

# Enantioselective Construction of Tricyclic Pyrrolidine-Fused Benzo[*b*]thiophene 1,1-Dioxides Derivatives *via* Copper(I)-Catalyzed Asymmetric 1,3-Dipolar Cycloaddition

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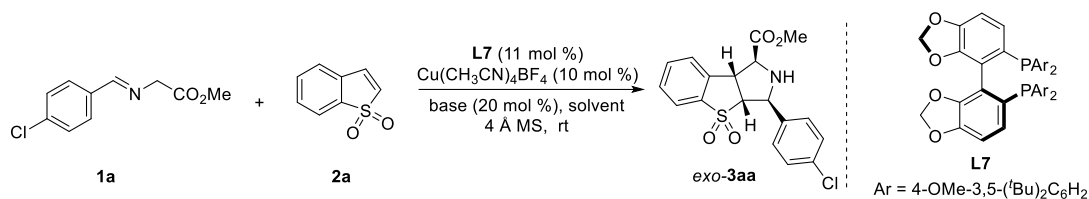
## Contents

1. General information	1
2. Table S1. Bases and solvents screening of the reaction conditions	2
3. General procedure for the asymmetric 1,3-dipolar cycloaddition	2
4. Gram scale procedure for the asymmetric cycloaddition of 1c to 2a	15
5. Transformation of cycloadduct 3ca	16
6. The absolute configuration determination of (1 <i>S</i> ,3 <i>S</i> ,3 <i>aR</i> ,8 <i>bR</i> )-3aa	17
7. References	19
8. Chiral HPLC chromatograms	19
9. <sup>1</sup> H NMR and <sup>13</sup> C NMR spectra	50

## 1. General information

<sup>1</sup>H NMR spectrum were recorded on a Bruker DPX 400 MHz spectrometer in CDCl<sub>3</sub>. Chemical shifts were reported in ppm with the internal TMS signal at 0.0 ppm as a standard. The spectrums are interpreted as: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = doublet of doublets, brs = broad singlet, coupling constant(s) *J* are reported in Hz and relative integrations are reported. <sup>13</sup>C NMR (100 MHz) spectrums were recorded on a Bruker DPX 400 MHz spectrometer in CDCl<sub>3</sub>. Chemical shifts were reported in ppm with the internal chloroform signal at 77.16 ppm as a standard. Optical rotations were measured on an AUTOPOL V. Diastereomeric ratios and enantiomeric excesses were determined from crude <sup>1</sup>H NMR spectroscopy interpretation or by analysis of HPLC traces, obtained by using chiralpak AS-H, AD-H, IA or chiralcel OD-H columns with *n*-hexane and *i*-propanol or ethanol as solvents. (Chiralpak AS-H, AD-H, IA and chiralcel OD-H columns were purchased from Daicel Chemical Industries, LTD.) Melting points were obtained in open capillary tubes using SGW X-4 micro melting point apparatus which were uncorrected. Mass spectrums were recorded on TOF mass Finigann MAT8401 spectrometer. Solvents were dried and distilled following usual protocols. Commercially available materials purchased from Adamas-beta, TCI or Energy Chemical and were used as received. Benzo[*b*]thiophene 1,1-dioxides **2** were prepared according to the literature procedure.<sup>1</sup>

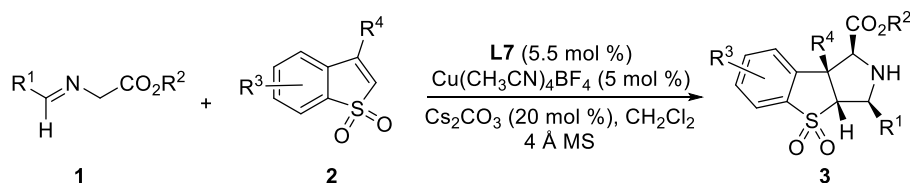
## 2. Table S1. Bases and solvents screening of the reaction conditions<sup>a</sup>



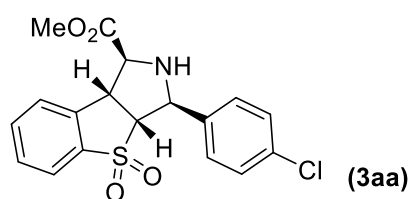
entry	solvent	base	yield (%) <sup>b</sup>	dr <sup>c</sup>	ee (%) <sup>c</sup>
1 <sup>d</sup>	CH <sub>2</sub> Cl <sub>2</sub>	DIPEA	nr	nd	nd
2 <sup>d</sup>	CH <sub>2</sub> Cl <sub>2</sub>	DABCO	trace	nd	nd
3	CH <sub>2</sub> Cl <sub>2</sub>	DBU	88	9:1	97
4 <sup>e</sup>	CH <sub>2</sub> Cl <sub>2</sub>	TMG	90	7:1	97
<b>5</b>	<b>CH<sub>2</sub>Cl<sub>2</sub></b>	<b>CS<sub>2</sub>CO<sub>3</sub></b>	<b>94</b>	<b>9:1</b>	<b>97</b>
6 <sup>d</sup>	THF	CS <sub>2</sub> CO <sub>3</sub>	74	9:1	96
7 <sup>d</sup>	Toluene	CS <sub>2</sub> CO <sub>3</sub>	90	3:1	96
8 <sup>d</sup>	Et <sub>2</sub> O	CS <sub>2</sub> CO <sub>3</sub>	45	3:1	90
9 <sup>d</sup>	CH <sub>3</sub> CN	CS <sub>2</sub> CO <sub>3</sub>	54	8:1	96
10 <sup>e</sup>	CPME	CS <sub>2</sub> CO <sub>3</sub>	73	4:1	95
11 <sup>e</sup>	TBME	CS <sub>2</sub> CO <sub>3</sub>	66	3:1	77
12 <sup>d</sup>	CH <sub>3</sub> Cl	CS <sub>2</sub> CO <sub>3</sub>	75	9:1	95
13 <sup>d</sup>	ClCH <sub>2</sub> CH <sub>2</sub> Cl	CS <sub>2</sub> CO <sub>3</sub>	74	7:1	97

<sup>a</sup>Unless otherwise stated, reactions were performed with **1a** (0.15 mmol), **2a** (0.10 mmol) in 1 mL of solvents (C = 0.1 M), under an N<sub>2</sub> atmosphere; nr = No reaction; nd = not detected; DIPEA = N,N-Diisopropylethylamine, DABCO = 1,4-Diazabicyclo[2.2.2]octane, DBU = 1,8-Diazabicyclo[5.4.0]undec-7-ene, TMG = Tetramethylguanidine, CPME = Cyclopentyl methyl ether, TBME = <sup>t</sup>Butyl methyl ether. <sup>b</sup>Isolated yield. <sup>c</sup>The dr was determined by <sup>1</sup>H NMR spectroscopy or/and chiral HPLC analysis, the ee was determined by chiral HPLC analysis. <sup>d</sup>24 h. <sup>e</sup>10 h.

## 3. General procedure for the asymmetric 1,3-dipolar cycloaddition



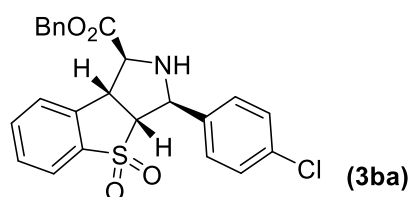
At nitrogen atmosphere, Cu(CH<sub>3</sub>CN)<sub>4</sub>BF<sub>4</sub> (3.1 mg, 0.01 mmol) and **L7** (13.0 mg, 0.011mmol) were dissolved in 2 mL CH<sub>2</sub>Cl<sub>2</sub>, and stirred at room temperature for about 1 h. Then, iminoester **1** (0.3 mmol) and Cs<sub>2</sub>CO<sub>3</sub> (13.0 mg, 0.04 mmol) were added, the mixture was cooled to 0 °C and benzo[*b*]thiophene 1,1-dioxide **2** (0.2 mmol) was added. Once starting material was consumed (monitored by TLC), the mixture was concentrated and the residue was purified by column chromatography (petroleum ether/ethyl acetate 15:1 to 6:1) on silica gel to afford the corresponding product **3**.



### Methyl

#### (1S,3S,3aR,8bR)-3-(4-chlorophenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide

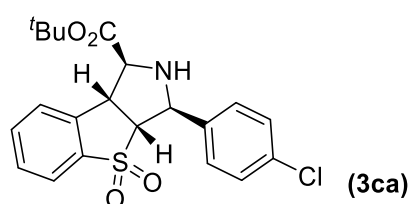
White solid, yield: 70.1 mg, 93%; m.p.: 158-160 °C;  $[\alpha]_D^{25} = -95.2$  (*c* 1.05, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 7.8 Hz, 1H), 7.71-7.59 (m, 2H), 7.61-7.52 (m, 1H), 7.53-7.48 (m, 2H), 7.40-7.34 (m, 2H), 4.83 (d, *J* = 7.1 Hz, 1H), 4.49 (dd, *J* = 9.4, 7.2 Hz, 1H), 3.97 (d, *J* = 7.1 Hz, 1H), 3.93 (dd, *J* = 9.5, 7.1 Hz, 1H), 3.88 (s, 3H), 2.76 (s, 1H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 171.8, 138.7, 138.2, 136.7, 134.4, 134.2, 130.2, 129.1, 128.5, 127.4, 122.1, 70.3, 66.2, 62.2, 53.0, 49.0; HRMS (ESI, *m/z*) calcd for C<sub>18</sub>H<sub>16</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 378.0561, found: 378.0566; HPLC (Chiralcel OD-H, *n*-hexane/EtOH = 90/10, 0.8 mL/min, 220 nm) *t*<sub>R</sub> = 33.95 min, 40.41 min, 45.16 min (minor diastereomer), 49.11 min (minor diastereomer).



### Benzyl

#### (1S,3S,3aR,8bR)-3-(4-chlorophenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide

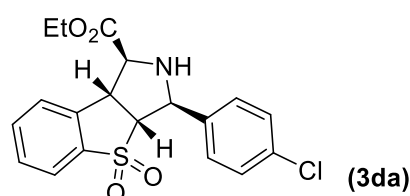
White solid, yield: 81.5 mg, 90%; m.p.: 78-80 °C;  $[\alpha]_D^{25} = -10.1$  (*c* 0.95, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.74 (d, *J* = 7.4 Hz, 1H), 7.60-7.47 (m, 5H), 7.46-7.32 (m, 7H), 5.34 (d, *J* = 12.1 Hz, 1H), 5.26 (d, *J* = 12.1 Hz, 1H), 4.84 (d, *J* = 6.9 Hz, 1H), 4.46 (dd, *J* = 9.4, 7.2 Hz, 1H), 4.00 (d, *J* = 7.1 Hz, 1H), 3.92 (dd, *J* = 9.4, 6.9 Hz, 1H), 2.78 (brs, 1H), 1.57 (s, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 171.2, 138.7, 138.3, 136.6, 135.1, 134.4, 134.2, 130.2, 129.1, 129.0, 128.9, 128.7, 128.5, 127.4, 122.1, 70.5, 67.9, 66.3, 62.1, 49.1; HRMS (ESI, *m/z*) calcd for C<sub>24</sub>H<sub>20</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 454.0874, found: 454.0880; HPLC (Chiralcel OD-H, *n*-hexane/EtOH = 90/10, 0.8 mL/min, 220 nm) *t*<sub>R</sub> = 33.41 min (minor diastereomer), 35.47 min (minor diastereomer), 38.01 min, 41.27 min.



### <sup>t</sup>Butyl

#### (1*S*,3*S*,3*aR*,8*bR*)-3-(4-chlorophenyl)-2,3,3*a*,8*b*-tetrahydro-1*H*-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide

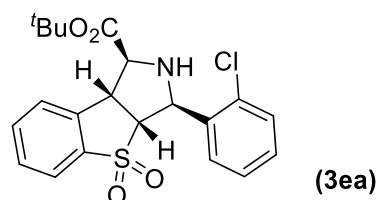
White solid, yield: 78.8 mg, 94%; m.p.: 144-146 °C;  $[\alpha]_{\text{D}}^{25} = -5.0$  (c 1.04, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 7.8 Hz, 1H), 7.70-7.54 (m, 3H), 7.51 (d, *J* = 8.4 Hz, 2H), 7.37 (d, *J* = 8.5 Hz, 2H), 4.81-4.73 (m, 1H), 4.41 (dd, *J* = 9.5, 6.9 Hz, 1H), 3.92 (dd, *J* = 9.5, 7.4 Hz, 1H), 3.90-3.82 (m, 1H), 2.71 (brs, 1H), 1.57 (s, 9H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 170.6, 138.7, 138.2, 137.2, 134.3, 134.2, 130.1, 129.1, 128.6, 127.3, 122.1, 83.2, 70.4, 67.1, 62.5, 49.6, 28.2; HRMS (ESI, *m/z*) calcd for C<sub>21</sub>H<sub>22</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 420.1031, found: 420.1036; HPLC (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 0.8 mL/min, 220 nm) *t*<sub>R</sub> = 22.40 min, 32.97 min (minor diastereomer), 40.85 min (minor diastereomer), 56.16 min.



### Ethyl

#### (1*S*,3*S*,3*aR*,8*bR*)-3-(4-chlorophenyl)-2,3,3*a*,8*b*-tetrahydro-1*H*-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide

White solid, yield: 70.4 mg, 90%; m.p.: 142-144 °C;  $[\alpha]_{\text{D}}^{25} = -12.5$  (c 0.96, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 7.8 Hz, 1H), 7.70-7.54 (m, 3H), 7.51 (d, *J* = 8.4 Hz, 2H), 7.37 (d, *J* = 8.5 Hz, 2H), 4.83 (d, *J* = 7.1 Hz, 1H), 4.48 (dd, *J* = 9.4, 7.1 Hz, 1H), 4.34 (qd, *J* = 7.1, 1.5 Hz, 2H), 3.98-3.90 (m, 2H), 2.77 (brs, 1H), 1.37 (t, *J* = 7.1 Hz, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 171.4, 138.7, 138.3, 136.9, 134.4, 134.2, 130.2, 129.2, 128.6, 127.4, 122.1, 70.4, 66.4, 62.3, 62.2, 49.2, 14.4; HRMS (ESI, *m/z*) calcd for C<sub>19</sub>H<sub>18</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 392.0718, found: 392.0723; HPLC (Chiralcel OD-H, *n*-hexane/EtOH = 90/10, 0.8 mL/min, 220 nm) *t*<sub>R</sub> = 22.49 min, 25.36 min, 30.45 min (minor diastereomer), 33.53 min (minor diastereomer).

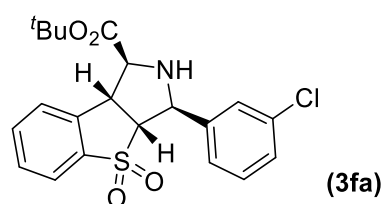


### <sup>t</sup>Butyl

#### (1*S*,3*S*,3*aR*,8*bR*)-3-(2-chlorophenyl)-2,3,3*a*,8*b*-tetrahydro-1*H*-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide

White solid, yield: 77.1 mg, 92%; m.p.: 130-132 °C;  $[\alpha]_{\text{D}}^{25} = +45.3$  (c 0.91, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR

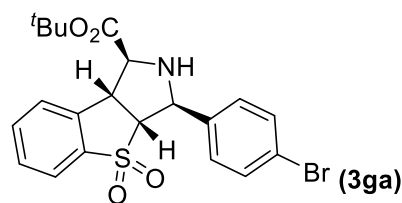
(400 MHz, CDCl<sub>3</sub>)  $\delta$  7.76 (d,  $J$  = 8.6 Hz, 2H), 7.67-7.60 (m, 1H), 7.60-7.51 (m, 2H), 7.41 (m, 1H), 7.36-7.27 (m, 2H), 5.27 (d,  $J$  = 5.1 Hz, 1H), 4.40 (dd,  $J$  = 9.0, 7.7 Hz, 1H), 4.17 (dd,  $J$  = 9.0, 5.1 Hz, 1H), 3.88 (d,  $J$  = 7.7 Hz, 1H), 3.06 (brs, 1H), 1.55 (s, 9H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.8, 138.4, 137.4, 136.7, 134.1, 133.3, 130.3, 130.1, 129.6, 129.5, 127.4, 127.4, 122.2, 82.9, 70.4, 67.5, 59.8, 49.0, 28.2; **HRMS** (ESI,  $m/z$ ) calcd for C<sub>21</sub>H<sub>22</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 420.1031, found: 420.1036; **HPLC** (Chiralpak IA, *n*-hexane/EtOH = 90/10, 0.8 mL/min, 220 nm)  $t_R$  = 24.06 min, 27.65 min (minor diastereomer), 34.14 min, 40.05 min (minor diastereomer).



#### <sup>t</sup>Butyl

#### **(1S,3S,3aR,8bR)-3-(3-chlorophenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 82.9 mg, 99%; m.p.: 110-112 °C;  $[\alpha]_D^{25}$  = +1.5 (*c* 1.00, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.75 (d,  $J$  = 7.8 Hz, 1H), 7.71-7.52 (m, 4H), 7.47-7.40 (m, 1H), 7.36-7.28 (m, 2H), 4.80 (d,  $J$  = 6.8 Hz, 1H), 4.42 (dd,  $J$  = 9.2, 7.1 Hz, 1H), 3.95 (dd,  $J$  = 9.4, 7.1 Hz, 1H), 3.86 (d,  $J$  = 6.9 Hz, 1H), 2.73 (brs, 1H), 1.57 (s, 9H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.5, 142.0, 138.6, 137.1, 134.9, 134.3, 130.3, 130.1, 128.5, 127.3, 127.2, 125.5, 122.1, 83.2, 70.4, 67.2, 62.4, 49.4, 28.2; **HRMS** (ESI,  $m/z$ ) calcd for C<sub>21</sub>H<sub>22</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 420.1031, found: 420.1036; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 0.8 mL/min, 220 nm)  $t_R$  = 24.05 min, 28.08 min (minor diastereomer), 33.47 min (minor diastereomer), 57.81 min.

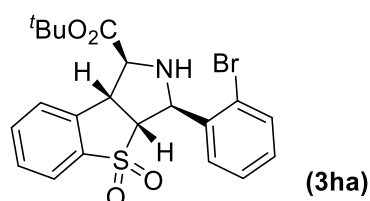


#### <sup>t</sup>Butyl

#### **(1S,3S,3aR,8bR)-3-(4-bromophenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 78.7 mg, 85%; m.p.: 132-135 °C;  $[\alpha]_D^{25}$  = -11.0 (*c* 1.04, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.75 (d,  $J$  = 7.8 Hz, 1H), 7.71-7.54 (m, 2H), 7.57-7.49 (m, 3H), 7.49-7.42 (m, 2H), 4.76 (t,  $J$  = 6.9 Hz, 1H), 4.40 (dd,  $J$  = 9.5, 6.9 Hz, 1H), 3.92 (dd,  $J$  = 9.5, 7.4 Hz, 1H),

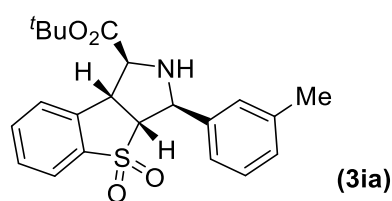
3.89-3.82 (m, 1H), 2.76-2.68 (m, 1H), 1.57 (s, 9H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  170.6, 138.7, 138.7, 137.1, 134.3, 132.1, 130.1, 128.9, 127.3, 122.3, 122.1, 83.2, 70.4, 67.1, 62.5, 49.6, 28.2; **HRMS** (ESI,  $m/z$ ) calcd for  $\text{C}_{21}\text{H}_{22}\text{BrNO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 464.0526, found: 464.0531; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm)  $t_{\text{R}}$  = 21.11 min, 32.47 min (minor diastereomer), 38.22 min (minor diastereomer), 62.05 min.



**<sup>t</sup>Butyl**

**(1S,3S,3aR,8bR)-3-(2-bromophenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 80.6 mg, 87%; m.p.: 60-62 °C;  $[\alpha]_{\text{D}}^{25} = +50.6$  (*c* 0.95,  $\text{CH}_2\text{Cl}_2$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.81-7.73 (m, 2H), 7.67-7.51 (m, 4H), 7.37 (td,  $J = 7.6, 1.0$  Hz, 1H), 7.20 (td,  $J = 7.7, 1.6$  Hz, 1H), 5.30 (d,  $J = 4.7$  Hz, 1H), 4.45-4.37 (m, 1H), 4.16 (dd,  $J = 8.9, 4.7$  Hz, 1H), 3.89 (d,  $J = 7.8$  Hz, 1H), 3.05 (brs, 1H), 1.55 (s, 9H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  170.9, 139.2, 138.4, 136.8, 134.1, 133.6, 130.1, 129.9, 129.7, 128.0, 127.4, 123.4, 122.2, 82.8, 70.8, 67.6, 61.6, 48.7, 28.2; **HRMS** (ESI,  $m/z$ ) calcd for  $\text{C}_{21}\text{H}_{22}\text{BrNO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 464.0526, found: 464.0531; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm)  $t_{\text{R}}$  = 13.50 min, 16.33 min, 18.13 min (minor diastereomer), 19.58 min (minor diastereomer).

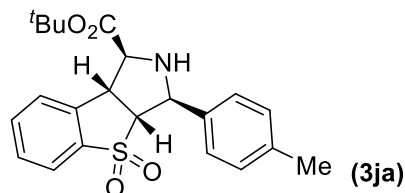


**<sup>t</sup>Butyl**

**(1S,3S,3aR,8bR)-3-(*m*-tolyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 75.8 mg, 95%; m.p.: 107-109 °C;  $[\alpha]_{\text{D}}^{25} = +0.7$  (*c* 1.09,  $\text{CH}_2\text{Cl}_2$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75 (d,  $J = 7.7$  Hz, 1H), 7.69-7.60 (m, 2H), 7.59-7.53 (m, 1H), 7.36-7.26 (m, 3H), 7.14 (d,  $J = 7.3$  Hz, 1H), 4.76 (t,  $J = 7.4$  Hz, 1H), 4.39 (dd,  $J = 9.6, 7.0$  Hz, 1H), 4.01 (dd,  $J = 9.5, 7.4$  Hz, 1H), 3.85 (t,  $J = 6.9$  Hz, 1H), 2.79-2.68 (m, 1H), 2.38 (s, 3H), 1.57 (s, 9H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  170.8, 139.4, 138.9, 138.7, 137.2, 134.2, 130.0, 129.2, 128.9, 127.8, 127.2, 124.2, 122.1, 83.1, 70.4, 67.4, 63.3, 50.3, 28.2, 21.6; **HRMS** (ESI,  $m/z$ ) calcd for  $\text{C}_{22}\text{H}_{25}\text{NO}_4\text{S}$

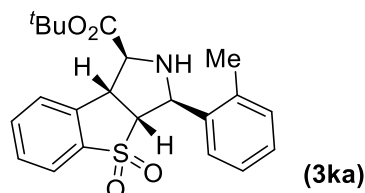
[M+H]<sup>+</sup>: 400.1577, found: 400.1583; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm) t<sub>R</sub> = 9.18 min (minor diastereomer), 15.09 min, 20.67 min (minor diastereomer), 41.76 min.



**Butyl**

**(1S,3S,3aR,8bR)-3-(*p*-tolyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 75.8 mg, 95%; m.p.: 143-145 °C; [α]<sub>D</sub><sup>25</sup> = -8.2 (*c* 0.90, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 7.8 Hz, 1H), 7.68-7.60 (m, 2H), 7.59-7.52 (m, 1H), 7.43 (d, *J* = 8.1 Hz, 2H), 7.21 (d, *J* = 7.9 Hz, 2H), 4.75 (d, *J* = 7.4 Hz, 1H), 4.39 (dd, *J* = 9.4, 7.0 Hz, 1H), 3.98 (dd, *J* = 9.5, 7.5 Hz, 1H), 3.85 (d, *J* = 6.9 Hz, 1H), 2.73 (brs, 1H), 2.36 (s, 3H), 1.57 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 170.8, 138.9, 138.1, 137.3, 136.4, 134.2, 130.0, 129.7, 127.2, 127.1, 122.1, 83.1, 70.4, 67.3, 63.2, 50.3, 28.2, 21.3; **HRMS** (ESI, *m/z*) calcd for C<sub>22</sub>H<sub>25</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 400.1577, found: 400.1583; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm) t<sub>R</sub> = 10.64 min (minor diastereomer), 17.31 min, 21.79 min (minor diastereomer), 63.66 min.

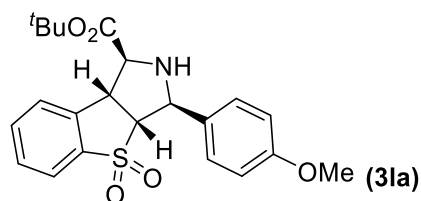


**Butyl**

**(1S,3S,3aR,8bR)-3-(*o*-tolyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 71.9 mg, 90%; m.p.: 188-190 °C; [α]<sub>D</sub><sup>25</sup> = +24.0 (*c* 0.99, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.74 (d, *J* = 7.7 Hz, 1H), 7.68-7.52 (m, 4H), 7.31-7.17 (m, 3H), 5.06 (d, *J* = 6.1 Hz, 1H), 4.45-4.33 (dd, *J* = 9.3, 6.2 Hz, 1H), 4.07 (dd, *J* = 9.3, 7.3 Hz, 1H), 3.86 (d, *J* = 7.4 Hz, 1H), 2.68 (brs, 1H), 2.49 (s, 3H), 1.56 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 170.8, 138.6, 137.9, 137.0, 136.8, 134.1, 131.1, 130.0, 128.2, 127.4, 126.7, 126.3, 122.1, 82.9, 70.9, 67.5, 58.9, 49.9, 28.2, 19.7; **HRMS** (ESI, *m/z*) calcd for C<sub>22</sub>H<sub>25</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 400.1577, found: 400.1583; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) t<sub>R</sub> = 12.74 min, 13.71 min, 17.91 min (minor diastereomer), 22.05 min (minor diastereomer).

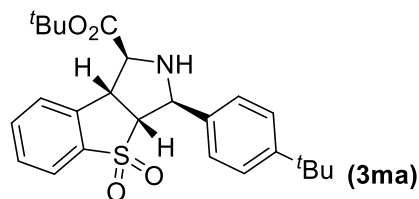




#### **<sup>t</sup>Butyl**

#### **(1S,3S,3aR,8bR)-3-(4-methoxyphenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

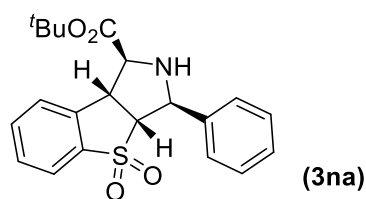
White solid, yield: 77.2 mg, 93%; m.p.: 146-148 °C;  $[\alpha]_{\text{D}}^{25} = -6.3$  (*c* 1.00, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.74 (d, *J* = 7.8 Hz, 1H), 7.70-7.59 (m, 2H), 7.58-7.52 (m, 1H), 7.49-7.41 (m, 2H), 6.98-6.84 (m, 2H), 4.71 (d, *J* = 7.6 Hz, 1H), 4.39 (dd, *J* = 9.4, 7.0 Hz, 1H), 3.96 (dd, *J* = 9.5, 7.7 Hz, 1H), 3.84 (d, *J* = 6.9 Hz, 1H), 3.82 (s, 3H), 2.71 (brs, 1H), 1.57 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.8, 159.6, 138.9, 137.3, 134.2, 131.4, 130.0, 128.4, 127.2, 122.1, 114.4, 83.1, 70.4, 67.3, 63.0, 55.5, 50.2, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>22</sub>H<sub>25</sub>NO<sub>5</sub>S [M+H]<sup>+</sup>: 416.1526, found: 416.1532; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 70/30, 0.8 mL/min, 220 nm) *t*<sub>R</sub> = 17.66 min, 19.97 min, 25.67 min (minor diastereomer), 28.17 min (minor diastereomer).



#### **<sup>t</sup>Butyl**

#### **(1S,3S,3aR,8bR)-3-(4-(tert-butyl)phenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

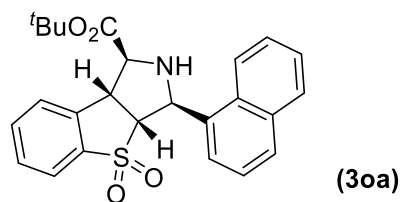
White solid, yield: 79.4 mg, 90%; m.p.: 158-159 °C;  $[\alpha]_{\text{D}}^{25} = -20.2$  (*c* 1.06, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.75 (d, *J* = 7.8 Hz, 1H), 7.69-7.60 (m, 2H), 7.58-7.52 (m, 1H), 7.49-7.40 (m, 4H), 4.77 (d, *J* = 7.4 Hz, 1H), 4.40 (dd, *J* = 9.5, 7.1 Hz, 1H), 4.01 (dd, *J* = 9.5, 7.5 Hz, 1H), 3.85 (d, *J* = 7.0 Hz, 1H), 2.74 (brs, 1H), 1.56 (s, 9H), 1.33 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.8, 151.3, 138.9, 137.3, 136.4, 134.2, 130.0, 127.2, 126.9, 126.0, 122.1, 83.1, 70.4, 67.4, 63.1, 50.3, 34.7, 31.5, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>25</sub>H<sub>31</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 442.2047, found: 442.2052; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm) *t*<sub>R</sub> = 13.56 min, 35.64 min.



**<sup>t</sup>Butyl**

**(1S,3S,3aR,8bR)-3-phenyl-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

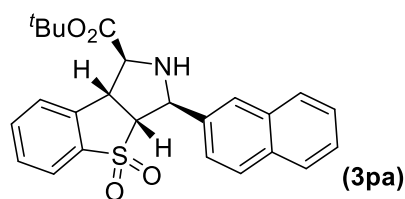
White solid, yield: 76.2 mg, 99%; m.p.: 142-143 °C;  $[\alpha]_D^{25} = -1.5$  (*c* 0.95, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 7.8 Hz, 1H), 7.70-7.59 (m, 2H), 7.59-7.51 (m, 3H), 7.44-7.37 (m, 2H), 7.36-7.30 (m, 1H), 4.80 (d, *J* = 7.2 Hz, 1H), 4.40 (dd, *J* = 9.4, 7.0 Hz, 1H), 4.00 (dd, *J* = 9.5, 7.3 Hz, 1H), 3.86 (d, *J* = 6.9 Hz, 1H), 2.76 (brs, 1H), 1.57 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 170.7, 139.5, 138.8, 137.2, 134.2, 130.0, 129.0, 128.4, 127.2, 127.2, 122.1, 83.1, 70.5, 67.3, 63.3, 50.1, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>21</sub>H<sub>23</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 386.1421, found: 386.1426; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm) *t<sub>R</sub>* = 18.69 min, 22.48 min (minor diastereomer), 24.68 min (minor diastereomer), 49.48 min.



**<sup>t</sup>Butyl**

**(1S,3S,3aR,8bR)-3-(naphthalen-1-yl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

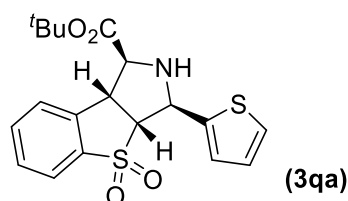
White solid, yield: 80.9 mg, 93%; m.p.: 154-156 °C;  $[\alpha]_D^{25} = +20.1$  (*c* 1.00, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 8.34 (d, *J* = 8.4 Hz, 1H), 7.93-7.81 (m, 3H), 7.77 (d, *J* = 7.8 Hz, 1H), 7.71-7.46 (m, 6H), 5.64 (d, *J* = 5.4 Hz, 1H), 4.48 (dd, *J* = 9.0, 7.4 Hz, 1H), 4.30 (dd, *J* = 9.1, 5.5 Hz, 1H), 3.98 (d, *J* = 7.3 Hz, 1H), 2.92 (brs, 1H), 1.53 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 170.9, 138.5, 137.2, 135.4, 134.2, 134.1, 131.2, 130.0, 129.1, 129.0, 127.5, 126.8, 126.1, 125.4, 124.5, 123.5, 122.1, 82.8, 70.2, 67.6, 59.1, 49.2, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>25</sub>H<sub>25</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 436.1577, found: 436.1583; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.2 mL/min, 220 nm) *t<sub>R</sub>* = 15.46 min, 41.03 min.



**<sup>t</sup>Butyl**

**(1S,3S,3aR,8bR)-3-(naphthalen-2-yl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

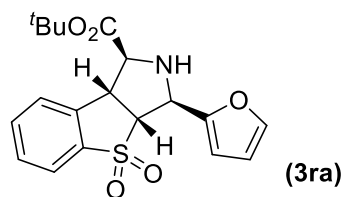
White solid, yield: 82.6 mg, 95%; m.p.: 151-153 °C;  $[\alpha]_D^{25} = -15.6$  (*c* 1.10, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 8.01 (s, 1H), 7.92-7.82 (m, 3H), 7.77 (d, *J* = 7.7 Hz, 1H), 7.71-7.62 (m, 3H), 7.60-7.54 (m, 1H), 7.53-7.45 (m, 2H), 4.99 (d, *J* = 7.2 Hz, 1H), 4.46 (dd, *J* = 9.5, 7.1 Hz, 1H), 4.10 (dd, *J* = 9.5, 7.2 Hz, 1H), 3.92 (d, *J* = 7.0 Hz, 1H), 2.88 (brs, 1H), 1.58 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 170.7, 138.9, 137.2, 136.9, 134.3, 133.4, 133.3, 130.1, 129.0, 128.2, 127.8, 127.3, 126.5, 126.4, 126.2, 124.9, 122.1, 83.1, 70.5, 67.3, 63.3, 50.0, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>25</sub>H<sub>25</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 436.1577, found: 436.1583; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) *t<sub>R</sub>* = 32.00 min, 34.45 min, 38.18 min (minor diastereomer), 40.56 min (minor diastereomer).



**<sup>t</sup>Butyl**

**(1S,3R,3aR,8bR)-3-(thiophen-2-yl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

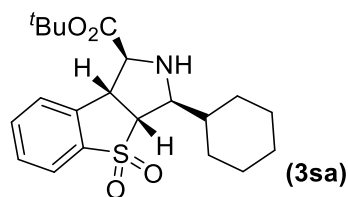
White solid, yield: 68.0 mg, 87%; m.p.: 151-154 °C;  $[\alpha]_D^{25} = -30.4$  (*c* 0.98, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 7.8 Hz, 1H), 7.70-7.60 (m, 2H), 7.59-7.53 (m, 1H), 7.31-7.25 (m, 1H), 7.21-7.16 (m, 1H), 7.02 (dd, *J* = 5.1, 3.5 Hz, 1H), 5.02 (brs, 1H), 4.46 (dd, *J* = 9.4, 6.8 Hz, 1H), 4.05 (dd, *J* = 9.4, 7.2 Hz, 1H), 3.85 (d, *J* = 6.7 Hz, 1H), 2.88 (brs, 1H), 1.56 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 170.4, 143.1, 138.7, 137.3, 134.4, 130.1, 127.3, 127.2, 125.5, 125.5, 122.1, 83.2, 70.6, 67.4, 59.5, 49.8, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>19</sub>H<sub>21</sub>NO<sub>4</sub>S<sub>2</sub> [M+H]<sup>+</sup>: 392.0985, found: 392.0990; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm) *t<sub>R</sub>* = 27.38 min, 31.36 min (minor diastereomer), 34.00 min (minor diastereomer), 52.75 min.



**<sup>t</sup>Butyl**

**(1S,3S,3aR,8bR)-3-(furan-2-yl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

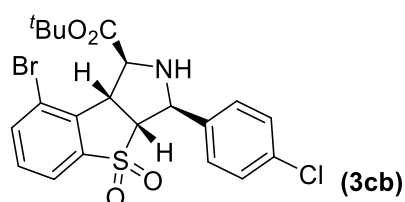
White solid, yield: 54.0 mg, 72%; m.p.: 163-165 °C;  $[\alpha]_D^{25} = -22.7$  (*c* 1.13, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.74 (d, *J* = 7.7 Hz, 1H), 7.70-7.63 (m, 1H), 7.62-7.52 (m, 2H), 7.44-7.40 (m, 1H), 6.43-6.35 (m, 2H), 4.87 (d, *J* = 6.0 Hz, 1H), 4.50 (dd, *J* = 9.3, 5.8 Hz, 1H), 4.18 (dd, *J* = 9.3, 6.0 Hz, 1H), 3.81 (d, *J* = 5.9 Hz, 1H), 2.88 (brs, 1H) 1.54 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 170.7, 151.7, 142.9, 138.6, 137.6, 134.4, 130.0, 127.1, 122.0, 110.8, 108.2, 83.1, 67.8, 67.6, 57.6, 50.1, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>19</sub>H<sub>21</sub>NO<sub>5</sub>S [M+H]<sup>+</sup>: 376.1213, found: 376.1218; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm) *t<sub>R</sub>* = 29.06 min, 50.07 min.



**<sup>t</sup>Butyl**

**(1S,3S,3aR,8bR)-3-cyclohexyl-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

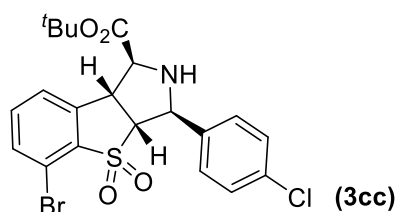
White solid, yield: 66.5 mg, 85%; m.p.: 156-158 °C;  $[\alpha]_D^{25} = -16.0$  (*c* 1.17, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.74-7.70 (m, 1H), 7.64-7.59 (m, 1H), 7.53 (m, 2H), 4.17 (dd, *J* = 9.7, 7.8 Hz, 1H), 3.74 (dd, *J* = 9.7, 6.6 Hz, 1H), 3.63 (d, *J* = 7.8 Hz, 1H), 3.55 (dd, *J* = 7.9, 6.6 Hz, 1H), 2.43 (brs, 1H), 1.98 (d, *J* = 12.4 Hz, 1H), 1.90-1.78 (m, 3H), 1.74-1.62 (m, 2H), 1.55 (s, 9H), 1.33-1.09 (m, 5H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 171.0, 139.2, 136.7, 133.9, 129.9, 127.2, 122.0, 83.0, 67.7, 67.2, 65.2, 50.7, 42.1, 30.5, 30.0, 28.2, 26.4, 26.2, 26.0; **HRMS** (ESI, *m/z*) calcd for C<sub>21</sub>H<sub>29</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 392.1890, found: 392.1895; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) *t<sub>R</sub>* = 15.91 min, 16.97 min.



**<sup>t</sup>Butyl**

**(1*S*,3*S*,3*aR*,8*bR*)-8-bromo-3-(4-chlorophenyl)-2,3,3*a*,8*b*-tetrahydro-1*H*-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide**

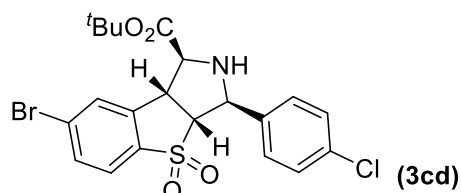
White solid, yield: 82.5 mg, 83%; m.p.: 167-170 °C;  $[\alpha]_D^{25} = -35.1$  (*c* 0.90, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.75 (d, *J* = 7.4 Hz, 1H), 7.69 (dd, *J* = 7.9, 0.9 Hz, 1H), 7.40 (t, *J* = 7.8 Hz, 1H), 7.36-7.29 (m, 4H), 4.60 (d, *J* = 3.0 Hz, 1H), 4.44 (dd, *J* = 8.3, 3.0 Hz, 1H), 4.27 (d, *J* = 8.0 Hz, 1H), 4.18 (t, *J* = 8.2 Hz, 1H), 2.84 (brs, 1H), 1.50 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.5, 140.4, 138.6, 137.8, 135.9, 134.3, 131.5, 129.3, 129.0, 122.5, 121.4, 83.1, 69.0, 68.6, 59.0, 53.1, 28.1; **HRMS** (ESI, *m/z*) calcd for C<sub>21</sub>H<sub>21</sub>BrClNO<sub>4</sub>S [M+H]<sup>+</sup>: 498.0136, found: 498.0141; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) *t<sub>R</sub>* = 16.76 min, 17.96 min, 21.60 min (minor diastereomer), 22.83 min (minor diastereomer).



**<sup>t</sup>Butyl**

**(1*S*,3*S*,3*aR*,8*bR*)-5-bromo-3-(4-chlorophenyl)-2,3,3*a*,8*b*-tetrahydro-1*H*-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 91.4 mg, 92%; m.p.: 208-210 °C;  $[\alpha]_D^{25} = -6.6$  (*c* 1.01, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.67 (d, *J* = 7.8 Hz, 1H), 7.59 (d, *J* = 7.8 Hz, 1H), 7.55-7.45 (m, 3H), 7.41-7.34 (m, 2H), 4.82 (d, *J* = 7.4 Hz, 1H), 4.35 (dd, *J* = 9.7, 7.2 Hz, 1H), 3.94 (dd, *J* = 9.7, 7.4 Hz, 1H), 3.82 (d, *J* = 7.1 Hz, 1H), 2.74 (brs, 1H), 1.56 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.3, 140.3, 138.0, 137.9, 135.1, 134.3, 134.3, 129.2, 128.6, 126.2, 116.8, 83.4, 71.0, 67.2, 62.8, 48.1, 28.2; **HRMS** (ESI, *m/z*) calcd for C<sub>21</sub>H<sub>21</sub>BrClNO<sub>4</sub>S [M+H]<sup>+</sup>: 498.0136, found: 498.0141; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) *t<sub>R</sub>* = 22.82 min, 29.49 min.

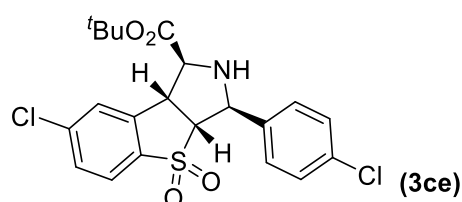


**<sup>t</sup>Butyl**

**(1*S*,3*S*,3*aR*,8*bR*)-7-bromo-3-(4-chlorophenyl)-2,3,3*a*,8*b*-tetrahydro-1*H*-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 93.4 mg, 94%; m.p.: 140-143 °C;  $[\alpha]_D^{25} = -16.7$  (*c* 0.98, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR**

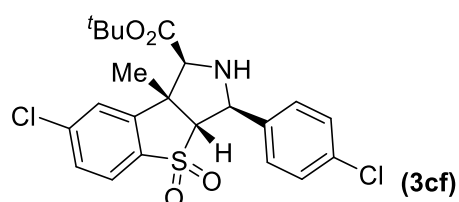
(400 MHz, CDCl<sub>3</sub>)  $\delta$  7.84 (s, 1H), 7.69 (dd,  $J$  = 8.3, 1.2 Hz, 1H), 7.61 (d,  $J$  = 8.3 Hz, 1H), 7.49 (d,  $J$  = 8.4 Hz, 2H), 7.37 (d,  $J$  = 8.4 Hz, 2H), 4.77 (t,  $J$  = 7.3 Hz, 1H), 4.34 (dd,  $J$  = 9.4, 7.4 Hz, 1H), 3.92 (dd,  $J$  = 9.5, 7.4 Hz, 1H), 3.84 (t,  $J$  = 7.3 Hz, 1H), 2.76-2.68 (m, 1H), 1.59 (s, 9H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.2, 139.0, 137.9, 137.8, 134.3, 133.5, 130.7, 129.2, 129.0, 128.5, 123.5, 83.6, 70.6, 66.9, 62.4, 49.2, 28.3; **HRMS** (ESI,  $m/z$ ) calcd for C<sub>21</sub>H<sub>21</sub>BrClNO<sub>4</sub>S [M+H]<sup>+</sup>: 498.0136, found: 498.0141; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm)  $t_R$  = 28.15 min, 30.49 min.



#### **<sup>t</sup>Butyl**

#### **(1S,3S,3aR,8bR)-7-chloro-3-(4-chlorophenyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 77.1 mg, 85%; m.p.: 126-128 °C; [ $\alpha$ ]<sub>D</sub><sup>25</sup> = -13.4 (*c* 0.91, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.68 (d,  $J$  = 8.5 Hz, 2H), 7.56-7.46 (m, 3H), 7.40-7.34 (m, 2H), 4.77 (t,  $J$  = 7.5 Hz, 1H), 4.34 (dd,  $J$  = 9.5, 7.2 Hz, 1H), 3.93 (dd,  $J$  = 9.6, 7.5 Hz, 1H), 3.84 (t,  $J$  = 7.2 Hz, 1H), 2.76-2.67 (m, 1H), 1.59 (s, 9H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  170.2, 140.7, 139.0, 137.9, 137.3, 134.3, 130.7, 129.2, 128.5, 127.7, 123.4, 83.5, 70.7, 66.8, 62.4, 49.2, 28.2; **HRMS** (ESI,  $m/z$ ) calcd for C<sub>21</sub>H<sub>21</sub>Cl<sub>2</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 454.0641, found: 454.0647; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm)  $t_R$  = 16.78 min, 42.65 min.

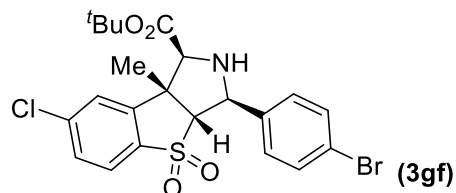


#### **<sup>t</sup>Butyl**

#### **(1S,3S,3aR,8bR)-7-chloro-3-(4-chlorophenyl)-8b-methyl-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 79.4 mg, 85%; m.p.: 149-152 °C; [ $\alpha$ ]<sub>D</sub><sup>25</sup> = -14.4 (*c* 1.00, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.77 (d,  $J$  = 1.8 Hz, 1H), 7.66 (d,  $J$  = 8.3 Hz, 1H), 7.56-7.48 (m, 3H), 7.41-7.35 (m, 2H), 4.71 (brs, 1H), 3.91 (brs, 1H), 3.50 (d,  $J$  = 7.7 Hz, 1H), 2.74 (brs, 1H), 1.65 (s, 3H), 1.61 (s, 9H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)  $\delta$  168.8, 144.1, 140.7, 137.8, 136.6, 134.3, 130.6,

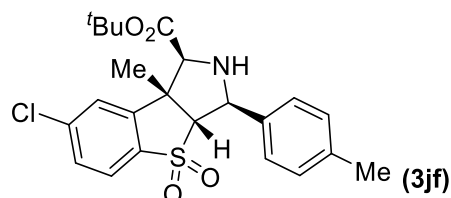
129.2, 128.5, 126.9, 123.3, 83.7, 78.1, 69.6, 61.0, 55.6, 28.3, 24.0; **HRMS** (ESI, *m/z*) calcd for C<sub>22</sub>H<sub>23</sub>Cl<sub>2</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 468.0798, found: 468.0803; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) t<sub>R</sub> = 17.61 min, 20.11 min.



**Butyl**

**(1S,3S,3aR,8bR)-3-(4-bromophenyl)-7-chloro-8b-methyl-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide**

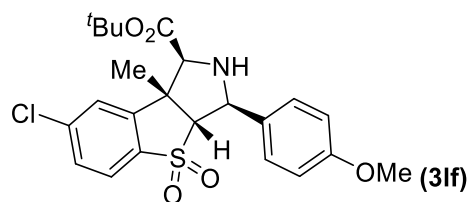
White solid, yield: 87.9 mg, 86%; m.p.: 140-141 °C; [α]<sub>D</sub><sup>25</sup> = -15.2 (*c* 0.90, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.77 (d, *J* = 1.6 Hz, 1H), 7.66 (d, *J* = 8.3 Hz, 1H), 7.58-7.51 (m, 3H), 7.45 (d, *J* = 8.3 Hz, 2H), 4.74-4.65 (m, 1H), 3.91 (d, *J* = 5.7 Hz, 1H), 3.49 (d, *J* = 7.7 Hz, 1H), 2.74 (brs, 1H), 1.64 (s, 3H), 1.61 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 168.8, 144.1, 140.7, 138.3, 136.5, 132.2, 130.6, 128.8, 126.9, 123.3, 122.4, 83.7, 78.0, 69.6, 61.0, 55.6, 28.3, 24.0; **HRMS** (ESI, *m/z*) calcd for C<sub>22</sub>H<sub>23</sub>BrClNO<sub>4</sub>S [M+H]<sup>+</sup>: 512.0292, found: 512.0298; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) t<sub>R</sub> = 20.49 min, 24.37 min.



**Butyl**

**(1S,3S,3aR,8bR)-7-chloro-8b-methyl-3-(*p*-tolyl)-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-*c*]pyrrole-1-carboxylate 4,4-dioxide**

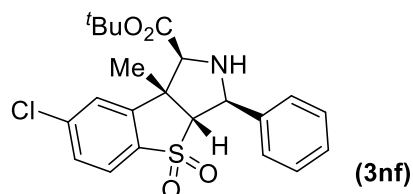
White solid, yield: 76.0 mg, 85%; m.p.: 145-147 °C; [α]<sub>D</sub><sup>25</sup> = -5.4 (*c* 1.08, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.76 (d, *J* = 1.8 Hz, 1H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.52 (dd, *J* = 8.3, 1.8 Hz, 1H), 7.42 (d, *J* = 8.2 Hz, 2H), 7.22 (d, *J* = 8.1 Hz, 2H), 4.74-4.66 (m, 1H), 3.89 (d, *J* = 8.2 Hz, 1H), 3.56 (d, *J* = 7.8 Hz, 1H), 2.85-2.78 (m, 1H), 2.37 (s, 3H), 1.65 (s, 3H), 1.61 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 168.9, 144.3, 140.6, 138.2, 136.8, 136.0, 130.5, 129.8, 126.9, 126.8, 123.2, 83.6, 78.2, 69.9, 61.7, 56.2, 28.3, 24.0, 21.3; **HRMS** (ESI, *m/z*) calcd for C<sub>23</sub>H<sub>26</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 448.1344, found: 448.1349; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) t<sub>R</sub> = 14.09 min, 17.68 min.



#### **<sup>t</sup>Butyl**

#### **(1S,3S,3aR,8bR)-7-chloro-3-(4-methoxyphenyl)-8b-methyl-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 86.1 mg, 93%; m.p.: 167-168 °C;  $[\alpha]_D^{25} = -11.4$  (*c* 1.06, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.76 (d, *J* = 1.8 Hz, 1H), 7.65 (d, *J* = 8.3 Hz, 1H), 7.53 (dd, *J* = 8.3, 1.8 Hz, 1H), 7.45 (d, *J* = 8.7 Hz, 2H), 6.94 (d, *J* = 8.7 Hz, 2H), 4.70-4.62 (m, 1H), 3.89 (d, *J* = 8.7 Hz, 1H), 3.82 (s, 3H), 3.53 (d, *J* = 8.0 Hz, 1H), 2.81-2.73 (m, 1H), 1.65 (s, 3H), 1.61 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 168.9, 159.7, 144.4, 140.6, 136.8, 130.9, 130.5, 128.3, 126.8, 123.2, 114.4, 83.6, 78.2, 69.9, 61.6, 56.1, 55.5, 28.3, 24.1; **HRMS** (ESI, *m/z*) calcd for C<sub>23</sub>H<sub>26</sub>ClNO<sub>5</sub>S [M+H]<sup>+</sup>: 464.1293, found: 464.1298; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) *t<sub>R</sub>* = 19.66 min, 25.39 min.



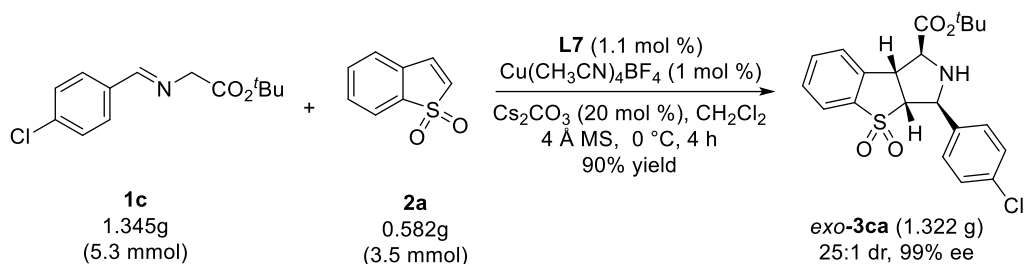
#### **<sup>t</sup>Butyl**

#### **(1S,3S,3aR,8bR)-7-chloro-8b-methyl-3-phenyl-2,3,3a,8b-tetrahydro-1H-benzo[4,5]thieno[2,3-c]pyrrole-1-carboxylate 4,4-dioxide**

White solid, yield: 82.3 mg, 95%; m.p.: 179-182 °C;  $[\alpha]_D^{25} = -11.7$  (*c* 0.89, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.77 (d, *J* = 1.7 Hz, 1H), 7.66 (d, *J* = 8.3 Hz, 1H), 7.59-7.49 (m, 3H), 7.46-7.39 (m, 2H), 7.38-7.30 (m, 1H), 4.75 (dd, *J* = 9.6, 7.7 Hz, 1H), 3.91 (d, *J* = 9.5 Hz, 1H), 3.58 (d, *J* = 7.7 Hz, 1H), 2.83 (t, *J* = 9.6 Hz, 1H), 1.65 (s, 3H), 1.61 (s, 9H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 168.8, 144.2, 140.6, 139.1, 136.7, 130.5, 129.1, 128.4, 127.0, 126.8, 123.2, 83.6, 78.2, 69.9, 61.8, 56.0, 28.3, 24.0; **HRMS** (ESI, *m/z*) calcd for C<sub>22</sub>H<sub>24</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 434.1187, found: 434.1193; **HPLC** (Chiralpak AS-H, *n*-hexane/EtOH = 90/10, 1.0 mL/min, 220 nm) *t<sub>R</sub>* = 11.27 min, 14.00 min.

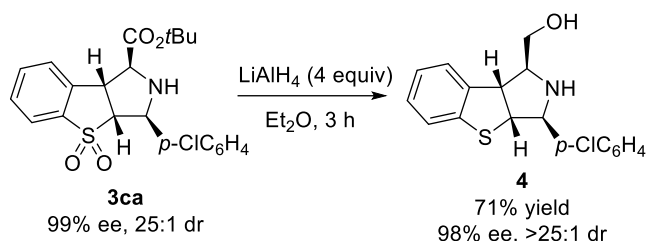
## **4. Gram scale procedure for the 1,3-dipolar cycloaddition of 1c to 2a**





Under a nitrogen atmosphere, Cu(CH<sub>3</sub>CN)<sub>4</sub>BF<sub>4</sub> (11.0 mg, 0.035 mmol) and **L7** (45.4 mg, 0.0385 mmol) were dissolved in CH<sub>2</sub>Cl<sub>2</sub> (40 mL), and stirred at room temperature for about 1 h. Then, glycine imine **1c** (1.345 g, 5.3 mmol) and Cs<sub>2</sub>CO<sub>3</sub> (228 mg, 0.7 mmol) were added, the mixture was cooled to 0 °C and benzo[*b*]thiophene 1,1-dioxides **2a** (0.582 g, 3.5 mmol) was added. Once starting material was consumed (monitored by TLC), the mixture was filtered through celite and the filtrate was concentrated, then the residue was purified by column chromatography (petroleum ether/ethyl acetate 6:1) on silica gel to afford the corresponding product **3ca** in 90% yield.

## 5. Transformation of cycloadduct **3ca**<sup>2,3</sup>

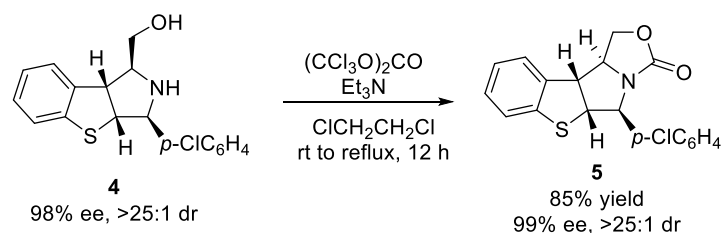


To a solution of **3ca** (251.5 mg, 0.6 mmol) in dry Et<sub>2</sub>O (8 mL) under nitrogen, LiAlH<sub>4</sub> (91.1 mg, 2.4 mmol) was added in small portions. The reaction mixture was stirred for 3 h at room temperature. To which water (0.4 mL) and 10% aqueous sodium hydroxide (0.6 mL) and more water (0.6 mL) carefully. The mixture was filtered over anhydrous Na<sub>2</sub>SO<sub>4</sub>, and the filtrate was concentrated. The residue was purified by column chromatography (petroleum ether/ethyl acetate 2:1) on silica gel to afford **4** in 71% yield.

### ((1*S*,3*S*,3*aR*,8*bR*)-3-(4-Chlorophenyl)-2,3,3*a*,8*b*-tetrahydro-1*H*-benzo[4,5]thieno[2,3-*c*]pyrrol-1-yl)methanol (**4**)

White solid, yield: 135.1 mg, 71%; m.p.: 146-148 °C; [α]<sub>D</sub><sup>25</sup> = -134.4 (*c* 1.00, CH<sub>2</sub>Cl<sub>2</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.44 (d, *J* = 8.4 Hz, 2H), 7.33 (d, *J* = 8.4 Hz, 2H), 7.21-7.16 (m, 3H), 7.15-7.05 (m, 1H), 4.16 (d, *J* = 8.6 Hz, 1H), 4.10 (dd, *J* = 9.6, 5.1 Hz, 1H), 3.96 (dd, *J* = 11.0, 3.5 Hz, 1H), 3.88 (dd, *J* = 11.0, 3.8 Hz, 1H), 3.81-3.73 (m, 1H), 3.70-3.63 (m, 1H), 2.21 (brs, 2H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 141.2, 140.1, 139.6, 133.7, 128.8, 128.3, 128.3, 124.9, 124.8, 122.6, 70.3, 66.2, 64.7, 58.9, 54.9; HRMS (ESI, *m/z*) calcd for C<sub>17</sub>H<sub>16</sub>ClNOS [M+H]<sup>+</sup>: 318.0714, found: 318.0719; HPLC (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) t<sub>R</sub> =

10.00 min, 11.25 min, 17.62 min (minor diastereomer), 20.74 min (minor diastereomer).

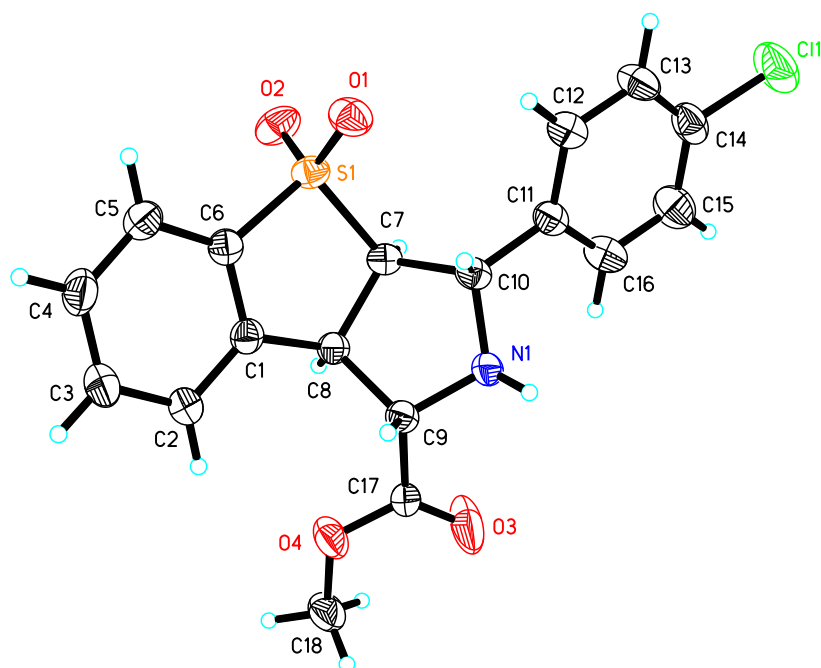


At nitrogen atmosphere, to a solution of compound **4** (0.15 mmol, 47.6 mg) in anhydrous 1,2-dichloroethane (2.0 mL), anhydrous triethylamine (0.225 mmol, 22.8 mg) and triphosgene (0.18 mmol, 53.4 mg) was added. The reaction mixture was stirred at rt for 1 h and refluxed for 12 h. The reaction mixture was cooled to rt and added 5 mL CH<sub>2</sub>Cl<sub>2</sub>, then pour into silica gel stirred for 4 h. The mixture was filtered over anhydrous Na<sub>2</sub>SO<sub>4</sub> and evaporated under vacuum, the residue was subjected to the preparative thin layer chromatography (petroleum ether/ethyl acetate 3:1) to afford the title compound **5** in 85% yield.

**(5*S*,5*aR*,10*bR*,10*cS*)-5-(4-Chlorophenyl)-5,5*a*,10*b*,10*c*-tetrahydro-1*H*,3*H*-benzo[4',5']thieno[3',2':3,4]pyrrolo[1,2-*c*]oxazol-3-one (**5**)**

White solid, yield: 43.7 mg, 85%; m.p.: 200-201 °C;  $[\alpha]_D^{25} = -136.5$  (*c* 1.15, CH<sub>2</sub>Cl<sub>2</sub>); **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>) δ 7.37 (d, *J* = 8.4 Hz, 2H), 7.32-7.15 (m, 4H), 7.16-7.07 (m, 2H), 4.72-4.63 (m, 2H), 4.59 (dd, *J* = 8.7, 5.5 Hz, 1H), 4.55-4.47 (m, 1H), 4.40 (dd, *J* = 8.6, 7.1 Hz, 1H), 4.05 (dd, *J* = 8.4, 7.0 Hz, 1H); **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>) δ 155.3, 140.3, 137.4, 134.8, 133.4, 129.5, 129.4, 129.1, 125.4, 124.7, 122.9, 68.0, 67.1, 65.8, 61.6, 57.4; **HRMS** (ESI, *m/z*) calcd for C<sub>18</sub>H<sub>14</sub>ClNO<sub>2</sub>S [M+H]<sup>+</sup>: 344.0507, found: 344.0512; **HPLC** (Chiralpak AD-H, *n*-hexane/*i*-propanol = 80/20, 0.8 mL/min, 220 nm) *t*<sub>R</sub> = 26.76 min, 32.61 min.

## 6. The absolute configuration determination of (1*S*,3*S*,3*aR*,8*bR*)-3aa



**Fig S1.** X-ray structure of (1*S*,3*S*,3*aR*,8*bR*)-**3aa**

**Crystal data and structure refinement for CCDC 1561030**

(CCDC 1561030 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via [www.ccdc.cam.ac.uk/conts/retrieving.html](http://www.ccdc.cam.ac.uk/conts/retrieving.html).)

**Table S2.** Crystal data and structure refinement for (1*S*,3*S*,3*aR*,8*bR*)-**3aa**

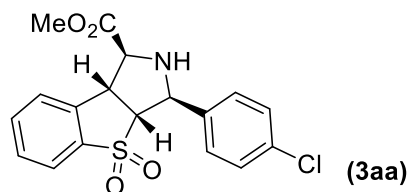
Identification code	cd1561030	
Empirical formula	C <sub>18</sub> H <sub>16</sub> Cl N O <sub>4</sub> S	
Formula weight	377.83	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P 21 21 21	
Unit cell dimensions	a = 5.1621(6) Å	α = 90 °
	b = 16.3247(18) Å	β = 90 °
	c = 20.251(2) Å	γ = 90 °
Volume	1706.5(3) Å <sup>3</sup>	
Z	4	
Density (calculated)	1.471 Mg/m <sup>3</sup>	
Absorption coefficient	0.370 mm <sup>-1</sup>	
F(000)	784	
Crystal size	0.200 x 0.150 x 0.110 mm <sup>3</sup>	

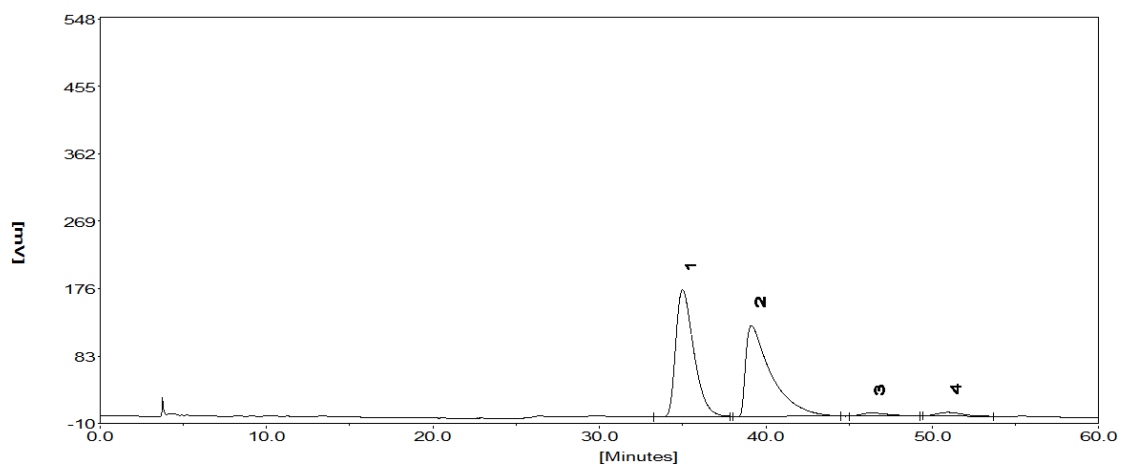
Theta range for data collection	1.602 to 26.000 °
Index ranges	-6<=h<=6, -20<=k<=14, -24<=l<=24
Reflections collected	10224
Independent reflections	3354 [R(int) = 0.0342]
Completeness to theta = 25.242 °	100.0 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.7456 and 0.6588
Refinement method	Full-matrix least-squares on F <sup>2</sup>
Data / restraints / parameters	3354 / 0 / 231
Goodness-of-fit on F <sup>2</sup>	1.035
Final R indices [I>2sigma(I)]	R1 = 0.0420, wR2 = 0.1066
R indices (all data)	R1 = 0.0476, wR2 = 0.1107
Absolute structure parameter	0.05(4)
Extinction coefficient	n/a
Largest diff. peak and hole	0.379 and -0.292 e.Å <sup>-3</sup>

## 7. References

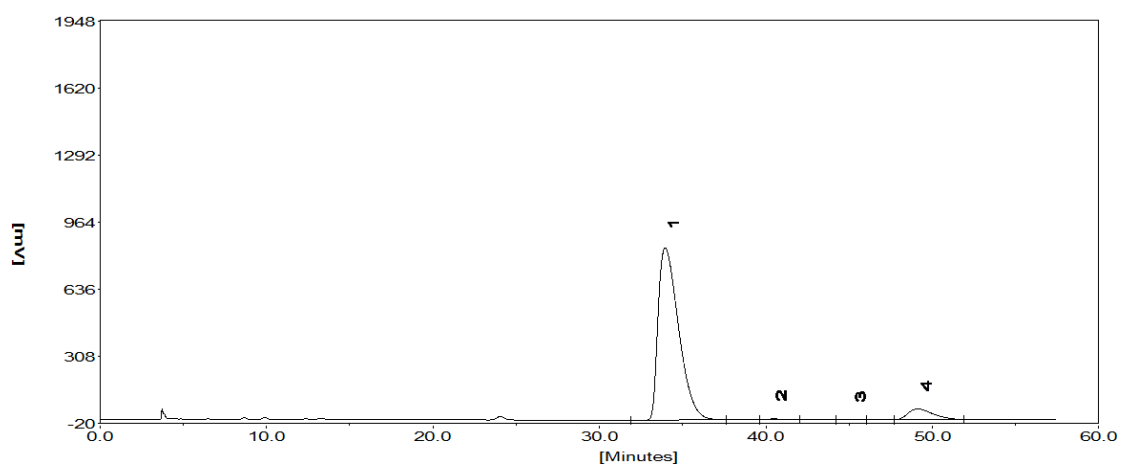
- (1) (a) Madec, D.; Mingoia, F.; Macovei, C.; Maitro, G.; Giambastiani, G.; Poli, G. *Eur. J. Org. Chem.* **2005**, 3, 552. (b) Zhang, W.; Ma, T.; Li, S.; Yang, Y.; Guo, J.; Yu, W.; Kong, L. *Eur. J. Med. Chem.* **2017**, 125, 538. (c) Antonow, D.; Marrafa, T.; Dawood, I.; Ahmed, T.; Haque, M. R.; Thurston, D. E.; Zinzalla, G. *Chem. Commun.*, **2010**, 46, 2289.
- (2) (a) Nandakumar, M.; Karunakaran, J.; Mohanakrishnan, A. K. *Org. Lett.* **2014**, 16, 3068. (b) He, F.-S.; Jin, J.-H.; Yang, Z.-T.; Yu, X.; Fossey, J. S.; Wei-Ping Deng, W.-P. *ACS Catal.* **2016**, 6, 652.
- (3) Yang, X.; Cheng, F.; Kou, Y.-D.; Pang, S.; Shen, Y.-C.; Huang, Y.-Y.; Shibata, N. *Angew. Chem. Int. Ed.* **2017**, 56, 1510.

## 8. Chiral HPLC Chromatograms

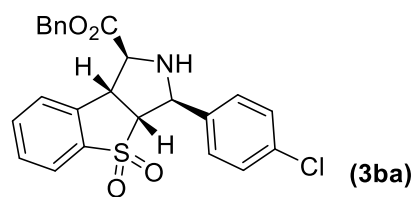


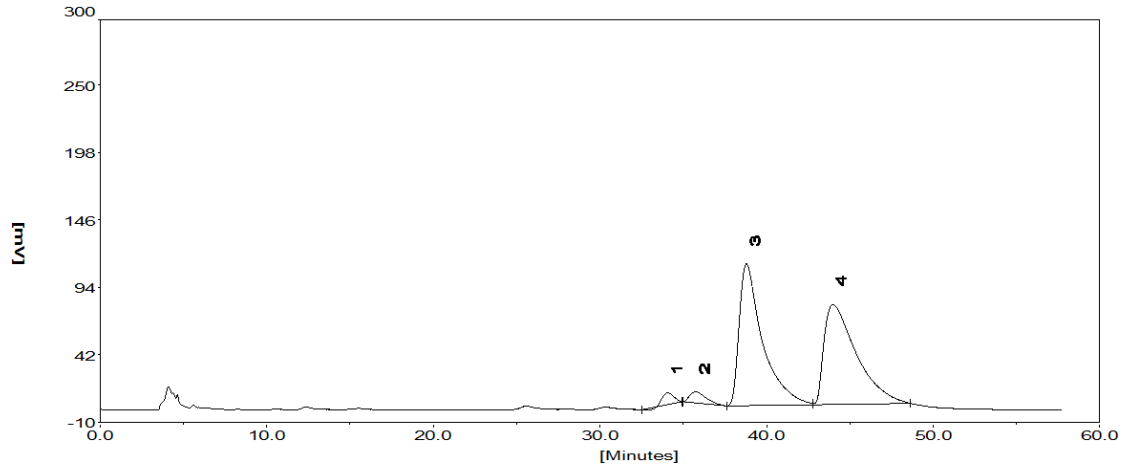


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	34.99167	175.06	13133.77	47.9385
2	39.13667	125.38	13215.14	48.2355
3	46.33583	4.90	530.62	1.8908
4	50.92333	5.21	542.44	1.9352

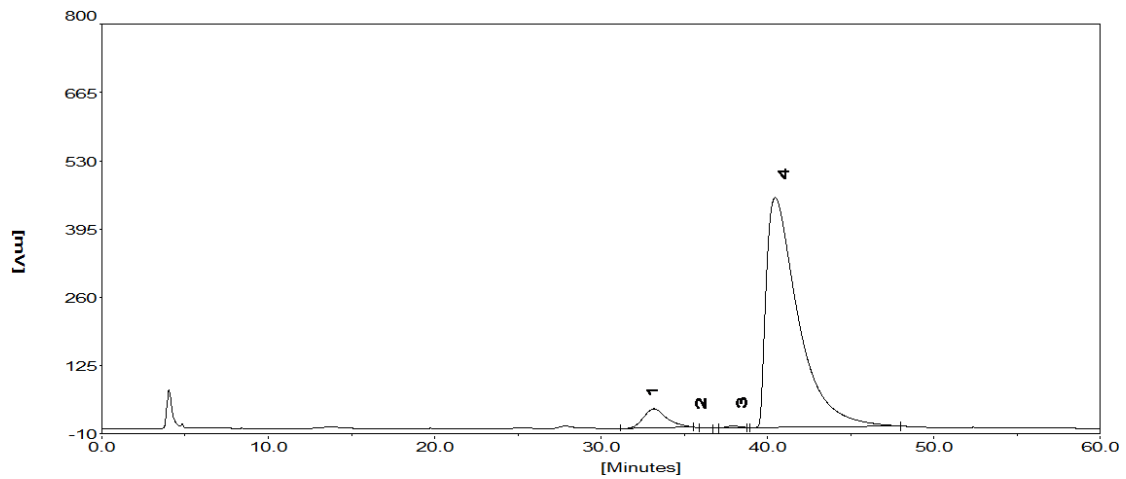


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	33.95167	842.62	71913.79	92.6071
2	40.41417	3.77	291.07	0.3748
3	45.15500	0.36	21.96	0.0283
4	49.11417	52.13	5427.93	6.9898

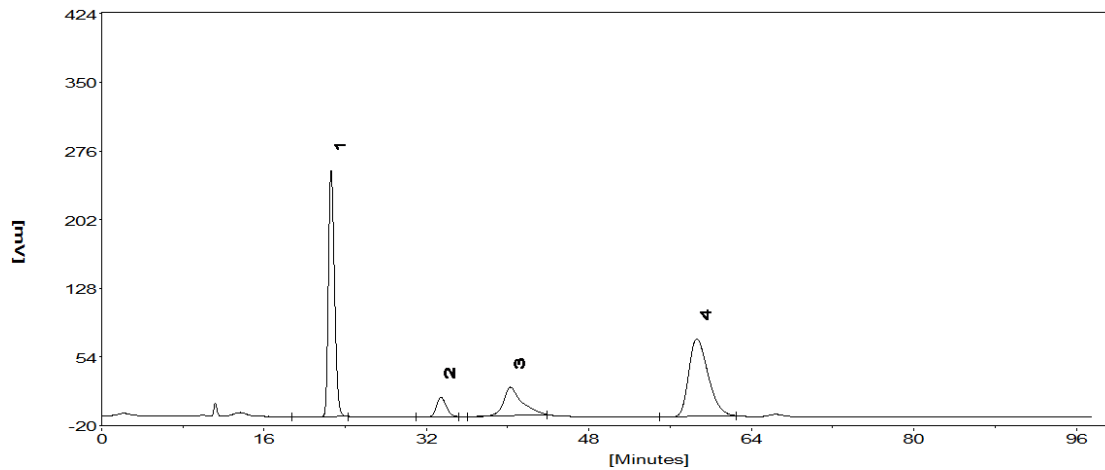
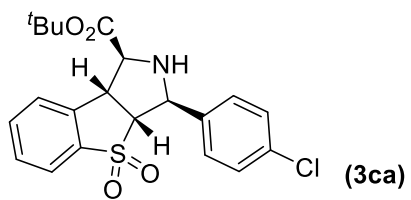




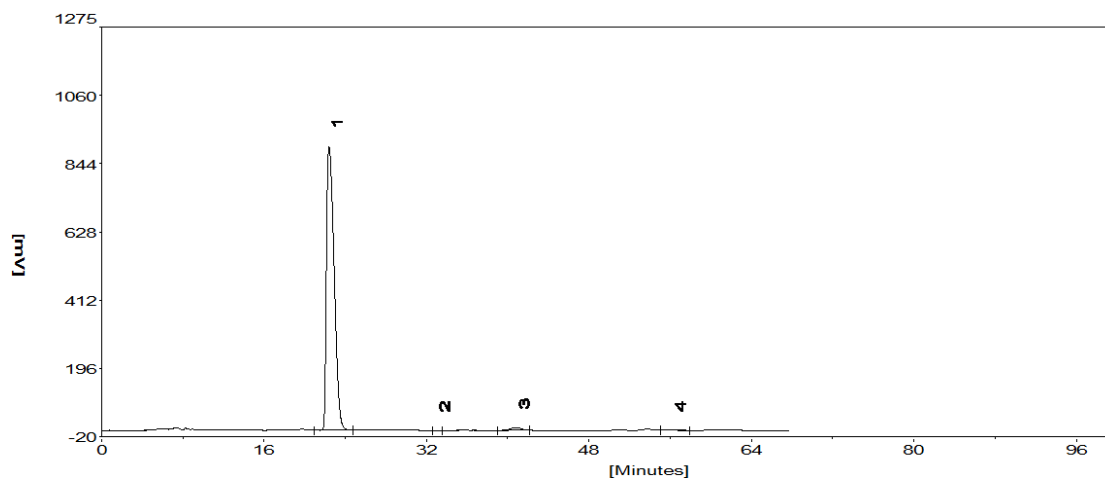
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	34.08917	8.97	400.00	1.8174
2	35.76833	8.59	583.67	2.6518
3	38.80250	109.27	10637.58	48.3304
4	42.79583	77.00	10388.87	47.2004



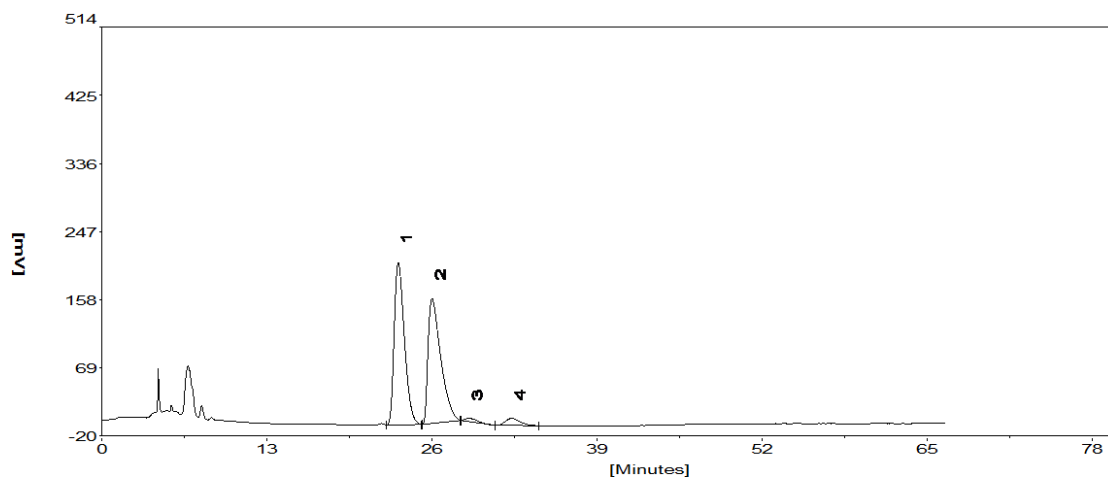
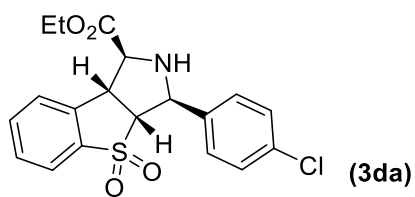
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	33.40833	29.60	1875.01	6.9895
2	35.46667	0.01	14.86	0.0237
3	38.01167	3.56	189.87	0.3027
4	41.26667	454.74	60640.73	92.6841



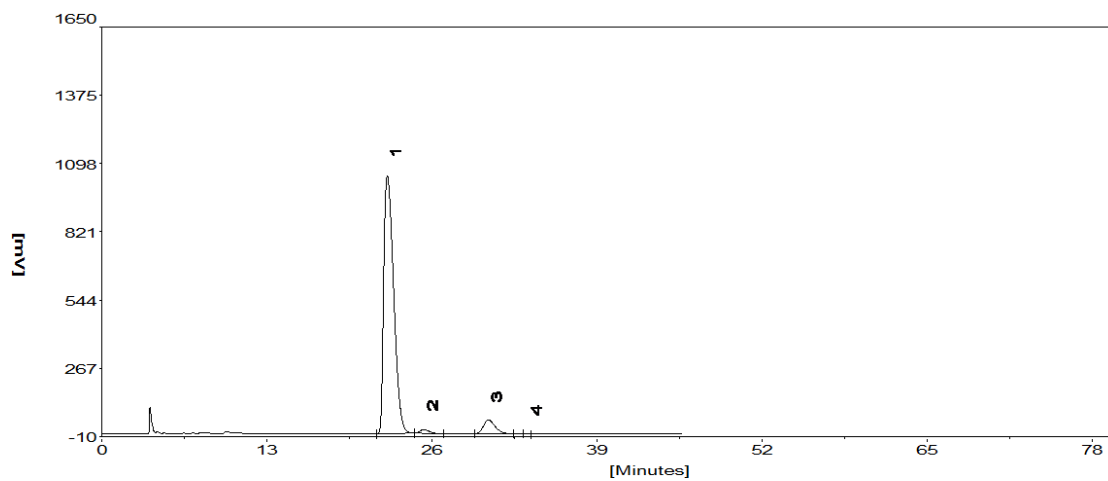
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	22.59917	265.20	10998.61	40.5199
2	33.43333	21.02	1570.97	8.0508
3	40.28833	30.53	2129.16	10.9113
4	58.62417	83.41	10998.09	40.5180



#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	22.40333	897.36	47086.23	98.4294
2	32.96583	0.10	2.02	0.0042
3	40.84833	8.73	627.27	1.3112
4	57.15667	1.41	122.03	0.2552

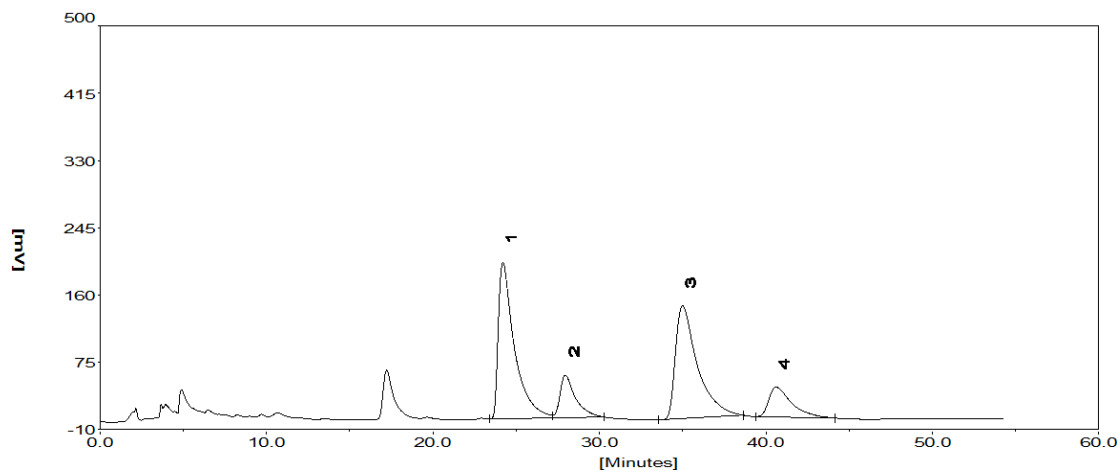
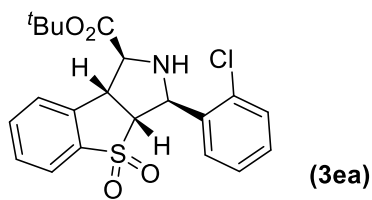


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	23.35167	211.98	11834.83	48.9742
2	26.00750	163.30	11318.42	46.8372
3	29.09917	4.23	276.93	1.6460
4	32.29000	9.14	427.79	2.5426

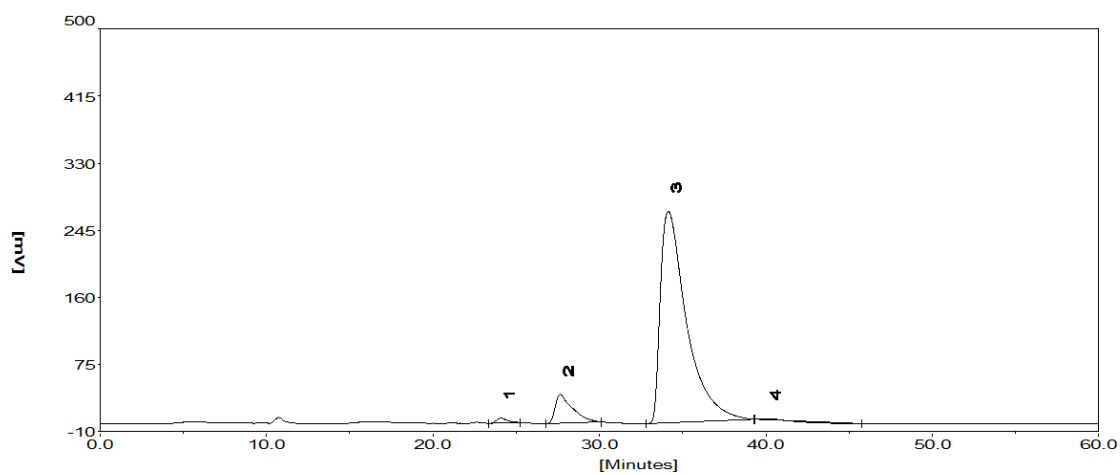


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	22.48833	1044.96	56720.04	93.0580
2	25.35917	15.31	685.64	1.1249
3	30.44500	55.78	3549.16	5.8167
4	33.53250	0.03	0.25	0.0004

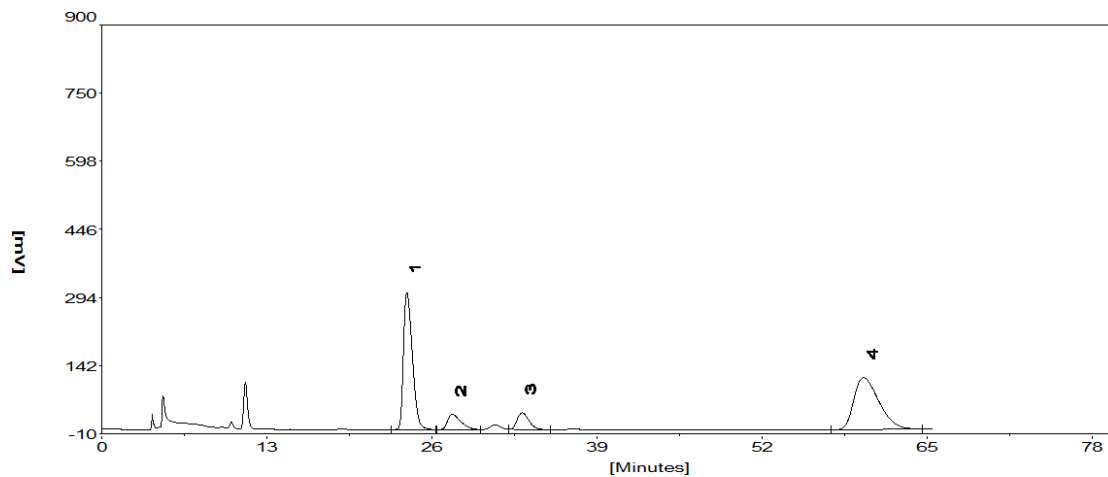
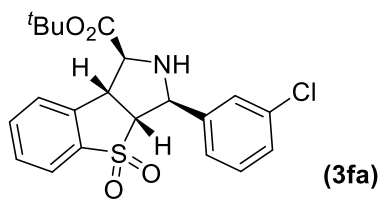




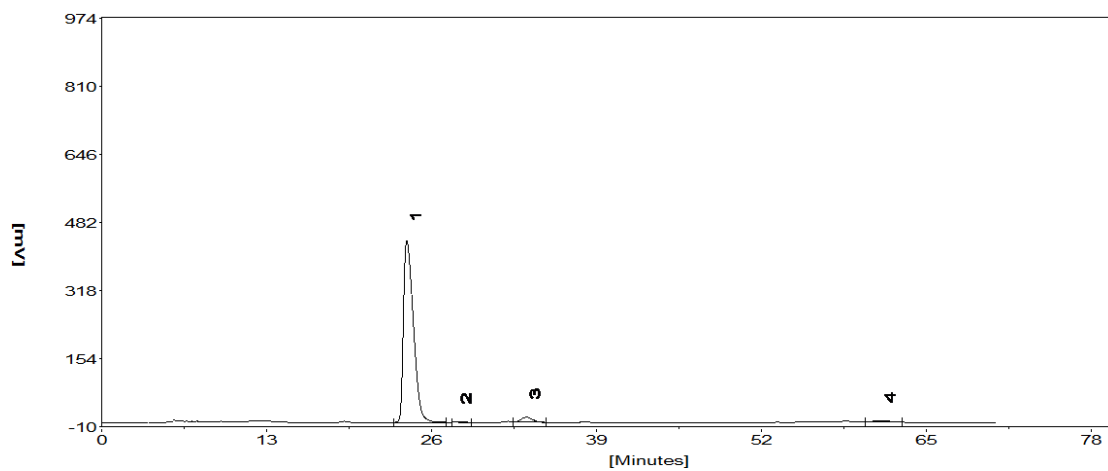
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	24.20250	197.94	13328.61	39.8415
2	27.95333	53.88	3465.04	10.3576
3	34.99667	142.56	13032.21	38.9555
4	40.61917	37.75	3628.24	10.8454



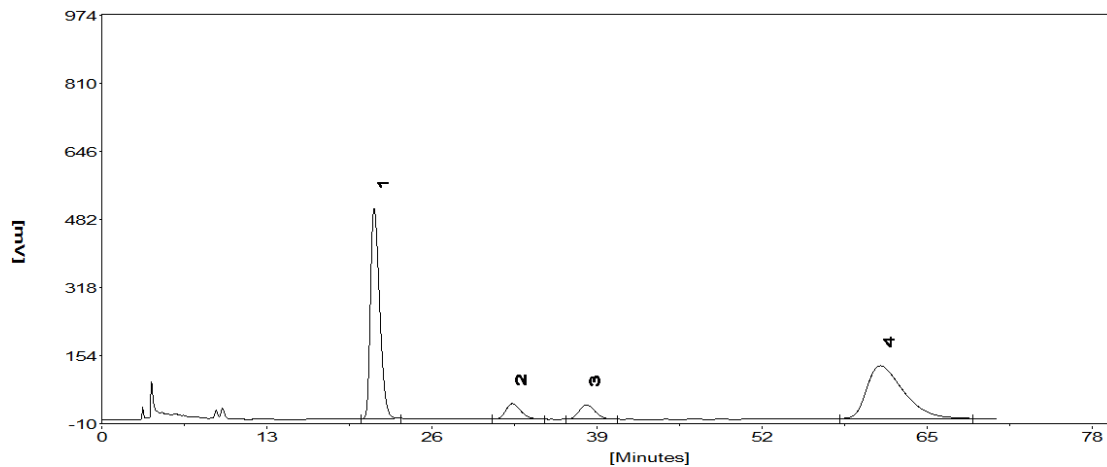
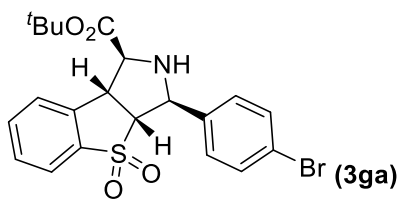
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	24.06250	6.14	277.71	0.8583
2	27.65000	36.61	2618.20	8.0920
3	34.13750	268.14	29326.64	90.6388
4	40.04917	1.63	132.95	0.4109



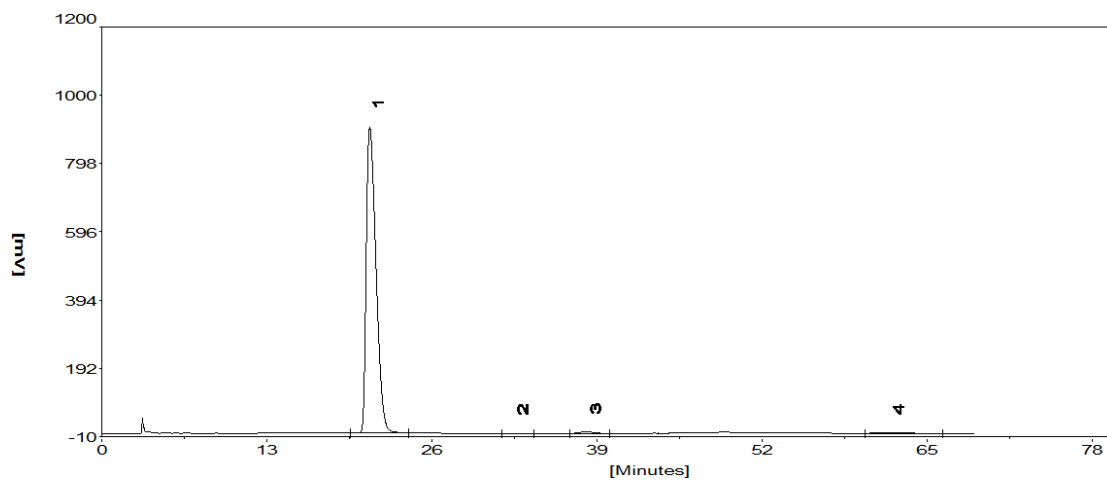
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	24.02833	305.84	14937.16	42.8965
2	27.60833	34.19	2463.83	6.9107
3	33.10917	37.18	2402.66	6.7391
4	59.98083	115.56	15131.18	43.4537



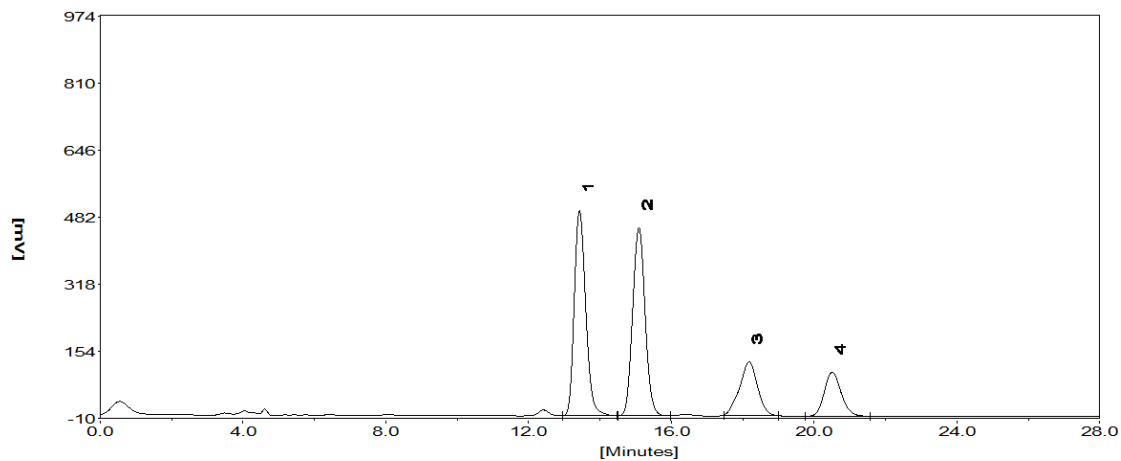
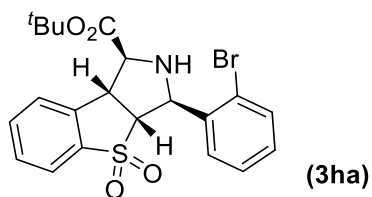
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	24.05333	437.50	23789.68	95.8562
2	28.08000	0.66	33.14	0.1335
3	33.47167	11.67	722.69	2.9119
4	60.43667	2.89	272.60	1.0984



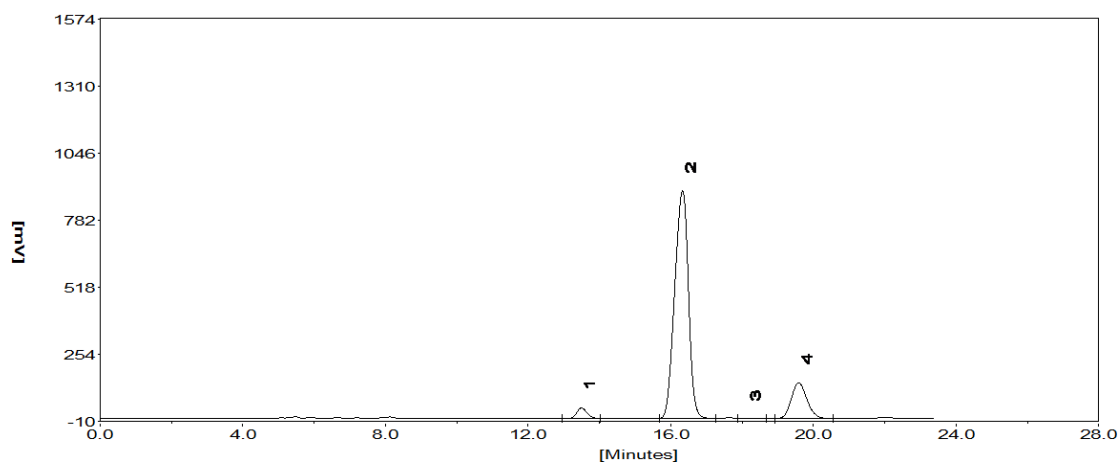
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	21.44833	505.69	25377.74	44.7536
2	32.32167	37.14	3021.45	5.3283
3	38.16833	34.59	3010.07	5.3083
4	61.30542	126.90	25296.22	44.6098



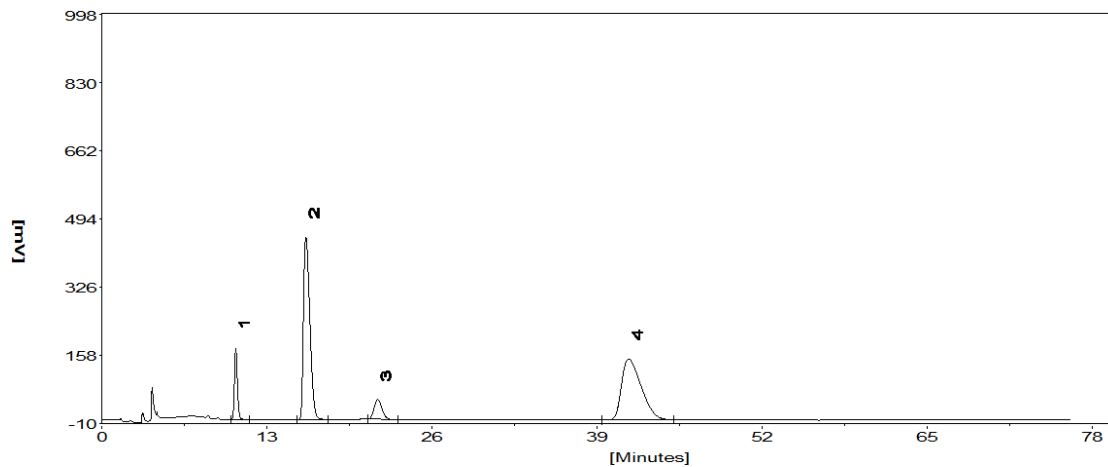
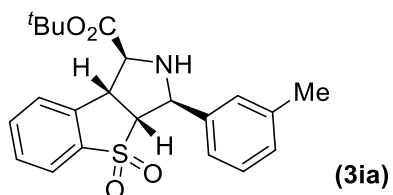
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	21.10667	903.30	48121.74	98.7536
2	32.47417	0.38	28.72	0.0589
3	38.22167	4.76	397.81	0.8164
4	62.05000	0.94	180.82	0.3711



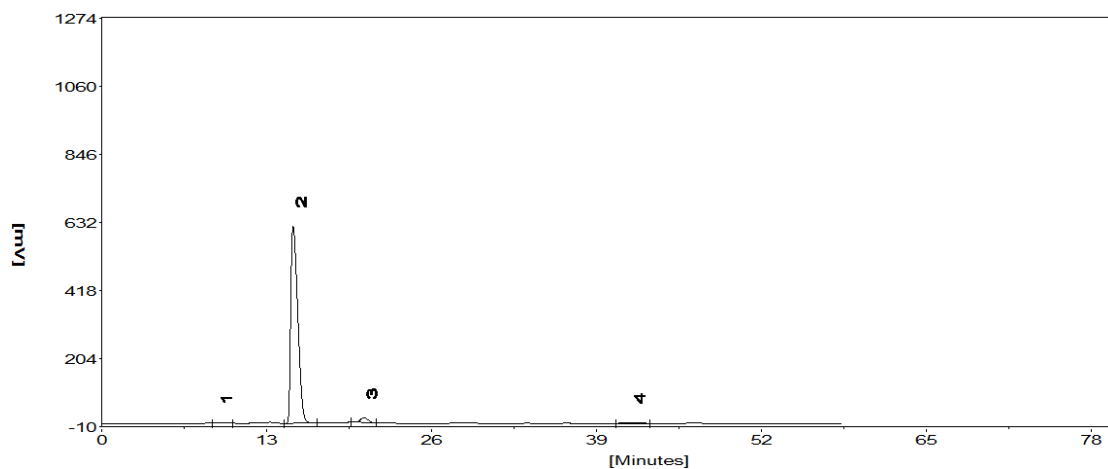
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	13.42583	500.51	11161.77	36.7201
2	15.09083	459.74	11174.50	36.7620
3	18.17583	131.03	4556.44	13.9898
4	20.50417	107.54	4080.37	12.5281



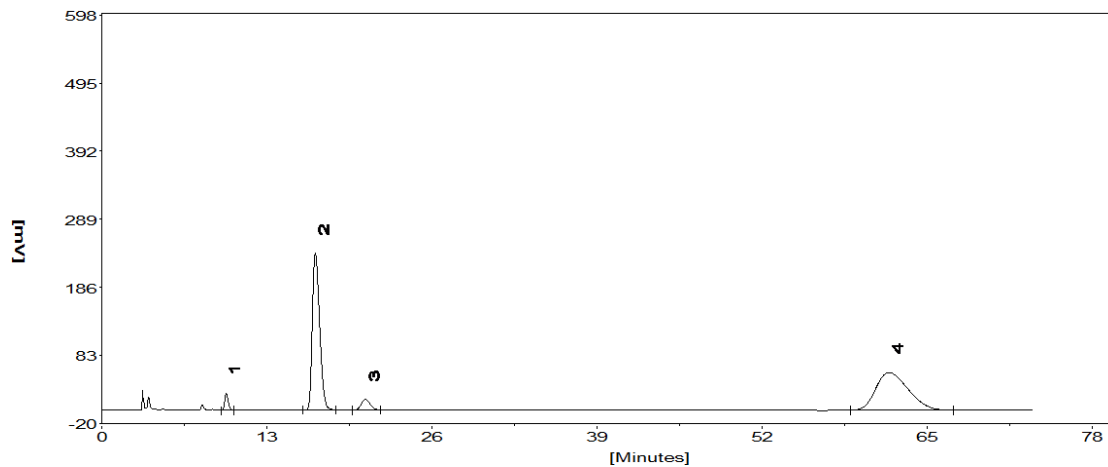
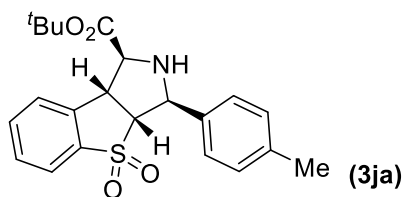
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	13.49500	41.56	853.59	2.9314
2	16.33167	896.71	23961.85	82.2904
3	18.13083	0.53	7.74	0.0266
4	19.58417	141.38	4295.47	14.7516



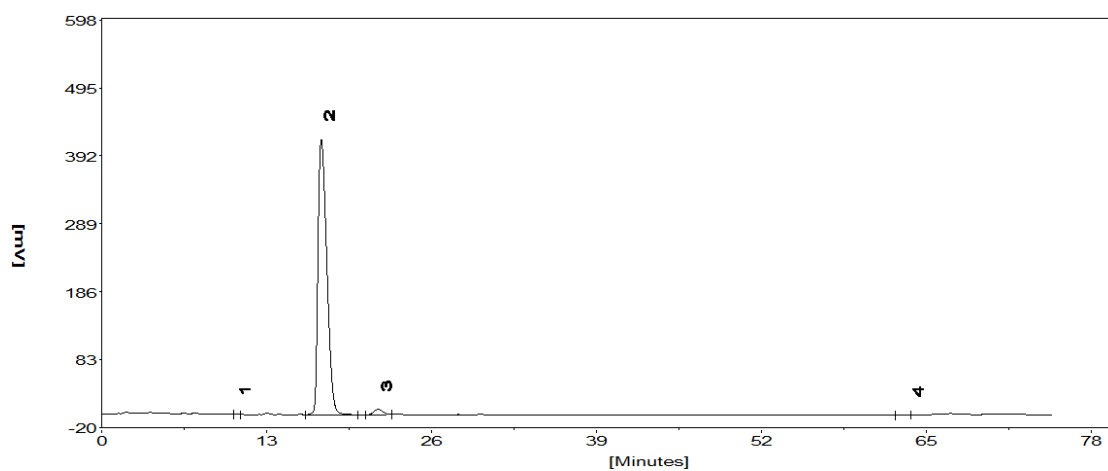
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	10.55833	175.20	2580.02	6.7632
2	16.07667	450.43	15316.69	43.7130
3	21.72750	47.96	2288.88	6.0001
4	41.48167	150.22	15250.30	43.5237



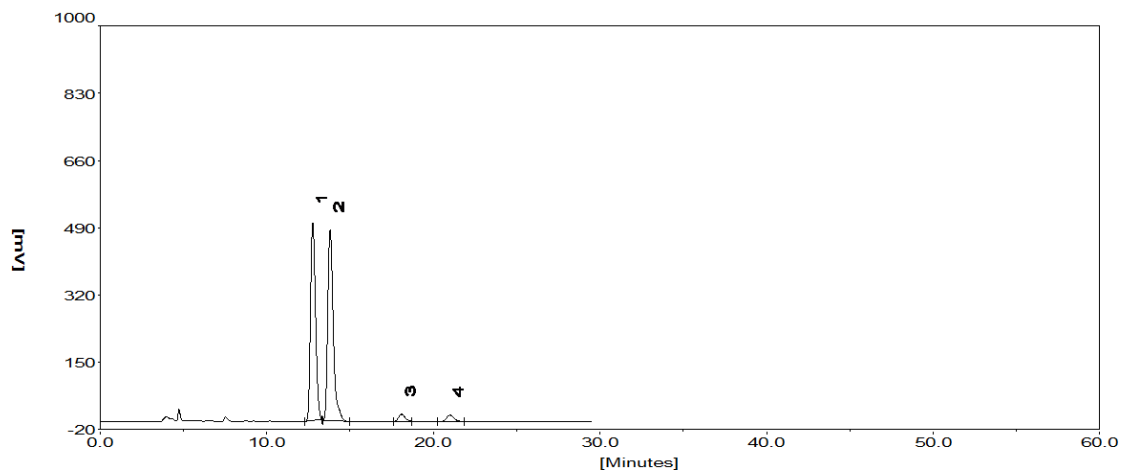
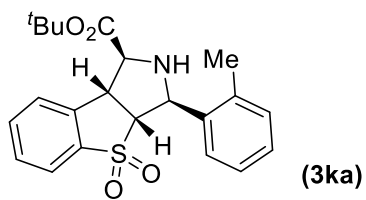
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	9.18000	0.17	1.79	0.0073
2	15.09250	619.02	23653.42	96.4214
3	20.67083	15.63	625.67	2.5505
4	41.76417	3.00	250.42	1.0208



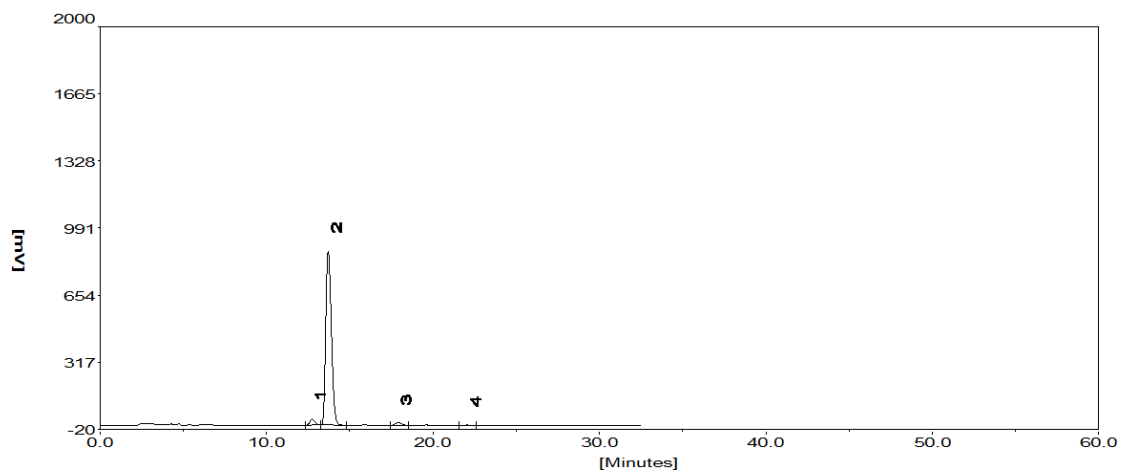
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	9.81167	25.28	665.89	2.7685
2	16.82167	236.48	9457.22	46.4253
3	20.77083	16.30	774.46	3.2199
4	62.26167	57.00	9693.73	47.5863



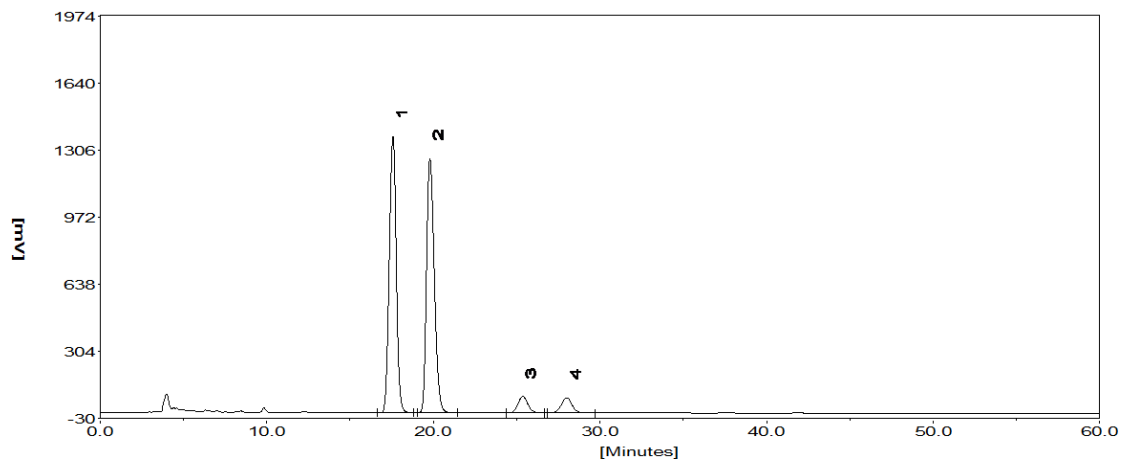
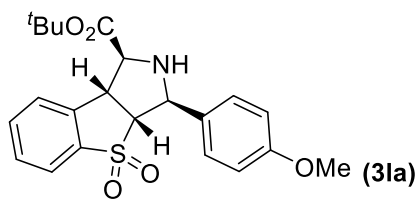
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	10.64333	0.10	0.89	0.0043
2	17.30917	417.25	20155.29	98.0406
3	21.78917	8.23	393.82	1.9157
4	63.66333	0.13	8.11	0.0394



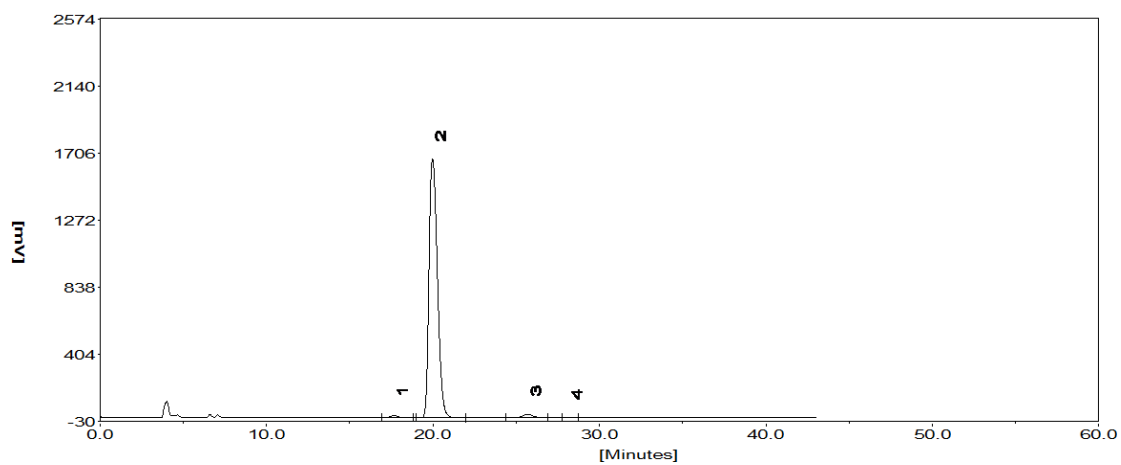
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	12.76000	500.63	10430.99	46.2312
2	13.80250	482.32	11162.69	49.4742
3	18.09083	17.67	468.75	2.0776
4	21.19750	15.96	500.24	2.2170



#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	12.74000	28.98	623.08	2.8961
2	13.70500	872.10	20469.11	95.1429
3	18.01167	13.68	359.15	1.6693
4	22.05333	2.15	62.75	0.2917

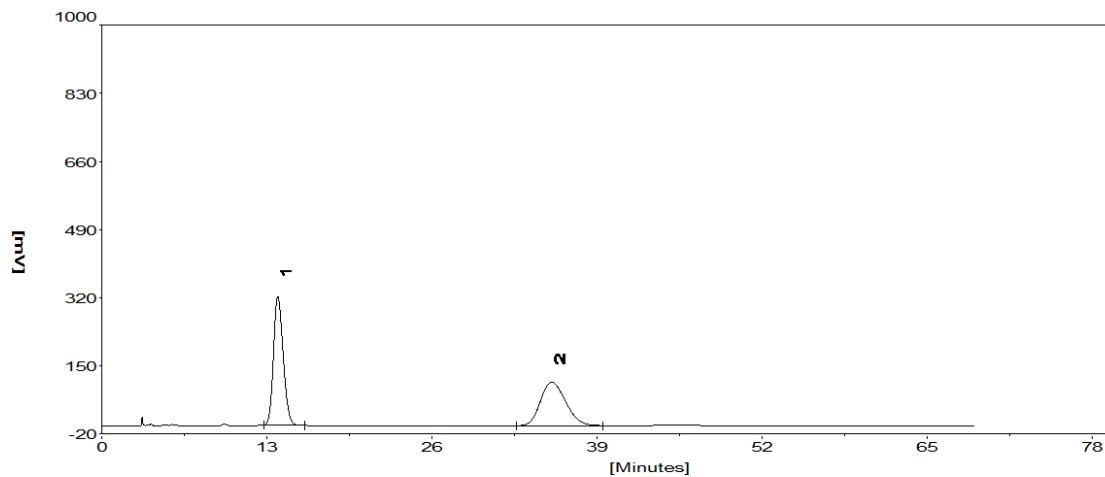
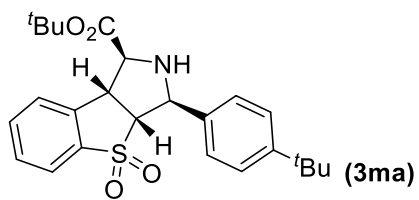


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.57667	1373.87	40236.63	45.8879
2	19.79083	1264.70	40813.39	46.5457
3	25.36250	82.05	3313.71	3.7791
4	28.00917	75.45	3320.83	3.7873

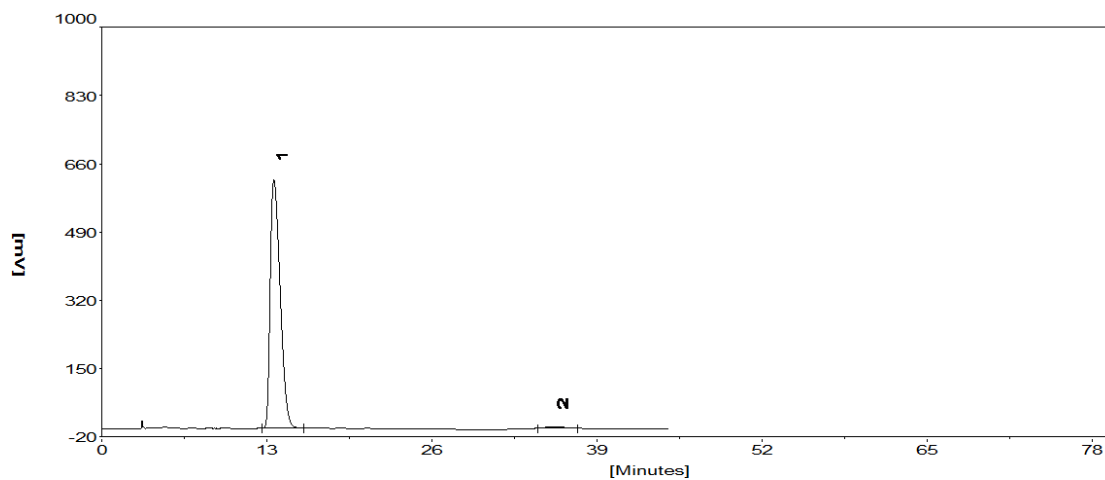


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.66167	14.48	424.83	0.7105
2	19.97167	1672.32	58512.59	97.8555
3	25.66833	20.67	848.04	1.4182
4	28.16667	0.31	9.43	0.0158

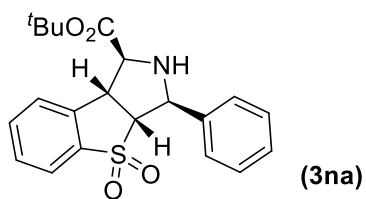


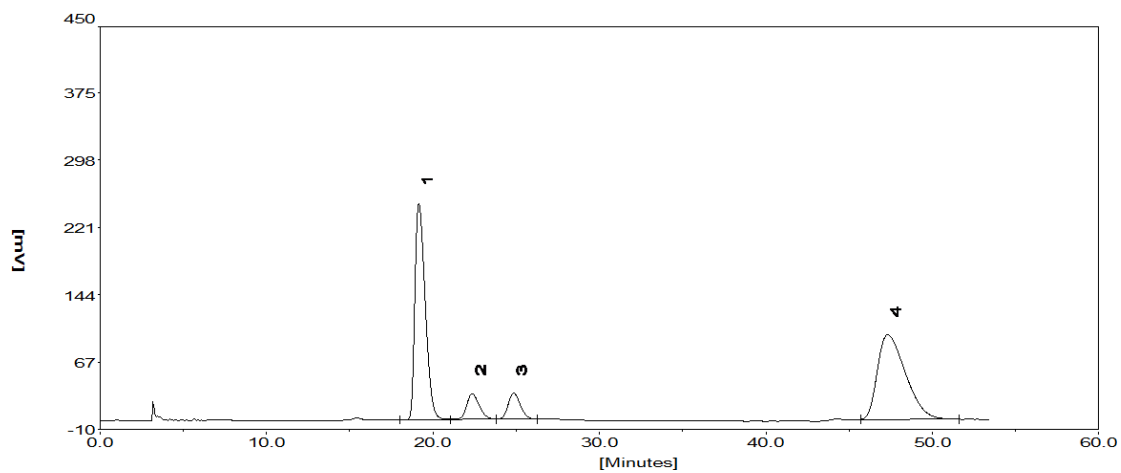


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	13.86250	320.83	16990.48	51.2406
2	35.42583	108.60	16167.76	48.7594

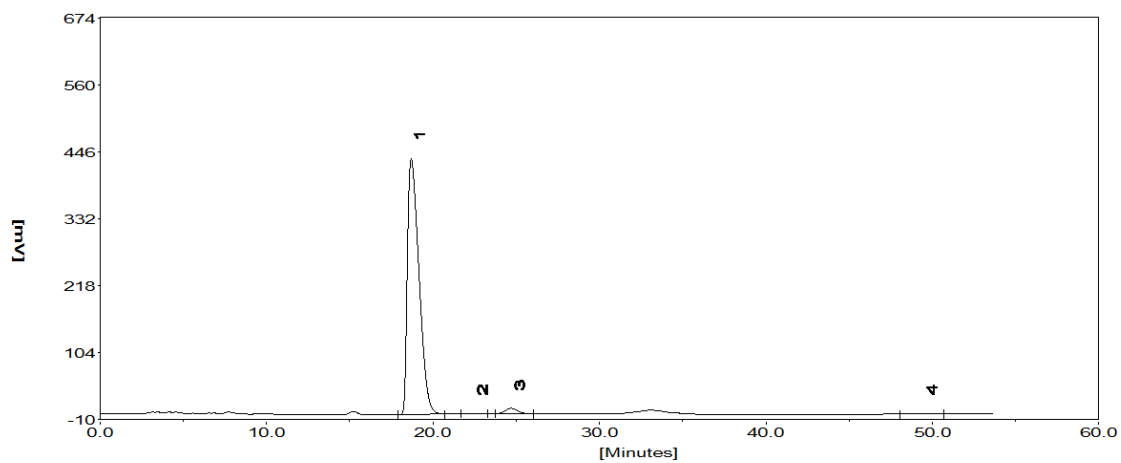


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	13.55667	618.88	33623.37	99.3253
2	35.64167	3.04	228.40	0.6747

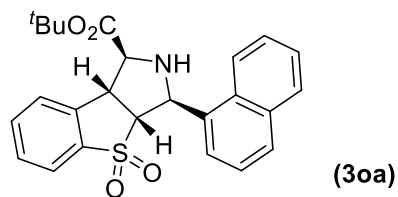


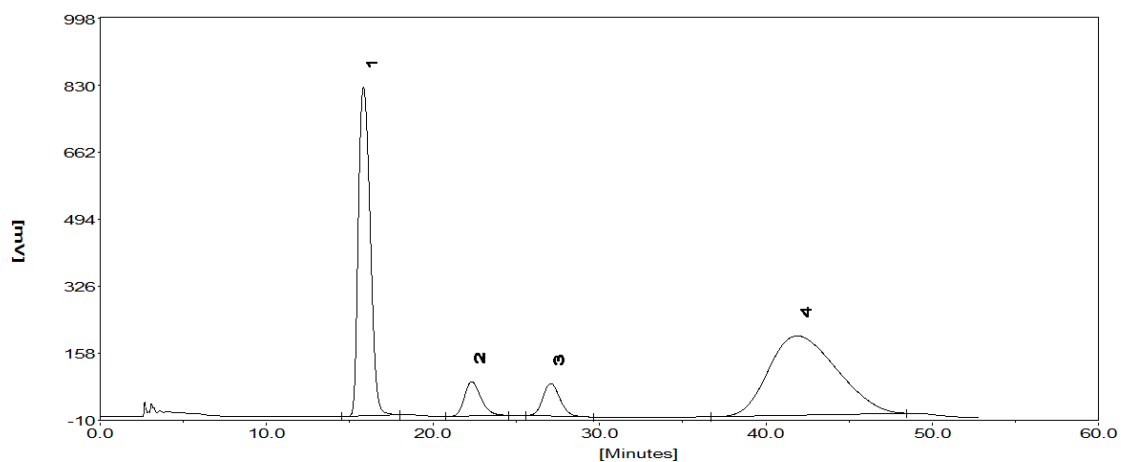


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	19.15083	247.22	10654.31	43.5836
2	22.35333	29.16	1523.81	6.0904
3	24.84500	29.57	1505.60	6.0176
4	48.31917	96.90	10831.47	44.3084

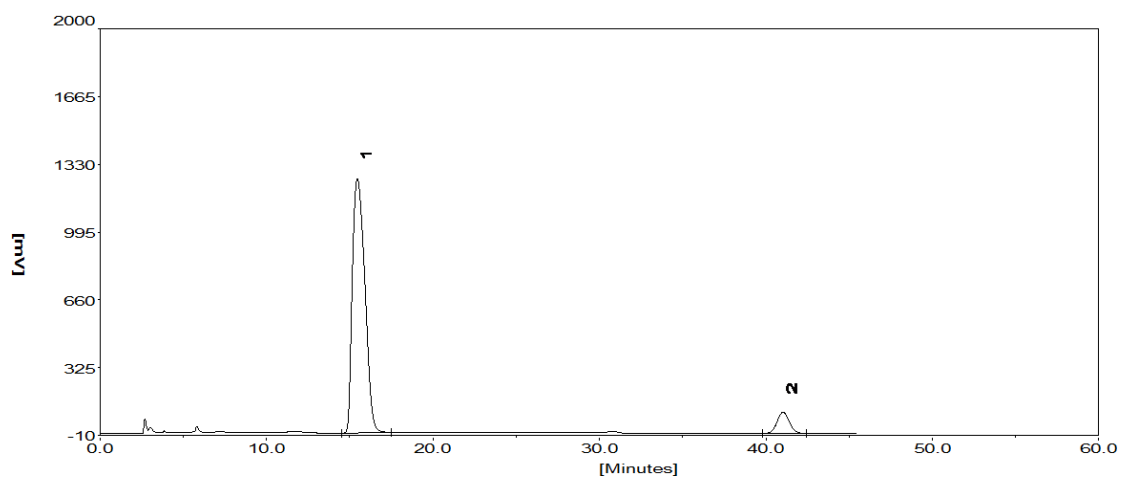


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	18.69250	435.51	21056.15	97.1700
2	22.47583	0.56	26.51	0.1223
3	24.68250	9.20	468.86	2.1637
4	49.08000	1.33	117.88	0.5440

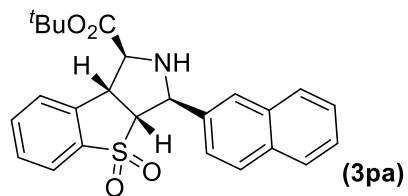


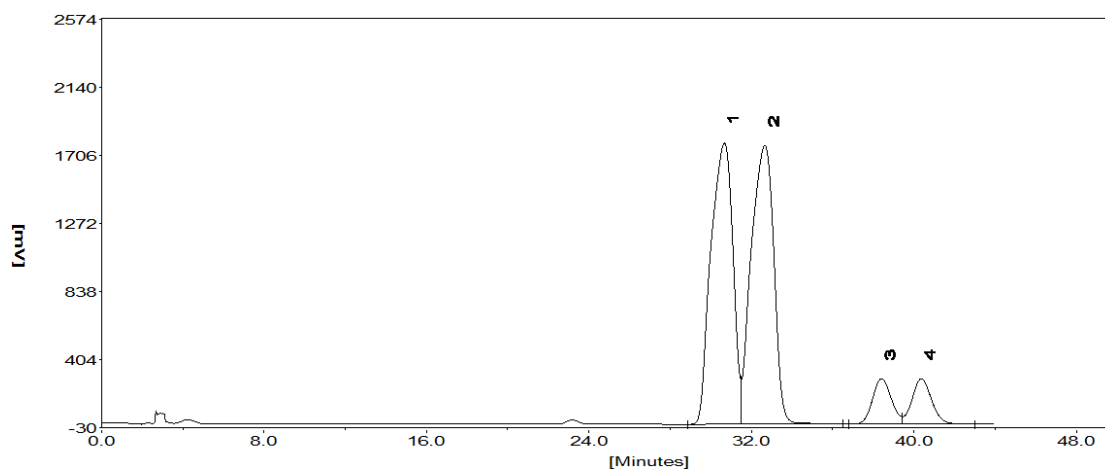


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	15.82333	823.70	40634.56	43.3618
2	22.32417	86.02	5883.98	5.4101
3	27.07333	81.51	5775.36	5.3102
4	41.89500	199.00	43029.89	45.9179

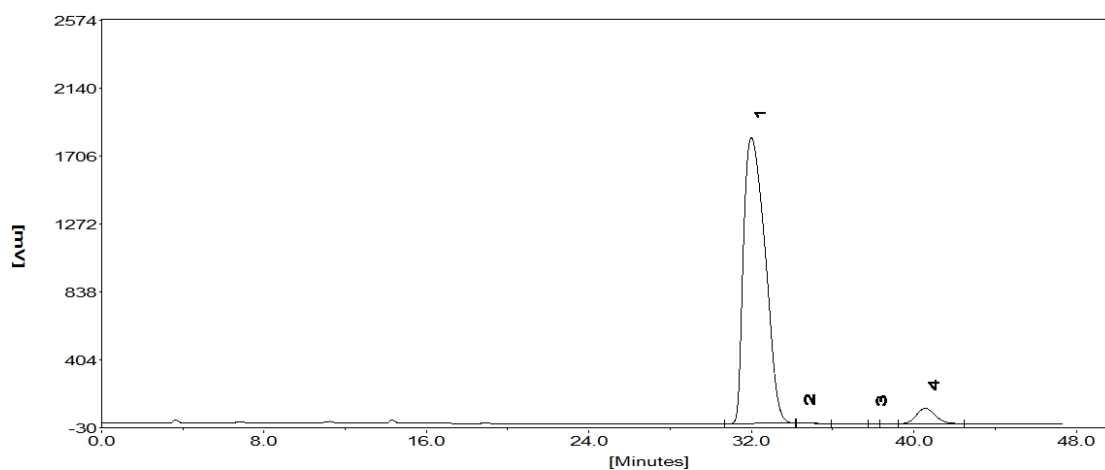


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	15.45583	1259.08	65882.90	92.6026
2	41.02833	104.84	5262.95	7.3974

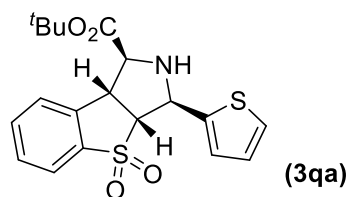


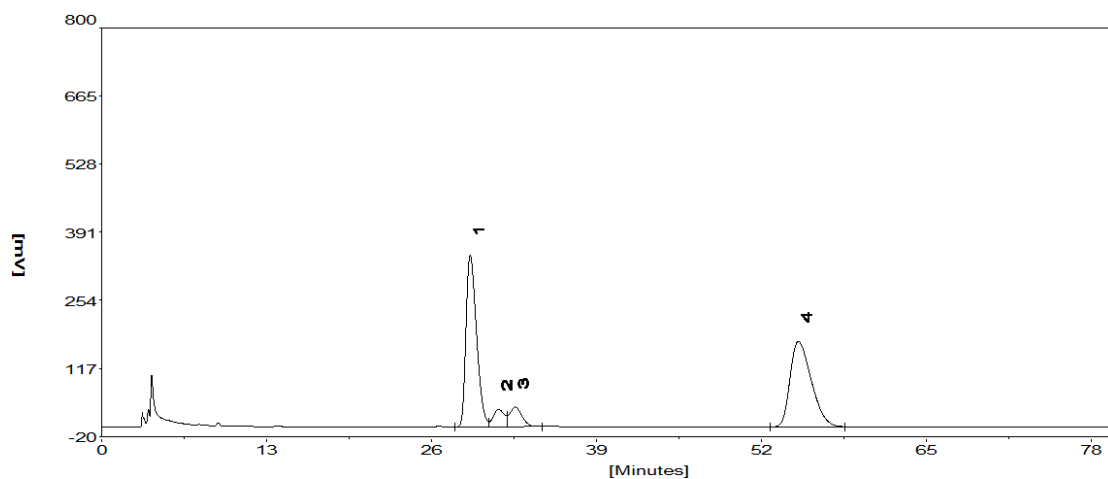


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	30.97167	1789.55	134475.27	43.4828
2	33.26167	1775.96	137229.43	44.3734
3	38.40917	288.92	18454.31	5.9672
4	40.36667	288.97	19101.76	6.1766

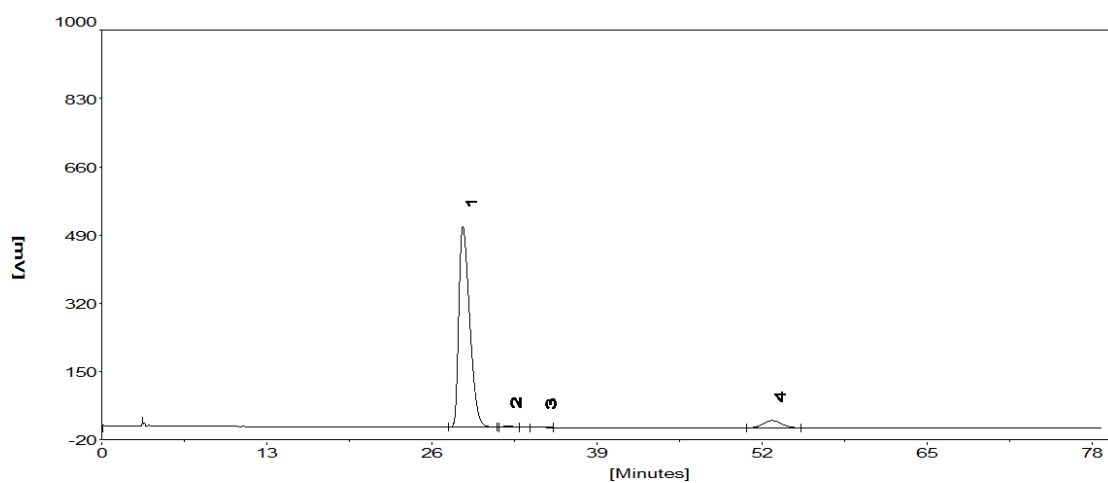


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	31.99833	1823.34	134042.30	95.4589
2	34.44583	1.08	12.29	0.0088
3	38.77833	0.09	1.21	0.0009
4	41.26333	97.92	6363.11	4.5315

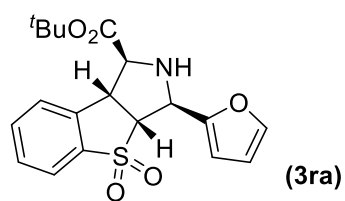


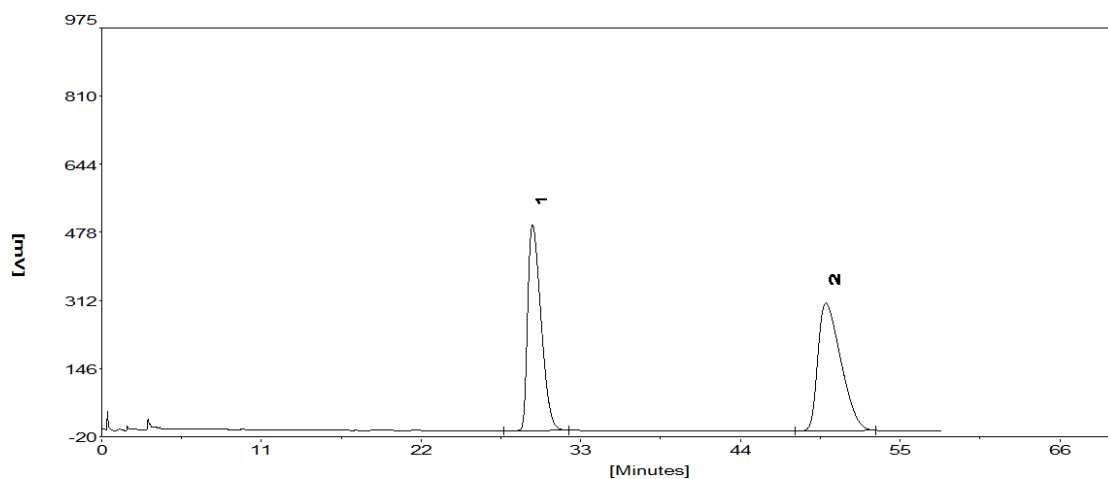


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	29.04250	344.79	19917.99	44.7218
2	31.27833	34.62	2109.31	5.0360
3	32.59500	36.24	2364.22	5.6446
4	54.90500	171.41	19862.69	44.5976

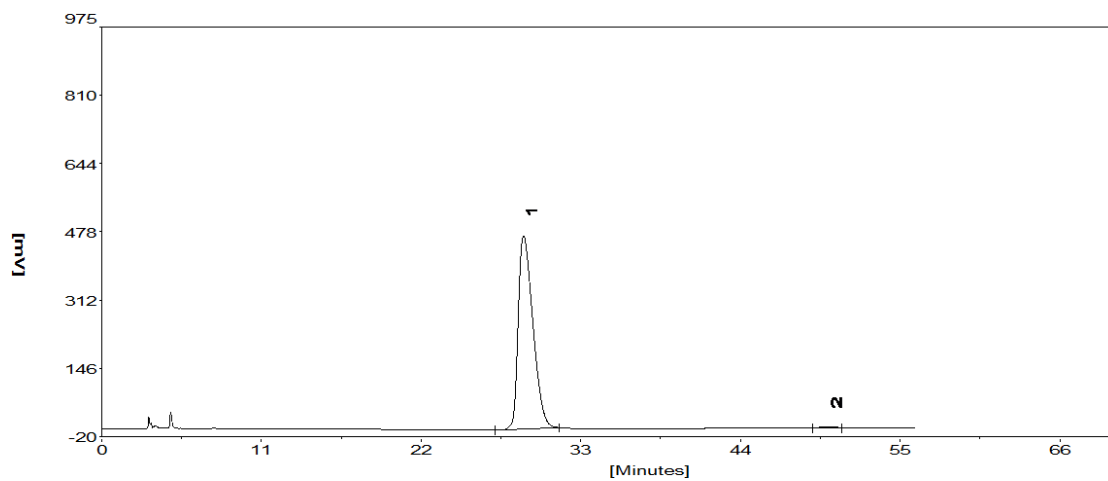


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	28.43833	499.43	29713.45	93.7778
2	31.97417	2.37	120.61	0.3807
3	33.72750	0.62	31.04	0.0980
4	53.25500	18.22	1819.86	5.7436

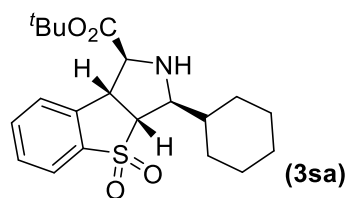


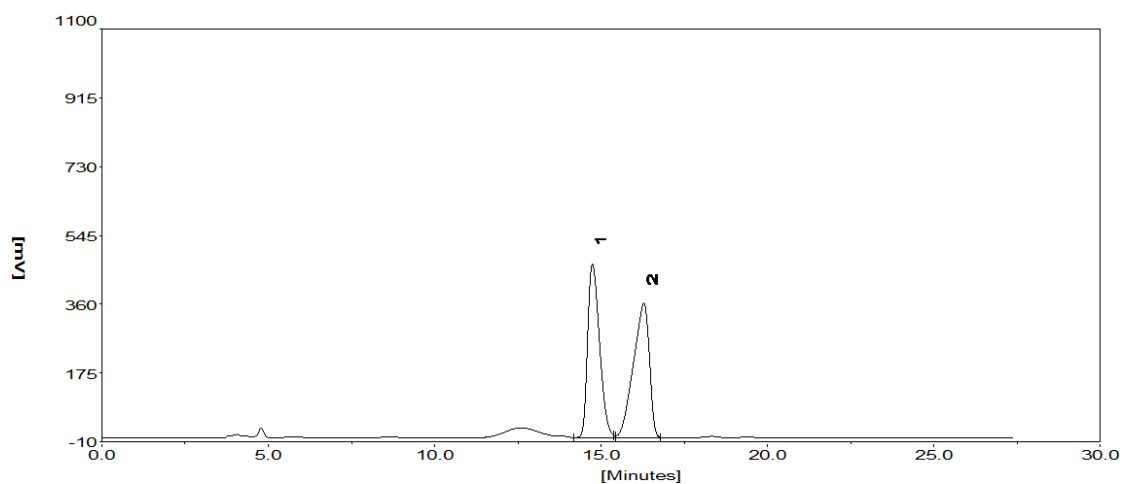


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	29.67917	501.24	31873.13	48.3450
2	49.88583	310.79	34055.40	51.6550

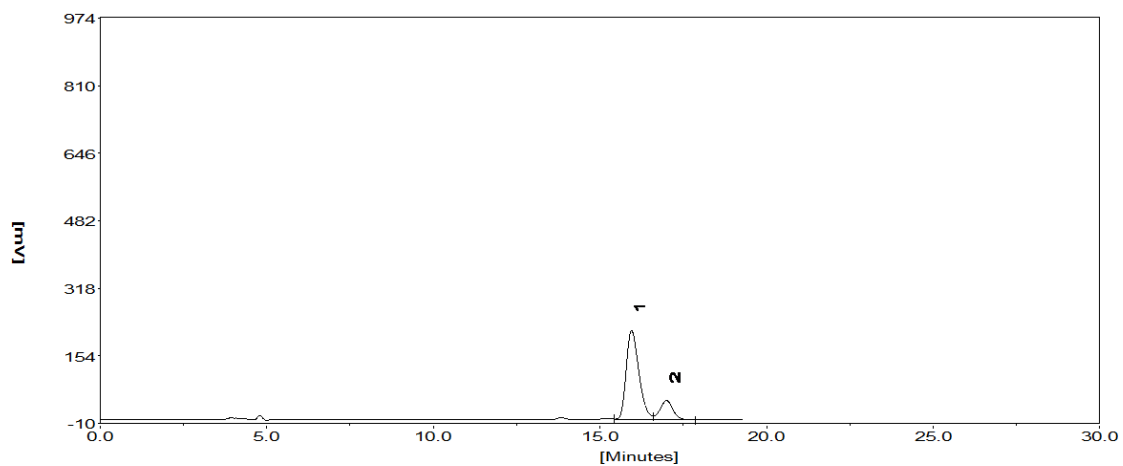


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	29.06333	470.27	32974.63	99.3609
2	50.06500	2.91	212.08	0.6391

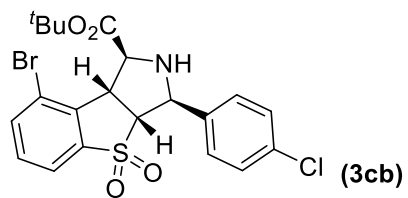


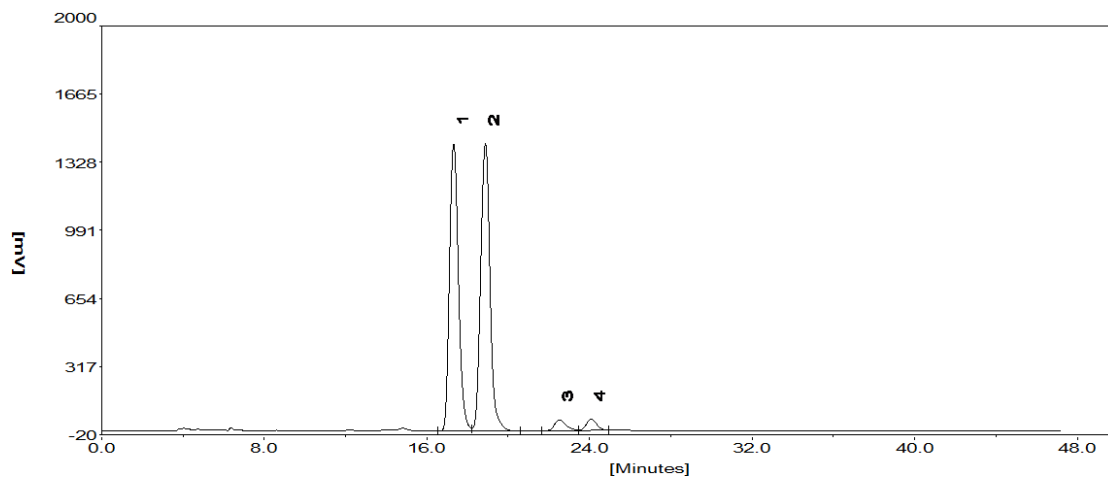


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	14.94000	467.50	11618.64	49.0748
2	16.28583	362.58	12056.73	50.9252

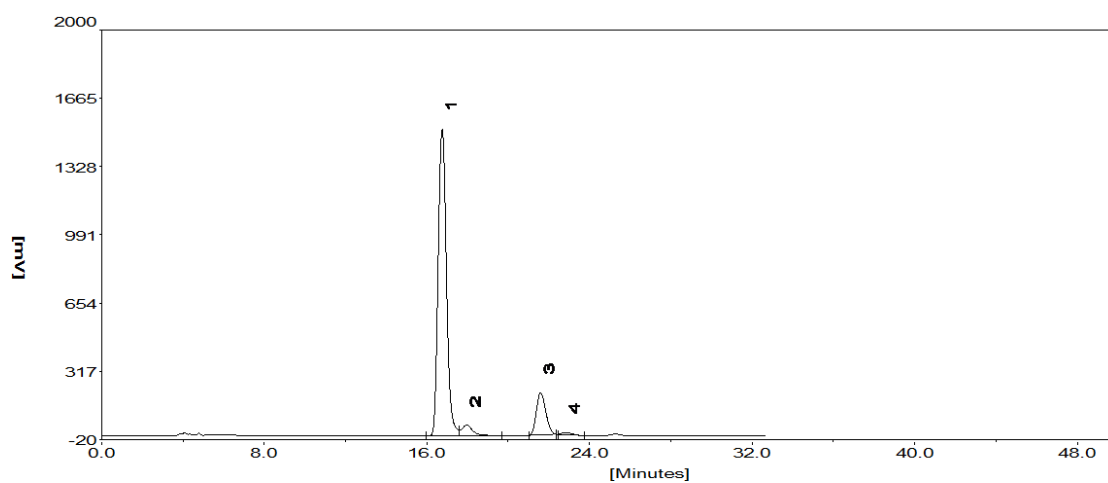


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	15.90583	400.23	11359.13	85.2666
2	16.96917	97.77	1962.77	14.7334

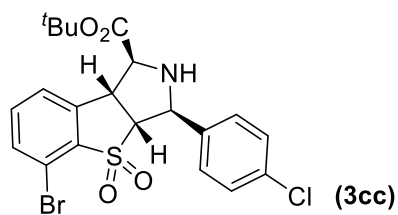




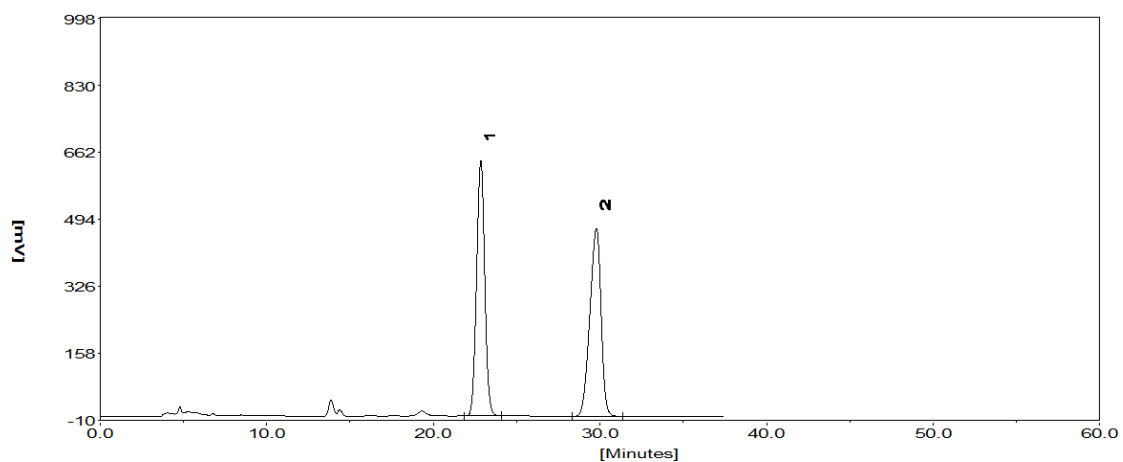
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.32333	1420.10	43429.82	46.7418
2	18.88333	1420.19	45440.34	48.9057
3	22.51250	54.11	2083.38	2.2423
4	24.08750	55.71	1960.73	2.1102



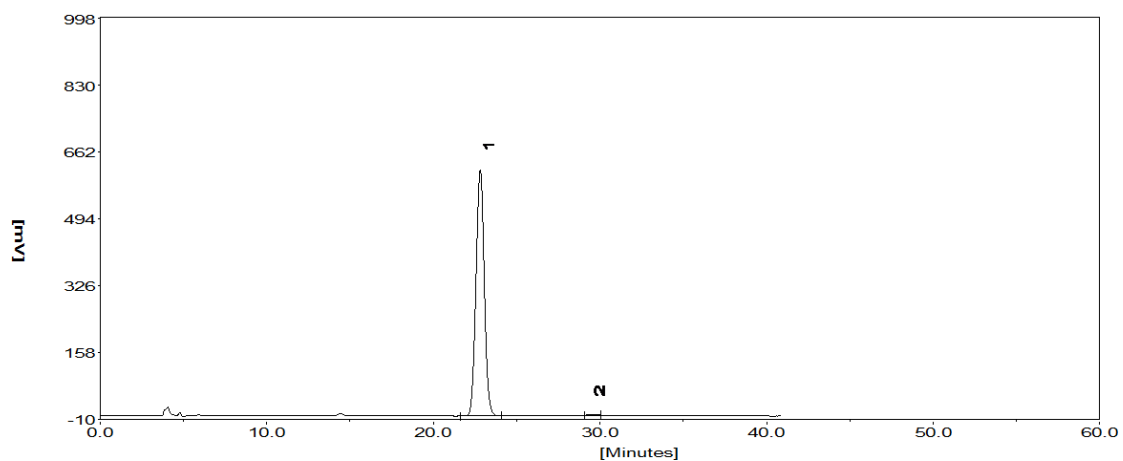
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	16.75500	1511.94	42920.02	83.2916
2	17.95583	53.31	1973.93	3.2031
3	21.59667	207.93	6646.04	12.8045
4	23.02750	11.44	363.75	0.7008



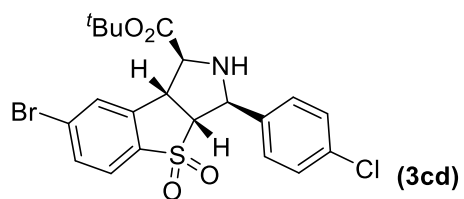


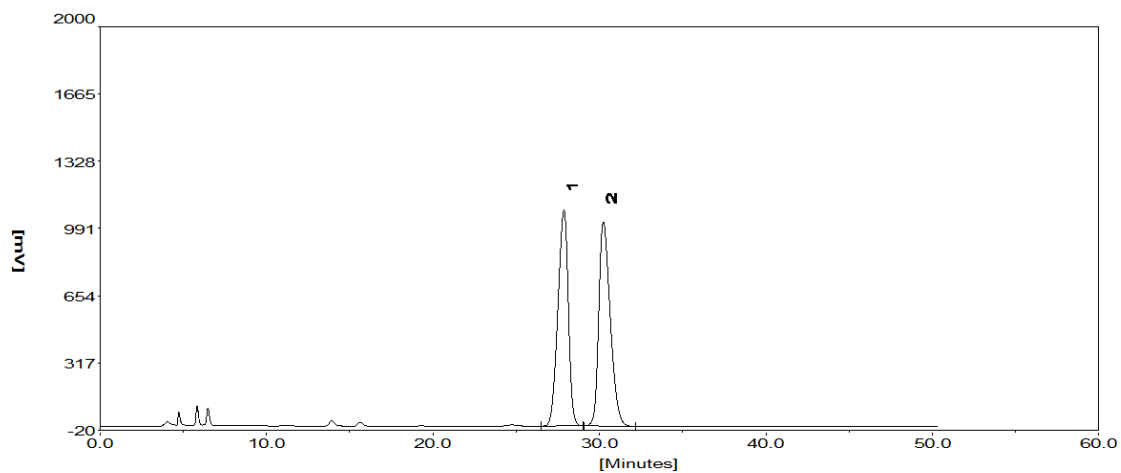


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	22.84833	640.75	21883.26	49.8176
2	29.78667	472.15	22043.53	50.1824

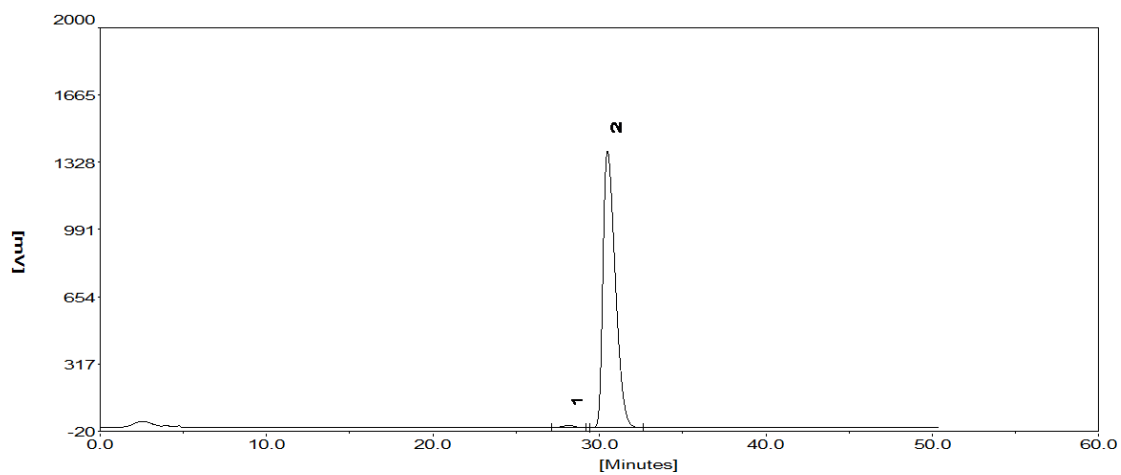


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	22.81667	619.16	21488.99	99.6512
2	29.49417	2.30	75.22	0.3488

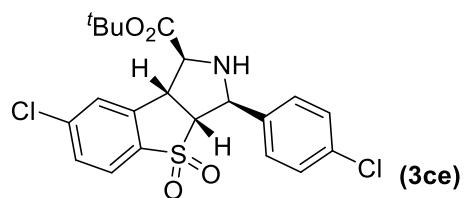


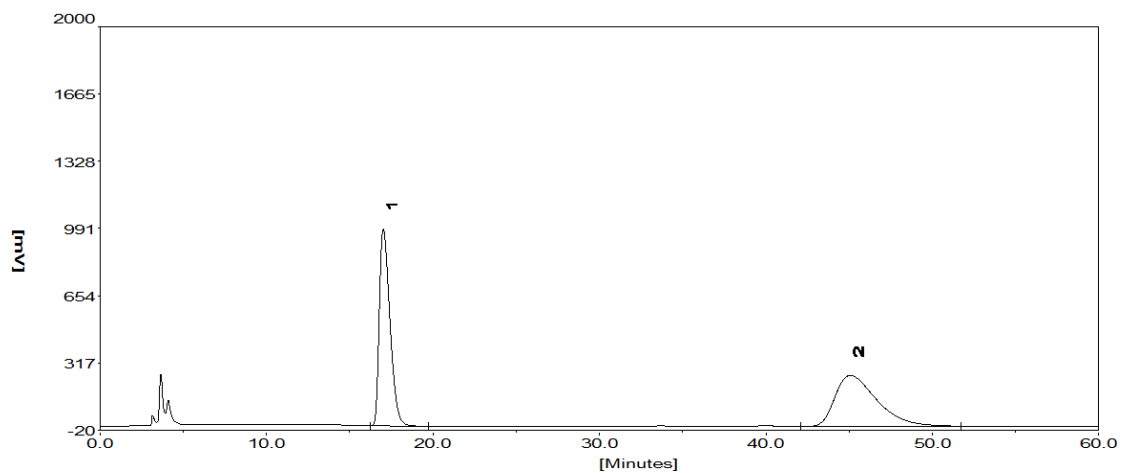


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	27.86917	1081.35	46862.13	48.9610
2	30.23500	1022.63	48851.00	51.0390

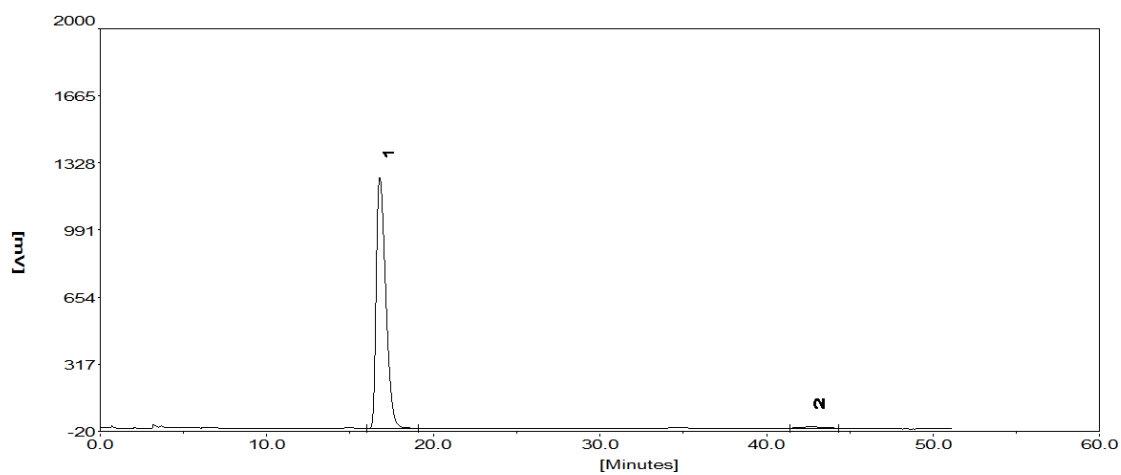


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	28.15333	9.97	422.72	0.5942
2	30.48583	1384.90	70715.81	99.4058

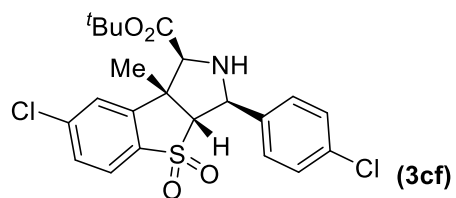


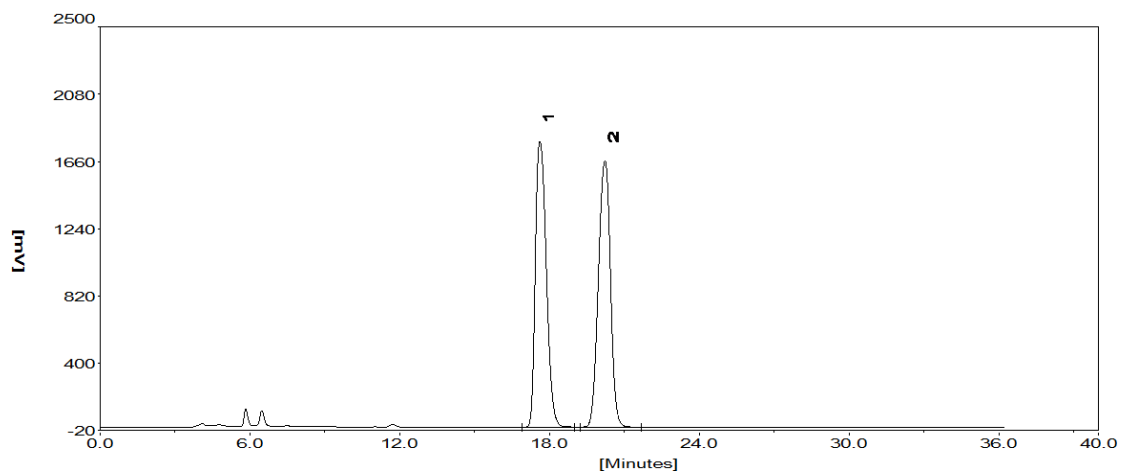


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.01667	986.36	43888.15	49.5529
2	44.06917	256.25	44680.15	50.4471

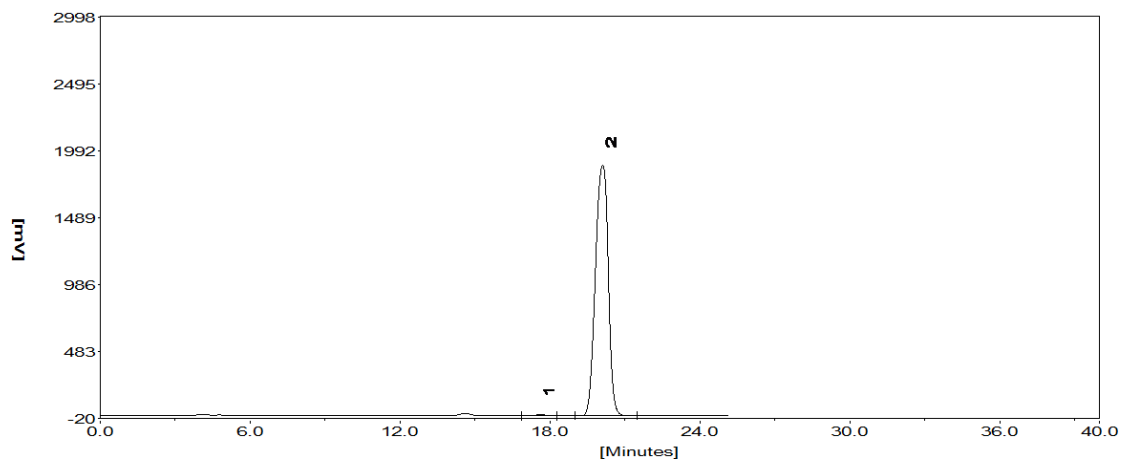


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	16.78417	1259.93	49878.81	98.9885
2	43.34667	5.94	509.68	1.0115

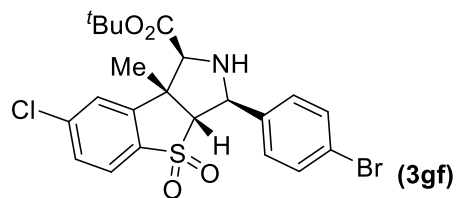


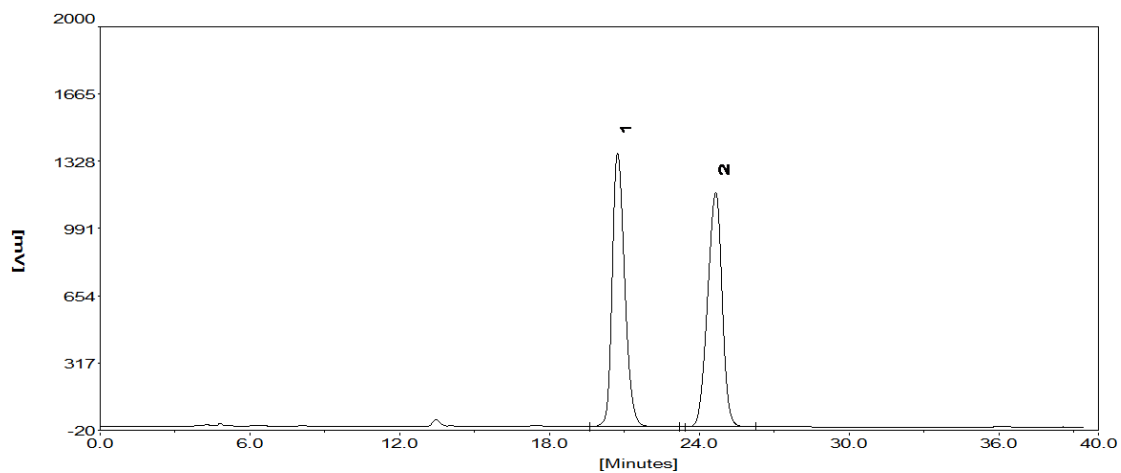


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.61750	1784.98	54288.17	49.3207
2	20.22250	1664.80	55783.61	50.6793

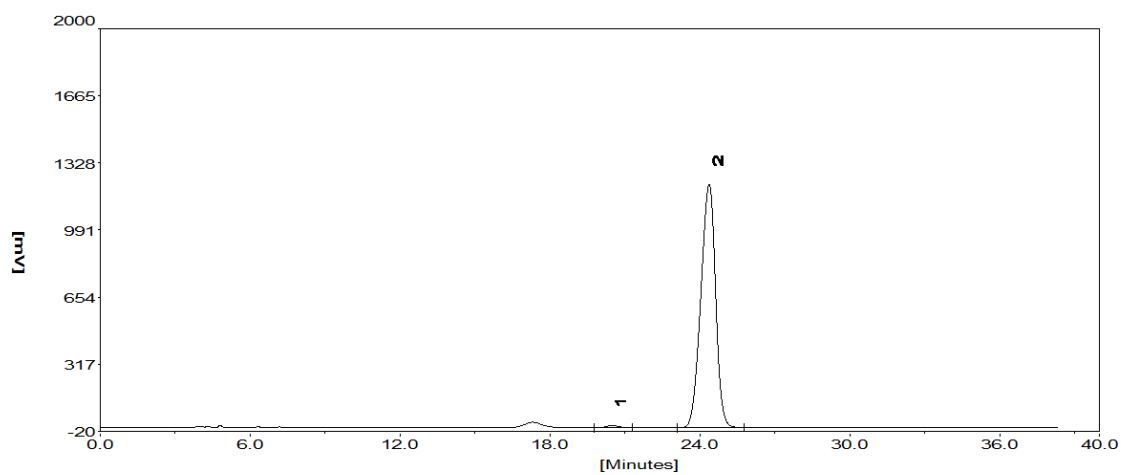


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	17.60500	8.82	229.25	0.3405
2	20.10917	1880.96	67100.55	99.6595

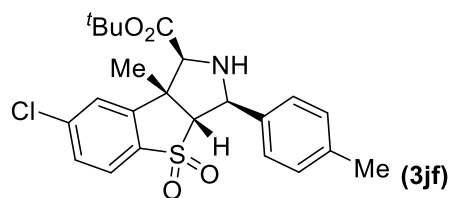


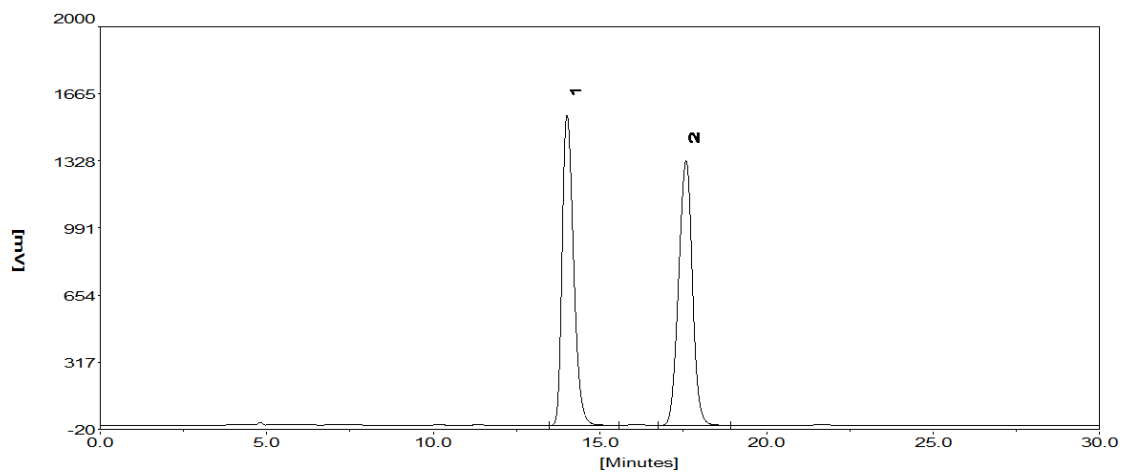


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	20.72750	1371.40	47593.04	50.0676
2	24.65833	1172.67	47464.52	49.9324

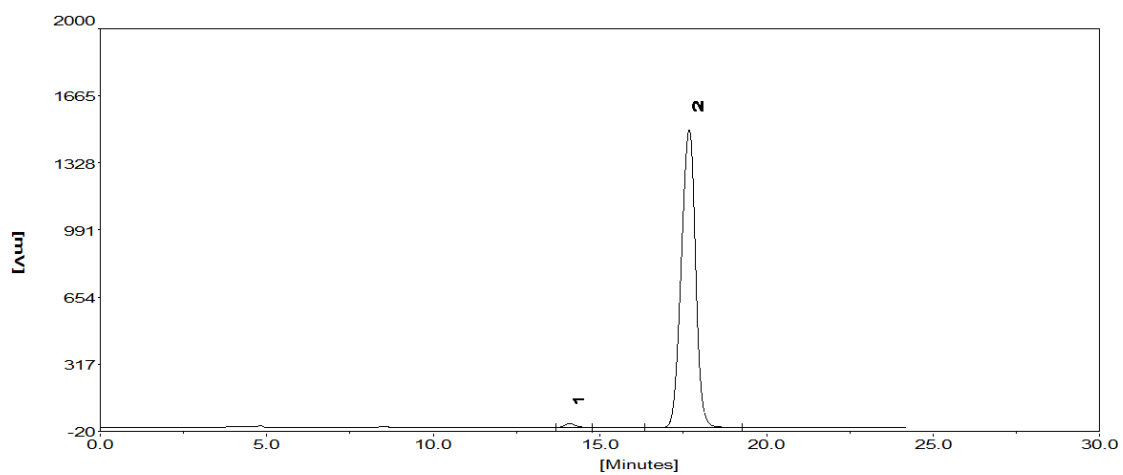


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	20.49083	10.66	334.25	0.6648
2	24.37167	1221.75	49947.55	99.3352

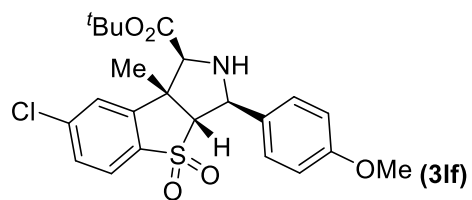


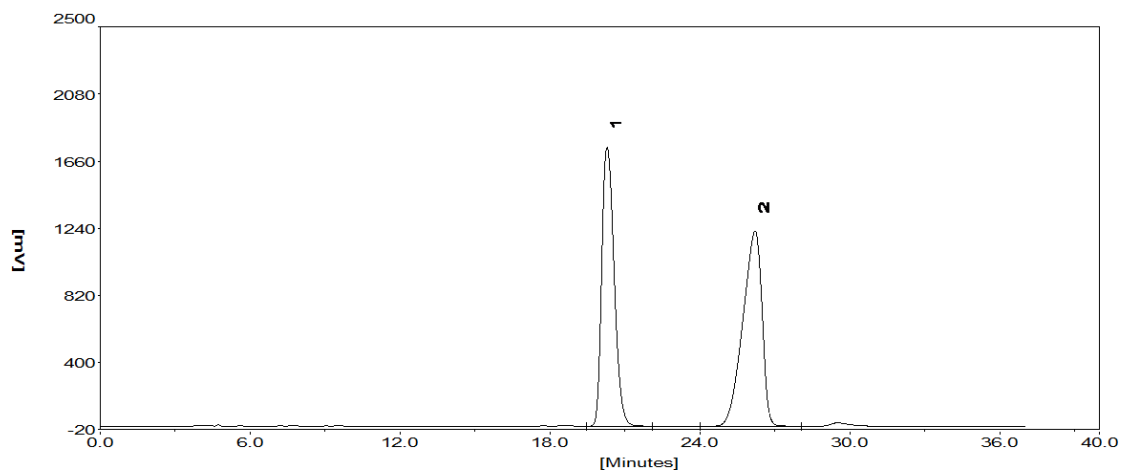


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	14.01167	1556.85	37119.84	49.3079
2	17.58500	1328.36	38161.93	50.6921

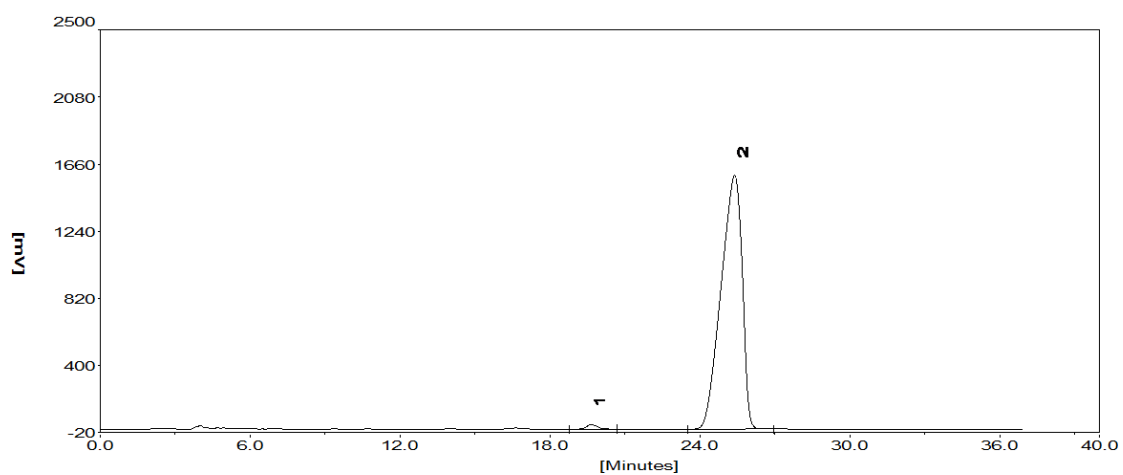


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	14.09083	19.44	425.14	0.9473
2	17.67917	1494.90	44452.08	99.0527

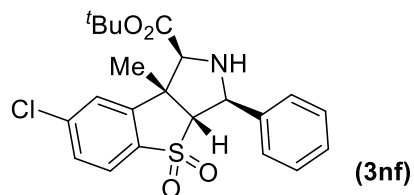


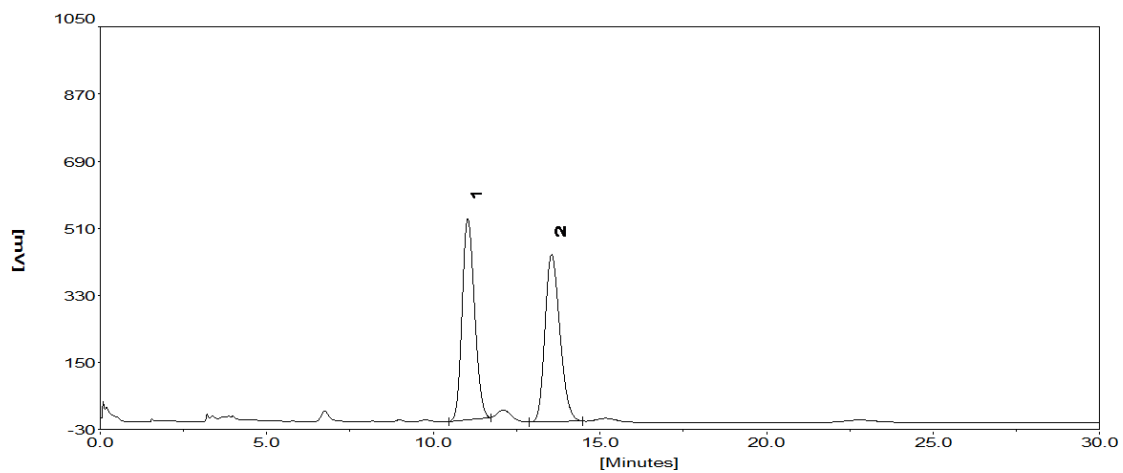


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	20.28500	1746.08	60271.40	48.0171
2	26.20500	1224.65	65249.18	51.9829

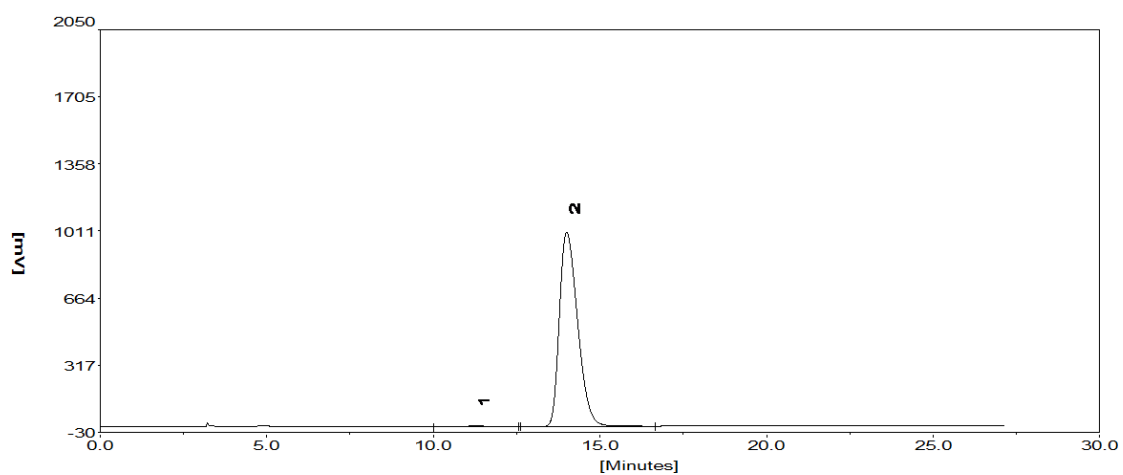


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	19.66333	27.86	841.42	0.8933
2	25.39000	1589.94	93346.36	99.1067

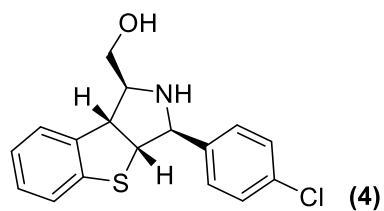




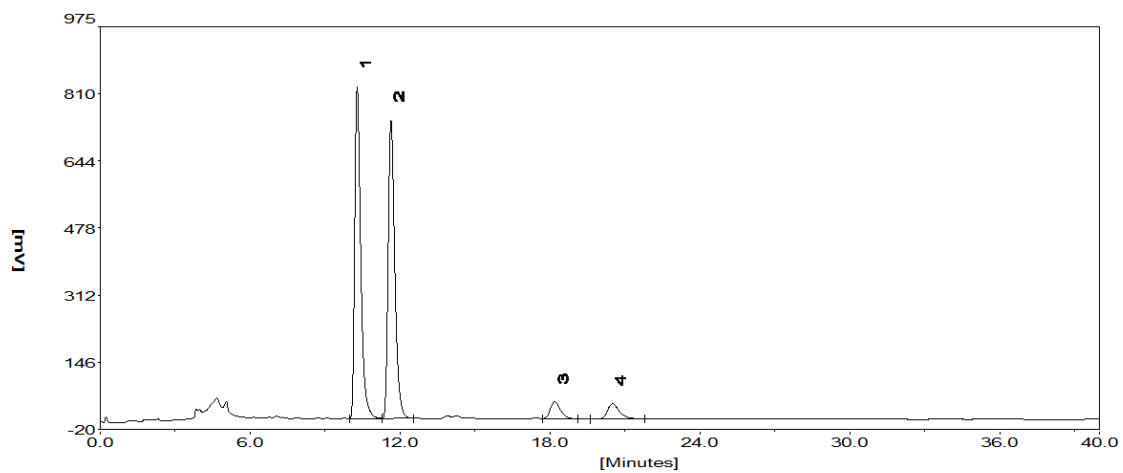
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	11.03250	540.55	13978.10	50.1506
2	13.54750	448.42	13894.13	49.8494



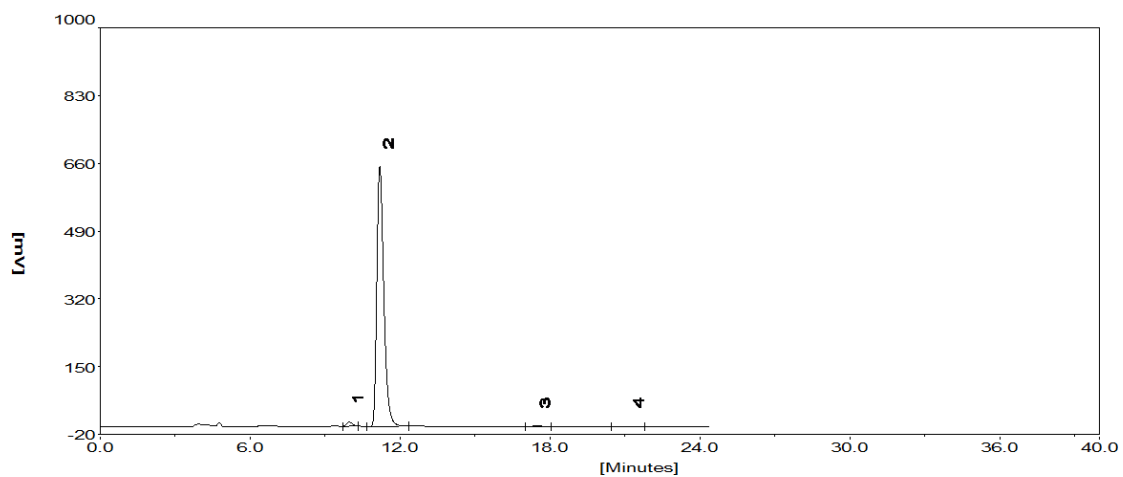
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	11.27333	7.55	228.87	0.5960
2	14.00333	1004.56	38173.87	99.4040



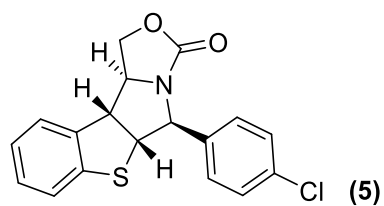


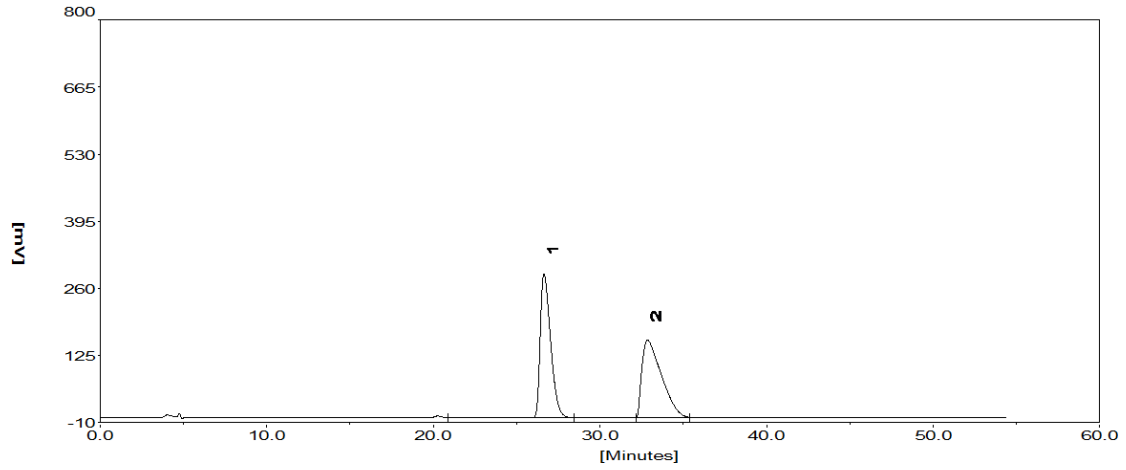


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	10.28417	820.38	13802.99	46.2436
2	11.63750	737.52	13613.68	45.6094
3	18.18750	42.07	1167.18	3.9104
4	20.50333	37.57	1264.58	4.2366

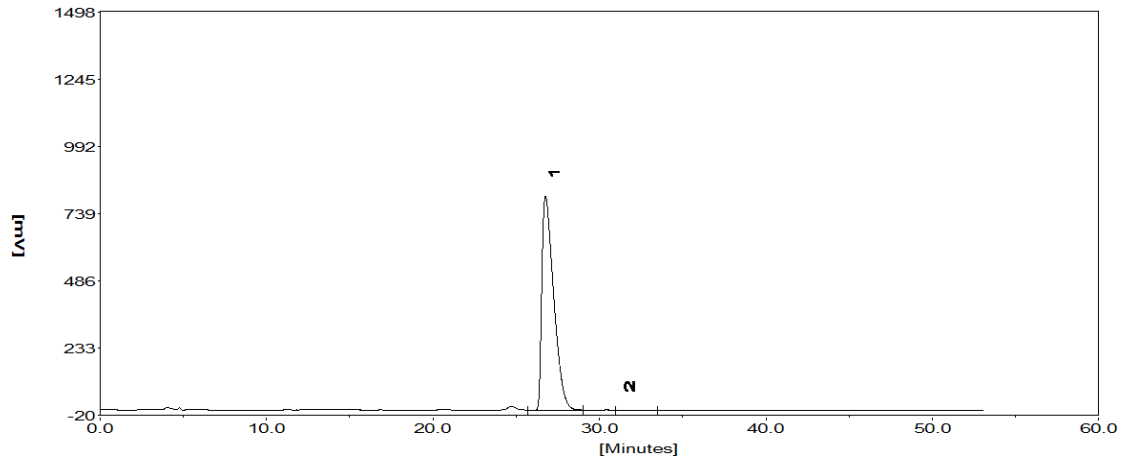


#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	9.95917	10.38	132.80	1.0372
2	11.19000	652.44	12632.75	98.6642
3	17.88000	1.15	32.88	0.2560
4	21.23083	0.13	5.47	0.0426





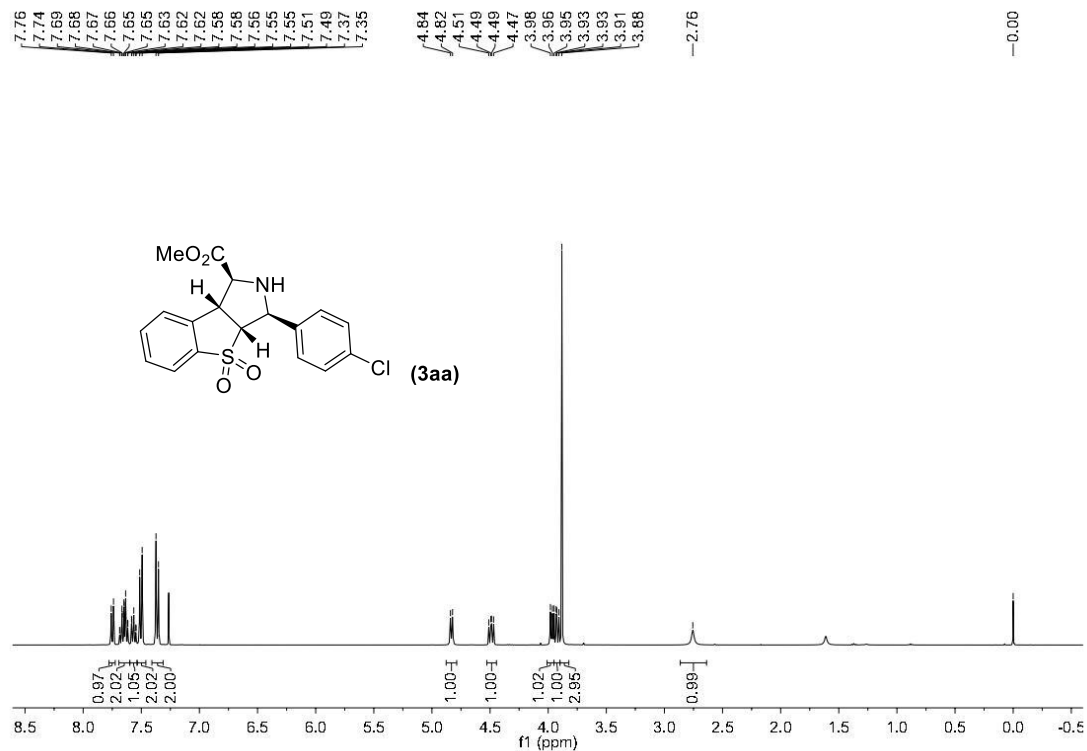
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	26.64333	289.72	12451.59	49.7744
2	32.85000	155.94	12564.44	50.2256



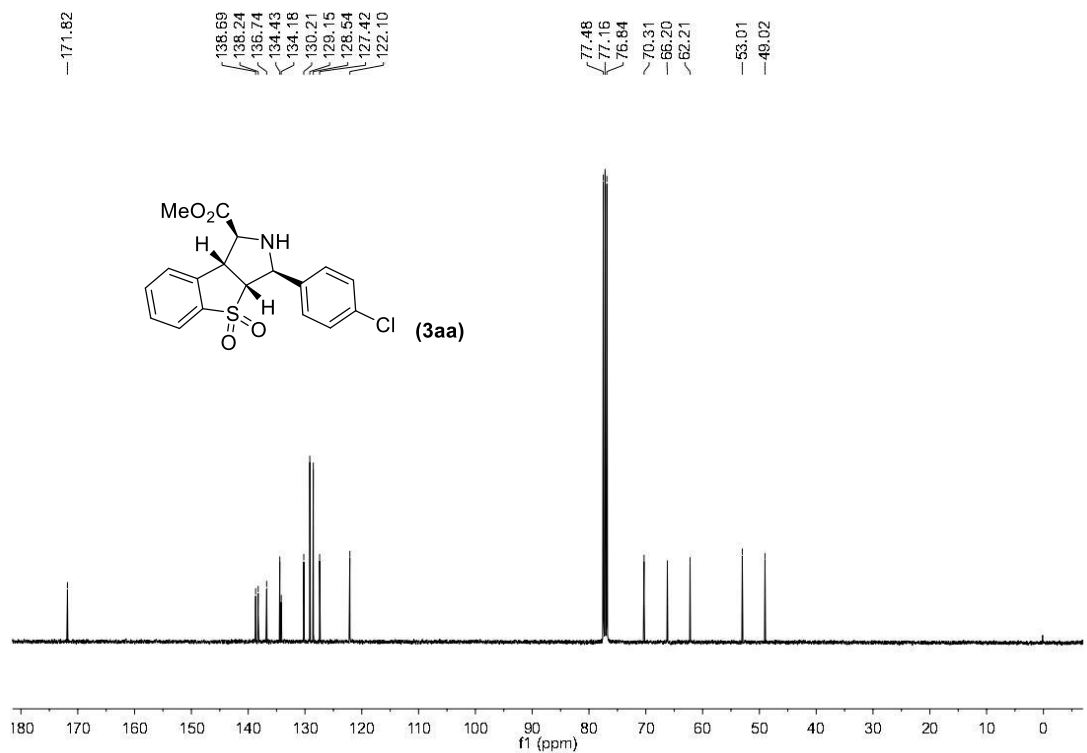
#	Ret Time (min)	Height (mV)	Area (mV.sec)	Area (%)
1	26.75917	804.56	39810.90	99.9933
2	32.61000	0.11	2.67	0.0067

## 9. $^1\text{H}$ NMR and $^{13}\text{C}$ NMR spectra

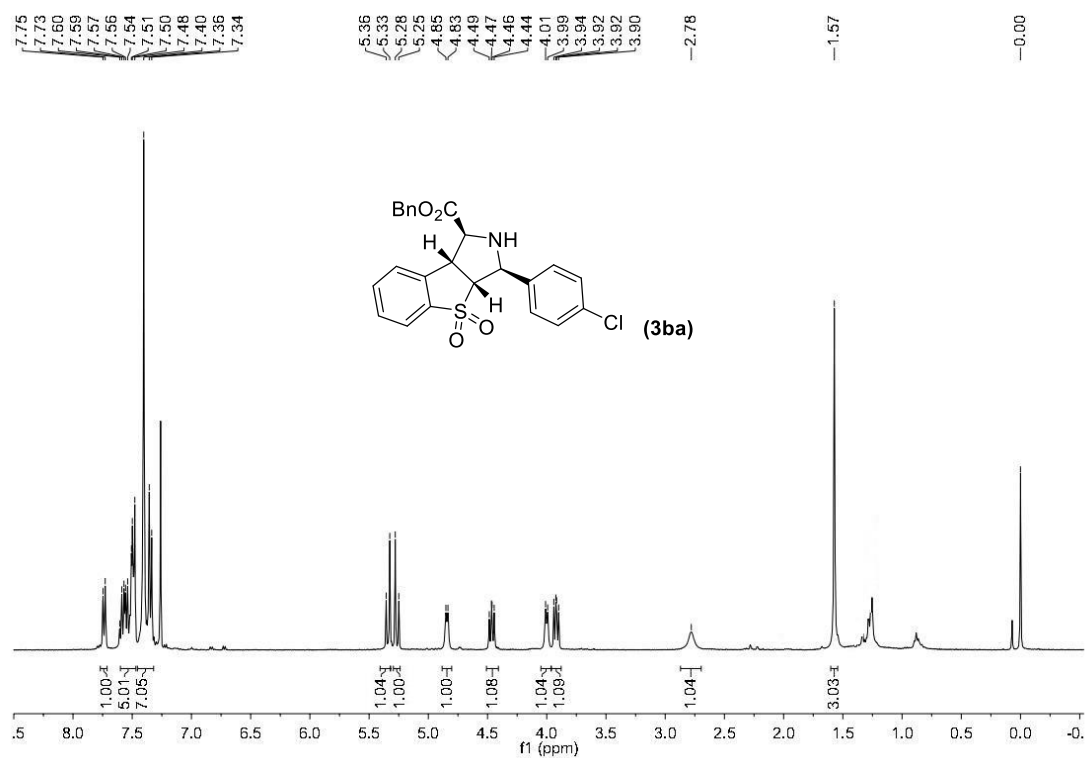
$^1\text{H}$  NMR spectrum of compound **3aa** ( $\text{CDCl}_3$ )



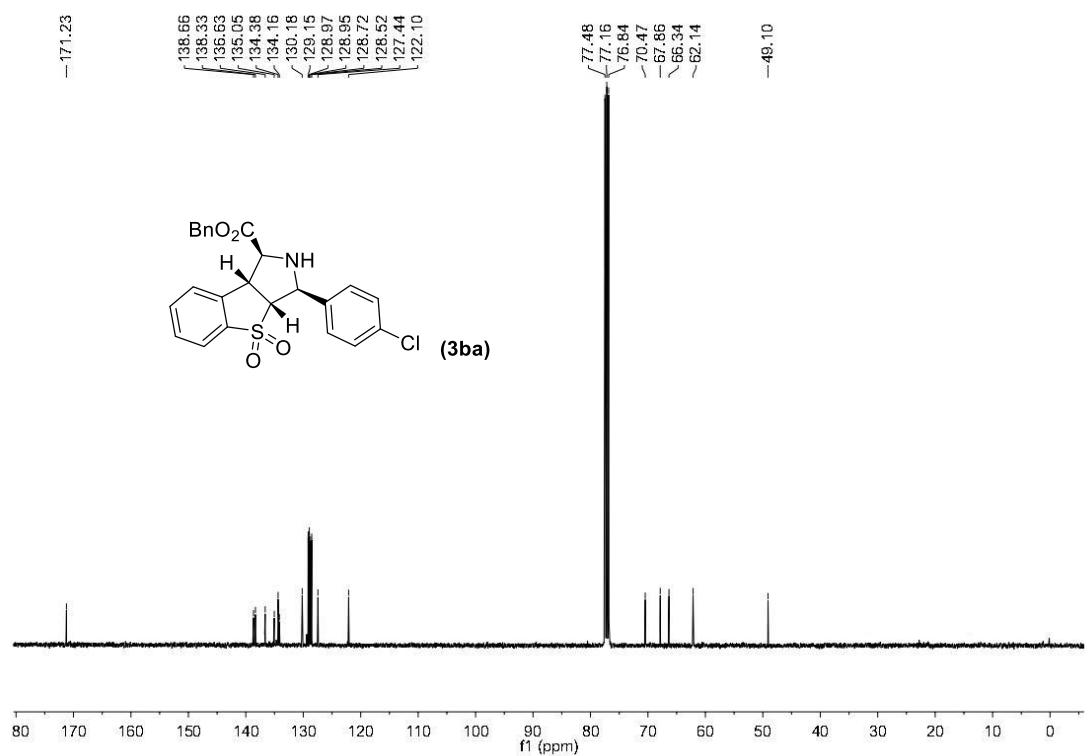
$^{13}\text{C}$  NMR spectrum of compound **3aa** ( $\text{CDCl}_3$ )



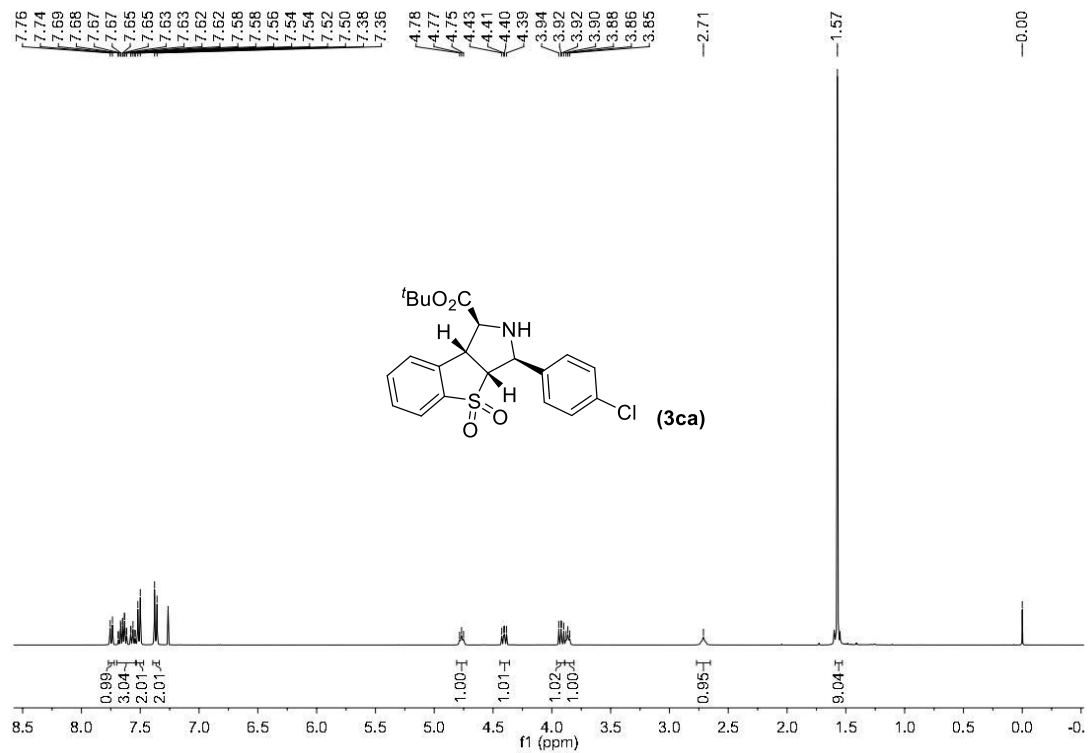
$^1\text{H}$  NMR spectrum of compound **3ba** ( $\text{CDCl}_3$ )



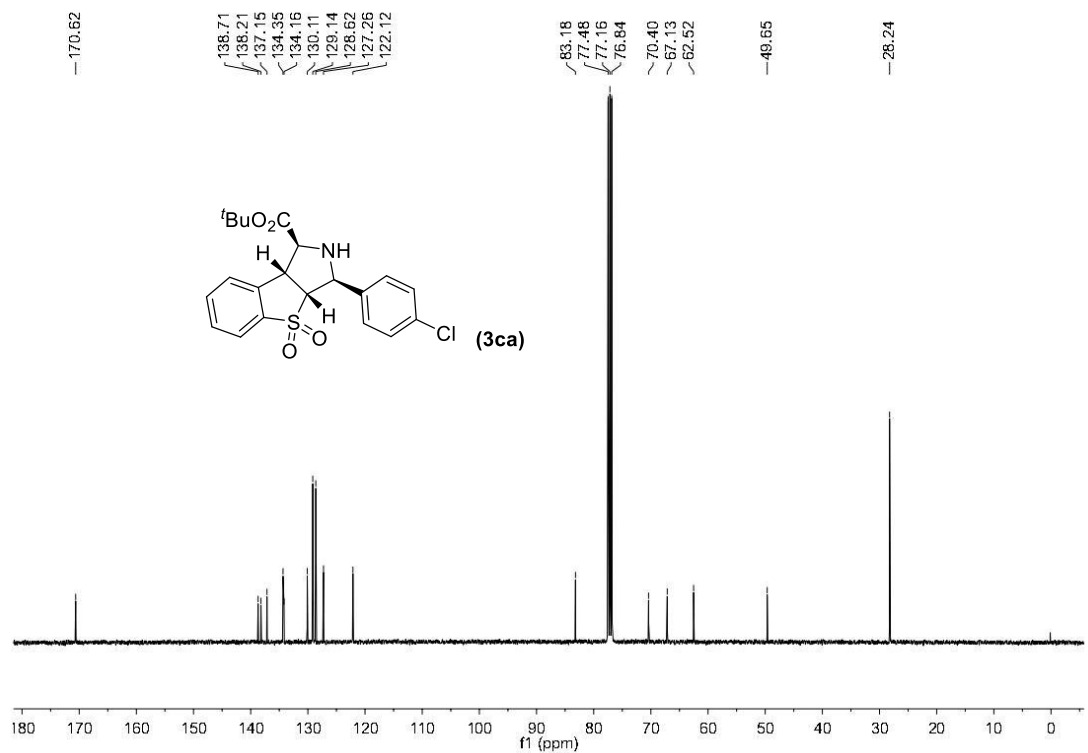
$^{13}\text{C}$  NMR spectrum of compound **3ba** ( $\text{CDCl}_3$ )



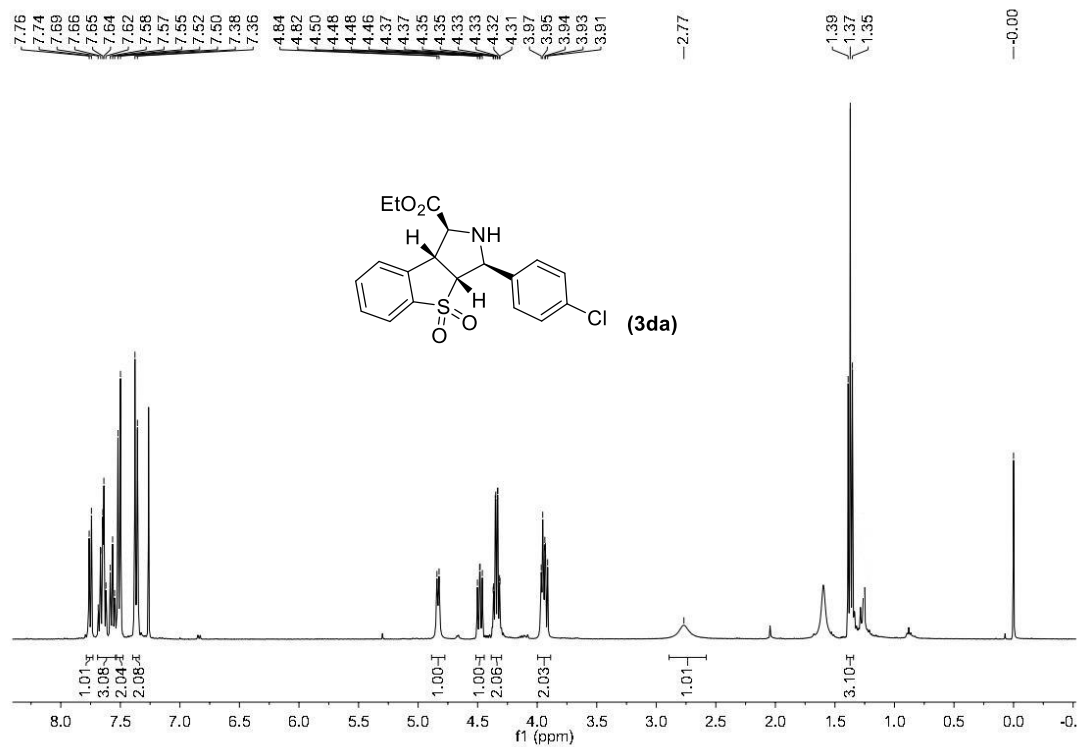
$^1\text{H}$  NMR spectrum of compound **3ca** ( $\text{CDCl}_3$ )



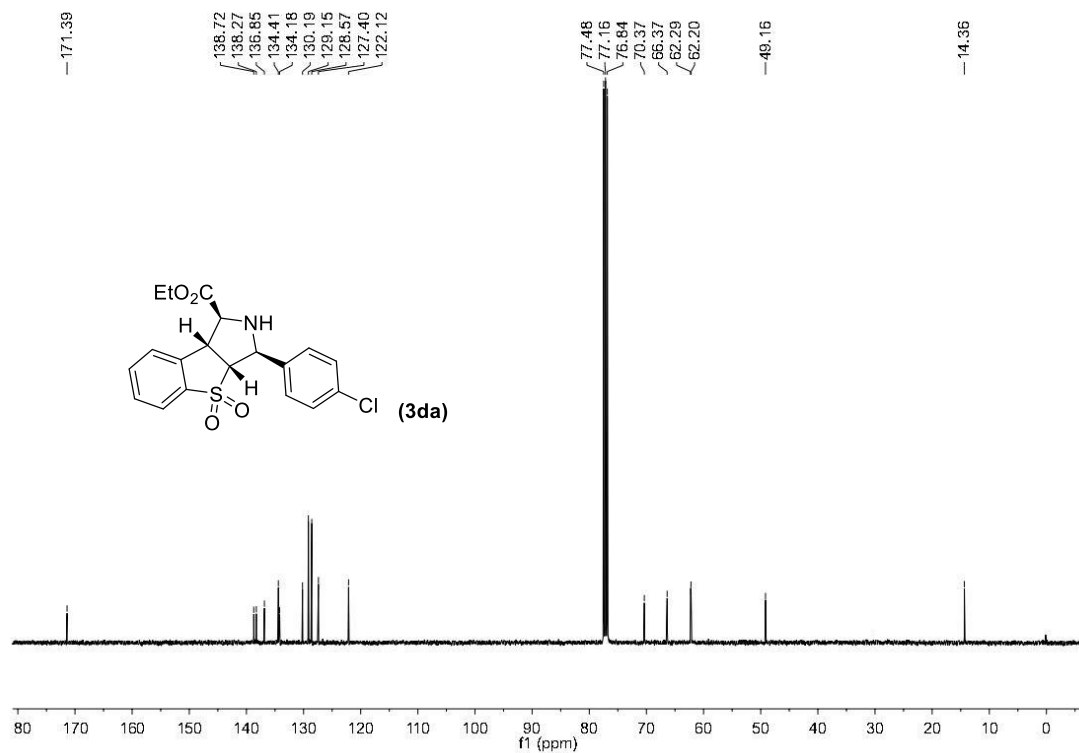
**<sup>13</sup>C NMR spectrum of compound 3ca (CDCl<sub>3</sub>)**



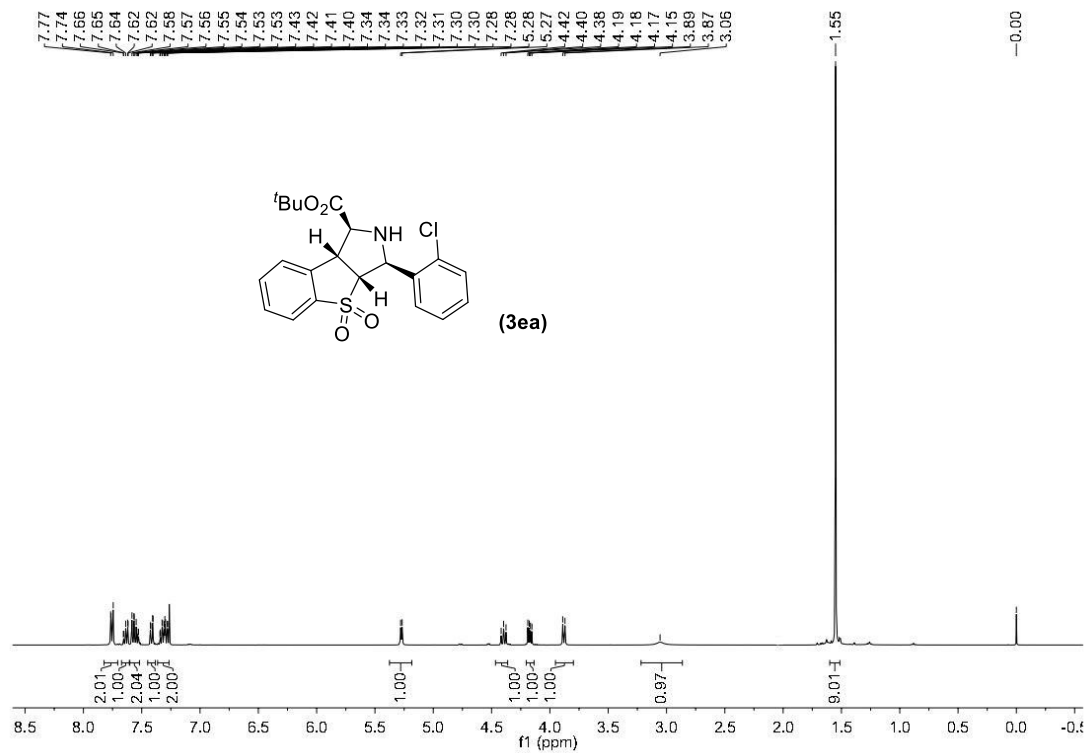
**<sup>1</sup>H NMR spectrum of compound 3da (CDCl<sub>3</sub>)**



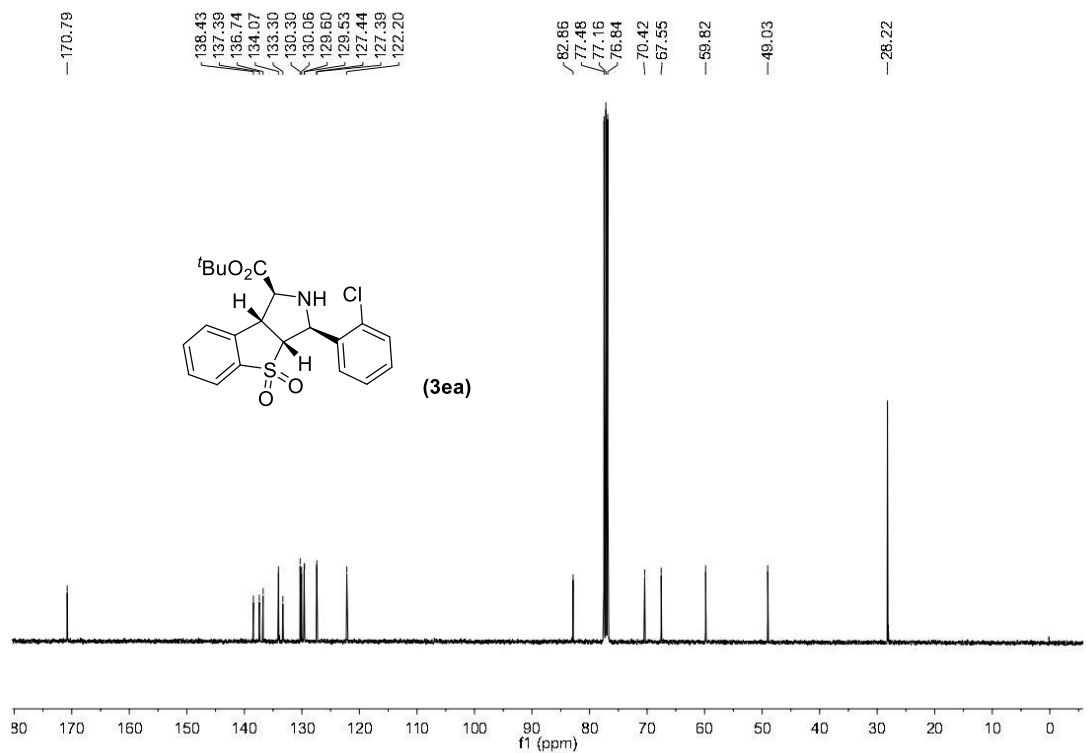
<sup>13</sup>C NMR spectrum of compound 3da (CDCl<sub>3</sub>)



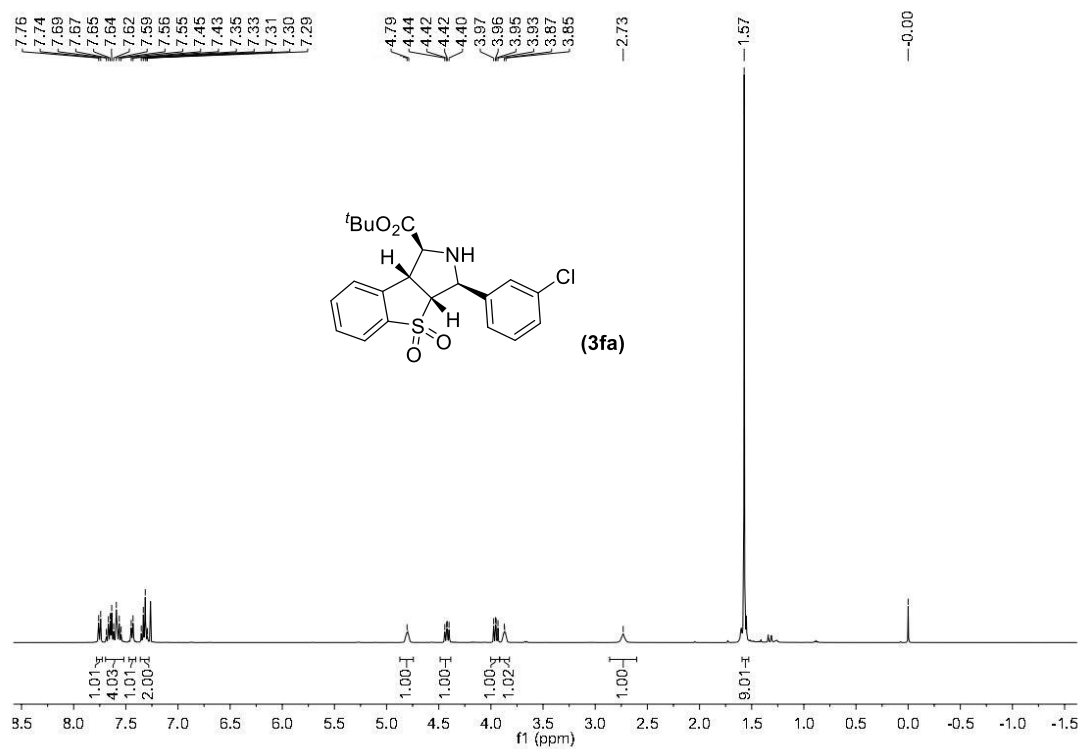
<sup>1</sup>H NMR spectrum of compound 3ea (CDCl<sub>3</sub>)



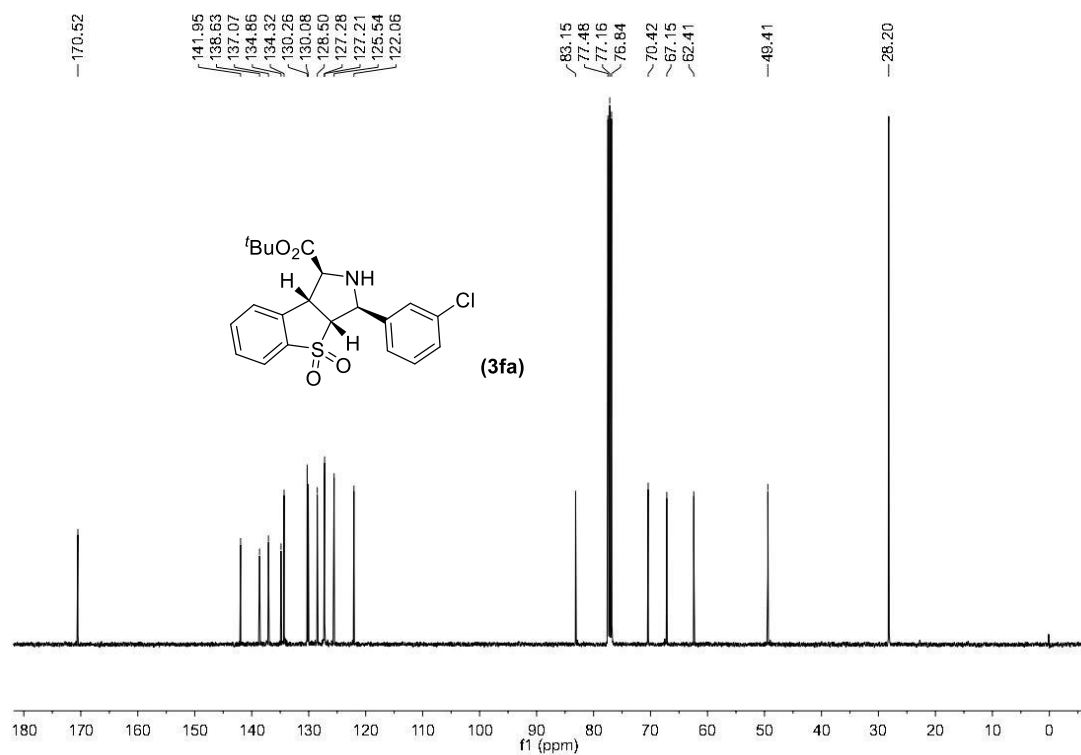
**<sup>13</sup>C NMR spectrum of compound 3ea (CDCl<sub>3</sub>)**



**<sup>1</sup>H NMR spectrum of compound 3fa (CDCl<sub>3</sub>)**

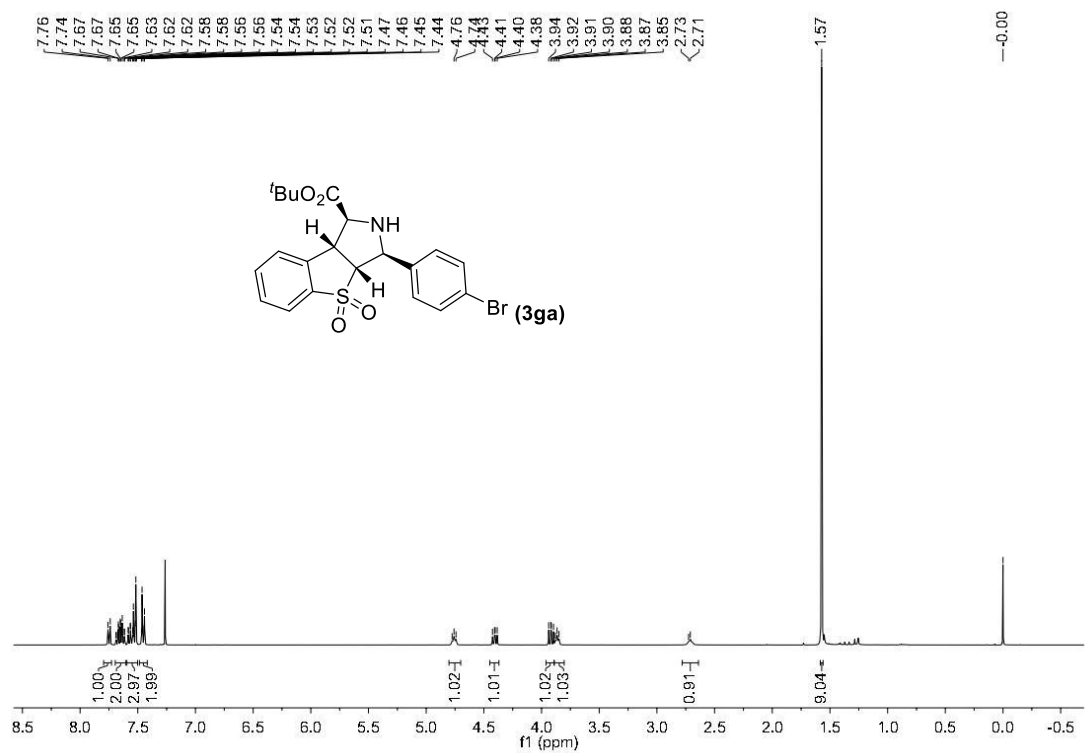


**<sup>13</sup>C NMR spectrum of compound **3fa** (CDCl<sub>3</sub>)**

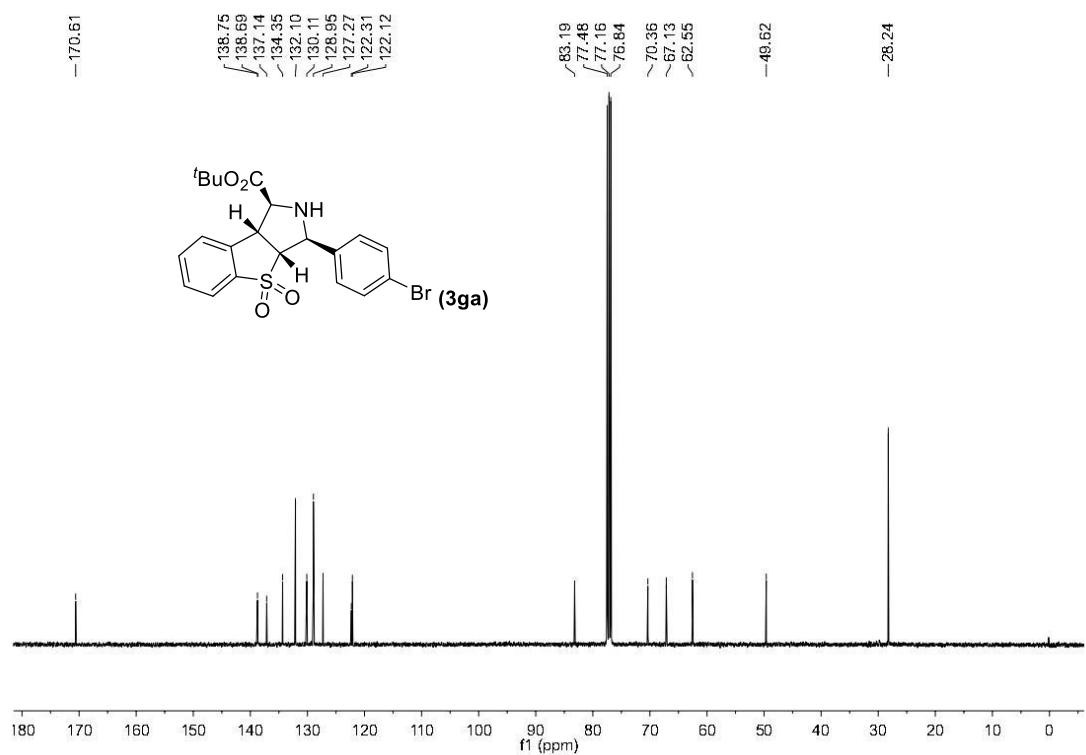


**<sup>1</sup>H NMR spectrum of compound **3ga** (CDCl<sub>3</sub>)**

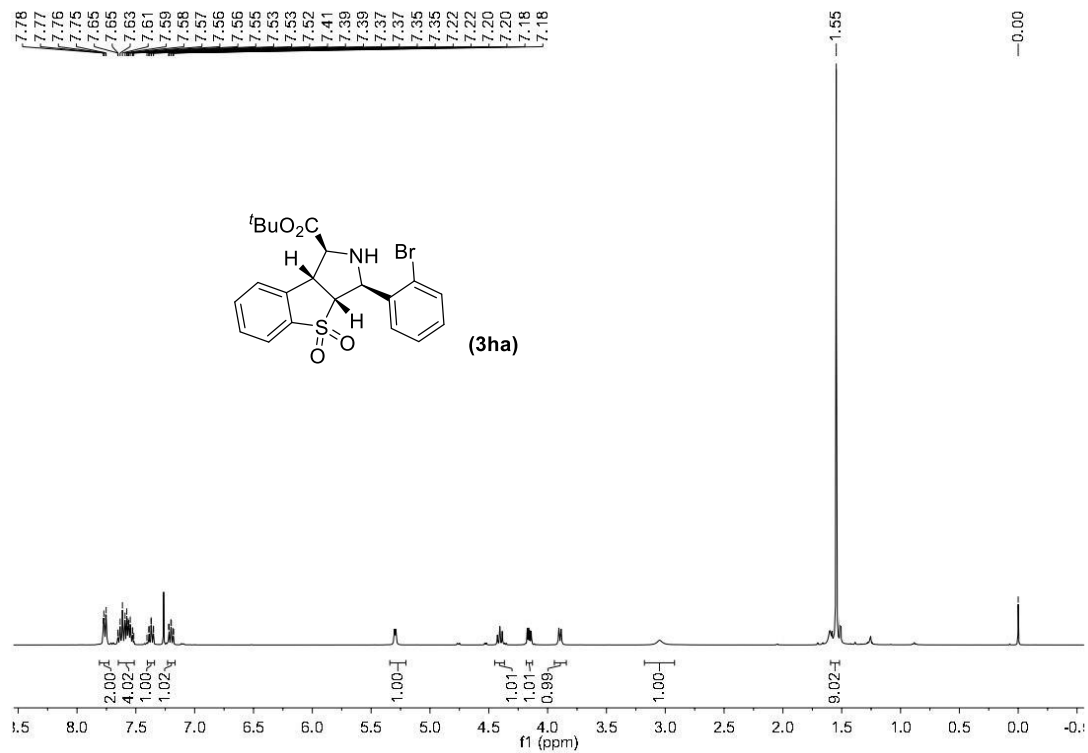




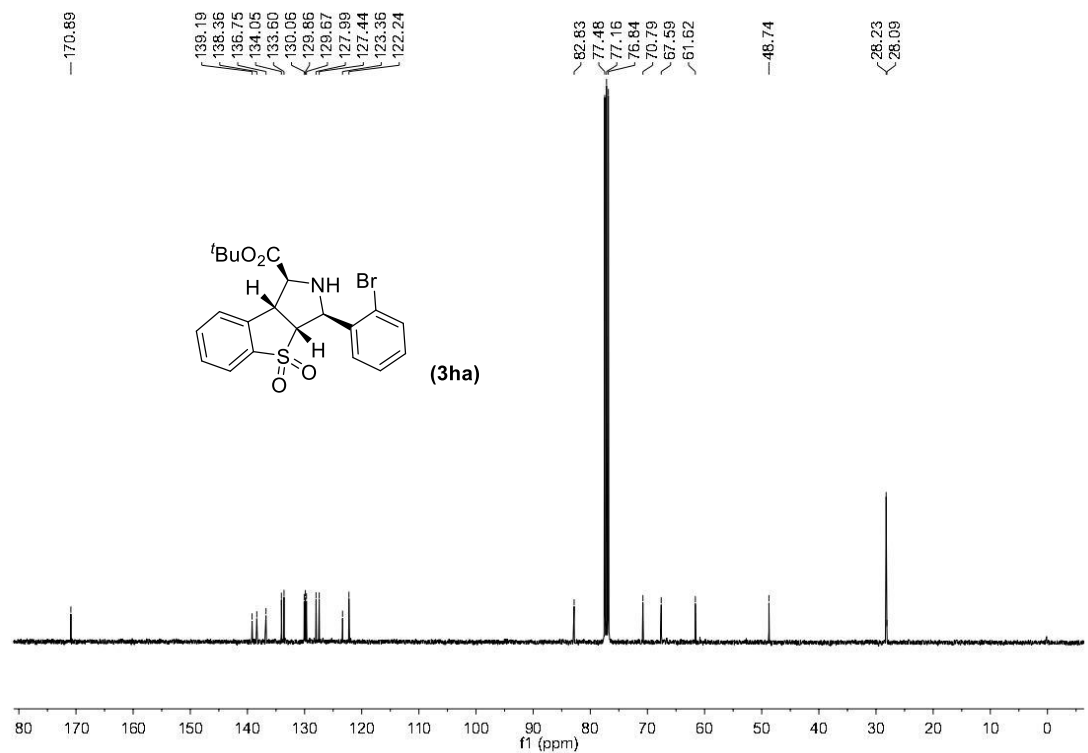
**<sup>13</sup>C NMR spectrum of compound **3ga** (CDCl<sub>3</sub>)**



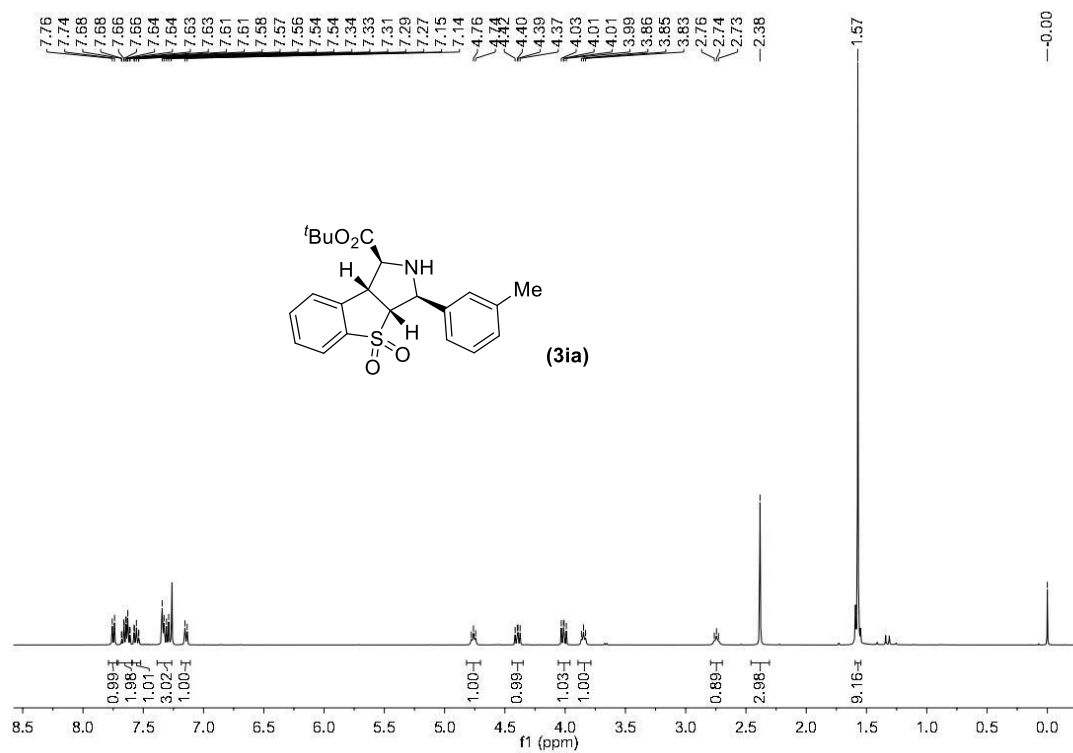
**<sup>1</sup>H NMR spectrum of compound **3ha** (CDCl<sub>3</sub>)**



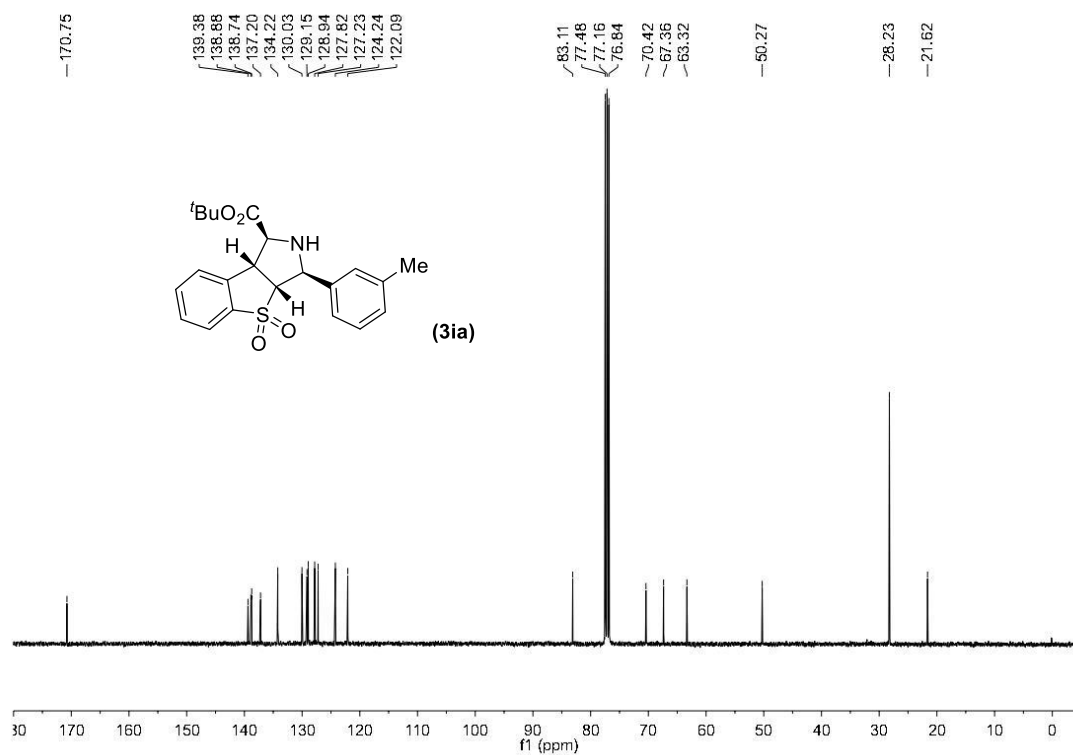
**<sup>13</sup>C NMR spectrum of compound **3ha** (CDCl<sub>3</sub>)**



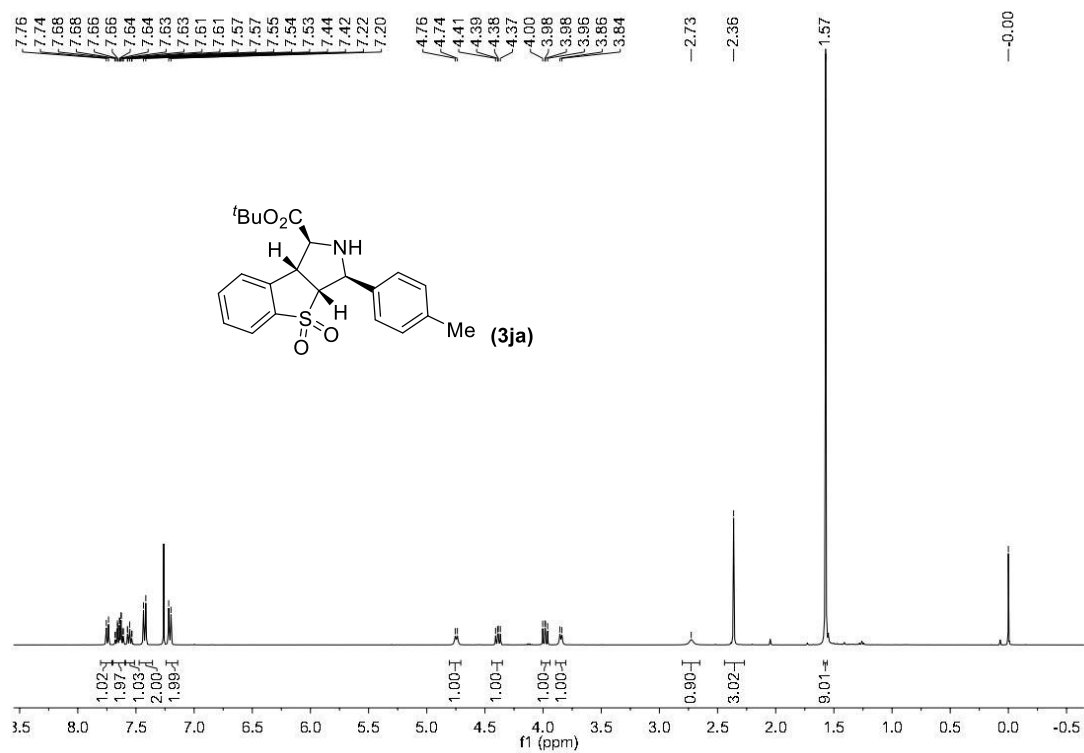
**<sup>1</sup>H NMR spectrum of compound **3ia** (CDCl<sub>3</sub>)**



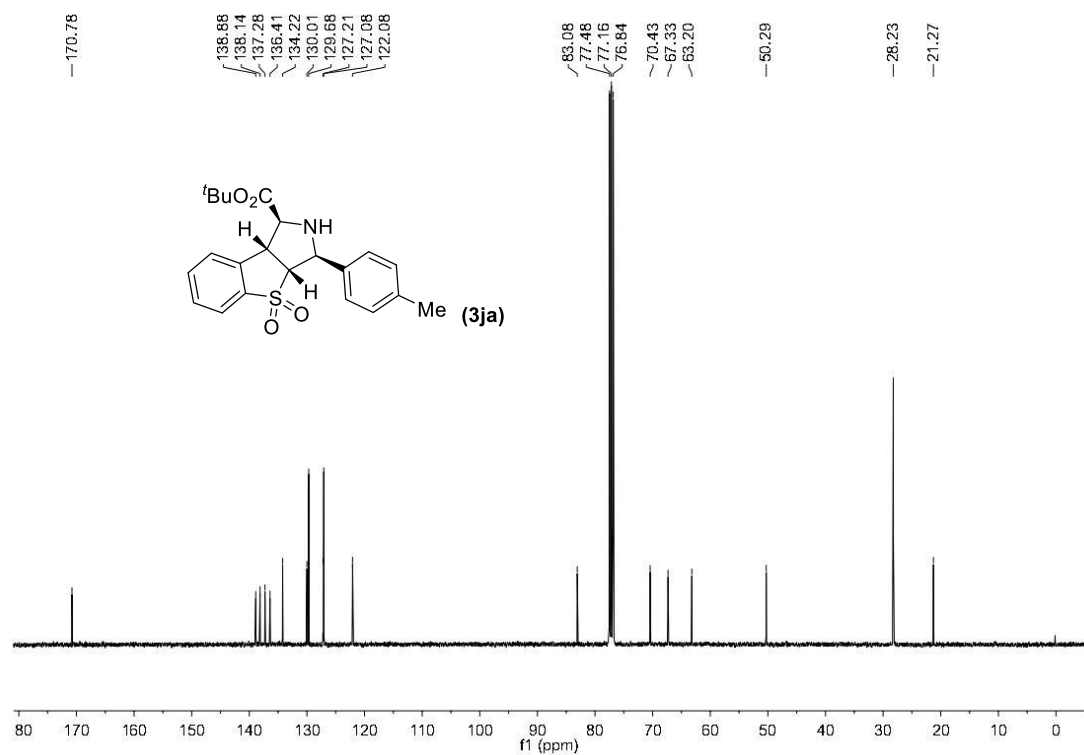
**<sup>13</sup>C NMR spectrum of compound **3ia** (CDCl<sub>3</sub>)**



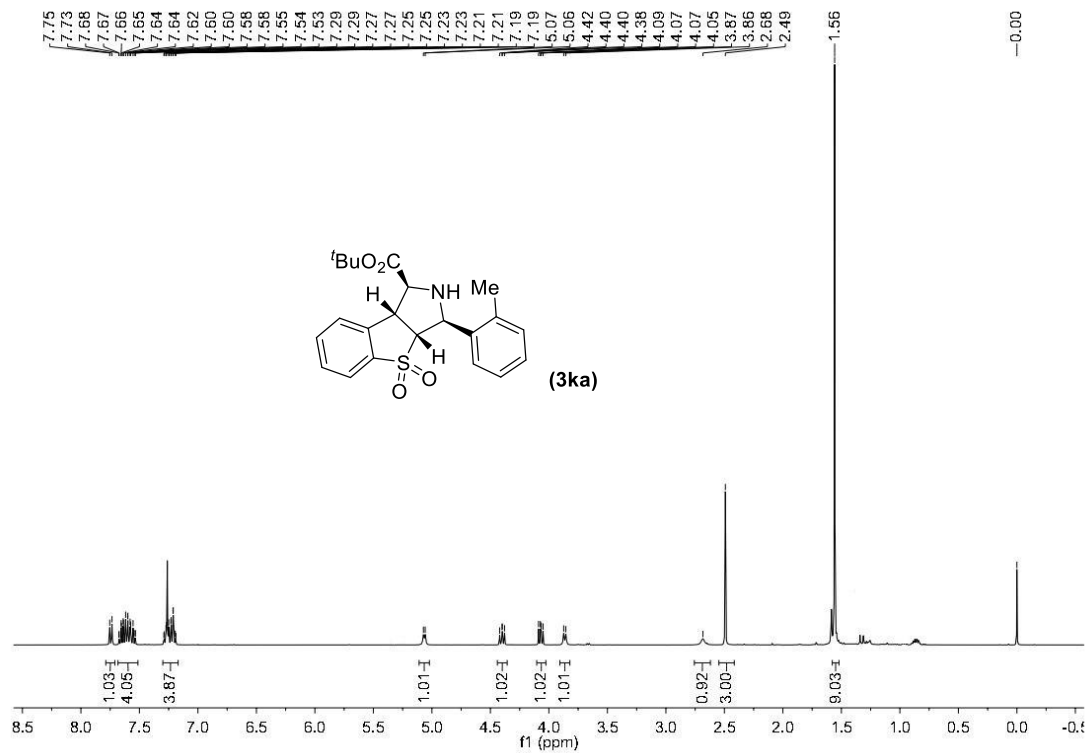
**<sup>1</sup>H NMR spectrum of compound **3ja** (CDCl<sub>3</sub>)**



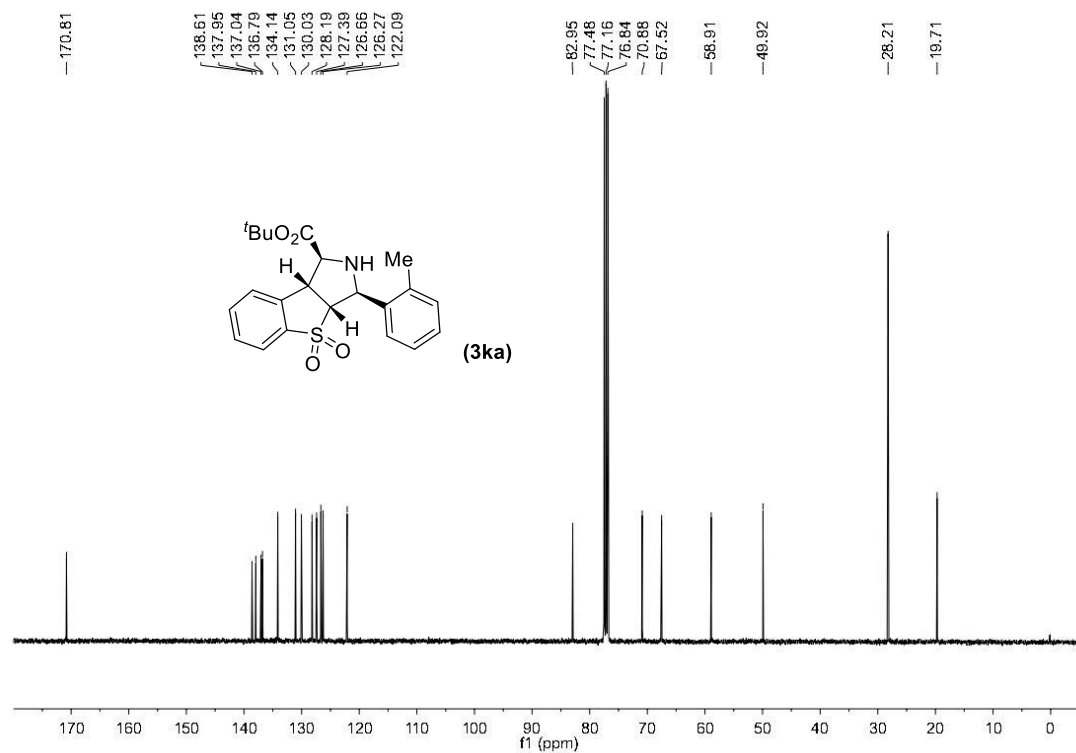
**<sup>13</sup>C NMR spectrum of compound 3ja (CDCl<sub>3</sub>)**



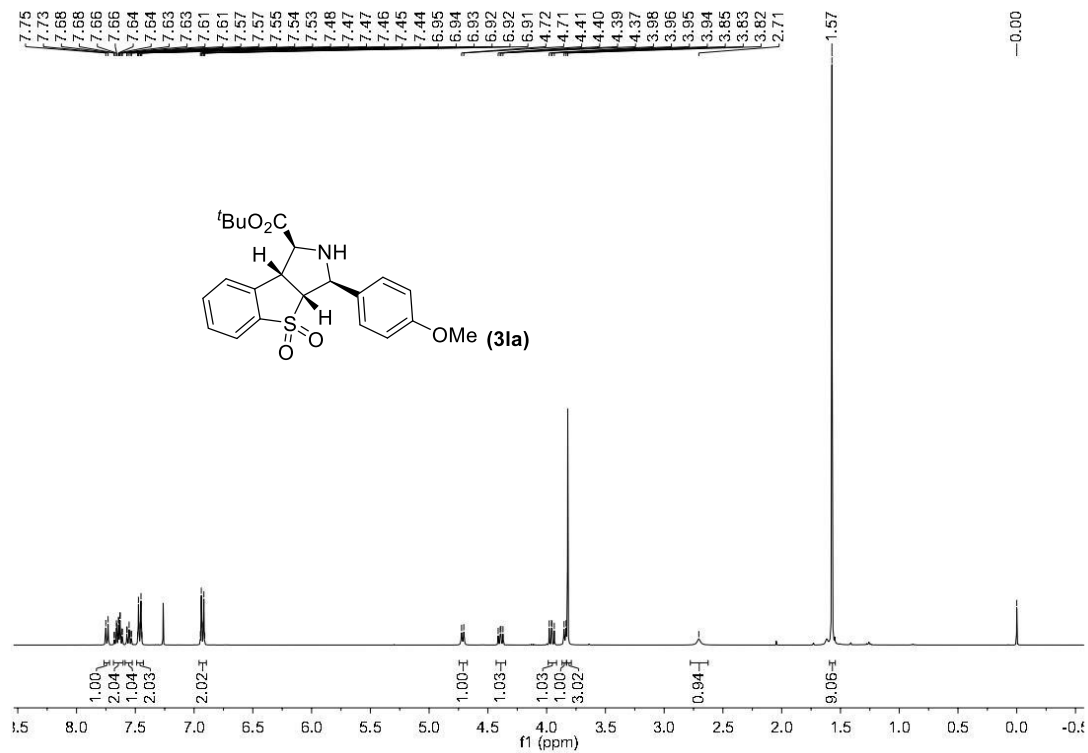
**<sup>1</sup>H NMR spectrum of compound 3ka (CDCl<sub>3</sub>)**



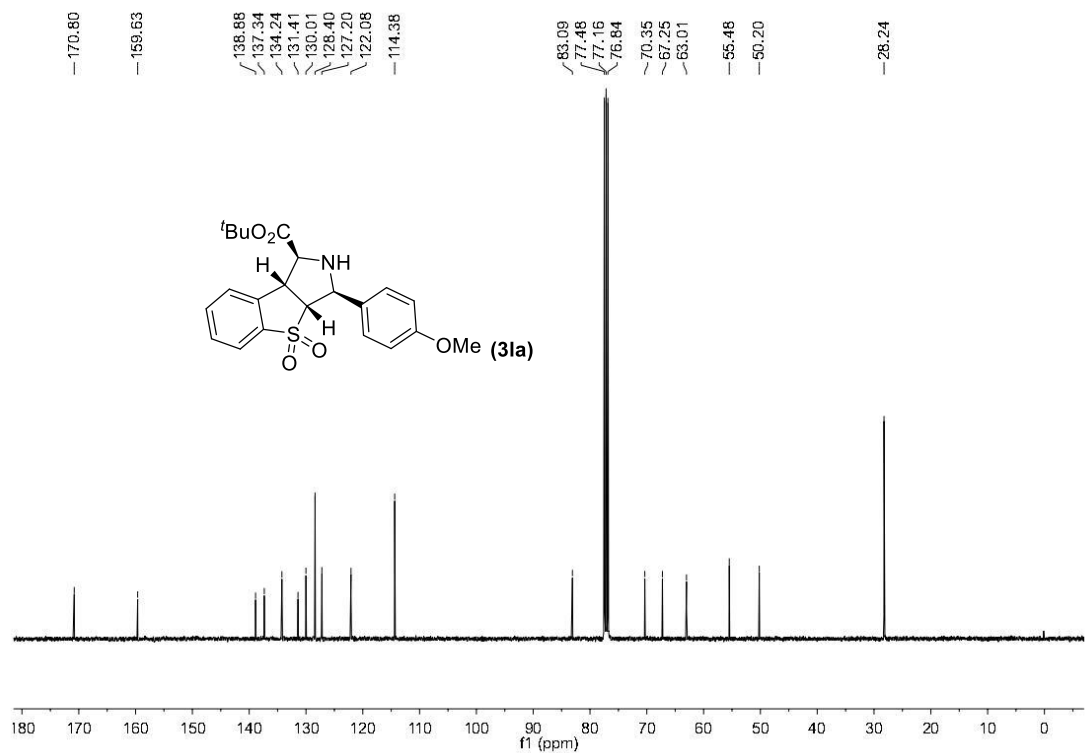
**<sup>13</sup>C NMR spectrum of compound **3ka** (CDCl<sub>3</sub>)**



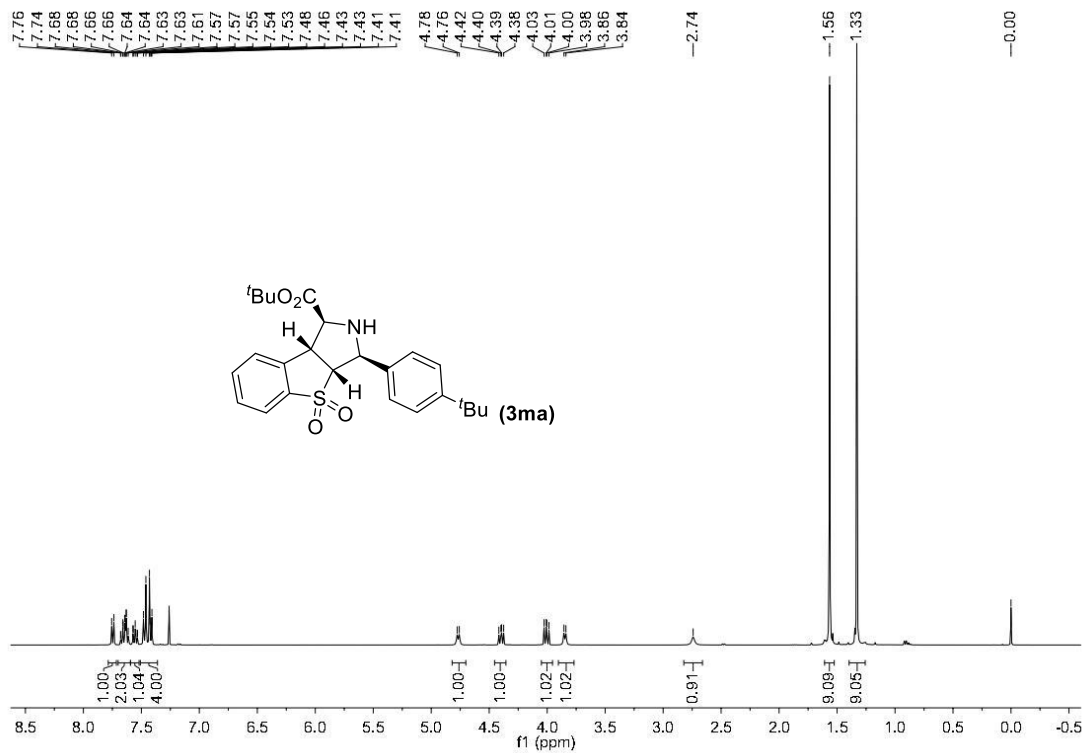
**<sup>1</sup>H NMR spectrum of compound **3la** (CDCl<sub>3</sub>)**



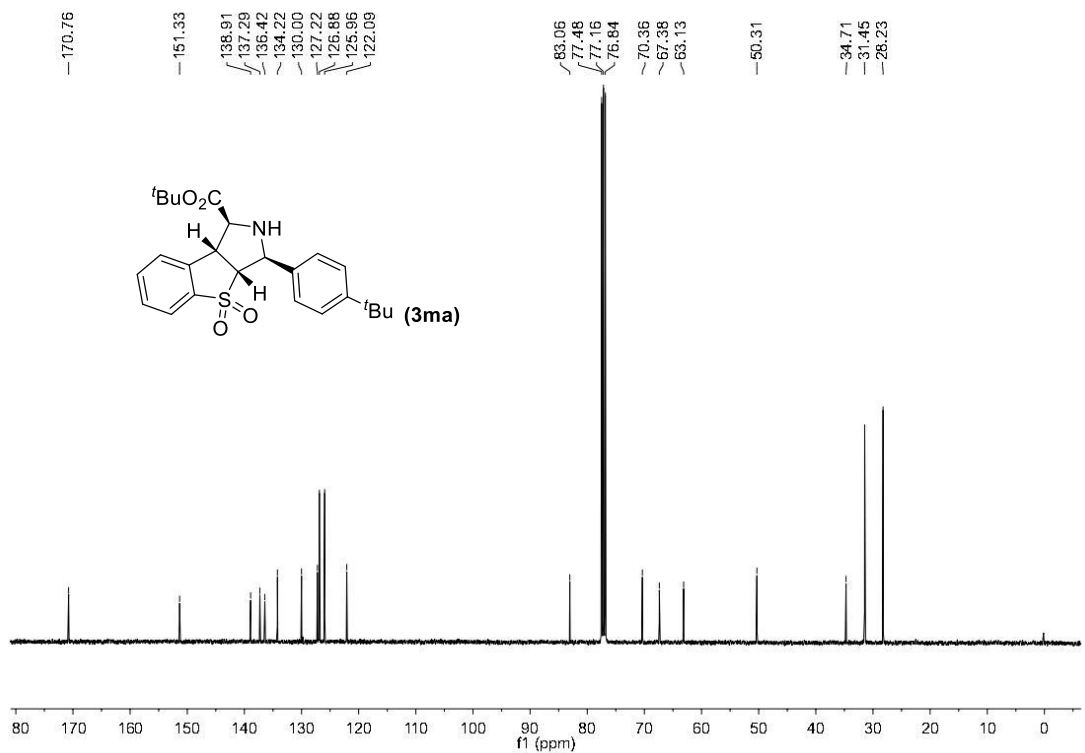
**<sup>13</sup>C NMR spectrum of compound **31a** (CDCl<sub>3</sub>)**



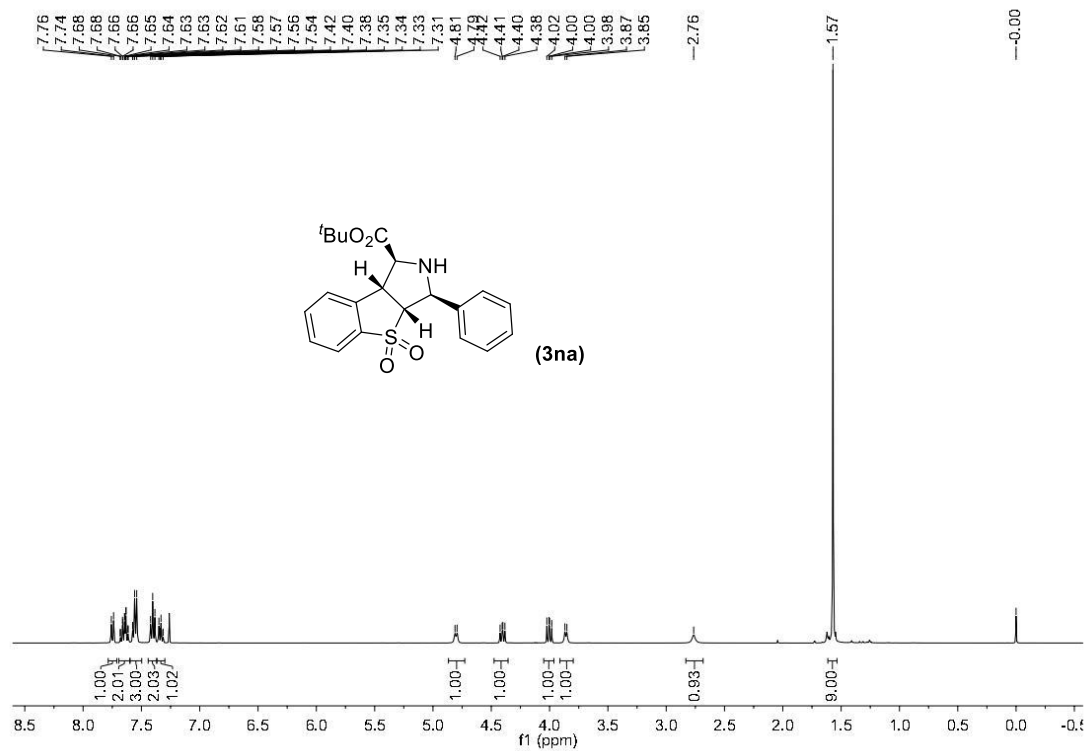
**<sup>1</sup>H NMR spectrum of compound **3ma** (CDCl<sub>3</sub>)**



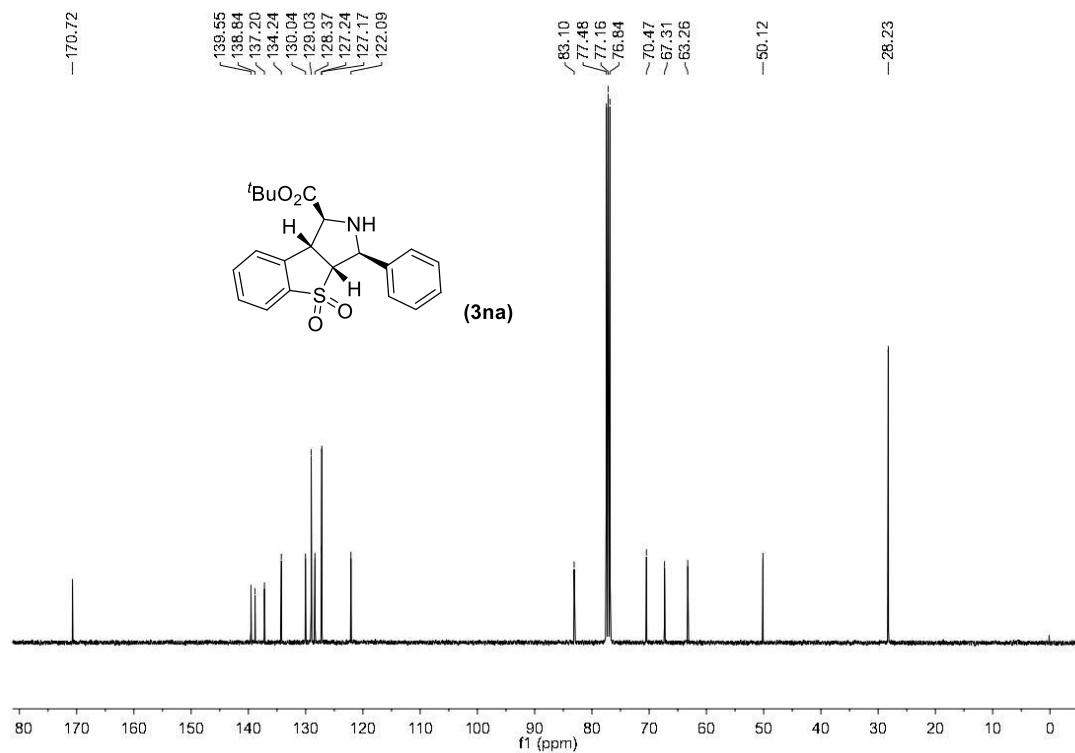
**<sup>13</sup>C NMR spectrum of compound **3ma** (CDCl<sub>3</sub>)**



**<sup>1</sup>H NMR spectrum of compound **3na** (CDCl<sub>3</sub>)**

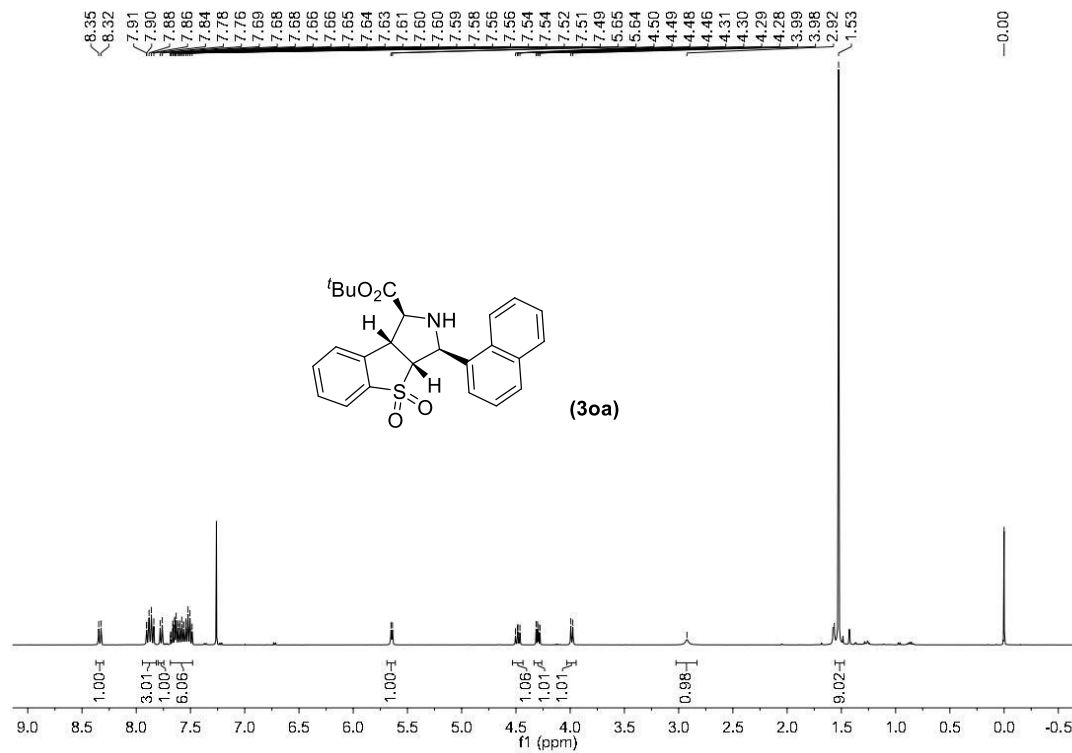


**<sup>13</sup>C NMR spectrum of compound 3na (CDCl<sub>3</sub>)**

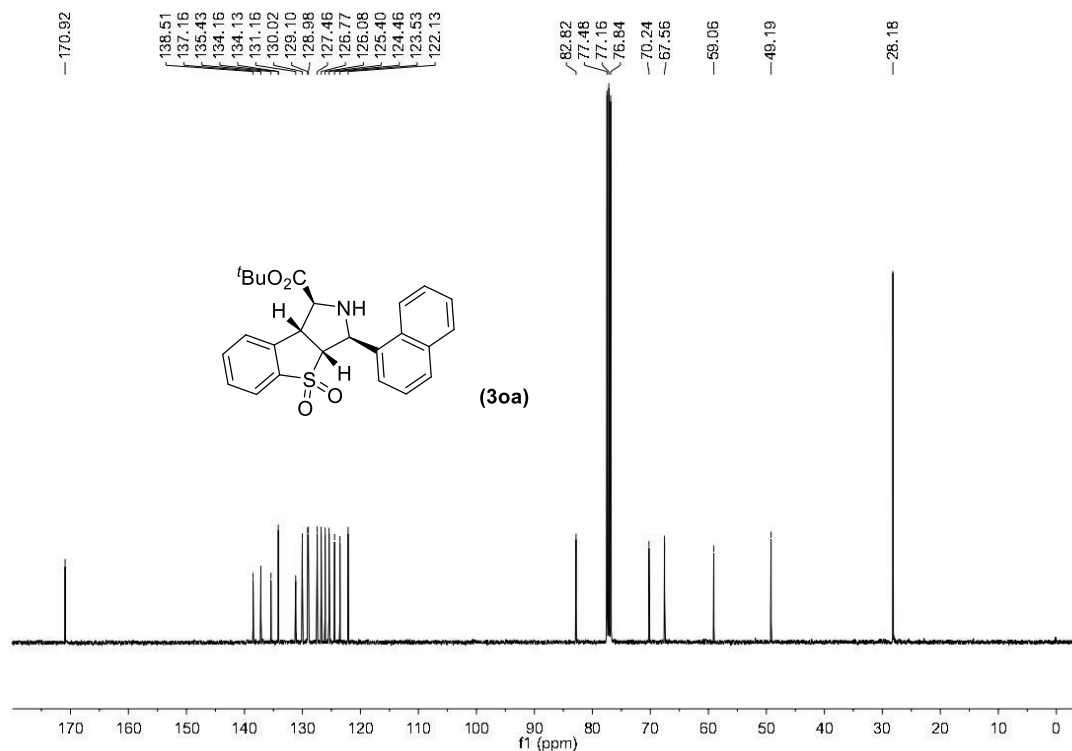


**<sup>1</sup>H NMR spectrum of compound 3oa (CDCl<sub>3</sub>)**

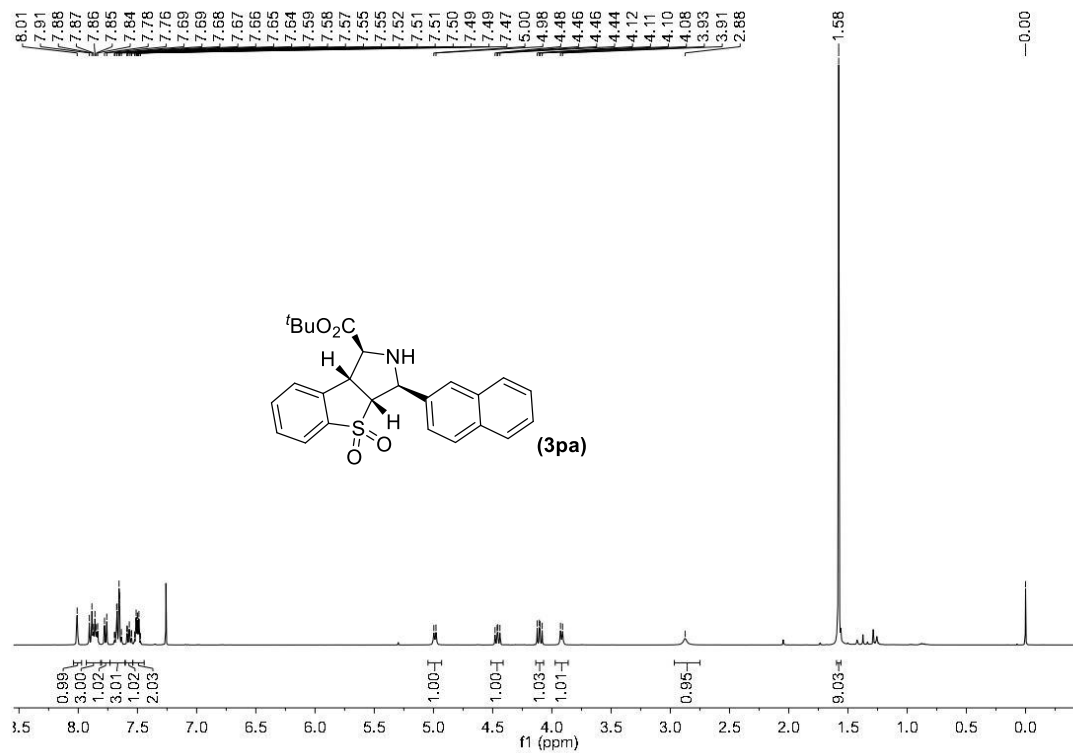




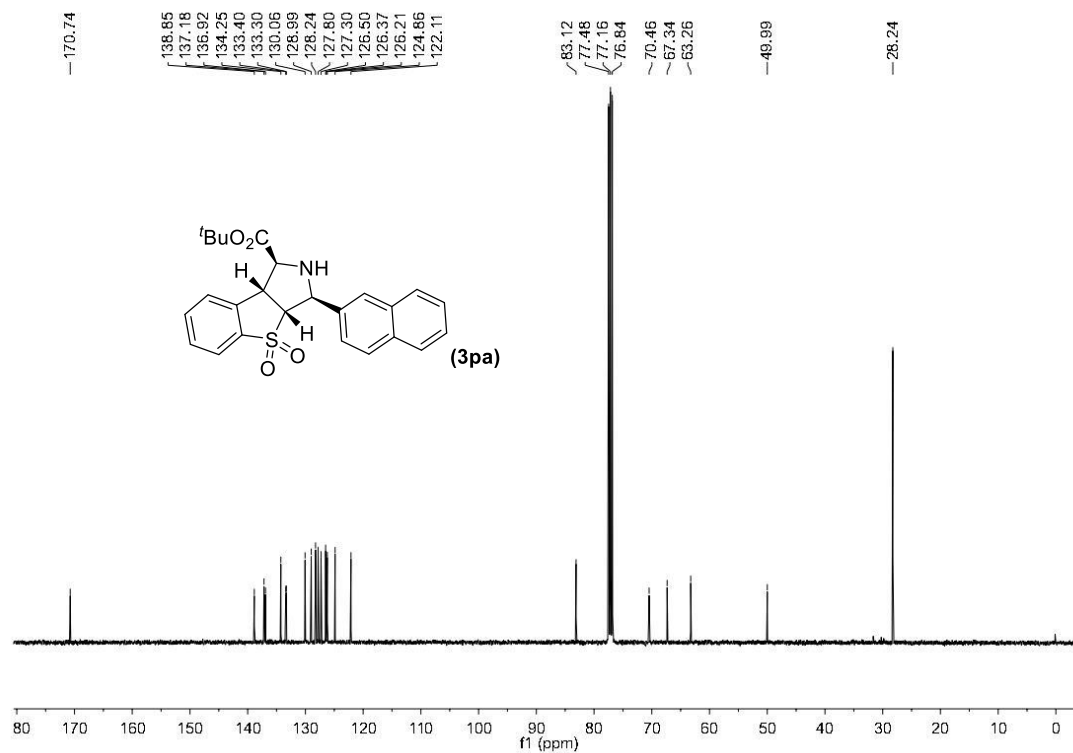
**<sup>13</sup>C NMR spectrum of compound 30a (CDCl<sub>3</sub>)**



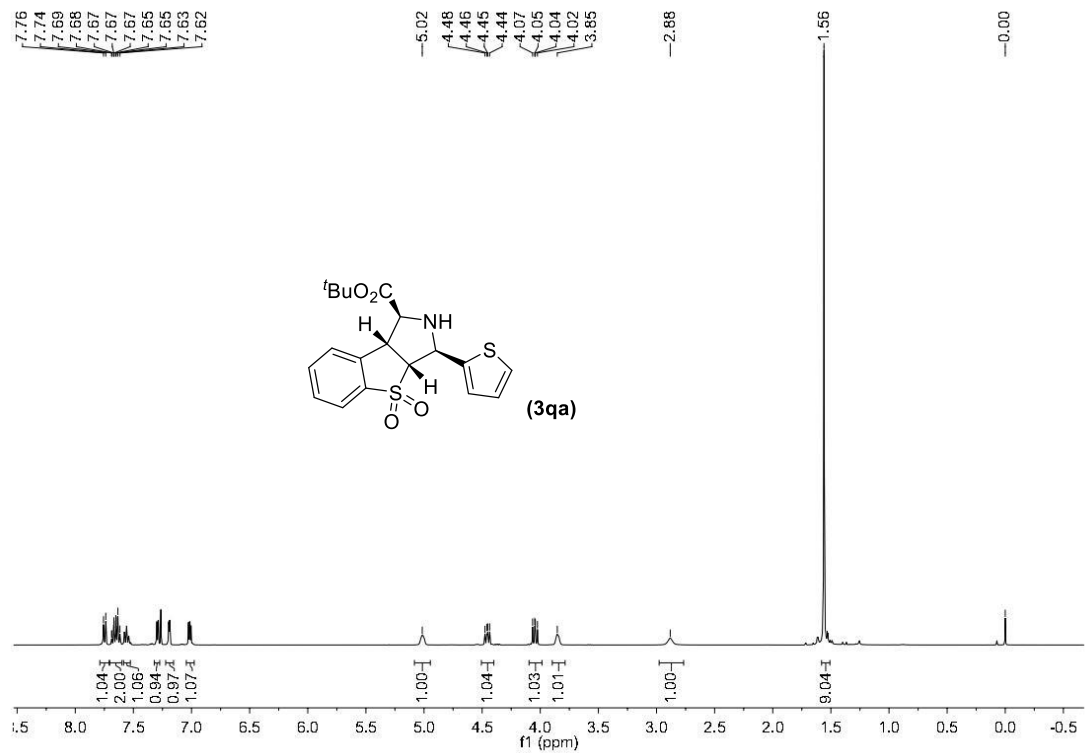
**<sup>1</sup>H NMR spectrum of compound 30a (CDCl<sub>3</sub>)**



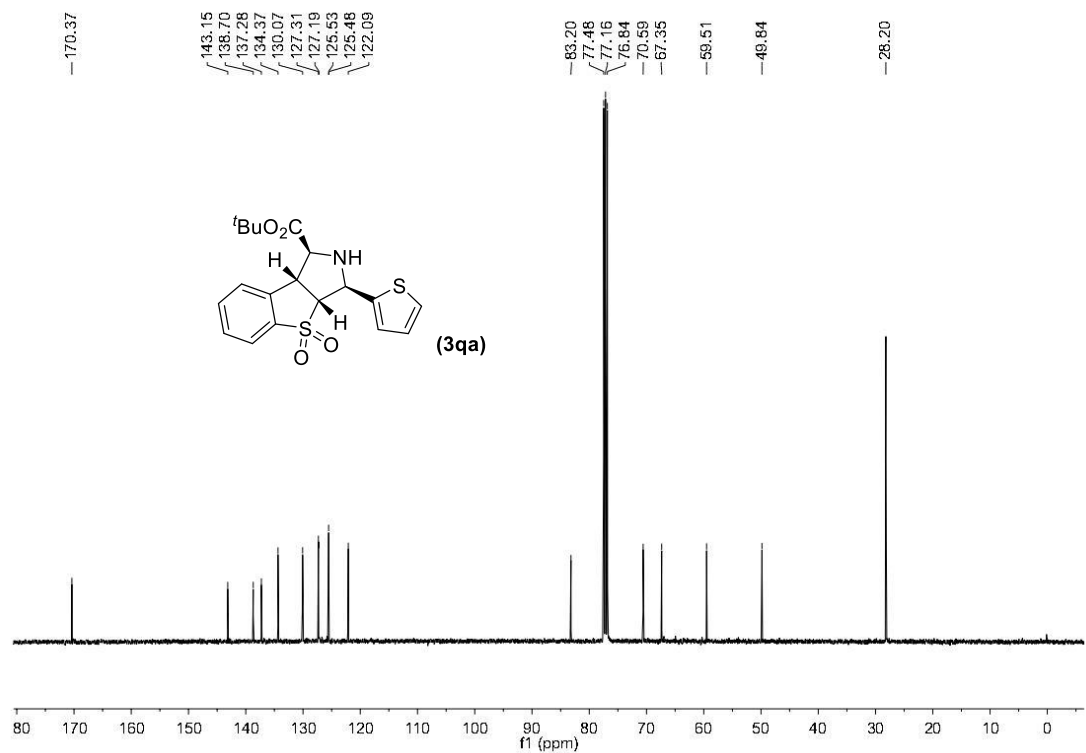
**<sup>13</sup>C NMR spectrum of compound **3pa** (CDCl<sub>3</sub>)**



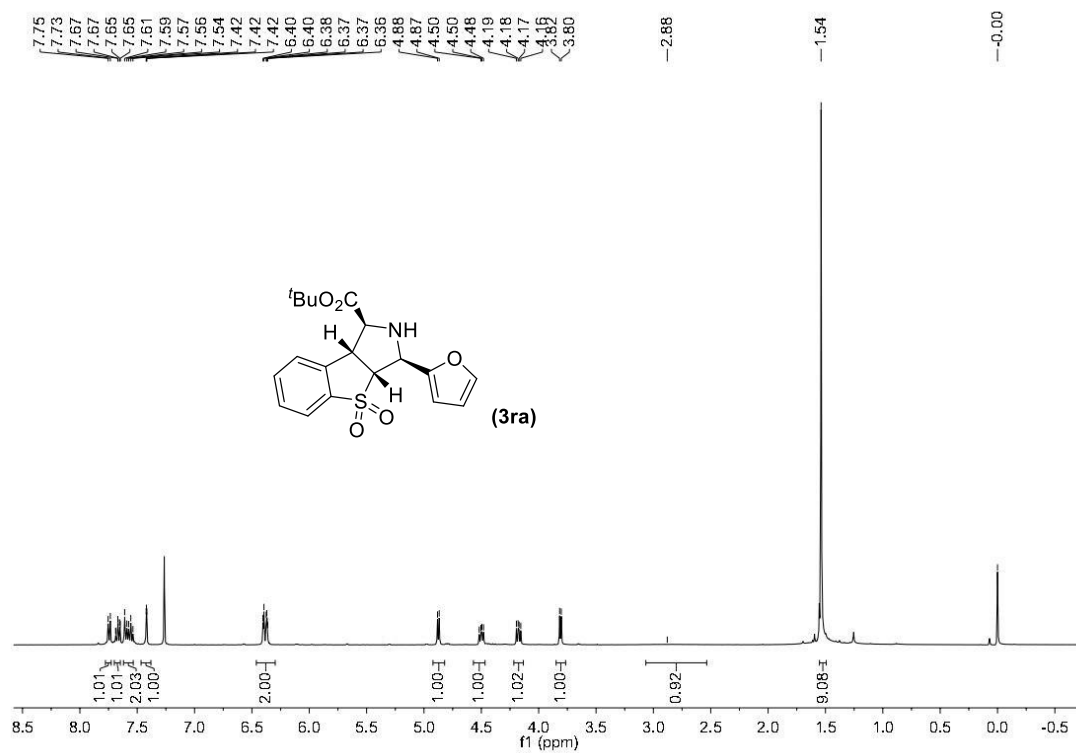
**<sup>1</sup>H NMR spectrum of compound **3qa** (CDCl<sub>3</sub>)**



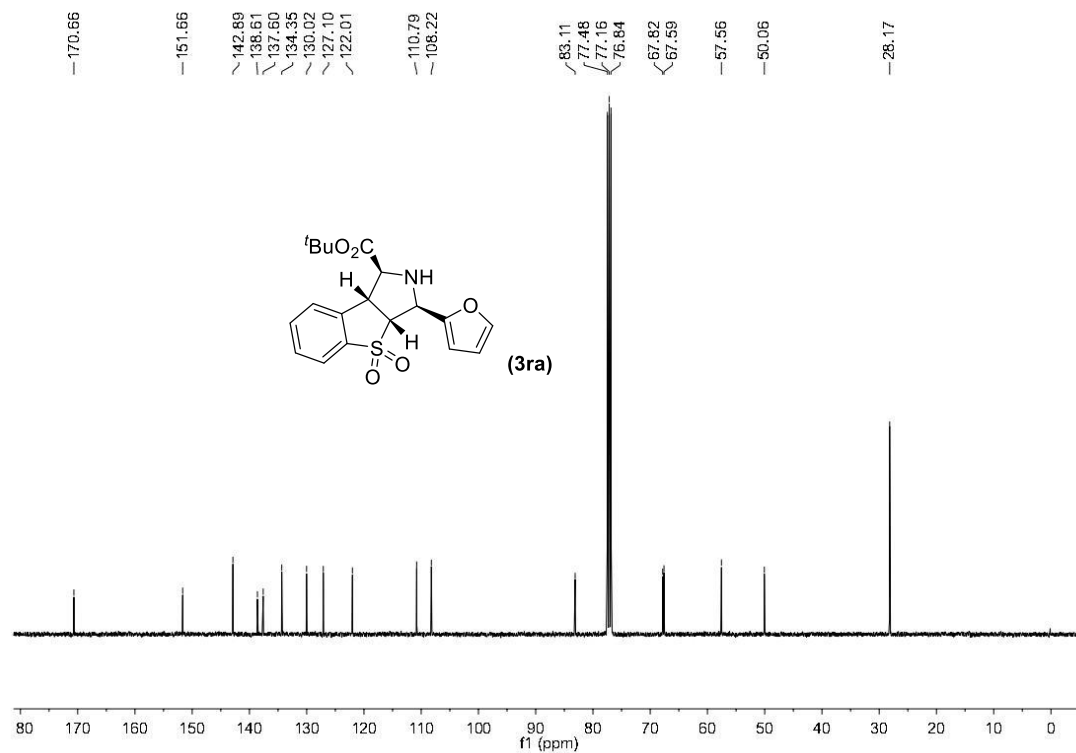
**<sup>13</sup>C NMR spectrum of compound 3qa (CDCl<sub>3</sub>)**



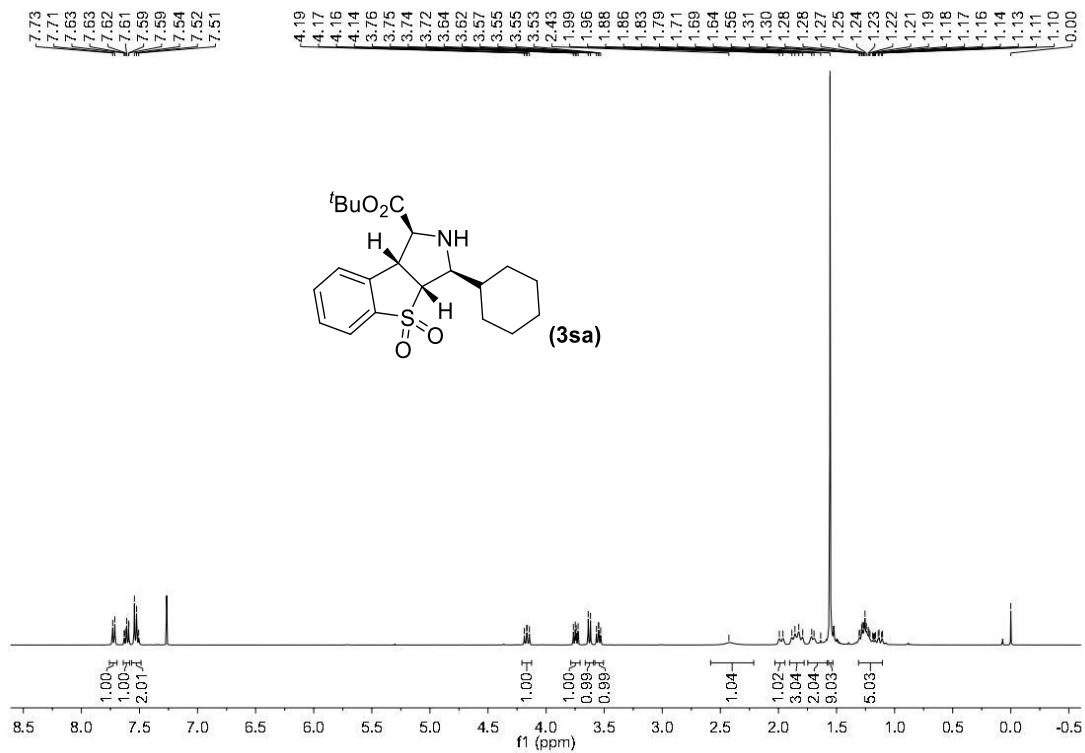
**<sup>1</sup>H NMR spectrum of compound 3ra (CDCl<sub>3</sub>)**



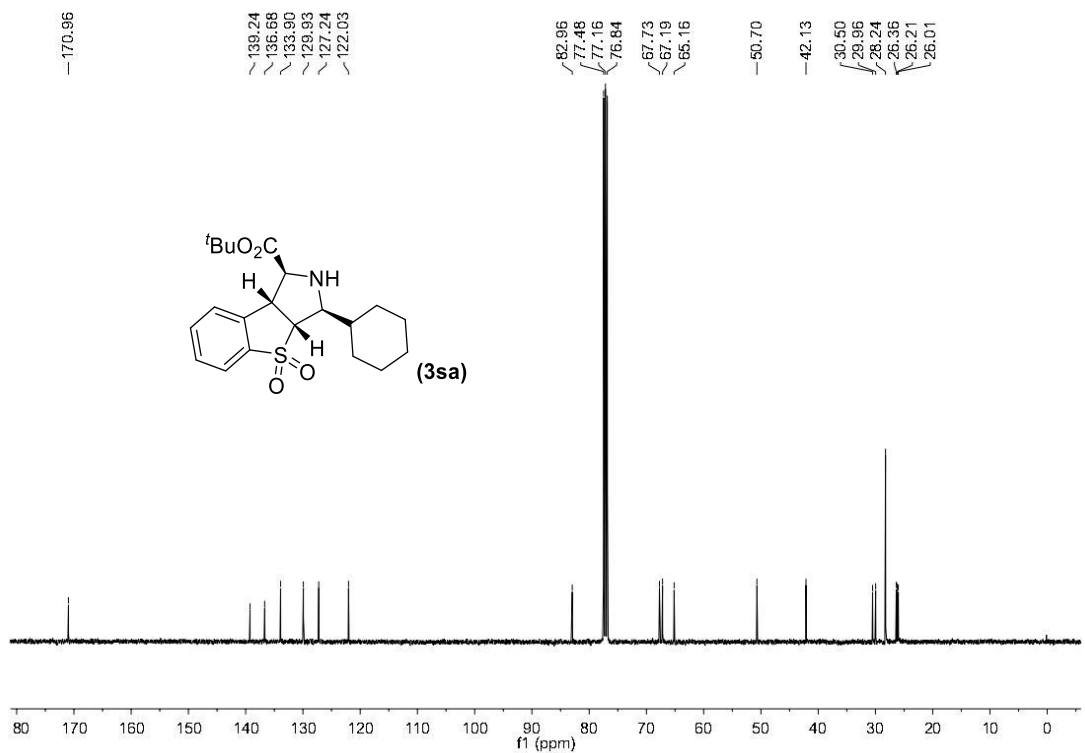
**<sup>13</sup>C NMR spectrum of compound 3ra (CDCl<sub>3</sub>)**



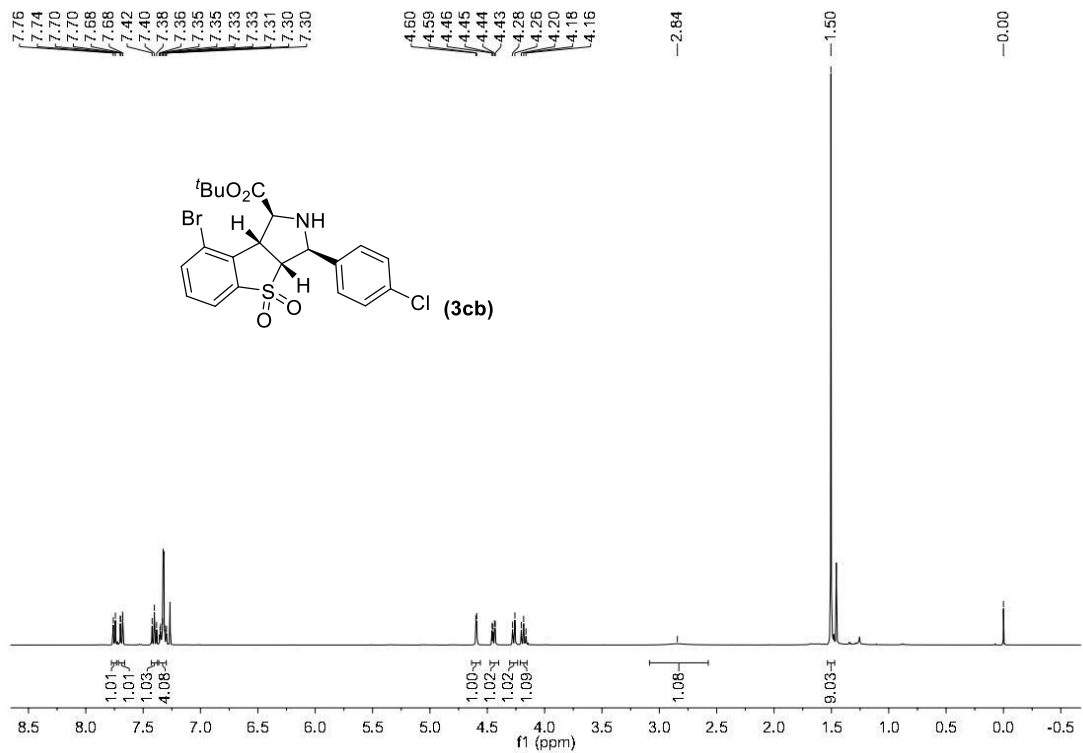
**<sup>1</sup>H NMR spectrum of compound 3sa (CDCl<sub>3</sub>)**



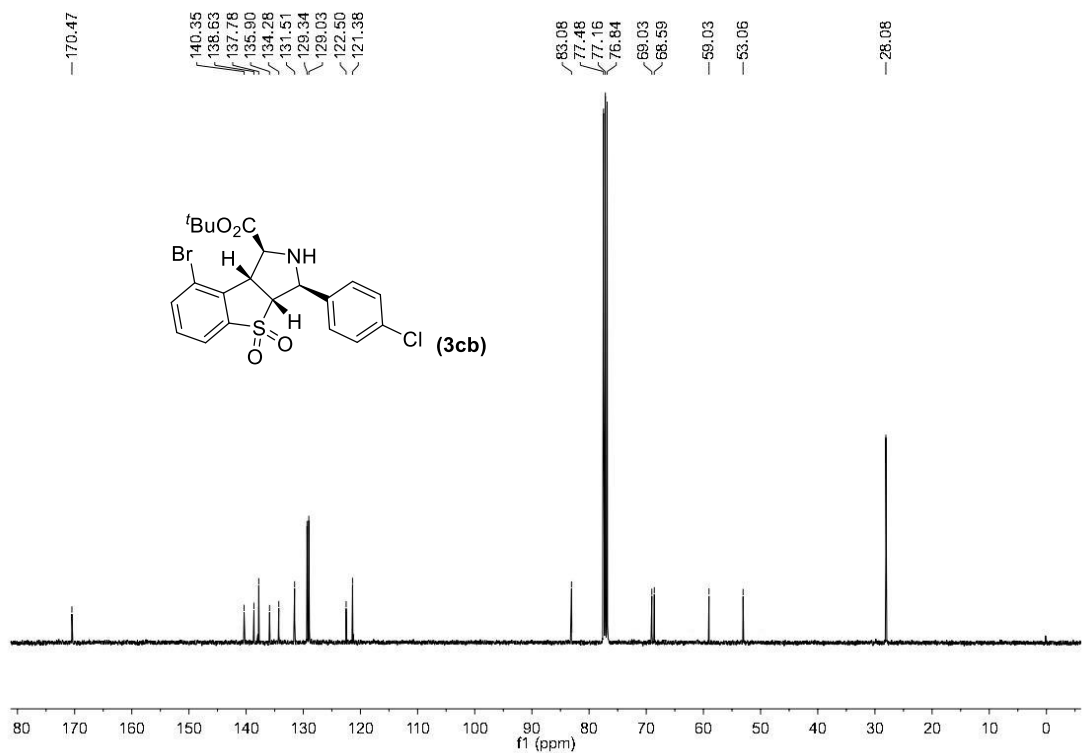
**<sup>13</sup>C NMR spectrum of compound 3sa (CDCl<sub>3</sub>)**



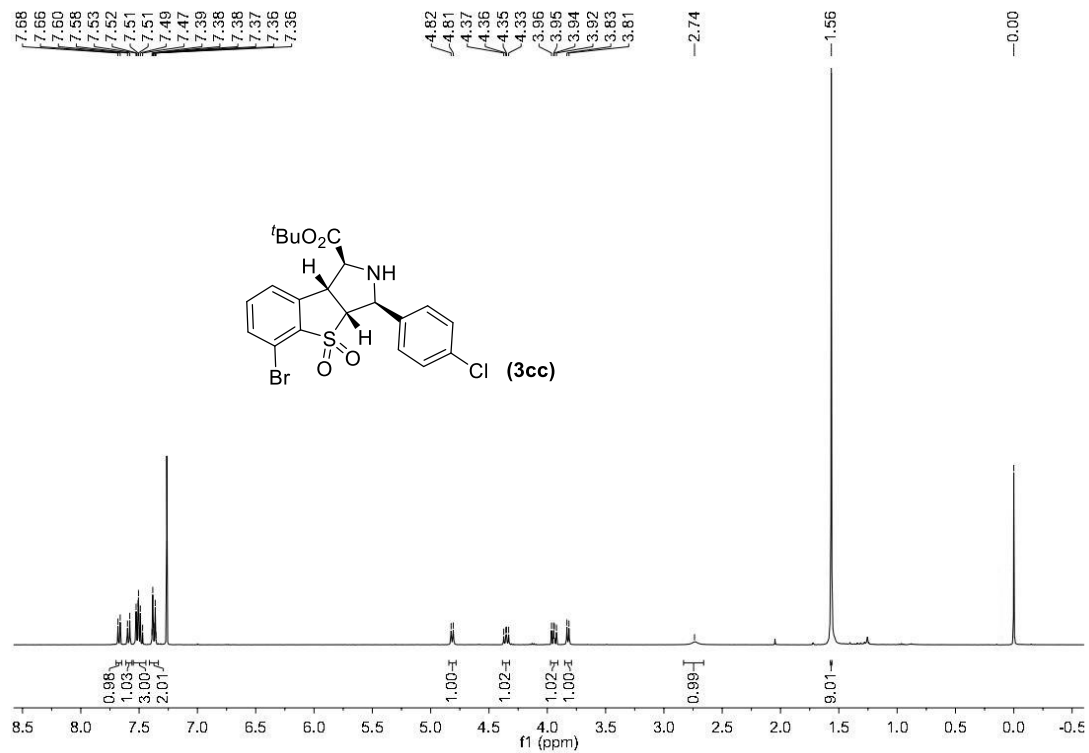
**<sup>1</sup>H NMR spectrum of compound 3cb (CDCl<sub>3</sub>)**



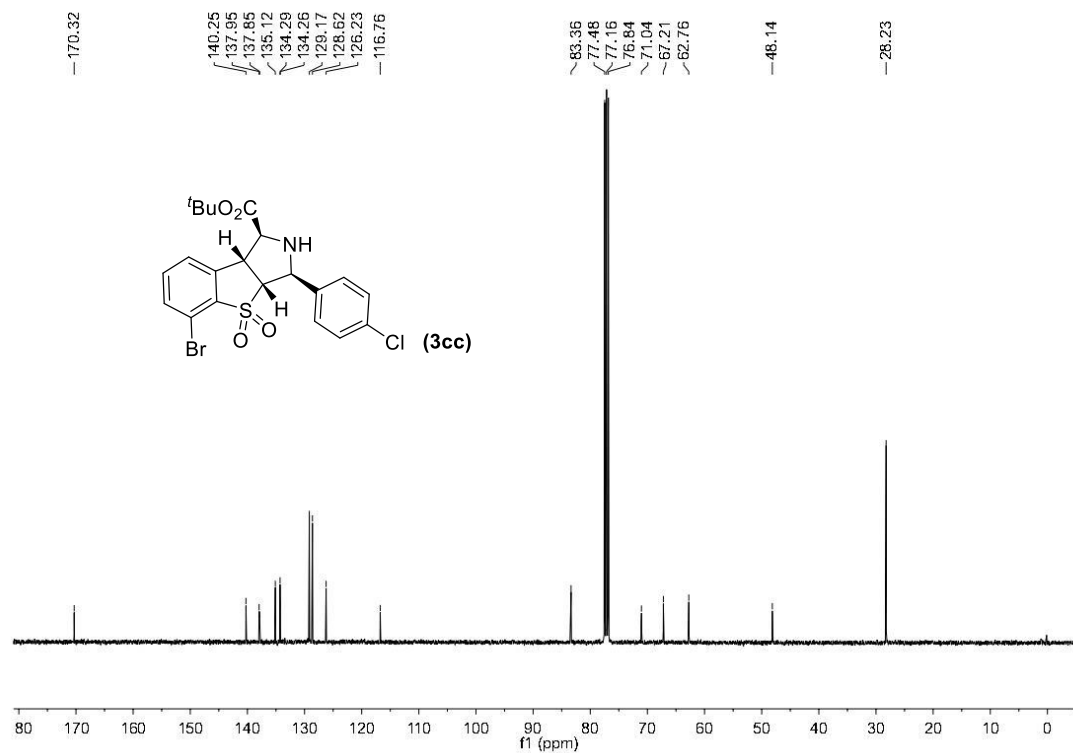
<sup>13</sup>C NMR spectrum of compound 3cb (CDCl<sub>3</sub>)



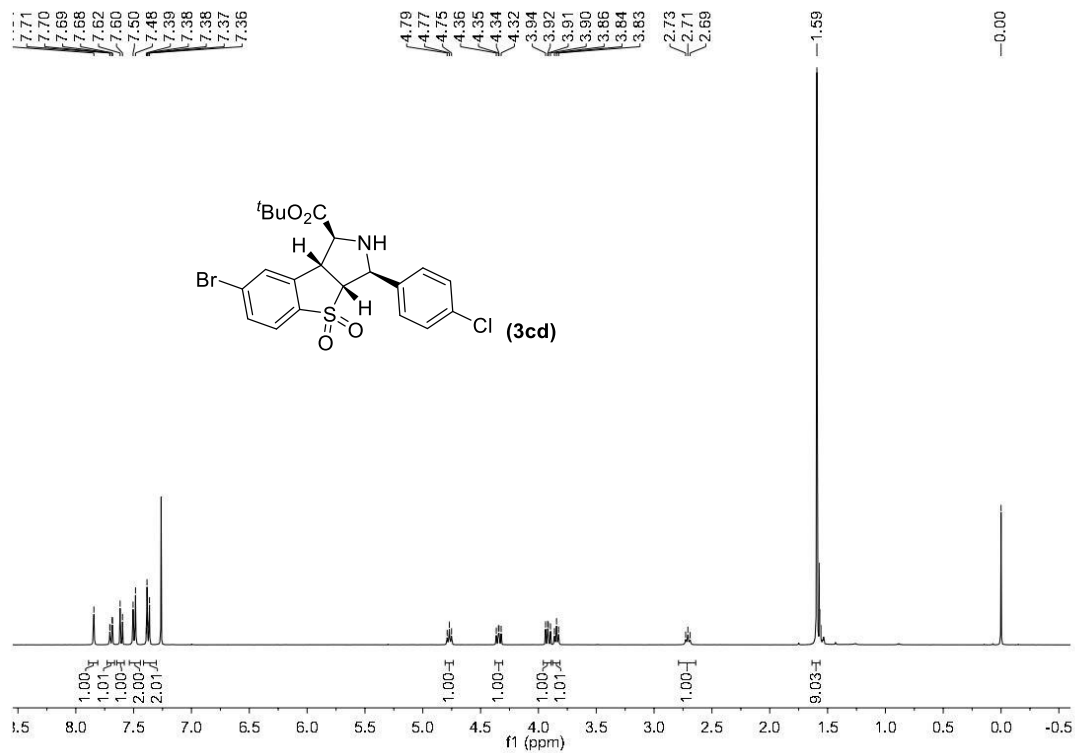
<sup>1</sup>H NMR spectrum of compound 3cc (CDCl<sub>3</sub>)



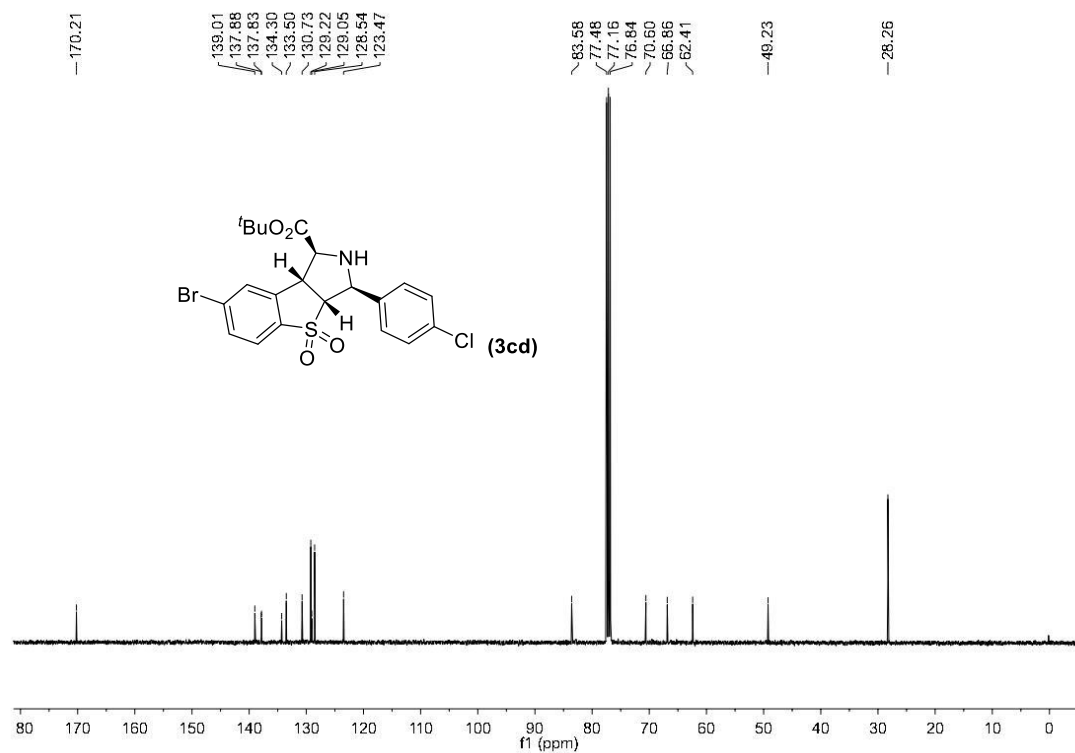
**<sup>13</sup>C NMR spectrum of compound 3cc (CDCl<sub>3</sub>)**



**<sup>1</sup>H NMR spectrum of compound 3cd (CDCl<sub>3</sub>)**

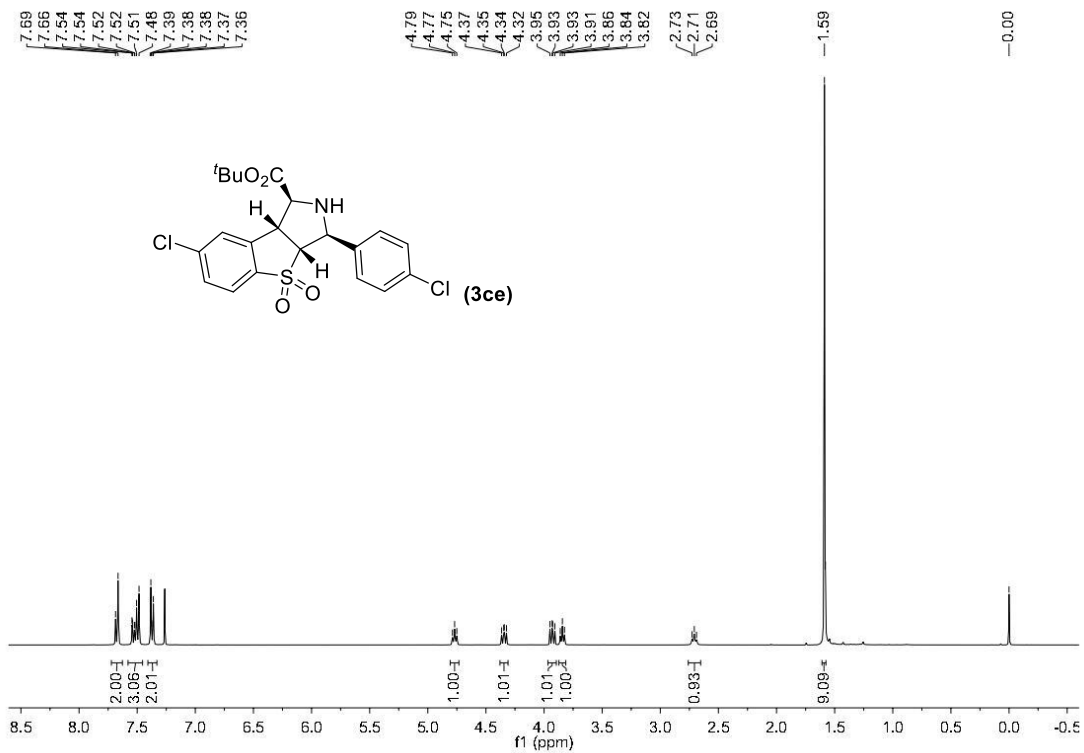


**<sup>13</sup>C NMR spectrum of compound 3cd (CDCl<sub>3</sub>)**

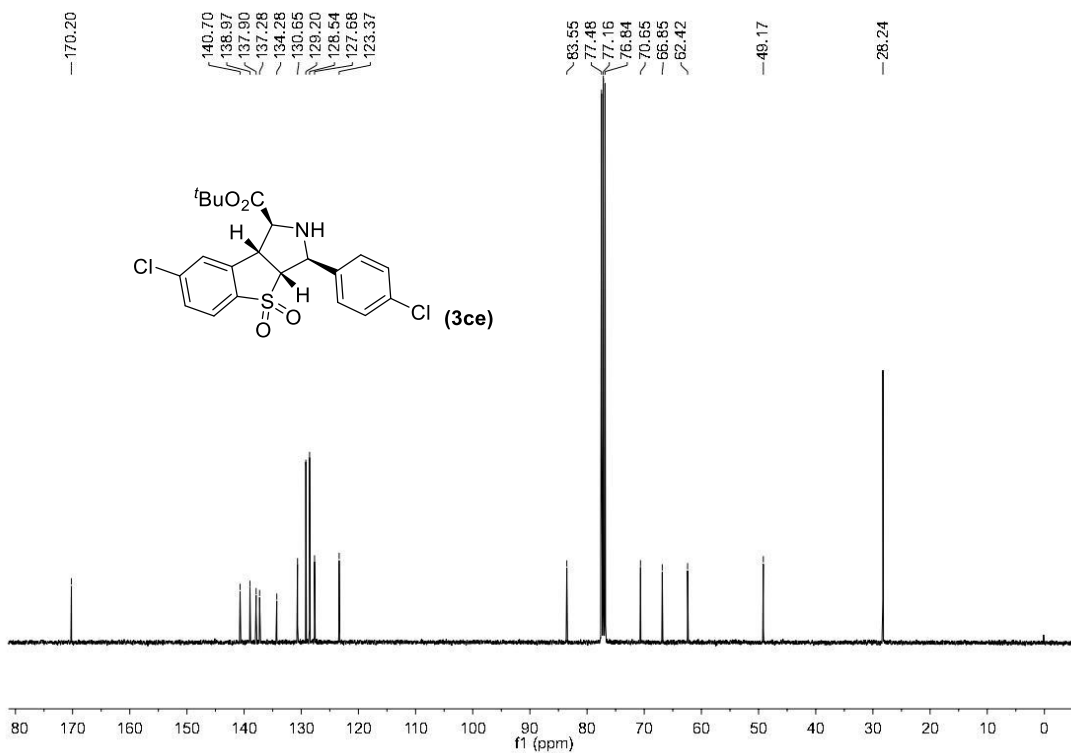


**<sup>1</sup>H NMR spectrum of compound 3ce(CDCl<sub>3</sub>)**

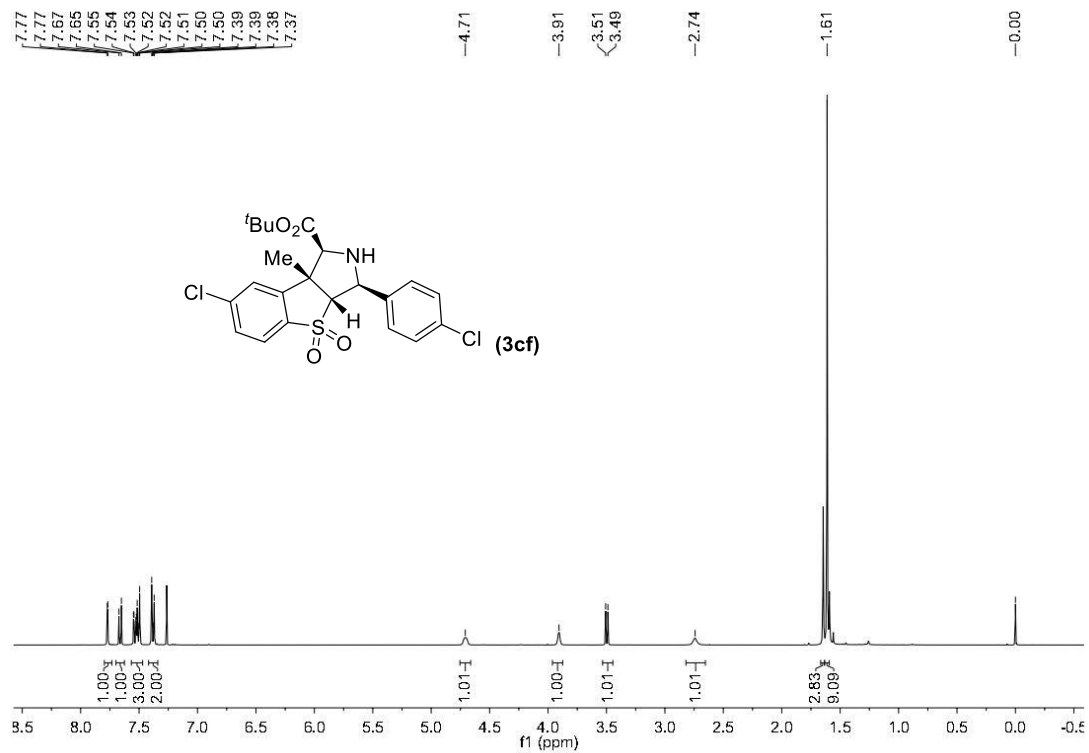




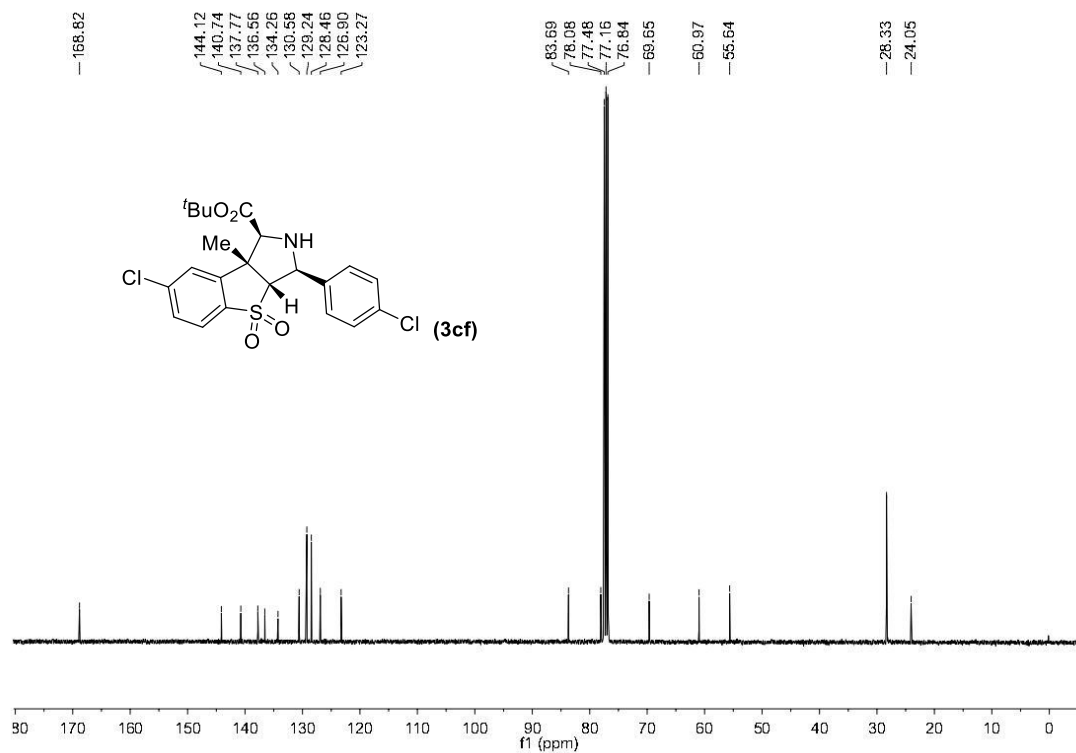
<sup>13</sup>C NMR spectrum of compound 3ce (CDCl<sub>3</sub>)



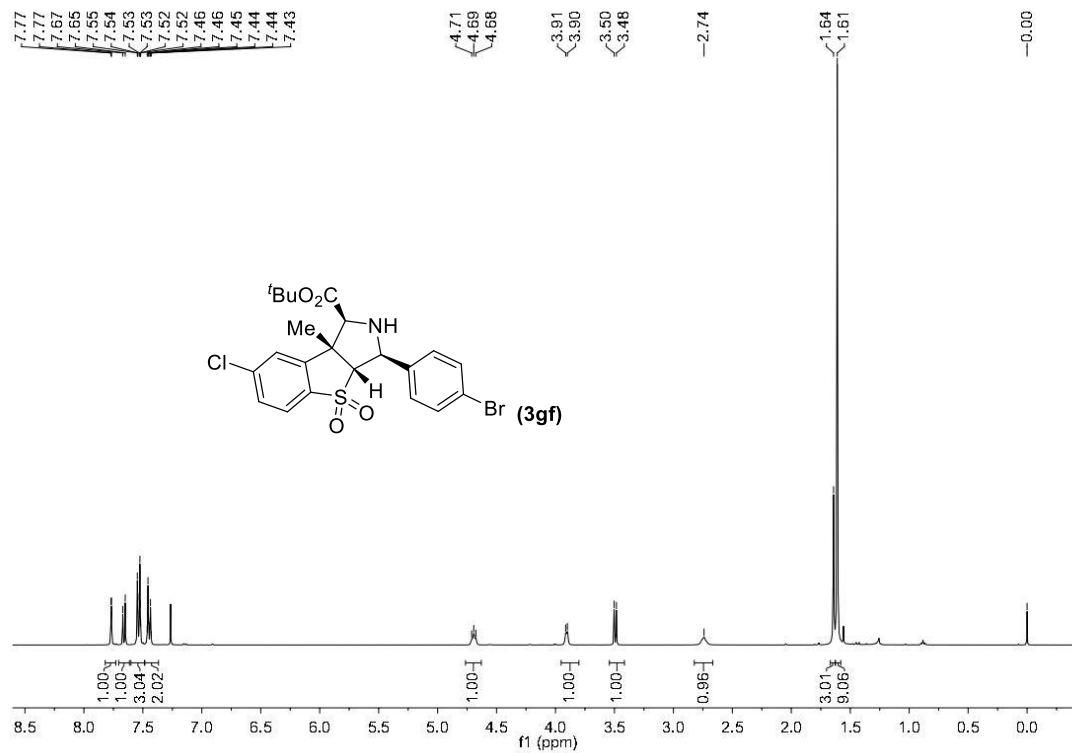
<sup>1</sup>H NMR spectrum of compound 3cf (CDCl<sub>3</sub>)



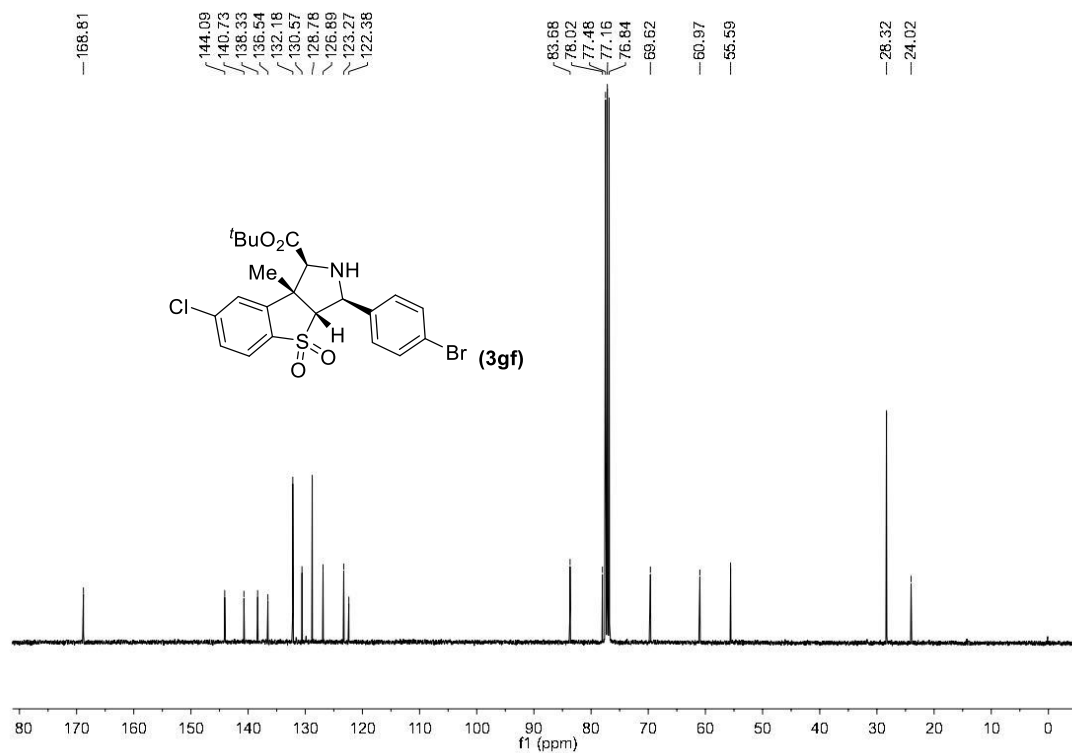
**<sup>13</sup>C NMR spectrum of compound **3cf** (CDCl<sub>3</sub>)**



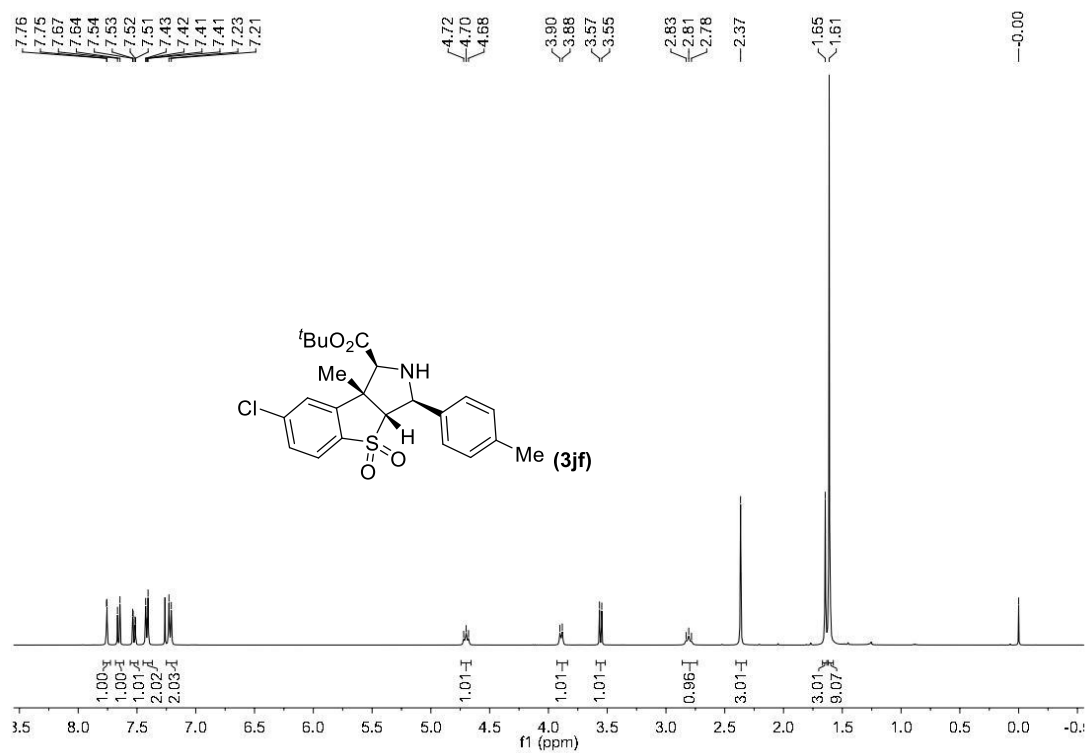
**<sup>1</sup>H NMR spectrum of compound **3gf** (CDCl<sub>3</sub>)**



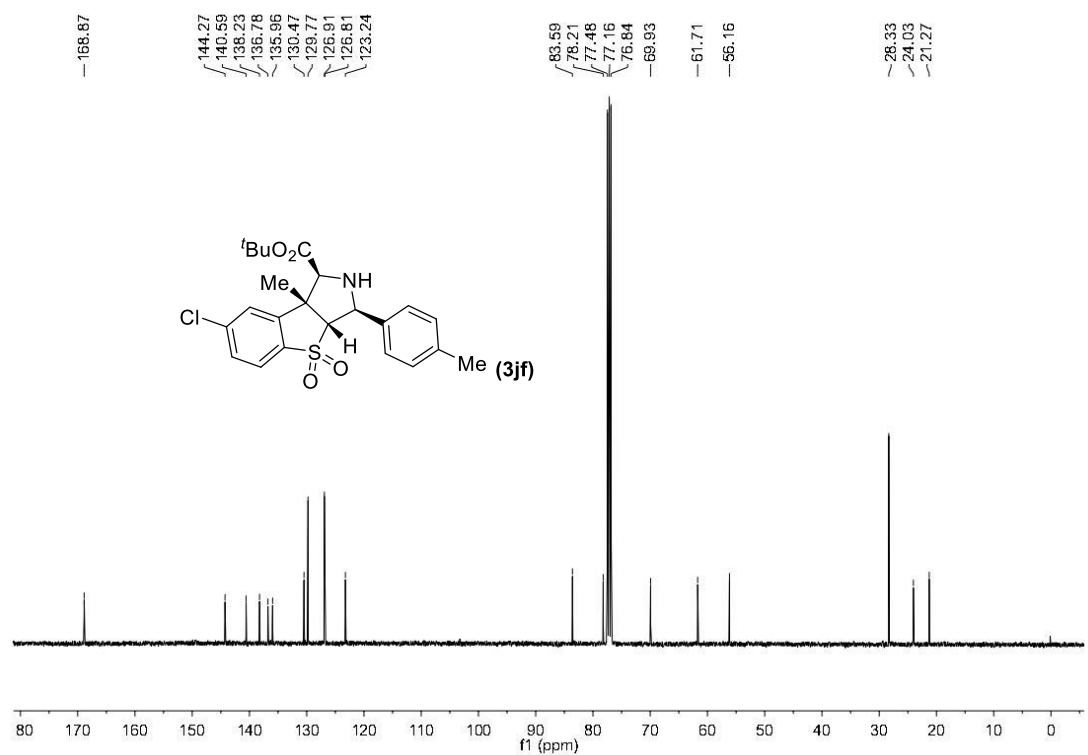
**<sup>13</sup>C NMR spectrum of compound **3gf** (CDCl<sub>3</sub>)**



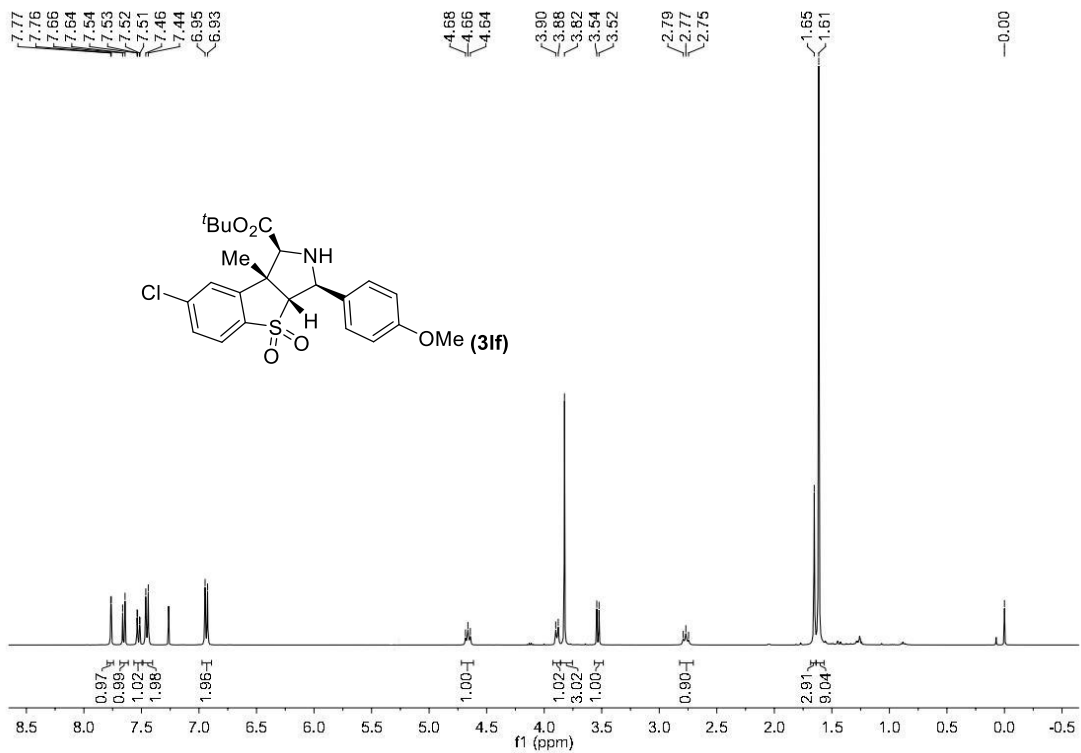
**<sup>1</sup>H NMR spectrum of compound **3jf**(CDCl<sub>3</sub>)**



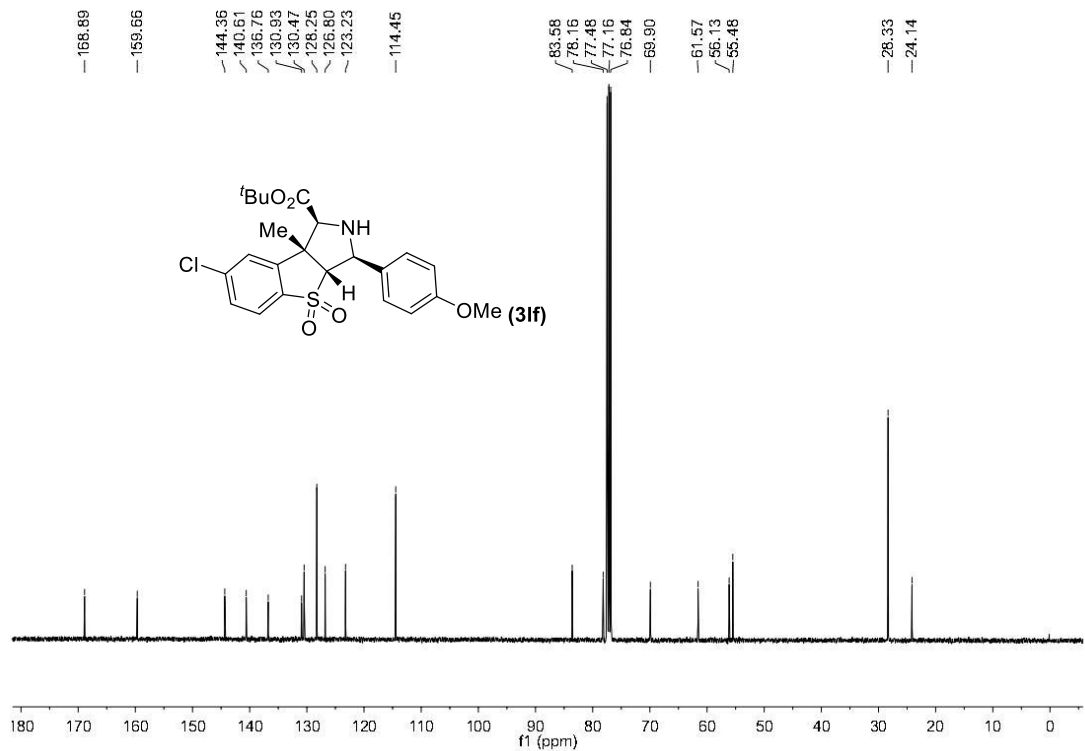
**<sup>13</sup>C NMR spectrum of compound **3jf** (CDCl<sub>3</sub>)**



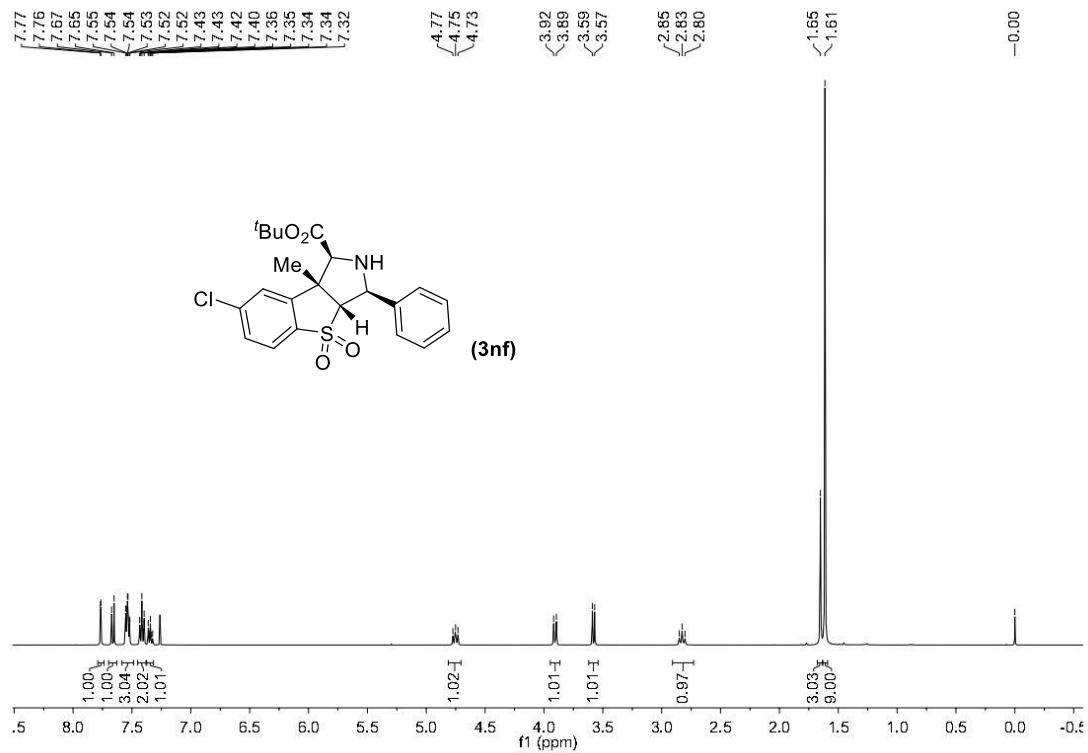
**<sup>1</sup>H NMR spectrum of compound **3lf** (CDCl<sub>3</sub>)**



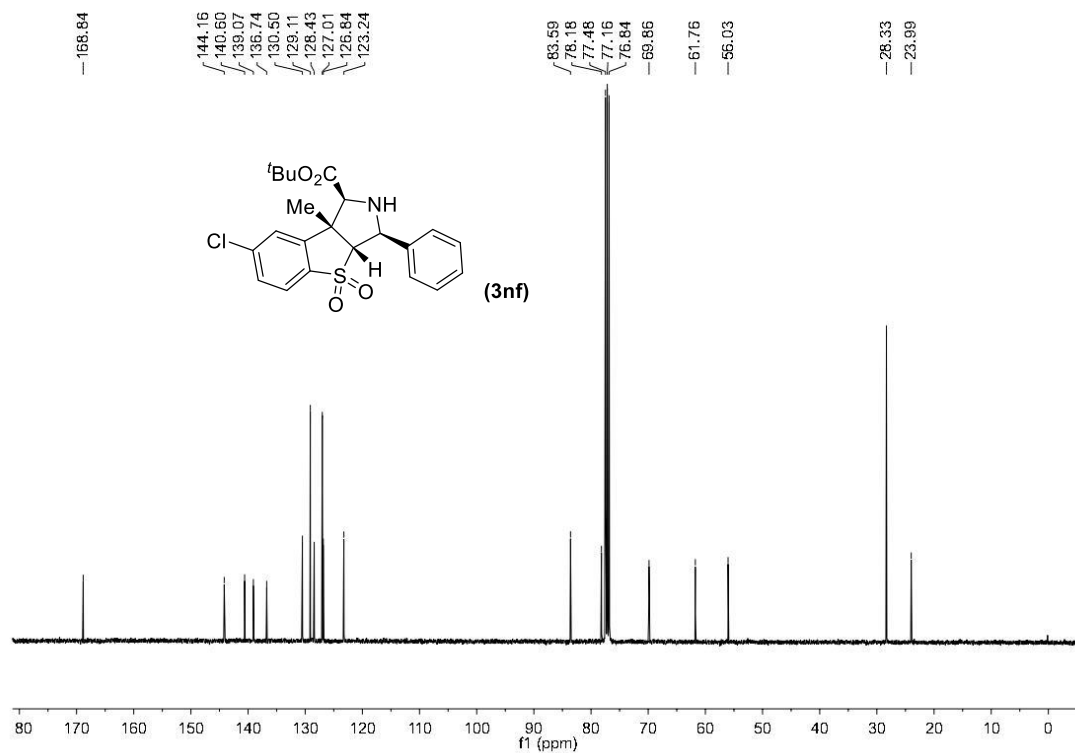
**<sup>13</sup>C NMR spectrum of compound **3f** (CDCl<sub>3</sub>)**



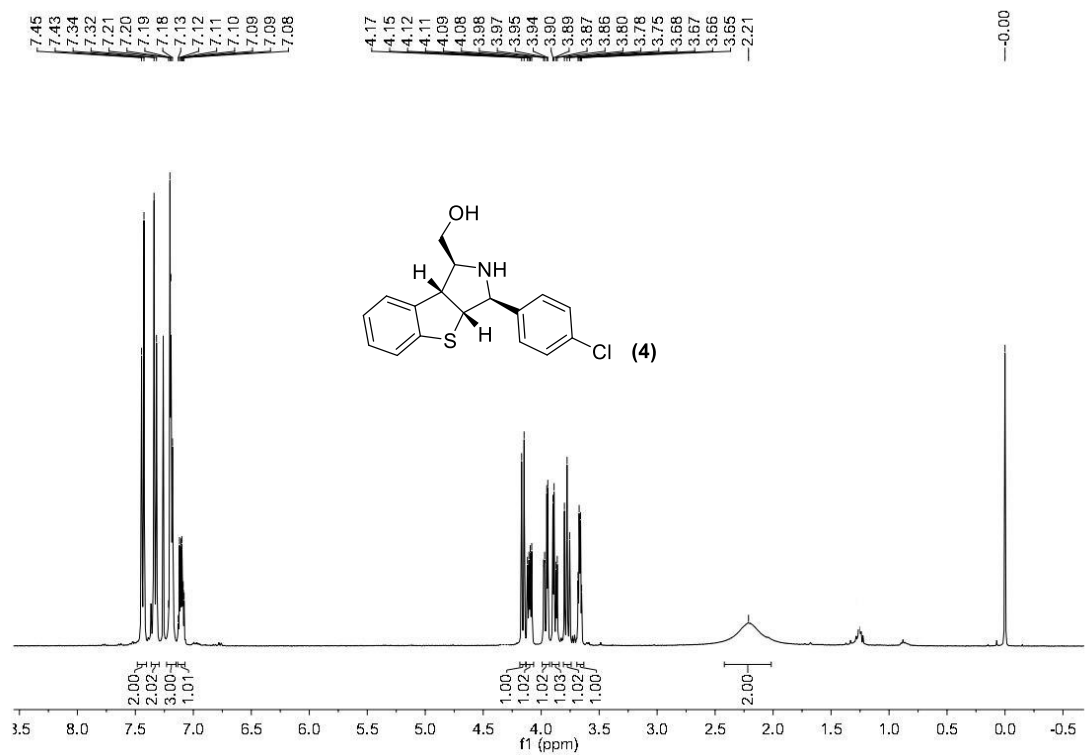
**<sup>1</sup>H NMR spectrum of compound **3nf** (CDCl<sub>3</sub>)**



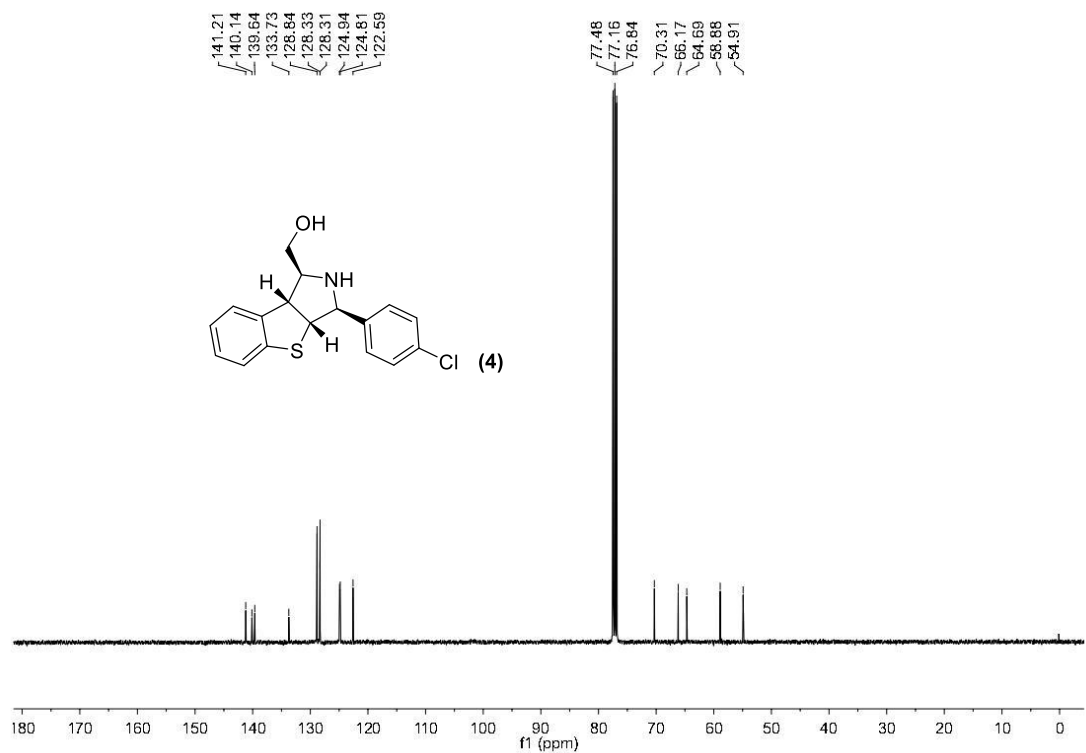
**<sup>13</sup>C NMR spectrum of compound 3nf (CDCl<sub>3</sub>)**



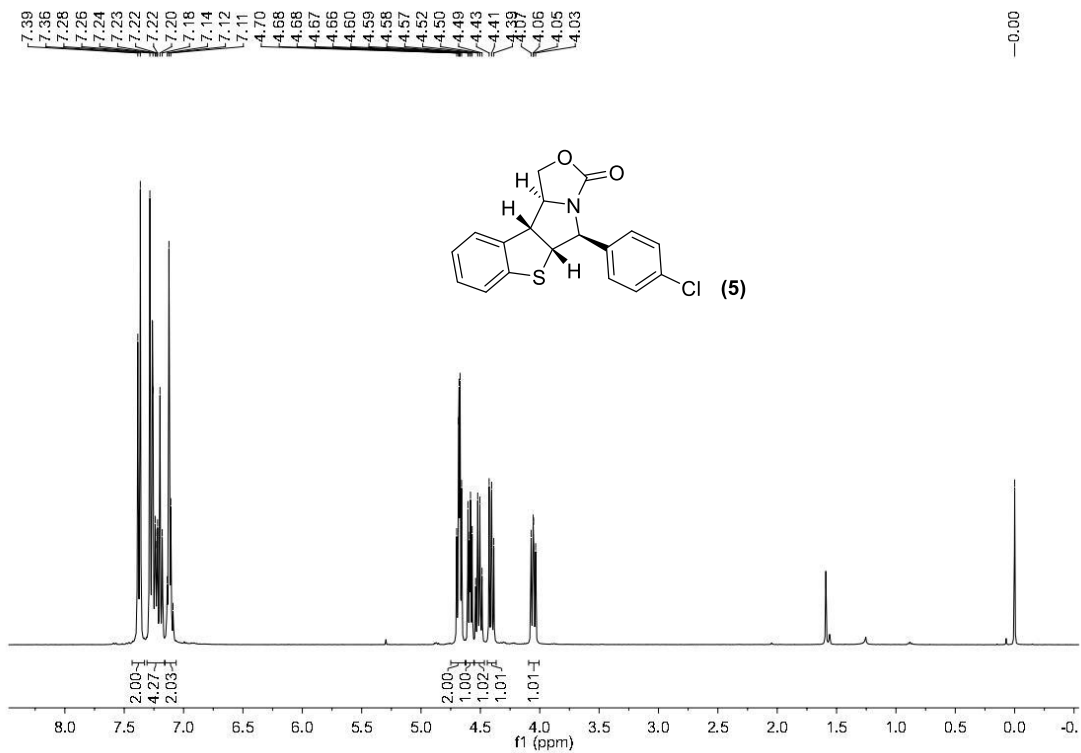
**<sup>1</sup>H NMR spectrum of compound 4 (CDCl<sub>3</sub>)**



<sup>13</sup>C NMR spectrum of compound 4 (CDCl<sub>3</sub>)



<sup>1</sup>H NMR spectrum of compound 5 (CDCl<sub>3</sub>)



<sup>13</sup>C NMR spectrum of compound **5** (CDCl<sub>3</sub>)

