

Supporting Information

“Catalytic asymmetric radical-polar crossover hydroalkoxylation”

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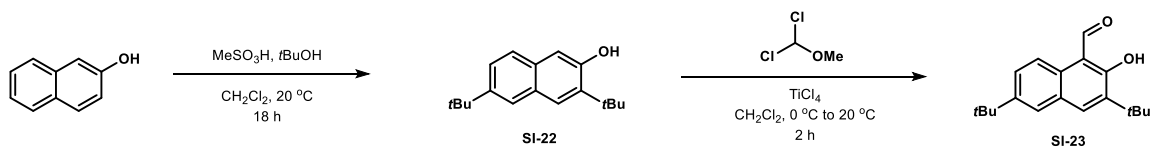
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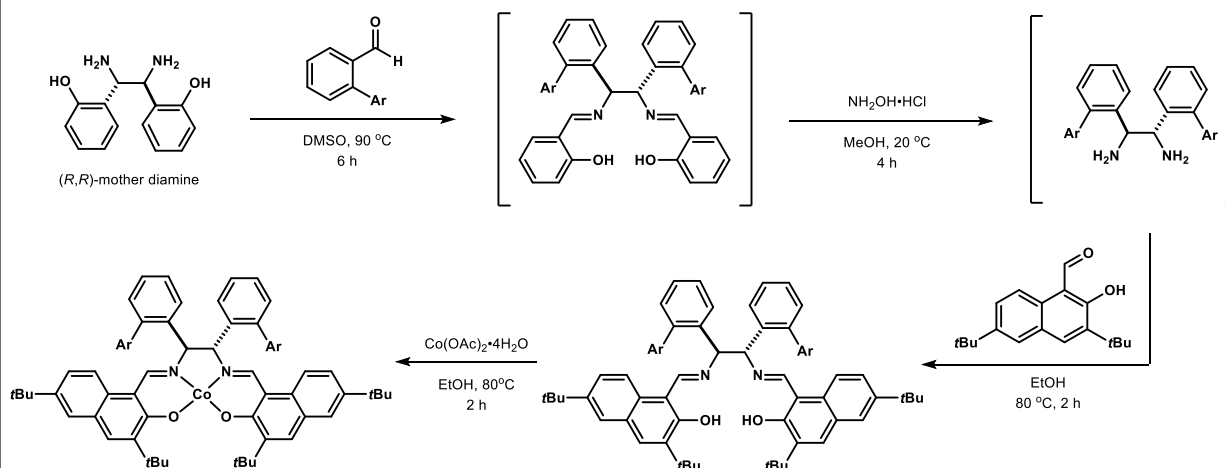
Materials and methods. All reactions were carried out in flame-dried glassware under positive pressure of dry nitrogen unless otherwise noted. Reaction solvents including tetrahydrofuran (THF, Fisher, HPLC Grade), dichloromethane (DCM, Fisher, HPLC Grade), dimethylformamide (DMF, Fisher, HPLC Grade), and toluene (Fisher, HPLC Grade), were dried by percolation through a column packed with neutral alumina and a column packed with a supported copper catalyst for scavenging oxygen (Q5) under positive pressure of argon. Acetone was dried over anhydrous powdered CaSO_4 overnight, distilled into a two-neck round bottom, and then transferred by cannula into a storage Schlenk. Solvents for extraction, thin layer chromatography (TLC), and flash column chromatography were purchased from Fischer (ACS Grade) and VWR (ACS Grade) and used without further purification. Chloroform- d and acetone- d_6 for ^1H and ^{13}C NMR analysis were purchased from Cambridge Isotope Laboratories and used without further purification. Commercially available reagents were used without further purification unless otherwise noted. Reactions were cooled in a Thermo Scientific EK90 immersion cooler. Reactions were monitored by thin layer chromatography (TLC) using precoated silica gel plates (EMD Chemicals, Silica gel 60 F₂₅₄). Flash column chromatography was performed over silica gel (Acros Organics, 60 Å, particle size 0.04-0.063 mm). Infrared (IR) spectra were obtained on a Nicolet iS5 FT-IR spectrometer with an iD5 ATR, and are reported in terms of frequency of absorption (cm^{-1}). GC/FID analysis was performed on Agilent 7820A system with helium as carrier gas. Enantiomeric ratio for enantioselective reactions was determined by chiral SFC analysis using an Agilent Technologies HPLC (1200 series) system and Aurora A5 Fusion. Optical rotations were collected on a JASCO P-1010 polarimeter. ^1H NMR and ^{13}C NMR spectra were recorded on Bruker DRX-500 (BBO probe), Bruker DRX-500 (TCI cryoprobe), Bruker AVANCE600 (TBI probe), and Bruker AVANCE600 (BBFO cryoprobe) spectrometers using residual solvent peaks as internal standards (CHCl_3 @ 7.26 ppm ^1H NMR, 77.00 ppm ^{13}C NMR; C_6H_6 @ 7.16 ppm ^1H NMR, 128.00 ppm ^{13}C NMR; $(\text{CD}_3)_2\text{CO}$ @ 2.05 ppm ^1H NMR, 29.84 ppm ^{13}C NMR; $(\text{CD}_3)_2\text{SO}$ @ 2.50 ppm ^1H NMR, 39.52 ppm ^{13}C NMR). High-resolution mass spectra (HRMS) were recorded on Waters LCT Premier TOF spectrometer with ESI and CI sources.

Scheme S2. general approach to the synthesis of cobalt (II) catalysts **8-11**

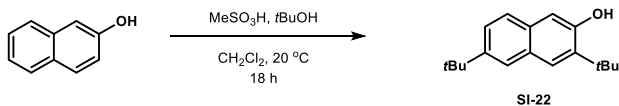
A. preparation of naphthalene salicylaldehyde



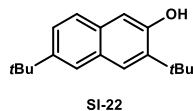
B. preparation of salen and cobalt complexation



Preparation of 3,6-di- t -butyl-2-naphthol, SI-22.



To a solution of 2-naphthol (7.2 g, 50 mmol, 1.0 equiv) and $t\text{BuOH}$ (14 mL, 150 mmol, 3.0 equiv) in CH_2Cl_2 (170 mL, 0.30 M w.r.t. 2-naphthol) in a 1 L roundbottom flask was added MeSO_3H (22 mL, 350 mmol, 7.0 equiv) dropwise with external cooling by a water bath and stirred for 18 h at room temperature following addition. The reaction mixture was poured onto ice water (500 mL) with vigorous stirring and then warmed to room temperature. The aqueous layer was extracted with CH_2Cl_2 (3 x 100 mL), washed with H_2O and brine, dried over MgSO_4 , filtered and concentrated under reduced pressure. The crude product was purified by flash SiO_2 chromatography (gradient elution 10% CH_2Cl_2 /hexanes to 40% CH_2Cl_2 /hexanes) to yield 3,6-di- t -butyl-2-naphthol as a white crystalline solid (5.2 g, 40% yield). The spectral data were identical to those reported in the literature.¹



^1H NMR (500 MHz, CDCl_3 , 25°C):

δ 7.68 (s, 2H)

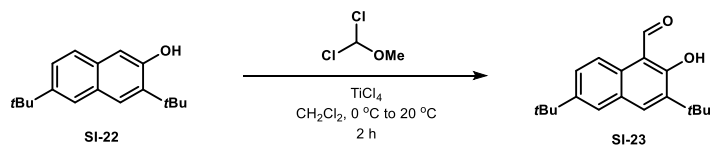
7.56 (d, $J = 8.9$ Hz, 1H)

7.47 (dd, $J = 8.6, 2.0$ Hz, 1H)

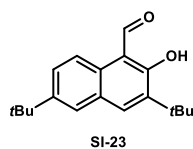
6.98 (s, 1H), 4.97 (s, 1H)

1.50 (s, 9H), 1.39 (s, 9H)

Preparation of naphthalene salicylaldehyde **SI-23**.



To a flame-dried, N₂-purged 250 mL roundbottom flask was added **SI-22** (4.4 g, 17.1 mmol, 1.0 equiv) and dichloromethylmethyl ether (1.5 mL, 17.1 mmol, 1.0 equiv) in CH₂Cl₂ (86 mL, 0.2 M w.r.t **SI-22**) and the flask was cooled to 0 °C in an ice bath. TiCl₄ (3.8 mL, 34.2 mmol, 2.0 equiv) was added dropwise to the reaction mixture at 0 °C. The ice bath was warmed to room temperature and stirred for 2 h. The reaction mixture was poured onto ice water (200 mL), and the aqueous layer was extracted with CH₂Cl₂ (3 x 100 mL). The combined organic layers were washed with brine, dried over MgSO₄, filtered, and concentrated under reduced pressure. The crude material was purified by flash silica chromatography (20% CH₂Cl₂/Hexanes) to yield 3.16 g (65% yield) of salicylaldehyde **SI-23**. The spectral data was identical to those reported in the literature.²



¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 14.02 (s, 1H)

10.80 (s, 1H)

8.23 (d, J = 8.8 Hz, 1H)

7.92 (s, 1H)

7.71 (d, J = 2.1 Hz, 1H)

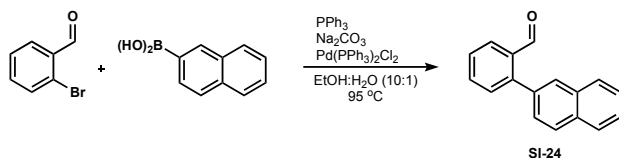
7.65 (dd, J = 8.8, 2.1 Hz, 1H)

1.51 (s, 9H)

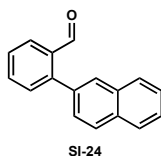
1.41 (s, 9H)

General Procedure I: Preparation of 2-arylbenzaldehydes SI-24-26.

To a flame dried 50 mL round bottom flask was added 2-bromobenzaldehyde (1.0 equiv), aryl boronic acid (1.2 equiv), Pd(PPh₃)₂Cl₂ (0.050 equiv), triphenylphosphine (0.10 equiv), and Na₂CO₃ (1.2 equiv). The flask was fitted with a septum and the atmosphere replaced with N₂. Degassed EtOH (0.2 M w.r.t. benzaldehyde) and degassed H₂O (2.0 M w.r.t. benzaldehyde) were added and the suspension stirred. The flask was equipped with a reflux condenser and the reaction was heated at 95 °C overnight. After allowing the reaction to cool to rt, the reaction was diluted with H₂O and the resulting mixture was extracted with Et₂O (3x). The organic layers were washed with brine and dried over MgSO₄. The crude material was purified by flash silica chromatography to yield 2-arylbenzaldehyde.



Benzaldehyde SI-24. Benzaldehyde SI-24 was prepared according to **General Procedure I** using 2-bromobenzaldehyde (0.23 mL, 2.0 mmol), 2-naphthylboronic acid (412.8 mg, 2.4 mmol), Pd(PPh₃)₂Cl₂ (70.2 mg, 0.1 mmol), triphenylphosphine (52.5 mg, 0.2 mmol), and Na₂CO₃ (254.4 mg, 2.4 mmol), and purified by flash silica chromatography (gradient elution: 100% hexanes to 5% v/v EtOAc/hexanes) to yield 455.0 mg (98% yield) of **SI-24** as a white solid. The spectral data matched those reported in the literature.³

**Benzaldehyde SI-24**

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 10.04 (d, *J* = 0.8 Hz, 1H)

8.08 (ddd, *J* = 7.8, 1.4, 0.5 Hz, 1H)

7.95 (d, *J* = 8.4 Hz, 1H)

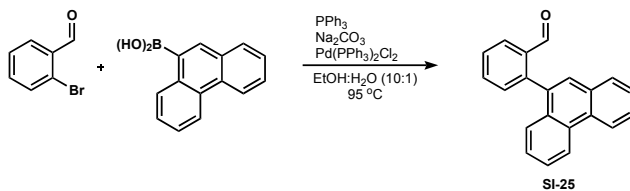
7.93-7.88 (m, 2H)

7.83 (d, *J* = 1.2 Hz, 1H)

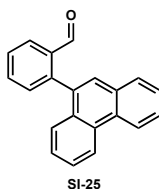
7.68 (ddd, *J* = 7.7, 7.3, 1.4 Hz, 1H)

7.57-7.52 (m, 5H)

TLC: R_f = 0.46 (10% EtOAc/Hex)



Benzaldehyde SI-25. Benzaldehyde SI-X was prepared according to **General Procedure I** using 2-bromobenzaldehyde (0.12 mL, 1.0 mmol), 9-phenanthrenylboronic acid (266.5 mg, 1.2 mmol), Pd(PPh₃)₂Cl₂ (35.1 mg, 0.05 mmol), triphenylphosphine (26.2 mg, 0.1 mmol), and Na₂CO₃ (127.2 mg, 1.2 mmol), and purified by flash silica chromatography (gradient elution: 100% hexanes to 5% v/v EtOAc/hexanes) to yield 248.5 mg (88% yield) of **SI-25** as a white solid. The spectral data matched those reported in the literature.⁴

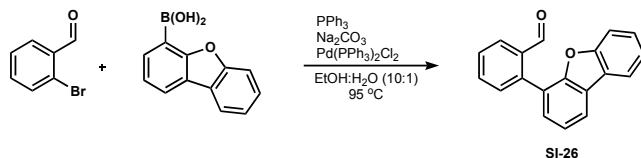


Benzaldehyde SI-25

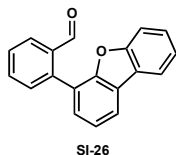
¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 9.74 (d, <i>J</i> = 0.8 Hz, 1H)	7.71 (s, 1H)
8.80 (d, <i>J</i> = 8.6 Hz, 1H)	7.70-7.68 (m, 1H)
8.76 (dd, <i>J</i> = 8.3, 0.5 Hz, 1H)	7.68-7.65 (m, 1H)
8.17-8.15 (m, 1H)	7.64-7.61 (m, 1H)
7.91-7.90 (m, 1H)	7.55-7.53 (m, 2H)
7.75-7.72 (m, 2H)	7.53-7.51 (m, 1H)

TLC: R_f = 0.41 (10% EtOAc/Hex)



Benzaldehyde SI-26. Benzaldehyde SI-X was prepared according to **General Procedure I** using 2-bromobenzaldehyde (0.58 mL, 5.0 mmol), 4-(dibenzofuranyl)boronic acid (1.2721 g, 6.0 mmol), Pd(PPh₃)₂Cl₂ (175.4 mg, 0.25 mmol), triphenylphosphine (131.1 mg, 0.5 mmol), and Na₂CO₃ (635.9 mg, 6.0 mmol), and purified by flash silica chromatography (gradient elution: 100% hexanes to 5% v/v EtOAc/hexanes) to yield 1.235 g (91% yield) of **SI-26** as a white solid.



Benzaldehyde SI-26

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 9.91 (d, <i>J</i> = 0.7 Hz, 1H)	8.01 (dd, <i>J</i> = 7.7, 0.6 Hz, 1H)	7.52-7.47 (m, 2H)
8.15 (dd, <i>J</i> = 7.8, 0.8 Hz, 1H)	7.75 (td, <i>J</i> = 7.5, 1.2 Hz, 1H)	7.45 (ddt, <i>J</i> = 6.7, 4.9, 1.7 Hz, 2H)
8.04 (dd, <i>J</i> = 7.4, 1.5 Hz, 1H)	7.64-7.59 (m, 2H)	7.39-7.36 (m, 1H)

¹³C NMR (126 MHz, CDCl₃, 25 °C):

δ 191.9	133.91	127.64	122.3
156.3	131.5	124.6	120.96
153.8	128.9	124.0	120.89
140.0	128.6	123.17	112.0
134.06	127.69	123.14	

HRMS (ESI) calculated for C₁₉H₁₂O₂ [M+Na]⁺: 295.0735, found: 295.0731

TLC: R_f = 0.43 (10% EtOAc/Hex)

General Procedure II: Preparation of Salen Ligands **SI-27-30**

A. Diaza-Cope

The procedure for the diaza-Cope was adapted from the Chin group's report on diaza-Cope transformations with sterically challenging benzaldehydes.⁵ (*R,R*)-Mother diamine (0.10 mmol, 24 mg, 1.0 equiv) and 2-arylbenzaldehyde (0.24 equiv, 2.4 equiv) in DMSO (0.50 mL, 0.20 M w.r.t. mother diamine) was added to a vial and stirred at 90 °C for 6 hours. The reaction mixture was diluted with CH₂Cl₂ and transferred to a separatory funnel. The organic layer was washed with H₂O (3 x 10 mL) and brine, dried with Na₂SO₄, filtered, and concentrated under reduced pressure. The crude diaza-Cope product was taken on to the next step without purification.

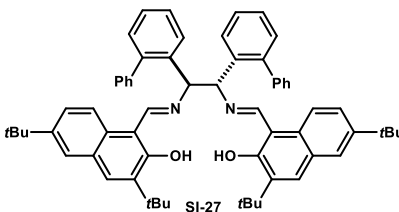
B. Salicylaldehyde deprotection

Crude diaza-Cope product (1.0 equiv) and NH₂OH•HCl (35 mg, 0.50 mmol, 5.0 equiv) in MeOH (1.0 mL, 0.10 M w.r.t. diaza-Cope product) was added to a vial and stirred at room temperature for 4 hours. 1 M NaOH (10 mL) was added to the reaction mixture and the aqueous layer was extracted with CH₂Cl₂ (5 x 10 mL), dried with Na₂SO₄, filtered, and concentrated under reduced pressure. The crude diamine was taken on to the next step without purification.

C. Salen Formation

Crude diamine (1.0 equiv) and naphthalene salicylaldehyde **SI-23** (0.20 mmol, 2.0 equiv) in EtOH (0.50 mL, 0.20 M w.r.t. diamine) was added to a vial and stirred at 60 °C for 4 hours. The reaction mixture was allowed to cool to room temperature, concentrated under reduced pressure, and purified by flash SiO₂ chromatography to afford salen as a yellow solid.

Ligand SI-27. Ligand **SI-27** was prepared according to General Procedure II with 2-phenylbenzaldehyde (44 mg, 0.24 mmol) and purified by flash silica chromatography (20% CH₂Cl₂/Hex) to afford ligand **SI-27** as a yellow solid (49 mg, 56% yield over three steps.)



Salen SI-27

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 14.90 (s, 1H)	7.25 (dtd, J = 14.8, 7.2, 3.5 Hz, 4H)
8.76 (s, 1H)	7.06 (dd, J = 6.6, 1.6 Hz, 2H)
7.55 (d, J = 8.8 Hz, 1H)	7.04 (d, J = 31.2 Hz, 3H)
7.47 (td, J = 13.9, 7.5 Hz, 4H)	5.11 (s, 1H)
7.43 (s, 1H), 7.37 (d, J = 1.9 Hz, 1H)	1.33 (s, 10H)
7.30 (dd, J = 8.8, 2.1 Hz, 1H)	1.31 (s, 9H).

¹³C NMR (151 MHz, CDCl₃, 25 °C):

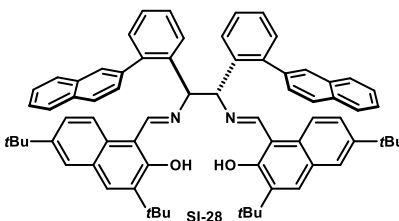
δ 169.0	131.9	125.4
160.8	130.1	124.1
145.2	128.22	117.7
142.4	128.13	107.8
140.7	127.6	72.1
140.3	127.4	31.3
135.3	126.3	29.4

LRMS (ESI) calc. for C₆₄H₆₈N₂O₂Na [M+Na]⁺: 919.5, found: 919.6

TLC R_f = 0.56 (35% v/v CH₂Cl₂ in hexanes)

[α]_D²³ = −6.6 ° (c = 1.8, CHCl₃)

Ligand SI-28. Ligand **SI-28** was prepared according to General Procedure II with **SI-24** (56 mg, 0.24 mmol) and purified by flash silica chromatography (20% CH₂Cl₂/Hex) to afford ligand **SI-28** as a yellow solid (52 mg, 51% yield over three steps.)



Salen SI-28

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 13.06 (s, 1H)	7.24 (d, J = 7.8 Hz, 1H)
8.16 (s, 1H)	7.20 (td, J = 7.7, 1.2 Hz, 1H)
7.98-7.96 (m, 1H)	7.12 (d, J = 7.6 Hz, 1H)
7.88 (d, J = 8.2 Hz, 1H)	7.10-7.02 (m, 3H)
7.80 (s, 1H)	6.80 (d, J = 8.2 Hz, 1H)
7.59 (dd, J = 6.2, 3.1 Hz, 1H)	6.76 (t, J = 7.4 Hz, 1H)
7.57-7.52 (m, 1H)	5.05 (s, 1H).

¹³C NMR (151 MHz, CDCl₃, 25 °C):

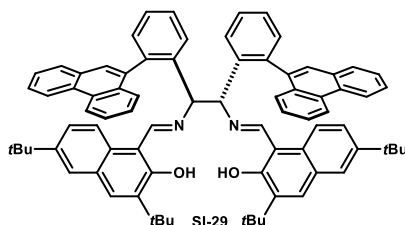
δ 165.6	131.7	126.2
160.7	130.0	118.7
141.9	128.7	118.5
138.1	127.96	116.7
136.1	127.87	74.2
132.44	127.0	
132.40	126.5	

LRMS (ESI) calc. for C₇₂H₇₂N₂O₂Na [M+Na]⁺: 1019.6, found: 1019.6.

TLC R_f = 0.61 (35% v/v CH₂Cl₂ in hexanes)

[α]_D²⁵ = -130.6 ° (c = 1.3, CHCl₃)

Ligand SI-29. Ligand **SI-29** was prepared according to General Procedure II with **SI-25** (68 mg, 0.24 mmol) and purified by flash silica chromatography (20% CH₂Cl₂/Hex) to afford ligand **SI-29** as a yellow solid (51 mg, 47% yield over three steps). NOTE: It was observed that **SI-29** is produced as a mixture of four atropisomers. This procedure was used to isolate a single (major) atropisomer of **SI-29** for characterization purposes. Control experiments determined that mixture of atropisomers is equally efficient in the hydrofunctionalization process (i.e. same yield and enantioenrichment).



Salen SI-29

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 14.72 (s, 1H)	7.30 (s, 2H)
8.91 (t, J = 9.0 Hz, 2H)	7.24-7.21 (m, 2H)
8.02 (d, J = 3.2 Hz, 1H)	7.18-7.13 (m, 2H)
7.85-7.82 (m, 2H), 7.79-7.76 (m, 1H)	7.05-7.01 (m, 2H)
7.62 (td, J = 7.6, 1.2 Hz, 1H)	4.55 (s, 1H)
7.44 (td, J = 7.4, 1.2 Hz, 1H)	1.33 (s, 9H)
7.34 (d, J = 2.0 Hz, 1H)	0.96 (s, 9H)

¹³C NMR (151 MHz, CDCl₃, 25 °C):

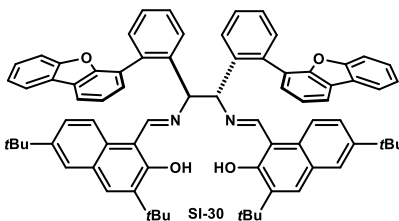
167.2	130.1	123.7
161.1	129.8	123.2
145.1	129.3	122.8
139.7	129.1	118.5
139.6	128.7	107.6
137.3	128.5	74.6
136.33	127.8	34.6
131.3	127.0	34.2
131.2,	126.8	31.3
131.1	126.7	28.9
130.4	126.2	
130.2	124.9	

LRMS (ESI) calc. for C₈₀H₇₆N₂O₂Na [M+Na]⁺: 1119.6, found: 1119.7.

TLC R_f = 0.65 (35% v/v CH₂Cl₂ in hexanes)

[α]_D²⁵ = -62.5 ° (c = 0.80, CHCl₃)

Ligand SI-30. Ligand **SI-30** was prepared according to General Procedure II with **SI-26** (65 mg, 0.24 mmol) and purified by flash silica chromatography (20% CH₂Cl₂/Hex) to afford ligand **SI-30** as a yellow solid (45 mg, 42% yield over three steps.)



Salen SI-30

¹H NMR (600 MHz, DMSO-d₆, 100 °C):

δ 14.68 (s, 1H)	7.08 (d, J = 51.2 Hz, 3H)
8.56 (s, 1H)	6.87 (d, J = 5.3 Hz, 2H)
8.15 (dd, J = 25.7, 7.7 Hz, 2H)	5.15 (s, 1H)
7.44-7.37 (m, 3H)	1.31 (s, 9H)
7.32 (t, J = 7.3 Hz, 2H)	1.21 (s, 9H)
7.21 (d, J = 6.6 Hz, 2H)	

¹³C NMR (600 MHz, DMSO-d₆, 100 °C):

δ 169.1	127.7	119.7
159.8	127.41	117.2
154.8	127.40	110.8
152.3	126.9	106.5
144.0	126.4	70.66
139.8	125.1	70.64
136.1	123.87	53.9
135.5	123.75	33.9
130.8	123.31	33.2
129.9	123.20	30.4
129.4	122.4	28.7
128.17	122.1	
128.17	120.2	

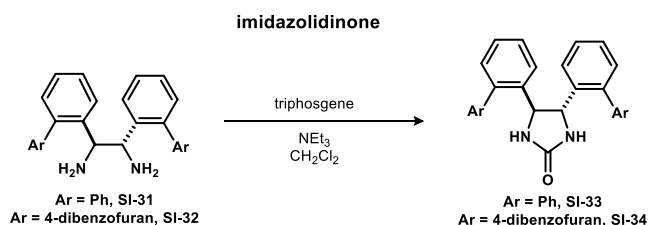
LRMS (ESI) calc. for C₇₆H₇₂N₂O₄Na [M+Na]⁺: 1099.5, found: 1099.6.

TLC R_f = 0.52 (35% v/v CH₂Cl₂ in hexanes)

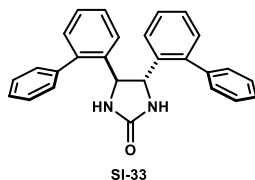
[α]_D²⁵ = 163 ° (c = 1.0, CHCl₃)

General Procedure III: Determination of Diamine Enantiopurity via Imidazolidinone

To a solution of crude diamine (0.05 mmol, 1.0 equiv) and triphosgene (22 mg, 0.075 mmol, 1.5 equiv) in CH_2Cl_2 (350 μL , 0.10 M w.r.t. diamine) was added triethylamine (21 μL , 0.15 mmol, 3.0 equiv) at 0 °C. Following addition, the reaction was allowed to warm to room temperature and stirred until completion by TLC analysis. The reaction mixture was diluted with CH_2Cl_2 (5 mL), washed with H_2O (10 mL), then brine (10 mL). The organic layer was dried over Na_2SO_4 , filtered, and concentrated under reduced pressure. The crude material was purified by flash silica chromatography to afford imidazolidinone as a white solid. The enantioenrichment of the purified imidazolidinones was determined using chiral phase SFC. NOTE: Racemic standards were prepared by performing diaza-Cope, salicylaldehyde deprotection, and imidazolidinone formation with racemic mother diamine.



Imidazolidinone SI-33: Imidazolidinone **SI-33** was prepared according to General Procedure III using diamine **SI-31** (18 mg, 0.050 mmol) and purified by flash silica chromatography (60% v/v CH₂Cl₂ in hexanes) to afford **SI-32** as a white solid (10 mg, 51% yield).



Imidazolidinone SI-33

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 7.47 (dd, J = 7.6, 1.3 Hz, 1H)	7.09 (s, 1H)
7.33-7.27 (m, 1H)	6.58 (s, 2H)
7.21 (t, J = 7.5 Hz, 1H)	4.88 (s, 1H)
7.13 (dd, J = 7.5, 1.4 Hz, 1H)	4.64 (s, 1H).

¹³C NMR (151 MHz, CDCl₃, 25 °C):

δ 161.9	129.8	127.71
142.2	128.9	127.5
139.7	128.3	126.8
136.0	127.91	61.8

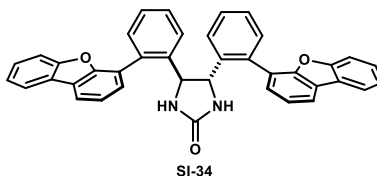
LRMS (ESI) calc. for C₂₇H₂₂N₂ONa [M+Na]⁺: 413.2, found: 413.2.

TLC R_f = 0.20 (50% v/v EtOAc in hexanes)

Chiral SFC: CHIRALPAK AD, 30% *i*PrOH, 2.0 mL/min, 210 nm, 44 °C, nozzle pressure = 200 bar CO₂, t_R = 4.8, 5.9 min.

[α]_D²⁵ = −23.1 ° (c = 0.80, CHCl₃); 97% ee.

Imidazolidinone SI-34: Imidazolidinone **SI-34** was prepared according to General Procedure III using diamine **SI-32** (27 mg, 0.050 mmol) and purified by flash silica chromatography (60% v/v CH₂Cl₂ in hexanes) to afford **SI-34** as a white solid (17 mg, 55% yield).



Imidazolidinone SI-34

¹H NMR (600 MHz, DMSO-d₆, 100 °C):

δ 8.09 (d, J = 7.6 Hz, 1H)	7.17 (t, J = 7.2 Hz, 1H)
7.99 (dd, J = 7.7, 1.2 Hz, 1H)	7.11-7.00 (m, 2H)
7.51 (d, J = 8.0 Hz, 1H)	6.84 (s, 1H)
7.46 (td, J = 7.7, 1.3 Hz, 1H)	6.39 (s, 1H)
7.40-7.37 (m, 1H)	4.60 (s, 1H)
7.26 (d, J = 7.8 Hz, 1H)	

¹³C NMR (151 MHz, DMSO-d₆, 100 °C):

δ 161.3	127.6	122.3
155.1	126.7	122.0
152.4	126.4	120.4
138.2	126.1	119.3
134.8	123.5	111.2
129.4	123.24	61.2
127.9	123.10	

LRMS (ESI) calc. for C₃₉H₂₆N₂O₃Na [M+Na]⁺: 593.2, found: 593.2.

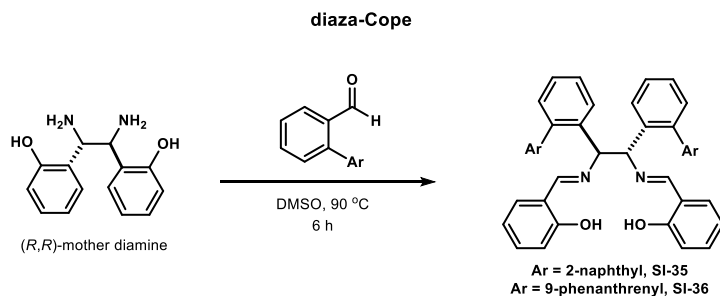
TLC R_f = 0.36 (50% v/v EtOAc in hexanes)

Chiral SFC: CHIRALPAK AD, 30% iPrOH, 2.0 mL/min, 210 nm, 40 °C, nozzle pressure = 200 bar CO₂, t_R = 16.9, 24.3 min.

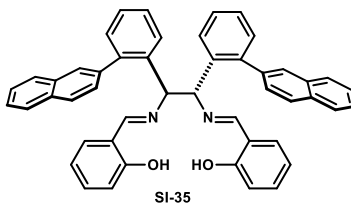
[α]_D²⁵ = 34.7 ° (c = 1.6, CHCl₃); 96% ee.

General Procedure IV: Determination of Diamine Enantiopurity via Diaza-Cope

(*R,R*)-Mother diamine (0.10 mmol, 24 mg, 1.0 equiv) and 2-arylbenzaldehyde (0.24 equiv, 2.4 equiv) in DMSO (0.50 mL, 0.20 M w.r.t. mother diamine) was added to a vial and stirred at 90 °C for 6 hours. The reaction mixture was diluted with CH₂Cl₂ and transferred to a separatory funnel. The organic layer was washed with H₂O (3 x 10 mL) and brine, dried with Na₂SO₄, filtered, and concentrated under reduced pressure. The crude material was purified by flash silica chromatography (40% v/v CH₂Cl₂ in hexanes) to afford diaza-Cope product as a white solid. The enantioenrichment of the purified diaza-Cope product was determined using chiral phase SFC. NOTE: Racemic standards were prepared by performing diaza-Cope with racemic mother diamine.



Diaza-Cope Product SI-35. Diaza-Cope product **SI-35** was prepared according to General Procedure IV using **SI-24** (60 mg, 0.24 mmol) and purified by flash silica chromatography (40% v/v CH₂Cl₂ in hexanes) to afford diaza-Cope product **SI-35** as a white solid (45 mg, 67% yield.)



Diaza-Cope product SI-35

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 13.06 (s, 1H)	7.20 (td, J = 7.7, 1.2 Hz, 1H)
8.16 (s, 1H)	7.12 (d, J = 7.6 Hz, 1H)
7.98-7.96 (m, 1H)	7.09 (d, J = 8.4 Hz, 1H)
7.88 (d, J = 8.2 Hz, 1H)	7.05-7.02 (m, 1H)
7.80 (s, 1H)	6.80 (d, J = 8.2 Hz, 1H)
7.59 (dd, J = 6.2, 3.1 Hz, 1H)	6.76 (t, J = 7.4 Hz, 1H)
7.57-7.52 (m, 1H)	5.05 (s, 1H)
7.26-7.23 (m, 1H)	

¹³C NMR (151 MHz, CDCl₃, 25 °C):

δ 165.6	131.7	126.2
160.7	130.0	118.7
141.9	128.7	118.5
138.1	127.96	116.7
136.1	127.87	74.2
132.44	127.0	
132.40	126.5	

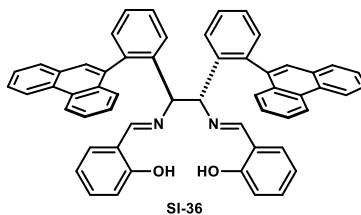
LRMS (ESI) calc. for C₄₈H₃₆N₂O₂Na [M+Na]⁺: 695.3, found: 695.3.

TLC R_f = 0.13 (40% v/v CH₂Cl₂ in hexanes)

Chiral SFC: CHIRALPAK AD, 20% *i*PrOH, 2.0 mL/min, 254 nm, 40 °C, nozzle pressure = 200 bar CO₂, t_R = 8.1, 11.8 min.

[α]_D²⁵ = −71.7 ° (c = 2.0, CHCl₃); 95% ee.

Diaza-Cope Product SI-36. Diaza-Cope product **SI-36** was prepared according to General Procedure IV using **SI-25** (67 mg, 0.24 mmol) and purified by flash silica chromatography (40% v/v CH₂Cl₂ in hexanes) to afford diaza-Cope product **SI-36** as a white solid (34 mg, 44% yield).



Diaza-Cope product SI-36

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 12.89 (s, 1H)	7.17 (ddd, J = 8.2, 6.9, 1.1 Hz, 1H)
8.85 (dd, J = 8.1, 5.9 Hz, 2H)	7.11 (tdd, J = 7.6, 3.7, 1.4 Hz, 2H)
7.83 (d, J = 7.6 Hz, 1H)	7.07 (dd, J = 7.9, 1.1 Hz, 1H)
7.80 (td, J = 7.7, 1.4 Hz, 1H)	7.03 (d, J = 7.5 Hz, 1H)
7.77-7.75 (m, 1H)	6.84 (s, 1H)
7.64 (ddd, J = 8.3, 6.9, 1.3 Hz, 1H)	6.73 (dd, J = 7.6, 1.6 Hz, 1H)
7.41 (td, J = 7.3, 1.3 Hz, 1H)	6.69-6.66 (m, 2H)
7.27 (s, 1H)	4.45 (s, 1H).
7.24 (dd, J = 7.4, 1.1 Hz, 1H)	

¹³C NMR (151 MHz, CDCl₃, 25 °C):

δ 165.8	130.14	126.54
160.6	130.12	126.42
139.6	129.27	123.2
137.6	129.08	122.8
136.2	129.05	118.5
132.1	128.3	118.1
131.5	127.6	116.5
131.25	127.2	75.3
131.17	126.92	
130.32	126.84	

LRMS (ESI) calc. for C₅₆H₄₀N₂O₂Na [M+Na]⁺:795.3, found:795.3.

TLC R_f = 0.15 (40% v/v CH₂Cl₂ in hexanes)

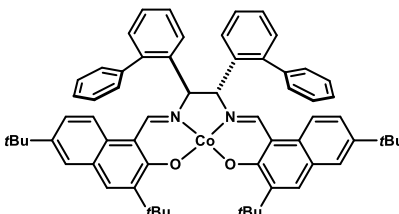
Chiral SFC: CHIRALPAK AD, 20% *i*PrOH, 2.0 mL/min, 210 nm, 40 °C, nozzle pressure = 200 bar CO₂, t_R = 15.1, 31.5 min.

[α]_D²⁵ = −126 ° (c = 1.0, CHCl₃); 99% ee.

General Procedure V: Preparation of Co(II) Salen Complexes 4-8

A vial was charged with $\text{Co}(\text{OAc})_2 \cdot 4\text{H}_2\text{O}$ (25 mg, 0.10 mmol, 1.0 equiv) and salen (0.10 mmol, 1.0 equiv) and purged with N_2 . EtOH (500 μL , 0.20 M w.r.t. salen) was degassed by sparging with Ar under sonication for 5 minutes and then added to the reaction vial. The reaction mixture was heated to 80 $^\circ\text{C}$ with vigorous stirring for 2 hours at which point the Co(II) salen had precipitated out of solution as a bright red solid. The solid transferred to a fine glass frit and washed with MeOH (3 x 10 mL). CH_2Cl_2 (15 mL) was then added to the fine glass frit to dissolve the bright red solid, filtered through into a clean flask, and then concentrated under reduced pressure to afford the Co(II) salen as a bright red powder.

Co(II) salen complex 5. Co(II) salen complex **5** was prepared according to General Procedure V with salen **SI-27** (90 mg, 0.10 mmol) to afford Co(II) salen complex **5** as a bright red powder (92 mg, 96% yield).

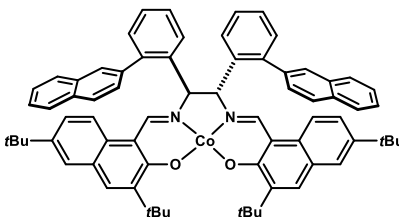


Co(II) salen complex 5

IR: 3057.98, 2955.83, 2860.67, 1594.55, 1569.99, 1538.49, 1497.48, 1478.37, 1409.33, 1388.18, 1380.67, 745.53, 700.62 cm^{-1}

LRMS (ES) calculated for $\text{C}_{64}\text{H}_{67}\text{CoN}_2\text{O}_2$ $[\text{M}+\text{H}]^+$ calc: 954.5, found 954.5:

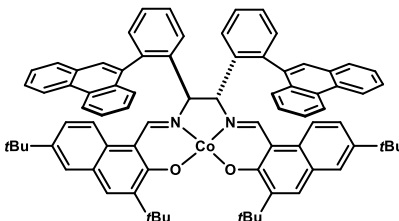
Co(II) salen complex 6. Co(II) salen complex **6** was prepared according to General Procedure V with salen **SI-28** (100 mg, 0.10 mmol) to afford Co(II) salen complex **6** as a bright red powder (103 mg, 98% yield).



IR: 3052.02, 2956.77, 2866.92, 1595.10, 1538.75, 1496.33, 1432.16, 1381.06, 1338.43, 757.36, 742.69, 691.94 cm^{-1}

LRMS (ES) calculated for $\text{C}_{72}\text{H}_{71}\text{CoN}_2\text{O}_2$ $[\text{M}+\text{H}]^+$ calc: 1054.5, found 1054.5:

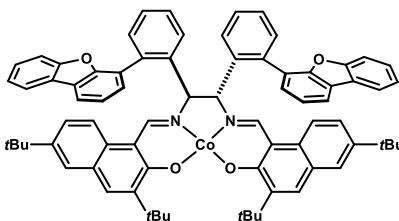
Co(II) salen complex 7. Co(II) salen complex **7** was prepared according to General Procedure V with salen **SI-29** (110 mg, 0.10 mmol) to afford Co(II) salen complex **7** as a bright red powder (105 mg, 91% yield).



IR: 2955.36, 1594.44, 1537.54, 1380.48, 1338.29, 1261.84, 815.49, 746.88, 725.89 cm^{-1}

LRMS (ES) calculated for $\text{C}_{80}\text{H}_{75}\text{CoN}_2\text{O}_2$ $[\text{M}+\text{H}]^+$ calc: 1154.6, found 1154.6.

Co(II) salen complex 8. Co(II) salen complex **8** was prepared according to General Procedure V with salen **SI-30** (108 mg, 0.10 mmol) to afford Co(II) salen complex **8** as a bright red powder (106 mg, 93% yield).

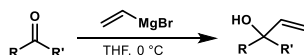


IR: 3705.87, 3680.15, 2966.13, 2922.03, 2864.92, 1537.86, 1380.04, 1186.19, 1055.94, 1014.08, 750.96 cm^{-1}

LRMS (ES) calculated for $\text{C}_{76}\text{H}_{71}\text{CoN}_2\text{O}_2$ $[\text{M}+\text{H}]^+$ calc: 1134.5, found 1134.5:

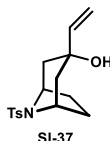
Preparation of starting materials

General procedure VI: Synthesis of allylic alcohols



Allylic alcohols. A solution of vinylmagnesium bromide (2.0 equiv.) in THF (0.6 M w.r.t. Grignard reagent) was cooled to 0 °C. A solution of ketone (1.0 equiv.) in THF (0.6 M w.r.t. ketone, final reaction concentration 0.2 M) was added slowly. After 1 h, the reaction was quenched by the addition of saturated aqueous NH₄Cl (30 mL). The resulting mixture was extracted with Et₂O 3x 30 mL. The organics were washed with brine and dried over MgSO₄. The desired allylic alcohols were purified by flash column chromatography.

Allylic alcohol SI-37. Allylic alcohol **SI-37** was prepared according to General Procedure VI with N-tosylnortropinone⁶ (100 mg, 0.36 mmol) and vinylmagnesium bromide (720 μ L, 0.72 mmol, 1.0 M solution in THF) in THF (1.8 mL) to afford allylic alcohol **SI-37** as a white crystalline solid (61 mg, 55% yield).



Allylic alcohol SI-37

¹H NMR (600 MHz, CDCl₃, 25 °C):

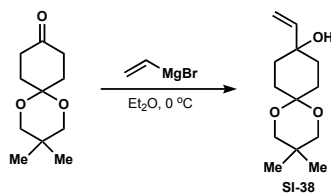
δ 7.75 (d, J = 8.2 Hz, 2H)	2.42 (s, 3H)
7.28 (s, 2H)	2.15-2.06 (m, 4H)
5.79 (dd, J = 17.2, 10.6 Hz, 1H)	1.66-1.63 (m, 2H)
5.17 (d, J = 17.2 Hz, 1H)	1.47-1.45 (m, 2H)
4.99 (d, J = 10.6 Hz, 1H)	1.14 (s, 1H).
4.25 (s, 2H)	

¹³C NMR (151 MHz, CDCl₃, 25 °C):

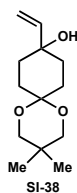
δ 158.5	129.6	56.1
147.0	127.3	44.7
143.3	111.2	27.8
137.3	71.6	21.5

LRMS (ESI) calc. for C₁₆H₂₁NO₃SNa [M+Na]⁺: 330.1, found: 330.1.

TLC R_f = 0.50 (50% v/v EtOAc in hexanes)



Allylic alcohol SI-38. A solution of vinylmagnesium bromide (5.0 mL, 1.0 M in THF, 5.0 mmol) in Et₂O (10 mL) was cooled to 0 °C. A solution of 1,4-cyclohexanedione mono(2,2-dimethyltrimethylene ketal) (594.8 mg, 3.0 mmol) in Et₂O (5.0 mL) was added slowly. After 1 h, the reaction was quenched by the addition of sat. aq. NH₄Cl (10 mL). The resulting mixture was extracted with Et₂O 3x 30 mL. The organics were washed with brine and dried over MgSO₄. The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 60% v/v Et₂O/hexanes) to yield 620.5 mg (91% yield) of **SI-38** as a white solid.



Allylic alcohol **SI-38**

¹H NMR (500 MHz, CDCl₃, 25 °C):

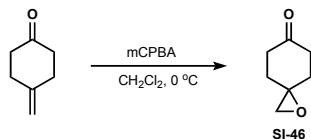
δ 5.96 (dd, <i>J</i> = 17.4, 10.8 Hz, 1H)	2.04-2.01 (m, 2H)
5.27 (dd, <i>J</i> = 17.3, 0.4 Hz, 1H)	1.87-1.81 (m, 2H)
5.05 (dd, <i>J</i> = 10.8, 0.2 Hz, 1H)	1.72 (td, <i>J</i> = 13.0, 3.8 Hz, 2H)
3.54 (s, 2H), 3.47 (s, 2H)	1.55 (d, <i>J</i> = 13.2 Hz, 2H)

¹³C NMR (126 MHz, CDCl₃, 25 °C):

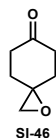
145.5	70.13	27.9
111.9	70.07	22.8
97.3	33.8	
71.4	30.3	

LRMS (ESI) calculated for C₁₃H₂₂O₃ [M+Na]⁺: 249.1468, found: 249.4133

TLC: R_f = 0.17 (50% Et₂O/Hex)



Epoxyketone SI-46. *m*CPBA (3.36 g, 19.46 mmol) was added in three equal portions over 15 min to a solution of 4-methylenecyclohexan-1-one⁷ (1.07 g, 9.73 mmol) in CH₂Cl₂ (32.4 mL, 0.3M) cooled to 0 °C. After 2.5 h the reaction was quenched with 15 mL sat aq. Na₂S₂O₃ and the mixture was extracted 3x with CH₂Cl₂ (25 mL each). The organic layers were washed with sat aq. NaHCO₃, brine, and then dried over MgSO₄. The crude material was purified by flash silica chromatography (gradient elution: 100% pentane to 50% v/v Et₂O/pentane) to yield 962.6 mg (78% yield) of epoxyketone **SI-46**.



Epoxyketone **SI-46**

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 2.80 (s, 2H)

2.64 (ddd, *J* = 15.3, 10.7, 5.4 Hz, 2H)

2.41 (dt, *J* = 14.0, 5.0 Hz, 2H)

2.16-2.10 (m, 2H)

1.75 (dt, *J* = 12.6, 5.8 Hz, 2H)

¹³C NMR (126 MHz, CDCl₃, 25 °C):

δ 209.9

56.9

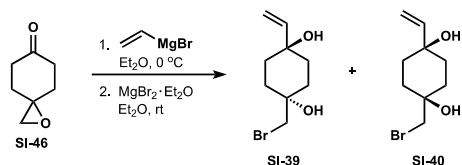
54.1

38.9

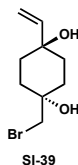
32.3

HRMS (CI) calculated for C₇H₁₀O₂ [M]⁺: 126.0681, found: 126.0680

TLC: R_f = 0.15 (50% Et₂O/Hex)



Bromohydrins SI-39 and SI-40. Vinylmagnesium bromide (1.0 M in THF, 8.0 mL, 8.0 mmol) was added slowly to a solution of **SI-46** (962.6 mg, 7.69 mmol) in Et₂O (34 mL, 0.23 M) cooled to 0 °C. After 1.5 h the reaction was quenched with sat. aq. NH₄Cl and the mixture was extracted with Et₂O 3x (50 mL each). The organic layers were washed with brine and dried over Na₂SO₄. The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 20% v/v Et₂O/hexanes) to yield 420.1 mg (35% yield) of an inseparable mixture of diastereomeric allylic alcohols. The mixture of allylic alcohols (100.0 mg, 0.648 mmol) was dissolved in THF (6.5 mL, 0.1 M) at 0 °C and MgBr₂·Et₂O (837.2 mg, 3.24 mmol) was added in a single portion.⁸ After 10 min the reaction was allowed to warm to rt and then stirred for a further 18 h. The reaction was quenched with H₂O and the mixture extracted with Et₂O 3x (25 mL each). The organics were washed with brine and dried over Na₂SO₄. The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 60% v/v EtOAc/hexanes) to yield 61.1 mg (40% yield) of **SI-39** and 64.7 mg (42% yield) of **SI-40** as white solids. The diastereomeric bromohydrins were distinguished on the basis of NOESY analysis and an observation that diastereomer **SI-39** undergoes formation of corresponding [2.2.2]-oxabicyclic product (in addition to the expected epoxide) upon exposure to NaH in THF.



Bromohydrin **SI-39**

¹H NMR (500 MHz, CDCl₃, 25 °C):

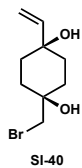
δ 5.99 (dd, <i>J</i> = 17.4, 10.7 Hz, 1H)	1.79 (td, <i>J</i> = 13.1, 3.3 Hz, 3H)
5.26 (d, <i>J</i> = 17.4 Hz, 1H)	1.68 (d, <i>J</i> = 12.9 Hz, 2H)
5.05 (d, <i>J</i> = 10.8 Hz, 1H)	1.49 (d, <i>J</i> = 13.0 Hz, 2H)
3.49 (s, 2H)	1.14 (s, 1H)
1.93-1.87 (m, 2H)	

¹³C NMR (126 MHz, CDCl₃, 25 °C):

δ 146.0	47.4
111.6	32.5
71.2	30.7
69.1	

HRMS (CI) calculated for C₉H₁₅BrO₂ [M]⁺: 234.0255, found: 234.0248

TLC: R_f = 0.21 (30% EtOAc/Hex)



Bromohydrin SI-40

^1H NMR (500 MHz, CDCl_3 , 25 °C):

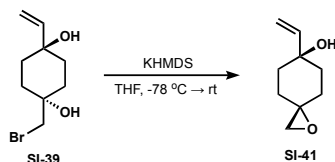
δ 5.97 (dd, J = 17.4, 10.8 Hz, 1H)	1.91 (dd, J = 10.7, 5.9 Hz, 2H)
5.31 (d, J = 17.4 Hz, 1H)	1.82 (t, J = 11.7 Hz, 2H)
5.15 (d, J = 10.7 Hz, 1H)	1.62 (dd, J = 11.6, 7.0 Hz, 4H)
3.52 (s, 2H)	1.51 (bs, 1H)
2.04 (bs, 1H)	

^{13}C NMR (126 MHz, CDCl_3 , 25 °C):

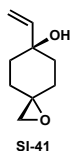
δ 143.2	44.7
113.7	34.0
71.2	32.3
69.5	

HRMS (CI) calculated for $\text{C}_9\text{H}_{15}\text{BrO}_2$ $[\text{M}]^+$: 234.0255, found: 234.0258

TLC: R_f = 0.25 (60% EtOAc/Hex)



Allylic alcohol SI-41. KHMDS (0.5 M in PhMe, 1.7 mL, 0.85 mmol) was added slowly to a solution of bromohydrin **SI-39** (50.0 mg, 0.213 mmol) in THF (5.0 mL, 0.04 M) at $-78\text{ }^{\circ}\text{C}$. After 5 min, the reaction was removed from the cooling bath and warmed to rt. After 45 min the reaction was quenched by the addition of sat. aq. NH_4Cl . The resulting mixture was extracted with Et_2O 3x 10 mL. The organics were washed with brine and dried over Na_2SO_4 . The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 30% v/v Et_2O /hexanes) to yield 27.3 mg (83% yield) of **SI-41** as a clear colorless oil.



Allylic alcohol **SI-41**

^1H NMR (500 MHz, CDCl_3 , $25\text{ }^{\circ}\text{C}$):

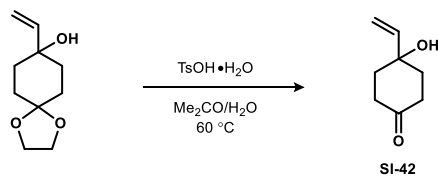
δ 5.99 (dd, $J = 17.4, 10.8$ Hz, 1H)	1.86 (td, $J = 13.3, 4.1$ Hz, 2H)
5.27 (d, $J = 17.4$ Hz, 1H)	1.64 (d, $J = 13.5$ Hz, 2H)
5.06 (d, $J = 10.8$ Hz, 1H)	1.50 (s, 1H)
2.66 (s, 2H)	1.19 (d, $J = 13.6$ Hz, 2H)
2.24 (td, $J = 13.3, 4.1$ Hz, 2H)	

^{13}C NMR (126 MHz, CDCl_3 , $25\text{ }^{\circ}\text{C}$):

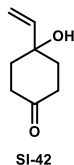
δ 145.8	54.1
111.8	34.8
71.0	28.4
58.0	

LRMS (ESI) calculated for $\text{C}_9\text{H}_{14}\text{O}_2$ $[\text{M}+\text{Na}]^+$: 177.0892, found: 177.0894

TLC: $R_f = 0.44$ (50% EtOAc /Hex)



Allylic Alcohol SI-42. *p*-Toluenesulfonic acid monohydrate (361 mg, 1.92 mmol, 0.10 equiv) was added to a solution of 8-vinyl-1,4-dioxaspiro[4.5]decan-8-ol⁹ (3.54 g, 19.2 mmol, 1.0 equiv) in Me₂CO/H₂O (1:1 v/v, 100 mL, 0.20 M w.r.t. allylic alcohol) and stirred for 5 minutes at 25 °C, then heated to 60 °C for 4 h. The reaction mixture was cooled to ambient temperature and the acetone was removed under reduced pressure. EtOAc (50 mL) and NaHCO₃ (sat. aq., 100 mL) was added to the reaction mixture and the aqueous layer was extracted with EtOAc (3 x 50 mL). The combined organic layers were dried over MgSO₄, filtered, and concentrated under reduced pressure. The crude material was purified by flash column chromatography (40% v/v EtOAc/hexanes) to afford **SI-42** as a white crystalline solid (2.50 g, 93% yield). The spectral data for **SI-42** matched those reported in the literature.¹⁰



Allylic Alcohol SI-42.

¹H NMR (600 MHz, CDCl₃, 25 °C):

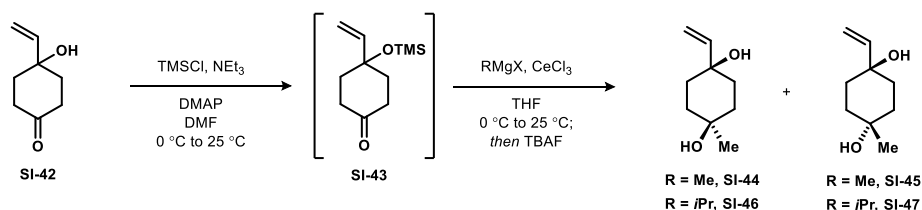
δ 6.02 (dd, J = 17.4, 10.7 Hz, 1H)	2.29 (ddt, J = 14.8, 5.4, 2.4 Hz, 2H)
5.35 (dd, J = 17.4, 0.8 Hz, 1H)	1.96 (dq, J = 9.3, 3.3 Hz, 4H)
5.16 (dd, J = 10.8, 0.8 Hz, 1H)	1.68-1.54 (m, 2H).
2.79-2.74 (m, 2H)	

¹³C NMR (151 MHz, CDCl₃, 25 °C):

δ 211.4	70.6
144.1	37.07
113.0	36.95

LRMS (ESI) calculated for C₈H₁₂O₂ [M+Na]⁺: 163.1, found: 163.1

TLC: R_f = 0.27 (40% EtOAc/Hex)

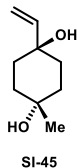


General Procedure for Preparation of *trans*-cyclohexanediols.

TMS Protection of SI-42. Trimethylsilyl chloride (2.5 mL, 19.7 mmol, 1.1 equiv) was added dropwise to a solution of **SI-42** (2.50 g, 17.9 mmol, 1.0 equiv), triethylamine (3.7 mL, 26.9 mmol, 1.5 equiv), and DMAP (122 mg, 1.79 mmol, 0.10 equiv) in DMF (45 mL, 0.40 M w.r.t. **SI-42**) at 0 °C. The reaction was stirred at 0 °C for 30 min and then allowed to warm to ambient temperature and stirred for an additional 2 h. The reaction was cooled to 0 °C and quenched by the addition of a saturated aqueous solution of NaHCO₃ (100 mL). The reaction mixture was diluted with Et₂O (150 mL) and the organic layer was washed with H₂O (3 x 100 mL). The combined aqueous layer was extracted with Et₂O (3 x 50 mL) and the organic layers were combined and washed with brine. The combined organic layer was dried over MgSO₄, filtered, and concentrated under reduced pressure. The crude product was used without further purification.

Grignard Addition into SI-43. Anhydrous CeCl₃ (579 mg, 2.35 mmol, 1.0 equiv) was added to a solution of **SI-43** (500 mg, 2.35 mmol, 1.0 equiv) in anhydrous THF (10 mL, 0.25 M w.r.t. **SI-43**) and sonicated under positive pressure of argon for 30 minutes at ambient temperature. The reaction mixture was cooled to 0 °C and vigorously stirred for 15 minutes. Grignard reagent (1.5 equiv) was added rapidly in a single portion to the reaction mixture with vigorous stirring. The reaction was stirred at 0 °C for 30 min and then allowed to warm to ambient temperature and stirred for 1 h. The reaction was then poured onto a vigorously stirred solution of EtOAc (50 mL) and a 15% aqueous solution of NH₄Cl (100 mL) at 0 °C. The aqueous layer was extracted with EtOAc (3 x 30 mL). The combined organic layer was washed with brine (50 mL), dried over MgSO₄, filtered, and concentrated under reduced pressure to afford crude *cis*- and *trans*-cyclohexanediols in a ca. 1:1 ratio. The crude product was used without further purification.

TMS Deprotection. The crude product was treated with TBAF (7.0 mL, 1.0 M solution in THF, 3.0 equiv) and stirred at ambient temperature for 2 h. The reaction mixture was quenched by addition of saturated aqueous solution of NH₄Cl (25 mL). The aqueous layer was extracted with EtOAc (3 x 30 mL) and the combined organic layer was dried with Na₂SO₄, filtered, and concentrated under reduced pressure. The crude product was purified by flash chromatography (40% v/v EtOAc/hexanes) to afford the *trans*-cyclohexanediol as a white crystalline solid. The relative stereochemistry was assigned by NOESY correlation.



Allylic Alcohol SI-45. The General Procedure for Preparation of *trans*-cyclohexanediols was used to prepare **SI-45** using MeMgBr (1.2 mL, 3.0 M solution in Et₂O). The crude product after TMS deprotection was purified by flash chromatography to afford **SI-45** as a white crystalline solid (130 mg, 0.83 mmol, 35% yield from **SI-42**).

¹H NMR (600 MHz, CDCl₃, 25 °C):

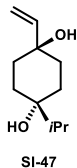
δ 5.98 (dd, J = 17.4, 10.8 Hz, 1H)	1.90-1.79 (m, 4H),
5.26 (dd, J = 17.4, 1.2 Hz, 1H)	1.52-1.43 (m, 4H)
5.04 (dd, J = 10.8, 1.2 Hz, 1H)	1.27 (s, 3H)

¹³C NMR (151 MHz, CDCl₃, 25 °C):

δ 146.3	34.0
111.3	32.7
71.1	31.3
68.8	

LRMS (ESI) calculated for C₉H₁₆O₂ [M+Na]⁺: 179.1, found: 179.1

TLC: R_f = 0.20 (40% EtOAc/Hex)



Allylic Alcohol SI-47. The General Procedure for Preparation of *trans*-cyclohexanediols was used to prepare **SI-47** using *i*PrMgCl (1.6 mL, 2.0 M solution in THF). The crude product after TMS deprotection was purified by flash chromatography to afford **SI-47** as a white crystalline solid (150 mg, 0.81 mmol, 34% yield from **SI-42**).

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 5.98 (dd, J = 17.4, 10.8 Hz, 1H)	1.79 (td, J = 13.6, 4.0 Hz, 2H)
5.25 (dd, J = 17.4, 1.2 Hz, 1H)	1.62 (dq, J = 13.8, 6.9 Hz, 1H)
5.02 (dd, J = 10.7, 1.2 Hz, 1H)	1.45 (dt, J = 14.7, 2.9 Hz, 4H)
1.88 (td, J = 13.5, 4.0 Hz, 2H)	0.94 (d, J = 6.9 Hz, 6H)

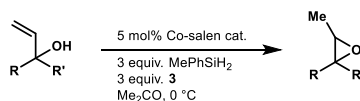
¹³C NMR (151 MHz, CDCl₃, 25 °C):

δ 146.6	38.5
111.1	32.5
72.5	29.0
71.3	16.8

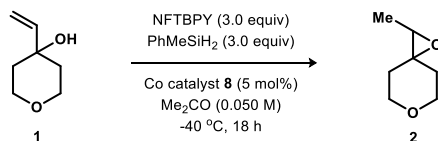
LRMS (ESI) calculated for C₁₁H₂₀O₂ [M+Na]⁺: 179.1, found: 179.1

TLC: R_f = 0.60 (40% EtOAc/Hex)

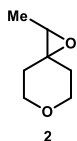
General Procedure VII. catalytic asymmetric radical-polar crossover hydroalkoxylation of allylic alcohols.



To an oven dried 2 dram vial was added Co-salen catalyst **8** (5.7 mg, 0.005 mmol, 0.05 equiv) and oxidant **3** (87 mg, 0.30 mmol, 3.0 equiv). The vial was then placed under an atmosphere of nitrogen. The allylic alcohol (0.10 mmol, 1.0 equiv) was added as a solution in dry acetone (0.10 M w.r.t. allylic alcohol). The resulting solution was sparged with argon and simultaneously subjected to sonication for 5 min. After cooling to -40 °C in an immersion cooler, MePhSiH₂ (41 μ L, 0.30 mmol, 3.0 equiv) was added at a rate of 1 drop/10 s. The reaction quickly developed a bright orange color. After 12-72 h, the reaction was quenched by the dropwise addition of pyridine as a degassed solution in dry acetone (0.1 M) and allowed to warm to ambient temperature following addition. The reaction was diluted with CH₂Cl₂ (5 mL), washed with sat. aq. NH₄Cl. The aqueous phase was extracted with CH₂Cl₂ (3 x 5 mL) and the combined organic layer was washed with brine, dried over Na₂SO₄, filtered, and concentrated under reduced pressure. The products were isolated using flash column chromatography. NOTE: ¹H NMR yields of epoxides **2** and **15** in radical-polar crossover epoxidations were determined by using acetone-d₆ and obtaining ¹H NMR of the crude reaction mixture after quenching with pyridine.

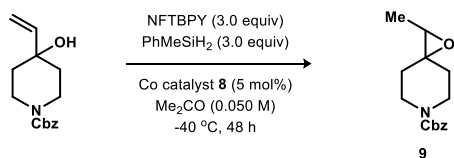


Epoxide 2. Epoxide **2** was prepared according to General Procedure VII with allylic alcohol **1** (13 mg, 0.10 mmol) to afford epoxide **2** in 69% yield by ¹H NMR with mesitylene as the internal standard. Spectral data match those reported in the literature.⁹ Epoxide **2** is volatile and losses of 20-30% of the product are observed after purification by flash silica chromatography. NOTE: A racemic standard of epoxide **2** was prepared according to the previously reported procedure.⁹

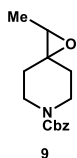


Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 80 °C, 75 min, t_R = 70.2, 74.0 min.

[α]_D²⁵ = 10.8 ° (c = 0.90, CHCl₃); 95% ee.



Epoxide 9. Epoxide **9** was prepared according to General Procedure VII with 1-carboxybenzyl-4-vinylpiperidin-4-ol¹¹ (28 mg, 0.10 mmol) and purified by flash chromatography (30% v/v EtOAc in hexanes) to afford epoxide **9** as a clear oil (18.5 mg, 71% yield). NOTE: A racemic standard of epoxide **9** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



Epoxide 9

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 7.35 (dd, J = 10.4, 3.2 Hz, 4H)	2.93 (q, J = 5.5 Hz, 1H)
7.32 (ddd, J = 8.5, 5.0, 3.6 Hz, 1H)	1.79 (s, 2H)
5.15 (s, 2H)	1.47 (dd, J = 59.2, 12.0 Hz, 3H)
3.83 (s, 2H)	1.30 (d, J = 5.6 Hz, 3H)
3.49-3.41 (m, 2H)	1.26 (s, 1H)

¹³C NMR (126 MHz, CDCl₃, 25 °C):

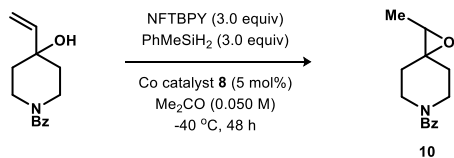
δ 155.2	127.88	42.50
136.7	67.2	42.47
128.5	60.5	13.4
128.01	59.6	

LRMS (ESI) calc. for C₁₅H₁₉NO₃Na [M+Na]⁺: 284.1, found: 284.1.

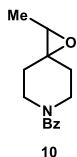
TLC R_f = 0.36 (40% v/v EtOAc in hexanes)

Chiral SFC: CHIRALCEL OD-H, 5% *i*PrOH, 2.0 mL/min, 210 nm, 40 °C, nozzle pressure = 200 bar CO₂, t_R = 8.6, 9.4 min.

[α]_D²⁵ = +5.35 ° (c = 0.9, CHCl₃); 89% ee.



Epoxide 10. Epoxide **10** was prepared according to General Procedure VII with 1-benzoyl-4-vinylpiperidin-4-ol¹² (13 mg, 0.10 mmol) and purified by flash chromatography (60% v/v EtOAc in hexanes) to afford epoxide **10** as a clear oil (16.3 mg, 68% yield). NOTE: A racemic standard of epoxide **10** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



Epoxide 10

¹H NMR (600 MHz, DMSO-d₆, 100 °C):

δ 7.44 (td, J = 4.3, 2.3 Hz, 2H)	1.76 (dddd, J = 22.6, 13.6, 8.9, 4.5 Hz, 2H)
7.41-7.40 (m, 2H)	1.56-1.52 (m, 1H)
3.65 (s, 2H)	1.47-1.43 (m, 1H)
3.50 (t, J = 10.4 Hz, 2H)	1.26 (t, J = 8.4 Hz, 4H).
2.93 (q, J = 5.5 Hz, 1H)	

¹³C NMR (151 MHz, DMSO-d₆, 100 °C):

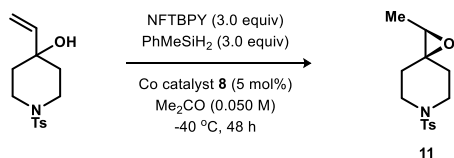
δ 168.8	126.1	28.1
136.0	59.5	12.7
128.7	58.1	
127.8	33.7	

LRMS (ESI) calc. for C₁₄H₁₇NO₂Na [M+Na]⁺: 254.1, found: 254.1.

TLC R_f = 0.50 (EtOAc)

Chiral SFC: CHIRALCEL OJ-H, 1% *i*PrOH, 2.0 mL/min, 254 nm, 44 °C, nozzle pressure = 200 bar CO₂, t_R = 4.9, 5.3 min.

[α]_D²⁵ = -3.75 ° (c = 0.80, CHCl₃); 87% ee.



Epoxide 11. Epoxide **11** was prepared according to General Procedure VII with 1-tosyl-4-vinylpiperidin-4-ol¹³ (30.4 mg, 0.10 mmol) and purified by flash chromatography (25% v/v EtOAc in hexanes) to afford epoxide **11** as a white crystalline solid (17.6 mg, 51% yield). X-ray quality crystals were obtained by slow evaporation of a solution of epoxide **11** in CH₂Cl₂. NOTE: A racemic standard of epoxide **11** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



Epoxide 11

¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 7.65 (d, J = 8.3 Hz, 2H)	2.44 (s, 3H)
7.32 (d, J = 7.9 Hz, 2H)	2.05-1.95 (m, 2H)
3.54 (ddtd, J = 24.3, 11.4, 4.7, 1.6 Hz, 2H)	1.54 (dddd, J = 13.7, 4.6, 3.1, 1.7 Hz, 1H)
2.88 (q, J = 5.5 Hz, 1H)	1.37 (dddd, J = 13.6, 4.5, 3.1, 1.7 Hz, 1H)
2.78 (dtd, J = 14.3, 11.2, 3.2 Hz, 2H)	1.24 (d, J = 5.5 Hz, 3H).

¹³C NMR (151 MHz, CDCl₃, 25 °C):

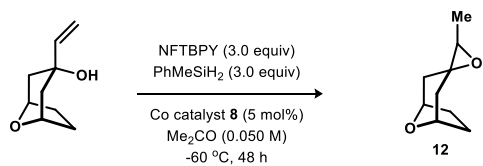
δ 143.7	59.53	33.9
133.0	59.51	28.3
129.7	44.67	21.5
127.7	44.60	13.3

LRMS (ESI) calc. for C₁₄H₁₉NO₃Na [M+Na]⁺: 304.1, found: 304.1.

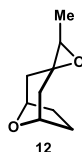
TLC R_f = 0.52 (40% v/v EtOAc in hexanes)

Chiral SFC: CHIRALPAK AD, 20% *i*PrOH, 2.0 mL/min, 210 nm, 40 °C, nozzle pressure = 200 bar CO₂, t_R = 4.1, 5.5 min.

[α]_D²⁵ = 1.88 ° (c = 1.13, CHCl₃); 95% ee.

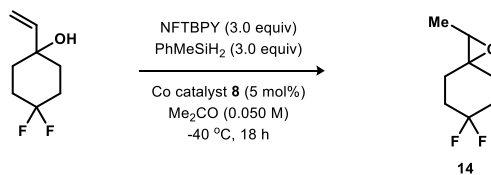


Epoxide 12. Epoxide **12** was prepared according to General Procedure VII with 3-vinyl-8-oxabicyclo[3.2.1]octan-3-ol⁹ (15.4 mg, 0.10 mmol) and purified by flash chromatography to afford epoxide **12** as a clear oil (10.8 mg, 70% yield). Spectral data match those reported in the literature.⁹

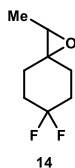


Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 105 °C, 120 min, t_R = 76.9, 78.7.

$[\alpha]_D^{25}$ = 6.1 ° (c = 0.30, CHCl₃); 93% ee.

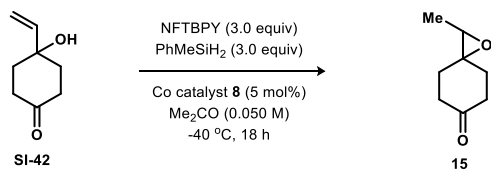


Epoxide 14. Epoxide **14** was prepared according to General Procedure VII with 4,4-difluoro-1-vinylcyclohexan-1-ol⁹ (13 mg, 0.10 mmol) to afford epoxide **14** in 53% yield by ¹H NMR with mesitylene as the internal standard. Spectral data match those reported in the literature.⁹ NOTE: Epoxide **14** is volatile and losses of 20-30% of the product are observed after purification by flash silica chromatography.

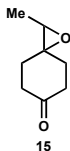


Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 80 °C, 75 min t_R = 53.0, 56.5.

$[\alpha]_D^{25} = 11.2^\circ$ (c = 0.90, CHCl₃); 88% ee.



Epoxide 15. Epoxide **15** was prepared according to General Procedure VII with allylic alcohol **SI-42** (14.0 mg, 0.10 mmol) and purified by flash chromatography (20% v/v EtOAc in hexanes) to afford epoxide **15** as a clear oil (7.8 mg, 56% yield). NOTE: A racemic standard of epoxide **15** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 3.09 (q, J = 5.5 Hz, 1H)	1.88 (dtd, J = 13.9, 5.8, 2.3 Hz, 1H)
2.70-2.60 (m, 2H)	1.76 (dtd, J = 13.8, 5.7, 2.3 Hz, 1H)
2.47-2.40 (m, 2H)	1.37 (d, J = 5.6 Hz, 3H)
2.11-2.02 (m, 2H)	

¹³C NMR (151 MHz, CDCl₃, 25 °C):

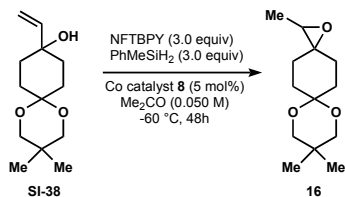
δ 210.4	38.60
60.4	33.6
60.1	27.7
38.69	14.0

LRMS (ESI) calc. for C₈H₁₂O₂ [M+Na]⁺: 140.1, found: 140.1

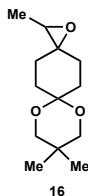
TLC R_f = 0.34 (40% EtOAc/Hex)

Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 100 °C, 120 min t_R = 114.7, 116.1

[α]_D²⁵ = +13.2 ° (c = 0.40, CHCl₃); 89% ee.



Epoxide 16. Epoxide **16** was prepared according to General Procedure VII with allylic alcohol **SI-38** (22.6 mg, 0.10 mmol) and purified by flash chromatography (20% v/v EtOAc in hexanes) to afford epoxide **16** as a clear oil (19.9 mg, 88% yield). NOTE: A racemic standard of epoxide **16** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 3.53 (s, 2H)	1.58-1.53 (m, 1H)
3.49 (s, 2H)	1.48-1.42 (m, 1H)
2.89 (q, <i>J</i> = 5.6 Hz, 1H)	1.28 (d, <i>J</i> = 5.6 Hz, 3H)
2.01-1.87 (m, 4H)	0.98 (s, 3H)
1.72 (td, <i>J</i> = 11.7, 4.2 Hz, 2H)	0.96 (s, 3H)

¹³C NMR (151 MHz, CDCl₃, 25 °C):

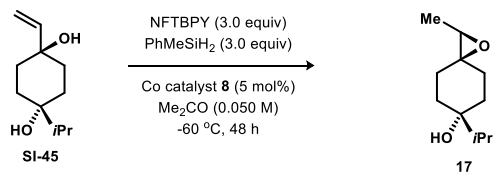
δ 97.3	30.9	22.77
70.32	30.35	22.72
70.13	30.25	13.7
61.8	30.10	
59.7	24.6	

HRMS (ESI) calc. for C₁₃H₂₂O₃ [M+Na]⁺: 249.1467, found: 249.1468

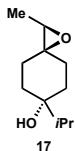
TLC R_f = 0.47 (30% EtOAc/Hex)

Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 130 °C, 180 min t_R = 163.4, 167.5.

[α]_D²⁵ = +8.3 ° (c = 1.0, CHCl₃); 82% ee.



Epoxide 17. Epoxide **17** was prepared according to General Procedure VII with allylic alcohol **SI-45** (18.4 mg, 0.10 mmol) and purified by flash chromatography (10% v/v Me₂CO in CH₂Cl₂) to afford epoxide **17** as a clear oil (9.4 mg, 51% yield). NOTE: A racemic standard of epoxide **17** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 2.91 (q, J = 5.6 Hz, 1H)	1.34 (ddt, J = 13.8, 4.5, 2.8 Hz, 1H)
2.21 (td, J = 13.5, 4.6 Hz, 1H)	1.29 (d, J = 5.6 Hz, 3H),
2.06 (td, J = 13.4, 4.8 Hz, 1H)	1.10 (ddt, J = 13.7, 4.5, 2.7 Hz, 1H)
1.74 (dtd, J = 24.4, 13.4, 4.5 Hz, 2H)	0.98 (s, 1H)
1.68-1.63 (m, 2H), 1.60-1.57 (m, 1H)	0.95 (d, J = 6.9 Hz, 6H)

¹³C NMR (151 MHz, CDCl₃, 25 °C):

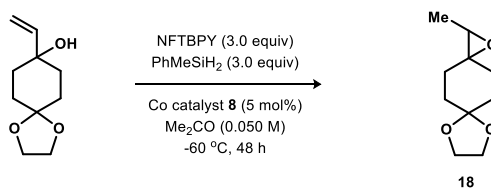
δ 73.2	30.0
62.0	23.8
59.9	16.88
38.3	16.86
31.36	13.4

LRMS (ESI) calc. for C₁₁H₂₀O₂ [M+Na]⁺: 184.1, found: 184.1

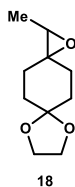
TLC R_f = 0.44 (40% EtOAc/Hex)

Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 110 °C, 180 min, then ramp to 200 °C at 10 °C per minute, t_R = 188.4, 188.7

[α]_D²⁵ = +8.66° (c = 0.60, CHCl₃); 86% ee.

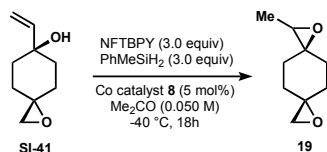


Epoxide 18. Epoxide **18** was prepared according to General Procedure VII with 8-vinyl-1,4-dioxaspiro[4.5]decan-8-ol⁹ (18.4 mg, 0.10 mmol) and purified by flash chromatography to afford epoxide **18** as a clear oil (10.3 mg, 56% yield). Spectral data match those reported in the literature.⁹

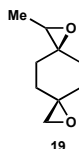


Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 110 °C, 180 min ramp to 150 °C, 40 min t_R = 179.1, 181.4.

[α]_D²⁵ = 7.5 ° (c = 0.30, CHCl₃); 92% ee.



Epoxide 19. Prepared according to General Procedure VII using vinylcyclohexanol **SI-41** (15.4 mg, 0.10 mmol). The crude was chromatographed (gradient elution: 100% pentane to 15% v/v Et₂O/pentane) to afford 7.5 mg (49% yield) of **19** as a clear colorless oil. NOTE: A racemic standard of epoxide **19** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



Epoxide **19**

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 2.96 (q, <i>J</i> = 5.6 Hz, 1H)	1.62-1.57 (m, 2H)
2.71 (s, 2H)	1.50-1.46 (m, 2H)
2.13-2.01 (m, 3H)	1.33 (d, <i>J</i> = 5.6 Hz, 3H)
2.01-1.95 (m, 1H)	

¹³C NMR (126 MHz, CDCl₃, 25 °C):

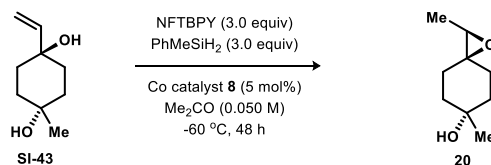
δ 61.4	32.5
60.1	30.8
58.3	26.3
54.3	13.6

LRMS (ESI) calculated for C₉H₁₄O₂ [M+Na]⁺: 177.0892, found: 177.3611

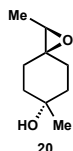
TLC: R_f = 0.41 (40% EtOAc/Hex)

Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 110 °C, 90 min t_R = 61.6, 64.5.

[α]_D²² = +10.3 (c = 0.5, CDCl₃); 91% ee.



Epoxide 20. Epoxide **20** was prepared according to General Procedure VII with allylic alcohol **SI-43** (15.6 mg, 0.10 mmol) and purified by flash chromatography (40% v/v EtOAc in hexanes) to afford epoxide **20** as a clear oil (9.8 mg, 63% yield). NOTE: A racemic standard of epoxide **20** was prepared according to the previously reported procedure for radical polar crossover epoxidation using racemic catalyst **4**.⁹



¹H NMR (600 MHz, CDCl₃, 25 °C):

δ 2.91 (q, J = 5.6 Hz, 1H)	1.63 (dtd, J = 13.6, 4.4, 2.3 Hz, 1H)
2.09 (ddd, J = 13.6, 12.3, 4.6 Hz, 1H)	1.37 (dtd, J = 13.8, 4.4, 2.1 Hz, 1H)
1.98 (ddd, J = 13.8, 11.9, 4.8 Hz, 1H)	1.30 (s, 3H)
1.75 (dtd, J = 24.7, 12.4, 4.5 Hz, 2H)	1.29 (d, J = 5.6 Hz, 3H)
1.68 (dtd, J = 13.6, 4.6, 2.4 Hz, 1H)	1.20-1.16 (m, 1H)

¹³C NMR (151 MHz, CDCl₃, 25 °C):

δ 69.5	30.57
61.7	30.43
59.9	24.2
36.50	13.5
36.49	

LRMS (ESI) calc. for C₉H₁₆O₂ [M+Na]⁺: 156.1, found: 156.1

TLC R_f = 0.24 (40% EtOAc/Hex)

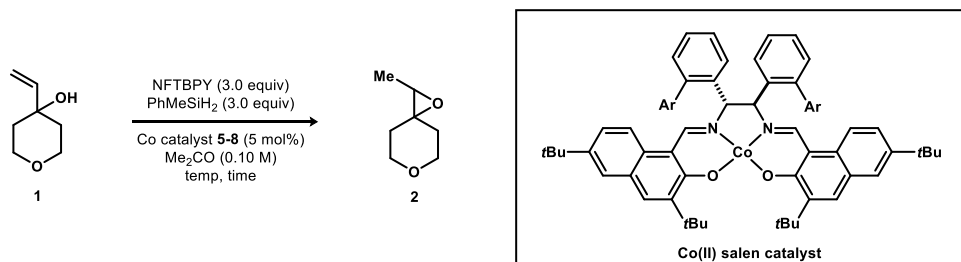
Chiral GC/FID: HP – chiral – 20B column, 6.88 psi, 0.50 mL/min, 130 °C, 30 min t_R = 17.8, 18.9

[α]_D²⁵ = +2.1 ° (c = 0.60, CHCl₃); 86% ee.

Eyring Data

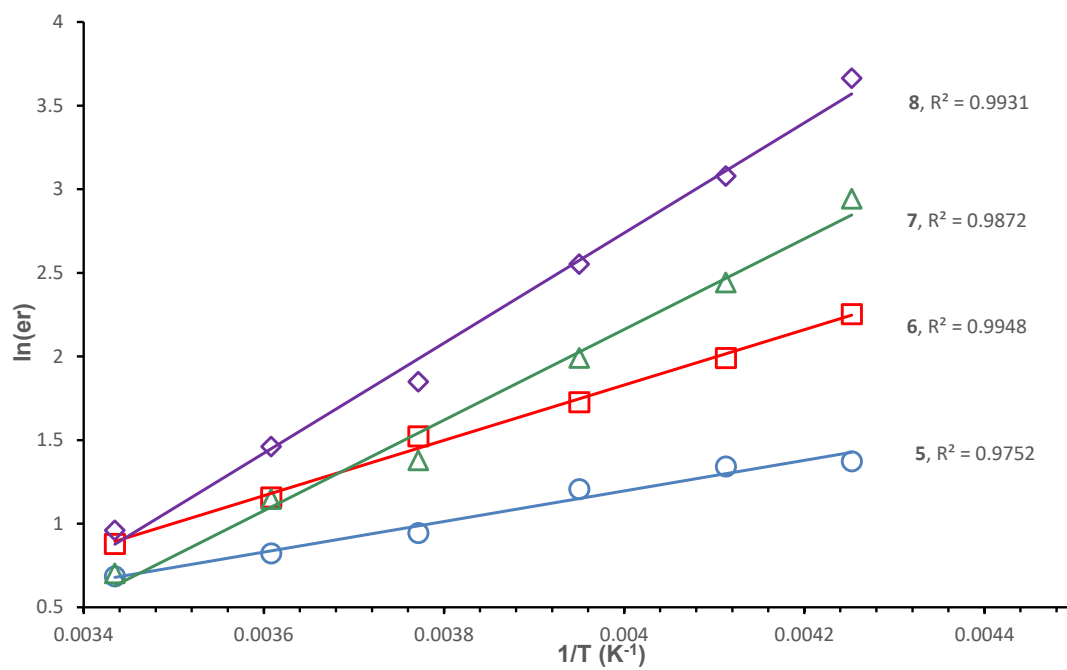
NOTE: The following Eyring analysis is based on those employed in Jacobsen's seminal publication on cation- π interactions in the context of thiourea-catalyzed cationic polycyclizations.¹⁴

General Procedure VIII. Eyring analysis of dependence of enantioenrichment on temperature

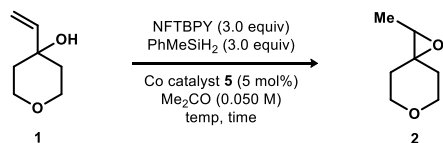


To an oven dried 2 dram vial was added Co-salen catalyst (0.00125 mmol, 0.050 equiv) and oxidant **3** (22 mg, 0.15 mmol, 3.0 equiv). The vial was then placed under an atmosphere of nitrogen. Allylic alcohol **1** (0.025 mmol, 1.0 equiv) was added as a solution in dry acetone (500 μ L, 0.10 M w.r.t. allylic alcohol). The resulting solution was sparged with argon and simultaneously subjected to sonication for 5 min. The reaction mixture was submerged in a bath at the specified temperature and allowed to equilibrate for 10 minutes. Then MePhSiH₂ (16 μ L, 0.075 mmol, 3.0 equiv) was added at a rate of 1 drop/10 s. The reaction quickly developed a bright orange color. Following addition, reactions at temperatures 19 °C and 4 °C were allowed to react for 1 h, reactions at temperature –10 to –20 °C were allowed to react for 4 h, and reactions at –30 to –40 °C were allowed to reaction for 12 h. After the specified amount of time, the reaction was quenched by the dropwise addition of pyridine as a degassed solution in dry acetone (0.1 M) and allowed to warm to ambient temperature following addition. The reaction was diluted with CH₂Cl₂ (5 mL), washed with sat. aq. NH₄Cl and brine, dried over Na₂SO₄, and filtered. An aliquot was taken out for chiral GC/FID analysis to determine enantioenrichment.

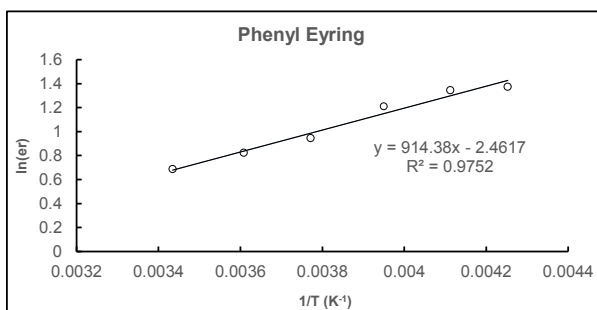
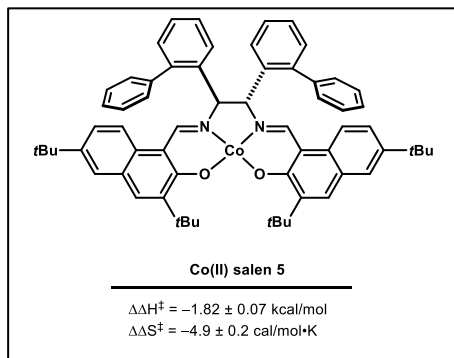
Overlaid Eyring Plot



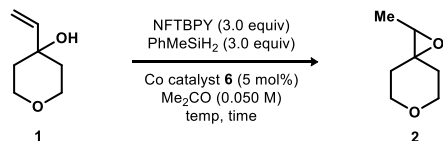
Eyring data for phenyl-substituted Co(II) salen 5



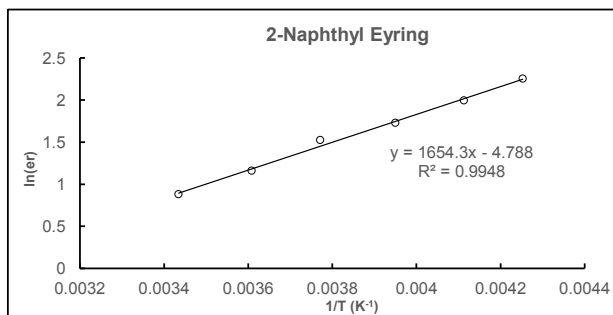
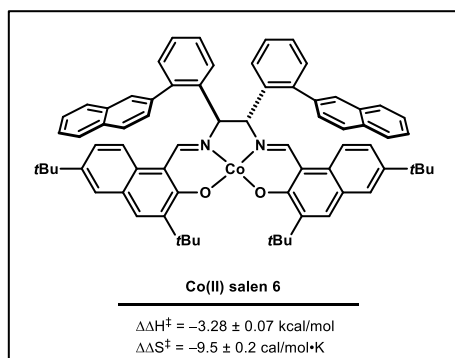
Entry	T °C	er
1	19	66.5:33.5
2	4	69.5:30.5
3	-10	72.0:28.0
4	-20	77.0:23.0
5	-30	79.3:20.7
6	-40	79.8:20.2



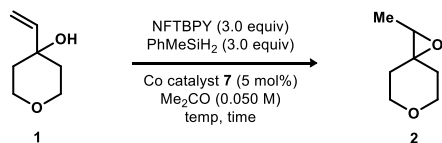
Eyring data for 2-naphthyl-substituted Co(II) salen 6



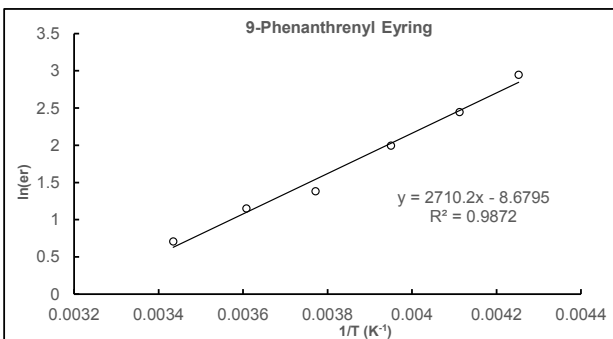
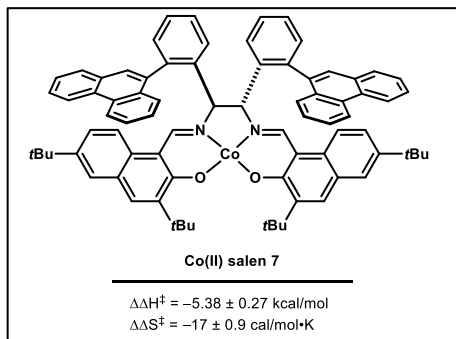
Entry	T °C	er
1	19	70.7:29.3
2	4	76.1:23.9
3	-10	82.1:17.9
4	-20	84.9:15.1
5	-30	88.0:12.0
6	-40	90.5:9.5



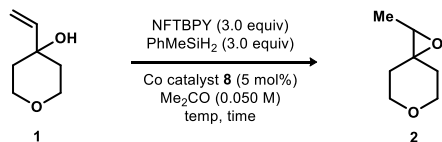
Eyring data for 9-phenanthrenyl-substituted Co(II) salen 7



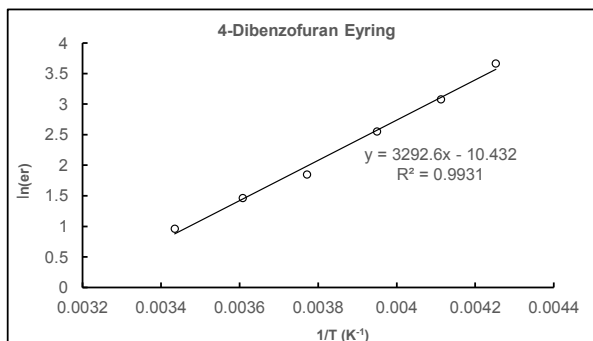
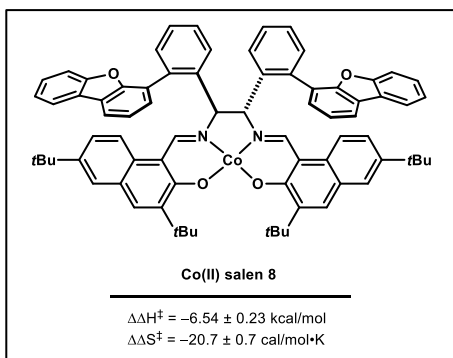
Entry	T °C	er
1	19	66.9:33.1
2	4	75.9:24.1
3	-10	79.9:20.1
4	-20	88.0:12.0
5	-30	92.0:8.0
6	-40	95.0:5.0



Eyring data for 4-dibenzofuran-substituted Co(II) salen 8



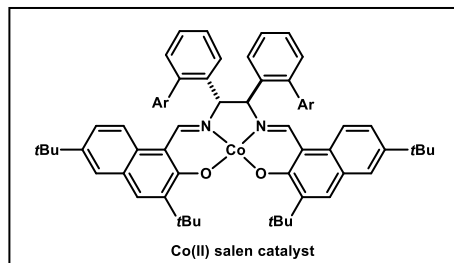
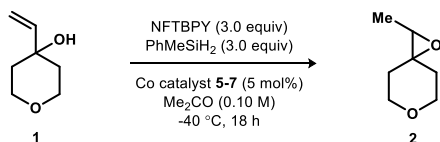
Entry	T °C	er
1	19	72.3:27.7
2	4	81.2:18.8
3	-10	86.4:13.6
4	-20	92.8:7.2
5	-30	95.6:4.4
6	-40	97.5:2.5



Correlation of Polarizability and Quadrupole Moment of Aromatic Substituent and Enantioselectivity

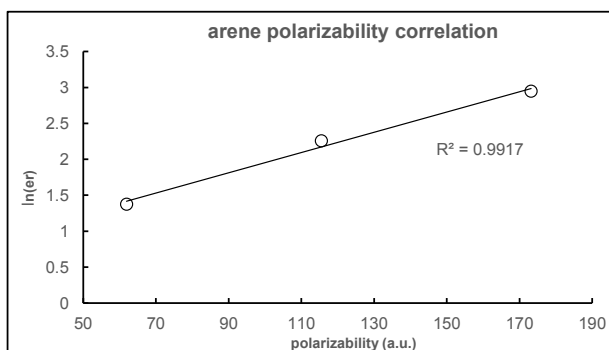
NOTE: The following correlations between polarizability and quadrupole moment of arenes and enantioselectivity are based on those employed by the Jacobsen group in their seminal publication on cation- π interactions in the context of thiourea-catalyzed cationic polycyclizations.¹⁴ The values for polarizabilities and quadrupole moments were obtained from previous reports of computational calculations for arene properties.¹⁵

linear correlation of polarizability of catalyst Ar with enantioselectivity

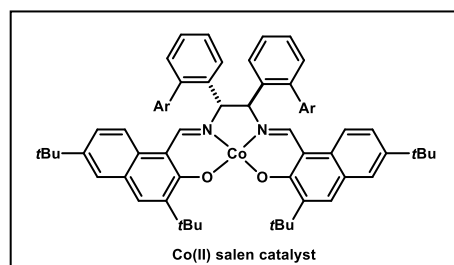
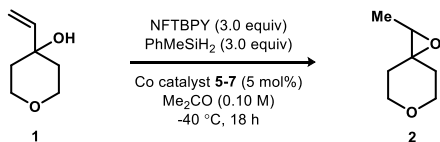


arene	polarizability	catalyst	er
benzene	61.9	5	79.8:20.2
naphthalene	115.5	6	90.5:9.5
phenanthrene	173.2	7	95.0:5.0

Polarizabilities: Waite et al. *J. Chem. Phys.* **1982**, 77, 2536.

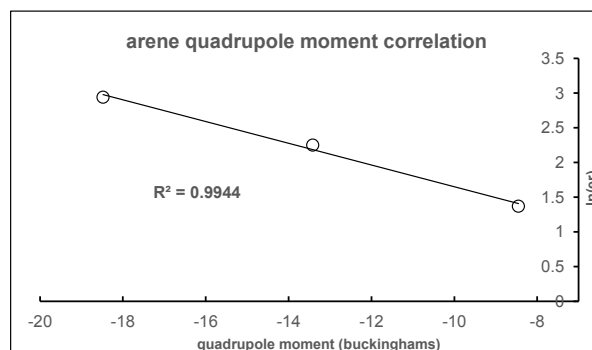


linear correlation of quadrupole moment of catalyst Ar with enantioselectivity

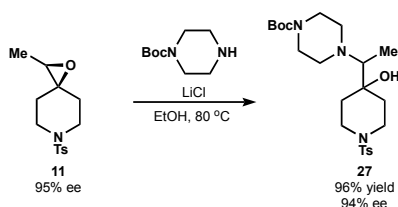


arene	quadrupole moment	catalyst	er
benzene	-8.45	5	79.8:20.2
naphthalene	-13.42	6	90.5:9.5
phenanthrene	-18.48	7	95.0:5.0

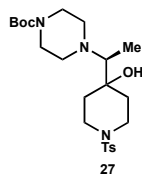
Quadrupole moments: Boyd et al. *J. Phys. Chem. A.* **1997**, 101, 5374



Derivatization of Enriched Epoxide **11**.



Aminoalcohol 27. Enriched epoxide **11** (5.0 mg, 0.018 mmol), 1-boc-piperazine (66.3 mg, 0.356 mmol) and LiCl (16.2 mg, 0.383 mmol) were dissolved in EtOH (0.3 mL) in a 1 dram vial. The vial was sealed with a Teflon cap and the reaction was stirred while heated to 80 °C for 20 h. After cooling to rt, the contents were diluted with DCM, transferred to a separatory funnel and extracted 3x (6 mL each) with DCM from 10 mL of H₂O. The combined organic layers were dried over Na₂SO₄. The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 20% v/v EtOAc/hexanes) to yield 8.0 mg (96% yield) of **27** as a tan solid. NOTE: Racemic **27** was prepared by subjecting racemic epoxide **11** to the above conditions.



Aminoalcohol **27**

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 7.64 (d, <i>J</i> = 8.2 Hz, 2H)	3.38 (d, <i>J</i> = 15.3 Hz, 4H)	1.83-1.73 (m, 2H)
7.30 (d, <i>J</i> = 7.9 Hz, 2H)	2.65-2.59 (m, 4H)	1.44 (s, 9H)
4.27 (s, 1H)	2.42 (s, 3H)	1.36 (td, <i>J</i> = 22.9, 9.1 Hz, 3H)
3.66-3.64 (m, 2H)	2.37 (dd, <i>J</i> = 14.5, 7.3 Hz, 3H)	1.01 (d, <i>J</i> = 7.1 Hz, 3H)

¹³C NMR (126 MHz, CDCl₃, 25 °C):

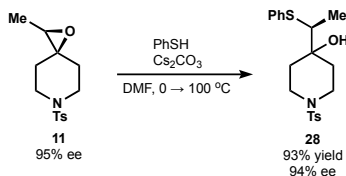
δ 154.6	79.9	35.2
143.4	69.3	32.1
133.2	68.3	28.4
129.6	42.8	21.5
127.7	42.2	8.0

HRMS (ESI) calculated for C₂₃H₃₇N₃O₅S [M+H]⁺: 468.2532, found: 468.2534

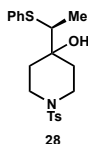
TLC: R_f = 0.47 (50% EtOAc/Hex)

Chiral SFC: CHIRALCEL OJ-H, 5% *i*PrOH, 2.0 mL/min, 240 nm, 44 °C, nozzle pressure = 200 bar CO₂, t_R = 9.2, 15.2 min.

[α]_D²² = +43.1 (*c* = 1.0, CDCl₃); 94% ee



Hydroxysulfide 28. Enriched epoxide **11** (5.0 mg, 0.018 mmol) and Cs_2CO_3 (57.8 mg, 0.178 mmol) were added to a flame dried Schlenk which was then evacuated and backfilled 3x with N_2 .¹⁶ Dry DMF was added and the suspension was degassed by freeze-pump-thaw. The mixture was cooled to 0 °C and PhSH (18.2 μL , 0.178 mmol) was added dropwise. The reaction was then transferred to an oil bath and heated to 100 °C. After 2 h the reaction was removed from heat and quenched with sat. aq. NH_4Cl . The mixture was extracted with DCM 3x (6 mL each) and the organic layers dried over Na_2SO_4 . The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 15% v/v EtOAc/hexanes) to yield 6.5 mg (93% yield) of **28** as a white solid. NOTE: Racemic **28** was prepared by subjecting racemic epoxide **11** to the above conditions.



Hydroxysulfide **28**

^1H NMR (500 MHz, CDCl_3 , 25 °C):

δ 7.64 (d, J = 7.9 Hz, 2H)	2.65-2.60 (m, 2H)
7.40 (d, J = 7.3 Hz, 2H)	2.43 (s, 3H)
7.31 (d, J = 8.3 Hz, 2H)	2.17 (s, 1H)
7.28 (d, J = 7.6 Hz, 2H)	1.85-1.77 (m, 2H)
7.24 (t, J = 7.3 Hz, 1H)	1.68 (dd, J = 13.7, 1.8 Hz, 1H)
3.65 (t, J = 14.2 Hz, 2H)	1.63 (dd, J = 13.3, 2.0 Hz, 1H)
3.18 (q, J = 7.0 Hz, 1H)	1.35 (d, J = 7.1 Hz, 3H)

^{13}C NMR (126 MHz, CDCl_3 , 25 °C):

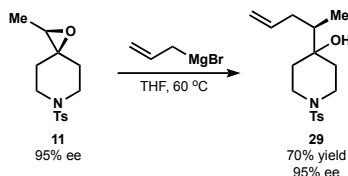
δ 143.5	129.7	71.2	34.8
135.2	129.2	57.4	32.4
133.3	127.7	42.4	21.6
131.9	127.4	42.0	17.2

HRMS (ESI) calculated for $\text{C}_{20}\text{H}_{25}\text{NO}_3\text{S}_2$ $[\text{M}+\text{Na}]^+$: 414.1174, found: 414.1167

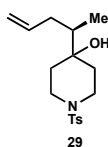
TLC: R_f = 0.38 (30% EtOAc/Hex)

Chiral SFC: CHIRALCEL OD-H, 20% *i*PrOH, 2.0 mL/min, 254 nm, 44 °C, nozzle pressure = 200 bar CO_2 , t_R = 4.9, 7.1 min.

$[\alpha]_D^{22} = -28.7$ (c = 1.0, CDCl_3); 94% ee



Hydroxyalkene 29. Allylmagnesium bromide (1.0 M in Et₂O, 0.2 mL, 0.2 mmol) was added dropwise to a solution of **11** (9.0 mg, 0.032 mmol) in 0.4 mL of THF at rt. The reaction was stirred for a further 5 min at rt and then heated to 60 °C in an oil bath. After 20 min the reaction was removed from heat and quenched with sat. aq. NH₄Cl. The mixture was extracted with DCM 3x (6 mL each) and the organic layers dried over Na₂SO₄. The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 15% v/v EtOAc/hexanes) to yield 7.2 mg (70% yield) of **29** as a tan solid. NOTE: Racemic **29** was prepared by subjecting racemic epoxide **11** to the above conditions.



Hydroxyalkene **29**

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 7.65 (d, <i>J</i> = 8.2 Hz, 2H)	2.32 (d, <i>J</i> = 13.0 Hz, 1H)
7.31 (d, <i>J</i> = 7.9 Hz, 2H)	1.84-1.70 (m, 3H)
5.82-5.74 (m, 1H)	1.58 (t, <i>J</i> = 2.2 Hz, 1H)
5.05-5.01 (m, 2H)	1.54 (d, <i>J</i> = 2.2 Hz, 1H)
3.64-3.60 (m, 2H)	1.48 (ddd, <i>J</i> = 9.6, 6.5, 3.3 Hz, 1H)
2.59 (tdd, <i>J</i> = 11.9, 6.3, 2.2 Hz, 2H)	0.92 (s, 1H)
2.43 (s, 3H)	0.89 (d, <i>J</i> = 6.9 Hz, 3H)

¹³C NMR (126 MHz, CDCl₃, 25 °C):

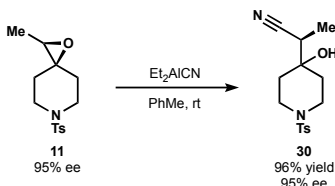
δ 143.4	116.5	35.4
137.7	71.3	34.2
133.3	43.2	33.0
129.6	42.17	21.5
127.7	42.10	13.5

HRMS (ESI) calculated for C₁₇H₂₅NO₃S [M+Na]⁺: 346.1453, found: 346.1462

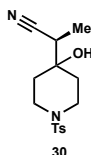
TLC: R_f = 0.41 (30% EtOAc/Hex)

Chiral SFC: CHIRALCEL OD-H, 3% *i*PrOH, 2.0 mL/min, 240 nm, 44 °C, nozzle pressure = 200 bar CO₂, t_R = 36.8, 40.0 min.

[α]_D²³ = -3.2 (*c* = 1.0, CDCl₃); 95% ee



Hydroxynitrile 30. Et₂AlCN (1.0 M in PhMe, 90 μL, 0.09 mmol) was added dropwise to a stirred solution of **11** (5.0 mg, 0.018 mmol) in 0.30 mL of dry PhMe at rt.¹⁷ The reaction was stirred for 18 h and then quenched with sat. aq. NH₄Cl. The mixture was extracted with DCM 3x (6 mL each) and the organic layers dried over Na₂SO₄. The crude material was purified by flash silica chromatography (gradient elution: 100% hexanes to 40% v/v EtOAc/hexanes) to yield 5.3 mg (96% yield) of **30** as a tan solid. NOTE: Racemic **30** was prepared by subjecting racemic epoxide **11** to the above conditions.



Hydroxynitrile **30**

¹H NMR (500 MHz, CDCl₃, 25 °C):

δ 7.65 (d, <i>J</i> = 8.2 Hz, 2H)	1.86 (td, <i>J</i> = 13.0, 4.6 Hz, 1H)
7.33 (d, <i>J</i> = 7.9 Hz, 2H)	1.79 (dd, <i>J</i> = 13.8, 2.1 Hz, 1H)
3.69 (d, <i>J</i> = 11.4 Hz, 2H)	1.73 (q, <i>J</i> = 9.2 Hz, 2H)
2.63-2.58 (m, 3H)	1.41 (d, <i>J</i> = 0.2 Hz, 1H)
2.44 (s, 3H)	1.31 (d, <i>J</i> = 7.2 Hz, 3H)

¹³C NMR (126 MHz, CDCl₃, 25 °C):

δ 143.8	120.4	34.7
133.1	69.4	33.0
129.8	41.7	21.6
127.7	38.2	12.0

HRMS (ESI) calculated for C₁₅H₂₀N₂O₃S [M+Na]⁺: 331.1092, found: 331.1086

TLC: R_f = 0.24 (50% EtOAc/Hex)

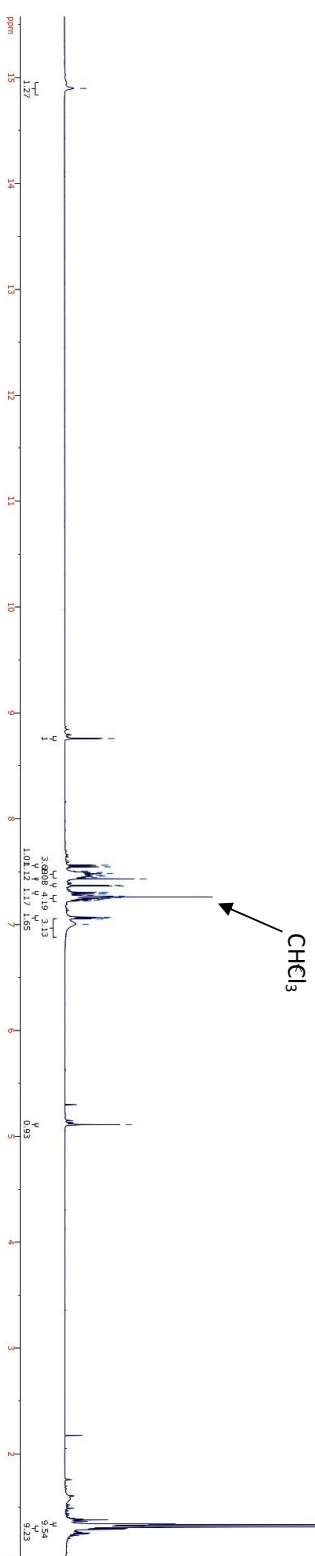
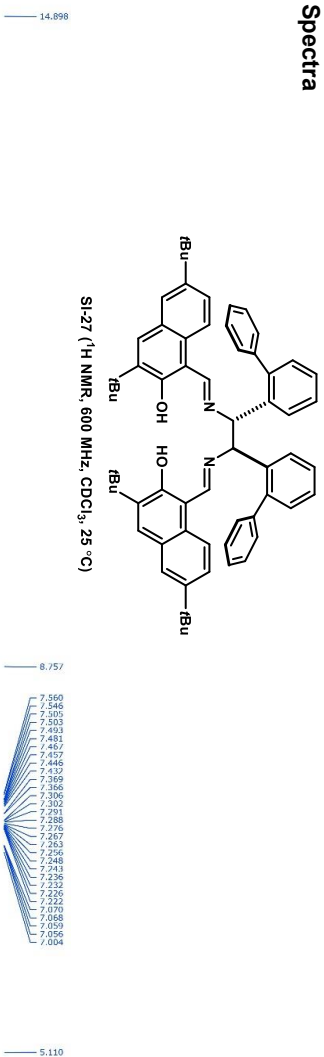
Chiral SFC: CHIRALCEL OJ-H, 20% *i*PrOH, 2.0 mL/min, 254 nm, 44 °C, nozzle pressure = 200 bar CO₂, t_R = 2.2, 3.8 min.

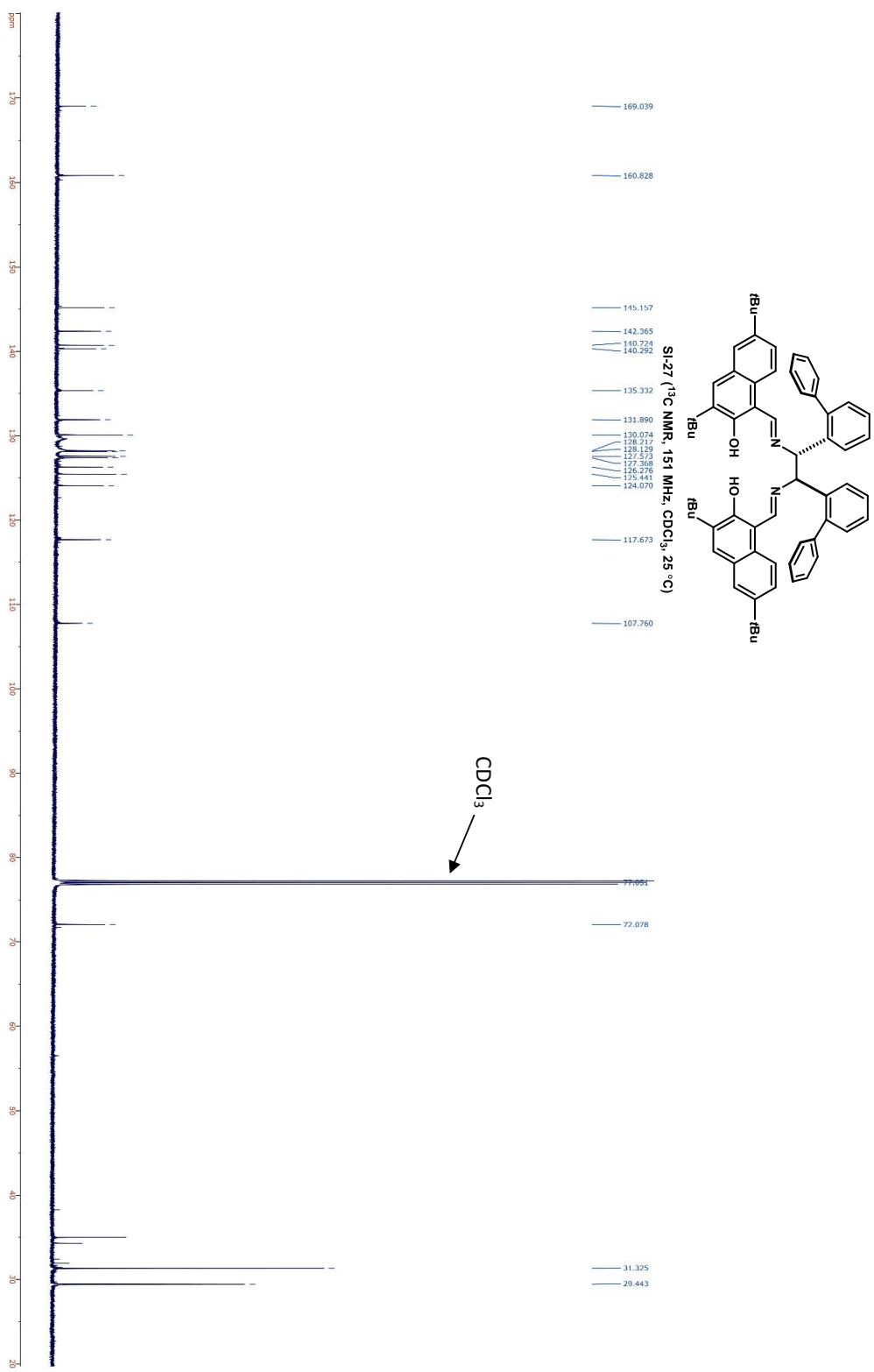
[α]_D²² = -3.9 (*c* = 1.0, CHCl₃); 95% ee

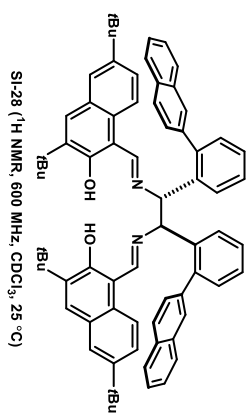
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NMR Spectra







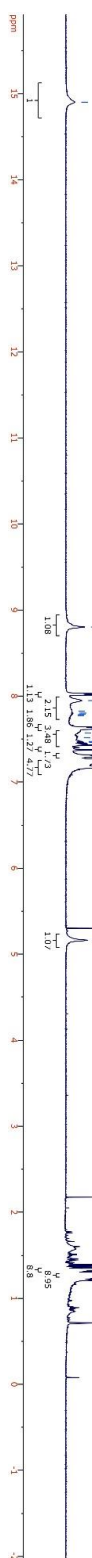
14.902

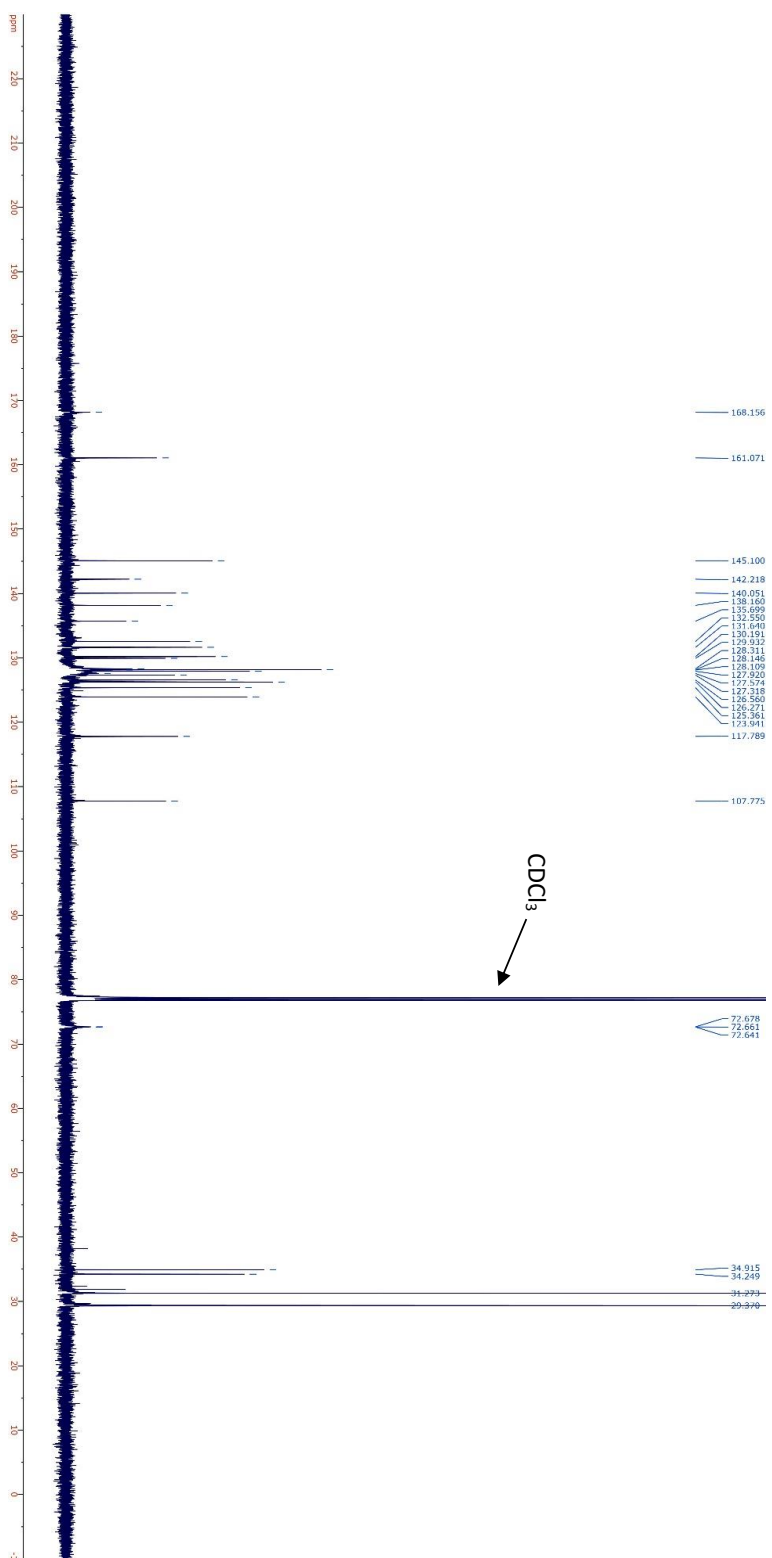
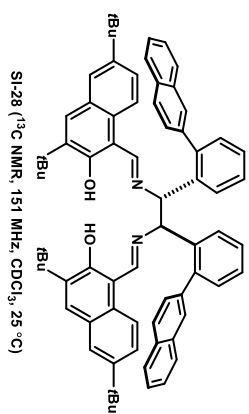
8.801
8.026
8.012
7.947
7.881
7.801
7.788
7.781
7.772
7.627
7.614
7.512
7.367
7.472
7.462
7.454
7.443
7.375
7.371
7.315
7.302
7.290
7.177
7.164

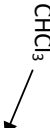
5.161

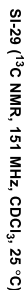
3.326
1.271

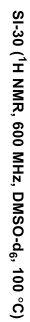
CHCl₃

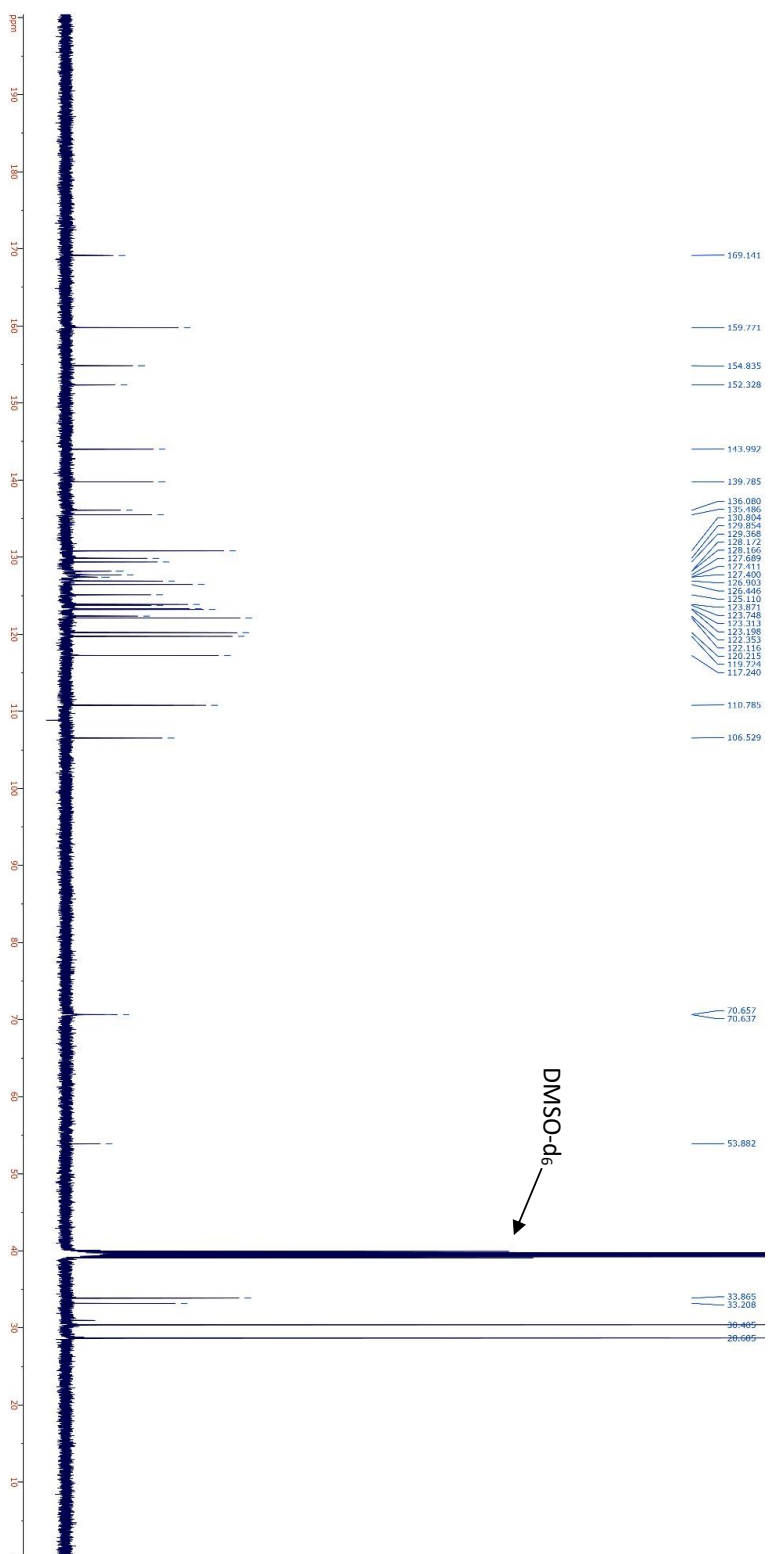
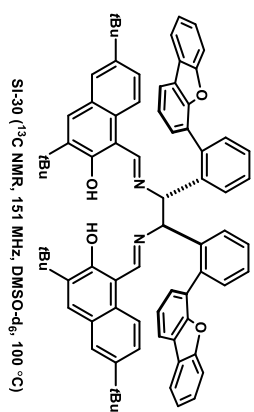


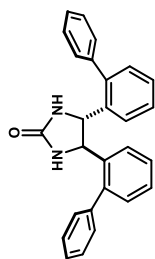












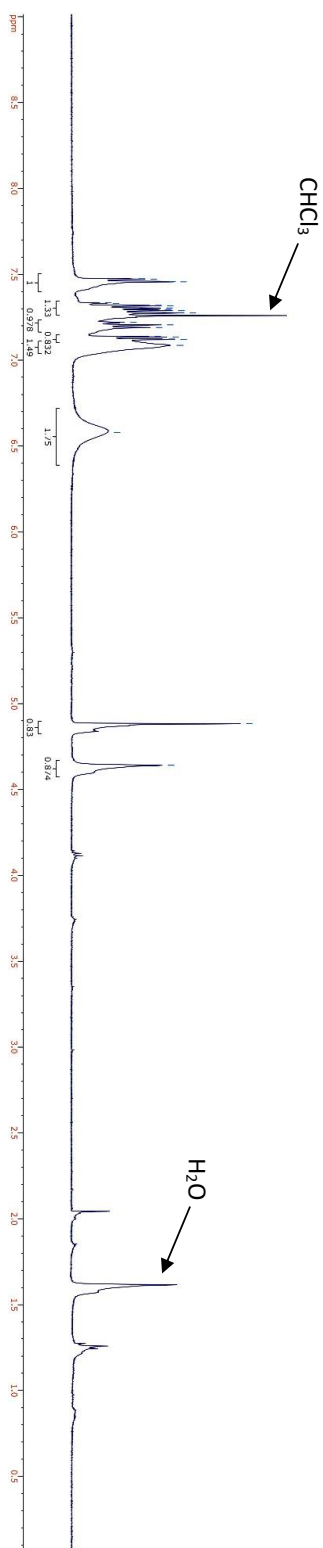
SI-33 (^1H NMR, 600 MHz, CDCl_3 , 25 $^\circ\text{C}$)

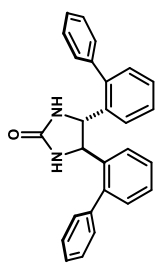


6.578

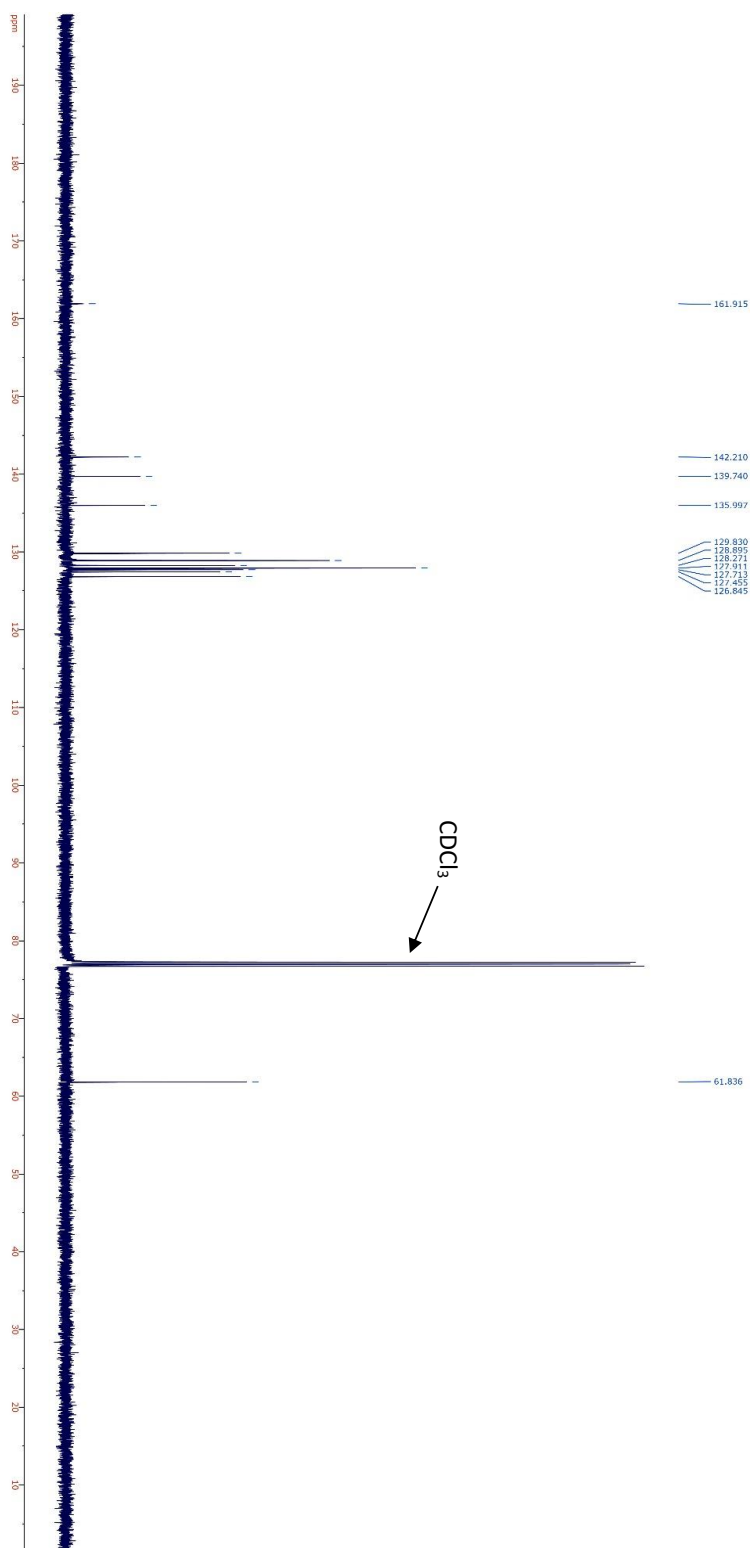
4.883

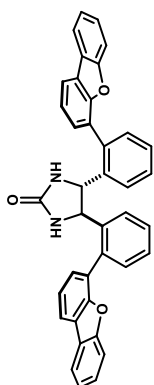
4.641



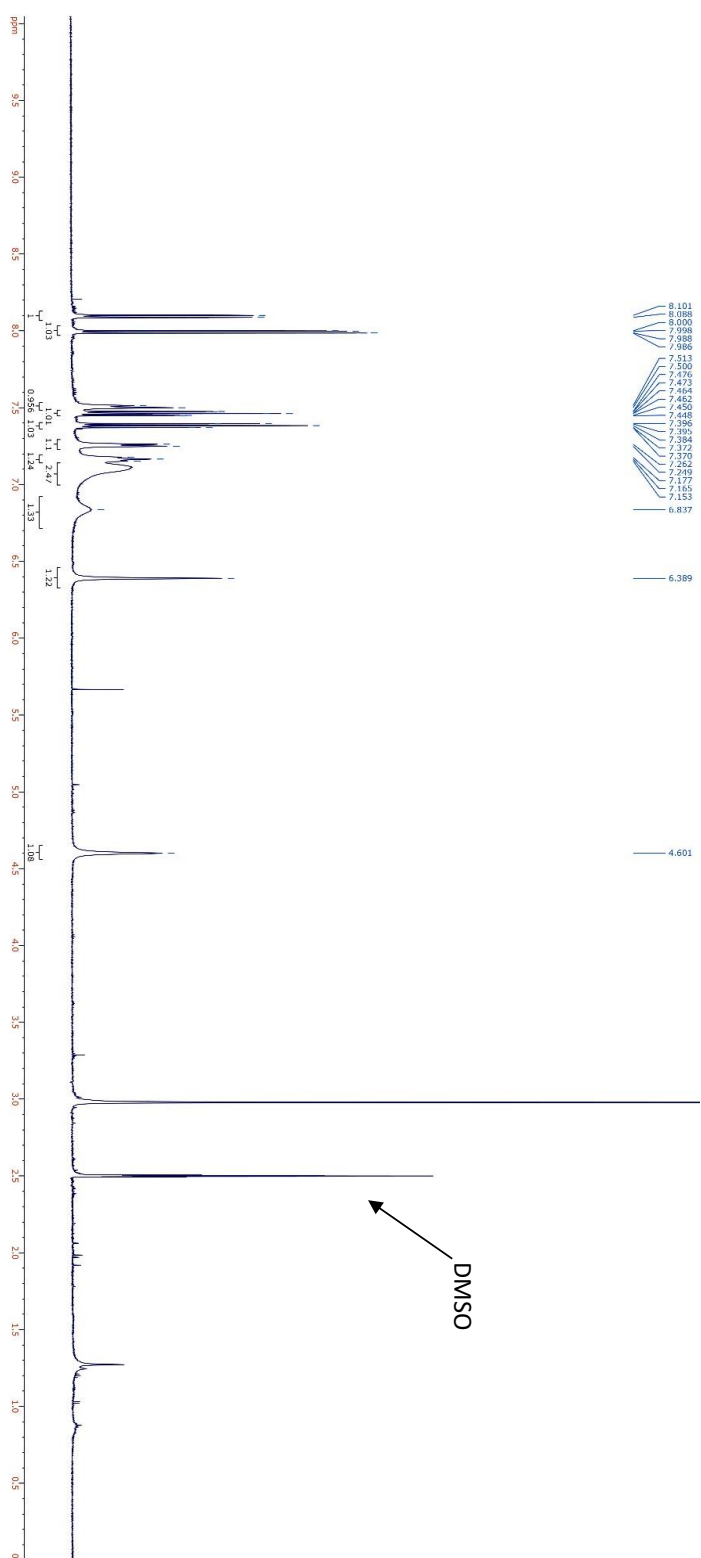


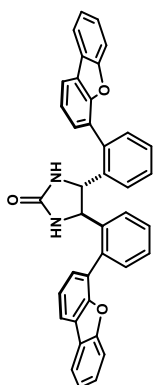
SI-33 (^{13}C NMR, 151 MHz, CDCl_3 , 25 °C)



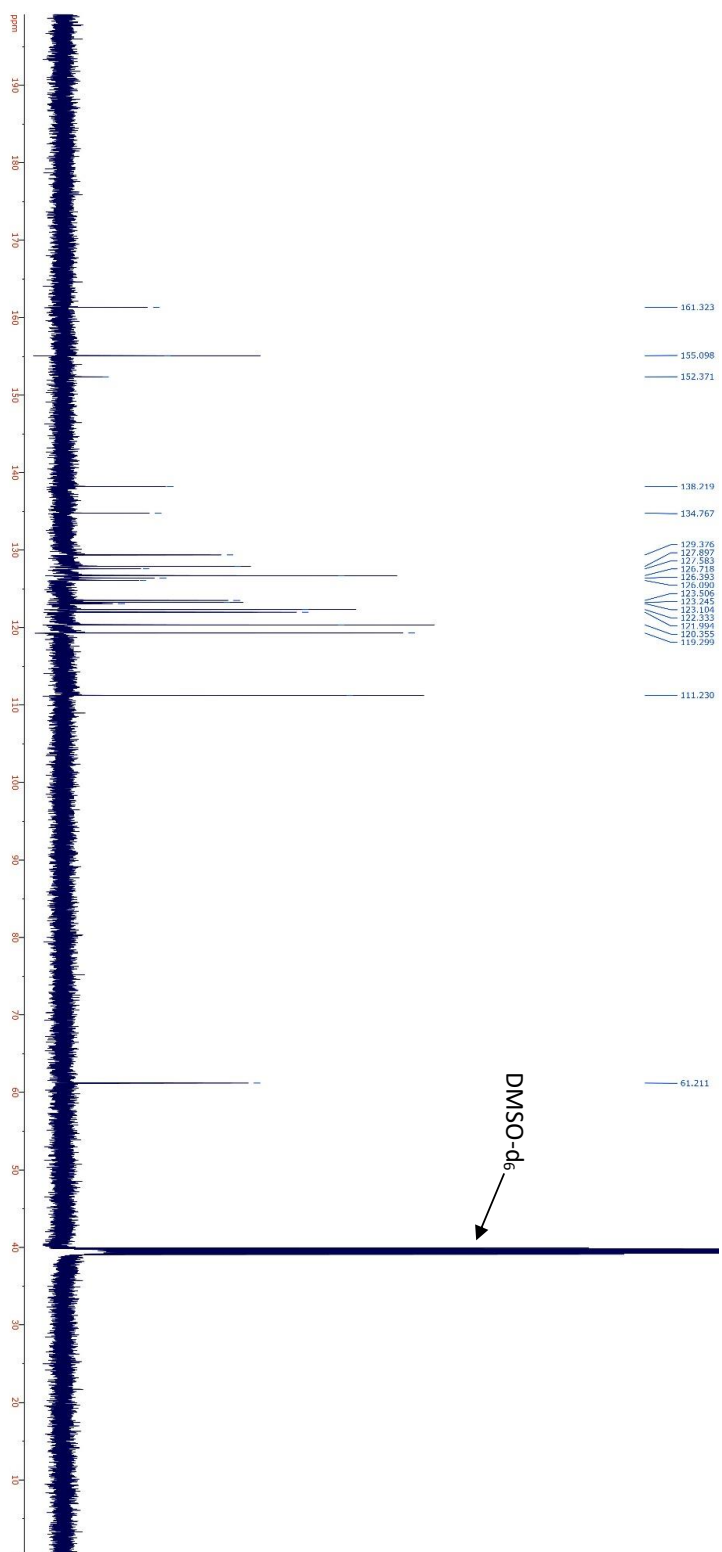


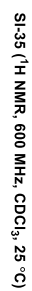
SI-34 (¹H NMR, 600 MHz, DMSO-d₆, 100 °C)

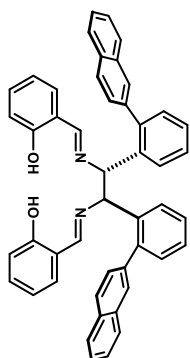




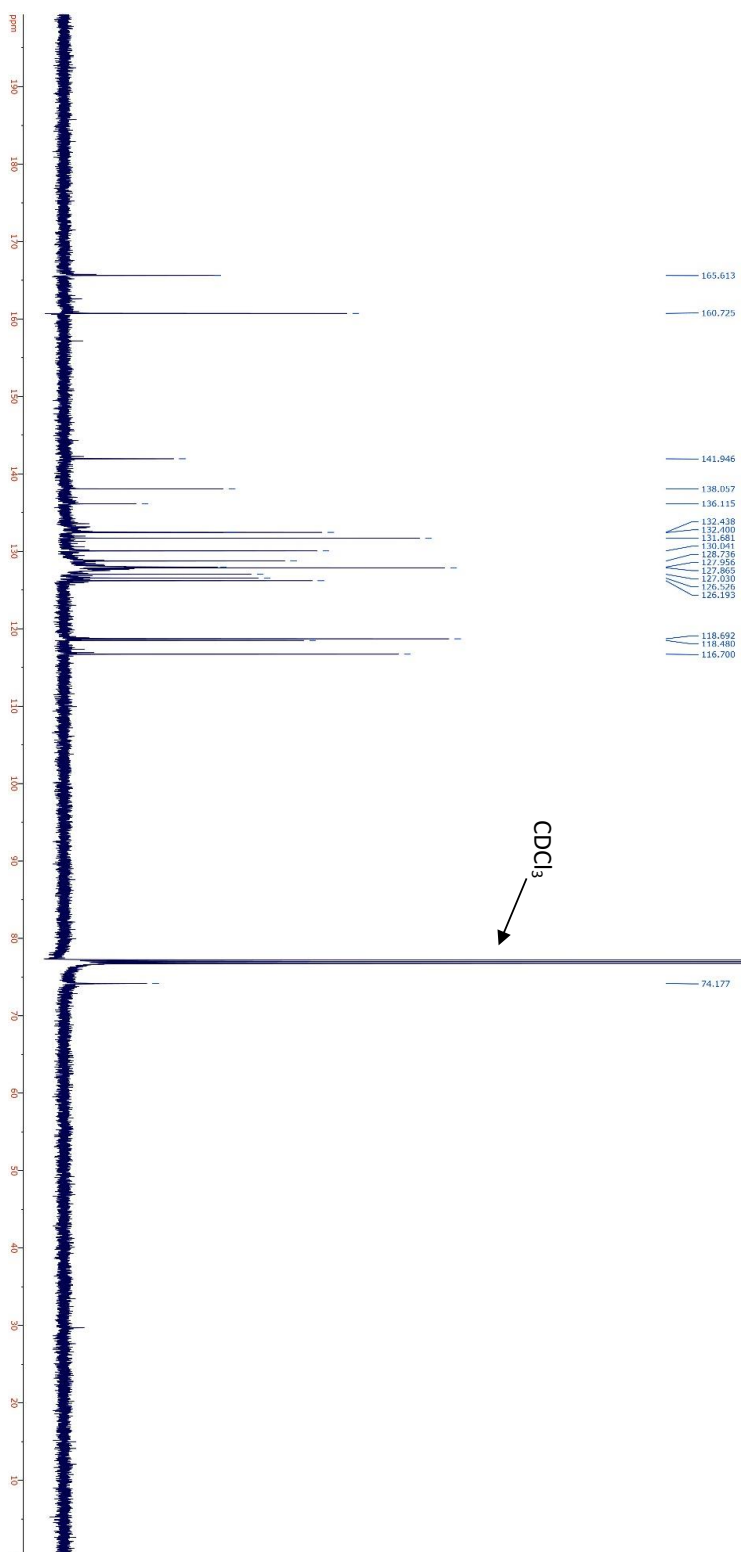
SI-34 (^{13}C NMR, 151 MHz, DMSO-d_6 , 100 °C)

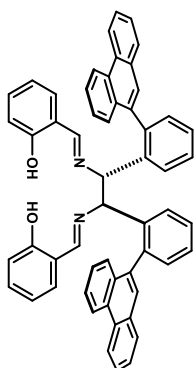




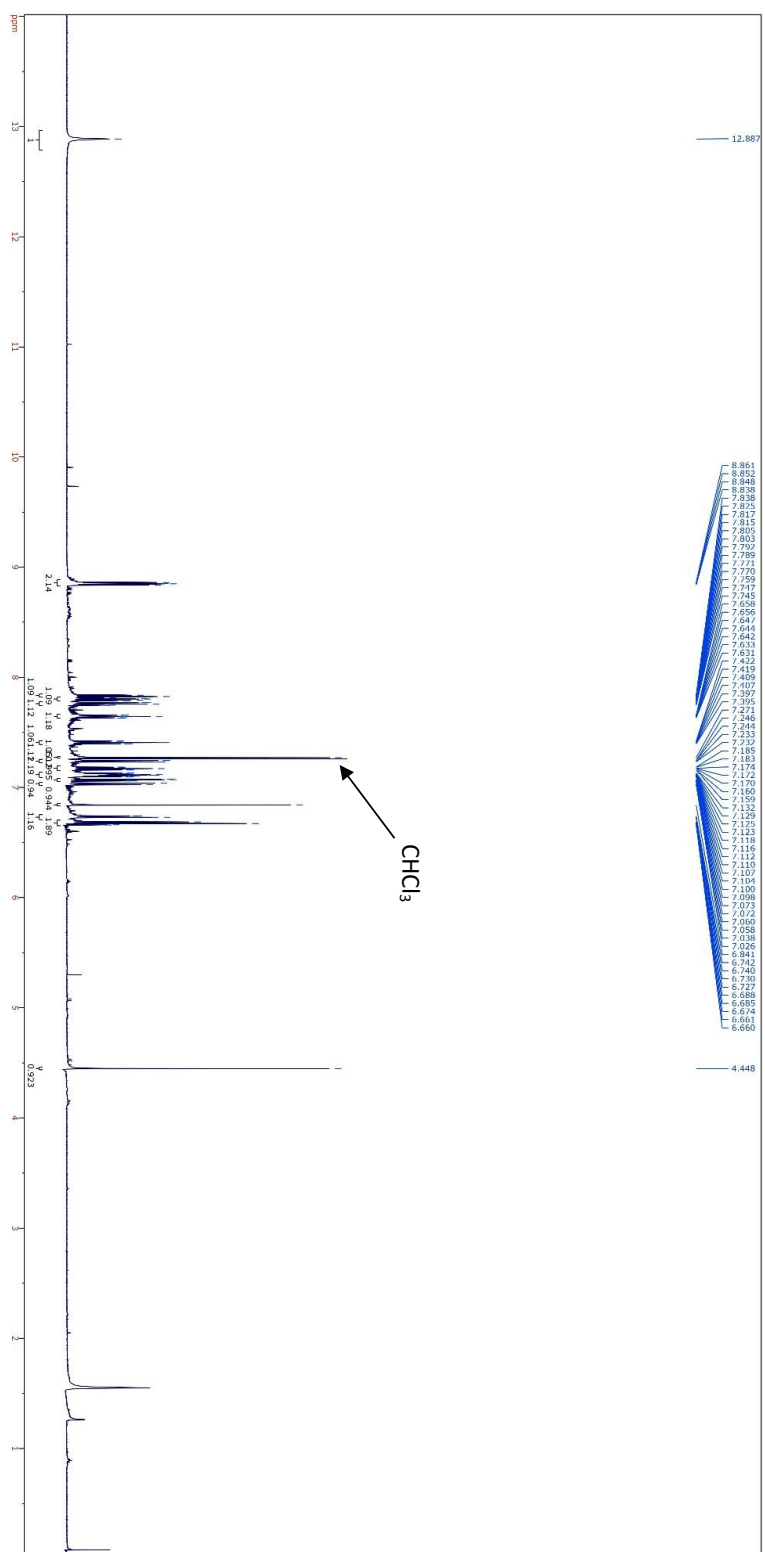


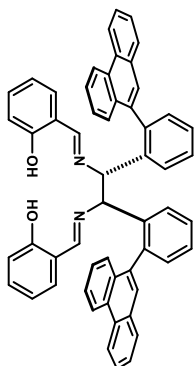
SI-35 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)



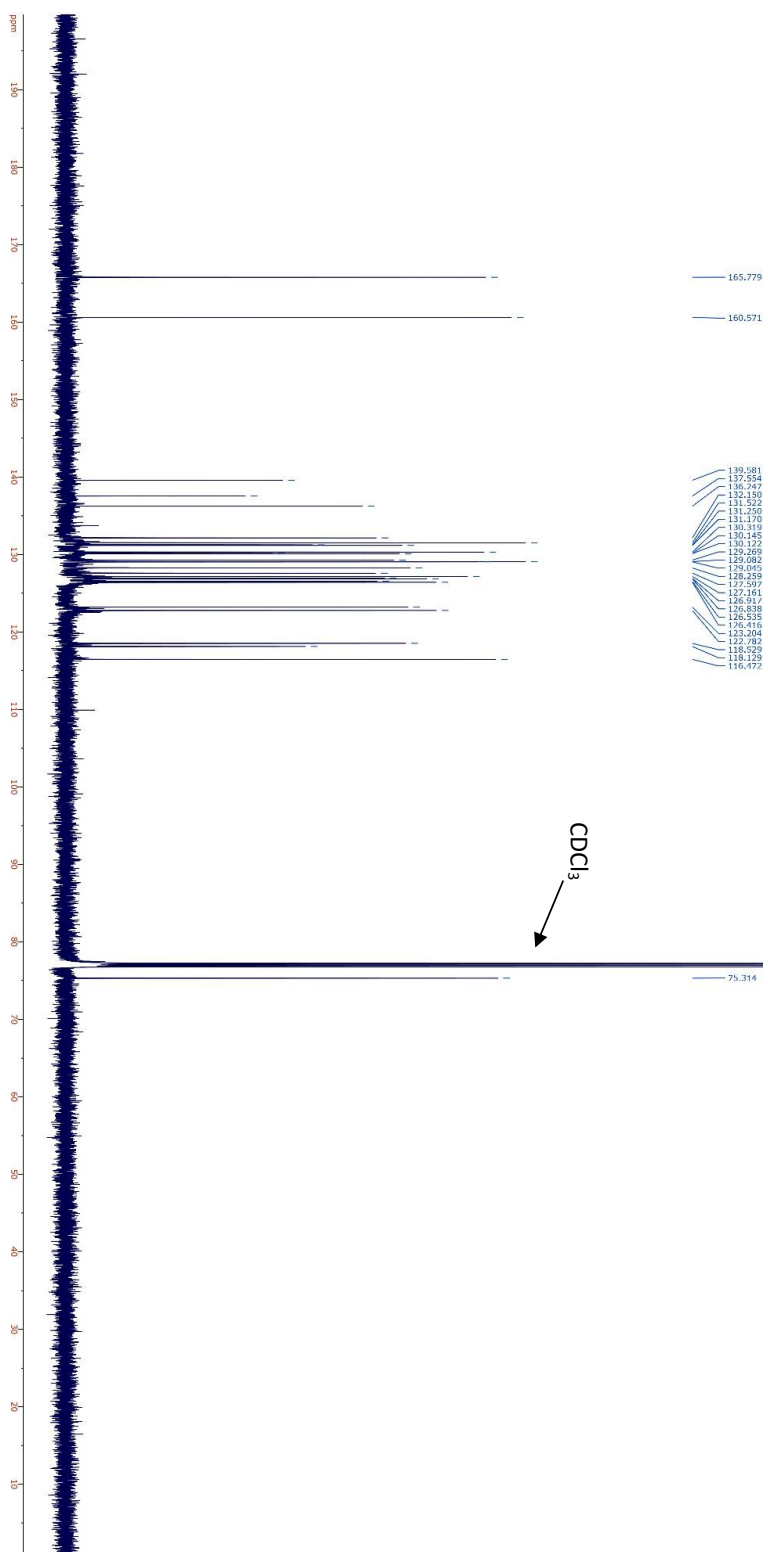


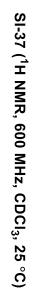
SI-36 (^1H NMR, 600 MHz, CDCl_3 , 25 $^\circ\text{C}$)

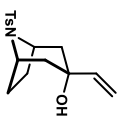




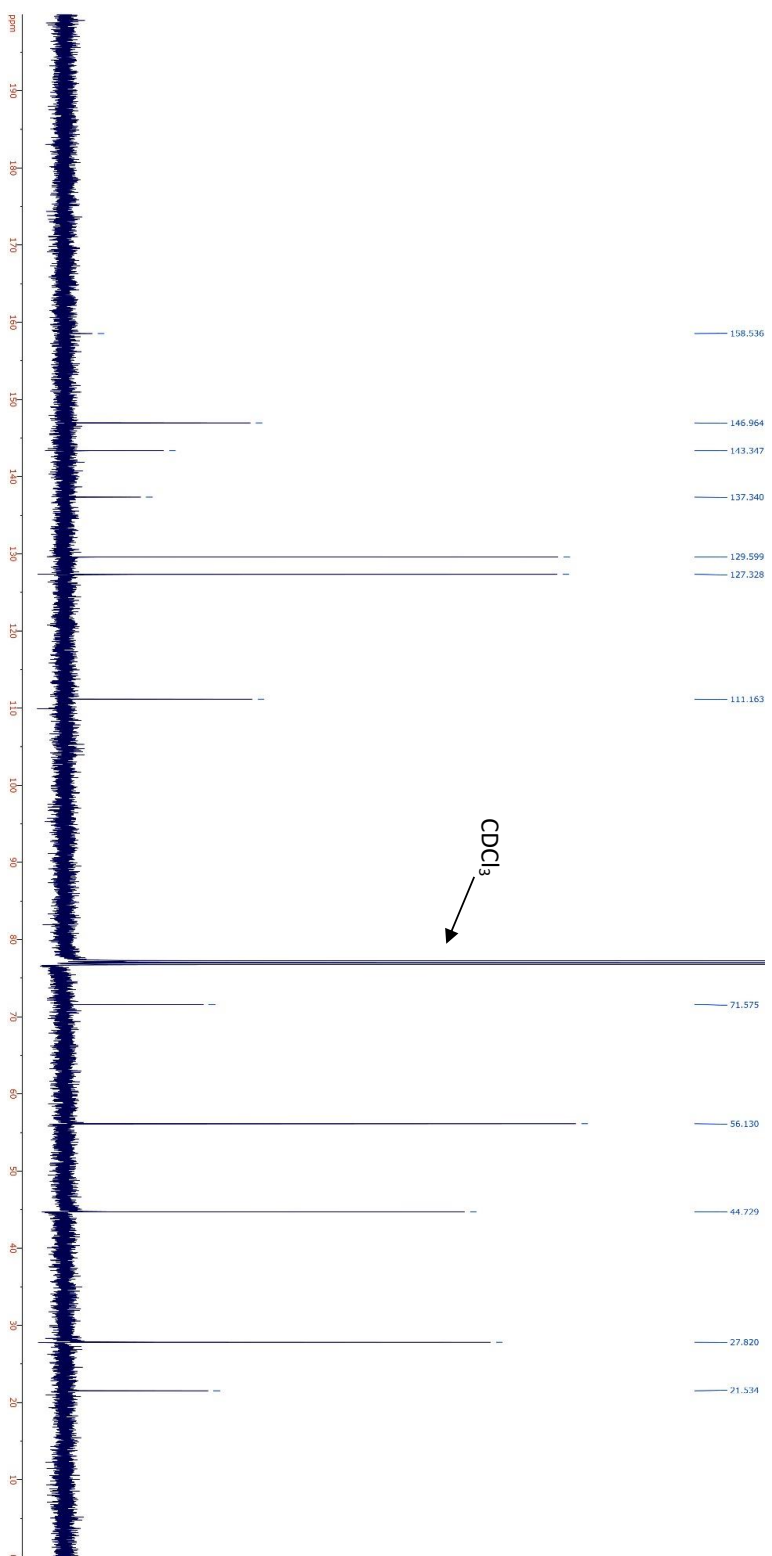
SI-36 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)

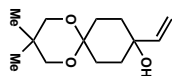




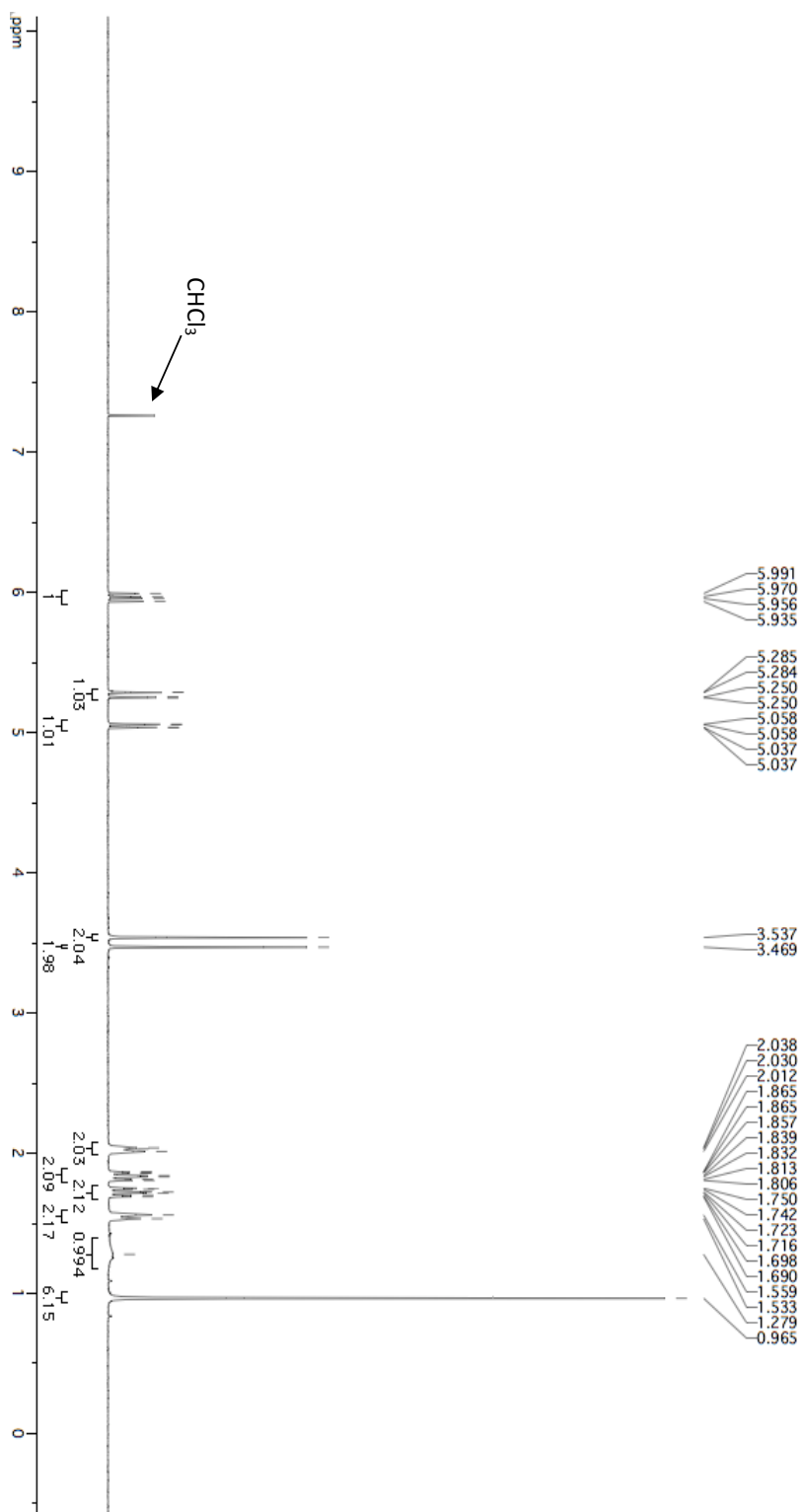


SI-37 (^{13}C NMR, 151 MHz, CDCl_3 , 25 °C)

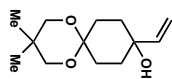




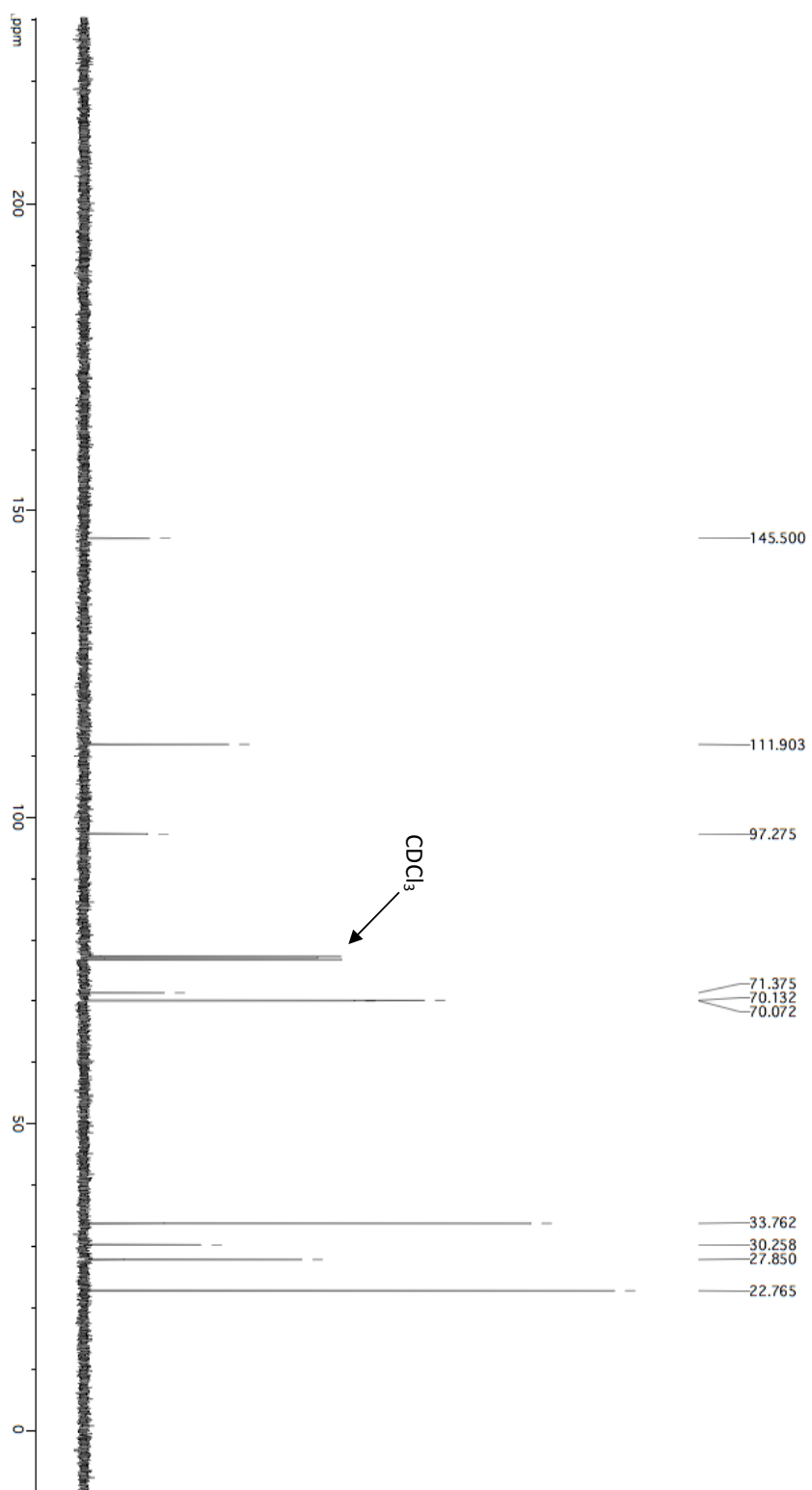
SI-38 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)



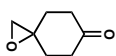
S72



SI-38 (¹³C NMR, 126 MHz, CDCl₃, 25 °C)

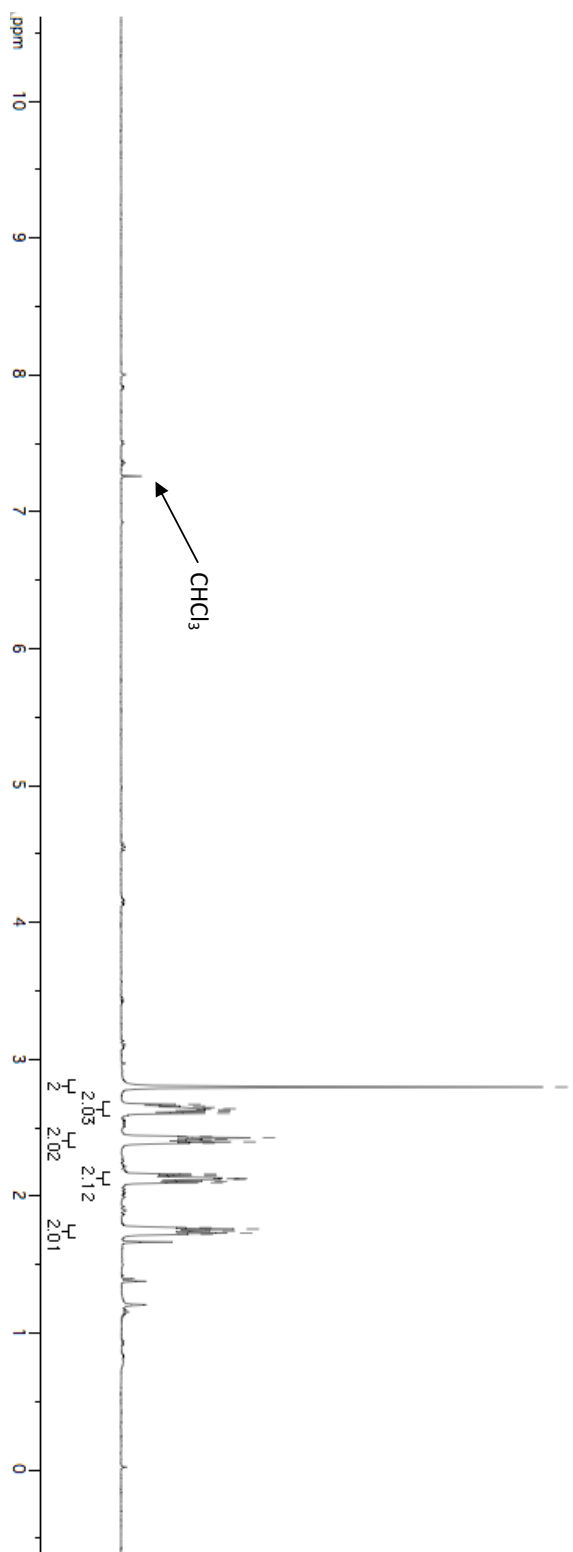


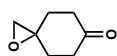
S73



SI-46 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)

2.798
2.671
2.659
2.648
2.639
2.630
2.619
2.607
2.436
2.427
2.416
2.409
2.398
2.389
2.161
2.150
2.133
2.129
2.124
2.111
2.100
1.770
1.760
1.747
1.733
1.724



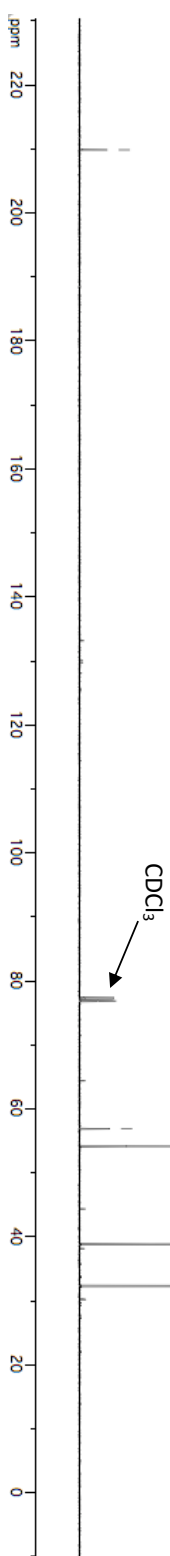


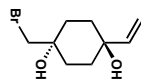
SI-46 (^{13}C NMR, 126 MHz, CDCl_3 , 25 $^\circ\text{C}$)

209.868

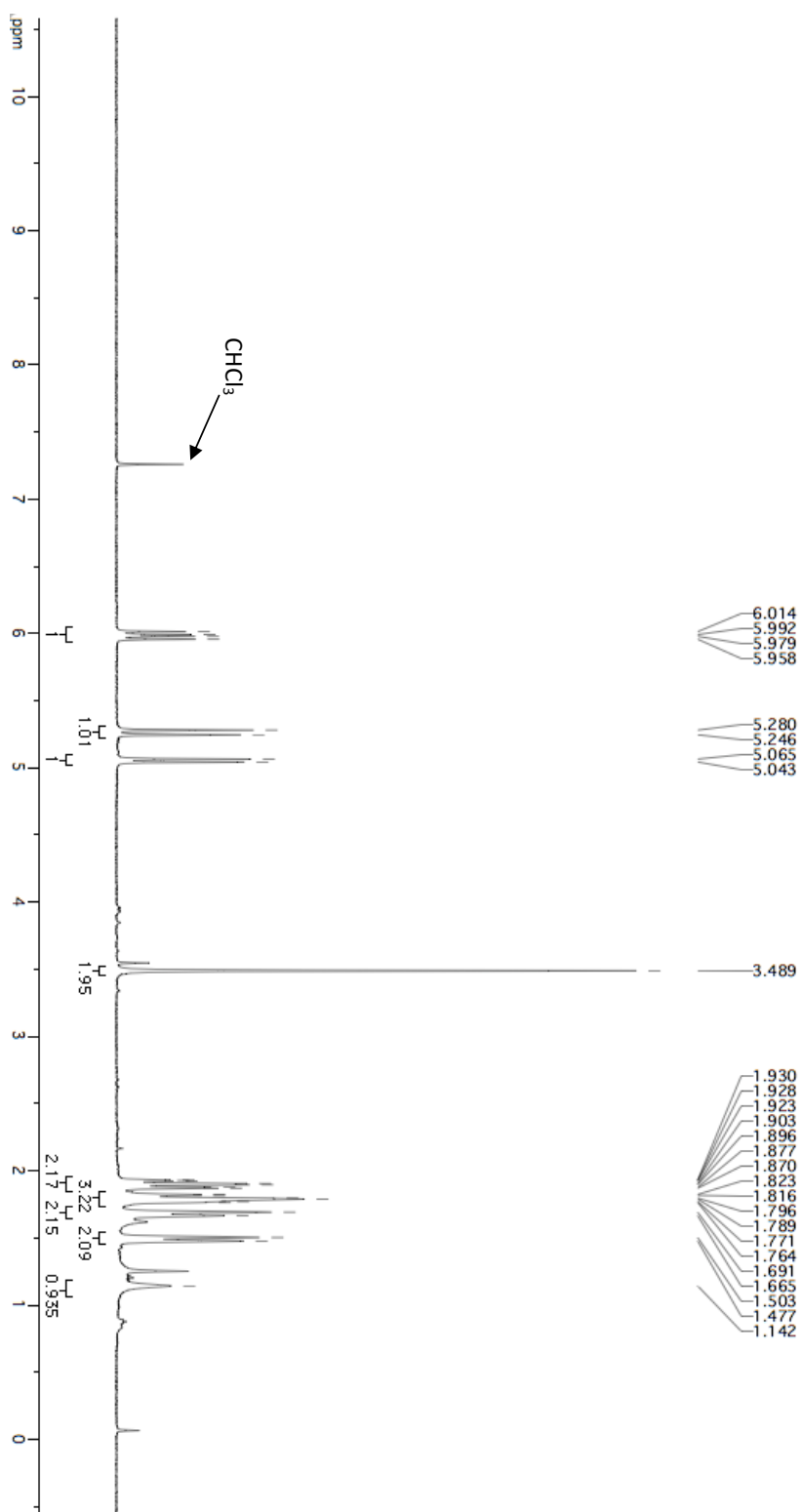
56.892
54.135

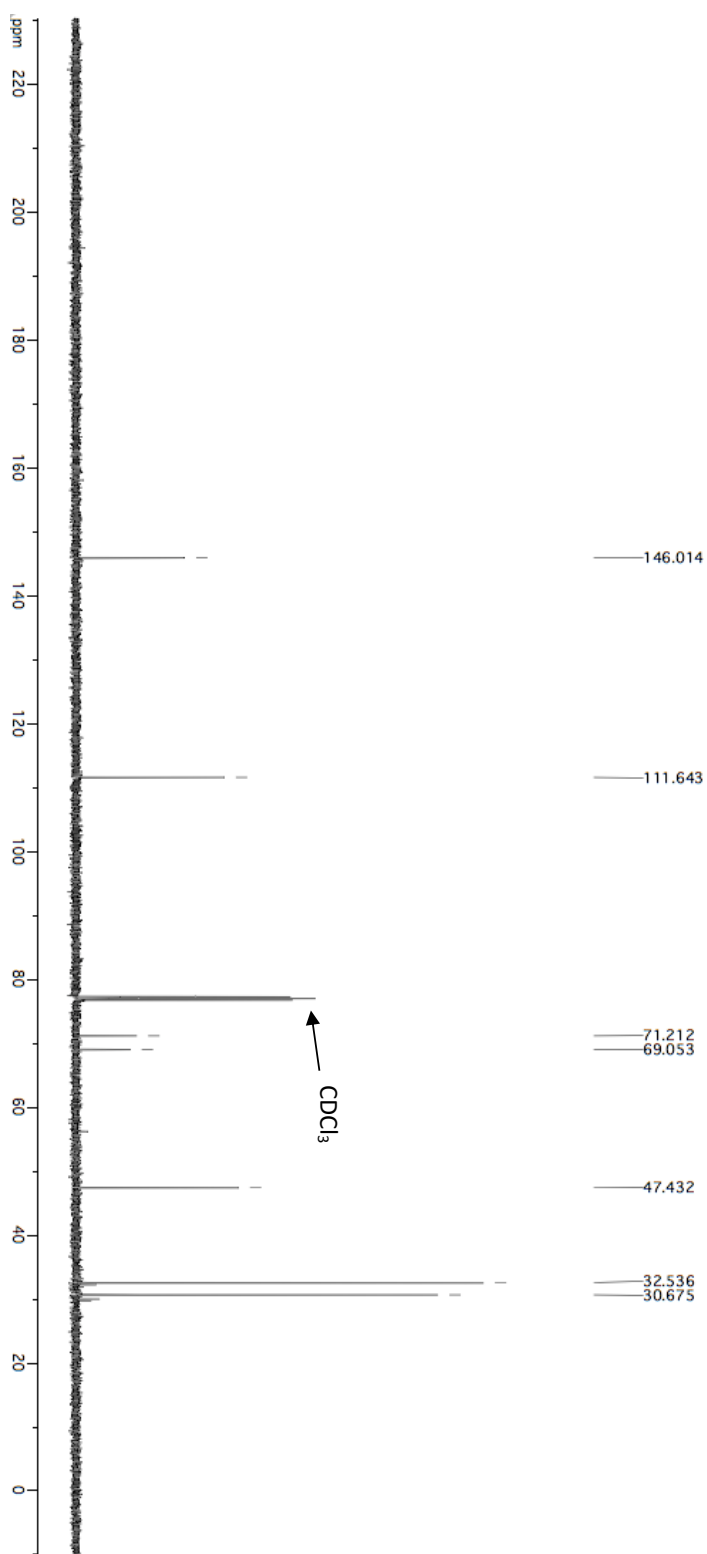
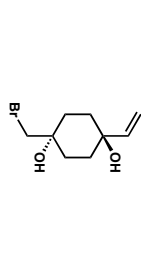
38.866
32.301

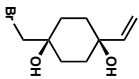




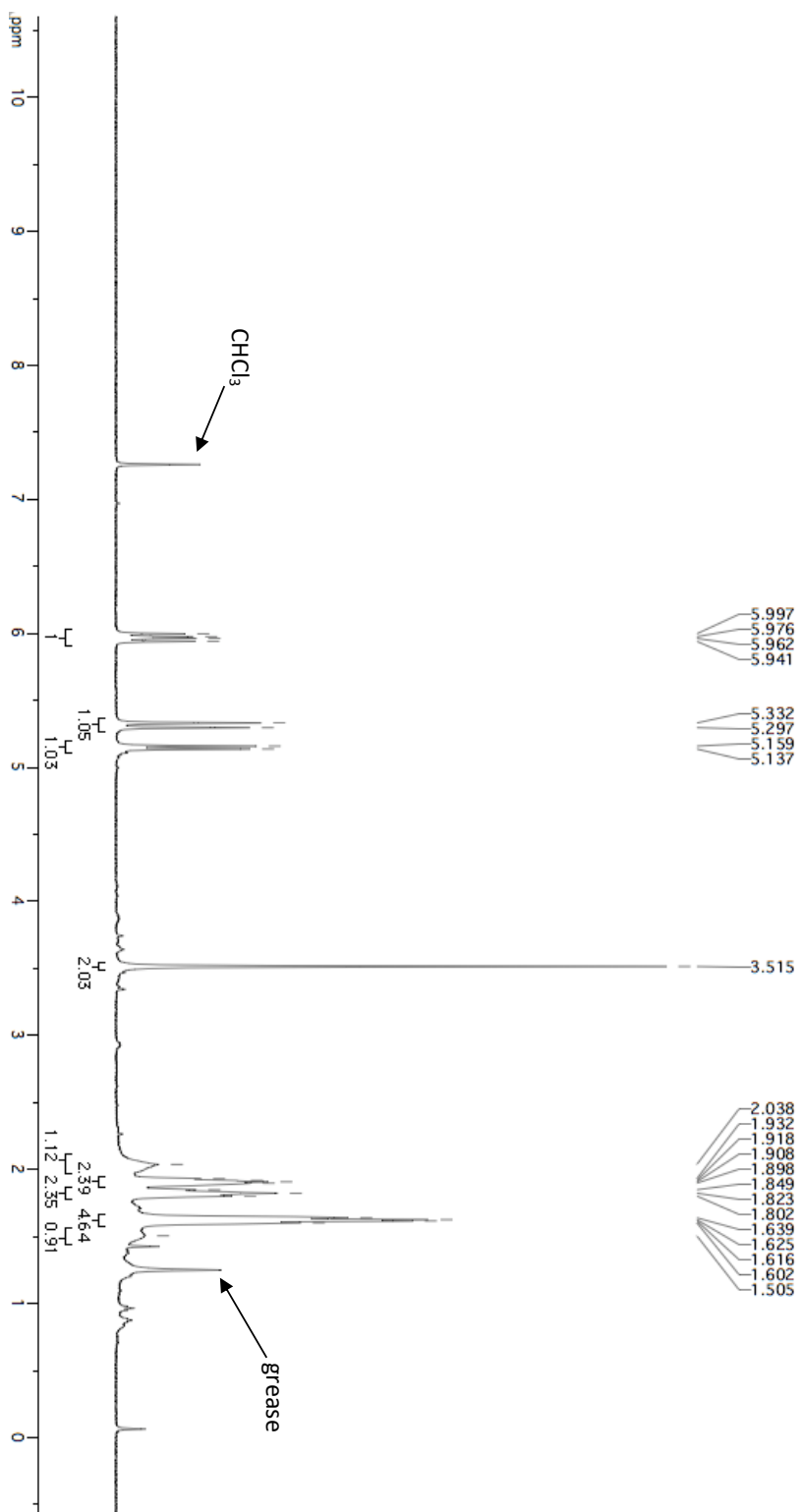
SI-39 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)

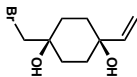




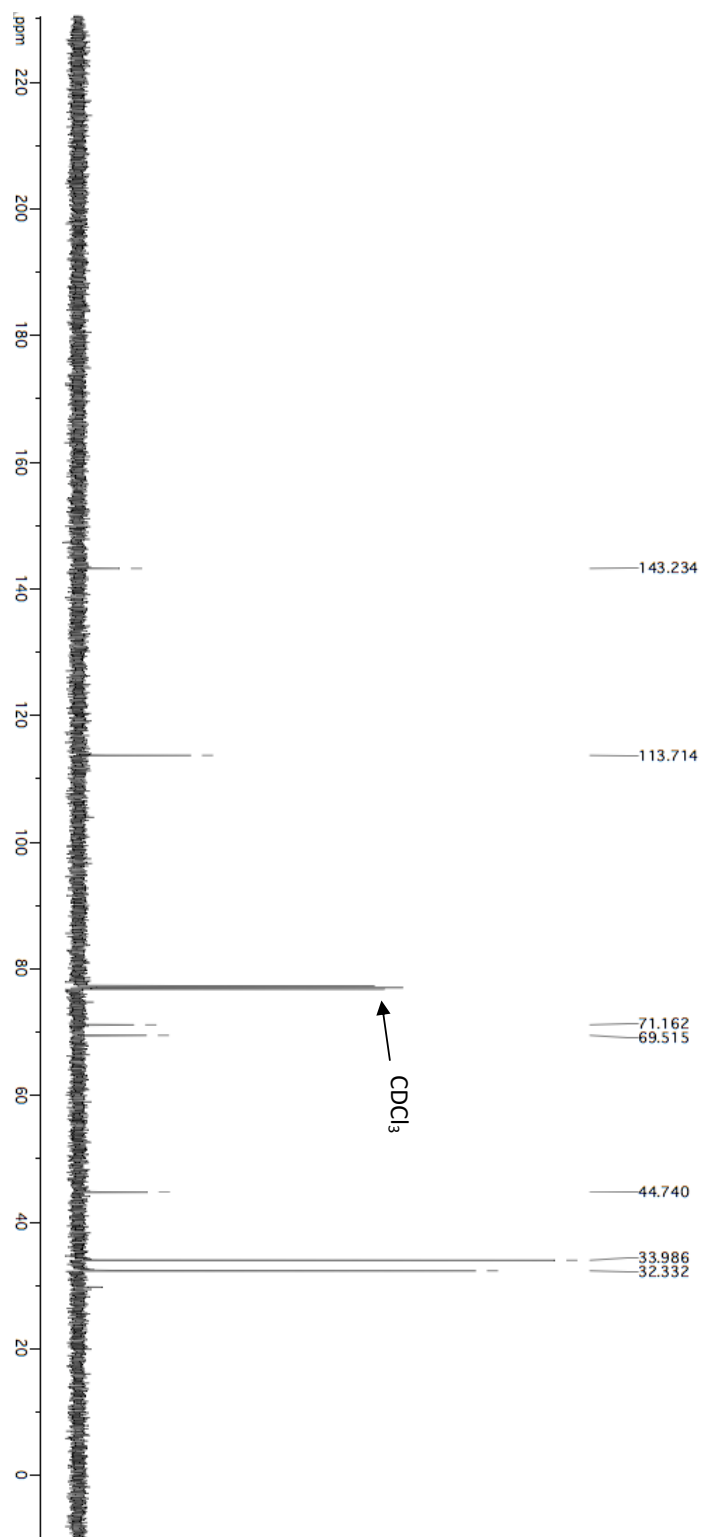


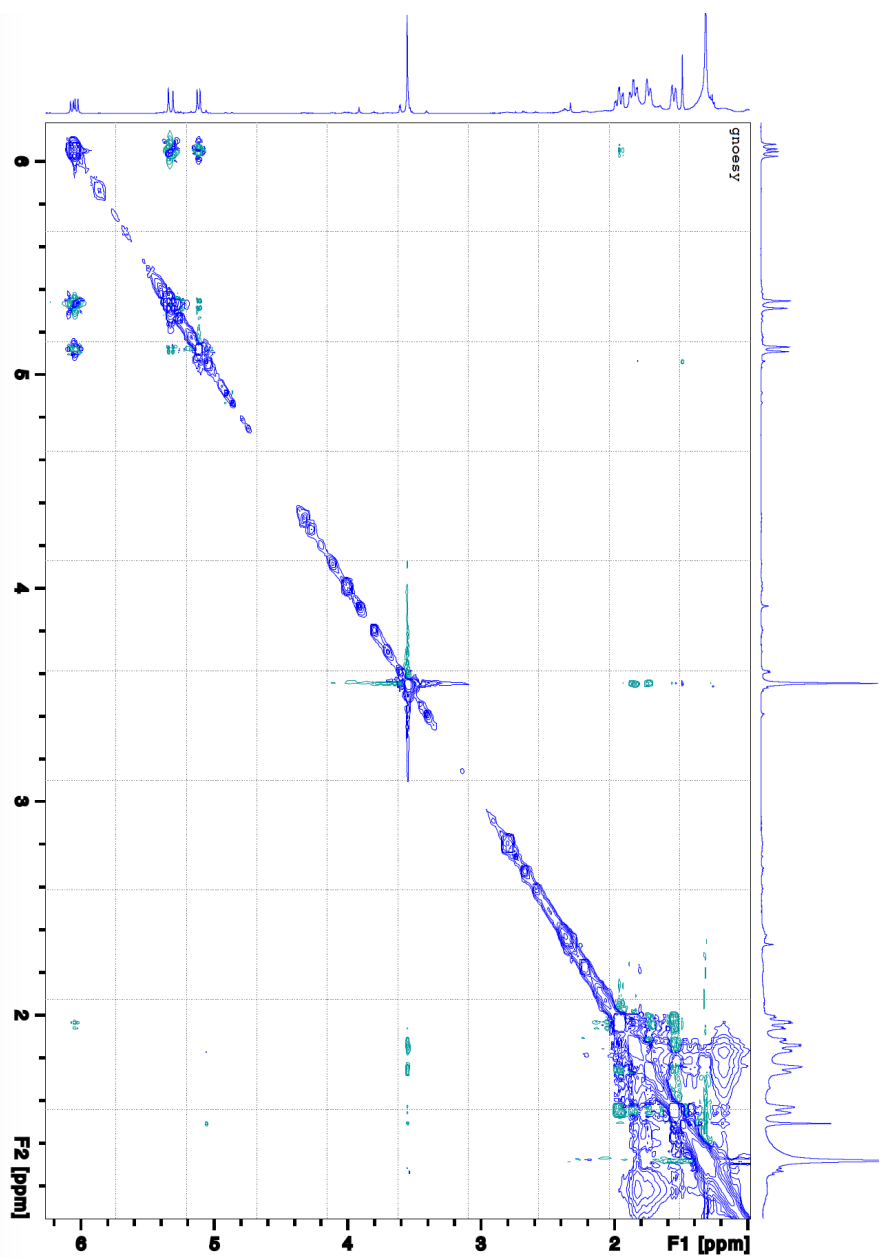
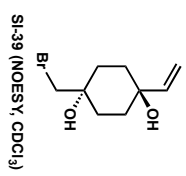
SI-40 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)

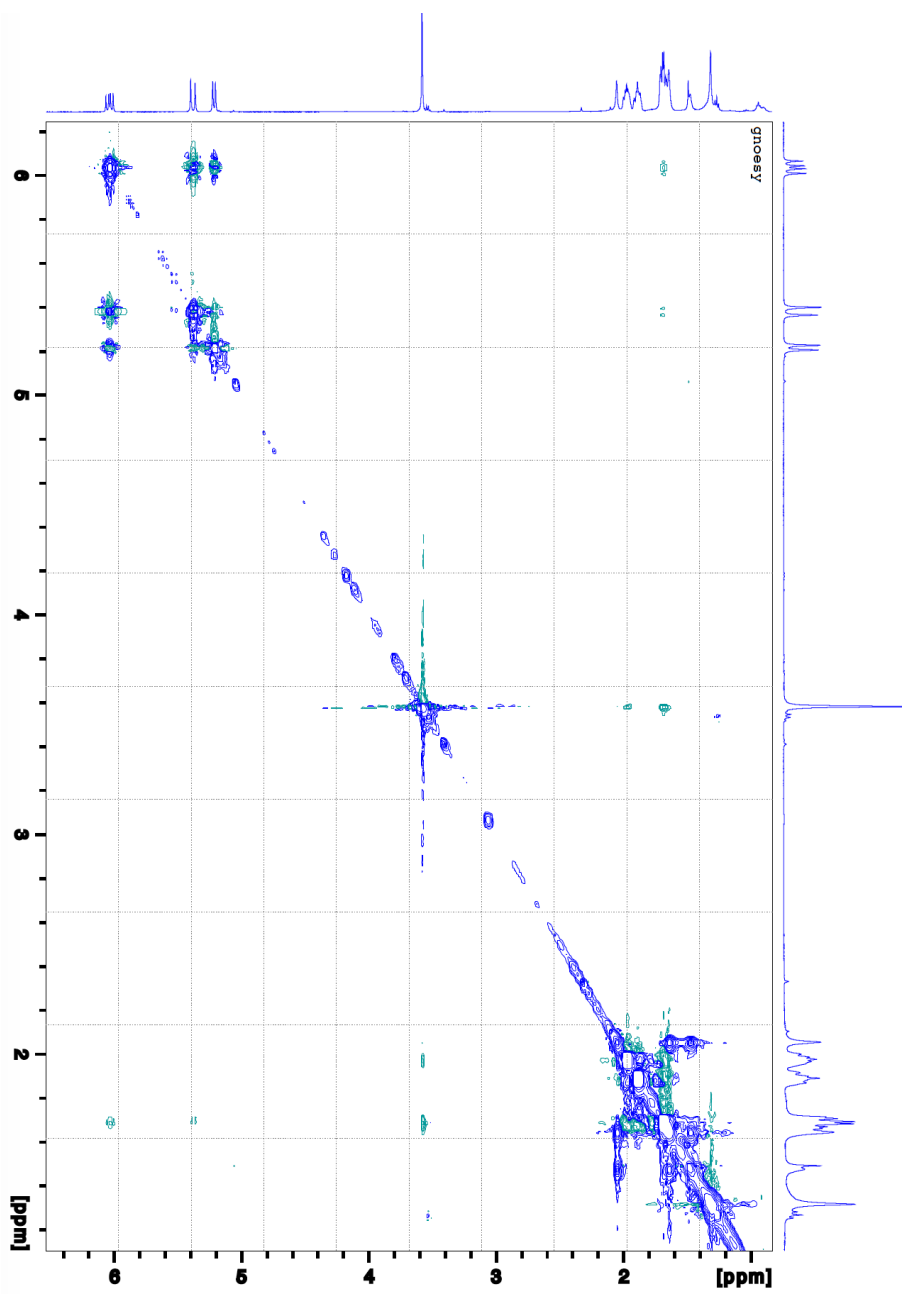
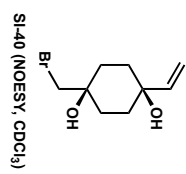


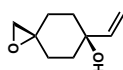


SI-40 (^{13}C NMR, 126 MHz, CDCl_3 , 25 $^\circ\text{C}$)

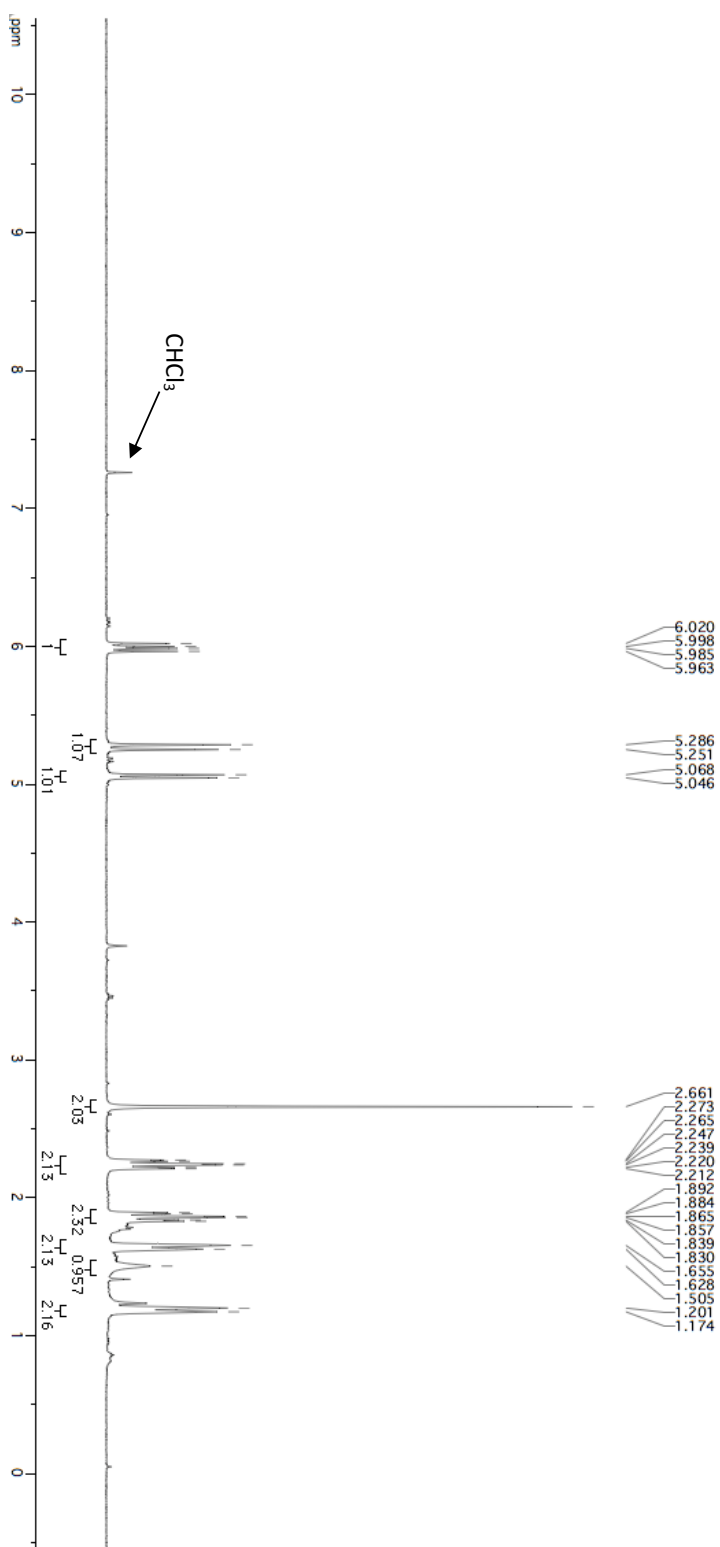


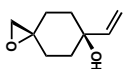




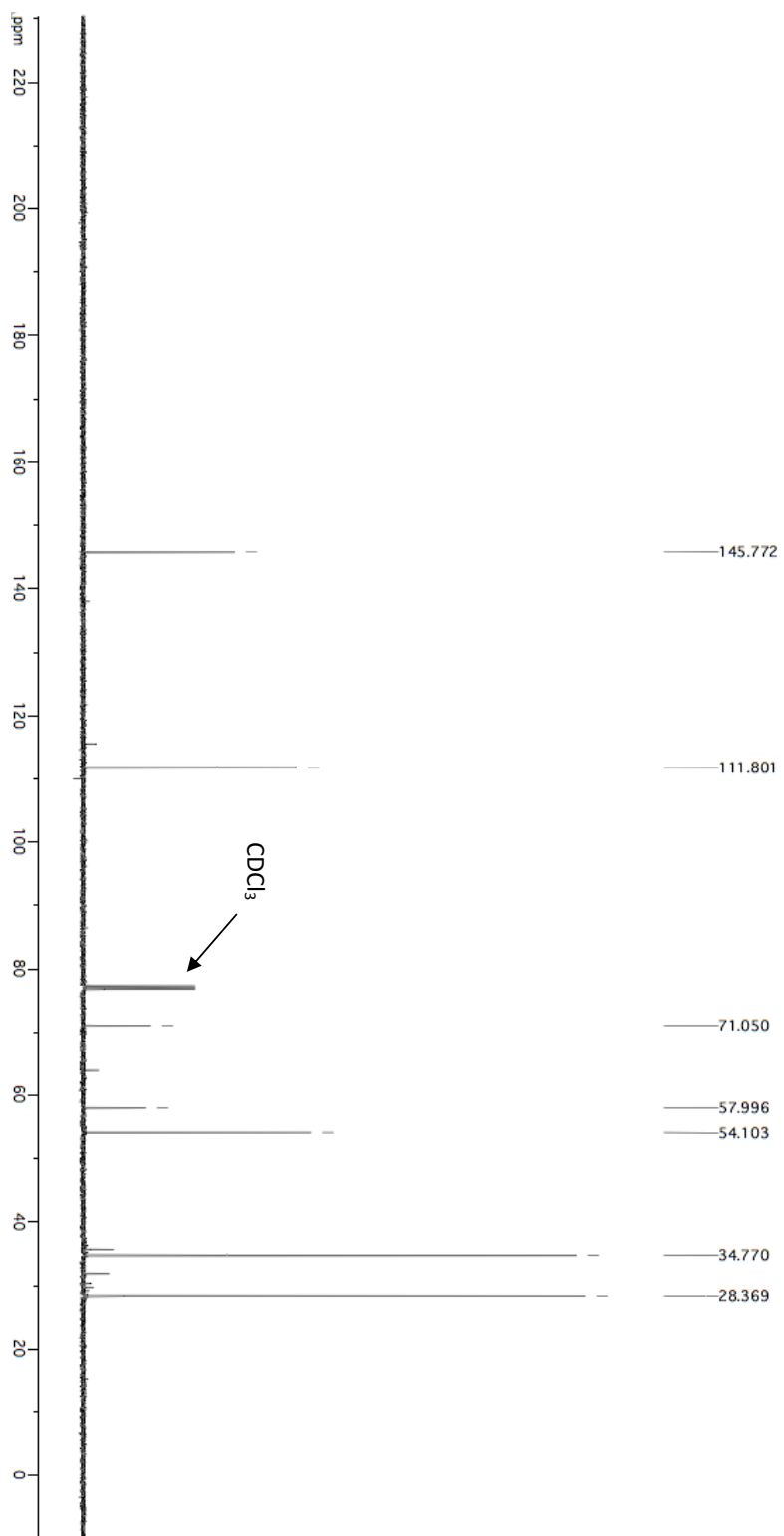


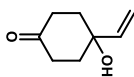
SI-41 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)



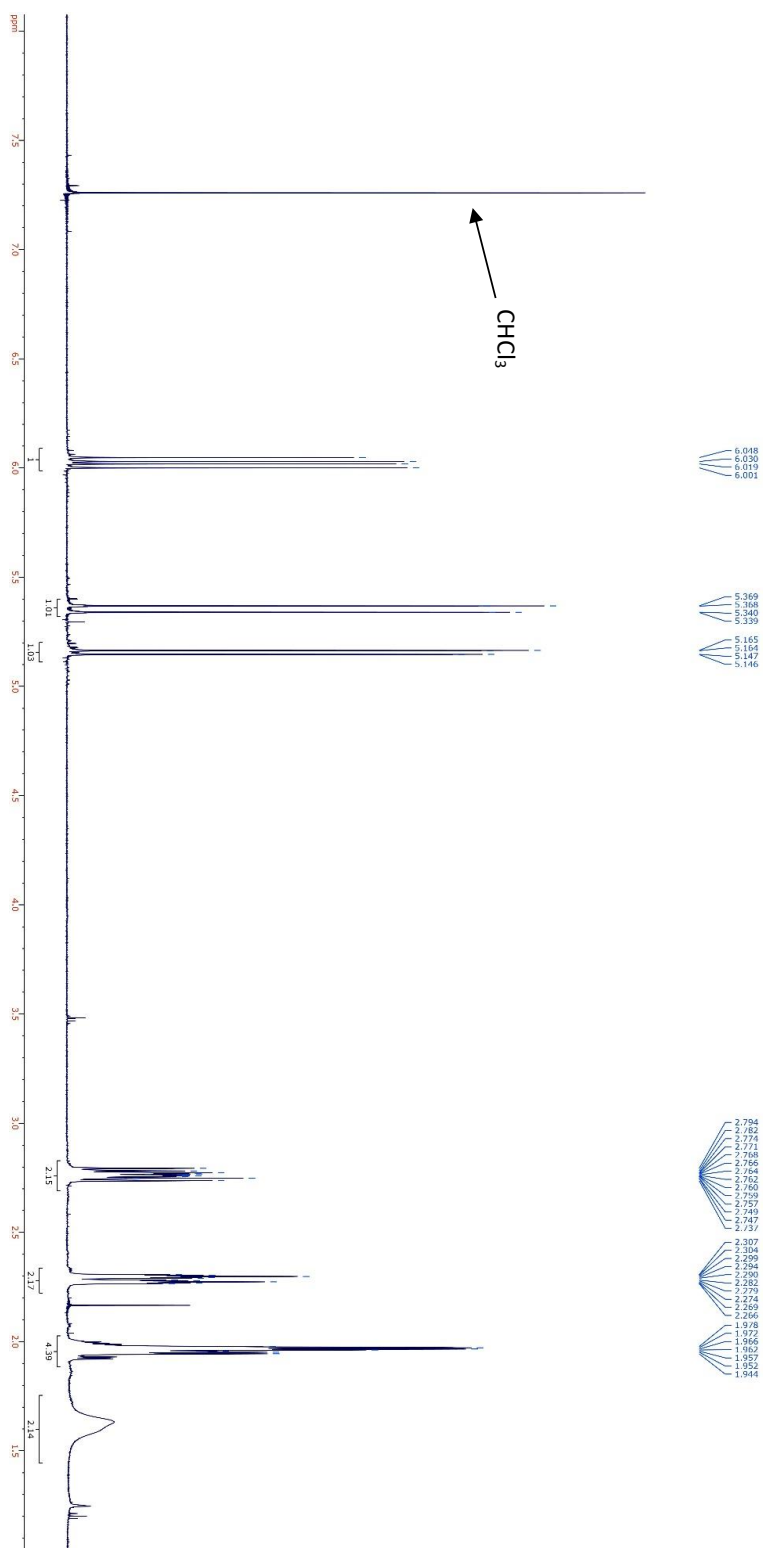


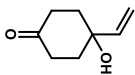
SI-41 (^{13}C NMR, 126 MHz, CDCl_3 , 25 $^\circ\text{C}$)



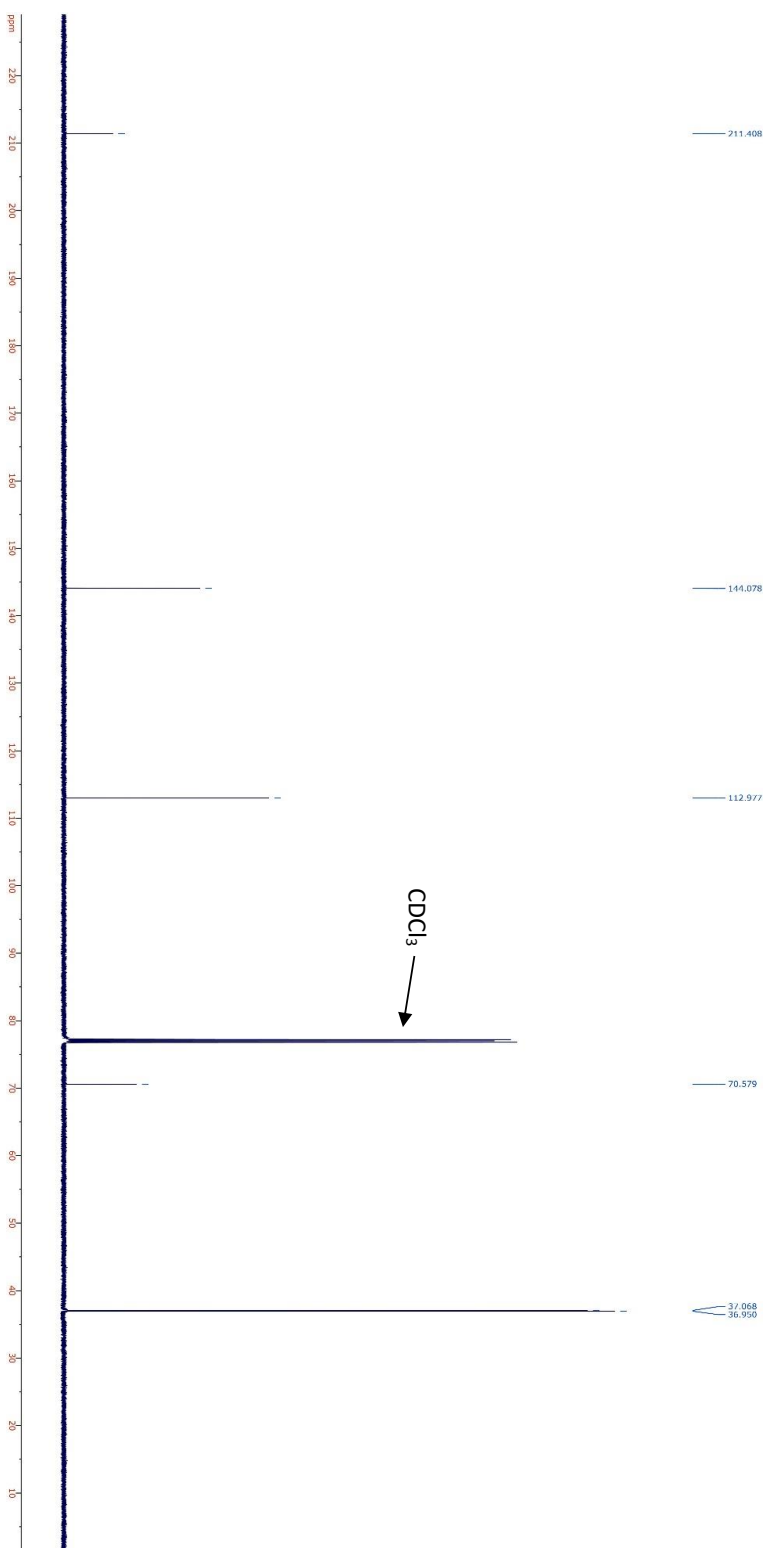


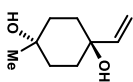
SI-42 (^1H NMR, 600 MHz, CDCl_3 , 25 °C)



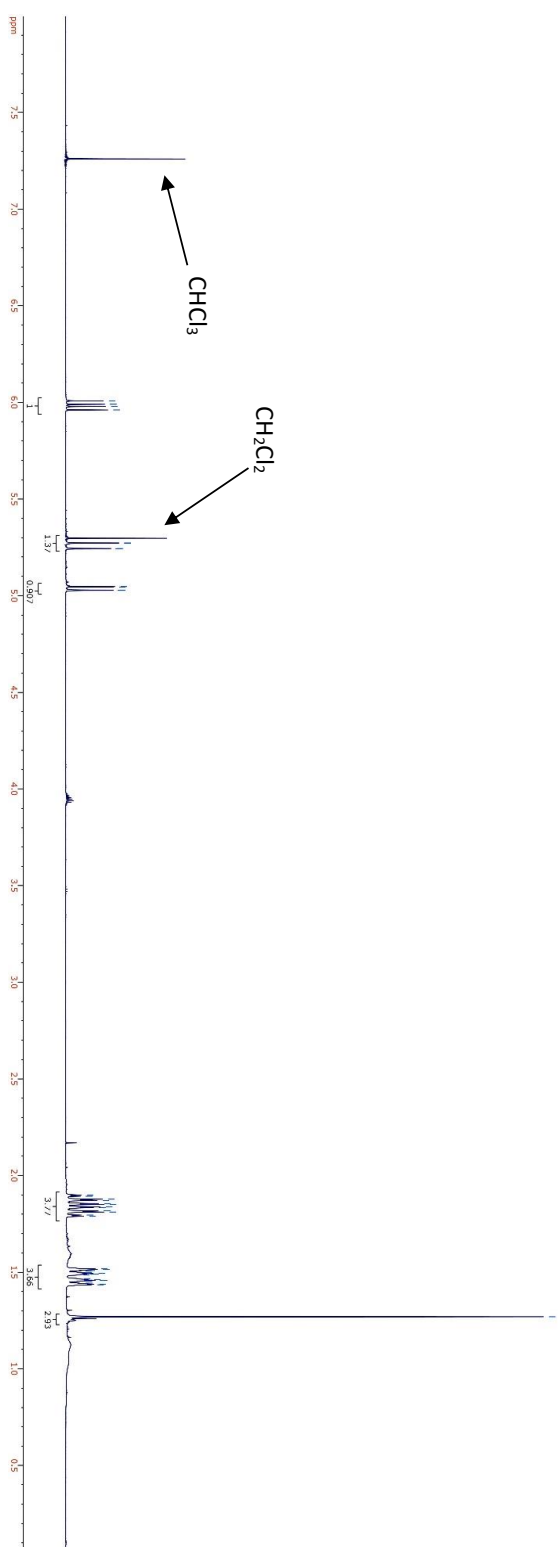


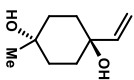
SI-42 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)



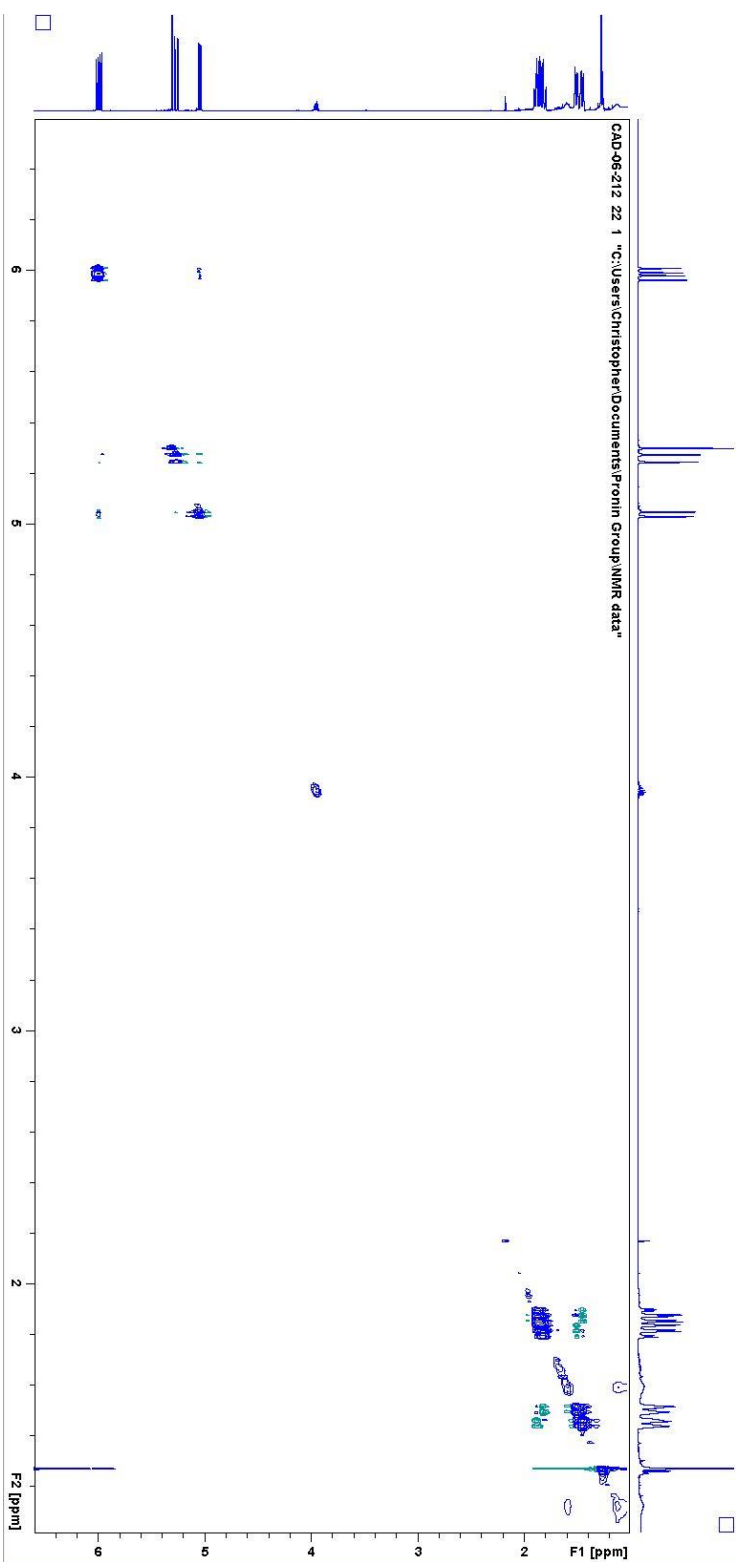


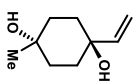
SI-43 (^1H NMR, 600 MHz, CDCl_3 , 25 $^\circ\text{C}$)



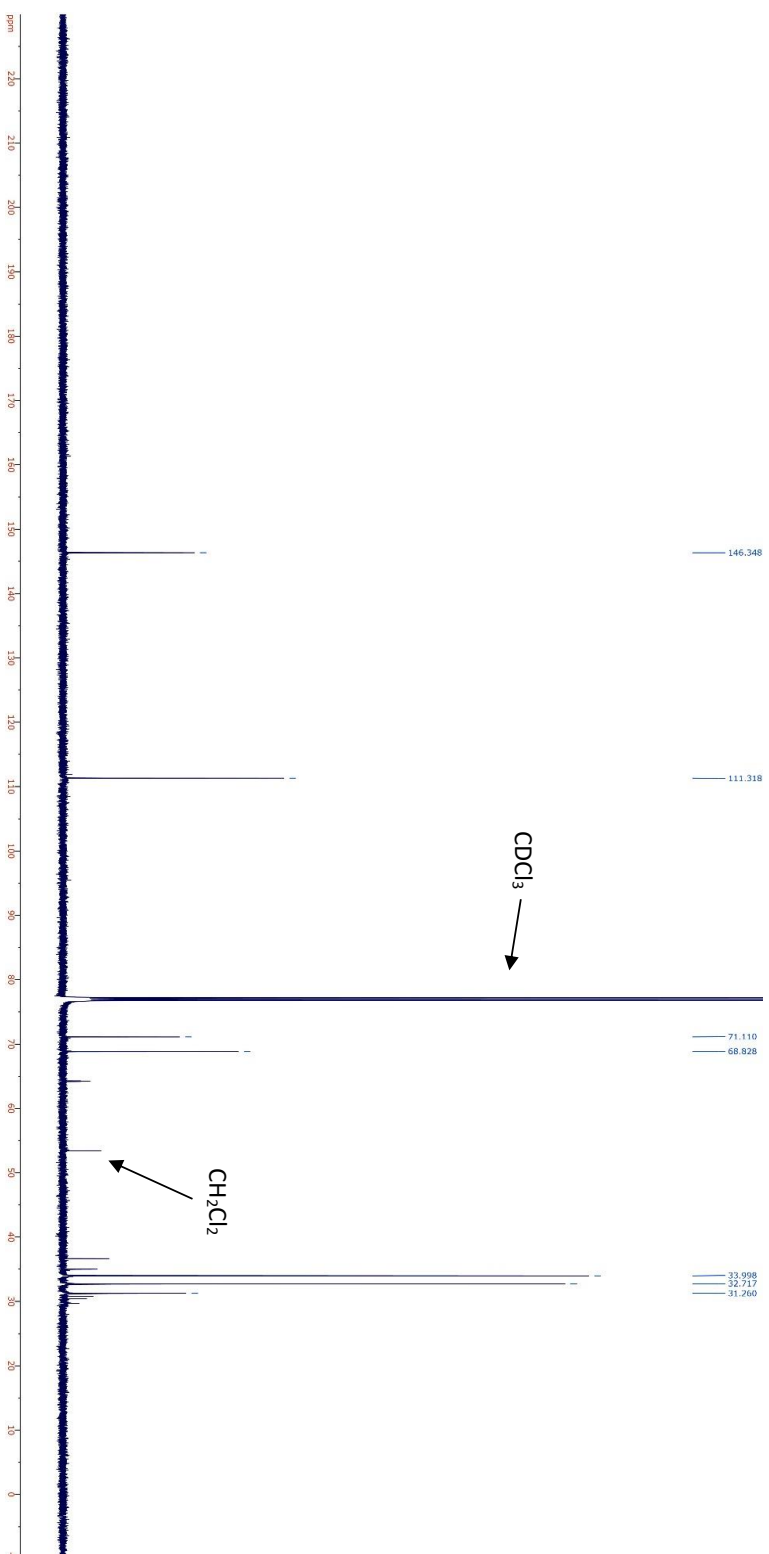


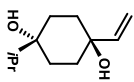
SI-43 (NOESY, CDCl₃, 25 °C)



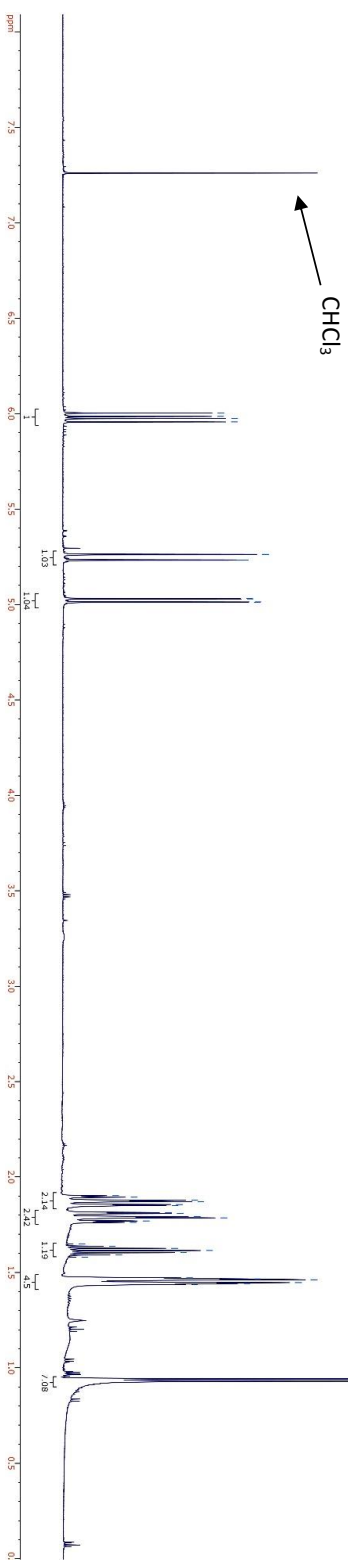


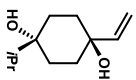
SI-43 (^{13}C NMR, 151 MHz, CDCl_3 , 25 °C)



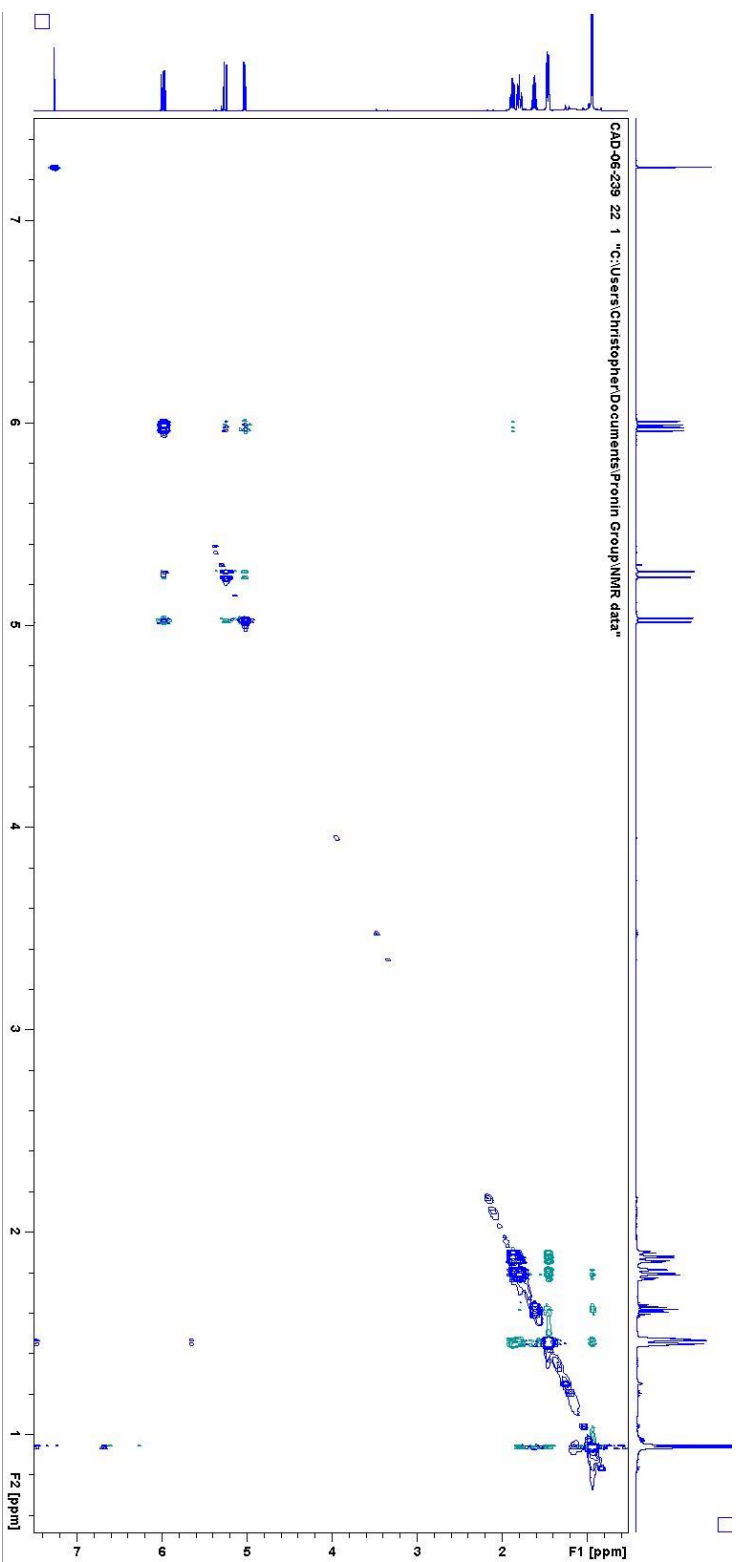


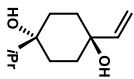
SI-45 (^1H NMR, 600 MHz, CDCl_3 , 25 $^\circ\text{C}$)



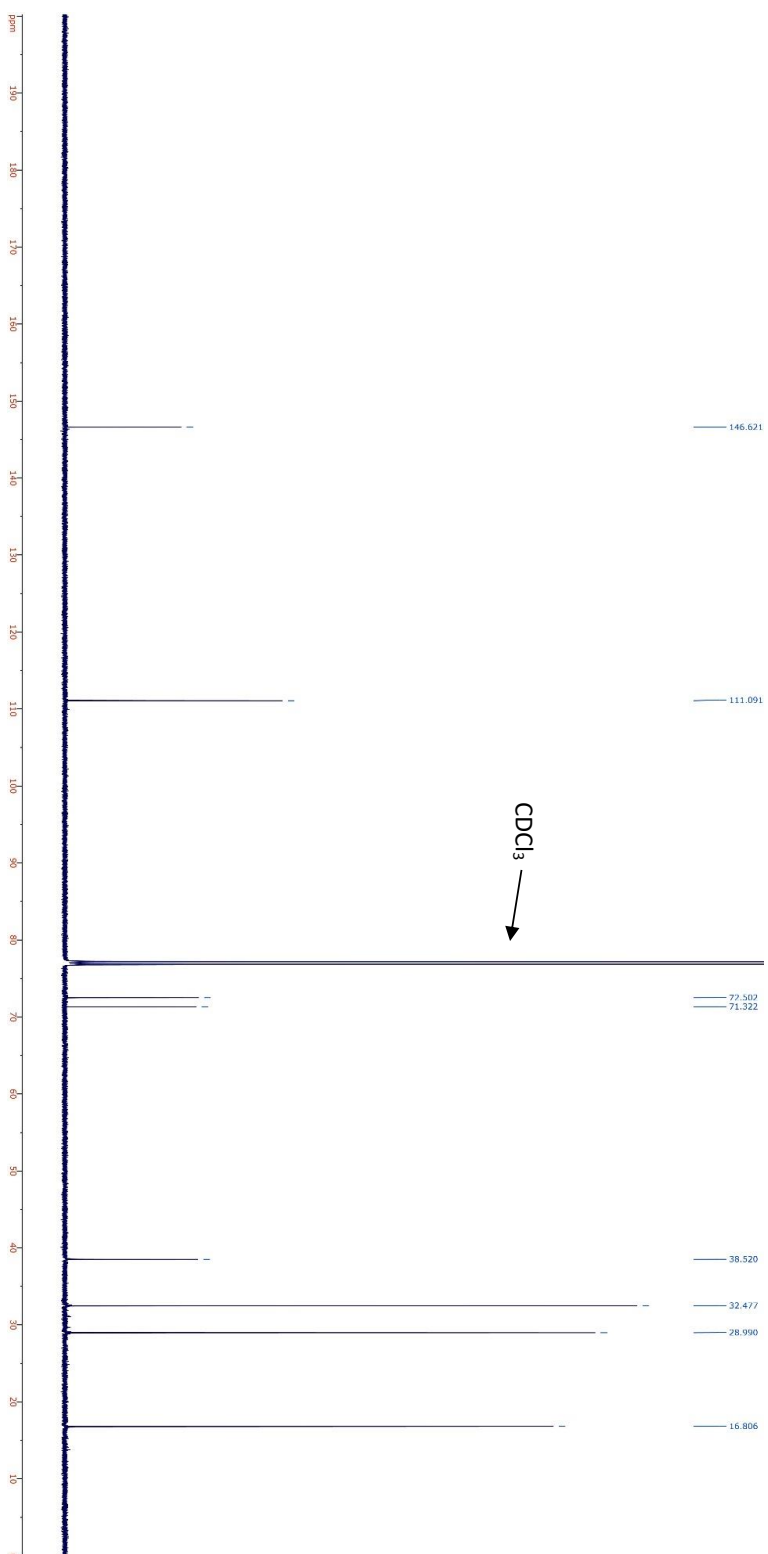


SI-45 (NOESY, CDCl₃, 25 °C)

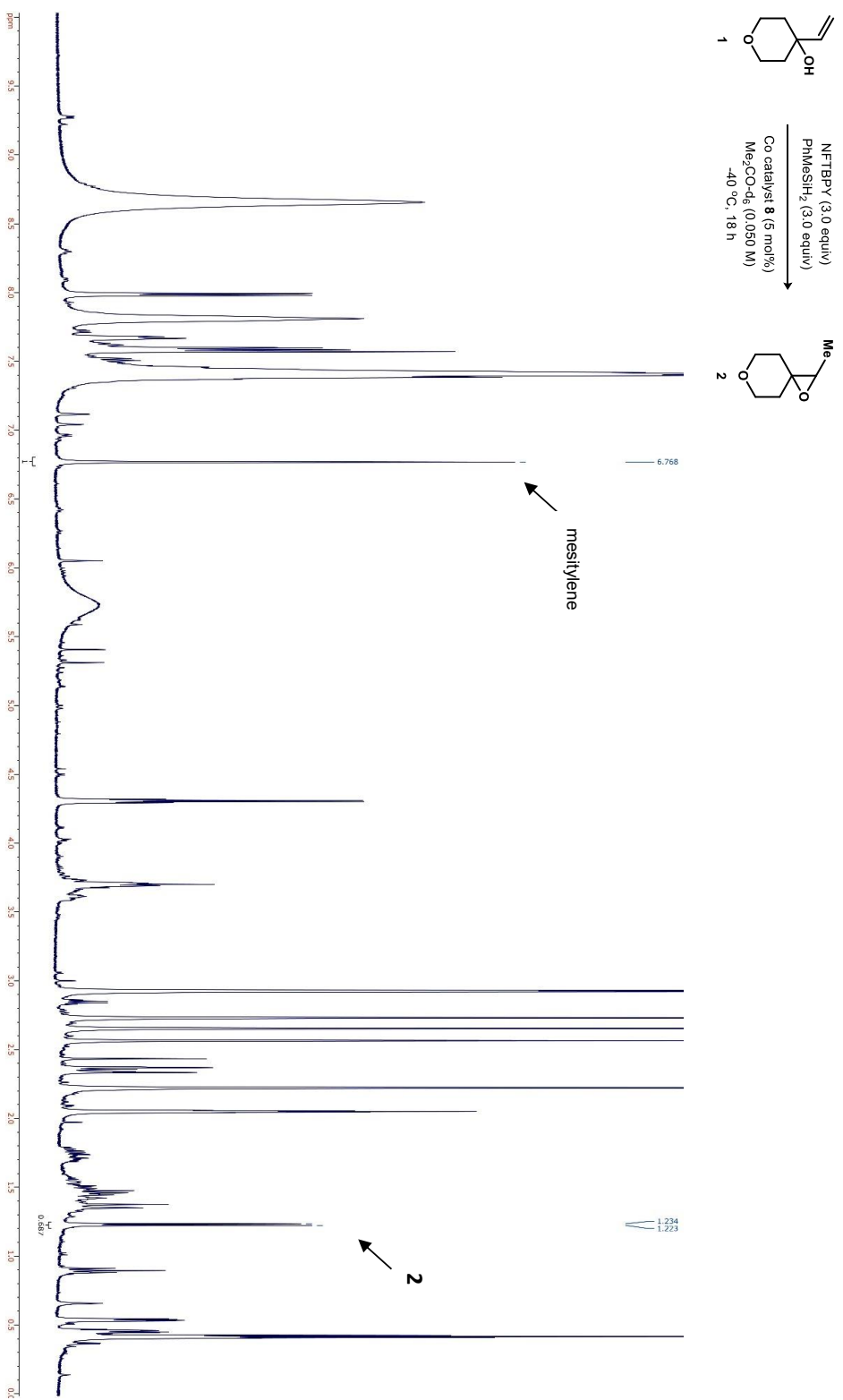




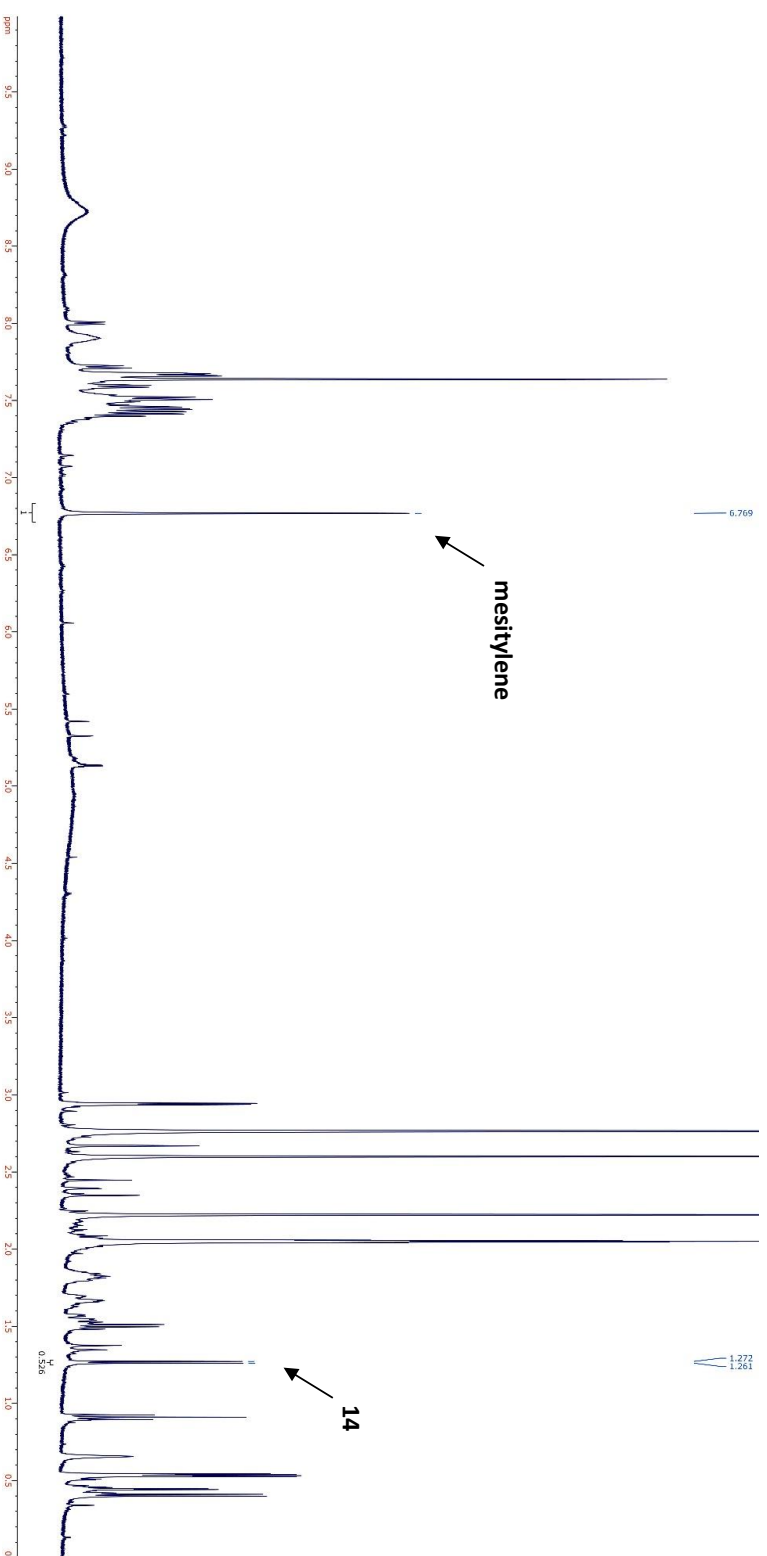
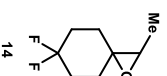
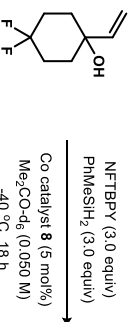
SI-45 (^{13}C NMR, 151 MHz, CDCl_3 , 25 °C)

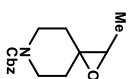


^1H NMR of crude radical-polar crossover epoxidation using allylic alcohol **1** (12.8 mg, 0.10 mmol) and catalyst **8** with mesitylene (12 mg, 0.10 mmol) as the internal standard to determine ^1H NMR yield. The methyl doublet of the epoxide **2** (1.23 ppm, d, $J = 5.5$ Hz, 3H) is integrated against the aromatic C–H resonance of mesitylene (6.77 ppm, s, 3H) indicating 69% ^1H NMR yield.

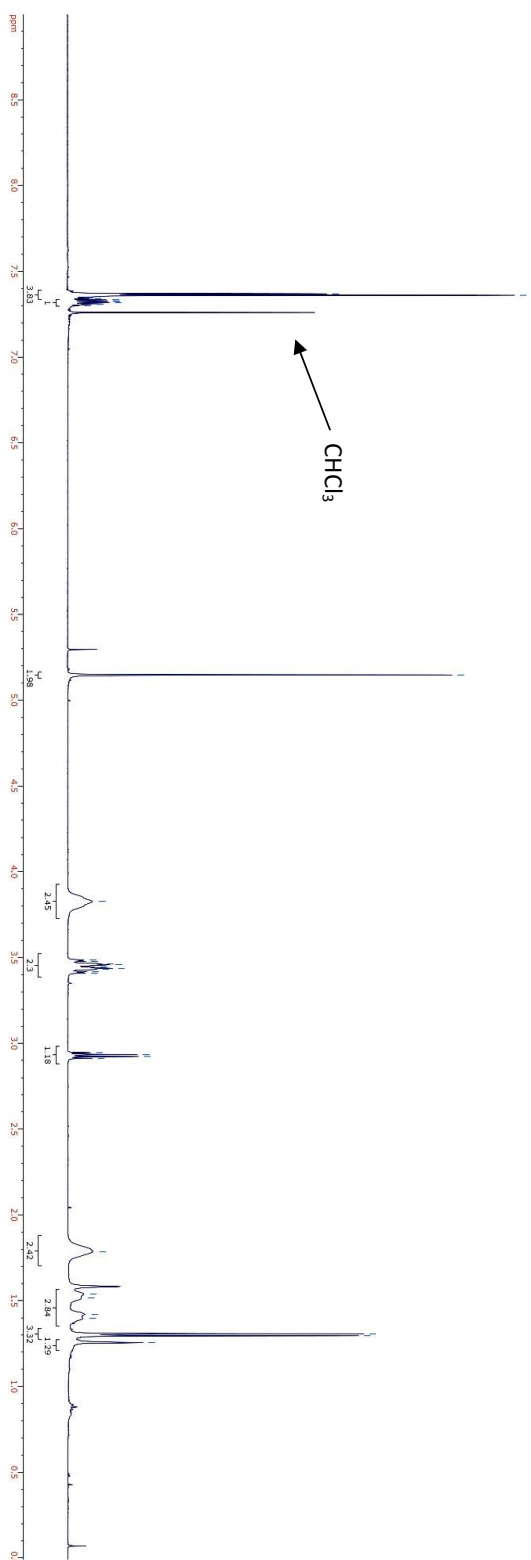


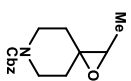
^1H NMR of crude radical-polar crossover epoxidation using 4,4-difluoro-1-vinylcyclohexan-1-ol (16.2 mg, 0.10 mmol) and catalyst **8** with mesitylene (12 mg, 0.10 mmol) as the internal standard to determine ^1H NMR yield. The methyl doublet of epoxide **14** (1.27 ppm, d, $J = 5.5$ Hz, 3H) is integrated against the aromatic C–H resonance of mesitylene (6.77 ppm, s, 3H) indicating 53% ^1H NMR yield.



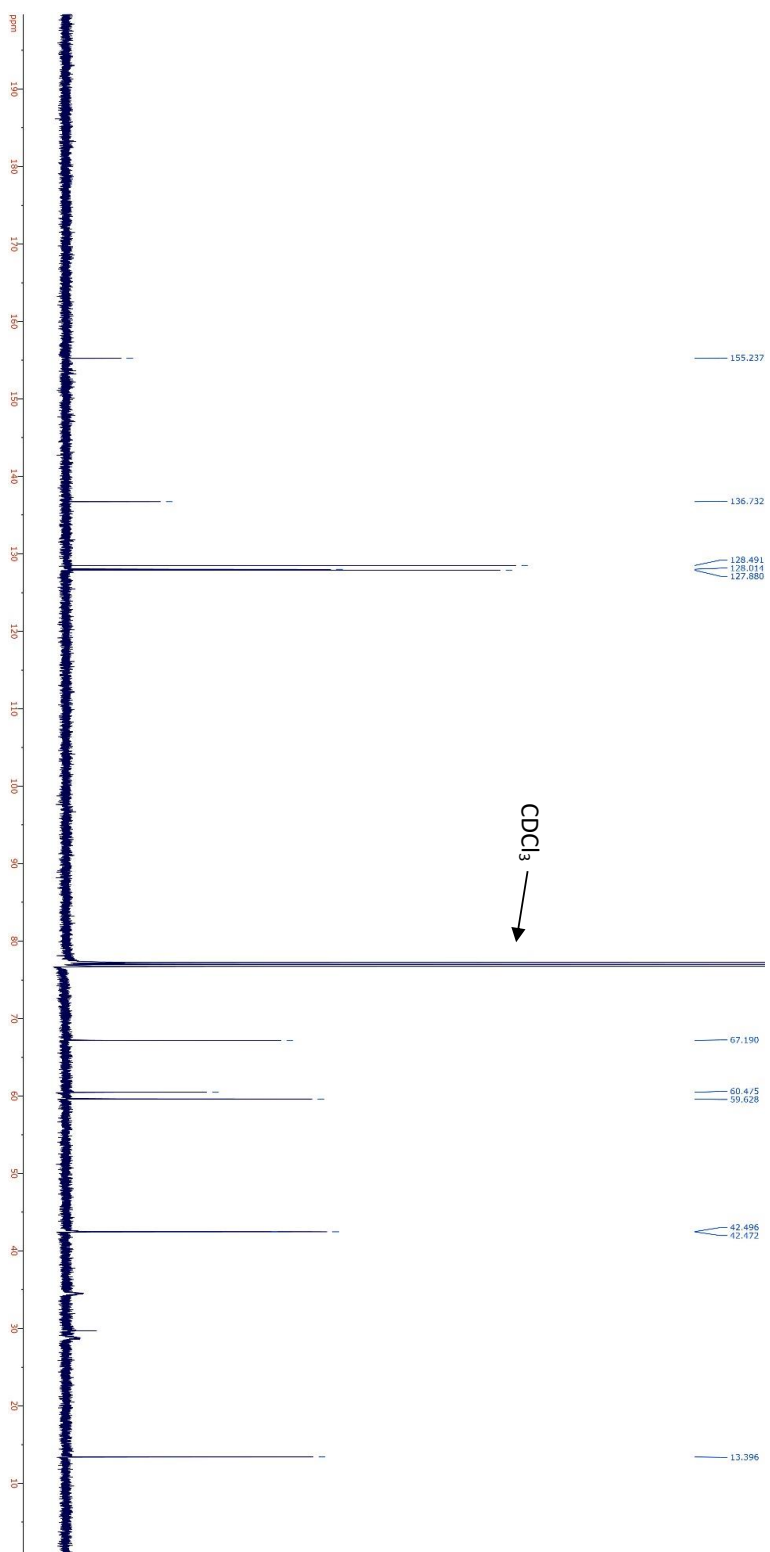


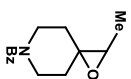
9 (¹H NMR, 600 MHz, CDCl₃, 25 °C)



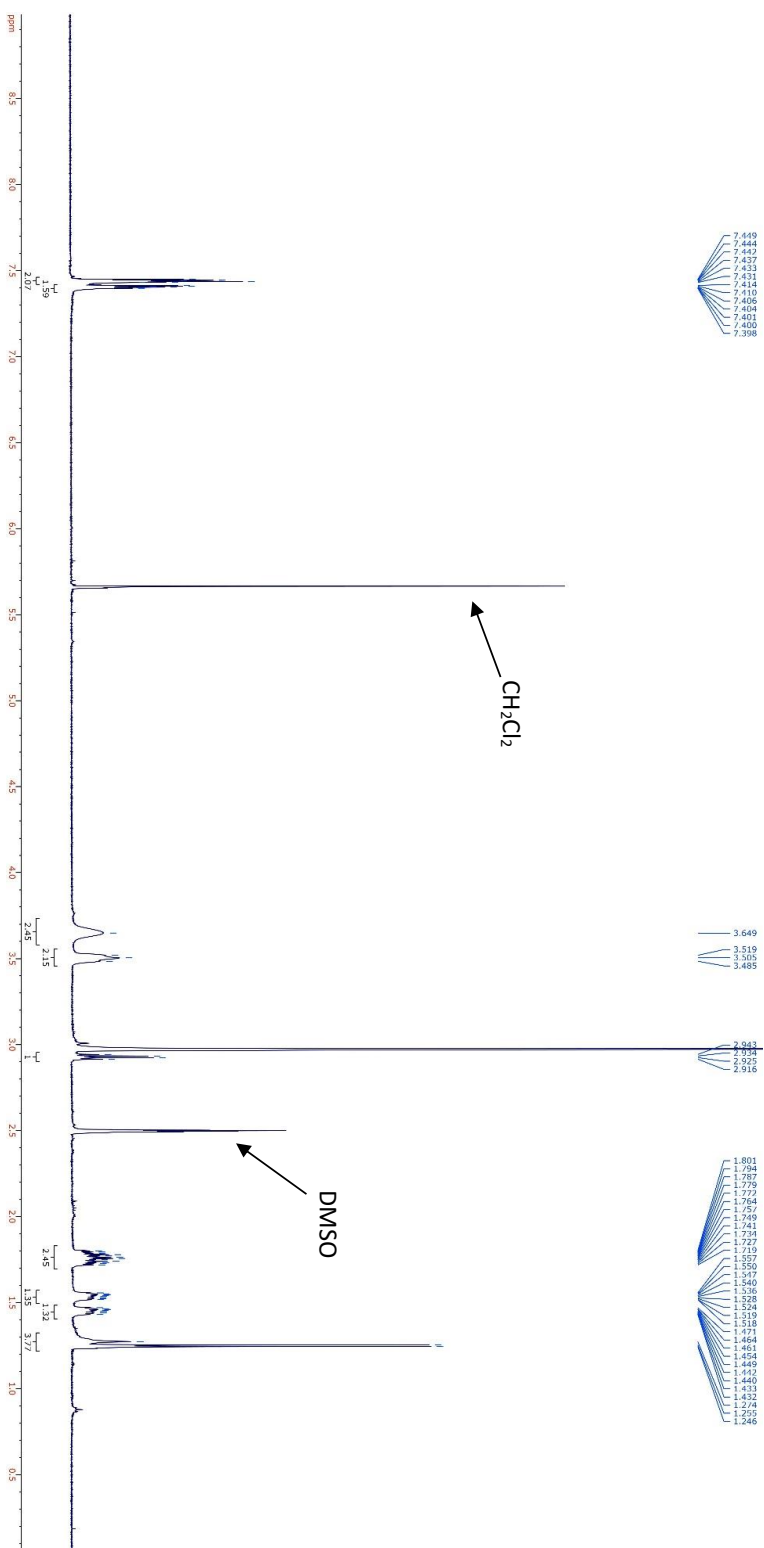


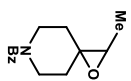
9 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)



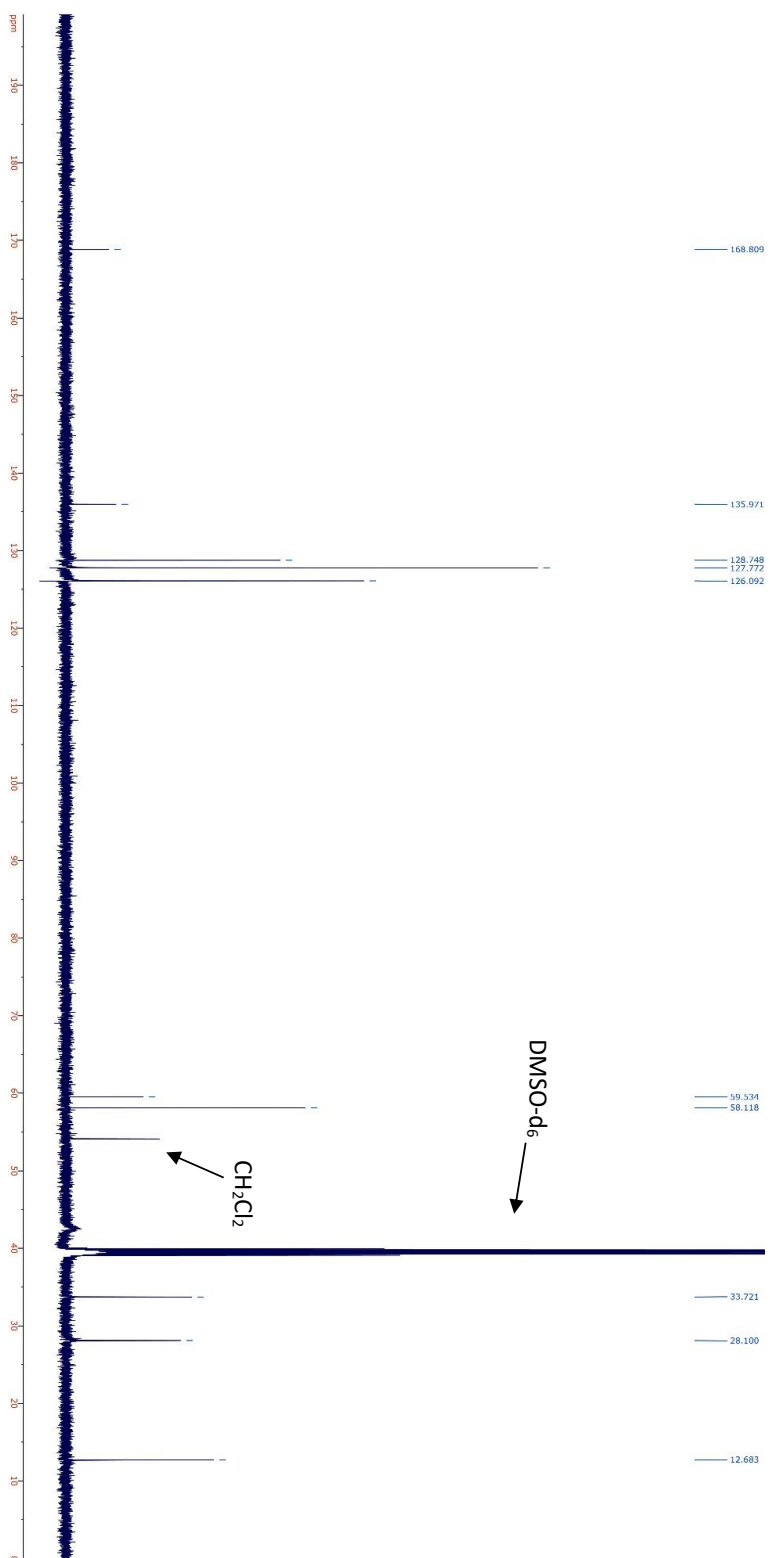


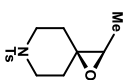
10 (^1H NMR, 600 MHz, DMSO- d_6 , 100 °C)





10 (¹³C NMR, 151 MHz, DMSO-d₆, 100 °C)



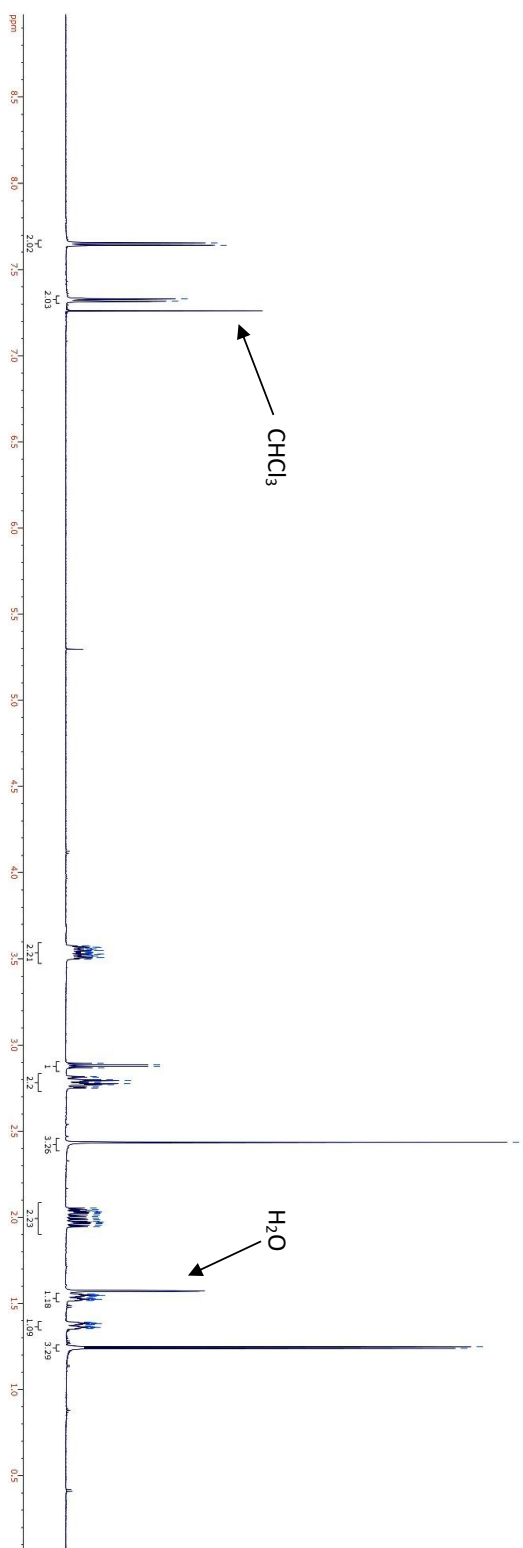


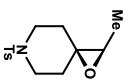
¹H NMR, 600 MHz, CDCl₃, 25 °C)

7.655
/ 641

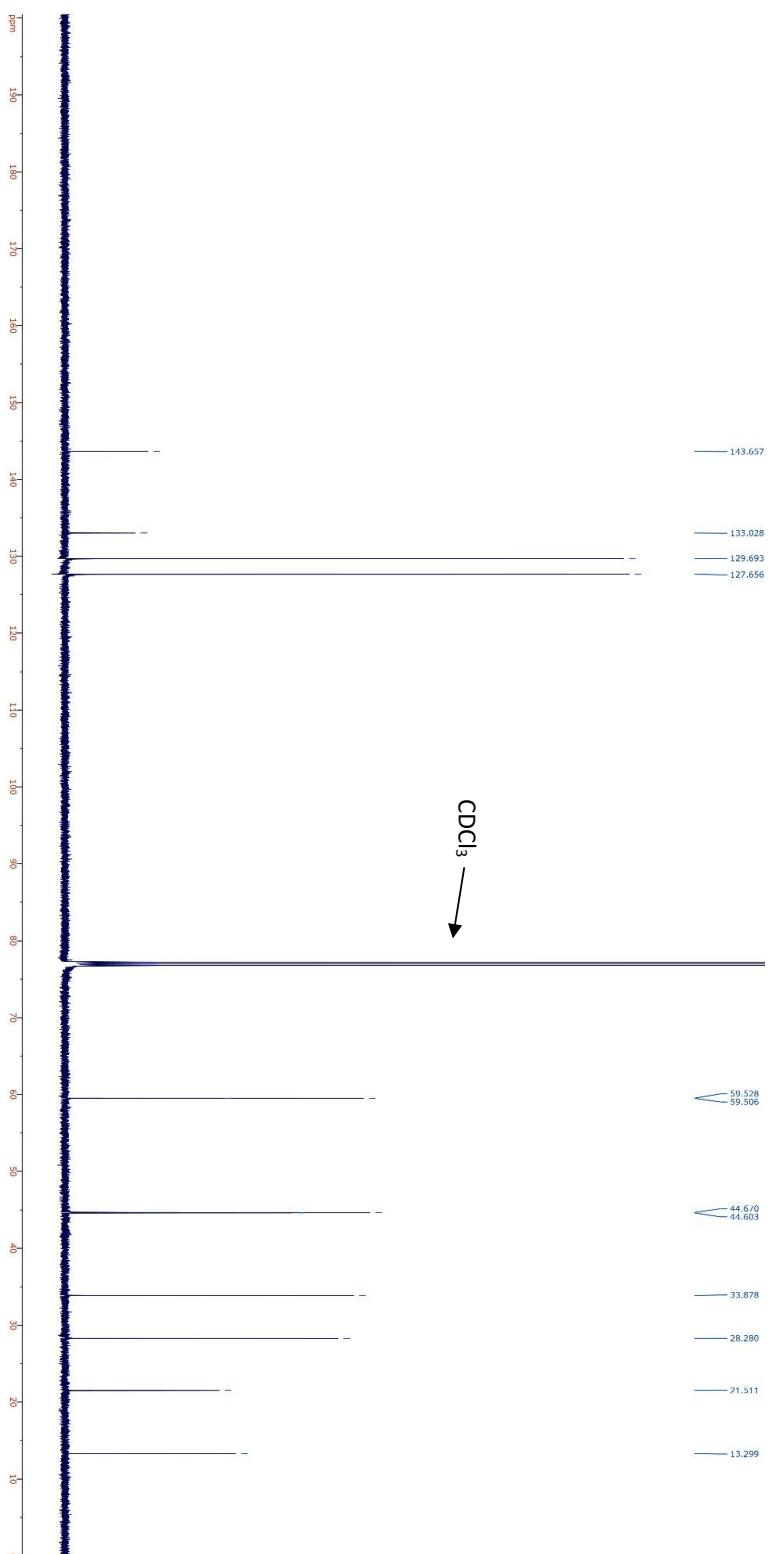
7.329
/ 7.315

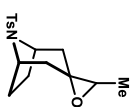
3.576
3.573
3.568
3.566
3.561
3.557
3.549
3.546
3.544
3.539
3.535
3.528
3.525
3.520
3.517
3.514
3.509
3.506
3.501
3.499
2.895
2.885
2.876
2.867
2.817
2.812
2.799
2.791
2.788
2.780
2.775
2.770
2.756
2.751
2.435
2.054
2.046
2.042
2.035
2.031
2.028
2.013
2.005
1.994
1.986
1.976
1.971
1.969
1.964
1.953
1.945
1.556
1.553
1.550
1.548
1.545
1.543
1.540
1.533
1.530
1.527
1.522
1.520
1.517
1.502
1.389
1.387
1.384
1.382
1.379
1.376
1.369
1.366
1.364
1.362
1.359
1.357
1.353
1.249
1.240





11 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)





^{13}C NMR, 600 MHz, CDCl_3 , 25 °C)

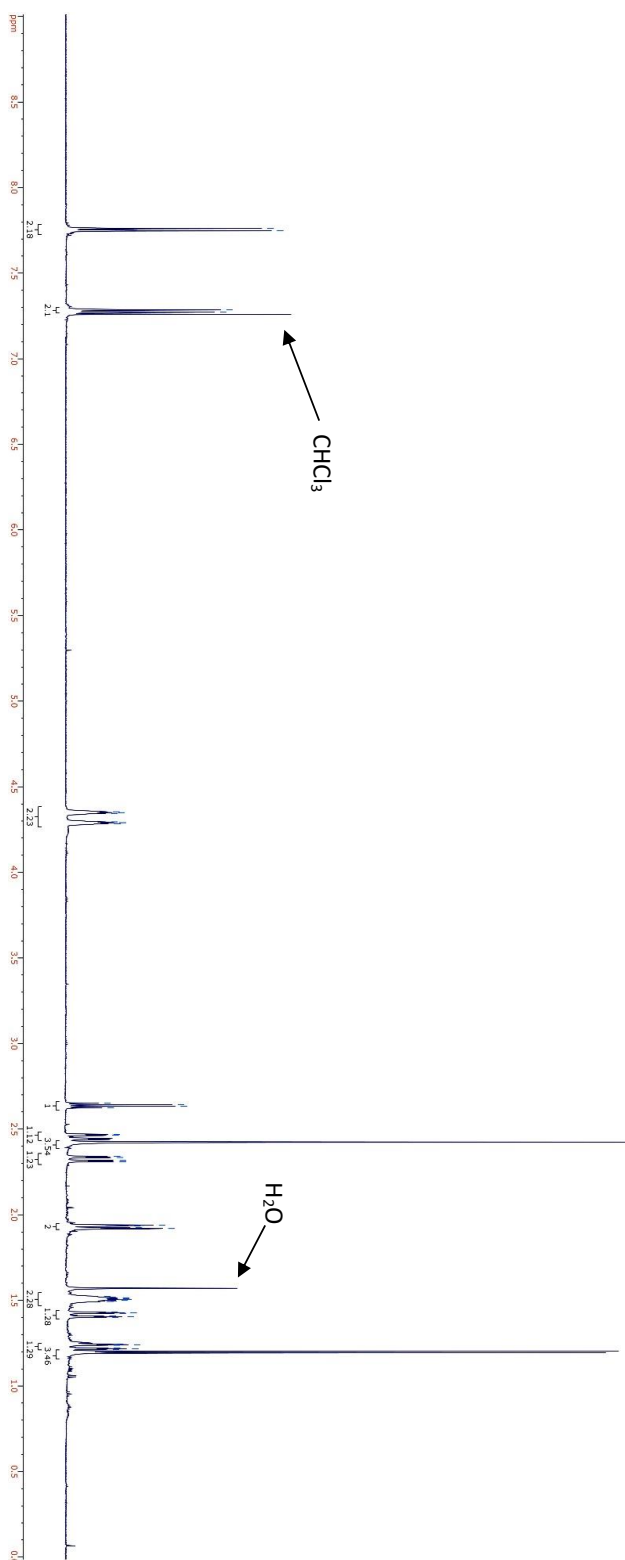
7.761
7.747

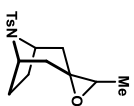
7.285
7.272

4.354
4.349
4.344
4.295
4.290
4.285

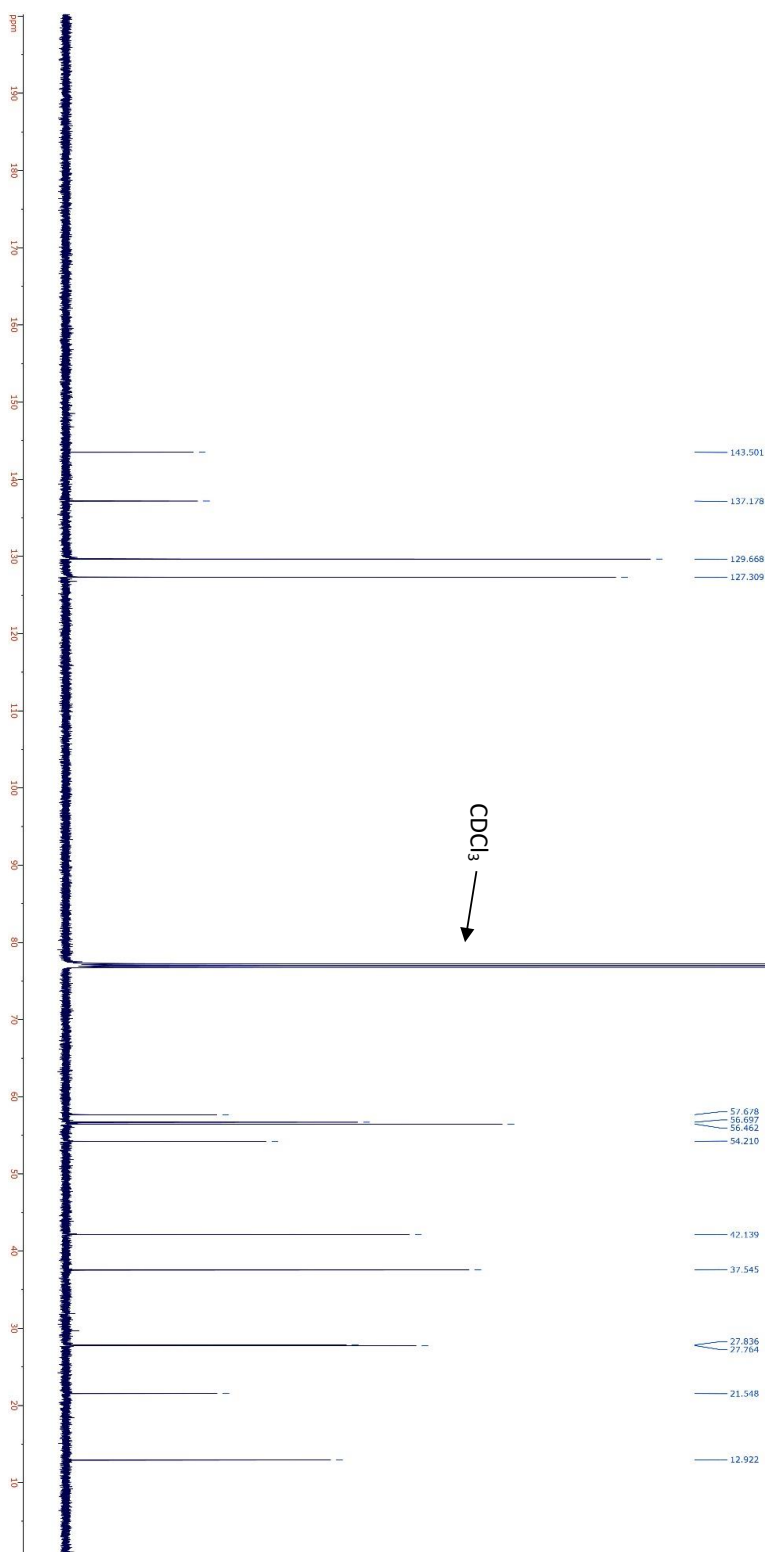
2.652
2.643
2.634
2.626
2.620
2.470
2.464
2.424
2.361
2.335
2.317
2.311

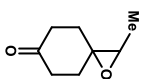
1.938
1.934
1.929
1.920
1.913
1.909
1.907
1.904
1.902
1.896
1.454
1.428
1.424
1.408
1.405
1.401
1.245
1.241
1.238
1.222
1.218
1.214





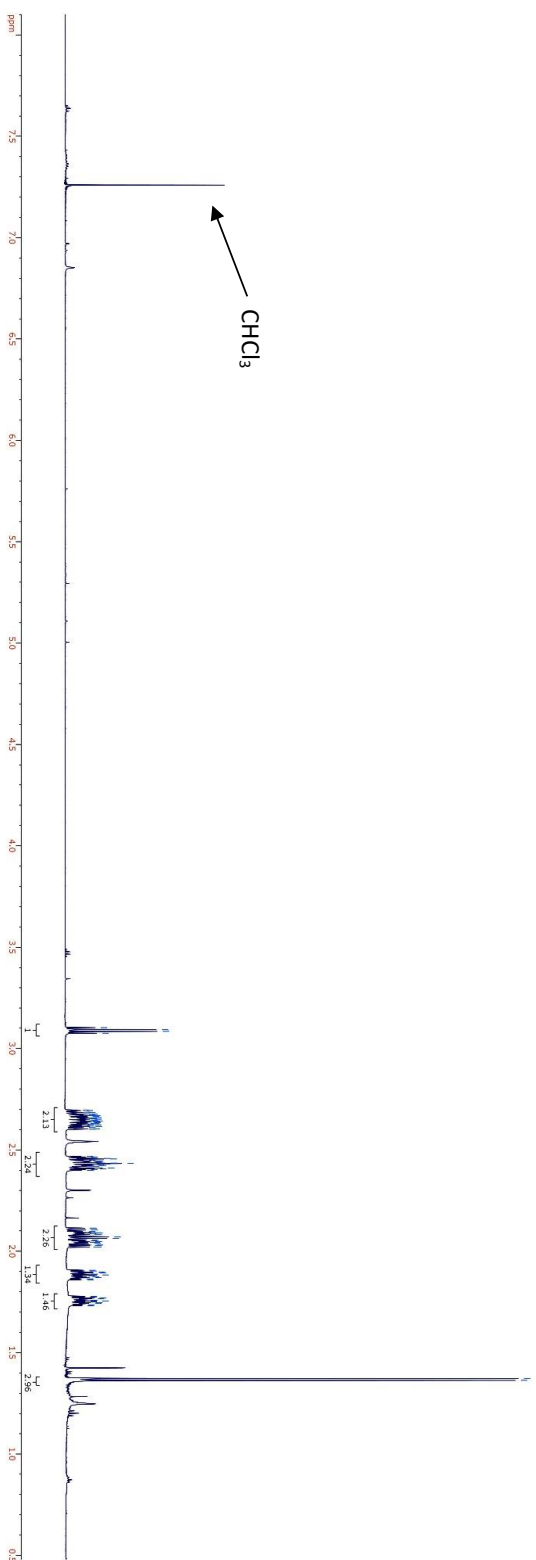
^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)

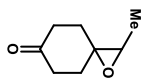




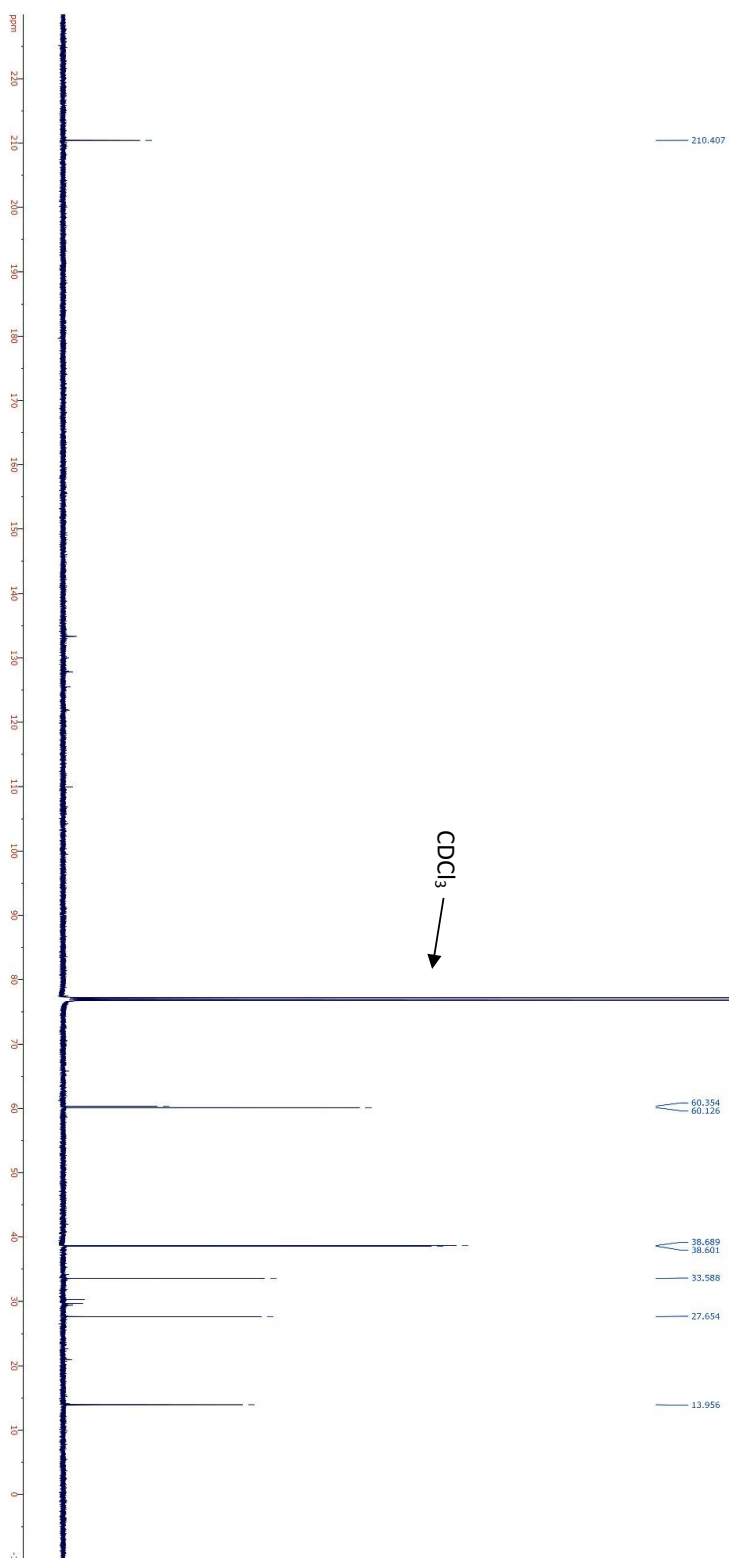
15 (¹H NMR, 800 MHz, CDCl₃, 25 °C)

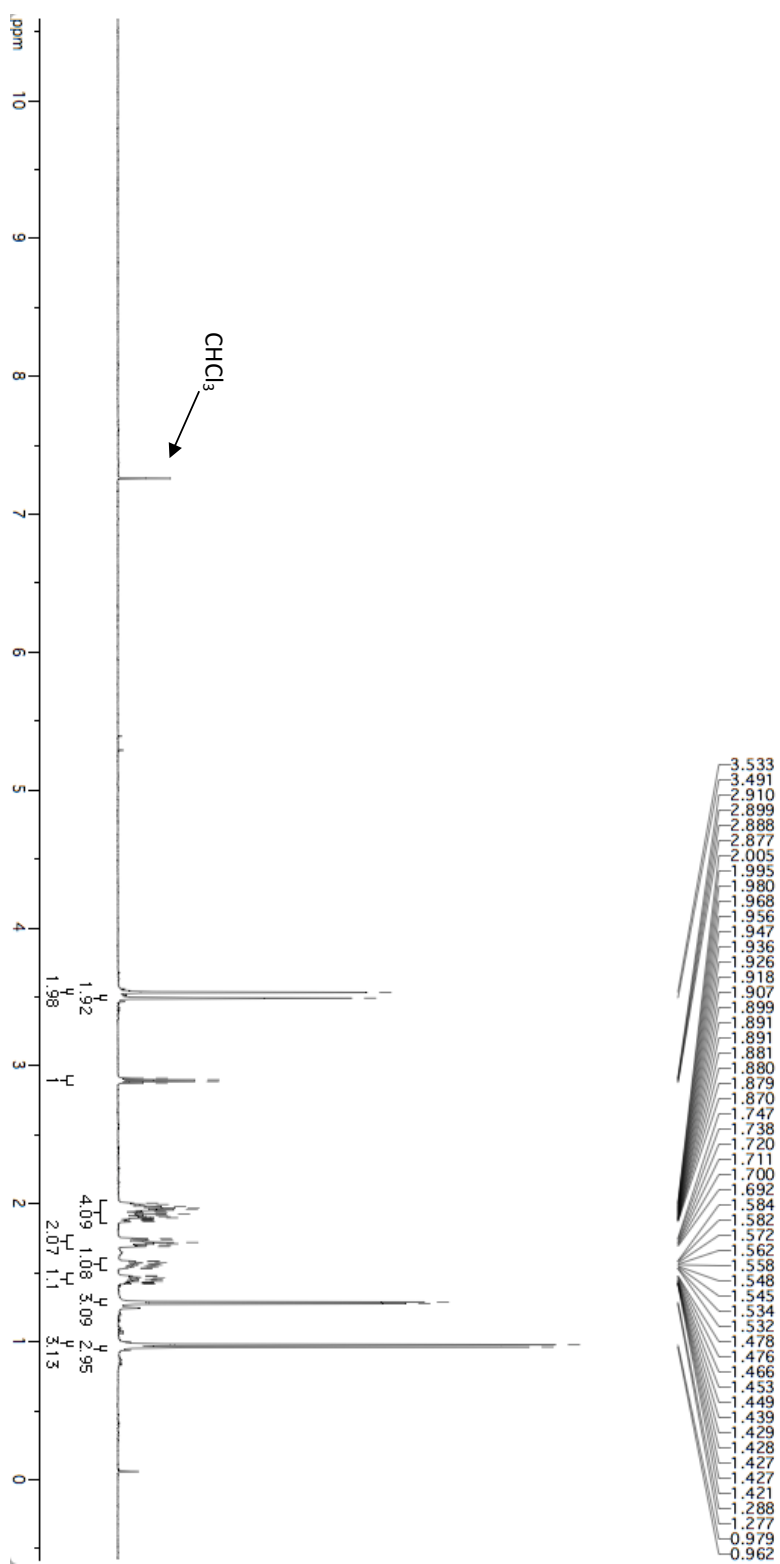
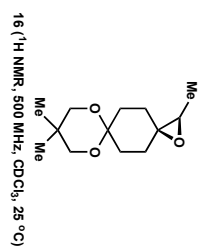
3.103
3.094
3.085
3.076
2.657
2.654
2.686
2.684
2.678
2.676
2.672
2.670
2.668
2.666
2.660
2.658
2.655
2.654
2.651
2.647
2.643
2.641
2.639
2.637
2.633
2.631
2.629
2.627
2.623
2.620
2.615
2.612
2.605
2.602
2.467
2.464
2.458
2.455
2.449
2.446
2.445
2.442
2.433
2.431
2.426
2.424
2.420
2.417
2.411
2.408
2.402
2.399
2.115
2.113
2.106
2.104
2.096
2.095
2.092
2.090
2.087
2.086
2.083
2.081
2.072
2.063
2.054
2.053
2.049
2.047
2.045
2.044
2.039
2.031
2.029
2.022
2.020
1.907
1.903
1.897
1.893
1.887
1.881
1.880
1.873
1.870
1.864
1.860
1.778
1.774
1.769
1.765
1.755
1.751
1.746
1.742
1.736
1.732
1.727
1.363

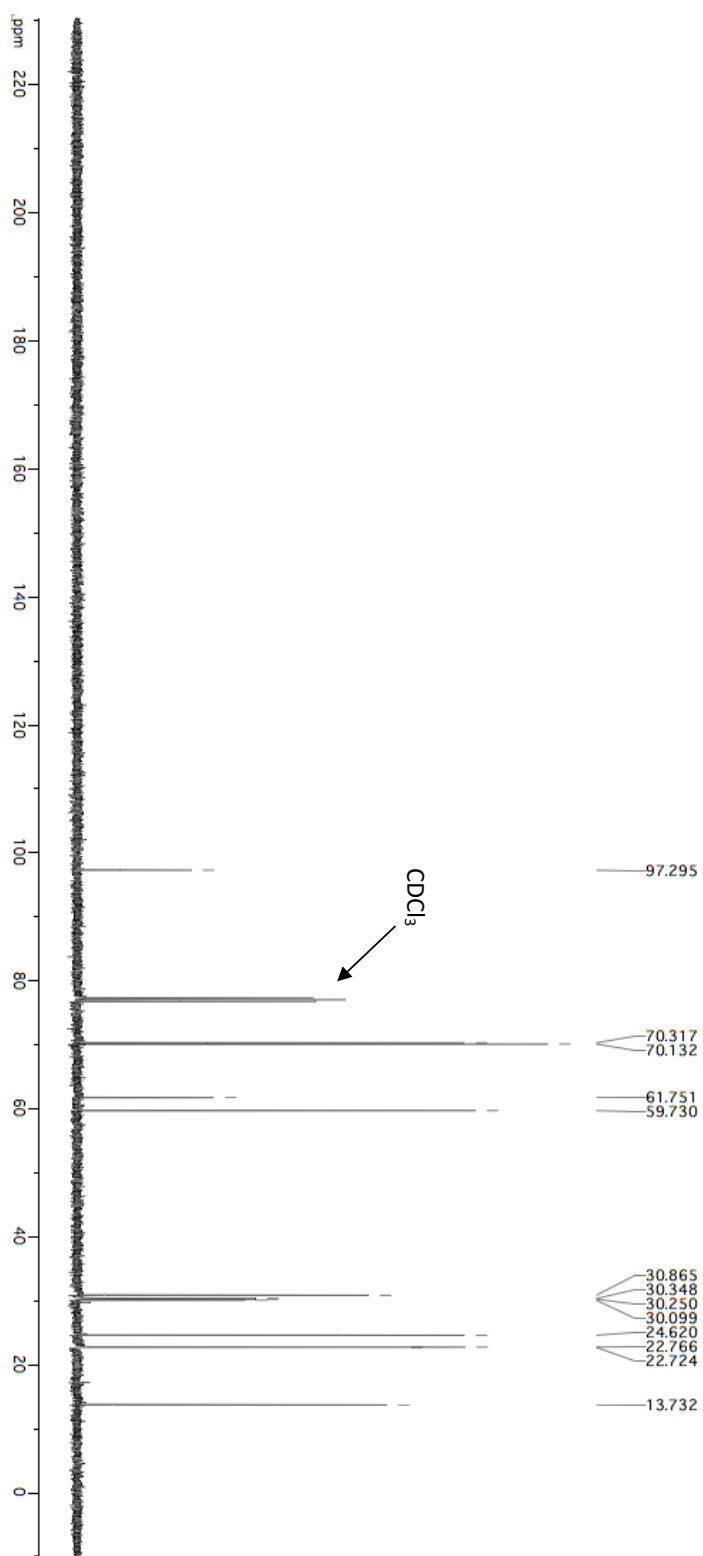
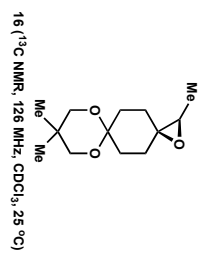


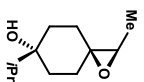


15 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)

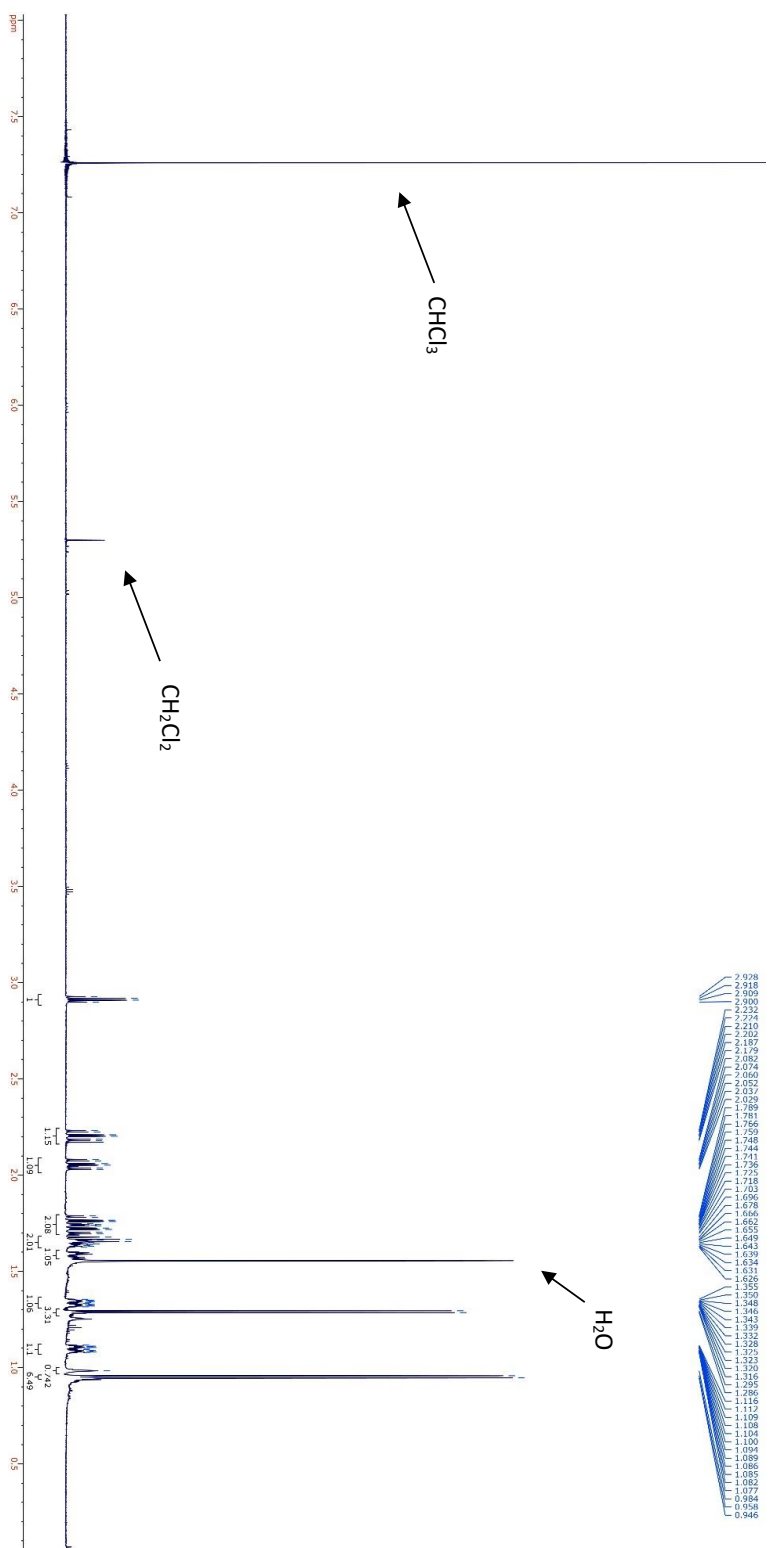


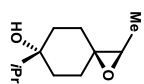




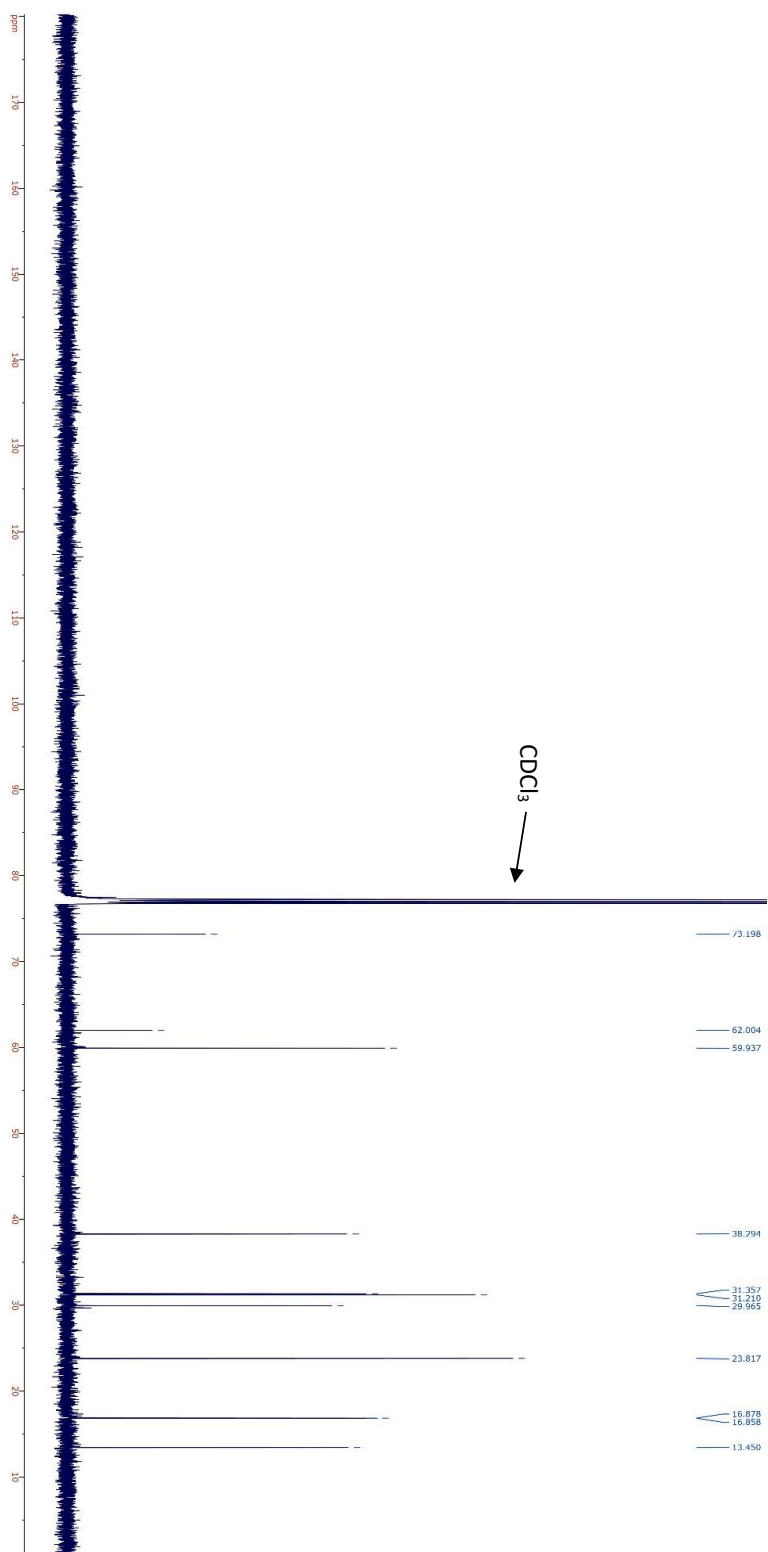


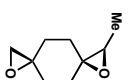
17 (^1H NMR, 600 MHz, CDCl_3 , 25 $^\circ\text{C}$)





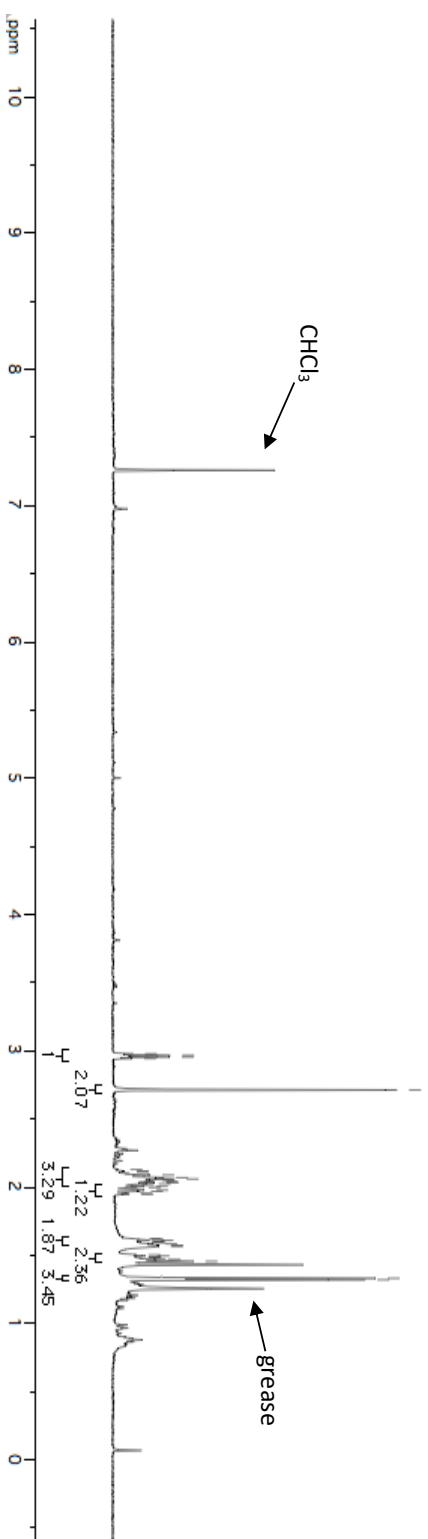
17 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)

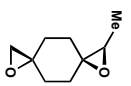




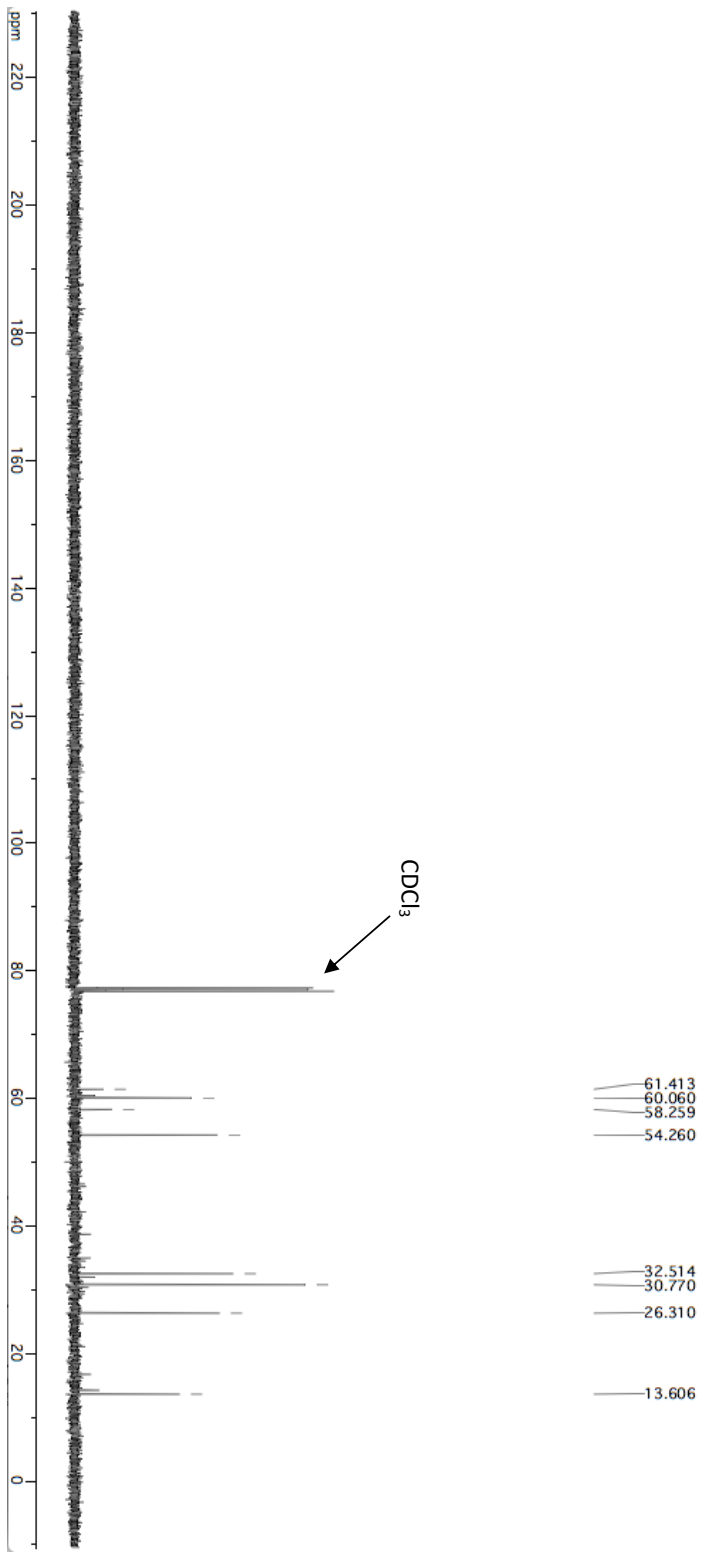
^{19}F NMR, 500 MHz, CDCl_3 , 25 °C)

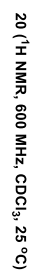
2.978
2.967
2.956
2.945
2.714
2.129
2.118
2.112
2.089
2.070
2.060
2.051
2.043
2.032
2.025
2.015
2.005
1.998
1.978
1.971
1.956
1.948
1.621
1.618
1.611
1.603
1.600
1.592
1.584
1.573
1.566
1.503
1.495
1.488
1.484
1.477
1.470
1.456
1.332
1.321

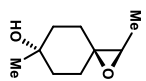




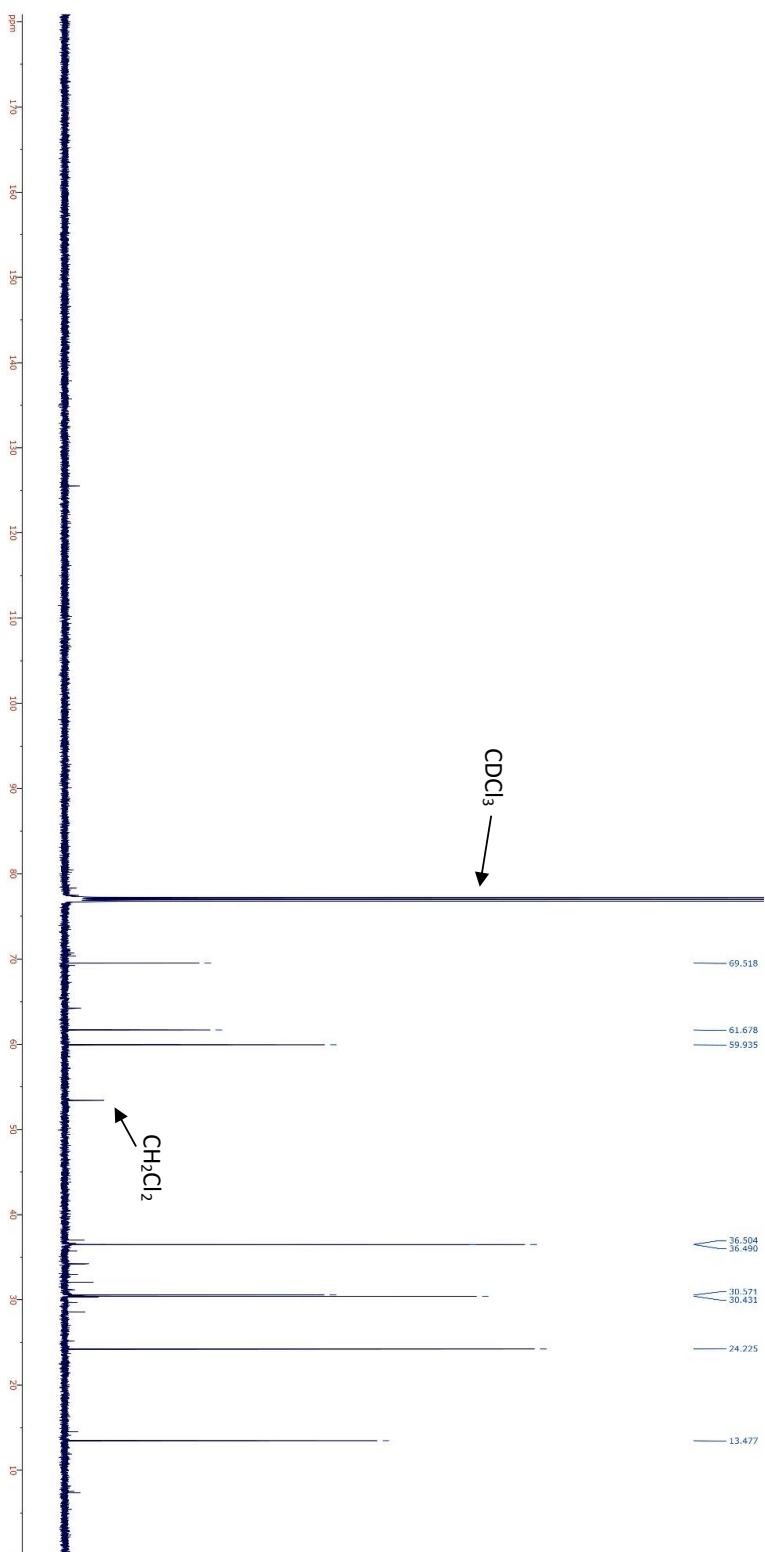
19 (¹³C NMR, 126 MHz, CDCl₃, 25 °C)

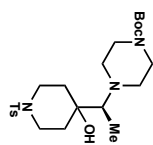






20 (^{13}C NMR, 151 MHz, CDCl_3 , 25 $^\circ\text{C}$)

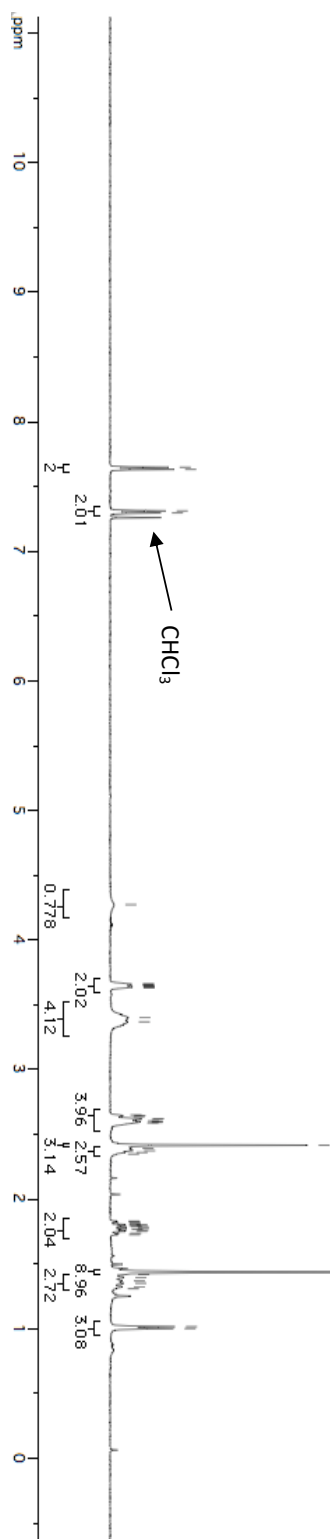


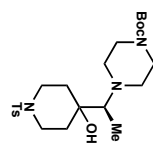


27 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)

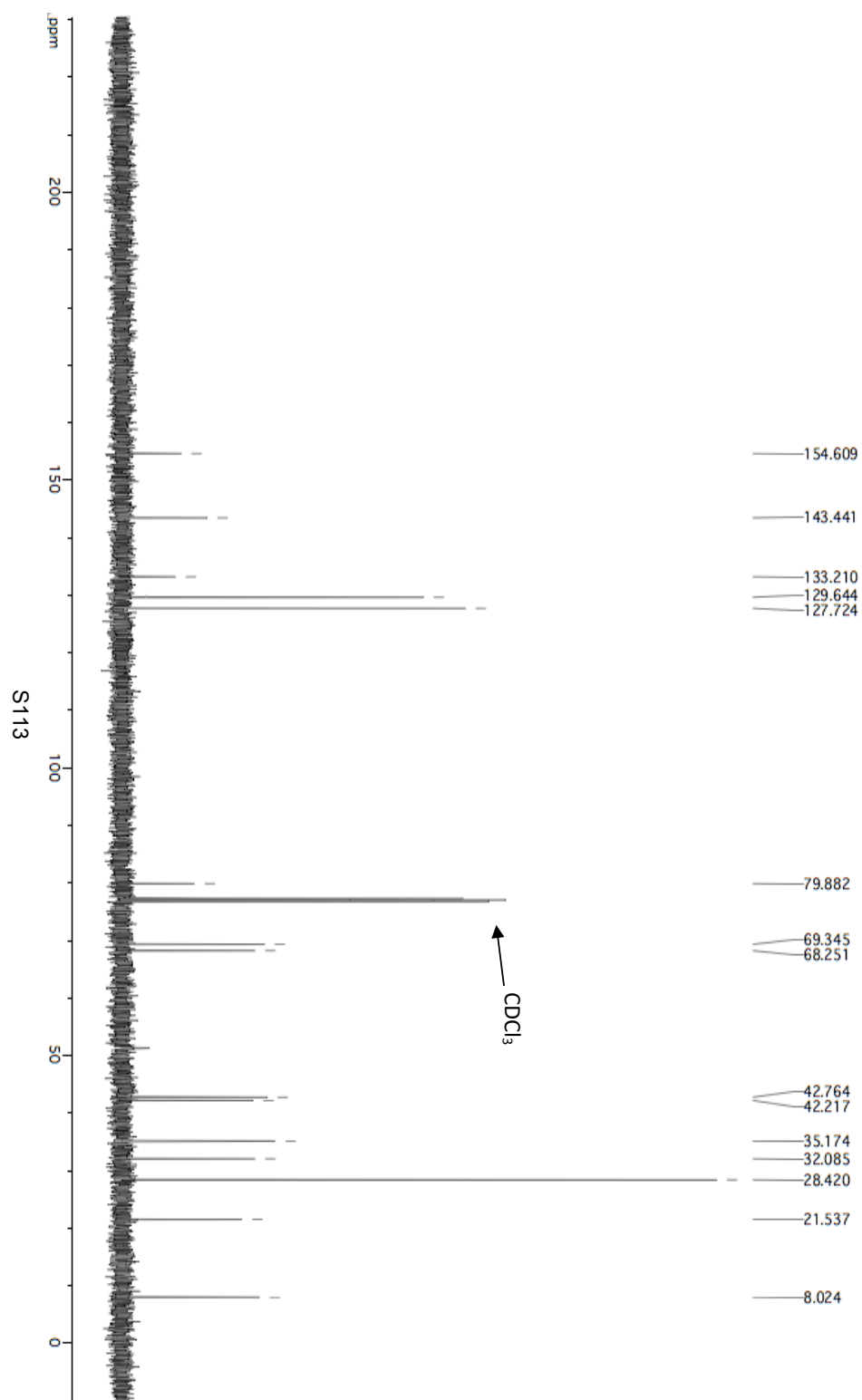
7.648
7.632
7.312
7.296

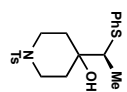
4.273
3.659
3.658
3.657
3.640
3.639
3.636
3.636
3.400
3.369
2.650
2.645
2.636
2.619
2.616
2.603
2.597
2.594
2.590
2.417
2.392
2.375
2.361
2.349
1.830
1.821
1.820
1.804
1.800
1.800
1.795
1.788
1.778
1.768
1.762
1.753
1.737
1.727
1.437
1.420
1.397
1.369
1.352
1.325
1.309
1.017
1.002



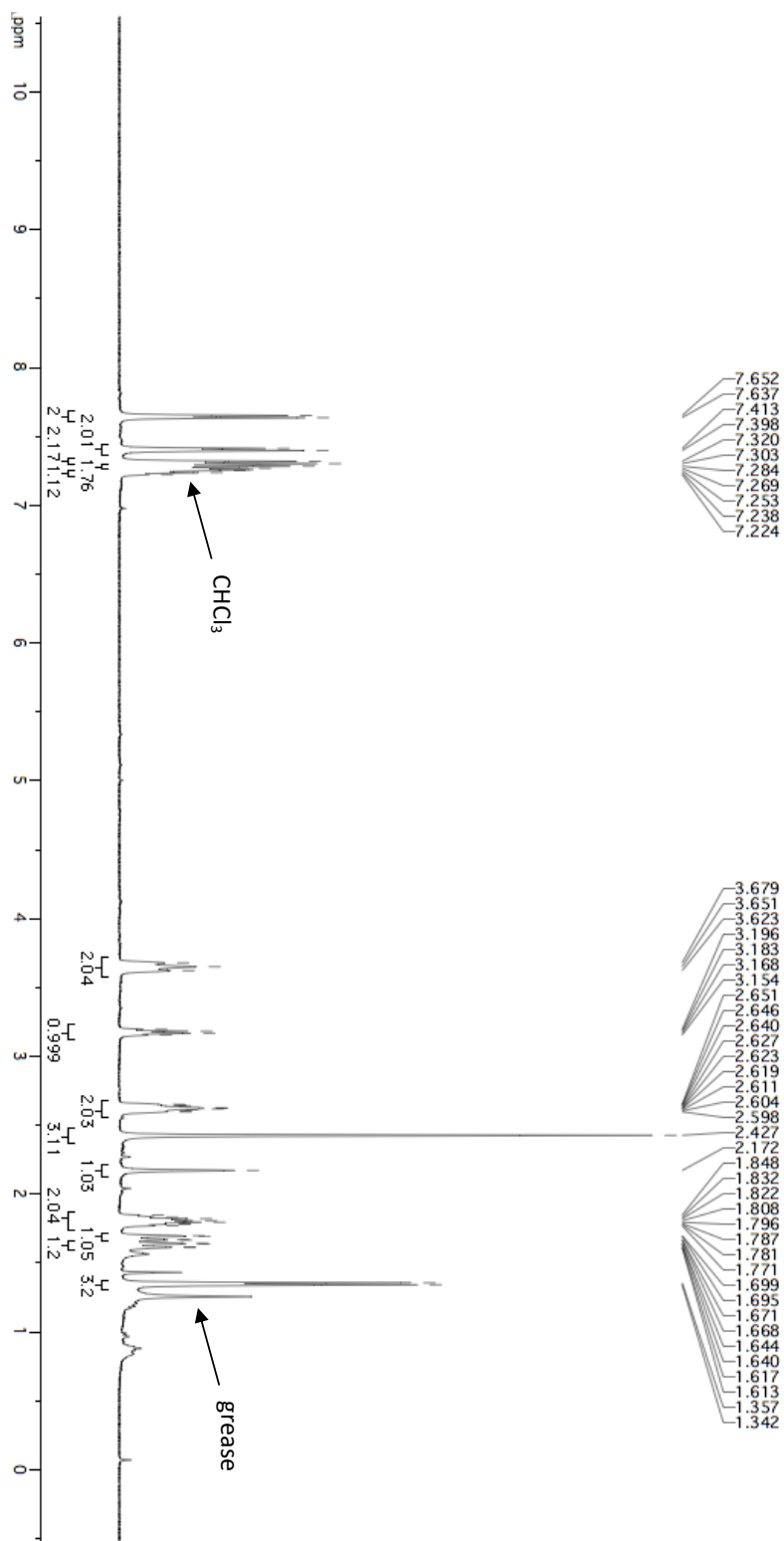


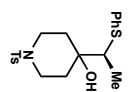
27 (^{13}C NMR, 126 MHz, CDCl_3 , 25 °C)



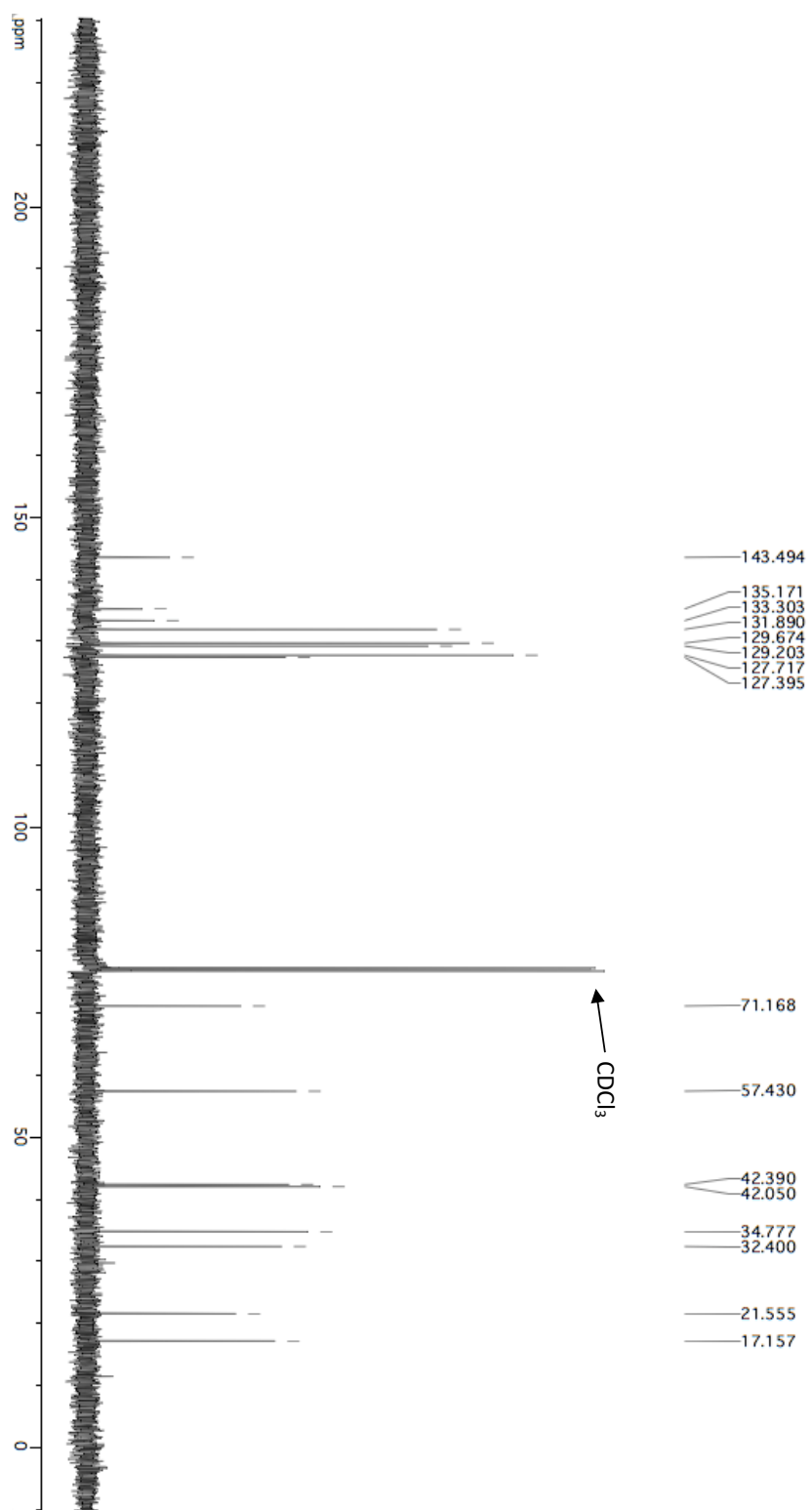


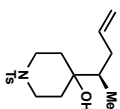
28 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)



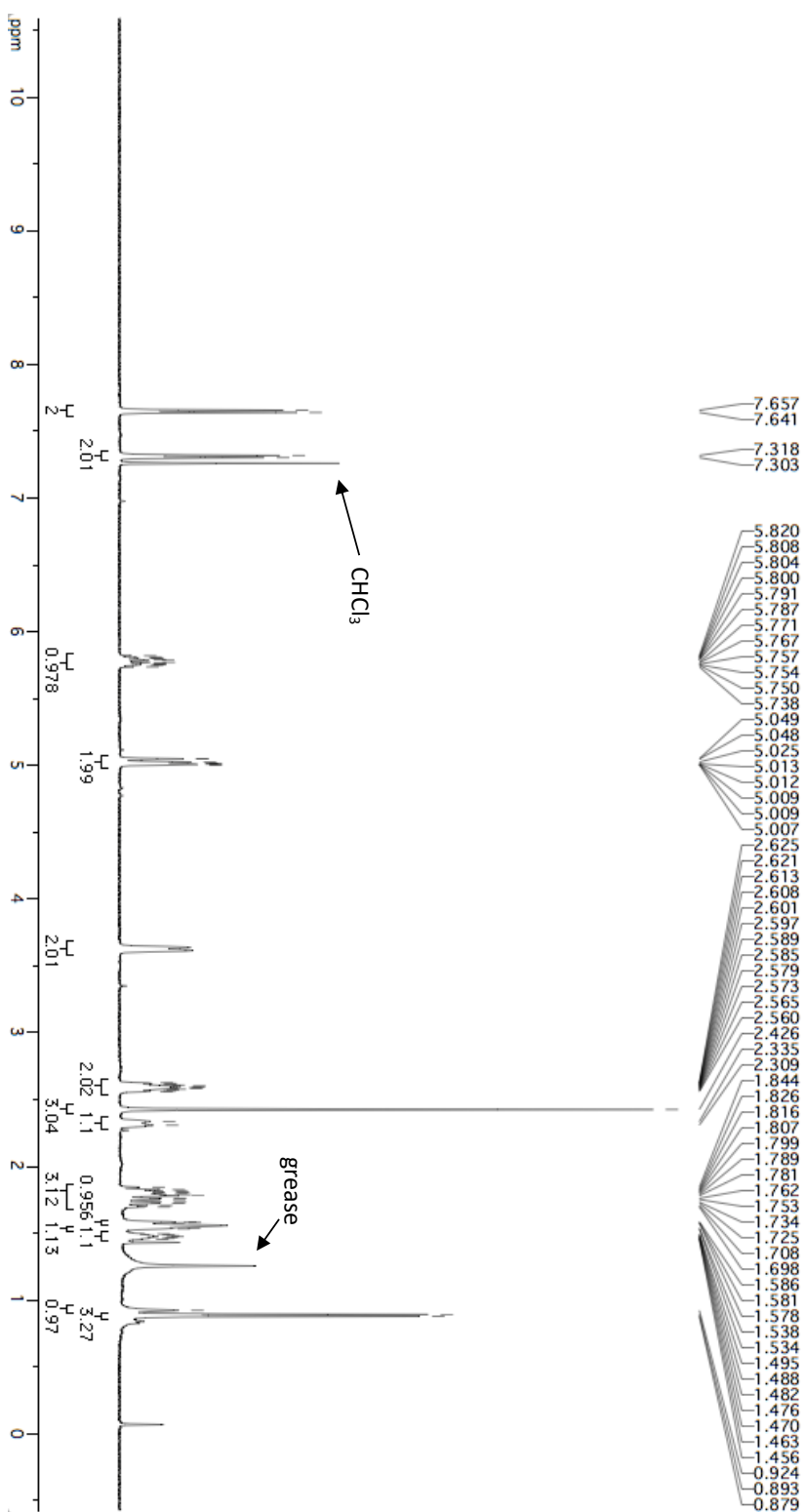


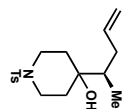
28 (^{13}C NMR, 126 MHz, CDCl_3 , 25 $^\circ\text{C}$)





29 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)





29 (^{13}C NMR, 126 MHz, CDCl_3 , 25 $^\circ\text{C}$)

143.436
137.657
133.286
129.642
127.748

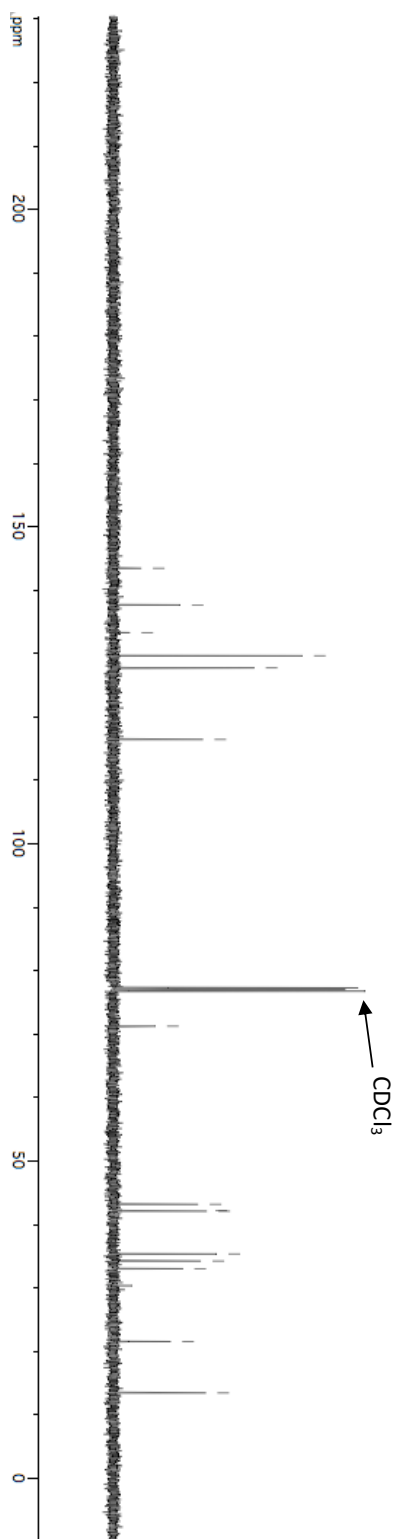
116.460

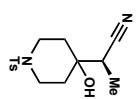
71.264

43.180
42.173
42.101
35.352
34.242
33.026

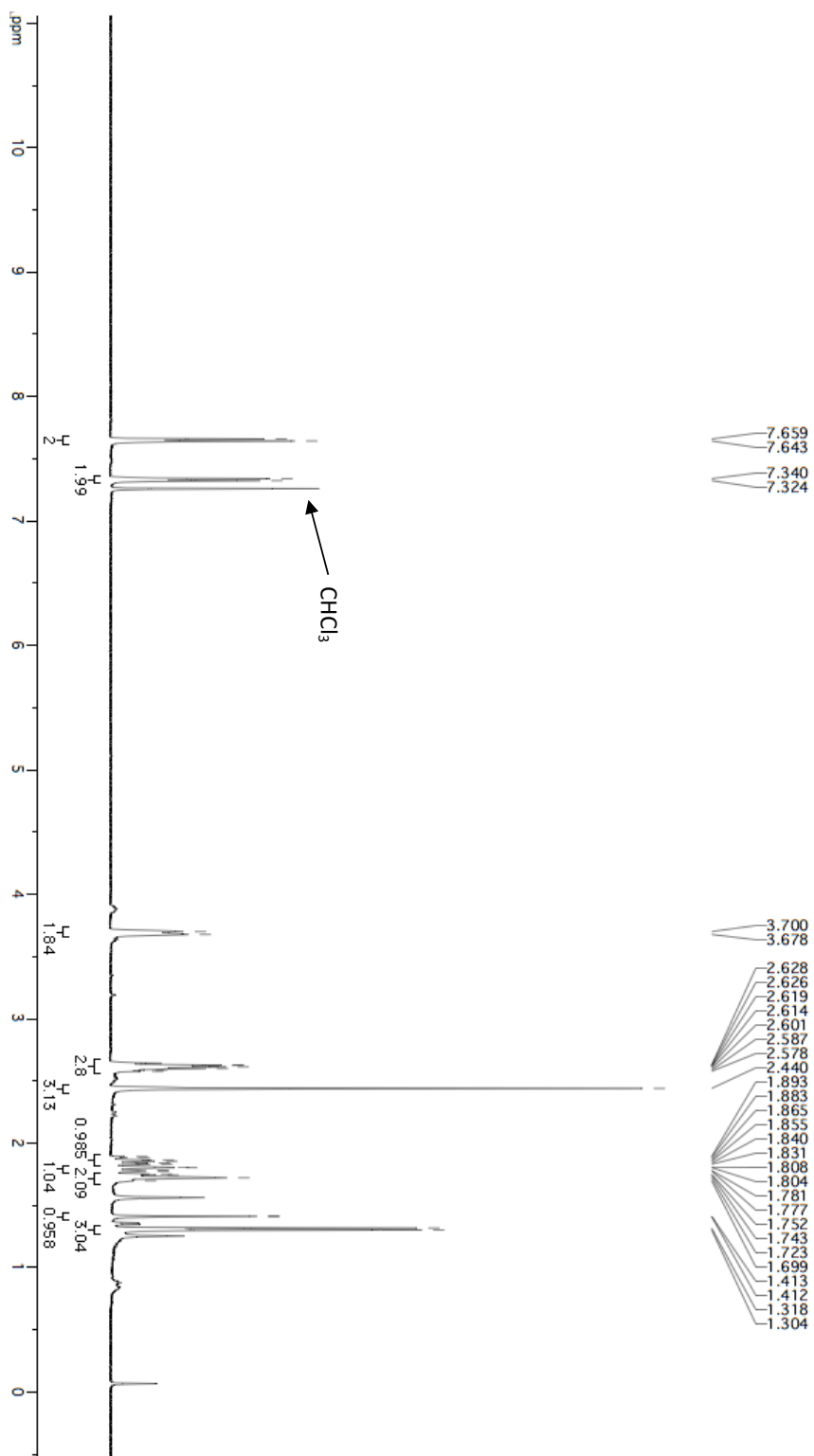
21.546

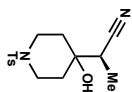
13.452



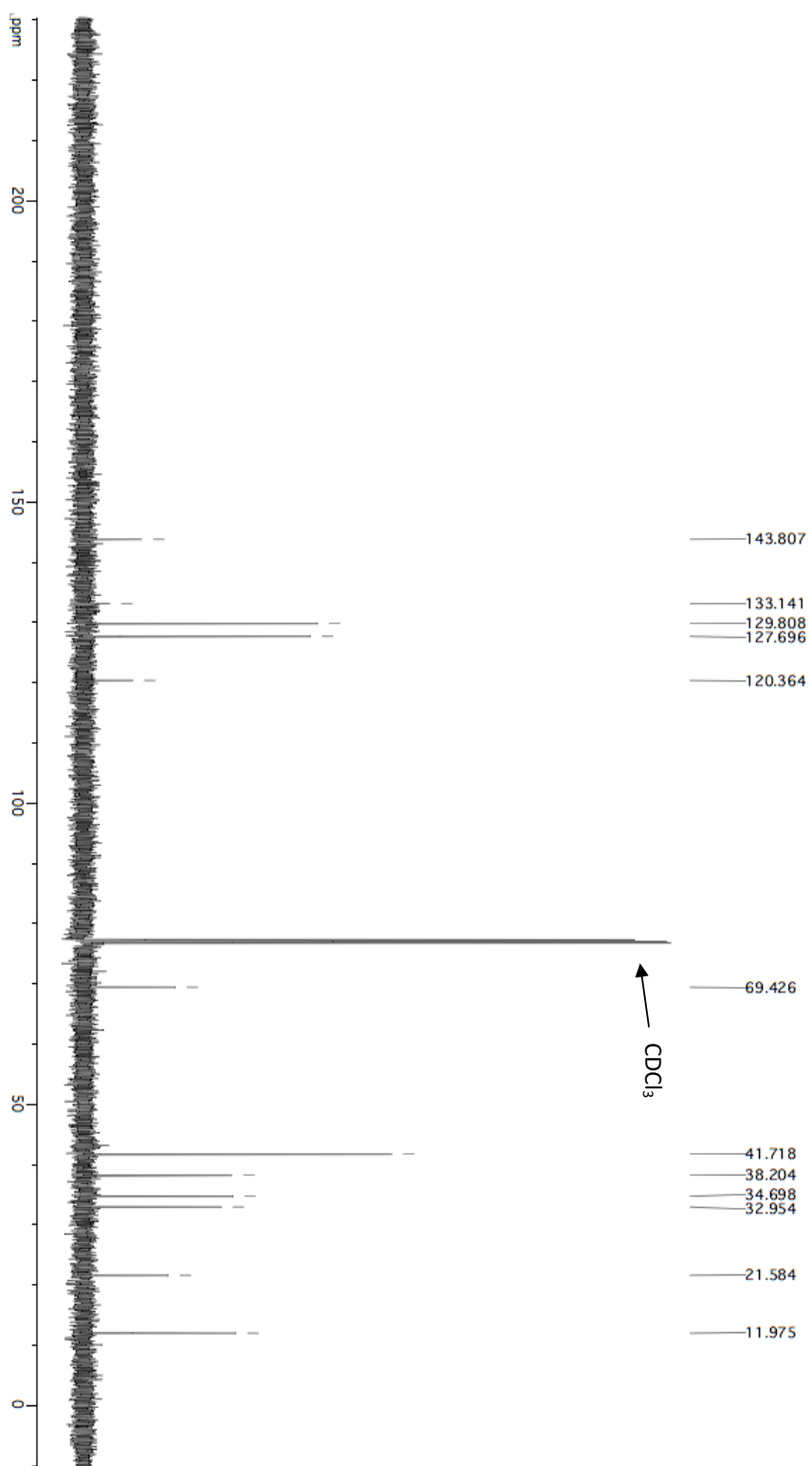


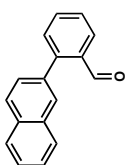
30 (^1H NMR, 500 MHz, CDCl_3 , 25 $^\circ\text{C}$)



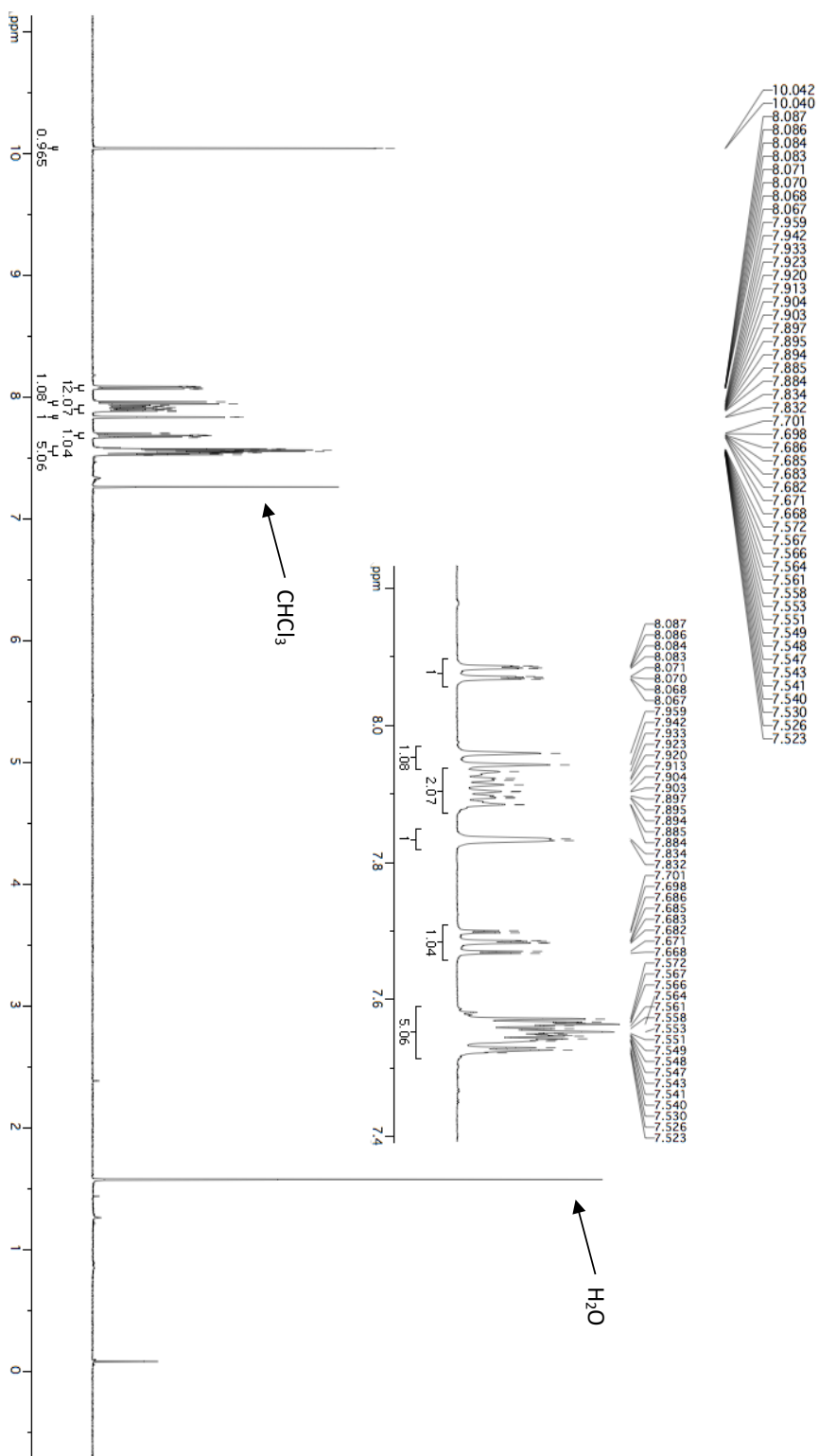


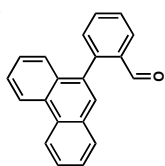
30 (^{13}C NMR, 126 MHz, CDCl_3 , 25 $^\circ\text{C}$)





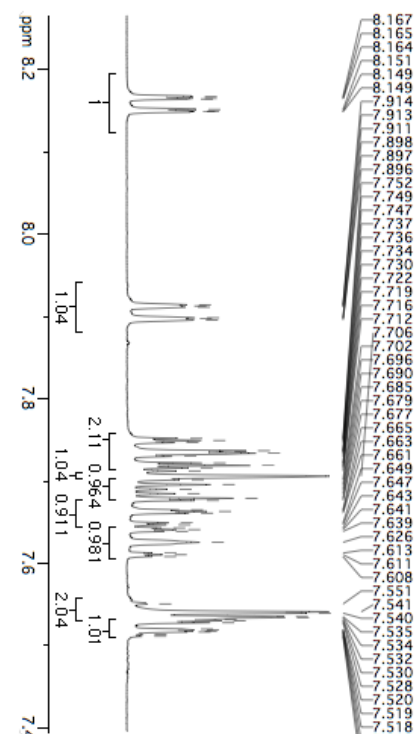
SI-24 (¹H NMR, 500 MHz, CDCl₃, 25 °C)



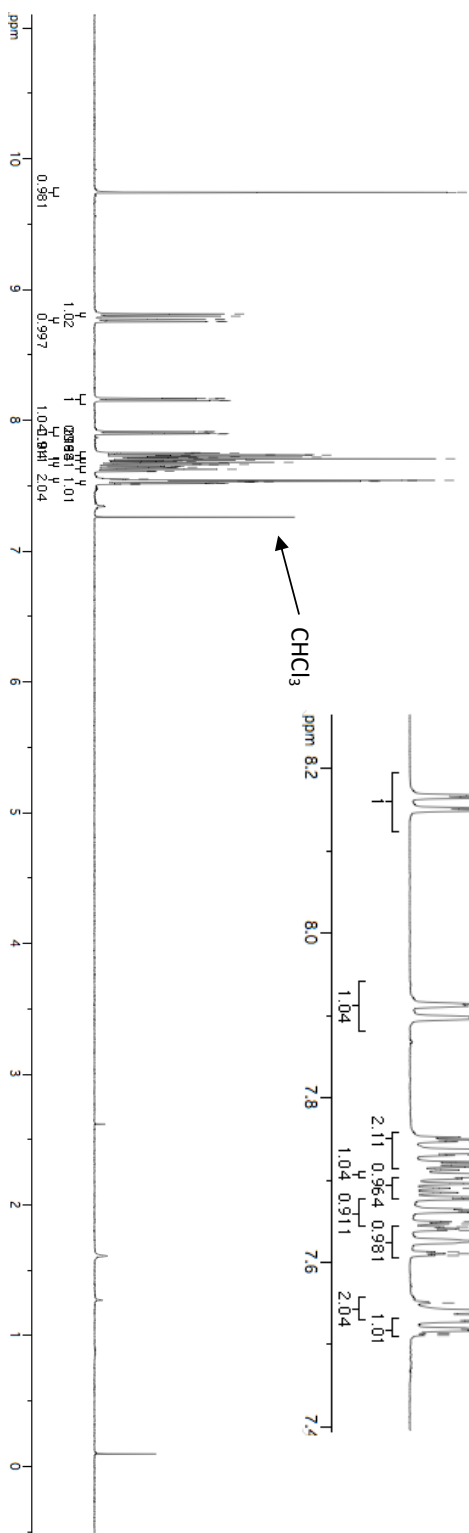


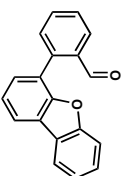
SI.25 (1H NMR, 500 MHz, CDCl₃, 25 °C)

8.744
8.742
8.813
8.796
8.772
8.771
8.755
8.755
8.167
8.165
8.164
8.151
8.149
8.149
7.914
7.913
7.911
7.898
7.897
7.896
7.752
7.749
7.747
7.737
7.736
7.734
7.730
7.722
7.719
7.716
7.712
7.706
7.702
7.696
7.690
7.685
7.679
7.677
7.665
7.663
7.661
7.649
7.647
7.643
7.641
7.639
7.626
7.613
7.611
7.608
7.551
7.541
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7.517
7.514
7.512

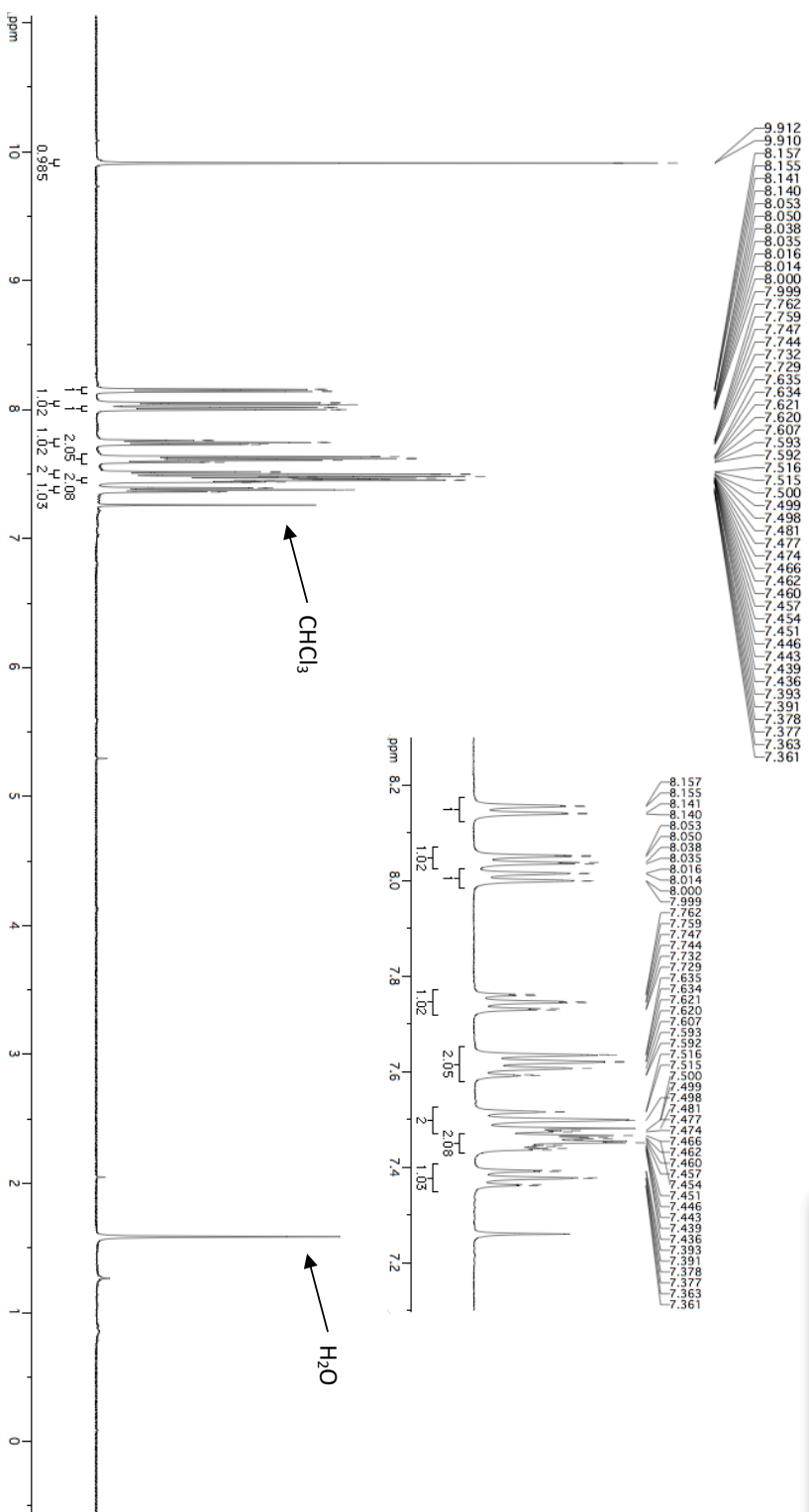


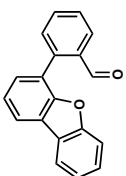
CHCl₃



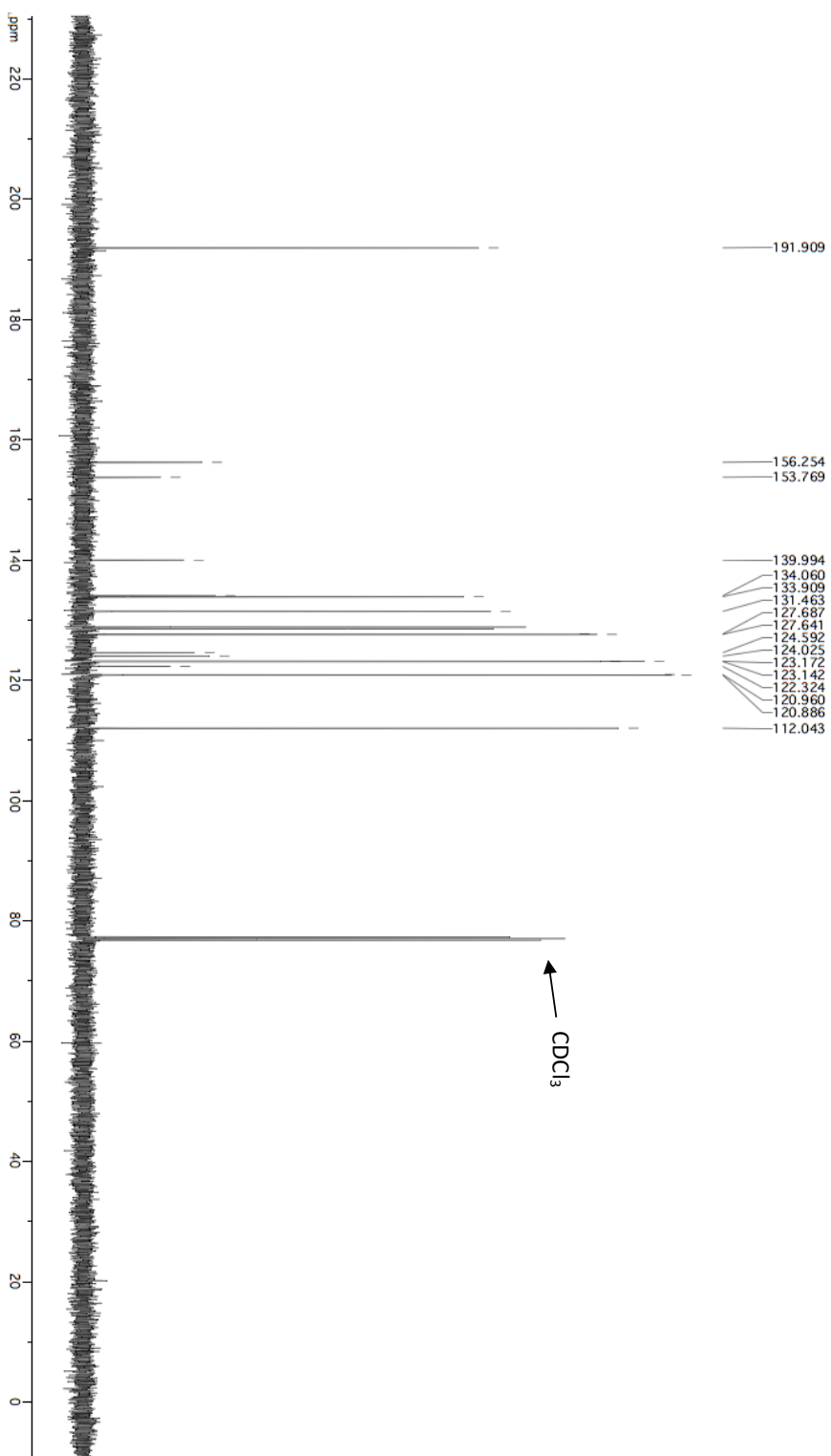


S126 (1H NMR, 500 MHz, CDCl₃, 25 °C)

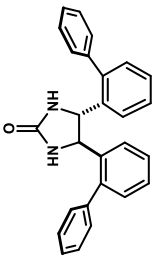




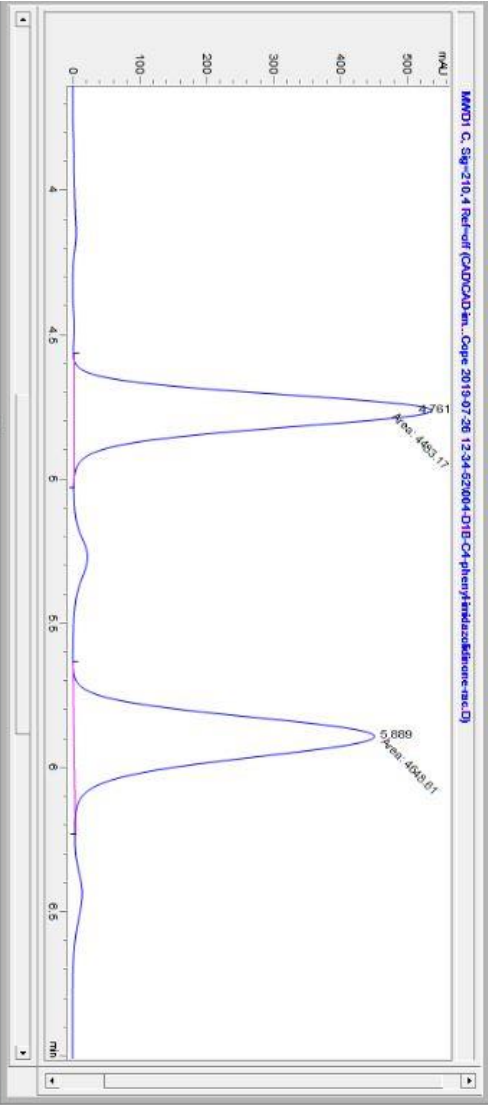
SI.26 (^{13}C NMR, 126 MHz, CDCl_3 , 25 $^\circ\text{C}$)



Chiral GC and SFC Traces

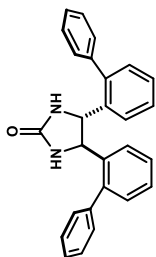


S1-33
SFC, AD, 30% IPA, CO₂
2 mL/min 44°C, 15 uL
racemic



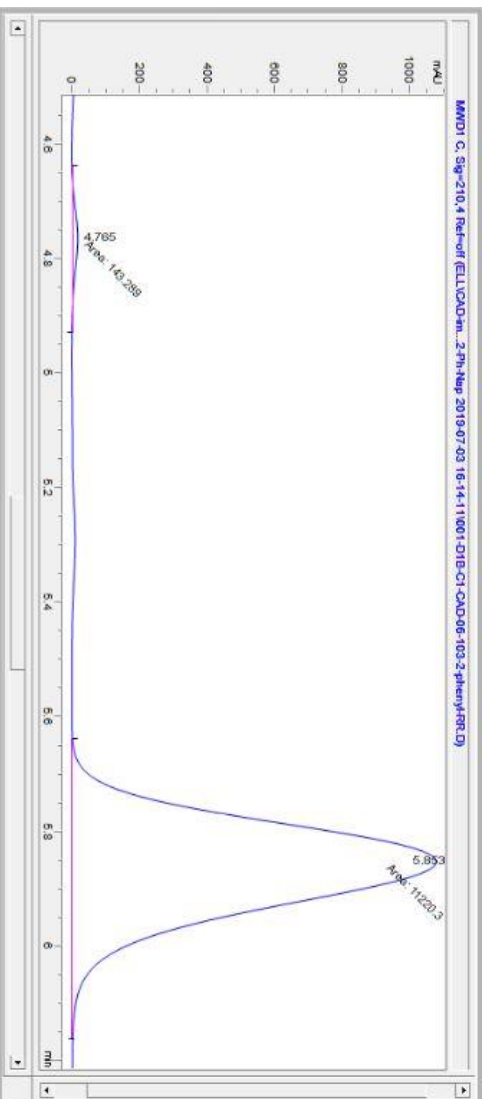
File Information						
LC File	004-018-C4-phenyl-indazolidinone-rac.D					
File Path	C:\Chem32\1\Data\CAD\CAD-indazolidinone-dlaza-					
Date	26-Jul-19, 15:08:12					
Sample	phenyl-indazolidinone-rac					
Sample Info						
Barcode						
Operator	SYSTEM					
Method	CAD 70_30-AD-30-min.M					
Reference						
Analyze Time	10.093 min					
Sampling Rate	0.0067 min (0.402 sec), 1515 datapoints					

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	4.761	NM	4483.2	536.9	0.1392	49.094	0.905
2	5.889	NM	4648.6	450.1	0.1721	50.906	0.897



S1-33

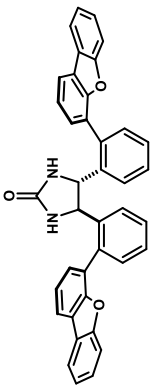
SFC, AD, 30% IPA:CO₂
2 mL/min 44°C, 15 µL
enantioenriched
97% ee



File Information

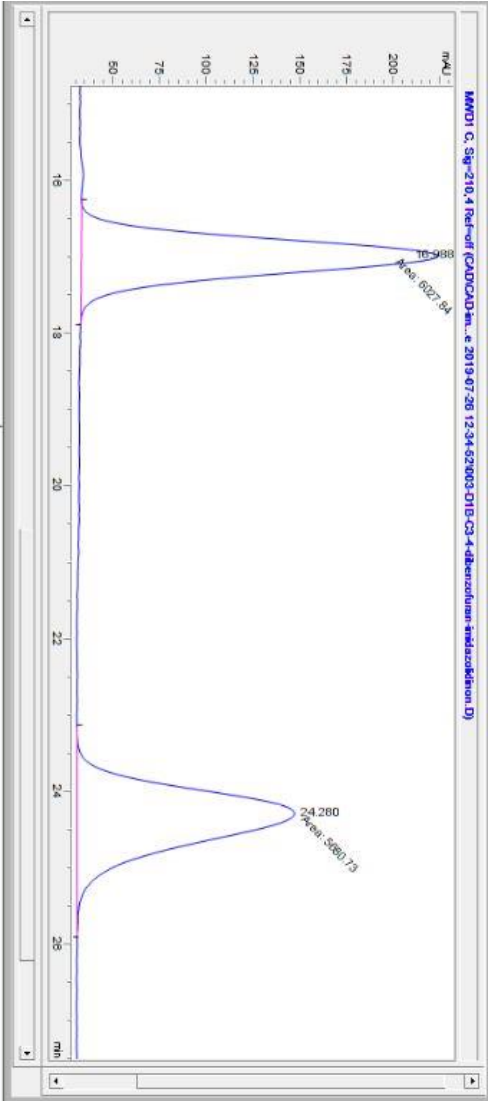
LC-File	001-D1B-C1-CAD-06-103-2-phenyl-RD
File Path	C:\Chem321\Data\ELL\CAD-midazolone-2-Ph-N
Date	03-Jul-19 16:15:06
Sample	CAD-06-103-2-phenyl-RD
Sample Info	
Barcode	
Operator	SYSTEM
Method	CAD 70_30-AD-10-min.M
Reference	
Analysis Time	9.993 min
Sampling Rate	0.0067 min (0.402 sec), 1500 datapoints

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	4.765	NM	143.3	17.9	0.1335	1.261	0.875
2	5.853	NM	11220.3	1086	0.1722	98.739	0.85



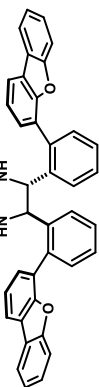
SI-34

SFC, AD, 30% IPA:CO₂
2 mL/min 44°C, 15 uL
racemic

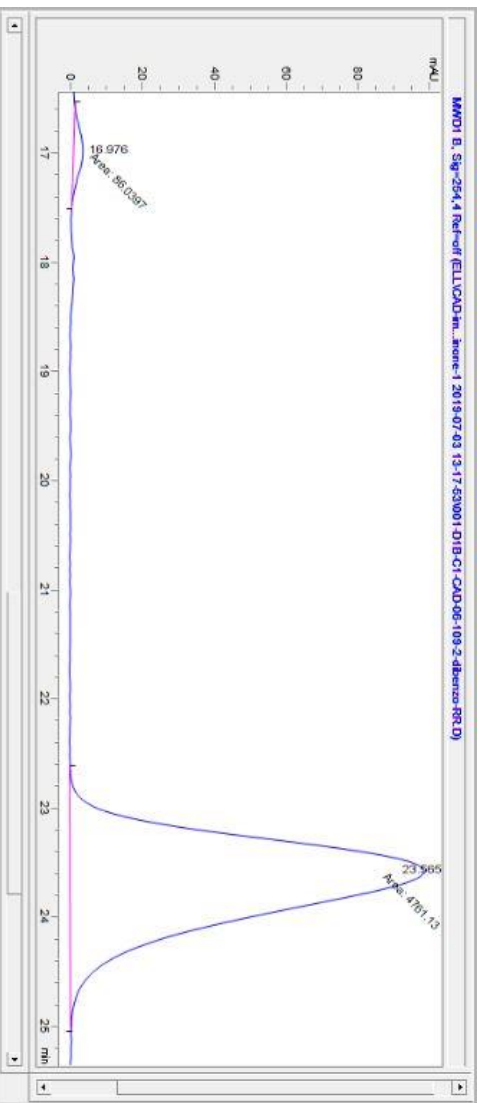


File Information					
LC File	003-D1B-C3-4-4benzofuran-indazolidinone.D	#	Time	Type	Area
File Path	C:\Chem32\1\Data\CAD\CAD-midazolhione-dlaza-	1	16.988	MM	6027.8
Date	26-Jul-19, 14:37:23	2	24.28	MM	5680.7
Sample	4-benzofuran-indazolidinone-rac				
Sample Info					
Barcode					
Operator	SYSTEM				
Method	CAD 70_30-AD-30-min.M				
Reference					
Analysis Time	29.993 min				
Sampling Rate	0.0067 min (0.402 sec), 4500 datapoints				

Area%	Symmetry
51.462	0.932
46.518	0.779

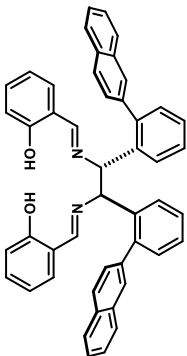


SI-34
 SFC, AD, 30% IPA:CO₂
 2 mL/min 44°C, 15 uL
 enantiomerically
 96% ee

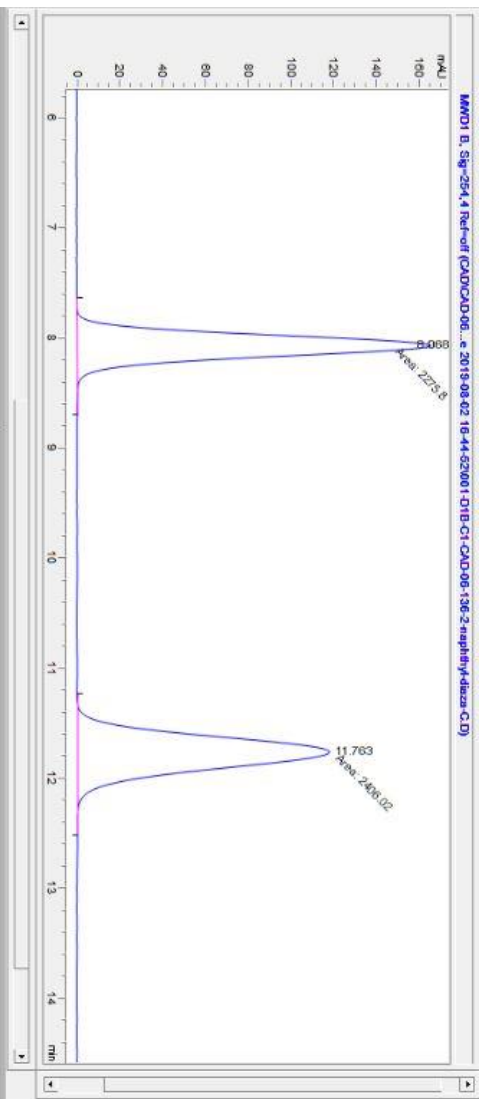


File Information									
LC-File	001-018-C1-CAD-06-109-2-dbenzo-R8.D								
File Path	G:\Chem321\Data\ELU\CAD-mthaloxindione-1.2019								
Date	03-Jul-19, 13:18:47								
Sample	CAD-06-109-2-dbenzo-R8								
Sample Info									
Barcode									
Operator	SYSTEM								
Method	CAD 70_30-40-30-min.M								
Reference									
Analysis Time	23.993 min								
Sampling Rate	0.0067 min (0.402 sec), 4500 datapoints								

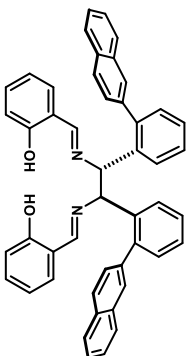
#	Time	Type	Area	Height	Width	Area%	Symmetry
1	16.976	MM	86	2.8	0.5116	1.775	0.829
2	23.965	MM	4761.1	99	0.8018	98.225	0.717



S1-35
SFC, AD, 20% IPA/CO₂
2 mL/min 44°C, 15 uL
racemic

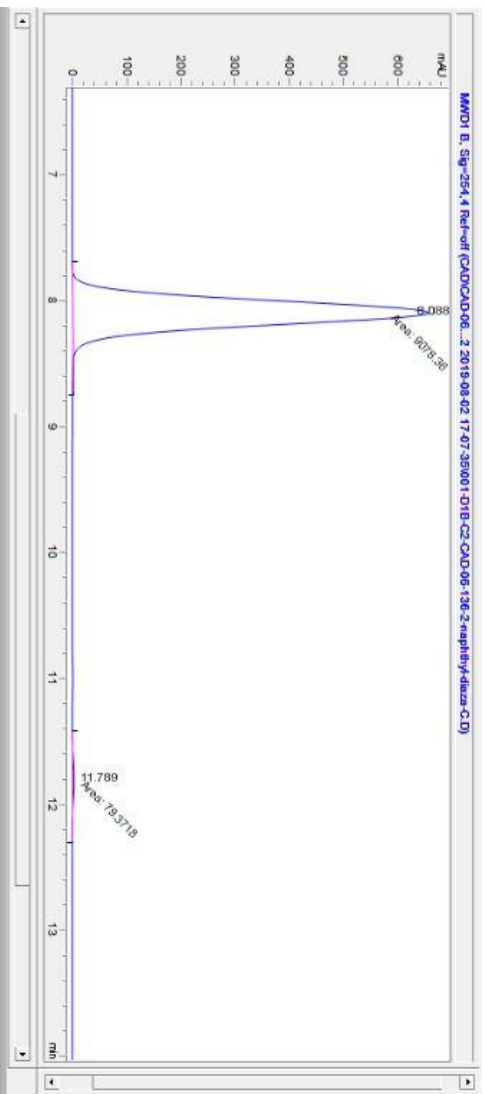


File Information					
LC-File	001-01B-C1-CAD-06-136-2-naphthyl-daza-C-D	#	1	Time	8.068
File Path	C:\Chem32\1\Data\CAD\CAD-06-136-2-naphthyl-d		2	Time	11.763
Date	02-Aug-19 16:45:46	Type	MM	Area	2275.8
Sample	CAD-06-136-2-naphthyl-daza-Cope-ee			Area	2406
Sample Info		Height	165.6	Width	0.2291
Barcode			118	Area%	48.609
Operator	SYSTEM	Symmetry			0.947
Method	CAD 80 AD 30min.M				
Reference					
Analysis Time	15.32 min				
Sampling Rate	0.0067 mm (0.402 sec), 2374 datapoints				

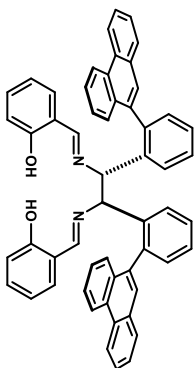


S1,35

SFC, AD, 20% IPA/CO₂
2 mL/min 44°C, 15 µL
enantioenriched
95% ee

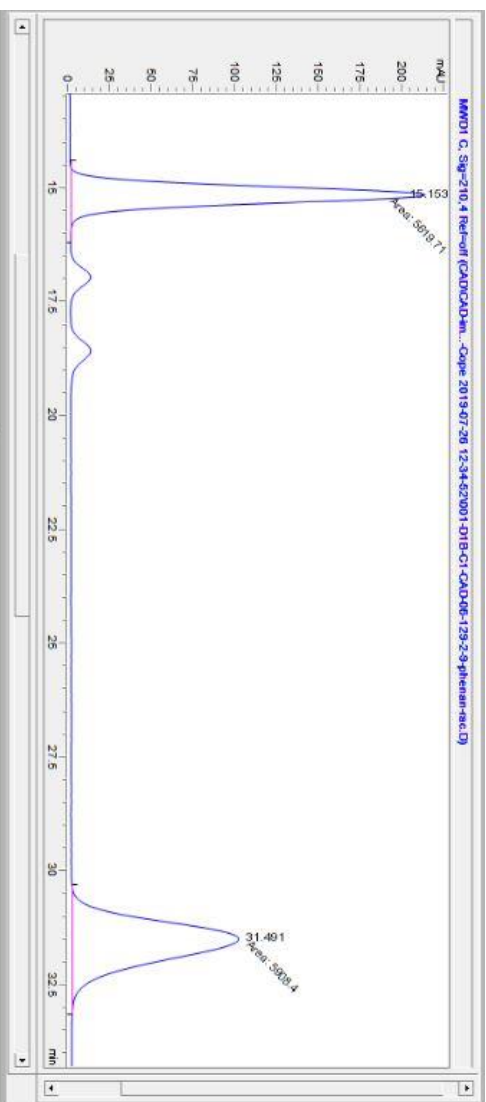


File Information		#	Time	Type	Area	Height	Width	Area%	Symmetry
LC-File	001-D1B-C2-CAD-06-136-2-naphthyl-dl-a-C-D	1	8.088	NM	9078.4	660.9	0.2289	99.133	0.988
File Path	C:\Chem32\10Data\CAD\CAD-06-136-2-naphthyl-dl	2	11.789	NM	79.4	3.7	0.3553	0.867	0.892
Date	02-Aug-19, 17:08:29								
Sample	CAD-06-136-2-naphthyl-dl-a-Cope-ee-2								
Sample Info									
Barcode									
Operator	SYSTEM								
Method	CAD 80_20 AD_30min.M								
Reference									
Analysis Time	16.66 min								
Sampling Rate	0.0067 mm (0.402 sec), 2500 datapoints								



SFC, AD, 20% IPA:CO₂
2 mL/min 44°C, 15 uL
racemic

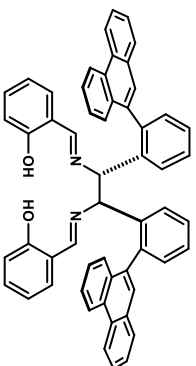
S1.36



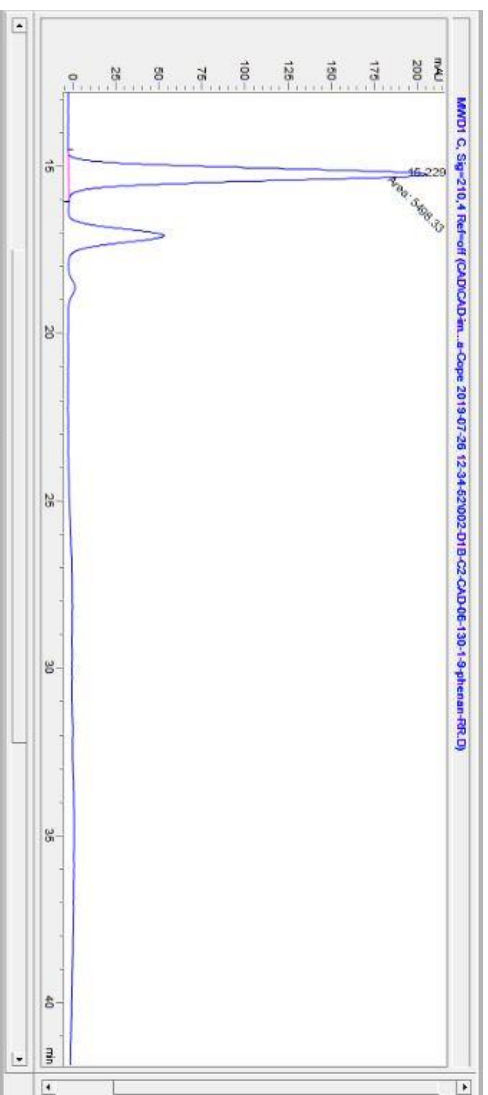
File Information	
LC-File	001-015-C1-CAD-Q6-129-2-9-phenan-rac.D
File path	C:\Chem321\Data\CAD\CAD-midazolone-dlaza-
Date	26-Jul-19, 12:35:48
Sample	CAD-Q6-129-2-9-phenan-rac
Sample Info	
Barcode	
Operator	SYSTEM
Method	CAD 80_20_AD_50min.M
Reference	
Analysis Time	59.993 min
Sampling Rate	0.0067 min (0.402 sec), 9000 datapoints

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	15.153	MM	5619.7	213.6	0.4384	48.748	0.988
2	31.491	MM	5908.4	100.3	0.5816	51.252	0.794

S130



S1-36
SFC, AD, 20% IPA:CO₂
2 mL/min 44°C, 15 uL
enantioenriched
99% ee

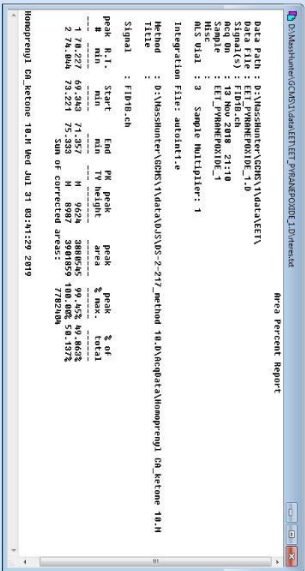


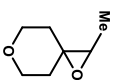
File Information							
LC-File	002-2018-C2-CAD-06-130-1-9-phenan-RR-D						
File Path	C:\Chem32\1\Data\CAD\CAD-midarololone-diaza-						
Date	26-Jul-19, 13:36:34						
Sample	CAD-06-130-1-9-phenan-RR						
Sample Info							
Barcode							
Operator	SYSTEM						
Method	CAD 80_20_AD_60min.M						
Reference							
Analyze Time	59.993 min						
Sampling Rate	0.0067 min (0.402 sec), 9000 datapoints						

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	15.229	NM	5498.3	208.9	0.4386	100.000	0.993

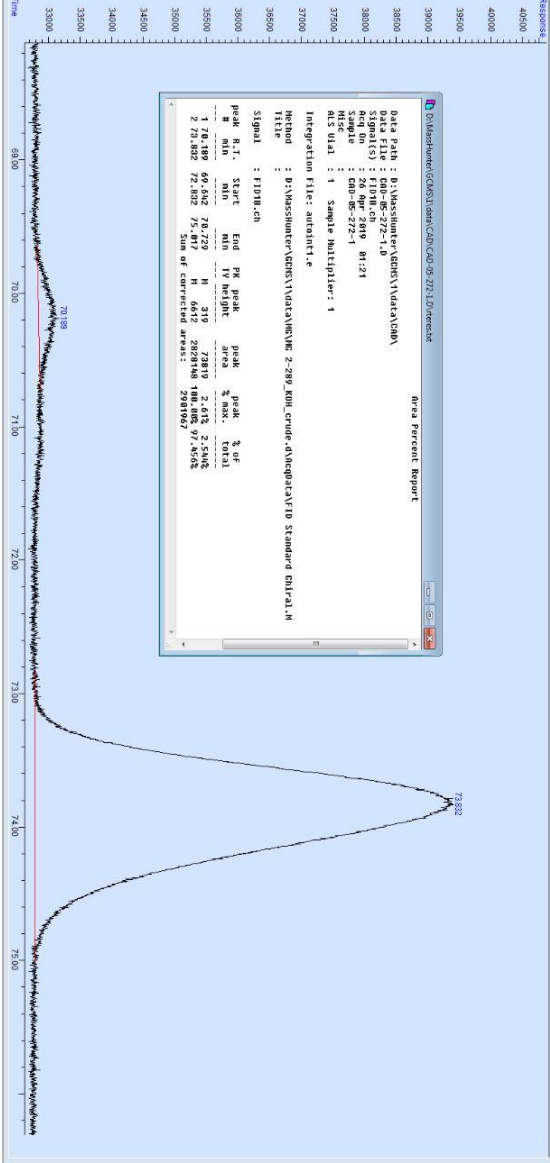


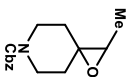
cemic





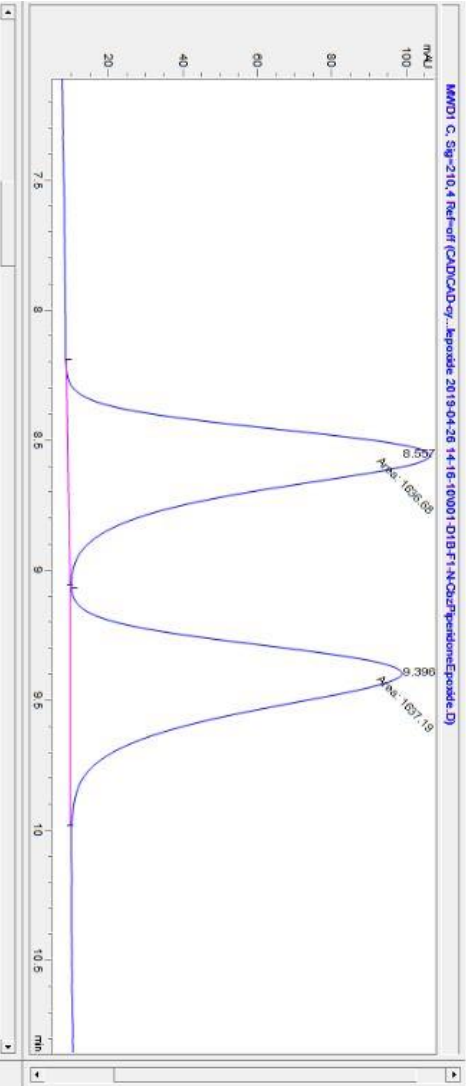
chiral GC/FID
80 °C, 75 min
enantiomeriched
95% ee





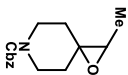
9

SFC, OD-H, 5% IPA,CO₂
2 mL/min, 44C, 15 uL
racemic

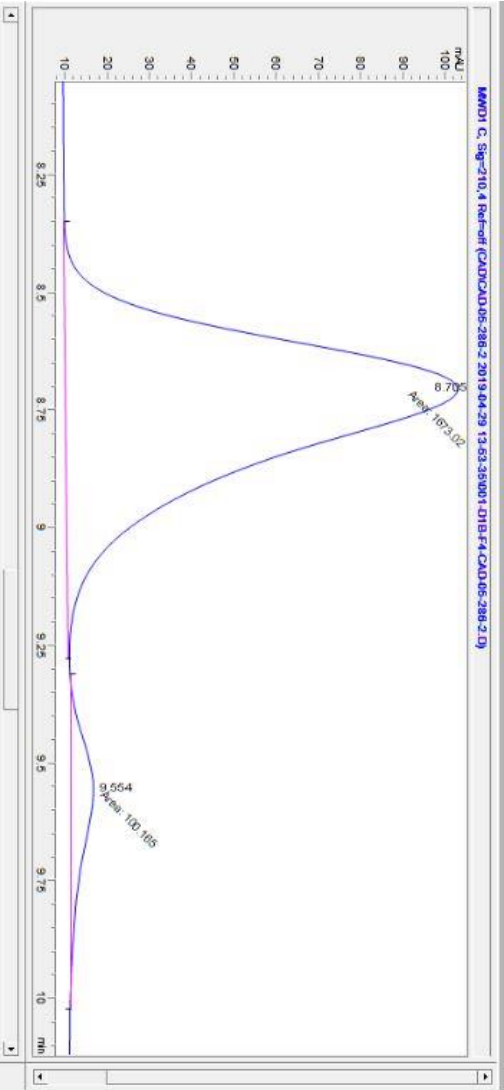


File Information									
LC-File	001-D18-F1-N-CbzperdoneEpoxide.D								
File Path	C:\Chem321\1Data\CAD\CAD-cydhexylepoxide								
Date	26-Apr-19, 14:17:04								
Sample	N-CbzperdoneEpoxide								
Sample Info									
Barcode									
Operator	SYSTEM								
Method	CAD-cydhexylepoxide.M								
Reference									
Analysis Time	44.993 min								
Sampling Rate	0.0067 min (0.402 sec), 6750 datapoints								

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	8.557	MM	1636.7	97.9	0.2785	49.992	0.758
2	9.396	MM	1637.2	89.7	0.3041	50.008	0.728

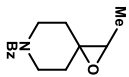


SFC, OD-H, 5% IPA:CO₂
 2 mL/min, 44°C, 15 uL
 enantioenriched
 89% ee



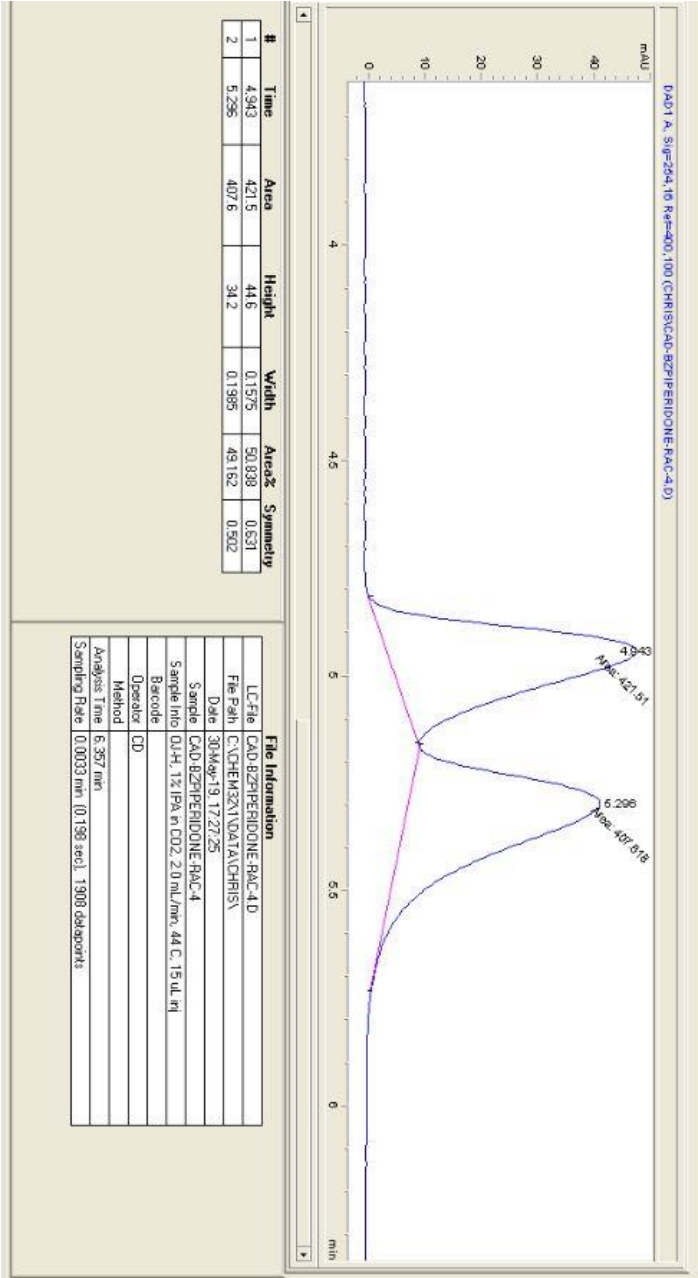
File Information					
LC-File	001-01B-F4-CAD-05-286-2.D				
File Path	C:\Chem221\Data\CAD\CAD-05-286-2 2019-04				
Date	29-Apr-19, 13:54:44				
Sample	CAD-05-286-2				
Sample Info					
Barcode					
Operator	SYSTEM				
Method	CAD MCDz Cyclohexyl epoxide.M				
Reference					
Analytes Time	14.993 min				
Sampling Rate	0.0067 min (0.402 sec), 2250 datapoints				

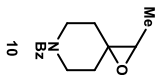
#	Time	Type	Area	Height	Width	Area%	Symmetry
1	8.705	MM	1673	92.9	0.3	94.351	0.687
2	9.554	MM	100.2	5.6	0.2997	5.649	0.652



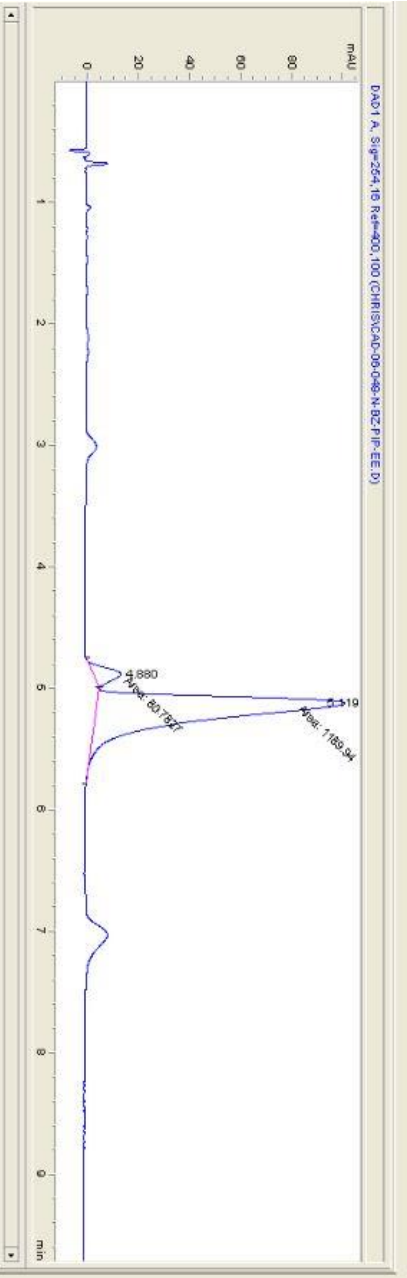
10

SFC, O₂H, 1% iPrCO₂
2 mL/min, 44°C, 15 uL
racemic



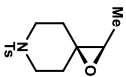


SFC, O₂H, 1% IPA/CO₂
 2 mL/min, 44°C, 15 uL
 enantioenriched
 87% ee



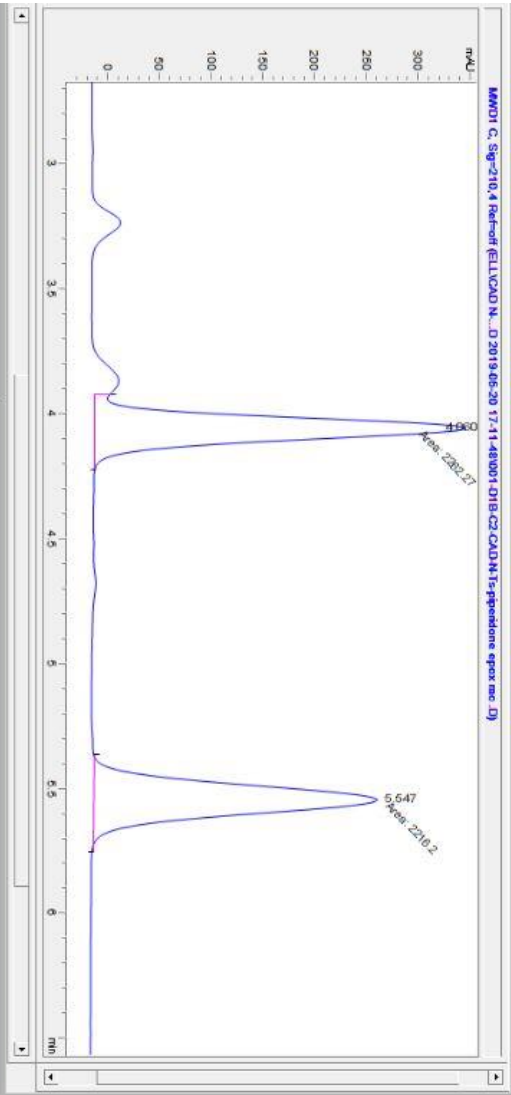
#	Time	Area	Height	Width	Area%	Symmetry
1	4.88	80.8	11.1	0.1208	6.367	1.058
2	5.119	1189.9	97.7	0.2037	93.643	0.393

File Information	
LC-File	CAD-06-049-NBz-PIP-EE.D
File Path	C:\CHEM\231\DATA\CHHIS\
Date	09-Jun-19, 18:51:42
Sample	CAD-06-049-NBz-06-ee
Sample Info	O ₂ H, 1% IPA in CO ₂ , 2.0 mL/min, 44°C, 15 uL inj
Barcode	
Operator	CHHIS
Method	
Analysis Time	9.713 min
Sampling Rate	0.0033 min (0.198 sec), 2915 datapoints



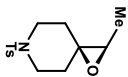
11

SFC, AD, 20% IPA/CO₂
2 mL/min 44°C, 15 uL
racemic



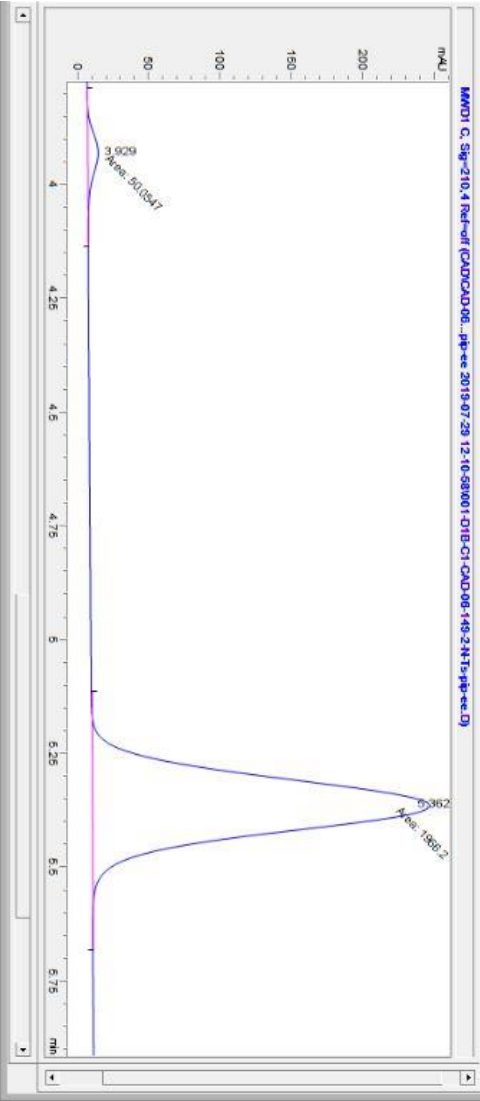
File Information	
LC-File	001-01B-C2-CAD-N-Ts-piperidine epox rac. D
File Path	C:\Open321\Data\ELU\CAD N-Ts-piperidine epox
Date	20-May-19, 17:12:42
Sample	CAD-N-Ts-piperidine epox rac. 80_20 AD-2
Sample Info	
Barcode	
Operator	SYSTEM
Method	CAD 80_20 AD. M
Reference	
Analysis Time	7.74 min
Sampling Rate	0.0067 min (0.402 sec), 1162 datapoints

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	4.06	MM	2262.3	362.1	0.1041	50.514	0.92
2	5.547	MM	2216.2	276.6	0.1335	49.486	1.028



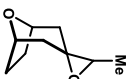
11

SFC AD 20% IPA/CO₂
2 mL/min 44C, 15 uL
enantioenriched
95% ee

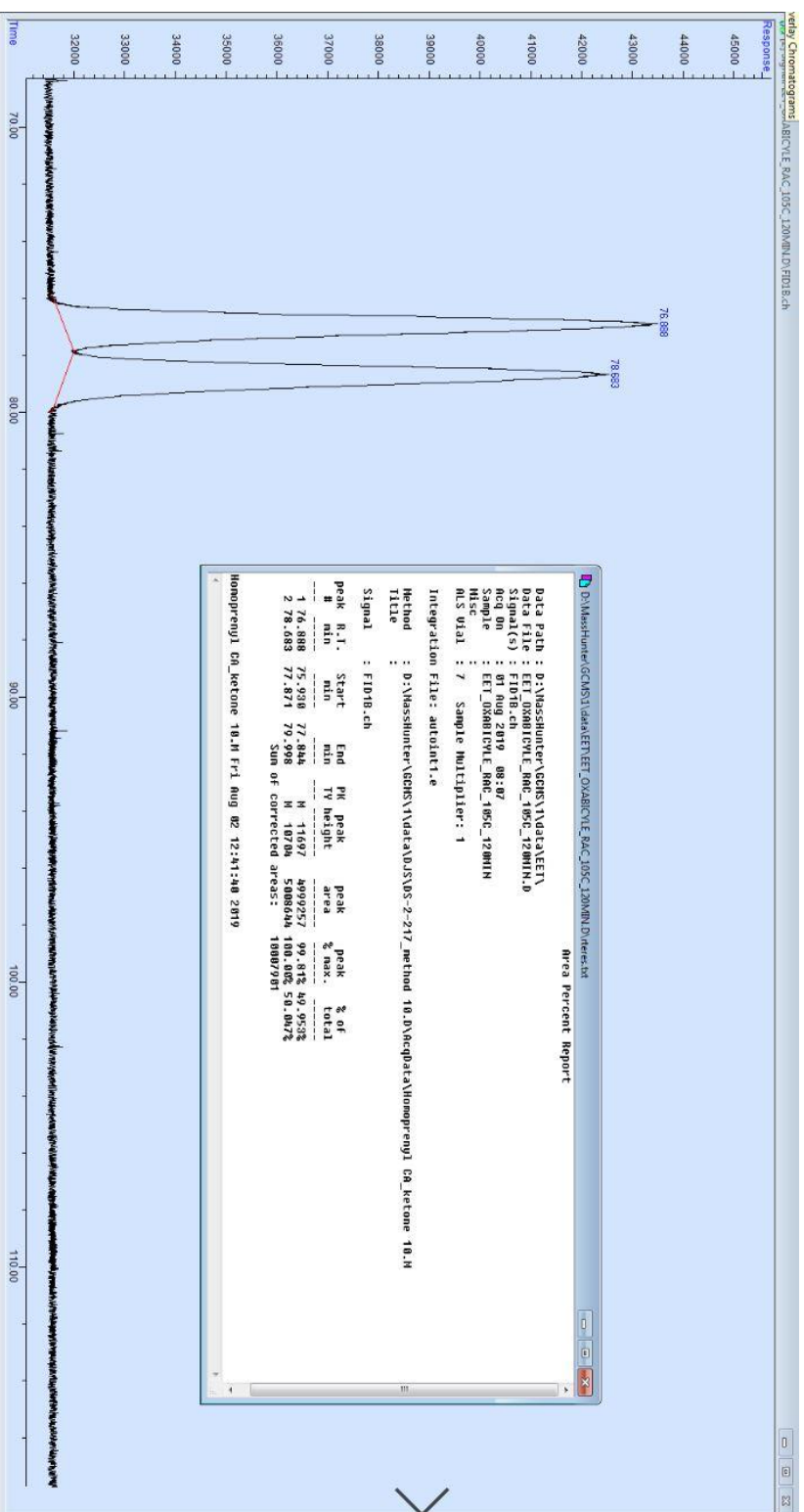


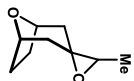
File Information						
LC File	001-01B-C1-CAD-06-149-2-N-Ts-PD-ee.D					
File Path	C:\Chem321\Data\CAD\CAD-06-149-2-N-Ts-PD-ee					
Date	29-Jul-19, 12:11:52					
Sample	CAD-06-149-2-N-Ts-PD-ee					
Sample Info						
Barcode						
Operator	SYSTEM					
Method	CAD 80_20 AD.M					

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	3.929	NM	50.1	7.5	0.1116	2.483	0.866
2	5.362	NM	1966.2	236.9	0.1363	97.517	1.031



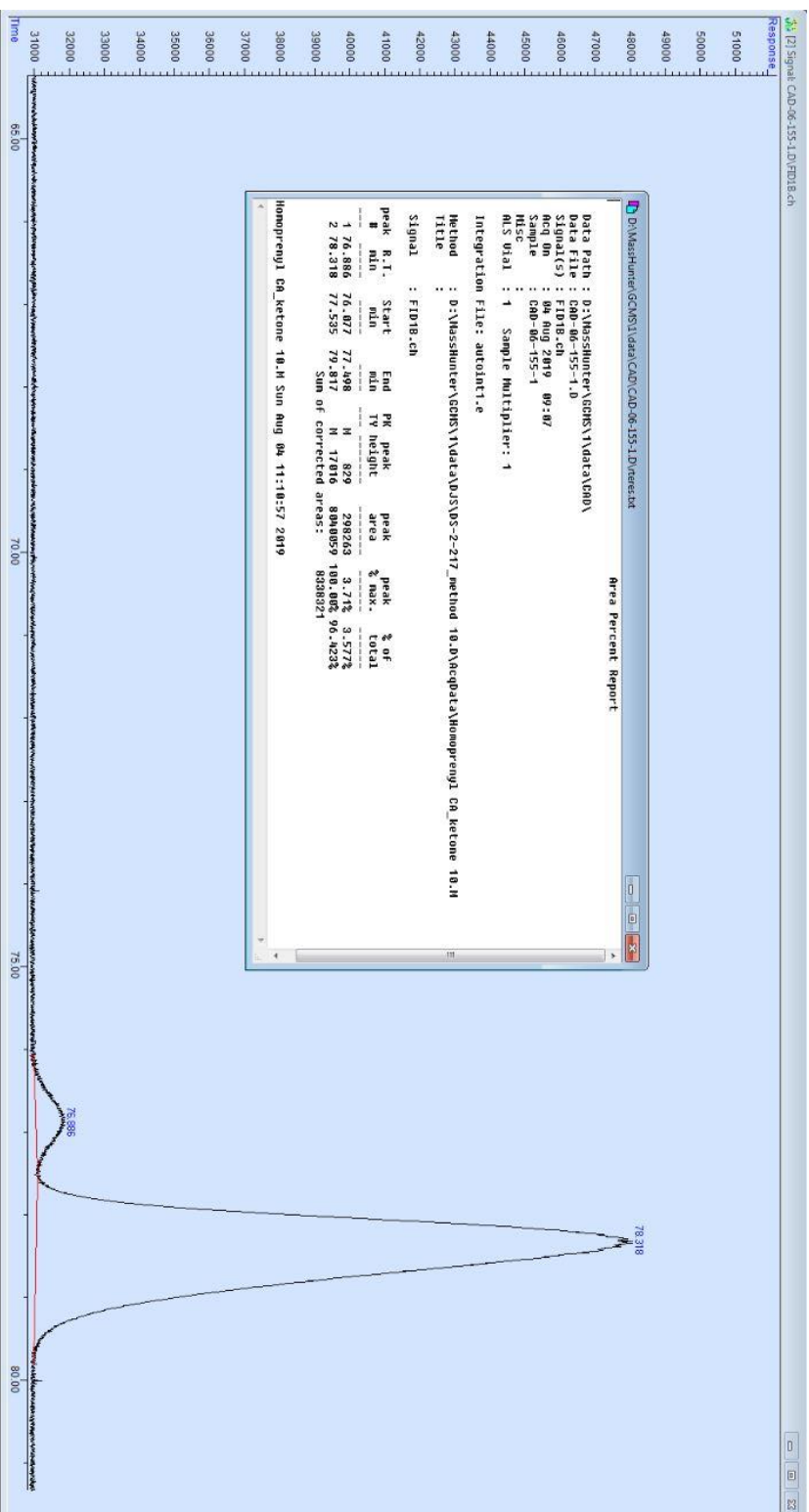
chiral GC/FID
105 °C, 120 min
racemic



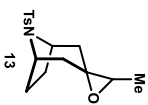


12

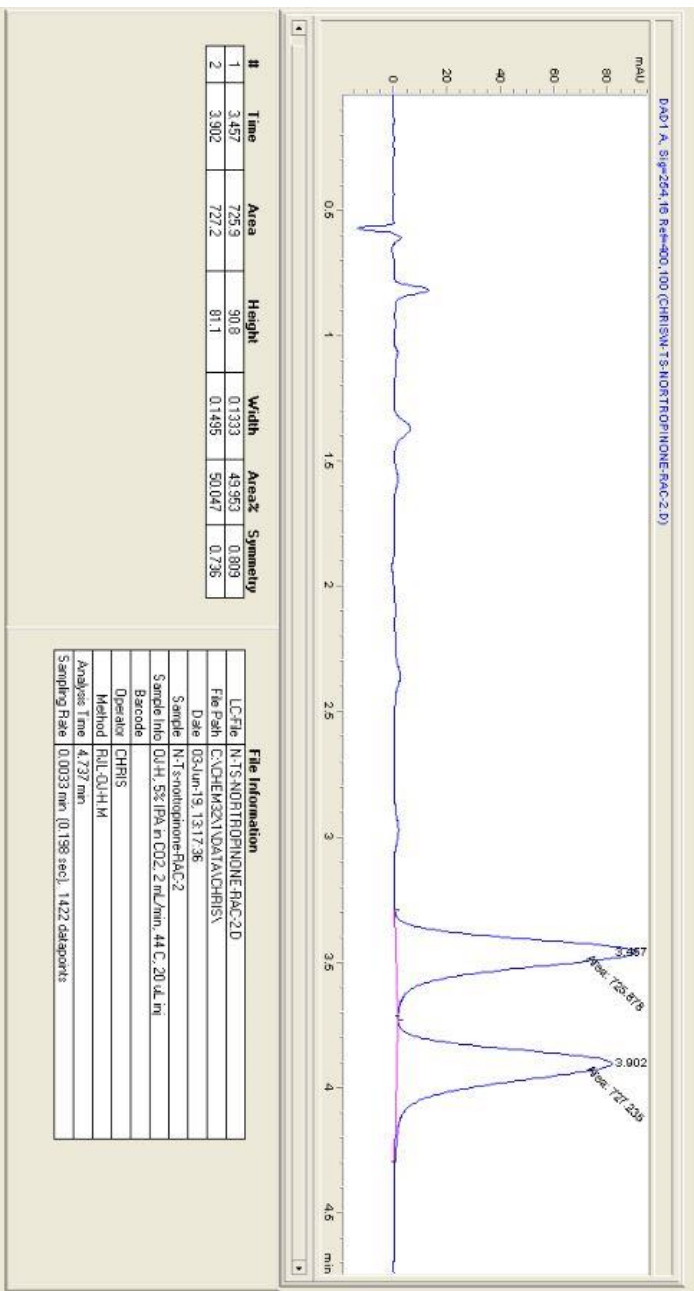
chiral GC/FID
105 °C, 120 min
enantiomerized
93% ee

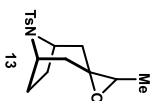


S141

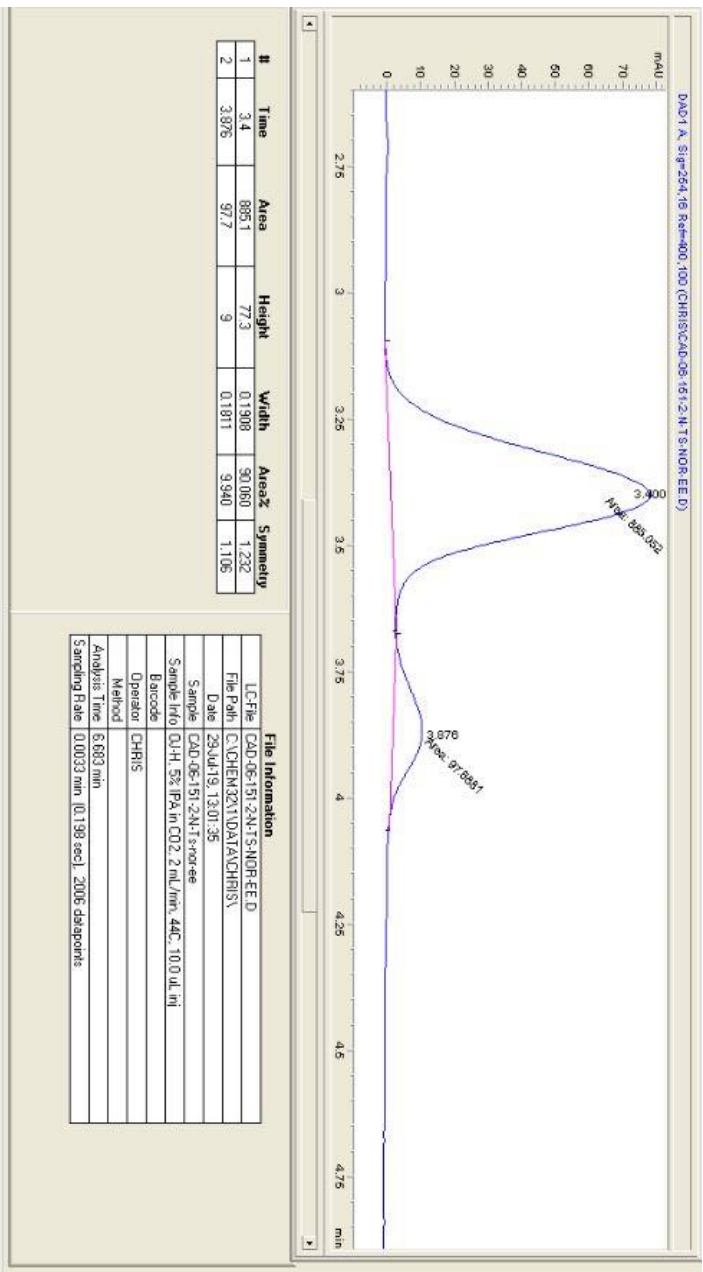


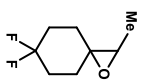
SFC, O_2/H , 5% IPAC/CO_2
 2 mL/min, 44°C, 15 uL
 racemic





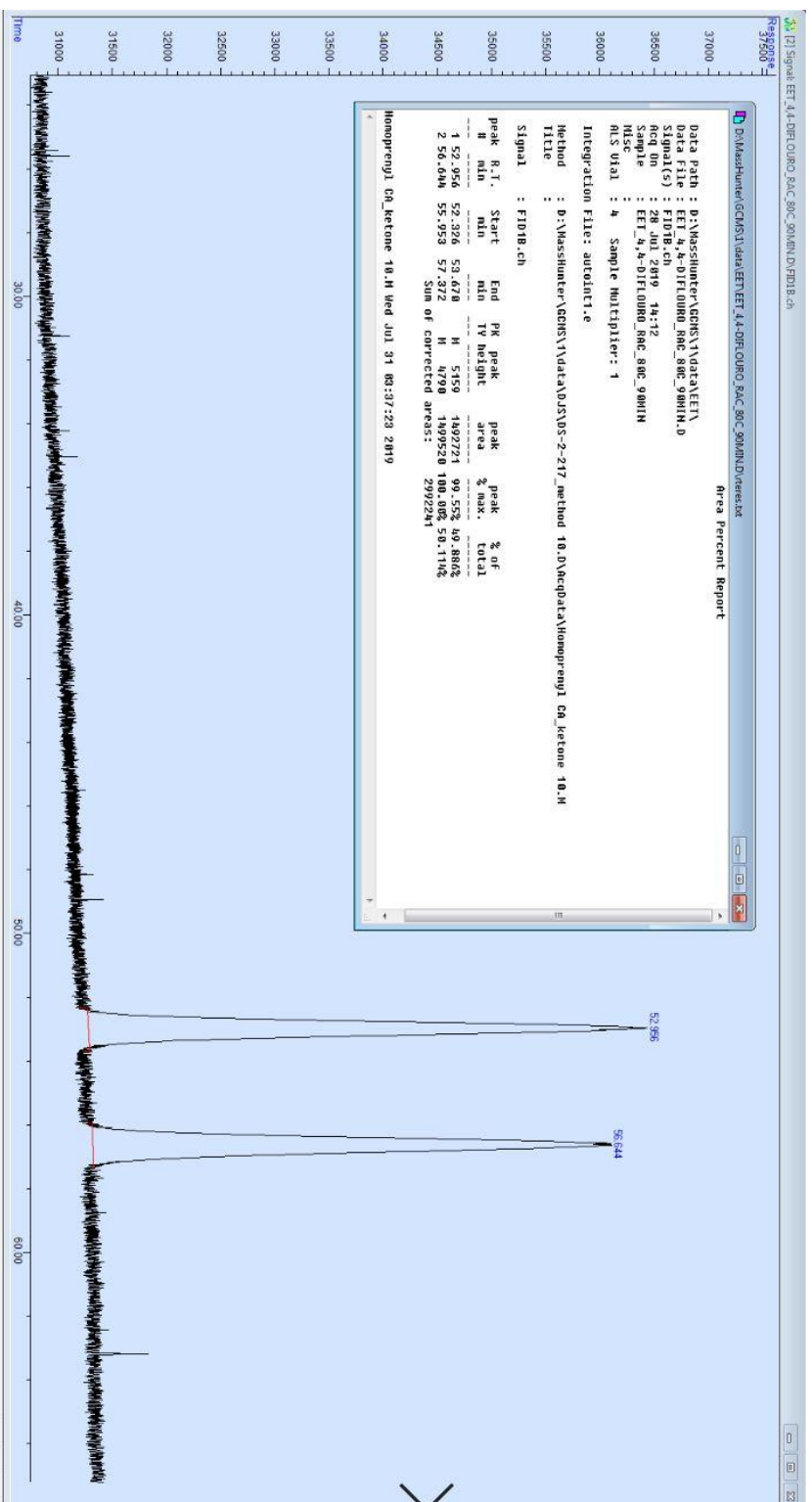
SFC, 0.1-H, 5% IPA:CO₂
 2 mL/min, 44°C, 15 uL
 enantioenriched
 80% ee



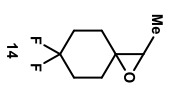


14

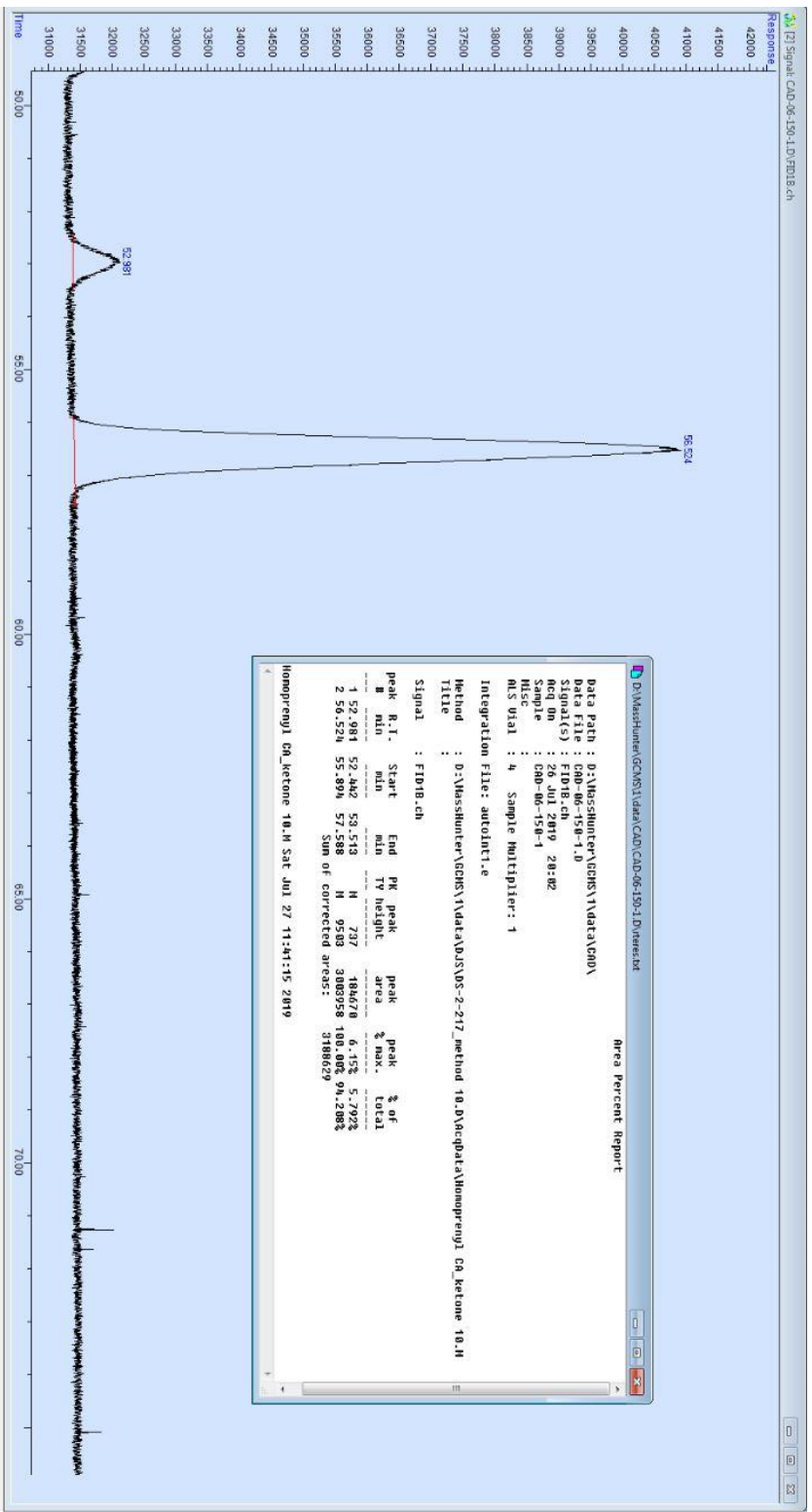
chiral GC/FID
80 °C, 75 min
racemic

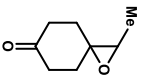


S144



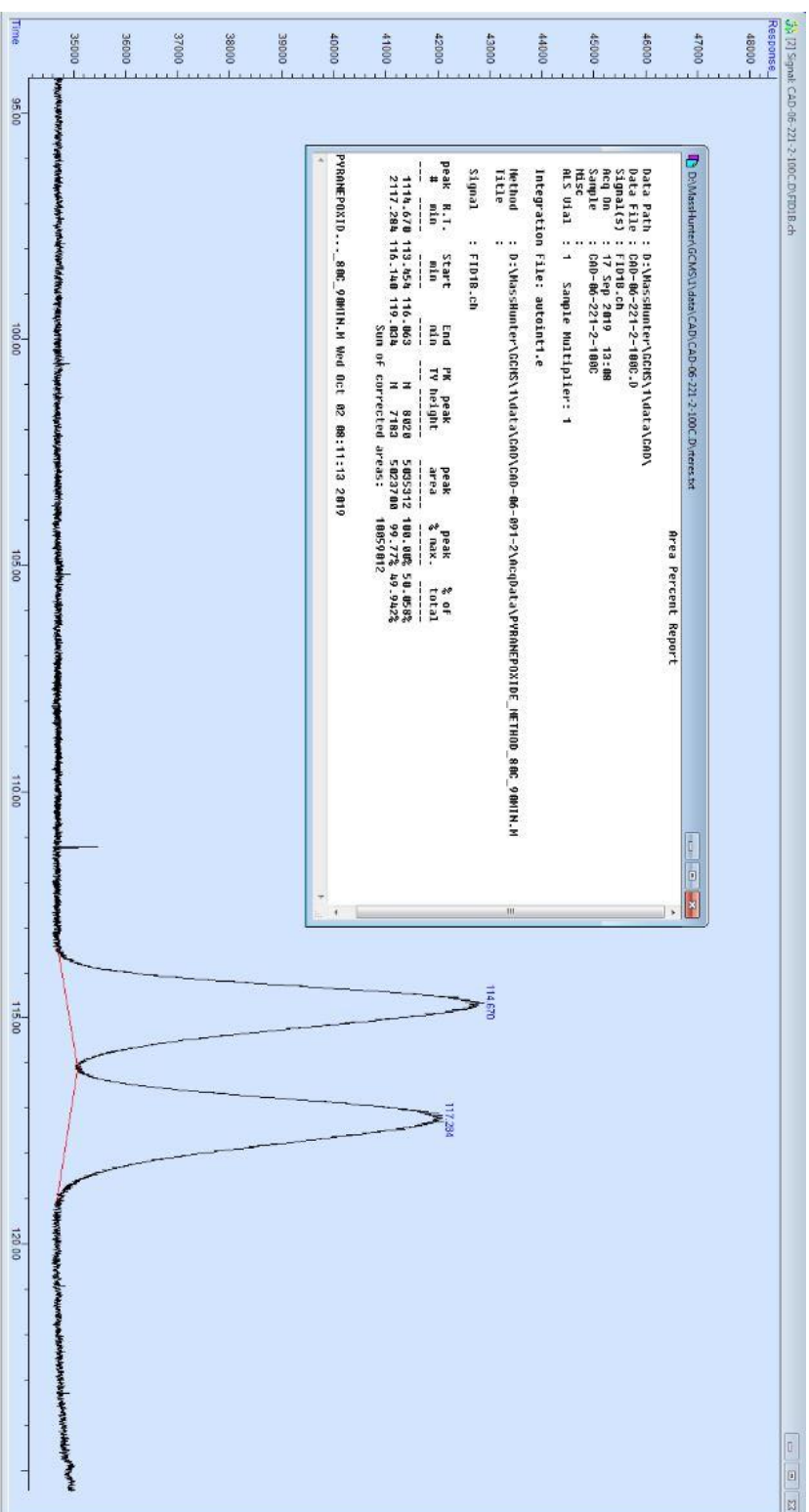
chiral GC/FID
80 °C, 75 min
enantiomerised
89% ee



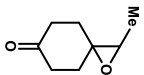


15

chiral GC/FID
110 °C, 120 min
racemic

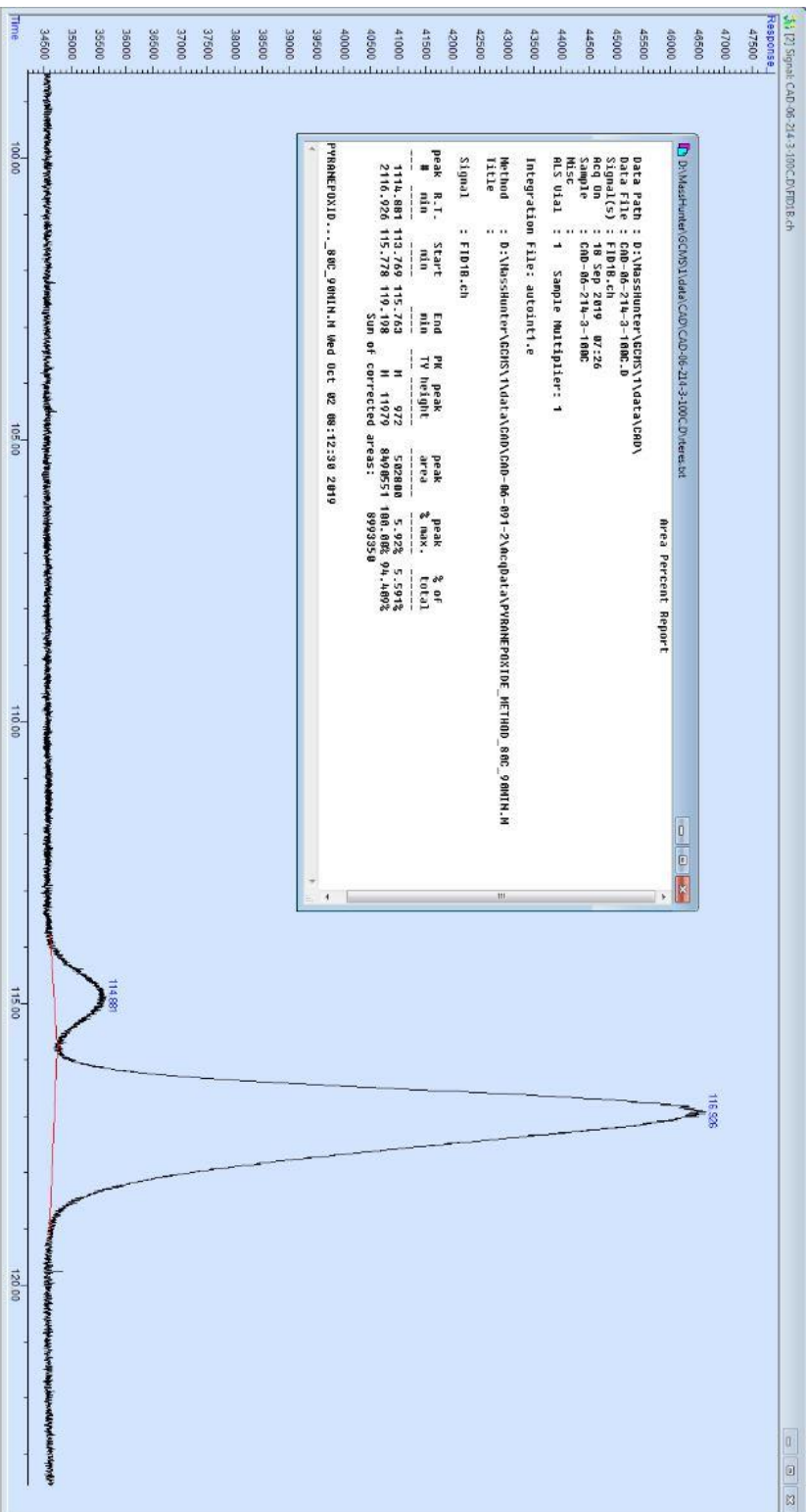


S146

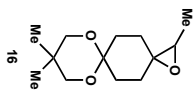


15

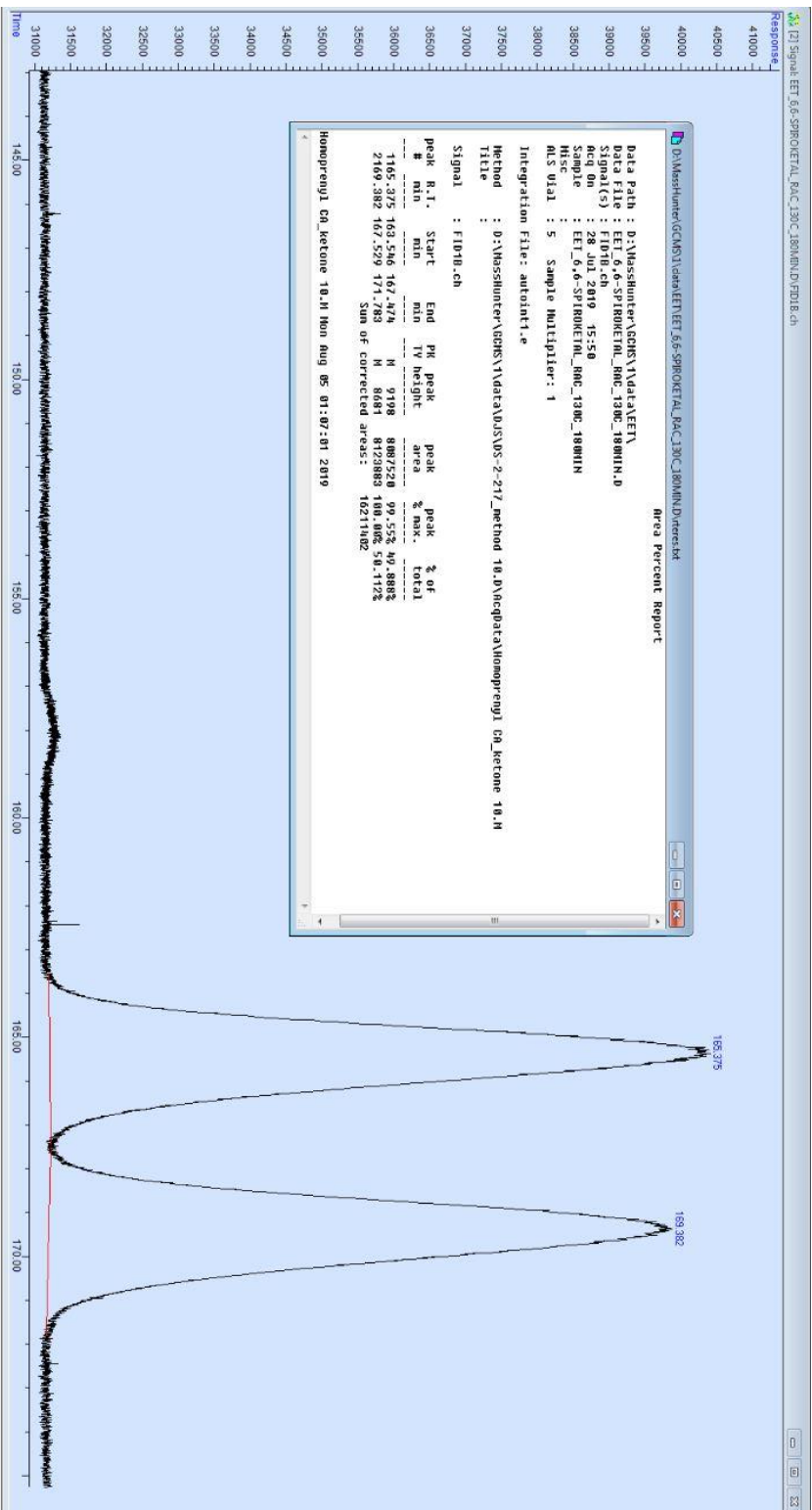
chiral GC/FID
110 °C, 120 min
enantiomeriched
89% ee



S147



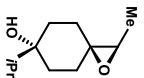
chiral GC/FID
130 °C, 180 min
racemic





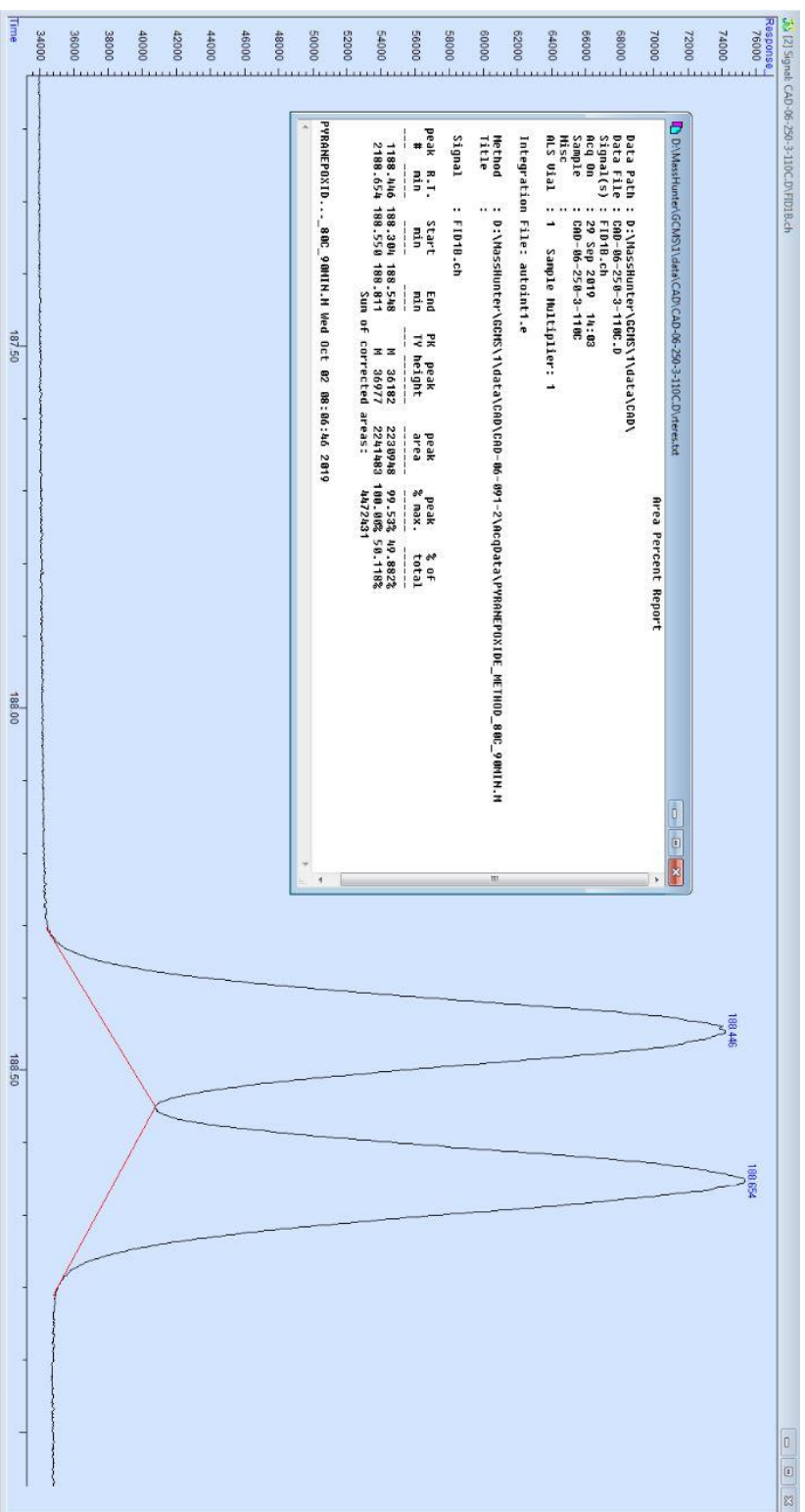
81% ee





17

chiral GC/FID
110 °C, 180 min
then ramp to 200 °C
at 10 °C per min
racemic

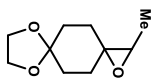


S150



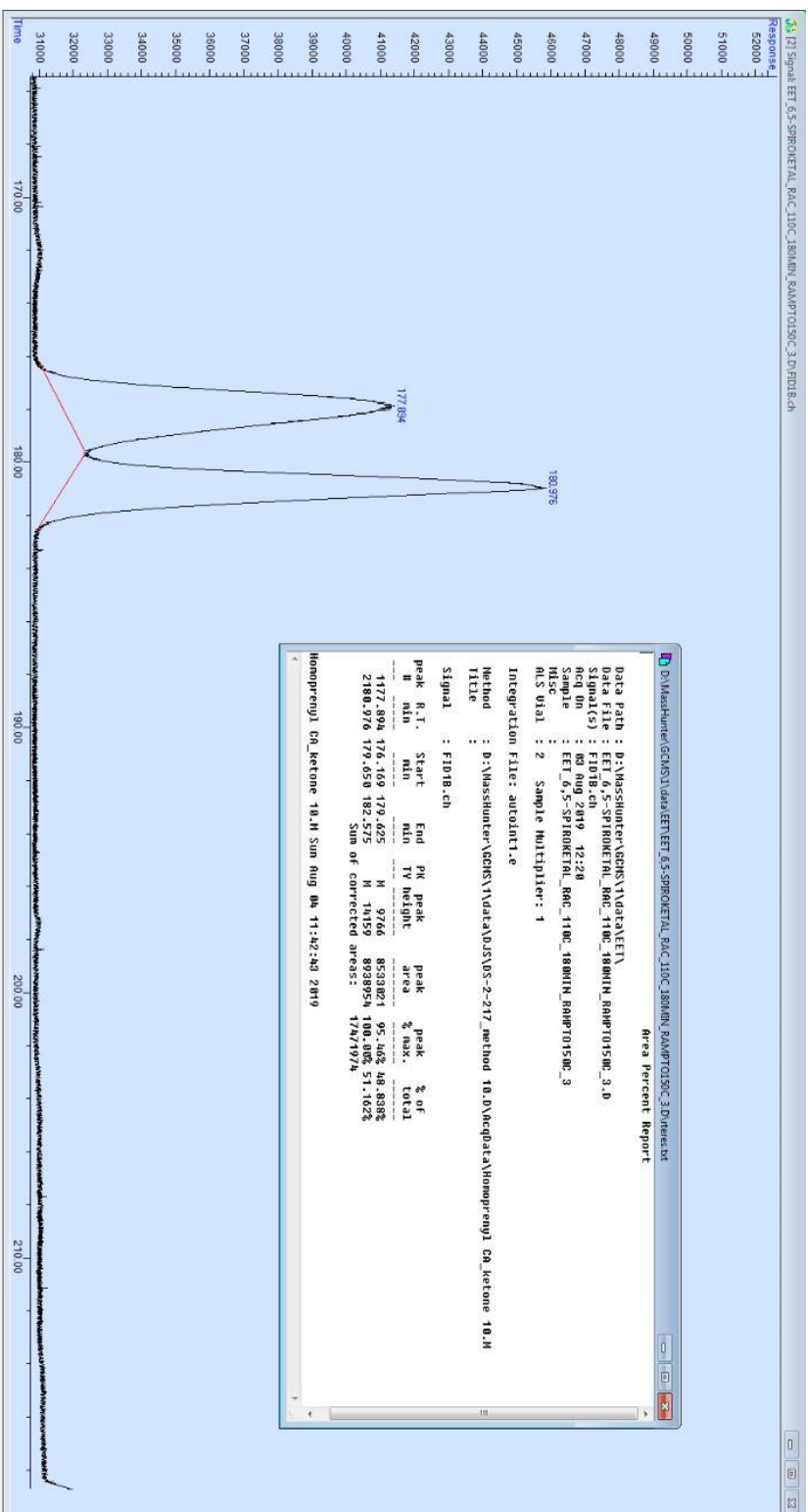
86% ee



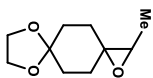


18

chiral GC/FID
110 °C, 180 min
ramp to 150 °C, 40 min
racemic

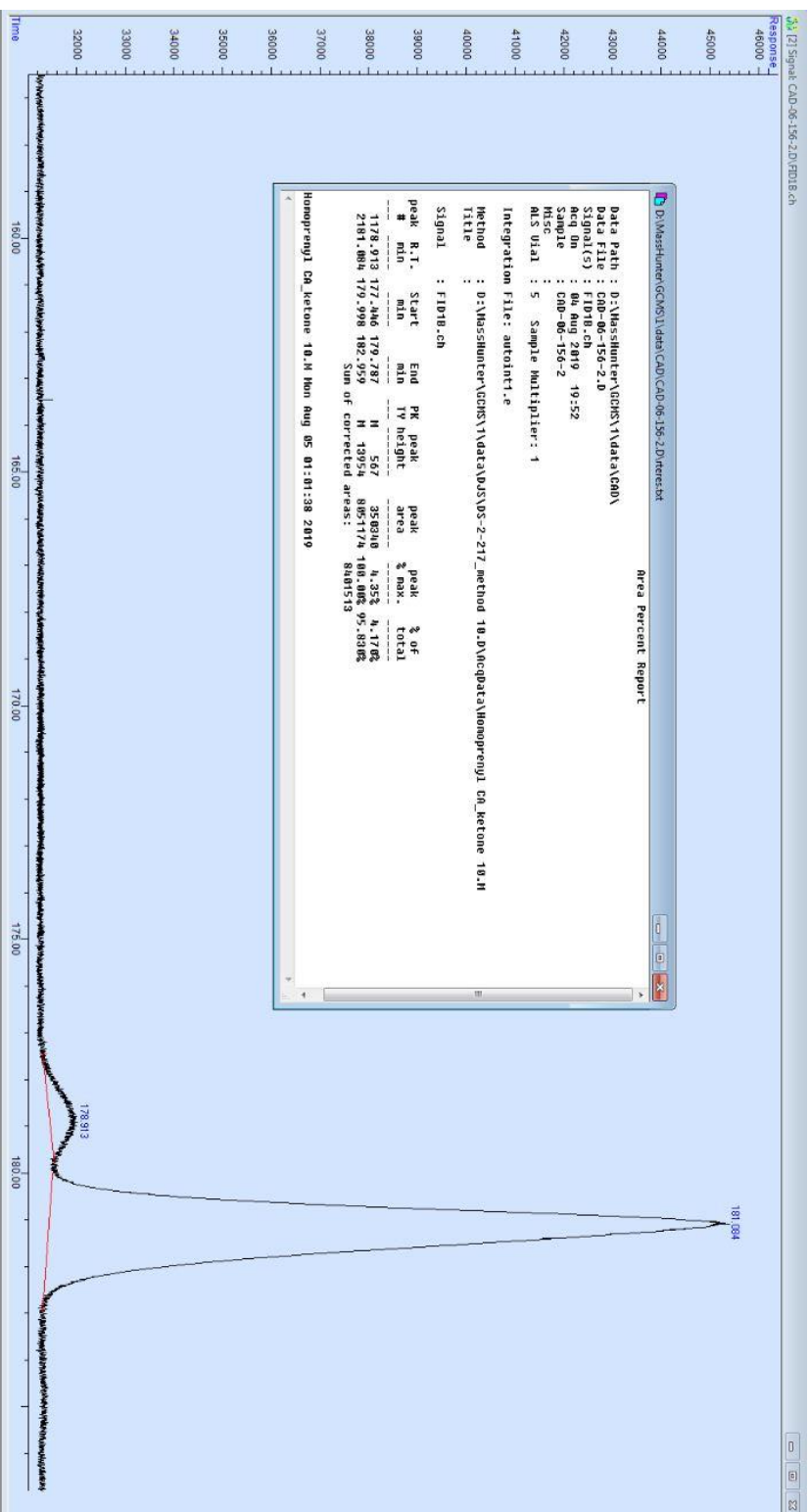


S152

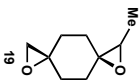


18

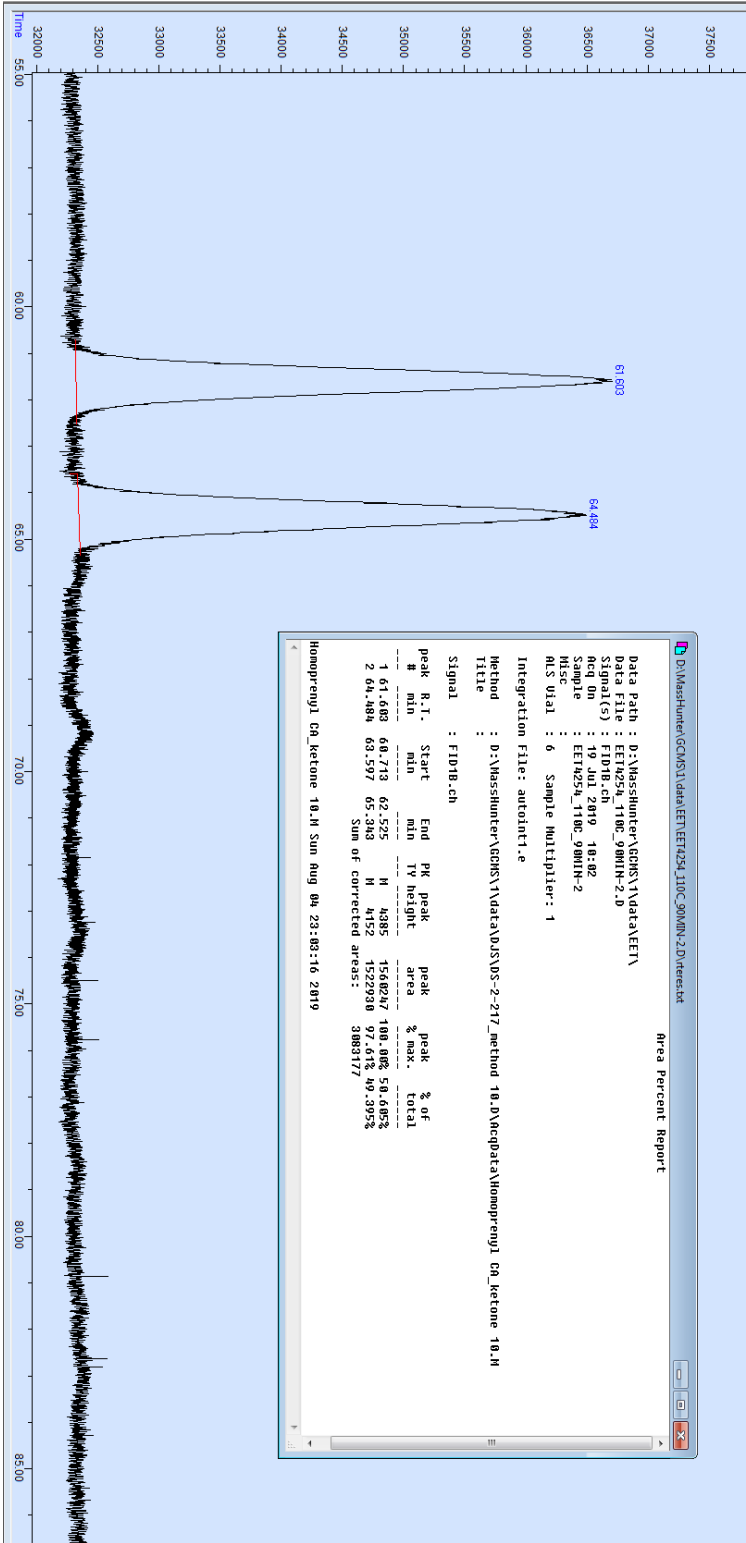
chiral GC/FID
110 °C, 180 min
ramp to 150 °C, 40 min
enantiomerized
92% ee

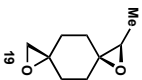


S153

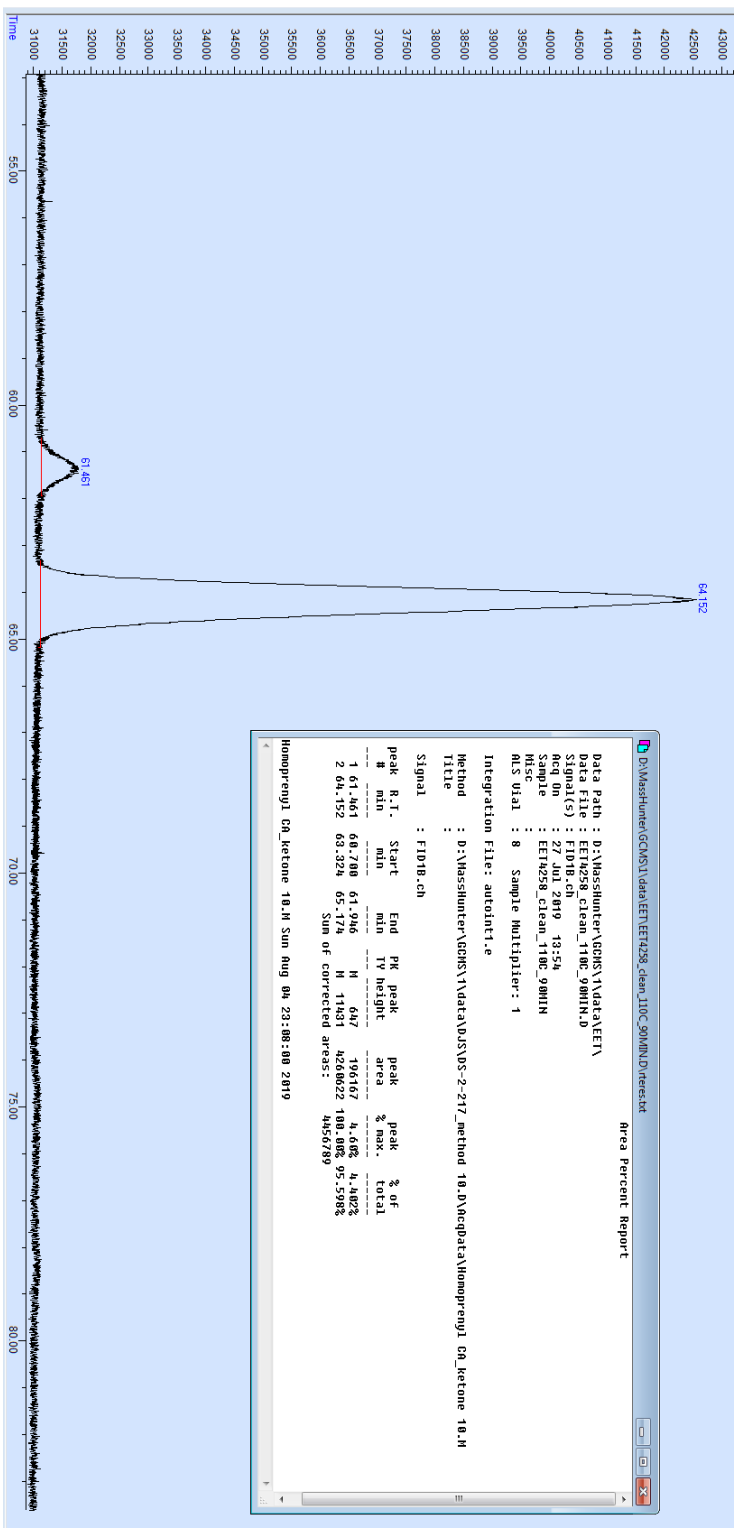


chiral GC/FID
 110 °C, 90 min
 racemic

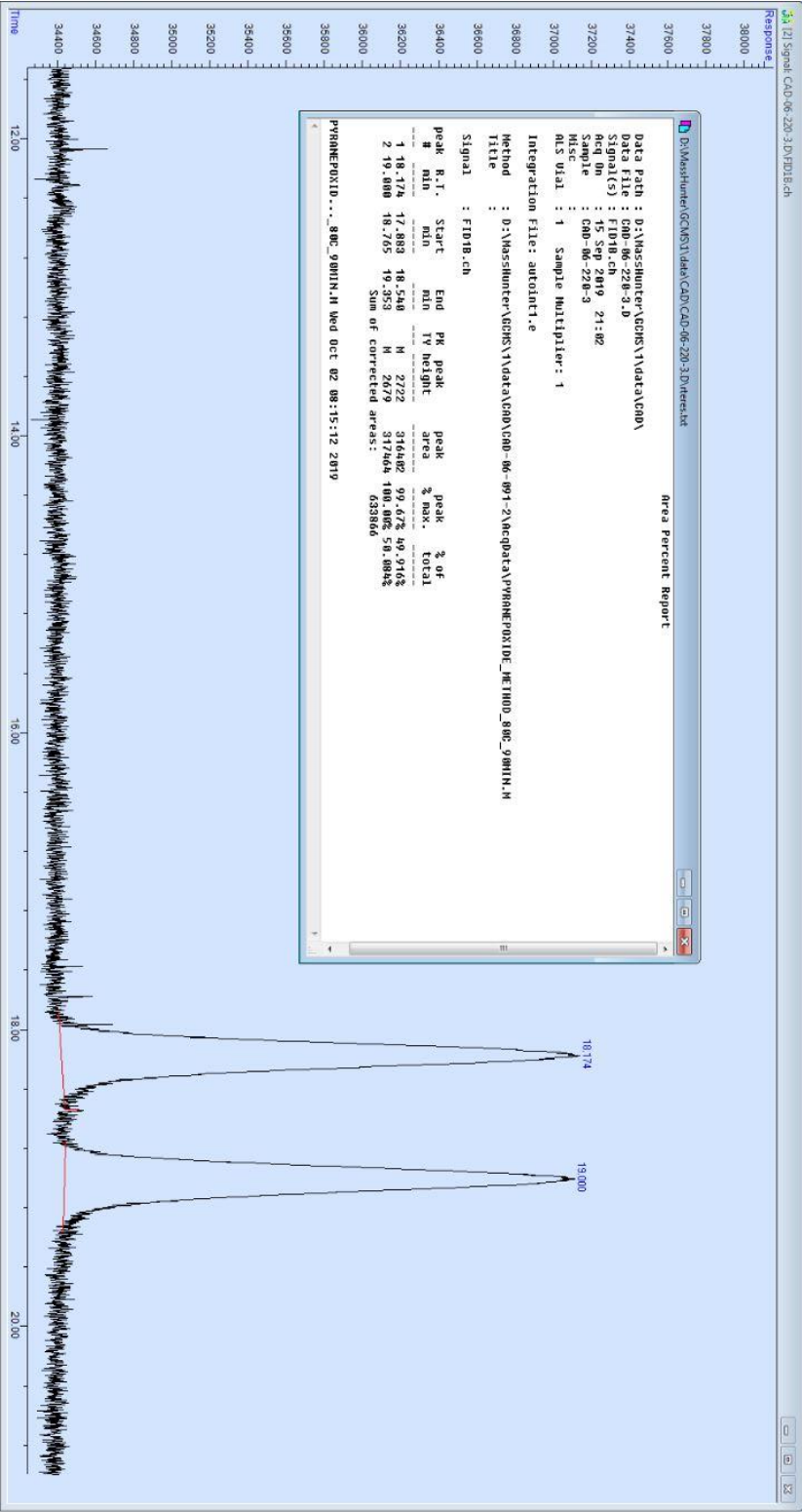
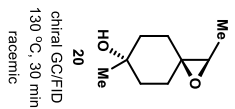


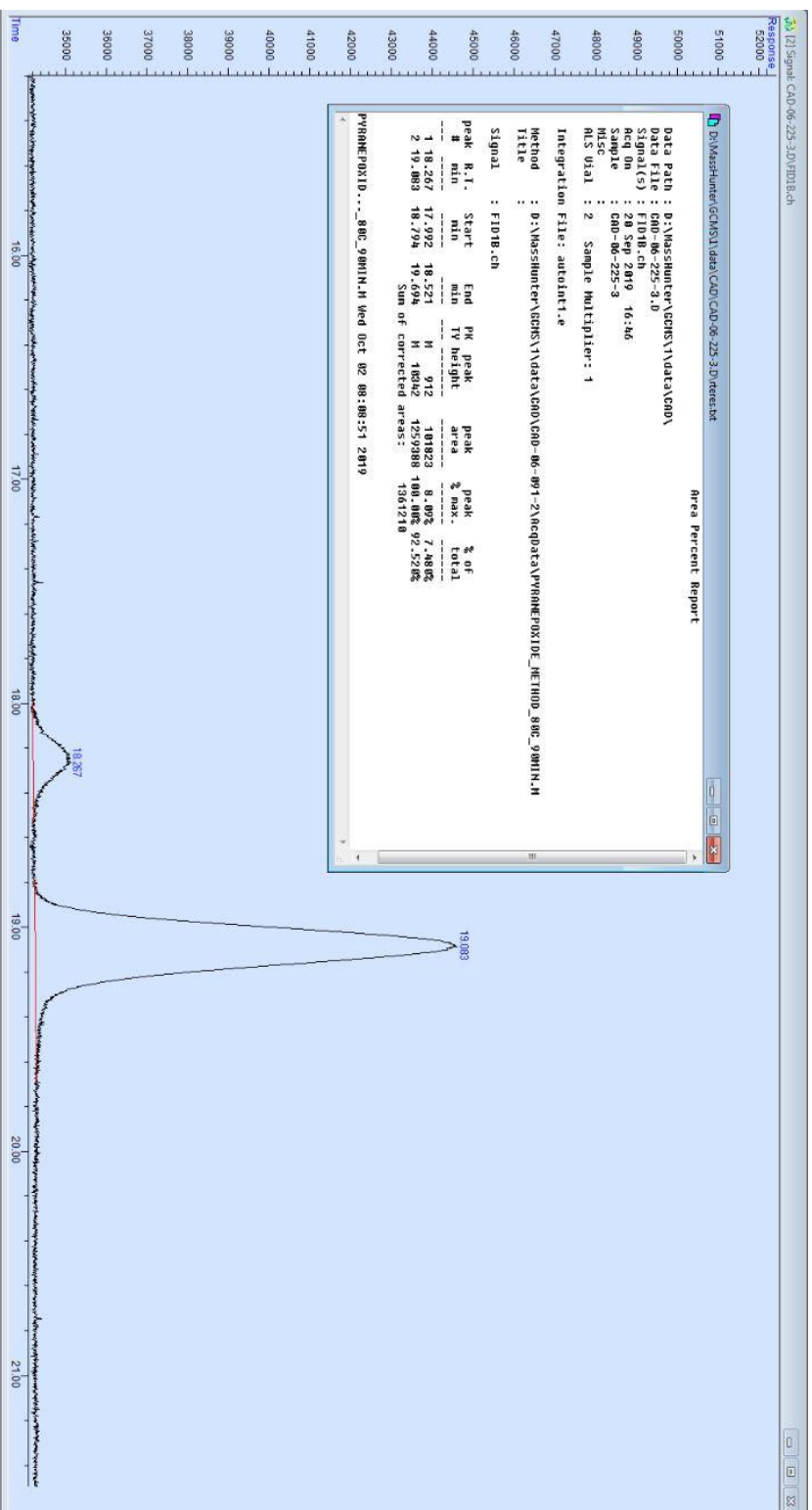
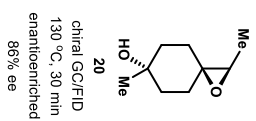


chiral GC/FID
110 °C, 90 min
enantiomerized
91% ee

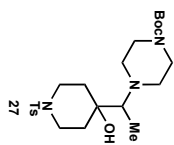


S155

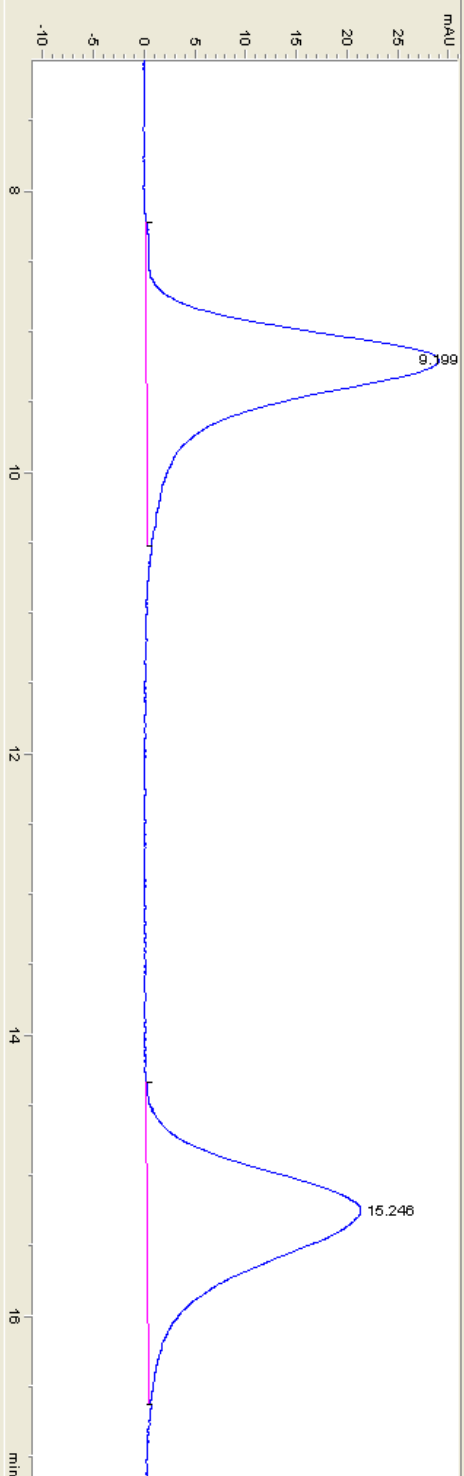




S157



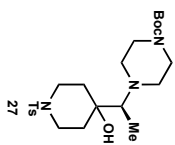
SFC OJ-H, 5% IPA/CO₂
2.0 mL/min
racemic



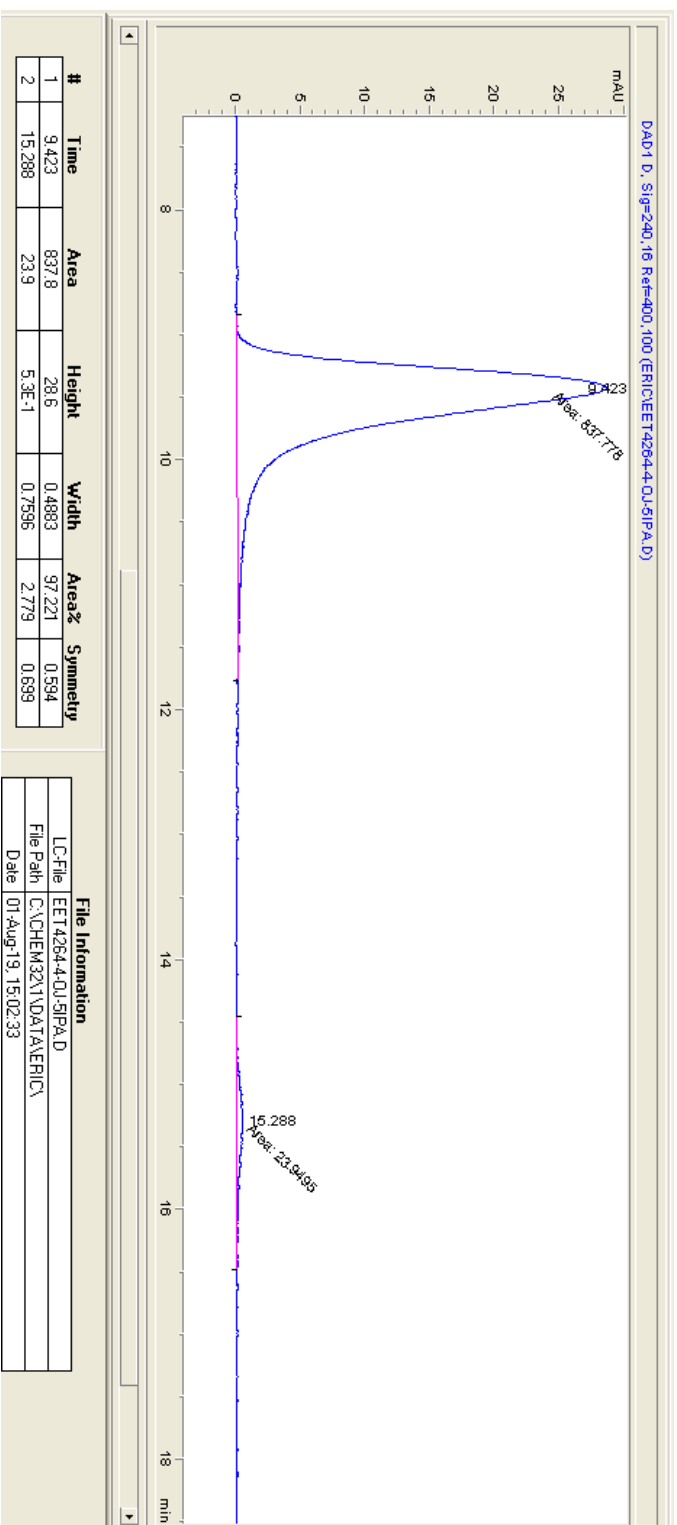
DAD1.D, Sig=240.16 Ref=400.100 (ERIC14201-1-OL5IPAD)

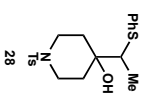
#	Time	Area	Height	Width	Area%	Symmetry
1	9.199	10436	28.9	0.5371	50.760	0.704
2	15.246	10123	21.1	0.6609	49.240	0.725

File Information	
LC-File	ET4201-1-OL5IPAD
File Path	C:\CHEM321\DATA\ERICY
Date	24-Jun-19, 18:59:57

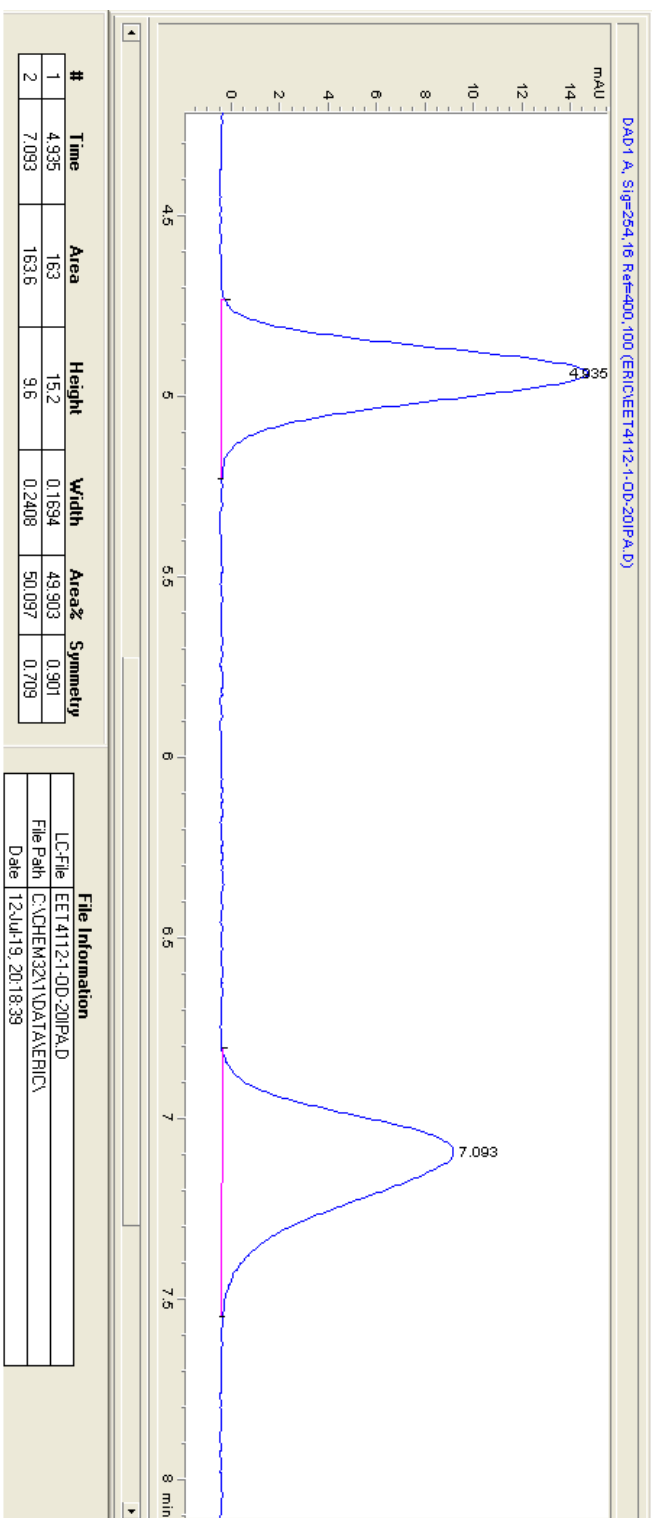


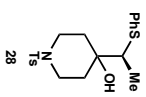
SFC O₂/H₂, 5% IPA/CO₂
 2.0 mL/min
 enantioenriched
 94% ee



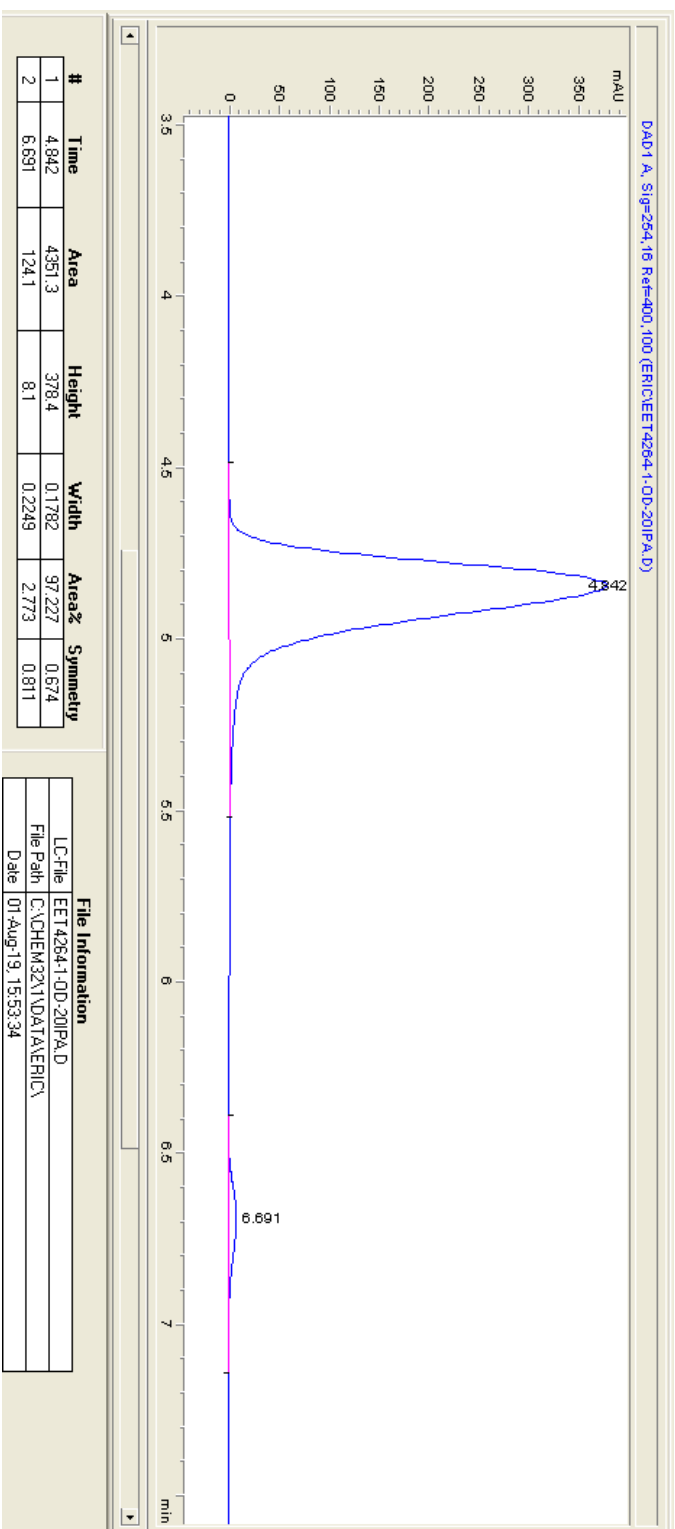


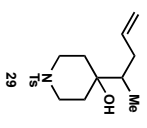
SFC, OD-H, 20% IPA, CO₂
2.0 mL/min
racemic



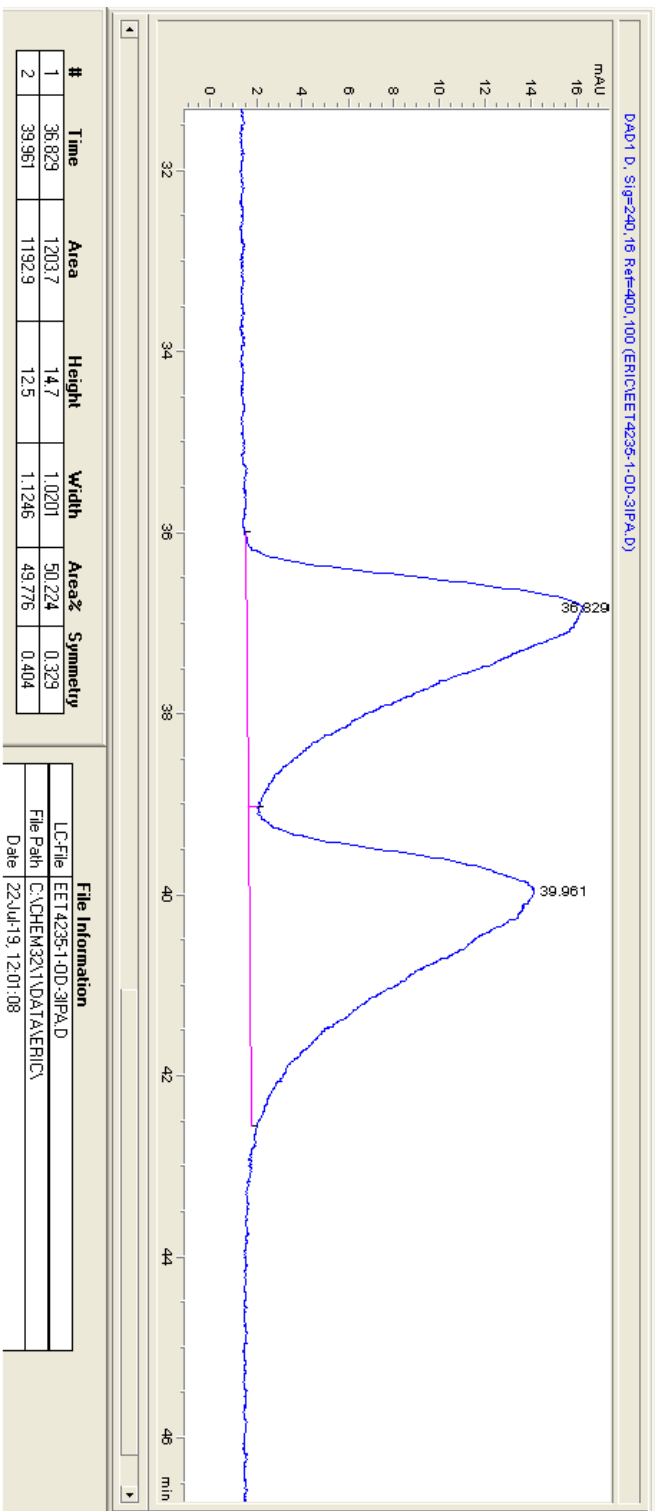


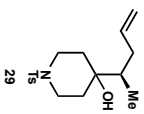
SFC, OD-H, 20% IPA/CO₂
2.0 mL/min
enantioenriched
94% ee



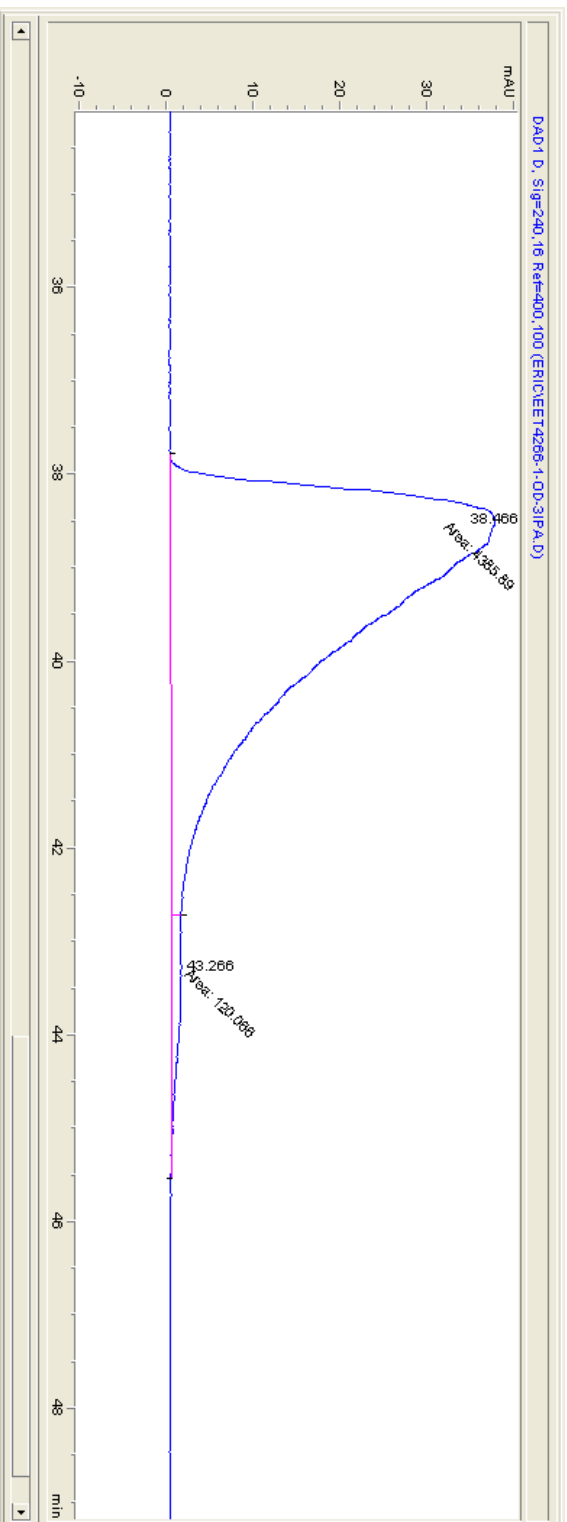


SFC, OD-H, 3% iPA/CO₂
2.0 mL/min
racemic



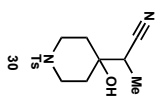


SFC, OD-H, 3% IPA/CO₂
2.0 mL/min
enantiomerized
95% ee

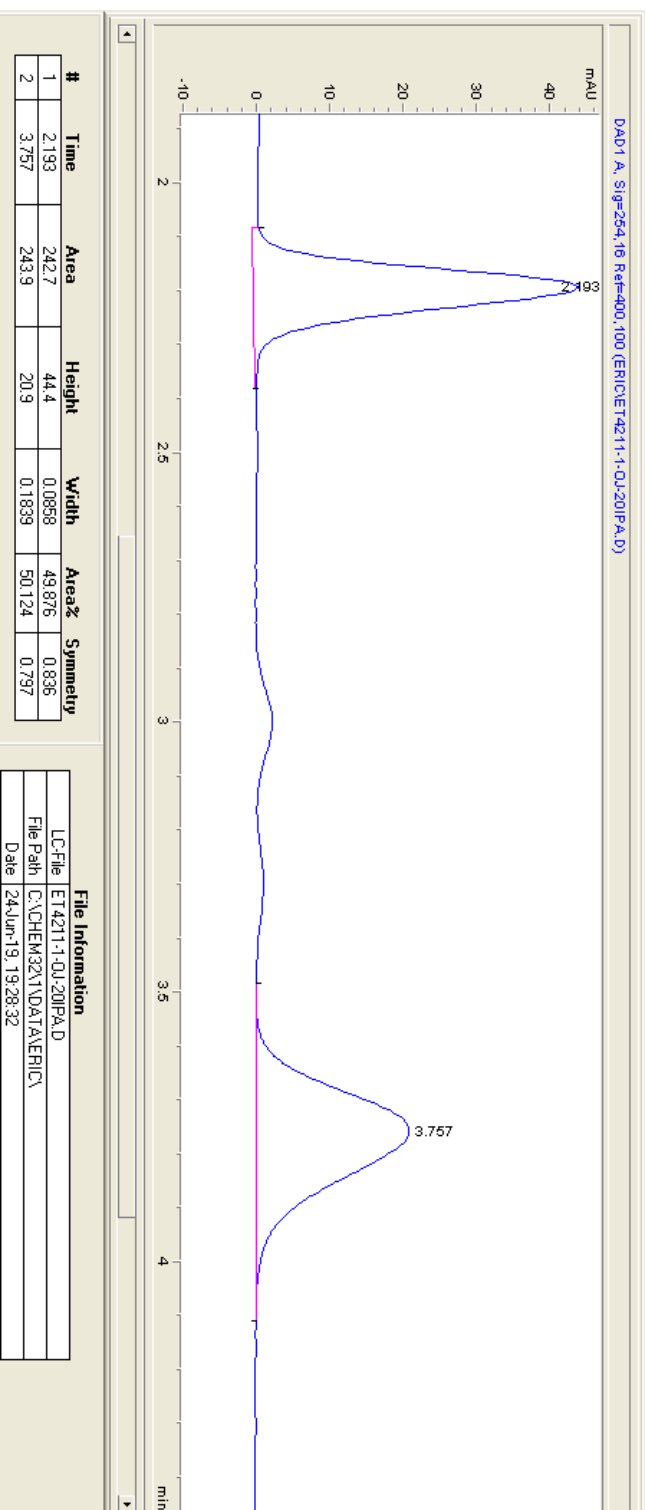


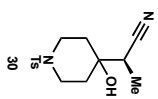
#	Time	Area	Height	Width	Area%	Symmetry
1	38.466	4385.9	37.4	1.9544	97.335	0.201
2	43.266	120.1	1.2	1.6246	2.665	0.495

File Information	
LC-File	EET4266-1-OD-3IPAD
File Path	C:\CHEM32\1\DATA\ERICA\
Date	01-Aug-19, 16:11:34



SFC, OJ-H, 20% IPAC:CO₂
2.0 mL/min
racemic





SFC, OJ-H, 20% IPA:CO₂
2.0 mL/min
enantiomerized
95% ee

