cm^{-1} (NH) was used to determine which fractions were to be retained and worked up further.

Dimethyl [α-(Methylthio)benzyl]bicarbamate.—A solution of benzyl methyl sulfide (3 ml) and dimethyl azodicarboxylate (0.4 ml) was irradiated with a sun lamp in a Pyrex apparatus for 8 hr. The reaction mixture was concentrated *in vacuo* to about ½ volume, and hexane (15 ml) was added to the concentrate, leading to a white crystalline precipitate. The supernatant was decanted, and the residue was washed with several portions of fresh hexane. The air-dried product weighed 444 mg (48%). The air-dried solid was dissolved in carbon tetrachloride (7 ml), and hexane was added until a precipitate formed. The suspension was redissolved by heating over a steam cone and then allowed to cool slowly to 4°, giving 237 mg of dimethyl [α-(methylthio)-benzyl]bicarbamate as a white, crystalline solid: mp 126°; nmr (DMSO-d_6) δ 2.30 (s, 3), 3.67 (s, 1), 3.80 (s, 6), 6.54 (s, 1), 7.40 (m, 5); mass spectrum *m/e* (rel intensity) 284 (<1), 239 (2.3), 238 (17.4), 237 (100), 193 (27.9), 161 (26.7), 139 (8.0), 138 (11.0), 137 (125.6), 122 (5.8), 121 (12.8), 118 (15.1), 105 (8.1), 104 (18.6), 103 (12.8), 92 (5.2), 91 (16.9), 90 (19.8), 89 (3.5), 78 (5.8), 77 (18.6), 65 (6.4), 58 (5.8), 51 (5.8), m* at 157.1 (237 → 193), 134.3 (193 → 161); ir ν_{max} (KBr) 1510, 1670, 1750, 3350, 3450 cm^{-1}.

Anal. Calcd for $C_{12}H_{16}N_2O_4S$: C, 50.69; H, 5.64; N, 9.86; S, 11.28, mol wt, 284.3. Found: C, 50.77; H, 5.98; N, 9.99; S, 11.08; mol wt, 284 (mass spectrum).

Dibenzyl [α-(Methylthio)benzyl]bicarbamate.—A solution of benzl methyl sulfide (1.5 ml) and dibenzyl azodicarboxylate (448 mg) was irradiated in a Pyrex vessel for 16 hr using a sunlamp. Petroleum ether–diethyl ether (1:1 by volume) was added to the reaction mixture and the resulting suspension was stored for 2 days at 4°. The resulting white, crystalline solid was collected on a filter, washed with fresh petroleum ether–diethyl ether solution, and air dried. The air-dried solid weighed 457 mg (69%). A portion (264 mg) was recrystallized from heptane–carbon tetrachloride (10:3 by volume) to give 208 mg of dibenzyl [α-(methylthio)benzyl]bicarbamate: mp 116–119°; nmr ($CDCl_3$) δ 2.20 (s, 3), 5.10 (s, 1), 5.20 (s, 4), 6.60 (s, 1), 7.30 (m, 15); ir ν_{max} (KBr) 1525, 1680, 1760, 3350, 3450 cm^{-1}.

Anal. Calcd for $C_{24}H_{24}N_2O_4S$: C, 66.06; H, 5.50; N, 6.42; S, 7.34; mol wt, 436.7. Found: C, 65.82; H, 5.53; N, 6.32; S, 6.82.

Using a mercury lamp and a quartz apparatus, a 60% yield was obtained.

Dimethyl (1,4-Oxathian-3-yl)bicarbamate.—A solution of 1,4-oxathiane (4 ml) and dimethyl azodicarboxylate (0.4 ml) was heated under reflux at 80° for 16 hr in the presence of 15 mg of benzoyl peroxide. A white, crystalline product (104 mg, 13%) was isolated by chromatography on silica gel. The material was recrystallized from heptane–chloroform (5:1), giving 53 mg of dimethyl (1,4-oxathian-3-yl)bicarbamate: mp 118–120°; nmr ($CDCl_3$) δ 2.70 (t, 2), 3.65 (s, 3), 3.70 (s, 3), 4.00 (m, 4), 5.20 (t, 3), 9.50 (s, 1); ir ν_{max} (KBr) 1540, 1720, 2950, 3300, 3350 cm^{-1}.

Anal. Calcd for $C_8H_{14}N_2O_5S$: C, 38.52; H, 5.64; N, 11.19; S, 12.81; mol wt, 250.3. Found: C, 37.92; H, 5.39; N, 11.04; S, 11.50.

Dimethyl [(Benzylthio)carboxymethyl]bicarbamate.—A solution of dimethyl azodicarboxylate (0.5 ml), methyl *S*-benzylthioglycollate (2.1 ml), and benzoyl peroxide (25 mg) was heated under reflux at 80° for 16 hr. The reaction was protected from atmospheric moisture by a calcium chloride drying tube. Chromatography on silica gel gave dimethyl [(benzylthio)carboxymethyl]bicarbamate (295 mg, 21%). The white solid was recrystallized from heptane–carbon tetrachloride (2:1) to give 124 mg of crystalline solid: mp 79–81°; nmr ($CDCl_3$) δ 3.65 (s, 6), 3.70 (s, 3), 3.90 (s, 2), 5.80 (s, 1), 7.30 (s, 5), and 9.50 (s, 1); ir ν_{max} (KBr) 1600, 1695, 1735, 2995, 3200, 3500 cm^{-1}; mass spectrum *m/e* (rel intensity) 344 (<1), 343 (<1), 342 (2.9), 283 (10.8), 235 (13.1), 234 (9.6), 222 (1.8), 221 (10.8), 220 (100), 195 (8.1), 175 (40), 161 (56.2), 147 (3.9), 146 (32.3), 143 (17.7), 135 (11.2), 123 (10.8), 122 (<1), 115 (38.5), 101 (7.8), 92 (24.3), 91 (111.7), 90 (6.2), 77 (6.2), 76 (16.2), 69 (3.2), 59 (32.3), 51 (5.3).

Anal. Calcd for $C_{14}H_{18}N_2O_6S$: C, 49.12; H, 5.30; N, 8.18; S, 9.36; mol wt, 342.3. Found: C, 49.01; H, 5.42; N, 8.19; S, 11.72; mol wt, 342 (mass spectrum).

Dibenzyl [(Benzylthio)carboxymethyl]bicarbamate.—A solution of methyl *S*-benzylthioglycollate (2 ml) and dibenzyl azodicarboxylate (538 mg) was heated at 80° under reflux for 80 hr. The reaction mixture was chromatographed on silica gel to give a white solid weighing 272 mg (30%). The white solid was recrystallized from carbon tetrachloride–heptane (1:1 by volume) to dibenzyl [(benzylthio)carboxymethyl]bicarbamate weighing 132 mg: mp 85–88°; nmr ($CDCl_3$) δ 3.70 (s, 3), 4.05 (s, 2), 5.10 (s, 4), 5.95 (s, 1), 7.00 (s, 1), 7.33 (s, 15); ir ν_{max} (KBr) 1520, 1680, 1750, 3350, 3450 cm^{-1}.

Anal. Calcd for $C_{26}H_{26}N_2O_6S$: C, 63.14; H, 5.30; N, 5.67; S, 6.48; mol wt, 494.6. Found: C, 63.35; H, 5.45; N, 5.86; S, 6.12.

Di-*tert*-Butyl (1,4-Oxathian-3-yl)bicarbamate.—A solution of 1,4-thioxane (5 ml) and di-*tert*-butyl azodicarboxylate (530 mg) was heated under reflux at 80° for 20 hr. Chromatography on silica gel gave a white solid weighing 440 mg (54%). A portion was recrystallized from carbon tetrachloride to give 126 mg of di-*tert*-butyl (1,4-oxathian-3-yl)bicarbamate: mp 162–163°; nmr (DMSO-d_6) δ 1.40 (s, 18), 2.15 (t, 2), 3.80 (m, 4), 5.00 (m, 1), 8.50 and 8.96 (s, 1); ir ν_{max} (KBr) 1255, 1260, 1520, 1725, 1750, 3030, 3350, 3550 cm^{-1}.

Anal. Calcd for $C_{14}H_{26}N_2O_5S$: C, 50.30; H, 7.78; N, 8.38; S, 9.58. Found: C, 49.98; H, 7.70; N, 8.61; S, 7.69.

Dibenzyl [1-(Butylthio)butyl]bicarbamate.—A solution of *n*-butyl sulfide (10 ml) and dibenzyl azodicarboxylate (800 mg) was irradiated in the quartz apparatus with a mercury lamp for 24 hr. The reaction mixture was chromatographed on silica gel, yielding 1.13 g (95%) of a white waxy solid. This material was crystallized from 18 ml of carbon tetrachloride–heptane (1:5) to give 403 mg of dibenzyl [1-(butylthio)butyl]bicarbamate: mp 68–70°; nmr ($CDCl_3$) δ 0 to 1.80 (m, 14), 2.50 (t, 2), 5.10 (s, 4), 5.50 (m, 1), 6.80 (s, 1), 7.30 (s, 10); ir ν_{max} (KBr) 1310, 1410, 1460, 1515, 1665, 1720, 1740, 3350, 3550 cm^{-1}.

Anal. Calcd for $C_{24}H_{32}N_2O_4S$: C, 64.86; H, 7.21; N, 6.31; S, 7.21. Found: C, 64.88; H, 6.96; N, 6.25; S, 6.90.

Registry No.—Id, 34792-31-9; IIa, 34804-18-7; IIb, 34804-19-8; IIc, 34804-20-1; IId, 34804-21-2; IIIa, 34804-22-3; IIIb, 34804-23-4; benzyl methyl sulfide, 766-92-7; dimethyl azodicarboxylate, 2446-84-6; dibenzyl azodicarboxylate, 2449-05-0; 1,4-oxathiane, 15980-15-1; methyl *S*-benzylthioglycollate, 17277-59-7; di-*tert*-butyl azodicarboxylate, 870-50-8; *n*-butyl sulfide, 544-40-1.

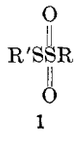
Aminothiosulfonates

LOWELL D. MARKLEY* AND JOSEPH E. DUNBAR

Ag-Organics Department, The Dow Chemical Company, Midland, Michigan 48640

Received February 29, 1972

Interest in various biologically active properties of the thiolsulfonate moiety has prompted investigations of compounds containing this group in combination with groups bearing greater or lesser degrees of electronegativity. Thiolsulfonates **1** whose R′ groups



1

consist of electron-withdrawing groups such as trichloromethyl[1,2] and trifluoromethyl[3] have been shown to exhibit biological and chemical properties different

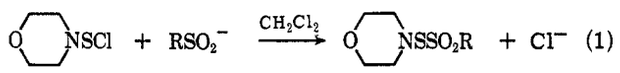
(1) J. E. Dunbar and J. H. Rogers, *Tetrahedron Lett.*, 4291 (1965); *J. Org. Chem.*, **31**, 2842 (1966).

(2) B. G. Boldyrev and S. A. Kolesnikova, *Zh. Obshch. Khim.*, **35**, 198 (1965).

(3) J. P. Weidner and S. S. Block, *J. Med. Chem.*, **10**, 1167 (1967).

from those of thiolsulfonates, having R′ groups consisting of simple alkyl and aryl groups.

This paper reports the synthesis and several reactions of a novel class of compounds, represented by three 4-morpholinethiolsulfonates (**2a–c**). Treatment of alkali metal salts of sulfinic acids with 4-morpholinesulfenyl chloride at ambient temperature in methylene chloride gave the aminothiolsulfonates in good yields (eq 1).

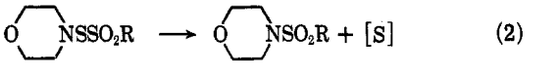


(1)

2a, R = CH_3
b, R = p-$CH_3C_6H_4$
c, R = p-$CH_3CONHC_6H_4$

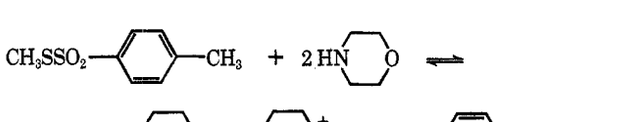
The infrared absorption by the sulfonyl groups of the aminothiolsulfonates occurs at slightly longer wavelengths (1105–1110 and 1293–1297 cm^{-1}) than do those of alkyl and aryl esters of thiosulfonic acids (1150 and 1340 cm^{-1}).[4]

Extrusion of sulfur from the aminothiolsulfonates (**2a–c**) occurred slowly at room temperature and rapidly at boiling temperatures in polar solvents such as acetone, methanol, and 2-propanol to give the corresponding sulfonmorpholides (eq 2). 4-(Methanesulfonylthio)morpholine (**2a**) converted in the solid state to methanesulfonmorpholide in less than 10 days on standing in a capped vial at room temperature, while 4-(*p*-acetamidophenylsulfonylthio)morpholine (**2c**) was stable for several months under similar conditions.



(2)

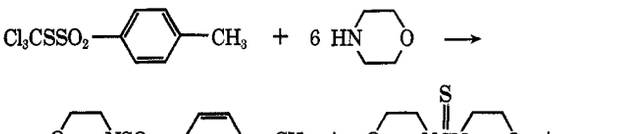
The reaction of primary and secondary amines with thiolsulfonates has been shown by one of us to give different products, depending upon the type of thiolsulfonate employed.[1] Alkyl and aryl thiolsulfonic acid esters are cleaved by the attack of the amine on the divalent sulfur atom with subsequent formation of sulfenamides, exemplified in eq 3. Thiolsulfonates



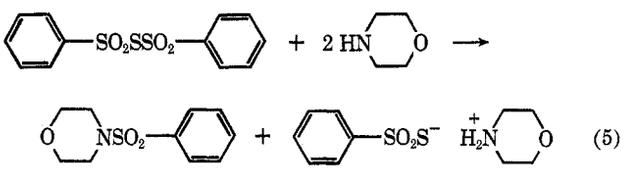
(3)

1, where the electron-withdrawing effects of R′ are similar in magnitude to those of RSO_2, react with morpholine by attack of the nucleophile on the sulfonyl moiety, exemplified in eq 4 and 5.

It was therefore of interest to us to determine the nature of a base attack upon a thiolsulfonate **1** where R′ is an electron-rich basic group, as in the aminothiolsulfonates **2a–c**. When 4-(*p*-acetamidophenylsulfonylthio)morpholine (**2c**) was treated with 2 equiv of morpholine in carbon tetrachloride at room temperature, quantitative amounts of 4-morpholinosulfide

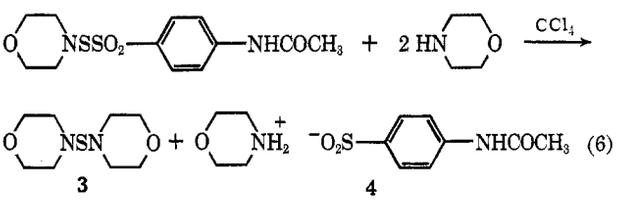


(4)



(5)

(**3**) and morpholinium *p*-acetamidobenzenesulfinate (**4**) were formed (eq 6).



(6)

We therefore conclude that when R′ of thiolsulfonate **1** is an electron-rich group such as morpholino, the site of the nucleophilic attack remains at the divalent sulfur atom.

Experimental Section[5]

4-(Methylsulfonylthio)morpholine (**2a**).—A solution of 8.2 g (0.053 mol) of 4-morpholinesulfenyl chloride[6] in 50 ml of methylene chloride was added to a stirred suspension of 6.3 g (0.053 mol) of potassium methanesulfinate in 30 ml of methylene chloride. After the mixture had been stirred for 18 hr at ambient temperature, the potassium chloride by-product was removed by filtration. The filtrate was washed with water, dried (Na_2SO_4), and concentrated *in vacuo*, leaving 5.3 g (50%) of white crystalline solid. Recrystallization from a mixture of benzene and petroleum ether (bp 60–70°) gave the pure product as colorless crystals: mp 83–83.5°; nmr ($CDCl_3$) δ 3.28 (s, 3, CH_3), 3.38–3.87 (m, 8, morpholine ring protons).

Anal. Calcd for $C_5H_{11}NO_3S_2$: C, 30.44; H, 5.62; N, 7.10; S, 32.50. Found: C, 30.50; H, 5.62; N, 7.10; S, 32.23.

4-(p-Tolylsulfonylthio)morpholine (**2b**).—Morpholinesulfenyl chloride (25 g, 0.16 mol) was treated with 35 g (0.16 mol) of sodium *p*-toluenesulfinate dihydrate by the same procedure used in the preparation of **2a** to obtain 36.5 g (84%) of product as colorless crystals. Recrystallization from 2-propanol gave the pure, colorless, crystalline product: mp 104.5–105°; nmr ($CDCl_3$) δ 2.50 (s, 3, CH_3), 3.22–3.82 (m, 8, morpholine ring protons), 7.33–8.08 (m, 4, aromatic protons).

Anal. Calcd for $C_{11}H_{15}NO_3S_2$: C, 48.33; H, 5.53; N, 5.13; S, 23.46. Found: C, 48.20; H, 5.52; N, 5.13; S, 23.57.

Repeated recrystallization of **2b** from 2-propanol resulted in the formation of *p*-toluenesulfonmorpholide, mp 148° (lit.[7] mp 147°).

4-(p-Acetamidophenylsulfonylthio)morpholine (**2c**).—A solution of 27 g (0.17 mol) of 4-morpholinesulfenyl chloride in 150 ml of methylene chloride was added to a stirred suspension of 38 g (0.17 mol) of sodium *p*-acetamidobenzenesulfinate in 150 ml of methylene chloride. The reaction mixture was stirred at room

(4) L. J. Bellamy, "The Infra-red Spectra of Complex Molecules," 2nd ed, Wiley, New York, N. Y., 1958, p 359.

(5) All melting points are uncorrected. Infrared spectral data were obtained on a Perkin-Elmer 337 grating infrared spectrophotometer as Nujol and Fluorolube mulls. All nmr spectra were obtained on a Varian A-60 spectrometer in deuteriochloroform using TMS as the internal standard. Elemental analyses were obtained from the Analytical Services Laboratory of The Dow Chemical Company.

(6) G. Weiss and G. Schulze, German Patent, 1,131,222 (1962); *Chem. Abstr.*, **57**, 13771e (1962).

(7) J. Sand, *Ber.*, **34**, 2906 (1901).

temperature for 36 hr, an additional 400 ml of methylene chloride was added, and the mixture was washed with water. Much of the product was insoluble in the organic layer and was collected on a filter (34 g). An additional 18 g of crystalline product was obtained by evaporation of the methylene chloride filtrate. The combined crude product (52 g, 95%) was dried and recrystallized from a mixture of benzene and petroleum ether to give colorless crystals: mp 133–133.5° dec; nmr ($CDCl_3$) δ 2.15 (s, 3, CH_3), 3.17–3.73 (m, 8, morpholine ring protons), 7.87 (s, 4, aromatic protons), 10.25 (m, 1, NH).

Anal. Calcd for $C_{12}H_{16}N_2O_4S_2$: C, 45.55; H, 5.10; N, 8.86; S, 20.27. Found: C, 45.61; H, 5.11; N, 8.90; S, 20.35.

Reaction of Morpholine with 4-(*p*-Acetamidophenylsulfonylthio)morpholine (2c).—Morpholine (2.75 g, 0.0316 mol) was added to a suspension of 5.00 g (0.0158 mol) of 4-(*p*-acetamidophenylsulfonylthio)morpholine in 100 ml of carbon tetrachloride, and the mixture was stirred at ambient temperature for 17 hr. The precipitated morpholinium *p*-acetamidobenzenesulfinate was collected on a filter, washed with carbon tetrachloride, and dried. The salt, obtained in quantitative yield (4.5 g), was recrystallized from 2-propanol to give colorless crystals, mp 171.5–172.5°.

Anal. Calcd for $C_{12}H_{18}N_2O_4S$: C, 50.33; H, 6.34; N, 9.79; S, 11.20. Found: C, 50.03; H, 6.28; N, 9.66; S, 11.23.

The carbon tetrachloride filtrate was concentrated *in vacuo*, leaving 3.0 g (94%) of crystalline 4-morpholinosulfide, mp 123.5–124.5°. Recrystallization from ethanol gave the pure substance, mp 124.5–125.5° (lit.[8] mp 125–126°).

Anal. Calcd for $C_8H_{16}N_2O_2S$: C, 47.03; H, 7.90; N, 13.72; S, 15.70. Found: C, 47.05; H, 7.87; N, 13.67; S, 15.72.

Registry No.—**2a**, 34764-81-3; **2b**, 34764-82-4; **2c**, 34764-83-5; **3**, 5038-11-9; **4**, 23837-27-6.

(8) E. S. Blake, *J. Amer. Chem. Soc.*, **65**, 1267 (1943).

Synthesis of 1,2-Dithiolane-3,5-diones and Thietane-2,4-diones[1a]

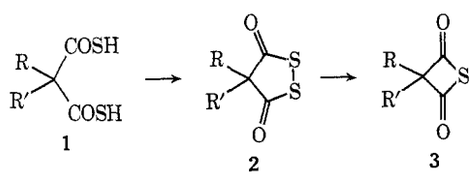
J. HERMAN SCHAUBLE* AND JACK D. WILLIAMS[1b]

Department of Chemistry, Villanova University, Villanova, Pennsylvania 19085

Received October 5, 1971

Although 1,2-dioxolane-3,5-diones (malonyl peroxides)[2] and oxetane-2,4-diones (malonic anhydrides)[3] are known, the sulfur analogs have not been reported. Herein we describe a simple sequence for obtaining dialkylated 1,2-dithiolane-3,5-diones and thietane-2,4-diones *via* the pyridinium salts of the corresponding bisthio acids (**1**) (Scheme I).

SCHEME I



1 **2** **3**

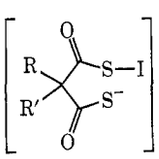
a, R = R′ = CH_3
b, R = R′ = CH_3CH_2
c, R, R′ = $(CH_2)_3$

Although bisthiomalonic acid has been reported to result by reaction of malonyl chloride with hydrogen sulfide in pyridine solution, followed by acidification of the reaction mixture,[4] we were unable to effect this preparation. Parallel attempts to prepare the bisthio acids (or the intermediate pyridinium salts) from monoalkylmalonyl chlorides also failed.[5] However, reaction of disubstituted malonyl chlorides under similar conditions afforded the bisthio acids **1a–c** as low-melting solids.

Since it is well documented that salts of monothiocarboxylic acids undergo oxidation with halogens to give diacyl disulfides,[6] it was anticipated that formation of 1,2-dithiolane-3,5-diones could be carried out analogously by oxidation of salts of the bisthiomalonic acids (**1**). Reconversion of the thio acids to their pyridinium salts,[7] followed by oxidation with iodine in anhydrous ether solution,[8] gave the cyclic disulfides **2a–c** in 55–80% yields, accompanied by small amounts (5%) of the corresponding thietane-2,4-diones **3a–c**. The thietanes were observed by gc, ir, and nmr analysis on the crude reaction mixtures and were identified by comparison with data obtained on pure samples obtained by alternate procedures (*vide infra*).

The ir spectra for the 1,2-dithiolane-3,5-diones **2a–c** exhibit strong absorptions at approximately 1720 and 1680 cm^{-1}, apparently as a result of vibrational coupling for the diacyl disulfide group. The structures for **2a–c** are further supported by elemental analysis and nmr and mass spectral data.

Oxidation of the salts of the bisthiomalonic acids with iodine presumably involves formation of intermediate sulfenyl iodides of type **4**,[9] which undergo



4

intramolecular displacement of iodide by thiocarboxylate ion to provide the expected 1,2-dithiolane-3,5-diones. The unexpected formation of thietane-2,4-diones **3a–c** appears to be the result of intramolecular displacement of the –SI group from the sulfenyl iodide intermediate. The possibility that **3a–c** might result from overoxidation of the disulfides was ruled out by subjecting **2a** to the conditions of the oxidation.

Reaction of the cyclic disulfides **2a–c** with triphenylphosphine in benzene at 60° gave the colorless, distillable thietanes **3a–c** in high yields.[10] The ir spectra of **3a–c** exhibit bands at 1850 and 1750 cm^{-1} which are attributed to vibrational coupling of the thioanhydride function.

(1) (a) Presented at the 7th Middle Atlantic Regional Meeting of the American Chemical Society, Philadelphia, Pa., Feb 1972. (b) NDEA Fellow, 1968–1971.

(2) W. Adam and R. Rucktaschel, *J. Amer. Chem. Soc.*, **93**, 557 (1971).

(3) A. C. Duckworth, *J. Org. Chem.*, **27**, 3146 (1962).

(4) S. Sunner, *Svensk Kem. Tidskr.*, **62**, 204 (1950).

(5) Considering the ease with which the acid chlorides undergo elimination in basic media [M. Rabjohn and H. M. Molotsky, *J. Org. Chem.*, **23**, 1642 (1958)], these results are not too surprising.

(6) E. E. Reid, "Organic Chemistry of Bivalent Sulfur," Vol. 4, Chemical Publishing Co., New York, N. Y., 1962, p 22.

(7) Isolation of the free thioacids was carried out in order to obtain pure pyridinium salts.

(8) It was necessary to run these reactions in a nonnucleophilic medium in order to avoid solvolysis of the disulfides.

(9) J. P. Danehy, C. P. Egan, and J. Switalski, *J. Org. Chem.*, **36**, 2530 (1971), have demonstrated the intermediacy of sulfenyl iodides during the oxidation of thiols.

(10) D. N. Harpp and J. G. Gleason, *J. Amer. Chem. Soc.*, **93**, 2437 (1971), have described the desulfurization of 1,2-dithiolanes to thietanes by treatment with tris(diethylamino)phosphine.