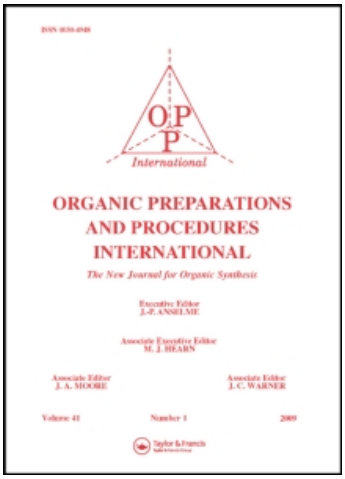


**Organic Preparations and Procedures International**
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t902189982

# REDUCTION OF SULFONYL CHLORIDES WITH SODIUM CYANOBOROHYDRIDE

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**To cite this Article** Kagabu, Shinzo(1989) 'REDUCTION OF SULFONYL CHLORIDES WITH SODIUM CYANOBOROHYDRIDE', Organic Preparations and Procedures International, 21: 3, 388 — 390
**To link to this Article: DOI:** 10.1080/00304948909356409
**URL:** http://dx.doi.org/10.1080/00304948909356409

4. X-Ray crystallographic experimental details and crystal structure parameters are available from the authors on request.

## REDUCTION OF SULFONYL CHLORIDES WITH SODIUM CYANOBOROHYDRIDE

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The increasing utilization of sodium cyanoborohydride to specific synthetic problems coupled with its selectivity and stability in acidic media,[1] prompted us to use it for the reduction

$$RSO_2Cl \xrightarrow{NaBH_3CN} RSSR$$

of sulfonyl chlorides to the corresponding disulfides. This successful reduction is to be contrasted to the reduction with lithium aluminum hydride[2] or sodium borohydride[3] which gives thiols or sulfinic acids at lower temperatures. Most reductions of sulfonyl chlorides with $NaBH_3CN$ can be performed in refluxing dioxane; in some cases, hexamethylphosphoramide (HMPA) was the solvent of choice, even though the formation of some N,N-dimethylsulfonamides resulting from the decomposition of HMPA by the sulfonyl chlorides could not be avoided.

Aromatic disulfides were obtained in satisfactory yields, while benzylsulfonyl chloride was reduced in only 45% yields. Although trialkylamine-trichlorosilane system[4] or $Mo(CO)_6$ in tetramethylurea[5] are known to reduce sulfonyl chlorides to the symmetric disulfides, the chemoselectivity, the stability of sodium cyanoborohydride as well as the simple experimental procedure, recommend the present method as an alternative synthetic tool.

### EXPERIMENTAL SECTION

Diphenyl Disulfide (1). Typical Procedure.- To a solution of 176 mg (1 mmol) of benzenesulfonyl chloride in 2 mL of dried dioxane, was added 252 mg (4 mmol) of sodium cyanoborohydride in portions over a 10 min period; the mixture was then stirred under reflux for 20 hrs and cooled to room temperature. After dilution with water and extraction with chloroform, the extract was dried over anhydrous magnesium sulfate and the chloroform was evaporated. The residue was recrystallized from ethanol to give 85 mg (78%) of diphenyl disulfide as colorless needles. Other sulfonyl chlorides (runs 2,3,4 and 9) were reduced similarly.

TABLE. Reduction of Sulfonyl Chlorides to Disulfides with $NaBH_3CN$[a]

| | Sulfonyl Chloride | solvent | time (hrs) | Yield (%) | mp.[k]/lit (°C) |
|---|---|---|---|---|---|
| 1 | Benzene- | dioxane | 15 | 78 | 60/61[b] |
| 2 | 4-Bromobenzene- | dioxane | 15 | 84 | 94/93.5[c,l] |
| 3 | 4-Chlorobenzene- | dioxane | 15 | 76 | 72/71[d,l] |
| 4 | 4-Methylbenzene- | dioxane | 22 | 68 | 48/46[e] |
| 5 | 4-Methoxybenzene- | HMPA | 6 | 60 | 44/44[f,m] |
| 6 | 3-Nitrobenzene- | dioxane | 15 | 72 | 84/82[g] |
| 7 | 2,5-Dimethylbenzene- | HMPA | 6 | 62 | 46/46[h] |
| 8 | 2-Naphthalene- | HMPA | 6 | 82 | 141/139[i] |
| 9 | Benzyl- | dioxane | 25 | 45 | 71/71[j] |

a) The sulfonyl chloride/$NaBH_3CN$ mole ratio was 1/4 in every case. The use of lower ratios gave poor conversion. The yields are isolated ones based on the sulfonyl chlorides. b) "Beilstein's Handbuch der Organischen Chemie", Bd. VI, p. 323, Springer Verlag, Berlin, 1923. c) ibid., p. 334. d) ibid., p. 330. e) ibid., p. 425. f) ibid., p. 863. g) ibid., p. 339. h) ibid., p. 498. i) ibid., p. 663. j) ibid., p. 465. k) Crystallized from ethanol unless otherwise noted. l) From ether. m) From methanol.



Di-(2-naphthyl) Disulfide (8).- To a suspension of 252 mg (4 mmol) of sodium cyanoborohydride in 3 mL of HMPA was added 226 mg (1 mmol) of 2-naphthalenesulfonyl chloride in portions over a 10 min period. The mixture was stirred at 60° for 6 hrs. The orange solution was poured onto ice-cold water. The precipitate was washed with water several times to give practically pure disulfide (110 mg). The combined filtrates were extracted with chloroform. The extract was dried over anhydrous magnesium sulfate and the chloroform was evaporated. The residue (50 mg) was chromatographed (preparative TLC; $SiO_2$) to give further amount of disulfide (20 mg; Rf 0.7). N,N-dimethyl 2-naphthalenesulfonamide, mp. 95° (ether), lit.[6] mp. 96°, was obtained from the lower zone (20 mg; Rf 0.1-0.2). Other sulfonyl chlorides (runs 5 and 7) were reduced in a similar way.

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## A CONVENIENT SYNTHESIS OF DIETHYL (MERCAPTOMETHYL)PHOSPHONATE

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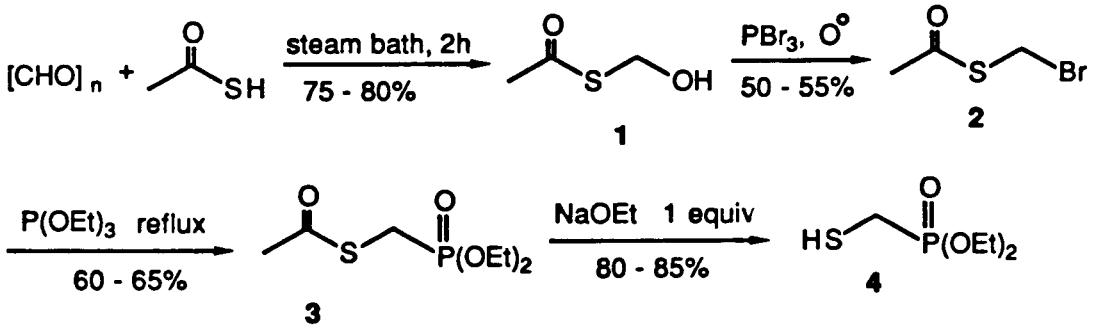
The design of α-thiomethylphosphonates as analogs of acylphosphates[1] and phosphate esters[2] has led to the development of a convenient new synthetic route to diethyl (mercaptomethyl)phosphonate (4). The synthetic scheme outlined below was developed because the previous synthesis[3] of 4 was found to be unreliable and difficult to scale up.




The previous synthesis of 4 was carried out by stepwise addition of the methylene and sulfur to the phosphorus. The design of the synthetic route above differs fundamentally, beginning with the sulfur (thiolacetic acid) and sequentially adding the methylene and the phosphorus. The desired product diethyl (mercaptomethyl)phosphonate (4) was found to be inherently unstable and underwent rapid oxidation and degradation to several products after