Electronic Supplementary Material (ESI) for ChemComm.

Supplementary Information-1

Stereoselective Synthesis of 4-Substituted-Cyclic Sulfamidate-5-Carboxylates By Asymmetric Transfer Hydrogenation Accompanying Dynamic Kinetic Resolution and Its Use in Concise Stereoselective Synthesis of (-)-*epi*-Cytoxazone and Taxotere Side-Chain.

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General

All commercial reagents were used as obtained commercially unless otherwise noted. Reactions were performed using oven dried glassware under an atmosphere of nitrogen. Dichloromethane (DCM), ether, THF were dried and purified using a solvent purification system. Flash column chromatography was carried out on Fuji Chromatorex silica gel (38-75 μm). Analytical thin layer chromatography (TLC) was performed on Merck silica gel 60 F_{254} plates. Preparative thin layer chromatography (PLC) was performed on Merck silica gel 60 F_{254} 2mm plates. Visualization of the developed chromatogram was accomplished with UV light and by staining with ethanolic phosphomolybdic acid (PMA) solution or ninhydrin solution followed by heating.

Nuclear magnetic resonance (NMR) spectra were recorded using Bruker 500 MHz NMR instrument (^{1}H NMR at 500 MHz and ^{13}C NMR at 125 MHz) or Bruker 300 MHz NMR instrument (^{1}H NMR at 300 MHz and ^{13}C NMR at 75 MHz). ^{1}H NMR data are reported as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), integration, coupling constants (Hz). Data for ^{13}C NMR are reported in terms of chemical shift (δ, ppm). High performance liquid chromatography (HPLC) was carried out on a Young Lin HPLC system (7725i Injector, SDV 30 Plus Solvent Degassor & Valve Module (Helium Sparging), SP930D Solvent Delivery Pump, UV 730D Absorbance Detector) equipped with a Chiralpak IB or Chiralpak AD-H column or an Aglient 1100 Series HPLC equipped with Chiralpak IB or Chiralpak IC column. Specific rotations were measured on a Rudolph Autopol IV (Automatic polarimeter). High-resolution mass spectra and elemental analysis were obtained from the Korea Research Institute of Chemical Technology (EI) or Korea Basic Science Institute (ESI). HR-MS were measured with electron impact (EI) ionization via double focusing mass analyzer (magnetic and electric fields) or electrospray ionization (ESI) via time of flight (TOF) analyzer.

The formic acid/triethylamine mixtures (molar ratio = 5/2 or 1:1) are commercially available. (*R,R*)-**1a**[1] and (*R,R*)-**1b**[2] were prepared according to the literature procedures. Chiral catalysts, (*R,R*)-**1c**, (*R,R*)-**1d**, and (*R,R*)-**1e** are commercially available.

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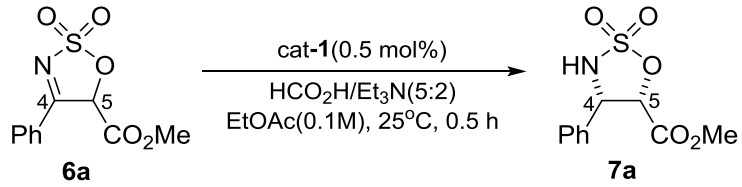
[1] Mao, J. M.; Baker, D. C. *Org. Lett*. 1999, **1**, 841.

[2] K. Mashima; T. Abe; K. Tani, *Chem. Lett*. 1998, 1199.

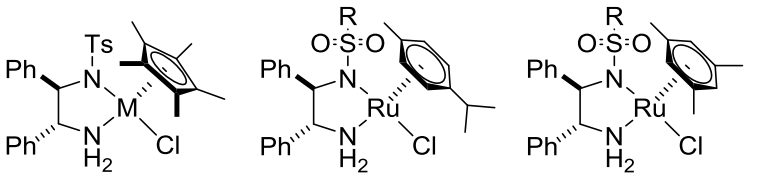
1. Optimization of the ATH-DKR reaction of 6

1-1. Optimization of ATH-DKR reaction of 6a with various catalysts

Table S1. Optimization of chiral catalysts **1a-e** in ATH-DKR of **6a** [a]



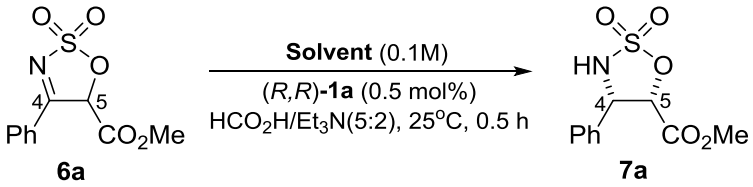
Entry	Cat.**1**	Convn (%)[b]	dr (*syn:anti*)	ee(%)[d]	config[e]
1	(*R,R*)-**1a**	>99	>25:1[c]	98	*S,S*
2	(*R,R*)-**1b**	>99	>25:1[c]	30	*S,S*
3	(*R,R*)-**1c**	13	-	95	*S,S*
4	(*R,R*)-**1d**	6	-	-	-
5	(*R,R*)-**1e**	17	-	83	*S,S*



[a]Reaction conditions: **6a** (0.5 mmol), cat-**1** (0.5 mol%), HCO_2H/Et_3N (5:2, 0.5 ml), EtOAc (5 mL), rt. [b]Determined by ^1H NMR analysis of the crude products. [c]Only 4,5-*cis* products were detected in ^1H NMR of crude products. [d]Determined by chiral HPLC. [e]See, Scheme S-1 below

1-2. Optimization of ATH-DKR reaction of 6a in various solvents

Table S2. Optimization of solvent effect in ATH-DKR of **3**[a]

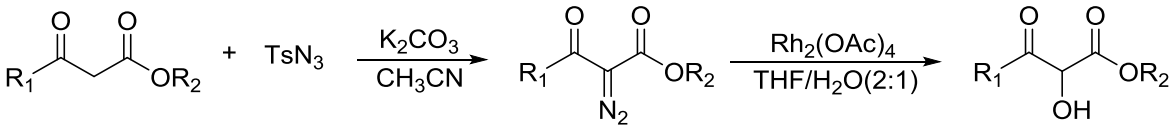


Entry	Solvent	Convn (%)[b]	ee (%)[c]
1	EtOAc	>99	98.1
2	CH_2Cl_2	>99	98.9
3	$Cl(CH_2)_2Cl$	>99	98.1
4	$CHCl_3$	>99	84.1
5	Toluene	>99	85.1
6	DMF	>99	88.1
7	MeOH	>99	97.1
8	THF	96	90.9
9	2-Propanol	>99	96.8

[a]Reaction conditions: **6a** (0.5 mmol), (*R,R*)-**1a** (0.5 mol%), HCO_2H/Et_3N (5:2, 0.5 ml), in 5.0 mL of solvent at rt. [b]Determined by ^1H NMR analysis of the crude products. [c]Determined by chiral HPLC of the crude products.

2. General procedure for the synthesis of α-hydroxy-β-keto esters from β-keto-ester

[Method A]



4-4-1.[3]

To a mixture of β-keto-ester (1.0 eq.) and potassium carbonate (1.25 eq.) in acetonitrile cooled in a water ice-bath, was added dropwise with stirring a solution of tosyl azide (1.25 eq) in acetonitrile. The reaction mixture was stirred at room temperature. The disappearance of

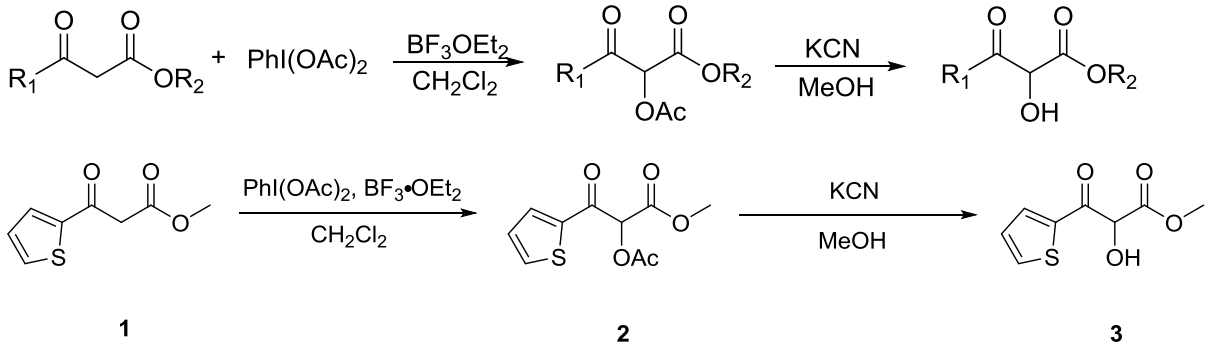
[3] Leost, F.; Chantegrel B.; Deshayes C., *Tetrahedron*, 1997, **5**, 7557.

ester was monitored by TLC. Potassium carbonate was filtered off and the filterate was evaporated in *vacuo* to afford a residue which was purified by silica-gel chromatography to give the diazo compund.

Step-2[4]

A solution of the diazo compound (1.0 eq) and $Rh_2(OAc)_4$ (0.03 eq) in THF- H_2O (2:1 ratio) was refluxed overnight and allowed to cool to room temperature. The mixture was concentrated in *vacuo* and the aqueous residue was extracted with EtOAc (x3). The combined organic layers were washed with water and brine, dried over anhydrous $MgSO_4$, filtered, and evaporated to dryness. The residue was purified by silica-gel chromatography to give the α-hydroxy β-ketocarbonates.

[Method B]



1 **2** **3**

Step-1

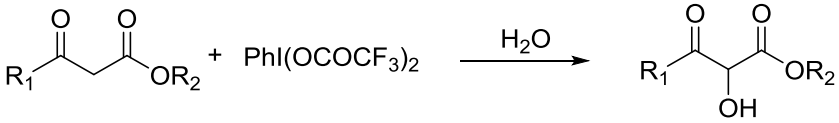
To a solution of **1** (4 g, 21.7 mmol) and $PhI(OAc)_2$ (7 g, 21.7 mmol) in dichloromethane (50 mL) was added $BF_3 \cdot OEt_2$ (1.4 mL, 10.85 mmol). The reaction mixture was stirred at room temperature for 20 min and then quenched by $NaHCO_3$. The layers were separated and the aqueous layer was extracted with dichloromethane(x3). The combined organic layers were washed with brine, dried over anhydrous $MgSO_4$, and evaporated. The residue was purified by silica-gel chromatography (Hexane/EtOAc=5:1) to give **2** (4.96 g, 94.4% yield).

Step-2

[4] Sun, C.-Q.; Cheng, P. T. W.; Stevenson, J.; Dejneka, T.; Brown, B.; Wang, T. C.; Robal, J. A.; Poss, M. A., *Tetrahedron Lett.*, 2002, **43**, 1161.

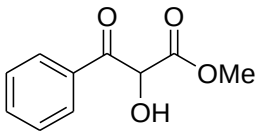
A solution of **2** (1.3 g, 5.4 mmol) in anhydrous MeOH (10 mL) was added dropwise to a solution of KCN (175 mg, 2.7 mmol) in anhydrous MeOH (40 mL) at 0 °C. The resulting mixture was stirred at 0 °C for 2 h. After removal of the solvent, the residue was dissolved in CH_2Cl_2 and then washed with brine. The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated. The residue was purified by silica-gel chromatography (Hexane/EtOAc, 5:1) to give **3** (0.815 g, 75.4% yield).

[Method C][5]



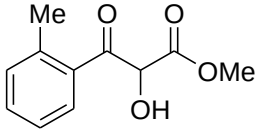
To a suspension of β-keto-ester in H_2O was added PIFA (2.0 eq) portionwise for 10 minutes. The reaction mixture was stirred at room temperature until TLC indicated the total consumption of the β-keto-ester. Then the reaction mixture was treated with saturated $NaHCO_3$ (aq) and extracted with EtOAc (x3). The combined organic layers were washed with water and brine, dried over anhydrous $MgSO_4$, filtered, and concentrated. The residue was purified by silica-gel chromatography to give the α-hydroxy-β-keto ester.

3-Phenyl-2-hydroxy-3-oxo-propionic acid methyl ester[6] **[Method A]**



yield: 89.3% (1.9 g as a yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04-8.05 (m, 2H), 7.59-7.62 (m, 1H), 7.45-7.48 (m, 2H), 5.60 (s, 1H), 4.42-4.49 (brs, 1H), 3.68 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 193.8, 169.1, 134.7, 133.0, 129.5, 128.9, 74.3, 53.1.; HRMS (EI): m/z calcd for $C_{10}H_{10}O_4$ 194.0579, found 194.0542.

3-(2-Tolyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method C]



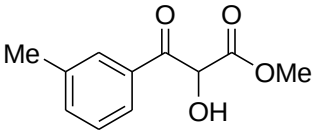
The ptoduct was unstable in silica-gel chloromatography and used next step without further purification. HRMS (EI): m/z calcd for $C_{11}H_{12}O_4$

[5] Wang, J.; Yuan, Y.; Xiong, R.; Zhang-Negrerie, D.; Du, Y.; Zhano, K. *Org. Lett*. 2012, **14**, 2210.

[6] (a) Scholte, Andrew A.; An, M. H.; Snapper, Marc L. *Org. Lett*. 2006, **8**, 4759. (b) Plietker, B. *J. Org. Chem.* 2004, **69**, 8287.

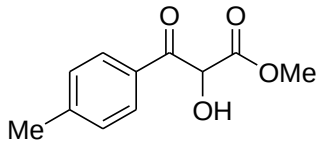
208.0736, found 208.0737.

3-(3-Tolyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method B]



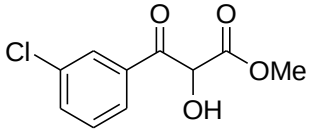
yield: 82.1% (683.5 mg as a pale yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86-7.87 (m, 2H), 7.45 (d, 1H, *J* = 7.6 Hz), 7.39 (t, 1H, *J* = 7.6 Hz), 5.59 (s, 1H), 4.30 (brs, 1H), 3.71 (s, 3H), 2.42 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 193.8, 169.1, 138.8, 135.6, 133.0, 129.8, 128.7, 126.7, 74.3, 53.3, 21.3.; HRMS (EI): m/z calcd for $C_{11}H_{12}O_4$ 208.0736, found 208.0732.

3-(4-Tolyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method C]



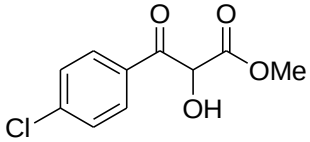
yield: 84.8% (84.8 mg as a yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 (d, 2H, *J* = 8.3 Hz), 7.30 (d, 2H, *J* = 8.2 Hz), 5.59 (s, 1H), 4.33-4.37 (brs, 1H), 3.71 (s, 3H), 2.43 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 193.1, 169.2, 146.1, 130.4, 129.6, 129.6, 74.2, 53.0, 21.9.; HRMS (EI): m/z calcd for $C_{11}H_{12}O_4$ 208.0736, found 208.0733.

3-(3-Chloro-phenyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method B]



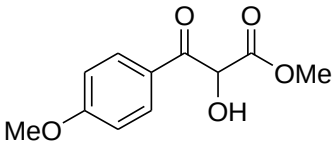
yield: 41.7% (0.11 g as a yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06 (s, 1H), 7.97 (d, 1H, *J* = 7.8 Hz), 7.62 (m, 1H), 7.47 (m, 1H), 5.57 (s, 1H), 3.76 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 192.7, 168.8, 135.3, 134.6, 134.6, 130.2, 129.4, 127.6, 74.5, 53.3.; HRMS (EI): m/z calcd for $C_{10}H_9ClO_4$ 228.0189, found 228.0177.

3-(4-Chloro-phenyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method A]



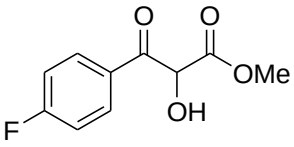
yield: 35.7% (0.24 g as a yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 (d, 2H, *J* = 8.3 Hz), 7.48 (d, 2H, *J* = 8.3 Hz), 5.56 (s, 1H), 4.21 (brs, 1H), 3.73 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 192.6, 168.9, 141.4, 131.3, 130.9, 129.3, 74.4, 53.2.; HRMS (EI): m/z calcd for $C_{10}H_9ClO_4$ 228.0189, found 228.0183.

3-(4-Methoxy-phenyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method A]



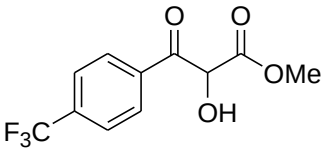
yield: 78% (5.6 g as a yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 (d, 2H, *J* = 8.5 Hz), 6.97 (d, 2H, *J* = 8.5 Hz), 5.55 (d, 1H, *J* = 5.6 Hz), 4.35 (d, 1H, *J* = 7.1 Hz), 3.88 (s, 3H), 3.71 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 191.7, 169.3, 164.9, 132.0, 125.7, 114.2, 74.1, 55.6, 53.0.; HRMS (EI): m/z calcd for $C_{11}H_{12}O_5$ 224.0685, found 224.0673.

3-(4-Fluoro-phenyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method C]



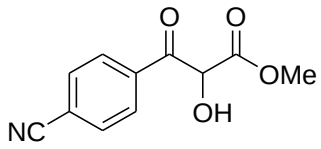
yield: 66% (0.66 g as a pale yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (m, 2H), 7.13 (m, 2H), 5.38 (s, 1H), 3.88 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 196.5, 167.3, 166.3 (q, J_{CF}= 248.7 Hz), 133.1 (d, J_{CF}= 10.0 Hz), 130.2 (d, J_{CF}= 3.4 Hz), 115.8 (d, J_{CF} = 21.7 Hz), 85.3, 53.9.; HRMS (EI): m/z calcd for $C_{10}H_9FO_4$ 212.0485, found 212.0456.

3-(4-Trifluoromethyl-phenyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method A]



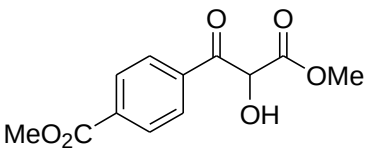
yield: 61% (0.77 g as a pale yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.20 (d, 2H, *J* = 7.9 Hz), 7.78 (d, 2H, *J* = 8.1 Hz), 5.65 (s, 1H), 3.76 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 193.2, 168.9, 135.4 (q, J_{CF}= 32.6 Hz), 130.5, 129.8, 125.9, 125.5 (q, J_{CF} = 271.2 Hz), 74.7, 53.3.; HRMS (EI): m/z calcd for $C_{11}H_9F_3O_4$ 262.0453, found 262.0441.

3-(4-Cyano-phenyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method A]



yield: 49.6% (0.93 g as a yellow solid), mp = 100.4-102.6 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (d, 2H, *J* = 8.0 Hz), 7.82 (d, 2H, *J* = 8.0 Hz), 5.59 (s, 1H), 4.09-4.17 (brs, 1H), 3.76 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 192.9, 168.7, 136.2, 132.6, 129.9, 117.7, 117.6, 74.7, 53.4.; HRMS (EI): m/z calcd for $C_{11}H_9NO_4$ 219.0532, found 219.0528.

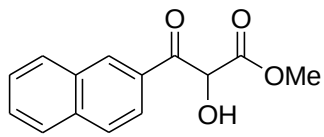
3-(4-Methoxycarbonyl-phenyl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method A]



yield: 42% (0.71 g as a pale yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06-8.11 (m, 4H), 5.60 (s, 1H), 3.91 (s, 3H), 3.68 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 193.6, 168.9, 165.9,

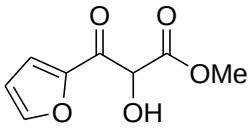
136.4, 135.0, 129.9, 129.3, 74.6, 53.2, 52.6.; HRMS (EI): m/z calcd for $C_{12}H_{12}O_6$ 252.0634, found 252.0632.

3-(Naphthalen-2-yl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method A]



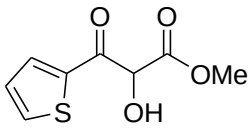
yield: 59% (1.64 g as a yellow oil).; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.68 (s, 1H), 8.11 (d, 1H, *J* = 8.6 Hz), 8.03 (d, 1H, *J* = 8.2 Hz), 7.90-7.95 (m, 2H), 7.67 (t, 1H, *J* = 7.1 Hz), 7.61 (t, 1H, *J* = 7.4 Hz), 5.81 (s, 1H), 4.46 (brs, 1H), 3.75 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 193.6, 169.2, 136.3, 132.3, 132.2, 130.3, 130.0, 129.5, 128.8, 127.9, 127.2, 124.2, 74.4, 53.1.; HRMS (EI): m/z calcd for $C_{14}H_{12}O_4$ 244.0736, found 244.0729.

3-(Furan-2-yl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method B]



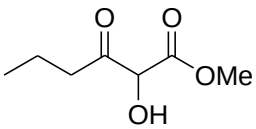
yield: 69.3% (0.95 g as a yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.71-7.72 (m, 1H), 7.49 (d, 1H, *J* = 3.5 Hz), 6.62-6.63 (m, 1H), 5.35 (d, 1H, *J* = 8.3 Hz), 4.01 (d, 1H, *J* = 8.3 Hz), 3.78 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 181.8, 169.1, 149.8, 148.5, 121.4, 113.1, 74.3, 53.3.; HRMS (EI): m/z calcd for $C_8H_8O_5$ 184.0372, found 184.0353.

3-(Thiophen-2-yl)-2-hydroxy-3-oxo-propionic acid methyl ester [Method B]



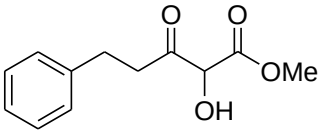
yield: 75.4% (0.81 g as a brown oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 (d, 1H, , *J* = 3.6 Hz), 7.79 (d, 1H, *J* = 4.9 Hz), 7.19 (t, 1H, *J* = 4.4 Hz), 5.42 (s, 1H), 4.22 (brs, 1H), 3.76 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 186.1, 169.2, 139.4, 136.4, 135.3, 128.7, 75.1. 53.3.; HRMS (EI): m/z calcd for $C_8H_8O_4S$ 200.0143, found 200.0139.

2-Hydroxy-3-oxo-hexanoic acid methyl ester [Method A]



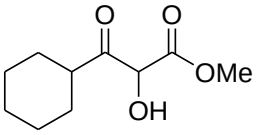
yield: 80.1% (1.36 g as a coloress oil); ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.77 (s, 1H), 4.32 (brs, 1H), 3.80 (s, 3H), 2.05-2.78 (m, 2H), 1.57-1.69 (m, 2H), 0.90 (t, 3H, *J* = 7.4 Hz).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 204.4, 169.0, 76.7, 53.2, 40.6, 17.0, 13.6.; HRMS (EI): m/z calcd for $C_7H_{12}O_4$ 160.0736, found 160.0728.

2-Hydroxy-3-oxo-5-phenyl-pentanoic acid methyl ester [Method A]



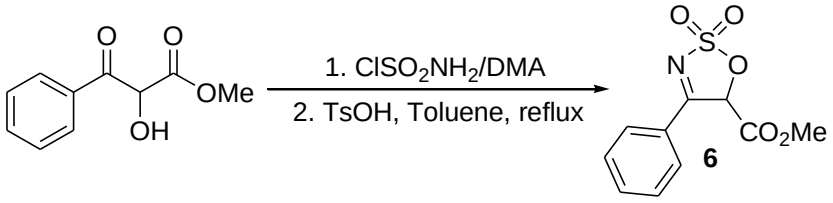
yield: 51.8% (1.14 g as a pale yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.26-7.30 (m, 2H), 7.16-7.22 (m, 3H), 4.76 (s, 1H), 3.85-3.89 (brs, 1H), 3.74 (s, 3H), 3.05-3.11 (m, 1H), 2.90-3.00 (m, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 203.7, 168.7, 140.2, 128.6, 128.3, 126.4, 77.9, 53.2, 40.4, 29.3.; HRMS (EI): m/z calcd for $C_{12}H_{14}O_4$ 222.0892, found 222.0888.

3-Cyclohexyl-2-hydroxy-3-oxo-propionic acid methyl ester[7] [Method A]



yield: 78.2% (2.18 g as a pale yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.24 (s, 1H), 3.71 (s, 3H), 3.05-3.10 (m, 1H), 1.63-1.87 (m, 5H), 1.17-1.36 (m, 6H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 212.1, 168.7, 84.0, 53.3, 46.5, 29.0, 28.6, 25.7.; HRMS (EI): m/z calcd for $C_{10}H_{16}O_4$ 200.1049, found 200.1040.

3. General procedure for the synthesis of cyclic imine 6 from α-hydroxy-β-keto-ester.[8,9]

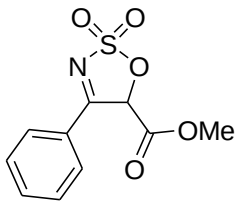


To the solution of 3-phenyl-2-hydroxy-3-oxo-propionic acid methyl ester (1.85 g, 9.53 mmol) in DMA (*N*,*N*-dimethyl acetamide, 18 mL) was added sulfamoyl chloride (2.2 g, 19 mmol) at 0 ℃. The reaction mixture was stirred at room temperature for 1.5 h and diluted with EtOAc (30 mL). The reaction mixture washed with brine and the organic layer was dried over anhydrous $MgSO_4$ and the solvent was evaporated under reduced pressure. The residue was re-dissolved in toluene (15 mL) and catalytic amount of PTSA (*p*-toluenesulfonic acid) was added. The reaction mixture was heated for 1 h at 110 ℃ and cooled to room temperature. The solvent was removed and the reaction mixture was diluted with EtOAc (30 mL) and

[7] Plietker, B. *J. Org. Chem.* 2004, **69**, 8287.
[8] Lee, H.-K.; Kang, S.; Choi, E. B., *J. Org. Chem.*, 2012, **77**, 5454.
[9] Han, J. A.; Kang, S. Y.; Lee, H-K. *Chem. Commun*. 2011, **47**, 4004.

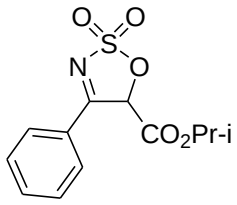
washed brine. The organic layers were dried over anhydrous $MgSO_4$ and the solvent was evaporated under reduced pressure. The residue was recrystallized from EtOAc/Hexane, to give the desired imine, as white crystals **6a**.

Methyl 2,2-dioxo-4-phenyl-5H-1,2,3-oxathiazole-5-carboxylate, 6a



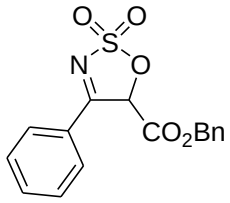
yield: 74.8% (1.81g as a white solid), mp = 149.5-151.5 ℃, ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.09 (d, 2H, *J* = 7.6 Hz), 7.77 (t, 1H, *J* = 7.5 Hz), 7.58 (t, 2H, *J* = 7.8 Hz), 6.19 (s, 1H), 3.82 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.7, 163.5, 136.3, 130.3, 129.6, 126.3, 83.7, 54.4.; HRMS (EI): m/z calcd for $C_{10}H_9NO_5S$ 255.0201, found 255.0233.

Isopropyl 2,2-dioxo-4-phenyl-5H-1,2,3-oxathiazole-5-carboxylate, 6b



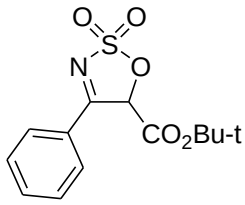
Yield: 53%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.08 (d, 2H, *J* = 7.8), 7.77-7.72 (t, 1H, *J* = 7.4), 7.62-7.55 (t, 2H, *J* = 7.8), 6.13 (s, 1H), 5.05 (m, 1H), 1.18 (d, 6H, *J* = 6.21); ^{13}C NMR (500 MHz, $CDCl_3$) δ 172.0, 162.3, 136.1, 130.3, 129.4, 126.5, 84.1, 72.6, 21.3, 21. 2; HRMS (EI): m/z calcd for $C_{12}H_{13}NO_5S$ 283.0514, found 283.0503.

Benzyl 2,2-dioxo-4-phenyl-5H-1,2,3-oxathiazole-5-carboxylate, 6c



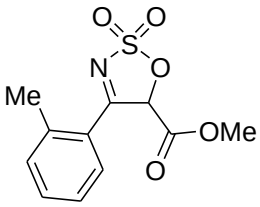
Yield: 66%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.97 (d, 2H, *J* = 7.4), 7.70 (t, 1H, *J* = 7.5), 7.49 (t, 2H, *J* = 7.8), 7.31-7.18 (m, 6H), 6.17 (s, 1H), 5.23 (q, 2H, *J* = 12.1).; ^{13}C NMR (500 MHz, $CDCl_3$) δ 171.7, 162.7, 136.1, 133.6, 130.3, 129.5, 128.9, 128.7, 128.4, 126.3, 83.8, 69.3.; HRMS (EI): m/z calcd for $C_{16}H_{13}NO_5S$ 331.0514, found 331.0519.

***t*-Butyl 2,2-dioxo-4-phenyl-5H-1,2,3-oxathiazole-5-carboxylate, 6d**



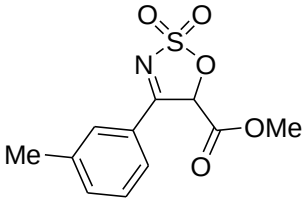
Yield: 48%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.07 (d, 2H, *J* = 7.5), 7.73 (t, 1H, *J* = 7.5), 7.57 (t, 2H, *J* = 7.7), 6.06 (s, 1H), 1.36 (s, 9H); ^{13}C NMR (500 MHz, $CDCl_3$) δ 172.3, 161.6, 136.0, 130.3, 129.4, 126.6, 86.2, 84.9, 27.5.; HRMS (EI): m/z calcd for $C_{13}H_{15}NO_5S$ 297.0671, found 297.0680.

Methyl 4-(2-tolyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6e



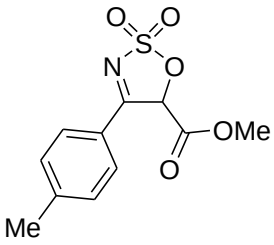
yield: 53.3% (0.93 g as a white solid), mp = 106.1-107.4 ℃, ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.68 (d, 1H, *J* = 7.9 Hz), 7.57 (t, 1H, *J* = 7.5 Hz), 7.37-7.43 (m, 2H), 6.24 (s, 1H), 3.75 (s, 3H), 2.69 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.7, 163.4, 142.8, 134.8, 133.1, 130.9, 126.5, 125.2, 84.6, 54.2, 22.9.; HRMS (EI): m/z calcd for $C_{11}H_{11}NO_5S$ 269.0358, found 269.0354.

Methyl 4-(3-tolyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6f



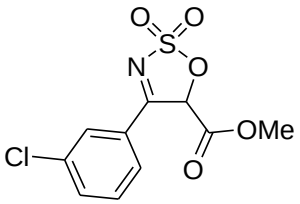
yield: 71.4% (498.2 mg as a white solid), mp = 128.3-129.1 ℃, ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.90 (s, 1H), 7.82-7.84 (m, 1H), 7.45-7.53 (m, 2H), 6.17 (s, 1H), 3.81 (s, 3H), 2.45 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.8, 163.7, 139.9, 137.3, 130.8, 129.5, 127.6, 126.4, 83.8, 54.5, 21.4.; HRMS (EI): m/z calcd for $C_{11}H_{11}NO_5S$ 269.0358, found 269.0364.

Methyl 4-(4-tolyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6g



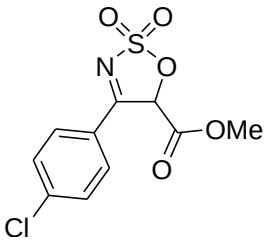
yield: 53% (670 mg as a white solid), mp = 147.7-148.3 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.96 (d, 2H, *J* = 8.3 Hz), 7.37 (d, 2H, *J* = 8.1 Hz), 6.16 (s, 1H), 3.81 (s, 3H), 2.48 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.5, 163.8, 148.2, 130.5, 130.5, 123.8, 83.7, 54.4, 22.2.; HRMS (EI): m/z calcd for $C_{11}H_{11}NO_5S$ 269.0358, found 269.0355.

Methyl 4-(3-chloro-phenyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6h



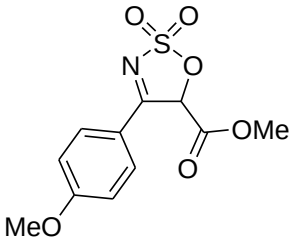
yield: 50.7% (176 mg as a white solid), mp = 149.0-150.5 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.10 (s, 1H), 7.93-7.95 (m, 1H), 7.70-7.72 (m, 1H), 7.52-7.55 (m, 1H), 6.15 (s, 1H), 3.84 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.7, 163.3, 136.2, 136.1, 130.9, 130.2, 128.5, 128.1, 83.6, 54.7.; HRMS (EI): m/z calcd for $C_{10}H_8ClNO_5S$ 288.9812, found 288.9818.

Methyl 4-(4-chloro-phenyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6i



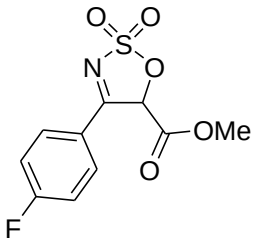
yield: 68% (650 mg as a white solid), mp = 140.4-142.8 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (d, 2H, *J* = 8.7 Hz), 7.57 (d, 2H, *J* = 8.7 Hz), 6.15 (s, 1H), 3.83 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.7, 163.5, 143.3, 131.7, 130.2, 124.8, 83.6, 54.6.; HRMS (EI): m/z calcd for $C_{10}H_8ClNO_5S$ 288.9812, found 288.9817.

Methyl 4-(4-methoxy-phenyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6j



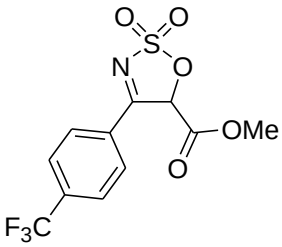
yield: 63% (0.5 g as a white solid), mp = 160.8-163.1 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 (d, 2H, *J* = 8.4 Hz), 7.17 (d, 2H, *J* = 8.5 Hz), 6.83 (s, 1H), 3.95 (s, 3H), 3.78 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.2, 172.2, 166.2, 164.0, 133.0, 119.0, 115.0, 83.9, 55.6, 53.5.; HRMS (EI): m/z calcd for $C_{11}H_{11}NO_6S$ 285.0307, found 285.0308.

Methyl 4-(4-fluoro-phenyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6k



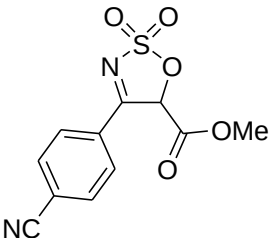
yield: 69% (750 mg as a white solid), mp = 130.6-133.5 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15-8.18 (m, 2H), 7.29-7.32 (m, 2H), 6.18 (s, 1H), 3.86 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.5, 167.6 (d, J_{CF} = 259.8 Hz), 163.5, 133.4 (d, J_{CF}= 9.9 Hz), 122.8 (d, J_{CF} = 3.1 Hz), 117.3 (d, J_{CF} = 22.3 Hz), 83.6, 54.6.; HRMS (EI): m/z calcd for $C_{10}H_8FNO_5S$ 273.0107, found 273.0107.

Methyl 4-(4- trifluoromethyl-phenyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6l



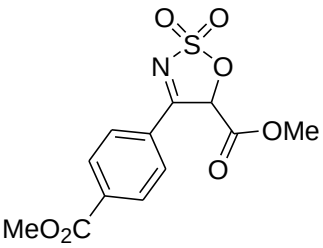
yield: 44% (0.37 g as a white solid), mp = 191.1-196.6 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.23 (d, 2H, *J* = 8.1 Hz), 7.86 (d, 2H, *J* = 8.1 Hz), 6.24 (s, 1H), 3.85 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.5, 163.0, 137.1 (q, J_{CF} = 33.2 Hz), 130.7, 129.4, 126.5, 123.0 (q, J_{CF} = 271.4 Hz), 83.6, 54.6.; HRMS (EI): m/z calcd for $C_{11}H_8F_3NO_5S$ 323.0075, found 323.0077.

Methyl 4-(4-cyano-phenyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6m



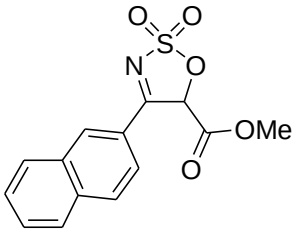
yield: 77.5% (0.62 g as a white solid), mp = 166.1-169.4 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.20 (d, 2H, *J* = 7.9 Hz), 7.87 (d, 2H, *J* = 7.8 Hz), 6.21 (s, 1H), 3.83 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.3, 162.9, 133.0, 130.7, 130.0, 119.2, 117.0, 83.5, 54.7.; HRMS (EI): m/z calcd for $C_{11}H_8N_2O_5S$ 280.0154, found 280.0140.

Methyl 4-(4-methoxycarbonyl-phenyl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6n



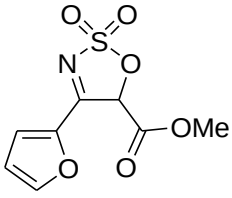
yield: 60.4% (1.13 g as a brown solid), mp = 118.2-123 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (d, 2H, *J* = 8.1 Hz), 8.14 (d, 2H, *J* = 8.2 Hz), 6.23 (s, 1H), 3.97 (s, 3H), 3.81 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.0, 165.4, 163.1, 136.5, 130.4, 130.3, 129.8, 83.7, 54.5, 52.9.; HRMS (EI): m/z calcd for $C_{12}H_{11}NO_7S$ 313.0256, found 313.0246.

Methyl 4-(naphthalen-2-yl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6o



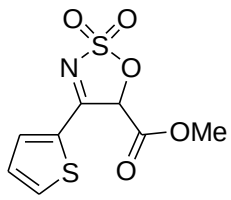
yield: 59% (1.1 g as a white solid), mp = 151.5-155.7 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.60 (s, 1H), 8.11 (d, 1H, *J* = 8.7 Hz), 8.01(t, 2H, *J* = 8.6 Hz), 7.95 (d, 1H, *J* = 8.2 Hz), 7.65-7.75 (m, 2H), 6.35 (s, 1H), 3.83 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 171.5, 163.9, 136.9, 133.5, 132.4, 130.6, 130.1, 129.9, 128.3, 128.0, 124.6, 123.9, 83.9, 54.5.; HRMS (EI): m/z calcd for $C_{14}H_{11}NO_5S$ 305.0358, found 305.0356.

Methyl 4-(furan-2-yl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6p



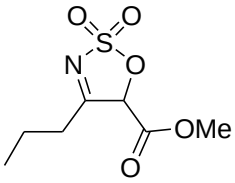
yield: 18% (0.14 g as a ivory solid), mp = 130.6-133.5 ℃, ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86-7.87 (m, 1H), 7.67-7.68 (m, 1H), 6.75-6.77 (m, 1H), 5.97 (s, 1H), 3.87 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.4, 159.8, 151.1, 143.3, 124.9, 114.6, 82.6, 54.5.; HRMS (EI): m/z calcd for $C_8H_7NO_6S$ 244.9994, found 244.9997.

Methyl 4-(thiophen-2-yl)-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6q



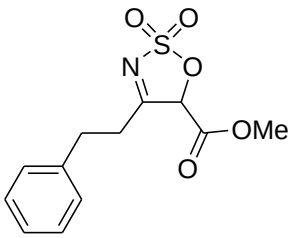
yield: 88.7% (0.51g as a ivory solid), mp = 106.2-110.2 ℃, ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.07-8.08 (m, 1H), 7.98-7.99 (m, 1H), 7.29-7.31 (m, 1H), 6.09 (s, 1H), 3.90 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 164.7, 163.9, 139.1, 138.0, 130.2, 129.8, 83.3, 54.6.; HRMS (EI): m/z calcd for $C_8H_7NO_5S_2$ 260.9766, found 260.9765.

Methyl 4-propyl-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6r



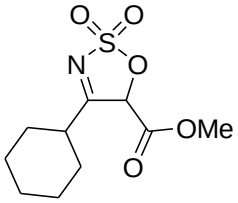
yield: 63.8% (2.79 g as a yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.56 (s, 1H), 3.91 (s, 3H), 2.65-2.75 (m, 2H), 1.79-1.87 (m, 2H), 1.04 (t, 3H, *J* = 7.4 Hz).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 179.9, 162.8, 85.1, 54.4, 33.2, 18.9, 13.9.; HRMS (EI): m/z calcd for $C_7H_{11}NO_5S$ 221.0358, found 221.0365.

Methyl 4-phenethyl-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6s



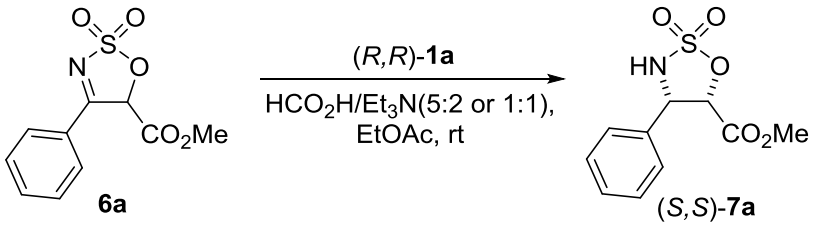
yield: 45% (0.63 g as a ivory solid), mp = 83-87.1 ℃, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.20-7.37 (m, 5H), 5.54 (s, 1H), 3.86 (s, 3H), 3.05-3.13 (m, 4H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 179.6, 162.4, 138.7, 129.0, 128.4, 127.0, 85.2, 54.3, 33.1, 31.3.; HRMS (EI): m/z calcd for $C_{12}H_{13}NO_5S$ 283.0514, found 283.0516.

Methyl 4-cyclohexyl-5H-1,2,3-oxathiazole-5-carboxylate 2,2-dioxide, 6t



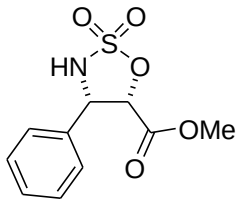
yield: 79.4% (2.26g as a pale yellow oil); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.64 (s, 1H), 3.86 (s, 3H), 2.69-2.70 (m, 1H), 1.37-2.06 (m, 10H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 183.0, 162.9, 83.9, 54.2, 40.0, 30.8, 29.1, 25.7, 25.3, 24.9.; HRMS (EI): m/z calcd for $C_{10}H_{15}NO_5S$ 261.0671, found 261.0683.

4. General procedure for the ATH-DKR reaction of 4,5-disubstituted cyclic imine 6 to 7



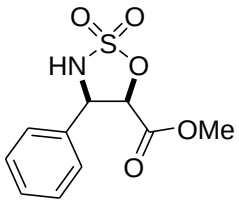
To the solution of **6a** (255 mg, 1.0 mmol) in EtOA (10 mL) was added added (*R*,*R*)-Cp*RhCl(TsDPEN) (**1a**) catalyst (3.2 mg, 0.5 mol%), and then added slowly an azeotroic mixtrure of HCO_2H/Et_3N (molar ratio = 5:2, 1.0 mL) *via* a syringe. The reaction mixture was stirred for 0.5 h at room temperature and diluted with EtOAc. The reaction mixture was washed with water and brine. The organic layer was dried over anhydrous $MgSO_4$ and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel (Hexane/EtOAc, 2:1) to give a white solid (234 mg, 91.6%).

Methyl (4*S*,5*S*)-4-phenyl-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7a



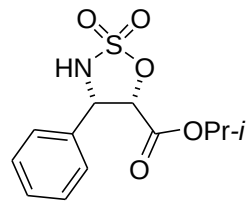
yield: 91.6% (234 mg as a white solid), mp = 101.9-104.7 ℃, 97% ee: Chiralpak IB, 20% ethanol/n-hexane, 1.0 ml/min, 215 nm t_R(major) = 10.7 min, t_R(minor) = 12.5 min; $[\alpha]_D^{30}$ = +102.9 (c 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41-7.42 (m, 3H), 7.29-7.32 (m, 2H), 5.39 (d, 1H, *J* = 6.8 Hz), 5.28 (m, 1H), 5.07 (brs, 1H), 3.40 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.7, 132.0, 129.8, 129.1, 126.6, 81.8, 61.4, 52.7.; HRMS (EI): m/z calcd for $C_{10}H_{11}NO_5S$ 257.0358, found 257.0340.

Methyl (4*R*,5*R*)-4-phenyl-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*R*,*R*)-7a



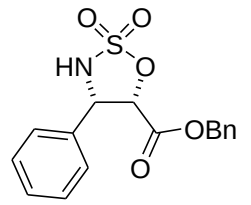
yield: 94% (24 mg as a white solid), mp = 103.2-105.4 ℃, 98.1% ee: Chiralpak IB, 20% ethanol/n-hexane, 1.0 ml/min, 215 nm t_R(major) = 9.9 min, t_R(minor) = 13.7 min; $[\alpha]_D^{30}$ = -101.7 (c 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41-7.42 (m, 3H), 7.30-7.31 (m, 2H), 5.38 (d, 1H, *J* = 6.8 Hz), 5.28 (d, 1H, *J* = 6.8 Hz), 5.02 (brs, 1H), 3.40 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.6, 131.9, 129.9, 129.2, 126.5, 81.6, 61.4, 52.7.; HRMS (EI): m/z calcd for $C_{10}H_{11}NO_5S$ 257.0358, found 257.0343.

Isopropyl (4*S*,5*S*)-4-phenyl-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7b



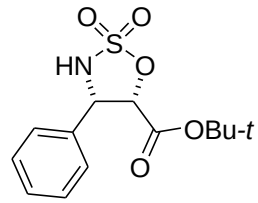
yield: 85%; $[\alpha]_D^{23}$ = +76.8 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39-7.34 (m, 5H), 5.33 (m, 3H), 4.69 (s, 1H), 1.02 (s, 3H), 0.72 (s, 3H); ^{13}C NMR (500 MHz, $CDCl_3$) δ 164.8, 132.2, 129.7, 129.1, 126.9, 81.6, 70.8, 61.5, 21.4, 20.8; HRMS (EI): m/z calcd for $C_{12}H_{15}NO_5S$ 285.0671, found 285.0664.

Benzyl (4*S*,5*S*)-4-phenyl-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7c



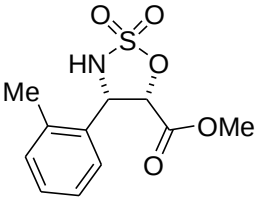
yield: 87%; $[\alpha]_D^{21}$ = +71.5 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39-7.29 (m, 8H), 7.04 (d, 2H. *J* = 6.8), 5.44 (d, 1H, *J* = 6.7), 5.33 (d, 1H, *J* = 6.9), 4.93 (d, 1H, *J* = 12.0), 4.68 (d, 1H, *J* = 12.0); ^{13}C NMR (500 MHz, $CDCl_3$) δ 165.2, 133.7, 131.9, 129.8, 129.2, 128.8, 128.7, 128.6, 126.7, 81.8, 68.1, 61.5; HRMS (EI): m/z calcd for $C_{16}H_{15}NO_5S$ 333.0671, found 333.0662.

***t*-Butyl (4*S*,5*S*)-4-phenyl-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7d**



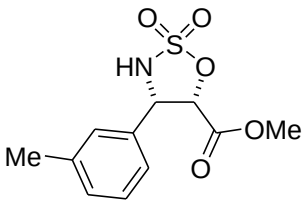
yield: 87%; 99.9% ee (Chiralpak AD-H, 5% isopropanol/hexanes, 1.0 mL/min, 215 nm, t_r(minor) = 32.27 min, t_r(major) = 36.25 min); $[\alpha]_D^{20}$ = +89.3 (c 0.3, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.41-7.33 (m, 5H), 5.27 (m, 3H), 1.08 (s, 9H); ^{13}C NMR (500 MHz, $CDCl_3$) δ 164.0, 132.6, 129.6, 129.1, 127.0, 84.5, 81.7, 61.5, 27.4; HRMS (EI): m/z calcd for $C_{13}H_{17}NO_5S$ 299.0827, found 299.0838.

Methyl (4*S*,5*S*)-4-(o-tolyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7e



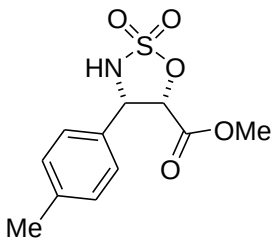
yield: 95.1% (25.7 mg as a white solid), mp = 119.8-120.4 ℃, 92.1% ee: Chiralpak AD-H, 20% isopropanol/n-hexane, 1.0 ml/min, 215 nm t_R(major) = 8.4 min, t_R(minor) = 10.1 min; $[\alpha]_D^{30}$ = +91.3 (c 0.15, MeOH); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.22-7.29 (m, 3H), 7.18 (d, 1H, *J* = 7.6 Hz), 5.52 (d, 1H, *J* = 7.0 Hz), 5.36 (d, 1H, *J* = 7.0 Hz), 3.31 (s, 3H), 2.41 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.7, 136.1, 131.2, 129.7, 129.6, 126.8, 124.2, 80.6, 57.8, 52.5, 19.4.; HRMS (EI): m/z calcd for $C_{11}H_{13}NO_5S$ 271.0514, found 271.0510.

Methyl (4*S*,5*S*)-4-(m-tolyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7f



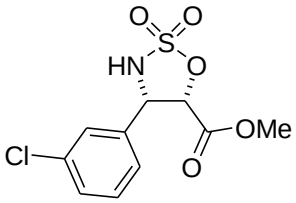
yield: 99.3% (31.4 mg as a white solid), mp = 97.1-99.4 ℃, 98.7% ee: Chiralpak AD-H, 10% isopropanol/n-hexane, 1.3 ml/min, 215 nm t_R(major) = 15.9 min, t_R(minor) = 17.0 min; $[\alpha]_D^{29}$ = +54.2 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29-7.33 (m, 1H), 7.23 (d, 1H, *J* = 7.6 Hz), 7.10-7.13 (m, 2H), 5.38 (d, 1H, *J* = 6.7 Hz), 5.28 (d, 1H, *J* = 6.5 Hz), 5.19 (brs, 1H), 3.44 (s, 3H), 2.39 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.9, 139.3, 131.8, 130.7, 129.2, 127.2, 123.6, 81.9, 61.5, 52.7, 21.5.; HRMS (EI): m/z calcd for $C_{11}H_{13}NO_5S$ 271.0514, found 271.0507.

Methyl (4*S*,5*S*)-4-(p-tolyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7g



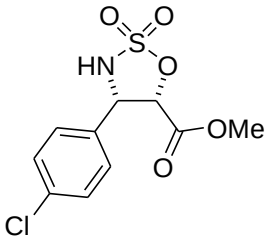
yield: 98.6% (50.8 mg as a white solid), mp = 103.8-105.8 ℃ ,99.2% ee: Chiralpak AD-H, 20% isopropanol/n-hexane, 1.0 ml/min, 215 nm t_R(major) = 10.1 min, t_R(minor) = 12.4 min; $[\alpha]_D^{30}$ = +93.0 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18-7.22 (m, 4H), 5.35 (d, 1H, *J* = 6.8 Hz), 5.25 (d, 1H, *J* = 6.9 Hz), 5.20 (brs, 1H), 3.42 (s, 3H), 2.36 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.8, 140.1, 130.0, 128.9, 126.5, 81.9, 61.4, 52.8, 21.3.; HRMS (EI): m/z calcd for $C_{11}H_{13}NO_5S$ 271.0514, found 271.0515.

Methyl (4*S*,5*S*)-4-(3-chloro-phenyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7h



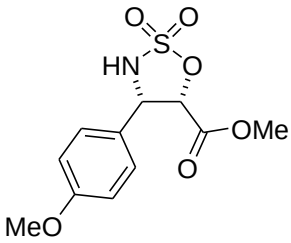
yield: 99.6% (36.1 mg as a white solid), mp = 79.6-80.8 ℃, 96.7% ee: Chiralpak AD-H, 10% isopropanol/n-hexane, 1.2 ml/min, 215 nm t_R(minor) = 13.8 min, t_R(major) = 15.0 min; $[\alpha]_D^{29}$ = +69.4 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33-7.40 (m, 3H), 7.24-7.25 (m, 1H), 5.39 (d, 1H, *J* = 6.8 Hz), 5.25-5.26 (m, 2H), 3.47 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.4, 135.3, 134.4, 130.6, 130.2, 127.2, 124.9, 81.4, 60.9, 53.0.; HRMS (EI): m/z calcd for $C_{10}H_{10}ClNO_5S$ 290.9968, found 290.9957.

Methyl (4*S*,5*S*)-4-(4-chloro-phenyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7i



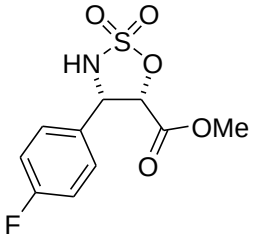
yield: 92.1% (28.3 mg as a white solid), mp = 123.2-125.8 ℃, 97.3% ee: Chiralpak AD-H, 20% isopropanol/n-hexane, 1.5 ml/min, 215 nm t_R(minor) = 9.3 min, t_R(major) = 14.1 min; $[\alpha]_D^{29}$ = +69.9 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 (d, 2H, *J* = 8.5 Hz), 7.28 (d, 2H, *J* = 8.5 Hz), 5.39 (d, 1H, *J* = 6.8 Hz), 5.25 (t, 1H, *J* = 8.0 Hz), 5.14 (d, 1H, *J* = 7.5 Hz), 3.46 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.4, 136.2, 130.9, 129.6, 128.2, 81.3, 61.0, 53.0.; HRMS (EI): m/z calcd for $C_{10}H_{10}ClNO_5S$ 290.9968, found 290.9943.

Methyl (4*S*,5*S*)-4-(4-methoxy-phenyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7j



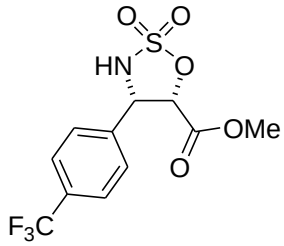
yield: 99.2% (28.5 mg as a white solid), mp = 120.8-123.7 ℃, 100% ee: Chiralpak AD-H, 20% isopropanol/n-hexane, 1.0 ml/min, 215 nm t_R(major) = 14.0 min, racemic: t_R(minor) = 18.7 min; $[\alpha]_D^{30}$ = +91.6 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.23 (d, 2H, *J* = 8.1 Hz), 6.91 (d, 2H, *J* = 8.1 Hz), 5.33 (d, 1H, *J* = 6.8 Hz), 5.22 (d, 1H, *J* = 6.8 Hz), 3.81 (s, 3H), 3.45 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.8, 160.8, 128.1, 123.9, 114.7, 81.8, 61.2, 55.5, 52.9.; HRMS (EI): m/z calcd for $C_{11}H_{13}NO_6S$ 287.0464, found 287.0466.

Methyl (4*S*,5*S*)-4-(4-fluoro-phenyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7k



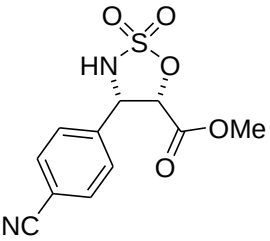
yield: 96.1% (45 mg as a white solid), mp = 142.5-146.4 ℃, 97.3% ee: Chiralpak IA, 20% ethanol/n-hexane, 1.0 ml/min, 215 nm t_R(minor) = 12.5 min, t_R(major) = 16.2 min; $[\alpha]_D^{29}$ = +78.3 (c 0.3, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32-7.35 (m, 2H), 7.10-7.13 (m, 2H), 5.38 (d, 1H, *J* = 6.7 Hz), 5.22-5.28 (m, 2H), 3.45 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165,6, 163.5 (d, J_{CF} = 248.8 Hz), 128.9 (d, J_{CF} = 8.5 Hz), 128.4, 116.5 (d, J_{CF} = 22.1 Hz), 81.6, 61.0, 53.0.; HRMS (EI): m/z calcd for $C_{10}H_{10}FNO_5S$ 275.0264, found 275.0234.

Methyl (4*S*,5*S*)-4-(4-trifluoromethyl-phenyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7l



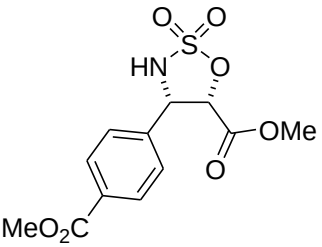
yield: 87.5% (28 mg as a white solid), mp = 146.2-150.6 ℃, 98.5% ee: Chiralpak IA, 20% ethanol/n-hexane, 1.5 ml/min, 215 nm t_R(minor) = 6.5 min, t_R(major) = 10.83 min; $[\alpha]_D^{30}$ = +33.6 (c 0.5, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, 2H, *J* = 7.9 Hz), 7.50 (d, 2H, *J* = 7.9 Hz), 5.45 (d, 1H, *J* = 6.9 Hz), 5.36 (d, 1H, *J* = 6.8 Hz), 3.42 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.2, 136.4, 132.0 (q, *J* = 32.9 Hz), 127.3, 126.1, 123.5 (q, J_{CF} = 270.5 Hz), 81.1, 60.9, 52.8.; HRMS (EI): m/z calcd for $C_{11}H_{10}F_3NO_5S$ 325.0232, found 325.0232.

Methyl (4*S*,5*S*)-4-(4-cyano-phenyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7m



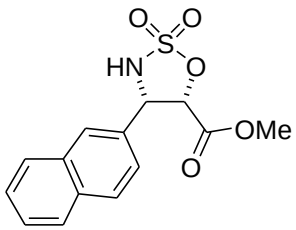
yield: 95% (26.5 mg as a white solid), mp = 162.7-167 ℃, 96.3% ee: Chiralpak IA, 30% ethanol/n-hexane, 1.3 ml/min, 215 nm t_R(minor) = 9.2 min, t_R(major) = 13.8 min; $[\alpha]_D^{30}$ = +22.7 (c 0.5, MeOH); ^{1}H NMR (500 MHz, acetone-d_6) δ 7.90 (d, 2H, *J* = 7.5 Hz), 7.78 (d, 2H, *J* = 7.6 Hz), 5.80 (d, 1H, *J* = 7.2 Hz), 5.71 (d, 1H, *J* = 7.2 Hz), 3.45 (s, 3H), 2.92 (brs, 1H).; ^{13}C NMR (125 MHz, acetone-d_6) δ 165.8, 141.0, 133.3, 129.5, 119.0, 113.8, 81.9, 61.5, 52.8.; HRMS (EI): m/z calcd for $C_{11}H_{10}N_2O_5S$ 282.0310, found 282.0304.

Methyl (4*S*,5*S*)-4-(4-methoxycarbonyl-phenyl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7n



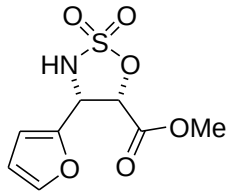
yield: 92% (29 mg as a white solid), mp = 145.6-147.1 ℃, 96.7% ee: Chiralpak IA, 20% ethanol/n-hexane, 1.5 ml/min, 215 nm t_R(minor) = 12.0 min, t_R(major) = 14.0 min; $[\alpha]_D^{20}$ = +57.4 (c 0.6, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.08 (d, 2H, *J* = 7.9 Hz), 7.44 (d, 2H, *J* = 7.9 Hz), 5.51-5.61 (brs, 1H), 5.45 (d, 1H, *J* = 6.8 Hz), 5.37 (d, 1H, *J* = 6.9 Hz), 3.94 (s, 3H), 3.41 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.2, 165.3, 137.1, 131.5, 130.3, 126.8, 81.2, 61.0, 52.8, 52.4.; HRMS (EI): m/z calcd for $C_{12}H_{13}NO_7S$ 315.0413, found 315.0411.

Methyl (4*S*,5*S*)-4-(naphthalen-2-yl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7o



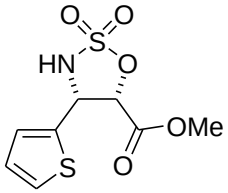
yield: 90.8% (27 mg as a white solid), mp = 134.9-137.4 ℃, 96.7% ee: Chiralpak AD-H, 20% isopropanol /n-hexane, 1.0 ml/min, 215 nm t_R(major) = 11.5 min, t_R(minor) = 13.7 min; $[\alpha]_D^{20}$ = +94.1 (c 0.4, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80-7.90 (m, 4H), 7.53-7.56 (m, 2H), 7.37 (d, 1H, *J* = 8.6 Hz), 5.46 (s, 2H), 3.29 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.7, 133.5, 132.9, 129.2, 128.2, 127.8, 127.3, 127.1, 126.4, 123.3, 81.7, 61.6, 52.7.; HRMS (EI): m/z calcd for $C_{14}H_{13}NO_5S$ 307.0514, found 307.0513.

Methyl (4*S*,5*S*)-4-(furan-2-yl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7p



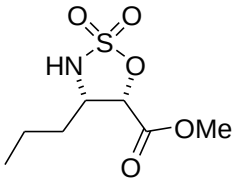
yield: 91.6% (22 mg as a white solid), mp = 97.9-110.2 ℃, 94.9% ee: Chiralpak IA, 30% ethanol /n-hexane, 1.3 ml/min, 215 nm t_R(major) = 8.7 min, t_R(minor) = 14.3 min; $[\alpha]_D^{28}$ = +95.8 (c 0.3, $CDCl_3$); ^{1}H NMR (500 MHz, $CHCl_3$) δ 7.44 (s, 1H), 6.43-6.53 (m, 2H), 5.29-5.32 (m, 1H), 5.22-5.23 (m, 1H), 5.16-5.18 (m, 1H), 3.65 (s, 3H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 166.1, 144.3, 143.8, 111.5, 111.4, 80.8, 55.8, 53.5.; HRMS (EI): m/z calcd for $C_8H_9NO_6S$ 247.0151, found 247.0155.

Methyl (4*S*,5*S*)-4-(thiophen-2-yl)-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7q



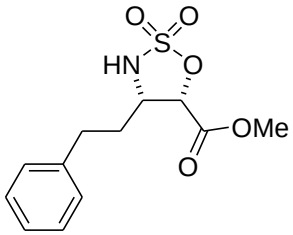
yield: 93.8% (38.3 mg as a white solid), mp = 96-97 ℃, 98.7% ee: Chiralpak IA, 20% ethanol /n-hexane, 1.5 ml/min, 215 nm t_R(minor) = 12.5 min, t_R(major) = 14.2 min; $[\alpha]_D^{29}$ = +70.6 (c 0.3, $CDCl_3$); ^{1}H NMR (500 MHz, $CHCl_3$) δ 7.37-7.38 (m, 1H), 7.14 (s, 1H), 7.04-7.05 (m, 1H), 5.49 (d, 1H, *J* = 5.9 Hz), 5.35 (d, 1H, *J* = 6.5 Hz), 5.13 (s, 1H), 3.59 (s, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 165.5, 133.5, 127.6, 127.4, 127.2, 81.7, 57.7, 53.0.; HRMS (EI): m/z calcd for $C_8H_9NO_5S_2$ 262.9922, found 262.9918.

Methyl (4*S*,5*S*)-4-propyl-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7r



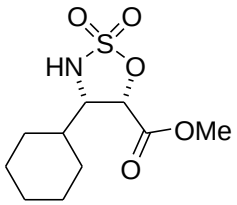
yield: 69% (98.5 mg as a coloress oil); $[\alpha]_D^{29}$ = +52.5 (c 0.3, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ 5.06 (d, 1H, *J* = 5.3 Hz), 4.48 (brs, 1H), 4.13 (brs, 1H), 3.86 (s, 3H), 1.48-1.61 (m, 4H), 0.97 (t, 3H, *J* = 6.9 Hz).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.1, 82.3, 58.5, 53.2, 30.8, 19.8, 13.7.; HRMS (EI): m/z calcd for $C_7H_{13}NO_5S$ 223.0514, found 223.0537.

Methyl (4*S*,5*S*)-4-phenethyl-1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7s



yield: 53.5% (14 mg as a ivory solid), mp = 90.6-92.3 ℃, 76.1% ee: Chiralpak IA, 20% ethanol /n-hexane, 1.5 ml/min, 215 nm t_R(minor) = 6.0 min, t_R(major) = 8.0 min; $[\alpha]_D^{20}$ = +41.3 (c 0.3, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ 7.33-7.36 (m, 2H), 7.26-7.29 (m, 1H), 7.20 (d, 2H, *J* = 7.4 Hz), 5.08 (d, 1H, *J* = 6.1 Hz), 4.66 (d, 1H, *J* = 2.2 Hz), 4.12-4.14 (m, 1H), 3.88 (s, 3H), 2.86-2.90 (m, 1H), 2.75-2.81 (m, 1H), 1.89-1.97 (m, 2H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.9, 139.2, 128.9, 128.4, 126.8, 82.0, 57.7, 53.2, 32.3, 30.5.; HRMS (EI): m/z calcd for $C_{12}H_{15}NO_5S$ 285.0671, found 285.0666.

Methyl (4*S*,5*S*)-4-cyclohexyl -1,2,3-oxathiazolidine-5-carboxylate 2,2-dioxide, (*S*,*S*)-7t



yield: 66.7% (179 mg as a coloress oil); $[\alpha]_D^{30}$ = +41.4 (c 0.68, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 5.09(d, 1H, *J* = 5.8 Hz), 4.60(bs, 1H), 3.87(s, 3H), 3.84 (m, 1H), 1.02-1.88 (m, 11H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.4, 82.5, 63.9, 53.1, 37.8, 30.7, 29.3, 25.7, 25.2, 25.1.; HRMS (EI): m/z calcd for $C_{10}H_{17}NO_5S$ 263.0827, found 263.0848.

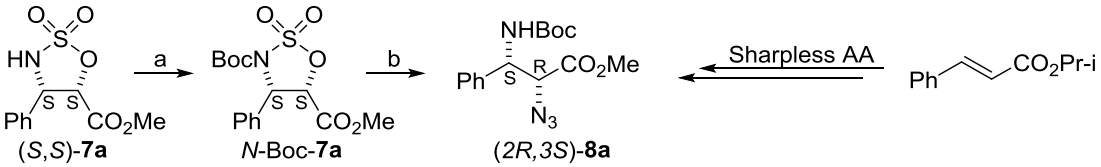
5. Assignment of absolute stereochemistry of 7a via converting to the known 8a

In order to determine the absolute stereochemistry of the ATH-DKR product, **7a** was converted to the known 2-azido-3-(*Boc*-amino)-3-phenyl propionic acid methyl ester **8a** and it was compared with the stereochemically defined **8a** which was derived from Sharpless asymmetric amino hydroxylation reaction.[10] The spectroscopic data and specific rotation data of synthetic **8a** were full agreement with those of the known ((*2R,3S*)-**8a**) in the

[10] S.-H. Lee, J. Yoon, S.-H. Chung and Y.-S. Lee, *Tetrahedron*, 2001, **57**, 2139.

literature. Additionally, the absolute stereochemistry of **7j** was unambiguously assigned by using single-crystal X-ray crystallographic analysis (deposited, CCDC-1007235).

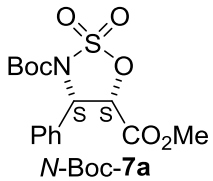
Scheme S1.



Reaction conditions: (a) $(Boc)_2O$, Et_3N, cat. DMAP, CH_2Cl_2, 100%; (b) i. NaN_3, DMF, 60 ^oC, 6 h; ii. 1N HCl, Et_2O, 12 h, rt, 92%.

5-1. Synthesis of (*S,S*)-*N*-Boc-7a

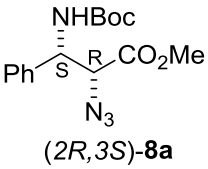
To a stirred mixture of (*S,S*)-**7a** (0.23 g, 0.92 mmol) and triethylamine (0.15 mL, 1.1 mmol) in dichloromethane (2.5 mL) was added successively di-*tert*-butyl dicarbonate (0.4 g, 1.83 mmol) and DMAP (catalytic amount). The reaction mixture was stirred at room temperature for 40 min. The reaction mixture was diluted with diethyl ether (20 mL) and washed successively with 1 N HCl, saturated aqueous $NaHCO_3$ solution and brine. The organic layer was dried over anhydrous $MgSO_4$, filtered and evaporated under reduced pressure. The residue was purified by column chromatography (Hexane/EtOAc=3:1) to give 0.33 g (99.7% yield) of (*S,S*)-***N*-Boc-7a**.



yield: 99.7% (0.33 g as a white solid), mp=126.3-130.2 ^oC, 97.8% ee: Chiralpak AD-H, 10% isopropanol/n-hexane, 1.0 ml/min, 215 nm t_R(minor) = 9.2 min, t_R(major) = 13.4 min; $[\alpha]_D^{20}$ = -14.6 (c 1.0, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ 7.35-7.39 (m, 5H), 5.50 (d, 1H, *J* = 6.35 Hz), 5.45 (d, 1H, *J* = 6.3 Hz), 3.42 (s, 3H), 1.44 (s, 9H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.1, 147.8, 133.6, 129.8, 129.0, 127.5, 86.4, 62.9, 52.9, 28.0,; HRMS (EI): m/z calcd for $C_{15}H_{19}NO_7S$ 357.0882, found 357.0887.

5-2. 2-Azido-3-tert-butoxycarbonylamino-3-phenyl-propionic acid methyl ester, (*2R,3S*)-8a

NaN_3 (22.3 mg, 0.343 mol, 5.0 equiv) was added in a single portion to a solution of (*S,S*)-***N*-Boc-7a** (24.5 mg, 68.6 mmol, 1.0 equiv) in DMF (2 ml) at 25 ℃. The resulting mixture was warmed to 60 ℃ and stirred for 6 h. Upon completion, the reaction mixture was cooled to rt and the contents were diluted with Et_2O (3 mL), treated with 1*N* aqueous HCl (3 mL), and allowed to stir for an additional 12 h at 25 ℃. Once this operation was complete, the reaction mixture was poured into saturated $NaHCO_3$ solution and extracted with Et_2O. The combined organic layers were then washed with water, dried ($MgSO_4$), and concentrated. The resultant light yellow solid was purified by flash column chromatography (silica gel, EtOAc/hexanes, 5:1).



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

White solid, yield: 92%; mp 133-134°C; $[\alpha]_D^{20}$ = +17.06 (c 0.8, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.37-7.30 (m, 5H), 5.33 (brs, 2H), 4.38 (brs, 1H), 3.82 (s, 3H), 1.42 (s, 9H); ^{13}C NMR (500 MHz, $CDCl_3$) δ 168.8, 155.0, 138.4, 128.9, 128.3, 126.7, 80.4, 66.9, 55.3, 53.2, 28.4.

The spectroscopic and specific rotation data of synthetic **8a** were full agreement with those of the known ((*2R,3S*)-**8a**) in the literature.[11]

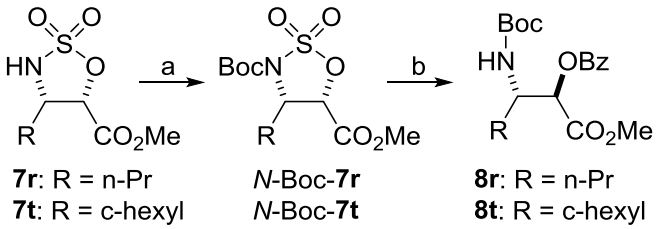
Lit.[11] mp 133–134℃; $[\alpha]_D^{20}$ = +16.5° (*c* 1, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.25–7.50 (m, 5H), 5.34 (br s, 2H), 4.38 (br s, 1H), 3.81 (s, 3H), 1.42 (s, 9H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 168.62, 154.78, 138.27, 128.71, 128.09, 126.51, 80.21, 66.71, 55.18, 52.95, 28.19.

6. Evaluation of ee's of 7r and 7t by convertion to ring-opened derivatives

Because of difficults in chiral separation of **7r** and **7t** themselves in various chiral columns and conditions, **7r** and **7t** were converted to the corresponding ring opened derivatives **8r** and **8t** and ee values were indirectly determined with these compounds.

Scheme S2.

[11] S.-H. Lee, J. Yoon, S.-H. Chung and Y.-S. Lee, *Tetrahedron*, 2001, **57**, 2139.

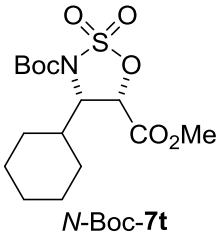


Reaction conditions: (a) $(Boc)_2O$, Et_3N, cat. DMAP, CH_2Cl_2; (b) i. $PhCO_2NH_4$, DMF, 55 ^oC, 12 h; ii. 1N HCl, CH_2Cl_2, 6 h, rt.

6-1. Synthesis of *N*-Boc-7r and *N*-Boc-7t

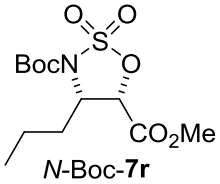
6-1-1. *N*-Boc-7t

To a stirred mixture of (*S*,*S*)-**7t** (16.4 mg, 0.062 mmol) and triethylamine (0.01mL, 0.072 mmol) in dichloromethane (1 mL) at 0 ^oC was added successively di-*tert*-butyl dicarbonate (27.2 mg, 0.125 mmol) and DMAP (catalytic amount). The reaction mixture was stirred at room temperature for 2 h, diluted with CH_2Cl_2 (5 mL) and washed successively with 1 N HCl, saturated $NaHCO_3$ solution and brine. The organic layer was dried over anhydrous $MgSO_4$, and evaporated. The residue was purified by column chromatography (Hexane/EtOAc=10:1) to give 20 mg (87% yield) of (*S*,*S*)-***N*-Boc-7t**.



Yield: 87% (20 mg); $[\alpha]_D^{30}$ = -15.01 (c 0.92, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 5.30 (d, *J* = 4.7 Hz, 1H), 4.56 (m, 1H), 3.89 (s, 3H), 1.66-1.83 (m, 6H), 1.56 (s, 9H), 1.08-1.26 (m, 5H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 164.1, 149.1, 85.9, 77.2, 63.8, 53.2, 40.1, 30.7, 27.8, 27.0, 26.3, 25.9, 25.6.; HRMS (EI): m/z calcd for $C_{15}H_{25}NO_7S$ 363.1352, found 363.1364.

6-1-2. *N*-Boc-7r

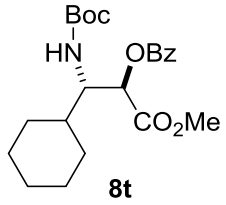


Yield: 97% (270 mg); $[\alpha]_D^{29}$ = -26.77 (c 1.48, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 5.28 (d, *J* = 5.4 Hz, 1H), 4.61-4.67 (m, 1H), 3.89 (s, 3H), 1.62-1.77 (m, 2H), 1.55 (s, 9H), 1.35-1.43 (m, 2H), 0.90-0.95 (t, *J* = 7.3 Hz, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.9, 148.4, 86.0, 77.0, 59.2, 53.3, 31.9, 27.9, 18.1, 13.9.; HRMS (EI): m/z calcd for $C_{12}H_{21}NO_7S$ 323.1039, found 323.1014.

6-2. Synthesis of 8r and 8t

6-2-1. (*2R,3S*)-8t

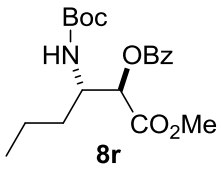
Ammonium benzoate (65.24 mg, 0.47 mmol) was added to a solution of (4*S*,5*S*)-***N*-*Boc*-7t** (85.2 mg, 0.23 mmol) in dry DMF (10 mL). The solution was heated to 60 ^{o}C under inert atmosphere (N_2) and stirred for 14 h at that temperature. The solvent was evaporated under reduced pressure and the residue was re-dissolved in dichloromethane (10 mL) and 1N HCl 10 mL) was added. The reaction mixture was stirred at room temperature for 6 h before the pH was adjusted to 8 with saturated aquous $NaHCO_3$ solution. The layers were separated and the aqueous layer was extracted three times with dichloromethane. The combined organic layers were washed with water and brine, dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography on silica-gel (Hexane/EtOAc, 4:1) to give 66 mg of **8t**.



8t

yield: 70.8% (66 mg); 47% ee, dr = 31:1.; Chiralpak IC, 10% isopropanol/n-hexane, 0.7 ml/min, 254 nm t_R(minor) = 8.35 min, t_R(major) = 9.55 min; $[\alpha]_D^{30}$ = -35.44 (c 0.35, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.07 (d, *J* = 7.3 Hz, 2H), 7.61 (m, 1H), 7.48 (m, 2H), 5.44 (d, *J* = 2.25 Hz, 1H), 4.78 (d, *J* = 10.5 Hz, 1H), 4.09 (m, 1H), 3.75 (s, 3H), 1.61-1.92 (m, 6H), 1.43 (s, 9H), 1.06-1.15 (m, 5H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 169.2, 165.7, 155.5, 133.6, 129.9, 129.2, 128.5, 79.6, 72.4, 56.0, 52.5, 39.8, 29.7, 29.6, 28.3, 26.0, 25.9.; HRMS (EI): m/z calcd for $C_{22}H_{31}NO_6$ 405.2151, found 405.2158.

6-2-2. (*2R,3S*)-8r

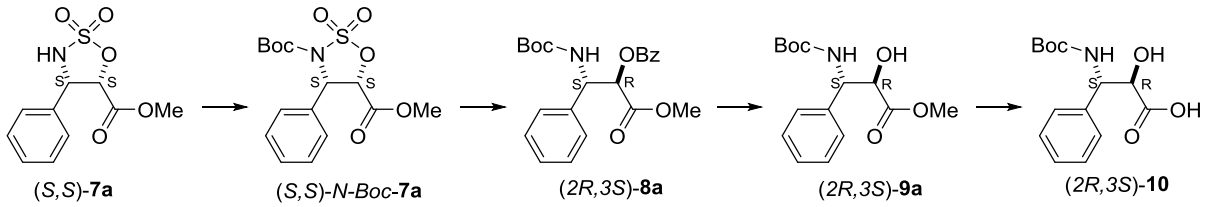


8r

yield: 72.3% (220 mg); 91% ee, dr = 100:0.; Chiralpak IC, 10% isopropanol/n-hexane, 0.7 ml/min, 254 nm t_R(minor) = 9.27 min, t_R(major) = 11.15 min; $[\alpha]_D^{29}$ = -70.5 (c 0.99, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.4 Hz, 2H), 7.61 (m, 1H), 7.47 (m, 2H), 5.27 (d, *J* = 2.3 Hz, 1H), 4.77(d, *J* =9.9 Hz, 1H), 4.32 (m, 1H), 3.77 (s, 3H), 1.53-1.62 (m, 2H), 1.46 (s, 9H), 1.36-1.48 (m, 2H), 0.93-0.97 (t, *J* = 7.3 Hz, 3H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 168.8, 165.7, 155.3, 133.6, 129.9, 129.1, 128.5, 79.7, 74.2, 52.5, 51.1, 34.4, 28.3, 19.2, 13.7.; HRMS (EI): m/z calcd for $C_{19}H_{27}NO_6$ 365.1838, found 365.1856.

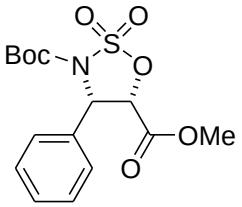
7. Synthesis of Taxotere side chain, (*2R,3S*)-10

Scheme S3.



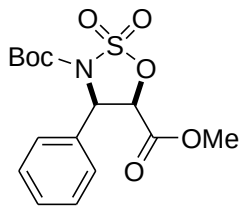
7-1. Synthesis of (4*S*,5*S*)-*N*-*Boc*-7a

To a stirred mixture of (*S*,*S*)-**7a** (0.23 g, 0.92 mmol) and triethylamine (0.15 mL, 1.1 mmol) in dichloromethane (2.5 mL) was added successively di-*tert*-butyl dicarbonate (0.4 g, 1.83 mmol) and DMAP (cat) and the mixture was stirred at room temperature for 40 min. It was then diluted with diethyl ether (20 mL) and washed successively with 1 N HCl, $NaHCO_3$ and brine. The organic layer was dried over anhydrous $MgSO_4$, and evaporated under reduced pressure. The residue was purified by column chromatography on silicagel (Hexane/EtOAc = 3:1) to give 0.33 g (99.7% yield) of (4*S*,5*S*)-***N*-*Boc*-7a**.



yield: 99.7% (0.33 g as a white solid), mp=126.3-130.2 ^{o}C, 97.8% ee: Chiralpak AD-H, 10% isopropanol/n-hexane, 1.0 ml/min, 215 nm t_R(minor) = 9.2 min, t_R(major) = 13.4 min; $[\alpha]_D^{20}$ = -14.6 (c 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35-7.39 (m, 5H), 5.50 (d, 1H, *J* = 6.35 Hz), 5.45 (d, 1H, *J* = 6.3 Hz), 3.42 (s, 3H), 1.44 (s, 9H).; ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.1, 147.8, 133.6, 129.8, 129.0, 127.5, 86.4, 62.9, 52.9, 28.0,; HRMS (EI): m/z calcd for $C_{15}H_{19}NO_7S$ 357.0882, found 357.0887.

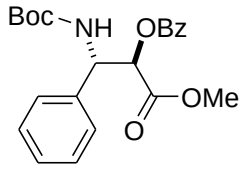
7-2. Synthesis of (4*R*,5*R*)-*N*-*Boc*-7a



yield: 94.2% (109 mg as a white solid), mp=127.2-129.4 ^{o}C, 98.1% ee: Chiralpak AD-H, 10% isopropanol/n-hexane, 1.0 ml/min, 215 nm t_R(major) = 9.3 min, t_R(minor) = 13.8 min; $[\alpha]_D^{20}$ = +12.3 (c 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35-7.38 (m, 5H), 5.49 (d, 1H, *J* = 6.35 Hz), 5.44 (d, 1H, *J* = 6.3 Hz), 3.42 (s, 3H), 1.43 (s, 9H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.0, 147.7, 133.4, 129.6, 128.8, 127.3, 86.2, 62.8, 52.8, 27.8.

7-3. Synthesis of (*2R*,*3S*)-8a

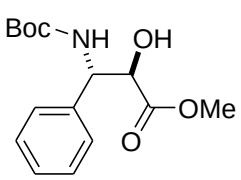
Ammonium benzoate (0.16 g, 1.17 mmol) was added to a solution of (4*S*,5*S*)-***N*-*Boc*-7a** (0.21 g, 0.58 mmol) in dry DMF (2 mL). The solution was heated to 60 ^{o}C and stirred for 12 h at that temperature. The solvent was evaporated under reduced pressure and the residue was re-dissolved in dichloromethane (3 mL) and 1N HCl (3 mL) was added. The reaction mixture was stirred at room temperature for 6 h before the pH was adjusted to 8 with saturated aquous $NaHCO_3$ solution. The layers were separated and the aqueous layer was extracted three times with dichloromethane. The combined organic layers were washed with water and brine, dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography on silica-gel (Hexane/EtOAc, 3:1) to give (*2R,3S*)-**8a** (0.23 g, 82.1% yield).



yield: 82.1% (0.23 g as a colorless oil), ; $[\alpha]_D^{22}$ = +11.49 (c 1.0, $CHCl_3$), (lit.[12] $[\alpha]_D^{21}$ = -9.1 (c 0.86, $CHCl_3$)); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.96-7.98 (m, 2H), 7.55-7.58 (m, 1H), 7.41-7.45 (m, 2H), 7.31-7.37 (m, 4H), 7.25-7.27 (m, 1H), 5.49 (s, 2H), 3.76 (s, 3H), 1.42 (s, 9H), 1.23-1.29 (brs, 1H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 168.3, 165.5, 155.0, 138.0, 133.6, 130.0, 129.9, 129.8, 128.9, 128.7, 128.5, 128.0, 127.2, 126.5, 80.3, 75.3, 54.9, 52.7, 31.6, 28.3, 22.7, 14.1.; HRMS (EI): m/z calcd for $C_{22}H_{25}NO_6$ 399.1682, found 399.1690.

7-4. Synthesis of (*2R,3S*)-9a

KCN (14 mg, 0.22 mmol) was added to a stirred solution of (*2R,3S*)-**8a** (0.17 g, 0.44 mmol) in MeOH (2 mL). The resulting mixture was stirred at 65 ^{o}C for 2 h. After removal of the solvent, the residue was dissolved in CH_2Cl_2 and then washed with brine. The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was purified by column chromatography on silica-gel (Hexane/EtOAc, 3:1) to give (*2R,3S*)-**9a** (0.11 g, 84.5% yield).



yield: 84.5% (0.11 g as a white solid), mp=113.2-116.2 ^{o}C, $[\alpha]_D^{23}$= -5.49 (c 1.0, $CHCl_3$), (lit.[13] $[\alpha]_D^{23}$ = -6.7 (c 0.85, $CHCl_3$)); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37-7.39 (m, 4H), 7.30-7.33 (m, 1H), 5.41 (d, 1H, *J* = 8.6 Hz),

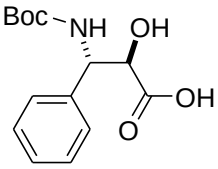
[12] For enantiomeric (*2S,3R*)-**8**. Bunnage, M. E.; Davies, S. G.; Goodwi, C. J., *J. Chem. Soc., Perkin Trans. 1*, 1994, 2385.

[13] Harris, L.; Mee, S. P. H.; Furneaux, R. H.; Gainsford, G. J.; Luxenburger, A., *J. Org. Chem.*, 2011, **76**, 358.

5.24 (d, 1H, *J* = 9.2 Hz), 4.50 (s, 1H), 3.87 (s, 3H), 3.15 (d, 1H, *J* = 3.7 Hz), 1.45 (s, 9H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4, 155.1, 139.1, 128.6, 127.8, 126.7, 80.0, 73.5, 56.1, 28.3.; HRMS (ESI): m/z calcd for $C_{15}H_{21}NO_5Na$ 318.1317, found 318.1313.

7-5. Synthesis of (*2R,3S*)-10, Toxotere side chain

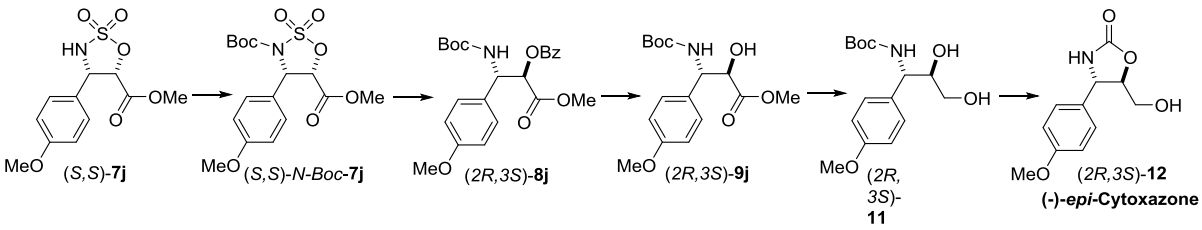
To a solution of compound (*2R,3S*)-**9a** (100 mg, 0.34 mmol) in methanol (2 mL) and THF (2 mL) was added 1N NaOH (1 mL). After being stirred at room temperature for 0.5 h, the solution was concentrated and H_2O (10 mL) was added. The aqueous solution was extracted with dichloromethane (3x10 mL). The remaining aqueous layer was acidified to pH 3~4 with 1N HCl and extracted with ethyl acetate (6x10 mL). The combined ethyl acetate fractions were dried over anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. The resulting residue was washed with H_2O and collected via filtration affording (*2R,3S*)-**10** (83.5 mg, 88%).



yield: 88% (83.5 mg as a white solid), mp = 122.5-123.9 °C; $[\alpha]_D^{23}$ = +26.58 (c 1.0, MeOH), (lit.[14] mp = 123.7-124.9 °C, $[\alpha]_D^{25}$ = +24.9 (c 1.0, MeOH)) ; ^{1}H NMR (500 MHz, DMSO-d_6) δ 7.27-7.31 (m, 4H), 7.20-7.23 (m, 1H), 7.06 (d, 1H, *J* = 9.4 Hz), 4.91-4.94 (dd, 1H, *J* = 3.5, 9.4 Hz), 4.17 (d, 1H, *J* = 3.5 Hz), 1.34 (s, 9H), 1.21-1.22 (brs, 1H); ^{13}C NMR (125 MHz, DMSO-d_6) δ 173.9, 155.4, 141.3, 128.4, 127.3, 127.3, 78.6, 74.2, 57.3, 28.6.; HRMS (ESI): m/z calcd for $C_{14}H_{19}NO_5Na$ 304.1161, found 304.1159.

8. Synthesis of (-)-*epi*-Cytoxazone, (*2R,3S*)-12

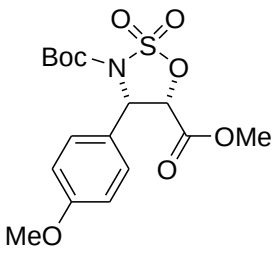
Scheme S4.



[14] Shen, X.; Yang, J.; Zhan, H.; Wang, H.; Wu, S.; Chen, Z. *Chin. J. Chem.* 2013, **31**, 31.

8-1. Synthesis of (4*S*,5*S*)-*N*-*Boc*-7j

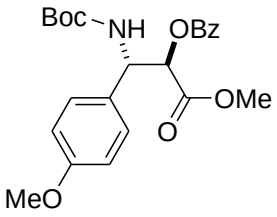
The (4*S*,5*S*)-*N*-*Boc*-**7j** was prepared by using the procedure for the synthesis of (4*S*,5*S*)-*N*-*Boc*-**7a** as depicted in **7-1**.



yield: 94.2% (109 mg as a white oil), $[\alpha]_D^{22}$ = -17.4 (c 1.07, CHCl3); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32 (d, 2H, *J* = 8.0 Hz), 6.88 (d, 2H, *J* = 8.0 Hz), 5.48 (d, 1H, *J* = 6.2 Hz), 5.41 (d, 1H, *J* = 5.9 Hz), 3.79 (s, 3H), 3.47 (s, 3H), 1.45 (s, 9H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.1, 160.4, 147.7, 128.8, 125.4, 114.2, 86.1, 62.4, 55.3, 52.8, 27.8.; HRMS (EI): m/z calcd for $C_{16}H_{21}NO_8S$ 387.0988, found 387.0991.

8-2. Synthesis of (*2R,3S*)-8j

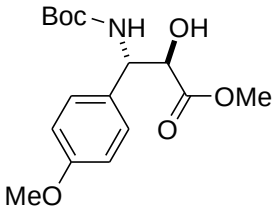
The (*2R,3S*)-**8j** was prepared by using the procedure for the synthesis of (*2R,3S*)-**8a** as depicted in **7-3**.



yield: 100% (96.6 mg as a colorless oil), $[\alpha]_D^{20}$ = +20.4 (c 1.0, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.00 (d, 2H, *J* = 7.6 Hz), 7.58 (t, 1H, *J* = 7.5 Hz), 7.45 (t, 2H, *J* = 7.6 Hz), 7.29 (d, 2H, *J* = 8.0 Hz), 6.86 (d, 2H, *J* = 8.2Hz), 5.44-5.47 (m, 3H), 3.77 (s, 6H), 1.43 (s, 9H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.2, 133.6, 129.9, 128.5, 127.7, 114.1, 55.3, 52.7, 28.3.; HRMS (EI): m/z calcd for $C_{23}H_{27}NO_7$ 429.1788, found 429.1781.

8-3. Synthesis of (*2R,3S*)-9j

The (*2R,3S*)-**9j** was prepared by using the procedure for the synthesis of (*2R,3S*)-**9a** as depicted in **7-4**.



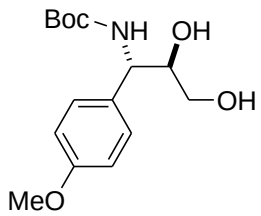
yield: 86.3% (63 mg as a white solid), mp = 127.1-129.2 ^{o}C, $[\alpha]_D^{20}$ = +3.9 (c 0.5, $CHCl_3$), (lit.[15] mp = 110-112 ^{o}C, $[\alpha]_D^{23}$ = -3.8 (c 0.5, $CHCl_3$)); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 (d, 2H, *J* = 7.9 Hz), 6.88 (t, 1H, *J* = 8.3 Hz), 5.35 (d, 1H, *J* = 9.3 Hz), 5.15 (d, 1H, *J* = 8.8 Hz), 4.43 (brs, 1H), 3.83 (s, 3H), 3.79 (s, 3H), 3.20 (brs, 1H), 1.41 (s, 9H).;

[15] For enantiomeric (*2S,3R*)-**9j**. Mishra, R. K.; Coates, C. M.; Revell, K. D.; Turos, E., *Org. Lett*., 2007, **9**, 575.

^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4, 159.1, 155.1, 131.3, 127.9, 114.0, 79.9, 73.6, 55.6, 55.3, 53.0, 28.3.; HRMS (ESI); m/z calcd for $C_{16}H_{23}NO_6Na$ 348.1423, found 348.1417.

8-4. Synthesis of (*2R,3S*)-11

The (*2R,3S*)-**9j** (63mg, 0.19 mmol) was dissolved in ethanol (2 mL) and cooled to 0 ℃. To this was added dropwise $NaBH_4$ (24 mg, 0.63 mmol) as a solution in ethanol (1 mL). After the addition was complete the ice bath was removed and the reaction mixture was stirred at room temperature for 4 h before the addition of a saturated aqueous NH_4Cl solution (5 mL). The ethanol was evaporated under reduced pressure. The remaining aqueous solution was extracted with ethyl acetate (3 x 5 mL) and the combined organic layers were washed with brine and dried over $MgSO_4$. Solvents were removed under reduced pressure and the residue was purified by silicagel chromatography eluting with CH_2Cl_2/MeOH (20/1), affording (*2R,3S*)-**11** as a white solid (51.7 mg, 91.7%).



yield: 91.7% (51.7 mg as a white solid), mp = 125.7-127.9 ℃, $[\alpha]_D^{20}$ = +36.9 (c 0.4, $CHCl_3$), (lit.[16] $[\alpha]_D^{23}$ = -36.1 (c 1.0, $CHCl_3$)); ^{1}H NMR (500 MHz, CD_3OD) δ 7.23 (d, 2H, *J* = 7.8 Hz), 6.86 (d, 2H, *J* = 7.6 Hz), 6.72 (brs, 1H), 4.62 (brs, 1H), 3.76 (s, 3H), 3.73 (brs, 1H), 3.43-3.46 (m, 1H), 3.35-3.39(m, 1H), 3.30 (s, 1H), 1.41 (s, 9H).; ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.1, 156.9, 128.6, 127.9, 114.3, 114.2, 80.4, 75.3, 63.7, 55.3, 28.3.; HRMS (EI): m/z calcd for $C_{15}H_{23}NO_5$ 297.1576, found 297.1556.

8-5. Synthesis of (*2R,3S*)-12, (-)-*epi*-Cytoxazone.

To a stirred solution of (*2R,3S*)-**11** (41 mg, 0.14 mmol) in dry THF (2 mL) at 0 ℃ was added sodium hydride (20 mg, 60% w/w in mineral oil, 0.45 mmol) at room temperature, and the reaction mixture was refluxed for 1 h. The reaction mixture was cooled to room temperature and quenched with a saturated aqueous NH_4Cl (10 mL), then extracted with ethyl acetate (2x10 mL). The organic layer was washed with water and brine, dried over anhydrous $MgSO_4$, and concentrated under reduced pressure. The residue was purified by column chromatography on silica-gel (Hexane/EtOAc = 2:1) to give (*2R,3S*)-**12** as a white solid (29 mg, 95.1%).

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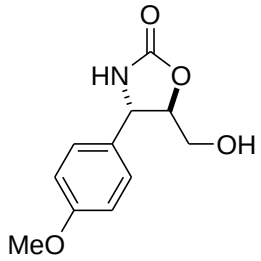
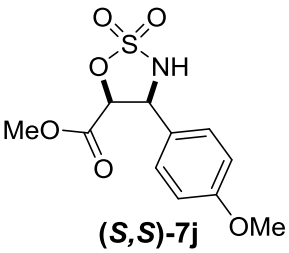
[16] For enantiomeric (*2S,3R*)-**11**. Kim, S.-G.; Park, T.-H., *Tetrahedron Asymmetry*, 2008, **19**, 1626.



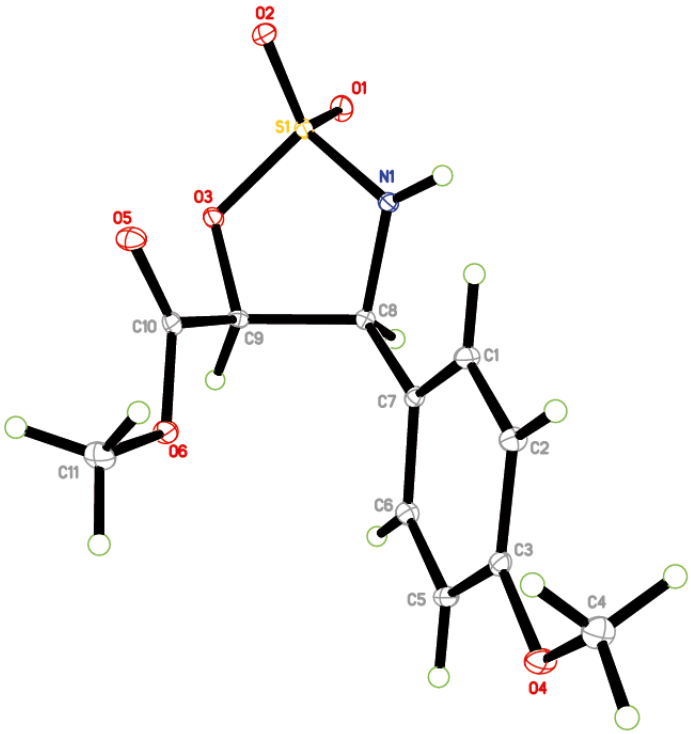
yield: 95.1% (29 mg as a white solid), mp = 141-142 °C, $[\alpha]_D^{19}$ = -28.2 (c 0.5, MeOH), lit.[17] $[\alpha]_D^{25}$ = -27.2 (c 1.1, MeOH), lit.[18] $[\alpha]_D^{28}$ = -22.8 (c 0.5, MeOH); ^{1}H NMR (500 MHz, CD_3OD-d_4) δ 7.36 (d, 2H, *J* = 8.2 Hz), 7.02 (d, 2H, *J* = 8.1 Hz), 4.81 (d, 1H, *J* = 6.5 Hz), 4.38-4.39 (m, 1H), 3.88 (m, 1H), 3.86 (s, 3H), 3.73-3.76 (dd, 1H, *J* = 4.2, 12.5 Hz).; ^{13}C NMR (125 MHz, CD_3OD-d_4) δ 160.1, 160.0, 132.2, 127.2, 114.0, 85.4, 61.1, 57.2, 54.4.; HRMS (EI): m/z calcd for $C_{11}H_{13}NO_4$ 223.0845, found 223.0829.

9. X-ray crystallography analysis data of (*S*,*S*)-7j

CCDC-1007235 contains the supplementary crystallographic data for (*S*,*S*)-**7j**. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre *via* www.ccdc.cam.ac.uk/data_request/cif.



(*S*,*S*)-7j



[17] Matsunaga, S.; Yoshida, T.; Morimoto, H.; Kumagai, N.; Shibasaki, M., *J. Am. Chem. Soc.*, 2004, **126**, 8777.

[18] Kim, I. S.; Kim, J. D.; Ryu, C. B.; Zee, O. P.; Jung, Y. H., *Tetrahedron*, 2006, **62**, 9349.

Crystal data and structure refinement for (*S*,*S*)-7j

Identification code	20131022lt_0m	
Empirical formula	C11 H13 N O6 S	
Formula weight	287.28	
Temperature	100(1) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P2(1)2(1)2(1)	
Unit cell dimensions	a = 5.3793(2) Å	α= 90°.
	b = 13.1499(5) Å	β= 90°.
	c = 17.4076(6) Å	γ = 90°.
Volume	1231.37(8) Å^3	
Z	4	
Density (calculated)	1.550 Mg/m^3	
Absorption coefficient	0.286 mm^{-1}	
F(000)	600	
Crystal size	0.25 x 0.20 x 0.08 mm^3	
Theta range for data collection	1.94 to 28.47°	
Index ranges	-7<=h<=7, -17<=k<=17, -22<=l<=23	
Reflections collected	34700	
Independent reflections	3107 [R(int) = 0.0235]	
Completeness to theta = 28.47°	99.8 %	
Absorption correction	Multi-scan	
Max. and min. transmission	0.9775 and 0.9319	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3107 / 0 / 172	
Goodness-of-fit on F^2	1.051	
Final R indices [I>2sigma(I)]	R1 = 0.0253, wR2 = 0.0722	
R indices (all data)	R1 = 0.0261, wR2 = 0.0732	
Absolute structure parameter	-0.01(6)	
Largest diff. peak and hole	0.404 and -0.530 e.Å^{-3}	