Supplementary Material (ESI) for Chemical Communications

SUPPORTING INFORMATION

A radical-based approach to hydroxytetralones from unprotected phenols

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Contents :

General Experimental Methods

Anhydrous THF was obtained by distillation from sodium-benzophenone ketyl under nitrogen. Other solvents were used as supplied by commercial sources. Petroleum ether refers to the fraction of light petroleum ether, boiling between 40-60°C. All liquid reagents were distilled prior to use. Purification procedures were in accordance with the instructions in D. D. Perrin and W. L. F. Armarego, "Purification of Laboratory Chemicals", Fourth Edition, The Bath Press, Bath, 2002. All reactions were carried out under dry, oxygen free nitrogen. Flash chromatography was performed on silica gel (SDS, 60 Å C. C. 40-63 μm) as the stationary phase. Thin Layer Chromatography (TLC) was performed on alumina plates pre-coated with silica gel (Merck silica gel, 60 F_{254}), which were visualized by the quenching of UV fluorescence (λ_{max} = 254 nm and/or 366 nm) and/or by staining with vanillin in acidic ethanol followed by heating. Melting points were recorded by heating on Reichert plates under a microscope and are uncorrected. Infrared spectra were recorded as solutions in CCl_4 using CaF_2 cells, on a Perkin-Elmer FT 1600. Absorption maxima (ν_{max}) are reported in wavenumbers (cm^{-1}) and only selected peaks are reported. Magnetic resonance spectra were recorded at ambient temperature on either a Bruker AMX 400, or a Bruker Avance DPX 400 instruments. Proton magnetic resonance spectra (^{1}H NMR) were recorded at 400 MHz and coupling constants (*J*) are reported to ± 0.5 Hz. The following abbreviations were utilized to describe peak patterns when appropriate: br = broad, s = singlet, d = doublet, t = triplet, q = quartet and m = multiplet. Carbon magnetic resonance spectra (^{13}C NMR) were recorded at 100.6 MHz. Chemical shifts (δ_H, δ_C) are quoted in parts per million (ppm) and are referenced to the residual solvent peak ($CDCl_3$: δ_H = 7.26 and δ_C = 77.0). Low-resolution mass spectra (*m/z*) were recorded by chemical ionization (CI/NH_3) on a Hewlett-Packard HP 5989B and only report molecular species ($[M+H]^+$, $[M+NH_4]^+$) and other major fragments. High-resolution mass spectra were recorded by positive electron impact ionization (EI+) at 70 eV on a JEOL JMS-GCmate II mass spectrometer. The quoted masses are accurate to ± 5 ppm.

General procedure for the preparation of xanthates derived from 2-hydroxyacetophenones.

To a hot suspension of $CuBr_2$ (2.5 n équiv.) in ethyl acetate (n mL), was added dropwise a solution of the 2-hydroxyacetophenone (n equiv.) in $CHCl_3$ (n mL). The mixture was then stirred at reflux until total consumption of the starting material. The reaction was monitored by ^1H NMR. After completion, the mixture was allowed to cool down to room temperature, filtered and the solvents were removed under reduced pressure. The crude brominated compound was dissolved in acetone (2 n mL) and the solution was cooled down to 0°C. Potassium xanthate salt (1.2 n equiv.) was then added portionwise and the mixture stirred at 0°C for 15 min. Removal of the solvent under reduced pressure was followed by dilution in CH_2Cl_2 and washing with water and brine. The organics were dried ($MgSO_4$), filtered and the solvent was removed under reduced pressure. Purification by flash chromatography on silica gel afforded pure xanthate.

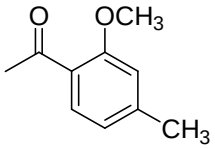
General procedure A for the intermolecular addition of xanthate:

A solution of xanthate (n mmol) and olefin (2-3n mmol) in ethyl acetate (n mL) was refluxed 10 min under nitrogen and 10 mol % of DLP were added followed by 5 mol % every 90 min until complete consumption of the olefin. The mixture was then cooled down to room temperature and the solvent was evaporated under reduced pressure. The residue was purified by flash chromatography on silica gel to yield the corresponding xanthate.

General procedure B for the radical cyclisation onto an aromatic ring:

A solution of addition xanthate (n mmol) in ethyl acetate (10-15n mL) was refluxed 10 min. under nitrogen. 20 mol % of DLP were then added followed by 20 mol % every 60 min until complete consumption of the xanthate. The mixture was then cooled down to room temperature and the solvent was evaporated under reduced pressure. The residue was purified by flash chromatography on silica gel to yield the corresponding tetralone.

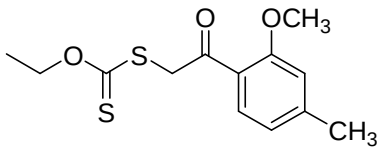
1-(2-methoxy-4-methylphenyl)ethanone



To a solution of 1-(2-hydroxy-4-methylphenyl)ethanone (2.0 g, 13.3 mmol, 1 equiv.) in acetone (36 mL) was added at room temperature, potassium hydroxyde (971 mg, 17.3 mmol, 1.3 equiv.). Dimethylsulfate (2.18 g, 17.3 mmol, 1.3 equiv.) was then added dropwise and the solution was stirred at room temperature during 15 h. The solvent was removed under vacuum and the residue was diluted in ethyl acetate and washed with water and brine. The organic layer was then dried ($MgSO_4$), filtered and concentrated under reduced pressure. The crude reaction mixture was purified by flash chromatography (petroleum ether/diethyl ether, 9:1 v/v) to afford the compound **1** in 99% yield.

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 7.48 (d, *J* = 8.2 Hz, 1H), 6.56 (m, 2H), 3.65 (s, 3H), 2.37 (s, 3H), 2.15 (s, 3H).
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 197.7 (C), 158.5 (C), 144.2 (C), 129.7 (CH), 124.5 (C), 120.6 (CH), 111.6 (CH), 54.6 (CH_3), 31.1 (CH_3), 21.0 (CH_3).
IR (CCl_4): ν_{max} 3049, 2983, 1675, 1607, 1261, 908.
MS (CI/NH3): 165 (MH^+).
HRMS (EI+): calculated 164.0837, found 164.0837.

***O*-ethyl S-2-(2-methoxy-4-methylphenyl)-2-oxoethyl carbonodithioate (3)**

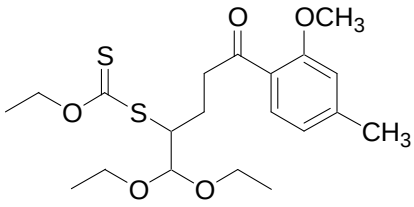


N-bromosuccinimide (1.55 g, 8.74 mmol, 1 equiv.) was slowly added, at room temperature to a magnetically stirred solution of 1-(2-methoxy-4-methylphenyl)ethanone (1.43 g, 8.74 mmol, 1 equiv.) and *para*-toluene sulfonic acid monohydrate (2.49 g, 13.10 mmol, 1.5 equiv.) in acetonitrile (300 mL). The reaction mixture was stirred 2 h at reflux. Acetonitrile was then removed under reduced pressure and the residue was diluted in DCM, washed with water and

brine. The organic layer was dried over $MgSO_4$, filtered and then concentrated under reduced pressure to yield brominated acetophenone (2.20 g). The crude brominated compound was dissolved in acetone (17 mL) and potassium xanthate salt (1.54 g, 9.61 mmol, 1.1 equiv.) was added portionwise at 0°C. The solution was stirred for 15 min at this temperature and then the solvent was removed under reduced pressure. The residue was diluted in ethyl acetate, washed with water and brine. The organic layer was dried over $MgSO_4$, filtered and then concentrated. The crude mixture was purified by flash chromatography on silica gel (toluene/ethyl acetate, 35/1 v/v) to afford xanthate **2** (1.61 g, 65 % over two steps).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 7.69 (d, *J* = 7.9 Hz, 1H), 6.81 (d, *J* = 7.9 Hz, 1H), 6.78 (s, 1H), 4.58 (m, 4H), 3.92 (s, 3H), 2.38 (s, 3H), 1.36 (t, *J* = 7.1 Hz, 3H).
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 213.8 (C), 193.1 (C), 158.9 (C), 145.7 (C), 131.9 (CH, C), 123.6 (C, C), 121.8 (CH), 112.2 (CH), 70.2 (CH_2), 55.5 (CH_3), 47.7 (CH_2), 21.9 (CH_3), 13.7 (CH_3).
IR (CCl_4): ν_{max} 3051, 2983, 2305, 1676, 1608, 1423, 1263.
MS (CI/NH3) : 285 $(MH)^+$.
HRMS (EI+): calculated for $C_{13}H_{16}O_3S_2$ 284.0541, found 284.0537.

***S*-1,1-diethoxy-5-(2-methoxy-4-methylphenyl)-5-oxopentan-2-yl *O*-ethyl carbonothioate (5)**



Following general procedure A for intermolecular radical addition, the reaction was carried out using xanthate **3** (400 mg, 1.406 mmol, 1 equiv.) and acrolein diethylacetal (0.429 mL, 2.812 mmol, 2 equiv.) in ethyl acetate (1.4 mL). The reaction needed 20 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/diethyl ether, 9/1) afforded xanthate **5** (445 mg, 77 %).
^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 7.63 (d, *J* = 7.9 Hz, 1H), 6.79 (d, *J* = 7.9 Hz, 1H), 6.73 (s, 1H), 4.57 (m, 3H), 4.12 (td, *J* = 10.2, 3.8 Hz, 1H), 3.87 (s, 3H), 3.72 (m, 2H), 3.46 (m, 2H), 2.54 (s, 3H), 2.36 (m, 1H), 1.96 (m, 1H), 1.39 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 6H).

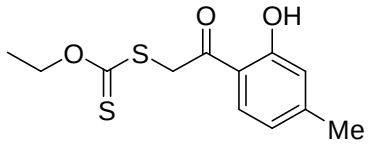
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 214.8 (C), 200.8 (C), 158.6 (C), 144.3 (C), 130.4 (CH), 125.1 (C), 122.1 (CH), 121.2 (CH), 103.8 (CH), 69.8 (CH_2), 64.2 (CH_2), 63.5 (CH_2), 55.2 (CH_3), 53.2 (CH), 40.8 (CH_2), 23.2 (CH_2), 21.9 (CH_3), 15.07 (CH_3), 15.02 (CH_3), 13.1 (CH_3).

IR (CCl_4): ν_{max} 4250, 4194, 3941, 3692, 3053, 2984, 2305, 1424, 1266, 1156, 909.

MS (CI/NH3): 415 (MH^+).

HRMS (EI+): calculated for $C_{20}H_{30}O_5S_2$, 414.1535, found 414.1532.

***O*-ethyl S-2-(2-hydroxy-4-methylphenyl)-2-oxoethyl carbonodithioate (9)**



Following general procedure for xanthate derived from acetophenone, the reaction was carried out using 2-hydroxy-4-methylacetophenone (10.0 g, 66.6 mmol, 1.0 equiv.) and $CuBr_2$ (29.68 g, 133.2 mmol, 2.0 equiv.) in ethyl acetate (55 mL) and chloroform (55 mL). After 14 hours, the solvent was removed under pressure and diluted in acetone (n mL). Potassium xanthate salt (12.81 g, 79.91 mmol (theoretical), 1.2 equiv. theoretical) was added. Xanthate **9** was obtained after usual work-up (13.78 g, 76%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 11.81 (s, 1H, OH), 7.74 (d, *J* = 8.2 Hz, 1H), 6.82 (s, 1H), 6.75 (dd, *J* = 8.2, 1.2 Hz, 1H), 4.66 (m, 4H), 2.37 (s, 3H), 1.40 (t, *J* = 7.1 Hz).

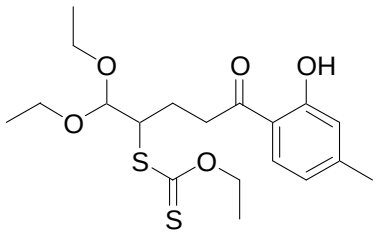
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 212.8 (C), 197.2 (C), 162.7 (C), 148.9 (C), 129.7 (CH), 120.6 (CH), 118.7 (CH), 116.5 (C), 70.8 (CH_2), 42.7 (CH_2), 22.0 (CH_3), 13.7 (CH_3).

IR (CCl_4): ν_{max} 3051,1679, 1605, 1423, 1263.

MS (CI/NH3) : 271 $(MH)^+$.

HRMS (EI+): calculated for $C_{12}H_{14}O_3S_2$ 270.0384, found 270.0382.

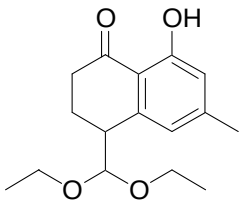
_S_-1,1-diethoxy-5-(2-hydroxy-4-methylphenyl)-5-oxopentan-2-yl O-ethyl carbonodithioate (10)



Following general procedure for intermolecular radical addition using xanthate **9** (13.73 g, 50.85 mmol, 1.0 equiv.) and acrolein diethylacetal (15.50 mL, 101.7 mmol, 2.0 equiv.) in ethyl acetate (50 mL). The reaction needed 30 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/diethyl ether, 9/1 to 8/2) afforded xanthate **10** (16.29 g, 80 %).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.36 (s, 1H, OH), 7.66 (d, *J* = 8.2 Hz, 1H), 6.81 (s, 1H), 6.72 (d, *J* = 8.2, 1H), 4.65 (m, 3H), 4.17 (m, 1H), 3.83-3.49 (m, 4H), 3.18 (m, 2H), 2.47 (m, 1H), 2.37 (s, 3H), 2.08 (m, 1H), 1.43 (t, *J* = 7.1 Hz, 3H), 1.25 (m, 6H).
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 214.6 (C), 205.1 (C), 162.4 (C), 147.6 (C), 129.8 (CH), 120.1 (CH), 118.3 (CH), 117.1 (C), 103.9 (CH), 70.1 (CH_2), 64.5 (CH_2), 63.7 (CH_2), 53.3 (CH), 35.3 (CH_2), 22.9 (CH_2), 21.8 (CH_3), 15.1 ($2CH_3$), 13.7 (CH_3).
MS (CI/NH3): 401 (MH^+).
HRMS (EI+): calculated for $C_{19}H_{28}O_5S_2$, 400.1378, found 400.1376.

4-(diethoxymethyl)-8-hydroxy-6-methyl-3,4-dihydronaphthalen-1(2*H*)-one (11)



Following general procedure for radical cyclisation, the reaction was carried out using xanthate **10** (9.93 g, 24.8 mmol, 1.0 equiv.) in ethyl acetate (250 mL), and needed 140 mol %

of DLP to go to completion. Purification by chromatography on silica gel (petroleum ether/diethyl ether 9/1 to 7/3) yielded tetralone **11** (3.17 g, 46%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.58 (s, 1H, OH), 6.64 (s, 2H), 4.54 (d, *J* = 5.8 Hz, 1H), 3.71-3.62 (m, 2H), 3.39-3.29 (m, 2H), 3.05 (dt, *J* = 5.4, 3.2 Hz, 1H), 2.94 (ddd, *J* = 18.8, 13.4, 3.2, 1H), 2.52 (ddd, *J* = 18.4, 5.2, 3.0, 1H), 2.33 (m, 1H), 2.31 (s, 3H), 2.09 (m, 1H), 1.45 (t, *J* = 5.6 Hz, 3H), 1.12 (t, *J* = 5.6 Hz, 3H).

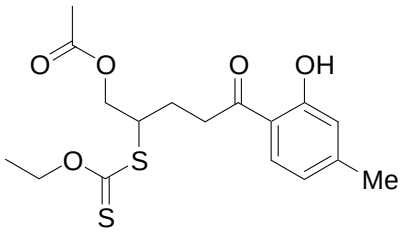
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 204.7 (C), 162.8 (C), 147.4 (C), 143.9 (C), 121.5 (CH), 116.4 (CH), 115.1 (C), 105.3 (CH), 64.2 (CH_2), 63.3 (CH_2), 42.0 (CH), 35.0 (CH_2), 22.8 (CH_2), 22.1 (CH_3), 15.1 ($3CH_3$).

IR (CCl_4): ν_{max} 2971, 2936, 2873, 1732, 1634.

MS (CI/NH3): 279 (MH^+).

HRMS (EI+): calculated for $C_{16}H_{22}O_4$, 278.1518, found 278.1518.

2-(ethoxycarbonothioylthio)-5-(2-hydroxy-4-methylphenyl)-5-oxopentyl acetate (10')



Following general procedure for intermolecular radical addition using xanthate **9** (1.33 g, 4.93 mmol, 1.0 equiv.) and allyl acetate (988 mg, 9.86 mmol, 2.0 equiv.) in ethyl acetate (5 mL). The reaction needed 20 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/diethyl ether, 9/1 to 8/2) afforded xanthate **10'** (1.54 g, 85 %).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.19 (s, 1H, OH), 7.61 (d, *J* = 8.2 Hz, 1H), 6.78 (s, 1H), 6.69 (dd, *J* = 8.2, 1.3 Hz, 1H), 4.63 (m, 2H), 4.36 (dd, *J* = 11.4, 4.8 Hz, 1H), 4.28 (dd, *J* = 11.4, 6.3 Hz, 1H), 4.12 (m, 1H), 3.72 (m, 2H), 2.34 (s, 3H), 2.30 (m, 1H), 2.08 (s, 3H), 2.01 (m, 1H), 1.41 (t, *J* = 7.1 Hz, 3H).

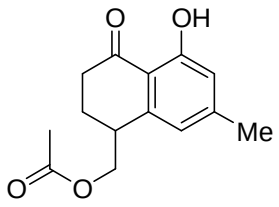
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 212.6 (C), 204.1 (C), 170.6 (C), 162.5 (C), 148.1 (C), 129.6 (CH), 120.3 (CH), 118.5 (CH), 116.9 (C), 70.4 (CH_2), 65.6 (CH_2), 48.9 (CH), 35.1 (CH_2), 25.0 (CH_2), 21.9 (CH_3), 20.7 (CH_3), 13.7 (CH_3).

IR (CCl_4): ν_{max} 2926, 1749, 1642, 1226.

MS (CI/NH3): 371 (MH^+).

HRMS (EI+): calculated for $C_{17}H_{22}O_5S_2$, 370.0909, found 370.0912.

(5-hydroxy-7-methyl-4-oxo-1,2,3,4-tetrahydronaphthalen-1-yl)methyl acetate (11')



Following general procedure for radical cyclisation, the reaction was carried out using xanthate **10'** (1.52 g, 4.09 mmol, 1.0 equiv.) in ethyl acetate (41 mL), and needed 140 mol % of DLP to go to completion. Purification by chromatography on silica gel (petroleum ether/diethyl ether 9/1 to 7/3) yielded tetralone **11'** (674 mg, 66%).

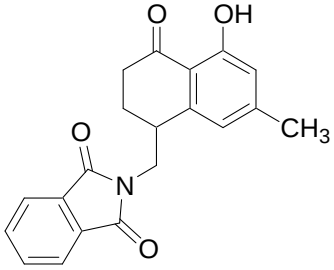
^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.52 (s, 1H, OH), 6.66 (s, 1H), 6.61 (s, 1H), 4.32 (dd, *J* = 11.3, 5.4 Hz, 1H), 4.25 (dd, *J* = 11.2, 8.8 Hz, 1H), 3.21 (tt, *J* = 9.7, 4.9 Hz, 1H), 2.85 (m, 1H), 2.60 (m, 1H), 2.32 (s, 3H), 2.30 (m, 1H), 2.10 (m, 1H), 2.08 (s, 3H).

^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 203.6 (C), 170.8 (C), 163.2 (C), 148.2 (C), 143.6 (C), 119.9 (CH), 116.8 (CH), 114.5 (C), 65.7 (CH_2), 37.3 (CH), 34.5 (CH_2), 24.2 (CH_2), 22.1 (CH_3), 20.9 (CH_3).

MS (CI/NH3): 249 (MH^+).

HRMS (EI+): calculated for $C_{14}H_{16}O_4$, 248.1049, found 248.1053.

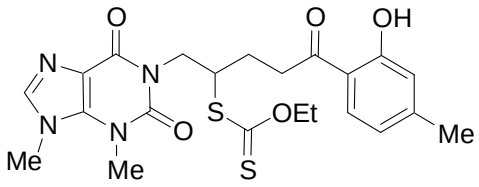
2-((5-hydroxy-7-methyl-4-oxo-1,2,3,4-tetrahydronaphthalen-1-yl)methyl)isoindoline-1,3-dione (14)



Following general procedure A for intermolecular radical addition, the reaction was carried out using xanthate **9** (178 mg, 0.658 mmol, 1 equiv.) and allylphthalimide (246 mg, 1.317 mmol, 2 equiv.) in ethyl acetate (0.6 mL) and needed 30 mol % of DLP to go to completion. The solution was then allowed to cool down to room temperature and ethyl acetate (9 mL) was added. Using general procedure B, the cyclisation reaction needed 60 mol % of DLP to go to completion. Purification (petroleum ether/ethyl acetate, 8/2) yielded tetralone **14** in 57% yield.

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.61 (s, 1H, OH), 7.93 (m, 2H), 7.80 (m, 2H), 6.71 (s, 2H), 4.02 (dd, *J* = 13.8, 11.0 Hz, 1H), 3.88 (dd, *J* = 13.8, 5.2 Hz, 1H), 3.44 (m, 1H), 3.19 (m, 1H), 2.66 (m, 1H), 2.34 (s, 3H), 2.19 (m, 1H), 1.95 (m, 1H).
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 203.7 (C), 168.3 (2C), 163.2 (C), 148.4 (C), 144.4 (C), 134.2 (2CH), 131.8 (2C), 123.4 (2CH), 120.3 (CH), 116.9 (CH), 114.3 (C), 41.0 (CH_2), 37.1 (CH), 33.5 (CH_2), 23.6 (CH_2), 22.0 (CH_3).
IR (CCl_4): ν_{max} 2958, 2873, 1773, 1719, 1643, 1393.
MS (CI/NH3): 336 (MH^+).
HRMS (EI+): calculated for $C_{20}H_{17}O_4N$, 335.1158, found 335.1160.

***S*-1-(3,9-dimethyl-2,6-dioxo-2,3-dihydro-6H-purin-1(9H)-yl)-5-(2-hydroxy-4-methylphenyl)-5-oxopentan-2-yl *O*-ethyl carbonodithioate (16)**



Following general procedure A for intermolecular radical addition, the reaction was carried out using xanthate **9** (209 mg, 0.775 mmol, 1.5 equiv.) and olefin **15** (114 mg, 0.517 mmol, 1 equiv.) in ethyl acetate (0.5 mL) and needed 30 mol % of DLP to go to completion. Purification (petroleum ether/ethyl acetate 1/1 to 1/9) yielded xanthate **16** (170 mg, 67%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.22 (s, 1H, OH), 7.65 (d, *J* = 8.2 Hz, 1H), 7.51 (s, 1H), 6.76 (s, 1H), 6.69 (d, *J* = 8.1 Hz, 1H), 4.58 (q, *J* = 7.1 Hz, 2H), 4.44-4.33 (m, 2H), 4.24 (dd, *J*

= 11.9, 5.4 Hz, 1H), 3.98 (s, 3H), 3.58 (s, 3H), 3.30-3.13 (m, 2H), 2.26 (s, 3H), 2.24 (m, 1H), 2.08 (m, 1H), 1.38 (t, *J* = 7.1 Hz, 3H).

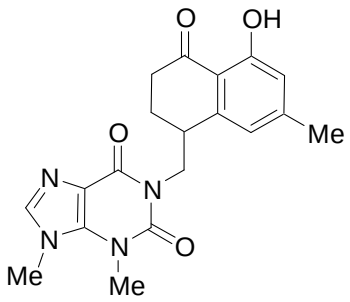
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 213.2 (C), 204.5 (C), 162.4 (C), 155.1 (C), 151.4 (C), 148.9 (C), 147.9 (C), 141.6 (CH), 129.8 (CH), 120.2 (CH), 118.4 (CH), 117.0 (C), 107.5 (C), 70.2 (CH_2), 48.6 (CH), 43.3 (CH_2), 35.2 (CH_2), 33.6 (CH_3), 29.8 (CH_3), 26.4 (CH_2), 21.9 (CH_3), 13.7 (CH_3).

IR (CCl_4): ν_{max} 2957, 1712, 1668, 1642, 1234.

MS (CI/NH3): 491 (MH^+).

HRMS (EI+): calculated for $C_{22}H_{26}O_5N_4S_2$, 490.1345, found 490.1345.

1-((5-hydroxy-7-methyl-4-oxo-1,2,3,4-tetrahydronaphthalen-1-yl)methyl)-3,9-dimethyl-1*H*-purine-2,6(3H,9H)-dione (17)



Following general procedure B for intramolecular radical cyclisation, the reaction was carried out using xanthate **16** (157 mg, 0.32 mmol, 1 equiv.) in ethyl acetate (5 mL) and needed 120 mol % of DLP to go to completion. Purification (ethyl acetate) yielded tetralone **17** (50 mg, 43%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.57 (s, 1H, OH), 7.54 (s, 1H), 6.79 (s, 1H), 6.66 (s, 1H), 4.49 (dd, *J* = 13.2, 11.2 Hz, 1H), 4.00 (s, 3H), 3.97 (dd, *J* = 13.2, 5.1 Hz, 1H), 3.61 (s, 3H), 3.48 (m, 1H), 3.31-3.22 (m, 1H), 2.59-2.54 (m, 1H), 2.32 (s, 3H), 2.10 (m, 1H), 1.88 (m, 1H).

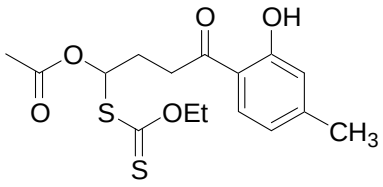
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 204.3 (C), 162.9 (C), 155.4 (C), 151.7 (C), 148.9 (C), 148.3 (C), 145.2 (C), 141.7 (CH), 120.4 (CH), 116.5 (C), 114.4 (C), 107.5 (C), 44.2 (CH_2), 36.5 (CH), 34.0 (CH_2), 33.6 (CH_3), 29.8 (CH_3), 23.4 (CH_2), 22.0 (CH_3).

IR (CCl_4): ν_{max} 3155, 2985, 2902, 1816, 1794, 1708, 1662, 1640, 1470, 1383.

MS (CI/NH3): 369 (MH^+).

HRMS (EI+): calculated for $C_{19}H_{20}O_4N_4$, 368.1485, found 368.1482

1-(ethoxycarbonothioylthio)-4-(2-hydroxy-4-methylphenyl)-4-oxobutyl acetate 19



Following general procedure A for intermolecular radical addition, the reaction was carried out using xanthate **9** (500 mg; 1.85 mmol; 1.0 equiv.) and vinyl acetate (0.22 mL, 2.40 mmol, 1.3 equiv.) in ethyl acetate (2.0 mL). The reaction needed 15 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/diethyl ether, 85/15) afforded xanthate **19** (547 mg, 83 %).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.08 (s, 1H, OH), 7.55 (d, *J* = 8.2 Hz, 1H), 6.70 (m, 3H), 4.57 (q, *J* = 7.1 Hz, 2H), 3.07 (m, 2H), 2.33 (m, 2H), 2.28 (s, 3H), 2.01 (s, 3H), 1.35 (t, *J* = 7.1 Hz, 3H).

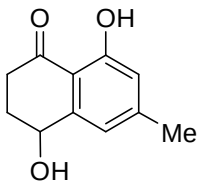
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 209.4 (C), 203.1 (C), 168.9 (C), 162.1 (C), 147.8 (C), 129.3 (CH), 120.0 (CH), 118.2 (CH), 116.8 (C), 79.7 (CH), 70.0 (CH_2), 33.3 (CH_2), 28.1 (CH_2), 21.6 (CH_3), 20.5 (CH_3), 13.3 (CH_3).

IR (CCl_4): ν_{max} 2984, 2939, 1753, 1641, 1575.

MS (CI/NH3): 357 (MH^+).

HRMS (EI+): calculated for $C_{16}H_{20}O_5S_2$, 356.0752, found 356.0748.

4,8-dihydroxy-6-methyl-3,4-dihydronaphthalen-1(2H)-one, shinanolone (20)

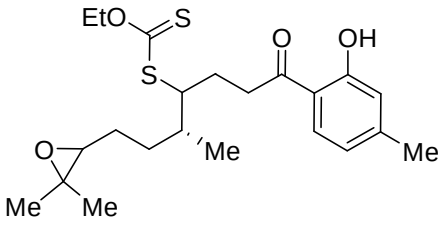


Following general procedure B for radical cyclisation, the reaction was carried out with xanthate **19** (421 mg, 1.18 mmol, 1.0 equiv.) in ethyl acetate (15 mL) and needed 100 mol % of DLP to go to completion. The solvent was then removed under reduced pressure and acetonitrile (5 mL) was added. The precipitated DLP derivatives were filtrated. Acetonitrile was then removed under reduced pressure and the residual oil was diluted in methanol (5

mL). Potassium carbonate (326 mg, 2.36 mmol, 2.2 equiv.) was added and the mixture was stirred at room temperature for 60 min. Diethylether and water were added and the aqueous layer was extracted with diethylether. The combined organics were washed with 1M HCl and brine, dried ($MgSO_4$), filtered and the solvent was removed under reduced pressure. Purification by flash chromatogtaphy on silica gel (petroleum ether / ethyl acetate 7/3 to 1/1) afforded pure shinanolone (123 mg, 54%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.44 (s, 1H, OH), 6.87 (s, 1H), 6.75 (s, 1H), 4.89 (dd, *J* = 7.0, 3.3 Hz, 1H), 2.96 (m, 1H), 2.66 (m, 1H), 2.38 (s, 3H), 2.34 (m, 1H), 2.20 (m, 2H).
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 203.6 (C), 166.7 (C), 148.7 (C), 145.6 (C), 118.6 (CH), 117.6 (CH), 113.1 (C), 67.7 (CH), 34.4 (CH_2), 31.2 (CH_2), 22.2 (CH_3).
IR (CCl_4): ν_{max} 3614, 3155, 2984, 1816, 1794.
MS (CI/NH3): 193 (MH^+).
HRMS (EI+): calculated for $C_{11}H_{12}O_3$, 192.0786, found 192.0790.

S-(5R)-7-(3,3-dimethyloxiran-2-yl)-1-(2-hydroxy-4-methylphenyl)-5-methyl-1-oxoheptan-4-yl *O*-ethyl carbonodithioate (22)



Following general procedure A for intermolecular radical addition, the reaction was carried out using xanthate **9** (2.20 g, 8.156 mmol, 1 equiv.) and citronelene epoxide (3.23 g, 16.31 mmol, 2 equiv.) in ethyl acetate (4 mL). The reaction needed 20 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/ethyl acetate 9/1) yielded xanthate **22** as an unseparable mixture of diasteromers (3.148 g, 91%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.25 (s, 1H, OH), 7.59 (d, *J* = 8.2 Hz, 1H), 6.75 (s, 1H), 6.66 (d, *J* =8.1 Hz, 1H), 4.63-4.51 (m, 2H), 4.00-3.88 (m), 3.13 (t, *J* = 7.0 Hz), 2.71-2.67 (m,

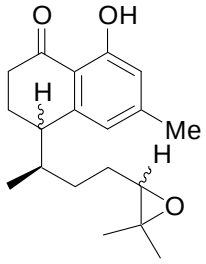
1H), 2.32 (s, 3H), 2.18 (m, 1H), 1.99 (m, 1H), 1.86-1.68 (m, 1H), 1.65-1.45 (m, 3H), 1.35 (m, 3H), 1.29-1.24 (m, 5H), 1.00 (m, 3H), 0.85 (m, 2H).

^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 214.4 (C), 204.8 (C), 162.4 (C), 147.8 (C), 129.7 (CH), 120.1 (CH), 118.4 (CH), 117.0 (C), 70.1 (CH_2), 64.1 (CH), 58.1 (C), 56.1 (CH), 37.6 (CH), 35.7 (CH_2), 31.0 (CH_2), 26.9 (CH_2), 24.9 (CH), 21.9 ($2CH_3$), 18.8 (CH_3), 16.2 (CH_3), 13.7 (CH_3).

MS (CI/NH3): 425 (MH^+).

HRMS (EI+): calculated for $C_{22}H_{32}O_4S_2$ 424.1742, found 424.1739.

4-((R)-4-(3,3-dimethyloxiran-2-yl)butan-2-yl)-8-hydroxy-6-methyl-3,4-dihydronaphthalen-1(2H)-one (23)



Following general procedure B for radical cyclisation, the reaction was carried out using xanthate **22** (200 mg, 0.471 mmol, 1 equiv.) in ethyl acetate (7 mL) and needed 100 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/diethyl ether 75/25) yielded tetralone **23** (70 mg, 49%).

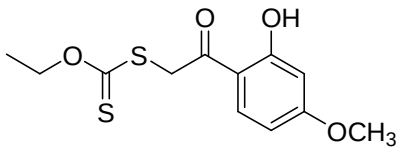
^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.62 (s, 1H, OH), 6.67 (s, 1H, H-Ar), 6.60 (s, 1H, H-Ar), 2.78-2.58 (m, 4H), 2.37 (s, 3H), 2.10 (m, 3H), 1.70-1.53 (m, 4H), 1.35-1.29 (m, 6H), 0.96 (m, 3H).

^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 204.3 (C), 163.2 (C), 147.5 (2C), 119.7 (CH), 115.9 (CH), 114.0 (C), 64.4 (CH), 58.1 (C), 43.7 (CH), 35.7 (CH_2), 34.7 (CH), 31.9 (CH_2), 26.9 (CH_2), 24.9 (CH_3), 23.3 (CH_2), 22.3 (CH_3), 18.5 (CH_3), 16.3 (CH_3).

MS (CI/NH3): 303 (MH^+).

HRMS (EI+): calculated for $C_{19}H_{26}O_3$, 302.1882, found 302.1882

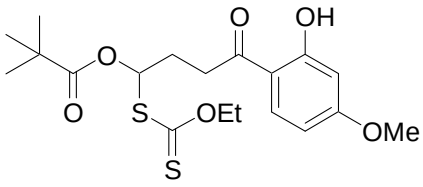
_O_-ethyl _S_-2-(2-hydroxy-4-methoxyphenyl)-2-oxoethyl carbonodithioate (24)



This xanthate was prepared as described in the literature.[1]

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.25 (s, 1H, OH), 7.74 (d, *J* = 8.9 Hz, 1H), 6.47 (dd, *J* = 8.9; 2.5 Hz, 1H), 6.41 (d, *J* = 2.5 Hz, 1H), 4.62 (q, *J* = 7.1 Hz, 2H), 4.58 (s, 2H), 3.83 (s, 3H), 1.37 (t, *J* = 7.1 Hz).

1-(ethoxycarbonothioylthio)-4-(2-hydroxy-4-methoxyphenyl)-4-oxobutyl pivalate (25)



Following general procedure A for intermolecular radical addition, the reaction was carried out using xanthate **24** (635 mg, 2.22 mmol, 1 equiv.) and vinyl pivalate (0.426 mL, 2.88 mmol, 1.3 equiv.) in ethyl acetate (2.5 mL). The reaction needed 15 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/diethyl ether, 85/15) afforded xanthate **25** (811 mg, 88 %).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.63 (s, 1H, OH), 7.62 (d, *J* = 8.8 Hz, 1H), 6.71 (t, *J* = 6.5 Hz, 1H), 6.42 (m, 2H), 4.63 (q, *J* = 7.1 Hz, 2H), 3.84 (s, 3H), 3.08 (m, 2H), 2.39 (m, 2H), 1.41 (t, *J* = 7.1 Hz, 3H), 1.19 (s, 9H).

^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 209.8 (C), 201.9 (C), 176.6 (C), 166.0 (C), 165.2 (C), 131.2 (CH), 113.4 (C), 107.7 (CH), 100.8 (CH), 80.0 (CH), 70.2 (CH_2), 55.5 (CH_3), 38.8 (C), 33.3 (CH_2), 28.4 (CH_2), 26.8 ($3CH_3$), 13.6 (CH_3).

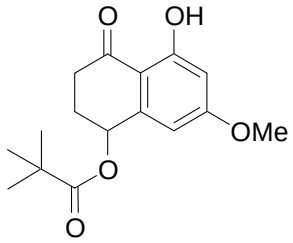
IR (CCl_4): ν_{max} 2978, 2936, 2870, 1740, 1633, 1580.

[1] Cordero Vargas, A.; Quiclet-Sire, B.; Zard, S. Z. *Org. Lett.* **2003**, *5*, 3717.

MS (CI/NH3): 415 (MH^+).

HRMS (EI+): calculated for $C_{19}H_{26}O_6S_2$, 414.1171, found 414.1170.

5-hydroxy-7-methoxy-4-oxo-1,2,3,4-tetrahydronaphthalen-1-yl pivalate (26)



Following general procedure B for radical cyclisation, the reaction was carried out with xanthate **25** (421mg, 1.01 mmol, 1 equiv.) in ethyl acetate (15 mL) and needed 100 mol % of DLP to go to completion. Purification by flash chromatography on silica gel (petroleum ether/diethyl ether, 85/15) afforded tetralone **26** (159 mg, 53 %).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.82 (s, 1H, OH), 6.42 (s, 1H), 6.38 (m, 2H), 3.83 (s, 3H), 2.89 (ddd, *J* = 17.8, 8.5, 4.9 Hz, 1H), 2.65 (ddd, *J* = 17.8, 7.8, 4.9 Hz), 2.34 (m, 1H), 2.13 (m, 1H), 1.22 (s, 9H, *t*-Bu).

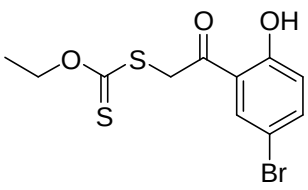
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 201.6 (C), 177.6 (C), 166.2 (C), 165.7 (C), 143.4 (C), 110.2 (C), 106.7 (CH), 100.5 (CH), 68.7 (CH), 55.6 (CH_3), 38.9 (C), 34.0 (CH_2), 28.0 (CH_2), 27.1 ($3CH_3$).

IR (CCl_4): ν_{max} 2971, 2936, 2873, 1732, 1634.

MS (CI/NH3): 293 (MH^+).

HRMS (EI+): calculated for $C_{16}H_{20}O_5$, 292.1311, found 292.1308.

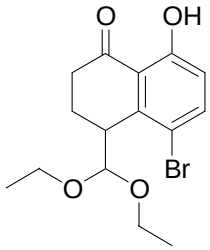
***S*-2-(5-bromo-2-hydroxyphenyl)-2-oxoethyl *O*-ethyl carbonodithioate (28)**



Following general procedure for the preparation of xanthate derived from 2-hydroxyacetophenone, the reaction was carried out using 2-hydroxy-5-bromoacetophenone (1.00 g, 4.65 mmol, 1 equiv.) and $CuBr_2$ (2.08 g, 9.30 mmol, 2 equiv.) in ethyl acetate (2.5 mL) and chloroform (2.5 mL). After 20h, the mixture was filtered and the solvent was removed under reduced pressure. The crude was diluted in acetone (10 mL) and xanthate salt (1.20 g, 1.2 equiv.) was added at 0°C. Usual work-up and purification yielded xanthate **28** (1.00 g, 64%).

^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 11.72 (s, 1H, OH), 7.98 (d, *J* = 2.4 Hz, 1H), 7.61 (dd, *J* = 8.9, 2.4 Hz, 1H), 6.93 (d, *J* = 8.9 Hz, 1H), 6.75 (dd, *J* = 8.2, 1.2 Hz, 1H), 4.66 (q, 2H, *J* = 7.1 Hz), 4.63 (s, 2H), 1.42 (t, *J* = 7.1 Hz).
^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 212.4 (C), 197.2 (C), 161.4 (C), 139.7 (CH), 132.1 (CH), 120.8 (CH), 119.9 (C), 110.8 (C), 71.1 (CH_2), 42.7 (CH_2), 13.7 (CH_3).
IR (CCl_4): ν_{max} 3155, 2986, 2902, 1817, 1650, 1471, 1234.
MS (CI/NH3) : 334, 336
HRMS (EI+): calculated for $C_{11}H_{11}O_3S_2Br$ 333.9333, found 333.9333.

5-bromo-4-(diethoxymethyl)-8-hydroxy-3,4-dihydronaphthalen-1(2H)-one (29)



Following general procedure for intermolecular radical addition, the reaction was carried out using xanthate **28** (439 mg, 1.309 mmol, 1 equiv.) and acrolein diethyl acetal (0.59 mL, 3.928 mmol, 3 equiv.) in ethyl acetate (1.5 mL). The reaction needed 45 mol % of DLP to go to completion. The solvent and excess olefin were removed under reduced pressure, and the crude was diluted in ethyl acetate (25 mL) and refluxed under nitrogen during 10 min. The reaction needed 140 mol % of DLP to go to completion. Purification by chromatography on silica gel (petroleum ether / diethyl ether 1/0 to 9/1) yielded tetralone **29** (139 mg, 31 %).

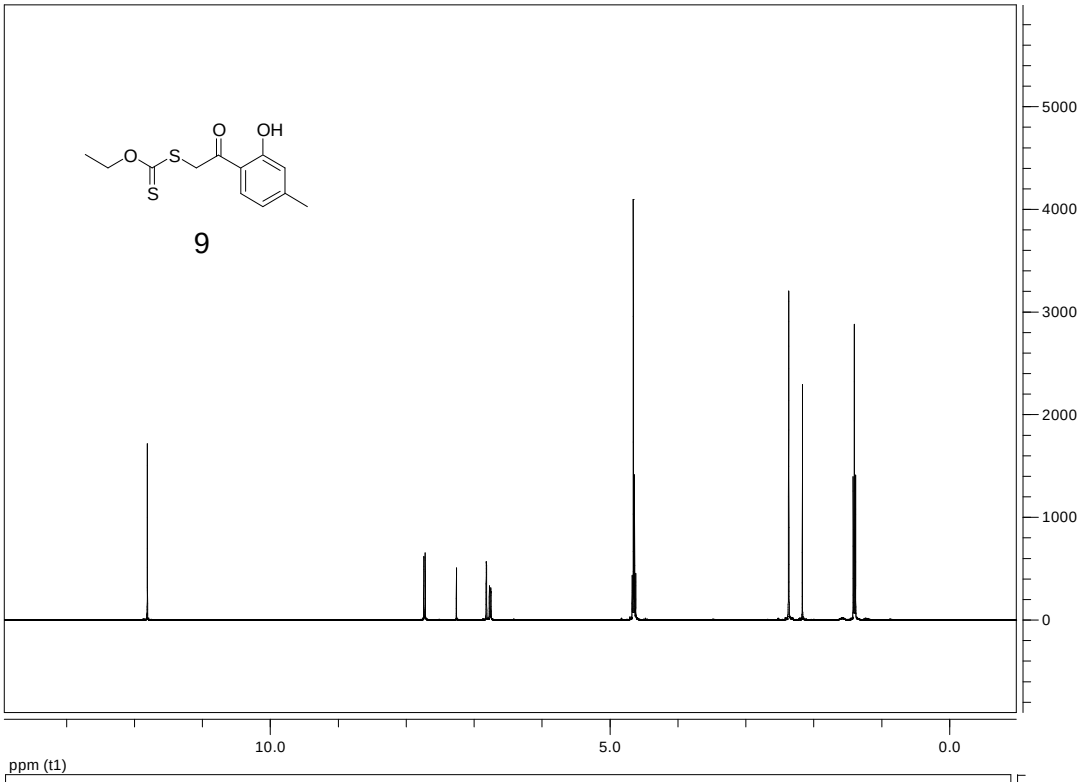
^{1}H-NMR (400 MHz, $CDCl_3$): δ_H 12.89 (s, 1H, OH), 7.60 (d, *J* = 8.9 Hz, 1H), 6.79 (d, *J* = 8.9 Hz, 1H), 4.70 (d, *J* = 3.2 Hz, 1H), 3.75 (m, 1H), 3.62 (m, 2H), 3.54 (m, 1H), 3.28 (m, 1H), 3.04 (m, 1H), 2.55 (H-1b+H-2a), 2.01 (m, 1H), 1.27 (t, *J* = 8.0 Hz, 3H), 0.9 (t, *J* = 8.1 Hz, 3H).

^{13}C-NMR (100 MHz, $CDCl_3$): δ_c 206.2 (C), 162, 3 (C), 142.3 (C), 139.7 (CH), 119.2 (C), 118.5 (CH), 112.1 (C), 104.4 (CH), 65.5 (CH_2), 64.1 (CH_2), 41.4 (CH), 35.2 (CH_2), 20.8 (CH_2), 15.4 (CH_3), 14.9 (CH_3).

MS (CI/NH3) : 342, 344

HRMS (EI+): calculated for $C_{15}H_{19}O_4Br$ 342.0467, found 342.0469.

Copies of 1H and 13C NMR spectra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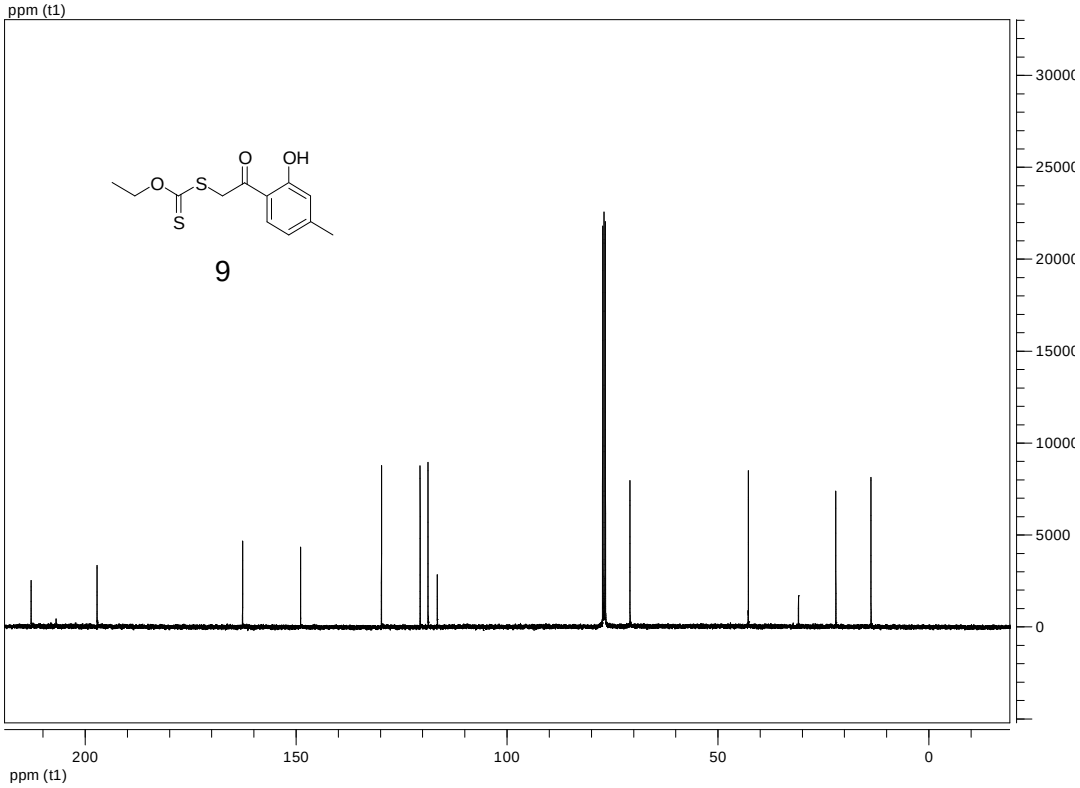
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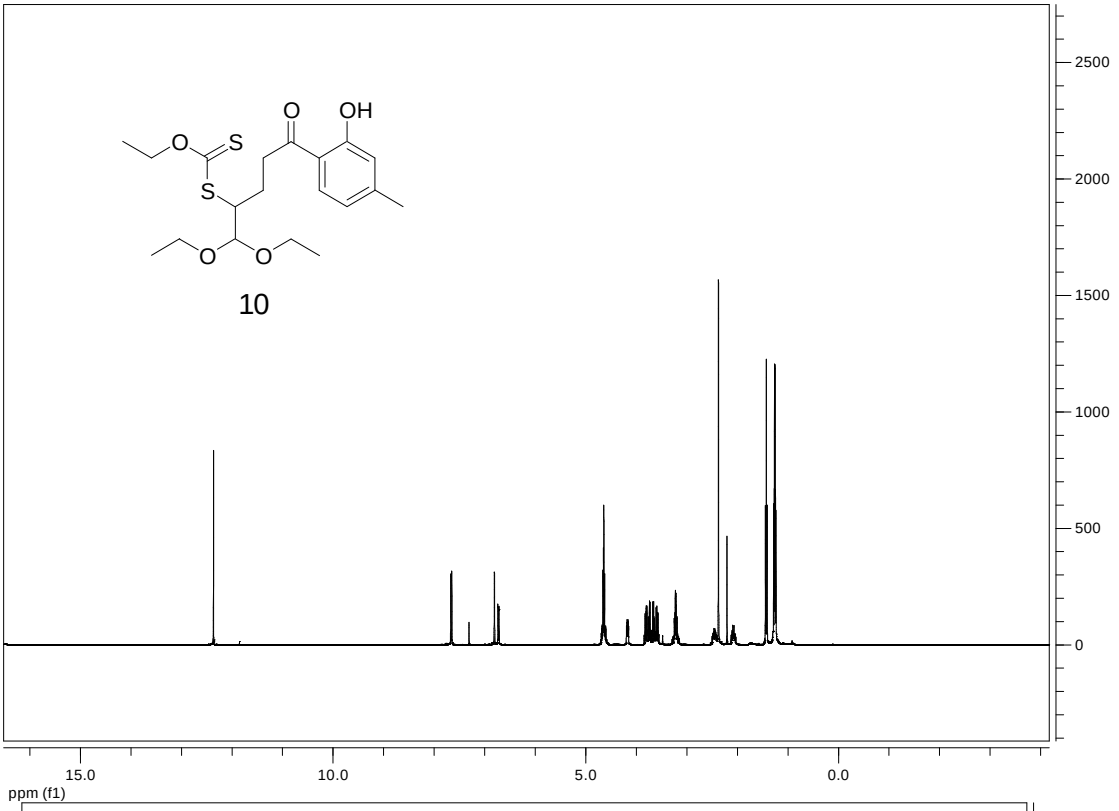
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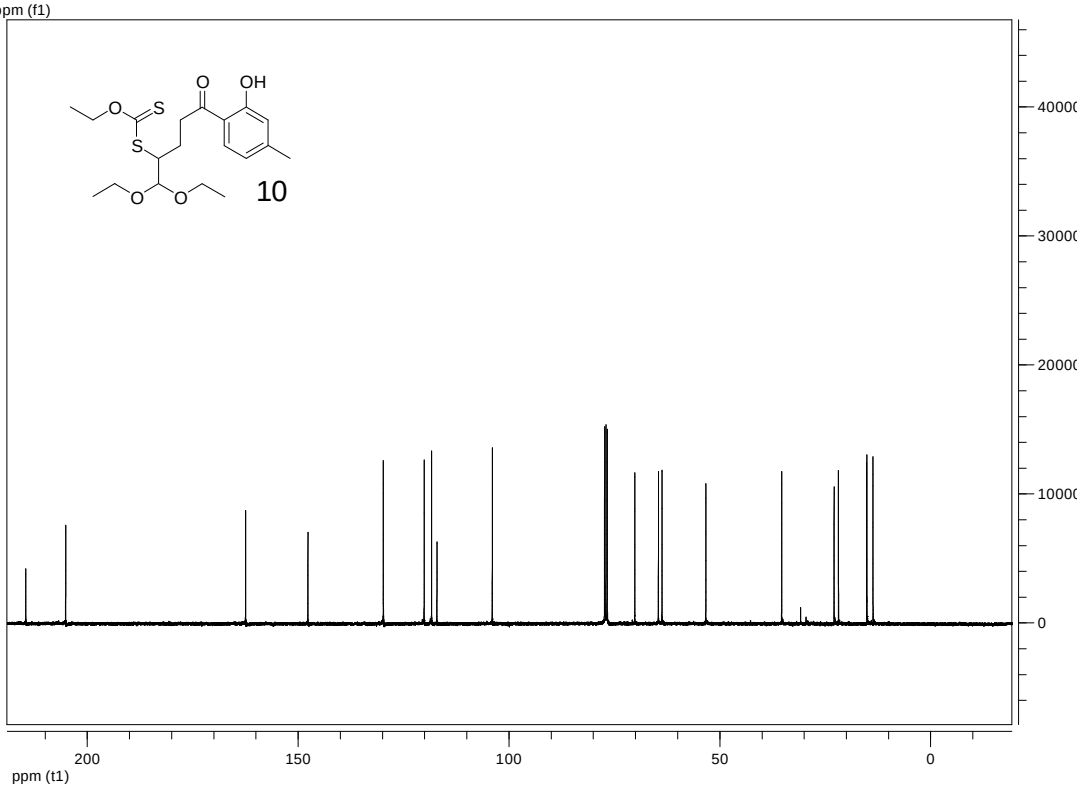
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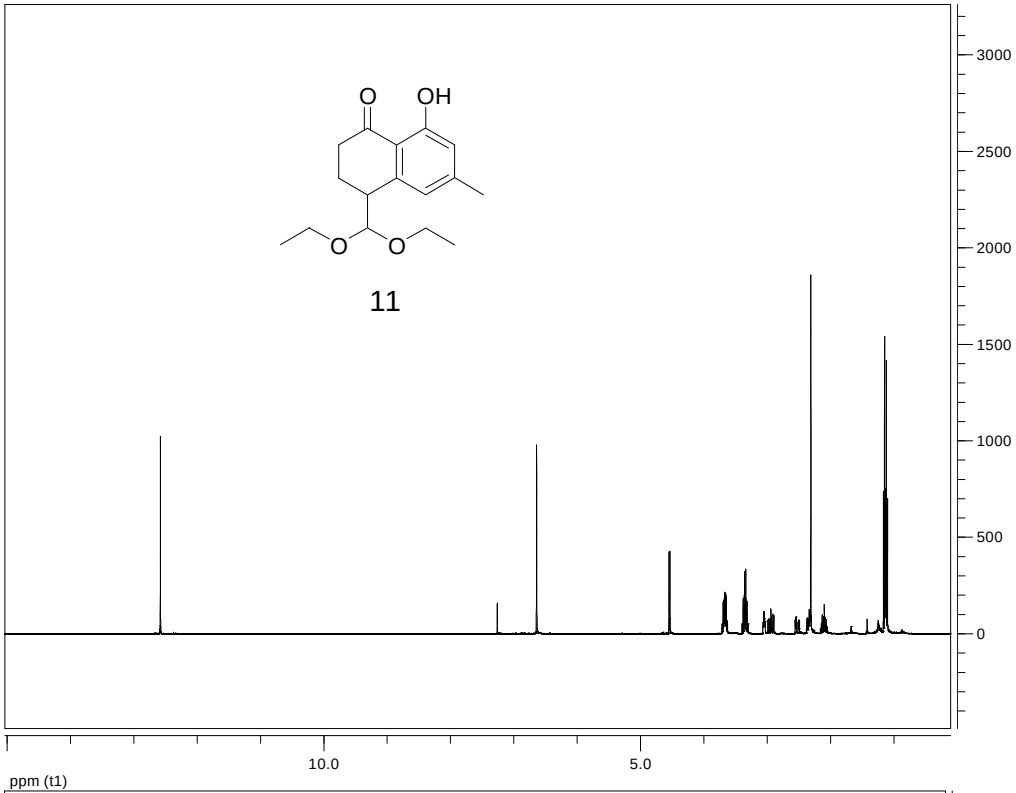
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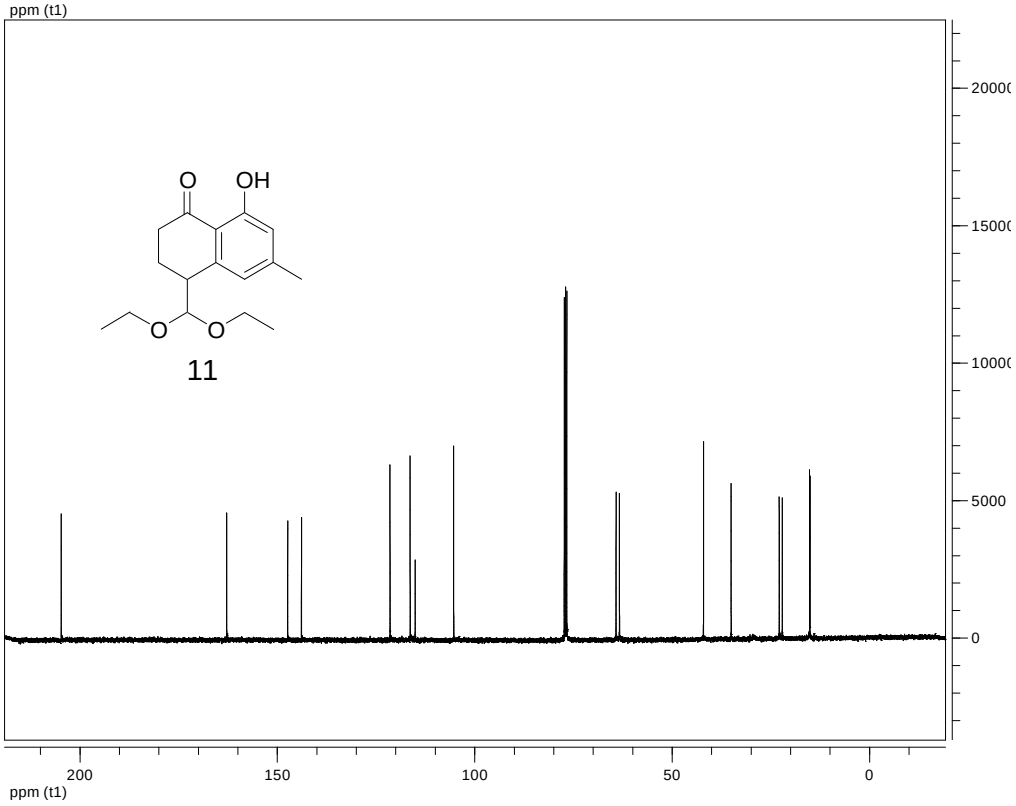
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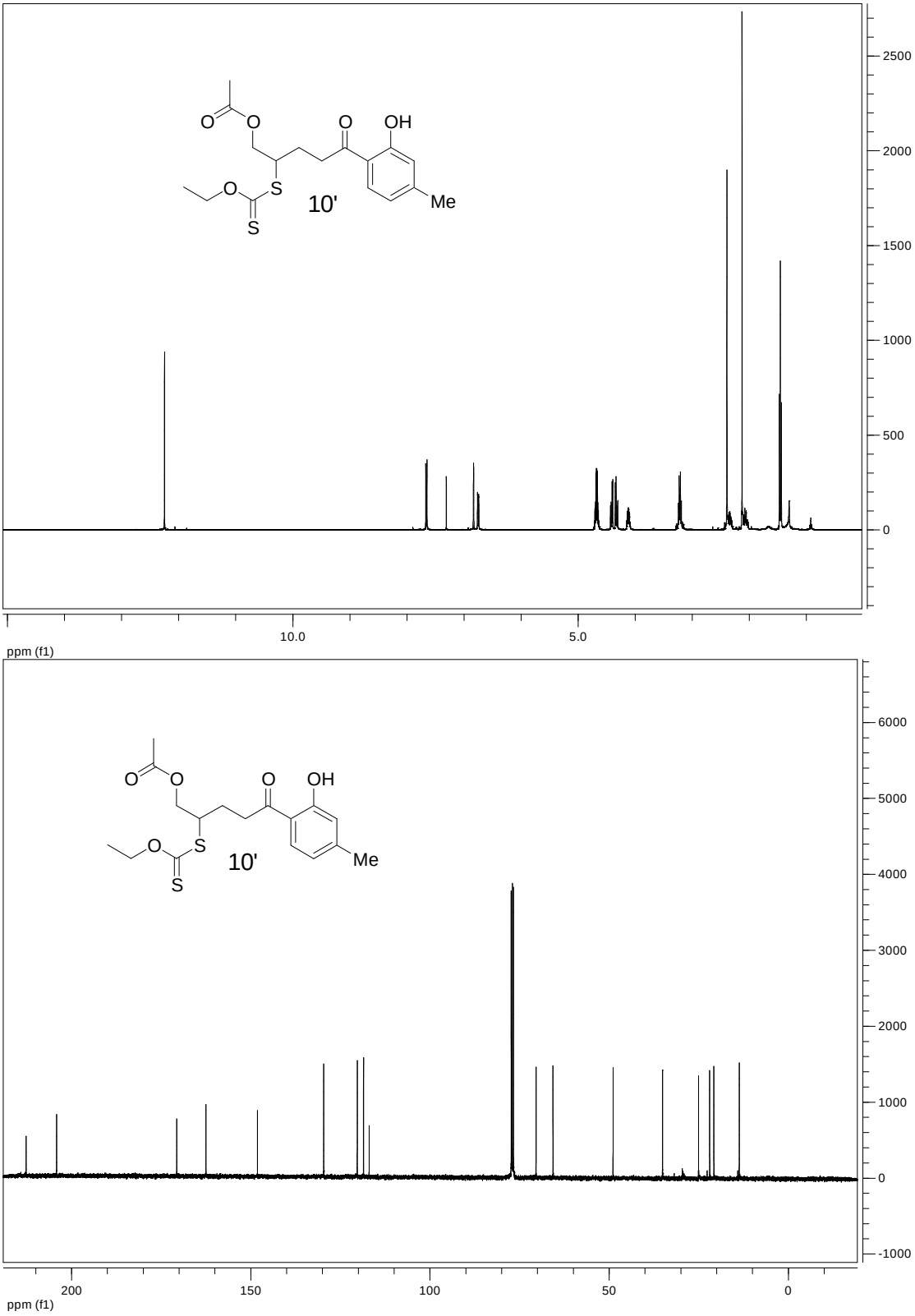
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OH
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S
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10'
Me
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5000
4000
3000
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1000
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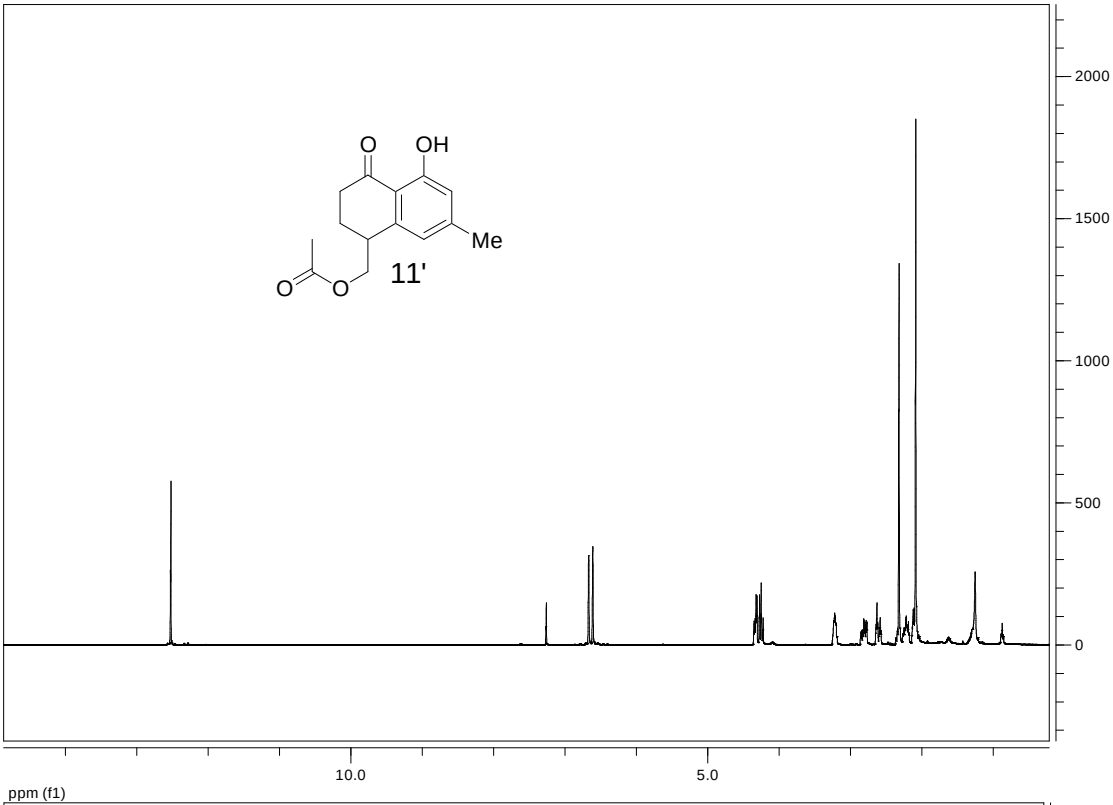
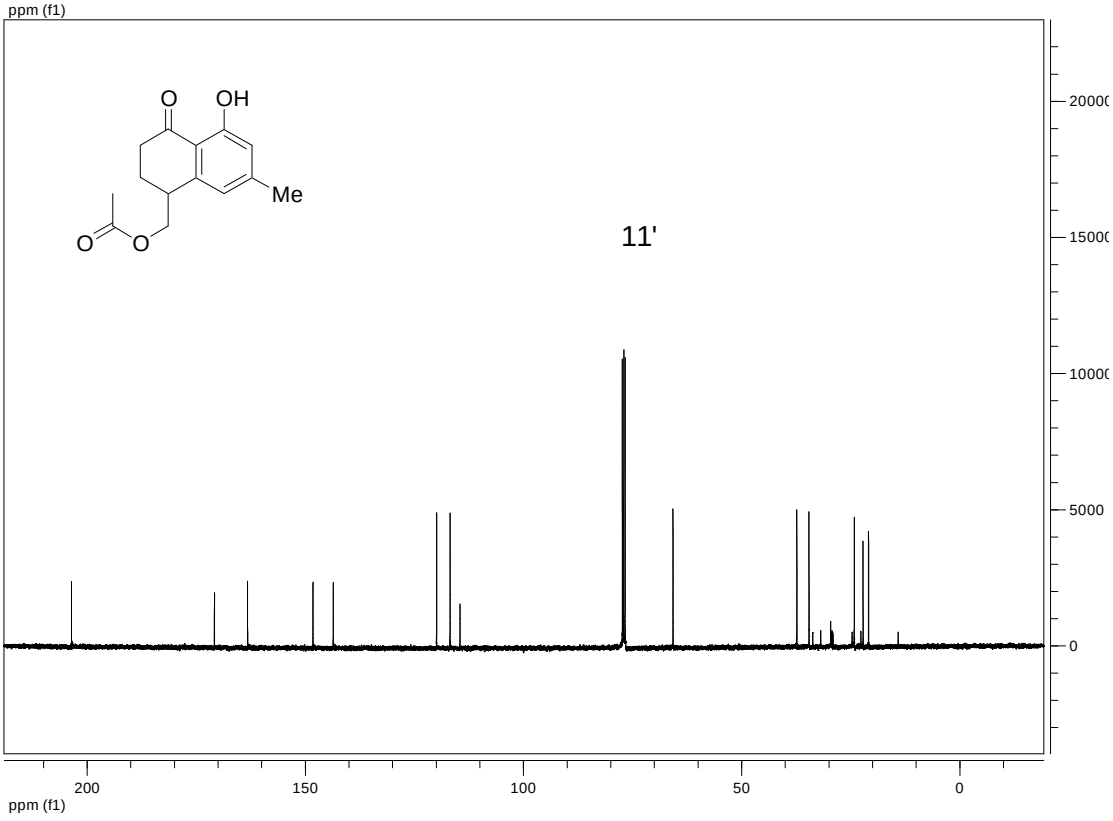
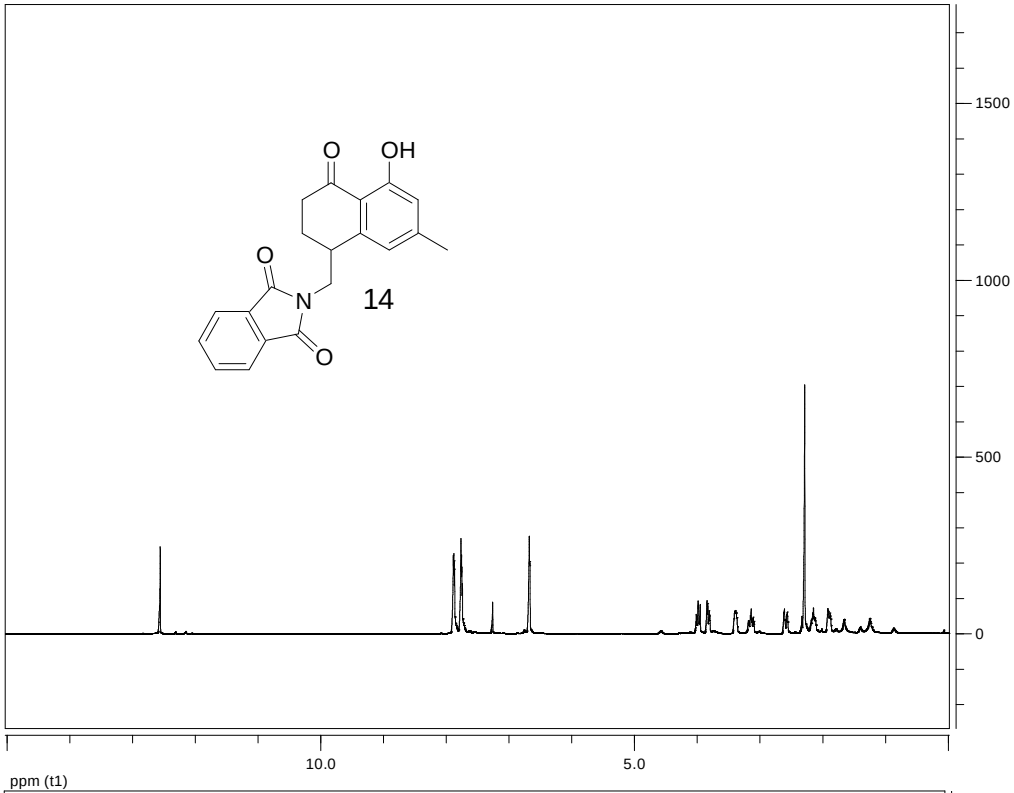
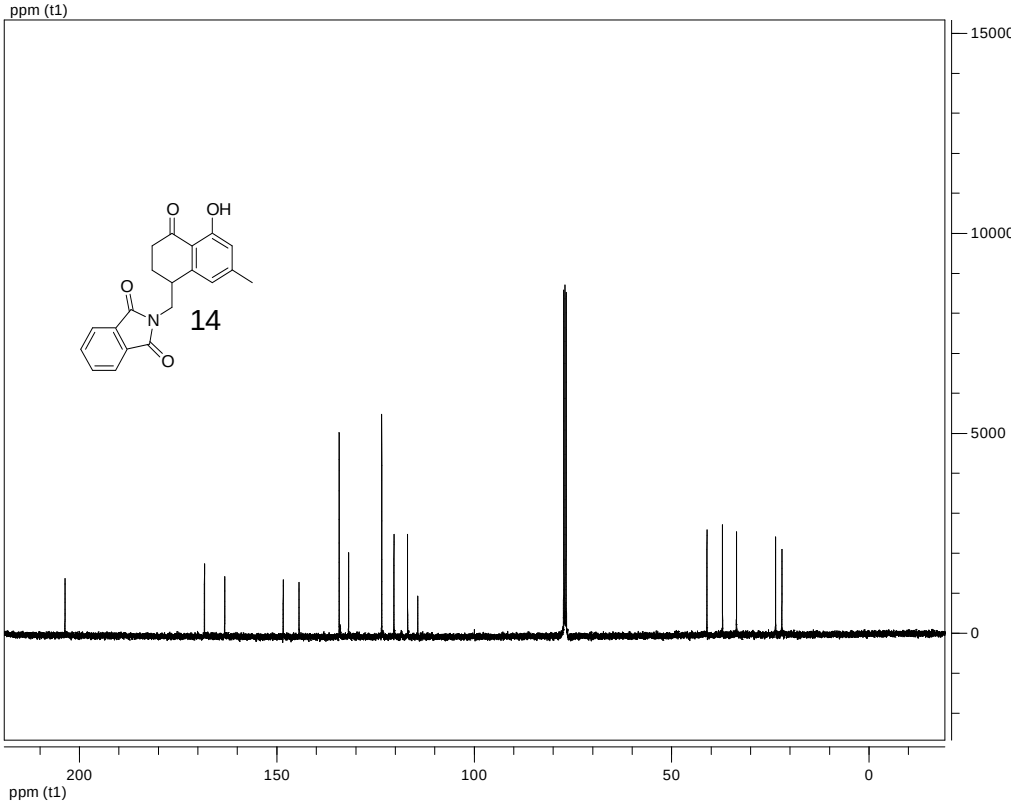
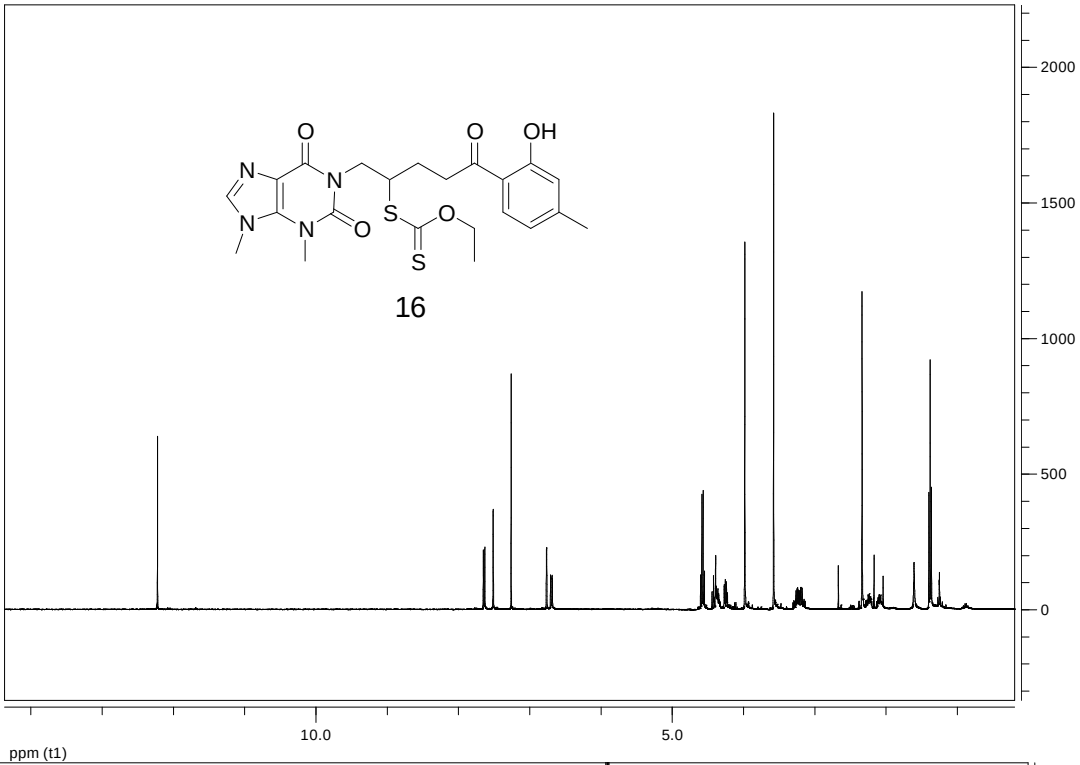
0
ppm (f1)

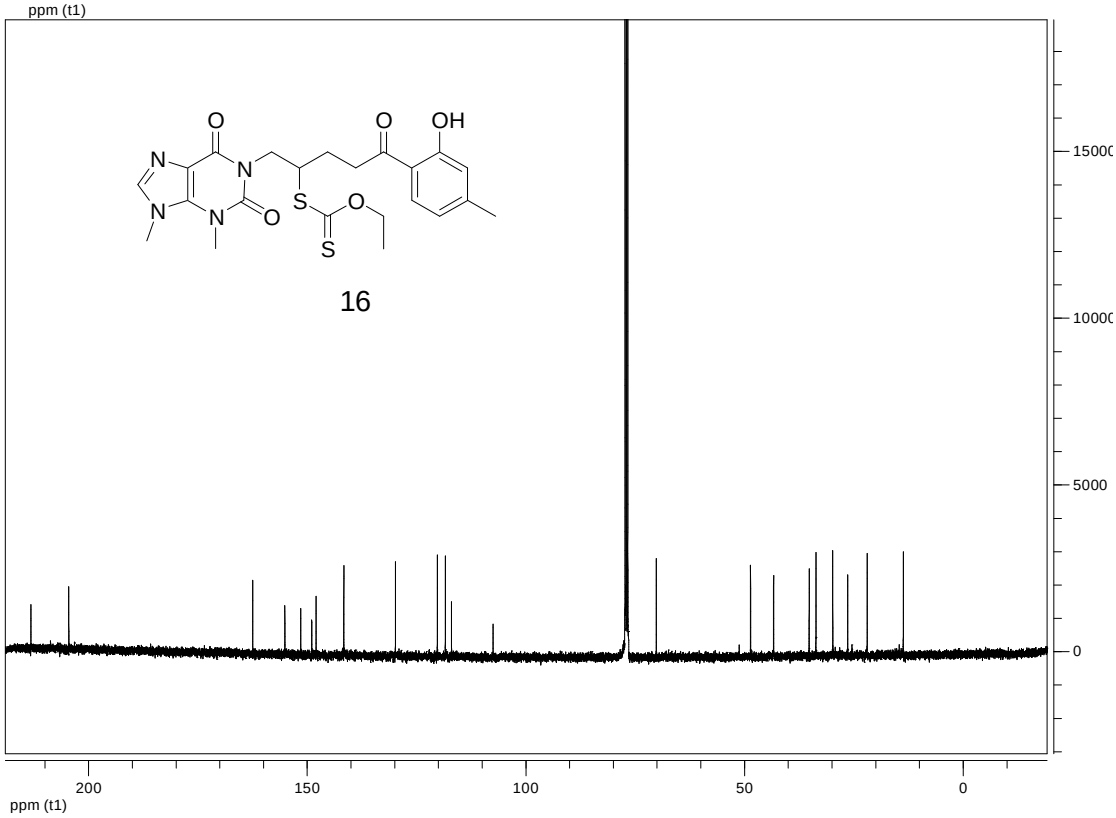

O
OH
Me
O
O
11'
2000
1500
1000
500
0
10.0
5.0
ppm (f1)

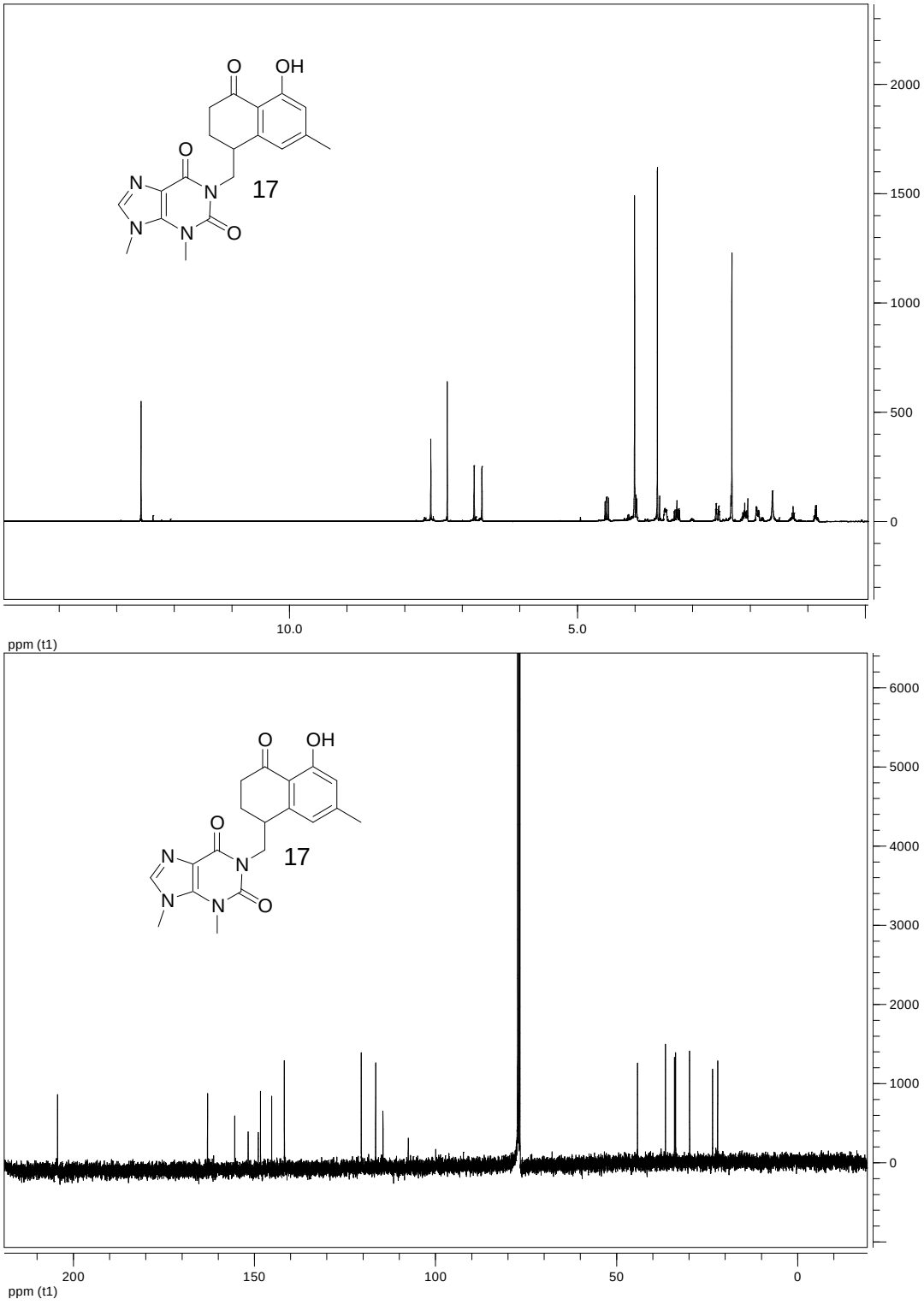

O
OH
Me
O
O
11'
2000
1500
1000
5000
0
200
150
100
50
0
ppm (f1)

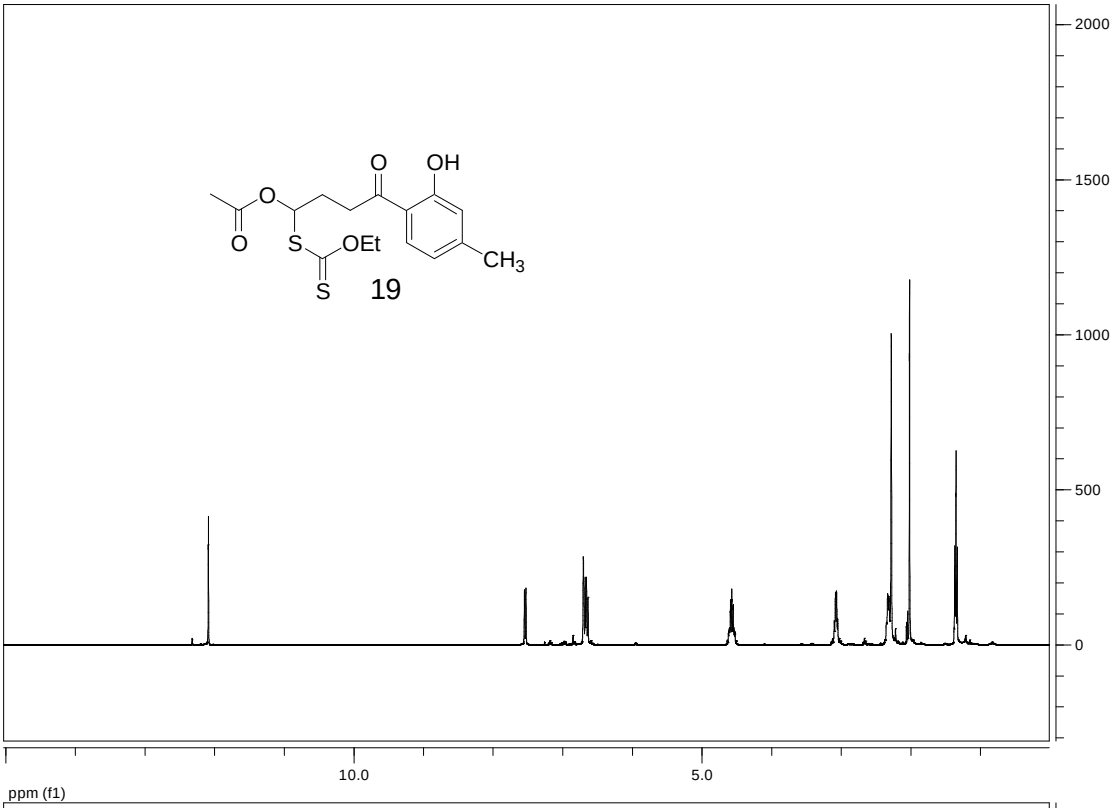

O
OH
O
N
O
14
1500
1000
500
0
10.0
5.0
ppm (t1)

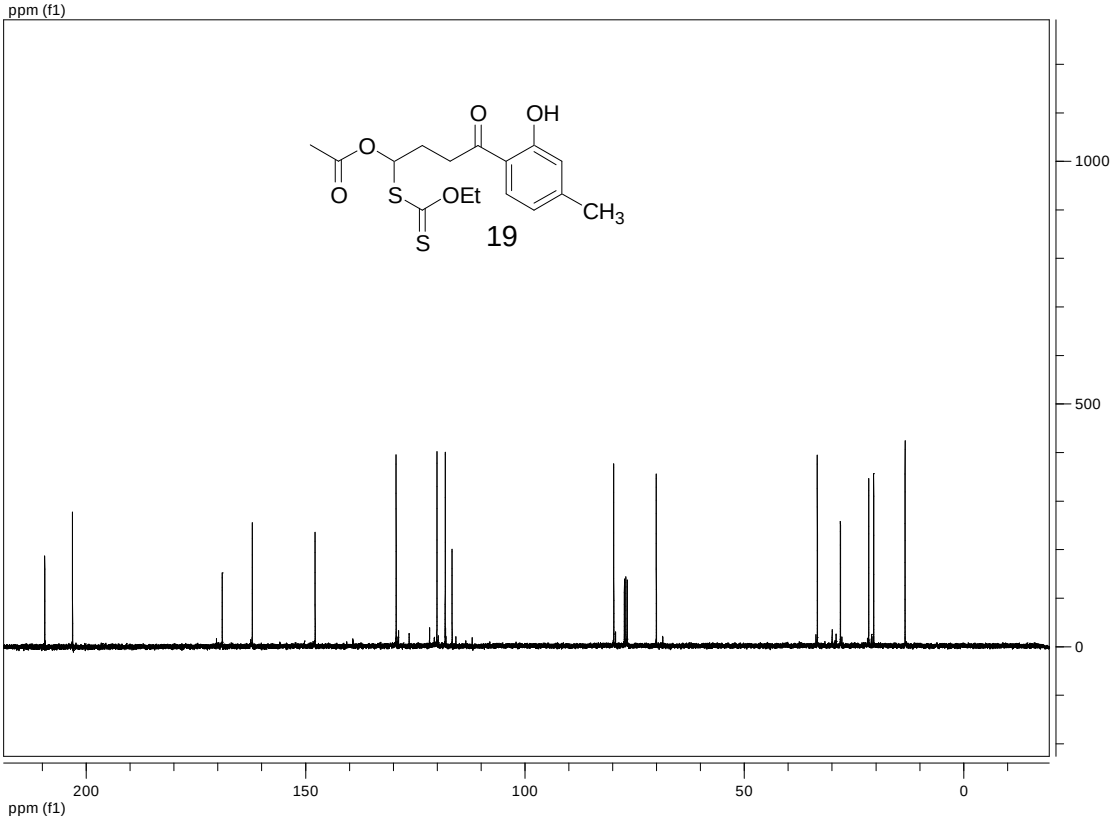

O
OH
O
N
O
14
15000
10000
5000
0
200
150
100
50
0
ppm (t1)

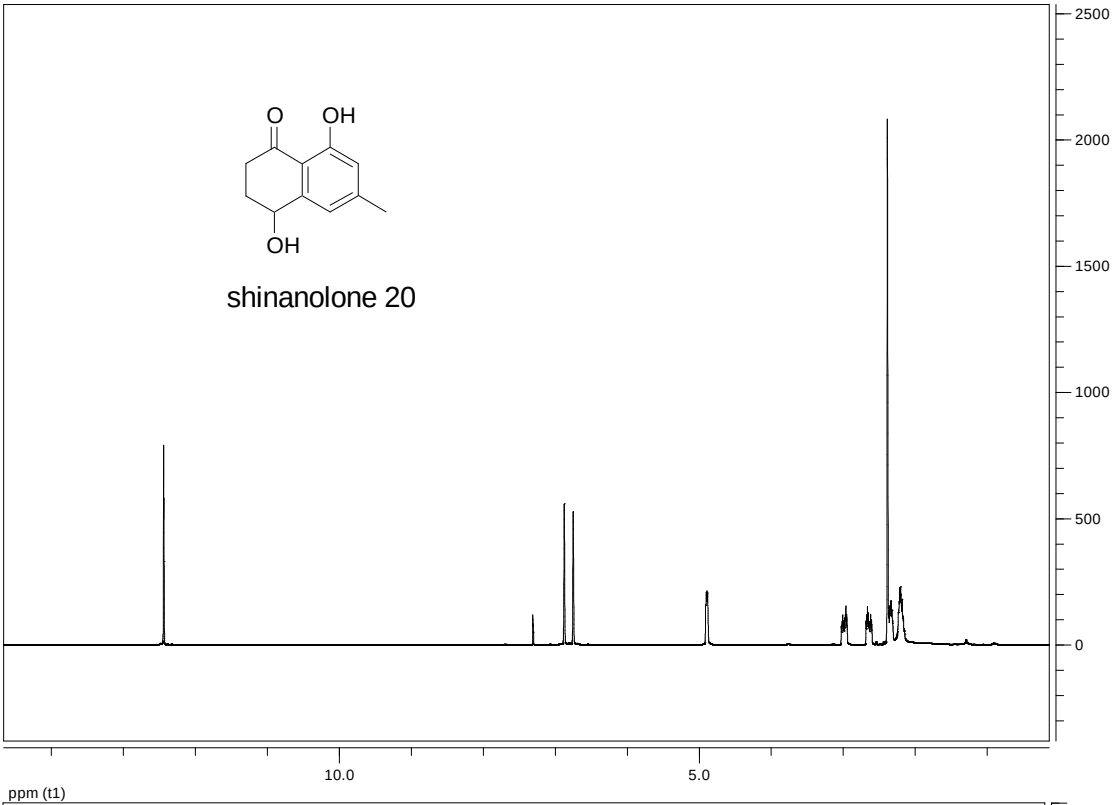

O
O
OH
N
N
S
O
N
N
O
S
16
2000
1500
1000
500
0
10.0
5.0
ppm (t1)

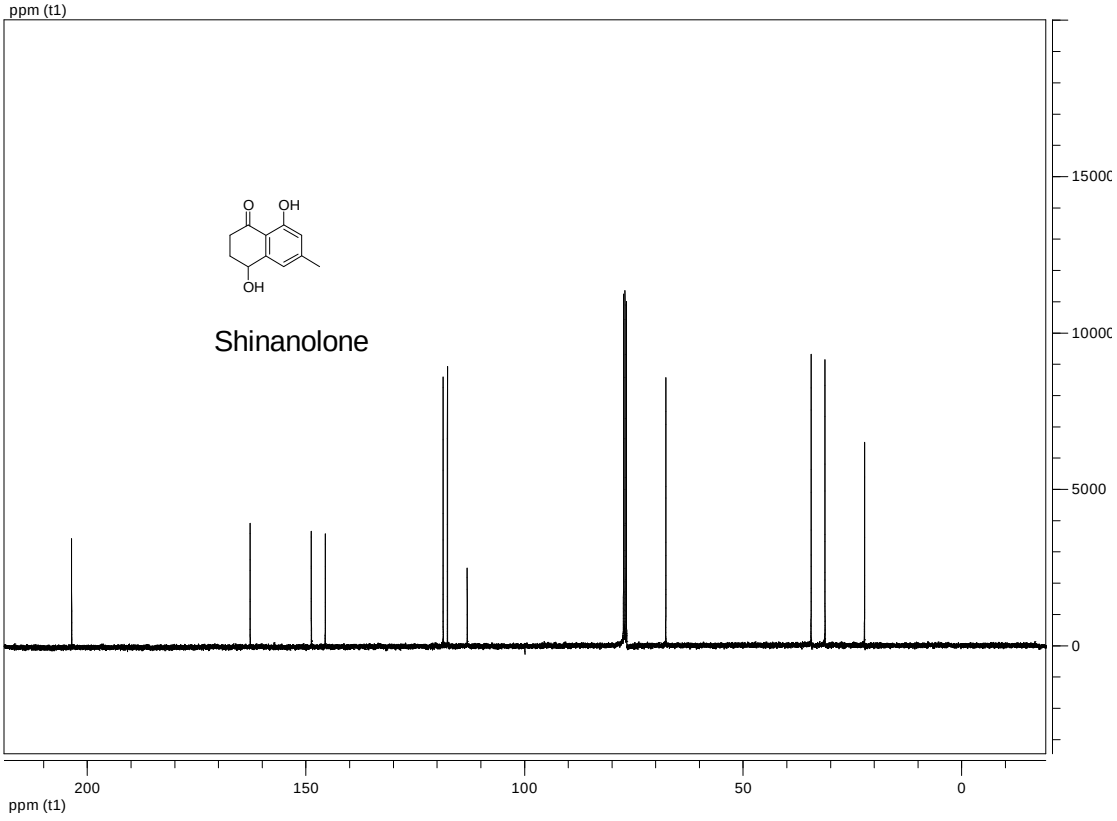

O
O
OH
N
N
S
O
N
N
O
S
16
15000
10000
5000
0
200
150
100
50
0
ppm (t1)

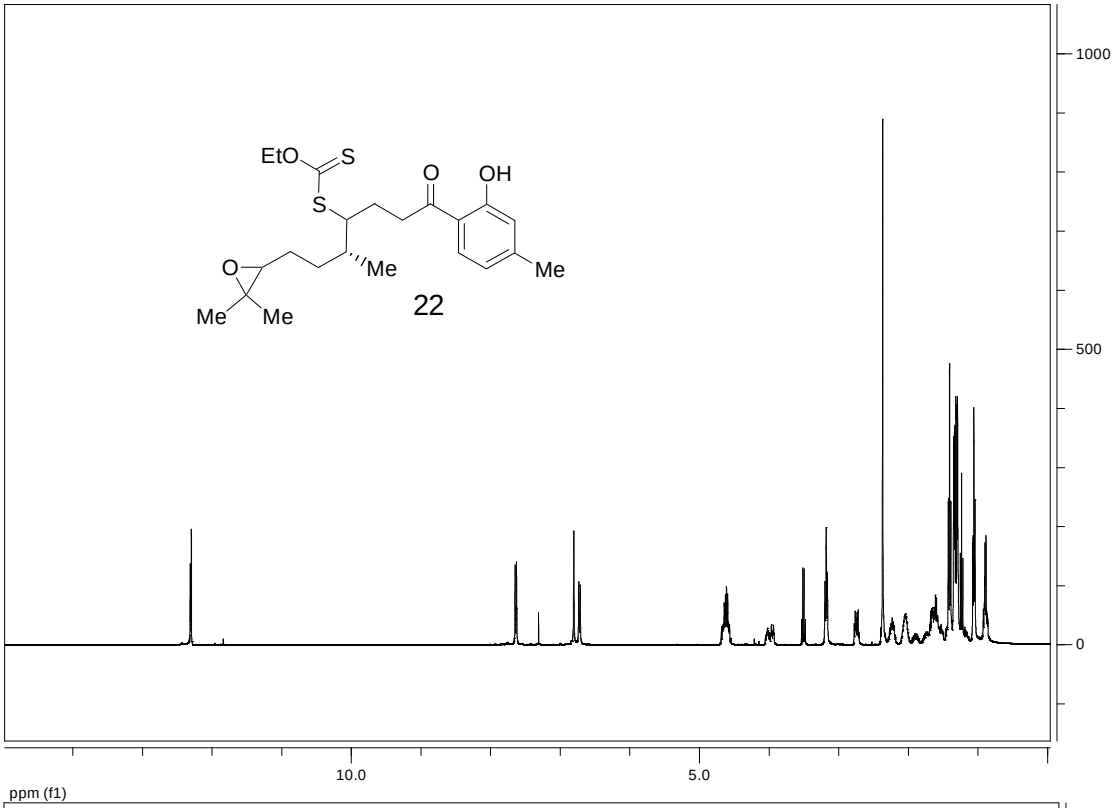

O
OH
O
N
N
N
N
O
17
2000
1500
1000
500
0
10.0
5.0
ppm (t1)
O
OH
O
N
N
N
N
O
17
6000
5000
4000
3000
2000
1000
0
200
150
100
50
0
ppm (t1)

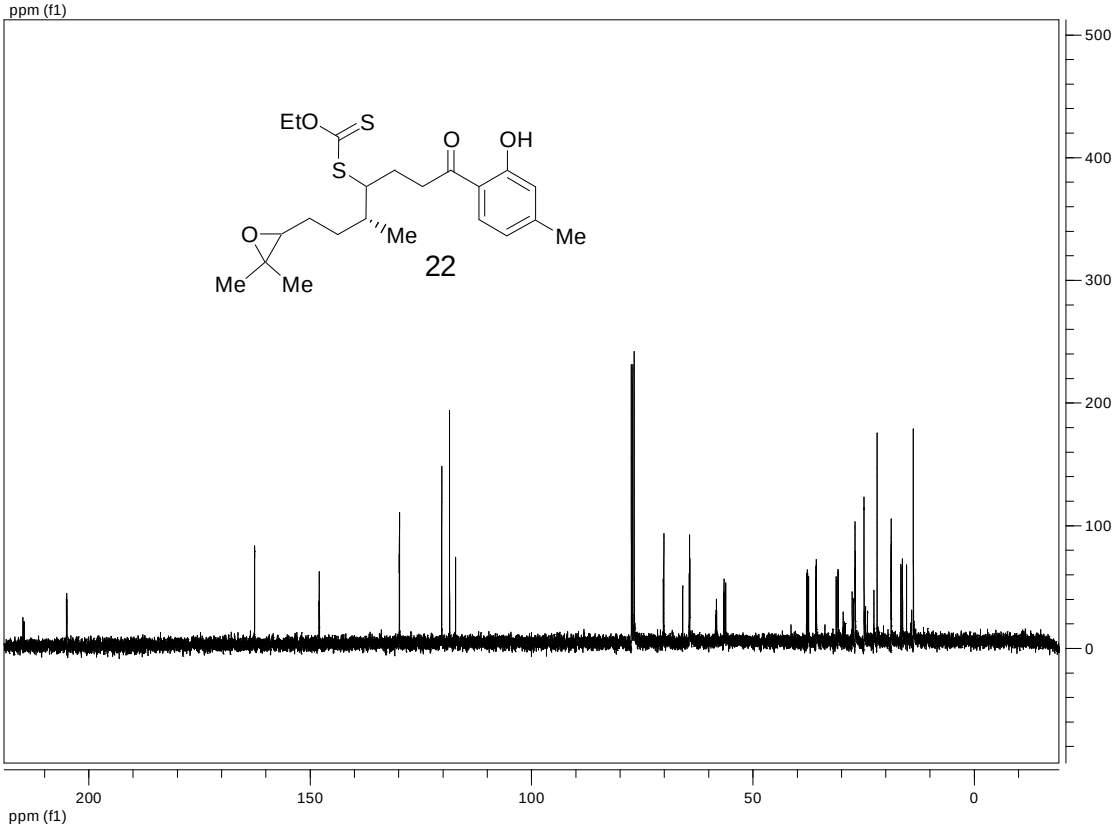

O
OH
O
O
S
OEt
S
CH3
19
2000
1500
1000
500
0
10.0
5.0
ppm (f1)

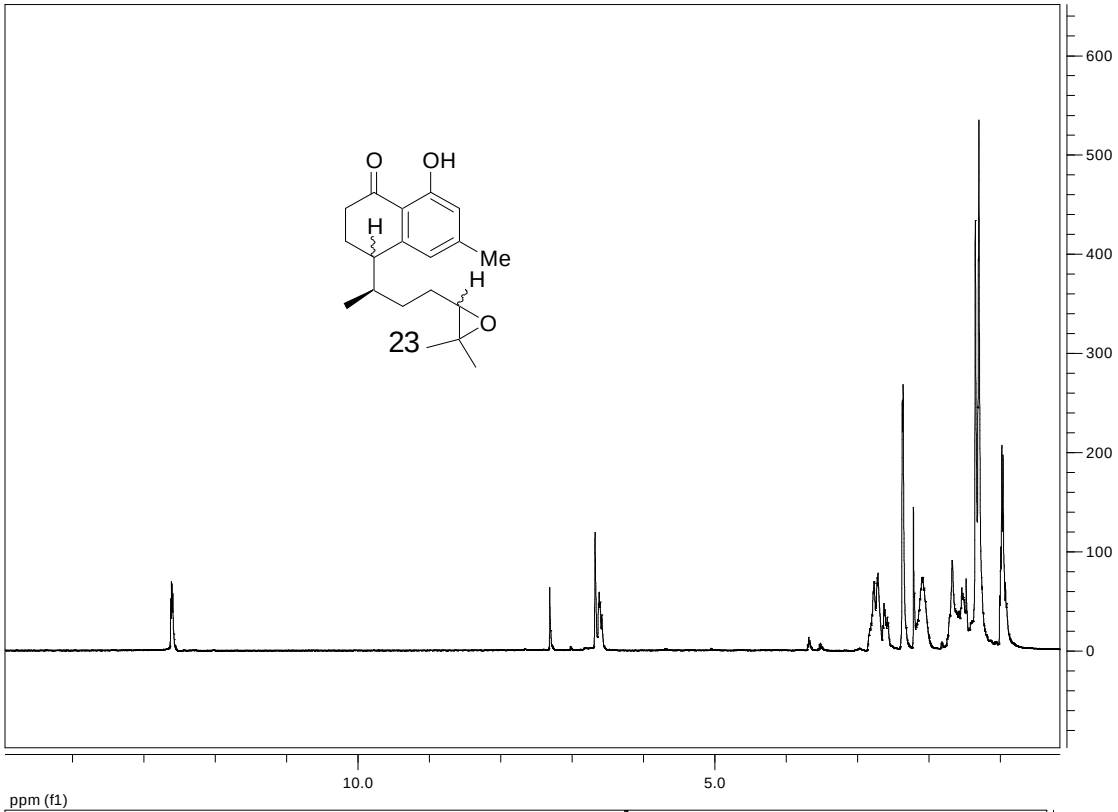

O
OH
O
O
S
OEt
S
CH3
19
1000
500
0
200
150
100
50
0
ppm (f1)

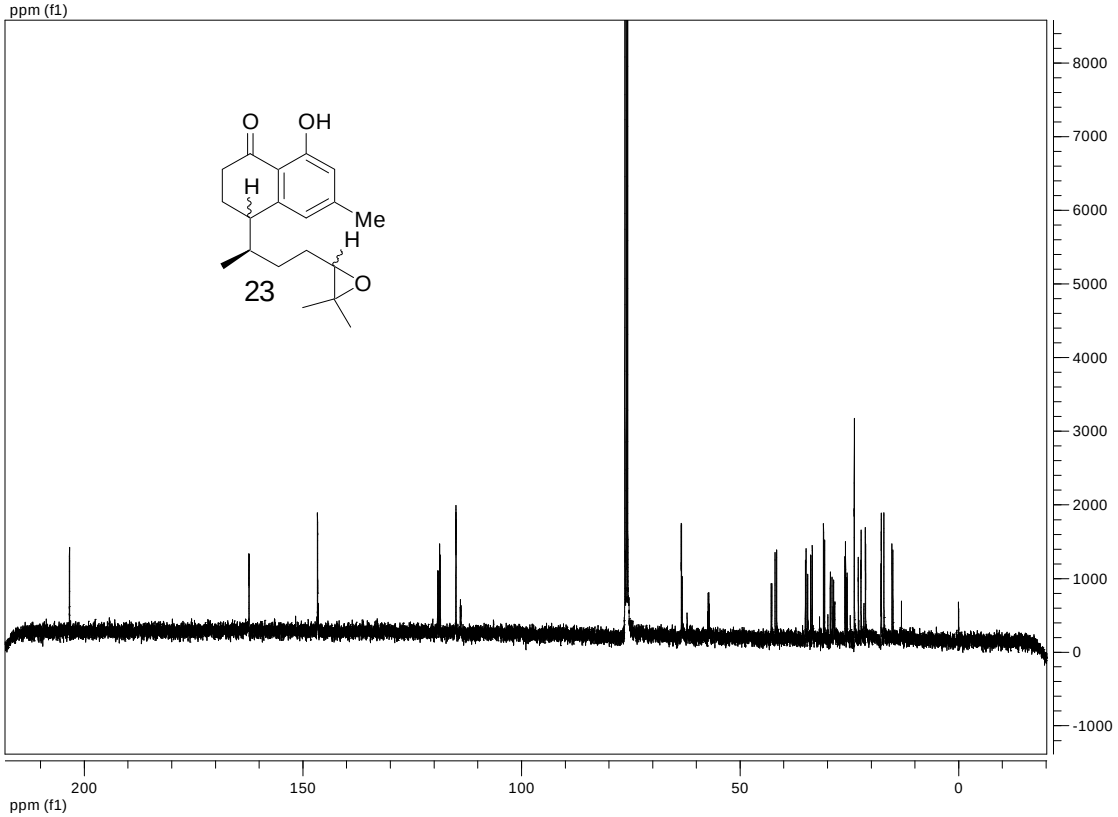

O
OH
OH
shinanolone 20
2500
2000
1500
1000
500
0
10.0
5.0
ppm (t1)

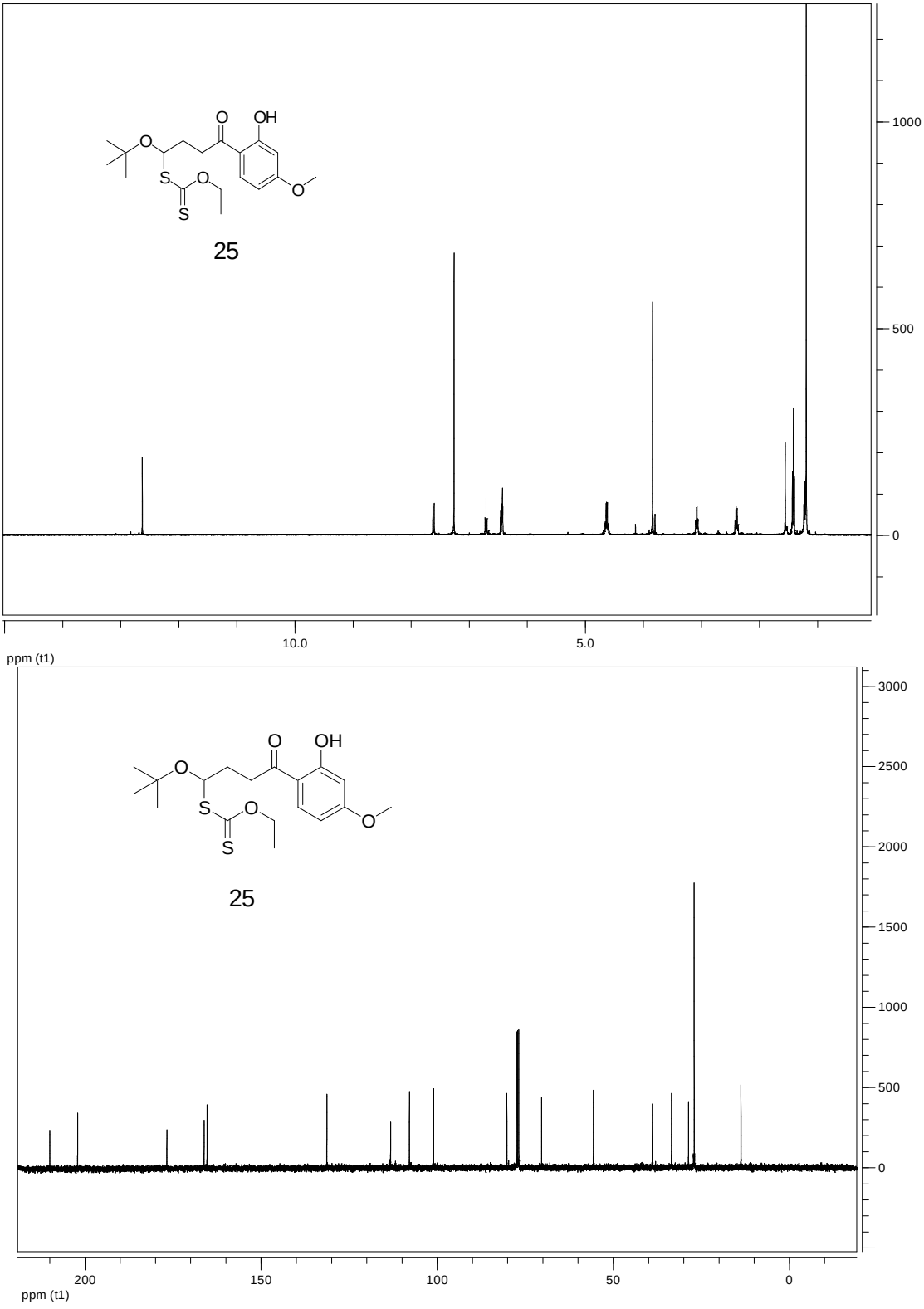

O
OH
OH
Shinanolone
15000
10000
5000
0
200
150
100
50
0
ppm (t1)

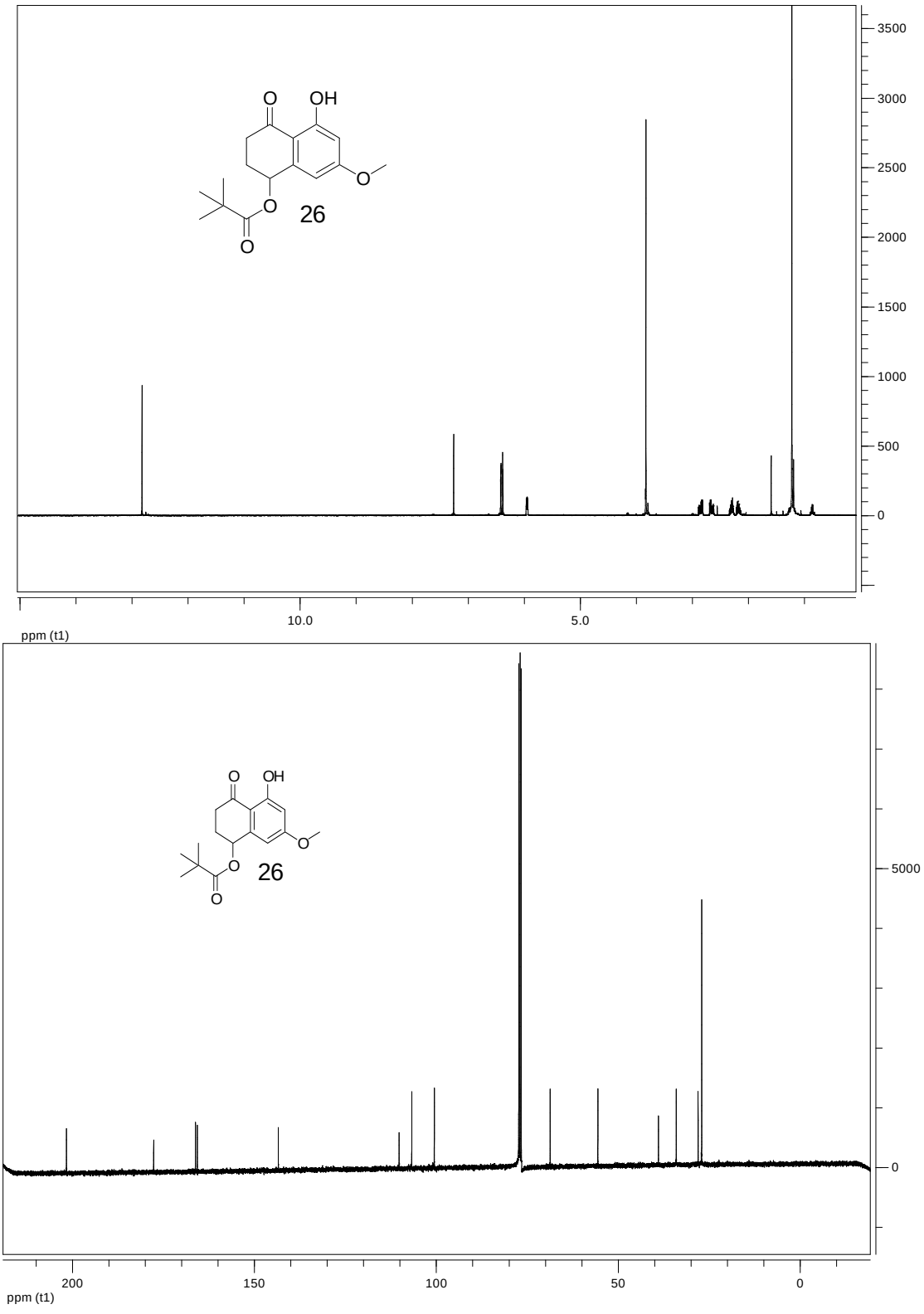

EtO
S
S
O
OH
Me
Me
O
Me
Me
22
1000
500
0
10.0
5.0
ppm (f1)

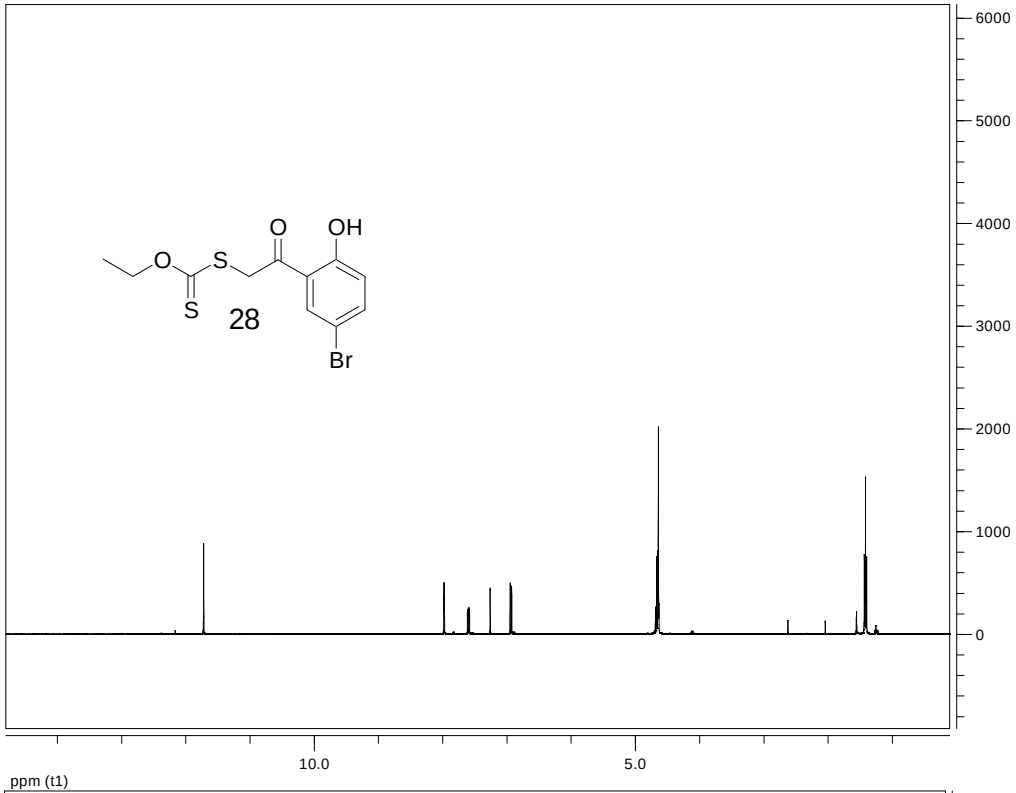

EtO
S
S
O
OH
Me
Me
O
Me
Me
22
500
400
300
200
100
0
200
150
100
50
0
ppm (f1)

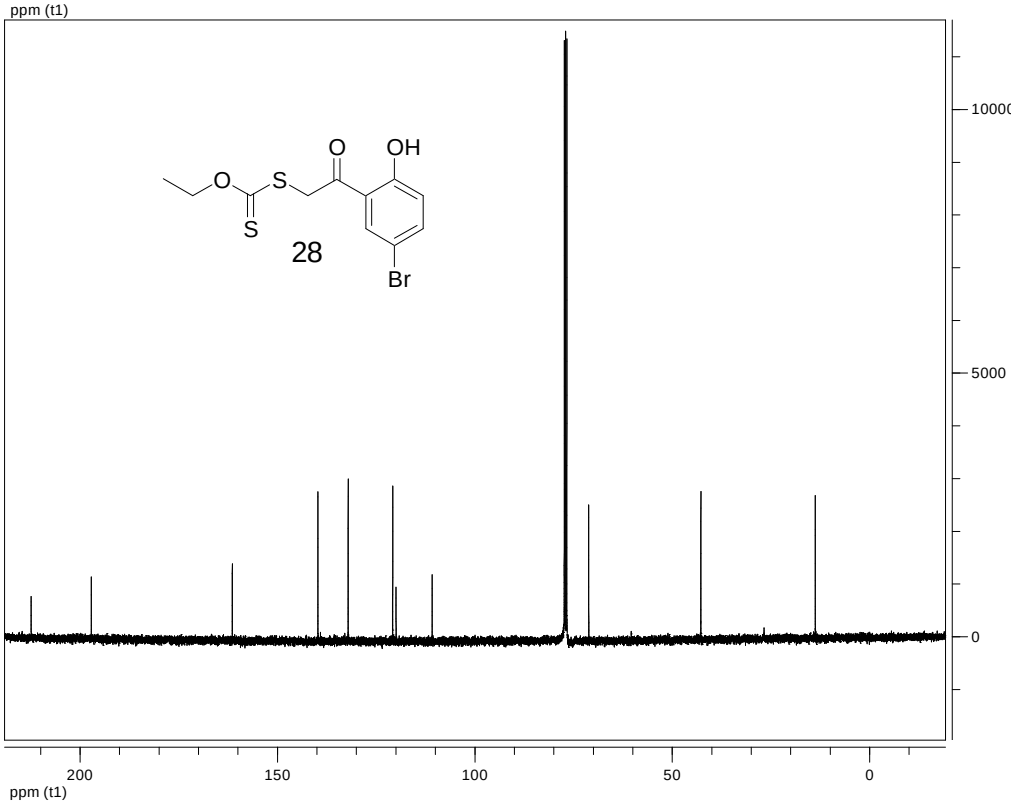

O
OH
H
Me
H
O
23
600
500
400
300
200
100
0
10.0
5.0
ppm (f1)

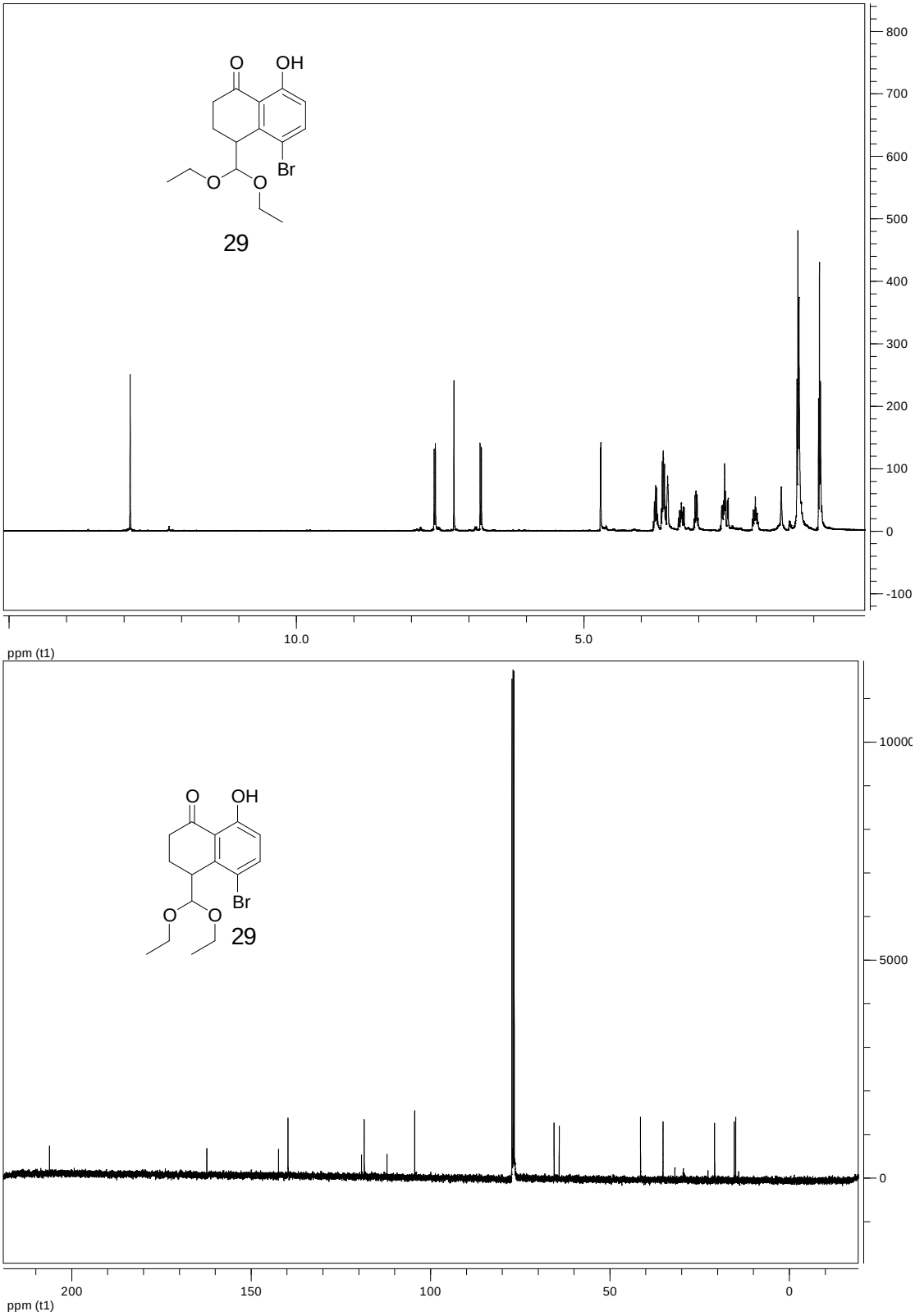

O
OH
H
Me
H
O
23
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
200
150
100
50
0
ppm (f1)


O
OH
O
S
O
S
O
25
1000
500
0
10.0
5.0
ppm (t1)
O
OH
O
S
O
S
O
25
3000
2500
2000
1500
1000
500
0
200
150
100
50
0
ppm (t1)


O
OH
O
O
O
26
3500
3000
2500
2000
1500
1000
500
0
10.0
5.0
ppm (t1)
O
OH
O
O
O
26
5000
0
200
150
100
50
0
ppm (t1)


O
OH
O
S
S
28
Br
6000
5000
4000
3000
2000
1000
0
10.0
5.0
ppm (t1)


O
OH
O
S
S
28
Br
10000
5000
0
200
150
100
50
0
ppm (t1)


O
OH
Br
O
O
29
800
700
600
500
400
300
200
100
0
-100
10.0
5.0
ppm (t1)
O
OH
Br
O
O
29
10000
5000
0
200
150
100
50
0
ppm (t1)