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Stereoselective Addition of α-Methylsulfenyl Benzyl Carbanions to *N*-Sulfinylketimines: Asymmetric Synthesis of α,α-Dibranched *β*-Sulfanyl Amines

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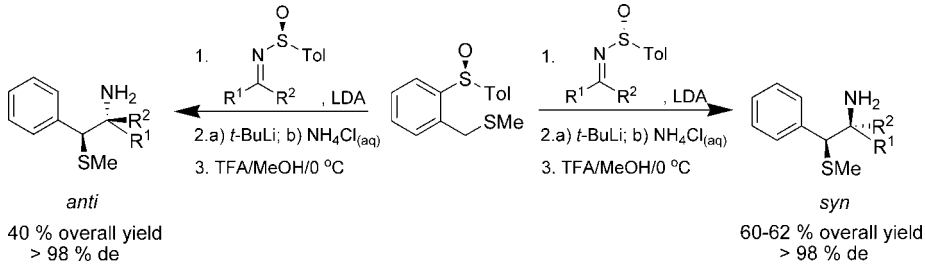
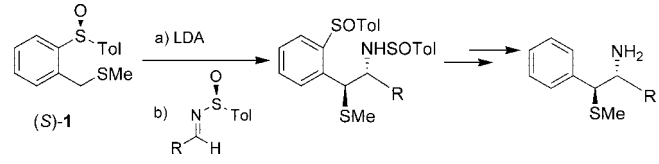


(*R*)- and (*S*)-*N*-sulfinylketimines react with the *ortho*-sulfinyl benzyl carbanion derived from (*S*)-**1** affording epimeric mixtures at the benzylic carbon of α,α-dibranched *β*-sulfanyl amines. The *N*-sulfinyl group completely controls the configuration at the quaternary carbon bonded to the nitrogen, whereas the *C*-sulfinyl group is responsible for the level of asymmetric induction. High stereoselectivity can be achieved when the configuration at the sulfur atoms of the reagents are opposite (matched pair). After a two-step desulfinylation process, this reaction provides a procedure for synthesizing diastereomerically pure *syn*-1,2-sulfanyl amines containing a chiral quaternary carbon adjacent to nitrogen.

Introduction

vic-Sulfanyl amines are valuable building blocks,[1] which are characteristic motifs in bioactive natural products,[2] and pharmacologically important compounds.[3] Furthermore, from a synthetic point of view, they have proven to be efficient heterobidentate *N*,*S*-ligands in asymmetric reactions.[4] As a consequence of their importance, numerous methods for the synthesis of these compounds have been reported.[5] In this field, we have demonstrated recently that carbanion derived from (*S*)-**1** reacts with (*S*)-*N*-sulfinylaldimines with complete control of the stereoselectivity at the two simultaneously formed chiral centers (Scheme 1) affording *anti*-1,2-sulfanyl amines.[6]

SCHEME 1



In this context, *vic*-sulfanyl amines possessing a quaternary *N*-substituted stereocenter potentially might have a major significance because of the restricted conformational mobility imposed by the quaternary carbon. However, to the best of our knowledge, the asymmetric synthesis of these compounds has never been reported, which prompted us to study the reactions of *N*-sulfinylketimines with (*S*)-**1**. The use of ketimines as electrophiles in reactions with organometallic reagents has always been a major challenge in asymmetric synthesis; their use suffers many drawbacks derived from their poor electrophilic

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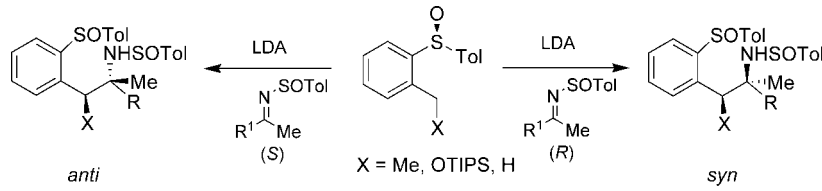
SCHEME 2



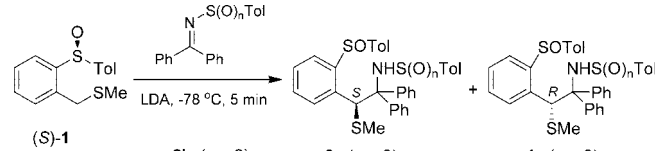
character and propensity for enolization.[7] Furthermore, the facile (*E,Z*) isomerization decreases the possibility of highly diastereoselective processes.[8] The breakthrough in this area came when Ellman discovered that reactions of *N-tert*-butanesulfinylketimines with organometallic reagents in the presence of Me_3Al provided a general method to prepare α,α-dibranched amines.[9] More recently, the enantioselective allylation of ketone-derived imino compounds[10] and the radical addition of alkyl iodides to *N*-acylhydrazonoesters via Mn-mediated coupling reactions[11] to afford *tert*-alkyl amines have been reported. In this field, we also have reported the stereoselective benzylation of *N*-sulfinylketimines with 2-(*p*-tolylsulfinyl) benzyl carbanions to afford any epimer of α,α-dibranched β-phenyl ethyl and propylamines (Scheme 2).[12] In these reactions, the *N*-sulfinyl group completely controls the configuration of the aminic carbon, whereas the *ortho*-sulfinyl group is responsible for the configuration at the benzylic carbon.

With these precedents, we have studied the behavior of (*S*)-**1** with *N*-sulfinylketimines. The synthetic results obtained in this study as well as the transformation of the resulting compounds into the desired optically pure α,α-dibranched β-sulfanyl amines and the theoretical calculations supporting the mechanistic proposal are reported in this paper.

Results and Discussion

We first studied the behavior of (*S*)-**1** with the symmetrical and nonenolizable *N*-sulfonyl and *N*-sulfinyl derivatives of benzophenone (Table 1). The reaction of (*S*)-**1** with *N*-sulfonylketimine **2′a** in the presence of LDA leads to an almost equimolecular mixture of two possible diastereoisomers, **3a** and **4a** (Table 1, entry 1). This is evidence that the sulfinyl group at the nucleophile is not able to control the stereoselectivity of the process, which contrasts with the results obtained in most of the reactions so far studied with these benzyl carbanions, suggesting a decisive role of the SMe group in this change of behavior. The reaction of (*S*)-**1** with *N*-sulfinylketimine (*S*)-**2a** affords in a few minutes a 78:22 mixture of two diastereoisomers, **5a** and **6a**, which are epimers at the newly created stereogenic center (Table 1, entry 2).[13] Under similar conditions, (*R*)-**2a** afforded a 94:6 mixture of **7a** and **8a** (88% de, Table 1, entry 3). The major **7a** was isolated in 85% yield.

TABLE 1. Reaction of (*S*)-1 with Ketimines 2a



2'a (n = 2) (*S*)-**2a** (n = 1) (*R*)-**2a** (n = 1) — **3a** (n = 2) **5a** (n = 1) **7a** (n = 1) — **4a** (n = 2) **6a** (n = 1) **8a** (n = 1)

entry	imine (equiv)	yield[a] (%)	diastereomeric ratio[b]	de (%)
1	**2′a** (1.5)	95	**3a** (55):**4a** (45)	10
2	(*S*)-**2a** (1.5)	84	**5a** (78):**6a** (22)	56
3	(*R*)-**2a** (1.5)	89	**7a** (94):**8a** (6)	88

[a] Combined yield. [b] Determined by ^{1}H NMR on the crude reaction mixture.

The configurational assignment of stereoisomers **5a** and **7a** was made by chemical correlation (Scheme 3). Both compounds **5a** and **7a** were transformed into the 1,2-sulfanyl amine **9** by TFA hydrolysis of their *N*-sulfinyl moieties, indicating that **5a** and **7a** have an identical configuration at the benzyl carbon (they only differ in the *N*-sulfinyl configuration), which reveals the

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(13) Under a substoichiometric amount of (*S*)-**2a**, a significant increase in stereoselectivity was observed with de increasing to more than 98% by adding 0.5 equiv of the electrophile.

SCHEME 3. Chemical Correlation of Compounds 5a and 7a

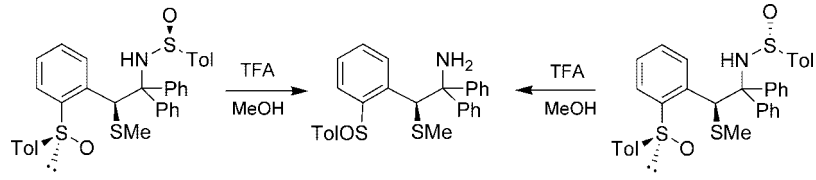
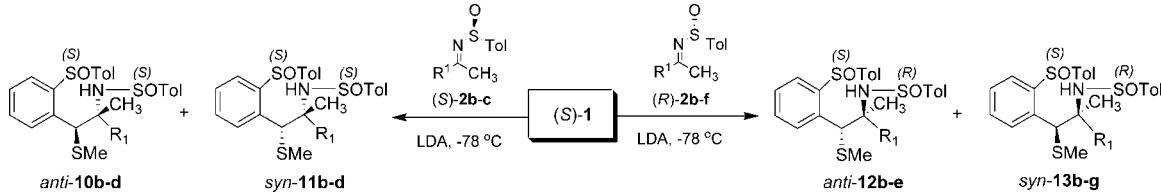


TABLE 2. Reaction of (*S*)-1 with *N*-Sulfinylketimines (*S*)- and (*R*)-2b−g



			diastereomeric ratio[a]			
entry	R^1	imine	*anti*-**10**:*syn*-**11**	*anti*-**12**:*syn*-**13**	de (%)	yield (%)[b]
1	Ph	(*S*)-**2b**	65:35		30	83
2	*p*-$MeOC_6H_4$	(*S*)-**2c**	68:32		36	76
3	*p*-BrC_6H_4	(*S*)-**2d**	60:40		20	67
4	Ph	(*R*)-**2b**		5:95	90	87
5	*p*-MeC_6H_4	(*R*)-**2c**		4:96	92	79
6	*p*-$MeOC_6H_4$	(*R*)-**2d**		4:96	92	84
7	*p*-BrC_6H_4	(*R*)-**2e**		8:92	84	70
8	*p*-CNC_6H_4	(*R*)-**2f**		−:>98	98	82
9	*i*-Pr	(*R*)-**2g**		−:>98	98	75

[a] Determined by ^{1}H NMR on the crude reaction mixture. [b] Combined yield.

configuration is mainly controlled by the *ortho*-sulfinyl group at the starting nucleophile (*S*)-**1**. Taking into account that all reactions so far studied of electrophiles with (*S*)-**1**[6,14] or other γ-sulfinyl benzyl carbanions[12,15] have afforded the (*S*) configuration at the benzylic carbon as the major or exclusive diastereoisomer, we have assumed that amine **9** and their precursors **5a** and **7a** also exhibit the (*S*) configuration at the benzylic carbon.

Next, we studied the reactions of (*S*)-**1** with both enantiomers of nonsymmetrical *N*-sulfinylketimines **2b** derived from acetophenone, where two stereogenic centers (one quaternary) were simultaneously formed. The reaction of (*S*)-**1** with (*S*)-**2b** afforded a 65:35 mixture of compounds *anti*-**10b** and *syn*-**11b**, readily separated by chromatography, with the *anti* isomer being the major one (Table 2, entry 1).[16] The reaction of (*S*)-**1** with (*R*)-**2b** is highly diastereoselective, affording a 95:5 mixture of *syn*-**13b** and *anti*-**12b** (Table 2, entry 4). As these reactions produced only two of the four possible diastereoisomeric β-sulfanyl amines, it must be concluded that they evolve with complete control of stereoselectivity in one of the two newly created chiral centers. On the other hand, the fact that the stereoselectivity is very similar to that observed in the reactions of (*S*)-**1** with (*R*)-**2a** and (*S*)-**2a** (Table 1) suggests that the resulting compounds must be epimers at the carbon joined to the SMe group.

To check the scope of these processes, we have studied the behavior of different *N*-sulfinylketimines with the carbanion derived from (*S*)-**1** (Table 2, entries 2, 3, and 5−9). Reactions carried out with ketimines (*S*)-**2c** and (*S*)-**2d**, with an aromatic ring electron-donating group and a weakly electron-withdrawing group, respectively, afforded diastereoisomeric mixtures of composition similar to that observed for (*S*)-**2b** (36 and 20% de, respectively; Table 2, entries 2 and 3). This indicates the limited influence of the electronic factors on the diastereoselectivity of these processes. Reactions carried out with (*R*)-*N*-sulfinylketimines showed a similar behavior with a very high stereoselectivity for (*R*)-ketimines containing an electron-donating group [(*R*)-**2c** and (*R*)-**2d**, Table 2, entries 5 and 6] or a weakly electron-withdrawing group [(*R*)-**2e**, Table 2, entry 7] (de ranges between 84 and 92%). Stereoselectivity becomes complete (de >98%) for (*R*)-**2f**, which contains a strongly electron-withdrawing group (Table 2, entry 8), and for the dialkyl ketimine (*R*)-**2g** (Table 2, entry 9). These results indicate that reactions of 2-*p*-tolylsulfinyl-α-methylsulfenyl benzyl carbanions with *N*-sulfinylketimines provide a good alternative for the asymmetric synthesis of β-sulfanyl amines. The *N*-sulfinyl group completely controls the configuration at the quaternary chiral carbon joined to the nitrogen. When the configuration at the sulfinyl groups of both reagents is opposite, the *ortho*-sulfinyl group is also highly efficient in controlling the configuration of its benzylic carbon, thus providing *syn*-**13** in a highly stereoselective manner and good yields. When the configuration of the reagents is the same, the efficiency of the *ortho*-sulfinyl group is lower and easily separable mixtures of diastereoisomers are obtained, with *anti* β-sulfanyl amines **10** being the major ones.

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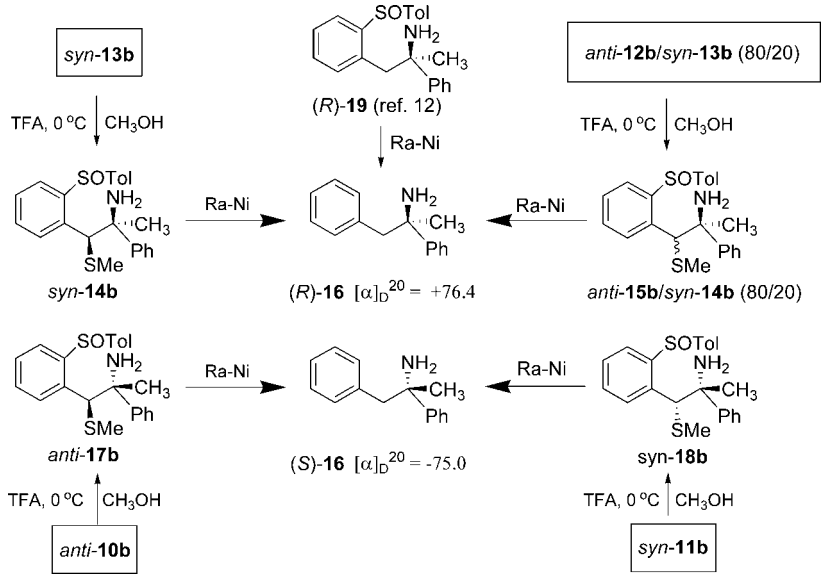
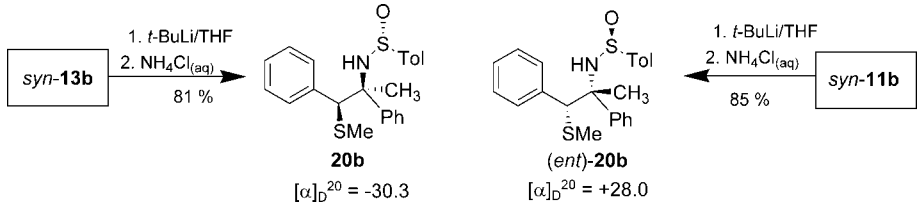
(16) As occurred with (*S*)-**2a** (see ref 13), we observed an increase in de (80%) when a substoichiometric amount of (*S*)-**2b** was added, but total control of the stereoselectivity was not possible in this case.

SCHEME 4. Chemical Correlation of Compounds 10b−13b Establishing the Configuration at the Aminic Carbon (C2)



SCHEME 5. Confirmation of the Stereochemical Assignments Indicated in Table 2



Configurational Assignment. The configurational assignment of compounds **10b−13b** was made by chemical correlation (Schemes 4 and 5). Compounds *syn*-**13b** (pure) and *anti*-**12b** (80:20 mixture of *anti*-**12b**:*syn*-**13b**), obtained by chromatographic separation from the reaction mixture resulting in entry 4 of Table 2, were both transformed into **16** by *N*-desulfinylation with TFA followed by hydrogenolysis of the two C−S bonds with Raney nickel (Ra-Ni). This means that the configuration of carbon bonded to the amine group is identical for *syn*-**13b** and *anti*-**12b**. Absolute stereochemistry for **16** was established as (*R*) by chemical correlation (*C*-desulfinylation with Ra-Ni) with the known (*R*)-**19**.[12] The optical purity of (*R*)-**16** (>98% ee) was established by ^{1}H NMR studies of its (*R*)- and (*S*)-MPTA amides. Compounds *syn*-**14b** and *anti*-**15b** (Scheme 4) then will exhibit the same configuration at aminic carbon (*R*) and at sulfur (*S*) (the last one depends only on the starting *N*-sulfinylketimine). As they are diastereoisomers (NMR), they and their precursors *syn*-**13b** and *anti*-**12b** should exhibit a different configuration at C3. Similar conclusions could be established for compounds *anti*-**10b** and *syn*-**11b** (both obtained pure by chromatography from the reaction mixture resulting in entry 1 of Table 2), which were both desulfinylated into the amine (*S*)-**16**, with identical spectroscopic parameters but specific rotation in the opposite sign of that observed for (*R*)-**16** (Scheme 4).

Taking into account that the major isomers obtained in the reactions of (*S*)-**1** with imines (*R*)-**2** and (*S*)-**2** must exhibit an (*S*) configuration at the benzylic carbon joined to the SMe group (see above), we have assigned the absolute configurations indicated in Table 2 for compounds **10b−13b**. In order to confirm these assignments, compounds *syn*-**13b** and *syn*-**11b** were *C*-desulfinylated with *t*-BuLi into **20b** and its enantiomer *ent*-**20b**, respectively (Scheme 5), which means they differ in configuration at their two chiral carbons. The configurational assignment of the different diastereoisomers **10−13** indicated in Table 2 is based on the assumption that the stereochemical evolution of the reactions of (*S*)-**1** with (*R*) and (*S*) enantiomers is identical for compounds **2c−g**.

The stereochemical model proposed for justifying the results indicated in Table 2 should explain that the configuration at the aminic carbon is completely controlled by the sulfinyl group at the starting ketimine [(*R*)-**2** and (*S*)-**2** yield isomers with (*S*) and (*R*) configuration at the aminic carbon, respectively] and that the sulfinyl group at the nucleophile is responsible for the configuration at the benzyl carbon in the major isomers (identical to that of the starting sulfinyl benzyl carbanion) and the level of asymmetric induction observed in each reaction (very high when the configurations at the two sulfinyl reagents are different, but moderate when they are the same).

Before formulating the mechanistic proposal, we needed to have some information about the conformational preferences of sulfinylketimines **2** and the configurational stability of the α-sulfenylcarbanion **1**, acting as the electrophile and nucleophile in these reactions, respectively. In this sense, information provided by theoretical calculations is highly valuable.

The conformational stabilities of the different rotamers of the ketimines around the N−S bond have been studied theoretically at the DFT (B3LYP)[17] level by using the Gaussian03 program.[18,19] The (*E*)-*N*-phenylsulfinylimine derived from ac-

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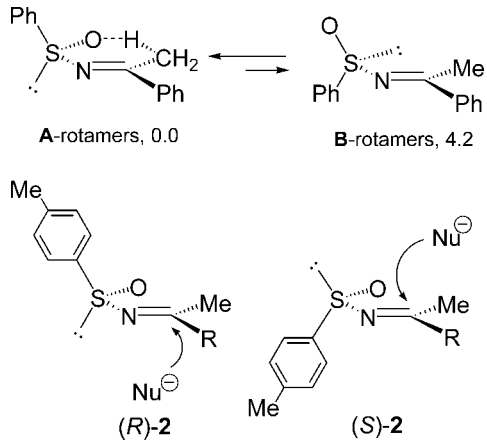


FIGURE 1. Relative energies of the most stable conformations of ketimines [kcal·mol^{-1}, zero-point energy (ZPE) correction included] and nucleophilic attack preferred for (*R*)-**2** and (*S*)-**2** in their most stable s-*cis* rotamers.

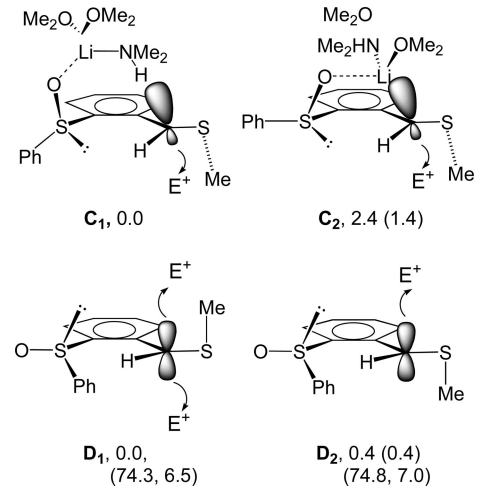


FIGURE 2. Molecular structures and energies (kcal·mol^{-1}) of possible carbanionic species and favored approaches for E^+. The first value indicates the relative energy, with the ZPE correction included, between structures **C** and **D**, separately. The free energy correction is indicated in parentheses. For structures **D** in the second row, relative free energies with respect to $\mathbf{C_2}$ [**D** + Li(NHMe$_2$)(OMe$_2$)$_3$-$\mathbf{C_2}$-OMe$_2$] are indicated first in vacuo, and second "in THF" (mimicked by IEFPCM).

etophenone was used as a model (Figure 1). Rotamer **A**, with the sulfinyl oxygen in s-*cis* arrangement with respect to the C=N bond, was 3.0 kcal/mol more stable than rotamer **B**, with the lone electron pair in the s-*cis* arrangement despite the latter being favored from the steric point of view. The higher stability of rotamer **A** may be because of the minimization of the dipolar moment (3.16 and 4.72 D for **A** and **B**, respectively), along with the significant contribution of a stabilizing hydrogen bond between the sulfinyl oxygen and the CH_3 group (d(SO···HCH$_2$) = 2.17 Å; θ(O···H−C) = 136.6°). This energy difference is enough to shift the conformational equilibrium toward rotamer **A** almost completely, which arranges the phenyl group blocking the upper face of the C=N plane (Figure 1), and therefore determines that the nucleophilic attack of the benzyl carbanion to imines (*R*)-**2** and (*S*)-**2** only takes place at the bottom and upper faces, respectively (Figure 1). It explains the configurations at the aminic carbons of the isomers shown in Table 2.

The formation of mixtures of epimers at benzylic carbon in reactions of (*S*)-**1** with (*R*)-**2** and (*S*)-**2** indicates that the approach of the electrophile to the benzyl carbanion takes place at either of its two diastereotopic faces. It could be due to a moderately stereoselective evolution of the carbanionic species generated from (*S*)-**1**. However, the complete control of the configuration observed in reactions of (*S*)-**1** with *N*-sulfinylaldimines[6] questioned this explanation. A second possibility could be the formation of two carbanionic species evolving into different diastereoisomers, whose relative reactivity is dependent on the electrophile. It would indicate that the configurational stability of the carbanion generated from (*S*)-**1** must be lower than that of the methyl 2-*p*-tolylsulfinyl benzyl carbanion previously studied, which reacted with ketimines and other electrophiles with complete control of the configuration.[12,15] We have studied the relative stability of the possible structures for the carbanion derived from (*S*)-**1** by theoretical calculations.[20] The most stable structures found for model carbanion−Li^+ complexes and free carbanions are shown in Figure 2. Dimethyl ether and dimethylamine were used as a simplified model for the solvent and base, respectively, and have been included as ligands for the lithium atom. The tolyl group also has been simplified as a phenyl one. The most stable carbanion−Li^+ complex is the chelated species $\mathbf{C_1}$, with the sulfinyl oxygen coordinated to the lithium atom and the carbanion stabilized by a hydrogen bond with the dimethylamine ligand. This type of complex probably would be the first formed after the deprotonation step. The boat-like structure $\mathbf{C_2}$, with the lone electron pair on sulfur and the hydrogen arranged toward the flagpoles of the boat,[21] exhibits the Me group joined to the sulfur atom in an antiperiplanar arrangement with respect to the C−Li bond, thus contributing to its stabilization by the interaction $\sigma_{C-Li}{}^2 \rightarrow \sigma^*_{S-Me}$.[22] In these two complexes, the presence of the metal with its ligands precludes the approach of the electrophile to the upper face of the anion (Figure 2), which will be attacked only by the bottom face. Taking into account steric effects during the approach of the electrophile, a higher reactivity for $\mathbf{C_2}$ could be expected. In the case of structures **D**, in which Li^+ is not stabilizing the carbanion, the upper face will show much less steric interaction during the approach of the electrophile,

(19) Geometries have been fully optimized using the standard 6-31G(d) basis set for all of the atoms: (a) Ditchfield, R.; Hehre, W. J.; Pople, J. A. *J. Chem. Phys.* **1971**, *54*, 724. Frequencies and ZPE were also computed at the same level of theory. Final energies have been obtained using the more extended 6-311+G** basis set for all atoms: (b) McLean, A. D.; Chandler, G. S. *J. Chem. Phys.* **1980**, *72*, 5639. (c) Krishnan, R.; Binkley, J. S.; Seeger, R.; Pople, J. A. *J. Chem. Phys.* **1980**, *72*, 650. Relative free energies (in kcal·mol^{-1} were evaluated at the B3LYP/6-311+G** level with ZPE and entropy corrections evaluated at 298 K using the frequencies previously calculated at the B3LYP/6-31G(d) level.

(20) Because of the importance of solvent effects, especially when charged species are involved, complexes **C** and **D** have also been optimized in a dielectric medium mimicking THF, using the IEF−PCM model: (a) Cancès, E.; Mennucci, B.; Tomasi, J. *J. Chem. Phys.* **1997**, *107*, 3032. (b) Cossi, M.; Barone, V.; Mennucci, B.; Tomasi, J. *Chem. Phys. Lett.* **1998**, *286*, 253.

(21) A similar structure has been suggested from theoretical calculations as the most reactive and, therefore, being responsible for the good selectivity observed in the reactions of methyl 2-*p*-tolylsulfinyl benzyl carbanions: García Ruano, J. L.; Alemán, J.; Alonso, I.; Parra, A.; Marcos, V.; Aguirre, J. *Chem.−Eur. J.* **2007**, *13*, 6179.

(22) (a) Wiberg, K. B.; Castejon, H. *J. Am. Chem. Soc.* **1994**, *116*, 10489. (b) Kaiser, B.; Hoppe, D. *Angew. Chem., Int. Ed. Engl.* **1995**, *34*, 323. (c) Dress, R. K.; Rolle, T.; Hoffmann, R. W. *Chem. Ber.* **1995**, *128*, 673. (d) Lehn, J. M.; Wipff, G.; Demuynck, J. *Helv. Chim. Acta* **1977**, *60*, 1239. (e) Brandt, P.; Haeffner, F. *J. Am. Chem. Soc.* **2003**, *125*, 48. Orbital interactions (kcal·mol^{-1}) evaluated by means of a second-order perturbational analysis of the Fock matrix on the NBO basis (natural bond orbital method of Weinhold) indicate that the charge is mainly delocalized to the aromatic ring ($C_{Bn} \rightarrow \pi^* C_{ipso}-C_{orthoSO} = 66.6$), but a stabilizing interaction with the S−Me bond is observed also ($C_{Bn} \rightarrow \sigma^*_{S-Me} = 10.6$). (f) Reed, A. E.; Curtiss, L. A.; Weinhold, F. *Chem. Rev.* **1988**, *88*, 899.

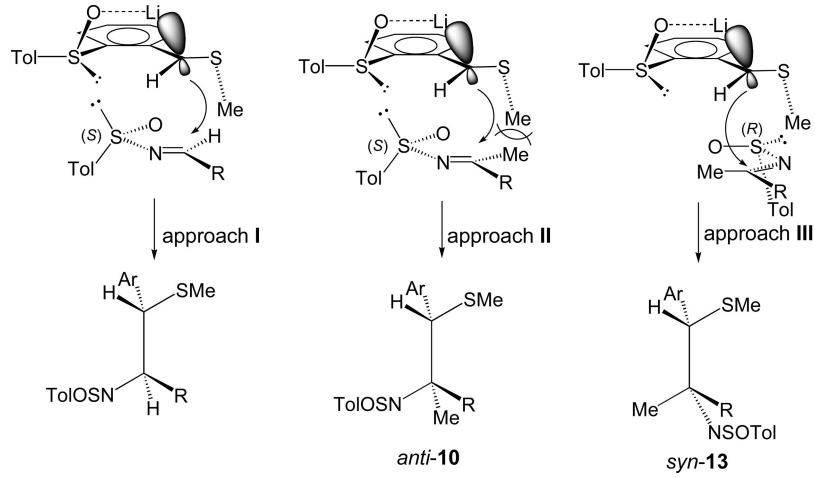


FIGURE 3. Favored approaches of the imines to Li^+[(*S*)-**1**] adopting the **C** structure.

especially in $\mathbf{D_2}$, which is quite close in energy to $\mathbf{D_1}$. These species are much more unstable in vacuo than the chelated species $\mathbf{C_2}$ (≈79 kcal·mol^{-1}). However, taking into account solvent effects, the difference in energy dramatically decreases (≈5 kcal·mol^{-1}), and the participation of these free carbanion species during the reaction cannot be underestimated.[23] In fact, they could explain the formation of minor products *anti*-**12** and *syn*-**11**. Because polar solvents stabilize uncoordinated species, and sulfinylimines are quite polar, a decrease in the degree of participation of species **D** could be the cause of the increase in stereoselectivity observed in the reaction using substoichiometric amounts of (*S*)-**2a** and (*S*)-**2b**.[13,16]

The favored approaches of (*R*)-**2** and (*S*)-**2** to the anion derived from (*S*)-**1** adopting the $\mathbf{C_2}$ structure are depicted in Figure 3. We also have included the reaction with (*S*)-*N*-sulfinylaldimines.[6] In the latter case, approach I does not present serious steric interactions, thus explaining the complete stereoselectivity observed, which only results in β-sulfanyl amines with the (*S*) configuration at benzylic carbon. A similar approach for (*S*)-ketimines (approach II) must be less stable because of the steric repulsion between the two methyl groups. It can be minimized by the SMe bond losing its antiperiplanar arrangement with respect to the C−Li bond, but it would decrease the stability of the benzyl carbanion, with the possiblity that other carbanionic species could participate in the reaction (see later). Finally, reactions of (*R*)-**2** with the anion $\mathbf{C_2}$, according to approach III (Figure 3), which would yield compounds *syn*-**13**, would be sterically more favorable than II (the size of the planar nitrogen is lower than the Me group) and significantly stabilized by the hydrogen bond between the nitrogen (negatively charged in the transition state) and the Me joined to sulfur.

The minor components of the reaction mixtures [*anti*-**12** with (*R*)-**2** and *syn*-**11** with (*S*)-**1**], with (*R*) configuration at the benzylic carbon, could come from the planar nonchelated species $\mathbf{D_2}$, in which the sulfinyl oxygen is arranged in the position minimizing the electrostatic repulsion with the carbanionic center (Figure 4). The evolution of $\mathbf{D_2}$ would explain the formation of the minor diastereoisomers *syn*-**11** [from (*S*)-**2**, approach IV] and *anti*-**12** [from (*R*)-**2**, approach **V**] obtained in the reactions of Table 2. The fact that the stereoselectivity of the reactions of (*S*)-**1** with (*R*)-**2** is higher than that with (*S*)-**2** can be explained by taking into account that the energy difference between the transition state corresponding to approaches III (Figure 3) and **V** (Figure 4) must be higher than that existing for approaches II and IV, mainly because of the expected higher stability of TS(III) with respect to TS(II) by steric grounds and hydrogen bond considerations (see before).

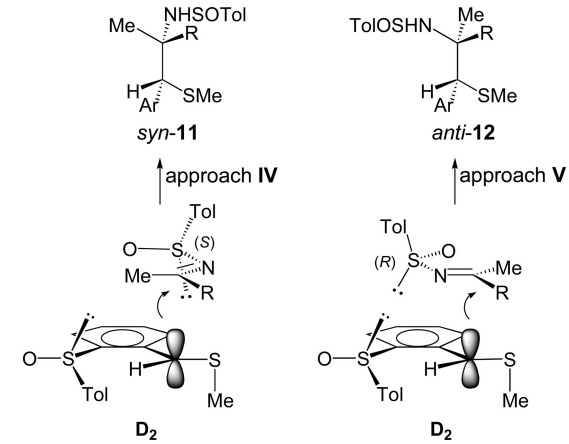


FIGURE 4. Favored approaches of the (*R*) and (*S*) imines to Li^+[(*S*)-**1**] adopting the $\mathbf{D_2}$ structure.

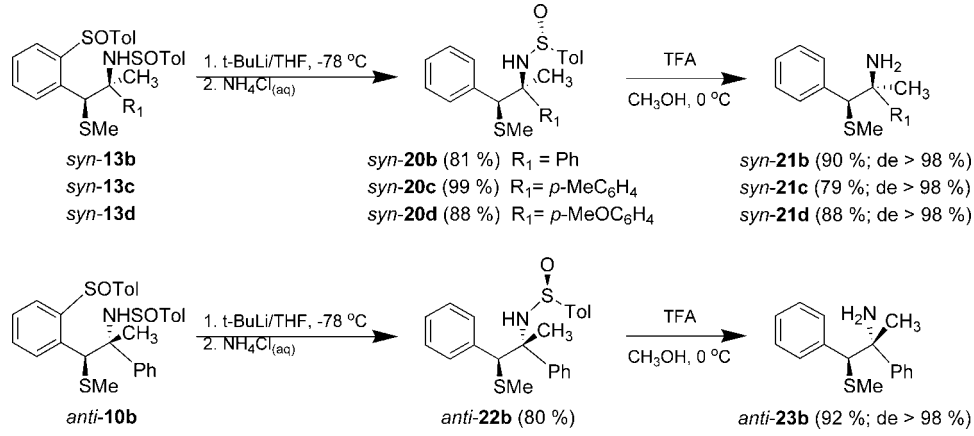
Compounds **10**−**13** were easily transformed into their corresponding α,α-dibranched β-sulfanyl amines *syn*-**21** and *anti*-**23** by subsequent *C*-desulfinylation (with *t*-BuLi) and *N*-desulfinylation (with TFA). These processes were investigated starting with *anti*-**10b**, *syn*-**13b**, *syn*-**13c**, and *syn*-**13d** (Scheme 6). In all cases, very high yields were obtained for both steps.

Conclusion

In summary, we have demonstrated that the reactions of the lithium carbanion derived from (*S*)-**1** with *N*-sulfinylketimines, followed by consecutive *C*- and *N*-desulfinylations of the resulting isomers, constitute a good alternative for the asymmetric synthesis of α,α-dibranched β-sulfanyl amines. When the configurations at the sulfinyl groups of the reagents are opposite, compounds with *syn* stereochemistry are obtained in a highly stereoselective manner and good yields, whereas for reagents with the same configuration, easily separable mixtures

(23) In the case of the methyl 2-phenylsulfinyl benzyl carbanion model, this difference is greater (13 kcal·mol^{-1}). This fact along with the lack of any steric hindrance at the bottom face of the equivalent $\mathbf{C_2}$ complex could explain the complete control of the configuration in the reactions of methyl 2-*p*-tolylsulfinyl benzyl carbanions with ketimines and other electrophiles (refs 12 and 15). These results confirm the lower configurational stability of the sulfenylated benzyl carbanion with respect to the methyl 2-*p*-tolylsulfinyl benzyl carbanion.

SCHEME 6. Conversion of *syn*-13b, *syn*-13c, *syn*-13d, and *anti*-10b into Corresponding Free *vic*-Sulfanyl Amines



of diastereoisomers are obtained, with the *anti* β-sulfanyl amines being the major ones. Theoretical calculations suggest that the presence of the SMe group at the benzylic position reduces the configurational stability of the carbanions generated at this position and supports the stereochemical proposal that explains the experimental results.

Experimental Section

General Procedure for the Reactions Summarized in Tables 1 and 2. A solution of *n*-BuLi (2.5 M in hexane, 1.5 mL, 0.6 mmol, 1.2 equiv) was added over *i*-Pr2NH (0.12 mL, 0.9 mmol, 1.8 equiv) in THF (3 mL) at 0 °C. After 30 min of stirring, the mixture was cooled to −78 °C, and then a solution of (*S*)-α-(methylsulfenyl)-2-(*p*-tolylsulfinyl)toluene[6] (138 mg, 0.5 mmol, 1 equiv) in THF (2 mL) was added. After 5 min of stirring, the electrophile [ketimine[12,8d] (**2′**, (*S*)-**2a**−**d** or (*R*)-**2a**−**g**), 1.0 mmol, 2 equiv] dissolved in THF (4 mL) was added at −78 °C. When the reaction was completed (3−5 min), the mixture was hydrolyzed at that temperature with saturated aqueous NH_4Cl solution (2 mL) and extracted with CH_2Cl_2 (3 × 10 mL). The combined organic layers were dried over $MgSO_4$, and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography.

[2*S*,*S*(*S*)]-*N*-{1,1-Diphenyl-2-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-2-(methylsulfenyl)ethyl}-*p*-toluenesulfinamide (5a). *N*-Sulfinylketimine (*S*)-**2a** was used as electrophile: eluent for chromatography hexane/Et_2O 1:5; yield 67%; white solid; mp 91−92 °C (hexane/Et_2O); $[\alpha]_D^{20} = -130.6$ (*c* 0.5, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.94 and 7.81 (2d, 3H, $J = 7.1$ Hz), 7.61−7.40 (m, 4H), 7.57, 7.50, 7.34, and 7.23 (two AA′BB′ systems, 8H), 7.40−7.16 (m, 6H), 7.01 (dd, 1H, $J = 7.7$, 4.9 Hz), 5.49 (bs, 1H), 5.14 (s, 1H), 2.43, 2.34 (2s, 6H), 0.89 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.2, 143.4, 142.7, 141.3, 140.4, 138.5, 135.7, 131.7, 130.3, 130.2, 130.1, 129.6, 129.0, 128.6, 128.0, 127.7, 127.5, 127.2, 125.0, 123.5, 73.2, 56.1, 21.4, 14.5; HRMS calcd for $C_{35}H_{34}NO_2S_3$ ($M^+ + 1$) 596.1746, found 596.1740.

[2*R*,3*S*,*S*(*S*)]-*N*-{2-Phenyl-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*anti*-10b). *N*-Sulfinylketimine (*S*)-**2b** was used as electrophile: eluent for chromatography hexane/Et_2O 1:4; yield 55%; white solid; mp 68−69 °C (hexane/Et_2O); $[\alpha]_D^{20} = -36.7$ (*c* 2.1, $CHCl_3$); FT IR(KBr) 3421, 1595, 1492, 1445, 1083 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.55 (d, $J = 8.7$ Hz, 1H), 7.48, 7.38, 7.20, and 7.08 (two AA′BB′ systems, 8H), 7.41 (dd, $J = 3.9$, 2.3 Hz, 2H), 7.40−7.22 (m, 6H), 6.39 (bs, 1H), 4.91 (s, 1H), 2.43 and 2.35 (2s, 6H), 2.21 (s, 3H), 1.23 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.6, 143.5, 140.9, 140.8, 140.5, 140.3, 139.5, 132.5, 131.7, 129.7, 129.4, 128.9, 128.2, 128.1, 127.8, 127.5, 125.3, 125.2, 64.9, 57.0, 29.4, 21.3, 21.2, 14.6; HRMS calcd for $C_{30}H_{32}NO_2S_3$ ($M^+ + 1$) 534.1589, found 534.1585.

[2*R*,3*S*,*S*(*S*)]-*N*-{2-(4-Methoxyphenyl)-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*anti*-10c). *N*-Sulfinylketimine (*S*)-**2c** was used as electrophile: eluent for chromatography hexane/Et_2O 1:15; yield 52%; white solid; mp 129−130 °C (hexane/Et_2O); $[\alpha]_D^{20} = -33.5$ (*c* 0.5, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.65 (t, 1H, $J = 8.6$ Hz), 7.55−7.48 (m, 2H), 7.44, 7.31, 7.30, 7.19, 7.08, and 6.79 (three AA′BB′ systems, 12H), 7.36−7.30 (m, 1H), 6.38 (bs, 1H), 4.88 (s, 1H), 3.78 (s, 3H), 2.42 and 2.35 (2s, 6H), 2.20 (s, 3H), 1.26 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.0, 143.7, 143.6, 140.9, 140.7, 131.8, 132.5, 131.6, 130.3, 129.6, 129.4, 128.2, 128.0, 125.3, 125.1, 112.7, 64.5, 57.3, 55.0, 28.2, 21.3, 21.2, 14.5; HRMS calcd for $C_{31}H_{34}NO_3S_3$ ($M^+ + 1$) 564.1695, found 564.1690.

[2*R*,3*S*,*S*(*S*)]-*N*-{2-(4-Bromophenyl)-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*anti*-10d). *N*-Sulfinylketimine (*S*)-**2d** was used as electrophile: eluent for chromatography hexane/Et_2O 1:15; yield 39%; white solid; mp 113−114 °C (hexane/Et_2O); $[\alpha]_D^{20} = -36.6$ (*c* 0.5, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.53−7.50 (m, 2H), 7.44, 7.41, 7.29, 7.28, 7.27, 7.24, and 7.08 (three AA′BB′ systems, 6H), 7.40−7.38 (m, 2H), 6.47 (bs, 1H), 4.87 (s, 1H), 2.43 and 2.37 (2s, 6H), 2.19 (s, 3H), 1.21 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.5, 143.4, 142.7, 142.6, 141.0, 139.5, 139.4, 122.2, 132.5, 131.8, 130.9, 130.6, 129.8, 129.5, 128.4, 128.2, 125.3, 125.0, 64.7, 56.8, 28.0, 21.4, 21.2, 15.0; HRMS calcd for $C_{30}H_{31}BrNO_2S_3$ 612.0694, found 612.0722.

[2*S*,*S*(*R*)]-*N*-{1,1-Diphenyl-2-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-2-(methylsulfenyl)ethyl}-*p*-toluenesulfinamide (7a). *N*-Sulfinylketimine (*R*)-**2a** was used as electrophile: eluent for chromatography hexane/Et_2O 1:5; yield 85%; white solid; mp 100−101 °C (hexane/Et_2O); $[\alpha]_D^{20} = -95.5$ (*c* 0.5, $CHCl_3$); FT IR(KBr) 3427, 1594, 1492, 1443, 1395, 1087 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.81 (dd, 1H, $J = 7.9$, 1.1 Hz), 7.58−7.23 (m, 18H), 7.50 (part of AA′BB′ system, 2H), 6.98 (d, 1H, $J = 7.0$ Hz), 5.41 (bs, 1H), 5.31 (s, 1H), 2.40 and 2.38 (2s, 6H), 1.05 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.7, 143.7, 142.7, 141.6, 141.0, 140.5, 136.0, 131.9, 130.5, 130.2, 129.6, 128.6, 128.1, 127.7, 127.5, 127.2, 125.4, 123.5, 71.8, 54.8, 21.5, 21.3, 13.9; HRMS calcd for $C_{35}H_{34}NO_2S_3$ ($M^+ + 1$) 596.1746, found 596.1751.

[2*S*,3*S*,*S*(*R*)]-*N*-{2-Phenyl-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*syn*-13b). *N*-Sulfinylketimine (*R*)-**2b** was used as electrophile: eluent for chromatography hexane/Et_2O 1:4; yield 84%; white solid; mp 132−133 °C (hexane/Et_2O); $[\alpha]_D^{20} = -14.0$ (*c* 0.5, $CHCl_3$); FT IR(KBr) 3417, 1601, 1491, 1402, 1126 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.71 and 7.67 (2dd, 3H, $J = 10.5$ Hz), 7.53 (td, $J = 8.7$, 4.4 Hz), 7.40, 7.22, 7.16, and 7.12 (two AA′BB′ systems, 8H), 7.45−7.28 (m, 5H), 6.15 (bs, 1H), 5.01 (s, 1H), 2.36 and 2.32 (2s, 6H), 2.10 (s, 3H), 1.10 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.9, 143.7, 143.1, 140.9, 140.8, 140.3, 139.2, 132.2, 129.7, 129.4, 128.6,

128.4, 128.0, 127.4, 125.2, 125.0, 64.4, 57.0, 22.4, 21.3, 21.2, 14.9; HRMS calcd for $C_{30}H_{32}NO_2S_3$ ($M^+ + 1$) 534.1589, found 534.1583.

[2*S*,3*S*,*S*(*R*)]-*N*-{2-(4-Methylphenyl)-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*syn*-13c). *N*-Sulfinylketimine (*R*)-**2c** was used as electrophile: eluent for chromatography hexane/Et_2O 1:15; yield 77%; white solid; mp 98−99 °C (hexane/Et_2O); $[\alpha]_D^{20} = -27.5°$ (*c* 0.5, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.73 (d, 1H, J = 8.2 Hz), 7.54, 7.47, 7.23, 7.22, 7.16, and 7.10 (three AA′BB′ systems, 12H), 7.40−7.31 (m, 3H), 5.85 (bs, 1H), 5.07 (s, 1H), 2.40, 2.38 and 2.35 (3s, 9H), 2.09 (s, 3H) and 1.23 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.2, 143.2, 141.4, 140.9, 140.8, 140.2, 139.1, 137.2, 132.0, 129.6, 129.4, 128.7, 128.4, 128.3, 127.4, 125.2, 125.0, 64.3, 57.1, 23.0, 21.3, 21.2, 21.1, 14.9; HRMS calcd for $C_{31}H_{34}NO_2S_3$ ($M^+ + 1$) 548.1746, found 548.1752.

[2*S*,3*S*,*S*(*R*)]-*N*-{2-(4-Methoxyphenyl)-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*syn*-13d). *N*-Sulfinylketimine (*R*)-**2d** was used as electrophile: eluent for chromatography hexane/Et_2O 1:15; yield 80%; white solid; mp 95−96 °C; $[\alpha]_D^{20} = -8.2$ (*c* 1.4, $CHCl_3$); FT IR(KBr) 3449,1606, 1512, 1460, 1379, 1088 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.69 (d, 1H, J = 8.0 Hz), 7.56, 7.46, 7.22, 7.15, 7.09, and 6.92 (three AA′BB′ systems, 12H), 7.36−7.31 (m, 3H), 5.83 (bs, 1H), 5.04 (s, 1H), 3.84 (s, 3H), 2.37 and 2.34 (2s, 6H), 2.07 (s, 3H), 1.23 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.7, 143.9, 143.0, 141.8, 140.7, 140.1, 138.9, 136.2, 131.9, 130.0, 129.3, 128.7, 128.3, 128.2, 125.1, 124.9, 113.1, 64.0, 57.1, 55.0, 23.1, 21.2 21.1, 14.8; HRMS calcd for $C_{31}H_{34}NO_3S_3$ ($M^+ + 1$) 564.1695, found 564.1690.

[2*S*,3*S*,*S*(*R*)]-*N*-{2-(4-Bromophenyl)-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*syn*-13e). *N*-Sulfinylketimine (*R*)-**2e** was used as electrophile: eluent for chromatography hexane/Et_2O 1:12; yield 65%; white solid; mp 100−101 °C (hexane/Et_2O); $[\alpha]_D^{20} = +18.3$ (*c* 0.5, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.73 (d, 1H, J = 8.0 Hz), 7.63−7.42 (m, 7H), 7.38, 7.22, 7.18, and 7.12 (two AA′BB′ systems, 8H), 6.41 (bs, 1H), 4.88 (s, 1H), 2.38 and 2.33 (2s, 6H), 2.05 (s, 3H), 1.02 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.5, 143.3, 143.1, 141.0, 140.8, 140.2 139.3, 121.6, 132.3, 131.0, 129.8, 129.4, 129.1, 128.8, 128.4, 125.1, 124.8, 64.1, 56.5, 21.9, 21.3, 21.2, 14.7; HRMS calcd for $C_{30}H_{31}BrNO_2S_3$ ($M^+ + 1$) 612.0694, found 612.0709.

[2*S*,3*S*,*S*(*R*)]-*N*-{2-(4-Cyanophenyl)-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*syn*-13f). *N*-Sulfinylketimine (*R*)-**2f** was used as electrophile: eluent for chromatography hexane/Et_2O 1:5; yield 82%; yellow solid; mp 81−82 °C (hexane/Et_2O); $[\alpha]_D^{20} = -81.0$ (*c* 0.4, $CHCl_3$); FT IR(KBr) 3423, 2227, 1600, 1490, 1461, 1403, 1083 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.74, 7.62, 7.19, and 7.09 (two AA′BB′ systems, 8H), 7.66 (dd, 1H, J = 7.6, 1.1 Hz), 7.58−7.20 (m, 2H), 7.10−7.05 (m, 5H), 6.93 (bs, 1H), 4.71 (s, 1H), 2.30 and 2.25 (2s, 6H), 1.94 (s, 3H), 0.70 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 152.0, 143.1, 142.6, 141.2, 140.9, 140.1, 139.7, 111.1, 132.7, 132.6, 131.8, 129.9, 129.5, 129.4, 128.4, 127.8, 125.0, 124.6, 119.0, 64.2, 55.9, 21.4, 21.2, 20.1, 14.4; HRMS calcd for $C_{31}H_{31}N_2O_2S_3$ ($M^+ + 1$) 559.1542, found 559.1556.

[2*S*,3*S*,*S*(*R*)]-*N*-{2-Isopropyl-3-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-3-(methylsulfenyl)propyl}-*p*-toluenesulfinamide (*syn*-13g). *N*-Sulfinylketimine (*R*)-**2g** was used as electrophile: eluent for chromatography hexane/Et_2O 1:6; yield 75%; white syrup; $[\alpha]_D^{20} = -122.2$ (*c* 0.5, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.98 and 7.89 (2d, 2H, J = 7.6 Hz), 7.65 (t, 1H, J = 7.5 Hz), 7.54, 7.24, 7.20, and 7.18 (two AA′BB′ systems, 8H), 7.49 (t, 1H, J = 7.5 Hz), 7.04 (bs, 1H), 4.64 (s, 1H), 2.36 and 2.32 (2s, 6H), 2.26−2.20 (m, 1H), 1.56 (s, 3H), 1.04 and 0.98 (2d, 6H, J = 6.7 Hz), 0.70 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.1, 142.9, 140.8, 140.6, 140.1, 133.9, 132.3, 130.1, 129.7, 129.2, 127.6, 125.1, 124.4, 64.3, 51.4, 36.2, 21.3, 21.1, 17.8, 17.2, 17.0, 12.9; HRMS calcd for $C_{27}H_{34}NO_2S_3$ ($M^+ + 1$) 500.1746, found 500.1735.

General Procedure for *C*- and *S*-Desulfinylation. To a stirred solution of *anti*-**10b**, *syn*-**11b**, *syn*-**13b**, *syn*-**13c**, or *syn*-**13d** (0.12 mmol) in THF (2 mL) was added *t*-BuLi (0.15 mL, 0.22 mmol, 1.5 M in hexane, 1.8 equiv) When the reaction was completed (5 min), the mixture was hydrolyzed with saturated aqueous NH_4Cl solution (1 mL) and extracted with CH_2Cl_2 (3 × 3 mL). The combined organic layers were dried over $MgSO_4$, and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography.

[2*S*,3*S*,*S*(*R*)]-*N*-[2,3-Diphenyl-3-(methylsulfenyl)propyl]-*p*-toluenesulfinamide (*syn*-20b). This product was obtained from *syn*-**13b**: eluent for chromatography hexane/Et_2O 1:5; yield 81%; white syrup; $[\alpha]_D^{20} = -30.3$ (*c* 0.9, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.58 and 7.30 (AA′BB′ system, 4H), 7.49 (dd, 2H, J = 8.1, 1.6 Hz), 7.41−7.33 (m, 3H), 7.24−7.11 (m, 5H), 4.59 (bs, 1H), 4.12 (s, 1H), 2.42 (s, 3H), 1.99 (s, 3H), 1.69 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 141.8, 141.1, 137.3, 130.5, 129.6, 129.5, 128.0, 127.9, 125.4, 125.3, 66.1, 64.1, 24.9, 21.3, 15.6.

[2*S*,3*S*,*S*(*R*)]-*N*-[2-(4-Methylphenyl)-3-(phenyl)-3-(methylsulfenyl)propyl]-*p*-toluenesulfinamide (*syn*-20c). This product was obtained from *syn*-**13c**: eluent for chromatography hexane/Et_2O 1:6; quantitative yield; white syrup; $[\alpha]_D^{20} = -18.5$ (*c* 0.6, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.50, 7.32, 7.21, and 7.15 (two AA′BB′ systems, 8H), 7.18−7.11 (m, 5H), 4.44 (bs, 1H), 4.05 (s, 1H), 2.34 and 2.30 (2s, 6H), 1.89 (s, 3H), 1.59 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.4, 141.1, 138.8, 137.6, 137.3, 130.5, 129.6, 128.7, 128.0, 125.5, 125.4, 66.0, 63.9, 24.8, 21.3, 21.1, 15.6; HRMS calcd for $C_{24}H_{27}NOS_2Na$ ($M^+ + Na$) 432.1432, found 432.1430.

[2*S*,3*S*,*S*(*R*)]-*N*-[2-(4-Methoxyphenyl)-3-(phenyl)-3-(methylsulfenyl)propyl]-*p*-toluenesulfinamide (*syn*-20d). This product was obtained from *syn*-**13d**: eluent for chromatography hexane/Et_2O 1:5; yield 88%; white syrup; $[\alpha]_D^{20} = +60.0$ (*c* 0.4, $CHCl_3$); FT IR(KBr) 3414, 1609, 1513, 1455, 1252 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.50, 7.35, 7.22, and 6.84 (two AA′BB′ systems, 8H), 7.18−7.11 (m, 5H), 4.43 (bs, 1H), 4.03 (s, 1H), 3.76 (s, 3H), 2.34 (s, 3H), 1.88 (s, 3H), 1.60 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.0, 147.1, 143.4, 141.1, 135.2, 137.3, 133.7, 130.5, 129.6, 129.5, 129.3, 129.2, 128.0, 125.4, 113.2, 66.1, 63.7, 55.2, 25.0, 21.3, 15.6.

[2*R*,3*S*,*S*(*S*)]-*N*-[2,3-Diphenyl-3-(methylsulfenyl)propyl]-*p*-toluenesulfinamide (*anti*-22b). This product was obtained from *anti*-**10b**: eluent for chromatography hexane/Et_2O 1:4; yield 80%; white syrup; $[\alpha]_D^{20} = +4.0$ (*c* 1.8, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.67 and 7.34 (AA′BB′system, 4H), 7.35−7.31 (m, 3H), 7.30−7.23 (m, 3H), 7.15−7.00 (m, 3H), 6.91 (dd, 1H, J = 8.0, 1.6 Hz), 5.42 (bs, 1H), 4.06 (s, 1H), 2.43 (s, 3H), 1.98 (s, 3H), 1.86 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.7, 142.1, 141.1, 137.6, 130.0, 129.6, 127.9, 127.6, 127.4, 127.2, 125.3, 125.2, 66.7, 65.0, 23.4, 21.4, 16.0.

Representative Procedure for *N*- and *S*-Desulfinylation. To a stirred solution of **5a**, **7a**, *anti*-**10b**, *syn*-**11b**, *anti*-**12b**, *syn*-**13b**, *syn*-**20b**−**d**, or *anti*-**22b** (0.05 mmol) in methanol (1 mL) was added TFA (12.5 μL, 0.15 mmol, 3 equiv). After the mixture was stirred for 3 h at 0 °C, the solvent was evaporated, and the residue was purified by SCX column chromatography (ammonia solution 7 M in methanol) to afford the corresponding amine.

(2*S*)-1,1-Diphenyl-2-[(*S*)-2-(*p*-toluenesulfinyl)phenyl]-2-(methylsulfenyl)ethyl}ethylamine (9). This product was obtained from **5a** and **7a**: yield 93%; white syrup; $[\alpha]_D^{20} = -90.0°$ (*c* 1.8, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.84 and 7.74 (2dd, 2H, J = 7.1, 1.8 Hz), 7.58−7.50 (m, 4H), 7.48−7.31 (m, 3H), 7.39 and 7.27 (AA′BB′ system, 4H), 7.21−7.08 (m, 5H), 5.19 (s, 1H), 2.40 (bs, 2H), 2.38 (s, 3H), 1.10 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.4, 145.2, 144.9, 142.4, 141.8, 136.6, 131.6, 130.2, 128.4, 128.1, 127.7, 127.6, 127.4, 127.1, 123.4, 65.5, 53.8, 21.4, 14.1.

(2*S*,3*S*)-3-(Methylsulfenyl)-2,3-diphenylpropylamine (*syn*-21b). This product was obtained from *syn*-**20b**: yield 90%; colorless oil; $[\alpha]_D^{20} = +280.0°$ (*c* 0.6, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.31 (bs, 6H), 7.20 (d, 2H, J = 6.7 Hz), 7.09 (d, 2H, J = 5.8 Hz), 4.22 (s, 1H), 1.80 and 1.73 (2s, 6H); ^{13}C NMR (75 MHz,

$CDCl_3$) δ 139.9, 137.1, 130.2, 27.9, 127.8, 126.5, 63.2, 60.7, 24.9, 15.6; HRMS calcd for $C_{15}H_{16}NS$ ($M^+ - CH_3$) 242.1003, found 242.0996.

(2*S*,3*S*)-2-(*p*-Methylphenyl)-3-(methylsulfenyl)-3-phenylpropylamine (*syn*-21c). This product was obtained from *syn*-**20c**: yield 79%; colorless oil; $[\alpha]_D^{20} = +62.9$ (*c* 0.7, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.25−7.13 (m, 7H), 7.07 (part of one AA′BB′ system, 2H), 4.05 (s, 1H), 2.40 (bs, 2H), 2.31 (s, 3H), 1.75 (s, 3H), 1.62 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.4, 136.4, 130.1, 128.4, 127.6, 127.2, 126.1, 65.4, 58.5, 27.7, 21.0, 15.6; HRMS calcd for $C_{17}H_{18}S$ ($M^+ - NH_3$) 254.1129, found 254.1126.

(2*S*,3*S*)-2-(*p*-Methoxyphenyl)-3-(methylsulfenyl)-3-phenylpropylamine (*syn*-21d). This product was obtained from *syn*-**20d**: yield 88%; yellow oil; $[\alpha]_D^{20} = +48.3$ (*c* 0.6, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.26 and 6.81 (AA′BB′ system, 4H), 7.23−7.13 (m, 5H), 4.04 (s, 1H), 3.80 (s, 3H), 2.40 (bs, 2H), 1.78 (s, 3H), 1.64 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.3, 141.1, 138.4, 138.0, 136.9, 130.0, 127.6, 127.3, 127.1, 112.9, 65.6, 58.3, 55.1, 28.0, 15.6; HRMS calcd for $C_{17}H_{18}OS$ ($M^+ - NH_3$) 270.1072, found 270.1078.

(2*R*,3*S*)-3-(Methylsulfenyl)-2,3-diphenylpropylamine (*anti*-23b). This product was obtained from *anti*-**22b**: yield 92%; white syrup; $[\alpha]_D^{20} = +60.0$ (*c* 0.8, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.46 (d, 2H, $J = 7.5$ Hz), 7.34−7.29 (m, 2H), 7.26−7.24 (m, 6H), 4.14 (s, 1H), 2.68 (bs, 2H), 1.71 (s, 3H), 1.41 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 146.2, 138.6, 129.9, 127.9, 127.8, 127.3, 126.8, 125.8, 65.3, 58.9, 28.6, 15.6.

Representative Procedure for *C*- and *S*-Desulfinylation with Ra-Ni. To a solution of the corresponding compound *syn*-**14b**, *anti*-**15b**, *anti*-**17b**, and *syn*-**18b** or (*R*)-**19**[12](0.09 mmol) in THF (1 mL) was added activated Raney nickel (0.6 g) in THF (2 mL). The reaction mixture was stirred for 3 h and filtered, and the residue was purified by SCX column affording the pure free amine.

(1*R*)-1-Methyl-1,2-diphenylethylamine [(*R*)-16]. This product was obtained from *syn*-**14b**, a mixture of compounds *anti*-**15b**/*syn*-**14b** (80:20) or (*R*)-**19**:[12] yield 86% from *syn*-**14b**, 77% from *anti*-**15b**/*syn*-**14b**, and 80% from (*R*)-**19**; white syrup; $[\alpha]_D^{20} = +76.4$ (*c* 0.9, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42 (dd, 2H, $J = 7.9$, 1.5 Hz), 7.32 and 7.23 (2dd, 3H, $J = 7.4$, 1.6 Hz), 7.16 (dd, 3H, $J = 4.9$, 1.7 Hz), 6.88 (dd, 2H, $J = 6.5$, 2.9 Hz), 3.04 (AB system, 2H, $J = 17.5$ Hz), 1.86 (bs, 2H), 1.55 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 148.3, 137.5, 130.2, 128.2, 127.9, 126.9, 126.7, 125.2, 57.8, 50.1, 29.8; HRMS calcd for $C_{14}H_{14}N$ ($M^+ - CH_3$) 196.1126, found 196.1129.

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Supporting Information Available: General experimental methods. Characterization data for **3a**, **4a**, **6a**, **8a**, *syn*-**11b**−**d**, *anti*-**12b**−**e**, *syn*-**14b**, *anti*-**15b**, (*S*)-**16**, *anti*-**17b**, *syn*-**18b**, and *ent*-**20b**. ^{1}H NMR and ^{13}C NMR spectra of compounds **3a**, **4a**, **5a**, **7a**, **8a**, **9**, *anti*-**10b**−**d**, *syn*-**11b**−**d**, *anti*-**12c**, *anti*-**12e**, *syn*-**13b**−**g**, *syn*-**14b**, (*R*)- and (*S*)-**16**, *anti*-**17b**, *syn*-**18b**, **20b**, *ent*-**20b**, *syn*-**20c**,**d**, *anti*-**22b**, *syn*-**21b**−**d**, and *anti*-**23b**. Full citation for ref 18 and Cartesian coordinates for all optimized structures, their electronic energies, and ZPVEs. This material is available free of charge via the Internet at http://pubs.acs.org.

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