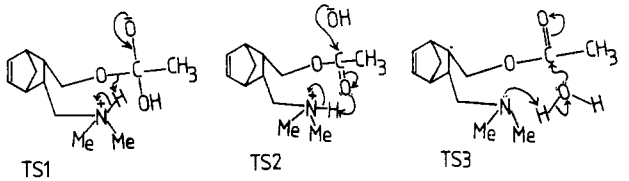
(5′). Actually, the internally hydrogen-bonded amine should have its hydrogen-bonding proton lying nearer the oxygen (5) or the nitrogen atom (5′). But the form 5′ is also a form of the zwitterion. When we refer to nucleophilic attack by the internally hydrogen-bonded alcohol we are including reaction via both species (5 and 5′). It is not possible to know which of the two will be responsible for most of the attack on A. The species 5′, while less abundant, should be much reactive in attacking by its oxygen atom. Hence there may be a significant amount of reaction via a hydrogen-bonded form of a zwitterion (5′), but we include this in the kind of process that can take place with the serine enzymes. We think that the factor of 39 by which the rate of such reaction exceeds that estimated for reactions via non-hydrogen-bonded zwitterion 6 is a good deal larger than the uncertainty of the estimate and, therefore, shows that the reaction by the proposed mechanism is occurring.

It is interesting to note that the ratio of $k_{n_1}{}^{OH}/k_w'$ is of the order of 10^6, where $k_w' = k_w/[H_2O]$ and $k_w(=5.5 \times 10^{-7}$ $s^{-1})$[6] is the pseudo-first-order rate constant for water-catalyzed cleavage of A. The ratio $k_{n_1}{}^{OH}/k_w'$ gives at least a qualitative measure of the enhancement caused by internally tertiary amine assisted hydroxy group catalyzed compared to unassisted hydroxy group catalyzed cleavage of A. Jersey et al.[8] have also observed the ratio of $k_{TRIS\ hydroxy}/k_{H_2O}$ hydroxy of the order of 10^6 for TRIS- and water-catalyzed cleavage of 4-*trans*-benzylidene-2-phenyloxazolin-5-one.

The value of k_2 of 2.45×10^{-5} s^{-1} at pH 8.80 may be used to calculate the hydroxide ion catalyzed bimolecular rate constant, k_{OH}, for the cleavage of 4. Assuming that water-catalyzed cleavage of 4 is negligible compared to the hydroxide ion catalyzed one at pH 8.80, the k_{OH} was found to be ~4 M^{-1} s^{-1}. This value is nearly 53 times larger than k_{OH} (4.5 M^{-1} min^{-1}) obtained for aqueous cleavage of ethyl acetate.[5] The significantly larger reactivity of 4 compared to that of ethyl acetate toward hydroxide ion could be attributed to the intramolecular general acid catalysis involving either transition-state TS1 (if expulsion of leaving group is the rate-determining step) or TS2 (if nucleophilic attack is the rate-determining step). TS2 is kinetically indistinguishable from TS3, which involves intramolecular general base catalysis. Furthermore, the possibility of the formation of TS1 via TS3 may be considered to be less likely for such a possibility could be expected to result in an enhanced reactivity of *o*-[(dimethylamino)methyl]-benzyl alcohol toward less active esters such as methyl formate and acetylcholine. But no enhanced reactivity could be observed in these reactions.[15] However, the present data are not sufficient to differentiate between TS1, TS2, and TS3.



Although the present model is certainly an incomplete one, at least for the acylation step, because of the proposed involvement in this step of an aspartic acid residue in the "charge relay system",[18] it does display the major aspects of the mechanism involved in acylation and deacylation steps of the reactions catalyzed by serine esterases.

Acknowledgment. I express my appreciation and gratitude to Professor Jack Hine of the Ohio State University for suggesting this problem and for his hospitality in providing laboratory space and facilities and a postdoctoral fellowship in the completion of this work. This investigation was supported in part by NIH Grant GM 18593 granted to Professor Jack Hine.

Appendix

Estimation of p*K* Value of $1H^+$. Fox and Jencks[19] have reported that the acidities of substituted aliphatic tertiary ammonium ions, $XCH_2N^+HR_1R_2$, could be satisfactorily correlated with a value of $\rho_I = -8.4$. After correction by a factor of 2.5 per methylene group for transmission of substituent effect through the carbon atom, the value of $\rho_I = -0.54$ was considered for $XCH_2CH_2CH_2CH_2N^+HMe_2$. The p$K_a$ of $CH_3(CH_2)_3N^+HMe_2$ has been found to be 10.37. The substitution of OH ($\sigma_I^{OH} = 0.25$) for H lowers the pK_a of $CH_3(CH_2)_3N^+HMe_2$ by −0.14 (=−0.54 × 0.25). Thus, the esimated pK_a of $HO(CH_2)_4N^+HMe_2$ is 10.27.

Registry No. 1, 56679-25-5; 2, 98540-23-9; 3, 98540-24-0; 4, 98540-25-1; *p*-$NO_2C_6H_4OAc$, 830-03-5.

Supplementary Material Available: A table of observed data including k_{calcd} for the effect of the concentration of 3 on the cleavage of PNPA at different pH (1 page). Ordering information is given on any current masthead page.

(18) Blow, D. M.; Birktoft, J. J.; Hartley, B. S. *Nature (London)* **1969**, *221*, 337.
(19) Fox, J. P.; Jencks, W. P. *J. Am. Chem. Soc.* **1974**, *96*, 1436.

Preparation of Mesoionic Dipyrido[1,2-*a*:1′,2′-*c*]imidazolium-11-thiolates from the Binz–Marx Reaction[1]

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The reaction of a mixture of pyridine and 2-picoline with sulfur dioxide in the presence of benzoyl chloride, followed by treatment with aqueous potassium hydroxide, affords the mesoionic compound 1 in a one-pot reaction. Variously substituted derivatives of 1 may be obtained by similar reactions starting with appropriately substituted pyridines and/or 2-picolines. In hot concentrated hydrobromic acid these compounds extrude elemental sulfur and yield the parent heterocyclic cations. Their solvatochromy makes them useful indicators of solvent polarity.

In 1907 Binz and Marx[2] reported that reaction of a mixture of benzoyl chloride and pyridine with sulfur dioxide, followed by treatment with aqueous potassium hydroxide, gave a deep red compound having the empirical

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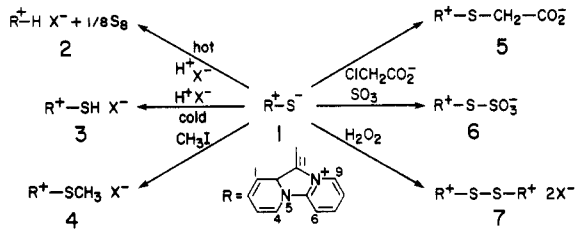
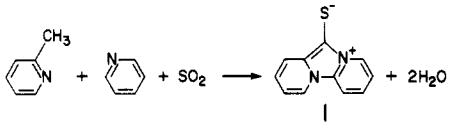
Scheme I



formula $C_{11}H_{10}N_2S$. Heating a mixture of pyridine and benzoyl chloride with sodium dithionite gave a pale yellow compound $C_{23}H_{16}N_4O_6S_4$, converted into the red compound with dilute alkali. No structure was advanced for either compound.

Many years later, Watson,[3] following the procedure of Binz and Marx, obtained the red compound but in very small yield. He found it to be protonated to a colorless cation (pK_{BH^+} 0.83) in dilute hydrochloric acid and showed that the same red compound was obtained when *m*-bromo- or *p*-chlorobenzoyl chloride replaced benzoyl chloride.

Our own studies, described below, showed that Binz and Marx's red compound has the structure **1** and is formed only when pyridine contains 2-picoline as an impurity.

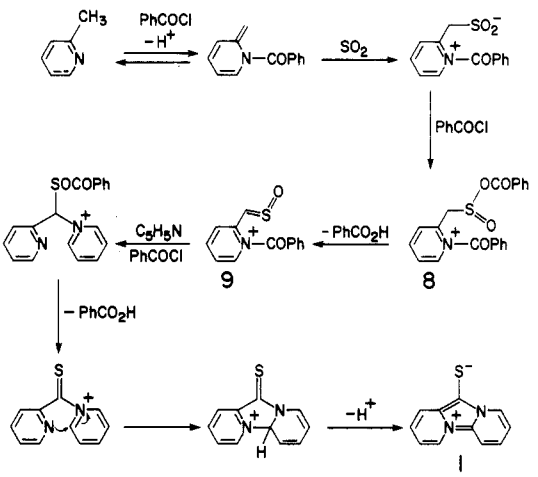


With a 1:10 mixture of 2-picoline in pyridine it was obtained in 90% crude yield (based on 2-picoline). It was formed in small amount from most samples of reagent-grade pyridine which we examined and could furnish the basis of a very sensitive colorimetric method for the analysis of 2-picoline in pyridine.

Mass spectrometry and combustion analysis showed the red compound to have the empirical formula $C_{11}H_8N_2S$ required by **1**, rather than $C_{11}H_{10}N_2S$ reported by Binz and Marx. When dissolved in various solvents, it was photo-oxidized fairly rapidly; solutions were handled in actinic glassware in dim light.

The chemical evidence for the structure **1** is summarized in Scheme I. When refluxed for 1 day in constant boiling hydrobromic acid, the red compound was decomposed to elemental sulfur (S_8) and dipyrido[1,2-*a*:1′,2′-*c*]imidazolium ion **2**,[4] isolated as either the hexafluorophosphate ($X^- = PF_6^-$) or perchlorate ($X^- = ClO_4^-$).[5] In cold 20% hydrochloric acid, on the other hand, only protonation of the

Scheme II



mercaptide sulfur took place, giving the cation **3**. This formed crystalline salts with perchlorate, hexafluorophosphate ($X^- = PF_6^-$), fluoborate ($X^- = BF_4^-$), or iodide counterions. Each of the first three salts showed a sharp IR peak between 2550 and 2510 cm^{-1}, indicative of the S–H stretching mode;[8] the iodide showed a single broad absorption at 2195 (KBr) or 2200 cm^{-1} (Nujol), unusually low, perhaps, because of hydrogen bonding of SH to iodide ion.[9]

With methyl iodide, the red compound formed a methiodide **4** ($X^- = I^-$), readily converted into a less soluble perchlorate or hexafluorophosphate; with chloroacetic acid it formed the zwitterion **5** and with sulfur trioxide the yellow Bunte salt **6**, $C_{11}H_8N_2O_3S_2$. The latter proved to be identical with the yellow compound of Binz and Marx, formulated by them as $C_{23}H_{16}N_4O_6S_4$. It could be prepared by their original procedure using dithionite only if 2-picoline as well as pyridine was used.

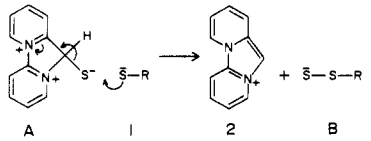
Further evidence for the presence of the ionized mercaptide group in the red compound came from its oxidation with 1 equiv of hydrogen peroxide to the disulfide dication **7**, isolated in 90% yield as the difluoborate ($X^- = BF_4^-$) salt. The disulfide was reduced back to the red compound by dithionite in nearly quantitative yield.[10] With aqueous sulfite it gave **1** and **6**, as expected,[11a] and with aqueous

$$\underset{7}{R^+—S—S—R^+} + SO_3^{2-} \rightarrow \underset{6}{R^+—S—SO_3^-} + \underset{1}{R^+—S^-}$$

carbonate it gave **1** and **2**, the latter probably coming from loss of SO_2 from an intermediate sulfite.[11b]

The location of the mercaptide group at the 11-position of the dipyrido[1,2-*a*:1′,2′-*c*]imidazolium ring system is suggested by the probable mechanism of the reaction shown in Scheme II. The various steps including the formation of the sulfine intermediate **9** by base-catalyzed elimination[12] from the anhydride **8** all find analogy in the literature.[13] This location of the mercaptide group was confirmed by the ^1H NMR and IR spectra of **1** and of various methyl- or ethyl-substituted derivatives **12**.[13,14]

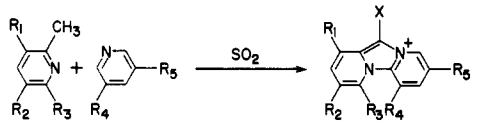
(1) Work supported by Abbott Laboratories and by the National Research Council of Canada.
(2) Binz, A.; Marx, T. *Ber.* **1907**, *40*, 3855.
(3) Watson, J. R. M.Sc. Thesis, McGill University, Montreal, Canada 1965.
(4) Brown, B. R.; Humphreys, J. *J. Chem. Soc.* **1959**, 2040. Hamano, M.; Umezowa, B.; Noda, K. *Chem. Pharm. Bull.* **1963**, *11*, 694. Leander, K.; Liining, B. *Tetrahedron Lett.* **1968**, 905.
(5) The results of Brown and White[6] indicate that attack of **1** by H^+ should take place at the 11-position to give the intermediate A. This



could react with **1** to give first the disulfide ion B and then the higher polysulfide ions up to $R^+S_7S^-$, which with H^+ could give **2** + S_8 (see Bartlett and Davis[7] for examples of the reverse reaction).
(6) Brown, B. R.; White, D. *J. Chem. Soc.* **1957**, 1589.
(7) Bartlett, P. D.; Davis, R. E. *J. Am. Chem. Soc.* **1958**, *80*, 2513.
(8) Bellamy, L. J. "The Infrared Spectra of Complex Molecules"; Methuen: London, 1960; pp 350–352.
(9) Wagner, A.; Becher, A. J.; Kottenhahn, K. G. *Chem. Ber.* **1956**, *89*, 1708.
(10) These reactions were in fact carried out with the 3-ethyl derivative of **1**.
(11) Parker, A. J.; Kharasch, N. *Chem. Rev.* **1958**, *59*, (a) 612, 614, (b) 608, 611.
(12) Sheppard, W. A.; Dickmann, J. *J. Am. Chem. Soc.* **1964**, *86*, 1891. Zwanenberg, B.; Thijs, L.; Strating, J. *Recl. Trav. Chim. Pays-Bas* **1967**, *86*, 577.
(13) Sheffler, R. H. Ph.D. Thesis, McGill University, Montreal, Canada, 1970.

The NMR spectrum of 1 showed peaks due to eight of the nine aromatic protons of the parent compound 2, the peak due to the proton at the 11-position being missing.

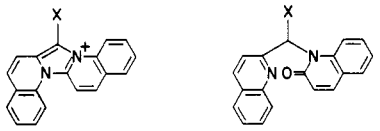
The NMR spectra made it possible to determine the structure of the product(s) formed in analogous reactions, when several were possible. Thus reaction of 2-picoline (10, $R_1 = R_2 = R_3 = H$) with 3-picoline (11, $R_4 = Me$; $R_5 = H$) could afford either 12 ($R_4 = Me$; $R_1 = R_2 = R_3 = R_5 = H$; $X = S^-$) or 12 ($R_5 = Me$; $R_1 = R_2 = R_3 = R_4 = H$; $X = S^-$); the NMR spectrum showed that the product isolated



10 11 12

had the former structure. On the other hand, reaction of 5-ethyl-2-methylpyridine (10, $R_2 = Et$; $R_1 = R_3 = H$) with 3-picoline (11, $R_4 = Me$; $R_5 = H$) gave both 12 ($R_2 = Et$; $R_4 = Me$; $R_1 = R_3 = R_5 = H$; $X = S^-$) and 12 ($R_2 = Et$; $R_5 = Me$; $R_1 = R_3 = R_4 = H$; $X = S^-$) but the latter in a much smaller amount so that it could not be isolated pure.

With quinaldine and quinoline the Binz–Marx reaction gave 13 ($X = S^-$). This compound is the thio analogue of Besthorn's Red (13; $X = O^-$),[15] one of the first compounds to be recognized as mesoionic.[16,17] Both Besthorn's Red and its thio analogue were protonated in acid to form the cations 13 (X = OH or SH), and with sufficiently strong



13 14

acids (48% hydrobromic acid, 72% perchloric acid) crystalline yellow salts could be isolated. Both compounds gave yellow methyl derivatives (13, $X = OCH_3$ or SCH_3), the thio compound with methyl iodide, Besthorn's Red only with the more reactive methyl sulfate. The UV spectra of these various derivatives were all very similar to the spectrum of the parent ion 13 (X = H).[18] Furthermore, alkaline hydrolysis of the three compounds 13 (X = H, OCH_3, or SCH_3) gave three products 14 (X = H, OCH_3, or SCH_3) having virtually identical UV spectra in cyclohexane, exhibiting 15 maxima or shoulders within 5 nm of each other. This may be regarded as strong evidence for the location of the sulfur atom in thio-Besthorn's Red (13; $X = S^-$), as shown.

Acid hydrolysis of 13 ($X = S^-$), like acid hydrolysis of 1, gave the parent ion, in this case 13 (X = H), and elemental sulfur. The mechanism of this reaction, discussed above, depends on the formation of intermediates having chains of sulfur atoms. Oxygen does not have this ability to form chains, and hence Besthorn's Red (13, $X = O^-$) decomposes by a different route to give quinaldic acid and quinoline.

Various modifications of the original Binz–Marx procedure have been developed (see Experimental Section),

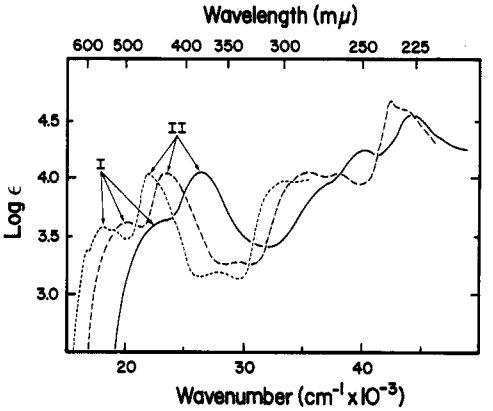


Figure 1. Ultraviolet and visible absorption spectra of dipyrido[1,2-a:1',2'-c]imidazolium-11-thiolate (1) in methanol (—), acetonitrile (– –), and benzene (------).

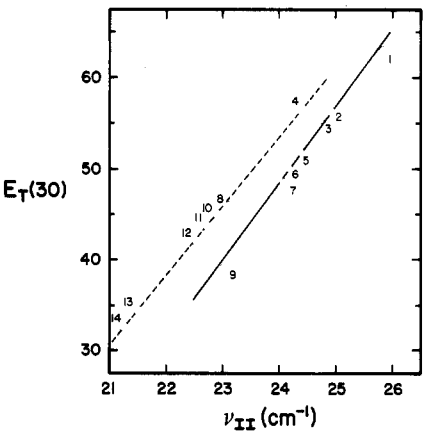


Figure 2. Solvent effects on band II of dipyrido[1,2-a:1',2'-c]-imidazolium-11-thiolate. Solvents: 1, H_2O; 2, ethylene glycol; 3, MeOH; 4, formamide; 5, EtOH; 6, 1-butanol; 7, 2-propanol; 8, acetonitrile; 9, $CHCl_3$; 10, Me_2SO; 11, dimethylformamide; 12, acetone; 13, benzene; 14, carbon disulfide (containing 4% $CHCl_3$).

and it furnishes a potentially convenient route to different heterocyclic systems.

Like other mesoionic compounds,[19,20] the various mesoionic compounds of this paper showed interesting solvatochromic properties. Thus solutions of 1 ranged in color from purplish red in nonpolar solvents to orange in water.

This solvatochromy is due to shifts in the two long-wavelength bands (I and II) shown in Figure 1; three other UV bands are shown by 1 and its derivatives which will be discussed elsewhere.[13,14] Bands I and II probably arise from transitions in which charge is transferred from sulfur toward the center of the dipyrido[1,2-a:1',2'-c]imidazolium ring system.[21,22] Kiwan and Irving[19] observed solvatochromic shifts of similar magnitude with another mesoionic thiolate.

In Figure 2 we show a plot of the frequency ν_{II} of band II[23] of 1 against the Dimroth–Reichardt $E_T(30)$ parameter.[21] The points fall on two straight lines: one for aprotic and one for protic solvents (alcohols and chloroform[24]).

(14) The IR, NMR, and UV spectra of the compounds described in this paper fully support the structures advanced,[13] but a detailed discussion would lengthen the paper inordinately. The NMR and UV spectra are discussed in two papers in preparation; the IR spectra and some UV and mass spectra are included in the supplementary material.

(15) Besthorn, E.; Ibele, J. *Ber.* **1904**, *37*, 1236. Besthorn, E. *Ber.* **1913**, *46*, 2762.

(16) Krollpfeiffer, F.; Schneider, K. *Ann.* **1937**, *530*, 34.

(17) Katritzky, A. R., *Chem. Ind. (London)* **1955**, 521. Baker, W.; Ollis, W. O. *Ibid.* **1955**, 910.

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(19) Kiwan, A. M.; Irving, H. M. N. H. *J. Chem. Soc. B* **1971**, 898.

(20) Talukdar, P. B.; Sengupta, S. K.; Datta, A. K.; Chakravorty, A. *Indian J. Chem.* **1973**, *11*, 611.

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(22) Kosower, E. M. *J. Am. Chem. Soc.* **1958**, *80*, 3253.

(23) Bands I and II exhibit about the same sensitivity to solvent, but only the position of the stronger band II can be measured accurately in all the solvents tested.

(24) The IR spectrum of 1 in $CHCl_3$ shows a very strong bond at 2922 cm^{-1}, which appears to be the C–H stretching mode shifted 93 cm^{-1} to lower frequency by hydrogen bonding; in $CDCl_3$ the C–D bond appeared at 2255 cm^{-1}, or 57 cm^{-1} below normal frequency.

The former solvents stabilize the ground state of 1 by a generalized dipole–dipole interaction; the latter solvents stabilize it additionally by hydrogen bonding to negative sulfur.[21] The results shown in Figure 2 indicate that hydrogen bonding is stronger to the sulfur of 1 than to the oxygen of the pyridinophenolate indicator used by Dimroth and Reichardt to establish their $E_T(30)$ scale,[21] perhaps because the sulfur has a greater negative charge than the oxygen. Regardless of the precise explanation, the results also show the fallacy of expecting *all* solvent effects to be encompassed by a parameter derived from a single indicator substance or reaction.

Experimental Section

IR spectra were recorded on Perkin-Elmer 521, 225, or 337 grating spectrophotometer. UV spectra were obtained with a Unicam SP 800 spectrophotometer having the cell compartment thermostated at 25 °C. NMR spectra were obtained with a Varian A-60 instrument. Mass spectra were measured by Morgan-Schaffer Corp., Montreal, using 70-eV electrons and a sample inlet heated to 250 °C. Melting points, unless otherwise indicated, are corrected. Molecular weights were determined in chloroform with a Mechrolab vapor-pressure osmometer calibrated with benzil. Analyses were done by Alfred Bernhardt, Mülheim, Germany, or A. Daesslé, Montreal.

Purification of Reagents. Sulfur dioxide and benzoyl chloride were used as received. 2-Methylpyridines and 2-methylquinolines were distilled and stored over potassium hydroxide pellets. However, pyridines and quinolines required removal of derivatives containing 2-methyl groups, which could also react in the Binz–Marx reaction. Pyridine was first purified via the picrate according to Boyer et al.,[25] but it was later found that pyridine and 3-substituted pyridines were most easily purified by the following procedure. A mixture of 300 mL of the desired pyridine and 50 mL of benzoyl chloride in a 1-L flask was rapidly saturated with sulfur dioxide. No provision was made for cooling, and the mixture soon became dark colored and quite hot. As the mixture gradually cooled, a slow stream of sulfur dioxide was bubbled through it until saturation at room temperature was achieved. The mixture was left for 3 days, and then the sulfur dioxide was evaporated by heating on a water bath at 500 mm with the temperature being gradually increased to 100 °C. The purified pyridine (along with residual sulfur dioxide and some benzoyl chloride) was then distilled at 90–100 °C at reduced pressure (20–30 mm). The distillate was shaken with 25% aqueous potassium hydroxide (caution) until no further heat was evolved. The organic layer was then separated and extracted once with 50% aqueous potassium hydroxide. Final drying was effected by heating first over potassium hydroxide pellets and then over barium oxide. Fractional distillation completed the purification, the pyridine being collected over a 1-deg boiling point range.

The purity of the pyridine could be tested by mixing a 2-mL portion with 1 mL of benzoyl chloride and saturating this solution with sulfur dioxide. A pale yellow color that was dispelled on addition of water indicated that all condensable impurities had been removed, while a red or brown color meant that the material had not been completely purified. A similar procedure described in detail elsewhere[13] was used to purify quinoline.

Dipyrido[1,2-*a*:1′,2′-*c*]imidazolium-11-thiolate (1). By the Binz–Marx Procedure (Procedure A). A mixture of 45 mL (44 g, 0.56 mol) of purified pyridine, 5.0 mL (4.7 g, 0.051 mol) of 2-picoline, and 28 mL (36 g, 0.25 mol) of benzoyl chloride was saturated at ice-bath temperature with dry sulfur dioxide. The reaction mixture, which soon became a deep red, was allowed to stand for about a day[26] at room temperature. Excess sulfur dioxide and pyridine were then removed on a rotary evaporator using a steam bath and a water aspirator. The dark viscous residue was treated with 100 mL of 50% aqueous potassium hydroxide, the addition being made in small portions followed by vigorous mixing and cooling.

The red suspension was filtered under vacuum and pressed with a rubber dam to remove as much adhering potassium hydroxide solution as possible. The filter cake was washed several times with peroxide-free ether and then broken up and vacuum dried over phosphorus pentoxide. The dry powdered filter cake was extracted in a Soxhlet apparatus with 250 mL of chloroform until the extracts were colorless. Evaporation of the chloroform gave the crude red compound (9.1 g), which was washed several times with ether. Recrystallization from chloroform gave 6.8 g (67% yield based on 2-picoline) of dark red plates, mp 251–255 °C dec. Several recrystallizations from absolute ethanol gave lustrous dark maroon needles of dipyrido[1,2-*a*:1′,2′-*c*]imidazolium-11-thiolate (1): mp 265–267 °C (in a N_2-filled tube), 260–263 °C dec (in an open tube); mass spectrum, *m/e* 202 (p + 2, 7), 201 (p + 1, 18), 200 (parent ion, 100).

Anal. Calcd for $C_{11}H_8N_2S$: C, 66.0; H, 4.0; N, 14.0; S, 16.0; M_r 200. Found: C, 65.9; H, 4.3; N, 13.7; S, 15.8; M_r (osmometry) 206.

Identical (mp, IR) red material could be obtained by the original Binz and Marx procedure using 50 mL of Fisher certified reagent pyridine (without additional 2-picoline), but the yield dropped to 0.48 g; with technical pyridine the yield rose to 5.4 g; with purified pyridine it dropped to zero.

By a Modified Procedure (Procedure B). The following procedure was found to give higher yields of some alkyl derivatives of 1.

A stirred, ice-cooled mixture of 2-picoline, pyridine, and benzoyl chloride in a round-bottom flask was saturated with gaseous sulfur dioxide. The flask was then equipped with a large Dewar condenser which was charged with dry ice–acetone. Gaseous sulfur dioxide was introduced through the bottom inlet tube of the condenser and condensed directly into the flask to the desired level. After chilling the flask in a dry ice–acetone bath, the red solution was transferred to chilled pressure bottles capable of withstanding a pressure of 3 atm. After being sealed, the bottles were left at room temperature in darkness for 2 weeks or until the red color had reached maximum intensity. The bottles were then chilled to ca. −70 °C and opened, and their contents were transferred to a chilled round-bottom flask. After most of the sulfur dioxide had evaporated, the remainder, along with the excess pyridine, was removed under suction on an all-glass, rotary evaporator. The red compound was then liberated by the usual workup with aqueous alkali.

Acid Hydrolysis of Dipyrido[1,2-*a*:1′,2′-*c*]imidazolium-11-thiolate (1). A solution of 0.60 g (3.0 mmol) of 1 in 60 mL of 48% hydrobromic acid was refluxed for 24 h. After cooling, the solution, flask, and condenser were extracted with carbon disulfide. The extract, upon evaporation, gave 65.3 mg (68% yield) of elemental sulfur, mp 118–119 °C (lit.[27] mp 119.25 °C), featureless IR spectrum, and burning with a characteristic blue flame with the choking odor of sulfur dioxide.

The clear hydrobromic acid solution was evaporated to dryness. The residue, dissolved in 20 mL of water (charcoal) and treated with 2 mL of 65% hexafluorophosphoric acid, gave 0.59 g (69% yield) of yellow needles of dipyrido[1,2-*a*:1′,2′-*c*]imidazolium hexafluorophosphate (2, $X^- = PF_6^-$); after recrystallization from water (charcoal), mp 261.5–264 °C.

Anal. Calcd for $C_{11}H_9F_6N_2P$: C, 42.0; H, 2.9; N, 8.9. Found: C, 41.7; H, 3.2; N, 8.5.

A second hydrolysis, run under identical conditions with HBr and 0.62 g of 1, followed by addition of 1.5 mL of 72% perchloric acid, gave 0.685 g (82% yield) of yellow crystals of perchlorate (2, $X^- = ClO_4^-$), mp 196–199 °C; after recrystallization from absolute ethanol, mp 201–202 °C, undepressed by admixture with perchlorate prepared from authentic dipyrido[1,2-*a*:1′,2′-*c*]-imidazolium bromide[4] and having an identical IR spectrum.

Anal. Calcd for $C_{11}H_9ClN_2O_4$: C, 49.2; H, 3.4, Cl, 13.2; N, 10.4. Found: C, 49.6; H, 3.5; Cl, 13.1; N, 10.6.

Salts 3 ($X^- = PF_6^-$, ClO_4^-, BF_4^-, and I^-) of 1. A solution of 200 mg of dipyrido[1,2-*a*:1′,2′-*c*]imidazolium-11-thiolate (1) in 20 mL of methanol was treated with an excess of concentrated aqueous hexafluorophosphoric acid. An orange-yellow salt rapidly crystallized: mp (N_2) 221–225 °C. The salt hydrolyzed instantly on contact with water to regenerate 1.

(25) Boyer, R.; Spencer, E. Y.; Wright, G. F. *Can. J. Res. Sec. B* **1946**, *24*, 200.

(26) When this procedure was applied to substituted 2-picolines or pyridines, it was found advantageous to increase the time to about 4 days.

(27) Hodgman, C. D., Ed. "Handbook of Chemistry and Physics", 37th ed.; The Chemical Rubber Co.: Cleveland, OH, 1955; p 382.

The perchlorate, mp (N_2) 237–239 °C, fluoroborate, mp (N_2) 216–217.5 °C, and iodide, mp (N_2) 215.5–218 °C, were prepared in similar fashion, and all had IR spectra very similar to that of the hexafluorophosphate, except that the S–H band for the iodide was at 2195 cm^{-1} instead of at 2545 cm^{-1}.

11-(Methylthio)dipyrido[1,2-a:1′,2′-c]imidazolium Iodide (4, X^- = I^-). A hot solution of 2 g of **1** in 50 mL of methanol was treated with excess methyl iodide. The color of the solution changed from deep red to yellow within 1 min. The solution was concentrated and cooled, yielding five crops of yellow-tan crystals, all mp 242–248 °C, total yield 80%. After four recrystallizations from ethanol (one charcoal treatment) 11-(methylthio)dipyrido-[1,2-a:1′,2′-c]imidazolium iodide (**4**, X^- = I^-) was obtained as bright yellow crystals: mp 249–251 °C; IR (KBr) 2980 cm^{-1} (CH_3).

Anal. Calcd for $C_{12}N_{11}IN_2S$: C, 42.1; H, 3.2; I, 37.1; N, 8.2; S, 9.4. Found: C, 42.1; H, 3.3; I, 37.3; N, 8.0; S, 9.3.

Treatment of the iodide **4** (X^- = I^-) with 65% hexafluorophosphoric acid gave the less soluble hexafluorophosphate, after two recrystallizations from dilute aqueous HPF_6 and one crystallization from methanol: yellow needles, mp 224–225 °C.

Anal. Calcd for $C_{12}H_{11}F_6N_2PS$: C, 40.0; H, 3.1; N, 7.8; S, 8.9. Found: C, 39.7; H, 3.3; N, 7.6; S, 9.3.

Similar treatment of **4** (X^- = I^-) with 72% perchloric acid gave the perchlorate: mp 192–195 °C; IR (KBr) [identical with that of fluoroborate except for the absence of intense bands due to PF_6^- at 875 and 860–820 cm^{-1} and the presence of weak bands at 850 and 840 cm^{-1}]; UV (MeOH) [identical with that of fluoroborate].

Anal. Calcd for $C_{14}H_{15}ClN_2O_4$: C, 49.1; H, 4.4. Found: C, 49.4; H, 4.9.

(Dipyrido[1,2-a:1′,2′-c]imidazolio-11-thio)acetate (5). A chloroform solution containing 500 mg of dipyrido[1,2-a:1′,2′-c]imidazolium-11-thiolate and 300 mg of chloracetic acid was refluxed until the color changed from red to yellow, whereupon a yellowish product precipitated. The product was recrystallized by adding dry isopropyl ether to a boiling ethanol solution to the point of incipient cloudiness and then allowing the solution to stand at 5 °C for 2 days. Filtration and drying at 100 °C gave 260 mg (40% yield) of (dipyrido[1,2-a:1′,2′-c]imidazolio-11-thio)acetate monohydrate (**5**) as yellow granular crystals, 248 °C dec.

Anal. Calcd for $C_{13}H_{10}N_2O_2S{\cdot}H_2O$: C, 56.5; H, 4.4. Found: C, 56.5; H, 4.2.

Dipyrido[1,2-a:1′,2′-c]imidazolio-11-*S*-thiosulfate (6). a. From the Reaction of 2-Picoline, Pyridine, and Benzoyl Chloride with Sodium Dithionite. A mixture of pyridine (45 mL) and 2-picoline (5 mL) was added at once to a vigorously stirred suspension of sodium dithionite (30 g) in benzoyl chloride (50 mL). After several minutes, heating and vigorous evolution of sulfur dioxide occurred. When frothing had subsided the stirred mixture was refluxed gently for 1 h and then cooled and poured into 800 mL of water. The mixture was vigorously stirred and allowed to settle, and the aqueous layer was decanted away. The dark oily residue was mixed with ether, and the insoluble residue was triturated and finally extracted with ether in a Soxhlet extractor until the extract was colorless. The residue was then extracted with chloroform for 1 day. Evaporation of the chloroform extract gave 1.9 g of crude dipyrido[1,2-a:1′,2′-c]-imidazolium-11-thiolate (**1**), mp 259–262 °C, after recrystallization from acetonitrile.

The chloroform-insoluble residue (1.2 g) was crystallized twice from 500 mL of distilled water (charcoal) to give 0.25 g of red-orange needles, 234 °C dec (N_2). Further recrystallization from water had no effect on the decomposition temperature; however, recrystallization from spectroquality nitromethane gave dipyrido[1,2-a:1′,2′-c]imidazolium-11-*S*-thiosulfate (**6**), 242 °C dec (N_2) (lit[2] 242 °C dec).

Anal. Calcd for $C_{11}H_8N_2O_3S_2$: C, 47.2; H, 2.9; N, 10.0; S, 22.8. Found: C, 48.8; H, 3.3, N, 9.4; S, 21.9.

Heating **6** with sodium hydroxide or aqueous pyridine converted it to **1**.

b. From the Reaction of 1 with Pyridine–Sulfur Trioxide Complex. A solution of 0.46 g of dipyrido[1,2-a:1′,2′-c]-imidazolium-11-thiolate (**1**) in 150 mL of warm acetonitrile was quickly mixed with a hot solution of 1.3 g (8.2 mmol) of pyridine–sulfur trioxide complex in 50 mL of acetonitrile. After 1 day, the reaction mixture gave 0.58 g (91%) of yellow needles of dipyrido[1,2-a:1′,2′-c]imidazolio-11-*S*-thiosulfate (**6**), 246–248 °C dec (N_2).

The product was recrystallized from 200 mL of spectroquality nitromethane to give 0.22 g of **6**, 242 °C dec (N_2), identical (IR, NMR) with the product above.

Anal. Calcd for $C_{11}H_8N_2O_3S_2$: C, 47.2; H, 2.9; N, 10.0; S, 22.8. Found: C, 47.4; H, 3.0; N, 9.8; S, 22.8.

11,11′-Dithiobis(dipyrido[1,2-a:1′,2′-c]imidazolium) Difluoborate (7, X^- = BF_4^-). A stirred ice-cooled solution of 0.95 g of **1** in 60 mL of methanol was acidified with 1 mL of concentrated sulfuric acid. A solution of 0.27 g of 31% hydrogen peroxide in 30 mL of methanol was then added over 30 min, and the solution was stirred at 5–10 °C for 1 h. Addition of 5 mL of 50% fluoboric acid precipitated 1.23 g (90% yield) of orange fluoborate. Recrystallization from water, followed by two recrystallizations from a 1:1 methanol–water mixture, gave 11,11′-dithiobis(dipyrido[1,2-a:1′,2′-c]imidazolium) difluoborate (**7**, X^- = BF_4^-) as red-orange crystals, mp 275–278 °C.

Anal. Calcd for $(C_{11}H_8BF_4N_2S)_2$: C, 46.0; H, 2.8; N, 9.8; S, 11.2. Found: C, 46.5; H, 3.0; N, 9.7; S, 11.1.

Alkaline Peroxide Oxidation of 1. A solution of 2.00 g (0.01 mol) of dipyrido[1,2-a:1′,2′-c]imidazolium-11-thiolate (**1**) in 200 mL of methanol was mixed with 7.5 g of sodium bicarbonate in 300 mL of water and was made just alkaline to phenolphthalein (pH 8.5) with a few drops of aqueous NaOH. While the temperature was maintained at 40 °C, a solution of 1.50 g of 50% hydrogen peroxide in 50 mL of water was added to the stirred solution over 2 h. The resulting yellow solution was then made weakly acidic (pH ~3) with dilute H_2SO_4. The solution was concentrated to about 100 mL, diluted with 200 mL of water, and finally concentrated to 150 mL. After 1 day at 5 °C, crystals (0.60 g, 230 °C dec) were collected. These were recrystallized from boiling water (charcoal), giving yellow crystals, 242 °C dec, identified as dipyrido[1,2-a:1′,2′-c]imidazolium-11-*S*-thiosulfate (**6**), identical (IR, NMR) with samples prepared above.

Anal. Calcd for $C_{11}H_8N_2O_3$: C, 47.2; H, 2.9; N, 10.0; S, 22.8. Found: C, 48.0; H, 2.7; N, 10.4; S, 21.6.

The filtrate after removal of **6** was treated with 3 mL of 65% hexafluorophosphoric acid. This precipitated 1.50 g (48% yield) of yellow-tan crystals of dipyrido[1,2-a:1′,2′-c]imidazolium hexafluorophosphate (**2**, X^- = PF_6^-), mp 258–263 °C after crystallization from dilute aqueous HPF_6 (charcoal), identical (mixture mp, IR, NMR) with material prepared above.

Anal. Calcd for $C_{11}H_9F_6N_2P$: C, 42.0; H, 2.9; N, 8.9. Found: C, 41.6; H, 3.2; N, 8.6.

3-Ethyldipyrido[1,2-a:1′,2′-c]imidazolium-11-thiolate (12, R_2 = Et; R_1 = R_3 = R_4 = R_5 = H; X = S^-). Using 5-ethyl-2-methylpyridine in place of 2-picoline, procedure A furnished 2.9 g (33% yield) of a dark maroon solid. Recrystallization from 1-propanol gave 1.5 g of fine, lustrous, very dark maroon needles, mp 225–232 °C. Concentration of the mother liquor gave an additional 0.6 g of product, mp 224–230 °C. The combined crops were recrystallized twice from absolute ethanol (charcoal) and once from reagent acetonitrile to give 3-ethyldipyrido[1,2-a:1′,2′-c]imidazolium-11-thiolate, mp 235–236 °C (under N_2).

Anal. Calcd for $C_{13}H_{12}N_2S$: C, 68.4; H, 5.3; N, 12.3; S, 14.0; M_r 228. Found: C, 68.4; H, 5.8; N, 11.6; S, 14.2; M_r 233 (vapor-phase pressure osmometry).

3-Ethyl-11-(methylthio)dipyrido[1,2-a:1′,2′-c]imidazolium (12, R_2 = Et; R_1 = R_3 = R_4 = R_5 = H; X = SMe) Iodide and Perchlorate. 3-Ethyldipyrido[1,2-a;1′,2-a;1′,2-c]imidazolium-11-thiolate was treated with methyl iodide following the procedure described above for **1**. The crude methiodide was recrystallized by slowly evaporating a cold acetone solution on a rotary evaporator to give a 75% yield of yellow crystals, mp 201–205 °C (after recrystallization, mp 202–206 °C).

Anal. Calcd for $C_{14}H_{15}IN_2S$: C, 45.4; H, 4.1; I, 34.3; N, 7.6; S, 8.6. Found: C, 45.6; H, 4.3; I, 33.9; N, 7.3; S, 8.8.

Treatment of a solution of the methiodide in water with 72% perchloric acid gave the perchlorate; after two crystallizations from water, yellow crystals were obtained, mp 192–195 °C.

Anal. Calcd for $C_{14}H_{15}ClN_2O_4$: C, 49.1; H, 4.4. Found: C, 49.4; H, 4.9.

11,11′-Dithiobis(3-ethyldipyrido[1,2-a:1′,2′-c]imidazolium) Difluoborate. Oxidation of 3-ethyldipyrido[1,2-a:1′,2′-c]-

imidazolium-11-thiolate with H_2O_2 in acid solution, following the procedure described for 1, gave an 80% yield of 11,11'-dithiobis(3-ethyldipyrido[1,2-*a*:1',2'-*c*]imidazolium) difluoborate as orange needles, mp 227.5–228.5 °C, after recrystallization from acetone.

Anal. Calcd for $(C_{13}H_{12}BF_4N_2S)_2$: C, 47.9; H, 4.0; N, 9.2; S, 10.5. Found: C, 48.1; H, 4.3; N, 9.0; S, 10.6.

Alkaline Hydrolysis of 11,11'-Dithiobis(3-ethyldipyrido-[1,2-*a*:1',2'-*c*]imidazolium) Difluoborate. A solution of 1.01 g of the disulfide difluoborate and 5.0 g of sodium bicarbonate in 90 mL of water was heated on a steam bath for 30 min. The cooled mixture was extracted with $CHCl_3$ to remove 3-ethyldipyrido[1,2-*a*:1',2'-*c*]imidazolium-11-thiolate (**12**, R_2 = Et; R_1 = R_3 = R_4 = R_5 = H; X^- = S^-), identified by mp and IR and UV spectra.

The pale yellow aqueous solution was acidified with a few drops of 72% perchloric acid, which precipitated yellow crystals. Recrystallization from an acetone–isopropyl ether mixture gave 70 mg (28% yield) of pale yellow crystals of 3-ethyldipyrido[1,2-*a*:1',2'-*c*]imidazolium (**12**, R_2 = Et; R_1 = R_3 = R_4 = R_5 = X = H) perchlorate, mp 242–245 °C, raised by a second crystallization from ethanol to 246–247 °C. Qualitative analysis showed that the compound contained no sulfur.

Anal. Calcd for $C_{13}H_{13}ClN_2O_4 \cdot H_2O$: C, 49.6; H, 4.8; N, 8.9. Found: C, 49.4; H, 4.4; N, 8.4.

6-Methyldipyrido[1,2-*a*:1',2'-*c*]imidazolium-11-thiolate (12, R_4 = CH_3; R_1 = R_2 = R_3 = R_5 = H). With 27 mL of purified 3-picoline in place of pyridine, procedure A gave 1.2 g (20% yield) of red solid. After crystallization from methanol or chloroform and recrystallization from acetonitrile (charcoal), maroon needles, mp 312–313.5 °C (N_2) (uncorrected), of 6-methyldipyrido[1,2-*a*:1',2'-*c*]imidazolium-11-thiolate were obtained.

Anal. Calcd for $C_{12}H_{10}N_2S$: C, 67.3; H, 4.7; N, 13.1; S, 14.9. Found: C, 68.0; H, 4.9; N, 12.6; S, 14.5.

3-Ethyl-6-methyldipyrido[1,2-*a*:1',2'-*c*]imidazolium-11-thiolate (12, R_2 = Et; R_4 = Me; R_1 = R_3 = R_5 = H). With 5-ethyl-2-methylpyridine in place of 2-picoline and purified 3-picoline in place of pyridine, procedure B after 2 weeks gave 4.3 g (47%) of colored solid. The NMR spectrum in $CDCl_3$ showed two methyl singlets (δ 2.55 and 3.05), but thin-layer chromatography with a variety of solvents and adsorbents failed to effect any separation.

The crude red product (4.3 g) was dissolved in chloroform and eluted through a short column of magnesium oxide. The residue, crystallized from ca. 1000 mL of acetonitrile and recrystallized from 800 mL of acetonitrile, gave 1.7 g (18% yield) of 3-ethyl-6-methyldipyrido[1,2-*a*:1',2'-*c*]imidazolium-11-thiolate, mp 290.5–292 °C (N_2) (uncorrected), raised to 291–292 °C (uncorrected) by further crystallization.

Anal. Calcd for $C_{14}H_{14}N_2S$: C, 69.4; H, 5.8; N, 11.6; S, 13.2. Found: C, 69.6; H, 5.9; N, 11.4; S, 13.4.

The acetonitrile mother liquor from the first recrystallization of the crude product was evaporated to about 150 mL and allowed to crystallize. The dark maroon crystals [0.40 g, mp 234–239 °C (N_2)] were removed by filtration. Further concentration of the mother liquor yielded 0.135 g of very dark maroon crystals melting under nitrogen at 232–234 °C. The NMR spectrum[13,14] indicated that this last crop was a mixture of predominantly 3-ethyl-8-methyldipyrido[1,2-*a*:1',2'-*c*]imidazolium-11-thiolate (**12**, R_2 = Et; R_5 = Me; R_1 = R_3 = R_4 = H) (65%) with a lesser amount of the 3-ethyl-6-methyl isomer (35%).

3-Ethyl-6-methyl-11-(methylthio)dipyrido[1,2-*a*:1',2'-*c*]-imidazolium (12, R_2 = Et; R_4 = Me; R_1 = R_3 = R_5 = H; X = SMe) Iodide. 3-Ethyl-6-methyl[1,2-*a*:1',2'-*c*] imidazolium-11-thiolate was treated with methyl iodide to give the 11-methylthio iodide, mp 229–230 °C, after three crystallizations from chloroform.

Anal. Calcd for $C_{15}H_{17}IN_2S$: C, 46.9; H, 4.5; I, 33.0; N, 7.3; S, 8.3. Found: C, 47.3; H, 4.7; I, 32.7; N, 6.9; S, 8.6.

Imidazo[1,2-*a*:3,4-*a*']diquinolinium-14-thiolate (13, X = S^-). With quinaldine (11.1 g) in place of 2-picoline and quinoline (100 g) in place of pyridine, procedure B was followed for 14 days. Treatment of the reaction mixture with aqueous KOH gave an organic layer, which was separated and concentrated slightly by rotatory evaporation [100 °C (20–30 mm)]. It was then diluted with 1300 mL of benzene. After standing for 2 days at 10 °C, the mixture was filtered to remove 6 g of dark maroon solid. A second crop (2.7 g) was obtained by evaporating the benzene and adding 200–300 mL of carbon tetrachloride to the residual solution (total yield 41%).

The crude material (3 g) was dissolved in 120 mL of boiling reagent pyridine and crystallized by allowing the solution to stand at −5 °C for 1 week.[28] The product was collected by filtration, was washed several times with benzene, and dried at ca. 0.5 mm over H_2SO_4 and P_2O_5 to yield 0.66 g of imidazo[1,2-*a*:3,4-*a*']diquinolinium-14-thiolate as dark maroon crystals with a bronze luster, mp 300.5–301.5 °C (N_2) (uncorrected).

Anal. Calcd for $C_{19}H_{12}N_2S$: C, 76.0; H, 4.0; N, 9.3; S, 10.7. Found: C, 76.4; H, 4.4; N, 9.1; S, 10.2.

Acid Hydrolysis of Imidazo[1,2-*a*:1',2'-*c*]diquinolinium-14-thiolate (13, X = S^-). A solution of 317 mg (1.06 mmol) of **13** (X = S^-) in 20 mL of 48% hydrobromic acid was refluxed for 18 h. After cooling and being diluted with a further 20 mL of 48% HBr, the solution and apparatus were extracted with carbon disulfide. Evaporation of the extract gave 23 mg (68% yield) of elemental sulfur, mp 118–119 °C, featureless IR spectrum.

The yellow aqueous acid solution was evaporated to dryness, and the residue was crystallized from 40 mL of water to give 205 mg (59% yield) of imidazo[1,2-*a*:3,4-*a*']diquinolinium (**13**, X = H) bromide, mp 301–306 °C, raised by recrystallization from chloroform to 305–308 °C (King and Abrams[18] reported mp 306 °C). The bromide was converted with excess picric acid to the picrate, yellow needles, mp 267–269.5 °C, undepressed by admixture with an authentic sample,[18] and with perchloric acid to the perchlorate, mp 280–284 °C, undepressed by admixture with an authentic sample.[18]

Anal. Calcd for $C_{19}H_{13}ClN_2O_4$: C, 61.9; H, 3.6; N, 7.6. Found: C, 61.7; H, 3.5; N, 7.4.

14-(Methylthio)imidazo[1,2-*a*:3,4-*a*']diquinolinium (13, X = SMe) Iodide. A solution of 1.5 g of **13** (X = S^-) in chloroform was treated with excess methyl iodide. The solution was treated with charcoal, filtered, and diluted with dry ether to precipitate the orange methiodide (2.0 g, 90% yield) [after three recrystallizations from methanol–ethanol, mp 287–289 °C dec (N_2)].

Anal. Calcd for $C_{20}H_{15}IN_2S$: C, 54.3; H, 3.4; I, 28.7; N, 6.3; S, 7.2. Found: C, 54.0; H, 3.8; I, 28.4; N, 6.1; S, 7.0.

14-(Methylthio)imidazo[1,2-*a*:3,4-*a*']diquinolinium (13, X = SMe) Perchlorate. A sample of crude methiodide (1.21 g) in 250 mL of boiling methanol was treated with decolorizing charcoal, filtered, and then treated with 72% perchloric acid. After several days at −10 °C, 1.05 g (93% yield) of orange needles of the methoperchlorate thus obtained was dissolved in a minimum of hot acetonitrile, 100–150 mL of butyronitrile was added, and the solution was allowed to stand for several days at −10 °C to obtain 0.82 g of orange-yellow plates, mp 261–273 °C dec.

Anal. Calcd for $C_{20}H_{15}ClN_2O_4S$: C, 57.9; H, 3.6; S, 7.7. Found: C, 57.4; H, 3.4; S, 7.6.

1-[(Methylthio)-2-quinolylmethyl]carbostyril (14, X = SMe). A hot solution of the methiodide **13** (X = SMe; I^-) (0.50 g) in 120 mL of water mixed with a few milliliters of 50% aqueous KOH deposited a solid (0.37 g), obtained as white crystals (0.28 g; 74% yield) from anhydrous ether: mp 138.5–139.5 °C, after recrystallization from ether and then hexane; UV (cyclohexane) (log ε) 358 (3.53), 350.5 (3.60), 340 (3.75), 335 (3.74), 325.5 (sh, 3.73), 319 (3.90), 311.5 (3.73), 305.5 (3.73), 298 (3.61), 291.5 (sh, 3.66), 284 (3.99) 274 (4.04), 266 (sh, 3.96), 234 (sh, 4.79), 228 (4.81) nm.

Anal. Calcd for $C_{20}H_{16}N_2OS$: C, 72.3; H, 4.8; N, 8.4; S, 9.6. Found: C, 72.3; H, 4.9; N, 8.4; S, 9.6.

Besthorn's Red (13, X = O^-). Besthorn's Red was prepared in 93% yield (crude) according to the method of Besthorn and Ibele.[15] Wasteful crystallization from absolute ethanol and then from a benzene–ethanol gave dark red, glistening crystals, mp

(28) While **1** was relatively easy to recrystallize, the crystallization of **13** (X = S^-) was always very slow—often requiring several weeks for appreciable amounts of crystals to settle from a supersaturated solution. Attempts to hasten its crystallization by addition of solvents in which it was completely insoluble (e.g., hexane, carbon tetrachloride) resulted in precipitation with little purification. Solutions of **13** (X = S^-) were sensitive to air and light, which further complicated purification procedures.

259–261 °C (N_2) (lit. mp 230–240 °C,[15] near 250 °C[16]). Preparation according to Krollpfeiffer and Schneider[16] gave a less pure product, which required chromatography on magnesium oxide with chloroform.

Anal. Calcd for $C_{19}H_{12}N_2O$: C, 80.3; H, 4.3; N, 9.8. Found: C, 80.8; H, 4.4; N, 9.4.

Perchlorate and Bromide Salts of Besthorn's Red. A saturated solution of Besthorn's Red in absolute EtOH with 72% aqueous perchloric acid in EtOH gave yellowish crystals, quickly washed with anhydrous ether and dried under vacuum over P_2O_5.

Anal. Calcd for $C_{19}H_{13}ClN_2O_5$: C, 59.3; H, 3.4; N, 7.3. Found: C, 59.0; H, 3.6; N, 7.2.

The IR spectrum (KBr) exhibited broad absorption at 2380 cm^{-1} (highly acidic O–H).

The bromide, prepared by treating Besthorn's Red with 48% hydrobromic acid, had a very similar IR spectrum, with a strong, very broad, O–H stretching mode at 2340 cm^{-1} and a strong O–H bending mode at 690 cm^{-1}.

14-Methoxyimidazo[1,2-*a*:3′,4′-*a*′]diquinolinium (13, X = OMe) Fluoborate. A solution of the methosulfate[15] (0.25 g, 0.61 mmol) of Besthorn's Red in 20 mL of water was extracted several times with $CHCl_3$ until the extracts were no longer red. The yellow aqueous layer was diluted to 50 mL with ethanol, and 1 mL of 50% fluoboric acid was added. Yellow-orange crystals (0.15 g, 65% yield) of 14-methoxyimidazo[1,2-*a*:3,4-*a*′]diquinolinium fluoborate precipitated: mp 222–226 °C, after crystallization from MeOH; UV (MeOH) (log ε) 406 (4.24), 385 (4.28), 368 (sh, 4.14), 349 (sh, 3.91), 313 (sh, 3.81), 297 (sh, 4.20), 292.5 (4.21), 261 (4.42), 256 (sh, 4.41), 246 (4.43), 230 (4.42).

Anal. Calcd for $C_{20}H_{15}BF_4N_2O$: C, 62.2; H, 3.9; N, 7.3. Found: C, 61.8; H, 4.1; N, 7.0.

1-(Methoxy-2-quinolylmethyl)carbostyril (14, X = OMe). A solution of 0.96 g (2.3 mmol) of the methosulfate[16] of Besthorn's Red in 200 mL of water treated with 4 mL of 50% potassium hydroxide solution according to Krollpfeiffer and Schneider[16] gave 300 mg of tan crystals, which after three recrystallizations from methanol (charcoal) gave 66 mg of white crystals: mp 210–212 °C (lit. mp 213.5–214.5 °C); UV (cyclohexane) (log ε) 353 (3.53), 347 (3.58), 335.5 (3.74), 331 (3.73), 318 (3.88), 311 (3.70), 305 (3.69), 297.5 (3.56), 290 (sh, 3.56), 281 (3.96), 271 (3.97), 264.5 (sh, 3.88), 231 (sh, 4.74), 227.5 (4.75) nm.

Anal. Calcd for $C_{20}H_{16}N_2O_2$: C, 75.9; H, 5.1; N, 8.9. Found: C, 75.7; H, 5.3; N, 8.8.

1-(2-Quinolylmethyl)carbostyril (14, X = H). Imidazo[1,2-*a*:3,4-*a*′]diquinolinium sulfate (13, X = H) (622 mg), hydrolyzed according to Brown and White,[6] gave 484 mg (86% yield) of 1-(2-quinolylmethyl)carbostyril (14, X = H): mp 108–109.5 °C [after fusion at 110 °C and recrystallization from pentane, mp 125–128 °C (lit.[6] mp 125 °C)]; UV (cyclohexane) (log ε) 355 (3.62), 348 (3.66), 337 (3.79), 332 (3.77), 323.5 (sh, 3.73), 317 (3.90), 310 (3.71), 304 (3.70), 296.5 (3.56), 290.5 (3.57), 279.5 (4.00), 270 (3.99), 262 (sh, 3.89), 235 (4.77), 226 (4.78) nm.

Registry No. 1, 98779-37-4; 2 (X^- = ClO_4^-), 98779-39-6; 2 (X^- = PF_6^-), 98779-38-5; 3 (X^- = BF_4^-), 98779-75-0; 3 (X^- = ClO_4^-), 98779-74-9; 3 (X^- = I^-), 98779-76-1; 3 (X^- = PF_6^-), 98779-73-8; 4 (X^- = CLO_4^-), 98779-43-2; 4 (X^- = I^-), 98779-40-9; 4 (X^- = PF_6^-), 98779-42-1; 5, 98779-44-3; 6, 98779-45-4; 7 (X^- = BF_4^-), 98779-47-6; 12 (R_2 = Et,R_1 = R_3 = R_4 = R_5 = H,X = S^-), 98779-48-7; 12 (R_4 = Me, R_1 = R_2 = R_3 = R_5 = H,X = S^-), 98779-52-3; 12 (R_2 = Et, R_4 = Me, R_1 = R_3 = R_5 = H, X = S^-), 98779-53-4; 12 (R_2 = Et, R_5 = Me, R_1 = R_3 = R_4 = H, X = S^-, 98779-54-5; 12 (R_2 = Et, R_1 = R3 = R_4 = R_5 = H, X = SMe)·ClO_4^-, 98779-51-2; 12 (R_2 = Et, R_1 = R_3 = R_4 = R_5 = H, X = SMe)·I^-, 98779-49-8; 12 (R_2 = Et, R_4 = Me, R_1 = R_3 = R_5 = H, X = SMe)·I^-, 98779-55-6; 13 (X = O^-), 98779-77-2; 13 (X = S^-), 98779-56-7; 13 (X = H)·Br^-, 98779-57-8; 13 (X = H)·ClO_4^-, 98779-59-0; 13 (X = H)·picrate$^-$, 98779-58-9; 13 (X = OH)·Br^-, 98779-66-9; 13 (X = OH)·ClO_4^-, 98779-65-8; 13 (X = OH)·$MeOSO_3^-$, 98779-67-0; 13 (X = OMe)·BF_4^-, 98779-69-2; 13 (X = SMe)·ClO_4^-, 98779-62-5; 13 (X = SMe)·I^-, 98779-60-3; 14 (X = H), 98779-71-6; 14 (X = OMe), 98779-70-5; 14 (X = SMe), 98779-63-6; benzoyl chloride, 98-88-4; chloroacetic acid, 79-11-8; 11,11′-dithiobis(3-ethyldipyrido[1,2-*a*:1′,2′-*c*]imidazolium bis(fluoroborate), 98800-53-4; 5-ethyl-2-methylpyridine, 104-90-5; 2-picoline, 109-06-8; 3-picoline, 108-99-6; pyridine, 110-86-1; pyridine sulfur trioxide complex, 26412-87-3; quinaldine, 91-63-4; quinoline, 91-22-5; sodium dithionite, 7775-14-6; sulfur dioxide, 7446-09-5.

Supplementary Material Available: Full IR data for all compounds, mass spectra for 1 and 12 (R_2 = Et; R_1 = R_3 = R_4 = R_5 = H; X = S^-), and UV data for most compounds (10 pages). Ordering information is given on any current masthead page.

Synthesis of Quinazoline-2,4,5,8(1*H*,3*H*)-tetrones and Their Amine Nucleophilic Addition Chemistry

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The amination of quinazoline-2,4,5,8(1*H*,3*H*)-tetrones was studied in conjunction with synthetic efforts toward the imidazo[4,5-*g*]quinazoline-4,6,8,9-tetrone system. Under the basic reaction conditions employed, the quinazolinetetrone system possesses a negative charge delocalized into both the pyrimidine and benzoquinone rings. Thus, unfavorable electrostatic effects preclude nucleophilic addition to this system by amines. Activation toward nucleophilic attack was realized by the placement of a 6-acetamido group (1). Even though this system is still anionic under the amination conditions, substitution products were observed under mild conditions. Thus, treatment of 1 with aniline/DMF resulted in the formation of the 8-phenylimino derivative (11) while treatment with methylamine (in water or DMF) resulted in formation of the 6-methylamino 8-methylimino derivative (3). The activating influence of the 6-acetamido group is proposed to involve the contribution of tautomeric species such as $\mathbf{1a}^-$. Nucleophilic attack at either the 8- or 6-position of $\mathbf{1a}^-$ is electrostatically favorable since the negative charge develops at the acetamido oxygen which is removed from the anionic quinazoline nucleus.

Only a few quinazoline-5,8-diones have been reported in the literature[1] whereas imidazo[4,5-*g*]quinazoline-4,9-diones are unknown. Since imidazo[4,5-*g*]quinazolines have been noted to mimic purines in enzymatic reactions,[2]

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