Notes

The Sulfide Group as an Aldehyde Precursor

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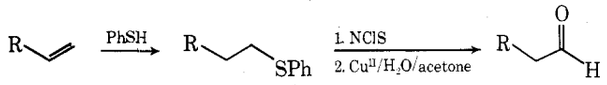
Aldehydes and their derivatives, such as dithianes, occupy a central position in organic synthesis. Accordingly, many synthetic methods have been developed to transform other functional groups into aldehydes or their derivatives but situations still arise where the conventional methods are not satisfactory. In this note we report an alternate sequence of reactions to the well-known hydroboration–oxidation method of transforming a terminal olefin into an aldehyde. Phenyl alkyl sulfides, intermediates in this process, can also be transformed into dithianes and other aldehyde derivatives.



Terminal olefins are readily transformed into phenyl alkyl sulfides by free-radical addition[1] of thiophenol (in appropriately substituted cases, the addition can also be carried out under heterolytic conditions via a Michael reaction). Thus, treatment of 1-octene with thiophenol at 80 °C in the presence of AIBN led to a 97% yield of phenyl octyl sulfide, which was oxidized[2] with 1 equiv of *N*-chlorosuccinimide by refluxing in carbon tetrachloride. After cooling, filtering, and removal of solvent, the crude chloro sulfide was hydrolyzed[3] in the presence of Cu^{II} (to oxidize the thiophenol formed),[7] the resulting octanal was reduced with $LiAlH_4$, and the product, 1-octanol, was isolated in 80% overall yield.

The crude chloro sulfides[8] were found to be useful substrates for the direct preparation of aldehyde derivatives such as dithiolanes and dithianes. Thus, treatment of chloro sulfide **1** with 1,3-propanedithiol and BF_3·Et_2O in methylene chloride

1 **2**

gave dithiane **2** in 74% yield (see Table I and the Experimental Section for examples of other transformations). The three-step transformation of terminal olefins into alkyl dithianes, important carbonyl synthons,[9] complements the other methods of their preparation and should offer advantages in cases where the aldehyde is not stable, since the free carbonyl compound need not be isolated.

Somewhat surprisingly,[10] 3-bromopropyl phenyl sulfide reacted with magnesium to give a Grignard solution which could be used for functional homologations[11] of alkyl bromides under dilithium tetrachlorocuprate catalysis.[12] Easier to separate product mixtures, however, were obtained by the reverse process. Thus, for example, the catalyzed coupling of pentylmagnesium bromide and 3-bromopropyl phenyl sulfide gave octyl phenyl sulfide in 87% isolated yield.[13]

$$PhS(CH_2)_3MgBr + Me(CH_2)_nBr \xrightarrow{Li_2CuCl_4} PhS(CH_2)_{n+3}Me$$

$$PhS(CH_2)_nBr + Me(CH_2)_mMgBr \xrightarrow{Li_2CuCl_4} PhS(CH_2)_{n+m}Me$$

Experimental Section

Free-radical additions of thiophenol to olefins were carried out under standard conditions,[1] although we found it convenient to use *tert*-butyl perbenzoate as the catalyst in photoinitiated reactions (at 254 nm, quartz tubes, room temperature). Chlorinations of sulfides were performed in CCl_4 with a slight excess of NClS at room or reflux temperatures, depending upon the sensitivity of the substrate to subsequent reactions (overoxidation or elimination). The crude chloro sulfides were unstable oils, but could be stored in the freezer for several days. The dithianes could be prepared from crude chloro sulfides without the use of BF_3·Et_2O as catalyst, but the reactions were slower and the product mixtures more complex. Representative examples of experimental details are presented below.

Addition of Thiophenol to 1-Octene. A mixture of 1.00 g of 1-octene, 150 mg of AIBN, and 3 ml of thiophenol was heated, under N_2, at 90 °C for 4 h. After cooling, the mixture was diluted with ether, washed with 1 N NaOH solution and water, and dried over Na_2SO_4. The resulting mixture, in 30 ml of ether, was treated with 50 mg of $LiAlH_4$ at room temperature for 6 h (to reduce the diphenyl disulfide formed as a by-product). Usual workup gave 1.91 g (97%) of octyl phenyl sulfide,[14] shown by GLC (DCC 550 at 230 °C) to be more than 98% pure.

Chlorination of Octyl Phenyl Sulfide. Preparation of 1-Octanol. A mixture of 444 mg of octyl phenyl sulfide and 267 mg of NClS was refluxed, under N_2, for 50 min in 10 ml of CCl_4. After cooling, the mixture was filtered and solvent removed on a rotovac. The residue was refluxed, under N_2, for 10 min with a mixture of 0.2 ml of H_2O, 10 ml of acetone, 680 mg of $CuCl_2$·$2H_2O$, and 680 mg of CuO. After cooling and filtering, the solution was diluted with 3 ml of H_2O and extracted with ether. The organic extract was washed three times with water, dried over Na_2SO_4, and reduced with excess $LiAlH_4$. The crude product was chromatographed on 15 g of silica gel, petroleum ether eluting traces of diphenyl disulfide and 1:1 ether/petroleum ether eluting 209 mg of 1-octanol (80%).

Preparation of 2-Heptyl-1,3-dithiane. The crude chloroalkyl phenyl sulfide, prepared as above from 888 mg of octyl phenyl sulfide, was stirred at room temperature, under N_2, for 10 h with 1.3 ml of 1,3-propanedithiol and 0.12 ml of BF_3·Et_2O in 5 ml of CH_2Cl_2. The

Table I. Conversion of Olefins and Sulfides to Aldehydes, Alcohols, Dithiolanes, or Dithianes[e]

Parent olefin	Sulfide (isolated yield, %)	Oxidation product (isolated yield, %)
Acrylonitrile (107-13-1)	2-Cyanoethyl phenyl sulfide (3055-87-6) (92)	2-Cyanomethyl-1,3-dithiolane (54902-80-6) (52[a])
Styrene (100-42-5)	2-Phenylethyl phenyl sulfide (13865-49-1) (100)	2-Phenylacetaldehyde (122-78-1) (60[b]) 2-Benzyl-1,3-dithiane (31593-52-9) (68[c])
1-Octene (111-66-0)	*n*-Octyl phenyl sulfide (13910-16-2) (97)	1-Octanol (111-87-5) (80[d]) 2-Heptyl-1,3-dithiane (59092-72-7) (74[c])

[a] From crude chloro sulfide, BF_3·Et_2O, and 1,2-ethanedithiol. [b] As DNP. [c] From crude chloro sulfide, BF_3·Et_2O, and 1,3-propanedithiol. [d] From $LiAlH_4$ reduction of crude aldehyde. [e] Registry no. are in parentheses.

crude product was poured into ice–water and extracted with ether. The organic layer was washed with 10% NaOH and water and dried over Na_2SO_4. Removal of solvent gave 863 mg of residue which was chromatographed on 50 g of silica gel. Elution with 1:1 petroleum ether/benzene gave 645 mg (74%) of 2-heptyl-1,3-dithiane (**2**). An analytical sample was prepared by bulb-to-bulb distillation: ir (neat) 6.82, 7.05, 7.86, 8.47, 10.98 μ; ^{1}H NMR (CCl_4) δ 3.96 (t, 1 H, J = 6.3 Hz, 2-dithiane H).

Anal. Calcd for $C_{11}H_{22}S_2$: C, 60.48; H, 10.15. Found: C, 60.37; H, 10.17.

Preparation of 2-Benzyl-1,3-dithiane. A mixture of 516 mg of 2-phenylethyl phenyl sulfide and 350 mg of NClS in 20 ml of CCl_4 was refluxed, under N_2, for 20 min. After cooling and filtering, the solvent was removed on a rotovac to give 583 mg of chloro sulfide, formed quantitatively by NMR (CCl_4) δ 3.27 (d, 2 H, J = 7.0 Hz) and 5.28 (t, 1 H, J = 7.0 Hz). The product and 1 ml of 1,3-propanedithiol in 20 ml of CH_2Cl_2, under N_2, was cooled to 0 °C and 0.5 ml of BF_3·Et_2O was added. The resulting mixture was stirred at room temperature overnight, then diluted with ether, washed with 10% NaOH solution and water, and dried over Na_2SO_4, and solvent was removed. The residue was chromatographed on silica gel with a 1:1 petroleum ether/benzene mixture to give 344 mg (68%) of the dithiane.[15]

Preparation of 2-Cyanomethyl-1,3-dithiolane. A mixture of 1.039 g of 2-cyanoethyl phenyl sulfide,[16] 0.850 g of NClS, and 25 ml of CCl_4, under N_2, was refluxed for 30 min. The usual workup gave 1.314 g of chloro sulfide, 80% pure by NMR. A mixture of 1.060 g of the crude chloro sulfide, 1.3 ml of 1,2-ethanedithiol, and 1.0 ml of BF_3·Et_2O in 5 ml of CH_2Cl_2 was stirred at room temperature for 24 h. The usual basic workup gave 1.16 g of crude product which was chromatographed on 30 g of silica gel. Elution with 1:1 petroleum ether/benzene followed by bulb-to-bulb distillation gave 405 mg (52%) of 2-cyanomethyl-1,3-dithiolane.[17]

Preparation of 3-Bromopropyl Phenyl Sulfide and 4-Bromobutyl Phenyl Sulfide. A mixture of 22 g of thiophenol, 100 g of 1,3-dibromopropane, 13 g of NaOH, 200 ml of H_2O, 200 ml of PhH, and 1.0 ml of a 40% aqueous solution of tetrabutylammonium hydroxide was stirred at room temperature, under N_2, for 25 min. The organic phase was washed with 10% NaOH solution and water and dried over Na_2SO_4. After removal of solvent, the residue was distilled at 52–54 °C (5.5 mm) to give 61.5 g of 1,3-dibromopropane and at 117–120 °C (1.5 mm) to give 34.6 g (75%) of 3-bromopropyl phenyl sulfide.[18] 4-Bromobutyl phenyl sulfide[18] (bp 112–114 °C at 0.6 mm) was prepared similarly in 76% yield.

Preparation of Octyl Phenyl Sulfide by the Coupling of Grignard Reagents and Bromoalkanes. To a Grignard solution, 1.1 equiv, prepared from 906 mg of bromopentane and 144 mg of Mg in 10 ml of THF, under N_2, and at 0 °C, was added 1 ml of a 0.1 M solution of Li_2CuCl_4[12] and 1.26 g of 3-bromopropyl phenyl sulfide, prepared as above, in 5 ml of THF. After stirring for 2 h at 0 °C and 4 h at room temperature, the mixture was poured into water and extracted with ether. The organic phase was washed with water, 5% NaOH solution, and water and dried over Na_2SO_4. Removal of solvent gave 1.23 g of residue which was carefully chromatographed on 50 g of silica gel. Elution with petroleum ether gave 902 mg (87%, based on unrecovered starting material) of octyl phenyl sulfide[14] and 186 mg of 3-bromopropyl phenyl sulfide. The same product was prepared in 70% yield by a similar coupling reaction between 4-bromobutyl phenyl sulfide and butylmagnesium bromide. Alternately, but less conveniently because of a more complex product mixture, the sulfide could be prepared by the coupling of 3-bromomagnesiopropyl phenyl sulfide and bromopentane.

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Registry No.—Thiophenol, 108-98-5; 1,3-propanedithiol, 109-80-8; 2-phenyl-1-chloroethyl phenyl sulfide, 59092-73-8; 1,3-dibromopropane, 109-64-8; 3-bromopropyl phenyl sulfide, 3238-98-0; 4-bromobutyl phenyl sulfide, 17742-54-0.

References and Notes

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(2) D. L. Tuleen and T. B. Stephens, *J. Org. Chem.*, **34**, 31 (1969); L. A. Paquette et al., *J. Am. Chem. Soc.*, **93**, 4508 (1971); and references cited therein.
(3) Chloro sulfides have been hydrolyzed to aromatic aldehydes previously,[4] but the yields were only moderate, except in sterically favorable cases, since the resulting thiophenol reacted with the chloro sulfide or aldehyde to form thioacetals as important by-products.[5,6]
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(8) The chloro sulfides were formed in near-quantitative yields (NMR).
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(10) The corresponding oxygen analogue, 3-phenoxypropyl bromide, reacts rapidly with magnesium in ether to give cyclopropane. Phenylmagnesium bromide in the presence of iron or cobalt salts reacts with 3-phenoxypropyl bromide to give a mixture of cyclopropane and propylene: L. H. Slaugh, *J. Am. Chem. Soc.*, **83**, 2734 (1961); M. S. Kharasch, M. Weiner, W. Nudenberg, A. Bhattacharya, T.-I Wang, and N. C. Yang, *ibid.*, **83**, 3232 (1961).
(11) For references to other functional homologation sequences see L. Friedman and A. Shani, *J. Am. Chem. Soc.*, **96**, 7101 (1974); M. Larcheveque and T. Cuvigny, *Tetrahedron Lett.*, 3851 (1975); J. C. Stowell, *J. Org. Chem.*, **41**, 560 (1976); and references cited therein.
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Formation of Thioacetals from Sulfoxides under Pummerer-Type Conditions

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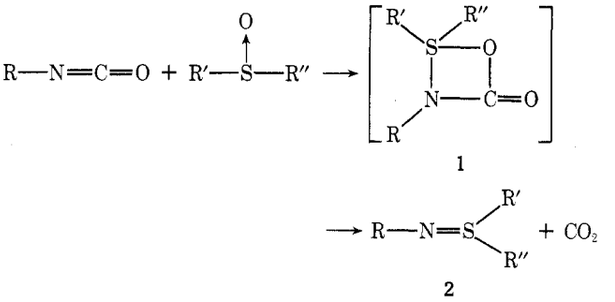
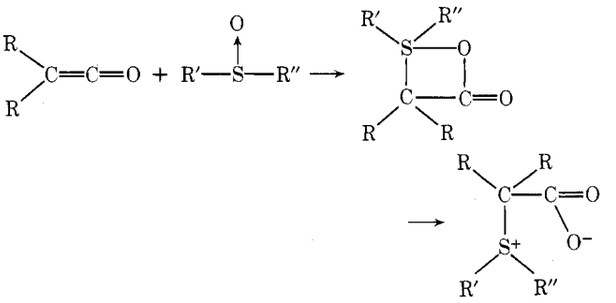
The reaction of isocyanates with sulfoxides has been reported to yield carbon dioxide and sulfilimine derivatives (**2**), presumably via a cyclic intermediate **1**.[1,2] By analogy we anticipated that reaction of sulfoxides with ketenes might lead to **3**. However, when dibenzyl sulfoxide (**4a**) was treated with



1

2



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