Supporting Information

Dealkenylative thiylation of C(sp^3)–C(sp^2) bonds

Andrew J. Smaligo and Ohyun Kwon*

Department of Chemistry and Biochemistry, University of California, Los Angeles, California 90095-1569, United States

*ohyun@chem.ucla.edu

Table of Contents

1. Materials and Methods

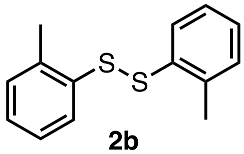
Unless otherwise stated, reactions were performed in flame-dried glassware fitted with rubber septa under an argon atmosphere and were stirred with Teflon-coated magnetic stirring bars. Liquid reagents and solvents were transferred via syringe using standard Schlenk techniques. Methanol (MeOH) was distilled over magnesium under an argon atmosphere. Dichloromethane and triethylamine were distilled over calcium hydride under an argon atmosphere. Tetrahydrofuran (THF), benzene, toluene, and diethyl ether were distilled over sodium/benzophenone ketyl under an argon atmosphere. All other solvents and reagents were used as received from commercial sources, unless otherwise noted. Reaction temperatures above 23 °C refer to oil bath temperatures. Thin layer chromatography (TLC) was performed using SiliCycle silica gel 60 F-254 precoated plates (0.25 mm) and visualized under UV irradiation, with a cerium ammonium molybdate (CAM) stain or a potassium permanganate ($KMnO_4$) stain. SiliCycle Silica-P silica gel (particle size: 40–63 µm) was used for flash column chromatography. ^1H and ^{13}C NMR spectra were recorded using Bruker AV-500, DRX-500, and AV-400 MHz spectrometers, with ^{13}C NMR spectroscopic operating frequencies of 125, 125, and 100 MHz, respectively. Chemical shifts (δ) are reported in parts per million (ppm) relative to the residual protonated solvent: $CDCl_3$ signal (δ = 7.26 for ^1H NMR; δ = 77.2 for ^{13}C NMR), C_6D_6 signal (δ = 7.16 for ^1H NMR; δ = 128.1 for ^{13}C NMR), or DMSO-d_6 (δ = 2.50 for ^1H NMR; δ = 39.5 for ^{13}C NMR). Data for ^1H NMR spectra are reported as follows: chemical shift, multiplicity, coupling constants (Hz), and number of hydrogen atoms. Data for ^{13}C NMR spectra are reported in terms of chemical shift. The following abbreviations are used to describe the multiplicities: s = singlet; d = doublet; t = triplet; q = quartet; quint = quintet; m = multiplet; br = broad. Melting points (MP) are uncorrected and were recorded using an Electrothermal® capillary melting point apparatus. IR spectra were recorded on a Jasco FTIR-4100 spectrometer with an ATR attachment. Optical rotations were recorded using an Autopol IV polarimeter and a 100-mm cell, at concentrations close to 1 g/100 mL. HRMS (ESI) was performed using a Waters LCT Premier spectrometer equipped with ACQUITY UPLC system and autosampler. HRMS (DART) was performed using a Thermo Fisher Scientific Exactive Plus spectrometer equipped with an IonSense ID-CUBE DART source. X-ray crystallographic data were collected using a Bruker SMART CCD-based diffractometer equipped with a low-temperature apparatus operated at 100 K. Ozonolysis experiments were performed using a Globalozone GO-D3G (3 g/h) ozone generator (2.0 L/min, 50% power, O_2 feed gas).

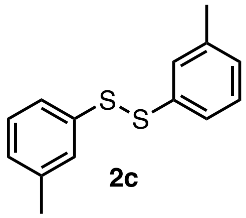
Caution: Ozone is an extremely toxic and reactive oxidant that can react with some compounds to form explosive and shock-sensitive products. Although we have not encountered any ozone-related safety issues in our lab, reactions with ozone should be performed only by properly trained individuals in a well-ventilated fume hood (use of a blast-shield is also recommended, especially for reactions performed on larger scales).

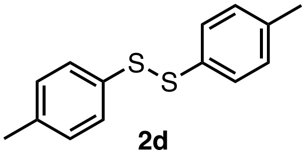
2. Starting Material Preparation

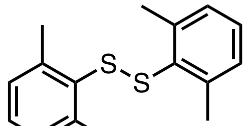
The disulfides **2a**, **2k** and **2l** were purchased from commercial sources and used as received.

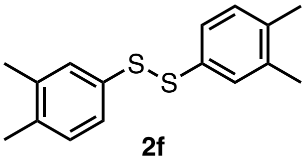
The substrates **1i**, **1l**, **1o**, **1q**, **4a**, **4b**, **4g**, **6a**, **6b**, **6d**, **6e**, and **6g** were purchased from commercial sources and used as received.

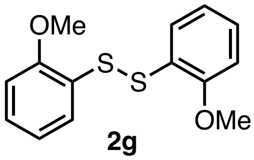

2b

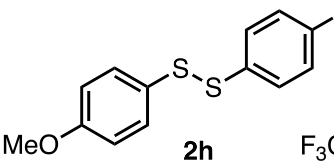

2c

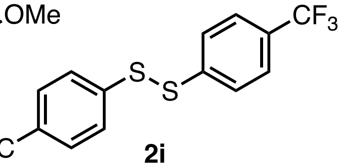

2d

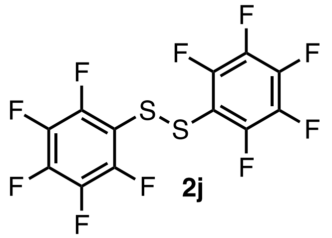

2e


2f

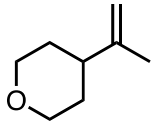

2g


2h


2i


2j

The disulfides **2b**–**2j** were prepared following a literature procedure.[1]


1a

Substrate **1a** was prepared using the following procedure adapted from the literature:[2]

A flame-dried round-bottom flask equipped with a magnetic stirrer bar was charged under an argon atmosphere with methyltriphenylphosphonium bromide (27.8 g, 78.0 mmol, 2.0 equiv) and anhydrous THF (0.4 M), then cooled to 0 °C in an ice-water bath. The flask was quickly charged with potassium *tert*-butoxide (8.70 g, 78.0 mmol, 2.0 equiv), and the resulting yellow suspension was stirred for 1 h at 0 °C. 1-(Tetrahydro-2*H*-pyran-4-yl)ethanone (5.00 g, 39.0 mmol, 1.0 equiv) was added dropwise via syringe. After the addition, the mixture was slowly warmed to room temperature and stirred for an additional 16 h. The reaction mixture was poured into 1.0 M aqueous hydrochloric acid (100 mL) and extracted with diethyl ether (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO_2) provided pure **1a**.

*39.0 mmol scale reaction

Yield: 57% (3.60 g).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 4.73 (s, 1H), 4.70 (s, 1H), 4.01 (dd, *J* = 11.2, 4.0 Hz, 2H), 3.41 (ddd, *J* = 11.7, 11.7, 1.7 Hz, 2H), 2.09 (dddd, *J* = 11.7, 11.7, 3.5, 3.5 Hz, 1H), 1.28 (s, 3H), 1.63 (d, *J* = 11.6 Hz, 2H), 1.54 (ddd, *J* = 24.9, 12.2, 4.2 Hz, 2H).

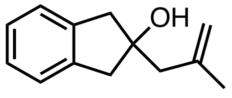
^{13}C NMR (125 MHz, CDCl$_3$): δ 148.9, 108.7, 68.1, 42.3, 31.5, 20.6.

IR (neat, ATR): ν_{max} 2936, 2918, 2840, 1645, 1132, 1091, 888 cm^{-1}.

HRMS (DART): calc'd for $C_8H_{15}O$ $[M + H]^+$ 127.1117, found 127.1121.

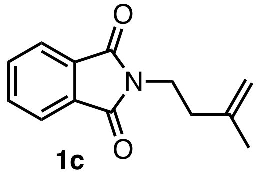
***R*$_f$** = 0.33 (5% EtOAc/hexanes).

Purification: (SiO$_2$, 5% EtOAc/hexanes).



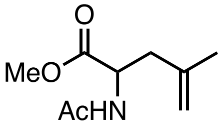
1b

Substrate **1b** was prepared following a literature procedure.[3]



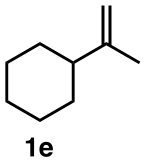
1c

Substrate **1c** was prepared following a literature procedure.[4]



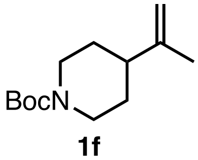
1d

Substrate **1d** was prepared following a literature procedure.[5]



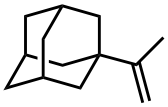
1e

Substrate **1e** was prepared following a literature procedure.[2]



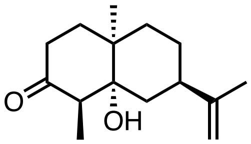
1f

Substrate **1f** was prepared following a literature procedure.[6]

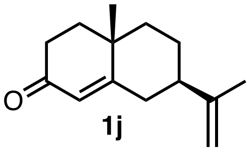


1g

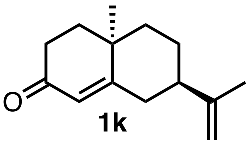
Substrate **1g** was prepared following a literature procedure.[4]



1h

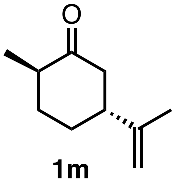


1j



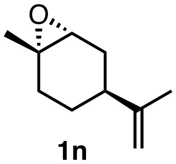
1k

Substrates **1h**, **1j**, and **1k** were prepared following literature procedures.[7]



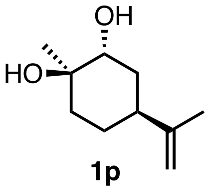
1m

Substrate **1m** was obtained in pure trans form following a literature procedure.[7]



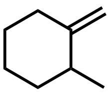
1n

Substrate **1n** was obtained in pure cis form following a literature procedure.[8]



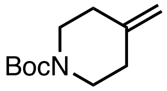
1p

Substrate **1p** was prepared following a literature procedure.[9]



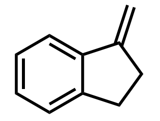
4c

Substrate **4c** was prepared following a literature procedure.[10]



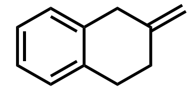
4d

Substrate **4d** was prepared following a literature procedure.[4]



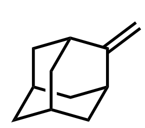
4e

Substrate **4e** was prepared following a literature procedure.[11]



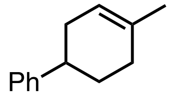
4f

Substrate **4f** was prepared following a literature procedure.[12]



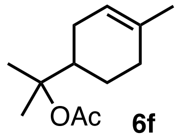
4h

Substrate **4h** was prepared following a literature procedure.[12]



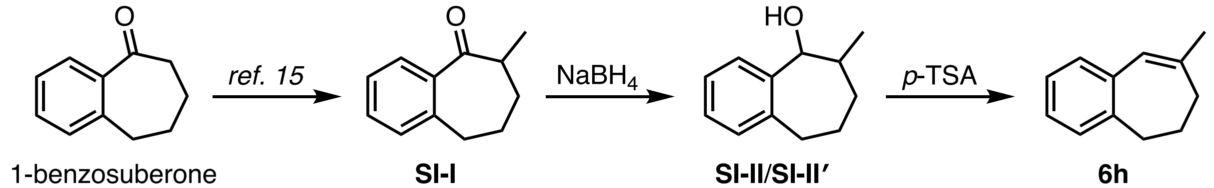
6c

Substrate **6c** was prepared following a literature procedure.[13]



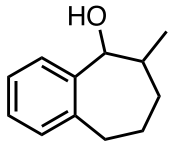
6f

Substrate **6f** was prepared following a literature procedure.[14]



Substrate **6h** was prepared from 1-benzosuberone by following the reaction sequence displayed above.

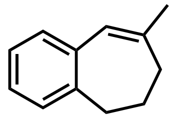
A round-bottom flask equipped with a magnetic stirrer bar was charged with the ketone **SI-I** (697 mg, 4.00 mmol, 1.0 equiv) and anhydrous MeOH (0.3 M), then cooled to 0 °C in an ice-water bath. Sodium borohydride (303 mg, 8.00 mmol, 2.0 equiv) was added in three equal portions over 10 min. The reaction mixture was warmed to room temperature and stirred until the starting material had been consumed (TLC). Upon completion, the reaction was quenched with water, and the aqueous layer was extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO_2) provided the alcohols **SI-II/SI-II′** (1:1 *d.r.*).



SI-II/SI-II′

*4.0 mmol scale reaction
Yield: 87% (615 mg).
Diastereomeric Ratio: 1:1 (*cis*/*trans*).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.36–7.28 (m, 2H), 7.22–7.13 (m, 4H), 7.12–7.06 (m, 2H), 4.89 (br s, 1H), 4.62 (d, J = 7.1 Hz, 1H), 3.11–2.92 (m, 2H), 2.72–2.61 (m, 2H), 2.19–1.99 (m, 3H), 1.96–1.50 (m, 9H), 0.91 (d, J = 7.0 Hz, 3H), 0.86 (d, J = 6.5 Hz, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 141.9, 141.7, 141.5, 141.1, 129.5, 129.4, 127.5, 127.3, 127.0, 126.7, 125.8, 125.8, 79.4, 77.2, 37.6, 36.4, 35.5, 35.1, 34.4, 33.3, 24.7, 23.8, 17.3, 16.5.
IR (neat, ATR): ν_{max} 3373, 3028, 2921, 2857, 1456, 1035, 749 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{12}H_{16}ONa$ [M + Na]$^+$ 199.1093, found 199.1084.
***R*$_f$** = 0.27 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 3 → 5% EtOAc/hexanes).

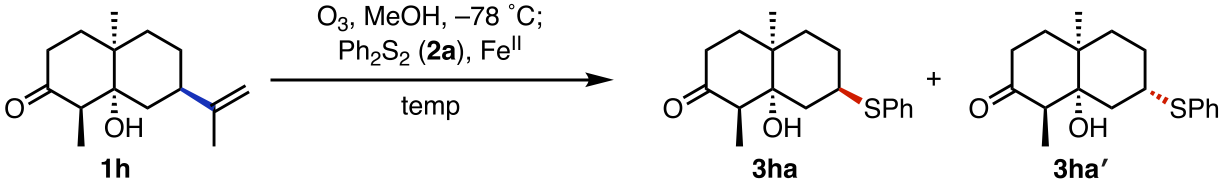
A round-bottom flask equipped with a magnetic stirrer bar was charged with the alcohols **SI-II**/**SI-II′** (616 mg, 3.50 mmol, 1.0 equiv), *p*-toluenesulfonic acid (30.1 mg, 0.175 mmol, 0.05 equiv), and anhydrous benzene (0.2 M). The flask was equipped with a Dean–Stark apparatus and a reflux condenser. The mixture was heated under reflux until the starting material had been consumed (TLC). Upon completion, the mixture was cooled to room temperature and poured into saturated aqueous sodium bicarbonate. The aqueous layer was extracted with EtOAc (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO$_2$) provided the dehydration product **6h**.



6h

*3.5 mmol scale reaction
Yield: 88% (487 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.22–7.07 (m, 4H), 6.33 (br s, 1H), 2.89–2.81 (m, 2H), 2.40–2.32 (m, 2H), 2.07–2.00 (m, 2H), 1.99 (s, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 141.1, 140.2, 136.6, 130.2, 128.7, 126.0, 125.8, 125.7, 36.4, 35.4, 27.3, 27.1.
IR (neat, ATR): ν_{max} 3056, 3020, 2925, 2893, 2865, 1496, 1436, 753, 734 cm^{-1}.
HRMS (DART): calc'd for $C_{12}H_{15}$ [M + H]$^+$ 159.1168, found 159.1157.
***R*$_f$** = 0.61 (hexanes).
Purification: (SiO$_2$, pentane).

3. Reaction Optimization



A 10-mL vial equipped with a magnetic stirrer bar was charged with the hydroxy ketone **1h** (47.3 mg, 0.200 mmol, 1.0 equiv) and MeOH (0.05 M), then placed in a dry-ice/acetone bath and cooled to –78 °C while open to air. Ozone was bubbled through the solution until complete consumption of the starting material (TLC, with CAM stain). The solution was then sparged with argon for 5 min to expel excess ozone. Diphenyl disulfide (**2a**) was added at the specified temperature, the mixture was stirred for 10 min, and then the Fe^{II} salt was added. Upon complete conversion of the intermediate α-alkoxy hydroperoxides (TLC), 1-chloro-2,4-dinitrobenzene (40.5 mg, 0.200 mmol, 1.0 equiv) was added to the reaction mixture. A 1.0-mL aliquot was removed and placed under high vacuum until the solvent had evaporated. Deuterated chloroform was added to the vial, and then the mixture was filtered through a short Celite plug directly into an NMR tube.

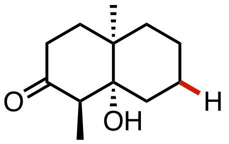
Table S1. Optimization of reaction conditions

entry	**Ph_2S_2 (equiv)**	**Fe^{II} (equiv)**	**temp (˚C)**	**cosolvent[a]**	**yield[b]**	***d.r.*[c]**
1	1.2	$FeSO_4\cdot 7H_2O$ (1.2)	–78	-	46	8:1
2	1.2	$FeSO_4\cdot 7H_2O$ (1.2)	0	-	62	5.8:1
3	1.2	$FeSO_4\cdot 7H_2O$ (1.2)	rt	-	63	5.6:1
4	1.2	$FeSO_4\cdot 7H_2O$ (1.2)	30	-	61	5.1:1
5	1.2	$FeSO_4\cdot 7H_2O$ (1.2)	40	-	59	4.9:1
6	1.2	$FeSO_4\cdot 7H_2O$ (1.2)	50	-	53	4.9:1
7	1.2	$FeSO_4\cdot 7H_2O$ (1.2)	60	-	46	4.1:1
8	1.5	$FeSO_4\cdot 7H_2O$ (1.2)	rt	-	62	5.8:1
9	2.0	$FeSO_4\cdot 7H_2O$ (1.2)	rt	-	66	5.6:1
10	2.5	$FeSO_4\cdot 7H_2O$ (1.2)	rt	-	67	5.7:1
11	3.0	$FeSO_4\cdot 7H_2O$ (1.2)	rt	-	70	5.9:1
12	4.0	$FeSO_4\cdot 7H_2O$ (1.2)	rt	-	68	6:1
13	5.0	$FeSO_4\cdot 7H_2O$ (1.2)	rt	-	70	5.9:1
14	3.0	$FeSO_4\cdot 7H_2O$ (0.5)	rt	-	28	6:1
15	3.0	$FeSO_4\cdot 7H_2O$ (1.0)	rt	-	63	6:1
16	3.0	$FeSO_4\cdot 7H_2O$ (1.5)	rt	-	70	5.9:1
17	3.0	$FeSO_4\cdot 7H_2O$ (2.0)	rt	-	65	6.2:1
18	3.0	$FeCl_2\cdot 4H_2O$ (1.2)	rt	-	trace	ND
19	3.0	$Fe(NH_4)_2(SO_4)_2\cdot 6H_2O$ (1.2)	rt	-	11	10:1
20	3.0	$Fe(BF_4)_2\cdot 6H_2O$ (1.2)	rt	-	50	2.6:1
21	3.0	$Fe(ClO_4)_2\cdot 6H_2O$ (1.2)	rt	-	28	10:1
22	3.0	$FeC_2O_4\cdot 2H_2O$ (1.2)	rt	-	14	6:1
23	3.0	ferrous gluconate$\cdot 2H_2O$ (1.2)	rt	-	14	6:1

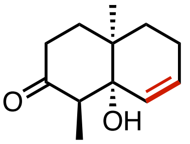
24	3.0	ferrous phthalocyanine (1.2)	rt	-	25	5:1
25	3.0	Fe(OTf)$_2$ (1.2)	rt	-	21	6:1
26	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	41[d]	2.2:1
27	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	68[e]	6.2:1
28	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	60[f]	6:1
29	3.0	$FeSO_4·7H_2O$ (1.2)	rt	DCM	52	3:1
30	3.0	$FeSO_4·7H_2O$ (1.2)	rt	EtOH	20	3:1
31	3.0	$FeSO_4·7H_2O$ (1.2)	rt	2-PrOH	13	5.5:1
32	3.0	$FeSO_4·7H_2O$ (1.2)	rt	MeCN	11	4.5:1
33	3.0	$FeSO_4·7H_2O$ (1.2)	rt	acetone	8	7:1
34	3.0	$FeSO_4·7H_2O$ (1.2)	rt	benzene	23	2.8:1
35	3.0	$FeSO_4·7H_2O$ (1.2)	rt	THF	16	1.8:1
36	3.0	$FeSO_4·7H_2O$ (1.2)	rt	toluene	21	3.2:1
37	3.0	$FeSO_4·7H_2O$ (1.2)	rt	DCE	36	2.3:1
38	3.0	$FeSO_4·7H_2O$ (1.2)	rt	water	32	3.6:1
39	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	70[g]	5.4:1
40	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	65[h]	5.5:1
41	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	70[i]	6:1
42	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	68[j]	5.8:1
43	3.0	$FeSO_4·7H_2O$ (1.2)	rt	-	68[k]	6.6:1
44	**3.0**	**$FeSO_4·7H_2O$ (1.2)**	**0 °C**	-	**83**[k]	**5.9:1**

[a] 1:1 Ratio MeOH/cosolvent. [b] Combined yield of **3ha** + **3ha′**, determined by ^{1}H-NMR using 1-chloro-2,4-dinitrobenzene as an internal standard. [c] Diastereomeric ratio determined by ^{1}H-NMR. [d] 0.01 M. [e] 0.025 M. [f] 0.1 M. [g] $NaHCO_3$ additive (2.0 equiv). [h] pyridine additive (2.0 equiv). [i] Ar atmosphere. [j] oxygen atmosphere. [k] $FeSO_4·7H_2O$ added as 5 wt/vol% aqueous solution.

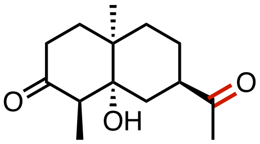
Note: The major byproduct formed during the dealkenylative thiylation was the hydrodealkenylation product **SI-III** along with small amounts of the elimination product **SI-IV**. Under some conditions (especially with the use of co-solvents and other iron salts), we observed appreciable formation of the ozonolysis product **SI-V** as well. The use of an aqueous solution of ferrous sulfate heptahydrate and an addition temperature of 0 °C minimized the formation of these byproducts (ca. 15% **SI-III**/**SI-IV** and trace amounts of **SI-V**). On larger scales (≥1.0 mmol), a concentration of 0.025 M provided results consistent with the optimized conditions. An analysis of the crude ^{1}H NMR spectrum for entry 44 is presented in Figure S1. A proposed mechanism for the formation of the major byproduct (**SI-III**) is provided in Figure S2.



SI-III



SI-IV



SI-V

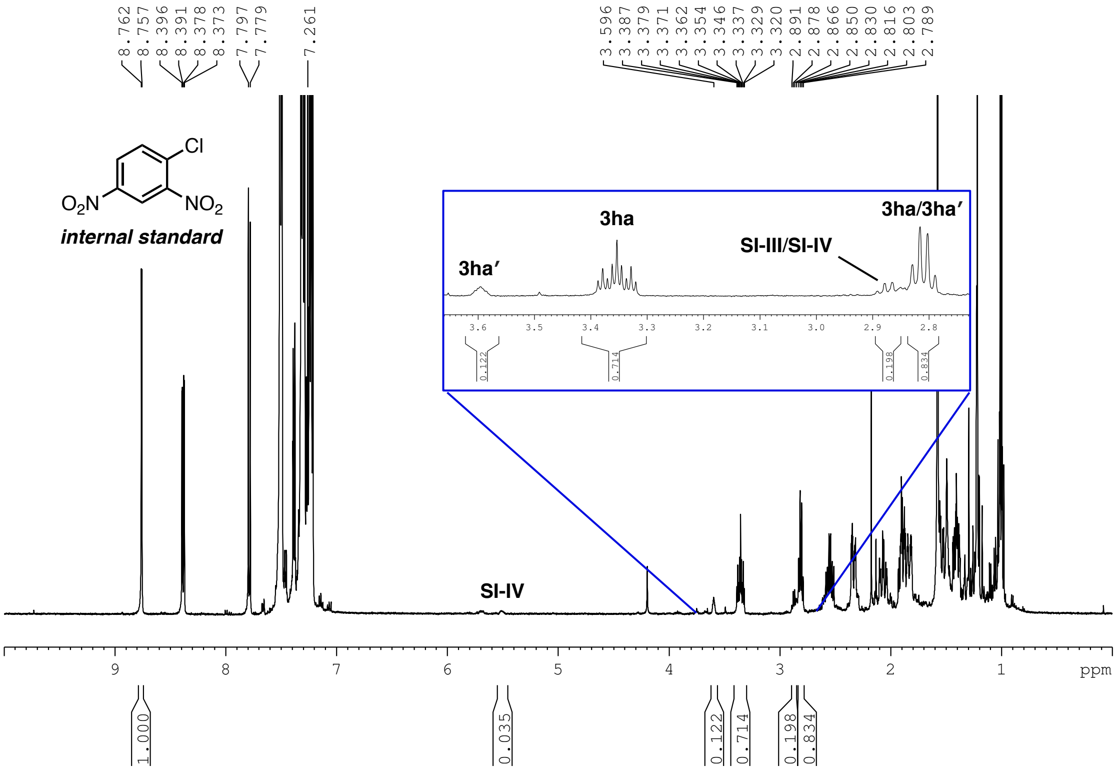


Figure S1. ^{1}H NMR spectrum of crude **3ha**/**3ha′** (Table S1, entry 44).

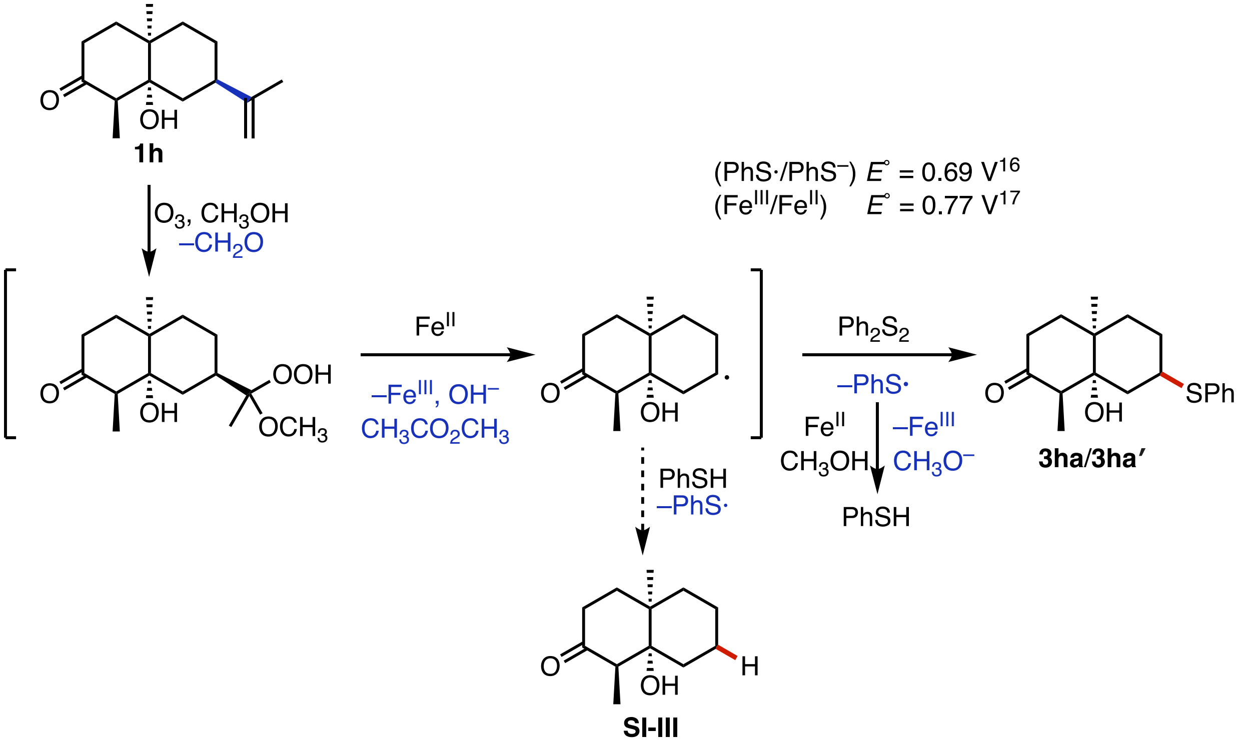
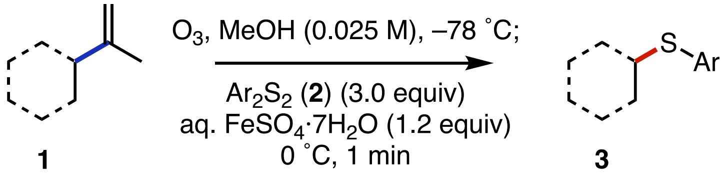


Figure S2. Proposed mechanism for the formation of **SI-III**.

4. Experimental Procedures and Characterization Data

4.1. General Procedure for Dealkenylative Thiylation



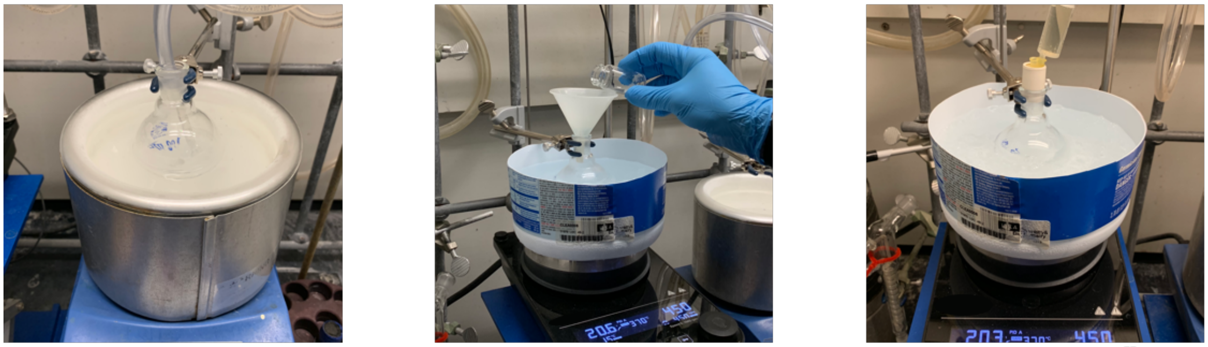
A round-bottom flask equipped with a magnetic stirrer bar was charged with **1** (1.0 equiv) and MeOH (0.025 M), then cooled to –78 °C with a dry-ice/acetone bath while open to the air. Ozone was bubbled through the solution until complete consumption of the starting material (as indicated by TLC and/or a blue color in the reaction mixture). The solution was then sparged with argon for 5 min to expel excess ozone. The aryl disulfide (**2**, 3.0 equiv) was added and then the reaction mixture was warmed to 0 °C in an ice-water bath and stirred for 10 min. An aqueous solution (5%, wt/vol) of ferrous sulfate heptahydrate (1.2 equiv) was added over a period of approximately 1 min. Upon completion of the reaction (TLC), the mixture was diluted with water and transferred to a separatory funnel. The MeOH/water layer was extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO_2) provided the thiylated product **3**.

Any modification of the above procedure is described below with the specific entry.

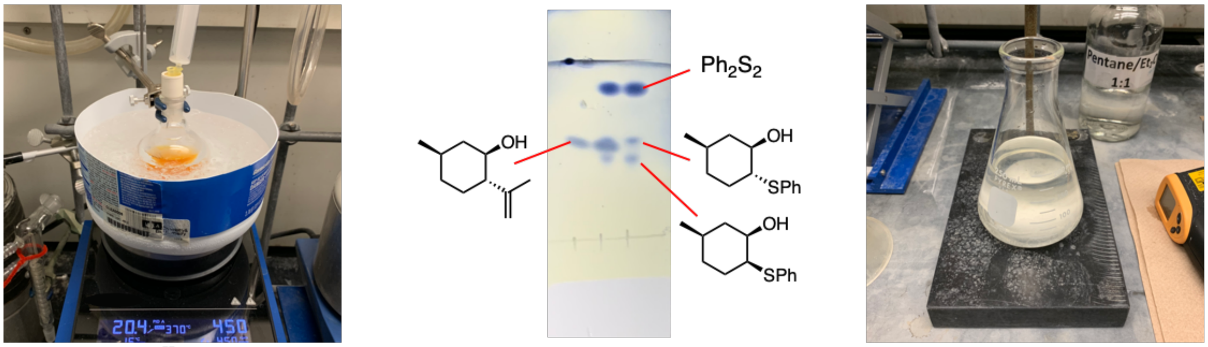
Note: All solid aryl disulfides were ground to a fine powder prior to use.

4.2. Graphical Procedure for Dealkenylative Thiylation

Cooling to –78 ˚C Complete consumption of SM after O_3 TLC after O_3 (20% EA/HEX)



Argon sparge Ph_2S_2 addition at 0 ˚C Addition of aq. Fe^{II}

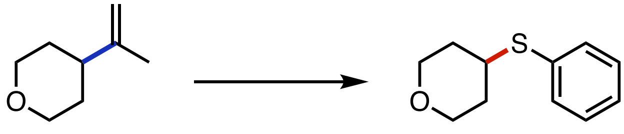


After Fe^{II} addition TLC after all additions (20% EA/HEX) Organic layer after aqueous workup

Figure S3. Graphical procedure for the synthesis of the thioether **3la**/**3la′**.

4.3. Characterization Data

Note: For products that generated a stereocenter at the newly formed C–S bond, structural assignments were based on a combination of 1D and 2D NMR spectroscopy experiments. It is known that tertiary and secondary axial/equatorial protons in cyclohexane derivatives typically appear at different fields (an axial proton resonance shift is upfield relative to the resonance shift of an equatorial proton).[18] Additionally, the coupling constant between neighboring axial protons is generally 2–3 times as large as the coupling constant between two neighboring equatorial protons. As a result, the signal for an axial α-proton is much broader relative to that of an equatorial α-proton. All structural assignments are consistent with these observations, which were further supported by single-crystal X-ray diffraction of the thioether **3la′** and the sulfone **8**.


1a **3aa**

*1.0 mmol scale reaction

Yield: 80% (155 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.45–7.40 (m, 2H), 7.24–7.28 (m, 2H), 7.28–7.23 (m, 1H), 3.97 (ddd, *J* = 11.7, 3.7, 3.7 Hz, 2H), 3.43 (ddd, *J* = 11.2, 11.2, 2.5 Hz, 2H), 3.27 (dddd, *J* = 10.6, 10.6, 4.0, 4.0 Hz, 1H), 1.95–1.87 (m, 2H), 1.67 (dddd, *J* = 13.7, 10.7, 10.7, 4.2 Hz, 2H).

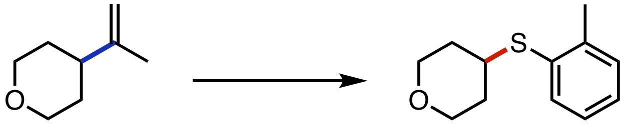
^{13}C NMR (125 MHz, CDCl$_3$): δ 133.6, 132.6, 128.8, 127.2, 67.2, 43.3, 33.1.

IR (neat, ATR): ν_{max} 3073, 3058, 2946, 2843, 1085, 740, 691 cm^{-1}.

HRMS (DART): calc'd for $C_{11}H_{14}OSNa$ [M + Na]$^+$ 217.0658, found 217.0661.

***R*$_f$** = 0.40 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).


1a **3ab**

*1.0 mmol scale reaction

Yield: 77% (160 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.42–7.37 (m, 1H), 7.24–7.19 (m, 1H), 7.19–7.12 (m, 2H), 3.98 (ddd, *J* = 11.7, 3.8, 3.8 Hz, 2H), 3.44 (ddd, *J* = 11.2, 11.2, 2.3 Hz, 2H), 3.27 (dddd, *J* = 10.5, 10.5, 4.0, 4.0 Hz, 1H), 2.44 (s, 3H), 1.96–1.87 (m, 2H), 1.76–1.65 (m, 2H).

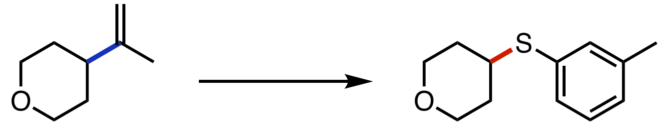
^{13}C NMR (125 MHz, CDCl$_3$): δ 140.0, 133.1, 132.3, 130.3, 127.0, 126.2, 67.2, 42.7, 33.1, 20.8.

IR (neat, ATR): ν_{max} 3059, 2944, 2921, 2843, 1468, 1085, 743, 691 cm^{-1}.

HRMS (DART): calc'd for $C_{12}H_{17}OS$ [M + H]$^+$ 209.0995, found 209.0955.

***R*$_f$** = 0.42 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).


1a **3ac**

*1.0 mmol scale reaction

Yield: 64% (133 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.26–7.16 (m, 3H), 7.09–7.05 (m, 1H), 3.97 (ddd, *J* = 11.7, 3.7, 3.7 Hz, 2H), 3.43 (ddd, *J* = 11.2, 11.2, 2.5 Hz, 2H), 3.26 (dddd, *J* = 10.6, 10.6, 4.0, 4.0 Hz, 1H), 2.34 (s, 3H), 1.94–1.87 (m, 2H), 1.72–1.62 (m, 2H).

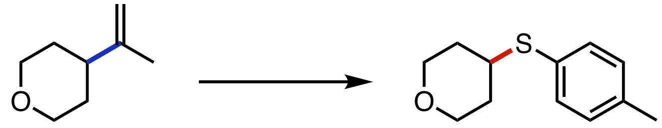
^{13}C NMR (125 MHz, CDCl$_3$): δ 138.6, 133.3, 133.2, 129.6, 128.6, 128.0, 67.2, 43.3, 33.1, 21.2.

IR (neat, ATR): ν_{max} 3058, 2945, 2843, 1591, 1131, 1085, 778 cm^{-1}.

HRMS (DART): calc'd for $C_{12}H_{17}OS$ $[M + H]^+$ 209.0995, found 209.0985.

***R*$_f$** = 0.45 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).


1a **3ad**

*1.0 mmol scale reaction

Yield: 71% (148 mg).

Physical State: colorless oil.

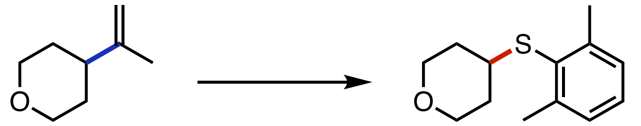
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.34 (d, *J* = 8.1 Hz, 2H), 7.12 (d, *J* = 7.9 Hz, 2H), 3.96 (ddd, *J* = 11.6, 3.7, 3.7 Hz, 2H), 3.41 (ddd, *J* = 11.3, 11.3, 2.1 Hz, 2H), 3.18 (dddd, *J* = 10.7, 10.7, 4.0, 4.0 Hz, 1H), 2.34 (s, 3H), 1.92–1.84 (m, 2H), 1.65 (dddd, *J* = 13.7, 10.7, 10.7, 4.1 Hz, 2H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 137.5, 133.4, 129.7, 129.6, 67.3, 43.8, 33.1, 21.0.

***R*$_f$** = 0.48 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).

All characterization data are consistent with that reported in the literature.[19]


1a **3ae**

*1.0 mmol scale reaction

Yield: 70% (156 mg).

Physical State: white solid.

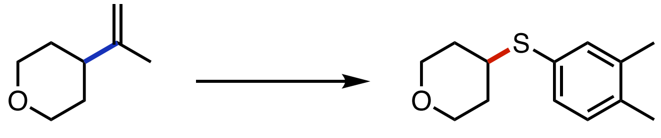
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.16–7.08 (m, 3H), 3.95 (ddd, *J* = 11.6, 3.7, 3.7 Hz, 2H), 3.36 (ddd, *J* = 11.2, 11.2, 2.6 Hz, 2H), 3.02 (dddd, *J* = 10.5, 10.5, 4.3, 4.3 Hz, 1H), 2.55 (s, 6H), 1.81–1.74 (m, 2H), 1.74–1.65 (m, 2H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 143.4, 131.8, 128.2, 128.0, 67.4, 43.7, 33.4, 22.2.

MP: 40 ˚C.

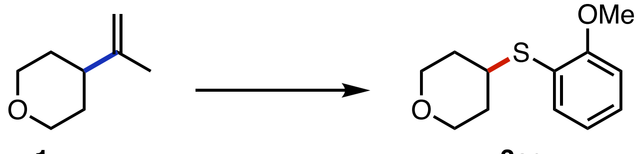
IR (neat, ATR): ν_{max} 3056, 2996, 2842, 1459, 1085, 830, 770 cm^{-1}.

HRMS (DART): calc'd for $C_{13}H_{19}OS$ $[M + H]^+$ 223.1151, found 223.1178.
***R*$_f$** = 0.57 (10% EtOAc/hexanes).
Purification: (SiO_2, 2 → 5% EtOAc/hexanes).



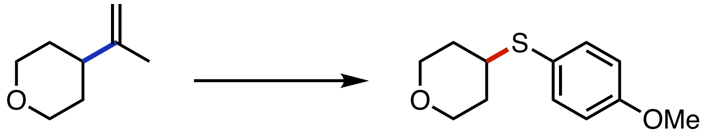
1a **3af**

*1.0 mmol scale reaction
Yield: 62% (138 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.23 (d, *J* = 1.2 Hz, 1H), 7.18 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.07 (d, *J* = 7.8 Hz, 1H), 3.96 (ddd, *J* = 11.6, 3.7, 3.7 Hz, 2H), 3.41 (ddd, *J* = 11.3, 11.3, 2.2 Hz, 2H), 3.18 (dddd, *J* = 10.7, 10.7, 4.0, 4.0 Hz, 1H), 2.24 (s, 6H), 1.92–1.85 (m, 2H), 1.70–1.61 (m, 2H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 137.2, 136.2, 134.6, 130.8, 130.0, 129.9, 67.3, 43.7, 33.1, 19.6, 19.3.
IR (neat, ATR): ν_{max} 3014, 2942, 2920, 2843, 1130, 1085, 884, 815 cm^{-1}.
HRMS (DART): calc'd for $C_{13}H_{19}OS$ $[M + H]^+$ 223.1151, found 223.1162.
***R*$_f$** = 0.48 (10% EtOAc/hexanes).
Purification: (SiO_2, 2 → 5% EtOAc/hexanes).



1a **3ag**

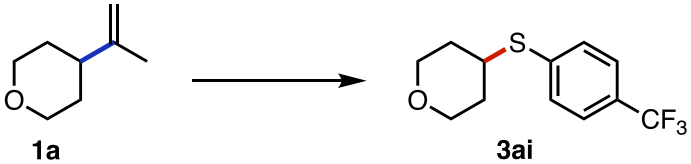
*1.0 mmol scale reaction
Yield: 51% (114 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.38 (dd, *J* = 7.6, 1.6 Hz, 1H), 7.25 (ddd, *J* = 8.1, 7.5, 1.6 Hz, 1H), 6.96–6.85 (m, 2H), 3.97 (ddd, *J* = 11.7, 3.8, 3.8 Hz, 2H), 3.89 (s, 3H), 3.44 (ddd, *J* = 11.2, 11.2, 2.4 Hz, 2H), 3.41–3.35 (m, 1H), 1.93–1.84 (m, 2H), 1.73–1.60 (m, 2H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 158.7, 133.5, 128.6, 121.5, 120.8, 110.7, 67.2, 55.7, 41.2, 32.9.
IR (neat, ATR): ν_{max} 3059, 2944, 2838, 1473, 1239, 1020, 746 cm^{-1}.
HRMS (DART): calc'd for $C_{12}H_{17}O_2S$ $[M + H]^+$ 225.0944, found 225.0954.
***R*$_f$** = 0.27 (10% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% EtOAc/hexanes).



1a **3ah**

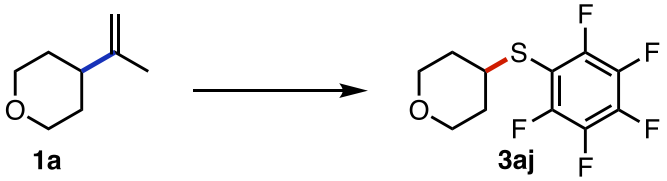
*1.0 mmol scale reaction
Yield: 75% (167 mg).
Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.44–7.37 (m, 2H), 6.88–6.82 (m, 2H), 3.95 (ddd, *J* = 11.6, 3.6, 3.6 Hz, 2H), 3.80 (s, 3H), 3.38 (ddd, *J* = 11.3, 11.3, 2.1 Hz, 2H), 3.07 (dddd, *J* = 10.8, 10.8, 4.0, 4.0 Hz, 1H), 1.88–1.81 (m, 2H), 1.68–1.57 (m, 2H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 159.6, 136.0, 123.5, 114.3, 67.3, 55.2, 44.4, 33.1.
***R*$_f$** = 0.27 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 5 → 10% EtOAc/hexanes).
All characterization data are consistent with that reported in the literature.[20]



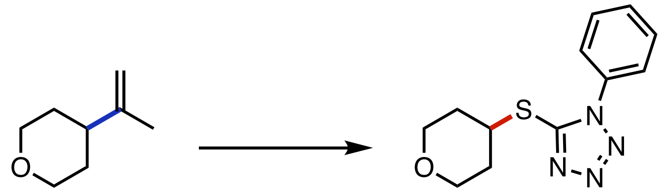
1a **3ai**

*1.0 mmol scale reaction
Yield: 50% (132 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.53 (dd, *J* = 8.6, 0.6 Hz, 2H), 7.45 (dd, *J* = 8.6, 0.6 Hz, 2H), 3.98 (ddd, *J* = 11.8, 3.8, 3.8 Hz, 2H), 3.47 (ddd, *J* = 11.6, 10.8, 2.3 Hz, 2H), 3.42 (dddd, *J* = 10.5, 10.5, 4.1, 4.1 Hz, 1H), 1.98–1.91 (m, 2H), 1.70 (dddd, *J* = 13.8, 10.5, 10.5, 4.1 Hz, 2H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 139.5 (q, $J_{C\text{–}F}$ = 1.3 Hz), 130.5, 128.5 (q, $J_{C\text{–}F}$ = 32.7 Hz), 125.6 (q, $J_{C\text{–}F}$ = 3.8 Hz), 123.9 (q, $J_{C\text{–}F}$ = 271.9 Hz), 67.1, 42.4, 32.8.
^{19}F NMR (282 MHz, CDCl$_3$): δ –62.6.
MP: 55 °C.
IR (neat, ATR): ν_{max} 2953, 2846, 1606, 1322, 1120, 1094, 1063, 1012, 829 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{12}H_{13}F_3OSNa$ [M + Na]$^+$ 285.0471, found 285.0458.
***R*$_f$** = 0.24 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).



1a **3aj**

*1.0 mmol scale reaction
Yield: 70% (199 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 3.96 (ddd, *J* = 11.8, 3.7, 3.7 Hz, 2H), 3.40 (ddd, *J* = 11.3, 11.3, 2.3 Hz, 2H), 3.29 (dddd, *J* = 10.7, 10.7, 4.1, 4.1 Hz, 1H), 1.89–1.81 (m, 2H), 1.72–1.61 (m, 2H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 147.8 (ddddd, $J_{C\text{–}F}$ = 245.6, 10.5, 4.0, 4.0, 4.0 Hz), 141.5 (ddddd, $J_{C\text{–}F}$ = 256.5, 13.6, 13.6, 5.1, 5.1 Hz), 137.5 (ddddd, $J_{C\text{–}F}$ = 253.7, 18.2, 12.8, 5.5, 2.1 Hz), 106.9 (ddd, $J_{C\text{–}F}$ = 21.5, 21.5, 4.1 Hz), 66.9, 43.9, 33.1.
^{19}F NMR (282 MHz, CDCl$_3$): δ –131.0, –131.0, –131.0, –131.1, –131.1, –131.1.
MP: 57 °C.
IR (neat, ATR): ν_{max} 2988, 2970, 2956, 2846, 1514, 1478, 970 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{11}H_{10}F_5OS$ [M + H]$^+$ 285.0367, found 285.0390.
***R*$_f$** = 0.40 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).



1a **3ak**

*1.0 mmol scale reaction

Yield: 51% (134 mg).

Physical State: white solid.

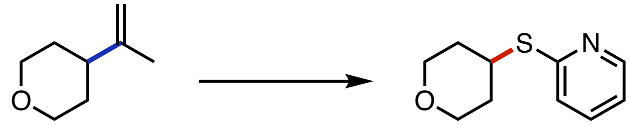
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.62–7.51 (m, 5H), 4.19 (dddd, J = 10.9, 10.9, 4.1, 4.1 Hz, 1H), 3.99 (ddd, J = 11.9, 3.7, 3.7 Hz, 2H), 3.58 (ddd, J = 11.8, 10.9, 2.2 Hz, 2H), 2.26–2.19 (m, 2H), 1.82 (dddd, J = 13.5, 10.8, 10.8, 4.2 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$): δ 153.3, 133.6, 130.2, 129.8, 124.0, 67.2, 43.8, 33.0.

***R*$_f$** = 0.20 (20% EtOAc/hexanes).

Purification: (SiO_2, 15 → 25% EtOAc/hexanes).

All characterization data are consistent with that reported in the literature.[21]



1a **3al**

*1.0 mmol scale reaction

Yield: 75% (148 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$): δ 8.41 (dd, J = 4.8, 0.8 Hz, 1H), 7.47 (ddd, J = 7.7, 7.7, 1.9 Hz, 1H), 7.16 (d, J = 8.1 Hz, 1H), 6.97 (ddd, J = 7.3, 5.0, 0.8 Hz, 1H), 4.06 (dddd, J = 10.5, 10.5, 4.1, 4.1 Hz, 1H), 3.97 (ddd, J = 11.7, 3.8, 3.8 Hz, 2H), 3.58 (ddd, J = 11.6, 10.5, 2.3 Hz, 2H), 2.11–2.02 (m, 2H), 1.84–1.71 (m, 2H).

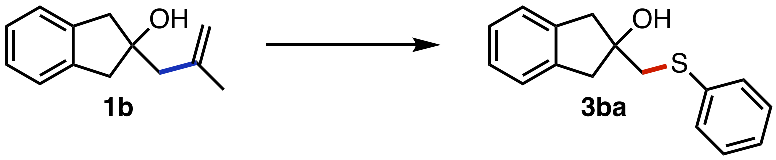
^{13}C NMR (125 MHz, $CDCl_3$): δ 158.1, 149.4, 135.9, 122.9, 119.5, 67.4, 39.3, 33.0.

IR (neat, ATR): ν_{max} 3045, 2952, 2843, 1577, 1556, 1452, 1414, 1122, 1084, 755, 722 cm^{-1}.

HRMS (DART): calc'd for $C_{10}H_{14}NOS$ $[M + H]^+$ 196.0791, found 196.0780.

***R*$_f$** = 0.27 (10% EtOAc/hexanes).

Purification: (SiO_2, 5 → 15% EtOAc/hexanes).



1b **3ba**

*1.0 mmol scale reaction

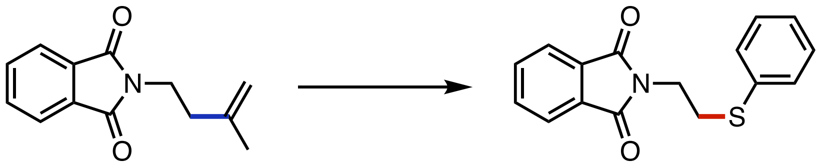
Yield: 71% (184 mg).

Physical State: white solid.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48–7.43 (m, 2H), 7.35–7.28 (m, 2H), 7.25–7.16 (m, 5H), 3.38 (s, 2H), 3.15–3.03 (m, 4H), 2.62 (s, 1H).

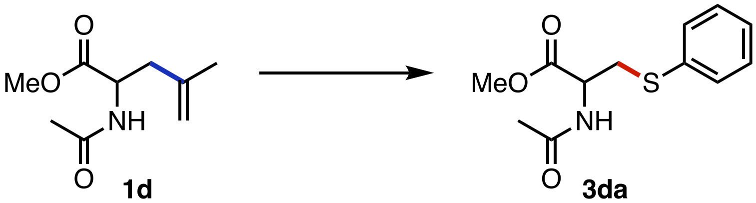
^{13}C NMR (125 MHz, $CDCl_3$): δ 140.6, 136.4, 129.7, 129.0, 126.7, 126.4, 124.8, 81.8, 46.2, 45.7.

MP: 72–74 °C.
IR (neat, ATR): ν_{max} 3418, 3069, 3058, 2937, 2922, 1480, 1023, 738 cm^{-1}.
HRMS (DART): calc'd for $C_{16}H_{15}S$ $[M - OH]^+$ 239.0889, found 239.0876.
***R*$_f$** = 0.50 (20% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% EtOAc/hexanes).



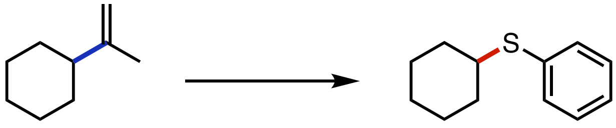
1c **3ca**

*1.0 mmol scale reaction
Yield: 80% (227 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.86–7.78 (m, 2H), 7.76–7.67 (m, 2H), 7.45–7.39 (m, 2H), 7.28–7.22 (m, 2H), 7.16–7.10 (m, 1H), 3.93 (dd, *J* = 7.0, 7.0 Hz, 2H), 3.23 (dd, *J* = 7.4, 6.7 Hz, 2H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 168.0, 134.7, 133.9, 131.9, 129.6, 128.9, 126.3, 123.2, 37.4, 31.5.
***R*$_f$** = 0.43 (20% EtOAc/hexanes).
Purification: (SiO_2, 5 → 15% EtOAc/hexanes).
All characterization data are consistent with that reported in the literature.[22]



1d **3da**

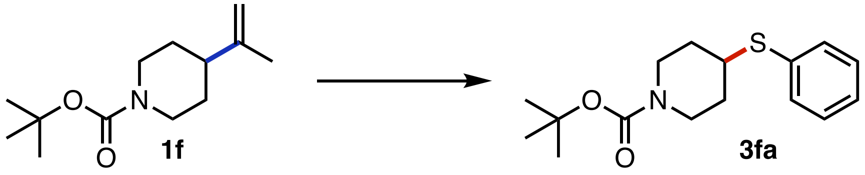
*1.0 mmol scale reaction
Yield: 58% (147 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.44–7.39 (m, 2H), 7.32–7.27 (m, 2H), 7.24–7.19 (m, 1H), 6.21 (d, *J* = 6.1 Hz, 1H), 4.87 (dt, *J* = 4.4, 7.6 Hz, 1H), 3.56 (s, 3H), 3.48 (dd, *J* = 14.3, 4.5 Hz, 1H), 3.36 (dd, *J* = 14.3, 4.5 Hz, 1H), 1.87 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 170.6, 169.6, 134.6, 130.9, 129.0, 127.0, 52.4, 52.3, 36.4, 22.8.
IR (neat, ATR): ν_{max} 3281, 3063, 2951, 1743, 1657, 1536, 1439, 1216 cm^{-1}.
HRMS (DART): calc'd for $C_{12}H_{16}NO_3S$ $[M + H]^+$ 254.0845, found 254.0830.
***R*$_f$** = 0.43 (50% EtOAc/hexanes).
Purification: (SiO_2, 30 → 60% EtOAc/hexanes).



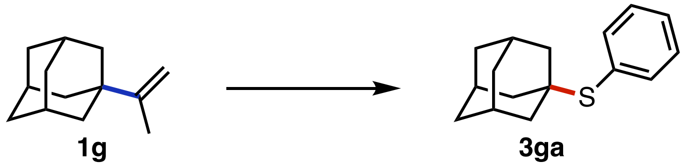
1e **3ea**

*1.0 mmol scale reaction
Yield: 82% (157 mg).
Physical State: colorless oil.

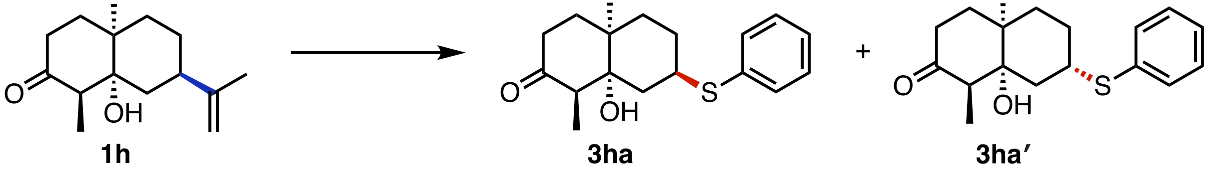
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.43–7.38 (m, 2H), 7.32–7.27 (m, 2H), 7.24–7.19 (m, 1H), 3.11 (dddd, J = 10.4, 10.4, 3.6, 3.6 Hz, 1H), 2.06–1.95 (m, 2H), 1.84–1.74 (m, 2H), 1.67–1.58 (m, 1H), 1.45–1.20 (m, 5H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 135.1, 131.8, 128.6, 126.5, 46.5, 33.2, 26.0, 25.7.
***R*$_f$** = 0.41 (pentane).
Purification: (SiO$_2$, pentane).
All characterization data are consistent with that reported in the literature.[23]



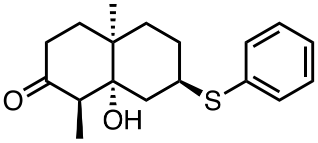
*1.0 mmol scale reaction
Yield: 79% (231 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.45–7.39 (m, 2H), 7.33–7.28 (m, 2H), 7.27–7.23 (m, 1H), 3.96 (br s, 2H), 3.21 (dddd, J = 10.2, 10.2, 3.9, 3.9 Hz, 1H), 2.91 (dd, J = 11.2, 11.2 Hz, 2H), 1.97–1.87 (m, 2H), 1.58–1.47 (m, 2H), 1.44 (s, 9H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 154.6, 133.7, 132.6, 128.8, 127.2, 79.5, 44.4, 32.0, 28.3, 28.2.
***R*$_f$** = 0.38 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 2 → 7% EtOAc/hexanes).
All characterization data are consistent with that reported in the literature.[24]



*1.0 mmol scale reaction
Yield: 74% (181 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.53–7.48 (m, 2H), 7.39–7.29 (m, 3H), 2.04–1.99 (m, 3H), 1.82 (d, J = 2.5 Hz, 6H), 1.68–1.57 (m, 6H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 137.6, 130.4, 128.4, 128.2, 47.7, 43.5, 36.1, 29.9.
***R*$_f$** = 0.31 (hexanes).
Purification: (SiO$_2$, 0 → 2% EtOAc/hexanes).
All characterization data are consistent with that reported in the literature.[25]



*1.0 mmol scale reaction
Combined Yield: 77% (234 mg).
Diastereomeric Ratio: 5.9:1 (determined from ^{1}H NMR spectrum of the crude products).



3ha

Yield: 67% (205 mg).

Physical State: yellow oil.

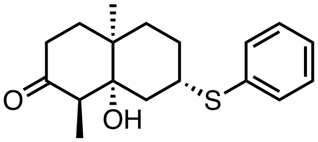
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.42–7.36 (m, 2H), 7.32–7.20 (m, 3H), 3.35 (dddd, *J* = 16.6, 8.4, 4.1, 4.1 Hz, 1H), 2.81 (q, *J* = 6.6 Hz, 1H), 2.55 (ddd, *J* = 14.1, 14.1, 7.1 Hz, 1H), 2.33 (dd, *J* = 14.2, 3.7 Hz, 1H), 2.06 (ddd, *J* = 13.9, 13.9, 5.0 Hz, 1H), 1.95–1.79 (m, 3H), 1.59–1.48 (m, 2H), 1.46–1.36 (m, 2H), 1.24–1.26 (m, 1H), 1.22 (s, 3H), 1.00 (d, *J* = 6.7 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 209.7, 134.0, 132.1, 128.8, 127.0, 78.3, 51.6, 42.0, 37.4, 37.3, 35.2, 35.2, 31.3, 27.9, 21.3, 6.3.

***R*$_f$** = 0.32 (20% EtOAc/hexanes).

Purification: (SiO$_2$, 5 → 20% EtOAc/hexanes).

All characterization data are consistent with that reported in the literature.[3]



3ha′

Yield: 10% (29 mg).

Physical State: white solid.

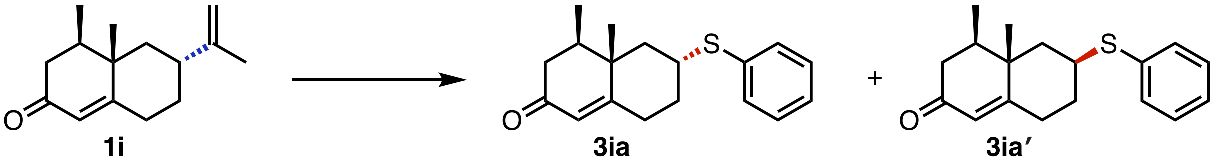
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.47–7.43 (m, 2H), 7.36–7.29 (m, 3H), 4.19 (br s, 1H), 3.61–3.57 (m, 1H), 2.81 (q, *J* = 6.5 Hz, 1H), 2.60 (dddd, *J* = 21.3, 7.1, 7.1, 1.1 Hz, 1H), 2.30 (ddd, *J* = 14.1, 4.9, 1.9 Hz, 1H), 2.16–1.95 (m, 3H), 1.85–1.78 (m, 2H), 1.47 (ddd, *J* = 13.9, 6.9, 2.0 Hz, 1H), 1.37 (dd, *J* = 15.7, 4.8 Hz, 1H), 1.34–1.29 (m, 1H), 1.28 (s, 3H), 0.97 (d, *J* = 6.7 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 210.8, 133.4, 132.9, 129.1, 127.9, 78.4, 51.2, 44.0, 38.0, 37.6, 31.3, 30.6, 29.6, 24.7, 22.0, 6.5.

***R*$_f$** = 0.49 (20% EtOAc/hexanes).

Purification: (SiO$_2$, 5 → 20% EtOAc/hexanes).

All characterization data are consistent with that reported in the literature.[3]



*1.0 mmol scale reaction

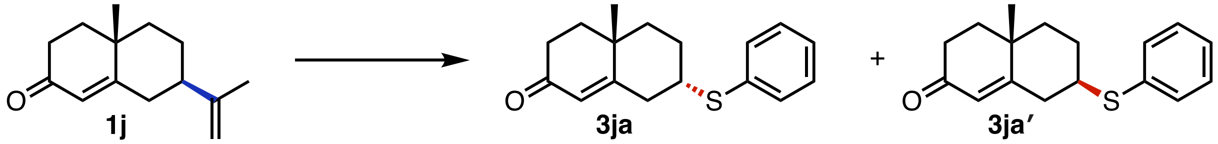
Combined Yield: 67% (192 mg, inseparable mixture).

Diastereomeric Ratio: 7:1 (determined from ^{1}H NMR spectrum of the crude products).

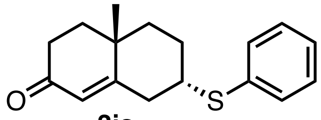
Physical State: yellow oil.

^{1}H NMR (500 MHz, CDCl$_3$) major: δ 7.44–7.39 (m, 2H), 7.34–7.29 (m, 2H), 7.28–7.25 (m, 1H), 5.75 (d, *J* = 1.1 Hz, 1H), 3.37 (dddd, *J* = 12.5, 12.5, 3.5, 3.5 Hz, 1H), 2.54–2.44 (m, 1H), 2.35 (ddd,

J = 15.3, 4.1, 2.6 Hz, 1H), 2.28–2.21 (m, 3H), 2.19–2.12 (m, 1H), 2.04–1.94 (m, 1H), 1.41 (ddd, *J* = 26.3, 12.8, 4.2 Hz, 1H), 1.30–1.21 (m, 1H), 1.10 (s, 3H), 0.93 (d, *J* = 6.8 Hz, 3H).
^{1}H NMR (500 MHz, $CDCl_3$) minor: δ 7.46–7.21 (m, 5H), 5.79 (s, 1H), 3.64–3.58 (m, 1H), 2.93 (dddd, *J* = 14.5, 12.7, 6.1, 1.7 Hz, 1H), 2.30–1.93 (m, 6H), 1.91–1.79 (m, 2H), 1.10 (s, 3H), 0.90 (d, *J* = 6.8 Hz, 3H).
^{13}C NMR (125 MHz, $CDCl_3$) major: δ 199.0, 168.2, 133.7, 132.3, 128.9, 127.2, 125.0, 44.9, 42.1, 41.7, 40.1, 40.0, 33.3, 32.7, 16.7, 14.8.
^{13}C NMR (125 MHz, $CDCl_3$) minor: δ 199.0, 170.8, 135.6, 131.3, 129.0, 126.9, 124.9, 43.1, 42.3, 41.8, 39.8, 39.3, 30.5, 28.3, 18.8, 14.8.
IR (neat, ATR): ν_{max} 3052, 2969, 2939, 2887, 1664, 911, 731, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{21.0}$ 93.8 (*c* 1.00, $CHCl_3$).
HRMS (DART): calc’d for $C_{18}H_{23}OS$ $[M + H]^+$ 287.1464, found 287.1446.
***R*f** = 0.35 (20% EtOAc/hexanes).
Purification: (SiO_2, 10 → 20% EtOAc/hexanes).
Note: 2D NMR spectra are consistent with the proposed structures of **3ia**/**3ia′**.

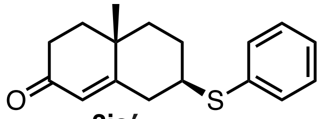


*1.0 mmol scale reaction
Combined Yield: 74% (202 mg).
Diastereomeric Ratio: 7.5:1 (determined from ^{1}H NMR spectrum of the crude products).
Note: 2D NMR spectra are consistent with the proposed structures of **3ja**/**3ja′**.



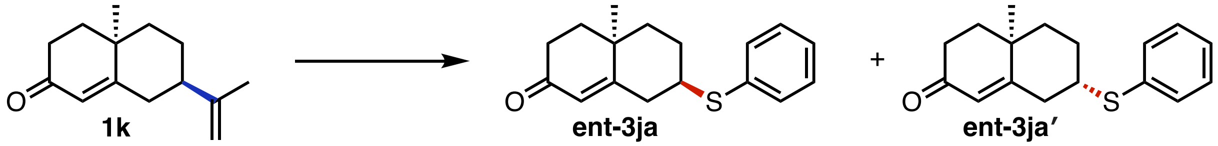
3ja

Yield: 65% (178 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.43–7.37 (m, 2H), 7.33–7.28 (m, 2H), 7.26–7.23 (m, 1H), 5.73 (d, *J* = 1.3 Hz, 1H), 3.79–3.73 (m, 1H), 2.77 (ddd, *J* = 15.3, 4.9, 2.0 Hz, 1H), 2.51 (ddd, *J* = 17.1, 14.7, 5.1 Hz, 1H), 2.45–2.35 (m, 2H), 2.11 (dddd, *J* = 14.0, 14.0, 3.8, 3.8 Hz, 1H), 2.06–1.91 (m, 2H), 1.89–1.76 (m, 2H), 1.49 (ddd, *J* = 13.6, 3.1, 3.1 Hz, 1H), 1.25 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 199.0, 166.1, 134.4, 132.3, 129.0, 127.2, 126.8, 45.8, 37.5, 36.7, 35.6, 35.5, 34.0, 25.7, 22.1.
IR (neat, ATR): ν_{max} 3060, 2928, 2860, 1664, 1261, 908, 731, 689 cm^{-1}.
Optical Rotation: $[\alpha]_D^{20.9}$ 34.2 (*c* 0.50, $CHCl_3$).
HRMS (DART): calc’d for $C_{17}H_{21}OS$ $[M + H]^+$ 273.1308, found 273.1291.
***R*f** = 0.37 (20% EtOAc/hexanes).
Purification: (SiO_2, 5 → 20% EtOAc/hexanes).

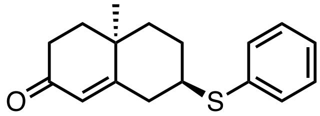


3ja′

Yield: 9% (24 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.46–7.40 (m, 2H), 7.35–7.26 (m, 3H), 5.71 (s, 1H), 3.12 (dddd, *J* = 12.4, 12.4, 4.0, 4.0 Hz, 1H), 2.59–2.38 (m, 3H), 2.35 (ddd, *J* = 17.1, 3.6, 3.6 Hz, 1H), 2.03–1.95 (m, 1H), 1.84–1.79 (m, 2H), 1.79–1.71 (m, 2H), 1.43 (ddd, *J* = 14.0, 14.0, 3.9 Hz, 1H), 1.22 (s, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 199.2, 167.1, 133.3, 132.5, 128.9, 127.4, 125.0, 46.5, 40.8, 39.2, 37.5, 35.2, 33.9, 28.8, 21.9.
IR (neat, ATR): ν_{max} 3060, 2928, 2860, 1668, 908, 727, 689 cm^{-1}.
Optical Rotation: $[\alpha]_D^{20.8}$ 43.4 (*c* 0.50, CHCl$_3$).
HRMS (DART): calc'd for $C_{17}H_{21}OS$ $[M + H]^+$ 273.1308, found 273.1290.
***R*$_f$** = 0.43 (20% EtOAc/hexanes).
Purification: (SiO$_2$, 5 → 20% EtOAc/hexanes).

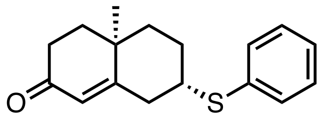


*1.0 mmol scale reaction
Combined Yield: 75% (204 mg).
Diastereomeric Ratio: 7.5:1 (determined from ^{1}H NMR spectrum of the crude products).
Note: 2D NMR spectra are consistent with the proposed structures of **ent-3ja**/**ent-3ja′**.



ent-3ja

Yield: 66% (180 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.43–7.37 (m, 2H), 7.33–7.28 (m, 2H), 7.26–7.23 (m, 1H), 5.73 (d, *J* = 1.3 Hz, 1H), 3.79–3.73 (m, 1H), 2.77 (ddd, *J* = 15.3, 4.9, 2.0 Hz, 1H), 2.51 (ddd, *J* = 17.1, 14.7, 5.1 Hz, 1H), 2.45–2.35 (m, 2H), 2.11 (dddd, *J* = 14.0, 14.0, 3.8, 3.8 Hz, 1H), 2.06–1.91 (m, 2H), 1.89–1.76 (m, 2H), 1.49 (ddd, *J* = 13.6, 3.1, 3.1 Hz, 1H), 1.25 (s, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 199.0, 166.1, 134.4, 132.3, 129.0, 127.2, 126.8, 45.8, 37.5, 36.7, 35.6, 35.5, 34.0, 25.7, 22.1.
IR (neat, ATR): ν_{max} 3060, 2928, 2860, 1664, 1261, 908, 731, 689 cm^{-1}.
Optical Rotation: $[\alpha]_D^{21.1}$ –34.2 (*c* 0.50, CHCl$_3$).
HRMS (DART): calc'd for $C_{17}H_{21}OS$ $[M + H]^+$ 273.1308, found 273.1292.
***R*$_f$** = 0.37 (20% EtOAc/hexanes).
Purification: (SiO$_2$, 5 → 20% EtOAc/hexanes).



ent-3ja′

Yield: 9% (24 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.46–7.40 (m, 2H), 7.35–7.26 (m, 3H), 5.71 (s, 1H), 3.12 (dddd, *J* = 12.4, 12.4, 4.0, 4.0 Hz, 1H), 2.59–2.38 (m, 3H), 2.35 (ddd, *J* = 17.1, 3.6, 3.6 Hz, 1H), 2.03–1.95 (m, 1H), 1.84–1.79 (m, 2H), 1.79–1.71 (m, 2H), 1.43 (ddd, *J* = 14.0, 14.0, 3.9 Hz, 1H), 1.22 (s, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 199.2, 167.1, 133.3, 132.5, 128.9, 127.4, 125.0, 46.5, 40.8, 39.2, 37.5, 35.2, 33.9, 28.8, 21.9.

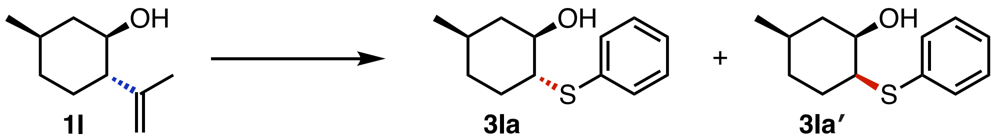
IR (neat, ATR): ν_{max} 3060, 2928, 2860, 1668, 908, 727, 689 cm^{-1}.

Optical Rotation: $[\alpha]_D^{21.3}$ –41.6 (*c* 0.50, CHCl$_3$).

HRMS (DART): calc'd for $C_{17}H_{21}OS$ $[M + H]^+$ 273.1308, found 273.1291.

***R*$_f$** = 0.43 (20% EtOAc/hexanes).

Purification: (SiO$_2$, 5 → 20% EtOAc/hexanes).

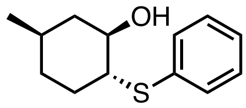


*1.0 mmol scale reaction

Combined Yield: 73% (162 mg).

Diastereomeric Ratio: 1.5:1 (determined from ^{1}H NMR spectrum of the crude products).

Note: To verify the stereochemistry of the newly formed C–S bond, approximately 5 mg of **3la′** was placed in a small crystallization tube and dissolved in a minimal amount of ethyl acetate. This vial was placed within a larger 4-mL vial containing approximately 1 mL of hexanes. The vial was capped and sealed with Teflon and Parafilm. After 2 days, single crystals suitable for X-ray diffraction had formed. 2D NMR spectra are also consistent with the proposed structures of **3la**/**3la′**.



3la

Yield: 44% (97 mg).

Physical State: white solid.

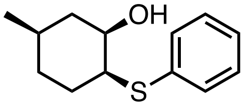
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.52–7.44 (m, 2H), 7.35–7.27 (m, 3H), 3.35 (ddd, *J* = 10.5, 10.5, 4.4 Hz, 1H), 2.95 (br s, 1H), 2.72 (ddd, *J* = 12.5, 10.1, 4.0 Hz, 1H), 2.13–2.04 (m, 2H), 1.69–1.62 (m, 1H), 1.50–1.41 (m, 1H), 1.36 (ddd, *J* = 26.0, 13.3, 3.8 Hz, 1H), 1.06 (dd, *J* = 23.4, 12.3 Hz, 1H), 0.96 (ddd, *J* = 25.1, 13.2, 3.6 Hz, 1H), 0.91 (d, *J* = 6.6 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 133.7, 132.4, 128.8, 127.7, 71.6, 56.3, 42.3, 34.7, 32.2, 31.0, 21.8.

MP: 68–69 ºC.

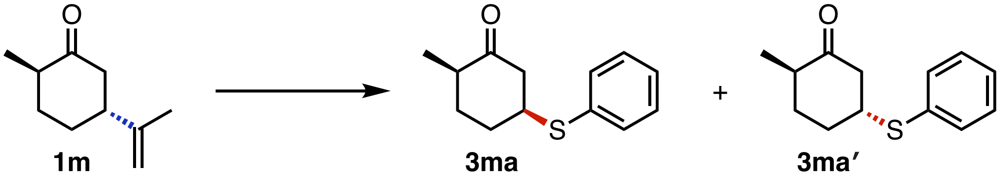
IR (neat, ATR): ν_{max} 3421, 3063, 2947, 2925, 2852, 1449, 1047, 743, 689 cm^{-1}.

Optical Rotation: $[\alpha]_D^{21.8}$ –36.4 (*c* 1.00, $CHCl_3$).
HRMS (DART): calc'd for $C_{13}H_{17}S$ $[M – OH]^+$ 205.1045, found 205.1033.
***R*$_f$** = 0.26 (10% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% EtOAc/hexanes).

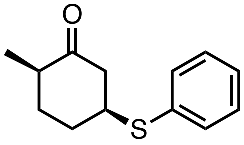


3la′

Yield: 29% (65 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.51–7.45 (m, 2H), 7.32–7.19 (m, 3H), 3.80 (ddd, *J* = 11.5, 4.2, 4.2 Hz, 1H), 3.64–3.59 (m, 1H), 2.31 (br s, 1H), 2.10 (ddd, *J* = 14.1, 6.5, 3.3 Hz, 1H), 1.86–1.78 (m, 1H), 1.73 (dddd, *J* = 13.6, 13.6, 3.5, 3.5 Hz, 1H), 1.55–1.41 (m, 2H), 1.35–1.24 (m, 1H), 1.13 (dd, *J* = 24.1, 11.6 Hz, 1H), 0.96 (d, *J* = 6.4 Hz, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 136.2, 131.3, 128.9, 126.7, 71.0, 56.3, 40.4, 31.1, 30.9, 28.9, 21.9.
MP: 98–99 ºC.
IR (neat, ATR): ν_{max} 3327, 3048, 2947, 2925, 2856, 1439, 1028, 735 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.0}$ 33.2 (*c* 1.00, $CHCl_3$).
HRMS (DART): calc'd for $C_{13}H_{17}S$ $[M – OH]^+$ 205.1045, found 205.1036.
***R*$_f$** = 0.20 (10% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% EtOAc/hexanes).



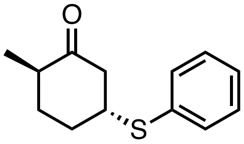
Combined Yield: 75% (1.0 mmol scale, 165 mg); 66% (10.0 mmol scale, 1.46 g).
Diastereomeric Ratio: 1.6:1 (determined from ^{1}H NMR spectrum of the crude products).
Note: 2D NMR spectra are consistent with the proposed structures of **3ma**/**3ma′**.



3ma

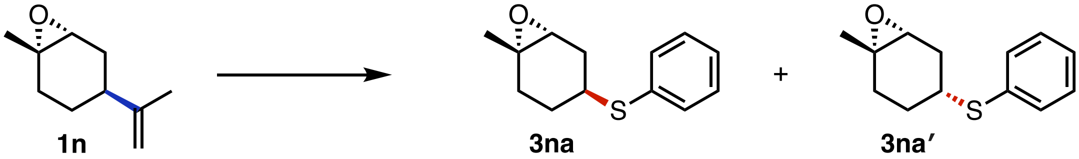
Yield: 47% (1.0 mmol scale, 104 mg); 41% (10.0 mmol scale, 900 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.44–7.39 (m, 2H), 7.34–7.24 (m, 3H), 3.86–3.80 (m, 1H), 2.67 (ddd, *J* = 14.5, 5.0, 1.1 Hz, 1H), 2.53 (ddd, *J* = 14.5, 4.7, 1.7 Hz, 1H), 2.45–2.36 (m, 1H), 2.14–2.05 (m, 1H), 1.98 (ddd, *J* = 8.8, 4.5, 1.7 Hz, 1H), 1.96–1.89 (m, 2H), 1.10 (d, *J* = 6.7 Hz, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 210.3, 133.6, 132.8, 129.0, 127.5, 47.0, 45.3, 44.7, 30.5, 28.7, 14.8.
MP: 55 ºC.

IR (neat, ATR): ν_{max} 3060, 2969, 2931, 2860, 1713, 746, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.1}$ –32.7 (*c* 1.00, $CHCl_3$).
HRMS (DART): calc'd for $C_{13}H_{17}OS$ $[M + H]^+$ 221.0995, found 221.0984.
***R*$_f$** = 0.39 (10% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% EtOAc/hexanes).



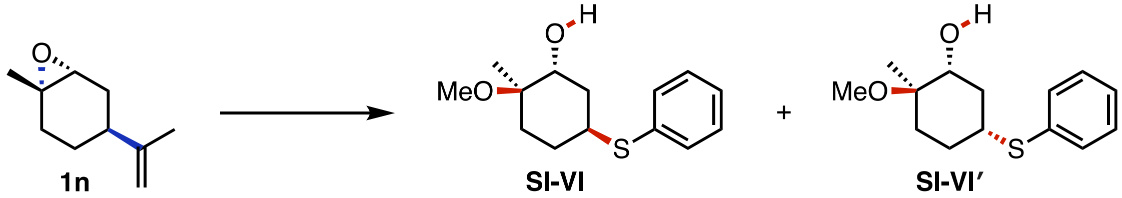
3ma′

Yield: 28% (1.0 mmol scale, 61 mg); 26% (10.0 mmol scale, 563 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.45–7.39 (m, 2H), 7.35–7.27 (m, 3H), 3.28 (dddd, *J* = 12.5, 12.5, 4.0, 4.0 Hz, 1H), 2.70 (ddd, *J* = 13.5, 4.3, 2.2 Hz, 1H), 2.41–2.30 (m, 2H), 2.24–2.16 (m, 1H), 2.16–2.09 (m, 1H), 1.76 (ddd, *J* = 25.3, 13.1, 3.7 Hz, 1H), 1.36 (ddd, *J* = 26.4, 13.1, 3.5 Hz, 1H), 1.01 (d, *J* = 6.5 Hz, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 209.9, 133.1, 132.8, 128.9, 127.7, 48.2, 46.7, 44.4, 33.8, 32.3, 14.1.
MP: 39–40 ºC.
IR (neat, ATR): ν_{max} 3063, 2968, 2932, 2861, 1710, 745, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.3}$ 102.7 (*c* 1.00, $CHCl_3$).
HRMS (DART): calc'd for $C_{13}H_{17}OS$ $[M + H]^+$ 221.0995, found 221.0982.
***R*$_f$** = 0.57 (10% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% EtOAc/hexanes).

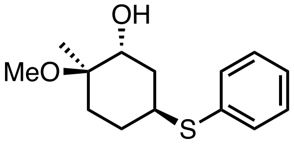


*1.0 mmol scale reaction
Combined Yield: 60% (132 mg, inseparable mixture).
Diastereomeric Ratio: 12:1 (determined from ^{1}H NMR spectrum of the crude products).
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$) major: δ 7.41–7.36 (m, 2H), 7.32–7.27 (m, 2H), 7.25–7.20 (m, 1H), 3.33–3.25 (m, 1H), 3.04–3.00 (m, 1H), 2.37 (dd, *J* = 15.2, 5.1 Hz, 1H), 1.98 (ddd, *J* = 15.2, 6.1, 6.1 Hz, 1H), 1.92–1.85 (m, 2H), 1.82–1.75 (m, 1H), 1.40 (dddd, *J* = 13.6, 8.5, 8.5, 6.0 Hz, 1H), 1.33 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$) major: δ 134.4, 131.8, 128.8, 126.8, 59.1, 57.0, 39.5, 31.4, 27.5, 26.2, 23.7.
IR (neat, ATR): ν_{max} 3067, 2980, 2928, 1435, 905, 727, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.4}$ –11.8 (*c* 1.00, $CHCl_3$).
HRMS (DART): calc'd for $C_{13}H_{17}OS$ $[M + H]^+$ 221.0995, found 221.0983.
***R*$_f$** = 0.24 (5% EtOAc/hexanes).
Purification: (SiO_2, 2 → 5% EtOAc/hexanes).

Note: 2D NMR spectra are consistent with the proposed structures of **3na**/**3na′**. When solid ferrous sulfate heptahydrate was added at room temperature for the reaction with **1n**, formation of the products **SI-VI** and **SI-VI′** was observed.

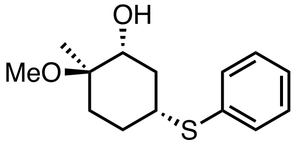


*1.0 mmol scale reaction
Combined Yield: 57% (143 mg).
Diastereomeric Ratio: 10:1 (determined from ^{1}H NMR spectrum of the crude products).
Note: Solid ferrous sulfate heptahydrate was added at room temperature.



SI-VI

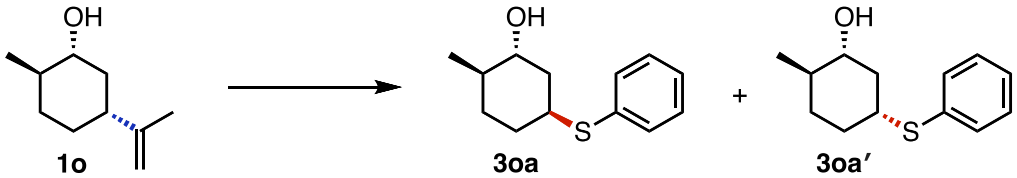
Yield: 53% (132 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.43–7.38 (m, 2H), 7.31–7.26 (m, 2H), 7.24–7.19 (m, 1H), 3.79 (br s, 1H), 3.48 (ddd, J = 13.4, 9.3, 4.2 Hz, 1H), 3.19 (s, 3H), 2.04 (ddd, J = 13.4, 9.8, 3.4 Hz, 1H), 1.92–1.83 (m, 2H), 1.80–1.71 (m, 2H), 1.66–1.59 (m, 2H), 1.15 (s, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 134.9, 131.6, 128.8, 126.6, 75.6, 72.0, 48.4, 41.3, 35.1, 28.7, 27.8, 18.5.
IR (neat, ATR): ν_{max} 3428, 3071, 2931, 1435, 1077, 743, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.6}$ –17.8 (c 1.00, CHCl$_3$).
HRMS (ESI-TOF): calc'd for $C_{14}H_{20}O_2SNa$ [M + Na]$^+$ 291.0816, found 291.0811.
***R*$_f$** = 0.33 (20% EtOAc/hexanes).
Purification: (SiO$_2$, 10 → 30% EtOAc/hexanes).



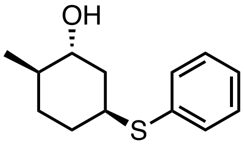
SI-VI′

Yield: 4% (11 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.45–7.38 (m, 2H), 7.34–7.25 (m, 3H), 3.62–3.53 (m, 1H), 3.21 (s, 3H), 3.15–3.05 (m, 1H), 2.36 (br s, 1H), 2.21–2.12 (m, 1H), 2.00–1.85 (m, 2H), 1.55–1.47 (m, 1H), 1.43–1.33 (m, 2H), 1.14 (s, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 133.9, 132.8, 129.0, 127.4, 77.4, 74.7, 48.8, 43.8, 36.1, 32.2, 29.7, 14.7.
IR (neat, ATR): ν_{max} 3436, 3048, 2943, 2868, 1126, 1073, 746 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.5}$ –6.4 (c 0.10, CHCl$_3$).

HRMS (ESI-TOF): calc'd for $C_{14}H_{20}O_2SNa$ $[M + Na]^+$ 291.0816, found 291.0822.
R_f = 0.19 (20% EtOAc/hexanes).
Purification: (SiO_2, 10 → 30% EtOAc/hexanes).

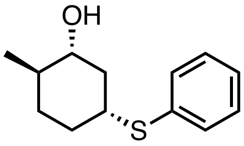


*1.0 mmol scale reaction
Combined Yield: 79% (175 mg).
Diastereomeric Ratio: 2:1 (determined from ^{1}H NMR spectrum of the crude products).
Note: 2D NMR spectra are consistent with the proposed structures of **3oa**/**3oa′**.



3oa

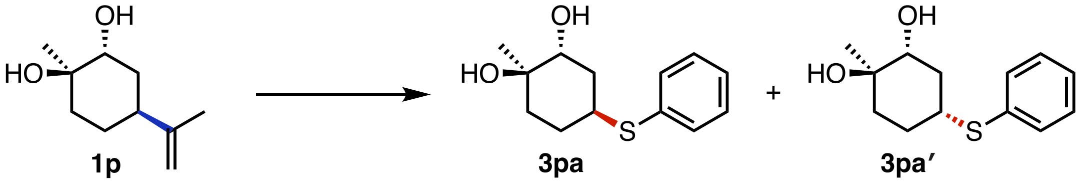
Yield: 55% (121 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42–7.37 (m, 2H), 7.33–7.27 (m, 2H), 7.25–7.19 (m, 1H), 3.73–3.68 (m, 1H), 3.67 (ddd, J = 8.7, 8.7, 3.7 Hz, 1H), 2.09 (dddd, J = 13.4, 4.3, 4.3, 1.3 Hz, 1H), 1.83–1.40 (m, 7H), 1.05 (d, J = 6.5 Hz, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 135.4, 131.3, 128.8, 126.6, 72.0, 44.7, 39.0, 38.3, 29.3, 28.1, 17.8.
MP: 48–49 °C.
IR (neat, ATR): ν_{max} 3346, 3067, 2925, 2872, 1439, 1055, 1028, 746, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.6}$ –0.8 (c 1.00, $CHCl_3$).
HRMS (DART): calc'd for $C_{13}H_{19}OS$ $[M + H]^+$ 223.1151, found 223.1141.
R_f = 0.38 (20% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% EtOAc/hexanes).



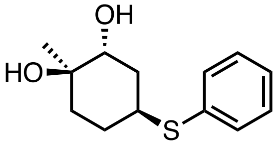
3oa′

Yield: 24% (54 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.44–7.39 (m, 2H), 7.32–7.27 (m, 2H), 7.26–7.22 (m, 1H), 3.15 (ddd, J = 10.3, 10.3, 4.1 Hz, 1H), 3.03 (dddd, J = 12.2, 12.2, 3.7, 3.7 Hz, 1H), 2.27 (dddd, J = 12.3, 3.8, 3.8, 2.2 Hz, 1H), 2.00–1.93 (m, 1H), 1.77 (dq, J = 13.7, 3.5 Hz, 1H), 1.54 (br s, 1H), 1.40–1.24 (m, 3H), 1.10–1.01 (m, 1H), 1.00 (d, J = 6.5 Hz, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 134.1, 132.5, 128.7, 127.0, 75.5, 44.5, 42.0, 39.4, 32.7, 32.6, 17.9.
MP: 94–95 °C.

IR (neat, ATR): ν_{max} 3364, 3063, 2925, 2864, 1439, 1043, 743, 689 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.7}$ 2.0 (*c* 0.50, CHCl$_3$).
HRMS (DART): calc'd for $C_{13}H_{19}OS$ [M + H]$^+$ 223.1151, found 223.1143.
***R*$_f$** = 0.42 (20% EtOAc/hexanes).
Purification: (SiO$_2$, 5 → 10% EtOAc/hexanes).

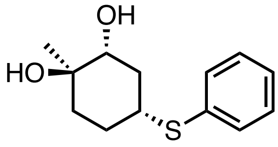


*1.0 mmol scale reaction
Combined Yield: 84% (200 mg).
Diastereomeric Ratio: 4:1 (determined from ^{1}H NMR spectrum of the crude products).
Note: 2D NMR spectra are consistent with the proposed structures of **3pa**/**3pa′**.



3pa

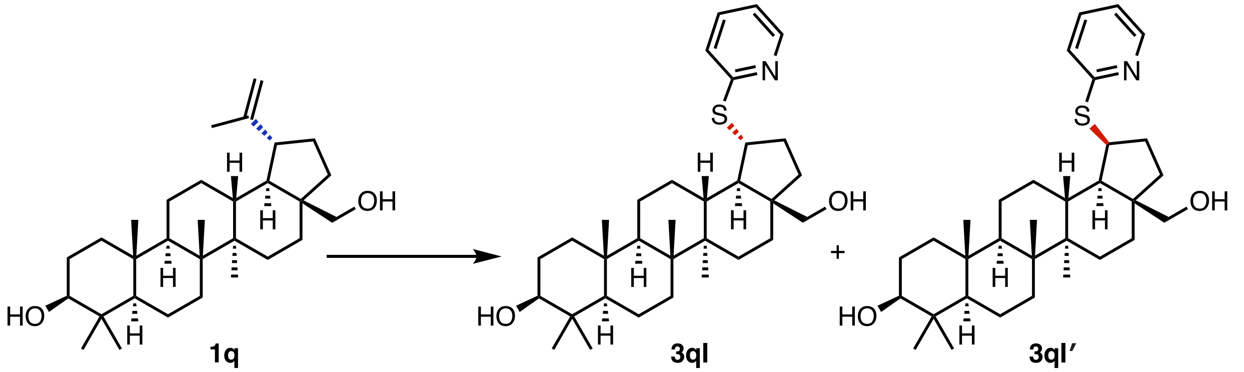
Yield: 67% (159 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.43–7.38 (m, 2H), 7.32–7.27 (m, 2H), 7.25–7.20 (m, 1H), 3.81 (dd, *J* = 7.1, 3.2 Hz, 1H), 3.59–3.50 (m, 1H), 2.12 (br s, 1H), 2.05 (ddd, *J* = 13.7, 7.7, 3.5 Hz, 1H), 1.84 (ddd, *J* = 13.6, 7.6, 4.3 Hz, 1H), 1.81–1.67 (m, 5H), 1.23 (s, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 134.8, 131.7, 128.8, 126.8, 73.5, 72.3, 42.2, 35.6, 33.8, 28.0, 23.0.
MP: 66–68 ˚C.
IR (neat, ATR): ν_{max} 3368, 3063, 2935, 2864, 1439, 1051, 1028, 746, 689 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.8}$ –7.2 (*c* 1.00, CHCl$_3$).
HRMS (ESI-TOF): calc'd for $C_{13}H_{18}O_2SK$ [M + K]$^+$ 277.0659, found 277.0663.
***R*$_f$** = 0.45 (50% EtOAc/hexanes).
Purification: (SiO$_2$, 30 → 50% EtOAc/hexanes).



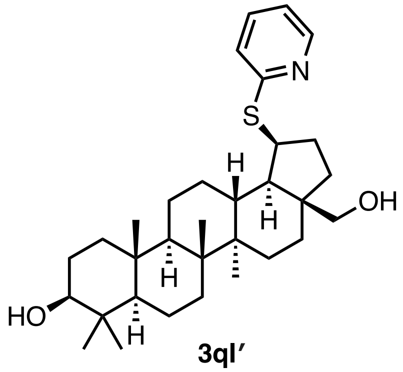
3pa′

Yield: 17% (41 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.46–7.40 (m, 2H), 7.33–7.24 (m, 3H), 3.52 (dd, *J* = 11.4, 4.3 Hz, 1H), 3.14–3.06 (m, 1H), 2.16 (dddd, *J* = 12.9, 4.3, 4.3, 2.1 Hz, 1H), 1.98–1.92 (m, 1H), 1.85 (br s, 2H), 1.82–1.77 (m, 1H), 1.50–1.38 (m, 3H), 1.20 (s, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 133.9, 132.9, 129.0, 127.5, 76.3, 73.5, 44.1, 37.7, 37.5, 30.3, 19.3.
MP: 80–82 ˚C.
IR (neat, ATR): ν_{max} 3384, 3056, 2992, 2935, 1134, 1069, 746, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{22.8}$ 6.4 (*c* 0.50, CHCl$_3$).
HRMS (ESI-TOF): calc'd for $C_{13}H_{19}O_2S$ $[M + H]^+$ 239.1100, found 239.1109.
***R*$_f$** = 0.32 (50% EtOAc/hexanes).
Purification: (SiO$_2$, 30 → 50% EtOAc/hexanes).



*0.5 mmol scale reaction
Combined Yield: approximately 78% (see Note).
Diastereomeric Ratio: 1.2:1 (determined from ^{1}H NMR spectrum of the crude products).
Note: The thioether **3ql** was inseparable from an unidentified byproduct (2.2:1 desired/undesired). Subsequent oxidation to the sulfone **8** (section 5.3.) enabled separation from this impurity. The combined yield is based on the yield of **3ql′** + the yield of the sulfone **8**.

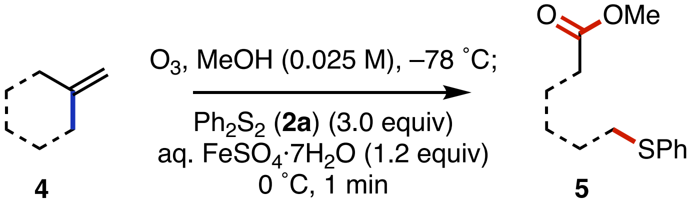


3ql′

Yield: 35% (91 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 8.39 (dd, *J* = 4.9, 0.8 Hz, 1H), 7.44 (ddd, *J* = 7.7, 7.7, 1.8 Hz, 1H), 7.11 (d, *J* = 8.1 Hz, 1H), 6.94 (ddd, *J* = 7.2, 5.1, 0.8 Hz, 1H), 4.35 (ddd, *J* = 8.5, 7.8, 2.9 Hz, 1H), 3.83–3.72 (m, 2H), 3.18 (dd, *J* = 11.4, 4.8 Hz, 1H), 2.61 (ddd, *J* = 15.0, 9.0, 9.0 Hz, 1H), 2.08–1.98 (m, 2H), 1.96–0.86 (m, 22H), 1.05 (s, 3H), 0.98 (s, 3H), 0.96 (s, 3H), 0.82 (s, 3H), 0.75 (s, 3H), 0.72–0.67 (m, 1H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 159.7, 149.3, 135.9, 122.4, 119.1, 79.0, 61.3, 55.4, 50.9, 50.7, 47.3, 43.3, 42.6, 41.0, 38.9, 38.7, 37.2, 35.4, 34.5, 34.5, 34.1, 29.1, 28.0, 27.4, 27.1, 25.4, 20.7, 18.3, 16.1, 16.0, 15.3, 15.2.

MP: 130–132 ˚C.
IR (neat, ATR): ν_{max} 3380, 3048, 2939, 2872, 1578, 1453, 1412, 1126, 1032, 761, 735 cm^{-1}.
Optical Rotation: $[\alpha]_D^{23.1}$ 35.8 (*c* 1.00, $CHCl_3$).
HRMS (ESI-TOF): calc'd for $C_{32}H_{50}NO_2S$ $[M + H]^+$ 512.3557, found 512.3563.
$\boldsymbol{R_f}$ = 0.32 (30% EtOAc/hexanes).
Purification: (SiO_2, 10 → 30% EtOAc/hexanes).
Note: The reaction was run at a concentration of 0.01 M because of the low solubility of **1q** in MeOH.

4.4. General Procedure for Carboxylic Ester Synthesis

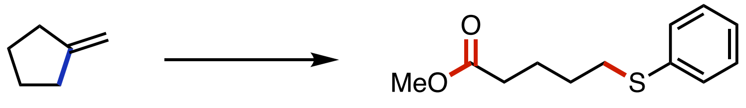


A round-bottom flask equipped with a magnetic stirrer bar was charged with **4** (1.0 equiv) and MeOH (0.025 M), then cooled to –78 °C in a dry-ice/acetone bath while open to the air. Ozone was bubbled through the solution until complete consumption of the starting material (as indicated by TLC and/or a blue color in the reaction mixture). The solution was then sparged with argon for 5 min to expel excess ozone. Diphenyl disulfide (**2a**, 3.0 equiv) was added, and then the reaction mixture was warmed to 0 °C in an ice-water bath and stirred for 10 min. An aqueous solution (5%, wt/vol) of ferrous sulfate heptahydrate (1.2 equiv) was added over a period of approximately 1 min. Upon completion of the reaction (TLC), the mixture was diluted with water and transferred to a separatory funnel. The MeOH/water layer was extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO_2) provided the thiylated carboxylic ester product **5**.

Any modification of the above procedure is described below with the specific entry.

Note: Solid phenyl disulfide was ground to a fine powder prior to use.

4.5. Characterization Data



4a **5aa**

*1.0 mmol scale reaction

Yield: 73% (164 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.35–7.30 (m, 2H), 7.30–7.25 (m, 2H), 7.20–7.14 (m, 1H), 3.66 (s, 3H), 2.93 (t, J = 7.2 Hz, 2H), 2.33 (t, J = 7.4 Hz, 2H), 1.82–1.73 (m, 2H), 1.71–1.63 (m, 2H).

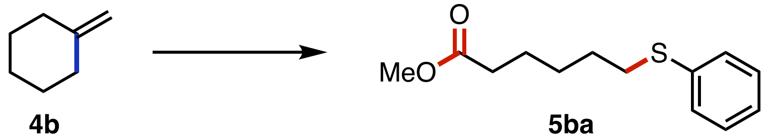
^{13}C NMR (125 MHz, CDCl$_3$): δ 173.6, 136.4, 129.0, 128.8, 125.8, 51.4, 33.4, 33.1, 28.4, 23.9.

IR (neat, ATR): ν_{max} 3060, 2943, 2860, 1736, 1439, 1205, 1172, 743, 686 cm^{-1}.

HRMS (ESI-TOF): calc'd for $C_{12}H_{16}O_2SK$ [M + K]$^+$ 263.0503, found 263.0503.

***R*$_f$** = 0.44 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 0 → 10% Et$_2$O/pentane).



4b **5ba**

*1.0 mmol scale reaction

Yield: 71% (168 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.34–7.30 (m, 2H), 7.30–7.25 (m, 2H), 7.19–7.14 (m, 1H), 3.66 (s, 3H), 2.91 (t, J = 7.3 Hz, 2H), 2.31 (t, J = 7.5 Hz, 2H), 1.71–1.59 (m, 4H), 1.52–1.41 (m, 2H).

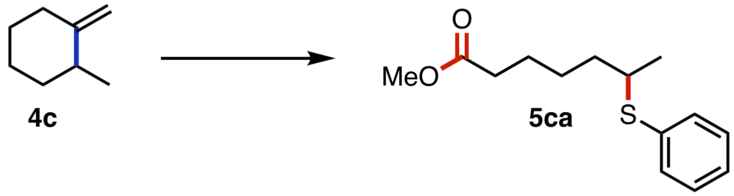
^{13}C NMR (125 MHz, CDCl$_3$): δ 173.9, 136.6, 128.9, 128.7, 125.7, 51.4, 33.8, 33.3, 28.7, 28.1, 24.4.

IR (neat, ATR): ν_{max} 3063, 2939, 2856, 1736, 1435, 1257, 1201, 1168, 739, 689 cm^{-1}.

HRMS (ESI-TOF): calc'd for $C_{13}H_{18}O_2SK$ [M + K]$^+$ 277.0659, found 277.0669.

***R*$_f$** = 0.44 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 0 → 10% Et$_2$O/pentane).



4c **5ca**

*1.0 mmol scale reaction

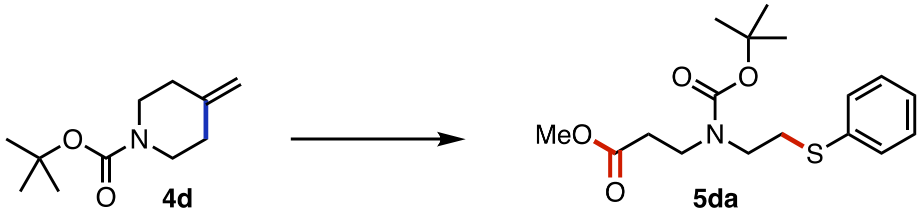
Yield: 75% (190 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.41–7.36 (m, 2H), 7.31–7.26 (m, 2H), 7.25–7.20 (m, 1H), 3.66 (s, 3H), 3.25–3.15 (m, 1H), 2.31 (t, J = 7.5 Hz, 2H), 1.68–1.57 (m, 3H), 1.56–1.44 (m, 3H), 1.27 (d, J = 6.7 Hz, 3H).

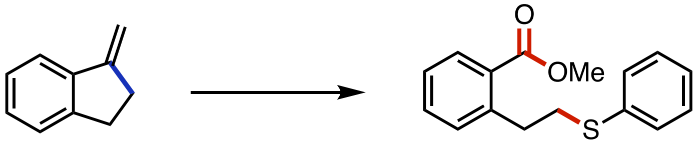
^{13}C NMR (125 MHz, CDCl$_3$): δ 173.9, 135.1, 131.9, 128.7, 126.6, 51.4, 43.0, 36.1, 33.8, 26.4, 24.6, 21.0.

IR (neat, ATR): ν_{max} 3060, 2935, 2864, 1732, 1435, 1198, 1164, 746, 693 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{14}H_{20}O_2SK$ [M + K]$^+$ 291.0816, found 291.0828.
***R*f** = 0.41 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 2 → 4% EtOAc/hexanes).



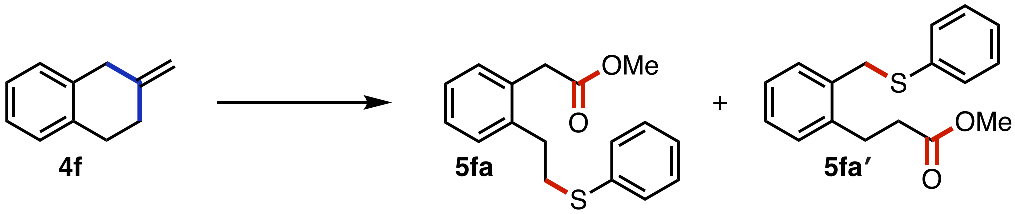
4d **5da**

*1.0 mmol scale reaction
Yield: 80% (273 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.39–7.33 (m, 2H), 7.30–7.26 (m, 2H), 7.21–7.14 (m, 1H), 3.68–3.62 (m, 3H), 3.52–3.37 (m, 4H), 3.14–2.98 (m, 2H), 2.60–2.49 (m, 2H), 1.47–1.40 (m, 9H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 172.4, 172.1, 155.0, 135.9, 135.6, 129.3, 129.0, 128.9, 127.5, 126.2, 126.0, 80.1, 51.7, 51.7, 48.0, 44.5, 44.1, 33.9, 33.4, 31.9, 31.5, 28.5, 28.4.
IR (neat, ATR): ν_{max} 3056, 2977, 2928, 1736, 1690, 1412, 1366, 1160, 739, 689 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{17}H_{25}NO_4SNa$ [M + Na]$^+$ 362.1309, found 362.1305.
***R*f** = 0.19 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 5 → 10% EtOAc/hexanes).
Note: The ester **5da** exists as a mixture of rotamers.

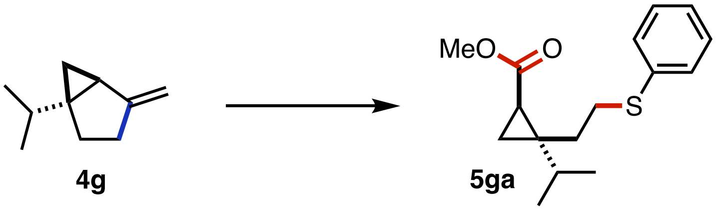


4e **5ea**

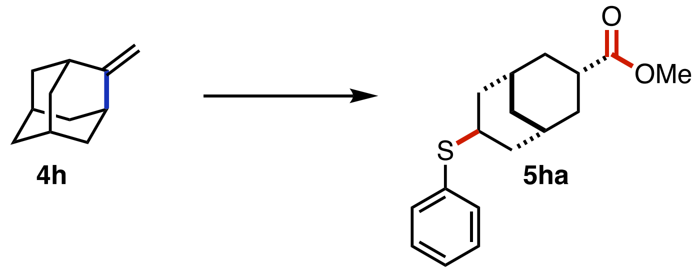
*1.0 mmol scale reaction
Yield: 51% (139 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.92 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.44 (ddd, *J* = 7.5, 7.5, 1.4 Hz, 1H), 7.42–7.37 (m, 2H), 7.33–7.24 (m, 4H), 7.21–7.16 (m, 1H), 3.86 (s, 3H), 3.32–3.26 (m, 2H), 3.25–3.19 (m, 2H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 167.6, 141.7, 136.5, 132.0, 131.4, 130.8, 129.4, 129.0, 128.8, 126.5, 125.7, 51.9, 34.7, 34.5.
IR (neat, ATR): ν_{max} 3060, 2992, 2951, 1716, 1431, 1269, 1251, 1119, 1077, 735, 686 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{16}H_{16}O_2SK$ [M + K]$^+$ 311.0503, found 311.0514.
***R*f** = 0.48 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 2 → 3% EtOAc/hexanes).



*1.0 mmol scale reaction
Combined Yield: 35% (100 mg).
Regioisomeric Ratio: 1.6:1 (inseparable mixture).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$) 5fa: δ 7.41–7.09 (m, 9H), 3.65 (s, 3H), 3.61 (s, 2H), 3.15–3.10 (m, 2H), 2.97–2.91 (m, 2H).
^{1}H NMR (500 MHz, CDCl$_3$) 5fa′: δ 7.41–7.09 (m, 9H), 4.15 (s, 2H), 3.68 (s, 3H), 3.07–3.02 (m, 2H), 2.70–2.65 (m, 2H).
^{13}C NMR (125 MHz, CDCl$_3$) 5fa: δ 171.9, 138.8, 136.2, 132.3, 130.7, 129.7, 129.5, 129.0, 127.7, 126.9, 126.2, 52.1, 38.3, 34.5, 32.9.
^{13}C NMR (125 MHz, CDCl$_3$) 5fa′: δ 173.3, 139.1, 136.4, 134.8, 130.5, 130.3, 129.2, 128.9, 127.8, 126.6, 126.6, 51.7, 37.0, 35.3, 27.5.
IR (neat, ATR): ν_{max} 3063, 3026, 2951, 2872, 1736, 1439, 1254, 1152, 743, 693 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{17}H_{18}O_2SK$ $[M + K]^+$ 325.0659, found 326.0665.
***R*$_f$** = 0.34 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).



*1.0 mmol scale reaction
Yield: 74% (205 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.36–7.31 (m, 2H), 7.30–7.25 (m, 2H), 7.19–7.14 (m, 1H), 3.64 (s, 3H), 2.99 (ddd, *J* = 12.5, 9.6, 7.0 Hz, 1H), 2.85 (ddd, *J* = 12.5, 9.5, 6.9 Hz, 1H), 1.95–1.83 (m, 2H), 1.58 (dd, *J* = 8.2, 5.7 Hz, 1H), 1.46 (sept, *J* = 6.9 Hz, 1H), 1.11 (dd, *J* = 5.3, 5.3 Hz, 1H), 0.94 (dd, *J* = 8.3, 4.8 Hz, 1H), 0.92 (d, *J* = 6.8 Hz, 3H), 0.88 (d, *J* = 6.9 Hz, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 172.9, 136.7, 128.9, 128.7, 125.7, 51.6, 35.1, 33.9, 31.6, 28.0, 24.5, 19.4, 19.2, 18.8.
IR (neat, ATR): ν_{max} 3067, 2954, 2879, 1724, 1435, 1194, 1168, 739, 689 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{16}H_{23}O_2S$ $[M + H]^+$ 279.1413, found 279.1371.
***R*$_f$** = 0.48 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 0 → 5% Et$_2$O/pentane).



*1.0 mmol scale reaction

Yield: 51% (149 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.43–7.38 (m, 2H), 7.32–7.27 (m, 2H), 7.24–7.19 (m, 1H), 3.66 (s, 3H), 3.49 (dddd, *J* = 12.5, 12.5, 4.5, 4.5 Hz, 1H), 2.52 (dddd, *J* = 12.2, 12.2, 6.1, 6.1 Hz, 1H), 2.25–2.06 (m, 4H), 1.93–1.85 (m, 2H), 1.67–1.59 (m, 1H), 1.55–1.41 (m, 4H), 1.21–1.13 (m, 1H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 176.8, 134.5, 131.8, 128.7, 126.6, 51.6, 40.0, 38.0, 35.5, 29.0, 28.4, 25.9.

IR (neat, ATR): ν_{max} 3067, 2928, 2872, 1736, 1435, 1198, 1168, 746, 693 cm^{-1}.

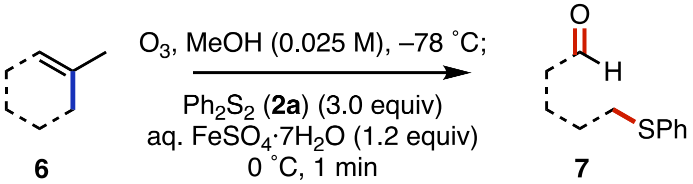
HRMS (ESI-TOF): calc'd for $C_{17}H_{22}O_2SK$ $[M + K]^+$ 329.0972, found 329.0965.

***R*$_f$** = 0.41 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).

Note: 2D NMR spectra are consistent with the proposed structure of **5ha**.

4.6. General Procedure for Aldehyde Synthesis

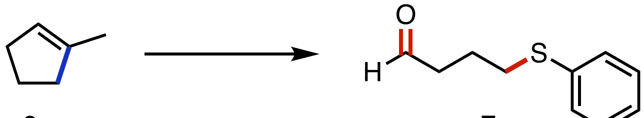


A round-bottom flask equipped with a magnetic stirrer bar was charged with **6** (1.0 equiv) and MeOH (0.025 M), then cooled to –78 °C in a dry-ice/acetone bath while open to the air. Ozone was bubbled through the solution until complete consumption of the starting material (as indicated by TLC and/or a blue color in the reaction mixture). The solution was then sparged with argon for 5 min to expel excess ozone. Diphenyl disulfide (**2a**, 3.0 equiv) was added, and then the reaction mixture was warmed to 0 °C in an ice-water bath and stirred for 10 min. An aqueous solution (5%, wt/vol) of ferrous sulfate heptahydrate (1.2 equiv) was added over a period of approximately 1 min. Upon completion of the reaction (TLC), the mixture was diluted with water and transferred to a separatory funnel. The MeOH/water layer was extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO_2) provided the thiylated aldehyde product **7**.

Any modification of the above procedure is described below with the specific entry.

Note: Solid phenyl disulfide was ground to a fine powder prior to use.

4.7. Characterization Data



6a **7aa**

*1.0 mmol scale reaction

Yield: 67% (121 mg).

Physical State: white solid.

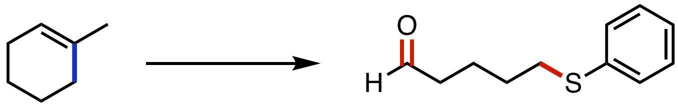
^{1}H NMR (500 MHz, CDCl$_3$): δ 9.77 (t, J = 1.3 Hz, 1H), 7.36–7.32 (m, 2H), 7.31–7.27 (m, 2H), 7.22–7.17 (m, 1H), 2.96 (t, J = 7.1 Hz, 2H), 2.62 (dt, J = 7.1, 1.3 Hz, 2H), 1.96 (tt, J = 7.1, 7.1 Hz, 2H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 201.4, 135.7, 129.3, 128.9, 126.1, 42.4, 32.9, 21.4.

***R*$_f$** = 0.30 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 5 → 10% Et$_2$O/pentane).

All characterization data are consistent with that reported in the literature.[26]



6b **7ba**

*1.0 mmol scale reaction

Yield: 63% (122 mg).

Physical State: white solid.

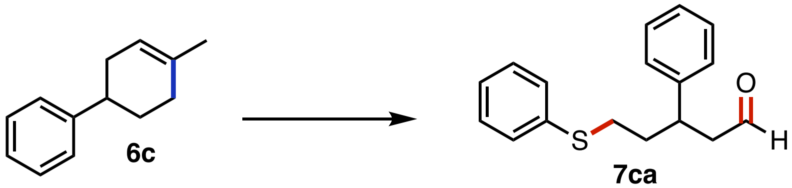
^{1}H NMR (500 MHz, CDCl$_3$): δ 9.75 (t, J = 1.6 Hz, 1H), 7.35–7.31 (m, 2H), 7.30–7.26 (m, 2H), 7.21–7.16 (m, 1H), 2.93 (t, J = 7.1 Hz, 2H), 2.45 (dt, J = 7.1, 1.6 Hz, 2H), 1.82–1.73 (m, 2H), 1.72–1.64 (m, 2H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 201.9, 136.3, 129.1, 128.8, 125.9, 43.2, 33.3, 28.4, 21.0.

***R*$_f$** = 0.30 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).

All characterization data are consistent with that reported in the literature.[27]



6c **7ca**

*1.0 mmol scale reaction

Yield: 75% (203 mg).

Physical State: white solid.

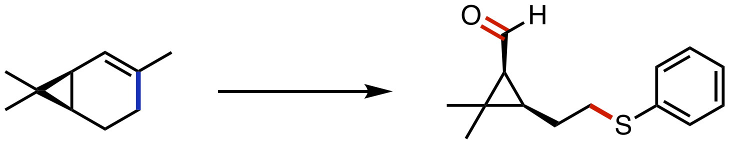
^{1}H NMR (500 MHz, CDCl$_3$): δ 9.64 (dd, J = 1.9, 1.9 Hz, 1H), 7.35–7.30 (m, 2H), 7.28–7.14 (m, 8H), 3.44–3.35 (m, 1H), 2.84–2.66 (m, 4H), 2.04–1.89 (m, 2H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 201.1, 142.3, 136.0, 129.0, 128.8, 128.8, 127.5, 126.9, 125.9, 50.2, 38.8, 35.6, 31.0.

MP: 58–59 °C.

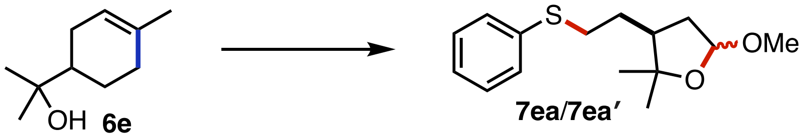
IR (neat, ATR): ν_{max} 3052, 3030, 2931, 2822, 2721, 1724, 743, 697 cm^{-1}.

HRMS (ESI-TOF): calc'd for $C_{17}H_{19}OS$ $[M + H]^+$ 271.1151, found 271.1149.
***R*$_f$** = 0.33 (10% EtOAc/hexanes).
Purification: (SiO_2, 2 → 5% EtOAc/hexanes).



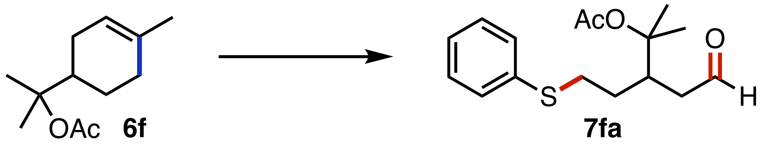
6d **7da**

*1.0 mmol scale reaction
Yield: 65% (152 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$): δ 9.51 (d, *J* = 5.6 Hz, 1H), 7.36–7.31 (m, 2H), 7.31–7.27 (m, 2H), 7.21–7.16 (m, 1H), 3.01–2.89 (m, 2H), 2.14–2.00 (m, 2H), 1.66 (dd, *J* = 8.6, 5.6 Hz, 1H), 1.52 (dd, *J* = 15.9, 7.5 Hz, 1H), 1.29 (s, 3H), 1.19 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$): δ 201.4, 136.2, 129.0, 128.8, 125.9, 38.4, 36.5, 33.6, 30.0, 28.8, 24.1, 15.0.
IR (neat, ATR): ν_{max} 3063, 2954, 2921, 2872, 2737, 1690, 739, 693 cm^{-1}.
Optical Rotation: $[\alpha]_D^{23.1}$ 41.8 (*c* 1.00, $CHCl_3$).
HRMS (ESI-TOF): calc'd for $C_{14}H_{18}OSK$ $[M + K]^+$ 273.0710, found 273.0712.
***R*$_f$** = 0.39 (10% EtOAc/hexanes).
Purification: (SiO_2, 5 → 10% Et_2O/pentane).



6e **7ea/7ea′**

*1.0 mmol scale reaction
Combined Yield: 42% (105 mg, inseparable mixture).
Diastereomeric Ratio: 1.2:1.
Physical State: colorless oil.
^{1}H NMR (500 MHz, $CDCl_3$) major: δ 7.35–7.27 (m, 4H), 7.22–7.16 (m, 1H), 4.88 (d, *J* = 4.9 Hz, 1H), 3.32 (s, 3H), 3.0–2.92 (m, 1H), 2.91–2.84 (m, 1H), 2.31–2.22 (m, 1H), 2.11 (dd, *J* = 12.5, 6.6 Hz, 1H), 1.77–1.52 (m, 3H), 1.32 (s, 3H), 1.01 (s, 3H).
^{1}H NMR (500 MHz, $CDCl_3$) minor: δ 7.35–7.27 (m, 4H), 7.22–7.16 (m, 1H), 4.97 (dd, *J* = 6.1, 4.5 Hz, 1H), 3.35 (s, 3H), 3.03–2.92 (m, 1H), 2.91–2.78 (m, 1H), 2.50–2.42 (m, 1H), 1.99 (dddd, *J* = 10.7, 10.7, 8.5, 3.9 Hz, 1H), 1.77–1.52 (m, 3H), 1.23 (s, 3H), 1.12 (s, 3H).
^{13}C NMR (125 MHz, $CDCl_3$) major: δ 136.2, 129.0, 128.8, 125.9, 102.9, 83.6, 54.1, 44.9, 38.6, 32.8, 29.6, 23.5.
^{13}C NMR (125 MHz, $CDCl_3$) minor: δ 136.1, 129.2, 128.8, 126.0, 104.2, 82.8, 55.3, 47.2, 38.7, 32.8, 29.7, 27.9, 23.0.
IR (neat, ATR): ν_{max} 3063, 2973, 2928, 2830, 1096, 1032, 968, 735, 686 cm^{-1}.
HRMS (ESI-TOF): calc'd for $C_{15}H_{22}O_2SK$ $[M + K]^+$ 305.0972, found 305.0964.
***R*$_f$** = 0.40 (10% EtOAc/hexanes).
Purification: (SiO_2, 2 → 6% EtOAc/hexanes).
Note: Solid ferrous sulfate heptahydrate was added at room temperature.



6f **7fa**

*1.0 mmol scale reaction

Yield: 61% (179 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 9.72 (dd, J = 2.8, 1.7 Hz, 1H), 7.37–7.27 (m, 4H), 7.22–7.17 (m, 1H), 3.03 (ddd, J = 13.1, 9.1, 4.7 Hz, 1H), 2.86 (ddd, J = 13.0, 8.8, 7.4 Hz, 1H), 2.69–2.62 (m, 1H), 2.55 (ddd, J = 16.8, 6.7, 2.9 Hz, 1H), 2.32 (ddd, J = 16.8, 5.3, 1.7 Hz, 1H), 1.91 (s, 3H), 1.85 (dddd, J = 13.9, 9.3, 7.3, 2.8 Hz, 1H), 1.54–1.47 (m, 1H), 1.46 (s, 3H), 1.38 (s, 3H).

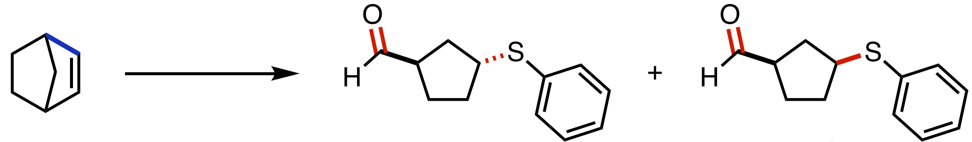
^{13}C NMR (125 MHz, CDCl$_3$): δ 201.4, 169.9, 135.6, 129.3, 128.9, 126.2, 84.0, 44.7, 41.7, 32.1, 29.8, 23.9, 22.2, 22.0.

IR (neat, ATR): ν_{max} 3056, 2939, 2830, 2729, 1724, 1370, 1247, 1134, 1024, 735, 693 cm^{-1}.

HRMS (ESI-TOF): calc'd for $C_{16}H_{22}O_3SNa$ [M + Na]$^+$ 317.1182, found 317.1166.

***R*$_f$** = 0.38 (20% EtOAc/hexanes).

Purification: (SiO$_2$, 5 → 15% EtOAc/hexanes).



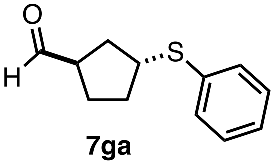
6g **7ga** **7ga′**

*1.0 mmol scale reaction

Combined Yield: 50% (102 mg).

Diastereomeric Ratio: 1.2:1 (determined from ^{1}H NMR spectrum of the crude products).

Note: 2D NMR spectra are consistent with the proposed structures of **7ga**/**7ga′**.



7ga

Yield: 27% (56 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 9.67 (d, J = 1.7 Hz, 1H), 7.39–7.35 (m, 2H), 7.32–7.27 (m, 2H), 7.24–7.19 (m, 1H), 3.69–3.62 (m, 1H), 3.10–3.02 (m, 1H), 2.35 (ddd, J = 13.7, 6.8, 6.8 Hz, 1H), 2.15–2.02 (m, 2H), 1.98–1.90 (m, 1H), 1.87 (ddd, J = 14.0, 8.7, 5.4 Hz, 1H), 1.77–1.68 (m, 1H).

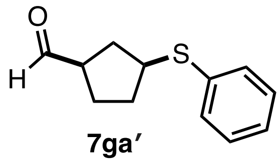
^{13}C NMR (125 MHz, CDCl$_3$): δ 202.5, 135.8, 130.1, 128.8, 126.5, 50.3, 45.9, 33.1, 32.6, 24.9.

IR (neat, ATR): ν_{max} 3056, 2958, 2856, 2717, 1716, 1476, 1435, 739, 689 cm^{-1}.

HRMS (ESI-TOF): calc'd for $C_{12}H_{14}OSK$ [M + K]$^+$ 245.0397, found 245.0418.

***R*$_f$** = 0.39 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 3% EtOAc/hexanes).



7ga′

Yield: 23% (46 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 9.66 (d, J = 2.2 Hz, 1H), 7.40–7.35 (m, 2H), 7.32–7.27 (m, 2H), 7.25–7.20 (m, 1H), 3.71–3.62 (m, 1H), 2.85–2.76 (m, 1H), 2.30 (ddd, J = 13.8, 9.0, 6.9 Hz, 1H), 2.19–2.03 (m, 2H), 2.01–1.88 (m, 2H), 1.77–1.68 (m, 1H).

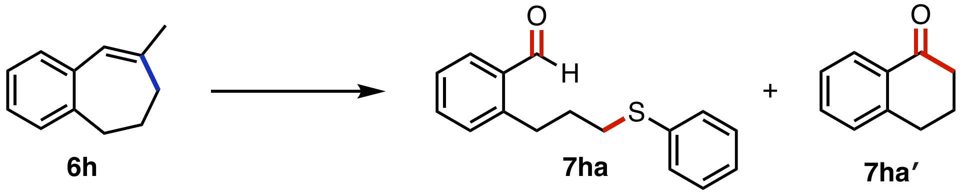
^{13}C NMR (125 MHz, CDCl$_3$): δ 202.8, 135.6, 131.0, 128.8, 126.6, 50.6, 46.4, 34.0, 32.8, 25.1.

IR (neat, ATR): ν_{max} 3060, 2947, 2864, 2713, 1716, 1476, 1439, 1093, 1028, 743, 693 cm^{-1}.

HRMS (ESI-TOF): calc'd for $C_{12}H_{14}OSK$ [M + K]$^+$ 245.0397, found 245.0409.

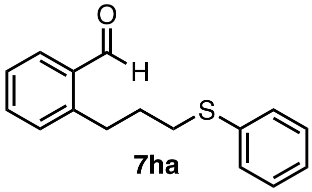
***R*$_f$** = 0.33 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 3% EtOAc/hexanes).



*1.0 mmol scale reaction

Combined Yield: 95% (144 mg).



7ha

Yield: 5% (12 mg).

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 10.22 (s, 1H), 7.81 (dd, J = 7.7, 1.3 Hz, 1H), 7.50 (ddd, J = 7.5, 7.5, 1.5 Hz, 1H), 7.38 (ddd, J = 7.5, 7.5, 1.0 Hz, 1H), 7.35–7.31 (m, 2H), 7.30–7.26 (m, 3H), 7.20–7.15 (m, 1H), 3.18 (t, J = 7.7 Hz, 2H), 2.98 (t, J = 7.2 Hz, 2H), 2.00–1.91 (m, 2H).

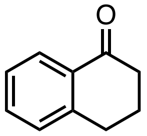
^{13}C NMR (125 MHz, CDCl$_3$): δ 192.5, 144.1, 136.3, 133.8, 133.8, 132.8, 131.2, 129.2, 128.9, 126.8, 125.9, 33.1, 31.5, 31.1.

IR (neat, ATR): ν_{max} 3063, 2928, 2860, 2739, 1694, 739, 693 cm^{-1}.

HRMS (ESI-TOF): calc'd for $C_{16}H_{16}OSK$ [M + K]$^+$ 295.0553, found 295.0566.

***R*$_f$** = 0.51 (10% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 6% EtOAc/hexanes).



7ha′

Yield: 90% (132 mg).
Physical State: colorless oil.
^{1}H NMR (500 MHz, CDCl$_3$): δ 8.03 (dd, *J* = 7.8, 1.0 Hz, 1H), 7.46 (ddd, *J* = 7.5, 7.5, 1.4 Hz, 1H), 7.33–7.27 (m, 1H), 7.26–7.23 (m, 1H), 2.96 (t, *J* = 6.1 Hz, 2H), 2.65 (t, *J* = 6.6 Hz, 2H), 2.18–2.10 (m, 2H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 198.3, 144.4, 133.3, 132.5, 128.7, 127.0, 126.5, 39.1, 29.6, 23.2.
***R*$_f$** = 0.43 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 2 → 6% EtOAc/hexanes).
All characterization data are consistent with that reported in the literature.[28]
Note: A proposed mechanism for the formation of **7ha′** is provided below; it is consistent with a literature precedent.[29]

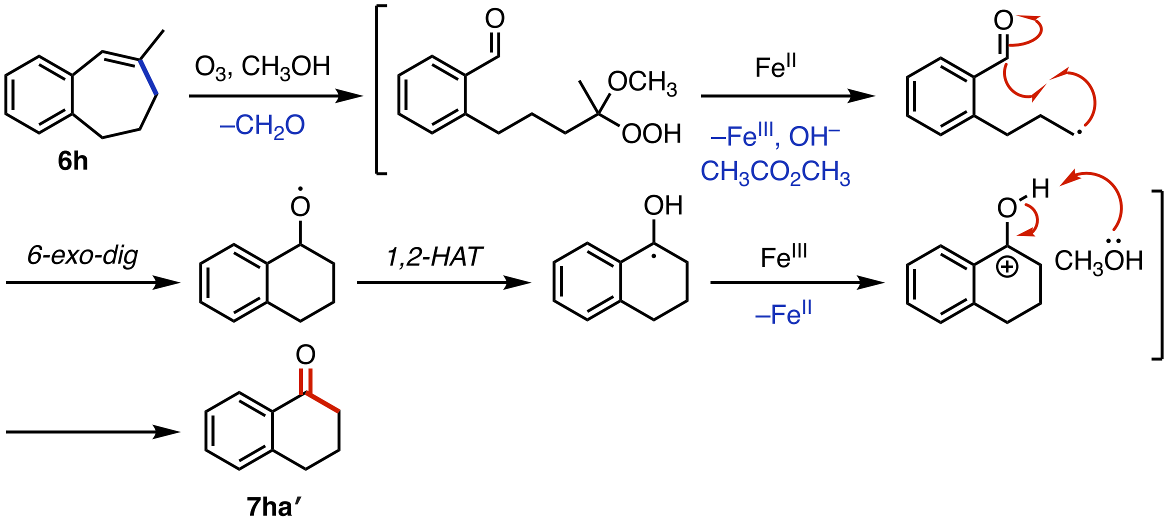


Figure S4. Proposed mechanism for the formation of **7ha′**.

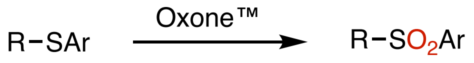
5. Experimental Procedures for Synthetic Applications

5.1. General Procedure A for Oxidation to Sulfones

$$\mathrm{R{-}SAr} \xrightarrow{m\mathrm{CPBA}} \mathrm{R{-}SO_2Ar}$$

A round-bottom flask equipped with a magnetic stirrer bar was charged with the thioether (1.0 equiv) and dichloromethane (0.1 M). *m*CPBA (2.5 equiv) was added in four portions over a period of 10 min at room temperature. The mixture was stirred until complete conversion to the sulfone had occurred (TLC; typically < 1 h). Upon its completion, the reaction was quenched through the addition of saturated aqueous sodium thiosulfate. The mixture was poured into saturated aqueous sodium bicarbonate and extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried, filtered, and concentrated under reduced pressure. If necessary, the sulfone was purified through flash column chromatography (SiO_2).

5.2. General Procedure B for Oxidation to Sulfones

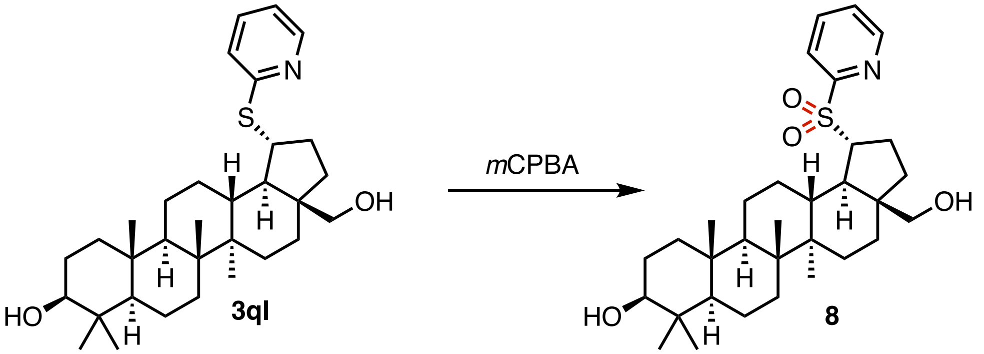


The following procedure was adapted from the literature.[30]

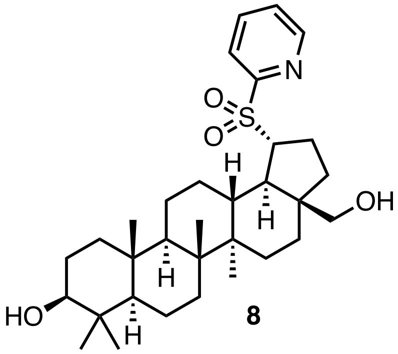
A round-bottom flask equipped with a magnetic stirrer bar was charged with the thioether (1.0 equiv) and MeOH (0.25 M), then cooled to 0 °C in an ice-water bath. A solution of Oxone™ (3.0 equiv) in water (0.75 M) was added. The cloudy mixture was warmed to room temperature and stirred until complete conversion to the sulfone had occurred (TLC). The mixture was diluted with water and extracted with dichloromethane (3x). The combined organic fractions were washed with water, brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. If necessary, the sulfone was purified through flash column chromatography (SiO_2).

Note: Upon addition of Oxone™, the thioether was immediately oxidized to the sulfoxides (a mixture of diastereoisomers; the most polar components on TLC). Once the mixture had been warmed to room temperature, both of the sulfoxides had been converted to the sulfone (medium-polarity component on TLC).

5.3. Synthesis of the Sulfone 8

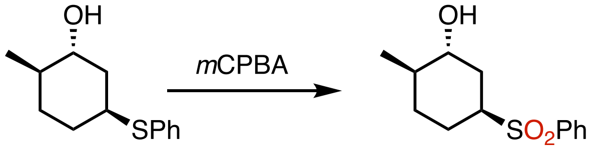


The thioether **3ql** was oxidized to the sulfone **8** following General Procedure A. To verify the structure of the product, approximately 5 mg of **8** was placed in a small crystallization tube and dissolved in a minimal amount of dichloromethane. This vial was placed within a larger 4-mL vial containing approximately 1 mL of pentane. The outer vial was capped and sealed with Teflon and Parafilm. After 3 days, single crystals suitable for X-ray diffraction had formed.


8

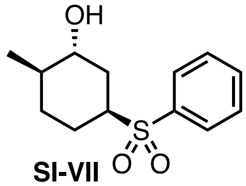
*0.5 mmol scale reaction (from **1q**)
Yield: 43% from **1q** (116 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 8.72 (ddd, *J* = 4.7, 1.6, 0.8 Hz, 1H), 8.07 (ddd, *J* = 7.8, 0.9, 0.9 Hz, 1H), 7.93 (ddd, *J* = 7.7, 7.7, 1.7 Hz, 1H), 7.50 (ddd, *J* = 7.6, 4.7, 1.1 Hz, 1H), 3.92 (ddd, *J* = 10.0, 10.0, 4.1 Hz, 1H), 3.85 (d, *J* = 11.0 Hz, 1H), 3.23 (d, *J* = 10.3 Hz, 1H), 3.20 (dd, *J* = 11.4, 4.7 Hz, 1H), 2.35 (dd, *J* = 11.8, 10.2 Hz, 1H), 1.96–0.86 (m, 24H), 1.05 (s, 3H), 1.04 (s, 3H), 0.97 (s, 3H), 0.83 (s, 3H), 0.76 (s, 3H), 0.73–0.67 (m, 1H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 158.8, 150.3, 137.9, 126.8, 122.0, 78.9, 61.2, 60.5, 55.1, 50.0, 49.5, 47.8, 43.3, 41.2, 38.9, 38.6, 37.1, 35.4, 34.3, 32.8, 29.3, 28.0, 28.0, 28.0, 27.4, 26.8, 20.9, 18.3, 16.1, 16.0, 15.4, 14.8.
MP: 258 ˚C (decomp).
IR (neat, ATR): ν_{max} 3410, 3004, 2943, 2872, 1299, 1036, 739 cm^{-1}.
Optical Rotation: $[\alpha]_D^{23.2}$ –6.4 (*c* 0.50, CHCl$_3$).
HRMS (ESI-TOF): calc'd for $C_{32}H_{50}NO_4S$ $[M + H]^+$ 544.3455, found 544.3455.
***R*$_f$** = 0.32 (50% EtOAc/hexanes).
Purification: (SiO$_2$, 30 → 60% EtOAc/hexanes).

5.4. Synthesis of the Sulfone 9



3oa **SI-VII**

The thioether **3oa** (133 mg, 0.600 mmol) was oxidized to the sulfone **SI-VII** following General Procedure A, then used without further purification.



SI-VII

*0.6 mmol scale reaction

Physical State: white solid.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.91–7.84 (m, 2H), 7.67–7.61 (m, 1H), 7.60–7.52 (m, 2H), 3.92–3.86 (m, 1H), 3.35 (dddd, *J* = 10.0, 10.0, 4.7, 4.7 Hz, 1H), 1.96 (ddd, *J* = 13.7, 10.6, 3.1 Hz, 1H), 1.91–1.68 (m, 6H), 1.54–1.46 (m, 1H), 0.94 (d, *J* = 7.1 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 137.4, 133.5, 129.0, 128.7, 70.4, 58.7, 34.4, 27.7, 25.1, 20.0, 16.3.

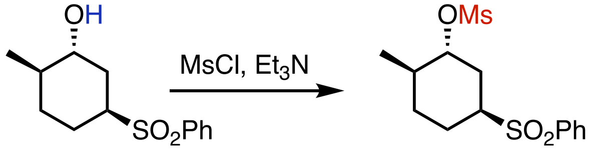
MP: 122–124 ˚C.

IR (neat, ATR): ν_{max} 3500, 2949, 2932, 2876, 1444, 1297, 1143, 725, 689, 590 cm^{-1}.

Optical Rotation: $[\alpha]_D^{23.2}$ –8.6 (*c* 1.00, CHCl$_3$).

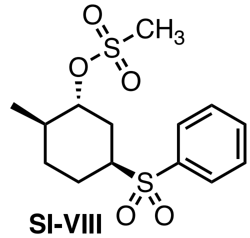
HRMS (ESI-TOF): calc’d for $C_{13}H_{18}O_3SNa$ $[M + Na]^+$ 277.0869, found 277.0860.

***R*$_f$** = 0.45 (50% EtOAc/hexanes).



SI-VII **SI-VIII**

A round-bottom flask equipped with a magnetic stirrer bar was charged with the sulfone **SI-VII** (153 mg, 0.600 mmol, 1.0 equiv) and anhydrous dichloromethane (0.1 M), then cooled to 0 °C in an ice-water bath. Triethylamine (126 µL, 0.900 mmol, 1.5 equiv) was added, followed by dropwise addition of methanesulfonyl chloride (70.0 µL, 0.900 mmol, 1.5 equiv). The mixture was warmed to room temperature and stirred until complete conversion to the mesylate had occurred (TLC, ca. 30 min). Upon completion of the reaction, the mixture was diluted with water and extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. The crude product was filtered through a short silica (SiO$_2$) plug to give the mesylate **SI-VIII**, which was used without further purification.



SI-VIII

*0.6 mmol scale reaction

Physical State: colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.93–7.86 (m, 2H), 7.72–7.64 (m, 1H), 7.63–7.55 (m, 2H), 4.88–4.81 (m, 1H), 3.31–3.22 (m, 1H), 2.98 (s, 3H), 2.17–2.03 (m, 3H), 1.97–1.87 (m, 1H), 1.87–1.72 (m, 2H), 1.68–1.59 (m, 1H), 1.02 (d, J = 7.2 Hz, 3H).

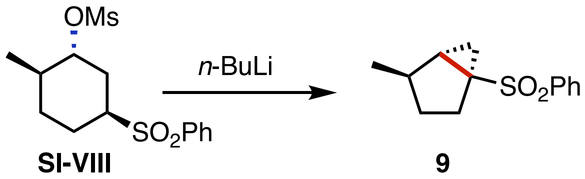
^{13}C NMR (125 MHz, CDCl$_3$): δ 136.8, 133.9, 129.2, 128.8, 81.5, 58.5, 38.5, 32.9, 26.6, 25.5, 19.7, 16.1.

IR (neat, ATR): ν_{max} 2972, 2940, 1345, 1301, 1174, 1147, 928, 901 cm^{-1}.

Optical Rotation: $[\alpha]_D^{23.4}$ –16.4 (*c* 1.00, CHCl$_3$).

HRMS (ESI-TOF): calc'd for $C_{14}H_{20}O_5S_2Na$ [M + Na]$^+$ 355.0644, found 355.0630.

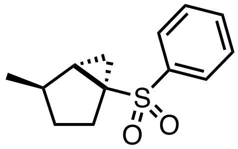
***R*$_f$** = 0.56 (50% EtOAc/hexanes).



The following procedure was adapted from the literature.[31]

A flame-dried round-bottom flask equipped with a magnetic stirrer bar was charged under argon protection with the mesylate **SI-VIII** (200 mg, 0.600 mmol, 1.0 equiv) and anhydrous THF (0.1 M), then cooled to –20 °C in a NaCl/ice bath. *n*-Butyllithium (2.3 M, 391 µL, 0.900 mmol, 1.5 equiv) was added dropwise. Once the starting material had been consumed (TLC), the reaction was quenched through the addition of saturated aqueous ammonium chloride. The aqueous layer was extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO$_2$) provided the sulfone **9**.

Note: The mesylate **SI-VIII** was azeotroped with benzene three times prior to use.



9

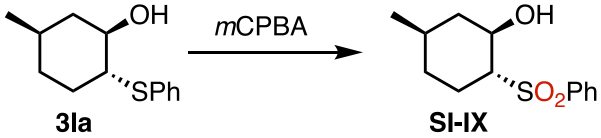
*0.6 mmol scale reaction

Yield: 85% from **3oa** (121 mg).

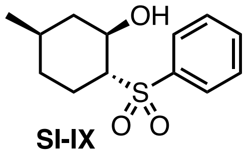
Physical State: white solid.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.91–7.85 (m, 2H), 7.65–7.60 (m, 1H), 7.57–7.50 (m, 2H), 2.20–2.10 (m, 2H), 1.95 (dd, *J* = 9.0, 5.1 Hz, 1H), 1.71 (dd, *J* = 12.4, 7.9 Hz, 1H), 1.65 (ddd, *J* = 9.0, 5.6, 1.2 Hz, 1H), 1.46–1.31 (m, 2H), 0.95 (dd, *J* = 5.3, 5.3 Hz, 1H), 0.80 (d, *J* = 7.0 Hz, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 139.2, 133.1, 128.8, 128.2, 48.0, 33.5, 33.4, 28.7, 25.0, 20.5, 14.2.
MP: 52–53 ˚C.
IR (neat, ATR): ν_{max} 3067, 2958, 2879, 1299, 1138, 1085, 723, 686, 592, 558 cm^{-1}.
Optical Rotation: $[\alpha]_D^{23.4}$ –2.5 (*c* 1.00, CHCl$_3$).
HRMS (DART): calc'd for $C_{13}H_{17}O_2S$ $[M + H]^+$ 237.0944, found 237.0930.
***R*$_f$ =** 0.32 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 5 → 10% EtOAc/hexanes).
Note: The sulfone **9** was also synthesized in 78% overall yield starting from a mixture of the thioethers **3oa**/**3oa′** (2:1 *d.r.*) by following the procedures given above.

5.5. Synthesis of the Sulfone 10



The thioether **3la** (111 mg, 0.500 mmol) was oxidized to the sulfone **SI-IX** following General Procedure A, then used without further purification.



SI-IX

*0.5 mmol scale reaction

Physical State: white solid.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.95–7.87 (m, 2H), 7.73–7.66 (m, 1H), 7.64–7.56 (m, 2H), 4.13 (br s, 1H), 3.96 (ddd, *J* = 10.3, 10.3, 4.8 Hz, 1H), 2.94 (ddd, *J* = 12.9, 9.5, 3.7 Hz, 1H), 2.14–2.04 (m, 1H), 1.88 (dddd, *J* = 13.3, 3.6, 3.6, 3.6 Hz, 1H), 1.71–1.62 (m, 1H), 1.46–1.34 (m, 1H), 1.33 (ddd, *J* = 26.2, 13.2, 3.9 Hz, 1H), 1.07 (q, *J* = 12.1 Hz, 1H), 0.89 (d, *J* = 6.6 Hz, 3H), 0.86 (ddd, *J* = 25.4, 13.6, 3.5 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$): δ 136.7, 134.0, 129.1, 128.9, 68.6, 67.8, 42.4, 32.7, 30.1, 25.3, 21.4.

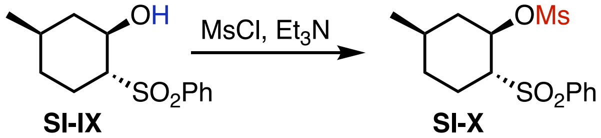
MP: 101–102 ˚C.

IR (neat, ATR): ν_{max} 3500, 3067, 2954, 2928, 2864, 1445, 1291, 1134, 1081, 610 cm^{-1}.

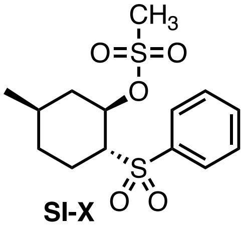
Optical Rotation: $[\alpha]_D^{23.5}$ –15.5 (*c* 1.00, $CHCl_3$).

HRMS (ESI-TOF): calc'd for $C_{13}H_{18}O_3SNa$ $[M + Na]^+$ 277.0869, found 277.0850.

***R*f** = 0.42 (30% EtOAc/hexanes).



A round-bottom flask equipped with a magnetic stirrer bar was charged with the sulfone **SI-IX** (127 mg, 0.500 mmol, 1.0 equiv) and anhydrous dichloromethane (0.1 M), then cooled to 0 °C in an ice-water bath. Triethylamine (105 µL, 0.750 mmol, 1.5 equiv) was added, followed by dropwise addition of methanesulfonyl chloride (58 µL, 0.750 mmol, 1.5 equiv). The mixture was warmed to room temperature and stirred until complete conversion to the mesylate had occurred (TLC, ca. 30 min). The mixture was diluted with water and extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. The crude product was filtered through a short silica (SiO_2) plug to give the mesylate **SI-X**, which was used without further purification.



SI-X

*0.5 mmol scale reaction

Physical State: white solid.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.93–7.86 (m, 2H), 7.71–7.65 (m, 1H), 7.63–7.56 (m, 2H), 4.99 (ddd, *J* = 10.7, 10.7, 4.7 Hz, 1H), 3.24 (ddd, *J* = 12.9, 10.2, 4.1 Hz, 1H), 3.09 (s, 3H), 2.47 (dddd, *J* = 12.7, 4.9, 3.0, 2.0 Hz, 1H), 1.79 (dq, *J* = 13.5, 3.7 Hz, 1H), 1.73–1.65 (m, 1H), 1.58–1.49 (m, 1H), 1.46 (dq, *J* = 13.3, 3.9 Hz, 1H), 1.37 (q, *J* = 12.1 Hz, 1H), 0.92 (d, *J* = 6.5 Hz, 3H), 0.87 (dq, *J* = 11.9, 3.7 Hz, 1H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 138.0, 133.9, 129.2, 128.5, 77.7, 65.1, 41.9, 39.1, 32.2, 30.4, 26.2, 21.1.

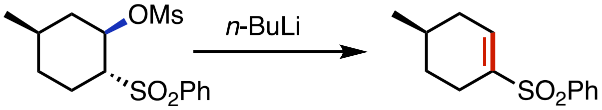
MP: 180–182 ˚C.

IR (neat, ATR): ν_{max} 3028, 2953, 2932, 2873, 1349, 1305, 1178, 1143, 944, 749, 607 cm^{-1}.

Optical Rotation: $[\alpha]_D^{23.5}$ –42.5 (*c* 1.00, CHCl$_3$).

HRMS (ESI-TOF): calc'd for $C_{14}H_{20}O_5S_2Na$ [M + Na]$^+$ 355.0644, found 355.0649.

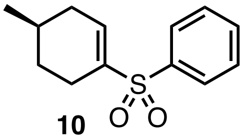
***R*$_f$** = 0.30 (30% EtOAc/hexanes).



SI-X **10**

A flame-dried round-bottom flask equipped with a magnetic stirrer bar under argon protection was charged with the mesylate **SI-X** (166 mg, 0.500 mmol, 1.0 equiv) and anhydrous THF (0.1 M), then cooled to –78 °C in a dry-ice/acetone bath. *n*-Butyllithium (2.3 M, 261 µL, 0.600 mmol, 1.2 equiv) was added dropwise. After stirring for 20 min, the mixture was warmed to room temperature and stirred until the starting material had been consumed (TLC). The reaction was quenched through the addition of half-saturated aqueous ammonium chloride. The aqueous phase was extracted with dichloromethane (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO$_2$) provided the sulfone **10**.

Note: The mesylate **SI-X** was azeotroped with benzene three times prior to use.



10

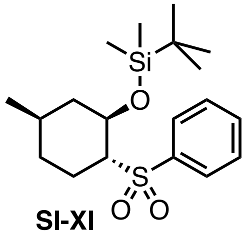
*0.5 mmol scale reaction

Yield: 96% from **3la** (112 mg).

Physical State: colorless oil.

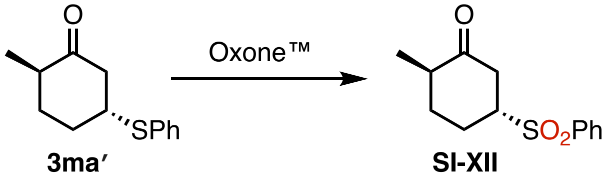
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.90–7.83 (m, 2H), 7.63–7.57 (m, 1H), 7.57–7.49 (m, 2H), 7.07–7.01 (m, 1H), 2.44–2.34 (m, 1H), 2.34–2.24 (m, 1H), 2.19–2.08 (m, 1H), 1.85 (ddddd, *J* = 19.1,

9.5, 3.9, 2.7, 2.7 Hz, 1H), 1.80–1.72 (m, 1H), 1.69–1.60 (m, 1H), 1.28–1.16 (m, 1H), 0.95 (d, *J* = 6.7 Hz, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 139.4, 139.4, 138.1, 133.0, 128.9, 127.9, 33.6, 29.8, 27.0, 22.8, 20.9.
IR (neat, ATR): ν_{max} 3063, 2954, 2928, 2875, 1307, 1288, 1148, 1081, 915, 735, 719, 686, 618, 569 cm^{-1}.
Optical Rotation: $[\alpha]_D^{23.5}$ 53.3 (*c* 1.00, CHCl$_3$).
HRMS (ESI-TOF): calc'd for $C_{13}H_{16}O_2SNa$ [M + Na]$^+$ 259.0763, found 259.0774.
***R*$_f$** = 0.33 (10% EtOAc/hexanes).
Purification: (SiO$_2$, 10% EtOAc/hexanes).
Note: The silyl ether **SI-XI** also underwent elimination to provide the sulfone **10** in 95% yield from **3la**.

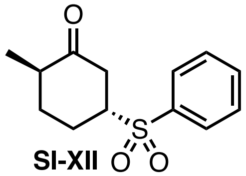

SI-XI

Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.90–7.83 (m, 2H), 7.62–7.56 (m, 1H), 7.55–7.48 (m, 2H), 4.17 (ddd, *J* = 10.7, 9.5, 4.5 Hz, 1H), 3.09 (ddd, *J* = 12.9, 9.3, 3.6 Hz, 1H), 2.04–1.97 (m, 1H), 1.74–1.63 (m, 2H), 1.51–1.38 (m, 1H), 1.10 (dd, *J* = 23.6, 12.4 Hz, 1H), 0.94–0.78 (m, 2H), 0.90 (d, *J* = 6.6 Hz, 3H), 0.86 (s, 9H), 0.12 (s, 3H), 0.04 (s, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 140.2, 132.8, 128.8, 127.9, 70.2, 68.3, 44.6, 32.8, 30.4, 25.8, 21.5, 18.0, –4.1, –4.2.
MP: 54–56 ˚C.
IR (neat, ATR): ν_{max} 3063, 2954, 2928, 2852, 1303, 1145, 829, 780, 607 cm^{-1}.
Optical Rotation: $[\alpha]_D^{23.5}$ –45.6 (*c* 1.00, CHCl$_3$).
HRMS (ESI-TOF): calc'd for $C_{19}H_{32}O_3SSiNa$ [M + Na]$^+$ 391.1734, found 391.1759.
***R*$_f$** = 0.42 (10% EtOAc/hexanes).
Note: The silyl ether **SI-XI** was prepared from the sulfone **SI-IX** by following a procedure adapted from the literature.[32]

5.6. Synthesis of the Ketals 11/11′

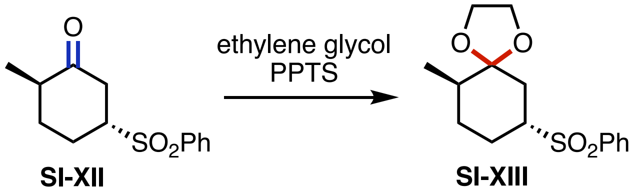


The thioether **3ma′** (528 mg, 2.40 mmol) was oxidized to the sulfone **SI-XII** following General Procedure B.

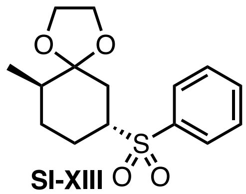


SI-XII

*2.4 mmol scale reaction
Yield: 94% (569 mg).
Physical State: white solid.
^{1}H NMR (500 MHz, CDCl$_3$): δ 7.92–7.83 (m, 2H), 7.73–7.65 (m, 1H), 7.64–7.55 (m, 2H), 3.27 (dddd, *J* = 12.5, 8.8, 8.8, 3.7 Hz, 1H), 2.58 (d, *J* = 9.4 Hz, 2H), 2.38 (sept, *J* = 6.4 Hz, 1H), 2.33–2.26 (m, 1H), 2.21 (dddd, *J* = 13.7, 5.8, 3.5, 3.5 Hz, 1H), 2.00 (dddd, *J* = 13.0, 13.0, 13.0, 3.7 Hz, 1H), 1.34 (dddd, *J* = 13.3, 13.3, 13.3, 3.5 Hz, 1H), 1.01 (d, *J* = 6.5 Hz, 3H).
^{13}C NMR (125 MHz, CDCl$_3$): δ 207.8, 136.6, 134.1, 129.3, 128.8, 62.9, 44.3, 40.4, 32.5, 24.0, 13.9.
MP: 146–148 ˚C.
IR (neat, ATR): ν_{max} 2977, 2931, 2872, 1709, 1281, 1257, 1141 cm^{-1}.
Optical Rotation: $[\alpha]_D^{23.6}$ 66.1 (*c* 1.00, CHCl$_3$).
HRMS (ESI-TOF): calc'd for $C_{13}H_{16}O_3SNa$ [M + Na]$^+$ 275.0712, found 275.0721.
***R*$_f$** = 0.43 (30% EtOAc/hexanes).
Purification: (SiO$_2$, 20 → 30% EtOAc/hexanes).



A round-bottom flask equipped with a magnetic stirrer bar was charged with the sulfone **SI-XII** (252 mg, 1.00 mmol, 1.0 equiv), pyridinium *p*-toluenesulfonate (38.0 mg, 0.15 mmol, 0.15 equiv), ethylene glycol (168 µL, 3.00 mmol, 3.0 equiv), and anhydrous benzene (0.1 M). The mixture was heated under reflux for 4 h using a Dean–Stark apparatus. Upon completion of the reaction (TLC), the mixture was cooled, poured into saturated aqueous sodium bicarbonate, and extracted with EtOAc (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO$_2$) provided the ketal **SI-XIII**.



SI-XIII

*1.1 mmol scale reaction

Yield: 91% (301 mg).

Physical State: white solid.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.89–7.83 (m, 2H), 7.68–7.62 (m, 1H), 7.59–7.52 (m, 2H), 4.00–3.85 (m, 4H), 3.19 (dddd, *J* = 12.6, 12.6, 3.4, 3.4 Hz, 1H), 2.18 (ddd, *J* = 12.7, 3.2, 2.4 Hz, 1H), 1.97–1.88 (m, 1H), 1.71 (ddd, *J* = 13.1, 7.1, 3.9 Hz, 1H), 1.71–1.59 (m, 1H), 1.51 (dd, *J* = 12.8, 12.8 Hz, 1H), 1.41 (dddd, *J* = 12.9, 12.9, 12.9, 3.8 Hz, 1H), 1.29 (dddd, *J* = 12.9, 12.9, 12.9, 3.6 Hz, 1H), 0.82 (d, *J* = 6.6 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 136.9, 133.6, 129.0, 128.9, 109.4, 65.3, 65.1, 61.4, 38.9, 34.0, 30.1, 25.0, 13.3.

MP: 104–105 ˚C.

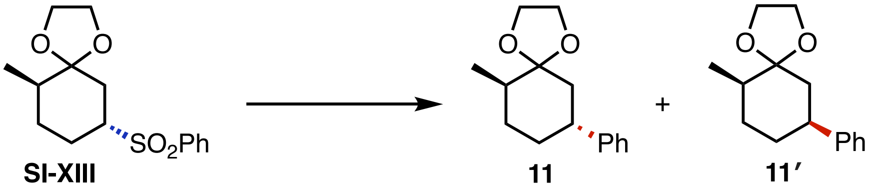
IR (neat, ATR): ν_{max} 3067, 2958, 2935, 2883, 1299, 1148, 1081 cm^{-1}.

Optical Rotation: $[\alpha]_D^{23.6}$ 6.5 (*c* 1.00, CHCl$_3$).

HRMS (ESI-TOF): calc'd for $C_{15}H_{20}O_4SNa$ $[M + Na]^+$ 319.0975, found 319.0969.

***R*$_f$** = 0.50 (30% EtOAc/hexanes).

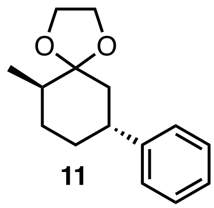
Purification: (SiO$_2$, 20 → 30% EtOAc/hexanes).



The ketal **SI-XIII** was converted to the arylated products **11**/**11**′ by following a procedure adapted from the literature.[33]

A flame-dried vial was charged with the ketal **SI-XIII** (148 mg, 0.500 mmol, 1.0 equiv) and Fe(acac)$_3$ (35.4 mg, 0.100 mmol, 0.2 equiv) in a glove box, then sealed with a rubber septum and removed. A flame-dried round-bottom flask equipped with a magnetic stirrer bar was charged under argon protection with tetramethylethylenediamine (598 µL, 4.00 mmol, 8.0 equiv) and stirring was commenced. The first vial was charged with cyclopentyl methyl ether (3.0 mL), then sonicated until the contents became homogeneous. The clear-red solution was transferred via syringe to the reaction flask. The vial was rinsed with another portion of cyclopentyl methyl ether (3.0 mL) and then the contents were also transferred to the reaction flask via syringe. Phenylmagnesium bromide (3.0 M in Et$_2$O, 0.500 mL, 1.50 mmol, 3.0 equiv) was added over 30 s (the color changed from red to black upon addition of the Grignard reagent). After stirring for 24 h, the reaction was quenched through the addition of water (5.0 mL). The mixture was filtered through a Celite plug and then the filter cake was washed with water (2x) and EtOAc (3x). The mixture was transferred to a separatory funnel. The aqueous phase was extracted with EtOAc (3x). The combined organic fractions were washed with brine, dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO$_2$) provided the arylated products **11**/**11**′.

Note: The ketal **SI-XIII** was azeotroped with benzene three times prior to use.



11

*0.5 mmol scale reaction

Yield: 55% (64 mg combined).

Diasteromeric Ratio: 4.3:1.

Physical State: white solid.

^{1}H NMR (500 MHz, CDCl$_3$) major: δ 7.34–7.27 (m, 2H), 7.26–7.17 (m, 3H), 4.05–3.92 (m, 4H), 2.84 (dddd, *J* = 12.5, 12.5, 3.4, 3.4 Hz, 1H), 1.97 (ddd, *J* = 12.9, 3.4, 2.1 Hz, 1H), 1.91–1.72 (m, 3H), 1.62 (t, *J* = 12.9 Hz, 1H), 1.56–1.42 (m, 2H), 0.94 (d, *J* = 6.5 Hz, 3H).

^{1}H NMR (500 MHz, CDCl$_3$) minor: δ 7.34–7.27 (m, 2H), 7.26–7.17 (m, 3H), 4.05–3.92 (m, 4H), 2.94–2.85 (m, 1H), 2.05–1.39 (m, 7H), 1.12 (d, *J* = 7.3 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$) major: δ 146.1, 128.3, 126.7, 126.0, 110.6, 65.3, 64.8, 42.4, 41.8, 39.3, 33.8, 32.3, 13.8.

^{13}C NMR (125 MHz, CDCl$_3$) minor: δ 146.2, 128.3, 126.7, 126.0, 111.4, 64.2, 64.1, 41.7, 36.7, 35.6, 29.8, 27.3, 14.6.

MP: 67–68 ˚C.

IR (neat, ATR): ν_{max} 2972, 2925, 2885, 2857, 1170, 1087, 761 cm^{-1}.

Optical Rotation: $[\alpha]_D^{20.7}$ –6.4 (*c* 0.50, CHCl$_3$).

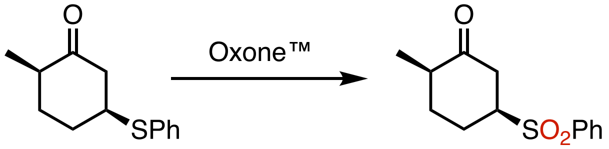
HRMS (ESI-TOF): calc'd for $C_{15}H_{21}O_2$ [M + H]$^+$ 233.3305, found 233.3301.

***R*$_f$** = 0.36 (5% EtOAc/hexanes).

Purification: (SiO$_2$, 2 → 5% EtOAc/hexanes).

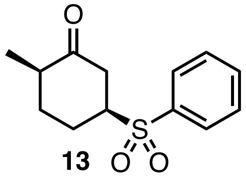
Note: Approximately 25 mg of the major diastereoisomer **11** was separated from the mixture of **11** and **11´** (the major product is *slightly* more polar). In contrast, the minor diastereoisomer could not be separated completely from the major product. NMR spectra are provided for both pure **11** and a mixture of **11** and **11´** (2.3:1 *d.r.*). All presented characterization data (MP, IR, optical rotation, HRMS) are those for pure **11**. 2D NMR spectra are consistent with the proposed structure of **11**.

5.7. Synthesis of the Lactone 12



3ma **SI-XIV**

The thioether **3ma** (682 mg, 3.10 mmol) was oxidized to the sulfone **SI-XIV** following General Procedure B.



13

*3.1 mmol scale reaction

Yield: 95% (751 mg).

Physical State: white solid.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.92–7.86 (m, 2H), 7.72–7.66 (m, 1H), 7.62–7.56 (m, 2H), 3.40 (dddd, *J* = 8.5, 8.5, 4.9, 4.9 Hz, 1H), 2.71 (dd, *J* = 15.4, 8.7 Hz, 1H), 2.52–2.41 (m, 2H), 2.31 (dddd, *J* = 14.1, 8.4, 8.4, 4.5 Hz, 1H), 2.15–2.06 (m, 1H), 2.05–1.96 (m, 1H), 1.96–1.87 (m, 1H), 1.15 (d, *J* = 7.0 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 208.9, 136.9, 134.0, 129.3, 128.8, 61.8, 43.4, 37.7, 29.5, 20.5, 15.6.

MP: 119–120 ˚C.

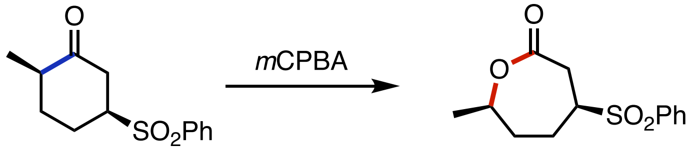
IR (neat, ATR): ν_{max} 3063, 2973, 2939, 2872, 1709, 1291, 1148, 1073, 723 cm^{-1}.

Optical Rotation: $[\alpha]_D^{23.7}$ –63.3 (*c* 1.00, CHCl$_3$).

HRMS (ESI-TOF): calc'd for $C_{13}H_{16}O_3SK$ $[M + K]^+$ 291.0452, found 291.0492.

***R*$_f$** = 0.52 (50% EtOAc/hexanes).

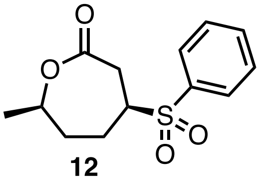
Purification: (SiO$_2$, 30 → 50% EtOAc/hexanes).



SI-XIV **12**

The sulfone **SI-XIV** was converted to the lactone **12** by following a procedure adapted from the literature.[34]

*m*CPBA (671 mg, 2.80 mmol, 1.4 equiv) was added to a stirred solution of the sulfone **SI-XIV** (504 mg, 2.00 mmol, 1.0 equiv) in dichloromethane (0.5 M) at room temperature. The mixture was stirred until complete conversion to the lactone had occurred (TLC, ca. 6 h). The mixture was filtered to remove solids and then the filter cake washed with dichloromethane (3x). The organic fractions were washed with aqueous sodium bisulfite (5%, wt/vol), saturated aqueous sodium bicarbonate (3x), and brine (2x), then dried (anhydrous sodium sulfate), filtered, and concentrated under reduced pressure. Purification through flash column chromatography (SiO_2) provided the lactone **12**.



12

*2.0 mmol scale reaction

Yield: 73% (390 mg).

Physical State: white solid.

^{1}H NMR (500 MHz, CDCl$_3$): δ 8.02–7.96 (m, 2H), 7.73–7.67 (m, 1H), 7.65–7.58 (m, 2H), 4.45 (ddq, J = 10.1, 6.2, 2.4 Hz, 1H), 3.31 (ddd, J = 10.9, 5.5, 5.5 Hz, 1H), 3.05 (dd, J = 15.7, 5.7 Hz, 1H), 2.92 (ddd, J = 15.8, 5.3, 0.7 Hz, 1H), 2.44 (dddd, J = 14.8, 6.3, 6.3, 4.2 Hz, 1H), 2.28 (dddd, J = 15.1, 9.6, 9.6, 4.1 Hz, 1H), 2.09 (dddd, J = 14.6, 9.6, 4.8, 4.8 Hz, 1H), 1.88 (J = 15.1, 6.9, 4.9, 2.0 Hz, 1H), 1.42 (d, J = 6.4 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$): δ 170.0, 136.8, 134.3, 129.4, 129.2, 75.7, 58.1, 34.5, 32.6, 25.1, 21.8.

MP: 173–175 ˚C.

IR (neat, ATR): ν_{max} 3060, 2935, 1720, 1307, 1287, 1263, 1181, 1143, 1081, 735, 693 cm^{-1}.

Optical Rotation: $[\alpha]_D^{23.7}$ –26.7 (*c* 1.00, $CHCl_3$).

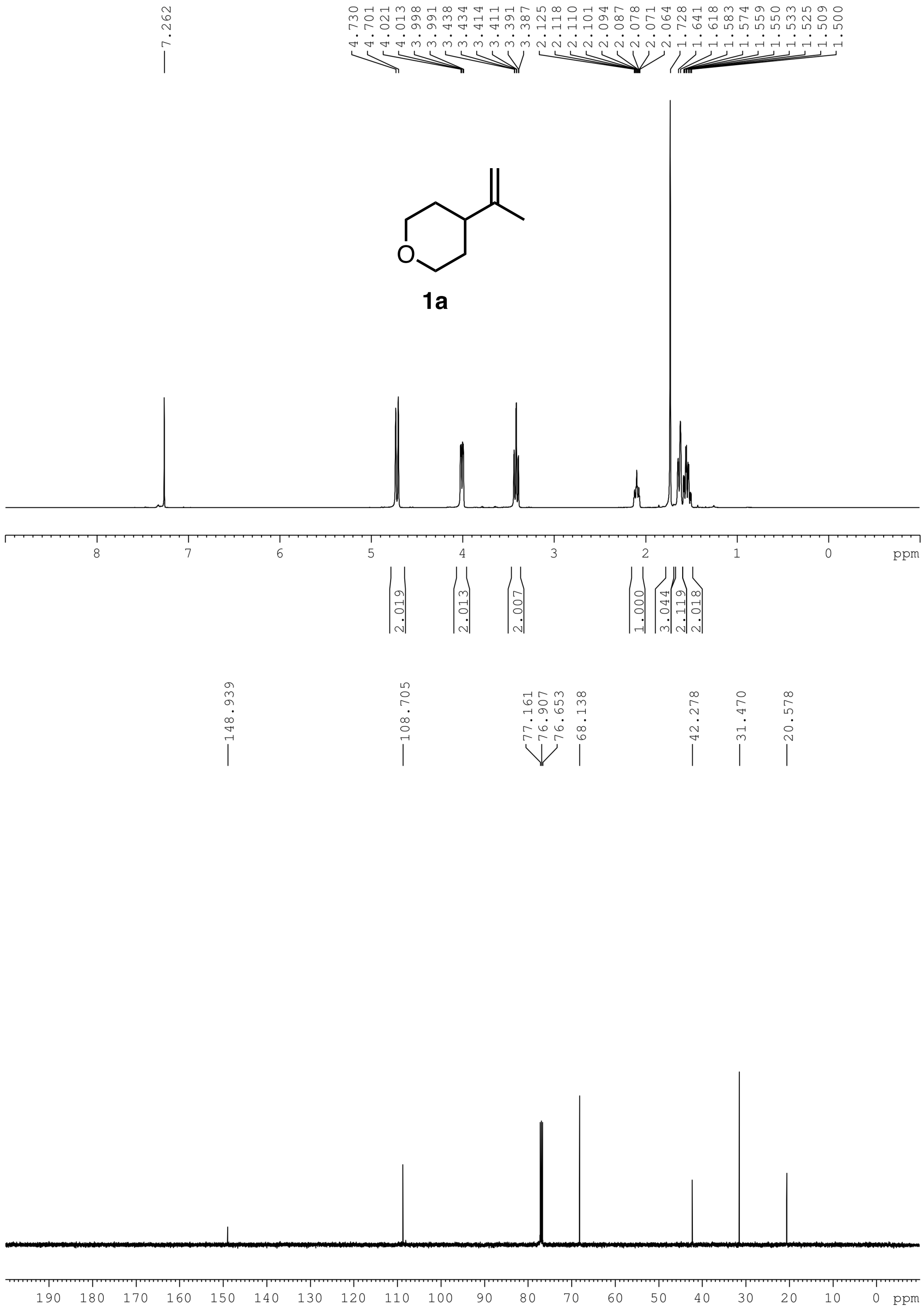
HRMS (ESI-TOF): calc'd for $C_{13}H_{16}O_4SNa$ $[M + Na]^+$ 291.0662, found 291.0661.

R_f = 0.22 (50% EtOAc/hexanes).

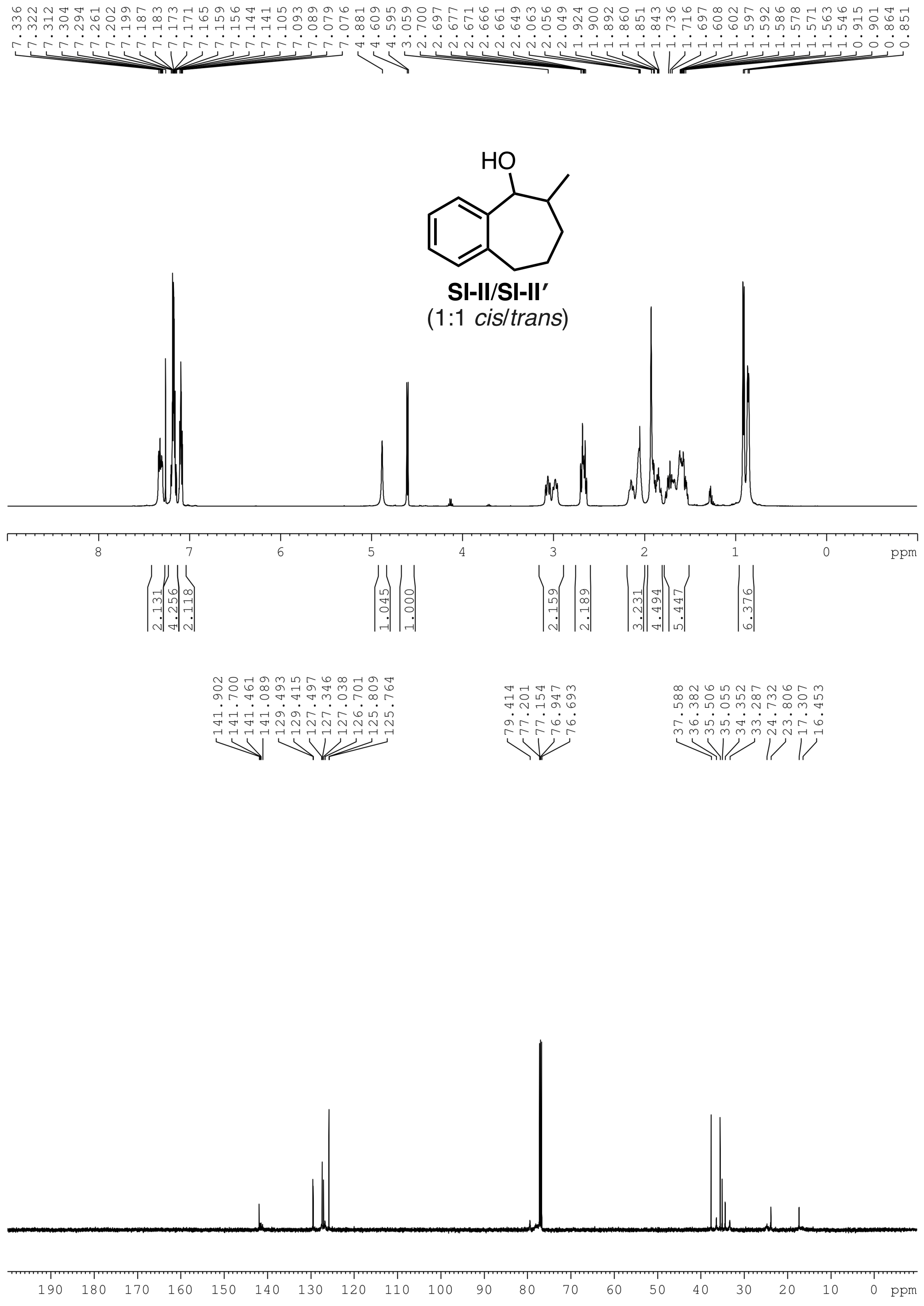
Purification: (SiO_2, 50 → 75% EtOAc/hexanes).

Note: 2D NMR spectra are consistent with the proposed structure of **12**.

6. Copies of ^{1}H, ^{13}C, and ^{19}F NMR Spectra

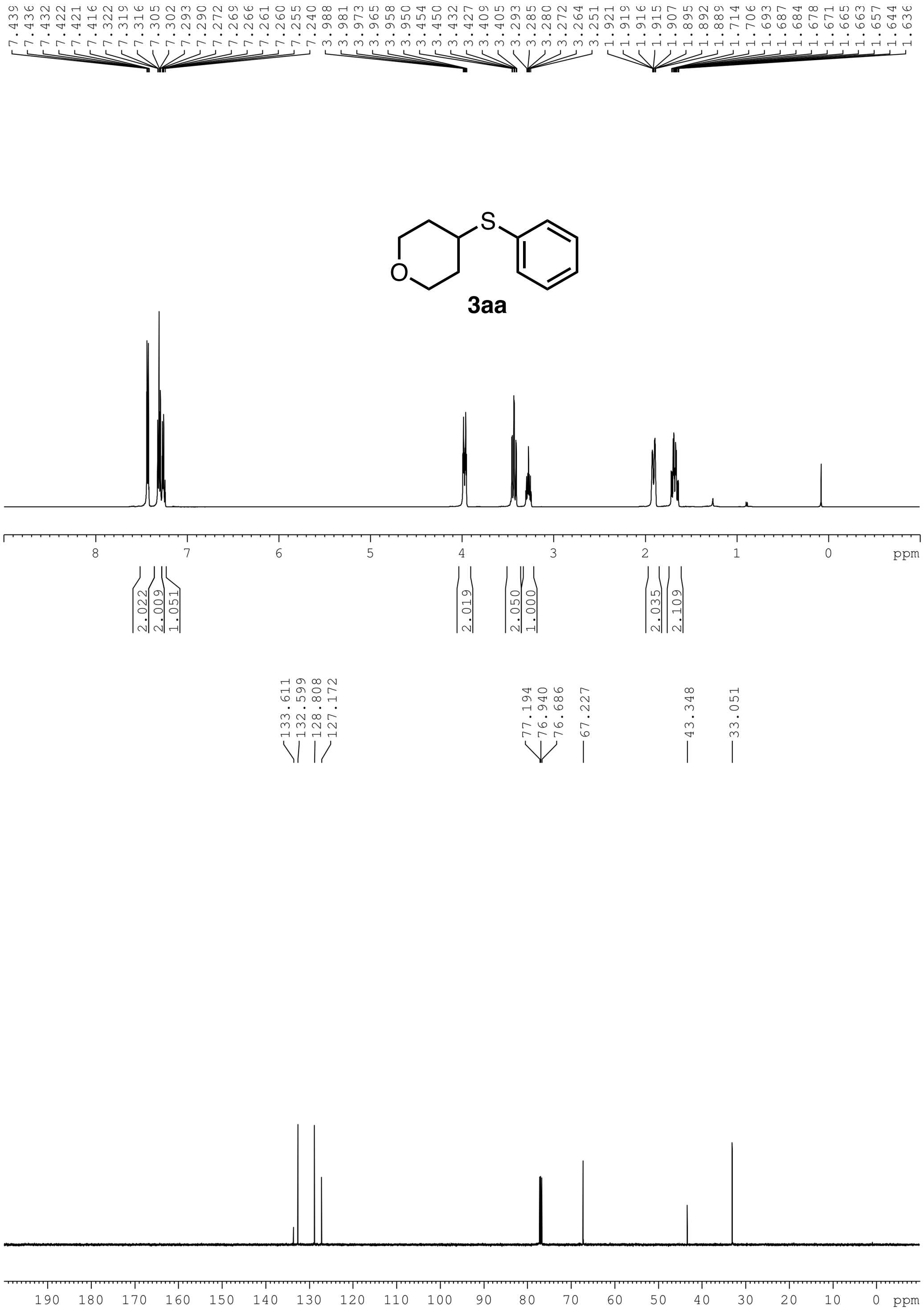


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **1a**

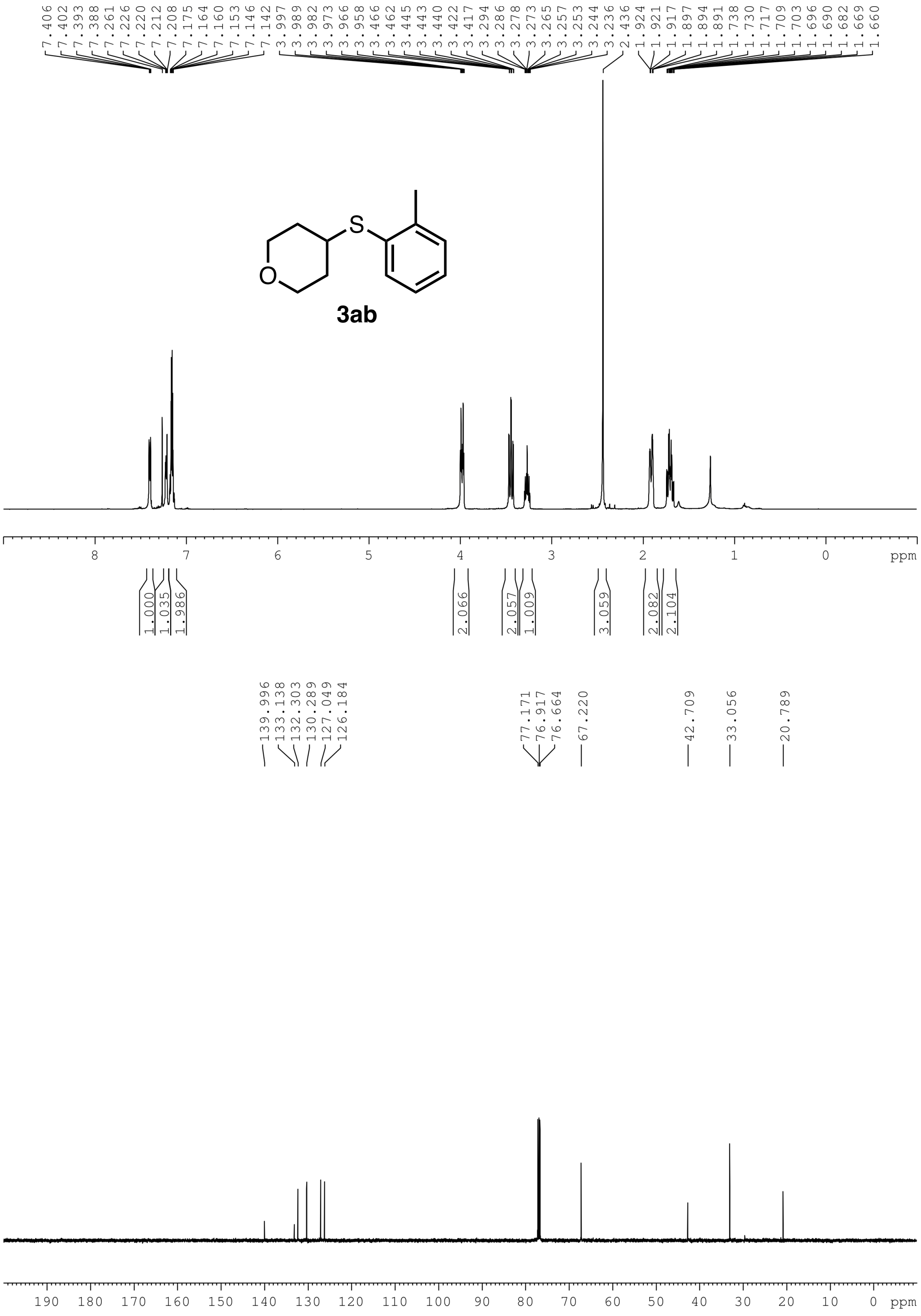


^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **SI-II**/**SI-II′** (1:1 *cis*/*trans*)

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **6h**

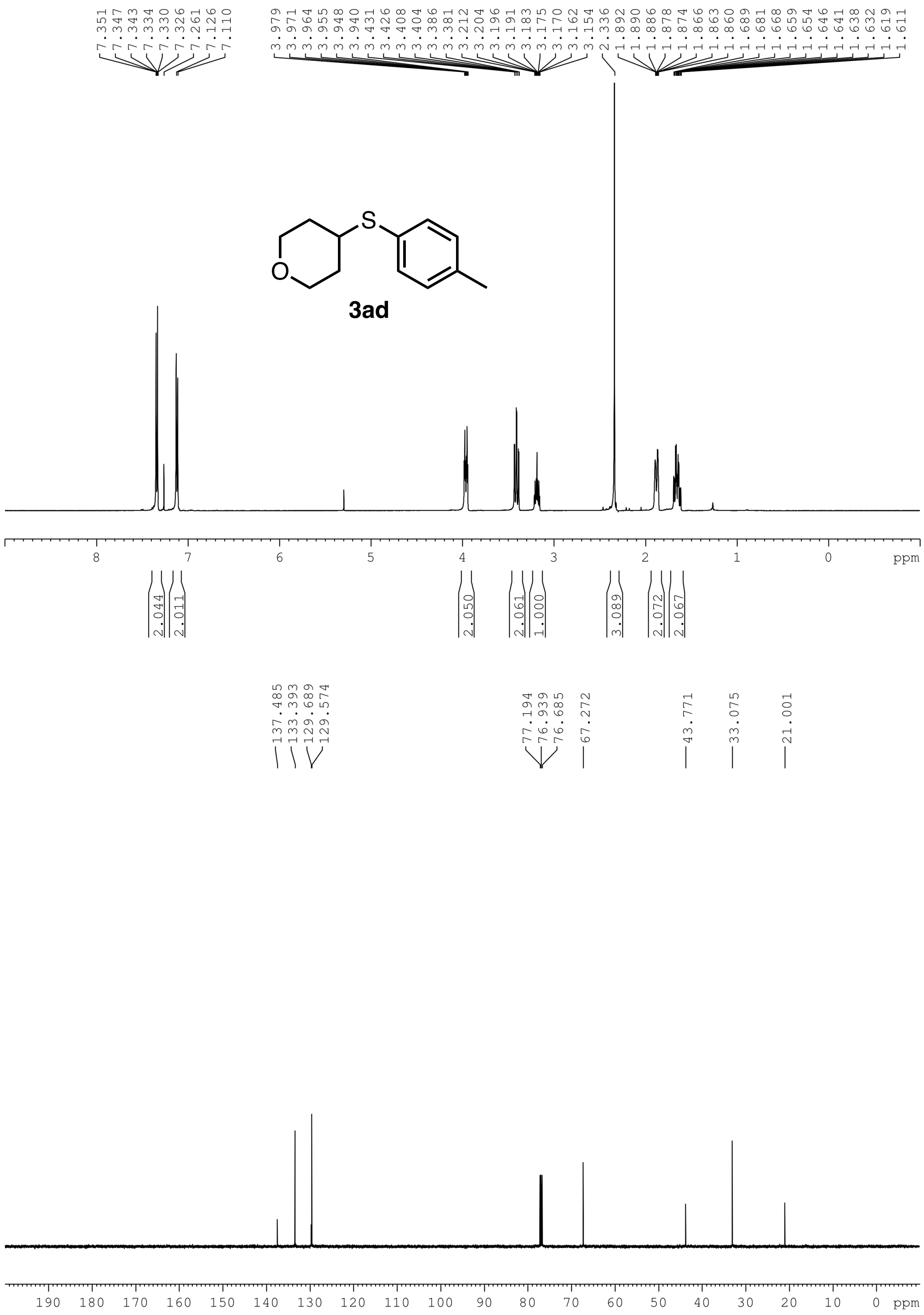


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3aa**



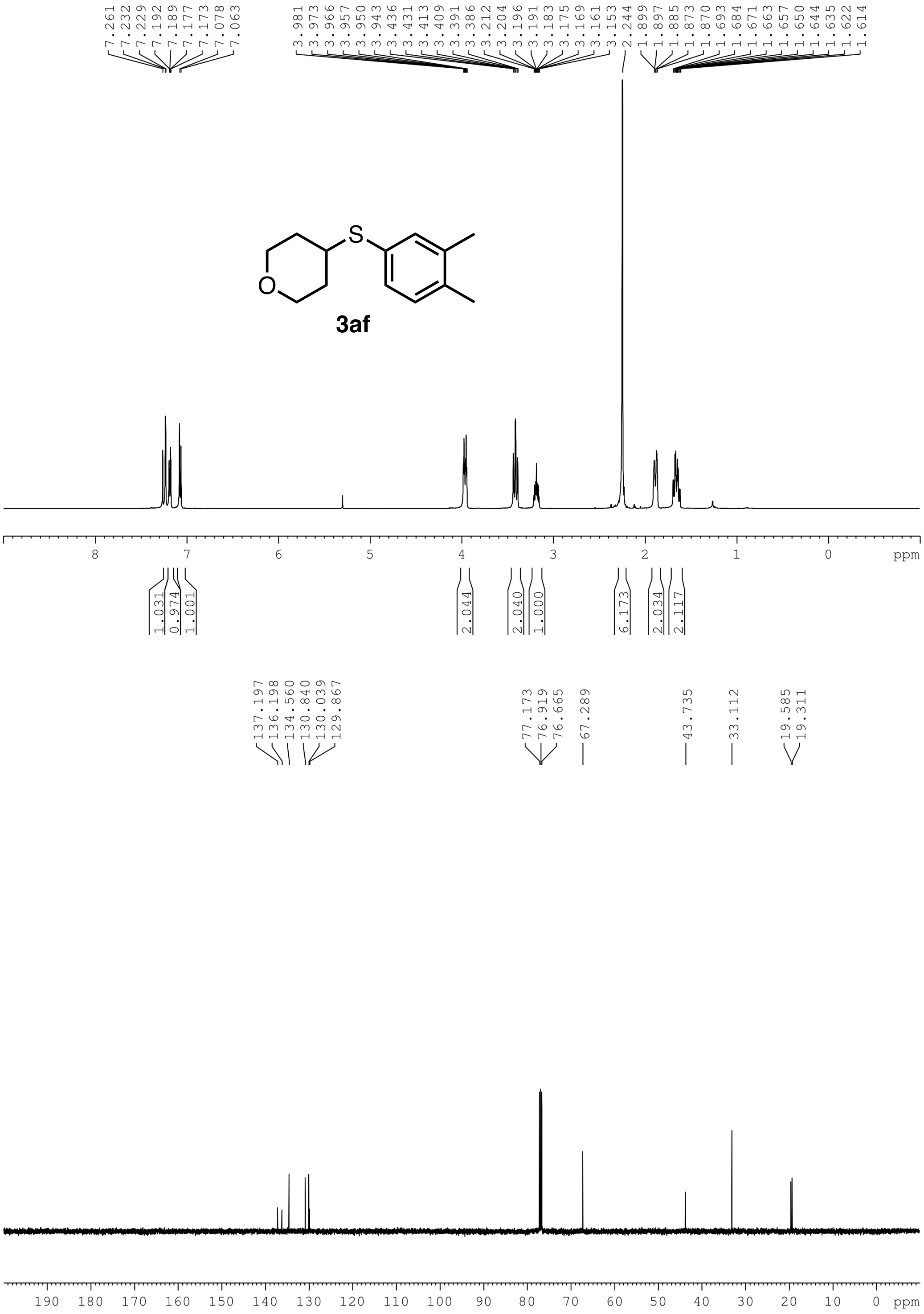
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ab**

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ac**

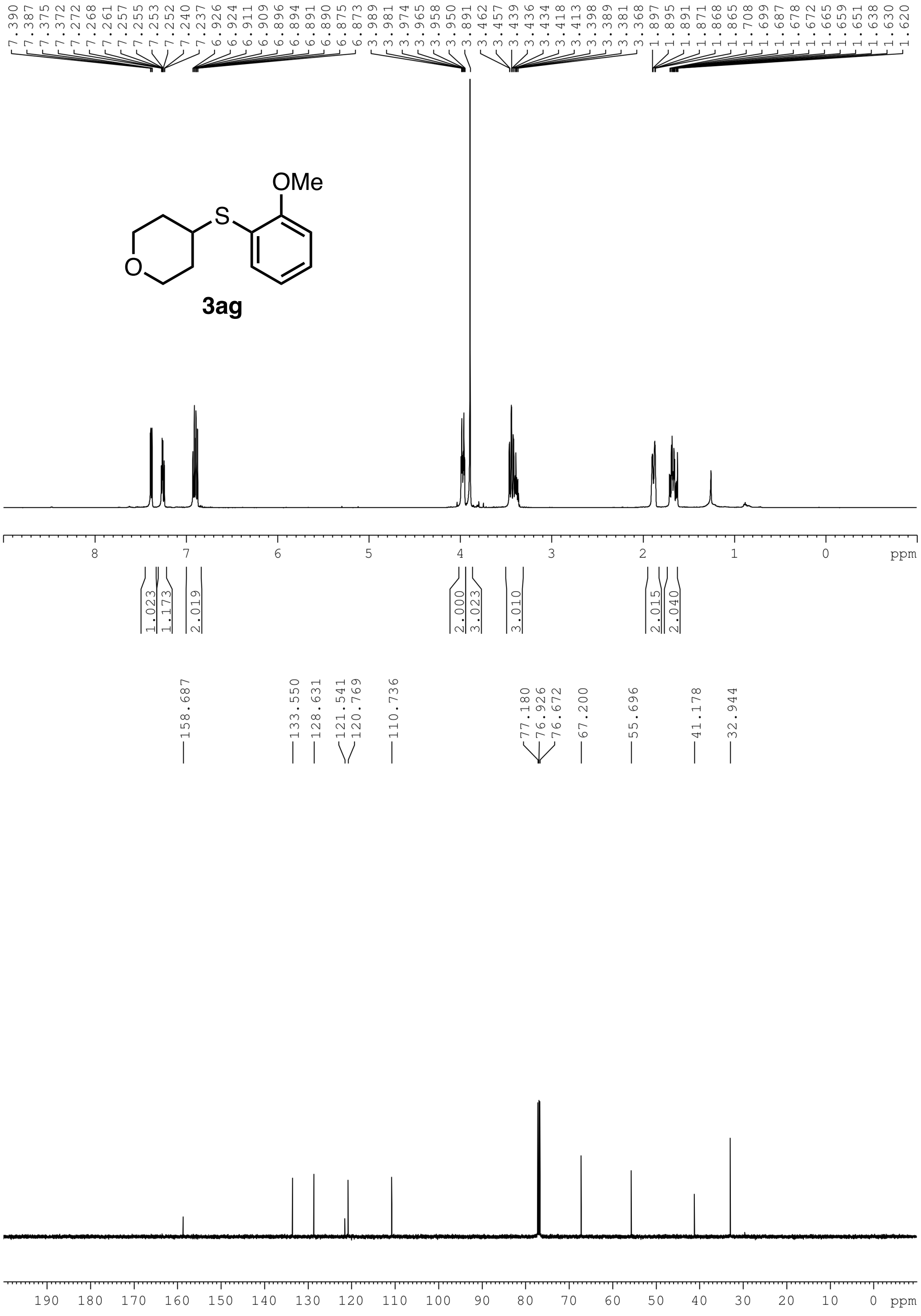


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ad**

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ae**

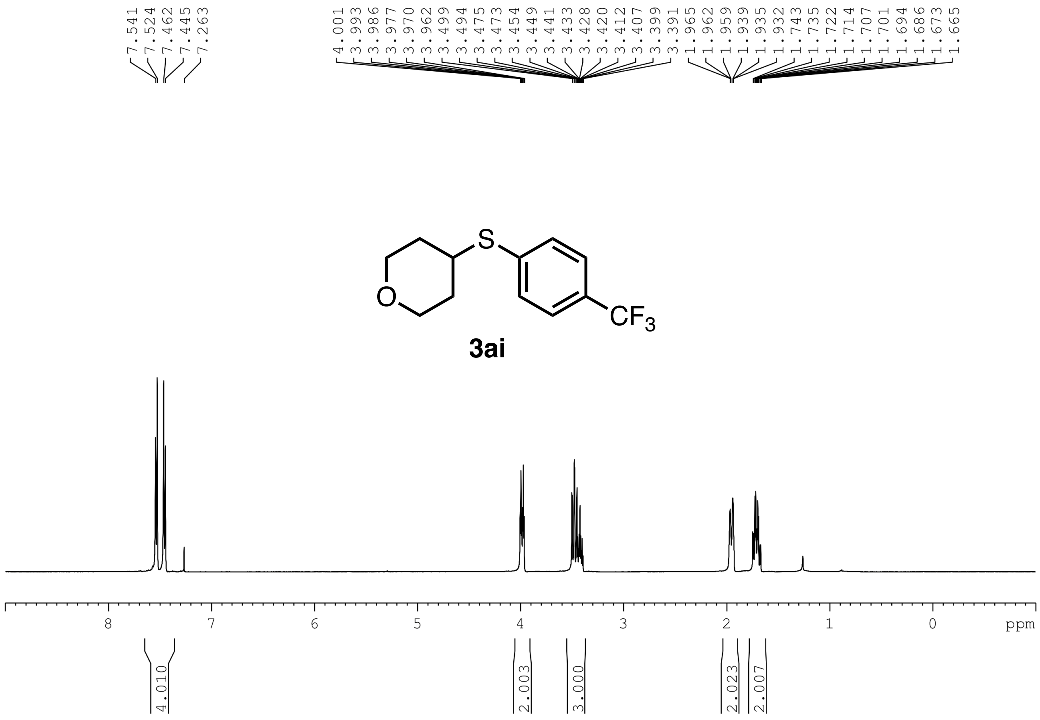


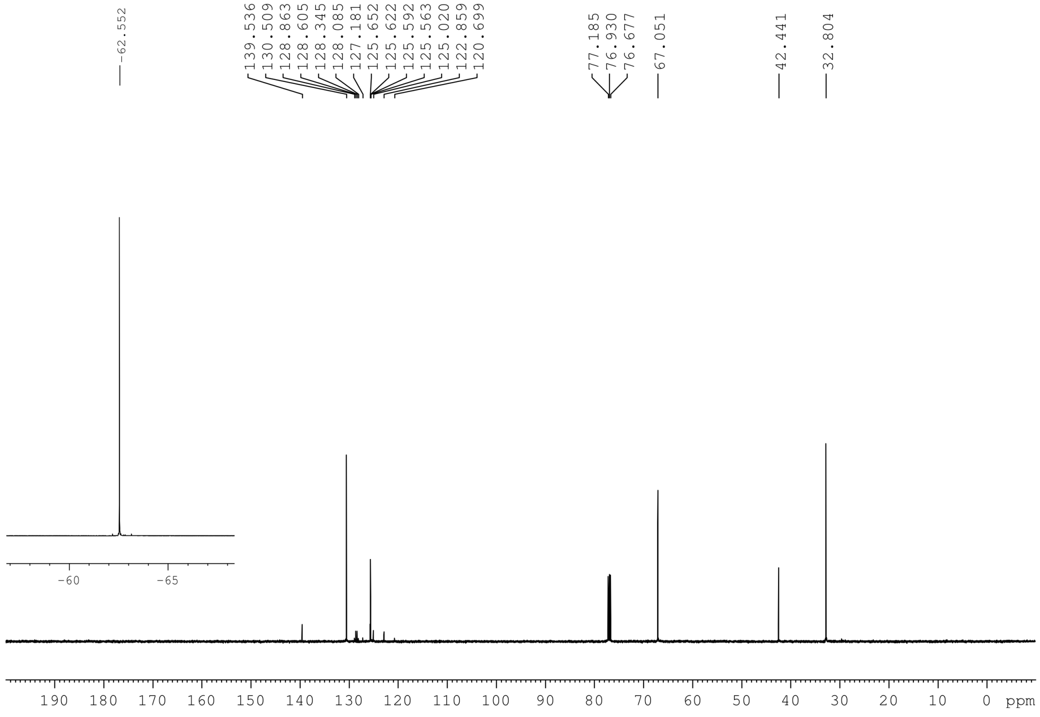
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3af**



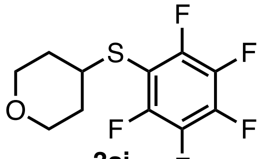
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ag**

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ah**

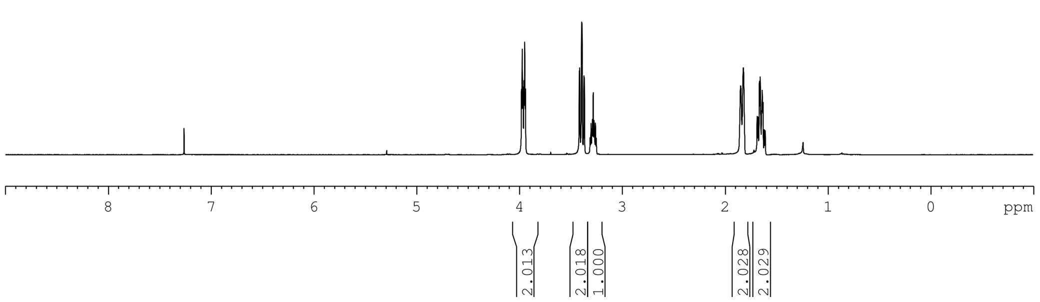


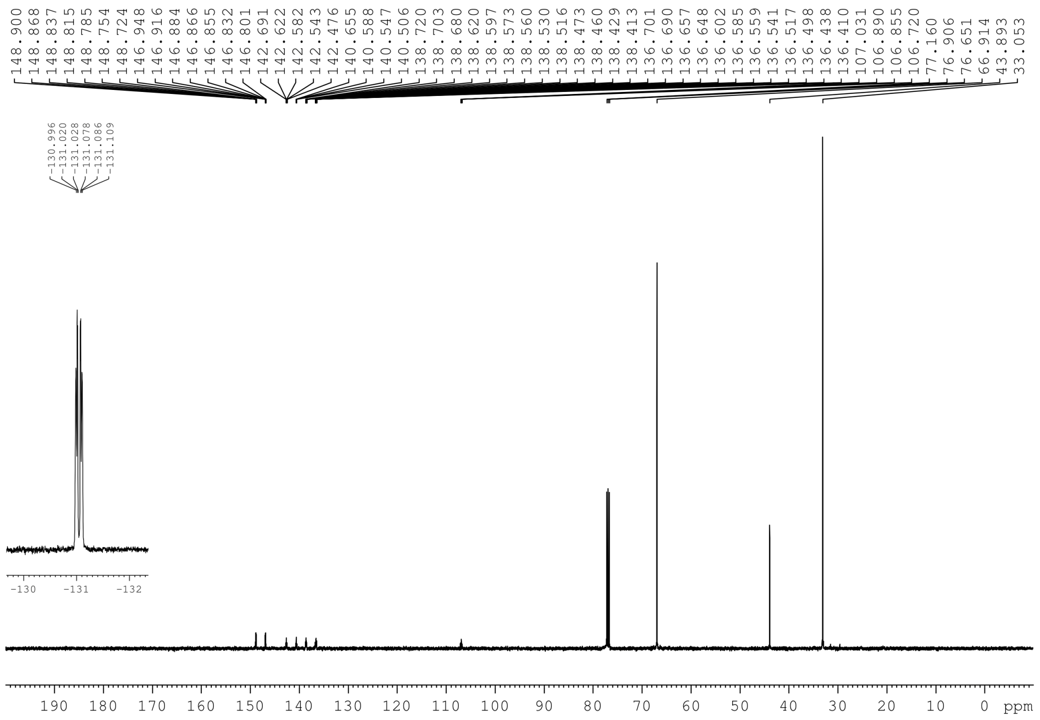


^{1}H (500 MHz, CDCl$_3$), ^{13}C (125 MHz, CDCl$_3$), and ^{19}F (282 MHz, CDCl$_3$) NMR Spectra of **3ai**

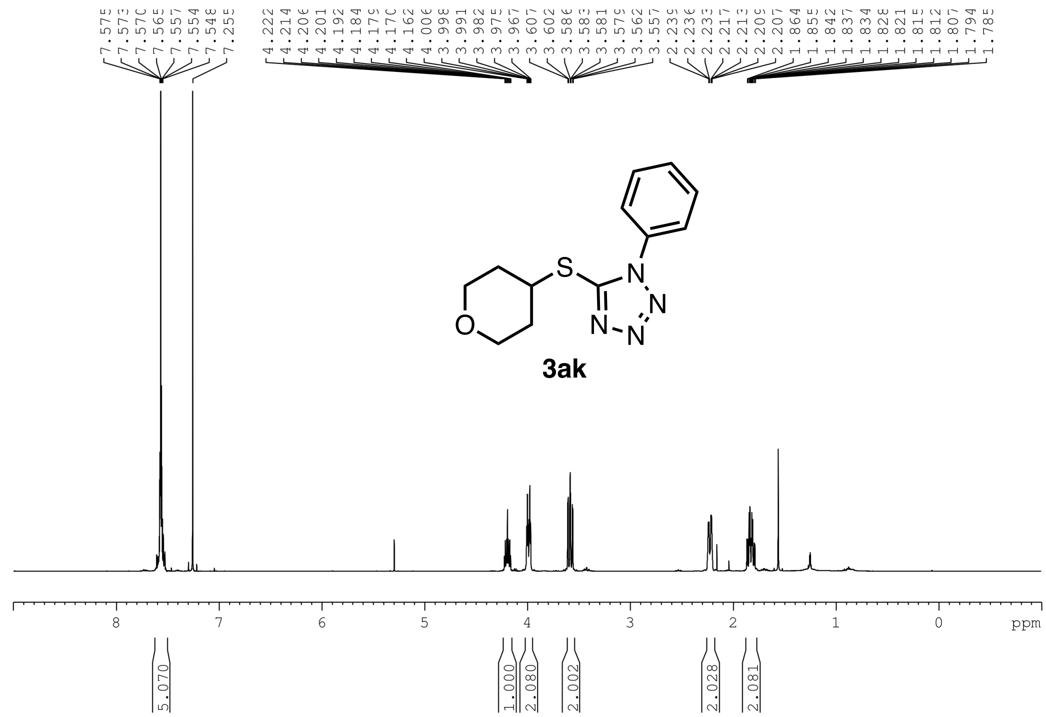


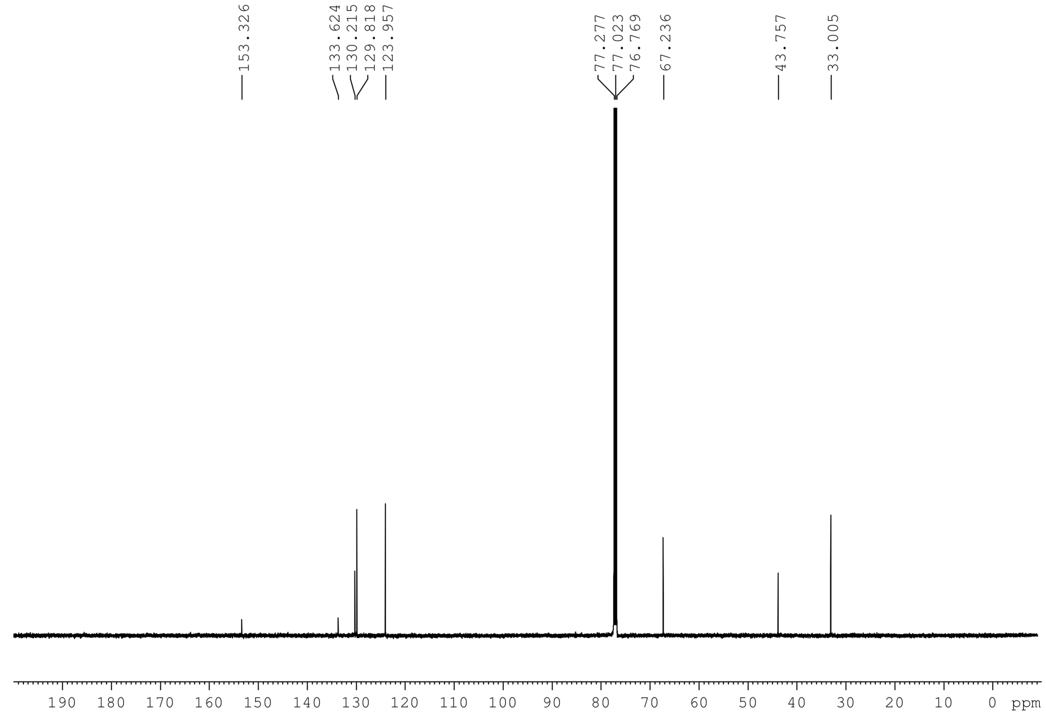
3aj



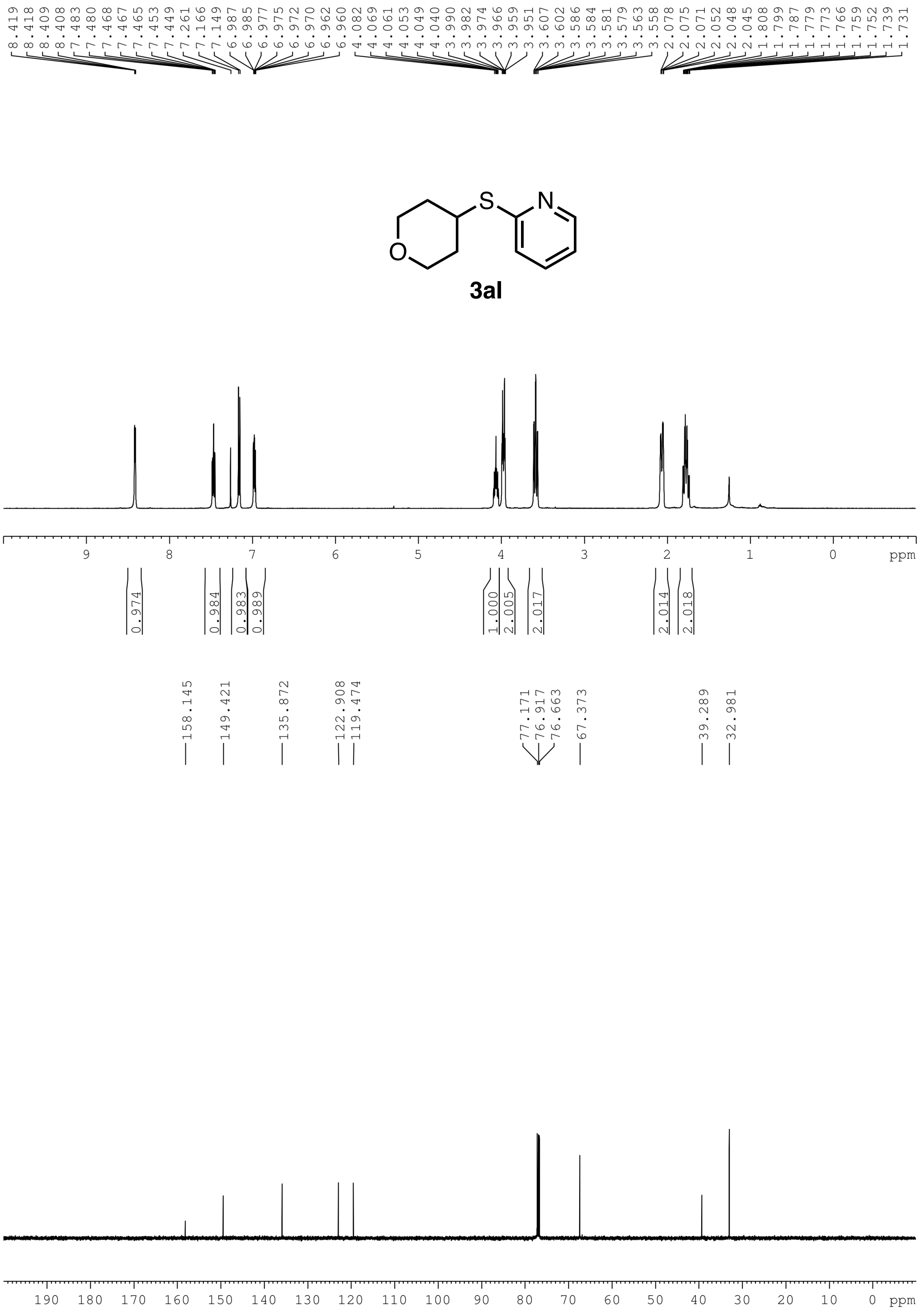


^{1}H (500 MHz, CDCl$_3$), ^{13}C (125 MHz, CDCl$_3$), and ^{19}F (282 MHz, CDCl$_3$) NMR Spectra of **3aj**

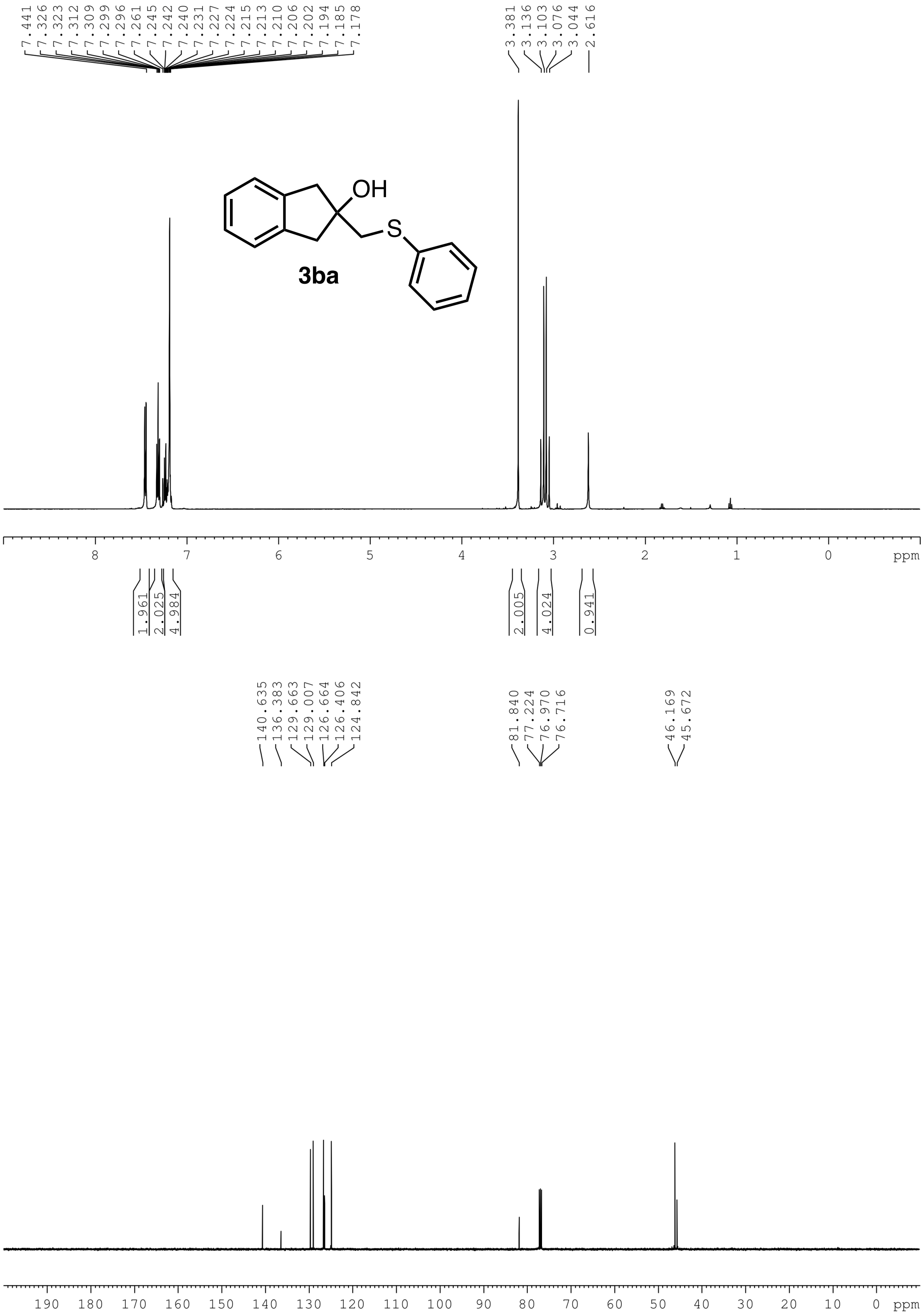




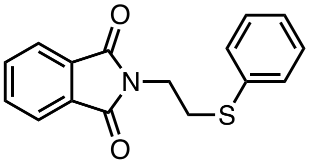
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ak**



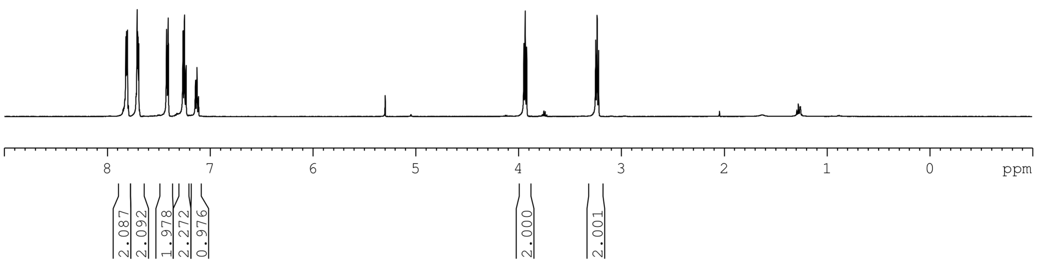
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3al**

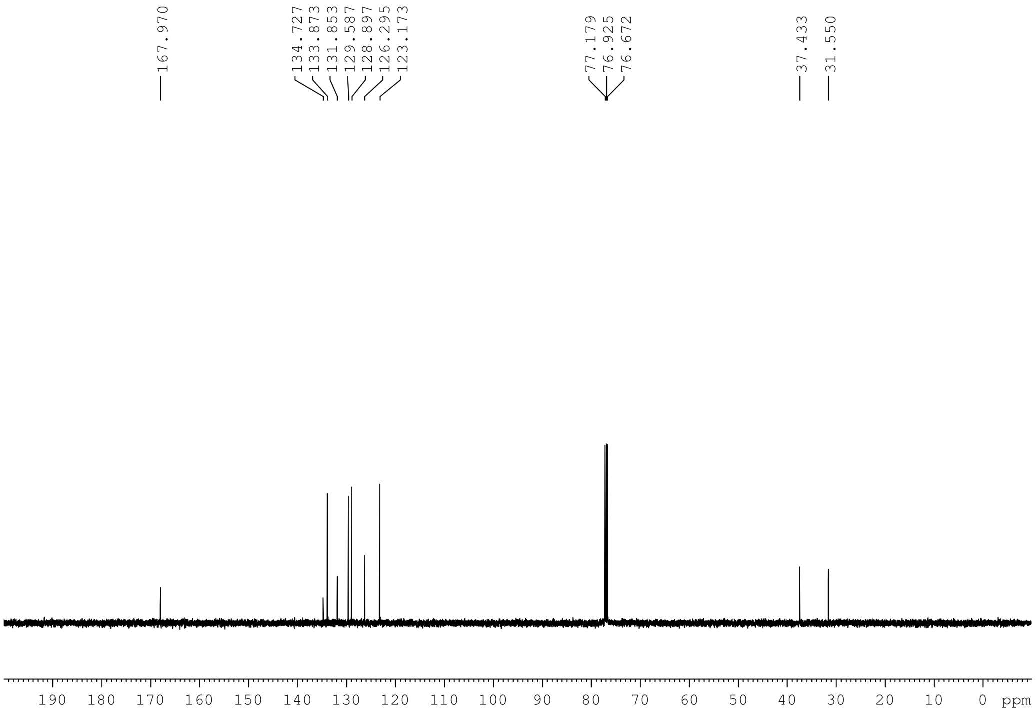

3ba

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ba**



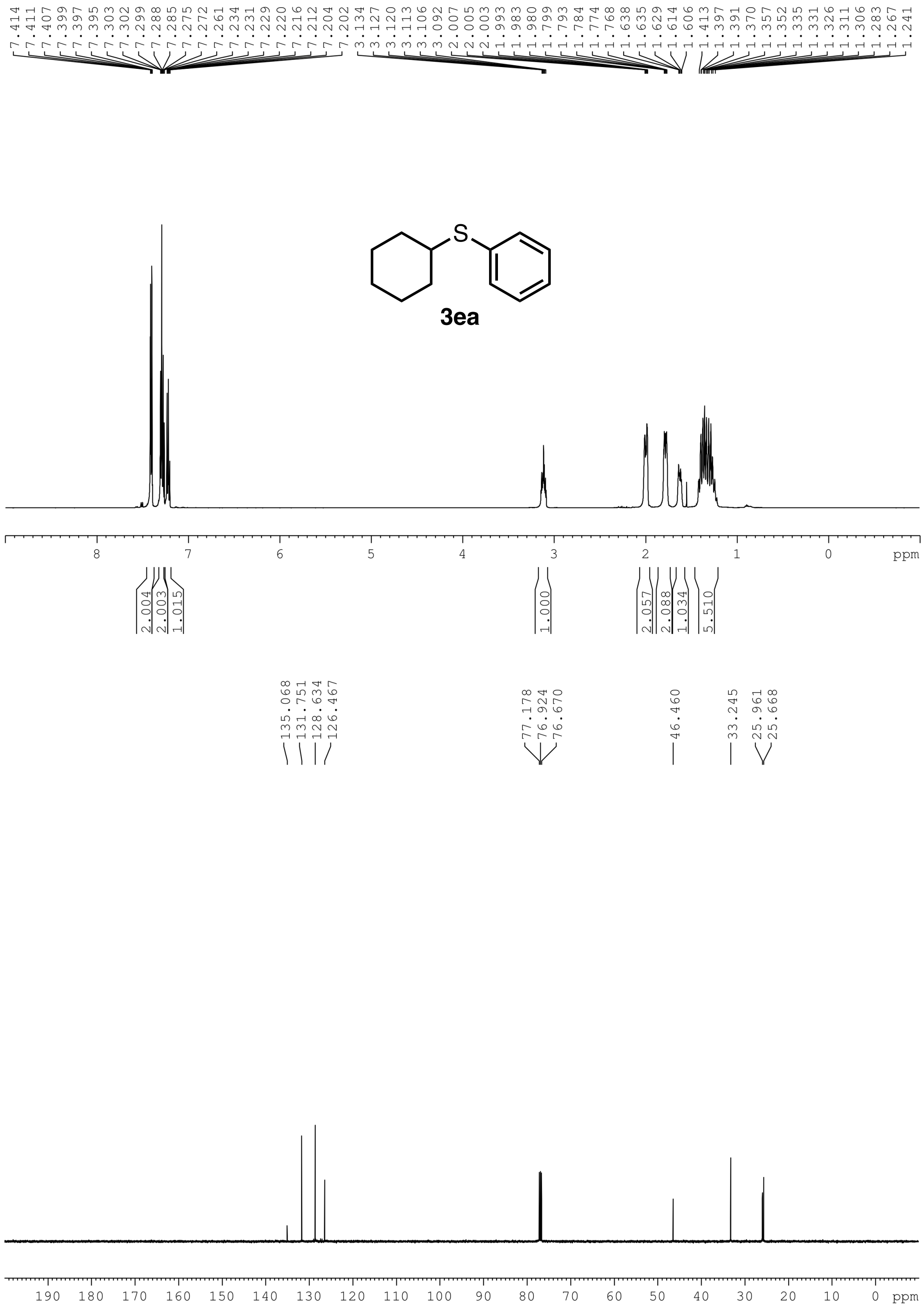
3ca



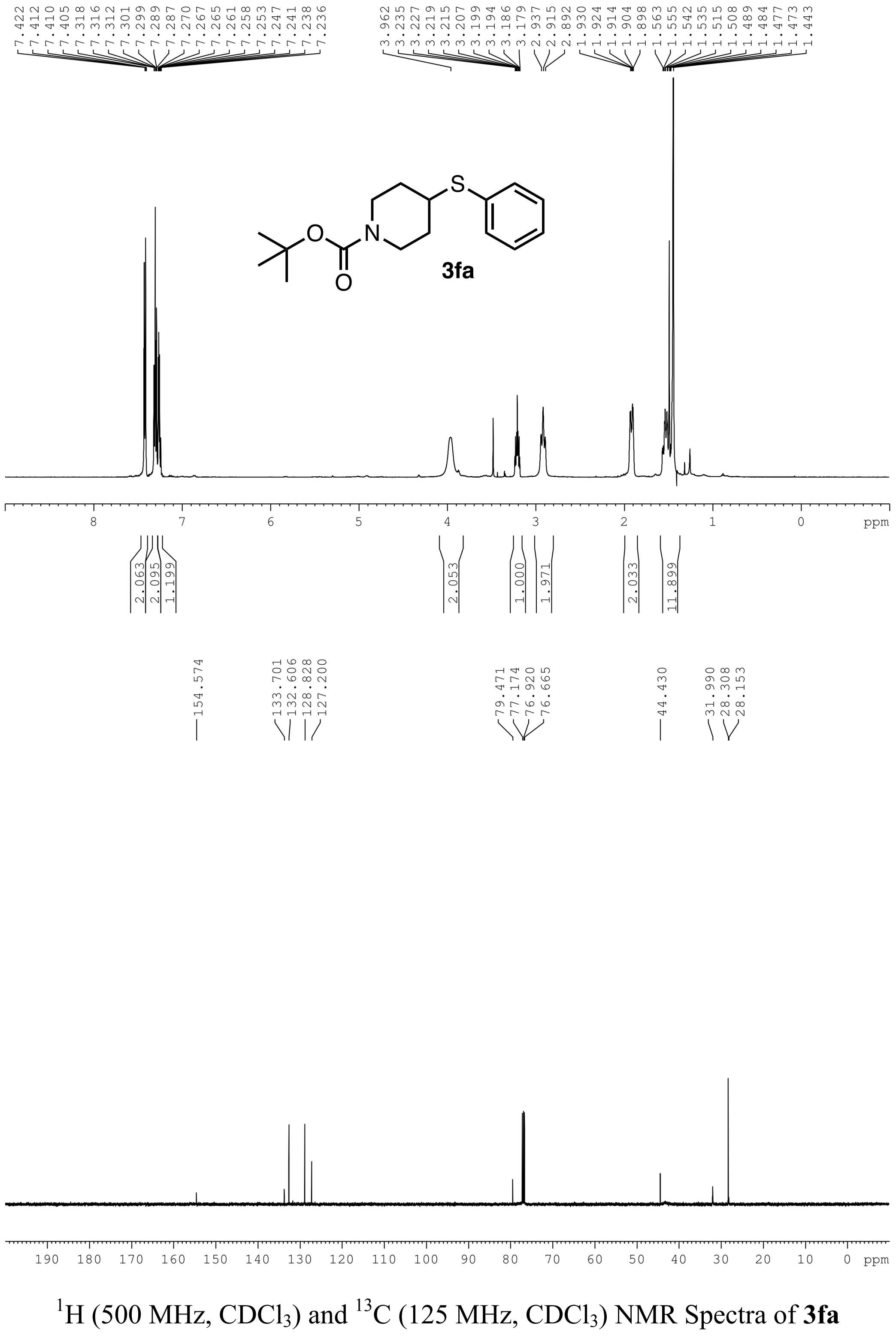


^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **3ca**

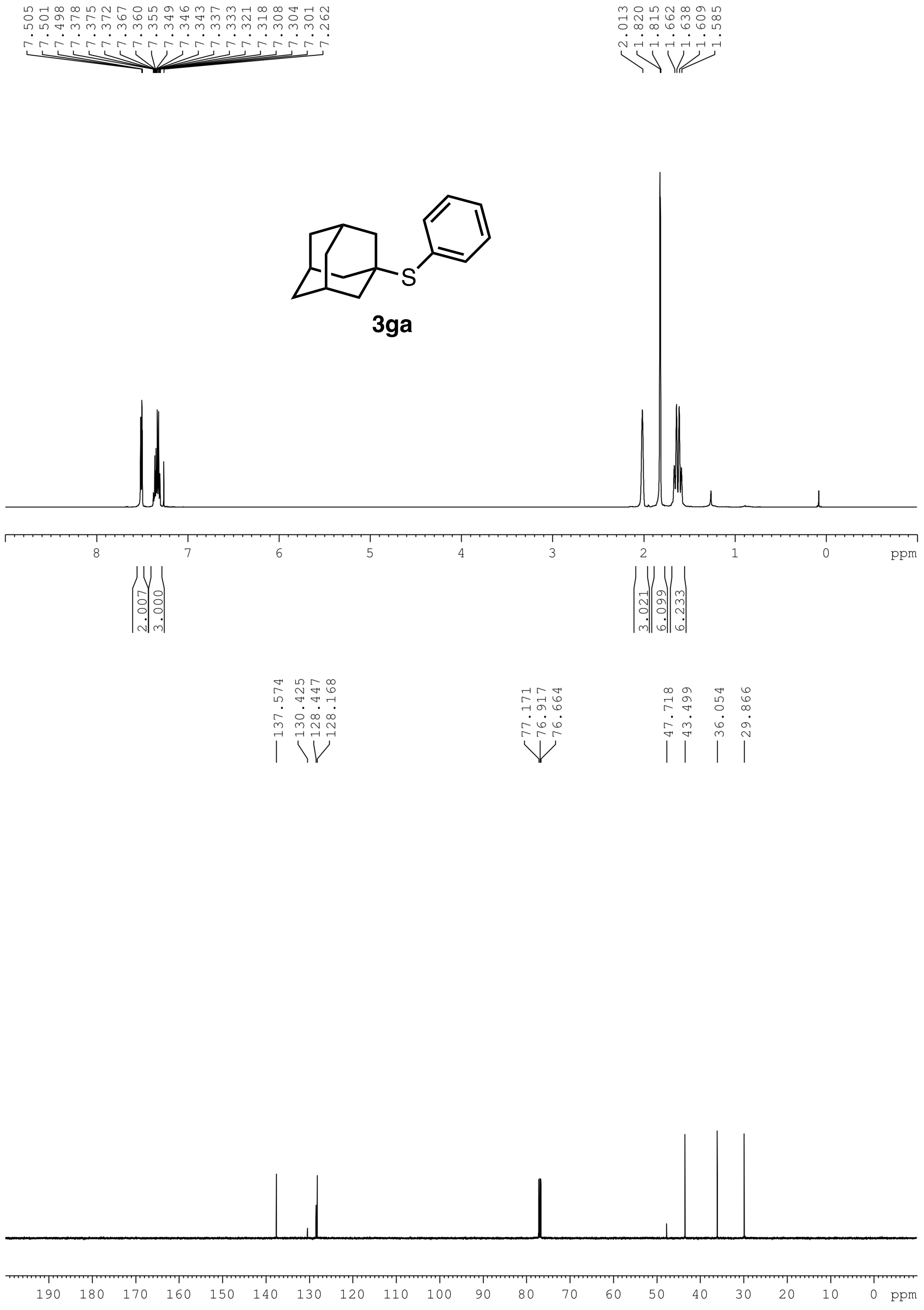
^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **3da**



^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ea**

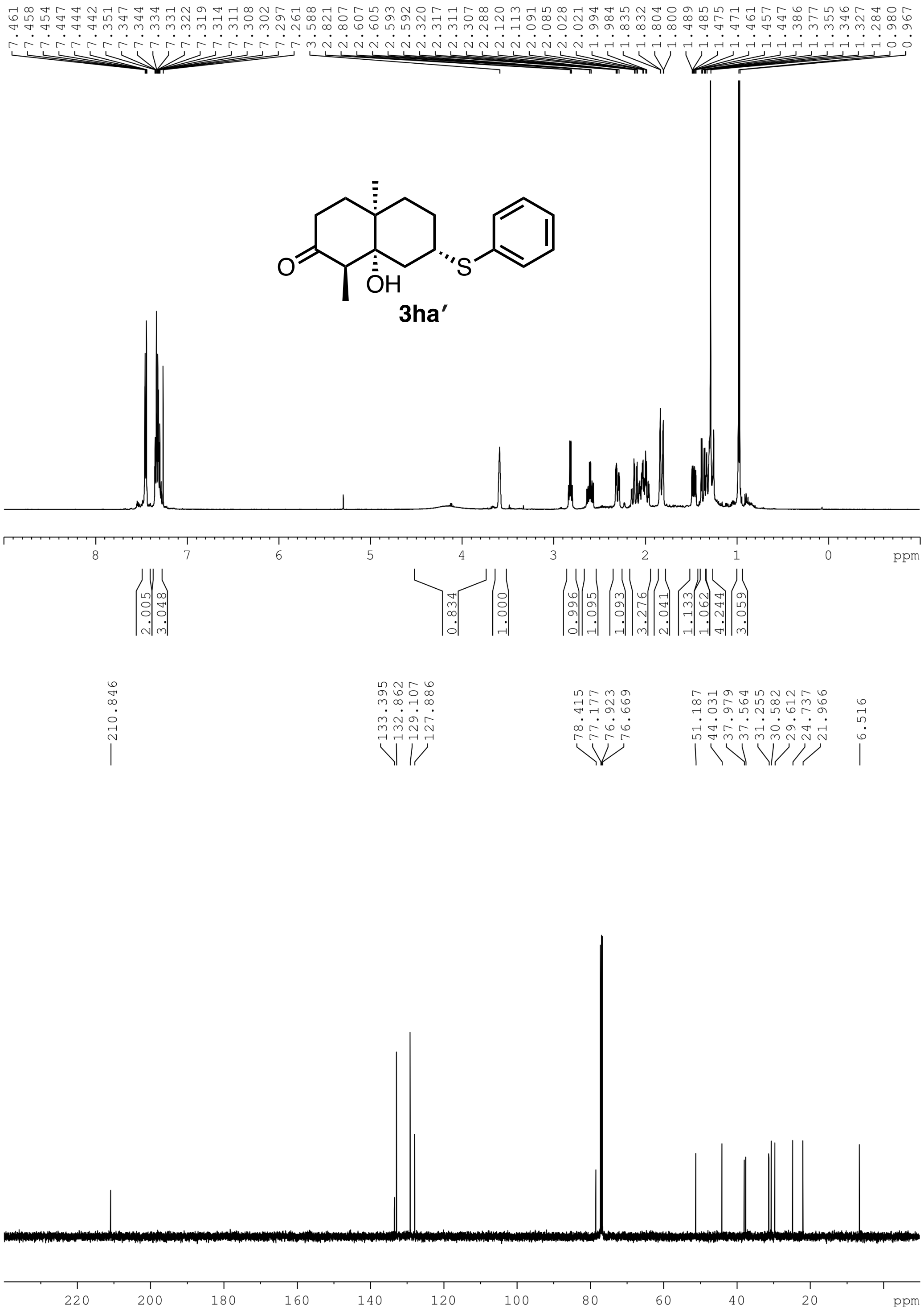


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3fa**

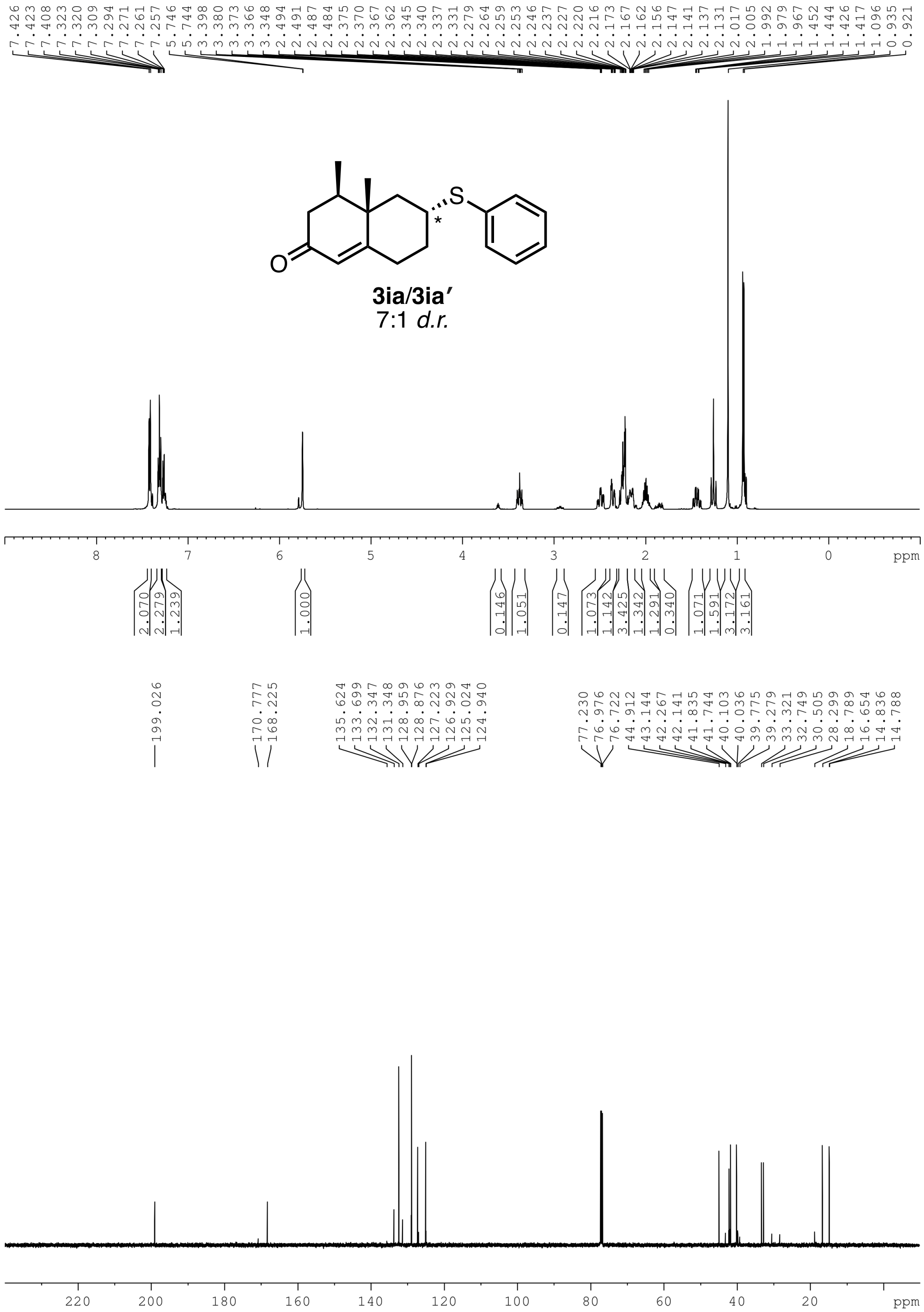


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ga**

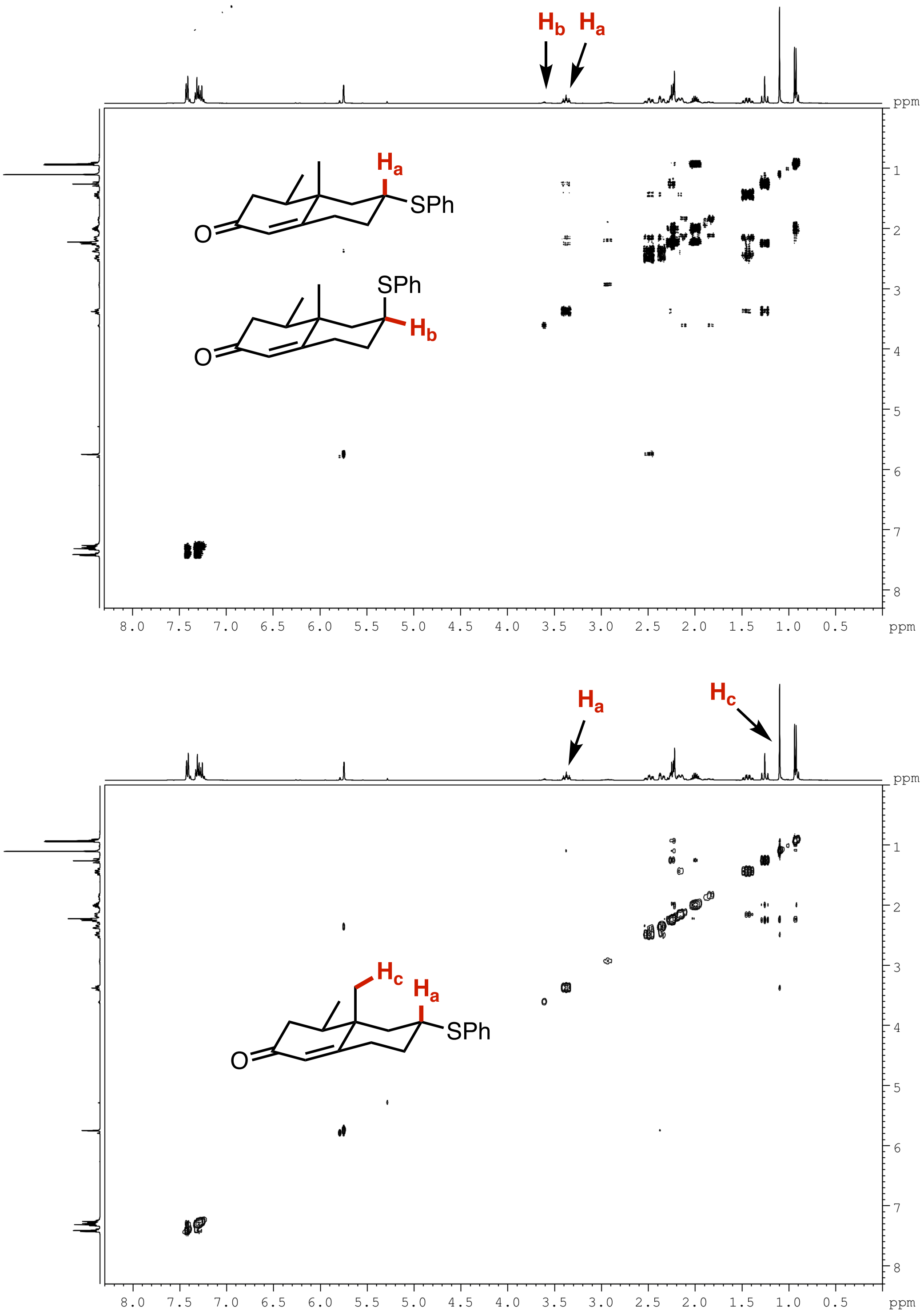
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ha**



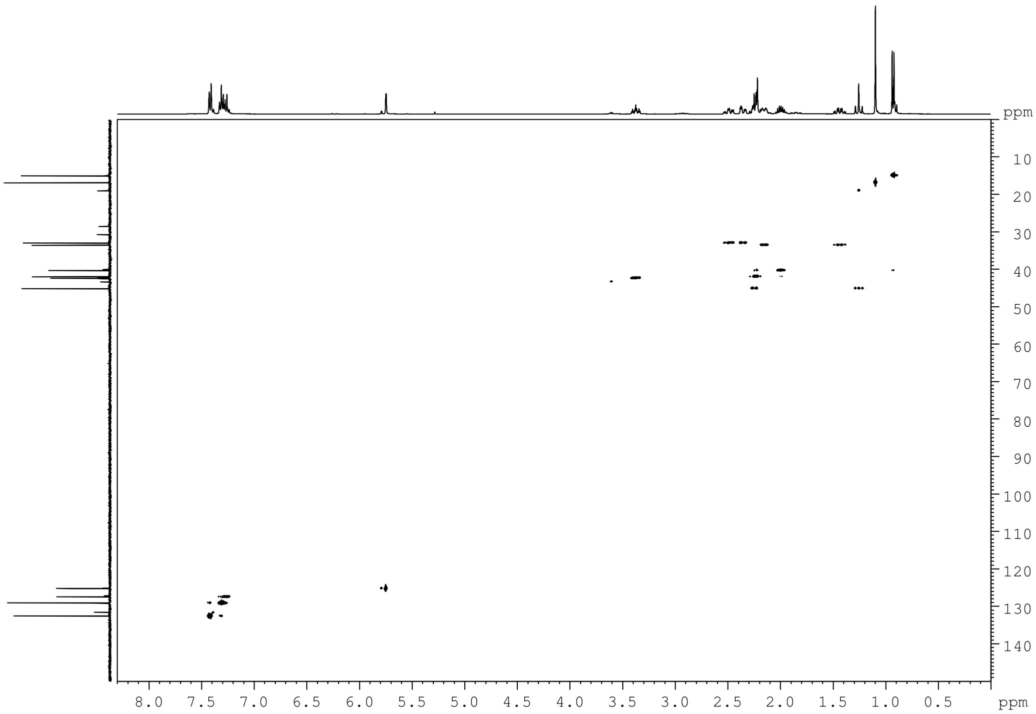
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ha′**

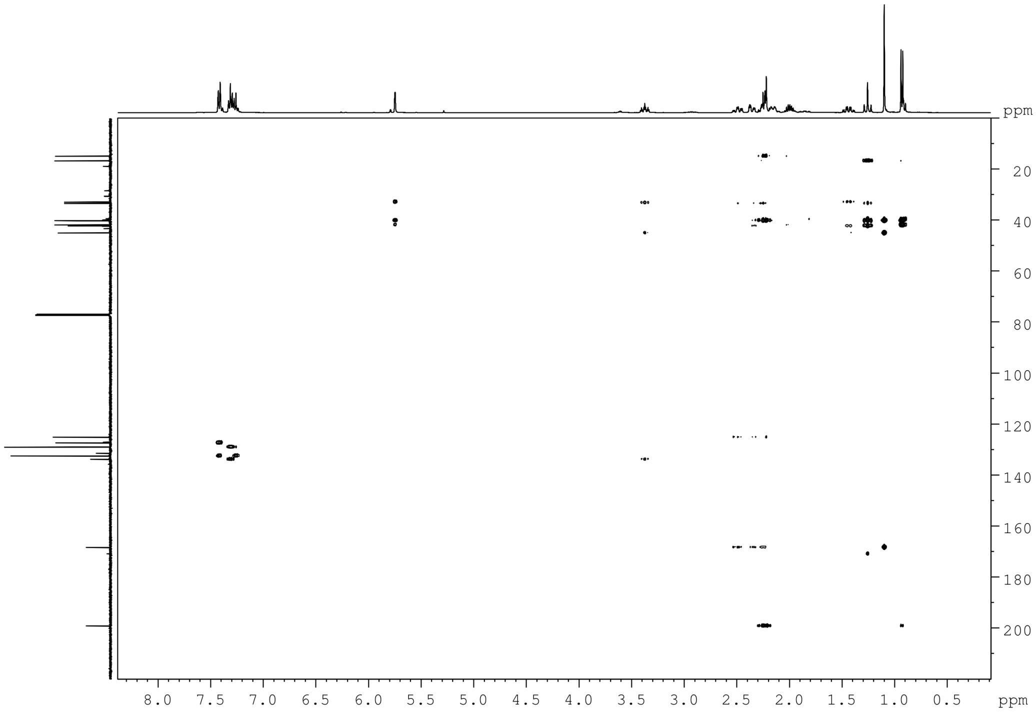


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ia**/**3ia′** (7:1 *d.r.*)

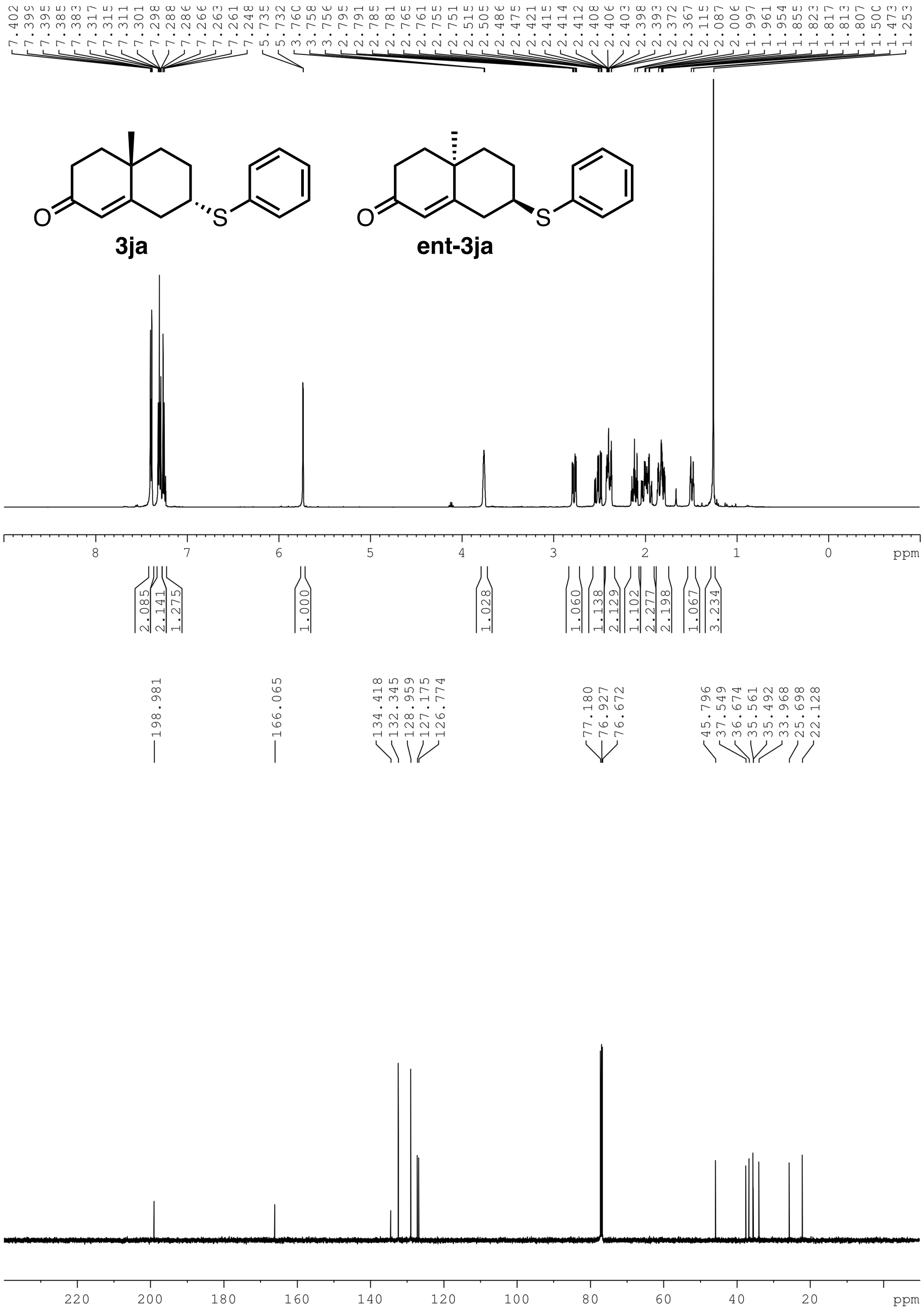


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3ia**/**3ia′**

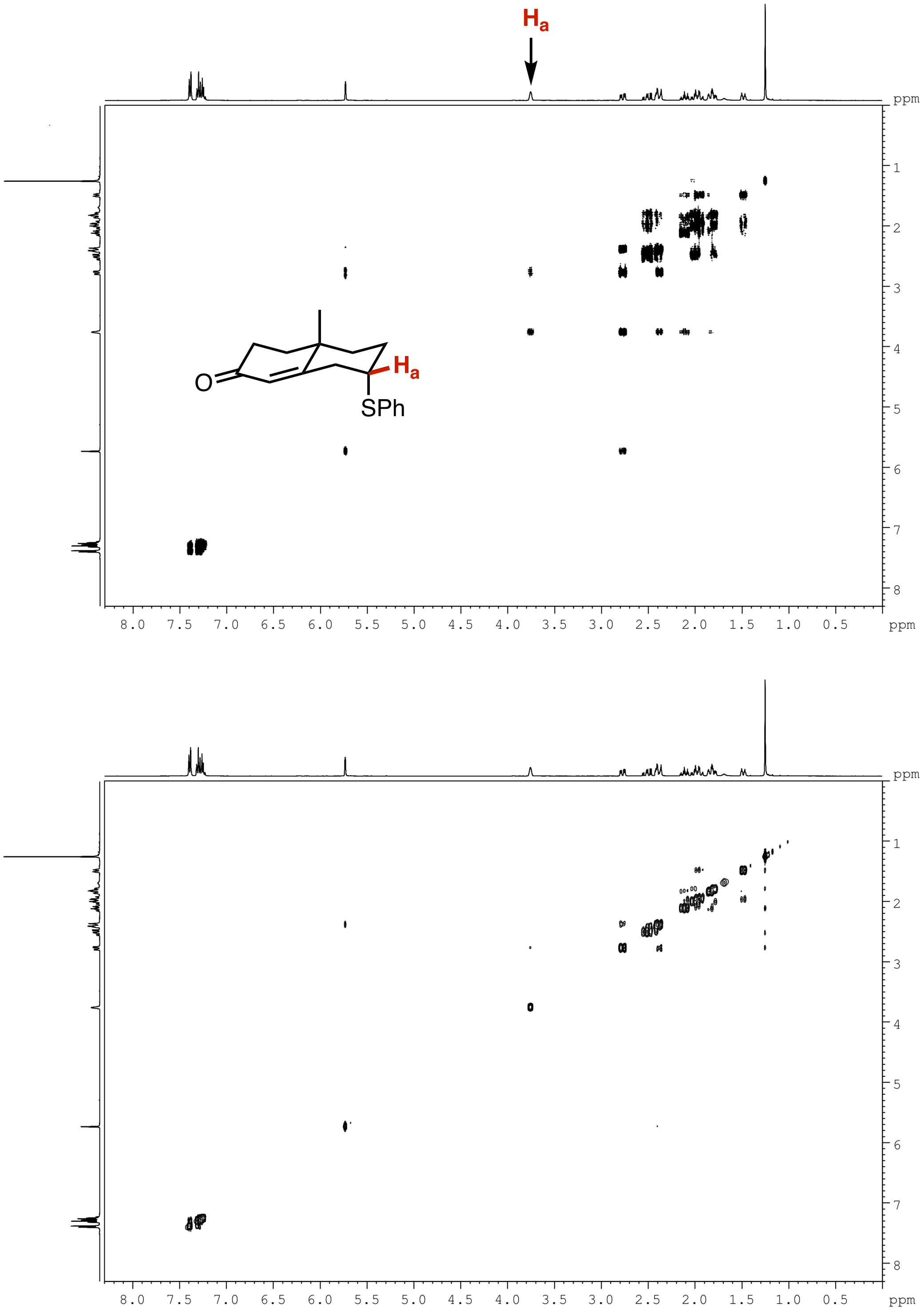




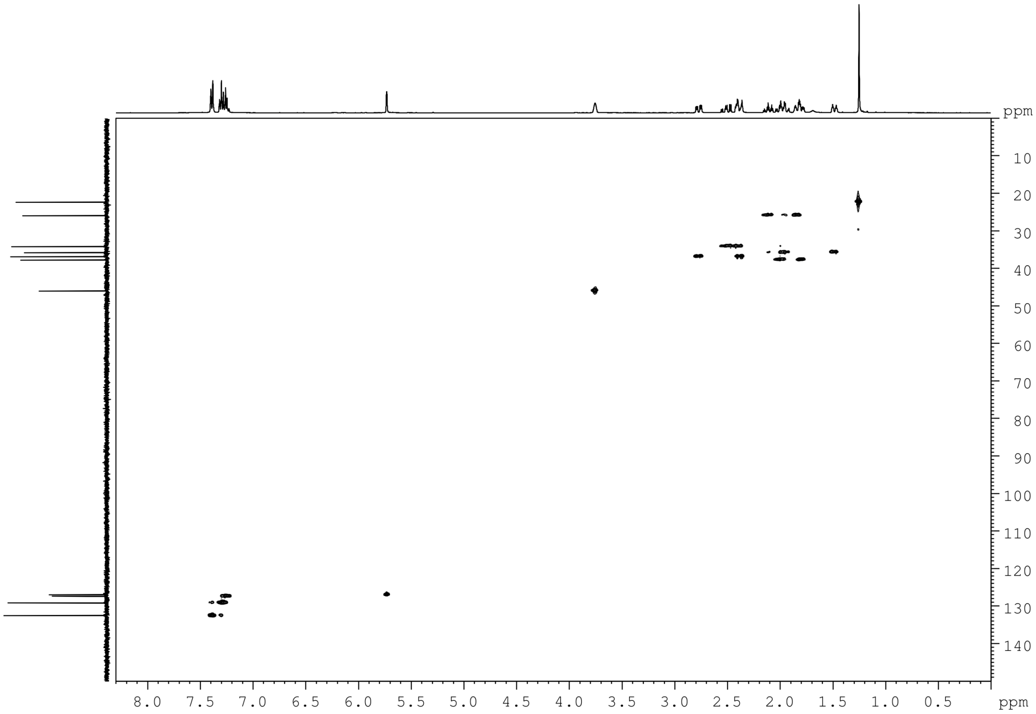
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3ia**/**3ia′**

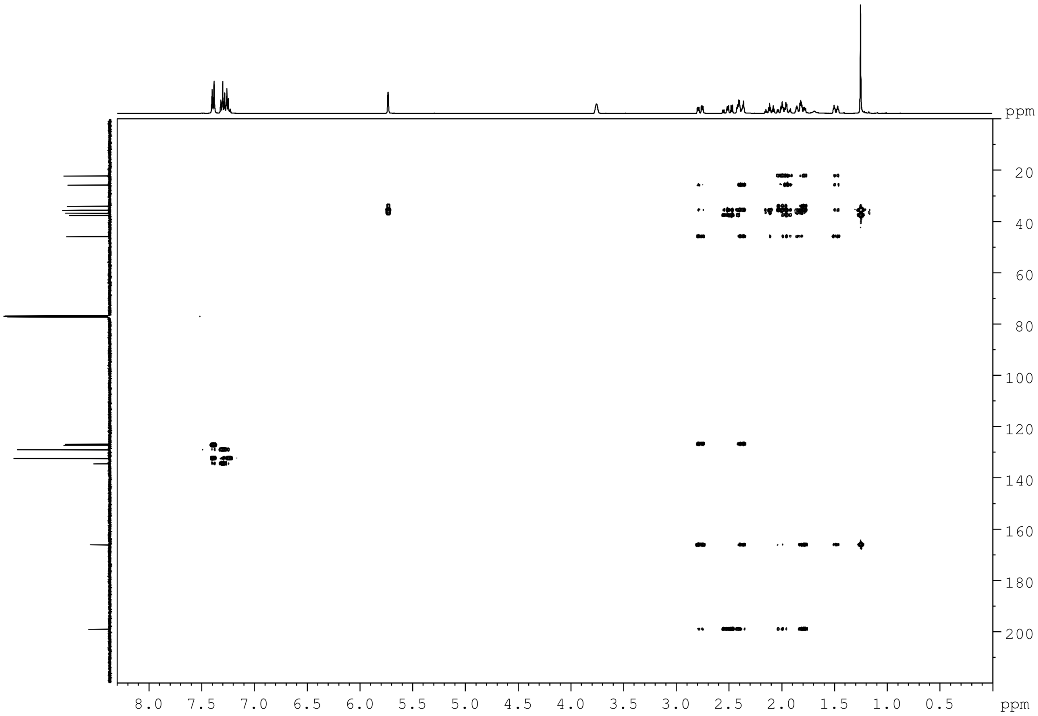


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ja**/**ent-3ja**



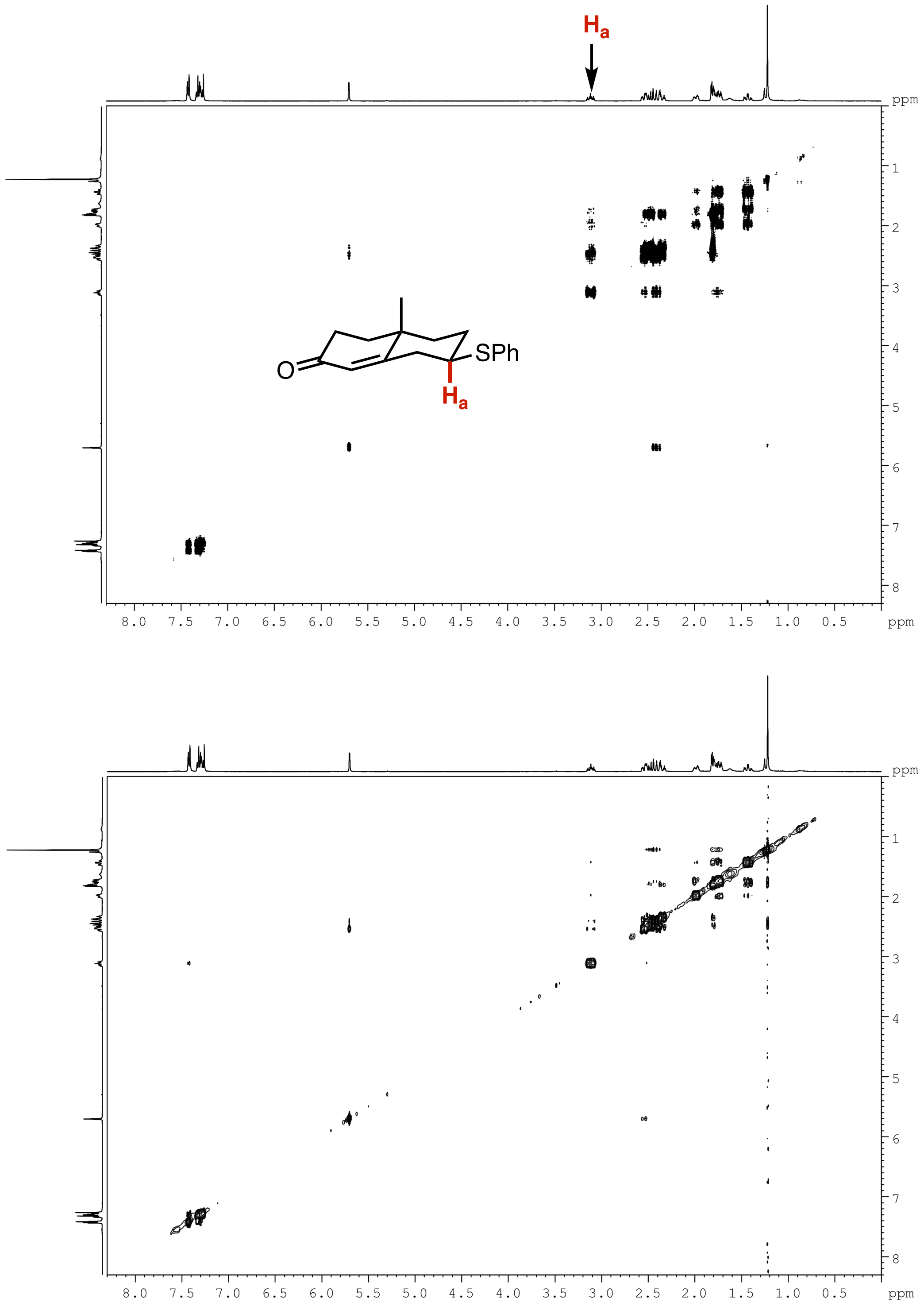
COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3ja**/**ent-3ja**



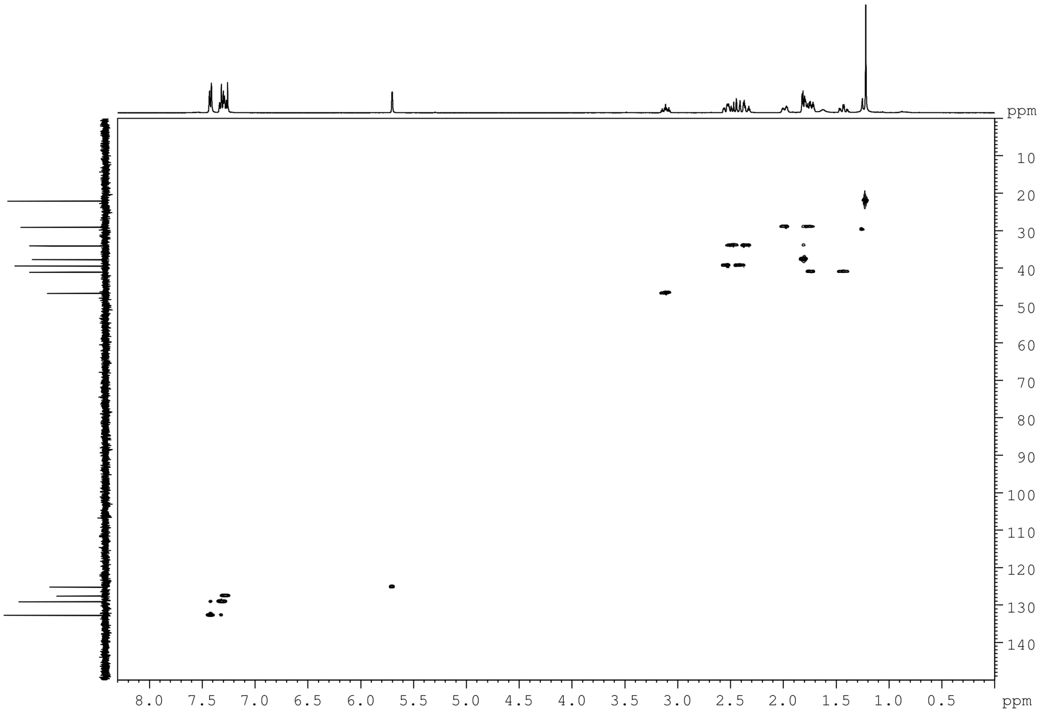


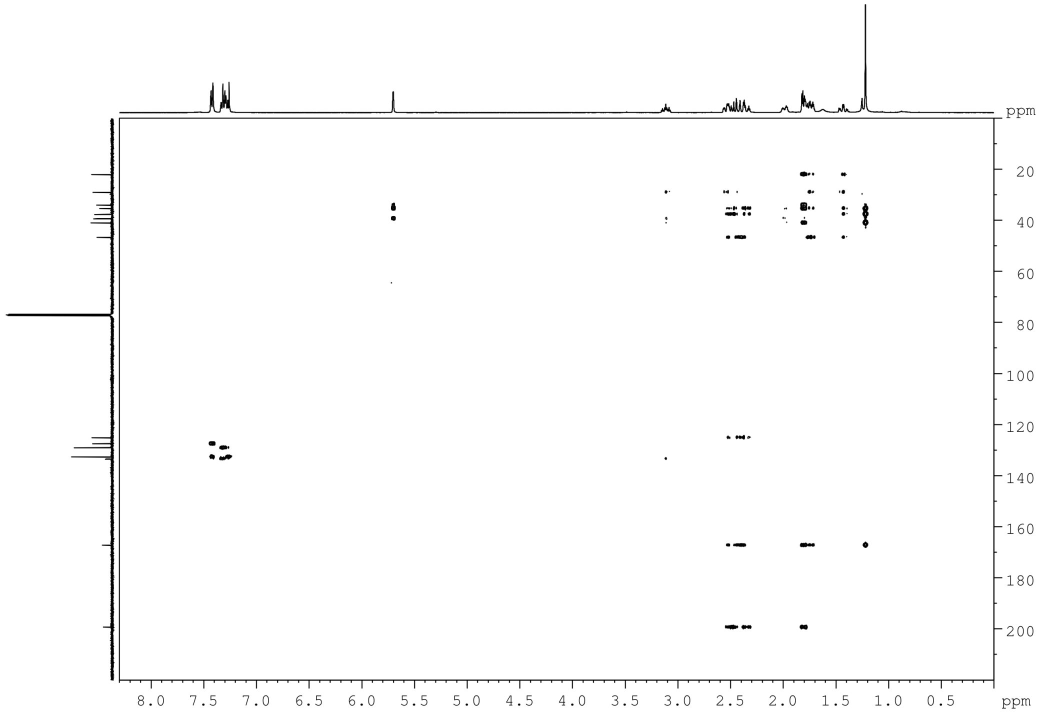
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3ja/ent-3ja**

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ja′**/**ent-3ja′**

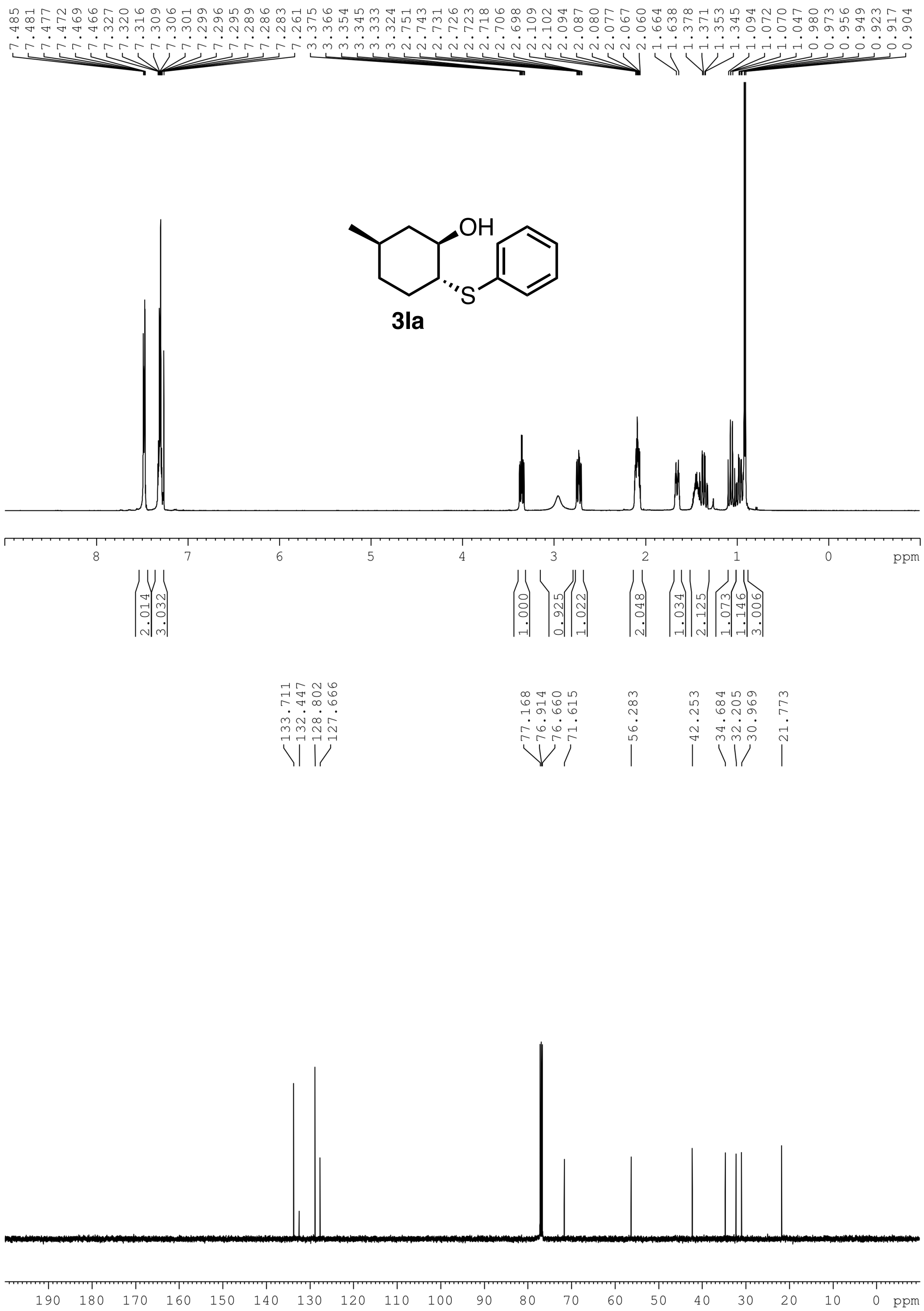


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3ja′/ent-3ja′**

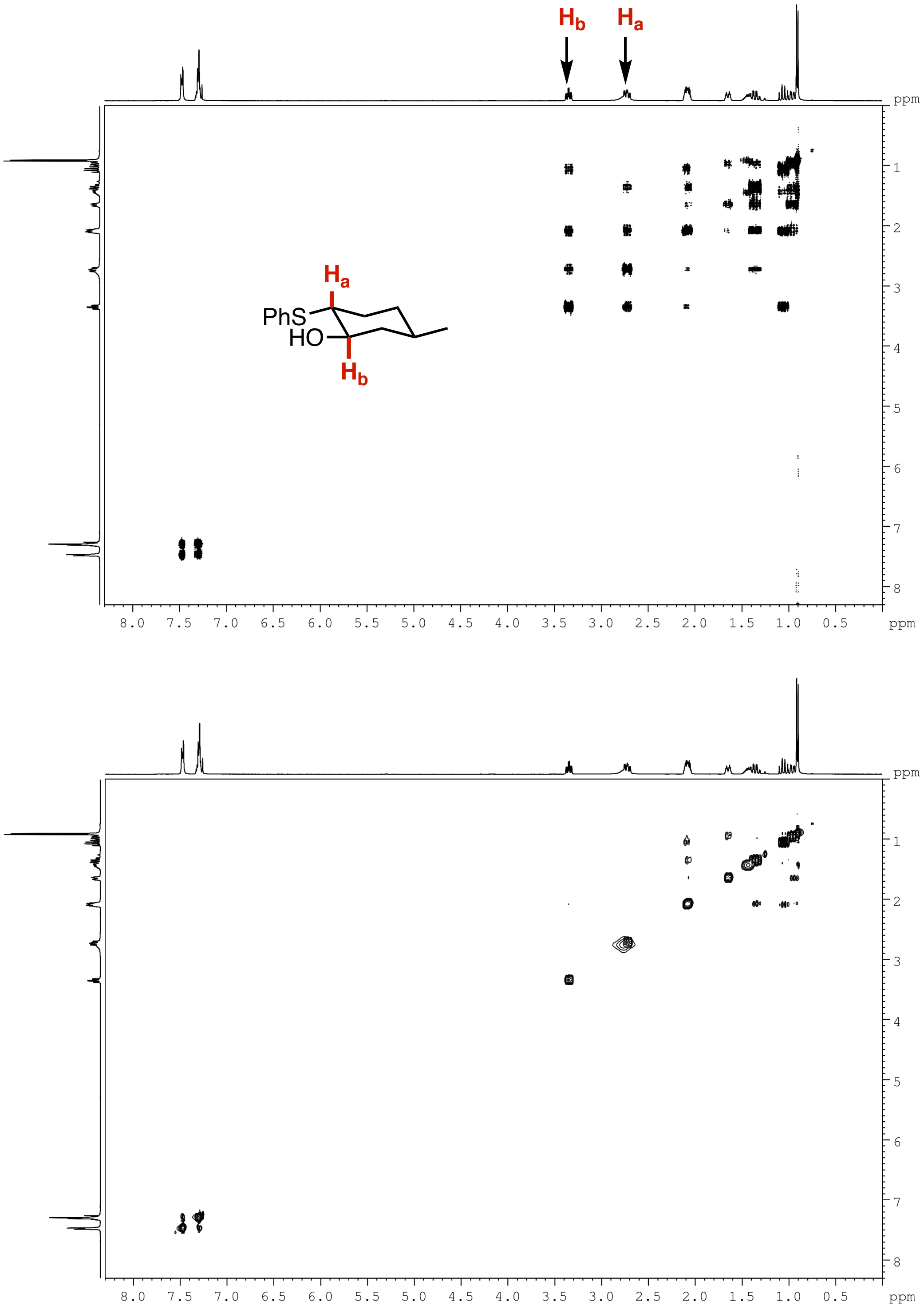




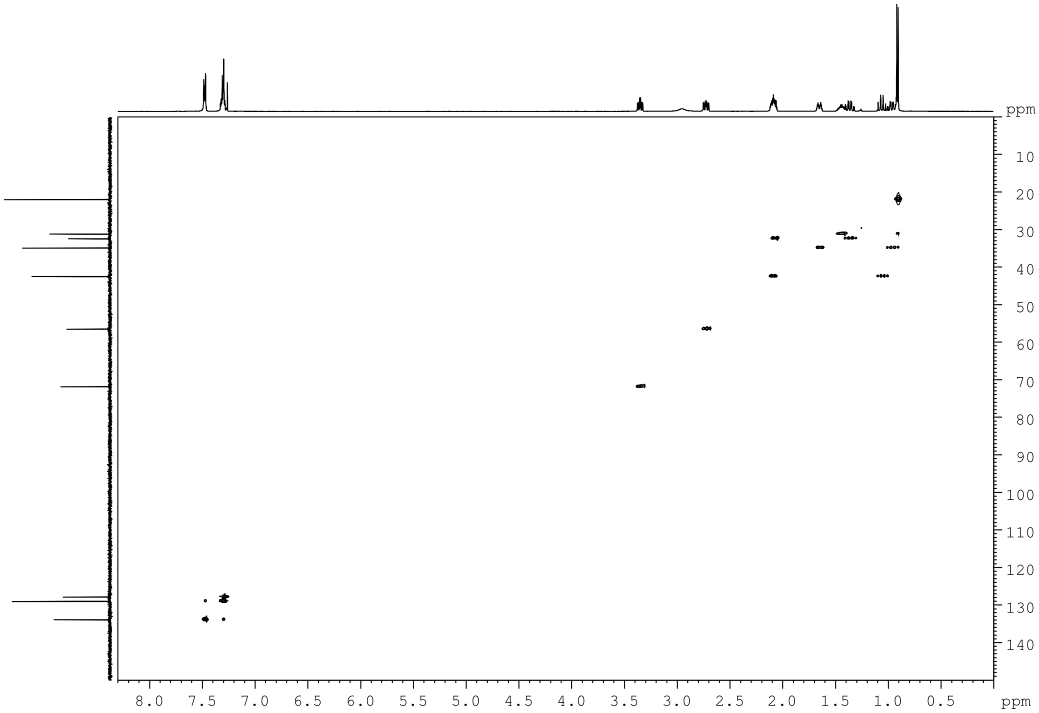
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3ja′/ent-3ja′**

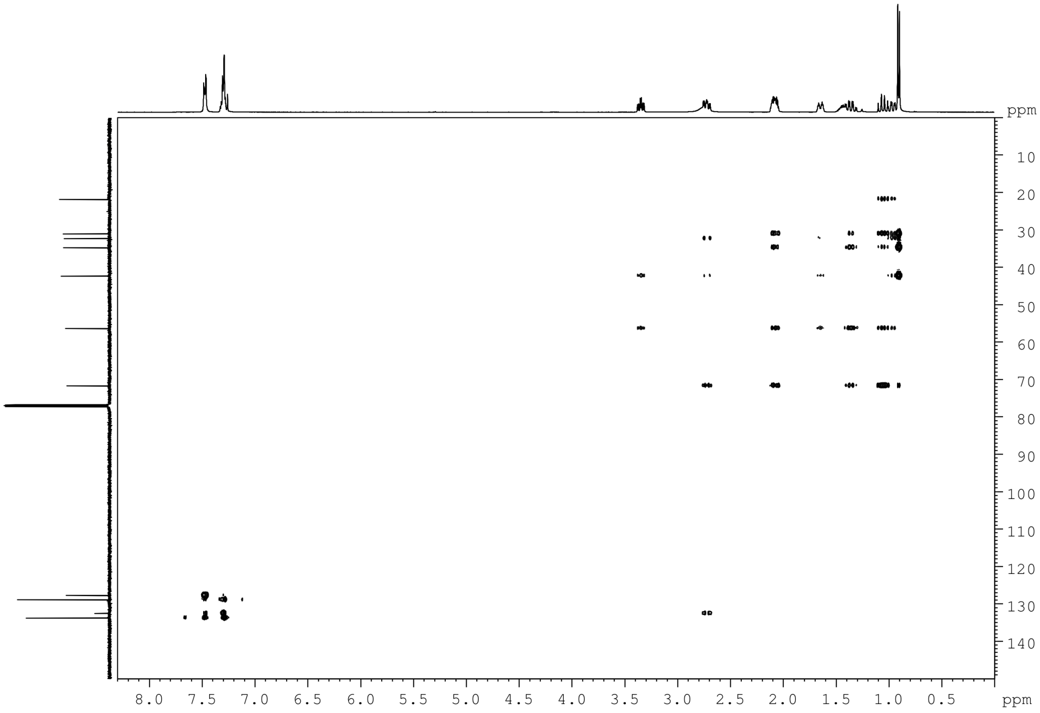


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3la**

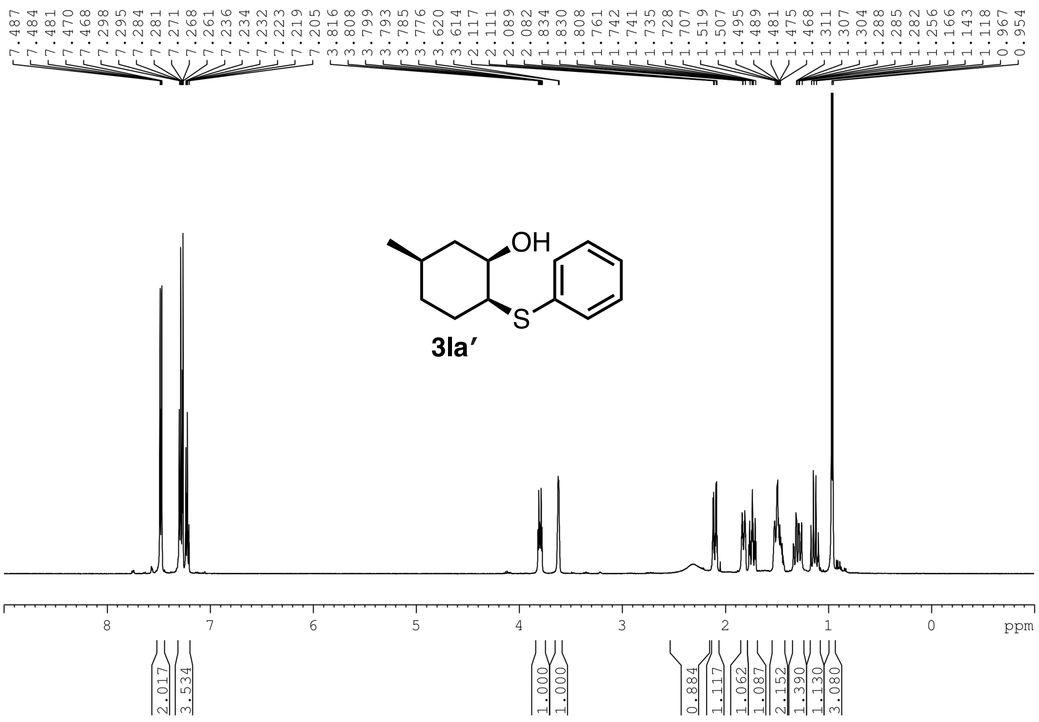


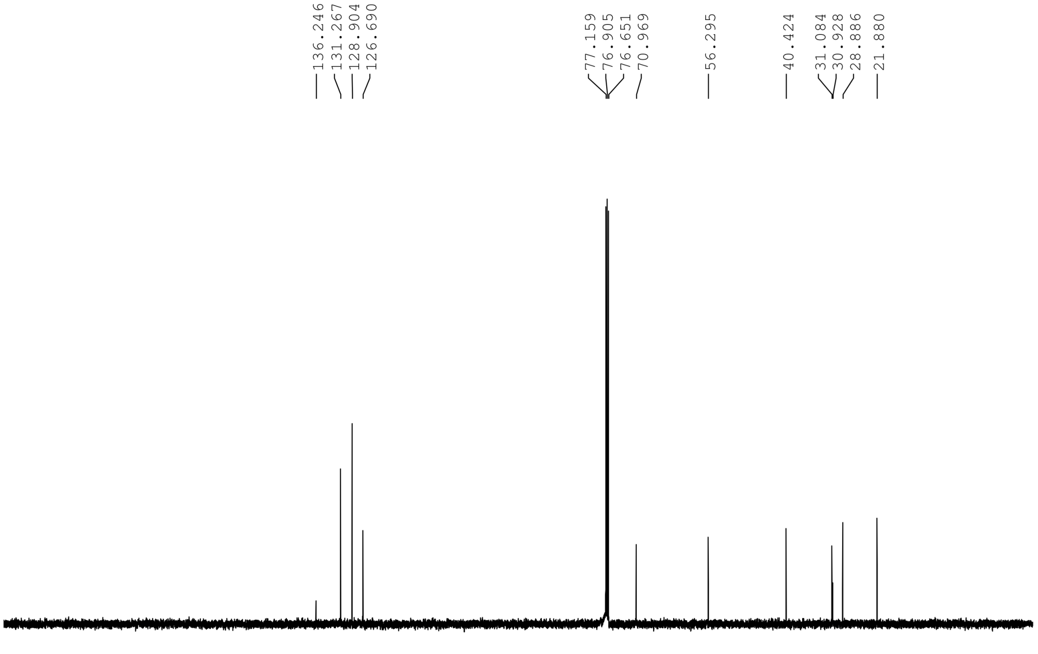
COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3la**



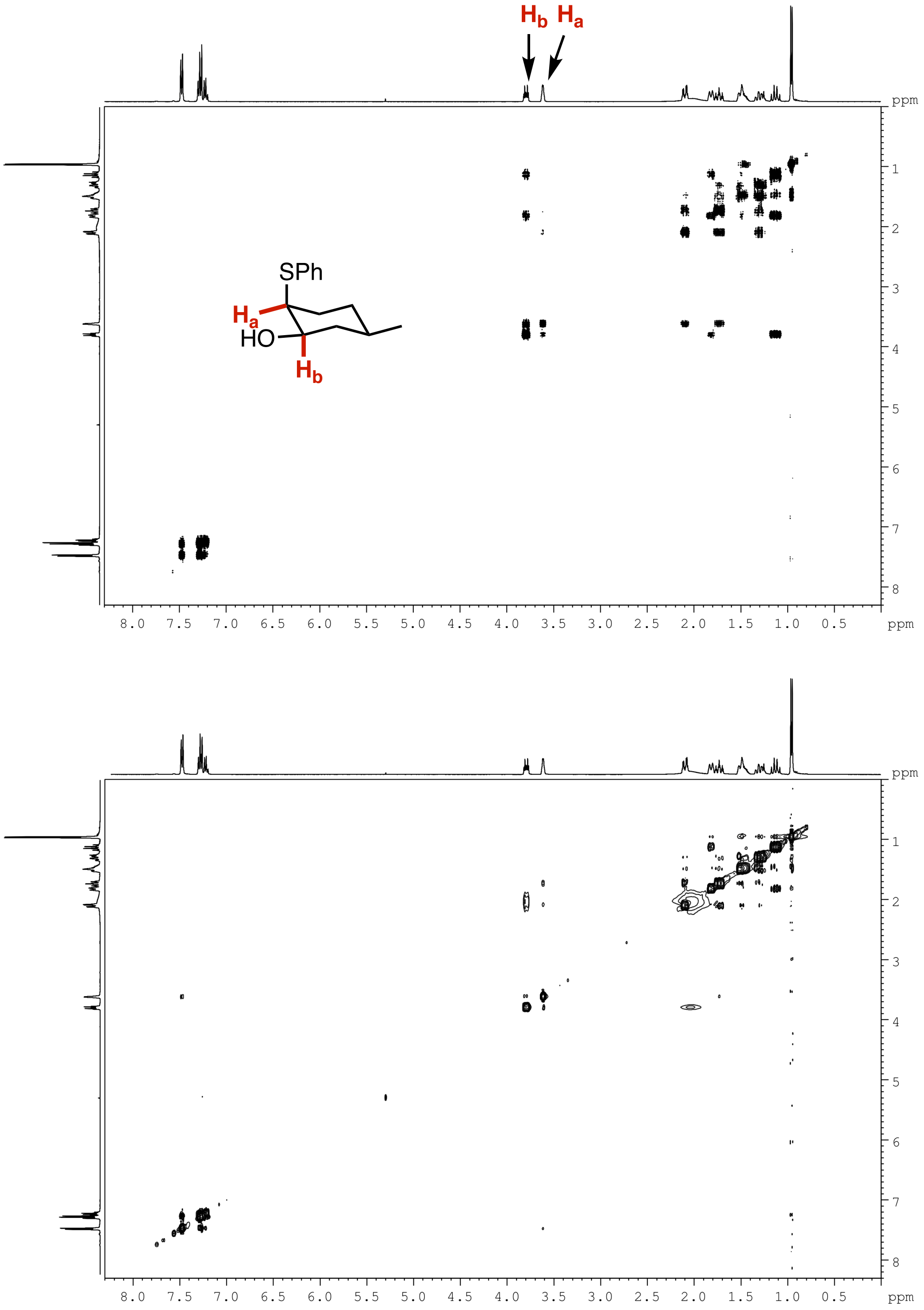


HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3la**

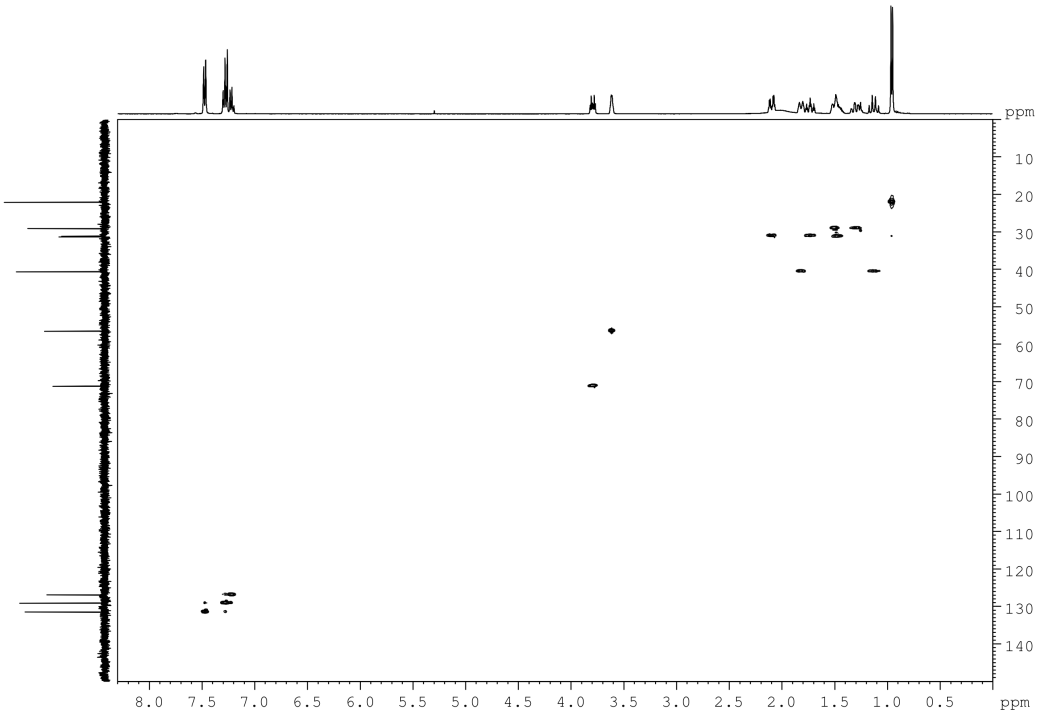


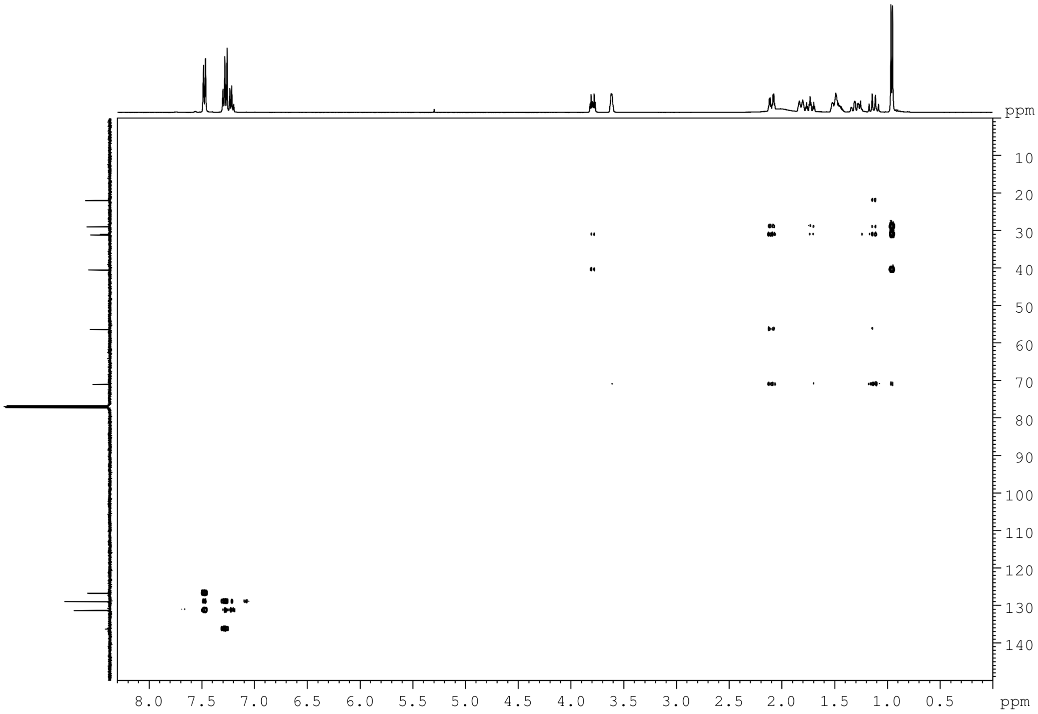


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3la′**



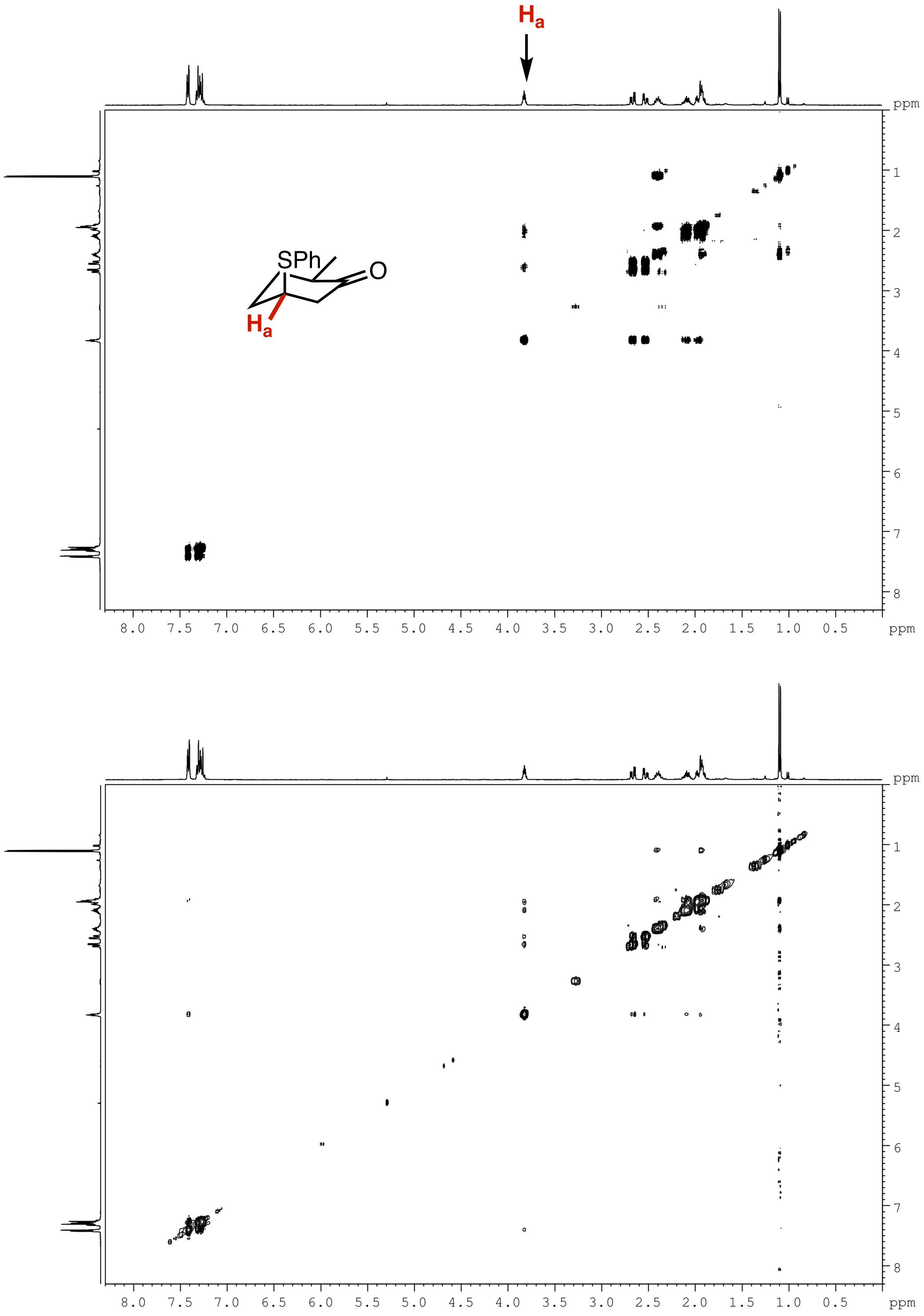
COSY (400 MHz, CDCl$_3$) and NOESY (400 MHz, CDCl$_3$) NMR Spectra of **3la′**



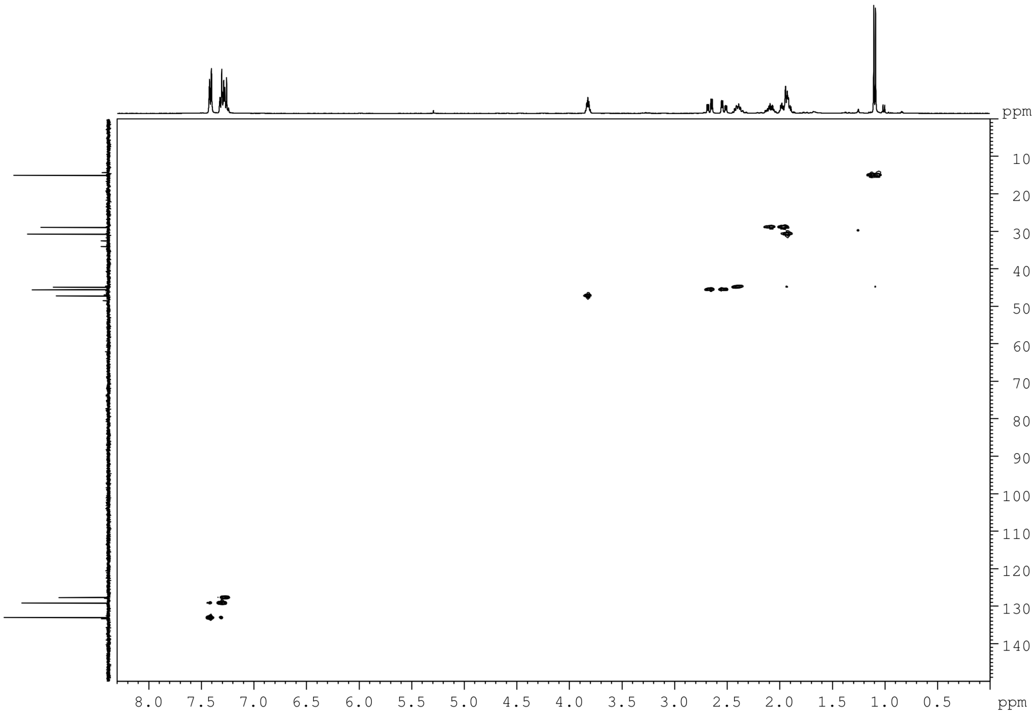


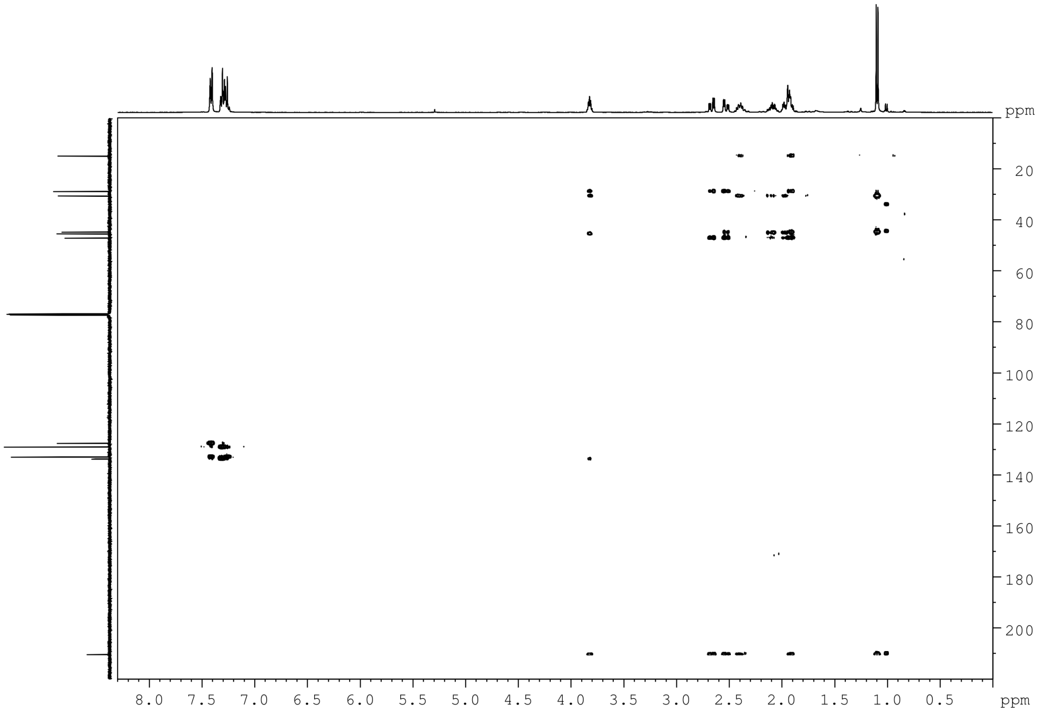
HSQC (400 MHz, CDCl$_3$) and HMBC (400 MHz, CDCl$_3$) NMR Spectra of **3la′**

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ma**

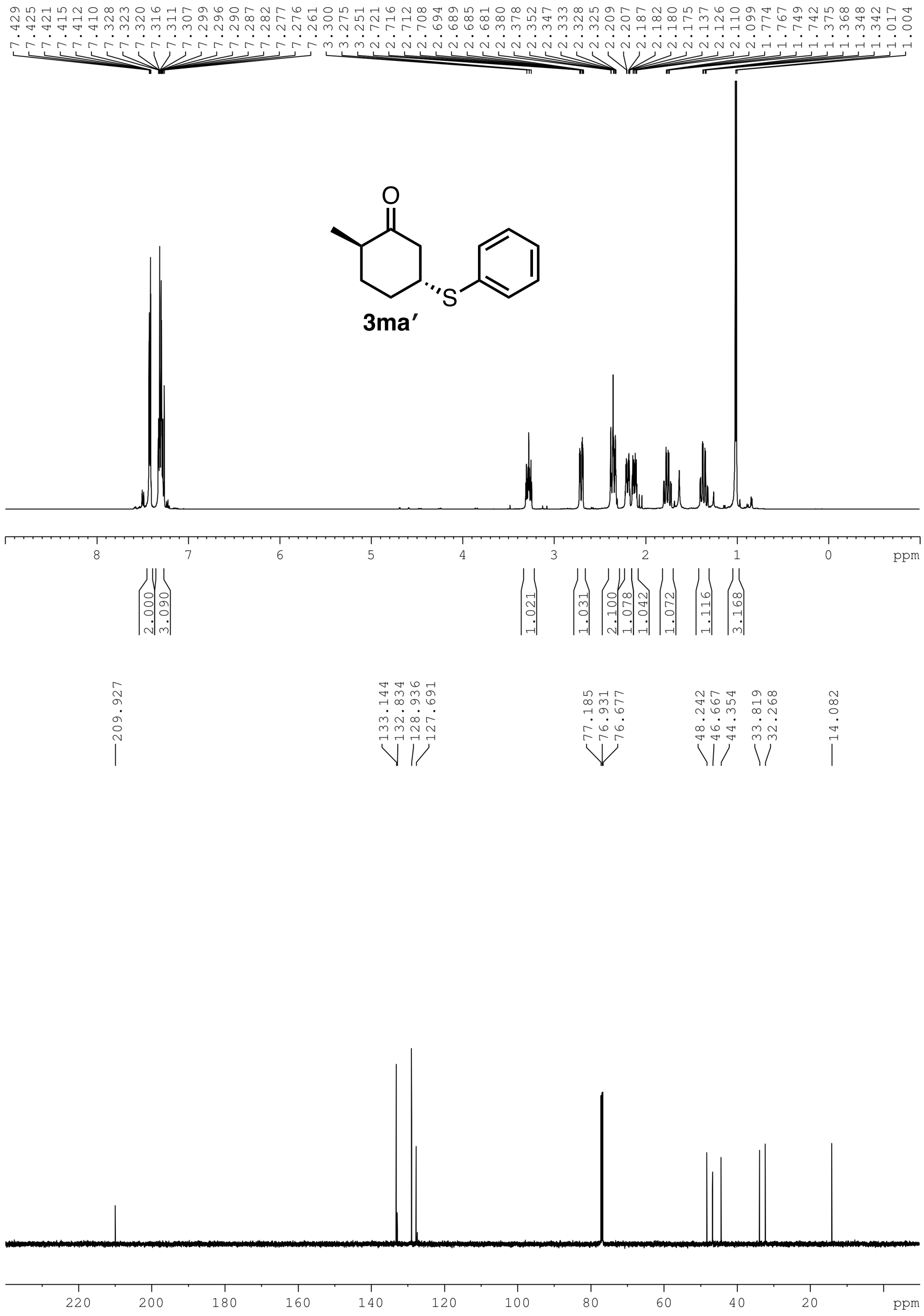


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3ma**

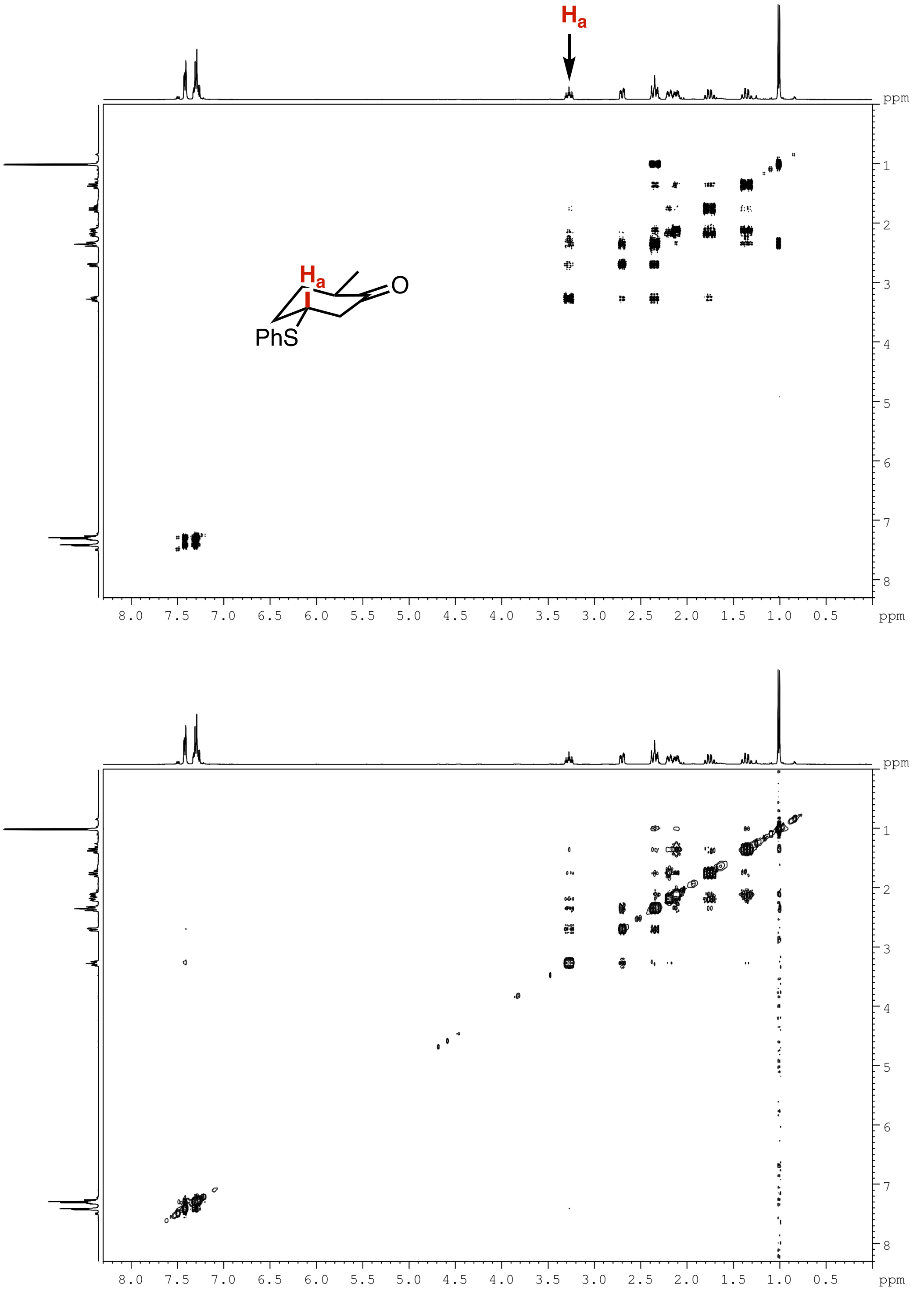




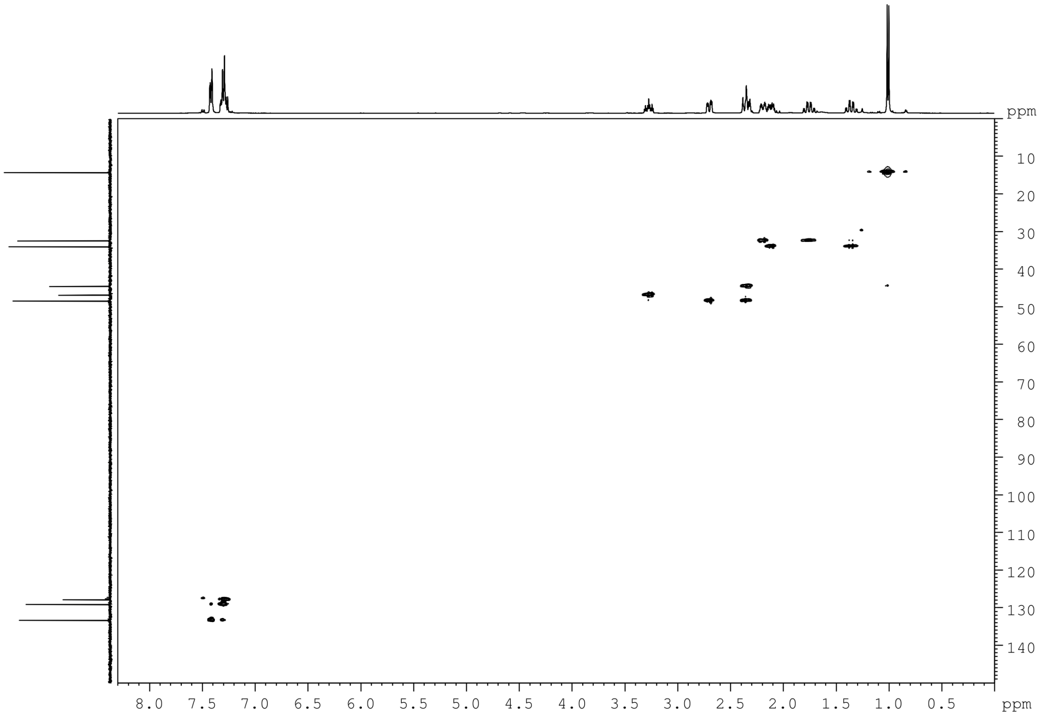
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3ma**

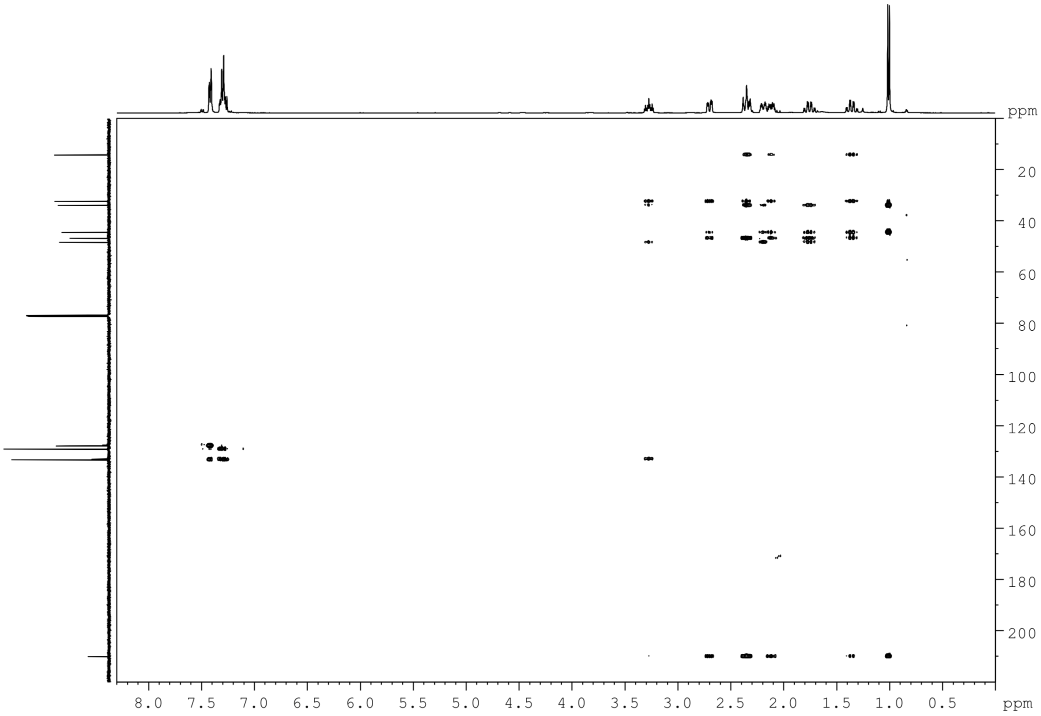


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ma′**

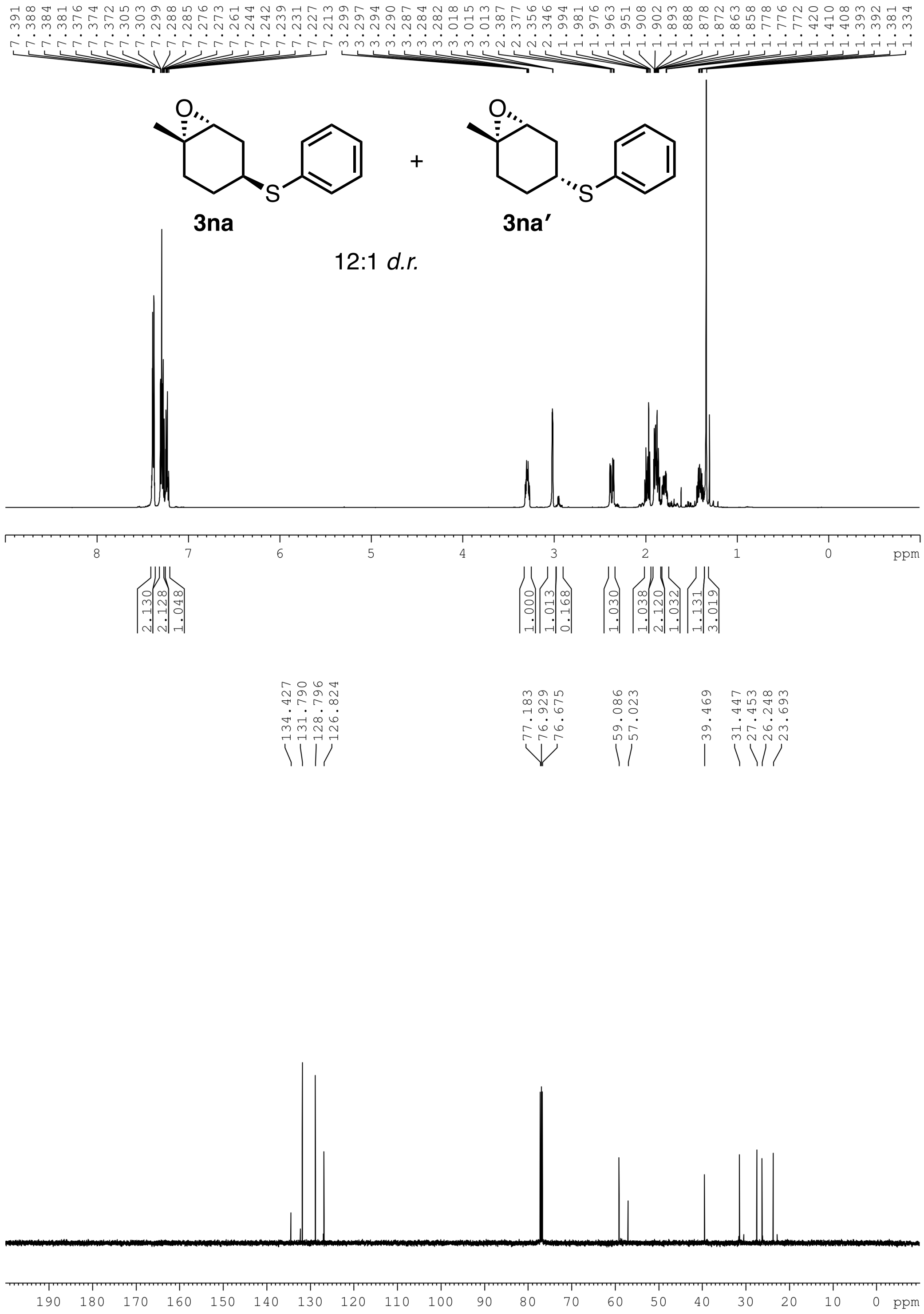


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3ma′**

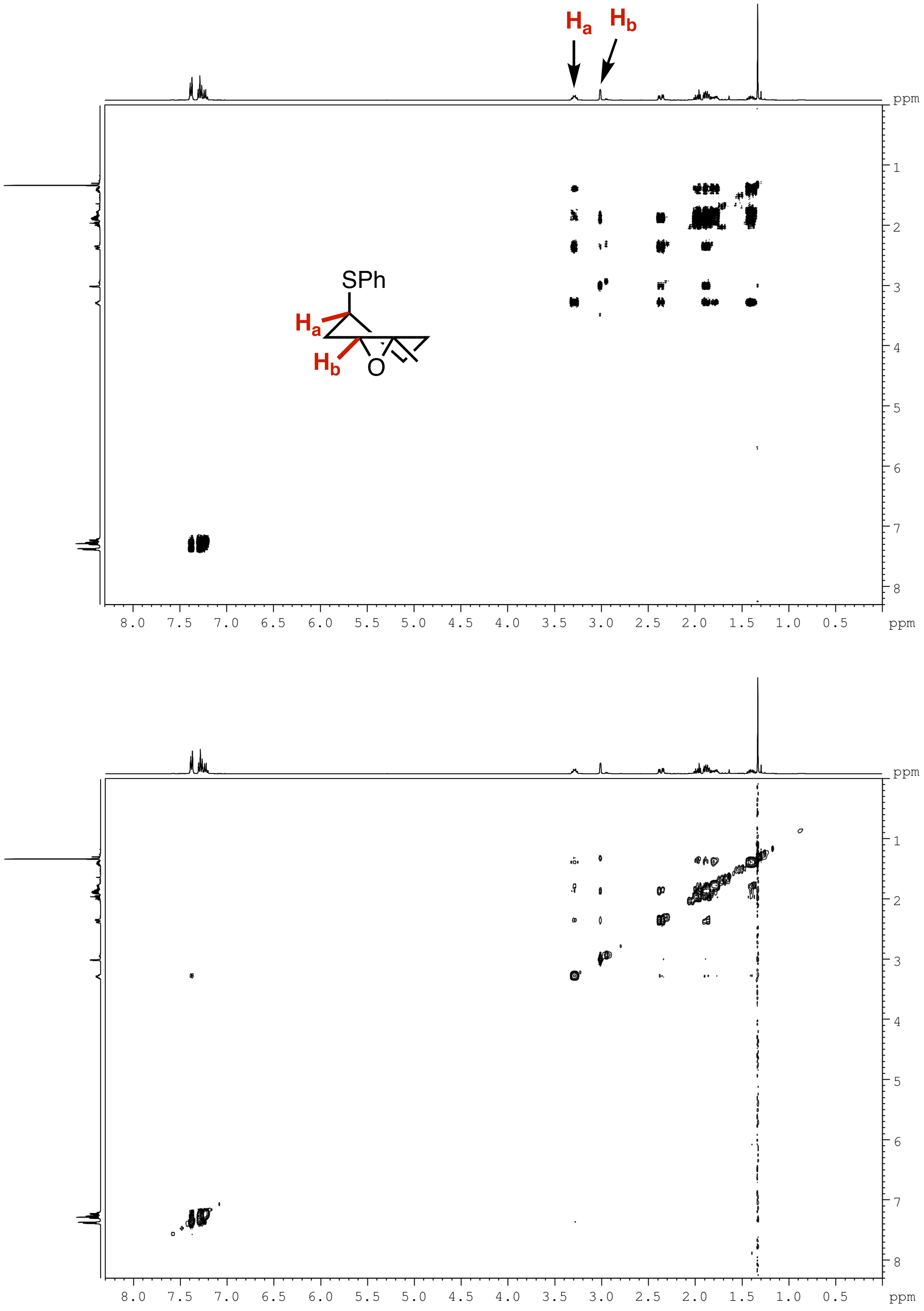




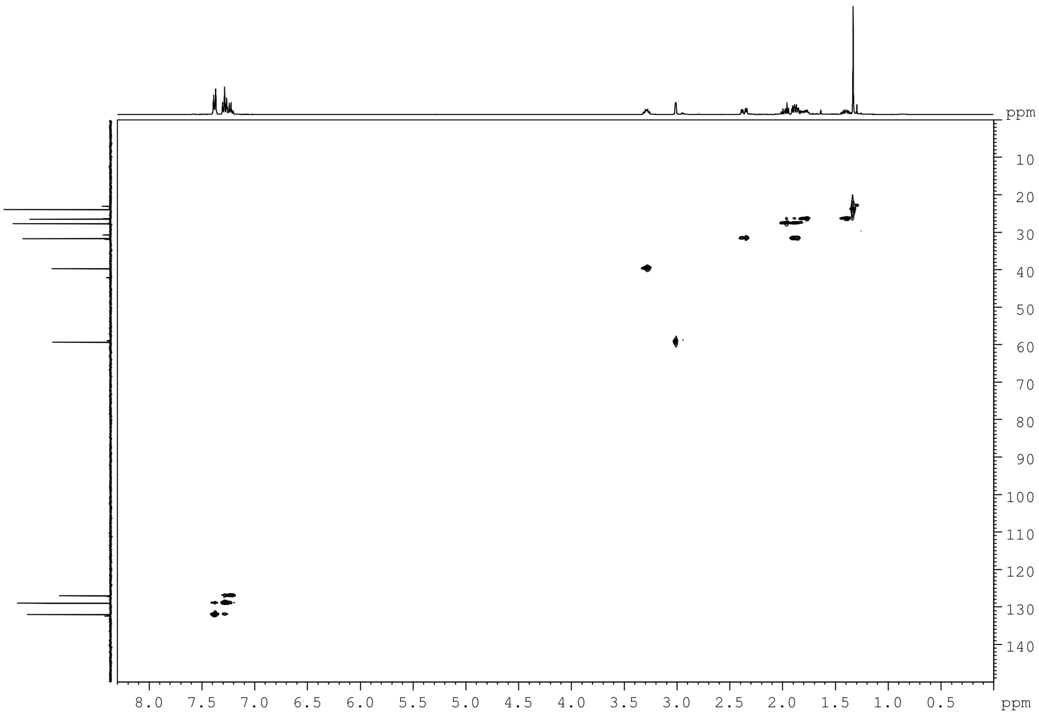
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3ma′**

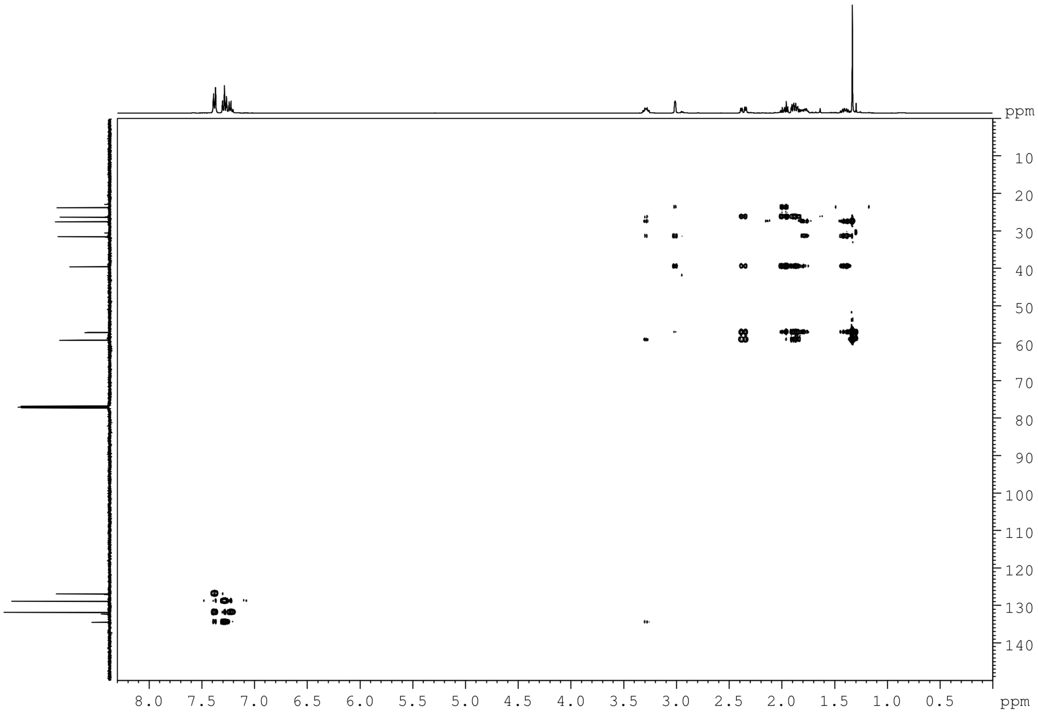


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3na**/**3na′** (12:1 *d.r.*)



COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3na**/**3na′** (12:1 *d.r.*)

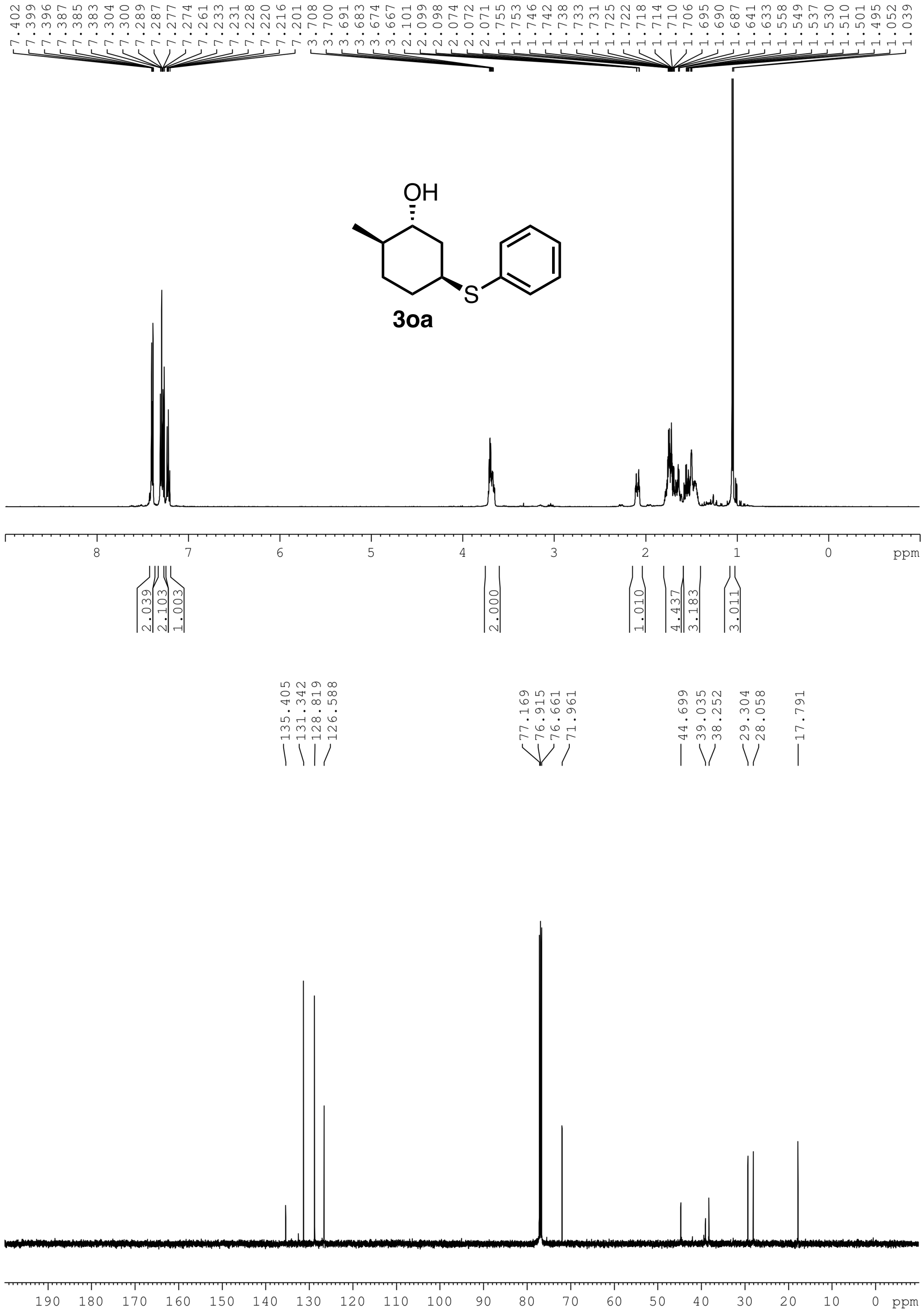




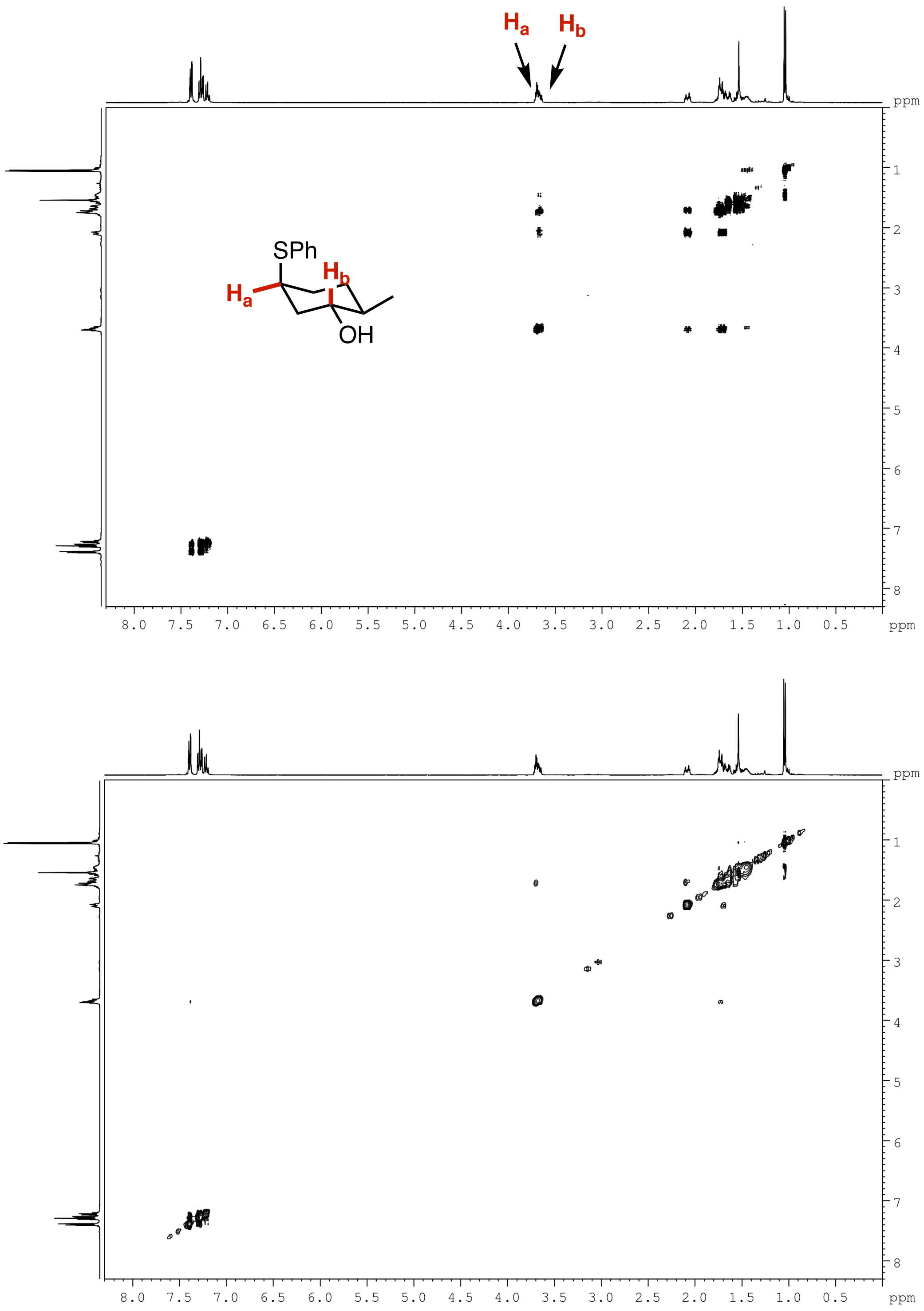
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3na**/**3na′** (12:1 *d.r.*)

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-VI**

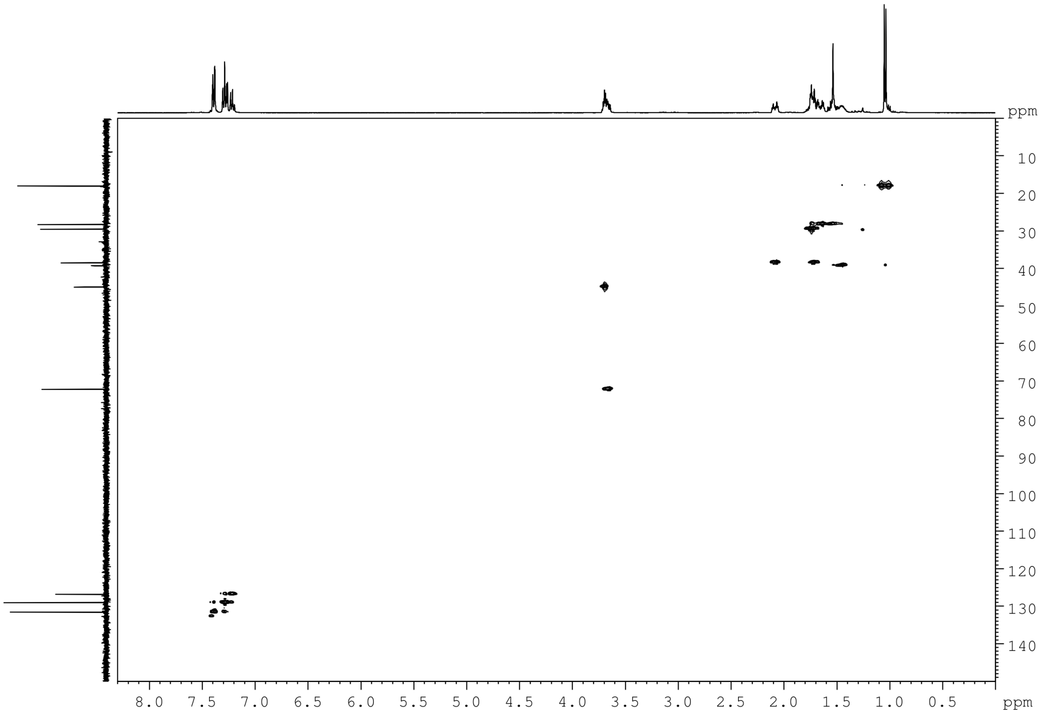
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-VI′**

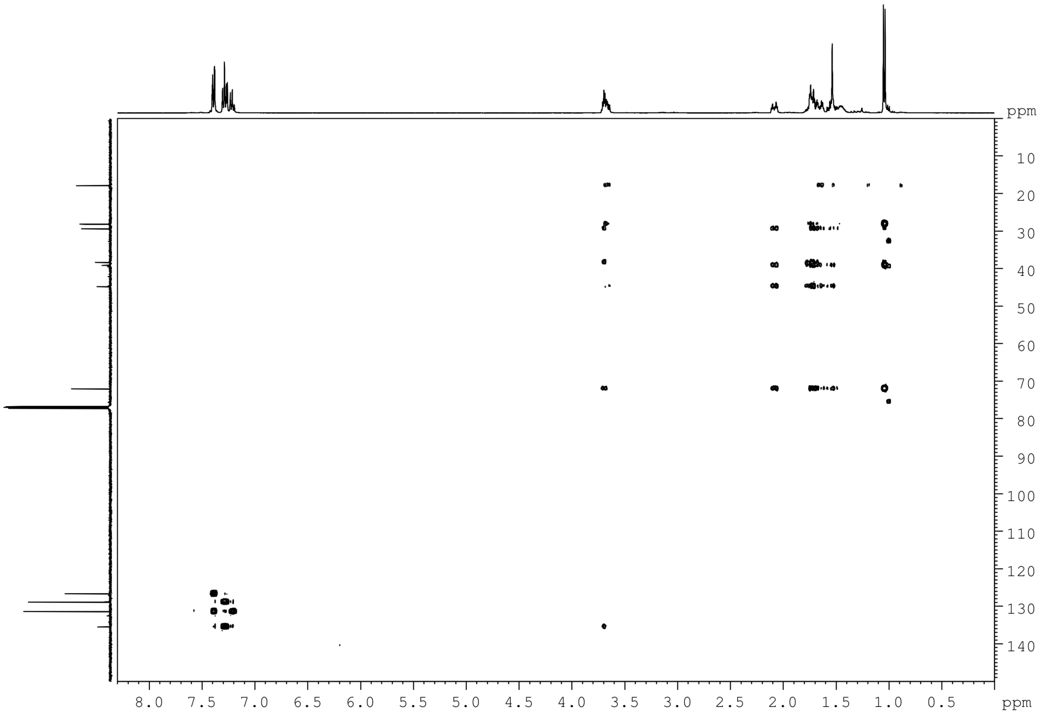


^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **3oa**

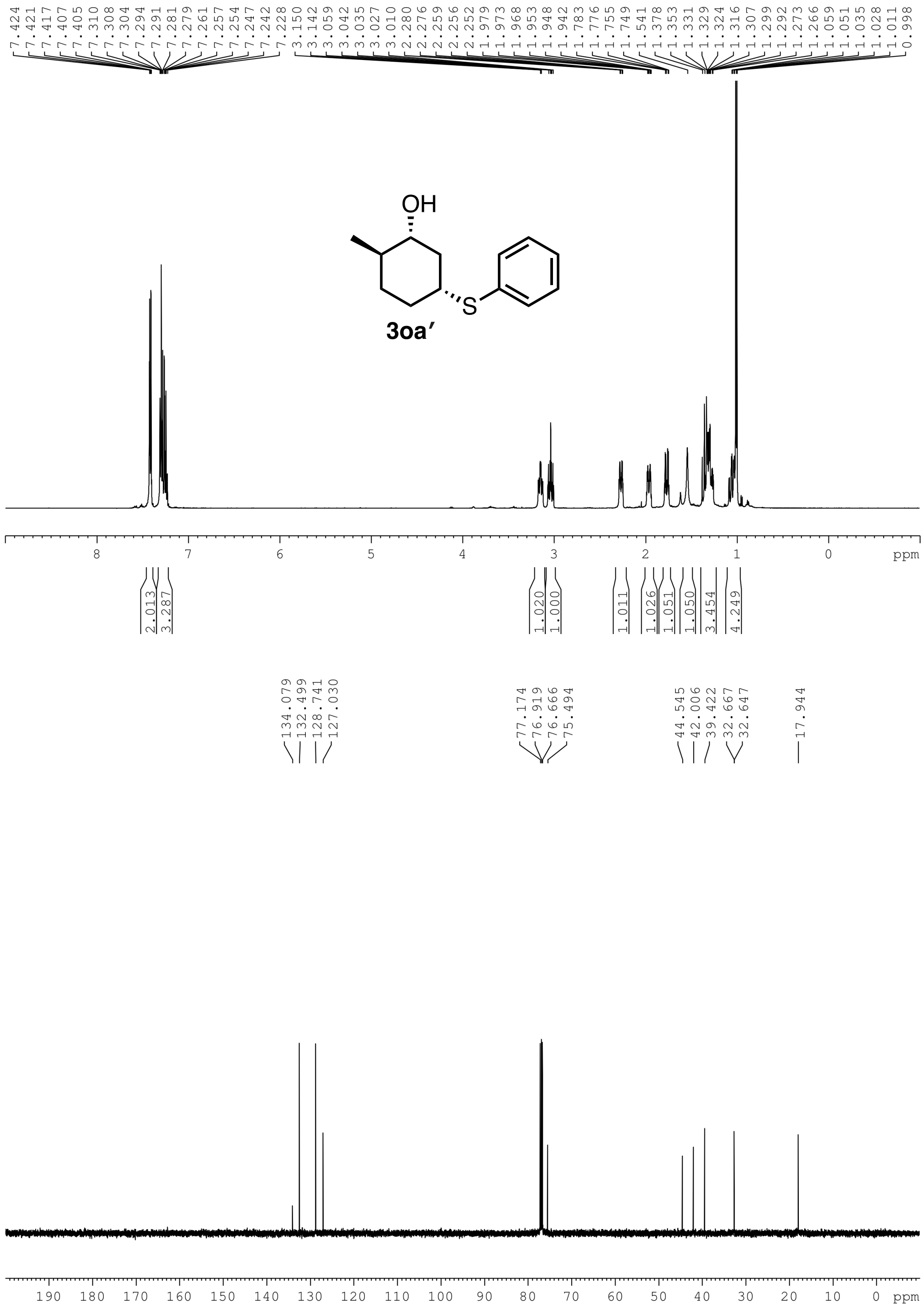


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3oa**

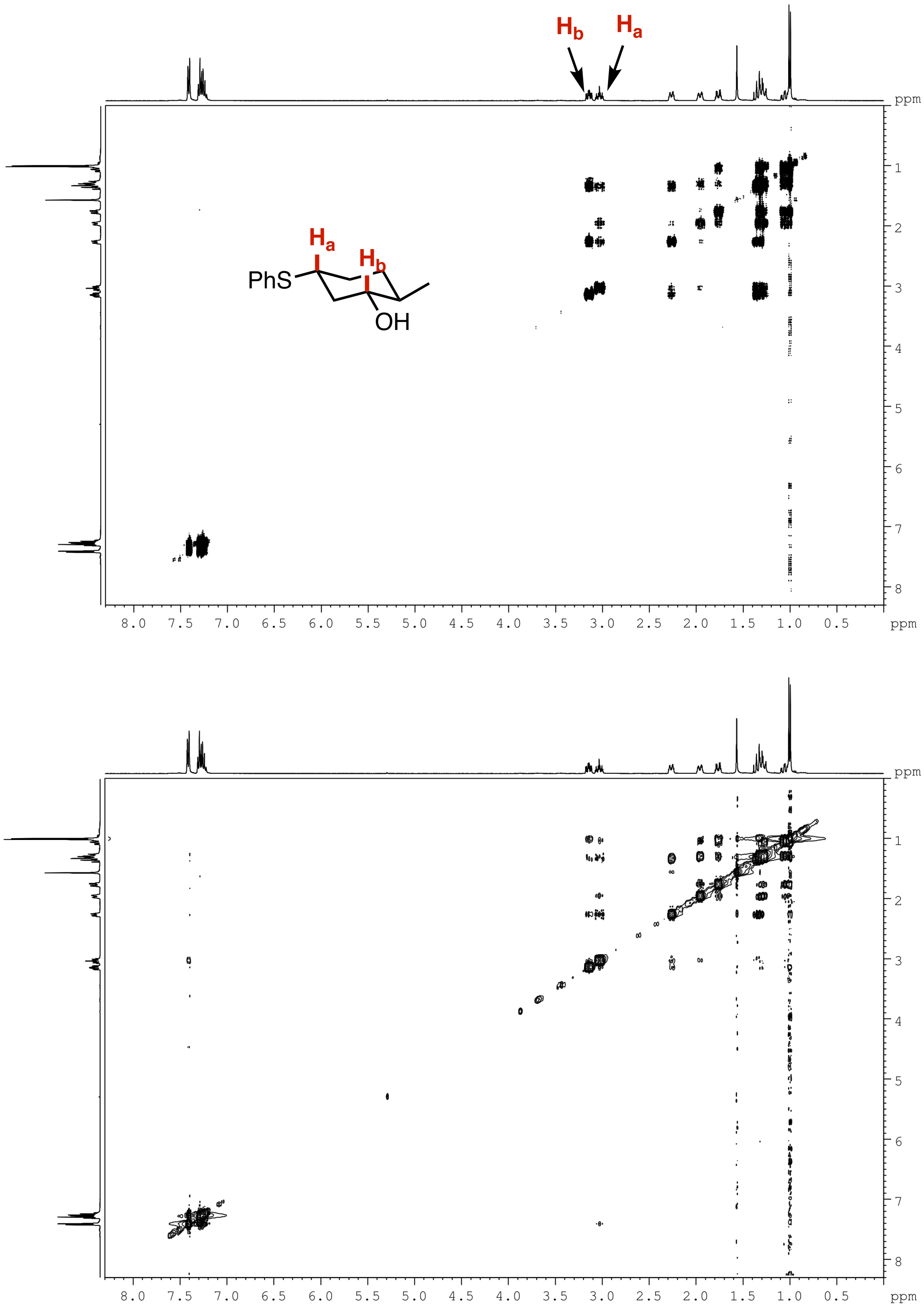




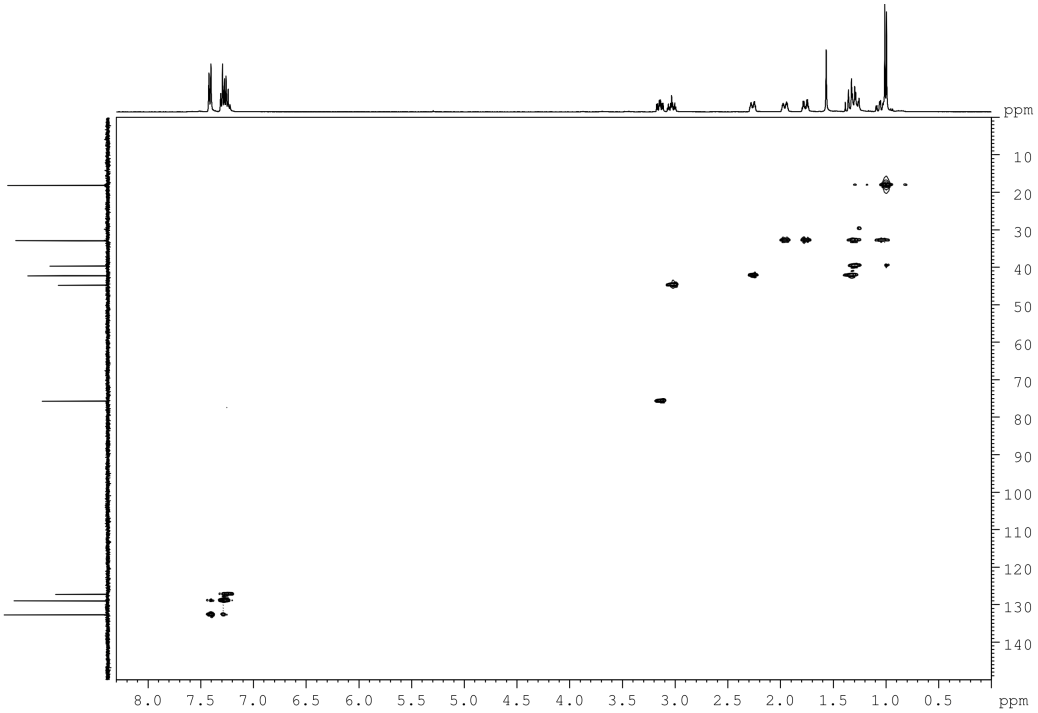
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3oa**

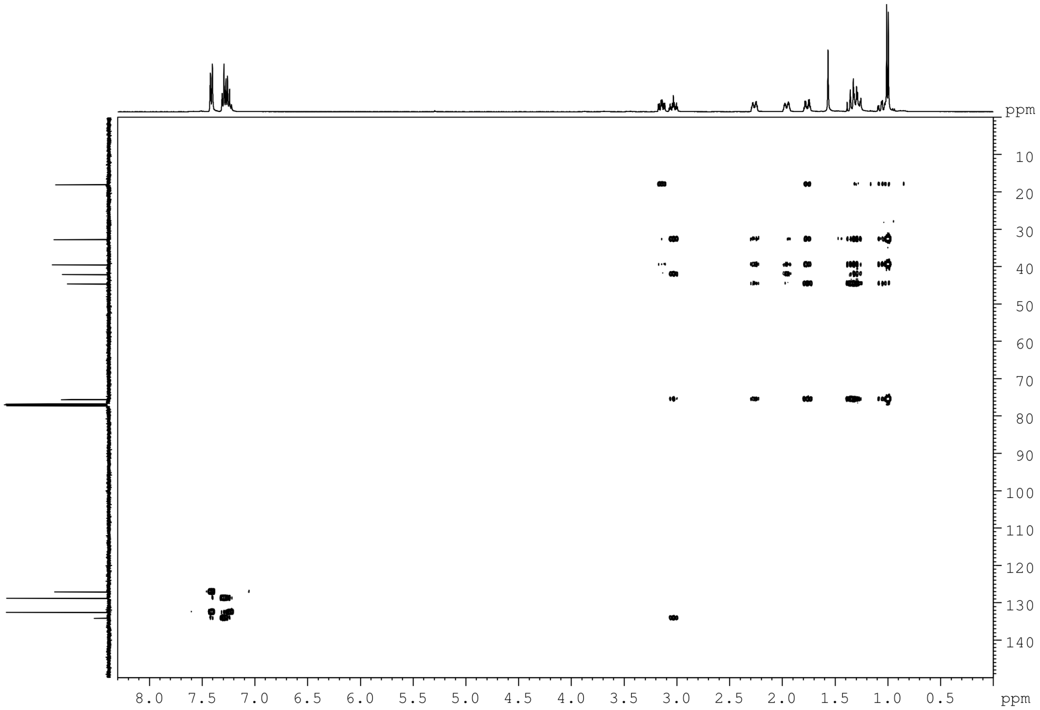


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3oa′**

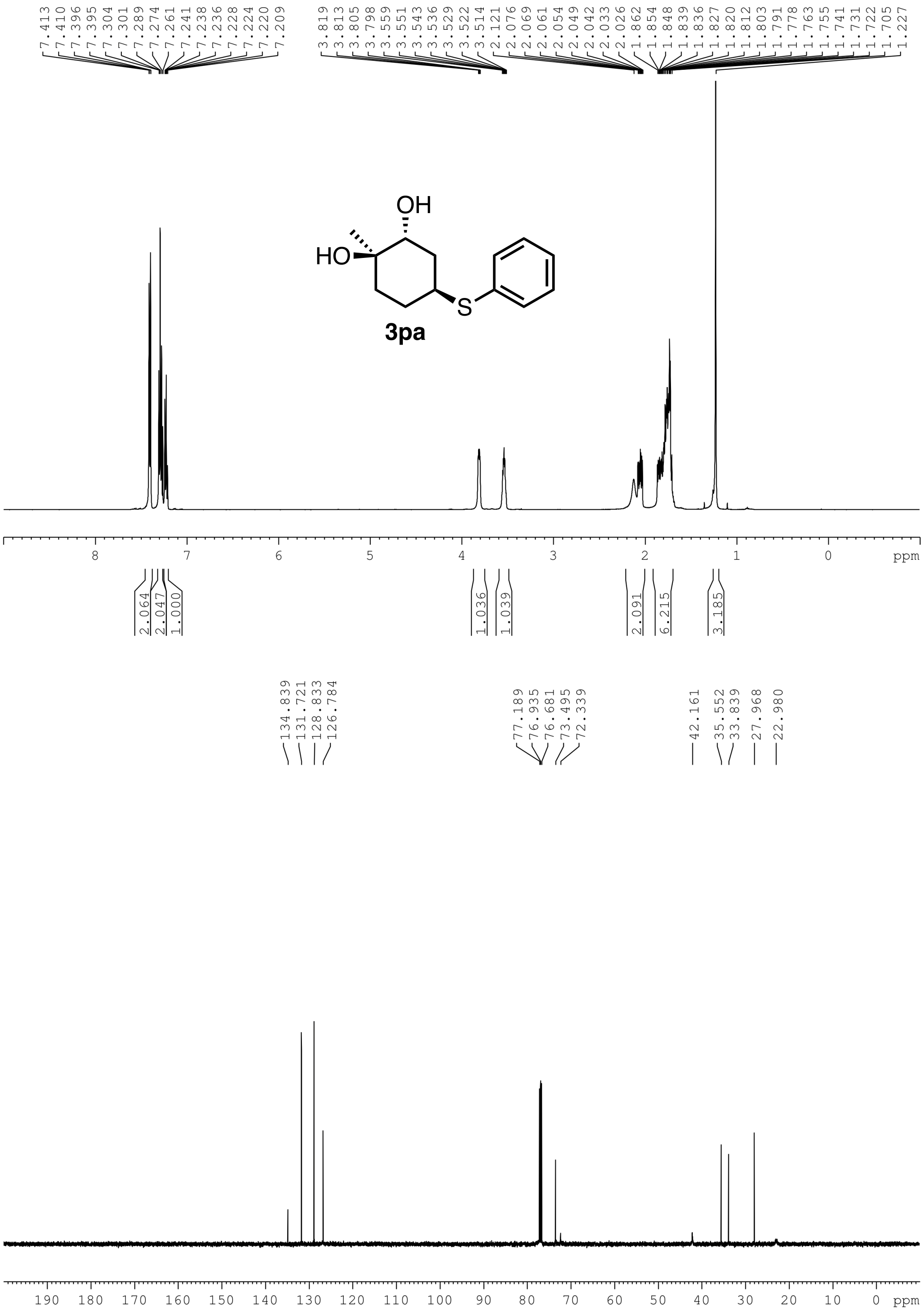


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **3oa′**

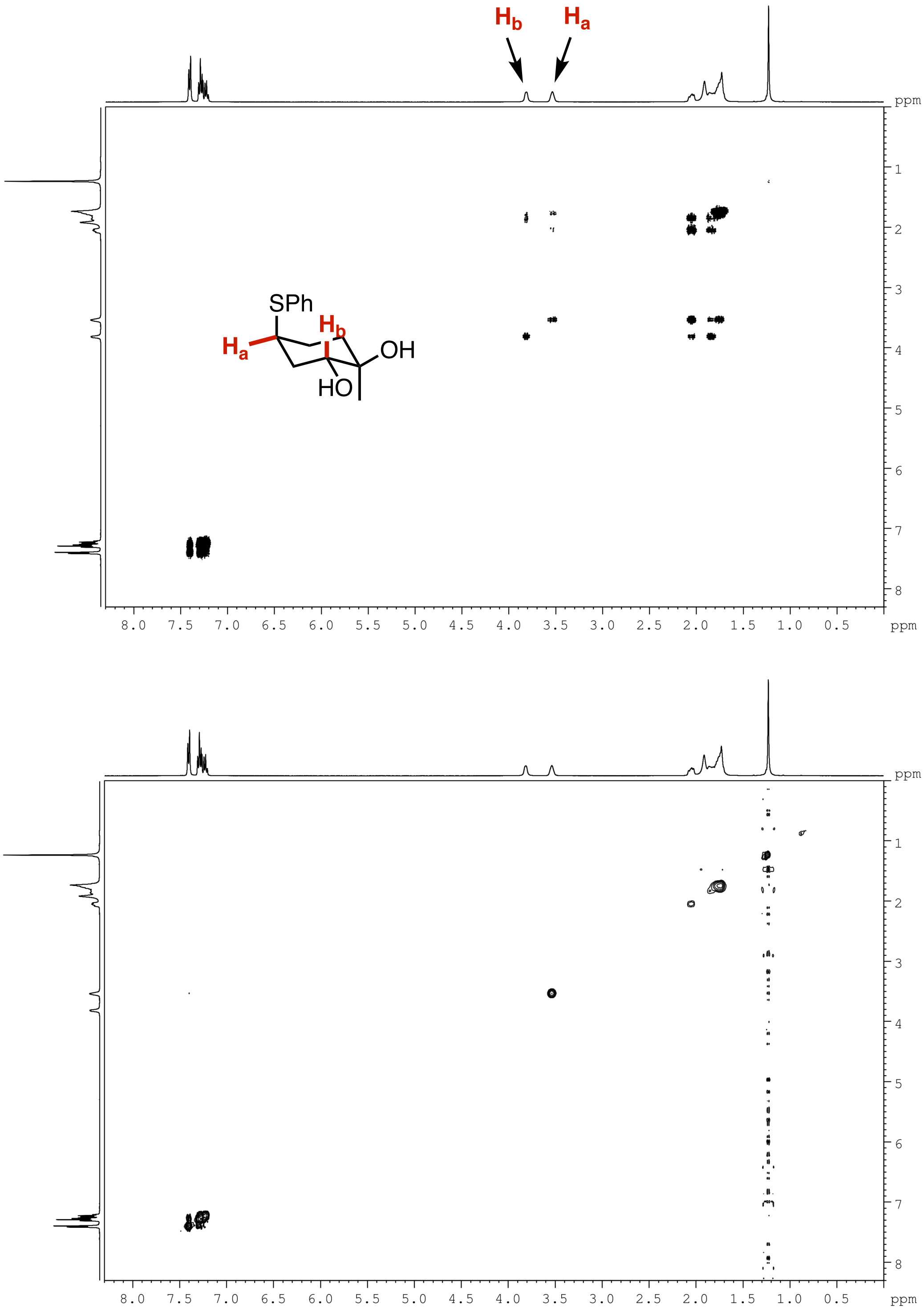




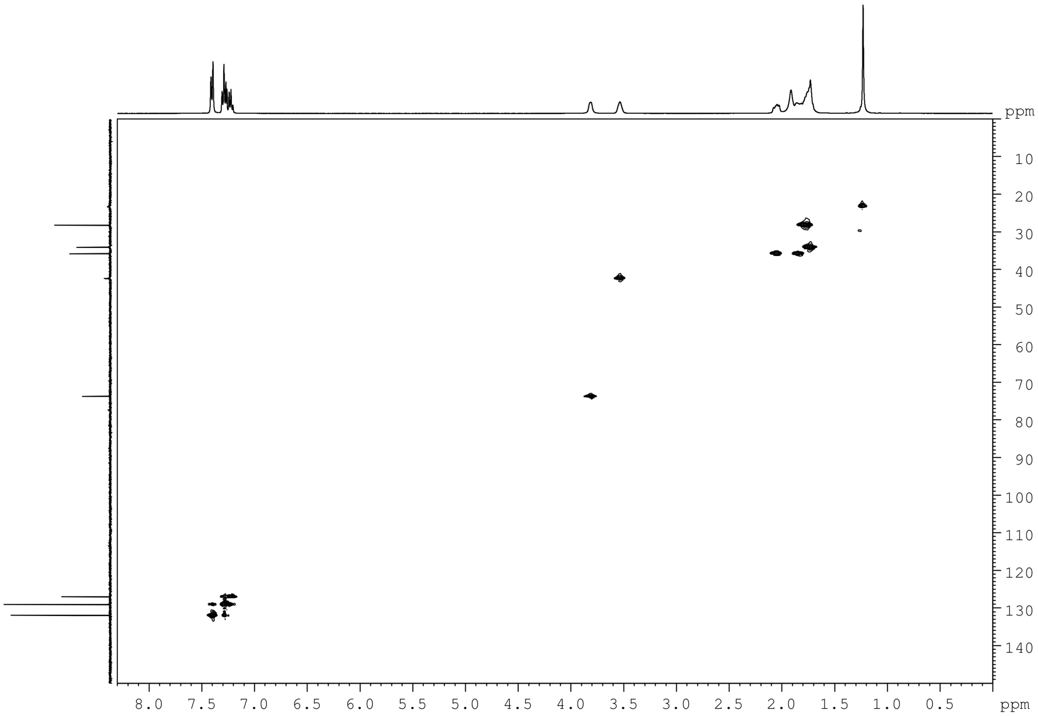
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3oa′**

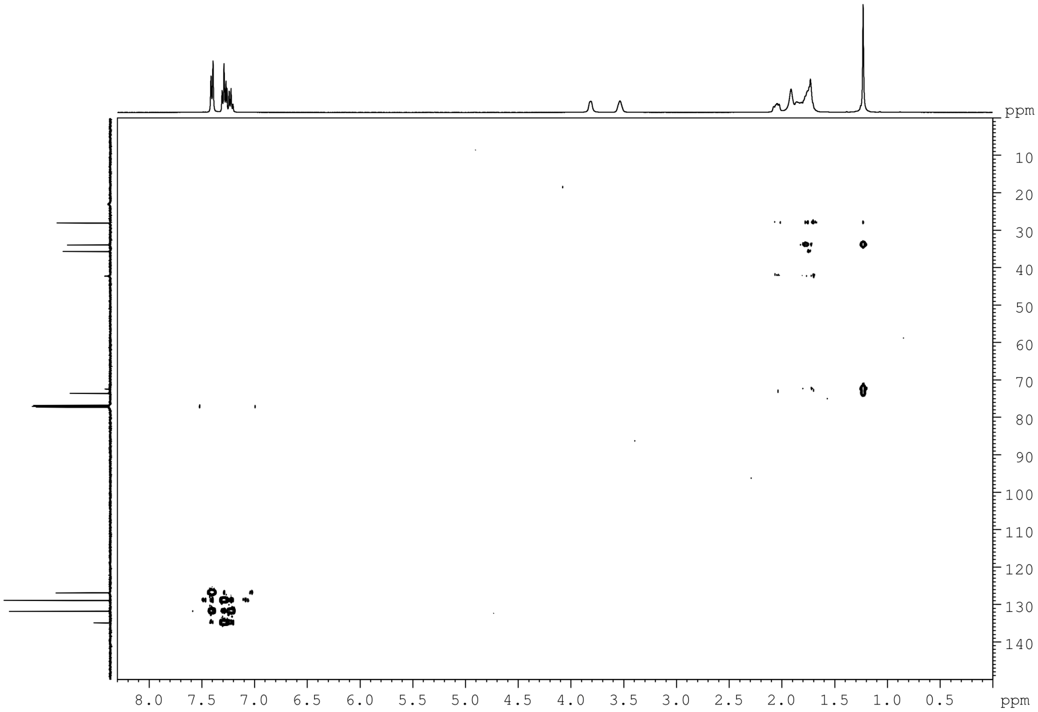


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3pa**

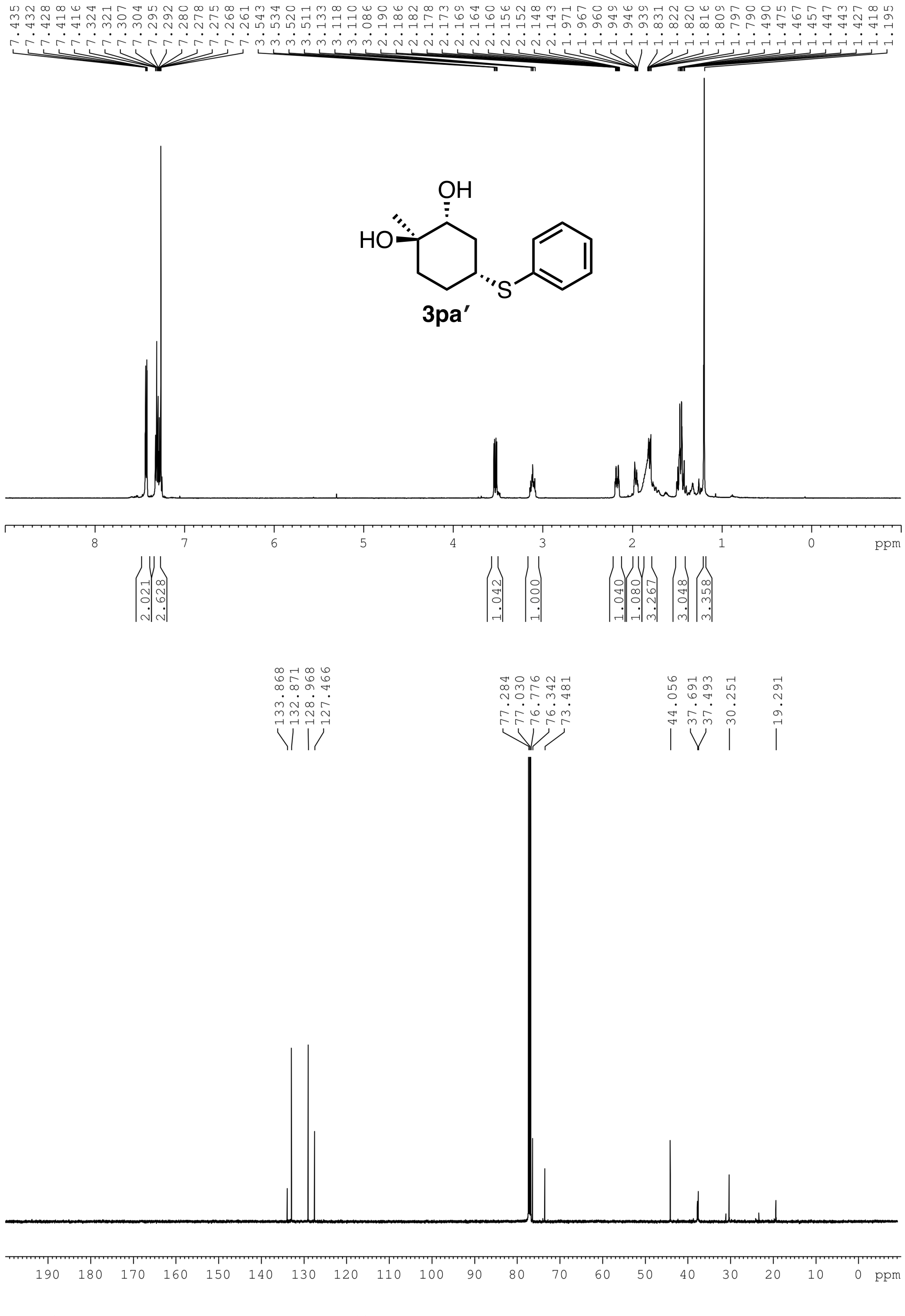


COSY (400 MHz, CDCl$_3$) and NOESY (400 MHz, CDCl$_3$) NMR Spectra of **3pa**

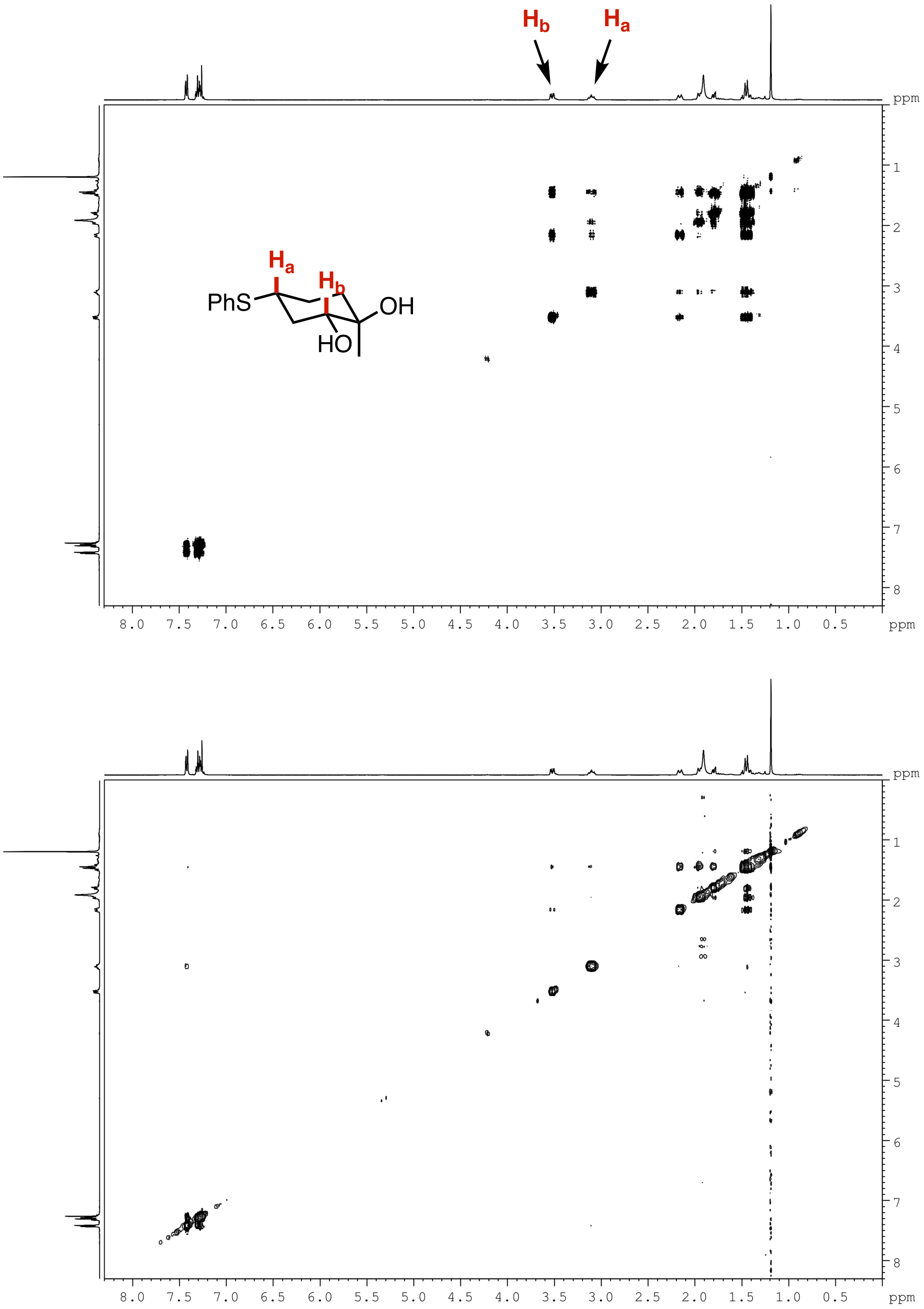




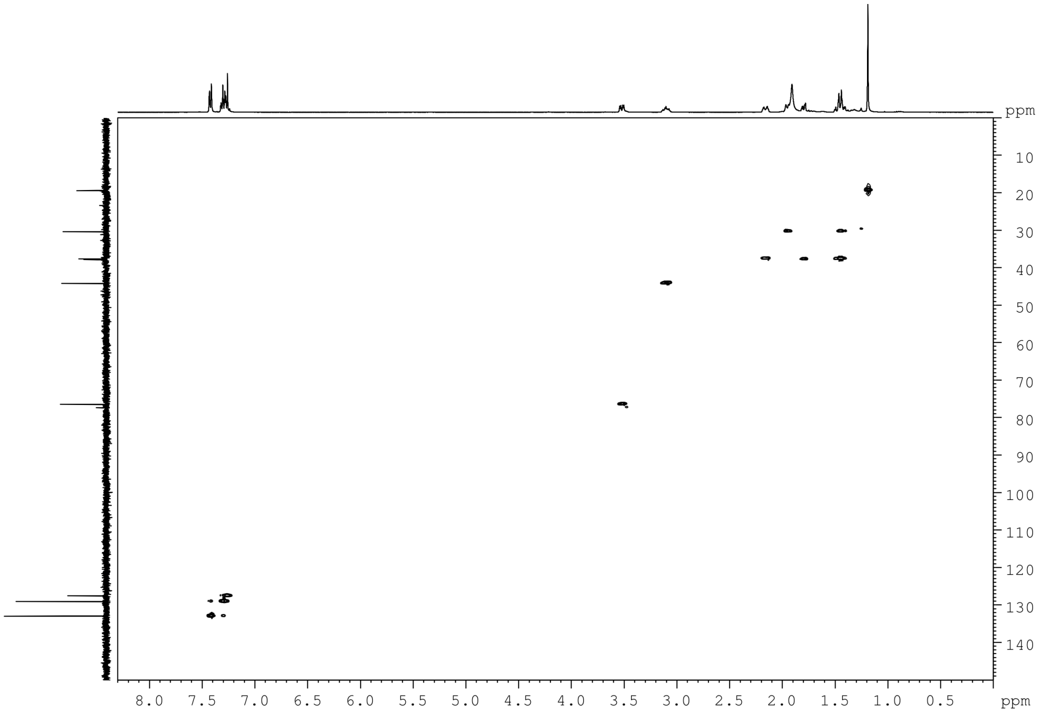
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3pa**

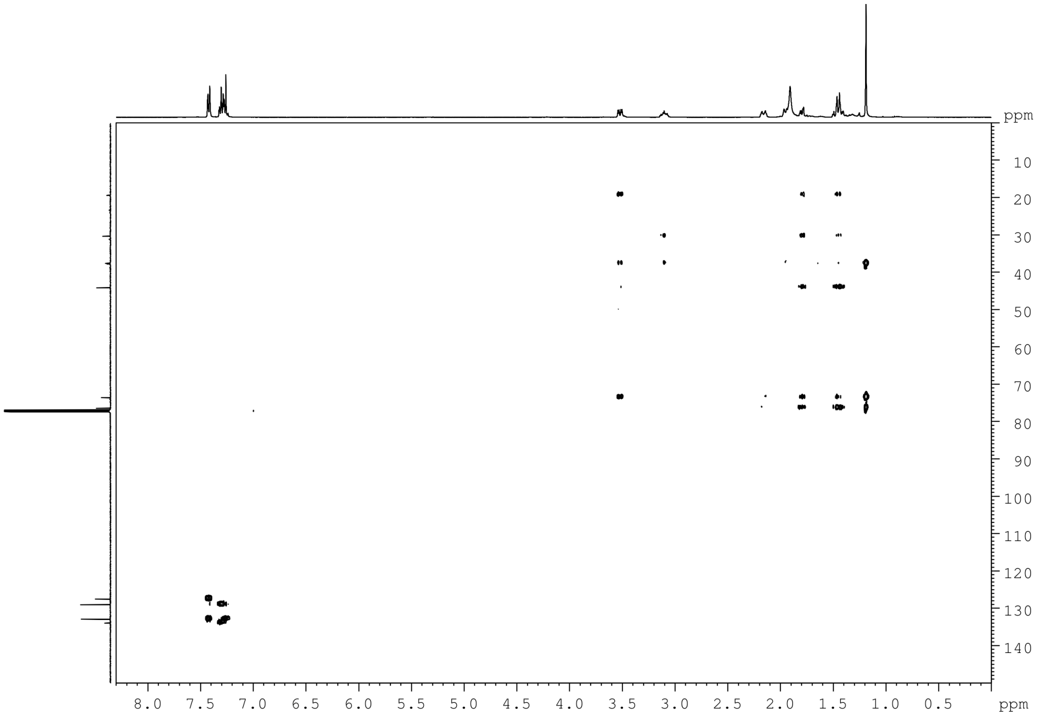


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3pa′**

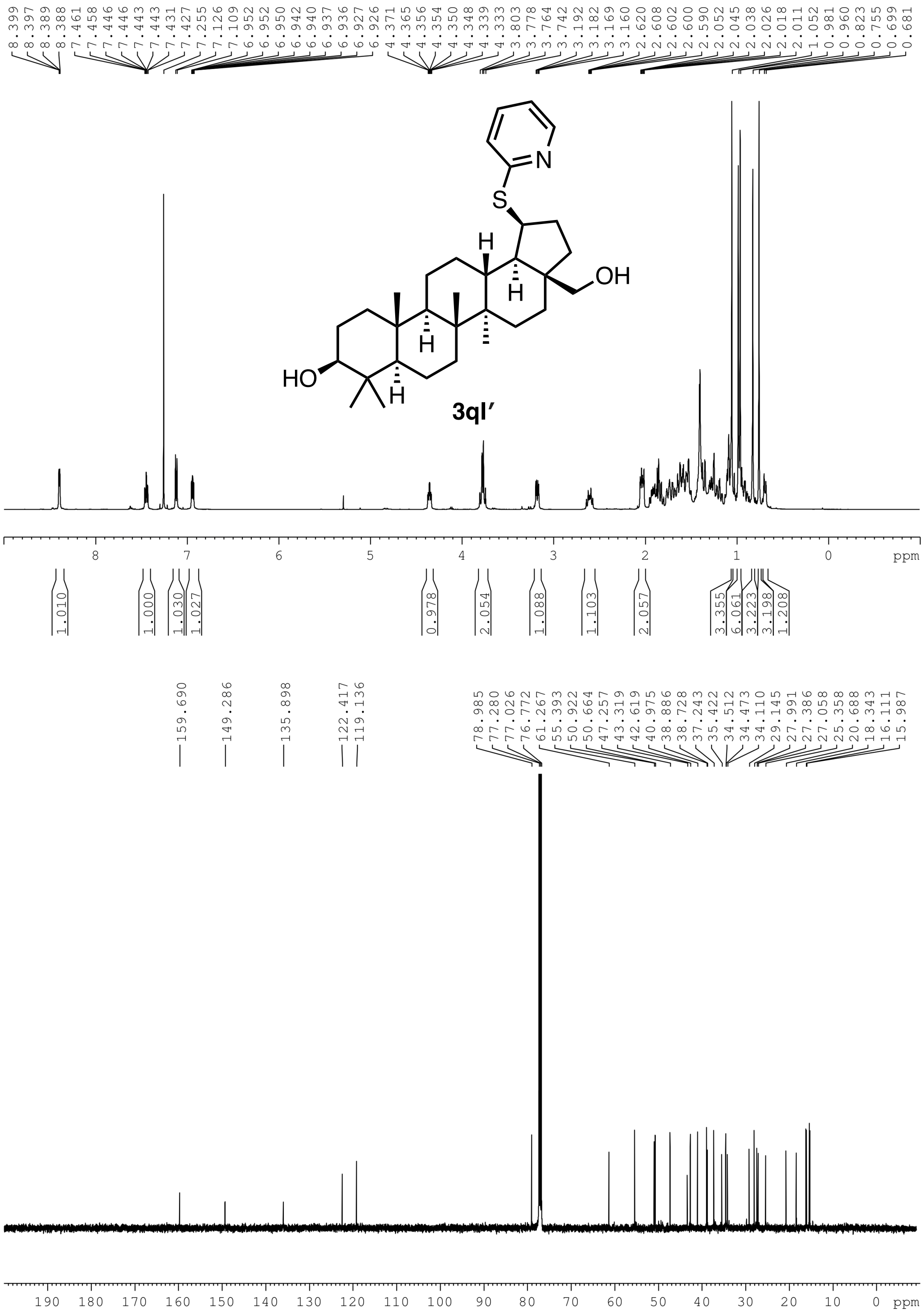


COSY (400 MHz, CDCl$_3$) and NOESY (400 MHz, CDCl$_3$) NMR Spectra of **3pa′**



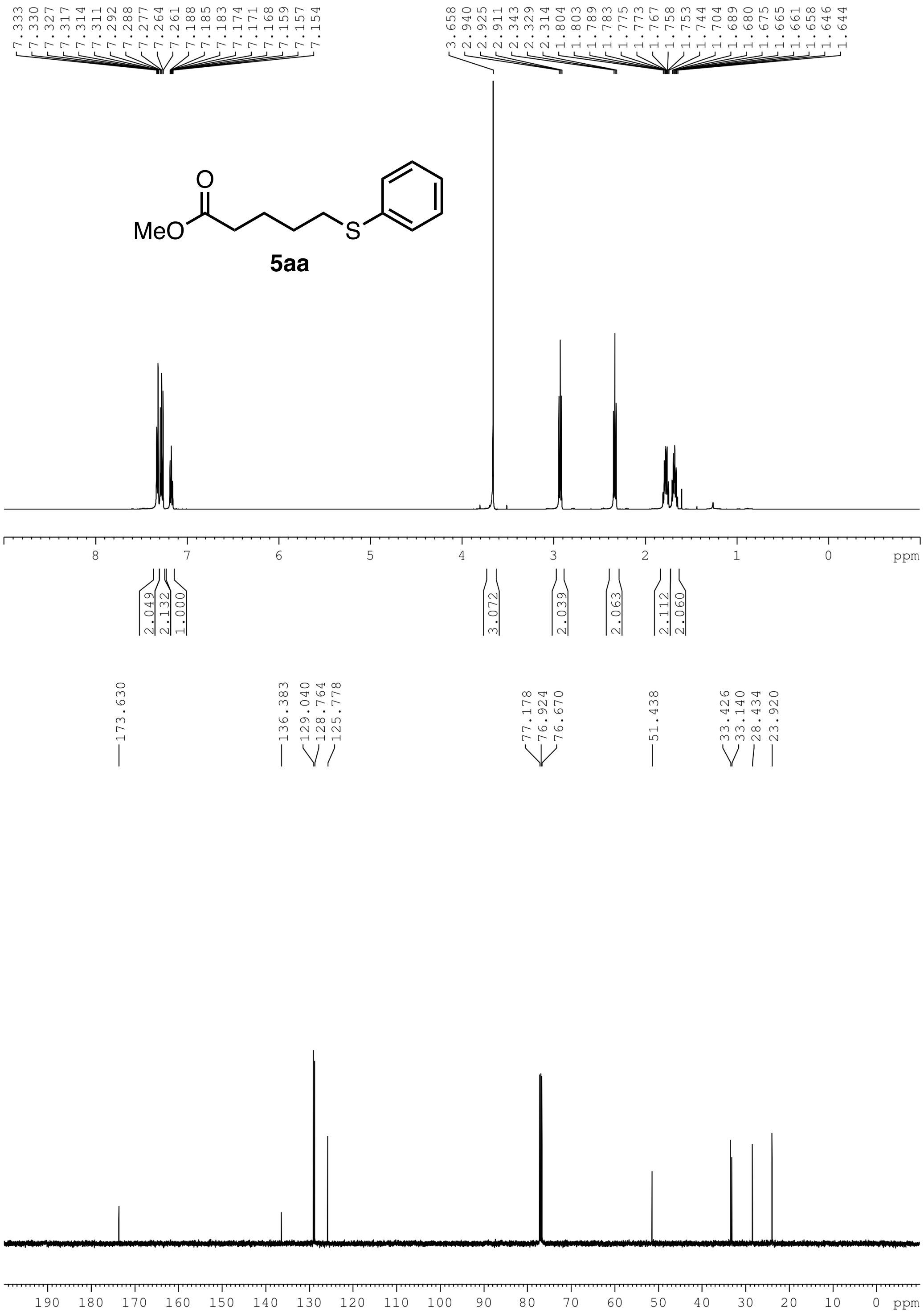


HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **3pa′**



3ql′

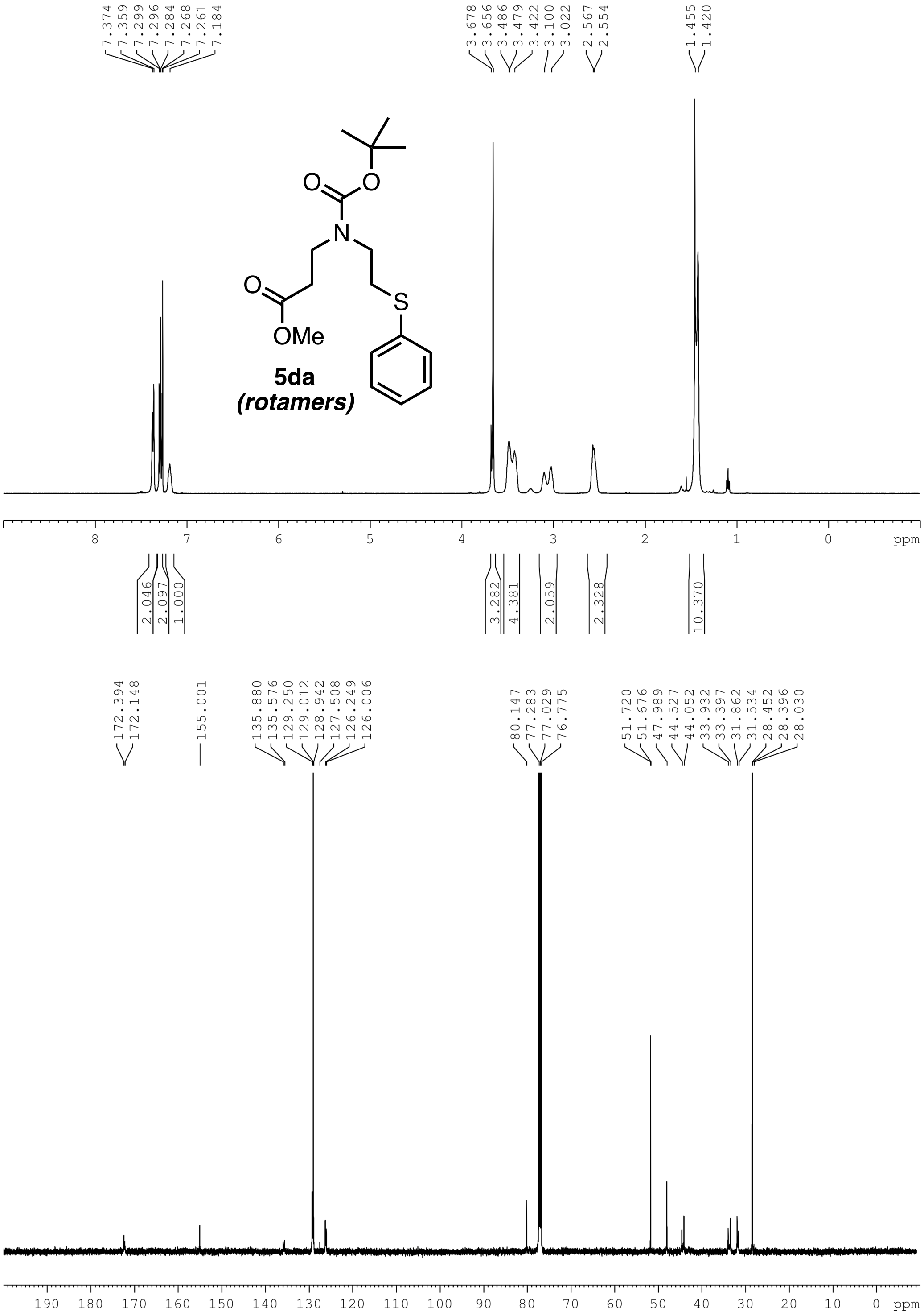
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **3ql′**



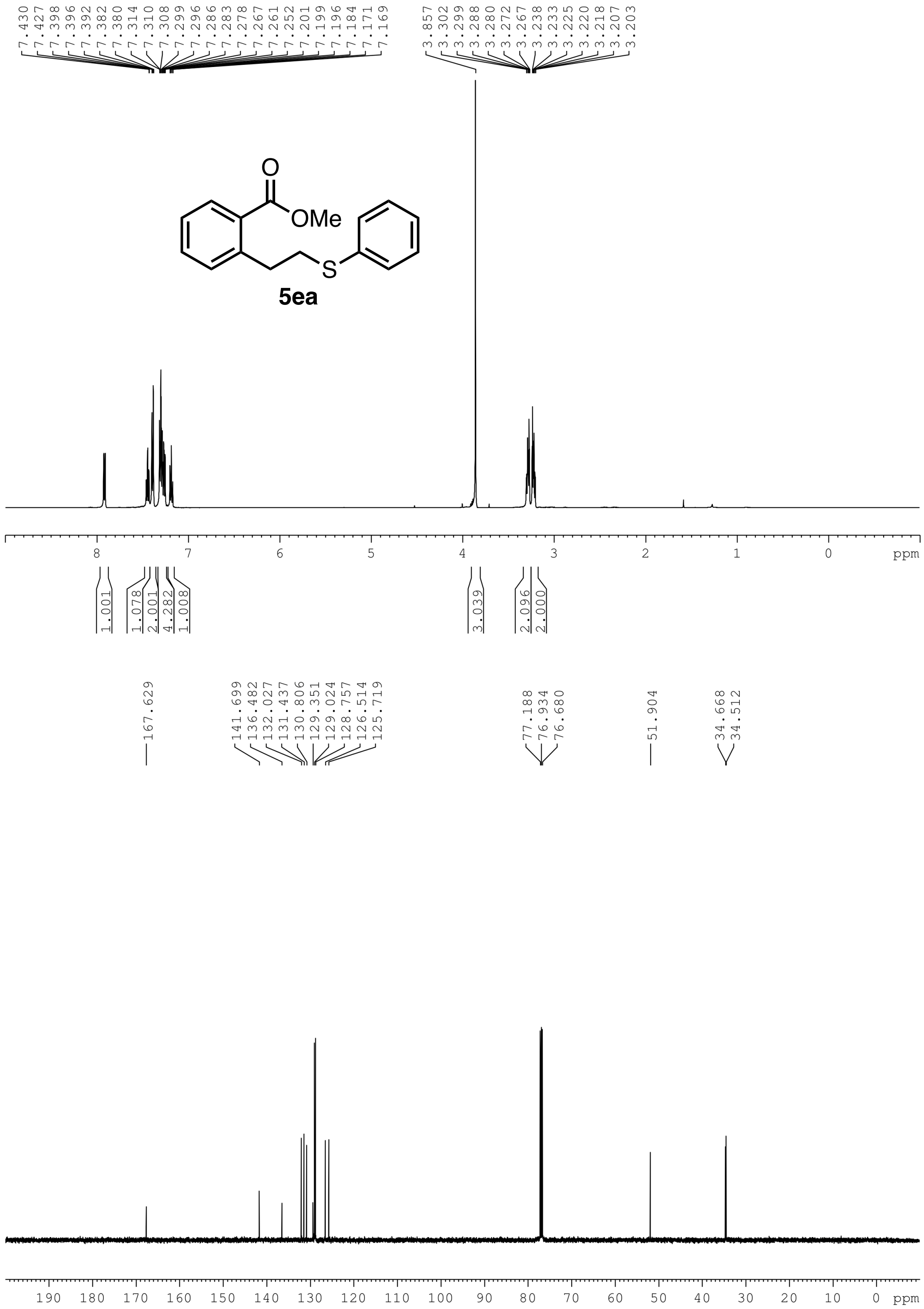
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **5aa**

^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **5ba**

^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **5ca**

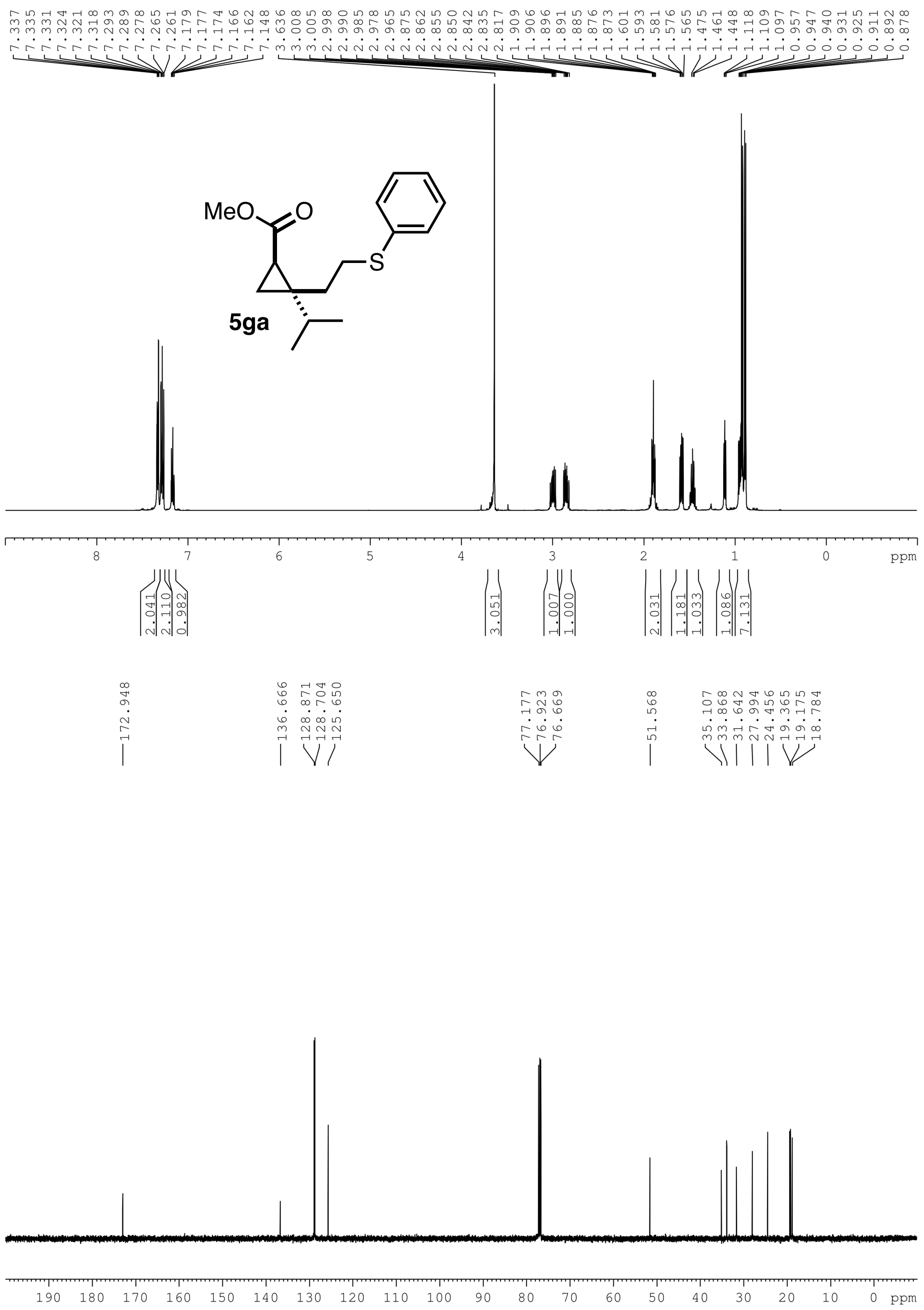


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **5da**

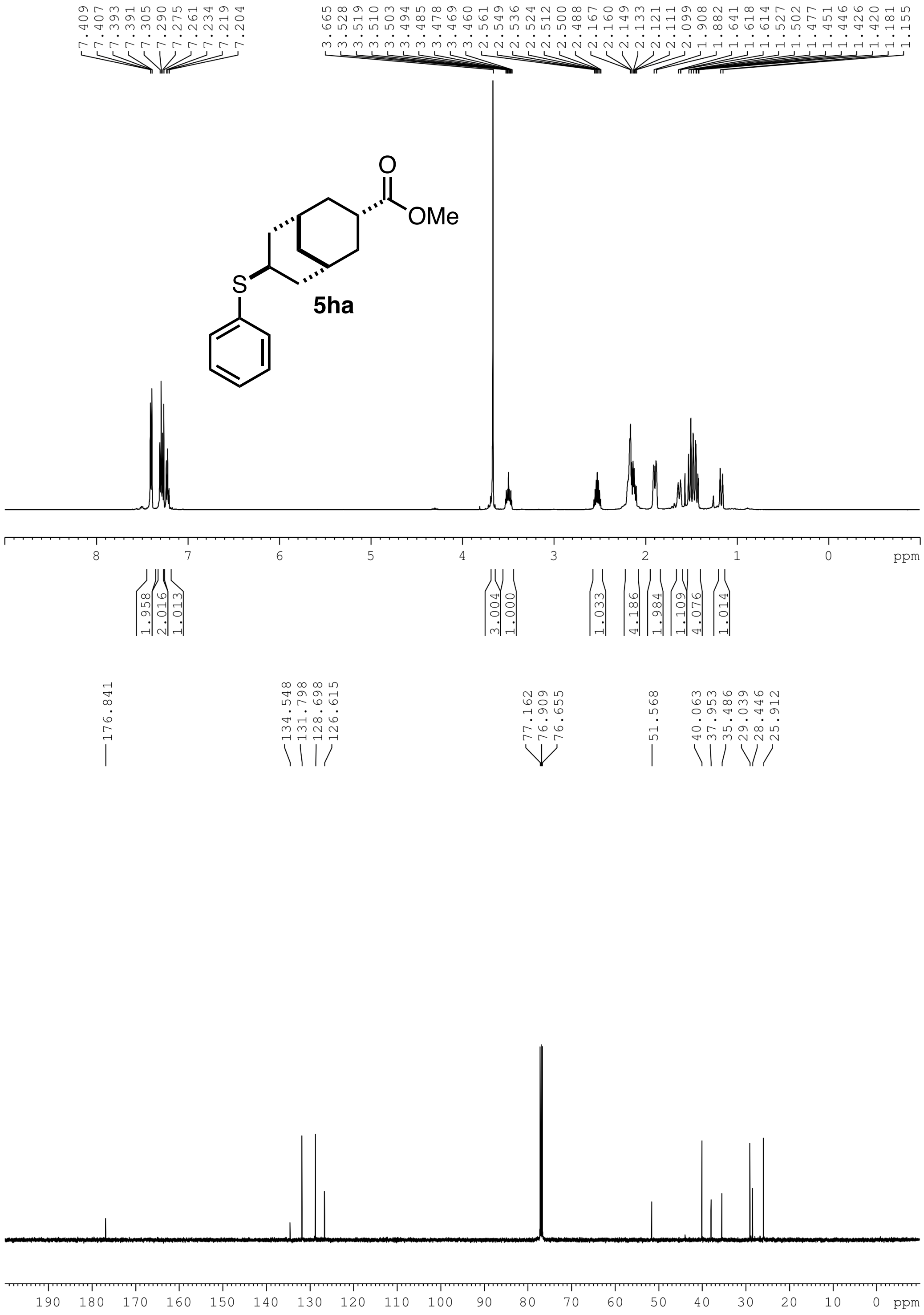


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **5ea**

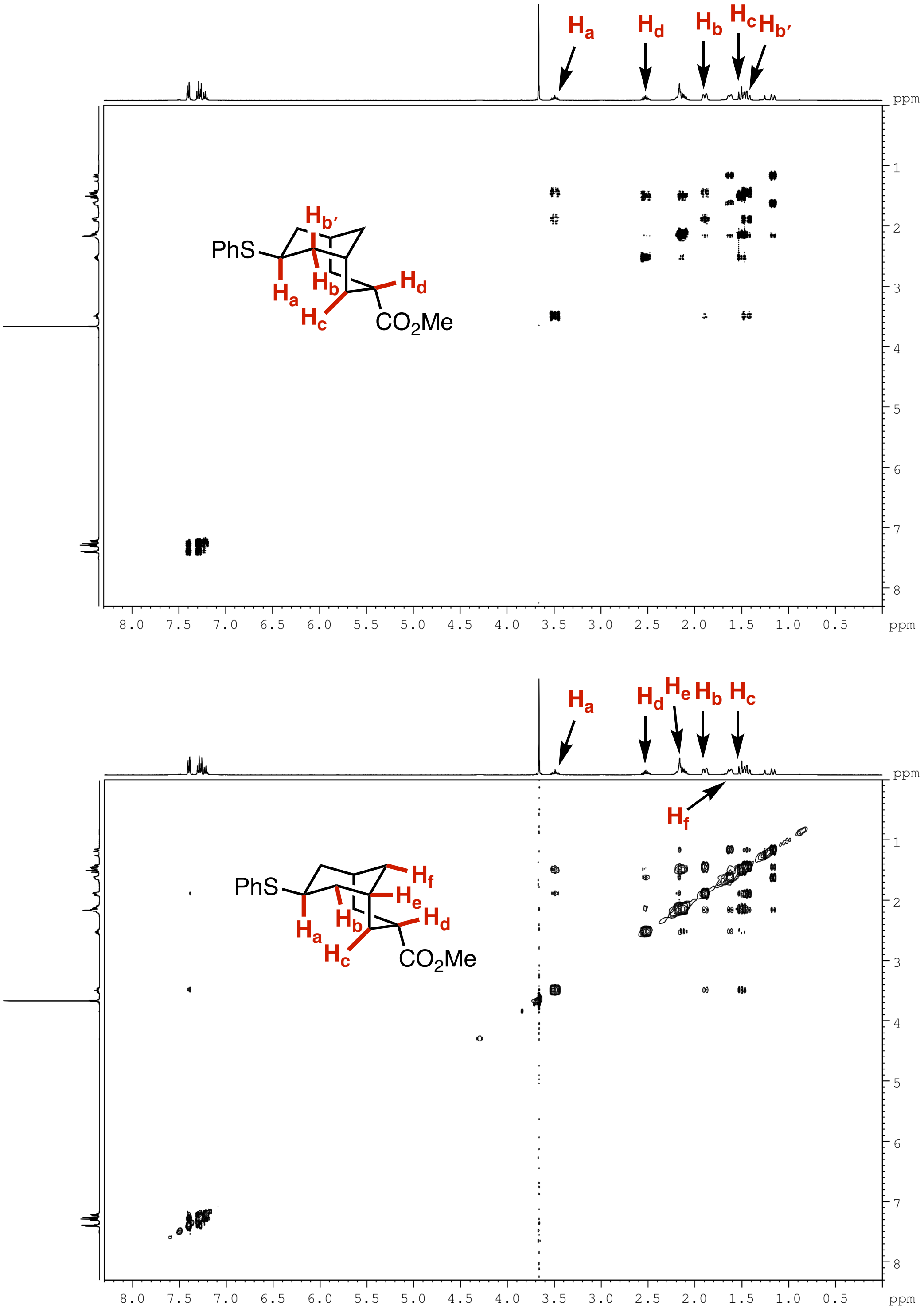
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **5fa**/**5fa′** (1.6:1 *r.r.*)



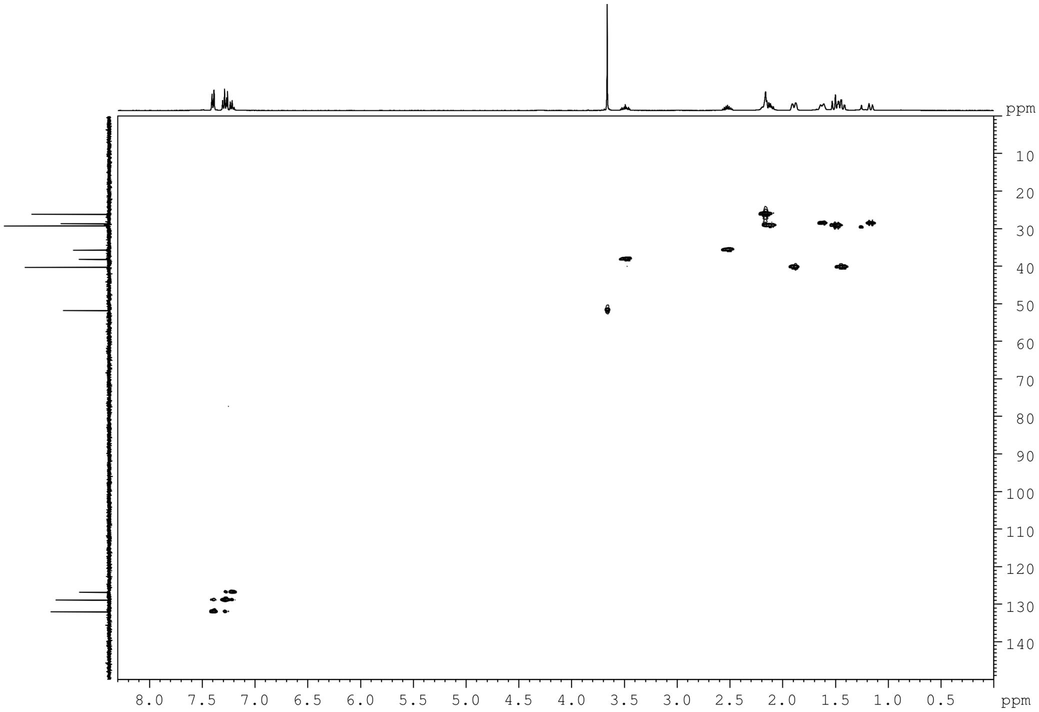
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **5ga**

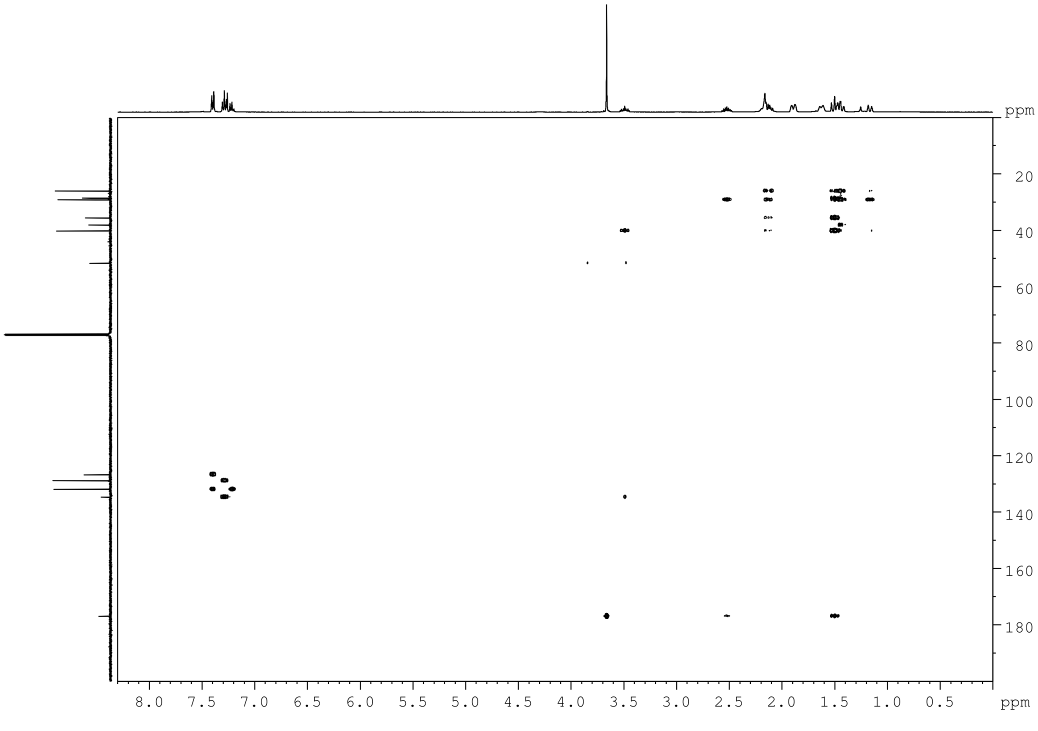


^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **5ha**

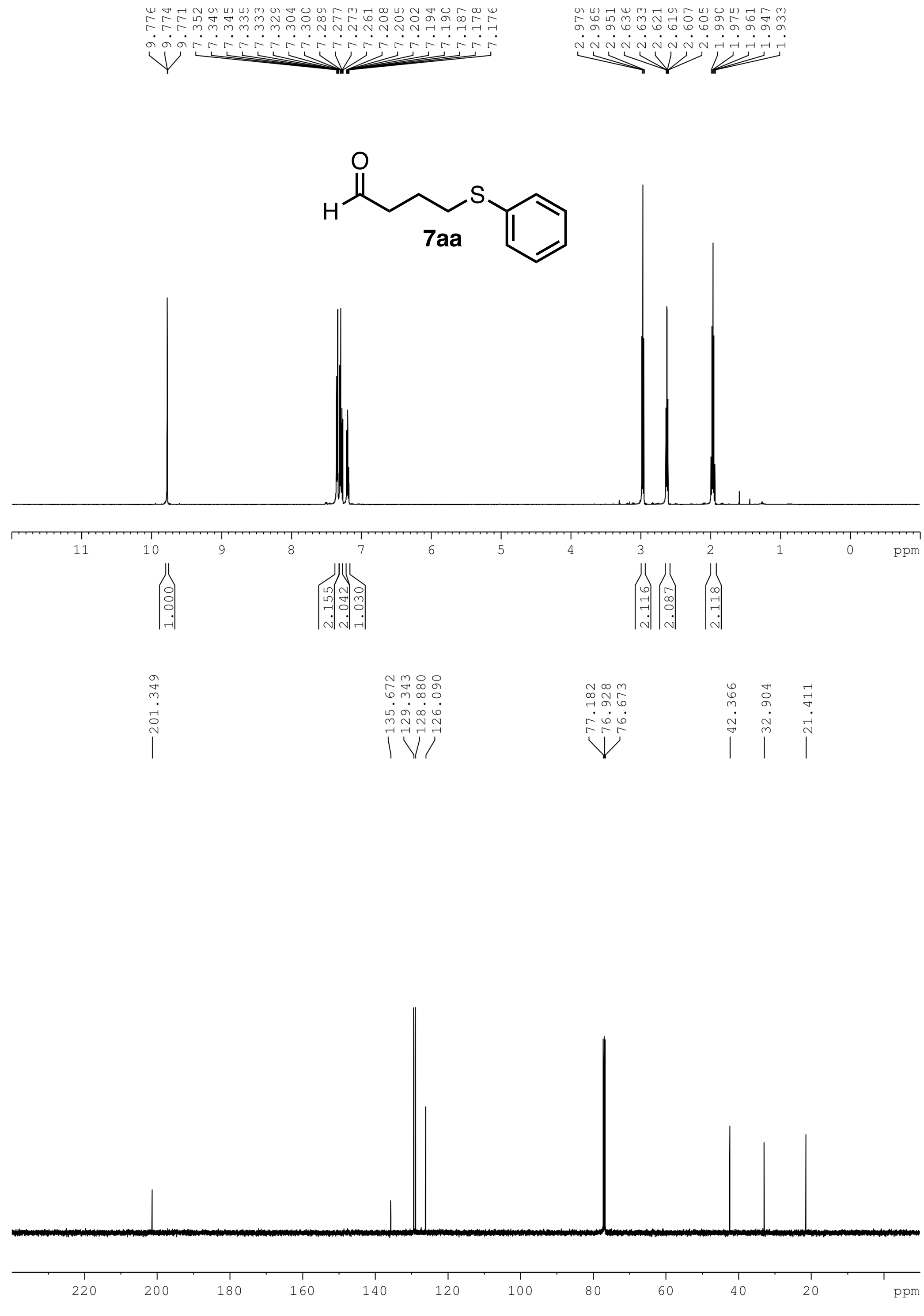


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **5ha**

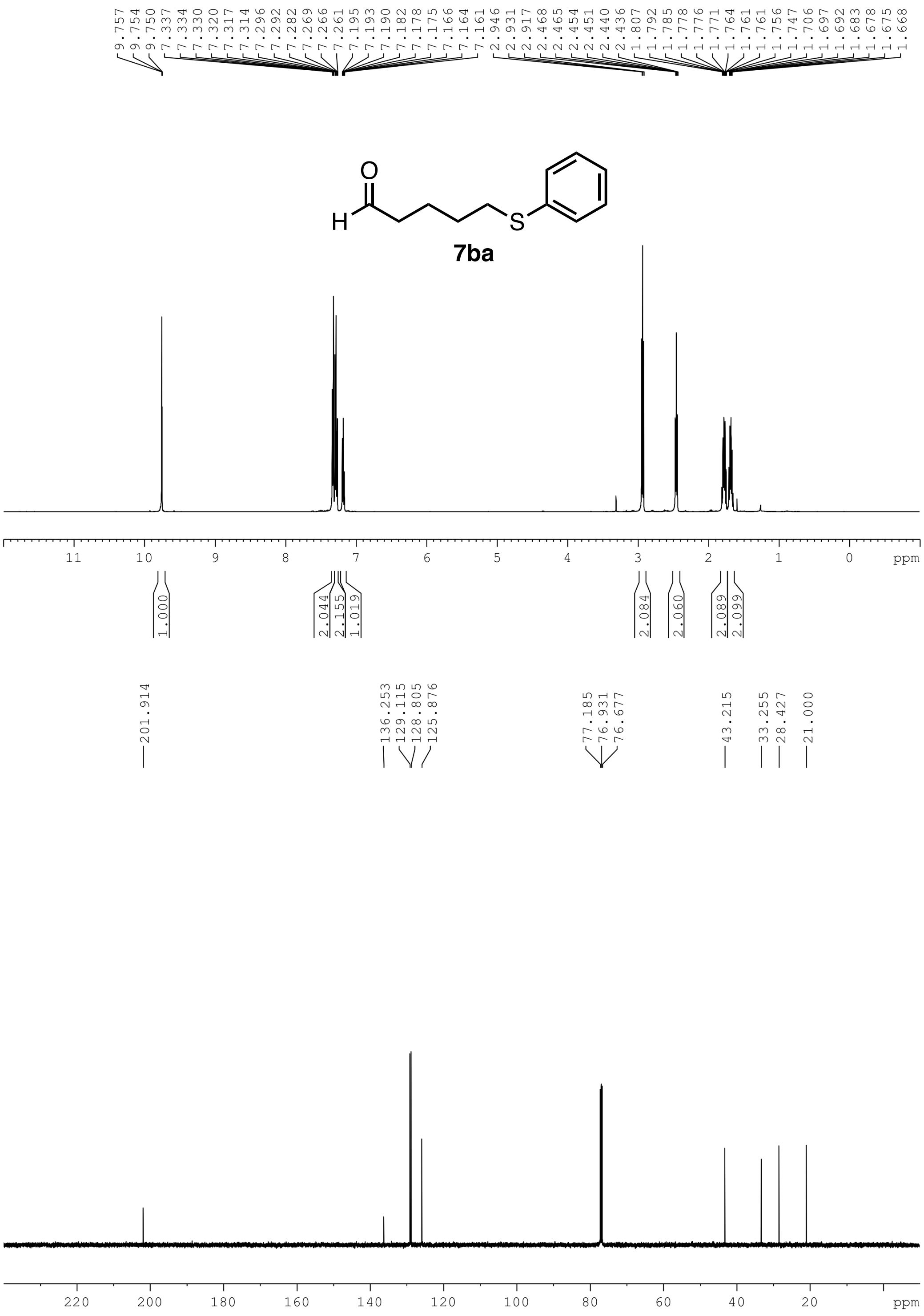




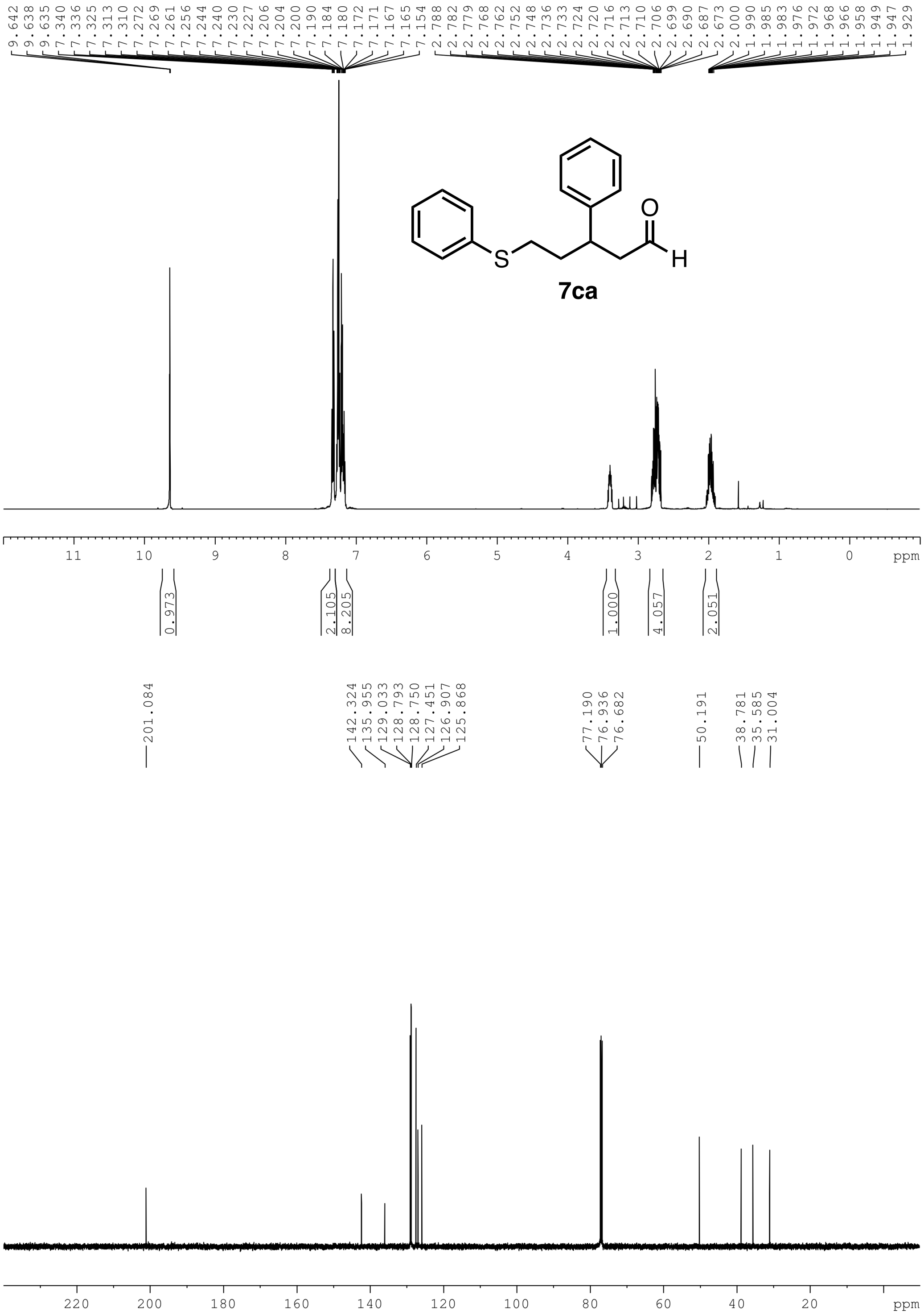
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **5ha**



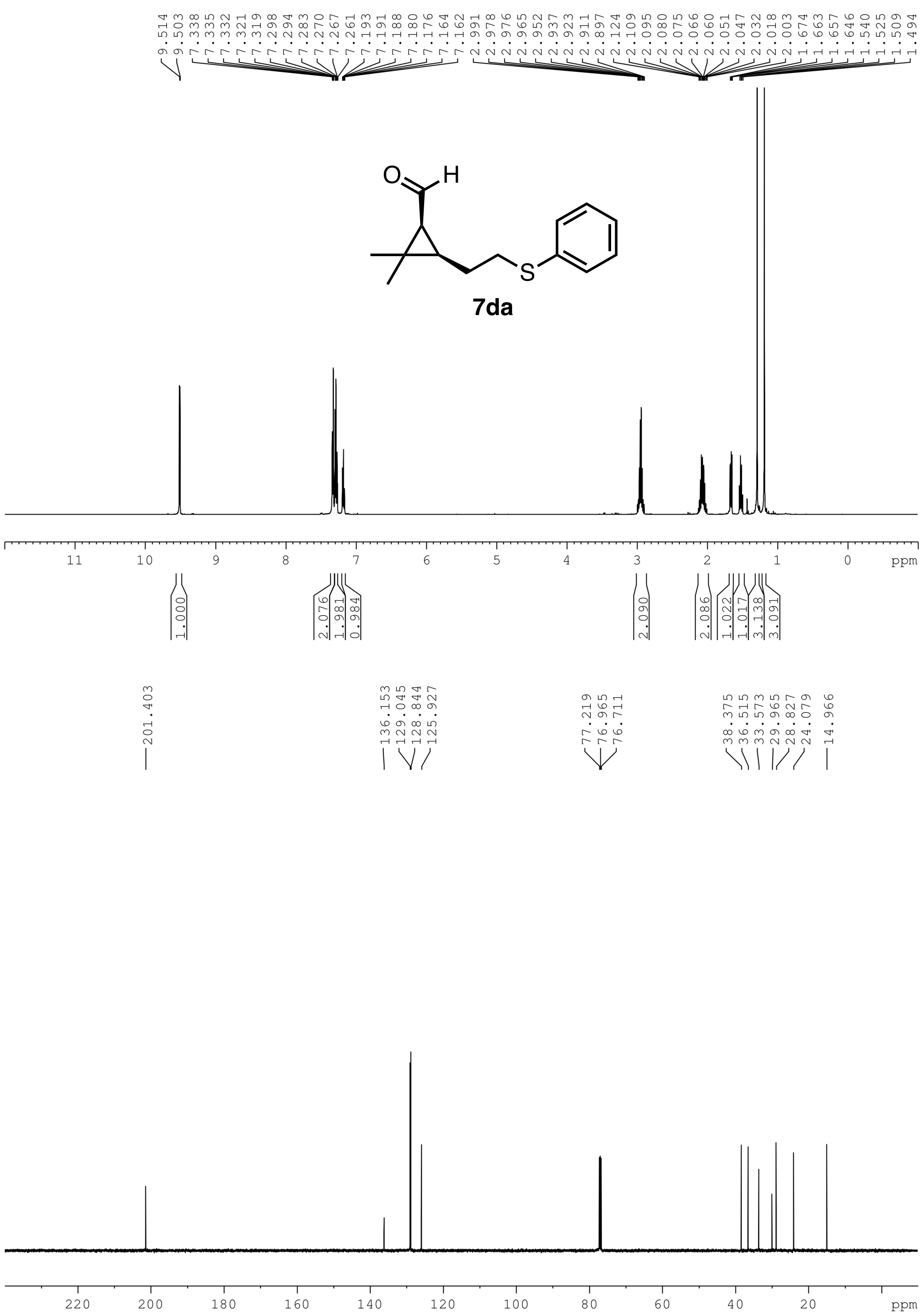
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7aa**



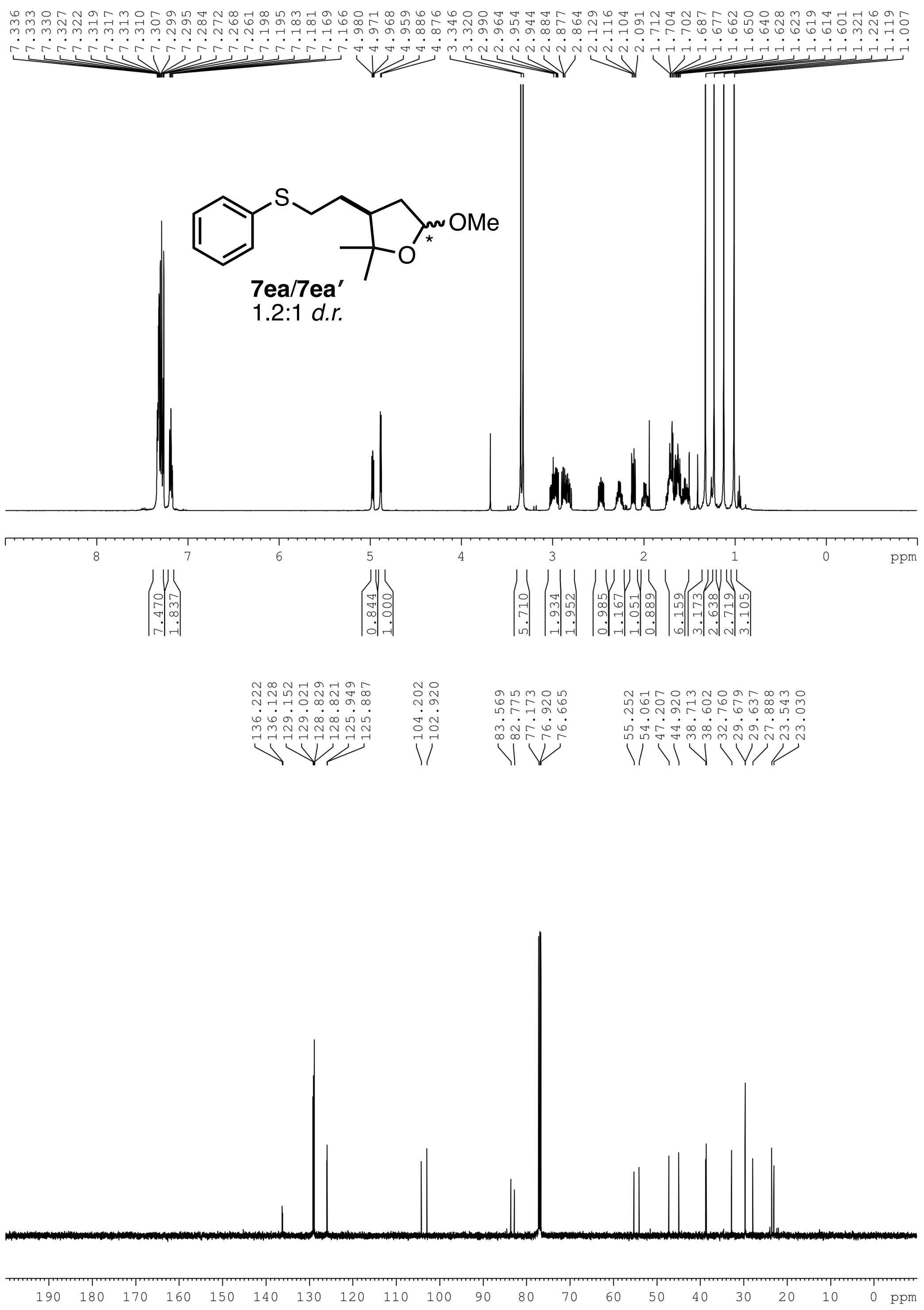
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7ba**



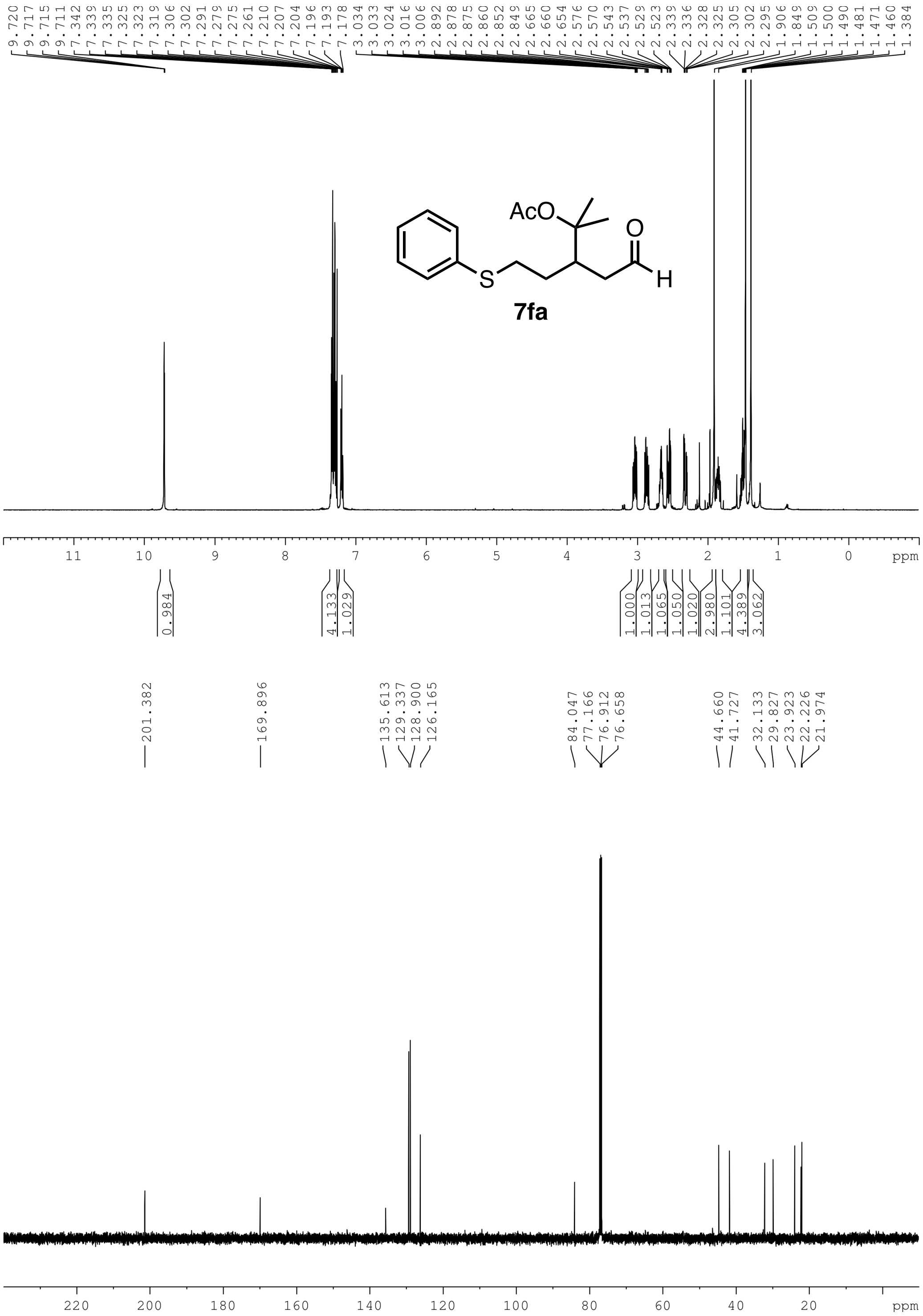
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7ca**



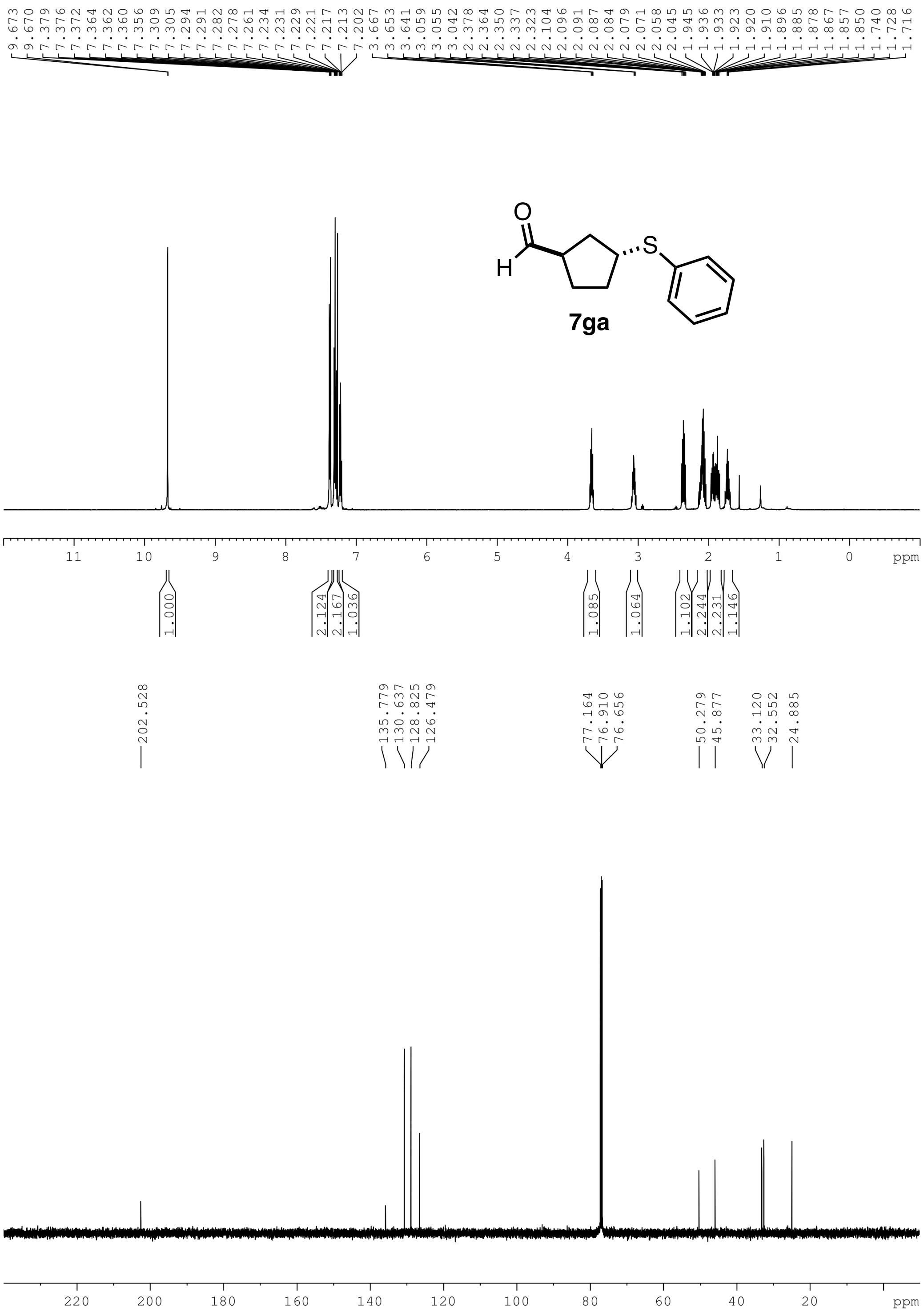
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7da**



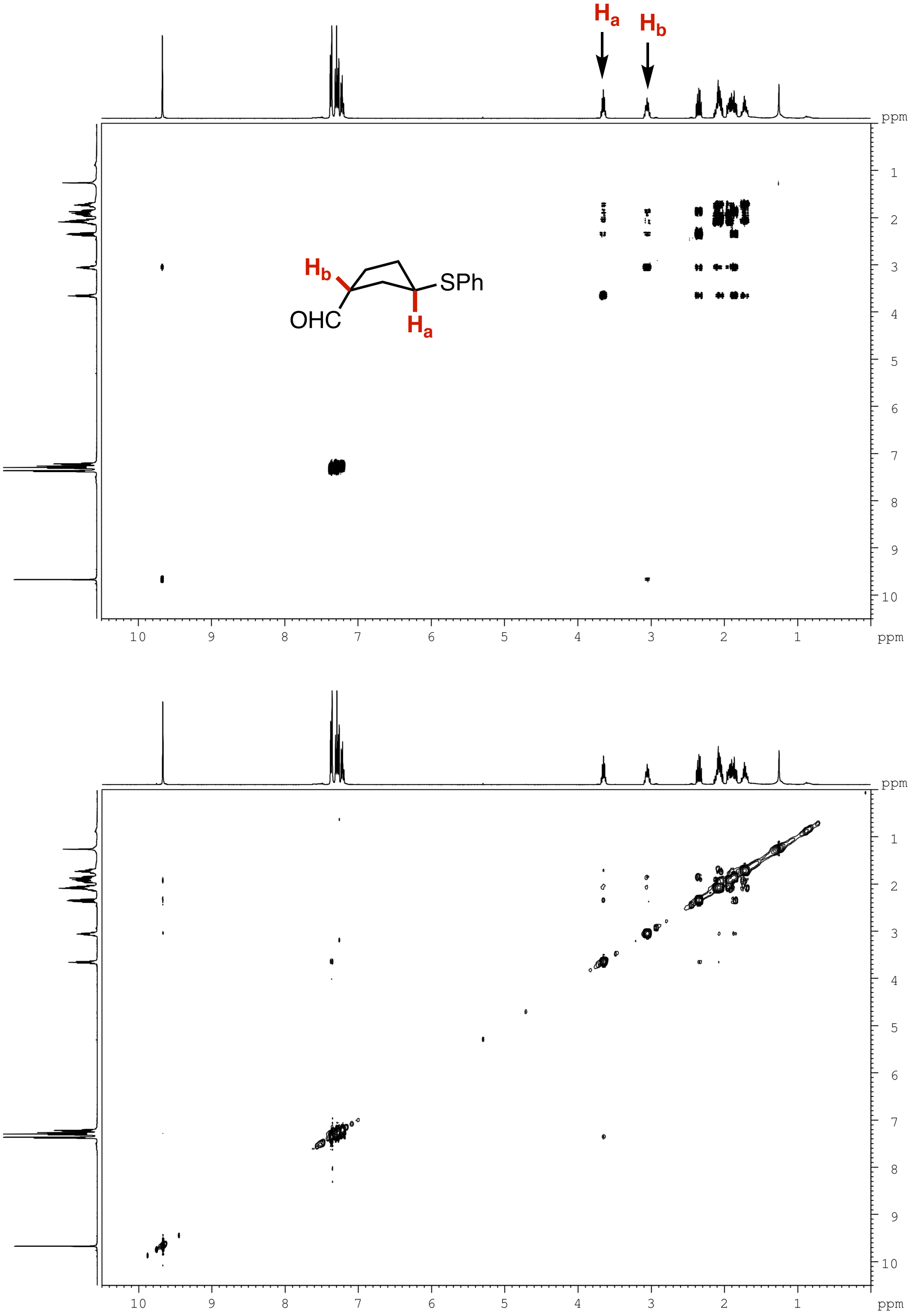
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7ea** and **7ea′**



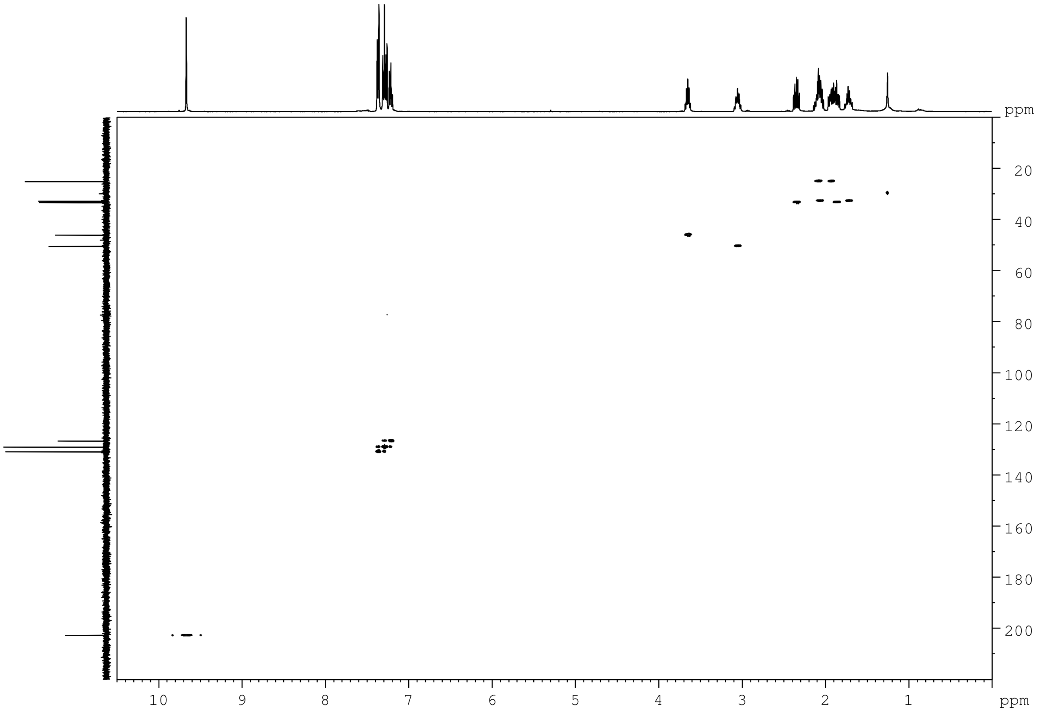
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7fa**

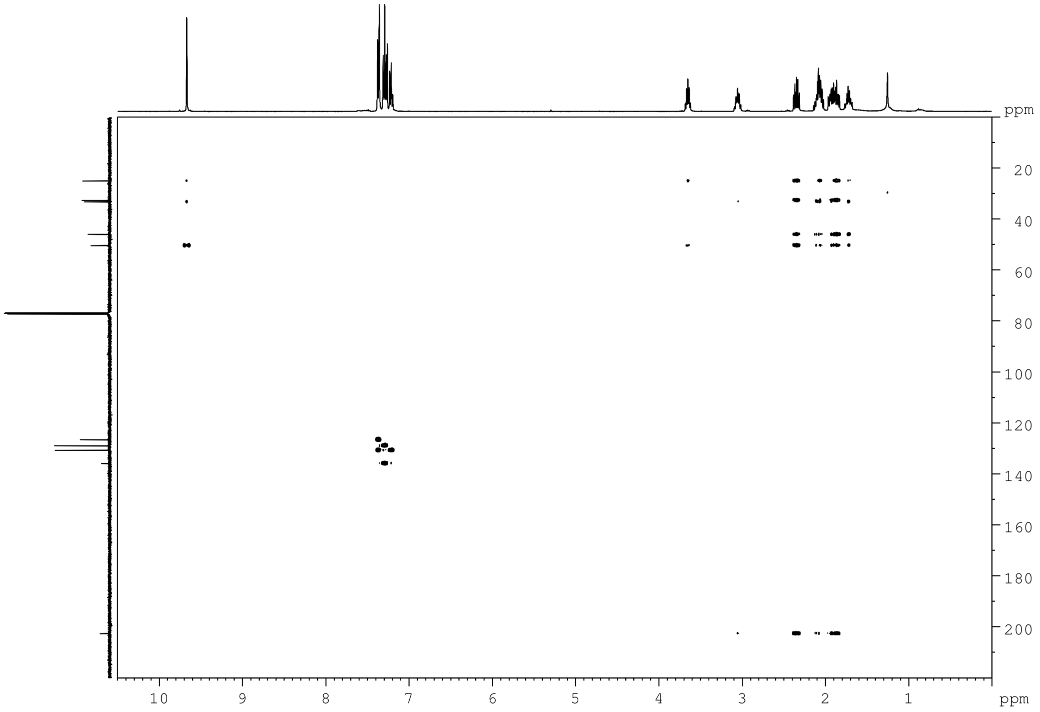


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7ga**

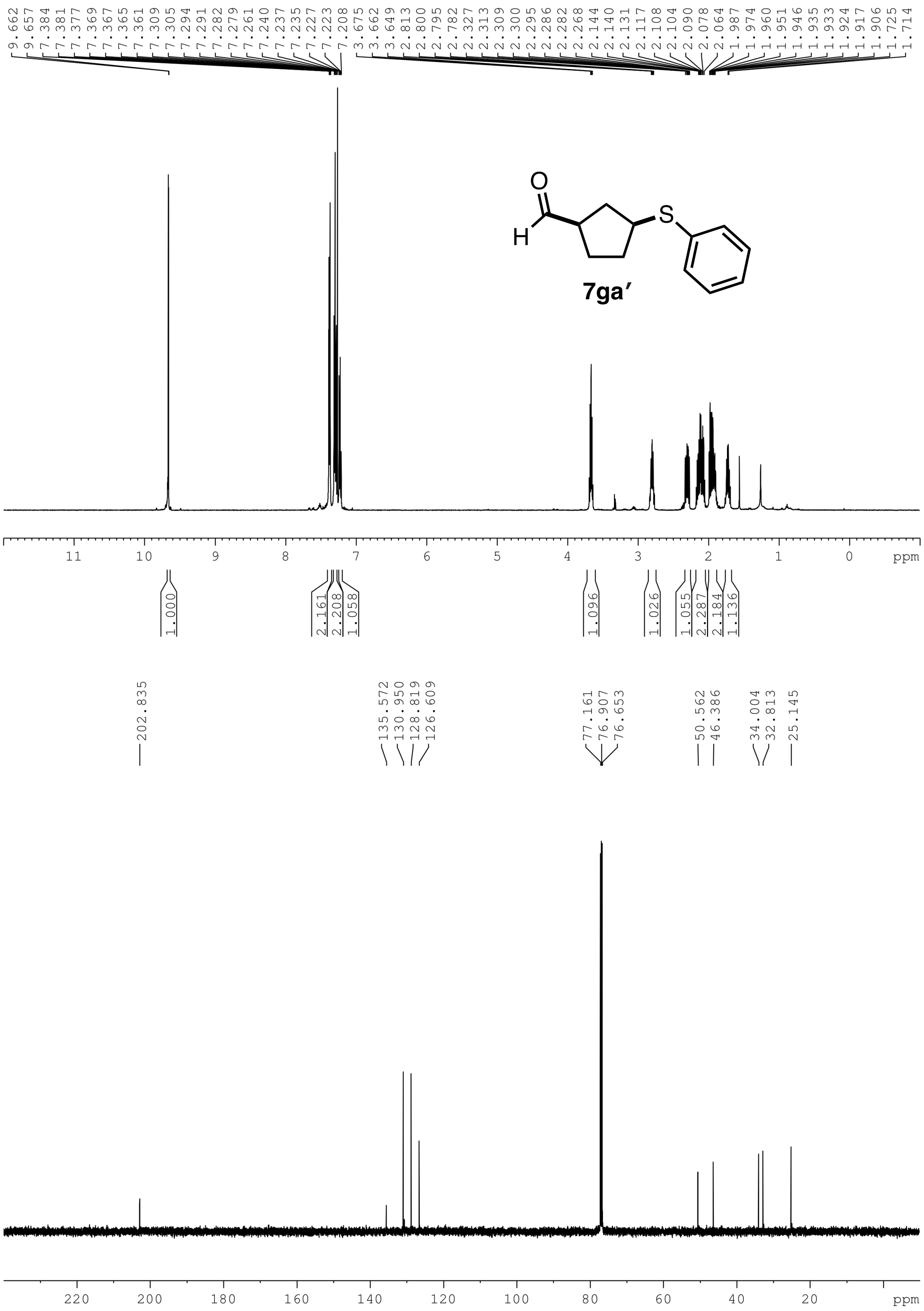


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **7ga**

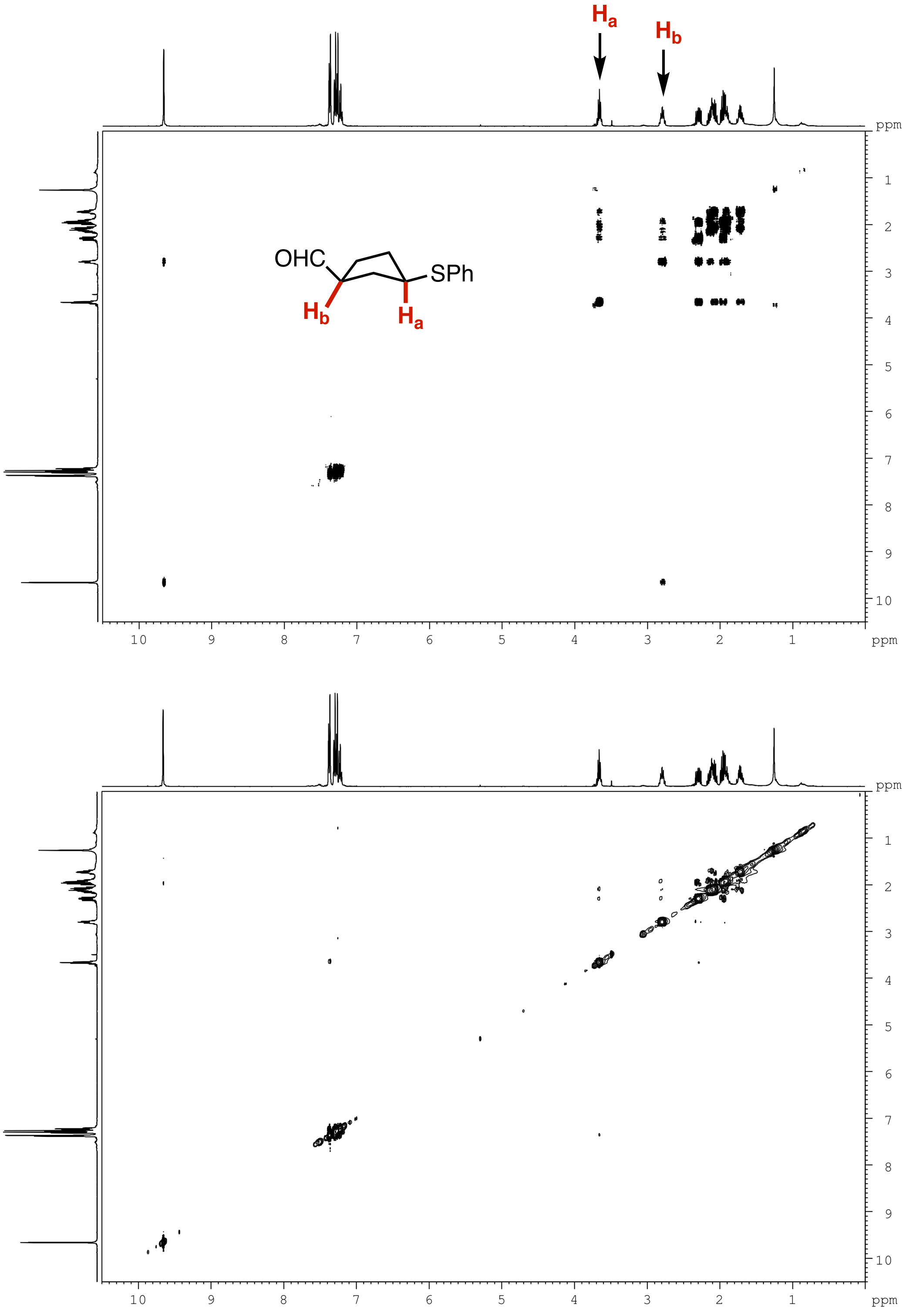




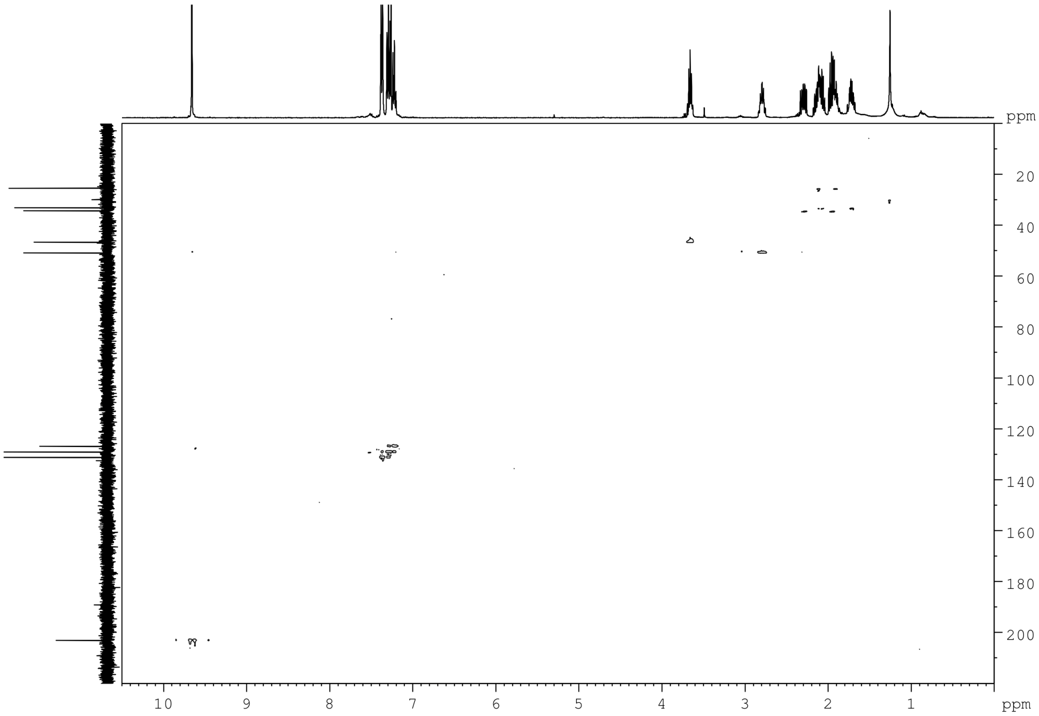
HSQC (400 MHz, CDCl$_3$) and HMBC (400 MHz, CDCl$_3$) NMR Spectra of **7ga**

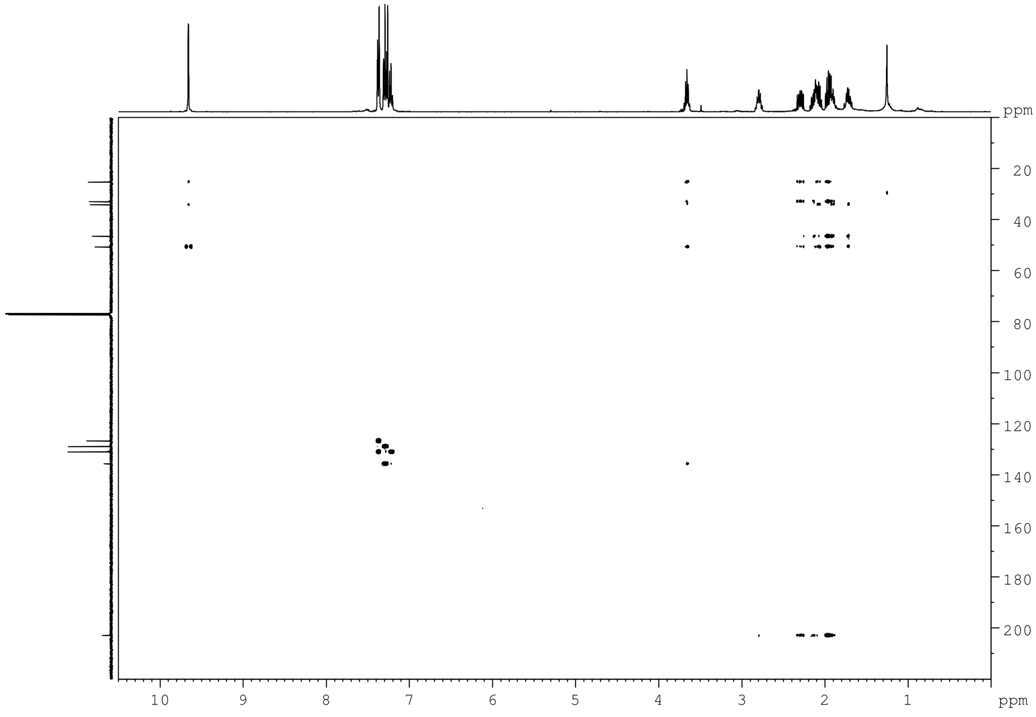


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7ga′**

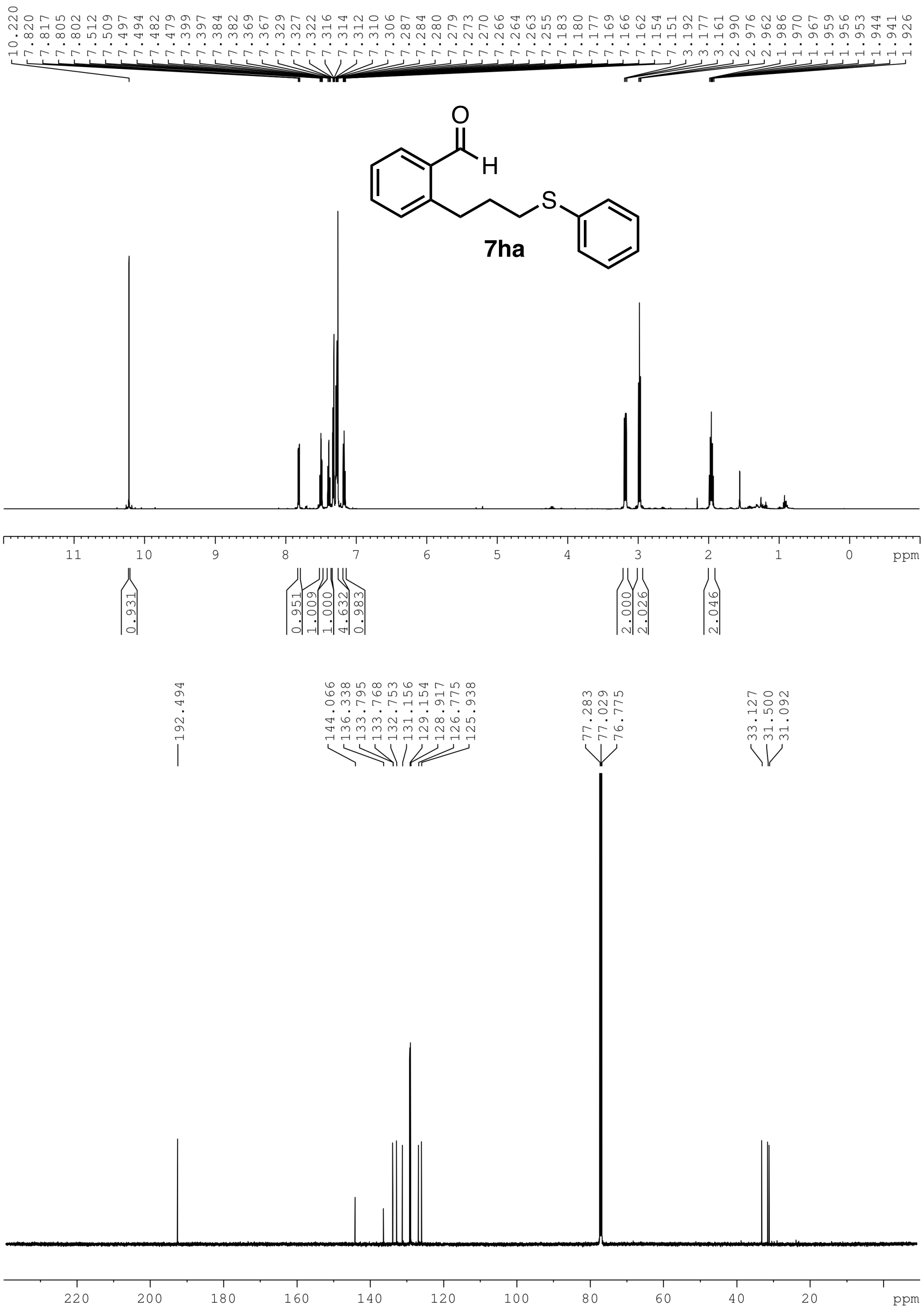


COSY (400 MHz, CDCl$_3$) and NOESY (400 MHz, CDCl$_3$) NMR Spectra of **7ga′**

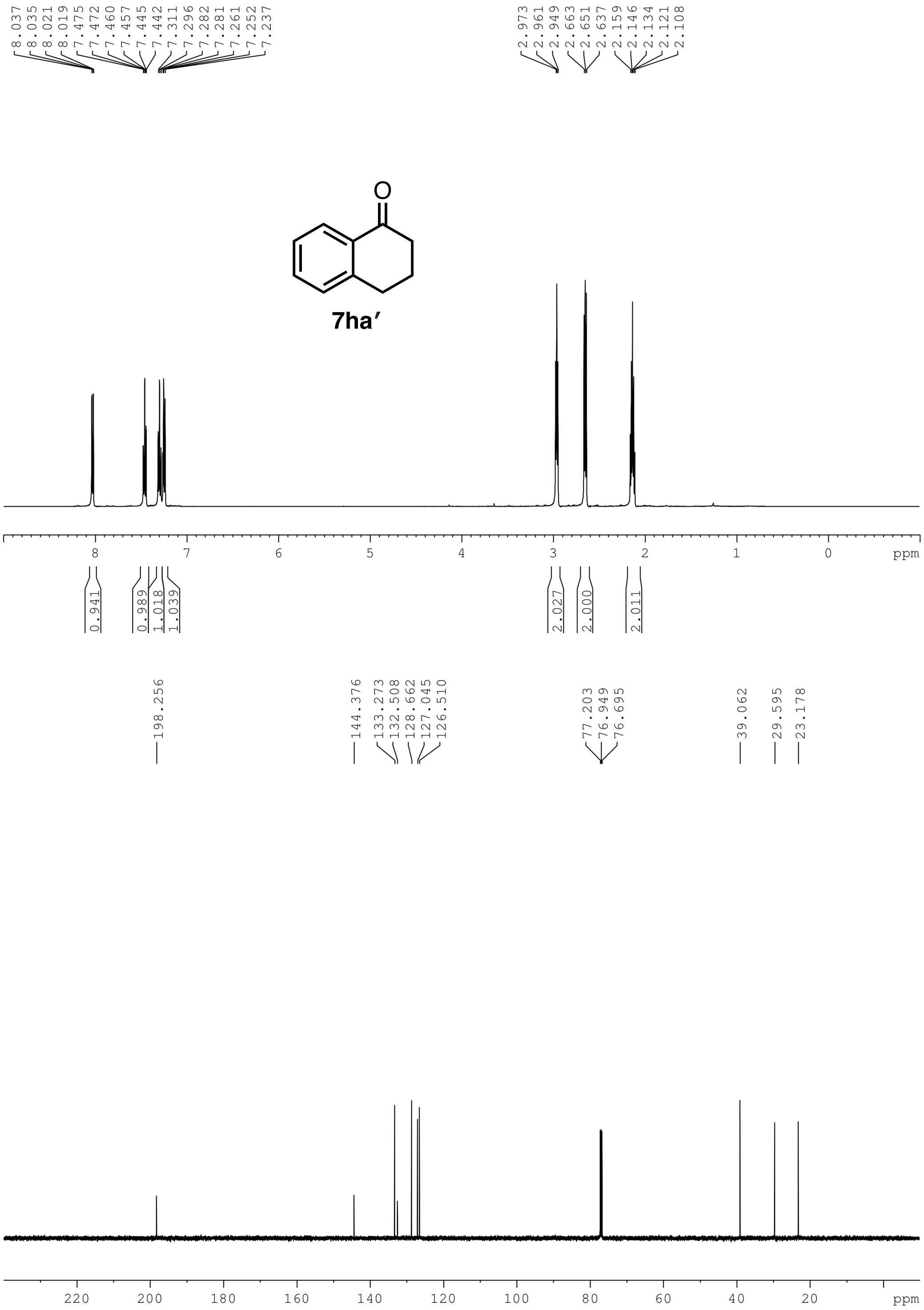




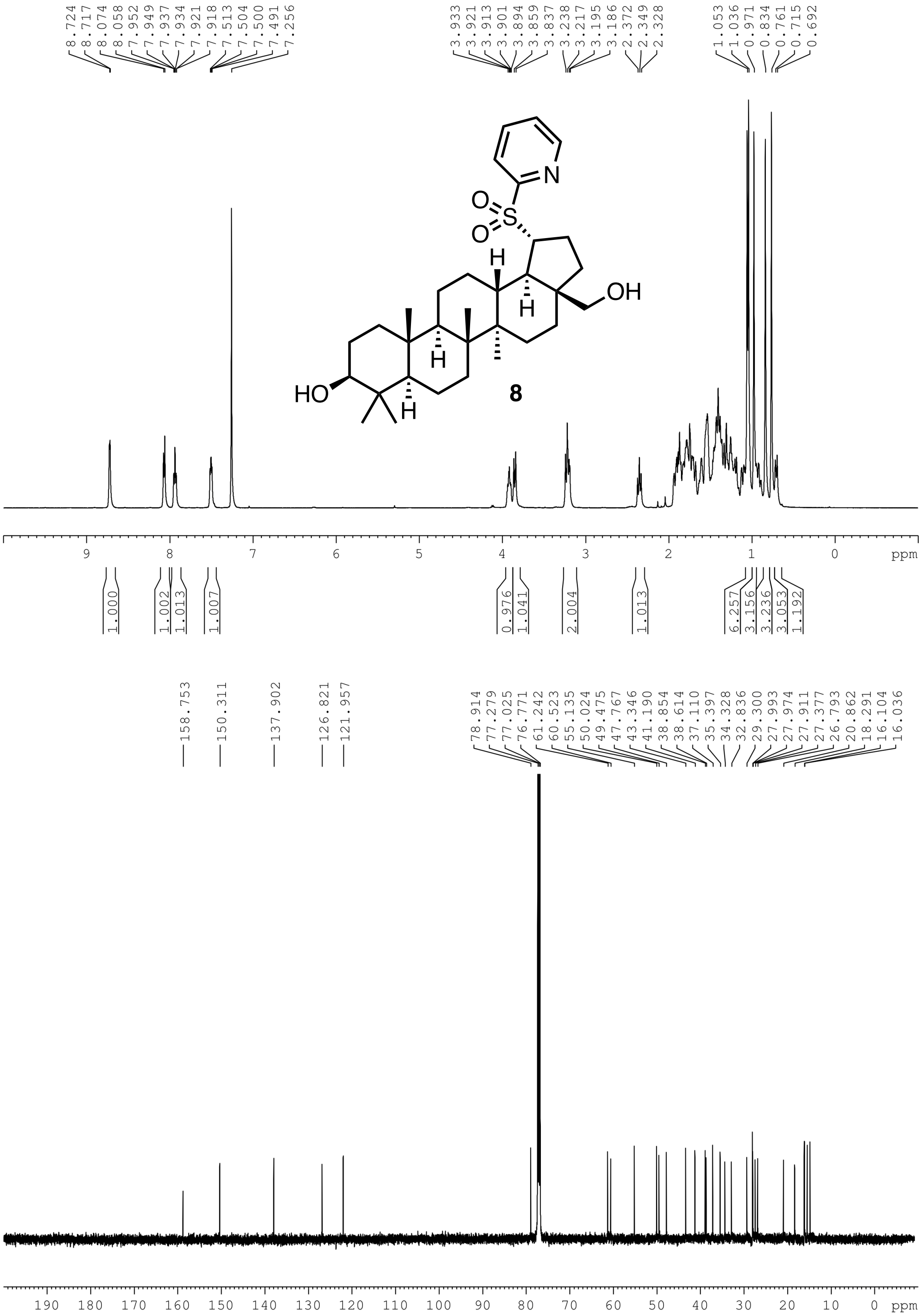
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **7ga′**



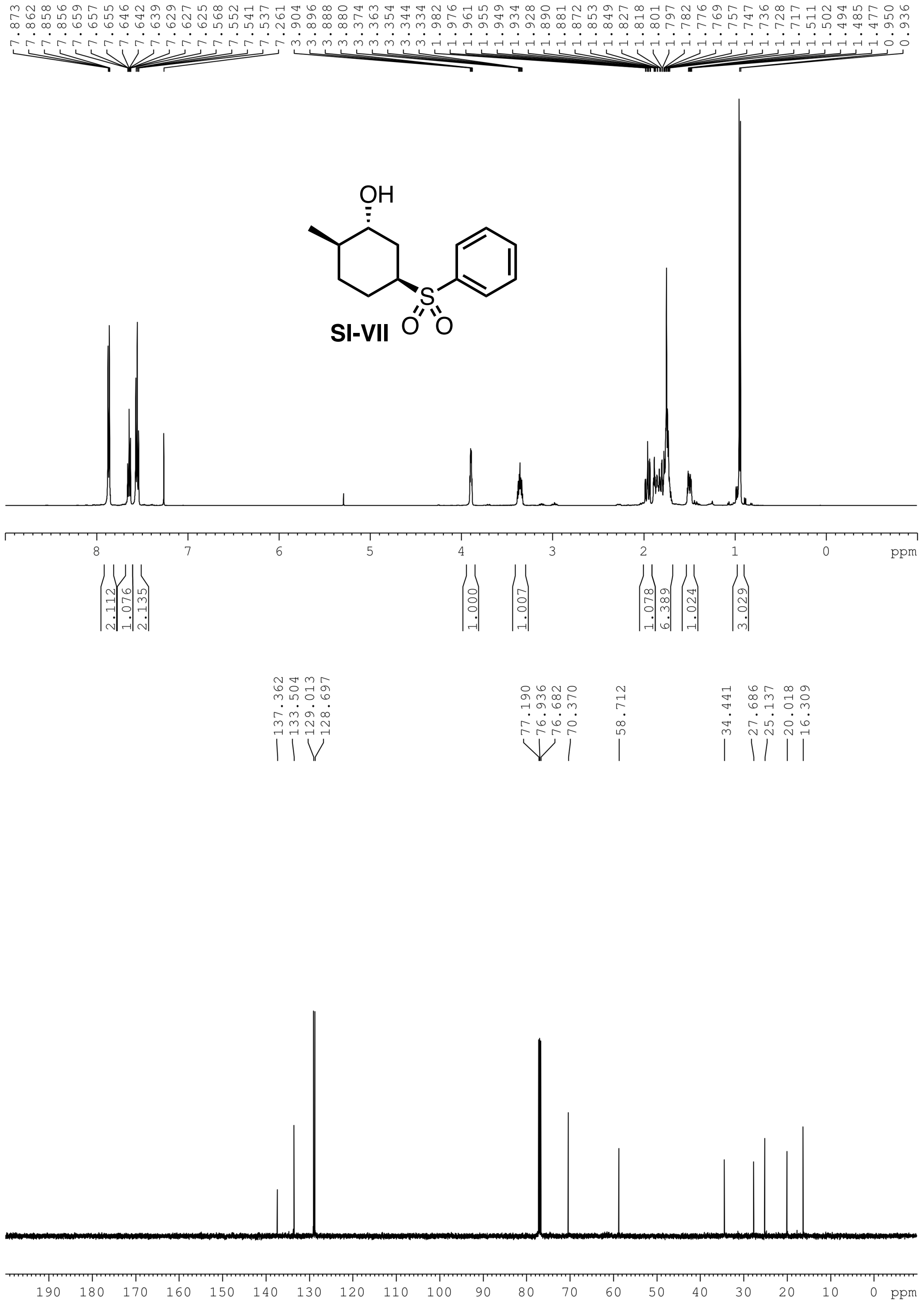
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7ha**



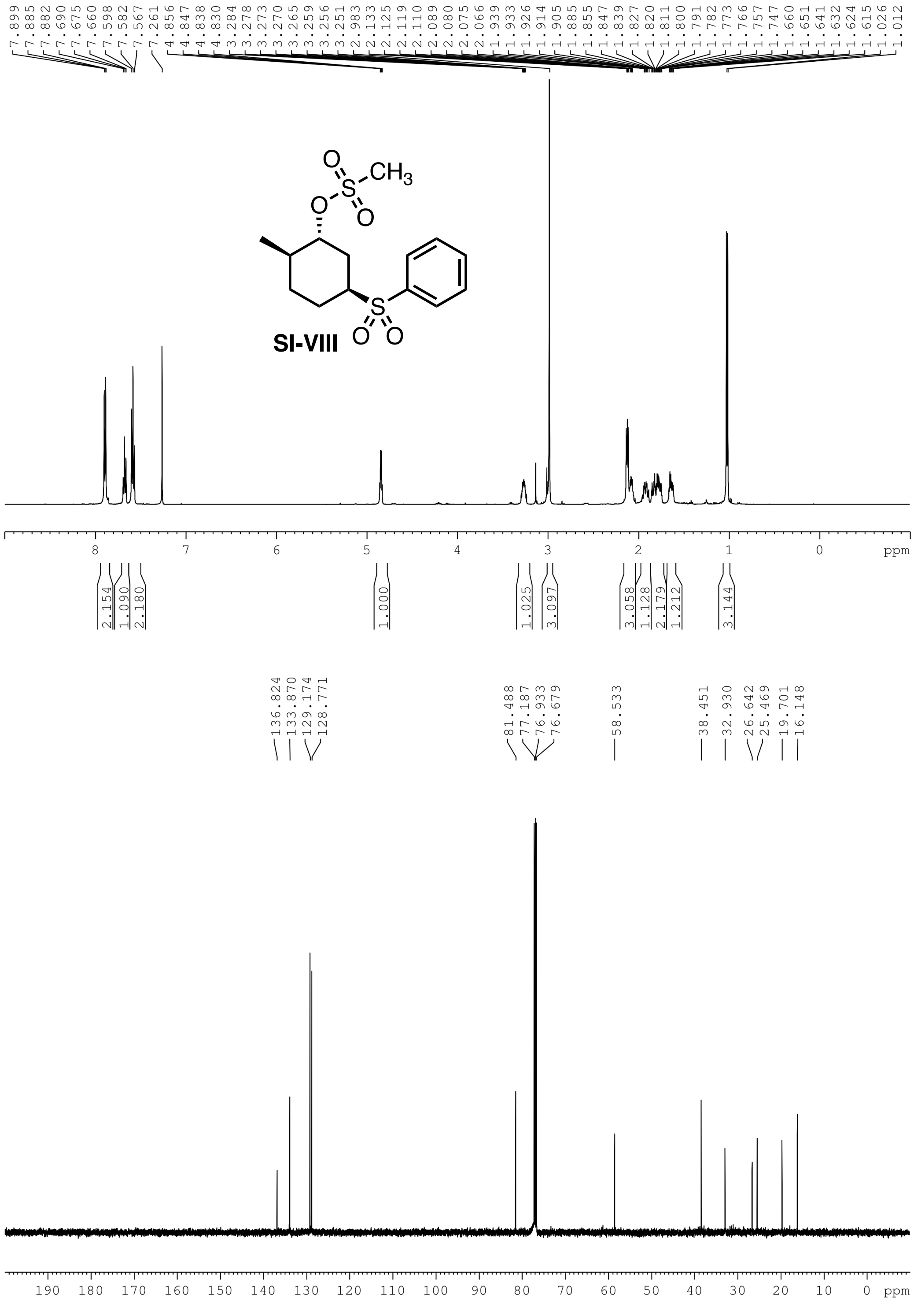
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **7ha′**



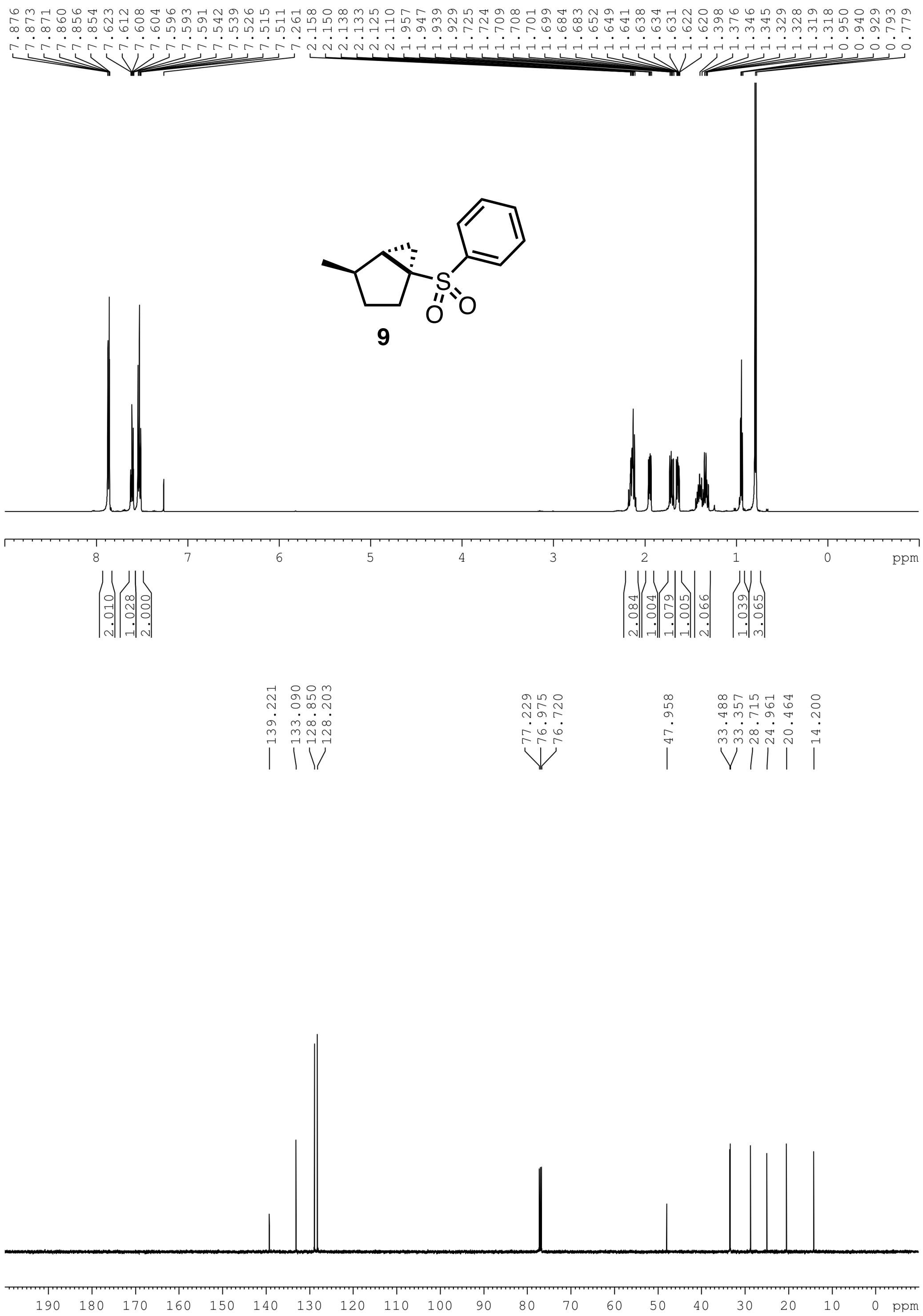
^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **8**



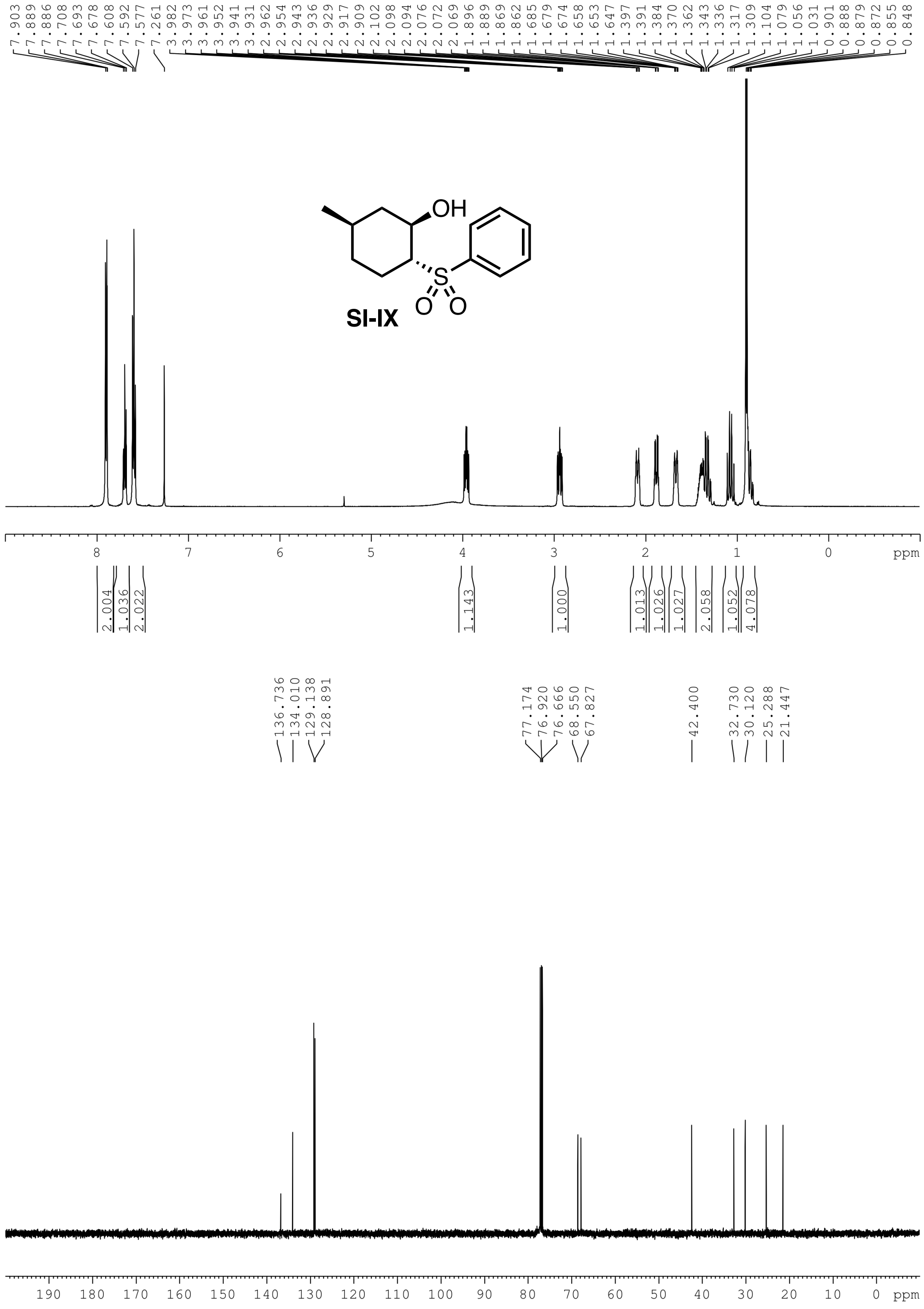
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-VII**



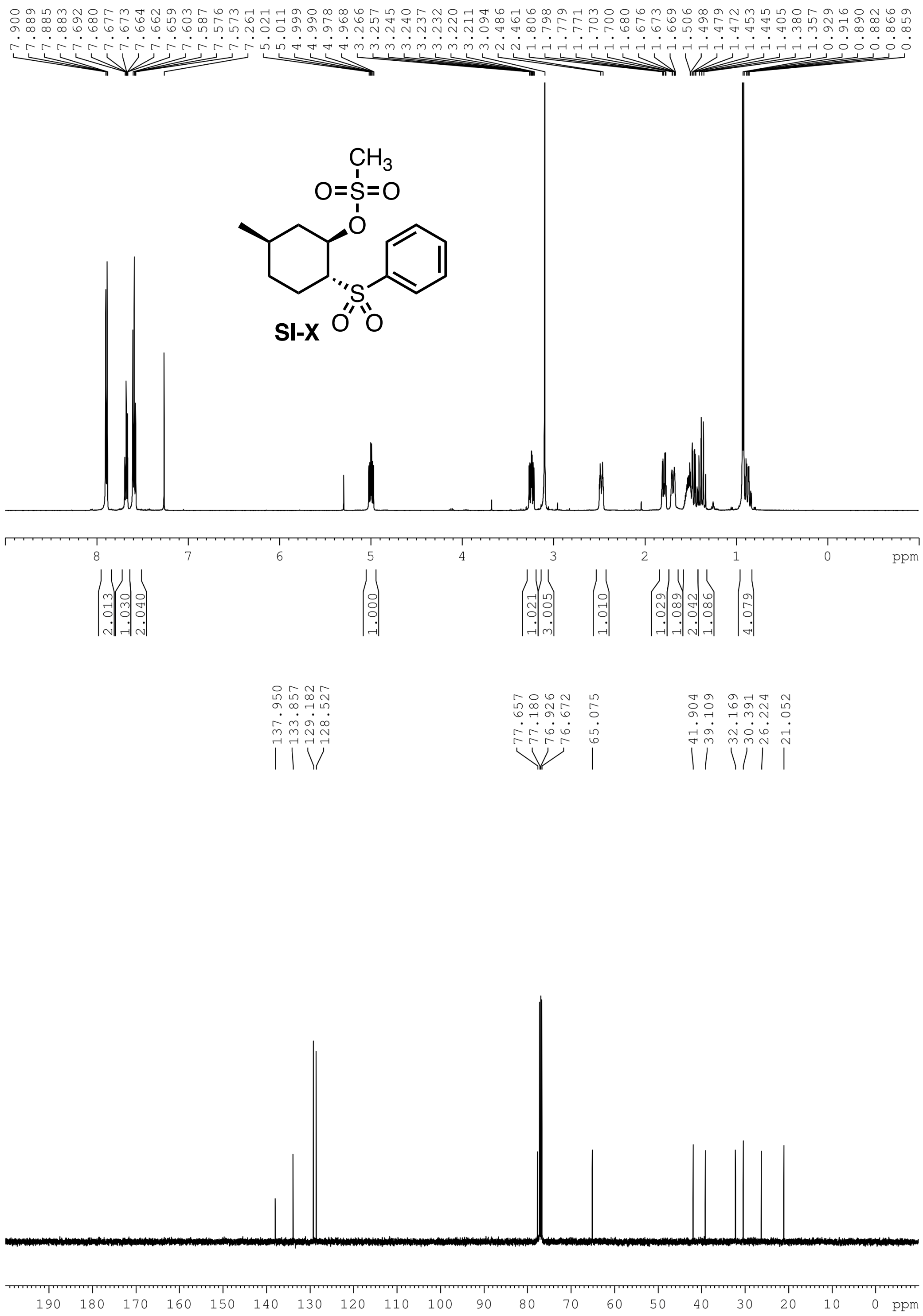
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-VIII**



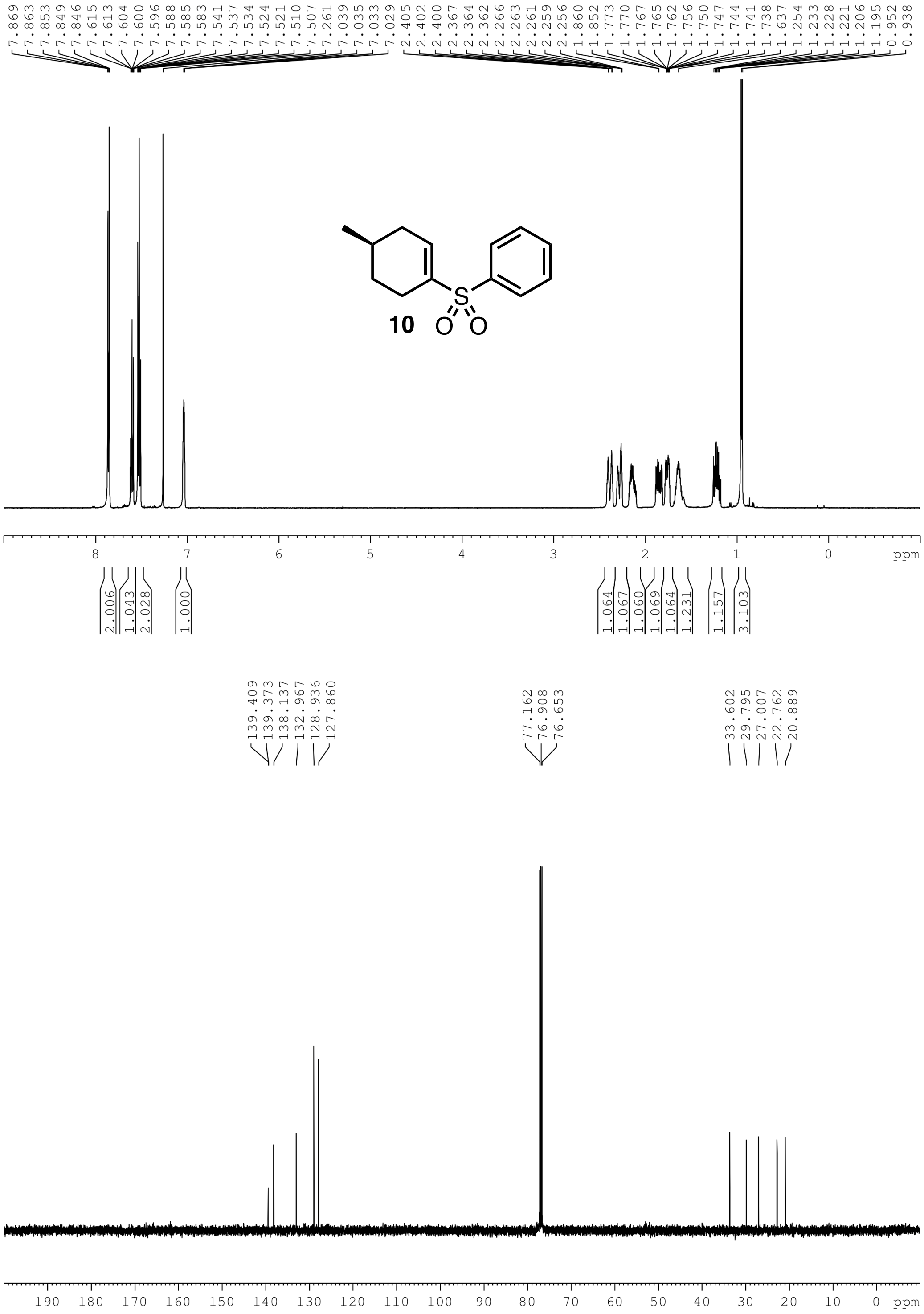
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **9**



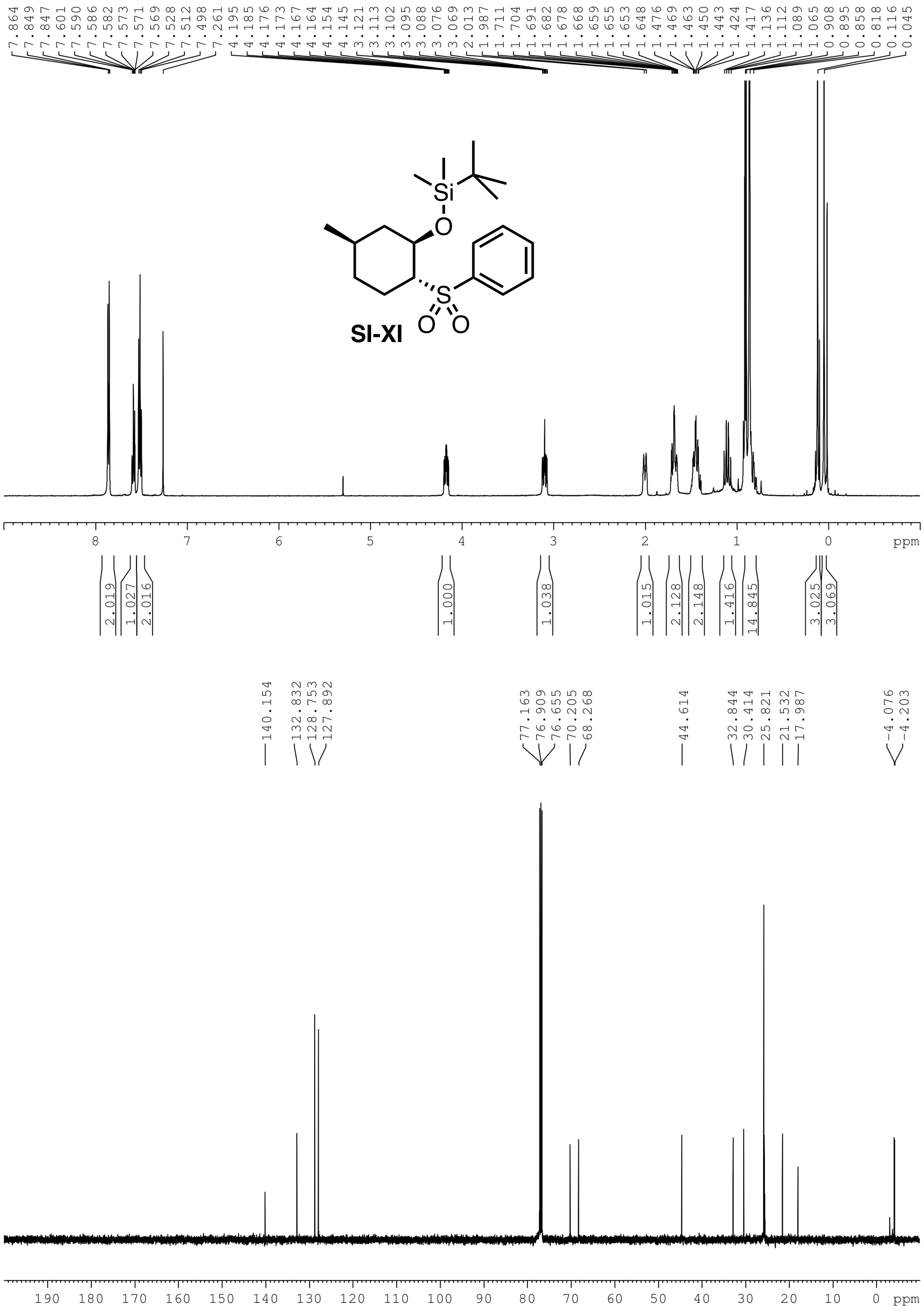
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-IX**



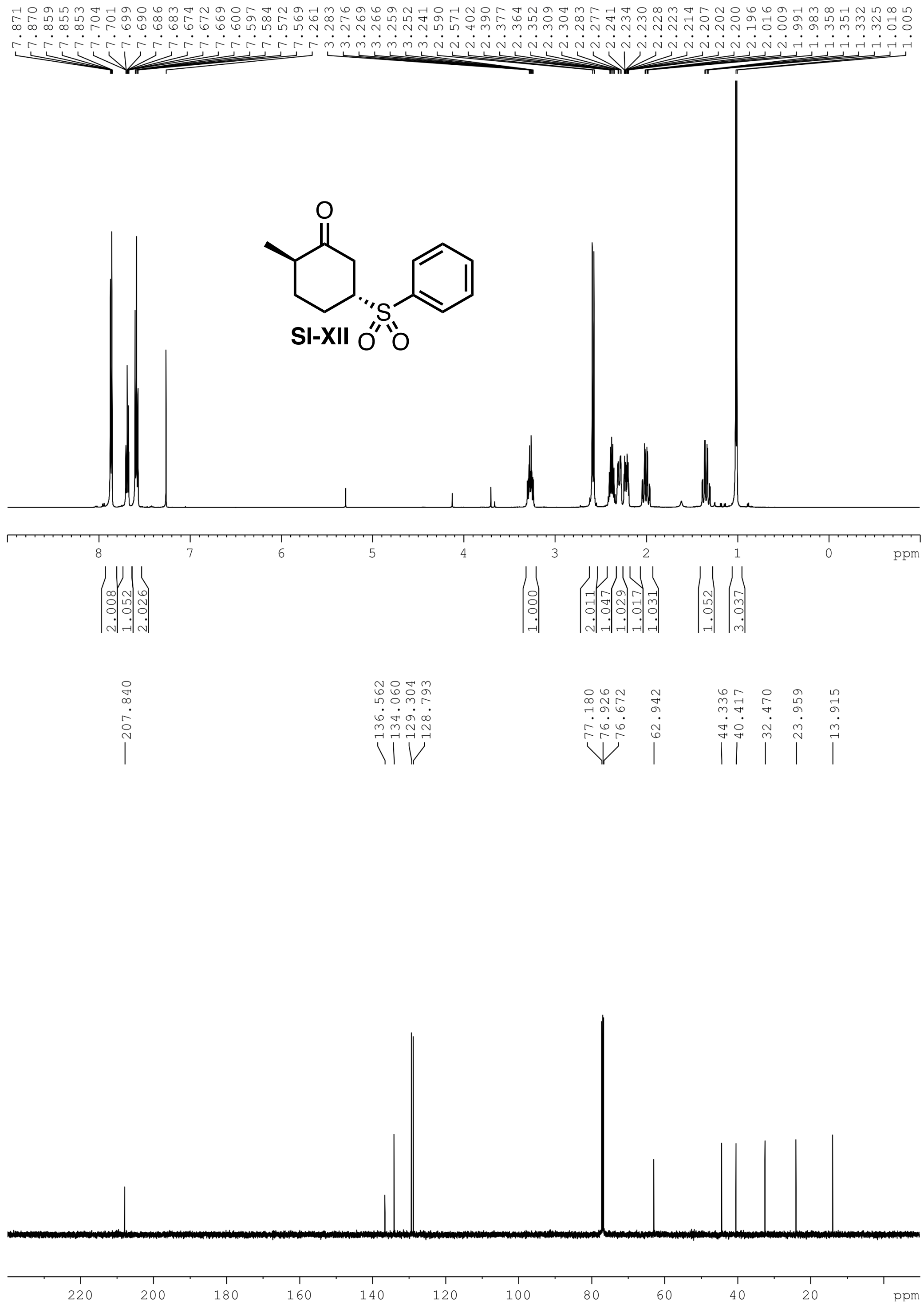
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-X**



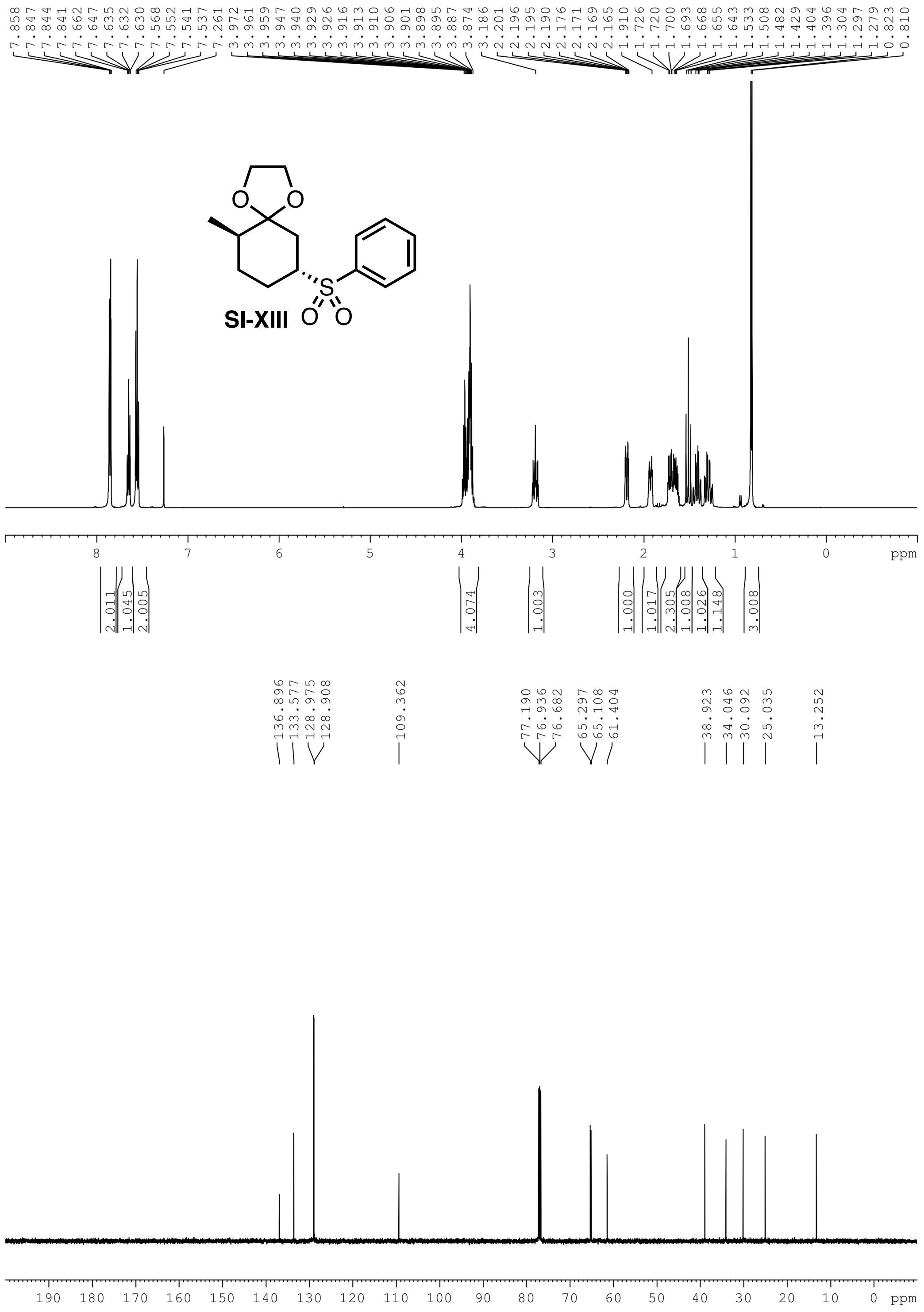
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **10**



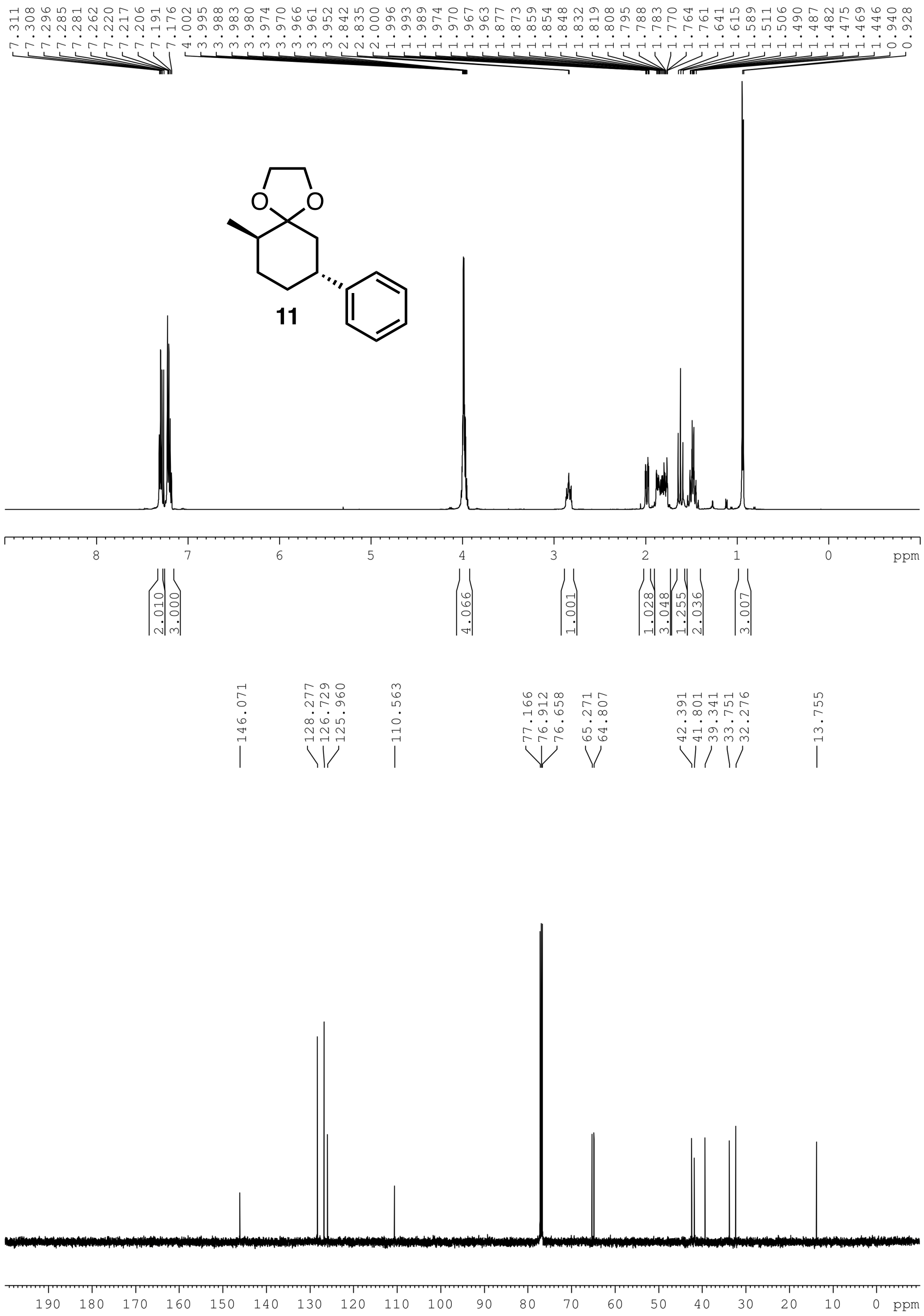
^{1}H (500 MHz, $CDCl_3$) and ^{13}C (125 MHz, $CDCl_3$) NMR Spectra of **SI-XI**



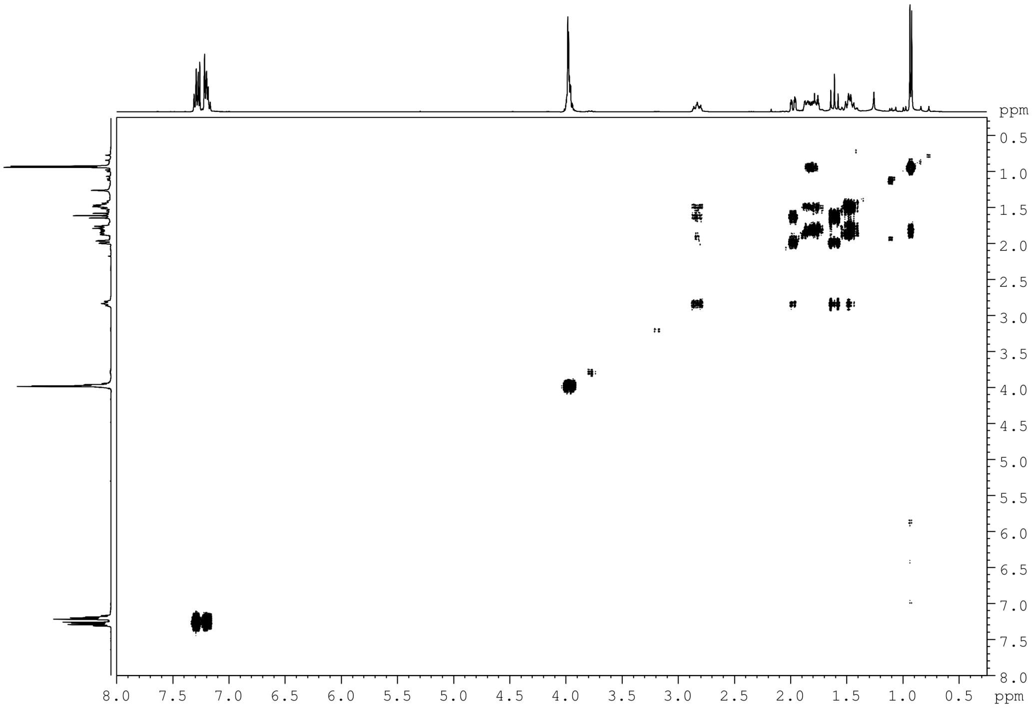
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-XII**

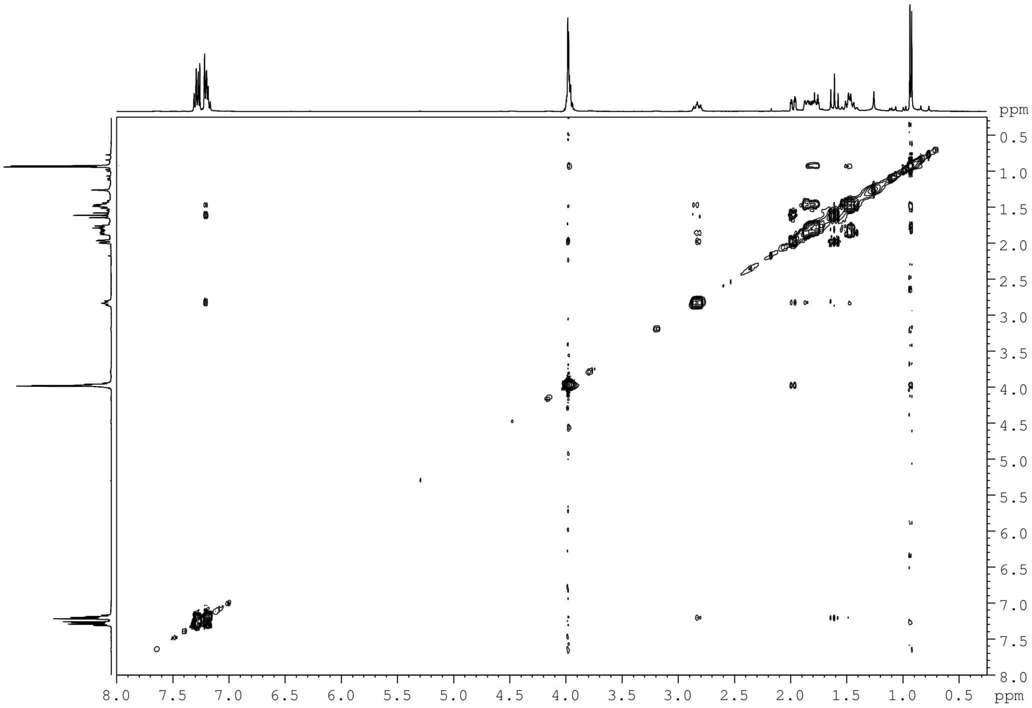


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-XIII**

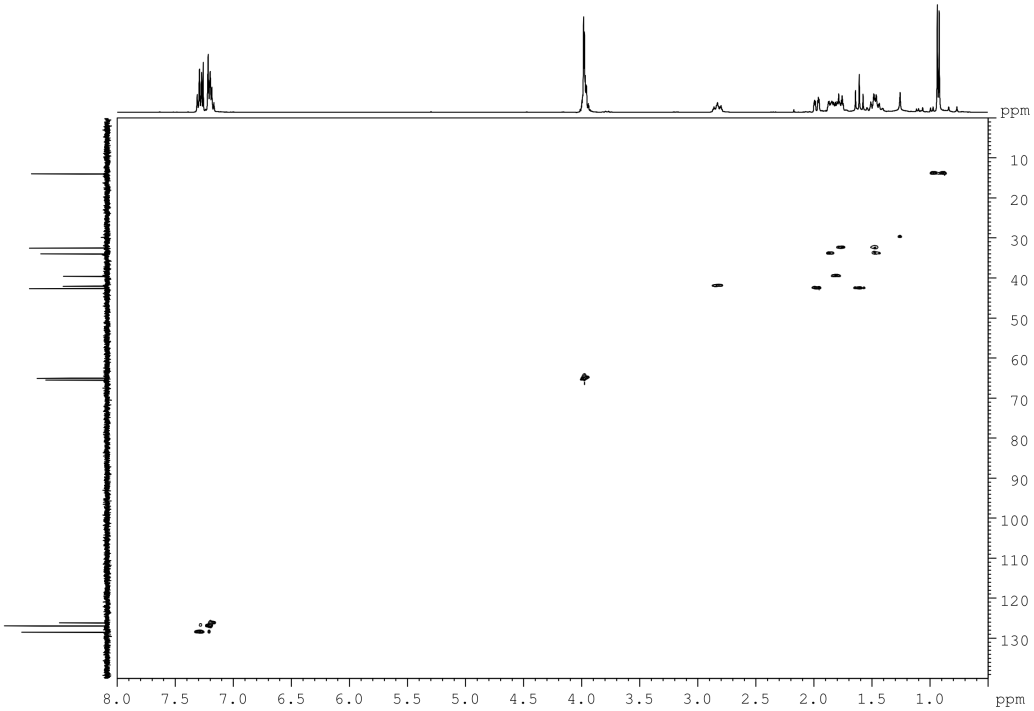


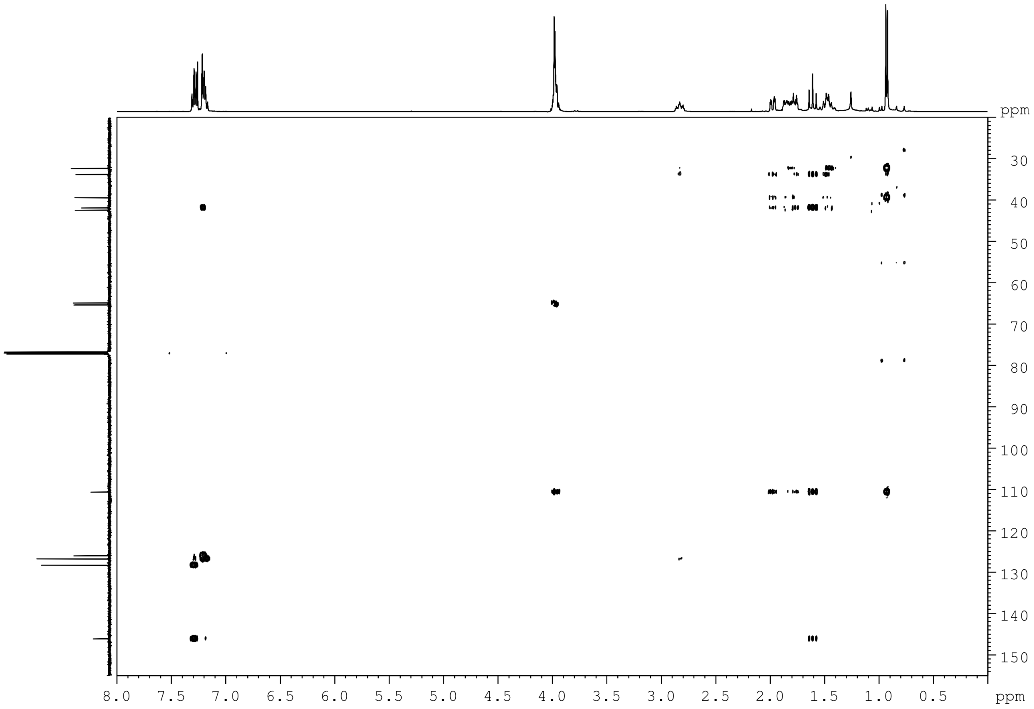
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **11**



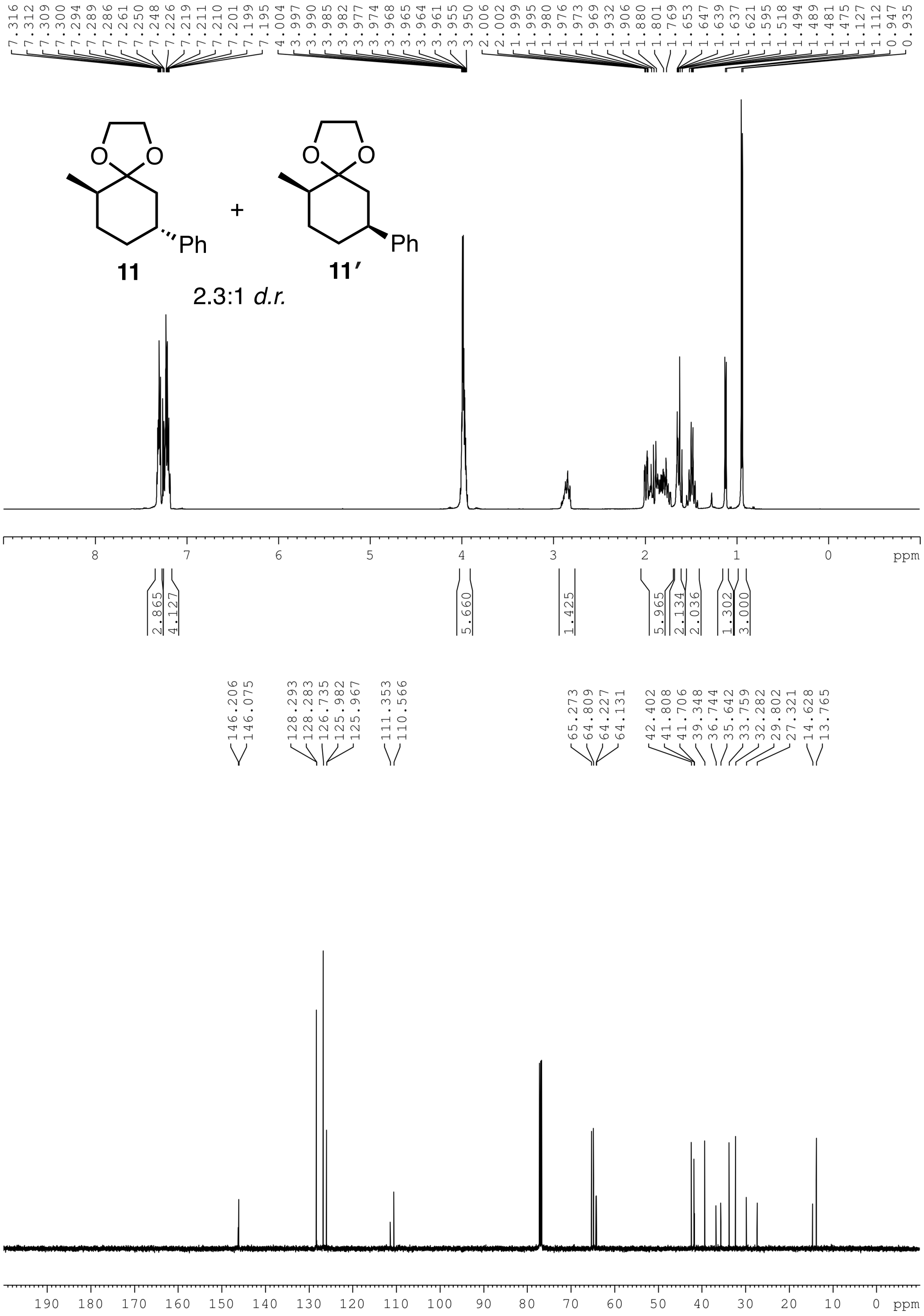


COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **11**

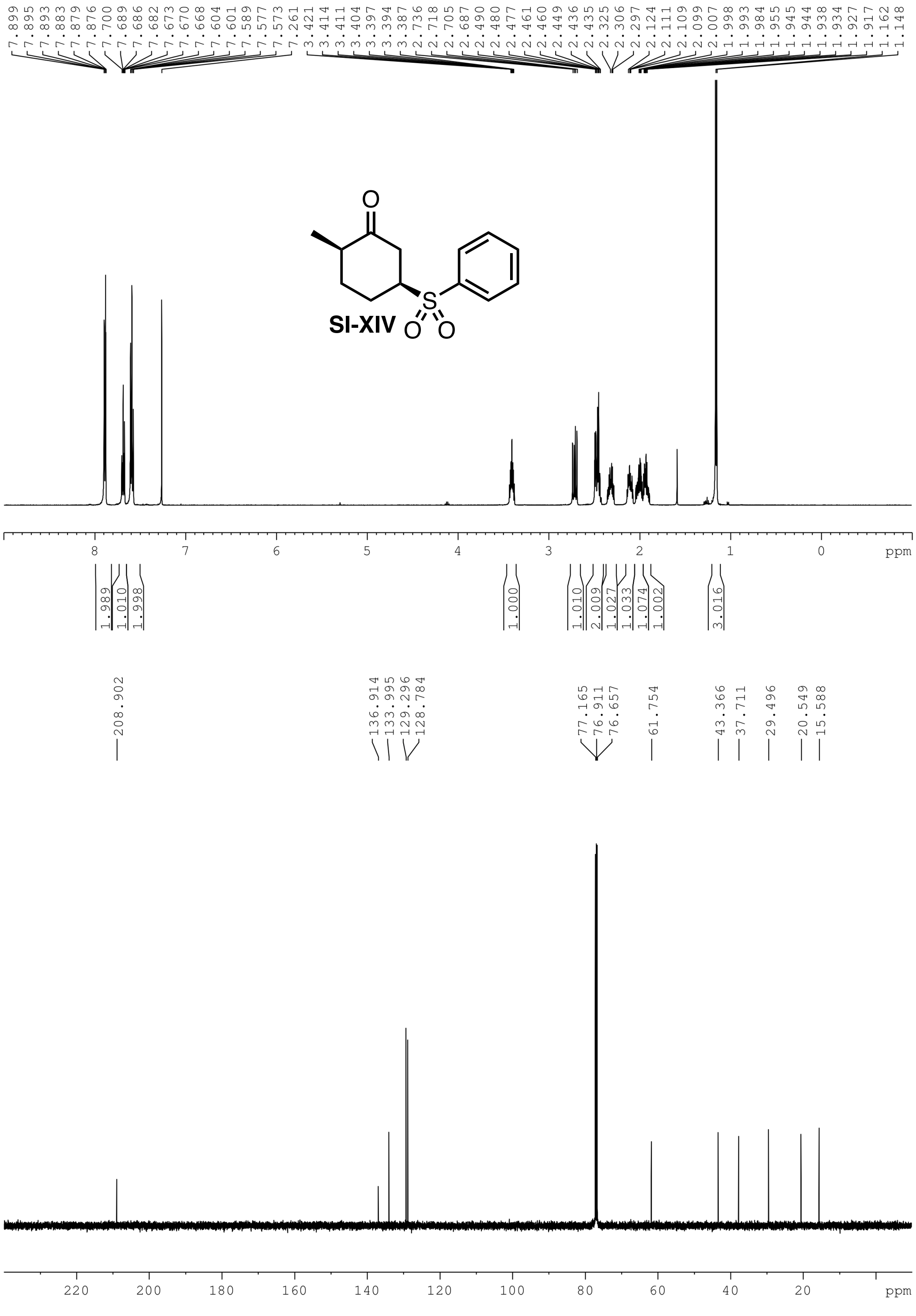




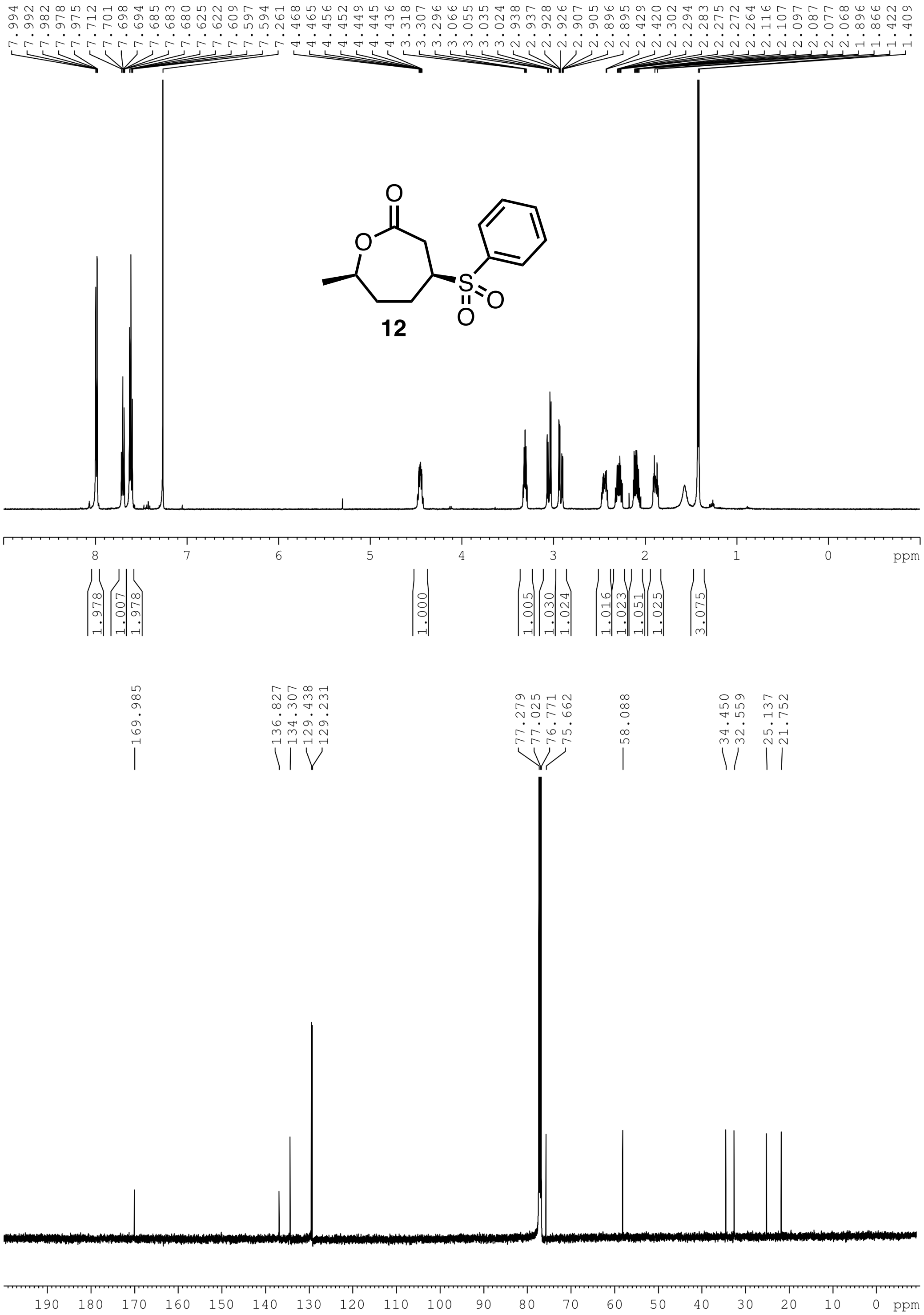
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **11**



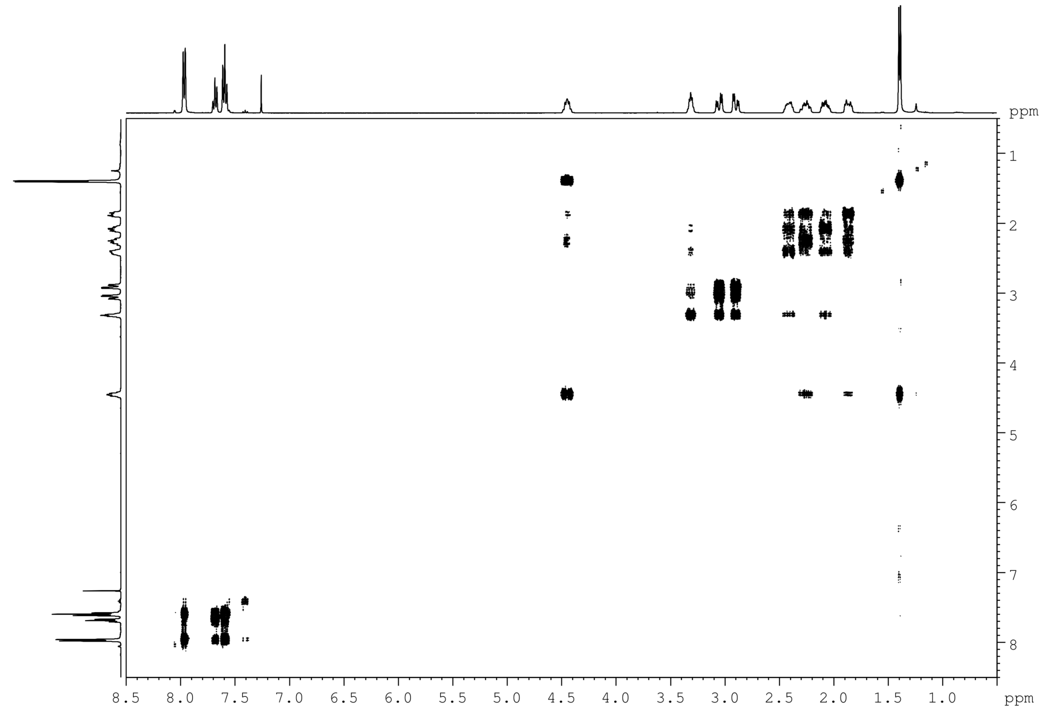
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **11**/**11′** (2.3:1 *d.r.*)

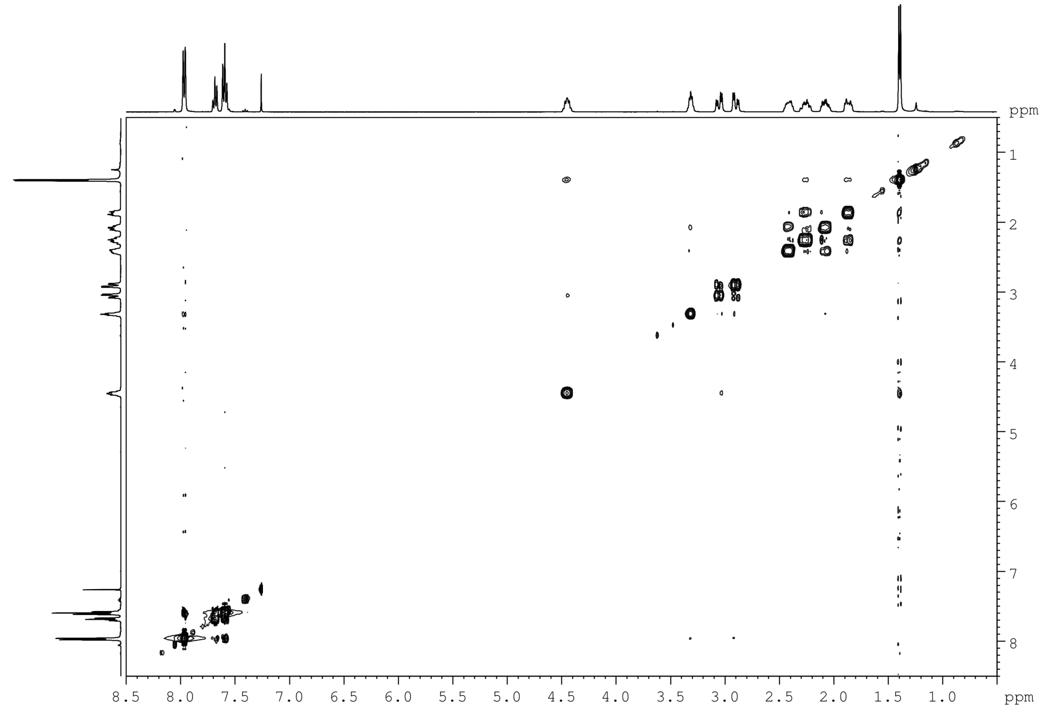


^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **SI-XIV**

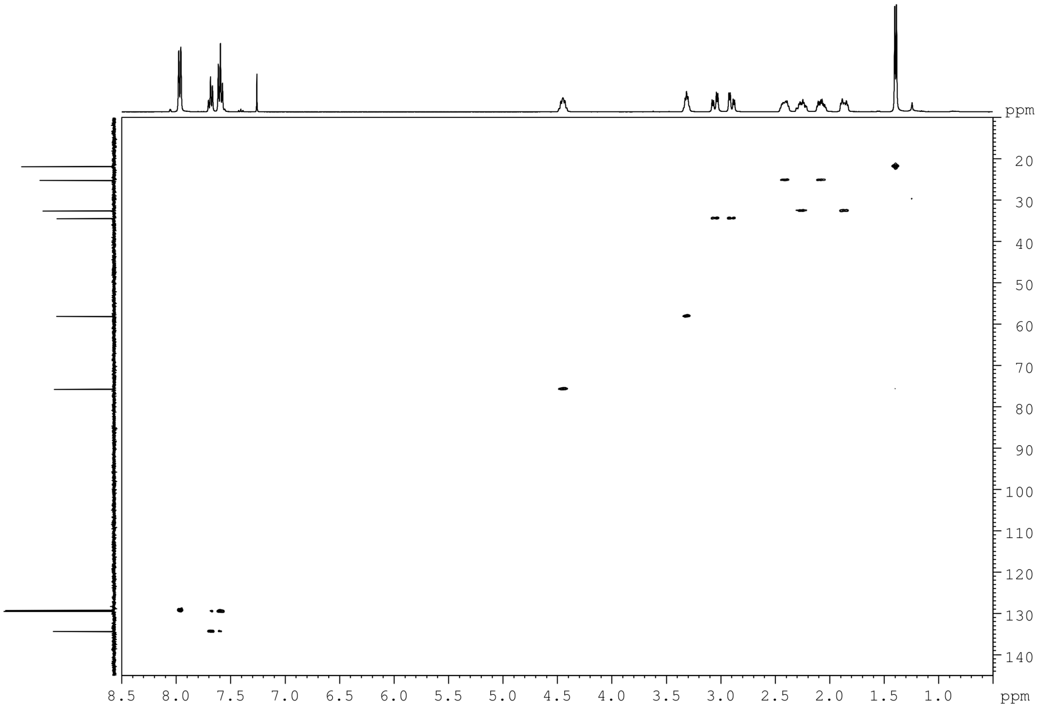


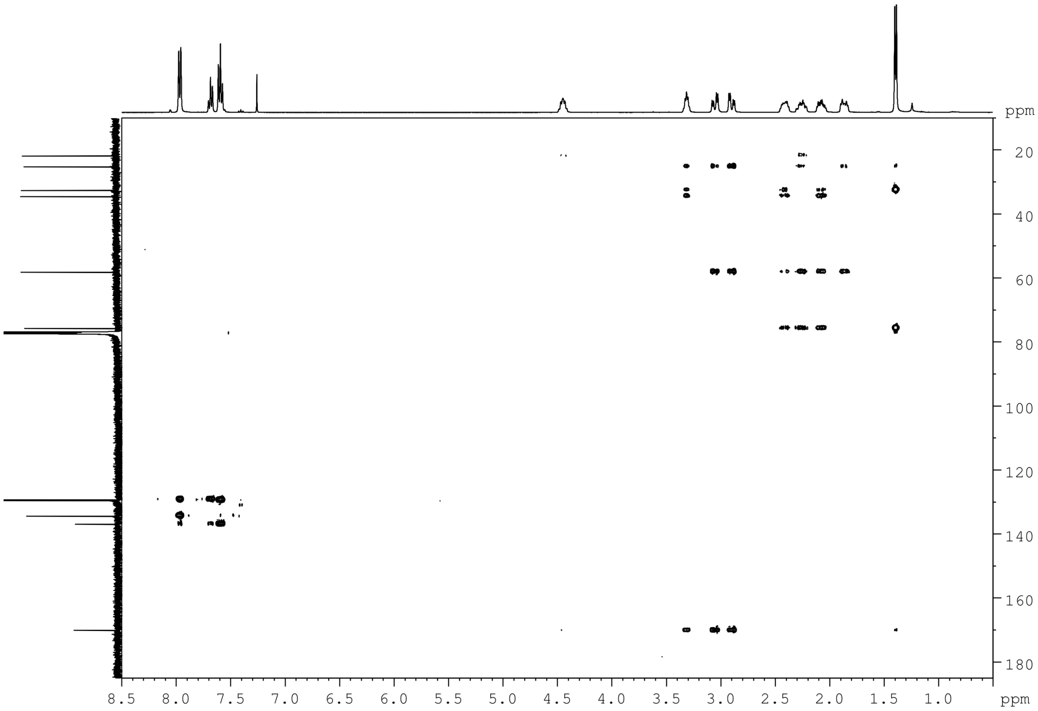
^{1}H (500 MHz, CDCl$_3$) and ^{13}C (125 MHz, CDCl$_3$) NMR Spectra of **12**





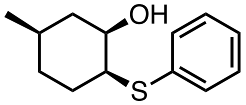
COSY (400 MHz, $CDCl_3$) and NOESY (400 MHz, $CDCl_3$) NMR Spectra of **12**



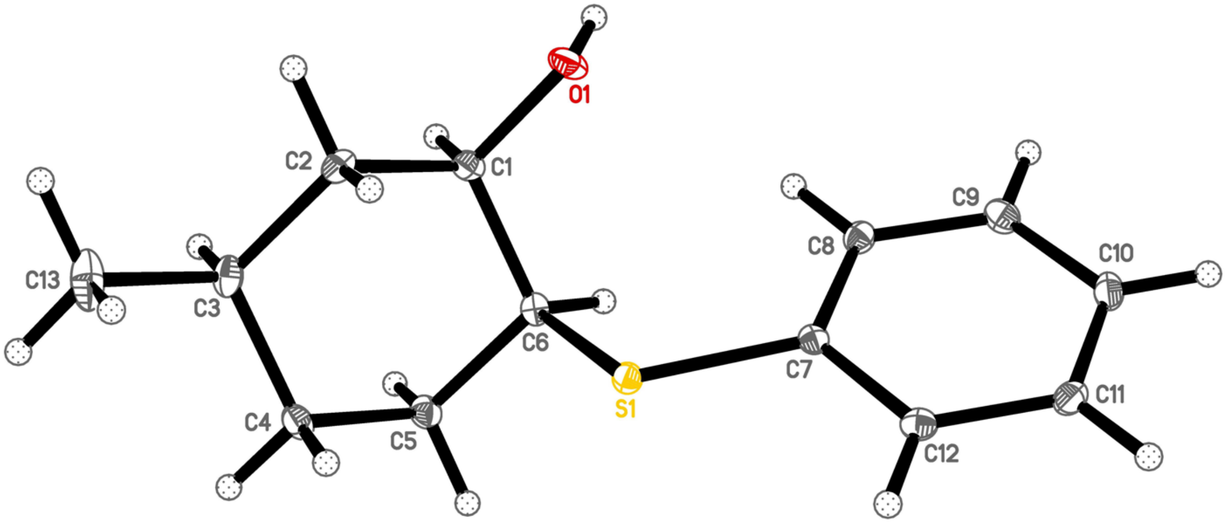


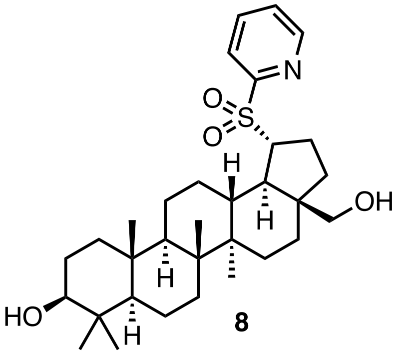
HSQC (400 MHz, $CDCl_3$) and HMBC (400 MHz, $CDCl_3$) NMR Spectra of **12**

7. ORTEP Representations of the Thioether 3la′ and the Sulfone 8

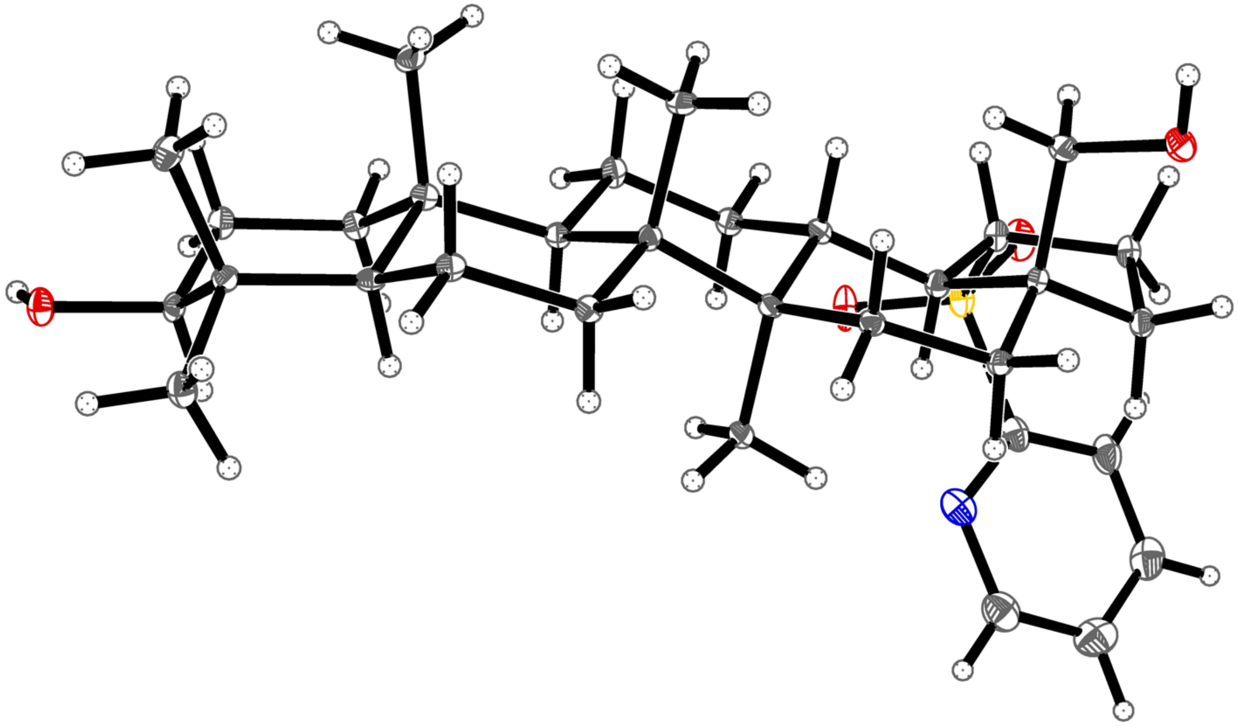


3la′





8



8. References

1. Ghafuri, H.; Hashemi, M. M. *Journal of Sulfur Chemistry* **2009**, *30* (6), 578–580.

2. Reid, W. B.; Watson, D. A. *Org. Lett.* **2018**, *20*, 6832–6835.

3. Smaligo, A. J.; Swain, M.; Quintana, J. C.; Tan, M. F.; Kim, D. A.; Kwon, O. *Science* **2019**, *364*, 681–685.

4. Siu, J. C.; Parry, J. B.; Lin, S. *J. Am. Chem. Soc.* **2019**, *141*, 2825–2831.

5. Barbie, P.; Kazmaier, U. *Org. Biomol. Chem.* **2016**, *14*, 6036–6054.

6. Gonnard, L.; Guérinot, A.; Cossy, J. *Chem. Eur. J.* **2015**, *21*, 12797–12803.

7. Huang, D.; Schuppe, A. W.; Liang, M. Z.; Newhouse, T. R. *Org. Biomol. Chem.* **2016**, *14*, 6197–6200.

8. Steiner, D.; Ivison, L.; Goralski, C. T.; Appell, R. B.; Gojkovic, J. R.; Singaram, B. *Tetrahedron: Asymmetry* **2002**, *13*, 2359–2363.

9. Blair, M.; Andrews, P. C.; Fraser, B. H.; Forsyth, C. M.; Junk, P. C.; Massi, M.; Tuck, K. L. *Synthesis* **2007**, *10*, 1523–1527.

10. Barluenga, J.; Fernández-Simón, J. L.; Concellón, J. M.; Yus, M. *J. Chem. Soc. Perkin Trans. 1* **1988**, *0*, 3339–3343.

11. Liwosz, T. W.; Chemler, S. R. *Chem. Eur. J.* **2013**, *19*, 12771–12777.

12. Yan, T.-H.; Tsai, C.-C.; Chien, C.-T.; Cho, C.-C.; Huang, P.-C. *Org. Lett.* **2004**, *6*, 4961–4963.

13. Posner, G. H.; Shulman-Roskes, E. M.; Oh, C. H.; Carry, J.-C.; Green, J. V.; Clark, A. B.; Dai, H.; Anjeh, T. E. N. *Tetrahedron Lett.* **1991**, *45*, 6489–6492.

14. Traber, B.; Pfander, H. *Tetrahedron Lett.* **2000**, *41*, 7197–7198.

15. Tsang, A S.-K.; Kapat, A.; Schoenebeck, F. *J. Am. Chem. Soc.* **2016**, *138*, 518–526.

16. Armstrong, D. A.; Sun, Q.; Schuler, R. H. *J. Phys. Chem.* **1996**, *100*, 9892–9899.

17. Harris, D. C. *Quantitative Chemical Analysis*, 7th Ed.; W. H. Freeman: New York, 2007.

18. Franklin, N. C.; Feltkamp, H. *Angew. Chem. Int. Ed.* **1965**, *4*, 774–783.

19. Tota, A.; Zenzola, M.; Chawner, S. J.; St John-Campbell, S.; Carlucci, C.; Romanazzi, G.; Degennaro, L.; Bull, J. A.; Luisi, R. *Chem. Comm.* **2017**, *53*, 348–351.

20. Schmees, N.; Haendler, B.; Stoeckigt, D.; Bissell, R. A.; Bouglas, R. A.; Stefanuti, I. Preparation of BET-protein inhibiting 3,4-dihydropyrido[2,3-b]pyrazinones with meta-substituted aromatic amino- or ether groups. U.S. Patent US20170121322, May 4, 2017.

21. Merchant, R. R.; Edwards, J. T.; Qin, T.; Kruszyk, M. M.; Bi, C.; Che, G.; Bao, D.-H.; Qiao, W.; Sun, L.; Collins, M. R.; Fadeyi, O. O.; Gallego, G. M.; Mousseau, J. J.; Nuhant, P.; Baran, P. S. *Science* **2018**, *360*, 75–80.

22. Bousquet, T.; Fleury, J.-F.; Daïch, A.; Netchitaïlo, P. *Tetrahedron* **2006**, *62*, 706–715.

23. Schaffner, A.-P.; Montermini, F.; Pozzi, D.; Darmency, V.; Scanlan, E. M.; Renaud, P. *Adv. Synth. Catal.* **2008**, *350*, 1163–1167.

24. Wu, J.; Grant, P. S.; Li, X.; Noble, A.; Aggarwal, V. K. *Angew. Chem. Int. Ed.* **2019**, *58*, 5697–5701.

25. Jones, K. D.; Power, D. J.; Bierer, D.; Gericke, K. M.; Stewart, S. G. *Org. Lett.* **2018**, *20*, 208–211.

26. Blowers, J. W.; Saxton, J. E.; Swanson, A. G. *Tetrahedron* **1986**, *42*, 6071–6095.

27. Ritter, R. H.; Cohen, T. *J. Am. Chem. Soc.* **1986**, *108*, 3718–3725.

28. Kirihara, M.; Noguchi, T.; Okajima, N.; Naito, S.; Ishizuka, Y.; Harano, A.; Tsukiji, H.; Takizawa, R. *Tetrahedron* **2012**, *68*, 1515–1520.

29. Che, C.; Huang, Q.; Zheng, H.; Zhu, G. *Chem. Sci.* **2016**, *7*, 4134–4139.

30. Trost, B. M.; Curran, D. P. *Tetrahedron Lett.* **1981**, *22*, 1287–1290.

31. Lopchuk, J. M.; Fjelbye, K.; Kawamata, Y.; Malins, L. R.; Pan, C.-M.; Gianatassio, R.; Wang, J.; Prieto, L.; Bradow, J.; Brandt, T. A.; Collins, M. R.; Elleraas, J.; Ewanicki, J.; Farrell, W.; Fadeyi, O. O.; Gallego, G. M.; Mousseau, J. J.; Oliver, R.; Sach, N. W.; Smith, J. K.; Spangler, J. E.; Zhu, H.; Zhu, J.; Baran, P. S. *J. Am. Chem. Soc.* **2017**, *139*, 3209–3226.

32. Chakraborty, T. K.; Chattopadhyay, A. K. *J. Org. Chem.* **2008**, *73*, 3578–3581.

33. Denmark, S. E.; Cresswell, A. J. *J. Org. Chem.* **2013**, *78*, 12593–12628.

34. Lowe, J. R.; Martello, M. T.; Tolman, W. B.; Hillmyer, M. A. *Polym. Chem.* **2011**, *2*, 702–708.