[(3*R*,4*S*,5*S*)/(3*S*,4*R*,5*R*)]-3-(4-Methoxyphenyl)-3,4,5-triphenyl-1,2-dioxolane (β-4d): ^{1}H NMR: δ 3.57 (s, 3 H, OCH_3), 4.73 (d, 1 H, J = 6 Hz), 5.56 (d, 1 H, J = 6 Hz), 6.94 (m, 19 H, Ar).

^{13}C NMR (of α- and β-**4d**): δ 54.9 (q), 55.3 (q), 68.2 (d), 85.7 (d), 93.5 (s).

The solution contained, besides α- and β-**4d**, two more dioxolanes as was revealed by the ^{1}H NMR spectrum, which showed two further OCH_3 groups with singlets at δ 3.65 and 3.82 in a ratio of 3:2, attributed to **[(3*S*,4*S*,5*R*)/(3*R*,4*R*,5*S*)]-** and **[(3*R*,4*S*,5*R*)/(3*S*,4*R*,5*S*)]-3-(4-methoxyphenyl)-3,4,5-triphenyl-1,2-dioxolane, γ-4d and δ-4d**, respectively. When the oily product, obtained after photooxygenation of **3d** and removal of MeCN, was resolved in $CDCl_3$, the four OCH_3 singlets at δ 3.77, 3.57, 3.65, and 3.82 were found in a ratio of 9:6:3:2 (≡ 45:30:15:10).

3,3-Bis(4-methoxyphenyl)-4,5-diphenyl-1,2-dioxolanes (4e). 1,1-Bis(4-methoxyphenyl)-*trans*-2,3-diphenylcyclopropane (**3e**) (1.0 g, 2.4 mmol) was oxygenated within 1 h to better than 95%. The workup procedure yielded 0.6 g of **3,3-bis(4-methoxyphenyl)-*cis*-4,5-diphenyl-1,2-dioxolane (*cis*-4e)** (57%, colorless needles from ethanol), mp 110–111 °C. ^{1}H NMR: δ 3.57 (s, 3 H, OCH_3), 3.75 (s, 3 H, OCH_3), 4.69 (d, 1 H, J = 5.5 Hz), 5.59 (s, 1 H, J = 5.5 Hz), 6.42–7.68 (m, 18 H, Ar). ^{13}C NMR: δ 54.9 (q), 55.3 (q), 68.3 (d), 85.7 (d), 93.4 (s). UV (CH_2Cl_2): λ_{max} = 265 nm (log ε = 3.63) and 275 nm (log ε = 3.57); shoulder at λ = 285 nm (log ε = 3.40).

Anal. Calcd for $C_{29}H_{26}O_4$ (438.50): C, 79.43; H, 5.98. Found: C, 79.60; H, 5.75.

3,3-Bis(4-methoxyphenyl)-*trans*-4,5-diphenyl-1,2-dioxolane (*trans*-4e). ^{1}H NMR: δ 3.65 (s, 3 H, OCH_3), 3.73 (s, 3 H, OCH_3), 4.68 (d, 1 H, J = 9 Hz), 5.48 (d, 1 H, J = 9 Hz), 6.42–7.68 (m, 18 H, Ar).

The ^{1}H NMR spectrum of the original product mixture, from which the ^{1}H NMR signals of *trans*-**4e** were extracted, showed OCH_3 singlets at 3.57, 3.65, 3.73, and 3.75 in a ratio of 3:2:2:3, indicating a *cis*-**4e**:*trans*-**4e** ratio of 3:2.

Acknowledgment. We gratefully acknowledge the help of Dr. K. Polborn, Institut für Organische Chemie der Universität München, who performed the X-ray analysis of compound **3e**. Financial support by Deutsche Forschungsgemeinschaft, Bonn-Bad Godesberg, is also gratefully acknowledged.

Supplementary Material Available: ^{1}H NMR spectrum of **2c**, ^{13}C NMR spectrum of α-**4b** (or β-**4b**), ^{13}C NMR spectra (off-resonance and noise decoupled) of mixture of (α-**4d** + β-**4d**), ^{1}H NMR spectrum of the original mixture of (α-**4d** + β-**4d** + γ-**4d** + δ-**4d**) used to determine their ratio from the 4 OCH_3 groups at about 4 ppm, and ORTEP drawing of **3e** (7 pages). Ordering information is given on any current masthead page.

Stereoselective Additions of Nucleophilic Alkenes to Chiral Thionium Ions[1]

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A convenient one-pot process has been developed for conversion of an aldehyde to an arylthionium ion (e.g., Schemes IV and V), which can be trapped by a nucleophilic alkene. The stereochemistry of the reactions of such chiral and prochiral arylthionium ions with achiral and prochiral nucleophilic alkenes has been studied. The major adducts are those predicted by qualitative application of the Cram–Felkin rule. Quantitatively, however, the nature of the thionium aryl group has a marked effect. For example, whereas **12** reacts with the phenylthionium ion derived from 2-phenylpropanol to give keto sulfides **13a** and **14a** in a ratio of 4:1, the corresponding reaction of the mesitylthionium ion affords the analogous keto sulfides **24a** and **25a** in a ratio of >98:2. In reactions between prochiral thionium ions and prochiral enol silanes, good simple (anti) relative stereochemistry is observed, especially with enol silane **35** (Scheme VII, Table IV). Mesitylthionium ions of α-chiral aldehydes react with prochiral enol silanes to give one of the four possible products in predominance (Scheme VIII, Table V). Again, however, enol silane **35** is found to be a superior reagent, giving **41** in 97% stereoisomeric purity. The α-methyl-β-arylthio ketones produced in these thionium ion reactions can be transformed by a straightforward process, which includes desulfurization, into chain compounds having anti 1,3-dimethyl branches (e.g., Scheme IX). An iterative application of this scheme can be used to prepare deoxypolypropionate structures, as shown in Scheme X.

Introduction

In previous papers in this series, we have reported that the diastereofacial preference of a chiral aldehyde derivative is often dependent on the size of the activating ligand X attached to the carbonyl oxygen (eq 1).[1,2] In this paper, we report an extension of this investigation to the related thionium ion system (eq 2).[3] In addition, we have studied the stereoselectivity of reactions of prochiral enol silanes with prochiral and chiral thionium ions (eqs 3 and 4) and have found that excellent stereoselectivity can be observed, even in cases such as that illustrated in eq 4, where four possible diastereomers can be formed. Finally, we demonstrate an application of the thionium ion method for preparation of acyclic systems having 1,3-stereorelationships.

Generation of Thionium Ions. The Pummerer reaction was discovered in 1909 when it was found that treatment of (phenylsulfinyl)acetic acid with acetic anhydride gives α-acetoxy-α-(phenylthio)acetic acid.[4] The reaction has been the subject of mechanistic investigation

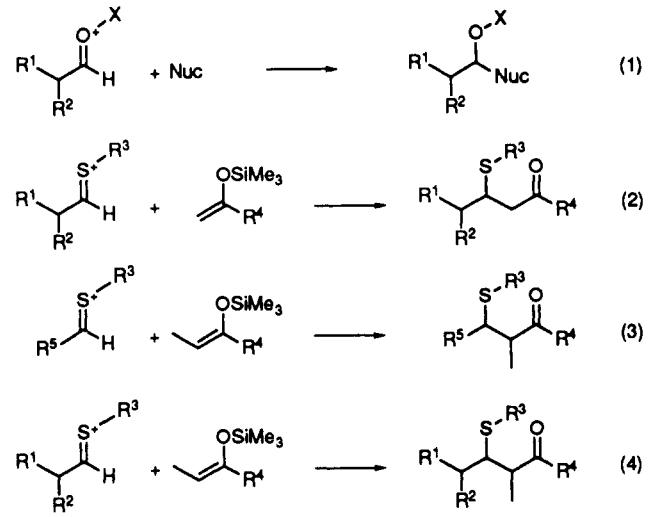
(1) Paper 51 in the series Acyclic Stereoselection. For paper 50, see: Mori, I.; Ishihara, K.; Heathcock, C. H. *J. Org. Chem.* **1990**, *55*, 1114.

(2) (a) Heathcock, C. H.; Flippin, L. A. *J. Am. Chem. Soc.* **1983**, *105*, 1667. (b) Lodge, E. P.; Heathcock, C. H. *J. Am. Chem. Soc.* **1987**, *109*, 2819.

(3) A portion of this work has appeared in preliminary communication form: Mori, I.; Bartlett, P. A.; Heathcock, C. H. *J. Am. Chem. Soc.* **1987**, *109*, 7199.

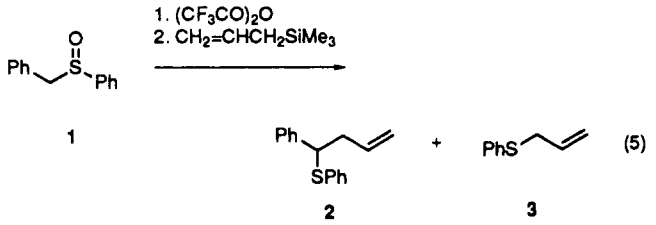
(4) (a) Pummerer, R. *Chem. Ber.* **1909**, *42*, 2282. (b) Pummerer, R. *Ibid.* **1910**, *43*, 1401. (c) Sugihara, H.; Tanikaga, R.; Kaji, A. *Synthesis* **1978**, 881.

0022-3263/90/1955-5966$02.50/0

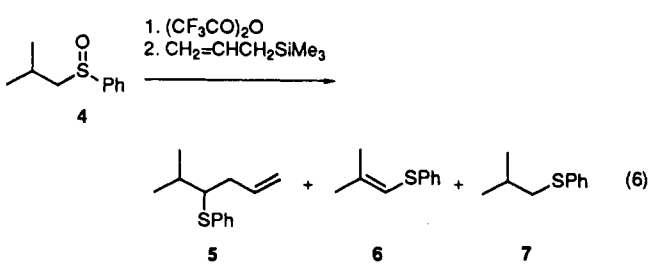


and is believed to proceed via a *S*-acetoxy sulfonium salt and a thionium ion.[5] The intermediate thionium ion can be effectively trapped by aromatic rings in Friedel–Crafts reactions, both inter- and intramolecularly.[6] Although one example of trapping a Pummerer-generated thionium ion with a nucleophilic alkene has been reported,[7] stereochemistry was not an issue in that case.

For a preliminary study of the feasibility of generating and trapping thionium ions via the Pummerer rearrangement, we prepared sulfoxides **1** and **4** by oxidation of the corresponding sulfides. Treatment of **1** with trifluoroacetic anhydride in the presence of allyltrimethylsilane under several conditions gave variable amounts of the allylated sulfide **2** (eq 5, Table I). Yields of **2** were generally poor, and in most solvents, the desired product was accompanied by an unexpected side product, allyl phenyl sulfide (**3**).



With sulfoxide **4**, the results were even less encouraging (eq 6, Table II). Under most conditions, the major product was vinyl sulfide **6**, formed by simple deprotonation of the intermediate thionium ion. The desired allylated sulfide **5** was formed only in acetonitrile and then only in 24% yield. Incorporation of 1 equiv of 2,6-lutidine, a modification that has been reported to be efficacious in the Pummerer rearrangement,[4c] did not improve the situation.



(5) For reviews, see: Oae, S. In *Organic Chemistry of Sulfur*, Oae, S., Ed.; Plenum Press: New York, 1977.

(6) (a) Stamos, I. K. *Tetrahedron Lett.* **1985**, *26*, 477, 2787. (b) Magnus, P; Gallagher, T.; Brown, P.; Pappalardo, P. *Acc. Chem. Res.* **1984**, *17*, 35.

(7) Hunter, R.; Simeon, C. D. *Tetrahedron Lett.* **1986** *27*, 1385.

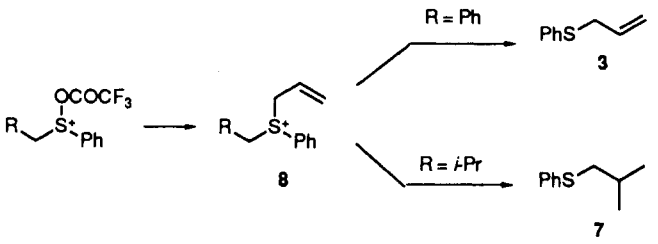
Table I. Pummerer Allylation of Sulfoxide 1 at 25 °C (eq 5)

		% yield	
solvent	time, h	2	3
CH_2Cl_2	18	62	16
CH_2Cl_2	10	62	27
CH_3CN	5	50	0
$CHCl_3$	10	14	20
CH_3NO_2	10	30	32

Table II. Pummerer Allylation of Sulfoxide 4 at 25 °C (eq 6)

			% yield		
solvent	2,6-lutidine (equiv)	time, h	5	6	7
CH_2Cl_2	0	24	0	38	13
CH_2Cl_2	1	24	0	0	61
CH_3CN	0	48	24	24	4
CH_3CN	1	48	0	40	0
CH_3NO_2	0	24	0	100	0

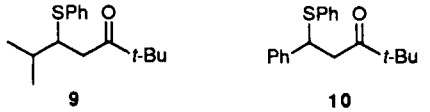
Scheme I



The unexpected byproducts **3** and **7** are proposed to result from the side reaction depicted in Scheme I. Displacement of trifluoroacetate from sulfur by allyltrimethylsilane provides salt **8**, which is attacked by a nucleophile (probably trifluoroacetate) at the benzylic position when R = phenyl and at the allylic position when R = isopropyl.

These preliminary investigations revealed a flaw in our original plan; we did not anticipate the reaction of the nucleophilic alkene with the intermediate in the Pummerer rearrangement. This led us to consider the other principle route to the thionium ions—Lewis acid mediated ionization of an α-substituted sulfide.[8,9] It occurred to us that we might separate the reaction into two parts by first rearranging the sulfoxide to the α-trifluoroacetoxy sulfide. This substance could then be treated with the nucleophilic alkene in the presence of a suitable Lewis acid.

This method served admirably; addition of a mixture of trifluoroacetic anhydride and slightly more than 1 equiv of 2,6-lutidine to a solution of sulfoxide **1** or **4** in CH_2Cl_2 at 0 °C, followed by cooling to −78 °C and addition of either allytrimethylsilane or the enol silane of pinacolone and 1 equiv of $SnCl_4$, provided the alkylated sulfides **5** (53%), **9** (72%), and **10** (77%).



(8) α-Chloro thioethers: (a) Meerwein, H.; Zimmer, K. F.; Gipp, R. *Justus Leibigs Ann. Chem.* **1965**, *688*, 67. (b) Eschenmoser, A. *Q. Rev. Chem. Soc.* **1970**, *24*, 366. (c) Paterson, I.; Fleming, I. *Tetrahedron Lett.* **1979**, *20*, 995. (d) Wada, M.; Shigehisa, T.: Akiba, K. *Tetrahedron Lett.* **1983**, *24*, 1711. (e) Wada, M.; Shigehisa, T.; Kitani, H.; Akiba, K. *Ibid.* **1983** *24*, 1715.

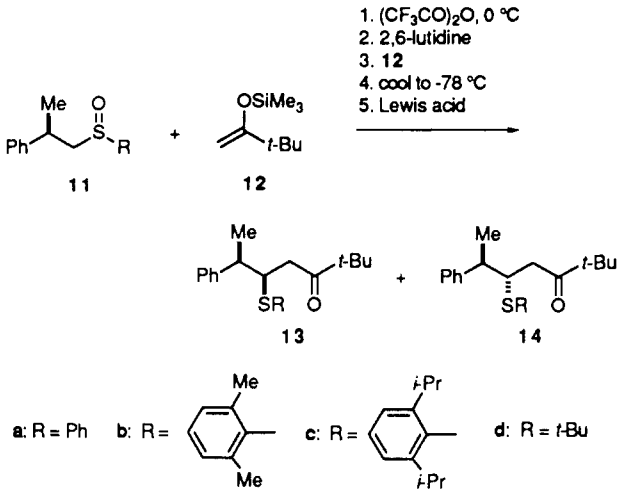
(9) Thioacetals and hemithioacetals: (a) Kim, J. K.; Pau, J. K.: Caserio, M. C. *J. Org. Chem.* **1979**, *44*, 1544. (b) Reetz, M. T.; Ginnauis, A. *Synth. Commun.* **1981**, *11*, 315. (c) Trost, B. M.; Sato, T. *J. Am. Chem. Soc.* **1985**, *107*, 719.

Table III. Stereoselectivity in Reactions of Thionium Ions with Silyl Enol Ether 12 in CH_2Cl_2 (Scheme II)

entry	sulfoxide	sulfoxide diastereomer ratio[a]	Lewis acid	temp, °C	% yield	13:14
1	11a	38:62	$SnCl_4$	−78	66	79:21
2	11a	38:62	$TiCl_4$	−78 to 0	83	83:17
3	11a	38:62	$BF_3{\cdot}Et_2O$	−78 to 0	64	76:24
4	11a	38:62	$ZnBr_2$	25	72	84:16
5	11b	50:50	$SnCl_4$	−78	61	>98:2
6	11c	50:50	$SnCl_4$	−78	73	>98:2
7	11d	43:57	$SnCl_4$	−78	79	>98:2

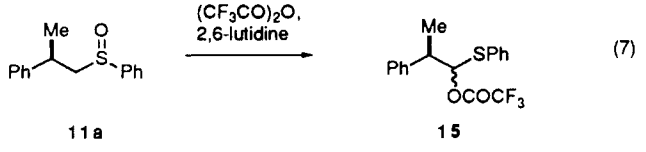
[a] Ratio of sulfoxides (more polar:less polar).

Scheme II



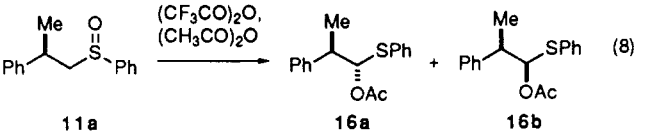
Diastereofacial Preferences of Chiral Thionium Ions. With a suitable method in hand for generation of a thionium ion in the presence of a nucleophilic alkene, we evaluated the concept that the diastereofacial preference of a chiral ion might depend on the size of the sulfur ligand. Chiral sulfoxides **11a–d** were prepared and subjected to the two-stage process described in the preceding section; enol silane **12** was employed as the nucleophilic alkene (Scheme II). Reactions of phenyl sulfoxide **11a** were examined under several different conditions, and the ratios of the diastereomeric thioether products were found to be in the range 3:1 to 5:1 (Table III, entries 1–4). However, sulfoxides **11b–d** each react with **12** in the presence of $SnCl_4$ to give a single diastereomeric β-thio ketone, within the limits of 250-MHz ^1H NMR spectral analysis (entries 5–7).

Sulfoxides **11a–d** consist of mixtures of diastereomers because of the presence of two stereogenic atoms. Furthermore, the intermediate α-trifluoroacetoxy sulfide can also exist in two diastereomeric forms. To have a more complete understanding of the full stereochemical personality of the process, we examined each of these aspects. Sulfoxide **11a** (in this case, 55:45 diastereomeric mixture) was separated by HPLC into diastereomers **11a-a** (less polar, 99% pure) and **11a-b** (more polar, 92% pure). Each was treated with trifluoroacetic anhydride and 2,6-lutidine at 0 °C, and the reaction was monitored by ^1H NMR spectrometry. Both isomers gave the same 57:43 ratio of diastereomeric α-trifluoroacetoxy sulfides **15** (eq 7), characterized by their methyl doublets at 1.52 and 1.43 ppm.



(7)

Because α-trifluoroacetoxy sulfides **15** are too unstable to isolate, the diastereomeric α-acetoxy sulfides **16** were prepared by reaction of **11a** with a mixture of acetic and trifluoroacetic anhydrides at room temperature.[10] Diastereomers **16a** and **16b**, formed in a ratio of 39:61, were separated by HPLC.[11,12] Each diastereomer was allowed to react with enol silane **12** in the presence of either $SnCl_4$ or $TiCl_4$. With $SnCl_4$ as the promoter, each α-acetoxy sulfide gave two diastereomeric β-phenylthio ketones in a ratio of 7:3,[13] proving that the nucleophilic substitution reaction does not occur by the S_N2 mechanism.



(8)

Direct Formation of Thionium Ions from Aldehydes: The "One-Pot Procedure". The results obtained with chiral sulfoxides **11b–d** were promising in that they showed that very high diastereofacial selectivity can be obtained in nucleophilic additions to thionium ions. However, for this to be a useful preparative process a more efficient way to generate thionium ions, preferably from aldehydes, was needed.

Treatment of 2-phenylpropanal with (phenylthio)trimethylsilane (**17**)[14,15] in the presence of $TiCl_4$ rapidly provided dithioacetal **18** (Scheme III). Reaction of **18** with enol silane **12** in the presence of $TiCl_4$ or $SnCl_4$ afforded sulfides **13a** and **14a** in a diastereomeric ratio of 4:1. A similar $TiCl_4$-mediated reaction of **18** with allyltrimethylsilane gave a mixture of the desired product accompanied by a number of uncharacterized byproducts. However, the use of $SnCl_4$ with this alkene gave a much cleaner reaction; **19** and **20** were formed in a ratio of 3:1.

To achieve higher diastereofacial selectivity, we turned to the mesityl analogue of **17**, reagent **21** (Scheme IV). The intermediate dithioacetal **23** forms more slowly, requiring 30 min at 0 °C. However, **23** appears to be more reactive than **18**, probably because of the relief of steric

(10) Tankiaga, R.; Yabuki, Y.: Ono, N.; Kaji, A. *Tetrahedron Lett.* **1976**, 2257.

(11) The relative stereochemistry of diastereomers **16a** and **16b** is assigned on the basis of the chemical shifts of the acetoxy resonances, 1.84 and 2.02 ppm, respectively; see ref 12.

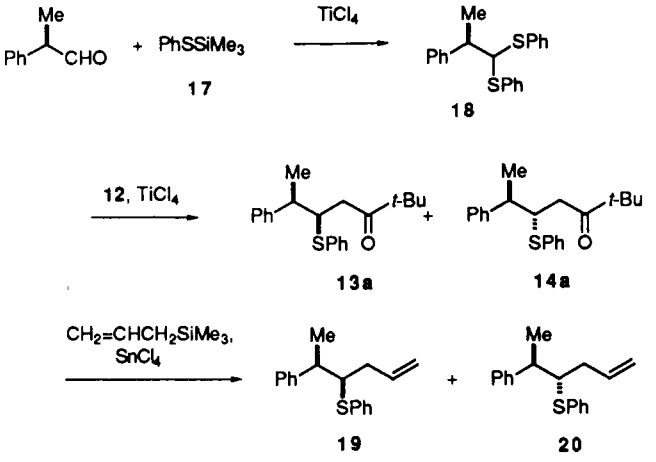
(12) For acyclic diastereomers having vicinal stereocenters, each having one hydrogen and one bearing an aryl group, the relative stereochemistry can be assigned if one assumes that (i) the molecules exist predominantly in conformations having the two hydrogens anti and (ii) the aryl group will cause an upfield shift of the ^1H NMR resonances of the group gauche to it on the vicinal stereocenter. For precedents, see: (a) Heathcock, C. H.; Kiyooka, S.; Blumenkopf, T. A. *J. Org. Chem.* **1984**, *49*, 4219. (b) Heathcock, C. H.; Lampe, J. *Ibid.* **1983**, *48*, 4330.

(13) With $TiCl_4$ the diastereomeric products were obtained in a ratio of 8:2 regardless of the configuration of the starting material.

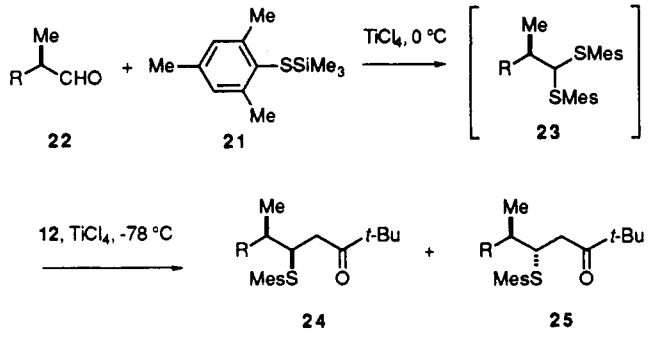
(14) Glass, R. S. *J. Organomet. Chem.* **1973**, *61*, 83.

(15) This procedure for the formation of thioacetals was developed by Evans and coworkers: (a) Evans, D. A.; Grimm, K. G.; Truesdale, L. K. *J. Am. Chem. Soc.* **1975**, *97*, 3329. (b) Evans, D. A.; Truesdale, L. K.; Grim, G. K.; Nesbitt, S. L. *Ibid.* **1977**, *99*, 5009.

Scheme III



Scheme IV



a: R = Ph b: R = cyclohexyl c: R = CH_2Ph d: R = Et

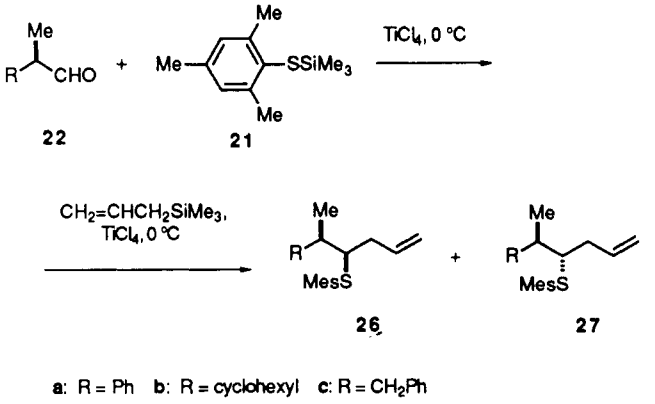
congestion that occurs upon ionization. Because of the greater reactivity of this dithioacetal it is possible to generate it from the aldehyde at 0 °C, cool to −78 °C, and add the nucleophilic alkene and more Lewis acid. This "one-pot procedure" is a very convenient method to convert aldehydes into β-mesitylthio ketones. The basic procedure is as follows: A solution of 1.0 equiv of aldehyde and 2.0 equiv of **21** in CH_2Cl_2 is treated with 0.5 equiv of $TiCl_4$ at 0 °C. It is important to use no more than 0.5 equiv of Lewis acid in this step in order to avoid formation of the vinyl sulfide. After 30 min the solution is cooled to −78 °C and treated with 1.0 equiv of enol silane or allylsilane and 4.0 equiv of $TiCl_4$. The use of excess Lewis acid is important to facilitate the reaction at −78 °C. Application of the process to 2-phenylpropanal provided keto sulfide **24a** as a single diastereomer in 84% yield.

High stereoselectivity was also achieved in the reactions of enol silane **12** with other chiral aldehydes. With 2-cyclohexylpropanal (**22b**), the syn sulfide **24b** was obtained in isomerically pure form in 73% yield. Aldehyde **22c** gave diastereomeric sulfides **24c** and **25c** in the surprisingly high ratio of 97:3 (80% yield). Even 2-methylbutanal (**22d**), in which stereodifferentiation results from the difference in size of methyl and ethyl groups, gave syn and anti products (**24d** and **25d**) in a ratio of 83:17. For comparison, diastereomer ratios in nucleophilic additions to aldehyde **22d** are commonly less than 60:40.[16]

As in Lewis acid mediated additions to the chiral aldehydes,[12a] allyltrimethylsilane was less selective than enol silane **12** (Scheme V). With aldehydes **22a**, **22b**, and **22c**,

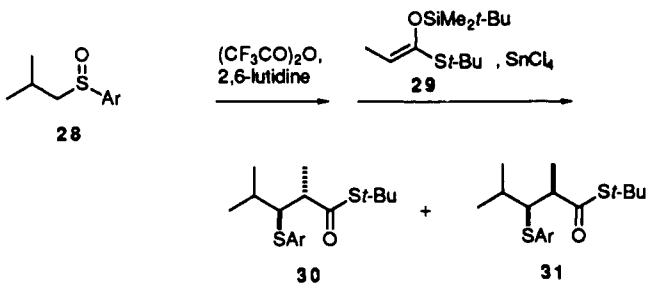
(16) See, inter alia: (a) Gault, Y.; Felkin, H. *Bull. Soc. Chim. Fr.* **1962**, 1342. (b) ref. 2a.

Scheme V



a: R = Ph b: R = cyclohexyl c: R = CH_2Ph

Scheme VI



a: Ar = Ph b: Ar = 2,4,6-$(Me)_3C_6H_2$ c: Ar = 2,4,6-$(i\text{-}Pr)_3C_6H_2$

allyltrimethylsilane provided sulfides **26a** and **27a** (97:3 ratio, 74% yield), **26b** and **27b** (94:6 ratio, 39% yield), and **26c** and **27c** (77:23 ratio, 77% yield).

Simple Diastereoselectivity. A systematic investigation of simple diastereoselectivity in reactions of thionium ions with prochiral nucleophilic alkenes has not been previously reported, although there are scattered examples in the literature. Mukaiyama and co-workers studied the reactions of diethyl thioacetals with prochiral enol silanes in the presence of trityl fluoborate. Although the stereostructures of the reaction products were not determined, in some cases γ-keto sulfides were obtained with good stereoselectivity.[17] Trost and Sato reported that the reaction of crotyltributylstannane (*E*:*Z* = 83:17) with dimethyl thioketals, mediated by dimethyl(methylthio)-sulfonium fluoborate gives 1:1 mixtures of diastereomers.[18] Nozaki and co-workers studied the $TiCl_4$-promoted reactions of α-methoxy sulfides with crotyltributylstannane and obtained syn and anti products in a ratio of 2:1.[19]

In this phase of our study, we turned again to sulfoxides as a way to generate thionium ions and used Gennari's silyl thio ketene acetal **29**[20] as the nucleophilic alkene. Reaction of the phenyl sulfoxide **28a** with trifluoroacetic anhydride and 2,6-lutidine followed by **29** and $SnCl_4$ gave the anti and syn diastereomeric sulfides **30a** and **31a** in a ratio of 1:1 (Scheme VI). However, application of the same procedure to sulfoxide **28b** gave **30b** and **31b** in a ratio of 93:7. With triisopropylphenyl sulfoxide **28c**, the selectivity was further increased and the anti isomer **30c** was the only detectable product. The stereochemistry of the major

(17) Oshima, M.; Murakami, M.; Mukaiyama, T. *Chem. Lett.* **1985**, 1871.
(18) Trost, B. M.; Sato, T. *J. Am. Chem. Soc.* **1985**, *107*, 719.
(19) Sato, T.; Okura, S.; Otera, J.; Nozaki, H. *Tetrahedron Lett.* **1987**, *28*, 6299.
(20) Gennari, C.; Bertta, M. G.; Bernardi, A.; Mori, G.; Scholastico, C.; Todesini, R. *Tetrahedron* **1980**, *42*, 893.

Scheme VII

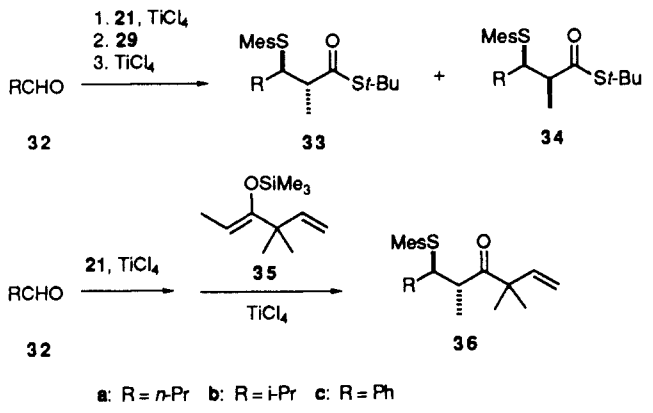


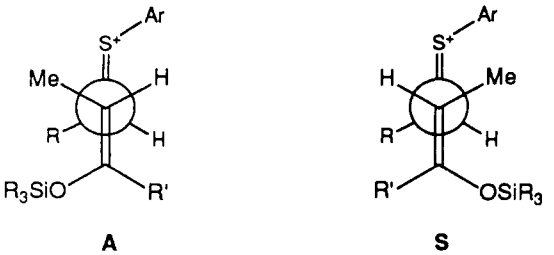
Table IV. Stereoselectivity in Reactions of Enol Silanes with Aldehydes by the One-Pot Procedure Using Reagent 21 (Scheme VII)

entry	aldehyde	enol silane	product(s)	% yield	anti/syn
1	**32a**	*E*-**29**	**33a, 34a**	50	75:25
2	**32b**	*E*-**29**	**33b, 34b**	60	92:8
3	**32b**	*Z*-**29**	**33b, 34b**	75	83:17
4	**32c**	*E*-**29**	**33c, 34c**	91	94:6
5	**32c**	*Z*-**29**	**33c, 34c**	88	89:11
6	**32a**	**35**	**36a**	86	>98:2
7	**32b**	**35**	**36b**	86	>98:2
8	**32c**	**35**	**36c**	83	>98:2

isomers (**30b** and **30c**) was assigned as anti by analogy to the stereochemistry observed in Lewis acid promoted aldol reactions of **29**.[20]

Since the thionium ion derived from mesityl sulfoxide **28b** showed respectable simple diastereoselectivity in its reaction with **29**, we investigated the one-pot procedure using reagent **21** and several aldehydes. Both the *E* and *Z* stereoisomers of **29** were employed in this study (Scheme VII). The results are summarized in Table IV (entries 1–5). The process gave acceptable simple diastereoselectivity with isobutyraldehyde and benzaldehyde, but with *n*-butyraldehyde the selectivity was only 3:1. However, application of the procedure to the same three aldehydes using enol silane **35**[21] was much more successful; the anti α-methyl-β-arylthio adducts **36a–c** were formed as the only detectable isomers in excellent yield (Table IV, entries 6–8).

The stereochemical trends in Table IV can be understood if one assumes that (a) the thionium ion aryl group to cis to the hydrogen and (b) the enol silane reacts with the thionium ion through the "extended" transition structures A (giving the anti product) and S (giving the syn product).[22] The results obtained with sulfoxides **28a–c**



and *E*-**29** can be explained as follows. The nonbonded interactions that are considered to be important are

Scheme VIII

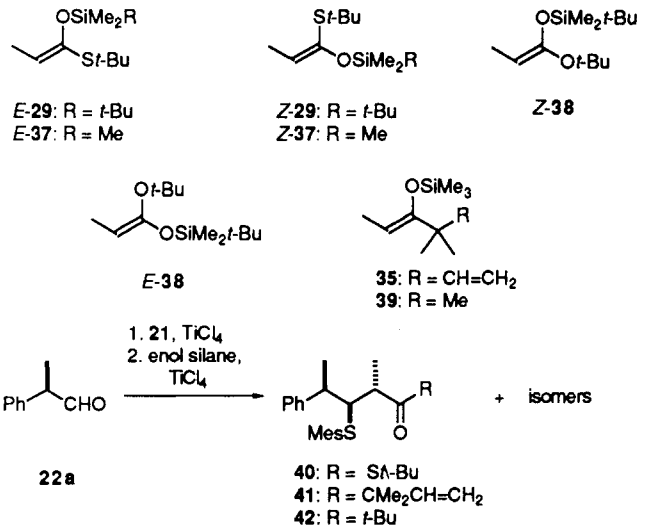


Table V. Stereoselectivity in Reactions of Various Enol Silanes with Aldehyde 22a by the One-Pot Procedure Using Reagent 21 (Scheme VIII)

entry	enol silane	*E*/*Z* ratio	% yield	isomer ratio	major product[a]
1	*E*-**29**	94:6	78	66:(16:17)	**40**
2	*Z*-**29**	5:95	88	76:(7:17)	**40**
3	*E*-**37**	86:14	69	60:(13:27)	**40**
4	*Z*-**37**	4:96	79	60:(7:33)	**40**
5	*Z*-**38**	5:95	–[b]	–	–
6	*E*-**38**	95:5	–[b]	–	–
7	**35**	>98:2	63	97:(3)	**41**
8	**39**	>98:2	79	97:(3)	**42**

[a] The structures of minor isomers were not determined. [b] No products having the desired structure were observed.

methyl/aryl and R/*t*-BuS for S and R/methyl for A; the R/*t*-BuMe$_2$SiO interaction in A is presumed to be small because of the small van der Waals radius of oxygen. In the phenyl-substituted thionium ion, the aromatic ring can lie in the plane of the thionium ion and the methyl/aryl interaction in S is negligible. If the R/*t*-BuS interaction in S and the R/methyl interaction in A are approximately equal, one would expect a stereorandom reaction, as is observed. However, mesityl or 2,4,6-triisopropylphenyl groups cannot achieve coplanarity for geometric reasons. With these compounds, we believe that the aryl group is tilted out of the general plane of the thionium ion. As a result, the methyl/aryl interaction becomes the dominant interaction and transition structure A is strongly favored.

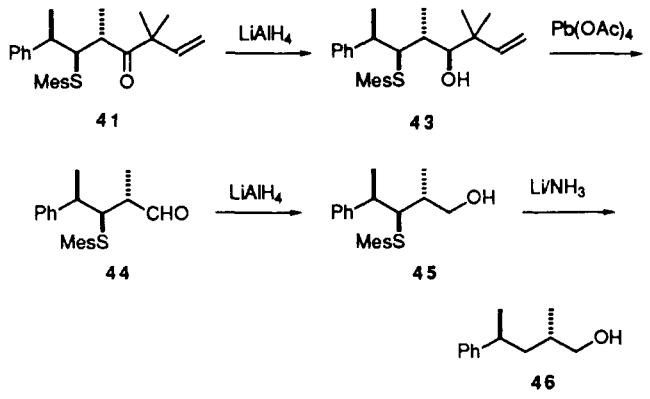
Similar arguments can be used to explain the results summarized in Table IV. Since both *E*- and *Z*-**29** give the anti product **33** as the major isomer, it is clear that the methyl/aryl interaction is dominant and that the R/*t*-BuS interaction is of lesser importance. Note, however, that with both **32b** and **32c**, *E*-**29** shows slightly greater anti selectivity than does the *Z* isomer. When R′ is a *tert*-alkyl group, as in enol silane **35**, the R/R′ interaction becomes of major importance and the only operative transition structure is A.

Reactions of Chiral Thionium Ions with Prochiral Enol Silanes. Since both simple diastereoselectivity and diastereofacial selectivity are high in thionium reactions using reagent **21**, we extended our investigation to the reactions of chiral thionium ions with prochiral enol silanes with the hope that one of the four possible diastereomeric products would be formed preferentially. In this study, the one-pot procedure was employed using 2-phenyl-

(21) Mori, I.; Ishihara, K.; Heathcock, C. H. *J. Org. Chem.* **1990**, *55*, 1114.

(22) Heathcock, C. H.; Davidson, S. K.; Hug, K. T.; Flippin, L. A. *J. Org. Chem.* **1986**, *51*, 3027.

Scheme IX



propanal (**22a**). The enol silanes that were evaluated were *E*- and *Z*-**29**, **35**, *E*- and *Z*-**37**, *E*- and *Z*-**38**, and **39**. The results of this study are summarized in Scheme VIII and Table V.

Surprisingly, the Gennari enol silanes **37** and **29** showed low stereoselectivity, and each gave two minor isomers (entries 1–4). The simple ketene acetals *E*- and *Z*-**38** gave none of the desired products (entries 5–6), perhaps because these substances are too acid-sensitive for the reaction conditions. However, enol silanes **35** and **39** reacted smoothly and with good stereoselectivity, giving major and minor isomers in a ratio of 97:3 (entries 7–8).

Keto sulfide **41** was converted into alcohol **46** (>98% diastereomeric purity) by the four-step process[21] illustrated in Scheme IX, thus demonstrating the utility of the overall process for preparing compounds with anti 1,3-branches.

The reduction of ketone **41** with lithium aluminum hydride provided crystalline alcohol **43** as a single isomer in 98% yield. The relative stereochemistry of **43** was determined by X-ray analysis (Figure 1). This determination confirmed several stereochemical assumptions that had been made on the basis of analogies. First, the C-5,C-6 anti stereochemistry is consistent with the idea that the major isomer is formed through a transition structure similar to A. Second, the C-6,C-7 syn stereochemistry confirms that the diastereofacial preference of the chiral thionium ion derived from 2-phenylpropanal is that predicted by the Cram–Felkin rule. Finally, the very high C-4,C-5 anti stereoselectivity in the reduction of **41** is expected by analogy to results presented by Felkin for a related *tert*-butyl ketone.[23]

Iterative Application for the Synthesis of Deoxypolypropionates. The combination of high simple and diastereofacial selectivity of the chiral mesitylthionium ions offers the opportunity for a process whereby an aldehyde can be transformed into a deoxypolypropionate chain by iterative application. Because of the syn simple stereoselectivity and the Cram–Felkin diastereofacial preference, the resulting chain will have alternating anti branches. This process was demonstrated by the reaction sequence shown in Scheme X. Reduction of β-keto sulfide **36b** provided homoallylic alcohol **47**, which was oxidized with lead tetraacetate to aldehyde **48**. A second application of the one-pot process converted **48** into **49**, which was smoothly reduced to homoallylic alcohol **50**. At this point we encountered a snag, as alcohol **50** resisted oxidation by lead tetraacetate. It is possible that the two mesitylthio groups in **50** adopt conformations that sterically hinder the secondary alcohol. We therefore carried out a desulfurization at this point, to obtain homoallylic alcohol **51** in 61% yield, accompanied by 14% of a byproduct (**52**; diastereomeric mixture) in which the intermediate secondary radical has added to the terminal double bond. Lead tetraacetate oxidation of **51** occurred as expected, providing aldehyde **53**, which was subjected to a third application of the one-pot procedure to obtain ketone **54**. Unfortunately, the stereoselectivity of this third application is not as high as in the first two; **54** was obtained in 90% diastereomeric purity, accompanied by two minor isomers, each in 5% yield. The mixture was reduced to homoallylic alcohol **55**, which was oxidatively cleaved to obtain aldehyde **56**. Two-stage reduction of this material provided **58**, still a 90:5:5 mixture of diastereomers. Recrystallization of the derived crystalline 3,5-dinitrobenzoate (**59**) afforded isomerically pure material.

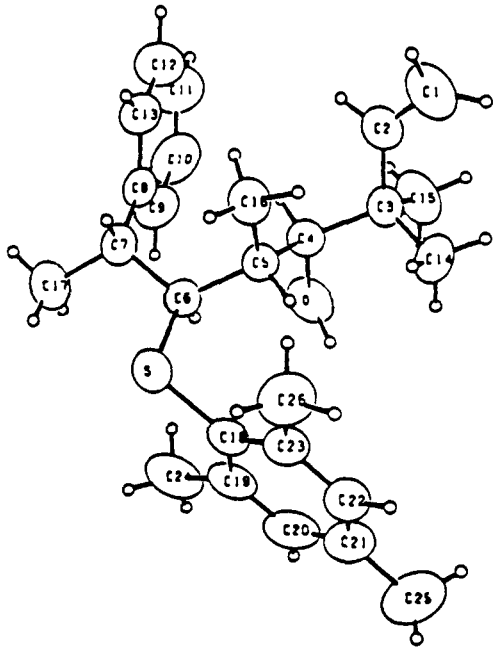


Figure 1. ORTEP representation of compound **43**.

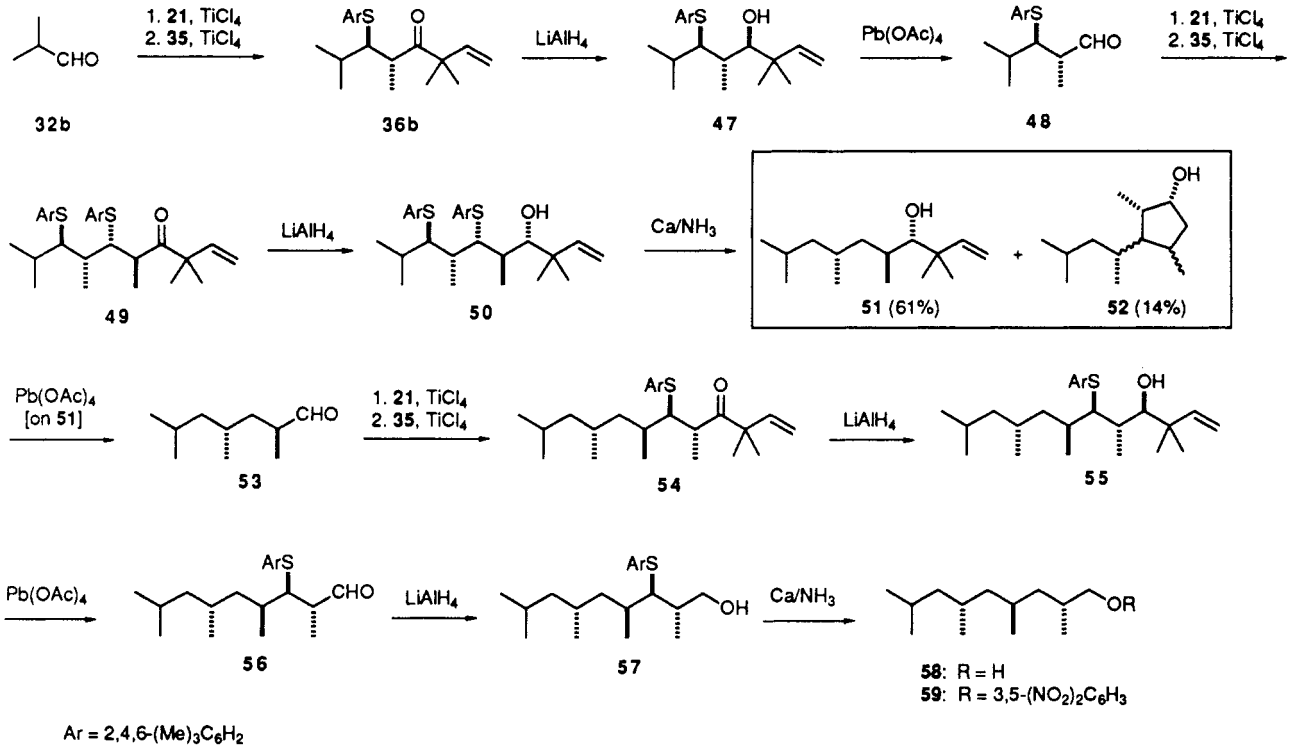
Conclusions. We have discovered that nucleophilic additions to α-chiral thionium ions have Cram–Felkin diastereofacial preferences. The magnitude of diastereofacial selectivity is significantly enhanced by the use of a bulky group (e.g., mesityl) attached to the thionium sulfur. The observed effect is accounted for by our previous proposals about perturbation of the trajectory of the attacking nucleophile.[2] Prochiral thionium ions and prochiral enol silanes react with excellent simple diastereoselectivity, giving anti α-alkyl-β-arylthio ketones. The high diastereofacial preference of chiral thionium ions can be combined with the high simple diastereoselectivity of prochiral enol silanes, giving very stereoselective processes wherein one of four possible diastereomeric products is obtained in large excess. Finally, an iterative application of the latter process serves to prepare deoxypolypropionate chains with alternating anti alkyl branches.

Experimental Section

General. Unless otherwise noted, materials were obtained from commercial sources and used without further purification. All reactions were performed under a dry N_2 atmosphere. Tetrahydrouran (THF), diethyl ether, and benzene were distilled from sodium/benzophenone ketyl immediately prior to use. Dichloromethane and acetonitrile were distilled from CaH_2. Dimethylformamide (DMF) was distilled from $CaSO_4$. In workups involving extraction with an organic solvent the extract was

(23) Chêrest, M.; Felkin, H.; Prudent, N. *Tetrahedron Lett.* **1968**, 2199.

Scheme X



washed with brine, dried over $MgSO_4$, and concentrated with a rotary evaporator. Melting and boiling points are uncorrected. Chromatgraphy was performed with silica gel 60 (E. Merck, Darmstadt) 100–120 mesh, with the indicated solvents. Analytical thin-layer chromatography was performed on precoated glass plates (250 m, silica gel 60, E. Merck, Darmstadt). ^1H NMR spectra were acquired in $CDCl_3$. J values are in hertz. ^{13}C NMR spectra were acquired at 50.78 or 125.73 MHz using broad-band ^1H decoupling. Capillary GC (VPC) was performed with a flame ionization detector and helium as carrier gas on a 25 m × 0.2 mm 5% crosslinked phenylmethyl silicone column. Preparative GC was performed with helium as carrier gas using a 6 ft × $^1/_4$ in. 3% Silicone OV-101 on a 80–100 mesh Chromosorb W-HP column. Mass spectral data are tabulated as m/z (intensity expressed as percent total ion current).

Typical Procedure for the Reaction of Sulfoxides 11 with Enol Silane 12. (5*R,6*R**)- and (5*S**,6*R**)-2,2-Dimethyl-6-phenyl-5-(phenylthio)-3-heptanone (13a and 14a).** To a solution of sulfoxide **11a** (122 mg, 0.5 mmol) in 2.5 mL of CH_2Cl_2 were added trifluoroacetic anhydride (0.1 mL, 0.75 mmol) and 2,6-lutidine (0.06 mL, 0.5 mmol) at 0 °C. After the resulting yellow solution was stirred for 40 min, **12** (0.24 mL, 1.5 mmol) was added followed by $SnCl_4$ (0.06 mL, 0.5 mmol) at −78 °C. The mixture was allowed to warm to 0 °C and poured into 20 mL of 1 N HCl. The dried organic layer was concentrated, and the residue was purified by flash chromatography on silica gel (hexane/CH_2Cl_2, 4:1) to give 108 mg (66%) of the sulfide as a colorless oil. Capillary GC analysis (temperature 200 °C for 1 min then 5 °C/min up to 300 °C) showed the sulfide is a mixture of diastereomers in a ratio of 76:24 (t_R(syn) = 15.04 min; t_R(anti) = 15.23).

Syn Isomer 13a. IR: 1710 cm^{-1}. ^1H NMR (250 MHz): δ 7.12–7.48 (m, 10), 4.03–3.86 (m, 2), 2.98–3.17 (m, 1), 2.51–2.85 (m, 1), 1.39 (d, 3, J = 7.0), 1.00 (s, 9). ^{13}C NMR (50.78 MHz): δ 213.2, 143.3, 136.3, 131.2, 128.8, 128.8, 128.3, 127.8, 126.5, 50.9, 44.4, 44.0, 41.0, 26.2, 18.9. Anal. Calcd for $C_{21}H_{26}OS$: C, 77.25; H, 8.02; S, 9.82. Found: C, 77.24; H, 8.05, S, 9.79.

Anti isomer 14a was not obtained free of the major (syn) diastereomer. Its NMR resonances were obtained from spectra of the mixture.[24] ^1H NMR (250 MHz): δ 1.42 (d, 3, J = 6.6), 1.06 (s, 9). ^{13}C NMR (50.78 MHz): δ 143.1, 136.0, 131.4, 128.9, 128.2, 128.0, 126.7, 50.4, 44.2, 42.4, 38.5, 26.3, 16.8.

The following keto sulfides were prepared by the procedure described for the reaction of sulfoxide **11a** with enol silane **12**.

(5*R,6*R**)-2,2-Dimethyl-5-[(2,6-dimethylphenyl)thio]-6-phenyl-3-heptanone (13b).** Sulfoxide **11b** (27 mg, 0.11 mol) gave 23 mg (61%) of **13b** as a colorless oil. ^1H NMR (250 MHz): δ 7.00–7.39 (m, 8), 3.70 (ddd, 1, J = 7.1, 5.7, 4.0), 3.15 (dq, 1, J = 7.1, 5.7), 2.86 (dd, 1, J = 18.5, 8.1), 2.44 (dd, 1, J = 18.5, 4.0), 2.35 (s, 6), 1.42 (d, 3 J = 7.1), 0.90 (s, 9). ^{13}C NMR (50.78 MHz, $CDCl_3$): δ 218.6, 144.5, 143.4, 137.1, 128.0, 127.9, 126.3, 50.0, 43.9, 42.7, 40.5, 26.2, 22.0, 16.3. Anal. Calcd for $C_{23}H_{30}OS$: C, 77.92, H, 8.53; S, 9.04. Found: C, 77.75, H, 8.53; S, 8.80.

(5*R,6*R**)-2,2-Dimethyl-5-[(2,6-diisopropylphenyl)-thio]-6-phenyl-3-heptanone (13c).** Sulfoxide **11c** (33 mg, 0.1 mmol) gave 30 mg (73%) of **13c** as a colorless oil. ^1H NMR (250 MHz): δ 7.03–7.46 (m, 8), 3.34–3.56 (m, 3), 3.10–3.20 (m, 1), 3.07 (dd, 1, J = 17.9, 10.5), 2.41 (dd, 1, J = 17.9, 3.0), 1.42 (d, 3 J = 7.2), 1.07 (d, 6, J = 6.8), 1.04 (d, 6, J = 6.8), 0.98 (s, 9). ^{13}C NMR (50.78 MHz): δ 214.5, 153.9, 144.6, 129.9, 129.31, 128.0, 127.9, 126.4, 123.6, 53.9, 44.2, 41.3, 40.3, 31.1, 26.1, 24.6, 24.5, 24.5, 23.9, 13.9. Anal. Calcd for $C_{27}H_{38}OS$: C, 78.97; H, 9.33; S, 7.80. Found: C, 78.69; H, 9.31; S, 7.62.

(5*R,6*R**)-2,2-Dimethyl-5-(*tert*-butylthio)-6-phenyl-3-propanone (13d).** Sulfoxide **11d**, (22.5 mg, 0.1 mmol) gave 24 mg (79%) of **13d** as a colorless oil. ^1H NMR (250 MHz): δ 7.15–7.37 (m, 5), 3.33 (ddd, 1, J = 4.0, 5.1, 8.3), 3.06 (dd, 1, J = 18.4, 8.3), 2.93–3.03 (m, 1), 2.74 (dd, 1, J = 18.4, 4.0), 1.31 (d, 3, J = 7.1), 1.06 (s, 18). ^{13}C NMR (50.78 MHz): δ 213.9, 144.9, 128.4, 127.9, 126.3, 45.0, 44.7, 43.9, 43.1, 42.9, 31.0, 26.3, 16.2. Anal. Calcd for $C_{19}H_{30}OS$: C, 74.45; H, 98.7; S, 10.46. Found: C, 74.52; H, 9.89; S, 10.11.

1-Acetoxy-2-phenyl-1-(phenylthio)propane (16). A mixture of acetic anhydride (5.0 mL) and trifluoroacetic anhydride (7.5 mmol, 1.05 mL) was stirred for 4 h at room temperature. The resulting mixed anhydride was cooled to 0 °C with an ice bath, and sulfoxide **11a** (5.0 mmol, 1.22 g) and 2.6-lutidine (7.5 mmol, 1.05 mL) were added in single portions. After 0.5 h, the ice bath was removed and the mixture was stirred for 4 h. The resulting mixture was concentrated, diluted with 20 mL of ether, washed with 20 mL of 1 N HCl, and 30 mL of 5% of $NaHCO_3$, dried, and concentrated to give 1.7 g of an orange oil. The crude material was purified by a flash chromatography (80 g of silica gel, hexane/EtOAc, 10:1) to give 1.07 g (75%) of a 1:1.6 mixture of **16a**

(24) Because the resonances of this minor diastereomer were extracted from the ^{13}C NMR spectrum of the mixture of diastereomers, not all of the resonances could be discerned.

and **16b**. The diastereomers were separated by HPLC (Particil M9, 10/50, 9.4 mm × 50 cm, hexane/EtOAc, 40:1, flow rate 9.0 mL/min).

Compound 16a: t_R = 10.4 min, mp 39–42 °C. ^{1}H NMR (250 MHz): δ 7.19–7.51 (m, 10), 6.27 (d, 1, J = 7.9), 3.18 (dq, 1, J = 7.0, 7.9), 1.84 (s, 3), 1.44 (d, 3, J = 7.0). ^{13}C NMR (50.78 MHz): δ 169.3, 141.7, 133.5, 128.9, 128.2, 128.1, 127.9, 126.9, 44.3, 20.7, 18.0. Anal. Calcd for $C_{13}H_{18}O_2S$: C, 71.29; H, 6.33; S, 11.19. Found: C, 71.41; H, 6.31; S, 11.47.

Compound 16b: t_R = 11.3 min. ^{1}H NMR (250 MHz): δ 7.17–7.50 (m, 10), 6.30 (d, 1, J = 7.3), 3.23 (dq, 1, J = 7.1, 7.3), 2.02 (s, 3), 1.40 (d, 3, J = 7.1) ^{13}C NMR (50.78 MHz): δ 169.8, 141.9, 133.6, 132.4, 128.9, 128.5, 128.1, 128.0, 127.2, 85.0, 44.5, 21.0, 17.7.

Reaction of Compounds 16a and 16b with Enol Silane 12. To α-acetoxy sulfide **16** (0.24 mmol, 68 mg, 38:62 diastereomeric mixture) and **12** (0.48 mmol, 80 mL) in 1.0 mL of CH_2Cl_2 at −78 °C was added $SnCl_4$ (0.24 mmol, 0.24 mL of 1.0 M in CH_2Cl_2) dropwise over 2 min. After stirring for 0.5 h at −78 °C, the mixture was washed with 20 mL of 1 N HCl and extracted with three 10-mL portions of CH_2Cl_2 to give 74 mg of oil after the normal workup. The crude product was purified by column chromatography on 5 g of silica gel (hexane/EtOAc, 10:1) to give 61 mg (79%) of **13a** and **14a**, shown by capillary GC analysis to be a 69:31 ratio. Identical results were obtained when the reaction was carried out with the individual diastereomers of **16**. When the experiment was carried out with $TiCl_4$ as the Lewis acid, the 38:62 mixture of diastereomers or either one individually gave **13a** and **14a** in a ratio of 80:20.

2-Phenyl-1,1-bis(phenylthio)propane (18). To the mixture of 2-phenylpropanal (0.67 g, 50 mmol) and (phenylthio)trimethylsilane (17) (1.9 mL, 10 mmol) in 25 mL of CH_2Cl_2 was added $TiCl_4$ (0.22 mL, 2.0 mmol) dropwise at 0 °C. After stirring for 30 min, the mixture was poured into 1 N HCl and extracted with CH_2Cl_2. The combined organic layers were treated in the normal manner to give sulfide **18** (1.35 g, 80%) as a slightly cloudy oil. Since the ^{1}H NMR spectrum showed that the crude product was practically pure, it was used for the next reaction. An analytical sample was obtained by flash chromatography on silica gel (hexane/EtOAc, 20:1). ^{1}H NMR (250 MHz): δ 7.30 (m, 15), 4.57 (d, 1, J = 4.3), 3.32 (dq, 1, J = 4.3, 7.1), 1.55 (d, 3, J = 7.1). ^{13}C NMR (50.78 MHz): δ 142.7, 135.3, 135.0, 132.7, 132.3, 129.0, 128.9, 128.7, 128.2, 128.1, 127.6, 127.4, 126.9, 67.6, 43.8, 16.4. Anal. Calcd for $C_{21}H_{20}S_2$: C, 74.96; H, 5.99; S, 19.05. Found: C, 74.67; H, 5.95; S, 18.96.

Reaction of Dithioacetal 18 and Enol Silane 12. To a mixture of **18** (168 mg, 0.5 mmol) and **12** (0.32 mL, 2.0 mmol) in 2.5 mL of CH_2Cl_2 was added $TiCl_4$ (0.11 mL, 2.0 mmol) dropwise at −78 °C. After 0.5 h, the mixture was warmed to 0 °C, stirred for 0.5 h, poured into 1 N HCl, and extracted with three 10-mL portions CH_2Cl_2. The combined organic layers were dried and concentrated and the resulting residue purified by flash chromatography on silica gel (hexane/CH_2Cl_2/isopropyl alcohol, 80:20:0.3) to give 118 mg (72%) of the product as a diastereomeric mixture. Capillary GC analysis (200 °C for 1 min, then 5 °C/min to 300 °C) indicated a 4:1 ratio of **13a** and **14a**, identical spectrally with the products obtained in the reaction of **12** with sulfoxide **11a**.

(4*R,5*R**)-5-Phenyl-4-(phenylthio)-1-hexene (19) and (4*S**,5*R**)-5-Phenyl-4-(phenylthio)-1-hexene (20).** To a mixture of dithioacetal **18** (168 mg, 0.5 mmol) and allyltrimethylsilane (0.16 mL, 1.0 mmol) in 2.5 mL of CH_2Cl_2 was added $SnCl_4$ (0.1 mL, 0.75 mmol) at 0 °C. After stirring for 15 min, the mixture was poured into 1 N HCl and extracted with three 10-mL portions CH_2Cl_2, The combined organic layers were dried and concentrated, and the residue was purified by flash chromatography on silica gel (hexane only) to give 75 mg (56% yield) of a product, showed by capillary GC analysis (200 °C for 1 min, then 5 °C/min to 300 °C) to be a 3:1 mixture of **19** (t_R = 10.39 min) and **20** (t_R = 10.52 min).

Compound 19. ^{1}H NMR (250 MHz): δ 7.23 (m, 10), 5.90 (m, 1), 5.05 (m, 2), 3.30 (dt, 1, J = 5.6, 7.2), 3.01 (dq, 1, J = 7.0, 7.2), 2.30 (m, 1), 2.18 (m, 1), 1.44 (d, 3, J = 7.0). ^{13}C NMR (50.78 MHz): δ 144.6, 136.0, 135.6, 131.9, 128.7, 128.2, 127.8, 126.6, 126.4, 117.1, 56.7, 43.1, 37.6, 18.7. Anal. Calcd for $C_{18}H_{20}S$: C, 80.55; H, 7.51; S, 11.94. Found: C, 80.31; H, 7.46; S, 11.81.

Compound 20 was not obtained free of the major (syn) diastereomer. Its NMR resonances were obtained from spectra of the mixture of isomers. ^{13}C NMR (50.78 MHz): δ 143.6, 136.2, 135.9, 128.8, 128.6, 128.1, 127.9, 126.6, 126.5, 116.9, 56.7, 43.1, 37.6, 18.7

2,4,6-Trimethythiophenol was prepared by the method of Häfelinger.[25] A 0.8-mol procedure is given in the supplementary material.

Trimethyl[(2,4,6-trimethylphenyl)thio]silane (21) was prepared by the method of Jutzi.[26] A 0.2-mol procedure is given in the supplementary material.

General Procedure for Generation of Thionium Ions from Aldehyde Using Thiosilane 21 (the One-Pot Procedure). To a mixture of aldehyde (0.5 mmol) and **21** (1.0 mmol, 224 mg) in 2.5 mL of CH_2Cl_2 was added $TiCl_4$ (0.2 mmol, 22 μL) dropwise at 0 °C to give a pale brown solution. After being stirred for 15 min, the mixture was cooled to −78 °C. To the mixture was added enol silane or allylsilane (1.0 mmol) and then $TiCl_4$ (2.0 mmol, 0.22 mL) dropwise to give a dark brown solution. After being stirred for 30 min, the mixture was poured into20 mL of 1 N HCl and extracted with three 10-mL portions of CH_2Cl_2. The combined organic layers were dried and concentrated to obtain the product. The ratio of isomers was determined by capillary GC analysis (200 °C for 1 min, then 5 °C/min to 300 °C). Products were purified by flash chromatography on silica gel.

(5*R,6*R**)-2,2-Dimethyl-6-phenyl-5-[(2,4,6-trimethylphenyl)thio]-3-heptanone (24a).** By the general one-pot procedure, from 67 mg (0.5 mmol) of 2-phenylpropanal, sulfide **24a** (84% yield) was obtained after chromatography of silica gel (hexane/CH_2Cl_2, 4:1). Analysis of the crude product by capillary GC indicated only one isomer. IR: 1710 cm^{-1}. ^{1}H NMR (250 MHz): δ 7.36–7.14 (m, 5), 6.86 (s, 2), 3.65 (ddd, 1, J = 4.0, 5.7, 8.2), 3.14 (dq, 1, J = 7.1, 5.7), 2.87 (dd, 1, J = 18.4, 8.2), 2.43 (dd, 1, J = 18.4, 4.0), 2.30 (s, 6), 2.21 (s, 3), 1.41 (d, 3, J = 7.1), 0.91 (s, 9). ^{13}C NMR (50.78 MHz): δ 213.9, 144.7, 143.3, 137.3, 129.0, 128.02, 127.98, 126.4, 50.2, 43.9, 42.6, 40.5, 26.2, 21.8, 20.9, 16.3. Anal. Calcd for $C_{24}H_{32}OS$: C, 78.20; H, 8.75; S, 8.69. Found: C, 77.98; H, 8.80; S, 8.49.

The following compounds were prepared from enol silane **12** and 0.5 mmol of the appropriate aldehydes by the general one-pot procedure.

(5*R,6*R**)-6-Cyclohexyl-2,2-dimethyl-5-[(2,4,6-trimethylphenyl)thio]-3-heptanone (24b)** was obtained in 73% yield in diastereomerically pure form (>98:2 by NMR spectrometry). IR: 1710 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.90 (s, 2), 3.80 (m, 1), 2.88 (dd, 1, J = 9.6, 17.8), 2.50 (s, 6), 2.34 (dd, 1, J = 3.8, 17.8), 2.23 (s, 3), 2.02–0.75 (m, 24). ^{13}C NMR (50.78 MHz): δ 214.3, 143.4, 137.9, 129.0, 45.9, 44.1, 41.6, 40.3, 40.2, 31.9, 30.8, 26.6, 26.4, 26.1, 22.2, 20.9, 12.1. Anal. Calcd for $C_{24}H_{38}OS$: C, 76.95; H, 10.22; S, 12.83. Found: C, 76.79; H, 10.16; S, 12.66.

(5*R,6*R**)-2,2,6-Trimethyl-5-[(2,4,6-trimethylphenyl)thio]-7-phenyl-3-heptanone (24c)** was obtained as the major isomer of a 97:3 diastereomeric ratio in 80% yield. IR: 1705: cm^{-1}. ^{1}H NMR (250 MHz): δ 7.32–7.11 (m, 5), 6.90 (s, 2), 3.67 (m, 1), 3.06 (dd, 1, J = 4.9, 13.6), 2.78 (dd, 1, J = 7.7, 17.7), 2.65–2.41 (m, 2), 2.49 (s, 6), 2.24 (s, 3), 2.16 (m, 1), 1.04 (s, 9), 0.89 (d, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 213.7, 143.3, 140.8, 138.0, 129.1, 128.8, 128.2, 125.8, 48.3, 44.2, 40.4, 38.9, 37.6, 26.3, 22.2, 20.9, 14.9. Anal. Calcd for $C_{25}H_{34}OS$: C, 78.48; H, 8.96; S, 8.38. Found: C, 78.29; H, 8.91; S, 8.19.

(5*R,6*R**)-2,2,6-Trimethyl-5-[(2,4,6-trimethylphenyl)thio]-3-octanone (24d)** was obtained as the major isomer of a 83:17 diastereomeric ratio in 70% yield. IR: 1730 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.90 (s, 2), 3.57 (dt, 1, J = 2.6, 6.8), 2.70 (dd, 1, J = 18.8, 7.2), 2.57 (dd, 1, J = 18.8, 6.5), 2.50 (s, 6), 2.24 (s, 3), 1.82, (m, 1), 1.49 (m, 1), 1.24 (m, 1), 1.07 (s, 9), 0.914 (t, 3, J = 7.4), 0.911 (d, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 213.9, 143.4, 137.8, 129.1, 128.9, 48.7, 44.2, 38.2, 37.7, 26.2, 22.0, 20.9, 15.3, 12.3. Anal. Calcd for $C_{20}H_{32}OS$: C, 74.94; H, 10.06; S, 10.00. Found: C, 74.88; H, 10.03; S, 9.88.

(5*S,6*R**)-2,2,6-Trimethyl-5-[(2,4,6-trimethylphenyl)-**

(25) Häfelinger, G.; Hack, F.; Westermayer, G. *Chem. Ber.* **1976**, *109*, 883.

(26) Jutzi, P.; König, E.; Huttner, G.; Frank, A.; Schubert, U. *Chem. Ber.* **1978**, *111*, 606.

thio]-3-octanone (25d) compound was not obtained free of the major (syn) diastereomer (**24d**), but its NMR resonances were obtained from spectra of the mixture of isomers.[24] ^{1}H NMR (250 MHz): δ 1.10 (s, 9), 0.83 (t, 3, J = 7.5). ^{13}C NMR (50.78 MHz): δ 213.7, 47.8, 36.9, 26.41, 26.36, 15.7, 12.1.

The following compounds were prepared from allyltrimethylsilane and 0.5 mmol of the appropriate aldehydes by the general one-pot procedure.

(4*R,5*R**)-5-Phenyl-4-[(2,4,6-trimethylphenyl)thio]-1-hexene (26a)** was obtained from aldehyde **22a** as the major isomer of a 97:3 diastereomeric mixture in 74% yield. IR: 1640 cm^{-1}. ^{1}H NMR (250 MHz): δ 7.32–7.08 (m, 5), 6.86 (s, 2), 5.87–5.71 (m, 1), 5.25–4.83 (m, 2), 3.17–3.03 (m, 2), 2.33 (s, 6), 2.22 (s, 3), 2.38–2.01 (m, 2), 1.44 (d, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 145.0, 143.1, 137.6, 135.6, 129.7, 129.0, 128.0, 127.9, 126.2, 117.1, 55.5, 41.6, 37.5, 22.0, 20.9, 16.8. Anal. Calcd for $C_{21}H_{26}S$: C, 81.23; H, 8.44; S, 10.33. Found: C, 81.19; H, 8.45; S, 10.30.

(4*R,5*R**)-5-Cyclohexyl-4-[(2,4,6-trimethylphenyl)thio]-1-hexene (26b)** was obtained from aldehyde **22b** as the major isomer of a 94:6 diastereomeric mixture in 39% yield. No attempt was made to optimize the yield in this reaction, which was only carried out one time. IR: 1640 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.91 (s, 2), 5.63 (m, 1), 4.94 (m, 2), 3.20 (m, 1), 2.49 (s, 6), 2.26 (s, 3), 1.01 (d, 3, J = 6.3), 2.58–0.80 (m, 14). ^{13}C NMR (50.78 MHz): δ 143.3, 137.6, 136.5, 129.6, 128.9, 116.5, 50.4, 40.0, 39.7, 37.2, 32.0, 30.4, 26.7, 26.6, 22.3, 21.0, 11.5. Anal. Calcd for $C_{21}H_{32}S$: C, 79.68; H, 10.18; S, 10.12. Found: C, 79.49; H, 10.12; S, 10.02.

(4*R,5*R**)-5-Methyl-4-[(2,4,6-trimethylphenyl)thio]-6-phenyl-1-hexene (26c)** was obtained from aldehyde **22c** as the major isomer of a 77:23 diastereomeric mixture in 77% yield. IR: 1640 cm^{-1}. ^{1}H NMR (250 MHz): δ 7.29–7.05 (m, 5), 6.90 (s, 2), 5.86–5.63 (m, 1), 5.08–4.95 (m, 2), 2.47 (s, 6), 2.25 (s, 3), 3.11–1.92 (m, 6), 0.96 (d, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 143.2, 141.0, 137.7, 136.4, 129.0, 128.1, 125.7, 116.6, 52.7, 40.3, 37.1, 36.7, 22.3, 20.9, 14.7. Anal. Calcd for $C_{22}H_{28}S$: C, 81.42; H, 8.70; S, 9.88. Found: C, 81.36; H, 8.96; S, 9.73.

(4*S,5*R**)-5-Methyl-4-[(2,4,6-trimethylphenyl)thio]-6-phenyl-1-hexene (27c)** was not obtained free of the major (syn) diastereomer (**26c**) but its NMR resonances were obtained from spectra of the mixture of isomers.[24] ^{1}H NMR (250 MHz): δ 6.86 (s, 2), 5.92–5.73 (m, 1), 5.15–5.00 (m, 2), 2.35 (s, 6), 2.25 (s, 3), 1.05 (d, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 143.1, 140.8, 137.5, 136.6, 129.6, 129.5, 128.9, 128.8, 116.4, 51.9, 39.6, 37.5, 34.7, 21.9, 15.9.

Typical Procedure for Reaction of Sulfoxides 28 with Silyl Thio Ketene Acetal 29. To a solution of sulfoxide **28b** (112 mg, 0.5 mmol) in 2.5 mL of CH_2Cl_2 was added trifluoroacetic anhydride (0.11 mL, 0.75 mmol) and 2,6-lutidine (85 μL, 0.7 mmol) at) °C to give a bright yellow solution. After stirring for 15 min, the mixture was cooled to −78 °C. To the mixture were added silyl ketene acetal **29** (260 mg, 1.0 mmol) and $SnCl_4$ (120 μL, 1.0 mmol). After being stirred for 30 min, the mixture was poured into 20 mL of 1 N HCl and extracted with three 10-mL portions of CH_2Cl_2. The combined organic layers were treated in the normal manner to obtain the product. Analysis by capillary GC and ^{1}H NMR indicated a 93:7 ratio of **30b** and **31b**. Purification by flash chromatography on silica gel (hexane/CH_2Cl_2, 3:1) gave 146 mg (83%) of sulfide **30b** as a colorless oil.

***tert*-Butyl (2*S**,3*S**)-2,4-Dimethyl-3-[(2,4,6-trimethylphenyl)thio]thiopentanoate (30b).** IR: 1680 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.88 (s, 2), 3.41 (dd, 1, J = 5.2, 5.3), 2.51 (s, 6), 2.62–2.42 (m, 1), 2.23 (s, 3), 1.90 (m, 1), 1.39 (s, 9), 1.29 (d, 3, J = 8.0), 1.07 (d, 3, J = 6.7), 0.96 (d, 3, J = 6.9). ^{13}C NMR (50.78 MHz): δ 202.7, 143.0, 137.7, 129.6, 129.1, 56.4, 51.6, 47.7, 30.1, 29.7, 22.1, 21.2, 20.9, 20.0, 13.6. Anal. Calcd for $C_{20}H_{32}OS_2$: C, 68.12; H, 9.14; S, 18.18. Found: C, 68.22; H, 9.19; S, 17.96.

***tert*-Butyl (2*R**,3*S**)-2,4-Dimethyl-3-[(2,4,6-trimethylphenyl)thio]thiopentanoate (31b)** was not obtained free of the major (anti) diastereomer but NMR resonances were obtained from spectra of the mixture of isomers. ^{1}H NMR (250 MHz): 6.86 (s, 2), 3.40 (m, 1), 1.42 (s, 9). ^{13}C NMR (50.78 MHz): δ 203.4, 142.8, 137.8, 130.7, 57.4, 53.8, 51.6, 32.5, 21.3, 20.2, 20.1, 16.5.

***tert*-Butyl (2*S**,3*S**)-2,4-dimethyl-3-(phenylthio)thiopentanoate (30a) and *tert*-butyl (2*R**,3*S**)-2,4-dimethyl-3-(phenylthio)thiopentanoate (31a)** were obtained from sulfoxide **28a** in 41% yield as a 1:1 diastereomeric mixture that was not separated. ^{1}H NMR (250 MHz, $CDCl_3$); δ 7.4 (m, 2), 7.11–7.31 (m, 3), 3.28–3.41 (m, 1), 2.78–2.96 (m, 1), 2.01–2.18 (m, 1), 1.46 (s, 9) and 1.44 (s, 9) in a 1:1 ratio, 1.25 (d, 3, J = 6.9) and 1.23 (d, 3, J = 6.9) in a 1:1 ratio, 1.09 (d, 3, J = 6.6) and 1.00 (d, 3, J = 6.7) in a 1:1 ratio, 0.98 (d, 3, J = 6.6) and 0.94 (d, 3, J = 6.6) in a 1:1 ratio. Anal. Cald for $C_{17}H_{26}OS_2$: C, 65.76; H, 8.44; S, 20.65. Found: C, 65.94; H, 8.51; S, 20.49.

***tert*-Butyl (2*S**,3*S**)-2,4-dimethyl-3-[(2,4,6-triisopropylphenyl)thio]thiopentanoate (30c)** was obtained from sulfoxide **28c** in 66% yield as a single diastereomer. IR: 1680 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.98 (s, 2), 3.92 (m, 2), 3.21 (dd, 1, J = 4.5, 5.2), 2.87 (m, 1), 2.54 (dq, 1, J = 5.2, 7.0), 1.91 (m, 1), 1.40 (s, 9), 1.32 (d, 3, J = 7.0), 1.26–1.21 (m, 18), 1.08 (d, 3, J = 6.8), 1.01 (d, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 202.6, 153.5, 149.3, 127.6, 121.8, 59.4, 51.0, 47.6, 34.2, 31.1, 29.8, 24.6, 23.9, 23.8, 20.9, 20.6, 13.5. Anal. Calcd for $C_{26}H_{44}OS_2$: C, 71.49; H, 10.15; S, 14.68. Found: C, 71.27; H, 10.01; S, 14.48.

Using the general one-pot procedure, sulfides **33a**, **33c**, and **36a–c** were obtained from the corresponding aldehydes and enol silanes.

***tert*-Butyl (2*R**,3*S**)-2-Methyl-3-phenyl-3-[(2,4,6-trimethylphenyl)thio]thiopropanoate (33c).** Mp: 82–83 °C. IR (CCl_4): 1680 cm^{-1}. ^{1}H NMR (250 MHz): δ 7.12 (m, 3), 6.93–7.01 (m, 2), 6.76 (s, 2), 3.91 (d, 1, J = 11.0), 3.12 (dq, 1, J = 11.0, 6.8), 2.18 (s, 3), 2.11 (s, 6), 1.54 (s, 9); 0.97 (d, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 201.9, 143.8, 140.2, 138.1, 128.6, 128.3, 128.2, 128.0, 127.0, 55.4, 52.5, 48.3, 29.7, 21.4, 21.0, 17.3. HRMS: calcd for $C_{23}H_{30}OS_2$ 386.1740, found 386.1732.

***tert*-Butyl (2*S**,3*S**)-2-Methyl-3-phenyl-3-[(2,4,6-trimethylphenyl)thio]thiopropanoate (34c).** This compound was not obtained free of the major (anti) diastereomer **33c**. Its NMR resonances were obtained from spectra of the mixture of isomers. ^{1}H NMR (250 MHz): δ 6.21 (s, 2), 3.20 (m, 1), 2.49 (s, 6), 2.25 (s, 3), 1.43 (d, 3, J = 7.0), 1.38 (s, 9).

***tert*-Butyl (2*R**,3*R**)-2-Methyl-3-[(2,4,6-trimethylphenyl)thio]thiohexanoate (33a).** IR: 1680 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.92 (s, 2), 3.37–3.42 (m, 1), 2.50 (s, 6), 2.40–2.50 (m, 1), 2.26 (s, 3), 1.40–1.62 (m, 4), 1.42 (s, 9), 1.23 (d, 3, J = 7.0), 0.90 (t, 3, J = 7.0). ^{13}C NMR (50.78 MHz): δ 202.5, 143.0, 137.9, 129.12, 129.1, 51.1, 50.5, 47.8, 32.2, 29.7, 22.0, 21.0, 19.9, 14.1, 11.6. Anal. Calcd for $C_{20}H_{32}OS_2$: C, 68.13; H, 9.15; S, 18.19. Found: C, 68.33; H, 8.98; S, 18.00.

***tert*-Butyl (2*S**,3*R**)-2-Methyl-3-[(2,4,6-trimethylphenyl)thio]thiohexanoate (34a).** ^{1}H NMR (250 MHz): δ 6.90 (s, 2), 3.22–3.38 (m, 1), 2.80 (m, 1), 2.50 (s, 6), 2.25 (s, 3), 1.43 (s, 9), 1.38 (m, 4), 1.29 (d, 3, J = 6.9), 0.82 (t, 3, J = 6.8). ^{13}C NMR (50.78 MHz): δ 202.4, 143.1, 137.8, 129.3, 129.0, 51.5, 51.1, 47.9, 35.1, 29.7, 22.2, 21.0, 19.5, 14.0, 13.9.

(5*S,6*S**)-3,3,5-Trimethyl-6-phenyl-6-[(2,4,6-trimethylphenyl)thio]-1-hexen-4-one (36c).** Mp: 77–78 °C. IR: 1710, 1640, 1605, 990, 920, 710 cm^{-1}. ^{1}H NMR (250 MHz): δ 7.11 (m, 3), 6.94 (m, 2), 6.73 (s, 2), 6.15 (dd, 1, J = 10.6, 17.4), 5.29 (dd, 1, J = 0.7, 17.4), 5.26 (dd, 1, J = 10.6, 0.7), 3.84 (d, 1, J = 12.3), 3.60 (dq, 1, J = 12.3, 6.7). 2.16 (s, 3), 2.03 (s, 6), 1.45 (s, 3), 1.34 (s, 3), 0.82 (d, 3, J = 6.7). ^{13}C NMR (50.78 MHz): δ 214.3, 143.8, 142.6, 140.9, 138.0, 128.5, 128.4, 128.3, 127.9, 126.7, 114.3, 56.0, 51.2, 43.7, 24.0, 23.8, 21.2, 20.9, 18.8. Anal. Calcd for $C_{24}H_{30}OS$: C, 78.64; H, 8.25; S, 8.75. Found: C, 78.84: H, 8.14; S, 8.69.

(5*S,6*R**)-3,3,5,7-Tetramethyl-6-[(2,4,6-trimethylphenyl)thio]-1-octen-4-one (36b).** IR: 1710, 1640, 1610, 1465, 990, 925, 860 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.90 (s, 2), 5.43 (dd, 1, J = 10.9, 16.9), 4.92 (d, 1, J = 10.9), 4.91 (d, 1, J = 16.9), 3.05 (m, 2), 2.48 (s, 6), 2.25 (s, 3), 2.24 (m, 1), 1.18 (d, 3, J = 6.4), 1.05 (s, 3), 1.03 (d, 3, J = 6.4), 1.00 (s, 3), 0.96 (d, 3, J = 7.0). ^{13}C NMR (50.78 MHz): δ 214.4, 143.2, 142.0, 137.8, 129.8, 128.9, 114.0, 56.0, 51.3, 43.2, 28.4, 23.8, 23.1, 22.2, 21.8, 20.9, 19.0, 15.0. Anal. Calcd for $C_{21}H_{32}OS$: C, 75.85; H, 9.70; S, 9.64. Found: C, 75.90; H, 9.51; S, 9.59.

(5*S,6*R**)-3,3,5-Trimethyl-6-[(2,4,6-trimethylphenyl)thio]-1-octen-4-one (36a).** IR: 1710, 1635, 1605, 1450, 990, 925, 860 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.93 (s, 2), 5.56 (dd, 1, J = 10.8, 17.1), 4.89 (dd, 1, J = 10.8, 0.9), 4.84 (dd, 1, J = 17.1, 0.9), 2.97 (dq, 1, J = 6.9, 4.3), 2.86 (ddd, 1, J = 2.6, 4.3, 9.2), 2.47 (s, 6), 2.26 (s, 3), 1.80 (ddq, 1, J = 2.6, 7.3, 14.6), 1.35 (ddq, 1, J = 7.3, 9.2, 14.6), 1.11 (d, 3, J = 6.9), 1.09 (t, 3, J = 7.3), 1.03 (s, 3), 0.95 (s, 3). ^{13}C NMR (50.78 MHz): δ 214.5, 143.5, 141.6, 138.2, 129.5, 128.9,

114.3, 52.4, 51.5, 42.1, 23.5, 22.8, 21.8, 20.9, 13.3, 11.4. Anal. Calcd for $C_{20}H_{30}OS$: C, 75.42; H, 9.49; S, 10.07. Found: C, 75.70; H, 9.32; S, 9.84.

(*Z*)-3,3-Dimethyl-4-(trimethylsiloxy)-1,4-hexadiene (35) was prepared by published procedure.[21]

***tert*-Butyl (2*S**,3*S**,4*R**)-2-Methyl-3-[(2,4,6-trimethylphenyl)thio]-4-phenylthiopentanoate (40).** By the general one-pot procedure, the reaction of 2-phenylpropanal (67 mg, 0.5 mmol) and enol silane *E*-**37** (260 mg, 1.0 mmol) afforded 162 mg (72% yield) of keto sulfides as a colorless oil. Capillary GC analysis indicated a 66:16:18 mixture of diastereomers (t_R = 21.57, 22.04, and 22.18 min, respectively). The major isomer was obtained by HPLC (hexane). IR: 1680, 1601 cm^{-1}. ^1H NMR (500 MHz): δ 7.15–7.31 (m, 5), 6.82 (s, 2), 3.70 (dd, 1, J = 4.4, 4.3), 3.19 (dq, 1, J = 4.9, 7.0), 2.50 (dq, 1, J = 3.4, 7.0), 2.99 (s, 6), 2.21 (s, 3), 1.46 (d, 3, J = 7.0), 1.39 (d, 3, J = 7.0), 1.32 (s, 9). ^{13}C NMR (50.78 MHz): δ 202.3, 145.4, 143.0, 137.8, 129.1, 128.1, 127.9, 126.2, 56.6, 52.4, 47.7, 39.9, 29.73, 29.70, 21.8, 17.7, 12.5. Anal. Calcd for $C_{25}H_{34}OS_2$: C, 72.41; H, 8.26; S, 15.46. Found: C, 72.25; H, 8.26; S, 15.26

(5*R,6*S**,7*R**)-3,3,5-Trimethyl-6-[(2,4,6-trimethylphenyl)thio]-7-phenyl-1-octen-4-one (41).** By the general one-pot procedure the reaction of 2-phenylpropanal (0.67 g 5.0 mmol) and enol silane **35** (1.49 g, 7.5 mmol) afforded 1.24 g (63%) of keto sulfide **41** as a white solid, mp 77–8 °C, after chromatography on silica gel (hexane/CH_2Cl_2/isopropyl alcohol, 80:20:1). IR: 1705, 1640, 1610, 990, 925, 855, 740, 705 cm^{-1}. ^1H NMR (250 MHz): δ 7.23 (m, 5), 6.81 (s, 2), 5.34 (dd, 1, J = 10.7, 17.1), 4.74 (dd, 1, J = 10.7, <0.1), 4.72 (dd, 1, J = 17.1, <0.1), 3.64 (dq, 1, J = 7.0, 0.3), 3.03 (m, 1), 2.96 (br s, 1), 2.21 (s, 3), 2.13 (s, 6), 1.45 (d, 3, J = 7.1), 1.35 (d, 3, J = 7.0), 0.96 (s, 3), 0.77 (s, 3). ^{13}C NMR (50.78 MHz): δ 214.3, 146.8, 143.6, 141.0, 138.0, 128.9, 127.9, 127.4, 126.0, 114.6, 57.6, 47.2, 37.2, 23.6, 22.2, 21.3, 20.8, 16.0, 13.7. Anal. Calcd for $C_{26}H_{34}OS$: C, 79.14, H, 8.68; S, 8.12. Found: 79.38; H, 8.49; S, 7.96.

(4*R,5*S**,6*R**)-2,2,4-Trimethyl-5-[(2,4,6-trimethylphenyl)thio]-6-phenyl-3-heptanone (42).** By the general one-pot procedure the reaction of 2-phenylpropanal (67 mg, 0.5 mmol) and enol silane **39** (140 mg, 0.75 mmol) afforded 150 mg (79%) of sulfide **42** as a white solid after flash chromatography on silica gel (hexanes/CH_2Cl_2, 8:1 then 4:1). Analysis of the crude product by capillary GC indicated that the product, mp 107–9 °C, is 97% isomerically pure. IR: 1700 cm^{-1}. ^1H NMR (250 MHz): δ 7.23 (m, 5), 6.79 (s, 2), 3.68 (dq, 1, J = 7.1, <1.0), 3.08 (dq, 1, J = 7.0, 3.1), 2.98 (dd, 1, J = 3.1, <1.0), 2.19 (s, 3), 2.16 (s, 6), 1.46 (d, 3, J = 7.1), 1.37 (d, 3, J = 7.0), 0.76 (s, 9). ^{13}C NMR (50.78 MHz): δ 217.2, 146.7, 143.4, 137.9, 128.9, 127.9, 127.4, 125.9, 57.4, 45.0, 42.3, 37.1, 25.8, 21.3, 20.8, 15.9, 13.9. Anal. Calcd for $C_{25}H_{34}OS$: C, 78.48; H, 8.96; S, 8.38. Found: C, 78.33; H, 9.04; S, 8.25.

(4*S,5*R**,6*S**,7*R**)-3,3,5-Trimethyl-6-[(2,4,6-trimethylphenyl)thio]-7-phenyl-1-octen-4-ol (43).** To a solution of 592 mg (1.5 mmol) of ketone **41** in 5 mL of ether was added 60 mg (1.5 mmol) of $LiAlH_4$ at 0 °C. After stirring for 15 min, the reaction mixture was quenched with 0.5 mL of saturated Na_2SO_4. The organic solution was decanted, and the white residue was extracted with three 10-mL portions of ether. The combined organic layers were filtered through $MgSO_4$ and concentrated to give 584 mg (98%) of alcohol **43** as a white solid. An analytical sample, mp 87–9 °C, was obtained by recrystallization from hexane. A sample for single-crystal X-ray analysis was obtained by slow recrystallization from 95% EtOH. IR: 3570, 1640, 1605, 1000, 920, 860, 710 cm^{-1}. ^1H NMR (250 MHz): δ 7.46 (m, 2), 7.25 (m, 3), 6.84 (s, 2), 5.49 (dd, 1, J = 11.8, 17.4), 4.77 (dd, 1, J = 11.8, <0.1), 4.71 (dd, 1, J = 17.4, <0.1), 3.52 (m, 1), 3.32 (dq, 1, J = 7.1, 6.9), 2.79 (dd, 1, J = 6.1, 6.4), 2.29 (s, 6), 2.21 (s, 3), 1.64 (m, 1), 1.48 (d, 3, J = 7.1), 1.24 (d, 3, J = 7.2), 1.14 (d, 1, J = 5.9). 0.64 (s, 3), 0.57 (s, 3). ^{13}C NMR (50.78 MHz): δ 147.5, 145.5, 143.5, 137.6, 129.7, 128.8, 127.9, 127.8, 126.0, 112.0, 80.1, 56.9, 42.2, 39.9, 39.0, 23.2, 22.3, 21.7, 20.9, 19.1, 16.4. Anal. Calcd for $C_{26}H_{36}OS$: C, 78.73; H, 9.15; S, 8.08. Found: C, 78.86; H, 9.08; S, 7.99.

(2*R,3*S**,4*R**)-2-Methyl-3-[(2,4,6-trimethylphenyl)-thio]-4-phenyl-1-pentanol (45).** To a solution of 160 mg (0.4 mmol) of crude alcohol **43** in 3 mL of CH_2Cl_2 was added 190 mg (0.42 mmol) of lead tetraacetate in one portion at room temperature. After 15 min, the reaction mixture became a slightly yellow milky suspension, and one drop of ethylene glycol and 0.2 g of silica gel (to help filtration) were added. The mixture was filtered through a thin column of silica gel and eluted with CH_2Cl_2. The organic solution was concentrated to give 135 mg of aldehyde **44** as a colorless oil. An analytical sample was obtained by flash chromatography on silica gel (10:1 hexane/EtOAc). IR: 1730, 1610, 920, 860, 780, 745, 710 cm^{-1}. ^1H NMR (250 MHz): δ 8.83 (br s, 1), 7.21 (m, 5), 6.91 (s, 2), 3.69 (dd, 1, J = 2.6, 10.0), 2.95 (dq, 1, J = 10.0, 6.9), 2.49 (s, 6), 2.24 (s, 3), 2.13 (dq, 1, J = 2.6, 6.9), 1.58 (d, 3, J = 6.9), 1.18 (d, 3, J = 6.9). ^{13}C NMR (50.78 MHz): δ 200.8, 143.8, 142.9, 138.3, 129.3, 128.9, 128.6, 127.7, 127.4, 55.7, 50.0, 41.3, 22.0, 20.9, 20.7, 9.1. Correct elemental analysis could not be obtained for this compound due to its instability.

The crude aldehyde **44** (135 mg) was treated with 30 mg (0.8 mmol) of $LiAlH_4$ in ether at 0 °C for 10 min. The reaction mixture was quenched with 0.2 mL of saturated Na_2SO_4, and the mixture was extracted with ether, filtered through Celite, and concentrated to give 126 mg of a colorless oil. The crude product was purified by flash chromatography on silica gel (10:1 hexane/EtOAc) to give 98 mg (75% yield from ketone **41**) of alcohol **45** as a colorless oil. IR: 3420, 1605, 855, 770, 745, 705 cm^{-1}. ^1H NMR (250 MHz): δ 7.24 (m, 5), 6.86 (s, 2), 3.40 (dd, 1, J = 7.3, 3.1), 3.11 (m, 3), 2.38 (s, 3), 2.21 (s, 3), 1.69 (m, 1), 1.46 (d, 2, J = 7.0), 1.07 (d, J = 7.0), 0.90 (br s, 1). ^{13}C NMR (50.78 MHz): δ 146.3, 142.7, 137.5, 130.0, 129.1, 128.3, 127.6, 126.4, 65.9, 56.5, 40.8, 40.2, 22.0, 20.9, 19.8, 13.6. Anal. Calcd for $C_{21}H_{28}OS$: C, 76.78; H, 8.59; S, 9.76. Found: C, 76.73; H, 8.70; S, 9.58.

(2*S,4*S**)-2-Methyl-4-phenyl-1-pentanol (46).** To a mixture of 2 mL of liquid ammonia and a solution of 144 mg (0.44 mmol) of **45** in 2 mL of ether at −78 °C was added 9 mg (1.3 mmol) of lithium. The mixture was stirred for 10 min and quenched with 5 drops of EtOH. The mixture was allowed to warm to room temperature, and the remaining gray residue was diluted with 20 mL of 1 N HCl and extracted with 20 mL of ether. The organic layer was dried over $MgSO_4$, concentrated, and purified by flash chromatography on silica gel (5:1 hexane/EtOAc) to give 63 mg (80%) of alcohol **46** as a colorless oil. IR: 3340, 1605, 760, 700 cm^{-1}. ^1H NMR (250 MHz): δ 7.20 (m, 5), 3.46 (dd, 1, J = 5.0, 10.5), 3.37 (dq, 1, J = 6.1, 10.5), 2.80 (sextet, 1, J = 7.0), 1.98 (br s, 1), 1.62 (m, 2), 1.40 (m, 1), 1.21 (d, 3, J = 6.9), 0.88 (d, 3, J = 6.5). ^{13}C NMR (50.78 MHz): δ 147.8, 128.3, 126.8, 125.8, 67.9, 41.9, 37.1, 33.4, 22.1, 16.9. Anal. Calcd for $C_{12}H_{18}O$: C, 80.85; H, 10.18. Found: C, 80.67; H, 10.14.

(5*R,6*R**,7*R**,8*R**)-3,3,5,7,9-Pentamethyl-6,8-bis[(2,4,6-trimethylphenyl)thio]-1-decen-4-one (49).** To a solution of 5.74 g (17.3 mmol) of ketone **36b** in 80 mL of ether was added 0.76 g (20 mmol) of $LiAlH_4$ at 0 °C in one portion. After the mixture was stirred for 1 h, the reaction was quenched with 3 mL of saturated Na_2SO_4. The organic layer was decanted, and the solid residue was washed with three 20-mL portions of ether. The combined organic layers were filtered through Celite and concentrated to give 5.67 g (98%) of crude alcohol **47** as a colorless oil. IR: 3550, 1640, 1605, 980, 920, 860 cm^{-1}. ^1H NMR (250 MHz): δ 6.89 (s, 2), 5.52 (dd, 1, J = 10.8, 17.5), 4.88 (dd, 1, J = 1.4, 10.8), 4.80 (dd, 1, J = 1.4, 17.5), 3.19 (t, 1, J = 2.5), 3.14 (d, 1, J = 5.7), 2.49 (s, 6), 2.24 (s, 3), 2.22 (m, 1), 1.68 (m, 1), 1.42 (br s, 1), 1.21 (d, 3, J = 7.2), 1.15 (d, 3, J = 6.7), 1.09 (d, 3, J = 6.8), 0.74 (s, 3), 0.60 (s, 3).

Alcohol **47** (3.85 g, 10 mmol) in 30 mL of benzene was treated with 4.65 g (10.5 mmol) of $Pb(OAc)_4$ at 0 °C. Immediately after addition of $Pb(OAc)_4$, a white precipitate appeared. The reaction mixture was allowed to warm to room temperature and stirred for 15 min. Ethylene glycol (32 mL, 0.75 mmol) was added to destroy the remaining $Pb(OAc)_4$, and 5 g of silica gel was added to make filtration easier. The resulting mixture was filtered through a 1-in. silica gel column and eluted with 150 mL of CH_2Cl_2. The combined organic layers were concentrated to give 2.67 6 (100%) of aldehyde **48**, which was >95% pure by ^1H NMR analysis. IR: 1730, 1605, 860 cm^{-1}. ^1H NMR (250 MHz): δ 9.55 (d, 1, J = 1.1), 6.91 (s, 2), 3.25 (dd, 1, J = 3.8, 6.5), 2.5 (s, 6), 2.25 (s, 3), 2.35 (ddq, 1, J = 1.1, 3.8, 7.1), 1.88 (dqq, 1, J = 6.5, 6.8, 6.7), 1.24 (d, 3, J = 7.1), 1.14 (d, 3, J = 6.7), 0.96 (d, 3, J = 6.8).

By the general one-pot procedure the reaction of 2.67 g (10 mmol) of aldehyde **48** and 2.97 g (15 mmol) of enol silane **35** gave 7.08 g of an oil. The crude product was purified by flash chromatography on silica gel (hexane/CH_2Cl_2, 4:1 to 2:1) to give 4.42

g (84%) of ketone **49**, mp 84–6 °C, greater than 95% isomerically pure by ^{1}H NMR. IR: 1710, 1640, 1610, 995, 925, 860 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.92 (s, 4), 5.20 (dd, 1, *J* = 10.6, 17.3), 4.81 (dd, 1, *J* = 0.7, 10.6), 5.20 (dd, 1, *J* = 0.7, 17.3), 3.15 (t, 1, *J* = 3.4)), 2.87 (dd, 1, *J* = 4.0, 1.3), 2.77 (dq, 1, *J* = 3.4, 7.2), 2.47 (s, 6), 2.46 (s, 6), 2.27 (s, 3), 2.26 (s, 3), 2.22 (m, 2), 1.38 (d, 3, *J* = 7.2), 1.11 (d, 3, *J* = 7.2), 1.08 (d, 3, *J* = 7.0), 1.03 (d, 3, *J* = 7.0), 0.77 (s, 3), 0.74 (s, 3). ^{13}C NMR (50.78 MHz): δ 212.2, 143.9, 143.2, 141.9, 138.3, 137.5, 129.6, 129.1, 129.0, 113.8, 60.9, 53.2, 51.2, 43.7, 37.1, 29.1, 23.6, 23.1, 22.6, 22.1, 22.06, 20.9, 19.6, 14.1, 13.4. Anal. Calcd for $C_{33}H_{48}OS_2$: C, 75.53; H, 9.23; S, 12.20. Found: C, 75.69; H, 9.22; S, 12.09.

(4*S,5*S**,7*R**)-3,3,5,7,9-Pentamethyl-1-decen-4-ol (51).** To a solution of 4.2 g (8 mmol) of ketone **49** in 40 mL of ether was added 0.3 g (8 mmol) of $LiAlH_4$ at 0 °C. Aftering the mixture was stirred for 15 min, the reaction was quenched with 2 mL of saturated Na_2SO_4. The organic layer was decanted, and the white residue was extracted with three 10-mL portions of ether. The combined organic layers were filtered through Celite and concentrated to give 4.12 g (98%) of alcohol **50**, mp 92–3 °C. IR: 3600, 1645, 1605, 920, 860 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.92 (s, 2), 6.85 (s, 2), 5.27 (dd, 1, *J* = 10.8, 17.5), 4.74 (dd, 1, *J* = 1.4, 10.8), 4.62 (dd, 1, *J* = 1.4, 17.5), 3.19 (br s, 1), 2.98 (dd, 1, *J* = 1.5, <1.0), 2.78 (ddq, 1, *J* = 6.8, 6.7, <1.0), 2.52 (s, 6), 2.42 (s, 6), 2.23 (s, 3), 2.21 (s, 3), 2.06 (dd, 1, *J* = 4.8, 7.3), 1.82 (m, 1), 1.55 (br s, 1), 1.37 (d, 3 *J* = 6.4), 1.25 (d, 3, *J* = 6.8), 1.23 (m, 1), 1.12 (d, 3, *J* = 6.7), 0.90 (d, 3, *J* = 7.1), 0.48 (s, 3), 0.45 (s, 3).

To a solution of 400 mg (10 mmol) of calcium in 20 mL of liquid NH_3 was added a solution of alcohol **50** (1.05 g, 2 mmol) in 5 mL of THF dropwise over 1 h at −78 °C. After stirring for 5 min, reaction was quenched by addition of 3 g of NH_4Cl and the solution was allowed to warm to room temperature. The resulting suspension was diluted with 20 mL of ether and 20 mL of 1 N HCl. The organic layer was separated, and the aqueous layer was extracted with two 10-mL portions of ether. The combined organic layer was dried and concentrated to give 894 mg of a colorless oil. The crude product was purified by flash chromatography on silica gel (20:1 hexane/EtOAc) to give 273 mg (61%) of **51** and 60 mg (14%) of alcohol **52**.

Compound 51. IR: 3500, 1645, 975, 920 cm^{-1}. ^{1}H NMR (250 MHz): δ 5.91 (dd, 1, *J* = 11.0, 17.3), 5.05 (dd, 1, *J* = 11.0, 1.2), 5.03 (dd, 1, *J* = 17.3, 1.2), 3.18 (d, 1, *J* = 2.3), 1.85 (m, 1), 1.65 (m, 1), 1.50 (m, 1), 1.48 (br s, 1), 1.19 (m, 1), 1.08–1.00 (m, 2), 0.82–0.89 (m, 1), 1.06 (s, 3), 1.05 (s, 3), 0.97 (d, 3, *J* = 6.8), 0.85 (d, 3, *J* = 6.6), 0.84 (d, 3, *J* = 6.8), 0.82 (d, 3, *J* = 6.6). ^{13}C NMR (50.78 MHz): 145.7, 112.5, 83.1, 48.2, 42.4, 37.8, 31.4, 27.9, 25.0, 24.5, 23.9, 23.0, 22.6, 20.1, 19.3. Anal. Calcd for $C_{15}H_{30}O$: C, 79.58; H, 13.36. Found: C, 79.39; H, 13.28.

Compound 52. IR: 3460 cm^{-1}. ^{1}H NMR (250 MHz): δ 3.79 (d, 1, *J* = 8.8), 2.05–1.45 (m, 6), 1.40 (s, 1), 1.30–1.05 (m, 1), 1.03 (d, 3, *J* = 7.2), 0.95 (s, 3), 0.94 (s, 3), 0.91 (d, 3, *J* = 6.6), 0.83 (d, 6, *J* = 6.3), 0.79 (d, 3, *J* = 7.5). ^{13}C NMR (50.78 MHz): δ 80.6, 53.4, 45.2, 44.5, 43.2, 37.9, 31.5, 25.2, 24.6, 23.8, 22.8, 21.1, 18.3, 16.9, 11.3. Anal. Calcd for $C_{15}H_{30}O$: C, 79.58; H, 13.36. Found: C, 79.29; H, 13.12.

(5*S,6*R**,7*S**,9*R**)-3,3,5,7,9,11-Hexamethyl-6-[(2,4,6-trimethylphenyl)thio]-1-dodecen-4-one (54).** A solution of 137 mg (0.6 mmol) of alcohol **51** in 10 mL of CH_2Cl_2 was cooled to −78 °C, and 310 mg (0.7 mmol) of $Pb(OAc)_4$ was added. The mixture was stirred for 10 min at −78 °C, allowed to warm to room temperature, and stirred for 30 min to give a lightly yellow solution with a white precipitate of $Pb(OAc)_2$. The reaction mixture was poured into ice water and extracted with hexane. The organic layer was washed with saturated $NaHCO_3$ and dried and concentrated in the normal manner (aspirator pressure) to give 105 mg of crude aldehyde **53** as a colorless oil.

By the general one-pot procedure, the reaction of 105 mg of aldehyde **53** and 240 mg (1.2 mmol) of enol silane **35** gave 152 mg (61%) of ketone **54** as a colorless oil after chromatography on silica gel (4:1 hexane/CH_2Cl_2). Capillary GC analysis indicated that ketone **54** (t_R= 18.88 min) was 90% isomerically pure and contained two other isomers (5% each at t_R = 19.15 and 19.36 min).

Compound 54. IR: 1700, 1630, 1601, 985, cm^{-1}. ^{1}H NMR (250 MHz): δ 6.90 (s, 2), 5.98 (dd, 1, *J* = 10.8, 17.1), 4.96 (dd, 1, *J* = 10.8, <1.0), 4.94 (dd, 1, *J* = 17.1, <1.0), 3.15 (dd, 1, *J* = 5.2, <1.0), 3.05 (quintet, 1, *J* = 6.6), 2.48 (s, 3), 2.25 (s, 3), 2.20 (m, 1), 1.58–0.80 (m, 6), 1.15 (d, 3, *J* = 6.8), 1.08 (s, 3), 1.04 (s, 3), 1.02 (d, 3, *J* = 6.8), 0.83 (d, 3, *J* = 6.6), 0.79 (d, 3, *J* = 6.6), 0.61 (d, 3, *J* = 6.4). ^{13}C NMR (50.78 MHz): δ 214.4, 143.1, 142.2, 137.8, 130.2, 130.0, 114.0, 54.6, 51.6, 51.4, 46.8, 43.9, 43.0. 30.3, 27.3, 25.0, 24.0, 23.3, 23.2, 22.3, 22.0. 20.9, 19.4, 15.9, 15.6. Anal. Calcd for $C_{27}H_{44}OS$: C, 77.82; H, 10.64; S, 7.69. Found: C, 77.79; H, 10.57; S, 7.73.

(2*R,4*S**,6*R**)-2,4,6,8-Tetramethyl-1-nonanol (58).** To a solution of 152 mg (0.37 mmol) of ketone **54** in 5 mL of ether as added 30 mg (0.74 mmol) of $LiAlH_4$ at 0 °C. The mixture was allowed to warm to room temperature, stirred for 15 min, cooled with an ice bath, and quenched with about 0.1 mL of saturated Na_2SO_4. The organic layer was separated, and the white residue was washed with three 10-mL portions of ether. The combined organic layer was filtered through silica gel and concentrated to give 160 mg of alcohol **55** as a colorless oil.

To a solution of the crude alcohol **55** (160 mg) in 3 mL of CH_2Cl_2 was added 172 mg (0.39 mmol) of $Pb(OAc)_4$ at 0 °C. The mixture was allowed to warm to room temperature and stirred for 20 min. Two drops of ethylene glycol was added to quench excess $Pb(OAc)_4$ and 2 g of silica gel for filtration aid. The mixture was filtered through silica gel and concentrated to give 132 mg of aldehyde **56** as a slightly yellow oil.

To the crude aldehyde **56** (132 mg) in 5 mL of ether was added 30 mg (0.74 mmol) of $LiAlH_4$ at 0 °C. The same workup procedure as above gave 130 mg (90% yield from ketone **54**) of alcohol **57** as a colorless oil. IR: 3400, 1601, 730 cm^{-1}. ^{1}H NMR (250 MHz): δ 6.88 (s, 2), 3.61 (br s, 2), 3.09 (dd, 1, *J* = 2.0, 5.6), 2.52 (s, 6), 2.34 (s, 3), 1.94 (m, 1), 1.79 (m, 1), 1.59 (m, 1), 1.48–0.95 (m, 6), 1.08 (d, 3, *J* = 7.0), 1.02 (d, 3, *J* = 6.7), 0.84 (d, 3, *J* = 6.6), 0.81 (d, 3, *J* = 6.6), 0.68 (d, 3, *J* = 6.4).

To a solution of 80 mg (1 mmol) of calcium in 5 mL of liquid NH_3 at −78 °C was added 106 mg (0.3 mmol) of alcohol **57** over 1 min. After stirring for 20 min, the reaction mixture was quenched with 1 g of NH_4Cl at −78 °C and allowed to warm to room temperature. The gray residue was dissolved in 20 mL of water, extracted with three 10-mL portions of ether. The combined organic layers were dried over $MgSO_4$, concentrated, and purified by flash chromatography on silica gel (5:1 hexane/EtOAc) to give 40 mg (67%) of alcohol **58** as a colorless oil. Analysis of ^{13}C NMR spectra indicated that alcohol **58** contained two other isomers (5% each).

Compound 58. IR: 3340, 1040 cm^{-1}. ^{1}H NMR (250 MHz): δ 3.48 (dd, 1, *J* = 10.4, 5.7), 3.39 (dd, 1, *J* = 10.4, 6.6), 1.48–1.80 (m, 5), 0.98–1.21 (m, 6), 0.90 (d, 3, *J* = 6.6), 0.86 (d, 3, *J* = 6.6), 0.85 (d, 3, *J* = 6.1), 0.82 (d, 3, *J* = 6.3), 0.81 (d, 3, *J* = 6.5). ^{13}C NMR (50.78 MHz): δ 68.9, 47.5, 45.9, 41.5, 33.1, 27.5, 27.1, 23.3, 22.4, 19.8, 19.2, 16.4 (resonances for minor isomers were observed at δ 69.0 ppm and δ 68.5 ppm. Anal. Calcd for $C_{13}H_{28}O$: C, 77.93; H, 14.09. Found: C, 77.87; H, 13.98.

(2*R,4*S**,6*R**)-2,4,6,8-Tetramethyl-1-nonyl 3,5-Dinitrobenzoate (59).** To a mixture of 34 mg (0.17 mmol) of alcohol **58** and 92 mg (0.4 mmol) of 3,5-dinitrobenzoyl chloride in 2 mL of CH_2Cl_2 was added 0.2 mL of pyridine at room temperature. After stirring for 30 min, the mixture was poured into water and extracted with three 10-ml portions of ether. The combined organic layers were washed with 1 N HCl, saturated $NaHCO_3$, and brine, dried over $MgSO_4$, and concentrated to give 76 mg of a yellow wax. The crude product was purified by flash chromatography on silica gel (20:1 hexane/EtOAc) to give 63 mg (94%) of white crystalline material. The ester was recrystallized from 95% EtOH containing 5% ether to give 47 mg (65%) of powdery crystals, mp 68–71 °C. This material was diastereomerically pure by NMR analysis. IR: 1740, 1630 cm^{-1}. ^{1}H NMR (500 MHz): δ 9.23 (t, 1, *J* = 2.2), 9.16 (d, 2, *J* = 2.2), 4.33 (dd, 1, *J* = 5.6, 10.6), 4.23 (dd, 1, *J* = 7.1, 10.6), 2.11 (m, 1), 1.64 (m, 3), 1.22 (m, 2), 1.04 (d, 3, *J* = 6.6), 1.20–0.95 (m, 4), 0.874 (d, 3, *J* = 6.5), 0.867 (d, 3, *J* = 6.6), 0.85 (d, 3, *J* = 7.0), 0.83 (d, 3, *J* = 7.3). ^{13}C NMR (125.8 MHz): δ 162.0, 148.7, 134.1, 129.3, 122.3, 72.3, 47.4, 45.7, 41.5, 30.2, 27.5, 27.2, 25.1, 23.3, 23.1, 22.8, 22.4, 19.7, 19.1, 16.9. Anal. Calcd for $C_{20}H_{30}O_6N_2$: C, 60.90; H, 7.67; N, 7.10. Found: C, 60.68; H, 7.62; N, 7.00.

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Registry No. **1**, 833-82-9; **2**, 21213-27-4; **3**, 5296-64-0; **4**, 22456-89-9; **5**, 64732-74-7; **6**, 13640-71-6; **7**, 13307-61-4; **9**, 129315-20-4; **10**, 129315-21-5; **11a-a**, 129389-04-4; **11a-b**, 129389-05-5; **11b**, 129315-22-6; **11c**, 129315-23-7; **11d-a**, 129315-24-8; **11d-b**, 129315-25-9; **12**, 17510-46-2; **13a**, 110874-42-5; **13b**, 129315-26-0; **13c**, 129315-27-1; **13d**, 129315-28-2; **14a**, 110874-43-6; **16a**, 110874-58-3; **16b**, 110874-57-2; **17**, 4551-15-9; **18**, 110874-41-4; **19**, 110874-44-7; **20**, 110874-45-8; **21**, 60253-72-7; **22b**, 2109-22-0; **22c**, 5445-77-2; **22d**, 96-17-3; **24a**, 110874-46-9; **24b**, 110874-47-0; **24c**, 110874-48-1; **24d**, 110903-55-4; **25d**, 110874-50-5; **26a**, 110874-51-6; **26b**, 110874-53-8; **26c**, 110874-55-0; **27c**, 110874-56-1; **28a**, 22456-89-9; **28b**, 129315-29-3; **28c**, 129315-30-6; **29**, 97250-84-5; **30a**, 129315-31-7; **30b**, 129315-32-8; **30c**, 129337-07-1; **31a**, 129315-33-9; **31b**, 129315-34-0; **32a**, 123-72-8; **32b**, 78-84-2; **32c**, 100-52-7; **33a**, 129315-35-1; **33c**, 129315-36-2; **34a**, 129315-37-3; **34c**, 129315-38-4; **35**, 124400-14-2; **36a**, 129315-39-5; **36b**, 129315-41-9; **36c**, 129315-41-9; (*E*)-**37**, 76943-95-8; **39**, 61878-68-0; **40**, 129315-42-0; **41**, 129315-43-1; **42**, 129315-44-2; **43**, 129315-45-3; **44**, 129315-46-4; **45**, 129315-47-5; **46**, 129315-48-6; **47**, 129315-49-7; **48**, 129315-50-0; **49**, 129315-51-1; **50**, 129315-52-2; **51**, 129315-53-3; **52**, 129315-54-4; **53**, 129315-55-5; **54**, 129315-56-6; **55**, 129315-57-7; **56**, 129315-58-8; **57**, 129315-59-9; **58**, 129389-06-6; **59**, 129315-60-2; (*S*)-1, 23430-41-3; (*S*)-2, 4148-81-6; (*S*)-3, 16241-12-6; (*S*)-4, 24010-73-9; (*S*)-5, 16241-13-7; (*S*)-6, 24010-52-4; (*S*)-7, 118-72-9; (*S*)-8, 91638-62-9; (*S*)-9, 129315-61-3; (*S*)-10, 129315-62-4; (*S*)-11, 129315-63-5; (*S*)-12, 1541-10-2; (*S*)-13, 22693-41-0; (*S*)-14, 129315-64-6; CH_2=$CHCH_2SiMe_3$, 762-72-1; PhSH, 108-98-5; $PhSCH_2Ph$, 831-91-4; $PhSCH_2CH(CH_3)_2$, 13307-61-4; 2,4,6-$(Me)_3C_6H_2SCH_2CH(CH_3)_2$, 129315-65-7; 2-phenylpropanal, 93-53-8; benzyl chloride, 100-44-7; isobutyl bromide, 78-77-3; pinacolone trimethylsilyl enol ether derivative, 55638-27-2; 2-phenyl-1-propanol, 1123-85-9; 2,6-dimethylphenol, 576-26-1; dimethylthiocarbamoyl chloride, 16420-13-6; 2,6-diisopropylphenol, 2078-54-8; 2-methyl-2-propanethiol, 75-66-1; 2,4,6-trimethylbenzenesulfonyl chloride, 773-64-8; 2,4,6-triisopropylbenzenesulfonyl chloride, 6553-96-4.

Supplementary Material Available: Full experimental details for the preparation of benzyl phenyl sulfide, 3-methyl-1-propyl phenyl sulfide, **1–7**, **9–10**, 2-phenylpropyl tosylate, phenyl 2-phenyl-1-propyl sulfide, **11a**, *O*-2,6-dimethylphenyl *N,N*-dimethylthiocarbamate, *O*-2,6-diisopropylphenyl *N,N*-dimethylthiocarbamate, *S*-2,6-dimethylphenyl *N,N*-dimethylthiocarbamate, *S*-2,6-diisopropylphenyl *N,N*-dimethylthiocarbamate, 2,6-dimethylthiophenol, 2,6-diisopropylthiophenol, 1-[(2,6-dimethylphenyl)thio]-2-phenylpropane, 1-[(2,6-diisopropylphenyl)thio]-2-phenylpropane, 1-(*tert*-butylthio)-2-phenylpropane, **11c–d**, 2,4,6-trimethylthiophenol, **21**, and **28b,c** and X-ray crystal data for compound **43** (27 pages). Ordering information is given on any current masthead page.

Utilization of Ethyl 2-((Phenylsulfonyl)methyl)acrylate for the Synthesis of α-Methylenevalerolactones[1]

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A two-step sequence is described for conversion of cyclic and acyclic ketone enolates into α-methylenevalerolactones. The first step involves Michael addition to ethyl α-((phenylsulfonyl)methyl)acrylate **1** with concomitant elimination of $PhSO_2$ and formation of unsaturated keto esters **2–7**. In the next sequence chemoselective ketone reduction is usually followed by spontaneous lactonization of acidification. Contrary to the five- and six-membered ring systems, the cis-fused isomer predominates in the seven- and eight-membered ring compounds **12** and **13**. Spiro α-methylenevalerolactones **17a,b** are as well obtainable by a short sequence of steps from 2-oxocyclohexanecarboxylate and **1**.

Introduction

The presence of the α-methylene lactone structural unit in various natural products has been credited as responsible for the biological activity exhibited by a number of these compounds.[2] Preparative activity in this area has been focused mainly on the synthesis of α-methylenebutyrolactones,[3] whereas the development of effective methods leading to α-methylenevalerolactones has received less attention,[4] although the latter lactones can be expected to exhibit similar biological properties due to the possibility of analogous 1,4-conjugate addition reactions involving functions present in peptides and proteins. Interesting biological activity is indeed exhibited by vernolepin,[5] vernomenin,[5] and pentalenolactone E,[6] which contain α-methylenevalerolactone moieties within their molecule.

In this context, α-(bromomethyl)acrylate has been utilized as an alkylating reagent for strongly activated methylene groups, like those of 1,3-diketones[7] or β-keto esters,[8] to give products which eventually could be used for further conversion to α-methylenevalerolactones.[7] For simple ketones devoid of additional activation, alkylation with the above acrylate reagent was considered to require, however, prior conversion to the corresponding enamines,[9]

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