Highly enantioselective intermolecular nucleophilic/alkylation of enals

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General Methods. ^{1}H (400 MHz or 300 MHz), ^{13}C (75 MHz) NMR spectra were recorded on a Bruker 400 FT or Bruker 300 FT NMR in $CDCl_3$, and chemical shift (δ) are given in ppm relative to residual $CHCl_3$. Multiplicity is indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), dd (doublet of doublet), dt (doublet of triplet), ddd (doublet of doublet of doublet), brs (broad singlet). Coupling constants are reported in Hertz (Hz). Mass spectra (MS) were obtained by ESI and High-resolution mass spectra HRMS by Electrospray Ionisation (ESI). Optical rotations were recorded on a Perkin-Elmer 241 polarimeter at 20°C in a 10 cm cell in $CHCl_3$; $[\alpha]_D$ values are given in 10^{-1} deg.cm^2 g^{-1} (concentration c given as g/100 ml). Enantiomeric excesses determined by Chiral-GC or by Chiral-SFC measurement on a Berger SFC with the stated column. Gradient programs are described as follows: initial methanol concentration (%) - initial time (min) - percent gradient of methanol (% / min) - final methanol concentration (%); retention times (RT) are given in min. Flash chromatographies were performed using silica gel 60 Å. Commercial solvents were used directly without any drying or purifications before used.

The racemate were prepared using nearly racemic diphenylprolinol silyl ether **5a**. Given the diastereomeric distribution of the racemic compounds (1/1 dr in most cases), the attribution of each stereoisomer signal was unambiguously confirmed in most cases by preparing the opposite enantiomer of the product separately. Optical rotations were not reported due to the large amount of diasteroisomeric product present and its interference on the optical rotation value. APY catalyst was prepared according to procedures developed in our group.[1] All the relative and absolute configurations were assigned by analogy. Indeed, the absolute configuration of the different organocatalytic steps are all known, and the mechanism is assumed to be the same in each single step than in the organocascade. [2]

Diasteroisomeric ratio were determined by ^{1}H NMR while the isolated yields refer to an isolated mixture of both diastereoisomers.

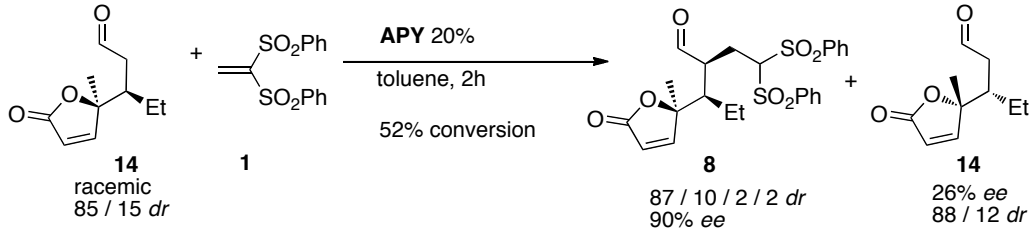
[1] A. Quintard, S. Belot, E. Marchal, A. Alexakis, *Eur. J. Org. Chem.* **2010**, 927-936.

[2] a) For the iminium catalyzed addition of benzaldoxime: Bertelsen, S.; Dinér, P.; Johansen, R. L.; Jørgensen, K. A. *J. Am. Chem. Soc.* **2007**, *129*, 1536; b) for the iminium catalyzed addition of triazole: Dinér, P.; Nielsen, M.; Marigo, M.; Jørgensen, K. A. *Angew. Chem. Int. Ed*. **2007**, *46*, 1983; c) for the iminium catalyzed addition of Angelica Lactone: Quintard, A.; Lefranc, A.; Alexakis, A. *Org. Lett*. **2011**, accepted manuscript; d) for the iminium catalyzed addition of thiol: Marigo, M.; Schulte, T.; Franzen, J.; Jørgensen, K. A. *J. Am. Chem. Soc.* **2005**, *127*, 15710; e) for the iminium catalyzed addition of **11**: Vesley, J.; Ibrahem, I.; Rios, R.; Zhao, G-L.; Xu, Y.; Cordova, A. *Tetrahedron Lett*. **2007**, *48*, 2193; f) for the enamine catalyzed addition to vinyl sulfones see: A. Quintard, S. Belot, E. Marchal, A. Alexakis, *Eur. J. Org. Chem*. **2010**, 927-936.

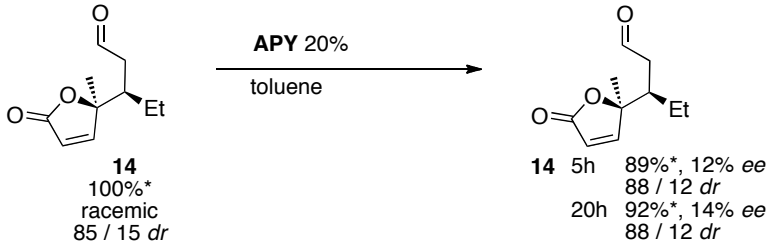
Evidences for Kinetic Resolution and Dynamic Kinetic Asymmetric Transformation:

Both Kinetic Resolution and Dynamic Kinetic Asymmetric Transformation are in action in such organocascade. One of the enantiomers of the starting material reacts faster than the other one (KR, eq 1). The other decomposes back to the enal and angelica lactone and finally reacts back to the favored enantiomer (DYKAT, eq 2).[3] These results demonstrate that in the case of hindered substrates, both selectivity and reactivity have their origin in a balance between those two phenomena: KR and DYKAT. If the stereoisomer obtained through the iminium step is more likely to react with the enamine electrophile, a global acceleration effect and increase in stereoselectivity will be observed. If the mismatch stereoisomer is obtained the system tends to undergo a slower electrophilic trapping leading to retro-Michael and substrate decomposition.

1) Kinetic Resolution (KR):

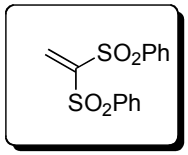


2) Dynamic Kinetic Asymmetric Resolution (DYKAT):



*Based on ^{1}H NMR with 4-methyl-anisole as internal standard

Experimental procedures:



(ethene-1,1-diyldisulfonyl)dibenzene – 1. To a methanol (30 mL) solution of paraformaldehyde (40% in water), (2.3 g; 0.03 mol; 3 equivalents), 4.9 mL of piperidine (0.15 mol; 5 equivalents) and 3.05 g of bis(phenylsulfonyl)methane (0.010 mol; 1 equivalent) were successively added slowly at 0°C. After 70 minutes at 0°C, a mixture of icy–water (70 mL) was added and stirred for 10 minutes. The white precipitate was filtered off and washed with additional 50 ml of cold water. The white solid thus obtained was re-dissolved in 30 ml of dichloromethane. 50 ml of HCl (1M) were added and the resulting biphasic mixture was stirred vigorously for 3 hours. Additional 25 ml of HCl (1M) were again added prior to separating the organic layer. The aqueous layer was further extracted 2 times with 50 ml of dichloromethane. The combined organic layers were dried on $MgSO_4$, filtered and the solvent evaporated to give the crude product (~ 95% pure). Recristallisation from CH_2Cl_2/cyclohexane (alternatively benzene can be used) yielded pure **1** as a white solid (2.096 g; 6.8 mmol; 68% yield). **^{1}H NMR (400 MHz, $CDCl_3$)**: δ = 7.19 (s, 2H), 7.58–7.54 (m, 4H), 7.69–7.65 (m, 2H), 7.97–7.95 (m, 4H). **m.p.** 123–126°C. All other spectroscopic analysis were in agreement with the literature data.[4]

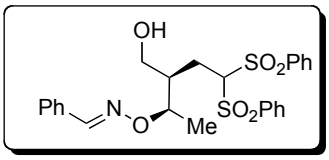
Procedure for the tandem hydro-alkylation:

To a solution of 0,13 mmol (1,3 eq) of enal in 0,2 ml of toluene at room temperature is added successively 3,8 mg 0,01 mmol (10 mol%) of the Aminal PYrrolidine catalyst and 2,3 mg (0,02 mmol, 20 mol%) of benzoic

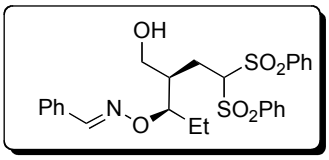
[3] For a recent review on aminocatalysis mechanism: Nielsen, M.; Worgull, D.; Zweifel, T.; Gschwend, B.; Bertelsen, S.; Jørgensen, K. A. *Chem. Commun*. **2011**, *47*, 632 For a recent DYKAT process in enamine catalysis: G-L. Zhao, F. Ullah, L. Deiana, S. Lin, Q. Zhang, J. Sun, I. Ibrahem, P. Dziedzic, A. Cordova, *Chem. Eur. J*. **2010**, *16*, 1585. For a corresponding review see: H. Pellissier, *Adv. Synth. Cata.* **2011**, DOI: 10.1002/adsc.201000751.

[4] S. Sulzer-Mossé, A. Alexakis, J. Mareda, G. Bollot, G. Bernardinelli, Y. Filinchuk, *Chem. Eur. J.* **2009**, *15*, 3204-3220.

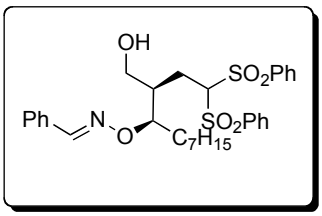
acid. 23,2 mg (0,2 mmol, 2,0 eq) of *E*-Benzaldoxime and then 31,1 mg (0,1 mmol, 1eq) of vinyl sulfone are added and the mixture is stirred at room temperature for 1h45. 0,5 ml of ethanol and 11,1 mg of $NaBH_4$ (0,3 mmol, 3 eq) are successively added and the mixture stirred at room temperature for 25 minutes. The reaction is quenched by addition of 4 ml of saturated NH_4Cl solution, the reaction mixture extracted by three times 4 ml of dichloromethane, dried over Na_2SO_4 and the solvent evaporated. Purification by flash chromatography using a cyclohexane / ethyl acetate (8/2 to 6/4) mixture affords the corresponding Michael adduct. The Michael adduct are highly polar and give rf around 0,20 (cyclohexane / ethyl acetate (7/3)).



4b.
According to general procedure, starting from **crotonaldehyde** (10,0 mg, 0,13 mmol), oxime (23,2 mg, 0,2 mmol), vinyl sulfone (31,1 mg, 0,1 mmol), and aminal-pyrrolidine (3,8 mg, 0,01 mmol). The product was isolated as a colourless oil in 58% yield (29,1 mg, 0,058 mmol). The enantiomeric excess was determined by SFC. (Chiralcel OJ: 2 mL/min., 200 bar, MeOH, 10%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R_t (maj): 11,0 min; (min): 13,0 min (min); **dia 2**: R_t (min): 13,9 min; (maj): 18,1 min.
^{1}H NMR (400 MHz, $CDCl_3$): δ = 1,26 (t, 3H, *J* = 6,8 Hz, CHC*H*$_3$), 2,19-2,39 (m, 4H, C*H*C*H*$_2$CH(SO$_2$Ph)$_2$, and C*H*CH$_2$OH and O*H*), 3,66 (dd, 1H, *J* = 6,0; 5,0 Hz, C*H*$_2$OH), 3,81 (dd, 1H, *J* = 7,6; 4,0 Hz, C*H*$_2$OH), 4,30 (m, 1H, OC*H*CH$_3$), 5,08 (t, 1H, *J* = 5,2 Hz, C*H*(SO$_2$Ph)$_2$), 7,38-7,67 (m, 11H, Ar), 7,92-7,99 (m, 5H, *Ar* and PhC*H*=N). **^{13}C NMR (75 MHz, $CDCl_3$):** δ = 17,5 (*CH*$_3$), 24,1 (*CH*$_2$CH(SO$_2$Ph)$_2$), 43,2 (*CH*CH$_2$OH), 63,8 (*CH*$_2$OH), 80,4(Oxime-*CH*CH$_2$), 81,4 (*CH*(SO$_2$Ph)$_2$), 127,0 (*CHarom*), 128,8 (*CHarom*), 129,0 (*CHarom*), 129,1 (*CHarom*), 129,6 (*CHarom*), 129,8 (*CHarom*), 130,1 (*CHarom*), 132,0 (*CHarom*), 134,5 (*Carom*), 137,6 (*Carom*), 137,8 (*Carom*), 148,9 (*CHN*).
IR ($CHCl_3$) *ν* (cm^{-1}): 3534, 2968, 2930, 2873, 1584, 1447, 1311, 1146, 1077, 975, 947, 756, 685. **MS ESI:** *m/z* = 501,5 $[M + H]^+$. **HRMS ESI:** $[M+H]^+$, calcd for $C_{25}H_{28}NO_6S_2$ 502,1352; found 502,1356.



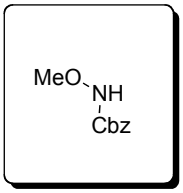
4a.
According to general procedure, starting from **pentenal** (8,9 mg, 0,1 mmol), oxime (19,8 mg, 0,15 mmol), vinyl sulfone (22,1 mg, 0,075 mmol), and aminal-pyrrolidine (2,9 mg, 0,075 mmol). The product was isolated as colourless oil in 61% yield (23,4 mg, 0,0456 mmol). The enantiomeric excess was determined by SFC. (Chiralcel OJ: 2 mL/min., 200 bar, MeOH, 5%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R_t (maj): 14,5 min; (min): 17,7 min; **dia 2**: R_t (maj): 15,1 min; (min): 16,9 min.
^{1}H NMR (400 MHz, $CDCl_3$): δ = 0,96 (t, 3H, *J* = 7,2 Hz, CH$_2$C*H*$_3$), 1,57-1,71 (m, 3H, C*H*$_2$CH$_3$ and OH), 2,27-2,37 (m, 3H, C*H*C*H*$_2$CH(SO$_2$Ph)$_2$ and C*H*CH$_2$OH), 3,66-3,69 (m, 1H, C*H*$_2$OH), 3,76-3,79 (m, 1H, C*H*$_2$OH), 4,09 (dt, 1H, *J* = 4,8; 3,7 Hz, OC*H*CH$_2$), 5,05 (dd, 1H, *J* = 4,0; 3,6 Hz, C*H*(SO$_2$Ph)$_2$), 7,25-7,69 (m, 11H, Ar), 7,88-8,0 (m, 5H, *Ar* and PhC*H*=N). **^{13}C NMR (75 MHz, $CDCl_3$):** δ = 10,4 (*CH*$_3$), 23,7 (*CH*$_2$CH(SO$_2$Ph)$_2$), 24,5 (*CH*$_2$CH$_3$), 41,9 (*CH*CH$_2$OH), 64,2 (*CH*$_2$OH), 81,2 (*CH*(SO$_2$Ph)$_2$), 86,2 (Oxime-*CH*CH$_2$), 127,0 (*CHarom*), 128,8 (*CHarom*), 128,9 (*CHarom*), 129,0 (*CHarom*), 129,5 (*CHarom*), 129,7 (*CHarom*), 130,0 (*CHarom*), 131,9 (*CHarom*), 134,5 (*Carom*), 137,7 (*Carom*), 137,9 (*Carom*), 148,8 (*CHN*).
IR ($CHCl_3$) *ν* (cm^{-1}): 3550, 2925, 2855, 1584, 1447, 1327, 1147, 1078, 951, 765. **MS ESI:** *m/z* = 516,0 $[M + H]^+$. **HRMS ESI:** $[M+H]^+$, calcd for $C_{26}H_{30}NO_6S_2$ 516,1509; found 516,1508.



4c.
According to general procedure, starting from **decenal** (15,6 mg, 0,1 mmol), oxime (19,6 mg, 0,15 mmol), vinyl sulfone (23,2 mg, 0,075 mmol), and aminal-pyrrolidine (2,7 mg, 0,07 mmol). The product was isolated as viscous oil in 49% yield (21,4 mg, 0,0365 mmol). The enantiomeric excess was determined by SFC. (Chiralcel OJ: 2 mL/min., 200 bar, MeOH, 5%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R_t (min): 11,9 min; (maj): 13,4 min; **dia 2**: R_t (min): 11,2 min; (maj): 14,4 min.
^{1}H NMR (300 MHz, $CDCl_3$): δ = 0,87 (t, 3H, *J* = 6,0 Hz, CH$_2$C*H*$_3$), 1,25-1,58 (m, 12H, (C*H*$_2$)$_2$CH$_3$ and OH), 2,28-2,35 (m, 3H, C*H*C*H*$_2$CH(SO$_2$Ph)$_2$ and C*H*CH$_2$OH), 3,65 (dd, 1H, *J* = 6,6; 5,1 Hz, C*H*$_2$OH), 3,77 (dd, 1H, *J* = 7,5; 3,9 Hz, C*H*$_2$OH), 4,15-4,19 (m, 1H, OC*H*CH$_2$), 5,07 (dd, 1H, *J* = 4,2; 3,9 Hz, C*H*(SO$_2$Ph)$_2$), 7,39-7,69 (m, 11H, Ar), 7,88-8,0 (m, 5H, *Ar* and PhC*H*=N). **^{13}C NMR (75 MHz, $CDCl_3$):** δ = 14,1 (*CH*$_3$), 22,6(*CH*$_2$CH$_3$), 23,7 (*CH*$_2$CH(SO$_2$Ph)$_2$), 25,9 (*CH*$_2$), 29,2 (*CH*$_2$), 29,5 (*CH*$_2$), 31,5 (*CH*$_2$), 31,8 (*CH*$_2$), 42,3 (*CH*CH$_2$OH), 64,2

(*CH*$_2$OH), 81,2 (*CH*(SO$_2$Ph)$_2$), 84,9 (Oxime-*CH*CH$_2$), 127,0 (*CHarom*), 128,8 (*CHarom*), 128,9 (*CHarom*), 129,0 (*CHarom*), 129,5 (*CHarom*), 129,7 (*CHarom*), 130,0 (*CHarom*), 131,9 (*CHarom*), 134,4 (*Carom*), 137,7 (*Carom*), 137,9 (*Carom*), 148,7 (*CHN*).
IR (CHCl$_3$) *v* (cm^{-1}): 3549, 2925, 1584, 1447, 1311, 1145, 1077, 952, 756, 684. **MS ESI:** *m/z* = 586 [M + H]$^+$. **HRMS ESI:** [M+H]$^+$, calcd for $C_{31}H_{40}NO_6S_2$ 586,2291; found 586,2296.

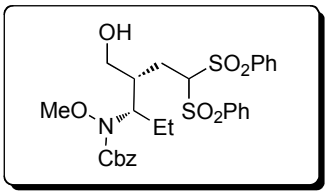
Preparation of 11:



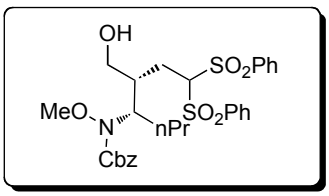
To a solution of 929,0 mg of MeONH$_2$.HCl (11,0 mmol, 1,1 eq) in a solution of 10 ml of toluene and 10 ml of water is added successively 2,11 g of Na$_2$CO$_3$ (20,0 mmol, 2eq) and 1,4 ml of benzyl chloroformate (10,0 mmol, 1eq). The mixture is then stirred at room temperature for 5 hours before being extracted by three times 20 ml of ethyl acetate. The combined organic layers are washed by 10 ml of brine, dried on Na$_2$SO$_4$, filtered and the solvent evaporated. Distillation under reduced pressure (bp = 140°C at 2 mmHg) leads to 980 mg (5,4 mmol, 54% yield) of the pure compound as a colourless oil. **^{1}H NMR (400 MHz, CDCl$_3$):** δ = 3,73 (s, 3H, OC*H*$_3$), 5,18 (s, 2H, COOC*H*$_2$Ph), 7,26-7,37 (m, 5H, Ar). **^{13}C NMR (75 MHz, CDCl$_3$):** δ = 64,7 (O*CH*$_3$), 67,5 (*CH*$_2$PH), 128,3 (*CHarom*), 128,5 (*CHarom*), 128,7 (*CHarom*), 135,7 (*Carom*), 157,5 (COO). Spectroscopic data are in accordance with the literature.[5]

Procedure for the tandem amino-alkylation:

To a solution of 0,45 mmol (1,5 eq) of enal in 0,6 ml of CHCl$_3$ at room temperature is added successively 19,5 mg (0,06 mmol, 20 mol%) of (*R*)-**5a** and 65,4 mg (0,36 mmol, 1,2 eq) of amine **11**. The resulting mixture is stirred at room temperature for 3 hours and then 91,6 mg (0,3 mmol, 1eq) of vinyl sulfone are added and the mixture is stirred at room temperature for 1h30. 1,0 ml of ethanol and 23,2 mg of NaBH$_4$ (0,6 mmol, 3 eq) are successively added and the mixture stirred at room temperature for 30 minutes. The reaction is quenched by addition of 10 ml of saturated NH$_4$Cl solution, the reaction mixture extracted by three times 6 ml of dichloromethane, dried over Na$_2$SO$_4$ and the solvent evaporated. Purification by flash chromatography using a cyclohexane / ethyl acetate (8/2 to 6/4) mixture affords the corresponding Michael adduct. The Michael adduct are highly polar and give rf around 0,25 (cyclohexane / ethyl acetate (7/3)).



12a.
According to general procedure, starting from **pentenal** (8,5 mg, 0,12 mmol), nitrogen nucleophile (21,6 mg, 0,11 mmol), vinyl sulfone (21,2 mg, 0,075 mmol), and (*R*)-**5a** (4,9 mg, 0,015 mmol). The product was isolated as a colourless oil in 56% yield (24,3 mg, 0,042 mmol). The enantiomeric excess was determined by SFC. (Chiralcel OJ: 2 mL/min., 200 bar, MeOH, 5%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R$_t$ (min): 11,1 min; (maj): 11,6 min; **dia 2**: R$_t$ (maj): 10,4 min; (min): 13,5 min.
^{1}H NMR (300 MHz, CDCl$_3$): δ = 0,96 (t, 3H, *J* = 7,1 Hz, CH$_2$C*H*$_3$), 1,59-1,71 (m, 3H, C*H*$_2$CH$_3$ and OH), 2,16-2,42 (m, 3H, C*H*C*H*$_2$CH(SO$_2$Ph)$_2$ and C*H*CH$_2$OH), 3,52-3,69 (m, 2H, C*H*$_2$OH), 3,73 (s, 1H, OC*H*$_3$), 3,93-3,97 (m, 1H, NC*H*CH$_2$), 4,89 (dd, 1H, *J* = 4,0; 3,6 Hz, C*H*(SO$_2$Ph)$_2$), 5,21 (brs, 2H, C*H*$_2$Ph), 7,37-7,69 (m, 10H, Ar), 7,87-7,97 (m, 4H, *Ar*). **^{13}C NMR (75 MHz, CDCl$_3$):** δ = 11,3 (*CH*$_3$), 21,6 (*CH*$_2$CH(SO$_2$Ph)$_2$), 24,5 (*CH*$_2$CH$_3$), 43,5 (*CH*CH$_2$OH), 62,2 (*CH*$_2$OH), 63,8 (NC*H*CH$_3$), 67,9 (O*CH*$_3$), 77,4 (C*H*$_2$Ph), 81,3 (*CH*(SO$_2$Ph)$_2$), 128,0 (*CHarom*), 128,3 (*CHarom*), 128,6 (*CHarom*), 129,0 (*CHarom*), 129,7 (*CHarom*), 134,5 (*Carom*), 137,7 (*Carom*), 135,8 (*Carom*), 137,7 (*Carom*), 158,1 (*C*OO).
IR (CHCl$_3$) *v* (cm^{-1}): 3548, 2978, 2928, 1698, 1448, 1397, 1311, 1146, 1076, 1025, 998, 756. **MS ESI:** *m/z* = 576,0 [M + H]$^+$. **HRMS ESI:** [M+H]$^+$, calcd for $C_{28}H_{34}NO_8S_2$ 576,1720; found 576,1718.



12e.
According to general procedure, starting from **hexenal** (44,7 mg, 0,45 mmol), nitrogen nucleophile (65,4 mg, 0,36 mmol), vinyl sulfone (91,6 mg, 0,3 mmol), and (*R*)-**5a** (19,5 mg, 0,06 mmol). The product was isolated as a colourless oil in 60% yield (106 mg, 0,179 mmol). The enantiomeric excess was determined by SFC. (Chiralcel AS: 2 mL/min., 200 bar, MeOH, 5%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R$_t$ (maj): 10,4 min; (min): 11,0 min; **dia 2**: R$_t$ (min): 10,4 min; (maj): 11,8 min. Remarque: one pic of the minor diastereoisomer overlaps with the pic of the major diasteroisomer. Thus the *ee* measured is

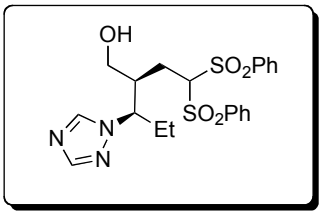
[5] M. Kawase, T. Kitamura, Y. Kikugawa, *J. Org. Chem.* **1989**, *54*, 3394.

not more precise than the >95% *ee* given here. Synthesis using the over enantiomer of the catalyst indicated around *ee* of 98%.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 0,90 (t, 3H, *J* = 7,2 Hz, CH_2CH_3), 1,25-1,73 (m, 5H, $CH_2CH_2CH_3$ and OH), 2,14-2,38 (m, 3H, $CHCH_2CH(SO_2Ph)_2$ and $CHCH_2OH$), 3,50-3,64 (m, 2H, CH_2OH), 3,73 (s, 1H, OCH_3), 4,02-4,06 (m, 1H, $NCHCH_2$), 4,87 (dd, 1H, *J* = 3,6; 2,7 Hz, $CH(SO_2Ph)_2$), 5,21 (brs, 2H, CH_2Ph), 7,36-7,69 (m, 10H, Ar), 7,88-7,97 (m, 4H, *Ar*). **^{13}C NMR (75 MHz, $CDCl_3$):** δ = 13,8 (CH_3), 19,8 (CH_2CH_3), 24,4 ($CH_2CH(SO_2Ph)_2$), 30,5 ($CH_2CH_2CH_3$), 44,8 ($CHCH_2OH$), 62,3 (CH_2OH), 63,8 ($NCHCH_3$), 67,9 (OCH_3), 77,4 (CH_2Ph), 81,3 ($CH(SO_2Ph)_2$), 128,0 (*CHarom*), 128,3 (*CHarom*), 128,6 (*CHarom*), 129,0 (*CHarom*), 129,7 (*CHarom*), 134,5 (*Carom*), 137,7 (*Carom*), 135,8 (*Carom*), 137,7 (*Carom*), 158,1 (*C*OO).
IR ($CHCl_3$) *ν* (cm^{-1}): 3524, 2957, 1924, 2873, 1700, 1448, 1397, 1313, 1152, 1077, 760. **MS ESI:** *m/z* = 607,0 $[M + NH_4]^+$. **HRMS ESI:** $[M+H]^+$, calcd for $C_{29}H_{36}NO_8S_2$ 590,1876; found 590,1868.

Procedure for the tandem triazole-alkylation:

To a solution of 9,0 mg (0,1 mmol, 2 eq) of pentenal in 0,15 ml of toluene at room temperature is added successively 3,2 mg 0,005 mmol (10 mol%) of aminal pyrrolidine catalyst and 1,3 mg (0,01 mmol, 20 mol%) of benzoic acid. 5,1 mg (0,065 mmol, 1,3 eq) of triazole are then added and the mixture is stirred at room temperature for 1h20. 14,8 mg (0,05 mmol, 1eq) of vinyl sulfone are added and the mixture is stirred at room temperature for 3h. 0,5 ml of ethanol and 5,9 mg of $NaBH_4$ (0,15 mmol, 3 eq) are successively added and the mixture stirred at room temperature for 25 minutes. The reaction is quenched by addition of 2 ml of saturated NH_4Cl solution, the reaction mixture extracted by three times 3 ml of dichloromethane, dried over Na_2SO_4 and the solvent evaporated. Purification by flash chromatography using a cyclohexane / ethyl acetate (8/2 to pure AcOEt) mixture affords the corresponding Michael adduct. Rf = 0,08 (cyclohexane / ethyl acetate (7/3)).



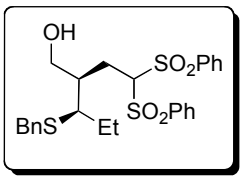
6.

The product was isolated as a white solid in 54% yield (12,7 mg, 0,027 mmol). The enantiomeric excess was determined by SFC. (Chiralcel OD: 2 mL/min., 200 bar, MeOH, 5%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R_t (min): 10,3 min; (maj): 13,2 min; **dia 2**: R_t (min): 12,9 min; (maj): 13,9 min.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 0,73 (t, 3H, *J* = 7,2 Hz, CH_2CH_3), 1,93-2,17 (m, 4H, CH_2CH_3, 1 $CHCH_2CH(SO_2Ph)_2$, and OH), 2,44-2,50 (m, 2H, 1 $CCH_2CH(SO_2Ph)_2$, and $CHCH_2OH$), 3,54-3,63 (m, 2H, CH_2OH), 4,28 (dt, 1H, *J* = 4,6; 3,6 Hz, triazole-$CHCH_2$), 4,67 (dd, 1H, *J* = 4,5; 2,1 Hz, $CH(SO_2Ph)_2$), 7,52-7,87 (m, 10H, Ar), 7,95 (s, 1H, *triazole*), 8,05 (s, 1H, *triazole*).
^{13}C NMR (75 MHz, $CDCl_3$): δ = 10,6 (CH_3), 24,3 ($CH_2CH(SO_2Ph)_2$), 24,6 (CH_2CH_3), 42,8 ($CHCH_2OH$), 61,9 (CH_2OH), 63,4 (triazole-*CH*), 81,7 ($CH(SO_2Ph)_2$), 129,1 (*CHarom*), 129,6 (*CHarom*), 129,8 (*CHarom*), 134,7 (*Carom*), 137,1 (*Carom*), 151,4 (*triazole*), 151,6 (*triazole*).
IR ($CHCl_3$) *ν* (cm^{-1}): 3265, 3928, 1505, 1447, 1328, 1144, 1078, 797. **MS ESI:** *m/z* = 463,8 $[M + H]^+$. **HRMS ESI:** $[M+H]^+$, calcd for $C_{21}H_{26}N_3O_5S_2$ 464,1308; found 464,1315.

Procedure for the sulfo-alkylation:

To a solution of 12,3 mg (0,15 mmol, 3 eq) of trans-2-pentenal in 0,1 ml of toluene at room temperature is added successively 3,8 mg (0,01 mmol, 20 mol%) of the (*S*)-**5a** and then 10,8 mg (0,09 mmol, 1,8 eq) of benzenethiol. This solution is stirred 20 min at room temperature before 15,2 mg of the vinyl sulfone (0,05 mmol, 1 eq) are added. The mixture is stirred at room temperature for 1h, 0,5ml of ethanol and 7,5 mg (0,2 mmol, 4eq) of $NaBH_4$ are successively added and the mixture stirred at room temperature for 15 minutes. The reaction is quenched by addition of 1,5 ml of 1M HCl, the reaction mixture extracted by three times 4 ml of dichloromethane, dried over Na_2SO_4 and the solvent evaporated. Purification by flash chromatography using a cyclohexane / ethyl acetate (8/2) mixture affords the corresponding Michael adduct. Rf = 0,18 (cyclohexane / ethyl acetate (7/3).



10.

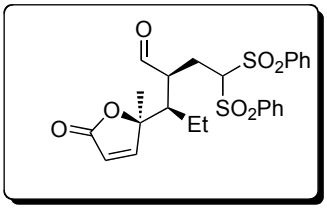
The product was isolated as a white solid in 58% yield (15,0 mg, 0,029 mmol). The enantiomeric excess was determined by SFC. (Chiralcel IC: 2 mL/min., 200 bar, MeOH, 5%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R_t (maj): 13,9 min; (min): 15,8 min; **dia 2**: R_t (min): 15,0 min; (maj): 15,4 min.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 0,89 (t, 3H, *J* = 7,2 Hz, CH_2CH_3), 1,25-1,55 (m, 2H, CH_2CH_3), 1,80 (brs, 1H, OH), 2,21-2,37 (m, 4H, $CHCH_2CH(SO_2Ph)_2$, $CHCH_2CH(SO_2Ph)_2$, and SC*H*), 3,42-3,76 (m, 4H, CH_2OH and CH_2Ph), 4,98 (t, 1H, *J* = 5,4 Hz, $CH(SO_2Ph)_2$), ,26-7,33 (m, 5H, *Ar*), 7,54-7,69 (m, 6H, *Ar*), 7,90-7,94 (m, 4H, *Ar*). **^{13}C NMR (75 MHz, $CDCl_3$):** δ = 12,3 (CH_3), 25,5 ($CH_2CH(SO_2Ph)_2$), 36,4 (CH_2CH_3),

42,3 (*C*HCH$_2$OH), 49,5 (S*CH*), 64,5 (*CH$_2$*OH), 81,2 (*CH*(SO$_2$Ph)$_2$), 127,2 (*CHarom*), 128,5 (*CHarom*), 129,1 (*CHarom*), 129,6 (*CHarom*), 134,5 (*Carom*), 137,3 (*Carom*), 138,3 (*Carom*).
IR (CHCl$_3$) *ν* (cm^{-1}): 3575, 2964, 2926, 1448, 1328, 1153, 1078, 1024, 780, 684. **MS ESI:** *m/z* = 535,5 [M + NH$_4$]$^+$. **HRMS ESI:** [M+H]$^+$, calcd for $C_{26}H_{31}O_5S_3$ 563,1593; found 536,1600.

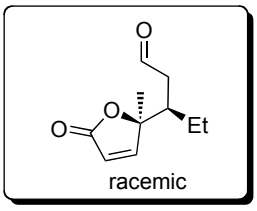
Procedure for the tandem vinylogous addition-alkylation:

To a solution of 24,9 mg (0,3 mmol, 3 eq) of pentenal in 0,2 ml of toluene at room temperature is added successively 7,4 mg (0,02 mmol, 20 mol%) of aminal pyrrolidine catalyst and 12,8 mg (0,13 mmol, 1,3 eq) of angelica lactone. The resulting mixture is stirred at room temperature for 17 hours and then 31,3 mg (0,1 mmol, 1eq) of vinyl sulfone are added and the mixture is stirred at room temperature for 1h30. The reaction is quenched by addition of 2 ml of 1 M HCl solution, the reaction mixture extracted by three times 3 ml of dichloromethane, dried over Na_2SO_4 and the solvent evaporated. Purification by flash chromatography using a cyclohexane / ethyl acetate (7/3 to 1/1) mixture affords the corresponding Michael adduct. Rf = 0,07 (cyclohexane / ethyl acetate (7/3)).



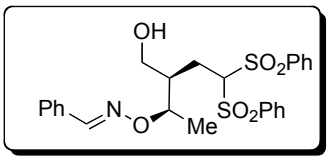
8.
The product was isolated as a white solid in 55% yield (27,1 mg, 0,055 mmol). The enantiomeric excess was determined by SFC. (Chiralcel AS: 2 mL/min., 200 bar, MeOH, 20%, 2 minutes – 2%/min. – 25% – 30 °C). **dia 1**: R$_t$ (maj): 3,2 min; (min): 3,6 min; **dia 2**: R$_t$: 2,9 min
^{1}H NMR (400 MHz, CDCl$_3$): δ = 0,95 (t, 3H, *J* = 7,6 Hz, CH$_2$C*H$_3$*), 1,42-1,48 (m, 2H, C*H$_2$*CH$_3$), 1,52 (s, 3H, CH$_3$), 2,10-2,17 (m, 2H, C*HCH$_2$*CH(SO$_2$Ph)$_2$), 2,51-2,57 (m, 1H, C*H*CH$_2$OH), 3,31-3,39 (m, 1H, C*H*CHO), 4,78 (dd, 1H, *J* = 4,8; 3,6 Hz, C*H*(SO$_2$Ph)$_2$), 6,02 (d, 1H, *J* = 5,6 Hz, CHC*H*COO), 7,46 (d, 1H, *J* = 5,8 Hz, C*H*CHCOO), 7,52-7,72 (m, 6H, *Ar*), 7,85-7,94 (m, 4H, *Ar*), 9,62 (s, 1H, C*H*O). **^{13}C NMR (75 MHz, CDCl$_3$):** δ = 13,7 (CH$_2$*CH$_3$*), 20,0 (*CH$_2$*CH$_3$), 24,1 (*CH$_2$*CH(SO$_2$Ph)$_2$), 24,7 (*CH$_3$*), 48,7 (*CH*CHO), 49,2 (*CH*CH$_2$CH$_3$), 80,3 (*CH*(SO$_2$Ph)$_2$), 90,4 (CQuat), 121,2 (*CH*COO), 129,1 (*CHarom*), 129,3 (*CHarom*), 129,7 (*CHarom*), 134,7 (*CHarom*), 134,8 (*CHarom*), 137,4 (*Carom*), 137,9 (*Carom*), 159,4 (*CH*CHCOO), 171,3 (*COO*), 202,4 (*CHO*).
IR (CHCl$_3$) *ν* (cm^{-1}): 2961, 1757, 1448, 1328, 1243, 1149, 1078, 951, 823, 758, 684. **MS ESI:** *m/z* = 508,1 [M + NH$_4$]$^+$. **HRMS ESI:** [M+NH$_4$]$^+$, calcd for $C_{24}H_{30}NO_7S_2$ 508,1458; found 508,1461.

Preparation of racemic **14**:



To a solution of 247,0 mg pentenal (3 mmol, 3eq) in 2 ml of toluene are added successively Angelica lactone (97,4 mg, 1,0 mmol, 1eq) and pyrrolidine (19,4 g, 0,3 mmol, 30 mol%). The mixture is then stirred at room temperature for 1h15 before being directly purified by silica gel chromatography (Cyclohexane/ethyl acetate = 8/2). 74 mg (0,40 mmol, 40% yield) of clear oil. Rf = 0,07 at Cyclohexane/ethyl acetate = 7/3). Product revealed using KMnO$_4$ solution.
^{1}H NMR (300 MHz, CDCl$_3$): δ = 0,91 (t, 3H, *J* = 7,2 Hz, CH$_2$C*H$_3$*), 1,22-1,26 (m, 1H, C*H$_2$*CH$_3$), 1,47 (s, 3H,CC*H$_3$*), 1,58-1,63 (m, 1H, C*H$_2$*CH$_3$), 2,33-2,51 (m, 3H, C*H$_2$*CHO and C*H*CH$_2$), 6,07 (d, 1H, *J* = 5,7 Hz, CHC*H*COO), 7,36 (d, 1H, *J* = 5,7 Hz, C*H*CHCOO), 9,76 (s, 1H, C*H*O). **^{13}C NMR (75 MHz, CDCl$_3$):** δ = 12,2 (CH$_2$*CH$_3$*), 23,0 (*CH$_3$*), 23,4 (*CH$_2$*CH$_3$), 41,4 (*CH*), 43,4 (*CH$_2$*CHO), 90,7 (Cquat), 121,5 (*CH*COO), 158,9 (*CH*CHCOO), 171,9 (*COO*), 200,6 (*CHO*). **IR (CHCl$_3$) *ν* (cm^{-1}):** 2966, 1749, 1720, 1601, 1460, 1380, 1249, 1114, 1028, 950, 909, 820. **MS ESI:** *m/z* = 183,3 [M + H]$^+$. **HRMS ESI:** [M+H]$^+$, calcd for $C_{10}H_{15}O_3$ 183,1015; found 183,1024.

4-methyl-anisole was used as ^{1}H NMR standard in the DYKAT transformation. The enantioenriched product arising from resolution was analyzed by chiral GC: (CP Chirasil Dex CB): 110°C – 1°C/min – 150°C – 20°C/min – 170°C – 5 min.; 32 cm/s. Major dia : R$_t$: 33,3; R$_t$: 34,6. Minor dia : R$_t$: 30,8; R$_t$: 32,7.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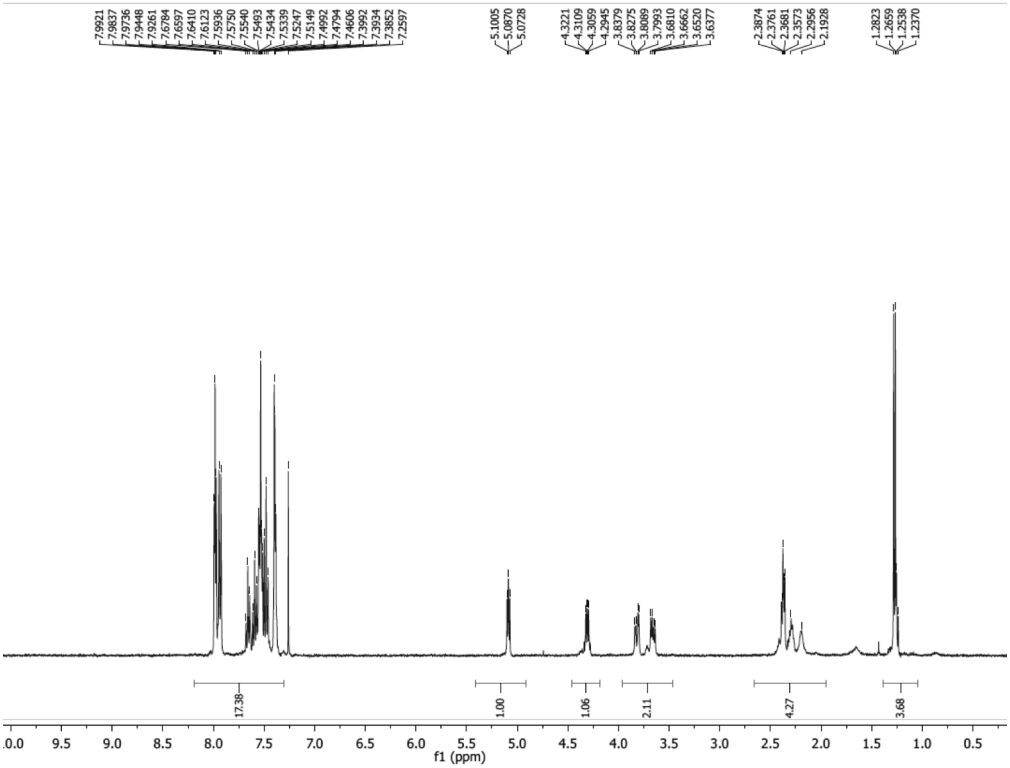
SO2Ph
Ph
N
O
Me
SO2Ph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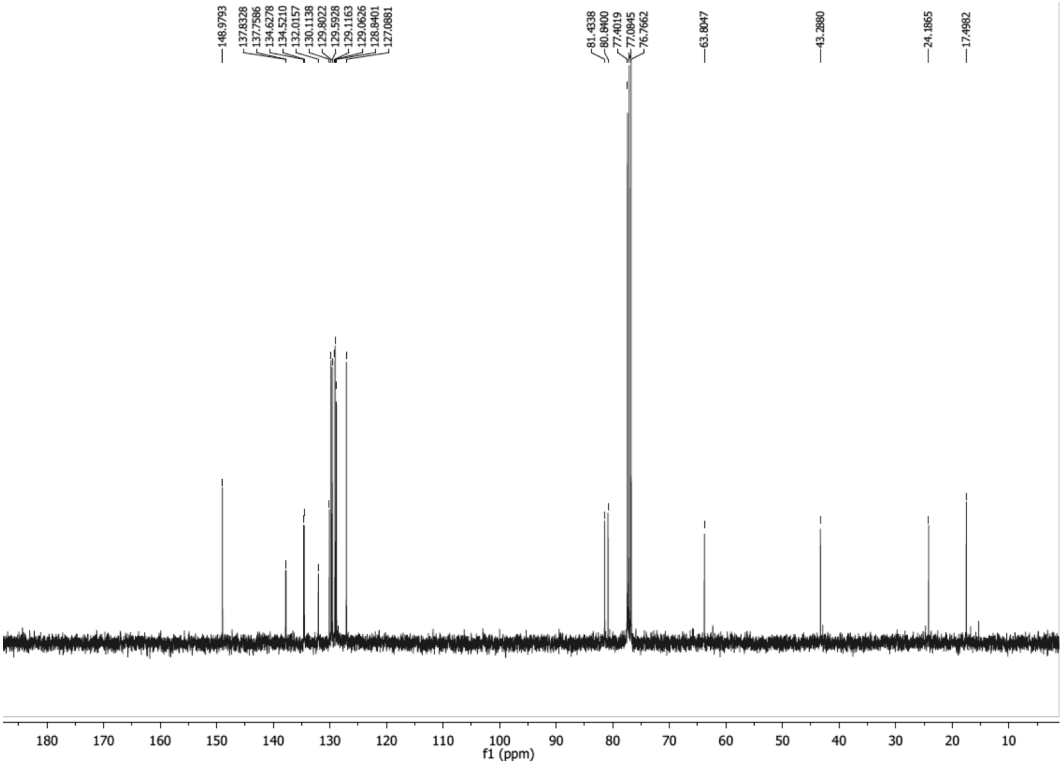
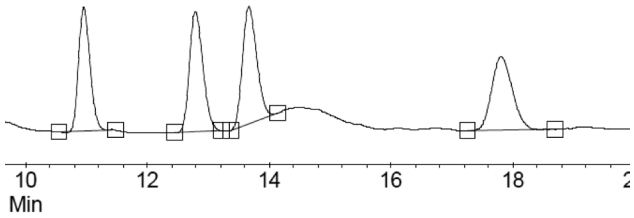

f1 (ppm)



Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
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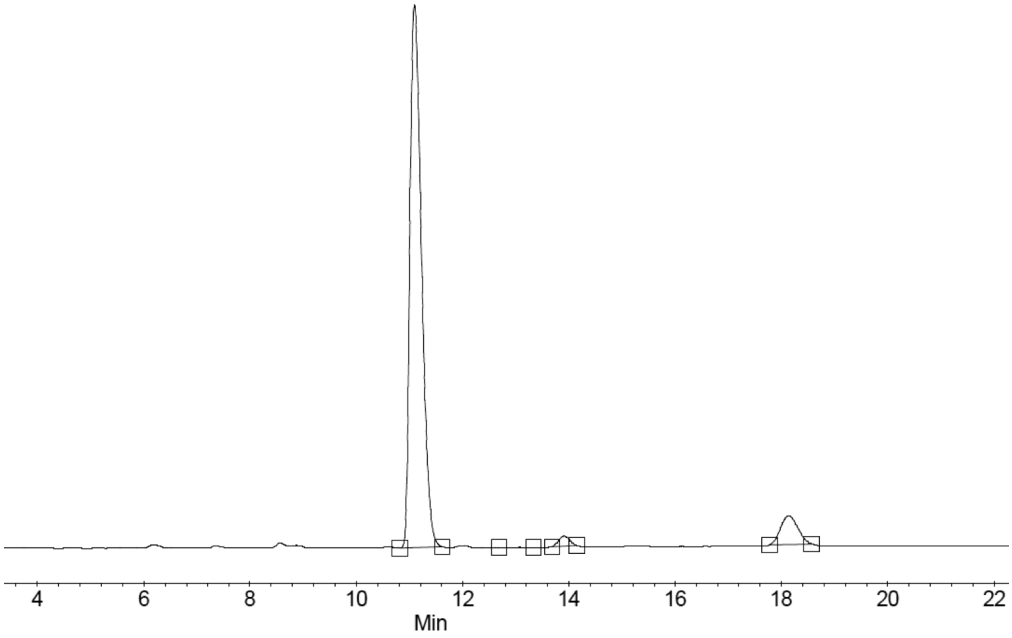
1	UNKNOWN	10.55	10.95	11.47	0.00	22.80	280.9	61.3	22.803
2	UNKNOWN	12.45	12.79	13.21	0.00	26.11	273.2	70.2	26.113
3	UNKNOWN	13.37	13.67	14.14	0.00	26.65	265.6	71.7	26.653
4	UNKNOWN	17.25	17.81	18.69	0.00	24.43	166.7	65.7	24.430
Total						100.00	986.4	269.0	100.000



Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
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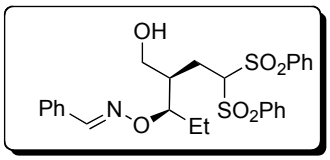
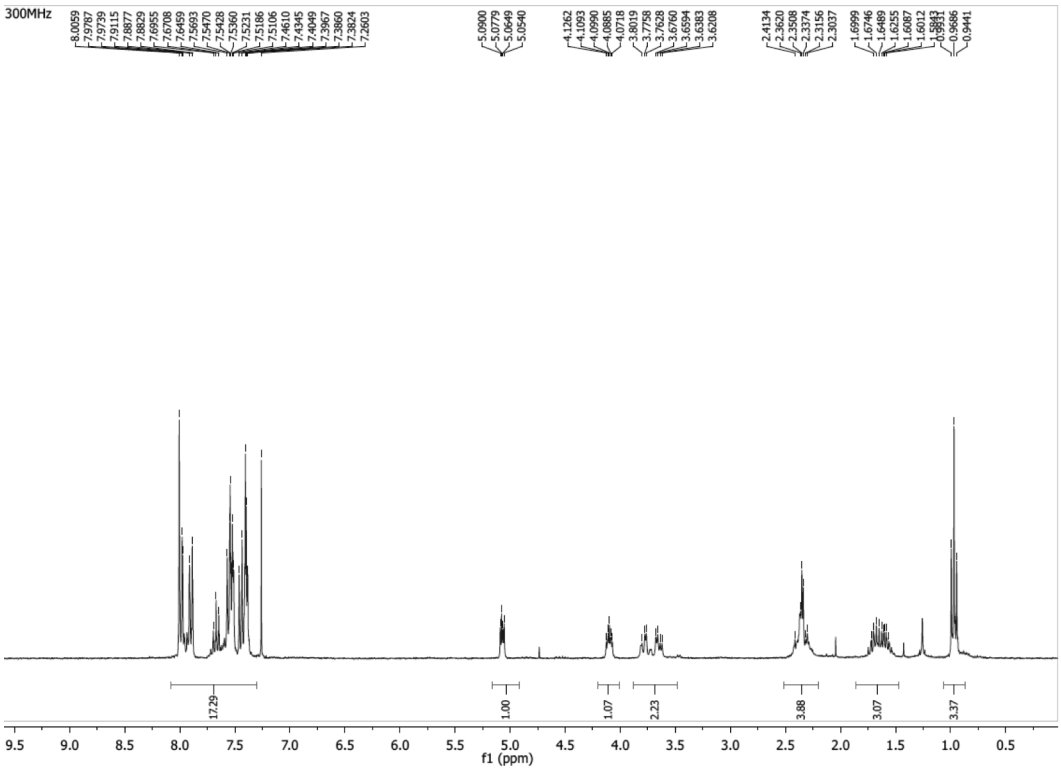
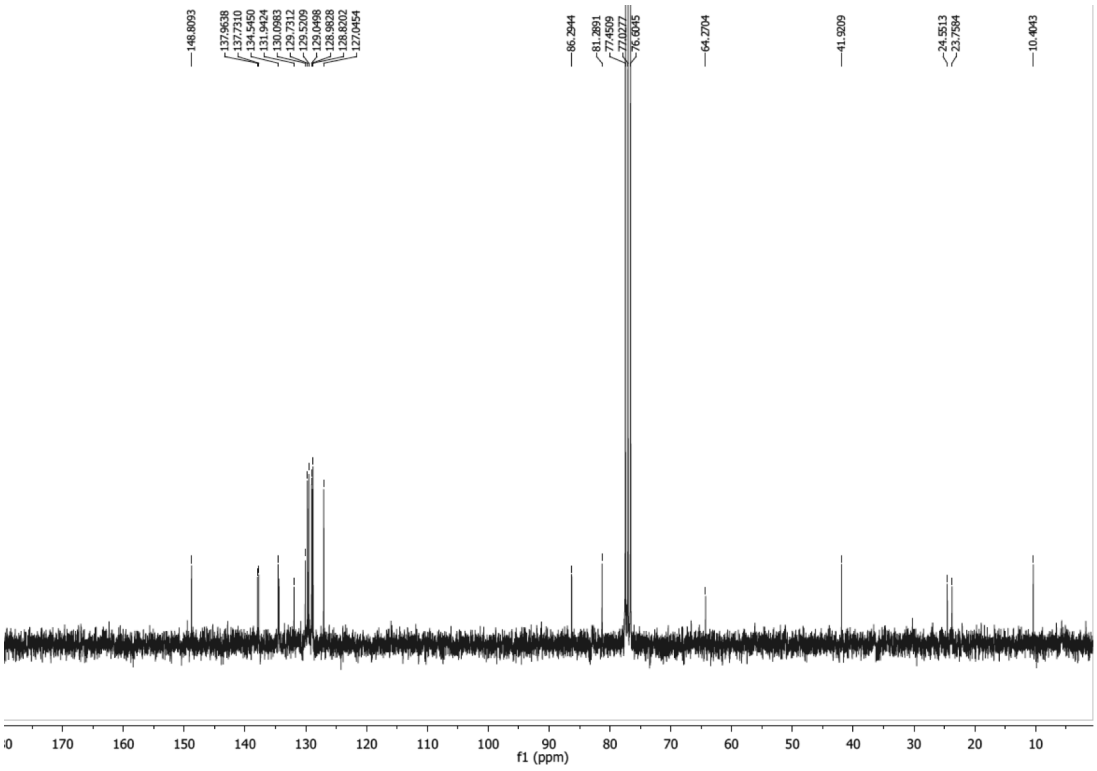
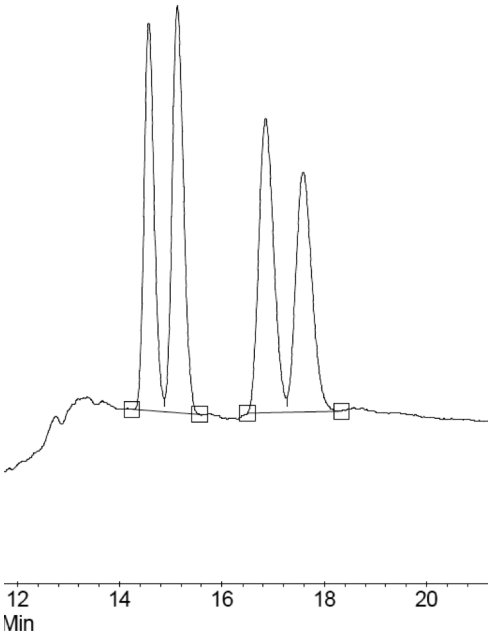
1	UNKNOWN	10.81	11.09	11.61	0.00	91.25	1906.8	480.4	91.246
4	UNKNOWN	12.68	13.07	13.33	0.00	0.07	1.7	0.4	0.074
2	UNKNOWN	13.68	13.90	14.15	0.00	1.59	35.5	8.4	1.589
3	UNKNOWN	17.77	18.13	18.56	0.00	7.09	100.2	37.3	7.091
Total						100.00	2044.1	526.5	100.000









Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
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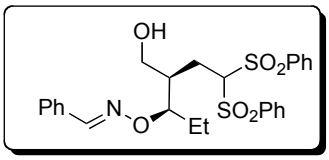
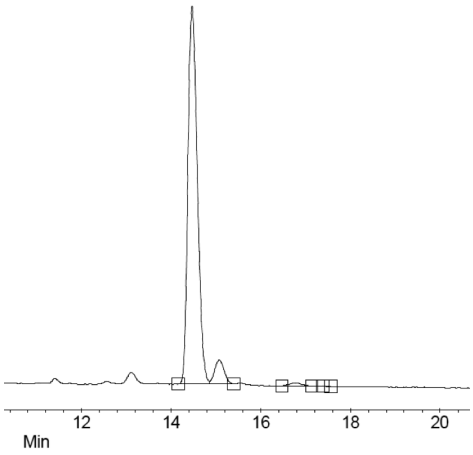
1	UNKNOWN	14.23	14.57	14.87	0.00	23.27	249.8	57.3	23.271
4	UNKNOWN	14.87	15.13	15.56	0.00	27.39	262.8	67.4	27.389
2	UNKNOWN	16.50	16.85	17.26	0.00	26.21	190.0	64.5	26.212
3	UNKNOWN	17.26	17.58	18.33	0.00	23.13	154.8	56.9	23.129
Total						100.00	857.5	246.1	100.000





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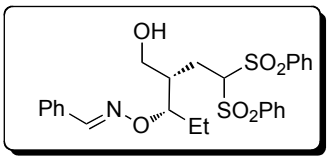
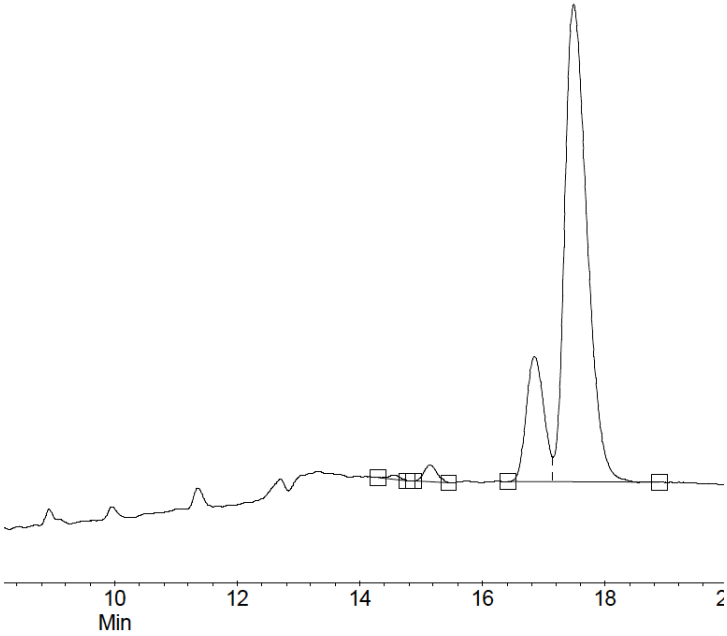
2	UNKNOWN	14.85	15.07	15.39	0.00	6.01	50.7	12.5	6.005
3	UNKNOWN	16.47	16.77	17.14	0.00	0.86	5.9	1.8	0.855
4	UNKNOWN	17.38	17.41	17.56	0.00	0.01	0.4	0.0	0.012
Total						100.00	855.1	207.9	100.000



Prepared with (*R*)-**5a**:



Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
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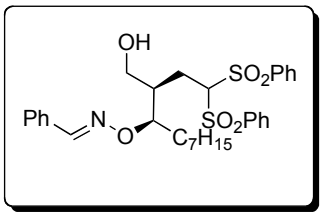
4	UNKNOWN	14.29	14.56	14.77	0.00	0.35	5.6	1.1	0.354
3	UNKNOWN	14.88	15.15	15.45	0.00	1.66	21.6	5.3	1.661
1	UNKNOWN	16.41	16.85	17.14	0.00	16.83	161.6	53.6	16.831
2	UNKNOWN	17.14	17.49	18.89	0.00	81.15	617.3	258.5	81.155
Total						100.00	806.1	318.6	100.000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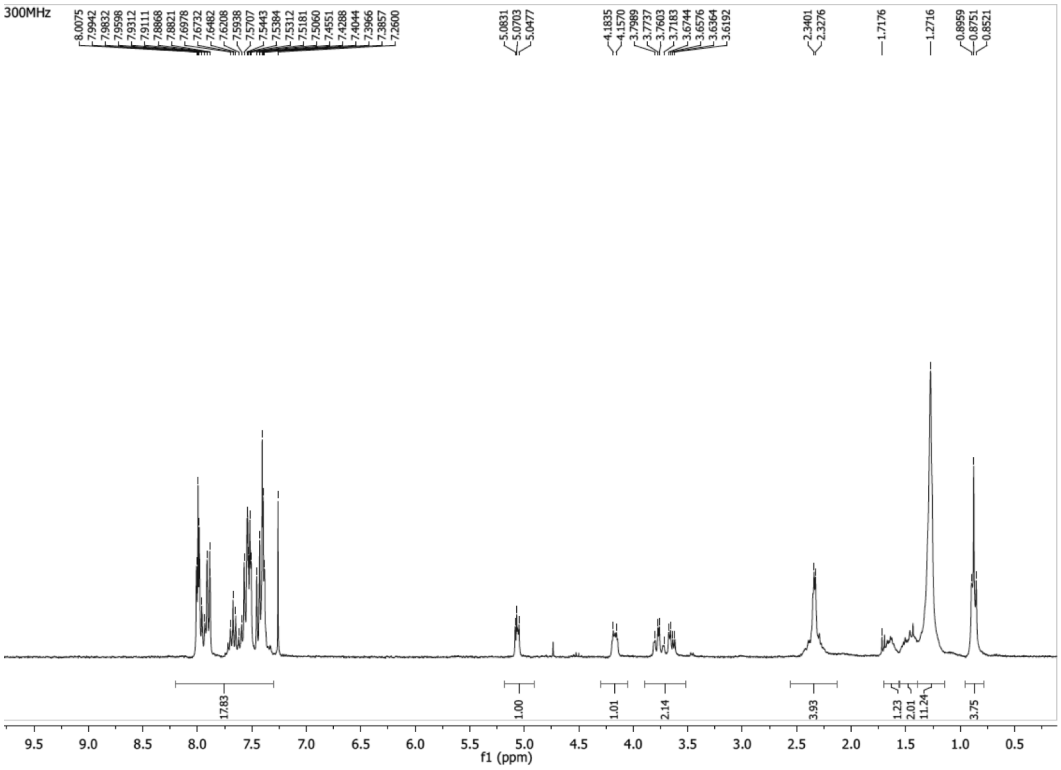
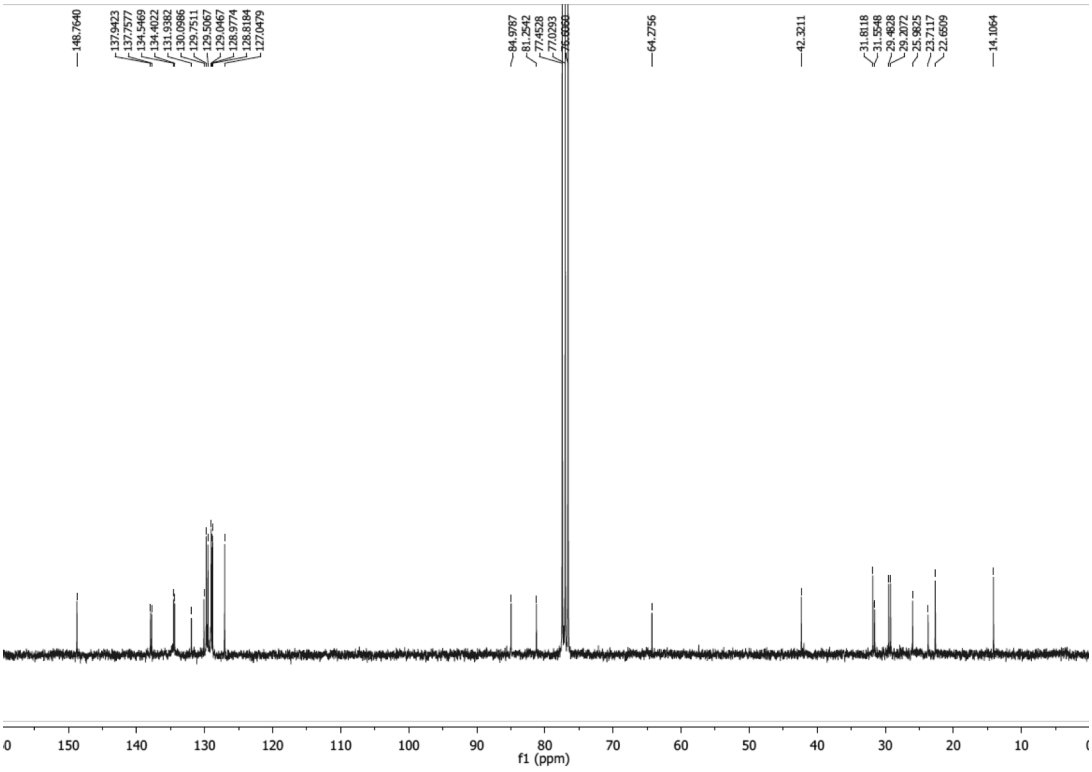
Ph
N
O
SO2Ph
C7H15


300MHz
f1 (ppm)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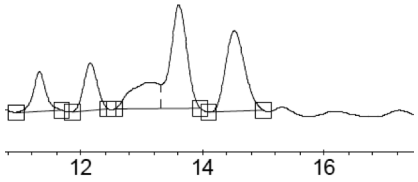

Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
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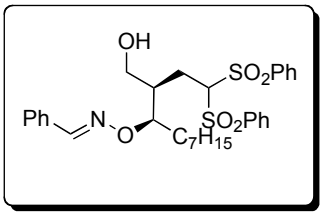
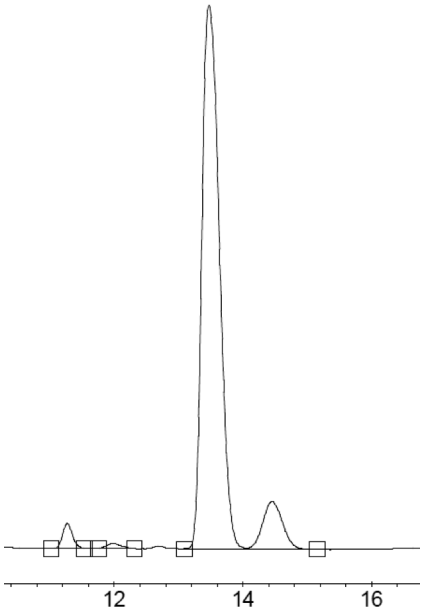
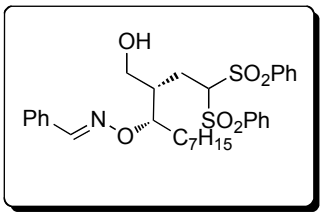
4	UNKNOWN	13.32	13.61	13.96	0.00	38.74	242.0	75.1	38.740
3	UNKNOWN	14.10	14.53	15.01	0.00	35.52	189.4	68.8	35.518
Total						100.00	634.5	193.8	100.000

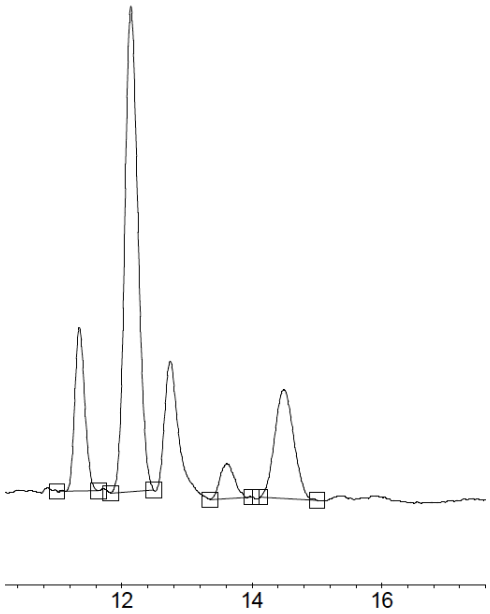




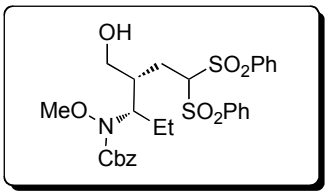
Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
3	UNKNOWN	11.02	11.27	11.54	0.00	2.30	56.3	10.0	2.299
4	UNKNOWN	11.76	11.97	12.31	0.00	0.67	10.1	2.9	0.668
1	UNKNOWN	13.09	13.47	14.04	0.00	88.24	1229.5	384.5	88.245
2	UNKNOWN	14.04	14.45	15.15	0.00	8.79	107.7	38.3	8.789
Total						100.00	1403.7	435.8	100.000

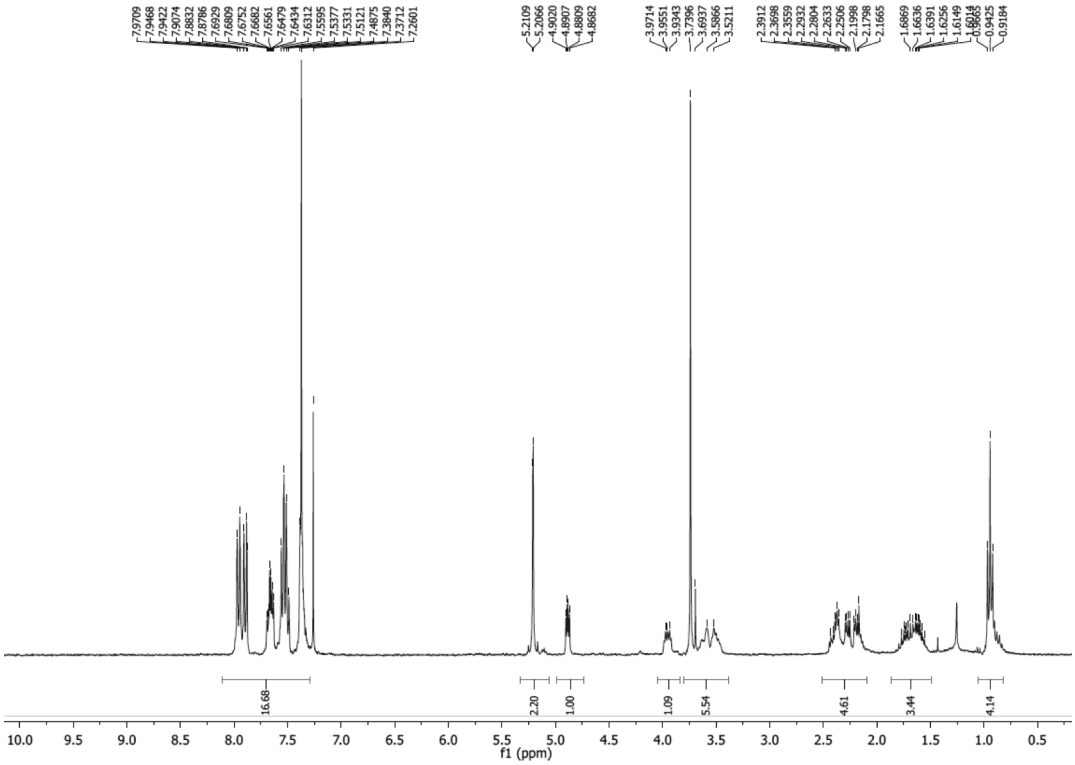


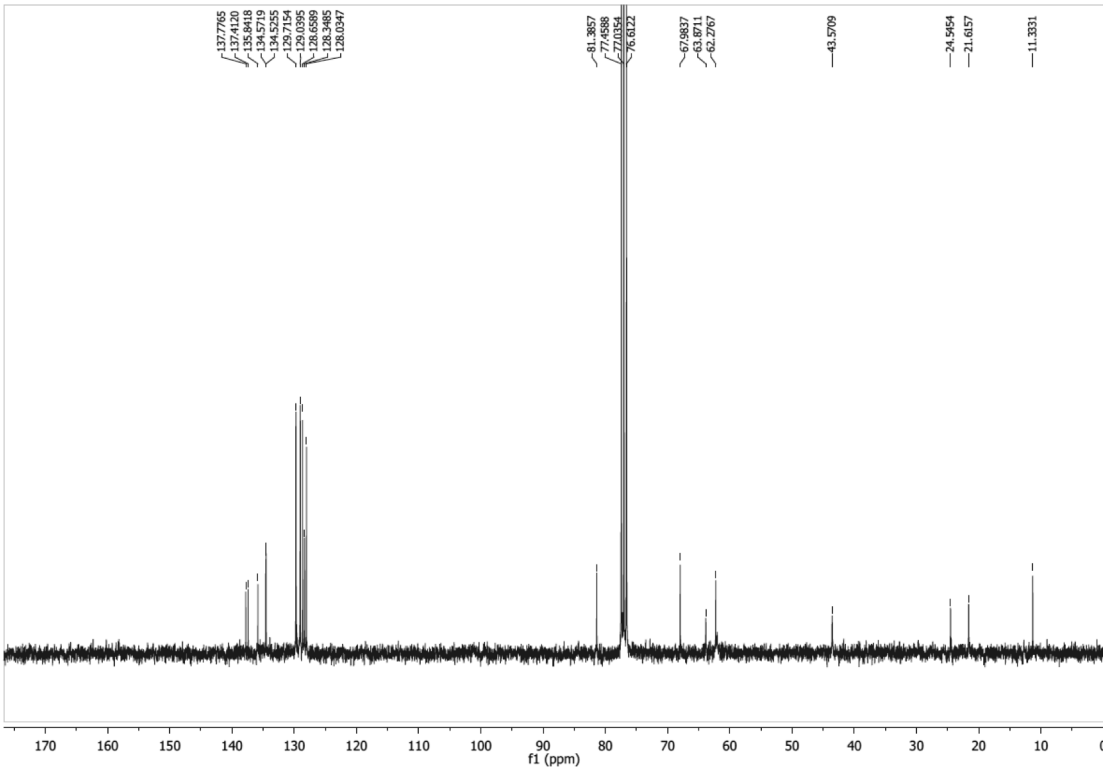
Prepared with (*R*)-**5a** (20 mol%, 3h reaction): 85% *ee*

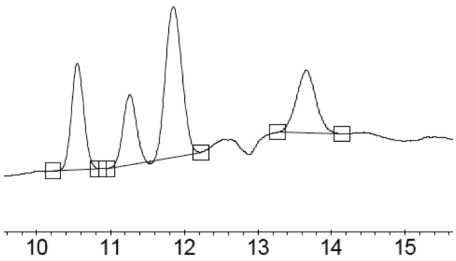


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
4	UNKNOWN	11.00	11.35	11.64	0.00	15.54	55.3	9.9	15.540
1	UNKNOWN	11.83	12.14	12.48	0.00	59.79	164.9	38.1	59.787
2	UNKNOWN	13.35	13.61	13.99	0.00	4.82	11.9	3.1	4.819
3	UNKNOWN	14.13	14.49	15.00	0.00	19.85	37.0	12.6	19.854
Total						100.00	269.1	63.7	100.000

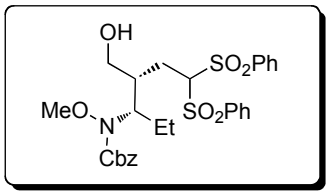

OH
SO2Ph
MeO
N
Et
SO2Ph
Cbz

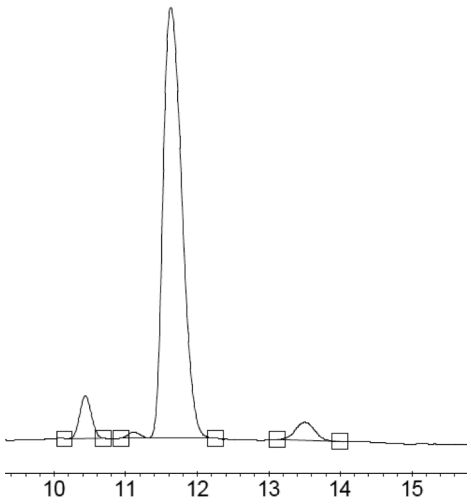

f1 (ppm)


f1 (ppm)

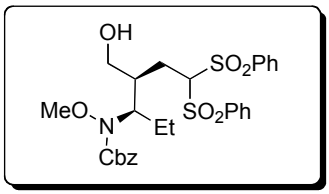


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	10.22	10.55	10.83	0.00	22.05	159.5	31.0	22.055
2	UNKNOWN	10.95	11.26	11.54	0.00	15.68	104.8	22.0	15.683
4	UNKNOWN	11.54	11.85	12.23	0.00	41.74	225.3	58.7	41.742
3	UNKNOWN	13.26	13.66	14.14	0.00	20.52	94.2	28.8	20.521
Total						100.00	583.9	140.6	100.000

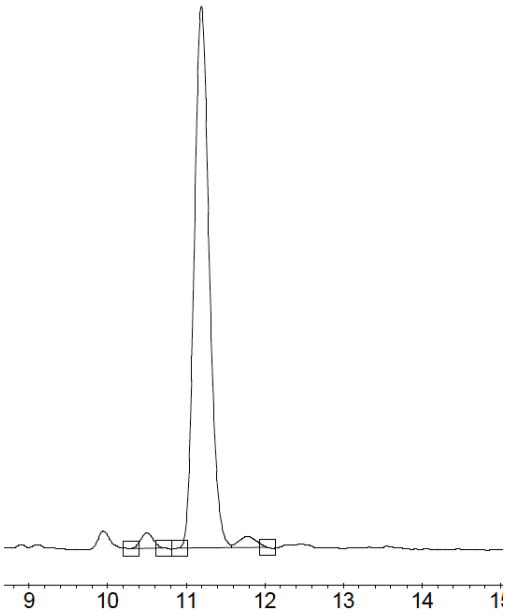




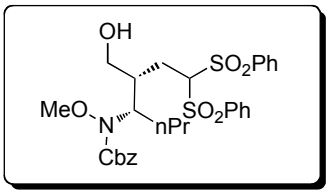
Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	10.14	10.43	10.69	0.00	5.46	105.4	19.7	5.457
2	UNKNOWN	10.93	11.11	11.31	0.00	0.81	14.8	2.9	0.805
4	UNKNOWN	11.31	11.63	12.26	0.00	89.77	1066.6	324.9	89.774
3	UNKNOWN	13.12	13.51	14.00	0.00	3.96	45.3	14.3	3.964
Total						100.00	1232.2	361.9	100.000

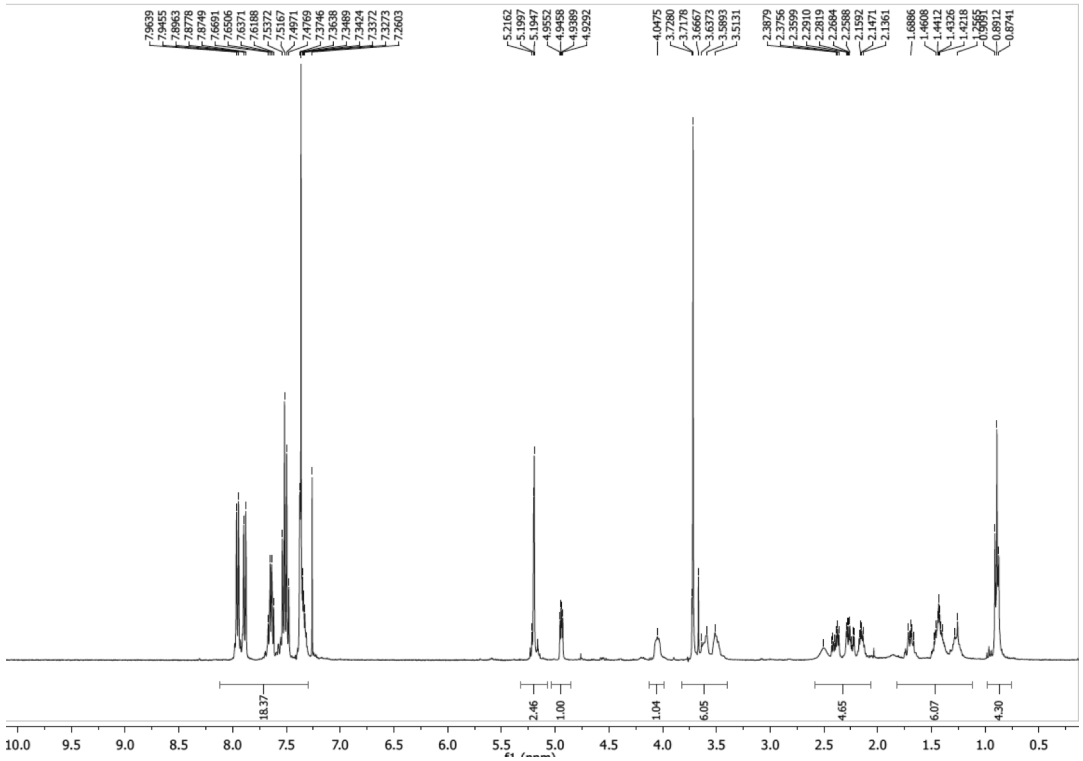


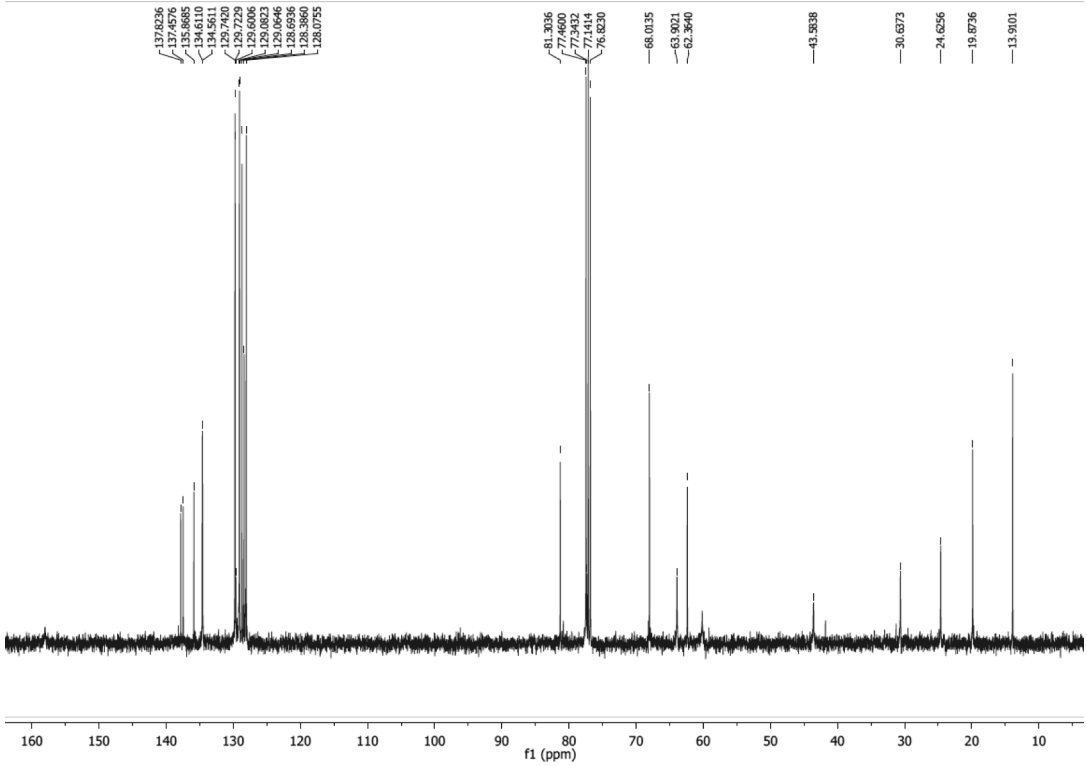
Prepared with **5b**:

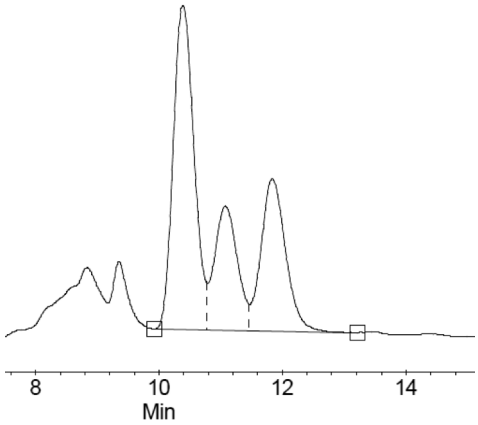


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	10.29	10.50	10.72	0.00	2.19	13.9	2.5	2.192
2	UNKNOWN	10.91	11.19	11.58	0.00	95.56	497.1	110.1	95.556
3	UNKNOWN	11.58	11.77	12.03	0.00	2.25	10.0	2.6	2.251
Total						100.00	520.9	115.2	100.000

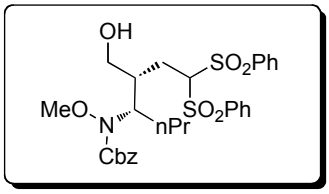

OH
SO2Ph
MeO
N
nPr
SO2Ph
Cbz

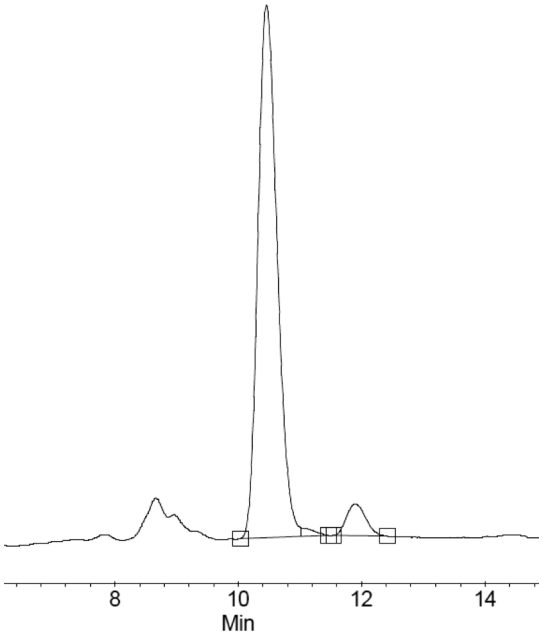

18.37
2.46
1.00
1.04
6.05
4.65
6.07
4.30
f1 (ppm)


f1 (ppm)

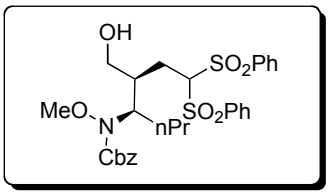


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	9.92	10.39	10.76	0.00	50.00	378.3	146.2	49.999
2	UNKNOWN	10.76	11.07	11.45	0.00	21.72	145.0	63.5	21.716
3	UNKNOWN	11.45	11.83	13.21	0.00	28.28	178.1	82.7	28.285
Total						100.00	701.4	292.3	100.000

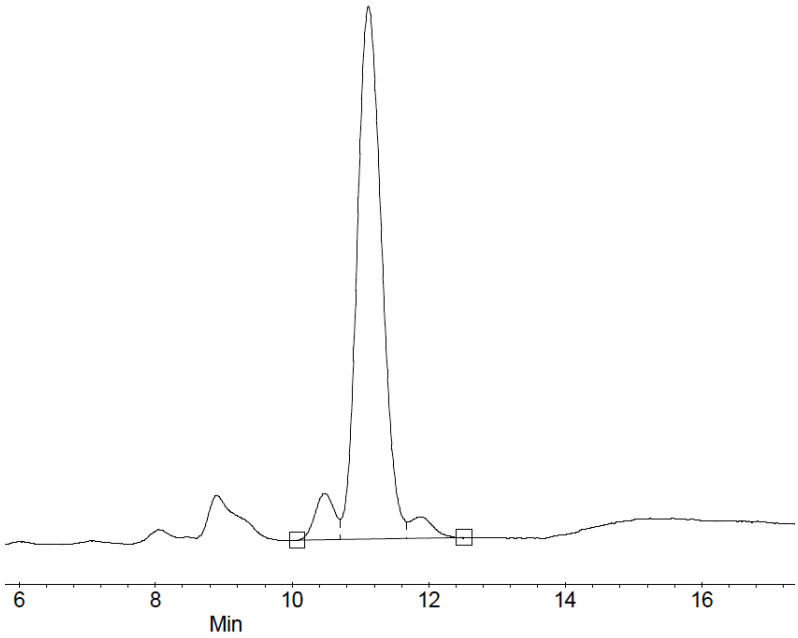




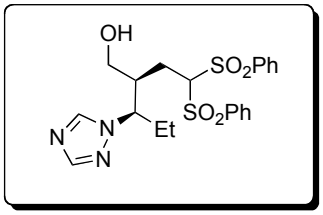
Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	10.04	10.46	11.02	0.00	93.40	544.2	196.5	93.396
3	UNKNOWN	11.02	11.02	11.46	0.00	0.98	8.6	2.1	0.982
2	UNKNOWN	11.55	11.90	12.42	0.00	5.62	32.5	11.8	5.622
Total						100.00	585.3	210.4	100.000

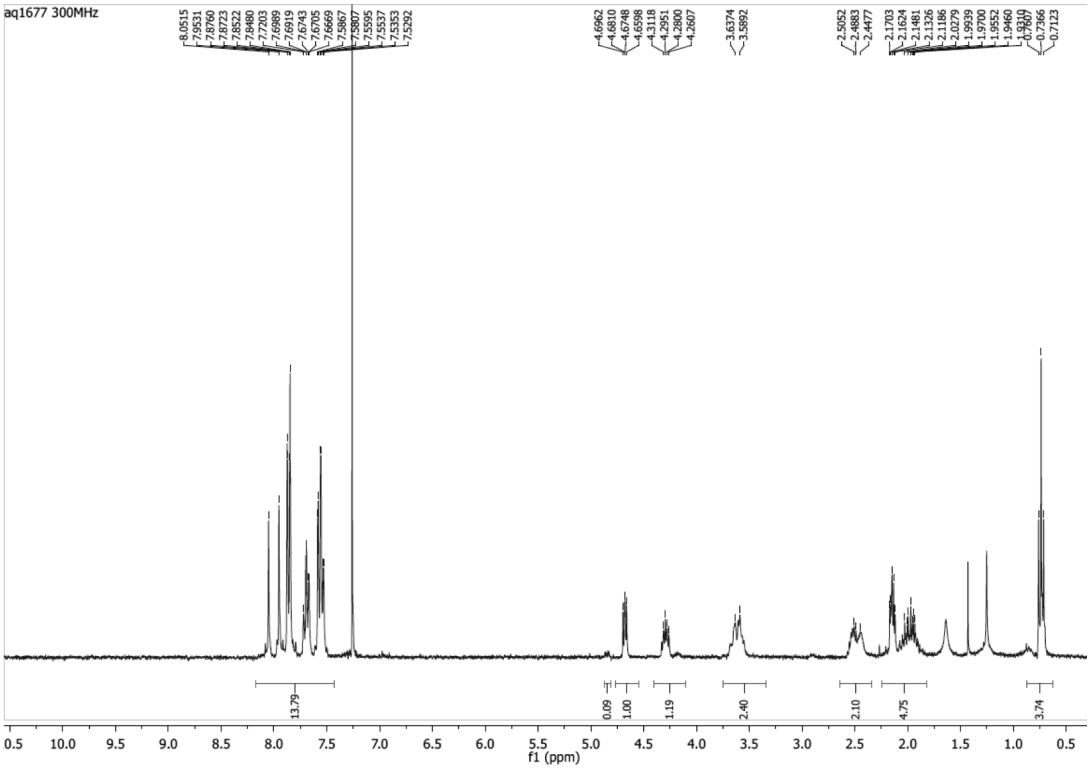


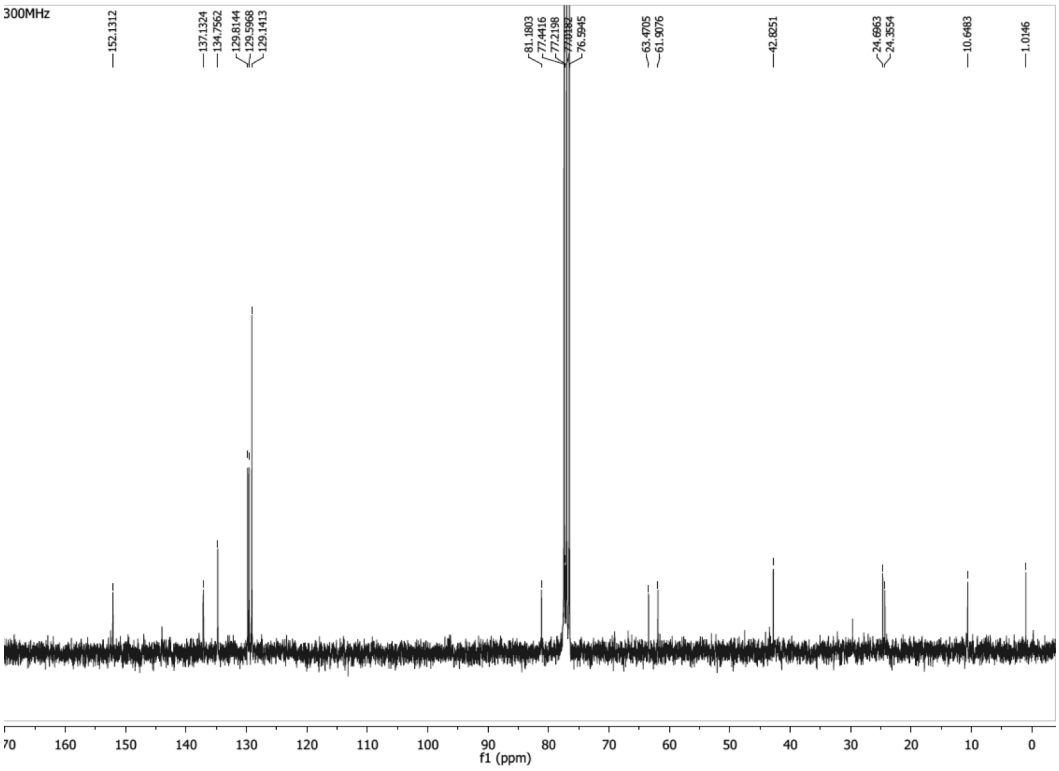
Prepared with **5b**:

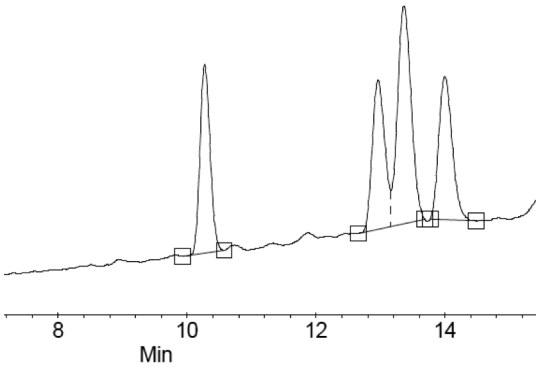


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	10.07	10.47	10.70	0.00	6.16	44.1	14.3	6.161
2	UNKNOWN	10.70	11.12	11.68	0.00	90.35	504.6	209.9	90.350
3	UNKNOWN	11.68	11.87	12.51	0.00	3.49	20.6	8.1	3.489
Total						100.00	569.3	232.3	100.000

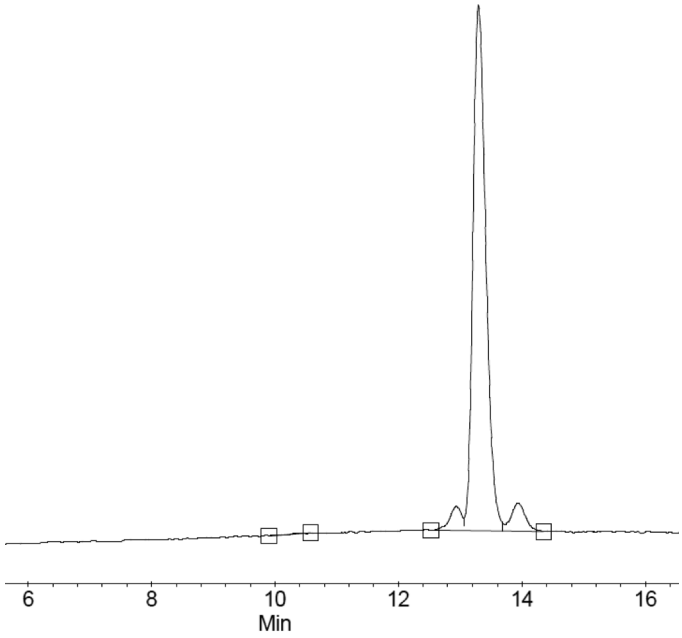

OH
SO2Ph
SO2Ph
Et
N
N
N


aq1677 300MHz
f1 (ppm)

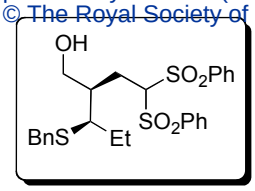

300MHz
f1 (ppm)

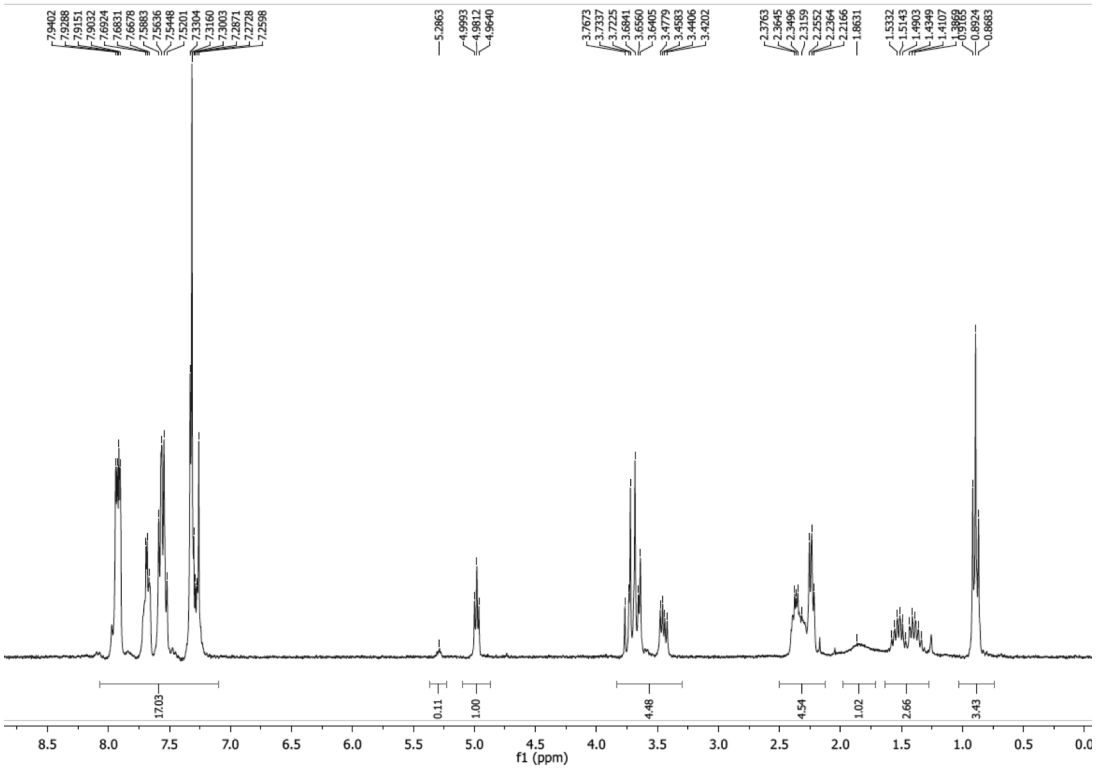


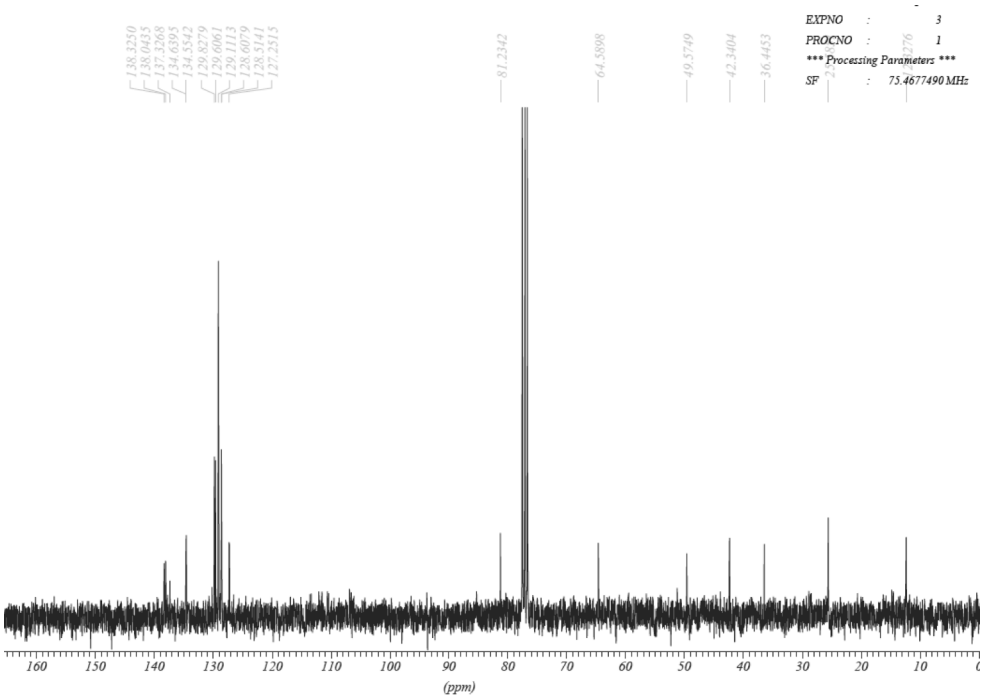
Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	9.93	10.27	10.57	0.00	22.21	213.9	39.2	22.209
2	UNKNOWN	12.66	12.96	13.16	0.00	21.35	168.6	37.7	21.351
4	UNKNOWN	13.16	13.37	13.69	0.00	34.30	247.1	60.6	34.303
3	UNKNOWN	13.77	14.00	14.48	0.00	22.14	162.3	39.1	22.137
Total						100.00	792.0	176.7	100.000

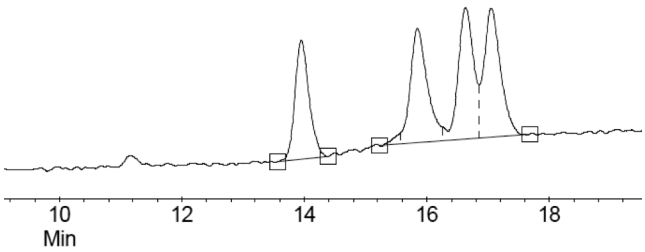


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
4	UNKNOWN	9.91	10.37	10.58	0.00	0.10	0.9	0.1	0.097
1	UNKNOWN	12.52	12.93	13.05	0.00	3.82	24.2	5.3	3.822
2	UNKNOWN	13.05	13.29	13.69	0.00	90.48	522.8	126.2	90.483
3	UNKNOWN	13.69	13.93	14.35	0.00	5.60	28.0	7.8	5.598
Total						100.00	575.9	139.5	100.000

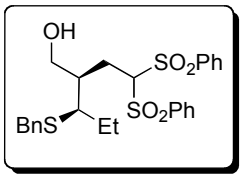


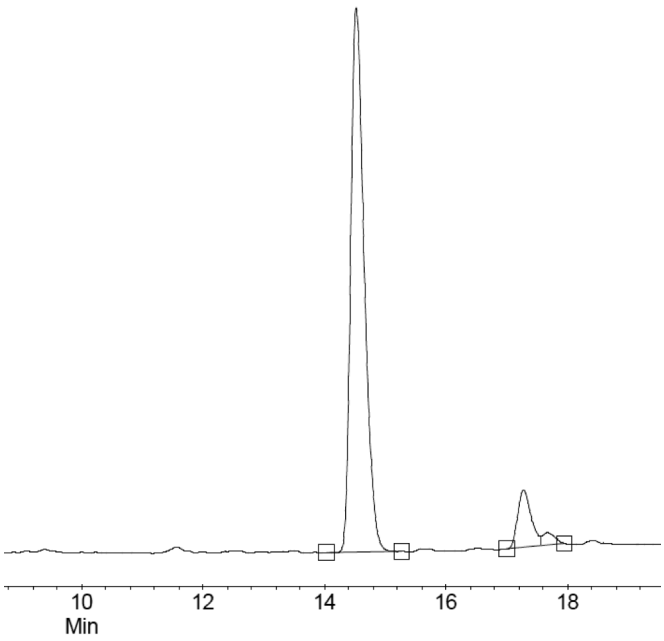




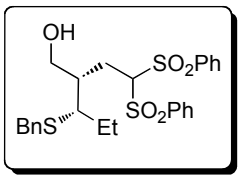


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	13.57	13.95	14.39	0.00	21.54	102.2	27.4	21.544
4	UNKNOWN	15.58	15.85	16.25	0.00	24.83	98.0	31.6	24.829
2	UNKNOWN	16.25	16.63	16.86	0.00	26.51	112.8	33.8	26.512
3	UNKNOWN	16.86	17.05	17.68	0.00	27.11	110.5	34.5	27.114
Total						100.00	423.5	127.3	100.000

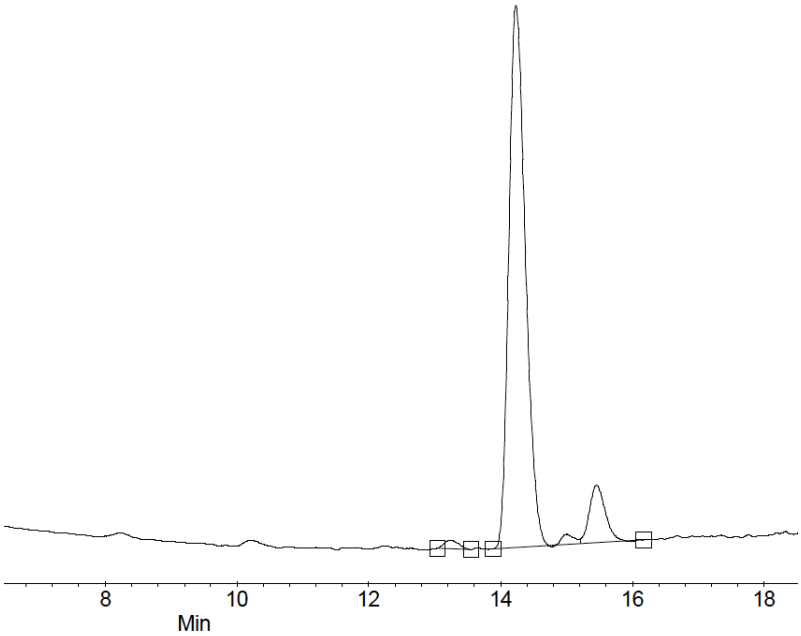




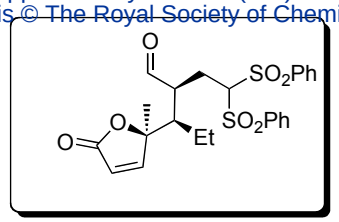
Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
3	UNKNOWN	14.03	14.52	15.28	0.00	88.79	1177.9	301.6	88.786
1	UNKNOWN	17.00	17.27	17.56	0.00	9.38	123.6	31.9	9.384
2	UNKNOWN	17.56	17.67	17.95	0.00	1.83	26.8	6.2	1.831
Total						100.00	1328.3	339.7	100.000

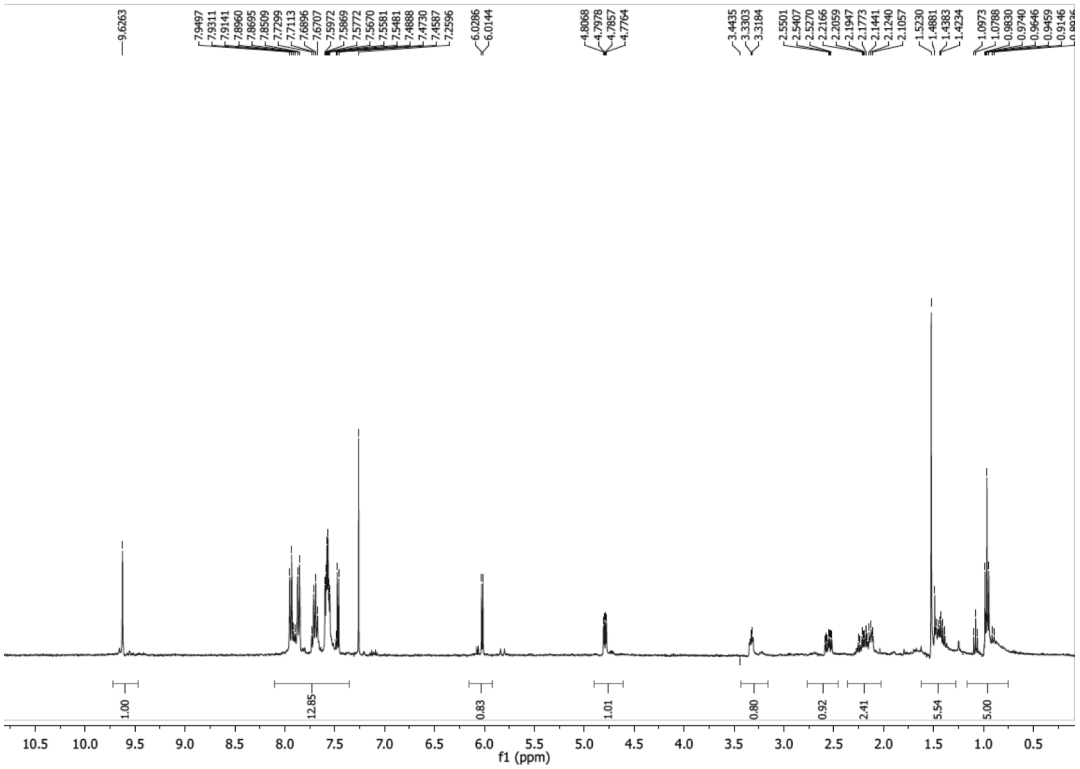


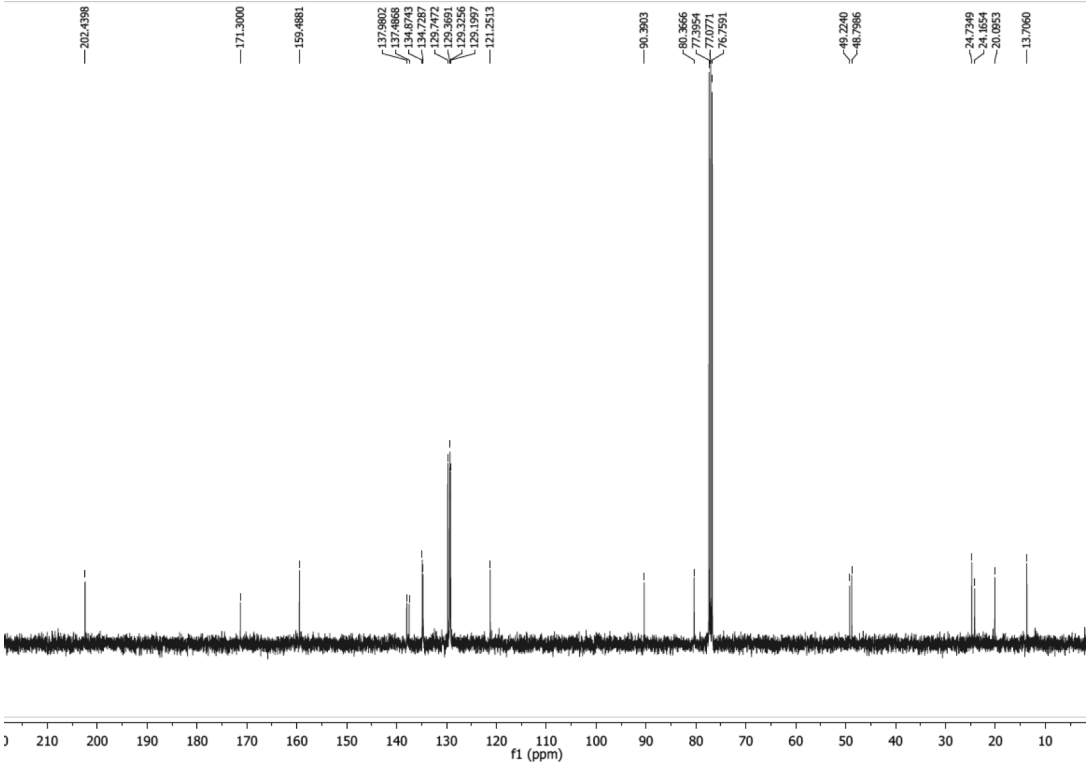
Prepared with (*R*)-**5a** and 2h30 reaction: 98% *ee*

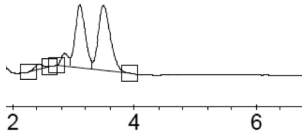


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	13.04	13.23	13.55	0.00	1.22	13.6	3.4	1.219
2	UNKNOWN	13.89	14.23	14.78	0.00	88.46	862.7	250.3	88.461
3	UNKNOWN	14.78	15.00	15.22	0.00	1.30	16.2	3.7	1.304
4	UNKNOWN	15.22	15.45	16.17	0.00	9.02	91.3	25.5	9.016
Total						100.00	983.8	283.0	100.000

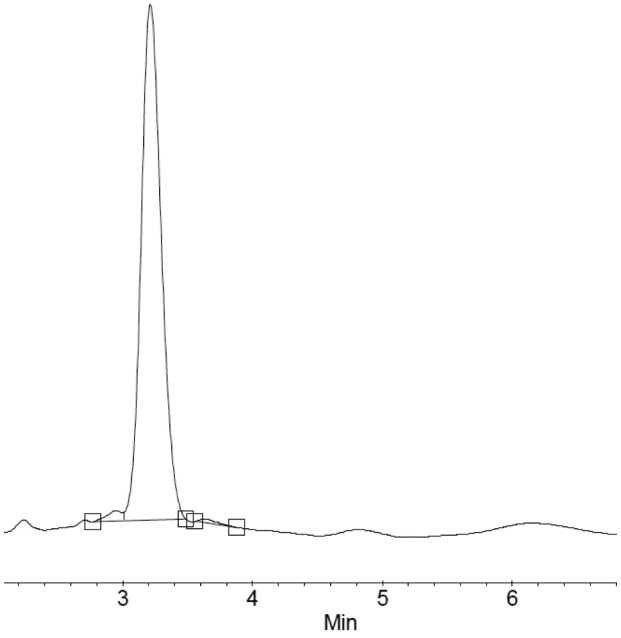




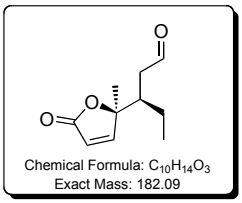


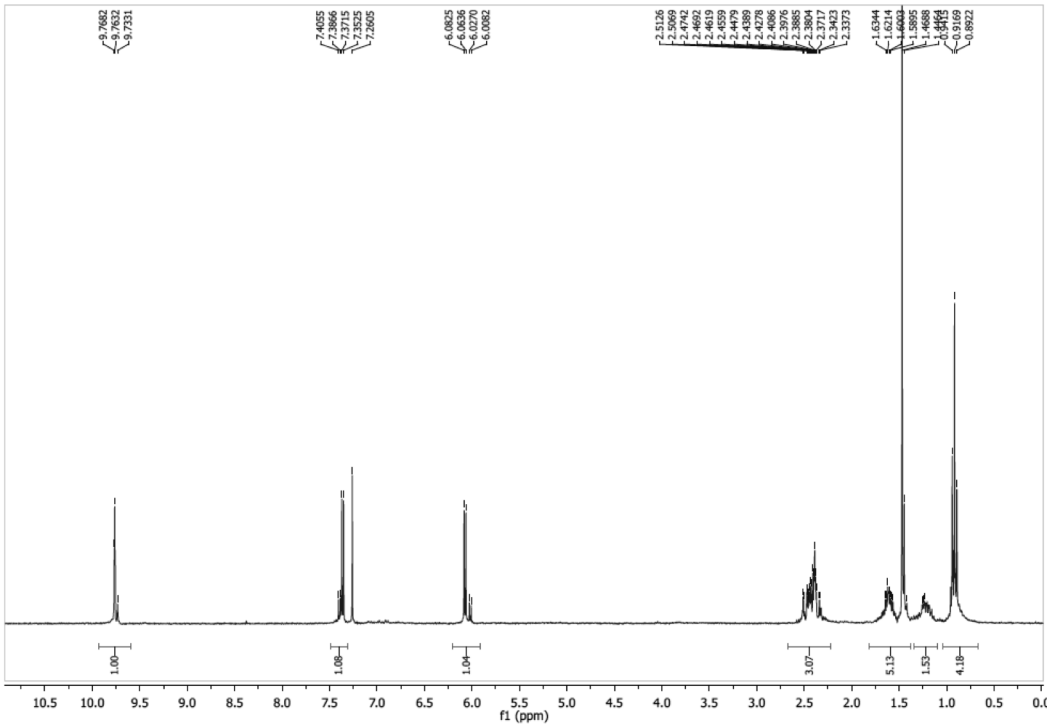


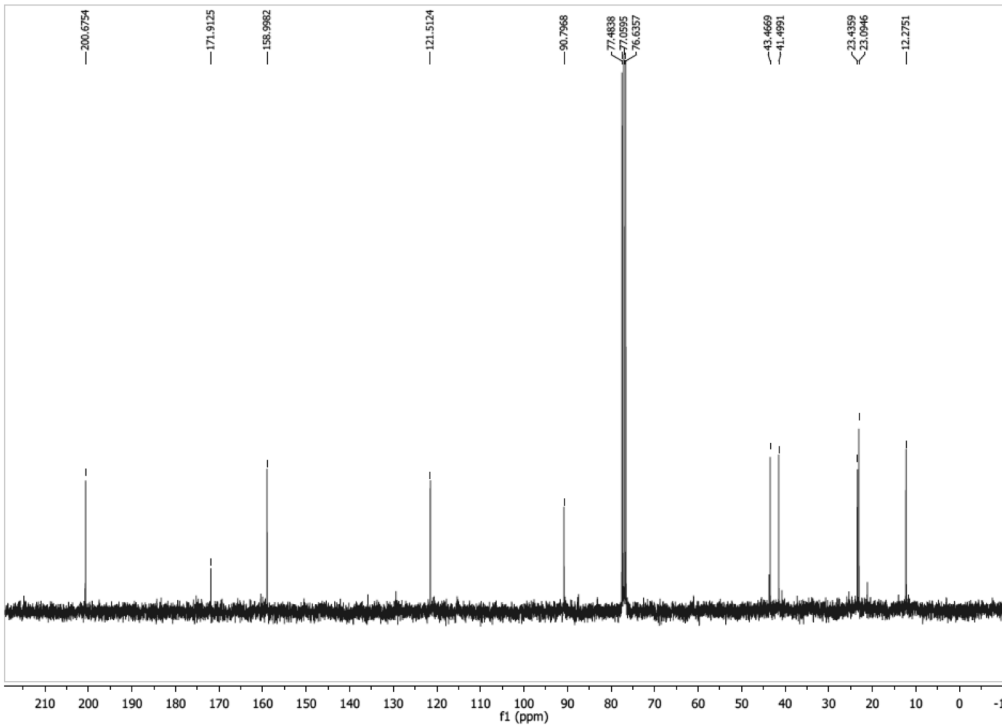
Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	2.26	2.43	2.61	0.00	2.58	22.1	3.3	2.577
2	UNKNOWN	2.73	2.86	2.95	0.00	5.94	56.2	7.6	5.942
3	UNKNOWN	2.95	3.11	3.30	0.00	40.67	273.2	51.8	40.669
4	UNKNOWN	3.30	3.49	3.92	0.00	50.81	280.7	64.7	50.812
Total						100.00	632.2	127.4	100.000



Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	2.77	2.95	3.01	0.00	1.51	30.0	4.1	1.508
3	UNKNOWN	3.01	3.21	3.49	0.00	97.89	1490.4	267.4	97.886
2	UNKNOWN	3.56	3.66	3.88	0.00	0.61	10.0	1.7	0.606
Total						100.00	1530.5	273.1	100.000


Chemical Formula: $C_{10}H_{14}O_3$
Exact Mass: 182.09


f1 (ppm)


f1 (ppm)