Enantiomerically Pure α-Alkylidene *β*-Amino Esters from Asymmetric Addition of Metal Dienolates to *N*-Sulfinylimines

J. L. García Ruano,*[,†] I. Fernández,*[,‡] M. del Prado Catalina,[†] J. A. Hermoso,[§] J. Sanz-Aparicio,[§] and M. Martínez-Ripoll[§]

Departamento de Química Orgánica, Universidad Autónoma, Cantoblanco, 28049 Madrid, Spain, Departamento de Química Orgánica y Farmacéutica, Facultad de Farmacia, Universidad de Sevilla, 41017 Sevilla, Spain, and Departamento de Cristalografía, Instituto de Química-Física Rocasolano, CSIC, 28006 Madrid, Spain

Received December 22, 1997

Lithium dienolate of 3-butenoic methyl ester was reacted with enantiomerically pure *N*-arylsulfinyl phenylimines (**1** and **2**) under different conditions. The reactions were completely regioselective—the C−C coupling occurs at the 2-position of dienolate—and highly stereoselective at the iminic carbon. In the presence of different Lewis acids ($ZnCl_2$, $ZnBr_2$, and $ScTf_3$) mixtures of two α-vinyl, *β*-arylsulfinylamino esters (epimers at C-α) were obtained, being the stereoselectivity depending on the nature of the aryl sulfinyl moiety and the Lewis acid used. Desulfinylation of these mixtures followed by isomerization of the double bond with Na_2CO_3 allowed the synthesis of the optically pure (*E*)-α-ethylidene-*β*-amino ester **10** in quite high overall yield. The addition of the lithium dienolate to sulfinylimines in the absence of the Lewis catalysts yielded mixtures containing important amounts of the optically pure *N*-arylsulfinyl α-ethylidene-*β*-amino esters, which became the exclusive product of the reaction when *N*-2-methoxynaphthylsulfinyl phenylimine **2** was used as starting product.

Introduction

Enantiopure sulfinimines (thiooxime *S*-oxides) are interesting building blocks in asymmetric synthesis, as they lead to important molecules bearing a chiral amino group. Although there are several groups actively working in this field,[1−3] the most significant contributions in both, preparation and synthetic applications of these substrates have been reported by Davis and co-workers.[3] One of the most interesting reactions of these substrates is that which takes place with ester enolates, affording compounds easily transformed into *β*-amino acids.[4] Nevertheless, to our knowledge, only alkyl acetates have been used as a source of enolates. This lack of diversity is due to the fact that esters other than acetates lead to α-substituted *β*-amino acids having two chiral centers (C-α and C-*β*), with the subsequent loss of diastereoselectivity.[5] A solution to this problem is the use of dienolates as nucleophiles, because the resulting products are susceptible to transformation to compounds lacking the C-α chiral center.[6]

The addition of dienolates to electrophiles is a useful and attractive process for C−C bond formation. As the dienolate possesses two nucleophilic sites, the coupling can occur either at the 2- or at the 4-position, depending on the metal counterion, the solvent, the temperature, and the structure of the starting material. A survey of the literature has shown that while the addition of dienolates to carbonyl compounds is a well-documented process,[7] examples of addition to imines are scarce.[8,9] The later condensation yields *β*- or *δ*-amino esters with at least one chiral center, important synthons, especially in optically pure form, as they constitute the framework of a large number of biologically active molecules. In the chiral version of this addition, the reactions of (−)-menthyl 3-butenoate with several achiral imines were studied with discouraging results, because neither the diastereoselectivity nor the asymmetric induction were satisfactory.[9] The long distance between the reaction site and the chiral centers is probably responsible for the low efficiency in the chiral induction. Chiral imines derived

† Universidad Autónoma.
‡ Universidad de Sevilla
§ CSIC.

(1) (a) Hua, D. H.; Lagneau, N.; Wang, H.; Chen, J. S. *Tetrahedron: Asymmetry* **1995**, *6*, 394 (and references therein). (b) Oppolzer, W.; Froelich, O.; Wiaux-Zamar, C.; Bernardinelli, G. *Tetrahedron Lett.* **1997**, *38*, 2825. (c) Viso, A.; Fernández de la Pradilla, R.; Guerrero-Strachan, C.; Alonso, M.; Martínez-Ripoll, M.; André, I. *J. Org. Chem.* **1997**, *62*, 2316. (d) Balasubramanian, T.; Hassner, A. *Tetrahedron Lett.* **1996**, *37*, 5755.

(2) (a) García-Ruano, J. L.; Fernández, I.; del Prado-Catalina, M.; Alcudia-Cruz, A. *Tetrahedron: Asymmetry* **1996**, *7*, 3407. (b) García-Ruano, J. L.; Fernández, I.; Hamdouchi, C. *Tetrahedron Lett.* **1995**, *36*, 295.

(3) Davis, F. A.; Reddy, R. E.; Szewczyk, J. M.; Reddy, G. V.; Portonovo, P. S.; Zhang, H.; Fanelli, D.; Reddy, R. T.; Zhou, P.; Carroll, P. J. *J. Org. Chem.* **1997**, *62*, 2555 (and references therein).

(4) (a) Davis, F. A.; Reddy, R. T.; Reddy, R. E. *J. Org. Chem.* **1992**, *57*, 6387. (b) Davis, F. A.; Reddy, R. E.; Szewczyk, J. M. *J. Org. Chem.* **1995**, *60*, 7037. (c) Davis, F. A.; Szewczyk, J. M.; Reddy, R. E. *J. Org. Chem.* **1996**, *61*, 2222. (d) Fujisawa, T.; Kooriyama, Y.; Shimizu, M. *Tetrahedron Lett.* **1996**, *37*, 3881.

(5) In this sense, we studied the reaction of the lithium enolate of ethyl butyrate with compound **1** at −78 °C. The formation of a mixture containing significant amounts of four different diastereomers was established from the proton NMR spectra of the reaction crude. Only one of them could be easily separated by flash chromatography, but its configurational assignment was not made.

(6) The double dond can be isomerized under basic conditions by treatment with Na_2CO_3.

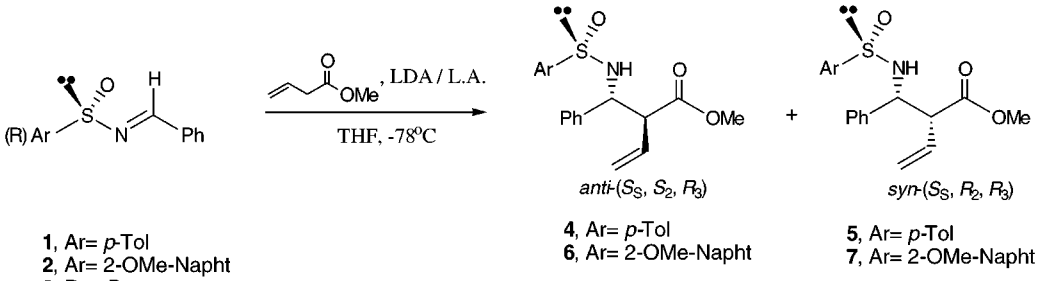
(7) For leading references on the addition of dienolates to carbonyl compounds see, for example: (a) Bellassoued, M.; Habbachi, F.; Gaudemar, M. *Tetrahedron* **1987**, *43*, 1785. (b) Bellassoued, M.; Habbachi, F.; Gaudemar, M. *Tetrahedron* **1985**, *41*, 1299. (c) Johnson, P. R.; White, J. D. *J. Org. Chem.* **1984**, *49*, 4424. (d) Dugger, R. W.; Heatchcock, C. H. *J. Org. Chem.* **1980**, *45*, 1181.

(8) El Borgi, A.; Bellassoued, M.; Moreau, J. L. *C. R. Acad. Sci. II* **1988**, *307*, 1805.

(9) van Maanen, H. L.; Kleijn, H.; Jastrzebski, J. T. B. H.; Lakin, M. T.; Spek, A. L.; van Koten, G. *J. Org. Chem.* **1994**, *59*, 7839.

S0022-3263(97)02303-7 CCC: $15.00
Published on Web 09/29/1998

Scheme 1



1, Ar= *p*-Tol
2, Ar= 2-OMe-Napht
3, R= *t*-Bu

4, Ar= *p*-Tol
6, Ar= 2-OMe-Napht

5, Ar= *p*-Tol
7, Ar= 2-OMe-Napht

from optically pure (*R*)-1-phenylethylamine afforded some good results.[9] For a most effective control of the stereoselectivity, the use of a sulfinyl sulfur as the chiral controller at the α position to the nitrogen atom of the imine (i.e. *N*-sulfinylimines) seemed very appealing. Moreover, the ability of the sulfinyl oxygen to be associated with the counterion metal of the dienolate could be an interesting factor to control the regioselectivity by favoring the coupling at the 2-position of the dienolate.

In the present paper, we report our ongoing studies directed toward the evaluation of the ability of the sulfinyl group as a chiral controller in the addition of dienolates to optically pure *N*-arylsulfinylimines. From the obtained results we have evidenced that the sulfinyl group completely controls the regioselection of the reaction (only products from the coupling at the 2-position are formed), in the opposite sense to that observed for the imines previously mentioned (only products from the coupling at the 4-position were formed).[9] Otherwise, the influence of the metal counterion of the dienolate and the arylsulfinyl moiety on the composition of the reaction mixtures has also been evaluated. The conditions allowing the obtained mixtures to evolve into optically pure α-alkylidene-*β*-amino esters, interesting building blocks in asymmetric synthesis, are also reported. From this study it has been shown that the sulfinyl group acts not only as a good chiral controller but also as a useful protective group for the amine, which can be easily removed.

Results and Discussion

The reactions of the lithium dienolate of (*E*)-methyl 2-butenoate with optically pure (+)-(*S*)-(*E*)-N-(benzylidene)-*p*-toluenesulfinamide **1**,[10] (+)-(*S*)-(*E*)-N-(benzylidene)-2-methoxy-1-naphthylsulfinamide **2**,[10] and (+)-(*S*)-(*E*)-N-(benzylidene)-*tert*-butylsulfinamide **3**[2a] under different conditions have been studied (Scheme 1). The results obtained for compounds **1** and **2** in the presence of Lewis acids as catalysts are summarized in Table 1. The reactions were conducted at −78 °C in THF as solvent. In other solvents, such as toluene or ether, the coupling did not occur. Warming the reaction mixture to −20 °C before quenching resulted in polymerization of dienolate and unaltered starting *N*-sulfinylimine was recovered. No reaction was observed in the case of the *N*-sulfinylimine **3**, which could be a consequence of the hindered *tert*-butylsulfinyl group.

The reactions of substrates **1** and **2** were completely regioselective affording exclusively the *β*-amino esters resulting from the coupling at the 2-position of dienolate.

Table 1. Reaction of *N*-Sulfinylimines 1 and 2 with Metal Dienolates of Methyl 3-Butenoate

entry	*N*-sulfinylimine	LA[a] (MX_n)	yield (%)	*anti*/*syn* ratio[b] **4**:**5** (or **6**:**7**)
1	**1**	$ZnCl_2$	70	78:22
2	**1**	$ZnBr_2$	82	65:35
3	**1**	$ScTf_3$	34	87:13
4	**2**	$ZnCl_2$	82	(30:70)
5	**2**	$ZnBr_2$	90	(37:64)
6	**2**	$ScTf_3$	89	(63:38)

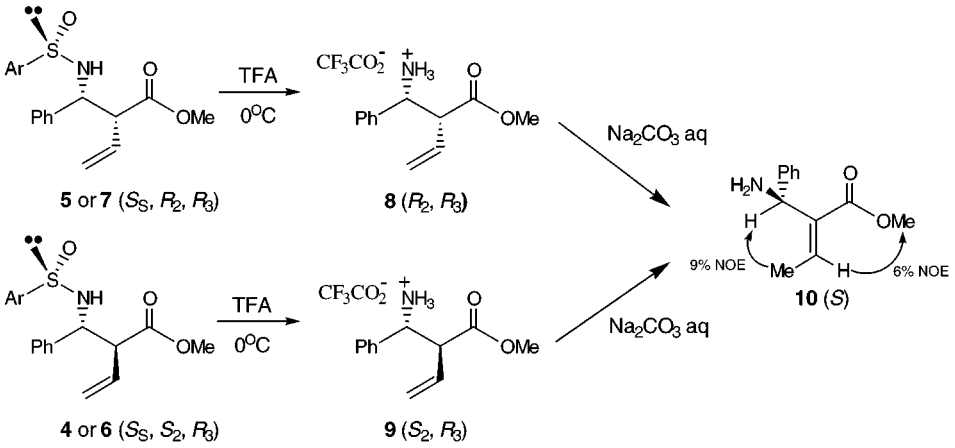
[a] The dienolates were generated by deprotonation of the ester with 1 equiv of LDA, followed by transmetalation with Lewis acid (MX_n). [b] The ratios of isomers were determined on the crude by integration of characteristic ^{1}H-NMR signals.

Moreover, only two of the four possible diastereoisomers were detected in the mixtures, which suggested that the control of the stereoselectivity of the addition had been complete just in one of the two prochiral centers. The configurational assignment of the obtained compounds was carried out as follows. Diastereomers **6** and **7**, resulting from the addition of the zinc dienolate of methyl 3-butenoate to compound **2**, were separated by column chromatography. The major one, **7**, was purified by crystallization from hexane, and these crystals were suitable for X-ray analysis. The molecular structure of **7** allowed us to know its relative configuration, which evidenced the syn relative stereochemistry of their chiral carbons. As the configuration at the sulfinyl sulfur was known to be S_S, the absolute configuration of **7** could be assigned as (S_S,R_2,R_3).

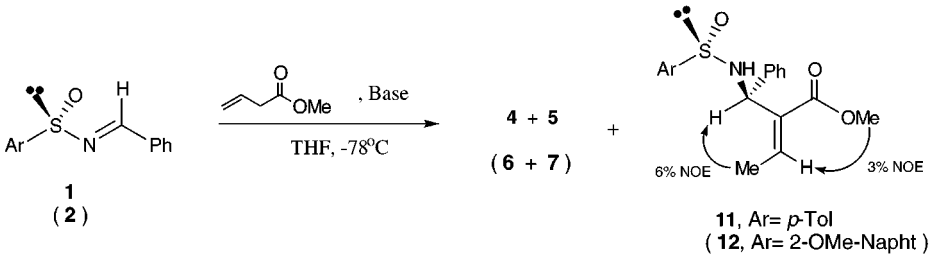
The configurational assignment of the other diastereomer **6**, as well as those of the *p*-tolyl derivatives **4** and **5**, could be ascertained according to the transformations indicated in Scheme 2. Desulfinylation of **7** (S_S,R_2,R_3) by treatment with TFA at 0 °C yielded the *syn* *β*-amino ester **8** with (R_2,R_3) configuration. The same treatment converted compound **6** into **9**, which is a diastereoisomer of **8**, and therefore indicated that **8** and **9** must exhibit the opposite relative configuration, thus allowing us to assign the *anti* stereochemistry to compound **9**. The reaction of **8**, **9**, or their mixture with a saturated Na_2CO_3 aqueous solution yielded optically pure, isomerized compound **10** with $[\alpha]_D = -40$ (*c* 0.1, $CHCl_3$). These results indicated that both trifluoroacetates, **8** and **9**, had the same configuration at C-3, but the opposite one at C-2, which allowed us to conclude that the configuration of **9** must be (S_2,R_3) and therefore that (S_S,S_2,R_3) must be assigned to its precursor **6**, as indicated in Scheme 1. Desulfinylation of compound **4** (which was diastereomerically pure isolated from the **4** + **5** mixture) yielded compound **9**, which indicated that configuration (S_S,S_2,R_3) must be assigned to **4**. Analogously, the mixture **4** + **5**

(10) Davis, F. A.; Zhou, P.; Liang, C.-H.; Reddy, R. E. *Tetrahedron: Asymmetry* **1995**, *6*, 1511.

Scheme 2



Scheme 3



was transformed into the mixture **8** + **9** with TFA, which evidenced identical absolute configuration for compounds **5** and **7**.

The results obtained in the above-mentioned chemical correlation prompted us to evaluate the synthetic scope of the sequence to obtain optically pure α-ethylidene β-amino acids from sulfinylimines. Thus, by treating the mixture **4** + **5**, obtained in conditions of the entry 2 (Table 1), with TFA (0 °C) for 5 h, followed by reaction of the resulting crude with saturated solution of Na_2CO_3 (3 h), afforded optically pure compound **10** in 65% overall yield starting from the sulfinylimine **1**. This yield was even higher (75%) when the same sequence was reproduced from the mixture **6** + **7** obtained from **2** in conditions of the entry 5 (Table 1). The (*E*)-configuration of the double bond of compound **10** was established by NOE experiments (Scheme 2).

We have also studied the reactions of compounds **1** with different metal enolates of methyl 3-butenoate in the absence of Lewis acids (Scheme 3). The results are collected in Table 2. When the reactions were conducted at −78 °C and the final protonation was carried out with aqueous NH_4Cl at room temperature, only two products (**4** + **11**) were isolated starting from **1**, their relative proportion depending on the base (entries 1, 3, and 4; with KHMDS the reaction does not work) but independent of the reaction time. The (*E*)-configuration of the double bond of compound **11** was established by NOE spectroscopic studies (Scheme 3). Under identical conditions lithium enolate of the ester, generated with LDA, reacts with **2**, yielding compound **12** as exclusive product (entry 6) in very good yield (82%).

The formation of compounds **11** and **12** could be explained as a consequence of the isomerization from their precursors, α-vinyl-β-sulfinylamino esters **4**−**7**. To know if the nucleophilic addition to sulfinylimine was completely stereoselective (only compound **4** was observed starting from **1**), we did the protonation of the reaction mixtures obtained from **1** and **2** at −78 °C (with methanolic solution of NH_4Cl). In these conditions **4** + **5** + **11** and **6** + **7** + **12** mixtures were, respectively, detected (entries 2 and 7), which showed a moderated stereoselectivity of these additions, similar to that observed in the presence of Lewis acids (Table 1). Moreover, these results suggest that the isomerization of the epimer **5** into **11** must be faster than that of **4**. Otherwise, the isomerization of the double bond must not be possible in the presence of the Lewis acids (conditions of Table 1), precluding the formation of compounds **11** and **12**.

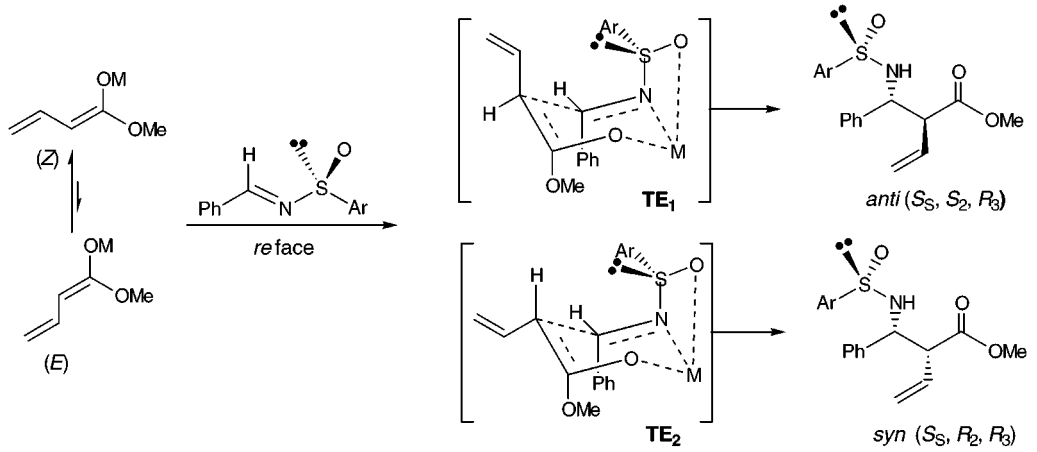
Assuming that the reaction is under kinetic control, the stereochemical results can be rationalized in terms of six-membered cyclic transition states. The fact that all the products obtained have the *R* configuration at C-3 indicates that the attack of dienolates on the C=N bond must take place from the *re* face (Scheme 4), which could easily be explained by assuming that the metal counter-

Table 2. Reaction of *N*-Sulfinylimines 1 and 2 with Lithium, Sodium, or Potasium Dienolates of Methyl 3-Butenoate

entry	*N*-sulfinylimine	base[a]	reaction time (h)	yield (%)	product ratio[b] **4**:**5**:**11** (or **6**:**7**:**12**)
1	**1**	LDA	2[c]	85	18:0:82
2	**1**	LDA	2[d]	75	31:9:60
3	**1**	LHMDS	3[c]	65	46:0:54
4	**1**	NaHMDS	3[c]	70	30:0:70
5	**1**	KHMDS	8[c]	–	–
6	**2**	LDA	8[c]	82	(0:0:100)
7	**2**	LDA	8[d]	75	(9:37:54)

[a] The dienolates were generated by deprotonation of the ester with different bases. [b] The ratios of isomers were determined on the crude by integration of characteristic ^{1}H-NMR signals. [c] Protonation was made with NH_4Cl(aq) at room temperature. [d] Protonation was made with NH_4Cl(methanolic solution) at −78 °C.

Scheme 4



ion, involved in a chairlike transition state, was additionally stabilized by association with the sulfinyl oxygen, according to the Davis's proposal to explain the attack of the ester enolate to sulfinylimines.[4] In such a case, the transition states resulting from the attack to the *si* face would be sterically destabilized because the aromatic substituent at sulfur would be placed inside the "chair". The energy differences of competing transition states TE_1 and TE_2 (Scheme 4), leading to *anti*- and *syn*-*β*-amino esters, respectively, must be relatively small (thus explaining the formation of epimeric mixtures at C-2), which have been rationalized in other additions of dienolates to imines by assuming that the vinyl substituent is coplanar with the enolate double bond and thus sterically not very demanding.[9] Nevertheless, the predominance of the *anti*-**4** isomer in reactions starting from **1** (see Table 1) is not easy to explain from a steric point of view, which suggests that other factors such as the nature of the metal and the structure of the aryl group joined to sulfur must also have some role in determining the configuration at C-2.[11]

The different course of the reaction, depending on the metal involved, could be rationalized as follows. The lithium *N*-sulfinyl amide resulting in the addition of dienolates (Table 2) would be able to abstract the acidic protons at C-2, making possible the migration of the double bond. The high stereoselectivity of the isomerization of the double bond (only the *E*-olefins, **11** or **12**, were detected) could be a consequence of the fact that the *N*-sulfinylamino group is more efficient than the ester group to stabilize the resulting allyllithium (Figure 1). The formation of a **11** + **4** mixture starting from **1**, the composition of which is not dependent on the reaction time, as well as the isolation of **12** as exclusive product when **2** was used as starting product, suggests the existence of an equilibrium between the α-ethylidene derivatives and the mixture of α-vinyl-*β*-amino esters (the

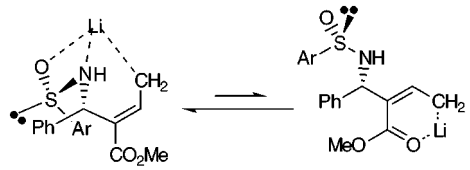


Figure 1.

anti isomers being the most stable), which is completely shifted toward the former in the case of Ar = 2-OMe-naphthyl. In the case of the reactions catalyzed by Lewis acids (Table 1) the higher stability and/or the lower basicity of the resulting metal amides could justify the absence of the isomerization products.

Conclusion

In summary, we have demonstrated that reactions of different metal dienolates with *N*-arylsulfinylimines are completely regioselective (only *β*-amino esters are formed). The control of the stereoselectivity is complete at C-3 but moderate or low at C-2. Mixtures of vinyl *β*-amino esters, epimers at C-α, are obtained in reactions conducted under Lewis acid catalysis, which can be transformed into optically pure 2-alkylidene 3-amino esters in high yields by desulfinylation with TFA and further treatment with Na_2CO_3. Reactions with lithium enolates yielded the optically pure 2-ethylidene-3-arylsulfinylamino esters as the major or exclusive product.

Experimental Section

Addition of Dienolate Methyl 3-Butenoate to *N*-Sulfinylimines Catalyzed by Lewis Acids (Table 1). General Procedure. To a solution of 1.26 mL of diisopropylamine (9.0 mmol, 2.2 equiv) in THF (8 mL) was added 3.5 mL of a 2.4 M solution of *n*-butyllithium in hexane (8.6 mmol, 2.1 equiv) at −78 °C. After 30 min, a solution of 0.82 g of methyl 3-butenoate (8.3 mmol, 2.0 equiv) in THF (4 mL) was added. After stirring for 30 min at −78 °C, the enolate was transmetalated by addition of a solution of 8.2 mmol of the appropriated Lewis acid (2.0 equiv) in THF (5 mL), followed by another 30 min of stirring. Next, a solution of 4.1 mmol of the *N*-sulfinylimine **1**−**3** (1.0 equiv) and 4.1 mmol of the Lewis acid (1.0 equiv) in THF (10 mL) was added. Stirring was continued for 8 h at −78 °C. The reaction was quenched by addition of saturated NH_4Cl solution (20 mL) at room temperature (or 20 mL of methanolic solution of NH_4Cl at −78 °C) and extracted with EtOAc (4 × 20 mL). The combined organic layers were dried over Na_2SO_4 and evaporated under

(11) These results are in concordance with the high *trans*-selectivity observed by other authors in the condensation of zinc enolate esters with imines.[9] These authors have also explained their results by assuming a transition state, type TE_1, involving an (*E*)-imine and a (*Z*)-enolate. In our case ET_1 would be even more favored because the *E*−*Z* equilibrium of the starting dienolate must be shifted to the *Z* form, as in other stabilized conjugated enolates.[12] On the other hand, the change of stereoselectivity, from *anti* to *syn*, observed in the addition of dienolate to the sulfinylimine **2** can be explained by considering the higher steric volume of the naphthyl group compared with the *p*-tolyl group, together with the possible competition between the sulfinylic oxygen and the OMe group for metal chelation.

(12) Ireland, R. E.; Willard, A. K. *Tetrahedron Lett.* **1975**, 3975.

vacuum to yield the addition products that were purified by flash chromatography (hexane/EtOAc, 4/1). The Lewis acid used and yields and ratio of products obtained are indicated in Table 1.

Methyl 3-[*N*-(*p*-Tolylsulfinyl)amino]-3-phenyl-2-vinylpropanoate. The product was obtained as a mixture of *anti* and *syn* diastereomers, **4** and **5**, respectively, from (+)-(*S*)-(*E*)-*N*-benzylidene)-*p*-toluenesulfinamide **1**. The diastereomer **4** was obtained optically pure by flash chromatography using Et_2O/hexane (3/2) as eluent.

Diastereomer 4(S_S,2*S*,3*R*). The product was obtained as a white crystalline solid by recrystallization from hexane. Mp 95 °C; $[\alpha]^{25}_D = +79$ (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 7.57−7.53 (m, 2H), 7.37−7.27 (m, 7H), 5.71 (ddd, *J* = 8.7, 10.1, 16.8 Hz, 1H), 5.17−5.04 (m, 2H), 4.99 (d, *J* = 6.7 Hz, 1H), 4.80(dd, *J* = 6.7, 7.1 Hz, 1H), 3.65 (s, 3H), 3.51 (dd, *J* = 7.1, 8.7 Hz, 1H), 2.42 (s, 3H); ^{13}C NMR ($CDCl_3$) δ 172.0, 142.2, 141.4, 139.2, 131.9, 129.5, 128.5, 128.0, 127.5, 125.4, 120.2, 60.0, 56.9, 52.1, 21.3; IR ($CHCl_3$, cm^{-1}) 3280, 2980, 1720, 1420, 1220, 1180, 1100, 920.

Diastereomer 5(S_S,2*R*,3*R*) (spectroscopic data taken from a mixture of both diastereomers **4** and **5**). ^{1}H NMR ($CDCl_3$, D_2O) δ 7.65−7.55 (m, 2H), 7.39−7.27 (m, 7H), 5.85 (ddd, *J* = 9.4, 10.2, 16.8 Hz, 1H), 5.31−5.18 (m, 2H), 4.76 (d, *J* = 8.6 Hz, 1H), 3.47 (s, 3H), 3.36 (dd, *J* = 8.6, 9.4 Hz, 1H), 2.41 (s, 3H).

Methyl 3-[*N*-(*p*-Tolylsulfinyl)amino]-3-phenyl-2-ethylidenepropanoate, 11(S_S,2*E*,3*S*). The major product was obtained from 1 equiv of the (*S*)-(*E*)-*N*-(benzylidene)-1-*p*-toluenesulfinamide **1** and 2 equiv of the lithium dienolate of methyl 3- butenoate. It was purified by flash chromatography using EtOAc/hexane (1/4) as eluent. $[\alpha]^{25}_D = +158$ (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 7.65−7.18 (m, 9H), 6.95 (q, *J* = 7.5 Hz, 1H), 5.73 (d, *J* = 10.4 Hz, 1H), 5.46 (d, *J* = 10.4 Hz, 1H), 3.62 (s, 3H), 2.40 (s, 3H), 1.57 (d, *J* = 7.5 Hz, 3H); ^{13}C NMR ($CDCl_3$) δ 166.5, 141.4, 141.1, 140.7, 139.4, 133.2, 129.5, 128.3, 127.0, 126.1, 126.0, 53.5, 51.6, 21.2, 13.6. Anal. Calcd for $C_{19}H_{21}NO_3S$: C, 66.45; H, 6.16; N, 4.08; S, 9.33. Found: C, 66.33; H, 6.46; N, 3.91; S, 8.92.

Methyl 3-[*N*-(2-Methoxy-1-naphthylsulfinyl)amino]-3-phenyl-2-vinylpropanoate. The product was obtained as a mixture of diastereomers, **6** and **7**, from (*S*)-(*E*)-*N*-(benzylidene)-2-methoxy-1-naphthalenesulfinamide **2**. Both diastereomers were separated by flash chromatography using Et_2O/hexane/CH_2Cl_2 (2/2/1) as eluent.

Diastereomer 6(S_S,2*S*,3*R*). $[\alpha]^{25}_D = +195$ (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 8.38 (d, *J* = 8.3 Hz, 1H), 7.91 (d, *J* = 9.1 Hz, 1H), 7.75 (d, *J* = 7.8 Hz, 1H), 7.50−7.10 (m, 8H), 6.85 (s_b, 1H), 5.77 (ddd, *J* = 8.8, 10.3, 17.0 Hz, 1H), 5.16 (dd, *J* = 10.3, 0.8 Hz, 1H), 5.12 (dd, *J* = 17.0, 0.8 Hz, 1H), 4.92 (dd, *J* = 8.6, 1.2 Hz, 1H), 4.10 (s, 3H), 3.70 (s, 3H), 3.62 (dd, *J* = 8.8, 8.6 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 172.2, 155.3, 138.5, 133.2, 132.0, 130.7, 128.9, 128.3, 128.2, 127.9, 124.4, 122.2, 120.2, 113.6, 60.7, 57.1, 56.8, 52.1; IR ($CHCl_3$, cm^{-1}) 3250, 2950, 1710, 1580, 1425, 1325, 1250, 1150, 1060. Anal. Calcd for $C_{23}H_{23}NO_4S$: C, 67.46; H, 5.66; N, 3.42; S, 7.83. Found: C, 67.35; H, 5.46; N, 3.26; S, 7.46.

Diastereomer 7(S_S,2*R*,3*R*). The product was obtained as a white crystalline solid by recrystallization from hexane. Mp 129 °C; $[\alpha]^{25}_D = +55$ (*c* 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 8.16 (d, *J* = 9.1 Hz, 1H), 7.94 (d, *J* = 9.1 Hz, 1H), 7.78 (d, *J* = 8.1 HZ, 1H), 7.48−7.23 (m, 8H), 6.63 (s_b, 1H), 6.04 (ddd, *J* = 9.6, 10.2, 17.0 Hz, 1H), 5.38 (dd, *J* = 1.3, 10.2 Hz, 1H), 5.29 (dd, *J* = 1.3, 17.0 Hz, 1H), 4.87 (dd, *J* = 1.6, 9.1 Hz, 1H), 4.10 (s, 3H), 3.50 (s, 3H), 3.38 (dd, *J* = 9.1, 9.6 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 171.1, 155.5, 137.9, 133.3, 133.0, 130.8, 128.3, 127.9, 124.4, 122.0, 121.2, 113.5, 58.7, 56.7, 51.8; IR ($CHCl_3$, cm^{-1}) 3300, 2980, 1750, 1420, 1340, 1290, 1270, 1080. Anal. Calcd for $C_{23}H_{23}NO_4S$: C, 67.46; H, 5.66; N, 3.42; S, 7.83. Found: C, 67.41; H, 5.59; N, 3.25; S, 7.52.

Methyl 3-[*N*-(2-Methoxy-1-naphthylsulfinyl)amino]-3-phenyl-2-ethylidenepropanoate, 12(S_S,2*E*,3*S*). The product was obtained as a unique diastereomer from 1 equiv of the (*S*)-(*E*)-*N*-(benzylidene)-2-methoxy-1-naphthalenesulfinamide **2** and 2 equiv of the lithium dienolate of methyl 3-butenoate. $[\alpha]^{25}_D = +8$ (*c* 0.5, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 8.62 (d, *J* = 8.6 Hz, 1H), 7.86 (d, *J* = 9.1 Hz, 1H), 7.73 (d, *J* = 8.1 Hz, 1H), 7.49−7.11 (m, 8H), 7.04 (q, *J* = 7.2 Hz, 1H), 5.63 (d, *J* = 10.4 Hz, 1H), 3.99 (s, 3H), 3.61 (s, 3H), 1.94 (d, *J* = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$) δ 166.9, 140.8, 139.7, 133.7, 133.1, 130.6, 129.0, 128.5, 128.2, 127.8, 126.9, 125.9, 124.3, 122.5, 113.5, 57.2, 56.8, 51.6, 14.2; IR ($CHCl_3$, cm^{-1}) 3300, 2980, 1700, 1590, 1420, 1300, 1280, 1260, 1100, 1060. Anal. Calcd for $C_{23}H_{23}NO_4S$: C, 67.46; H, 5.66; N, 3.42; S, 7.83. Found: C, 67.59; H, 5.49; N, 3.27; S, 7.40.

Desulfinylation of Methyl 3-[*N*-(Arylsulfinyl)amino]-3-phenyl-2-vinylpropanoates. General Procedure. To a solution of 0.14 mmol of *N*-(2-(methoxycarbonyl)-1-phenyl-3-butenyl)sulfinamide (1 equiv) in 3 mL of MeOH, at 0 °C, was added 42 mL of TFA (0.56 mmol, 4 equiv). After stirring 5 h at 0 °C, the solvent was evaporated under vacuum, and the residue was treated with 5 mL of water and extracted with CH_2Cl_2 (2 × 5 mL). The aqueous phase was evaporated under vacuum, yielding the corresponding trifluoroacetate.

(1*R*,2*R*)-1-Phenyl-2-(methoxycarbonyl)but-3-enylammonium Trifluoroacetate, 8(1*R*,2*R*). It was obtained from compound **7(S_S,2*R*,3*R*)**. Yield: 90%; $[\alpha]^{25}_D = +43$ (*c* 1.2, water); ^{1}H NMR (D_2O): 7.29−7.20 (m, 5H), 5.70 (ddd, *J* = 11.6, 12.3, 20.9 Hz, 1H), 5.38 (dd, *J* = 1.4, 12.3 Hz, 1H), 5.32 (dd, *J* = 1.4, 20.1 Hz, 1H), 4.45 (d, *J* = 9.6 Hz, 1H), 3.62 (dd, *J* = 9.6, 11.6 Hz, 1H), 3.28 (s, 3H); ^{13}C NMR (D_2O) δ 172.1, 133.8, 130.0, 129.9, 129.4, 127.4, 124.0, 55.5, 55.1, 52.9; IR ($CHCl_3$, cm^{-1}) 2890, 1660, 1515, 1425, 1140. Anal. Calcd for $C_{14}H_{16}NO_4F_3$: C, 52.67; H, 5.05; N, 4.39. Found: C, 52.30; H, 4.87; N, 4.38.

(1*R*,2*S*)-1-Phenyl-2-(methoxycarbonyl)but-3-enylamonium Trifluoroacetate, 9(1*R*,2*S*). It was obtained from compound **4(S_S,2*S*,3*R*).** Yield: 90%; $[\alpha]^{25}_D = -30$ (*c* 0.7, water); ^{1}H NMR (D_2O) δ 7.26−7.11 (m, 5H), 5.45 (ddd, *J* = 8.8, 10.6, 19.5 Hz, 1H), 5.04−4.95 (m, 2H), 4.57 (d, *J* = 8.3 Hz, 1H), 3.66 (dd, *J* = 8.8, 8.3 Hz, 1H), 3.51 (s, 3H); ^{13}C NMR (D_2O) δ 172.7, 147.5, 129.6, 129.5, 127.5, 126.5, 124.0, 55.3, 53.1, 52.8; IR ($CHCl_3$, cm^{-1}) 2850, 1655, 1500, 1420, 1140. Anal. Calcd for $C_{14}H_{16}NO_4F_3$: C, 52.67; H, 5.05; N, 4.39. Found: C, 52.20; H, 4.85; N, 4.41.

Methyl (2*E*,3*R*)-2-(α-Aminobenzyl)-3-propenoate, 10-(2*E*,3*S*). To a solution of trifluoroacetate **9(1*R*,2*S*)** in water was added saturated Na_2CO_3 solution. After stirring for 1 h at room temperature, the aqueous phase was extracted with CH_2Cl_2, dried over Na_2SO_4, filtered, and evaporated to yield the amine **10** in quantitative yield. The same product was obtained starting from trifluoroacetate **8(1*R*,2*R*)**. $[\alpha]^{25}_D = -40$ (*c* 0.01, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 7.29−7.20 (m, 5H), 7.0 (q, *J* = 7.0 Hz, 1H), 5.11 (s, 1H), 3.64 (s, 3H), 2.14 (d, *J* = 7.0 Hz, 3H); ^{13}C NMR ($CDCl_3$) δ 166.5, 143.7, 137.6, 136.0, 127.7, 126.0, 125.4, 51.4, 50.9, 13.9; IR ($CHCl_3$, cm^{-1}) 3280, 2910, 1680, 1425, 1240, 1130. Anal. Calcd for $C_{14}H_{16}NO_4F_3$: C, 70.22; H, 7.37; N, 6.82. Found: C, 69.73; H, 7.42; N, 6.60.

Acknowledgment. This work was supported by the "Ministerio de Educación y Ciencia" (Spain) under DGICYT Grants PB95-210 and PB94-1431.

Supporting Information Available: ORTEP representation of the X-ray structure of compound **7** and ^{1}H NMR and ^{13}C NMR spectra of compound **4** (10 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

JO972303Q