

S0040-4020(96)00229-3

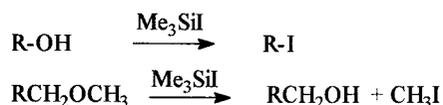
Formation of Cyclic Sulfonium Salts by Me₃SiI-Promoted Intramolecular Displacement of Hydroxide or Methoxide by Sulfide. Ring contraction Thiepane → Thiolane

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Abstract. A suitably positioned (1,2-, 1,4-, and 1,5-) intramolecular sulfide interferes with the iodotrimethylsilane-promoted iodine for hydroxyl substitution, as well as the related alcohol deprotection procedure (regioselective cleavage of methyl ethers). The outcome may be a cyclic sulfonium salt or an iodide arising from cleavage of a sulfonium intermediate. Cyclization is especially favored with secondary and tertiary alcohols or ethers, and with an aliphatic more than an aromatic sulfide function. A transannular version of the reaction results in the facile ring contraction of a 7- to a 5-membered cyclic sulfide. Copyright © 1996 Elsevier Science Ltd

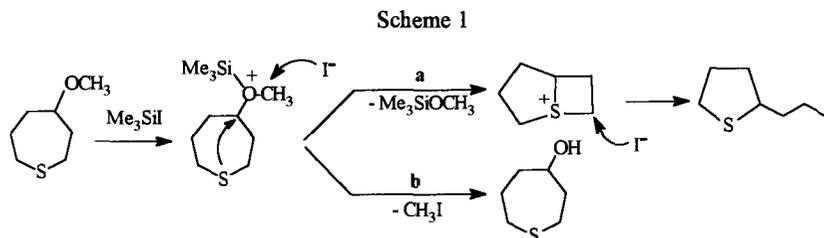
Trimethylsilyl iodide¹ is an effective reagent for the conversion of alcohols to iodides² as well as for the regioselective C-O bond cleavage, widely used in the latter capacity for the deprotection of hydroxyl groups protected as methyl ethers.^{3,4}



Although this deprotection procedure is reported to be compatible with a variety of functional groups, including multiple carbon-carbon bonds, ketones, amines, aromatic halides,^{3,4} certain limitations are apparently encountered with substrates carrying a nucleophilic functionality "soft" enough to maintain nucleophilic reactivity in the presence of trimethylsilyl iodide (a "hard" electrophile). This we have found to be the case of alcohols and ethers which carry a sulfide sulfur 2, 4 and 5 carbons away. Under such circumstances the expected substitution or ether cleavage may be accompanied, or be completely superseded, by an intramolecular displacement of the oxygen functionality with attending formation of a cyclic sulfonium salt or of products arising therefrom. Actually this turns out to be an effective one-step procedure for the synthesis of 5- and 6-membered cyclic sulfur compounds from δ-, or ε- hydroxy (-alkoxy) sulfides.

RESULTS AND DISCUSSION

We first encountered an example of this type of interaction while attempting to recover 4-hydroxythiepane from the corresponding methyl ether. Working under the usual conditions (Me₃SiI/NaI/MeCN/reflux)^{3,4} a ring contracted product was obtained, 2-(2-iodoethyl)-thiolane, instead of the expected alcohol (Table 2, compound 12). If, consistent with the accepted mechanism for Me₃SiI-promoted ether cleavage, the reaction is assumed to proceed through an oxonium intermediate⁵ (Scheme 1), this result



can be accounted for in terms of competition between nucleophilic displacement of methyl trimethylsilyl ether by transannular sulfide (Scheme 1, path a), and intermolecular demethylation by iodide (path b). Path a leads to a 1-thioniabicyclo[3.2.0]heptane intermediate which will give the ring contracted product by iodide attack at the α position of the 4-membered ring moiety. It thus appears that, in the presence of a "soft" nucleophile such as sulfide, intramolecular demethoxylation may successfully compete with demethylation.

To establish the scope of this competition, its possible applications to the synthesis of cyclic sulfonium salts and sulfides, and the cautions to be exercised while using this reagent for alcohol deprotection, trimethylsilyl iodide (actually $\text{Me}_3\text{SiCl} + \text{NaI}$) has been reacted with a number of α,ω hydroxy- and methoxy-sulfides having a variety of structural features, such as the number of carbons separating the sulfur and the oxygen functions (i.e. the size of the ring potentially formed), the degree of substitution at the oxygen-carrying center, and the nature of the sulfide function. The results, collected in Tables 1 (alcohols) and 2 (methyl ethers), allow a number of observations.

1. The relative position of the sulfide and oxygen functions is the all important factor. Thus (acyclic) 1,2-, 1,3-, and 1,6- *thiophenoxy primary* alcohols (Table 1, cmpds **1_{d2}**, **2_{d2}**, and **5**) which would give rise, respectively, to 3-, 4-, and 7-membered S-phenyl cyclic sulfonium salts, undergo iodide for hydroxy substitution exclusively, while 1,4- and 1,5-hydroxy sulfides (entry **3**, **4**) undergo, along with substitution, substantial cyclization to a 5- and 6-membered ring, respectively. The sulfonium salt product appears to arise directly from displacement of the OH group (coordinated with the silicon reagent) rather than from displacement of an iodide intermediate. Indeed no cyclic sulfonium salt was proven to be formed upon heating the 1,4- or 1,5- thiophenoxy iodides for 5 h under the conditions of the Me_3SiI reaction. Although for the 1,2-hydroxy-sulfide (**1_{d2}**) no cyclic product is formed, complete deuterium scrambling is observed consistent with formation of a thiiranium intermediate which is subsequently cleaved by iodide at one or the other α position. On the other hand, for the 1,3-hydroxy-sulfide (**2_{d2}**) no deuterium scrambling was observed. These observations are consistent with the neighboring group effect of sulfide-sulfur in solvolysis, which is known to depend on the size of the potential ring to be formed in the order: $3 > 5 \sim 6$.^{6,7}

2. Aliphatic sulfur appears to be considerably more effective at promoting cyclization than the aromatic one in agreement with the greater nucleophilicity of the former: unlike the aromatic sulfide counterpart, **3**, the aliphatic 1,4 hydroxy sulfide **7** gives raise to the cyclic product exclusively. Moreover, even for the 1,6-compound **10** cyclization appreciably competes with iodide substitution.

3. The cyclization path becomes more favorable as the degree of substitution at the reaction center increases (Table 1, cmpds **7-9**). For the secondary and tertiary alcohols cyclization occurs in few minutes, such

that it becomes the exclusive pathway. The dependence on the degree of substitution was confirmed by a competition experiment where an equimolar mixture of **8** and **9**, treated with a 50% deficit of Me_3SiI , yielded a

Table 1. Reaction of Me_3SiI (1.1 eq) with ω -Phenylthio- or -Alkylthio Alcohols

| # | Substrate | Time, min | % | Products |
|-----------------|-----------|-----------|----|--|
| 1 _{d2} | | 300 | 85 | completely deuterium scrambled iodide 15 |
| 2 _{d2} | | 300 | 88 | unscrambled iodide 16 |
| 3 | | 300 | 93 | iodide 17 + 1-phenylthiolanium iodide 18 (ca. 3:7) |
| 4 | | 300 | 92 | iodide 19 + 1-phenylthianium iodide 20 (ca. 1:3) |
| 5 | | 300 | 93 | iodide 21 |
| 6 | | 15 | 90 | <i>trans</i> - and <i>cis</i> -2-methyl-1-phenylthiolanium iodides 22 (ca. 4:1) |
| 7 | | 300 | 90 | 1- <i>n</i> -butylthiolanium iodide 23 |
| 8 | | 15 | 90 | <i>trans</i> - and <i>cis</i> -1- <i>n</i> -butyl-2-methylthiolanium iodides 24 (ca. 4:1) |
| 9 | | 15 | 90 | 1- <i>n</i> -butyl-2,2-dimethylthiolanium iodide 25 |
| 10 | | 60 | 80 | start. mat, ca. 30%; iodide 26 , ca. 55%; 1- <i>n</i> -butylthiepanium iodide 27 , ca. 15% |
| 11 | | 60 | 80 | 1-(2-phenylethyl)thiolanium iodide 28 |

product consisting almost exclusively (ca. 20 to 1) of the sulfonium salt arising from the tertiary alcohol. That the cyclization path becomes more favorable as the reaction center becomes more substituted, the greater steric encumbrance notwithstanding, suggests the transition state has considerable carbocation character. However, no inference is warranted at this stage on whether a carbocation may actually be involved.⁸

4. As to the feasibility of deprotecting alcohols protected as methyl ethers when intramolecular sulfide is present, the results in Table 2 indicate that with a *thiophenoxide* group at positions δ (**3a**) and, presumably, γ or ϵ , deprotection can be carried out with primary, but not with secondary or (*a fortiori*) tertiary methyl ethers (Table 2, **6a**), further evidence of how cyclization is favored by branching at the reaction center. However, with

Table 2. Reactions of Me₃SiI (1.1 eq) with ω-Phenylthio- or -Alkylthio alkyl Methyl Ethers

| # | Substrate | Time, min | % | Products |
|-----|-----------|-----------|----|---|
| 3a | | 120 | 80 | start. mat. + iodide 17 (ca 1:1) |
| 6a | | 60 | 90 | <i>trans</i> - and <i>cis</i> -2-methyl-1-phenylthiolanium iodide 22 (ca 4:1) |
| 7a | | 120 | 82 | start. mat., ca. 25%, alcohol, 7 ca. 10%, 1- <i>n</i> -butylthiolanium iodide 23, ca. 65% |
| 8a | | 15 | 90 | <i>trans</i> - and <i>cis</i> -1- <i>n</i> -butyl-2-methylthiolanium iodide 24 (95:5) |
| 10a | | 60 | 80 | start. mat., ca. 25%; alcohol 10, ca. 60%; 1- <i>n</i> -butylthiopianium iodide 27, ca. 15% |
| 12 | | 15 | 95 | 2-(2-iodoethyl)thiolane 29 |
| 13 | | 15 | 80 | <i>cis</i> -7- <i>n</i> -butyl-7-thioniabicyclo[4.3.0]nonane iodide 30 (ca. 7:1 diastereomeric mixture) |
| 14 | | 180 | 80 | <i>trans</i> -7- <i>n</i> -butyl-7-thioniabicyclo[4.3.0]nonane iodide 31 |

an aliphatic sulfide deprotection is not feasible even with a primary methyl ether, for which cyclization is the highly predominant path (entries 7a, 10a, 13, 14).

5. The intramolecular cyclization may be subject to geometrical constraints other than ring size. A pertinent case is that of entries 13 and 14: *cis*-1-(methoxymethyl)-2-(thiobutoxymethyl)cyclohexane cyclizes considerably more readily than the *trans* isomer even though the *trans* thiahyrindane product is thermodynamically more stable.¹⁰ This can be explained on the basis of the transition state for intramolecular S_N2 reaction requiring the sulfur atom, the oxonium leaving group, and the carbon center to be approximately collinear, a conformation which models suggest to be considerably more strained for the *trans* than for the *cis* isomer.

Two main conclusions can be drawn from our results: 1) Alcohols protected as methyl ethers and carrying a sulfide function at position 2, 4, or 5 cannot in general be deprotected by the Me₃SiI method, but give cyclic sulfonium salts either as final products or as intermediates. However, methyl ethers of primary (but not of secondary or tertiary) alcohols may be deprotected in the presence of intramolecular *aromatic sulfide*. 2) Me₃SiI may be a practical reagent for the synthesis of cyclic 5- and 6-membered sulfonium salts directly from 1,4- and 1,5-thioalkoxy alcohols and ethers. The procedure can be of particular interest for the preparation of the S-aryl salts, which are otherwise difficult to prepare. It can be used also for the preparation of cyclic sulfides. In this latter capacity, compounds such as 11, where the sulfur atom carries a phenylethyl

group, may be especially useful since the sulfonium salt will give the cyclic sulfide simply by base catalyzed elimination of styrene.¹¹

EXPERIMENTAL

General. All moisture sensitive reactions were performed in flame-dried glassware equipped with rubber septa under a positive pressure of dry nitrogen. Organic extracts were dried over CaSO₄. Thin layer chromatography was performed on Merck Kieselgel 60 F₂₅₄ the spots being developed with an aqueous solution of (NH₄)₆Mo₇O₂₄ (2.5%), (NH₄)₄Ce(SO₄)₄ (1%) in 10% H₂SO₄. Preparative liquid chromatography was performed on Merck Kieselgel 60 (0.040-0.063 mm). ¹H and ¹³C NMR spectra were recorded on a Varian Gemini 200 at 200 and 50.3 MHz respectively. Chemical shifts, unless otherwise specified, were measured in δ, and referenced to CDCl₃ (7.25 ppm for ¹H NMR and 77.20 ppm for ¹³C NMR). Signal multiplicities were established by DEPT experiments. Melting points are uncorrected. Solvents were reagent grade. Solvents and reagents were obtained dry as follows: tetrahydrofuran (THF) was distilled from benzophenone ketyl, CH₃CN and CH₂Cl₂ were refluxed over, and distilled from CaH₂ then stored over molecular sieves (3Å), pyridine was distilled from KOH, CH₃OH from Mg. NaI was heated at 100°C and 0.1 mm Hg for 48 h.

Preparation of 1,n thioalkoxy alcohols and their methyl ethers. The hydroxy sulfides employed in this work have been prepared from the pertinent thiols and 1,n choro alcohols (for details see the preparation of phenyl 4-hydroxybutyl sulfide, **3**) according to a published procedure.¹² A number of them (**2-5**) had already been reported.¹² The preparations of the few which required a different procedure are specified below. The methyl ethers were obtained from the alcohols as described below for phenyl 4-methoxybutyl sulfide (**3a**).

Reactions of alcohols or ethers with Me₃SiCl/NaI. Sodium iodide (1.1 mmol) was added to 10 mL of a 0.1 M acetonitrile solution of the alcohol or ether substrate, followed by 1.1 mmol of freshly distilled Me₃SiCl added dropwise, the mixture being refluxed for the time indicated in the Tables. After cooling to rt, few drops of aq 10% NH₄Cl were added, followed by CH₂Cl₂ extraction. The organic layer was sequentially washed with aq 20% Na₂S₂O₃ and brine, dried, and evaporated. The nature, composition and product yields were determined by ¹H and ¹³C NMR spectroscopy as reported in the sequel.

Phenyl 2,2-dideutero-2-hydroxyethyl sulfide, 1_{d2}. Was obtained by LiAlD₄ (0.20 g, 4.8 mmol) reduction of commercial phenyl carboxymethyl sulfide (1.00 g, 5.9 mmol, in THF, 25 mL) for 2h at reflux. After cooling, excess hydride was spent with 10% aq NH₄Cl added dropwise and the solution filtered. The solid was washed with CH₂Cl₂ and the combined organic solution was concentrated to a small volume and flash chromatographed (SiO₂, ether:light petroleum ether 1:1) to give the title compound as an oil (0.84 g, 91%). ¹H NMR: 7.39-7.11 (m, 5H), 3.51 (br s, 1H), 3.05 (s, 2H); ¹³C NMR: 135.45 (s), 130.18, 129.23, 126.71 (d's), 36.72 (t).

Phenyl 1,1-dideutero-3-hydroxypropyl sulfide, 2_{d2}. Was obtained by LiAlD₄¹³ (0.04 g, 0.09 mmol) reduction of the corresponding sulfoxide (see below) (0.45 g, 2.4 mmol, in THF, 20 mL). After 4 hours at room temperature, 10 % aq NH₄Cl solution was added dropwise to destroy the unreacted hydride. The organic layer, obtained by filtration of solid, was concentrated to give the sulfide as an oil (0.35 g, 85%). ¹H NMR: 7.40-7.10 (m, 5 H), 3.77 (t, 2 H), 3.15 (br s, 1 H), 1.82 (t, 2 H); ¹³C NMR: 136.26 (s), 128.94, 128.84, 125.82 (d's), 60.87, 31.43 (t's).

Phenyl 1,1-dideutero-3-hydroxypropyl sulfoxide was obtained from the corresponding protio-compound, by H/D exchange with 2M NaOD in D₂O for 48 h at reflux. The mixture was repeatedly extracted with CH₂Cl₂ and the organic extract was washed with brine, dried, and evaporated (0.46 g, 98%). ¹H NMR: 7.50-7.25 (m, 5 H), 4.20 (br s, 1 H), 3.50 (m, 2 H), 1.77 (m, 2 H); ¹³C NMR: 142.57 (s), 130.88, 129.03, 123.84 (d's), 60.03, 25.01 (t's).

Phenyl 3-hydroxypropyl sulfoxide was obtained by NaIO₄ oxidation (1.05 g, 4.9 mmol in 9 mL H₂O) of the corresponding sulfide (2)¹² (0.77 g, 4.6 mmol, in 2 mL MeOH). The mixture was stirred for 5 h at 0 °C and extracted with CH₂Cl₂. The organic layer was washed with brine, dried and chromatographed (SiO₂, ether:methanol 9:1) to give the sulfoxide as an oil, 0.69 g, 71%. ¹H NMR: 7.45 (m, 2 H), 7.35 (m, 3 H), 4.18 (s, 1 H), 3.52 (m, 2 H), 2.80 (m, 2 H), 1.75 (m, 2 H); ¹³C NMR: 142.57 (s), 130.88, 129.04, 123.83 (d's), 60.18, 53.73, 25.23 (t's).

Phenyl 4-hydroxybutyl sulfide, 3.¹² Commercial 4-chlorobutanol (2.17 g, 20.0 mmol) was added dropwise to a solution of PhSNa previously prepared from thiophenol (2.20 g, 20 mmol) and Na (0.46 g, 20 mmol) in 10 mL of CH₃OH. After 2 h at reflux, 2 mL of H₂O were added and the solvent evaporated. The residue, extracted with CH₂Cl₂ dried and evaporated, gave 3.17 g, 87 % of product as an oil. ¹H NMR: 7.22 (m, 5 H), 3.55 (t, 2 H), 3.00 (br s, 1 H), 2.88 (t, 2 H), 1.67 (m, 4 H); ¹³C NMR: 136.74 (s), 128.98 (2 signals), 125.88 (d's), 61.85, 33.13, 31.44, 25.26 (t's).

Phenyl 4-methoxybutyl sulfide, 3a, was obtained by adding 3 (0.73 g, 4.0 mmol) to a suspension of NaH (0.10 g, 4.0 mmol) in THF (5 mL) and, after stirring for 1 h at rt, MeI (0.85 g, 6.0 mmol). After 12 h at rt water was added (2 mL) and the mixture extracted with light petroleum ether. Evaporation of the solvent gave the title compound (0.67 g, 85%) as an oil. ¹H NMR: 7.25 (m, 5 H), 3.37 (t, 2 H), 3.10 (s, 3 H), 2.92 (t, 2 H), 1.70 (m, 4 H); ¹³C NMR: 137.134 (s), 129.30, 129.11, 125.99 (d's), 72.27 (t), 58.57 (q), 33.45, 28.68, 25.91 (t's).

Phenyl 4-hydroxypentyl sulfide, 6. The pertinent iodo-alcohol, obtained as *t*-butyldimethylsilyl ether by *t*-BuMe₂SiI cleavage of 2-methyltetrahydrofuran,¹⁴ was reacted directly with sodium thiophenoxide, and desilylated by reaction with tetrabutylammonium fluoride to give the title compound (81%). ¹H NMR: 7.30-7.05 (m, 5 H), 3.72 (m, 1 H), 2.85 (t, 2 H), 2.67 (br s, 1 H), 1.80-1.40 (m, 4 H), 1.10 (d, 3 H); ¹³C NMR: 136.93 (s), 129.14, 129.04, 125.93, 67.41 (d's), 38.04, 33.49, 29.57 (t's), 23.35 (q).

Phenyl 4-methoxypentyl sulfide, 6a, (88 %). ¹H NMR: 7.32-7.07 (m, 5 H), 3.17 (m, 1 H), 3.15 (s, 3 H), 2.88 (t, 2 H), 1.77-1.48 (m, 4 H), 1.09 (d, 3 H); ¹³C NMR: 137.36 (s), 129.34, 129.21, 126.06, 76.46 (d's), 56.08 (q), 35.51, 33.82, 25.21 (t's), 19.07 (q).

***n*-Butyl 4-hydroxybutyl sulfide, 7.** From *n*-BuSNa and 4-chlorobutanol (92 %). ¹H NMR: 3.48 (t, 2H), 3.18 (br s, 1 H), 2.45 (t, 4 H), 1.60-1.20 (m, 8 H), 0.78 (t, 3H). ¹³C NMR: 62.05, 31.82 (3 signals), 26.02, 22.08 (t's), 13.76 (q).

***n*-Butyl 4-methoxybutyl sulfide, 7a,** (92 %). ¹H NMR: 3.32 (t, 2 H), 3.28 (s, 3 H), 2.45 (m, 4 H), 1.55-1.25 (m, 8 H), 0.85 (t, 3 H); ¹³C NMR: 72.29 (t), 58.53 (q), 31.90, 31.74 (2 signals), 28.86, 26.36, 22.06 (t's), 13.73 (q).

***n*-Butyl 4-hydroxypentyl sulfide, 8**, (88 %). ¹H NMR: 3.70 (m, 1 H), 2.95 (br s, 1 H), 2.45 (m, 4 H), 1.65-1.25 (m, 8H), 1.10 (d, 3H), 0.80 (t, 3H); ¹³C NMR: 67.39 (d), 38.27 (s), 32.10, 31.74, 25.83, 25.67 (t's), 23.36 (q), 21.95 (t), 13.61 (q).

***n*-Butyl 4-methoxypentyl sulfide, 8a**, (87 %). ¹H NMR: 3.28 (s, 3 H), 3.25 (m, 1 H), 2.47 (2 overlapping t's, 4 H), 1.65-1.15 (m, 8 H), 1.10 (d, 3 H), 0.85 (t, 3H); ¹³C NMR: 76.42 (d), 55.95 (q), 35.58 (2 signals), 32.30, 31.87, 25.65, 22.06 (t's), 19.07, 13.71 (q's).

***n*-Butyl 4-hydroxy-4-methylpentyl sulfide, 9**. To Mg (0.06 g, 2.4 mmol) in 2 mL of THF, under nitrogen, was added *n*-butyl 3-chloropropyl sulfide (0.43 g, 2.4 mmol) (see below). The mixture was refluxed for 3 h then (CH₃)₂CO (0.17 g, 3.0 mmol) was added and reflux was continued for 3 h. The reaction mixture was quenched with 0,5 mL of NH₄Cl and filtered; the organic layer, dried and evaporated, gave the product (0.37 g, 80 %). ¹H NMR: 2.40 (m, 4H), 1.65-1.15 (m, 8H), 1.10 (m, 6H), 0.80 (t, 3H); ¹³C NMR: 70.49 (s), 43.03, 32.81, 31.86 (t's), 29.29 (q), 24.64, 21.89 (t's), 13.50 (q).

***n*-Butyl 3-chloropropyl sulfide**. To a solution of 1-bromo-4-chlorobutane (0.50 g, 3.0 mmol) in 2 mL of CH₃OH was added *n*-BuSNa previously prepared from Na (0.07 g, 3.0 mmol) in 2 mL of CH₃OH and 1-butanethiol (0.27 g, 3.0 mmol) under N₂. After 12 h at rt the solvent was evaporated, the residue treated with H₂O and extracted with CH₂Cl₂. The organic layer, dried and evaporated, yielded the title compound (0.49 g, 90 %). ¹H NMR: 3.61 (t, 2 H), 2.60 (t, 2 H), 2.47 (t, 2 H), 1.88 (m, 2 H), 1.60-1.28 (m, 4 H), 0.88 (t, 3 H); ¹³C NMR: 43.54, 32.42, 31.92, 31.81, 29.10, 22.01 (t's), 13.68 (q).

***n*-Butyl 6-hydroxyhexyl sulfide, 10**, (84%). ¹H NMR: 3.42 (t, 2 H), 3.20 (br s, 1 H), 2.35 (2 t, 4 H), 1.52-1.15 (m, 12 H), 0.77 (t, 3 H); ¹³C NMR: 62.07, 32.34, 31.86, 31.61, 29.46, 28.55, 25.28, 21.85 (t's), 13.55 (q).

***n*-Butyl 6-methoxyhexyl sulfide, 10a**, (81%). ¹H NMR: 3.33 (t, 2 H), 3.28 (s, 3 H), 2.47 (2t, 4 H), 1.55 (m, 6 H), 1.33 (m, 6 H), 0.88 (t, 3 H); ¹³C NMR: 72.86 (t), 58.62 (q), 32.14, 31.89 (2 signals), 29.72, 29.63, 28.86, 25.88, 22.13 (t's), 13.79 (q).

2-Phenylethyl 4-hydroxybutyl sulfide, 11, from 4-chlorobutanol and sodium 2-phenylethanethiolate, (85 %). ¹H NMR: 7.27 (m, 5 H), 3.62 (m, 2 H), 2.90 (m, 2 H), 2.78 (m, 2 H), 2.67 (m, 2 H), 2.05 (br s, 1 H), 1.68 (m, 4H); ¹³C NMR: 140.66 (s), 128.53, 126.39, 62.25, 36.38, 33.65, 32.12, 31.84, 25.94 (t's).

4-methoxy thiepane, 12, from 4-hydroxy thiepane¹⁵ (92 %). ¹H NMR: 3.40 (m, 1 H), 3.22 (s, 3 H), 2.58 (m, 4 H), 2.18-1.60 (m, 6 H); ¹³C NMR: 80.50 (t), 56.09 (q), 36.79, 33.02, 31.94, 27.73, 25.94 (t's).

***cis*-1-Methoxymethyl-2-*n*-thiobutoxymethylcyclohexane, 13**, was obtained by reacting (rt overnight) *cis*-1-methoxymethyl-2-tosyloxymethylcyclohexane (1.64 g, 5.0 mmol) with a MeOH solution of sodium *n*-butanethiolate, prepared from *n*-BuSH (0.45 g, 5.0 mmol) and Na (0.12 g, 5.0 mmol) in 5 mL of MeOH. The residue after solvent evaporation was extracted with H₂O and CH₂Cl₂. The residue after evaporation of the organic layer was evaporated and purified by flash chromatography (SiO₂, light petroleum ether:ether 95:5) to give 1.68 g, 90%, of the title compound. ¹H NMR: 3.18 (s, 3 H), 3.18 (m, 2 H), 2.34 (m, 4 H), 1.98-1.65 (m, 2 H), 1.60-1.10 (m, 12 H), 0.78 (t, 3 H); ¹³C NMR: 73.31 (t), 58.46 (q), 38.72, 36.56 (d's), 32.30, 31.79, 31.57, 28.01, 26.01, 23.60, 22.90, 21.76 (t's), 13.39 (q).

***cis*-1-Methoxymethyl-2-tosyloxymethylcyclohexane** was obtained by tosylation of *cis*-1-methoxymethyl-2-hydroxymethylcyclohexane and tosyl chloride under standard conditions (tosyl chloride, pyridine, 0 °C to 5 °C, 12 h) and purified by flash chromatography (SiO₂, 95:5 light petroleum ether:ether), (80 %). ¹H NMR: 7.70 (d, 2 H), 7.26 (d, 2 H), 3.91 (m, 2 H), 3.12 (s, 3 H), 3.12 (m, 2 H), 2.37 (s, 3 H), 2.05-1.78 (m, 2 H), 1.50-1.10 (m, 8 H); ¹³C NMR: 144.86, 133.31 (s's), 129.95, 127.99, 73.26, 71.42 (d's), 58.54 (q), 36.97, 36.82, 26.56, 25.58, 23.20, 22.99 (t's), 21.40 (q).

***cis*-1-Methoxymethyl-2-hydroxymethylcyclohexane**. Commercial *cis*-1,2-cyclohexanedimethanol (2.88 g, 20.0 mmol) dissolved in THF (10 mL) was added dropwise to a suspension of NaH (0.53 g, 22.0 mmol) in 10 mL of THF at 0°C. After warming to rt MeI (3.55 g, 25.0 mmol) was added quickly. After 2 h, 2 mL of H₂O were added and the solvent evaporated. The residue consisted of the mono methyl and the dimethyl ethers in a *ca* 5:1 ratio, which were separated by flash chromatography (SiO₂, light petroleum ether:ether 9:1). The second eluted material was the title product (2.20 g, 70%). ¹H NMR: 3.42 (br s, 1 H), 3.24 (m, 4 H), 3.05 (s, 3 H), 3.05 (m, 1 H), 1.78 (m, 1 H), 1.57 (m, 1 H), 1.40-1.00 (m, 8 H); ¹³C NMR: 73.62, 63.38, (t's), 58.15 (q), 40.08, 36.24 (d's), 27.48, 25.48, 23.83, 22.97 (t's).

***trans*-1-Methoxymethyl-2-*n*-thiobutoxymethylcyclohexane, 14**, (92 %). Was prepared as described above for the *cis* isomer starting from *trans*-1,2-cyclohexanedimethanol *via* the mono methyl ether and monomethyl ether monotosylate. ¹H NMR: 3.28 (s, 3 H), 3.30 (m, 2H), 2.78-2.25 (m, 4 H), 1.98-1.00 (m, 14 H), 0.88 (t, 3 H); ¹³C NMR: 76.32 (t), 58.99 (q), 41.89, 39.84 (d's), 37.22, 32.94, 32.03, 31.89, 30.24, 26.08 (2 signals), 22.16 (t's), 13.82 (q).

***trans*-1-Methoxymethyl-2-tosyloxymethylcyclohexane**, (83 %). ¹H NMR: 7.70 (d, 2 H), 7.28 (d, 2 H), 4.05, 3.85 (m, 2 H), 3.28-3.00 (m, 2 H), 3.12 (s, 3 H), 2.38 (s, 3 H), 1.70-0.96 (m, 10 H); ¹³C NMR: 144.92, 138.32 (s's), 129.91, 128.03, 75.90, 73.44 (d's), 58.52 (q), 39.57, 38.81 (d's), 29.63, 29.18, 25.52, 25.32 (t's), 21.27 (q).

***trans*-1-Hydroxymethyl-2-methoxymethylcyclohexane**, (70 %). ¹H NMR: 3.65-3.20 (m, 5 H), 3.30 (s, 3H), 1.78-1.55 (m, 2 H), 1.40-1.15 (m, 8 H); ¹³C NMR: 77.76, 66.46 (t's), 58.43 (q), 44.33, 40.34 (d's), 29.77, 29.61, 25.77 (t's).

1,1-Dideutero-2-iodoethyl phenyl sulfide and 2,2-Dideutero-2-iodoethyl phenyl sulfide, 15. The 1:1 composition of crude reaction mixture from **1_{d2}** was established by ¹H NMR and confirmed by integration of the ¹³C NMR spectrum. ¹H NMR: 7.42-7.15 (m, 10 H), 3.30 (br s, 2 H), 3.25 (br s, 2 H); ¹³C NMR: 134.39 (s), 130.91, 129.49, 126.88 (d's), 37.16, 2.14 (t's).

1,1-Dideutero-3-iodopropyl phenyl sulfide, 16. ¹H NMR: 7.35-7.10 (m, 5 H), 3.20 (t, 2 H), 1.63 (t broad, 2H); ¹³C NMR: 134.16 (s), 129.90, 129.31, 126.14 (d's), 32.43, 4.73 (t's).

4-Iodobutyl phenyl sulfide, 17¹⁶. ¹H NMR: 7.35-7.10 (m, 5 H), 3.15 (t, 2 H), 2.95 (t, 2 H), 1.95 (m, 2 H), 1.75 (m, 2 H); ¹³C NMR: 136.85 (s), 129.52, 126.03, 125.95 (d's), 32.54, 32.17, 29.75, 29.59, 5.73 (t's).

1-Phenyl thiolanium iodide, 18¹⁶. ¹H NMR (acetone-*d*₆): 8.18 (m, 2 H), 7.90 (m, 3 H), 4.45 (m, 2 H), 4.15 (m, 2 H), 2.78 (m, 4 H), 2.10 (s, 3 H); ¹³C NMR (acetone-*d*₆): 137.37 (s), 134.34, 131.59, 130.70 (d's), 49.21, 29.78 (t's).

5-Iodopentyl phenyl sulfide, 19¹⁶. ¹H NMR: 7.20 (m, 5H), 3.18 (t, 2 H), 2.88 (t, 2 H), 2.00-1.60 (m, 6 H); ¹³C NMR: 131.25 (s), 129.47, 129.03, 125.97 (d's), 32.51, 28.59, 24.55, 22.94, 5.68 (t's)

1-Phenyl thianium iodide, 20¹⁶. ¹H NMR (acetone-*d*₆): 7.95 (m, 5 H), 4.30 (m, 2 H), 4.05 (m, 2 H), 3.75 (m, 6 H); ¹³C NMR (acetone-*d*₆): 131.40 (s), 129.47, 129.03, 125.97 (d's), 49.39, 29.49, 27.99 (t's).

6-Iodobexyl phenyl sulfide, 21. ¹H NMR: 7.18 (m, 5 H), 3.15 (t, 2 H), 2.80 (t, 2 H), 2.00-1.65 (m, 8 H); ¹³C NMR: 132.50 (s), 128.62, 128.31, 125.28 (d's), 33.05, 32.44 (2 signals), 29.49, 27.10, 7.02 (t's).

2-Methyl-1-phenylthiolanium iodide, 22. Major isomer ¹H NMR (acetone-*d*₆): 7.95 (m, 2 H), 7.68 (m, 3 H), 4.15 (m, 2 H), 3.90 (m, 2 H), 2.48 (m, 4 H); ¹³C NMR (acetone-*d*₆): 134.39 (s), 130.91, 129.49, 126.88, 58.84 (d's), 44.60, 28.97 (t's), 21.66 (q), 18.92 (t).

1-*n*-Butylthiolanium iodide, 23.¹⁶ ¹H NMR (acetone-*d*₆): 3.90-3.60 (m, 6 H), 2.50 (m, 4 H), 1.78 (m, 2H), 1.50 (m, 2 H), 0.90 (t, 3 H); ¹³C NMR (acetone-*d*₆): 43.95, 41.88, 28.87, 27.07, 21.17 (t's), 13.37 (q).

1-*n*-Butyl-2-methylthiolanium iodide, 24. Major isomer ¹H NMR (acetone-*d*₆): 4.42 (m, 1 H), 4.00-3.63 (m, 4 H), 2.80-2.35 (m, 4 H), 1.90-1.45 (m, 2 H), 1.65 (d, 3 H), 1.60-1.45 (m, 2 H), 0.92 (t, 3 H). ¹³C NMR (acetone-*d*₆): 58.84 (d), 44.60, 42.79, 37.73, 28.97, 27.56 (t's), 21.66 (q), 18.92 (t), 13.74 (q).

1-*n*-Butyl-2,2-dimethylthiolanium iodide, 25. ¹H NMR (acetone-*d*₆): 4.20-3.45 (m, 4 H), 2.68-2.30 (m, 4 H), 1.75-1.50 (m, 4H), 1.88 (s, 3 H), 1.78 (s, 3 H), 0.70 (t, 3 H); ¹³C NMR (acetone-*d*₆): 71.57 (s), 43.54 (2 signals), 39.45, 27.89, 27.77 (t's), 24.22 (2 signals, q), 22.18 (t), 13.76 (q).

***n*-Butyl 6-iodohexyl sulfide, 26**.¹⁶ ¹H NMR: 3.15 (t, 2 H), 2.45 (2t, 4 H), 1.78 (m, 2 H), 1.60-1.28 (m, 10 H), 0.87 (t, 3H); ¹³C NMR: 33.38, 32.00, 31.84 (2 signals), 30.12, 29.45, 27.78, 22.06 (t's), 13.77 (q), 7.14 (t).

1-*n*-Butylthiepanium iodide, 27.¹⁶ ¹H NMR (acetone-*d*₆): 4.05-3.65 (m, 6 H), 2.30-1.45 (m, 12 H), 0.97 (t, 3 H); ¹³C NMR (acetone-*d*₆): 42.70, 42.34, 27.67, 27.27, 26.08, 22.74, (t's), 14.38 (q).

1-(2-Phenylethyl)thiolanium iodide, 28, was obtained as a white solid, mp 67-8°C. ¹H NMR (acetone-*d*₆): 7.40 (m, 5 H), 3.65-3.40 (m, 6 H), 3.15 (t, 2 H), 2.47-2.25 (m, 4 H); ¹³C NMR (acetone-*d*₆): 136.87 (s), 128.67, 127.14, 43.43, 42.96, 30.57, 28.35 (d's). The sulfonium salt, treated with *t*-BuOK/*t*-BuOH in THF at 80°C for 3 h, gave thiolane (75 % by glc, 50% isolated). ¹H NMR: 2.75 (m, 4 H), 1.85 (m, 4 H); ¹³C NMR: 31.72, 31.03 (t's)

2-(2-Iodoethyl)thiolane, 29. ¹H NMR: 3.38 (m, 1 H), 3.13 (m, 2 H), 2.80 (t, 2 H), 2.20-1.80 (m, 5 H), 1.55 (m, 1 H); ¹³C NMR: 49.48 (d), 41.28, 36.65, 32.14, 30.17, 4.41 (t's)

***cis*-7-*n*-Butyl-7-thioniabicyclo[4.3.0]nonane iodide, 30**. Major isomer ¹³C NMR: 46.42, 43.76 (t's), 41.56 (d), 27.51, 25.85, 21.98, 21.45 (t's), 13.58 (q). The sulfonium salts, treated with *t*-BuOK/*t*-BuOH at 80°C for 3 hours, gave the *cis*-7-thiabicyclo[4.3.0]nonane. ¹H NMR: 2.87 (dd, 2 H), 2.68 (dd, 2 H), 2.28 (m, 2 H), 1.65-1.25 (m, 8 H); ¹³C NMR: 43.03 (d), 35.04, 26.41, 23.06 (t's).

***trans*-7-*n*-Butyl-7-thioniabicyclo[4.3.0]nonane iodide, 31**. ¹H NMR: 4.02 (m, 1 H), 3.57 (m, 2 H), 3.35-3.03 (m, 2 H), 2.10-1.10 (m, 15 H), 0.88 (t, 3 H); ¹³C NMR: 48.68, 47.55(t's), 46.83, 44.76 (d's), 43.51, 29.69 (2 signals), 27.40, 24.59, 24.50, 21.24 (t's), 13.34 (q). The sulfonium salt, treated with *t*-BuOK/*t*-BuOH at

80°C for 3 h, gave the *trans*-7-thiabicyclo[4.3.0]nonane. ¹H NMR: 2.75 (dd, 2 H), 2.42 (m, 2 H), 2.00-1.65 (m, 4 H), 1.50-0.95 (m, 6 H); ¹³C NMR: 48.47 (d), 37.08, 31.63, 25.84 (t's)

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(Received in UK 30 January 1996; revised 19 February 1996; accepted 22 February 1996)