Regio- and Enantioselective Intermolecular Hydroacylation: Substrate-Directed Addition of Salicylaldehydes to Homoallylic Sulfides

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Supporting Information

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1. General Considerations

Commercial reagents were purchased from Sigma Aldrich, Strem or Alfa Aesar and used without further purification. Reactions were monitored using thin-layer chromatography (TLC) on EMD Silica Gel 60 F_{254} plates. Visualization of the developed plates was performed under UV light (254 nm) or $KMnO_4$ stain. Organic solutions were concentrated under reduced pressure on a Büchi rotary evaporator. ^1H and ^{13}C NMR spectra were recorded on a Varian Mercury 300, Varian Mercury 400, VRX-S (Unity) 400, or Bruker AV-III 400 spectrometer. ^1H NMR spectra were internally referenced to the residual solvent signal or TMS. ^{13}C NMR spectra were internally referenced to the residual solvent signal. Data for ^1H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), coupling constant (Hz), integration. Data for ^{13}C NMR are reported in terms of chemical shift (δ ppm).

High resolution mass spectra (HRMS) were obtained on a micromass 70S-250 spectrometer (EI) or an ABI/Sciex QStar Mass Spectrometer (ESI). Infrared (IR) spectra were obtained on a Perkin-Elmer Spectrum 1000 FT-IR Systems and are reported in terms of frequency of absorption (cm^{-1}). Melting point ranges were determined on a Fisher-Johns Melting Point Apparatus. Enantiomeric excesses (ee's) were ascertained on an Agilent 1100 Series HPLC. Optical rotations were measured on a Rudolph Research Analytical Autopol IV Automatic Polarimeter. Column chromatography was performed with Silicycle Silia-P Flash Silica Gel, using either glass columns or a Biotage SP-1 system. All salts were purchased from Aldrich and used without purification. Solvents were purchased from Caledon and were purified according to standard procedures.[1] Solvents used in hydroacylations were degassed by three freeze-pump-thaw cycles before being taken into a glove box. Tosylates were synthesized from the corresponding alcohols via standard literature procedures.[2] Chiral ligands were purchased from Strem.

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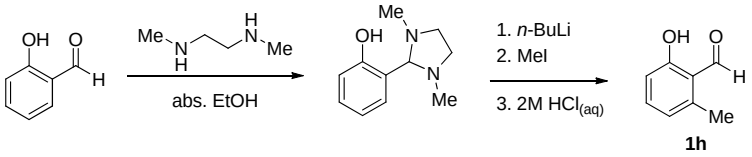
[1] Perrin, D. D.; Armarego, W. L. F. Purification of Laboratory Chemicals; 5th ed., Pregamon Press, Oxford, 1988.
[2] Ren, X.-F.; Turos, E.; Lake, C. H.; Churchill, M. R. *J. Org. Chem.*, **1995**, *60*, 6468–6483.

2. Preparation of Substrates

Salicylaldehydes **1a-1c**, and **1e-1g** are commercially available.

1d was synthesized according to a literature procedure.[3]

2-hydroxy-6-methylbenzaldehyde (1h)



1h

2-Hydroxy-6-methylbenzaldehyde (**1h**) was prepared based on a modified literature procedure according to the scheme above.[4] Salicylaldehyde (1.8 mL, 17 mmol) was dissolved in 93 mL absolute ethanol and *N,N'*-dimethylethylenediamine (2.4 mL, 22.3 mmol) was added dropwise. The reaction immediately became a bright yellow solution which was left to stir at rt for 24 h. Anhydrous $MgSO_4$ (7.3 g, 61 mmol) was then added to the reaction, which was then stirred for 30 minutes, filtered and concentrated *in vacuo.* The crude imidazolidine was dissolved in 130 mL Et_2O under argon and TMEDA (10.3 mL, 69.1 mmol) was added. With stirring at rt, a solution of 1.6 M *n*-BuLi in hexanes (43.0 mL, 68.8 mmol) was carefully added over 25 minutes via syringe pump. The resulting yellow solution was left to stir for 5 h and then iodomethane (4.3 mL, 69.1 mmol) was added over 15 minutes via syringe pump. A white solid gradually precipitated from solution and the reaction was left to stir for an additional 12 h. The resulting turbid brown suspension was subsequently poured into 280 mL 2 M $HCl_{(aq)}$, stirred for 1 h and extracted three times with $CHCl_3$. The organic layers were combined, washed with brine, dried with anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The title product was isolated by flash column chromatography (0% – 5% ethyl acetate in hexanes) as a yellow liquid (500 mg, 21%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.28 (s, 3H), 6.93 (t, J = 7.5 Hz, 1H), 7.36-7.44 (m, 2H), 9.88 (s, 1H), 11.27 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.2, 119.5, 120.2, 127.0, 131.5, 138.0, 160.1, 196.9; IR (neat): 2921, 2851, 2739, 1656, 1642, 1618, 1482, 1436, 1383, 1317, 1269, 1247, 1217, 1084, 1024, 954, 844, 744, 698. HRMS (EI) Calcd. for $[C_8H_8O_2]^+$ 136.0524, found 136.0525.

2a-g, 5 and **6** were prepared via alkylation of thiophenol derivatives according to the following scheme:

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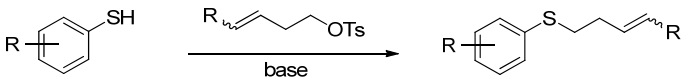
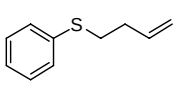
[3] Phan, D. H. T.; Kim, B.; Dong, V. M. *J. Am. Chem. Soc.* **2009,** *131*, 15608.
[4] Parsons, P. J.; Gray, M. *Synlett* **1991,** *10,* 729.



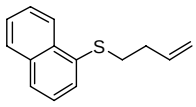
Alkylations using 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) were performed according to a modified literature procedure.[5]

but-3-en-1-yl(phenyl)sulfane (2a)



In a flame dried flask equipped under argon, 1.0 ml thiophenol (9.8 mmol, 1.0 equiv) was dissolved in 45 mL dimethylformamide and cooled to 0 °C. 587 mg (14.7 mmol, 1.5) equiv of NaH (available as a 60 % oil dispersion) was added and the slurry was allowed to stir for 5 min. *O*-tosyl-3-butene-1-ol (1.1 equiv) was then added via syringe. The reaction was allowed to warm to room temperature over 16 h, at which point full conversion was observed by TLC analysis. The reaction mixture was cooled to 0 °C, carefully quenched via the dropwise addition of H_2O, then diluted with ~ 450 mL H_2O. The aqueous phase was extracted three times with diethyl ether. The combined organics were washed with brine, dried over anhydrous Na_2SO_4, filtered, and concentrated to dryness *in vacuo*. **2a** was isolated as a clear oil (1.6 g, quant.) by flash column chromatography in pentane. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.40-2.43 (m, 2H), 2.99 (t, *J* = 7.5 Hz, 2H), 5.05-5.12 (m, 2H), 5.86 (ddt, *J* = 16.9, 10.2, 6.6 Hz, 1H), 7.16-7.20 (m, 1H), 7.27-7.31 (m, 2H), 7.33-7.35 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 33.2, 33.5, 116.4, 126.1, 129.0, 129.4, 136.5, 136.6; IR (neat): 3075, 3002, 2972, 2926, 1639, 1584, 1480, 1438, 1279, 1092, 1025, 993, 915, 738, 691 cm^{-1}; HRMS (EI) Calcd. for $[C_{10}H_{12}S]^+$ 164.0660, found 164.0660.

but-3-en-1-yl(naphthalen-1-yl)sulfane (2b)



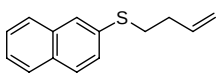
To a flask equipped with a stirbar was added naphthalene-1-thiol (321 mg, 2.0 mmol) in 4 ml toluene. The flask was purged with and maintained under argon, then cooled to 0 °C. 1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU, 329 µL, 2.2 mmol) was added via syringe. *O*-tosyl-3-butene-1-ol was added in 2 ml toluene via syringe. The reaction was stirred for 2.5 h, at which point complete conversion was observed via TLC analysis. The crude reaction

[5] Ono, N.; Miyake, H.; Saito, T.; Kaji, A. *Synthesis-Stuttgart* **1980**, 95

mixture was diluted with diethyl ether and washed three times with aqueous NaOH (1 M). The separated aqueous phase was extracted with diethyl ether and the combined organics were washed twice with brine, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The crude reaction mixture was flashed through Si gel (hexanes:ethyl acetate) and the product was concentrated to dryness. The product was further purified via reduction of residual contaminating disulfide according to the procedure below.

To a flame dried flask under argon was added 13.1 mg $LiAlH_4$ (10 eq. to disulfide according to crude ^{1}H NMR analysis) and 2.5 mL tetrahydrofuran. The substrate was then dissolved in 2.5 mL tetrahydrofuran and carefully added dropwise via syringe. The reaction mixture was heated at reflux for 19 h, at which point complete reaction was observed via TLC. The reaction mixture was then cooled to 0 °C and quenched via the dropwise addition of 5 mL aqueous NaOH (1 M), then diluted with diethyl ether. The organics were washed repeatedly with NaOH (1 M), then brine, dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The desired product was isolated via flash chromatography (hexanes/ethyl acetate) as a yellow oil (282 mg, 51 %). ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.37-2.44 (m, 2H), 3.04 (t, J = 7.5 Hz, 2H), 5.04-5.12 (m, 2H), 5.87 (ddt, J = 16.9, 10.2, 6.6 Hz, 1H), 7.39-7.60 (m, 4H), 7.74 (d, J = 8.2 Hz, 1H), 7.83-7.87 (m,1H), 8.42 (d, J = 8.2 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 33.6, 33.8, 116.4, 125.3, 125.7, 126.3, 126.5, 127.4, 128.5, 128.7, 133.2, 133.7, 134.1, 136.6; IR (neat): 3052, 1639, 1564, 1503, 1433, 1382, 1255, 1201, 993, 976, 915, 788, 770, 666 cm^{-1}; HRMS (EI) Calcd. for $[C_{14}H_{14}S]^+$ 214.0816, found 214.0815.

but-3-en-1-yl(naphthalen-2-yl)sulfane (2c)

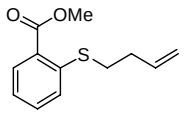


To a flask equipped with a stirbar was added naphthalene-2-thiol (644 mg, 4.0 mmol) in 6 mL benzene. The flask was purged with and maintained under argon, then cooled to 0 °C. 1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU, 650 µL, 4.34 mmol) was added via syringe. The color of the solution changed from clear to yellow. *O*-tosyl-3-butene-1-ol was added in 4 ml benzene via syringe. The reaction was stirred for 2.5 h, at which point complete conversion was observed via TLC analysis. The crude reaction mixture was diluted with diethyl ether and water. The separated organics were washed three times with aqueous NaOH (1 M), water and brine, then dried over anhydrous Na_2SO_4, filtered, and concentrated *in vacuo*. The crude reaction mixture was flashed through a plug of Si gel

(pentane) and the product was concentrated to dryness. Contaminating disulfide was removed as a solid via precipitation with hexanes. The desired product was further purified via reduction of residual contaminating disulfide according to the procedure below.

To a flame dried flask under argon was added 8.0 mg $LiAlH_4$ (7 equiv. to disulfide according to ^1H NMR analysis) and 2.5 mL tetrahydrofuran. The substrate was then dissolved in 2.5 ml tetrahydrofuran and carefully added dropwise via syringe. The reaction mixture was heated at reflux for 5 h, at which point completion of the reaction was observed via TLC. The reaction was then cooled to 0 °C and quenched via the dropwise addition of 5 ml aqueous NaOH (1 M). The reaction mixture was diluted with diethyl ether and the separated organics were washed repeatedly with NaOH (1 M), then brine. The combined organics were dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The desired product was isolated via flash chromatography (hexanes/ethyl acetate) as a clear oil (857 mg, 25 %). ^1H NMR (400 MHz, $CDCl_3$) δ 2.42-2.48 (m, 2H), 3.09 (t, J = 7.5 Hz, 2H), 5.06-5.10 (m, 2H), 5.89 (ddt, J = 16.9, 10.2, 6.6 Hz, 1H), 7.45-7.49 (m, 3H), 7.77-7.80 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 33.1, 33.5, 116.5, 125.7, 126.7, 127.0, 127.2, 127.6, 127.8, 128.5, 131.9, 133.9, 134.1, 136.5; IR (neat): 3052, 1625, 1589, 1501, 1431, 1338, 1280, 1133, 1069, 993, 943, 916, 851, 811, 743 cm^{-1}; HRMS (EI) Calcd. for $[C_{14}H_{14}S]^+$ 214.0816, found 214.0812.

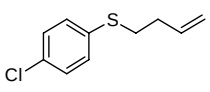
methyl 2-(but-3-en-1-ylthio)benzoate (2d)



To a flame dried flask equipped with a stirbar was added methyl thiosalicylate (657 mg, 3.9 mmol) in 10 mL acetone, then K_2CO_3 (809 mg, 5.9 mmol). *O*-tosyl-3-butene-1-ol (930 mg, 4.1 mmol) in 10 mL acetone was then added via syringe. The reaction was stirred at room temperature for 21 h, at which point full conversion was observed via TLC analysis. Acetone was removed under reduced pressure and the crude reaction mixture was diluted with diethyl ether and water. The separated aqueous phase was extracted an additional two times with diethyl ether. The combined organics were washed with brine, dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo.* The desired product was isolated via flash chromatography (hexanes/ethyl acetate) as a clear oil (540 mg, 62 %). ^1H NMR (300 MHz, $CDCl_3$) δ 2.44-2.51 (m, 2H), 3.00 (t, J = 7.6 Hz, 2H), 3.91(s, 3H), 5.05-5.18 (m, 2H), 5.91 (ddt, J = 16.9, 10.2, 6.6 Hz, 1H), 7.13-7.18 (m, 1H), 7.32 (d, J = 7.6 Hz, 1H), 7.41-7.47 (m,1H), 7.96 (dd, J = 8.2, 1.5 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 31.6, 32.5, 52.2, 116.5, 124.0, 125.7,

127.9, 131.4, 132.4, 136.4, 141.9, 167.1; IR (neat): 2950, 1714, 1640, 1588, 1562, 1463, 1433, 1272, 1247, 1189, 1144, 1108, 1062, 1046, 993, 963, 916, 824, 743, 714, 693, 655 cm^{-1}; HRMS (EI) Calcd. for $[C_{12}H_{14}O_2S]^+$ 222.0715, found 222.0719.

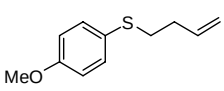
but-3-en-1-yl(4-chlorophenyl)sulfane (2e)



4-Chlorothiophenol was prepared based on a modified literature procedure.[6] Bis(4-chlorophenyl)disulfide (574 mg, 2.0 mmol) and sodium borohydride (190 mg, 5.0 mmol) were suspended in tetrahydrofuran in a flame-dried round bottom flask equipped with a reflux condenser under argon. The reaction mixture was heated to 75 °C and anhydrous methanol (800 μL, 20 mmol) was added via syringe pump over 1 h. The resulting solution was heated at reflux for 4 h, then cooled to rt and quenched by subsequent addition of 1 M HCl (4 mL) and 6 M HCl (6 mL) and extracted three times with dichloromethane. The organic layers were combined, washed with brine, dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo* to give the crude 4-chlorothiophenol. The isolated product was dissolved in 17.5 mL dimethylformamide in a flame-dried round bottom flask under argon and cooled to 0°C. Sodium hydride (60% oil dispersion, 231 mg, 5.78 mmol) was added to the cooled solution. After stirring for 5 minutes *O*-tosyl-3-butene-1-ol (955 mg, 4.22 mmol) was added. The turbid yellow reaction mixture was allowed to gradually warm to rt over 12 h, then diluted with 150 mL H_2O and extracted three times with diethyl ether. The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The title product was isolated via flash column chromatography (0% – 4% ethyl acetate in hexanes) as a pale yellow liquid (652 mg, 85%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.32-2.42 (m, 2H), 2.95 (t, J = 7.4 Hz, 2H), 5.03-5.13 (m, 2H), 5.83 (ddt, J = 16.9, 10.2, 6.6 Hz, 1H), 7.26 (s, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 33.36, 33.42, 116.6, 129.1, 130.8, 132.1, 135.1, 136.3; IR (neat): 3073, 2972, 2952, 2927, 1640, 1474, 1435, 1389, 1279, 1222, 1095, 1011, 993, 916, 810. HRMS (EI) Calcd. for $[C_{10}H_{11}SCl]^+$ 198.0270, found 198.0269.

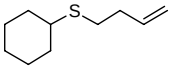
but-3-en-1-yl(4-methoxyphenyl)sulfane (2f)

[6] Ookawa, A.; Yokoyama, S.; Soai, K. *Synth. Commun.* **1986,** *16,* 819.



To a flame-dried round bottom flask was added lithium aluminum hydride (146 mg, 3.9 mmol) and 5 mL tetrahydrofuran. The reaction mixture was maintained under argon. Bis(4-methoxyphenyl) disulfide (1.00 g, 3.6 mmol) in 5 mL tetrahydrofuran was added dropwise over a period of 20 minutes. The reaction was heated at reflux for 4 h, then at room temperature for 23 h. The reaction was then cooled to 0 °C and quenched via the dropwise addition of wet ethyl acetate and acidified via the dropwise addition of H_2SO_4 (2 M). The reaction was then diluted with diethyl ether and filtered through a plug of celite. The organics were washed with water and the separated aqueous phase was extracted three times with diethyl ether. The combined organics were washed with brine, dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The crude 4-methoxythiophenol product was then dissolved in 30 mL toluene and added to a flame-dried flask under argon. *O*-tosyl-3-butene-1-ol (1.78 g, 7.8 mmol) was added via syringe, followed by 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU, 1.1 mL, 7.4 mmol). The reaction was stirred at room temperature for 20 h then diluted with diethyl ether. The organics were washed with NaOH (1 M), water, and brine, then dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo.* The desired product was isolated via flash chromatography (0 – 10% ethyl acetate in hexanes) as a clear oil (325 mg, 23 %). ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.29-2.36 (m, 2H), 2.88 (t, J = 7.5 Hz, 2H), 3.80 (s, 3H), 5.02-5.09 (m, 2H), 5.83 (ddt, J = 16.9, 10.2, 6.6 Hz, 1H), 6.85 (d, J = 8.7 Hz, 1H), 7.36 (d, J = 8.8 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 33.7, 35.3, 55.5, 114.7, 116.2, 126.5, 133.5, 136.7, 159.1; IR (neat): 2920, 2835, 1639, 1592, 1493, 1462, 1440, 1284, 1244, 1173, 1103, 1032, 995, 916, 826 cm^{-1}; HRMS (EI) Calcd. for $[C_{11}H_{14}OS]^+$ 194.0765, found 194.0767.

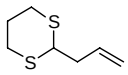
but-3-en-1-yl(cyclohexyl)sulfane (2g)



Cyclohexanethiol (320 μL, 2.62 mmol) was dissolved in 12 mL dimethylformamide in a flame-dried round bottom flask under argon. The reaction was cooled to 0 °C and sodium hydride (60% oil dispersion, 157 mg, 3.92 mmol) was added. After stirring at 0 °C for 5 minutes, *O*-tosyl-3-butene-1-ol (637 mg, 2.81 mmol) was added and the reaction was allowed to slowly warm to rt and stirred for 20 h. The resulting reaction mixture was diluted with 100 mL H_2O and extracted three times with diethyl ether. The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo.* The title product was isolated by flash column chromatography (0 – 10%

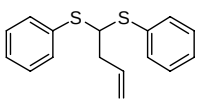
ethyl acetate in hexanes) as a clear, colorless oil (442 mg, quant.). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.18-1.40 (m, 5H), 1.57-1.67 (m, 1H), 1.70-1.85 (m, 2H), 1.90-2.02 (m, 2H), 2.28-2.37 (m, 2H), 2.60 (t, *J* = 7.5 Hz, 2H), 2.63-2.70 (m, 1H), 5.02 (dd, *J* = 10.2, 1.3 Hz, 1H,), 5.04-5.12 (m, 1H), 5.84 (tdd, , *J* = 16.9, 10.2, 6.6Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 26.0, 26.3, 29.6, 33.9, 34.4, 43.7, 115.8, 137.2; IR (neat): 2927, 2852, 1640, 1448, 1279, 1265, 1202, 996, 913, 887. HRMS (EI) Calcd. for $[C_{10}H_{18}S]^+$ 170.1129, found 170.1127.

2-allyl-1,3-dithiane (2h)



2h was prepared by a modified literature procedure.[7] To a flame-dried flask, under argon, 1,3-dithiane (0.24 g, 2 mmol) was added and dissolved in anhydrous tetrahydrofuran and cooled to −20 °C. A solution of 1.21 M *n*-butyllithium in hexanes (2.5 mL, 3.0 mmol) was added dropwise. The mixture was allowed to stir for 40 minutes, after which time it was cooled to −60 °C and allyl bromide (0.35 mL, 4.0 mmol) was added dropwise via syringe. The resulting colorless solution was allowed to warm to room temperature over 5 h, and was subsequently quenched with saturated NH_4Cl solution. This crude mixture was extracted three times with diethyl ether, and the organic layers were dried over anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. Purification via flash column chromatography (ethyl acetate/pentane) afforded **2h** as a colorless oil (39 mg, 12%) with 96% purity by ^{1}H NMR analysis. ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.78-1.92 (m, 1H), 2.07-2.16 (m, 1H), 2.51(td, *J* = 7.0, 0.9 Hz, 2H), 2.78-2.94 (m, 4H), 4.10 (t, *J* = 6.9 Hz, 1H), 5.11-5.18 (m, 2H), 5.79-5.93 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.892, 30.592, 39.867, 47.171, 118.095, 133.855; IR (neat): 2896, 1639, 1422, 1276, 1242, 1181, 990, 917, 772, 670 cm^{-1}; HRMS (EI) Calcd. for $[C_7H_{12}S_2]^+$ 160.0380, found 160.0381.

But-3-ene-1,1-diylbis(phenylsulfane) (2i)

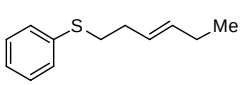


2i was prepared by a modified literature procedure.[7] To a flame-dried flask, under argon, bis(phenylthio)methane (1.3 g, 5.5 mmol) was added and dissolved in anhydrous tetrahydrofuran and cooled to −30 °C. A solution of 1.47 M *n*-butyllithium in hexanes (5.6 mL, 8.25 mmol) was added dropwise, producing a pale yellow solution. After cooling to −60 °C, allyl bromide (0.95 mL, 11.0 mmol) was added dropwise via

[7] Karlson, S.; Högberg, H.-K. *Synthesis* **2000**, 13, 1863.

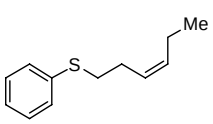
syringe. The resulting colorless solution was allowed to warm to rt over 3 h, and was subsequently quenched with saturated NH_4Cl solution. This crude mixture was extracted three times with diethyl ether, and the organic layers were dried over anhydrous $MgSO_4$, filtered and concentrated *in vacuo*. Purification via flash column chromatography (ethyl acetate/hexanes) afforded **2i** as a colorless oil (1.16g, 78%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.63 (tt, *J* = 6.7, 1.1 Hz, 2H), 4.46 (t, *J* = 6.6 Hz, 1H), 5.12-5.18 (m, 2H), 6.00 (ddt, *J* = 17.0, 10.3, 6.8 Hz, 1H), 7.27-7.35 (m, 6H), 7.47-7.50 (m, 4H); ^{13}C NMR (100 MHz $CDCl_3$) δ 40.0, 57.7, 118.2, 127.9, 129.0, 132.9, 134.2, 134.3; IR (neat): 3056, 2356, 1638, 1582, 1479, 1438, 1157, 1088, 1067, 1025, 990, 918, 739, 691 cm^{-1}; HRMS (EI) Calcd. for $[C_{16}H_{16}S_2]^+$ 272.0693, found 272.0700.

(*E*)-hex-3-en-1-yl(phenyl)sulfane (5)



A flame-dried flask equipped with a stirbar was charged with 119 mg (5.0 mmol) of sodium hydride (60 % oil dispersion) and 10 mL dimethylformamide and maintained under argon. The mixture was cooled to 0 °C. Thiophenol (340 μL, 3.3 mmol) was added via syringe, followed by (*E*)-hex-3-en-1-yl 4-methylbenzenesulfonate (928 mg, 3.7 mmol) in 10 mL dimethylformamide. The reaction was allowed to warm to rt and stirred for 20 h, at which point full conversion was observed via TLC analysis. The reaction was then cooled to 0 °C, quenched via the dropwise addition of water and diluted with diethyl ether. The organics were washed repeatedly with water and the separated aqueous phase was extracted three times with diethyl ether. The combined organics were washed with brine, dried over anhydrous Na_2SO_4, filtered and concentrated *in vacuo*. The desired product was isolated via flash chromatography (hexanes/ethyl acetate) as a clear oil (308 mg, 47 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.97 (t, 3H), 2.01 (quintet, *J* = 7.2 Hz, 2H), 2.33 (q, *J* = 7.1, 2H), 2.95 (t, *J* = 7.5, 2H), 5.40-5.57 (m, 2H), 7.17 (t, *J* = 7.2 Hz, 1H), 7.26-7.34 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 13.9, 25.7, 32.5, 33.8, 125.9, 126.8, 129.0, 129.2, 134.2, 136.9; IR (neat): 2961, 2921, 1585, 1480, 1438, 1271, 1090, 1025, 967, 736, 690 cm^{-1}; HRMS (EI) Calcd. for $[C_{12}H_{16}S]^+$ 192.0973, found 192.0977.

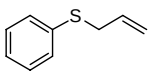
(*Z*)-hex-3-en-1-yl(phenyl)sulfane (6)



To a flask equipped with a stirbar was added thiophenol (254 mg, 2.29 mmol) in 4 ml benzene. The flask was purged with and maintained under argon, then

cooled to 0 °C. 1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU, 380 μL, 2.50 mmol) was added via syringe. The color of the solution changed from clear to yellow. (*Z*)-Hex-3-en-1-yl 4-methylbenzenesulfonate (700 mg, 2.75 mmol) was added in 4 ml benzene via syringe. The reaction was stirred for 4 h, at which point complete reaction was observed via TLC analysis. The crude reaction mixture was diluted with diethyl ether and water. The organics were washed three times with aqueous NaOH (1 M), water and brine, then dried over anhydrous Na_2SO_4, filtered, and concentrated *in vacuo*. The desired product was isolated via flash chromatography (pentane) as a clear oil (204 mg, 46%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.95 (t, *J* = 7.5 Hz, 3H), 2.01 (quintet, *J* = 7.0 Hz, 2H), 2.38 (q, *J* = 7.1 Hz, 2H), 2.94 (t, *J* = 7.5 Hz, 2H), 5.34-5.51 (m, 2H), 7.15-7.20 (m, 1H), 7.27-7.36 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.3, 20.7, 27.0, 33.6, 125.9, 126.5, 128.9, 129.1, 133.7, 136.7; IR (neat): 3058, 3004, 2962, 1505, 1480, 1438, 1280, 1216, 1093, 1069, 1025, 737, 691, 668 cm^{-1}; HRMS (EI) Calcd. for $[C_{12}H_{16}S]^+$ 192.0973, found 192.0969.

allyl(phenyl)sulfane (8)



A flame-dried flask equipped with a stirbar was charged with 1.56g (11.3 mmol) of K_3CO_3 and 40 mL dimethylformamide and maintained under argon at rt. Thiophenol (770 μL, 7.5 mmol) was added via syringe, followed by allyl bromide (1.30 mL, 15 mmol). The reaction was allowed to stir for 6 h, at which point full conversion was observed via TLC analysis. The reaction was then diluted with diethyl ether and the organics were washed three times with NaOH (1M) and water, and once with brine. The combined organics were dried over $MgSO_4$, filtered and concentrated *in vacuo.* The desired product was isolated via flash chromatography (hexanes) as a clear oil (833 mg, 74 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.54 (dt, *J* = 6.9, 1.2 Hz, 2H), 5.06 (dq, *J* = 10.0, 1.1 Hz, 1H), 5.13 (dq, *J* = 17.0, 1.4 Hz, 1H), 5.87 (ddt, *J* = 16.9, 10.0, 6.9 Hz, 1H), 7.15-7.20 (m, 1H), 7.23-7.30 (m, 2H), 7.31-7.36 (m, 2H); ^{13}C NMR (100 MHz $CDCl_3$) δ 37.3, 117.7, 126.3, 128.9, 129.9, 133.7, 136.0; IR (neat) 3075, 3008, 2911, 1636, 1583, 1480, 1438, 1228, 1089, 1025, 987, 918, 738, 690 cm^{-1}; HRMS (EI) Calcd. for $[C_9H_{10}S]^+$ 150.0503, found 150.0502.

3. Rh-catalyzed Intermolecular Olefin Hydroacylation

(i) Standard Procedures

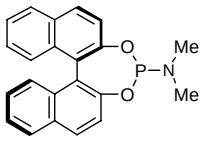
General Method A - A typical Rh-catalyzed hydroacylation procedure with salicylaldehyde **1a**: In a glove box 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE was dissolved in 800 μL of degassed dichloromethane. The resultant solution was added to 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$. This solution was transferred to a vial containing 0.01 mmol (5 mol %) K_3PO_4. 0.3 mmol (1.5 equiv) of olefin was dissolved in 800 μL degassed dichloromethane and transferred to the reaction mixture. 0.2 mmol (1.0 equiv) salicylaldehyde **1a** was added via syringe. The reaction was stirred at ambient glovebox temperature (30 °C) for the indicated period of time. The crude reaction mixture was purified via thin layer chromatography in hexanes/ethyl acetate.

General Method B - A typical Rh-catalyzed hydroacylation procedure with solid salicylaldehyde derivatives: In a glove box 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE was dissolved in 800 μL of degassed dichloromethane. The resultant solution was added to 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$. This solution was transferred to a vial containing 0.01 mmol (5 mol %) K_3PO_4. 0.3 mmol (1.5 equiv) of olefin was dissolved in 600 μL degassed dichloromethane and transferred to a vial containing 0.2 mmol (1.0 equiv) of the salicylaldehyde derivative. The resulting solution was added to the reaction mixture via syringe. The vial containing the salicylaldehyde derivative was rinsed with an additional 200 μL degassed dichloromethane, which was transferred to the reaction mixture. The reaction was stirred at ambient glovebox temperature (30 °C) for the indicated period of time. The crude reaction mixture was purified via thin layer chromatography in hexanes/ethyl acetate.

(ii) Chiral Ligand Screen, Test Reaction with no Added Base

Ligand screening was performed according to a modification of Method A using salicylaldehyde **1a** (0.1 mmol), **2a** (0.15 mmol), 0.005 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (10 mol %) ligand and 0.02 mmol (0.2 equiv) K_3PO_4.

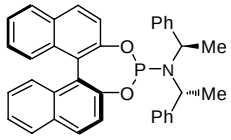
Figure 1: Names and structures of ligands tested in this study:



L1

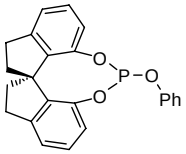
(*R*)-MonoPhos

(*R*)-(-)-(3,5-Dioxa-4-phospha-cyclohepta [2,1-a:3,4-a']di-naphthalen-4-yl)dimethylamine



L2

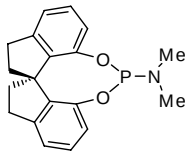
(*S*,*R*,*R*)-(+)-(3,5-Dioxa-4-phosphacyclohepta [2,1-a:3,4-a']dinaphthalen-4-yl)bis(1-phenylethyl)amine



L3

(*R*)-ShiP

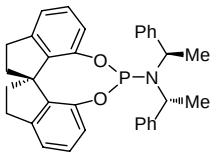
(11a*R*)-(+)-10,11,12,13-Tetrahydrodiindeno [7,1-de:1',7'-fg][1,3,2]dioxaphosphocin-5-phenoxy



L4

(*R*)-SIPHOS

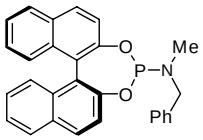
(11a*R*)-(+)-10,11,12,13-Tetrahydrodiindeno [7,1-de:1',7'-fg][1,3,2]dioxaphosphocin-5-dimethylamine



L5

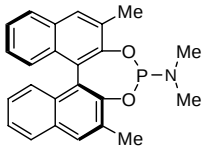
(*R*)-SIPHOS-PE

(11a*R*)-(+)-10,11,12,13-Tetrahydrodiindeno [7,1-de:1', 7'-fg][1,3,2]dioxaphosphocin-5-bis[(*R*)-1-phenylethyl]amine



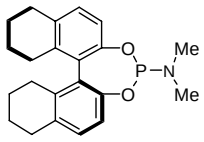
L6

(*S*)-(+)-Benzyl(3,5-dioxa-4-phospha-cyclohepta [2,1-a;3,4-a']dinaphthalen-4-yl)methylamine



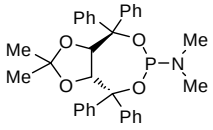
L7

(*S*)-(+)-(2,6-Dimethyl-3,5-dioxa-4-phosphacyclohepta [2,1-a;3,4-a']dinaphthalen-4-yl)dimethylamine



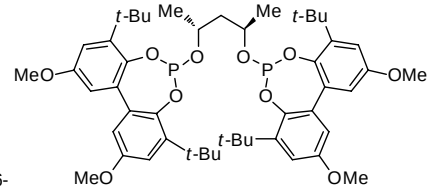
L8

(11b*S*)-N,N-dimethyl-8,9,10,11,12,13,14,15-octahydrodinaphtho[2,1-d:1',2'-f][1,3,2] dioxaphosphepin-4-amine

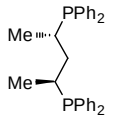


L9

(3a*R*,8a*R*)-(-)-(2,2-Dimethyl-4,4,8,8-tetraphenyl-tetrahydro-[1,3]dioxolo[4,5-e][1,3,2]dioxaphosphepin-6-yl)dimethylamine

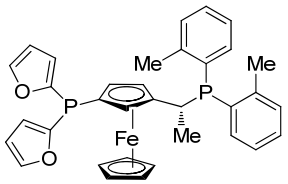


L10



L11

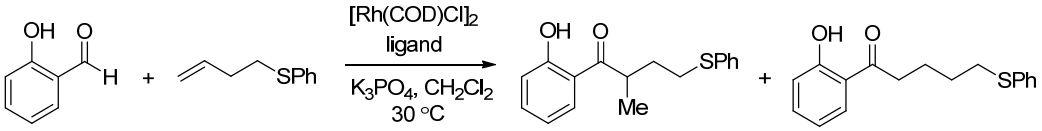
(*S*,*S*)-BDPP
(2*S*,4*S*)-2,4-Bis(diphenylphosphino)pentane



L12

(*R*)-1-{(S_P)-2-[Di(2-furyl)phosphino]ferrocenyl}ethylbis(2-methylphenyl)phosphine

Table 1. Ligand Effects in Regio- and Enantioselective Intermolecular Hydroacylation[a]



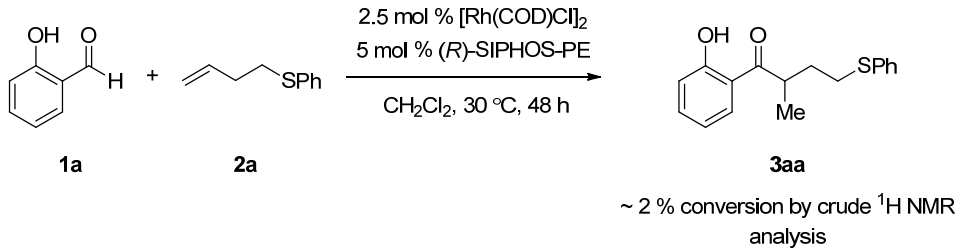
1a + **2a** → **3aa** + **4aa**

Entry	Ligand	Time (h)	Conversion (%)[b]	Selectivity[c]	ee (%)[d]
1	**L1**	48	>95	>20:1	-51
2	**L2**	24	Full	>20:1	62
3	**L3**	72	91	>20:1	52
4	**L4**	20	Full	>20:1	66
5	**L5**	20	Full	>20:1	92
6	**L6**	72	Full	>20:1	43
7	**L7**	20	Full	>20:1	64
8	**L8**	86	Full	>20:1	56
9	**L9**	19	Full	>20:1	18
10	**L10**	72	Trace	N/A	N/A
11	**L11**	104	<5%	N/A	N/A
12	**L12**	46	Trace	N/A	N/A
13[e]	**L12**	50	None	N/A	N/A
14	PPh_3	22	Full	>20:1	-
15	none	96	41	4:1	-

Table 1. [a] Conditions: salicylaldehyde **1a** (1.0 equiv), olefin **2a** (1.5 equiv), $[Rh(COD)Cl]_2$ (5 mol %) (COD = 1,5-cyclooctadiene), ligand (10 mol %), K_3PO_4 (0.2 equiv.), CH_2Cl_2, 30 °C. [b] Determined via ^1H NMR or GC/MS analysis. [c] Selectivities for **3aa** over **4aa** were calculated via ^1H NMR analysis of crude reaction mixtures. [d] Ee's of **3aa** were determined by chiral HPLC

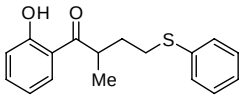
analysis. [e] Conditions: salicylaldehyde **1a** (1.0 equiv), olefin **2e** (1.5 equiv), $[Rh(COD)Cl]_2$ (2.5 mol %), ligand (5 mol %), K_3PO_4 (5 mol %), CH_2Cl_2, 30 °C.

Test Reaction with No Added Base:



(iii) Substrate Scope

1-(2-hydroxyphenyl)-2-methyl-4-(phenylthio)butan-1-one (3aa)

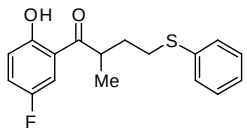


a) (Table 2, entry 1) The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **2a** (0.3 mmol) according to Method A using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (16:1 hexanes:ethyl acetate) afforded the product as a clear oil (55.5 mg, 97%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.25 (d, *J* = 6.9 Hz, 3H), 1.74-1.83 (m, 1H), 2.22 (dq, *J* = 14.2, 7.2 Hz, 1H), 2.91-3.02 (m, 2H), 3.77 (sextet, *J* = 6.9 Hz, 1H), 6.84-6.88 (m, 1H), 6.99 (d, *J* = 8.4 Hz, 1H), 7.15-7.19 (m, 1H), 7.25-7.33 (m, 4H), 7.46 (ddd, *J* = 8.6, 7.4, 1.6 Hz, 1H), 7.74 (dd, *J* = 7.7 Hz, 1H), 12.45 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.7, 31.5, 32.7, 38.9, 118.6, 118.9, 119.1, 126.2, 129.1, 129.3, 130.0, 136.0, 136.6, 163.3, 209.8; COSY (see below); IR (neat): 2920, 1634, 1581, 1482, 1445, 1376, 1349, 1284, 1241, 1207, 1155, 1090, 1025, 975, 739, 691, 654, 600 cm^{-1}; HRMS (EI) Calcd. for $[C_{17}H_{18}O_2S]^+$ 286.1028, found 286.1015. HPLC analysis: 92% ee (CHIRALPAK IA), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 7.7 min, t_{R2} = 9.3 min; $[\alpha]_D^{27}$ + 64 (*c* = 1.0, $CHCl_3$).

b) With $AgClO_4$ (Table 2, entry 2): The title compound was prepared according to a variation of Method A. 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$ and 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE were stirred in 800 μL dichloromethane for 15 minutes at ambient glovebox temperature. The solution was transferred to a vial containing 0.01 mmol (5 mol %) $AgClO_4$ and stirred for an

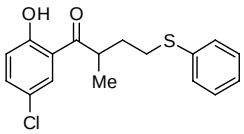
additional 15 minutes. The mixture was transferred to a vial containing 0.010 mmol (5 mol %) K_3PO_4. 0.3 mmol (1.5 equiv) **2a** in 800 μL dichloromethane was added to the reaction mixture followed by 0.2 mmol (1.0 equiv) salicylaldehyde. Purification via preparative TLC (16:1 hexanes:ethyl acetate) afforded both regioisiomers in a combined yield of 55.7 mg (97 %) with >20:1 selectivity for **3aa.** HPLC analysis: 93% ee; $[\alpha]_D^{27}$ + 65 (*c* = 1.0, $CHCl_3$).

1-(5-fluoro-2-hydroxyphenyl)-2-methyl-4-(phenylthio)butan-1-one (3ba)



(Table 2, entry 3) The title compound was prepared from 5-fluoro-2-hydroxybenzaldehyde **1b** (28.1 mg, 0.2 mmol) and **2a** (0.3 mmol) according to Method B using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE, and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (12:1 hexanes:ethyl acetate) afforded the product as a clear oil (57.0 mg, 93%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.24 (d, *J* = 6.9 Hz, 3H), 1.74-1.82 (m, 1H), 2.21 (dq, *J* = 14.1, 7.1, 1H), 2.91-3.02 (m, 2H), 3.65 (sextet, *J* = 6.8 Hz, 1H), 6.96 (dd, *J* = 9.1, 4.6 Hz, 1H), 7.13-7.35 (m, 6H), 7.41 (dd, *J* = 9.1, 1.0 Hz, 1H), 12.12 (s, 0.7H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 17.7, 31.5, 32.7, 39.1, 114.9 (d, *J* = 23.3 Hz), 118.0 (d, *J* = 6.1 Hz), 120.1 (d, *J* = 7.3Hz), 124.2 (d, *J* = 23.7 Hz), 126.4, 129.3 (d, *J* = 21.3Hz), 135.8, 153.4, 156.5, 159.4, 209.0 (d, *J*= 2.5 Hz); IR (neat): 2973, 1642, 1623, 1585, 1480, 1439, 1425, 1378, 1347, 1305, 1280, 1248, 1195, 1157, 1119, 1025, 992, 872, 829, 789, 739, 691 cm^{-1}; HRMS (EI) Calcd. for $[C_{17}H_{17}O_2SF]^+$ 304.0933, found 304.0942. HPLC analysis: 92% ee (CHIRALCEL OD-H), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 8.7 min, t_{R2} = 10.6 min; $[\alpha]_D^{27}$ + 61 (*c* = 1.0, $CHCl_3$).

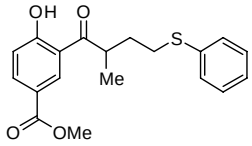
1-(5-chloro-2-hydroxyphenyl)-2-methyl-4-(phenylthio)butan-1-one (3ca)



(Table 2, entry 4) The title compound was prepared from 5-chloro-2-hydroxybenzaldehyde **1c** (31.3 mg, 0.2 mmol) and **2a** (0.3 mmol) according to Method B using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (12:1 hexanes:ethyl acetate) afforded the product as a clear yellow oil (61.0 mg, 95%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.24 (d, *J* = 6.9 Hz, 3H), 1.74-1.83 (m, 1H), 2.21 (dq, *J* = 14.1, 7.2, 1H), 2.90-3.02 (m, 2H), 3.63-3.71 (m, 1H), 6.95 (d, *J* = 8.91, 1H), 7.16 (t, *J* = 7.3 Hz, 1H), 7.27 (t, *J* =

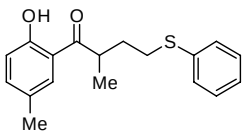
7.3 Hz, 2H), 7.33 (d, *J* = 7.9 Hz, 2H), 7.41 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.71 (d, *J* = 2.5 Hz, 1H), 12.34 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.9, 31.5, 32.7, 39.0, 119.1, 120.5, 123.8, 126.4, 129.1, 129.2, 129.4, 135.8, 136.4, 161.7, 209.0; IR (neat): 2935, 1638, 1469, 1438, 1409, 1377, 1342, 1284, 1238, 1188, 1093, 1025, 981, 829, 793, 739, 691 cm^{-1}; HRMS (EI) Calcd. for $[C_{17}H_{17}O_2SCl]^+$ 320.0638, found 320.0652. HPLC analysis: 92% ee (CHIRALPAK AD-H), 1:99 isopropanol:hexanes, 0.5 mL/min, 254 nm, t_{R1} = 17.0 min, t_{R2} = 18.6 min; $[\alpha]_D^{27}$ + 3 (*c* = 1.0, $CHCl_3$).

methyl 4-hydroxy-3-(2-methyl-4-(phenylthio)butanoyl)benzoate (3da)



(Table 2, entry 5) The title compound was prepared from methyl 3-formyl-4-hydroxybenzoate **1d** (0.2 mmol) and **2a** (0.3 mmol) according to Method B using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (19:1 hexanes:ethyl acetate) afforded the product as a clear oil (66.7 mg, 97%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.26 (d, *J* = 7.0 Hz, 3H), 1.82 (ddt, *J* = 14.1, 8.0, 6.3 Hz, 1H), 2.23 (dtd, *J* = 14.0, 7.7, 6.5 Hz, 1H), 2.87-3.04 (m, 2H), 3.77-3.87 (m, 1H), 3.93 (s, 3H), 7.02 (d, *J* = 8.8 Hz, 1H), 7.11-7.16 (m, 1H), 7.21-7.26 (m, 2H), 7.33-7.29 (m, 2H), 8.13 (dd, *J* = 8.8, 2.1 Hz, 1H), 8.53 (d, *J* = 2.1 Hz, 1H), 12.87 (s, 0.8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.3, 31.5, 32.8, 39.1, 52.3, 118.0, 119.1, 121.2, 126.2, 129.1, 129.3, 132.5, 135.9, 137.3, 166.0, 166.8, 209.9; IR (neat): 3063, 2951, 1718, 1638, 1584, 1482, 1438, 1359, 1309, 1274, 1228, 1111, 992, 967, 913, 807, 765, 740, 692 cm^{-1}; HRMS (ESI) Calcd. for $[C_{19}H_{21}O_4S]^+$ ($[M+H]^+$) 345.1155, found 345.1150. HPLC analysis: 92% ee (CHIRALCEL OD-H), 3:73 isopropanol:hexanes, 1.0 mL/min, 254.8 nm, t_{R1} = 11.4 min, t_{R2} = 13.7 min; $[\alpha]_D^{27}$ □ 15 (*c* = 1.0, $CHCl_3$).

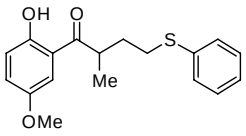
1-(2-hydroxy-5-methylphenyl)-2-methyl-4-(phenylthio)butan-1-one (3ea)



(Table 2, entry 6) The title compound was prepared from 2-hydroxy-5-methylbenzaldehyde **1e** (26.9 mg, 0.2 mmol) and **2a** (0.3 mmol) according to Method B using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (20:1 hexanes:ethyl acetate) afforded the product as a clear oil (53.4 mg, 90%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.24 (d, *J* = 6.9 Hz, 3H), 1.74-1.83 (m, 1H), 2.18-2.27 (m, 1H), 2.28 (s, 3H),

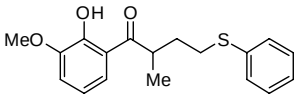
2.90-3.02 (m, 2H), 3.71-3.79 (m, 1H), 6.90 (d, J = 8.5 Hz, 1H), 7.14-7.18 (m, 1H), 7.24-7.33 (m, 5H), 7.53 (d, J = 1.6 Hz, 1H), 12.34 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.9, 20.7, 31.5, 32.9, 38.8, 118.3, 118.6, 126.2, 128.1, 129.1, 129.2, 129.7, 136.2, 137.7, 161.2, 209.7; IR (neat): 2924, 1637, 1612, 1585, 1482, 1439, 1289, 1245, 1211, 1025, 980, 788, 739, 691 cm^{-1}; HRMS (EI) Calcd. for $[C_{18}H_{20}O_2S]^+$ 300.1184, found 300.1181. HPLC analysis: 93% ee (CHIRALCEL OJ-H), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 16.8 min, t_{R2} = 23.3 min; $[\alpha]_D^{27}$ + 33 (c = 1.0, $CHCl_3$).

1-(2-hydroxy-5-methoxyphenyl)-2-methyl-4-(phenylthio)butan-1-one (3fa)



(Table 2, entry 7) The title compound was prepared from 2-hydroxy-5-methylbenzaldehyde **1f** (30.5 mg, 0.2 mmol) and **2a** (0.3 mmol) according to Method B using 0.01 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-SIPHOS-PE and 0.02 mmol (10 mol %) K_3PO_4. Purification via preparative TLC (16:1 hexanes:ethyl acetate) afforded the product as a clear yellow oil (59.2 mg, 93%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.25 (d, J = 6.9 Hz, 3H), 1.75-1.84 (m, 1H), 2.23 (dq, J = 14.1, 7.2 Hz, 1H), 2.90-3.04 (m, 2H), 3.76 (sextet, J = 6.9 Hz, 1H), 3.78 (s, 3H), 6.94 (d, J = 9.1 Hz, 1H), 7.12 (dd, J = 9.1, 3.0 Hz, 1H), 7.14-7.18 (m, 1H), 7.24-7.33 (m, 5H), 12.07 (s, 0.8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.7, 31.5, 32.9, 38.9, 56.1, 112.8, 118.1, 119.7, 124.4, 126.2, 129.1, 129.2, 136.1, 151.9, 157.7, 209.3; IR (neat): 2937, 1639, 1612, 1584, 1484, 1439, 1378, 1283, 1164, 1039, 984, 830, 791, 740, 691 cm^{-1}; HRMS (ESI) Calcd. for $[C_{18}H_{21}O_3S]^+$ ($[M+H]^+$) 317.1205, found 317.1198. HPLC analysis: 93% ee (CHIRALCEL OD-H), 5:95 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 8.1 min, t_{R2} = 9.0 min; $[\alpha]_D^{27}$ + 41 (c = 1.0, $CHCl_3$).

1-(2-hydroxy-3-methoxyphenyl)-2-methyl-4-(phenylthio)butan-1-one (3ga)

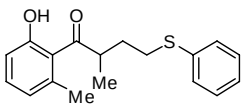


a) (Table 2, entry 8) The title compound was prepared from 2-hydroxy-3-methoxybenzaldehyde **1g** (30.6 mg, 0.2 mmol) and **2a** (0.3 mmol) according to Method B using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (10:1-8:1 hexanes:ethyl acetate) afforded the product as a clear yellow oil (58.1 mg, 91%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.24 (d, J = 6.9 Hz, 3H), 1.73-1.82 (m, 1H), 2.22 (dq, J = 14.3, 7.2 Hz, 1H), 2.91-3.02 (m, 2H), 3.71-3.79 (m, 1H), 3.91 (s, 3H), 6.80 (t, J = 8.1 Hz, 1H), 7.05 (d, J = 7.9,

1H), 7.14-7.19 (m, 1H), 7.24-7.36 (m, 5H), 12.78 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.7, 31.5, 32.7, 39.3, 56.3, 117.1, 118.3, 118.7, 121.2, 126.2, 129.1, 129.3, 136.0, 149.3, 153.7, 210.2; IR (neat): 2935, 1633, 1584, 1453, 1436, 1360, 1251, 1087, 1003, 783, 739, 691 cm^{-1}; HRMS (ESI) Calcd. for $[C_{18}H_{21}O_3S]^+$ ($[M+H]^+$) 317.1205, found 317.1198. HPLC analysis: 92% ee (CHIRALCEL OD-H), 5:95 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 14.1 min, t_{R2} = 18.0 min; $[\alpha]_D^{27}$ + 63 (*c* = 1.0, $CHCl_3$).

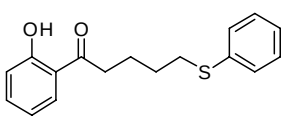
b) With 2 equiv. 2a (Table 2, entry 9) Using 30.5 mg (0.2 mmol) **1g.** Purification via preparative TLC (10:1-8:1 hexanes:ethyl acetate) afforded the product as a clear yellow oil (57.7 mg, 91%). HPLC analysis: 93% ee; $[\alpha]_D^{27}$ + 63 (*c* = 1.0, $CHCl_3$).

1-(2-hydroxy-6-methylphenyl)-2-methyl-4-(phenylthio)butan-1-one (3ha)



(Table 2, entry 10) The title compound was prepared from 6-methylsalicylaldehyde **1h** (0.2 mmol) and **2a** (0.3 mmol) according to Method B using 0.01 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-SIPHOS-PE, and 0.02 mmol (10 mol %) K_3PO_4 at 40 °C. Purification via preparative TLC (40:1 hexanes:ethyl acetate) afforded the product as a yellow oil (56.5 mg, 94%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.23 (d, 3H, *J* = 6.9Hz), 1.71-1.83 (m, 1H), 2.15-2.26 (m, 1H), 2.26 (s, 3H), 2.87-3.03 (m, 2H), 3.76 (sextet, *J* = 6.9Hz, 1H), 6.76 (t, *J* = 8.0 Hz, 1H), 7.13-7.19 (m, 1H), 7.23-7.29 (m, 2H), 7.29-7.35 (m, 3H), 7.60 (d, *J* = 7.8 Hz, 1H), 12.79 (s, 0.8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.7, 17.8, 31.5, 32.8, 38.9, 117.9, 118.4, 126.2, 127.6, 127.9, 129.1, 129.3, 136.1, 137.3, 161.8, 210.0; IR (neat): 2967, 2929, 1629, 1583, 1481, 1426, 1379, 1348, 1279, 1265, 1245, 1087, 1056, 1024, 987, 822, 740, 691 cm^{-1}; HRMS (ESI+) Calcd. for $[C_{18}H_{20}O_2NaS]^+$ ($[M+Na]^+$) 323.1076, found 323.1067. HPLC analysis: 84% ee (CHIRALCEL AD-H), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 7.3 min, t_{R2} = 8.2 min; $[\alpha]_D^{27}$ + 70 (*c* = 1.0, $CHCl_3$).

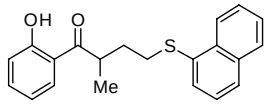
1-(2-hydroxyphenyl)-5-(phenylthio)pentan-1-one (4aa)



The title compound was isolated via a modification of Method A using salicylaldehyde **1a** (0.2 mmol), **2a** (0.3 mmol), 0.02 mmol (10 mol %) $[Rh(COD)Cl]_2$ and 0.04 mmol (0.2 equiv.) K_3PO_4. After heating at 40°C for 96 h, **4aa** was isolated via preparative TLC (25:1-35:1 hexanes:ethyl acetate) as a white solid

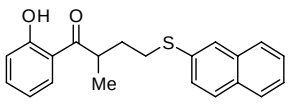
(< 10% isolated yield 2.7:1 selectivity **3aa**:**4aa**); mp 59-60 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.71-1.79 (m, 2H), 1.87-1.94 (m, 2H), 2.98 (t, *J* = 7.1 Hz, 2H), 3.01 (t, *J* = 7.2 Hz, 2H), 6.89 (ddd, *J* = 8.2, 7.3, 1.1 Hz, 1H), 6.98 (dd, *J* = 8.4, 1.1 Hz, 1H), 7.16-7.20 (m, 1H), 7.26-7.30 (m, 2H), 7.33-7.35 (m, 2H), 7.46 (ddd, *J* = 8.6, 7.2, 1.1 Hz, 1H), 7.74 (dd, *J* = 8.1, 1.7 Hz, 1H), 12.31 (s, 0.9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.5, 28.8, 33.6, 37.8, 118.7, 119.0, 119.4, 126.1, 129.0, 129.4, 130.0, 136.46, 136.53, 162.6, 206.2; IR (film): 2930, 1638, 1614, 1582, 1482, 1446, 1353, 1286, 1262, 1206, 1156, 1091, 1025, 977, 754, 691 cm^{-1}; HRMS (ESI) Calcd. for $[C_{17}H_{19}O_2S]^+$ ($[M+H]^+$) 287.1100, found 287.1087.

1-(2-hydroxyphenyl)-2-methyl-4-(naphthalen-1-ylthio)butan-1-one (3ab)



(Table 3, entry 1) The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **2b** (0.3 mmol) according to Method A using 0.01 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-SIPHOS-PE and 0.02 mmol (10 mol %) K_3PO_4. Purification via preparative TLC (30:1-24:1 hexanes:ethyl acetate) afforded the product as a clear yellow oil (49.6 mg, 74%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.23 (d, *J* = 6.9 Hz, 3H), 1.75-1.84 (m, 1H), 2.24 (dq, *J* = 14.1, 7.2, 1H), 2.99-3.10 (m, 2H), 3.78 (sextet, *J* = 6.9 Hz, 1H), 6.76 (ddd, *J* = 8.2, 7.2, 8.2, 1H), 6.98 (dd, *J* = 8.4, 1.1 Hz, 1H), 7.39 (dd, *J* = 7.3, 8.1 Hz, 1H), 7.44 (ddd, *J* = 8.6, 7.3, 1.6, 1H), 7.50-7.57 (m, 3H), 7.68 (dd, *J* = 8.1, 2.5 Hz, 1H), 7.72 (d, *J* = 8.2 Hz, 1H), 7.85 (dd, *J* = 7.2, 2.2 Hz, 1H), 8.38-8.41 (m, 1H), 12.46 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.8, 32.1, 32.7, 38.9, 118.6, 118.8, 119.0, 125.0, 125.7, 126.4, 126.6, 127.5, 128.3, 128.8, 130.0, 133.06, 133.12, 134.1, 136.5, 163.3, 209.8; IR (neat): 2968, 1634, 1581, 1564, 1486, 1445, 1382, 1349, 1288, 1241, 1205, 1155, 975, 790, 770 cm^{-1}; HRMS (EI) Calcd. for $[C_{21}H_{20}O_2S]^+$ 336.1184, found 336.1175. HPLC analysis: 95% ee (CHIRALPAK IB), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 9.8 min, t_{R2} = 10.8 min; $[\alpha]_D^{27}$ + 102 (*c* = 0.5, $CHCl_3$).

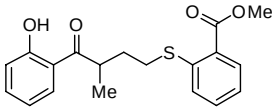
1-(2-hydroxyphenyl)-2-methyl-4-(naphthalen-2-ylthio)butan-1-one (3ac)



(Table 3, entry 2) The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **2c** (0.3 mmol) according to Method A using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (16:1 hexanes:ethyl acetate)

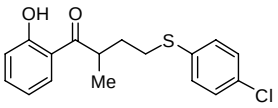
afforded the product as a clear oil (64.8 mg, 96%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.26 (d, *J* = 6.9 Hz, 3H), 1.79-1.87 (m, 1H), 2.28 (dq, *J* = 14.2, 7.2 Hz, 1H), 3.01-3.13 (m, 2H), 3.80 (sextet, *J* = 6.9 Hz, 1H), 6.75 (ddd, *J* = 8.2, 7.3, 1.1 Hz, 1H), 6.97 (dd, *J* = 8.4, 1.0 Hz, 1H), 7.38-7.49 (m, 4H), 7.70-7.78 (m, 5H), 12.46 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.8, 31.3, 32.7, 38.9, 118.5, 118.8, 119.0, 125.8, 126.7, 127.1, 127.2, 127.3, 127.8, 128.6, 129.9, 131.9, 133.5, 133.9, 136.5, 163.3, 209.8; IR (neat): 2970, 1634, 1581, 1487, 1445, 1380, 1349, 1267, 1241, 1207, 1155, 1133, 1071, 975, 943, 852, 812, 755 cm^{-1}; HRMS (EI) Calcd. for $[C_{21}H_{20}O_2S]^+$ 336.1184, found 336.1176. HPLC analysis: 92% ee (CHIRALPAK IA), 1:99 isopropanol:hexanes, 0.5 mL/min, 254 nm, t_{R1} = 28.0 min, t_{R2} = 31.3 min; $[\alpha]_D^{27}$ + 58 (*c* = 0.5, $CHCl_3$).

methyl 2-((4-(2-hydroxyphenyl)-3-methyl-4-oxobutyl)thio)benzoate (3ad)



(Table 3, entry 3) The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **2d** (0.3 mmol) according to Method A using 0.010 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-SIPHOS-PE and 0.02 mmol (10 mol %) K_3PO_4. Purification via preparative TLC (6:1-8:1 hexanes:ethyl acetate) afforded the product as a clear oil (63.1 mg, 92%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.27 (d, *J* = 6.9 Hz, 3H), 1.86 (ddt, *J* = 14.1, 8.0, 6.3, 1H), 2.33 (dtd, *J* = 14.2, 7.8, 6.7 Hz, 1H), 2.87-3.03 (m, 2H), 3.75-3.82 (m, 1H), 3.90 (s, 3H), 6.86 (ddd, *J* = 8.2, 7.2, 1.2, 1H), 6.98 (dd, *J* = 8.4, 1.0 Hz, 1H), 7.14 (dd, *J* = 8.4, 7.7, 1.1 Hz, 1H), 7.29 (dd, *J* = 8.1, 0.7 Hz, 1H), 7.39-7.45 (m, 2H), 7.77 (dd, *J* = 8.1, 1.6 Hz, 1H), 7.94 (dd, *J* = 7.8, 1.5 Hz, 1H), 12.45 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.1, 29.8, 31.7, 39.3, 52.2, 118.5, 118.8, 119.1, 124.1, 125.8, 128.0, 130.0, 131.4, 132.5, 136.6, 141.1, 163.3, 167.0, 209.7; IR (neat): 2949, 1713, 1634, 1586, 1487, 1445, 1378, 1350, 1272, 1248, 1209, 1144, 1108, 1062, 975, 825, 744, 694 cm^{-1}; HRMS (EI) Calcd. for $[C_{19}H_{20}O_4S]^+$ 344.1082, found 344.1086. HPLC analysis: 97% ee (CHIRALPAK IC), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 26.1 min, t_{R2} = 30.5 min; $[\alpha]_D^{27}$ + 80 (*c* = 1.0, $CHCl_3$).

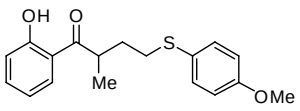
4-((4-chlorophenyl)thio)-1-(2-hydroxyphenyl)-2-methylbutan-1-one (3ae)



(Table 3, entry 4) The title compound was prepared from salicylaldehyde (0.2 mmol) and **2e** (0.3 mmol) according to Method A using 0.01 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-SIPHOS-PE and 0.02 mmol (10 mol %) K_3PO_4. Purification via preparative TLC (40:1 hexanes:ethyl acetate) afforded the product as a

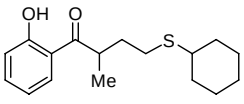
yellow oil (63.5 mg, 99%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.25 (d, *J* = 6.9Hz, 3H), 1.72-1.81 (m, 1H), 2.17-2.26 (m, 1H), 2.86-2.99 (m, 2H), 3.68-3.77 (m, 1H), 6.86 (ddd, *J* = 8.2, 7.2, 1.2 Hz 1H), 6.99 (dd, *J* = 8.4, 1.1 Hz, 1H), 7.22 (s, 4H), 7.47 (ddd, *J* = 8.6, 7.2, 1.6 Hz, 1H), 7.72 (dd, *J* 8.1, 1.6 Hz, 1H,), 12.43 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.0, 31.8, 32.6, 38.9, 118.5, 119.0, 119.1, 129.2, 129.9, 130.6, 132.2, 134.6, 136.7, 163.3, 209.6; IR (neat): 2967, 2932, 2876, 1635, 1611, 1579, 1476, 1446, 1381, 1348, 1290, 1241, 1208, 1155, 1095, 1011, 975, 815, 758. HRMS (EI) Calcd. for $[C_{17}H_{17}O_2SCl]^+$ 320.0638, found 320.0632. HPLC analysis: 93% ee (CHIRALCEL OD-H), 1:99 isopropanol:hexanes, 0.5 mL/min, 254 nm, t_{R1} = 24.8 min, t_{R2} = 28.6 min; $[\alpha]_D^{27}$ + 55 (*c* = 1.0, $CHCl_3$).

1-(2-hydroxyphenyl)-4-((4-methoxyphenyl)thio)-2-methylbutan-1-one (3af)



(Table 3, entry 5) The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **2f** (0.3 mmol) according to Method A using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (16:1 hexanes:ethyl acetate) afforded the product as a yellow oil (56.7 mg, 90%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.22 (d, *J* = 6.9 Hz, 3H), 1.67-1.77 (m, 1H), 2.15 (dq, *J* = 14.1, 7.1 Hz, 1H), 2.81-2.92 (m, 2H), 3.71-3.78 (m, 4H), 6.82 (d, *J* = 8.9, 2H), 6.87 (ddd, *J* = 8.3, 7.2, 1.2 Hz, 1H), 6.98 (dd, *J* = 8.4, 1.0 Hz, 1H), 7.32 (d, *J* = 8.9, 2H), 7.46 (ddd, *J* = 8.5, 7.2, 1.6 Hz, 1H), 7.75 (dd, *J* = 8.1, 1.6 Hz, 1H), 12.47 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.7, 33.0, 33.6, 38.8, 55.4, 114.8, 118.6, 118.8, 119.0, 126.0, 130.0, 133.2, 136.5, 159.1, 163.3, 209.9; IR (neat): 2934, 1634, 1592, 1498, 1445, 1376, 1349, 1284, 1243, 1208, 1180, 1155, 1105, 1033, 975, 826, 756, 700 cm^{-1}; HRMS (ESI) Calcd. for $[C_{18}H_{21}O_3S]^+$ ($[M+H]^+$) 317.1205, found 317.1206. HPLC analysis: 87% ee (CHIRALCEL OD-H), 10:90 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 13.0 min, t_{R2} = 14.4 min; $[\alpha]_D^{27}$ + 45 (*c* = 1.0, $CHCl_3$).

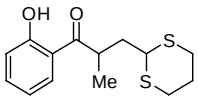
4-(cyclohexylthio)-1-(2-hydroxyphenyl)-2-methylbutan-1-one (3ag)



(Table 3, entry 6) The title compound was prepared from salicylaldehyde (0.2 mmol) and **2g** (0.3 mmol) according to Method A using 0.010 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-SIPHOS-PE, and 0.02 mmol (10 mol %) K_3PO_4. Purification via preparative TLC (40:1 hexanes:ethyl acetate) afforded the product as a

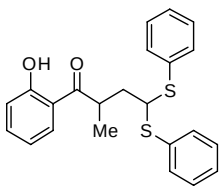
yellow oil (58.0 mg, 99%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.20-1.35 (m, 8H), 1.57-1.65 (m, 1H), 1.65-1.82 (m, 3H), 1.86-2.00 (m, 2H), 2.14 (dq, *J* = 14.3, 7.2 Hz, 1H), 2.48-2.64 (m, 3H), 3.75 (sextet, *J* = 6.8 Hz, 1H), 6.88-6.95 (m, 1H), 7.00 (dd, *J* = 0.9Hz, *J* = 8.4Hz, 1H), 7.44-7.51 (m, 1H), 7.86 (dd, *J* = 8.1, 1.4 Hz, 1H), 12.51 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.6, 26.0, 26.21, 26.24, 27.9, 33.66, 33.76, 33.82, 39.0, 43.6, 118.7, 118.9, 119.0, 130.1, 136.5, 163.3, 210.2; IR (neat): 2928, 2851, 1635, 1611, 1581, 1487, 1446, 1375, 1349, 1285, 1241, 1206, 1154, 975, 756. HRMS (ESI+) Calcd. for $[C_{17}H_{25}O_2S]^+$ 293.1569, found 293.1557. HPLC analysis: 55% ee (CHIRALCEL OJ-H), 1:99 isopropanol:hexanes, 0.5 mL/min, 254 nm, t_{R1} = 10.6 min, t_{R2} = 11.6 min; $[\alpha]_D^{27}$ + 36 (*c* = 1.0, $CHCl_3$).

3-(1,3-dithian-2-yl)-1-(2-hydroxyphenyl)-2-methylpropan-1-one (3ah)



(Table 3, entry 7) The title compound was prepared from salicylaldehyde **1a** (0.1 mmol) and **2h** (0.15 mmol) according to Method A using 0.005 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (10 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (10 mol %) K_3PO_4. Purification via preparative TLC (3% ethyl acetate in hexanes) afforded the product as a colorless oil (23.7 mg, 84%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.26 (d, *J* = 7.0 Hz, 3H), 1.81-1.92 (m, 2H), 2.05-2.13 (m, 1H), 2.42 (ddd, *J* = 14.3, 7.8, 7.2 Hz, 1H), 2.77-2.85 (m, 4H), 3.86-3.85 (m, 1H), 4.01 (t, *J* = 7.5 Hz, 1H), 6.92 (ddd, *J* = 8.4, 7.4, 1.1 Hz, 1H), 6.99 (dd, *J* = 8.4, 0.8 Hz, 1H), 7.48 (ddd, *J* = 8.6, 7.4, 1.5 Hz, 1H), 7.85 (dd, *J* = 8.1, 1.5 Hz, 1H), 12.41 (s, 0.7H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.6, 26.0, 30.1, 30.2, 37.4, 38.6, 45.2, 118.5, 118.8, 119.2, 130.1, 136.6, 163.3, 209.2; IR (neat): 2898, 1634, 1580, 1487, 1446, 1376, 1348, 1276, 1243, 1207, 1158, 1035, 974, 908, 862, 828, 756, 733, 700 cm^{-1}; HRMS (EI) Calcd. for $[C_{14}H_{18}O_2S_2]^+$ 282.0748, found 282.0752. HPLC analysis: 36% ee (CHIRALPAK IA), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 11.5 min, t_{R2}= 17.1 min; $[\alpha]_D^{25}$ +23 (*c* = 0.89, $CHCl_3$).

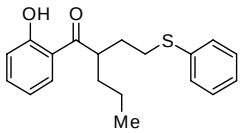
1-(2-hydroxyphenyl)-2-methyl-4,4-bis(phenylthio)butan-1-one (3ai)



(Table 3, entry 8) The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **2i** (0.3 mmol) according to Method A using 0.005 mmol (2.5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (5 mol %) (*R*)-SIPHOS-PE and 0.01 mmol (5 mol %) K_3PO_4. Purification via preparative TLC (3% ethyl acetate

in hexanes) afforded the product as a pale yellow oil (74.7 mg, 95%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.19 (d, *J* = 7.0 Hz, 3H), 1.92 (ddd, *J* = 14.2, 8.3, 5.7 Hz, 1H), 2.51 (ddd, *J* = 14.5, 7.9, 6.6 Hz, 1H), 3.99-4.08 (m, 1H), 4.38 (dd, *J* = 8.3, 6.6 Hz, 1H), 6.86 (ddd, *J* = 8.2, 7.2, 1.2 Hz, 1H), 6.97 (dd, *J* = 8.5, 1.2 Hz, 1H), 7.21-7.36 (m, 8H), 7.43-7.48 (m, 3H), 7.79 (dd, *J* = 8.1, 1.6 Hz, 1H), 12.36 (s, 0.8H); ^{13}C NMR (100 MHz $CDCl_3$) δ 18.4, 38.3, 39.6, 56.5, 118.6, 118.8, 119.2, 127.9, 128.1, 129.1, 129.1, 130.1, 132.5, 133.0, 133.5, 134.0, 136.7, 163.3, 209.3; IR (neat): 2970, 1634, 1581, 1482, 1439, 1379, 1348, 1295, 1240, 1208, 1157, 1111, 1067, 1025, 973, 908, 827, 751, 691 cm^{-1}; HRMS (EI) Calcd. for $[C_{23}H_{22}O_2S_2]^+$ 394.1061, found 394.1057. HPLC analysis: 95% ee (CHIRALCEL OJ-H), 10:90 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 15.1 min, t_{R2}= 23.4 min; $[\alpha]_D^{26}$ □ 2 (*c* = 1.0, $CHCl_3$).

1-(2-hydroxyphenyl)-2-(2-(phenylthio)ethyl)pentan-1-one (7)

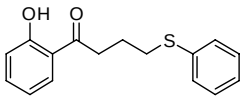


With (*E*)-olefin 5: The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **5** (0.3 mmol) according to Method A using 0.01 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-SIPHOS-PE, 0.04 mmol (0.2 equiv) K_3PO_4 and heating at 40 °C. Purification via preparative TLC (16:1 hexanes:ethyl acetate) afforded the product as a clear oil (44.8 mg, 71%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, *J* = 7.3 Hz, 3H), 1.26-1.33 (m, 2H), 1.44-1.54 (m, 1H), 1.71-1.87 (m, 2H), 2.19 (dtd, *J* = 14.1, 7.9, 6.2 Hz, 1H), 2.80-2.87 (m, 1H), 2.97 (ddd, *J* = 13.7, 7.8, 6.1 Hz, 1H), 3.69-3.76 (m, 1H), 6.86-6.90 (m, 1H), 6.99 (dd, *J* = 8.4, 0.9, 1H), 7.14-7.18 (m, 1H), 7.24-7.31 (m, 4H), 7.48 (ddd, *J* = 8.5, 7.4, 1.6 Hz, 1H), 7.80 (dd, *J* = 8.1, 1.5 Hz, 1H), 12.59 (s, 0.8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.3, 20.7, 31.3, 31.7, 34.9, 44.0, 118.8, 119.1, 119.5, 126.2, 129.1, 129.3, 130.1, 136.0, 136.7, 163.2, 210.0; COSY (see below); IR (neat): 3063, 2957, 2927, 2871, 1633, 1581, 1483, 1444, 1383, 1348, 1292, 1241, 1203, 1155, 1025, 807, 739, 691 cm^{-1} cm^{-1}; HRMS (EI) Calcd. for $[C_{19}H_{22}O_2S]^+$ 314.1341, found 314.1339. HPLC analysis: 90% ee (CHIRALCEL OD-H), 1:99 isopropanol:hexanes, 1.0 mL/min, 254 nm, t_{R1} = 7.5 min, t_{R2} = 8.2 min; $[\alpha]_D^{27}$ + 52 (*c* = 1.0, $CHCl_3$).

With (*Z*)-olefin 6: Purification via preparative TLC (hexanes:ethyl acetate) afforded the product as a clear yellow oil (52.7 mg, 84%). HPLC analysis: 90% ee (CHIRALCEL OD-H), 1:99 isopropanol:hexanes, 0.5 mL/min, 254 nm, t_{R1} = 7.5 min, t_{R2} = 8.2 min; $[\alpha]_D^{27}$ + 53 (*c* = 1.0, $CHCl_3$).

As noted in the manuscript, both (*E*)-olefin **5** and (*Z*)-olefin **6** underwent hydroacylation to give the same enantiomer of **7.** The hydroacylation also proceeds with the nearly same ee (within detection limits), which was reported as 90 % for both entries. Based on our current data, we can provide two reasonable preliminary rationales for this outcome: (1) The relative disposition of the substituents (ie. (*E*) or (*Z*)) on the olefin does not significantly affect the enantioselective outcome. In this scenario, the catalyst is nearly equally selective for installing the acyl unit at the olefin carbon closest to the sulfur, with the observed sense of enantioinduction, regardless of whether the ethyl substituent on the other carbon of the olefin is *cis* or *trans*. (2) The rate of hydroacylation of one of the olefin stereoisomers is much faster than the other. In this case, a (*E*)/(*Z*) isomerization that is fast compared to hydroacylation of the less reactive isomer would also have to take place. This would likely occur via a rapid and reversible olefin insertion step, which would scramble the original olefin geometry. The more reactive isomer would undergo hydroacylation and the same enantioselectivity would be observed, regardless of the initial stereochemistry of the olefin.

1-(2-hydroxyphenyl)-4-(phenylthio)butan-1-one (9)



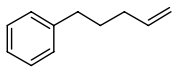
With (*R*)-MonoPhos: The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **8** (0.3 mmol) according to Method A using 0.01 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02 mmol (10 mol %) (*R*)-MonoPhos, and 0.04 mmol (0.2 equiv) K_3PO_4 at 40 °C. Purification via preparative TLC (30:1 hexanes:ethyl acetate) afforded the product as an oil (41.6 mg, 76%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.10 (quintet, *J* = 7.0 Hz, 2H), 3.05 (t, *J* = 6.9 Hz, 2H), 3.18 (t, *J* = 7.1 Hz, 2H), 6.88 (ddd, *J* = 8.4, 7.3, 1.1, 1H), 6.98 (dd, *J* = 8.4, 1.1, 1H), 7.16-7.21 (m, 1H), 7.27-7.31 (m, 2H), 7.35-7.38 (m, 2H), 7.46 (ddd, *J* = 8.6, 7.3, 1.6, 1H), 7.73 (dd, *J* = 8.1, 1.6, 1H), 12.59 (s, 0.9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 23.5, 33.3, 36.8, 118.7, 119.1, 119.4, 126.3, 129.1, 129.5, 130.0, 136.0, 136.5, 162.6, 205.8; IR (neat): 2920, 1637, 1614, 1581, 1482, 1446, 1352, 1294, 1271, 1239, 1209, 1157, 1089, 1025, 982, 754, 691 cm^{-1}; HRMS (EI) Calcd. for $[C_{16}H_{16}O_2S]^+$ 272.0871, found 272.0868.

With (*R*)-SIPHOS-PE: The title compound was prepared from salicylaldehyde **1a** (0.2 mmol) and **8** (0.3 mmol) according to Method A using 0.01 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.02

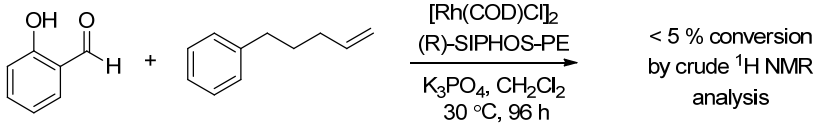
mmol (10 mol %) (*R*)-SIPHOS-PE, and 0.04 mmol (0.2 equiv) K_3PO_4 at 40 °C. Purification via preparative TLC (30:1 hexanes:ethyl acetate) afforded the product as an oil (42.1 mg, 77%)

Intermolecular hydroacylation with analogue of* 2a *lacking sulfur atom:

pent-4-en-1-ylbenzene



To a flame dried flask equipped with a stirbar and magnesium turnings (533 mg, 22 mmol) under argon, was added 50 mL dry tetrahydrofuran. The mixture was cooled to 0 °C and (2-bromoethyl)benzene (3.70g, 20 mmol) was added dropwise via syringe, followed by heating at reflux for 1 h. The reaction was cooled to rt and allyl bromide (2.90g, 24 mmol) was added dropwise via syringe, followed by heating at reflux for 2 h. The crude reaction mixture was then quenched with sat. NH_4Cl and extracted with diethyl ether. The organics were washed with brine, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The desired product was isolated via flash chromatography (hexanes) as a clear oil (1.52 g, 52%). NMR analysis was consistent with literature values .[8] ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.63-1.77 (m, 2H), 2.00-2.13 (m, 2H), 2.60 (t, *J* = 7.7 Hz, 2H), 4.84-5.13 (m, 2H), 5.81 (ddt, *J* = 16.9, 10.2, 6.6 Hz, 1H), 7.08-7.30 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 30.8, 33.4, 35.5, 114.8, 125.8, 128.4, 128.6, 138.8, 142.6.



1a

The above reaction was carried out with salicylaldehyde **1a** (0.1 mmol) and **pent-4-en-1-ylbenzene** (0.15 mmol, 1.5 equiv.) according to Method A using 0.005 mmol (5 mol %) $[Rh(COD)Cl]_2$, 0.01 mmol (10 mol %) (*R*)-SIPHOS-PE and 0.02 mmol (0.2 equiv.) K_3PO_4.

Preparation of racemic samples:

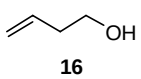
Racemic samples of **3aa-3ha**, **3ab-3ai** and **7** were prepared via modifications of conditions developed by Suemune.[9] General procedure: 0.005 mmol (5 mol %) $Rh(PPh_3)_3Cl$ was

[8] Movassaghi, M.; Ahmad, O. K. *Angew. Chem., Int. Ed.* **2008**, *47*, 8909.
[9] Imai, M.; Tanaka, M.; Tanaka, K.; Yamamoto, Y.; Imai-Ogata, N.; Shimowatari, M.; Nagumo, S.; Kawahara, N.; Suemune, H. *J. Org. Chem.* **2004,** *69*, 1144.

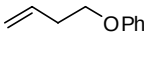
dissolved in 400 μL degassed dichloromethane and 40 μL ethanol. The solution was transferred to a vial containing 0.005 mmol (5 mol %) $AgClO_4$ and the mixture was stirred for 15 minutes, then transferred to a vial containing 0.02 mmol (0.2 eq) NaOAc. 0.15 mmol (1.5 equiv) of the corresponding olefin was dissolved in 400 μL degassed dichloromethane and transferred to the reaction mixture. 0.1 mmol (1.0 equiv) of the salicylaldehyde derivative was added via syringe or in solution with the olefin. The reaction was stirred at ambient glovebox temperature (30 °C) or 40 °C [at the same temperature as the corresponding enantioselective reaction using (*R*)-SIPHOS-PE was performed] until complete conversion or no further reaction was observed by GC/MS analysis. The crude reaction mixture was purified via thin layer chromatography in hexanes/ethyl acetate.

Preliminary comparison of reactivities of heteroatom-based directing groups in intermolecular hydroacylation:

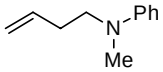
Reactions with $Rh(PPh_3)_3Cl$ were performed according to the general procedure outlined for the preparation of racemic samples, above. Entry 3 was performed according to *General Procedure A* (see page S 12).



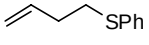
16



17



18

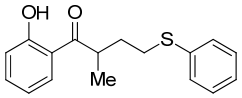


2a

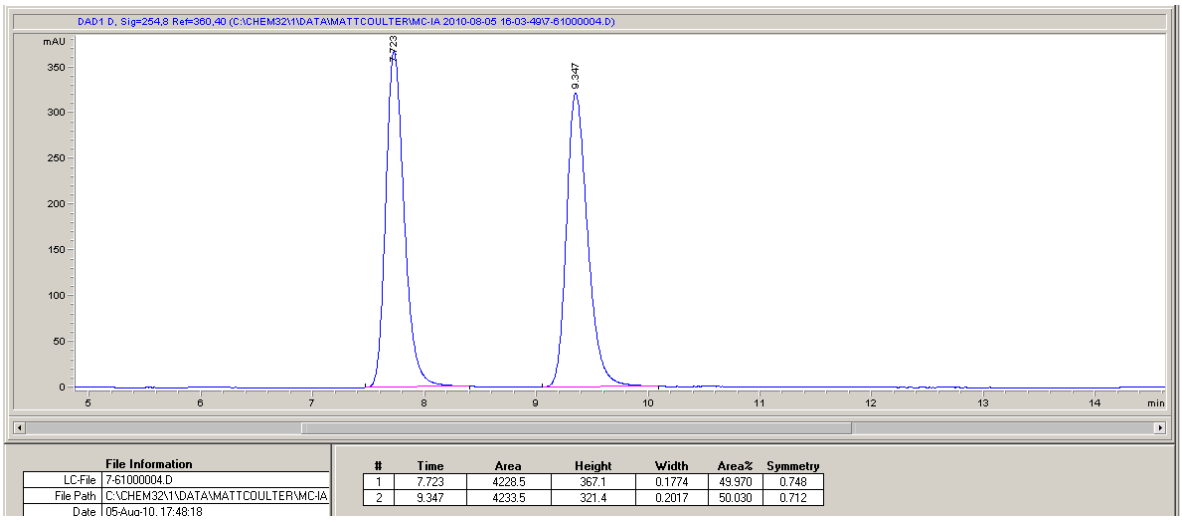
Entry	Catalyst	Olefin	Time	Conversion[b]
1	$Rh(PPh_3)_3Cl$	**16**	3 d	none
2[c]	$Rh(PPh_3)_3Cl$	**17**	2 d	none
3[d]	$[Rh(COD)Cl]_2$/ (*R*)-MonoPhos	**17**	3d	trace
4[e]	$Rh(PPh_3)_3Cl$	**18**	4 d	trace
5	$Rh(PPh_3)_3Cl$	**2a**	4 h	>95 % (17:1 selectivity for **3aa**:**4aa**) [f]

Table 2. [a] Conditions: salicylaldehyde **1a** (1.0 equiv), olefin (1.5 equiv), $Rh(PPh_3)_3Cl$ (5 mol %), $AgClO_4$ (5 mol %), NaOAc (0.2 equiv.), CH_2Cl_2/EtOH, 30 °C. [b] Determined via ^1H NMR or LC/MS analysis. [c] Using 1.0 equiv. of **17**. [d] Conditions: salicylaldehyde **1a** (1.0 equiv), olefin **17** (1.5 equiv), $[Rh(COD)Cl]_2$ (5 mol %), (*R*)-MonoPhos (10 mol %), K_3PO_4 (10 mol %), CH_2Cl_2, 30 °C. [e] Using PhMe/EtOH at 100 °C. [f] Determined via ^1H NMR analysis of crude reaction mixture.

4. Determination of Enantiomeric Excesses: HPLC Analyses

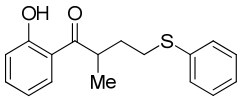


(±)-3aa



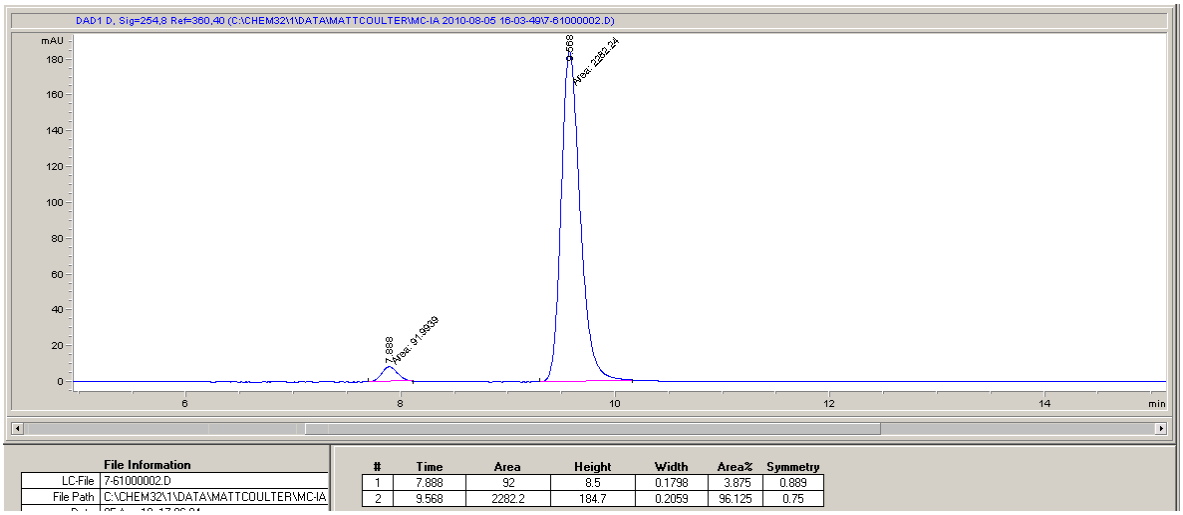
File Information	
LC-File	7-61000004.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-IA
Date	05-Aug-10, 17:48:18

#	Time	Area	Height	Width	Area%	Symmetry
1	7.723	4228.5	367.1	0.1774	49.970	0.748
2	9.347	4233.5	321.4	0.2017	50.030	0.712



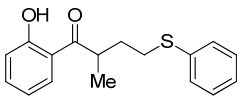
(+)-3aa

(Table 1, entry 1)



File Information	
LC-File	7-61000002.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-IA

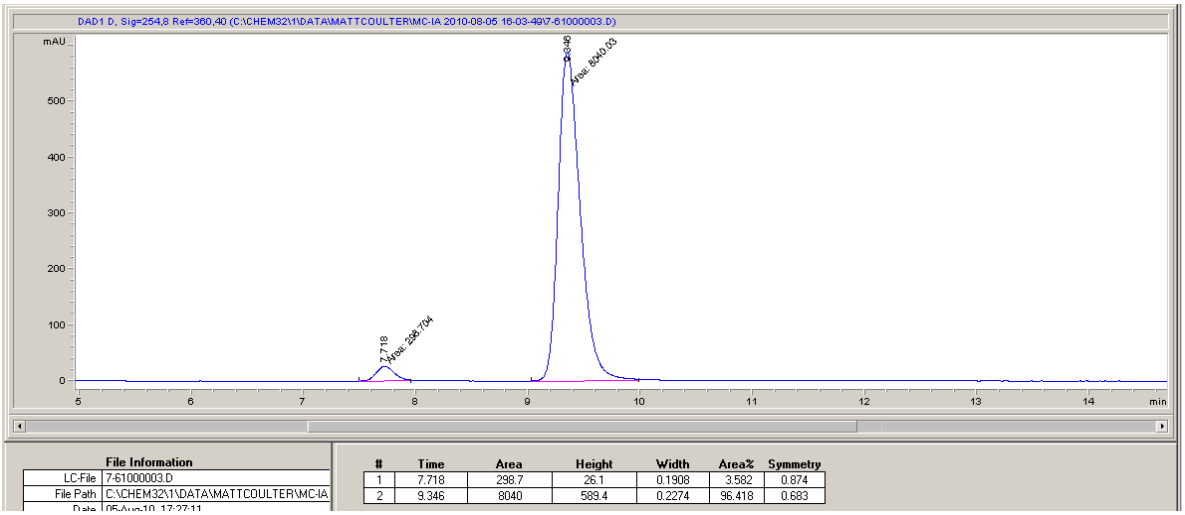
#	Time	Area	Height	Width	Area%	Symmetry
1	7.888	92	8.5	0.1798	3.875	0.889
2	9.568	2282.2	184.7	0.2059	96.125	0.75



(+)-3aa

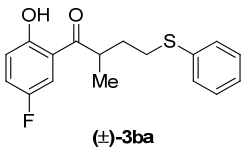
With 5 mol % $AgClO_4$

(Table 1, entry 2)

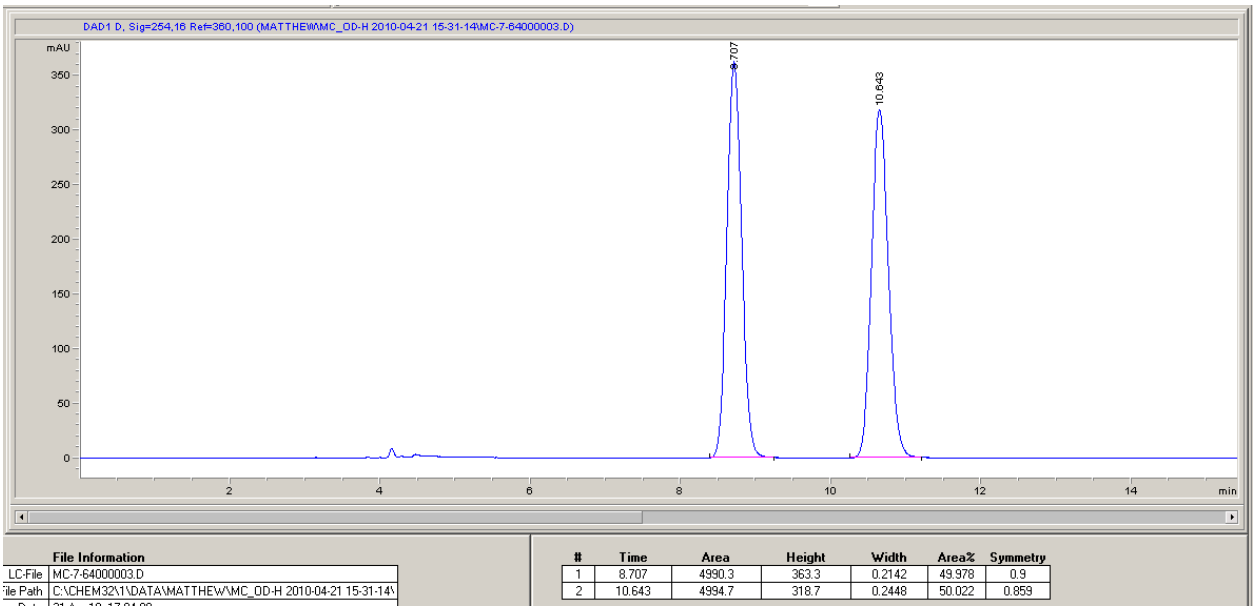


File Information	
LC-File	7-61000003.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-IA
Date	05-Aug-10, 17:27:11

#	Time	Area	Height	Width	Area%	Symmetry
1	7.718	298.7	26.1	0.1908	3.582	0.874
2	9.346	8040	589.4	0.2274	96.418	0.683

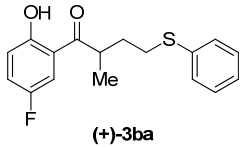


(±)-3ba

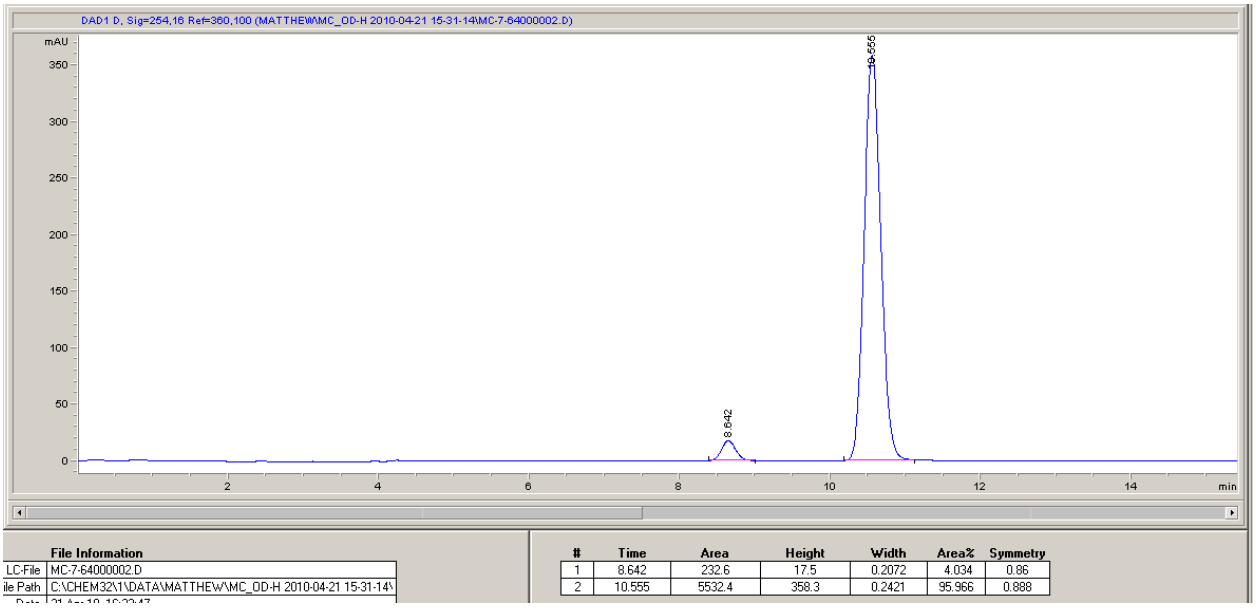


File Information	
LC-File	MC-7-64000003.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-04-21 15-31-14\

#	Time	Area	Height	Width	Area%	Symmetry
1	8.707	4990.3	363.3	0.2142	49.978	0.9
2	10.643	4994.7	318.7	0.2448	50.022	0.859

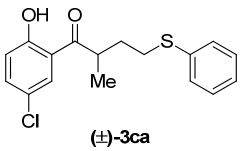


(+)-3ba

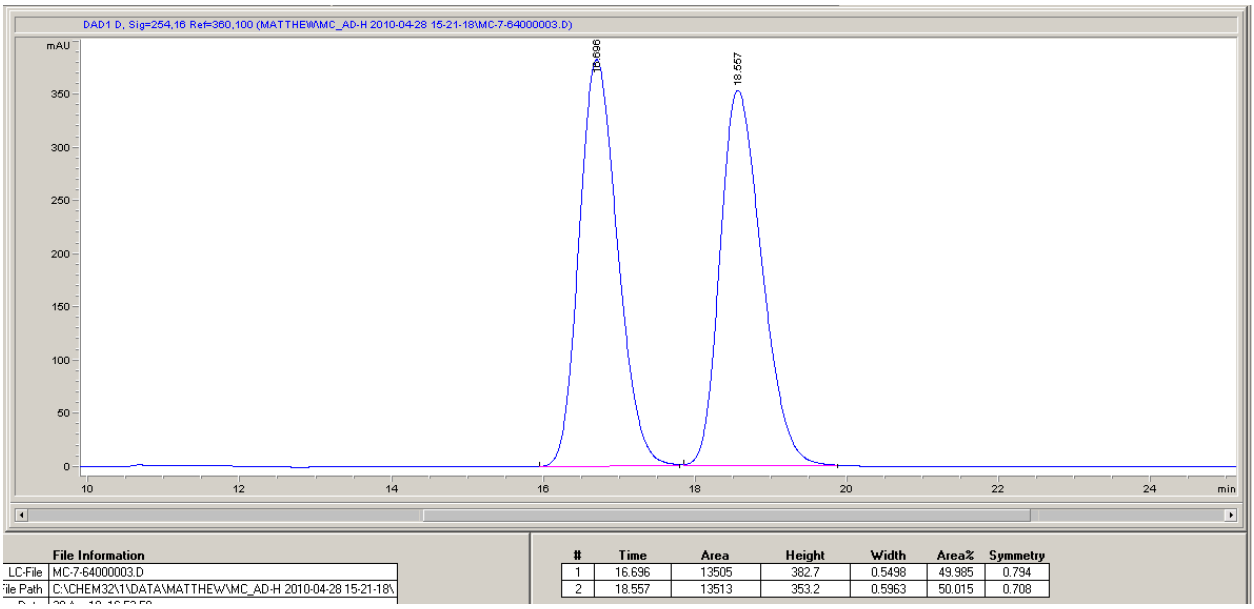


File Information	
LC-File	MC-7-64000002.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-04-21 15-31-14\

#	Time	Area	Height	Width	Area%	Symmetry
1	8.642	232.6	17.5	0.2072	4.034	0.86
2	10.555	5532.4	358.3	0.2421	95.966	0.888

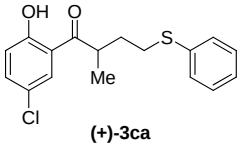


(±)-3ca

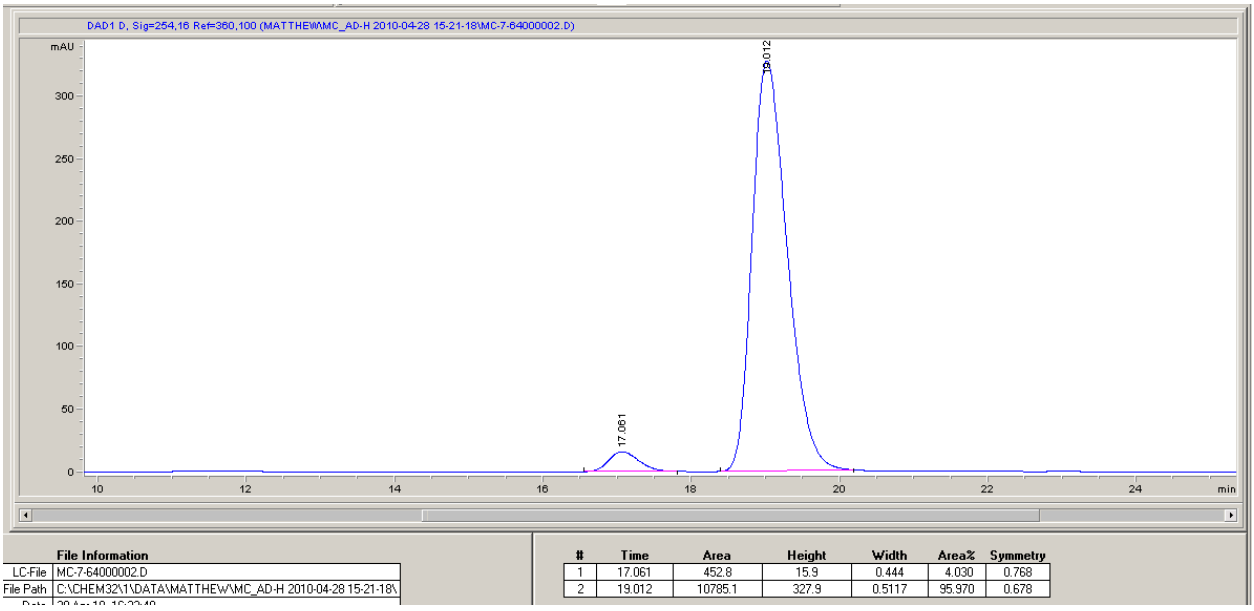


File Information	
LC-File	MC-7-64000003.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_AD-H 2010-04-28 15-21-18\

#	Time	Area	Height	Width	Area%	Symmetry
1	16.696	13505	382.7	0.5498	49.985	0.794
2	18.557	13513	353.2	0.5963	50.015	0.708



(+)-3ca



File Information	
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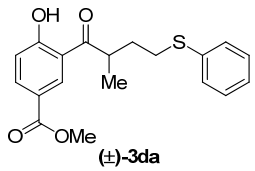
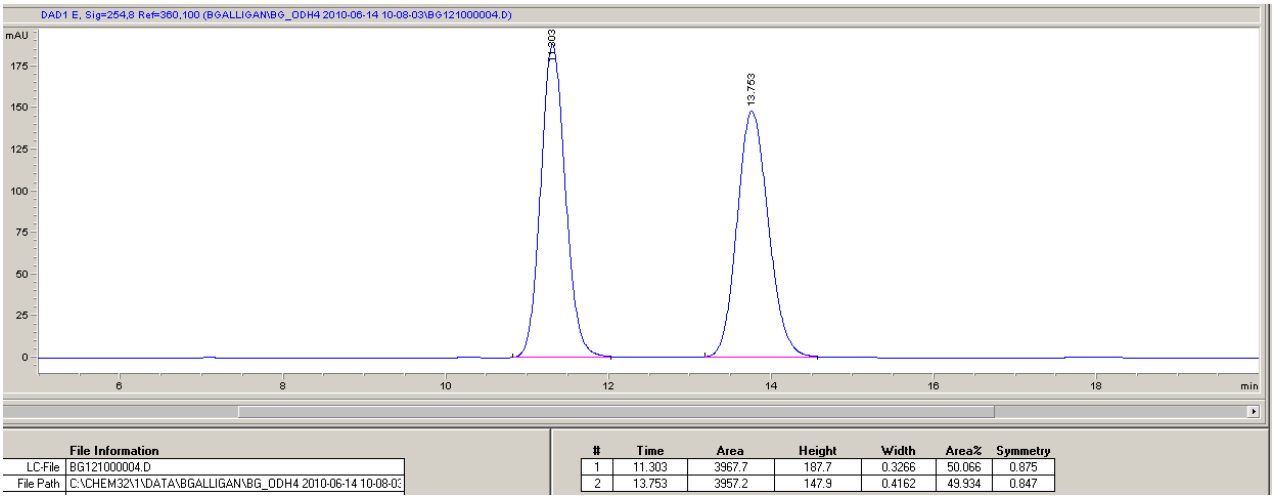
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_AD-H 2010-04-28 15-21-18\

#	Time	Area	Height	Width	Area%	Symmetry
1	17.061	452.8	15.9	0.444	4.030	0.768
2	19.012	10785.1	327.9	0.5117	95.970	0.678



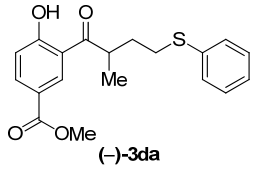
(±)-3da



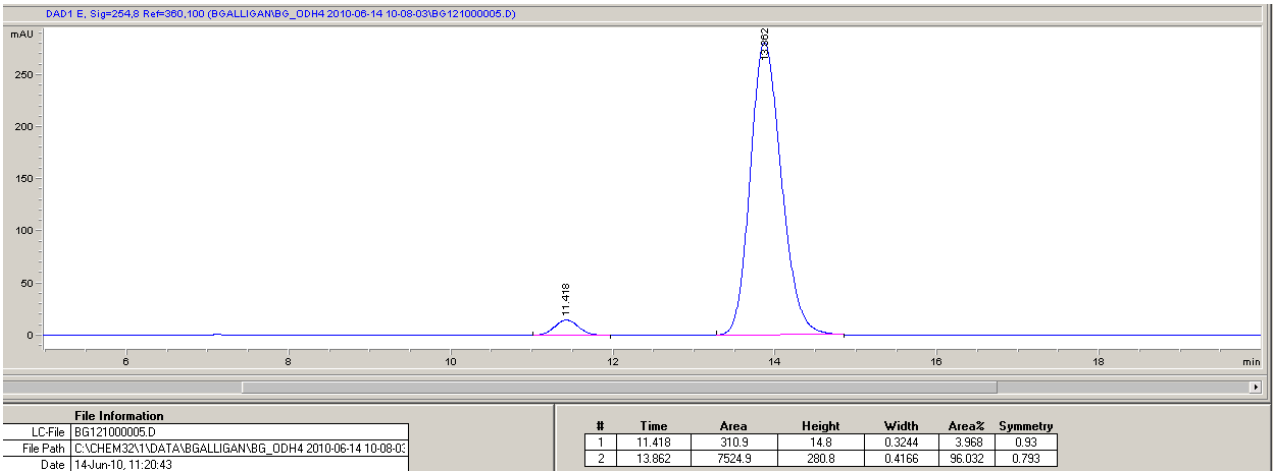
File Information

LC-File	BG121000004.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG_ODH4 2010-06-14 10-08-0

#	Time	Area	Height	Width	Area%	Symmetry
1	11.303	3967.7	187.7	0.3266	50.066	0.875
2	13.753	3957.2	147.9	0.4162	49.934	0.847



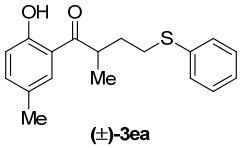
(–)-3da



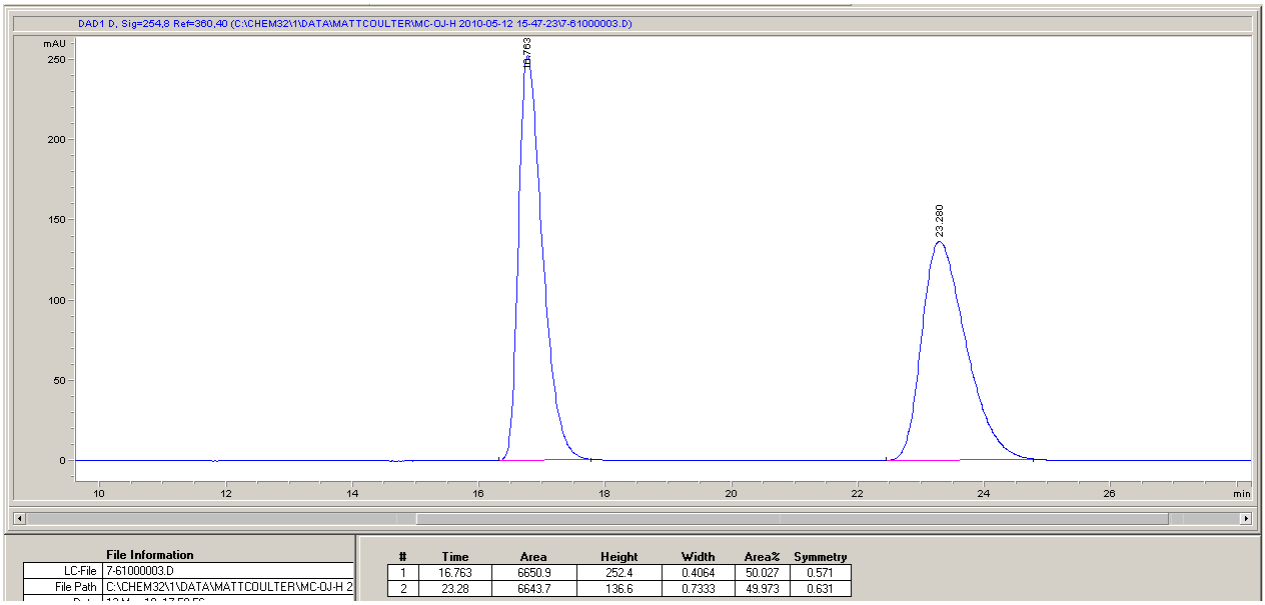
File Information

LC-File	BG121000005.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG_ODH4 2010-06-14 10-08-0
Date	14-Jun-10, 11:20:43

#	Time	Area	Height	Width	Area%	Symmetry
1	11.418	310.9	14.8	0.3244	3.968	0.93
2	13.862	7524.9	280.8	0.4166	96.032	0.793



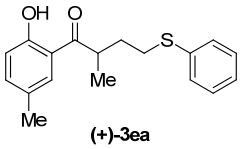
(±)-3ea



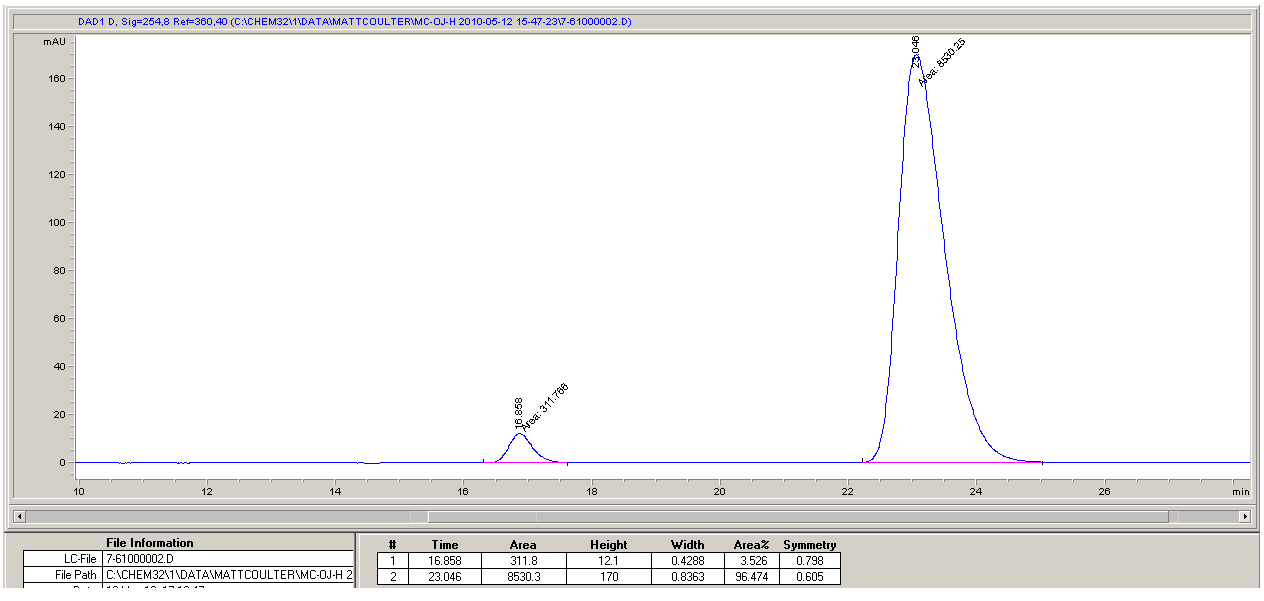
File Information

LC-File	7-61000003.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-OJ-H 2

#	Time	Area	Height	Width	Area%	Symmetry
1	16.763	6650.9	252.4	0.4064	50.027	0.571
2	23.28	6643.7	136.6	0.7333	49.973	0.631



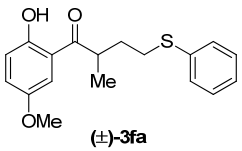
(+)-3ea



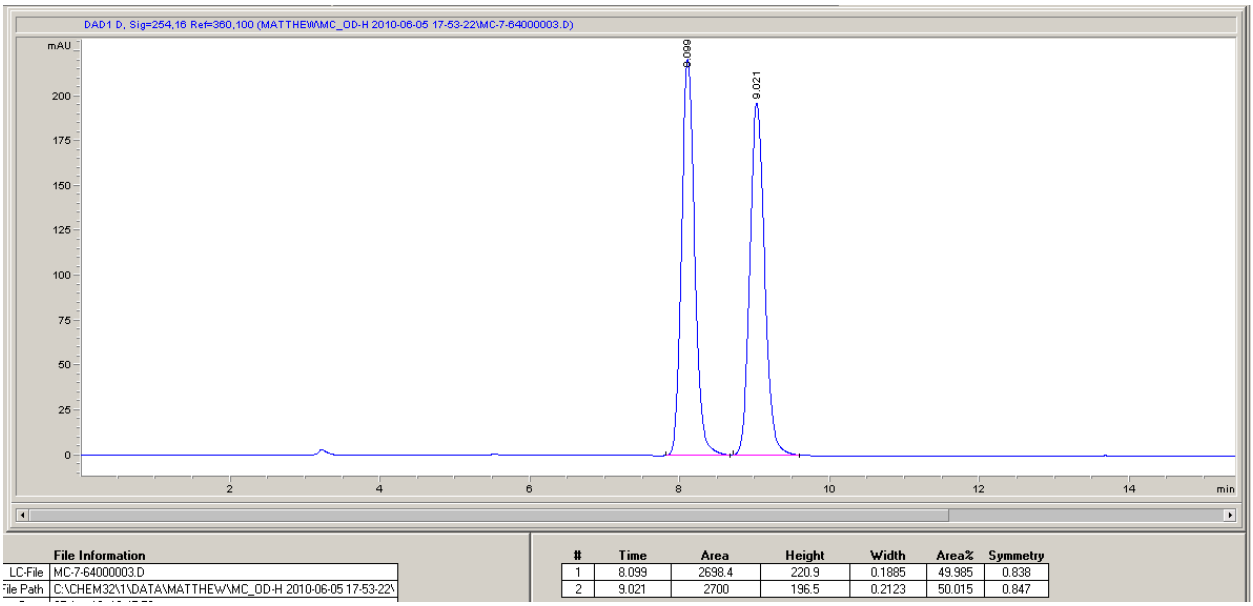
File Information

LC-File	7-61000002.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-OJ-H 2

#	Time	Area	Height	Width	Area%	Symmetry
1	16.858	311.8	12.1	0.4288	3.526	0.798
2	23.046	8530.3	170	0.8363	96.474	0.605

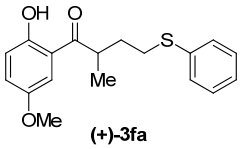


(±)-3fa

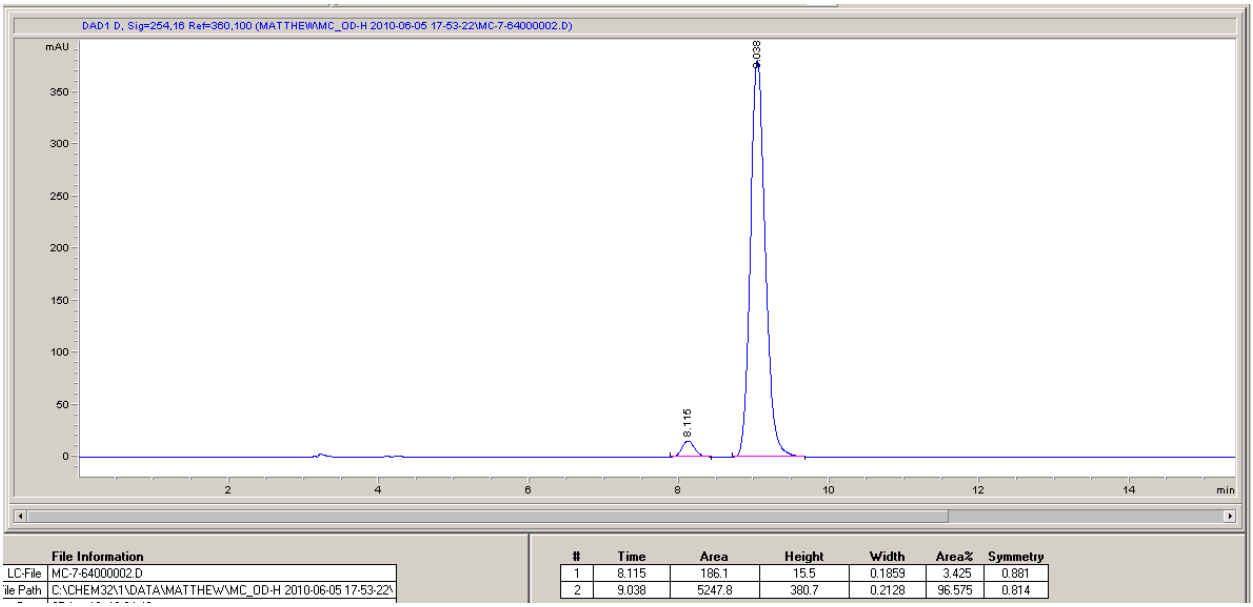


File Information	
LC-File	MC-7-64000003.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-06-05 17-53-22\

#	Time	Area	Height	Width	Area%	Symmetry
1	8.099	2698.4	220.9	0.1885	49.985	0.838
2	9.021	2700	196.5	0.2123	50.015	0.847

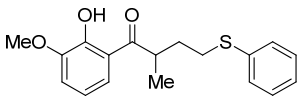


(+)-3fa

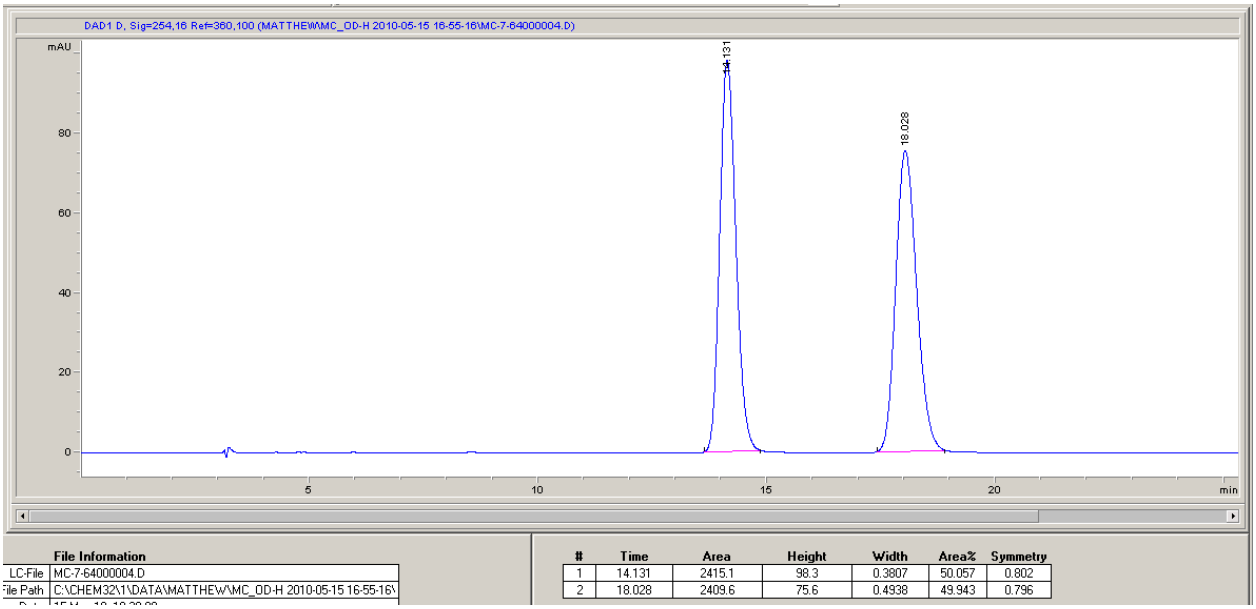


File Information	
LC-File	MC-7-64000002.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-06-05 17-53-22\

#	Time	Area	Height	Width	Area%	Symmetry
1	8.115	186.1	15.5	0.1859	3.425	0.881
2	9.038	5247.8	380.7	0.2128	96.575	0.814



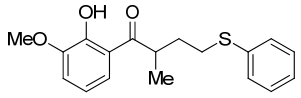
(±)-3ga



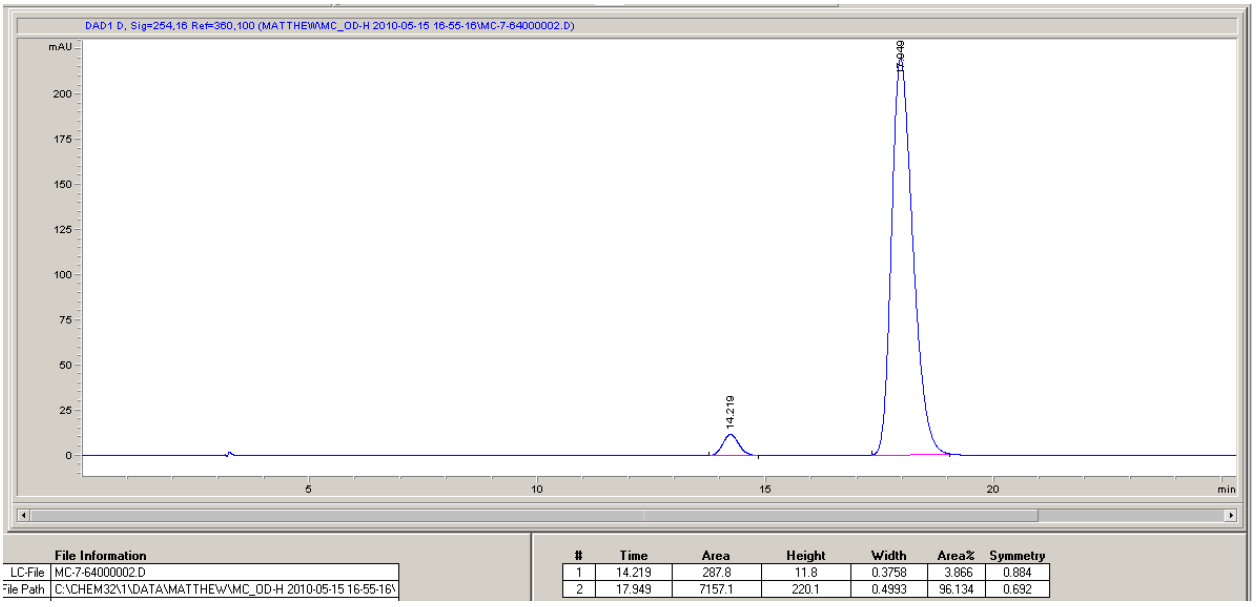
File Information

LC-File	MC-7-64000004.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-05-15 16-55-16\

#	Time	Area	Height	Width	Area%	Symmetry
1	14.131	2415.1	98.3	0.3807	50.057	0.802
2	18.028	2409.6	75.6	0.4938	49.943	0.796



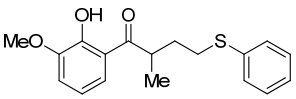
(+)-3ga
With 1.5 equiv. **2a**
(Table 2, entry 8)



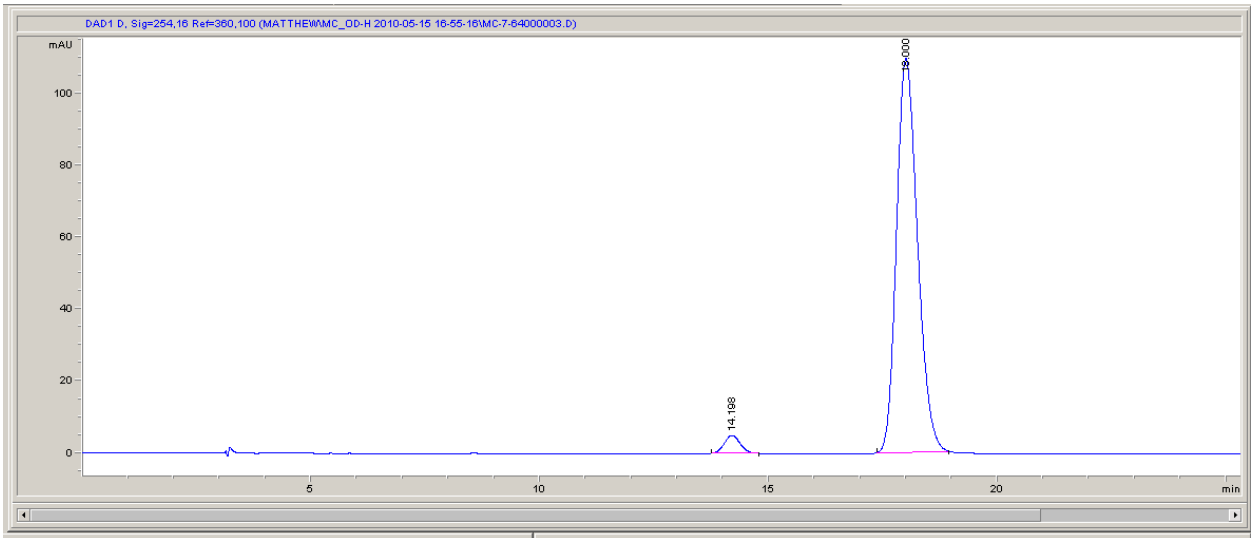
File Information

LC-File	MC-7-64000002.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-05-15 16-55-16\

#	Time	Area	Height	Width	Area%	Symmetry
1	14.219	287.8	11.8	0.3758	3.866	0.884
2	17.949	7157.1	220.1	0.4993	96.134	0.692

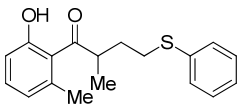


(+)-3ga
With 2.0 equiv. **2a**
(Table 2, entry 9)

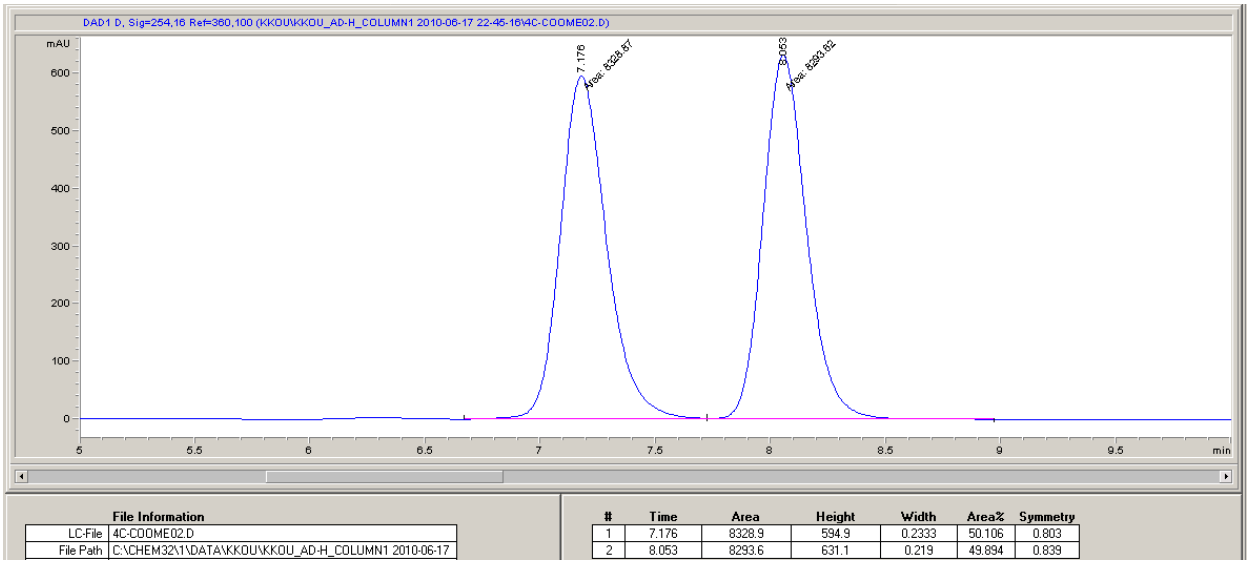


File Information	
LC-File	MC-7-64000003.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-05-15 16-55-16\

#	Time	Area	Height	Width	Area%	Symmetry
1	14.198	119.9	5	0.3713	3.302	0.891
2	18	3509.7	109.8	0.4929	96.698	0.764

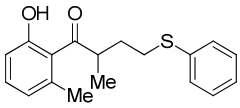


(±)-3ha

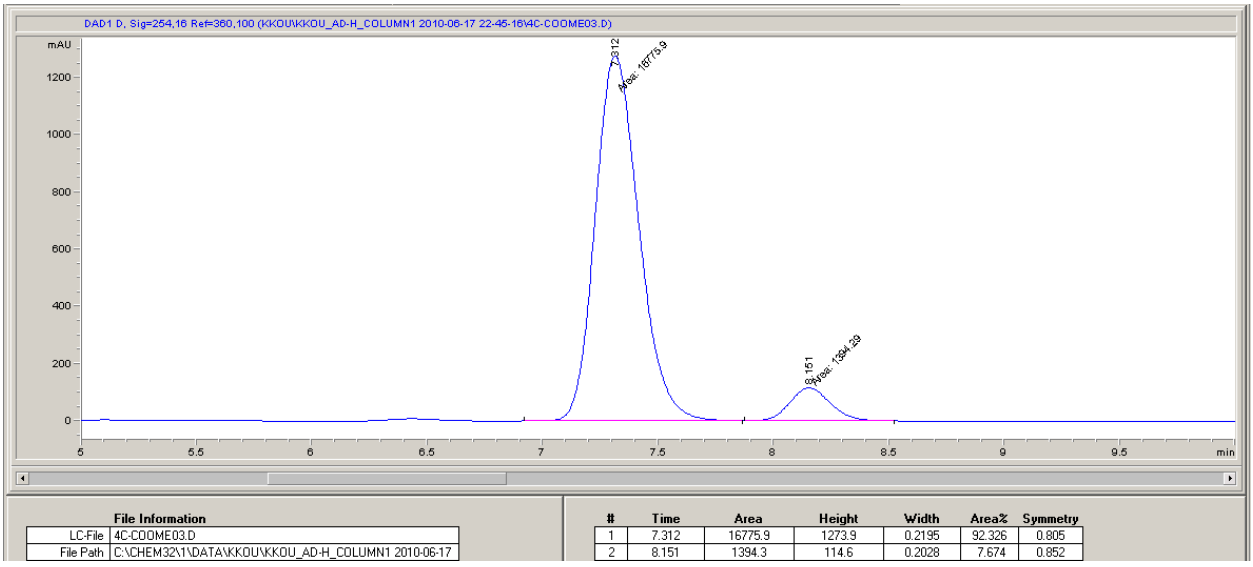


File Information	
LC-File	4C-COOME02.D
File Path	C:\CHEM32\1\DATA\KKOU\KKOU_AD-H_COLUMN1 2010-06-17

#	Time	Area	Height	Width	Area%	Symmetry
1	7.176	8328.9	594.9	0.2333	50.106	0.803
2	8.053	8293.6	631.1	0.219	49.894	0.839

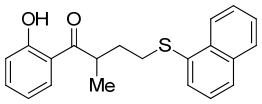


(+)-3ha

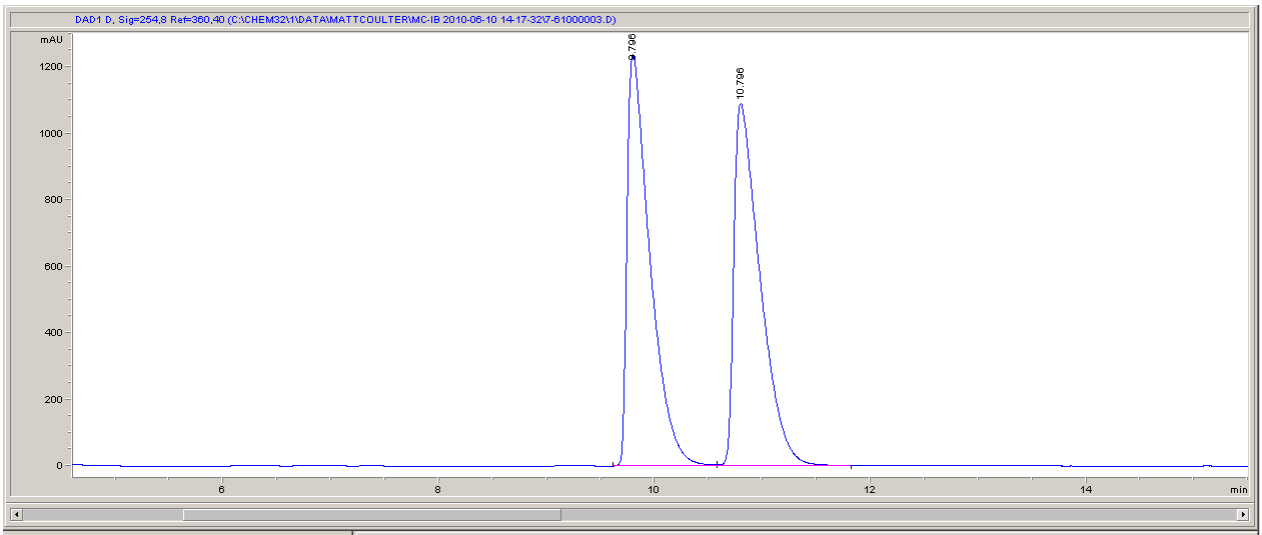


File Information	
LC-File	4C-COOME03.D
File Path	C:\CHEM32\1\DATA\KKOU\KKOU_AD-H_COLUMN1 2010-06-17

#	Time	Area	Height	Width	Area%	Symmetry
1	7.312	16775.9	1273.9	0.2195	92.326	0.805
2	8.151	1394.3	114.6	0.2028	7.674	0.852



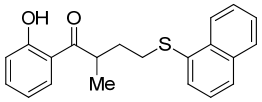
(±)-3ab



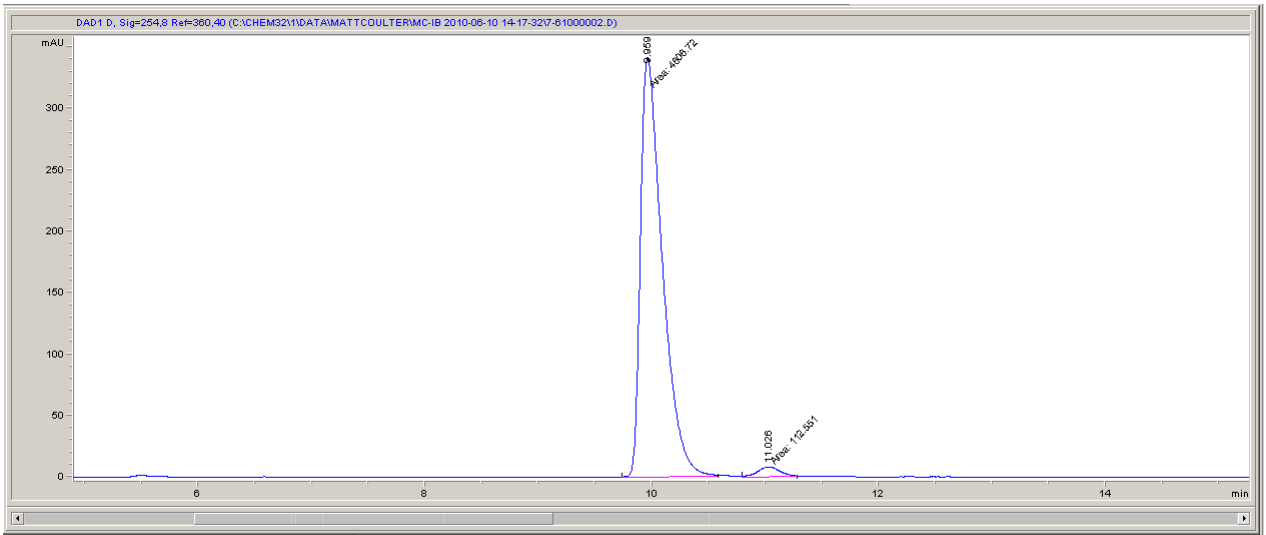
File Information

LC-File	7-61000003.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-IB 2010

#	Time	Area	Height	Width	Area%	Symmetry
1	9.796	18206.4	1238.5	0.2165	49.825	0.314
2	10.796	18334.6	1089.2	0.2514	50.175	0.33



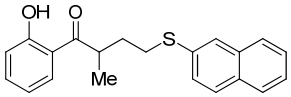
(+)-3ab



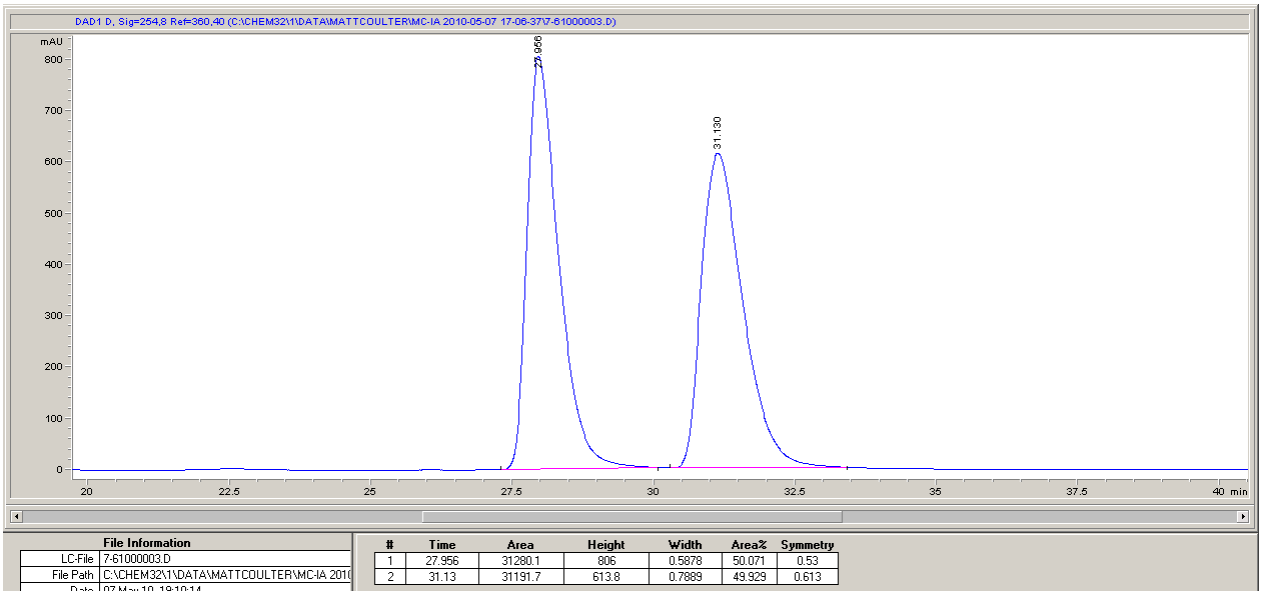
File Information

LC-File	7-61000002.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-IB 2010

#	Time	Area	Height	Width	Area%	Symmetry
1	9.959	4606.7	342.4	0.2242	97.615	0.462
2	11.026	112.6	8.1	0.2308	2.385	0.981

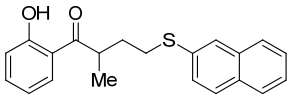


(±)-3ac

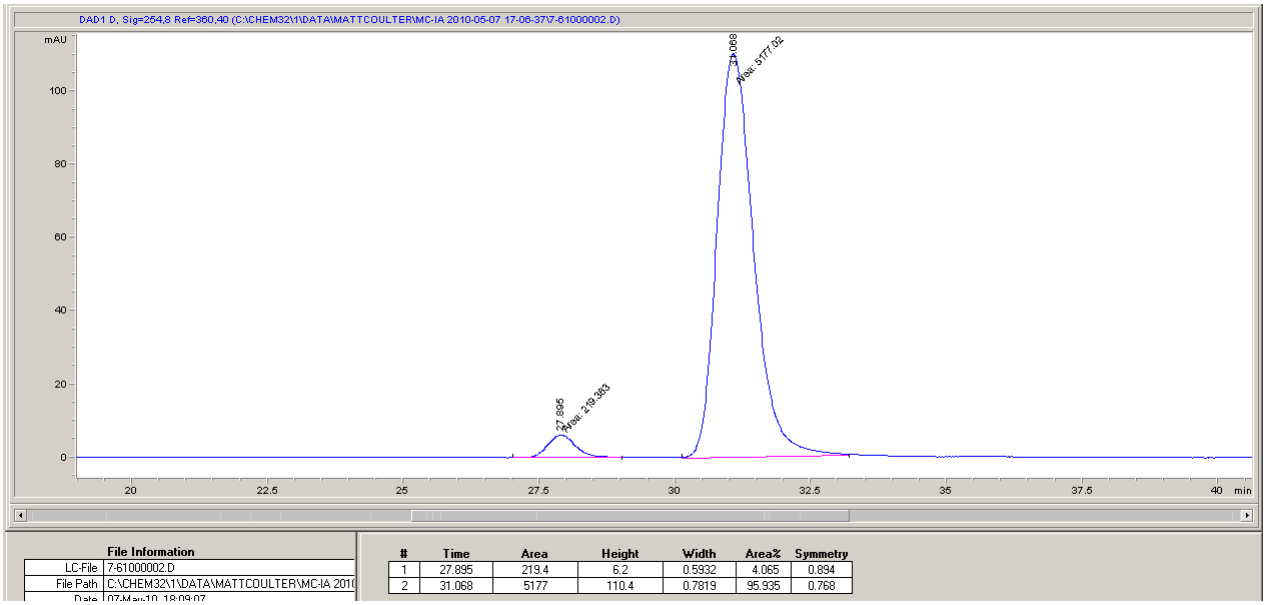


File Information	
LC-File	7-61000003.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-IA 2010

#	Time	Area	Height	Width	Area%	Symmetry
1	27.956	31280.1	806	0.5878	50.071	0.53
2	31.13	31191.7	613.8	0.7889	49.929	0.613

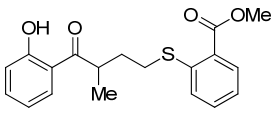


(+)-3ac

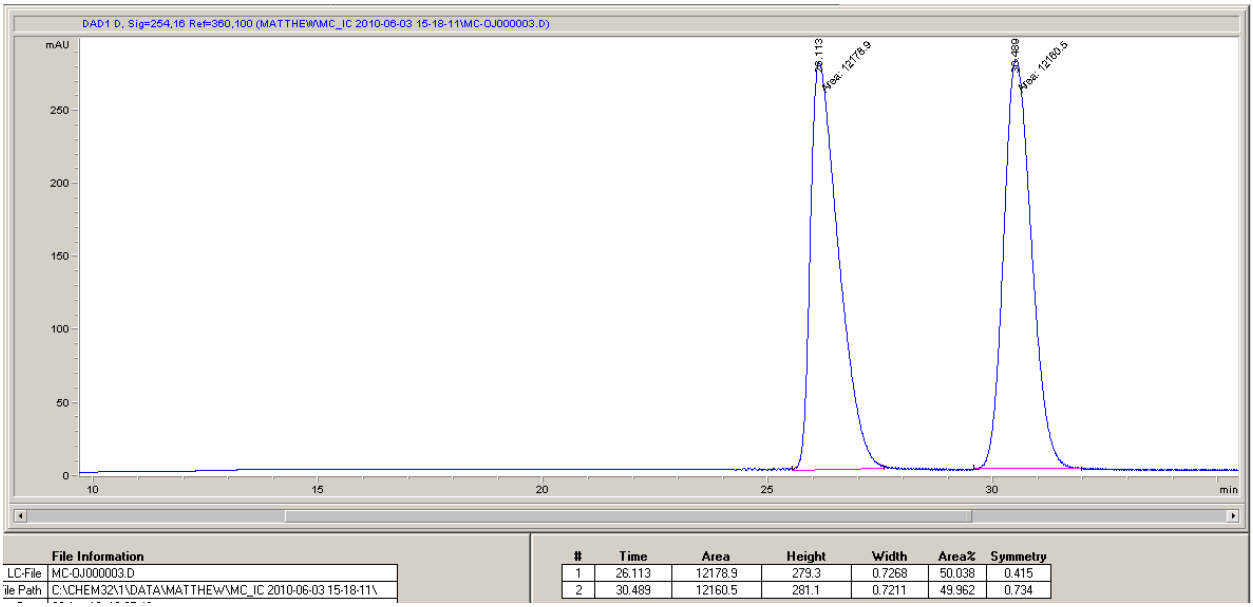


File Information	
LC-File	7-61000002.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-IA 2010

#	Time	Area	Height	Width	Area%	Symmetry
1	27.895	219.4	6.2	0.5932	4.065	0.894
2	31.068	5177	110.4	0.7819	95.935	0.768

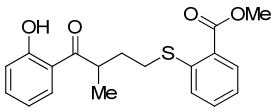


(±)-3ad

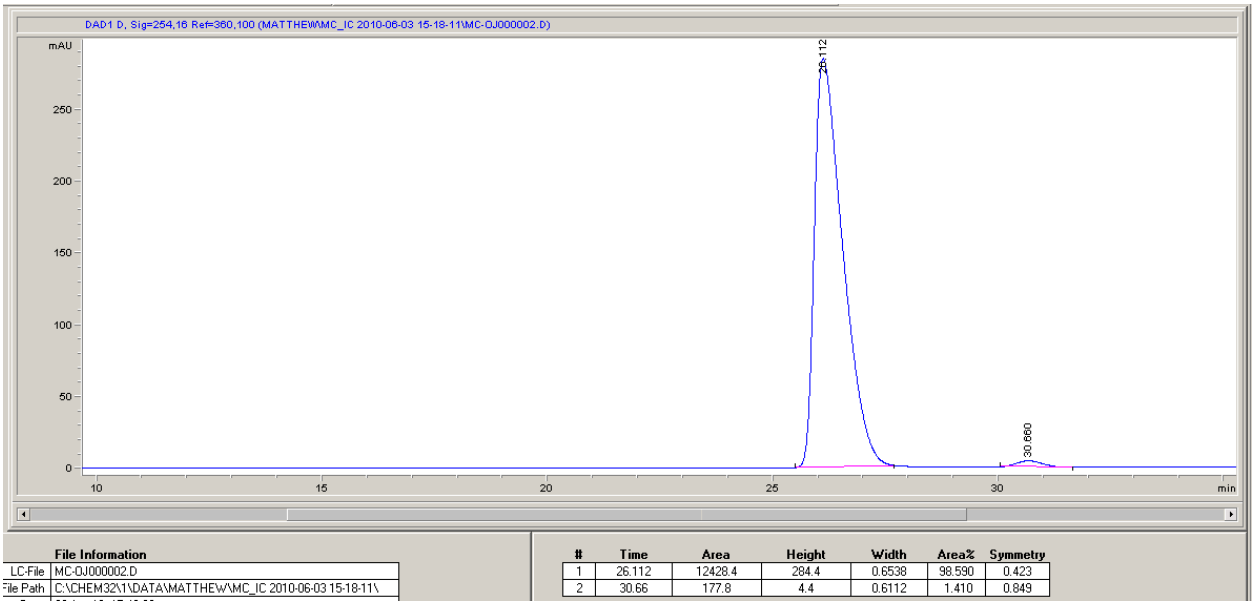


File Information	
LC-File	MC-OJ000003.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_IC 2010-06-03 15-18-11\

#	Time	Area	Height	Width	Area%	Symmetry
1	26.113	12178.9	279.3	0.7268	50.038	0.415
2	30.489	12160.5	281.1	0.7211	49.962	0.734

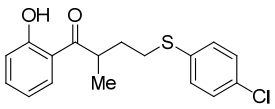


(+)-3ad

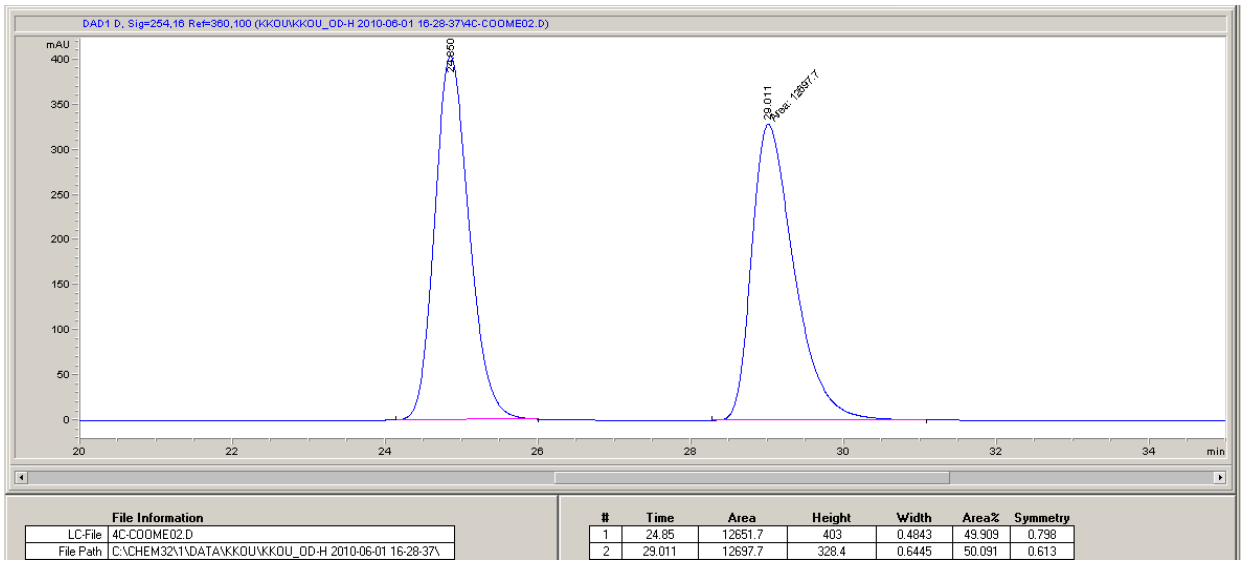


File Information	
LC-File	MC-OJ000002.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_IC 2010-06-03 15-18-11\

#	Time	Area	Height	Width	Area%	Symmetry
1	26.112	12428.4	284.4	0.6538	98.590	0.423
2	30.66	177.8	4.4	0.6112	1.410	0.849

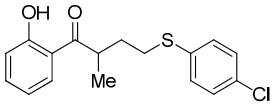


(±)-3ae

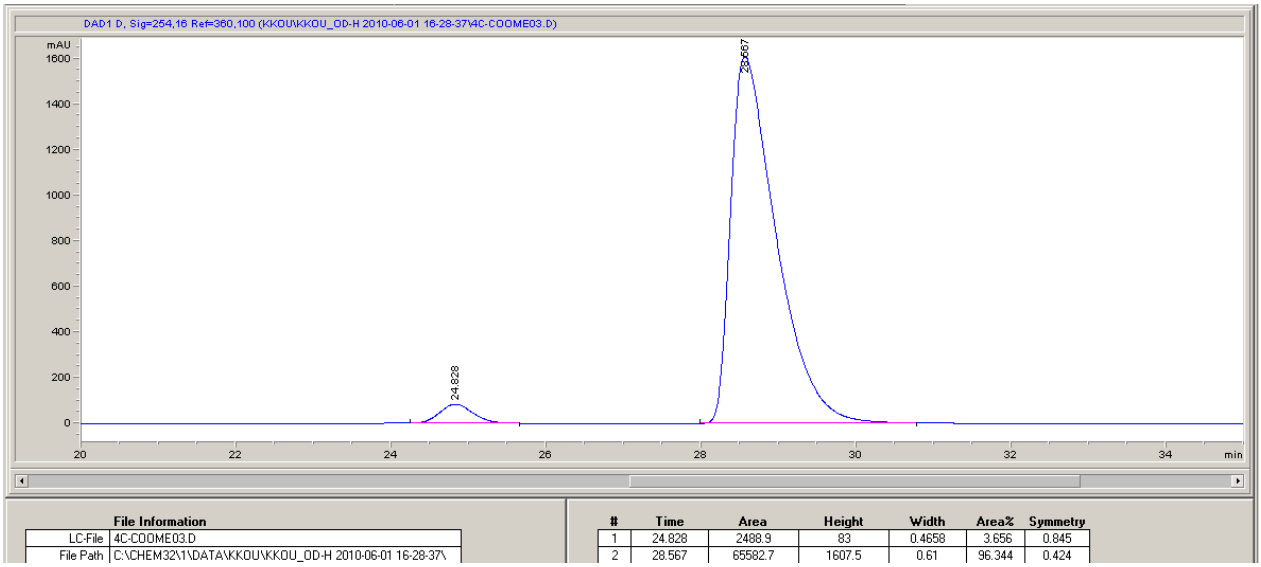


File Information	
LC-File	4C-COOME02.D
File Path	C:\CHEM32\1\DATA\KKOU\KKOU_OD-H 2010-06-01 16-28-37\

#	Time	Area	Height	Width	Area%	Symmetry
1	24.85	12651.7	403	0.4843	49.909	0.798
2	29.011	12697.7	328.4	0.6445	50.091	0.613

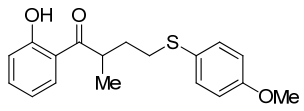


(+)-3ae

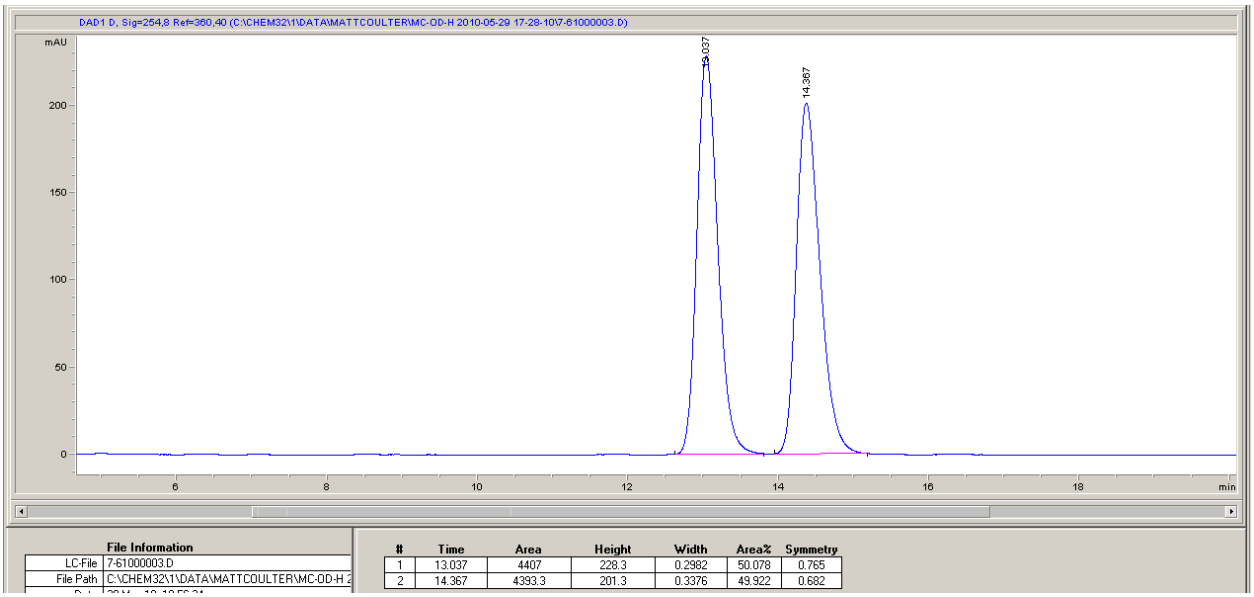


File Information	
LC-File	4C-COOME03.D
File Path	C:\CHEM32\1\DATA\KKOU\KKOU_OD-H 2010-06-01 16-28-37\

#	Time	Area	Height	Width	Area%	Symmetry
1	24.828	2488.9	83	0.4658	3.656	0.845
2	28.567	65582.7	1607.5	0.61	96.344	0.424

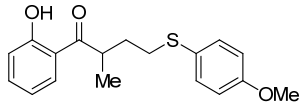


(±)-3af

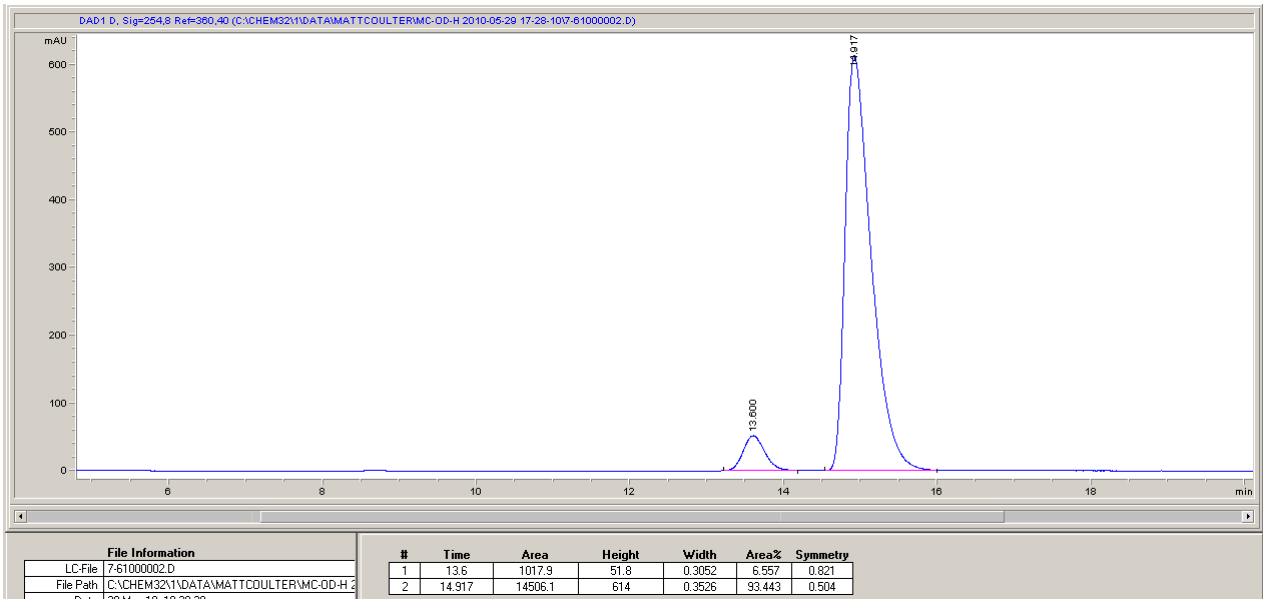


File Information	
LC-File	7-61000003.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-OD-H 2

#	Time	Area	Height	Width	Area%	Symmetry
1	13.037	4407	228.3	0.2982	50.078	0.765
2	14.367	4393.3	201.3	0.3376	49.922	0.682

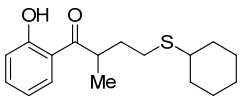


(+)-3af

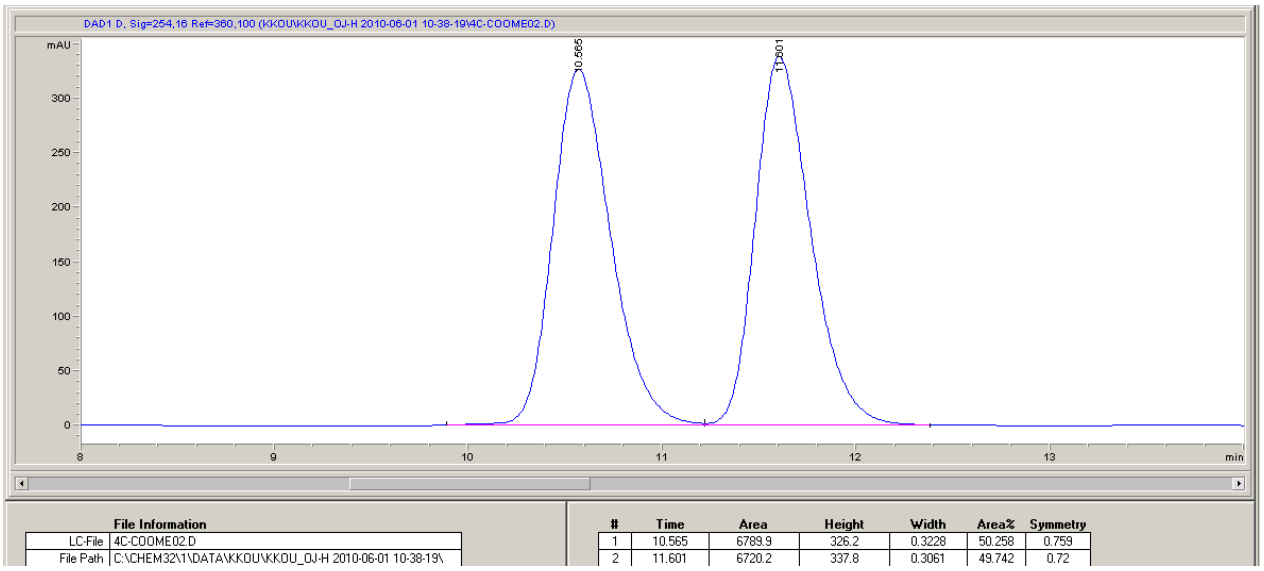


File Information	
LC-File	7-61000002.D
File Path	C:\CHEM32\1\DATA\MATTCOULTER\MC-OD-H 2

#	Time	Area	Height	Width	Area%	Symmetry
1	13.6	1017.9	51.8	0.3052	6.557	0.821
2	14.917	14506.1	614	0.3526	93.443	0.504

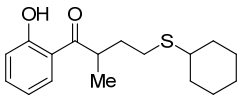


(±)-3ag

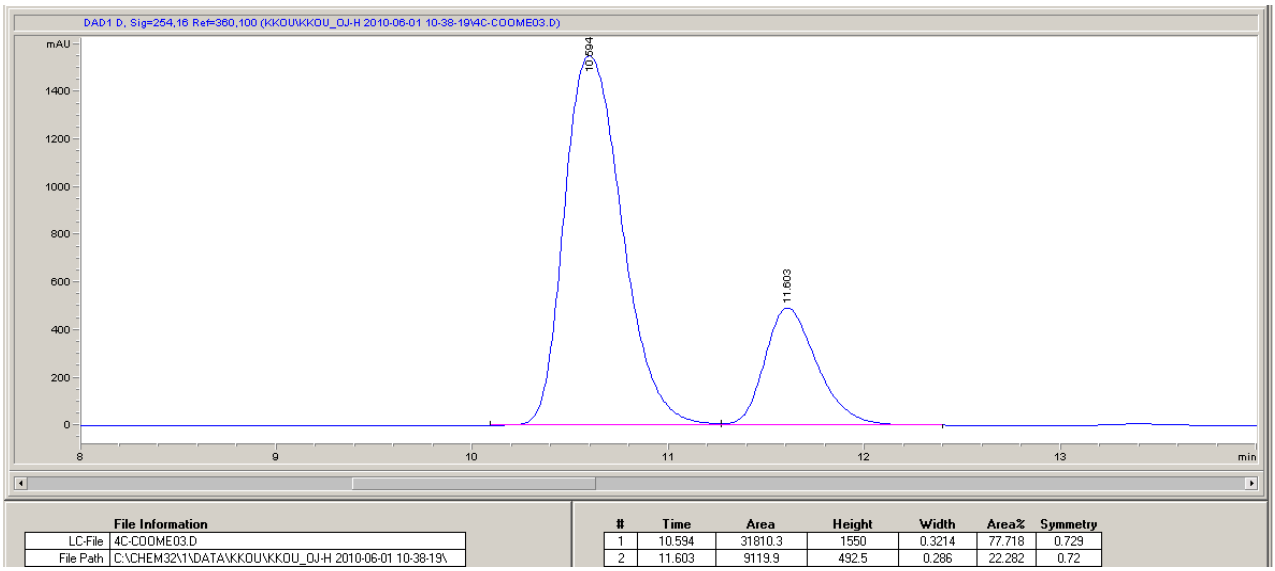


File Information	
LC-File	4C-COOME02.D
File Path	C:\CHEM32\1\DATA\KKOU\KKOU_OJ-H 2010-06-01 10-38-19\

#	Time	Area	Height	Width	Area%	Symmetry
1	10.565	6789.9	326.2	0.3228	50.258	0.759
2	11.601	6720.2	337.8	0.3061	49.742	0.72

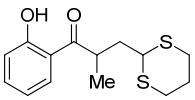


(+)-3ag

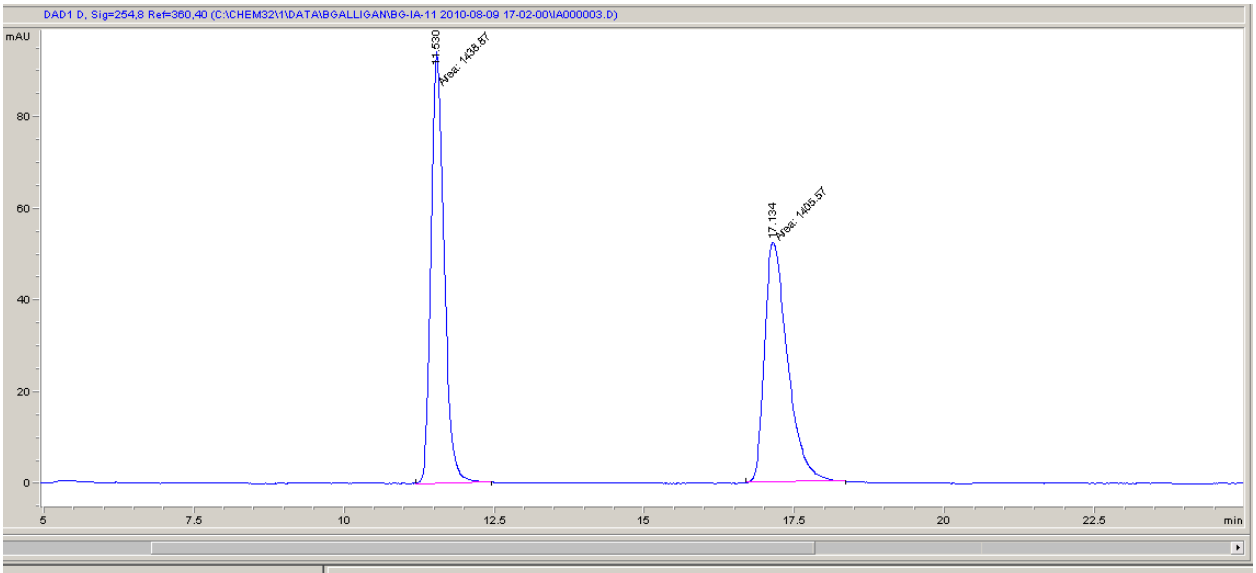


File Information	
LC-File	4C-COOME03.D
File Path	C:\CHEM32\1\DATA\KKOU\KKOU_OJ-H 2010-06-01 10-38-19\

#	Time	Area	Height	Width	Area%	Symmetry
1	10.594	31810.3	1550	0.3214	77.718	0.729
2	11.603	9119.9	492.5	0.286	22.282	0.72

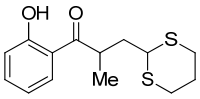


(±)-3ah

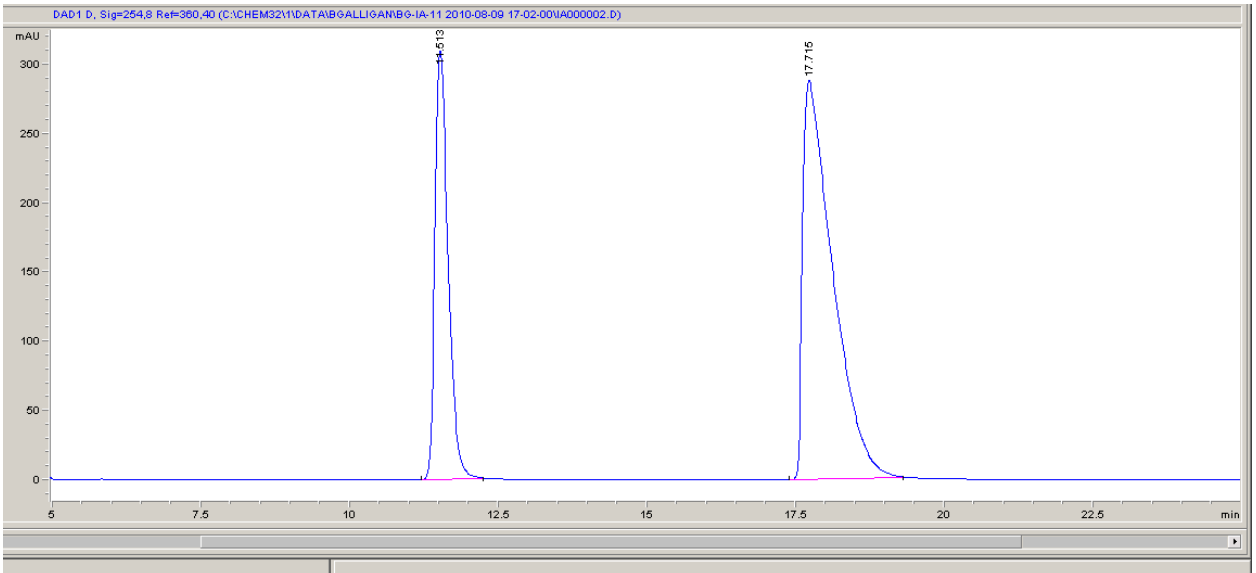


File Information	
LC-File	IA000003.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG-IA-11 2

#	Time	Area	Height	Width	Area%	Symmetry
1	11.53	1438.9	94.3	0.2543	50.585	0.737
2	17.134	1405.6	52.3	0.4475	49.415	0.573

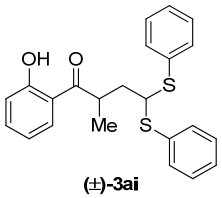


(+)-3ah

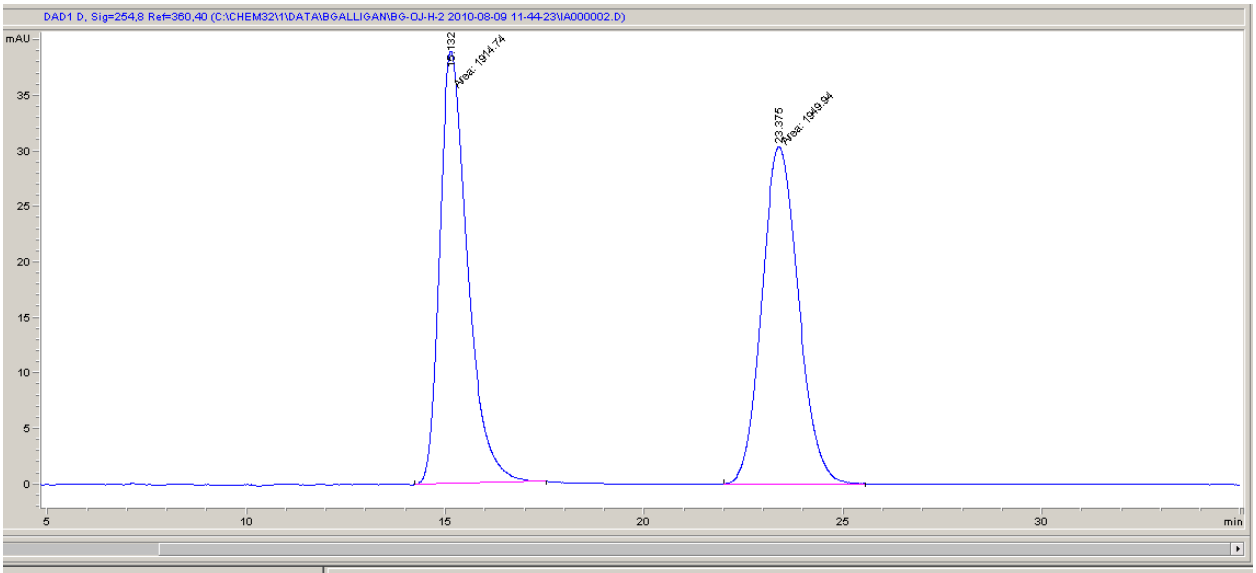


File Information	
LC-File	IA000002.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG-IA-11 2

#	Time	Area	Height	Width	Area%	Symmetry
1	11.513	4740.3	309.5	0.2337	31.869	0.597
2	17.715	10134.1	287.9	0.5036	68.131	0.239

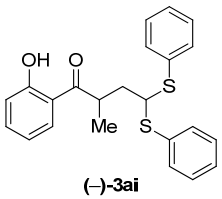


(±)-3ai

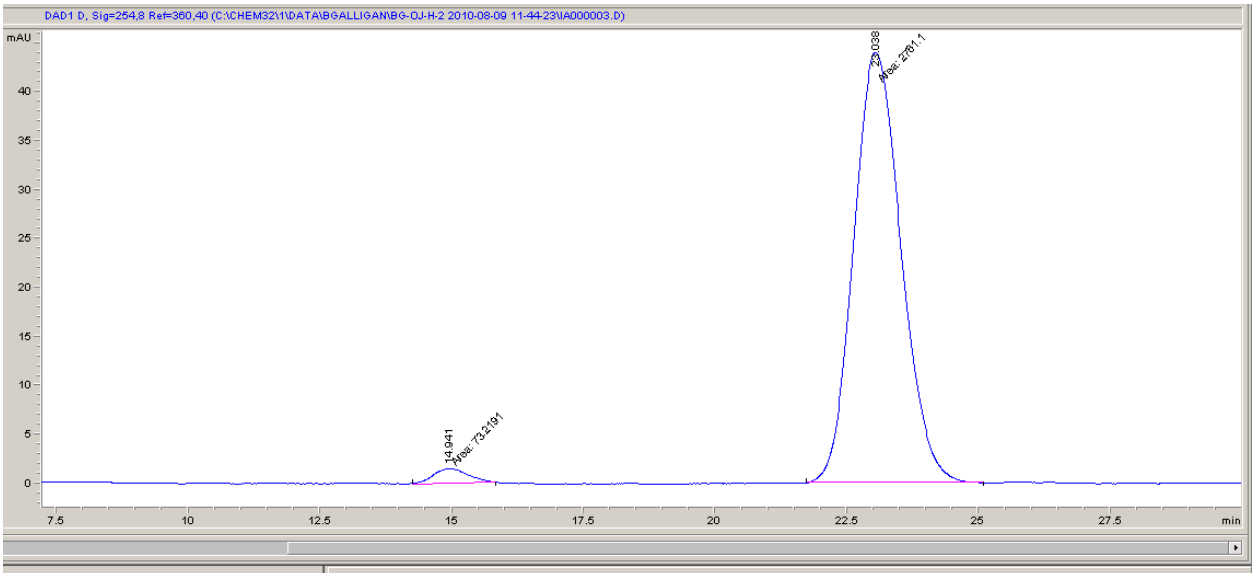


File Information	
LC-File	IA000002.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG-OJ-H-2

#	Time	Area	Height	Width	Area%	Symmetry
1	15.132	1914.7	39	0.8184	49.545	0.677
2	23.375	1949.9	30.4	1.0703	50.455	0.866

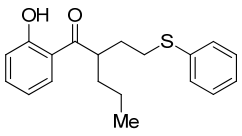


(–)-3ai

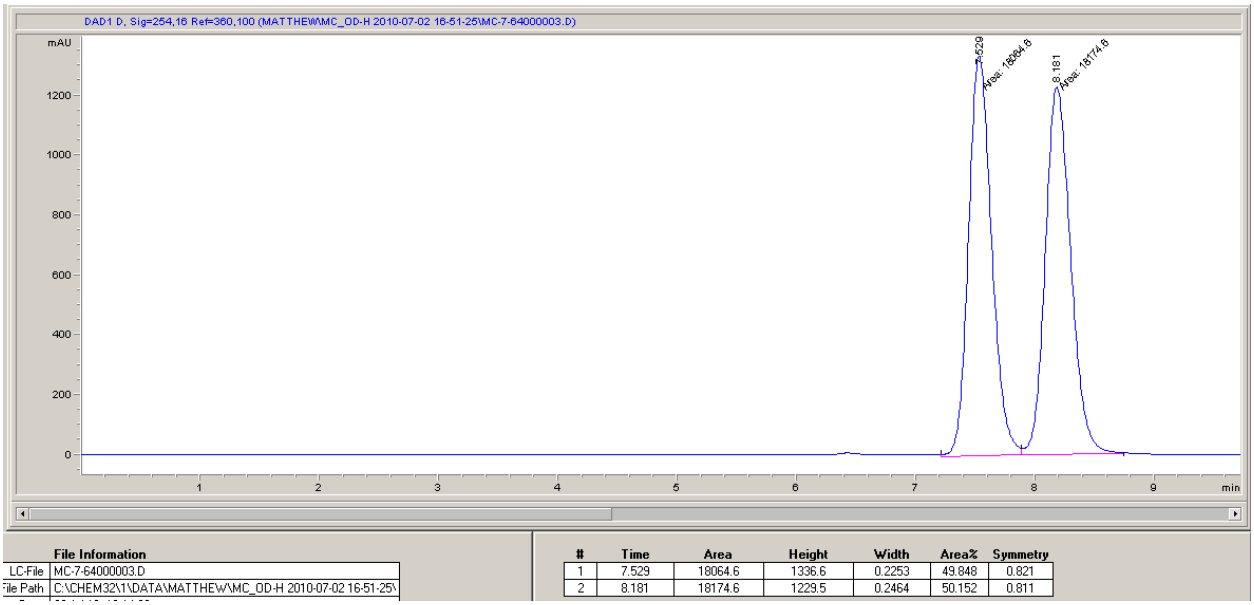


File Information	
LC-File	IA000003.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG-OJ-H-2

#	Time	Area	Height	Width	Area%	Symmetry
1	14.941	73.2	1.6	0.7797	2.583	0.809
2	23.038	2761.1	44	1.046	97.417	0.838

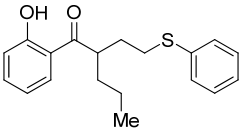


(±)-7

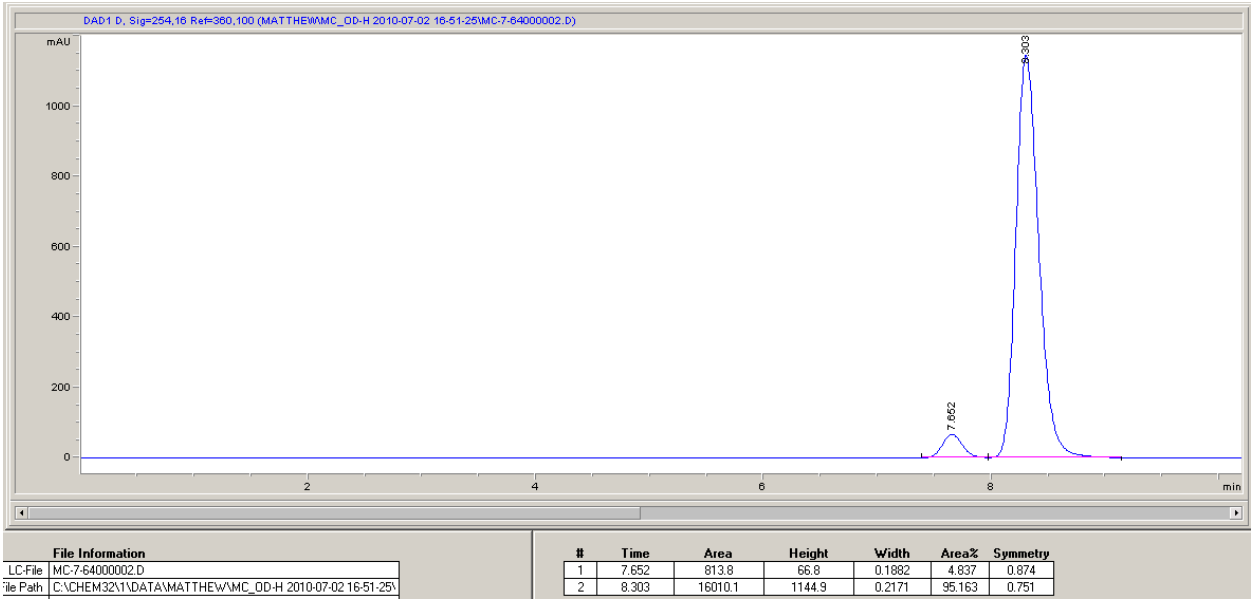


File Information	
LC-File	MC-7-64000003.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-07-02 16-51-25\

#	Time	Area	Height	Width	Area%	Symmetry
1	7.529	18064.6	1336.6	0.2253	49.848	0.821
2	8.181	18174.6	1229.5	0.2464	50.152	0.811

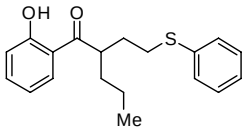


(+)-7
With (*E*)-olefin **5**

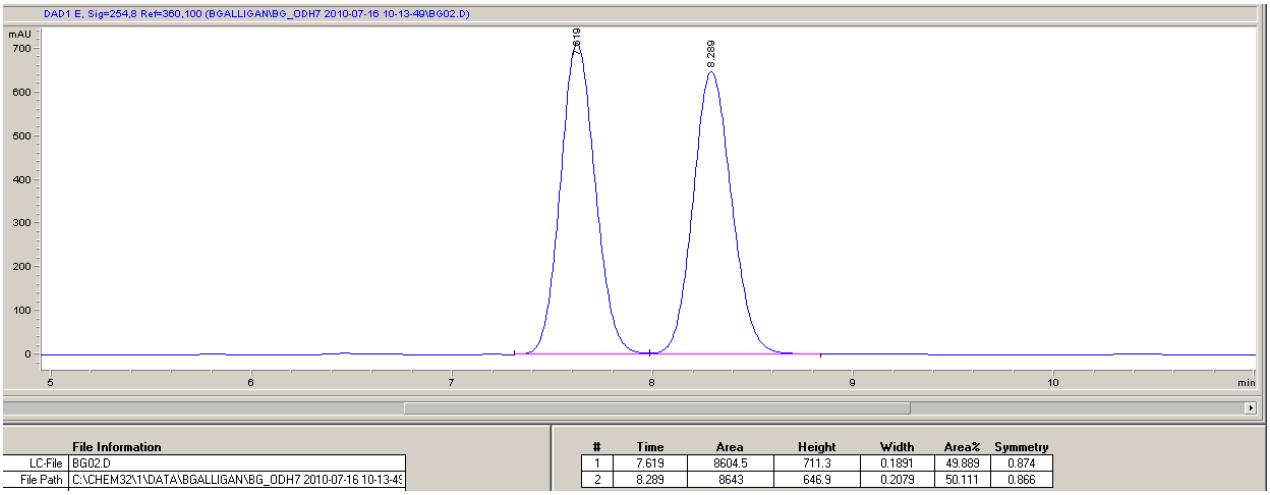


File Information	
LC-File	MC-7-64000002.D
File Path	C:\CHEM32\1\DATA\MATTHEW\MC_OD-H 2010-07-02 16-51-25\

#	Time	Area	Height	Width	Area%	Symmetry
1	7.652	813.8	66.8	0.1882	4.837	0.874
2	8.303	16010.1	1144.9	0.2171	95.163	0.751

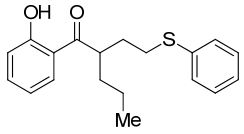


(±)-7

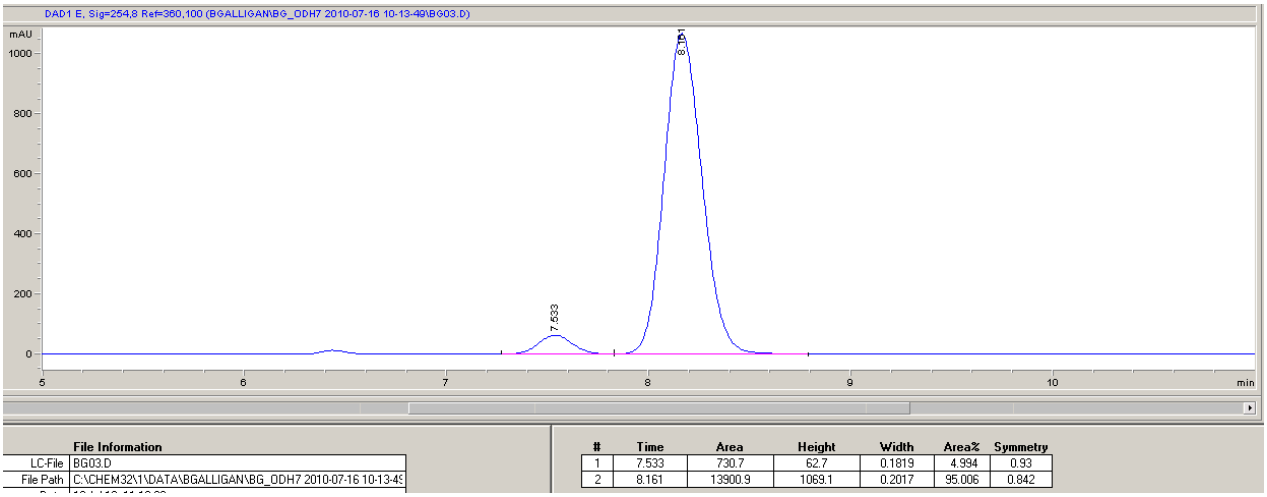


File Information	
LC-File	BG02.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG_ODH7 2010-07-16 10-13-4

#	Time	Area	Height	Width	Area%	Symmetry
1	7.619	8604.5	711.3	0.1891	49.889	0.874
2	8.289	8643	646.9	0.2079	50.111	0.866



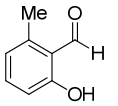
(+)-7
With (*Z*)-olefin **6**



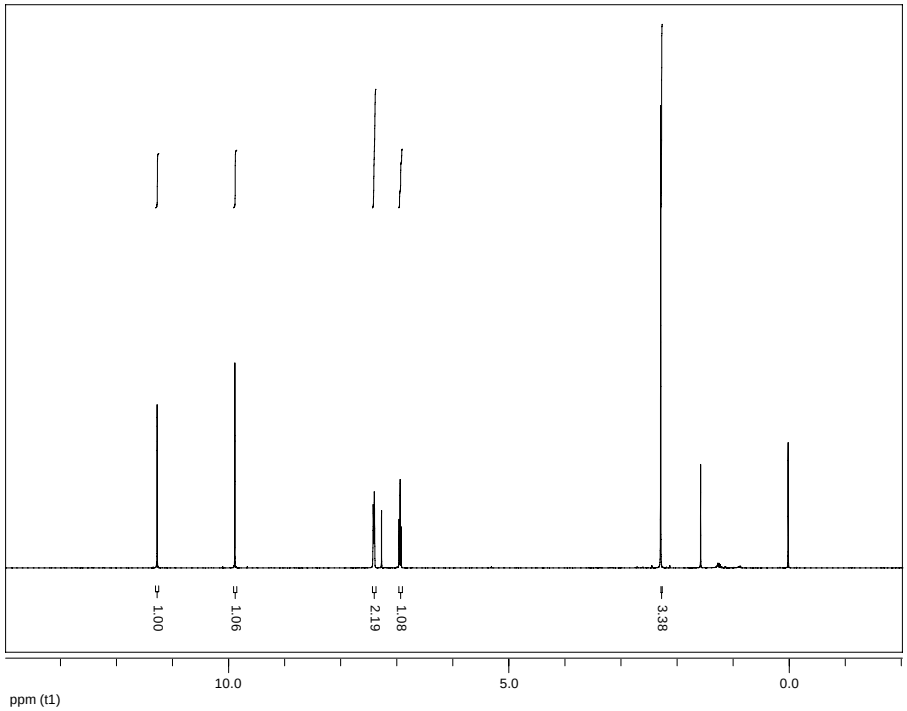
File Information	
LC-File	BG03.D
File Path	C:\CHEM32\1\DATA\BGALLIGAN\BG_ODH7 2010-07-16 10-13-4

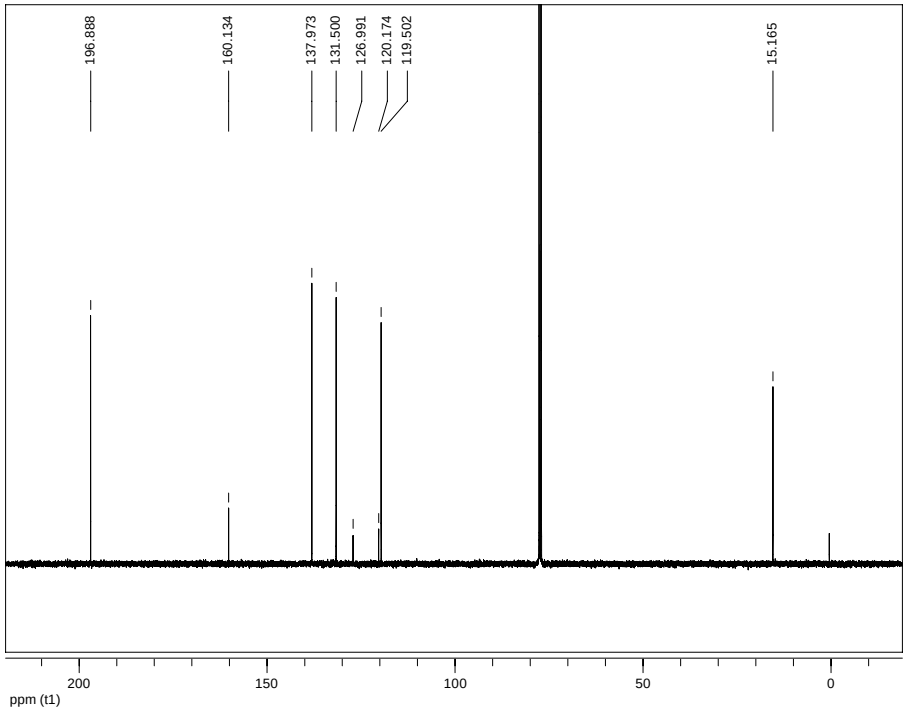
#	Time	Area	Height	Width	Area%	Symmetry
1	7.533	730.7	62.7	0.1819	4.994	0.93
2	8.161	13900.9	1069.1	0.2017	95.006	0.842

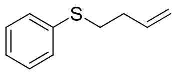
5. NMR Spectra



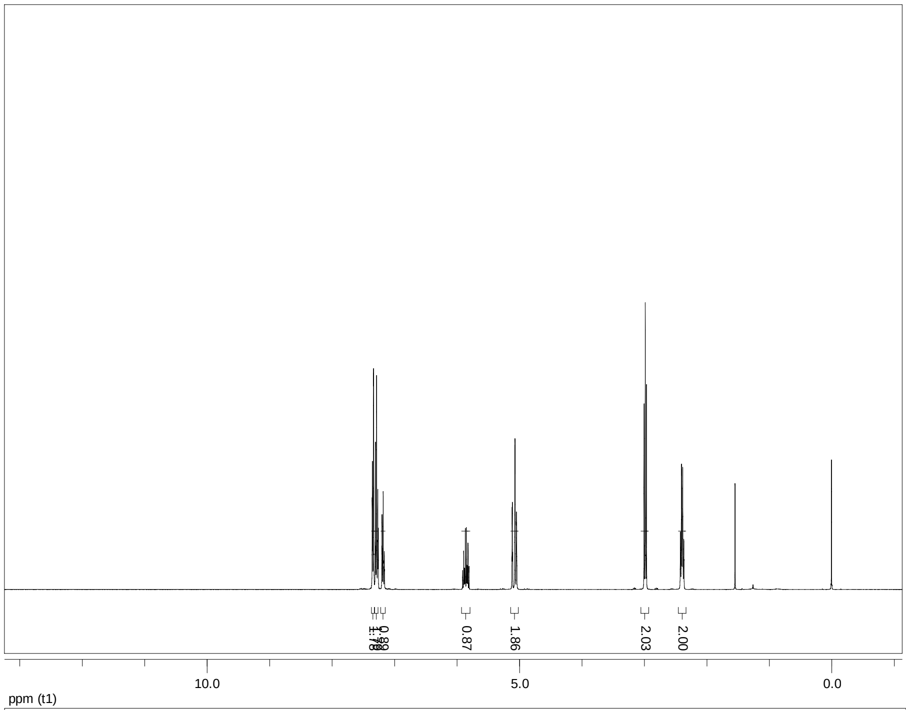
1h

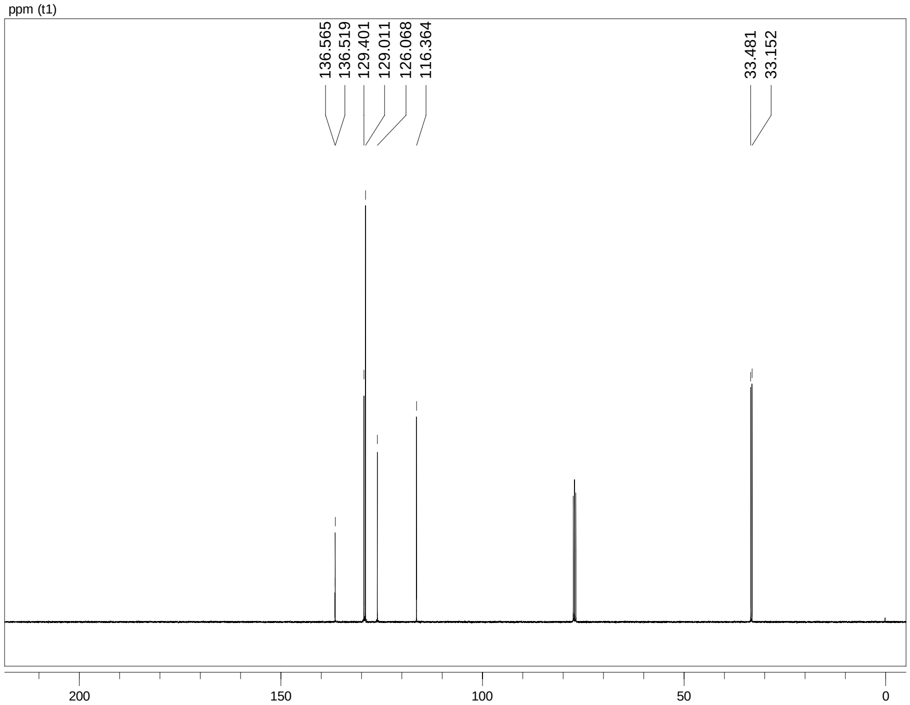


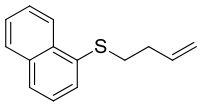



S

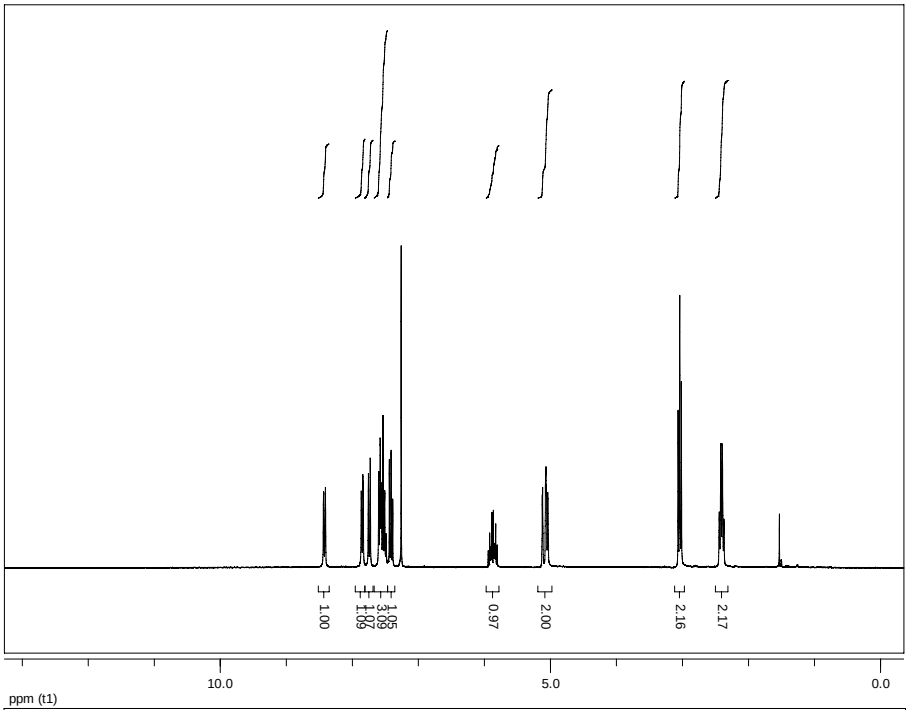
2a

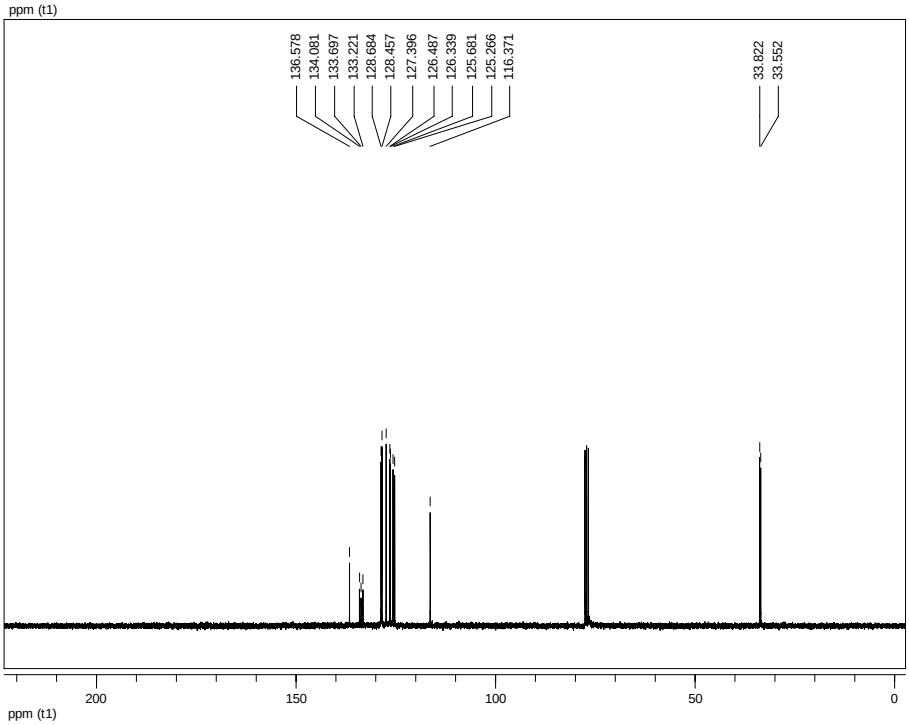

0.87
1.86
2.03
2.00
10.0
5.0
0.0
ppm (t1)

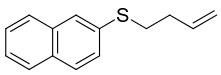

136.565
136.519
129.401
129.011
126.068
116.364
33.481
33.152
200
150
100
50
0
ppm (t1)



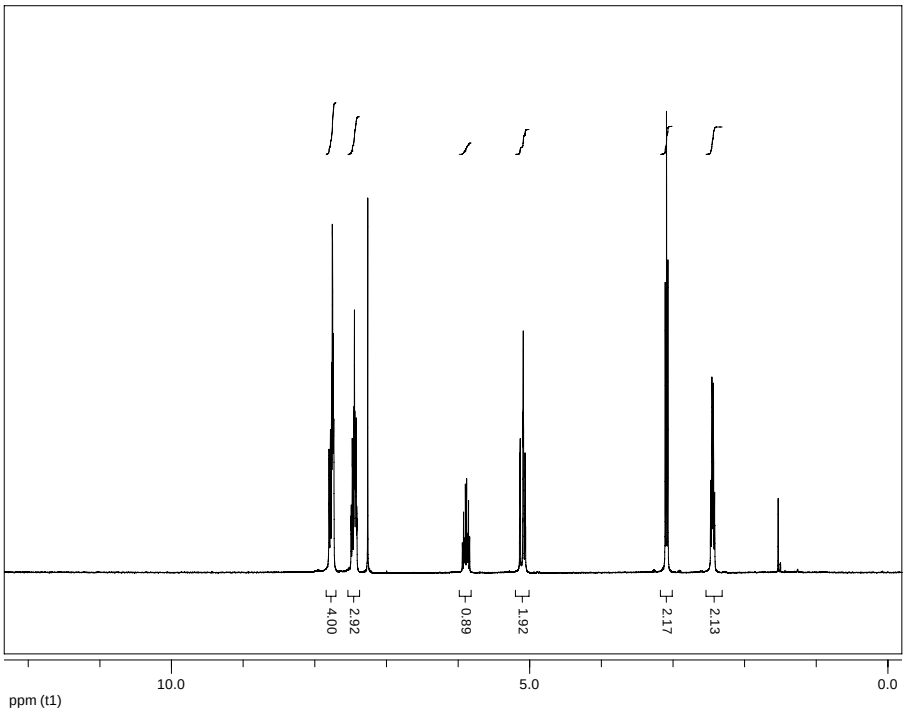
2b

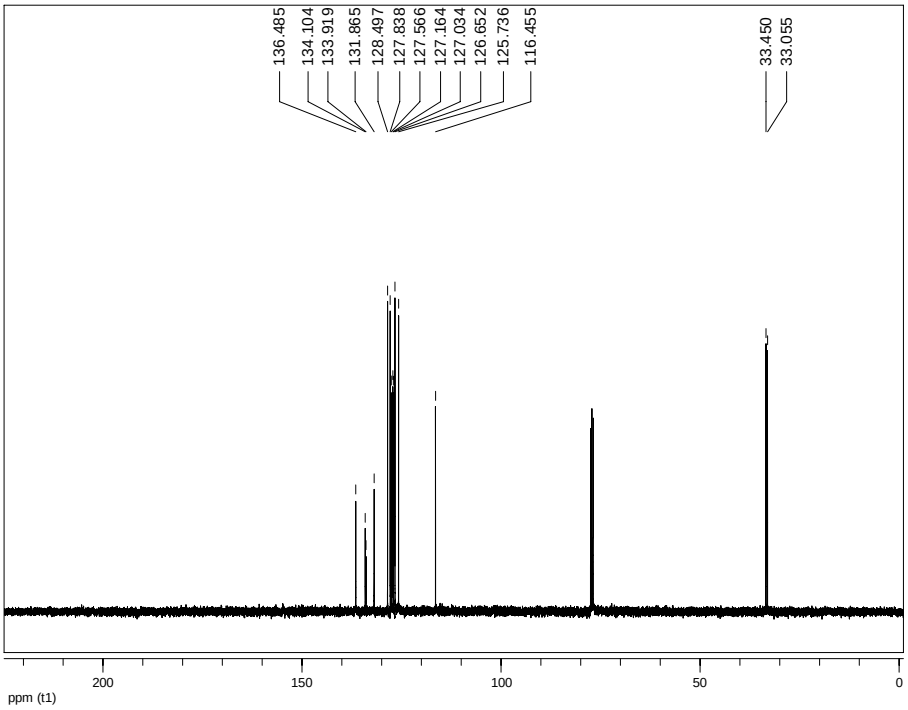

1.00
1.09
1.07
3.05
3.00
0.97
2.00
2.16
2.17
10.0
5.0
0.0
ppm (t1)

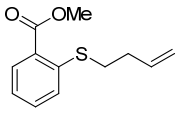

136.578
134.081
133.697
133.221
128.684
128.457
127.396
126.487
126.339
125.681
125.266
116.371
33.822
33.552
200
150
100
50
0
ppm (t1)



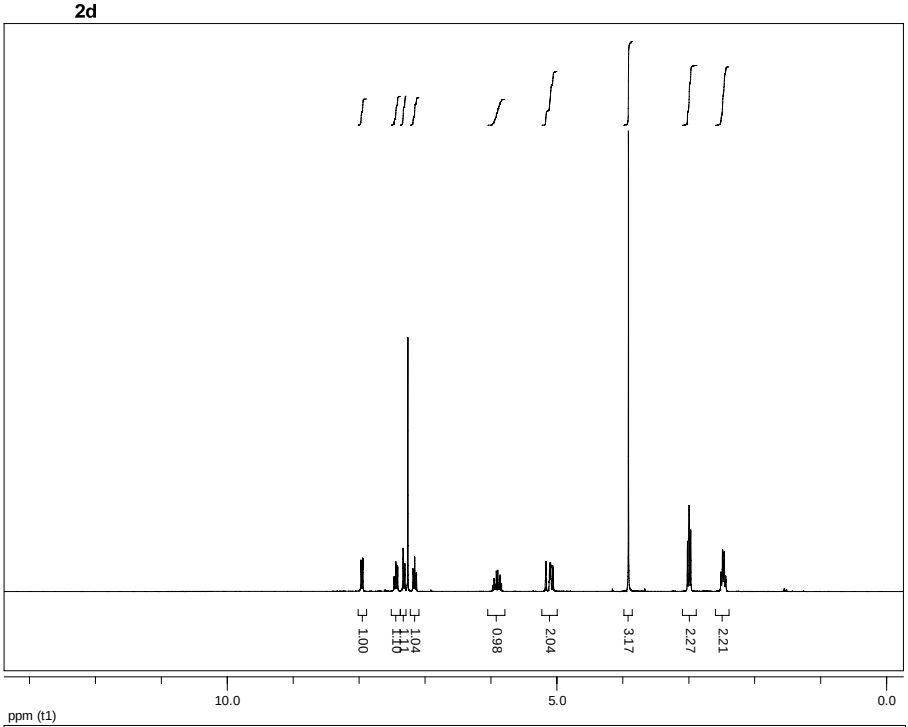
2c

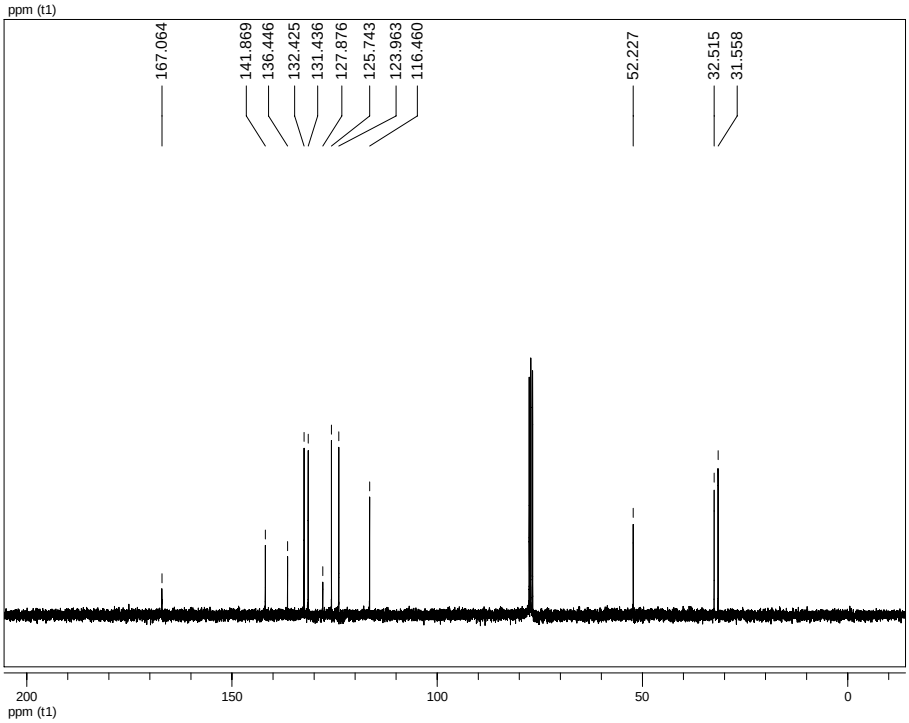

4.00
2.62
0.89
1.92
2.17
2.13
10.0
5.0
0.0
ppm (t1)

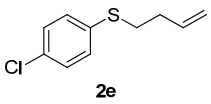

136.485
134.104
133.919
131.865
128.497
127.838
127.566
127.164
127.034
126.652
125.736
116.455
33.450
33.055
200
150
100
50
0
ppm (t1)


O
OMe
S

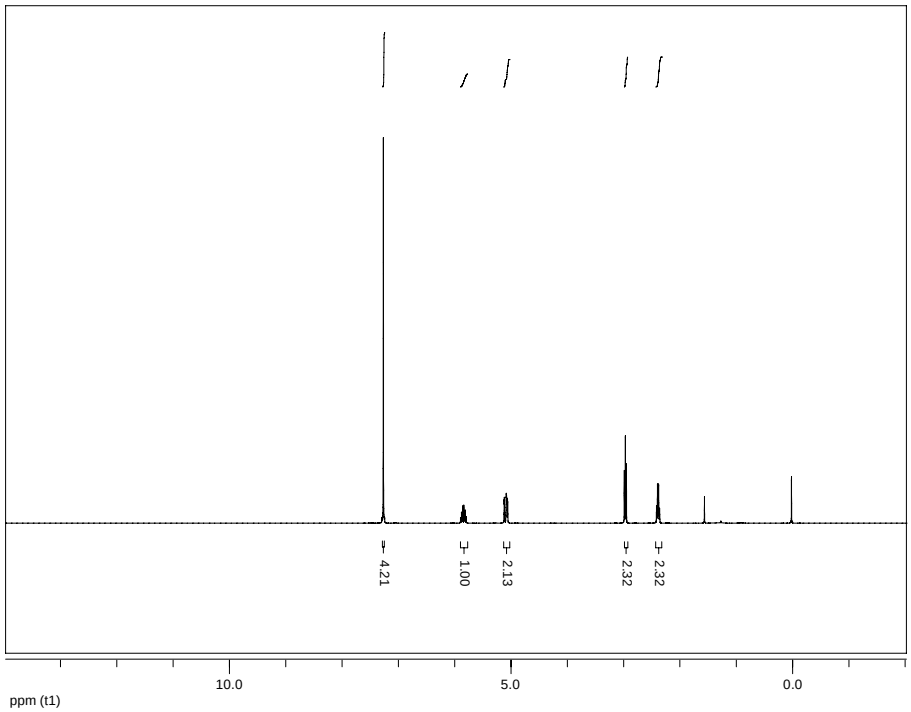
2d

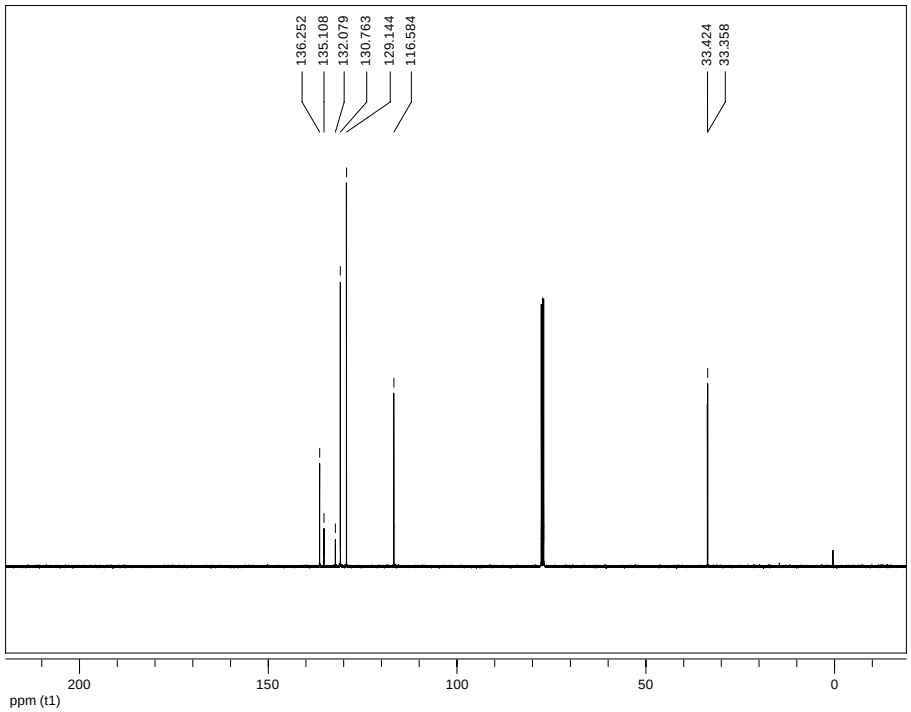

1.00
1.15
1.04
0.98
2.04
3.17
2.27
2.21
10.0
5.0
0.0
ppm (t1)

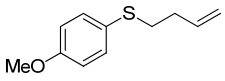

167.064
141.869
136.446
132.425
131.436
127.876
125.743
123.963
116.460
52.227
32.515
31.558
200
150
100
50
0
ppm (t1)


S
Cl

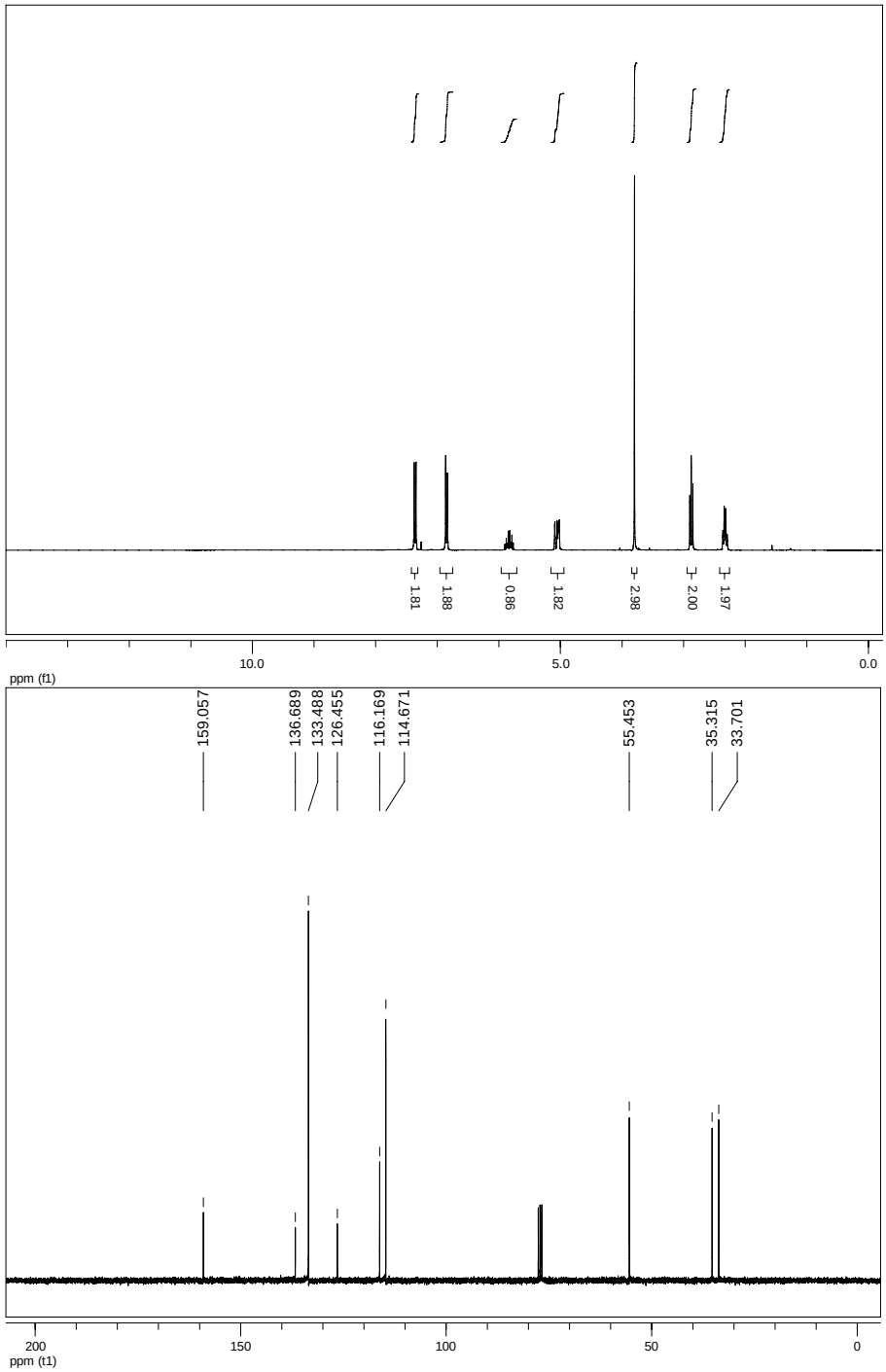
2e

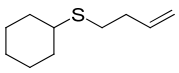

4.21
1.00
2.13
2.32
2.32
10.0
5.0
0.0
ppm (t1)


136.252
135.108
132.079
130.763
129.144
116.584
33.424
33.358
200
150
100
50
0
ppm (t1)

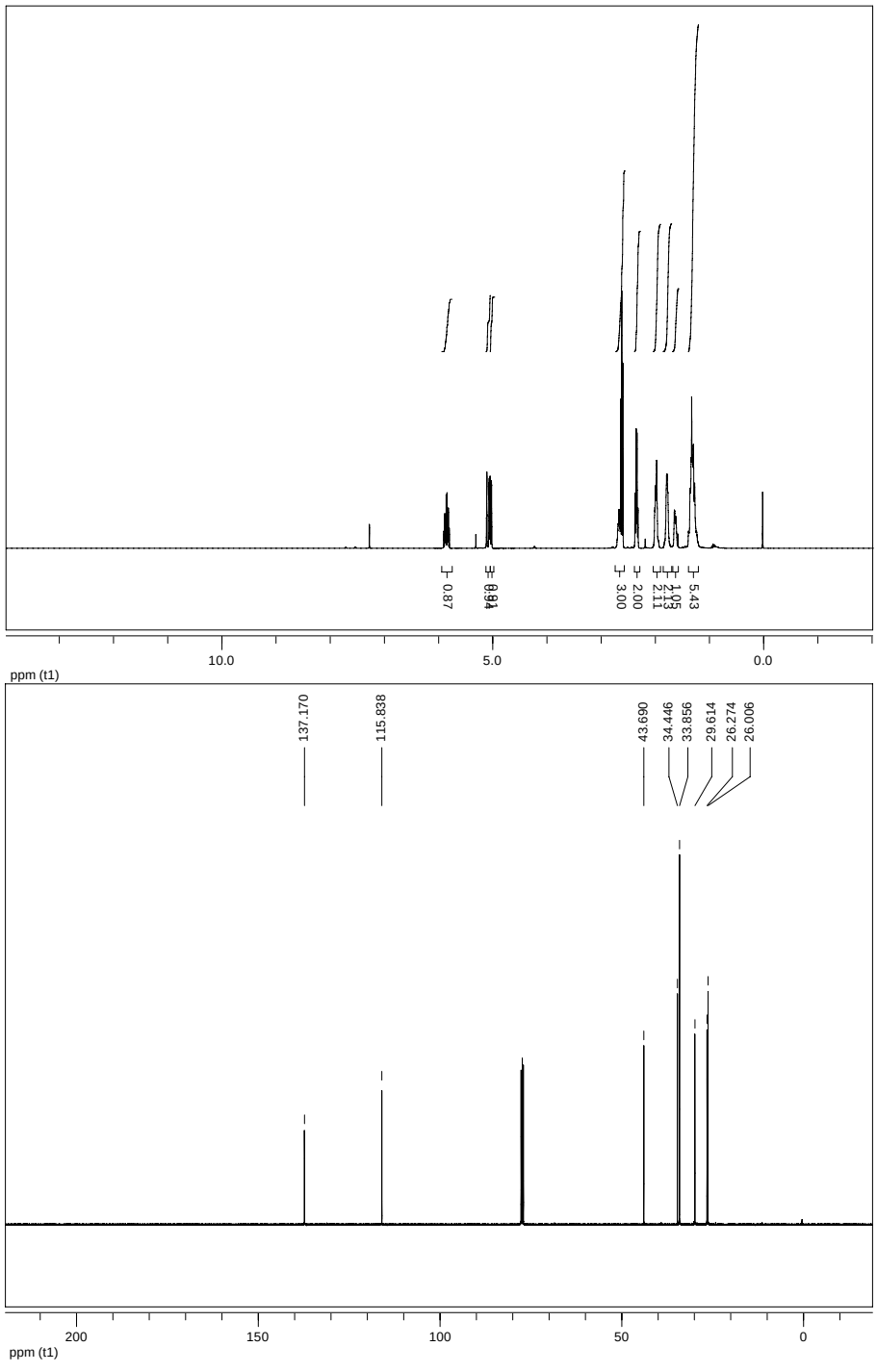

S
MeO

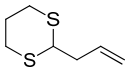
2f


1.81
1.88
0.86
1.82
2.98
2.00
1.67
10.0
5.0
0.0
ppm (f1)
159.057
136.689
133.488
126.455
116.169
114.671
55.453
35.315
33.701
200
150
100
50
0
ppm (f1)

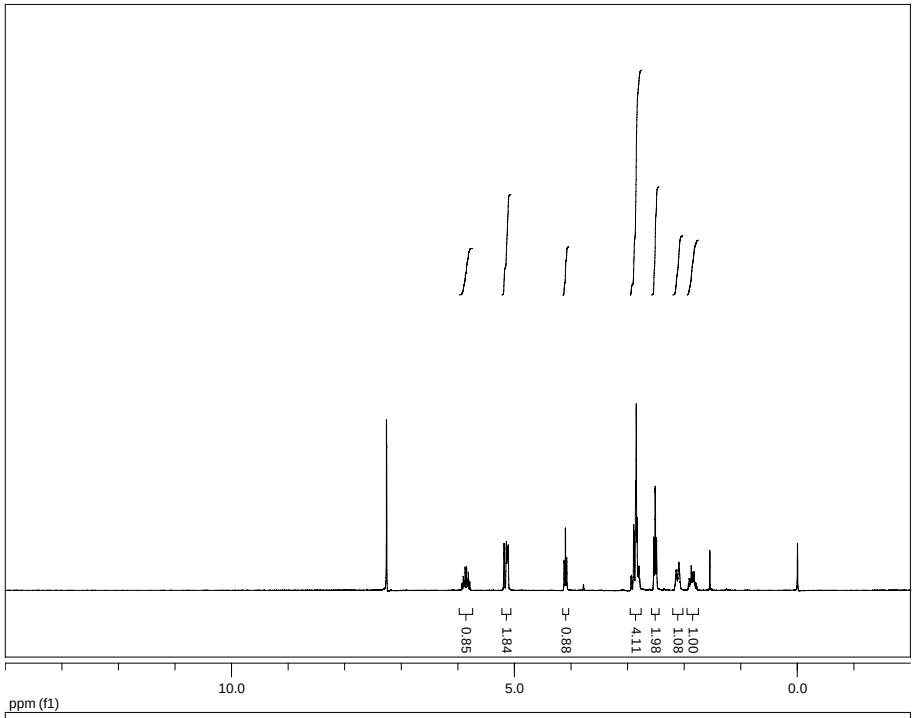


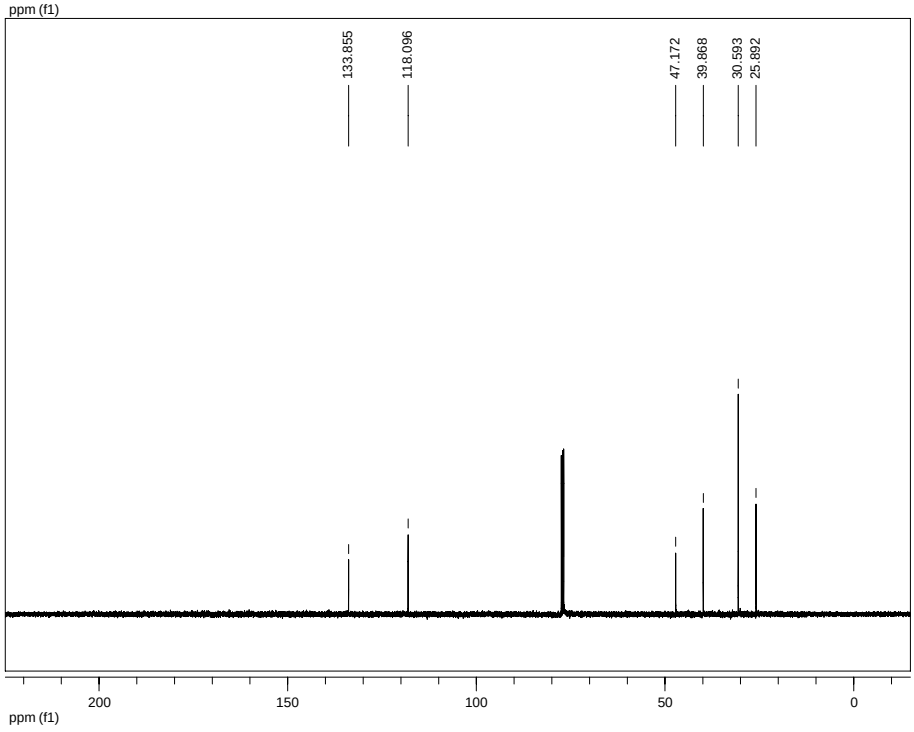
2g

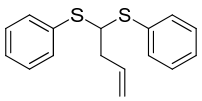

0.87
0.94
3.00
2.00
2.11
2.05
5.43
10.0
5.0
0.0
ppm (t1)
137.170
115.838
43.690
34.446
33.856
29.614
26.274
26.006
200
150
100
50
0
ppm (t1)



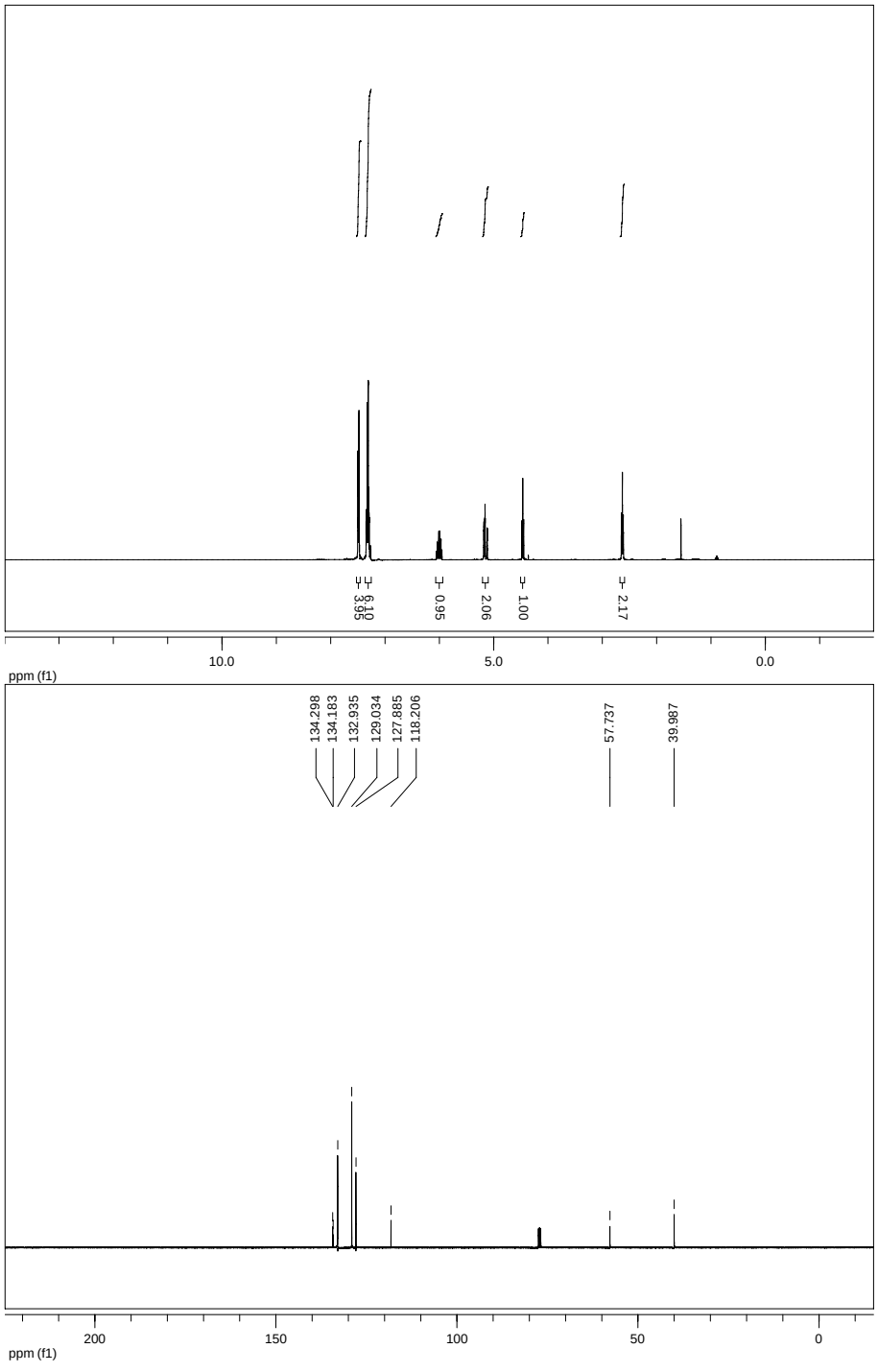
2h

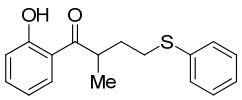

0.85
1.84
0.88
4.11
1.98
1.08
1.00
10.0
5.0
0.0
ppm (f1)


133.855
118.096
47.172
39.868
30.593
25.892
200
150
100
50
0
ppm (f1)

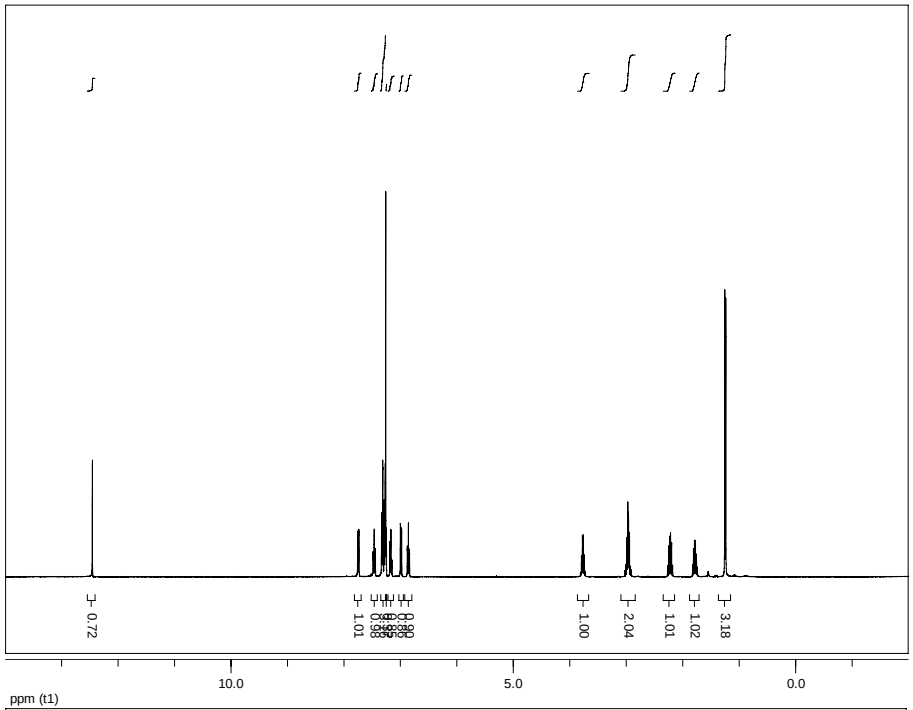


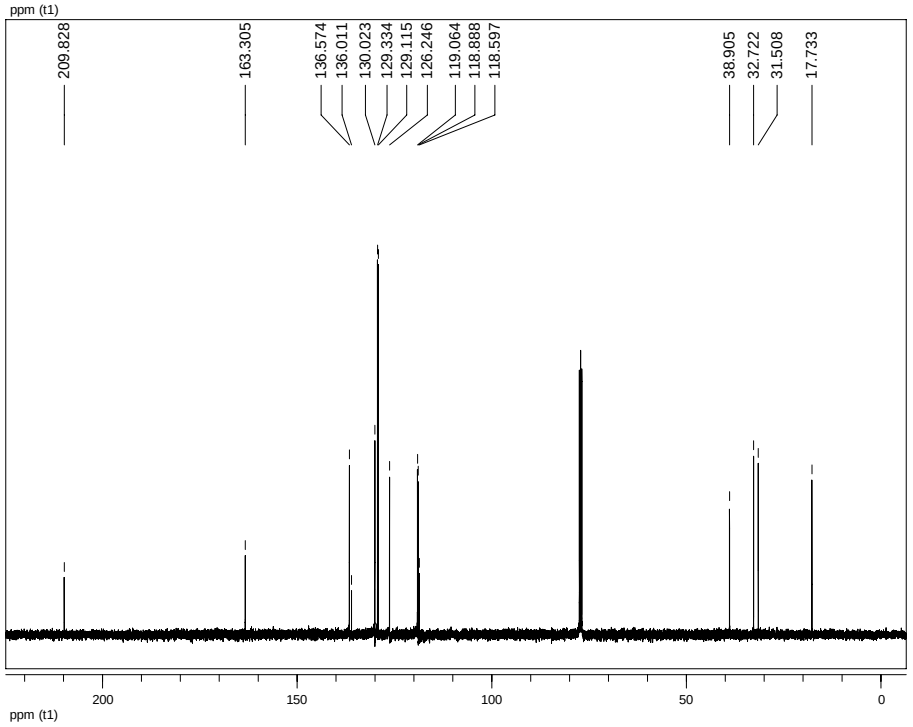
2i


3.95
6.10
0.95
2.06
1.00
2.17
10.0
5.0
0.0
ppm (f1)
134.298
134.183
132.935
129.034
127.885
118.206
57.737
39.987
200
150
100
50
0
ppm (f1)

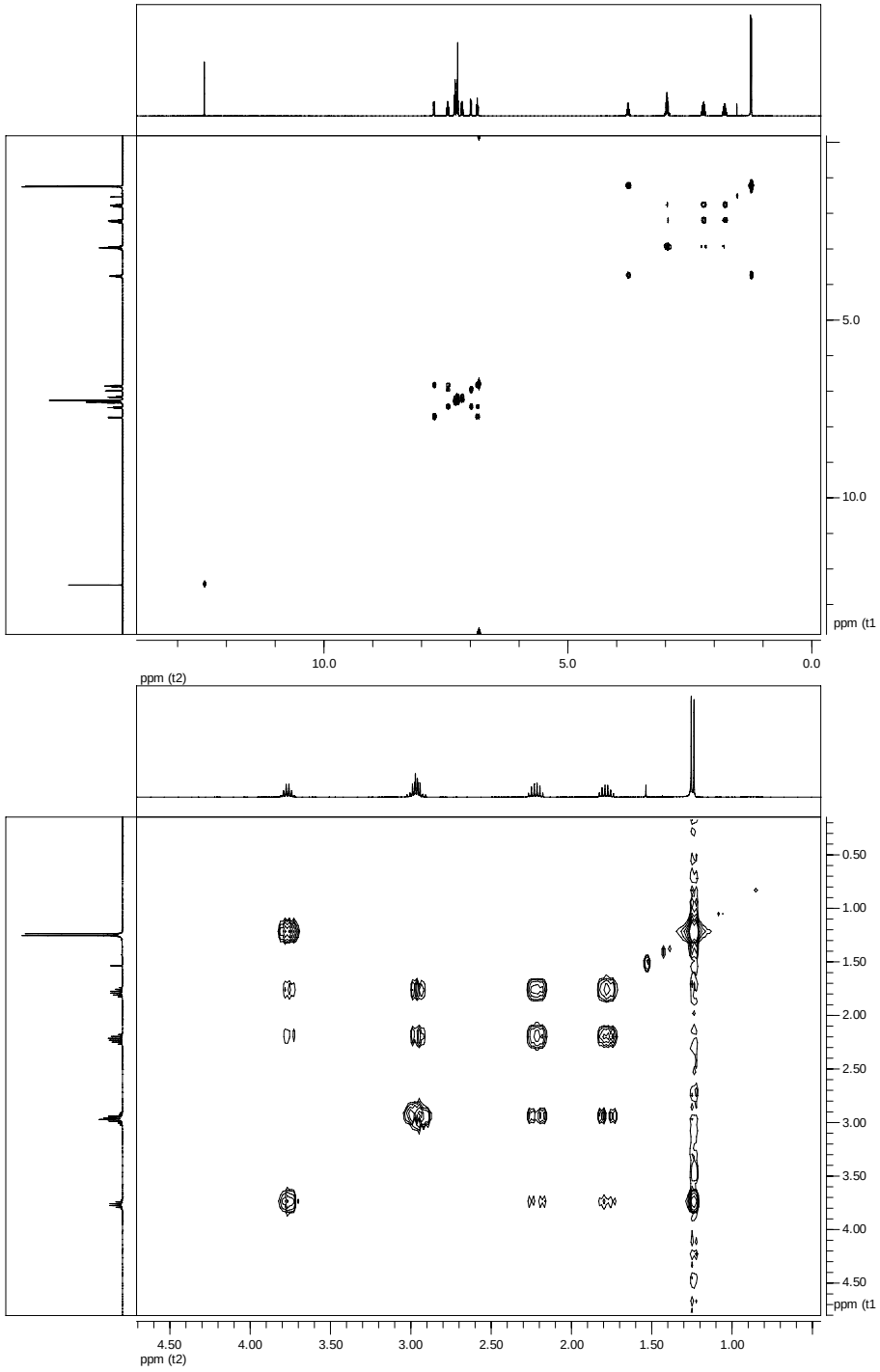

OH
O
S
Me

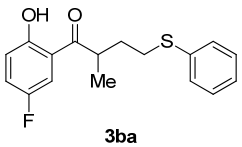
3aa


0.72
1.01
1.00
2.04
1.01
1.02
3.18
10.0
5.0
0.0
ppm (t1)

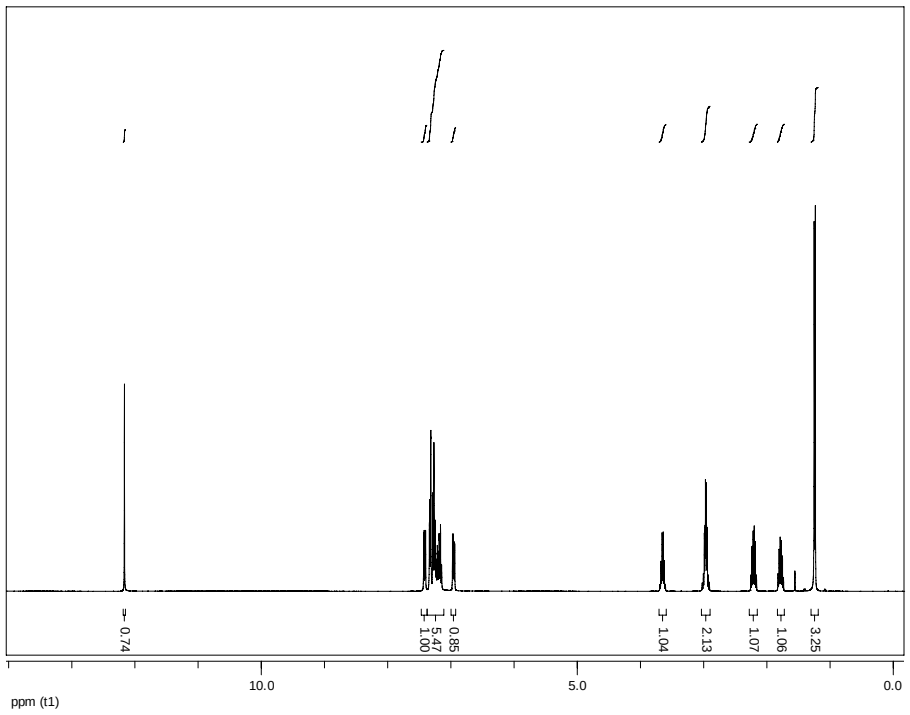

209.828
163.305
136.574
136.011
130.023
129.334
129.115
126.246
119.064
118.888
118.597
38.905
32.722
31.508
17.733
200
150
100
50
0
ppm (t1)

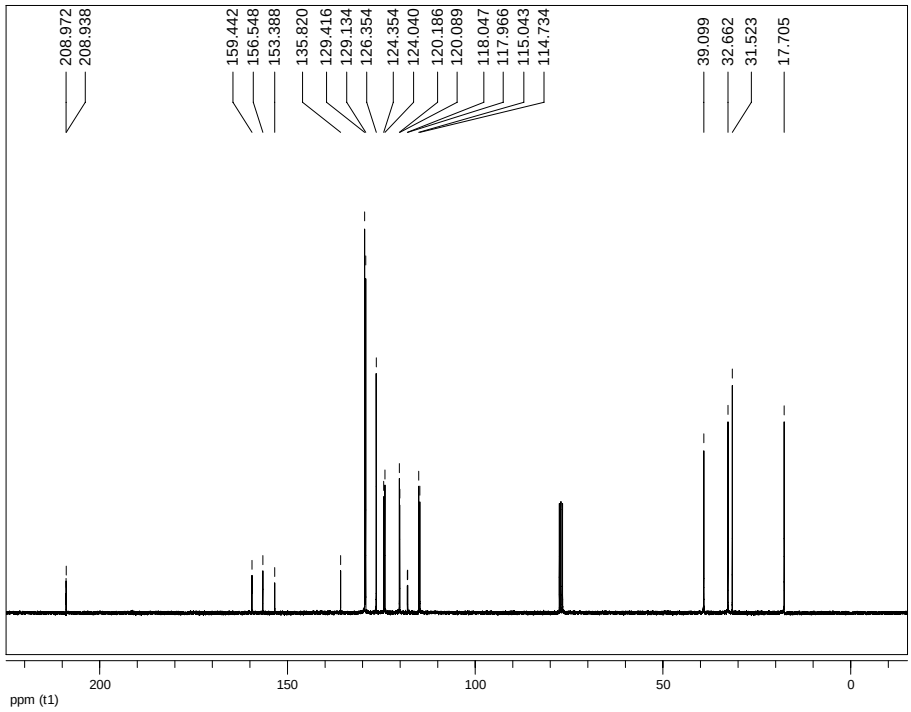
3aa COSY

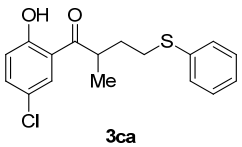

5.0
10.0
ppm (t1
10.0
5.0
0.0
ppm (t2)
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
ppm (t1
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
ppm (t2)


OH
O
S
Me
F

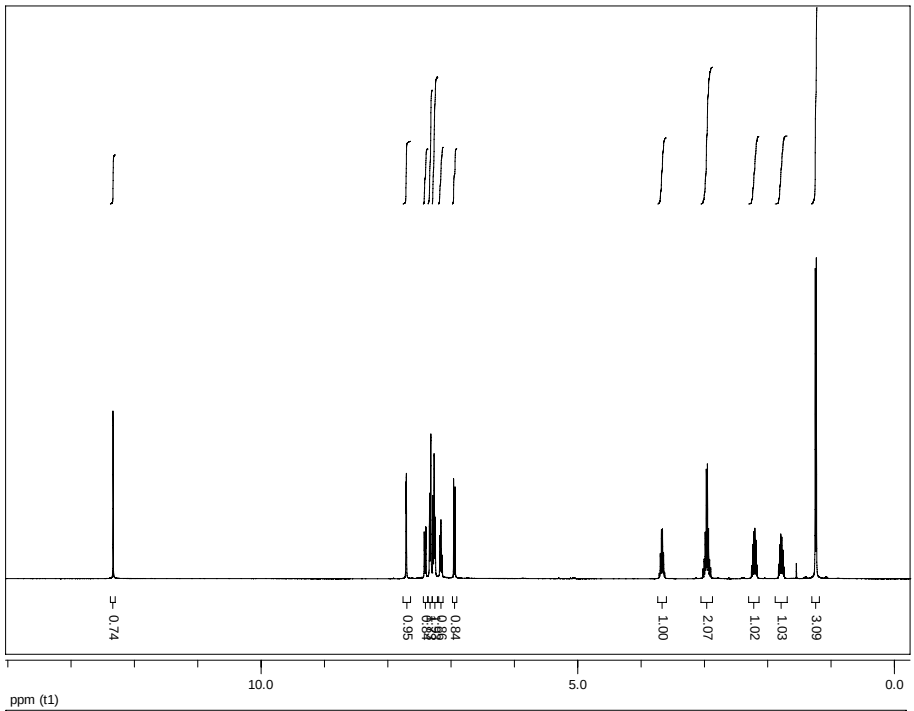
3ba

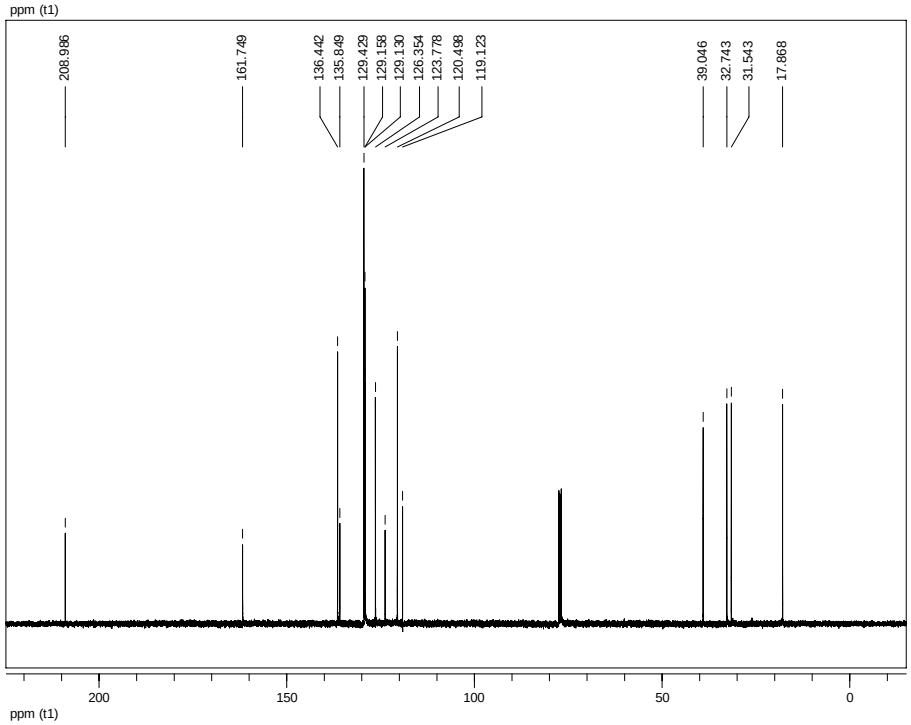

0.74
1.00
5.47
0.85
1.04
2.13
1.07
1.06
3.25
10.0
5.0
0.0
ppm (t1)

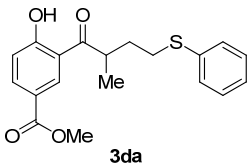

208.972
208.938
159.442
156.548
153.388
135.820
129.416
129.134
126.354
124.354
124.040
120.186
120.089
118.047
117.966
115.043
114.734
39.099
32.662
31.523
17.705
200
150
100
50
0
ppm (t1)


OH
O
S
Me
Cl

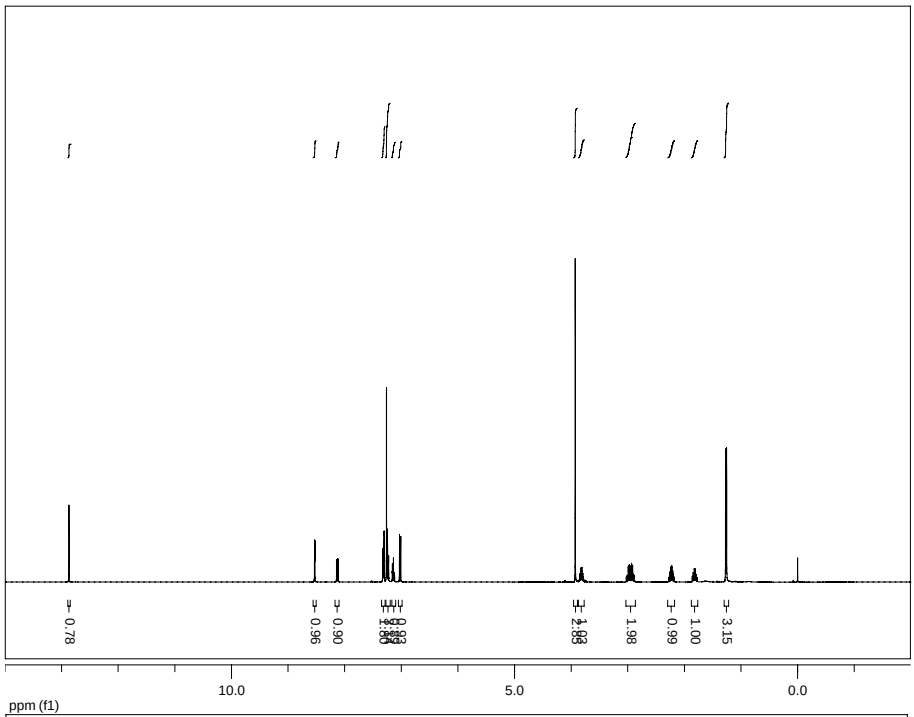
3ca

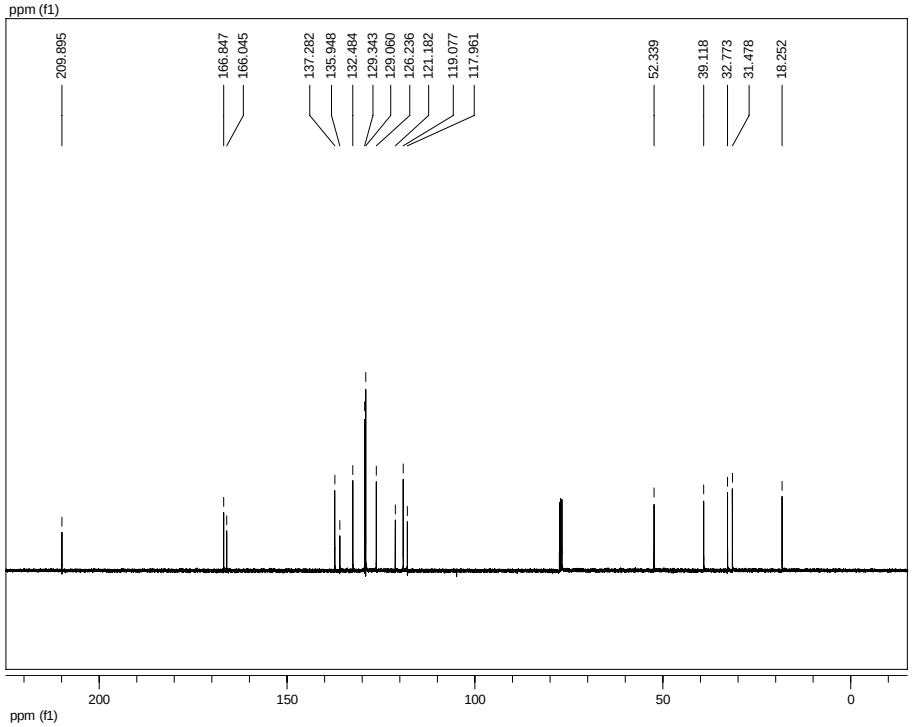

0.74
0.95
0.84
1.00
2.07
1.02
1.03
3.09
10.0
5.0
0.0
ppm (t1)

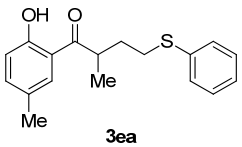

208.986
161.749
136.442
135.849
129.429
129.158
129.130
126.354
123.778
120.498
119.123
39.046
32.743
31.543
17.868
200
150
100
50
0
ppm (t1)


OH
O
S
Me
O
OMe

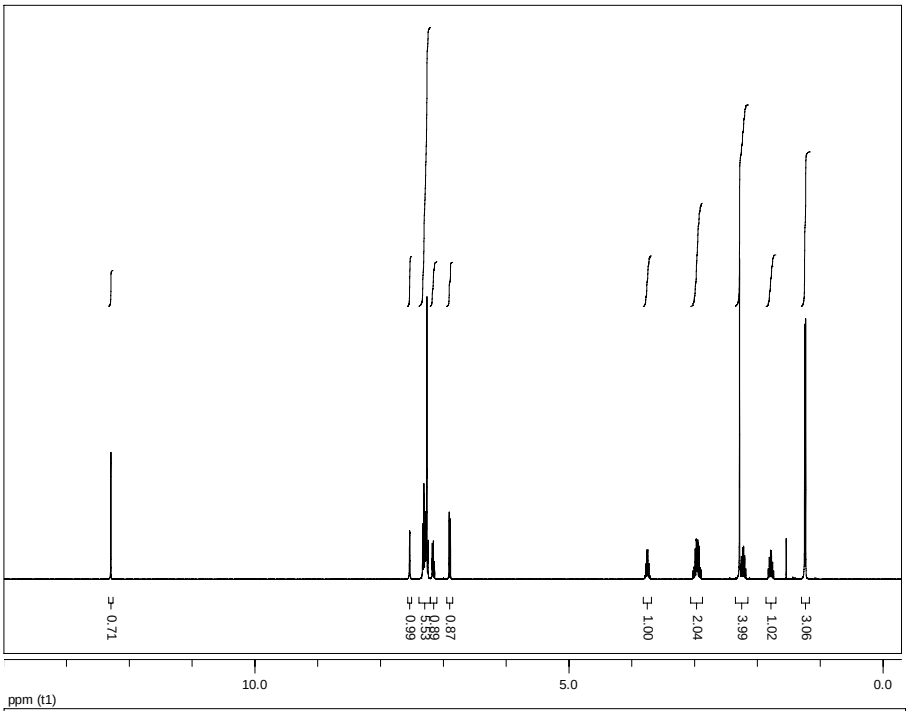
3da

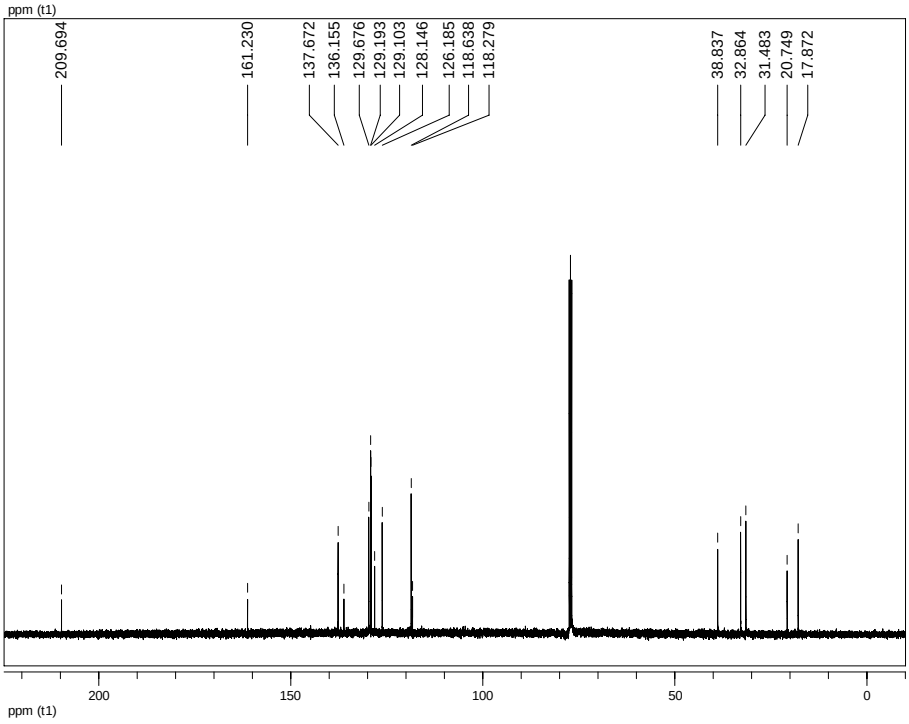

0.78
0.96
0.90
2.88
1.98
0.99
1.00
3.15
10.0
5.0
0.0
ppm (f1)

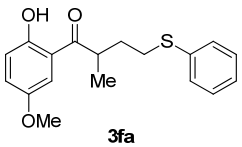

209.895
166.847
166.045
137.282
135.948
132.484
129.343
129.060
126.236
121.182
119.077
117.961
52.339
39.118
32.773
31.478
18.252
200
150
100
50
0
ppm (f1)


OH
O
S
Me
Me

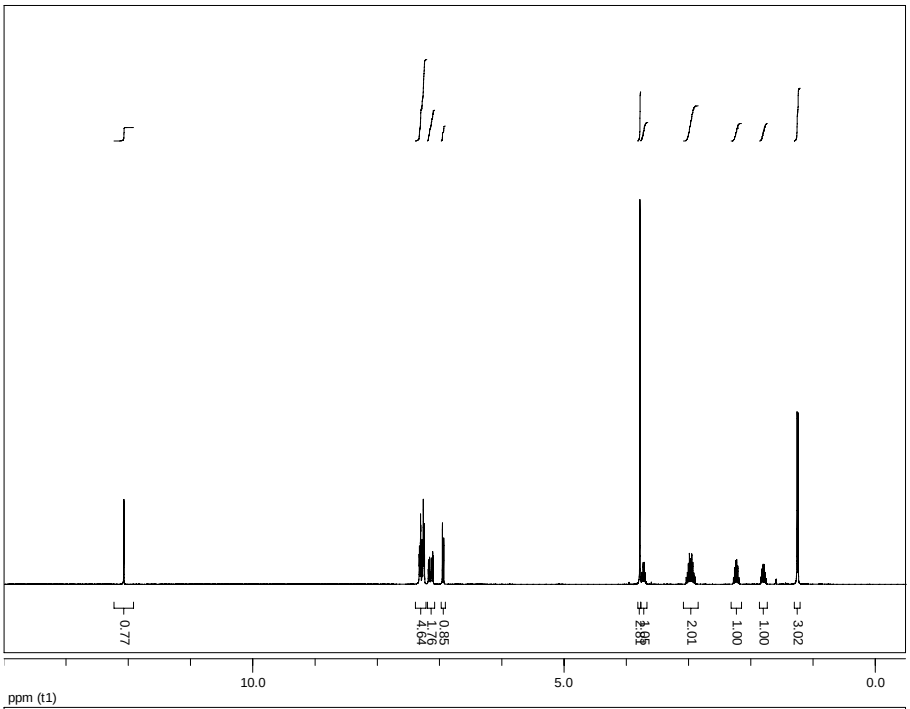
3ea

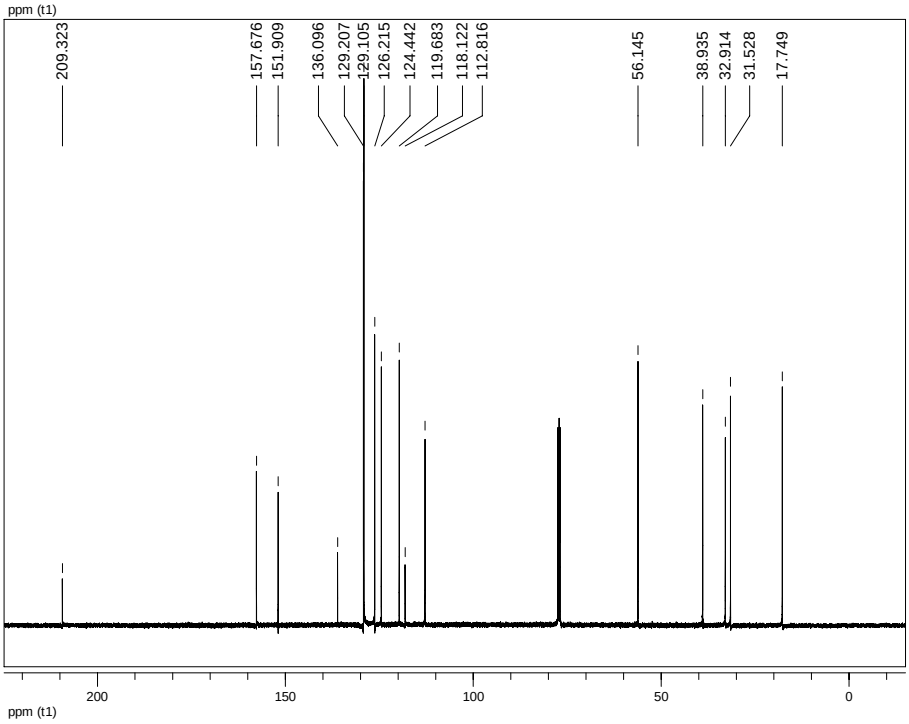

0.71
0.99
0.87
1.00
2.04
3.99
1.02
3.06
10.0
5.0
0.0
ppm (t1)

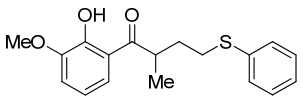

209.694
161.230
137.672
136.155
129.676
129.193
129.103
128.146
126.185
118.638
118.279
38.837
32.864
31.483
20.749
17.872
200
150
100
50
0
ppm (t1)


OH
O
S
Me
OMe

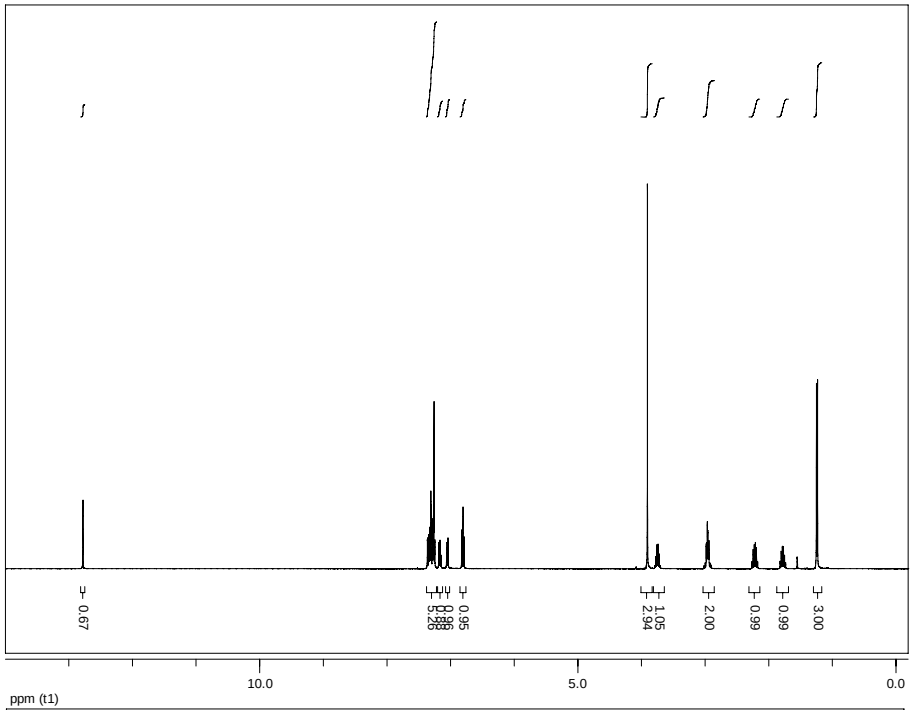
3fa

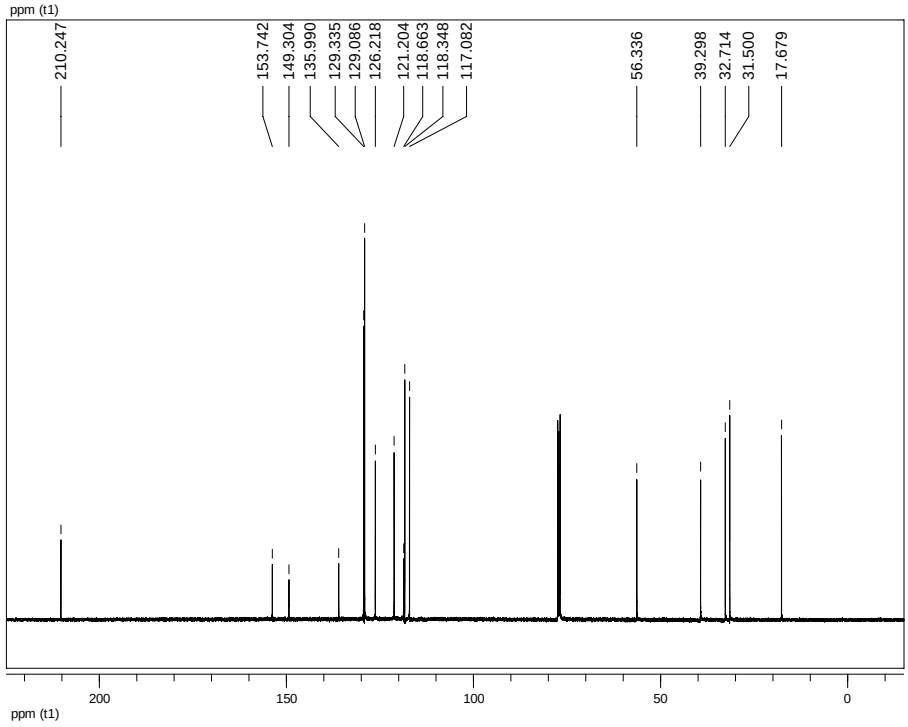

0.77
1.76
1.74
0.85
4.88
4.85
2.01
1.00
1.00
3.02
10.0
5.0
0.0
ppm (t1)

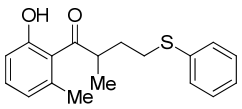

209.323
157.676
151.909
136.096
129.207
129.105
126.215
124.442
119.683
118.122
112.816
56.145
38.935
32.914
31.528
17.749
200
150
100
50
0
ppm (t1)


OH
O
MeO
S
Me

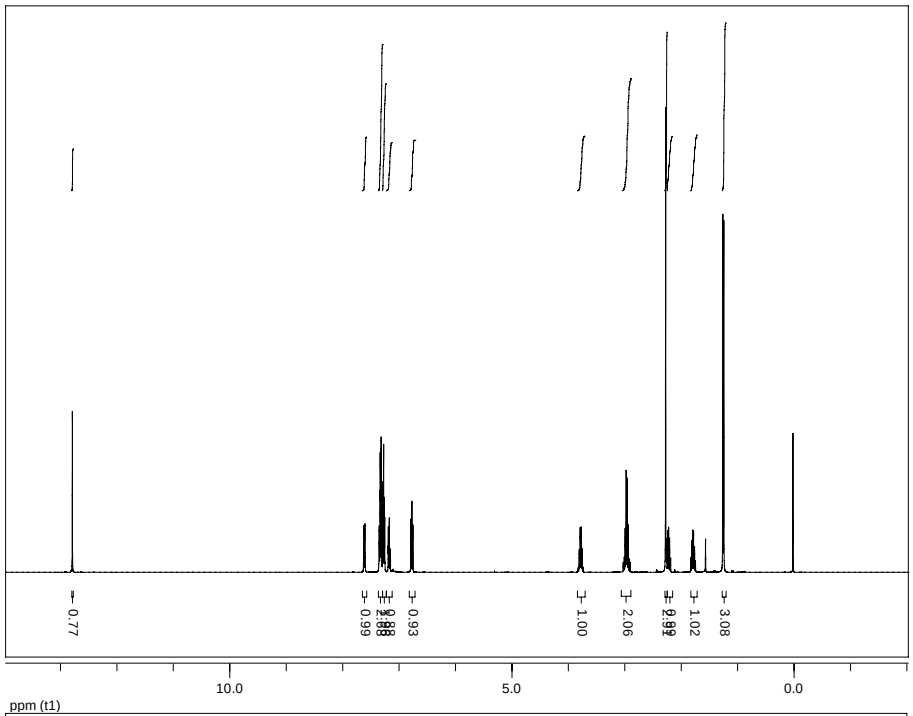
3ga

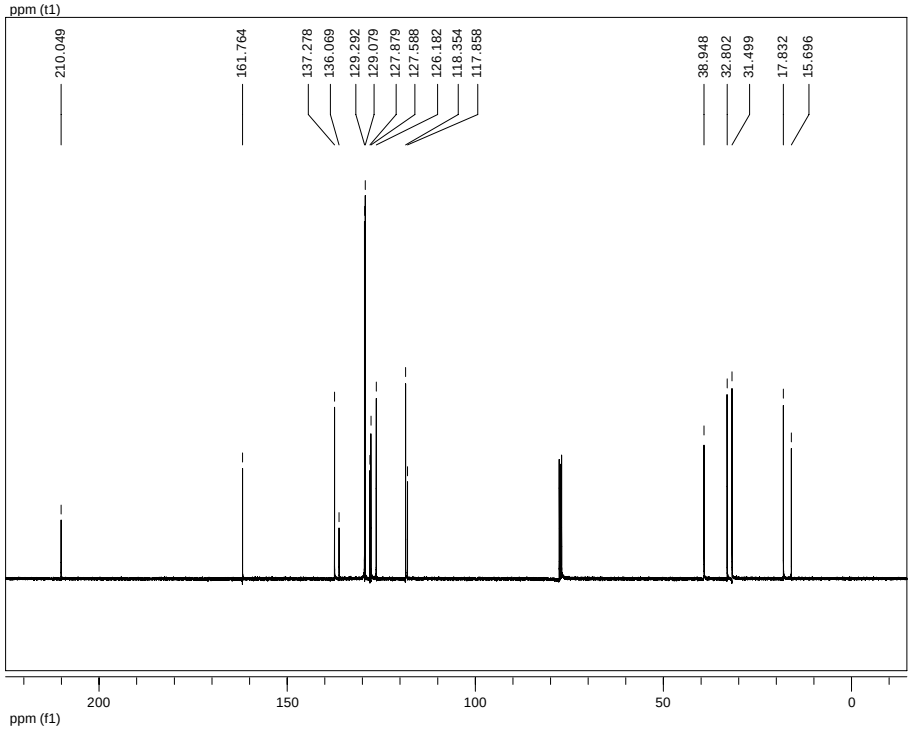

0.67
0.95
1.05
2.94
2.00
0.99
0.99
3.00
10.0
5.0
0.0
ppm (t1)

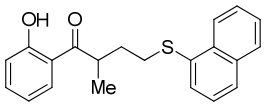

210.247
153.742
149.304
135.990
129.335
129.086
126.218
121.204
118.663
118.348
117.082
56.336
39.298
32.714
31.500
17.679
200
150
100
50
0
ppm (t1)


OH
O
S
Me
Me

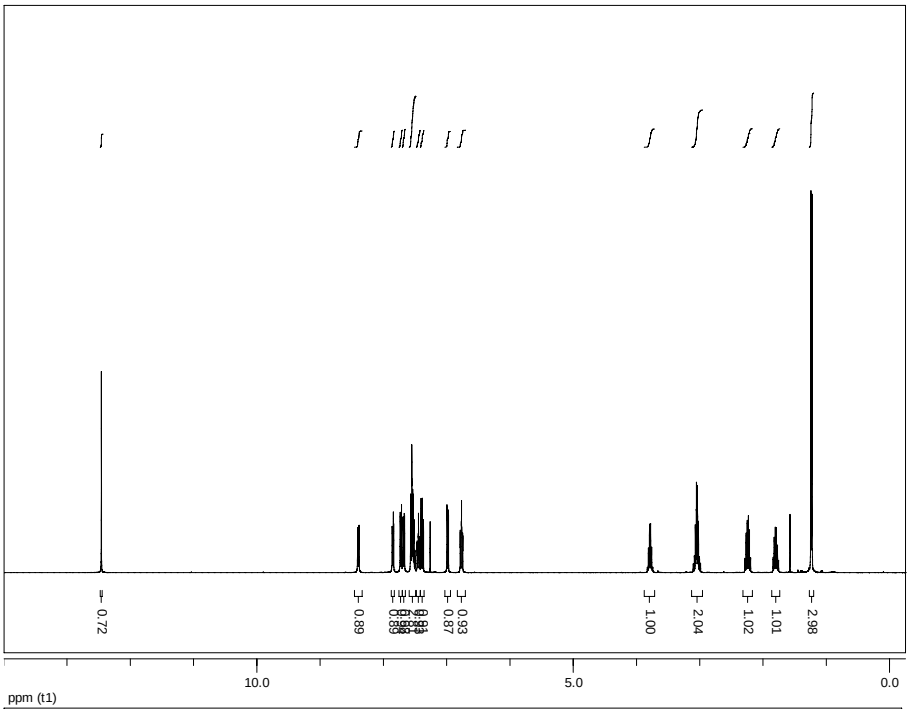
3ha

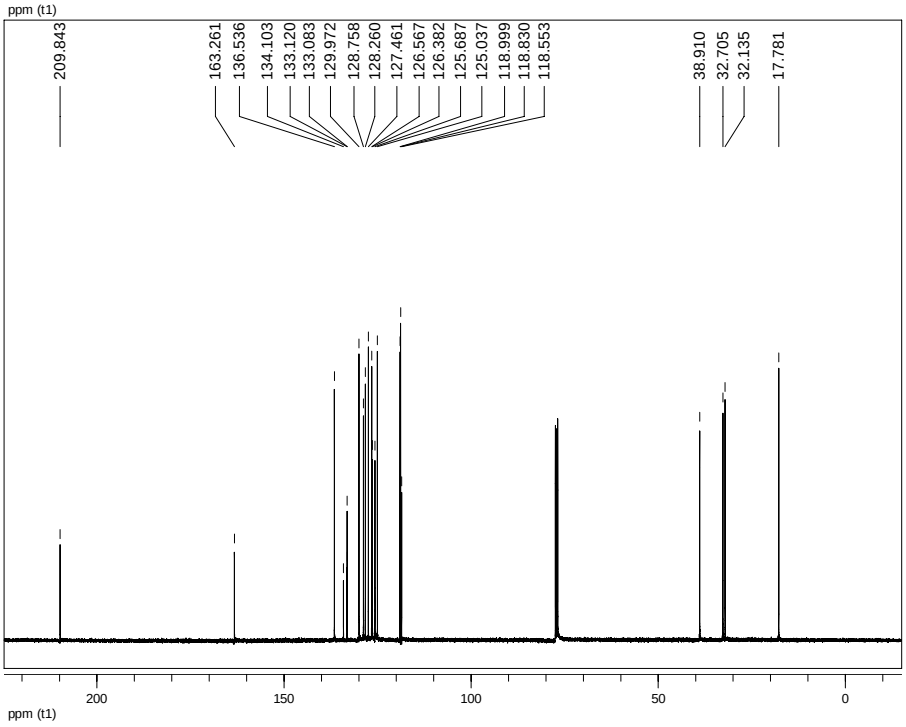

0.77
0.99
0.93
1.00
2.06
1.02
3.08
10.0
5.0
0.0
ppm (t1)

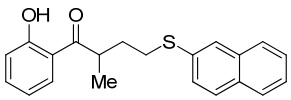

210.049
161.764
137.278
136.069
129.292
129.079
127.879
127.588
126.182
118.354
117.858
38.948
32.802
31.499
17.832
15.696
200
150
100
50
0
ppm (f1)


OH
O
S
Me

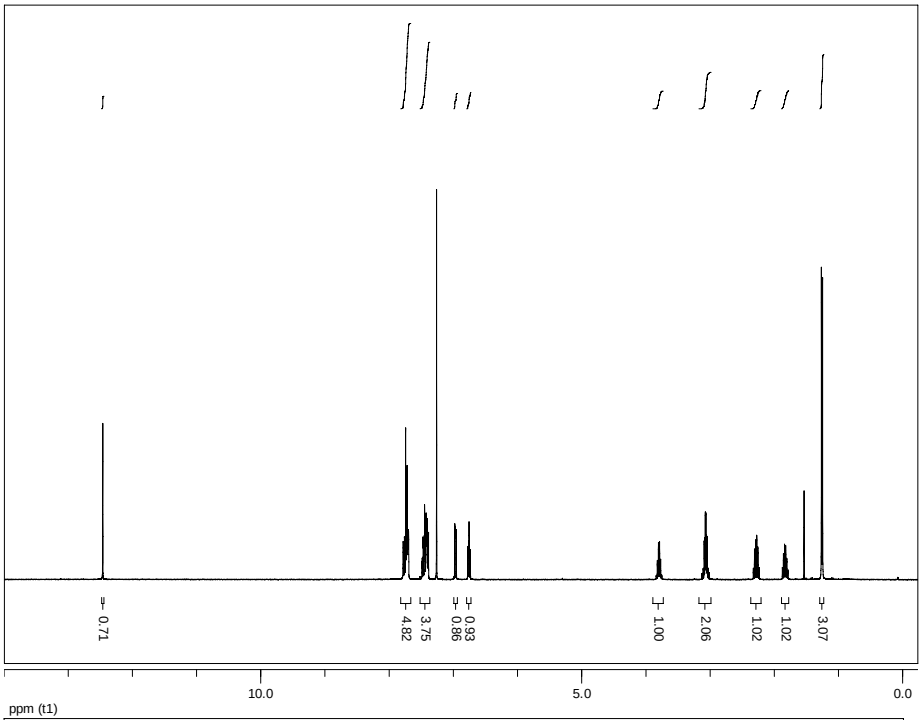
3ab

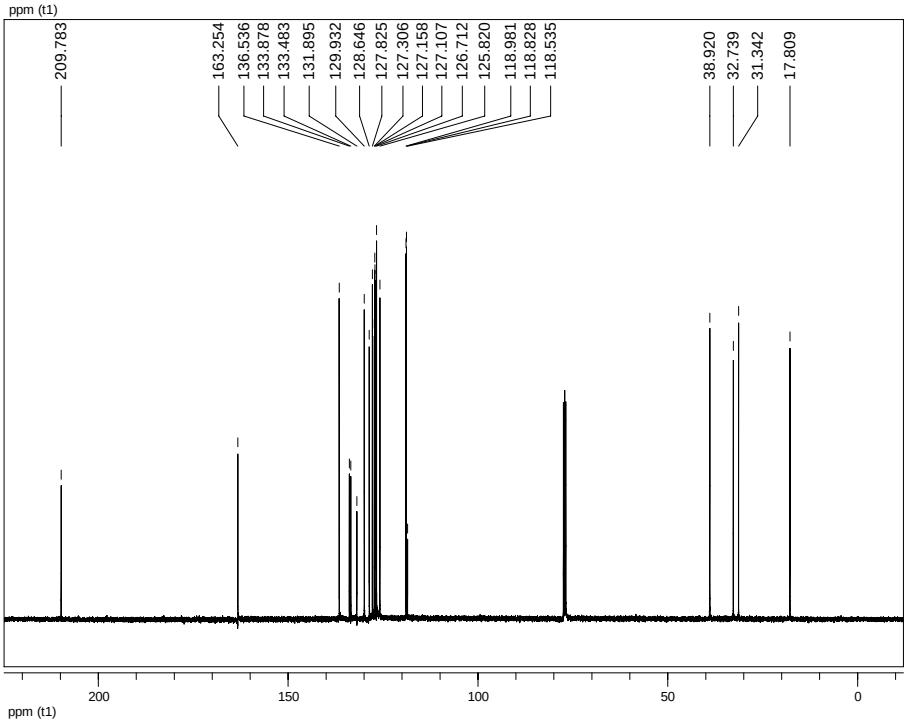

0.72
0.89
0.87
0.93
1.00
2.04
1.02
1.01
2.98
10.0
5.0
0.0
ppm (t1)

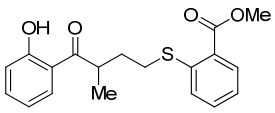

209.843
163.261
136.536
134.103
133.120
133.083
129.972
128.758
128.260
127.461
126.567
126.382
125.687
125.037
118.999
118.830
118.553
38.910
32.705
32.135
17.781
200
150
100
50
0
ppm (t1)


OH
O
S
Me

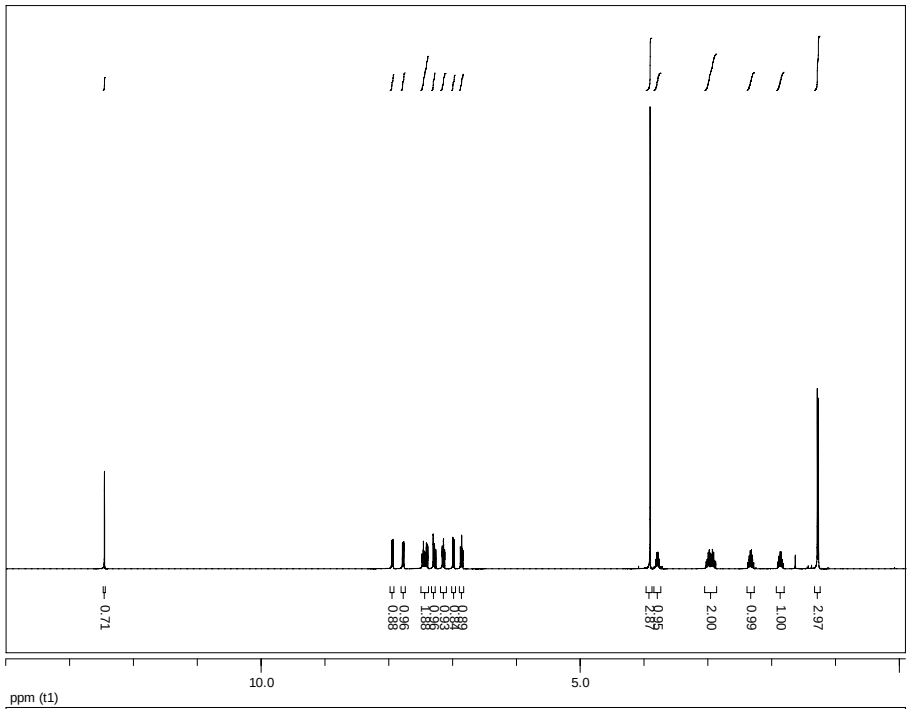
3ac

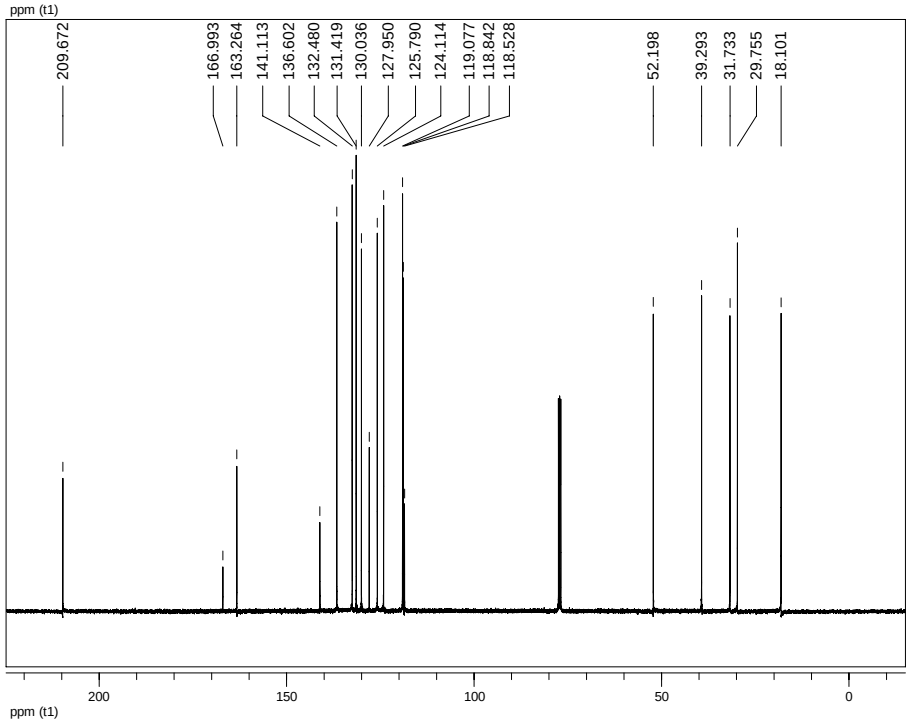

0.71
4.82
3.75
0.86
0.93
1.00
2.06
1.02
1.02
3.07
10.0
5.0
0.0
ppm (t1)

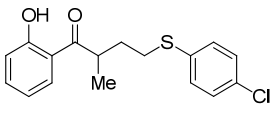

209.783
163.254
136.536
133.878
133.483
131.895
129.932
128.646
127.825
127.306
127.158
127.107
126.712
125.820
118.981
118.828
118.535
38.920
32.739
31.342
17.809
200
150
100
50
0
ppm (t1)


OH
O
O
OMe
S
Me

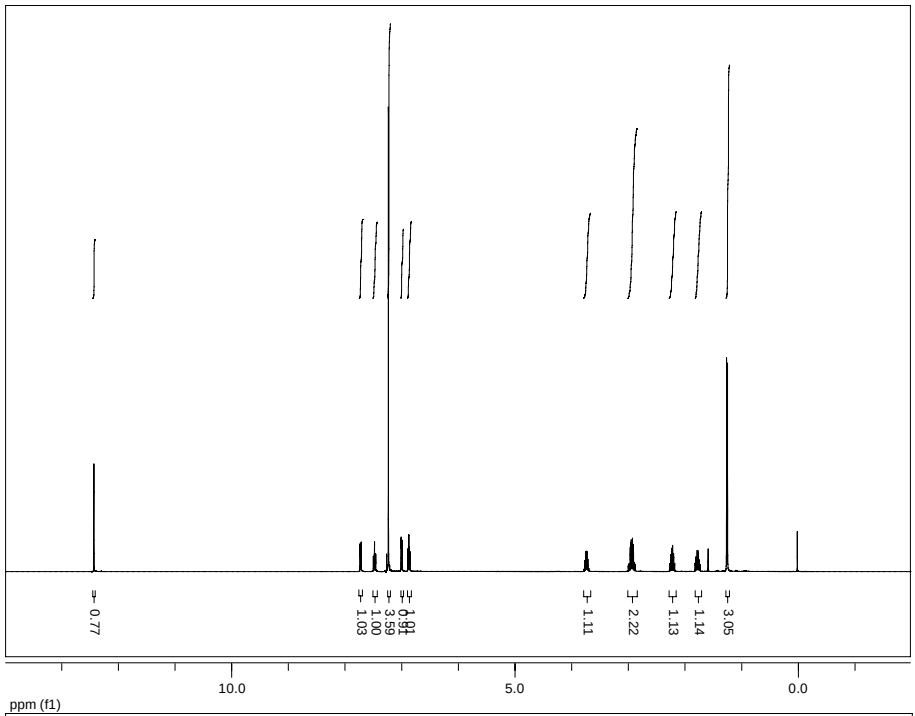
3ad

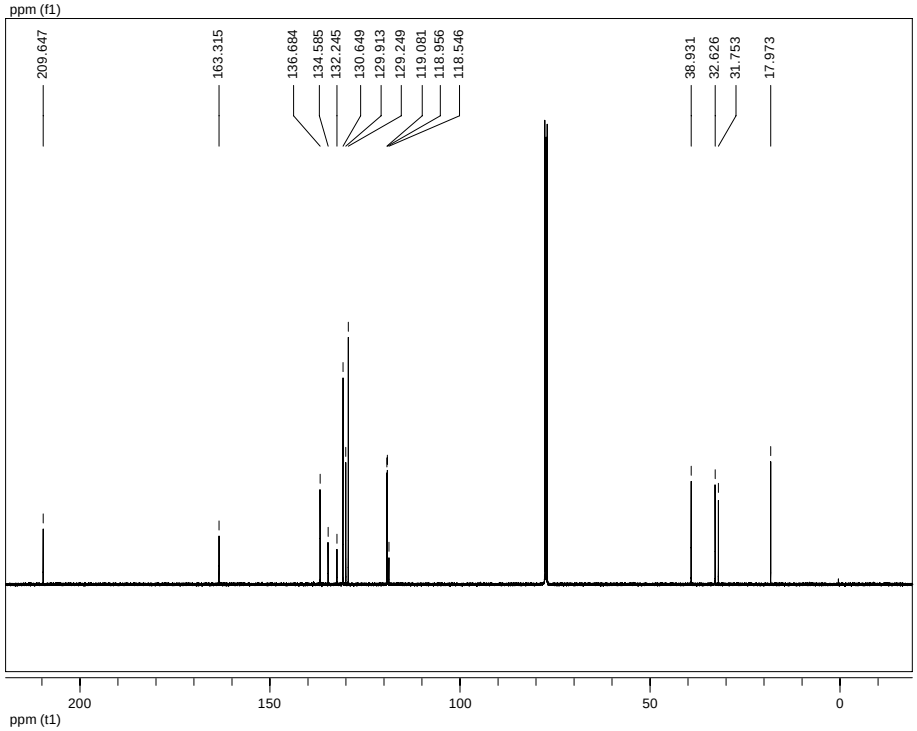

0.71
0.96
0.98
0.88
1.88
2.87
2.00
0.99
1.00
2.97
10.0
5.0
ppm (t1)

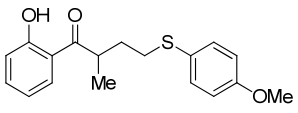

209.672
166.993
163.264
141.113
136.602
132.480
131.419
130.036
127.950
125.790
124.114
119.077
118.842
118.528
52.198
39.293
31.733
29.755
18.101
200
150
100
50
0
ppm (t1)


OH
O
S
Me
Cl

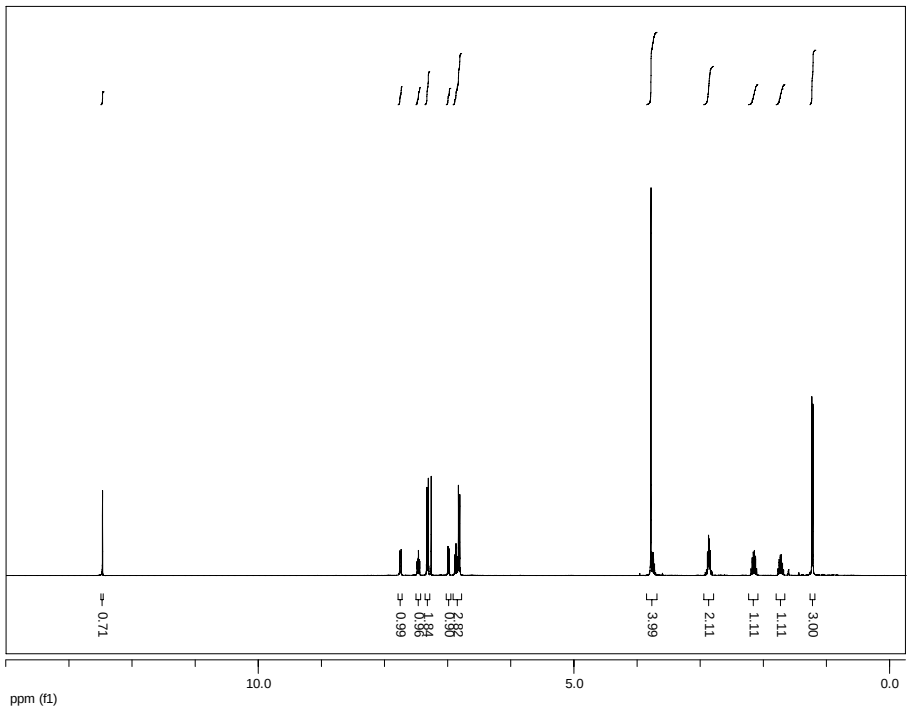
3ae

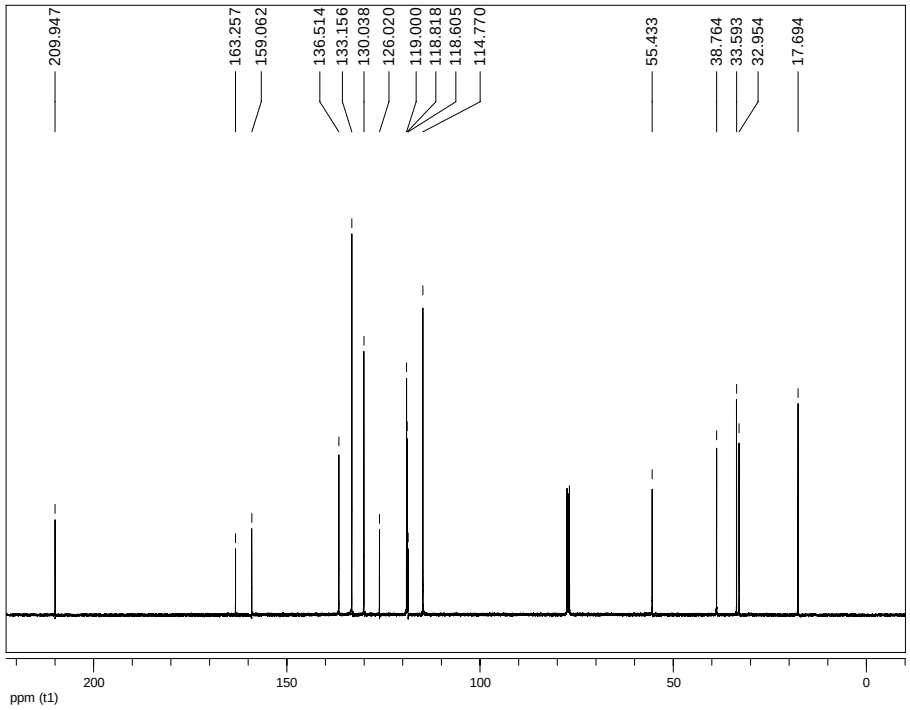

0.77
1.03
1.00
3.59
1.01
0.98
1.11
2.22
1.13
1.14
3.05
10.0
5.0
0.0
ppm (f1)

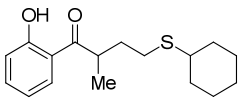

209.647
163.315
136.684
134.585
132.245
130.649
129.913
129.249
119.081
118.956
118.546
38.931
32.626
31.753
17.973
200
150
100
50
0
ppm (t1)


OH
O
S
Me
OMe

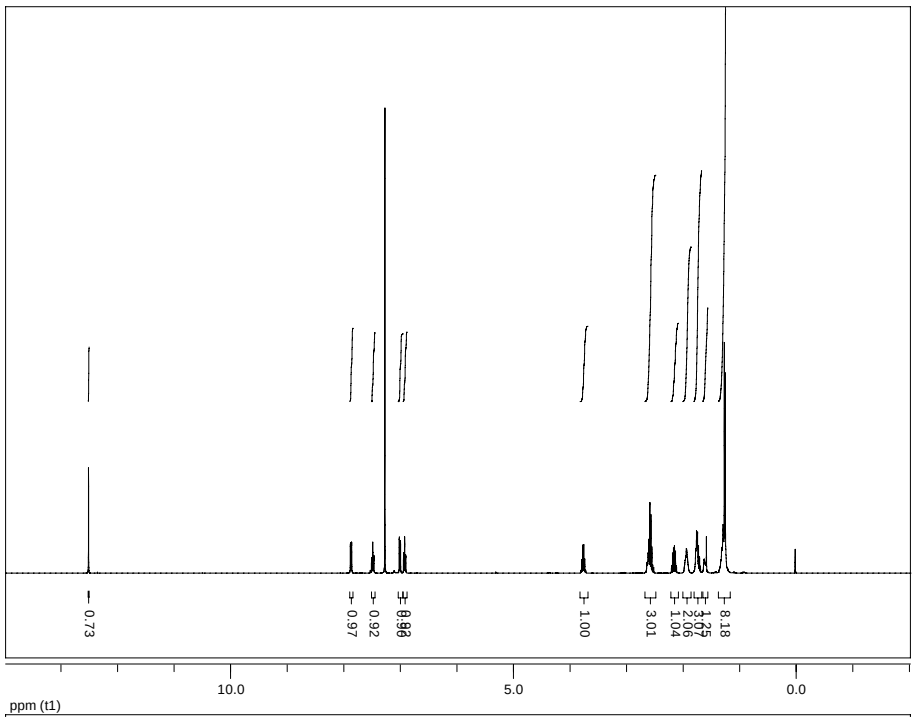
3af

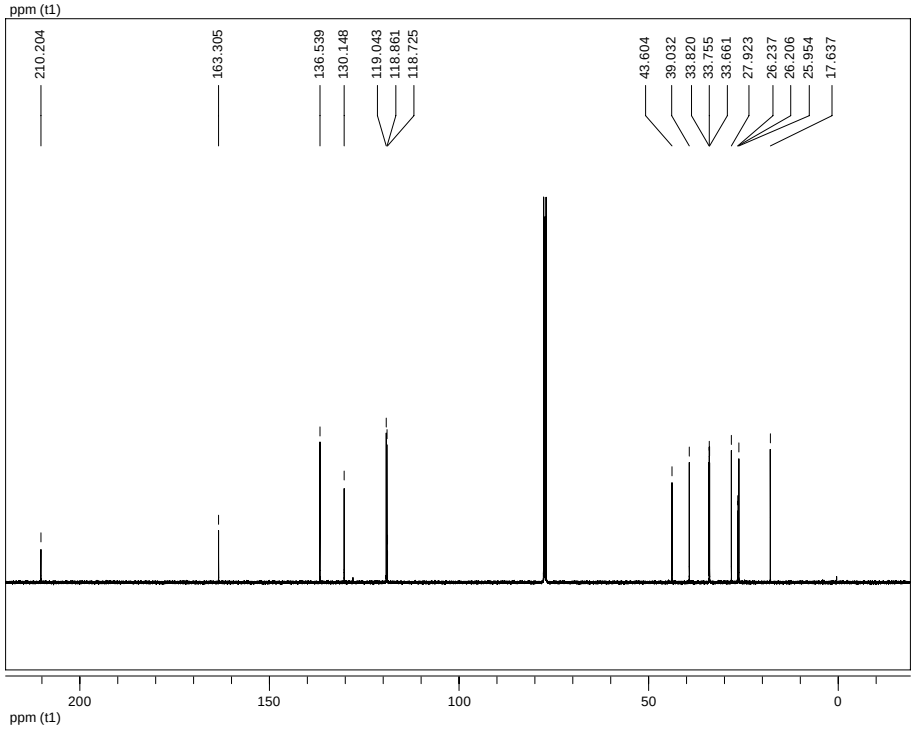

0.71
0.99
1.84
1.96
2.82
2.90
3.99
2.11
1.11
1.11
3.00
10.0
5.0
0.0
ppm (f1)

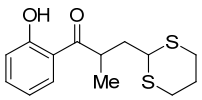

209.947
163.257
159.062
136.514
133.156
130.038
126.020
119.000
118.818
118.605
114.770
55.433
38.764
33.593
32.954
17.694
200
150
100
50
0
ppm (t1)


OH
O
S
Me

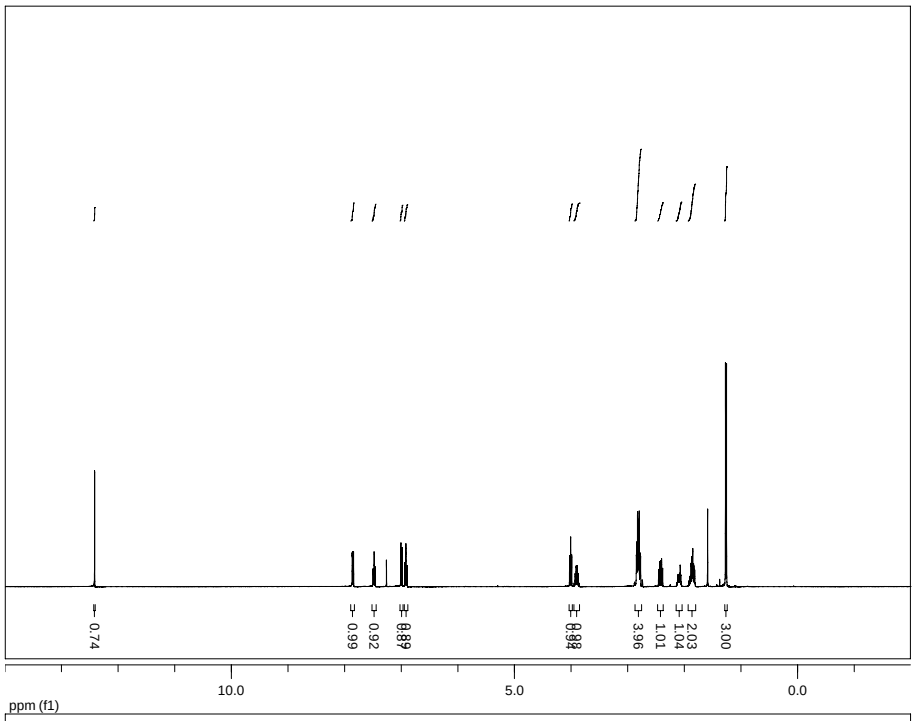
3ag

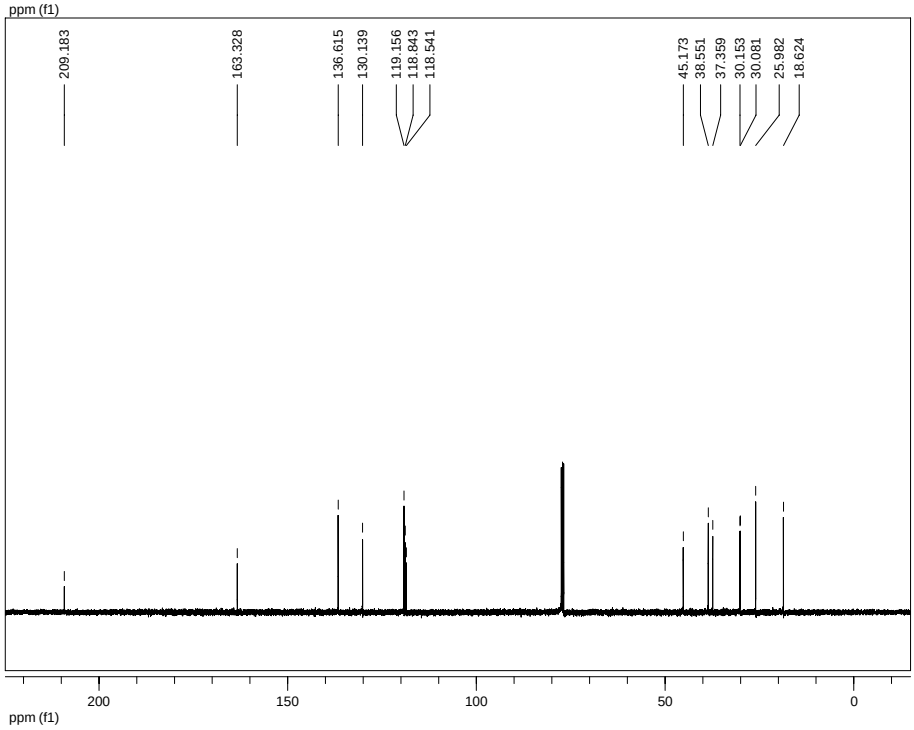

0.73
0.97
0.92
1.00
3.01
1.04
2.06
1.75
1.07
8.18
10.0
5.0
0.0
ppm (t1)

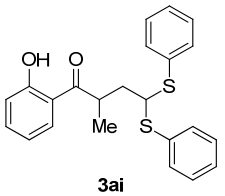

210.204
163.305
136.539
130.148
119.043
118.861
118.725
43.604
39.032
33.820
33.755
33.661
27.923
26.237
26.206
25.954
17.637
200
150
100
50
0
ppm (t1)


OH
O
S
Me
S

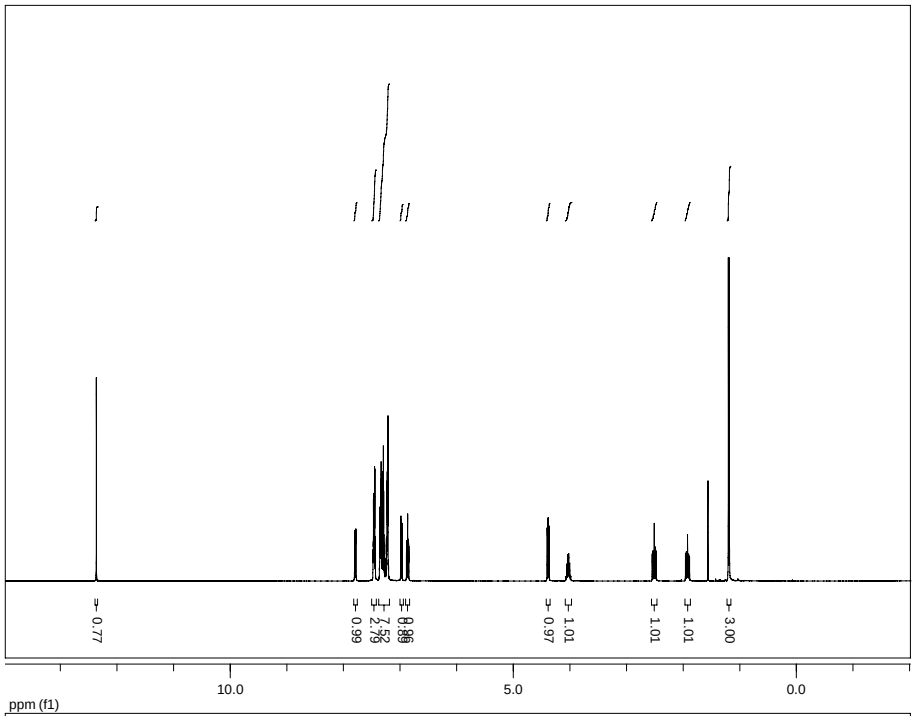
3ah

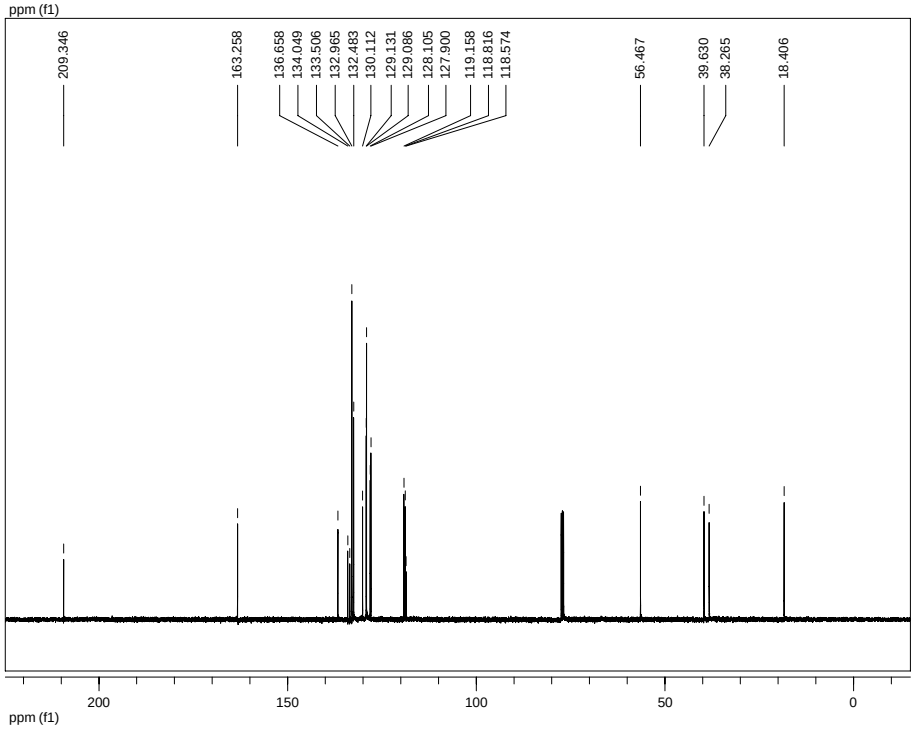

0.74
0.99
0.92
0.89
0.88
0.98
0.97
3.96
1.01
1.04
2.03
3.00
10.0
5.0
0.0
ppm (f1)

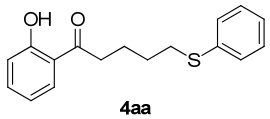

209.183
163.328
136.615
130.139
119.156
118.843
118.541
45.173
38.551
37.359
30.153
30.081
25.982
18.624
200
150
100
50
0
ppm (f1)


OH
O
S
Me
S

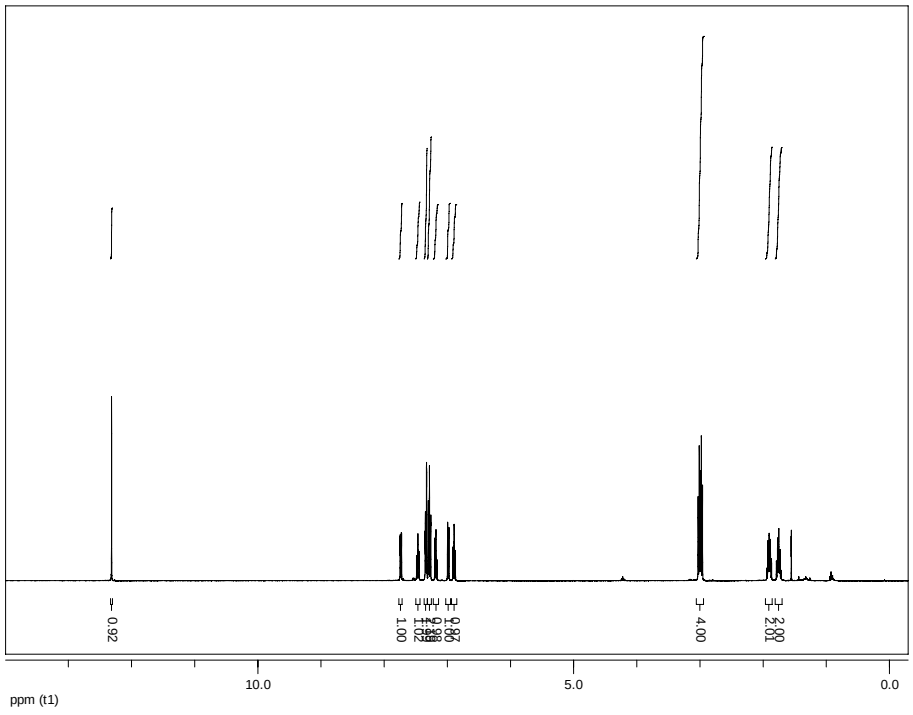
3ai

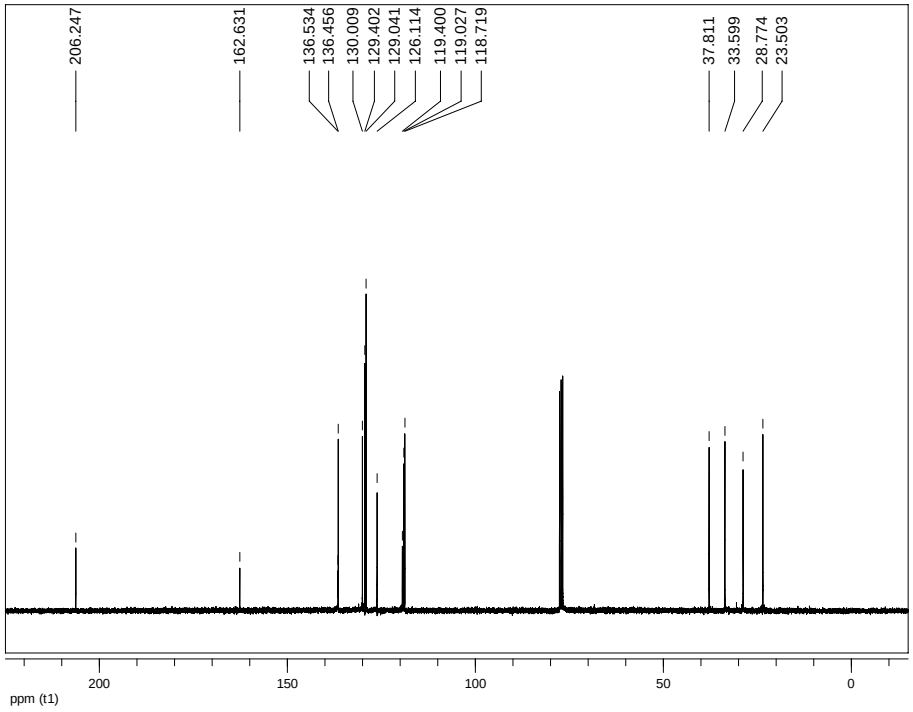

0.77
0.99
2.23
2.25
2.26
2.28
0.97
1.01
1.01
1.01
3.00
10.0
5.0
0.0
ppm (f1)

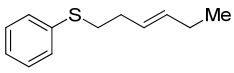

209.346
163.258
136.658
134.049
133.506
132.965
132.483
130.112
129.131
129.086
128.105
127.900
119.158
118.816
118.574
56.467
39.630
38.265
18.406
200
150
100
50
0
ppm (f1)


OH
O
S

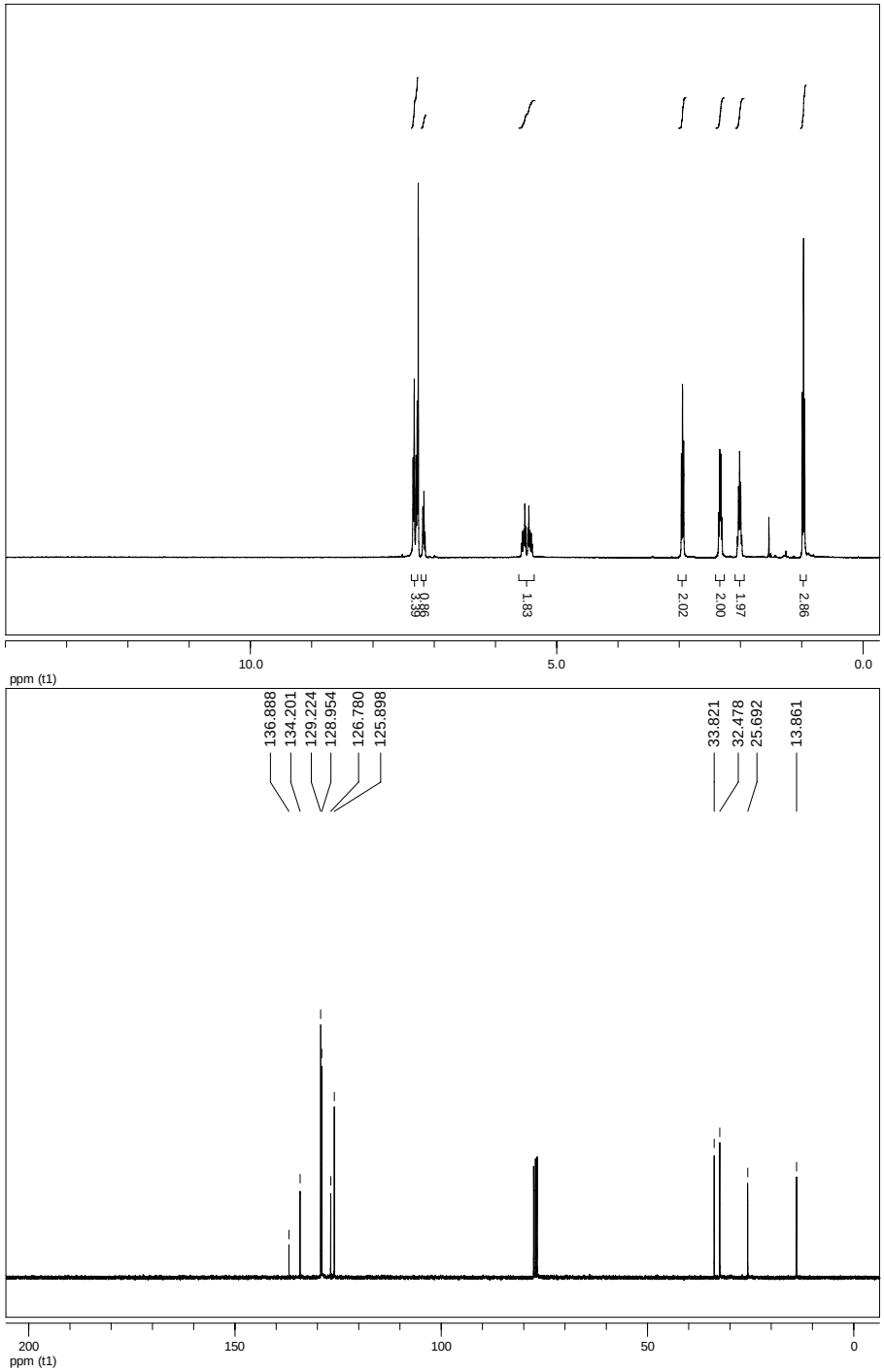
4aa

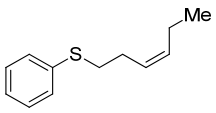

0.92
1.00
2.07
4.00
2.01
10.0
5.0
0.0
ppm (t1)


206.247
162.631
136.534
136.456
130.009
129.402
129.041
126.114
119.400
119.027
118.719
37.811
33.599
28.774
23.503
200
150
100
50
0
ppm (t1)

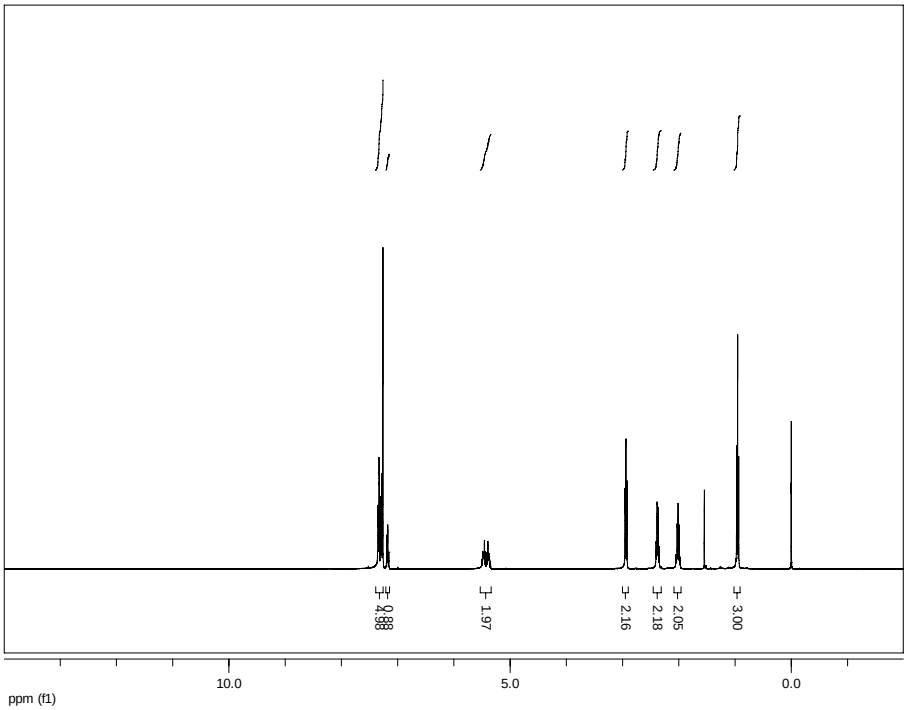

S
Me

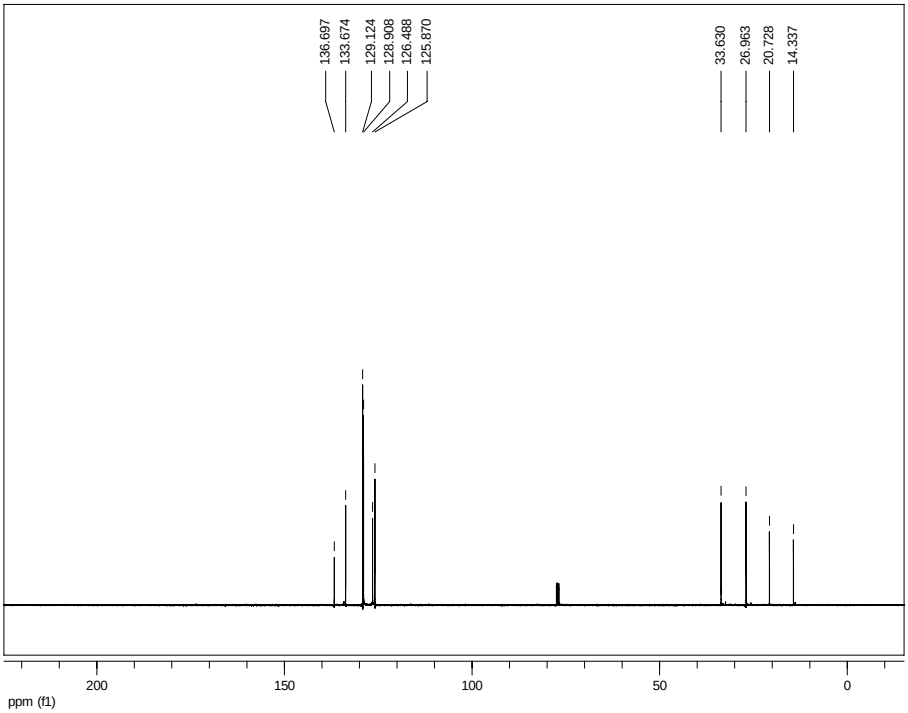
5

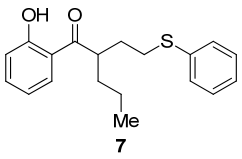

3.00
1.83
2.02
2.00
1.97
2.86
10.0
5.0
0.0
ppm (t1)
136.888
134.201
129.224
128.954
126.780
125.898
33.821
32.478
25.692
13.861
200
150
100
50
0
ppm (t1)


Me
S

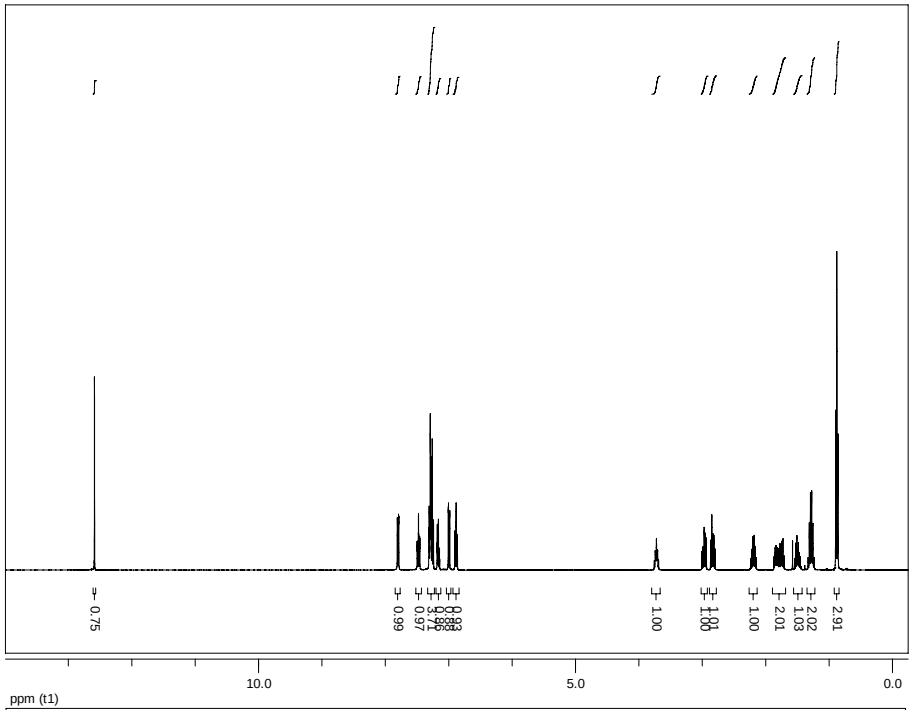
6

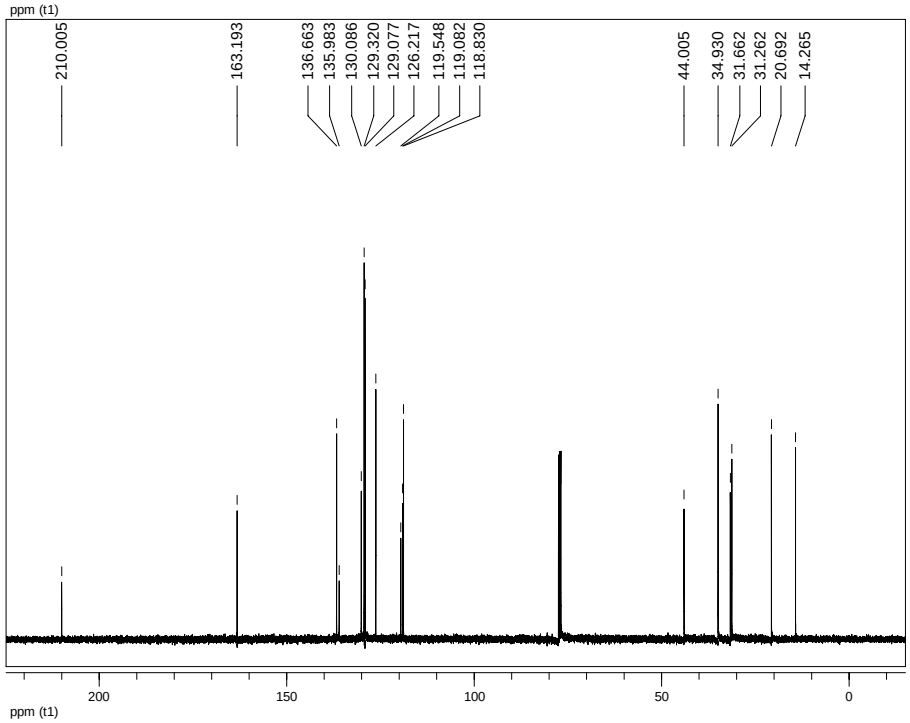

4.98
4.98
1.97
2.16
2.18
2.05
3.00
10.0
5.0
0.0
ppm (f1)


136.697
133.674
129.124
128.908
126.488
125.870
33.630
26.963
20.728
14.337
200
150
100
50
0
ppm (f1)

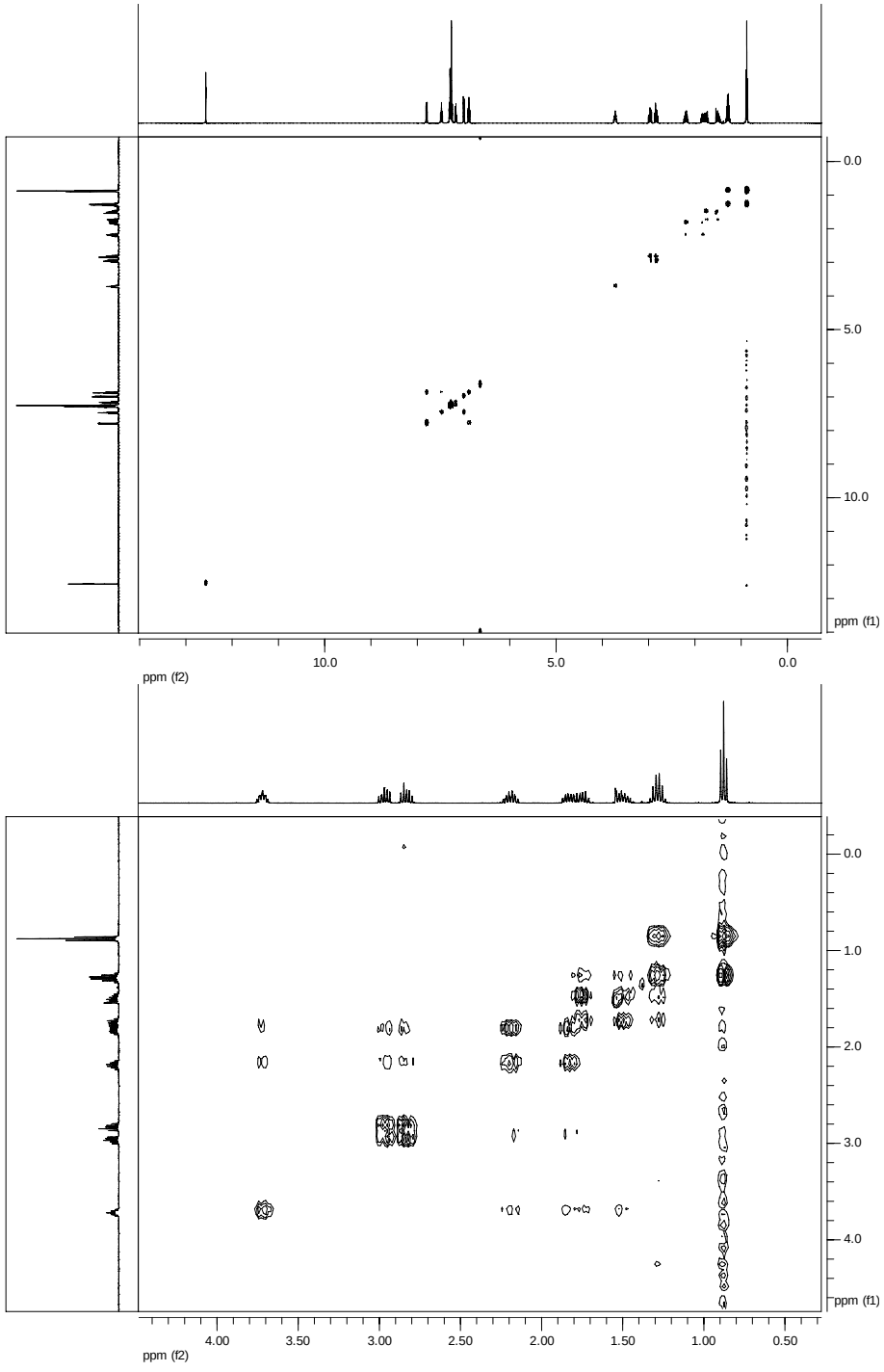

OH
O
S
Me

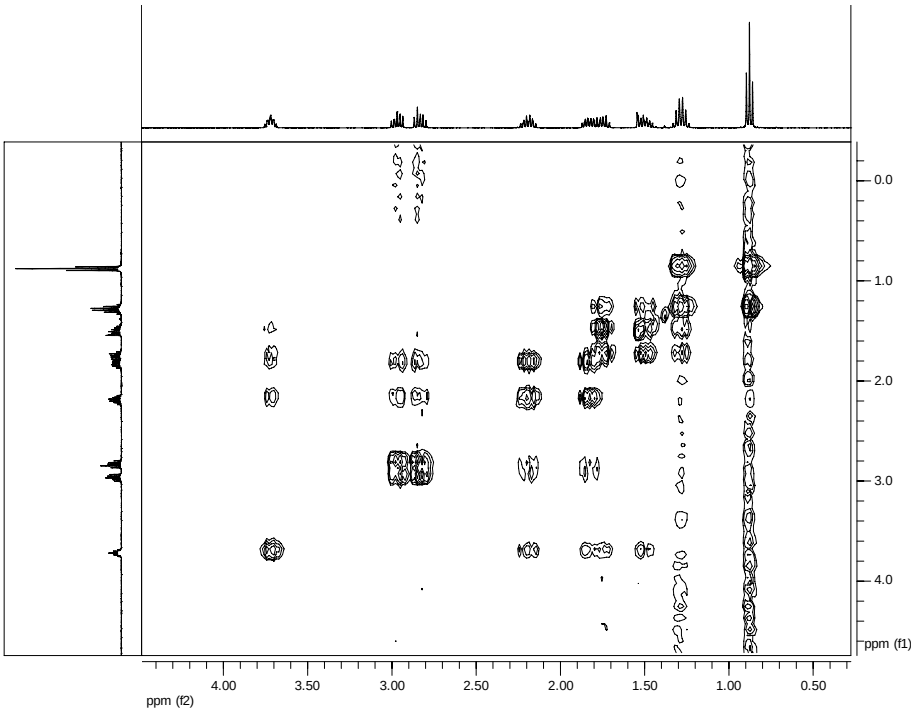
7

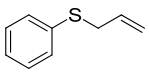

0.75
0.99
0.97
1.00
1.04
1.00
2.01
1.03
2.02
2.61
10.0
5.0
0.0
ppm (t1)


210.005
163.193
136.663
135.983
130.086
129.320
129.077
126.217
119.548
119.082
118.830
44.005
34.930
31.662
31.262
20.692
14.265
200
150
100
50
0
ppm (t1)

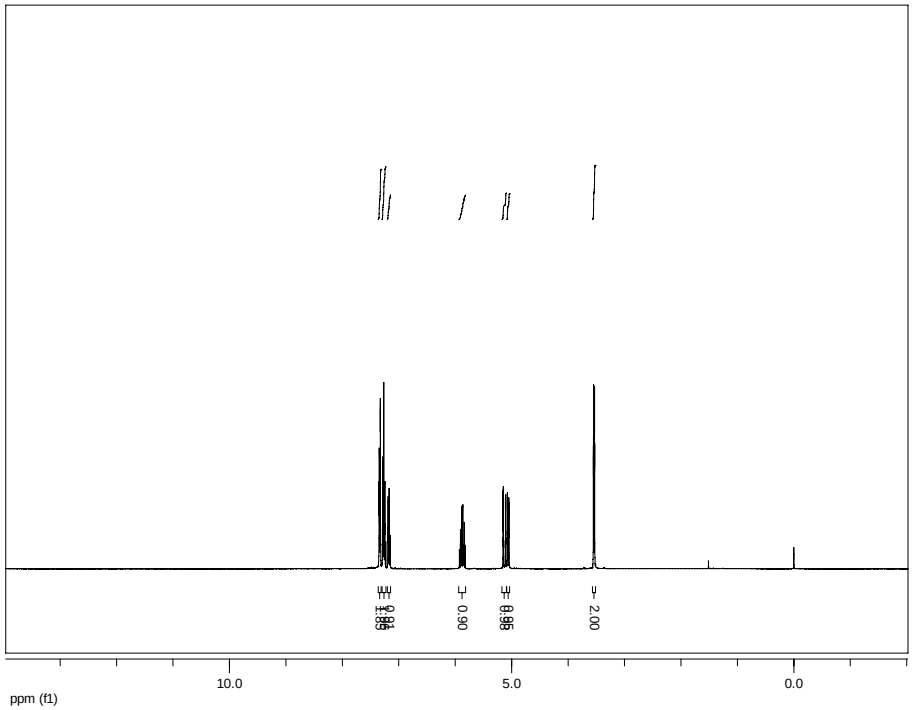
COSY 7

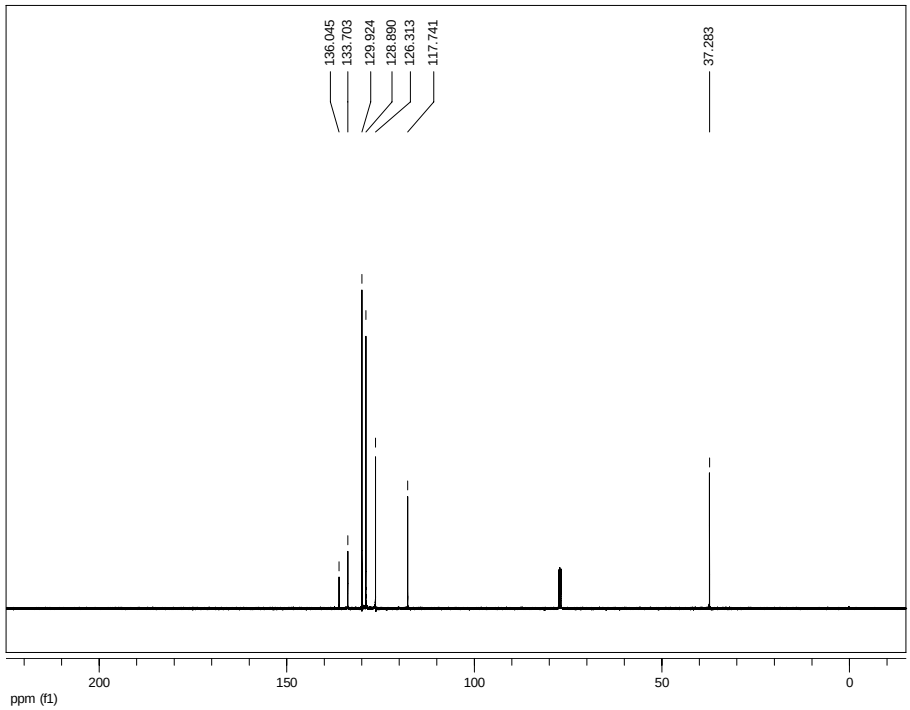

0.0
5.0
10.0
ppm (f1)
10.0
5.0
0.0
ppm (f2)
0.0
1.0
2.0
3.0
4.0
ppm (f1)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
ppm (f2)

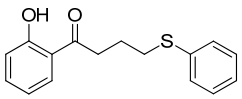

0.0
1.0
2.0
3.0
4.0
ppm (f1)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
ppm (f2)



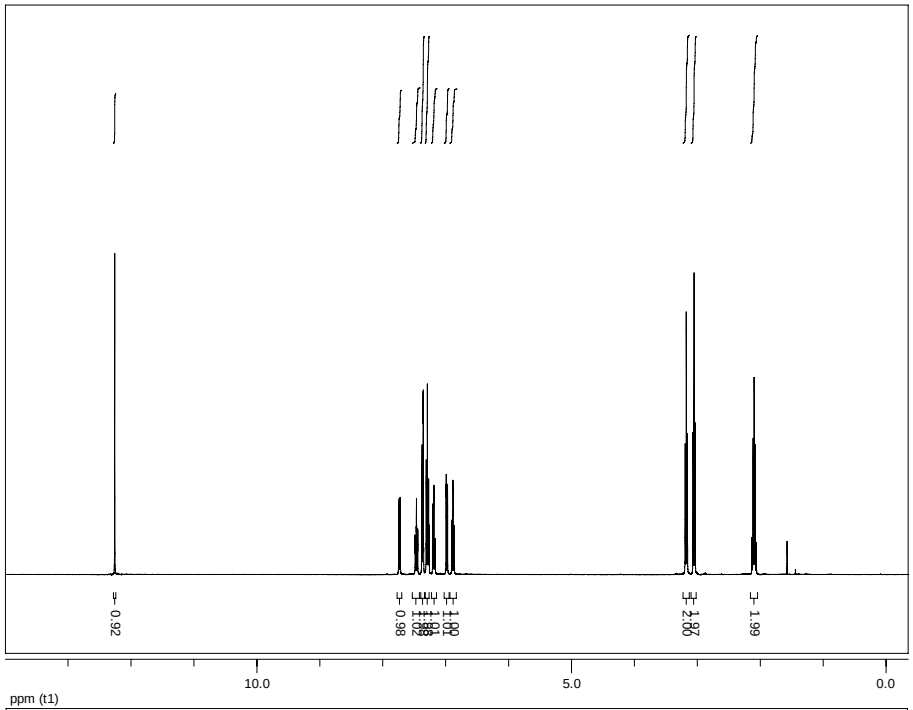
8

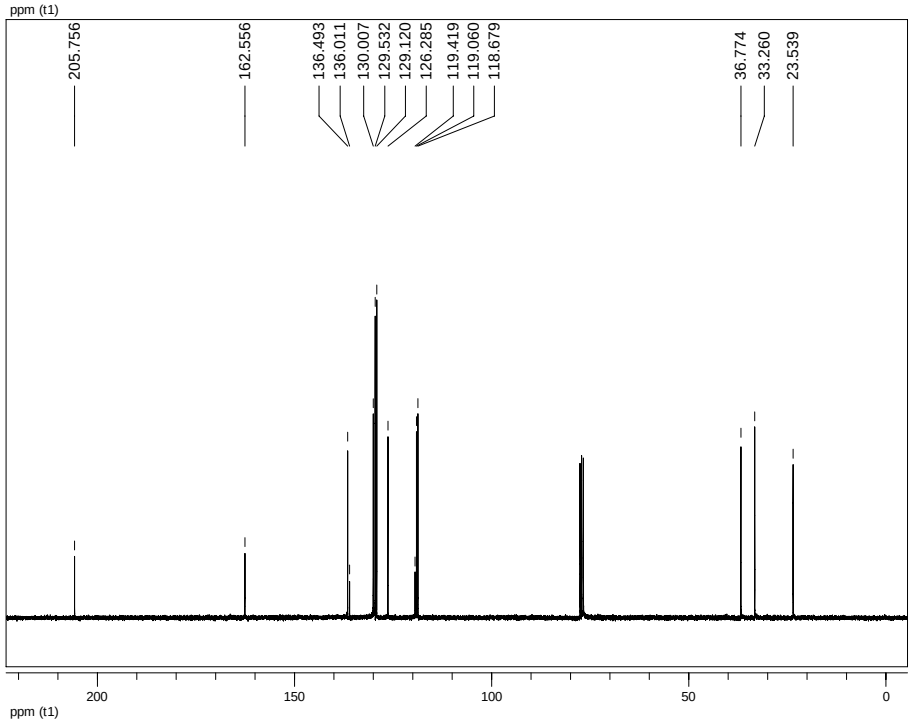

2.00
0.90
2.00
10.0
5.0
0.0
ppm (f1)


136.045
133.703
129.924
128.890
126.313
117.741
37.283
200
150
100
50
0
ppm (f1)


OH
O
S

9


0.92
0.98
1.00
1.87
1.99
10.0
5.0
0.0
ppm (t1)


205.756
162.556
136.493
136.011
130.007
129.532
129.120
126.285
119.419
119.060
118.679
36.774
33.260
23.539
200
150
100
50
0
ppm (t1)