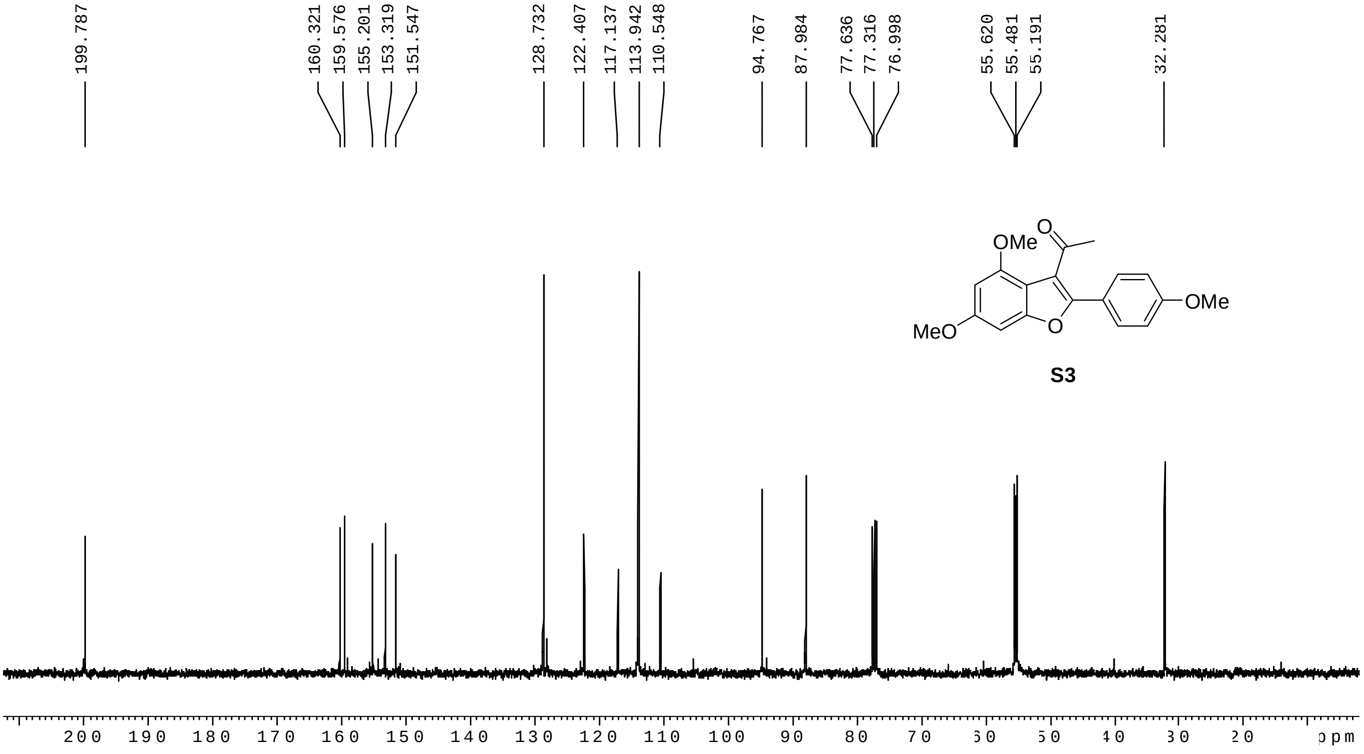
1.085
0.988
3.108
3.563
3.225
2.964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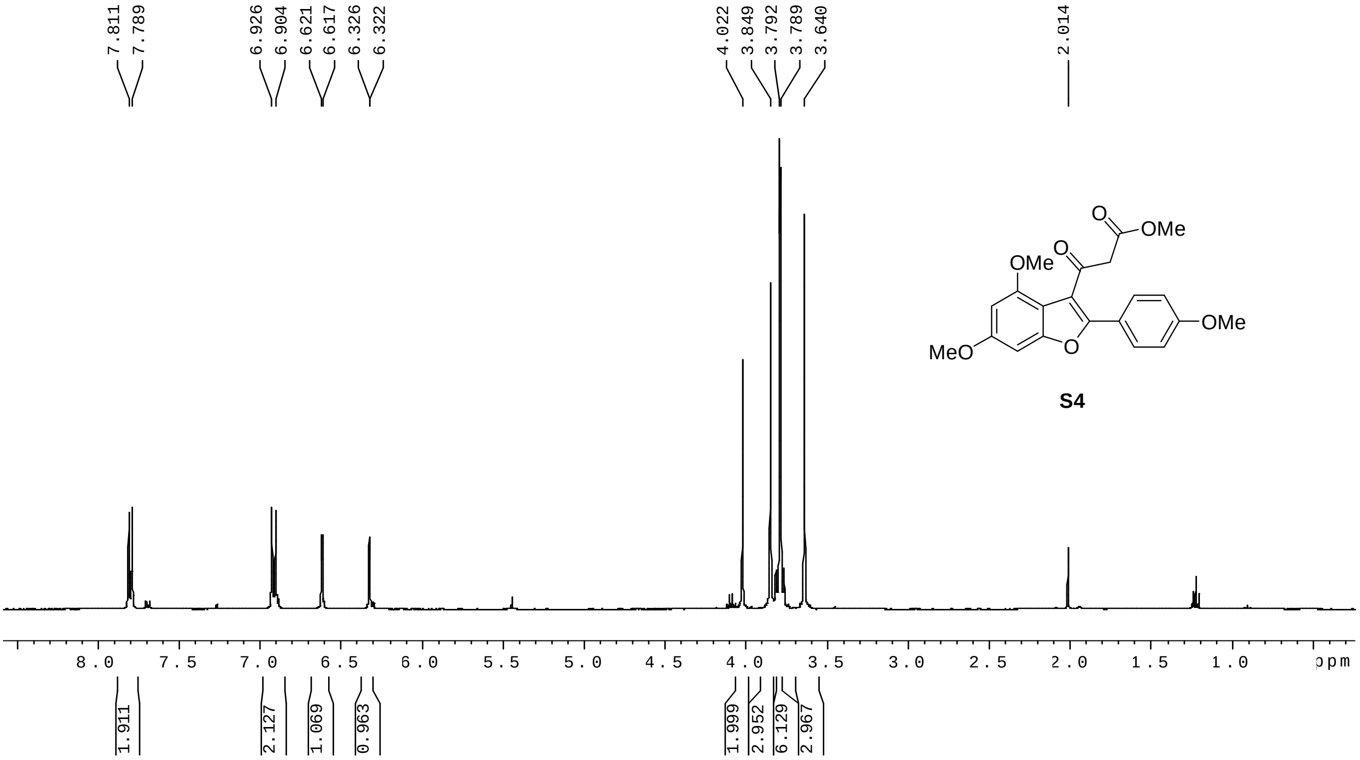
153.319
151.547
128.732
122.407
117.137
113.942
110.548
94.767
87.984
77.636
77.316
76.998
55.620
55.481
55.191
32.281
OMe
O
MeO
O
OMe
S3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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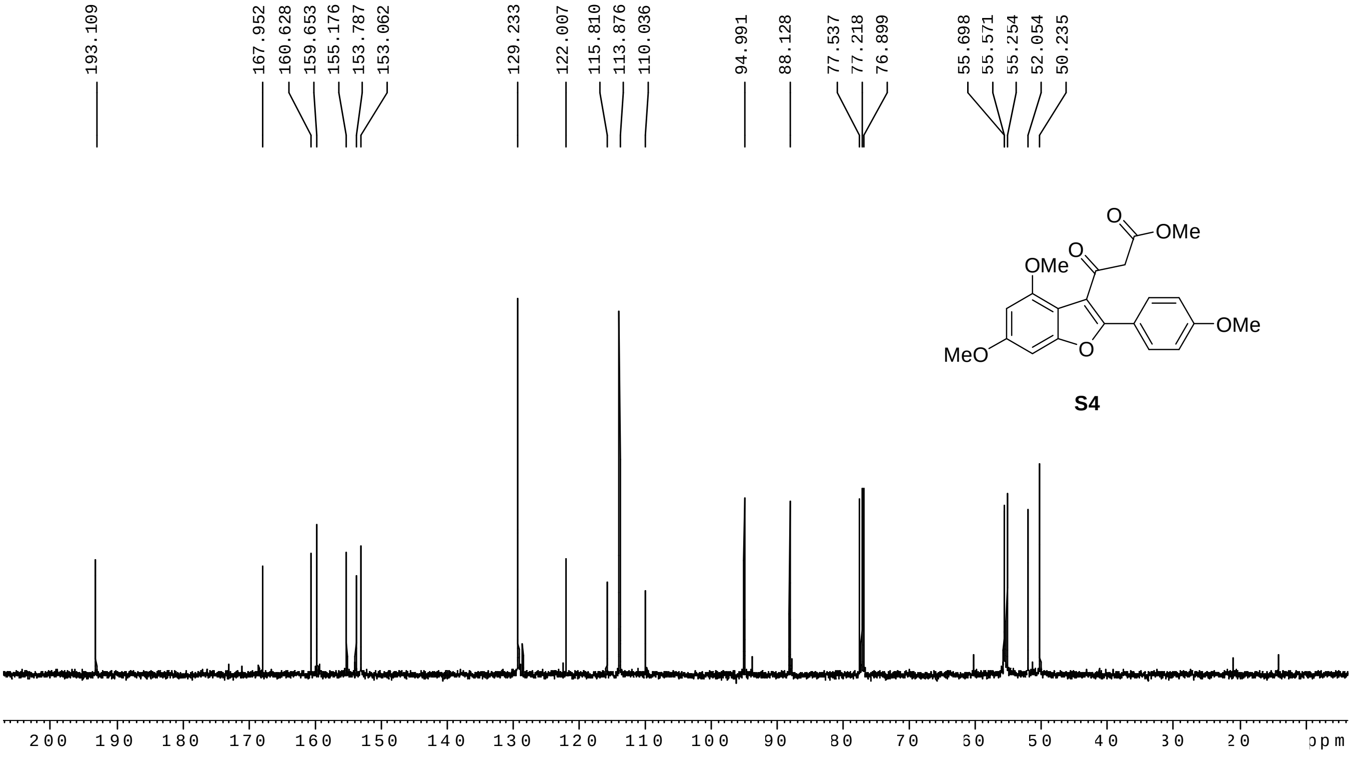
7.789
6.926
6.904
6.621
6.617
6.326
6.322
4.022
3.849
3.792
3.789
3.640
2.014
OMe
O
O
OMe
OMe
MeO
O
S4
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 ppm
1.911
2.127
1.069
0.963
1.999
2.952
6.129
2.967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167.952
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159.653
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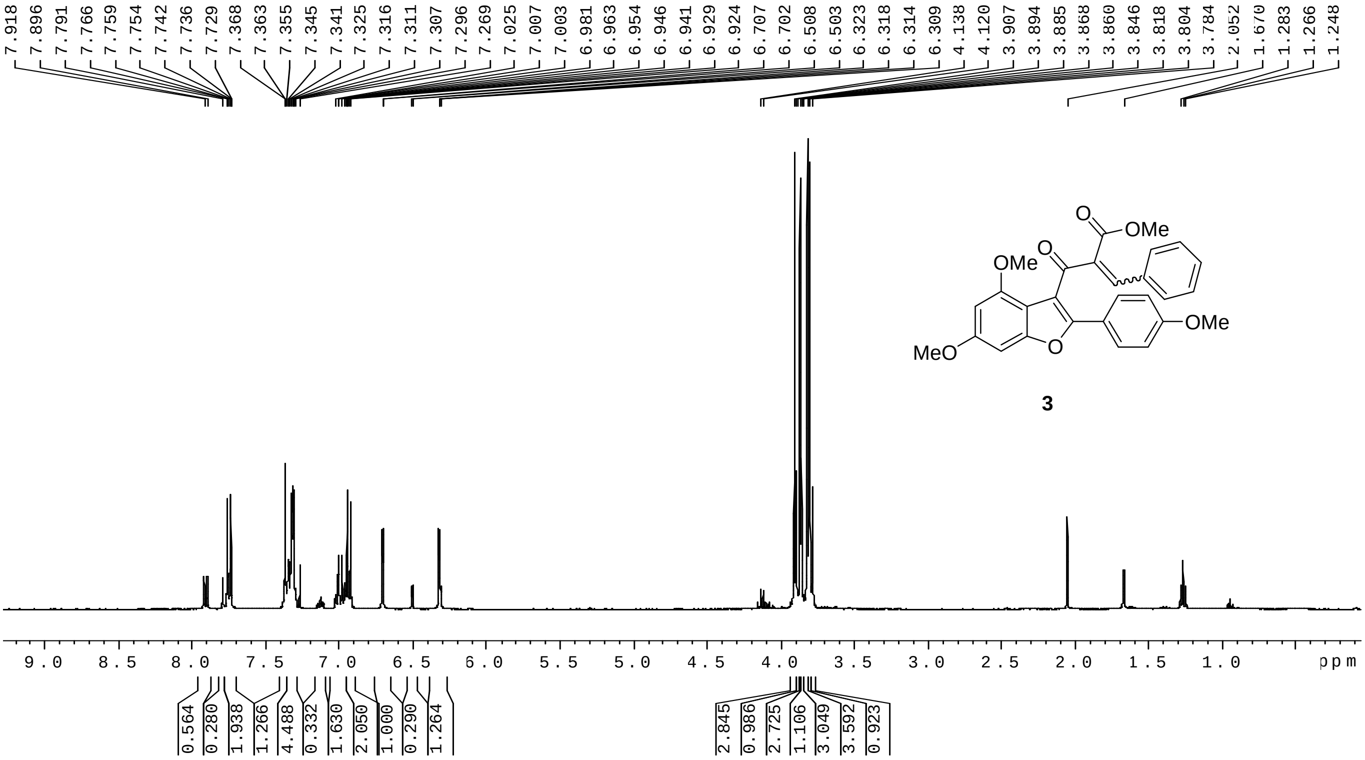
153.062
129.233
122.007
115.810
113.876
110.036
94.991
88.128
77.537
77.218
76.899
55.698
55.571
55.254
52.054
50.235
OMe
O
O
OMe
OMe
MeO
O
S4
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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7.759
7.754
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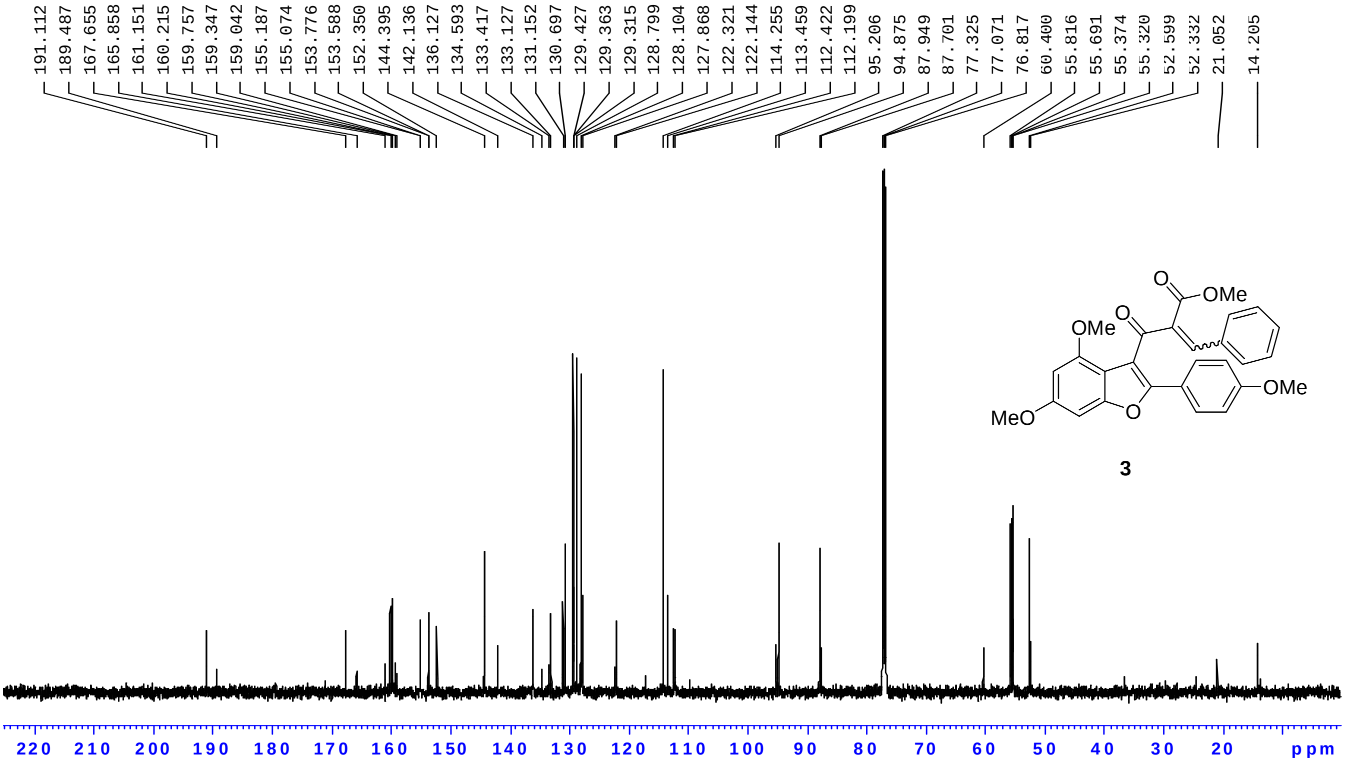
7.736
7.729
7.368
7.363
7.355
7.345
7.341
7.325
7.316
7.311
7.307
7.296
7.269
7.025
7.007
7.003
6.981
6.963
6.954
6.946
6.941
6.929
6.924
6.707
6.702
6.508
6.503
6.323
6.318
6.314
6.309
4.138
4.120
3.907
3.894
3.885
3.868
3.860
3.846
3.818
3.804
3.784
2.052
1.670
1.283
1.266
1.248
OMe
O
O
OMe
OMe
MeO
O
3
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
ppm
0.564
0.280
1.938
1.266
4.488
0.332
1.630
2.050
1.000
0.290
1.264
2.845
0.986
2.725
1.106
3.049
3.592
0.923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161.151
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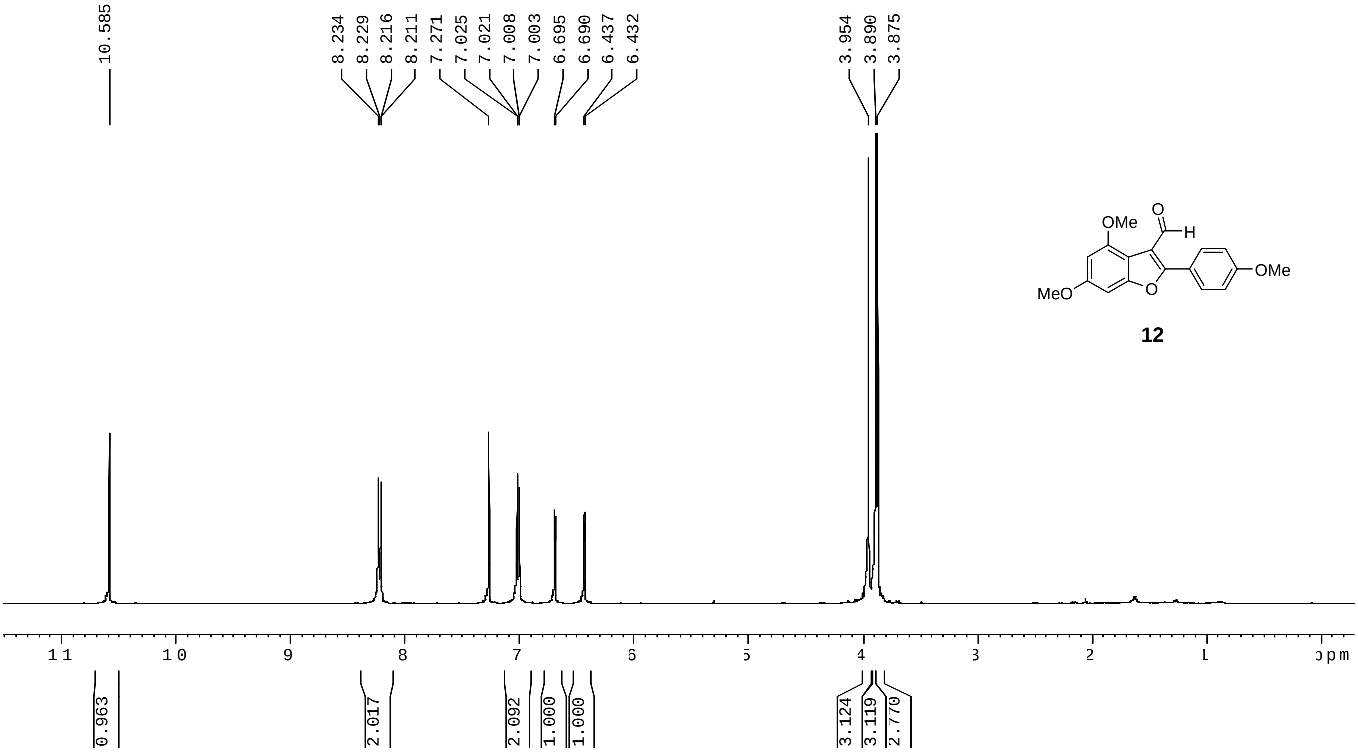
159.757
159.347
159.042
155.187
155.074
153.776
153.588
152.350
144.395
142.136
136.127
134.593
133.417
133.127
131.152
130.697
129.427
129.363
129.315
128.799
128.104
127.868
122.321
122.144
114.255
113.459
112.422
112.199
95.206
94.875
87.949
87.701
77.325
77.071
76.817
60.400
55.816
55.691
55.374
55.320
52.599
52.332
21.052
14.205
O
OMe
O
OMe
OMe
MeO
O
3
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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7.021
7.008
7.003
6.695
6.690
6.437
6.432
3.954
3.890
3.875
OMe
O
H
MeO
O
OMe
11
10
9
8
7
6
5
4
3
2
1
ppm
0.963
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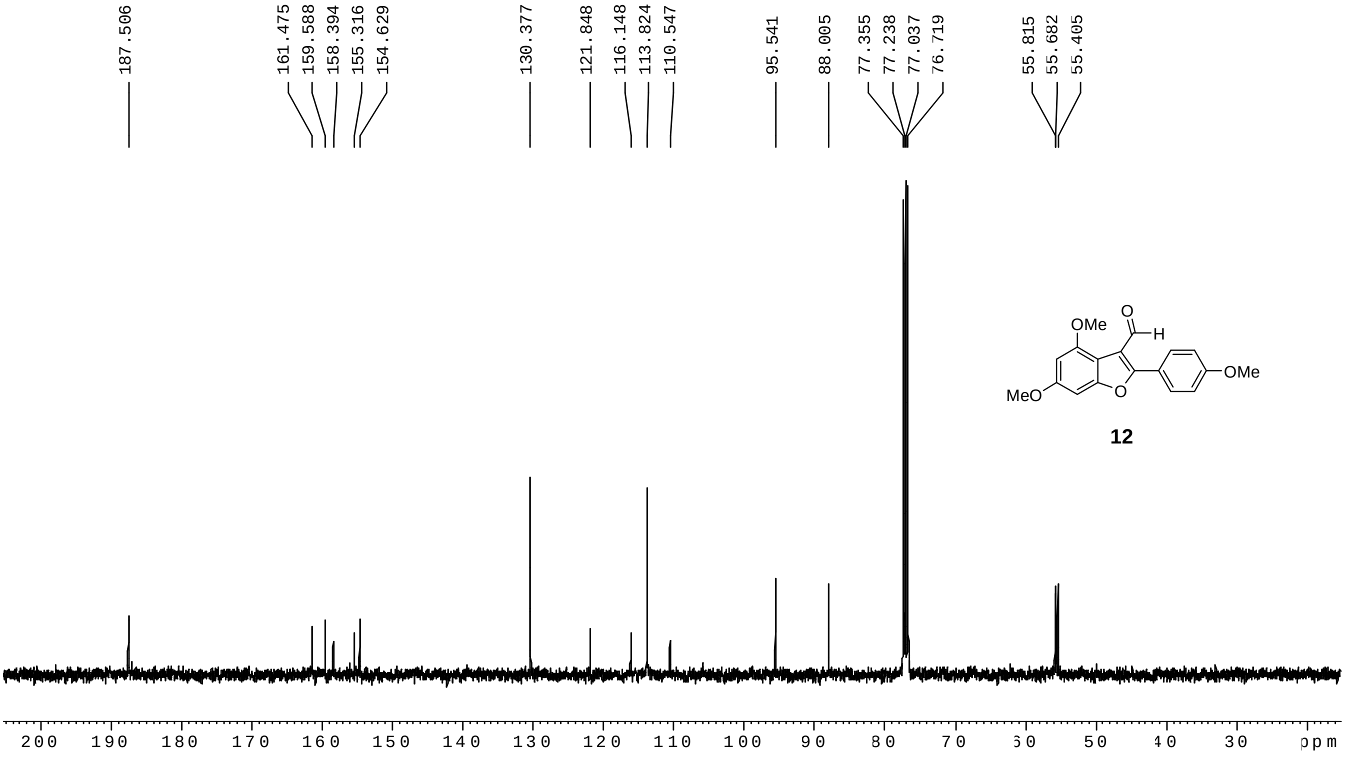
2.092
1.000
1.000
3.124
3.119
2.770

**12**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159.588
158.394
155.316
154.629
130.377
121.848
116.148
113.824
110.547
95.541
88.005
77.355
77.238
77.037
76.719
55.815
55.682
55.405
OMe
O
H
MeO
O
OMe
200
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180
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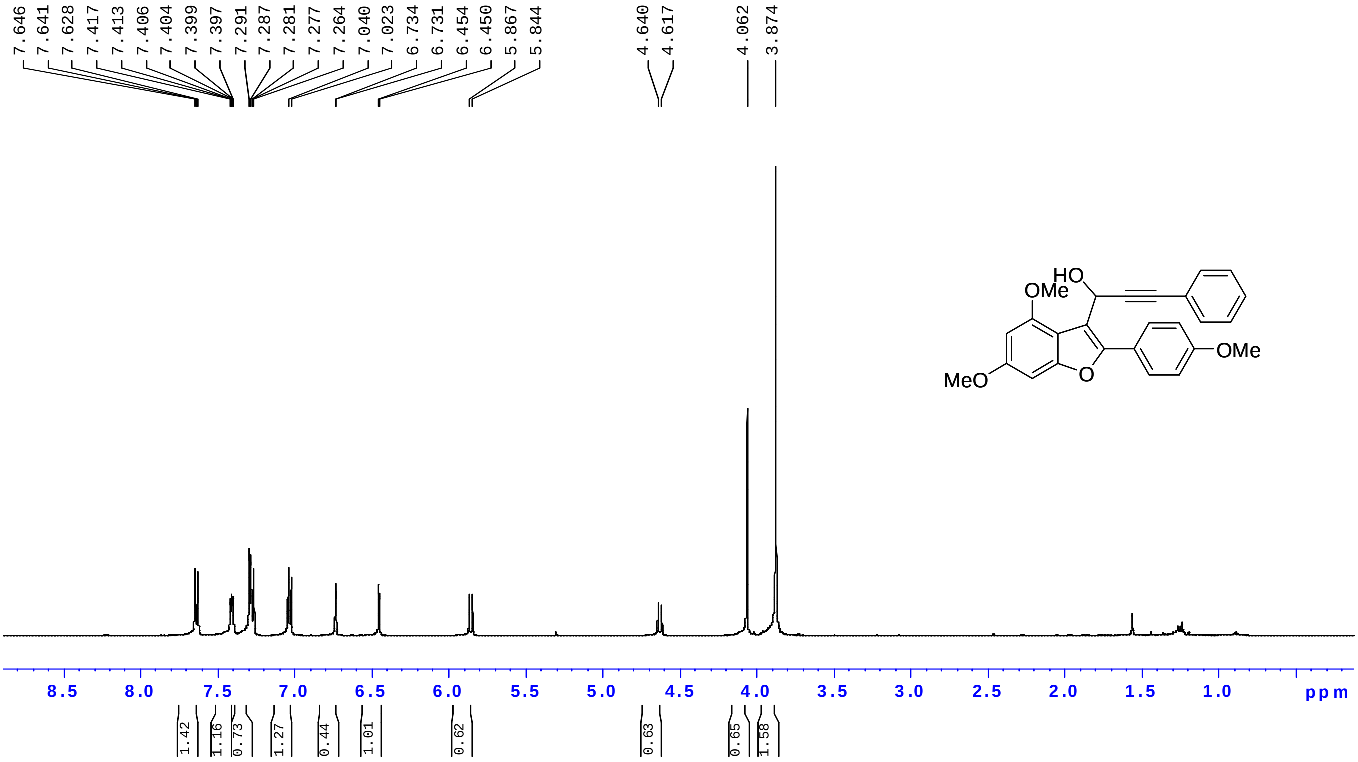
160
150
140
130
120
110
100
90
80
70
60
50
40
30
ppm

**12**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7.404
7.399
7.397
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7.287
7.281
7.277
7.264
7.040
7.023
6.734
6.731
6.454
6.450
5.867
5.844
4.640
4.617
4.062
3.874
HO
OMe
OMe
MeO
O
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
ppm
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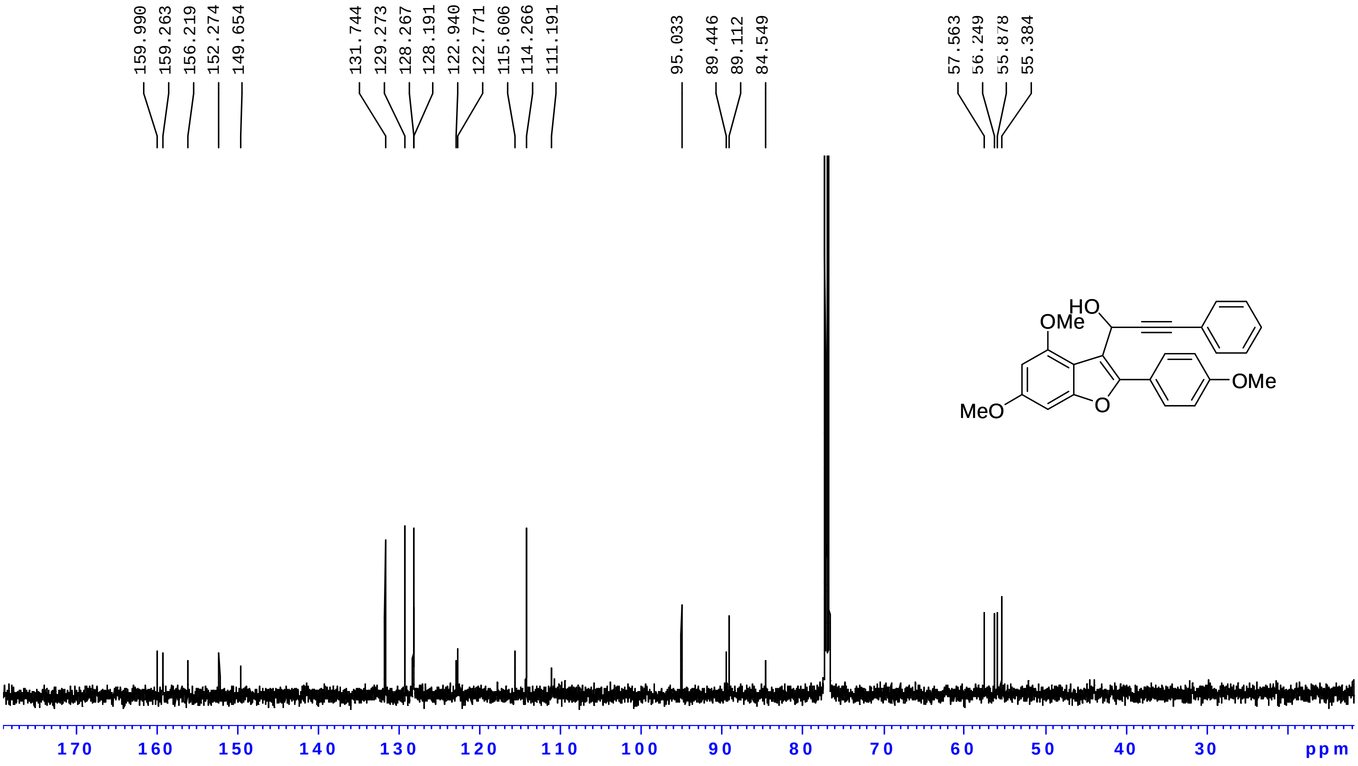
1.16
0.73
1.27
0.44
1.01
0.62
0.63
0.65
1.58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128.267
128.191
122.940
122.771
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114.266
111.191
95.033
89.446
89.112
84.549
57.563
56.249
55.878
55.384
HO
OMe
OMe
MeO
O
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160
150
140
130
120
110
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90
80
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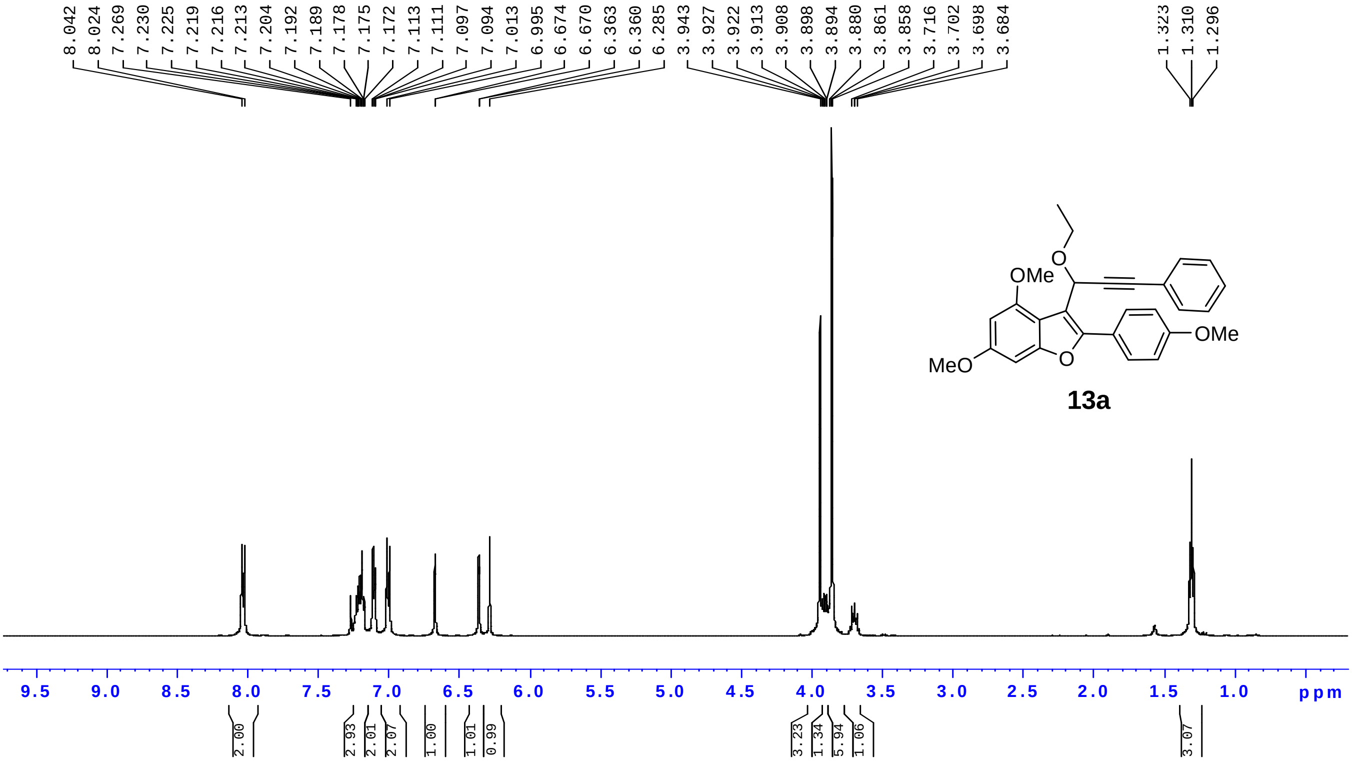
60
50
40
30
ppm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7.204
7.192
7.189
7.178
7.175
7.172
7.113
7.111
7.097
7.094
7.013
6.995
6.674
6.670
6.363
6.360
6.285
3.943
3.927
3.922
3.913
3.908
3.898
3.894
3.880
3.861
3.858
3.716
3.702
3.698
3.684
1.323
1.310
1.296
OMe
O
OMe
MeO
O
13a
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9.0
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
ppm
2.00
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2.07
1.00
1.01
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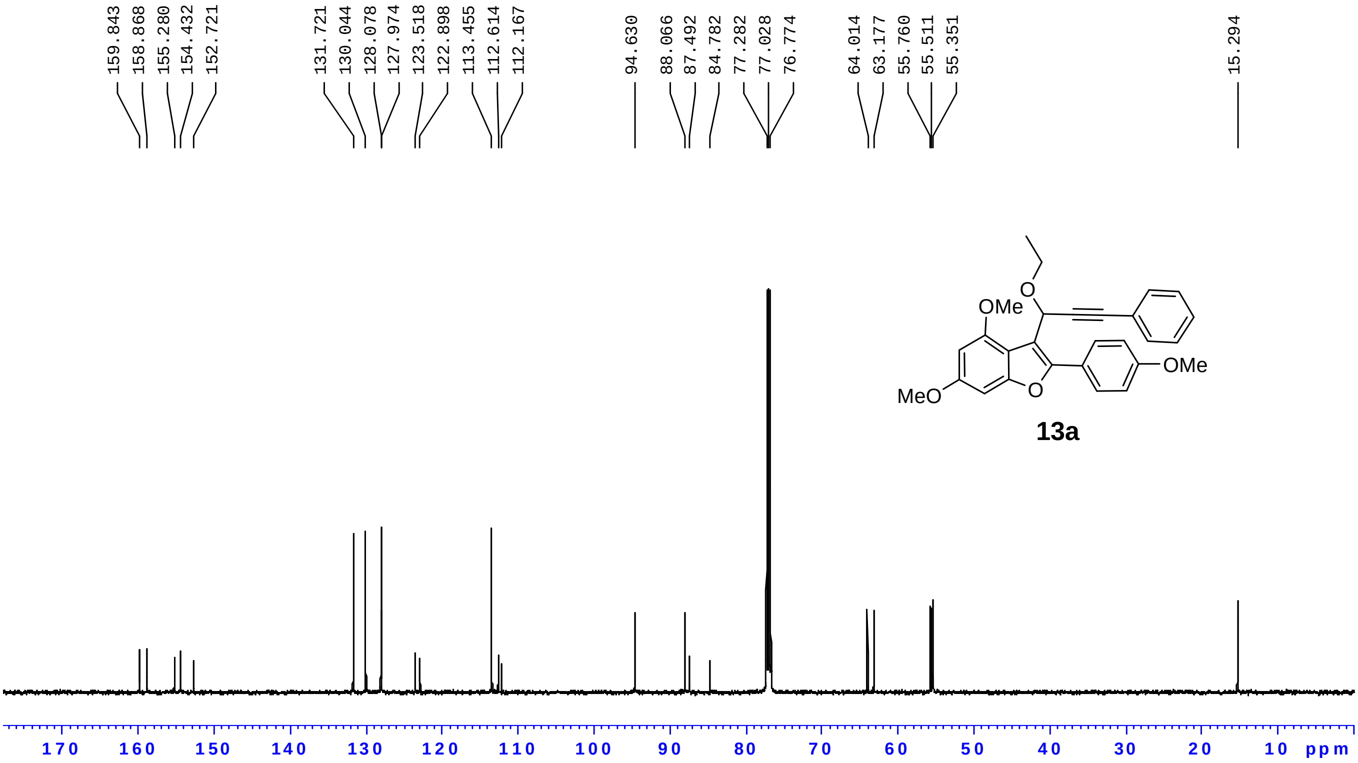
1.34
5.94
1.06
3.07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112.614
112.167
94.630
88.066
87.492
84.782
77.282
77.028
76.774
64.014
63.177
55.760
55.511
55.351
15.294
OMe
O
OMe
MeO
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150
140
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120
110
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90
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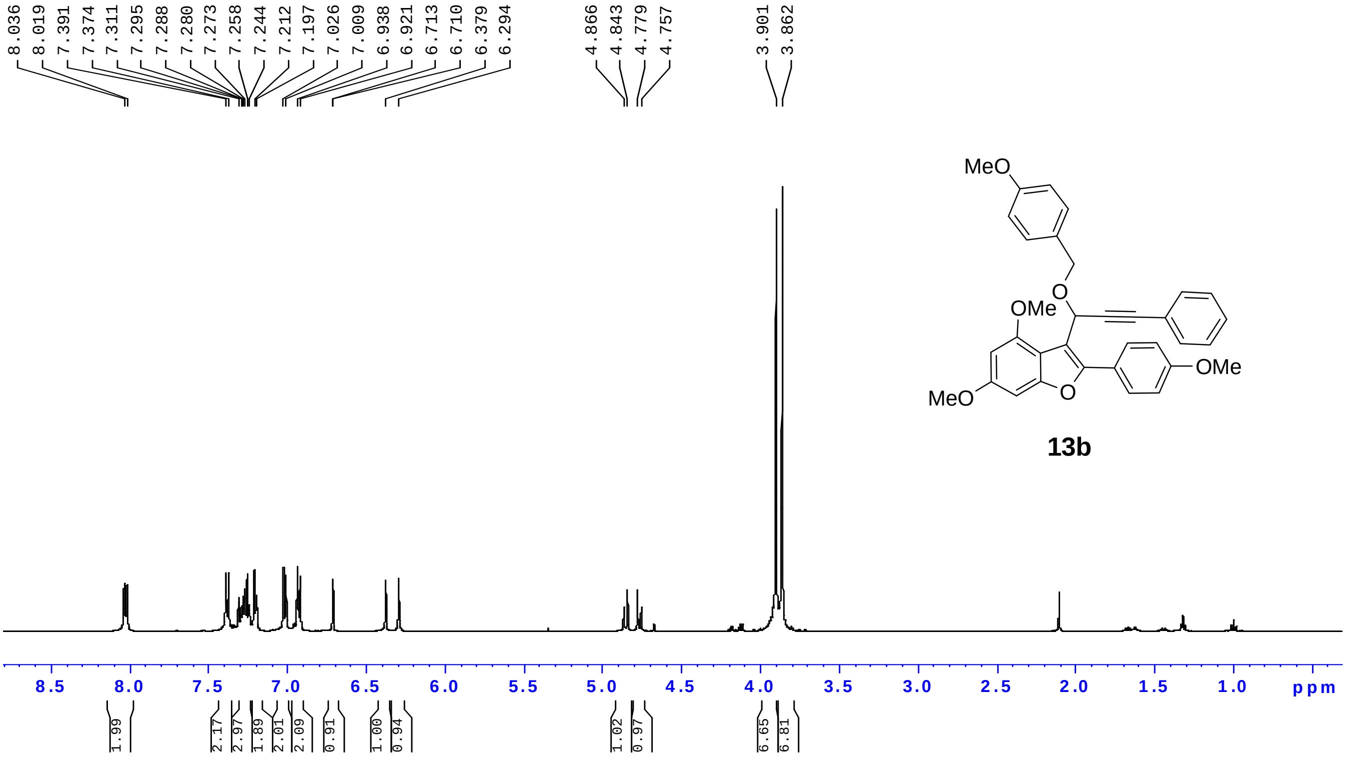
60
50
40
30
20
10
ppm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7.197
7.026
7.009
6.938
6.921
6.713
6.710
6.379
6.294
4.866
4.843
4.779
4.757
3.901
3.862
MeO
O
OMe
OMe
MeO
O
13b
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm
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0.94
1.02
0.97
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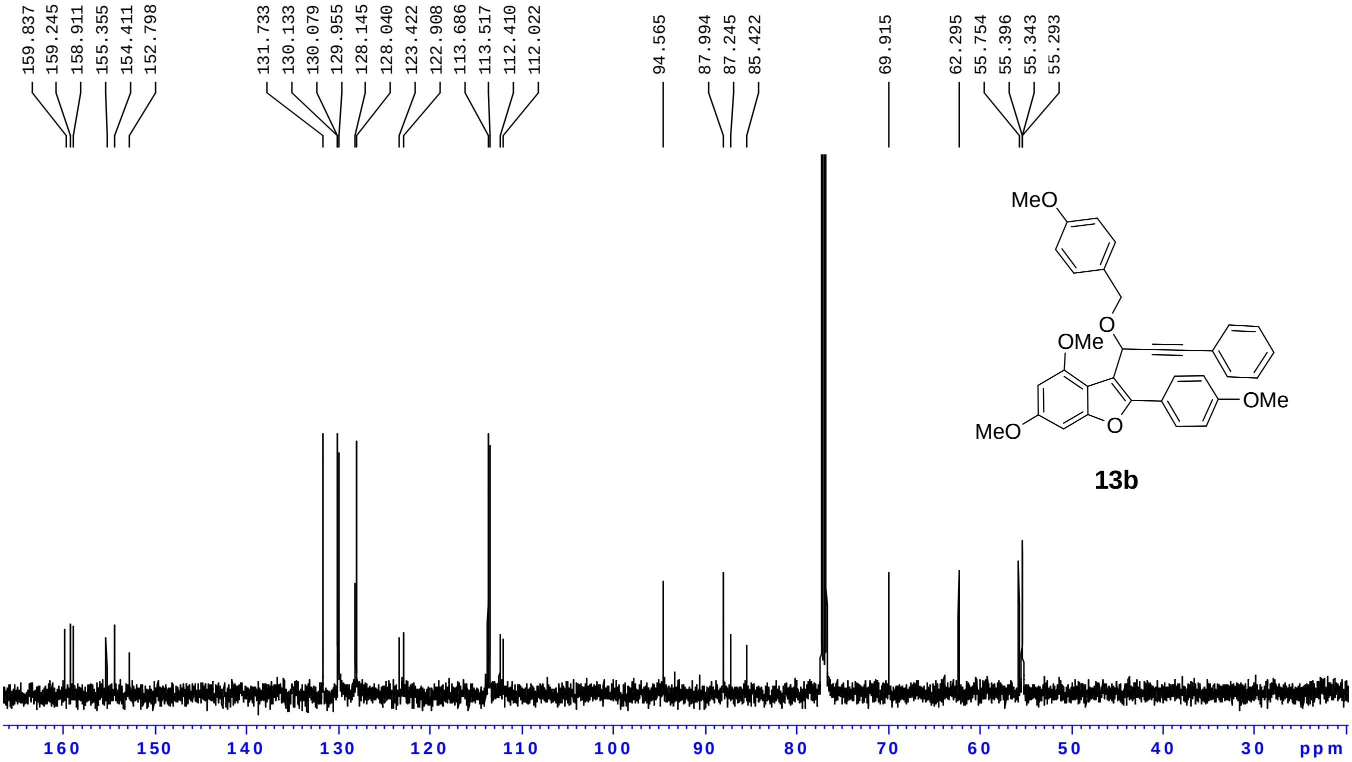
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128.145
128.040
123.422
122.908
113.686
113.517
112.410
112.022
94.565
87.994
87.245
85.422
69.915
62.295
55.754
55.396
55.343
55.293
MeO
O
OMe
OMe
MeO
O
13b
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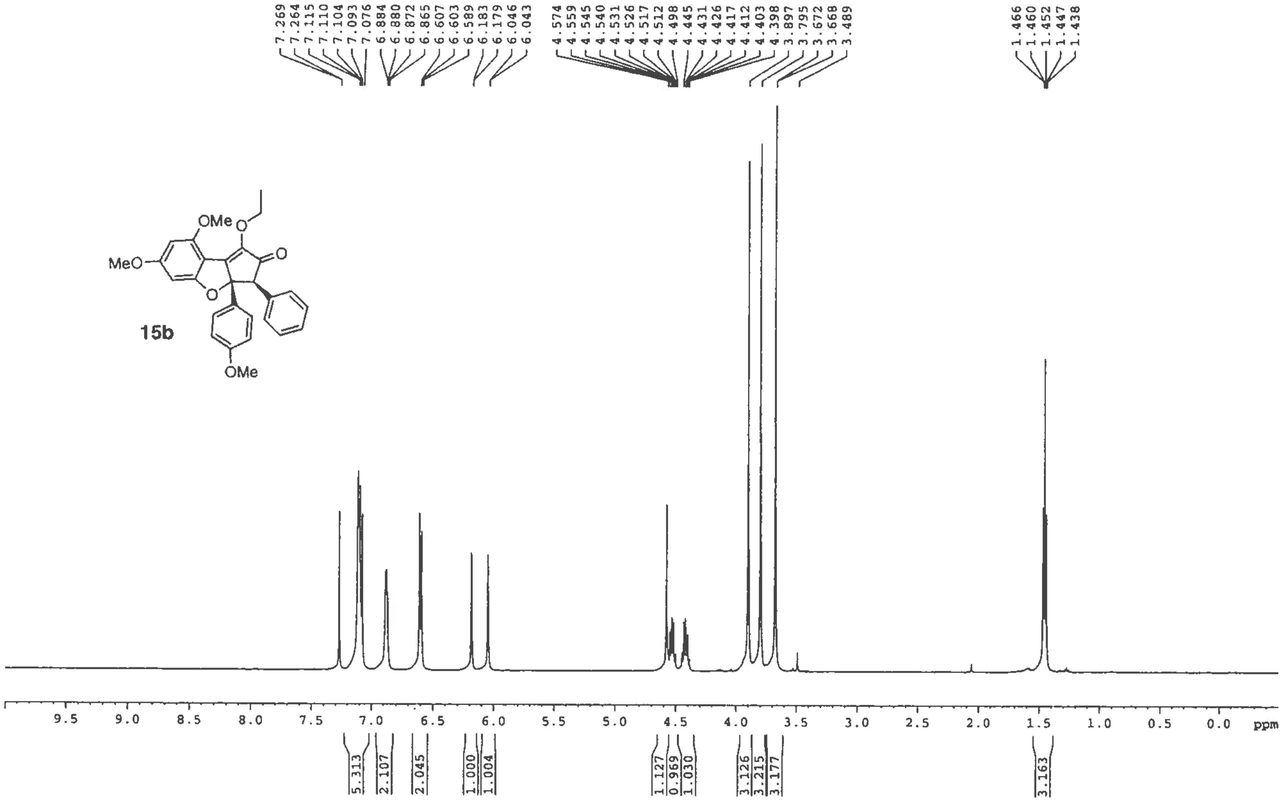
150
140
130
120
110
100
90
80
70
60
50
40
30
ppm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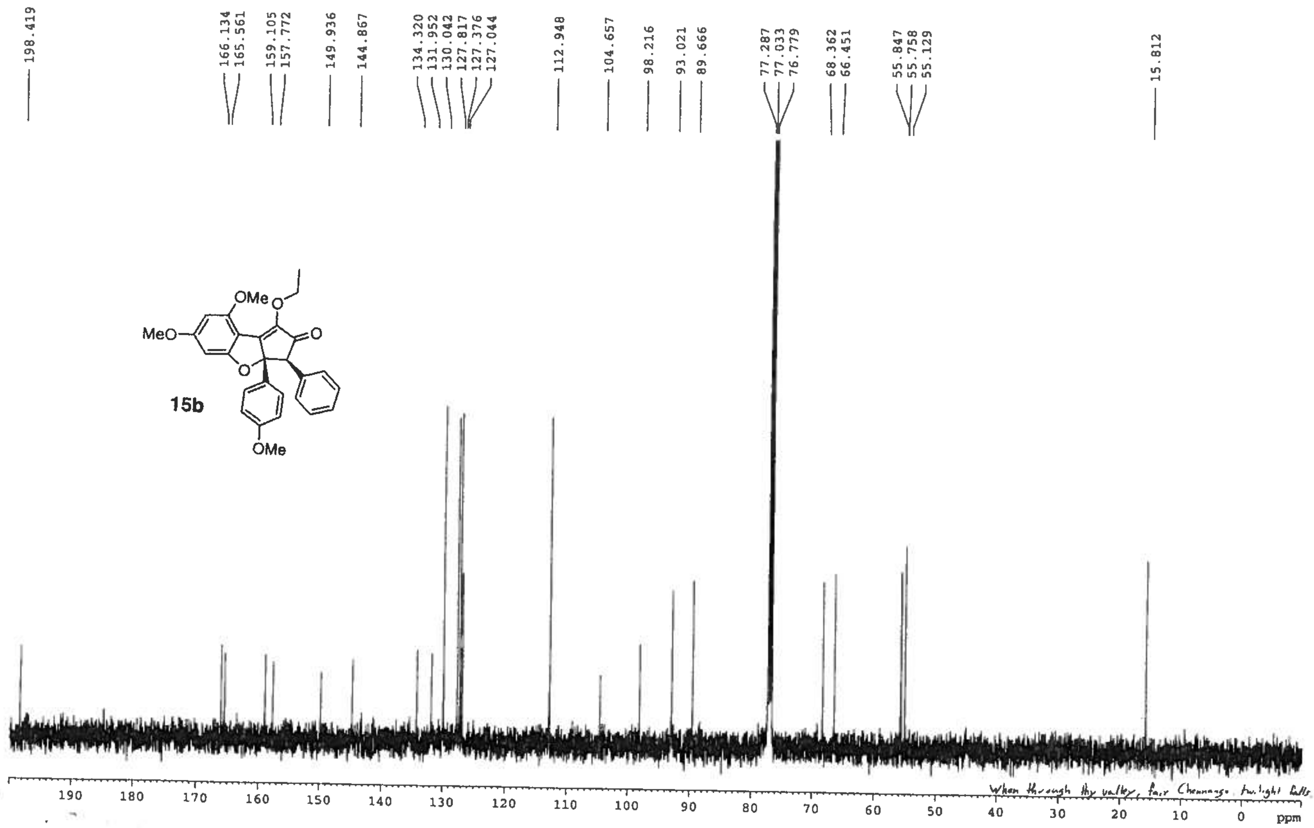
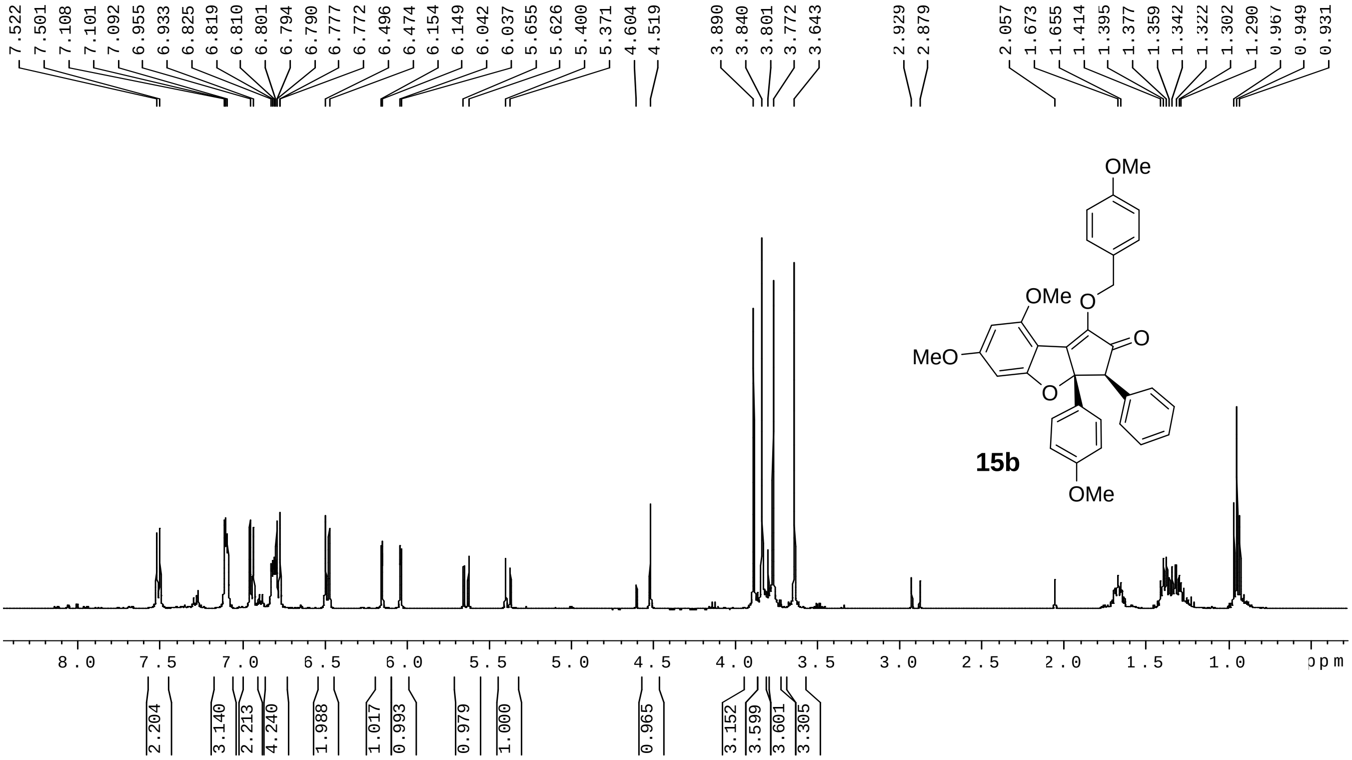

15b

When through thy valley, fair Chenango, twilight falls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6.825
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6.810
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6.790
6.777
6.772
6.496
6.474
6.154
6.149
6.042
6.037
5.655
5.626
5.400
5.371
4.604
4.519
3.890
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2.057
1.673
1.655
1.414
1.395
1.377
1.359
1.342
1.322
1.302
1.290
0.967
0.949
0.931
OMe
OMe
O
MeO
O
O
15b
OMe
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
ppm
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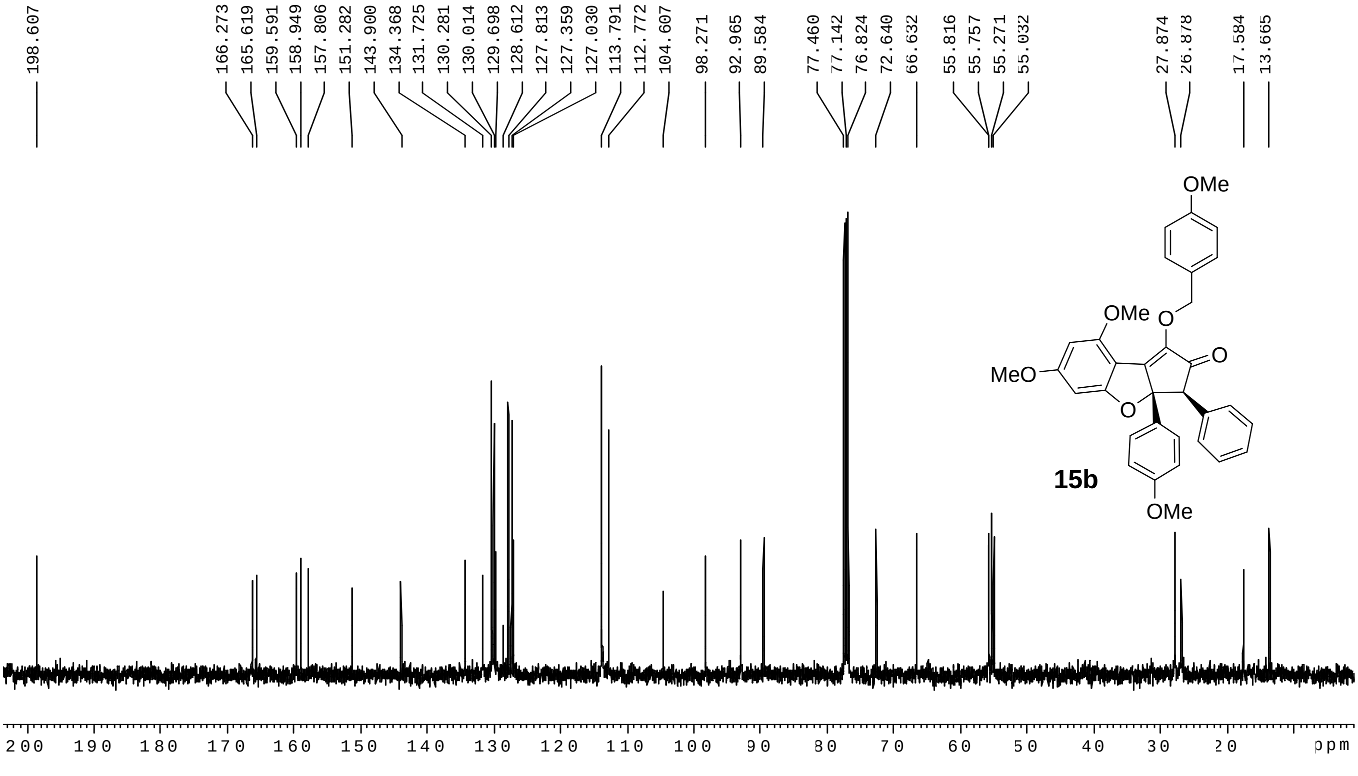
3.601
3.305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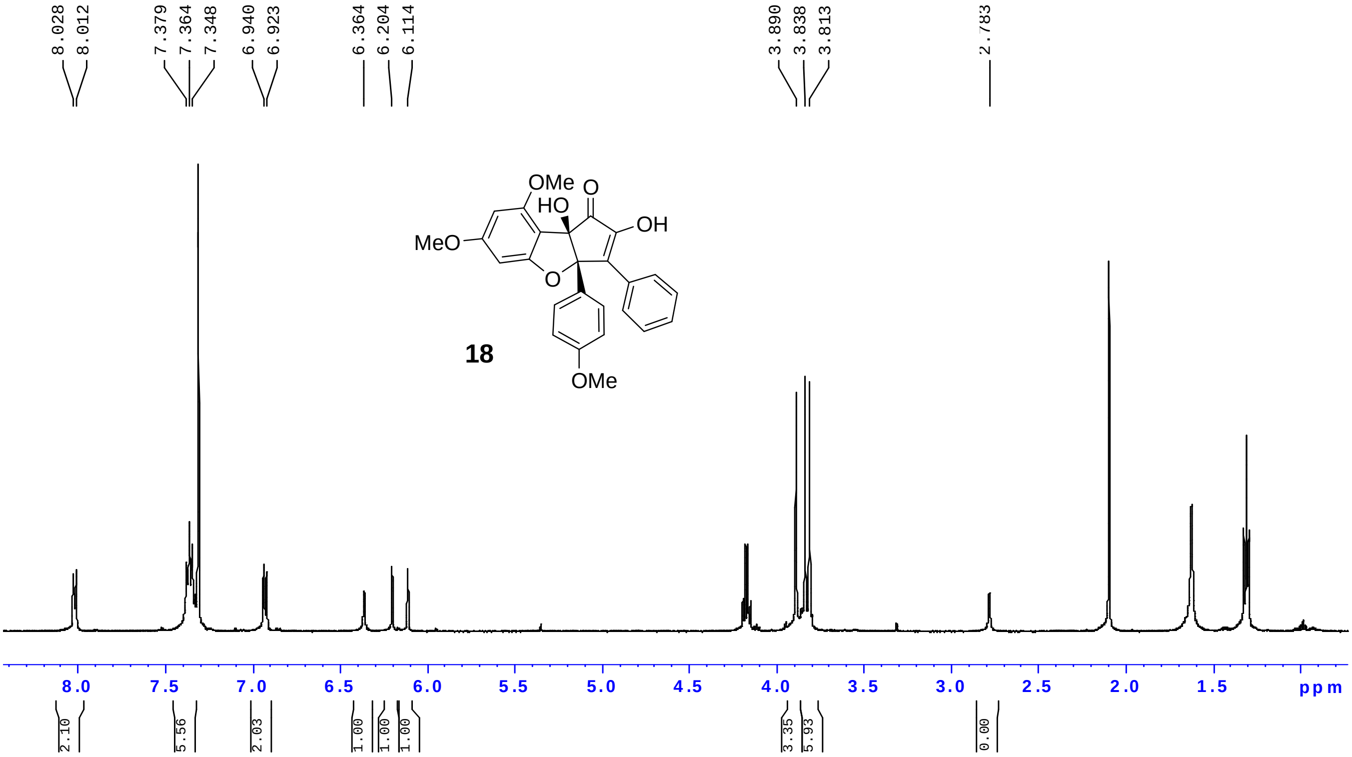
129.698
128.612
127.813
127.359
127.030
113.791
112.772
104.607
98.271
92.965
89.584
77.460
77.142
76.824
72.640
66.632
55.816
55.757
55.271
55.032
27.874
26.878
17.584
13.665
OMe
OMe
O
MeO
O
O
15b
OMe
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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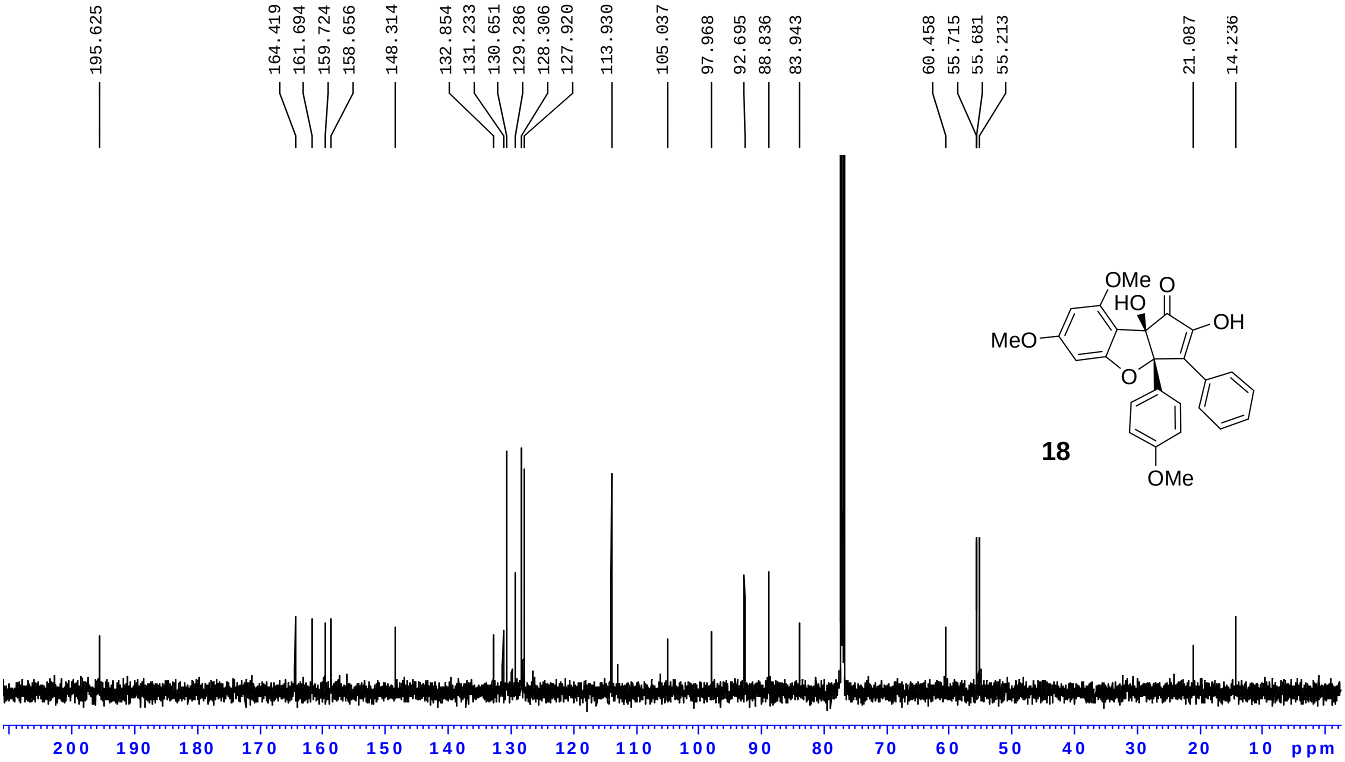
7.364
7.348
6.940
6.923
6.364
6.204
6.114
3.890
3.838
3.813
2.783
OMe
O
HO
OH
MeO
O
OMe
18
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
ppm
2.10
5.56
2.03
1.00
1.00
1.00
3.35
5.93
0.00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161.694
159.724
158.656
148.314
132.854
131.233
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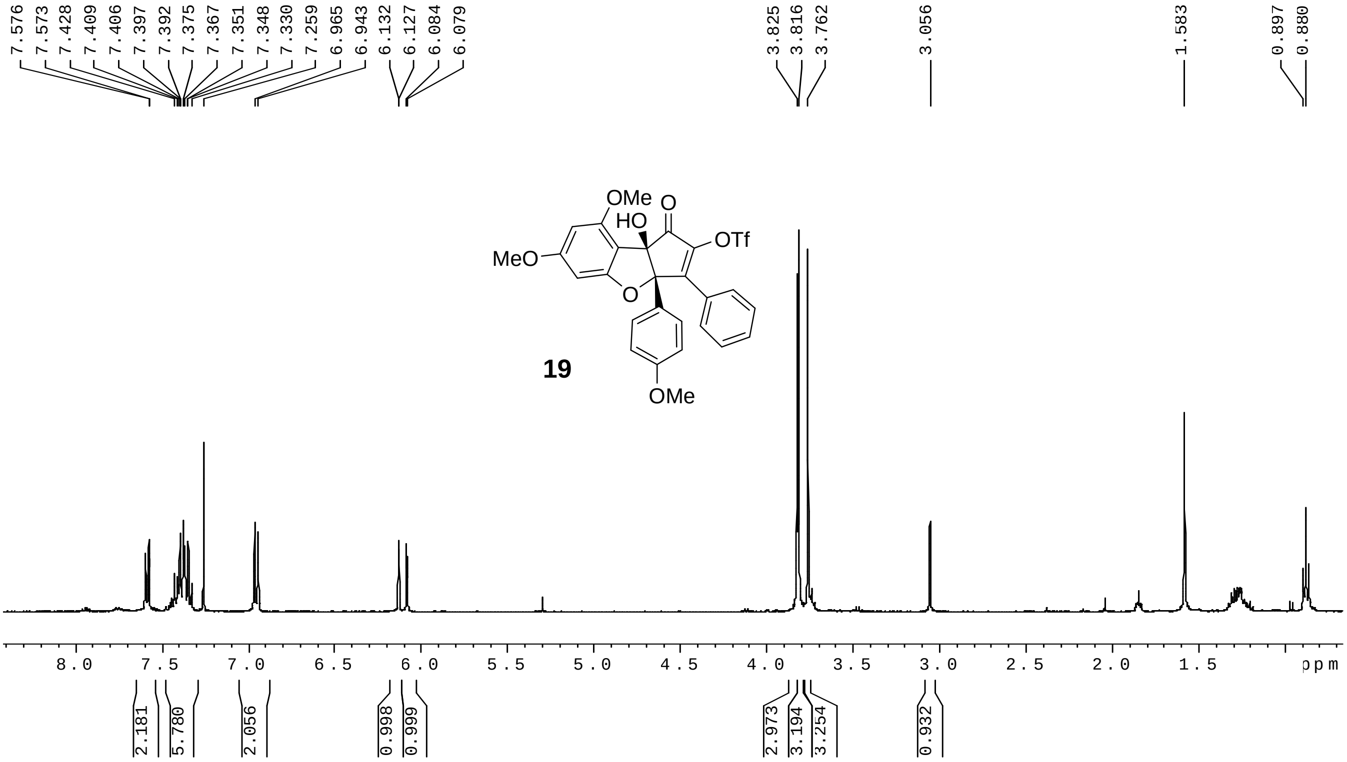
129.286
128.306
127.920
113.930
105.037
97.968
92.695
88.836
83.943
60.458
55.715
55.681
55.213
21.087
14.236
OMe
O
HO
OH
MeO
O
OMe
18
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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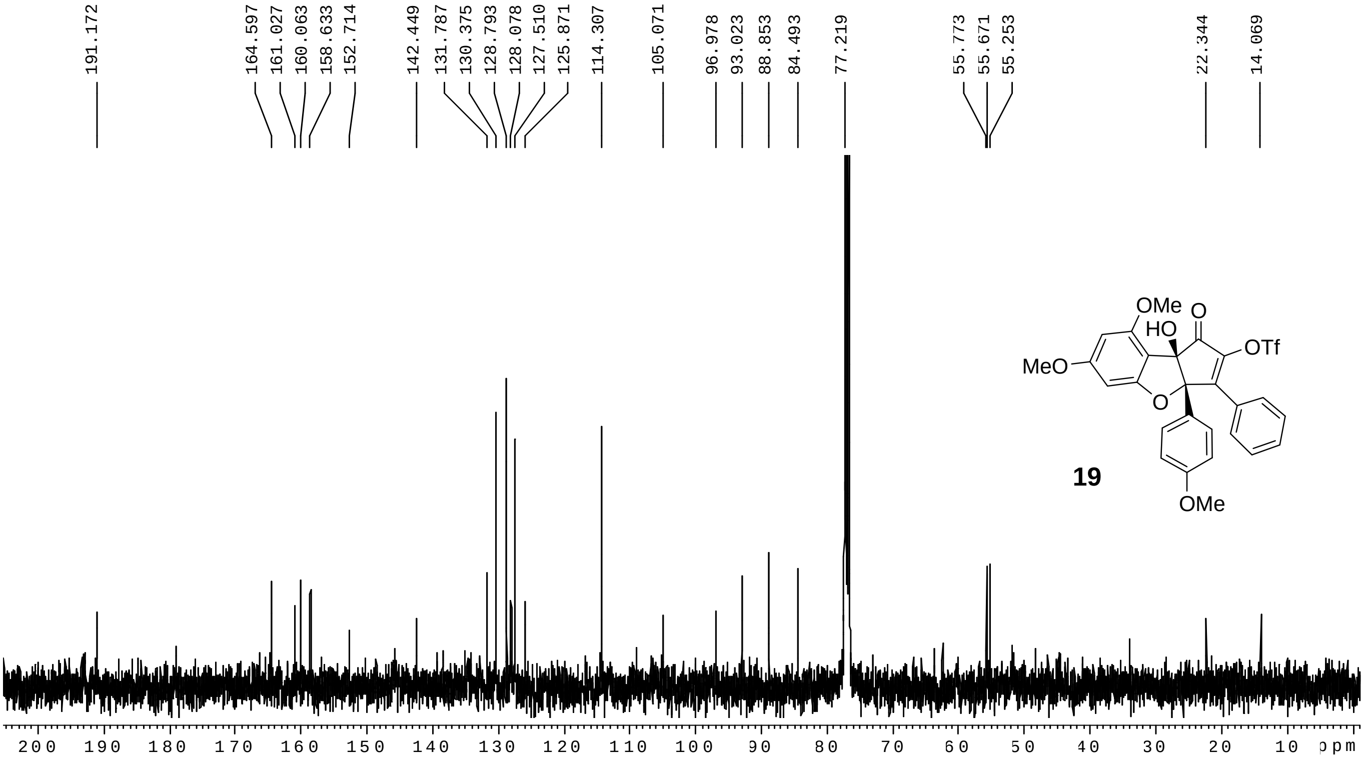
7.573
7.428
7.409
7.406
7.397
7.392
7.375
7.367
7.351
7.348
7.330
7.259
6.965
6.943
6.132
6.127
6.084
6.079
3.825
3.816
3.762
3.056
1.583
0.897
0.880
OMe
HO
O
OTf
MeO
O
19
OMe
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
ppm
2.181
5.780
2.056
0.998
0.999
2.973
3.194
3.254
0.932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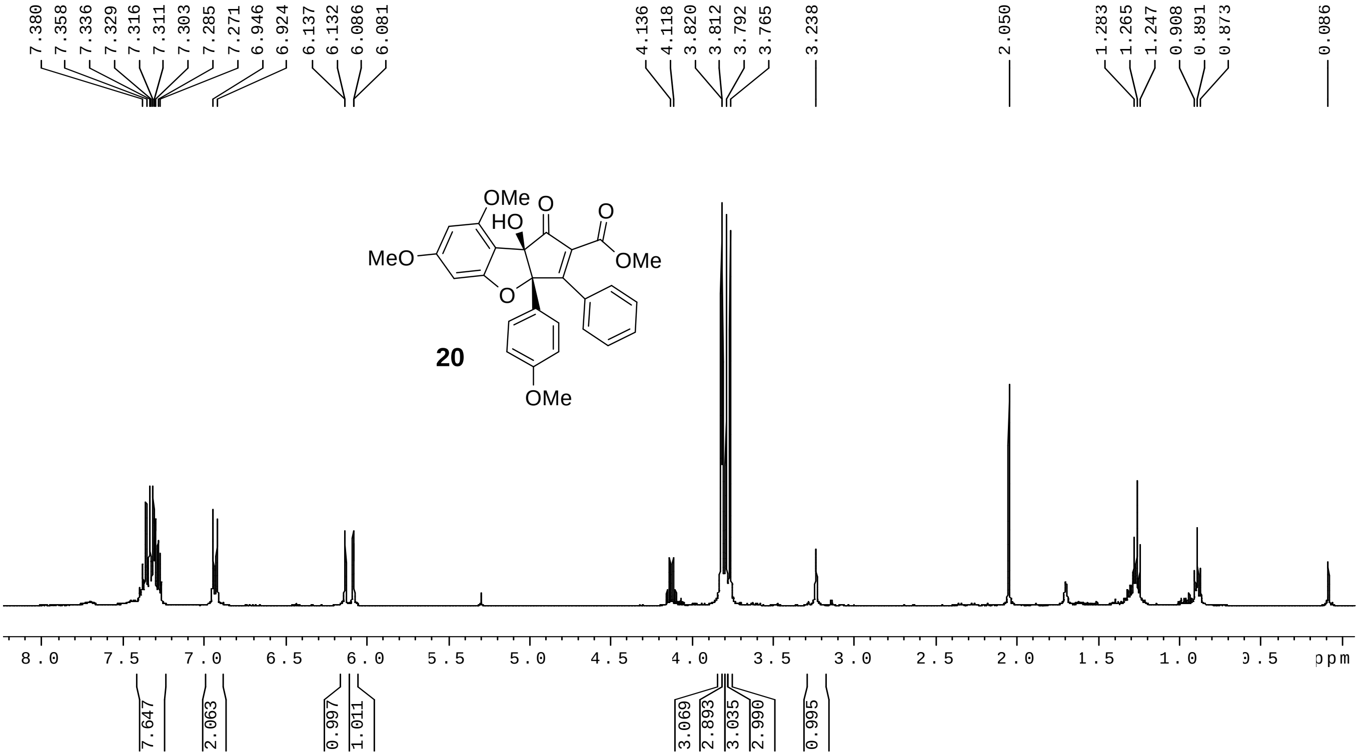
164.597
161.027
160.063
158.633
152.714
142.449
131.787
130.375
128.793
128.078
127.510
125.871
114.307
105.071
96.978
93.023
88.853
84.493
77.219
55.773
55.671
55.253
22.344
14.069
OMe
HO
O
OTf
MeO
O
19
OMe
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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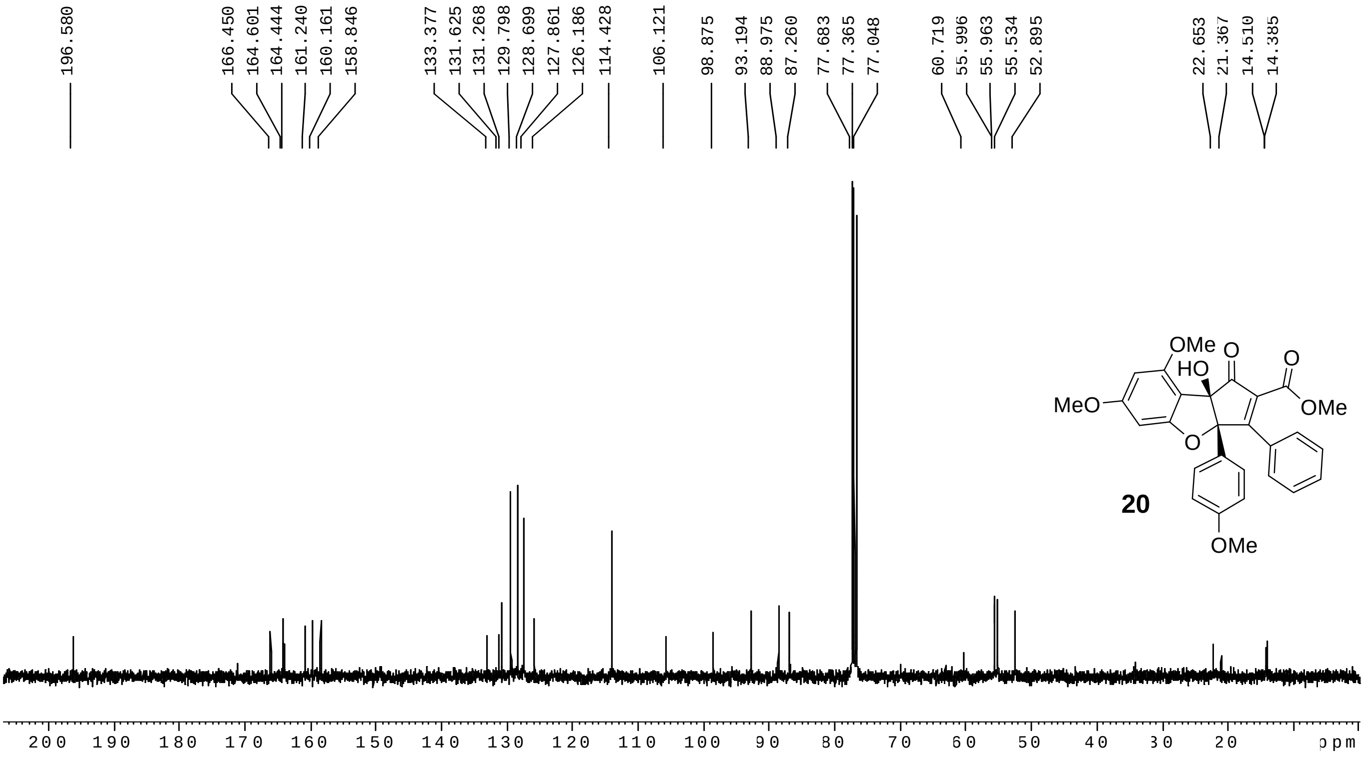
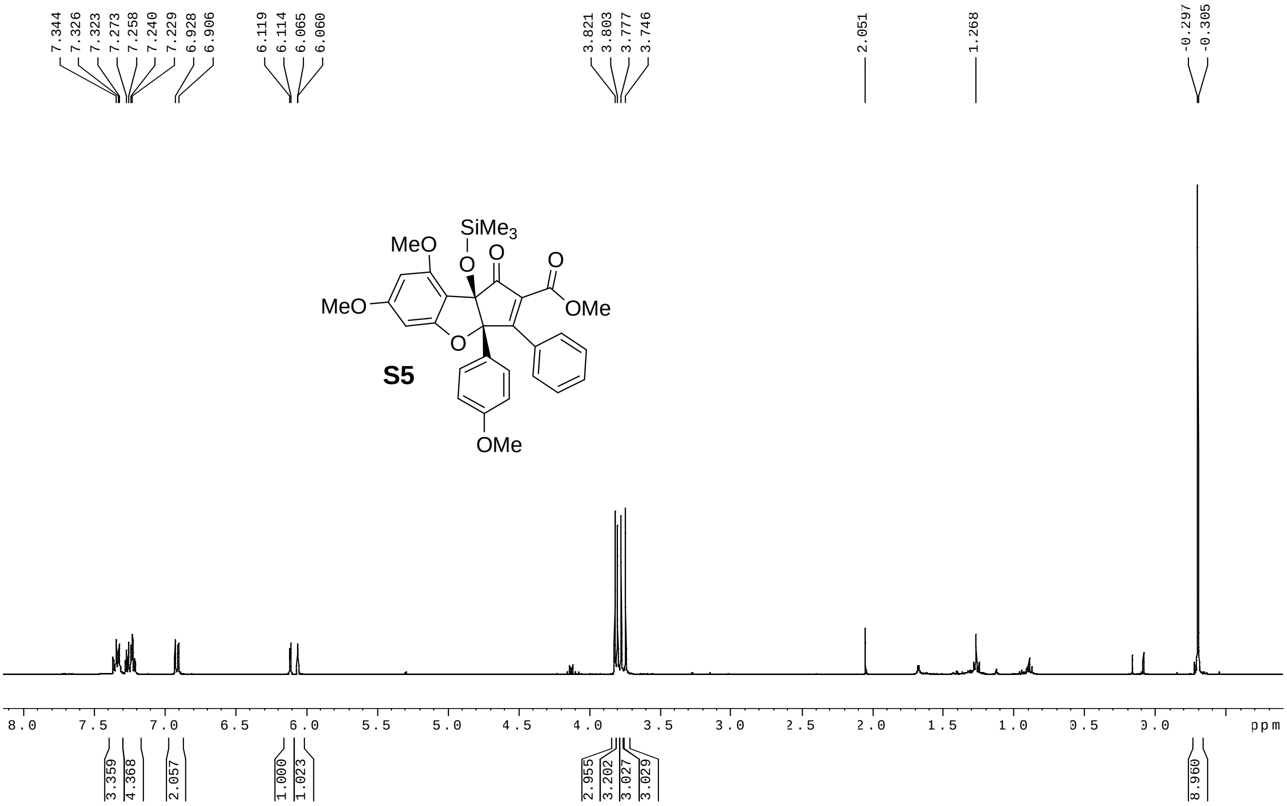
7.358
7.336
7.329
7.316
7.311
7.303
7.285
7.271
6.946
6.924
6.137
6.132
6.086
6.081
4.136
4.118
3.820
3.812
3.792
3.765
3.238
2.050
1.283
1.265
1.247
0.908
0.891
0.873
0.086
OMe
HO
O
O
MeO
OMe
O
OMe
20
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
7.647
2.063
0.997
1.011
3.069
2.893
3.035
2.990
0.995


196.580
166.450
164.601
164.444
161.240
160.161
158.846
133.377
131.625
131.268
129.798
128.699
127.861
126.186
114.428
106.121
98.875
93.194
88.975
87.260
77.683
77.365
77.048
60.719
55.996
55.963
55.534
52.895
22.653
21.367
14.510
14.385
OMe
HO
O
O
MeO
OMe
O
OMe
20
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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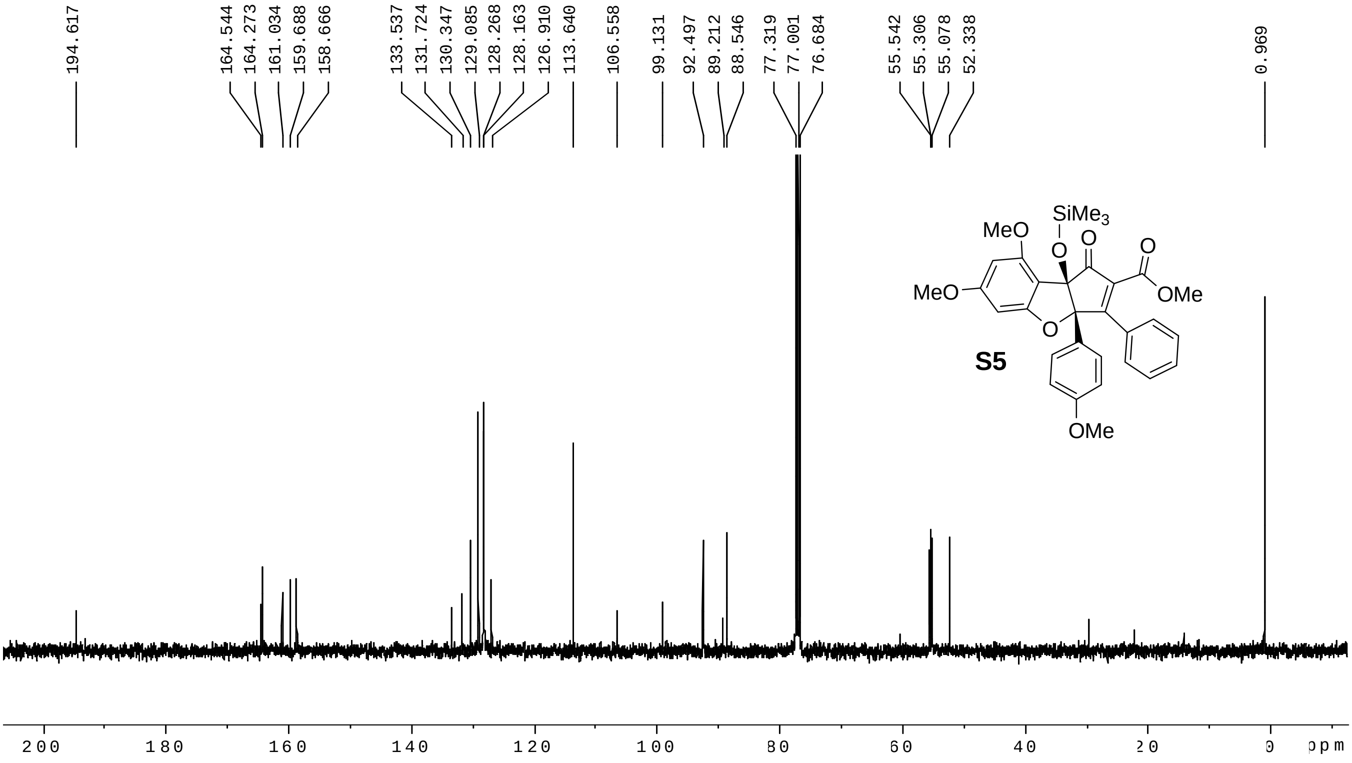
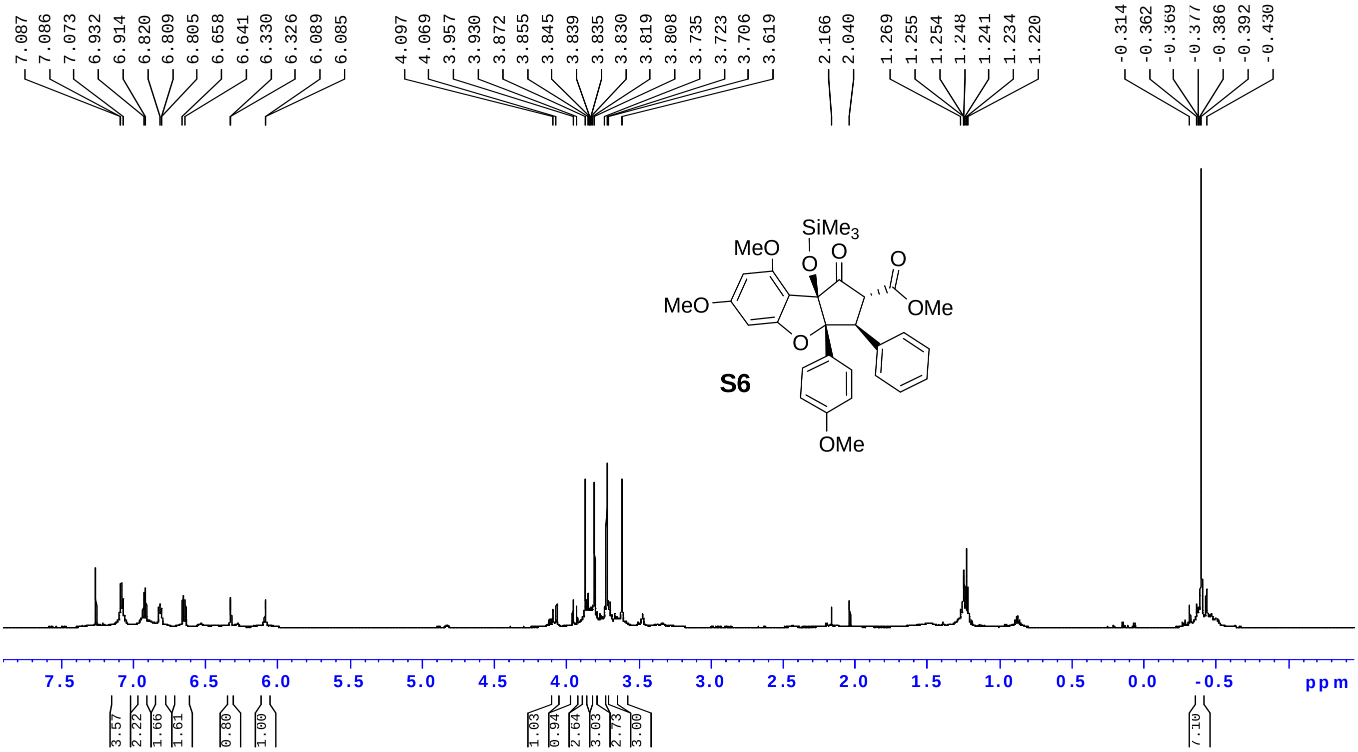
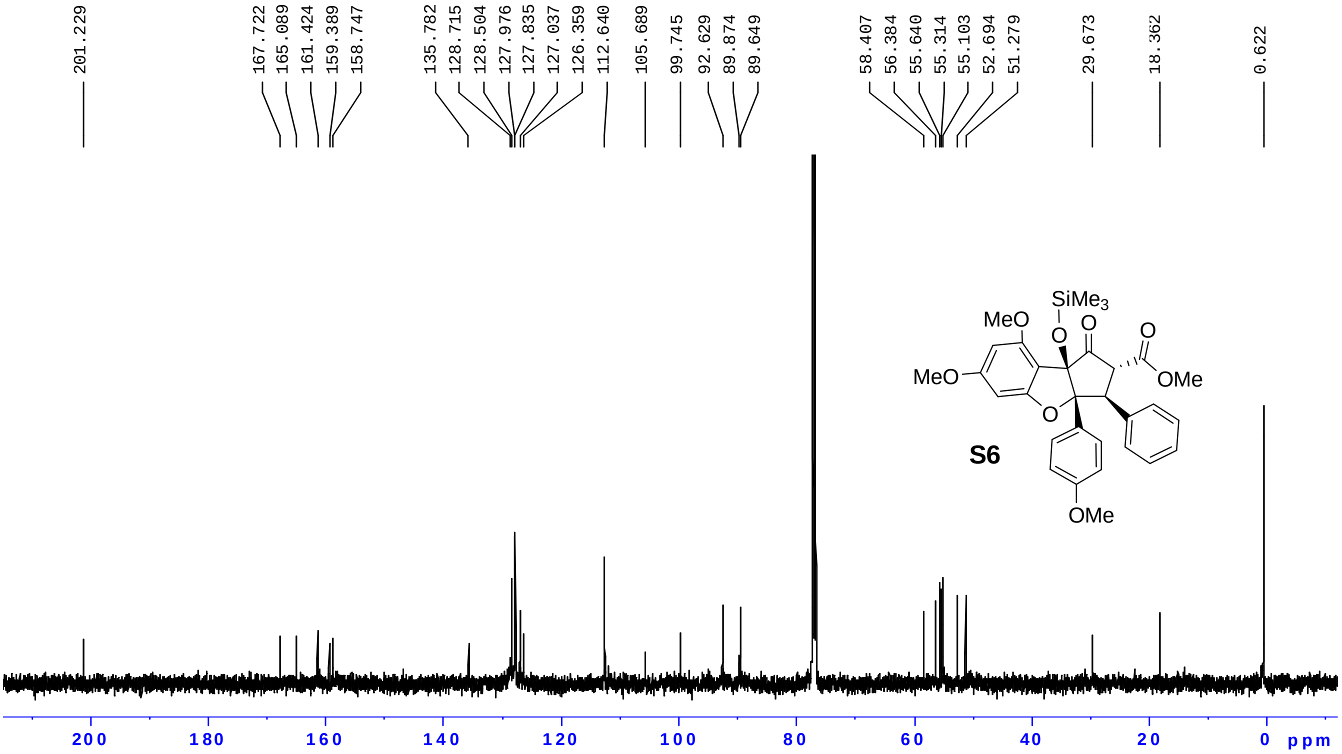
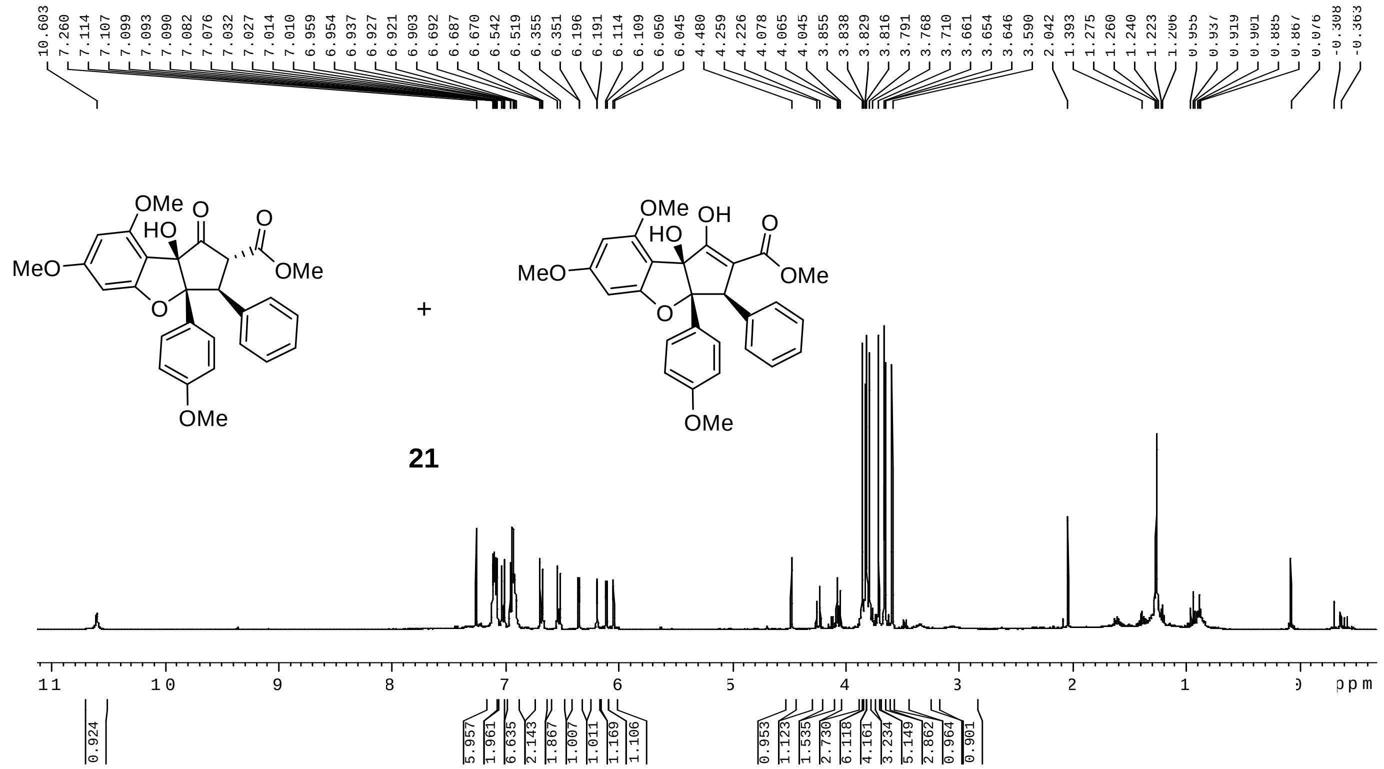
7.326
7.323
7.273
7.258
7.240
7.229
6.928
6.906
6.119
6.114
6.065
6.060
3.821
3.803
3.777
3.746
2.051
1.268
-0.297
-0.305
MeO
SiMe$_3$
O
O
O
MeO
OMe
O
S5
OMe
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
3.359
4.368
2.057
1.000
1.023
2.955
3.202
3.027
3.029
8.960

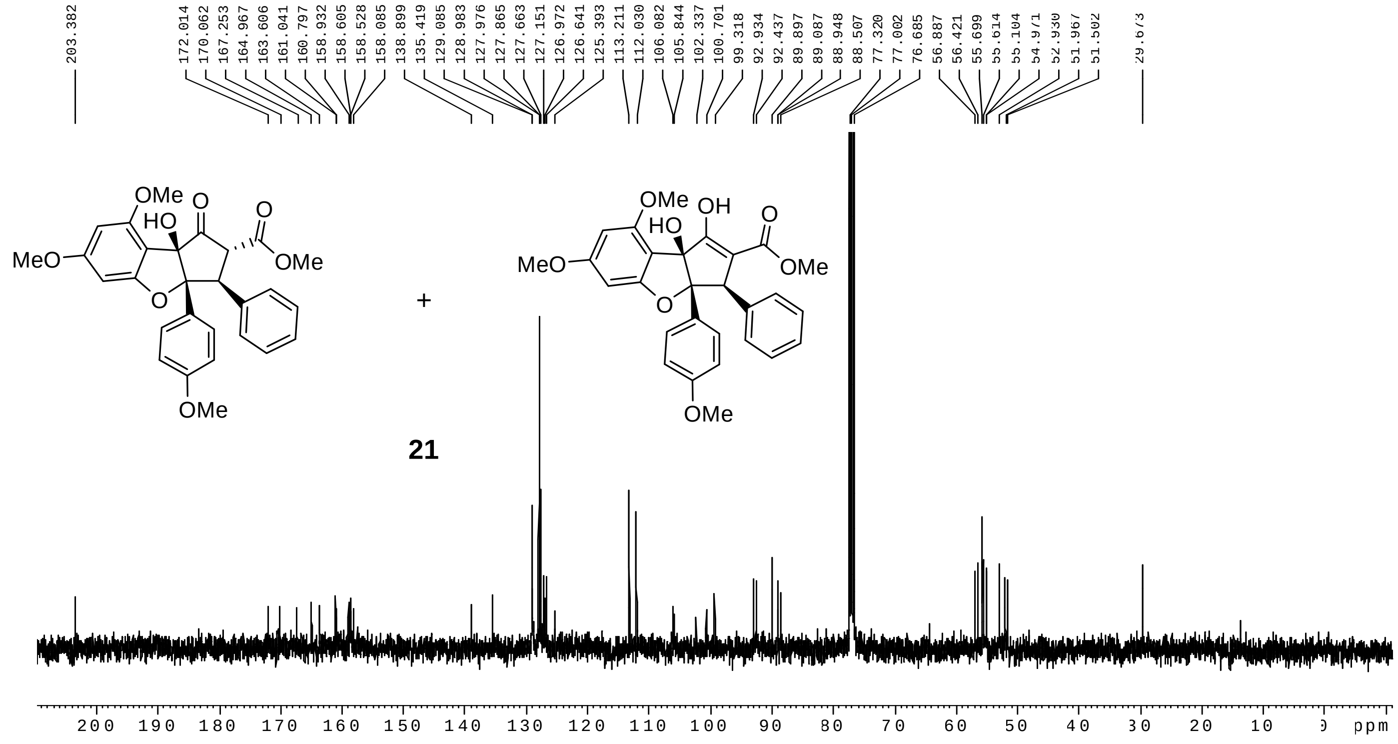

194.617
164.544
164.273
161.034
159.688
158.666
133.537
131.724
130.347
129.085
128.268
128.163
126.910
113.640
106.558
99.131
92.497
89.212
88.546
77.319
77.001
76.684
55.542
55.306
55.078
52.338
0.969
MeO
SiMe$_3$
O
O
O
MeO
OMe
O
S5
OMe
200
180
160
140
120
100
80
60
40
20
0
ppm


7.087
7.086
7.073
6.932
6.914
6.820
6.809
6.805
6.658
6.641
6.330
6.326
6.089
6.085
4.097
4.069
3.957
3.930
3.872
3.855
3.845
3.839
3.835
3.830
3.819
3.808
3.735
3.723
3.706
3.619
2.166
2.040
1.269
1.255
1.254
1.248
1.241
1.234
1.220
-0.314
-0.362
-0.369
-0.377
-0.386
-0.392
-0.430
SiMe3
MeO
O
O
O
MeO
OMe
O
S6
OMe
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
ppm
3.57
2.22
1.66
1.61
0.80
1.00
1.03
0.94
2.64
3.03
2.73
3.00
7.10

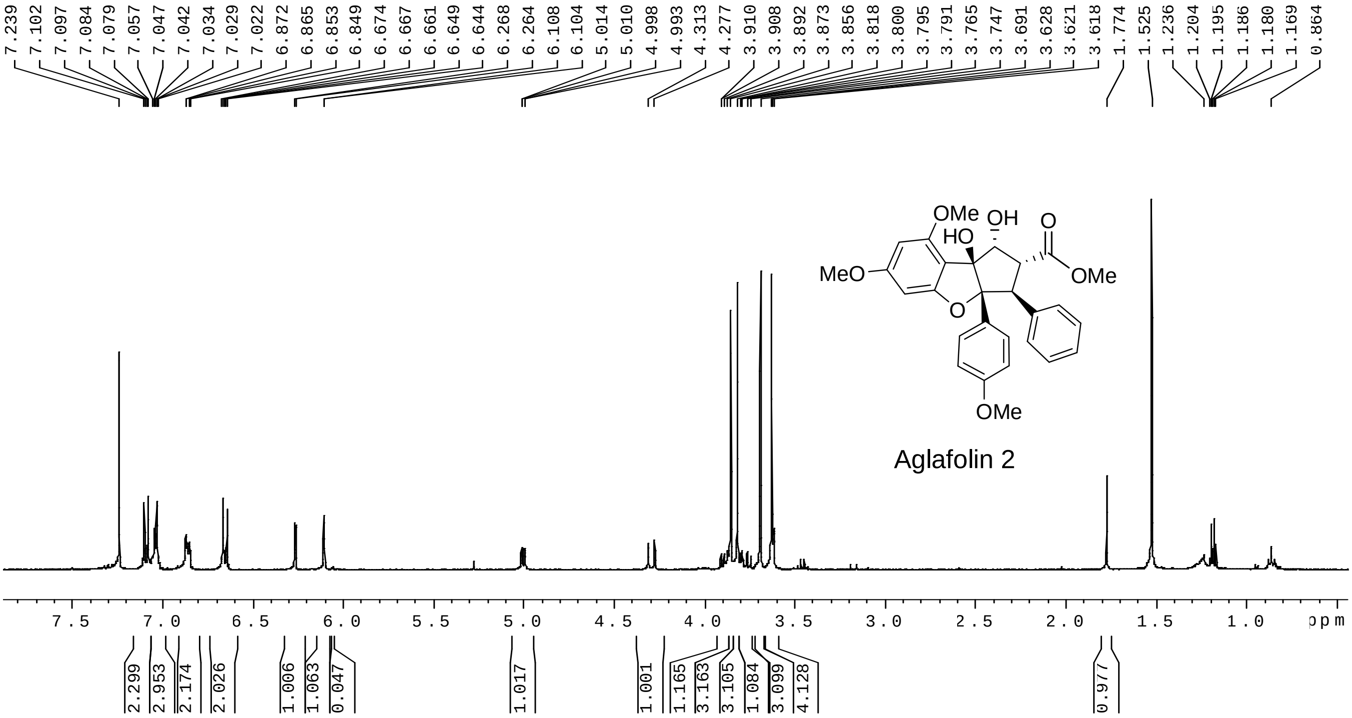

201.229
167.722
165.089
161.424
159.389
158.747
135.782
128.715
128.504
127.976
127.835
127.037
126.359
112.640
105.689
99.745
92.629
89.874
89.649
58.407
56.384
55.640
55.314
55.103
52.694
51.279
29.673
18.362
0.622
SiMe3
MeO
O
O
O
MeO
OMe
O
S6
OMe
200
180
160
140
120
100
80
60
40
20
0
ppm


10.603
7.260
7.114
7.107
7.099
7.093
7.090
7.082
7.076
7.032
7.027
7.014
7.010
6.959
6.954
6.937
6.927
6.921
6.903
6.692
6.687
6.670
6.542
6.519
6.355
6.351
6.196
6.191
6.114
6.109
6.050
6.045
4.480
4.259
4.226
4.078
4.065
4.045
3.855
3.838
3.829
3.816
3.791
3.768
3.710
3.661
3.654
3.646
3.590
2.042
1.393
1.275
1.260
1.240
1.223
1.206
0.955
0.937
0.919
0.901
0.885
0.867
0.076
-0.308
-0.363
OMe
HO
O
MeO
O
OMe
O
OMe
+
OMe
HO
OH
O
MeO
OMe
O
OMe
11 10 9 8 7 6 5 4 3 2 1 0 ppm
0.924
5.957
1.961
6.635
2.143
1.867
1.007
1.011
1.169
1.106
0.953
1.123
1.535
2.730
6.118
4.161
3.234
5.149
2.862
0.964
0.901

**21**


203.382
172.014
170.062
167.253
164.967
163.606
161.041
160.797
158.932
158.605
158.528
158.085
138.899
135.419
129.085
128.983
127.976
127.865
127.663
127.151
126.972
126.641
125.393
113.211
112.030
106.082
105.844
102.337
100.701
99.318
92.934
92.437
89.897
89.087
88.948
88.507
77.320
77.002
76.685
56.887
56.421
55.699
55.614
55.104
54.971
52.930
51.967
51.502
29.673
OMe
HO
O
MeO
O
OMe
O
OMe
+
OMe
HO
OH
O
MeO
OMe
O
OMe
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

**21**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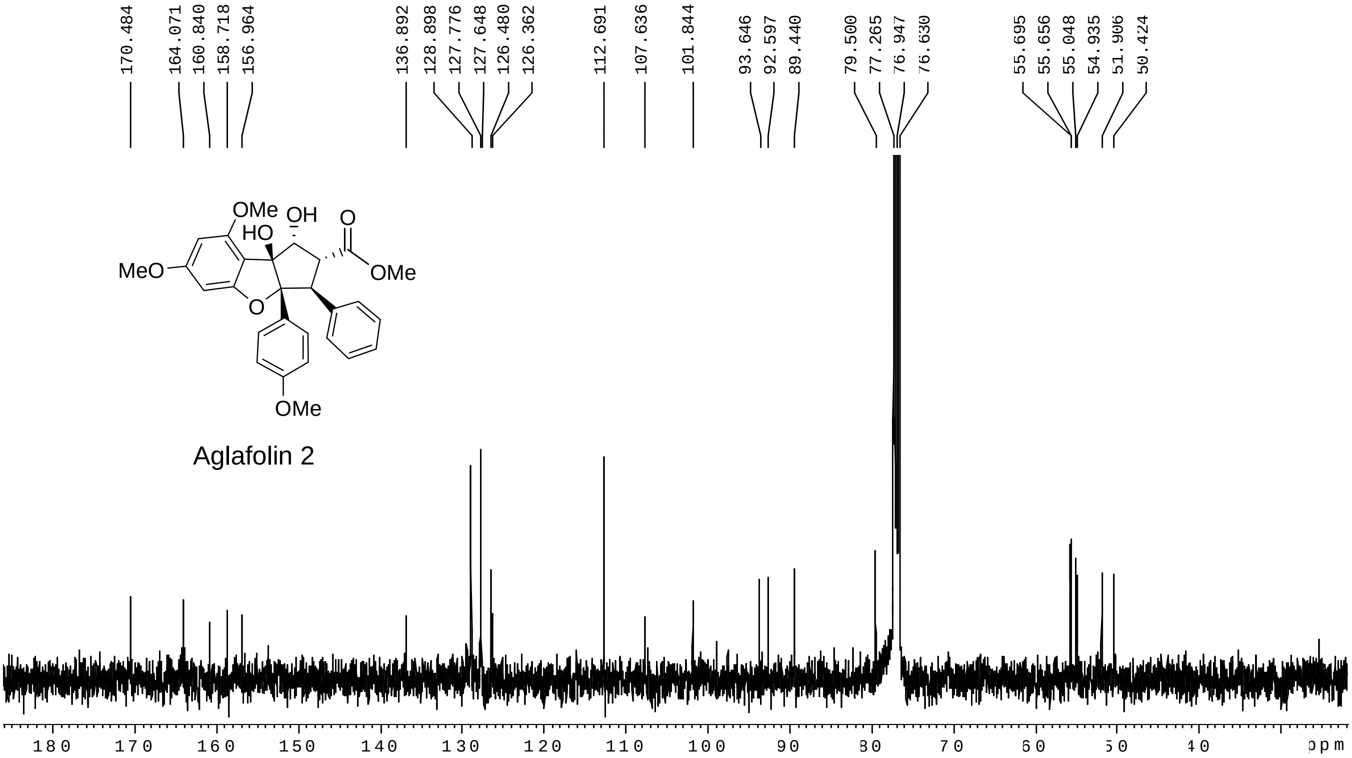
7.097
7.084
7.079
7.057
7.047
7.042
7.034
7.029
7.022
6.872
6.865
6.853
6.849
6.674
6.667
6.661
6.649
6.644
6.268
6.264
6.108
6.104
5.014
5.010
4.998
4.993
4.313
4.277
3.910
3.908
3.892
3.873
3.856
3.818
3.800
3.795
3.791
3.765
3.747
3.691
3.628
3.621
3.618
1.774
1.525
1.236
1.204
1.195
1.186
1.180
1.169
0.864
OMe
OH
HO
O
MeO
OMe
O
OMe
Aglafolin 2
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
ppm
2.299
2.953
2.174
2.026
1.006
1.063
0.047
1.017
1.001
1.165
3.163
3.105
1.084
3.099
4.128
0.977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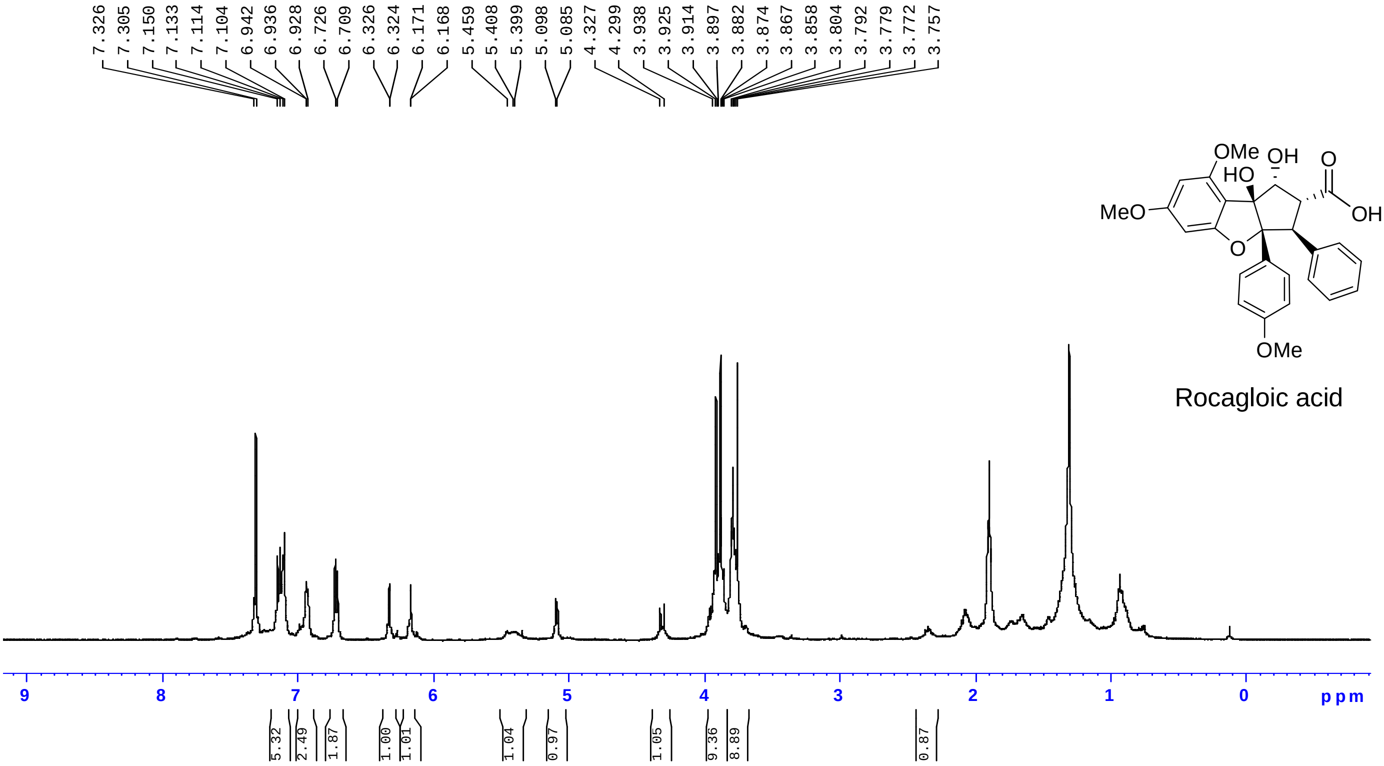
127.776
127.648
126.480
126.362
112.691
107.636
101.844
93.646
92.597
89.440
79.500
77.265
76.947
76.630
55.695
55.656
55.048
54.935
51.906
50.424
OMe
OH
HO
O
MeO
OMe
O
OMe
Aglafolin 2
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
ppm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7.305
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7.133
7.114
7.104
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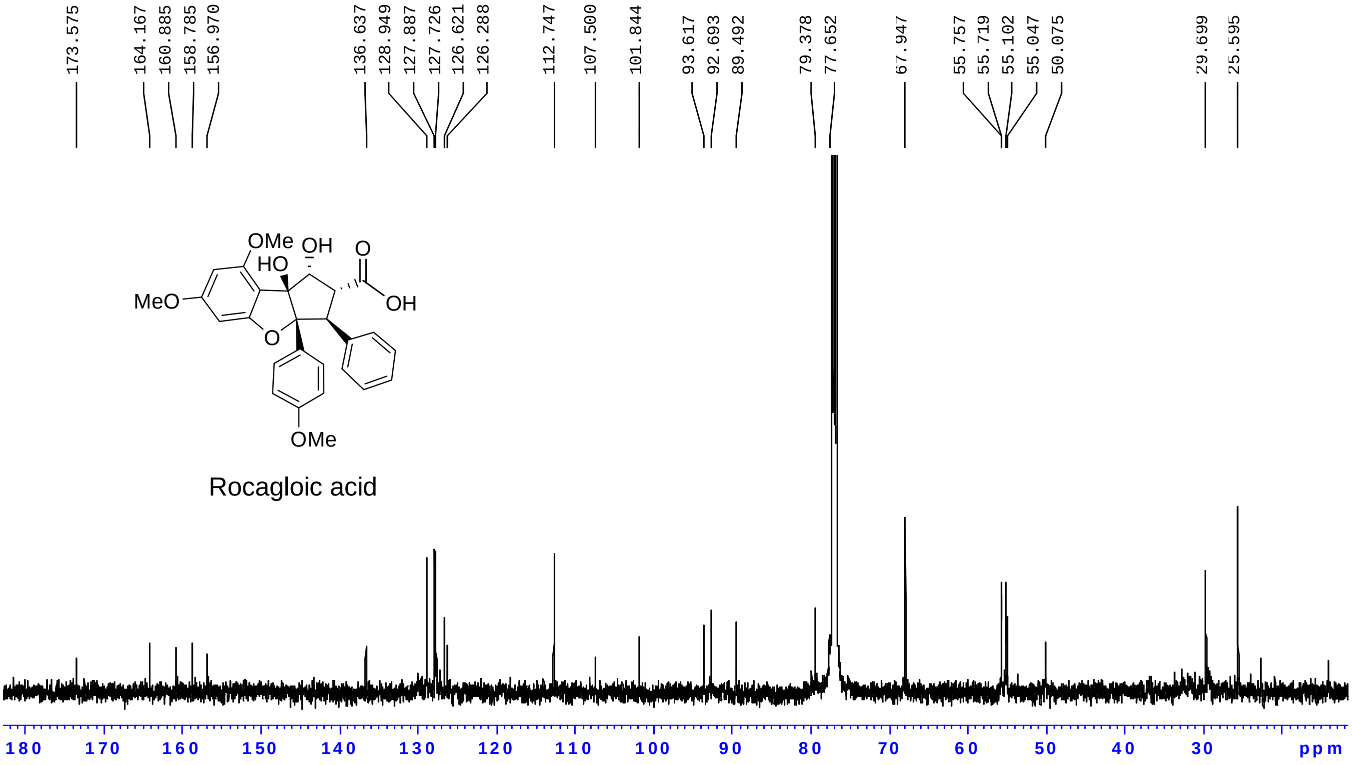
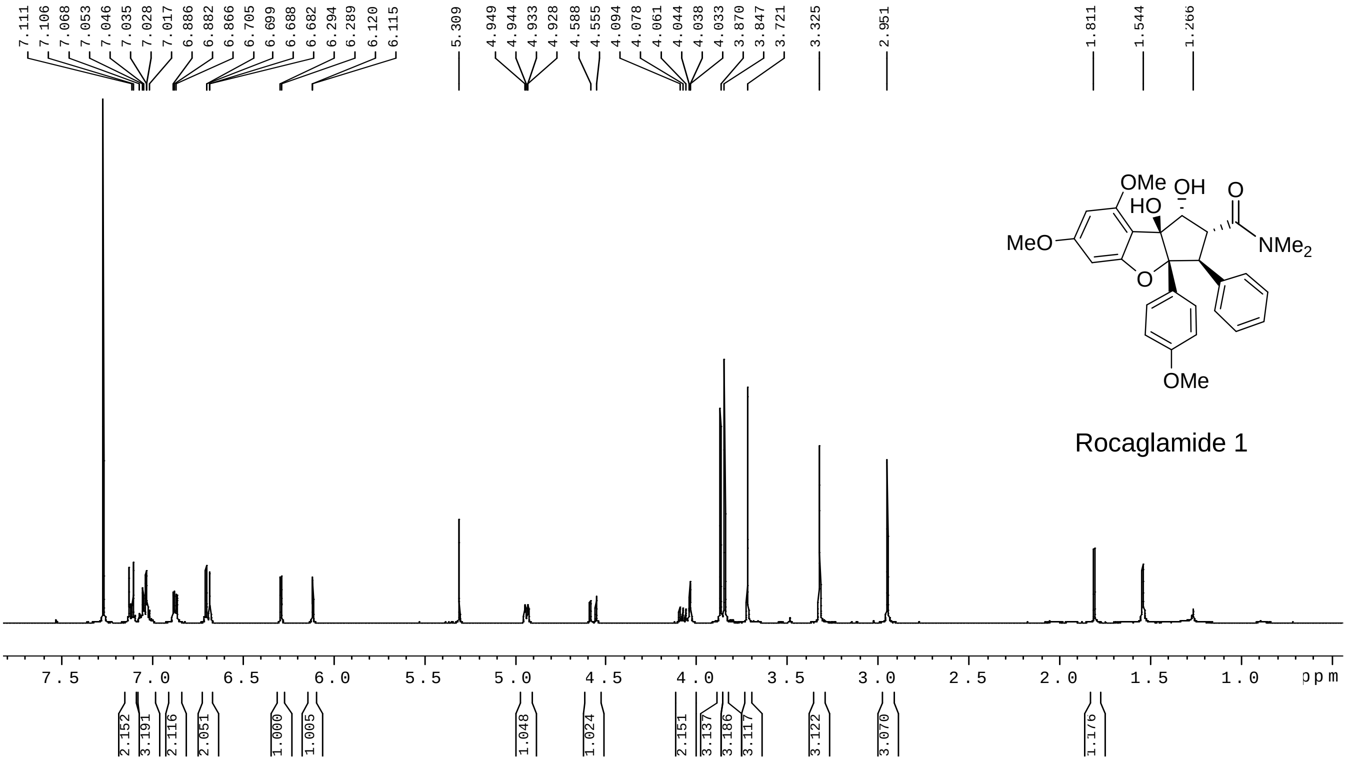
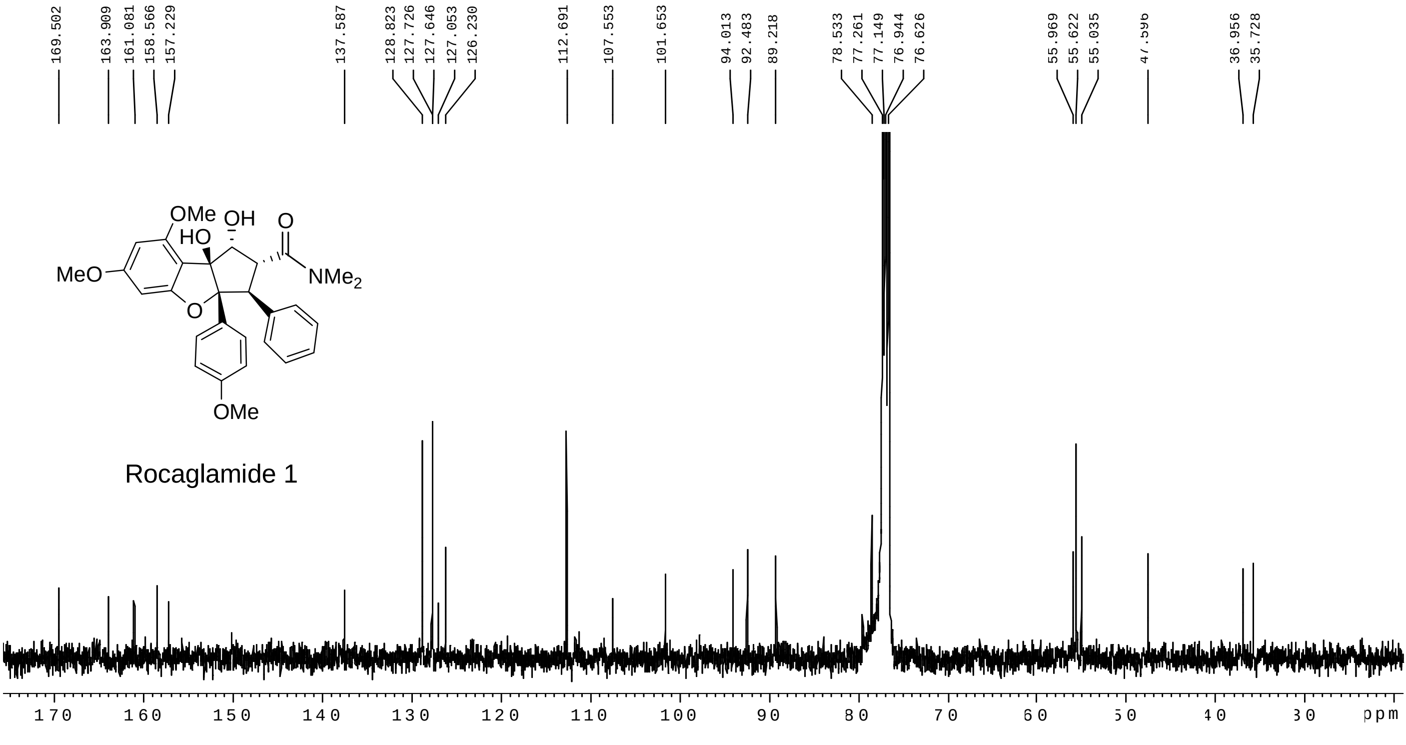
6.936
6.928
6.726
6.709
6.326
6.324
6.171
6.168
5.459
5.408
5.399
5.098
5.085
4.327
4.299
3.938
3.925
3.914
3.897
3.882
3.874
3.867
3.858
3.804
3.792
3.779
3.772
3.757
OMe
OH
HO
O
MeO
OH
O
OMe
Rocagloic acid
9
8
7
6
5
4
3
2
1
0
ppm
5.32
2.49
1.87
1.00
1.01
1.04
0.97
1.05
9.36
8.89
0.87


173.575
164.167
160.885
158.785
156.970
136.637
128.949
127.887
127.726
126.621
126.288
112.747
107.500
101.844
93.617
92.693
89.492
79.378
77.652
67.947
55.757
55.719
55.102
55.047
50.075
29.699
25.595
OMe
OH
HO
O
MeO
OH
O
OMe
Rocagloic acid
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
ppm



Rocaglamide 1



Rocaglamide 1