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Enantioselective Synthesis of α-Silylamines by Meerwein–Ponndorf–Verley-Type Reduction of α-Silylimines by a Chiral Lithium Amide

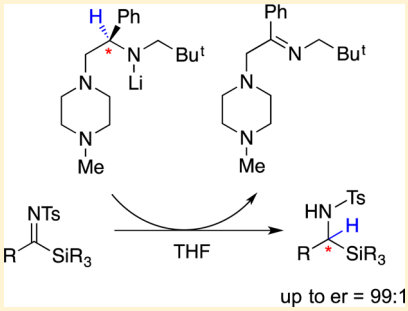
Yasuhiro Kondo,[†] Michiko Sasaki,*[,†] Masatoshi Kawahata,[‡] Kentaro Yamaguchi,[‡] and Kei Takeda[†]

[†]Department of Synthetic Organic Chemistry, Institute of Biomedical and Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-Ku, Hiroshima 734-8553, Japan

[‡]Pharmaceutical Sciences at Kagawa Campus, Tokushima Bunri University, 1314-1 Shido, Sanuki, Kagawa 769-2193, Japan

Supporting Information

ABSTRACT: Meerwein–Ponndorf–Verley-type reduction of *N*-tosylsilylimines with chiral lithium amide **2** affords α-silylamines in high enantioselectivity. Since the enantioselectivity observed was inconsistent with our previously proposed chairlike six-membered transition structure, we performed density functional theory (DFT) calculations on transition states leading to (*S*)- and (*R*)-**7a** and (*S*)- and (*R*)-**7e** using an *N*-phenylsulfonyl derivatives **12** and **13** as model systems. Results of the calculations showed that the structures are considerably deformed from the chairlike form with steric repulsions between the 1′-methylene group and the imine-carbon substituents playing an important role in the control of the enantioselectivity.



INTRODUCTION

Introducing silicon into bioactive compounds has attracted considerable interest in medicinal chemistry in view of potentially induced changes in conformations, lipophilicity, bonding property, and electronic nature.[1] One of the major applications for silicon-containing molecules is their use as a carbon isostere, in which, for example, silicon-based amino acids can act as an active tetrahedral intermediate of a protease inhibitor.[2,3] From that of point of view, enantioselective synthesis of α-silylamines has recently attracted considerable attention.[4] Although there have been many reports[5] on the synthesis of racemic α-silylamines since the first preparation by Speier and Sommer in 1951,[6] only a few methods for enantioselective synthesis of these compounds are available. The first report of an enantioselective synthesis of α-silylamines was by Tacke and Hengelsberg,[7] who used enzymatic hydrolysis of *rac*-*N*-acyl-α-silylamines, derived from alkylation followed by amination of dimethylphenylsilylmethyl chloride. The reaction of enantioenriched α,β-epoxysilanes with sodium azide followed by $LiAlH_4$ was used for the preparation of α-silylamines bearing a β-hydroxy group by Bassindale and co-workers.[8] Picard and Fortis also reported the synthesis of an α-silylamine by reduction of the corresponding α-silyliminium chloride using lithium borohydride and diethyl tartrate.[9] Although this method is applicable to aliphatic nonconjugated silylamines, the yield (43%) and enantioselectivity (60% ee) are moderate. A retro aza-Brook rearrangement (N to C) in Boc-protected *N*-silyl allyl, benzyl, or propargylamines in the presence of (−)-sparteine provides the corresponding α-silylamines in >90% ee as reported by Sieburth.[10] Scheidt and co-workers reported the synthesis of α-silylamines by the addition of silyl anions to chiral *tert*-butanesulfinimines.[11] Although this method was originally limited to non-enolizable imines as substrates, Skrydstrup found some sulfinimine substrates with α-protons to be tolerated under the addition conditions.[12]

Fifteen years ago, we reported an enantioselective Meerwein–Ponndorf–Verley (MPV)-type reduction of acylsilanes[13] by chiral lithium amide **2**,[14] in which hydride transfer occurs enantioselectively from a stereogenic carbon atom adjacent to a nitrogen atom of a chiral lithium amide to a carbonyl carbon atom (**1** → **3**) (Scheme 1). The method was recently applied to the enantioselective synthesis of silox-

Scheme 1. Enantioselective Reduction of Acylsilane Using Chiral Lithium Amide

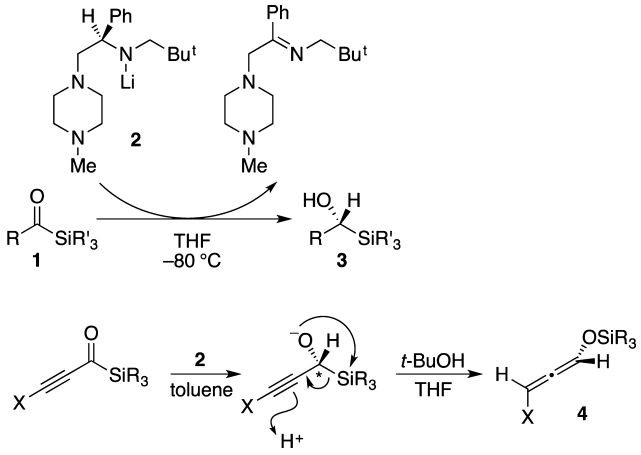


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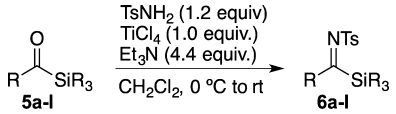
Table 1. Syntheses of *N*-Tosylimine



entry	6	R	SiR_3	time	yield (%)[a]
1	**6a**	Ph	$SiMe_3$	1 h	67
2	**6b**	Ph	$SiMe_2Bu^t$	2 h then reflux 2.5 h	74
3	**6c**	Ph	$SiMe_2Ph$	7 h	57
4	**6d**	Ph	$SiMePh_2$	38 h then reflux 3 h	56
5	**6e**	TMSC≡C-	$SiMe_2Bu^t$	reflux 7 h	97
6	**6f**	PhC≡C-	$SiMe_2Bu^t$	14 h then reflux 8 h	83
7	**6g**	$Ph(CH_2)_3C$≡C-	$SiMe_2Bu^t$	reflux 8 h[b]	55
8	**6h**	TMSCH=CH-	$SiMe_2Bu^t$	2 h	79
9	**6i**	^{t}BuCH=CH-	$SiMe_2Bu^t$	3 h	73
10	**6j**	PhCH=CH-	$SiMe_2Bu^t$	4 h	46
11	**6k**	3-$MeOC_6H_4$CH=CH-	$SiMe_2Bu^t$	21 h	62
12	**6l**	2-ClC_6H_4CH=CH-	$SiMe_2Bu^t$	3.5 h	71

[a]NMR spectroscopies indicated the presence of only one isomer in every case, double-bond geometries of which were not determined. [b]The reaction was performed using $TsNH_2$ (4.0 equiv) and $Ti(OEt)_4$ (4.0 equiv) in THF.

yallenes **4** in combination with a Brook rearrangement.[15] We envisaged this chemistry could be applicable to the enantioselective preparation of α-silylamines using α-silylimines that are readily available from the corresponding acylsilanes. Enantioslelective MPV-type reduction of α-silylimines is unprecedented, although there is one example for ketimines using (BINOL)Al^{III}/2-propanol.[16,17]

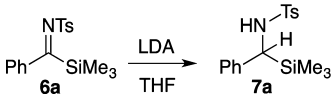
RESULTS AND DISCUSSION

On application of the MPV-type reduction for acylsilanes to imines, several issues were recognized: (1) less electrophilic reactivity of silylimines in comparison with silylketones and (2) possibility of the occurrence of an aza-Brook rearrangement[18] in the reduction product before quenching. Taking into account the electron-withdrawing nature of a sulfonyl group capable of stabilizing the developing anion in the hydride transfer and convenient availability of starting materials, we chose *N*-tosylsilylimine **6** as a substrate, which can be prepared by the reaction of acylsilanes with tosylamine in the presence of triethylamine and $TiCl_4$ (Table 1).

At the outset, we examined the feasibility of hydride transfer to **6a** from LDA[14,19] and found that the reaction can proceed over a wide range of temperatures with no products resulting from an aza-Brook rearrangement being detected (Table 2).

Having demonstrated the possibility of the desired MPV-type reduction of an *N*-tosylsilylimine, we then proceeded to examine enantioselective variants using enantioenriched known lithium amides including **2** (Table 3, entries 1−3).

Table 2. Reduction of *N*-Tosylimine Using LDA



entry	*T* (°C)	yield (%)
1	0	54
2	−40	66
3	−80	73
4	−100	17[a]

[a]54% of starting material was recovered.

The best result was obtained with lithium amide **2** as in the case of acylsilanes, suggesting an important role of the nitrogen atom of piperazine. The absolute configurations of **7a**−**d** were determined on the basis of X-ray analysis of **7a**. The fact that benzaldehyde was obtained with **9** suggests that not the methyne hydrogen on the stereogenic carbon atom but the methylene hydrogen was used for hydride transfer. The inverse addition of the imine to a solution of **2** resulted in lowering the chemical yield and enantioselectivity (entry 4). The use of THF as a solvent is crucial to the success of the reaction; toluene and Et_2O resulted in recovered starting material and racemization, respectively (entries 5 and 6). The reaction proceeded with high selectivity even at 0 °C, and lowering the reaction temperature to −100 °C led to improvement in enantioselectivity to 99:1 but at the expense of chemical yield (entries 7 and 8). A prolonged reaction time or the use of additional amounts of lithium amide **2** (2.4 equiv) at −100 °C did not improve the chemical yield (entries 9 and 10). Occurrence of significant racemization with an excess amount of **2** (entries 4 and 10) indicates the possibility of deprotonation of **7a** by the base. Also, the possibility of intra- and/or intermolecular proton transfer from an α-silyl carbon atom to a nitrogen atom before quenching, leading to an α-silyl benzyl carbanion, cannot be ruled out. However, the fact that enantioenriched **7a** (er = 99:1) did not racemize upon treatment with **2** at −80 °C makes these possibilities unlikely (Scheme 2). While TBS derivative **6b** gave the product with same enantiomeric ratio as that in the case of **6a**, introduction of a phenyl group on the silyl group caused a decline in enantioselectivity. This may reflect a change in *E*/*Z* geometry of the imine moiety (vide infra) (Table 3, entries 11−13). Another possibility for the partial racemization is that the resulting lithium amide **7a′** acts as a nonselective reducing agent. To test the feasibility of the process, dimethylphenylsilyl derivative **6c** was treated with **7a′**, which was generated from **7a** by deprotonation. In this reaction and the reaction using the opposite combination of trimethylsilyl and dimethylphenylsilyl groups, hydride transfer was not observed. Consequently, a decrease in enantioselectivity with an excess amount of a base might be due to other factors such as a nonselective hydride transfer from aggregated species.

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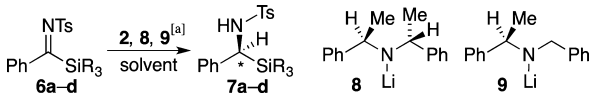
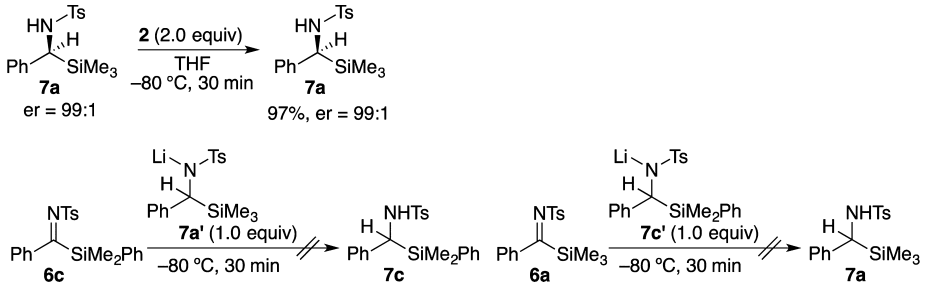
Table 3. Reduction of *N*-tosylimines Using Chiral Lihium Amide



entry	2, 8–10	6	SiR_3	T (°C)	solvent	yield (%)	er	sm (%)
1	**8**	**6a**	$SiMe_3$	−80	THF	0		
2	**9**	**6a**	$SiMe_3$	−80	THF	65[b]	50:50	
3	**2**	**6a**	$SiMe_3$	−80	THF	76	93:7	7
4[c]	**2**	**6a**	$SiMe_3$	−80	THF	50	82:18	36
5	**2**	**6a**	$SiMe_3$	−80	toluene	0		78
6	**2**	**6a**	$SiMe_3$	−80	Et_2O	7	48:52	69
7	**2**	**6a**	$SiMe_3$	0	THF	65	97:3	
8	**2**	**6a**	$SiMe_3$	−100	THF	58	99:1	28
9	**2**	**6a**	$SiMe_3$	−100	THF	53	93:7	19
10	**2**	**6a**	$SiMe_3$	−100	THF	59	78:22	29
11	**2**	**6b**	$SiMe_2Bu^t$	−80	THF	68	92:8	
12	**2**	**6c**	$SiMe_2Ph$	−80	THF	71	75:25	
13	**2**	**6d**	$SiMePh_2$	−80	THF	53	84:16	15

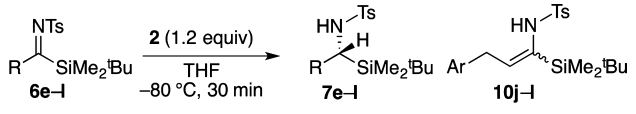
[a]All reactions were performed using 1.2 equiv of lithium amide except for entry 10 (2.4 equiv) and for 30 min except for entry 9 (180 min). [b]Benzaldehyde (21%) was obtained as a byproduct. [c]Inverse addition of **6a** to a cooled solution of **2**.

Scheme 2. Possibility for Partial Racemization via Deprotonation of 7 by 2 or Reduction of 6 by Reduction Product 7′



The same type of hydride transfer reaction can be applied to α,β-unsaturated imines **6e–l** to give the corresponding amines **7e–l** in good to excellent enantioselectivity (Table 4). The absolute configurations of **7e–l** were determined on the basis of X-ray analysis of **7e**. In the case of β-aryl-substituted derivatives, enamine **10**, a product that can arise from the above-mentioned proton transfer followed by an allylic and then a C-to-N lithio migration, was formed as a byproduct.

Table 4. Reduction of *N*-Tosylimines Using Chiral Lihium Amide 2



			7		10	6
entry	6	R	yield (%)	er	yield (%)	yield (%)
1	**6e**	TMSC≡C-	91	88:12		
2	**6f**	PhC≡C-	84	91:9		
3	**6g**	$Ph(CH_2)_3C$≡C-	58	97:3		
4	**6h**	TMSCH=CH-	90	99:1		
5	**6i**	^{t}BuCH=CH-	77	99:1		
6	**6j**	PhCH=CH-	67	99:1	22	
7	**6k**	3-$MeOC_6H_4$CH=CH-	60	97:3	18	
8	**6l**	2-ClC_6H_4CH=CH-	27	97:3	31	20

Regarding the enantioselectivity observed in the MPV-type reduction of a carbonyl group by chiral lithium amides, we have previously rationalized this by invoking a model of a chairlike six-membered transition state (early transition state), in which the silyl and the chelated piperazinylmethyl groups occupy an axial position.[14] The results obtained with **6a–d** and **6e–l**, however, were inconsistent with those expected from the model as shown in Scheme 3. Thus, the axial/equatorial preference of the silyl group is reversed between chairlike transition states **11a** and **11e**, leading to (*S*)-**7a** and (*R*)-**7e**, respectively. The results indicate that in the chairlike model, phenyl and *tert*-butyldimethylsilyl groups must each occupy an axial position, respectively. Considering results showing that the extents of the enantioselectivities observed with **7a,b** and **7e–l** are almost the same despite differences in the relative sizes of the two substituents in the imine carbon atom (Ph vs $SiMe_3$ and RC≡C vs TBS), the chairlike model does not seem appropriate. Also, a distinct structural difference between *N*-tosyl imines and acylsilanes or ketones that potentially affects the enantioselectivity should be the presence of *E*/*Z* geometry concerning the *N*-tosyl group in imines. The geometries of *E*- and *Z*-**6a** and **6e** were optimized at the B3LYP level with the 6-31G(d) basis set, and it was found that *E*-isomers were more stable than the *Z*-isomer (**6a**, 0.54 kcal/mol; **6e**, 3.81 kcal/mol). There have been some reports[20,21] suggesting that *N*-sulfonylimines are configurationally unstable even at low temperatures, and in fact, there was no peak separation in each case when ^{1}H NMR of **6a** and that of **6e** were measured at room temperature. The fact

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Scheme 3. Chair-Like Six-Membered Transition State Models of the Reduction

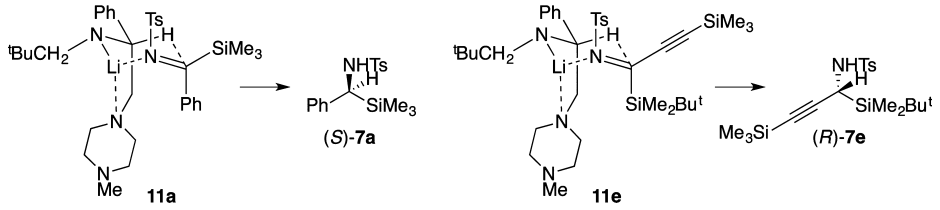
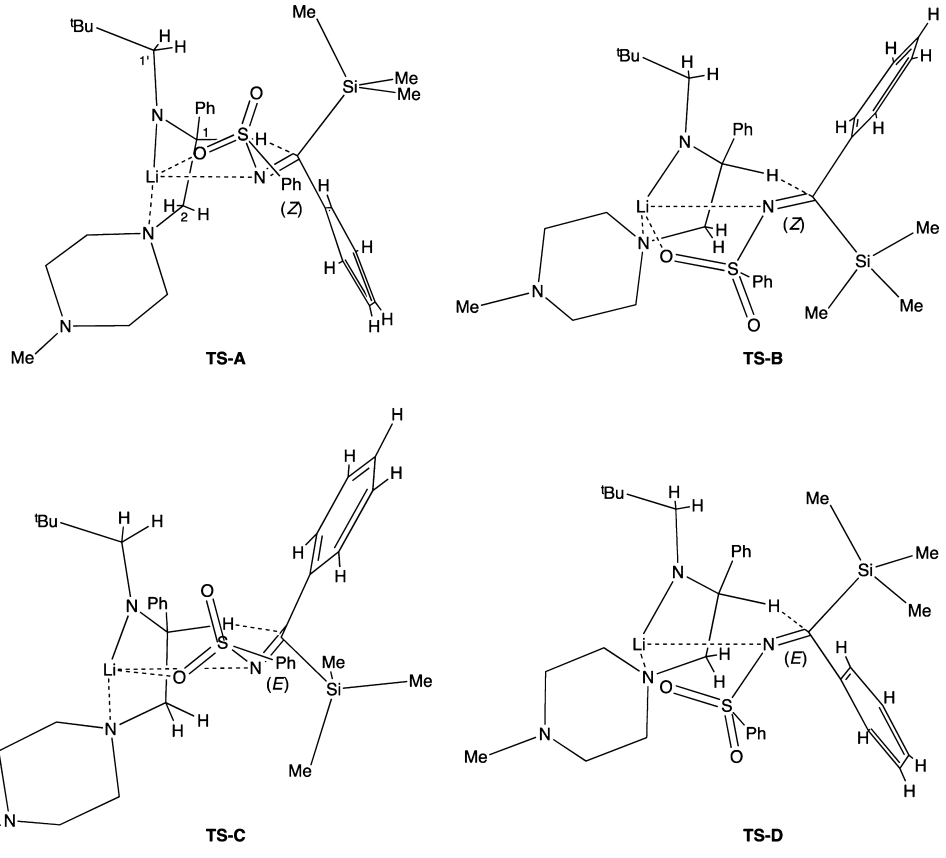


Table 5. B3LYP/6-31G* Optimized Geometries of Transition-State Structures of Reduction of 12 and Their relative Energies



	TS-A	TS-B	TS-C	TS-D
G°_{298} (au)	−2389.049 91	−2389.040 30	−2389.039 51	−2389.044 92
G°_{rel} (kcal/mol)	0.0	6.0	6.5	3.1

that the degree of enantioselectivity is not affected by the reaction temperature (Table 3, entries 3, 7, and 8) also indicates that the configuration of *N*-tosylimine in the ground state is not an important factor to control the enantioselectivity.

To obtain information on the origin of the observed enantioselectivities, we performed density functional theory (DFT) calculations on transition states leading to (*S*)-**7a** and (*R*)-**7a** using a *N*-phenylsulfonyl derivative **12** as a model system, assuming that the reduction proceeds by a concerted hydride transfer in a six-membered ring transition state.[22] Two transition structures for each, corresponding to the (*Z*)- and (*E*)-imines in a ground state, TS-A–TS-D, were located at a B3LYP/6-31+G* level. These calculations account for the enantioselectivity observed by showing that TS-A leading to (*S*)-**7a** is the most stable (Table 5).[23] The fact that the conformation of the imine in the most stable TS-A is *Z* suggests that *E*-to-*Z* isomerization can occur under the reaction conditions. Apparent differences between the calculated structures and the previously proposed ones in Scheme 3 are deformation from a chairlike six-membered ring in which the lithium atom coordinates to the sulfone oxygen atom rather than the imine nitrogen and increase in the double-bond character of the C1-nitrogen bond. The latter is likely to be a major factor in determining the enantioselectivity because it causes a steric interaction between the 1′-methylene group and the imine-carbon substituents. Thus, the selectivity results from a balance of steric repulsions of the imine carbon substituents with C2 and C1′.

A similar analysis can be applied to **6e** (*N*-phenylsulfonyl derivative **13**), in which the two substituents on the imine carbon atom are different in their bulkiness in comparison with those for **6a** (Table 6). Thus, in TS-C leading to **7e**, calculated to be the most stable, a much bulkier TBS group is preferably disposed at a position to avoid steric repulsions with 1′-methylene and the Ts group occupies the same side as the much less bulky silylethynyl group.

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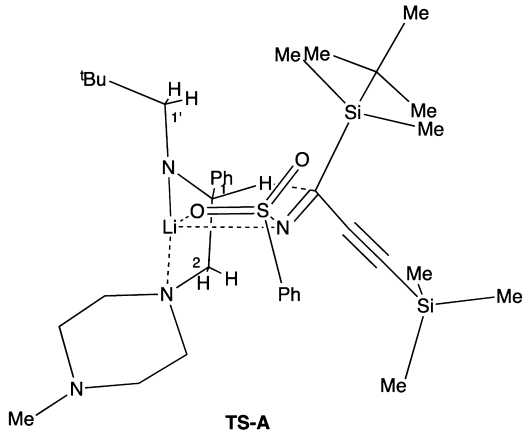
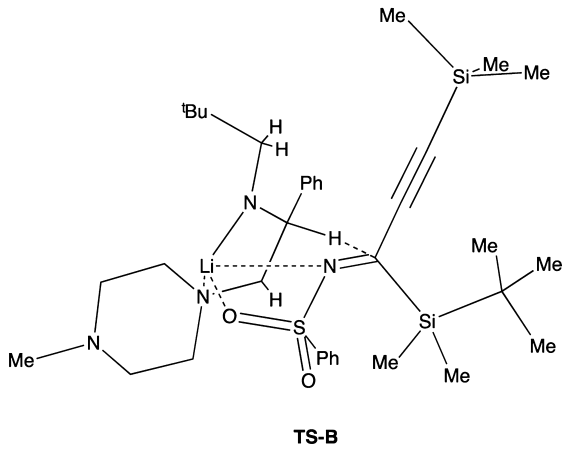
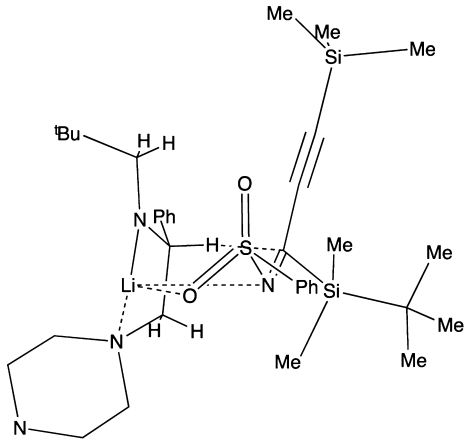
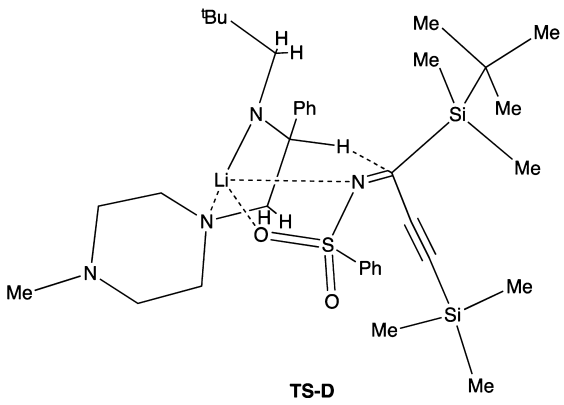
Table 6. B3LYP/6-31G* Optimized Geometries of Transition-State Structures of Reduction of 13 and Their Relative Energies









	TS-A	TS-B	TS-C	TS-D
$G°_{298}$ (au)	−2360.649 46	−2360.651 12	−2360.662 81	−2360.660 27
$G°_{rel}$ (kcal/mol)	8.4	7.3	0.0	1.6

CONCLUSION

We have developed a new and efficient method for the enantioselective formation of α-silylamine by Meerwein−Ponndorf−Verley-type reduction of *N*-tosylsilylimines with lithium amide **2**. A rationale for the excellent enantioselectivity of the hydride transfer was offered on the basis of analysis of transition state models obtained from DFT calculations.

EXPERIMENTAL SECTION

General Methods. All moisture-sensitive reactions were performed under a positive pressure of nitrogen. Anhydrous $MgSO_4$ was used for drying all organic solvent extracts in work-up unless otherwise indicated, and removal of the solvents was performed with a rotary evaporator. Dry solvents and reagents were obtained by using standard procedures. Thin-layer chromatography was performed on precoated glass-backed silica gel 60 F-254 plates. For routine chromatography, the following adsorbents were used: silica gel 60N of particle size 63-210 μm or 40−50 μm. Liquid chromatography under medium pressures (MPLC) was carried out using prepacked columns (22 mm × 100 mm (5 μm silica gel) or 22 mm × 300 mm (10 μm silica gel)). ^{1}H NMR spectra (500 MHz) were taken in $CDCl_3$ with reference to $CHCl_3$ (δ 7.26). ^{13}C NMR spectra (125 MHz) were measured in $CDCl_3$ with reference to $CHCl_3$ (δ 77.2). The assignment of ^{1}H and ^{13}C NMR spectra was based on H−H decoupling and HMQC experiments. Mass spectra (HRMS) were obtained on an Orbitrap mass spectrometer.

Preparation of Acylsilanes. Compounds **5a**,[24] **5b**,[25] **5c**,[26] **5e**,[27] **5f**,[28] **5g**,[15] **5h**,[29] **5i**,[30] **5j**,[31] and **5k**[32] were prepared according to literature procedures.

Diphenylmethylbenzoylsilane (5d).[31] To a cooled (−80 °C) solution of 2-phenyl-1,3-dithiane (934 mg, 4.76 mmol) in THF (20 mL) was added a solution of *n*-BuLi (1.83 M in hexane, 2.86 mL, 5.23 mmol). After 2 h of stirring at the same temperature, a solution of $Ph_2MeSiCl$ (1.2 mL, 1.33 g, 5.71 mmol) in THF (6 mL) was added. After being allowed to warm to 0 °C over 30 min, the reaction mixture was diluted with saturated aqueous NH_4Cl solution (30 mL) and extracted with Et_2O (30 mL × 3). The combined organic phases were washed with saturated brine (30 mL), dried, and concentrated. The residual oil was subjected to column chromatography (silica gel, 50 g; elution with hexane/CH_2Cl_2 = 4:1) to give methyldiphenyl(2-phenyl-1,3-dithian-2-yl)silane (1.77 g, 95%). To a cooled (ice−water) solution of the above compound (807 mg, 2.06 mmol) in acetone (21 mL) and H_2O (630 μL) was added NBS (1.83 g, 10.3 mmol). After being stirred at room temperature for 30 min, the reaction mixture was diluted with 15% aqueous $Na_2S_2O_3$ (10 mL) and extracted with Et_2O (30 mL × 3). The combined organic phases were washed with H_2O (30 mL × 3) and saturated brine (30 mL), dried, and concentrated. The residual oil was subjected to column chromatography (silica gel, 10 g; elution with hexane/Et_2O = 20:1) to give **5d** (164 mg, 26%).

1-(*tert*-Butyldimethylsilyl)-3-(trimethylsilyl)prop-2-yn-1-one (5e). To a cooled (ice−water) solution of 1-(*tert*-butyldimethylsilyl)-3-

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(trimethylsilyl)prop-2-yn-1-ol[32] (568 mg, 2.34 mmol) in acetone (9.4 mL) was added Jones reagent (1.94 M, 1.45 mL, 2.81 mmol). After 10 min of stirring at the same temperature, *i*-PrOH (1 mL) was added to the reaction mixture, which was diluted with saturated aqueous $NaHCO_3$ solution (10 mL) and extracted with Et_2O (10 mL × 3). The combined organic phases were washed with H_2O (10 mL × 3) and saturated brine (10 mL), dried, and concentrated. The residual oil was subjected to column chromatography (silica gel, 20 g, elution with hexane/Et_2O = 30:1) to give **5e** (479 mg, 85%) as an orange oil. R_f = 0.52 (hexane/Et_2O = 3:1); IR (NaCl) 2953, 2931, 2889, 2858, 1637, 1581 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.34 (6H, s), 0.98 (9H, s), 6.84 (1H, d, J = 16.5 Hz), 7.28−7.34 (2H, m), 7.43 (1H, dd, J = 7.8, 1.2 Hz), 7.65 (1H, dd, J = 7.6 Hz, 2.1), 7.88 (1H, d, J = 16.5 Hz); ^{13}C NMR ($CDCl_3$) δ −5.5, 16.9, 26.8, 127.3, 127.3, 130.3, 131.3, 133.3, 134.6, 135.6, 139.0, 236.1; HRMS-APCI (m/z) $[M + H]^+$ calcd for $C_{15}H_{21}OClSi$ 281.1123, found 281.1126.

(*E*)-1-(*tert*-Butyldimethylsilyl)-3-(2-chlorophenyl)prop-2-en-1-one (5l). To a cooled (ice−water) suspension of NaH (60%, 157 mg, 3.91 mmol) in THF (14 mL) was added a solution of HWE reagent (1.14 g, 4.27 mmol) in THF (13 mL). The reaction mixture was allowed to warm to room temperature and was stirred for 10 min. The mixture was cooled to 0 °C, and then 2-chlorobenzaldehyde (0.40 mL, 3.56 mmol) was added. After being stirred at room temparature for 1.5 h, the reaction mixture was diluted with saturated aqueous NH_4Cl solution (30 mL) and extracted with Et_2O (30 mL × 3). The combined organic phases were washed with saturated brine (30 mL), dried, and concentrated. The residual oil was subjected to column chromatography (silica gel, 50 g; elution with hexane/AcOEt = 15:1) to give **5l** (957 mg, 96%) as an orange oil. R_f = 0.52 (hexane/Et_2O = 3:1); IR (NaCl) 2953, 2931, 2889, 2858, 1637, 1581 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.34 (6H, s), 0.98 (9H, s), 6.84 (1H, d, J = 16.5 Hz), 7.28−7.34 (2H, m), 7.43 (1H, dd, J = 7.8, 1.2 Hz), 7.65 (1H, dd, J = 7.6 Hz, 2.1), 7.88 (1H, d, J = 16.5 Hz); ^{13}C NMR ($CDCl_3$) δ −5.5, 16.9, 26.8, 127.3, 127.3, 130.3, 131.3, 133.3, 134.6, 135.6, 139.0, 236.1; HRMS-APCI (m/z) $[M + H]^+$ calcd for $C_{15}H_{21}OClSi$ 281.1123, found 281.1126.

Representative Procedure for the Preparation of *N*-Silylimine (6i). To a cooled solution of acylsilane (325 mg, 1.44 mmol), $TsNH_2$ (294 mg, 1.72 mmol), and Et_3N (881 μL, 6.32 mmol) in CH_2Cl_2 (7.2 mL) was added $TiCl_4$ (1.0 M in CH_2Cl_2, 1.44 mL, 1.44 mmol). After 3 h of stirring at room temperature, saturated aqueous $NaHCO_3$ (10 mL) was added. The mixture was filtered through a plug of Celite, and the filtrate was extracted with CH_2Cl_2 (20 mL × 2). The combined organic phases were washed with H_2O (10 mL) and saturated brine (10 mL), dried, and concentrated. The residual oil was subjected to column chromatography (silica gel, 30 g; elution with hexane/CH_2Cl_2/Et_2O = 40:20:1) to give **6i** (397 mg, 73%).

Preparation of *N*-Silylimine (6g). To a solution of asylsilane (493 mg, 1.72 mmol) and $TsNH_2$ (1.18 g, 6.88 mmol) in THF (5.7 mL) was added $Ti(OEt)_4$ (1.44 mL, 1.57 g, 6.88 mmol). The mixture was heated to reflux for 8 h. After cooling to room temperature, saturated aqueous $NaHCO_3$ (10 mL) was added. The mixture was filtered through a plug of Celite, and the filtrate was extracted with AcOEt (10 mL × 2). The combined organic phases were dried and concentrated. After the residue was passed through a pad of silica gel eluting with hexane/CH_2Cl_2/Et_2O = 5:5:1, the residual oil was subjected to column chromatography (silica gel, 30 g; elution with hexane/Et_2O = 5:1) to give **6g** (419 mg, 55%)

***N*-(Phenyl(trimethylsilyl)methylene)-*p*-toluenesulfonamide (6a).** Colorless needles (CH_2Cl_2/hexane). 67% yield, 2.45 g (from 1.99 g of **5a**); mp = 112.0−113.0 °C; R_f = 0.43 (hexane/AcOEt = 5:1); IR (KBr) 3358, 3260, 2965, 1740, 1550 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.07−0.41 (9H, brs), 2.40 (3H, s), 7.14−7.29 (4H, brm), 7.33−7.29 (3H, m), 7.71−7.82 (2H, br); ^{13}C NMR ($CDCl_3$) δ −2.2 (br), 21.7, 125.0 (br), 127.7, 128.2, 129.2−129.8 (br), 205.8; HRMS-ESI (m/z) $[M + Na]^+$ calcd for $C_{17}H_{21}NO_2SSi$ 354.0955, found 354.0957.

***N*-(Phenyl(trimethylsilyl)methylene)-*p*-toluenesulfonamide (6b).** Colorless needles (CH_2Cl_2/hexane). 74% yield, 634 mg (from 508 mg of **5b**); mp = 69.5−70.0 °C; R_f = 0.48 (hexane/AcOEt = 5:1); IR (KBr) 3055, 2959, 2927, 2890, 2856, 1597, 1548; ^1H NMR ($CDCl_3$) δ 0.14 (6H, s), 0.90 (9H, s), 2.41 (3H, s), 7.18−7.20 (2H, m), 7.24 (2H, d, J = 8.3 Hz), 7.35−7.39 (3H, m), 7.74 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −5.8, 17.9, 21.7, 26.8, 125.1, 127.6, 128.2, 129.2, 129.4, 138.6, 140.8, 143.5, 205.3; HRMS-ESI (m/z) $[M + Na]^+$ calcd for $C_{20}H_{27}NO_2SSi$ 396.1424, found 396.1427.

***N*-((Methyldiphenylsilyl)(phenyl)methylene)-*p*-toluenesulfonamide (6d).** Pale yellow oil. 56% yield, 133 mg (from 164 mg of **5d**); R_f = 0.44 (hexane/Et_2O = 3:2); IR (NaCl) 3065, 3024, 2965, 2922, 1595, 1551 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.74 (1H, brs), 2.42 (3H, s), 7.07 (2H, d, J = 7.4 Hz), 7.21−7.26 (4H, m), 7.28−7.35 (5H, m), 7.40−7.44 (2H, m), 7.48 (4H, d, J = 7.1 Hz), 7.72 (2H, d, J = 8.2 Hz); ^{13}C NMR ($CDCl_3$) δ −4.1, 21.7, 125.9, 127.7, 128.0, 128.2, 129.5, 129.6, 130.3, 132.5, 135.4, 138.3, 143.6, 202.0; HRMS-ESI (m/z) $[M + Na]^+$ calcd for $C_{27}H_{25}NO_2SSi$ 478.1268, found 478.1267.

***N*-(1-(*tert*-Butyldimethylsilyl)-3-(trimethylsilyl)prop-2-yn-1-ylidene)-*p*-toluenesulfonamide (6e).** Off-white plates (CH_2Cl_2/hexane). 97% yield, 852 mg (from 538 mg of **5e**); mp = 65.0−66.0 °C; R_f = 0.34 (hexane/Et_2O = 3:1); IR (KBr) 2967, 2930, 2897, 2859, 1596, 1555; ^1H NMR ($CDCl_3$) d 0.22 (s, 6H), 0.24 (9H, s), 0.91 (9H, s), 2.43 (3H, s), 7.29 (2H, d, J = 8.3 Hz), 7.85 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −6.7, −0.7, 17.9, 21.8, 26.6, 100.5, 128.1, 128.3, 129.5, 137.1, 144.0, 184.6; HRMS-ESI (m/z) $[M + Na]^+$ calcd for $C_{19}H_{31}NO_2SSi_2$ 416.1506, found 416.1500.

***N*-(1-(*tert*-Butyldimethylsilyl)-3-phenylprop-2-yn-1-ylidene)-*p*-toluenesulfonamide (6f).** Pale yellow needles (CH_2Cl_2/hexane). 83% yield, 366 mg (from 270 mg of **5f**); mp = 70.5−71.0 °C; R_f = 0.50 (hexane/Et_2O = 2:1); IR (KBr) 2948, 2929, 2897, 2855, 2170, 1509 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.30 (6H, s), 0.96 (9H, s), 2.41 (3H, s), 7.30 (2H, d, J = 8.3 Hz), 7.41 (2H, dd, J = 7.7, 7.7 Hz), 7.47 (1H, tt, 7.7, 1.2 Hz), 7.57 (2H, dd, J = 7.7, 1.2 Hz), 7.90 (1H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −6.6, 18.0, 21.8, 26.6, 87.7, 118.3, 121.2, 128.1, 128.8, 129.6, 131.3, 133.0, 137.3, 144.0, 183.5; HRMS-ESI (m/z) $[M + Na]^+$ calcd for $C_{22}H_{27}NO_2SSi$ 420.1424, found 420.1421.

***N*-(1-(*tert*-Butyldimethylsilyl)-6-phenylhex-2-yn-1-ylidene)-*p*-toluenesulfonamide (6g).** Pale yellow oil. R_f = 0.29 (hexane/Et_2O = 5:1); IR (NaCl) 3061, 3027, 2952, 2931, 2893, 2859, 2189, 1600, 1515 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.24 (6H, s), 0.94 (9H, s), 1.93 (2H, tt, J = 7.1. 7.6 Hz), 2.41 (3H, s), 2.57 (2H, t, J = 7.1 Hz), 2.77 (2H, t, J = 7.6 Hz), 7.19−7.22 (3H, m), 7.28−7.32 (4H, m), 7.86 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −6.7, 17.7, 20.2, 21.7, 26.5, 29.6, 34.9, 80.6, 122.1, 126.2, 127.9, 128.6, 128.7, 129.4, 137.6, 141.1, 143.7; HRMS-ESI (m/z) $[M + Na]^+$ calcd for $C_{25}H_{33}NO_2SSi$ 462.1894 found 462.1894.

***N*-(2*E*)-1-(*tert*-Butyldimethylsilyl)-3-(trimethylsilyl)-allylidene)-*p*-toluenesulfonamide (6h).** Orange oil. 79% yield, 877 mg (from 682 mg of **5h**); R_f = 0.47 (hexane/Et_2O = 5:1); IR (NaCl) 2956, 2931, 2894, 2859, 1599, 1515; ^1H NMR ($CDCl_3$) δ 0.17 (9H, s), 0.21 (6H, s), 0.89 (9H, s), 2.43 (3H, s), 6.64 (1H, d, J = 19.5 Hz), 7.56 (1H, d, J = 19.5 Hz), 7.30 (2H, d, J = 8.3 Hz), 7.84 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −4.3, −1.7, 17.6, 21.7, 26.9, 127.3, 129.5, 139.2, 142.2, 143.4, 149.8, 199.8; HRMS-ESI (m/z); $[M + Na]^+$ calcd for $C_{19}H_{33}NO_2SSi_2$ 418.1663, found 418.1659.

***N*-((*E*)-1-(*tert*-Butyldimethylsilyl)-4,4-dimethylpent-2-en-1-ylidene)-*p*-toluenesulfonamide (6i).** Pale yellow oil. R_f = 0.28 (hexane/Et_2O = 8:1); IR (NaCl) 2959, 2932, 2860, 1623, 1513 cm^{-1}; ^1H NMR ($CDCl_3$) d 0.23 (6H, s), 0.89 (9H, s), 1.12 (9H, s), 6.58 (1H, d, J = 16.1 Hz), 7.24 (1H, d, J = 16.1 Hz), 7.29 (2H, d, J = 8.3 Hz), 7.84 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) d −3.8, 17.5, 21.7, 27.0, 28.7, 35.0, 126.3, 127.2, 129.5, 139.5, 143.2, 162.2, 198.7; HRMS-ESI (m/z) $[M + Na]^+$ calcd for $C_{20}H_{33}NO_2SSi$ 402.1894, found 402.1898.

***N*-((*E*)-1-(*tert*-Butyldimethylsilyl)-3-phenylallylidene)-*p*-toluenesulfonamide (6j).** Pale yellow needles (CH_2Cl_2/hexane). 46% yield, 512 mg (from 687 mg of **5j**); mp = 105.0−105.5 °C; R_f = 0.39 (hexane/Et_2O = 3:1); IR (KBr) 2952, 2928, 2887, 2857, 1613 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.32 (6H, s), 0.94 (9H, s), 2.43 (3H, s), 7.29−7.34 (3H, m), 7.41−7.42 (3H, m), 7.58−7.59 (2H, m), 8.07 (1H, d, J = 16.3 Hz); ^{13}C NMR ($CDCl_3$) δ −3.7, 17.7, 21.7, 27.0, 127.1, 127.6, 128.7, 129.2, 129.5, 131.1, 135.0, 139.3, 143.3, 147.3, 197.1; HRMS-

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ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{29}NO_2SSi$ 422.1581, found 422.1583.

***N*-((*E*)-1-(*tert*-Butyldimethylsilyl)-3-(3-methoxyphenyl)-allylidene)-*p*-toluenesulfonamide (6k).** Yellow prisms (CH_2Cl_2/hexane). 62% yield, 462 mg (from 482 mg of **5k**); mp = 90.0−91.0 °C; R_f = 0.30 (hexane/Et_2O = 3:1); IR (KBr) 2958, 2926, 2857, 1615, 1588 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.32 (6H, s), 0.94 (9H, s), 2.40 (3H, s), 3.83 (3H, s), 6.95 (1H, dd, J = 8.3, 1.6 Hz), 7.08 (1H, brs), 7.17 (1H, d, J = 7.6 Hz), 7.29−7.32 (4H, m), 7.88 (2H, d, J = 8.2 Hz), 8.05 (1H, d, J = 16.3 Hz); ^{13}C NMR ($CDCl_3$) δ −3.9, 17.6, 21.6, 26.9, 55.4, 113.3, 116.8, 121.3, 127.0, 127.7, 129.4, 130.1, 136.3, 139.2, 143.3, 147.0, 160.1, 197.0; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{23}H_{31}NO_3SSi$ 452.1686, found 452.1687.

***N*-((*E*)-1-(*tert*-Butyldimethylsilyl)-3-(2-chlorophenyl)-allylidene)-*p*-toluenesulfonamide (6l).** Yellow prisms (CH_2Cl_2/hexane). 71% yield, 662 mg (from 606 mg of **5l**); mp = 113.0−114.0 °C; R_f = 0.33 (hexane/Et_2O = 3:1); IR (KBr) 2952, 2926, 2885, 2853, 1611, 1503 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.35 (6H, s), 0.95 (9H, s), 2.41 (3H, s), 7.29−7.33 (4H, m), 7.39−7.43 (1H, m), 7.78 (1H, d, J = 16.3 Hz), 7.78−7.80 (1H, m), 7.89 (2H, d, J = 8.0 Hz), 8.07 (1H, d, J = 16.3 Hz); ^{13}C NMR ($CDCl_3$) δ −4.0, 17.6, 21.7, 26.9, 127.1, 127.5, 127.9, 129.1, 129.5, 130.1, 131.7, 133.1, 135.4, 139.1, 142.4, 143.4, 197.2; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{28}NO_2ClSSi$ 456.1191, found 456.1190.

Representative Procedure for the Reduction of *N*-Silylimine (6b). To a cooled (−80 °C) solution of **6b** (92.7 mg, 0.248 mmol) in THF (1.2 mL) was added dropwise a solution of chiral lithium amide generated from (*S*)-2,2-dimethyl-*N*-(2-(4-methylpiperazin-1-yl)-1-phenylethyl)propan-1-amine (83.4 mg, 0.288 mmol) and *n*-BuLi (1.97 M in *n*-hexane, 151 μL, 0.298 mmol) in THF (1.1 mL) at 0 °C. The reaction mixture was stirred at the same temperature for 30 min before the addition of a solution of AcOH (0.5 M in THF, 0.600 mmol). The mixture was diluted with hydrochloric acid (1%, 10 mL) and extracted with AcOEt (10 mL × 3). The combined organic phases were successively washed with saturated aqueous $NaHCO_3$ solution (5 mL) and saturated brine (5 mL), dried, and concentrated. The residual oil was subjected to flash column chromatography (silica gel, 7 g, elution with hexane/CH_2Cl_2/Et_2O = 20:20:1) to give **7b** (54.1 mg, 68%).

***N*-(Phenyl(trimethylsilyl)methyl)-*p*-toluenesulfonamide (7a).** Colorless needles (CH_2Cl_2/hexane). 58% yield, 38 mg (from 73 mg of **6a**); mp = 170−171 °C; R_f = 0.34 (hexane/AcOEt = 5:1); $[\alpha]^{27}_D$ −60.0 (c 0.35, $CHCl_3$); Chiralcel OD-H (25 cm), hexane/*i*-PrOH = 10:1, flow rate 1.0 mL/min, detection at 254 nm, t_R = 7.91 min (major) and 11.6 min (minor), er = >99:1; IR (KBr) 3284, 2964, 1598; ^{1}H NMR ($CDCl_3$) δ −0.02 (9H, s), 2.29 (3H, s), 3.97 (1H, d, J = 8.4 Hz), 5.23 (1H, d, J = 8.4 Hz), 6.81 (2H, d, J = 7.1 Hz), 6.97−7.05 (5H, m), 7.49 (2H, d, J = 8.2 Hz); ^{13}C NMR ($CDCl_3$) δ −3.7, 21.5, 50.4, 125.6, 126.3, 127.4, 128.1, 129.2, 137.7, 139.4, 143.0; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{17}H_{23}O_2NSSi$ 356.1111, found 356.1114.

***N*-((*tert*-Butyldimethylsilyl)(phenyl)methyl)-*p*-toluenesulfonamide (7b).** Colorless prisms (CH_2Cl_2/hexane); mp = 135.5−136.5 °C; R_f = 0.35 (hexane/AcOEt = 5:1); $[\alpha]^{26}_D$ −23.0 (c 1.02, $CHCl_3$) (er = 93:7); Chiralcel OD-H (25 cm), hexane/*i*-PrOH = 8:1, flow rate 1.00 mL/min, detection at 254 nm, t_R = 5.99 min (major) and 7.22 min (minor), er = 93:7; IR (KBr) 3476, 3304, 2954, 2927, 2886, 2855, 1599 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ −0.29 (3H, s), 0.05 (3H, s), 0.90 (9H, s), 2.26 (3H, s), 4.19 (1H, d, J = 8.9 Hz), 4.98−5.05 (1H, brm), 6.78 (2H, d, J = 6.9 Hz), 6.92−7.00 (5H, m), 7.41 (2H, d, J = 8.0 Hz); ^{13}C NMR ($CDCl_3$) δ −8.5, −7.0, 17.5, 21.5, 26.9, 48.0, 125.6, 126.7, 127.4, 128.1, 129.1, 137.9, 139.9, 142.8; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{20}H_{29}NO_2SSi$ 398.1581, found 398.1585.

***N*-((Dimethyl(phenyl)silyl)(phenyl)methyl)-*p*-toluenesulfonamide (7c).** Colorless needles (AcOEt/hexane). 71% yield, 41 mg (from 66 mg of **6c**); mp = 151.0−152.0 °C; R_f = 0.33 (hexane/AcOEt = 4:1); $[\alpha]^{25}_D$ −25.9 (c 1.03, $CHCl_3$) (er = 68:32); Chiralcel OD-H (25 cm), hexane/*i*-PrOH = 10:1, flow rate 1.00 mL/min, detection at 254 nm, t_R = 7.96 min (major) and 21.9 min (minor), er = 75:25; IR (KBr) 3267, 3063, 3026, 2957, 1595 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.24 (3H, s), 0.27 (3H, s), 2.29 (3H, s), 4.14 (1H, d, J = 8.3 Hz), 5.26−5.29 (1H, m), 6.72−6.73 (2H, m), 6.96 (2H, d, J = 8.1 Hz), 6.99−7.02 (3H, m), 7.28−7.31 (4H, m), 7.37−7.42 (1H, m), 7.41 (2H, d, J = 8.1 Hz); ^{13}C NMR ($CDCl_3$) δ −5.6, −4.8, 21.5, 49.9, 125.6, 126.5, 127.3, 127.9, 128.1, 129.1, 130.0, 134.1, 134.5, 137.4, 138.9, 142.8 ; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{25}NO_2SSi$ 418.1268, found 418.1261.

***N*-((Methyldiphenylsilyl)(phenyl)methyl)-*p*-toluenesulfonamide (7d).** White prisms (CH_2Cl_2/hexane). 53% yield, 39 mg (from 73 mg of **6d**); mp = 174.0−175.0 °C; R_f = 0.34 (hexane/Et_2O = 3:2); $[\alpha]^{27}_D$ −23.8 (c 0.72, $CHCl_3$) (er = 84:16); Chiralpak AD-H (25 cm), hexane/*i*-PrOH = 15:1, flow rate 1.00 mL/min, detection at 254 nm, t_R = 10.3 min (major) and 15.8 min (minor), er = 84:16; IR (KBr) 3266, 3063, 3022, 2957, 2918, 1597 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.39 (3H, s), 2.29 (3H, s), 4.57 (1H, d, J = 8.0 Hz), 4.79 (1H, d, J = 8.0 Hz), 6.65 (2H, d, J = 6.7 Hz), 6.94−7.00 (5H, m), 7.30−7.47 (12H, m); ^{13}C NMR ($CDCl_3$) δ −5.6, 21.5, 48.5, 125.9, 126.9, 127.5, 127.9, 128.2, 128.4, 129.2, 130.2, 130.5, 132.1, 133.0, 135.2, 135.6, 137.5, 138.5, 143.0; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{27}H_{27}NO_2SSi$ 480.1424, found 480.1424.

***N*-(1-(*tert*-Butyldimethylsilyl)-3-(trimethylsilyl)prop-2-yn-1-yl)-*p*-toluenesulfonamide (7e).** Colorless plates (CH_2Cl_2/hexane). 91% yield, 72 mg (from 85 mg of **6e**); mp = 161.0−161.5 °C; R_f = 0.50 (hexane/Et_2O = 2:1); $[\alpha]^{26}_D$ +70.9 (c 1.03, $CHCl_3$) (er = 95:5); Chiralpak AS-3 (25 cm), hexane/*i*-PrOH/EtOH = 30:1:1, flow rate 0.40 mL/min, detection at 254 nm, t_R = 11.4 min (major) and 13.6 min (minor), er = 95:5; IR (KBr) 3279, 2955, 2935, 2861, 2161, 1734, 1600 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ −0.08 (9H, s), 0.09 (3H, s), 0.11 (3H, s), 0.99 (9H, s), 2.42 (3H, s), 3.80 (1H, d, J = 10.5 Hz), 4.15 (1H, d, J = 10.5 Hz), 7.28 (2H, d, J = 8.1 Hz), 7.80 (2H, d, J = 8.1 Hz); ^{13}C NMR ($CDCl_3$) δ −8.0,, −7.5, −0.2, 17.6, 21.7, 27.0, 35.3, 90.3, 103.6, 128.1, 129.7, 137.6, 143.5; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{19}H_{33}NO_2SSi_2$ 418.1663, found 418.1656.

***N*-(1-(*tert*-Butyldimethylsilyl)-3-phenylprop-2-yn-1-yl)-*p*-toluenesulfonamide (7f).** Colorless needles (CH_2Cl_2/hexane). 84% yield, 65 mg (from 84 mg of **6f**); mp = 135.0−136.0 °C; R_f = 0.44 (hexane/Et_2O = 2:1); $[\alpha]^{26}_D$ +118.8 (c 1.08, $CHCl_3$) (er = 90:10); Chiralcel OD-H (25 cm), hexane/*i*-PrOH = 12:1, flow rate 1.00 mL/min, detection at 254 nm, t_R = 5.46 min (minor) and 7.29 min (major), er = 90:10; IR (KBr) 3290, 3060, 2926, 2853, 1599 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.15 (3H, s), 0.17 (3H, s), 1.03 (9H, s), 2.31 (3H, s), 4.01 (1H, d, J = 10.7 Hz), 4.27 (1H, d, J = 10.7 Hz), 6.93 (2H, d, J = 8.3 Hz), 7.17−7.25 (5H, m), 7.84 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −7.9, −7.3, 17.6, 21.6, 27.0, 34.8, 85.6, 87.2, 123.2, 128.1, 129.7, 129.7, 131.4, 131.4, 137.7, 143.7 ; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{29}NO_2SSi$ 422.1581, found 422.1574.

***N*-(1-(*tert*-Butyldimethylsilyl)-6-phenylhex-2-yn-1-yl)-*p*-toluenesulfonamide (7g).** Colorless prisms (CH_2Cl_2/hexane). 58% yield, 43 mg (from 78 mg of **6g**); mp = 82.5−83.5 °C; R_f = 0.50 (hexane/Et_2O = 2:1); $[\alpha]^{25}_D$ +71.3 (c 1.08, $CHCl_3$) (er = 97:3); Chiralcel OD-H (25 cm), hexane/*i*-PrOH = 10:1, flow rate 1.0 mL/min, detection at 254 nm, t_R = 5.69 min (minor) and 9.38 min (major), er = 97:3; IR (KBr) 3254, 2951, 2931, 2900, 2854, 1600 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.08 (3H, s), 0.11 (3H, s), 0.99 (9H, s), 1.49 (2H, tt, J = 7.2, 7.2 Hz), 1.82 (2H, td, J = 7.2, 2.3 Hz), 2.31 (3H, s), 2.48 (2H, t, J = 7.2 Hz), 3.78 (1H, dd, J = 10.6, 2.3 Hz), 4.20 (1H, d, J = 10.6 Hz), 7.09 (2H, d, J = 7.3 Hz), 7.18−7.29 (5H, m), 7.80 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −8.0, −7.3, 17.4, 18.4, 21.6, 27.0, 30.3, 34.5, 35.0, 78.1, 85.6, 126.2, 128.1, 128.5, 129.4, 129.5, 137.9, 141,7, 143.3; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{25}H_{35}NO_2SSi$ 464.2050, found 464.2048.

***(E)*-*N*-(1-(*tert*-Butyldimethylsilyl)-3-(trimethylsilyl)allyl)-*p*-toluenesulfonamide (7h).** Colorless prisms (CH_2Cl_2/hexane). 90% yield, 69 mg (from 79 mg of **6h**); mp = 136.0−137.0 °C; R_f = 0.22 (hexane/Et_2O = 5:1); $[\alpha]^{24}_D$ +17.5 (c 1.03, $CHCl_3$) (er = >99:1); Chiralcel OD-H (25 + 25 cm), hexane/*i*-PrOH = 25:1, flow rate 0.30 mL/min, detection at 254 nm, t_R = 34.7 min (minor) and 36.3 min (major), er = >99:1; IR (KBr) 3296, 2958, 2930, 2859, 1600 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ −0.19 (9H, s), −0.09 (3H, s), −0.02 (3H, s), 0.93 (9H, s), 2.37 (3H, s), 3.77−3.80 (1H, m), 4.84−4.89 (1H, brm), 5.19

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(1H, dd, J = 18.9, 1.2 Hz), 5.58 (1H, dd, J = 18.9, 6.7 Hz), 7.20 (2H, d, J = 8.3 Hz), 7.71 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −8.2, −7.2, −1.3, 17.6, 21.6, 27.1, 49.2, 126.7, 127.7, 129.5, 138.6, 143.1, 143.3; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{19}H_{35}NO_2SSi_2$ 420.1819, found 420.1813.

(*E*)-*N*-(1-(*tert*-Butyldimethylsilyl)-4,4-dimethylpent-2-en-1-yl)-*p*-toluenesulfonamide (7i). Colorless prisms (CH_2Cl_2/hexane). 77% yield, 63 mg (from 88 mg of **6i**); mp = 136.0−137.0 °C; R_f = 0.32 (hexane/Et_2O = 3:1); $[\alpha]^{27}_D$ −18.9 (c 1.12, $CHCl_3$) (er = 94:6); Chiralcel OD-H (25 + 25 cm), hexane/*i*-PrOH = 20:1, flow rate 0.50 mL/min, detection at 254 nm, t_R = 19.7 min (minor) and 20.8 min (major), er = 99:1; IR (KBr) 3299, 2959, 2830, 2859, 1599 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ −0.08 (3H, s), −0.01 (3H, s), 0.72 (9H, s), 0.93 (9H, s), 2.38 (3H, s), 3.64 (1H, dd, J = 8.3, 8.3 Hz), 4.49 (1H, brd, J = 8.3 Hz), 4.88 (1H, dd, J = 8.3, 15.7 Hz), 5.06 (1H, d, J = 15.7 Hz), 7.22 (2H, d, J = 8.3 Hz), 7.71 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −8.1, −7.1, 17.5, 21.6, 27.2, 29.4, 32.7, 46.3, 122.7, 127.7, 129.6, 138.9, 140.2, 143.1; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{20}H_{35}NO_2SSi$ 404.2050, found 404.2060.

(*E*)-*N*-(1-(*tert*-Butyldimethylsilyl)-3-phenylallyl)-*p*-toluenesulfonamide (7j). Colorless needles (CH_2Cl_2/hexane). 67% yield, 56 mg (from 80 mg of **6j**); mp = 140.0−140.5 °C; R_f = 0.13 (hexane/Et_2O = 3:1); $[\alpha]^{28}_D$ +91.7 (c 1.05, $CHCl_3$) (er = 97:3); Chiralcel OD-H (25 + 15 cm), hexane/*i*-PrOH = 20:1, flow rate 0.70 mL/min, detection at 254 nm, t_R = 18.4 min (minor) and 27.9 min (major), er = 97:3; IR (KBr) 3252, 2953, 2931, 2856, 2361, 2337, 1597 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ −0.07 (3H, s), 0.06 (3H, s), 0.96 (9H, s), 2.20 (3H, s), 3.84 (1H, dd, J = 8.4, 8.4 Hz), 4.85−4.92 (1H, brm), 5.69 (1H, dd, J = 15.9, 8.4 Hz), 5.97 (1H, d, J = 15.9 Hz), 6.98 (2H, d, J = 7.3 Hz), 7.11 (2H, d, J = 8.1 Hz), 7.14 (1H, t, J = 7.3 Hz), 7.21 (2H, dd, J = 7.3, 7.3 Hz), 7.74 (2H, d, J = 8.1 Hz) ; ^{13}C NMR ($CDCl_3$) δ −8.0, −7.1, 17.5, 21.4, 27.1, 46.9, 126.0, 127.0, 127.7, 128.0, 128.4, 128.4, 129.5, 137.1, 138.5, 143.4; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{31}NO_2SSi$ 424.1737, found 424.1735.

(*E*)-*N*-(1-(*tert*-Butyldimethylsilyl)-3-(3-methoxyphenyl)allyl)-*p*-toluenesulfonamide (7k). Colorless needles (CH_2Cl_2/hexane). 60% yield, 52 mg (from 89 mg of **6k**); mp = 139.0−140.0 °C; R_f = 0.16 (hexane/Et_2O = 2:1); $[\alpha]^{27}_D$ −24.3 (c 1.25, $CHCl_3$) (er = 97:3); Chiralcel OD-H (25 + 15 cm), hexane/*i*-PrOH = 10:1, flow rate 0.70 mL/min, detection at 254 nm, t_R = 17.0 min (minor) and 29.4 min (major), er = 97:3; IR (KBr) 3299, 3029, 2948, 2931, 2890, 2857, 1645, 1604, 1576 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ −0.02 (3H, s), 0.04 (3H, s), 0.95 (9H, s), 2.23 (3H, s), 3.77 (3H, s), 3.84 (1H, dd, J = 8.3, 8.3 Hz), 4.65−4.70 (1H, brm), 5.67 (1H, dd, J = 15.8, 8.3 Hz), 5.93 (1H, d, J = 15.8 Hz), 6.50 (1H, brs), 6.58 (1H, d, J = 7.6 Hz), 6.70 (1H, dd, J = 8.3, 2.5 Hz), 7.10−7.14 (3H, m), 7.72 (2H, d, J = 8.1 Hz); ^{13}C NMR ($CDCl_3$) δ −8.0, −7.1, 17.5, 21.5, 27.1, 46.9, 55.3, 111.8, 112.3, 118.8, 127.8, 128.3, 128.4, 129.4, 129.6, 138.5, 138.6, 143.5, 159.8; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{23}H_{33}NO_3SSi$ 454.1843, found 454.1842.

(*E*)-*N*-(1-(*tert*-Butyldimethylsilyl)-3-(2-chlorophenyl)allyl)-*p*-toluenesulfonamide (7l). Colorless needles (CH_2Cl_2/hexane). 27% yield, 23 mg (from 87 mg of **6l**); mp = 139.0−140.0 °C; R_f = 0.24 (hexane/Et_2O = 2:1); $[\alpha]^{26}_D$ +66.9 (c 1.07, $CHCl_3$) (er = 97:3); Chiralcel OD-H (25 + 15 cm), hexane/*i*-PrOH = 20:1, flow rate 0.70 mL/min, detection at 254 nm, t_R = 20.5 min (minor) and 30.2 min (major), er = 97:3; IR (KBr) 3291, 2952, 2931, 2891, 2856, 1633, 1597 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.00 (3H, s), 0.07 (3H, s), 0.96 (9H, s), 2.22 (3H, s), 3.85 (1H, dd, J = 8.5, 8.5 Hz), 4.68 (1H, d, J = 8.5 Hz), 5.69 (1H, dd, J = 16.1, 8.5 Hz), 6.36 (1H, d, J = 16.1 Hz), 6.96−6.98 (1H, m), 7.07−7.11 (2H, m), 7.15 (2H, d, J = 8.1 Hz), 7.26−7.28 (1H, m), 7.74 (2H, d, J = 8.1 Hz) ; ^{13}C NMR ($CDCl_3$) δ −8.0, −7.1, 17.5, 21.4, 27.1, 47.1, 124.6, 126.5, 126.6, 127.8, 128.1, 129.6, 131.2, 132.5, 135.2, 138.1, 143.4; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{30}NO_2ClSSi$ 458.1347, found 458.1347.

***N*-(1-(*tert*-Butyldimethylsilyl)-3-phenylprop-1-en-1-yl)-*p*-toluenesulfonamide (10j).** Colorless plates (CH_2Cl_2/hexane). 22% yield, 18 mg (from 80 mg of **6j**); mp = 96.5−97.0 °C; R_f = 0.26 (hexane/Et_2O = 3:1); IR (KBr) 3276, 2954, 2926, 2891, 2853, 1599 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.13 (6H, s), 0.87 (9H, s), 2.42 (3H, s), 3.38 (2H, d, J = 8.0 Hz), 5.56 (1H, s), 6.35 (1H, t, J = 8.0 Hz), 6.97 (2H, d, J = 7.4 Hz), 7.17−7.24 (5H, m), 7.67 (2H, d, J = 8.3 Hz); ^{13}C NMR ($CDCl_3$) δ −4.2, 18.1, 21.7, 26.8, 36.2, 126.2, 128.0, 128.3, 128.5, 129.4, 129.6, 133.5, 137.0, 140.3, 143.7; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{31}NO_2SSi$ 424.1737, found 424.1734.

***N*-(1-(*tert*-Butyldimethylsilyl)-3-(3-methoxyphenyl)prop-1-en-1-yl)-*p*-toluenesulfonamide (10k).** Colorless prisms (CH_2Cl_2/hexane). 18% yield, 16 mg (from 89 mg of **6k**); mp = 97.0−98.0 °C; R_f = 0.28 (hexane/Et_2O = 2:1); IR (KBr) 3282, 3060, 2961, 2926, 2884, 2852, 1908, 1598 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.13 (6H, s), 0.87 (9H, s), 2.41 (3, s), 3.35 (2H, d, J = 8.0 Hz), 3.78 (3H, s), 5.54 (1H, s), 6.33 (1H, t, J = 8.0 Hz), 6.57−6.58 (2H, m), 6.74 (1H, dd, J = 8.0, 2.3 Hz), 7.15 (1H, dd, J = 8.0, 8.0 Hz), 7.22 (2H, d, J = 8.1 Hz), 7.67 (2H, d, J = 8.1 Hz); ^{13}C NMR ($CDCl_3$) δ −4.2, 18.1, 21.7, 26.8, 36.2, 55.3, 111.6, 114.1, 120.7, 127.9, 129.4, 129.5, 129.7, 133.5, 137.1, 141.9, 143.8, 159.9; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{23}H_{33}NO_3SSi$ 454.1843, found 454.1843.

***N*-(1-(*tert*-Butyldimethylsilyl)-3-(2-chlorophenyl)prop-1-en-1-yl)-*p*-toluenesulfonamide (10l).** Colorless plates (Et_2O/hexane). 31% yield, 27 mg (from 87 mg of **6l**); mp = 120.0−120.5 °C; R_f = 0.39 (hexane/Et_2O = 2:1); IR (KBr) 3444, 3279, 2953, 2928, 2852, 1597 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.12 (6H, s), 0.87 (9H, s), 2.43 (3H, s), 3.44 (2H, d, J = 8.0 Hz), 5.59 (1H, s), 6.30 (1H, t, J = 8.0 Hz), 6.91 (1H, d, J = 7.5 Hz), 7.10 (1H, dd, J = 7.5, 7.5 Hz), 7.14 (1H, dd, J = 7.5, 7.5 Hz), 7.26 (2H, d, J = 8.1 Hz), 7.31 (1H, d, J = 7.5 Hz), 7.72 (2H, d, J = 8.1 Hz); ^{13}C NMR ($CDCl_3$) δ −4.3, 18.1, 21.8, 26.8, 33.5, 126.9, 127.6, 128.0, 129.3, 129.4, 129.7, 133.9, 134.7, 137.1, 138.1, 143.9; HRMS-ESI (m/z) [M + Na]$^+$ calcd for $C_{22}H_{30}O_2NClSSi$ 458.1347, found 458.1346.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

Copies of ^{1}H and ^{13}C NMR spectra of all new compounds, chiral HPLC analyses of compound **7a**−**l**, computational methods and crystallographic data of (*S*)-**7a** and (*R*)-**7e**. This material is available free of charge via the Internet at http://pubs.acs.org.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: misasaki@hiroshima-u.ac.jp.

Notes

The authors declare no competing financial interest.

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(23) All of these transition structures were located using chairlike six-membered conformations as an initial geometry, in which the amide-lithium atom coordinates to the imine-nitrogen atom. Attempts to locate a chairlike six-membered conformation resulted in conversion to deformed ones. We also calculated energies of the corresponding transition state structures in which a piperazine acts as a bidentate ligand to the lithium atom by adopting a boat-like conformation, showing that they have energies higher than that of TS-A. Although we also tried to locate transition structures with one THF molecule, the search failed in some cases. In successful cases, the geometry of the selectivity-determining groups was not much different from that of ones without THF.
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