Supporting Information

$Sc(OTf)_3$ Catalyzed [3 + 2]-Annulation Reaction of Donor–Acceptor Aziridines with Methylene *exo*-Glycals: Synthesis of Chiral Carbohydrate-spiro-heterocycles

Jie-Hui Zhang, Cheng-Lin Pan, Huan-Huan Zhang, Peng-Fei Xu* and Yong-Chun Luo*

State Key Laboratory of Applied Organic Chemistry, College of Chemistry and Chemical Engineering, Lanzhou

University, Lanzhou 730000, P. R. China

luoych@lzu.edu.cn

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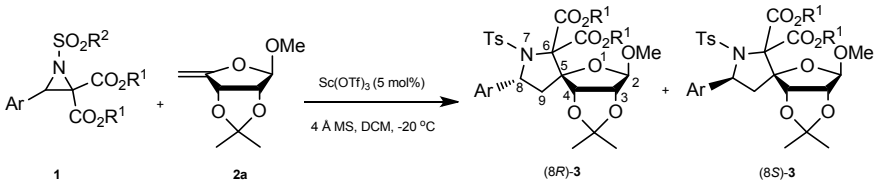
1. General information

Chemicals and solvents were either purchased from commercial suppliers or purified by standard techniques. Analytical thin-layer chromatography (TLC) was performed on silica gel plates with F-254 indicator and compounds were visualized by irradiation with UV light. Flash chromatography was carried out utilizing silica gel 200-300 mesh. The ^{1}H NMR spectra was recorded on 400 MHz spectrometers, and the ^{13}C NMR was recorded on 100 MHz spectrometer. The spectra were recorded in $CDCl_3$ at room temperature. ^{1}H and ^{13}C NMR chemical shifts are reported in ppm relative to either the residual solvent peak (^{13}C) (δ = 77.00 ppm) or TMS (^{1}H) (δ = 0 ppm) as an internal standard. Data for ^{1}H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, dd = double of doublet, td = triplet of doublet, m = multiplet), integration, coupling constant (Hz) and assignment. HRMS were performed on FT–ICRMS mass instrument (ESI). Optical rotation was measured on the Perkin Elmer 341 polarimeter with $[\alpha]_D$ values reported in degrees. Concentration (c) is in g/100 mL.

2. Procedure for the $Sc(OTf)_3$ catalyzed [3 + 2]-annulation reaction of aziridine 1 with *exo*-glycal 2a and 2c



1 2a (8*R*)-3 (8*S*)-3

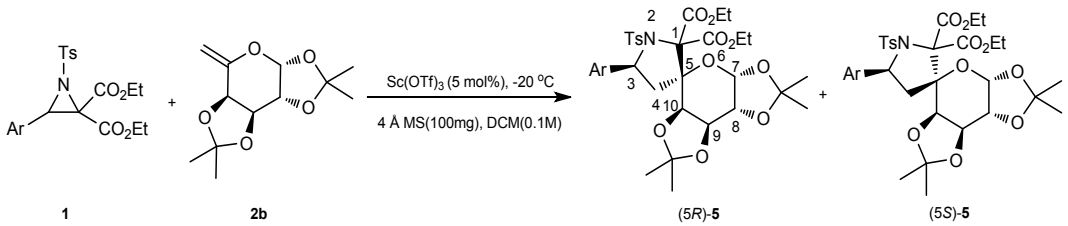
Under an atmosphere of dry nitrogen, activated 4 Å molecular sieves (100 mg), aziridine **1**[1] (0.20 mmol, 1.0 equiv), exo-glycal **2**[2] (0.24 mmol, 1.2 equiv) and 2mL of

(1) (a) X. X. Wu, L. Li, J . L. Zhang. *Adv. Synth. Catal.*, 2012, **354**, 3485. (b) B. Wang, M. Liang, J. Tang, Y. T. Deng, J. H. Zhao, H. Sun, C. H. Tung, Jiong. Jia, and Z. H. Xu, *Org. Lett.* 2016, **18**, 4614-4617. (c) Y. T. Liao, X. H. Liu, Y. Zhang, Y. L. Xu, Y. Xia, L. L. Lin, and X. M. Feng, *Chem. Sci.,* 2016, **7**, 3775–3779.

(2) (a) W. M. Li, Y. H. Niu, D. C. Xiong, X. P. Cao, and X. S. Ye, *J. Med. Chem.* 2015, **58**,

anhydrous DCM were added into an over-dried reaction tube equipped with a stir bar, and the solution was stirred at -20 ℃ for 15min. Subsequently, the 0.01mmol of $Sc(OTf)_3$ (4.9 mg, 0.05 eq) was added. The reaction mixture was stirred at the indicated temperature until the aziridine was completely exhausted (monitored by TLC). Then, the solvent was removed under reduced pressure, and the residue was purified by column chromatography on silica gel (petroleum ether/EtOAc) to give the corresponding product.

3. General procedure for the $Sc(OTf)_3$ catalyzed [3 + 2]-annulation reaction of aziridine 1 with *exo*-glycal 2b

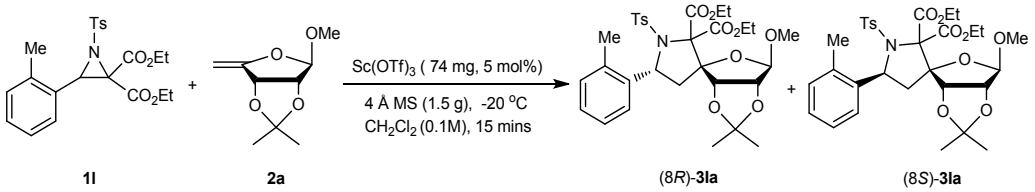


Under an atmosphere of dry nitrogen, activated 4 Å molecular sieves (100 mg), aziridine **1** (0.20 mmol, 1.0 equiv), exo-glycal **2b**[3] (0.6 mmol, 3 equiv) and 2mL of anhydrous DCM were added into an over-dried reaction tube equipped with a stir bar, and the solution was stirred at -20 ℃ for 15min. Subsequently, the 0.01mmol of $Sc(OTf)_3$ (4.9 mg, 0.05 eq) was added. The reaction mixture was stirred at the indicated temperature until the aziridine was completely exhausted (monitored by TLC). Then, the solvent was removed under reduced pressure, and the residue was purified by column chromatography on silica gel (petroleum ether/EtOAc) to give the corresponding product.

7972−7990. (b) S. N. Malkowski, C. F. Dishuck, G. G. Lamanilao, C. P. Embry, C. S. Grubb, M. Cafiero, L. W. Peterson. *Molecules* 2017, **22**, 1682.

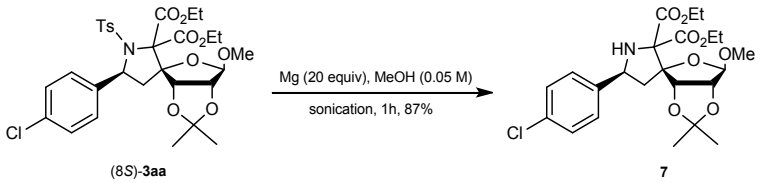
(3) (a) S. Meng, W. H. Zhong, W. Yao, Z. J. Li, *Org. Lett.* 2020, **22**, 2981–2986. (b) N. Hussain, M. Babu Tatina, D. Mukherjee, *Org. Biomol. Chem.*, 2018, **16**, 2666–2677.

4. Procedure for the gram-scale reaction of aziridine 1l with *exo*-glycal 2a



Under an atmosphere of dry nitrogen, activated 4 Å molecular sieves (1.5 g), aziridine **1l** (3 mmol, 1.0 equiv, 1.29g), exo-glycal **2a** (3.6 mmol, 1.2 equiv, 0.67 g) and 30 mL of anhydrous DCM were added into an over-dried reaction tube equipped with a stir bar, and the solution was stirred at -20 ℃ for 15min. Subsequently, the 0.15 mmol of $Sc(OTf)_3$ (74mg, 0.05 eq) was added. The reaction mixture was stirred at the indicated temperature until the aziridine was completely exhausted (monitored by TLC). Then, the solvent was removed under reduced pressure, and the residue was purified by column chromatography on silica gel (petroleum ether/EtOAc) to give the corresponding products (8*R*)-**3la** (1.06 g, 1.66 mmol, 58%) and (8*S*)-**3la** (0.62g, 0.97 mmol, 34%) .

5. Procedure for the detosylation of the annulation product (8*S*)-3aa

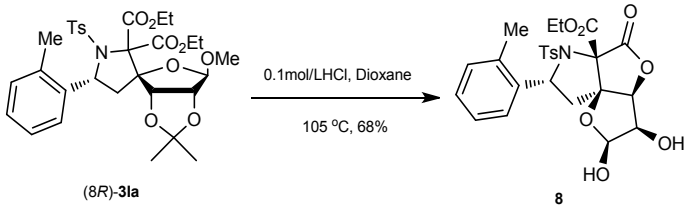


According to the previous report on the method for detosylation,[4] compound (8*S*)-**3aa** (63.7 mg, 0.1 mmol) in anhydrous MeOH (2 mL) was treated with Mg powder (48.6mg, 2 mmol) and the mixture was sonicated for 1 h. After removal of the solvent

(4) W. G. He, J. D. Hu, P. Y. Wang, L. Chen, K. Ji, S. Y. Yang, Y. Li, Z. L. Xie, W. Q. Xie, *Angew. Chem. Int. Ed.,* 2018, **57**, 3806 –3809.

under vacuum, the residue was diluted with CH_2Cl_2 and filtrated with Celite pad. The solvent was removed under vacuum and the residue was purified by column chromatography on silica gel directly (petroleum ether/EtOAc = 4:1, R_f = 0.37) to afford **7** (42.1 mg, 87% isolated yield).

6. Procedure for the hydrolysis of annulation product (8*R*)-3la

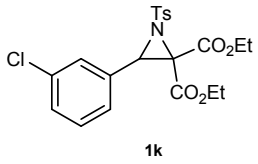


Hydrolysis of the product (8*R*)-**3la** was carried out according to the literature.[5] To a solution of (8*R*)-**3la** (185.3 mg, 0.3 mmol) in dioxane (2ml) was added 0.1M HCl (1ml) and the reaction mixture was refluxed for 4h. The solution was neutralized with 0.5M NaOH, the solvent were removed in vacuo and the residue was dissolved in EtOAc. The combined organic layer was dried and concentrated in vacuo to afford the crude product, which was purified by column chromatography on silica gel (EtOAc /petroleum ether = 2: 1, R_f = 0.4) to afford **8** (105.4 mg, 68% isolated yield).

(5) D. W. Gammon, R. Hunter, S. Wilson, *Tetrahedron Lett.* 2002**, 43** , 3141-3144.

7. Characterization data of Products

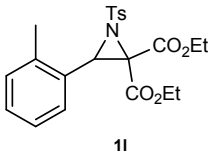
Diethyl 3-(3-chlorophenyl)-1-tosylaziridine-2,2-dicarboxylate (1k)



1k

Colorless liquid (petroleum ether/EtOAc = 5:1, 72% isolated yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.97 (d, *J* = 8.4 Hz, 2H), 7.37 (d, *J* = 8.0 Hz, 2H), 7.33 (d, *J* = 7.6 Hz, 1H), 7.24—7.20 (m, 1H), 7.12-7.09 (m, 2H), 5.05 (s, 1H), 4.44—4.38 (q, *J* = 7.2 Hz, 2H), 3.99-3.87 (m, 2H), 2.46 (s, 3H), 1.38 (t, *J* = 7.2 Hz, 3H), 0.86 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.8, 162.3, 145.1, 136.2, 134.1, 130.1, 129.9, 129.4, 129.2, 128.5, 127.9, 126.7, 63.4, 62.2, 56.7, 48.1, 21.8, 13.8, 13.6; HRMS calcd for $C_{21}H_{23}ClNO_6S$ $[M+H]^+$ 452.0929, found 452.0928.

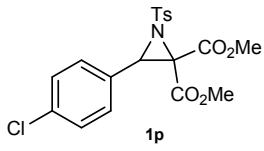
Diethyl 3-(o-tolyl)-1-tosylaziridine-2,2-dicarboxylate (1l)



1l

White solid (petroleum ether/EtOAc = 5:1, 66% isolated yield); mp:90–93 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.99 (d, *J* = 8.4 Hz, 2H), 7.37 (d, *J* = 8.0 Hz, 2H), 7.19—7.14 (m, 1H), 7.11 (d, *J* = 6.8 Hz, 1H), 7.03 (d, *J* = 4.0 Hz, 2H), 4.85 (s, 1H), 4.44—4.38 (m, 2H), 3.93—3.85 (m, 2H), 2.47 (s, 3H), 2.43 (s, 3H), 1.38 (t, *J* = 7.0 Hz, 3H), 0.80 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.3, 162.7, 145.0, 137.2, 136.2, 129.9, 129.8, 129.3, 128.8, 128.0, 126.7, 125.8, 63.5, 62.2, 56.7, 48.8, 21.9, 18.9, 13.9, 13.6; HRMS calcd for $C_{22}H_{26}NO_6S$ $[M+H]^+$ 432.1475, found 432.1472.

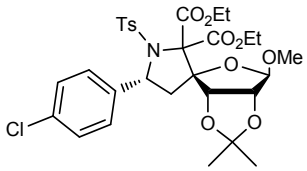
Dimethyl 3-(4-chlorophenyl)-1-tosylaziridine-2,2-dicarboxylate (1p)



1p

White solid (petroleum ether/EtOAc = 5:1, 75% isolated yield); mp:115–118 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.93 (d, *J* = 8.4 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 7.25 (d, *J* = 8.4 Hz, 2H), 7.18 (d, *J* = 8.8 Hz, 2H), 4.84 (s, 3H), 3.93 (s, 3H), 3.52 (s, 3H), 2.46 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.5, 162.9, 145.2, 136.1, 135.1, 130.0, 129.6, 128.9, 128.5, 127.9, 57.4, 54.2, 53.3, 49.0, 21.8; HRMS calcd for $C_{19}H_{19}ClNO_6S[M+H]^+$ 424.0616, found 424.0617.

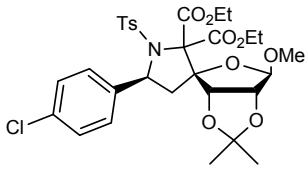
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3aa)



(8*R*)-**3aa**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.45, 54% isolated yield); mp:129–131 ℃; $[\alpha]_D^{20}$ = -43 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 8.4 Hz, 2H), 7.08 (d, *J* = 8.4 Hz, 2H), 6.98 (dd, *J* = 16.0, 8.0 Hz, 4H), 5.53 (d, *J* = 10.4 Hz, 1H), 4.99 (d, *J* = 6.8 Hz, 1H), 4.62 (d, *J* = 2.0 Hz, 1H), 4.52–4.38 (m, 4H), 3.33 (dd, *J* = 13.6, 10.4 Hz, 1H), 3.11 (s, 3H), 2.32 (s, 3H), 1.82 (d, *J* = 14.4 Hz, 1H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.42 (s, 3H), 1.38 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.3, 165.8, 143.4, 140.3, 137.3, 132.3, 129.1, 128.8, 128.4, 127.5, 114.5, 109.0, 98.1, 85.1, 83.5, 80.3, 63.1, 63.0, 62.6, 56.6, 43.0, 26.2, 24.8, 21.6, 14.1, 14.1; HRMS calcd for $C_{30}H_{37}ClNO_{10}S$ $[M+H]^+$: 638.1822, found for: 638.1824.

(2*R*,3*R*,4*S*,5*R*,8*S*)-diethyl 8-(4-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3aa)

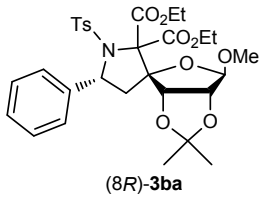


(8*S*)-**3aa**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.37, 45% isolated yield); mp:150–152 ℃; $[\alpha]_D^{20}$ = -30 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (d, *J* = 8.4 Hz, 2H), 7.01–6.98 (m, 4H), 6.92 (d, *J* = 8.4 Hz, 2H), 5.05 (t, *J* = 7.4 Hz, 1H), 5.00 (d, *J* = 6.4 Hz, 1H), 4.93 (d, *J* = 1.2 Hz, 1H), 4.56 (dd, *J* = 6.4, 1.2 Hz, 1H), 4.52–4.42 (m, 2H), 4.39-4.27 (m, 2H), 3.41 (s, 3H), 2.72 (dd, *J* = 13.2, 7.2 Hz, 1H), 2.42 (dd, *J* = 13.2, 7.6 Hz, 1H), 2.35 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.41 (t, *J* = 7.2, 3H), 1.33 (s, 3H), 1.21 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.5, 143.0, 138.8, 136.6, 133.6, 130.2, 128.7, 128.1, 127.8, 113.3, 110.0, 95.8, 85.6, 81.3, 81.2, 62.7, 62.5, 61.9, 56.9, 42.6, 26.2, 24.9, 21.6, 14.2, 14.1; HRMS calcd for $C_{30}H_{37}ClNO_{10}S$ $[M+H]^+$: 638.1822, found for: 638.1821.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-phenyl-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3ba)

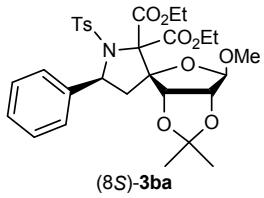
White solid (petroleum ether/EtOAc = 4:1, R_f = 0.45, 62% isolated yield); mp:110–112 ℃; $[\alpha]_D^{20}$ = -27 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.0



(8*R*)-**3ba**

Hz, 2H), 7.17 (d, *J* = 6.8 Hz, 2H), 7.05–6.99 (m, 3H), 6.94 (d, *J* = 8.0 Hz, 2H), 5.60 (d, *J* = 10.4 Hz, 1H), 5.00 (d, *J* = 7.2 Hz, 1H), 4.62 (d, *J* = 2.0 Hz, 1H), 4.53–4.47 (m, 2H), 4.42–4.14 (m, 2H), 4.20–4.14 (m, 1H), 3.34 (dd, *J* = 13.6, 10.8 Hz, 1H), 3.11 (s, 3H), 2.28 (s, 3H), 1.88 (d, *J* = 13.6 Hz, 1H), 1.43(t, *J* = 7.2 Hz, 3H), 1.42 (s, 3H), 1.40–1.36(t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.5, 165.8, 142.9, 141.6, 137.6, 128.8, 128.3, 127.7, 127.5, 126.6, 114.5, 108.9, 97.9, 85.1, 83.5, 80.4, 63.8, 62.9, 62.5, 56.6, 42.9, 26.2, 24.8, 21.5, 14.1; HRMS calcd for $C_{30}H_{38}NO_{10}S$ $[M+H]^+$: 604.2212, found for: 604.2213.

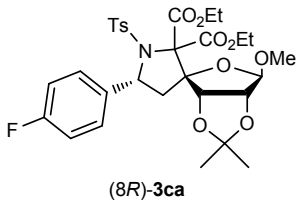
(2*R*,3*R*,4*S*,5*R*,8*S*)-diethyl 8-phenyl-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-**3ba)**



(8*S*)-**3ba**

White solid (petroleum ether/EtOAc = 5:1, R_f = 0.36, 37% isolated yield); mp: 99–101 ℃; $[\alpha]_D^{20}$ = -50 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, *J* = 8.0 Hz, 2H), 7.10–7.07 (m, 3H), 7.00–6.93 (m, 4H), 5.09 (t, *J* = 7.6 Hz, 1H), 5.01 (d, *J* = 6.4 Hz, 1H), 4.93 (s, 1H), 4.55 (d, *J* = 1.2 Hz, 1H), 4.54–4.42 (m, 2H), 4.38–4.28 (m, 2H), 3.41 (s, 3H), 2.77 (dd, *J* = 13.2, 7.2 Hz, 1H), 2.43 (dd, *J* = 12.8, 7.6 Hz, 1H), 2.31 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.41 (t, *J* = 7.2, 3H), 1.32 (s, 3H), 1.18 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.6, 142.5, 138.8, 138.0, 128.8, 128.6, 128.1, 127.7, 127.5, 113.2, 110.0, 95.8, 85.5, 81.4, 81.2, 62.6, 62.6, 62.4, 56.9, 42.8, 26.2, 24.8, 21.5, 14.2, 14.0; HRMS calcd for $C_{30}H_{38}NO_{10}S$ $[M+H]^+$: 604.2212, found for: 604.2213.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-fluorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-**3ca)**

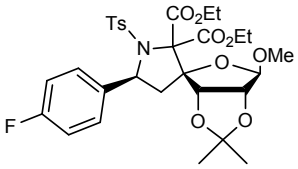


(8*R*)-**3ca**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.46, 53% isolated yield); mp: 118–120 ℃; $[\alpha]_D^{20}$ = -26 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 8.4 Hz, 2H), 7.13 (dd, *J* = 8.8, 5.6 Hz, 2H), 6.99 (d, *J* = 8.0 Hz, 2H), 6.69 (t, *J* = 8.8 Hz, 2H), 5.57 (d, *J* = 10.4 Hz, 1H), 4.99 (d, *J* = 6.8 Hz, 1H), 4.62 (d, *J* = 2.0 Hz,

1H), 4.54–4.47 (m, 2H), 4.46–4.38 (m, 2H), 4.18–4.14(m,1H), 3.33 (dd, *J* = 13.6, 10.4 Hz, 1H), 3.12 (s, 3H), 2.30 (s, 3H), 1.83 (d, *J* = 14.0 Hz, 1H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.41 (s, 3H), 1.38 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -116.72; ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.4, 165.8, 161.7 (d, *J* = 14.0 Hz), 160.5, 143.2, 137.5, 137.4, 137.4, 129.3 (d, *J* = 8.0 Hz), 128.6(d, *J* = 39.5 Hz), 114.2(d, *J* = 21.2 Hz), 114.1, 109.0, 98.0, 85.1, 83.5, 80.3, 63.1, 63.0, 62.6, 56.7, 43.0, 26.2, 24.8, 21.6, 14.1; HRMS calcd for $C_{30}H_{37}FNO_{10}S$ $[M+H]^+$: 622.2117, found for: 622.2117.

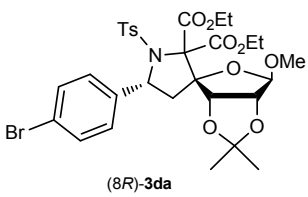
(2*R*,3*R*,4*S*,5*R*,8*S*)-diethyl 8-(4-fluorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3ca)



(8*S*)-**3ca**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.37, 36% isolated yield); mp:145–147 ℃; $[\alpha]_D^{20}$ = -46 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (d, 8.4 Hz, 2H), 7.04 (dd, *J* = 8.4, 5.2 Hz, 2H), 6.99 (d, *J* = 8.0 Hz, 2H), 6.66 (t, *J* = 8.8 Hz, 2H), 5.07 (t, *J* = 7.2 Hz, 1H), 5.02 (d, *J* = 6.4 Hz, 1H), 4.94 (d, *J* = 1.2 Hz, 1H), 4.56 (dd, *J* = 6.4, 1.2 Hz, 1H), 4.53–4.43 (m, 2H), 4.39–4.28 (m, 2H), 3.41 (s, 3H), 2.73 (dd, *J* = 12.8, 7.2 Hz, 1H), 2.41 (dd, *J* = 12.8, 7.6 Hz, 1H), 2.33 (s, 3H), 1.42 (t, J = 7.2 Hz, 3H), 1.41 (t, J = 7.2, 3H), 1.33 (s, 3H), 1.21 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -114.97; ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.6, 162.3 (d, *J* = 244.9 Hz), 142.8, 138.8, 133.6 (d, *J* = 2.9 Hz), 130.4 (d, *J* = 8.3 Hz), 128.6, 128.0, 114.4 (d, *J* = 21.3 Hz), 113.2, 109.9, 95.7, 85.5, 81.3, 81.1, 62.7, 62.4, 61.8, 56.9, 42.6, 26.2, 24.8, 21.5, 14.1, 14.0; HRMS calcd for $C_{30}H_{37}FNO_{10}S$ $[M+H]^+$: 622.2117, found for: 622.2119.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-bromophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3da)

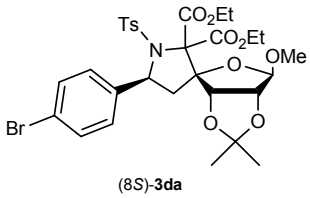


(8*R*)-**3da**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.46, 62% isolated yield); mp:102–110 ℃; $[\alpha]_D^{20}$ = -23 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 8.4 Hz, 2H), 7.11 (d, *J* = 8.4 Hz, 2H), 7.01 (t, *J* = 8.8 Hz, 4H), 5.51 (d, *J* = 10.4 Hz, 1H), 4.99 (d, *J* = 7.2 Hz, 1H), 4.62 (d, *J* = 2.0 Hz, 1H), 4.54–4.46 (m, 2H), 4.46–4.38 (m, 2H), 4.20–4.12 (m, 1H), 3.33 (dd, *J* = 13.6, 10.4 Hz, 1H), 3.12 (s, 3H),

2.33 (s, 3H), 1.82 (d, J = 14.0 Hz, 1H), 1.42 (t, J = 7.2 Hz, 3H), 1.42 (s, 3H), 1.38 (t, J = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.3, 165.7, 143.4, 140.8, 137.3, 130.5, 129.5, 128.8, 128.5, 120.4, 114.5, 109.1, 98.1, 85.2, 83.5, 80.4, 63.1, 63.0, 62.6, 56.7, 43.0, 26.2, 24.8, 21.6, 14.1, 14.1; HRMS calcd for $C_{30}H_{37}BrNO_{10}S$ $[M+H]^+$: 682.1316, found for: 682.1319.

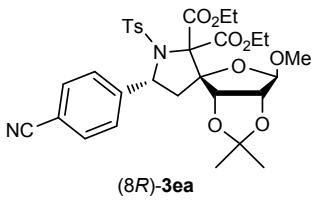
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-bromophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3da)



(8*S*)-**3da**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.37, 36% isolated yield); mp:133–136 ℃; $[\alpha]_D^{20}$ = -25 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, J = 5.6 Hz, 2H), 7.07 (d, J = 8.8 Hz, 2H), 6.99 (d, J = 8.0 Hz, 2H), 6.94 (d, J = 8.4 Hz, 2H), 5.01 (d, J = 6.8 Hz, 2H), 4.93 (s, 1H), 4.55 (d, J = 6.0 Hz, 1H), 4.52–4.42 (m, 2H), 4.39–4.27 (m, 2H), 3.41 (s, 3H), 2.71 (dd, J = 12.8, 7.2 Hz, 1H), 2.40 (dd, J = 12.8, 7.6 Hz, 1H), 2.36 (s, 3H), 1.42 (t, J = 7.2 Hz, 3H), 1.41 (t, J = 7.2, 3H), 1.34 (s, 3H), 1.21 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.5, 143.0, 138.8, 136.9, 130.7, 130.5, 128.7, 128.0, 121.8, 113.3, 109.9, 95.7, 85.6, 81.3, 81.2, 62.7, 62.5, 61.9, 56.9, 42.5, 26.2, 24.9, 21.6, 14.2, 14.0; HRMS calcd for $C_{30}H_{37}BrNO_{10}S$ $[M+H]^+$: 682.1316, found for: 682.1318.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-cyanophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3ea)

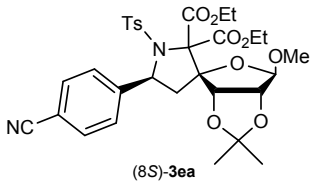


(8*R*)-**3ea**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.34, 71% isolated yield); mp: 212–214 ℃; $[\alpha]_D^{20}$ = -52 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, J = 8.4 Hz, 2H), 7.29–7.22 (m, 4H), 7.01 (d, J = 8.4 Hz, 2H), 5.59 (d, J = 10.4 Hz, 1H), 4.98 (d, J = 7.2 Hz, 1H), 4.55 (d, J = 2.4 Hz, 1H), 4.55–4.47 (m, 2H), 4.45–4.39 (m, 2H), 4.18–4.14 (m, 1H), 3.38 (dd, J = 13.6, 10.4 Hz, 1H), 3.06 (s, 3H), 2.33 (s, 3H), 1.83 (d, J = 14.0 Hz, 1H), 1.42 (s, 3H), 1.42 (t, J = 7.2 Hz, 3H), 1.40 (t, J = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 165.8, 147.4, 143.7, 137.0, 131.2, 128.8, 128.6, 128.2, 119.1, 114.5, 110.1, 109.1, 98.2, 85.1, 83.5, 80.2, 63.1, 63.0, 62.7, 56.6, 43.3, 26.1, 24.7, 21.6, 14.0, 14.0; HRMS calcd for

$C_{31}H_{37}N_2O_{10}S$ [M+H]$^+$: 629.2163, found for: 629.2167.

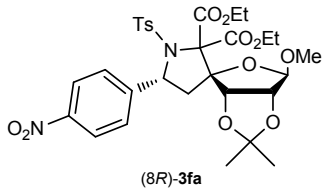
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-cyanophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3ea)



(8*S*)-**3ea**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.31, 25% isolated yield); mp:170–172 ℃; $[\alpha]_D^{20}$ = -42 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 (d, *J* = 8.4 Hz, 2H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.18 (d, *J* = 8.0 Hz, 2H), 7.04 (d, *J* = 8.4 Hz, 2H), 5.19 (dd, *J* = 8.0, 5.6 Hz, 1H), 4.91 (d, *J* = 1.2 Hz, 1H), 4.86 (d, *J* = 6.30 Hz, 1H), 4.56–4.42 (m, 3H), 4.36–4.28 (m, 2H), 3.39 (s, 3H), 2.71–2.62 (m, 2H), 2.36 (s, 3H), 1.43 (t, *J* = 7.2 Hz, 3H), 1.41 (t, *J* = 7.2, 3H), 1.27 (s, 3H), 1.11 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.7, 165.5, 144.7, 143.5, 138.1, 131.4, 128.9, 128.8, 128.3, 118.8, 113.1, 111.0, 110.2, 96.2, 85.8, 81.4, 81.2, 62.8, 62.6, 61.6, 56.8, 42.2, 26.1, 24.7, 21.6, 14.1, 14.0; HRMS calcd for $C_{31}H_{37}N_2O_{10}S$ [M+H]$^+$: 629.2163, found for: 629.2165.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-nitrophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3fa)

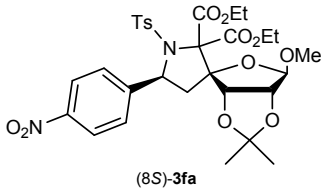


(8*R*)-**3fa**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.36, 70% isolated yield); mp: 121–125 ℃; $[\alpha]_D^{20}$ = -26 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 8.8 Hz, 2H), 7.57 (d, *J* = 8.4 Hz, 2H), 7.29 (d, *J* = 8.8 Hz, 2H), 7.01 (d, *J* = 8.0 Hz, 2H), 5.63 (d, *J* = 10.4 Hz, 1H), 4.99 (d, *J* = 6.8 Hz, 1H), 4.57–4.48 (m, 3H), 4.46–4.40 (m, 2H), 4.21–4.13 (m, 1H), 3.41 (dd, *J* = 13.6, 10.4 Hz, 1H), 3.07 (s, 3H), 2.30 (s, 3H), 1.85 (d, *J* = 14.0 Hz, 1H), 1.43 (t, *J* = 7.2 Hz, 3H), 1.41 (s, 3H), 1.41 (t, *J* = 7.2 Hz, 3H), 1.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 165.8, 149.5, 146.5, 143.9, 137.0, 128.9, 128.7, 128.3, 122.6, 114.5, 109.2, 98.4, 85.2, 83.5, 80.3, 63.1, 62.9, 62.8, 56.6, 43.4, 26.2, 24.7, 21.6, 14.1, 14.1; HRMS calcd for $C_{30}H_{37}N_2O_{12}S$ [M+H]$^+$: 649.2062, found for: 649.2064.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-nitrophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3fa)

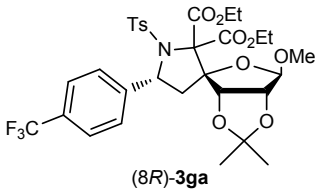
White solid (petroleum ether/EtOAc = 4:1, R_f = 0.31, 27% isolated yield); mp: 146–



(8*S*)-**3fa**

148 °C; $[\alpha]_D^{20}$ = -44 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 8.8 Hz, 2H), 7.40 (d, *J* = 8.4 Hz, 2H), 7.24 (d, *J* = 8.4 Hz, 2H), 7.00 (d, *J* = 8.4 Hz, 2H), 5.22 (dd, *J* = 8.0, 5.6 Hz, 1H), 4.92 (d, *J* = 6.4 Hz, 2H), 4.56–4.43 (m, 3H), 4.38–4.29 (m, 2H), 3.40 (s, 3H), 2.74–2.61 (m, 2H), 2.34 (s, 3H), 1.44 (t, *J* = 7.2, 3H), 1.42 (t, *J* = 7.2, 3H), 1.27 (s, 3H), 1.13 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.4, 147.1, 146.6, 143.7, 138.1, 129.1, 128.8, 128.3, 122.8, 113.2, 110.2, 96.2, 85.8, 62.9, 62.7, 61.4, 56.9, 42.3, 26.2, 24.8, 21.6, 14.2, 14.0; HRMS calcd for $C_{30}H_{37}N_2O_{12}S$ $[M+H]^+$: 649.2062, found for: 649.2064.

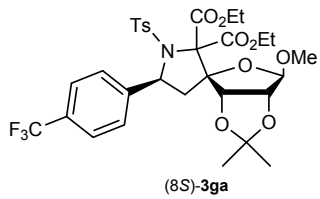
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-trifluoromethylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)**-3ga)**



(8*R*)-**3ga**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.45, 60% isolated yield); mp:120–124°C; $[\alpha]_D^{20}$ = -16 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (d, *J* = 6.8 Hz, 2H), 7.26–7.20 (m, 4H), 6.94 (d, *J* = 7.2 Hz, 2H), 5.58 (d, *J* = 10.4 Hz, 1H), 5.00–4.99 (m, 1H), 4.61 (s, 1H), 4.54–4.40 (m, 4H), 4.24–4.13 (m, 1H), 3.37 (t, *J* = 12.4 Hz, 1H), 3.11 (d, *J* = 1.6 Hz, 3H), 2.27 (s, 3H), 1.86 (d, *J* = 13.6 Hz, 1H), 1.43 (t, *J* = 7.2 Hz, 3H), 1.42 (s, 3H), 1.40 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.48; ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 165.7, 145.8, 143.5, 137.1, 128.8, 128.5, 128.4, 128.0, 124.3 (q, *J* = 3.7 Hz), 114.5, 109.1, 98.2, 85.2, 83.5, 80.3, 63.1, 63.0, 62.6, 56.6, 43.0, 26.2, 24.8, 21.4, 14.1, 14.1; HRMS calcd for $C_{31}H_{37}F_3NO_{10}S$ $[M+H]^+$: 672.2085, found for: 672.2086.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-trifluoromethylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)**-3ga)**

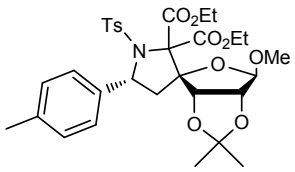


(8*S*)-**3ga**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.38, 26% isolated yield); mp: 128–130 °C; $[\alpha]_D^{20}$ = -34 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, *J* = 8.8 Hz, 2H), 7.21–7.16 (m, 4H), 6.93 (d, *J* = 8.0 Hz, 2H), 5.15 (t, *J* = 7.2 Hz, 1H), 5.00 (d, *J* = 6.4 Hz, 1H), 4.94 (d, *J* = 1.2 Hz, 1H), 4.56 (dd, *J* = 6.4, 1.2

Hz, 1H), 4.54–4.43 (m, 2H), 4.39–4.29 (m, 2H), 3.41 (s, 3H), 2.74 (dd, *J* = 13.2, 6.4 Hz, 1H), 2.50 (dd, *J* = 13.2, 8.0 Hz, 1H), 2.31 (s, 3H), 1.43 (t, *J* = 7.2 Hz, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.31 (s, 3H), 1.18 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.66; ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.5, 143.1, 142.3, 138.5, 129.0, 128.7, 128.0, 124.5, 124.5, 113.3, 110.1, 95.9, 85.6, 81.4, 81.2, 62.8, 62.5, 61.8, 56.9, 42.4, 26.2, 24.8, 21.4, 14.2, 14.0; HRMS calcd for $C_{31}H_{37}F_3NO_{10}S$ $[M+H]^+$: 672.2085, found for: 672.2089.

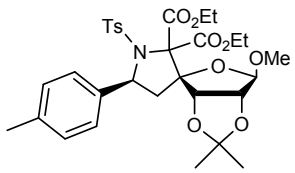
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-methylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-**3ha)**



(8*R*)-**3ha**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.46, 55% isolated yield); mp:130–132 ℃; $[\alpha]_D^{20}$ = -32 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.4 Hz, 2H), 7.07 (d, *J* = 7.6 Hz, 2H), 6.94 (d, *J* = 8.0 Hz, 2H), 6.83 (d, *J* = 7.6 Hz, 2H), 5.55 (d, *J* = 10.4 Hz, 1H), 5.00 (d, *J* = 6.8 Hz, 1H), 4.66 (d, *J* = 1.6 Hz, 1H), 4.53–4.47 (m, 2H), 4.45–4.39 (m, 2H), 4.19–4.11 (m, 1H), 3.32 (dd, *J* = 13.6, 10.8 Hz, 1H), 3.15 (s, 3H), 2.28 (s, 3H), 2.24 (s, 3H), 1.86 (d, *J* = 13.6 Hz, 1H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.40 (s, 3H), 1.37 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (400 MHz, $CDCl_3$) δ 167.6, 165.7, 142.7, 138.7, 137.7, 136.2, 128.7, 128.2, 128.2, 127.8, 114.4, 109.0, 97.9, 85.1, 83.5, 80.4, 63.7, 62.8, 62.4, 56.6, 42.9, 29.8, 26.2, 24.8, 21.5, 21.1, 14.1; HRMS calcd for $C_{30}H_{40}NO_{10}S$ $[M+H]^+$: 618.2367, found for: 618.2369.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-methylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-**3ha)**

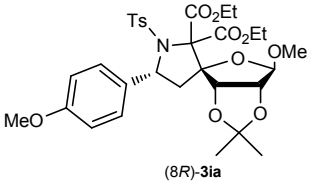


(8*S*)-**3ha**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.33, 43% isolated yield); mp:162–174 ℃; $[\alpha]_D^{20}$ = -34 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 7.6 Hz, 2H), 6.92 (dd, *J* = 10.8, 6.8 Hz, 4H), 6.77 (d, *J* = 6.4 Hz, 2H), 5.07 (d, *J* = 6.0 Hz, 1H), 4.97 (t, *J* = 7.4 Hz, 1H), 4.94 (s, 1H), 4.54 (d, *J* = 6.4 Hz, 1H), 4.49–4.41 (m, 2H), 4.39–4.26 (m, 2H), 3.41 (s, 3H), 2.81–2.76 (m, 1H), 2.32 (s, 4H), 2.24 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.41 (s, 3H), 1.35 (s, 3H), 1.24 (s, 3H); ^{13}C NMR (100 MHz, CDCl3) δ 167.7, 165.4, 142.1, 138.9, 137.4, 134.2, 128.9, 128.3, 128.2,

127.8, 113.2, 109.5, 95.4, 85.3, 81.1, 81.0, 62.5, 62.5, 62.2, 56.8, 42.9, 29.7, 26.0, 24.7, 21.4, 21.1, 14.0, 13.9; HRMS calcd for $C_{30}H_{40}NO_{10}S$ $[M+H]^+$: 618.2367, found for: 618.2369.

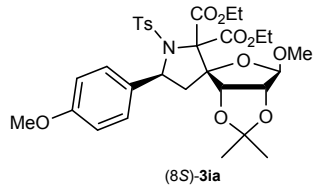
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-methoxyphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3ia)



(8*R*)-**3ia**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.45, 58% isolated yield); mp:102–104 ℃; $[\alpha]_D^{20}$ = -34 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.4 Hz, 2H), 7.07 (d, *J* = 8.0 Hz, 2H), 6.94 (d, *J* = 8.0 Hz, 2H), 6.83 (d, *J* = 8.0 Hz, 2H), 5.54 (d, *J* = 10.8 Hz, 1H), 5.00 (d, *J* = 6.8 Hz, 1H), 4.66 (d, *J* = 1.6 Hz, 1H), 4.51–4.47 (m, 2H), 4.45–4.39 (m, 2H), 4.18–4.13 (m, 1H), 3.35 (dd, *J* = 13.2, 10.8 Hz, 1H), 3.15 (s, 3H), 2.29 (s, 3H), 2.24 (s, 3H), 1.86 (d, *J* = 13.6 Hz, 1H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.40 (s, 3H), 1.37 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 165.7, 142.8, 138.7, 137.8, 136.2, 128.8, 128.2, 128.2, 127.8, 114.5, 109.0, 98.0, 85.2, 83.5, 80.5, 63.8, 62.9, 62.4, 56.7, 42.9, 26.2, 24.9, 21.5, 21.1, 14.1; HRMS calcd for $C_{31}H_{40}NO_{11}S$ $[M+H]^+$: 634.2317, found for: 634.2321.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-methoxyphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3ia)

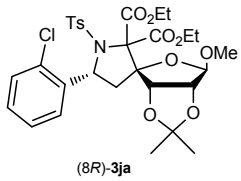


(8*S*)-**3ia**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.37, 41% isolated yield); mp:120–122 ℃; $[\alpha]_D^{20}$ = -37 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 8.4 Hz, 2H), 6.95 (dd, *J* = 17.2, 8.0 Hz, 4H), 6.77 (d, *J* = 8.0 Hz, 2H), 5.07 (d, *J* = 6.4 Hz, 1H), 4.99 (t, *J* = 7.6 Hz, 1H), 4.94 (d, *J* = 1.2 Hz, 1H), 4.56 (dd, *J* = 6.8, 1.6 Hz, 1H), 4.51–4.22 (m, 2H), 4.41–4.26 (m, 2H), 3.41 (s, 3H), 2.78 (dd, *J* = 13.2, 8.4 Hz, 1H), 2.32 (s, 3H), 2.31–2.28 (m, 1H), 2.24 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.40 (t, *J* = 7.2 Hz, 3H), 1.35 (s, 3H), 1.24 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.5, 142.2, 139.0, 137.5, 134.3, 129.0, 128.4, 128.3, 127.9, 113.3, 109.6, 95.6, 85.4, 81.2, 81.1, 62.6, 62.6, 62.3, 56.9, 43.0, 26.2, 24.8, 21.5, 21.2, 14.1, 14.0; HRMS calcd for $C_{31}H_{40}NO_{11}S$ $[M+H]^+$: 634.2317, found for: 634.2318.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(2-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-

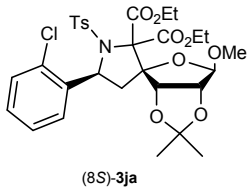
7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3ja)



(8*R*)-**3ja**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.45, 34% isolated yield); mp:169–171 ℃; $[\alpha]_D^{20}$ = -8 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.0 Hz, 2H), 7.21 (dd, *J* = 7.6, 0.8 Hz, 1H), 7.14 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.00 (d, *J* = 8.0 Hz, 2H), 6.95 (td, *J* = 7.6, 1.6 Hz, 1H), 6.60 (td, *J* = 8.0, 0.8 Hz,, 1H), 5.86 (d, *J* = 10.0 Hz, 1H), 4.98 (d, *J* = 6.8 Hz, 1H), 4.56–4.50 (m, 2H), 4.48–4.41 (m, 3H), 4.21–4.13 (m, 1H), 3.35 (dd, *J* = 13.6, 10.0 Hz, 1H), 3.01 (s, 3H), 2.29 (s, 3H), 1.90 (d, *J* = 13.6 Hz, 1H), 1.43 (d, *J* = 7.2 Hz, 1H), 1.42 (d, *J* = 7.2 Hz, 1H), 1.40 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 166.1, 143.3, 138.5, 137.0, 131.6, 130.4, 128.9, 128.5, 128.5, 127.7, 125.2, 114.6, 108.9, 98.0, 85.1, 83.6, 80.4, 63.0, 62.6, 61.1, 56.5, 41.8, 26.2, 24.8, 21.6, 14.1, 14.1; HRMS calcd for $C_{30}H_{37}ClNO_{10}S$ $[M+H]^+$: 638.1822, found for: 638.1823.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(2-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3ja)

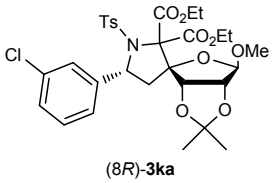


(8*S*)-**3ja**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.39, 61% isolated yield); mp:100–102 ℃; $[\alpha]_D^{20}$ = -80 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.0 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 1H), 7.05 (d, *J* = 8.0 Hz, 2H), 7.00 (t, *J* = 7.8 Hz, 2H), 6.70 (t, *J* = 7.6 Hz, 1H), 5.66 (d, *J* = 7.2 Hz, 1H), 4.86 (s, 1H), 4.62–4.50 (m, 1H), 4.50–4.40 (m, 3H), 4.38–4.23 (m, 2H), 3.35 (s, 3H), 2.99 (dd, *J* = 12.4, 9.6 Hz, 1H), 2.75 (dd, *J* =12.8, 2.4 Hz, 1H), 2.32 (s, 3H), 1.43 (t, *J* = 7.2, 3H), 1.42 (t, *J* = 7.2, 3H), 1.19 (s, 3H), 0.90 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 165.8, 143.3, 137.6, 137.5, 132.2, 129.1, 128.7, 128.7, 128.0, 125.6, 112.6, 110.7, 97.1, 86.0, 82.1, 81.3, 62.6, 62.6, 56.4, 40.5, 26.2, 24.5, 21.6, 14.1, 14.0; HRMS calcd for $C_{30}H_{37}ClNO_{10}S$ $[M+H]^+$: 638.1822, found for: 638.1828.

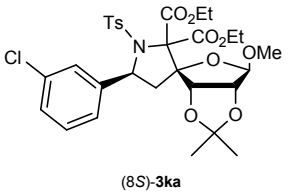
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(3-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3ka)

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.45, 75% isolated yield); mp:168–170 ℃; $[\alpha]_D^{20}$ = -8 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.4 Hz,


(8*R*)-**3ka**

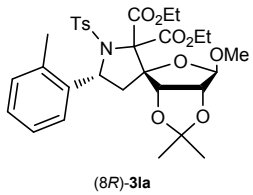
2H), 7.21 (dd, *J* = 8.0, 0.8 Hz, 1H), 7.15 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.00 (d, *J* = 8.0 Hz, 2H), 6.95 (td, *J* = 7.6, 1.6 Hz, 1H), 6.63–6.59 (m, 1H), 5.86 (d, *J* = 10.0 Hz, 1H), 4.98 (d, *J* = 6.8 Hz, 1H), 4.56–4.41 (m, 5H), 4.21–4.15 (m, 1H), 3.35 (dd, *J* = 13.6, 10.0 Hz, 1H), 3.01 (s, 3H), 2.29 (s, 3H), 1.90 (d, *J* = 14.0 Hz, 1H), 1.44 (s, 3H), 1.43 (t, *J* = 7.2 Hz, 3H), 1.40 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 166.1, 143.3, 138.5, 137.1, 131.6, 130.4, 128.9, 128.6, 128.5, 127.7, 125.2, 114.6, 109.0, 98.1, 85.1, 83.6, 80.4, 63.0, 62.6, 61.1, 56.5, 41.9, 26.2, 24.8, 21.6, 14.1, 14.1; HRMS calcd for $C_{30}H_{37}ClNO_{10}S$ $[M+H]^+$: 638.1822, found for: 638.1825.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(3-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-**3ka)**


(8*S*)-**3ka**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.37, 24% isolated yield); mp:122–124 ℃; $[\alpha]_D^{20}$ = -71 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.4 Hz, 2H), 7.23 (d, *J* = 7.6 Hz, 1H), 7.06 (d, *J* = 8.0 Hz, 2H), 7.02–6.97 (m, 2H), 6.70 (t, *J* = 7.2 Hz, 1H), 5.66 (dd, *J* = 9.2, 2.0 Hz, 1H), 4.86 (d, *J* = 1.6 Hz, 1H), 4.60–4.56 (m, 1H), 4.50–4.39 (m, 3H), 4.38–4.25 (m, 2H), 3.35 (s, 3H), 3.02–2.96 (m, 1H), 2.75 (dd, *J* = 12.8, 2.4 Hz, 1H), 2.33 (s, 3H), 1.43 (t, *J* = 7.2, 3H), 1.42 (t, *J* = 7.2, 3H), 1.19 (s, 3H), 0.90 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 165.8, 143.4, 137.6, 137.5, 132.3, 129.1, 128.8, 128.7, 128.0, 125.6, 112.6, 110.7, 97.1, 86.1, 82.1, 81.3, 62.6, 62.6, 59.1, 56.5, 40.5, 26.2, 24.5, 21.6, 14.2, 14.0; HRMS calcd for $C_{30}H_{37}ClNO_{10}S$ $[M+H]^+$: 638.1822, found for: 638.1828.

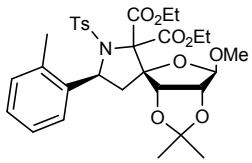
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(2-methylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-**3la)**


(8*R*)-**3la**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.46, 58% isolated yield); mp:165–168 ℃; $[\alpha]_D^{20}$ = -7 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 (d, *J* = 8.2 Hz, 2H), 7.12 (d, *J* = 7.6 Hz, 1H), 7.02 (d, *J* = 7.2 Hz, 1H), 6.96–6.90 (m, 3H), 6.57 (t, *J* = 7.4 Hz, 1H), 5.77 (d, *J* = 10.4 Hz, 1H), 5.00 (d, *J* = 6.8 Hz, 1H), 4.59 (d, *J* = 1.6

Hz, 1H), 4.56–4.41 (m, 4H), 4.21–4.13 (m, 1H), 3.34 (dd, *J* = 12.8, 10.8 Hz, 1H), 3.09 (s, 3H), 2.36 (s, 3H), 2.28 (s, 3H), 1.78 (d, *J* = 13.2 Hz, 1H), 1.43 (t, *J* = 7.2 Hz, 3H), 1.41 (s, 3H), 1.39 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 165.8, 142.9, 139.1, 137.4, 133.8, 129.4, 128.8, 128.7, 128.2, 126.3, 124.8, 114.4, 109.0, 98.2, 85.1, 83.5, 80.6, 62.8, 62.4, 60.6, 56.5, 41.5, 26.2, 24.8, 21.5, 19.6, 14.1; HRMS calcd for $C_{30}H_{40}NO_{10}S$ $[M+H]^+$: 618.2367, found for: 618.2366.

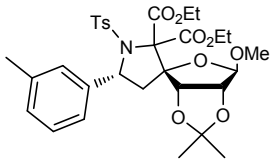
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(2-methylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-**3la)**



(8*S*)-**3la**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.28, 39% isolated yield); mp:110–112 ℃; $[\alpha]_D^{20}$ = -26 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (d, *J* = 8.0 Hz, 2H), 7.02 (d, *J* = 7.6 Hz, 1H), 6.95 (d, *J* = 8.0 Hz, 3H), 6.84 (d, *J* = 7.6 Hz, 1H), 6.54 (t, *J* = 7.4 Hz, 1H), 5.46 (t, *J* = 6.8 Hz, 1H), 4.91 (d, *J* = 1.6 Hz, 1H), 4.86 (d, *J* = 6.4 Hz, 1H), 4.57–4.51 (m, 2H), 4.49–4.43 (m, 1H), 4.37–4.28 (m, 2H), 3.40 (s, 3H), 2.69–2.55 (m, 2H), 2.36 (s, 3H), 2.30 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.26 (s, 3H), 1.09 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 165.8, 142.6, 138.4, 136.4, 135.7, 129.9, 128.5, 128.2, 127.9, 126.9, 125.1, 112.9, 110.2, 96.3, 85.6, 81.6, 81.2, 62.5, 62.4, 58.4, 56.7, 41.7, 26.2, 24.6, 21.5, 19.7, 14.2, 14.0; HRMS calcd for $C_{30}H_{40}NO_{10}S$ $[M+H]^+$: 618.2367, found for: 618.2367.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(3-methylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-**3ma)**

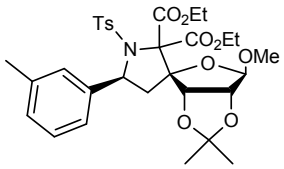


(8*R*)-**3ma**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.46, 65% isolated yield); mp:167–169 ℃; $[\alpha]_D^{20}$ = -13 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.4 Hz, 2H), 6.96–6.92 (m, 5H), 6.85 (d, *J* = 6.4 Hz, 1H), 5.57 (d, *J* = 10.8 Hz, 1H), 5.00 (d, *J* = 7.2 Hz, 1H), 4.65 (s, 1H), 4.54–4.48 (m, 2H), 4.46–4.39 (m, 2H), 4.20–4.12 (m, 1H), 3.33 (dd, *J* = 13.6, 10.8 Hz, 1H), 3.13 (s, 3H), 2.28 (s, 3H), 2.03 (s, 3H), 1.88 (d, *J* = 14.0 Hz, 1H), 1.43 (t, *J* = 7.2 Hz, 1H), 1.41 (s, 3H), 1.38 (t, *J* = 7.2 Hz, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz,$CDCl_3$) δ 167.6, 165.7, 142.8, 141.4, 137.6, 137.0, 128.8, 128.7, 128.1, 127.5, 127.2, 124.6, 114.4, 109.0, 98.1, 85.2, 83.5,

80.5, 63.8, 62.9, 62.4, 56.5, 42.9, 26.2, 24.8, 21.5, 21.2, 14.1; HRMS calcd for $C_{30}H_{40}NO_{10}S$ $[M+H]^+$: 618.2367, found for: 618.2371.

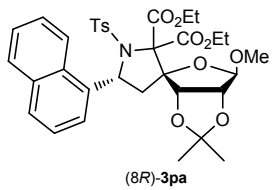
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(3-methylphenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3ma)



(8*S*)-**3ma**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.36, 34% isolated yield); mp: 120–123 ℃; $[\alpha]_D^{20}$ = -55 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 (d, *J* = 8.4 Hz, 2H), 6.94 (dd, *J* = 10.4, 6.0 Hz, 4H), 6.88 (d, *J* = 6.4 Hz, 1H), 6.77(s, 1H), 5.11 (d, *J* = 6.4 Hz, 1H), 5.03 (t, *J* = 7.6 Hz, 1H), 4.93 (d, *J* = 1.6 Hz, 1H), 4.56 (dd, *J* = 6.4, 1.6 Hz, 1H), 4.51–4.42 (m, 2H), 4.39–4.29 (m, 2H), 3.42 (s, 3H), 2.75 (dd, *J* = 13.2, 7.6 Hz, 1H), 2.35 (dd, *J* = 13.2, 7.6 Hz, 1H), 2.31 (s, 3H), 2.01 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.34 (s, 3H), 1.23 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 165.6, 142.2, 139.0, 137.1, 129.4, 128.3, 127.8, 127.6, 126.6, 113.1, 109.9, 95.4, 85.3, 81.2, 80.9, 62.5, 62.5, 62.3, 56.8, 42.4, 26.2, 24.8, 21.4, 21.0, 14.1, 14.0; HRMS calcd for $C_{30}H_{40}NO_{10}S$ $[M+H]^+$: 618.2367, found for: 618.2371.

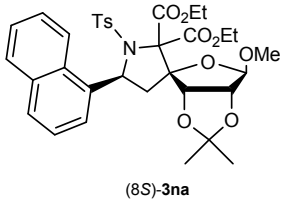
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(naphthalen-1-yl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3na)



(8*R*)-**3pa**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.42, 63% isolated yield); mp:150–152 ℃; $[\alpha]_D^{20}$ = -8 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.4 Hz, 1H), 7.84 (d, *J* = 7.6 Hz, 1H), 7.58–7.53 (m, 2H), 7.51–7.47 (m, 3H), 7.27 (d, *J* = 7.6 Hz, 1H), 6.93 (d, *J* = 8.0 Hz, 2H), 6.84 (t, *J* = 7.8 Hz, 1H), 6.36 (d, *J* = 10.0 Hz, 1H), 5.00 (d, *J* = 6.8 Hz, 1H), 4.60–4.52 (m, 1H), 4.51 - 4.44 (m, 3H), 4.39 (d, *J* = 2.4 Hz, 1H), 4.23 - 4.15 (m, 1H), 3.53 (dd, *J* = 13.6, 10.4 Hz, 1H), 2.97 (s, 3H), 2.28 (s, 3H), 2.01 (d, *J* = 13.6 Hz, 1H), 1.47 (t, *J* = 7.2 Hz, 3H), 1.41 (t, *J* = 7.0 Hz, 3H), 1.37 (s, 3H), 1.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 166.2, 143.2, 137.4, 135.6, 133.5, 130.1, 129.0, 129.0, 128.4, 126.9, 126.4, 126.0, 125.1, 124.6, 122.9, 114.5, 109.0, 98.0, 85.0, 83.7, 80.6, 63.0, 62.6, 60.9, 56.5, 42.1, 26.2, 24.8, 21.5, 14.1, 14.1; HRMS calcd for $C_{34}H_{40}NO_{10}S$ $[M+H]^+$: 654.2367, found for: 654.2368.

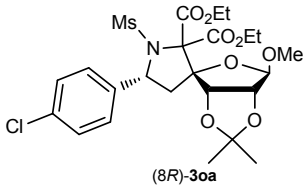
(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(naphthalen-1-yl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3na)



(8*S*)-**3na**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.36, 22% isolated yield); mp: 168–170 ℃; $[\alpha]_D^{20}$ = -46 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.4 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.56–7.45 (m, 5H), 7.06 (d, *J* = 7.2 Hz, 1H), 6.97 (d, *J* = 8.0 Hz, 2H), 6.85 (t, *J* = 7.6 Hz, 1H), 6.18 (d, *J* = 8.8 Hz, 1H), 4.81 (s, 1H), 4.66–4.58 (m, 1H), 4.53–4.37 (m, 4H), 4.31–4.23 (m, 1H), 3.36 (s, 3H), 3.20 (dd, *J* = 12.0, 9.6 Hz, 1H), 2.84 (d, *J* = 12.0 Hz, 1H), 2.30 (s, 3H), 1.47 (t, *J* = 7.2, 3H), 1.44 (t, *J* = 7.2, 3H), 0.85 (s, 3H), 0.73 (s, 3H); ^{13}C NMR (400 MHz, $CDCl_3$) δ 168.0, 166.3, 143.2, 137.7, 135.1, 133.7, 130.8, 128.8, 128.7, 128.5, 127.3, 125.9, 125.2, 124.7, 124.4, 123.2, 112.3, 110.9, 97.3, 86.0, 82.4, 81.4, 62.6, 62.5, 58.6, 56.4, 41.1, 29.8, 25.9, 24.3, 21.6, 14.2, 14.1; HRMS calcd for$C_{34}H_{40}NO_{10}S$ $[M+H]^+$: 654.2367, found for: 654.2369.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-methylsulfonyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-3oa)

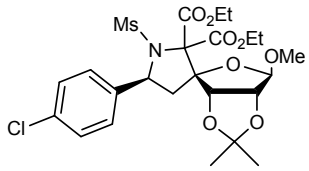


(8*R*)-**3oa**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.45, 50% isolated yield); mp: 138–142 ℃; $[\alpha]_D^{20}$ = -32 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.4 Hz, 2H), 7.30 (d, *J* = 8.4 Hz, 2H), 5.47 (d, *J* = 10.8 Hz, 1H), 5.01 (d, *J* = 6.8 Hz, 1H), 4.81 (d, *J* = 1.2 Hz, 1H), 4.55 (dd, *J* = 6.8, 1.2 Hz, 1H), 4.53–4.45 (m, 1H), 4.38–4.32 (m, 2H), 4.23–4.15 (m, 1H), 3.32 (s, 3H), 3.30–3.27 (m, 1H), 2.94 (s, 3H), 1.83 (d, *J* = 14.0 Hz, 1H), 1.42(s, 3H), 1.39 (t, *J* = 6.8 Hz, 3H), 1.37 (t, *J* = 6.6 Hz, 3H), 1.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.4, 166.2, 140.5, 133.4, 129.5, 128.5, 114.4, 109.3, 98.4, 85.4, 83.4, 80.2, 63.1, 63.0, 62.8, 56.7, 43.6, 42.5, 26.2, 24.8, 14.0; HRMS calcd for $C_{24}H_{33}ClNO_{10}S$ $[M+H]^+$: 562.1508, found for: 562.1508.

(2*R*,3*R*,4*S*,5*R*,8*R*)-diethyl 8-(4-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-methylsulfonyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-3oa)

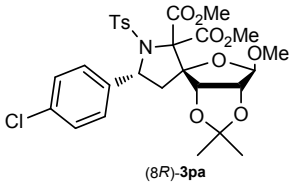
White solid (petroleum ether/EtOAc = 4:1, R_f = 0.38, 45% isolated yield); mp: 110–



(8*S*)-**3oa**

112 ℃; $[\alpha]_D^{20}$ = -58 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (dd, *J* = 8.4, 6.0 Hz, 4H), 5.16 (dd, *J* = 8.4, 6.0 Hz, 1H), 4.94 (d, *J* = 24.4, 8.4 Hz, 4H), 4.86 (d, *J* = 6.4 Hz, 1H), 4.56 (dd, *J* = 6.4, 1.6 Hz, 1H), 4.52–4.18 (m, 4H), 3.37 (s, 3H), 2.97 (s, 3H), 2.79–2.62 (m, 2H), 1.40 (t, *J* = 7.2 Hz, 3H), 1.36 (t, *J* = 7.2 Hz, 3H), 1.34 (s, 3H), 1.22 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 165.6, 139.1, 133.7, 129.2, 128.5, 113.4, 110.1, 96.7, 86.1, 81.5, 81.4, 62.8, 62.6, 62.0, 56.6, 42.8, 42.6, 26.2, 24.8, 14.1, 14.0; HRMS calcd for $C_{24}H_{33}ClNO_{10}S$ $[M+H]^+$: 562.1508, found for: 562.1508.

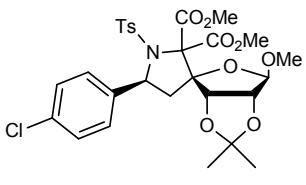
(2*R*,3*R*,4*S*,5*R*,8*R*)-dimethyl 8-(4-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*R*)-**3pa)**



(8*R*)-**3pa**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.33, 52% isolated yield); mp: 118–120 ℃; $[\alpha]_D^{20}$ = -43 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (d, *J* = 8.4 Hz, 2H), 7.08 (d, *J* = 8.4 Hz, 2H), 6.99 (dd, *J* = 14.4, 8.0 Hz, 4H), 5.55 (d, *J* = 10.4 Hz, 1H), 4.94 (d, *J* = 6.8 Hz, 1H), 4.65 (d, *J* = 1.6 Hz, 1H), 4.49 (dd, *J* = 6.8, 2.0 Hz, 1H), 3.96 (s, 3H), 3.87 (s, 3H), 3.33 (dd, *J* = 13.6, 10.8 Hz, 1H), 3.14 (s, 3H), 2.32 (s, 3H), 1.84 (d, *J* = 13.6 Hz, 1H), 1.41 (s, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.1, 166.2, 143.5, 140.1, 137.2, 132.4, 129.1, 128.8, 128.4, 127.6, 114.4, 109.4, 98.5, 85.3, 83.7, 80.5, 63.1, 56.6, 53.8, 53.2, 43.1, 26.2, 24.8, 21.5; HRMS calcd for $C_{28}H_{33}ClNO_{10}S$ $[M+H]^+$: 610.1508, found for: 610.1509.

(2*R*,3*R*,4*S*,5*R*,8*R*)-Dimethyl 8-(4-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-7-tosyl-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate ((8*S*)-**3pa)**

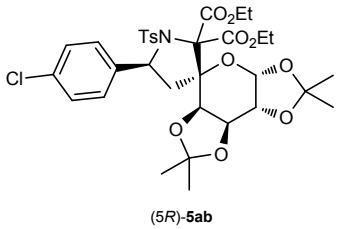


(8*S*)-**3pa**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.26, 47% isolated yield); mp:144–146 ℃; $[\alpha]_D^{20}$ = -25 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 (d, *J* = 6.8 Hz, 2H), 7.01–6.99 (m, 4H), 6.93 (d, *J* = 8.4 Hz, 2H), 5.03 (t, *J* = 6.4 Hz, 2H), 4.93 (d, *J* = 1.2 Hz, 1H), 4.55 (dd, *J* = 6.4, 1.2 Hz, 1H), 3.95 (s, 3H), 3.92 (s, 3H), 3.41 (s, 3H), 2.72 (dd, *J* = 13.2, 7.2 Hz, 1H), 2.39(dd, *J* = 13.2, 8.0 Hz, 1H), 2.35 (s, 3H), 1.34 (s, 3H), 1.22 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.3,

166.2, 143.0, 138.6, 136.2, 133.6, 130.2, 128.7, 127.9, 127.8, 113.3, 110.0, 95.8, 85.5, 81.2, 81.2, 61.8, 56.9, 53.4, 53.2, 42.4, 26.2, 24.9, 21.6; HRMS calcd for $C_{28}H_{33}ClNO_{10}S$ $[M+H]^+$: 610.1508, found for: 610.1508.

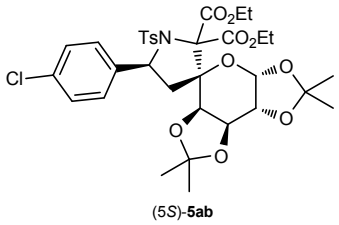
(3*S*,5*R*,7*S*,8*R*,9*S*,10*R*)-diethyl 7,8:9,10-di-O-isopropylidene-3-(4-chlorophenyl)-2-tosyl-6-oxa-2-azaspiro[4.5]decane-1,1-dicarboxylate ((5*R*)-5ab)



(5*R*)-**5ab**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.35, 20% isolated yield); mp: 186–190 ℃; $[\alpha]_D^{20}$ = -61 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.4 Hz, 2H), 7.13 (d, *J* = 8.4 Hz, 2H), 7.00 (dd, *J* = 11.8, 8.6 Hz, 4H), 5.59 (d, *J* = 10.0 Hz, 1H), 4.92 (d, *J* = 6.8 Hz, 1H), 4.60–4.50 (m, 2H), 4.41–4.26 (m, 3H), 4.19–4.11 (m, 1H), 4.00 (d, *J* = 2.4 Hz, 1H), 3.22 (dd, *J* = 14.0, 10.4 Hz, 1H), 2.32 (s, 3H), 1.99 (d, *J* = 14.4 Hz, 1H), 1.44 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.37 (d, *J* = 7.2 Hz, 3H), 1.33 (s, 3H), 1.31 (s, 3H), 1.20 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 165.3, 143.3, 139.4, 137.9, 132.8, 129.2, 128.9, 128.5, 128.1, 110.8, 109.1, 93.5, 89.3, 83.8, 75.7, 75.1, 68.5, 62.9, 62.9, 62.4, 34.5, 27.7, 26.2, 26.0, 25.3, 21.7, 14.3, 14.1. HRMS calcd for $C_{33}H_{41}ClNO_{11}S$ $[M+H]^+$: 694.2083, found for: 694.2093.

(3*S*,5*R*,7*S*,8*R*,9*S*,10*R*)-diethyl 7,8:9,10-di-O-isopropylidene-3-(4-chlorophenyl)-2-tosyl-6-oxa-2-azaspiro[4.5]decane-1,1-dicarboxylate ((5*S*)-5ab)

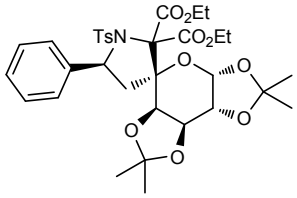


(5*S*)-**5ab**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.24, 64% isolated yield); mp: 180–182 ℃; $[\alpha]_D^{20}$ = –16 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (d, *J* = 8.0 Hz, 2H), 7.01 (dd, *J* = 21.2, 8.4 Hz, 4H), 6.90 (d, *J* = 8.0 Hz, 2H), 5.56 (d, *J* = 3.2 Hz, 1H), 5.16 (t, *J* = 7.4 Hz, 1H), 4.51– 4.39 (m, 3H), 4.37–4.25 (m, 2H), 4.23 (d, *J* = 5.2 Hz, 1H), 3.88 (d, *J* = 3.2 Hz, 1H), 2.84 (dd, *J* = 12.8, 6.8 Hz, 1H), 2.35 (s, 3H), 2.20 (dd, *J* = 12.8, 8.4 Hz, 1H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.41(s, 3H), 1.40(s, 3H), 1.39 (t, *J* = 7.2 Hz, 3H), 1.29 (s, 3H), 1.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.3, 165.6, 143.0, 138.7, 135.5, 133.8, 130.0, 128.7, 128.1, 127.9, 109.7, 109.7, 95.9, 84.5, 82.7, 73.5, 72.3, 62.5, 62.1, 62.0, 46.4, 27.4, 26.9, 25.4, 25.3, 21.5, 14.2, 14.0. HRMS calcd for $C_{33}H_{41}ClNO_{11}S$ $[M+H]^+$: 694.2083,

found for: 694.2083.

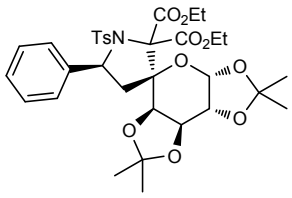
(3*S*,5*R*,7*S*,8*R*,9*S*,10*R*)-diethyl 7,8:9,10-di-O-isopropylidene-3-phenyl-2-tosyl-6-oxa-2-azaspiro[4.5]decane-1,1-dicarboxylate ((5*R*)-**5bb)**



(5*R*)-**5bb**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.38, 15% isolated yield); mp: 172–174 ℃; $[\alpha]_D^{20}$ = -59 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 8.4 Hz, 2H), 7.20–7.18 (m, 2H), 7.09–7.04 (m, 3H), 6.94 (d, *J* = 8.0 Hz, 2H), 5.66 (d, *J* = 10.4 Hz, 1H), 4.94 (d, *J* = 6.8 Hz, 1H), 4.60–4.53 (m, 1H), 4.50 (d, *J* = 6.8 Hz, 1H), 4.44–4.36 (m, 2H), 4.34– 4.26 (m, 1H), 4.18–4.10 (m, 1H), 3.99 (d, *J* = 3.2 Hz, 1H), 3.24 (dd, *J* = 14.0, 10.0 Hz, 1H), 2.29 (s, 3H), 2.02 (d, *J* = 14.0 Hz, 1H), 1.45 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.35 (t, *J* = 7.2 Hz, 3H), 1.33 (s, 3H), 1.31 (s, 3H), 1.18 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 165.2, 142.8, 140.6, 138.0, 128.8, 128.2, 127.9, 127.7, 127.0, 110.5, 109.0, 93.5, 89.2, 83.6, 75.6, 75.1, 68.4, 63.5, 62.8, 62.2, 34.5, 27.6, 26.2, 25.9, 25.2, 21.6, 14.2, 14.0. HRMS calcd for $C_{33}H_{42}NO_{11}S$ $[M+H]^+$: 660.2473, found for: 660.2473.

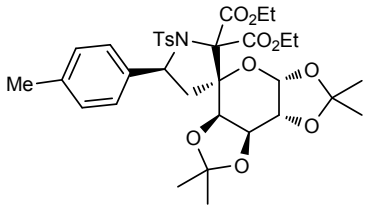
(3*S*,5*S*,7*S*,8*R*,9*S*,10*R*)-diethyl 7,8:9,10-di-O-isopropylidene-3-phenyl-2-tosyl-6-oxa-2-azaspiro[4.5]decane-1,1-dicarboxylate ((5*S*)-**5bb)**



(5*S*)-**5bb**

White solid (petroleum ether/EtOA = 4:1, R_f = 0.26, 66% isolated yield); mp: 166–170 ℃; $[\alpha]_D^{20}$ = -37 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (d, *J* = 8.4 Hz, 2H), 7.12–7.06 (m, 3H), 6.95 (dd, *J* = 13.6, 7.8 Hz, 4H), 5.57 (d, *J* = 3.2 Hz, 1H), 5.24 (t, *J* = 7.4 Hz, 1H), 4.52–4.24 (m, 5H), 4.18 (d, *J* = 5.2 Hz, 1H), 3.87 (d, *J* = 3.2 Hz, 1H), 2.91 (dd, *J* = 12.8, 7.2 Hz, 1H), 2.31 (s, 3H), 2.22 (dd, *J* = 12.4, 7.6 Hz, 1H), 1.42(t, *J* = 7.2 Hz, 3H), 1.41(t, *J* = 7.2 Hz, 3H), 1.41 (s, 3H), 1.40 (s, 3H), 1.28 (s, 3H), 1.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.2, 165.8, 142.6, 138.6, 137.5, 128.6, 128.6, 128.3, 127.9, 127.8, 109.7, 109.7, 96.0, 84.6, 82.5, 73.4, 72.5, 62.9, 62.4, 61.9, 46.6, 29.8, 27.5, 26.9, 25.5, 25.3, 21.5, 14.2, 14.1. HRMS calcd for $C_{33}H_{42}NO_{11}S$ $[M+H]^+$: 660.2473, found for: 660.2473.

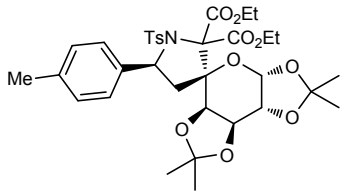
(3*S*,5*R*,7*S*,8*R*,9*S*,10*R*)-diethyl 7,8:9,10-di-O-isopropylidene-3-(4-methylphenyl)-2-tosyl-6-oxa-2-azaspiro[4.5]decane-1,1-dicarboxylate ((5*R*)-**5hb)**



(5*R*)-**5hb**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.36, 16% isolated yield); mp: 190–192 ℃; $[\alpha]_D^{20}$ = -48 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, *J* = 8.4 Hz, 2H), 7.09 (d, *J* = 8.4 Hz, 2H), 6.93 (d, *J* = 8.0 Hz, 2H), 6.87 (d, *J* = 8.0 Hz, 2H), 5.60 (d, *J* = 10.4 Hz, 1H), 4.94 (d, *J* = 6.4 Hz, 1H), 4.59–4.53 (m, 1H), 4.52–4.50 (m, 2H), 4.43–4.35 (m, 1H), 4.34–4.26 (m, 1H), 4.16–4.08 (m, 1H), 4.01 (d, *J* = 3.2 Hz, 1H), 3.20 (dd, *J* = 14.0, 10.4 Hz, 1H), 2.29 (s, 3H), 2.26 (s, 3H), 1.98 (d, *J* = 14.4 Hz, 1H), 1.45 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.34(t, *J* = 7.2 Hz, 3H), 1.34 (s, 3H), 1.31 (s, 3H), 1.20 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 165.2, 142.7, 138.1, 137.7, 136.5, 128.8, 128.6, 128.2, 127.6, 110.6, 108.9, 93.6, 89.1, 83.5, 75.6, 75.2, 68.5, 63.5, 62.7, 62.1, 34.3, 27.6, 26.2, 25.9, 25.2, 21.5, 21.2, 14.2, 14.0. HRMS calcd for $C_{34}H_{44}NO_{11}S$ $[M+H]^+$: 674.2630, found for: 674.2630.

(3*S*, 5*R*, 7*S,* 8*R*, 9*S*, 10*R*)-diethyl 7,8:9,10-di-O-isopropylidene-3-(4-methylphen-yl)-2-tosyl-6-oxa-2-azaspiro[4.5]decane-1,1-dicarboxylate ((5*S*)-**5hb)**

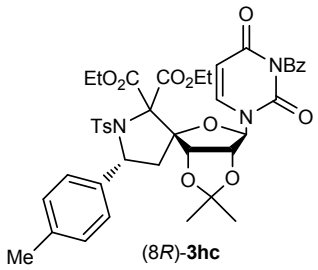


(5*S*)-**5hb**

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.25, 76% isolated yield); mp: 180–182 ℃; $[\alpha]_D^{20}$ = -49 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (d, *J* = 8.4 Hz, 2H), 6.95 (dLd, *J* = 21.6, 8.0 Hz, 4H), 6.74 (d, *J* = 7.6 Hz, 2H), 5.56 (d, *J* = 2.8 Hz, 1H), 5.15 (t, *J* = 7.6 Hz, 1H), 4.49–4.45 (m, 2H), 4.42–4.38 (m, 1H), 4.36–4.27 (m, 2H), 4.22 (d, *J* = 5.2 Hz, 1H), 3.87 (d, *J* = 2.8 Hz, 1H), 2.81 (dd, *J* = 12.4, 6.4 Hz, 1H), 2.32 (s, 3H), 2.28–2.18 (m, 4H), 1.41–1.40 (m, 12H), 1.28 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.3, 165.8, 142.4, 138.9, 137.6, 133.9, 128.7, 128.5, 128.4, 128.2, 109.8, 109.6, 95.9, 84.5, 82.7, 73.6, 72.5, 62.7, 62.4, 61.9, 46.6, 27.5, 27.0, 25.5, 25.3, 21.5, 21.2, 14.1. HRMS calcd for $C_{34}H_{44}NO_{11}S$ $[M+H]^+$: 674.2630, found for: 674.2630.

Compound (8*R*)-3hc

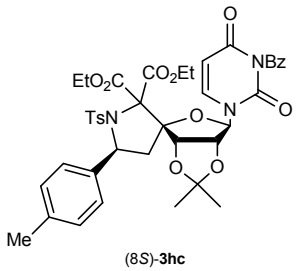
White solid (petroleum ether/EtOAc = 1:1, R_f = 0.36, 47% isolated yield); mp: 100–102 ℃; $[\alpha]_D^{20}$ = +38 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.4 Hz, 2H), 7.97–7.95 (m, 2H), 7.66 (t, *J* = 7.4 Hz, 1H), 7.50 (dd, *J* = 17.2, 8.4 Hz, 3H),



(8*R*)-**3hc**

7.29 (d, *J* = 8.0 Hz, 2H), 7.08 (dd, *J* = 38.4, 8.0 Hz, 4H), 6.32 (s, 1H), 6.05 (d, *J* = 8.4 Hz, 1H), 5.80 (d, *J* = 6.0 Hz, 1H), 5.55 (d, *J* = 10.8 Hz, 1H), 5.27 (d, *J* = 11.6 Hz, 1H), 4.81 (d, *J* = 6.0 Hz, 1H), 4.50 (s, 1H), 4.32–4.18 (m, 4H), 2.39 (s, 3H), 2.27 (s, 3H), 1.38 (s, 3H), 1.33 (s, 3H), 1.29 (t, *J* = 7.2, 3H), 1.28 (t, *J* = 7.2, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 167.6, 166.2, 161.9, 159.3, 149.0, 144.1, 139.8, 137.9, 136.8, 135.3, 134.5, 131.5, 130.6, 129.7, 129.3, 129.2, 128.6, 127.2, 114.4, 103.5, 101.8, 90.9, 83.3, 76.3, 62.6, 62.5, 61.5, 57.6, 26.8, 25.9, 21.6, 21.0, 14.1, 13.9. HRMS calcd for $C_{41}H_{44}N_3O_{12}S$ $[M+H]^+$: 802.2640, found for: 802.2644.

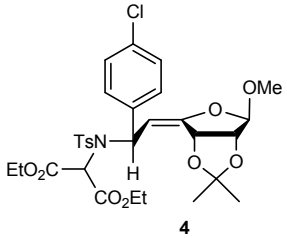
Compound (8*S*)-3hc



(8*S*)-**3hc**

White solid (petroleum ether/EtOAc = 1:1, R_f = 0.31, 20% isolated yield); mp: 126–130 ℃; $[\alpha]_D^{20}$ = +133 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 7.2 Hz, 2H), 7.88 (d, *J* = 8.4 Hz, 2H), 7.60 (t, *J* = 7.6 Hz, 1H), 7.55 (d, *J* = 8.4 Hz, 1H), 7.47 (t, *J* = 7.8 Hz, 2H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.00 (s, 4H), 5.92 (d, *J* = 8.4 Hz, 2H), 5.76 (d, *J* = 9.2 Hz, 1H), 5.28 (d, *J* = 6.0 Hz, 1H), 5.14 (d, *J* = 9.2 Hz, 1H), 5.01 (d, *J* = 5.6 Hz, 1H), 4.44 (s, 1H), 4.19–4.04 (m, 4H), 2.39 (s, 3H), 2.26 (s, 3H), 1.44 (s, 3H), 1.38 (s, 3H), 1.16 (t, *J* = 7.2 Hz, 3H), 1.15 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 167.1, 166.4, 162.2, 156.9, 149.3, 143.8, 138.1, 137.5, 135.4, 134.2, 131.4, 131.0, 129.5, 129.4, 129.3, 128.6, 127.9, 114.2, 103.2, 82.9, 79.4, 62.5, 62.2, 61.7, 56.9, 27.0, 25.9, 21.7, 21.2, 14.0, 13.9. HRMS calcd for $C_{41}H_{44}N_3O_{12}S$ $[M+H]^+$: 802.2640, found for: 802.2643.

Uncyclized product 4

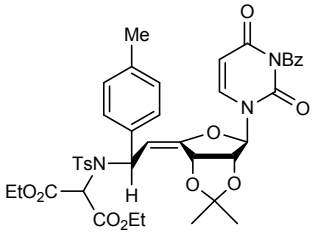


4

White solid (petroleum ether/EtOAc = 4:1, R_f = 0.21); mp: 132–136 ℃; $[\alpha]_D^{20}$ = -16 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (d, *J* = 8.4 Hz, 2H), 7.28 (d, *J* = 4.8 Hz, 2H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.4 Hz, 2H), 5.78 (d, *J* = 8.4 Hz, 1H), 5.08 (s, 1H), 5.02 (d, *J* = 8.8 Hz, 1H), 4.96 (d, *J* = 6.0 Hz, 1H), 4.58 (s, 1H), 4.45 (d, *J* = 5.6 Hz, 2H), 4.32-4.18 (m, 2H), 4.14-4.10 (m, 2H), 3.40 (s,

3H), 2.40 (s, 3H), 1.35 (s, 3H), 1.34 (s, 3H), 1.30 (t, J = 7.2, 3H), 1.21 (t, J = 7.2, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.8, 166.4, 156.5, 143.5, 137.7, 136.3, 133.9, 130.1, 129.2, 128.3, 128.3, 113.2, 109.1, 100.2, 82.2, 78.7, 62.5, 62.2, 62.0, 57.1, 56.2, 27.0, 25.9, 21.7, 14.0, 14.0; HRMS calcd for $C_{30}H_{37}ClNO_{10}S$ $[M+H]^+$: 638.1822, found for: 638.1816.

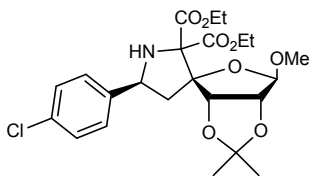
Uncyclized product 6



6

White solid (petroleum ether/EtOAc = 1:1, R_f = 0.26, 26% isolated yield); mp: 102–104 ℃; $[\alpha]_D^{20}$ = -24 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, J = 8.4 Hz, 2H), 7.96 (d, J = 7.2 Hz, 2H), 7.70 (t, J = 7.4 Hz, 1H), 7.55 (t, J = 7.8 Hz, 2H), 7.30 (dd, J = 8.2, 3.4 Hz, 1H), 7.25 (s, 2H), 6.92 (d, J = 6.8 Hz, 2H), 6.64 (s, 2H), 5.86 (d, J = 8.0 Hz, 1H), 5.65 (d, J = 8.0 Hz, 1H), 5.57 (s, 1H), 5.29 (d, J = 8.0 Hz, 1H), 4.90 (dd, J = 36.4, 6.0 Hz, 2H), 4.36–4.22 (m, 3H), 4.05 –3.99 (m, 2H), 2.41 (s, 3H), 2.16 (s, 3H), 1.50 (s, 3H), 1.31 (t, J = 7.2 Hz, 3H), 1.30 (t, J = 7.2 Hz, 3H), 1.13 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.1, 167.1, 166.3, 161.9, 158.5, 149.3, 143.4, 137.9, 137.4, 135.6, 133.8, 131.4, 130.6, 129.4, 129.2, 129.1, 128.9, 114.1, 102.9, 100.3, 97.7, 83.2, 78.1, 62.5, 61.9, 61.7, 57.5, 26.7, 25.8, 21.7, 21.1, 14.1, 13.9. HRMS calcd for $C_{41}H_{44}N_3O_{12}S$ $[M+Na]^+$: 824.2460, found for: 824.2459.

(2*R*,3*R*,4*S*,5*R*,8*S*)-diethyl 8-(4-chlorophenyl)-3,4-O-isopropylidene-2-methoxy-1-oxa-7-azaspiro[4.4]nonane-6,6-dicarboxylate (7)

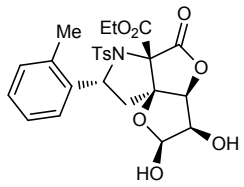


7

White solid (petroleum ether/EtOAc = 3:1, R_f = 0.47, 87% isolated yield); mp:102–106 ℃; $[\alpha]_D^{20}$ = -75 (c 1.0, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (d, J = 1.6 Hz, 4H), 5.27 (d, J = 6.8 Hz, 1H), 4.98 (s, 1H), 4.62 (dd, J = 11.2, 6.0 Hz, 1H), 4.57 (d, J = 6.8 Hz, 1H), 4.42–4.36 (m, 1H), 4.34–4.18 (m, 2H), 4.12–4.04 (m, 1H), 3.63 (s, 1H), 3.31 (s, 3H), 2.48 (dd, J = 13.2, 11.2 Hz, 1H), 2.24 (dd, J = 13.2, 6.0 Hz, 1H), 1.48 (s, 3H), 1.35 (s, 3H), 1.29 (t, J = 7.2 Hz, 3H), 1.29 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.4, 168.2, 143.1, 132.6, 128.5,

128.1, 113.1, 108.5, 99.1, 86.2, 80.8, 77.7, 62.3, 61.7, 59.4, 56.5, 46.2, 26.3, 24.8, 14.1, 14.0. HRMS calcd for $C_{23}H_{31}ClNO_8$ $[M+H]^+$: 484.1732, found for: 484.1732.

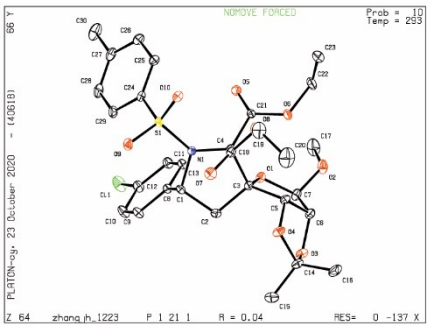
Ethyl-2,3-dihydroxy-5-oxo-7-(o-tolyl)-6-tosyloctahydrofuro[2',3':4,5]furo[3,4-b]pyrrole-5a-carboxylate (8)

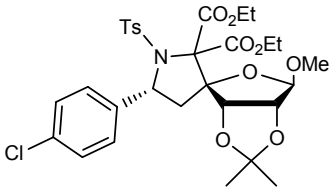


8

White solid (petroleum ether/EtOAc = 1:2, R_f = 0.4, 68% isolated yield); mp: 228–230 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (d, *J* = 8.4 Hz, 2H), 7.12 (d, *J* = 7.6 Hz, 1H), 7.01 (dd, *J* = 10.8, 8.0 Hz, 3H), 6.56 (t, *J* = 7.6 Hz, 1H), 6.26 (d, *J* = 8.0 Hz, 1H), 5.82 (d, *J* = 10.4 Hz, 1H), 5.43 (t, *J* = 3.8 Hz, 1H), 4.62 (d, *J* = 3.2 Hz, 1H), 4.51–4.42 (m, 2H), 4.40 (d, *J* = 5.2 Hz, 1H), 4.06–4.04 (m, 1H), 3.44 (d, *J* = 12.0 Hz, 1H), 3.17–3.11 (m, 1H), 2.34 (s, 3H), 2.32 (s, 3H), 1.98 (d, *J* = 12.8 Hz, 1H), 1.46 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.0, 166.0, 144.0, 137.1, 137.1, 134.7, 131.0, 129.2, 128.0, 127.4, 125.7, 124.7, 95.4, 95.2, 80.6, 75.0, 72.3, 63.0, 60.5, 40.3, 21.6, 19.6, 14.2. HRMS calcd for $C_{25}H_{27}NO_9SNa$ $[M+Na]^+$: 540.1299 , found for: 540.1297.

8. X-ray crystallographic data of the compounds



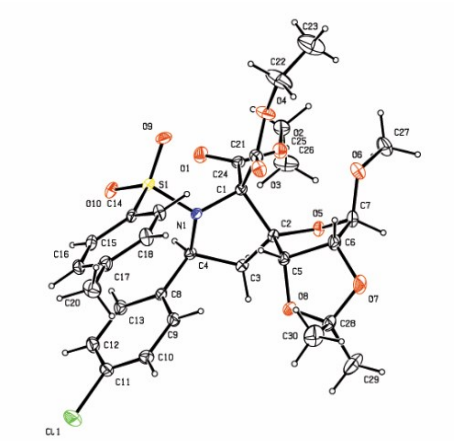


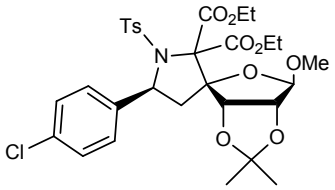
CCDC 2027409

X-ray Crystallographic Data of Compound (8*R*)-3aa

Bond precision:	C-C = 0.0056 A	Wavelength=1.54184	
Cell:	a=9.45912(18)	b=18.2843(3)	c=9.6046(7)
	alpha=90	beta=106.411(2)	gamma=90
Temperature:	293 K		
	Calculated	Reported	
Volume	1593.47(5)	1593.48(6)	
Space group	P 21	P 1 21 1	
Hall group	P 2yb	P 2yb	
Moiety formula	C_{30} H_{35} Cl N O_{10} S	C_{30} H_{35} Cl N O_{10} S	
Sum formula	C_{30} H_{35} Cl N O_{10} S	C_{30} H_{35} Cl N O_{10} S	
Mr	637.10	637.10	
Dx,g cm-3	1.328	1.328	
Z	2	2	
Mu (mm-1)	2.152	2.152	
F000	670.0	670.0	
F000’	673.46		
h,k,lmax	11, 21, 11	11, 21, 11	
Nref	5641[2919]	5634	
Tmin,Tmax	0.793, 0.860	0.481, 1.000	
Tmin’	0.789		
Correction method= # Reported T Limits: Tmin=0.414 Tmax=1.000			
AbsCorr = MULTI-SCAN			
Data completeness= 1.93/1.00		Theta(max)= 66.590	
R(reflections)= 0.0330 (5312)		wR2(reflections)= 0.0921(5634)	
S = 1.038		Npar= 394	

X-ray Crystallographic Data of Compound (8*S*)-3aa





CCDC 2025635

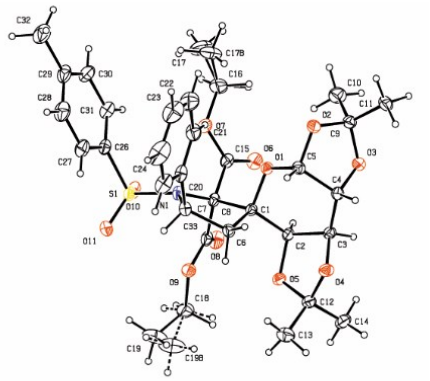
Bond precision:	C-C = 0.0076 A	Wavelength=1.54184	
Cell:	a=11.1994(3)	b=13.4972(5)	c=21.4716(7)
	alpha=90	beta=106.660(2)	gamma=90
Temperature:	293 K		
	Calculated	Reported	
Volume	3245.66(18)	3245.68(18)	
Space group	P 21/c	P 1 21/c 1	
Hall group	-P 2ybc	-P 2ybc	
Moiety formula	C_{30} H_{36} Cl N O_{10} S	C_{30} H_{36} Cl N O_{10} S	
Sum formula	C_{30} H_{36} Cl N O_{10} S	C_{30} H_{36} Cl N O_{10} S	
Mr	638.11	638.11	
Dx,g cm-3	1.306	1.306	
Z	4	4	
Mu (mm-1)	2.113	2.113	
F000	1344.0	1344.0	
F000’	1350.93		
h,k,lmax	13, 16, 25	13, 16, 25	
Nref	5718	4959	
Tmin,Tmax	0.881, 0.919	0.414, 1.000	
Tmin’	0.810		

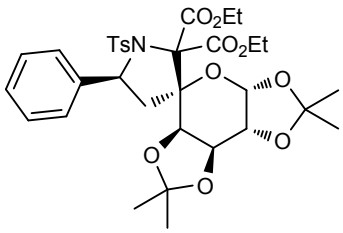
Correction method= # Reported T Limits: Tmin=0.414 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.54/0.87	Theta(max)= 66.596
R(reflections)= 0.0487(4323)	wR2(reflections)= 0.1345(4959)

S = 1.058 Npar= 394

X-ray Crystallographic Data of Compound (5*R*)-5bb





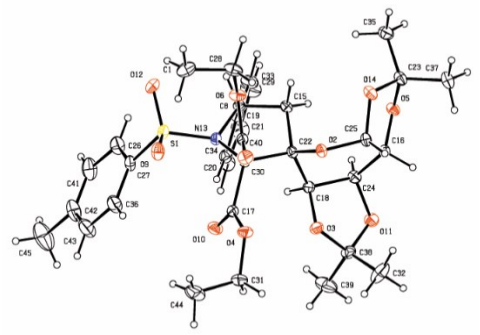
CCDC 2025967

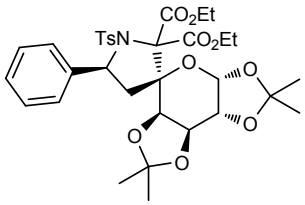
Bond precision:	C-C = 0.0050 A	Wavelength=1.54184	
Cell:	a=10.7929(2)	b=14.1343(3)	c=22.1643(5)
	alpha=90	beta=90	gamma=90
Temperature:	295 K		
	Calculated	Reported	
Volume	3381.17(12)	3381.19(12)	
Space group	P 21 21 21	P 21 21 21	
Hall group	P 2ac 2ab	P 2ac 2ab	
Moiety formula	C_{33} H_{41} Cl N O_{11} S	C_{33} H_{41} Cl N O_{11} S	
Sum formula	C_{33} H_{41} Cl N O_{11} S	C_{33} H_{41} Cl N O_{11} S	
Mr	659.73	659.73	
Dx,g cm-3	1.296	1.296	
Z	4	4	
Mu (mm-1)	1.358	1.358	
F000	1400.0	1400.0	
F000’	1405.86		
h,k,lmax	12, 16, 26	12, 16, 26	
Nref	5977[3366]	5138	
Tmin,Tmax	0.805, 0.850	0.593, 1.000	
Tmin’	0.805		

Correction method= # Reported T Limits: Tmin=0.593 Tmax=1.000
AbsCorr = MULTI-SCAN

Data completeness= 1.53/0.86	Theta(max)= 66.571
R(reflections)= 0.0354(4695)	wR2(reflections)= 0.0903(5138)
S = 1.062	Npar= 442

X-ray Crystallographic Data of Compound (5*S*)-5bb





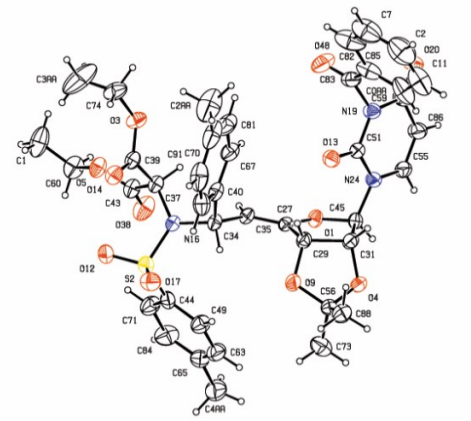
CCDC 2025642

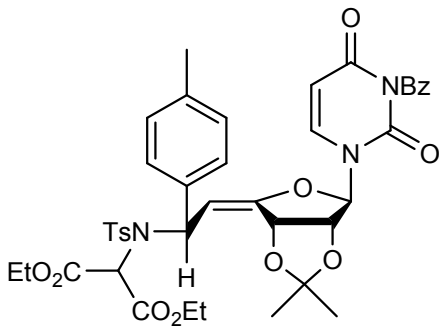
Bond precision:	C-C = 0.0049 A	Wavelength=1.54184	
Cell:	a=9.96904(13)	b=10.69984(16)	c=31.3952(4)
	alpha=90	beta=90	gamma=90
Temperature:	293 K		
	Calculated	Reported	
Volume	3348.84(8)	3348.84(8)	
Space group	P 21 21 21	P 21 21 21	
Hall group	P 2ac 2ab	P 2ac 2ab	
Moiety formula	C_{33} H_{41} Cl N O_{11} S	C_{33} H_{41} Cl N O_{11} S	
Sum formula	C_{33} H_{41} Cl N O_{11} S	C_{33} H_{41} Cl N O_{11} S	
Mr	659.73	661.23	
Dx,g cm-3	1.309	1.311	
Z	4	4	
Mu (mm-1)	1.371	1.367	
F000	1400.0	1403.0	
F000’	1405.86		
h,k,lmax	11, 12, 37	11, 12, 37	
Nref	5913[3360]	5233	
Tmin,Tmax	0.782, 0.849	0.663, 1.000	
Tmin’	0.782		

Correction method= # Reported T Limits: Tmin=0.663 Tmax=1.000
AbsCorr = MULTI-SCAN
Data completeness= 1.56/0.88 Theta(max)= 66.578

R(reflections)= 0.0393(4959)	wR2(reflections)= 0.0989(5233)
S = 1.062	Npar= 422

X-ray Crystallographic Data of Compound 6





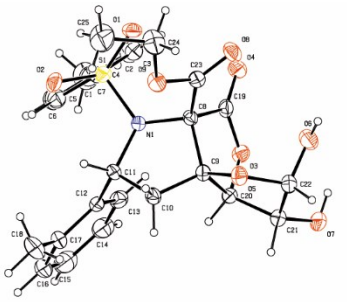
CCDC 2027410

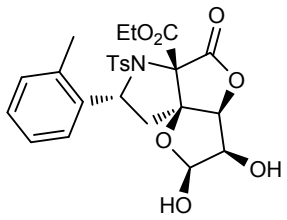
Bond precision:	C-C = 0.0091 A	Wavelength=1.54184	
Cell:	a=11.6704(12)	b=19.5166(19)	c=11.8028(11)
	alpha=90	beta=99.959(10)	gamma=90
Temperature:	293 K		
	Calculated	Reported	
Volume	2647.8(5)	2647.8(5)	
Space group	P 21	P 1 21 1	
Hall group	P 2yb	P 2yb	
Moiety formula	C_{41} H_{43} Cl N O_{12} S	C_{41} H_{43} Cl N O_{12} S	
Sum formula	C_{41} H_{43} Cl N O_{12} S	C_{41} H_{43} Cl N O_{12} S	
Mr	801.84	801.84	
Dx,g cm-3	1.006	1.006	
Z	2	2	
Mu (mm-1)	0.971	0.971	
F000	844.0	844.0	
F000’	847.41		
h,k,lmax	13, 23, 14	13, 23, 14	
Nref	9337 [4818]	7975	
Tmin,Tmax	0.954, 0.971	0.306, 1.000	
Tmin’	0.916		

Correction method= # Reported T Limits: Tmin=0.306 Tmax=1.000
AbsCorr = MULTI-SCAN
Data completeness= 1.66/0.85 Theta(max)= 66.597

R(reflections)= 0.0502(5501)	wR2(reflections)= 0.1567(7975)
S = 1.016	Npar= 508

X-ray Crystallographic Data of Compound 8





CCDC 2025644

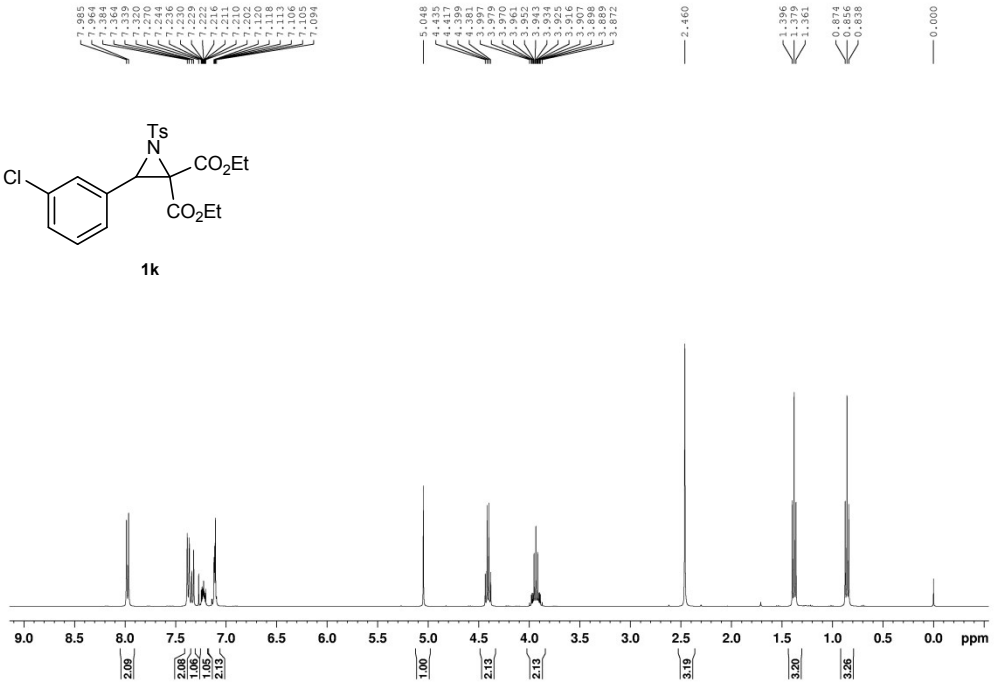
Bond precision:	C-C = 0.0081 A	Wavelength=0.71073	
Cell:	a=7.633(3)	b=14.652(5)	c=31.395222.078(8)
	alpha=90	beta=90	gamma=90
Temperature:	296 K		
	Calculated	Reported	
Volume	2469.2(16)	2469.1(15)	
Space group	P 21 21 21	P 21 21 21	
Hall group	P 2ac 2ab	P 2ac 2ab	
Moiety formula	$C_{25}H_{27}ClNO_9S$	$C_{25}H_{27}ClNO_9S$	
Sum formula	$C_{25}H_{27}ClNO_9S$	$C_{25}H_{27}ClNO_9S$	
Mr	571.54	571.53	
Dx,g cm-3	1.392	1.392	
Z	4	4	
Mu (mm-1)	0.186	0.186	
F000	1088.0	1088.0	
F000’	1089.11		
h,k,lmax	9, 17, 26	9, 17, 26	
Nref	4363[2505]	4345	
Tmin,Tmax	0.956, 0.963	0.647, 0.745	
Tmin’	0.946		

Correction method= # Reported T Limits: Tmin=0.647 Tmax=0.745
AbsCorr = MULTI-SCAN
Data completeness= 1.73/1.00 Theta(max)= 25.028

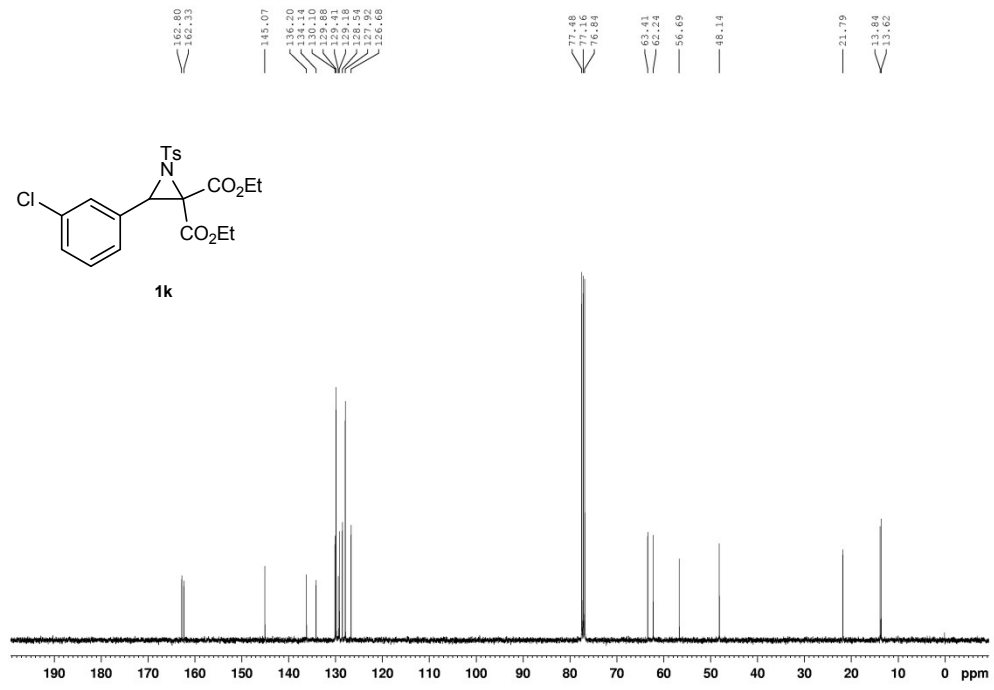
R(reflections)= 0.0468(3039)	wR2(reflections)= 0.1225(4345)
S = 0.998	Npar= 331

9. ^{1}H NMR、^{13}C NMR and ^{19}F NMR spectra of the compounds

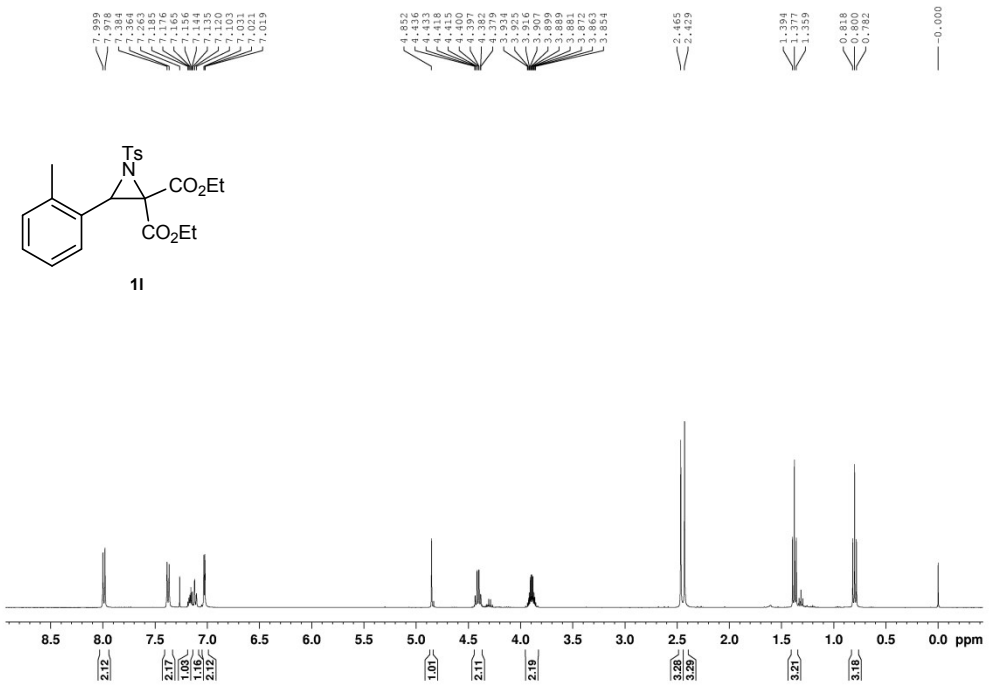
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (1k)



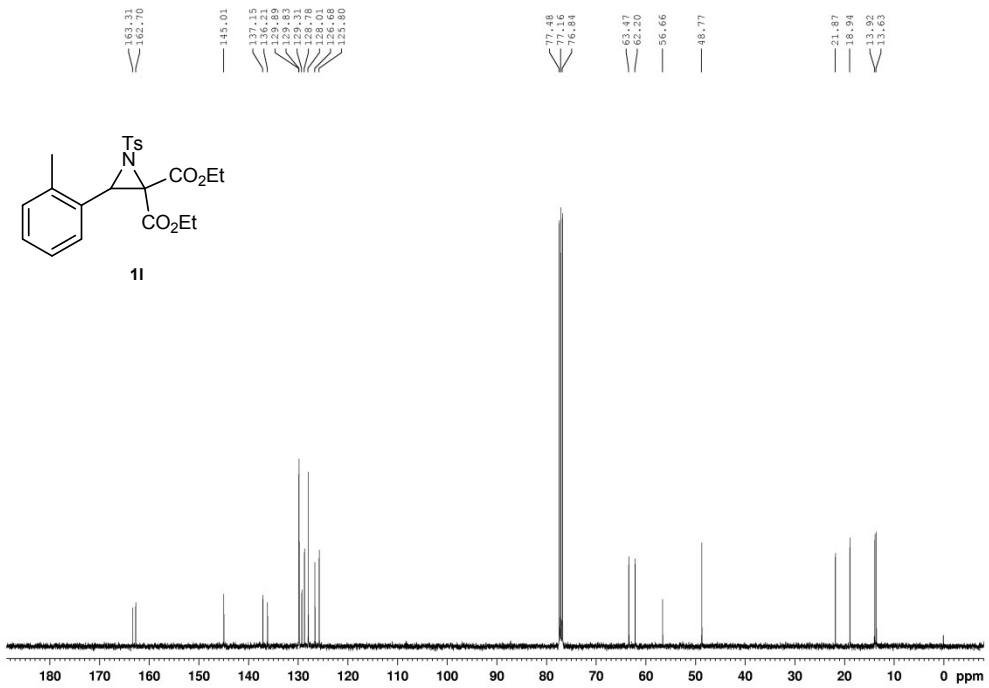
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (1k)



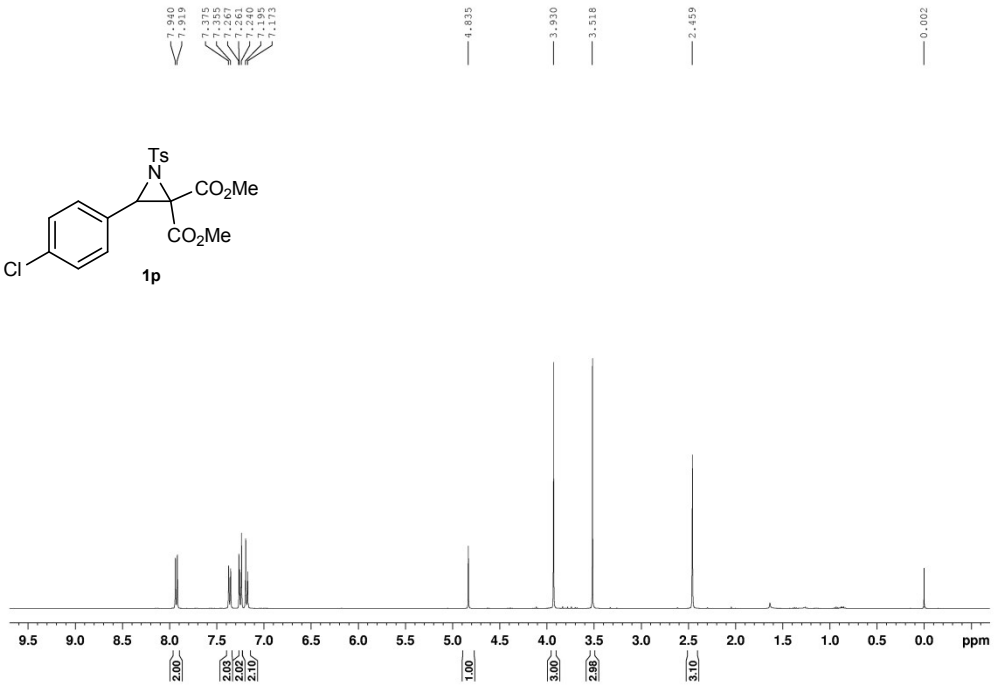
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (1l)



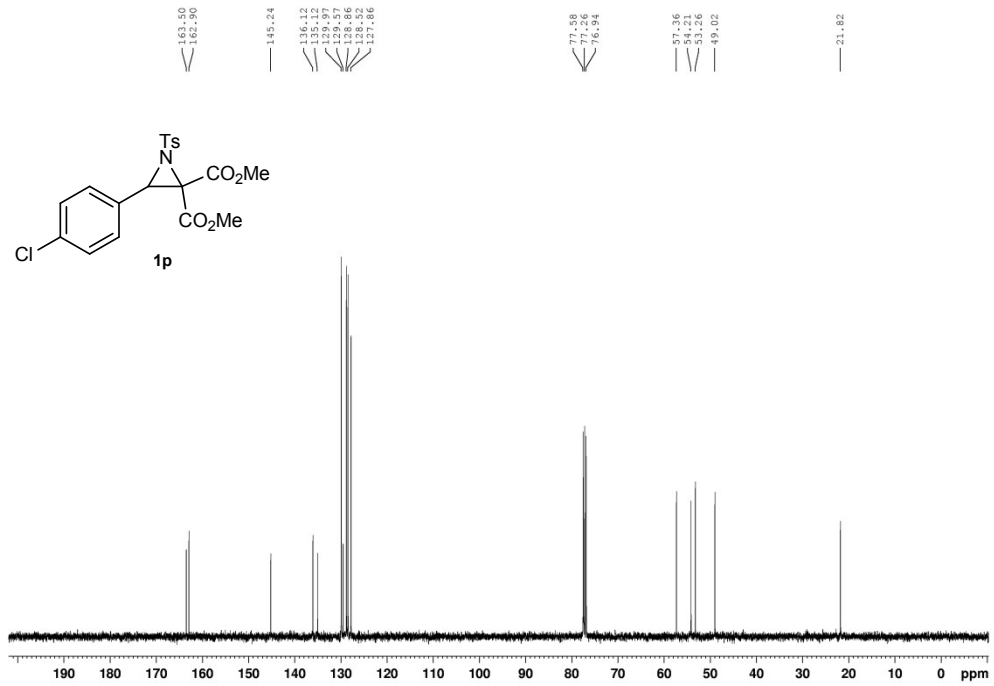
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (1l)



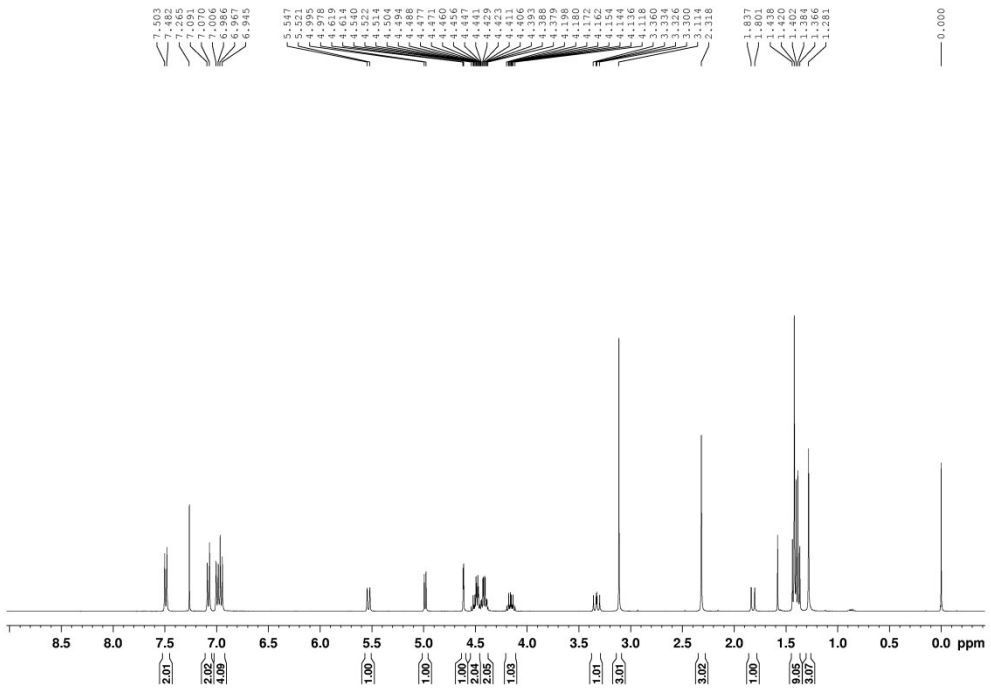
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (1P)



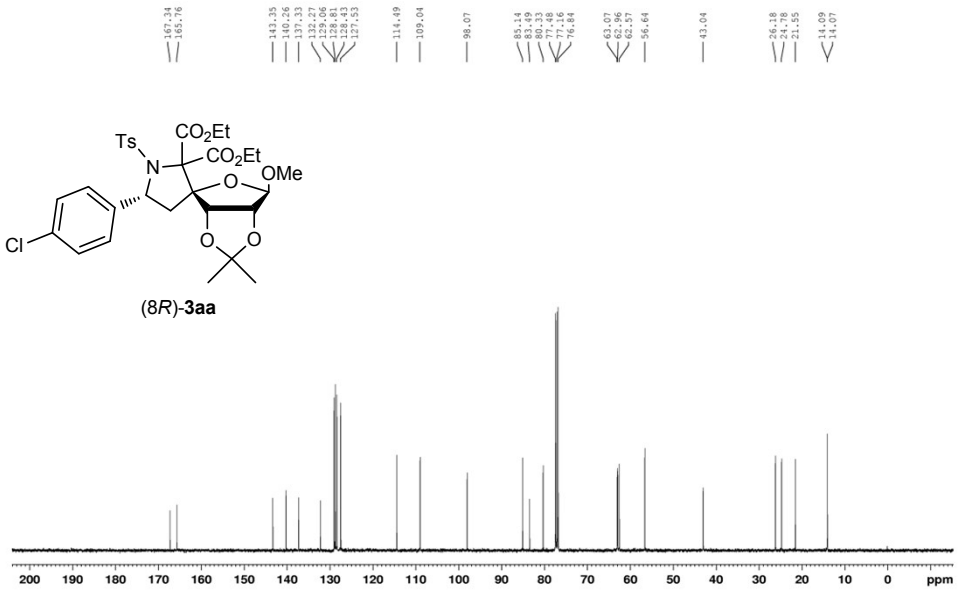
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (1P)



^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3aa

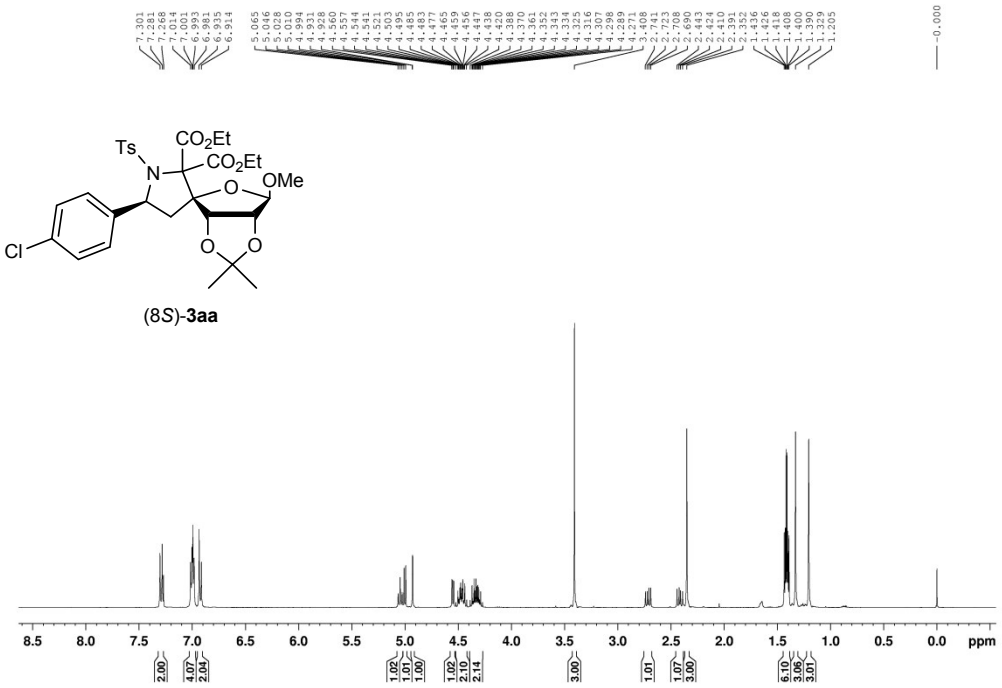


^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3aa

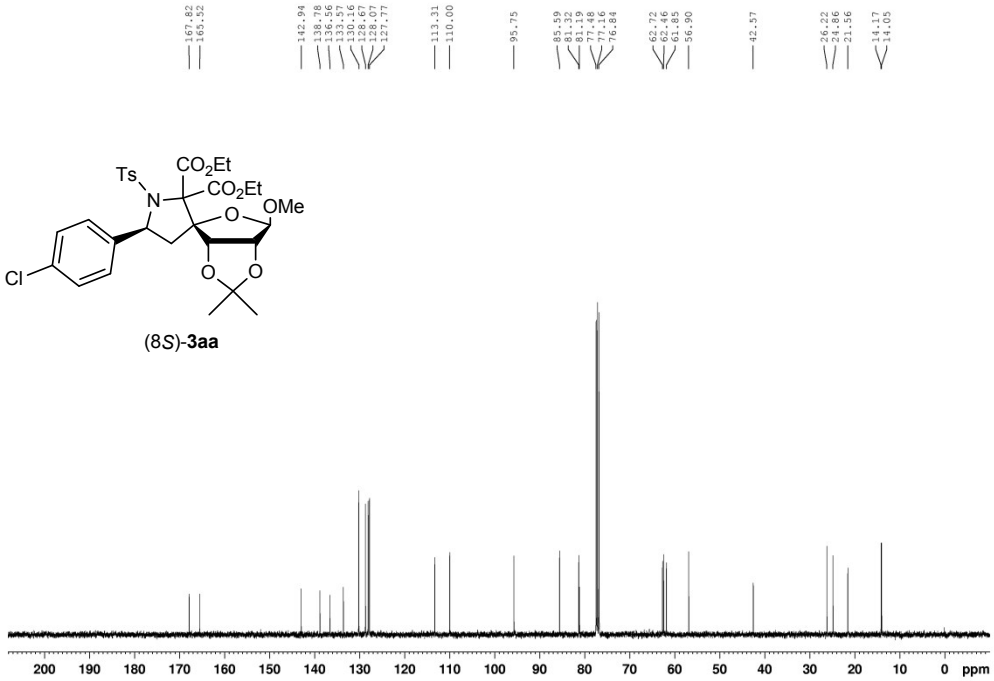


(8*R*)-**3aa**

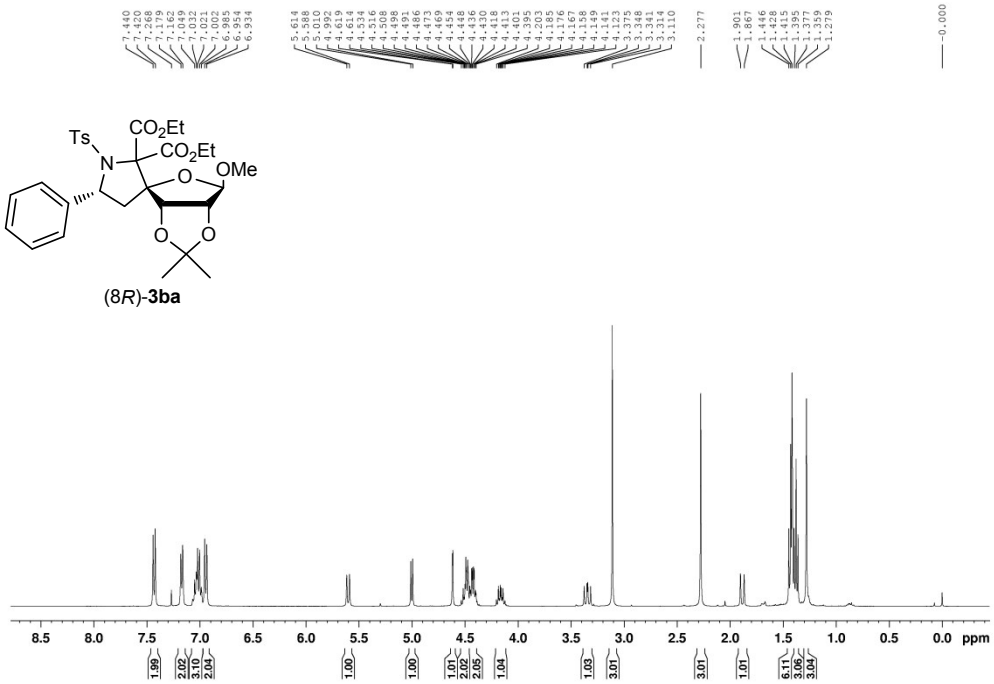
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3aa



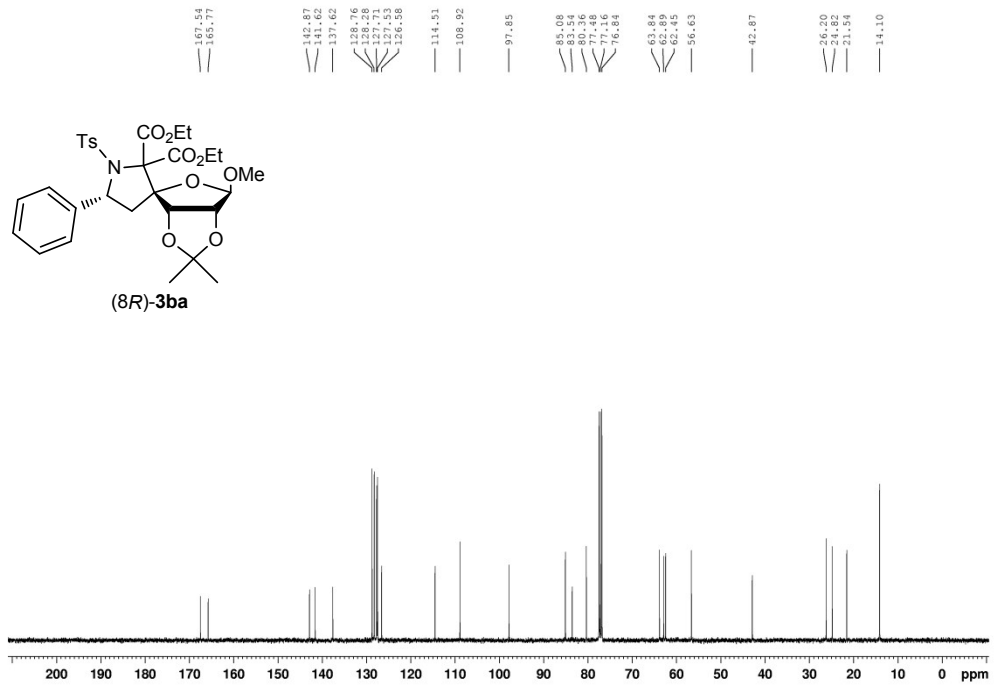
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3aa



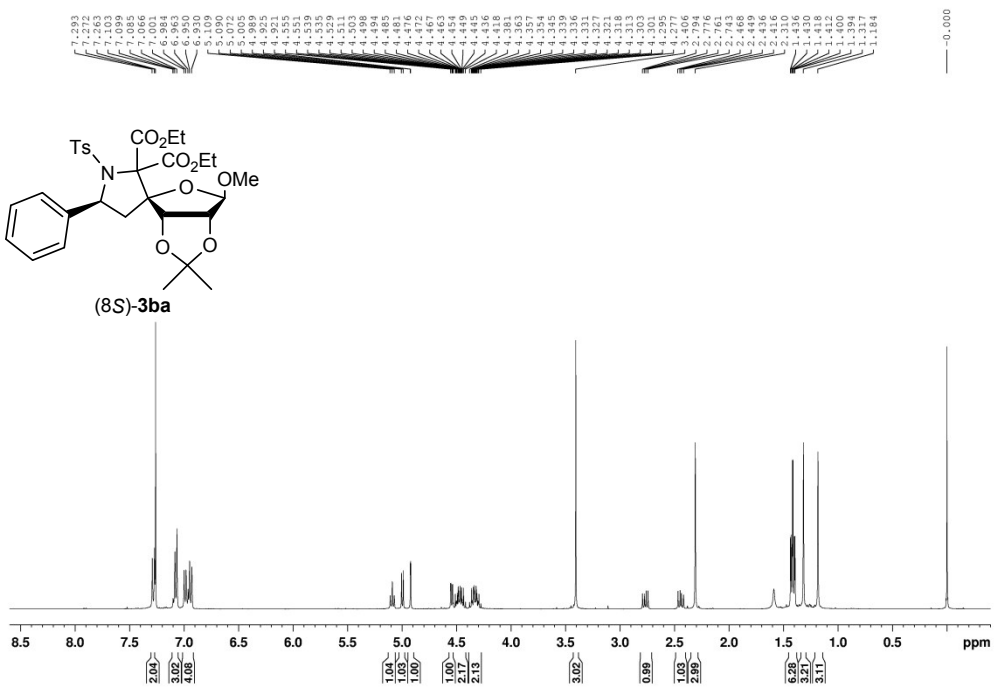
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ba



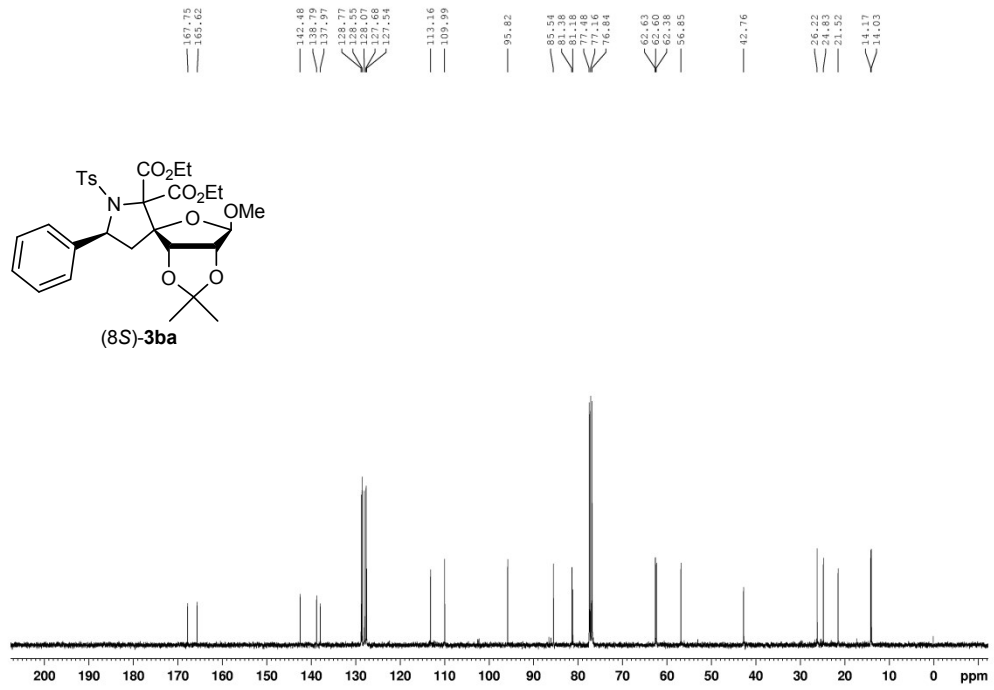
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ba



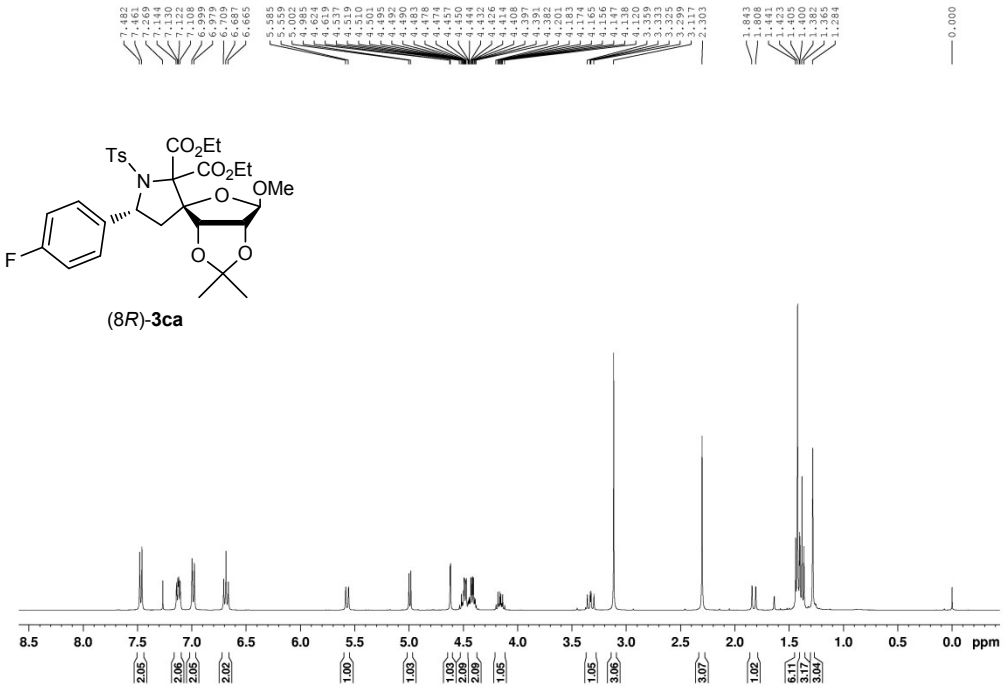
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ba



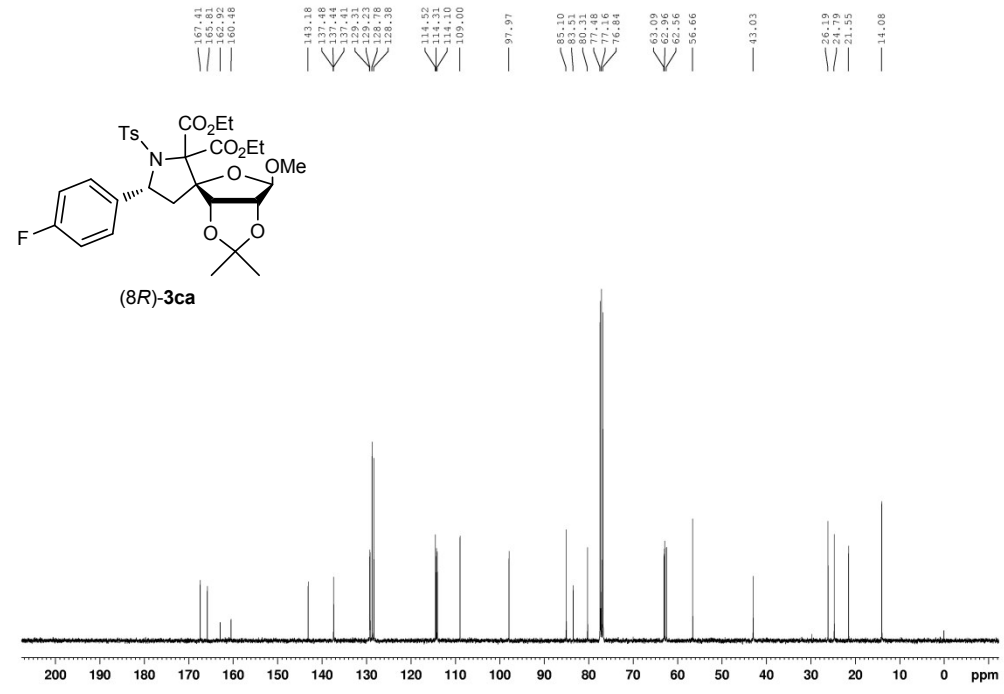
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ba



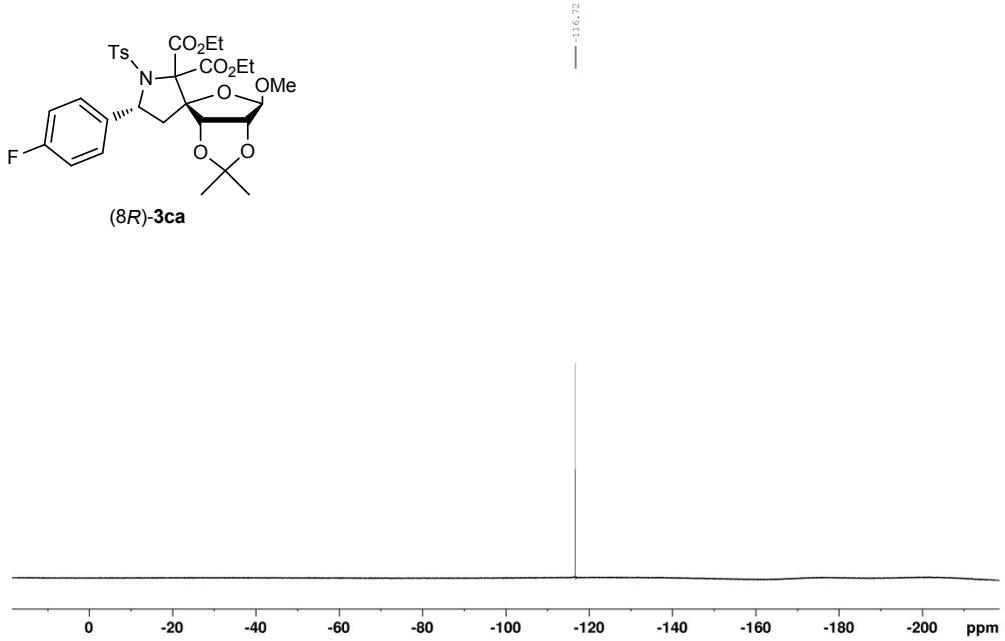
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ca



^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ca

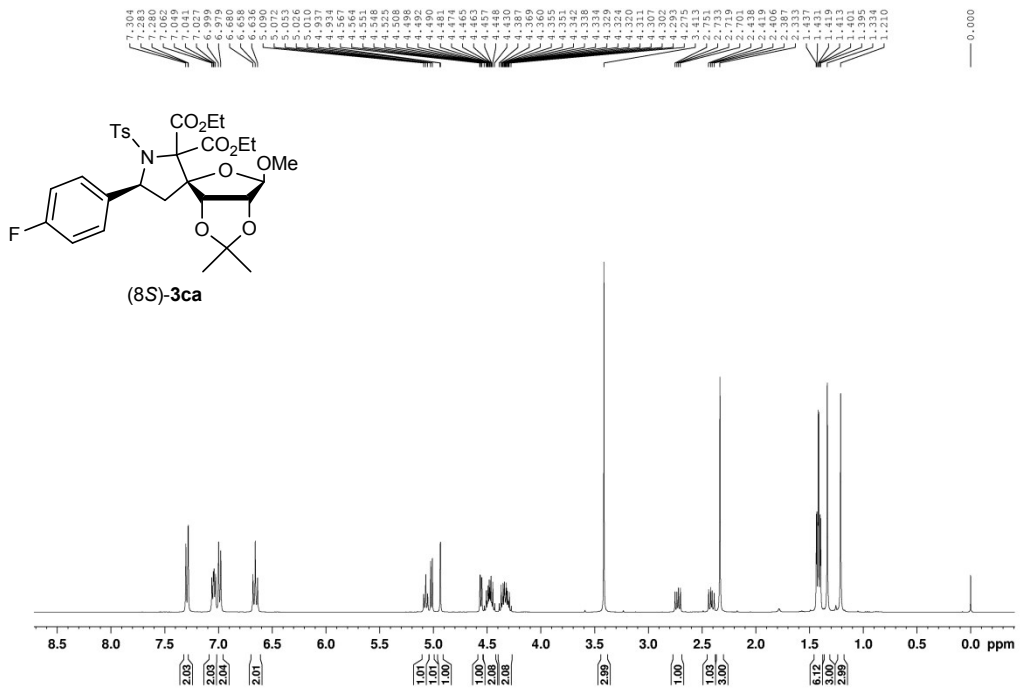


^{19}F-NMR (376 MHz, $CDCl_3$) spectra of compound (8*R*)-3ca



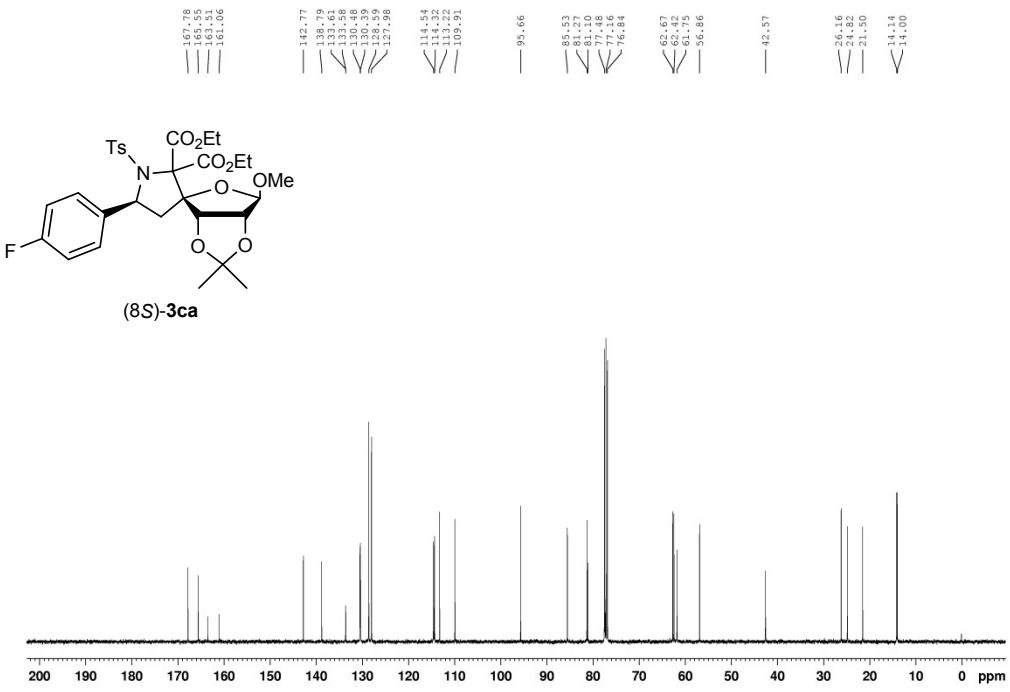
(8*R*)-**3ca**

^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ca

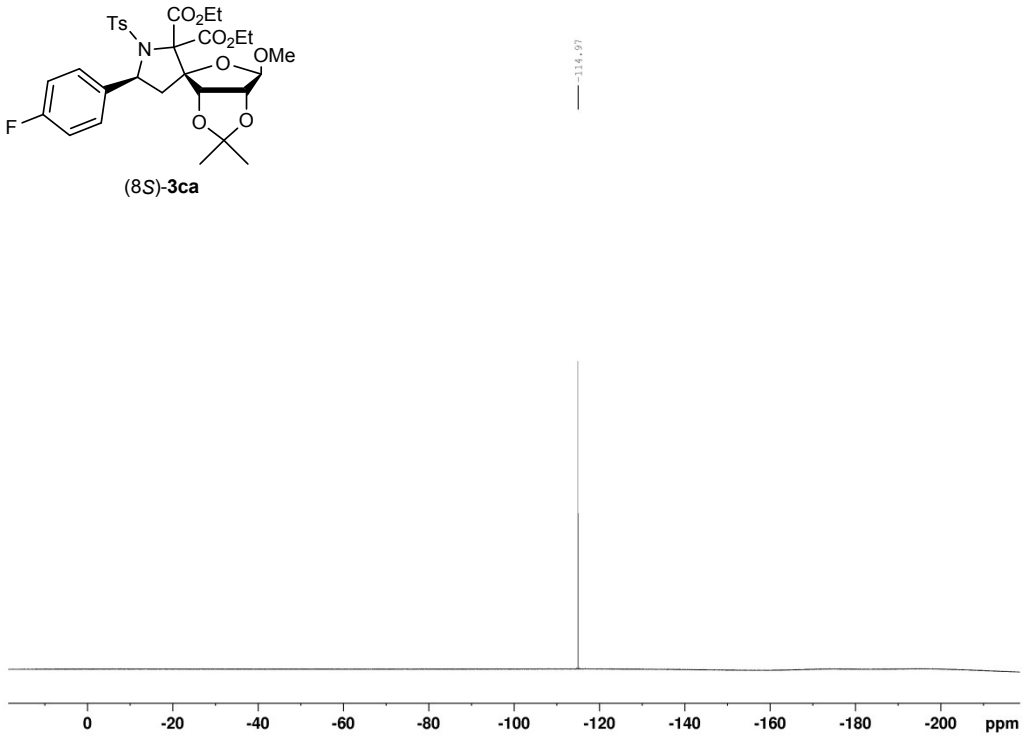


(8*S*)-**3ca**

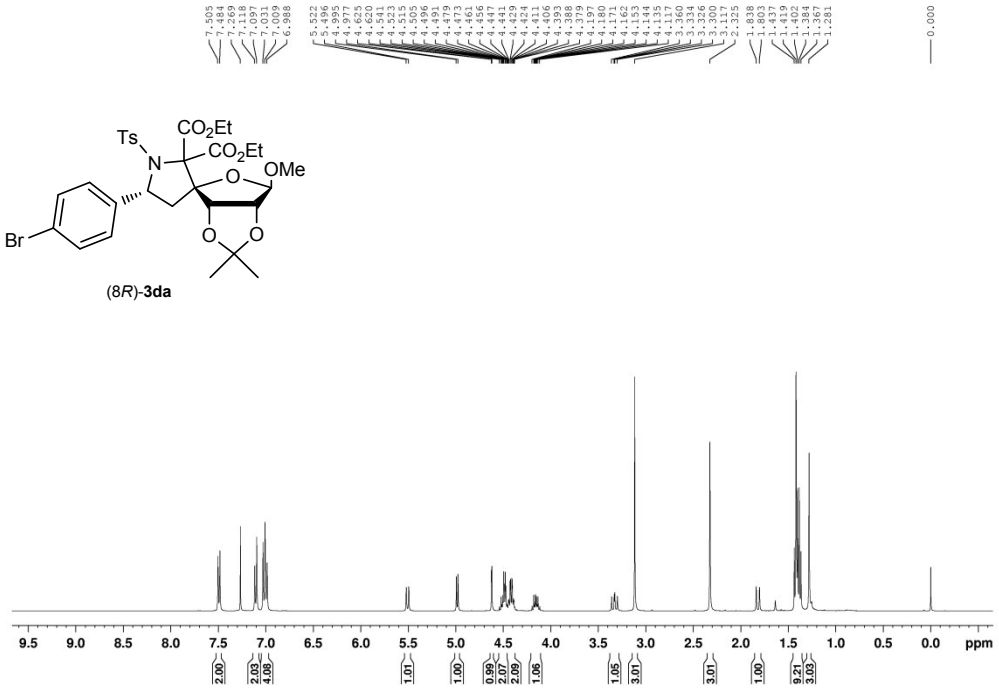
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ca



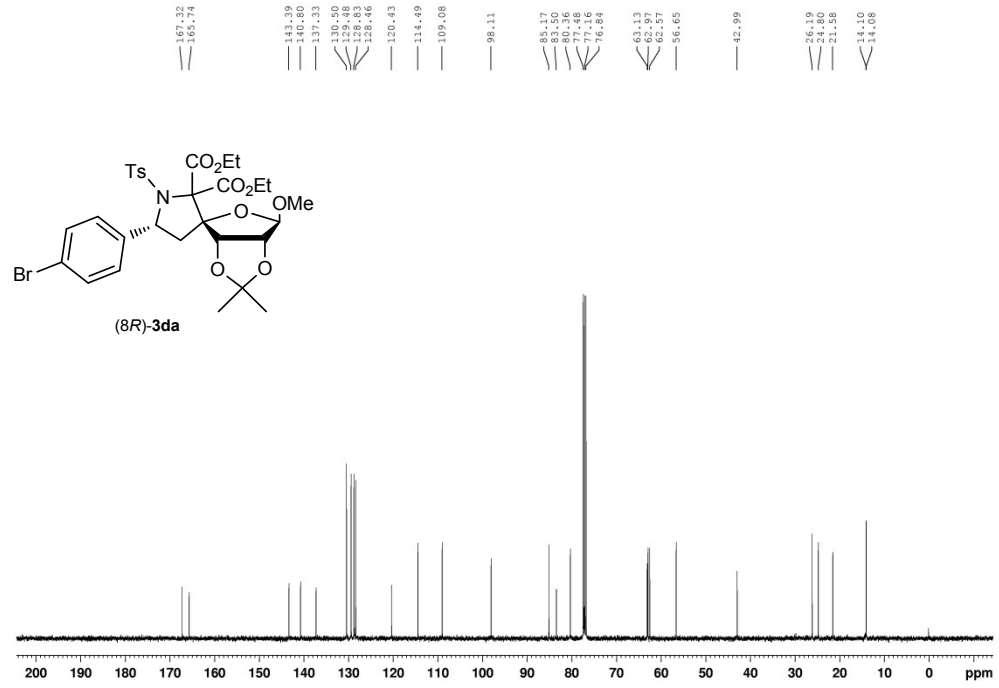
^{19}F-NMR (376 MHz, $CDCl_3$) spectra of compound (8*S*)-3ca



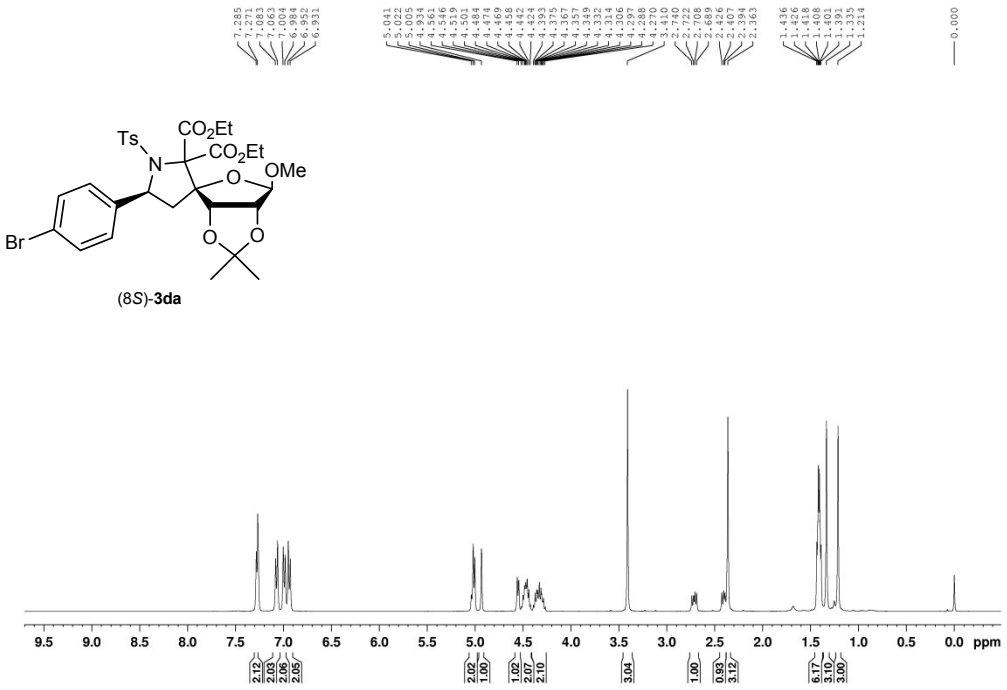
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3da



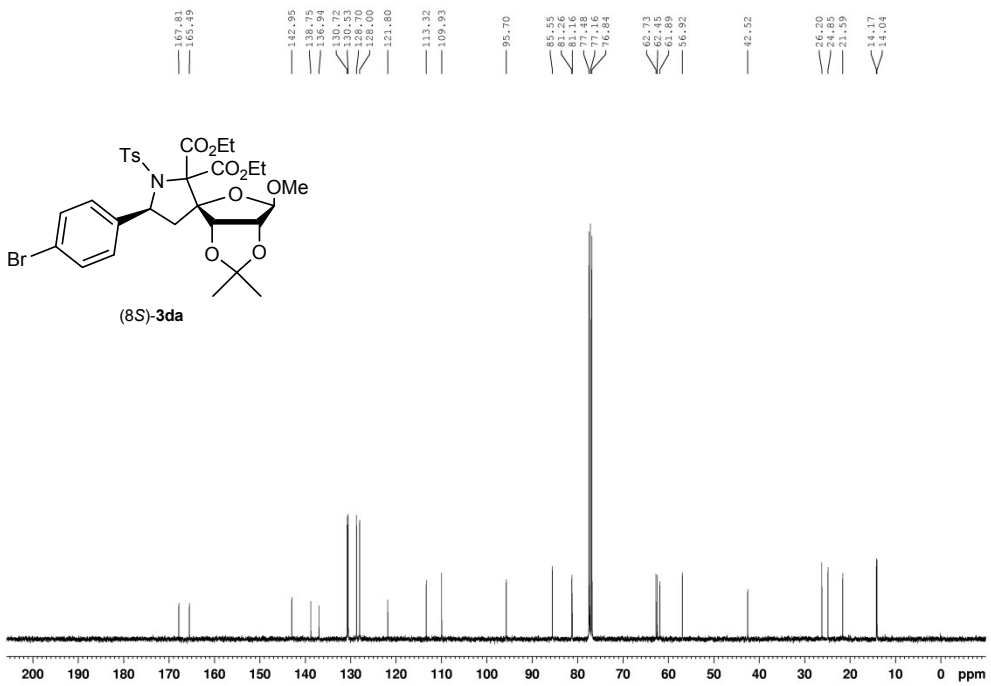
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3da



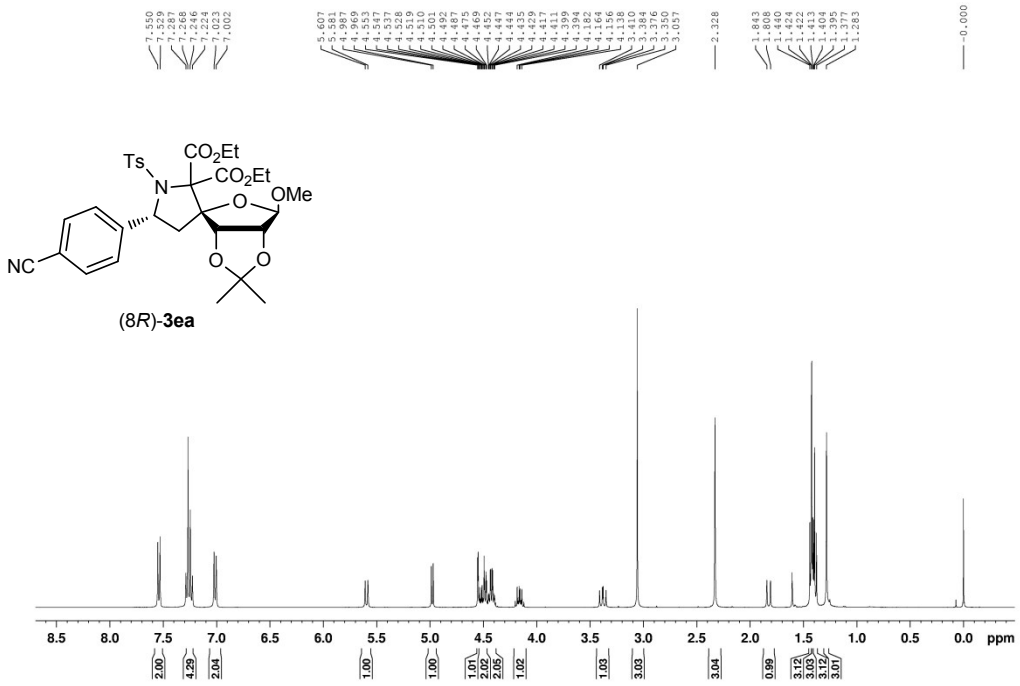
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3da



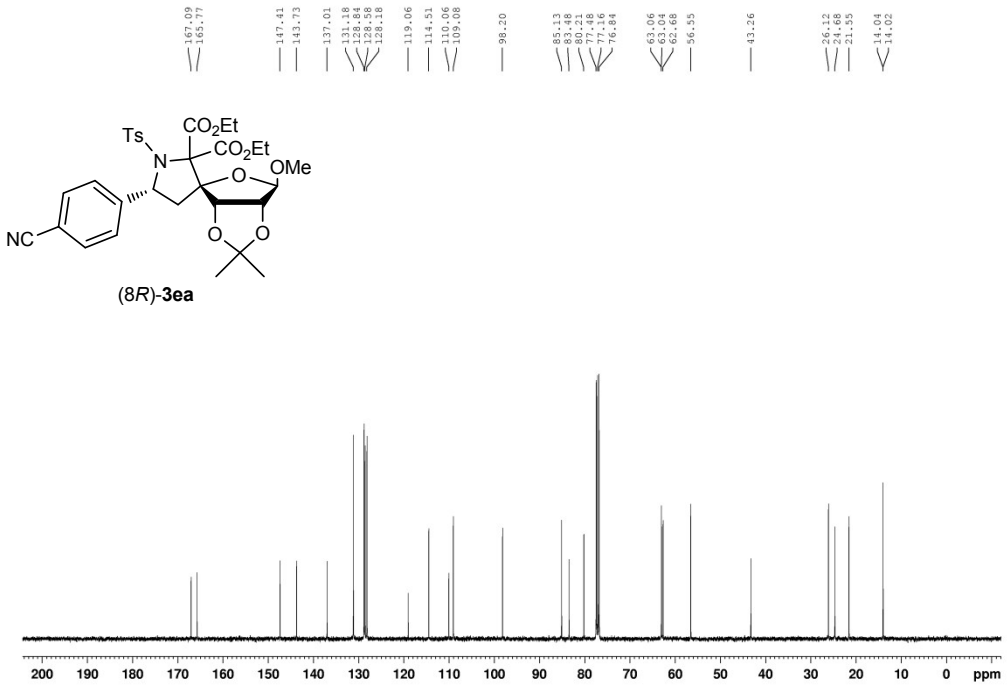
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3da



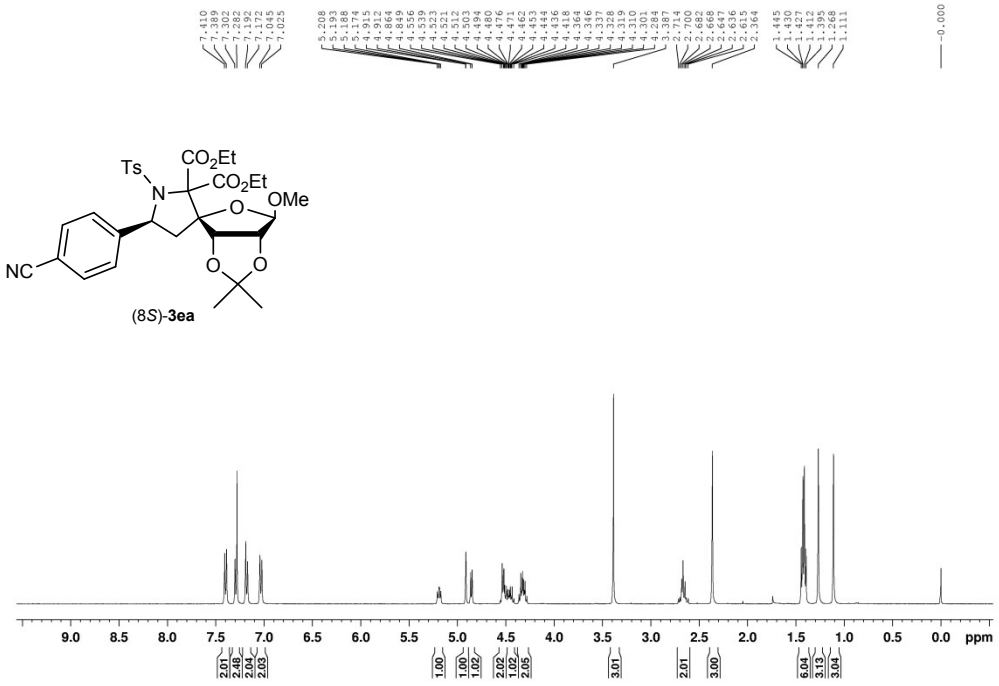
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ea



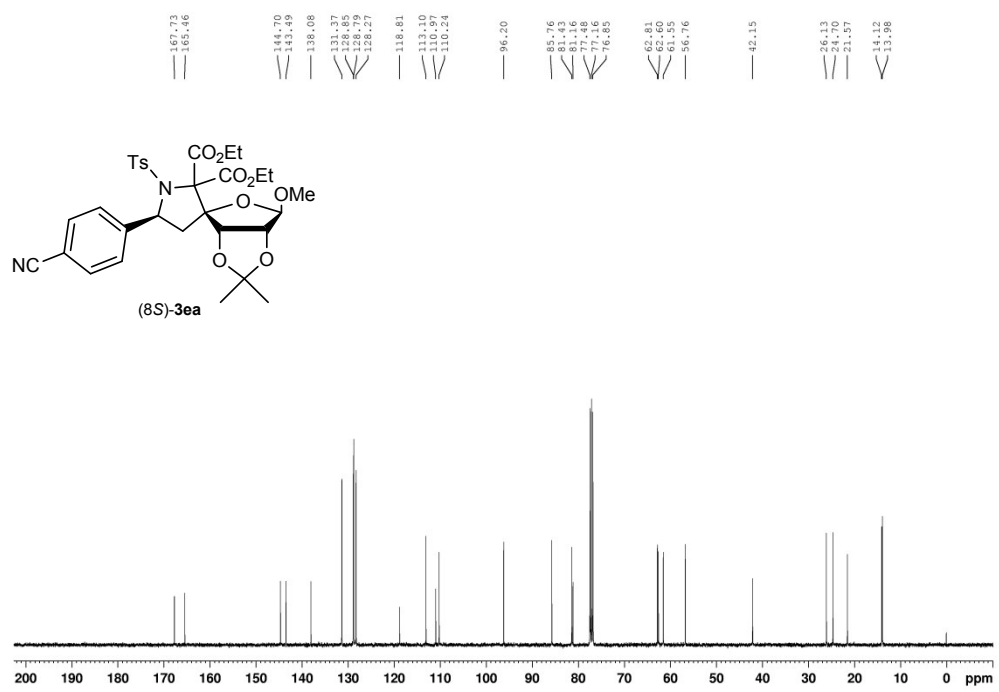
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ea



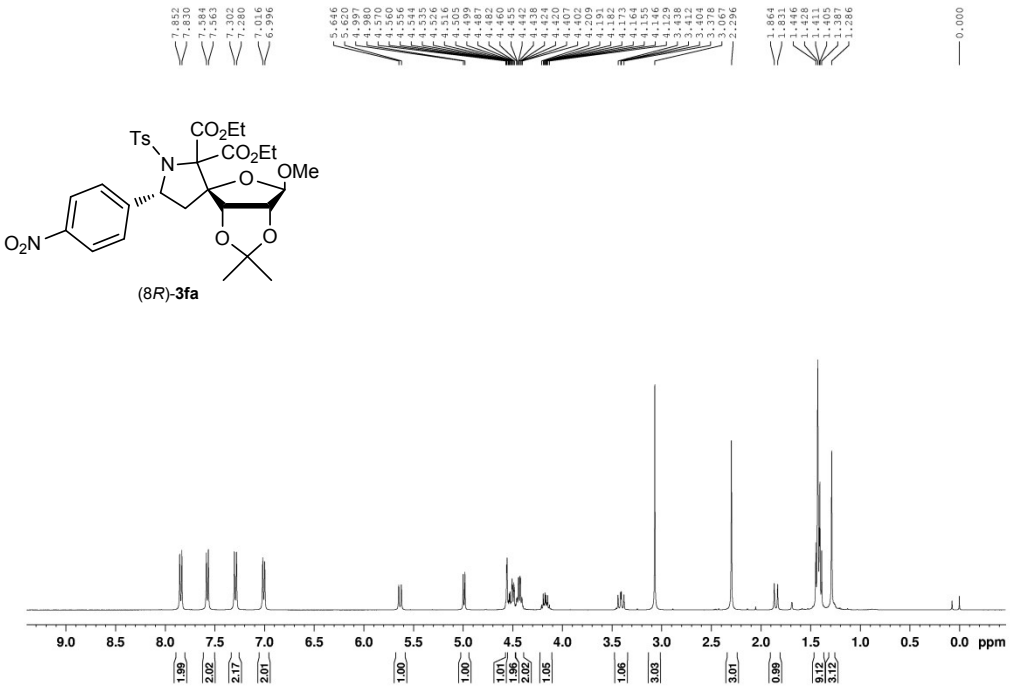
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ea



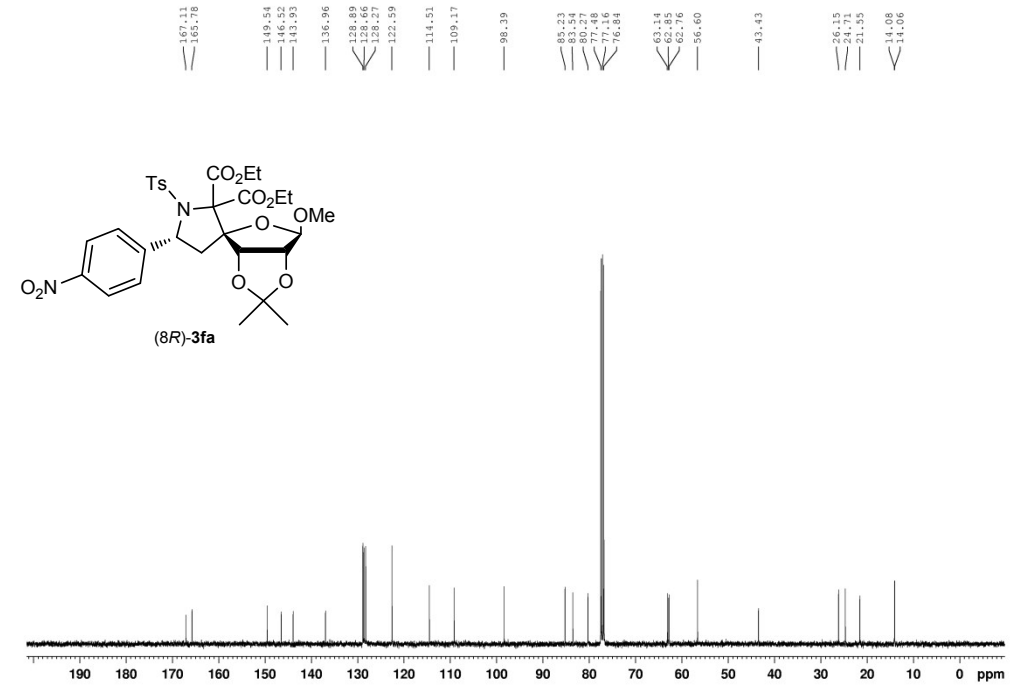
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ea



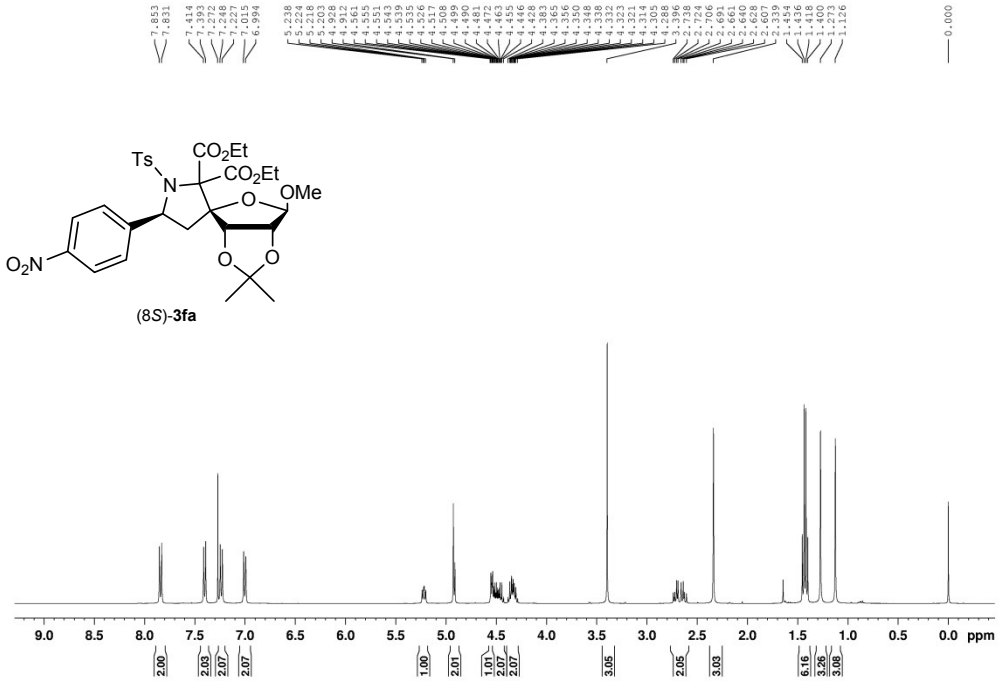
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3fa



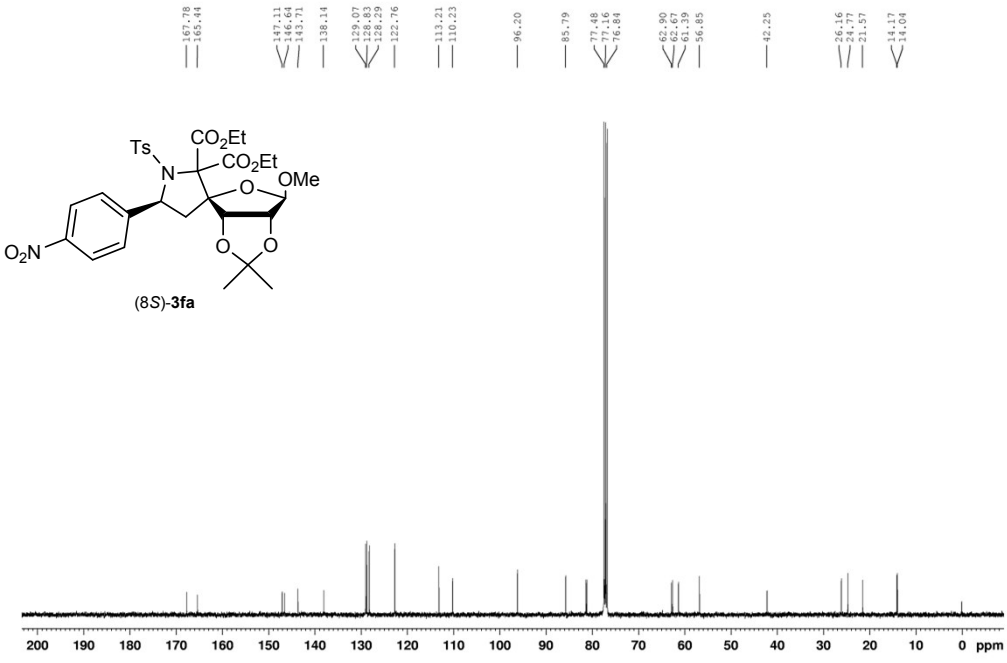
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3fa



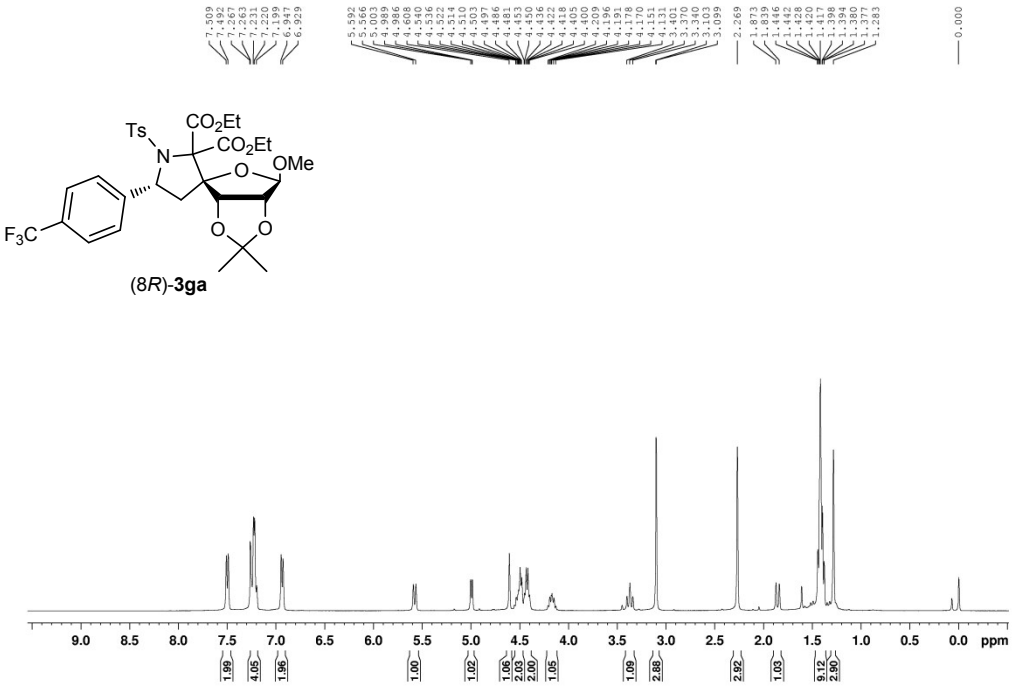
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3fa



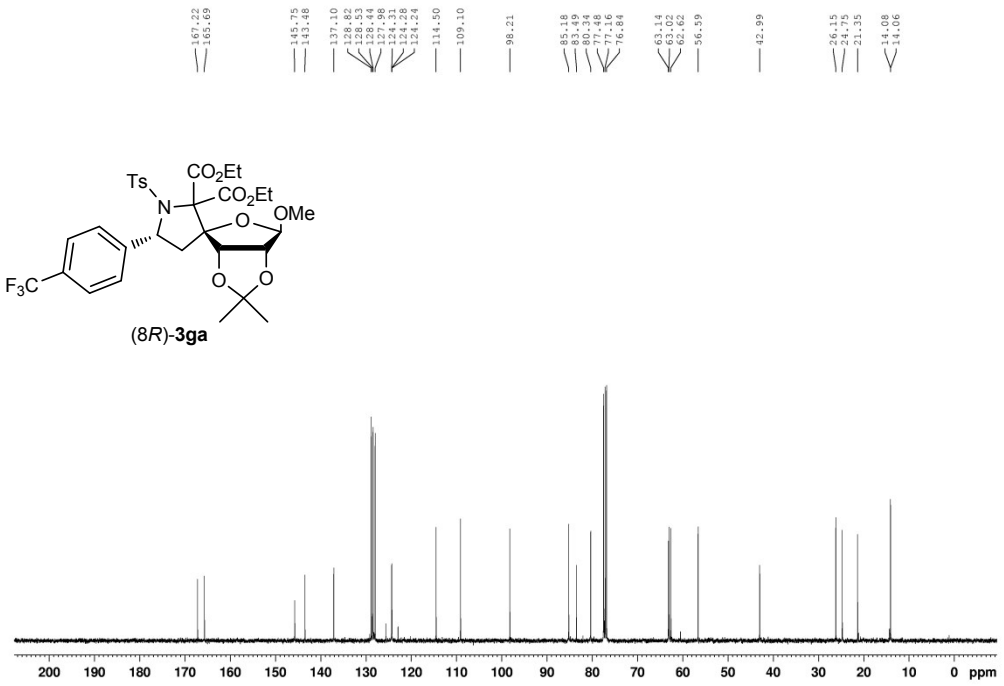
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3fa



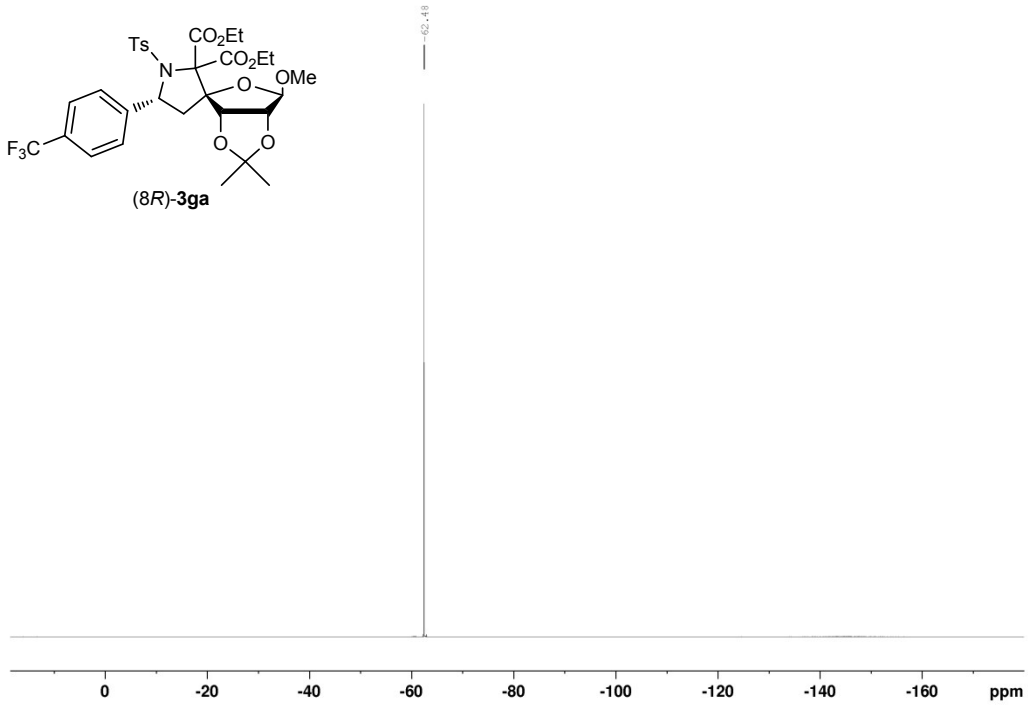
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ga



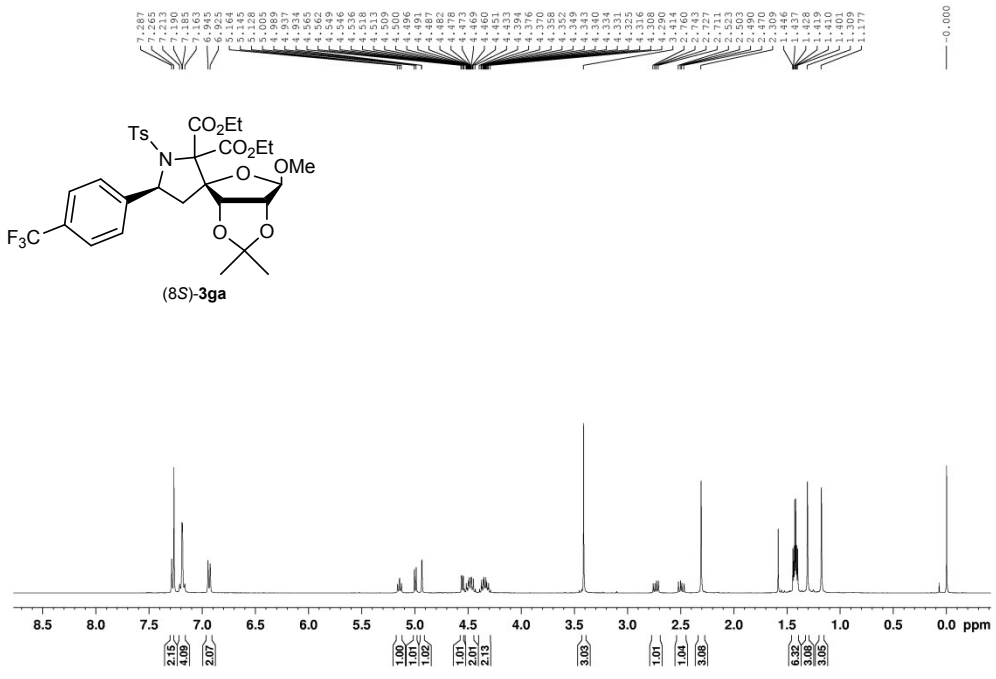
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ga



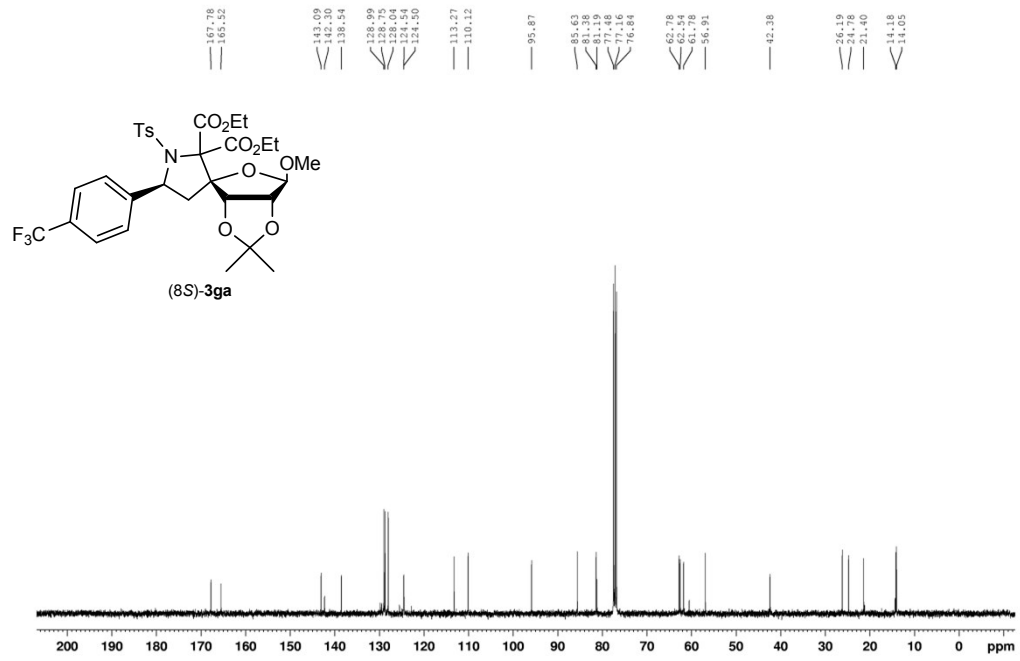
^{19}F-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ga



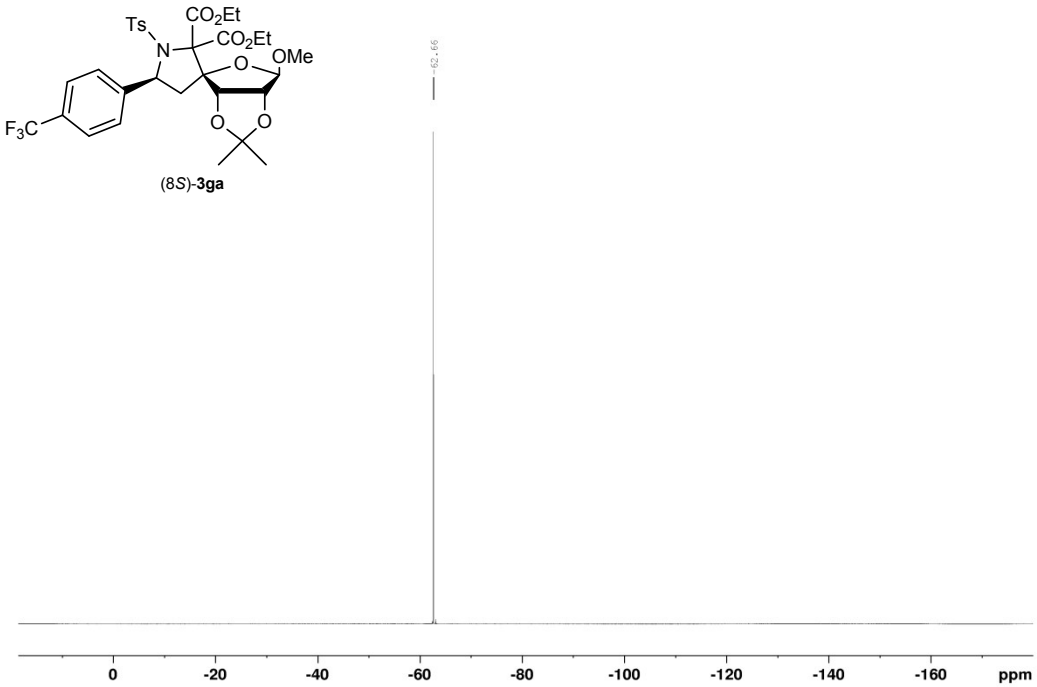
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ga



^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ga

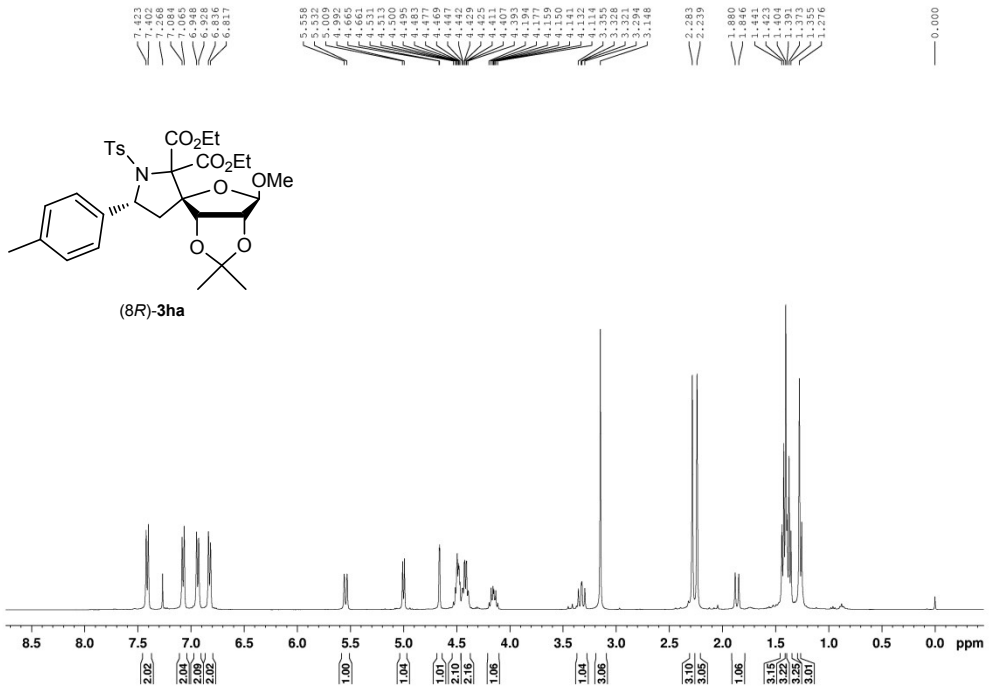


^{19}F-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ga

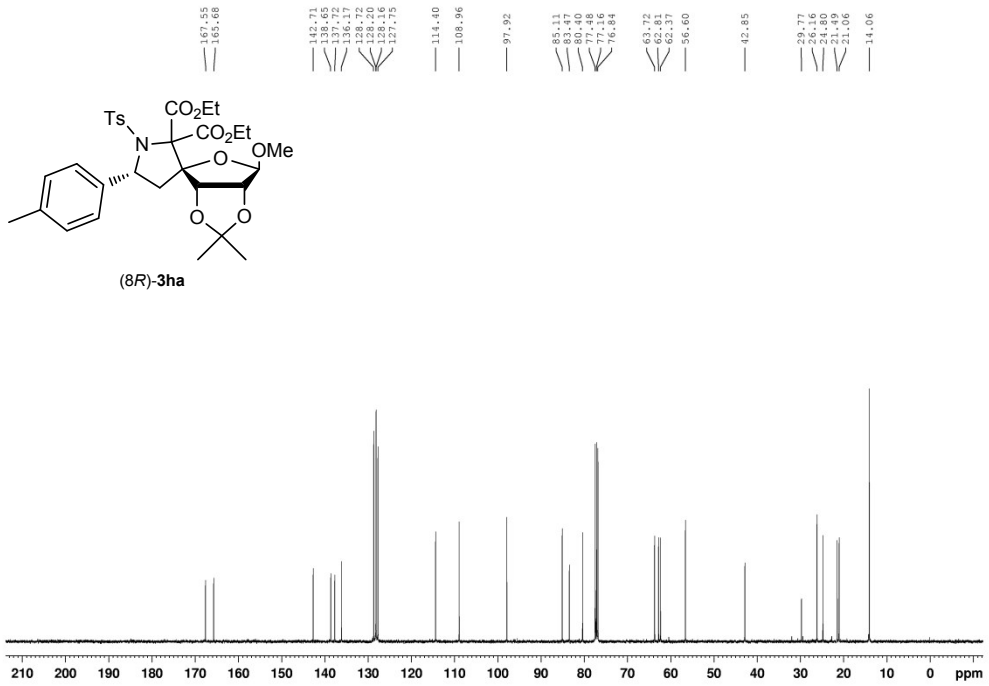


x

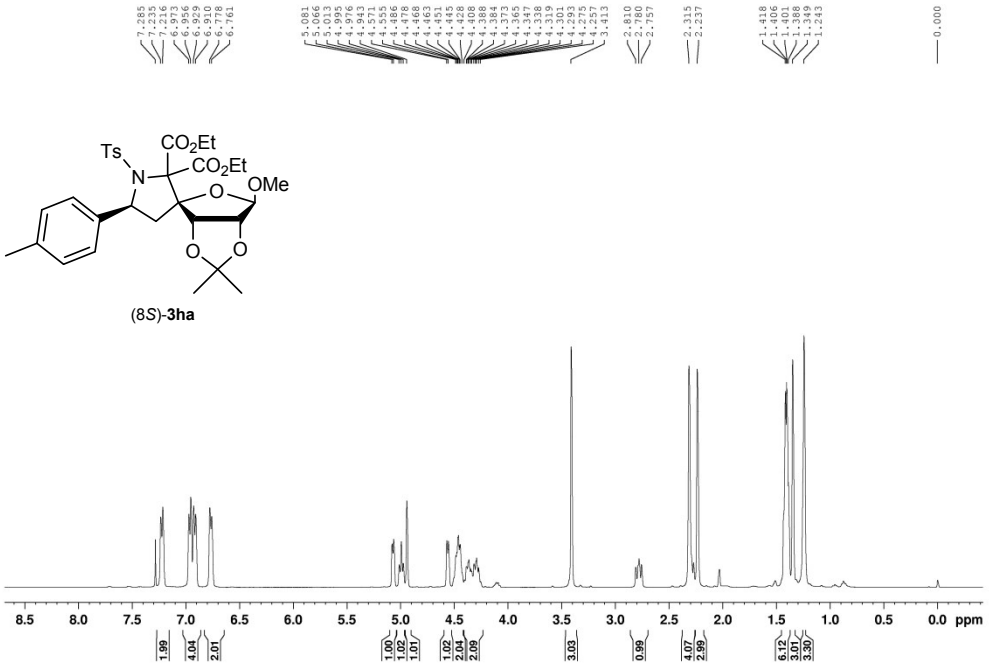
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ha



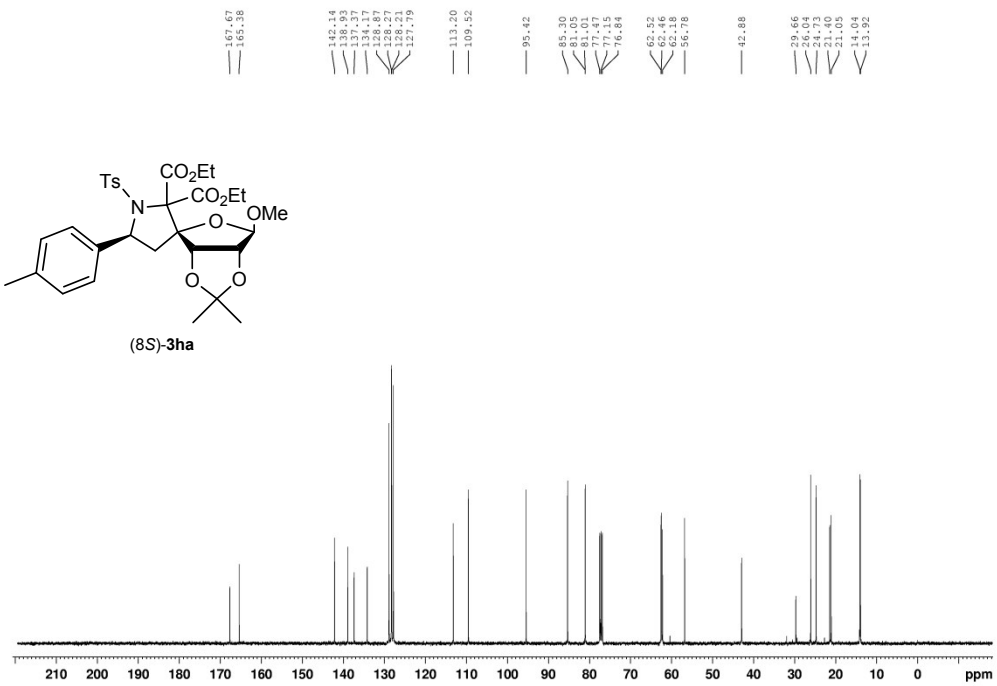
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ha



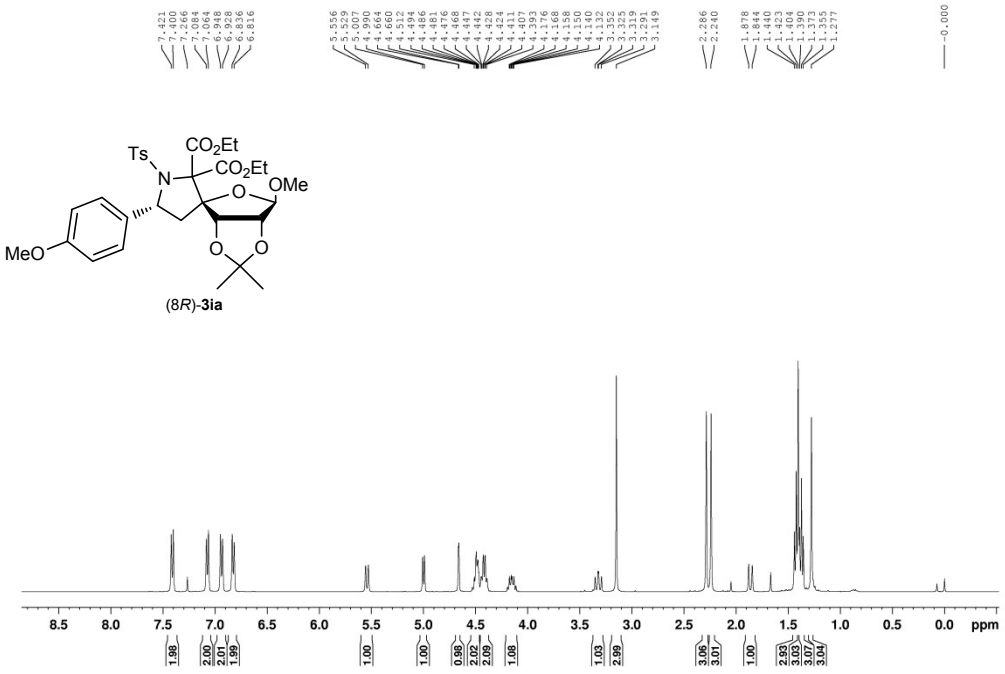
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ha



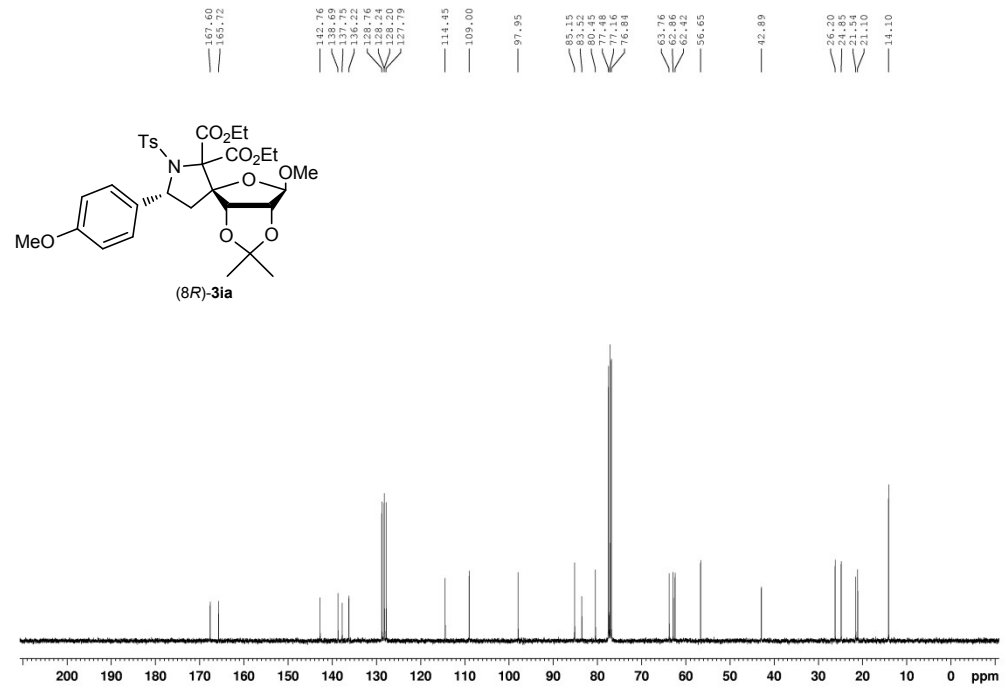
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ha



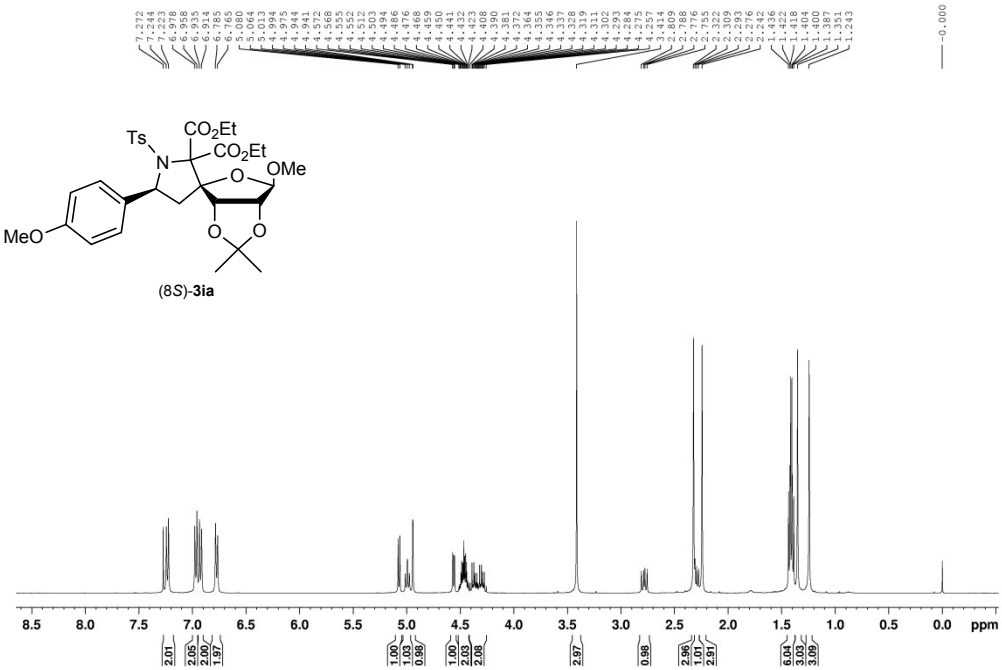
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ia



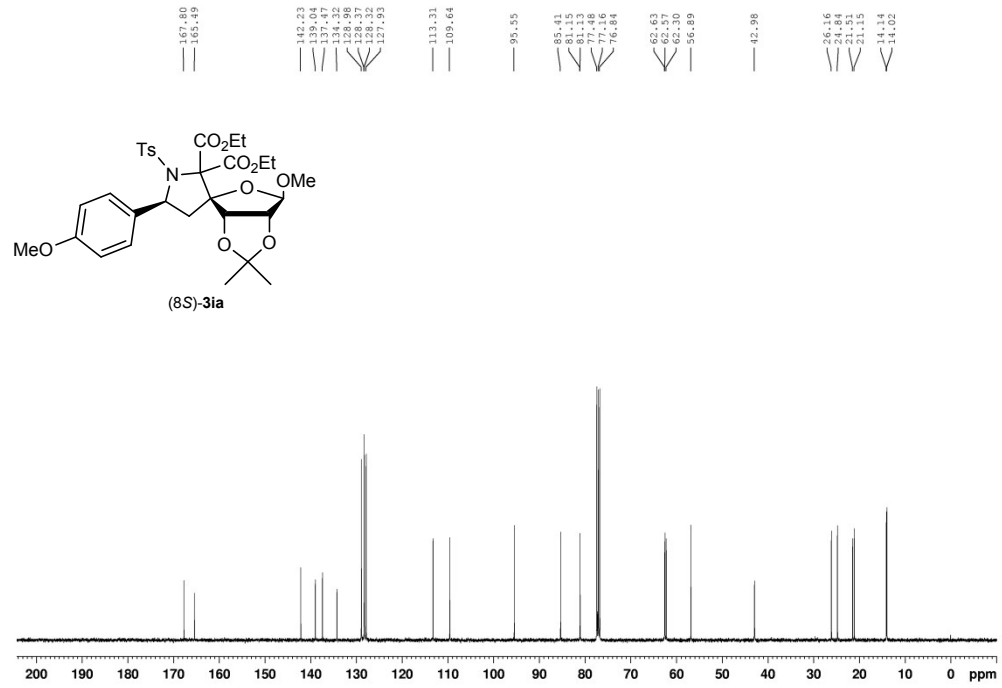
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ia



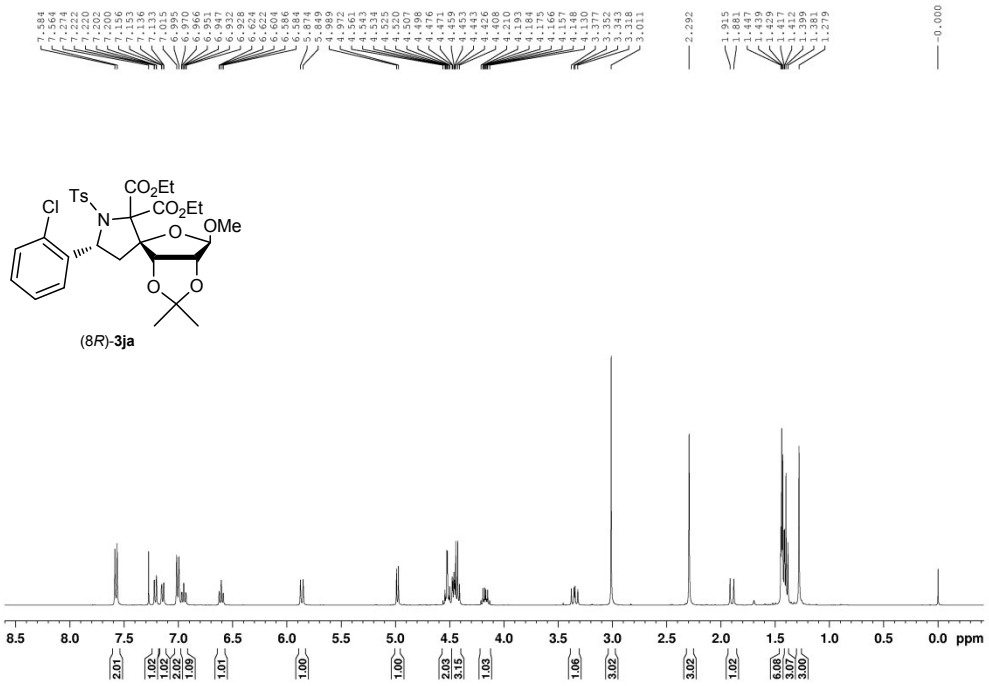
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ia



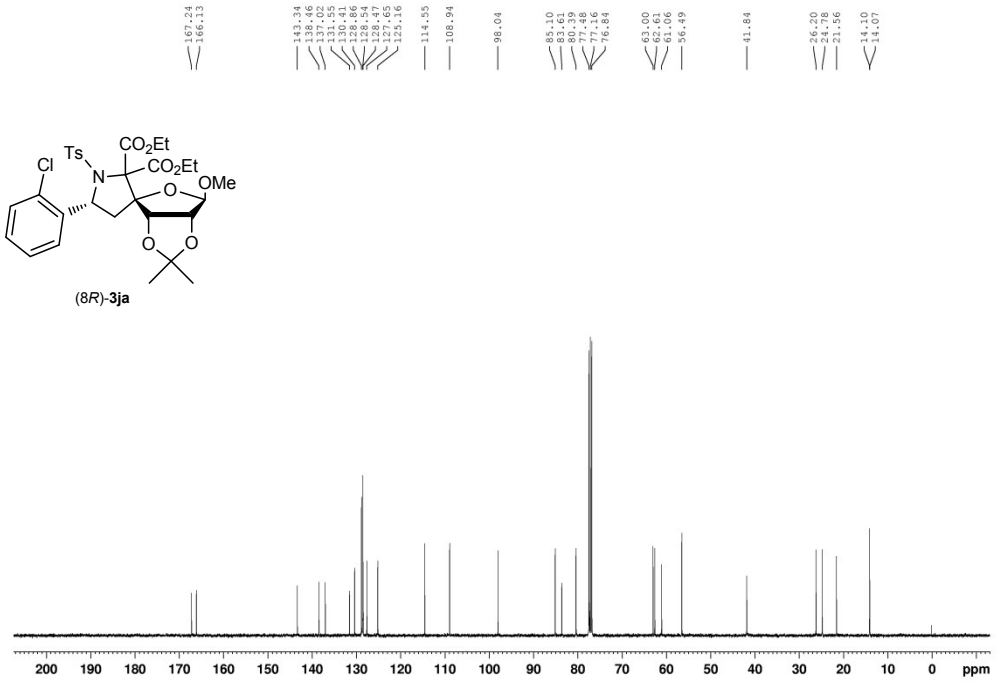
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ia



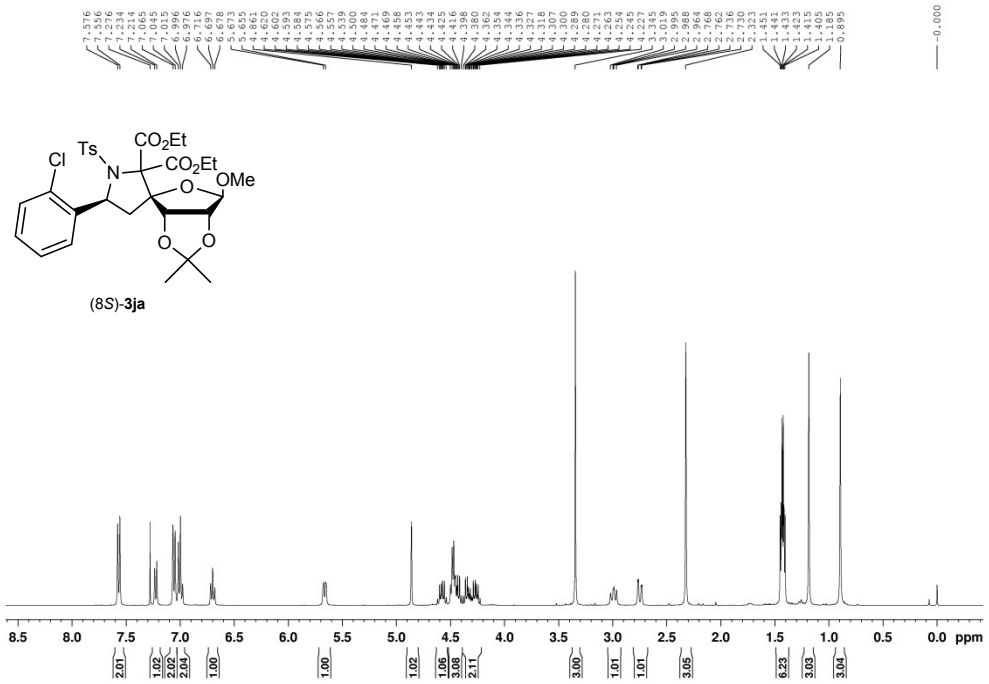
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ja



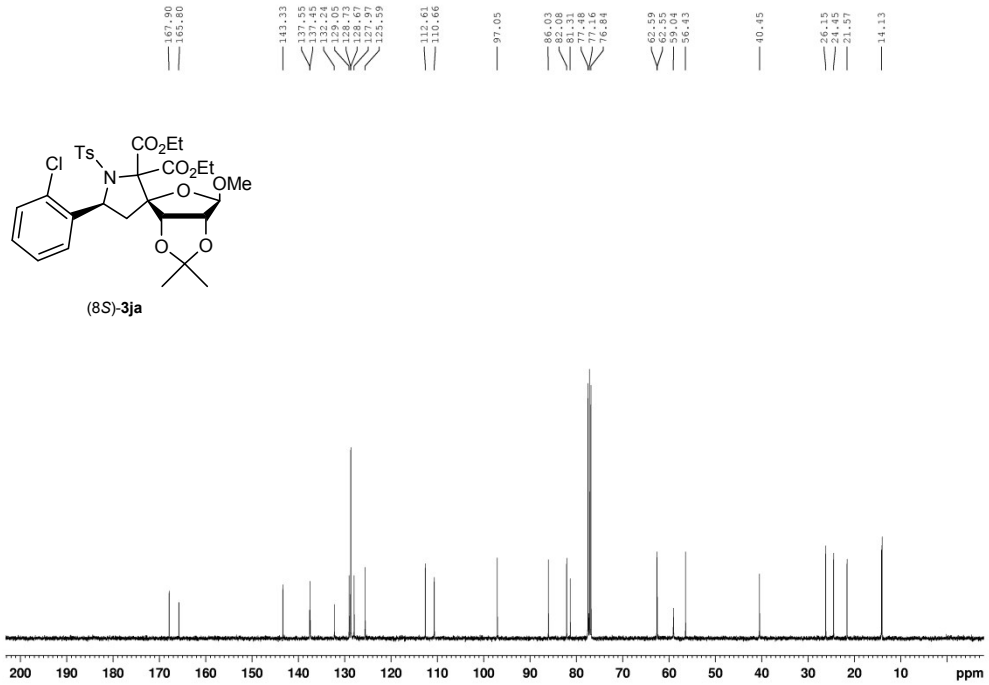
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ja



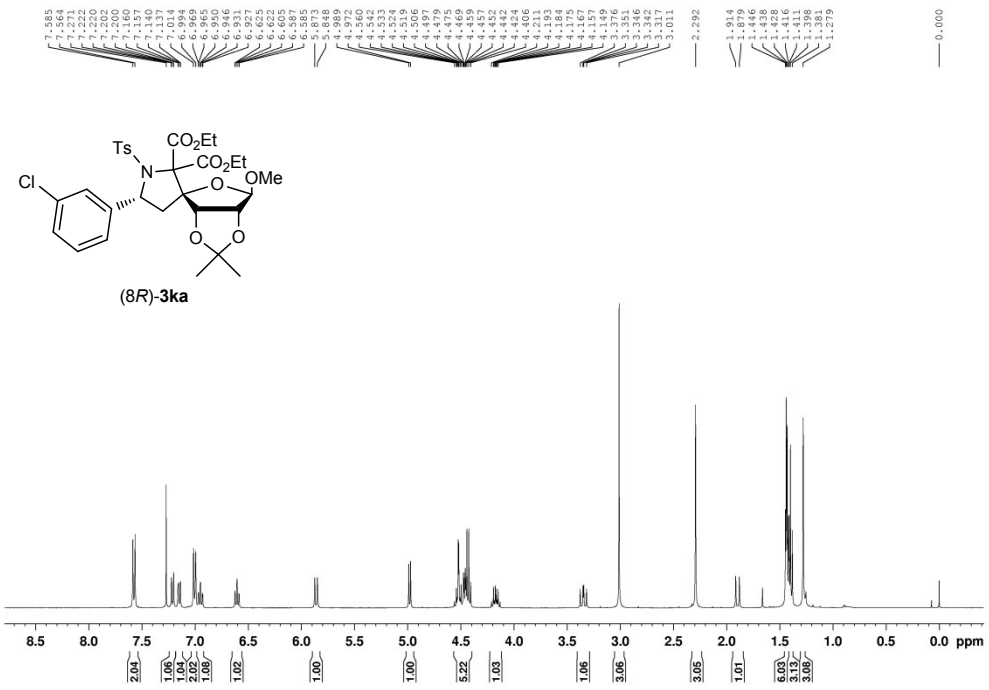
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ja



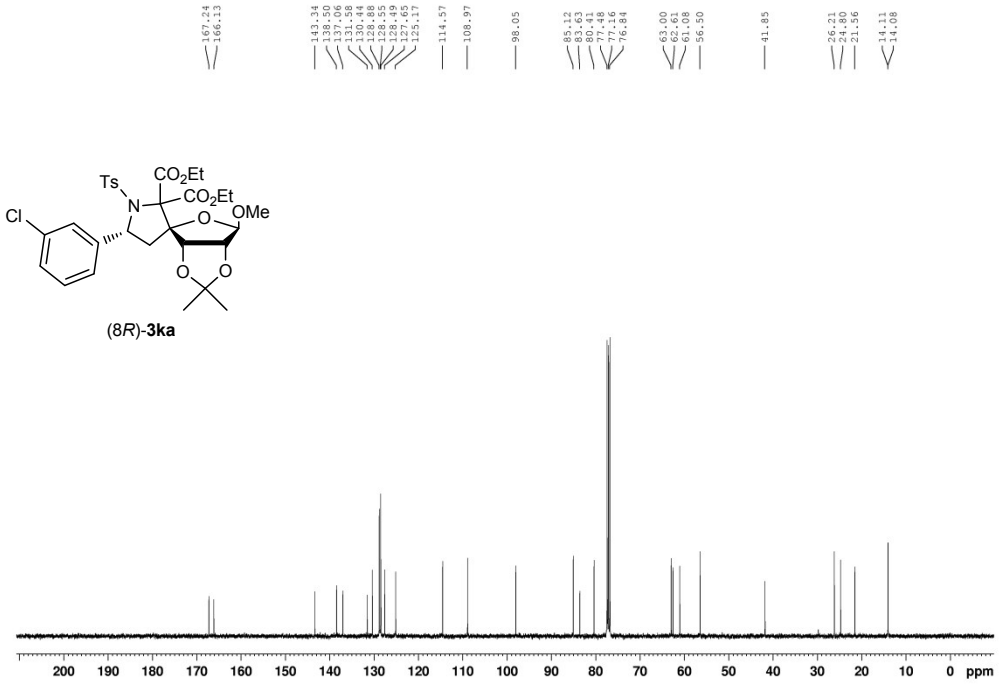
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ja



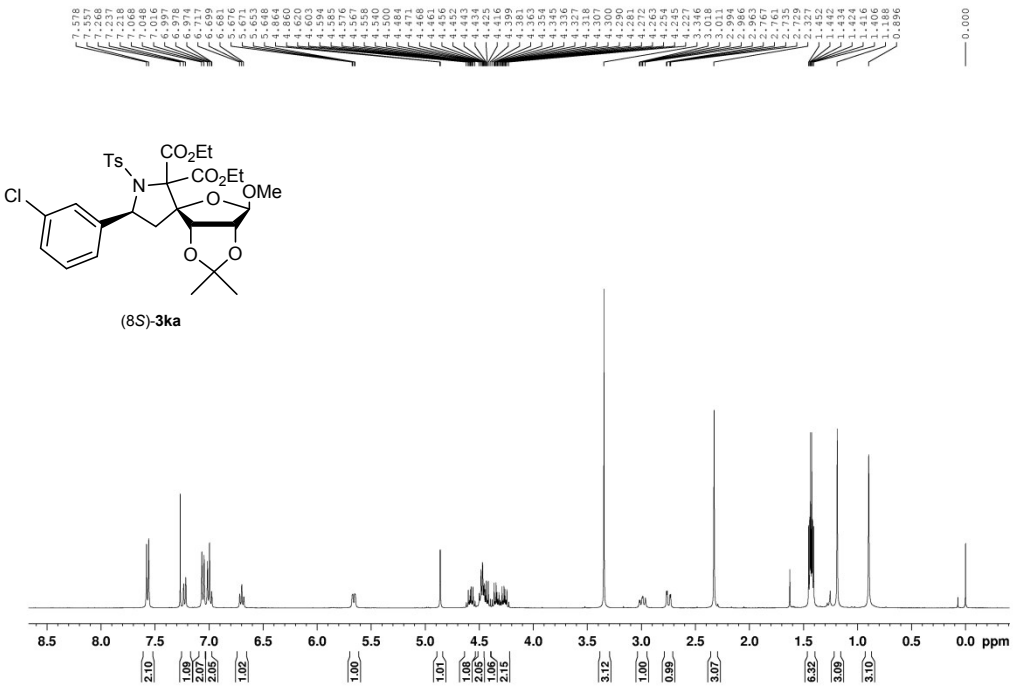
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ka



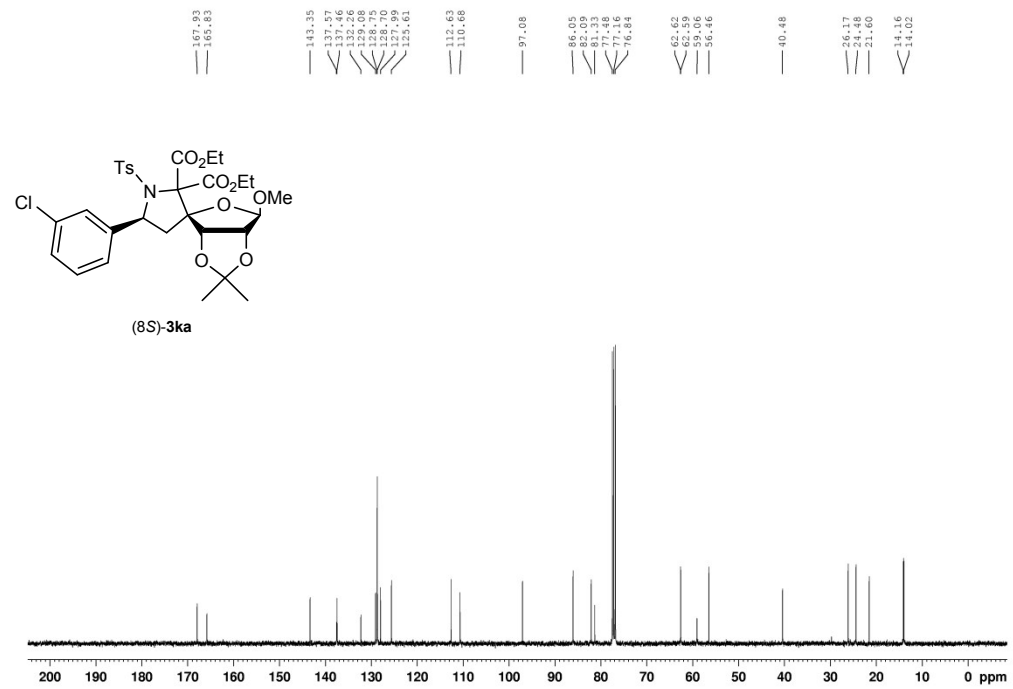
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ka



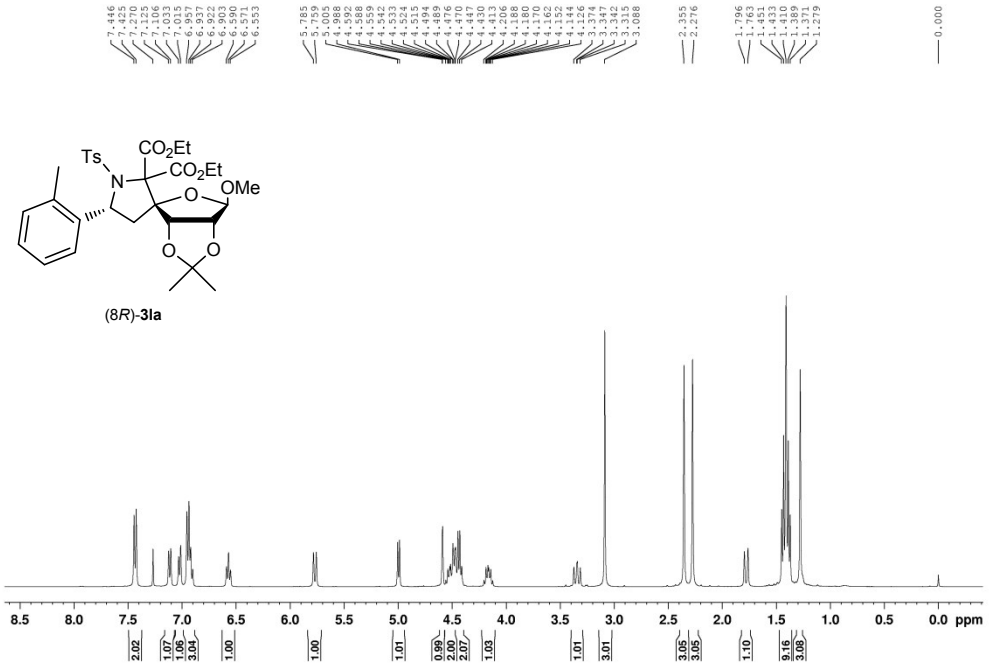
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ka



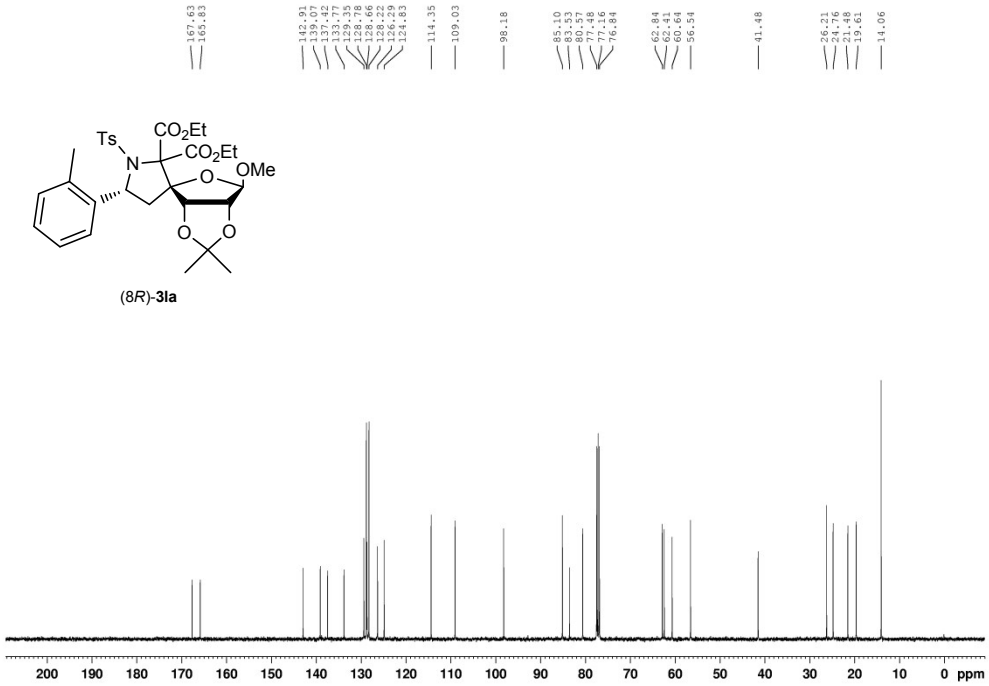
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ka



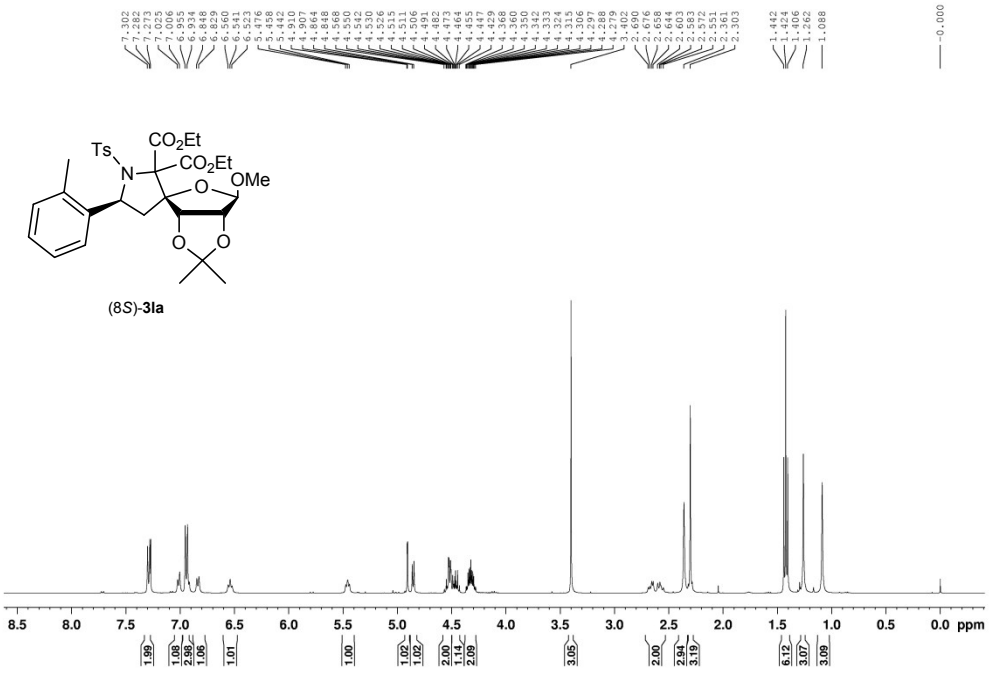
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3la



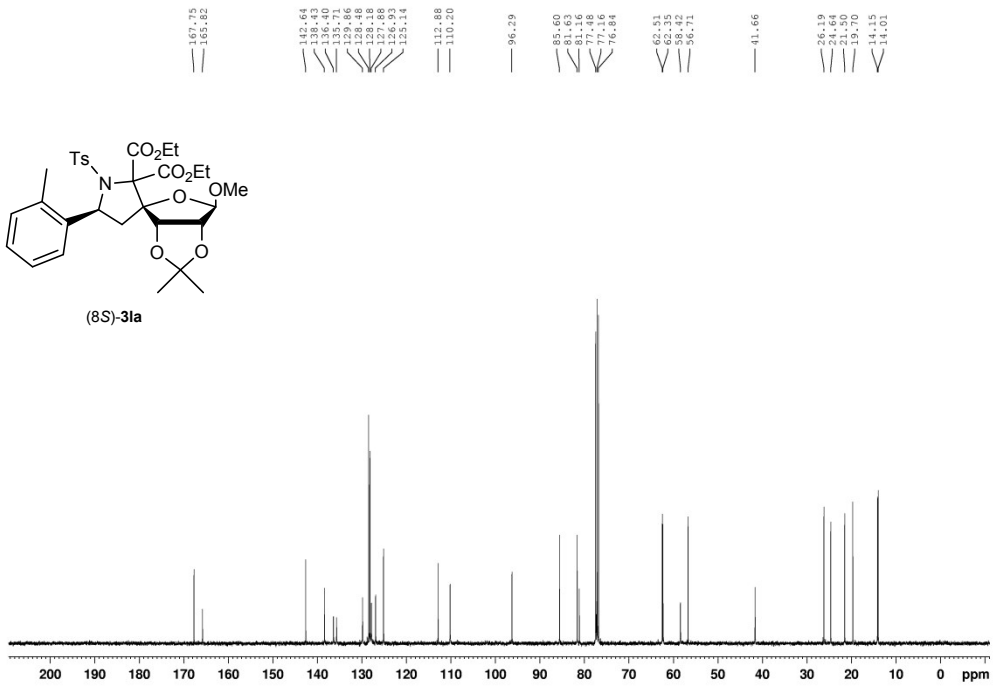
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3la



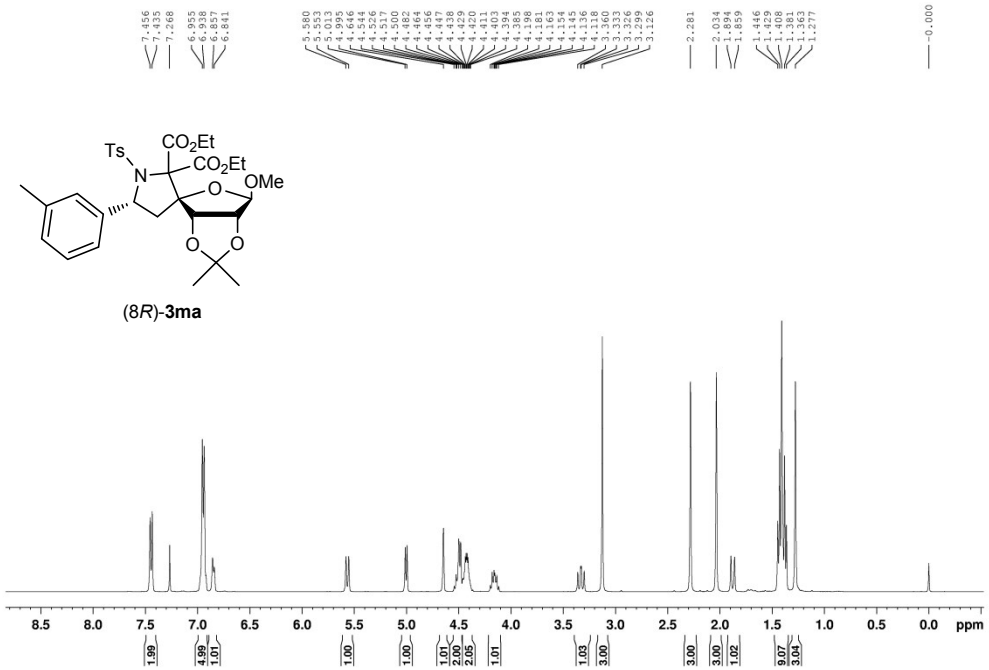
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3la



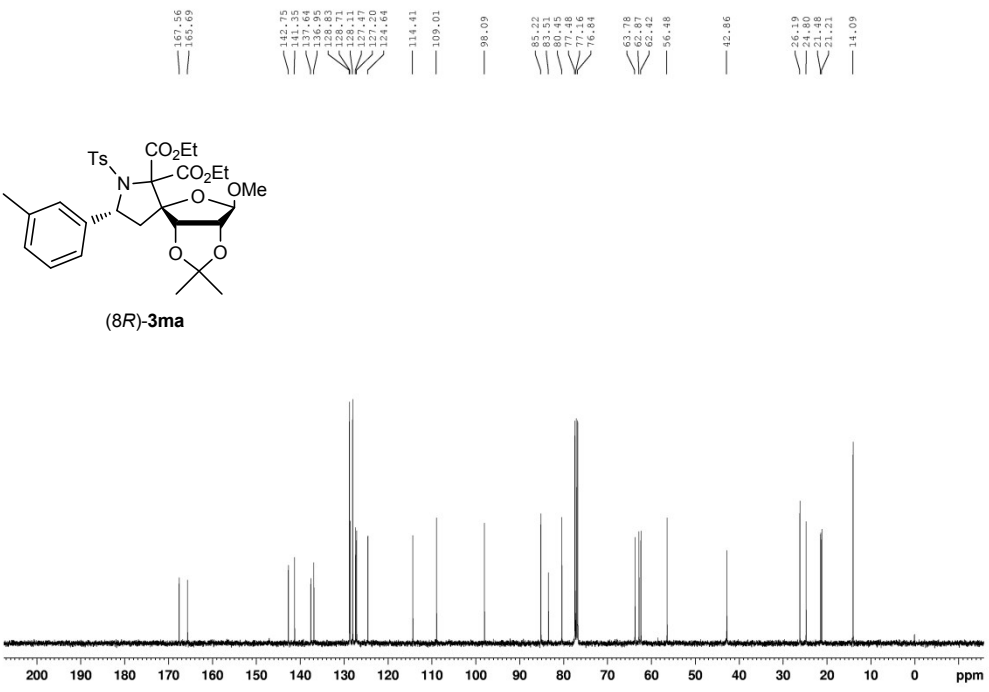
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **(8*S*)-3la**



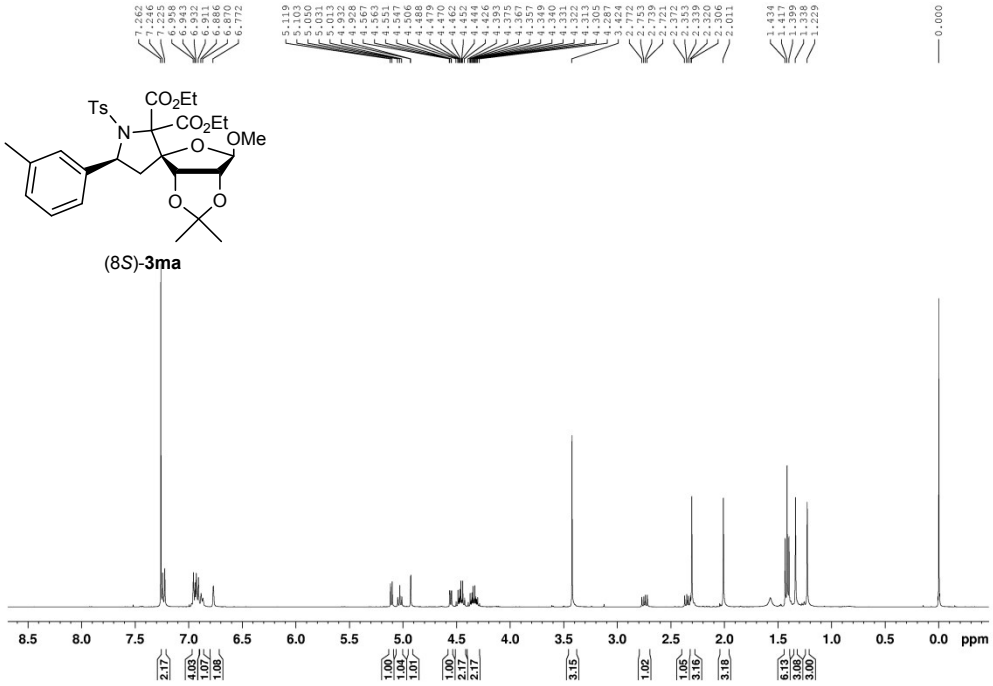
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3ma



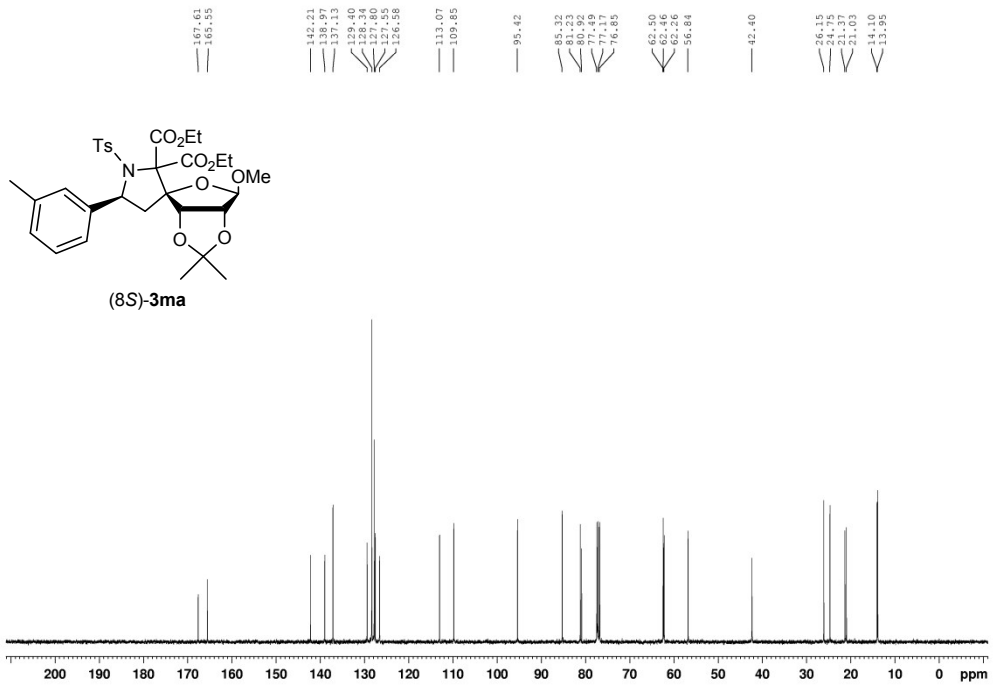
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3ma



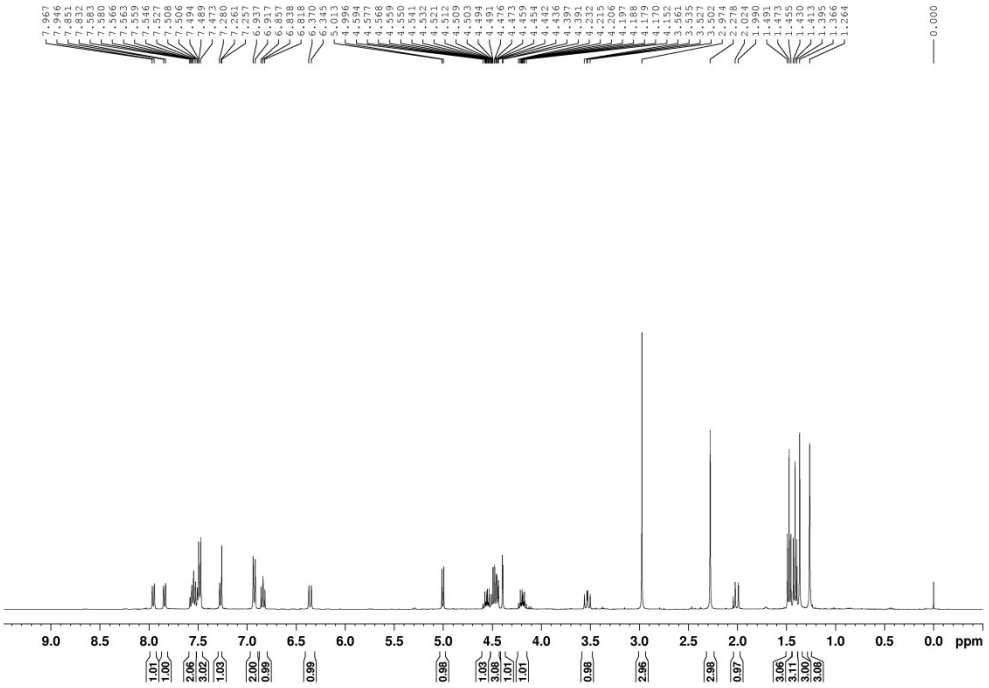
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3ma



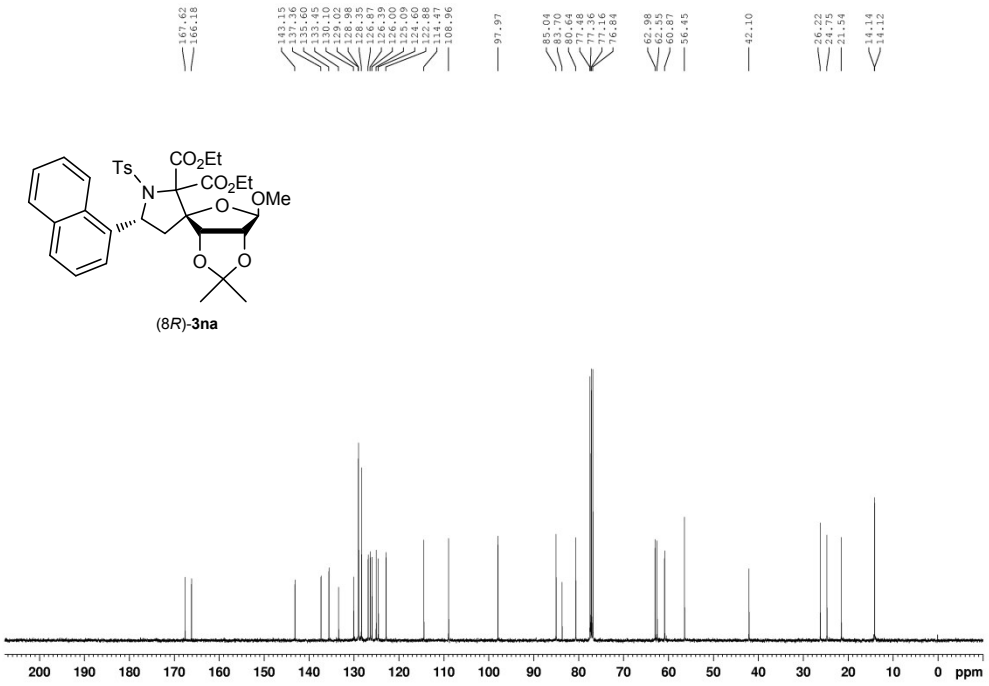
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3ma



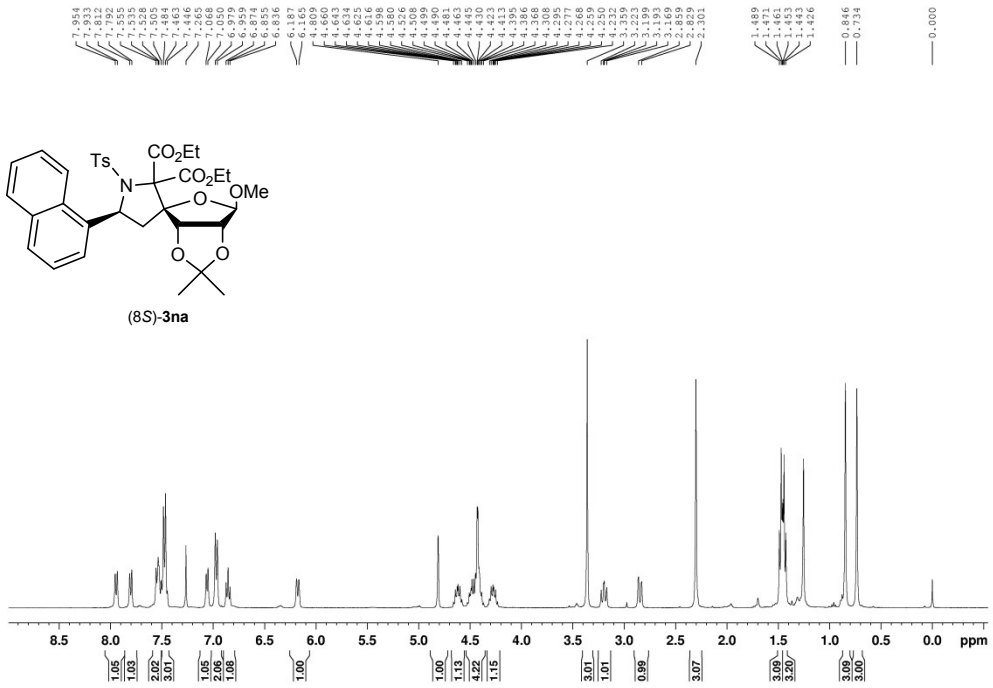
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3na



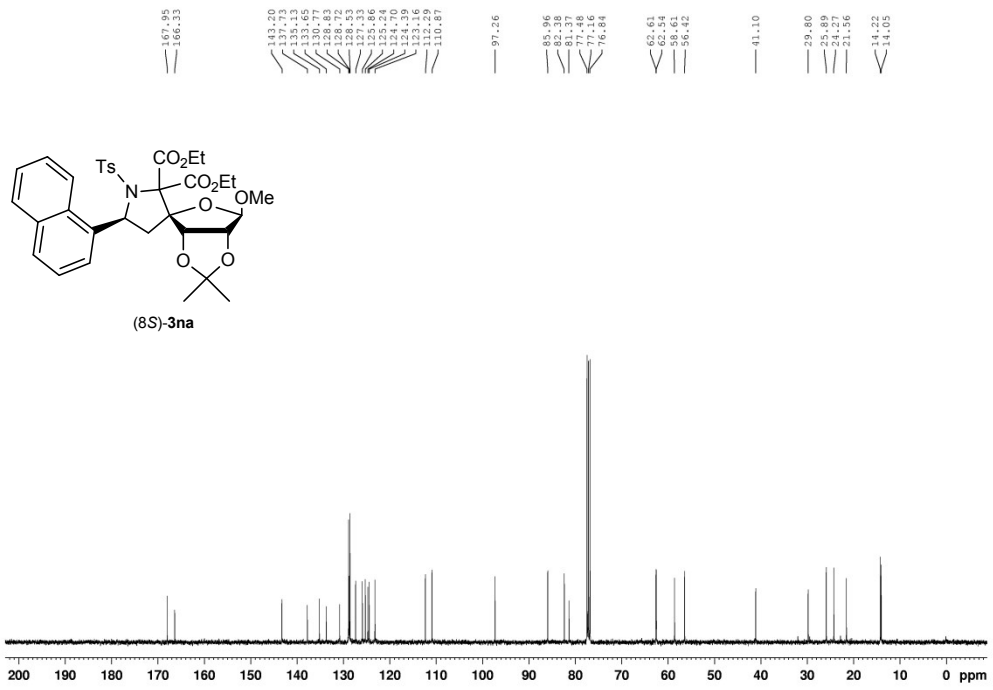
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3na



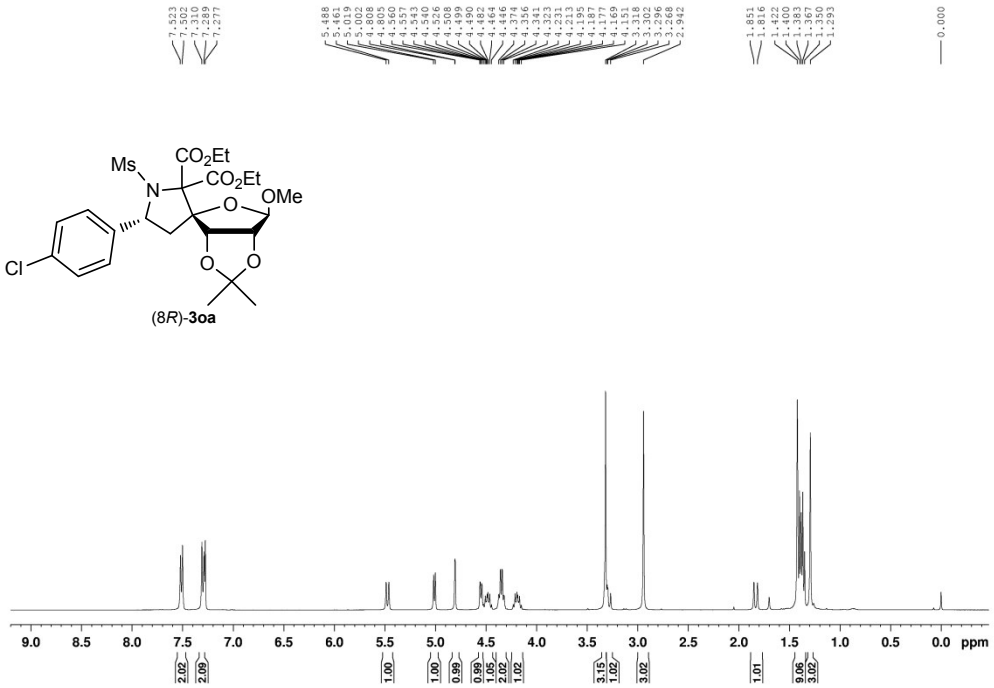
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3na



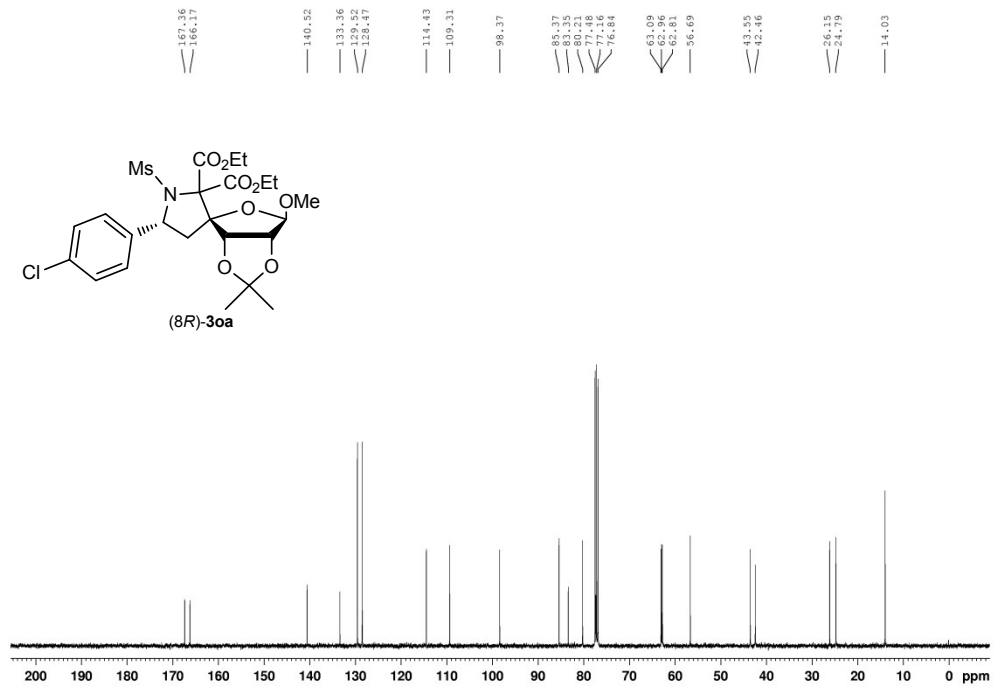
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3na



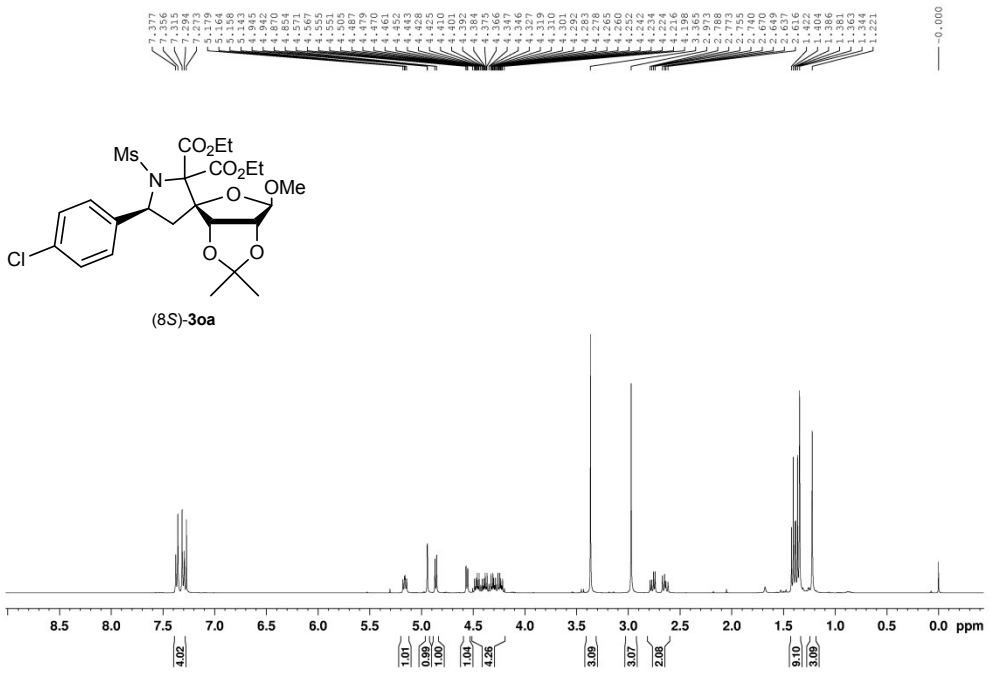
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3oa



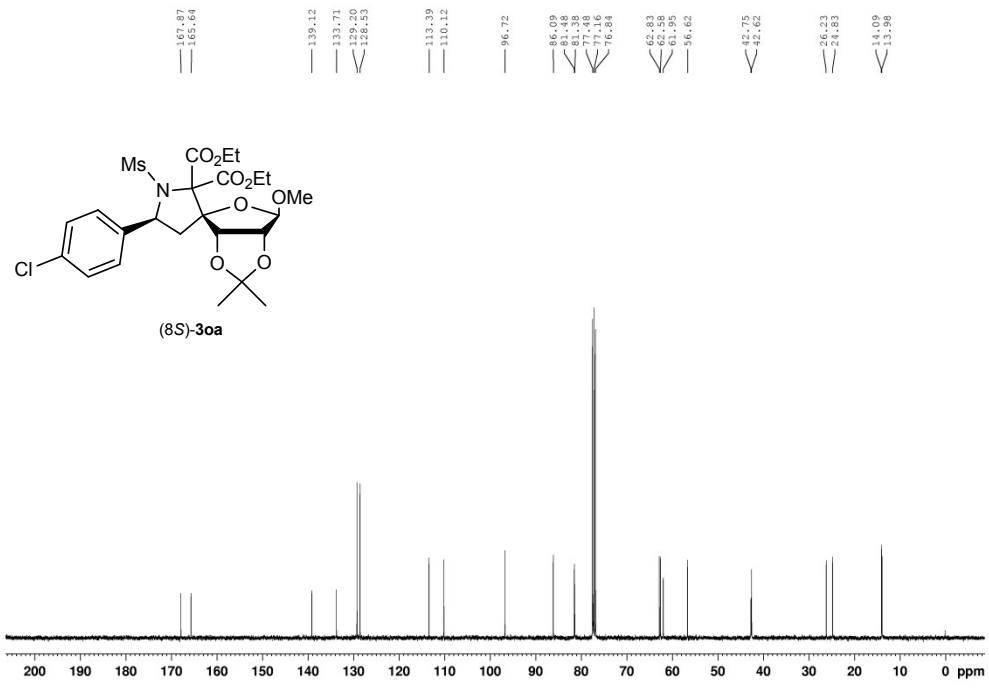
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3oa



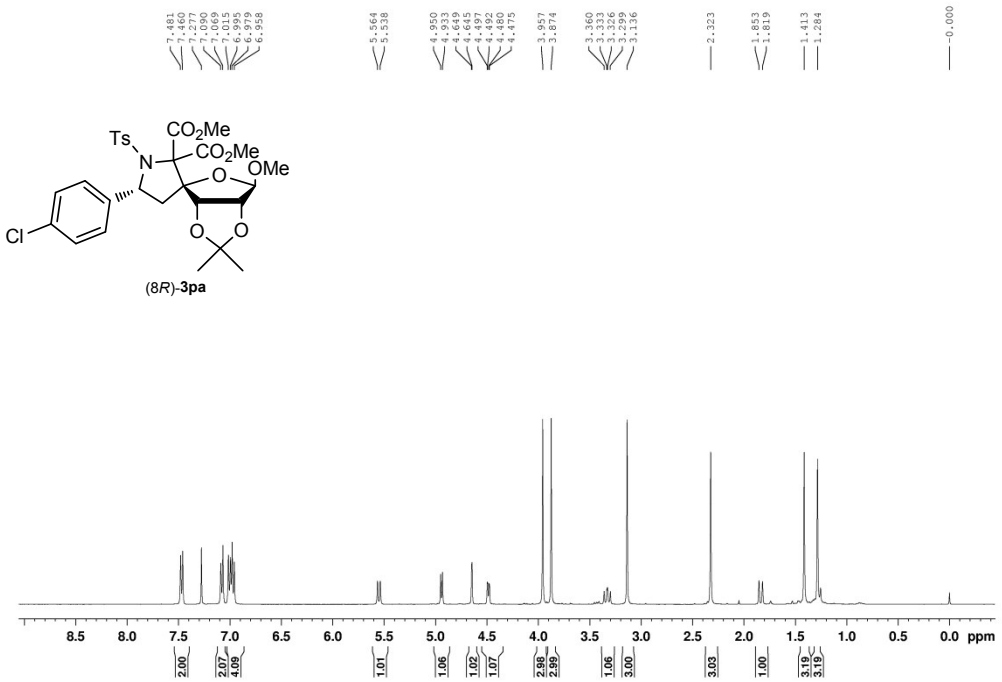
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3oa



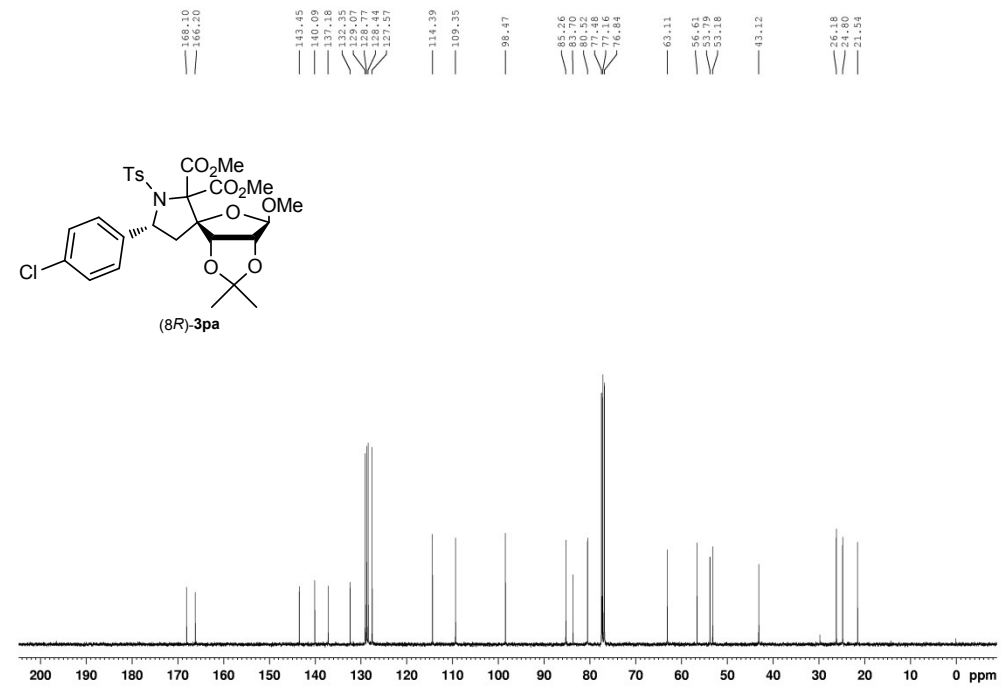
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3oa



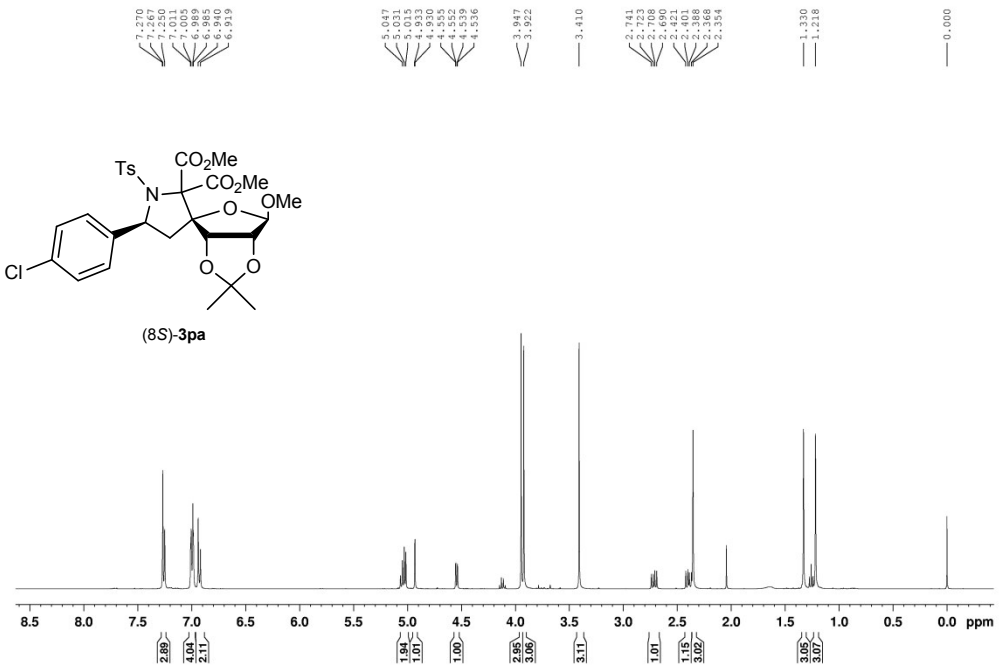
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3pa



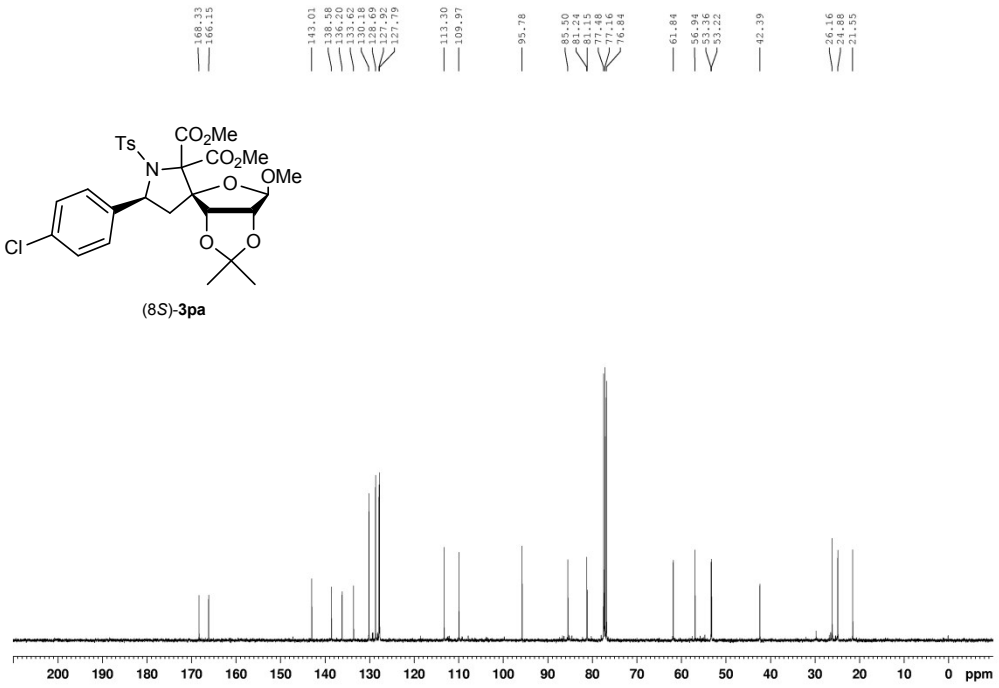
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3pa



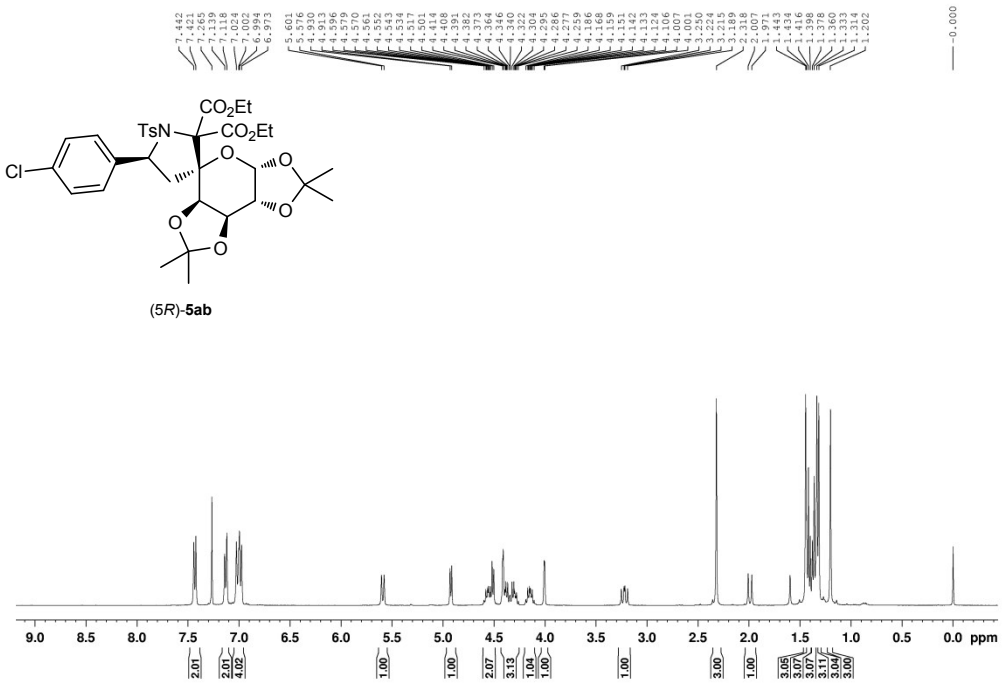
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3pa



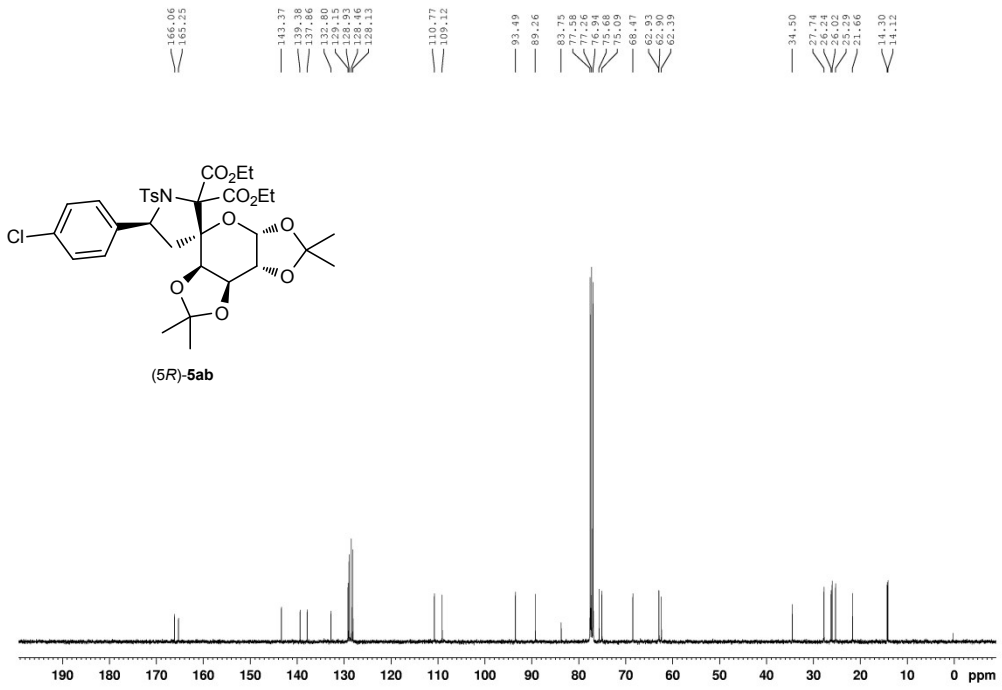
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3pa



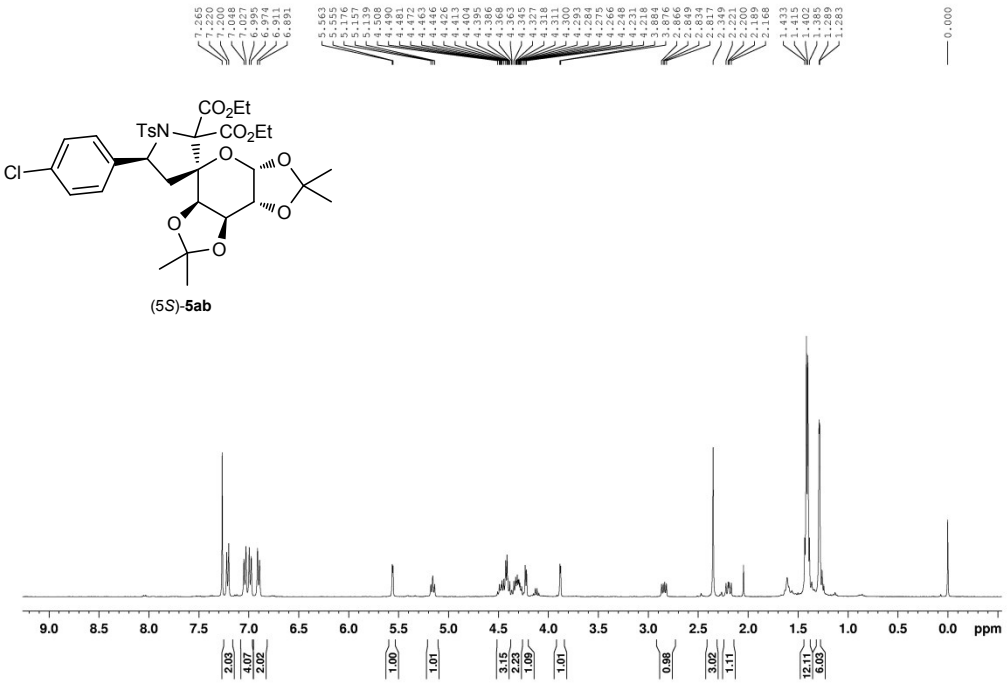
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (5*R*)-5ab



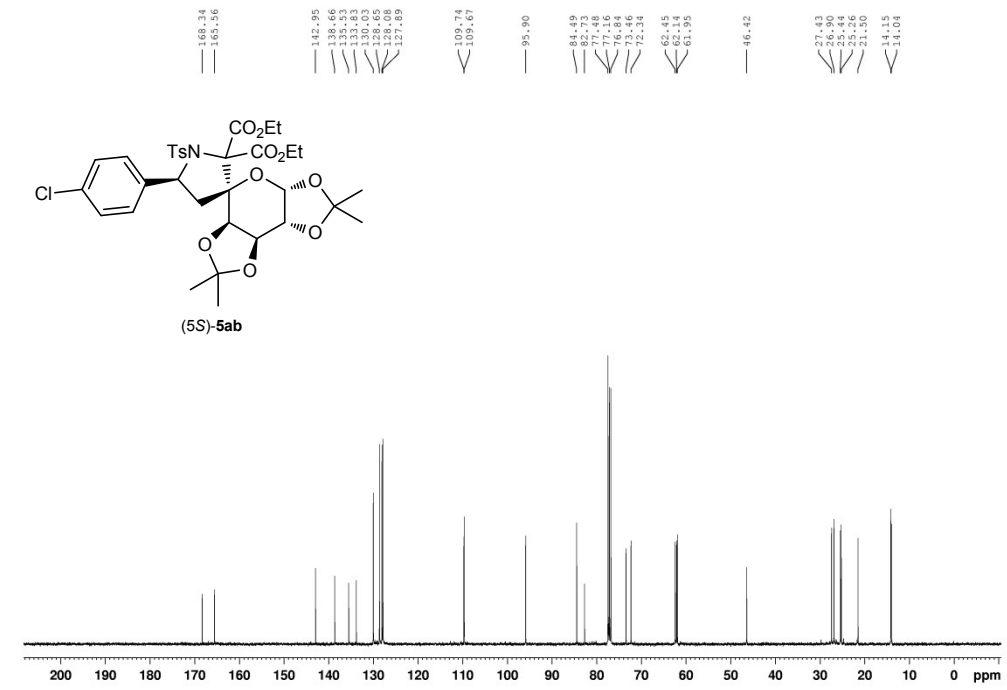
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (5*R*)-5ab



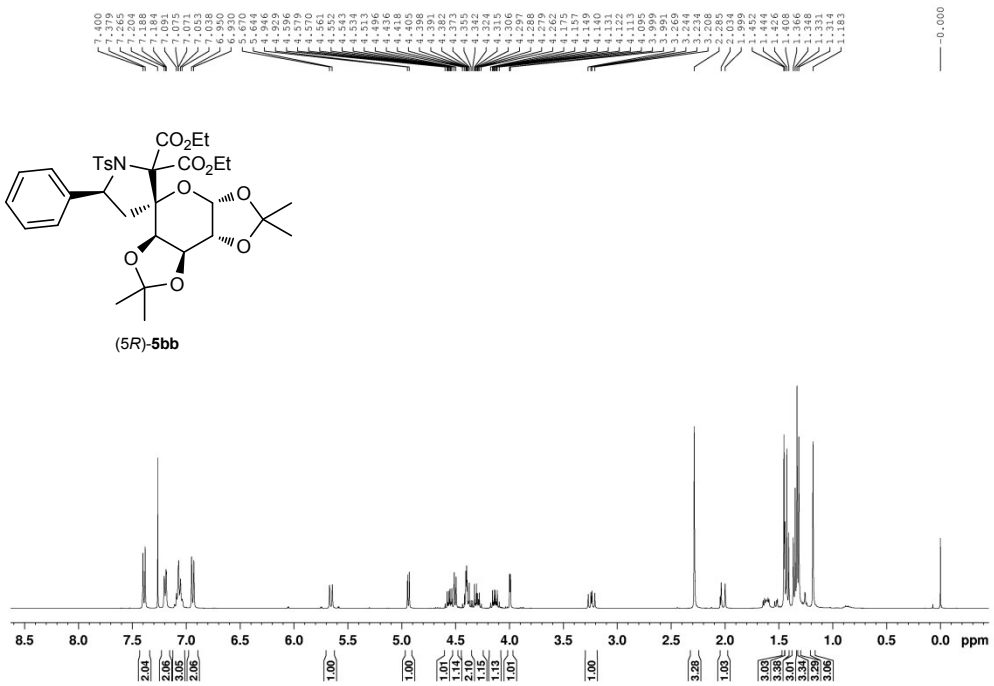
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (5*S*)-5ab



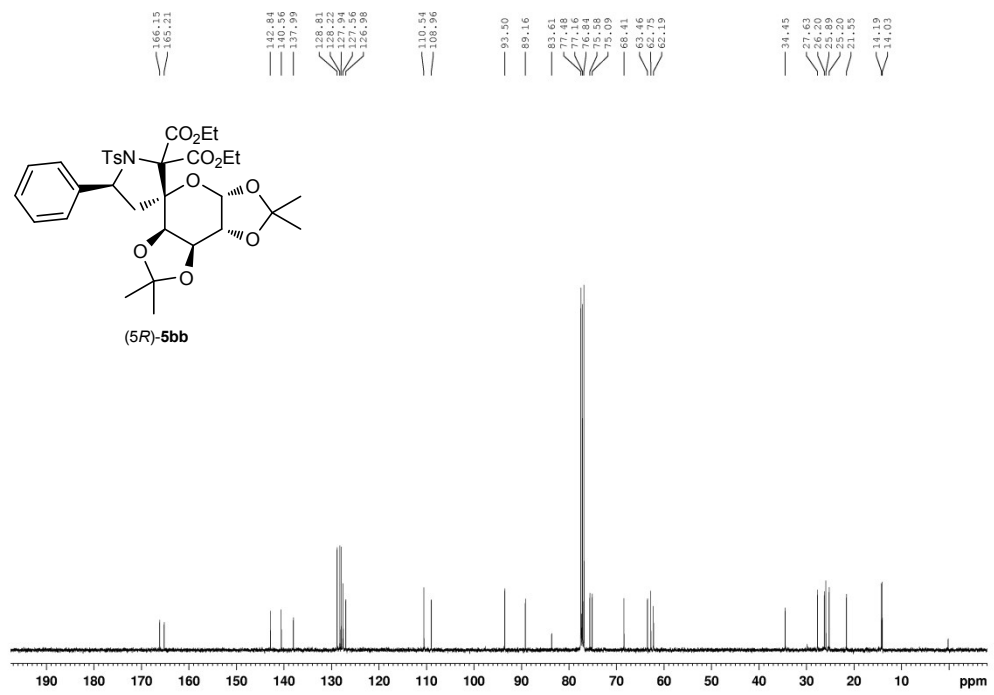
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (5*S*)-5ab



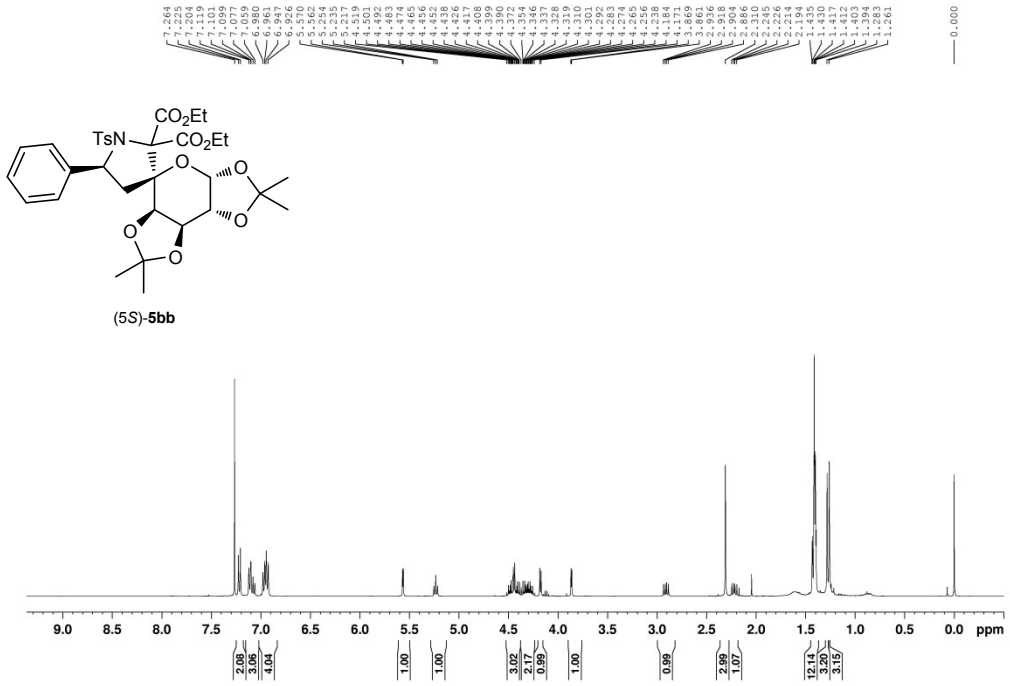
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (5*R*)-5bb



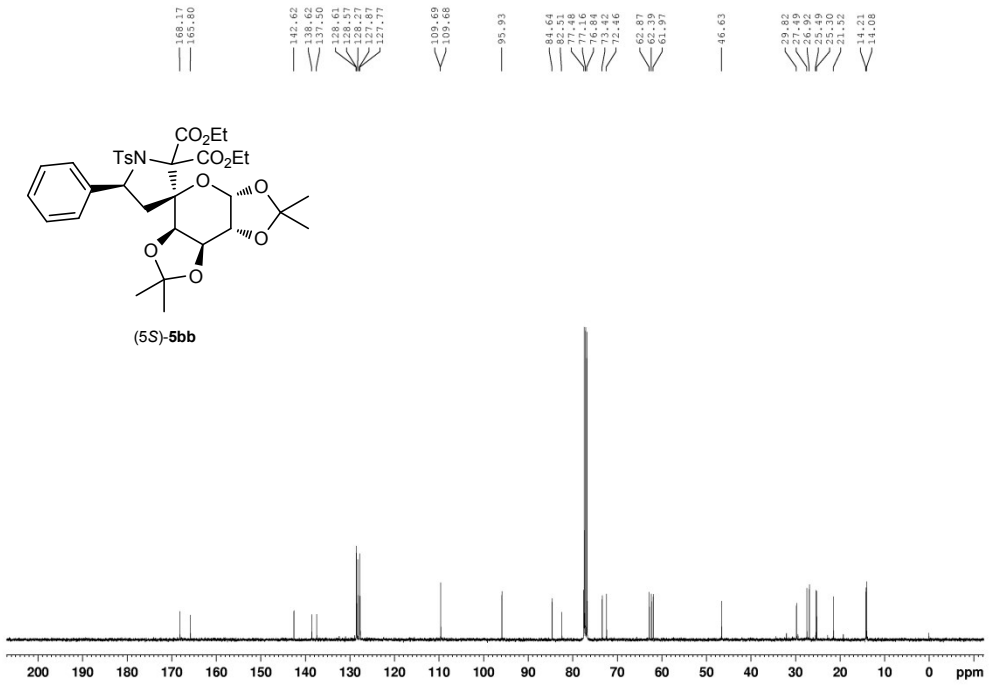
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (5*R*)-5bb



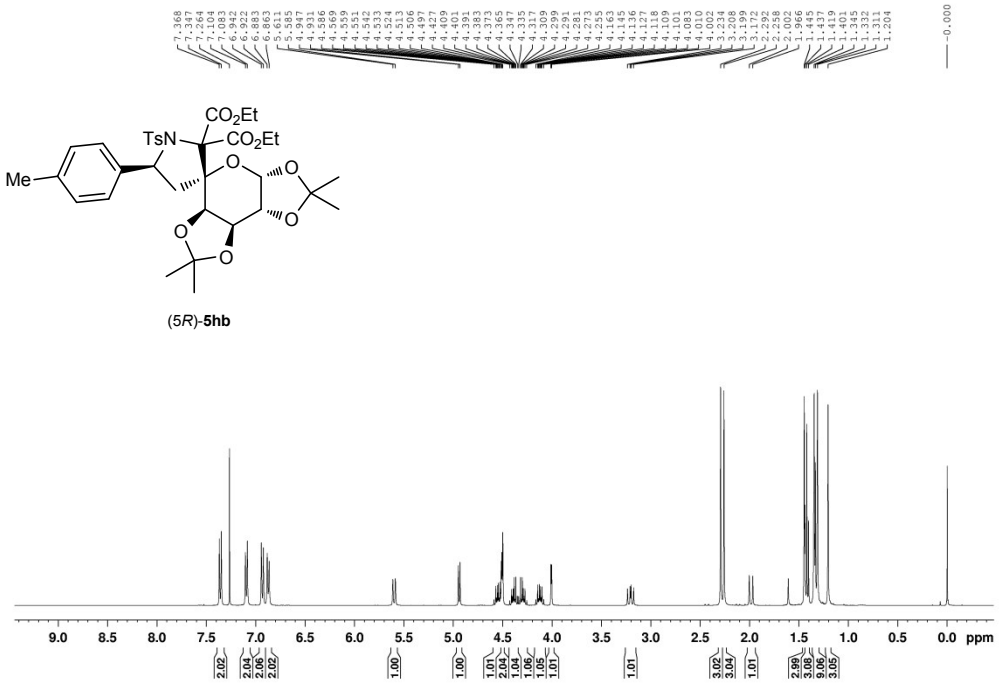
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (5*S*)-5bb



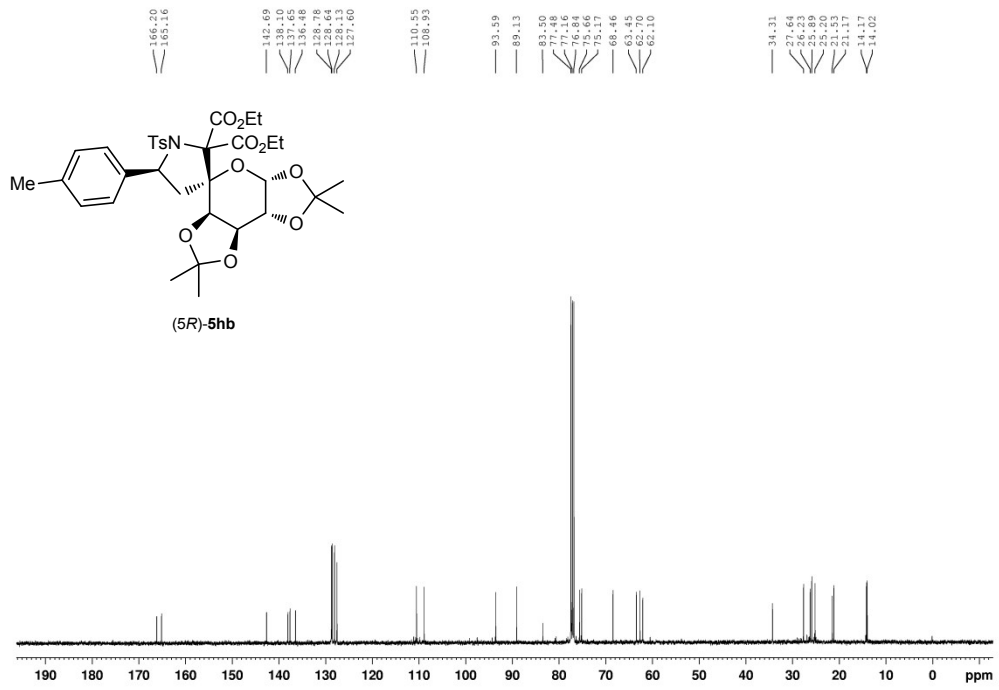
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (5*S*)-5bb



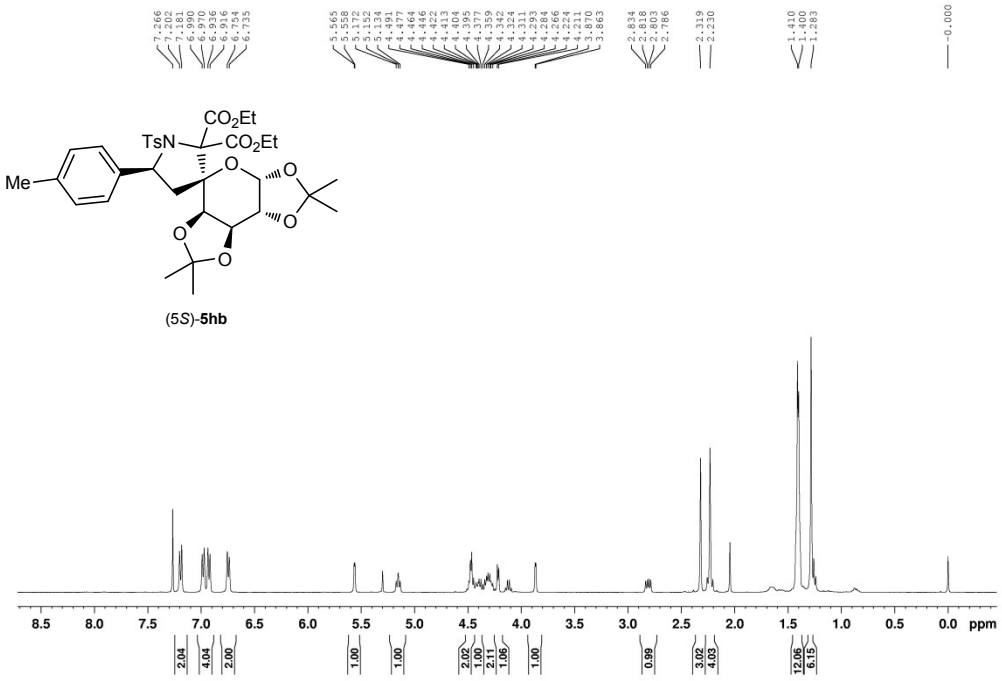
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (5*R*)-5hb



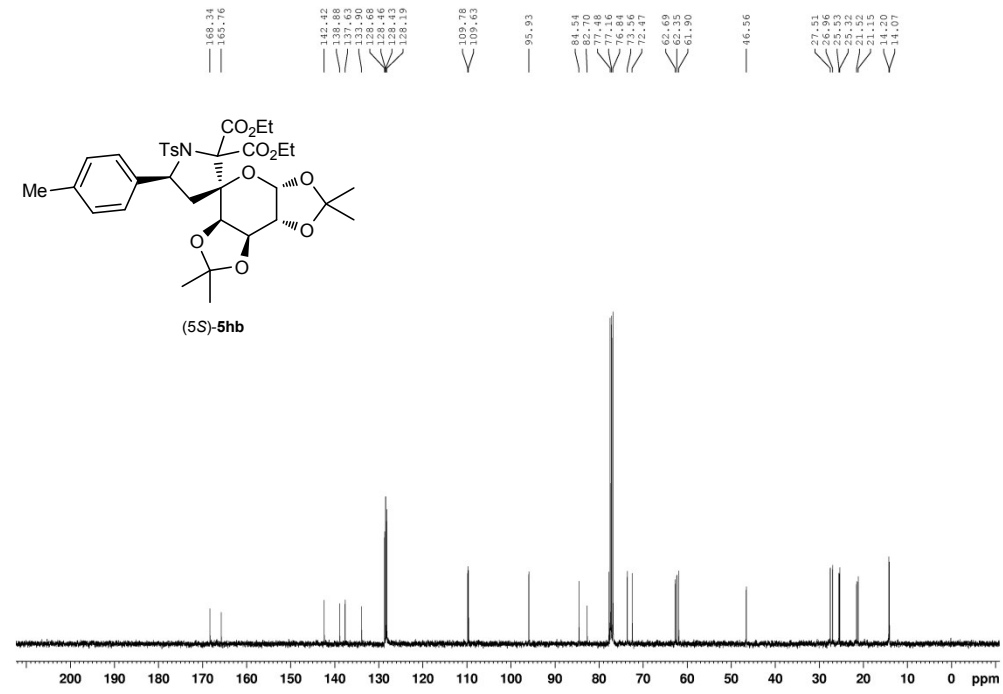
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (5*R*)-5hb



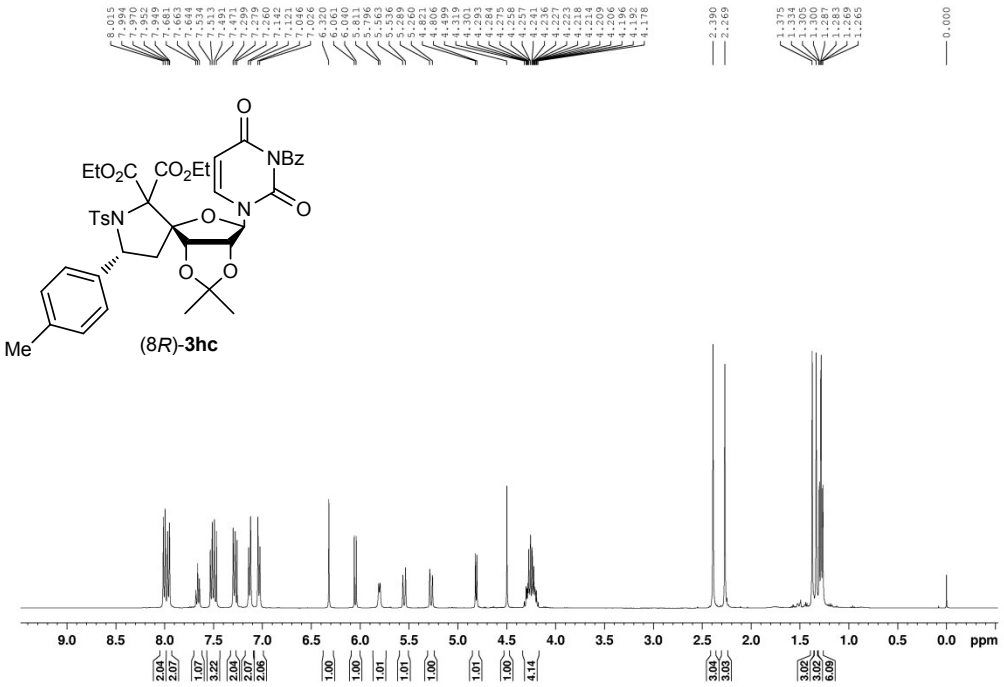
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (5*S*)-5hb



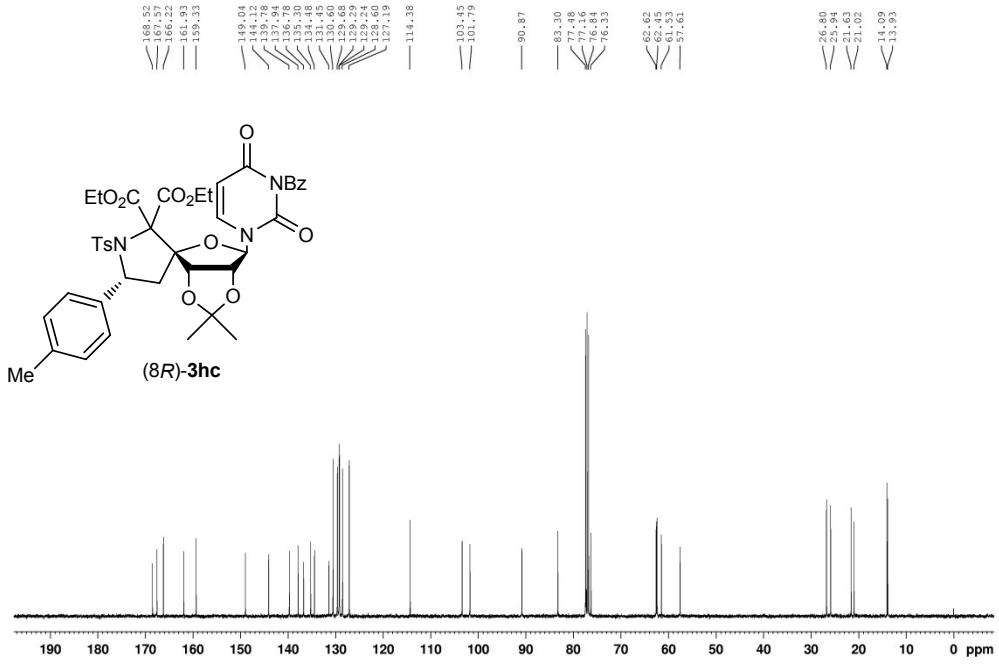
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (5*S*)-5hb



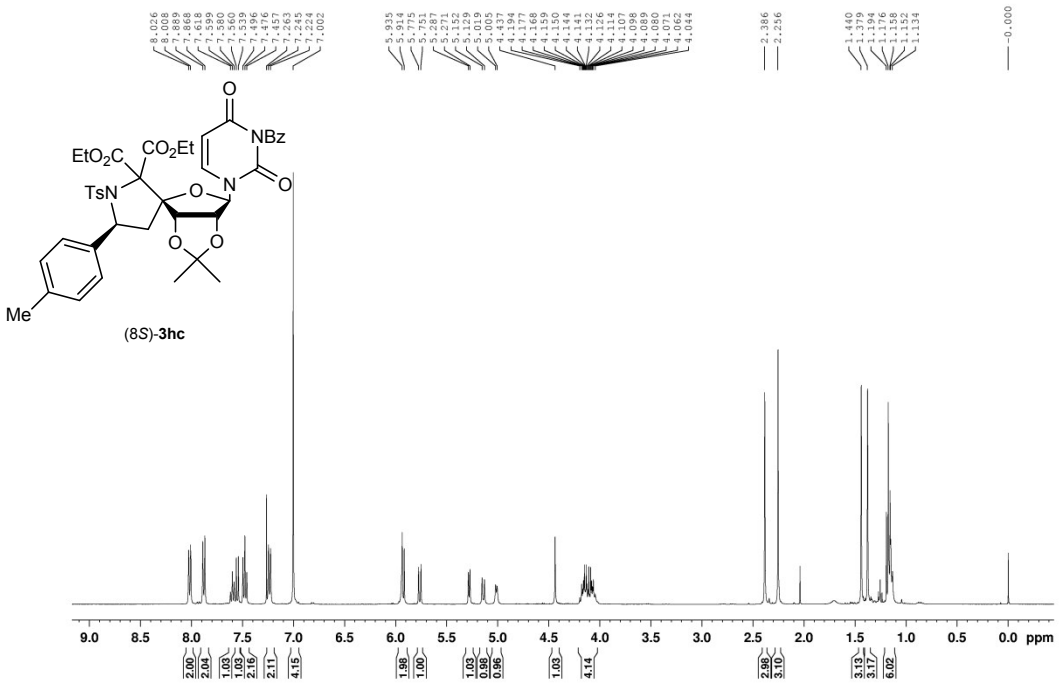
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*R*)-3hc



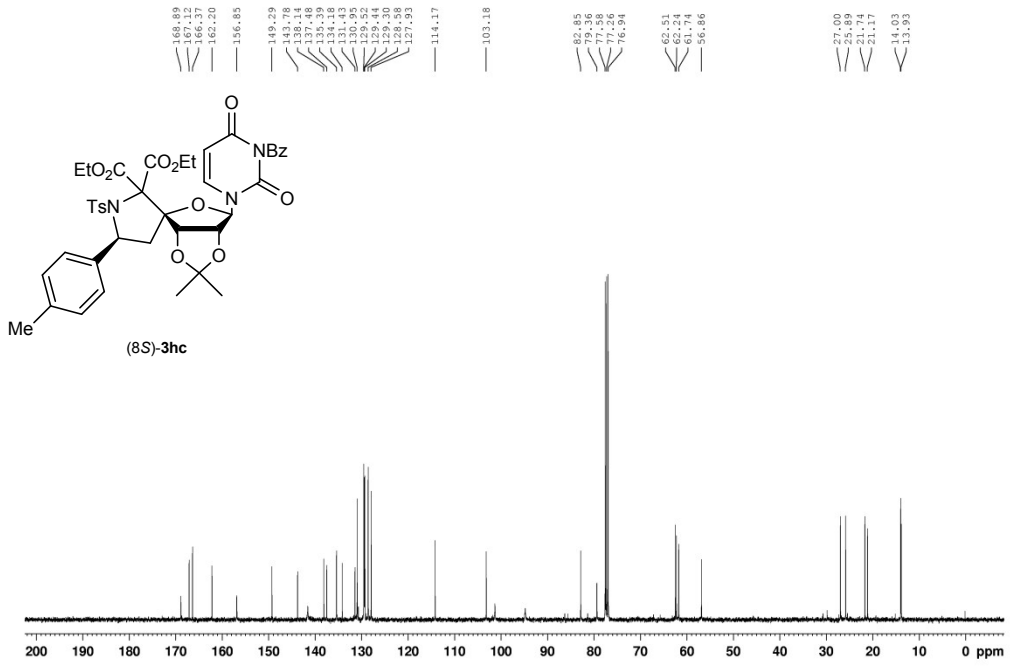
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*R*)-3hc



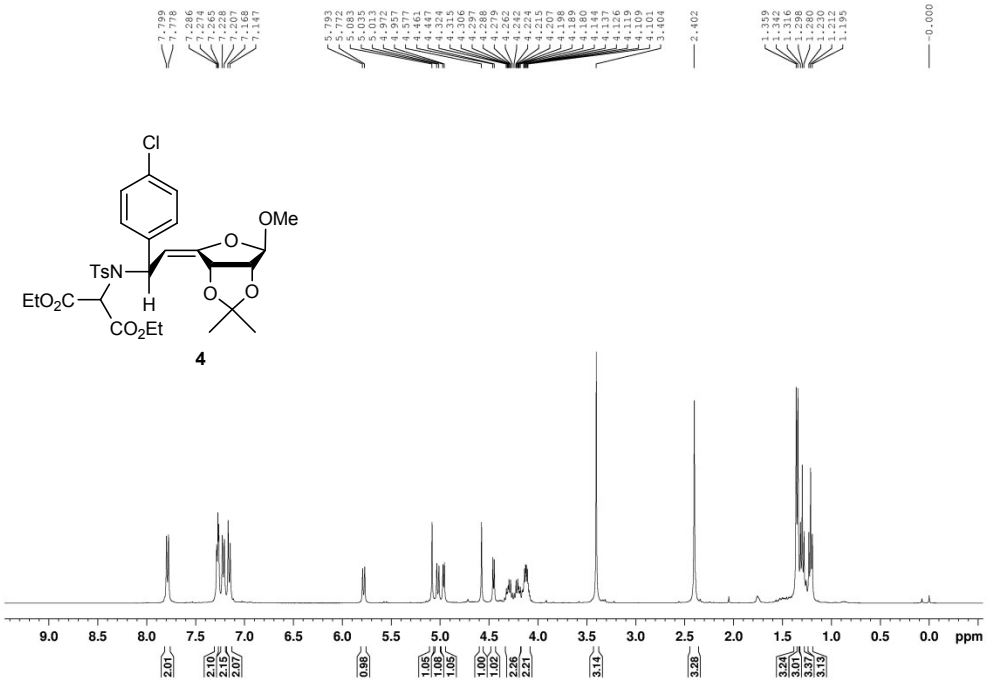
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound (8*S*)-3hc



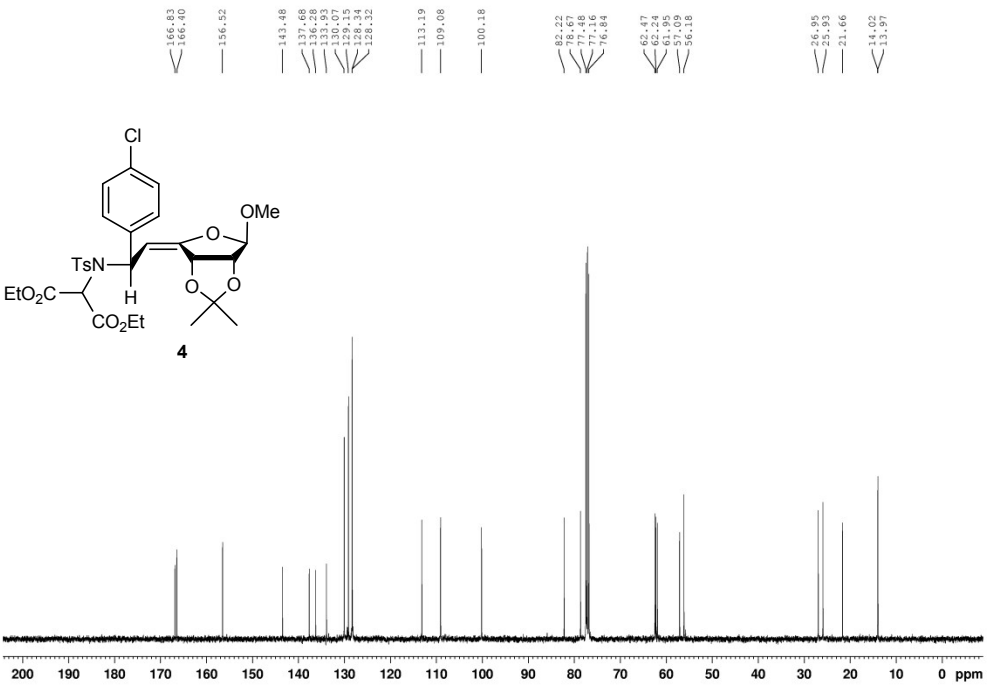
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound (8*S*)-3hc



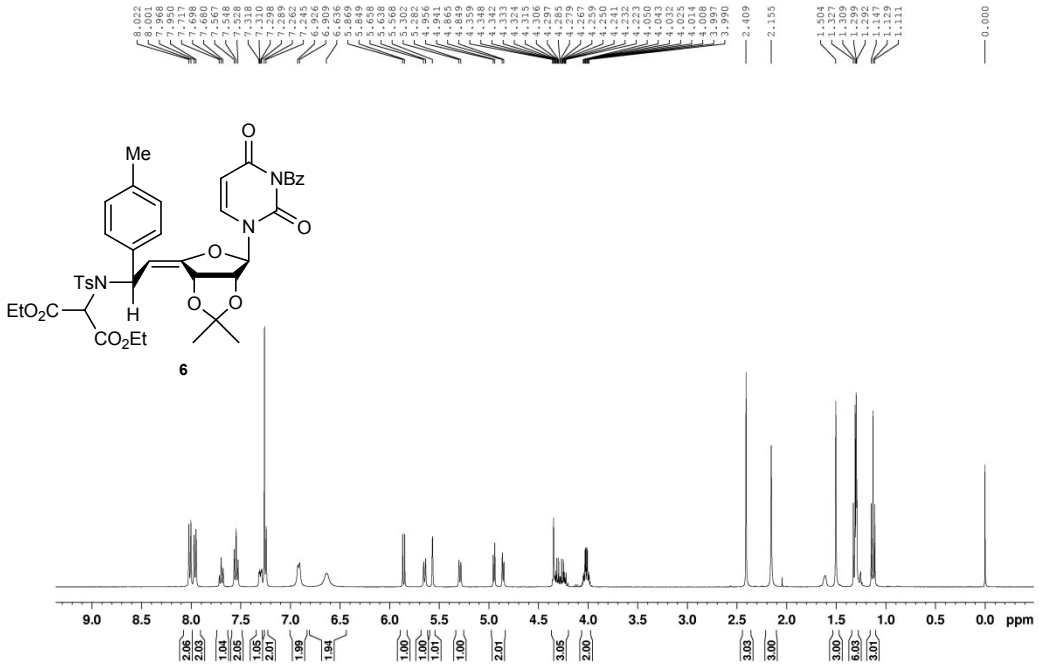
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound 4



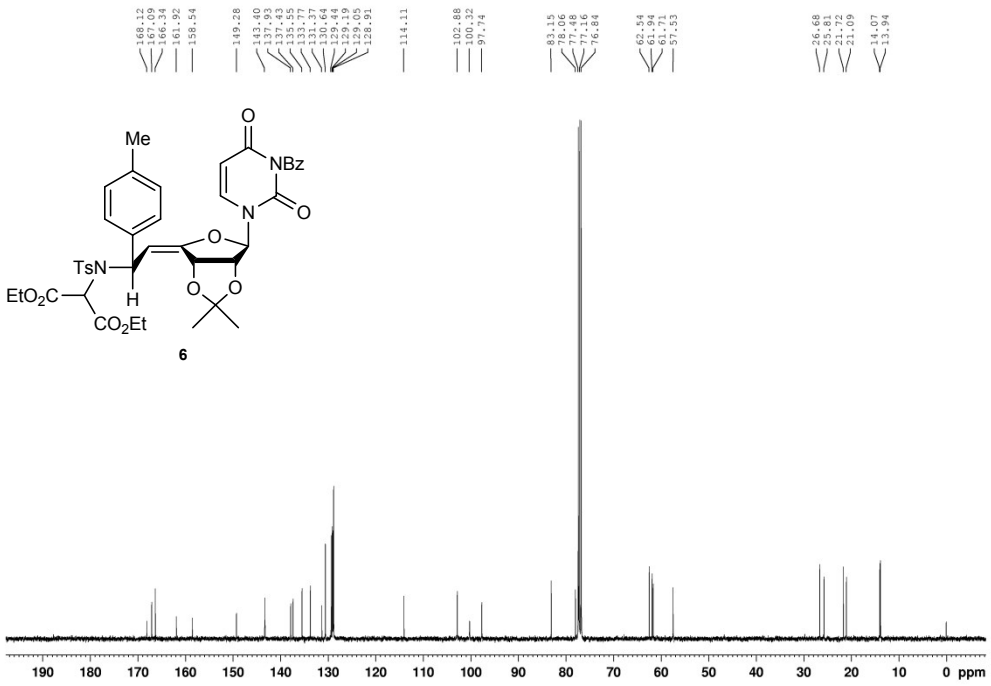
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound 4



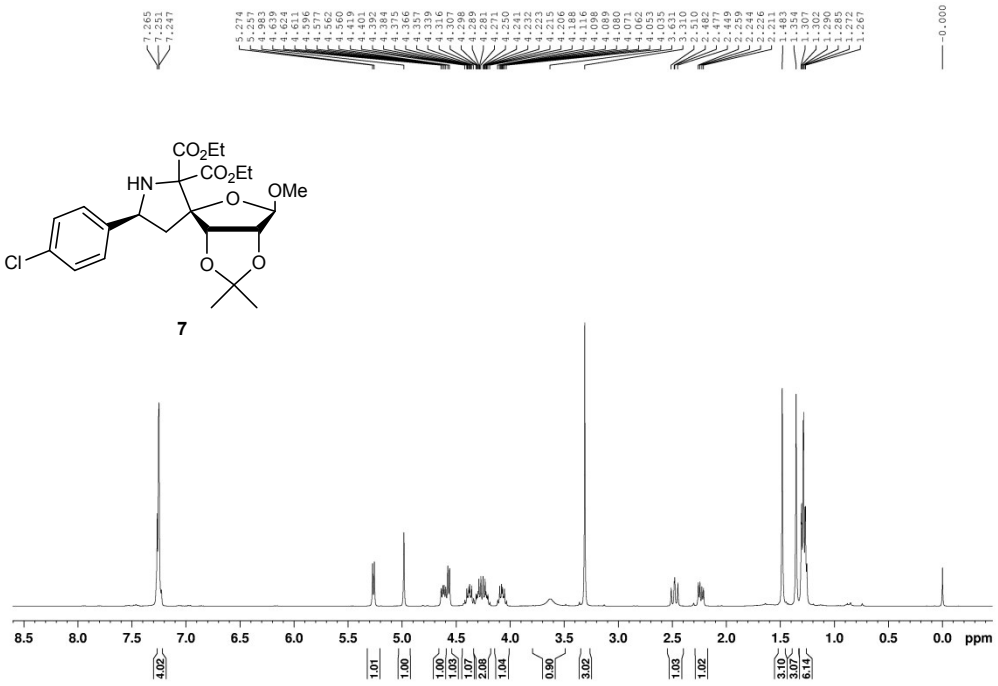
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound 6



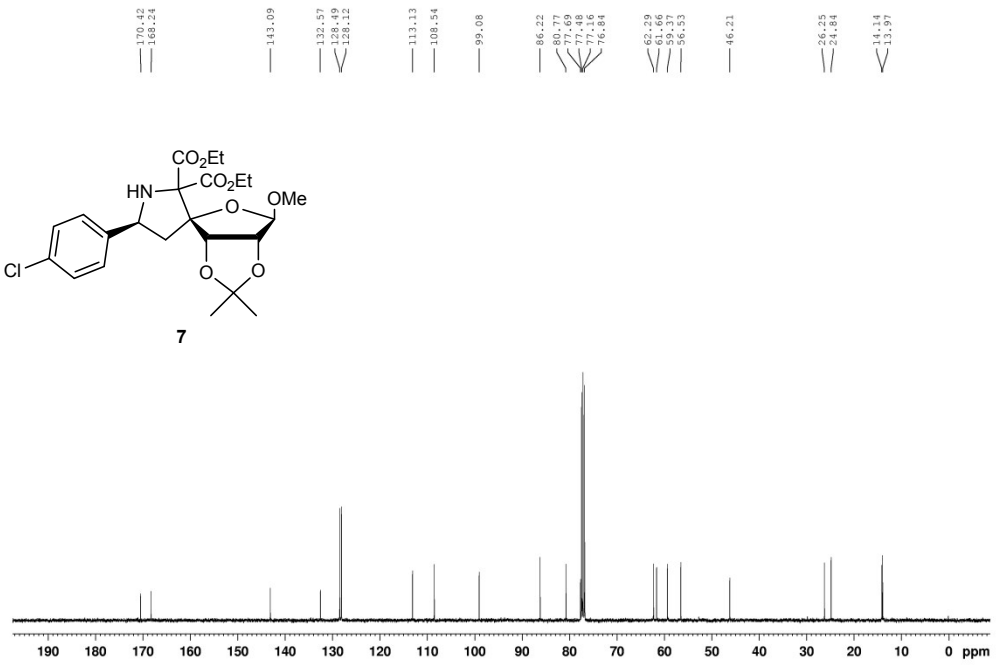
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound 6



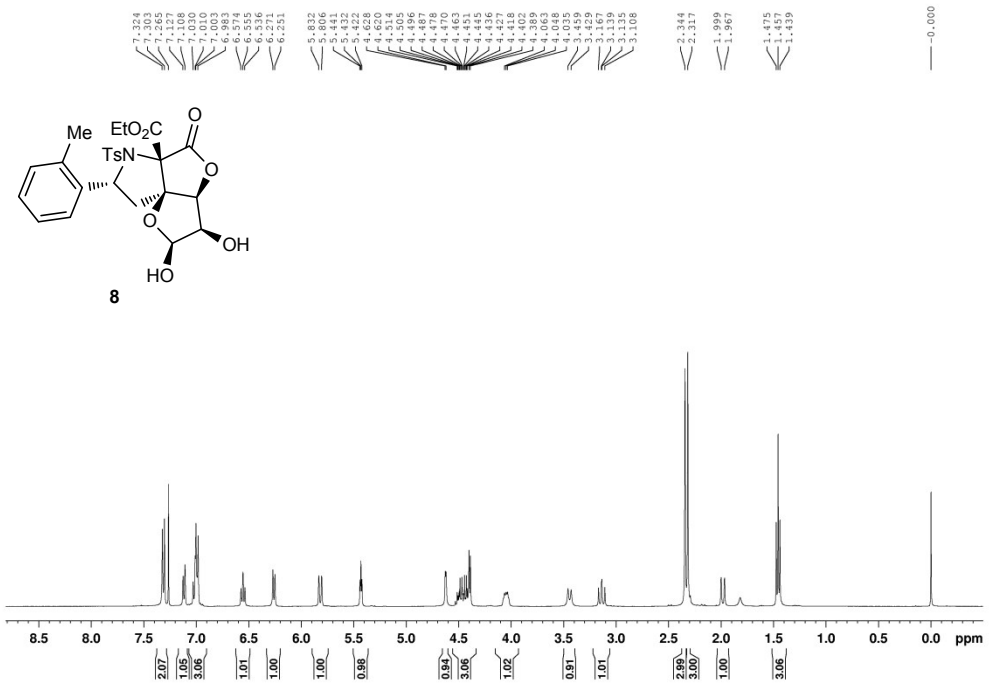
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound 7



^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound 7



^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound 8



^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound 8