[2,3]-Thia-Wittig Rearrangements of α-Lithiated Sulfides Via De-aromatized Cyclohexadiene Intermediates Proceed with Inversion of Configuration at the Carbanionic Center

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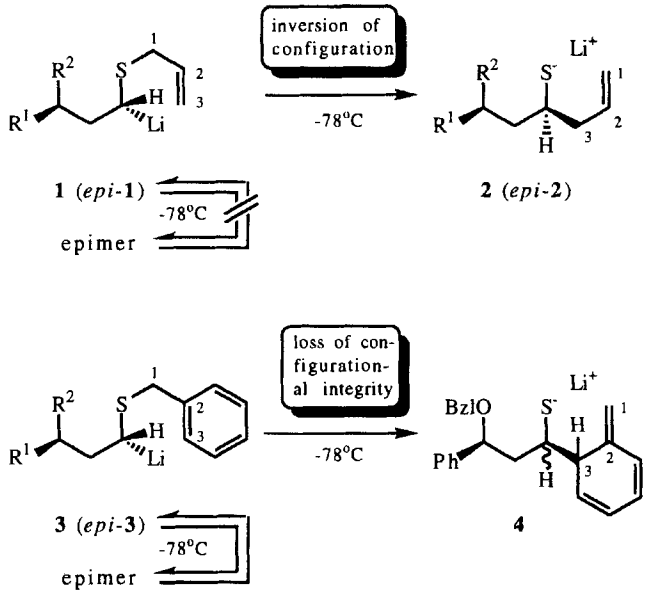
The *n*BuLi-induced tin/lithium exchange reactions of the diastereomeric γ-[(methoxyethoxy)methoxy]-α-(tributylstannyl) sulfides *anti*- and *syn*-**8** delivered the α-(lithioalkyl) benzyl sulfides *anti*- and *syn*-**11**, respectively. Within 1 h at −78°C, these species underwent [2,3]-thia-Wittig rearrangements in THF via the de-aromatized cyclohexadiene intermediates *syn*- and *anti*-**12**. Tautomerization and protonation yielded 81:19 (85%) and 19:81 mixtures (96%) of the *ortho*-functionalized toluenes *syn*- and *anti*-**13**. Probably, both Wittig rearrangements proceeded with 100% inversion of configuration at the carbanionic stereocenter, and the overall loss of stereoselectivity is due to an epimerization *anti*-**11** ⇄ *syn*-**11** of the lithio sulfide intermediates at a rate which is 3.3 times slower than the rearrangement.

Recently, we have shown that the (α-lithioalkyl) allyl sulfides **1** (*epi*-**1**) undergo stereospecific [2,3]-thia-Wittig rearrangements[1] leading to thiolates **2** (*epi*-**2**)[2]. On the one hand, this finding implied that no epimerization **1** ⇄ *epi*-**1** of these lithio sulfides took place prior to rearrangement and constituted thus one of the few examples for a certain configurational stability of such species[3]. On the other hand, it was demonstrated that *[2,3]-thia*-Wittig rearrangements proceed with 100% inversion of configuration at the carbanionic stereocenter; i.e., stereochemically they follow the analogous course of *oxa*-[2,3]-Wittig rearrangements[4].

In the same study[2] we reported that the (α-lithioalkyl) benzyl sulfides **3** (*epi*-**3**) underwent [2,3]-thia-Wittig rearrangements giving thiolates **4**. These rearrangements exhibited only moderate albeit opposite stereoselectivities (71:29 and 28:72, respectively). This was probably due to a partial epimerization **3** ⇄ *epi*-**3** of the starting material whose rearrangement should be retarded compared to that of the allyl sulfides **1** and *epi*-**1**: The [2,3] shifts of the benzyl sulfides **3** and *epi*-**3** proceed via the de-aromatized cyclohexadienes **4**, a structural change which is not required in the rearrangements of **1** and *epi*-**1**.

However, we could not elucidate the steric course of the benzyl sulfide thia-Wittig rearrangements. Whether they display inversion or retention of configuration at the former carbanionic and then sulfur-bearing stereocenter was therefore not clarified. In the present communication this question is solved for thia-Wittig rearrangements of the (methoxyethoxy)methyl ("MEM")-protected analogs *syn*-**11** and *anti*-**11** of lithio sulfides **3** and *epi*-**3**.

Scheme 1



These intermediates were obtained *in situ* (Scheme 3) from the stannylated sulfides **8** which were synthesized and stereochemically assigned as summarized in Scheme 2. Acetalization of 1-phenyl-3-buten-1-ol[5,9d] with MEMCl pro-

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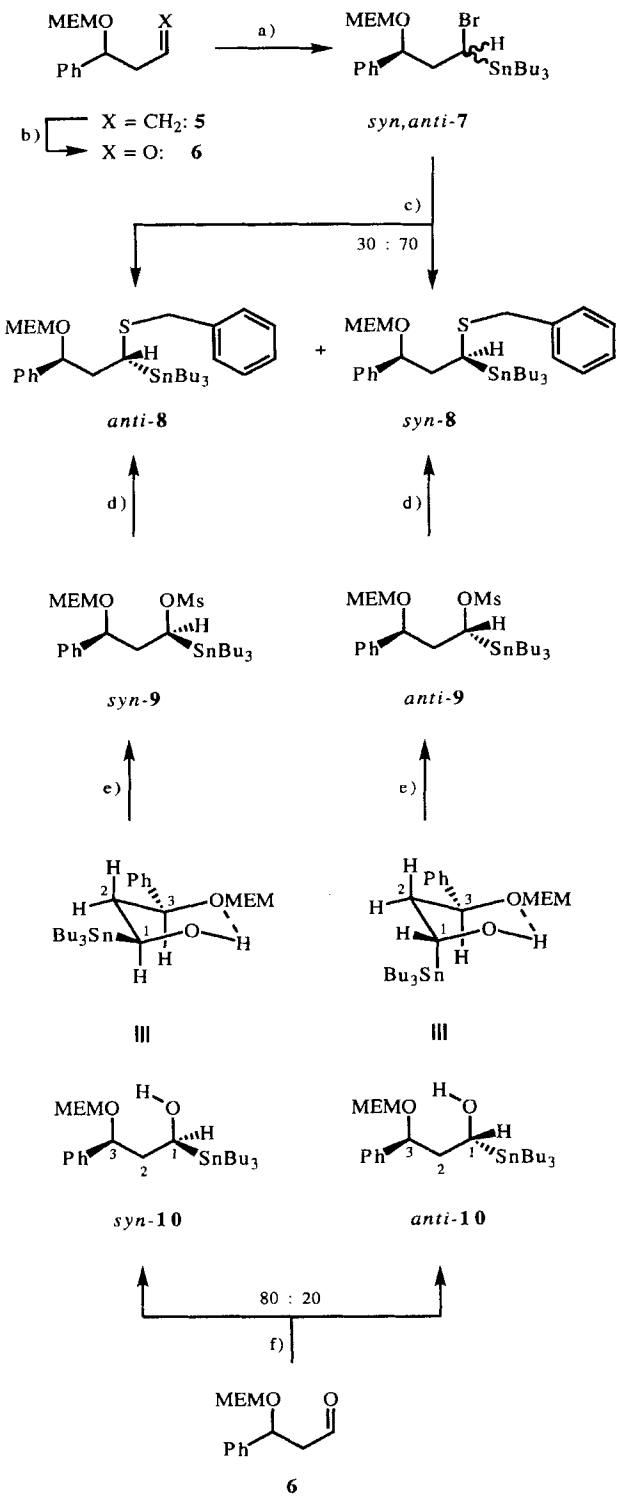
vided the unsaturated ether **5** which was ozonolyzed to give aldehyde **6**. Addition of $LiSnBu_3$[6] furnished an α-stannylated alcohol after quenching with water. This alcohol was treated crude with CBr_4/PPh_3[7] and gave a configurationally unassigned 73:27 mixture of bromides *syn*- and *anti*-**7**. These bromides were stirred with a suspension of $K^{+-}SCH_2C_6H_5$ in THF to give the desired stannylated sulfides **8** as a 30:70 *anti*:*syn* mixture. Several filtrations through a flash-chromatography column charged with silica gel[8] allowed separation of the stereochemically homogeneous constituents *anti*-(35%) and *syn*-**8** (10%) after.

The stereochemistry of the sulfides **8** was inferred from an independent synthesis (Scheme 2, bottom half). It started from chromatographically purified tributylstannylated alcohol **10** (which we had earlier used as an unpurified intermediate in the conversion of aldehyde **6** into the bromides *syn,anti*-**7**). Pure *syn*- and *anti*-configured epimers of alcohol **10** were isolated after careful flash chromatography on silica gel[8]. γ-Alkoxy alcohols like *syn*- and *anti*-**10** contain an intramolecular hydrogen bond which fixes them in six-membered chair-like rings as depicted in Scheme 2[2,9]. The *syn*-configured diastereomer prefers unequivocally *one* chair conformation while the *anti*-isomer constitutes a mixture of *two* rapidly interconverting chair conformers (of which Scheme 2 shows only one). Accordingly, the ^{1}H-NMR resonance signals of the diastereotopic methylene protons on C-2 of the diastereomers of alcohol **10** are distinctly different: In *syn*-**10**, one 2-H displays two large J_{vic} values ($J_{2,1}$ = 11.4, $J_{2,3}$ = 9.2 Hz) and the other two small ones ($J_{2,1}$ = 1.6, $J_{2,3}$ = 4.6 Hz) since the former 2-H is axially *fixed* and couples with two axially *fixed* vicinal protons and the latter 2-H is equatorially *fixed*. In the isomeric alcohol *anti*-**10**, 2-H_A and 2-H_B reveal one large and one small J_{vic} value *each* (2-H_A: $J_{2,3}$ = 10.0, $J_{2,1}$ = 2.1 Hz; 2-H_B: $J_{2,1}$ = 12.3, $J_{2,3}$ = 2.5 Hz). If an intramolecular hydrogen bond exists this indicates an equilibrium between two distorted – otherwise the conformational average should result in one small and one *medium J* value for each 2-H – chair-like conformations.

The stannylated alcohol *syn*-**10** was converted without affecting its stereocenters into mesylate *syn*-**9**, its counterpart *anti*-**10** into the epimeric mesylate *anti*-**9**. Then, each mesylate was treated separately with potassium phenylmethanethiolate in THF. The *anti*-configured mesylate provided a single subsitution product (53%) to which stereostructure *syn*-**8** was therefore assigned. To our surprise – halides are more likely than sulfonates to be replaced by nucleophiles by an electron transfer-mediated substitution mechanism and hence without rigorous stereocontrol – mesylate *syn*-**9** and potassium phenylmethanethiolate gave a 81:19 *mixture* of sulfides **8** (51%). However, since the major component was different from the only substitution product obtained from *anti*-**9**, it was in all likelihood the *anti*-isomer.

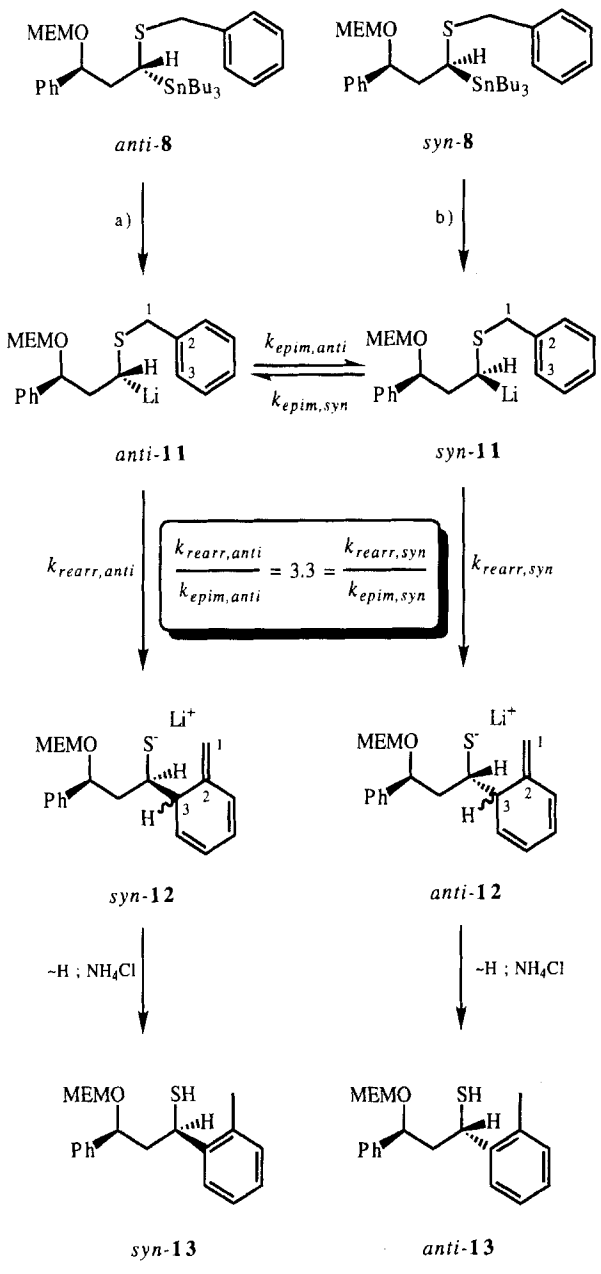
Their stereostructures being established, the stannylated sulfides *anti*- and *syn*-**8** were treated in separate experiments at −78°C in THF with 2 equiv. of *n*BuLi (Scheme 3). They are presumably first converted by Sn/Li exchange with retention of configuration[10] into the corresponding lithio

Scheme 2



a) $LiSnBu_3$, THF, −78°C, 1 h; →0°C, aq. workup; CBr_4, PPh_3, CH_2Cl_2, room temp., 12 h; 38% over the 2 steps (73:27 mixture of unassigned diastereomers of *syn,anti*-**7**). – b) O_3, CH_2Cl_2, −78°C; PPh_3; →room temp. during 12 h; 76%. – c) $K^{+-}SCH_2C_6H_5$ in THF, 0°C → room temp., 12 h; 95% (*anti*:*syn* 30:70; from this mixture 35% of pure *syn* and 10% of pure *anti* isomer). – d) $K^{+-}SCH_2C_6H_5$ in THF, room temp., 14 h; 51% of a 81:19 mixture of *anti*:*syn*-**8** from *syn*-**9**, 53% of *syn*-**8** from *anti*-**9**. – e) MsCl, NEt_3, CH_2Cl_2, −20°C, 1 h; 68% of *syn*-**9** from *syn*-**10**, 56% of *anti*-**9** from *anti*-**10**. – f) $LiSnBu_3$, THF, −78°C, 30 min; 47% (*syn*:*anti* 62:38; from this mixture 18% of pure *syn*-**10** and 15% of pure *anti*-**10**).

Scheme 3



a) *n*BuLi (2 equiv.), THF, −78°C, 60 min; 85% of a 81:19 mixture of *syn*- and *anti*-**13**. − b) Same as[a]; 96% of a 81:19 mixture of *anti*- and *syn*-**13**.

sulfides *anti*- and *syn*-**11**, respectively. The latter compounds then undergo [2,3]-thia-Wittig rearrangements which proceed chemoselectively − without competing [1,2] shifts − via the intermediacy of the de-aromatized cyclohexadiene intermediates **12**. Aqueous workup after 60 min delivered the toluene-derived thiols **13** whose formation from **12** requires re-aromatization by tautomerism and protonation. The thiols **13** were obtained by flash chromatography[8] as non-separable *syn,anti* mixtures. Starting from *anti*-**8**, we obtained a *syn*:*anti* ratio of **13** of 81:19 (85% yield), whereas with *syn*-**8** as starting compound it was exactly reversed (19:81; 96% yield).

Accordingly, these [2,3]-thia-Wittig rearrangements occur with preponderant inversion of configuration at the carbanionic center. But since the need to de-aromatize a benzene ring must slow down the sigmatropic bond shift **11** → **12**, since the configurational stability of α-lithiated sulfides is low anyway[4], and since the [2,3]-thia-Wittig rearrangements **1** → **2** and *epi*-**1** → *epi*-**2** proceed with 100% inversion of configuration at the carbanionic center, *the toluenes syn- and anti*-**13** *stem most likely from [2,3]-thia-Wittig rearrangements anti*-**11** → *syn*-**12** *and syn*-**11** → *anti*-**12** *which show 100% inversion of configuration at the lithium-bearing stereocenter.* That the stereoselectivity of the overall process **8** → **13** is incomplete is explicable by an epimerization *anti*-**11** ⇄ *syn*-**11** of the lithio sulfides which competes with their rearrangement. (In the less likely scenario that the lithio sulfides of this study do not epimerize under the reaction conditions, their [2,3]-thia-Wittig rearrangements would proceed with 81% retention and 19% inversion of configuration at the carbanionic stereocenter.)

In what we consider the more likely interpretation, each of the lithio sulfides *anti,syn*-**11** is partitioned between epimerization and rearrangement. This partitioning is described (cf. Scheme 3) for lithio sulfide *anti*-**11** by the ratio $k_{epim,anti}/k_{rearr,anti}$ of the rate constants $k_{epim,anti}$ for the epimerization *anti*-**11** → *syn*-**11** and $k_{rearr,anti}$ for the rearrangement *anti*-**11** → *syn*-**12**. Similarly, the partitioning of lithio sulfide *syn*-**11** between epimerizing *syn*-**11** → *anti*-**11** with the rate constant $k_{epim,syn}$ and rearranging *syn*-**11** → *anti*-**12** with the rate constant $k_{rearr,syn}$ is characterized by the ratio $k_{epim,syn}/k_{rearr,syn}$. When in our experiments the competition between epimerization vs. rearrangement pathways concerned lithio sulfide *anti*-**11** as the starting material or concerned lithio sulfide *syn*-**11** as the starting material the *extent* of stereocontrol (81:19 ratio of product isomers) was the *same.* This observation requires that both lithio sulfides are subject to the *same* partitioning (henceforth abbreviated as k_{epim}/k_{rearr}) between these pathways. This makes it possible to express the obtained fraction of the configurationally inverted rearrangement product by the rate constants of Eq. (1), the fraction of the configurationally retained rearrangement product by those of Eq. (2). Factorizing Eq. (2) as Eq. (3) and dividing Eq. (1) by Eq. (3) provides in Eq. (4) a means of quantifying $k_{rearr}/k_{epim} = k_{rearr,anti}/k_{epim,anti} = k_{rearr,syn}/k_{epim,syn} = 3.3$: The thia-Wittig rearrangement of each lithio sulfide **11** is 3.3 times faster than its epimerization.

The configurational assignment of the rearrangement products *syn*- vs. *anti*-**13** was made after their acid-catalyzed cyclization to the oxathianes *cis*- and *anti*-**14** (Table 1). This reaction was capricious in that isomerically oppositely composed rearrangement products (entry 1: *syn*/*anti*-**13** = 82:18, entry 2: *syn*/*anti*-**13** = 19:81) cyclized *uniformly* with *cis* preference (entry 1: → *cis*:*trans*-**14** = 90:10; entry 2: *cis*:*trans*-**14** = 77:23) by treatment with HBF_4 for 12 h. Control experiments (entries 3−5) revealed two reasons for that. Firstly, the *syn*-configured rearrangement product cy-

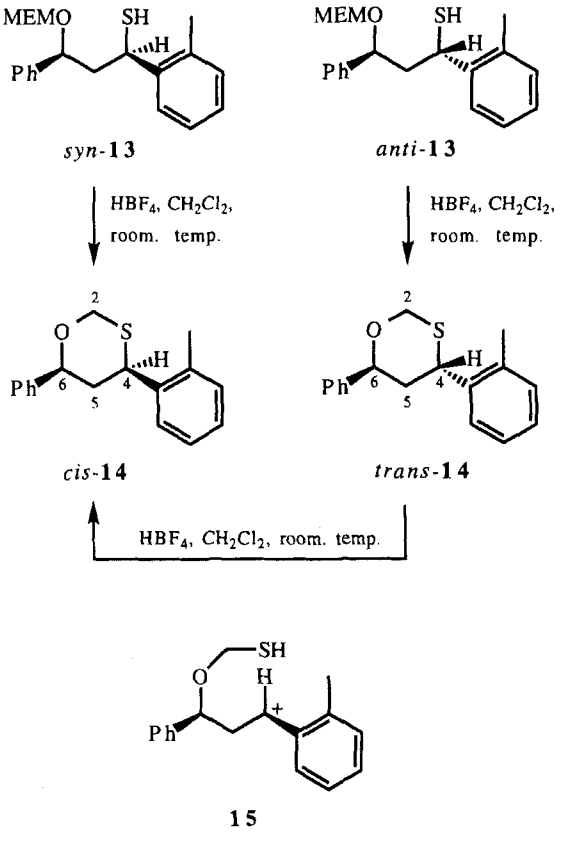
$$\frac{\%\ \text{inversion}}{100} = \frac{k_{rearr}}{k_{rearr} + k_{epim}} \cdot \sum_{n=0}^{\infty} \left(\frac{k_{epim}}{k_{rearr} + k_{epim}} \right)^{2n} \qquad \text{(Eq. 1)}$$

$$\frac{\%\ \text{retention}}{100} = \frac{k_{rearr}}{k_{rearr} + k_{epim}} \cdot \sum_{n=0}^{\infty} \left(\frac{k_{epim}}{k_{rearr} + k_{epim}} \right)^{2n+1} \qquad \text{(Eq. 2)}$$

$$= \frac{k_{rearr}}{k_{rearr} + k_{epim}} \cdot \frac{k_{epim}}{k_{rearr} + k_{epim}} \cdot \sum_{n=0}^{\infty} \left(\frac{k_{epim}}{k_{rearr} + k_{epim}} \right)^{2n} \qquad \text{(Eq. 3)}$$

$$\Rightarrow \frac{k_{rearr}}{k_{epim}} = 3.26$$

$$\frac{\%\ \text{inversion}}{\%\ \text{retention}} = \frac{k_{rearr} + k_{epim}}{k_{epim}} = \frac{k_{rearr}}{k_{epim}} + 1 \qquad \text{(Eq. 4)}$$



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clizes faster than its *anti* isomer; i.e., if the starting material was only partially cyclized, thiol *syn*-**13** delivered *cis*-**14** more rapidly than *anti*-**13** afforded *trans*-**14**. Thus, *trans*-oxathiane enrichments only attained a 80:20 ratio even if *anti*-rich fractions of **13** were cyclized (entries 3, 4); concomitantly, reisolated non-cyclized rearrangement product **13** was essentially devoid of *syn*-**13**[11] in these experiments. However, these kinetic resolutions succeeded only if exposure time to HBF_4 was drastically reduced from the initially used 12 h to 10–15 min. This is because HBF_4 converts the less stable *trans*-configured oxathiane *trans*-**14** nearly completely into the more stable *cis* isomer when present for a sufficiently long time (entry 5, 23 h). One is forced to assume that this isomerization proceeds via protonated oxathiane *trans*-**14** and the benzylic cation **15** formed from the former.

Under these circumstances, the sequence 77:23, 55:45, and 20:80 of *cis*:*trans* selectivities of the increasingly prudent cyclizations of increasingly *anti*-rich fractions of rearrangement product **13** of entries 2–4 (Table 1) must be taken as evidence for configurational identities between *syn*-**13** and *cis*-**14** and between *anti*-**13** and *trans*-**14**, respectively.

The final step of the elucidation of the stereochemical course of our thia-Wittig rearrangements was the distinction between *cis*- and *trans*-oxathiane **14** by ^{1}H-NMR comparison with reference compounds **16** and **17** (Table 2). Since the J_{vic} values of the methylene protons at C-5 of *one* isomer of **14** coincide with those of the *cis*-substituted oxathianes *cis*-**16**/*cis*-**17**, *this* isomer is also designated as *cis*. The correspondence of the J_{vic} values of the remaining isomer of **14** with those of *trans*-**16**/*trans*-**17** is low; however, this is not astounding considering that *trans*-**14** other than *trans*-**16**/*trans*-**17** is likely to consist of two equilibrating chair conformers. The assignment of *cis*- vs. *trans*-oxathiane **14** is supported by the ^{13}C shifts of the ring carbons C-2, C-4, C-5, and C-6: They are deshielded in the former compared to the latter isomer ($\Delta\delta$ = 5.86, 6.26, 5.47, and 7.03 ppm, respectively) similarly as previously determined for the oxathiane pair *cis*- vs. *trans*-**16** ($\Delta\delta$ = 5.02, 4.69, ≥2.87, and 6.37 ppm)[2].

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Experimental

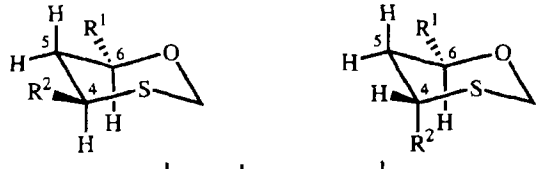
All reactions were performed in oven-dried (100°C) glassware under N_2. THF was freshly distilled from K/Na; CH_2Cl_2 from CaH_2. Products were purified by flash chromatography[8] on Merck silica gel 60 (eluents given in brackets) and isolated as oils. Yields refer to analytically pure samples. Isomer ratios of diastereomeric

Table 1. Elucidation of the stereostructure of rearrangement products **13**

	Oxathiane Preparation No.				
	1	2	3	4	5
From:	*syn:anti*-**13**	*syn:anti*-**13**	*syn:anti*-**13**	*syn:anti*-**13**	*cis:trans*-**14**
diaster. ratio	82:18	19:81	18:82	7:93	55:45
time	12 h	12 h	15 min	10 min	23 h
Yield **14**	73%	54%	33%[a]	43%[a]	82%
cis:trans	90:10	77:23	55:45	20:80	only *cis*

[a] In addition, non-cyclized starting material was retrieved (footnote[11]).

Table 2. Selected ^{1}H-NMR shifts of the newly prepared (**14**, 500 MHz, $CDCl_3$) and known 1,3-oxathianes (**16**[2], 400 MHz, $CDCl_3$; **17**[12], 60 MHz, CCl_4)



	R^1	R^2	
cis-**14**	Ph	*o*-C_6H_4Me	*trans*-**14**
cis-**16**	Ph	allyl	*trans*-**16**
cis-**17**	Me	Me	*trans*-**17**

Compound	$J_{6,5\text{-}H^{ax}}$	$J_{6,5\text{-}H^{eq}}$	$J_{4,5\text{-}H^{ax}}$	$J_{4,5\text{-}H^{eq}}$	$\delta_{6\text{-}H}$
cis-**14**	11.4	2.2	11.4	2.2	4.60
cis-**16**	11.4	2.2	11.5	2.4	4.39
cis-**17**	10.4	2.0	11.2	2.7	3.44
trans-**14**	4.3[a]	5.8[a]	7.5[a]	4.4[a]	5.17
trans-**16**	10.7	2.4	3.9	3.9	4.73
trans-**17**	9.7	3.0	4.5	4.0	3.81

[a] These *J* values are pairwise all at once exchangeable.

mixtures were derived from suitable ^{1}H-NMR integrals. – ^{1}H and ^{13}C NMR [tetramethylsilane or $CHCl_3$ (C_6HD_5) as internal standard in $CDCl_3$ (C_6D_6)]: Varian XR 200, Bruker AMX 300, and Varian VXR 500S; integrals in accord with assignments; coupling constants in Hz; AB spectra: H_A refers to high- and H_B to low-field resonance; ^{13}C spectra: values refer to $\delta(^{13}CDCl_3) = 77.00$, $\delta(^{13}C_6D_6) = 128.00$; ^{13}C APT spectra: "+" for CH or CH_3, "–" for CH_2 or C. – IR: Perkin Elmer FT-IR 1600. – Combustion analyses: Mr. Beller, Instituted of Organic Chemistry, University of Göttingen. – MTB = methyl *tert*-butyl ether.

4-[(2-Methoxyethoxy)methoxy]-4-phenyl-1-butene (**5**): At 0°C to a suspension of NaH (1.86 g, 77.3 mmol, 1.05 equiv.) in THF (100 ml) was added slowly 1-phenyl-3-buten-1-ol[9d] (10.9 g, 73.6 mmol) in THF (30 ml). The suspension was warmed to room temp., stirred for 6 h, and then recooled to 0°C. (2-Methoxyethoxy)methyl chloride (10 ml, 11 g, 88 mmol, 1.2 equiv.) was added, and the reaction mixture was stirred overnight at room temp. The reaction was quenched at 0°C with a satd. aqueous NH_4Cl solution (25 ml) and extracted with water (100 ml) and ether (3 × 50 ml). The combined organic extracts were dried with Na_2SO_4, and the solvent was evaporated under reduced pressure to yield alkene **5** (17.0 g, 98%). – ^{1}H NMR (200 MHz): δ = 2.37–2.70 (m, 3-H_2), 3.38 (s, OCH_3), 3.41–3.63 and 3.75–3.90 (2 m, 3H and 1H, respectively; OCH_2CH_2O), AB signal (δ_A = 4.62, δ_B = 4.68, J_{AB} = 7.1, OCH_2O), superimposes in part 4.67 [dd, $J_{4,3\text{-}H(1)}$ = 8.1, $J_{4,3\text{-}H(2)}$ = 5.4, 4-H], 5.03 (dm_c, $J_{cis} \approx 10$, J_{gem} and J_{allyl} incompletely resolved, *cis*-1-H), 5.08 (dm_c, $J_{trans} \approx 18$, J_{gem} and J_{allyl} incompletely resolved, *trans*-1-H), 5.79 (ddt, J_{trans} = 17.1, J_{cis} = 10.2, $J_{2,3}$ = 6.9, 2-H), 7.20–7.40 (m, C_6H_5). – IR (film): $\tilde{\nu}$ = 3070 cm^{-1}, 2935, 2885, 2815, 1640, 1495, 1455, 1365, 1260, 1105, 1025, 915, 845, 805, 760, 700. – $C_{14}H_{20}O_3$ (236.3): calcd. C 71.16, H 8.53; found C 71.31, H 8.32.

3-[(2-Methoxyethoxy)methoxy]-3-phenylpropanal (**6**): Alkene **5** (12.74 g, 53.91 mmol) in CH_2Cl_2 (100 ml) was ozonolyzed at –78°C until the solution turned blue (4 h). Triphenylphosphane (16.97 g, 64.70 mmol, 1.2 equiv.) was added, and the solution was warmed with stirring very slowly (12 h) to room temp. The resulting triphenylphosphane oxide was removed by diluting the crude product with petroleum ether/ether (1:1, 400 ml). Flash chromatography [petroleum ether/MTB (8:1) → MTB] of the residue obtained by evaporation of the solvents yielded aldehyde **6** (9.824 g, 76%). – ^{1}H NMR (200 MHz): δ = AB signal (δ_A = 2.68, δ_B = 2.97, J_{AB} = 16.4, in addition split by $J_{A,3}$ = 4.2, $J_{A,1}$ = 1.3, $J_{B,3}$ = 9.3, $J_{B,1}$ = 2.7, 2-H_2), 3.37 (s, OCH_3), 3.42–3.61 and 3.67–3.88 (2 m, 3H and 1H, respectively; OCH_2CH_2O), AB signal (δ_A = 4.61, δ_B = 4.65, J_{AB} = 7.0, OCH_2O), 5.22 (dd, $J_{3,2\text{-}H(B)}$ = 9.3, $J_{3,2\text{-}H(A)}$ = 4.1, 3H), 7.28–7.39 (m, C_6H_5), 9.81 (dd, $J_{1,2\text{-}H(B)}$ = 2.7, $J_{1,2\text{-}H(A)}$ = 1.5, 1-H). – IR (film): $\tilde{\nu}$ = 2930 cm^{-1}, 2890, 2725, 1725, 1495, 1455, 1365, 1170, 1105, 1025, 850, 765, 700. – $C_{13}H_{18}O_4$ (238.3): calcd. C 65.53, H 7.61; found C 65.50, H 7.70.

syn- and anti-1-Bromo-3-[(2-methoxyethoxy)methoxy]-3-phenyl-1-(tributylstannyl)propane (*syn,anti*-**7**): Diisopropylamine (3.6 g, 36 mmol, 1.2 equiv.) in THF (50 ml) was treated with *n*BuLi (1.85 mol/l in hexane; 17.6 ml, 32.6 mmol, 1.1 equiv.) for 10 min at –78°C. After 30 min tributyltin hydride (9.48 g, 32.6 mmol, 1.1 equiv.) was added followed 1 h later by aldehyde **6** (7.051 g, 29.59 mmol) in THF (20 ml). After another 1 h at –78°C the mixture was allowed to warm to room temp., the reaction was quenched with a satd. aqueous NH_4Cl solution (200 ml) and the mixture extracted with MTB (2 × 70 ml). The combined organic extracts

were washed with a satd. aqueous NaCl solution (250 ml), dried with Na_2SO_4, and the solvent was evaporated under reduced pressure. The residue, tetrabromomethane (9.813 g, 29.59 mmol, ≥ 1 equiv.), and triphenylphosphane (7.761 g, 29.59 mmol, ≥ 1 equiv.) were stirred in CH_2Cl_2 (160 ml) at room temp. for 12 h. Aqueous workup (CH_2Cl_2/H_2O), trituration of the crude product with petroleum ether (3 × 50 ml), and flash chromatography [petroleum ether/MTB (50:1 → 2:1)] led to a configurationally unassigned 73:27 mixture of *syn,anti*-**7** (6.589 g, 38%).

Major Diastereomer: ^{1}H NMR (500 MHz): δ = 0.85−1.06 (m, 3 × $SnCH_2$, 3 × CH_2CH_3), 1.32 (tq, both *J* values ≈ 7−8, 3 × $CH_2CH_2CH_3$), 1.40−1.55 (m, 3 × $CH_2CH_2CH_2$), AB signal (δ_A = 2.11, δ_B = 2.25, J_{AB} = 15.3, in addition split by $J_{A,1}$ = 13.2, $J_{A,3}$ = 2.3, $J_{B,3}$ = 10.2, $J_{B,2}$ = 2.3, 2-H_2), 3.36 (s, OCH_3), 3.41−3.62 and 3.85−3.92 (2 m, OCH_2CH_2O), 4.01 (dd, topping a "mountain" of tin satellites, $J_{1,2\text{-H(A)}}$ = 13.2, $J_{1,2\text{-H(B)}}$ = 2.2, 1-H), AB signal (δ_A = 4.65, δ_B = 4.73, J_{AB} = 6.9, OCH_2O), 5.01 (dd, $J_{3,2\text{-H(B)}}$ = 10.1, $J_{3,2\text{-H(A)}}$ = 2.3, 3-H), 7.25−7.40 (m, C_6H_5).

Minor Diastereomer: Superimposed in part by the major diastereomer. ^{1}H NMR (500 MHz): δ = 1.26 (tq, both *J* values ≈ 7−8, 3 × $CH_2CH_2CH_3$), 2.20−2.30 (m, 2-H^1), 2.51 (ddd, J_{gem} = 14.6, $J_{2\text{-H(2)},1}$ = 12.9, $J_{2\text{-H(2)},3}$ = 4.5, 2-H^2), 3.05 (dd, topping a "mountain" of tin satellites, $J_{1,2\text{-H(2)}}$ = 12.6, $J_{1,2\text{-H(1)}}$ = 2.5, 1-H), 3.37 (s, OCH_3), 3.76 (ddd, *J* = 8.9, *J* = 6.0, *J* = 3.0, 1 H of OCH_2CH_2O), AB signal (δ_A = 4.61, δ_B = 4.67, J_{AB} = 6.7, OCH_2O), 4.95 (dd, $J_{3,2\text{-H(1)}}$ = 9.5, $J_{3,2\text{-H(2)}}$ = 4.4, 3-H). − IR (film): $\tilde{\nu}$ = 3030 cm^{-1}, 2955, 2925, 2870, 1685, 1455, 1200, 1110, 1075, 1040, 865, 760, 700. − $C_{25}H_{45}BrO_3Sn$ (591.2): calcd. C 50.70, H 7.66; found C 50.85, H 7.63.

syn- and anti-1-(Benzylthio)-3-[(2-methoxyethoxy)methoxy]-3-phenyl-1-(tributylstannyl)propane (*syn-* and *anti*-**8**): Phenylmethanethiol (3.29 ml, 3.45 g, 27.8 mmol, 2.5 equiv.) was added at −78°C to KH (0.970 g, 24.18 mmol, 2.2 equiv.) in THF (30 ml). After 1 h the suspension was first warmed to room temp. and then recooled to 0°C. A configurationally unassigned 73:27 mixture of *syn,anti*-**7** (6.589 g, 11.12 mmol) in THF (7 ml) was added with stirring. After 12 h at room temp. the reaction was quenched with a satd. aqueous NH_4Cl solution (100 ml) and extracted with ether (2 × 100 ml). The crude product was subjected to flash chromatography once [petroleum ether/ether (30:1 → 10:1)] to give *syn,anti*-**8** as a 70:30 mixture (6.714 g, 95%) and subsequently several times [petroleum ether:ether (15:1)] to yield *syn*-**8** (2.463 g, 35%) in the early and *anti*-**8** (0.732 g, 10%) in the late fractions. − IR (film): $\tilde{\nu}$ = 3060 cm^{-1}, 3030, 2955, 2925, 1495, 1455, 1375, 1200, 1110, 1070, 1025, 865, 760, 700. − $C_{32}H_{52}OSSn$ (635.5): calcd C 60.48, H 8.25; found C 60.52, H 8.18.

syn-**8**: ^{1}H NMR (500 MHz): δ = ca. 0.84−0.93 (m, 3 × $SnCH_2$), superimposed by 0.87 (t, *J* = 7.2, 3 × CH_2CH_3), 1.27 (tq, both *J* values ≈ 7−8, 3 × $CH_2CH_2CH_3$), 1.37−1.47 (m, 3 × $CH_2CH_2CH_2$), 2.13 (ddd, J_{gem} = 14.0, $J_{2\text{-H(1)},1}$ = 6.3, $J_{2\text{-H(1)},3}$ = 4.9, 2-H^1), 2.27−2.37 (m, 1-H, 2-H^2), 3.33 (s, OCH_3), superimposes 3.28−3.44 and 3.38−3.48 and 3.62−3.68 (3 m, 1H, 2H, and 1H, respectively; OCH_2CH_2O), AB signal (δ_A = 3.64, δ_B = 3.71, J_{AB} = 13.1, SCH_2), AB signal (δ_A = 4.60, δ_B = 4.64, J_{AB} = 6.7, OCH_2O), 4.72 (dd, $J_{3,2\text{-H(2)}}$ = 8.4, $J_{3,2\text{-H(1)}}$ = 4.7, 3-H), 7.19−7.36 (m, 2 × C_6H_5). − ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, $CDCl_3$ as internal standard in $CDCl_3$): δ = "−" 9.79 (including doublet satellites for $^1J_{C,^{119}Sn}$ = 323.0 and $^1J_{C,^{117}Sn}$ = 308.7, 3 × $SnCH_2$), "+" 13.60 (3 × CH_2CH_3), "+" 22.34 (C-1), "−" 27.38 (including doublet satellites for $^3J_{C,Sn}$ = 58.4, 3 × $CH_2CH_2CH_3$), "−" 28.96 (including doublet satellites for $^2J_{C,Sn}$ = 19.7, 3 × $CH_2CH_2CH_2$), "−" 37.21 and "−" 42.01 (C-2, SCH_2), "+" 58.85 (OCH_3), "−" 67.12, "−" 71.53 (OCH_2CH_2O), "+" 77.51 (C-3), "−" 93.75 (OCH_2O), "+" 126.55, "+" 127.01*, "+" 127.53, "+" 128.19*, "+" 128.27*, "+" 129.11* (6 × Ar-CH), "−" 138.60, "−" 142.04 (2 × *ipso*-Ar-C); **o*- or *m*- and not *p*-C because of relatively high intensity.

anti-**8**: ^{1}H NMR (500 MHz): δ = 0.84−0.94 (m, 3 × $SnCH_2$), superimposed by 0.87 (t, *J* = 7.4, 3 × CH_2CH_3), 1.28 (tq, both *J* values = 7.4, 3 × $CH_2CH_2CH_3$), 1.36−1.50 (m, 3 × $CH_2CH_2CH_2$), 2.15−2.22 and 2.24−2.36 (2 m, 2H and 1H, respectively; 1-H, 2-H_2), 3.32 (s, OCH_3), 3.33−3.39, 3.42−3.47, 3.48−3.54, and 3.70−3.75 (4 m, OCH_2CH_2O), AB signal (δ_A = 3.59, δ_B = 3.65, J_{AB} = 12.7, SCH_2Ph), AB signal (δ_A = 4.57, δ_B = 4.64, J_{AB} = 7.0, OCH_2O), 4.68 (dd, $J_{3,2\text{-H(1)}}$ = $J_{3,2\text{-H(2)}}$ = 6.2, 3-H), 7.10−7.36 (m, 2 × C_6H_5). − ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, $CDCl_3$ as internal standard in $CDCl_3$): δ = "−" 9.65 (including doublet satellites for $^1J_{C,^{119}Sn}$ = 319.9 and $^1J_{C,^{117}Sn}$ = 305.7, 3 × $SnCH_2$), "+" 13.56 (3 × CH_2CH_3), "+" 22.65 (C-1), "−" 27.29 (including doublet satellits for $^3J_{C,Sn}$ = 56.9, 3 × $CH_2CH_2CH_3$), "−" 28.93 (including doublet satellites for $^2J_{C,Sn}$ = 19.9, 3 × $CH_2CH_2CH_2$), "−" 37.70 and "−" 43.40 (C-2, SCH_2), "+" 58.78 (OCH_3), "−" 67.06, "−" 71.52 (OCH_2CH_2O), "+" 77.46 (C-3), "−" 93.47 (OCH_2O), "+" 126.46, "+" 127.02*, "+" 127.57, "+" 128.16*, "+" 128.32*, "+" 128.83* (6 × Ar-CH), "−" 138.54, "−" 141.92 (2 × *ipso*-Ar-C); **o*- or *m*- and not *p*-C because of relatively high intensity.

syn- and anti-3-[(2-Methoxyethoxy)methoxy]-1-(2-methylphenyl)-3-phenyl-1-propanethiol (*syn-* and *anti*-**13**)

a) At −78°C *n*BuLi (1.85 mol/l in hexane; 2.13 ml, 3.95 mmol, 2.0 equiv.) was added dropwise to stannyl sulfide *syn*-**8** (1.254 g, 1.973 mmol) in THF (10 ml). After 1 h the reaction was quenched with a satd. aqueous NH_4Cl solution (10 ml) and the resulting mixture extracted with ether (3 × 40 ml). Purification of the crude products by flash chromatography [petroleum ether/ether (100:1 → 2:1)] yielded the thiols **13** (0.656 g, 96%) as a 19:81 *syn,anti* mixture. A similarly conducted second experiment gave 86% of a 18:82 *syn,anti* mixture.

b) At −78°C *n*BuLi (1.85 mol/l in hexane; 0.48 ml, 0.88 mmol 2.0 equiv.) was added dropwise to stannyl sulfide *anti*-**8** (0.292 g, 0.440 mmol) in THF (5 ml). After 1 h the reaction was quenched with a satd. aqueous NH_4Cl solution (5 ml), and the resulting mixture extracted with ether (3 × 20 ml). Purification of the crude products by flash chromatography [petroleum ether/ether (100:1→ 2:1)] yielded the thiols **13** (0.129 g, 85%) as a slightly impure 82:18 *syn,anti* mixture. A similarly conducted second experiment provided 84% of a 79:21 *syn,anti* mixture which, too, could not be entirely liberated from contaminations. − IR (film): $\tilde{\nu}$ = 3025 cm^{-1}, 2925, 2885, 2550, 1600, 1490, 1455, 1365, 1245, 1200, 1105, 1025, 850, 755, 700. − $C_{20}H_{26}O_3S$ (346.5): calcd. C 69.33, H 7.56; found C 69.36, H 7.53.

syn-**13**: ^{1}H NMR (500 MHz, signals in part superimposed by those of *anti*-**13**): δ = 1.86 (d, $J_{SH,1}$ = 6.5, SH), 2.25 (s, $C_6H_4CH_3$), AB signal (δ_A = 2.39, δ_B = 2.53, J_{AB} = 14.1, in addition split by $J_{A,1}$ = 7.9, $J_{A,3}$ = 5.7, $J_{B,3}$ = 8.4, $J_{B,1}$ = 7.2, 2-H_2), 3.29 (s, OCH_3), 3.22−3.32, 3.39−3.45, and 3.51−3.56 (3 m, 2H and 1H and 1H, respectively; OCH_2CH_2O), 4.22 (ddd, $J_{1,2\text{-H(A)}}$ = $J_{1,2\text{-H(B)}}$ = $J_{1,SH}$ 7.2, 1-H), 4.53 (s, OCH_2O), 4.57 (dd, $J_{3,2\text{-H(B)}}$ = 8.5, $J_{3,2\text{-H(A)}}$ = 5.8, 3-H), 7.09−7.40 (m, C_6H_5 and $C_6H_4CH_3$). − ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, $CDCl_3$ as internal standard in $CDCl_3$): δ = "+" 18.96 (C-1), "+" 35.50 (CH_3), "−" 46.96 (C-2), "+" 58.76 (OCH_3), "−"66.75, "−" 71.39 (OCH_2CH_2O), "+" 76.54 (C-3), "−" 93.26 (OCH_2O), "+" 125.35, "+" 126.59, "+" 126.90, "+" 127.83, "+" 130.59 (5 × Ar-CH), "+"

126.80, "+" 128.39 (2 × *o*- and 2 × *m*-C because of relatively high intensity), "−" 135.08 (CH_3-Ar-ipso-C), "−" 141.19, "−" 141.62 (2 × *ipso*-Ar-C).

anti-**13**: ^{1}H NMR (500 MHz, signals in part superimposed by those of *syn*-**13**): δ = 1.99 (d, $J_{SH,1}$ = 6.8, SH), 2.30 (s, $C_6H_4CH_3$), superimposes in part AB signal (δ_A = 2.23, δ_B = 2.48, J_{AB} = 14.4, in addition split by $J_{A,1}$ = 9.5, $J_{A,3}$ = 4.7, $J_{B,3}$ = 9.2, $J_{B,1}$ = 5.3, 2-H_2), 3.39 (s, OCH_3), 3.47−3.63 and 3.87−3.93 (2 m, 3H and 1H, respectively; OCH_2CH_2O), 4.31 (ddd, $J_{1,2\text{-H(A)}}$ = 9.6, $J_{1,SH}$ = 6.7, $J_{1,2\text{-H(B)}}$ = 5.3, 1-H), AB signal (δ_A = 4.61, δ_B = 4.67, J_{AB} = 7.1, OCH_2O), 4.86 (dd, $J_{3,2\text{-H(B)}}$ = 9.2, $J_{3,2\text{-H(A)}}$ = 4.6, 3-H), 7.08−7.38 (m, C_6H_5 and $C_6H_4CH_3$). − ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, $CDCl_3$ as internal standard in $CDCl_3$): δ = "+" 19.03 (C-1), "+" 35.67 (CH_3), "−" 47.06 (C-2), "+" 58.89 (OCH_3), "−" 67.16, "−" 71.26 (OCH_2CH_2O), "+" 75.93 (C-3), "−" 93.22 (OCH_2O), "+" 125.44, "+" 126.53, "+" 126.84*, "+" 127.74, "+" 130.47 (5 × Ar-CH), "+" 126.48*, "+" 128.37** (2 × *o*-C, 2 × *m*-C), "−" 134.77 (CH_3-Ar-*ipso*-C), "−" 141.29, "−" 142.15 (2 × *ipso*-Ar-C); *since the total intensity of this resonance is three times as high as that of 125.44 or 126.53 or 127.74 or 130.47, it is interpreted as a superposition of 1 Ar-CH and 2 × *o*- or 2 × *m*-C; **assigned *o*- or *m*-C because of relatively high intensity.

cis- and trans-4-(2-Methylphenyl)-6-phenyl-1,3-oxathiane (*syn*- and *anti*-**14**)

a) To a 82:18 *syn,anti* mixture of thiols **13** (0.132 g, 0.381 mmol) in CH_2Cl_2 (5 ml) were added at room temp. 2 drops of HBF_4 (54% solution in Et_2O). After 12 h the reaction was quenched with a satd. aqueous $NaHCO_3$ solution (5 ml), the mixture was extracted with ether (3 × 30 ml), the combined extracts were dried with Na_2SO_4, and the solvent was evaporated in vacuo. Flash chromatography [petroleum ether/ether (100:1 → 20:1)] of the residue yielded oxathianes **14** as a 93:7 *cis,trans* mixture (0.075 g, 73%). A similarly conducted second experiment provided 66% of a 90:10 *cis,trans* mixture.

b) To a 19:81 *syn,anti* mixture of thiols **13** (0.411 g, 1.19 mmol) in CH_2Cl_2 (5 ml) were added at room temp. 2 drops of HBF_4 (54% solution in Et_2O). After 12 h the reaction was quenched with a satd. aqueous $NaHCO_3$ solution (5 ml), the mixture was extracted with ether (3 × 30 ml), the combined extracts were dried with Na_2SO_4, and the solvent was evaporated in vacuo. Flash chromatography [petroleum ether/ether (100:1 → 5:1)] of the residue yielded oxathianes **14** as a 77:23 *syn,anti* mixture (0.173 g, 54%). A similarly conducted second experiment gave 48% of an identically composed mixture.

c) To a 18:82 *syn,anti* mixture of thiols **13** (0.101 g, 0.292 mmol) in CH_2Cl_2 (2 ml) was added at room temp. 1 drop of HBF_4 (54% solution in Et_2O). After 15 min the reaction was quenched with a satd. aqueous $NaHCO_3$ solution (3 ml), the mixture was extracted with ether (3 × 10 ml), the combined extracts were dried with Na_2SO_4, and the solvent was evaporated in vacuo. Flash chromatography [petroleum ether/ether (100:1 → 2:1)] of the residue yielded oxathianes **14** as a 55:45 *syn,anti* mixture (0.026 g, 33%; 67% with respect to reisolated starting compound[11]) and in the late fractions nearly isomerically pure *anti*-**13** contaminated with an impurity[11] (ca. 80:20 mixture, 0.051 g, 50%).

d) To a 7:93 *syn,anti* mixture of thiols **13** obtained by kinetic resolution by *partial* cyclization of a 18:82 *syn,anti* mixture with HBF_4 (0.065 g, 0.19 mmol) in CH_2Cl_2 (2 ml) was added at room temp. 1 drop of HBF_4 (54% solution in Et_2O). After 10 min the reaction was quenched with a satd. aqueous $NaHCO_3$ solution (3 ml), the mixture was extracted with ether (3 × 10 ml), the combined extracts were dried with Na_2SO_4, and the solvent was evaporated in vacuo. Flash chromatography [petroleum ether/ether (30:1 → 2:1)] of the residue yielded a 20:80 *cis,trans* mixture of oxathianes **14** (0.022 g, 43%; 83% with respect to reisolated starting compound[11]) and in the late fractions nearly isomerically pure *anti*-**13** contaminated with an impurity[11] (ca. 70:30 mixture, 0.031 g, 48%).

e) To a 55:45 *cis,trans* mixture of oxathianes **14** (0.022 g, 0.081 mmol) in CH_2Cl_2 (2 ml) was added at room temp. 1 drop of HBF_4 (54% solution in Et_2O). After 23 h the reaction was quenched with a satd. aqueous $NaHCO_3$ solution (3 ml), the mixture was extracted with ether (3 × 10 ml), the combined extracts were dried with Na_2SO_4, and the solvent was evaporated in vacuo. Flash chromatography [petroleum ether/ether (30:1)] of the residue yielded nearly isomerically pure oxathiane *syn*-**14** (0.018 g, 82%).

IR (film): $\tilde{\nu}$ = 3060 cm^{-1}, 3025, 2950, 2900, 1600, 1490, 1450, 1305, 1250, 1205, 1160, 1070, 1030, 995, 960, 910, 760, 725, 700. − $C_{17}H_{18}OS$ (270.4): calcd. C 75.51, H 6.71; found C 75.27, H 6.62.

cis-**14**: ^{1}H NMR (500 MHz): δ = AB signal (δ_A = 2.15, δ_B = 2.31, J_{AB} = 13.9, in addition split by $J_{A,4}$ = $J_{A,6}$ = 2.2, $J_{B,4}$ = $J_{B,6}$ = 11.4, 5-H_2), 2.49 (s, $C_6H_4CH_3$), 4.50 (dd, $J_{4,5\text{-H(B)}}$ = 11.7*, $J_{4,5\text{-H(A)}}$ = 2.3*, 4-H**), 4.60 (dd, $J_{6,5\text{-H(B)}}$ = 11.0*, $J_{6,5\text{-H(A)}}$ = 1.8*, 6-H**), AB signal (δ_A = 5.15, δ_B = 5.21, J_{AB} = 11.3, 2-H_2), 7.13−7.44 (m, C_6H_5 and $C_6H_4CH_3$); *assignments of the coupling constants are simultaneously interchangeable; **4-H and 6-H were assigned by a C,H correlation spectrum. − ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, $CDCl_3$ as internal standard in $CDCl_3$): δ = "+" 19.23 ($C_6H_4CH_3$), "−" 40.90 (C-5), "+" 43.08 (C-4), "−" 72.42 (C-2), "+" 82.38 (C-6), "+" 125.83, "+" 128.48 (2 × *o*- and 2 × *m*-C because of relatively high intensity), "+" 126.56, "+" 126.85, "+" 127.40, "+" 127.86, "+" 130.56 (5 × Ar-CH), "−" 135.41 (CH_3-Ar-*ipso*-C), "−" 138.97, "−" 141.72 (2 × *ipso*-Ar-C).

trans-**14**: ^{1}H NMR (500 MHz): δ = 2.35 (s, $C_6H_4CH_3$), AB signal (presumably with transition to higher-order spectrum, tentative evaluation: δ_A = 2.60, δ_B = 2.63, J_{AB} = 14.4, in addition split by $J_{A,4}$ = 7.4, $J_{A,6}$ = 4.3, $J_{B,6}$ = 5.8, $J_{B,4}$ = 4.3, 5-H_2), 4.51 (dd, $J_{4,5\text{-H(A)}}$ = 7.6, $J_{4,5\text{-H(B)}}$ = 4.4, 4-H*), AB signal (δ_A = 4.95, δ_B = 5.11, J_{AB} = 11.3, 2-H_2), 5.17 (br. dd, $J_{6,5\text{-H(A)}} \approx J_{6,5\text{-H(B)}} \approx 5$, 6-H*), 7.14−7.23 and 7.26−7.43 (2 m, 8 × Ar-H), 7.63 (br. d, J_o = 7.6, *o*-Ar-H); *4-H and 6-H were assigned by a C,H correlation spectrum. − ^{13}C NMR (ATP spectrum at 125 MHz, $CDCl_3$ as internal standard in $CDCl_3$): δ = "+" 19.34 ($C_6H_4CH_3$), "−" 35.43 (C-5), "+" 36.82 (C-4), "−" 66.56 (C-2), "+" 75.35 (C-6), "+" 126.37, "+" 127.09, "+" 127.31, "+" 127.65, "+" 130.89 (5 × Ar-CH), 126.57, "+" 128.81 (2 × *o*- and 2 × *m*-C because of relatively high intensity), "−" 135.77 (CH_3-Ar-*ipso*-C), "−" 139.96, "−" 140.14 (2 × *ipso*-Ar-C).

syn- and anti-3-[(2-Methoxyethoxy)methoxy]-3-phenyl-1-(tributylstannyl)-1-propanol (*syn*- and *anti*-**10**): A solution of diisopropylamine (0.40 ml, 0.29 g, 2.8 mmol, 1.4 equiv.) in THF (5 ml) was treated with *n*BuLi (1.85 mol/l in hexane; 1.43 ml, 2.65 mmol, 1.3 equiv.) at −78°C. After 30 min tributyltin hydride (0.70 ml, 0.77 g, 2.6 mmol, 1.3 equiv.) was added and after another 30 min aldehyde **6** (0.485 g, 2.04 mmol) in THF (10 ml). After 30 min the reaction was quenched with a satd. aqueous NH_4Cl solution (10 ml) and the mixture extracted with brine (30 ml) and ether (3 × 30 ml). The crude product was purified by flash chromatography [petroleum ether/ether (10:1 → 1:1)] to yield *anti*-**10** (0.166 g, 15%), a 80:20 mixture of *syn*- and *anti*-**10** (0.148 g, 14%), and *syn*-**10** (0.190 g, 18%); i.e., the alcohol was produced as a 62:38 *syn,anti* mixture of diastereomers (0.504 g, 47%). − IR (film): $\tilde{\nu}$ = 3490 cm^{-1}, 3030,

2925, 1495, 1455, 1415, 1375, 1245, 1040, 845, 760, 700, 595. – $C_{25}H_{46}O_4Sn$ (529.3): calcd. C 56.73, H 8.76; found C 56.06, H 8.52. – No better combustion analysis could be obtained.

syn-**10**: ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.76–1.02 (m, including flanking multiplets caused by $^2J_{H,Sn}$, 3 × $SnCH_2$), superimposed by 0.88 (t, J = 7.2, 3 × CH_2CH_3), 1.29 (tq, both J = values ≈ 7–8, 3 × $CH_2CH_2CH_3$), 1.38–1.63 (m, 3 × $CH_2CH_2CH_2$), 1.92 (ddd, J_{gem} = 14.9, $J_{2\text{-H}(1),3}$ = 4.6, $J_{2\text{-H}(1),1}$ = 1.6, 2-H^1), 2.41 (ddd, J_{gem} = 14.9, $J_{2\text{-H}(2),1}$ = 11.4, $J_{2\text{-H}(2),3}$ = 9.2, 2-H^2), 3.11 (d including Sn satellites, $J_{OH,1}$ = 2.7, OH), 3.37 (s, OCH_3), 3.42–3.62 and 3.81–3.91 (2 m, 3H and 1H, respectively; OCH_2CH_2O), 4.23 (ddd, $J_{1,2\text{-H}(2)}$ = 11.3, $J_{1,OH}$ = $J_{1,2\text{-H}(1)}$ = 2.1, 1-H), AB signal (δ_A = 4.57, δ_B = 4.64, J_{AB} = 7.2, OCH_2O), 4.89 (dd, $J_{3,2\text{-H}(2)}$ = 9.0, $J_{3,2\text{-H}(1)}$ = 4.5, 3-H), 7.24–7.38 (m, C_6H_5). – ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, C_6D_6 as internal standard in C_6D_6): δ = "–" 8.86 (including doublet satellites for $^1J_{C,^{119}Sn}$ = 306.5 and $^1J_{C,^{117}Sn}$ = 292.9 3 × $SnCH_2$), "+" 13.95 (3 × CH_2CH_3), "–" 27.85 (including doublet satellites for $^3J_{C,Sn}$ = 51.2, 3 × $CH_2CH_2CH_3$), "–" 29.65 (including doublet satellites for $^2J_{C,Sn}$ = 20.2, 3 × $CH_2CH_2CH_2$), "–" 46.23 (C-2), "+" 58.66 (OCH_3), "+" 66.99 (C-1), "–" 67.72, "–" 72.12 (OCH_2CH_2O), "+" 81.09 (including flanking doublet satellites caused by $^3J_{C,Sn}$, C-3), "–" 93.11 (OCH_2O), "+" 127.28*, "+" 128.00, "+" 128.78* (Ar-CH), "–" 141.96 (*ipso*-Ar-C); *o- or m- and not p-C because of relatively high intensity.

anti-**10**: ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.83–0.93 (m, 3 × $SnCH_2$), superimposed by 0.88 (t, J = 7.4, 3 × CH_2CH_3), 1.30 (tq, both J values ≈ 7–8, 3 × $CH_2CH_2CH_3$), 1.38–1.59 (m, 3 × $CH_2CH_2CH_2$), AB signal (δ_A = 1.91, δ_B = 2.16, J_{AB} = 14.5, in addition split by $J_{A,3}$ = 10.0, $J_{A,1}$ = 2.1, $J_{B,1}$ = 12.3, $J_{B,3}$ = 2.5, 2-H$_2$), 3.36 (d, $J_{OH,1}$ = 6.3, OH), 3.40 (s, OCH_3), 3.48–3.64 and 3.94–4.05 (2 m, 3H and 1H, respectively; OCH_2CH_2O), 4.43 (ddd, $J_{1,2\text{-H}(B)}$ = 12.4, $J_{1,OH}$ = 5.6, $J_{1,2\text{-H}(A)}$ = 2.0, 1-H), AB signal (δ_A = 4.60, δ_B = 4.64, J_{AB} = 7.2, OCH_2O), 5.03 (dd, $J_{3,2\text{-H}(A)}$ = 10.0, $J_{3,2\text{-H}(B)}$ = 2.5, 3-H), 7.22–7.38 (m, C_6H_5). – ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, C_6D_6 as internal standard in C_6D_6): δ = "–" 8.82 (including doublet satellites for $^1J_{C,^{119}Sn}$ = 302.4 and $^1J_{C,^{117}Sn}$ = 289.1, 3 × $SnCH_2$), "+" 13.94 (3 × CH_2CH_3), "–" 27.84 (including doublet satellites for $^3J_{C,Sn}$ = 50.1, 3 × $CH_2CH_2CH_3$), "–" 29.70 (including doublet satellites for $^2J_{C,Sn}$ = 20.1, 3 × $CH_2CH_2CH_2$), "–" 47.70 (C-2), "+" 58.70 (OCH_3), "+" 62.39 (C-1), "–" 67.27, "–" 72.08 (OCH_2CH_2O), "+" 74.29 (C-3), "–" 92.67 (OCH_2O), "+" 126.96*, "+" 127.54, "+" 128.73* (Ar-CH), "–" 143.47 (*ipso*-Ar-C); *o- or m- and not p-C because of relatively high intensity.

syn-{3-[(2-Methoxyethoxy)methoxy]-3-phenyl-1-(tributylstannyl)propyl} Methanesulfonate (*syn*-**9**): At –20°C methanesulfonyl chloride (0.07 ml, 0.1 g, 0.9 mmol, 2.5 equiv.) and NEt_3 (0.25 ml, 0.18 g, 1.8 mmol, 5.0 equiv.) were added to alcohol *syn*-**10** (0.190 g, 0.359 mmol) in CH_2Cl_2 (3 ml). After 1 h the reaction was quenched with a satd. aqueous $NaHCO_3$ solution (5 ml), the mixture extracted with ether (3 × 25 ml), the combined extracts were dried with Na_2SO_4, and the solvent was evaporated in vacuo at 0°C. Flash chromatography [petroleum ether/ether (100:1 → 1:1)] of the residue yielded *syn*-**9** (0.149 g, 68%). – ^{1}H NMR (300 MHz, C_6D_6): δ = 0.92 (t, J = 7.4, 3 × CH_2CH_3), 1.04–1.15 (m, 3 × $SnCH_2$), 1.34 (tq, both J values ≈ 7–8, 3 × $CH_2CH_2CH_3$), 1.50–1.64 (m, 3 × $CH_2CH_2CH_2$), 2.35 (s, SCH_3), AB signal (δ_A = 2.43, δ_B = 2.77, J_{AB} = 14.9, in addition split by $J_{A,1}$ = 7.7, $J_{A,3}$ = 4.5, $J_{B,3}$ = 9.0, $J_{B,1}$ = 5.9, 2-H$_2$), 3.10 (s, OCH_3), 3.21-3.34, 3.39–3.48, and 3.73–3.80 (3 m, 2H and 1H and 1H, respectively; OCH_2CH_2O), AB signal (δ_A = 4.60, δ_B = 4.62, J_{AB} = 6.6, OCH_2O), 4.99 (dd, $J_{3,2\text{-H}(B)}$ = 8.9, $J_{3,2\text{-H}(A)}$ = 4.4, 3-H*), 5.06 (dd, $J_{1,2\text{-H}(A)}$ = $J_{1,2\text{-H}(B)}$ = 6.8, 1-H*), 7.02–7.30 and 7.40–7.49 (2 m, 3H and 2H, respectively; C_6H_5); *the assignments of 1-H vs. 3-H and their coupling constants are interchangeable. – ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, C_6D_6 as internal standard in C_6D_6): δ = "–" 10.29 (including doublet satellites for $^1J_{C,^{119}Sn}$ = 330.2 and $^1J_{C,^{117}Sn}$ = 315.5, 3 × $SnCH_2$), "+" 13.86 (3 × CH_2CH_3), "–" 27.75 (including doublet satellites for $^3J_{C,Sn}$ = 58.0, 3 × $CH_2CH_2CH_3$), "–" 29.28 (including doublet satellites for $^2J_{C,Sn}$ = 20.0, 3 × $CH_2CH_2CH_2$), "+" 37.65 (SCH_3), "–" 43.43 (C-2), "+" 58.61 (OCH_3), "–" 67.69, "–" 72.09 (OCH_2CH_2O), "+" 74.69, "+" 75.73 (C-1, C-3), "–" 93.48 (OCH_2O), "+" 127.68*, "+" 128.20, "+" 128.78* (Ar-CH), "–" 141.48 (*ipso*-Ar-C); *o- or m- and not p-C because of relatively high intensity. – IR (film): $\tilde{\nu}$ = 2955 cm^{-1}, 2925, 1455, 1335, 1200, 1170, 1110, 1045, 965, 895. – $C_{26}H_{48}O_6SSn$ (607.4): calcd. C 51.41, H 7.97; found C 51.88, H 7.78.

anti-{3-[(2-Methoxyethoxy)methoxy]-3-phenyl-1-(tributylstannyl)propyl} Methanesulfonate (*anti*-**9**): A similar experiment as described above starting from alcohol *anti*-**10** (0.166 g, 0.313 mmol) gave *anti*-**9** (0.106 g, 56%). – ^{1}H NMR (300 MHz, C_6D_6): δ = 0.93 (t, J = 7.4, 3 × CH_2CH_3), 1.08–1.16 (m, 3 × $SnCH_2$), 1.36 (tq, both J values ≈ 7–8, 3 × $CH_2CH_2CH_3$), 1.56–1.69 (m, 3 × $CH_2CH_2CH_2$), 2.29–2.51 (m, 2-H$_2$), 2.54 (s, SCH_3), 3.07 (s, OCH_3), 3.24–3.30, 3.40–3.48, and 3.76–3.84 (3 m, 2H and 1H and 1H, respectively; OCH_2CH_2O), AB signal (δ_A = 4.64, δ_B = 4.70, J_{AB} = 6.6, OCH_2O), 5.03 (dd, $J_{3,2\text{-H}(1)}$ = 9.6, $J_{3,2\text{-H}(2)}$ = 2.5, 3-H*), 5.53 (dd, $J_{1,2\text{-H}(1)}$ = 11.2**, $J_{1,2\text{-H}(2)}$ = 2.9**, 1-H*), 7.00–7.43 (m, C_6H_5); *assignments interchangeable, ** dto. – ^{13}C NMR (broad-band-decoupled and APT spectrum at 75 MHz, C_6D_6 as internal standard in C_6D_6): δ = "–" 10.12 (including doublet satellites for $^1J_{C,^{119}Sn}$ = 322.1 and $^1J_{C,^{117}Sn}$ = 315.9, 3 × $SnCH_2$), "+" 13.85 (3 × CH_2CH_3), "–" 27.72 (including doublet satellites for $^3J_{C,Sn}$ = 57.3, 3 × $CH_2CH_2CH_3$), "–" 29.31 (including doublet satellites for $^2J_{C,Sn}$ = 20.3, 3 × $CH_2CH_2CH_2$), "+" 37.43 (SCH_3), "–" 44.70 (C-2), "+" 58.58 (OCH_3), "–" 67.98, "–" 72.09 (OCH_2CH_2O), "+" 75.05, "+" 75.76 (C-1, C-3), "–" 94.17 (OCH_2O), "+" 126.91*, "+" 128.00, "+" 128.85* (Ar-CH), "–" 142.65 (*ipso*-Ar-C); *o- or m- and not p-C because of relatively high intensity.

anti-1-(Benzylthio)-3-[(2-methoxyethoxy)methoxy]-3-phenyl-1-(tributylstannyl)propane (*anti*-**8**): Phenylmethanethiol (0.06 ml, 0.07 g, 0.5 mmol, 3.0 equiv.) was added at –78°C to KH (0.018 g, 0.44 mmol, 2.5 equiv.) in THF (3 ml). After 1 h the suspension was first warmed to room temp. and then recooled to 0°C. With stirring methanesulfonate *syn*-**9** (0.108 g, 0.177 mmol) in THF (1 ml) was added. After 14 h at room temp. the reaction was quenched with a satd. aqueous NH_4Cl solution (5 ml), the mixture extracted with ether (3 × 20 ml), and the combined extracts were dried with Na_2SO_4. The crude product was subjected to flash chromatography [petroleum ether/ether (20:1 → 5:1)] to give a 81:19 mixture of *anti,syn*-**8** (0.057 g, 51%) as evidenced by its 500-MHz ^{1}H-NMR spectrum in $CDCl_3$.

syn-1-(Benzylthio)-3-[(2-methoxyethoxy)methoxy]-3-phenyl-1-(tributylstannyl)propane (*syn*-**8**): A similar experiment as described above starting from methanesulfonate *anti*-**9** (0.106 g, 0.175 mmol) gave pure *syn*-**8** (0.059 g, 53%) as evidenced by its 500-MHz ^{1}H-NMR spectrum in $CDCl_3$.

[1] General references: Ref.[2].
[2] K. Brickmann, R. Brückner, *Chem. Ber.* **1993**, *126*, 1227–1239.
[3] P. G. McDougal, B. D. Condon, M. D. Laffosse, Jr., A. M. Lauro, D. VanDerveer, *Tetrahedron Lett.* **1988**, *29*, 2547–2550;

H. J. Reich, M. D. Bowe, *J. Am. Chem. Soc.* **1990**, *112*, 8994–8995; R. W. Hoffmann, T. Rühl, J. Harbach, *Liebigs Ann. Chem.* **1992**, 725–730; R. H. Ritter, T. Cohen, *J. Am. Chem. Soc.* **1986**, *106*, 3718–3725.

[4] [4a] E. J. Verner, T. Cohen, *J. Am. Chem. Soc.* **1992**, *114*, 375–377 (cf. also footnote 20 in ref.[4b]). – [4b] R. Hoffmann, R. Brückner, *Angew. Chem.* **1992**, *104*, 646–648; *Angew. Chem. Int. Ed. Engl.* **1992**, *31*, 647–649. – [4c] T. Tomooka, T. Igarashi, M. Watanabe, T. Nakai, *Tetrahedron Lett.* **1992**, *33*, 5795–5898.

[5] Method: S. R. Wilson, M. E. Guazzaroni, *J. Org. Chem.* **1989**, *54*, 3087–3091.

[6] Review of synthesis applications of this reagent: T. Sato, *Synthesis* **1990**, 259–270.

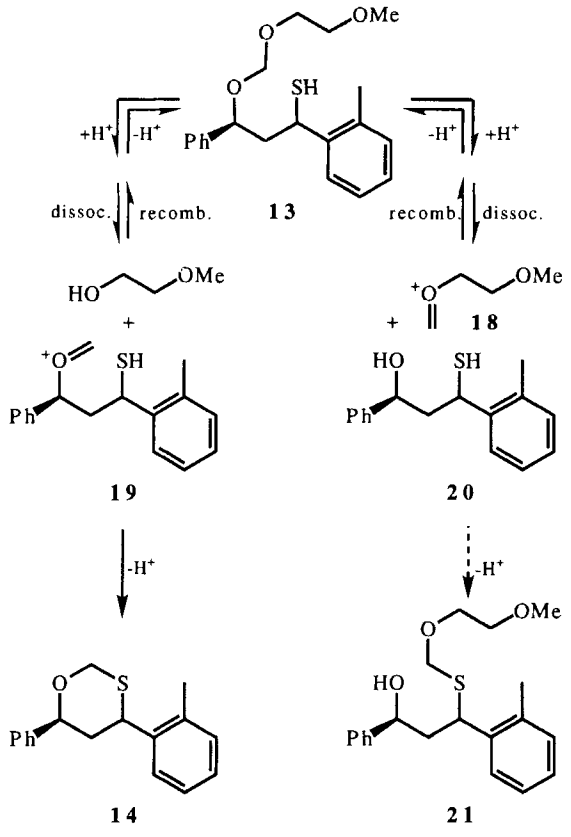
[7] Method: Y. Torisawa, M. Shibasaki, S. Ikegami, *Tetrahedron Lett.* **1981**, *22*, 2397–2400.

[8] W. C. Still, M. Kahn, A. Mitra, *J. Org. Chem.* **1978**, *43*, 2923–2925.

[9] [9a] R. W. Hoffmann, U. Weidmann, *Chem. Ber.* **1985**, *118*, 3980–3992. – [9b] R. Brückner, H. Priepke, *Chem. Ber.* **1990**, *123*, 153–168. – [9c] R. Hoffmann, R. Brückner, *Angew. Chem.* **1992**, *104*, 646–648; *Angew. Chem. Int. Ed. Engl.* **1992**, *31*, 647–649. – [9d] R. Hoffmann, R. Brückner, *Chem. Ber.* **1992**, *125*, 1471–1484. – [9e] R. Hoffmann, R. Brückner, *Chem. Ber.* **1992**, *125*, 2731–2739.

[10] Retention of configuration was *proven* in 1-propenylstannanes [D. Seyferth, L. G. Vaughan, *J. Am. Chem. Soc.* **1964**, *86*, 883–890] and in α-stannylated ethers [W. C. Still, C. Sreekumar, *J. Am. Chem. Soc.* **1980**, *102*, 1201–1202].

[11] The reisolated samples of *anti*-**13** (entry 3 of Table 1: ca. 50% yield; entry 4: ca. 48%) were essentially free from *syn*-**13** yet not pure: In the 500-MHz ^{1}H-NMR spectra the following additional signals were recorded: δ = 1.87 (d, 1H, exchangeable with D_2O), 2.31 (s, 3H), 4.36 (ddd, 1H), and 4.94 (br. dt, 1H). Speculatively, the contaminant(s) is/are considered as *O,S*-acetal(s) **21**. Compound **21** could form from MEM ether **13**, if protonation by HBF_4 led not only via the carboxonium ion **19** to oxathiane(s) **14** but delivered also carboxonium ion **18** and hydroxy thiol **20** which could revert to the *O*-protected compound **13** or give the *S*-protected isomer **21**.



[12] P. Pasanen, *Suomen Kemistilehti B* **1972**, *45*, 363–374.

[98/94]