Supporting Information for

Asymmetric Vinylogous Mannich Reactions: A Versatile Approach to Functionalized Heterocycles

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Contents (76 pages) :

Experimental

General Methods. Melting points were uncorrected. Infrared spectra were measured using film KBr pellet techniques. HRFABMS spectra were recorded on a 7.0T FT-MS. ^{1}H NMR and ^{13}C NMR spectra were recorded at 400 and 100 MHz, respectively. Chemical shifts are expressed in parts per million (δ) relative to an internal standard of residual chloroform (7.28 ppm for ^{1}H NMR and 77.0 ppm for ^{13}C NMR) or methanol (3.31 ppm for ^{1}H NMR and 49.0 ppm for ^{13}C NMR). Silica gel (300-400 mesh) was used for flash column chromatography, eluting (unless otherwise stated) with ethyl acetate/petroleum ether (PE) (60-90°C) mixture. THF was distilled over sodium benzophenone ketyl under N_2. Dichloromethane was distilled over calcium hydride under N_2.

General procedure A: Synthesis of *t*-butanesulfinimines (3).

Ellman's procedure[1] was used for the synthesis of *t*-butanesulfinimines (**3**) starting from enantiopure *N*-*t*-butanesulfinamide (S_S) or (R_S)-**6**.

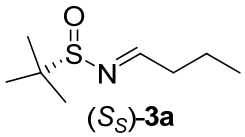
To a solution of 1.00 g (8.3 mmol) of *N*-*t*-butanesulfinamide in 14 mL of CH_2Cl_2 was added successively 103 mg (0.4 mmol) of pyridinium *p*-toluenesulfonate (PPTS), 4.97 g (41.3 mmol) of anhydrous $MgSO_4$ and an aldehyde (16.5 mmol, 2.0 equiv). The mixture was stirred at room temperature for 20 h. $MgSO_4$ was filtered off through a pad of Celite and washed with CH_2Cl_2. The combined filtrates were concentrated and chromatographed on silica gel (eluent: PE/CH_2Cl_2 = 1:10, *v*/*v*) to provide sulfinimine **3**.

General procedure B: Synthesis of *t*-butanesulfinimines (3).

Ellman's procedure[1] was used for the synthesis of *t*-butanesulfinimines (**3**) starting from enantiopure *N*-*t*-butanesulfinamide (S_S)-**6**.

To a solution of 1.00 g (8.3 mmol) of *N*-*t*-butanesulfinamide in 14 mL of CH_2Cl_2 was added successively 3.95 g (24.8 mmol) of anhydrous $CuSO_4$ and an aldehyde (16.5 mmol, 2.0 equiv). The mixture was stirred at room temperature for 20 h. $CuSO_4$ was filtered off through a pad of Celite and washed well with CH_2Cl_2. The combined filtrates were concentrated and chromatographed on silica gel (eluent: PE/CH_2Cl_2 = 1:10, *v*/*v*) to provide sulfinimine **3**.

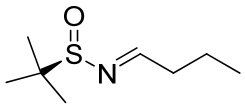
(*S*,*E*)-*N*-Butylidene-*tert*-butanesulfinamide (S_S)-3a



(S_S)-**3a**

Following the general procedure A, the condensation between (S_S)-*t*-butanesulfinamide (120 mg, 1.0 mmol) and butyraldehyde (0.17 mL, 2.0 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/20, *v*/*v*), *t*-butanesulfinimine (S_S)-**3a** (147 mg, yield: 85%) as a pale yellow oil. $[\alpha]_D^{20}$ +303.5 (*c* 1.0, $CHCl_3$) {lit.[2] $[\alpha]_D^{20}$ –305.0 (*c* 0.94, $CHCl_3$)}. The spectral data of (S_S)-**3a** are identical with those reported in the literature.[2]

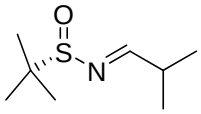
(*R*,*E*)-*N*-Butylidene-*tert*-butanesulfinamide (R_S)-3a



(R_S)-**3a**

Following the general procedure A, the condensation between (R_S)-*t*-butanesulfinamide (1.00 g, 8.27 mmol) and butyraldehyde (1.10 mL, 16.5 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (R_S)-**3a** (1.23 g, yield: 85%) as a pale yellow oil. $[\alpha]_D^{20}$ –302.1 (*c* 1.1, $CHCl_3$) {lit.[2] $[\alpha]_D^{20}$ –305.0 (*c* 0.94, $CHCl_3$)}. The spectral data of (R_S)-**3a** are identical with those reported in the literature.[2]

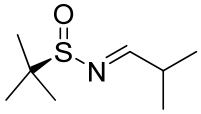
(*S*,*E*)-*N*-Isobutylidene-*tert*-butanesulfinamide (S_S)-3b



(S_S)-**3b**

Following the general procedure A, the condensation between (S_S)-*t*-butanesulfinamide (120 mg, 1.0 mmol) and isobutyraldehyde (0.18 mL, 2.0 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (S_S)-**3b** (145 mg, yield: 83%) as a colorless oil. $[\alpha]_D^{20}$ +316.2 (*c* 1.2, $CHCl_3$) {lit.[3] $[\alpha]_D^{26}$ +320.3 (*c* 1.18, $CHCl_3$)}. The spectral data of (S_S)-**3b** are identical with those reported in the literature.[3]

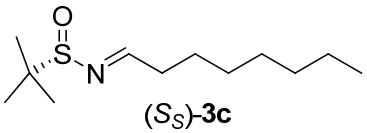
(*R*,*E*)-*N*-Isobutylidene-*tert*-butanesulfinamide (R_S)-3b



(R_S)-**3b**

Following the general procedure A, the condensation between (R_S)-*t*-butanesulfinamide (1.00 g, 8.26 mmol) and isobutyraldehyde (1.13 mL, 16.5 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/7, *v*/*v*), *t*-butanesulfinimine (R_S)-**3b** (1.28 g, yield: 90%) as a colorless oil. $[\alpha]_D^{20}$ –315.3 (*c* 1.2, $CHCl_3$) {lit.[3] $[\alpha]_D^{26}$ +320.3 (*c* 1.18, $CHCl_3$)}. The spectral data of (R_S)-**3b** are identical with those reported in the literature.[3]

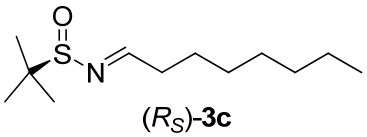
(*S*,*E*)-*N*-Octylidene-*tert*-butanesulfinamide (S_S)-3c



(S_S)-**3c**

Following the general procedure A, the condensation between (S_S)-*t*-butanesulfinamide (120 mg, 1.0 mmol) and octanal (0.31 mL, 2.0 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (S_S)-**3c** (172 mg, yield: 75%) as a colorless oil. $[\alpha]_D^{20}$ +177.0 (*c* 1.0, $CHCl_3$) {lit.[4] $[\alpha]_D^{20}$ –180.9 (*c* 0.96, $CHCl_3$)}. The spectral data of (S_S)-**3c** are identical with those reported in the literature.[4]

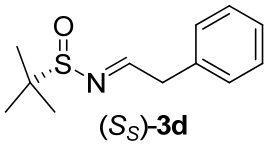
(*R*,*E*)-*N*-Octylidene-*tert*-butanesulfinamide (R_S)-3c



(R_S)-**3c**

Following the general procedure A, the condensation between (R_S)-*t*-butanesulfinamide (2.00 g, 16.5 mmol) and octanal (5.2 mL, 33 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (R_S)-**3c** (3.09 g, yield: 81%) as a colorless oil. $[\alpha]_D^{20}$ –176.2 (*c* 1.0, $CHCl_3$) {lit.[4] $[\alpha]_D^{20}$ –180.9 (*c* 0.96, $CHCl_3$)}. The spectral data of (R_S)-**3c** are identical with those reported in the literature.[4]

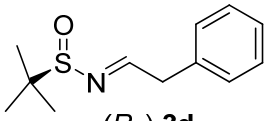
(*S*,*E*)-*N*-Phenylethylidene-*tert*-butanesulfinamide (S_S)-3d



(S_S)-**3d**

Following the general procedure A, the condensation between (S_S)-*t*-butanesulfinamide (100 mg, 0.83 mmol) and phenylacetaldehyde (0.20 mL, 1.6 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/6, *v*/*v*), *t*-butanesulfinimine (S_S)-**3d** (151 mg, yield: 82%) as a colorless oil. $[\alpha]_D^{20}$ +249.5 (*c* 1.1, $CHCl_3$) {lit.[3] $[\alpha]_D^{26}$ +252.5 (*c* 1.08, $CHCl_3$)}. The spectral data of (S_S)-**3d** are identical with those reported in the literature.[3]

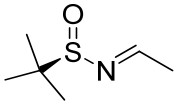
(*R*,*E*)-*N*-Phenylethylidene-*tert*-butanesulfinamide (R_S)-3d



(R_S)-**3d**

Following the general procedure A, the condensation between (R_S)-*t*-butanesulfinamide (2.00 g, 33.1 mmol) and phenylacetaldehyde (3.9 mL, 66.2 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/6, *v*/*v*), *t*-butanesulfinimine (R_S)-**3d** (3.02 g, yield: 82%) as a colorless oil. $[\alpha]_D^{20}$ –246.6 (*c* 1.1, $CHCl_3$) {lit.[3] $[\alpha]_D^{26}$ +252.5 (*c* 1.08, $CHCl_3$)}. The spectral data of (R_S)-**3d** are identical with those reported in the literature.[3]

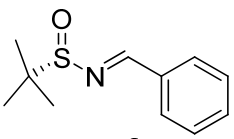
(*R*,*E*)-*N*-Ethylidene-*tert*-butanesulfinamide (R_S)-3e



(R_S)-**3e**

To a mixture of (R_S)-*t*-butanesulfinamide (3.25 g, 26.86 mmol) and $CuSO_4$ (12.86 g, 80.58 mmol) in anhydrous CH_2Cl_2 (45 mL) was added acetaldehyde flow continuously at room temperature. After being stirred for 12 h, the mixture was filtered through silica gel to remove the solid and then concentrated. The filtrate was purified by flash column chromatography on silica gel (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*) to give *t*-butanesulfinimine (R_S)-**3e** (3.55 g, yield: 90%) as a colorless oil. $[\alpha]_D^{20}$ –215.3 (*c* 1.1, $CHCl_3$); IR (film): 3228, 2959, 1622, 1031 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.16 (s, 9H), 2.20 (d, *J* = 5.1 Hz, 3H), 8.04 (q, *J* = 5.1 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.2 (3C), 22.3, 56.4, 165.8; HRMS calcd for $C_6H_{13}NOS$ $[M+H]^+$: 148.0791; found: 148.0792.

(*S*,*E*)-*N*-Benzylidene-*tert*-butanesulfinamide (S_S)-3f

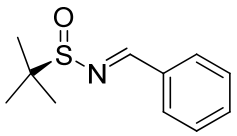


(S_S)-**3f**

Following the general procedure A, the condensation between (S_S)-*t*-butanesulfinamide (100 mg, 0.83 mmol) and benzaldehyde (0.17 mL, 1.6 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*),

t-butanesulfinimine (S_S)-**3f** (141 mg, yield: 82%) as a pale yellow oil. $[\alpha]_D^{20}$ +120.3 (*c* 1.0, $CHCl_3$) {lit.[5] $[\alpha]_D^{23}$ −122.0 (*c* 1.0, $CHCl_3$)}. The spectral data of (S_S)-**3f** are identical with those reported in the literature.[5]

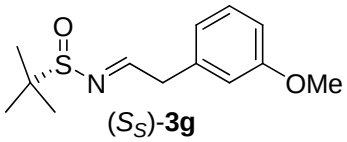
(*R*,*E*)-*N*-Benzylidene-*tert*-butanesulfinamide (R_S)-3f



(R_S)-**3f**

Following the general procedure A, the condensation between (R_S)-*t*-butanesulfinamide (1.00 g, 8.25 mmol) and benzaldehyde (1.7 mL, 16.5 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (R_S)-**3f** (1.52 g, yield: 88%) as a pale yellow oil. $[\alpha]_D^{20}$ −120.8 (*c* 1.1, $CHCl_3$) {lit.[5] $[\alpha]_D^{23}$ −122.0 (*c* 1.0, $CHCl_3$)}. The spectral data of (R_S)-**3f** are identical with those reported in the literature.[5]

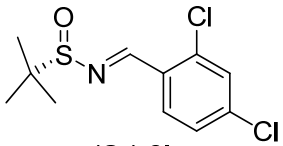
(*S*,*E*)-*N*-3-Methoxyphenylethylidene-*tert*-butanesulfinamide (S_S)-3g



(S_S)-**3g**

Following the general procedure A, the condensation between (S_S)-*t*-butanesulfinamide (120 mg, 1.0 mmol) and (3-methoxyphenyl)acetaldehyde (300 mg, 2.0 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (S_S)-**3g** (196 mg, yield: 78%) as a colorless oil. $[\alpha]_D^{20}$ +41.2 (*c* 1.0, $CHCl_3$); IR (film): 2959, 1692, 1600, 1584, 1489, 1454, 1262, 1165, 1044 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.19 (s, 9H), 3.78 (s, 3H), 3.80 (dd, *J* = 5.4, 2.5 Hz, 2H), 6.75-7.28 (m, 4H), 8.12 (t, *J* = 5.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.3 (3C), 42.5, 55.1, 56.8, 112.5, 114.7, 121.4, 129.8, 136.1, 159.9, 167.2; MS (ESI) *m*/*z* 276 ($M+Na^+$, 100%); Anal. calcd for $C_{13}H_{19}NO_2S$: C, 61.63; H, 7.56; N, 5.53. Found: C, 61.49; H, 7.39; N, 5.22.

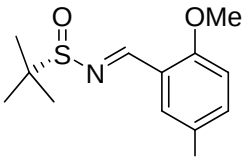
(*S*,*E*)-*N*-2,4-Dichlorobenzylidene-*tert*-butanesulfinamide (S_S)-3h



(S_S)-**3h**

Following the general procedure B, the condensation between (S_S)-*t*-butanesulfinamide (100 mg, 0.83 mmol) and 2,4-dichlorobenzaldehyde (287 mg, 1.66 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (S_S)-**3h** (171 mg, yield: 75%) as a pale yellow oil. $[\alpha]_D^{20}$ +139.7 (*c* 1.2, $CHCl_3$); IR (film): 2961, 2925, 1595, 1583, 1470, 1384, 1364, 1135, 1090, 1052 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.24 (s, 9H), 7.30-8.01 (m, 3H), 8.95 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6 (3C), 58.1, 127.7, 129.9, 130.0, 130.1, 137.0, 138.8, 158.7; MS (ESI) *m*/*z* 278 ($M+H^+$, 100%); Anal. calcd for $C_{11}H_{13}Cl_2NOS$: C, 47.49; H, 4.71; N, 5.03. Found: C, 47.32; H, 4.57; N, 5.18.

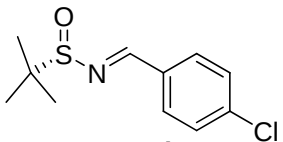
(*S*,*E*)-*N*-2,5-Dimethoxybenzylidene-*tert*-butanesulfinamide (S_S)-3i



(S_S)-**3i**

Following the general procedure B, the condensation between (S_S)-*t*-butanesulfinamide (120 mg, 1.0 mmol) and 2,5-dimethoxybenzaldehyde (332 mg, 2.0 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/10, *v*/*v*), *t*-butanesulfinimine (S_S)-**3i** (213 mg, yield: 80%) as a pale yellow oil. $[\alpha]_D^{20}$ +125.3 (*c* 1.2, $CHCl_3$); IR (film): 2958, 2836, 1591, 1496, 1464, 1279, 1263, 1179, 1165, 1083, 1044, 810, 710 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.25 (s, 9H), 3.80 (s, 3H), 3.85 (s, 3H), 6.88-7.52 (m, 3H), 9.04 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.5 (3C), 55.7, 56.0, 57.6, 111.6, 112.8, 120.3, 123.0, 153.4, 154.3, 158.5; MS (ESI) *m*/*z* 292 ($M+Na^+$, 100%); Anal. calcd for $C_{13}H_{19}NO_3S$: C, 57.97; H, 7.11; N, 5.20. Found: C, 57.65; H, 7.45; N, 5.37.

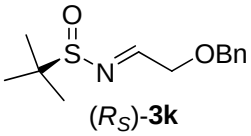
(*S*,*E*)-*N*-4-Chlorobenzylidene-*tert*-butanesulfinamide (S_S)-3j



(S_S)-**3j**

Following the general procedure B, the condensation between (S_S)-*t*-butanesulfinamide (120 mg, 1.0 mmol) and 4-chlorobenzaldehyde (282 mg, 2.0 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/20, *v*/*v*), *t*-butanesulfinimine (S_S)-**3j** (208 mg, yield: 86%) as colorless crystals. mp 39 °C (EtOAc/PE) {lit.[6] mp 38-40 °C}; $[\alpha]_D^{20}$ +91.3 (*c* 1.0, $CHCl_3$) {lit.[7] $[\alpha]_D^{26}$ –93.1 (*c* 1.0, $CHCl_3$)}. The spectral data of (S_S)-**3j** are identical with those reported in the literature.[7]

(*R*,*E*)-*N*-Benzyloxyethylidene-*tert*-butanesulfinamide (R_S)-3k



(R_S)-**3k**

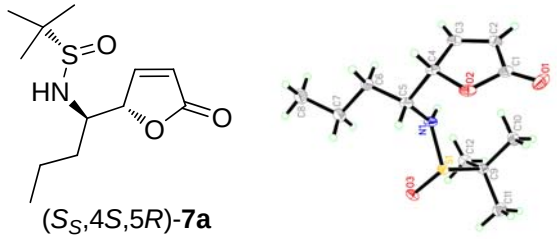
Following the general procedure A, the condensation between (R_S)-*t*-butanesulfinamide (403 mg, 3.3 mmol) and benzyloxyacetaldehyde (0.9 mL, 6.7 mmol) produced, after flash chromatography (eluent: PE/CH_2Cl_2 = 1/20, *v*/*v*), *t*-butanesulfinimine (R_S)-**3k** (733 mg, yield: 87%) as a pale yellow oil. $[\alpha]_D^{20}$ –214.3 (*c* 1.0, $CHCl_3$) {lit.[8] $[\alpha]_D^{23}$ –212 (*c* 1.0, $CHCl_3$)}. The spectral data of (R_S)-**3k** are identical with those reported in the literature.[8]

General procedure C: Synthesis of butenolides (7).

2-(*tert*-Butyldimethylsilyloxy)furan (TBSOF) (1.5 mmol) was added to a solution of **3** (1.0 mmol) in CH_2Cl_2 (2 mL) and the solution was cooled to –78 °C under N_2. TMSOTf (0.18 mL, 1.0 mmol) was added dropwise. After being stirred for 1 h at the same temperature, the reaction was quenched by addition of a saturated aqueous $NaHCO_3$. The mixture was extracted with CH_2Cl_2 (10 mL × 3). The combined organic layers were dried over Na_2SO_4, filtered, and concentrated under reduced pressure to provide an oily residue that was purified by flash chromatography on silica gel (eluent: EtOAc/PE = 1:1, *v*/*v*). The ratio of diastereomers was determined by ^{1}H NMR.

(*S*,*R*)-5-[(*S*)-Propyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (S_S,4*S*,5*R*)

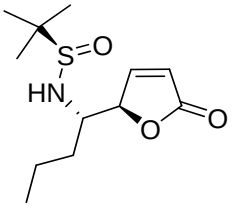
-7a



(S_S,4*S*,5*R*)-**7a**

Following the general procedure C, the VM reaction between TBSOF (186 mg, 0.94 mmol) and (S_S)-**3a** (110 mg, 0.63 mmol) produced butenolide (S_S)-**7a** (133 mg, yield: 82%) as a diastereomeric mixture (dr = 91:9, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (S_S,4*S*,5*R*)-**7a** as white crystals. mp 112-114 °C (EtOAc/PE); $[\alpha]_D^{20}$ –52.4 (*c* 0.4, $CHCl_3$); IR (film): 3233, 2960, 2872, 1753, 1460, 1416, 1364, 1166, 1103, 1048 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.95 (d, *J* = 6.9 Hz, 3H), 1.19 (s, 9H), 1.38-1.68 (m, 4H), 3.01 (d, *J* = 7.4 Hz, 1H), 3.52-3.60 (m, 1H), 5.03 (dt, *J* = 5.0, 1.8 Hz, 1H), 6.21 (dd, *J* = 5.8, 1.8 Hz, 1H), 7.48 (dd, *J* = 5.8, 1.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.7, 19.0, 22.6 (3C), 34.4, 56.4, 57.9, 85.4, 123.7, 152.6, 172.4; MS (ESI) *m*/*z* 282 (M+Na$^+$, 100%); HRMS calcd for $C_{12}H_{21}NO_3S$ [M+Na]$^+$: 282.1134; found: 282.1132.

(*R*,*S*)-5-[(*R*)-Propyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (R_S,4*R*,5*S*-7a

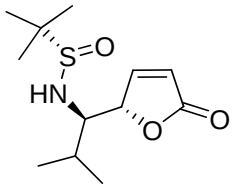


(R_S,4*R*,5*S*)-**7a**

Following the general procedure C, the VM reaction between TBSOF (3.40 g, 17.1 mmol) and (R_S)-**3a** (2.00 g, 11.4 mmol) produced butenolide (R_S)-**7a** (2.40 g, yield: 81%) as a diastereomeric mixture (dr = 93:7, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (R_S,4*R*,5*S*)-**7a** as a white solid. mp 110-111 ºC (EtOAc/PE); $[\alpha]_D^{20}$ +55.3 (*c* 1.2, $CHCl_3$). The spectral data of (R_S,4*R*,5*S*)-**7a** are identical with those of (S_S,4*S*,5*R*)-**7a**. HRMS calcd for $C_{12}H_{21}NO_3S$ [M+Na]$^+$: 282.1134; found: 282.1133.

(*S*,*R*)-5-[(*S*)-2-Propyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (S_S,4*S*,5

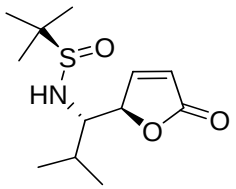
***R*)-7b**



(S_S,4*S*,5*R*)-**7b**

Following the general procedure C, the VM reaction between TBSOF (104 mg, 0.52 mmol) and (S_S)-**3b** (61 mg, 0.35 mmol) produced butenolide (S_S)-**7b** (77 mg, yield: 86%) as a diastereomeric mixture (dr = 97:3, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (S_S,4*S*,5*R*)-**7b** as a white solid. mp 152-154 °C (EtOAc/PE); $[\alpha]_D^{20}$ –133.7 (*c* 1.0, $CHCl_3$); IR (film): 3237, 3061, 2972, 2927, 1750, 1469, 1413, 1168, 1125, 1059 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.04 (d, *J* = 6.8 Hz, 3H), 1.07 (d, *J* = 6.8 Hz, 3H), 1.17 (s, 9H), 1.94-2.06 (m, 1H), 3.10 (d, *J* = 7.4 Hz, 1H), 3.32-3,38 (m, 1H), 5.05 (dt, *J* = 6.0, 1.8 Hz, 1H), 6.17 (dd, *J* = 5.8, 1.8 Hz, 1H), 7.49 (dd, *J* = 5.8, 1.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.3, 19.7, 22.6 (3C), 30.4, 56.5, 63.1, 83.8, 123.5, 153.3, 172.3; MS (ESI) *m*/*z* 282 (M+Na$^+$, 100%); HRMS calcd for $C_{12}H_{21}NO_3S$ [M+Na]$^+$: 282.1134; found: 282.1132.

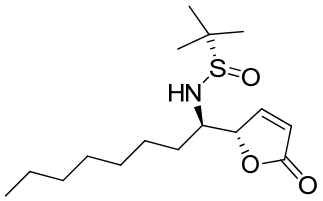
(*R*,*S*)-5-[(*R*)-2-Propyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*R*$_S$,4*R*, 5*S*)-7b



(R_S,4*R*,5*S*)-**7b**

Following the general procedure C, the VM reaction between TBSOF (1.70 g, 8.6 mmol) and (R_S)-**3b** (1.00 g, 5.7 mmol) produced butenolide (R_S)-**7b** (1.24 g, yield: 84%) as a diastereomeric mixture (dr = 97:3, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/hexane = 1/1, *v*/*v*) to give butenolide (R_S,4*R*,5*S*)-**7b** as a white solid. mp 155-156 ºC; $[\alpha]_D^{20}$ +135.1 (*c* 1.0, $CHCl_3$). The spectral data of (R_S,4*R*,5*S*)-**7b** are identical with those of (S_S,4*S*,5*R*)-**7b**. HRMS calcd for $C_{12}H_{21}NO_3S$ [M+Na]$^+$: 282.1134; found: 282.1132.

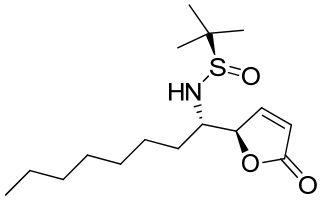
(*S*,*R*)-5-[(*S*)-Heptyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*S*$_S$,4*S*,5*R*)-7c



(*S*$_S$,4*S*,5*R*)-**7c**

Following the general procedure C, the VM reaction between TBSOF (172 mg, 0.87 mmol) and (*S*$_S$)-**3c** (134 mg, 0.58 mmol) produced butenolide (*S*$_S$)-**7c** (159 mg, yield: 87%) as a diastereomeric mixture (dr = 92:8, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (*S*$_S$,4*S*,5*R*)-**7c** as a pale yellow oil. $[\alpha]_D^{20}$ –69.6 (*c* 1.1, $CHCl_3$); IR (film): 3237, 2955, 2926, 2857, 1756, 1466, 1364, 1164, 1053 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.84 (brs, 3H, CH_3), 1.16 (s, 9H), 1.20-1.70 (m, 12H), 3.05 (d, *J* = 7.0 Hz, 1H), 3.51 (m, 1H), 5.01 (m, 1H), 6.17 (dd, *J* = 5.6, 2.0 Hz, 1H), 7.47 (dd, *J* = 5.6, 1.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.9, 22.5, 22.6 (3C), 25.6, 28.9, 29.2, 31.6, 32.4, 56.3, 58.2, 85.3, 123.6, 152.7, 172.3; MS (ESI) *m*/*z* 338 (M+Na$^+$, 100%); HRMS calcd for $C_{16}H_{29}NO_3S$ $[M+H]^+$: 316.1941; found: 316.1933.

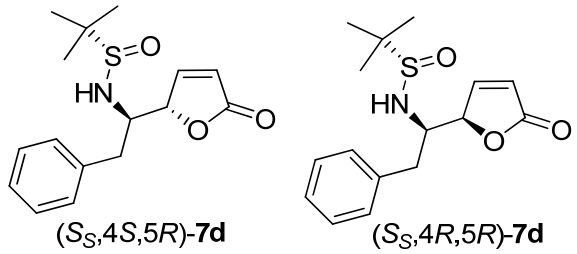
(*R*,*S*)-5-[(*R*)-Heptyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*R*$_S$,4*R*,5*S*)-7c



(*R*$_S$,4*R*,5*S*)-**7c**

Following the general procedure C, the VM reaction between TBSOF (350 mg, 1.8 mmol) and (*R*$_S$)-**3c** (270 mg, 1.2 mmol) produced butenolide (*R*$_S$)-**7c** (302 mg, yield: 82%) as a diastereomeric mixture (dr = 90:10, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (*R*$_S$,4*R*,5*S*)-**7c** as a pale yellow oil. $[\alpha]_D^{20}$ +68.8 (*c* 1.0, $CHCl_3$). The spectral data of (*R*$_S$,4*R*,5*S*)-**7c** are identical with those of (*S*$_S$,4*S*,5*R*)-**7c**. HRMS calcd for $C_{16}H_{29}NO_3S$ $[M+Na]^+$: 338.1760; found: 338.1762.

(*S*,*R*)-5-[(*S*)-Benzyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*S*$_S$,4*S*,5*R*) -7d and (*S*$_S$,4*R*,5*R*)-7d



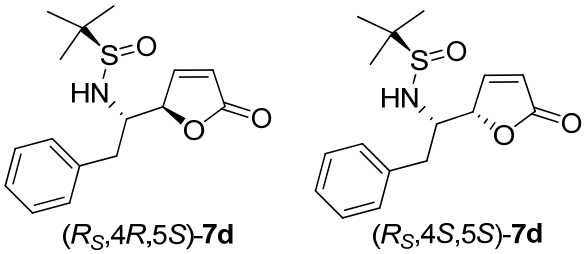
(*S*$_S$,4*S*,5*R*)-**7d** (*S*$_S$,4*R*,5*R*)-**7d**

Following the general procedure C, the VM reaction between TBSOF (186 mg, 0.94 mmol) and (*S*$_S$)-**3d** (140 mg, 0.63 mmol) produced butenolide (*S*$_S$)-**7d** (155 mg, yield: 80%) as a diastereomeric mixture (dr = 91:9, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (*S*$_S$,4*S*,5*R*)-**7d** (141 mg) and (*S*$_S$,4*R*,5*R*)-**7d** (14 mg).

(*S*$_S$,4*S*,5*R*)-**7d**: pale yellow oil. $[\alpha]_D^{20}$ –34.4 (*c* 1.1, $CHCl_3$); IR (film): 3207, 2962, 2927, 1755, 1455, 1416, 1165, 1094, 1042 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.18 (s, 9H), 3.08 (dd, *J* = 14.0, 6.3 Hz, 1H), 3.25 (dd, *J* = 14.0, 5.0 Hz, 1H), 3.39 (d, *J* = 8.7 Hz, 1H), 3.71-3.81 (m, 1H), 4.89 (dt, *J* = 7.0, 1.8 Hz, 1H), 6.17 (dd, *J* = 5.8, 1.8 Hz, 1H), 7.26-7.39 (m, 5H), 7.42 (dd, *J* = 5.8, 1.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.5 (3C), 38.5, 56.5, 58.5, 83.0, 123.0, 127.3, 128.9 (2C), 130.3 (2C), 134.9, 153.7, 172.3; MS (ESI) *m*/*z* 330 (M+Na$^+$, 100%); HRMS calcd for $C_{16}H_{21}NO_3S$ $[M+H]^+$: 308.1315; found: 308.1313.

(*S*$_S$,4*R*,5*R*)-**7d**: pale yellow oil. $[\alpha]_D^{20}$ +78.9 (*c* 0.8, $CHCl_3$). The spectral data of (*S*$_S$,4*R*,5*R*)-**7d** are identical with those of (*R*$_S$,4*S*,5*S*)-**7d**.

(*R*,*S*)-5-[(*R*)-Benzyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*R*$_S$,4*R*,5*S*) -7d and (*R*$_S$,4*S*,5*S*)-7d



(*R*$_S$,4*R*,5*S*)-**7d** (*R*$_S$,4*S*,5*S*)-**7d**

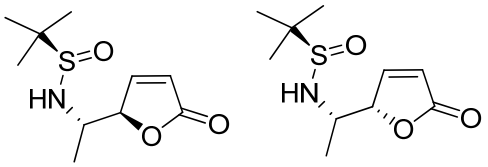
Following the general procedure C, the VM reaction between TBSOF (3.60 g, 18.2

mmol) and (R_S)-**3d** (2.70 g, 12.1 mmol) produced butenolide (R_S)-**7d** (2.90 g, yield: 78%) as a diastereomeric mixture (dr = 89:11, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (R_S,4*R*,5*S*)-**7d** (2.58 g) and (R_S,4*S*,5*S*)-**7d** (319 mg).

(R_S,4*R*,5*S*)-**7d**: pale yellow oil. $[\alpha]_D^{20}$ +36.2 (*c* 1.1, $CHCl_3$). The spectral data of (R_S,4*R*,5*S*)-**7d** are identical with those of (R_S,4*R*,5*S*)-**7d**. HRMS calcd for $C_{16}H_{21}NO_3S$ $[M+Na]^+$: 330.1134; found: 330.1134.

(R_S,4*S*,5*S*)-**7d**: pale yellow oil. $[\alpha]_D^{20}$ –79.4 (*c* 1.2, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.15 (s, 9H), 3.06 (dd, *J* = 13.4, 10.4 Hz, 1H), 3.22 (d, *J* = 7.5 Hz, 1H), 3.27 (dd, *J* = 13.4, 5.6 Hz, 1H), 3.80-3.86 (m, 1H), 4.96 (dt, *J* = 3.6, 1.8 Hz, 1H), 6.13 (dd, *J* = 5.7, 1.8 Hz, 1H), 7.29-7.37 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.7 (3C), 40.7, 56.9, 58.0, 82.3, 122.9, 127.3, 129.0 (2C), 129.6 (2C), 136.4, 154.7, 172.7.

(*R*,*S*)-5-[(*R*)-Methyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (R_S,4*R*,5*S*)-7e and (R_S,4*S*,5*S*)-7e



(R_S,4*R*,5*S*)-**7e** (R_S,4*S*,5*S*)-**7e**

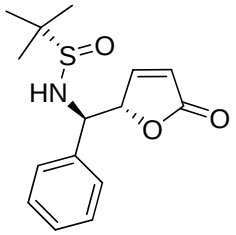
Following the general procedure C, the VM reaction between TBSOF (350 mg, 1.7 mmol) and (R_S)-**3e** (170 mg, 1.16 mmol) produced butenolide (R_S)-**7e** (203 mg, yield: 76%) as a diastereomeric mixture (dr = 82:18, ^{1}H NMR), which was separated by flash chromatography on silica gel (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (R_S,4*R*,5*S*)-**7e** (167 mg) and (R_S,4*S*,5*S*)-**7e** (36 mg).

(R_S,4*R*,5*S*)-**7e**: pale yellow oil. $[\alpha]_D^{20}$ +44.8 (*c* 1.2, $CHCl_3$); IR (film): 3237, 2979, 1788, 1754, 1459 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.20 (s, 9H), 1.33 (d, *J* = 6.8 Hz, 3H), 3.22 (d, *J* = 8.0 Hz, 1H), 3.68-3.76 (m, 1H), 5.03-5.05 (m, 1H), 6.22 (dd, *J* = 5.8, 2.0 Hz, 1H), 7.48 (dd, *J* = 5.8, 1.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.2, 22.5 (3C), 53.9, 56.3, 86.0, 123.5, 152.7, 172.4; HRMS calcd for $C_{10}H_{17}NO_3S$ $[M+Na]^+$: 254.0821; found: 254.0826.

(R_S,4*S*,5*S*)-**7e**: pale yellow oil. $[\alpha]_D^{20}$ –21.3 (*c* 1.2, $CHCl_3$); IR (film): 3249, 2920,

1754, 1459, 1163, 1052 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.17 (s, 9H), 1.45 (d, *J* = 6.9 Hz, 3H), 3.18 (d, *J* = 6.6 Hz, 1H), 3.73-3.81 (m, 1H), 5.01-5.03 (m, 1H), 6.22 (dd, *J* = 5.7, 2.0 Hz, 1H), 7.48 (dd, *J* = 5.7, 1.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 19.7, 22.6 (3C), 53.0, 56.6, 86.0, 123.2, 153.7, 172.5; HRMS calcd for $C_{10}H_{17}NO_3S$ $[M+Na]^+$: 254.0821; found: 254.0825.

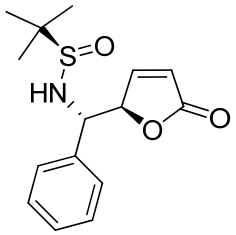
(*S*,*R*)-5-[(*S*)-Phenyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*S*$_S$,4*S*,5*R*) -7f



(*S*$_S$,4*S*,5*R*)-**7f**

Following the general procedure C, the VM reaction between TBSOF (166 mg, 0.84 mmol) and (*S*$_S$)-**3f** (117 mg, 0.56 mmol) produced butenolide (*S*$_S$)-**7f** (123 mg, yield: 75%) as a diastereomeric mixture (dr = 93:7, ^1H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (*S*$_S$,4*S*,5*R*)-**7f** as a pale yellow oil. $[\alpha]_D^{20}$ –83.3 (*c* 1.0, $CHCl_3$); IR (film): 3226, 2961, 2925, 1758, 1455, 1364, 1163, 1047 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.24 (s, 9H), 3.83 (d, *J* = 6.2 Hz, 1H), 4.84 (dd, *J* = 6.2, 4.3 Hz, 1H), 5.44 (m, 1H), 6.03 (dd, *J* = 5.7, 1.8 Hz, 1H), 7.27-7.43 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.5 (3C), 56.7, 59.9, 84.6, 123.5, 127.3 (2C), 128.7, 128.8 (2C), 136.1, 152.5, 172.2; MS (ESI) *m*/*z* 316 ($M+Na^+$, 100%); HRMS calcd for $C_{15}H_{19}NO_3S$ $[M+H]^+$: 294.1158; found: 294.1152.

(*R*,*S*)-5-[(*R*)-Phenyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*R*$_S$,4*R*,5 *S*)-7f

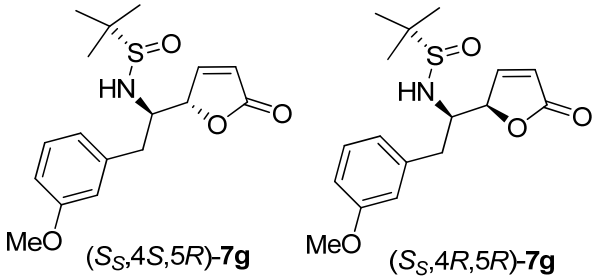


(*R*$_S$,4*R*,5*S*)-**7f**

Following the general procedure C, the VM reaction between TBSOF (852 mg, 4.4

mmol) and (R_S)-**3f** (600 mg, 2.87 mmol) produced butenolide (R_S)-**7f** (648 mg, yield: 77%) as a diastereomeric mixture (dr = 93:7, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (R_S,4*R*,5*S*)-**7f** as a pale yellow oil. $[\alpha]_D^{20}$ +83.4 (*c* 1.3, $CHCl_3$). The spectral data of (R_S,4*R*,5*S*)-**7f** are identical with those of (S_S,4*S*,5*R*)-**7f**. HRMS calcd for $C_{15}H_{19}NO_3S$ $[M+Na]^+$: 316.0978; found: 316.0984.

(*S*,*R*)-5-[(*S*)-3-Methoxybenzyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (S_S,4*S*,5*R*)-7g and (S_S,4*R*,5*R*)-7g



(S_S,4*S*,5*R*)-**7g** (S_S,4*R*,5*R*)-**7g**

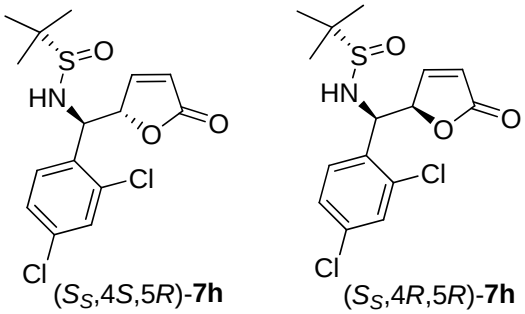
Following the general procedure C, the VM reaction between TBSOF (179 mg, 0.90 mmol) and (S_S)-**3g** (153 mg, 0.60 mmol) produced butenolide (S_S)-**7g** (171 mg, yield: 84%) as a diastereomeric mixture (dr = 89:11, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1.5, *v*/*v*) to give butenolide (S_S,4*S*,5*R*)-**7g** (152 mg) and (S_S,4*R*,5*R*)-**7g** (19 mg).

(S_S,4*S*,5*R*)-**7g**: pale yellow oil. $[\alpha]_D^{20}$ –26.8 (*c* 1.2, $CHCl_3$); IR (film): 3217, 2959, 1755, 1601, 1585, 1490, 1455, 1436, 1261, 1165, 1042 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.18 (s, 9H), 3.05 (dd, *J* = 13.8, 6.6 Hz, 1H), 3.22 (dd, *J* = 13.8, 5.0 Hz, 1H), 3.53 (d, *J* = 8.8 Hz, 1H), 3.73-3.79 (m, 1H), 3.80 (s, 3H), 4.91 (dt, *J* = 6.8, 1.7 Hz, 1H), 6.17 (dd, *J* = 5.8, 1.7 Hz, 1H), 6.78-7.28 (m, 4H), 7.47 (dd, *J* = 5.8, 1.7 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.3 (3C), 38.4, 55.0, 56.3, 58.3, 82.9, 112.7, 115.5, 122.2, 122.7, 129.7, 136.3, 153.7, 159.8, 172.1; MS (ESI) *m*/*z* 360 ($M+Na^+$, 100%); HRMS calcd for $C_{17}H_{23}NO_4S$ $[M+H]^+$: 338.1421; found: 338.1408.

(S_S,4*R*,5*R*)-**7g**: pale yellow oil. $[\alpha]_D^{20}$ +47.6 (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.15 (s, 9H), 3.02 (dd, *J* = 13.4, 10.4 Hz, 1H), 3.21-3.28 (m, 2H), 3.80 (s, 3H), 3.82-3.86 (m, 1H), 4.98 (dt, *J* = 3.6, 2.0 Hz, 1H), 6.13 (dd, *J* = 5.7, 2.0 Hz, 1H), 6.79-7.28 (m, 4H), 7.32 (dd, *J* = 5.7, 2.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6

(3C), 40.7, 55.2, 56.9, 57.9, 82.3, 112.8, 115.1, 121.8, 122.9, 130.0, 138.0, 154.7, 160.0, 172.7.

(*S*,*R*)-5-[(*S*)-2,4-Dichlorophenyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*S*$_S$,4*S*,5*R*)-7h and (*S*$_S$,4*R*,5*R*)-7h



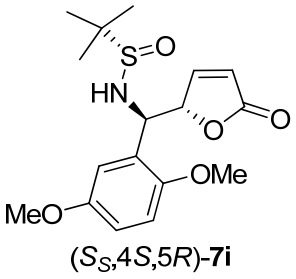
(*S*$_S$,4*S*,5*R*)-**7h** (*S*$_S$,4*R*,5*R*)-**7h**

Following the general procedure C, the VM reaction between TBSOF (141 mg, 0.71 mmol) and (*S*$_S$)-**3h** (132 mg, 0.48 mmol) produced butenolide (*S*$_S$)-**7h** (146 mg, yield: 85%) as a diastereomeric mixture (dr = 81:19, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/2, *v*/*v*) to give butenolide (*S*$_S$,4*S*,5*R*)-**7h** (118 mg) and (*S*$_S$,4*R*,5*R*)-**7h** (28 mg).

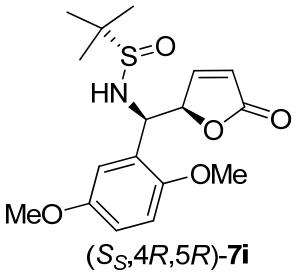
(*S*$_S$,4*S*,5*R*)-**7h**: pale yellow oil. $[\alpha]_D^{20}$ –80.0 (*c* 1.0, $CHCl_3$); IR (film): 2981, 2925, 1760, 1590, 1474, 1417, 1385, 1165, 1102, 1052 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.18 (s, 9H), 4.24 (d, *J* = 7.8 Hz, 1H), 5.31 (dd, *J* = 7.8, 3.8 Hz, 1H), 5.46 (m, 1H), 5.97 (dd, *J* = 5.7, 2.0 Hz, 1H), 7.21-7.36 (m, 3H), 7.47 (dd, *J* = 5.7, 1.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.4 (3C), 55.1, 57.0, 84.2, 123.5, 127.7, 129.4, 130.4, 132.1, 133.3, 135.1, 151.8, 171.7; MS (ESI) *m*/*z* 384 (M+Na$^+$, 100%); HRMS calcd for $C_{15}H_{17}Cl_2NO_3S$ $[M+H]^+$: 362.0379; found: 362.0381.

(*S*$_S$,4*R*,5*R*)-**7h**: pale yellow oil. $[\alpha]_D^{20}$ +57.8 (*c* 1.2, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.04 (s, 9H), 4.44 (d, *J* = 8.6 Hz, 1H), 5.14 (dd, *J* = 8.6, 3.2 Hz, 1H), 5.25 (m, 1H), 6.17 (dd, *J* = 5.7, 1.8 Hz, 1H), 7.16-7.43 (m, 3H), 7.44 (dd, *J* = 5.7, 1.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.4 (3C), 53.4, 57.3, 84.5, 123.1, 127.7, 129.4, 130.5, 132.8, 134.7, 134.9, 154.3, 172.4.

(*S*,*R*)-5-[(*S*)-2,5-Dimethoxyphenyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (*S*$_S$,4*S*,5*R*)-7i and (*S*$_S$,4*R*,5*R*)-7i



(S_S,4*S*,5*R*)-**7i**



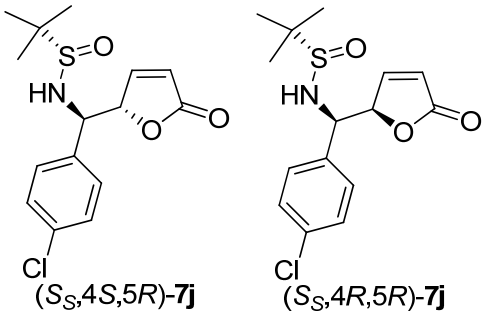
(S_S,4*R*,5*R*)-**7i**

Following the general procedure C, the VM reaction between TBSOF (143 mg, 0.72 mmol) and (S_S)-**3i** (130 mg, 0.48 mmol) produced butenolide (S_S)-**7i** (140 mg, yield: 82%) as a diastereomeric mixture (dr = 78:22, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (S_S,4*S*,5*R*)-**7i** (109 mg) and (S_S,4*R*,5*R*)-**7i** (31 mg).

(S_S,4*S*,5*R*)-**7i**: pale yellow oil. $[\alpha]_D^{20}$ −39.0 (*c* 0.9, $CHCl_3$); IR (film): 3225, 2959, 2837, 1756, 1501, 1464, 1428, 1222, 1164, 1044 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.21 (s, 9H), 3.74 (s, 3H), 3.82 (s, 3H), 4.37 (d, *J* = 8.6 Hz, 1H), 5.01 (dd, *J* = 8.6, 4.7 Hz, 1H), 5.36 (dt, *J* = 4.7, 1.7 Hz, 1H), 6.04 (dd, *J* = 5.8, 1.7 Hz, 1H), 6.79-6.87 (m, 3H), 7.41 (dd, *J* = 5.8, 1.7 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.4 (3C), 55.6, 55.7, 56.4, 56.7, 84.6, 111.8, 114.0, 114.8, 122.7, 125.4, 150.2, 153.0, 153.6, 172.3; MS (ESI) *m/z* 376 ($M+Na^+$, 100%); HRMS calcd for $C_{17}H_{23}NO_5S$ $[M+H]^+$: 354.1370; found: 354.1369.

(S_S,4*R*,5*R*)-**7i**: pale yellow oil. $[\alpha]_D^{20}$ +52.2 (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.15 (s, 9H), 3.69 (s, 3H), 3.76 (s, 3H), 4.32 (d, *J* = 8.4 Hz, 1H), 4.95 (dd, *J* = 8.4, 4.6 Hz, 1H), 5.29 (dt, *J* = 4.6, 1.8 Hz, 1H), 5.99 (dd, *J* = 5.7, 1.8 Hz, 1H), 6.73-6.79 (m, 3H), 7.35 (dd, *J* = 5.7, 1.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.4 (3C), 55.6, 55.7, 56.5, 56.7, 85.2, 111.9, 113.8, 114.9, 122.4, 125.4, 150.2, 153.1, 153.6, 172.5.

(*S*,*R*)-5-[(*S*)-4-Chlorophenyl-(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (S_S,4*S*,5*R*)-7j and (S_S,4*R*,5*R*)-7j



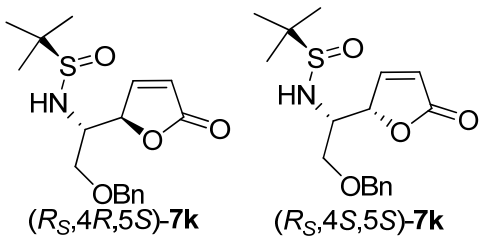
(S_S,4*S*,5*R*)-**7j** (S_S,4*R*,5*R*)-**7j**

Following the general procedure C, the VM reaction between TBSOF (255 mg, 1.29 mmol) and (S_S)-**3j** (210 mg, 0.86 mmol) produced butenolide (S_S)-**7j** (220 mg, yield: 78%) as a diastereomeric mixture (dr = 81:19, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (S_S,4*S*,5*R*)-**7j** (178 mg) and (S_S,4*R*,5*R*)-**7j** (42 mg).

(S_S,4*S*,5*R*)-**7j**: pale yellow oil. $[\alpha]_D^{20}$ –54.8 (*c* 1.1, $CHCl_3$); IR (film): 3224, 2959, 2924, 1755, 1599, 1493, 1455, 1415, 1364, 1164, 1092, 1044 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.18 (s, 9H), 3.87 (d, *J* = 5.9 Hz, 1H), 4.69 (dd, *J* = 5.9, 4.0 Hz, 1H), 5.35 (dt, *J* = 4.0, 1.8 Hz, 1H), 6.16 (dd, *J* = 5.7, 1.8 Hz, 1H), 7.33-7.38 (m, 4H), 7.40 (dd, *J* = 5.7, 1.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.5 (3C), 57.0, 58.8, 84.8, 123.4, 129.0 (2C), 129.1 (2C), 134.6, 136.2, 153.5, 172.1; MS (ESI) *m*/*z* 350 (M+Na$^+$, 100%); HRMS calcd for $C_{15}H_{18}ClNO_3S$ $[M+H]^+$: 328.0769; found: 328.0762.

(S_S,4*R*,5*R*)-**7j**: pale yellow oil. $[\alpha]_D^{20}$ +34.4 (*c* 0.8, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.18 (s, 9H), 3.72 (d, *J* = 5.6 Hz, 1H), 4.66 (dd, *J* = 5.6, 4.0 Hz, 1H), 5.35 (dt, *J* = 4.0, 1.8 Hz, 1H), 6.17 (dd, *J* = 5.8, 1.8 Hz, 1H), 7.34-7.40 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6 (3C), 57.1, 59.1, 84.8, 123.7, 129.1 (2C), 129.3 (2C), 134.9, 136.2, 153.4, 172.1.

(*R*,*S*)-5-[(*R*)-(Benzyloxymethyl)(*tert*-butanesulfinylamino)methyl]furan-2(5*H*)-one (R_S,4*R*,5*S*)-7k and (R_S,4*S*,5*S*)-7k



(R_S,4*R*,5*S*)-**7k** (R_S,4*S*,5*S*)-**7k**

Following the general procedure C, the VM reaction between TBSOF (155 mg, 0.75

mmol) and (R_S)-**3k** (130 mg, 0.51 mmol) produced butenolide (R_S)-**7k** (139 mg, yield: 80%) as a diastereomeric mixture (dr = 75:25, ^{1}H NMR), which was separated by flash chromatography (eluent: EtOAc/PE = 1/1, *v*/*v*) to give butenolide (*R*$_S$,4*R*,5*S*)-**7k** (104 mg) and (*R*$_S$,4*S*,5*S*)-**7k** (35 mg).

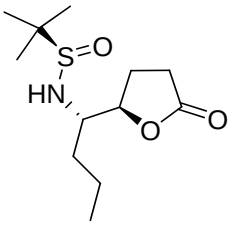
(*R*$_S$,4*R*,5*S*)-**7k**: pale yellow oil. $[\alpha]_D^{20}$ +96.5 (*c* 1.3, $CHCl_3$); IR (film): 3280, 2924, 2868, 1758, 1454, 1388, 1065, 1020 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.22 (s, 9H), 3.68-3.71 (m, 1H), 3.79 (d, *J* = 9.6 Hz, 1H), 3.81 (dd, *J* = 9.6, 4.2 Hz, 1H), 3.91 (dd, *J* = 9.6, 2.3 Hz, 1H), 4.53 (d, *J* = 11.5 Hz, 1H), 4.60 (d, *J* = 11.5 Hz, 1H), 5.14 (dt, *J* = 5.8, 1.8 Hz, 1H), 6.17 (dd, *J* = 5.8, 1.8 Hz, 1H), 7.32-7.39 (m, 5H), 7.55 (dd, *J* = 5.8, 1.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6 (3C), 56.4, 58.4, 70.4, 73.7, 83.2, 122.8, 127.9 (2C), 128.1, 128.6 (2C), 137.2, 154.2, 172.4; HRMS calcd for $C_{17}H_{23}NO_4S$ $[M+Na]^+$: 360.1240; found: 360.1245.

(*R*$_S$,4*S*,5*S*)-**7k**: pale yellow oil. $[\alpha]_D^{20}$ –90.5 (*c* 1.3, $CHCl_3$); IR (film): 3265, 2924, 2867, 1755, 1453, 1364, 1071, 1019 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.17 (s, 9H), 3.51 (d, *J* = 7.8 Hz, 1H), 3.68-3.71 (m, 1H), 3.76-3.80 (m, 2H), 4.51-4.60 (m, 2H), 5.33 (dd, *J* = 3.8, 2.0 Hz, 1H), 6.14 (dd, *J* = 5.8, 2.0 Hz, 1H), 7.31-7.39 (m, 5H), 7.41 (dd, *J* = 5.8, 2.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6 (3C), 56.5, 56.7, 69.7, 73.4, 82.2, 122.5, 127.8 (2C), 128.0, 128.5 (2C), 137.2, 154.4, 172.7; HRMS calcd for $C_{17}H_{23}NO_4S$ $[M+Na]^+$: 360.1240; found: 360.1241.

General procedure D: Synthesis of lactones 8.

To a stirred solution of butenolide (R_S)-**7** (1.0 mmol) in EtOAc (15 mL) was added 10% Pd/C, and the resulting suspension was stirred under a balloon filled with hydrogen for 20 h. The catalyst was filtered off through a Celite pad, and the pad was washed with EtOAc. The filtrates were concentrated and purified by flash chromatography on silica gel (eluent: PE/EtOAc = 3/1, *v*/*v*) to give lactones **8**.

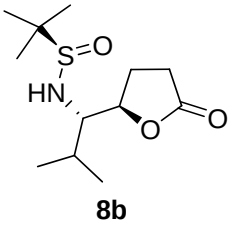
(*R*,*S*)-5-[(*R*)-Propyl-(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-one (8a)



8a

Following the general procedure D, (R_S,4*R*,5*S*)-**7a** (500 mg, 1.9 mmol) and 10% Pd/C (100 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 3/1, *v*/*v*), lactone **8a** (458 mg, yield: 91%) as a colorless oil. $[\alpha]_D^{20}$ –54.2 (*c* 1.0, $CHCl_3$); IR (film): 3324, 2958, 1777, 1763, 1188, 1147, 1061, 1028 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.94 (t, *J* = 7.0 Hz, 3H), 1.20 (s, 9H), 1.39-1.63 (m, 4H), 1.99-2.09 (m, 1H), 2.21-2.29 (m, 1H), 2.51-2.55 (m, 2H), 3.08 (d, *J* = 6.3 Hz, 1H), 3.45-3.52 (m, 1H), 4.42-4.48 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.7, 18.7, 22.6 (3C), 23.2, 28.4, 33.8, 56.1, 58.6, 82.0, 176.5; HRMS calcd for $C_{12}H_{23}NO_3S$ $[M+Na]^+$: 284.1291; found: 284.1294.

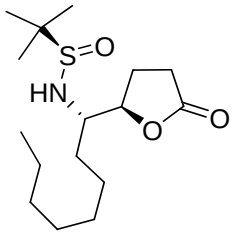
(*R*,*S*)-5-[(*R*)-2-Propyl-(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-one (8b)



8b

Following the general procedure D, (R_S,4*R*,5*S*)-**7b** (300 mg, 1.16 mmol) and 10% Pd/C (60 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 3/1, *v*/*v*), lactone **8b** (287 mg, yield: 95%) as a white solid. mp 127-128 ºC; $[\alpha]_D^{20}$ –35.6 (*c* 1.0, $CHCl_3$); IR (film): 3329, 2963, 2873, 1769, 1468, 1056, 1030 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.03 (d, *J* = 6.8 Hz, 3H), 1.05 (d, *J* = 6.8 Hz, 3H), 1.22 (s, 9H), 1.98-2,10 (m, 2H), 2.22-2.30 (m, 1H), 2.52-2.56 (m, 2H), 3.13 (d, *J* = 6.6 Hz, 1H), 3.31 (m, 1H), 4.53 (dd, *J* = 14.5, 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.9, 19.6, 22.7 (3C), 24.1, 28.4, 29.3, 56.3, 63.8, 80.4, 176.4; HRMS calcd for $C_{12}H_{23}NO_3S$ $[M+Na]^+$: 284.1291; found: 284.1291.

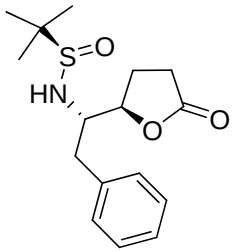
(*R*,*S*)-5-[(*R*)-Heptyl-(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-one (8c)



8c

Following the general procedure D, (*R*$_S$,4*R*,5*S*)-**7c** (100 mg, 0.32 mmol) and 10% Pd/C (20 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 2/1, *v*/*v*), lactone **8c** (96 mg, yield: 95%) as a white solid. mp 66-67 ºC; $[\alpha]_D^{20}$ –51.0 (*c* 0.8, $CHCl_3$); IR (film): 3290, 2926, 2856, 1777, 1462, 1384, 1180, 1049, 1019 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, *J* = 6.9 Hz, 3H), 1.23 (s, 9H), 1.28-1.32 (m, 8H), 1.51-1.59 (m, 2H), 1.64-1.73 (m, 2H), 2.01-2.11 (m, 1H), 2.24-2.32 (m, 1H), 2.54-2.58 (m, 2H), 3.04 (d, *J* = 6.2 Hz, 1H), 3.48-3.53 (m, 1H), 4.46-4.51 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.0, 22.6 (4C), 23.3, 25.5, 28.5, 29.0, 29.3, 31.7, 31.8, 56.2, 58.9, 82.0, 176.6; HRMS calcd for $C_{16}H_{31}NO_3S$ $[M+Na]^+$: 340.1917; found: 340.1920.

(*R*,*S*)-5-[(*R*)-Benzyl-(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-one (8d)

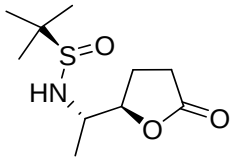


8d

Following the general procedure D, (*R*$_S$,4*R*,5*S*)-**7d** (500 mg, 1.63 mmol) and 10% Pd/C (100 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 2/1, *v*/*v*), lactone **8d** (468 mg, yield: 93%) as a white solid. mp 69-70 ºC; $[\alpha]_D^{20}$ –41.4 (*c* 1.3, $CDCl_3$); IR (film): 3293, 2960, 1776, 1455, 1178, 1095 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.17 (m, 9H), 2.00-2.10 (m, 1H), 2.20-2.29 (m, 1H), 2.51-2.57 (m, 2H), 3.07 (dd, *J* = 13.9, 6.0 Hz, 1H), 3.21 (dd, *J* = 13.9, 4.9 Hz, 1H), 3.35 (d, *J* = 8.3 Hz, 1H), 3.68-3.75 (m, 1H), 4.28 (dd, *J* = 13.9, 4.9 Hz, 1H), 7.26-7.36 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.5 (3C), 24.4, 28.3, 37.8, 56.3, 59.5, 79.3, 127.0, 128.7 (2C), 130.3 (2C), 135.0, 176.4; HRMS calcd for $C_{16}H_{23}NO_3S$ $[M+Na]^+$:

332.1291; found: 332.1292.

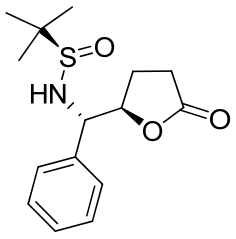
(*R*,*S*)-5-[(*R*)-Methyl-(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-one (8e)



8e

Following the general procedure D, (R_S,4*R*,5*S*)-**7e** (630 mg, 2.73 mmol) and 10% Pd/C (126 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 2/1, *v*/*v*), lactone **8e** (591 mg, yield: 93%) as a pale yellow oil. $[\alpha]_D^{20}$ –62.9 (*c* 1.1, $CHCl_3$); IR (film): 3229, 2979, 1772, 1460, 1420, 1364, 1183, 1146, 1050 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.22 (s, 9H), 1.36 (d, *J* = 6.8 Hz, 3H), 1.99-2.09 (m, 1H), 2.26-2.35 (m, 1H), 2.54-2.58 (m, 2H), 3.13 (d, *J* = 7.3 Hz, 1H), 3.55-3.64 (m, 1H), 4.41-4.49 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.1, 22.5 (3C), 23.6, 28.3, 55.1, 56.1, 83.0, 176.5; HRMS calcd for $C_{10}H_{19}NO_3S$ $[M+Na]^+$: 256.0978; found: 256.0986.

(*R*,*S*)-5-[(*R*)-Phenyl-(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-one (8f)

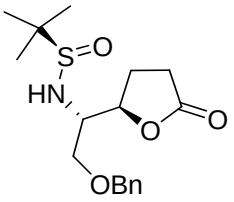


8f

Following the general procedure D, (R_S,4*R*,5*S*)-**7f** (252 mg, 0.86 mmol) and 10% Pd/C (50 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 2/1, *v*/*v*), lactone **8f** (233 mg, yield: 92%) as a white solid. mp 125-128 ºC; $[\alpha]_D^{20}$ –34.6 (*c* 1.3, $CHCl_3$); IR (film): 3294, 2950, 1776, 1455, 1123, 1095, 1038 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.24 (s, 9H), 1.87-2.01 (m, 2H), 2.24-2.37 (m, 2H), 3.86 (d, *J* = 5.5 Hz, 1H), 4.56 (dd, *J* = 5.5, 3.8 Hz, 1H), 4.94-5.01 (m, 1H), 7.34-7.41 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6 (3C), 23.7, 27.6, 56.5, 61.2, 81.1, 128.3 (2C), 128.8, 129.0 (2C), 136.5, 176.6; HRMS calcd for $C_{15}H_{21}NO_3S$ $[M+Na]^+$: 318.1134; found: 318.1136.

(*R*,*S*)-5-[(*R*)-(Benzyloxymethyl)(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-on

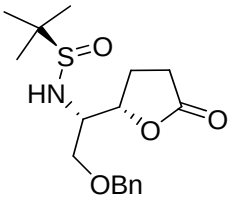
e (R_S,4*R*,5*S*)-8g



8g

Following the general procedure D, (R_S,4*R*,5*S*)-**7g** (800 mg, 2.37 mmol) and 10% Pd/C (170 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 2/1, *v*/*v*), lactone (R_S,4*R*,5*S*)-**8g** (716 mg, yield: 89%) as a pale yellow oil. $[\alpha]_D^{20}$ –22.4 (*c* 1.2, $CHCl_3$); IR (film): 3287, 2924, 2868, 1776, 1415, 1385, 1181, 1070, 1019 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.24 (s, 9H), 2.08-2.16 (m, 1H), 2.28-2.36 (m, 1H), 2.52-2.57 (m, 2H), 3.49-3.53 (m, 1H), 3.79 (ddd, *J* = 9.5, 3.8, 1.3 Hz, 1H), 3.88-3.95 (m, 2H), 4.52-4.63 (m, 3H), 7.28-7.39 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6 (3C), 25.0, 28.4, 56.3, 59.5, 70.1, 73.5, 79.1, 127.8 (2C), 127.9, 128.5 (2C), 137.5, 176.5; HRMS calcd for $C_{17}H_{25}NO_4S$ $[M+Na]^+$: 362.1397; found: 362.1400.

(*S*,*S*)-5-[(*R*)-(Benzyloxymethyl)(*tert*-butanesulfinylamino)methyl]furan-2(4*H*)-on e (R_S,4*S*,5*S*)-8g

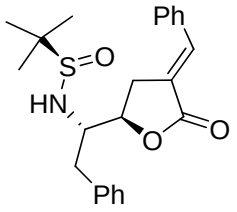


(R_S,4*S*,5*S*)-**8g**

Following the general procedure D, (R_S,4*S*,5*S*)-**7k** (330 mg, 0.98 mmol) and 10% Pd/C (70 mg) produced, after flash chromatography on silica gel (eluent: PE/EtOAc = 2/1, *v*/*v*), lactone (R_S,4*S*,5*S*)-**8g** (295 mg, yield: 89%) as a pale yellow oil. $[\alpha]_D^{20}$ +14.0 (*c* 0.7, $CHCl_3$); IR (film): 3255, 2925, 2867, 1776, 1415, 1384, 1187, 1075, 1029 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.24 (s, 9H), 2.07-2.17 (m, 1H), 2.19-2.28 (m, 1H), 2.51-2.58 (m, 2H), 3.46-3.51 (m, 1H), 3.64-3.68 (m, 1H), 3.83-3.86 (m, 1H), 4.53 (d, *J* = 11.6 Hz, 1H), 4.58 (d, *J* = 11.6 Hz, 1H), 4.87 (ddd, *J* = 9.9, 7.7, 2.6 Hz, 1H), 7.31-7.39 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.6 (3C), 23.8, 28.5, 56.5,

59.1, 70.2, 73.5, 78.9, 127.8 (2C), 127.9, 128.4 (2C), 137.5, 176.7; HRMS calcd for $C_{17}H_{25}NO_4S$ $[M+Na]^+$: 362.1397; found: 362.1400.

(5*R*)-3-Benzylidene-5-{(1*S*)-1-[(*R*)-(*tert*-butanesulfinyl)amino]-2-phenylethyl}dihydrofuran-2-one (9)

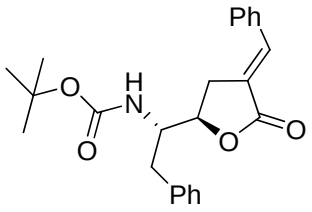


9

A solution of compound **8d** (1.60 g, 5.2 mmol) in tetrahydrofuran (5 mL) was added to a solution of lithium diisopropylamide [freshly prepared from *n*-butyllithium (5.2 mL of a 2.5 M solution in hexane) and diisopropylamide (2.0 mL)] in tetrahydrofuran (25 mL) at −78 ºC. After being stirred for 40 min at −78 ºC, benzaldehyde (1.1 mL) was added. After 30 min, the reaction mixture was quenched with aqueous ammonium chloride (5 mL) and water (2 mL). The resulting mixture was extracted with CH_2Cl_2 (5 mL × 3) and the combined extracts were washed successively with aqueous citric acid (5 mL), aqueous $NaHCO_3$ solution (5 mL) and brine (5 mL). The combined extracts were dried (Na_2SO_4), filtered and concentrated under reduced pressure to give a thick yellow oil. This residue was treated with acetic anhydride (2.5 mL), triethylamine (5.1 mL) and heated at 120 ºC for 1.5 h. The reaction mixture was cooled to room temperature, diluted with ether (4 mL) and washed successively with aqueous citric acid (3 mL), aqueous $NaHCO_3$ solution (5 mL) and brine (5 mL). The organic phase was dried (Na_2SO_4), filtered and concentrated under reduced pressure, after flash chromatography (eluent: PE/EtOAc = 2/1, *v*/*v*) to give compound **9** (1.5 g, yield: 73%) as a pale yellow foam. $[\alpha]_D^{20}$ −48.1 (*c* 1.2, $CHCl_3$); IR (film): 3196, 2962, 2923, 1745, 1651, 1402, 1169, 1123, 1095, 1039 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.16 (s, 9H), 2.95-3.07 (m, 2H), 3.22 (ddd, *J* = 17.8, 8.3, 2.8 Hz, 1H), 3.25 (dd, *J* = 13.8, 5.0 Hz, 1H), 3.29 (d, *J* = 8.6 Hz, 1H), 3.77-3.83 (m, 1H), 4.43-4.48 (m, 1H), 7.29-7.45 (m, 10H), 7.56 (t, *J* = 2.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.5 (3C), 29.9, 38.0, 56.4, 59.9, 76.5, 123.9, 127.2, 128.9 (2C), 129.0 (2C), 129.9 (2C), 130.0, 130.2 (2C), 134.5, 135.2, 136.9, 171.5; MS (ESI) *m*/*z* 420 ($M+Na^+$, 100%);

HRMS calcd for $C_{23}H_{27}NO_3S$ $[M+Na]^+$: 420.1604; found: 420.1607.

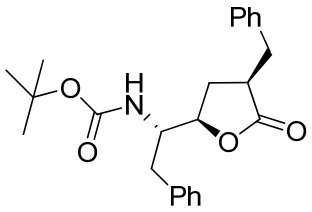
(5*R*)-3-Benzylidene-5-{(1*S*)-1-[(*tert*-butoxycarbonyl)amino]-2-phenylethyl}dihydrofuran-2-one (10)



10

To a solution of ester **9** (540 mg, 1.36 mmol) in MeOH, HCl (4 M in 1,4-dioxane, 10 equiv) was added (HCl/MeOH = 1:1, *v*/*v*). The mixture was stirred at room temperature for 15 h and then concentrated under reduced pressure. The residue was dissolved in CH_2Cl_2 (2 mL). After cooling 0-5 ºC with an ice bath, triethylamine was added until the mixture reached pH 7. Then triethylamine (4.1 mmol) and $(Boc)_2O$ (2.7 mL) were added successively. The mixture was stirred at room temperature for 15 hours and quenched by addition of H_2O (4 mL). The aqueous layer was separated and extracted with CH_2Cl_2 (4 mL × 3). The combined organic phases were washed with brine (5 mL), dried (Na_2SO_4), and the filtrates were concentrated and purified by flash chromatography on silica gel (eluent: PE/EtOAc = 4:1, *v*/*v*) to give compound **10** (451 mg, yield: 84%) as a white foam. $[\alpha]_D^{25}$ –108.5 (*c* 0.8, $CHCl_3$); IR (film): 3352, 2917, 1755, 1700, 1520, 1368, 1161, 1043 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.39 (s, 9H), 2.88 (dd, *J* = 13.5, 8.0 Hz, 1H), 3.01 (dd, *J* = 13.5, 3.0 Hz, 1H), 3.10 (ddd, *J* = 18.0, 5.2, 3.0 Hz, 1H), 3.27 (ddd, *J* = 18.0, 8.0, 2.7 Hz, 1H), 4.06 (br s, 1H), 4.62 (br s, 2H), 7.22-7.50 (m, 10H), 7.60 (t, *J* = 2.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.2 (3C), 30.4, 35.6, 54.9, 77.8, 79.9, 123.6, 126.7, 128.6 (2C), 128.9 (2C), 129.4 (2C), 129.9, 130.0 (2C), 134.4, 136.5, 137.3, 155.3, 171.7; MS (ESI) *m*/*z* 416 ($M+Na^+$, 100%); HRMS calcd for $C_{24}H_{27}NO_4$ $[M+Na]^+$: 416.1832; found: 416.1838.

(3*R*,5*R*)-3-Benzyl-5-{(1*S*)-1-[(*tert*-butoxycarbonyl)amino]-2-phenylethyl}dihydrofuran-2-(3*H*)-one (5)



5

To a solution of ester **10** (110 mg, 0.3 mmol) in EtOAc (0.8 mL) and MeOH (0.2 mL) was added 10% Pd/C (22 mg), and the resulting mixture was hydrogenated at 60 psi for 2 h. The catalyst was filtered through a Celite pad, and the pad was washed with ethyl acetate. The filtrates were concentrated and purified by flash chromatography on silica gel (eluent: PE/EtOAc = 1:4, *v*/*v*) to give compound **5** (107 mg, yield: 97%) as a white solid. mp 127.0-128.6 °C {lit.[9] mp 123-125 °C, lit.[10] mp 127-128.5 °C)}; $[\alpha]_D^{20}$ –68.9 (*c* 1.04, $CHCl_3$) {lit.[9] $[\alpha]_D^{25}$ –69.5 (*c* 1.02, $CHCl_3$)}; IR (film): 3343, 2960, 2923, 1762, 1710, 1454, 1384, 1164, 1124, 1096, 1040 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.35 (s, 9H), 1.79 (dt, *J* = 11.6, 11.6 Hz, 1H), 2.17-2.26 (m, 1H), 2.69-2.93 (m, 4H), 3.28 (dd, *J* = 13.9, 4.1 Hz, 1H), 3.90 (br s, 1H), 4.27 (br s, 1H), 4.38 (br s, 1H), 7.15-7.31 (m, 10H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.2 (3C), 31.3, 36.1, 42.4, 54.3, 78.9, 79.8, 126.7 (2C), 128.5 (2C), 128.6 (2C), 128.8 (2C), 129.4 (2C), 136.6, 138.3, 155.2, 177.6; MS (ESI) *m*/*z* 418 ($M+Na^+$, 100%); HRMS calcd for $C_{24}H_{29}NO_4$ $[M+Na]^+$: 418.1989; found: 418.1993.

General procedure E: Synthesis of 5-hydroxypiperidin-2-one derivatives 11.

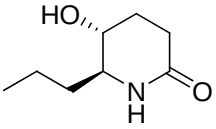
To a solution of lactone (R_S)-**8** (1.0 euqiv) in MeOH (MeOH/HCl = 1:1, *v*/*v*) was added HCl (4 M in 1,4-dioxane, 10 equiv). The mixture was stirred at room temperature for 15 h and then concentrated under reduced pressure. The residue was dissolved in dry toluene (0.2 M) under N_2 atmosphere, and DBU (3 equiv) was added at room temperature. Then the mixture was reflux at 120 °C for 3 h. The mixture was concentrated under reduced pressure, and the residue was purified by flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one derivatives **11**.

General procedure F: Synthesis of 5-hydroxypiperidin-2-one derivatives 11.

To a solution of sulfinamide (R_S)-**8** (1.0 euqiv) in MeOH (MeOH/HCl = 1:1, *v*/*v*) was added HCl (4 M in 1,4-dioxane, 10 equiv). The mixture was stirred at room

temperature for 15 h and then concentrated under reduced pressure. The residue was dissolved in dry MeOH (0.2 M), and then K_2CO_3 (5 equiv) was added at room temperature. The mixture was stirred overnight. The crude was purified by flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one derivative **11**.

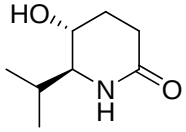
(5*R*,6*S*)-5-Hydroxy-6-propylpiperidin-2-one (11a)



11a

Following the general procedure F, sulfinamide (R_S)-**8a** (190 mg, 0.73 mmol) was treated with HCl (7 mL) and K_2CO_3 (504 mg, 3.65 mmol), after flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **11a** (100 mg, yield: 87%) as a colorless oil. $[\alpha]_D^{20}$ –30.5 (*c* 1.3, MeOH); IR (film): 3288, 2957, 2934, 2873, 1650, 1466, 1409, 1360, 1076 cm^{-1}; ^1H NMR (400 MHz, CD_3OD) δ 0.97-1.00 (m, 3H), 1.47-1.57 (m, 4H), 1.79-1.89 (m, 1H), 1.97-2.03 (m, 1H), 2.24-2.33 (m, 1H), 2.43-2.52 (m, 1H), 3.27 (dd, *J* = 11.6, 5.2 Hz, 1H), 3.75-3.79 (m, 1H), 4.89 (br s, 2H); ^{13}C NMR (100 MHz, CD_3OD) δ 14.4, 19.5, 26.9, 28.2, 37.5, 59.7, 67.4, 174.4; HRMS calcd for $C_8H_{15}NO_2$ $[M+Na]^+$: 180.0995; found: 180.0992.

(5*R*,6*S*)-5-Hydroxy-6-isopropylpiperidin-2-one (11b)

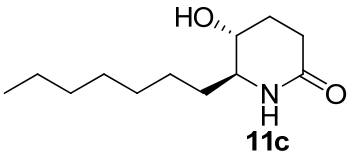


11b

Following the general procedure E, sulfinamide (R_S)-**8b** (380 mg, 1.46 mmol) was treated with HCl (10 mL) and DBU (0.4 mL, 2.3 mmol), after flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **11b** (183 mg, yield: 80%) as a white solid. mp 81-82 ºC (EtOAc/PE) {lit.[11] mp 84-85 ºC (EtOAc/PE)}; $[\alpha]_D^{20}$ –8.2 (*c* 0.4, $CHCl_3$) {lit.[11] $[\alpha]_D^{23}$ –7.7 (*c* 0.4, $CHCl_3$)}; IR (film): 3307, 2961, 1644, 1469, 1409, 1385, 1218, 1058 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.94 (d, *J* = 6.8 Hz, 3H), 0.98 (d, *J* = 7.0 Hz, 3H), 1.86 (m, 3H), 2.32 (ddd, *J* = 18.0, 8.3, 6.4 Hz, 1H), 2.50 (dt, *J* = 18.0, 6.4 Hz, 1H), 3.08-3.11 (m, 2H), 3.87 (ddd, *J* = 8.5, 6.0, 3.4 Hz,

1H), 6.12 (br s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 16.7, 19.4, 27.6, 27.9, 29.8, 64.2, 65.4, 172.4; HRMS calcd for $C_8H_{15}NO_2$ $[M+Na]^+$: 180.0995; found: 180.0993.

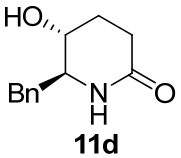
(5*R*,6*S*)-6-Heptyl-5-hydroxypiperidin-2-one (11c)



11c

Following the general procedure F, sulfinamide (R_S)-**8c** (100 mg, 0.32 mmol) was treated with HCl (3 mL) and K_2CO_3 (207 mg, 1.5 mmol), after flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **11c** (52 mg, yield: 77%) as a colorless oil. $[\alpha]_D^{20}$ –35.6 (*c* 1.7, $CHCl_3$); IR (film): 3290, 2926, 2855, 1656, 1466, 1409, 1357, 1337, 1075 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.89 (t, *J* = 6.9 Hz, 3H), 1.28-1.49 (m, 12H), 1.64-1.71 (m, 1H), 1.83-1.92 (m, 1H), 1.97-2.05 (m, 1H), 2.35 (ddd, *J* = 18.0, 7.6, 6.6 Hz, 1H), 2.49 (dt, *J* = 18.0, 6.6 Hz, 1H), 3.24-3.28 (m, 1H), 3.76 (ddd, *J*= 8.4, 5.6, 3.2 Hz, 1H), 6.03 (br s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.0, 22.6, 25.3, 27.1, 27.8, 29.1, 29.4, 31.7, 34.3, 59.0, 67.8, 171.7; HRMS calcd for $C_{12}H_{23}NO_2$ $[M+Na]^+$: 236.1621; found: 236.1622.

(5*R*,6*S*)-6-Benzyl-5-hydroxypiperidin-2-one (11d)

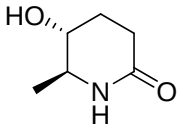


11d

Following the general procedure E, sulfinamide (R_S)-**8d** (123 mg, 0.4 mmol) was treated with HCl (4 mL) and DBU (0.1 mL, 0.6 mmol), after flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **11d** (64 mg, yield: 78%) as a white solid. mp 97-98 ºC (EtOAc/PE), {lit.[11] mp 101-102 ºC (EtOAc)}; $[\alpha]_D^{20}$ –34.4 (*c* 1.2, MeOH), {lit.[11] $[\alpha]_D^{23}$ –37.9 (*c* 1.2, MeOH)}; IR (film): 3292, 2932, 1650, 1494, 1454, 1410, 1069 cm^{-1}; ^{1}H NMR (400 MHz, CD_3OD) δ 1.79-1.88 (m, 1H), 1.97-2.05 (m, 1H), 2.24 (dt, *J* = 18.0, 6.4 Hz, 1H), 2.46 (ddd, *J* = 18.0, 8.0, 6.4 Hz, 1H), 2.83 (dd, *J* = 13.8, 6.8 Hz, 1H), 2.93 (dd, *J* = 13.8, 6.3 Hz, 1H), 3.53-3.58 (m, 1H), 3.71-3.75 (m, 1H), 4.88 (br s, 2H), 7.24-7.36 (m, 5H); ^{13}C NMR (100 MHz, CD_3OD) δ 26.5, 28.1, 41.1, 61.1, 66.4, 127.8, 129.7 (2C), 130.6 (2C), 138.4, 174.3;

HRMS calcd for $C_{12}H_{15}NO_2$ $[M+Na]^+$: 228.0995; found: 228.0999.

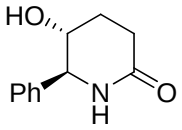
(5*R*,6*S*)-5-Hydroxy-6-methylpiperidin-2-one (11e)



11e

Following the general procedure E, sulfinamide (R_S)-**8e** (270 mg, 1.16 mmol) was treated with HCl (2 mL) and DBU (0.3 mL, 1.8 mmol), after flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **11e** (97 mg, yield: 65%) as a white solid. mp 136-137 ºC (EtOAc/PE), {lit.[11] mp 141-142 ºC (EtOAc/PE)}; $[\alpha]_D^{20}$ –17.2 (*c* 0.5, MeOH), {lit.[11] $[\alpha]_D^{23}$ –20.0 (*c* 0.5, MeOH)}; IR (film): 3296, 2969, 1643, 1452, 1410, 1327, 1066 cm^{-1}; ^1H NMR (400 MHz, CD_3OD) δ 1.24 (d, *J* = 6.6 Hz, 3H), 1.79-1.87 (m, 1H), 2.00-2.03 (m, 1H), 2.28-2.37 (m, 1H), 2.43-2.50 (m, 1H), 3.30-3.36 (m, 1H), 3.51-3.61 (m, 1H), 4.87 (br s, 2H); ^{13}C NMR (100 MHz, CD_3OD) δ 20.3, 27.6, 28.9, 55.7, 70.1, 174.2; HRMS calcd for $C_6H_{11}NO_2$ $[M+Na]^+$: 152.0682; found: 152.0682.

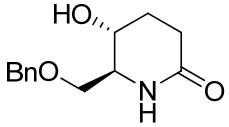
(5*R*,6*S*)-5-Hydroxy-6-phenylpiperidin-2-one (11f)



11f

Following the general procedure F, sulfinamide (R_S)-**8f** (78 mg, 0.26 mmol) was treated with HCl (3 mL) and K_2CO_3 (207 mg, 1.5 mmol), after flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **11f** (38 mg, yield: 76%) as a white solid. mp 177-178 ºC (EtOAc/PE) {lit.[11] mp 182-182 ºC (EtOAc)}; $[\alpha]_D^{20}$ –32.5 (*c* 0.8, MeOH) {lit.[11] $[\alpha]_D^{23}$ +31.6 (*c* 0.75, MeOH)}; IR (film): 3291, 2959, 2896, 1633, 1590, 1574, 1452, 1358, 1073, 1084 cm^{-1}; ^1H NMR (400 MHz, CD_3OD) δ 1.77-1.86 (m, 1H), 1.88-1.96 (m, 1H), 2.43 (dt, *J* = 11.8, 6.2 Hz, 1H), 2.55-2.63 (m, 1H), 3.92 (ddd, *J* = 7.1, 4.6, 2.8 Hz, 1H), 4.48 (d, *J* = 4.6 Hz, 1H), 4.89 (br s, 2H), 7.31-7.43 (m, 5H); ^{13}C NMR (100 MHz, CD_3OD) δ 25.8, 28.3, 64.5, 70.4, 128.0 (2C), 128.8, 129.7 (2C), 142.0, 174.8; HRMS calcd for $C_{11}H_{13}NO_2$ $[M+Na]^+$: 214.0838; found: 214.0838.

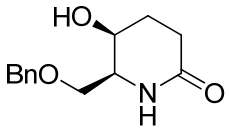
(5*R*,6*S*)-6-(Benzyloxymethyl)-5-hydroxypiperidin-2-one (11g)



11g

Following the general procedure F, sulfinamide (R_S)-**8g** (150 mg, 0.44 mmol) was treated with HCl (4 mL) and K_2CO_3 (304 mg, 2.5 mmol), after flash chromatography (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **11g** (72 mg, yield: 70%) as a colorless oil. $[\alpha]_D^{20}$ –21.4 (*c* 0.9, $CHCl_3$) {lit.[12] $[\alpha]_D^{23}$ +23.8 (*c* 1.2, $CHCl_3$)}; IR (film): 3379, 2917, 1642, 1458, 1434, 1120, 1090 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.87-1.91 (m, 1H), 2.00-2.04 (m, 1H), 2.35 (ddd, *J* = 17.9, 10.4, 6.2 Hz, 1H), 2.50 (dt, *J* = 17.9, 5.8 Hz, 1H), 3.00 (br s, 1H), 3.43 (t, *J* = 8.8 Hz, 1H), 3.49-3.54 (m, 1H), 3.72 (dd, *J* = 8.8, 4.6 Hz, 1H), 3.74-3.76 (m, 1H), 4.55 (s, 2H), 6.19 (br s, 1H), 7.32-7.40 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.3, 28.5, 58.0, 66.8, 72.0, 73.5, 127.8 (2C), 128.0, 128.5 (2C), 137.2, 171.3; HRMS calcd for $C_{13}H_{17}NO_3$ $[M+Na]^+$: 258.1101; found: 258.1102.

(5*S*,6*S*)-6-(Benzyloxymethyl)-5-hydroxypiperidin-2-one (18)



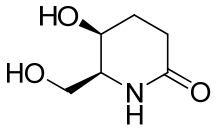
18

Following the general procedure F, sulfinamide (R_S,4*S*,5*S*)-**8g** (240 mg, 0.71 mmol) was treated with HCl (7 mL) and K_2CO_3 (480 mg, 3.5 mmol), after flash chromatography on silica gel (eluent: EtOAc) to give 5-hydroxypiperidin-2-one **18** (118 mg, yield: 71%) as a colorless oil. $[\alpha]_D^{20}$ –13.7 (*c* 2.0, $CHCl_3$); IR (film): 3305, 2924, 2870, 1650, 1454, 1406, 1120, 1094 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.78-1-87 (m, 1H), 1.98-2.05 (m, 1H), 2.30 (ddd, *J* = 18.0, 6.5, 2.4 Hz, 1H), 2.61 (ddd, *J* = 18.0, 11.8, 6.8 Hz, 1H), 3.58-3.73 (m, 4H), 4.10 (m, 1H), 4.51 (d, *J* = 11.8 Hz, 1H), 4.55 (d, *J* = 11.8 Hz, 1H), 6.39 (s, 1H), 7.29-7.37 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 26.2, 27.5, 56.1, 64.1, 70.7, 73.6, 127.8 (2C), 128.1, 128.6 (2C), 137.2, 171.8; HRMS calcd for $C_{13}H_{17}NO_3$ $[M+Na]^+$: 258.1101; found: 258.1106.

(5*R*,6*S*)-6-(Benzyloxymethyl)-5-(*tert*-butyldimethylsilyloxy)piperidin-2-one (12)

To a solution of compound **11g** (24 mg, 0.1 mmol), imidazole (40 mg, 0.7 mmol) and DMAP (cat.) in anhydrous DMF (0.8 mL), was added TBSCl (61 mg, 0.4 mmol) in anhydrous DMF (0.3 mL). After being stirred at room temperature overnight, water was added. The organic layer was separated, and washed with brine (5 mL), dried over anhydrous Na_2SO_4, filtered and concentrated. The crude was purified by flash chromatography on silica gel (eluent: *n*-hexane/EtOAc = 1:5, *v*/*v*) on silica gel to give **12** (30 mg, yield: 84%) as a colorless oil. $[\alpha]_D^{20}$ –40.2 (*c* 1.0, $CHCl_3$) {lit.[13] $[\alpha]_D^{25}$ –39.7 (*c* 0.6, $CHCl_3$)}; IR (film): 3406, 2953, 2928, 2856, 1672, 1095 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.06 (s, 3H, CH_3), 0.08 (s, 3H, CH_3), 0.88 (s, 9H), 1.85-1.92 (m, 2H), 2.29-2.37 (m, 1H), 2.53 (dt, *J* = 17.8, 5.7 Hz, 1H), 3.33 (t, *J* = 8.6 Hz, 1H), 3.47-3.52 (m, 1H), 3.64 (dd, *J* = 9.0, 3.9 Hz, 1H), 3.75 (ddd, *J* = 10.0, 6.6, 3.6 Hz, 1H), 4.51 (d, *J* = 11.8 Hz, 1H), 4.56 (d, *J* = 11.8 Hz, 1H), 6.11 (br s, 1H), 7.31-7.39 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ –5.0, –4.4, 17.8, 25.6 (3C), 28.3, 28.6, 58.7, 66.6, 71.4, 73.4, 127.7, 127.9 (2C), 128.5 (2C), 137.4, 171.0; HRMS calcd for $C_{19}H_{31}NO_3Si$ $[M+Na]^+$: 372.1965; found: 372.1965.

(5*S*,6*S*)-5-Hydroxy-6-(hydroxymethyl)piperidin-2-one (19)



19

To a stirred solution of ester **18** (40 mg, 0.17 mmol) in MeOH (2.1 mL) and formic acid (0.5 mL), 10% Pd/C (20 mg) was added and the resulting mixture was stirred under 120 psi of hydrogen for 23 h. After this period, the catalyst was filtered off through a Celite pad, and the pad was washed with MeOH. The filtrate was concentrated and then purified by flash chromatography on silica gel (eluent: EtOAc) to give compound **19** (20 mg, yield: 83%) as a colorless oil. $[\alpha]_D^{20}$ +21.4 (*c* 0.7, MeOH) {lit.[14] $[\alpha]_D^{23}$ +20.3}; IR (film): 3404, 2918, 2849, 1658, 1642, 1384, 1019 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.87-1.95 (m, 1H), 1.99-2.06 (m, 1H), 2.30 (ddd, *J* = 18.1, 6.5, 2.6 Hz, 1H), 2.56 (ddd, *J* = 18.1, 11.6, 6.8 Hz, 1H), 3.49 (ddd, *J*= 7.5, 5.3, 3.0 Hz, 1H), 3.66 (dd, *J* = 10.9, 7.5 Hz, 1H), 3.77 (dd, *J* = 10.9, 5.3 Hz, 1H), 4.11-4.14 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 27.2, 28.2, 59.3, 63.1, 63.9, 174.9;

MS (ESI) *m*/*z* 146 ($M+H^+$, 100%); HRMS calcd for $C_6H_{11}NO_3$ $[M+Na]^+$: 168.0631; found: 168.0638.

REFERENCES

1. Liu, G.-C.; Cogan, D. A.; Owens, T. D.; Tang, T.-P.; Ellman, J. A. *J. Org. Chem.* **1999**, *64*, 1278-1284.
2. Chemla, F.; Ferreira, F. *J. Org. Chem.* **2004**, *69*, 8244-8250.
3. Maji, M. S.; Fröhlich, R.; Studer, A. *Org. Lett.* **2008**, *10*, 1847-1850.
4. Ferreira, F.; Audouin, M.; Chemla, F. *Chem.-Eur. J.* **2005**, *11*, 5269-5278.
5. Liu, G.-C.; Cogan, D. A.; Ellman, J. A. *J. Am. Chem. Soc.* **1997**, *119*, 9913-9914.
6. Bolshan, Y.; Batey, R. A. *Org. Lett.* **2005**, *7*, 1481-1484.
7. Kells, K. W.; Chong, J. M. *J. Am. Chem. Soc.* **2004**, *126*, 15666-15667.
8. Tang, T. P.; Volkman, S. K.; Ellman, J. A. *J. Org. Chem.* **2001**, *66*, 8772-8778.
9. Nadin, A.; Sánchez López, J. M.; Neduvelil, J. G.; Thomas, S. R. *Tetrahedron*. **2001**, *57*, 1861-1864.
10. Litera, J.; Budesinsky, M.; Urban, J.; Soucek, M. *Collect. Czech. Chem. Commun.* **1998**, *63*, 231-244.
11. Andrés, J. M.; Pedrosa, R.; Pérez-Encabo, A. *Tetrahedron Lett.* **2006**, *47*, 5317-5320.
12. Campbell, J. A.; Lee, W. K.; Rapoport, H. *J. Org. Chem.* **1995**, *60*, 4602-4616.
13. Liu, R.-C.; Wei, J.-H.; Wei, B.-G.; Lin, G.-Q. *Tetrahedron: Asymmetry* **2008**, *19*, 2731-2734.
14. Kumar, P. S.; Kumar, G. D. K.; Baskaran, S. *Eur. J. Org. Chem.* **2008**, 6063-6067.

C50-RST-H1
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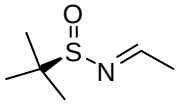
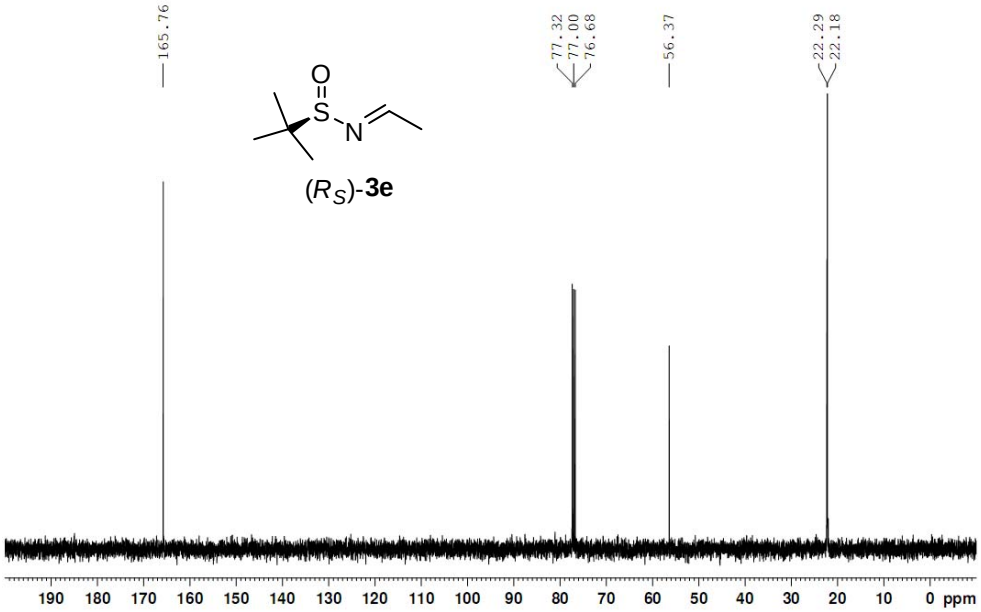
2011.05.24



(R_S)-**3e**

C50-RST-c13
CDCl3
2011.05.24



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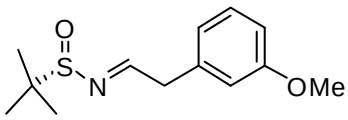
CDCl3
09-04-09



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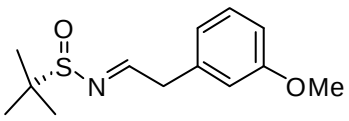
CDCl3
09-04-09



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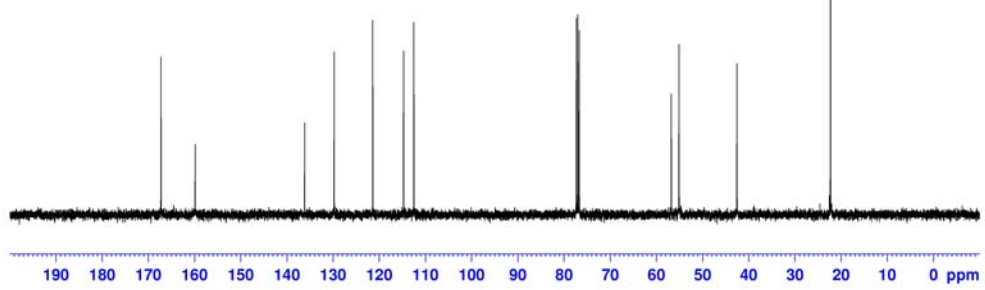

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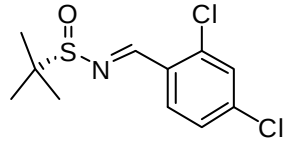
CDC13
09-03-09



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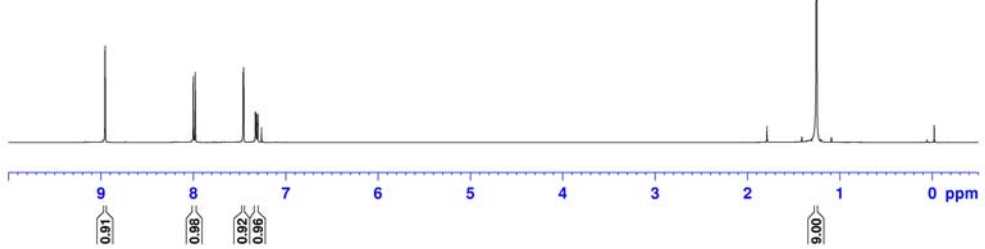

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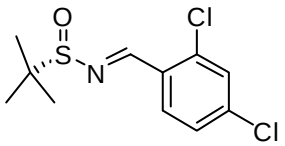
09-03-09



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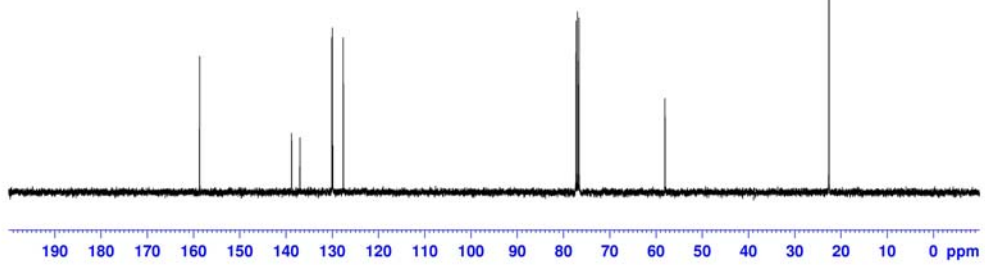

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CDC13
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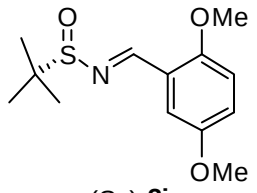

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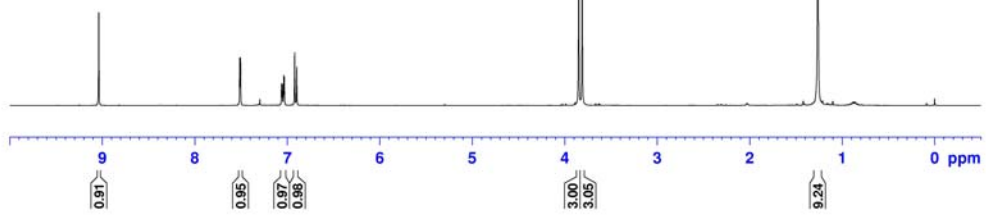

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CDC13
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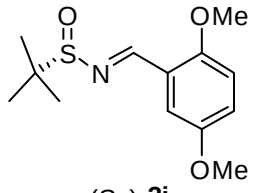

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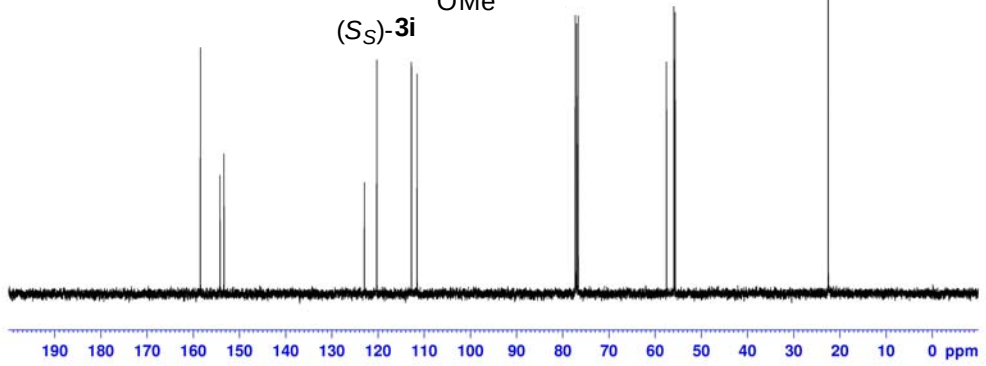

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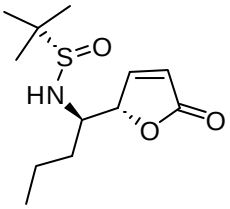

(S_S,4*S*,5*R*)-**7a**

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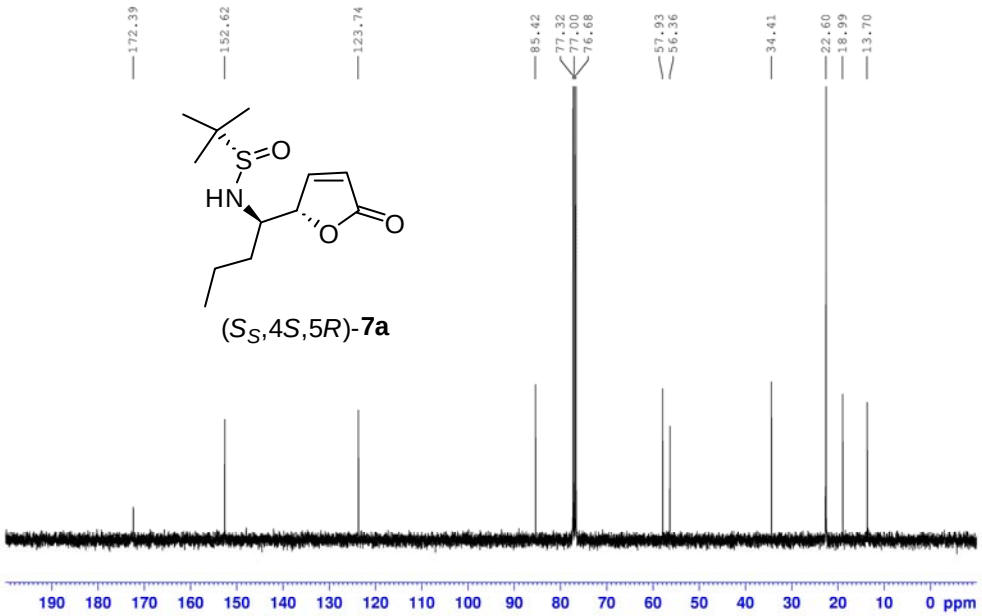
CDCl3
09-02-20



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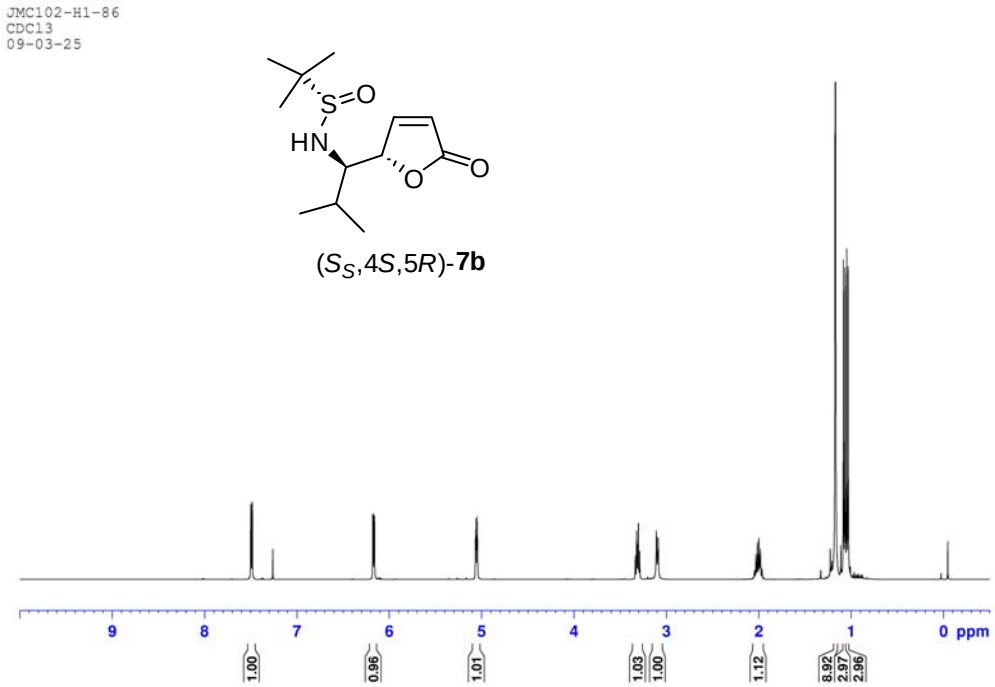
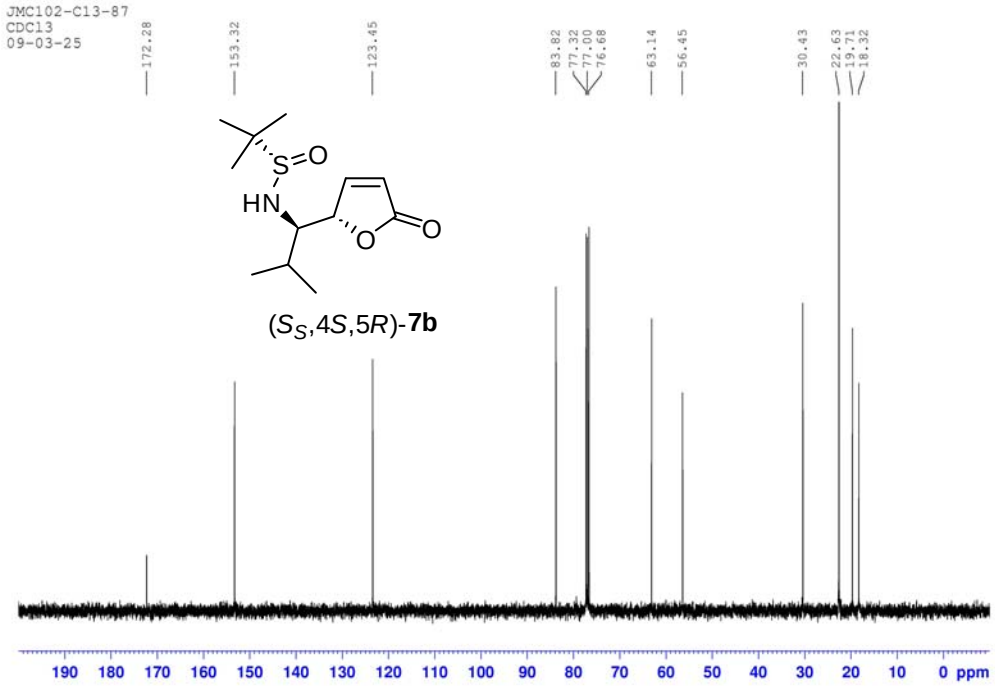


(S_S,4*S*,5*R*)-**7b**



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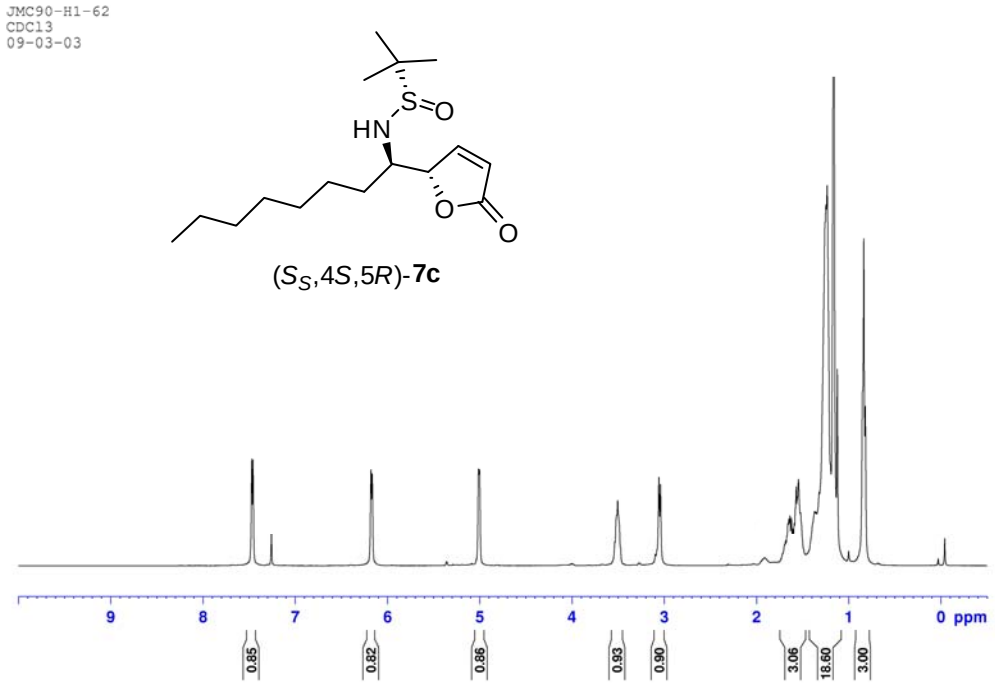

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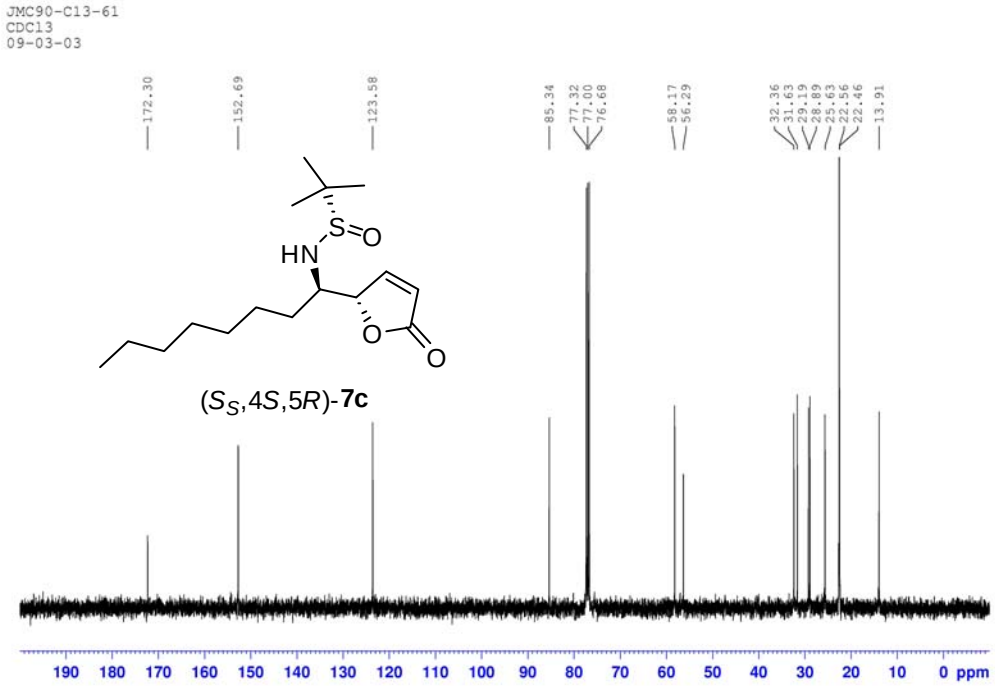

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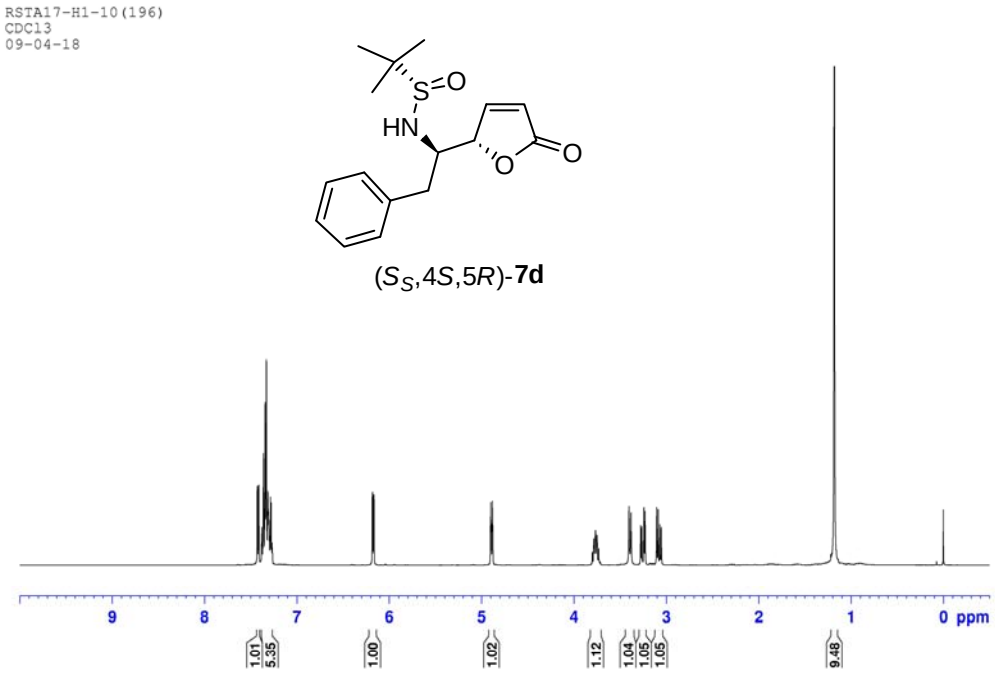

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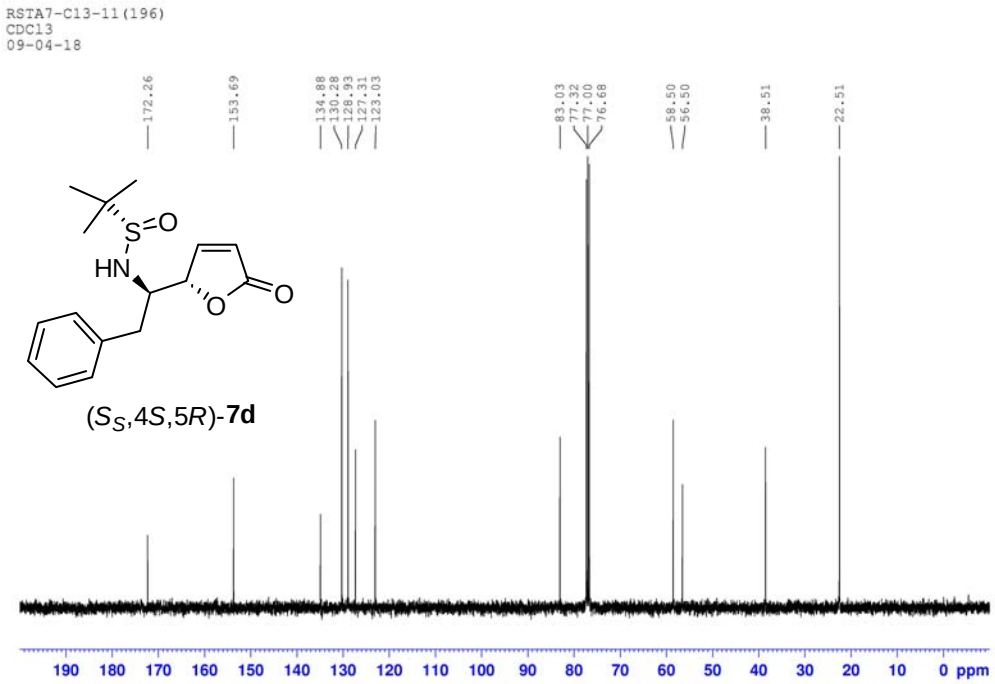
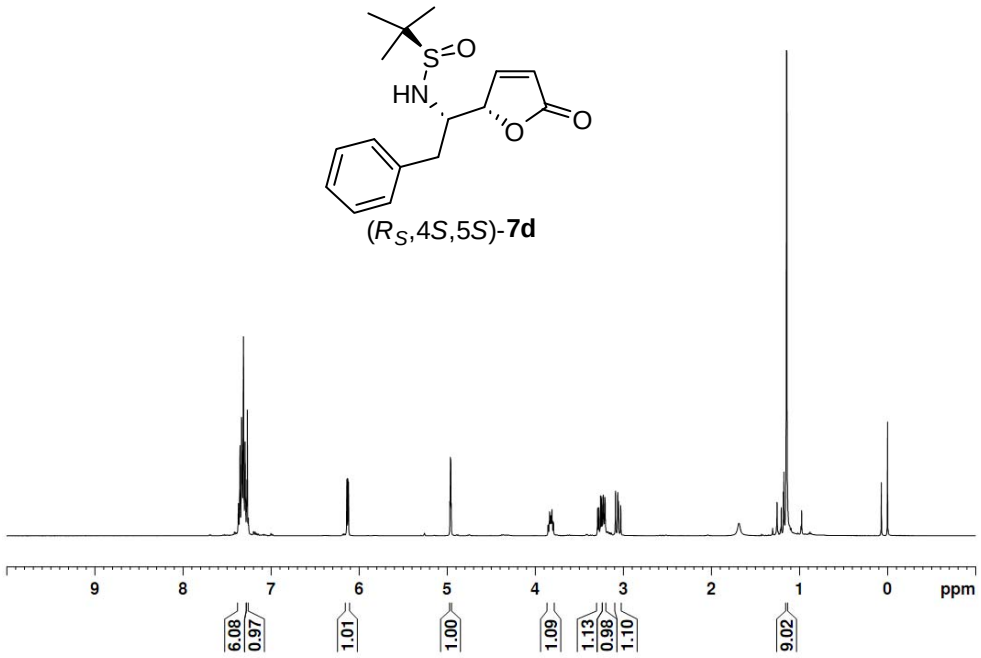


(S_S,4*S*,5*R*)-**7d**

RST-A45a-H1
CDCl3
2009.12.25



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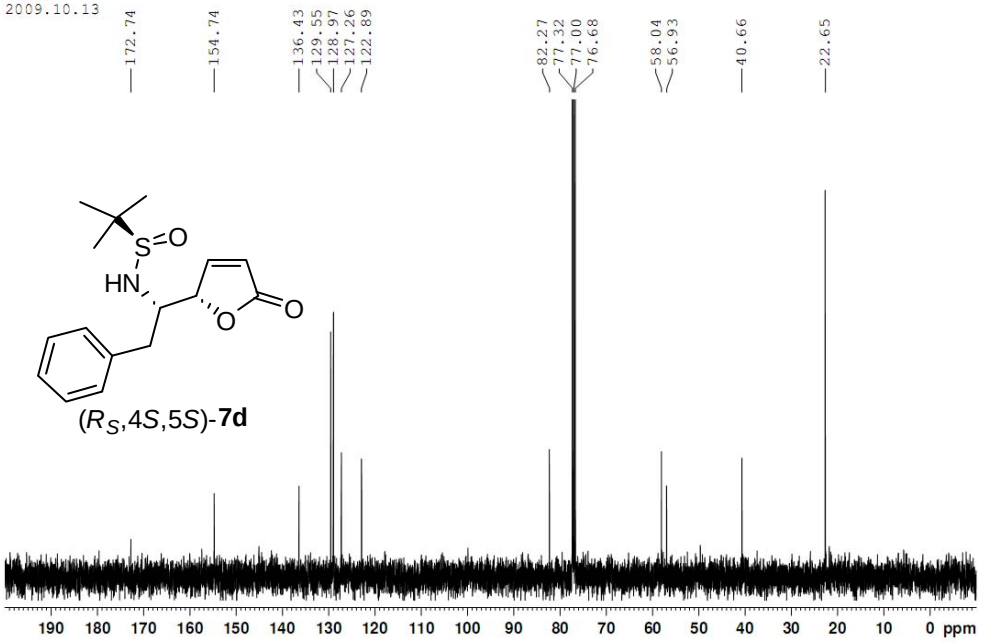

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95bB-RST-H1
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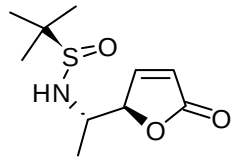
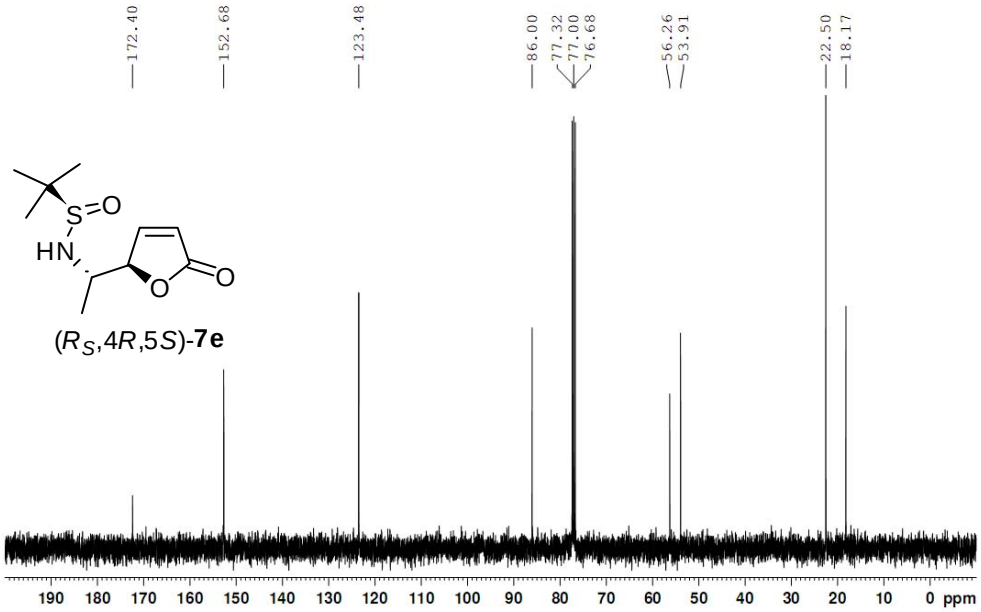
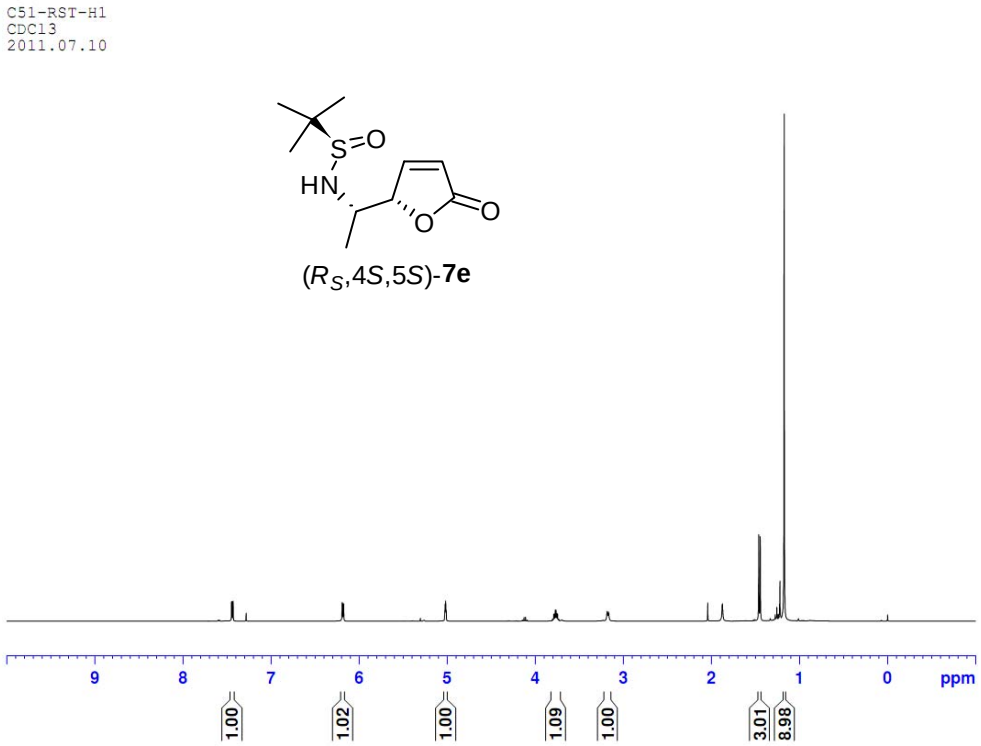


(R_S,4*R*,5*S*)-**7e**

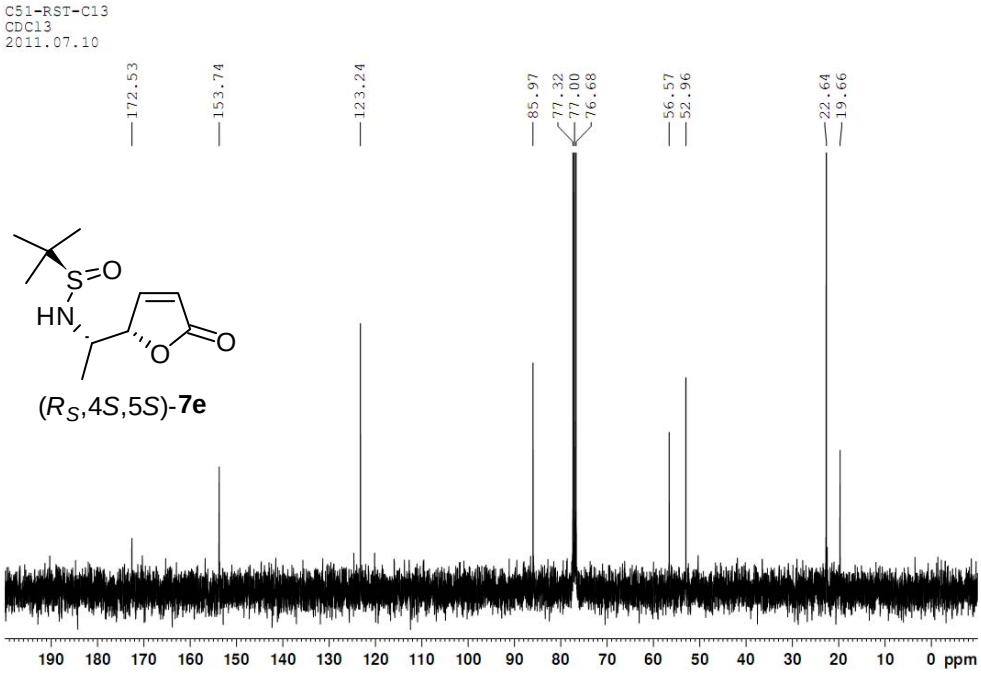
95bB-RST-C13
CDCl3
2010.12.18



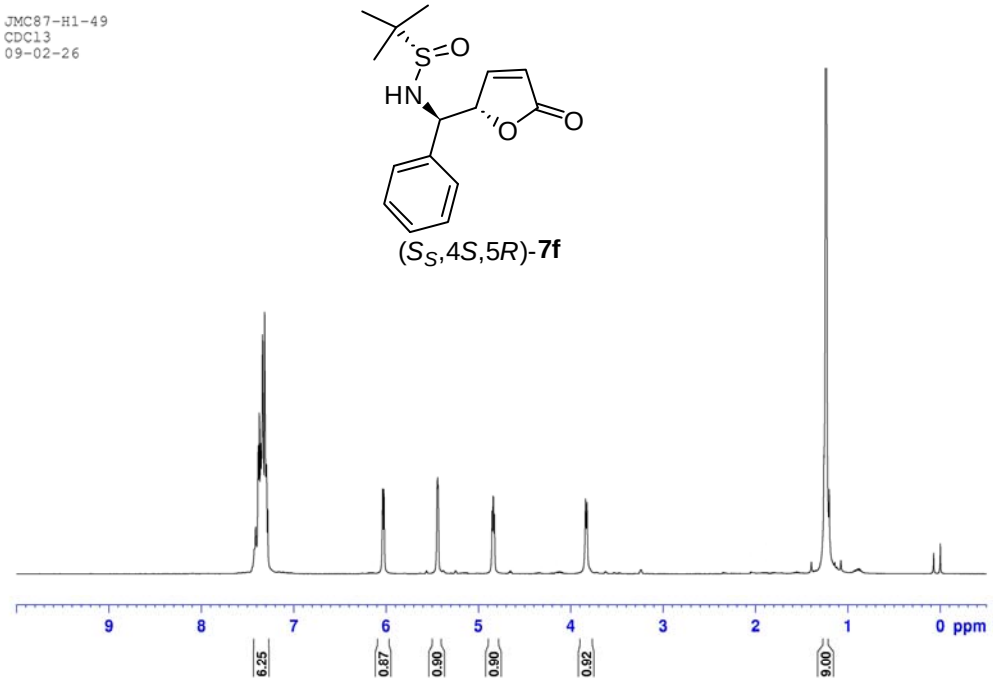
(R_S,4*R*,5*S*)-**7e**



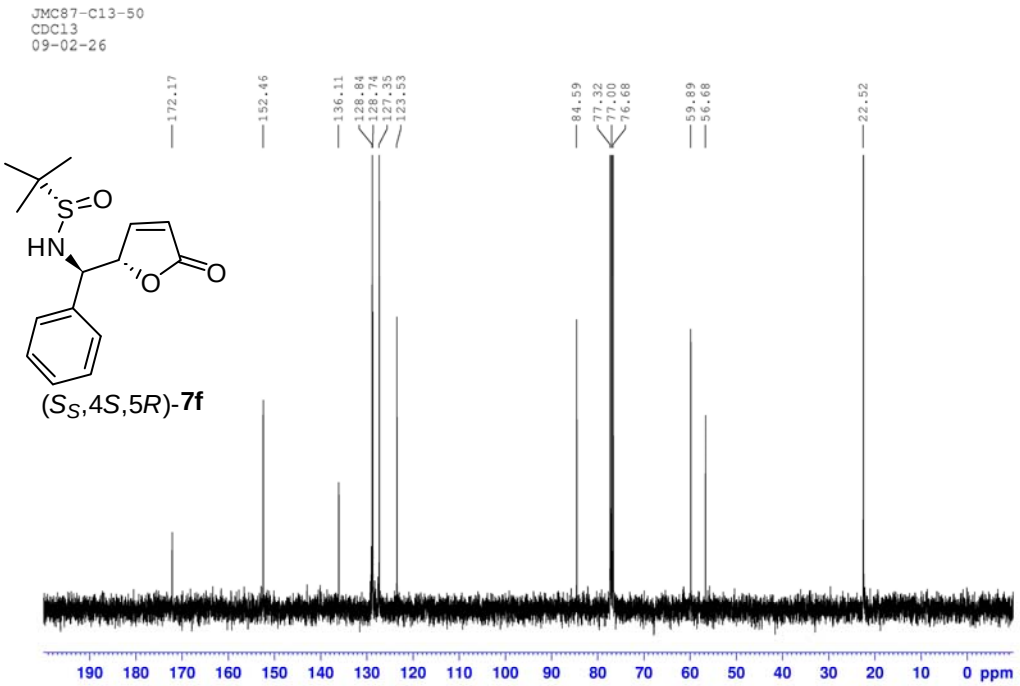
(R_S,4*S*,5*S*)-**7e**



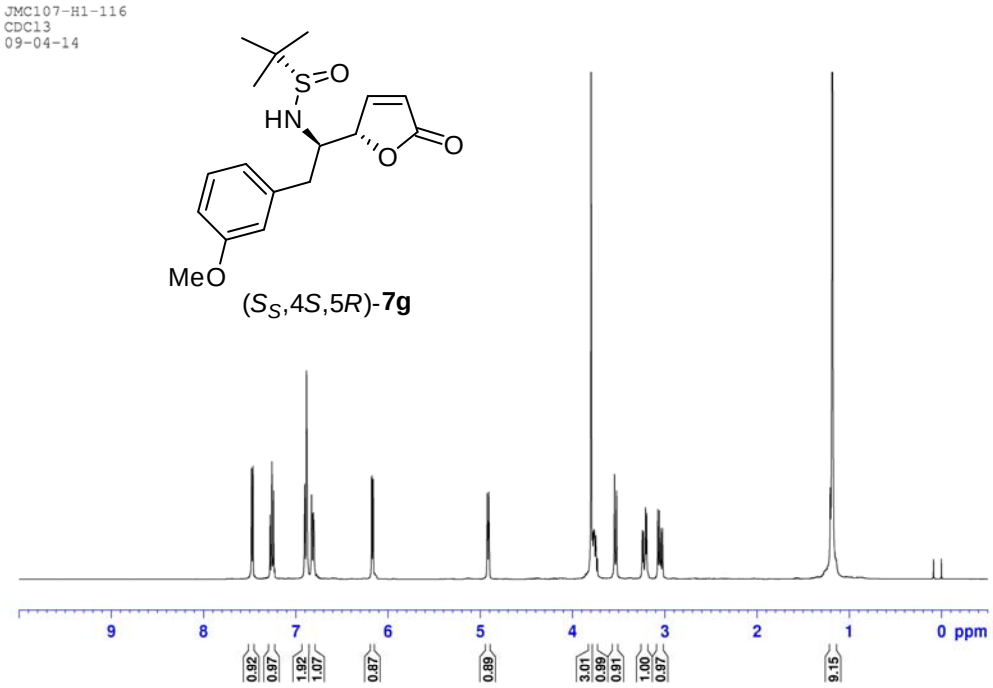
(R_S,4*S*,5*S*)-**7e**



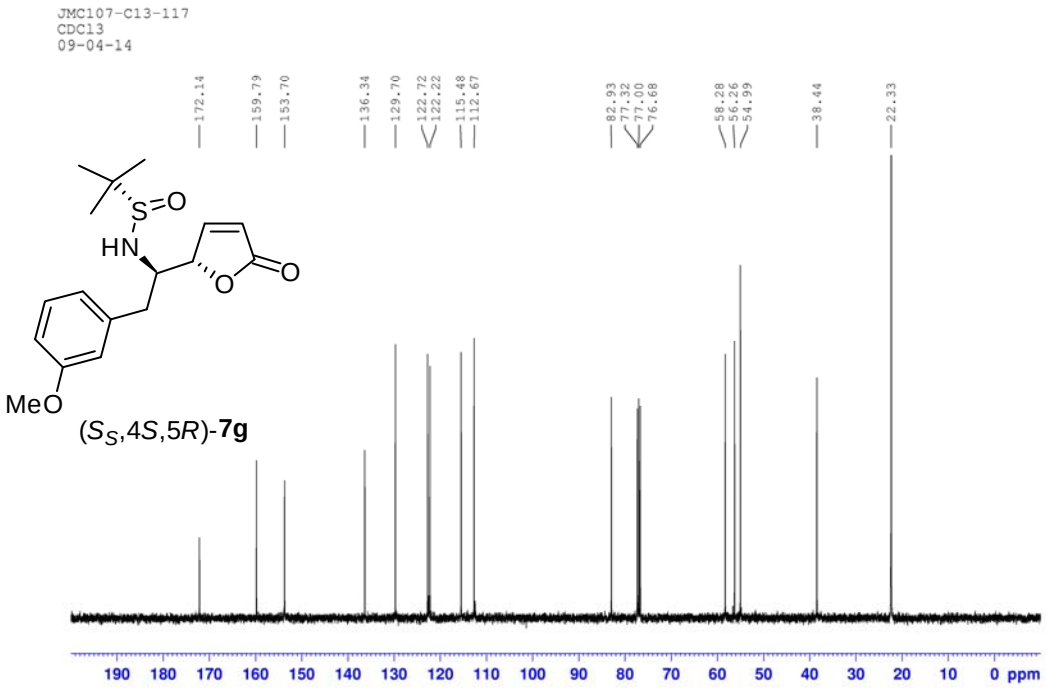
(S_S,4*S*,5*R*)-**7f**



(S_S,4*S*,5*R*)-**7f**

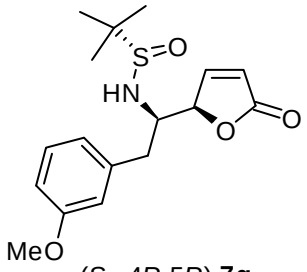


(S_S,4*S*,5*R*)-**7g**



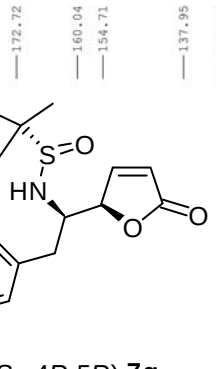
(S_S,4*S*,5*R*)-**7g**

JMC109_1-H1-684
CDCl3
2011-07-06

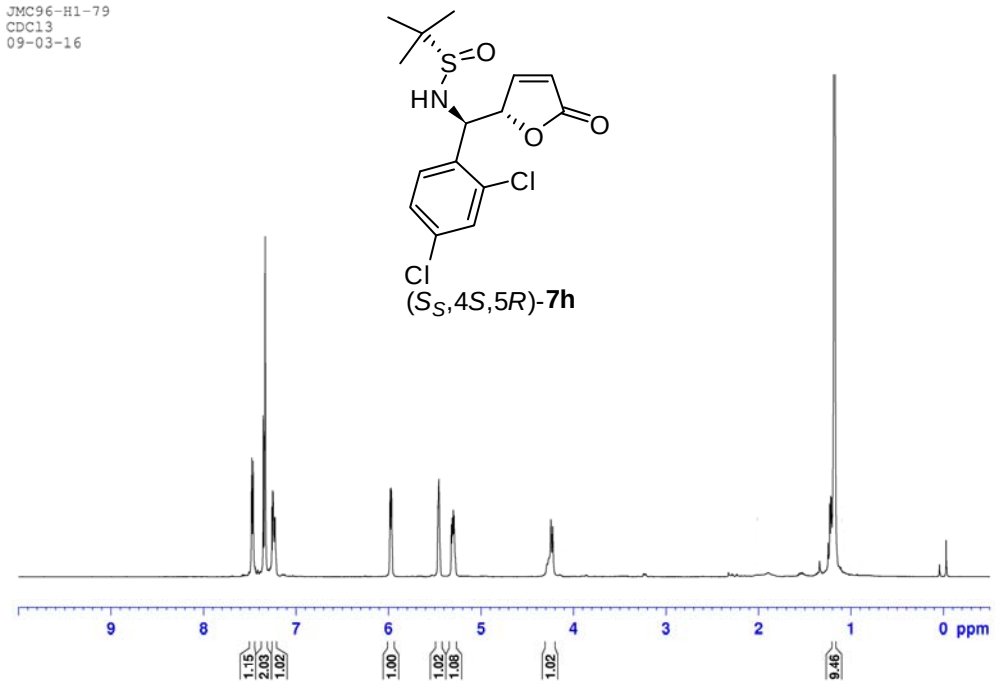


(S_S,4*R*,5*R*)-**7g**

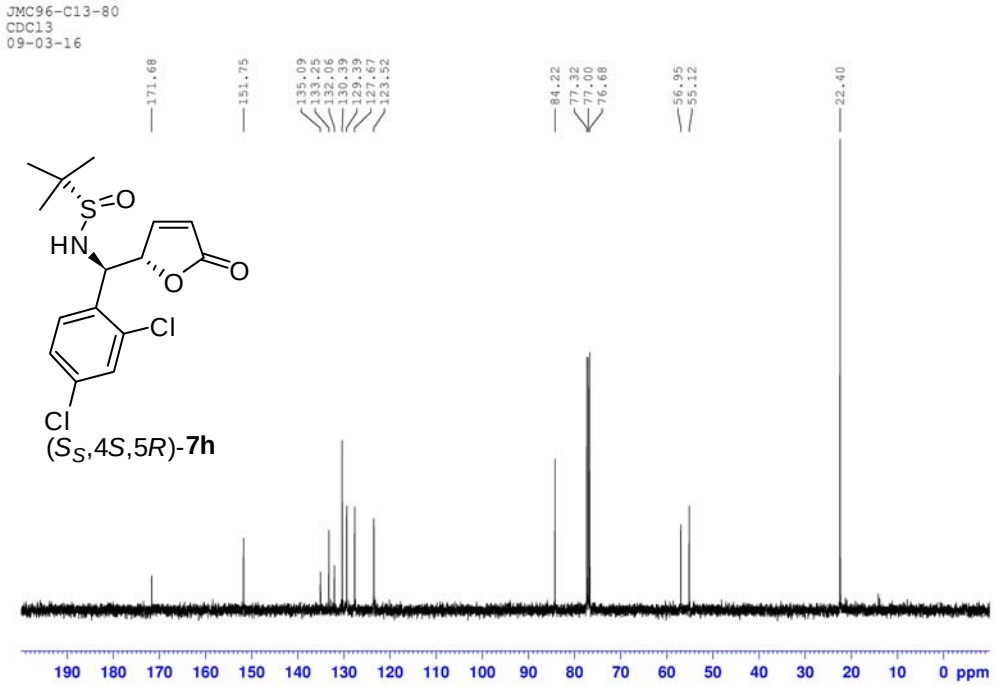
JMC109_1-C13-685
CDCl3
2011-07-06



(S_S,4*R*,5*R*)-**7g**

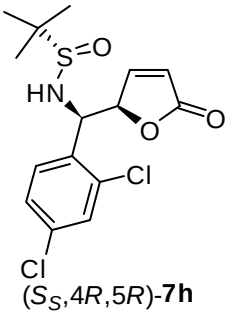


(S_S,4*S*,5*R*)-**7h**



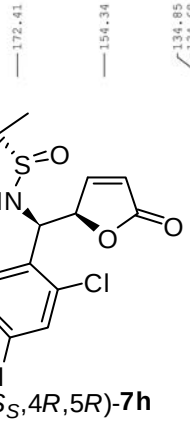
(S_S,4*S*,5*R*)-**7h**

JMC96_1-H1-680
CDCl3
2011-07-06

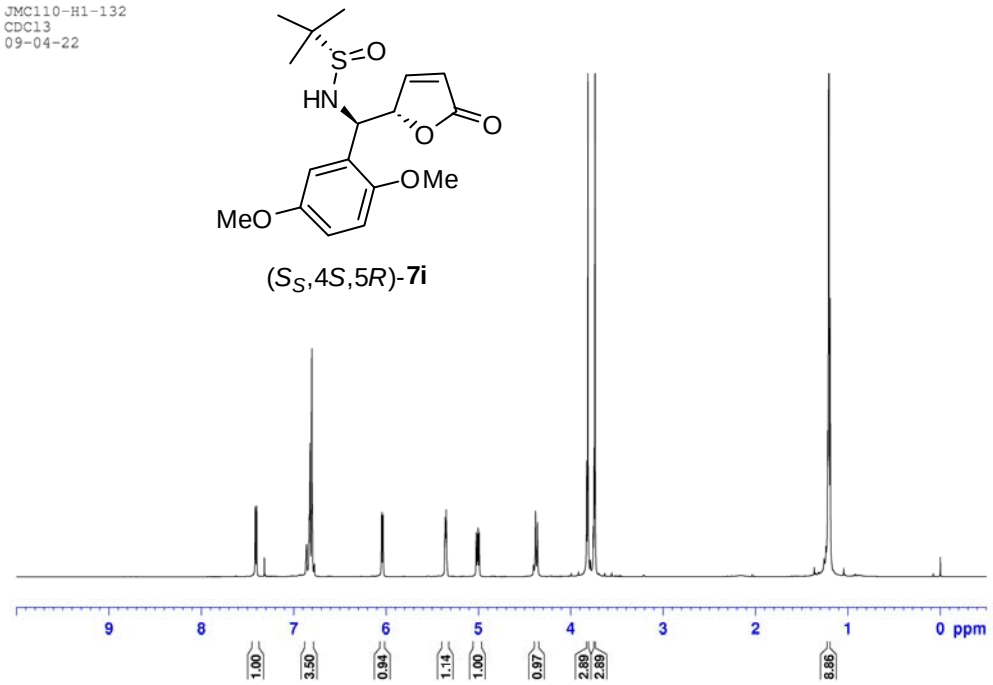


(S_S,4*R*,5*R*)-**7h**

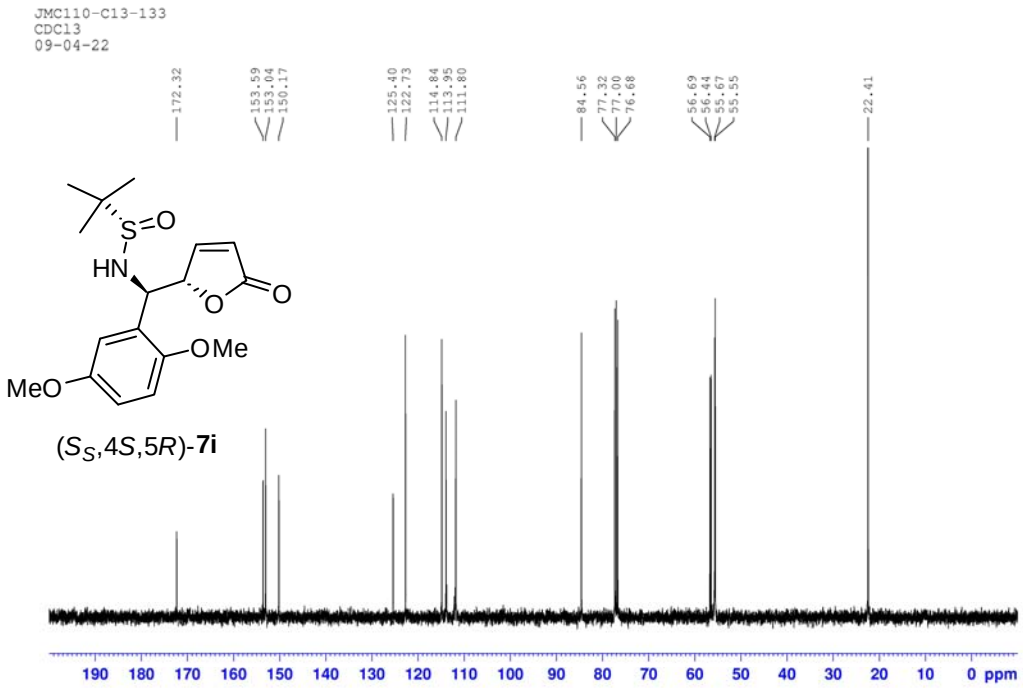
JMC96_1-C13-681
CDCl3
2011-07-06



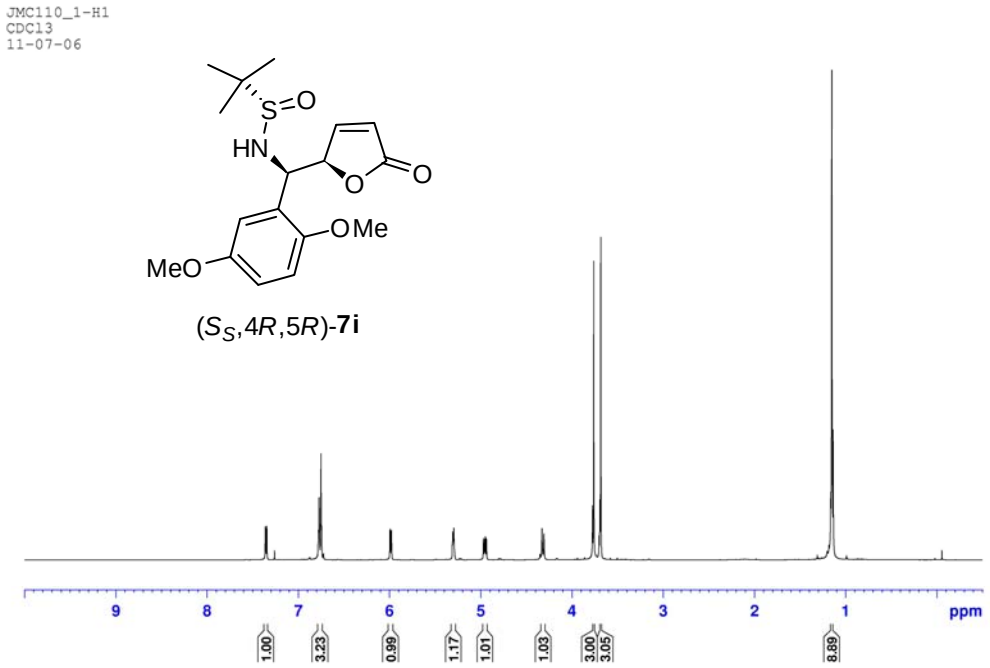
(S_S,4*R*,5*R*)-**7h**



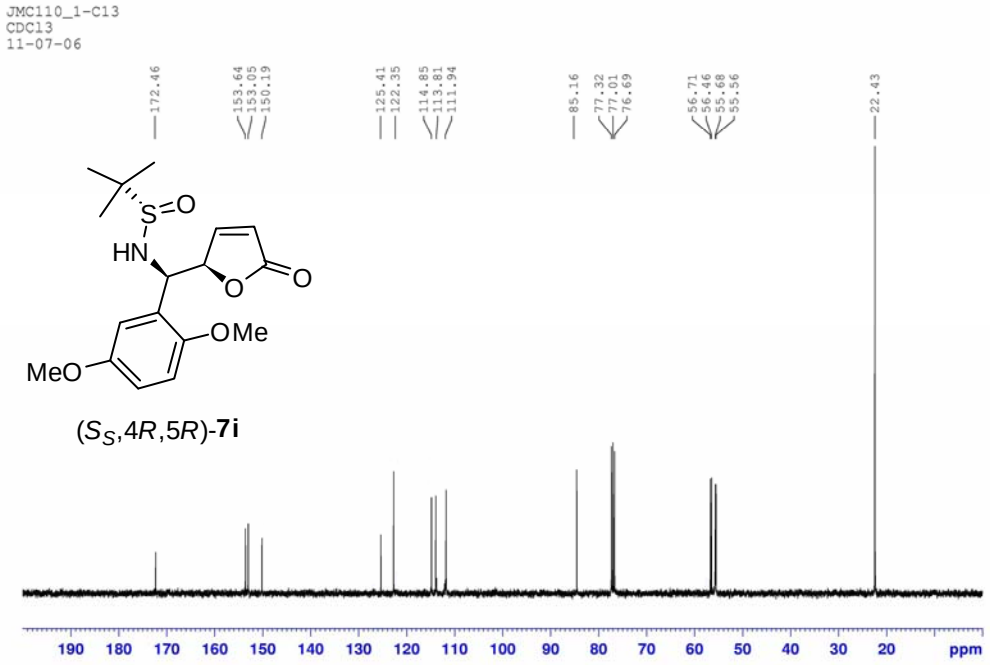
(S_S,4*S*,5*R*)-**7i**



(S_S,4*S*,5*R*)-**7i**

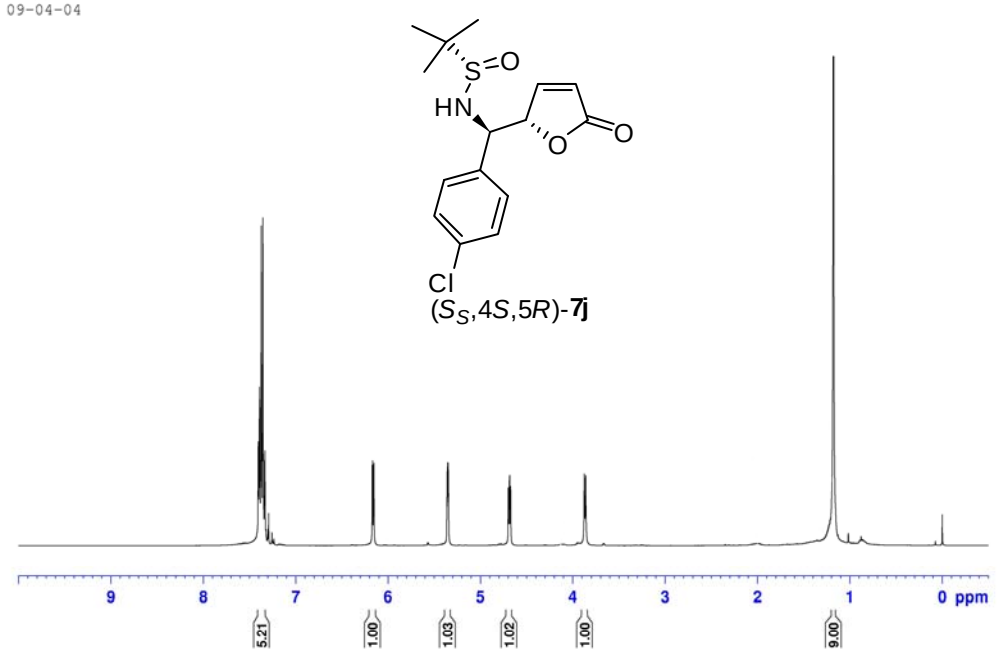


(S_S,4*R*,5*R*)-**7i**



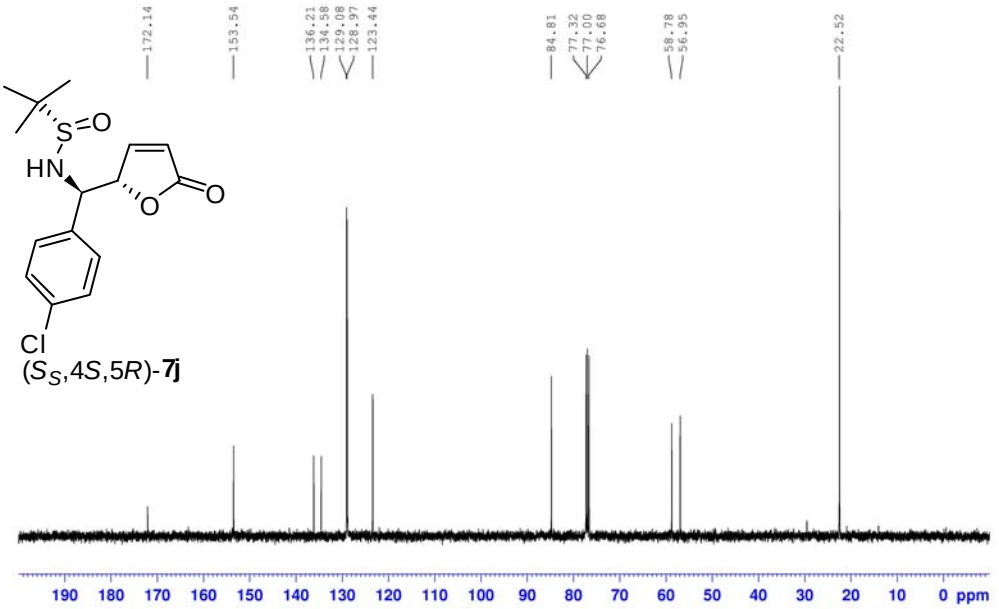
(S_S,4*R*,5*R*)-**7i**

JMC106-H1-105
CDCl3
09-04-04

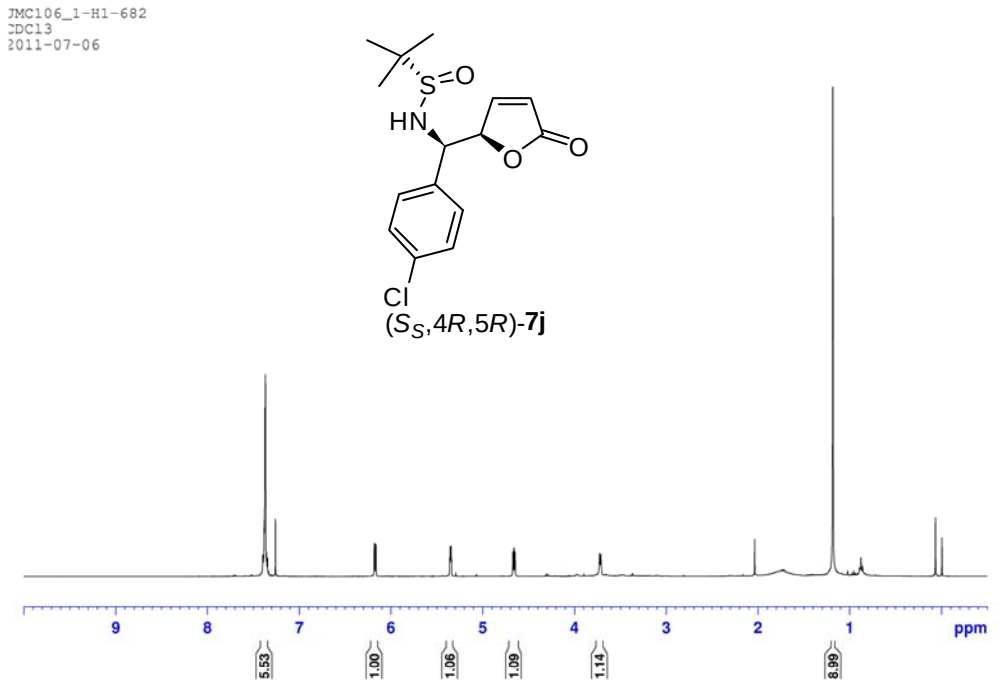


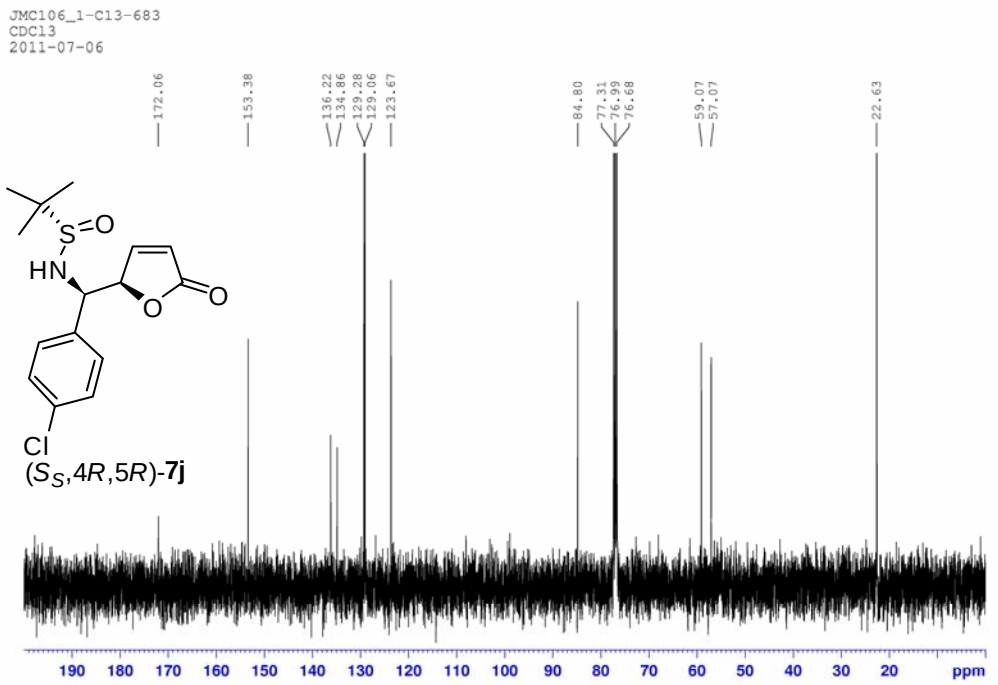
(S_S,4*S*,5*R*)-**7j**

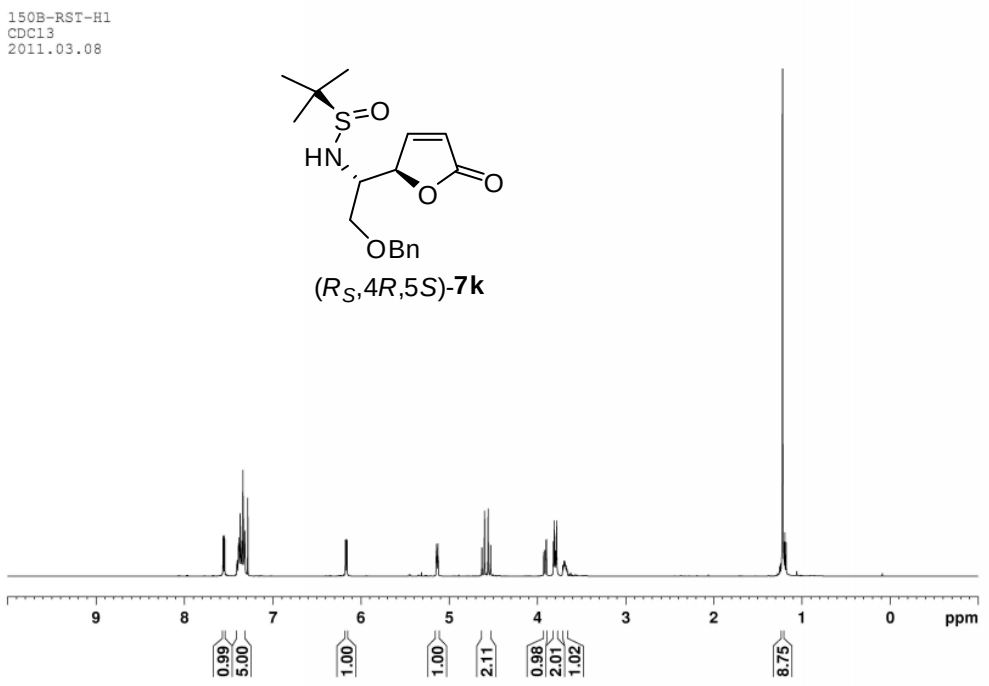
JMC106-C13-106
CDCl3
09-04-04



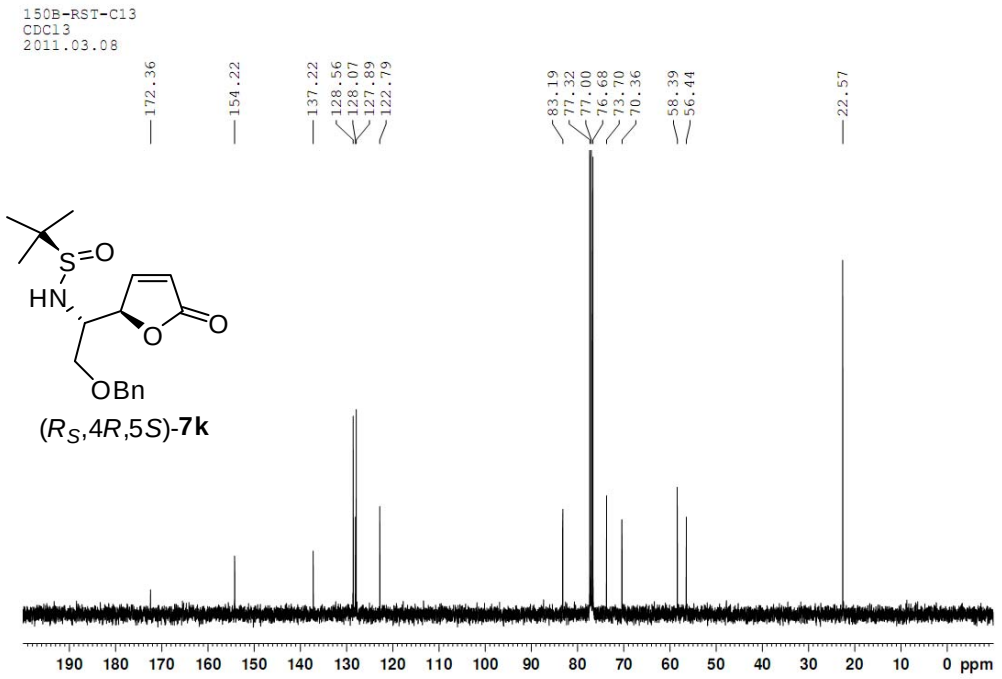
(S_S,4*S*,5*R*)-**7j**


JMC106_1-H1-682
CDC13
2011-07-06
S=O
HN
O
O
Cl
(S_S,4R,5R)-7j
9
8
7
6
5
4
3
2
1
ppm
5.53
1.00
1.06
1.09
1.14
8.99

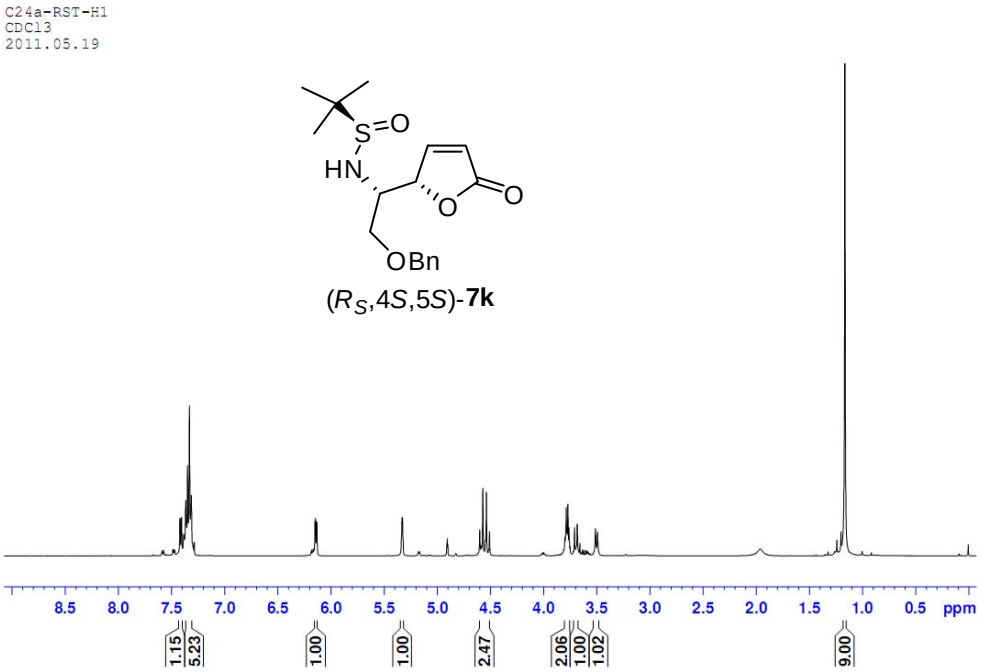

JMC106_1-C13-683
CDC13
2011-07-06
172.06
153.38
136.22
134.86
129.28
129.06
123.67
84.80
77.31
76.99
76.68
59.07
57.07
22.63
S=O
HN
O
O
Cl
(S_S,4R,5R)-7j
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm



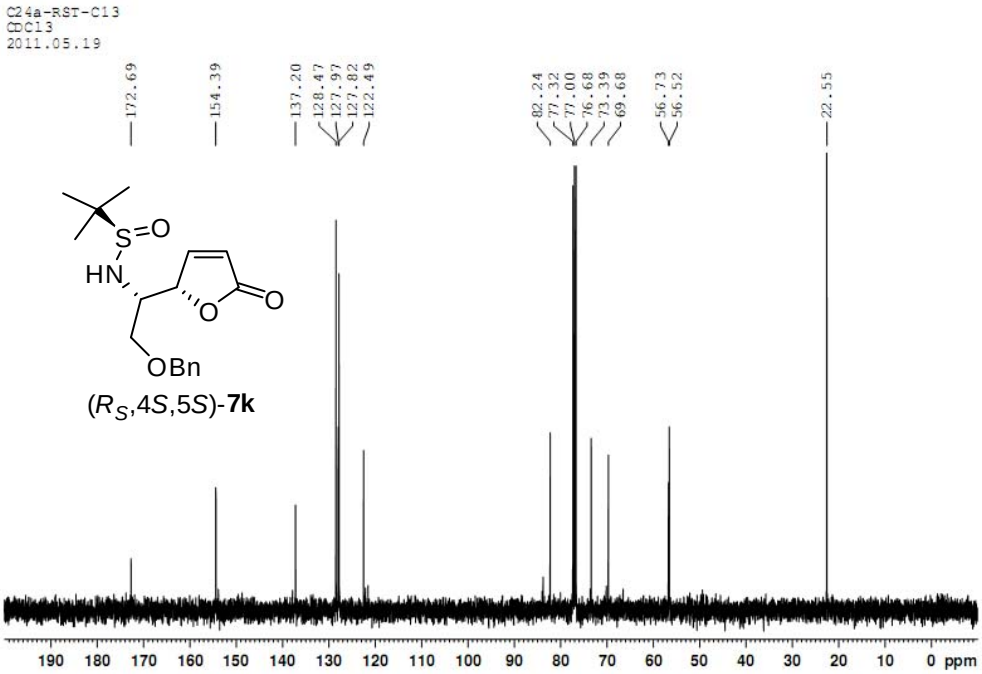
(R_S,4*R*,5*S*)-**7k**



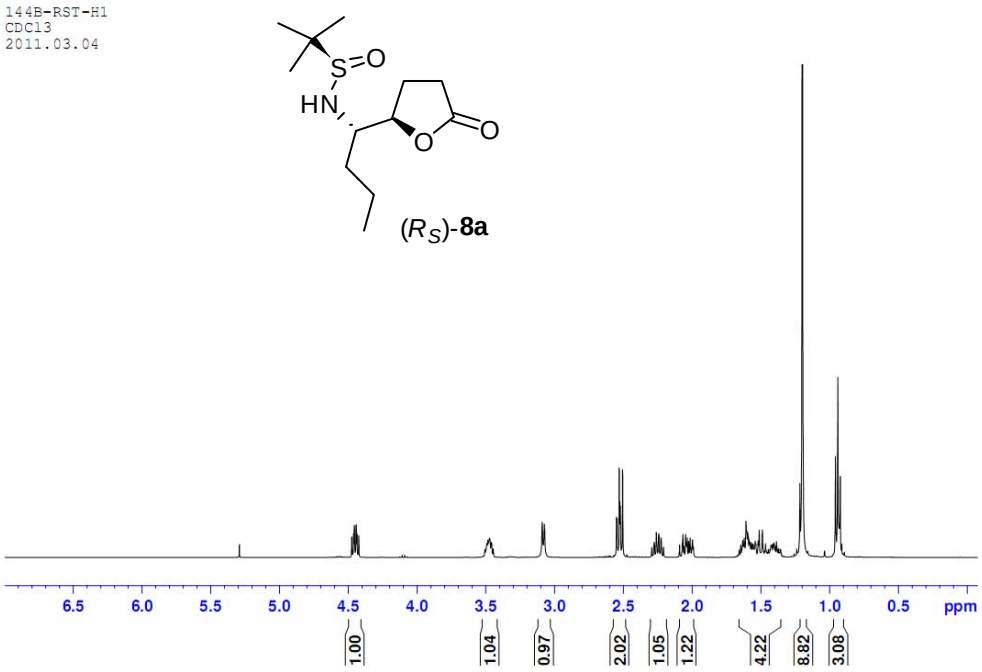
(R_S,4*R*,5*S*)-**7k**

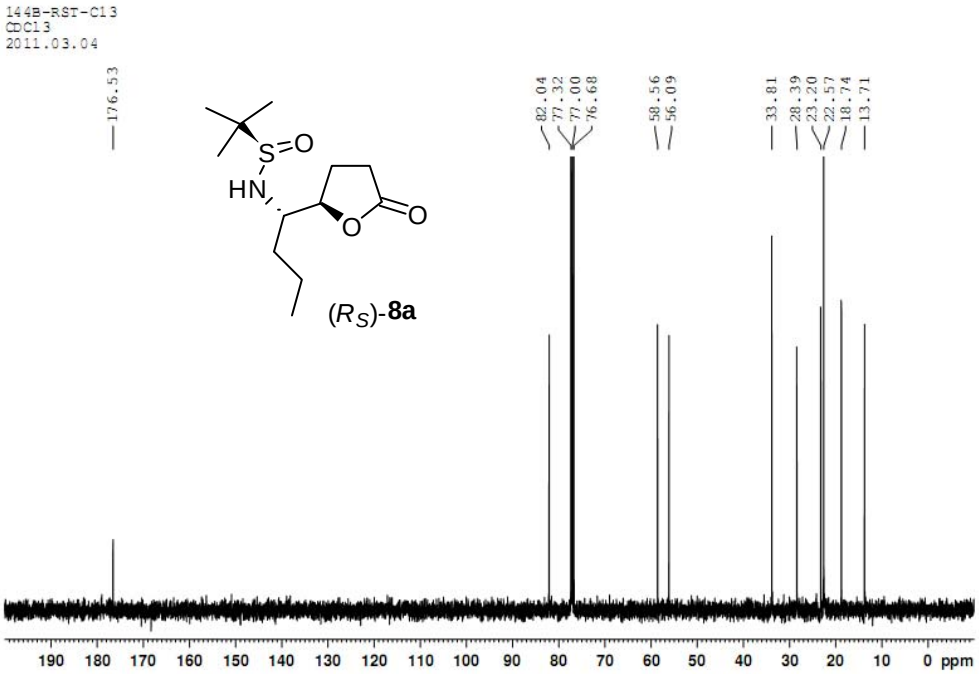


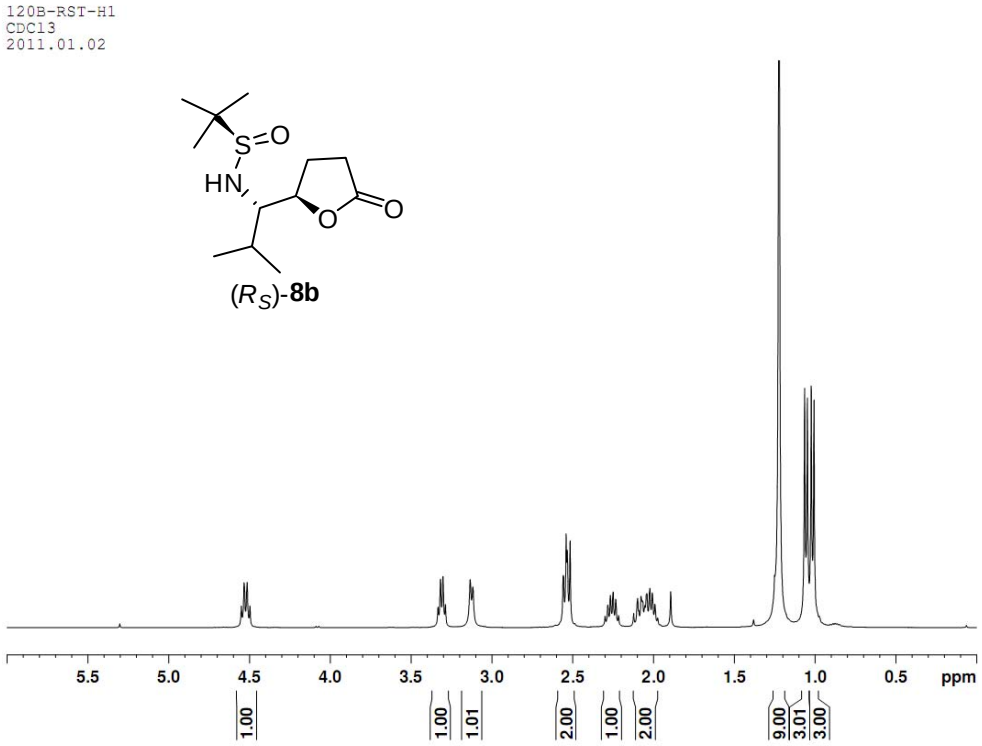
(R_S,4*S*,5*S*)-**7k**



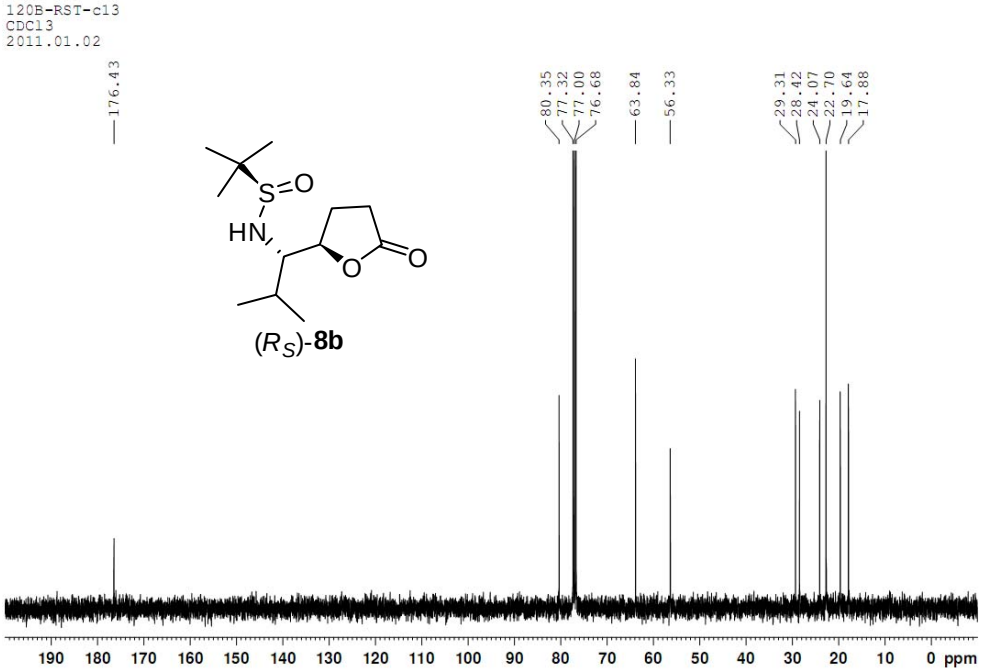
(R_S,4*S*,5*S*)-**7k**


144B-RST-H1
CDCl3
2011.03.04
S=O
HN
O
O
(RS)-8a
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.00
1.04
0.97
2.02
1.05
1.22
4.22
8.82
3.08

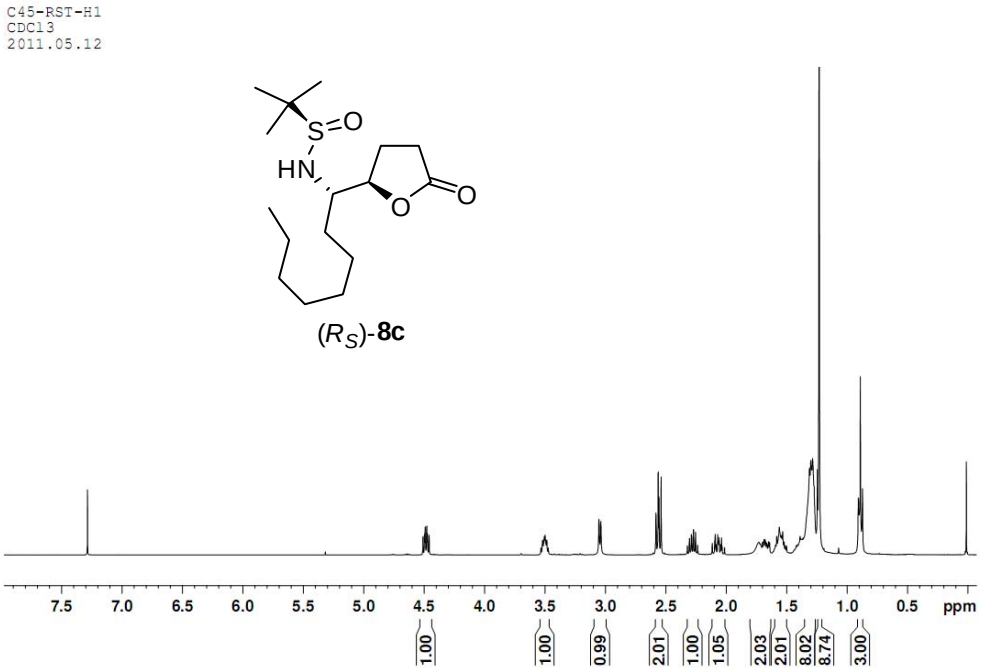

144B-RST-C13
CDCl3
2011.03.04
176.53
82.04
77.32
77.00
76.68
58.56
56.09
33.81
28.39
23.20
22.57
18.74
13.71
S=O
HN
O
O
(RS)-8a
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm


120B-RST-H1
CDCl3
2011.01.02
S=O
HN
O
O
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.00
1.00
1.01
2.00
1.00
2.00
9.00
3.01
3.00

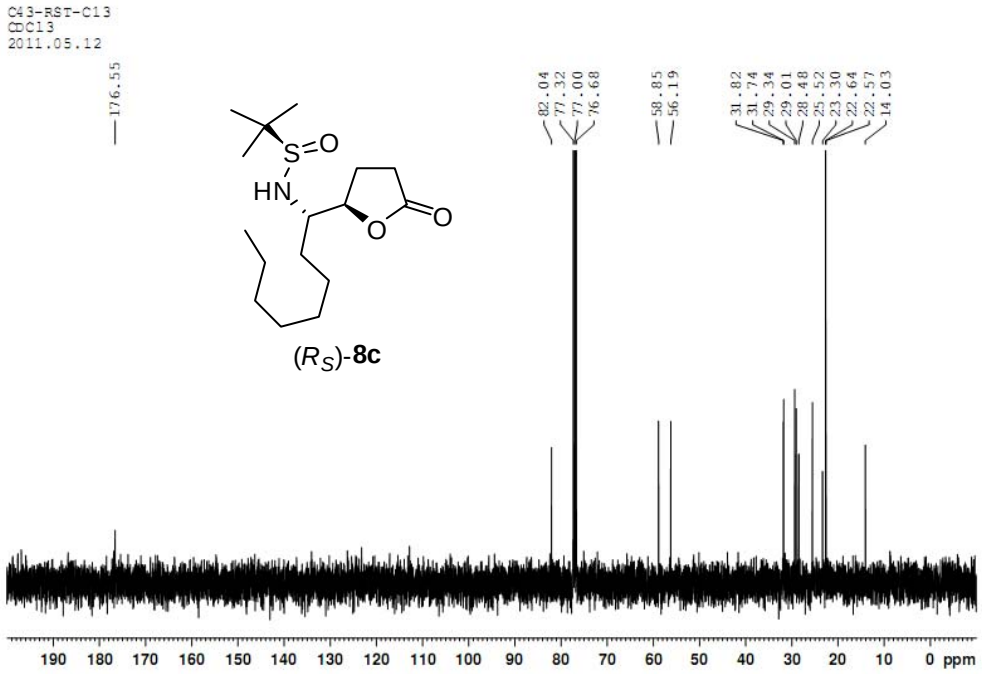
(R_S)-**8b**


120B-RST-c13
CDCl3
2011.01.02
176.43
80.35
77.32
77.00
76.68
63.84
56.33
29.31
28.42
24.07
22.70
19.64
17.88
S=O
HN
O
O
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

(R_S)-**8b**

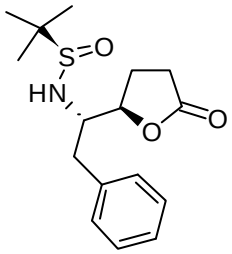

C45-RST-H1
CDCl3
2011.05.12
S=O
HN
O
O
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.00 1.00 0.99 2.01 1.00 1.05 2.03 2.01 8.02 8.74 3.00

(R_S)-**8c**

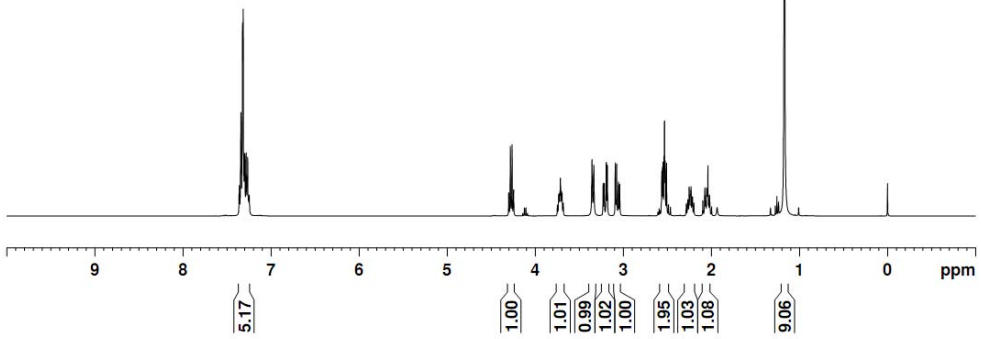

C43-RST-C13
CDCl3
2011.05.12
176.55
82.04
77.32
77.00
76.68
58.85
56.19
31.82
31.74
29.34
29.01
28.48
25.52
23.30
22.64
22.57
14.03
S=O
HN
O
O
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

(R_S)-**8c**

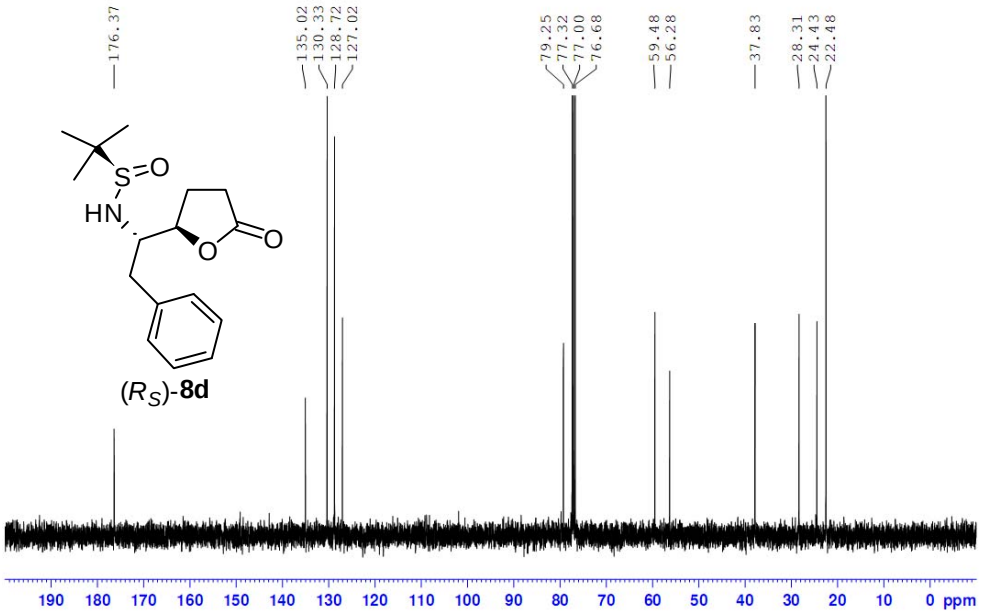
RST-A95-H1
CDCl3
2010.01.02



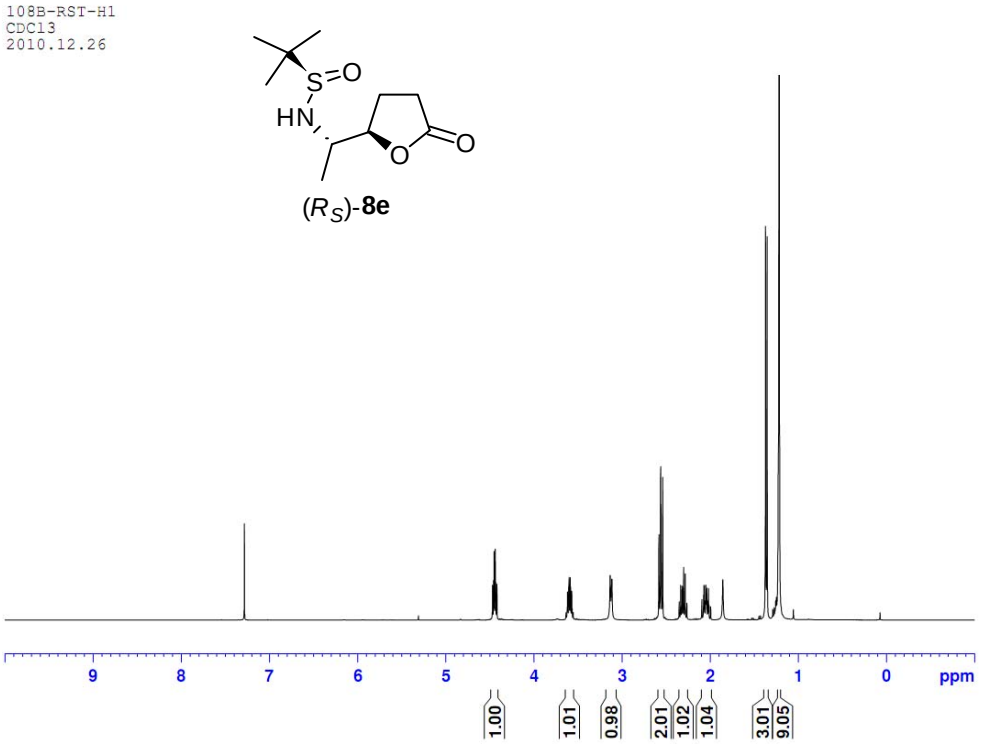
(R_S)-**8d**

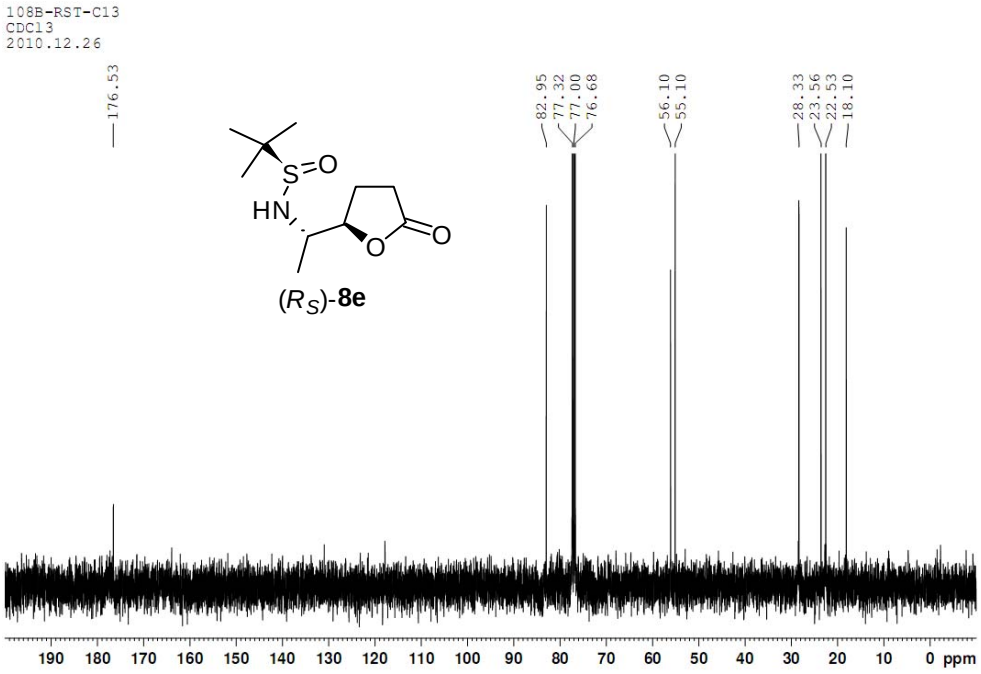


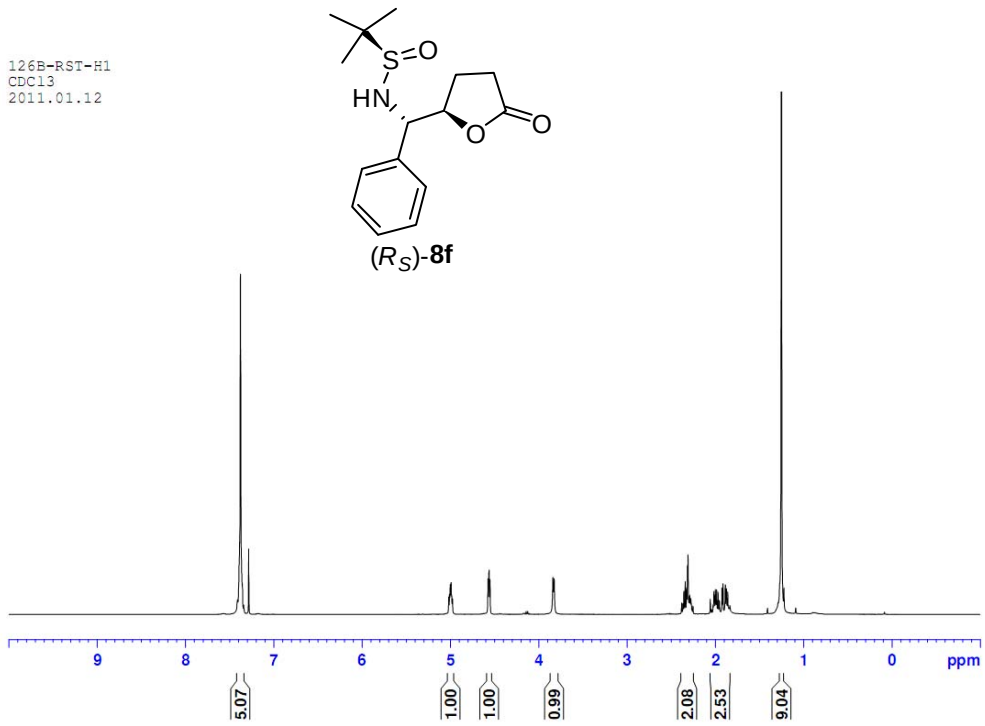
RST-A95-C13
CDCl3
2010.01.02



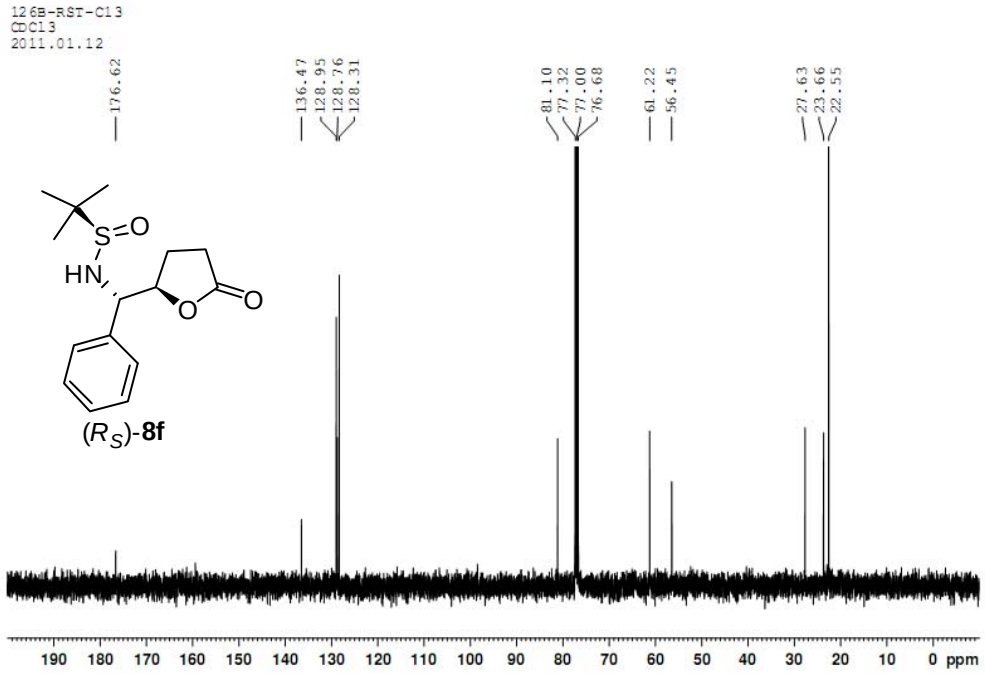
(R_S)-**8d**


108B-RST-H1
CDCl3
2010.12.26
S=O
HN
O
O
(RS)-8e
9
8
7
6
5
4
3
2
1
0
ppm
1.00
1.01
0.98
2.01
1.02
1.04
3.01
9.05

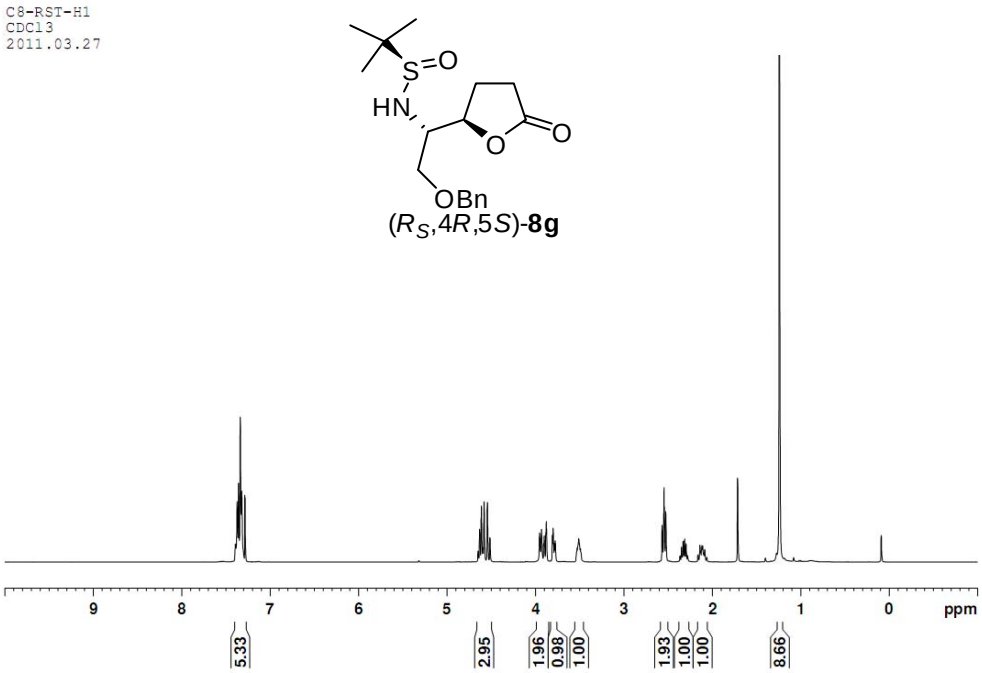

108B-RST-C13
CDCl3
2010.12.26
176.53
82.95
77.32
77.00
76.68
56.10
55.10
28.33
23.56
22.53
18.10
S=O
HN
O
O
(RS)-8e
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

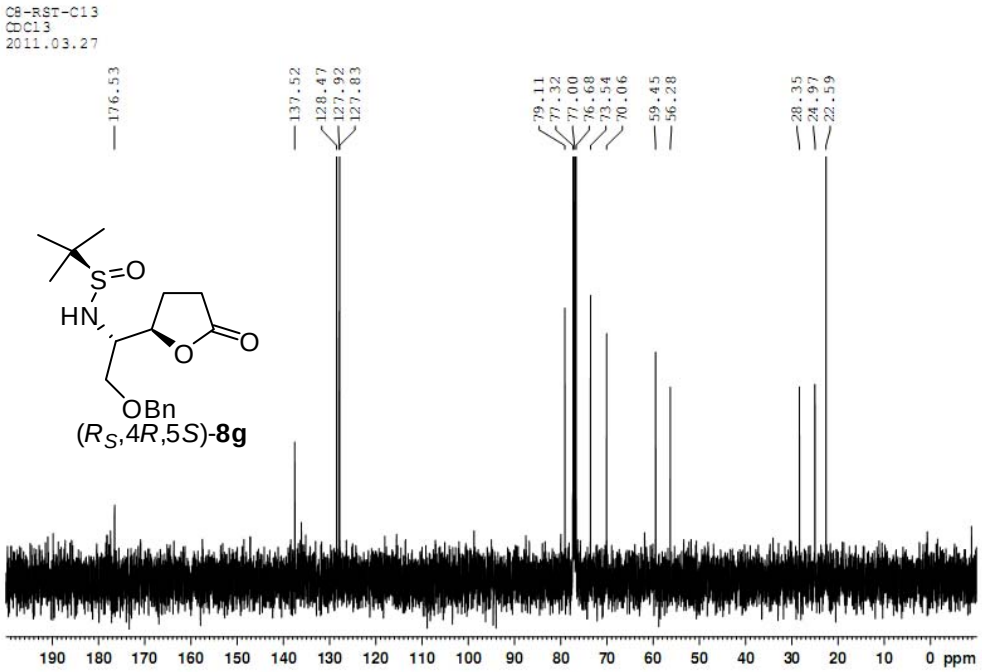

126B-RST-H1
CDCl3
2011.01.12
S=O
HN
O
O
9
8
7
6
5
4
3
2
1
0
ppm
5.07
1.00
1.00
0.99
2.08
2.53
9.04

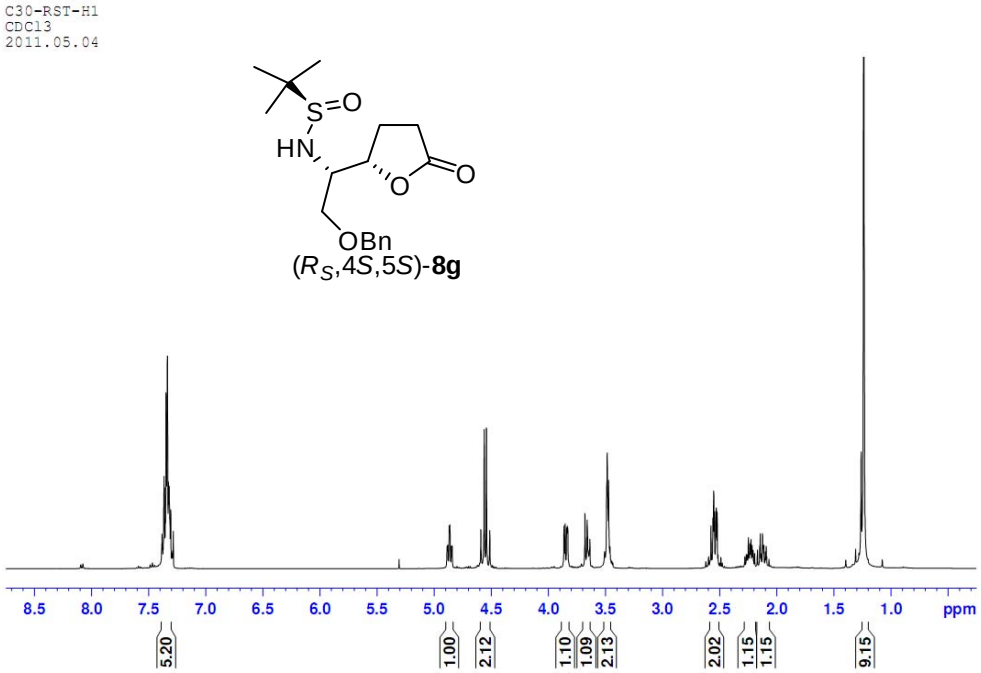
(R_S)-**8f**


126B-RST-C13
CDCl3
2011.01.12
176.62
136.47
128.95
128.76
128.31
81.10
77.32
77.00
76.68
61.22
56.45
27.63
23.66
22.55
S=O
HN
O
O
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

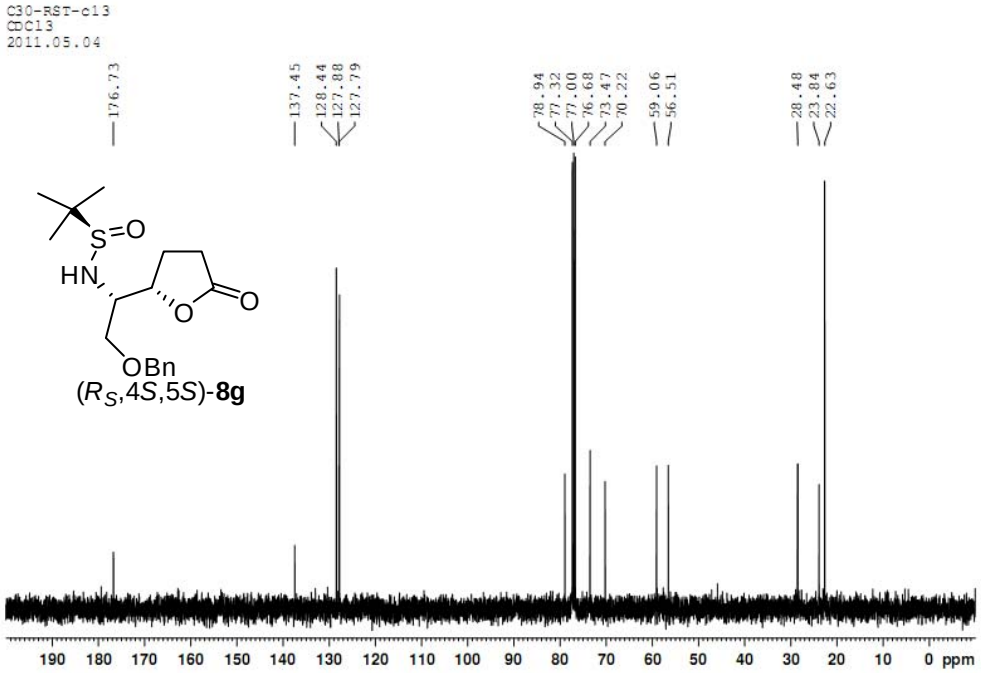
(R_S)-**8f**


C8-RST-H1
CDCl3
2011.03.27
S=O
HN
O
O
OBn
(RS,4R,5S)-8g
9
8
7
6
5
4
3
2
1
0
ppm
5.33
2.95
1.96
0.98
1.00
1.93
1.00
1.00
8.66

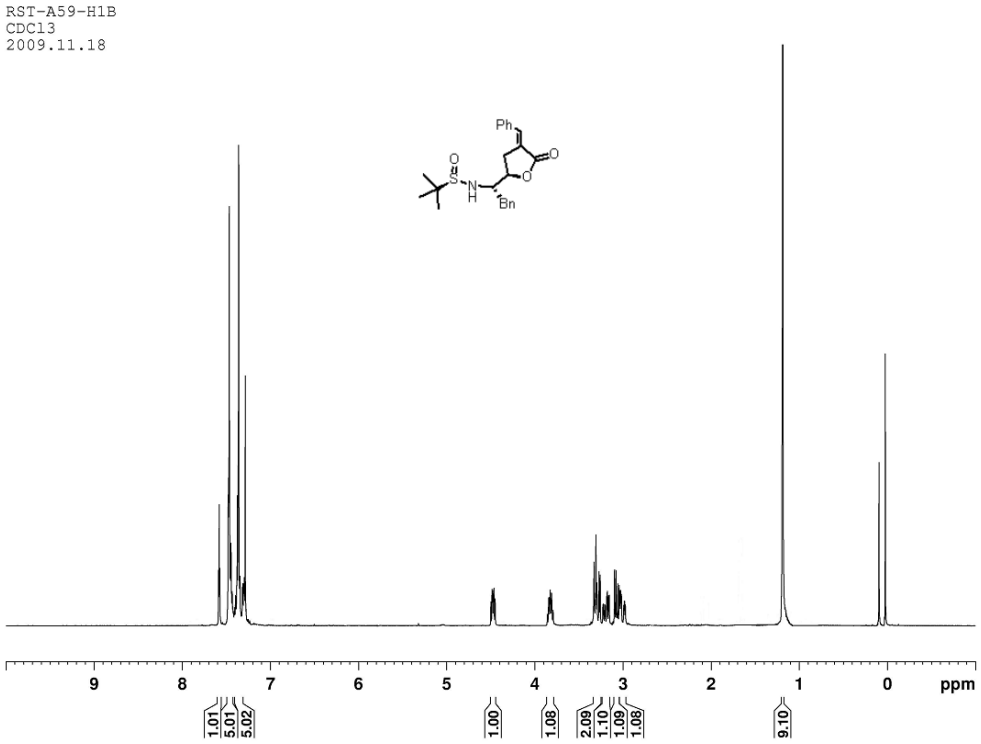

C8-RST-C13
CDCl3
2011.03.27
176.53
137.52
128.47
127.92
127.83
79.11
77.32
77.00
76.68
73.54
70.06
59.45
56.28
28.35
24.97
22.59
S=O
HN
O
O
OBn
(RS,4R,5S)-8g
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

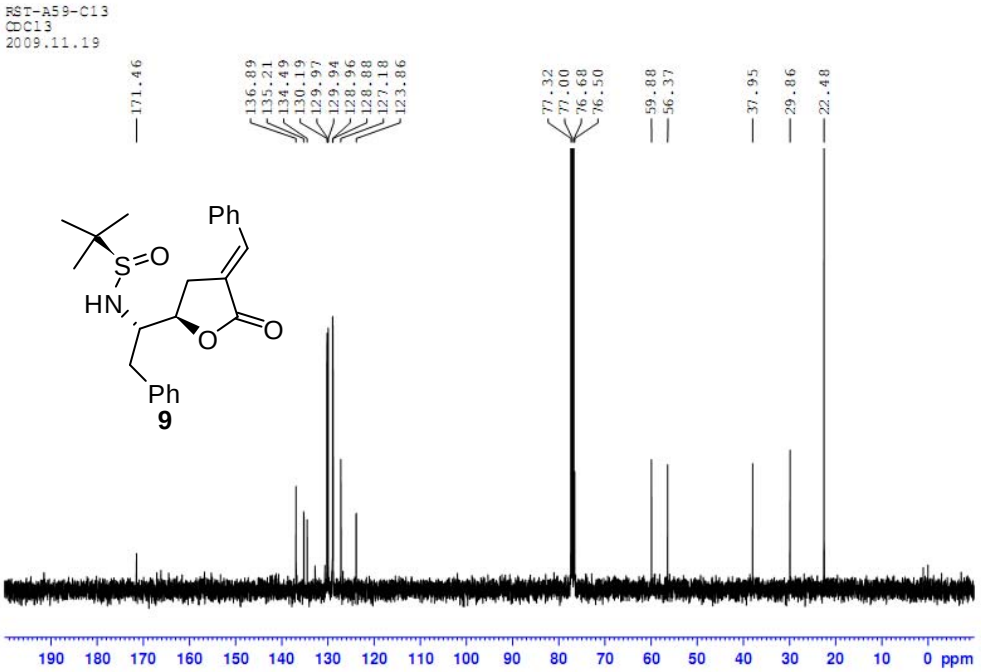


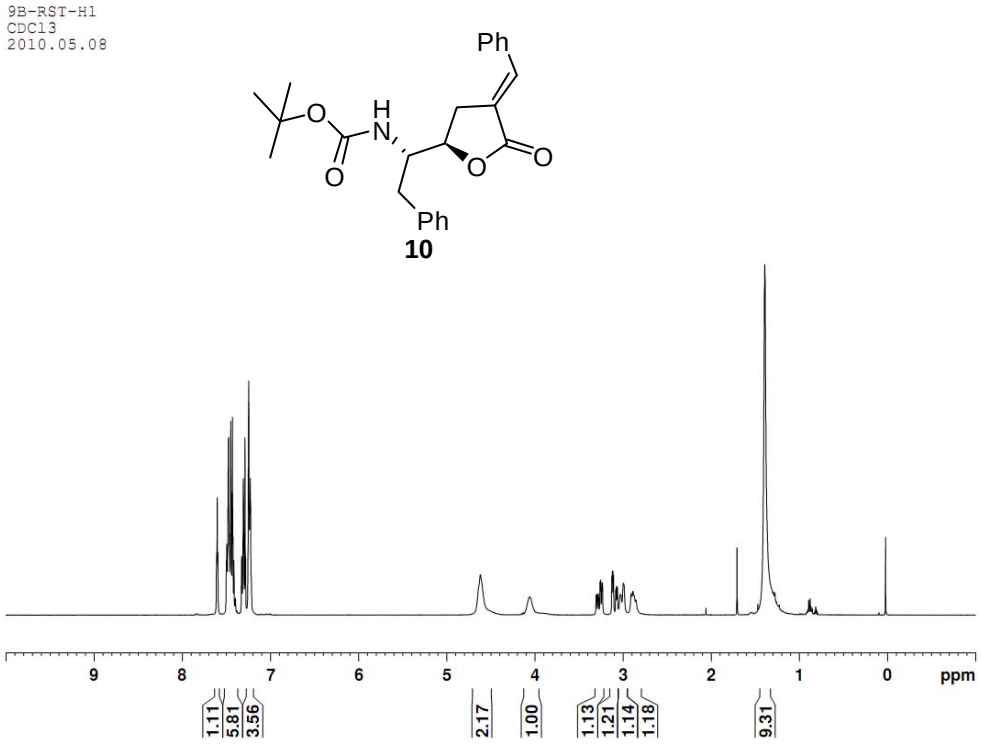
(R_S,4*S*,5*S*)-**8g**

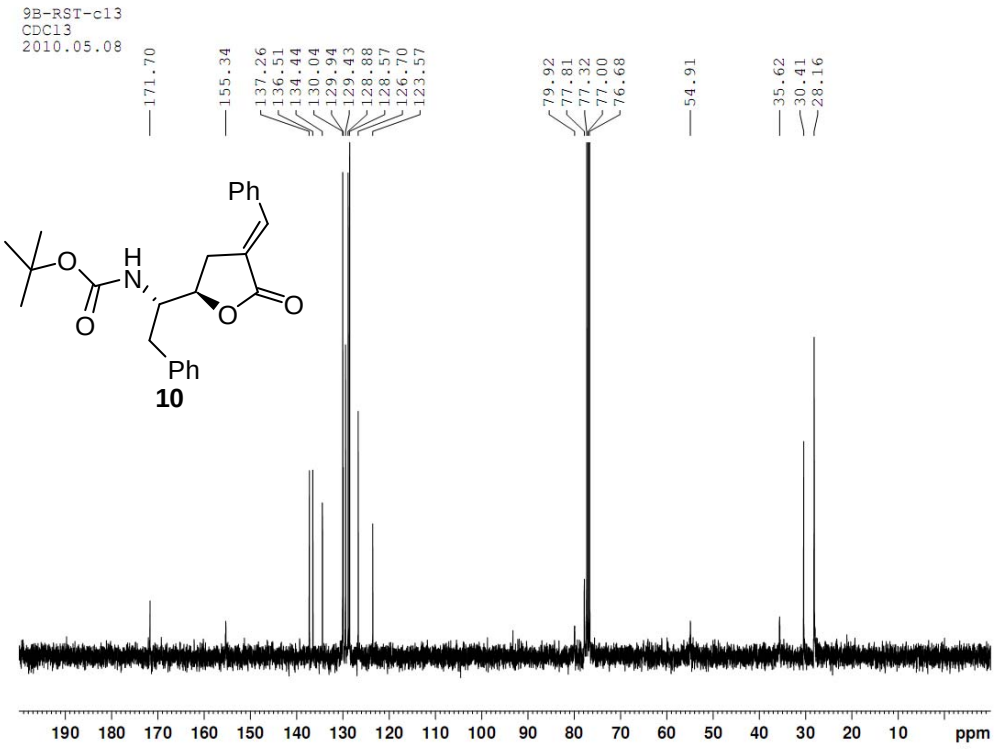


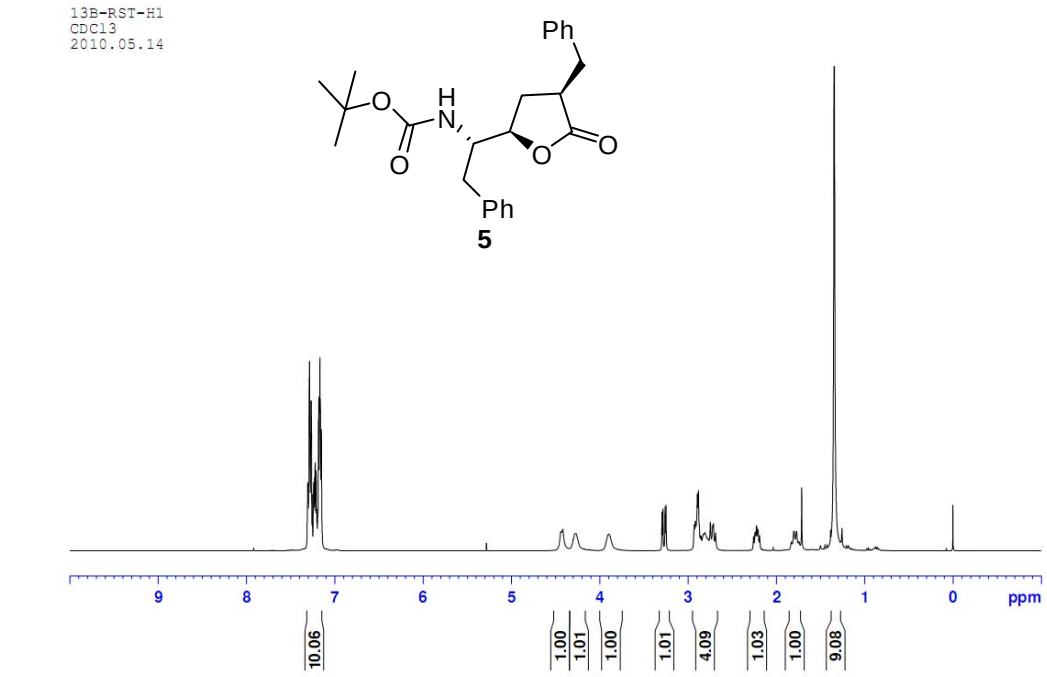
(R_S,4*S*,5*S*)-**8g**

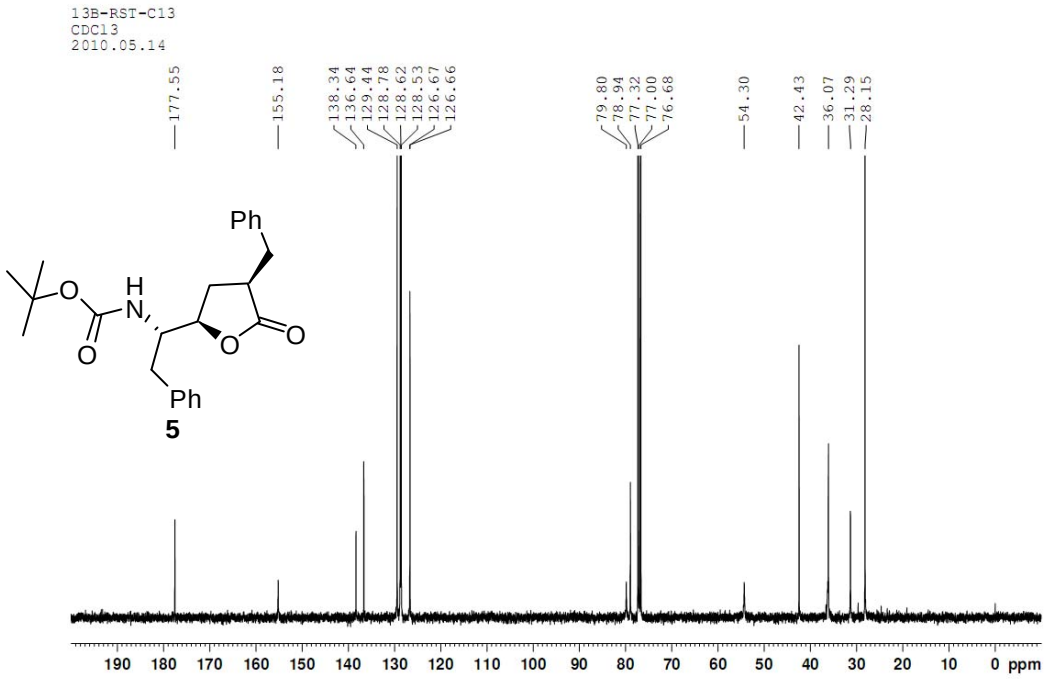

RST-A59-H1B
CDCl3
2009.11.18
Ph
O
S
N
H
Bn
O
O
9
8
7
6
5
4
3
2
1
0
ppm
1.01
5.01
5.02
1.00
1.08
2.09
1.10
1.09
1.08
9.10


RST-A59-C13
CDCl3
2009.11.19
171.46
136.89
135.21
134.49
130.19
129.97
129.94
128.96
128.88
127.18
123.86
77.32
77.00
76.68
76.50
59.88
56.37
37.95
29.86
22.48
Ph
S=O
HN
O
O
Ph
9
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

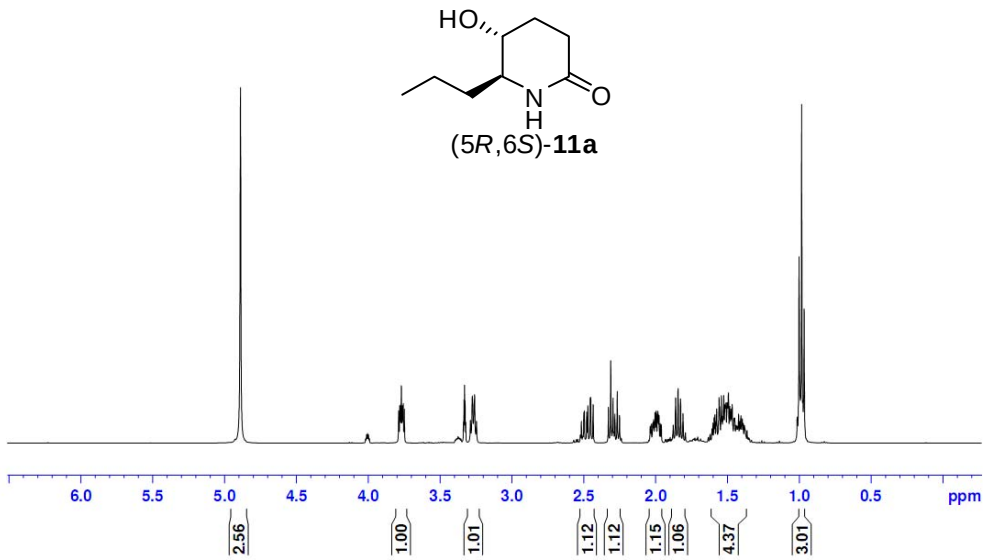

9B-RST-H1
CDCl3
2010.05.08
Ph
H
N
O
O
O
O
Ph
10
9
8
7
6
5
4
3
2
1
0
ppm
1.11
5.81
3.56
2.17
1.00
1.13
1.21
1.14
1.18
9.31


9B-RST-c13
CDCl3
2010.05.08
171.70
155.34
137.26
136.51
134.44
130.04
129.94
129.43
128.88
128.57
126.70
123.57
79.92
77.81
77.32
77.00
76.68
54.91
35.62
30.41
28.16
Ph
H
N
O
O
O
O
Ph
10
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


13B-RST-H1
CDCl3
2010.05.14
Ph
H
N
O
O
O
O
Ph
5
9
8
7
6
5
4
3
2
1
0
ppm
10.06
1.00
1.01
1.00
1.01
4.09
1.03
1.00
9.08

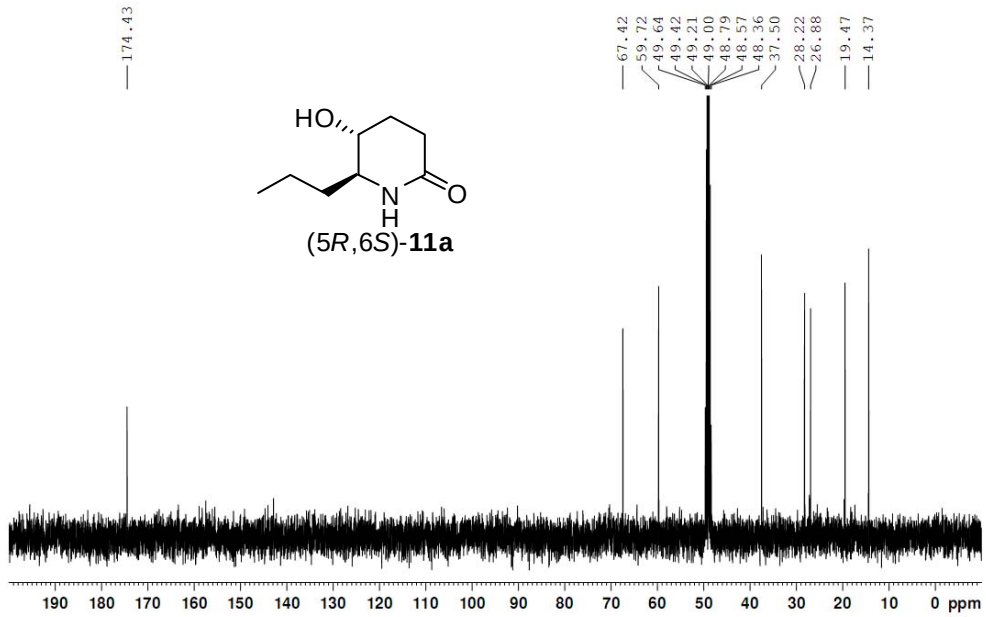

13B-RST-C13
CDCl3
2010.05.14
177.55
155.18
138.34
136.64
129.44
128.78
128.62
128.53
126.67
126.66
79.80
78.94
77.32
77.00
76.68
54.30
42.43
36.07
31.29
28.15
Ph
H
N
O
O
O
O
Ph
5
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

96B-RST-H1
MeOD
2010.12.16

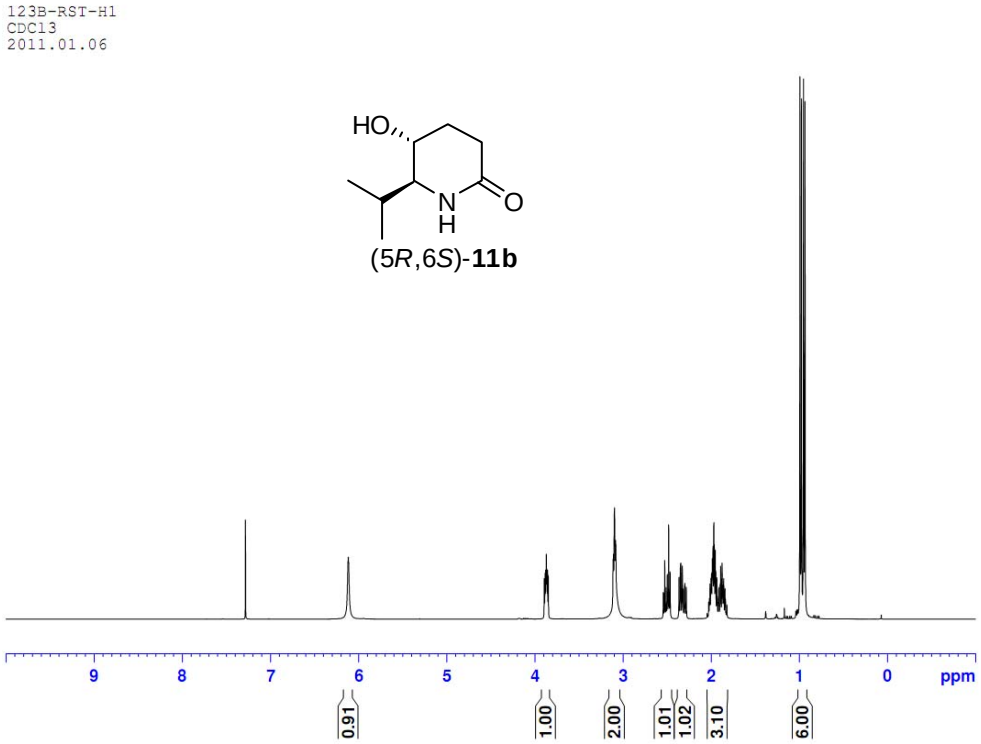


(5*R*,6*S*)-**11a**

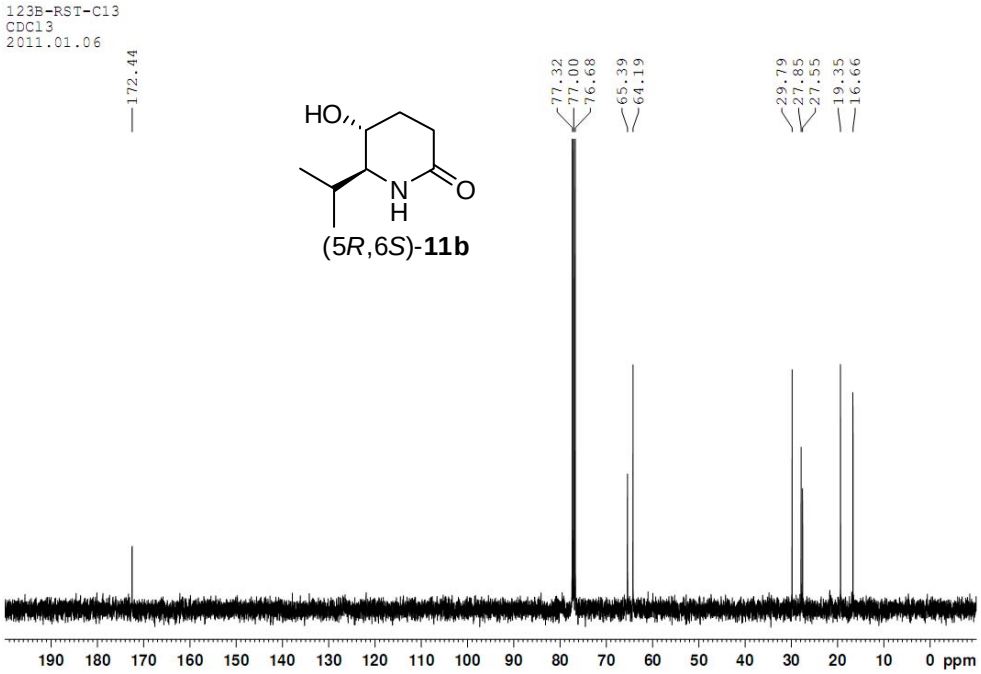
96B-RST-C13
CD3OD
2010.12.16



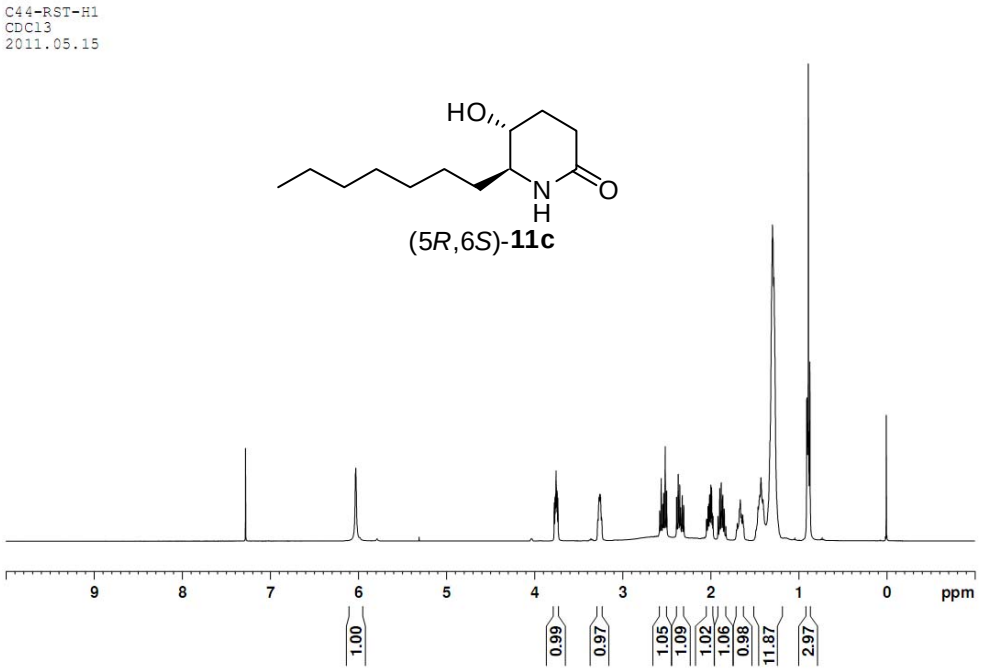
(5*R*,6*S*)-**11a**



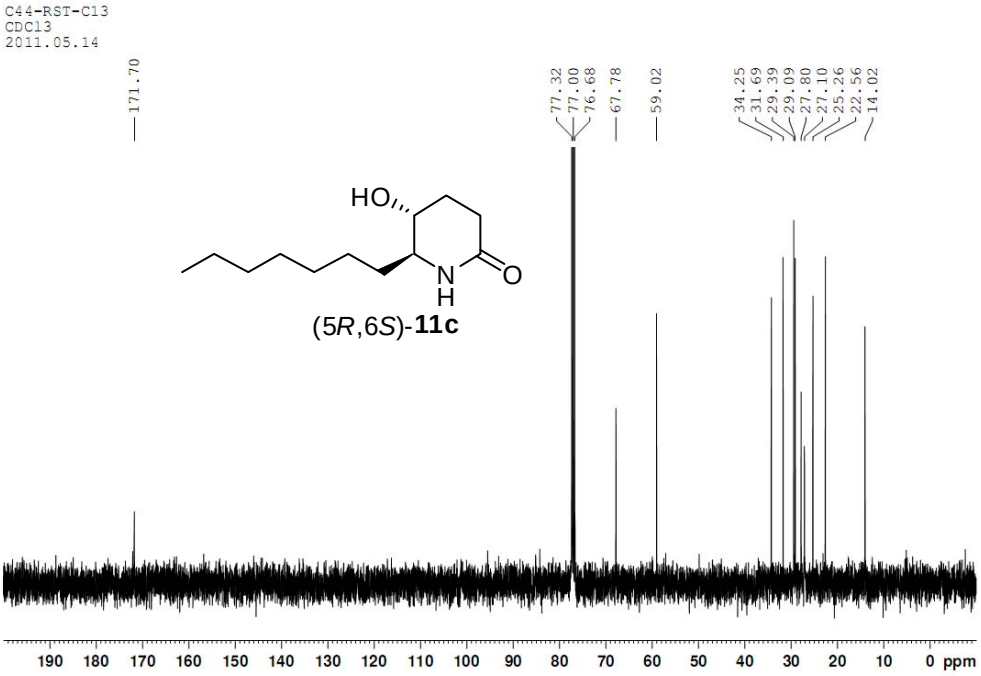
(5*R*,6*S*)-**11b**



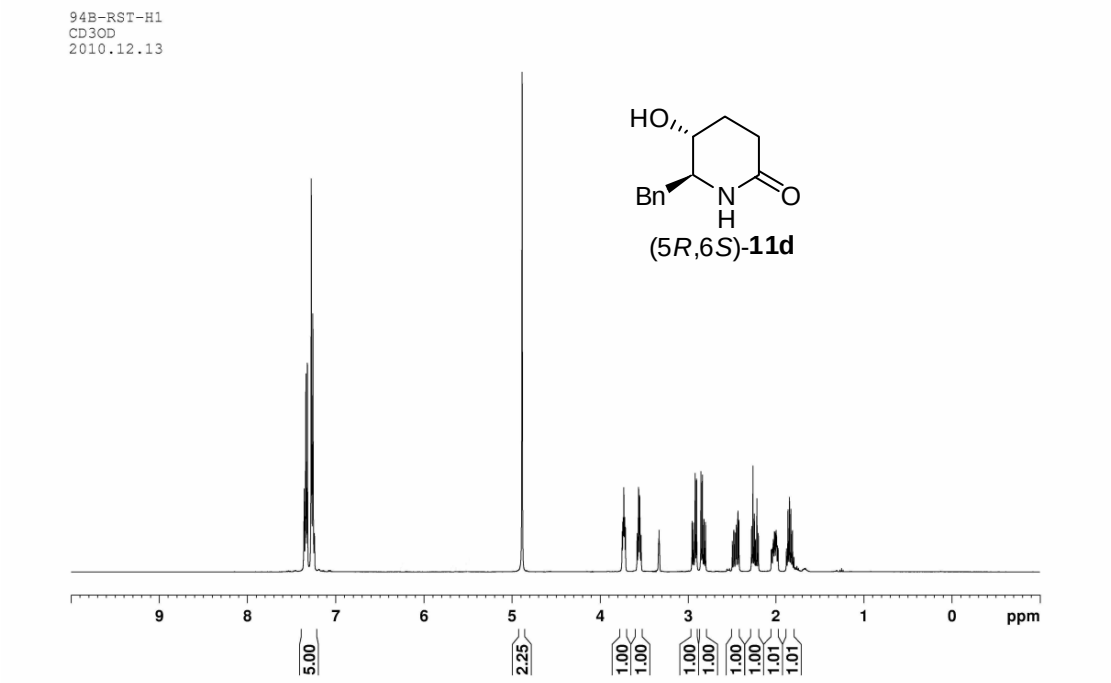
(5*R*,6*S*)-**11b**

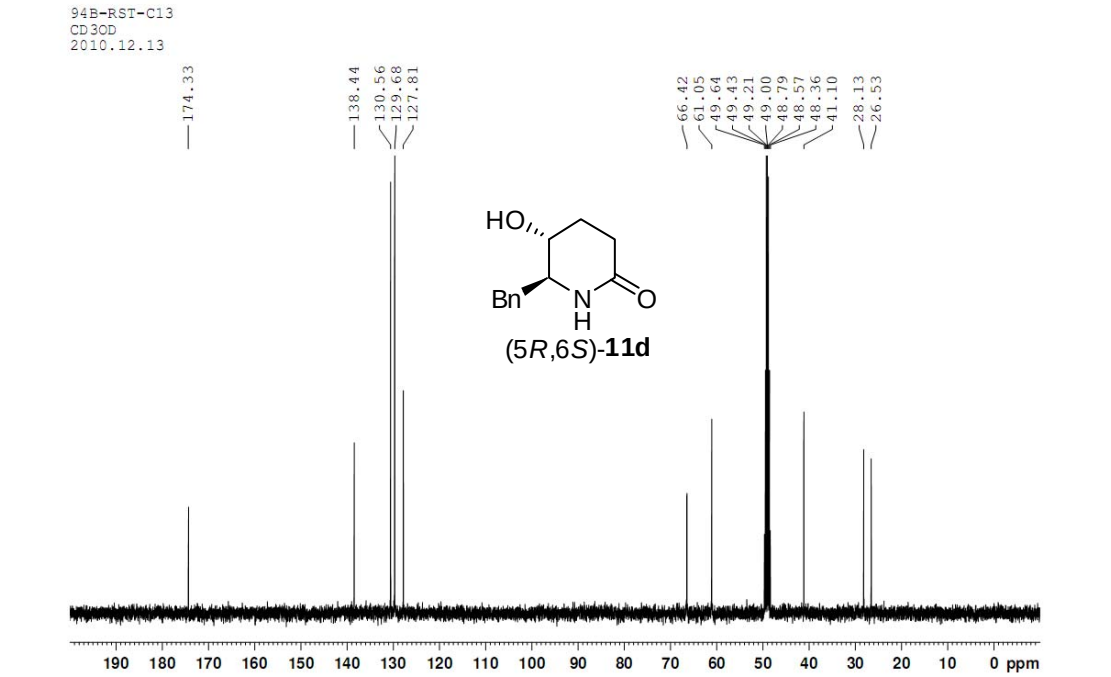


(5*R*,6*S*)-**11c**



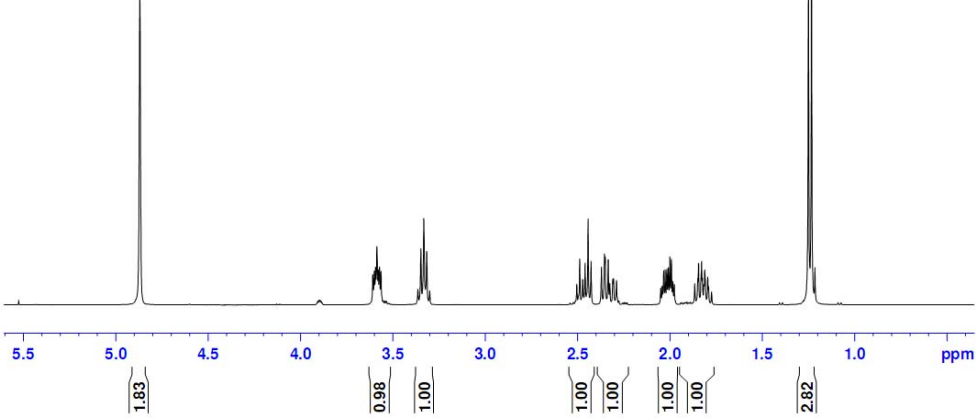
(5*R*,6*S*)-**11c**


94B-RST-H1
CD3OD
2010.12.13
HO
Bn
N
H
O
(5R,6S)-11d
9
8
7
6
5
4
3
2
1
0
ppm
5.00
2.25
1.00
1.00
1.00
1.00
1.00
1.00
1.01
1.01

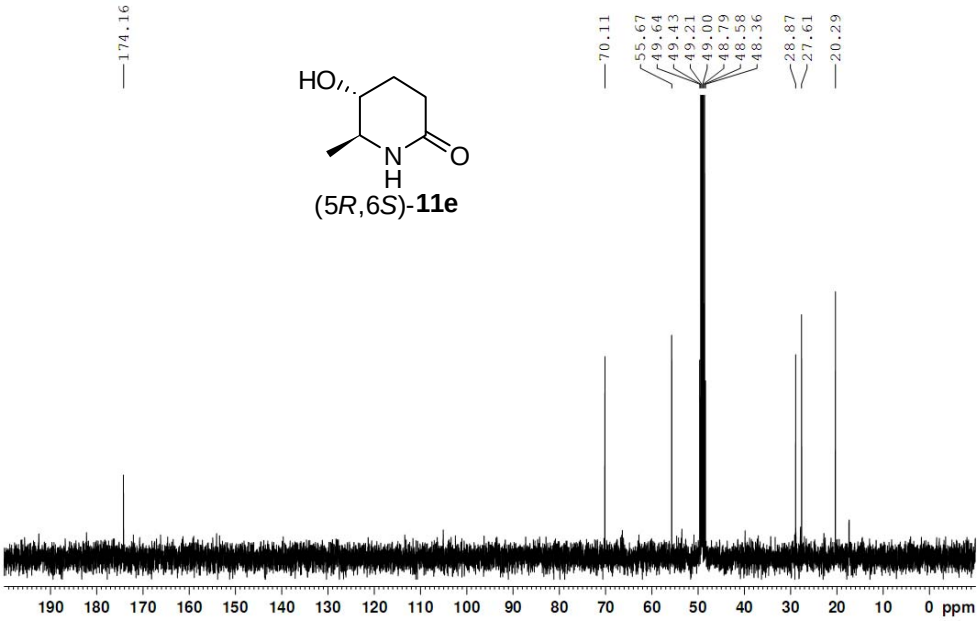

94B-RST-C13
CD3OD
2010.12.13
174.33
138.44
130.56
129.68
127.81
66.42
61.05
49.64
49.43
49.21
49.00
48.79
48.57
48.36
41.10
28.13
26.53
HO
Bn
N
H
O
(5R,6S)-11d
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

111B-RST-H1
MeOD
2010.12.26

(5*R*,6*S*)-**11e**



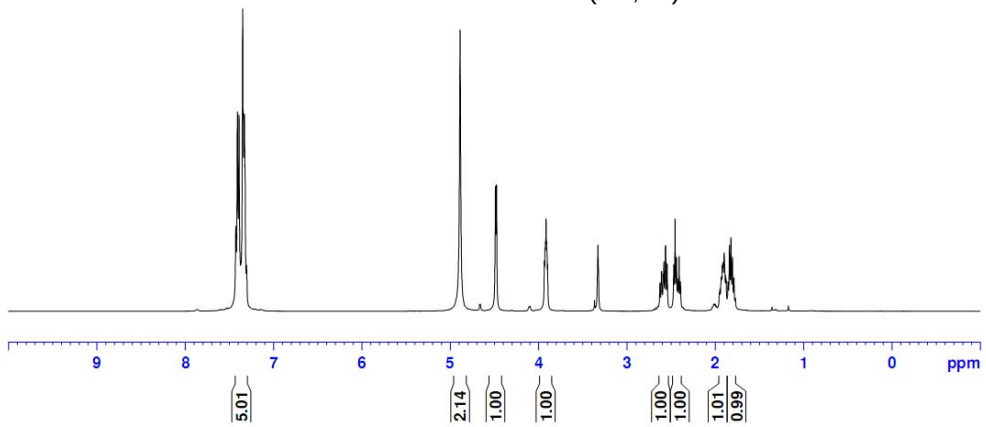
111bB-RST-C13
CD3OD
2010.12.28



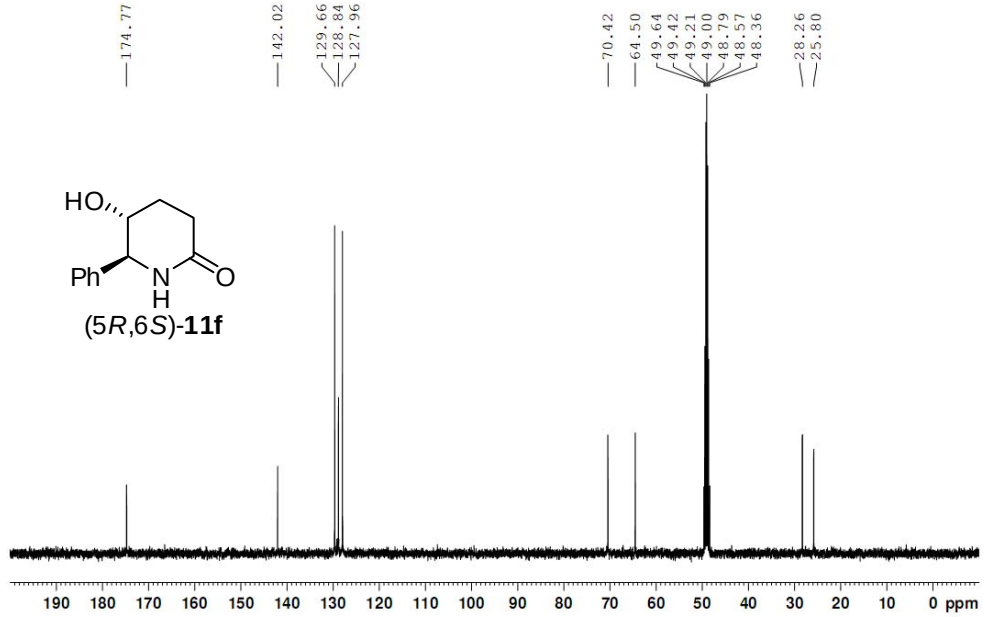
(5*R*,6*S*)-**11e**

129B-RST-H1
MeOD
2011.01.16

(5*R*,6*S*)-**11f**

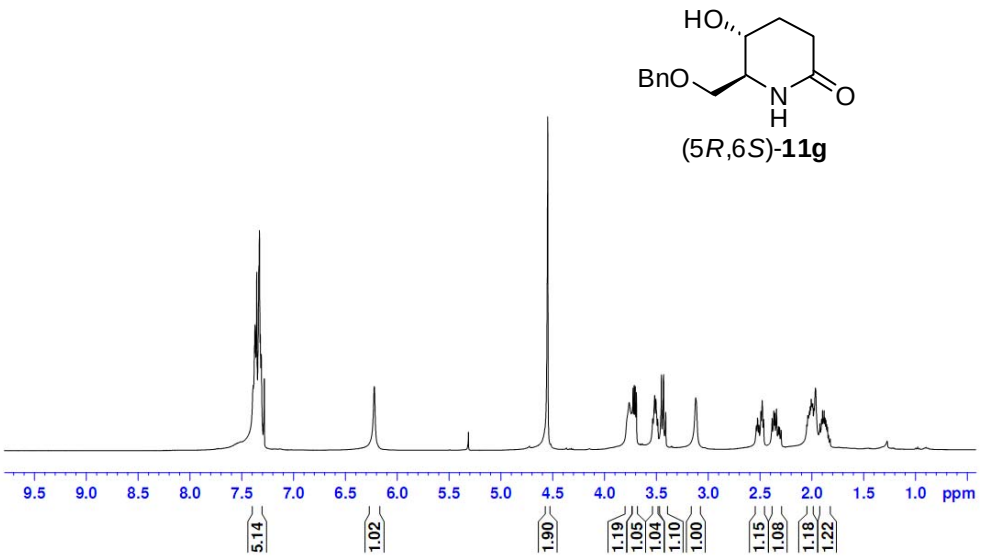


129B-RST-C13
CD3OD
2011.01.16



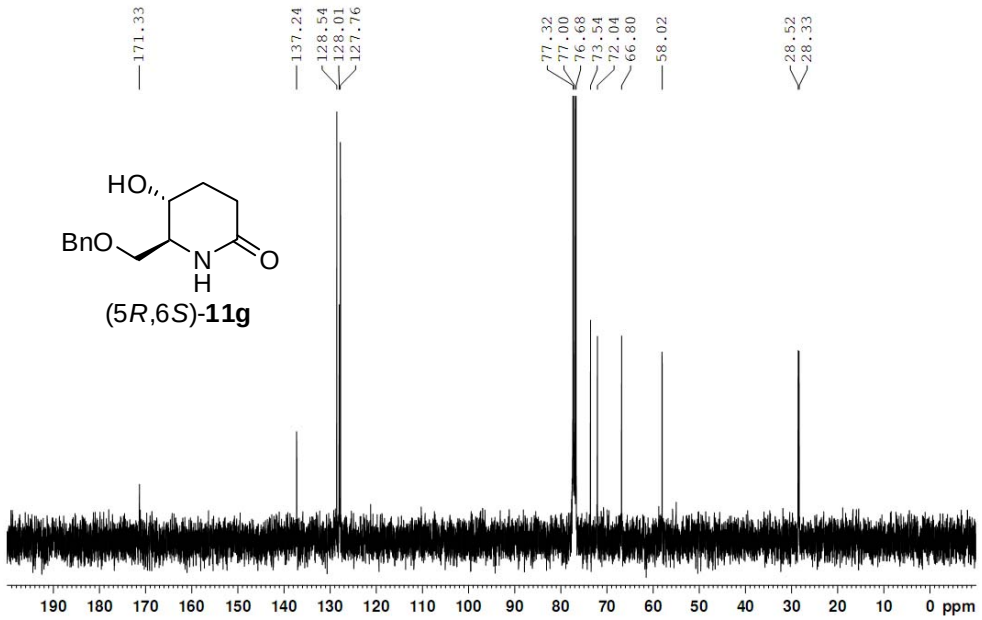
(5*R*,6*S*)-**11f**

C11-RST-H1
CDCl3
2011.04.03



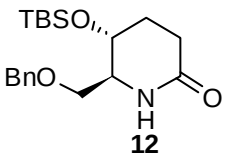
(5*R*,6*S*)-**11g**

C11-RST-C13
CDCl3
2011.03.31



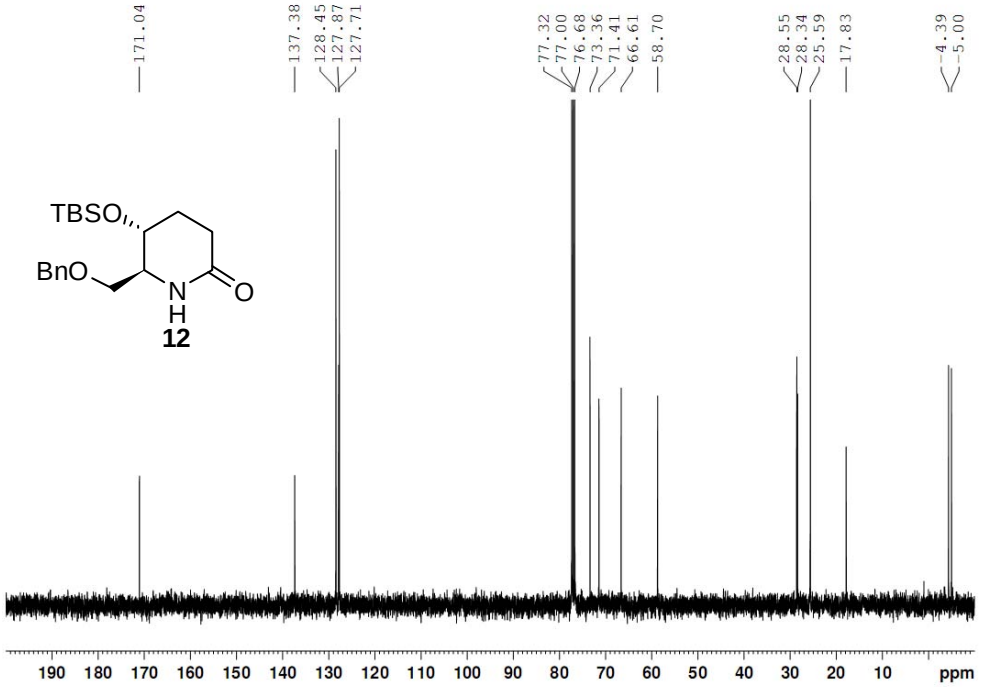
(5*R*,6*S*)-**11g**

C16-RST-H1
CDCl3
2011.04.15



12

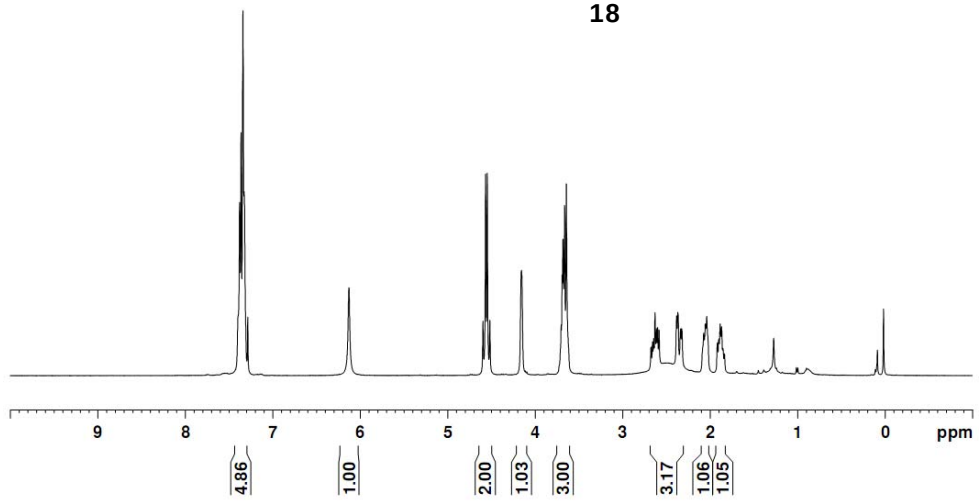
C16-RST-c13
CDCl3
2011.04.15



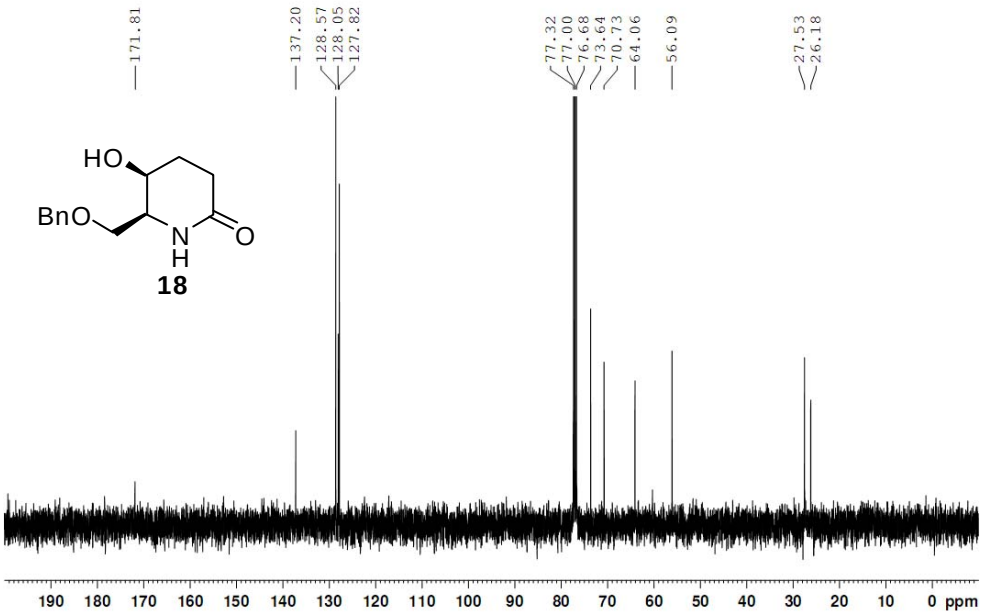
12

C21-RST-H1
CDCl3
2011.04.24

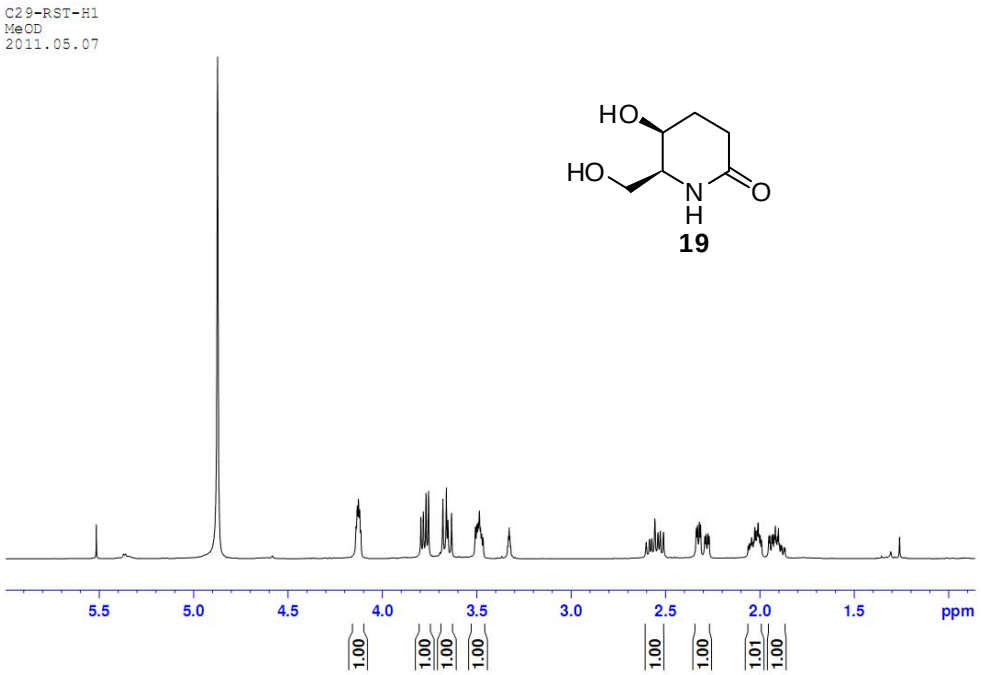
18

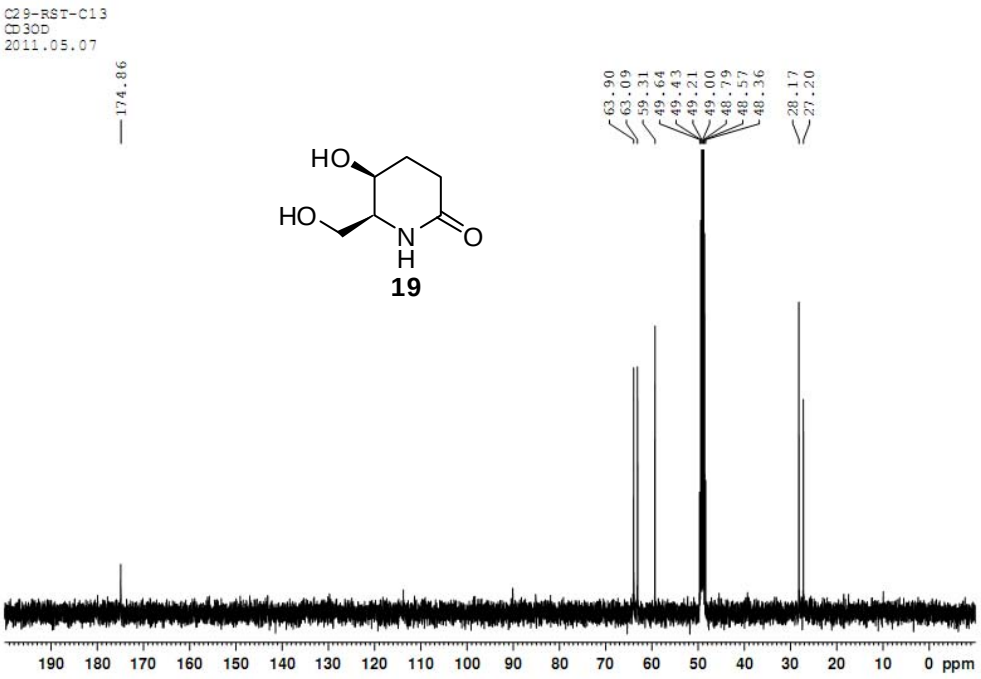


C21-RST-C13
CDCl3
2011.04.24



18


C29-RST-H1
MeOD
2011.05.07
HO
HO
N
H
O
19
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
ppm
1.00
1.00
1.00
1.00
1.00
1.00
1.01
1.00


C29-RST-C13
CD3OD
2011.05.07
174.86
63.90
63.09
59.31
49.64
49.43
49.21
49.00
48.79
48.57
48.36
28.17
27.20
HO
HO
N
H
O
19
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm