JOC Article

Stereocontrolled Aziridination of Imines via a Sulfonium Ylide Route and a Mechanistic Study

Xiao-Fang Yang, Ming-Jie Zhang, Xue-Long Hou,* and Li-Xin Dai

State Key Laboratory of Organometallic Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences, 354 Fengling Road, Shanghai 200032, China

xlhou@pub.sioc.ac.cn

Received March 20, 2002

The reaction of *N*-diphenylphosphinoyl imines **1** with [3-(trimethylsilyl)allyl]dimethylsulfonium bromide (**5**) in the presence of NaH at room temperature predominantly gave *trans*-vinylaziridines **4**. On the other hand, *cis*-vinylaziridines **4** were the main products when the preformed ylide prepared from the reaction of [3-(trimethylsilyl)allyl]diphenylsulfonium perchlorate (**6**) was reacted with the same imines **1** at low temperature. *trans*-Aziridines were also obtained when imines **1** and sulfinimines **9** were reacted with *N*,*N*-dimethylacetamide-2-dimethylsulfonium bromide (**7**) in the presence of a base, respectively. A mechanistic study showed that the stereochemistry of these reactions was controlled by the reactivity of the imines and ylides. A higher reactivity of imines and ylides favors the formation of *cis*-aziridines, whereas a lower reactivity leads to *trans*-products.

Introduction

Aziridines are versatile building blocks that have many uses in organic synthesis.[1] They are also subunits in some natural products.[2] Thus, the synthesis of aziridines is an active field. Recently, several procedures have been reported regarding the preparation of these useful compounds. Among them, the direct approach to formation of the aziridine ring via a carbene or nitrene route is the most attractive because of its efficiency.[3,4] However, most of these procedures normally give *cis*-aziridines or a mixture of *cis*- and *trans*-aziridines with low stereoselectivity, and only a few give *trans*-aziridines or provide a means to control the stereochemistry of the reaction.[3g,5] Recently, we developed a convenient and facile way to prepare aziridines with various functionalities through the reaction of sulfonium ylides and *N*-tosyl imines.[4] High *cis*-stereoselectivity was achieved with allyl and propargyl *S*-ylides, or when a Lewis acid was used as an activating reagent.[4f−h] Later, we found that when diphenylphosphinoyl imines were used, either *cis*- or *trans*-vinylaziridines were obtained stereoselectively.[6] Further studies showed that *trans*-aziridines could also be obtained by using other weakly activated imines, and the stereoselectivity of the reactions could be controlled by choosing the activating group on the nitrogen atom of the imines, the sulfonium ylides, and the reaction conditions. We report here our detailed investigation of the *trans*- and *cis*-selectivities of aziridination via sulfonium ylide routes and important aspects of the reaction mechanism.

Results and Discussion

Stereocontrolled Aziridination of Sulfonium Ylides with *N*-Diphenylphosphinoyl Imines 1. In our previous study, we found that the reaction of *N*-tosyl imine with *S*-ylide proceeded very rapidly.[4a−d,g,h] Thus, we reasoned that the lower stereoselectivity of the reaction might be related to the higher reactivity of *N*-tosyl imine. To verify this notion, a competition reaction between *N*-tosyl imine **2** and *N*-diphenylphosphinoyl imine **1** with sulfonium salt **5** in the presence of NaH was carried out (eq 1). The reaction gave *N*-tosyl- and *N*-diphenylphosphinoylaziridines in a ratio of 7:1, indicating that *N*-diphenylphosphinoyl imine is less active. Therefore,

(1) (a) Stamm, H. *J. Prakt. Chem.* **1999**, *341*, 319. (b) Osborn, H. M. I.; Sweeney, J. B. *Tetrahedron: Asymmetry* **1997**, *8*, 1693. (c) Li, A. H.; Dai, L. X.; Aggarwal, V. K. *Chem. Rev.* **1997**, *97*, 2341. (d) Tanner, D. *Angew. Chem., Int. Ed. Engl.* **1994**, *33*, 599. (e) Ibuka, T. *Chem. Soc. Rev.* **1998**, *27*, 145.

(2) (a) For reviews, see: Remers, W. A.; Iyengar, B. S. In *Recent Progress in the Chemical Synthesis of Antibiotics*, Lukacs, G.; Ohno, M. Eds.; Springer: Berlin, 1990, p 415. (b) Ziegler, F. E.; Belema, M. *J. Org. Chem.* **1997**, *62*, 1083. (c) Fukuyama, T.; Nakatsubo, F.; Cocuzza, A. J.; Kishi, Y. *Tetrahedron Lett.* **1977**, 295.

(3) (a) Evans, D. A.; Faul, M. M.; Bilodeau, M. T. *J. Am. Chem. Soc.* **1994**, *116*, 2724. (b) Li, Z.; Conser, K. R.; Jacobsen, E. N. *J. Am. Chem. Soc.* **1993**, *115*, 5326. (c) Minakata, S.; Ando, T.; Nishimura, M.; Ryu, I.; Komatsu, M. *Angew. Chem., Int. Ed.* **1998**, *37*, 3392. (d) Muller, P.; Baud, C.; Jacquier, Y. *Tetrahedron* **1996**, *52*, 1543. (e) Nageli, I.; Baud, C.; Bernardinelli, G.; Jacquier, Y.; Moran, M.; Muller, P. *Helv. Chim. Acta* **1997**, *80*, 1087. (f) Knight, J. G.; Muldownery, M. P. *Synlett* **1995**, 949. (g) Mohan, J. M.; Uphade, B. S.; Choudhary, V. R.; Ravindranathan, Y.; Sudalai, A. *Chem. Commun.* **1997**, 1429. (h) Zhu, Z.; Espenson, J. H. *J. Org. Chem.* **1995**, *60*, 7090. (i) Haynes, J. S.; Sams, J. R.; Thompson, R. C. S. *Can. J. Chem.* **1981**, *59*, 669. (j) Zhu, Z.; Espenson, J. H. *J. Am. Chem. Soc.* **1996**, *118*, 9901. (k) Casarrubios, L.; Perez, J. A. *J. Org. Chem.* **1996**, *61*, 8358. (l) Aggarwal, V. K.; Thompson, A.; Jones, R. V. H.; Standen, M. C. H. *J. Org. Chem.* **1996**, *61*, 8368; (m) Aggarwal, V. K. *Synlett* **1998**, 329. (n) Davis, F. A.; Zhou, P.; Reddy, G. V. *J. Org. Chem.* **1994**, *59*, 3243. (o) Cantrill, A. A.; Hall, L. D.; Jarvis, A. N.; Osborn, H. M. L.; Rappy, J.; Sweeney, J. B. *Chem. Commun.* **1996**, 2631. (p) Aggarwal, V. K.; Ferrara, M. *Org. Lett.* **2000**, *2*, 4107. (q) Aggarwal, V. K.; Alonso, E.; Fang, G.; Ferrara, M.; Hynd, G.; Porcelloni, M. *Angew. Chem., Int. Ed.* **2001**, *40*, 1433.

(4) (a) Li, A.-H.; Dai, L.-X.; Hou, X.-L. *Chem. Commun.* **1996**, 491. (b) Li, A.-H.; Dai, L.-X.; Hou, X.-L. *J. Chem. Soc., Perkin Trans. 1* **1996**, 867. (c) Li, A.-H.; Dai, L.-X.; Hou, X.-L.; Chen, M.-B. *J. Org. Chem.* **1996**, *61*, 4641. (d) Li, A.-H.; Dai, L.-X.; Hou, X.-L. *J. Chem. Soc., Perkin Trans. 1* **1996**, 2725. (e) Zhou, Y.-G.; Li, A.-H.; Hou, X.-L.; Dai, L.-X. *Tetrahedron Lett.* **1997**, *38*, 7225. (f) Wang, D. K.; Dai, L. X.; Hou, X. L. *Chem. Commun.* **1997**, 1231. (g) Li. A.-H.; Zhou, Y.-G.; Dai, L.-X.; Hou, X.-L.; Xia, L.-J.; Lin L. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 1317. (h) Li, A.-H.; Zhou, Y.-G.; Dai, L.-X.; Hou, X.-L.; Xia, L.-J.; Tang, M.-H. *J. Org. Chem.* **1998**, *63*, 4338. (j) Hou, X.-L.; Yang, X.-F.; Dai, L.-X.; Chen, X.-F. *Chem. Commun.* **1998**, 747.

(5) (a) Matano, Y.; Yoshimune, M.; Suzuki, H. *J. Org. Chem.* **1995**, *60*, 4663. (b) McLaren, A. B.; Sweeney, J. B. *Org. Lett.* **1999**, *1*, 1339.

(6) Part of this work appeared as a preliminary communication (see ref 4j).

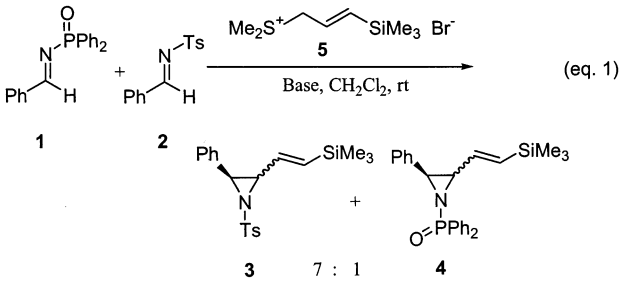
10.1021/jo0257389 CCC: $22.00
Published on Web 10/22/2002

TABLE 1. Stereoselective Preparation of Aziridines 4

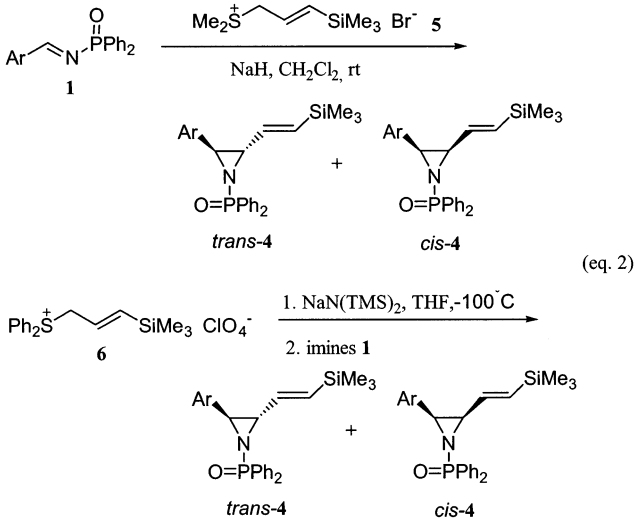
entry	Ar	sulfonium salt	base	yield[a] (%)	*cis*:*trans*[b]
1	Ph	**5**	NaH[c]	92	10:90
2	Ph	**5**	KOH[c]	78	24:76
3	*p*-ClC_6H_4	**5**	NaH[c]	93	12:88
4	*p*-$MeOC_6H_4$	**5**	NaH[c]	95	20:80
5	1-naphthyl	**5**	NaH[c]	86	22:78
6	Ph	**6**	$NaN(TMS)_2$[d]	93	91:9
7	*p*-$MeOC_6H_4$	**6**	$NaN(TMS)_2$[d]	90	99:<1
8	*p*-MeC_6H_4	**6**	$NaN(TMS)_2$[d]	94	99:<1
9	*p*-ClC_6H_4	**6**	$NaN(TMS)_2$[d]	84	85:15
10	*p*-$CF_3C_6H_4$	**6**	$NaN(TMS)_2$[d]	72	85:15
11	Ph	**6**	$NaN(TMS)_2$[e,f]	91	87:13
12	Ph	**6**	$NaN(TMS)_2$[f]	93	85:15

[a] Isolated yield. [b] Determined by 300 MHz ^{1}H NMR spectra. [c] Run at rt. [d] A 1 equiv sample of LiBr was added, and the reaction proceeded at −100 °C. [e] A 1 equiv sample of LiBr was added. [f] Reaction temperature −78 °C.

N-diphenylphosphinoyl imines **1** were tried in the aziridination reaction.



N-Diphenylphosphinoyl imines **1**[7] reacted with [3-(trimethylsilyl)allyl]dimethylsulfonium bromide (**5**) in the presence of a base at room temperature to give *trans*-vinylaziridines **4** predominantly. On the other hand, *cis*-vinylaziridines **4** were the main products when the preformed ylide prepared from [3-(trimethylsilyl)allyl]-diphenylsulfonium perchlorate (**6**) reacted with the same imines **1** at low temperature (eq 2, Table 1).



a. Ar = Ph; **b**. Ar = *p*-ClC_4H_6; **c**. Ar = *p*-$MeOC_6H_4$; **d**. Ar = *p*-MeC_6H_4; **e**. Ar = *p*-$CF_3C_6H_4$; **f**. Ar = 1-naphthyl.

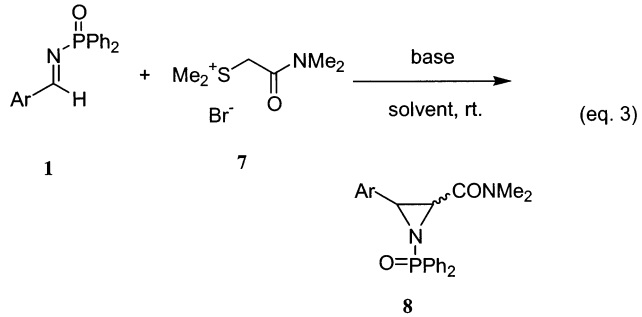
TABLE 2. Reactions of *N*-Diphenylphosphinoyl Imines with Stabilized Sulfonium Ylide[a]

entry	Ar	base	solvent	yield[b] (%)	*trans*:*cis*[c]
1	Ph	KOH	CH_3CN*d*	79	79:21
2	Ph	Cs_2CO_3	CH_3CN*d*	75	80:20
3	Ph	NaH	CH_3CN	98	95:5
4	Ph	NaH	CH_2Cl_2	92	91:9
5[e]	Ph		CH_2Cl_2	82	80:20
6	*p*-MeC_6H_4	NaH	CH_3CN	90	93:7
7	*p*-$MeOC_6H_4$	NaH	CH_3CN	89	89:11
8	*p*-ClC_6H_4	NaH	CH_3CN	98	90:10
9	1-naphthyl	NaH	CH_3CN	98	96:4

[a] All reactions were carried out at rt on a scale of 1 mmol with a ratio of imine to sulfonium salt to base of 1:1.1:1.5 at rt. [b] Isolated yields based on imine. [c] Determined by 300 MHz ^{1}H NMR spectra before purification. [d] The solvent was commercially available and used without further purification. [e] The reaction was carried out with preformed ylide.

Table 1 shows that the *cis*- and *trans*-aziridines were obtained in satisfactory yields. Stereocontrol was realized simply by changing the ligand on the S-atom (i.e., phenyl or methyl) or by changing the reaction conditions. The reactions at room temperature with dimethylsulfonium salt gave *trans*-aziridines **4**, with *trans*:*cis* ratios between 78:22 and 90:10, although *cis*-aziridines were considered to be thermodynamically more stable and were often formed as the main products.[3o,8] In this reaction, the selection of the base is important. High stereoselectivity is obtained when NaH is used (entry 1), while a lower stereoselectivity is obtained if KOH is used (entry 2). NaOH, K_2CO_3, and LiOH gave a selectivity similar to that of KOH. In addition, the stereoselectivity of the reaction in CH_2Cl_2 was better than that in CH_3CN, benzene, or DMF. At low temperature, the reaction of preformed ylide produced from sulfonium salt **6** with imines **1** gave *cis*-aziridines in high stereoselectivity. A lower temperature favored the *cis*-isomer (entry 6 vs entry 12). In some cases, the reaction gave *cis*-products almost exclusively (entries 7, 8, and 10). In contrast to epoxidation and cyclopropanation reactions, the presence of LiBr was not crucial for the stereochemistry of this aziridination reaction (entries 12 and 13).[9]

These results suggest that *trans*-selectivity can be realized if we decrease the reactivity of the imines. To show whether *trans*-products can be favored by decreasing the reactivities of the sulfonium ylides and the imines, the aziridination of diphenylphosphinoyl imines **1** with stabilized sulfonium salt **7** was further investigated (eq 3), and the results are summarized in Table 2.



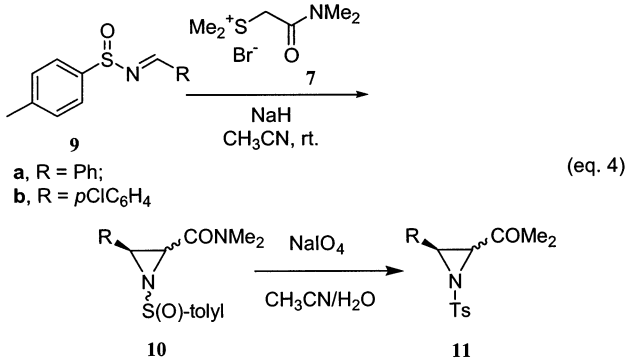
We initially carried out this aziridination of diphenylphosphinoyl imine **1a** with sulfonium salt **7** in CH_3-

(7) (a) Krzyzanowska, B.; Stec, W. J. *Synthesis* **1978**, 521. (b) Krzyzanowska, B.; Stec, W. J. *Synthesis* **1982**, 270. (c) Zweierzak, A.; Napieraj, A. *Tetrahedron* **1996**, *52*, 8789.

(8) Ibuka, T.; Mimura, N.; Ohno, H.; Nakai, K.; Akaji, M.; Habashita, H.; Tamamura, H.; Miwa, Y.; Taga, T.; Fuji, N.; Yamamoto, Y. *J. Org. Chem.* **1997**, *62*, **2982**.

CN using KOH as the base. The reaction proceeded smoothly and generated the expected product **8a** with a *trans*:*cis* ratio of 79:21 (entry 1, Table 2). This result was slightly better than that in the reaction of *N*-tosyl imines with sulfonium salt **7**.[4e] To increase the *trans*:*cis* selectivity, the effects of the solvent and base on this reaction were investigated. We found that acetonitrile and dichloromethane were suitable for this reaction, and acetonitrile gave the best results (entry 3, Table 2). Among various bases, NaH gave the highest yield and stereoselectivity (entry 3 vs entries 1 and 2, Table 2). When KOH or Cs_2CO_3 was used as the base, small amounts of diphenylphosphoramide and aldehyde were detected, which may be produced from hydrolysis of the imine. The yield and stereoselectivity decreased if preformed ylide was used (entry 5, Table 2). The aziridination of various diphenylphosphinoyl imines was further investigated. The reaction was usually complete within 1 h in almost quantitative yields with a high *trans*:*cis* ratio. This result is in contrast to the Darzens reaction, which gave similar aziridinyl carboxylic acid derivatives in high *cis*-stereoselectivity.[3n,o] Interestingly, the reaction of imines **1** with sulfonium salt derived from methyl 2-bromoacetate did not give the corresponding aziridines.[4e]

Aziridination of Sulfonium Ylides with Sulfinimine 9.[10] The reaction of sulfinimines **9** with sulfonium salt **7** was also carried out to further examine the relationship between *trans*-selectivity and the reactivity of the imine. The reaction of sulfinimine **9a**[10a] with sulfonium salt **7** proceeded in CH_3CN with NaH as the base (eq 4). After workup, a mixture of two isomers was

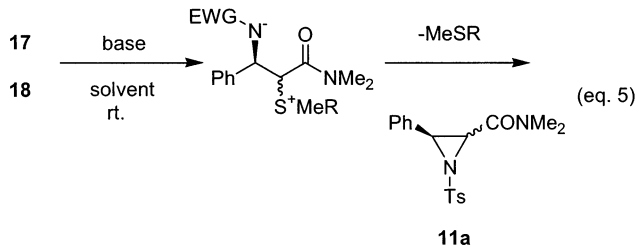


obtained in a ratio of ca. 2:1 by 300 MHz ^{1}H NMR. The coupling constants of the two hydrogens on the rings of the two isomers were 3.8 and 4.3 Hz, respectively, while those of the *trans*- and *cis*-isomers were ca. 4 and 7 Hz, respectively.[3n,11] On the basis of a comparison with known compounds, we thought that the coupling constants of 3.8 and 4.3 Hz might be caused by the hydrogens on the rings of isomers in which the stereochemistry regarding the group on the nitrogen is other than in the *trans*- and *cis*-isomers. When **10** was oxidized to the corresponding *N*-tosylaziridine by $NaIO_4$, ^{1}H NMR showed that the *trans*:*cis* ratio was 97:3. Imines **9b** also reacted smoothly with sulfur ylide derived from **7**. Good yields were achieved, and the *trans*:*cis* ratio was 92:8. However, perhaps due to low reactivity, some sulfinimines such as *tert*-butanesulfinyl imines[10b,c] and *N*-(*p*-methoxybenzylidene)-*p*-toluenesulfinamide did not react with this sulfur ylide.

Mechanism of Aziridination via a Sulfonium Ylide Route. Johnson studied the mechanism of nucleophilic alkylidene transfer by sulfonium and oxosulfonium ylides and proposed a two-step process for epoxidation via sulfonium and oxosulfonium ylides, where the first step, the initial attack of carbonyl groups by an oxosulfonium ylide, was "reversible", and the attack by a simple sulfonium ylide was "irreversible".[12] We conjectured that the initial attack of a C═N bond by sulfonium ylide was also reversible.

To verify this assumption, analogues of the proposed intermediates of the reaction of imines **1** and *N*-tosyl imines with sulfonium salt **7**, i.e., sulfonium salts **17** and **18**, were synthesized. Reactions of imines with 2-thioacetamide **14** under basic conditions provided compounds **15** and **16**. Treatment of compounds **15** and **16** with MeI in the presence of silver perchlorate afforded sulfonium salts **17** and **18** (Scheme 1). Under basic conditions, **17** and **18** were converted to aziridines **11** through an anion intermediate. If the initial attack is irreversible (path a), **17** and **18** will give only *cis*- and *trans*-aziridines, respectively. On the other hand, if the initial attack is reversible (path b), a mixture of *cis*- and *trans*-aziridines will be obtained regardless of whether **17** or **18** is the starting material (Scheme 2).

The reaction of sulfonium salt **17** or **18** with base was carried out (eq 5), and the results are shown in Table 3.



As shown in Table 3, the ratio of *trans*- and *cis*-products strongly depends on the groups on the nitrogen and the sulfur atoms. When EWG is a strong electron-withdrawing group, such as a tolylsulfonyl group, a lower ratio of *trans*- and *cis*-aziridines is obtained (entries 1 and 2, Table 3). When EWG is a weak electron-withdrawing group, such as a tolylsulfinyl group, a *trans*-sulfonium salt gives a *trans*-product (entries 5 and 6, Table 3), even though a different base is used. On the other hand, the group on the sulfur atom also influenced the results. When the R group was Ph, *cis*- and *trans*-aziridines were obtained with **17** and **18**, respectively (entries 3 and 4 vs entries 1 and 2, Table 3).

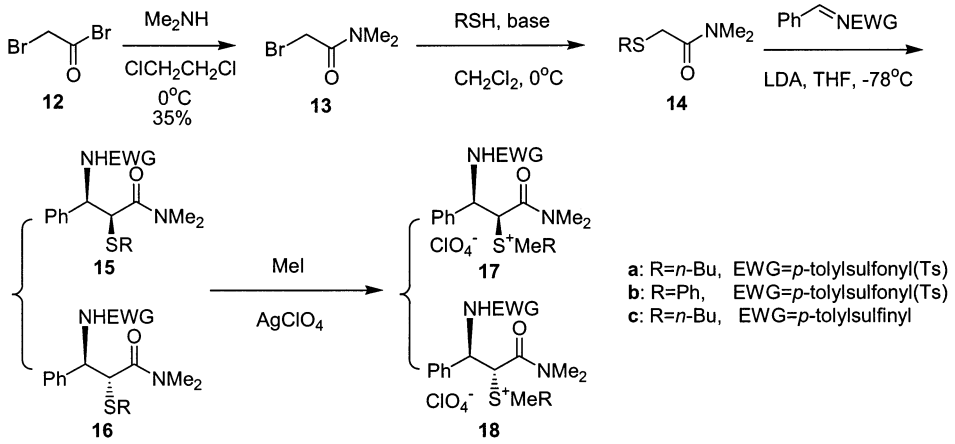
(9) (a) Tang, Y.; Huang, Y.-Z.; Dai, L.-X.; Chi, Z.-F.; Shi, L.-P. *J. Org. Chem.* **1996**, *61*, 5762. (b) Tang, Y.; Huang, Y.-Z.; Dai, L.-X.; Sun, J.; Xia, W. *J. Org. Chem.* **1997**, *62*, 954. (c) Huang, Z. Z.; Ye, S.; Xia, W.; Tang, Y. *Chem. Commun.* **2001**, 1384. (d) Zhou, Y. G.; Li, A. H.; Hou, X. L.; Dai, L. X. *Chem. Commun.* **1996**, 1353. (e) Zhou, Y. G.; Li, A. H.; Dai, L. X.; Hou, X. L. *Huaxue Xuebao* **2000**, *58*, 473.

(10) (a) Davis, F. A.; Zhang, Y.; Andemichael, Y.; Fang, T.; Fanelli, D. L. and Zhang, H., *J. Org. Chem.* **1999**, *64*, 1403. (b) Cogan, D. A.; Liu, G.; Kim, K.; Backes, B. J.; Ellman, J. A. *J. Am. Chem. Soc.* **1998**, *120*, 8011. (c) Liu, G.; Cogan, D. A.; Owens, T. D.; Tang, T. P.; Ellman, J. A. *J. Org. Chem.* **1999**, *64*, 1278.

(11) Davis, F. A.; Zhou, P. *Tetrahedron Lett.* **1994**, *35*, 7525.

(12) (a) Johnson, C. R.; Schroeck, C. W. *J. Am. Chem. Soc.* **1971**, *93*, 5303. (b) Johnson, C. R.; Schroeck, C. W.; Shanklin, J. R. *J. Am. Chem. Soc.* **1973**, *95*, 7424.

SCHEME 1. Synthesis of Sulfonium Salts 17 and 18



SCHEME 2. Aziridination of 17 and 18

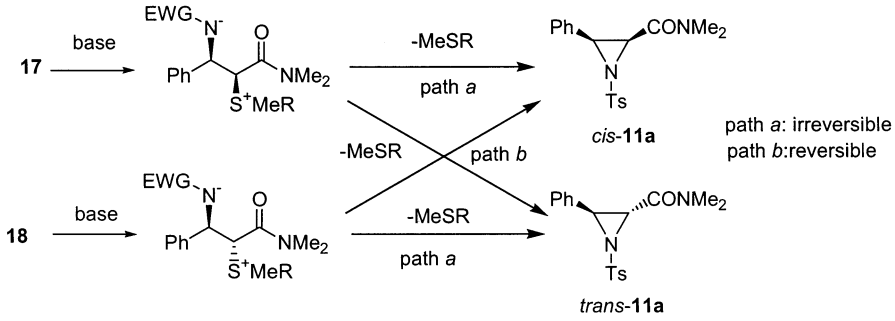


TABLE 3. Aziridination of 17 and 18[a,b]

entry	substrate	base	reaction time (min)	yield (%)	*trans*:*cis*[c]
1	**17a**	KOH	30	94	56:44
2	**18a**	KOH	30	92	69:31
3	**17b**	KOH	30	95	5:95
4	**18b**	KOH	20	95	94:6
5	**18c**	KOH	20	81	97:3
6	**18c**	NaH	15	82	97:3

[a] All reactions were carried out on a scale of 0.5 mmol at a molar ratio of substrate to base of 1:1. [b] The products were oxidized to **11a** with $NaIO_4$ when substrate **18c** was used. [c] Determined by 300 MHz ^{1}H NMR before purification.

On the basis of these results, the following mechanism can be proposed for the reaction of imines with sulfonium (Scheme 3). The reaction proceeds in two steps. First, the sulfonium ylide attacks the imine to form intermediates **A** and **C**, which rotate to their conformers, intermediates **B** and **D**, leading to the products through *anti*-elimination. In this mechanism, the first step, the initial attack of the C=N bond by sulfonium ylide, is reversible. Two intermediates, **A** and **B** or **C** and **D**, are involved, where **B** and **C** are favorable and **A** and **D** are unfavorable because of steric repulsion. The formation of intermediate **A** or **C** is driven by electrostatic attraction.[13] Imines with a high reactivity will benefit the first step (relatively large k_1), while a better "leaving group" will increase the rate of elimination.

Conclusions

Stereoselective syntheses of *cis*- and *trans*-aziridines via an *S*-ylide route were realized. Mechanistic studies showed that the stereochemistry of the reactions could be controlled by the reactivities of the imines and ylides. Imines and ylides with a higher reactivity favor the formation of *cis*-aziridines, whereas those with a lower reactivity prefer *trans*-products. This study provides one of the simplest direct routes to aziridines with different substituents in high stereoselectivity.

Experimental Section

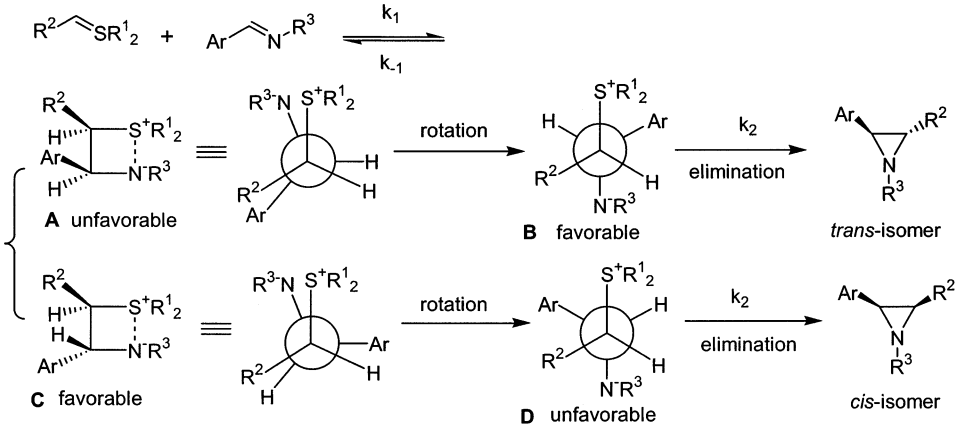
Materials and General Procedures. All reagents and solvents, unless otherwise specified, were treated according to standard methods. *N*-Diphenylphosphinoyl imines 1,[7] *N*-sulfonyl imine **2**[14] and *N*-sulfinyl imines **9**[10] were prepared according to literature methods. ^{1}H NMR spectra were recorded in $CDCl_3$ at rt. Chemical shifts are given in parts per million relative to that of TMS as an internal standard. IR spectra were recorded neat and are measured in inverse centimeters.

General Procedure for the Room-Temperature Reaction of Imine 1 with Sulfonium 5. To a solution of sulfonium salt **5** (0.44 mmol) and diphenylphosphinoyl imine **1** (0.4 mmol) in CH_2Cl_2 (4 mL) was added NaH (15 mg, 0.6 mmol) at rt. The resulting mixture was stirred at rt until the starting material **1** disappeared (monitored by TLC). Water (10 mL) was added, and the mixture was extracted by CH_2Cl_2 (15 mL × 3). The organic solution was combined and dried by $MgSO_4$. Removal of solvent under reduced pressure and flash chromatography (silicon gel, eluted by petroleum ether/acetate, 5:1) afforded pure *trans*-aziridine **4** and *cis*-aziridine **4**.

(13) Fernández, M. V.; Durante-Lanes, P. and López-Herrera, F. J. *Tetrahedron* **1990**, *46*, 7911.

(14) Love, B. E.; Raje, P. S.; Williams, T. C., II. *Synlett* **1994**, 493.

SCHEME 3. Mechanism of Aziridination via an Ylide Route



General Procedure for Low-Temperature Reaction. To a solution of sulfonium salt **6** (0.48 mmol) in THF (6 mL) under argon at −100 °C was added $NaN(SiMe_3)_2$ (2 M in THF, 0.24 mL, 0.48 mmol). The resulting mixture was stirred for 10 min. The solution of imine **1** (0.4 mmol) in THF (2 mL) was added and the stirring continued for another 1 h. Then the reaction temperature was allowed to rise to rt. Workup as above and flash chromatography provided pure *trans*-aziridine **4** and *cis*-aziridine **4.**

***N*-Diphenylphosphinoyl-2-(*β*-trimethylsilyl)vinyl-3-phenylaziridine (4a).** Data for *trans*-**4a.** White solid. Mp: 146−147 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.94−7.88 (m, 4H), 7.46−7.23 (m, 11H), 6.39 (dd, $J_1 = 9.2$ Hz, $J_2 = 18.5$ Hz, 1H), 5.87 (d, $J = 18.5$ Hz, 1H), 3.98 (dd, $J_1 = 2.8$ Hz, $J_2 = 13$ Hz, 1H), 3.13 (ddd, $J_1 = 2.8$ Hz, $J_2 = 9.2$ Hz, $J_3 = 12.2$ Hz, 1H), −0.03 (s, 9H). ^{31}P NMR: 30.2 ppm. EIMS (*m*/*z*, relative intensity): 417 (8, M^+), 201 (100). Anal. Calcd for $C_{25}H_{28}NOPSi$: C, 71.91; H, 6.76; N, 3.36; P, 7.42. Found: C, 71.89; H, 6.82; N, 3.56; P, 7.31. Data for *cis*-**4a.** Colorless thick oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98−7.92 (m, 4H), 7.47−7.24 (m, 11H), 6.02 (d, $J = 18.7$ Hz, 1H), 5.59 (dd, $J_1 = 7.6$ Hz, $J_2 = 18.7$ Hz, 1H), 4.10 (dd, $J_1 = 6.1$ Hz, $J_2 = 16.4$ Hz, 1H), 3.53 (m, 1H), −0.08 (s, 9H). ^{31}P NMR: 33.3 ppm. EIMS (*m*/*z*, relative intensity): 417 (27, M^+), 216 (100), 201 (79). Anal. Calcd for $C_{25}H_{28}NOPSi$: C, 71.91; H, 6.76; N, 3.36. Found: C, 72.05; H, 7.06; N, 3.23.

***N*-Diphenylphosphinoyl-2-(*β*-trimethylsilyl)vinyl-3-(*p*-chloro)phenylaziridine(4b).** Data for *trans*-**4b.** White solid. Mp: 172−174 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.92−7.84 (m, 4H), 7.50−7.26 (m, 10H), 6.35 (dd, $J_1 = 9.1$ Hz, $J_2 = 18.5$ Hz, 1H), 5.87 (d, $J = 18.5$ Hz, 1H), 3.93 (dd, $J_1 = 2.8$ Hz, $J_2 = 13$ Hz, 1H), 3.08 (ddd, $J_1 = 2.8$ Hz, $J_2 = 9.2$ Hz, $J_3 = 12.3$ Hz, 1H), −0.04 (s, 9H). ^{31}P NMR: 30.3 ppm. EIMS (*m*/*z*, relative intensity): 452 (40, M^+), 250 (100). Anal. Calcd for $C_{25}H_{27}ClNOPSi$: C, 66.50; H, 6.03; N, 3.10; P, 6.87. Found: C, 66.71; H, 6.15; N, 3.22; P, 6.77. Data for *cis*-**4b.** Colorless thick oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.96−7.56 (m, 4H), 7.51−7.25 (m, 10H), 6.03 (d, $J = 18.7$ Hz, 1H), 5.57 (dd, $J_1 = 7.3$ Hz, $J_2 = 18.7$ Hz, 1H), 4.05 (dd, $J_1 = 6.2$ Hz, $J_2 = 16.2$ Hz, 1H), 3.54 (m, 1H), −0.05 (s, 9H). ^{31}P NMR: 33.4 ppm. EIMS (*m*/*z*, relative intensity): 452 (63, M^+), 250 (100). Anal. Calcd for $C_{25}H_{27}ClNOPSi$: C, 66.50; H, 6.03; N, 3.10. Found: C, 66.62; H, 6.15; N, 3.10.

***N*-Diphenylphosphinoyl-2-(*β*-trimethylsilyl)vinyl-3-(*p*-methoxy)phenylaziridine (4c).** Data for *trans*-**4c.** White solid. Mp: 146−147 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.92−7.85 (m, 4H), 7.45−7.34 (m, 6H), 7.25 (dd, $J_1 = 1.6$ Hz, $J_2 = 8.6$ Hz, 2H), 6.85 (dd, $J_1 = 1.8$ Hz, $J_2 = 6.9$ Hz, 2H), 6.36 (dd, $J_1 = 9.1$ Hz, $J_2 = 18.4$ Hz, 1H), 5.86 (d, $J = 18.4$ Hz, 1H), 3.92 (dd, $J_1 = 2.9$ Hz, $J_2 = 16.0$ Hz, 1H), 3.10 (ddd, $J_1 = 2.9$ Hz, $J_2 = 9.2$ Hz, $J_3 = 12.2$ Hz, 1H), −0.04 (s, 9H). ^{31}P NMR: 30.2 ppm. EIMS (*m*/*z*, relative intensity): 447 (29, M^+), 246 (100). Anal. Calcd for $C_{26}H_{30}NO_2PSi$: C, 69.77; H, 6.76; N, 3.13; P, 6.93. Found: C, 69.68; H, 6.82; N, 3.32; P, 6.96. Data for *cis*-**4c.** Colorless thick oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.93 (m, 4H), 7.45 (m, 6H), 7.22 (d, $J = 8.7$ Hz, 2H), 6.82 (d, $J = 8.7$ Hz, 2H), 6.01 (d, $J = 18.7$ Hz, 1H), 5.61 (dd, $J_1 = 7.4$ Hz, $J_2 = 18.7$ Hz, 1H), 4.04 (dd, $J_1 = 6.1$ Hz, $J_2 = 16.5$ Hz, 1H), 3.78 (s, 3H), 3.48 (m, 1H), −0.07 (s, 9H). ^{31}P NMR: 33.4 ppm. EIMS (*m*/*z*, relative intensity): 452 (63, M^+), 250 (100). Anal. Calcd for $C_{26}H_{30}NO_2PSi$: C, 69.77; H, 6.76; N, 3.13. Found: C, 70.01; H, 6.87; N, 3.17.

***N*-Diphenylphosphinoyl-2-(*β*-trimethylsilyl)vinyl-3-(*p*-methyl)phenylaziridine (4d).** Data for *trans*-**4d.** White solid. Mp: 145−147 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.93−7.86 (m, 4H), 7.45−7.33 (m, 6H), 7.22 (d, $J = 8.1$ Hz, 2H), 6.95 (d, $J = 8.1$ Hz, 2H), 6.37 (dd, $J_1 = 9.2$ Hz, $J_2 = 18.6$ Hz, 1H), 5.85 (d, $J = 18.5$ Hz, 1H), 3.94 (dd, $J_1 = 2.9$ Hz, $J_2 = 16.0$ Hz, 1H), 3.09 (ddd, $J_1 = 2.9$ Hz, $J_2 = 9.2$ Hz, $J_3 = 12.4$ Hz, 1H), 2.33 (s, 3H), −0.04 (s, 9H). ^{31}P NMR: 30.2 ppm. EIMS (*m*/*z*, relative intensity): 432 (81, M^+), 431 (100). Anal. Calcd for $C_{26}H_{30}NOPSi$: C, 72.36; H, 7.01; N, 3.25; P, 7.18. Found: C, 72.33; H, 6.97; N, 2.82; P, 7.20. Data for *cis*-**4d**. Colorless thick oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98−7.90 (m, 4H), 7.51−7.38 (m, 6H), 7.20 (d, $J = 8.0$ Hz, 2H), 7.09 (d, $J = 8.0$ Hz, 2H), 6.01 (d, $J = 18.7$ Hz, 1H), 5.62 (dd, $J_1 = 7.5$ Hz, $J_2 = 18.7$ Hz, 1H), 4.06 (dd, $J_1 = 6.1$ Hz, $J_2 = 16.5$ Hz, 1H), 3.51 (m, 1H), 2.31 (s, 3H), −0.06 (s, 9H). ^{31}P NMR: 33.4 ppm. EIMS (*m*/*z*, relative intensity): 431 (27, M^+), 230 (100). Anal. Calcd for $C_{26}H_{30}NOPSi$: C, 72.36; H, 7.01; N, 3.25; P, 7.18. Found: C, 72.29; H, 6.90; N, 2.78; P, 7.07.

***N*-Diphenylphosphinoyl-2-(*β*-trimethylsilyl)vinyl-3-(*p*-trifluoromethyl)phenylaziridine (4e).** Data for *trans*-**4e.** White solid. Mp: 169−170 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.79−7.71 (m, 4H), 7.46−7.22 (m, 10H), 6.37 (dd, $J_1 = 9.1$ Hz, $J_2 = 18.5$ Hz, 1H), 5.90 (d, $J = 18.5$ Hz, 1H), 4.02 (dd, $J_1 = 2.4$ Hz, $J_2 = 15.6$ Hz, 1H), 2.96 (m, 1H), −0.2 (s, 9H). ^{31}P NMR: 30.3 ppm. EIMS (*m*/*z*, relative intensity): 486 (100, M + 1), 485 (74, M^+). Anal. Calcd for $C_{26}H_{27}F_3NOPSi$: C, 64.31; H, 5.61; N, 2.89; P, 6.38. Found: C, 64.20; H, 5.75; N, 2.64; P, 6.18. Data for *cis*-**4e.** ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98−7.90 (m, 4H), 7.55−7.39 (m, 10H), 6.04 (d, $J = 18.5$ Hz, 1H), 5.52 (dd, $J_1 = 6.9$ Hz, $J_2 = 18.5$ Hz, 1H), 4.12 (dd, $J_1 = 5.5$ Hz, $J_2 = 15.9$ Hz, 1H), 3.58 (m, 1H), −0.09 (s, 9H). ^{31}P NMR: 33.4 ppm. EIMS (*m*/*z*, relative intensity): 485 (42, M^+), 284 (100). Anal. Calcd for $C_{26}H_{27}F_3NOPSi$: C, 64.31; H, 5.61; N, 2.89; P, 6.38. Found: C, 64.29; H, 5.70; N, 2.64; P, 6.11.

***N*-Diphenylphosphinoyl-2-(*β*-trimethylsilyl)vinyl-3-(1-naphthyl)aziridine (4f).** Data for *trans*-**4f.** White solid. Mp: 134−136 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.06−8.00 (m, 5H), 7.84 (m, 1H), 7.74 (m, 1H), 7.50−7.39 (m, 10H), 6.53 (dd, $J_1 = 9.2$ Hz, $J_2 = 18.5$ Hz, 1H), 5.91 (d, $J = 18.5$ Hz, 1H), 4.63 (dd, $J_1 = 3.00$ Hz, $J_2 = 15.7$ Hz, 1H), 3.17 (m, 1H), −0.03 (s, 9H). ^{31}P NMR: 30.3 ppm. EIMS (*m*/*z*, relative intensity): 266 (100), 467 (29, M^+). Anal. Calcd for $C_{29}H_{30}NOPSi$: C, 74.49; H, 6.47; N, 3.00; P, 6.63. Found: C, 74.53; H, 6.55; N, 2.62; P, 6.28.

Data for *cis*-**4f.** ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.06−8.00 (m, 5H), 7.91−7.57 (m, 2H), 7.38−7.20 (m, 10H), 5.85 (d, J = 18.7 Hz, 1H), 5.25 (dd, J_1 = 7.5 Hz, J_2 = 18.7 Hz, 1H), 4.44 (dd, J_1 = 6.2 Hz, J_2 = 16.0 Hz, 1H), 3.64 (m, 1H), −0.02 (s, 9H). ^{31}P NMR: 33.9 ppm. EIMS (*m*/*z*, relative intensity): 201 (100), 467 (39, M^+). Anal. Calcd for $C_{29}H_{30}NOPSi$: C, 74.49; H, 6.47; N, 3.00; P, 6.63. Found: C, 74.19; H, 6.87; N, 3.10; P, 6.33.

General Procedure for the Reaction of Imines 1 with Sulfonium Salt 7. To a solution of imine **1** (1 mmol) and sulfonium salt **7** (251 mg, 1.1 mmol) in acetonitrile (10 mL) was added NaH (1.1 mmol). The mixture was allowed to stir at rt till the disappearance of imine from TLC. The mixture was then diluted with 20 mL of methylene chloride and washed with 10 mL of water and 20 mL of brine successively. After the solution was dried over magnesium sulfate, the solvent was evaporated to give a solid. This solid was determined by 300 MHz ^{1}H NMR for its ratio of *trans* to *cis* and purified by chromatography on a short column of silica gel with 1:1 ethyl acetate/petroleum ether to provide aziridine **8**.

Procedure for the Reaction of Imines 1 with Preformed Ylide Derived from Sulfonium Salt 7. To a solution of sulfonium salt **7** (250 mg, 1.1 mmol) in acetonitrile (7 mL) was added NaH (27 mg, 1.1 mmol). The resulting mixture was allowed to stir for 2 h at rt. The mixture was then diluted with 20 mL of methylene chloride and quickly washed with 10 mL of water and 20 mL of brine successively to provide the expected ylide, which was used without further purification.

To a solution of imine **1** (1 mmol) in acetonitrile (7 mL) was added preformed ylide obtained in the above procedure. The mixture was allowed to stir at rt till the disappearance of imine from TLC. Workup as above provided aziridine **8**.

***N*-Diphenylphosphinoyl-2-(*N*,*N*-dimethylaminocarbonyl)-3-phenylaziridine (8a).** White solid. Mp: 157−158 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.97−7.91 (m, 2H), 7.80−7.74 (m, 2H), 7.42−7.23 (m, 11H), 4.10 (dd, J_1 = 3.1 Hz, J_2 = 14.2 Hz, 1H), 3.80 (dd, J_1 = 3.1 Hz, J_2 = 13.7 Hz, 1H), 2.92 (s, 3H), 2.86 (s, 3H). MS (*m*/*z*, relative intensity): 390 (47, M^+), 201 (100). Anal. Calcd for $C_{23}H_{23}N_2O_2P$: C, 70.74; H, 5.94; N, 7.18; P, 7.94. Found: C, 70.74; H, 5.92; N, 7.07; P, 7.69.

***N*-Diphenylphosphinoyl-2-(*N*,*N*-dimethylaminocarbonyl)-3-(*p*-methylphenyl)aziridine (8b).** White solid. Mp: 183−184 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98−7.91 (m, 2H), 7.80−7.74 (m, 2H), 7.42−7.33 (m, 6H), 7.18 (d, J = 8.1 Hz, 2H), 7.05 (d, J = 8.0 Hz, 2H), 4.06 (dd, J_1 = 3.1 Hz, J_2 = 14.2 Hz, 1H), 3.79 (dd, J_1 = 3.1 Hz, J_2 = 13.8 Hz, 1H), 2.86 (s, 3H), 2.30 (s, 3H). MS (*m*/*z*, relative intensity): 404 (49, M^+), 201 (100). Anal. Calcd for $C_{24}H_{25}N_2O_2P$: C, 71.26; H, 6.23; N, 6.93; P, 7.66. Found: C, 71.25; H, 6.23; N, 6.99; P, 7.74.

***N*-Diphenylphosphinoyl-2-(*N*,*N*-dimethylaminocarbonyl)-3-(*p*-methoxyphenyl)aziridine (8c).** White solid. IR (KBr): 3054, 1655, 1410, 1140, 1074, 823, 750 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.82−7.77 (m, 2H), 7.61−7.55 (m, 2H), 7.22−7.14 (m, 6H), 7.06 (d, 2H), 6.61 (d, 2H), 3.87 (dd, J_1 = 3.2 Hz, J_2 = 14.1 Hz, 1H), 3.71 (dd, J_1 = 3.2 Hz, J_2 = 14.0 Hz, 1H), 3.63 (s, 3H), 2.78 (s, 3H), 2.74 (s, 3H). MS (*m*/*z*, relative intensity): 420 (18, M^+), 201 (100). Anal. Calcd for $C_{24}H_{25}N_2O_3P$: C, 68.55; H, 6.00; N, 6.67; P, 7.37. Found: C, 68.53; H, 6.02; N, 6.54; P, 7.15.

***N*-Diphenylphosphinoyl-2-(*N*,*N*-dimethylaminocarbonyl)-3-(*p*-chlorophenyl)aziridine (8d).** White solid. IR (KBr): 3050, 1660, 1500, 1450, 1380, 1140, 980, 740 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.96−7.90 (m, 2H), 7.81−7.75 (m, 2H), 7.47−7.19 (m, 10H), 4.08 (dd, J_1 = 3.0 Hz, J_2 = 14.1 Hz, 1H), 3.78 (dd, J_1 = 3.0 Hz, J_2 = 13.7 Hz, 1H), 2.93 (s, 3H), 2.84 (s, 3H). MS (*m*/*z*, relative intensity): 424 (19, M^+), 201 (100). Anal. Calcd for $C_{23}H_{23}N_2O_2P$: C, 65.08; H, 5.23; N, 6.60; P, 7.30. Found: C, 64.89; H, 5.24; N, 6.42; P, 7.23.

***N*-Diphenylphosphinoyl-2-(*N*,*N*-dimethylaminocarbonyl)-3-(1-naphthyl)aziridine (8e).** White solid. Mp: 168−170 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.04−7.98 (m, 2H), 7.81−7.74 (m, 2H), 7.50−7.26 (m, 13H), 4.82 (dd, J_1 = 3.2 Hz, J_2 = 14.9 Hz, 1H), 3.78 (dd, J_1 = 3.2 Hz, J_2 = 13.6 Hz, 1H), 2.96 (s, 3H), 2.78 (s, 3H). MS (*m*/*z*, relative intensity): 440 (40, M^+), 201 (100). Anal. Calcd for $C_{27}H_{25}N_2O_2P$: C, 73.61; H, 5.72; N, 6.36; P, 7.04. Found: C, 73.52; H, 5.81; N, 6.53; P, 6.95.

***N*-(*p*-Bromobenzylidene)-*p*-toluenesulfinamide (9b).** To a solution of *p*-toluenesulfinamide (1 g, 6.45 mmol) and *p*-bromobenzaldehyde (1.193 g, 6.45 mmol) in methylene chloride (60 mL) was added titanium(IV) ethoxide (6.8 mL, 32.3 mmol). After being refluxed for 5 h and monitored by TLC, the reaction mixture was quenched at 0 °C by addition of H_2O (10 mL). The turbid solution was filtered through Celite, and the filter cake was washed with CH_2Cl_2 (2 × 50 mL). The phases were separated, the aqueous phase was washed with 10 mL of CH_2Cl_2, and the combined organic portions were dried ($MgSO_4$) and concentrated. Chromatography of the residue on a short column of silica gel gave 1.974 g (95%) of **9b** as a white solid. Mp: 96−98 °C. IR (KBr): 3050, 1914, 1606, 1587, 1561, 1484, 1398, 1107, 1068 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.36 (s, 1H), 7.70 (d, J = 8.6 Hz, 2H), 7.64−7.57 (m, 4H), 7.32 (d, J = 8.3 Hz, 2H), 2.40 (s, 3H). EIMS (*m*/*z*, relative intensity): 323 (2, M + 1), 139 (100), 102 (24), 183 (23), 181 (22), 91 (20), 140 (20), 75 (9). Anal. Calcd for $C_{14}H_{12}BrNOS$: C, 52.18; H, 3.75; N, 4.35. Found: C, 52.19; H, 3.83; N, 4.21.

General Procedure for the Reaction of Imines 9 with Sulfonium Ylide 7. To a solution of 1 mmol of imine **9** and 251 mg (1.1 mmol) of sulfonium salt **7** in 10 mL of acetonitrile was added 27 mg (1.1 mmol) of NaH. This mixture was allowed to stir at rt till the disappearance of imine from TLC. The mixture was then diluted with 20 mL of methylene chloride and washed with 10 mL of water and 20 mL of brine successively. After the solution was dried over magnesium sulfate, the solvent was evaporated. The residue was solved with 10 mL of acetonitrile, and then to the solution were added 10 mL of water, 321 mg (1.5 mmol) of sodium periodate, and a catalytic amount of ruthenium(III) chloride hydrate. The mixture was stirred for about 30 min. After normal workup a solid was obtained. This solid was determined by 300 MHz ^{1}H NMR for its ratio of *trans* to *cis* and purified by chromatography on a short column of silica gel with 1:1 ethyl acetate/petroleum ether.

***N*-(*p*-Toluenesulfonyl)-2-(*N*,*N*-dimethylaminocarbonyl)-3-phenylaziridine (11a).** ^{1}H NMR (300 MHz, $CDCl_3$): (*trans*) δ 7.76 (d, J = 8.3 Hz, 2H), 7.27−7.18 (m, 7H), 4.45 (d, J = 4.2 Hz, 1H), 3.55 (d, J = 4.2 Hz, 1H), 3.24 (s, 3H), 3.04 (s, 3H), 2.39 (s, 3H).

***N*-(*p*-Toluenesulfonyl)-2-(*N*,*N*-dimethylaminocarbonyl)-3-(*p*-chlorophenyl)aziridine (11b).** ^{1}H NMR (300 MHz, $CDCl_3$): (*trans*) δ 7.78 (dd, J_1 = 6.8 Hz, J_2 = 1.5 Hz, 2H), 7.30−7.13 (m, 6H), 4.42 (d, J = 4.1 Hz, 1H), 3.53 (d, J = 4.1 Hz, 1H), 3.25 (s, 3H), 3.05 (s, 3H), 2.42 (s, 3H).

Competition Reaction of *N*-Diphenylphosphinoyl Imine 1a and *N*-Tosyl Imine 2 with Sulfonium Salt 5. To a solution of diphenylphosphinoyl imine **1a** (153 mg, 0.5 mmol), *N*-tosyl imine **2** (130 mg, 0.5 mmol), and sulfonium salt **5** (128 mg, 0.5 mmol) in CH_2Cl_2 (10 mL) was added NaH (18 mg, 0.75 mmol) in one portion at rt. The mixture was stirred and monitored by TLC. After the disappearance of sulfonium, water (10 mL) was added. The organic layer was separated, and the aqueous layer was washed with CH_2Cl_2 (10 mL × 3). The organic layer was combined and dried with anhydrous $MgSO_4$. The solvent was evaporated. The crude mixture showed the ratio of *N*-tosylaziridine **3** and *N*-diphenylphosphinoylaziridine **4a** was 7:1. Flash chromatography provided 146 mg (78%) of *N*-tosylaziridine **3** and 20 mg (10%) of *N*-diphenylphosphinoylaziridine **4a**.

***N*-Tosyl-2-phenyl-3-(β-trimethylsilyl)vinylaziridine (3).**[4c] ^{1}H NMR (300 MHz, $CDCl_3$): (*cis*-**3**) δ 7.89 (d, J = 8.3 Hz, 2 H), 7.15−7.34 (m, 7 H), 6.12 (d, J = 18.5 Hz, 1 H), 5.41(dd, J = 7.3, 18.71 Hz, 1 H), 4.01 (d, J = 7.3 Hz, 1 H), 3.63 (dd, J = 7.6, 7.0 Hz, 1 H), 2.43 (s, 3 H), −0.04 (s, 9 H); (*trans*-**3**) δ 7.82 (d, J = 8.3 Hz, 2 H), 7.15−7.34 (m, 7 H), 6.42 (dd, J = 8.9,

18.3 Hz, 1 H), 6.21 (d, J = 18.4 Hz, 1 H), 4.08 (d, J = 4.1 Hz, 1 H), 3.27 (dd, J = 4.0, 9.0 Hz, 1 H), 2.40 (s, 3 H), 0.03 (s, 9 H).

General Procedure for the Preparation of Compounds 15 and 16. To a solution of *N*,*N*-dimethyl-2-bromoacetamide (**13**) (1.66 g, 10 mmol) and Et_3N (1.4 mL, 10 mmol) in 40 mL of methylene chloride was added 1.1 g (1 mL, 10 mmol) of phenylthiol at 0 °C under argon. This mixture was allowed to stir for 20 min. The solution was then washed with water. After the solution was dried over magnesium sulfate, the solvent was evaporated to give the residue. Chromatography on a short column of silica gel with 1:1 ethyl acetate/petroleum ether gave *N*,*N*-dimethyl-2-*n*-butylthioacetamide (**14**) as a light yellow oil: IR (film): 2956, 2931, 1645, 1496, 1466, 1427, 1395 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 3.30 (s, 2H), 3.08 (s, 3H), 2.97 (s, 3H), 2.66 (t, J = 7.6 Hz, 2H), 1.63−1.55(m, 2H), 1.45−1.37 (m, 2H), 0.91 (t, J = 7.3 Hz, 3H). EIMS (*m*/*z*, relative intensity): 175 (8, M), 87 (100), 72 (47), 45 (40), 42 (9).

To a solution of **14** (5 mmol) in THF (10 mL) was added LDA (2 M in THF/*n*-heptane, 2.5 mL, 5 mmol) under argon at −78 °C, and the resulting solution was stirred for 30 min. To the mixture was then added the solution of imine (5 mmol) in THF (10 mL) dropwise. After the mixture was stirred for another 40 min at the same temperature, the reaction was broken with saturated NH_4Cl (20 mL). The mixture was extracted with ethyl acetate (2 × 30 mL). After the organic layer was dried with magnesium sulfate, chromatography on a short column (silica gel, eluted by petroleum ether/acetate/Et_3N with a ratio of 75:25:1) gave the expected products.

***N*,*N*-Dimethyl-2-butylthio-3-(*p*-toluenesulfonyl)aminophenylpropionamide.** Flash chromatography gave 0.43 g (33%) of **15a** and 0.86 g (67%) of **16a**. Data for **15a**. White solid (*erythro*). Mp: 177−178 °C. IR (KBr): 3242, 2930, 1635, 1497, 1457, 1412, 1327, 1160 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 7.53 (d, J = 8.3 Hz, 2H), 7.25 (m, 2H), 7.14 (m, 5H), 5.86 (d, J = 1.8 Hz, 1H), 4.58 (dd, J_1 = 1.8 Hz, J_2 = 9.9 Hz, 1H), 3.60 (d, J = 9.9 Hz, 1H), 2.75 (s, 3H), 2.71 (s, 3H), 2.39 (m, 1H), 2.36 (s, 3H), 2.20 (m, 1H), 1.41−1.27 (m, 4H), 0.87 (t, J = 7.2 Hz, 3H). EIMS (*m*/*z*, relative intensity): 435 (11, M + 1), 175 (100), 91 (74), 87 (46), 155 (37), 72 (37), 119 (29), 176 (27), 118 (22). Anal. Calcd for $C_{22}H_{30}N_2O_3S_2$: C, 60.80; H, 6.96; N, 6.45; S, 14.76. Found: C, 60.86; H, 7.19; N, 6.42; S, 14.89. Data for **16a**. White solid (*threo*). Mp: 122−123 °C. IR (KBr): 3196, 2930, 1620, 1496, 1461, 1409, 1331, 1162 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 7.25 (d, J = 7.3 Hz, 2H), 7.34 (d, J = 7.1 Hz, 1H), 7.18−7.08 (m, 7H), 4.75 (dd, J_1 = 4.0 Hz, J_2 = 7.1 Hz, 1H), 3.84 (d, J = 4.0 Hz, 1H), 2.78 (s, 3H), 2.60 (s, 3H), 2.56 (m, 1H), 2.44 (m, 1H), 2.33(s, 3H), 1.48−1.31 (m, 4H), 0.90 (t, J = 7.1 Hz, 3H). EIMS (*m*/*z*, relative intensity): 434 (0.43, M), 175 (100), 91 (79), 87 (52), 155 (38), 72 (35), 119 (33), 118 (28), 176 (23). Anal. Calcd for $C_{22}H_{30}N_2O_3S_2$: C, 60.80; H, 6.96; N, 6.45; S, 14.76. Found: C, 60.82; H, 7.25; N, 6.42; S, 14.81.

***N*,*N*-Dimethyl-2-phenylthio-3-(*p*-toluenesulfonyl)aminophenylpropionamide.** Flash chromatography gave 0.636 g (30%) of **15b** and 1.501 g (70%) of **16b**. Data for **15b.** White solid (*erythro*). Mp: 195−197 °C. IR (film): 3222, 3050, 1625, 1495, 1461, 1401, 1328, 1160 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 7.52 (d, J = 8.3 Hz, 2H,), 7.37−7.12 (m, 12H), 6.00 (d, J = 3.3 Hz, 1H), 4.58 (dd, J_1 = 3.3 Hz, J_2 = 9.2 Hz, 1H), 4.09 (d, J = 9.2 Hz, 1H), 2.64 (s, 3H), 2.53 (s, 3H), 2.37 (s, 3H). EIMS (*m*/*z*, relative intensity): 455 (11, M + 1), 195 (100), 72 (46), 91 (37), 155 (19), 260 (12), 178 (4). Anal. Calcd for $C_{24}H_{26}N_2O_3S_2$: C, 63.41; H, 5.76; N, 6.16; S, 14.11. Found: C, 63.27; H, 5.74; N, 6.01; S, 14.50. Data for **16b**. White solid (*threo*). Mp: 116−117 °C. IR (KBr): 3261, 3050, 1624, 1495, 1454, 1400, 1328, 1162 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 7.58 (d, J = 8.3 Hz, 2H), 7.48 (d, J = 7.7 Hz, 1H), 7.39 (m, 2H), 7.31 (m, 3H), 7.14−7.04 (m, 7H), 4.79 (dd, J_1 = 3.8 Hz, J_2 = 7.7 Hz, 1H), 4.15 (d, J = 3.8 Hz, 1H), 2.73 (s, 3H), 2.35 (s, 3H), 2.32 (s, 3H). EIMS (*m*/*z*, relative intensity): 195 (100.00), 72 (67.28), 91 (64.58), 155 (35.53), 196 (14.00), 260 (8.38), 77 (10.45). Anal. Calcd for $C_{24}H_{26}N_2O_3S_2$: C, 63.41; H, 5.76; N, 6.16; S, 14.11. Found: C, 63.35; H, 5.81; N, 6.09; S, 14.34.

***N*,*N*-Dimethyl-2-butylthio-3-(*p*-toluenesulfinyl)aminophenylpropionamide.** Flash chromatography gave 1.126 g (54%) of **16c** as a white solid (*threo*). Mp: 158−159 °C. IR (film): 3205, 2925, 1620, 1494, 1456, 1408, 1095, 1071 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 7.59 (d, J = 8.2 Hz, 2H), 7.42−7.26 (m, 7H), 5.92 (d, J = 5.4 Hz, 1H), 4.73 (dd, J_1 = 5.4 Hz, J_2 = 6.6 Hz, 1H), 3.79 (d, J = 6.6 Hz, 1H), 2.85 (s, 3H), 2.77 (s, 3H), 2.40 (s, 3H), 2.53−2.34 (m, 2H), 1.48−1.29 (m, 4H), 0.87 (t, J = 7.2 Hz, 3H). EIMS (*m*/*z*, relative intensity): 419 (3, M + 1), 175 (100), 139 (63), 72 (30), 119 (29), 87 (28), 91 (19), 77 (12). Anal. Calcd for $C_{22}H_{30}N_2O_2S_2$: C, 63.12; H, 7.22; N, 6.69; S, 15.32. Found: C, 63.32; H, 6.97; N, 6.71; S, 15.48. A 0.685 g (33%) sample of an unseparated mixture of various isomers was also obtained.

Procedure for the Methylation of 15 and Its Aziridination Reaction. To a solution of **15** (1 mmol) in methyl iodide (4 mL) was added silver perchlorate (208 mg, 1 mmol). The mixture was stirred for 2 h at rt and then filtered through a pad of Celite, the filtrate was washed with methylene chloride (50 mL) and concentrated to ca. 10 mL, and then 70 mL of ether was added for recrystallization. Such recrystallization gave the required salt **17** as a white solid, which was used without further purification.

To a solution of **17** (0.5 mmol) in CH_2Cl_2 (5 mL) was added base (0.5 mmol). The mixture was stirred for ca. 30 min at rt. The reaction was quenched with 10 mL of water, and the mixture was extracted with methylene chloride (2 × 15 mL). The organic layer was dried with anhydrous magnesium sulfate, and the solvent was then evaporated. The residue was determined for its ratio of *trans* to *cis* by NMR and separated by chromatography on a short column of silica gel.

Procedure for the Methylation of 16 and Its Aziridination Reaction. Salt **18** was prepared by using the same procedure as that to prepare salt **17**. The same procedure was also used for the aziridination reaction of salt **18**.

Acknowledgment. This work was supported by the National Natural Science Foundation of China, Major Basic Research Development Program (Grant No. G2000077506), National Outstanding Youth Fund, Chinese Academy of Sciences, and Shanghai Committee of Science and Technology. This paper is dedicated to Professor Yao-Zeng Huang on the occasion of his 90th birthday.

JO0257389