(16,400), 302 (16,200), 317.5 (shoulder) (14,300), and 336 (shoulder) (7200).

Anal. Calcd. for $C_{11}H_8N_4S$: C, 57.9; H, 3.5; N, 24.5; S, 14.0. Found: C, 58.3; H, 3.2; N, 24.2; S, 14.2.

B. From the Sodium Salt of 4-Amino-6-mercapto-5-benzamidopyrimidine.–4-Amino-6-mercapto-5-benzamidopyrimidine (3 g.) was dissolved in 32 ml. of 0.5 *N* sodium hydroxide and the solution was evaporated to dryness *in vacuo*. The residue was mixed with 25 g. of phosphorus pentoxide and to this mixture, cooled to 0°, 18 ml. of 85% phosphoric acid was added. The mixture was heated to 160–170° and stirred for 1.5 hr. After cooling to room temperature, the sirup was poured over crushed ice and the precipitate was collected after cooling at 4° for 18 hr. This crude material, weighing 2.6 g., was extracted with 150 ml. of 2 *N* sodium hydroxide, which upon acidification to pH 5 with glacial acetic acid deposited 0.3 g. of a yellow solid. It was not 6-mercapto-8-phenylpurine as shown by comparison of its ultraviolet and infrared spectra with those of an authentic sample. The residue left from the extraction, weighing 2 g., was recrystallized with the help of Darco from 600 ml. of 2 *N* hydrochloric acid to deposit 2 g. (61.9%) of light yellow needles, m.p. 272–273° dec.

Anal. Calcd. for $C_{11}H_8N_4S \cdot HCl$: C, 49.9; H, 3.4; Cl, 13.4; N, 21.2; S, 12.1. Found: C, 50.0; H, 3.3; Cl, 13.2; N, 21.4; S, 11.9.

Neutralization of this compound with 1 *N* sodium hydroxide gave a product which was identical with the one obtained in A.

Ultraviolet Absorption Spectra.—The quantitative ultraviolet absorption spectra of both the pyrimidines and purines synthesized were measured at 0.1 *N* hydrochloric acid, 0.1 *N* sodium chloride (by neutralization of equal volumes of 0.1 *N* HCl and 0.1 *N* NaOH solutions), and 0.1 *N* sodium hydroxide. A Cary Model 11 spectrophotometer, employing 1-cm. silica cells, was used.

Infrared Absorption Spectra.—The infrared absorption spectra of the various compounds were determined in the solid state in potassium bromide disks, using a Perkin-Elmer Model 137B spectrophotometer.

Paper Chromatography.—The R_f values of both the pyrimidines and purines were determined by ascending paper chromatography using Whatman No. 1 paper. The solvents used were methanol–concentrated hydrochloric acid–water (70:20:10, v./v.; solvent A) and *n*-butylalcohol–2 *N* ammonium hydroxide–ethanol (20:5:2, v./v.; solvent B).

Synthesis and Properties of α-Aminothiol Esters[1,2]

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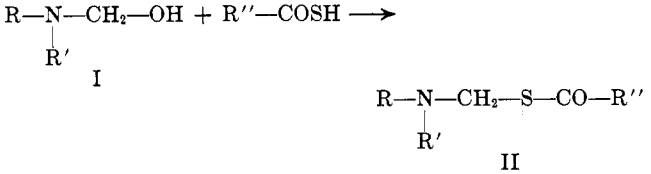
Received December 24, 1964

Acetate esters of one aromatic and five aliphatic α-aminothiols and the benzoate esters of two of these were synthesized by condensation of the appropriate dialkylaminomethanol and thiolcarboxylic acid in the presence of potassium carbonate. The reaction appears to have considerable generality. All of the α-aminothiol esters were found to undergo rearrangement on heating to the corresponding N,N-disubstituted amide and (poly)-thioformaldehyde. Hydrolysis of diethylaminomethanethiol acetate in dilute hydrochloric acid gave diethylaminomethanethiol hydrochloride, accompanied by diethylamine hydrochloride, while basic hydrolysis gave diethylamine, thioformaldehyde, and acetate, accompanied by some diethylacetamide.

Esters of aliphatic α-aminothiols have not been previously described[3] although an ester of an aromatic α-aminothiol is known, the adduct of benzalanthranilic acid and thiolacetic acid.[5] We were interested in this class of compounds for possible antioxidant and anti-radiation drug activity, and as possible synthetic precursors for α-aminothiols.

The synthesis of α-aminothiol esters was accomplished by the reaction of dialkylaminomethanols (I) with thiolcarboxylic acids in the presence of potassium carbonate. The dialkylaminomethanols were



prepared *in situ* from formaldehyde and dialkylamines, and the method is analogous to the synthesis of α-aminosulfides from I and mercaptans and thiophenols[6–8] and to the only reported synthesis of α-aminothiols,[4] employing the reaction of I with hydrogen sulfide. Unfortunately the scope of the latter reaction seems to be very limited.[4,9]

This synthesis of α-aminothiol esters has been successful in each case taken where the amino group is tertiary, as listed in Table I. It is of interest that the diethylamino and dimethylamino derivatives IIa and IIb were obtained in moderate yields, since attempted synthesis of the corresponding α-aminothiols was unsuccessful.[4] The synthesis was successful also for diisopropylaminomethanethiol acetate (IIc) indicating that steric hindrance in the amine is not a serious factor. The method is capable of extension to arylamino derivatives, as shown by the formation of N-methylanilinomethanethiol acetate (IIh), but it is not practical for monoalkylaminomethanethiol esters, *e.g.*, IIi, due to predominance of polymer formation.

Except in this last case, purification of the products was achieved by low-pressure distillation or by crystallization, as shown in Table III. In some cases difficulty was encountered from the tendency to undergo a rearrangement which is described below, and it was generally best to carry out the distillation quickly and at as low a temperature as possible without use of a fractionating column. Because of its high boiling point, diethylaminomethanethiol benzoate (IIc) could

(1) Presented at the Kansas City Chemistry Conference, Kansas City, Mo., Nov. 20, 1964.

(2) This work was supported by National Institutes of Health Grant RN-00300-02 and U. S. Army Medical Command Contract MD-2026.

(3) Since this work was completed, E. E. Smissman and J. R. J. Sorenson [*J. Org. Chem.*, **30**, 300 (1965)] of the University of Kansas synthesized 1-piperidinemethanethiol acetate and benzoate by acylation of 1-piperidinemethanethiol[4] with the corresponding thiolcarboxylic acid. We thank Dr. Smissman for advising us of this work before it was published.

(4) A. H. Binz and L. H. Pence, *J. Am. Chem. Soc.*, **61**, 3134 (1939).

(5) G. W. Stacy and R. J. Morath, *ibid.*, **74**, 3885 (1952).

(6) C. M. McLeod and G. M. Robinson, *J. Chem. Soc.*, **119**, 1470 (1921).

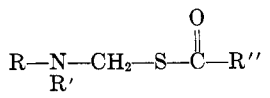
(7) G. F. Grillot, H. R. Felton, B. R. Garrett, H. Greenburg, R. Green, R. Clementi, and M. Moskowitz, *J. Am. Chem. Soc.*, **76**, 3969 (1954).

(8) G. F. Grillot and R. E. Schaffraht, *J. Org. Chem.*, **24**, 1035 (1959).

(9) Unpublished experiments in this laboratory.

TABLE I

α-AMINOTHIOL ESTERS



No.	R	R′	R″	B.p., °C. (mm.)	$n^{30}D$	Yield, %[a]	N.m.r. of NCH_2S, δ[b]
IIa	CH_3	CH_3	CH_3	45–46 (6)	1.4785	45	4.09
IIb	C_2H_5	C_2H_5	CH_3	38–40 (0.5)	1.4760	51	4.66
IIc	C_2H_5	C_2H_5	C_6H_5	120–121 (1)	1.5573	37	4.92
IId	i-C_3H_7	i-C_3H_7	CH_3	54–55 (0.5)	1.4767	54	4.76
IIe		$(CH_2)_5$	CH_3	60–61 (0.5)	1.5082	52	4.52
IIf		$O(CH_2)_4$	CH_3	80–82 (1)	1.5100	51	4.60
IIg		$O(CH_2)_4$	C_6H_5	62–63[c]		35	4.86
IIh	C_6H_5	CH_3	CH_3	60–65 (0.01)	1.6072	25	4.96
IIi	i-C_3H_7	H	CH_3	25–28 (2)	1.4961	3	

[a] Of analytical pure product, except in the case of IIa. [b] For dilute solutions in carbon tetrachloride. [c] Melting point.

TABLE II

REARRANGEMENT OF α-AMINOTHIOL ESTERS

Ester	Temp., °C.	Time, hr.	Amide formed	Yield, %	B.p., °C. (mm.) Obsd.	B.p., °C. (mm.) Lit.	n_D (°C.) Obsd.	n_D (°C.) Lit.
IIa	70	20	$CH_3CON(CH_3)_2$	46	60–62 (18)	165.0[a]	1.4360 (25)	1.4351 (25)[a]
IIb	70	15	$CH_3CON(C_2H_5)_2$	89	83–84 (20)	90–91 (30)[b]	1.4402 (29)	1.4412 (17.6)[c]
IIc	73	20	$C_6H_5CON(C_2H_5)_2$	53	155–159 (20)	268–270[d]	1.5190 (30)	...
IId	100	40	$CH_3CON(i\text{-}C_3H_7)_2$	33	192–197	196[e]	1.4338 (30)	
IIe	73	12	$CH_3CON(CH_2)_5$	80	125–126 (35)	125 (30)[f]	1.4748 (29)	
IIf	73	20	$CH_3CON(CH_2)_4O$	84	138–140 (32)	111–112 (10)[g]	1.4818 (28)	1.4840 (20)[g]
IIg	100	180	$C_6H_5CON(CH_2)_4O$	60	M.p. 73–74	73.5–74[h]		
IIh	100	35	$CH_3CON(CH_3)C_6H_5$	56	240–247	245[i]		
					M.p. 100–101	101–102[j]		

[a] J. R. Rerhoff and E. E. Reid, *J. Am. Chem. Soc.*, **59**, 401 (1937). [b] S. Stephanou, C. A. VanderWerf, and H. H. Sisler, *ibid.*, **70**, 265 (1948). [c] K. V. Auwers, *Z. physik. Chem.*, **147**, 458 (1930). [d] F. Hallmann, *Ber.*, **9**, 846 (1876). [e] A. W. Campbell and P. F. Tryon, *Ind. Eng. Chem.*, **45**, 125 (1953). [f] H. Staudinger and H. Schneider, *Ber.*, **56**, 704 (1923). [g] H. Böhme, K. Hartke, and A. Müller, *ibid.*, **96**, 595 (1963). [h] G. E. McCasland and E. C. Horswill, *J. Am. Chem. Soc.*, **73**, 3923 (1951). [i] A. W. Hofmann, *Ber.*, **10**, 599 (1877). [j] P. Hepp, *ibid.*, **10**, 328 (1877).

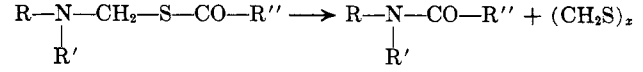
not be obtained analytically pure by distillation, and its hydrochloride was purified by recrystallization.

The structures assigned were supported by elemental analyses and by spectral data. The compounds all showed the expected infrared spectra, including the thiol acetate and thiol benzoate carbonyl frequencies at 5.95 and 6.1 μ, respectively, and the S—C=O frequencies at 8.8 and 10.5 μ for the thiol acetates and 8.6 and 11 μ for the thiol benzoates.[10] The n.m.r. spectra showed, in addition to the bands associated with R, R′, and R″ in II, a singlet at δ 4.1 to 5.0 (the position depending on the compound as shown in Table I), which would be attributable to the methylene hydrogen atoms between the nitrogen and sulfur atoms. For a carbon tetrachloride solution of IIa, this appears at δ 4.1, which is reasonably close to the position of δ 4.00 that would be predicted by application of Shoolery's rule in this case.[11]

A preliminary study was made of the hydrolysis of diethylaminomethanethiol acetate (IIb) under basic and acidic conditions. Treatment with aqueous alcoholic sodium hydroxide at room temperature gave diethylamine (78%), diethylacetamide (20%), and thioformaldehyde (isolated in polymeric form). The diethylacetamide is considered to have arisen from concurrent rearrangement, rather than hydrolysis. No diethylaminomethanethiol was isolated; it probably decomposes in base to form diethylamine and thioformaldehyde.

Since 1-piperidinemethanethiol is reported to be moderately stable in dilute hydrochloric acid,[4] the hydrolysis of IIb was carried out with this reagent at room temperature. This gave some hydrogen sulfide and a mixture of the hydrochlorides of diethylamine and diethylaminomethanethiol, as judged by the infrared spectrum and sodium nitroprusside test. The hydrolysis results are in agreement with the α-aminothiol ester structure, and acid hydrolysis appears to warrant further study as a method for α-aminothiols not available by direct synthesis.[4]

All of the α-aminothiol esters prepared were observed to rearrange readily on standing or heating to form the corresponding amides and thioformaldehyde, as shown in Table II. The products were identified by comparison of boiling points, melting points, refractive indices, and infrared spectra with those previously reported or observed here for authentic samples. Except with diisopropylaminomethanethiol acetate (IId), the rearrangement appeared to be very clean, with no other products observed. From IId a 28% yield of diisopropylamine was also isolated.



The ease of this rearrangement was found to vary greatly with the structure of the α-aminothiol ester.

(10) R. A. Nyquist and W. J. Potts, *Spectrochim. Acta*, **15**, 514 (1954).

(11) L. M. Jackman, "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry," Pergamon Press, London, 1959, p. 59. An effective shielding constant of 2.16 was used for the thiol acetate group, which was deduced from the position of the S-methyl group in ethanethiol acetate at δ 2.86.

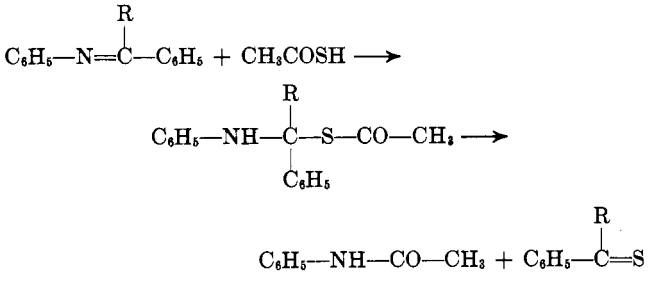
TABLE III
ANALYTICAL DATA ON α-AMINOTHIOL ESTERS

Compd.	Formula	% C Calcd.	% C Found	% H Calcd.	% H Found	% N Calcd.	% N Found
IIa[a]	$C_5H_{11}NOS$					10.51	10.69
IIb[b]	$C_7H_{15}NOS$	52.14	52.34	9.38	9.38	8.69	8.70
IIc·HCl[a]	$C_{12}H_{18}ClOS$					5.40	5.26
IIa[a]	$C_9H_{19}NOS$					7.40	7.45
IIe[b]	$C_8H_{15}NOS$	55.46	55.59	8.73	8.68	8.08	8.11
IIf[b]	$C_7H_{13}NO_2S$	47.98	48.12	7.48	7.56	7.99	8.15
IIg[a]	$C_{12}H_{15}NO_2S$					5.90	5.86
IIh[b]	$C_{10}H_{13}NOS$					7.17	7.54

[a] Analyses were by Mr. S. N. Rogers, Department of Biochemistry, Kansas State University; average of duplicate analyses. [b] Analyses were by Galbraith Laboratories, Knoxville, Tenn.

In some cases, such as IIa, b, e, and probably i, it proceeded so easily at moderate temperatures as to cause some difficulty in purification of the ester, as noted above. In other cases, notably IId, g, and h, the rearrangement proceeded relatively slowly, with higher temperatures and longer times needed to obtain moderate yields of products. Kinetic and other studies of the mechanism are in progress.

This rearrangement was independently observed very recently by Smissman and Johnson in the case of piperidinomethanethiol acetate and benzoate,[3] and it appears to have been previously encountered by Mikhailov and Savel'eva,[12] who obtained acetanilide and thiobenzophenone or thioacetophenone from the reaction of thiolacetic acid with benzophenone anil or acetophenone anil. These workers do not seem to have considered the intermediacy of the α-aminothiol esters which they had expected but did not observe, but the heating employed in their method of processing the products could well have brought about a rearrangement similar to that observed here.



Results of testing of these compounds will be reported elsewhere, but it may be noted here that many of them, particularly dimethylaminomethanethiol acetate (IIa), were observed to cause mild dermatitis.

Experimental

Diethylaminomethanethiol Acetate (IIb).—This preparation illustrates the general procedure used for the synthesis of the α-aminothiol esters. Gaseous formaldehyde, generated by heating 9.0 g. (0.3 mole) of paraformaldehyde at 150–170°, was bubbled into 14.6 g. (0.2 mole) of diethylamine with cooling to maintain the temperature below 30°. After addition of 5 g. of potassium carbonate and 100 ml. of ether, the ethereal layer was decanted and 30 g. of additional potassium carbonate was added, followed by addition of 15.2 g. (0.2 mole) of thiolacetic acid during a 15-min. period. After the mixture had been stirred for 9 hr. at room temperature, the potassium carbonate was removed by filtration, and the ether was removed by distillation. Vacuum distillation of the residual oil gave 16.5 g. of colorless liquid, b.p. 38–40° (0.5 mm.), $n^{30}D$ 1.4770. Its hydrochloride formed as white needles, m.p. 98–100°, when hydrogen chloride was bubbled into an ether solution of IIb.

For diethylaminomethanethiol benzoate, the distillation temperature even under 0.005 mm. pressure, was sufficient to cause sufficient rearrangement to affect the elemental analysis. Therefore, its hydrochloride salt was formed by passing hydrogen chloride into the ether solution and was recrystallized from alcohol–ether, m.p. 108–111°. The same situation occurred with N-methylanilinomethanethiol acetate, but unfortunately its hydrochloride could not be crystallized. 4-Morpholinomethanethiol benzoate was obtained as pink needles, m.p. 62–63° (from petroleum ether). The results of elemental analyses on these compounds are summarized in Table III.

Basic Hydrolysis.—A solution of 5 g. of diethylaminomethanethiol acetate (IIb) in 50 ml. of 50% aqueous ethanol containing 2.5 g. of sodium hydroxide was allowed to stand 15 hr. at room temperature and was then extracted with ether. The extract was dried over magnesium sulfate and distilled to give an alcohol fraction and 0.7 g. (20%) of N,N-diethylacetamide, b.p. 175–178°, $n^{20}D$ 1.4320 (lit.[13] b.p. 185–186°, $n^{20}D$ 1.4330). Its infrared spectrum was identical in all respects with that of an authentic sample of N,N-diethylacetamide.

Addition of a solution of ethereal hydrogen chloride to the alcohol fraction brought about a precipitate of diethylamine hydrochloride, which after recrystallization from ethanol had m.p. 228–230° (lit.[14] m.p. 228°) and weighed 2.55 g. (78%).

The distillation residue, after repeated washing with ether, consisted of 0.93 g. (66%) of white solid, m.p. 205–210°,[15] containing sulfur (sodium fusion), and had an infrared spectrum identical with that of authentic polythioformaldehyde, prepared by the reaction of hydrogen sulfide with aqueous formaldehyde.

The aqueous solution was acidified with hydrochloric acid and distilled, with determination of Duclaux values as 6.7, 7.1, and 7.35 fo the first, second, and third fractions, respectively (lit.[16] for acetic acid, 6.8, 7.1, and 7.35).

Acid Hydrolysis.—A mixture of 5 g. of IIb in 15 ml. of 10% hydrochloric acid was stirred at room temperature for 6 hr. Evaporation of solvent under vacuum gave a semisolid product, which could not be purified by crystallization from ethanol or chloroform. The presence of thiol functionality was shown by the sodium nitroprusside test and by an infrared absorption band at 3.95 μ. It showed infrared absorption in the 4-μ region typical of amine salts, and additional bands at 4.9 and 6.6 μ indicated that the product was a mixture of diethylamine hydrochloride and diethylaminomethanethiol hydrochloride. Evolution of hydrogen sulfide during the hydrolysis was noted by odor and by lead acetate test paper.

Rearrangement of α-aminothiol esters was carried out by heating the compounds without solvent, as shown in Table II.

(12) B. M. Mikhailov and I. S. Savel'eva, *Izv. Akad Nauk SSSR, Otd. Khim. Nauk*, 1304 (1959).

(13) J. H. Robson and J. Reinhart, *J. Am. Chem. Soc.*, **77**, 498 (1955).

(14) P. Waldon, H. Ulich, and G. Busch, *Z. physik. Chem.* (Leipzig), **123**, 445 (1926).

(15) Polythioformaldehyde is reported to have m.p. 123° and higher, probably depending on molecular weight [De Lattre, *Chem. Zentr.*, **II**, 1192 (1912)], while the cyclic trimer, 1,3,5-trithiane, has m.p. 214–215° [R. W. Bost and E. W. Constable, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1963, p. 610].

(16) S. M. McElvain, "The Characterization of Organic Compounds," The Macmillan Co., New York, N. Y., 1953, p. 141.

The progress of the rearrangement could be followed easily by the shift of the carbonyl absorption in the infrared spectrum from the thiol ester position (5.95 μ in the case of the acetate esters) to the amide position at about 6.15 μ. In most cases the amide was isolated by direct distillation, the polythioformaldehyde remaining undistilled, m.p. 185–190°.[15] The infrared and n.m.r. spectra of the latter were identical with those of an authentic sample.

Organic Disulfides and Related Substances. XIV. Aspects of the Reaction of Thiolsulfonates with Thiols[1a,c]

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Received January 25, 1965

In the presence of base, a typical thiolsulfonate reacts readily and completely with a thiol to form a disulfide and a sulfinic acid salt even at −86°. In the absence of base, fairly rapid reaction occurs, which proceeds only part way, but can be pushed toward completion by use of excess thiol or thiolsulfonate. Steric factors significantly affect reactivity of thiolsulfonates, more so than do electronic effects noted thus far. As ancillary points, gas–liquid chromatography was investigated for qualitative and quantitative analysis of thiols, and a tertiary alkyl thiolsulfonate was synthesized, apparently for the first time.

The reaction of thiolsulfonates with thiols has provided a route to disulfides, which has been little exploited[2] and about which little is known except that it occurs readily even at 0°.[3] The principal reaction is formulated in eq. 1 and important subsidiary reactions in eq. 2 and 3. Having found recently that the reaction provides a clean and useful synthesis for many types of disulfides,[4–8] we felt attention to its characteristics was well warranted.

$$R_1SO_2SR_2 + R_3SH \longrightarrow R_1SO_2H + R_2SSR_3 \quad (1)$$

$$3R_1SO_2H \longrightarrow R_1SO_2SR_1 + R_1SO_3H + H_2O \quad (2)$$

$$2R_2SSR_3 \rightleftharpoons R_2SSR_2 + R_3SSR_3 \quad (3)$$

Of several techniques considered for following the reaction,[1b] only two proved promising in practice. These led to useful conclusions, although unhappily they were not adaptable to detailed kinetic work. The first technique was the potentiometric determination of sulfinic acid formed (eq. 1), using as the end point a rather sharp break found for sulfinic acids (*e.g.*, *p*-toluenesulfinic acid) at pH 5.5–7.5; it was hoped that thiol would not interfere since many thiols (*e.g.*, *p*-toluenethiol) are neutralized only at about pH 9.5–10.5. Barnard and Cole quantitatively determined thiolsulfonates essentially in this way, allowing them to react with excess thiol and titrating the sulfinic acid formed.[9]

The data obtained, puzzling at first, soon showed the inadequacy of titration for studying the kinetics of eq. 1. One difficulty was the very short survival time sometimes observed for the sulfinic acid. Kice and coworkers have shown both that sulfinic acids themselves decompose by complex mechanisms and that they may react with species such as disulfides present in our system.[10] Equation 2 suggests disproportionation as a principal cause of loss.

When *p*-tolyl *p*-toluenethiolsulfonate reacted at 0° with *p*-toluenethiol, *p*-toluenesulfinic acid which formed survived quite well. For example, titration after 4 min. required 101% of one molar proportion of alkali and after 5–72 hr. the result was virtually the same; at −86°, 93% resulted after 4 min. and change again was negligible after many hours. In marked contrast, 2-mercaptoethylamine hydrochloride (**1**), a thiol of special interest to us, resulted at 0° in 70% of sulfinic acid after 2 min. but in only 12% after 2 hr., obviously because the sulfinic acid began to be destroyed soon after formation; at −86°, 80% was found after 2 min. but only 55% after 1.5 hr. Addition of pyridine in the hope of stabilizing *p*-toluenesulfinic acid as its pyridine salt at −8° caused eq. 3 to become more important, and cystamine dihydrochloride resulted in 65% yield.

A second and even more serious difficulty was that the titration itself affected the reaction. The yields of 80–93% of sulfinic acid rapidly produced even at −86° implied that the reaction was fast and complete. At odds with this conclusion is the recovery of 25% of *p*-toluenethiol after its reaction with 2-aminoethyl 2-aminoethanethiolsulfonate dihydrochloride (**2**).[4] The explanation for the paradox is that alkali titration must actually produce enough thiolate ion to drive the reaction toward completion. Rather good yields of aminodisulfide hydrochlorides found in our synthetic applications of the reaction no doubt have this explanation also—alkali intended only to convert aminodisulfide hydrochloride products to free bases in isolations actually no doubt functioned also to form thiolate ions and thus to force the thiolsulfonate reactions toward completion[4,6–8]; in substantiation, when thiols have been extracted before addition of alkali, recoveries of thiol have been about 50%.[1b]

(1) (a) This investigation was supported by the U. S. Army Medical Research and Development Command, Department of the Army, under Research Contract No. DA-49-193-MD-2030. Results are abstracted from portions of the Ph.D. Dissertation of T. F. P.[1b] and that forthcoming of J. D. B. (b) T. F. Parsons, Ph.D. Dissertation, Vanderbilt University, May 1964. (c) Paper XIII: L. Field and T. F. Parsons, *J. Org. Chem.*, **30**, 657 (1965). (d) Du Pont Postgraduate Teaching Assistant, 1962–1963. (e) To whom correspondence should be addressed.

(2) *Cf.* A. Schöberl and A. Wagner, "Methoden der Organischen Chemie (Houben–Weyl)," Vol. 9, E. Müller, Ed., 4th Ed., Georg Thieme Verlag, Stuttgart, 1955, p. 72.

(3) H. Gilman, L. E. Smith, and H. H. Parker, *J. Am. Chem. Soc.*, **47**, 851 (1925).

(4) L. Field, T. C. Owen, R. R. Crenshaw, and A. W. Bryan, *ibid.*, **83**, 4414 (1961).

(5) R. R. Crenshaw and T. C. Owen, *Proc. Chem. Soc.*, 250 (1961).

(6) L. Field, H. Härle, T. C. Owen, and A. Ferretti, *J. Org. Chem.*, **29**, 1632 (1964).

(7) L. Field, A. Ferretti, and T. C. Owen, *ibid.*, **29**, 2378 (1964).

(8) R. R. Crenshaw and L. Field, *ibid.*, **30**, 175 (1965).

(9) D. Barnard and E. R. Cole, *Anal. Chim. Acta*, **20**, 540 (1959).

(10) *Cf.* J. L. Kice and N. E. Pawlowski, *J. Org. Chem.*, **28**, 1162 (1963), and references cited therein; J. L. Kice and K. W. Bowers, *J. Am. Chem. Soc.*, **84**, 605, 2384, 2390 (1962).