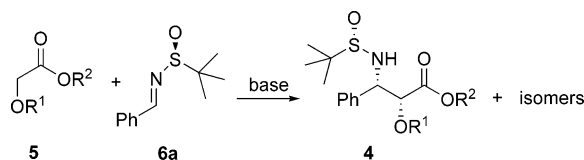


FIGURE 1. Structure of taxol, bacctin III, and taxol side chains.

SCHEME 1. Diastereoselective Addition of **5** to *tert*-Butanesulfinylimine **6a**



Results and Discussion

In recent years, Davis, Ellman, and co-workers have demonstrated well the diastereoselective sulfinylimine enolate addition reaction as one of the important reactions of C–C bond formation for preparing chiral β -amino acid ester and α,β -diamino acid ester.^{5,6} In continuing our study on chiral *tert*-butanesulfinamide chemistry,⁷ we envisioned that enantiopure 3-phenylisoserine ester **4** with a (2*R*,3*S*) configuration may be directly assembled by the diastereoselective addition of an enolate of *O*-protected α -hydroxyacetate **5** to enantiopure *tert*-butanesulfinylimine **6a**, although theoretically four isomers will be formed in the addition reaction (Scheme 1).

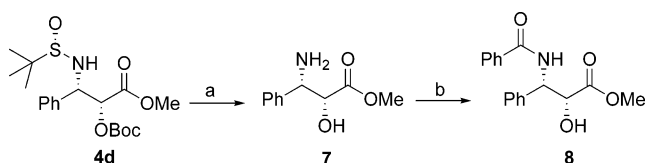
Initial experiments showed that the addition reaction of imine **6a** with a series of lithium enolates of benzyl acetates **5** (R¹ = Et₃Si, ^tBuMe₂Si, Bn, *p*-MeOC₆H₄, ^tBuCO, and Bz, R² = Bn), generated by the reaction of **5** with LDA at –78 °C in THF, respectively, gave unexceptionally a complicated mixture in low yield. When the hydroxyl-protecting group of benzyl acetate **5** was changed to a carbonate group (**5a**, R¹ = MeOCO, R² = Bn), we were pleased to find that the major *syn*-adduct **4a** with a (2*R*,3*S*) configuration was isolated in 45% yield and moderate diastereoselectivity (Table 1, entry 1).⁸ With the size increase of R¹ from methoxy carbonyl group to *tert*-butoxy carbonyl group, the yield and diastereoselectivity were greatly improved (Table 1, entries 1–3). Only one adduct, **4c**, was observed and

TABLE 1. Diastereoselective Addition of **5** to (*S_R*)-*N*-(Benzylidene)-*tert*-butanesulfinamide **6a**^a

entry	acetate 5	R ¹	R ²	base	yield of 4 ^b	dr
1	5a	MeOCO	Bn	LDA	4a (45)	88:12:0:0 ^c
2	5b	Cbz	Bn	LDA	4b (56)	— ^d
3	5c	Boc	Bn	LDA	4c (86)	>99:0:0:0 ^e
4	5c	Boc	Bn	BuLi	4c (36)	>99:0:0:0 ^e
5	5c	Boc	Bn	^t BuLi	4c (43)	>99:0:0:0 ^e
6	5c	Boc	Bn	LiHMDS	4c (97)	>99:0:0:0 ^e
7 ^f	5c	Boc	Bn	LiHMDS	4c (50)	>99:0:0:0 ^e
8 ^g	5c	Boc	Bn	LiHMDS	4c (85)	>99:0:0:0 ^e
9	5d	Boc	Me	LiHMDS	4d (96)	>99:0:0:0 ^e

^a All reactions were conducted at –78 °C in THF using 1 equiv of **6a**, 5 equiv of **5**, and 5 equiv of base unless specifically indicated. ^b Isolated yield. In parentheses, percent value. ^c The dr value was based on isolated isomers, and the absolute configuration of minor isomer was not identified. ^d Other isomers were isolated as an inseparable and unidentified mixture contaminated with byproducts. ^e A dr value of >99% indicated that other isomers were not observed. ^f At –45 °C. ^g At –78 °C, 3 equiv of **5c** and LiHMDS were used.

SCHEME 2^a



^a Reagents and conditions: (a) 6 N HCl in MeOH, 1 h, 96%. (b) PhCOCl/NaHCO₃, aq. THF, 85%.

was isolated in 86% yield when acetate **5c** (R¹ = Boc, R² = Bn) was used. After screening a couple of bases (Table 1, entries 3–6), the best result was achieved using 5 equiv of LiHMDS as a base and 5 equiv of **5c** at –78 °C in THF. Under the best condition, we were able to isolate **4c** (R¹ = Boc, R² = Bn) in 97% yield as sole adduct (Table 1, entry 6). Attempts to raise the reaction temperature and reduce the quantity of lithium enolate of **5c** unfortunately resulted in lower yields, although the diastereoselectivities were kept the same (Table 1, entries 7 and 8). Methyl acetate **5d** gave a similar result compared with benzyl acetate **5c** (Table 1, entry 9).

The absolute stereochemistry of major adduct **4** was verified by converting **4d** into the known methyl ester of (2*R*,3*S*)-3-benzoyl-3-phenylisoserine (–)-**8** with the same rotation and identical ¹H NMR spectrum compared with that of the literature data (Scheme 2). (–)-**8**, mp: 183–184 °C, [α]_D²⁵ –48.8 (c 1.25, MeOH) {lit.^{1d} [α]_D²³ –49.6 (MeOH), lit.⁹ [α]_D²³ –48.0 (MeOH)}. The absolute configuration of the major adduct was further unambiguously confirmed by the X-ray crystallographic analysis of **4c** as *S_R*,2*R*,3*S*.¹⁰

It was interesting to find the applicable scope and efficiency of current imine enolate addition strategy for the preparation of enantiopure isoserine **4** with different substituents at position-3, since taxol analogues with a variety of substituents instead of phenyl group at position-3 of the side chain have shown equal or even better anticancer profile, and some of them are being studied in different stages of clinical trials.¹¹

(5) For reviews on chiral sulfinylimine chemistry, see: (a) Zhou, P.; Chen, B. C.; Davis, F. A. *Tetrahedron* **2004**, *60*, 8003. (b) Ellman, J. A.; Owens, T. D. *Pure Appl. Chem.* **2003**, *75*, 39. (c) Ellman, J. A.; Owens, T. D.; Tang, T. P. *Acc. Chem. Res.* **2002**, *35*, 984. (d) Davis, F. A.; Zhou, P.; Chen, B. C. *Chem. Soc. Rev.* **1998**, *27*, 13.

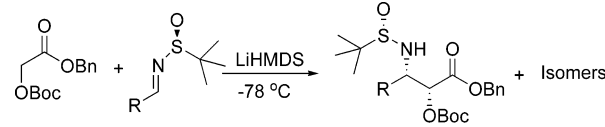
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(8) The *syn*-adducts with a typical double doublet ascribed to H-3 were readily differentiated from the *anti*-adducts with a typical triplet in the ¹H NMR spectrum.

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(10) A colorless crystal of **4c** (C₂₅H₃₁N₁O₆S₁, mp 148–149 °C) suitable for X-ray analysis was obtained by crystallization from acetone/petroleum 1:3. The crystallographic data have been deposited with the Cambridge Crystallographic Data Centre, CCDC 276473, and are also available in Supporting Information (the ORTEP/X-ray figure of **4c** is shown in Supporting Information).

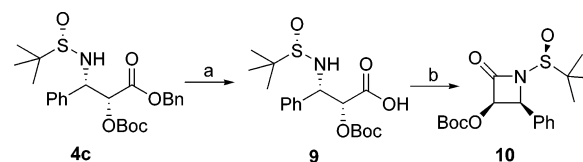
TABLE 2. Diastereoselective Addition of **5c** to (*S_R*)-*tert*-Butanesulfinylimines **6**


entry	6	R	4	yield ^a	dr ^c
1	6b	4-ClC ₆ H ₄	4e	96	>99:0:0:0
2	6c	3,4-(MeO) ₂ C ₆ H ₃	4f	89	>99:0:0:0
3	6d	4-MeOC ₆ H ₄	4g	96 ^b	91:9:0:0 ^c
4	6e	2-BrC ₆ H ₄	4h	89	93:5:2:0 ^c
5	6f	4-NO ₂ C ₆ H ₄	4i	98	>99:0:0:0
6	6g	2-pyridinyl	4j	94	97:3:0:0 ^c
7	6h	3-pyridinyl	4k	84	>99:0:0:0
8	6i	4-pyridinyl	4l	83	>99:0:0:0
9	6j	2-furyl	4m	84 ^b	91:9:— ^d
10	6k	2-thienyl	4n	97	>99:0:0:0
11	6l	C ₆ H ₄ (CH ₂) ₂	4o	89	>99:0:0:0
12	6m	<i>i</i> Pr	4p	95	98:2:0:0 ^c
13	6n	cyclopropyl	4q	96	>99:0:0:0

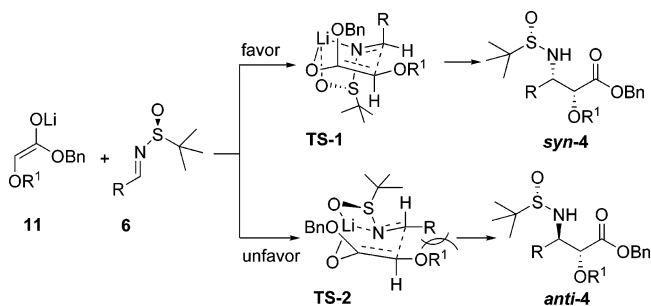
^a Isolated yield. ^b Inseparable mixture of two isomers in 11:1 ratio. ^c The ratio was based on ¹H NMR integration of crude product; a dr value of >99% indicated that other isomers were not observed, and the absolute configuration of minor isomer was not identified. ^d Other isomers were isolated as an inseparable and unidentified mixture contaminated with byproducts.

As shown in Table 2, the additions of **5c** to both aromatic and alkyl imines **6** were completed within 6 h to afford the desired *syn*-**4** as the major adduct in high to excellent yields and diastereoselectivities under our best conditions. The ratio was determined by careful ¹H NMR analyses of the crude product and each purified minor component. For most of the addition reactions, the reactions were very clean and only one adduct was detected by TLC analysis after quenching the reactions. The reactions with electron-rich imines such as **6c**, **6d**, **6j**, and **6k** proceeded rapidly and were completed within 1 h (Table 2, entries 2, 3, 9, and 10), whereas the electron-poor imines **6f**–**6i** exhibited a lower reactivity and required a longer reaction time (4–6 h) (Table 2, entries 5–8). For the addition reaction generating minor isomers (Table 2, entries 4, 6, and 12), the major adduct *syn*-**4** was easily separated from its minor isomers by chromatography purification. The exception was the reaction with imines **6d** and **6j**, where the major adducts **4g** and **4m** were isolated, respectively, as an inseparable mixture contaminated with one minor isomer (Table 2, entries 3 and 9).

The *N*,*O*-protected isoserine acid and β -lactam were commonly used for the *semi-synthesis* of taxol.^{2b,4l,12} With adduct **4c** in hands, our attention was then focused on preparing the isoserine acid **9** and β -lactam **10** by selective manipulating of the protecting groups in **4c**. Acid **9** and β -lactam **10** were readily synthesized by the following two steps. Thus, hydrogenolysis of **4c** under 1 atm of hydrogen pressure for 12 h in the presence of 5% Pd(OH)₂ (Pearlman's catalyst) afforded **9** in 94% yield. When **9** was treated with 1.5 equiv of 2-chloro-1-methylpyridinium iodide and Et₃N in MeCN at 60 °C for 6 h, the β -lactam **10** was obtained in 45% yield as well as some unidentified byproducts (Scheme 3).

SCHEME 3^a

^a Reagents and conditions: (a) 10% Pd(OH)₂, 1 atm H₂ in MeOH, 12 h, 94% yield. (b) 1.5 equiv of 2-chloro-1-methylpyridinium iodide and Et₃N in MeCN at 60 °C, 45% yield.

**FIGURE 2.** Plausible mechanism for the lithium enolate imine addition.

To provide a rationale for the observed excellent diastereoselectivity using lithium enolate of *O*-Boc- α -hydroxyacetate **11** as a nucleophile, a tentative mechanism was suggested (Figure 2), which adopted the six/four-membered bicyclic transition state proposed by Davis, Ellman, and co-workers in their asymmetric addition reaction of lithium enolate to sulfinylimine.^{6a,d} Both *trans*-enolate **11** and imine **6** were linked together through lithium chelation to form six/four-membered bicyclic transition states **TS-1** and **TS-2**. **TS-1** should be the favored low-energy transition state, since the *cis* relationship between α -orientation R and *e*-orientation R¹ in **TS-1** has less steric hindrance and allows the easier access of C-2 to C-3, compared with the *trans* relationship between both *e*-orientation R and R¹ in **TS-2**. With the size increase of R¹ from methoxy carbonyl group to *tert*-butoxy carbonyl group, the addition reaction should be more likely to occur through **TS-1** to afford *syn*-**4** as the dominating adduct. The suggested mechanism explained well our experimental observation (Table 1, entries 1–3).

Conclusion

We have described that the enantiopure 3-substituted isoserine **4** with a (*S_R*,2*R*,3*S*) absolute stereochemistry can be readily prepared in high to excellent yields by the diastereoselective enolate addition of *O*-Boc- α -hydroxyacetate **5** with (*S_R*)-*tert*-butanesulfinylimine **6**. To the best of our knowledge, the current method provides the most straightforward access to enantiopure 3-substituted isoserine **4**, which is useful for the *semi-syntheses* of taxol and its derivatives.

Experimental Section

General Procedure for the Addition of *O*-Protected α -Hydroxyacetate **5 with (*S_R*)-*tert*-Butanesulfinylimine **6**.** Under N₂, to a solution of *O*-protected α -hydroxyacetate **5** (10.0 mmol) in 25 mL of dry THF was added a solution of base (10.0 mmol) at –78 °C. After being stirred for 1 h at –78 °C, the mixture was added to (*S_R*)-*tert*-butanesulfinylimine **6** (2.0 mmol in 5 mL of dry THF) and was stirred at –78 °C for 1–6 h until imine **6** was completely consumed and checked by TLC analysis. The reaction mixture was

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quenched at $-78\text{ }^{\circ}\text{C}$ with saturated NH_4Cl solution and extracted with ethyl acetate ($3 \times 20\text{ mL}$). The combined organic phases were dried with anhydrous MgSO_4 . The solvent was removed under vacuum, and the residue was purified by chromatography to give adduct **4** and other isomers. The results were shown in Tables 1 and 2.

(*S_R*,*2R*,*3S*)-*N*-*tert*-Butanesulfinyl-*O*-methoxycarbonyl-3-phenylisoserine Benzyl Ester **4a:** Purified by chromatography (acetone/petroleum 1:4, R_f 0.4) as viscous oil, ^1H NMR (400 MHz, CDCl_3) δ 7.28–7.41 (m, 10H), 5.27 (d, $J = 2.8\text{ Hz}$, 1H), 5.21 (d, $J = 12.4\text{ Hz}$, 1H), 5.14 (d, $J = 12.4\text{ Hz}$, 1H), 5.03 (dd, $J = 10.0, 2.8\text{ Hz}$, 1H), 4.13 (d, $J = 9.6\text{ Hz}$, 1H), 3.76 (s, 3H), 1.14 (s, 9H) ppm; ^{13}C NMR (100 MHz, CDCl_3) δ 167.1, 154.6, 137.7, 134.67, 134.60, 128.58, 128.52, 128.4, 128.3, 128.2, 127.0, 78.6, 67.6, 60.2, 56.6, 55.2, 22.3 ppm; HRMS-ESI calcd for $\text{C}_{22}\text{H}_{27}\text{N}_1\text{Na}_1\text{O}_4\text{S}_1$ ($M + \text{Na}$) $^+$ 456.1457, found 456.1451.

Isomer of **4a:** Purified by chromatography (acetone/petroleum 1:4, R_f 0.35) as viscous oil, ^1H NMR (400 MHz, CDCl_3) δ 7.19–7.39 (m, 10H), 5.39 (d, $J = 5.2\text{ Hz}$, 1H), 5.10 (d, $J = 12.4\text{ Hz}$, 1H), 5.03 (d, $J = 12.4\text{ Hz}$, 1H), 4.91 (t, $J = 5.2\text{ Hz}$, 1H), 4.22 (d, $J = 4.8\text{ Hz}$, 1H), 3.79 (s, 3H), 1.16 (s, 9H) ppm; HRMS-ESI calcd for $\text{C}_{22}\text{H}_{27}\text{N}_1\text{Na}_1\text{O}_4\text{S}_1$ ($M + \text{Na}$) $^+$ 456.1457, found 456.1454.

(*S_R*,*2R*,*3S*)-*N*-*tert*-Butanesulfinyl-*O*-Cbz-3-phenylisoserine Benzyl Ester **4b:** Purified by chromatography (acetone/petroleum 1:7, R_f 0.2) as viscous oil, IR (KBr) 3300, 2959, 1750, 1498, 1455, 1385, 1270, 1242, 1073, 1040 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.24–7.40 (m, 15H), 5.32 (d, $J = 2.8\text{ Hz}$, 1H), 5.18 (d, $J = 12.4\text{ Hz}$, 1H), 5.15 (d, $J = 12.4\text{ Hz}$, 1H), 5.12 (d, $J = 12.4\text{ Hz}$, 1H), 5.09 (d, $J = 12.4\text{ Hz}$, 1H), 5.03 (dd, $J = 9.6, 2.8\text{ Hz}$, 1H), 4.12 (d, $J = 9.6\text{ Hz}$, 1H), 1.12 (s, 9H) ppm; ^{13}C NMR (100 MHz, CDCl_3) δ 167.2, 154.1, 137.7, 134.7, 128.6, 128.58, 128.53, 128.4, 128.21, 128.13, 127.1, 78.7, 70.3, 67.6, 60.3, 56.7, 22.6, 22.5 ppm; HRMS-ESI calcd for $\text{C}_{28}\text{H}_{31}\text{N}_1\text{Na}_1\text{O}_6\text{S}_1$ ($M + \text{Na}$) $^+$ 532.1770, found 532.1764.

(*S_R*,*2R*,*3S*)-*N*-*tert*-Butanesulfinyl-*O*-Boc-3-phenylisoserine Benzyl Ester **4c:** Purified by chromatography (acetone/petroleum 1:8, R_f 0.2) as a white solid, recrystallized from acetone and petroleum; X-ray (see CIF file); mp 148–149 $^{\circ}\text{C}$; $[\alpha]_D^{25} +1.0^{\circ}$ (c 1.0, EtOH); IR (KBr) 3296, 2975, 1746, 1497, 1458, 1426, 1395, 1366, 1291, 1243, 1208, 1160, 1113, 1046, 1009, 956, 862 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.22–7.41 (m, 10H), 5.27 (d, $J = 0.8\text{ Hz}$, 1H), 5.17 (s, 2H), 5.01 (d, $J = 9.6\text{ Hz}$, 1H), 4.14 (d, $J = 9.6\text{ Hz}$, 1H), 1.39 (s, 9H), 1.15 (s, 9H) ppm; ^{13}C NMR (100 MHz, CDCl_3) δ 167.5, 152.1, 137.8, 134.6, 128.5, 128.4, 128.0, 127.1, 83.3, 77.6, 67.4, 60.4, 56.6, 27.4, 22.3 ppm; Anal. Calcd for $\text{C}_{25}\text{H}_{33}\text{N}_1\text{O}_6\text{S}_1$: C, 63.13; H, 6.99; N, 2.95. Found: C, 63.08; H, 6.98; N, 3.08; HRMS-ESI calcd for $\text{C}_{25}\text{H}_{33}\text{N}_1\text{Na}_1\text{O}_6\text{S}_1$ ($M + \text{Na}$) $^+$ 498.1926, found 498.1921.

(*S_R*,*2R*,*3S*)-*N*-*tert*-Butanesulfinyl-*O*-Boc-3-phenylisoserine Methyl Ester **4d:** Purified by chromatography (acetone/petroleum 1:8, R_f 0.2) as a white solid, mp 85–87 $^{\circ}\text{C}$; $[\alpha]_D^{25} +8.6^{\circ}$ (c 1.2, CHCl_3); IR (KBr) 3345, 2957, 1745, 1499, 1461, 1393, 1370, 1352, 1310, 1280, 1162, 1136, 1080, 1018, 951 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.28–7.43 (m, 5H), 5.25 (d, $J = 2.8\text{ Hz}$, 1H), 5.01 (dd, $J = 10.0, 2.8\text{ Hz}$, 1H), 4.16 (d, $J = 10.0\text{ Hz}$, 1H), 3.78 (s, 3H), 1.41 (s, 9H), 1.19 (s, 9H) ppm; ^{13}C NMR (100 MHz, CDCl_3) δ 168.1, 152.2, 138.0, 128.6, 128.1, 127.1, 83.4, 60.3, 56.7, 52.4, 27.5, 22.6, 22.4 ppm; Anal. Calcd for $\text{C}_{19}\text{H}_{29}\text{N}_1\text{O}_6\text{S}_1$: C, 57.14; H, 7.32; N, 3.51. Found: C, 57.10; H, 7.30; N, 3.64; HRMS-ESI calcd for $\text{C}_{19}\text{H}_{29}\text{N}_1\text{Na}_1\text{O}_6\text{S}_1$ ($M + \text{Na}$) $^+$ 422.1613, found 422.1608.

Correlation of the Absolute Configurations by Chemical Transformation. Adduct **4d** (0.202 g, 0.5 mmol) was dissolved in 10 mL of 6 M HCl in MeOH overnight. The mixture was poured into an ice-cooled saturated NaHCO_3 solution and was extracted with CH_2Cl_2 ($3 \times 10\text{ mL}$). The organic phases were combined and dried with anhydrous Na_2SO_4 . The solvent was removed under vacuum to afford 0.098 g of crude **7** (96% yield), which was pure enough for the next step. The crude **7** was dissolved in 15 mL of THF. To the THF solution, saturated NaHCO_3 (5 mL) and benzoyl

chloride (1.0 mmol) were added successively at 0 $^{\circ}\text{C}$. After being stirred for 2 h at 0 $^{\circ}\text{C}$, the reaction mixture was extracted with CH_2Cl_2 ($3 \times 10\text{ mL}$). The combined organic phases were dried, and the solvent was removed under vacuum to give a residue, which was purified by chromatography to give **8** (0.123 g, 82% overall yield two steps).

(*2R*,*3S*)-3-Phenylisoserine Methyl Ester **7.** The analytic sample was purified by chromatography (acetone/petroleum 1:4, R_f 0.2) as a white solid, mp 103–105 $^{\circ}\text{C}$, $[\alpha]_D^{25} +10.6^{\circ}$ (c 1.0, MeOH); IR (KBr) 3367, 3308, 3070, 2855, 2707, 1730, 1449, 1434, 1365, 1280, 1198, 1160, 1082, 922 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.41–7.26 (m, 5H), 4.30 (m, 2H), 3.80 (s, 3H), 2.00 (s, br, 2H) ppm; ^{13}C NMR (100 MHz, CDCl_3) δ 173.6, 141.9, 128.4, 127.5, 126.6, 75.0, 57.8, 52.3 ppm.

(*2R*,*3S*)-*N*-Benzoyl-3-phenylisoserine Methyl Ester **8:** Purified by chromatography (acetone/petroleum 1:4, R_f 0.5) as a white solid, mp 183–184 $^{\circ}\text{C}$, $[\alpha]_D^{25} -48.8$ (c 1.3, MeOH) {lit.^{1d} $[\alpha]_D^{25} -49.6$ (MeOH), lit.⁹ $[\alpha]_D^{25} -48.0$ (MeOH)}. ^1H NMR was identical to literature report.^{1d,9} IR (KBr) 3391, 3367, 1735, 1639, 1580, 1521, 1489, 1449, 1292, 1261, 1208, 1111 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.77 (m, 2H), 7.27–7.56 (m, 8H), 6.98 (d, $J = 8.8\text{ Hz}$, 1H), 5.74 (dd, $J = 9.2, 0.8\text{ Hz}$, 1H), 4.64 (dd, $J = 4.0, 2.4\text{ Hz}$, 1H), 3.85 (s, 3H), 3.27 (d, $J = 3.6\text{ Hz}$, 1H) ppm.

Synthesis of β -Lactam **10.** Adduct **4c** (1.255 g, 2.6 mmol) in 20 mL of MeOH was subjected to hydrogenolysis under 1 atm hydrogen pressure in the presence of 10% of $\text{Pd}(\text{OH})_2$ for 12 h. After we removed the $\text{Pd}(\text{OH})_2$ by filtration, we evaporated the mixture to dryness. The residue was purified by chromatography ($\text{CH}_2\text{Cl}_2/\text{MeOH}/\text{AcOH}$ 10:1:0.1, R_f 0.3) to afford acid **9** (0.931 g, 93% yield). Under N_2 , a mixture of acid **7** (0.820 g, 2.1 mmol), Et_3N (0.323 g, 3.2 mmol), and 2-chloro-1-methylpyridinium iodide (0.800 g, 3.2 mmol) in 15 mL of dry MeCN was refluxed for 6 h. The solvent was removed by evaporation, and the residue was subjected to chromatography (acetone/petroleum 1:8, R_f 0.2) to give β -lactam **10** (0.347 g, 45% yield).

(*S_R*,*2R*,*3S*)-*N*-*tert*-Butanesulfinyl-*O*-Boc-3-phenylisoserine Acid **9:** mp 144–146 $^{\circ}\text{C}$; $[\alpha]_D^{25} +23.0^{\circ}$ (c 1.2, CHCl_3); IR (KBr) 3357, 2980, 1741, 1610, 1452, 1372, 1351, 1309, 1279, 1249, 1229, 1166, 1132, 1098, 1006 cm^{-1} ; ^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ 7.40 (d, $J = 7.6\text{ Hz}$, 2H), 7.27 (t, $J = 7.6\text{ Hz}$, 2H), 7.22 (m, 1H), 6.32 (br, 1H), 4.85 (s, 1H), 4.70 (dd, $J = 9.2, 4.0\text{ Hz}$, 1H), 1.34 (s, 9H), 1.09 (s, 9H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO}-d_6$) δ 170.0, 152.8, 140.9, 128.2, 127.9, 127.1, 80.9, 78.8, 67.2, 58.8, 56.2, 27.7, 25.3, 22.6 ppm; Anal. Calcd for $\text{C}_{18}\text{H}_{27}\text{N}_1\text{O}_6\text{S}_1$: C, 56.08; H, 7.06; N, 3.63. Found: C, 55.71; H, 7.06; N, 3.85; HRMS-ESI calcd for $\text{C}_{18}\text{H}_{27}\text{N}_1\text{Na}_1\text{O}_6\text{S}_1$ ($M + \text{Na}$) $^+$ 408.1457, found 408.1451.

(*S_R*,*3R*,*4S*)-*N*-*tert*-Butanesulfinyl-3-(*tert*-butoxycarbonate)-4-phenyl- β -lactam **10:** White solid, mp 125–127 $^{\circ}\text{C}$; $[\alpha]_D^{25} +56.2^{\circ}$ (c 1.2, CHCl_3); IR (KBr) 2979, 1792, 1745, 1458, 1369, 1278, 1252, 1130, 1101, 1047, 1014 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.33–7.45 (m, 5H), 5.74 (d, $J = 6.0\text{ Hz}$, 1H), 5.36 (d, $J = 6.0\text{ Hz}$, 1H), 1.16 (s, 9H), 1.03 (s, 9H) ppm; ^{13}C NMR (100 MHz, CDCl_3) δ 167.8, 150.6, 133.0, 129.7, 129.1, 128.4, 83.6, 57.7, 57.3, 27.1, 22.3 ppm; Anal. Calcd for $\text{C}_{18}\text{H}_{25}\text{NO}_5\text{S}_1$: C, 58.83; H, 6.86; N, 3.81. Found: C, 58.77; H, 6.94; N, 3.86; HRMS-ESI calcd for $\text{C}_{18}\text{H}_{25}\text{N}_1\text{Na}_1\text{O}_5\text{S}_1$ ($M + \text{K}$) $^+$ 406.1091, found 406.1098.

Acknowledgment. This work was supported by the National Natural Science Foundation of China (No. 20372048 and No. 20572072), Ministry of Education (NCET, RFDP and EYTP), Sichuan Province Government (No. 04ZQ026-011 and 05JY029-025-1), and Sichuan University (2005CF01).

Supporting Information Available: ^1H NMR and ^{13}C NMR spectra of compounds **4**, **7**–**10**, and X-ray crystallographic data for **4c** as a CIF file. This material is available free of charge via the Internet at <http://pubs.acs.org>.

JO052298N