Int. Ed. Engl., **13**, 229 (1974); (c) E. H. White and D. F. Roswell, *Acc. Chem. Res.*, **3**, 54 (1970); (d) F. McCapra, *Pure Appl. Chem.*, **24**, 611 (1970); (e) F. McCapra, *Prog. Org. Chem.*, **8**, 231 (1971); (f) F. McCapra, *Acc. Chem. Res.*, **9**, 201 (1976); (g) M. J. Cormier, D. M. Hercules, and J. Lee, Ed., "Chemiluminescence and Bioluminescence", Plenum Press, New York, N.Y., 1973; (h) D. M. Hercules, *Acc. Chem. Res.*, **2**, 30 (1969); (i) D. M. Hercules, *Phys. Methods Chem.*, **1b**, 257 (1971); (j) N. J. Turro, P. Lechtken, N. E. Shore, G. Schuster, H.-C. Steinmetzer, and A. Yekta, *Acc. Chem. Res.*, **7**, 97 (1974).
(2) (a) W. H. Richardson, J. H. Anderegg, M. E. Price, and R. Crawford, *J. Org. Chem.*, in press; (b) W. H. Richardson, J. H. Anderegg, M. E. Price, W. A. Tappen, and H. E. O'Neal, *ibid.*, in press; (c) W. H. Richardson, F. C. Montgomery, P. Siusser, and M. B. Yelvington, *J. Am. Chem. Soc.*, **97**, 2819 (1975); (d) W. H. Richardson, F. C. Montgomery, M. B. Yelvington, and H. E. O'Neal, *ibid.*, **94**, 1619 (1972).
(3) T. Wilson and A. P. Schaap, *J. Am. Chem. Soc.*, **93**, 4126 (1971).
(4) N. J. Turro, P. Lechtken, G. Schuster, J. Orell, H.-C. Steinmetzer, and W. Adam, *J. Am. Chem. Soc.*, **96**, 1627 (1974).
(5) W. H. Richardson, F. C. Montgomery, M. B. Yelvington, and G. Ranney, *J. Am. Chem. Soc.*, **96**, 4045 (1974).
(6) E. H. White, P. D. Wildes, J. Wiecko, H. Doshan, and C. C. Wei, *J. Am. Chem. Soc.*, **95**, 7050 (1973).
(7) (a) D. Valentine, Jr., and G. S. Hammond, *J. Am. Chem. Soc.*, **94**, 3449 (1972); (b) H. A. Hammond, D. E. DeMeyer, and J. L. R. Williams, *ibid.*, **91**, 5180 (1969).
(8) T. Wilson, D. E. Golan, M. S. Harris, and A. L. Baumstark, *J. Am. Chem. Soc.*, **98**, 1086 (1976).
(9) J.-Y. Koo and G. B. Schuster, *J. Am. Chem. Soc.*, **99**, 5403 (1977).
(10) L. B. Harding and W. A. Goddard III, *J. Am. Chem. Soc.*, **99**, 4520 (1977).
(11) (a) C. Walling and P. J. Wagner, *J. Am. Chem. Soc.*, **86**, 3368 (1964); (b) C. Walling, *Pure Appl. Chem.*, **15**, 69 (1967).
(12) S. L. Murov, "Handbook of Photochemistry," Marcel Dekker, New York, N.Y., 1973, p 306.
(13) H. E. O'Neal and W. H. Richardson, *J. Am. Chem. Soc.*, **92**, 6553 (1970).
(14) M. A. Umbreit and E. H. White, *J. Org. Chem.*, **41**, 479 (1976).
(15) E. J. H. Bechara, A. L. Baumstark, and T. Wilson, *J. Am. Chem. Soc.*, **98**, 4648 (1976).
(16) A previous report from this laboratory gives $\alpha_{T_1} = 30\%$ for TMD[8] compared to our value of 36%.
(17) K. R. Kopecky, P. A. Lockwood, and J. E. Filby, Abstracts, 174th National Meeting of the American Chemical Society, Chicago, Ill., Aug 29–Sept 2, 1977.
(18) N. J. Turro and P. Lechtken, *Pure Appl. Chem.*, **33**, 353 (1973).
(19) K. R. Kopecky, J. E. Filby, C. Mumford, P. A. Lockwood, and J.-Y. Ding, *Can. J. Chem.*, **53**, 1103 (1975).
(20) G. B. Schuster, N. J. Turro, H.-C. Steinmetzer, A. P. Schaap, G. Faler, W. Adam, and J. C. Liu, *J. Am. Chem. Soc.*, **97**, 7110 (1975).
(21) Temperatures are corrected. GLC analyses were performed with a Varian-Aerograph Hy-Fi-III FID instrument or a Hewlett-Packard 5830-A FID chromatograph.
(22) W. H. Richardson, R. S. Smith, G. Snyder, B. Anderson, and G. L. Kranz, *J. Org. Chem.*, **37**, 3915 (1972).
(23) F. C. Montgomery, R. W. Larson, and W. H. Richardson, *Anal. Chem.*, **45**, 2258 (1973).

The Ortho Functionalization of Aromatic Amines. Benzylation, Formylation, and Vinylation of Anilines

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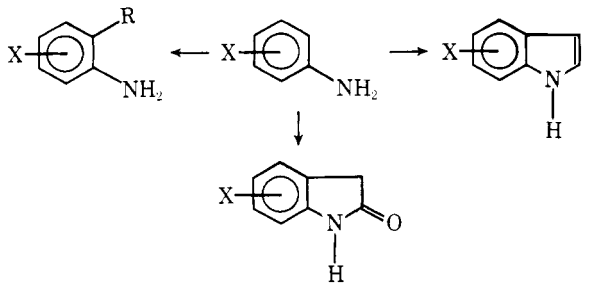
Abstract: New synthetic procedures have been developed for the specific ortho functionalization of aromatic amines. Utilizing reactions which involve the intramolecular rearrangement of ylides derived from azasulfonium salts, processes have been developed which permit the selective introduction of the benzyl, formyl, and vinyl moieties ortho to the amino function of anilines.

Although the use of [2,3]-sigmatropic rearrangements for the selective ortho substitution of aromatic rings was pioneered by Sommelet[3] and extended by Hauser,[4] it was only recently (1972–1977) that extensive synthetic use was made of the rearrangement of ylides derived from *N*-arylazasulfonium salts.[5] These rearrangements provide for a simple, high-yield conversion of anilines into ortho-alkylated anilines, indoles, and oxindoles.[3] Of particular importance is the ability to carry out these conversions over a wide temperature range (down to −78 °C), with mild reagents, and in the presence of a wide range of substituents. Since the crucial step in the reaction sequence involves the [2,3]-sigmatropic rearrangement



of an ylide derived from an *N*-arylazasulfonium salt, little (if any) charge is built up on the aromatic ring. Thus, electron-withdrawing and electron-donating substituents can both be tolerated. In view of the useful interconversions described above, it was of interest to utilize this conceptual approach for the introduction of functionality directly onto the ortho position of anilines. This paper provides the details of our benzylation, formylation, and vinylation of anilines.[6]

Benzylation of Anilines. Synthesis of 2-Aminodiphenylmethane Derivatives

2-Aminodiphenylmethane derivatives are of interest both as intermediates in the pharmaceutical industry and as precursors of fluorenes.[7] Of the various methods reported for the synthesis of 2-aminodiphenylmethane derivatives,[8] the most successful probably involved the dissolving-metal reduction of the corresponding 2-aminobenzophenones. However, a wide range of substituted 2-aminobenzophenones is not readily available, which makes this approach somewhat limited. It appeared that our method for the substitution of anilines might lend itself to the straightforward preparation of these useful intermediates. In order to meet our objectives, we used benzyl phenyl sulfide as our reagent.

Treatment of aniline with 1 equiv of *tert*-butyl hypochlorite followed by excess benzyl phenyl sulfide in methylene chloride at −78 °C gave no azasulfonium salt formation. Since the aryl sulfide apparently was not sufficiently nucleophilic under these reaction conditions, the solvent was changed to one of a higher dielectric constant and the temperature was raised. These

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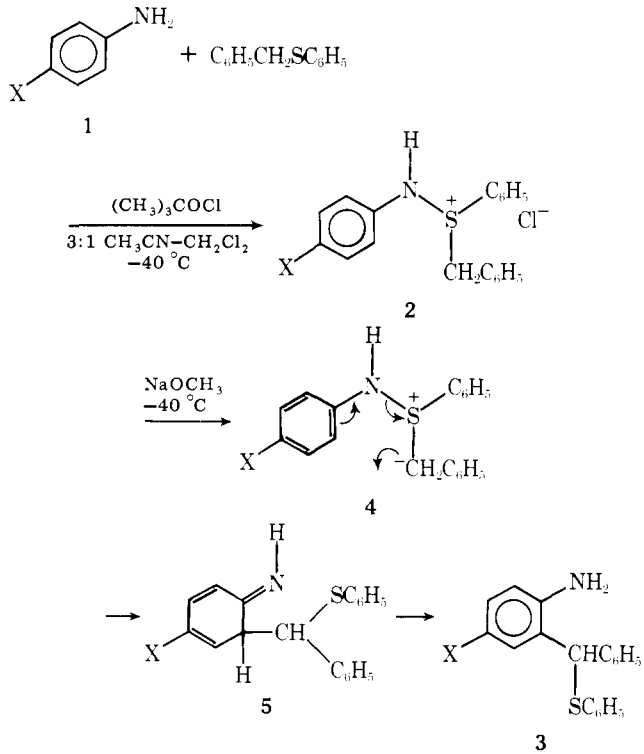
conditions led to such rapid solvolysis of the *N*-chloroaniline that the major product was *o*-chloroaniline. However, when the sulfide was combined with the aniline before the addition of the chlorinating agent, the azasulfonium salt was formed. Thus, 1 equiv of an aniline, **1,** was combined with 2 equiv of benzyl phenyl sulfide in a 3:1 mixture of acetonitrile–methylene chloride at −40 °C under a positive pressure of nitrogen. Addition of a solution of 1.3 equiv of *tert*-butyl hypochlorite

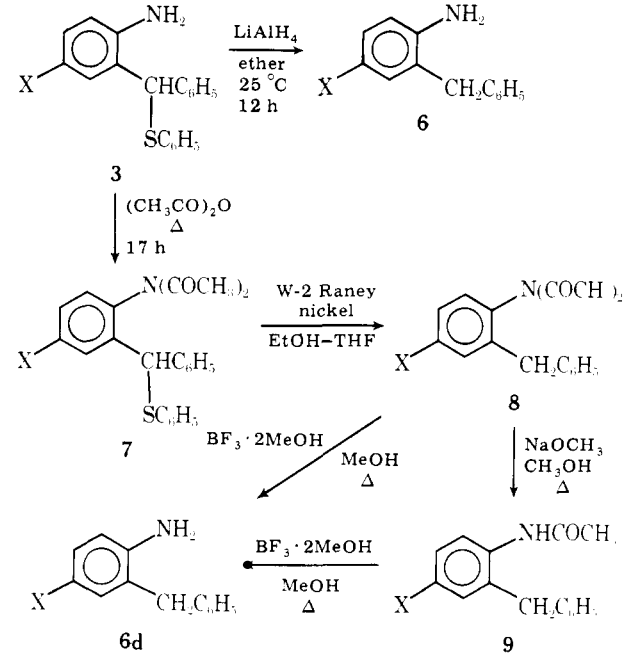


at −78 °C in methylene chloride produced the azasulfonium salt **2.** After stirring for 4 h at −40 °C and 3 h at −20 °C a solution of sodium methoxide in methanol was added and the reaction mixture was warmed, affording the desired 2-aminodiphenylmethane derivatives **3.** Mechanistically, it was presumed that the base treatment of **2** gave **4** which underwent a spontaneous [2,3]-sigmatropic rearrangement to the dienone imine, **5.**[5] Hydrogen migration and accompanying rearomatization would then produce **3.** Table I lists the yields of **3** based on consumed aniline. As can be seen from examination of Table I, the yields obtained in the orthobenzylation of anilines were quite reasonable. Desulfurization of **3** with W-2 Raney nickel was accompanied by extensive reduction of the amino-substituted ring. However, when **3a, 3b,** and **3c** were treated with an equimolar amount of lithium aluminum hydride at 25 °C for 12 h in ether, we obtained **6a, 6b,** and **6c** in 89, 95, and 83% yields, respectively. The yield of the desulfurized chloro derivative was lower because 10% of chlorine displacement (reduction) accompanied the reaction. An alternate desulfurization process was developed for the carbomethoxy derivative. To avoid the difficulty previously observed with Raney nickel, the aniline ring was first deactivated. Refluxing **3d** overnight in acetic anhydride formed the *N,N*-diacetyl derivative (imide), **7,** in 88% yield.[9] This deactivated material was then treated with W-2 Raney nickel in ethanolic tetrahydrofuran to give the desulfurized imide **8** in 93% yield. Either one or both of the acetyl protecting groups could then be removed, depending upon the reaction conditions. Refluxing **8** with sodium methoxide in methanol removed one acetyl group to form the amide **9** in excellent yield. The use of boron trifluoride–methanol complex in methanol permitted the conversion of the imide **8** directly to the amine **6d.** This reagent also converted **9d** to **6d** in good yield. The overall three-step

Table I. Yields of 2-Aminodiphenylmethane Derivatives from Para-Substituted Anilines

aniline	substituent	product	% yield
1a	CH_3	**3a**	73
1b	H	**3b**	72
1c	Cl	**3c**	93
1d	CO_2CH_3	**3d**	61
1e	NO_2	**3e**	65

desulfurization procedure taking **7d** to **6d** was accomplished in 79% yield.



Ortho Formylation. Synthesis of *o*-Aminobenzaldehydes

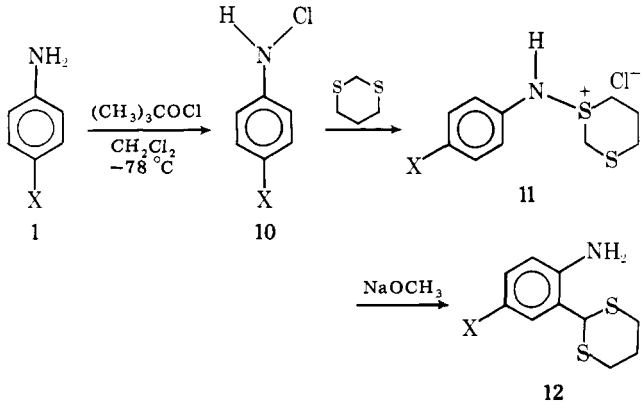
We next turned our attention to the introduction of the aldehyde moiety, which we felt was a much more versatile functional group. Relatively few methods for the formylation of aromatic rings are known. Those which do exist fail to offer much in the way of selectivity.[10] More specifically, methods for the preparation of derivatives of *o*-aminobenzaldehydes, which have extensive value in the synthesis of certain heterocycles, are generally limited to the reduction of *o*-nitrobenzaldehydes[11] and to the oxidation of *o*-toluidines.[12] In principle, the substitution of a 1,3-disulfide for the usual monosulfide in our reaction should provide an ortho substituent with the requisite oxidation state. In practice, simple 1,3-disulfides gave poor results, as did methylthiomethyl methyl ether and methylsulfinylmethyl methyl sulfide.

Further pursuing the 1,3-disulfide concept, 1,3-dithiane was examined. There was sufficient evidence that this molecule might behave differently than its open-chain analogues. Corey and Seebach have shown that 1,3-dithiane is the far superior reagent in metalation reactions leading to aldehyde synthesis.[13] Hopefully, the fact that the alkyl ends were "tied back" would allow the azasulfonium salt formation to proceed as desired. Indeed, when anilines were treated sequentially with 1.0 equiv of *tert*-butyl hypochlorite, 1.0 equiv of dithiane, and excess sodium methoxide in methylene chloride at −78 °C, the desired amino sulfides were obtained in 25–54% yields. By analogy with earlier studies,[5] it was assumed that **1** reacted with the chlorinating agent to produce **10,** which in turn reacted with dithiane to give the azasulfonium salt **11.** On treatment with base **11** was converted into the protected *o*-aminobenzaldehyde **12.** As can be seen from Table II, the yield

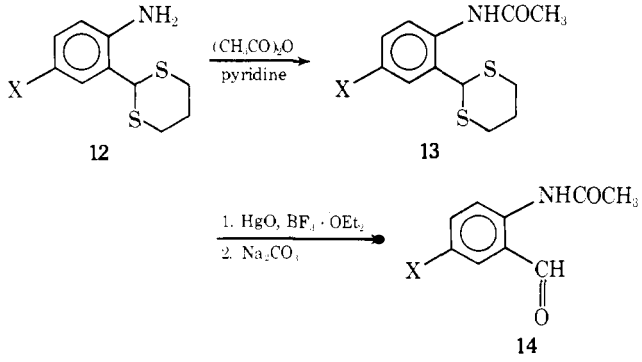
Table II. Yields Obtained in the Ortho Formylation of Anilines

aniline	substitutent	% yield of **12**	% yield of **13**	% yield of **14**	overall % yield
1a	*p*-CH_3	25	90	92	21
1b	H	54	95	85	44
1c	*p*-Cl	30	91	88	24
1d	*p*-CO_2CH_3	32	92	86	25

for the parent aniline was substantially higher than for the substituted variants. The reasons for these differences were not obvious.



The dithioacetals, **12a–d,** could have been hydrolyzed to the corresponding *o*-aminobenzaldehydes at this point. However, these aldehydes are known to condense quite readily to give cyclic dimers, trimers, and other linear oligomers. This condensation reaction was avoided by protecting the amino group in such a fashion that subsequent reactions could still be investigated at a later time. Thus, the amino sulfides were treated with acetic anhydride and pyridine to form the amides **13.** Treatment of the amides with 2 equiv of red mercuric oxide and boron trifluoride etherate in aqueous tetrahydrofuran[14] followed by neutralization with sodium carbonate afforded the acetaminobenzaldehydes, **14,** in excellent yield. This is one of



many methods[15] for the hydrolysis of thioacetals to aldehydes. It worked extremely well, the conditions used were mild, and completion of the reaction was indicated when the red mercuric oxide was replaced by a white alkylthio mercury salt. The use of 1 equiv of mercuric oxide for each sulfur in the molecule enabled the reaction completion to be equated with total disappearance of any red coloration. The acetaminobenzaldehydes are stable, white, crystalline compounds.

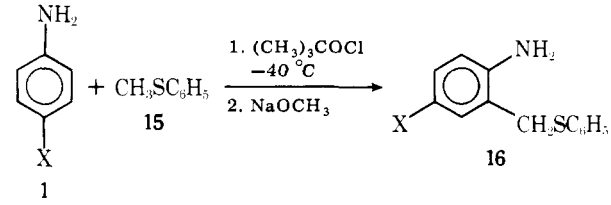
Ortho Formylation via Oxidation of *o*-Thiophenoxymethylated Anilines

Although the yields in the dithiane route compared favorably with those for other methods reported in the literature for the preparation of aminobenzaldehydes, it was thought that another method would prove even better. This approach involved functionalizing (oxidizing) the sulfide after rearrangement of the azasulfonium salt.

Table III. Yields for the Conversion of Anilines to Protected *o*-Aminobenzaldehydes via Oxidative Chlorination of Intermediate 2-(Thiophenoxymethyl)anilines

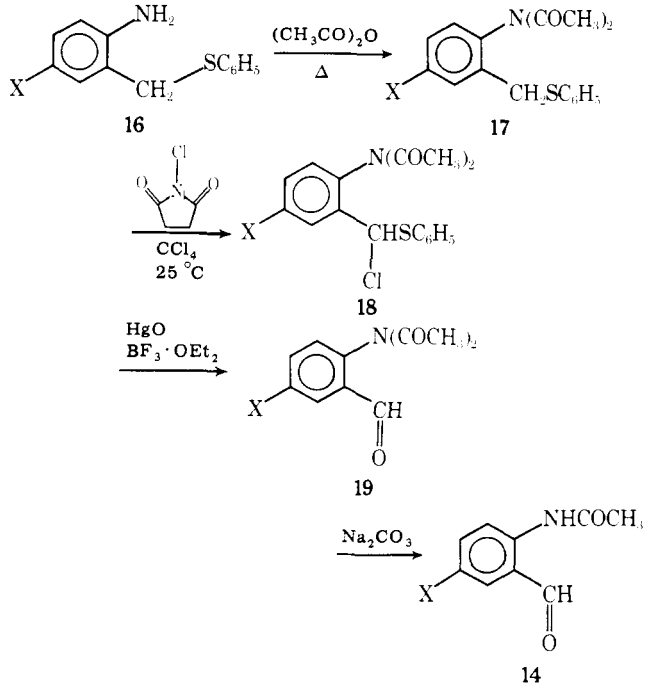
compd	substituent	% yield of **16**	% yield of **14** from **16**	overall % yield
1a	*p*-CH_3	63	52	33
1b	H	61	73	45
1c	*p*-Cl	68	73	50
1d	*p*-CO_2CH_3	58	63	37
1f	*p*-CN	73	49	36

In principle, *o*-(thiomethoxymethyl)anilines could have served as precursors of *o*-aminobenzaldehydes. However, an adaptation of that *o*-methylthiomethylation procedure was used. Thioanisole was utilized instead of dimethyl sulfide. Thus, the sequential treatment of a mixture of an aniline (**1**) and thioanisole (**15**) in 3:1 acetonitrile–methylene chloride at



−40 °C with *tert*-butyl hypochlorite and sodium methoxide afforded the corresponding 2-(thiophenoxymethyl)anilines (**16**) in good yield. The yields for this reaction are summarized in Table III. The reaction conditions used in this procedure closely resembled those of the preparation of aminodiphenylmethane derivatives, **3.** Whenever the reaction involved an aryl sulfide, the more polar solvent system and higher temperatures were necessitated. Thus, the 3:1 mixture of acetonitrile and methylene chloride at −40 °C was used for this reaction.

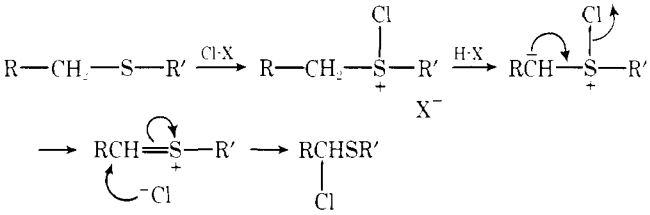
Conversion of the aminosulfides, **16,** to the corresponding *o*-acetaminobenzaldehydes was accomplished in the following manner. The imides, **17,** were formed by refluxing **16** for 24



h in acetic anhydride. Treatment of **17** with *N*-chlorosuccinimide in carbon tetrachloride at 25 °C for 2 h gave the α-chloro

sulfide **18.** Hydrolysis of **18** with 1 equiv of red mercuric oxide and boron trifluoride etherate in 85% aqueous tetrahydrofuran afforded the imide aldehyde **19,** which was further hydrolyzed to the amide aldehyde **14** by stirring over aqueous sodium carbonate. For the case where X = H, **17** was formed in 97% yield, **18** in 75% yield, and **14** in 91% yield from **18.** For the other substituents, no attempt was made to isolate the intermediate compounds. The overall yields for the preparation of **14** from the amino sulfides **16,** are shown in Table III.

The conversion of **16** to **17** was essentially quantitative. Examination of crude product mixtures by NMR spectroscopy showed no evidence of the amino or amide functions. In the one instance (X = H) where purification and isolation were attempted, distillation yielded 97% of the desired product. In other cases, excess acetic anhydride and acetic acid were removed at 60 °C under vacuum. The conversion of **17** to **18** generally was the lowest yield reaction in this sequence, averaging approximately 75%. Owing to the instability of the α-halo sulfides, isolation and purification were not attempted. Rather, the yields cited for this step were based upon the relative integration of the methine proton and the aromatic protons in the NMR spectrum. Generally, the best yields were obtained by using a 10% excess of chlorinating agent. The side products were the α,α-dihalo compound and starting material. The procedure used was analogous to that reported by Tuleen and co-workers.[16] The reaction does not involve direct attack on the benzylic position, but rather a Pummerer-type rearrangement of an initially formed chlorosulfonium salt.[17] The most probable mechanism involves abstraction of an α proton by the counterion to form an ylide, followed by attack of a chloride ion on the α carbon. Other methods of chlorinating sulfides[18] were investigated, but the yields obtained were not comparable.



An adaptation of the hydrolysis method for 1,3-dithianes[14] was used for the chloro sulfides. In this instance, only one sulfur was present in each molecule, so only 1 equiv of red mercuric oxide was employed. Completion of the reaction once again was designated by the color change of red to white. Workup by stirring over 10% aqueous sodium carbonate not only neutralized the Lewis acid present, but also selectively removed one acetyl group from nitrogen, affording the desired amide.

A comparison of the yields of monoacetylated *o*-aminobenzaldehyde obtained from the two routes is of interest. For all substituents, the amino sulfide **16** was prepared in higher yield than the dithiane derivative **12.** Conversely, for all substituents the hydrolysis sequence to form the aldehyde proceeds in higher yield via the dithiane route. Examination of the overall yields, from aniline to *o*-acetaminobenzaldehyde, shows the chloro sulfide route to be as good as, or better than, the other route in all cases. In choosing between the two routes, one must consider the higher cost and lower average yield of the 1,3-dithiane route against the less elegant chloro sulfide route which involves two extra steps.

Use of 14 in the Synthesis of Carbostyrils

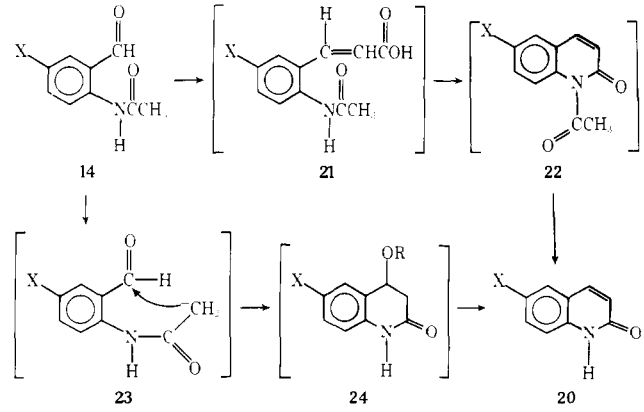
As indicated earlier, *o*-aminobenzaldehydes are useful intermediates in the synthesis of a wide variety of heterocyclics. In 1882 Friedlander[19] reported that when *o*-aminobenzaldehyde was heated for an extended period of time with acetic anhydride and sodium acetate, a cyclized product, carbostyril (**20**), was observed. Although this was not the first reported preparation of carbostyril, it was the first time it had been prepared in this manner. Apparently owing to the difficulty in handling and storing *o*-aminobenzaldehyde, this route was not further pursued. Other methods for the preparation of carbostyril are, for example, the oxidation of quinoline with fused potassium hydroxide at elevated temperatures,[20] lactam formation from various derivatives of 2-aminocinnamic acid,[21] and the hydrolysis of 2-chloroquinoline.[22]

Table IV. Yields Obtained in the Conversion of *o*-Acetylaminobenzaldehydes to Carbostyrils (**20**)

starting material	substituent	carbostyril	% yield
14a	*p*-CH_3	**20a**	80
14b	H	**20b**	79
14c	*p*-Cl	**20c**	76
14d	*p*-CO_2CH_3	**20d**	74

Having the acetyl derivative of *o*-aminobenzaldehyde already in hand, we investigated the synthesis of a series of 6-substituted carbostyrils. The reaction was approached as a modified Perkin condensation.[23] Thus, the substituted acetaminobenzaldehyde, **14,** was combined with 3 equiv of acetic anhydride and 0.8 equiv of freshly fused potassium acetate. This reaction mixture was heated under reflux for 5 h with effective removal of acetic acid by a stream of nitrogen gas. Excellent yields of carbostyrils (otherwise known as 2-quinolones) were obtained as indicated in Table IV. As demonstrated by a perusal of this table, the reaction was relatively insensitive to substituents. The reaction conditions proved to be very critical. Specifically a 3:1 molar ratio of acetic anhydride to 2-acetaminobenzaldehyde was used. Fused potassium acetate was found to give higher yields than sodium acetate, fused or unfused. Increasing the amount of base above the ratio of 0.8:1.0 was found to have no positive effect. The necessary removal of acetic acid during the reaction was accomplished by using an air-cooled condenser and maintaining a flow rate of 20 mL/min of dry nitrogen over the reaction mixture and up through the condenser. This removed acetic acid from the refluxing acetic anhydride.

Mechanistically, the conversion of **14** into **20** in high yield raises some interesting questions. Two mechanisms seem possible. In analogy to the classical Perkin condensation, it could be suggested that **14** first condensed with acetic acid to produce **21,**[23] which cyclized to **22.** Loss of the acetyl group



would then produce **20.** A major complication with this route involves the stereochemistry of the olefinic portion of **21.** By analogy to the related derivative of salicylaldehyde, the *trans*-cinnamic acid derivative should be stable.[23] However, this was not detected. An alternate mechanistic scheme would involve the conversion of **14** into **23** followed by cyclization to

Table V. Yields for the Conversion of 2-(Thiomethoxymethyl)-anilines into 2-Acetaminostyrenes

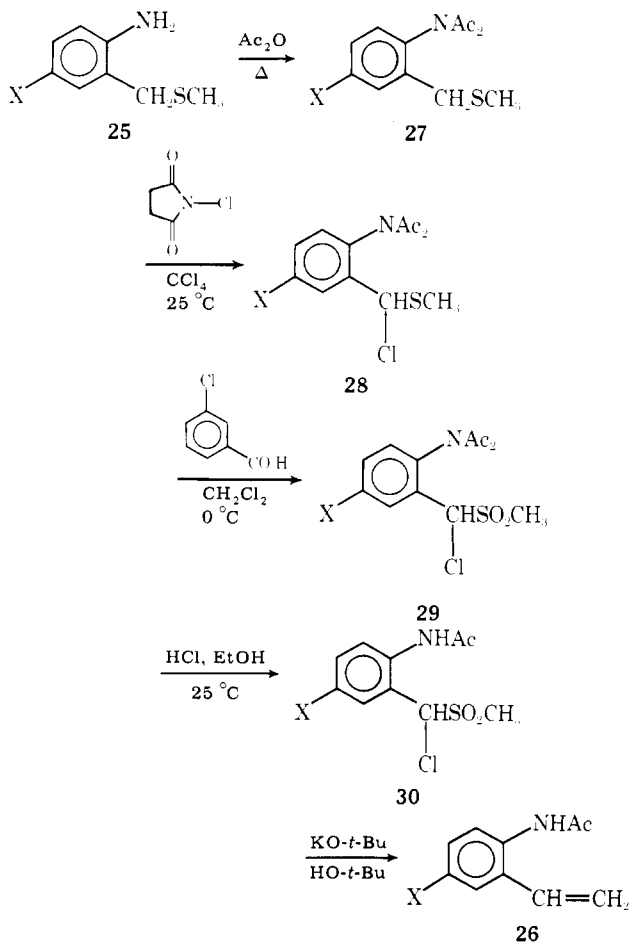
starting sulfide	substituent	% yields 27	29	30	26	overall % yield of **26** from **25**
25a	p-CH_3	99	86	88	77	58
25b	H	97	79	83	76	48
25g	p-$CO_2C_2H_5$	93	87	91	62	46

give **24.** Elimination of water (R = H) or of acetic acid (R = $COCH_3$) from **24** would then produce **20.** An experimental distinction between these two mechanistic paths has not been attempted.

Ortho Vinylation. Synthesis of 2-Acetaminostyrenes

In addition to their widespread use as polymer precursors, styrenes have attracted considerable attention as synthetic intermediates. Of particular interest relative to the present study are 2-acetaminostyrenes, which have previously been shown to be useful intermediates in the synthesis of indoles and quinolines.[24] An obvious limitation to the widespread use of these procedures was the availability of an assortment of 2-acetaminostyrenes. Our earlier work on the selective ortho substitution of aromatic amines indicated to us that a ready source of 2-acetaminostyrenes might be derived from our earlier work on the synthesis of 2-(thiomethoxymethyl)anilines by [2,3]-sigmatropic rearrangements.[5] We outline here a relatively straightforward method for the conversion of 2-(thiomethoxymethyl)anilines (**25**) into 2-acetaminostyrenes (**26**).

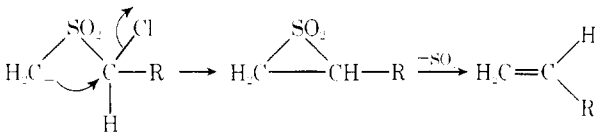
A key step in the conversion of **25** to **26** was the classical Ramberg-Backlund reaction.[25] The overall procedure involved



five steps. The first step was formation of the imide, **27.** It was necessary to protect the amino group because the subsequent step was α-chlorination of the sulfide under conditions where nitrogen would also have been oxidized. Since, eventually, one of the acetyl groups was to be removed, formation of the amide instead of the imide was investigated. For a number of reasons this proved unsatisfactory in the chlorination step: solubility problems, solvent changes, product isolation difficulties, and lower yields. Therefore, the nitrogen was protected as the imide in the same manner as that discussed previously. The yields are shown in Table V.

The imide **27** was chlorinated using N-chlorosuccinimide in carbon tetrachloride at 25 °C by the same procedure as discussed previously to afford the chloro sulfide **28,** which was not isolated. After the succinimide was removed by filtration, the carbon tetrachloride was removed under vacuum at 25 °C. The crude **28** was dissolved in methylene chloride previously dried over molecular sieves, and was added to 2.1–2.5 equiv of 85% m-chloroperbenzoic acid in dry methylene chloride at 0 °C. Stirring overnight at 25 °C afforded the α-chlorosulfone **29** in good yield after workup. Interestingly, when the reaction was carried out in chloroform, large amounts of aldehyde, presumably from hydrolysis of the chloro sulfide, were encountered.

Treatment of **29** directly with base failed to give good yields of the sytrene. However, it was found that prior acid-catalyzed hydrolysis of **29** to the amide **30** resulted in a high yield of the styrene upon base treatment. Thus, **29** was stirred with ethanolic hydrochloric acid for 4 h to give **30.** Treatment of the amide chlorosulfone **30** with 3 equiv of potassium *tert*-butoxide in *tert*-butyl alcohol and tetrahydrofuran afforded high yields of the olefin **26.** Such base-induced rearrangements of α-halosulfones have become known as Ramberg-Backlund rearrangements. Mechanistically, this rearrangement involves



the formation of an episulfone by intramolecular 1,3-displacement of chloride ion, followed by expulsion of sulfur dioxide.[25] A summary of the yields of all four isolated intermediates is contained in Table V. It should be noted that the overall yields for the five-step sequence range from 46 to 58%. Both electron-donating and electron-withdrawing substituents could be tolerated.

Summary

In conclusion, we have provided new methodology which makes diphenylmethane derivatives, protected o-aminobenzaldehydes, and 2-acetaminostyrenes readily available as synthetic intermediates. In the case of the 2-acetaminobenzaldehydes, we have demonstrated one aspect of their utility in our carbostyril synthesis. Overall, the role of [2,3]-sigmatropic rearrangements in the specific ortho substitution of aromatic amines has been expanded.

Experimental Section

Boiling points and melting points are uncorrected. Nuclear magnetic resonance spectra were determined on a Varian Model A-60A or Jeolco Model MH-100 spectrometer. Infrared spectra were determined on a Perkin-Elmer Model 137 spectrophotometer. Mass spectra were determined on an AEI MS-9 mass spectrometer. Elemental analyses were carried out by Scandinavian Microanalytical Laboratory, Herlev, Denmark.

General Procedure for the Preparation of 2-Aminodiphenylthiophenoxymethanes. To a rapidly stirred solution of 0.025 mol of an aniline and 0.050–0.080 mol of benzyl phenyl sulfide in 300 mL of dry acetonitrile and 100 mL of methylene chloride under nitrogen at −40

°C was added dropwise 3.5 g (0.032 mol) of *tert*-butyl hypochlorite in 25 mL of methylene chloride at −78 °C in diffuse light. The reaction mixture was stirred for 4 h at −40 °C, then allowed to warm slowly to −20 °C over a 3-h period. Sodium methoxide (7.0 g, 0.13 mol)[26] in 50 mL of methanol at 25 °C was added and the reaction mixture was stirred for 1 h, during which the reaction mixture warmed to room temperature. The solution was concentrated in vacuo, 250–500 mL of dry toluene and 30–50 mL of triethylamine were added, and the solution was refluxed for 12 h. The solution was concentrated in vacuo, 100 mL of water was added, and the reaction mixture was extracted with five 100-mL portions of methylene chloride. The combined organic phases were washed with 50 mL of 5% aqueous sodium hydroxide and 100 mL of saturated sodium chloride solution, dried over anhydrous magnesium sulfate, and filtered. The solvent was removed in vacuo, leaving an oil which was chromatographed on 300–500 g of Fisher basic alumina (activity I) using ether–pentane or ether as eluant.

2-Amino-5-methyldiphenylthiophenoxymethane (3a). Using the general procedure with 2.7 g of *p*-toluidine (**1a**) we obtained 5.7 g (73% based on **1a**) of **3a** as a yellow oil: NMR (CCl_4) δ 7.6–6.3 (13 H, m), 5.54 (1 H, s), 3.85–3.6 (2 H, br s), 2.15 (3 H, s). The corresponding *p*-nitrobenzamide (**3a'**) was prepared from the amino sulfide and *p*-nitrobenzoyl chloride: mp 156–157 °C; NMR ($CDCl_3$) δ 8.8–6.8 (18 H, m), 5.66 (1 H, s), 2.25 (3 H, s); mass spectrum *m/e* (rel intensity) 454 (1), 345 (100), 218 (4), 194 (32), 150 (12).

Anal. Calcd for $C_{27}H_{22}N_2O_3S$: C, 71.35; H, 4.88; N, 6.16. Found: C, 71.37; H, 5.04; N, 5.90.

2-Aminodiphenylthiophenoxymethane (3b). According to the general procedure, 2.3 g of aniline (**1b**) gave 5.2 g (72% yield based on **1b**) of **3b.** Recrystallization from ethanol–water gave light yellow crystals: mp 64.0–65.5 °C; NMR (CCl_4) δ 7.6–6.3 (14 H, m), 5.49 (1 H, s), and 4.0–3.6 (2 H, br s).

Anal. Calcd for $C_{19}H_{17}NS$: C, 78.31; H, 5.88; N, 4.81. Found: C, 78.28; H, 5.85; N, 4.88.

2-Amino-5-chlorodiphenylthiophenoxymethane (3c). Using the general procedure, 3.2 g of *p*-chloroaniline (**1c**) gave 7.6 g (93% yield based on **1c**) of **3c** as a light yellow oil: NMR (CCl_4) δ 7.5–6.3 (13 H, m), 5.39 (1 H, s), 3.85–3.60 (2 H, br s). The corresponding *p*-nitrobenzamide (**3c'**) was prepared from the amino sulfide and *p*-nitrobenzoyl chloride: mp 159–161 °C; NMR ($CDCl_3$) δ 8.8–7.0 (18 H, m), 5.62 (1 H, s).

Anal. Calcd for $C_{26}H_{19}ClN_2O_3S$: C, 65.75; H, 4.03; N, 5.90. Found: C, 65.68; H, 4.10; N, 5.84.

2-Amino-5-carbomethoxydiphenylthiophenoxymethane (3d). According to the general procedure 4.1 g of *p*-carbomethoxyaniline (**1d**) gave 5.3 g (61% yield based on **1d**) of **3d** as an oil which solidified on standing. Recrystallization from methylcyclohexane–tetrahydrofuran gave white crystals: mp 89–91 °C; NMR ($CDCl_3$) δ 8.0–6.5 (13 H, m), 5.54 (1 H, s), 4.5–3.7 (2 H, br s), and 3.80 (3 H, s).

Anal. Calcd for $C_{21}H_{19}NO_2S$: C, 72.18; H, 5.48; N, 4.01. Found: C, 72.39; H, 5.69; N, 3.90.

2-Amino-5-nitrodiphenylthiophenoxymethane (3e). According to the general procedure 3.5 g of *p*-nitroaniline (**1e**) yielded 5.5 g (65% based on **1e**) of **3e** as yellow crystals: mp 103–105 °C; NMR ($CDCl_3$) δ 8.2–6.5 (13 H, m), 5.50 (1 H, s), 4.8–4.6 (2 H, br s).

Anal. Calcd for $C_{19}H_{16}N_2O_2S$: C, 67.84; H, 4.79; N, 8.33. Found: C, 67.69; H, 4.97; N, 8.30.

2-Amino-5-methyldiphenylmethane (6a). To a rapidly stirred suspension of 0.50 g (13.2 mmol) of lithium aluminum hydride in 100 mL of dry ether under nitrogen at room temperature was added 2.0 g (6.6 mmol) of 2-amino-5-methyldiphenylthiophenoxymethane (**3a**) in 30 mL of ether. The suspension was stirred for 12 h at 25 °C. Sulfuric acid (0.5 N, 100 mL) was added and the product was extracted with five 100-mL portions of ether. The combined organic phases were washed with 50 mL of 5% aqueous sodium hydroxide and 100 mL of saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated. Distillation of the residue gave 1.16 g (89%) of 2-amino-5-methyldiphenylmethane (**6a**), bp 124–127 °C (0.27 mm) [lit.[27] bp 150–170 °C (0.1 mm)].

2-Aminodiphenylmethane (6b). To a rapidly stirred suspension of 0.20 g (5.25 mmol) of lithium aluminum hydride in 50 mL of dry ether under nitrogen at room temperature was added 1.0 g (3.45 mmol) of 2-aminodiphenylthiophenoxymethane (**3b**) in 20 mL of ether. The suspension was stirred for 12 h at 25 °C. Sulfuric acid (0.5 N, 50 mL) was added, and the product was extracted with five 50-mL portions of ether. The combined organic phases were washed with 50 mL of 5% aqueous sodium hydroxide and 100 mL of saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated. Distillation of the residue gave 0.60 g (95%) of 2-aminodiphenylmethane (**6b**), bp 102 °C (0.07 mm) [lit.[28] bp 184–185 °C (20 mm)]. Crystallization from methylcyclohexane gave mp 52–53 °C (lit.[28] mp 52–54 °C).

2-Amino-5-chlorodiphenylmethane (6c). To a rapidly stirred suspension of 0.25 g (6.6 mmol) of lithium aluminum hydride in 100 mL of dry ether under nitrogen at room temperature was added 2.0 g (6.15 mmol) of 2-amino-5-chlorodiphenylthiophenoxymethane (**3c**) in 30 mL of ether. The suspension was stirred for 12 h at 25 °C. Sulfuric acid (0.5 N, 100 mL) was added and the product was extracted with five 100-mL portions of ether. The combined organic phases were washed with 100 mL of 5% aqueous sodium hydroxide and 100 mL of saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated. Distillation of the residue gave 1.09 g (83%) of 2-amino-5-chlorodiphenylmethane (**6c**), bp 135 °C (0.07 mm) [lit.[27] bp 140–145 °C (0.1 mm)].

5-Carbomethoxy-*N,N*-diacetyl-2-[α-phenyl-α-(phenylthio)]methylaniline (7d). Into a 100-mL, round-bottomed flask were placed 50 mL of acetic anhydride and 2.3 g (6.6 mmol) of 5-carbomethoxy-α-phenyl-α-(phenylthio)-*o*-toluidine. The solution was heated under reflux for 12 h, then most of the acetic anhydride was removed by distillation. Trituration of the residue with 20 mL of water produced a white solid. The solid was dissolved in 150 mL of methylene chloride, washed with two 50-mL portions of water, 50 mL of a 10% aqueous sodium bicarbonate solution, and 50 mL of saturated sodium chloride solution, and dried over anhydrous magnesium sulfate. The solution was filtered and concentrated to give a light yellow oil which crystallized upon standing. Recrystallization from methylcyclohexane and tetrahydrofuran yielded 2.50 g (88%) of the *N,N*-diacetyl derivative: mp 136.0–138.5 °C; NMR ($CDCl_3$) δ 8.3–7.1 (13 H, m), 5.44 (1 H, s), 3.92 (3 H, s), 2.33 (3 H, s), and 1.79 (3 H, s).

Anal. Calcd for $C_{25}H_{23}NO_4S$: C, 69.26; H, 5.35; N, 3.23. Found: C, 69.39; H, 5.37; N, 3.18.

***N*-Acetyl-5-carbomethoxy-2-aminodiphenylmethane (9d).** Into a 250-mL flask equipped with a magnetic stirrer were placed 100 mL of absolute ethanol, 50 mL of tetrahydrofuran, and 2.25 g (5.2 mmol) of 4-carbomethoxy-*N,N*-diacetyl-2-methyl-α-phenyl-α-(phenylthio)aniline (**7d**). Under an atmosphere of nitrogen, 4 teaspoonsful (ca. 15 g) of a slurry of W-2 Raney nickel in absolute ethanol was added and the suspension was stirred vigorously for 8 min at 25 °C. Methylene chloride (50 mL) was added, the suspension was allowed to settle, and the solvent was decanted and filtered through fluted filter paper. The catalyst was washed with six 50-mL portions of methylene chloride and 100 mL of a 10% ammonium hydroxide–ethanol solution. The combined filtrates were concentrated in vacuo, dissolved in 150 mL of methylene chloride, washed with two 50-mL portions of water and 50 mL of saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated to give 1.64 g (93%) of white crystals of desulfurized material. This material was taken up in 30 mL of absolute methanol containing 3.0 g of sodium methoxide and heated under reflux for 12 h. The cooled solution was neutralized with 6 N hydrochloric acid, concentrated, and extracted with four 50-mL portions of methylene chloride. The combined extracts were washed with 50 mL of water and 50 mL of a saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo. Recrystallization from methylcyclohexane–tetrahydrofuran afforded 1.34 g (91%) of white crystals: mp 170–171 °C; NMR ($CDCl_3$) δ 8.2–7.9 (3 H, m), 7.6–7.0 (6 H, m), 4.07 (2 H, s), 3.93 (3 H, s), and 1.96 (3 H, s); exact mass calcd for $C_{17}H_{17}NO_3$, *m/e* 283.1208, obsd *m/e* 283.1211.

2-Amino-5-carbomethoxydiphenylmethane (6d). Into a 250-mL flask equipped with a magnetic stirrer were placed 100 mL of absolute ethanol, 50 mL of tetrahydrofuran, and 2.25 g (5.2 mmol) of 4-carbomethoxy-*N,N*-diacetyl-2-methyl-α-phenyl-α-(phenylthio)aniline (**7d**). Under an atmosphere of nitrogen, 4 teaspoonsful (ca. 15 g) of a slurry of W-2 Raney nickel in absolute ethanol was added and the suspension was stirred vigorously for 8 min at 25 °C. Methylene chloride (50 mL) was added, the suspension was allowed to settle, and the solvent was decanted and filtered through fluted filter paper. The catalyst was washed with six 50-mL portions of methylene chloride and 100 mL of a 10% ammonium hydroxide–ethanol solution. The combined filtrates were concentrated in vacuo, dissolved in methylene chloride, washed with two 50-mL portions of water and 50 mL of saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated to give 1.64 g (93%) of white crystals of the desulfurized material, **8d.** This material was immediately taken

up in 30 mL of absolute methanol and 10 mL of boron trifluoride-methanol complex (Aldrich) and heated under reflux for 16 h with a Newman condenser to remove methyl acetate. After cooling, the solution was poured into 50 mL of saturated sodium bicarbonate solution and extracted with five 50-mL portions of methylene chloride. The combined extracts were washed with 50 mL of water and 50 mL of saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated. The white residue was chromatographed on Fisher basic alumina (activity I) using methylene chloride as eluant to yield 1.17 g (90%) of a colorless liquid: bp 164–165 °C (0.07 mm); mp 66–67 °C; NMR ($CDCl_3$) δ 7.9–6.4 (8 H, m), 3.86 (2 H, s), 3.79 (3 H, s), and 4.1–3.5 (2 H, br s).

Anal. Calcd for $C_{15}H_{15}NO_2$: C, 74.67; H, 6.27; N, 5.80. Found: C, 74.72; H, 6.47; N, 5.94.

2-Amino-5-methylbenzaldehyde Trimethylene Mercaptal (12a). To a rapidly stirred solution of 5.4 g (0.050 mol) of *p*-toluidine (**1a**) and 6.0 g (0.050 mol) of 1,3-dithiane in 600 mL of dry methylene chloride under nitrogen at −78 °C was added dropwise 5.4 g (0.050 mol) of *tert*-butyl hypochlorite in 25 mL of dry methylene chloride in diffuse light. The reaction mixture was stirred for 6 h at −78 °C. A solution of 5.4 g (0.100 mol) of sodium methoxide in 50 mL of absolute methanol at 25 °C was added while keeping the temperature below −70 °C. The reaction mixture was stirred for 30 min at −78 °C, then the cooling bath was removed, and the stirred solution was allowed to warm to room temperature. The solvent was removed in vacuo, 300 mL of dry toluene was added, and the suspension was heated under reflux for 12 h. After cooling, the solution was concentrated in vacuo, and the residue was dissolved in 300 mL of methylene chloride, washed with two 100-mL portions of water and 100 mL of saturated sodium chloride solution, and dried over anhydrous magnesium sulfate. The solution was filtered and concentrated in vacuo leaving 12.1 g of a brown oil. After low-boiling materials were removed by distillation, the residue was chromatographed on 450 g of Fisher basic alumina (activity I) using 0.5% methanol–ether. This yielded 3.8 g of a mixture which was then distilled under reduced pressure to yield 2.8 g (25%) of 2-amino-5-methylbenzaldehyde trimethylene mercaptal (**12a**): bp 188–191 °C (0.10 mm); $n^{24.8}{}_D$ 1.6500; NMR ($CDCl_3$) δ 7.14 (1 H, d, J = 2 Hz), 6.92 (1 H, d of d, J = 2, 8 Hz), 6.57 (1 H, d, J = 8 Hz), 5.27 (1 H, s), 3.93 (2 H, br s), 3.2–2.7 (4 H, m), 2.22 (3 H, s), and 2.3–1.7 (2 H, m); exact mass for $C_{11}H_{15}NS_2$, calcd *m/e* 225.0646, obsd *m/e* 225.0649.

Anal. Calcd for $C_{11}H_{15}NS_2$: C, 58.62; H, 6.71; N, 6.21. Found: C, 58.83; H, 6.72; N, 6.18.

***o*-Aminobenzaldehyde Trimethylene Mercaptal (12b).** To a rapidly stirred solution of 4.6 g (0.050 mol) of aniline (**1b**) in 500 mL of dry methylene chloride under nitrogen at −78 °C was added dropwise 5.4 g (0.050 mol) of *tert*-butyl hypochlorite in 25 mL of dry methylene chloride at −78 °C in diffuse light. The reaction mixture was stirred for 15 min at −78 °C. To this solution was added 6.0 g (0.050 mol) of 1,3-dithiane in 40 mL of dry methylene chloride, and the reaction mixture was stirred for 4 h at −78 °C. A solution of 5.4 g (0.100 mol) of sodium methoxide in 50 mL of absolute methanol at 25 °C was added, keeping the temperature below −70 °C. The reaction mixture was stirred for 30 min at −78 °C, then the cooling bath was removed and the stirred solution was allowed to warm to room temperature. The solvent was removed in vacuo, 300 mL of dry toluene was added, and the solution was heated under reflux for 12 h. After cooling, the solution was concentrated in vacuo, and the residue was dissolved in 300 mL of methylene chloride, washed with two 100-mL portions of water and 100 mL of saturated sodium chloride solution, and dried over anhydrous magnesium sulfate. The solution was filtered and concentrated in vacuo leaving 11.4 g of an orange oil which was chromatographed on 450 g of Fisher basic alumina (activity I). The product was eluted with 0.5% methanol–ether. Recovered was 5.7 g (54%) of *o*-aminobenzaldehyde trimethylene mercaptal (**12b**) as an oil which solidified upon standing. Recrystallization from methylcyclohexane–ether gave white crystals: mp 114–115 °C; NMR ($CDCl_3$) δ 7.4–6.8 (4 H, m), 5.21 (1 H, s), 3.9–3.7 (2 H, br s), 3.2–2.6 (4 H, m), and 2.2–1.6 (2 H, m); exact mass for $C_{10}H_{13}NS_2$, calcd *m/e* 211.0489, obsd *m/e* 211.0492.

Anal. Calcd for $C_{10}H_{13}NS_2$: C, 56.83; H, 6.20; N, 6.63. Found: C, 56.89; H, 6.27; N, 6.61.

2-Amino-5-chlorobenzaldehyde Trimethylene Mercaptal (12c). To a rapidly stirred solution of 6.4 g (0.050 mol) of *p*-chloroaniline (**1c**) in 600 mL of dry methylene chloride under nitrogen at −78 °C was added dropwise 5.4 g (0.050 mol) of *tert*-butyl hypochlorite in 25 mL of dry methylene chloride in diffuse light. The reaction mixture was stirred for 20 min at −78 °C. To this solution was added 6.0 g (0.050 mol) of 1,3-dithiane in 50 mL of dry methylene chloride, and the reaction mixture was stirred for 6 h at −78 °C. A solution of 3.0 g (0.055 mol) of sodium methoxide in 35 mL of absolute methanol at 25 °C was added, while keeping the temperature below −70 °C. The reaction mixture was stirred for 30 min at −78 °C, then the cooling bath was removed and the stirred solution was allowed to warm to room temperature. The solvent was removed in vacuo, 300 mL of dry toluene was added, and the suspension was heated under reflux for 12 h. After cooling, the solution was concentrated in vacuo and the residue was dissolved in 300 mL of methylene chloride, washed with two 100-mL portions of water and 100 mL of saturated sodium chloride solution, and dried over anhydrous magnesium sulfate. The solution was filtered and concentrated leaving 12.6 g of a yellow-orange oil. Low-boiling materials were removed by distillation. The residue was chromatographed on 450 g of Fisher basic alumina (activity I) using 1% methanol–ether as eluant. Recovered was 3.65 g (30%) of 2-amino-5-chlorobenzaldehyde trimethylene mercaptal (**12c**) as a light yellow oil: $n^{24.8}{}_D$ 1.6647; NMR ($CDCl_3$) δ 7.33 (1 H, d, J = 2.5 Hz), 7.07 (1 H, d of d, J = 2.5, 8.5 Hz), 6.60 (1 H, d, J = 8.5 Hz), 5.24 (1 H, s), 4.12 (2 H, br s), 3.2–2.6 (4 H, m), and 2.3–1.7 (2 H, m); exact mass for $C_{10}H_{12}ClNS_2$, calcd *m/e* 245.0100, obsd *m/e* 245.0103.

Anal. Calcd for $C_{10}H_{12}ClNS_2$: C, 48.87; H, 4.92; N, 5.70. Found: C, 48.93; H, 4.98; N, 5.59.

2-Amino-5-carbomethoxybenzaldehyde Trimethylene Mercaptal (12d). To a rapidly stirred solution of 3.76 g (0.025 mol) of methyl 4-aminobenzoate (**1d**) and 4.0 g (0.033 mol) of 1,3-dithiane in 400 mL of dry methylene chloride under nitrogen at −79 °C was added dropwise 2.7 g (0.025 mol) of *tert*-butyl hypochlorite in 25 mL of dry methylene chloride in diffuse light. The reaction mixture was stirred for 7 h at −78 °C. A solution of 2.7 g (0.050 mol) of sodium methoxide in 35 mL of absolute methanol at 25 °C was added, keeping the temperature below −70 °C. The reaction mixture was stirred for 30 min at −78 °C, then the cooling bath was removed, and the stirred solution was allowed to warm to room temperature. The solvent was removed in vacuo, 300 mL of dry toluene was added, and the solution was heated under reflux for 12 h. After cooling, the solution was concentrated in vacuo, and the residue was dissolved in 300 mL of methylene chloride, washed with two 100-mL portions of water and 100 mL of saturated sodium chloride solution, and dried over anhydrous magnesium sulfate. The solution was filtered and concentrated in vacuo leaving 8.8 g of orange solid. This material was chromatographed on 450 g of Fisher basic alumina (activity I) using methanol–ether as eluant, which gave 2.15 g (32%) of 2-amino-5-carbomethoxybenzaldehyde trimethylene mercaptal (**12d**) as a light yellow oil which crystallized upon scratching. Sublimation and recrystallization from tetrahydrofuran–cyclohexane gave light yellow crystals: mp 180.5–181.5 °C; NMR ($CDCl_3$) δ 7.99 (1 H, d, J = 2 Hz), 7.73 (1 H, d of d, J = 2, 8.5 Hz), 6.72 (1 H, d, J = 8.5 Hz), 5.36 (1 H, s), 5.2–4.6 (2 H, br s), 3.82 (3 H, s), 3.3–2.7 (4 H, m), 2.3–1.7 (2 H, m); exact mass for $C_{12}H_{15}NO_2S_2$, calcd *m/e* 269.0544, obsd *m/e* 269.0548.

Anal. Calcd for $C_{12}H_{15}NO_2S_2$: C, 53.50; H, 5.61; N, 5.20. Found: C, 53.35; H, 5.67; N, 5.10.

General Procedure for the Acetylation of 2-Aminobenzaldehyde Trimethylene Mercaptals. Into a 25-mL round-bottomed flask were placed approximately 1–3 mmol of **12**, 5 mL of acetic anhydride, and 3 mL of dry pyridine.[29] The solution was heated on a steam bath for 5 min, allowed to cool, and poured into 50 mL of water, whereupon the product precipitated. Sodium carbonate was added until the solution was basic. The product was collected by filtration, washed with water, and dried under vacuum. The product was then further purified by recrystallization.

2-Acetamino-5-methylbenzaldehyde Trimethylene Mercaptal (13a). According to the general procedure 300 mg of **12a** gave 320 mg (90% yield) of **13a**, mp 150–160 °C. Further recrystallization afforded fine, white needles: mp 159–160 °C; NMR ($CDCl_3$) δ 8.35 (1 H, br s), 7.90 (1 H, m), 7.4–7.0 (2 H, m), 5.34 (1 H, s), 3.3–2.8 (4 H, m), 2.34 (3 H, s), 2.22 (3 H, s), 2.3–1.7 (2 H, m); exact mass for $C_{13}H_{17}NOS_2$, calcd *m/e* 267.0740, obsd *m/e* 267.0744.

Anal. Calcd for $C_{13}H_{17}NOS_2$: C, 58.39; H, 6.41; N, 5.24. Found: C, 58.39; H, 6.42; N, 5.22.

2-Acetaminobenzaldehyde Trimethylene Mercaptal (13b). Using the general procedure, we converted 200 mg of **12b** into 230 mg (95% yield) of **13b**, mp 140–145 °C. Recrystallization from cyclohexane–

tetrahydrofuran afforded fine, white needles: mp 152–153 °C; NMR ($CDCl_3$) δ 8.50 (1 H, br s), 8.05 (1 H, m), 7.6–7.0 (3 H, m), 5.36 (1 H, s), 3.3–2.7 (4 H, m), 2.21 (3 H, s), 2.4–1.6 (2 H, m); exact mass for $C_{12}H_{15}NOS_2$, calcd *m/e* 253.0595, obsd *m/e* 253.0598.

Anal. Calcd for $C_{12}H_{15}NOS_2$: C, 56.88; H, 5.97; N, 5.53. Found: C, 57.10; H, 5.96; N, 5.57.

2-Acetamino-5-chlorobenzaldehyde Trimethylene Mercaptal (13c). According to the general procedure 650 mg of **12c** gave 690 mg (91% yield) of **13c,** mp 180–187 °C. Recrystallization from cyclohexane–tetrahydrofuran produced fine, white needles: mp 204–205 °C; NMR ($CDCl_3$) δ 8.40 (1 H, br s), 8.05 (1 H, d, J = 9 Hz), 7.50–7.20 (2 H, m), 5.32 (1 H, s), 3.3–2.7 (4 H, m), 2.22 (3 H, s), 2.3–1.7 (2 H, m); exact mass for $C_{12}H_{14}ClNOS_2$, calcd *m/e* 287.0205, obsd *m/e* 287.0210.

Anal. Calcd for $C_{12}H_{14}ClNOS_2$: C, 50.08; H, 4.90; N, 4.87. Found: C, 49.98; H, 4.89; N, 4.79.

2-Acetamino-5-carbomethoxybenzaldehyde Trimethylene Mercaptal (13d). According to the general procedure 2.15 g of **12d** gave a crude product, **13d,** which on recrystallization from ethanol–water yielded 2.30 g (92%) of material, mp 121–127 °C. Further recrystallization from cyclohexane–tetrahydrofuran afforded fine, white needles: mp 129–130 °C; NMR ($CDCl_3$) δ 8.80 (1 H, br s), 8.37 (1 H, d, J = 9 Hz), 8.2–7.8 (2 H, m), 5.44 (1 H, s), 3.90 (3 H, s), 3.3–2.8 (4 H, m), 2.28 (3 H, s), 2.4–1.7 (2 H, m); exact mass for $C_{14}H_{17}NO_3S_2$, calcd *m/e* 311.0650, obsd *m/e* 311.0655.

Anal. Calcd for $C_{14}H_{17}NO_3S_2$: C, 54.00; H, 5.50; N, 4.50. Found: C, 53.99; H, 5.57; N, 4.50.

General Procedure for the Hydrolysis of 2-Acetaminobenzaldehyde Trimethylene Mercaptals. Into a 5-mL, round-bottomed flask equipped with a magnetic stirrer and nitrogen atmosphere were placed 0.7–0.8 mmol of red mercuric oxide, 0.7–0.8 mmol of boron trifluoride etherate, and 2 mL of 15% aqueous tetrahydrofuran. To this stirred suspension under nitrogen was added 0.35–0.40 mmol of the trimethylene mercaptal, **13,** in a minimum amount of tetrahydrofuran. The reaction mixture was stirred for 1 h at 25 °C and poured into 10 mL of ethyl ether, and 2 mL of 10% sodium carbonate solution was added. After mixing, the organic phase was separated, and the aqueous layer was extracted with two 5-mL portions of ether. The combined organic phases were washed with two 5-mL portions of water and 5 mL of saturated sodium chloride solution and dried over anhydrous magnesium sulfate. The reaction mixture was then filtered and concentrated under reduced pressure.

2-Acetamino-5-methylbenzaldehyde (14a). According to the general procedure, 100 mg of **13a** gave 70 mg of **14b,** mp 72–77 °C. Recrystallization from cyclohexane–tetrahydrofuran followed by sublimation gave 61 mg (92% yield) of **14b,** mp 77.0–78.5 °C. This material gave spectral data identical with those obtained from a sample prepared by an alternate route (vide post).

2-Acetaminobenzaldehyde (14b). Using the general procedure, we converted 100 mg of **13b** into 54 mg (85% yield) of **14b,** which was collected as white crystals, mp 66–69 °C. This material was spectrally identical with a sample prepared by an alternate procedure (vide post).

2-Acetamino-5-chlorobenzaldehyde (14c) According to the general procedure, 110 mg of **13c** gave 74 mg of crude aldehyde, mp 148–153 °C. Recrystallization from cyclohexane–tetrahydrofuran, followed by sublimation, afforded 66 mg (88% yield) of **14c,** mp 151.0–153.5 °C. IR and NMR spectral data were identical with those of a sample of **14c** prepared by an alternate route (vide post).

2-Acetamino-5-carbomethoxybenzaldehyde (14d). According to the general procedure, 110 mg of **13d** yielded 67 mg (86%) of **14d,** mp 139–142 °C. This material was spectrally identical with a sample prepared by an alternate procedure (vide post).

General Procedure for the *o*-Thiophenoxymethylation of Anilines. To a rapidly stirred solution of 0.10 mol of an aniline (**1**) and 0.16 mol of thioanisole in 600 mL[30] of a 3:1 mixture of dry acetonitrile and methylene chloride under nitrogen at −40 °C was added dropwise 0.1 mol of *tert*-butyl hypochlorite in 25 mL of methylene chloride in diffuse light. The reaction mixture was stirred for 6 h at −40 °C, followed by rapid addition of 0.20 mol of sodium methoxide in 75 mL of absolute methanol. The reaction mixture was stirred for 1 h, while it was allowed to warm to room temperature. The solution was concentrated under reduced pressure. The residue was dissolved in 500 mL of dry toluene; 50 mL of triethylamine was added and the reaction mixture was refluxed for 12 h. After cooling, the solution was concentrated in vacuo and the residue was dissolved in 300 mL of ethyl ether, washed with three 100-mL portions of water and 100 mL of saturated sodium chloride solution, and dried over anhydrous magnesium sulfate. After filtration, the solution was concentrated under reduced pressure to yield crude **16.**

4-Methyl-2-(thiophenoxymethyl)aniline (16a). According to the general procedure, 10.7 g of *p*-toluidine gave a brown oil which solidified on standing. After the unreacted starting materials were removed by distillation, the solid residue was recrystallized from ethanol–water to give 14.5 g (63% yield) of **16a,** mp 70–72 °C. Recrystallization raised the melting point to 77–78 °C: NMR ($CDCl_3$) δ 7.5–6.4 (8 H, m), 4.03 (2 H, s), 3.71 (2 H, s), 2.17 (3 H, s); exact mass for $C_{14}H_{15}NS$, calcd *m/e* 229.0925, obsd *m/e* 229.0929.

Anal. Calcd for $C_{14}H_{15}NS$: C, 73.32; H, 6.59; N, 6.11. Found: C, 73.18; H, 6.65; N, 6.05.

2-(Thiophenoxymethyl)aniline (16b). According to the general procedure, 9.3 g of aniline (**1b**) gave a yellow oil which solidified on standing. Unreacted starting materials were removed by distillation up to 110 °C (40 mm). The solid residue was recrystallized twice from ethanol–water to yield 13.0 g (61%) of **16b** as white platelets, mp 79–81 °C (lit.[31] mp 81 °C).

4-Chloro-2-(thiophenoxymethyl)aniline (16c). According to the general procedure, 12.7 g of *p*-chloroaniline (**1c**) gave a brown oil which solidified on standing. Unreacted starting materials were removed by distillation. The solid residue was recrystallized from ethanol–water to give 16.9 g (68% yield) of **16c,** mp 67–71 °C. Recrystallization from the same solvent gave mp 72–73 °C: NMR ($CDCl_3$) δ 7.50–6.30 (8 H, m), 3.91 (2 H, s), 3.83 (2 H, s); exact mass for $C_{13}H_{12}ClNS$, calcd *m/e* 249.0379, obsd *m/e* 249.0383.

Anal. Calcd for $C_{13}H_{12}ClNS$: C, 62.52; H, 4.84; N, 5.61. Found: C, 62.71; H, 4.87; N, 5.55.

4-Carbomethoxy-2-(thiophenoxymethyl)aniline (16d). According to the general procedure, 15.1 g of methyl 4-aminobenzoate (**1d**) gave a light orange solid. After removal of the unreacted starting materials by distillation, the residue was triturated with hexane to produce 15.65 g (58% yield) of **16d** as a light yellow solid, mp 66–71 °C. Recrystallization from ethanol–water gave 14.90 g (55%) of white needles: mp 92–93 °C; NMR ($CDCl_3$) δ 7.40–6.40 (8 H, m), 4.25 (2 H, br s), 4.03 (2 H, s), 3.77 (3 H, s); exact mass for $C_{15}H_{15}NO_2S$, calcd *m/e* 273.0823, obsd *m/e* 273.0827.

Anal. Calcd for $C_{15}H_{15}NO_2S$: C, 65.91; H, 5.53; N, 5.12. Found C, 65.89; H, 5.54; N, 5.03.

4-Cyano-2-(thiophenoxymethyl)aniline (16f). According to the general procedure, 11.8 g of *p*-aminobenzonitrile (**1f**) gave a dark brown oil, which solidified on standing. Removal of starting materials by distillation, followed by recrystallization of the residue from tetrahydrofuran–cyclohexane, gave 17.59 g (73% yield) of **16f** as a tan powder, mp 93–106 °C. Recrystallization from ethanol–water gave mp 106.5–107.5 °C: NMR ($CDCl_3$) δ 7.40–6.50 (8 H, m), 4.5 (2 H, br s), 3.92 (2 H, s); exact mass for $C_{14}H_{12}N_2S$, calcd *m/e* 240.0721, obsd *m/e* 240.0724.

Anal. Calcd for $C_{14}H_{12}N_2S$: C, 69.97; H, 5.03; N, 11.66. Found: C, 70.21; H, 5.09; N, 11.61.

***N,N*-Diacetyl-2-(thiophenoxymethyl)aniline (17b).** To 25 mL of acetic anhydride was added 10.75 g (0.050 mol) of **16b.** The solution was heated under reflux for 24 h. Acetic acid and residual acetic anhydride were removed by distillation at reduced pressure, leaving a light brown oil. The oil was purified by molecular distillation, yielding 14.5 g (97%) of a water-white liquid: bp 170–173 °C (0.21 mm); NMR ($CDCl_3$) δ 7.40–6.90 (9 H, m), 3.91 (2 H, s), 2.25 (6 H, s); exact mass for $C_{17}H_{17}NO_2S$, calcd *m/e* 299.0980, obsd *m/e* 299.0984.

Anal. Calcd for $C_{17}H_{17}NO_2S$: C, 68.20; H, 5.72; N, 4.68. Found: C, 68.01; H, 5.77; N, 4.63.

Phenyl α-Chloro-2-(*N,N*-diacetyl)aminobenzyl Sulfide (18b). To 9.0 g (0.03 mol) of **18b** in 150 mL of dry carbon tetrachloride at 25 °C was added in portions over 5 min, 4.4 g (0.033 mol, 10% excess) of *N*-chlorosuccinimide. The suspension was stirred at 25 °C for 1 h, then refluxed for 1 h. The succinimide was removed by filtration. The filtrate was concentrated in vacuo to give a light yellow oil which was not further purified. The yield, 75%, was determined by relative integration of signals in the NMR spectrum: NMR ($CDCl_3$) δ 7.9–6.9 (9 H, m), 5.98 (1 H, s), 2.26 (3 H, s), 2.20 (3 H, s); exact mass for $C_{17}H_{16}ClNO_2S$, calcd *m/e* 333.0638, obsd *m/e* 333.0641.

2-Acetaminobenzaldehyde (14b). Into a 250-mL, round-bottomed flask equipped with a magnetic stirrer and containing 100 mL of a 4:1 water–tetrahydrofuran mixture were placed 4.3 g (0.02 mol) of red

mercuric oxide and 2.8 g (0.02 mol) of boron trifluoride etherate complex. To this stirred suspension at 25 °C was added dropwise 6.6 g (0.02 mol) of **18b** in 20 mL of tetrahydrofuran. The reaction mixture was stirred for 25 min. During this time the red color gradually disappeared and a white precipitate formed. The mixture was then stirred for an additional 30 min. The reaction mixture was poured into 200 mL of ethyl ether, and the white precipitate was removed by filtration. The solvent layers were separated. The aqueous phase was extracted with three 50-mL portions of ether. The combined ether fractions were stirred over 200 mL of a 10% aqueous sodium carbonate solution for 5 h. The layers were separated and the aqueous phase was extracted with three 50-mL portions of ether. The combined organic fractions were washed with two 100-mL portions of water and 100 mL of a saturated aqueous sodium chloride solution and dried over anhydrous magnesium sulfate. The drying agent was removed by filtration, and the solvent was removed in vacuo. The residue was distilled to yield 2.95 g (91%) of a clear liquid, bp 99–103 °C (0.24 mm), which solidified upon standing. Recrystallization from ethanol–water gave 2.80 g (87%) of **14b** as white needles, mp 70–71 °C (lit.[19] mp 70–71 °C).

General Procedure for the Direct Conversion of 2-(Thiophenoxymethyl)anilines into 2-Acetaminobenzaldehydes. Into a 100-mL, round-bottomed flask containing 25–30 mL of acetic anhydride was placed 0.03–0.05 mol of 2-(thiophenoxymethyl)aniline (**16**). The solution was refluxed for 12–24 h to produce **17.** After cooling, the acetic acid and residual acetic anhydride were removed by distillation under reduced pressure.

The residual oil was dissolved in 150 mL of carbon tetrachloride. To this stirred solution under nitrogen at 25 °C was added 0.03–0.05 mol (0–10% excess) of *N*-chlorosuccinimide. The suspension was stirred for 1 h at 25 °C and then 1 h at either 25 °C or reflux. The succinimide was removed by filtration, and the filtrate was concentrated in vacuo.

The α-chloro sulfide obtained above was dissolved in 25–30 mL of tetrahydrofuran. This solution was added dropwise to a rapidly stirred suspension of 0.03–0.05 mol (1 equiv) of red mercuric oxide and 0.03–0.05 mol (1 equiv) of boron trifluoride etherate complex in 125–200 mL of 80–85% water–tetrahydrofuran at 25 °C. After approximately 30 min the red color of the mercuric oxide had completely disappeared and a white precipitate had formed. This suspension was stirred for 30–60 min at room temperature, poured into 250–400 mL of ether, and filtered. The organic layer was separated and the aqueous phase was extracted with three 50-mL portions of ether.

The combined organic solutions were stirred vigorously with 200–250 mL of 10% aqueous sodium carbonate solution for 12–18 h. The layers were separated and the aqueous phase was extracted with three 50-mL portions of ether. The combined ether fractions were washed with two 100-mL portions of water and 100 mL of saturated sodium chloride solution and dried over anhydrous magnesium sulfate. The solution was filtered and concentrated in vacuo.

2-Acetamino-5-methylbenzaldehyde (14a). According to the general procedure, 10.0 g of **16a** gave a solid residue, which was sublimed at 0.08 mm to yield 4.0 g (52%) of **14a** as white, crystalline material, mp 73–77 °C. A portion was recrystallized from cyclohexane to give an analytical sample as white needles: mp 78.5–79.5 °C; NMR ($CDCl_3$) δ 11.1 (1 H, br s), 9.92 (1 H, s), 8.7 (1 H, d, J = 9 Hz), 7.5 (1 H, s), 7.45 (1 H, d, J = 9 Hz), 2.37 (3 H, s), 2.25 (3 H, s); exact mass for $C_{10}H_{11}NO_2$, calcd *m/e* 177.0790, obsd *m/e* 177.0792.

Anal. Calcd for $C_{10}H_{11}NO_2$: C, 67.78; H, 6.26; N, 7.90. Found: C, 67.79; H, 6.29; N, 7.95.

2-Acetaminobenzaldehyde (14b). According to the general procedure, 8.7 g of **16b** gave an oil which was distilled at 99–103 °C (0.24 mm) to yield 4.8 g (73%) of **14b,** which solidified on standing, mp 64–66 °C. Recrystallization from ethanol–water gave needles, mp 70–71 °C (lit.[19] mp 70–71 °C).

2-Acetamino-5-chlorobenzaldehyde (14c). According to the general procedure, 10.0 g of **16c** gave a solid residue which was twice sublimed to yield 5.8 g (73%) of **14c** as a light yellow solid, mp 140–146 °C. Recrystallization from absolute ethanol gave 5.3 g: mp 154.5–155.5 °C; NMR ($CDCl_3$) δ 11.1 (1 H, br s), 9.94 (1 H, s), 8.83 (1 H, d, J = 9 Hz), 7.67 (1 H, d, J = 2.5 Hz), 7.60 (1 H, d of d, J = 9, 2.5 Hz), and 2.25 (3 H, s); exact mass for $C_9H_8ClNO_2$, calcd *m/e* 197.0244, obsd *m/e* 197.0246.

Anal. Calcd for $C_9H_8ClNO_2$: C, 54.70; H, 4.08; N, 7.09. Found: C, 54.57; H, 4.15; N, 7.05.

2-Acetamino-5-carbomethoxybenzaldehyde (14d). Through the use of the above-described process, 8.6 g of **16d** gave a solid residue, which was sublimed at 0.1 mm and then recrystallized from absolute ethanol to yield 4.4 g (63%) of **14d** as white crystals, mp 136–140 °C. Recrystallization from tetrahydrofuran–cyclohexane gave white needles: mp 144–145 °C; NMR ($CDCl_3$) δ 11.4 (1 H, br s), 10.05 (1 H, s), 8.87 (1 H, d, J = 9 Hz), 8.42 (1 H, d, J = 2 Hz), 8.24 (1 H, d of d, J = 2, 9 Hz), 3.96 (3 H, s), and 2.30 (3 H, s); exact mass for $C_{11}H_{11}NO_4$, calcd *m/e* 221.0688, obsd *m/e* 221.0690.

Anal. Calcd for $C_{11}H_{11}NO_4$: C, 59.73; H, 5.01; N, 6.33. Found: C, 59.56; H, 5.12; N, 6.38.

2-Acetamino-5-cyanobenzaldehyde (14f). According to the general procedure, 11.3 g of **16f** gave a residue which was sublimed at 0.1 mm to yield 4.3 g (49%) of **14f** as white, crystalline material, mp 151–157 °C. Recrystallization from absolute ethanol gave white needles: mp 156–157 °C; NMR ($CDCl_3$) δ 11.3 (1 H, br s), 10.01 (1 H, s), 8.92 (1 H, d, J = 9 Hz), 8.04 (1 H, d, J = 2 Hz), 7.86 (1 H, d of d, J = 2, 9 Hz), and 2.27 (3 H, s); exact mass for $C_{10}H_8N_2O_2$, calcd *m/e* 188.0586, obsd *m/e* 188.0589.

Anal. Calcd for $C_{10}H_8N_2O_2$: C, 63.83; H, 4.28; N, 14.89. Found: C, 63.62; H, 4.28; N, 14.70.

General Procedure for the Conversion of 2-Acetaminobenzaldehydes into 2-Quinolones (Carbostyrils, 20). Into a 10-mL, round-bottomed flask equipped with a magnetic stirrer were placed 1.0 g (1 equiv) of **14,** 3 equiv of acetic anhydride, and 0.8 equiv of freshly fused potassium acetate. The flask was fitted with a nitrogen inlet tube and air-cooled condenser. A nitrogen flow of 20 mL/min was maintained throughout the reaction in order to remove the acetic acid as it was formed. The reaction mixture was heated to the refluxing temperature of acetic anhydride for 5 h, with the bath temperature being maintained at 170–175 °C (critical). After cooling, the reaction mixture was dissolved in 100–300 mL of chloroform and washed with 50 mL of water, 50 mL of 10% sodium carbonate solution, 50 mL of water, and 50 mL of saturated sodium chloride solution. After drying over anhydrous magnesium sulfate and filtration the solution was concentrated to give the crude product.

6-Methyl-2-quinolone (20a) According to the general procedure, 1.0 g of **14a** gave a crude product which was purified by chromatography on 100 g of Fisher basic alumina (activity 1). Elution with 10% methanol–methylene chloride gave 0.72 g (80% yield) of 6-methyl-2-quinolone (**20a**), mp 236–238 °C. Sublimation and recrystallization yielded white crystals, mp 237–238.5 °C (lit. mp 237,[32] 236–238,[33] 241 °C[34]). Spectral data agreed with that previously published.[33] Exact mass for $C_{10}H_9NO$: calcd *m/e* 159.0684, obsd *m/e* 159.0686.

2-Quinolone (20b). According to the general procedure, 1.0 g of **14b** gave a crude product which was purified by chromatography on 40 g of silica gel (100–200 mesh). Elution with 0.5% methanol in methylene chloride gave 0.70 g (79% yield) of 2-quinolone (**20b**), mp 193–195 °C. Recrystallization from tetrahydrofuran–cyclohexane gave white crystals, mp 196–197 °C (lit. mp 192–193,[33] 197,[32] 199 °C[34]). Spectral data were identical with those obtained on an authentic sample of 2-quinolone obtained from the Eastman Kodak Co. Exact mass for C_9H_7NO: calcd *m/e* 145.0528, obsd *m/e* 145.0530.

6-Chloro-2-quinolone (20c). Using the general procedure, we converted 1.0 g of **14c** into a crude product which was purified by chromatography on 100 g of Fisher basic alumina (activity 1). Elution with 2% methanol in methylene chloride gave 0.69 g (76% yield) of 6-chloro-2-quinolone, mp 263–264 °C. Recrystallization of a portion of this material from tetrahydrofuran–cyclohexane gave white crystals, mp 266–267 °C (lit. mp 262–263,[35] 266–267,[33] 275 °C[34]). Spectral data agreed with that published previously. Exact mass for C_9H_6ClNO: calcd *m/e* 179.0138, obsd *m/e* 179.0141.

6-Carbomethoxy-2-quinolone (20d). According to the general procedure, 1.0 g of **14d** gave a crude product which was chromatographed on 100 g of Fisher basic alumina (activity 1). Elution with 2% methanol in methylene chloride gave 0.68 g (74% yield) of 6-carbomethoxy-2-quinolone, mp 250–251 °C. Recrystallization from tetrahydrofuran–cyclohexane followed by sublimation produced white crystals: mp 252–253 °C; NMR (Me_2SO-d_6) δ 12.1 (1 H, br s), 8.5–8.0 (3 H, m), 7.42 (1 H, d, J = 9 Hz), 6.64 (1 H, d, J = 9 Hz), 6.64 (1 H, d, J = 9 Hz), 3.90 (3 H, s); exact mass for $C_{11}H_9NO_3$, calcd *m/e* 203.0582, obsd *m/e* 203.0584.

Anal. Calcd for $C_{11}H_9NO_3$: C, 65.02; H, 4.46; N, 6.89. Found: C, 64.47; H, 4.64; N, 6.84.

2-(Thiomethoxymethyl)anilines. The 2-(thiomethoxymethyl)anilines used in this study were prepared according to the method of Gassman

and Gruetzmacher.[5]

***N,N*-Diacetyl-4-methyl-2-(thiomethoxymethyl)aniline (27a).** To 100 mL of acetic anhydride was added 10.0 g (0.06 mol) of 4-methyl-2-(thiomethoxymethyl)aniline. The solution was heated under reflux with stirring for 24 h. Acetic acid and residual acetic anhydride were removed by distillation at reduced pressure. Distillation of the remaining liquid yielded 14.94 g (99%) of a water-white liquid: bp 135–139 °C (0.05 mm); $n^{24.8}$D 1.5575; NMR ($CDCl_3$) δ 7.40–6.95 (3 H, m), 3.50 (2 H, s), 2.39 (3 H, s), 2.30 (6 H, s), 2.02 (3 H, s); exact mass for $C_{13}H_{17}NO_2S$, calcd *m/e* 251.0980, obsd *m/e* 251.0983.

Anal. Calcd for $C_{13}H_{17}NO_2S$: C, 62.12; H, 6.82; N, 5.57. Found: C, 62.07; H, 6.85; N, 5.65.

***N,N*-Diacetyl-2-(thiomethoxymethyl)aniline (27b).** To 30 mL of acetic anhydride was added 15.0 g (0.098 mol) of 2-(thiomethoxymethyl)aniline. The solution was heated under reflux with stirring for 24 h. Acetic acid and residual acetic anhydride were removed by distillation at reduced pressure, leaving a yellow oil. Distillation of this oil provided 22.5 g (97%) of a water-white liquid: bp 131–132 °C (0.03 mm); $n^{24.2}$D 1.5633; NMR ($CDCl_3$) δ 7.6–7.0 (4 H, m), 3.52 (2 H, s), 2.30 (6 H, s), 2.01 (3 H, s); exact mass for $C_{12}H_{15}NO_2S$, calcd *m/e* 237.0823, obsd *m/e* 237.0826.

Anal. Calcd for $C_{12}H_{15}NO_2S$: C, 60.73; H, 6.37; N, 5.90. Found: C, 60.65; H, 6.47; N, 5.91.

4-Carboethoxy-*N,N*-diacetyl-2-(thiomethoxymethyl)aniline (27g). To 100 mL of acetic anhydride was added 20.0 g (0.089 mol) of 4-carboethoxy-2-(thiomethoxymethyl)aniline. The solution was heated under reflux with stirring for 24 h. Upon cooling the product crystallized as a fine, white powder. Filtration and drying yielded 25.5 g (93%) of white, amorphous powder, mp 114–115 °C. An analytical sample was prepared by recrystallizing a small portion twice from benzene–hexane: mp 115–116 °C; NMR ($CDCl_3$) δ 8.17 (1 H, d, *J* = 2 Hz), 8.10 (1 H, d of d, *J* = 2, 9 Hz), 7.24 (1 H, d, *J* = 9 Hz), 4.45 (2 H, q, *J* = 8 Hz), 3.59 (2 H, s), 2.32 (6 H, s), 2.06 (3 H, s), 1.42 (3 H, t, *J* = 8 Hz); exact mass for $C_{15}H_{19}NO_4S$, calcd *m/e* 309.1035, obsd *m/e* 309.1038.

Anal. Calcd for $C_{15}H_{19}NO_4S$: C, 58.23; H, 6.19; N, 4.53. Found: C, 58.27; H, 6.35; N, 4.48.

General Procedure for the Conversion of *N,N*-Diacetyl-2-(thiomethoxymethyl)anilines (27) into 2-(α-Chloro-α-methylsulfonyl)-methyl-*N,N*-diacetylanilines (29). Into a 250-mL, round-bottomed flask containing 150–175 mL of carbon tetrachloride were placed 0.03–0.04 mol of **27** and 0.031–0.042 mol (5–6% excess) of *N*-chlorosuccinimide. The reaction mixture was stirred for 4 h at 25 °C. The succinimide was removed by filtration and washed with two 25-mL portions of carbon tetrachloride. The combined organic phases were concentrated in vacuo at 25 °C.

The crude α-chloro sulfide was dissolved in 30–50 mL of methylene chloride (previously dried over 4 A molecular sieves) and added dropwise to 2.1–2.5 equiv of 85% *m*-chloroperbenzoic acid in 250–300 mL of methylene chloride at 0 °C under nitrogen. The reaction mixture was stirred at 0 °C for 1 h, and then allowed to warm to room temperature with stirring overnight. The *m*-chlorobenzoic acid was removed by filtration and washed with methylene chloride. The combined organic phases were washed with five 100–150-mL portions of 10% sodium carbonate solution, 100 mL of water, and 150 mL of a saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated under reduced pressure to yield a crude product.

2-(α-Chloro-α-methylsulfonyl)methyl-*N,N*-diacetyl-4-methylaniline (29a). According to the general procedure, 10.0 g of **27a** gave a light yellow oil which crystallized from methylene chloride–cyclohexane to yield 10.78 g (86%) of **29a** as prisms, mp 135–141 °C. An analytical sample was prepared by recrystallizing a small portion from benzene–cyclohexane: mp 144–145 °C; NMR ($CDCl_3$) δ 7.83 (1 H, d, *J* = 2 Hz), 7.35 (1 H, d of d, *J* = 2, 8 Hz), 7.05 (1 H, d, *J* = 8 Hz), 5.56 (1 H, s), 3.04 (3 H, s), 2.46 (3 H, s), 2.38 (3 H, s), 2.27 (3 H, s); exact mass for $C_{13}H_{16}ClNO_4S$, calcd *m/e* 317.0489, obsd *m/e* 317.0493.

Anal. Calcd for $C_{13}H_{16}ClNO_4S$: C, 49.13; H, 5.07; N, 4.41. Found: C, 49.21; H, 5.11; N, 4.37.

2-(α-Chloro-α-methylsulfonyl)methyl-*N,N*-diacetylaniline (29b). According to the general procedure, 6.68 g of **27b** gave a residue which was chromatographed on 250 g of silica gel (60–200 mesh). Elution with chloroform provided 6.61 g (79% yield) of a clear oil which crystallized upon scratching, mp 118.5–120.5 °C. An analytical sample of **29b** was prepared by recrystallizing a small portion twice from methylene chloride–cyclohexane: mp 120–121 °C; NMR ($CDCl_3$) δ 8.3–7.1 (4 H, m), 5.59 (1 H, s), 3.05 (3 H, s), 2.41 (3 H, s), 2.27 (3 H, s); exact mass for $C_{12}H_{14}ClNO_4S$, calcd *m/e* 303.0332, obsd *m/e* 303.0337.

Anal. Calcd for $C_{12}H_{14}ClNO_4S$: C, 47.45; H, 4.65; N, 4.61. Found: C, 47.29; H, 4.63; N, 4.57.

4-Carboethoxy-2-(α-chloro-α-methylsulfonyl)methyl-*N,N*-diacetylaniline (29g). According to the general procedure, 8.6 g of **27g** gave a light yellow oil which crystallized from methylene chloride–cyclohexane giving 9.75 g (93% yield) of **29g** as white platelets, mp 112–116 °C. Recrystallization from the same solvent mixture afforded 9.1 g (87%), mp 121–123 °C. An analytical sample was prepared by recrystallizing a small portion three times from benzene–cyclohexane: mp 124.5–125.5 °C; NMR ($CDCl_3$) δ 8.60 (1 H, d, *J* = 2 Hz), 8.14 (1 H, d of d, *J* = 2, 8.5 Hz), 7.24 (1 H, d, *J* = 8.5 Hz), 5.48 (1 H, s), 4.35 (2 H, q, *J* = 8.0 Hz), 3.05 (3 H, s), 2.44 (3 H, s), 2.18 (3 H, s), 1.39 (3 H, t, *J* = 8.0 Hz); exact mass for $C_{15}H_{18}ClNO_6S$, calcd *m/e* 375.0543, obsd *m/e* 375.0546.

Anal. Calcd for $C_{15}H_{18}ClNO_6S$: C, 47.94; H, 4.83; N, 3.73. Found: C, 48.00; H, 4.89; N, 3.71.

General Procedure for the Monodeacetylation of 29. Into a 250-mL, round-bottomed flask containing 100 mL of 95% ethanol and 5 mL of concentrated hydrochloric acid was added 1–2 g of **29.** The solution was stirred for 4 h at room temperature. Solid sodium carbonate was added carefully until gas evolution ceased. Water was added, and the solution was extracted with 300 mL of methylene chloride. The aqueous phase was extracted with two additional 50-mL portions of methylene chloride. The combined organic phases were washed with two 100-mL portions of saturated sodium bicarbonate solution, water, and saturated sodium chloride solution. After drying over anhydrous magnesium sulfate, filtration, and concentration of the filtrate under reduced pressure, the residue was chromatographed on 100 g of silica gel (60–200 mesh) using chloroform as eluant.

***N*-Acetyl-2-(α-chloro-α-methylsulfonyl)methyl-4-methylaniline (30a).** According to the general procedure, 2.00 g of **29a** gave 1.52 g (88% yield) of **30a** as a clear oil which crystallized on standing, mp 162–164 °C. Recrystallization from tetrahydrofuran–methylcyclohexane gave analytically pure material: mp 163–164 °C; NMR ($CDCl_3$) δ 8.08 (1 H, br s) 7.5–7.3 (2 H, m), 7.16 (1 H, d, *J* = 8 Hz), 5.9 (1 H, s), 3.03 (3 H, s), 2.35 (3 H, s), 2.13 (3 H, s); exact mass for $C_{11}H_{14}ClNO_3S$, calcd *m/e* 275.0383, obsd *m/e* 275.0387.

Anal. Calcd for $C_{11}H_{14}ClNO_3S$: C, 47.91; H, 5.12; N, 5.08. Found: C, 47.57; H, 5.19; N, 4.95.

***N*-Acetyl-2-(α-chloro-α-methylsulfonyl)methylaniline (30b).** As described in the general procedure, 1.00 g of **29b** gave 0.71 g (83% yield) of an oil which crystallized on standing, mp 139–141 °C. Analytically pure **30b** was obtained by recrystallization from methylene chloride–cyclohexane: mp 141.5–142.5 °C; NMR ($CDCl_3$) δ 8.20 (1 H, br s), 7.70–7.10 (4 H, m), 5.94 (1 H, s), 3.00 (3 H, s), 2.15 (3 H, s); exact mass for $C_{10}H_{12}ClNO_3S$, calcd *m/e* 261.0226, obsd *m/e* 261.0229.

Anal. Calcd for $C_{10}H_{12}ClNO_3S$: C, 45.89; H, 4.62; N, 5.35. Found: C, 45.79; H, 4.70; N, 5.28.

***N*-Acetyl-4-carboethoxy-2-(α-chloro-α-methylsulfonyl)methylaniline (30g).** According to the general procedure, 1.00 g of **29g** gave 0.80 g (91% yield) of **30g,** mp 108–110 °C. Recrystallization from tetrahydrofuran–methylcyclohexane gave material: mp 111–112 °C; NMR ($CDCl_3$) δ 8.56 (1 H, br s), 8.22 (1 H, d, *J* = 2 Hz), 8.02 (1 H, d of d, *J* = 2, 10 Hz), 7.84 (1 H, d, *J* = 10 Hz), 6.03 (1 H, s), 4.33 (2 H, q, *J* = 8 Hz), 3.06 (3 H, s), 2.17 (3 H, s), 1.38 (3 H, t, *J* = 8 Hz); exact mass for $C_{13}H_{16}ClNO_5S$, calcd *m/e* 333.0438, obsd *m/e* 333.0443.

Anal. Calcd for $C_{13}H_{16}ClNO_5S$: C, 46.78; H, 4.83; N, 4.20. Found: C, 47.40; H, 5.19; N, 3.97.

General Procedure for the Conversion of 30 into 2-Acetaminostyrenes (26). To a solution of 3 equiv of potassium *tert*-butoxide in 15 mL of *tert*-butyl alcohol in a 100-mL, round-bottomed flask was added 0.64–0.95 g (1 equiv) of **30,** which had been dissolved in a minimum amount of tetrahydrofuran. The reaction mixture was stirred for 1 h at 25 °C, then for 30 min at 60 °C. After cooling, the reaction mixture was poured into 50 mL of water and extracted with three 75-mL portions of methylene chloride. The combined organic fractions were washed with two 100-mL portions of water, saturated sodium bicarbonate solution, and saturated sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated under reduced pressure at 25 °C. The crude product was then purified

by chromatography on alumina using chloroform as eluant.

2-Acetamino-5-methylstyrene (26a). According to the general procedure, 0.64 g of **30a** gave 0.31 g (77% yield) of **26a** as an oil which solidified on standing, mp 96–98 °C. An analytical sample of **26a** was prepared by recrystallization from cyclohexane: NMR ($CDCl_3$) δ 7.47 (1 H, d, J = 8 Hz), 7.30 (1 H, br s), 7.20 (1 H, s), 7.00 (1 H, d, J = 8 Hz), 6.72 (1 H, d of d, J = 12, 17 Hz), 5.60 (1 H, d, J = 17 Hz), 5.3 (1 H, d, J = 12 Hz), 2.30 (3 H, s), 2.11 (3 H, s); exact mass for $C_{11}H_{13}NO$, calcd m/e 175.0997, obsd m/e 175.1000.

Anal. Calcd for $C_{11}H_{13}NO$: C, 75.40; H, 7.48; N, 7.99. Found: C, 75.06; H, 7.49; N, 7.78.

2-Acetaminostyrene (26b). According to the general procedure, 0.95 g of **30b** gave 0.44g (76% yield) of **26b** as an oil which crystallized on scratching, mp 90–93 °C. Recrystallization from cyclohexane gave **26b,** mp 94–95 °C (lit.[36] mp 94.5 °C).

2-Acetamino-5-carboethoxystyrene (26g). According to the general procedure, 0.90 g of **30g** gave 0.39 g (62% yield) of **26g,** mp 116–119 °C. Recrystallization from ether–hexane gave mp 121–122 °C; NMR ($CDCl_3$) δ 8.00–7.70 (3 H, m), 7.42 (1 H, br s), 6.69 (1 H, d of d, J = 12, 21 Hz), 5.64 (1 H, d, J = 21 Hz), 5.39 (1 H, d, J = 12 Hz), 4.29 (2 H, q, J = 8 Hz), 2.14 (3 H, s), 1.37 (3 H, t, J = 8 Hz); exact mass for $C_{13}H_{15}NO_3$, calcd m/e 233.1052, obsd m/e 233.1056.

Anal. Calcd for $C_{13}H_{15}NO_3$: C, 66.94; H, 6.48; N, 6.00. Found: C, 67.04; H, 6.61; N, 5.85.

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Supplementary Material Available: Detailed infrared spectral data on all new compounds (2 pages). Ordering information is given on any current masthead page.

References and Notes

(1) Stauffer Chemical Co. Fellow, 1971–1972, The Ohio State University, Dissertation Fellow, 1972–1973.
(2) Address to which correspondence concerning this article should be sent.
(3) M. Sommelet, *C. R. Acad. Sci.*, **205,** 56 (1937).
(4) G. C. Jones and C. R. Hauser, *J. Org. Chem.*, **27,** 3572 (1962); G. C. Jones, W. Q. Beard, and C. R. Hauser, *ibid.*, **28,** 199 (1963); C. R. Hauser, S. W. Kantor, and W. R. Brasen, *J. Am. Chem. Soc.*, **75,** 2660 (1953). See also L. A. P. Fery, *Bull. Soc. Chim. Belg.*, **71,** 376 (1962); K. E. Pfitzner and J. G. Moffatt, *J. Am. Chem. Soc.*, **85,** 3027 (1963); **87,** 5661, 5670 (1965); M. G. Burdon and J. G. Moffatt, *ibid.*, **87,** 4656 (1965); **88,** 5855 (1966); **89,** 4725 (1967); K. E. Pfitzner, J. P. Marino, and R. A. Olofson, *ibid.*, **87,** 4658 (1965); J. P. Marino, K. E. Pfitzner, and R. A. Olofson, *Tetrahedron,* **27,** 4181 (1971), R. A. Olofson and J. P. Marino, *ibid.*, **27,** 4195 (1971); P. Claus, *Monatsh. Chem.*, **102,** 913 (1971); Y. Hayashi and R. Oda, *J. Org. Chem.*, **32,** 457 (1967); G. R. Pettit and T. H. Brown, *Can. J. Chem.*, **45,** 1306 (1967); P. Claus, *Monatsh. Chem.*, **99,** 1034 (1968); P. Claus, N. Vavra, and P. Schilling, *ibid.*, **102,** 1072 (1972); J. Doucet and A. Robert, *C. R. Acad. Sci., Ser. C,* **272,** 1562 (1971). For a review of The Somnelet–Hauser rearrangement see S. H. Pine, *Org. React.*, **18,** 403 (1970).
(5) P. G. Gassman, G. Gruetzmacher, and R. H. Smith, *Tetrahedron Lett.*, 497 (1972); P. G. Gassman and G. D. Gruetzmacher, *J. Am. Chem. Soc.*, **95,** 588 (1973); P. G. Gassman and T. J. van Bergen, *ibid.*, **95,** 590, 591, 2718 (1973); P. G. Gassman and C.-T. Huang, *ibid.*, **95,** 4453 (1973); P. G. Gassman, T. J. van Bergen, and G. D. Gruetzmacher, *ibid.*, **95,** 5608 (1973); P. G. Gassman, D. P. Gilbert, and T. J. van Bergen, *J. Chem. Soc., Chem. Commun.*, 201 (1974); P. G. Gassman and C.-T. Huang, *ibid.*, 684 (1974); P. G. Gassman and G. D. Gruetzmacher, *J. Am. Chem. Soc.*, **96,** 5487 (1974); P. G. Gassman, T. J. van Bergen, D. P. Gilbert, and B. W. Cue, Jr., *ibid.*, **96,** 5495 (1974); P. G. Gassman and T. J. van Bergen, *ibid.*, **96,** 5508 (1974); P. G. Gassman, G. D. Gruetzmacher, and T. J. van Bergen, *ibid.*, **96,** 5512 (1974); P. G. Gassman, B. W. Cue, Jr., and T.-Y. Luh, *J. Org. Chem.*, **42,** 1344 (1977); P. G. Gassman and W. N. Schenk, *ibid.*, **42,** 3240 (1977); P. G. Gassman and R. L. Parton, *Tetrahedron Lett.*, 2055 (1977); P. G. Gassman and R. J. Balchunis, *ibid.*, 2235 (1977); P. G. Gassman and R. L. Parton, *J. Chem. Soc., Chem. Commun.*, 694 (1977).
(6) For preliminary reports of part of this work see P. G. Gassman and H. R. Drewes, *J. Chem. Soc., Chem. Commun.*, **488** (1973); P. G. Gassman and H. R. Drewes, *J. Am. Chem. Soc.*, **96,** 3002 (1974).
(7) W. D. Zahler and R. Huisgen, *Chem. Ber.*, **96,** 765 (1963).
(8) H. Nozaki, R. Noyori, and K. Sisido, *Tetrahedron,* **20,** 1125 (1964); F. G. Mann and F. H. C. Stewart, *J. Chem. Soc.*, 4127 (1954); H. J. Scheifele, Jr., and D. F. DeTar, *Org. Synth.*, **32,** 8 (1952); H. Hellmann and W. Unseld, *Justus Liebigs Ann. Chem.*, **631,** 82 (1960); O. Fischer and H. Schmidt, *Chem. Ber.*, **27,** 2786 (1894); C. L. Hewett, L. J. Lermit, H. T. Openshaw, A. R. Todd, A. H. Williams, and F. N. Woodward, *J. Chem. Soc.*, 292 (1948).
(9) J. J. Brown and R. K. Brown, *Can. J. Chem.*, **33,** 1819 (1955); see also J. J. Sudborough, *J. Chem. Soc.*, **79,** 533 (1901); A. L. Lumiere and H. Barbier, *Bull. Soc. Chim. Fr.*, **33,** 783 (1905).
(10) For selected examples of formylation of aromatics see L. Gattermann, *Chem. Ber.*, **31,** 1149 (1898); W. E. Truce, *Org. React,* **9,** 37 (1957); L. Gattermann and J. A. Koch, *Chem. Ber.*, **30,** 1622 (1897); N. N. Crouse, *Org. React.*, **5,** 290 (1957); K. Reimer and F. Tiemann, *Chem. Ber.*, **9,** 824, 1268, 1285 (1876); H. Wynberg, *Chem. Rev.*, **60,** 169 (1960); A. Vilsmaier and A. Haack, *Chem. Ber.*, **60,** 119 (1927); L. N. Ferguson, *Chem. Rev.*, **38,** 227 (1946); J. C. Duff and E. J. Bills, *J. Chem. Soc.*, 1987 (1932); J. C. Duff, *ibid.*, 547 (1941); W. E. Smith, *J. Org. Chem.*, **37,** 3972 (1972); G. Cosnati, M. Crisafulli, and A. Ricca, *Tetrahedron Lett.*, 243 (1965); T. M. Cresp, M. V. Sargent, and J. A. Elix, *J. Chem. Soc., Chem. Commun.*, 214 (1972); S. Julia, C. Huynh, and D. Michelot, *Tetrahedron Lett.*, 3587 (1972); C. Huynh, S. Julia, R. Lorne, and D. Michelot, *Bull. Soc. Chim. Fr.*, 4057 (1972).
(11) F. Sachs and R. Kempf, *Chem. Ber.*, **35,** 2704 (1902); P. Friedlander, *ibid.*, **15,** 2572 (1882); P. Friedlander and C. F. Gohring, *ibid.*, **17,** 456 (1884); F. Sachs and E. Sichel, *ibid.*, **37,** 1861 (1904); F. Mayer, *ibid.*, **47,** 408 (1914); E. Bamberger, *ibid.*, **60,** 314 (1927); P. Ruggli and O. Schmid, *Helv. Chim. Acta,* **18,** 1229 (1935); L. I. Smith and J. W. Opie, "Organic Syntheses", Collect. Vol. III, Wiley, New York, N.Y., 1955, p 56.
(12) J. J. Brown and G. T. Newbold, *J. Chem. Soc.*, 4878 (1952); J. J. Brown and R. K. Brown, *Can. J. Chem.*, **33,** 1819 (1955).
(13) D. Seebach, *Synthesis,* **17** (1969); E. J. Corey and D. Seebach, *Angew. Chem., Int. Ed. Engl.*, **4,** 1075, 1077 (1965); D. Seebach, *ibid.*, **8,** 639 (1969).
(14) E. Vedejs and P. L. Fuchs, *J. Org. Chem.*, **36,** 366 (1971).
(15) For a leading reference to other methods of hydrolyzing sulfides see W. Huurdeman and H. Wynberg, *Synth. Commun.*, **2,** 7 (1972).
(16) D. L. Tuleen and T. B. Stevens, *J. Org. Chem.*, **34,** 31 (1969); D. L. Tuleen, *ibid.*, **32,** 4006 (1967); D. L. Tuleen and V. C. Marcum, *ibid.*, **32,** 204 (1967); D. L. Tuleen and T. B. Stevens, *Chem. Ind. (London)*, 1555 (1966).
(17) For a review of the Pummerer reaction see G. A. Russell and G. J. Mikol in "Mechanisms of Molecular Migrations", Vol. 1, B. S. Thyagarajan, Ed., Interscience, New York, N.Y., 1968, Chapter 4.
(18) For additional discussions of the α-chlorination of sulfides see G. E. Wilson, Jr., and R. Albert, *J. Org. Chem.*, **38,** 2156, 2160 (1973); H. Bohme, H. Fischer, and R. Frank, *Justus Liebigs Ann. Chem.*, **563,** 54 (1949); H. Bohme and H. Gran, *ibid.*, **577,** 68 (1952); E. Vilsmaier and W. Sprugel, *ibid.*, **747,** 151 (1971); W. E. Truce, G. H. Birum, and E. T. McBee, *J. Am. Chem. Soc.*, **74,** 3594 (1952); F. G. Bordwell and B. M. Pitt, *ibid.*, **77,** 572 (1955); E. Vilsmaier and W. Sprugel, *Tetrahedron Lett.*, 625 (1972); R. Harville and S. F. Reed, Jr., *J. Org. Chem.*, **33,** 3976 (1968); T. Zincke and W. Frohneberg, *Chem. Ber.*, **42,** 2721 (1909); F. G. Mann and W. J. Pope, *J. Chem. Soc.*, 121, 594 (1922); W. E. Lawson and T. P. Dawson, *J. Am. Chem. Soc.*, **49,** 3119, 3125 (1927).
(19) P. Friedlander, *Chem. Ber.*, **15,** 2572 (1882).
(20) A. E. Chichibabin and A. I. Kursanove, *J. Russ. Phys.-Chem. Soc.*, **62,** 1211 (1930).
(21) H. Kauffmann, *Chem. Ber.*, **37,** 294 (1904); G. Heller, *ibid.*, **43,** 1907 (1910); T. Posner, *Justus Liebigs Ann. Chem.*, **389,** 44 (1912).
(22) P. Friedlander and H. Ostermaier, *Chem. Ber.*, **15,** 332 (1882).
(23) For a review of the Perkin reaction, see J. R. Johnson in "Organic Reactions", Vol. 1, R. Adams, Ed., Wiley, New York, N.Y., 1942, Chapter 8.
(24) For examples see T. W. J. Taylor and P. M. Hobson, *J. Chem. Soc.*, 181 (1936).
(25) For a review of the α-halosulfone rearrangement, see L. A. Paquette in ref 17, Chapter 3. See also L. A. Paquette, *Org. React.*, **25,** 1 (1977).
(26) For the preparation of **3d,** only 0.05 mol of sodium methoxide was used.
(27) C. L. Hewett, L. J. Lermit, H. T. Openshaw, A. R. Todd, A. H. Williams, and F. N. Woodward, *J. Chem. Soc.*, 292 (1948).
(28) W. D. Zahler and R. Huisgen, *Chem. Ber.*, **96,** 765 (1963).
(29) In the case of **12d,** 8 mmol of mercaptal was used and the quantities of all of the other reagents were doubled.
(30) In the preparation of **16d,** 400 mL of solvent was used.
(31) A. Luttringhaus and A. Kolb, *Z. Naturforsch. B,* **16,** 762 (1961).
(32) J. Colonge and R. Chambard, *Bull. Soc. Chim. Fr.*, 982 (1953).
(33) O. Buchardt and P. L. Kumler, *Acta Chem. Scand.*, **23,** 159 (1969).
(34) F. Effenberger and W. Hartmann, *Angew. Chem.*, **76,** 188 (1964).
(35) A. Einhorn and R. Lauch, *Justus Liebigs Ann. Chem.*, **243,** 342 (1888).
(36) S. Sabetay, J. Bleger, and Mme Y. De Lestrange, *Bull. Soc. Chim. Fr.*, **49,** 3 (1931).