Isoindolo[2,1-*a*]quinazoline-5,11-dione (III).—To a mixture (1:1) of 40 ml of acetic anhydride and pyridine was added 2.0 g of 2′-carbamoylphthalanilic acid (I). The solution was stirred slowly for 23 hr at room temperature, during which time yellow solids separated out. The crystals were collected: yield 0.25 g (14.3%); mp 246°. Recrystallization from ethanol gave III: mp 247°; ir (KBr) 1760, 1680 (C=O), 1620 cm^{-1} (C=N); uv_{max} 230 mμ (ε 26,500), 245 (18,690), 255 (19,400), 265 (15,500), 283 (9060), 310 (4,340); nmr δ 8.78 (d) 8.20 (m), 7.64.

Anal. Calcd for $C_{15}H_8O_2N_2$: C, 72.57; H, 3.25; N, 11.27. Found: C, 72.37; H, 3.12; N, 11.39.

From the filtrate, on addition of ethyl ether, there was obtained 1.40 g (74.8%) of *o*-phthalimidobenzamide (II), mp 220°. Recrystallization from ethanol yielded pure II, mp 239°.

Isoindolo[1,2-*b*]quinazoline-10,12-dione (IV). Method A. Cyclization of 2′-Carbamoylphthalanilic Acid (I).—A 2.84-g portion of 2′-carbamoylphthalanilic acid (I) was heated at 188° for 20 min to obtain white crystals. Sublimation at 260° yielded white crystals melting at 233°. The yield was 2.50 g (99%): ir (KBr) 1780, 1700 (C=O), 1640 cm^{-1} (C=N); uv_{max} 275 mμ (ε 10,170), 303 (7690), 315 (5750); nmr δ 8.16 (d) 7.20, 8.00 (m).

Anal. Calcd for $C_{15}H_8O_2N_2$: C, 72.57; H, 3.25; N, 11.27. Found: C, 72.58, H, 3.29; N, 11.45.

Method B. Cyclization of *o*-phthalimidobenzamide (II). a.—By the treatment of *o*-phthalimidobenzamide (II) at 260° for 1 hr, isoindolo[1,2-*b*]quinazoline-10,12-dione (IV) was obtained quantitatively, mp 233°. The structure was confirmed by the comparison of its infrared spectrum with those of an authentic sample of IV prepared directly from 2′-carbamoylphthalanilic acid by the thermal cyclization.

b.—To a mixture (1:1) of 10 ml of acetic anhydride and pyridine was added for 200 mg of *o*-phthalimidobenzamide (II). The solution was refluxed for 2 hr. By removal of the solvent under vacuum, there was obtained 180 mg of IV, mp 225°, recrystallization from ethanol yielded III as pure yellow crystals, mp 233°.

Method C. Intramolecular Acyl Rearrangement of Isoindolo[2,1-a]quinazoline-5,11-dione (III) to Isoindolo[1,2-b]quinazoline-10,12-dione (IV) by Heating.—Isoindolo[2,1-*a*]quinazoline-5,11-dione (III, 200 mg) was heated in a test tube at 260° for 30 min and cooled, affording 188 g of a precipitate, mp 225°. One sublimation raised the melting point to 232°. The infrared, ultraviolet, and nmr spectra are in good agreement with those of an authentic sample.

Anal. Calcd for $C_{15}H_8O_2N_2$: C, 72.57; H, 3.25; N, 11.27. Found: C, 72.38; H, 3.19; N, 11.25.

Method D. Reaction of Anthranilamide with Phthalic Anhydride without Solvent.[3]—A mixture of 2.72 g (0.02 mol) of anthranilamide and 2.96 g (0.02 mol) of phthalic anhydride was heated at 135–160° for 2.5 hr by the method of Crippa and Caracci,[2] cooled, and 4.5 g of the product (90.8% yield, mp 225°) was obtained. Recrystallization from ethanol gave pure IV, mp 234°. A previous paper[2] reported that this product was II. The infrared, ultraviolet, and nmr data are identical with those of pure IV.

Registry No.—I, 18257-54-0; II, 18257-55-1; III, 18257-78-8; IV, 19910-55-5.

Acknowledgments.—The author gratefully acknowledges the interest and encouragement of Drs. T. Hoshino, R. Nakanishi, and N. Yoda of Basic Research Laboratories, Toyo Rayon Co., Ltd. The author is indebted to Mr. Y. Ebata and his staff for microanalyses, and Dr. K. Nukada for helpful discussion of the nmr data.

Equilibration Studies. 2-Methylthiopyridine–N-Methyl-2-thiopyridone

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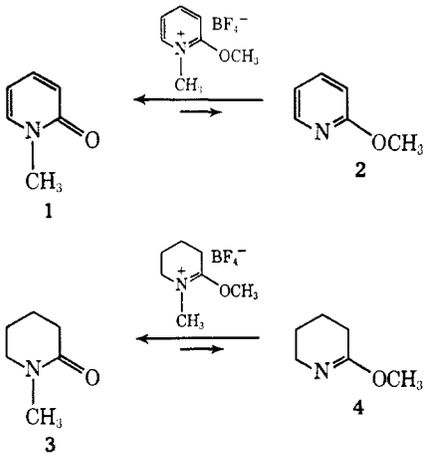
Equilibration of N-methyl-2-thiopyridone (**7**) with 2-methylthiopyridine (**9**) through the catalytic action of N-methyl-2-methylthiopyridinium fluoroborate at 145–188° indicates that **9** is favored in the liquid phase by an enthalpy of 2.6 ± 1.3 kcal/mol. Conversion of this enthalpy difference to the gas phase with correction for differences in kinetic and zero-point energies gives a difference in chemical binding energy between **7** and **9** of 7.6 ± 4.3 kcal/mole in favor of **9**. This order of stabilities is contrasted with those observed for the analogous protomeric and oxygen-substituted systems.

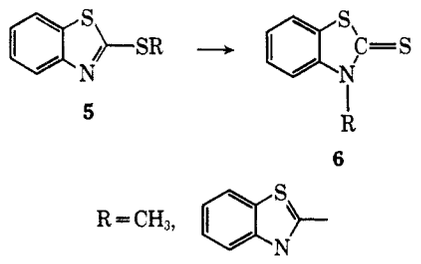
Relative chemical binding energies have been obtained for amide–imidate isomer pairs by measurements of liquid-phase enthalpies, extrapolations to the gas phase, and estimates of differences in kinetic and zero-point energies.[1] For the pairs N-methyl-2-pyridone (**1**)–2-methoxypyridine (**2**) and N-methyl-2-piperidone (**3**)–O-methylvalerolactim (**4**) the amides are the more stable isomers in chemical binding energies by 8.0 ± 3.5 and 14.1 ± 3.5 kcal/mol, respectively. Extension of the equilibration procedure and estimates of differences in binding energies to the corresponding thioamides–thioimidates is of interest for determination of the relative stabilities of these isomeric functionalities, comparison of the chemical-binding abilities of sulfur and oxygen, and insight into the relative stabilization energies of pyridine–pyridone isomer pairs.



Few thioamide–thioimidate equilibrations have been reported. However, at least one system which has a formal resemblance to a simple thioamide–thioimidate pair has been equilibrated; 2-thiobenzothiazoles (**5**) may be transformed to the isomeric 2,3-dihydro-3-thiobenzothiazoles (**6**) under equilibrating conditions.[2]

(1) P. Beak, J. Bonham, and J. T. Lee, Jr., *J. Am. Chem. Soc.*, **90**, 1569 (1968).

(2) D. J. Fry and J. D. Kendall, *J. Chem. Soc.*, 1716 (1951); J. J. D'Amico, S. T. Webster, R. H. Campbell, and C. E. Twine, *J. Org. Chem.*, **30**, 3628 (1965).

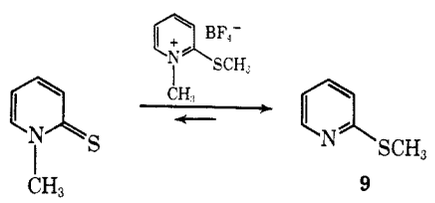


5 6

R = CH_3,

Results

When separate mixtures of N-methyl-2-thiopyridone (**7**) and N-methyl-2-methylthiopyridinium fluoroborate (**8**) and of 2-methylthiopyridine (**9**) and **8** are heated at 190° for 20 hr, an equilibrium mixture consisting of *ca.* 10% **7** and 90% **9** is produced, as shown by the relative areas of the methyl resonances of each isomer in the nmr spectra of the mixtures. Competing reactions involving either isomer or the catalyst cannot be detected by infrared or nmr spectroscopy or by thin layer chromatography. However, attempts to measure accurately the equilibrium constant at 150 and 190° by ultraviolet spectroscopy, the method of choice, gave poor results. The values obtained starting with each isomer, **7** or **9**,



7 9

are (K = [**9**]/[**7**]) 12.9 ± 2.9 (190°, five runs) and 9.1 ± 1.7 (150°, four runs). This low precision is attributed to the formation of side products which escape detection by the alternate methods of analysis. In an effort to minimize this source of scatter, a series of equilibrations was carried out at 145 and 188° for *ca.* one half-life with mixtures of **9** and **7** which were chosen to narrowly bracket the expected equilibrium values.[3] Equilibrium constants (K = [**9**]/[**7**]) of 14.4 ± 1.0 (188°, four runs) and 10.7 ± 0.8 (145°, three runs) are obtained. These values give a plot of log K *vs.* $1/T$ which reveals a liquid-phase enthalpy difference ($\Delta H_l°_{190°}$) between **7** and **9** of −2.3 ± 1.3 kcal/mol in favor of **9**. The heats of vaporization ($\Delta H_{vap}°_{190°,\ 1\ atm}$) of **7** and **9** were estimated as previously described[1] with nonreduced Cox–Antoine vapor pressure data at 189 and 191° and the Clasius–Clapeyron equation. The values of $\Delta H_{vap}°_{190°}$ obtained are 16.1 ± 0.75 kcal/mol for N-methyl-2-thiopyridone (**7**) and 11.1 ± 0.75 kcal/mol for 2-methylthiopyridine (**9**). Combination of the difference in these values and the liquid-phase enthalpy difference for isomers **7** and **9** gives a gas-phase standard enthalpy difference of −7.6 ± 2.8 kcal/mol. On the basis of previous arguments[1] the kinetic energy difference between these isomers may be presumed to be negligible and the difference in zero-point energies no greater than ±1.5 kcal/mol. This correction gives a difference in chemical binding energy between **7** and **9** of −7.6 ± 4.3 kcal/mol in favor of **9**.

(3) G. S. Hammond, J. Saltiel, A. A. Lamola, N. J. Turro, J. S. Bradshaw, D. O. Cowan, R. C. Counsell, V. Vogt, and C. Dalton, *J. Am. Chem. Soc.*, **86**, 3197 (1964).

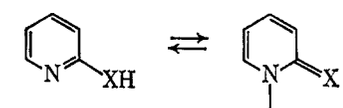
Attempts to equilibrate N-methyl-2-thiopiperidone (**10**) and 2-methylthio-3,4,5,6-tetrahydropyridine (**11**) by the catalytic action of N-methyl-2-methylthiopiperidinium fluoroborate (**12**) at 170° starting from **10** and **12** gave only **10**, but a mixture of **11** and **12** gives an 80% loss of **11** and formation of only 10% of **12**. Of incidental interest is our observation of an unusual long-range coupling between the N-methyl protons and the methylene groups at C-3 (J = <1 Hz) and C-6 (J = 1.5 Hz) in the nmr spectrum of **12**.

Discussion

Comparison of the chemical binding energy differences for members of the structurally related isomer pairs **1–2** and **7–9** shows that there is a reversal in the relative stabilities of the 2-pyridone–2-substituted pyridine systems with the change of sulfur for oxygen. Amide **1** is more stable than the imidate **2** by 8.0 ± 3.5 kcal/mol, but thioamide **7** is less stable than the thioimidate **9** by 7.6 ± 4.3 kcal/mol.

This difference in relative stabilities could be attributed to differences in localized bond energies and/or the relative π-delocalization energies of the functional groups. Although the models and assumptions are controvertible, it appears that both effects would predict the observed result. Differences in localized bond energies suggest that a carbonyl group is favored relative to an ether group (amide–imidate) by several kilocalories per mol more than a thiocarbonyl group is favored relative to a thioether (thioamide–thioimidate).[4] Hückel calculations, with the parameters suggested by Streitwieser,[5] show the thioimidate to have a larger π-delocalization energy than the thioamide by 0.48 β. The same method shows the imidate function to have a 0.13 β smaller π-delocalization energy than the amide.

Tautomeric equilibrium constants have been determined from ionization constants for the protomeric isomer pairs corresponding to **7–9** and **1–2**. In both cases, in aqueous solution at 20°, the amide isomer is heavily favored. The energy differences are 6.3 kcal/mol[6]



13, X = S 14, X = S

15, X = O 16, X = O

between **13** and **14**, in favor of **14**, and 4.1 kcal/mol between **15** and **16**, in favor of **16**.[7] The contrast between these equilibria and those of the alkylated isomers **1–2** and **7–9** is striking and clearly demonstrates that tautomeric equilibria in protomeric systems cannot reliably serve as a predictive guide for the corresponding alkyl-

(4) (a) T. L. Cottrell, "The Strengths of Chemical Bonds," 2nd ed, Butterworth and Co. Ltd., London, 1958, Chapter 10: >C=O, 162; ≫CO, 77; >C=S, 121; ≫CS, 59 kcal/mol; (b) L. Pauling, "The Nature of the Chemical Bond," Cornell University Press, Ithaca, N. Y., 1960, pp 53, 131: >C=O, 142; ≫CO, 70; >C=S, 103; ≫CS, 55 kcal/mol.

(5) A. Streitwieser, Jr., "Molecular Orbital Theory," John Wiley and Sons, Inc., New York, N. Y., 1961, p 135.

(6) (a) A. Albert and G. B. Barlin, *J. Chem. Soc.*, 2384 (1959); (b) R. A. Jones and A. R. Katritzky, *ibid.*, 3610 (1958).

(7) (a) A. Albert and J. N. Phillips, *ibid.*, 1294 (1956); (b) S. F. Mason, *ibid.*, 674 (1958).

ated isomers. The latter are the models of choice for discussions of relative chemical binding energies.[1]

The failure of equilibration of the isomers **10** and **11** with the salt **12** suggests a limitation on the equilibration procedure.[1] Resolution of this difficulty might be achieved by the use of a nucleophilic anion which could act as the alkyl transfer agent[8] or by measurement of the heats of methylation of **10** and **11**.

Experimental Section[9]

Materials.—Commercially available, reagent grade solvents were used without additional purification. The following reagents were obtained from the indicated suppliers and were used without further purification: silver fluoroborate, Ozark-Mahoning Company; iodomethane, N-methyl-2-piperidone, and 2-piperidone, Aldrich Chemical Co.; phosphorus pentasulfide, Eastman Organic Chemicals; 2-pyridone, J. T. Baker Chemical Co.; iodomethane-d_3, Stohler Isotope Chemicals.

Pyrex tubes were charged and sealed as previously described. Sealed tubes were placed in an electrically heated, stirred bath whose temperature was regulated (±1.5°) with a proportional controller.[10]

N-Methyl-2-thiopyridone (**7**) was prepared in 60% yield from N-methyl-2-pyridone[1] and phosphorus pentasulfide according to the method of Renault[11] and purified by sublimation at 75° (0.1 mm), mp 88–90° (lit.[11] 89–90°). The infrared spectrum (chloroform) showed absorptions at 2950, 1620, 1530, 1485, 1470, 1410, 1305, 1140, 1110, and 1020 cm^{-1}. The nmr spectrum (chloroform-*d*) showed resonances centered at δ 4.00 (3 H, singlet, N-methyl), 6.68 and 7.25, (1 H each, apparent triplet of doublets with line spacings of 1 and 6 Hz, protons at C-4 and C-5), and 7.70 (2 H, complex multiplet, ring protons at C-3 and C-6).

2-Methylthiopyridine (**9**) was prepared in 65% yield by methylation–deprotonation of 2-thiopyridone[11] according to the method of Renault,[12] bp 82–83° (17 mm) [lit.[12] 91° (22 mm)]. The infrared spectrum (neat) showed prominent absorptions at 2950, 2900, 1580, 1450, 1430, 1410, 1320, 1280, 1170, 1150, 1125, 1090, and 1045 cm^{-1}. The nmr spectrum (chloroform-*d*) displayed resonances centered at δ 2.53 (3 H, singlet, S-methyl), 6.60–7.50 (3 H, complex multiplet, ring protons at C-3, C-4, and C-5), and 8.29 (1 H, broadened doublet, line spacing 5 Hz, ring proton at C-6).

N-Methyl-2-methylthiopyridinium iodide was prepared in 70% yield from N-methyl-2-thiopyridone and iodomethane according to the procedure of Renault,[12] mp 155–157° (lit.[12] 156°). The infrared spectrum (chloroform) showed absorptions at 2830, 1615, 1560, 1490, 1450, 1430, 1330, 1160, 1120, and 1020 cm^{-1}. The nmr spectrum (dimethyl sulfoxide-d_6) showed resonances centered at δ 2.91 (3 H, singlet, S-methyl), 4.20 (3 H, singlet, N-methyl), 7.65–8.20 (2 H, complex multiplet, ring protons at C-4 and C-5), 8.42 (1 H, apparent triplet of doublets, line spacings 8, 2 Hz, ring proton at C-3), and 9.15 (1 H, broadened doublet, line spacing of 7 Hz, ring proton at C-6).

The same compound was obtained when 2-methylthiopyridine was treated with iodomethane. Identity was established by melting point (155–157°), mixture melting point (153–155°), and the nmr spectrum.

N-Methyl-2-methyl-d_3-thiopyridinium Iodide.—A mixture of 0.817 g (6.5 mmol) of N-methyl-2-thiopyridone and 1.14 g (7.7 mmol) of iodomethane-d_3 in 10 ml of acetone was stirred at ambient temperature for 3 hr. The crystalline precipitate was isolated by suction filtration and dried at reduced pressure. The yield of N-methyl-2-methyl-d_3-thiopyridinium iodide was 1.73 g (98%), mp 153–154°.

Anal. Calcd for $C_7H_7D_3NSI$: C, 31.10; H, 3.73; N, 5.19. Found: C, 31.31; H, 3.80; N, 5.02.

The infrared and nmr spectra were consistent with the assigned structure. The nmr spectrum displayed resonances corresponding to those of the isotopically normal material except for the absence of a signal at δ 2.8–3.0.

N-Methyl-2-methylthiopyridinium Fluoroborate (**8**).—A mixture of 2.11 g (0.02 mol) of N-methyl-2-thiopyridone, 3.22 g (0.02 mol) of silver fluoroborate, and 9.0 g (0.06 mol) of iodomethane in 60 ml of 1,2-dichloroethane was stirred at ambient temperature for 26 hr. After filtration the silver iodide paste was leached with 550 ml of boiling methanol and the filtrate and washings were combined and concentrated at reduced pressure to give a crystalline residue. Clarification of a 60-ml ethanol solution of this material with activated carbon followed by cooling gave 2.45 g (65%) of N-methyl-2-methylthiopyridinium fluoroborate as colorless prisms, mp 119–121°.

Anal. Calcd for $C_7H_{10}NSBF_4$: C, 37.02; H, 4.45; N, 6.17; S, 14.07. Found: C, 37.12; H, 4.55; N, 6.07; S, 14.12.

The infrared spectrum (potassium bromide) showed absorptions at 2970, 2900, 1605, 1555, 1475, 1430, 1300, 1265, 1165, 1180, 1020 (broad), 780, and 705 cm^{-1}. The nmr spectrum (dimethyl sulfoxide-d_6) was identical with that of N-methyl-2-methylthiopyridinium iodide.

This material was alternately prepared in 78% yield by treating N-methyl-2-methylthiopyridinium iodide with 1 equiv of silver fluoroborate in 1,2-dichloroethane. Identity was established by melting point (118–120°), mixture melting point (118.5–121°) and the nmr spectrum.

Thermal Stability of 7, 8, and 9 at 190°.—Separate sealed tubes containing these materials were heated at 190° for 19.3 hr, cooled to ambient temperature, and opened. The infrared and nmr spectra were indistinguishable from those of authentic samples. The recovered N-methyl-2-thiopyridone had mp 87–89° and mmp 87.5–90° with authentic material. The recovered N-methyl-2-methylthiopyridinium fluoroborate had mp 118.5–121.5° and mmp 118.5–121.5° with authentic material.

Equilibration of N-Methyl-2-thiopyridone (**7**) **and 2-Methylthiopyridine** (**9**) **at 190°.**—A sealed tube containing 0.150 g of 2-methylthiopyridine and 0.024 g of N-methyl-2-methylthiopyridinium fluoroborate was heated at 190° for 19.5 hr, cooled to ambient temperature, and opened. The contents were triturated with 1.0 ml of chloroform and the resultant slurry was filtered. The nmr spectrum of the filtrate indicated the presence of *ca.* 10% of N-methyl-2-thiopyridone and *ca.* 90% of 2-methylthiopyridine. The residue (0.023 g, 90%) was identified as N-methyl-2-methylthiopyridinium fluoroborate by melting point (120–121.5°), mixture melting point with an authentic sample (119–121.5°), and infrared analysis. Parallel runs with N-methyl-2-thiopyridone and N-methyl-2-methylthiopyridinium fluoroborate at 190° for 19.5 hr gave 85% recovery of N-methyl-2-methylthiopyridinium fluoroborate and a mixture identified by nmr as *ca.* 10% N-methyl-2-thiopyridone and *ca.* 90% 2-methylthiopyridine. Competing reactions involving either isomer or the catalyst could not be detected by infrared or nmr spectroscopy or by tlc.

Direct Determination of the N-Methyl-2-thiopyridone (**7**)**–2-Methylthiopyridine** (**9**) **Liquid-Phase Equilibrium Constant.**—The multicomponent spectral technique of Dewar and Urch[13] was employed for direct determinations of the equilibrium isomer ratios at several temperatures. Catalyst **8** was isolated by diethyl ether precipitation prior to measurement. The spectral measurements were made with anhydrous ethanol as solvent and absorbance data were taken at six wavelengths (2925, 2900, 2875, 2850, 2825, and 2800 Å) centered about the N-methyl-2-thiopyridone maximum at 2860 Å to maximize the sensitivity of the mixture spectra to low concentrations of this isomer. Absorbance data were processed with an IBM 1800 digital computer using a modified version of a least-squares plotting program provided by S. G. Smith. Control experiments established that ethanol solutions of each isomer obey Beer's law over the concentration

(8) H. J. Teague and W. P. Tucker, *J. Org. Chem.*, **32**, 3144 (1967).

(9) Melting points were determined on a Reichert block equipped with thermometers accurate to ±1°, as determined by melting point measurements for appropriate standards. Boiling points are uncorrected. Infrared spectra were measured on Perkin-Elmer Models 521 and 137 instruments with sodium chloride plates or cells. Ultraviolet spectra were measured with a Cary Model 14 spectrophotometer and 1.0-cm matched silica cells. The proton magnetic resonance spectra were measured with Varian Associates A-60, A-60A, and A-56/60 spectrometers with chloroform-*d* solutions unless otherwise noted. Chemical shifts are reported in δ, parts per million relative to the internal standard tetramethylsilane. Spin decoupling experiments were conducted using a Varian Associates HA-100 instrument. Molecular weight mass spectra at *ca.* 15-eV ionizing potential were determined on an Atlas Model CH4 instrument equipped with a vacuum lock inlet system. Microanalyses were performed by J. Nemeth and associates. Aerograph Models A-600-B and A-90-P gas chromatographs were used for analytical and preparative glpc.

(10) R. W. Anderson, *J. Chem. Educ.*, **44**, 569 (1967).

(11) J. Renault, *Bull. Soc. Chim. France*, **20**, 1001 (1953).

(12) J. Renault, *Ann. Chim.* (Paris), **10**, 135 (1955).

(13) M. J. S. Dewar and D. S. Urch, *J. Chem. Soc.*, 345 (1957).

and wavelength ranges employed in the analyses. The equilibrium constants obtained from this analysis were $K_{190°} = 12.9 \pm 2.9$ (reaction time 19.5 hr) and $K_{150°} = 9.1 \pm 1.7$ (reaction time 174 hr).

It was found in preliminary experiments that unless the catalyst, N-methyl-2-methylthiopyridinium fluoroborate, is removed prior to spectral measurement, spurious results are obtained. Separation of the pyridinium salt was achieved by its precipitation from the reaction mixture with diethyl ether.

The products of equilibration reactions at 188 and 145° were analyzed after partial reaction by the techniques described above.

2-Methylthio-3,4,5,6-tetrahydropyridine.—A solution of 5.25 g (0.02 mol) of 2-methylthio-3,4,5,6-tetrahydropyridinium iodide[14] in 160 ml of pH 10 buffer (*ca.* 0.20 *M*) was vigorously stirred at ambient temperature for 60 sec, then rapidly extracted with two 100-ml portions of ethyl ether. The ether extracts were combined, dried (anhydrous magnesium sulfate), and concentrated at reduced pressure with minimal heating to provide 2.39 g of yellow residue. Glpc analysis (20% Apiezon L on Firebrick, 120°) of this material indicated the presence of one major component and at least two minor components. The major component was collected and identified as 2-methylthio-3,4,5,6-tetrahydropyridine.

Anal. Calcd for $C_6H_{11}NS$: C, 55.77; H, 8.58; N, 10.84. Found: C, 56.10; H, 8.74; N, 10.71.

The infrared spectrum (neat) showed prominent absorptions at 2910, 2850, 1640, 1440, 1420, 1340, 1325, 1310, 1270, and 1250 cm^{-1}. The nmr spectrum (chloroform-*d*) displayed resonances centered at δ 1.77 (4 H, complex multiplet, ring protons at C-4 and C-5), 2.27 (2 H, complex multiplet, ring protons at C-3), 2.27 (3 H, singlet, S-methyl), and 3.63 (2 H, complex multiplet, ring protons at C-6).

N-Methyl-2-thiopiperidone was prepared in 50% yield from N-methyl-2-piperidone and phosphorus pentasulfide according to the procedure of Renault,[11] and purified by recrystallization from ligroin–ethyl ether (50:50) at −20°, mp 37–38° (lit.[11] 37–38°).

Anal. Calcd for $C_6H_{11}NS$: C, 55.77; H, 8.58; N, 10.84. Found: C, 56.03; H, 8.71; N, 10.78.

The infrared spectrum (chloroform) included prominent absorptions at 2875, 1540, 1530, 1450, 1420, 1350, and 1330 cm^{-1}. The nmr spectrum (chloroform-*d*) displayed resonances centered at δ 1.82 (4 H, complex multiplet, ring protons at C-4 and C-5), 2.98 (2 H, complex multiplet, ring protons at C-3), 3.44 (2 H, complex multiplet, ring protons at C-6), and 3.46 (3 H, singlet, N-methyl).

N-Methyl-2-methylthio-3,4,5,6-tetrahydropyridinium Fluoroborate.—A mixture of 0.628 g (2.0 mmol) of N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium iodide[12] and 0.421 g (2.0 mmol) of silver fluoroborate in 35 ml of 1,2-dichloroethane was stirred at ambient temperature for 19 hr. After silver iodide had been removed by gravity filtration, 30 ml of ethyl ether was added to the filtrate and the resultant clear solution was allowed to stand at −20° for 2 hr. The colorless crystals which formed were isolated and dried at reduced pressure. The yield of N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate was 0.191 g (36%), mp 95–96°.

Anal. Calcd for $C_7H_{14}NSBF_4$: C, 36.39; H, 6.11; N, 6.06; S, 13.88. Found: C, 36.45; H, 6.08; N, 5.72; S, 13.97.

The infrared spectrum (Nujol) showed prominent absorptions at 2950, 1590, 1340, 1320, 1275, 1225, 1175, 1020 (broad), 950, and 910 cm^{-1}. The nmr spectrum (acetone-d_6) displayed resonances centered at δ 1.95 (4 H, complex multiplet, ring protons at C-4 and C-5), 2.80 (3 H, singlet), 3.04 (2 H, complex multiplet, ring protons at C-3), 3.52 (3 H, complex multiplet), and 3.90 (2 H, complex multiplet, ring protons at C-6). Spin decoupling experiments (100 MHz) provided clarification of the 60 MHz spectrum. The complex pattern at δ 3.52 collapsed to a triplet (J = 1.5 Hz) upon irradiation at 3.90 and to a broad singlet (J < 1 Hz) upon irradiation at 3.04. Irradiation at δ 3.52 resulted in perceptible simplifications of the multiplets at 3.90 and 3.04. These results indicate that one of the methyl groups, probably that bound to nitrogen on the basis of its chemical shift, and two sets of ring protons are coupled.

Attempted Equilibration of N-Methyl-2-thiopiperidone (14) and 2-Methylthio-3,4,5,6-tetrahydropyridine (15) at 170°.—Sealed tube experiments, analogous to those described above, established that N-methyl-2-thiopiperidone, 2-methylthio-3,4,5,6-tetrahydropyridine, and N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate are thermally stable at 170° for at least 20 hr.

A sealed tube containing 0.080 g of N-methyl-2-thiopiperidone and 0.011 g of N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate was heated at 170° for 21.3 hr, cooled to ambient temperature, and opened. After trituration of the orange product mixture with ethyl ether, tlc and gas chromatographic (20% Apiezon L on Firebrick, 120°) analyses of the ether solution indicated the presence of one component, N-methyl-2-thiopiperidone. It was established that at least 2% of 2-methylthio-3,4,5,6-tetrahydropyridine would have been detected. Concentration of the ether solution under a dry nitrogen jet gave 0.078 g (98%) of N-methyl-2-thiopiperidone, as shown by infrared and nmr spectra. An infrared spectrum of the material insoluble in ether was essentially indistinguishable from that of authentic N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate.

A tube containing 0.046 g of 2-methylthio-3,4,5,6-tetrahydropyridine and 0.014 g of N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate was heated at 170° for 20 hr, cooled to ambient temperature, and opened. The orange product mixture was triturated with ethyl ether. Although tlc of the ether solution indicated the presence of 2-methylthio-3,4,5,6-tetrahydropyridine, N-methyl-2-thiopiperidone and at least two other components were present. A glpc analysis (20% Apiezon L on Firebrick, 120°) of this solution showed the presence of only 2-methylthio-3,4,5,6-tetrahydropyridine under conditions allowing detection of at least 9% of N-methyl-2-thiopiperidone.

The orange, ether-insoluble material, which remained an intractable gum after extensive evacuation at 0.01 mm, was highly impure, as shown by its four-component thin layer chromatogram, its weight (0.032 g, 230%), and its infrared spectrum, which resembled that of authentic N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate, but displayed several substantial absorptions not observed in the authentic spectrum.

A second tube, containing 0.033 g of 2-methylthio-3,4,5,6-tetrahydropyridine and 0.009 g of N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate, was heated at 170° for 20 hr, cooled to ambient temperature, and opened. The contents were triturated with 1.0 ml of ethyl ether. A glpc analysis of the solution showed the presence of only *ca.* 18% of the original 2-methylthio-3,4,5,6-tetrahydropyridine charge.

Registry No.—**7**, 2044-27-1; **8**, 19766-06-4; **9**, 18438-38-5-; N-methyl-2-methyl-d_3-thiopyridinium iodide, 19766-28-0; 2-methylthio-3,4,5,6-tetrahydropyridine, 19766-29-1; N-methyl-2-methylthio-3,4,5,6-tetrahydropyridinium fluoroborate, 19795-94-9.

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