Notes

Arylation of Dialkyl Sulfides and of Aryl Alkyl Sulfides To Provide Sulfonium Salts

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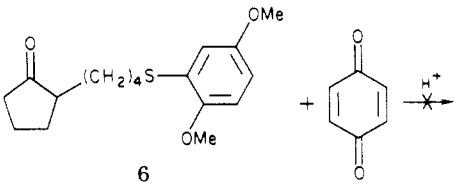
Recent application of sulfonium salts in intramolecular ylide reactions[3] and as electrophiles with β-dicarbonyls[4] focused our attention on the need for methods to convert alkyl aryl sulfides into alkyl diaryl sulfonium salts (**1** to **2**).[5] In this note, we describe a solution to this problem

$$\underset{\mathbf{1}}{\mathrm{RSAr}} \rightarrow \underset{\mathbf{2}}{\mathrm{RS^+(Ar)Ar'X^-}}$$

(Table I) and demonstrate that these salts can be used in ylide and in alkylation reactions.

The acid-catalyzed addition of thioethers to benzoquinone has been used by Bosshard[6] to prepare hydroquinone sulfonium salts. Thus treatment of the sulfide and benzoquinone with fluoboric acid in methylene chloride afforded an oily salt that could be purified by filtration through Florisil. Methylation of the dihydroxy sulfonium salt could be effected by treatment with diazomethane or by alkylation with dimethyl sulfate–potassium carbonate. These salts were purified by filtration through Florisil to give a viscous oil, which was >85% pure as judged by ^{1}H NMR spectroscopy. Entries IV and V indicate certain functional group tolerance to these reaction conditions.

Three applications of this technique failed. We were unable to convert butanethiol into *S,S*-bis(2,4-dihydroxyphenyl)-*S*-butylsulfonium fluoborate. Treatment of sulfide **6** with benzoquinone under a variety of conditions also failed to afford a sulfonium salt. In the latter case, it appeared that a redox reaction between the quinone and hydroquinone ether effectively competed with the expected alkylation process. Finally, diphenyl sulfide failed to react with benzoquinone.



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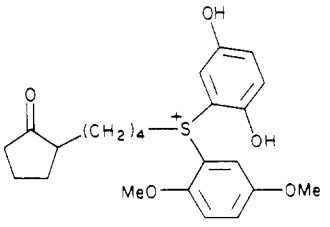
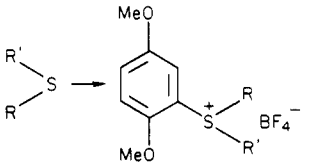


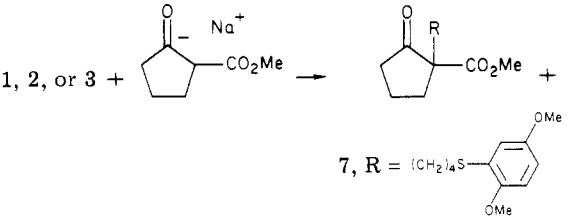
Table I. Aryl Sulfonium Salts



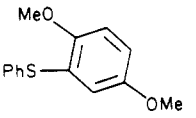
entry	sulfide	salt (% yield)[a]	methylation method[b]
I	R = R' = $-(CH_2)_4-$	1 55	A
		1 57	B
II	R = Bu; R' = Ph	2 64	A
		2 42	B
III	R = *i*-Pr; R' = Ph	3 70	A
IV	R = CH_2CO_2Me; R' = Ph	4 58	A
V	R = cyclopropyl; R' = Ph	5 61	A

[a] Isolated yield for two steps. [b] A = diazomethane; B = Me_2O_4S; Na_2CO_3 in MeOH.

A variety of experiments were completed to establish the structures of these salts and to demonstrate their utility in common reactions. Salts **1**, **2**, or **3** with the sodium enolate from methyl 2-oxocyclopentanecarboxylate gave the expected carbon alkylation products **7–9** in 83%,



8, R = Bu
9, R = *i*-Pr



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62%, and 87% yields, respectively.[4,7] The only byproduct from the reaction of **2** was the expected 2,4-dimethoxyphenyl phenyl sulfide (**10**) (90% yield). Furthermore generation of the ylide from **2** according to the method of Corey, Jautelat, and Oppolzer[8] followed by quenching with benzaldehyde gave a 41% yield of epoxide **11**. Finally, generating the ylide from **4** and quenching with methyl acrylate produced dimethyl 1,2-cyclopropanedicarboxylate (**12**) (56%).

Corey and Jautelat[9] have previously shown that treatment of phenyl alkyl sulfides with methyl iodide yields an

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(4) Garst, M. E.; McBride, B. *J. J. Org. Chem.* **1983**, *48*, 1362–1364.
(5) For other arylation procedures, see: Crivello, J. V.; Lam, J. H. W. *J. Org. Chem.* **1978**, *43*, 3055–3058 and references therein.
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(9) Corey, E. J.; Jautelat, M. *Tetrahedron Lett.* **1968**, 5787–5790.

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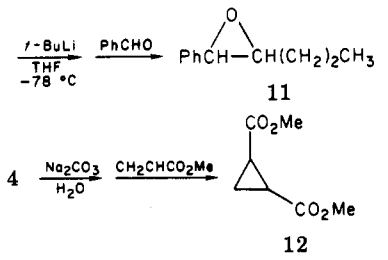

ω-alkyl iodide and thioanisole. This arylation–methylation protocol with a cyclic thioether, followed by our previously reported alkylation reaction,[2] and then the Corey–Jautelat[9] iodination makes the cyclic sulfide a useful α,ω-bis(electrophile).

This method for the conversion of sulfides into sulfonium salts should be a useful alternative to other procedures yielding sulfonium salts activated at only one carbon site.

Experimental Section

Infrared spectra were recorded on a Beckman IR 18 AX, a Perkin-Elmer Infracord, a Pye-Unicam SP100, or a Pye-Unicam SP 3-200 spectrophotometer; bands yielding structural information are reported in reciprocal centimeters (cm^{-1}), using polystyrene calibration as neat films unless indicated otherwise. Nuclear magnetic resonance spectra were recorded on a Varian EM 390 instrument at 25 °C in deuteriochloroform, and the peak positions are reported in parts per million from tetramethylsilane internal standard, using multiplet (m), quartet (q), triplet (t), doublet (d), or singlet (s) to describe the multiplicity. The low-resolution mass spectra were obtained on a Finigan 4000 GCMS DS instrument with sample introduction via direct probe or through a 6-ft GC column containing 3% Dexil 300 on Supelcoport.

GC analyses were performed on a Varian 3700 gas chromatography with an FID detector outfitted with a 6 ft × 0.25 in. glass column containing 3% Dexil 300 on 100/120 Supelcoport or 3% SE 30 on 100/120 Supelcoport.

Methylene chloride was purified by washing with sulfuric acid and brine. It was dried over magnesium sulfate and distilled.

General Procedure for Sulfide Addition to Quinone. To a stirred solution of 2.5 mmol of sulfide and 3.7 mmol of benzoquinone in 50 mL of methylene chloride was added 7.75 mmol of a 62% solution of fluoboric acid in ether. This solution was stirred for 1 h and then concentrated to about 5 mL. This solution was placed on a pad of Florisil (60–100 mesh, Fisher). The Florisil was washed with 300 mL of ether, which contained unreacted starting materials. Washing the Florisil with chloroform afforded the oily sulfonium salt, which was used directly in the next step.

Methylation, Procedure A. A solution of 5 mmol of hydroquinone sulfonium salt, 15 mmol of dimethyl sulfate, and 15 mmol of sodium carbonate in 50 mL of methanol was stirred for 15 h. The methanol was evaporated and the residue processed as above on Florisil to give the sulfonium salt.

Methylation, Procedure B. A suspension of 4 mmol of the sulfonium salt in methylene chloride was treated with an ethereal solution of diazomethane prepared from 20 mmol of *N*-methyl-*N*-nitrosourea and 25 mmol of potassium hydroxide.[10]

Salt 1: NMR 2.43 (m, 4), 3.82 (s, 3), 3.87 (s, 3), 3.60–4.00 (m, 4), 6.90–7.20 (m, 2), 7.20–7.35 ppm (m, 1).

Salt 2: NMR 1.90 (t, J = 8 Hz, 3), 2.65 (m, 4), 3.85 (s, 3), 3.90 (s, 3), 4.05 (J = 8 Hz, 2), 7.15 (m, 2), 7.65 (m, 4), 7.85 ppm (m, 2).

Salt 3: NMR 1.40–1.65 (m, 6), 3.85 (s, 3), 3.90 (s, 3), 4.9 (m, 1), 7.15 (m, 2), 7.60 (m, 2), 7.85 (m, s), 7.95 ppm (m, 2).

Salt 4: 3.65 (s, 3), 3.80 (s, 3), 3.90 (s, 3), 5.35 (s, 2), 7.15 (m, 2), 7.40–7.70 (m, 4), 7.95 ppm (m, 2).

Salt 5: IR (Nujol) 2960, 2770, 1365 (bd), 1170, 1120, 900–1000 cm^{-1}; NMR 1.20–1.75 (m, 4), 3.70 (m, 1), 3.75 (s, 3), 3.90 (s, 3), 7.20 (m, 2), 7.40–7.65 (m, 4), 7.95 (m, 2).

Methyl 1-[4-[(2,5-Dimethoxyphenyl)thio]butyl]-2-oxocyclopentane-1-carboxylate (7). From 0.93 g (2.98 mmol) of **1**, 0.63 g (4.46 mmol) of methyl 2-oxocyclopentanecarboxylate, and 0.23 g (50% oil dispersion) of sodium hydride in 50 mL of tetrahydrofuran (THF) there was obtained 0.95 g (87%) of **7**: IR 2940, 1720 (br), 1460, 1270, 1215, 1040 cm^{-1}; NMR 1.20–2.15 (m, 10), 2.15–2.50 (m, 2), 2.85 (t, J = 6 Hz, 2), 3.70 (s, 3), 3.75 (s, 3), 3.82 (s, 3), 6.70 (m, 2), 6.89 ppm (m, 1); MS (70 eV), m/z 366 (M^+).

Ketone **6** was prepared by the standard lithium iodide decarboxylation[11] in 81% yield: IR 2930, 2850, 1725, 1590, 1580, 1480, 1270, 1215, 1060, 1040 cm^{-1}; NMR 1.20–2.50 (m, 13), 2.87 (t, J = 6 Hz, 2), 3.66 (s, 3), 3.72 (s, 3), 6.70 (m, 2), 6.80 ppm (m, 1); MS (70 eV), m/z 308 (M^+).

Methyl 1-Butyl-2-oxocyclopentane-1-carboxylate (8). A solution of 0.64 g (4.5 mmol) of methyl 2-oxocyclopentanecarboxylate in 30 mL of dry THF was treated with 0.23 g (4.5 mmol) of sodium hydride (50% oil dispersion). After 30 min this solution was poured onto 1.47 g (3.77 mmol) of **2** and refluxed for 12 h. The solution was cooled and partitioned between brine and ether. Processing of the ether layer afforded 1.55 g of liquid. Evaporative distillation using a Kugelrohr oven at 70 °C and ca. 0.10 mm afforded 0.62 g of keto ester **8** as distillate (83%).[12] This sample was identical with a sample prepared by treatment of the β-keto ester with sodium hydride and *n*-butyl bromide.[14] The pot residue contained 0.83 g of **9**:[13] NMR 3.90 (s, 3), 4.05 (s, 3), 6.85 (m, 1), 7.00 (m, 1), 7.30–7.70 ppm (m, 6).

Methyl 1-(2-Propyl)-2-oxocyclopentane-1-carboxylate (9). A solution of 0.42 g (3 × 10^{-3} mol) of β-keto ester, 0.050 g (10^{-3} mol) of sodium hydride, and 0.350 g (8.97 × 10^{-4} mol) of **3** afforded 0.106 g (62%) of **9** by using the same workup. An authentic sample of **9** was prepared by treatment of the β-keto ester with sodium hydride and 2-propyl iodide.[14]

(1,2-Epoxypentyl)benzene (11). A suspension of 1.95 g (5 × 10^{-3} mol) of **2** in 100 mL of dry THF was cooled to −78 °C and treated with 3.0 mL (5 × 10^{-3} mol) of a 1.65 M solution of *tert*-butyllithium in pentane (Alfa) over 30 min.[8] The resulting solution was stirred at −78 °C for 30 min and then treated with 0.53 g (5 × 10^{-3} mol) of benzaldehyde. The solution was stirred at −78 °C for 1 h and 0 °C for 1 h and processed as for **8**. The product was filtered through Florisil to give 0.33 g (41%) of **11**.[15] This was identical with a sample of **11** prepared from benzyldimethylsulfonium chloride according to Hatch.[14,16] In both cases the trans product predominated.

Dimethyl 1,2-Cyclopropanedicarboxylate (12). According to Payne,[17] a rapidly stirred solution of 2.10 g (5 mmol) of **4** in 50 mL of chloroform was cooled to 0 °C and treated with 1.04 g (7.5 mmol) of potassium carbonate in 20 mL of water. After 30 min, the layers were separated and the chloroform layer was dried over anhydrous potassium carbonate for 2 h. The chloroform was decanted and treated with 0.43 g (5 mmol) of methyl acrylate. After 24 h at ambient temperature, the solvent was evaporated and the residue filtered though Florisil to leave 0.44 g (56%) of **12**, identical with a sample prepared from treatment with dimethyl fumerate with dimethyloxosulfonium methylide.[14,18]

Registry No. **1**, 89363-70-2; **1** (sulfide), 110-01-0; **2**, 89363-72-4; **2** (sulfide), 1126-80-3; **3**, 89363-74-6; **3** (sulfide), 3019-20-3; **4**, 89363-76-8; **4** (sulfide), 17277-58-6; **5**, 89363-78-0; **5** (sulfide), 14633-54-6; **6**, 89363-79-1; **7**, 89363-80-4; **8**, 61777-25-1; **9**, 74036-92-3; **10**, 89363-81-5; *trans*-**11**, 65094-89-5; **12**, 702-28-3; HBF_4, 16872-11-0; PhCHO, 100-52-7; benzoquinone, 106-51-4; methyl 2-oxocyclopentanecarboxylate, 10472-24-9; methyl acrylate, 96-33-3.

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(14) Samples were compared by IR and NMR spectroscopy and by GC retention times.

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