The Effect of Triethylamine on the Deoxydative Substitution of Pyridine N-Oxides by Mercaptans[1]

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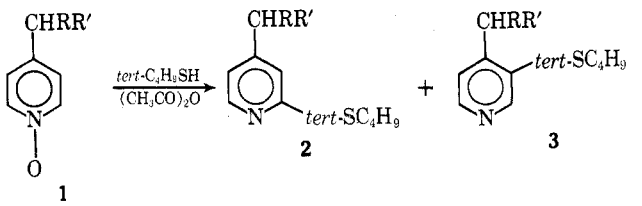
The reaction of a number of pyridine 1-oxides with mercaptans in acid anhydrides was studied in the presence of 2 equiv of triethylamine. 2- and 3-pyridyl sulfides were isolated, with a notable increase of the 2 isomer from those cognate reactions in which triethylamine had been omitted. The reaction of 4-picoline and 4-ethyl-, 4-*n*-propyl-, and 4-isopropylpyridine 1-oxides with *tert*-butyl mercaptan in acetic anhydride containing triethylamine furnished a new series of 1-acetyl-2-acetoxy-3-*tert*-butylthio-4-alkylidene-1,2,3,4-tetrahydropyridines. When triethylamine was absent, similar reactions of 4-*n*- and 4-isopropylpyridine 1-oxides produced the expected 1-acetyl-2-acetoxy-3,6-di(*tert*-butylthio)-4-alkyl-1,2,3,6-tetrahydropyridines. Pyridine and 3-picoline 1-oxide reacted with *tert*- and *n*-butyl mercaptan in acetic anhydride and triethylamine to give rise to another series of 1-acetyl-2-alkylthio-3,4-diacetoxy-1,2,3,4-tetrahydropyridines. The structure of the piperideines was established by spectral analysis.

It was discovered that triethylamine influenced the reaction of pyridine *N*-oxides with mercaptans in acetic anhydride. Basically, two distinct changes were observed when the reaction was conducted in the presence of 2 equiv of triethylamine. The percentage of α over β substitution rose sharply compared to that observed when triethylamine was omitted,[4] and a number of new tetrahydropyridines were isolated which were not encountered previously.[5,6]

The reaction of a number of 4-substituted pyridine 1-oxides **1** with *tert*-butyl mercaptan in acetic anhydride produced the expected sulfides **2** and **3** whose yields and isomer distributions are listed in Table I.



The change in the ratio of **2** and **3** due to the inclusion of triethylamine is interpreted in terms of the mechanisms proposed for α and β substitution.[5] Triethylamine can facilitate removal of the α proton from the intermediate 1-acetoxy-2-*tert*-butylthio-1,2-dihydropyridine[4] and thus expedite the process which would lead to an increased proportion of **2**.

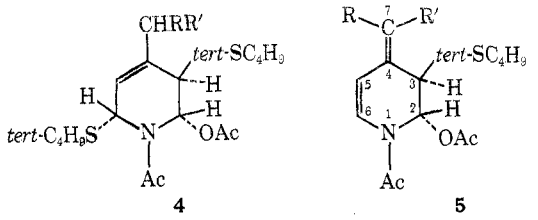
The reaction of a number of pyridine 1-oxides with *tert*-butyl mercaptan in acetic anhydride had yielded previously a series of 1-acetyl-2-acetoxy-3,6-di(*tert*-butylthio)-1,2,3,6-tetrahydropyridines **4** (Ac = CH_3CO).[5,6] In this reported work, the reactions of 4-picoline and 4-ethyl-, 4-*n*-propyl-, and 4-isopropylpyridine 1-oxides with *tert*-butyl mercaptan in acetic anhydride containing triethylamine produced a series of 1-acetyl-2-acetoxy-3-*tert*-butylthio-4-alkylidene-1,2,3,4-tetrahydropyridines **5**. Spectral data established for the previous piperideines **4**[5,6] were utilized in the determination of the structure of type **5**.

TABLE I

SUBSTITUTION PATTERN OF SULFIDES OBTAINED FROM THE REACTION OF PYRIDINE 1-OXIDES WITH *tert*-BUTYL MERCAPTAN IN ACETIC ANHYDRIDE, WITH AND WITHOUT TRIETHYLAMINE

Substituent on *N*-oxide	Method[a]	Yield, %	Isomer distribution: 2-Substitution	Isomer distribution: 3-Substitution
	A	62[b]	70	30
	B	41	90	10
3-CH_3	A	66[b]	64[c]	36[e]
	B	20	95[d]	5[e]
4-CH_3	A	41[b]	71	29
	B	33	82	18
4-C_2H_5	A	49	67	33
	B	32	87	13
4-*n*-C_3H_7	A	54	63	37
	B	45	70	30
4-*i*-C_3H_7	A	61	62	38
	B	39	80	20
4-*tert*-C_4H_9	A	48[b]	83	17
	B	48	96	4

[a] Experiments designated by method A are those performed without triethylamine and those by method B contained 2 equiv of triethylamine. [b] Reported initially in ref 4. [c] Distributed over positions 2 and 6 in the ratio of 45:19 (ref 4). [d] Ratio of 2 and 6 substitution was determined to be 61:34 (gc). [e] Represents 5-*tert*-butylthio-3-picoline.



a, R = R' = H; **b**, R = R' = CH_3; **c**, R = CH_3, R' = H; **c'**, R = H, R' = CH_3; **d**, R = CH_3, R' = D; **d'**, R = D, R' = CH_3; **e**, R = C_2H_5, R' = H; **e'**, R = H, R' = C_2H_5

Corresponding members of the series **4** and **5** differed by $C_4H_{10}S$, which is equivalent to *tert*-butyl mercaptan. Unlike the pmr spectra of **4**[6] which were complicated due to restricted rotation about the N–Ac bond at 35°, those of **5** were more readily analyzed (see Experimental

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(2) Taken in part from the Ph.D. dissertation of B. A. M., University of Illinois (Medical Center), June 1971.

(3) National Science Foundation Trainee.

(4) F. M. Hershenson and L. Bauer, *J. Org. Chem.*, **34**, 655 (1969).

(5) F. M. Hershenson and L. Bauer, *ibid.*, **34**, 660 (1969).

(6) R. S. Egan, F. M. Hershenson, and L. Bauer, *ibid.*, **34**, 665 (1969).

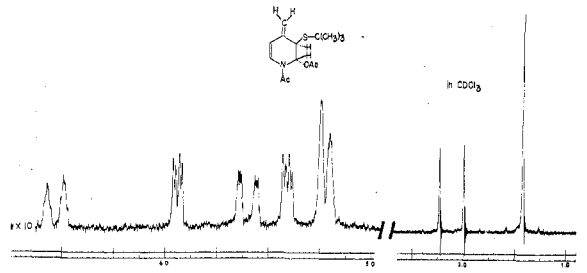


Figure 1.—100-MHz spectrum of **5a** in $CDCl_3$.

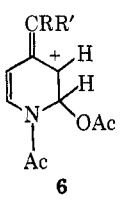
Figure 2.—100-MHz spectrum of **5c**, **5c′** in C_5D_5N; the top spectrum is enriched in **5c**.

Section). Singlets expected from $NCOCH_3$, $OCOCH_3$, and *tert*-SC_4H_9 protons were found in the upfield region. Characteristic signals due to the 4-alkyl groups were absent, but appropriate resonances downfield suggested the presence of additional alkene protons in **5**. These facts are accommodated by the presence of an 4-alkylidene group which locks the double bond of the piperideines **5**, into the α,β position. In accordance with this partial picture, the α-enamido proton (H-6) comes into resonance furthest downfield and its large coupling constant ($J_{5,6}$ = 8 Hz) clearly demonstrated that C-5 was unsubstituted. The absence of characteristic CH_2 resonances dictated that C-2 and C-3 bore one substituent each.

Pyrolysis of each member in the series **5** furnished the corresponding 3-*tert*-butylthio-4-alkylpyridine. This proved that the sulfide is attached to C-3 and the formula of **5** is completed by attaching the acetoxy group to C-2.

An analysis of the 100-MHz spectra of **5** provided the coupling constant, $J_{2,3}$ (3.0 ± 0.1 Hz). The magnitude of this coupling constant is remarkably close to that reported previously for members of series **4** ($J_{2,3}$ = 2.0–2.4 Hz) and this would place the H-2 and H-3 trans diequatorial and the sulfide and ester in both **4** and **5** are then trans diaxial.

Additional structure proof was provided by the mass spectra of **5**. The molecular ion was visible in each spectrum and the ensuing major fragmentation was common to each member of **5**. This pattern involved the loss of *tert*-$C_4H_9S\cdot$ to produce an (M − 89) ion **6**



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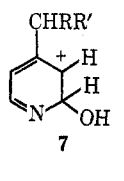

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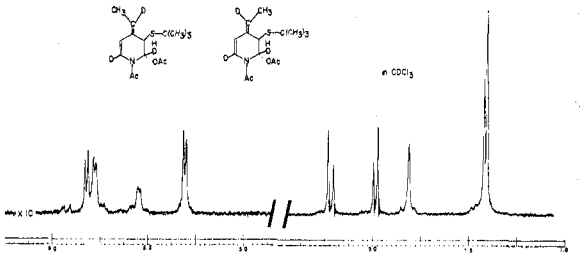


Figure 3.—100-MHz spectrum of **5d**, **5d′** in $CDCl_3$.

which eliminated ketene, twice, to produce **7** (shown as the 2,3-dihydropyridine tautomer) which represents a logical precursor for the molecular ion of the corresponding 4-alkylpyridine after the loss of HO·.

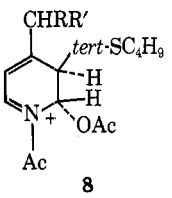
Although the spectra of **5a** and **5b** represented single compounds (Figure 1), the product from 4-ethylpyridine 1-oxide was clearly a mixture (Figure 2) which was obtained in varying composition from chromatography and crystallization. The results are readily explained in terms of the geometric isomers **5c**, **5c′**. Pmr parameters for the major and minor isomers were identified in the 100-MHz spectrum of the 2,6,7-d_3 analogs **5d**, **5d′** (Figure 3) which were synthesized from 4-ethylpyridine-2,6,7,7-d_4 1-oxide. By using nuclear Overhauser effects[7] (NOE; see Experimental Section), it was found that the major isomer was **5d**, subsequently related to the proton analog **5c**, and it is the one in which the methyl is trans to the bulky *tert*-butylthio group. This assignment gave rise to another interesting observation. In this fixed 4-alkylidene-Δ^2-piperideine system, compared to H-7, the CH_3 group at C-7 deshielded the ring protons closest to it, *viz.*, H-3 and H-5. Thus, in **5c** and **5d**, H-5 is 0.24-ppm downfield when contrasted to the chemical shifts of H-5 in **5c′** and **5d′**; similarly, H-3 is 0.52-ppm downfield in **5c′** and **5d′** compared to **5c** and **5d**. These findings corroborate the report by Cárdenas that in a fixed system, alkyl groups exert considerable magnetic anisotropic effects on nearby hydrogen atoms.[8]

A similar stereochemical problem was anticipated from the products of the cognate reaction of 4-*n*-propylpyridine 1-oxide. However, the crystalline solid which was isolated appeared to be uniform and was assigned structure **5e**, from a close comparison of the chemical shift data of **5c** and **5d** in identical solvents. This conclusion was based primarily on the excellent correspondence of the chemical shifts of H-3 and H-5 in **5e** with those in **5c** and **5d**, in $CDCl_3$ and C_5D_5N. These structure assignments of **5c**, **5d**, and **5e** logically follow the expectation that, in the thermodynamically more stable isomer, the alkyl group on C-7 is situated on the side opposite to the bulky *tert*-butyl sulfide group on C-3.

The mechanism for the formation of **5** is in line with that advanced for the previously reported products.[5] The change in forming **5** rather than **4** is attributed to triethylamine in solution. It is proposed that **1** is converted to **8**, *via* an episulfonium intermediate,[5] in which the acidic H-7 is neutralized by triethylamine to form **9**, which is the dipolar form of **5**. In the absence of triethylamine, *tert*-butyl mercaptan attacks C-6 of **8** to afford **4**. As a matter of fact, reaction of 4-*n*-propyl-

(7) For a summary of NOE, see P. D. Kennewell, *J. Chem. Educ.*, **47**, 278 (1970).

(8) C. G. Cárdenas, *Tetrahedron Lett.*, 4013 (1969); *J. Org. Chem.*, **36**, 1631 (1971).



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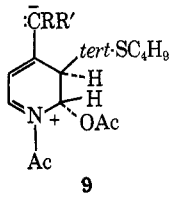

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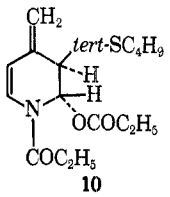
and 4-isopropylpyridine 1-oxides with *tert*-butyl mercaptan in acetic anhydride, without triethylamine, yielded the sulfides (Table I) and the tetrahydropyridines **4e** and **4b**, respectively. Their structures were established in the manner reported previously.[4-6] The reaction of 4-picoline 1-oxide with *tert*-butyl mercaptan in propionic anhydride and triethylamine produced both types of tetrahydropyridines **10** and **11** which were identified by means of their spectra.



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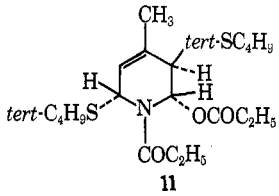

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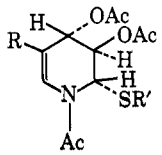
The presence of triethylamine during the reaction of pyridine 1-oxide with *tert*-butyl mercaptan in acetic anhydride produced yet another series of tetrahydropyridines, represented by the general structure **12**.



12

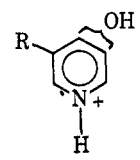
a, R = H, R′ = *tert*-C_4H_9; **b**, R = H, R′ = *n*-C_4H_9; **c**, R = CH_3, R′ = *tert*-C_4H_9; **d**, R = CH_3, R′ = *n*-C_4H_9

Although triethylamine was essential to produce **12a** from pyridine 1-oxide, the homolog **12c** was isolated from 3-picoline 1-oxide, with or without added base. The reaction was extended to *n*-butyl mercaptan with pyridine and 3-picoline 1-oxides to give (in the presence of triethylamine) **12b** and **12d**, respectively. Structure elucidation was aided by the availability of the 2,6-d_2 analogs of **12a** and **12c**.

The molecular ions for **12** and their ir and pmr spectra confirmed that each of these piperideines possessed two acetoxy groups and one acetamido and one butyl sulfide group. Their uv maxima narrowed the number of isomers to the 1,2,3,4-tetrahydropyridine system (*i.e.*, the double bond $\alpha\beta$ to the ring nitrogen) and the characteristic α-enamido proton resonance downfield (H-6) reinforced this assumption. Furthermore, the large coupling constant, $J_{5,6}$ for **12a**, **12b**, confined substitution to C-2, C-3, and C-4. At first impulse, and without decisive pmr data for this series and with analogy to structure **4**, one might place the sulfide group at C-3. Subsequent experiments proved that the sulfide group is attached to C-2 in this series.

Pyrolysis of **12a** at 200° for 0.5–1 hr produced 2- and 3-*tert*-butylthiopyridines (83:17), acetic anhydride, and acetic acid, identified by gc. Similarly, **12c** was decomposed thermally to a mixture of 2- and 3-*tert*-butylthio-5-picoline (3:1). Since all criteria pointed to the homogeneity of **12**, the sulfide group is attached at C-2 and it is assumed that in this system some of the sulfide migrated to C-3 under the condition of the pyrolysis. This behavior of **12** differs from **4** and **5**, which pyrolyzed to give the 3-sulfide only. The mass spectral fragmentation of **12** also departed from the pattern consistently shown by **4**.[5]

From the molecular ion of **4**, characteristic losses followed this order: a butylthio radical from C-6, followed by acetic acid, and then ketene and isobutylene. At 70 eV, the major fragmentation of **12** consisted of consecutive losses of an alkylthio radical, acetic acid, and then ketene, twice, leading to the aromatic ion **13**. However, at 10 eV, this path competed with one in which the first loss is acetic acid, followed by acetoxy radical leading to the 1-acetyl-2-alkylthiopyridinium cation **14**. When the 2,6-d_2 analogs of **12a** and **12c** were prepared from the corresponding 2,6-d_2 1-oxides, their fragmentation at 70 eV to **13** retained two deuterium atoms, while the alternate path at 10 eV involved the loss of CH_3CO_2D leading to **14**, which contained one deuterium atom (on C-6). The fragmentations upon electron impact of the *n*-butyl analogs **12b** and **12d** were quite analogous.



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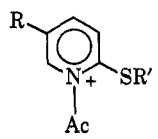

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The 100-MHz spectra of **12** revealed $J_{2,3}$ to be around 3.0 Hz which agrees with the trans-diequatorial arrangement of H-2,H-3 and the sulfide and acetoxy groups at C-2 and C-3 would again be trans-diaxial. The small coupling constant $J_{3,4}$ in the order of 1.5 Hz indicated a trans-diequatorial arrangement of H-3,H-4 and the stereochemistry of the esters at C-3 and C-4 is trans diaxial. The molecules of type **12** appeared to be conformationally stable at 35° since the pmr spectra indicated no other species in solution.

The mechanism advanced for the formation of **4** and **5** can explain that of **12** also. Attack of acetate ion at C-3 can occur either by direct neutralization of the positive charge as the acetate departs from nitrogen of the 1-acetoxy-2-alkylthio-1,2-dihydropyridine intermediate[4,5] to yield the 2-alkylthio-3-acetoxy-2,3-dihydropyridine, *or*, by ring opening of the episulfonium ion.[5] The role of triethylamine so vital in forming **12a** is not clearly understood since **12c** is produced in its absence. Quaternization of this 2,3-dihydropyridine as suggested for the formation of **4** and **5** would produce 1-acetyl-2-alkylthio-3-acetoxy-2,3-dihydropyridinium acetate which, in the particular milieu, could be attacked preferentially at the electrophilic C-4 site by acetate, instead of mercaptan, to produce **12**.

Experimental Section[9]

Starting Materials.—We gratefully acknowledge generous gifts of *n*- and *tert*-butyl mercaptans (from Penn-Salt Chemical

(9) Boiling and melting points (Thomas-Hoover apparatus) are uncorrected. Microanalyses were performed by Micro-Tech Laboratories, Inc., Skokie, Ill., and those for nitrogen, in this Department, using a Coleman, Model D29 analyzer. Uv spectra were recorded on a Beckman DK-1, ir spectra on a Perkin-Elmer 337 spectrophotometer. Pmr spectra were obtained on either a Varian A-60 or a HA-100 spectrometer. Mass spectra were obtained by Mr. Richard Dvorak using a Hitachi Perkin-Elmer RMU-6D mass spectrometer.

Co. and Phillips Petroleum Co.) and 4-ethylpyridine, 4-*n*- and 4-isopropylpyridine, pyridine, and 4-picoline 1-oxides (from Reilly Tar and Chemical Co.). *N*-Oxides were synthesized by literature methods.[4] 4-Ethylpyridine 1-oxide: bp 160–163° (0.02 mm); mp 108–109° [lit.[10] bp 201–203° (2 mm), mp 108–110°]; pmr ($CDCl_3$) δ 8.18 (H-2, H-6), 7.18 (H-3, H-5), 2.69 (CH_2), 1.22 (CH_3). 4-*n*-Propylpyridine 1-oxide: mp 53–55° [lit.[11] bp 124–125° (1 mm)]; pmr ($CDCl_3$) δ 8.28 (H-2, H-6), 7.27 (H-3, H-5), 2.62 ($CH_2C_2H_5$), 1.63 ($CH_2CH_2CH_3$), 0.90 (CH_3). 4-Isopropylpyridine 1-oxide: mp 77–79° (lit.[12] mp 78–79°); pmr ($CDCl_3$) δ 8.12 (H-2, H-6) 7.12 (H-3, H-5), 2.85 (CH), 1.15 (CH_3).

3-Picoline-2,6-d_2 1-oxide was prepared by heating the *N*-oxide (15 g) with D_2O (25 ml) at 160° for 30 hr in a Monel bomb. Solvents were removed and the residue was reheated with D_2O (30 ml) under similar conditions. This procedure could not be applied to synthesize 4-ethylpyridine-2,6,7,7-d_4 1-oxide. Extensive charring occurred. The exchange was conducted according to an adaptation of the published procedure.[13] The *N*-oxide (15 g) was boiled with 1% NaOD (50 ml) and the exchange followed by pmr. After 3 hr, one-half of the solvent was removed and fresh D_2O was added and boiling continued for 1 hr longer. The solution was neutralized by 38% DCl to pH 6, solvents were removed *in vacuo*, and the residue was distilled [bp 130–133° (0.01 mm)].

General Considerations for the Reactions of Mercaptans with *N*-Oxides.—The reactions were carried out along the lines described previously.[4,5] One example is described in detail and only pertinent details are reported on the others.

Extreme care was exercised in handling *tert*-butyl mercaptan.[4] Exits from reaction flasks and distillations were connected to a long tower filled with 1/8-in. pellets of Purafil Odoroxidant (Marbon Chemical Co., Division of Borg-Warner Corp.).

Reactions of *N*-Oxides with *tert*-Butyl Mercaptan in Acetic Anhydride, with Triethylamine. A. 4-Ethylpyridine 1-Oxide.—4-Ethylpyridine 1-oxide (12.3 g, 0.1 mol) was dissolved with stirring in acetic anhydride (100 ml) containing *tert*-butyl mercaptan (32 ml, 0.3 mol) at ambient temperature. Triethylamine (28 ml, 0.2 mol) was slowly added (5 min) and the resultant solution heated at 95° (steam bath) for 2 hr. The solution was cooled somewhat and a low-boiling fraction distilled at 20 mm from a steam bath. This distillate consisted of aliphatic materials (pmr) and was not examined further. Further fractionation yielded a yellow liquid, 44.2 g, bp 42–94° (0.02 mm). The bath temperature during this distillation should be kept at a minimum and not to exceed 150°. No attempt was made to separate triethylamine and acetic acid by distillation at this stage since these did not interfere in the subsequent isolation of the products.[5] The following compounds were collected by means of gc (injection temperature 100°).[14]

4-(1-Acetoxyethyl)pyridine (5.6%, rt 38.4 min): pmr ($CDCl_3$) δ 8.45 (H-2, H-6), 7.10 (H-3, H-5), 5.87 (CHOAc), 2.10 ($OCOCH_3$), 1.51 ($CHCH_3$). *Anal.* Calcd for $C_9H_{11}NO_2$: N, 8.48. Found: N, 7.95.

3-Acetoxy-4-ethylpyridine (3.1%, rt 40.7 min): pmr ($CDCl_3$) δ 8.42 (H-6), 8.33 (H-2), 7.24 (H-5), 2.58 (CH_2CH_3), 2.32 ($OCOCH_3$), 1.20 (CH_2CH_3). *Anal.* Calcd for $C_9H_{11}NO_2$: N, 8.48. Found: N, 8.78.

2-*tert*-Butylthio-4-ethylpyridine (31.6%, rt 56.4 min): pmr ($CDCl_3$) δ 8.42 (H-6), 7.19 (H-3), 6.90 (H-5), 2.57 (CH_2CH_3), 1.50 (*tert*-C_4H_9), 1.20 (CH_2CH_3). *Anal.* Calcd for $C_{11}H_{17}NS$: C, 67.66; H, 8.78; N, 7.17. Found: C, 67.38; H, 8.73; N, 7.14.

3-*tert*-Butylthio-4-ethylpyridine (4.7% rt 58.0 min): pmr ($CDCl_3$) δ 8.70 (H-2), 8.50 (H-6), 8.08 (H-5), 2.98 (CH_2CH_3), 1.30 (*tert*-C_4H_9), 1.21 (CH_2CH_3). *Anal.* Calcd for $C_{11}H_{17}NS$: C, 67.66; H, 8.78; N, 7.17. Found: C, 67.41; H, 8.58; N, 6.92.

Based on the starting *N*-oxide, the yield of the sulfides was 31.6%, and the yield of the acetates was 8.4%.

The dark brown residue (8.0 g) which remained after high-vacuum distillation was chromotagraphed on alumina (Alcoa, Grade F-20, 180 g). Elution with benzene (500 ml) afforded, after removal of the solvent, a yellow oil. Addition of 15 ml of petroleum ether (bp 30–60°) precipitated a colorless solid which was recrystallized from petroleum ether (bp 30–60°) to give **1-acetyl-2-acetoxy-3-*tert*-butylthio-4-ethylidene-1,2,3,4-tetrahydropyridine** (**5c** and **5c′**) (0.9 g, 3.0%, mp 94–95°): ir 1750 (ester C=O), 1690 cm^{-1} (amide C=O); pmr for major isomer **5c** ($CDCl_3$) δ 6.54 (H-6), 5.93 (H-2), 5.77 (H-5), 5.67 (H-7), 5.30 (H-3), 2.24 ($NCOCH_3$), 1.98 ($OCOCH_3$), 1.82 (7-CH_3), 1.41 (*tert*-C_4H_9) ($J_{2,3}$ = 3.0, $J_{2,6}$ = 1.2, $J_{3,5}$ = 1.5, $J_{3,7}$ = 0.5, $J_{5,6}$ = 8.2, $J_{7,6}$ = 1.2, J_{7,CH_3} = 7.2, J_{3,CH_3} = J_{5,CH_3} ~ 0, J_{6,CH_3} ~ 0.5 Hz).

The pmr parameter for the minor isomer **5c′** in $CDCl_3$ could not be ascertained. In C_5D_5N, some of these data could be extracted from the spectrum in that solvent (Figure 2). The chemical shifts for H-6 in **5c** and **5c′** are most discernible around δ 6.75 in Figure 2; the bottom spectrum was typical of the mixture of **5c**, **5c′** usually isolated by the procedure outlined above. In an attempt to obtain additional quantities of **5c**, **5c′**, the filtrates from the solid were concentrated and the oily residue was subjected to molecular distillation. The solid which crystallized subsequently proved to be a mixture rich in **5c**, as shown in the top half of Figure 2; the mass spectra (70 eV) of all mixtures were similar, *m/e* (rel intensity) 297 (6), 238 (3), 209 (6), 208 (47), 196 (4), 167 (11), 166 (100), 149 (10), 139 (25), 138 (20), 125 (6), 124 (64), 123 (5), 122 (5), 108 (3), 107 (29), 106 (42), 105 (4), 104 (4), 96 (4), 94 (6), 80 (4), 79 (8), 78 (4), 77 (5), 57 (17), 45 (4), 43 (37), 42 (3), 41 (14), 39 (6), 29 (7), 28 (10); at 8.5 eV, ion *m/e* 208 was the base peak and *m/e* 297, 237, 149, and 107 were most prominent. *Anal.* Calcd for $C_{15}H_{23}NO_3S$: C, 60.59; H, 7.80; N, 4.71. Found: C, 61.28; H, 7.82; N, 4.82.

Pyrolysis of **5c**, **5c′** (0.5 g) at 200 ± 10° for 0.25 hr yielded, after distillation *in vacuo*, 3-*tert*-butylthio-4-ethylpyridine (75 mg), identified by its pmr spectrum.

B. 4-Ethylpyridine-2,6,7,7-d_4 1-Oxide.—From a reaction analogous to A, there was isolated **5d**, **5d′** (0.4 g, 1.1%), mp 92–94°, in the ratio of 64:36 (Figure 3), and the following pmr parameters were established in $CDCl_3$: for **5d**, δ 5.30 (H-3), 5.78 (H-5), 2.24 ($NCOCH_3$), 1.98 ($OCOCH_3$), 1.81 (7-CH_3), 1.40 (*tert*-C_4H_9); for **5d′**, δ 5.82 (H-3), 5.54 (H-5), 2.20 ($NCOCH_3$), 2.00 ($OCOCH_3$), 1.81 (7-CH_3), 1.42 (*tert*-C_4H_9) $J_{3,5}$ = 1.5 Hz). The following NOE effects were observed. Irradiation of the CH_3 groups at C-7 (with identical chemical shifts) caused the integrated intensity of H-5 in **5d** to be increased by 32.4%, that of H-3 in **5d′** by 20.0%, while that of H-5 in **5d′**, H-3 in **5d** remained unchanged. Irradiation of the *tert*-SC_4H_9 protons of **5d** caused an increase in the integrated intensity of H-3 in **5d** by 22.6% and in **5d′** by 11.3%, while H-5's were unaffected. Irradiation of the close-by *tert*-SC_4H_9 protons in **5d′** increased the integration of H-3 in **5d** by 13.6%, H-3 in **5d′** by 14.8%, and again caused no effect on either H-5's. The mass spectrum (70 eV) of the mixture was *m/e* (rel intensity) 301 (2), 300 (5), 299 (2), 241 (4), 240 (3), 212 (14), 211 (44), 210 (16), 199 (6), 198 (3), 171 (4), 170 (25), 169 (100), 168 (34), 167 (5), 157 (4), 156 (13), 155 (7), 143 (5), 142 (18), 141 (22), 140 (10), 139 (3), 128 (16), 127 (71), 126 (30), 125 (10), 124 (4), 113 (5), 112 (3), 111 (13), 110 (56), 109 (75), 108 (33), 107 (10), 106 (5), 105 (4), 57 (34), 43 (98), 41 (49).

C. 4-Picoline 1-Oxide.—The reaction was performed as delineated under A. The volatile fraction contained 3-acetoxypyridine (14.7%), 4-picolyl acetate (19.6%), 2-*tert*-butylthiopyridine (52.6%), 3-*tert*-butylthiopyridine (11.3%), and 4-picolyl *tert*-butyl sulfide (1.6%) which were identified as described previously.[4] Chromatography of the nonvolatile fraction afforded, on elution with benzene, **1-acetyl-2-acetoxy-3-*tert*-butylthio-4-methylene-1,2,3,4-tetrahydropyridine** (**5a**) (3.1 g, 10.6%): mp 85–87°; uv max (95% ethanol) 275 mμ (log ε 4.29); ir 1751 (ester C=O), 1690 cm^{-1} (amide C=O); pmr at 100 MHz (C_5D_5N) δ 6.78 (H-6), 6.28 (H-2), 5.69 (H-5), 5.60 (H-3), 5.25 (H-7, H-7′), 2.19 ($NCOCH_3$), 1.90 ($OCOCH_3$) 1.41 (*tert*-

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(14) Preparative gas chromatography utilized the Varian Aerograph Autoprep, Model 700. All separations (0.005–0.2 ml) were carried out on a 3/8 in. × 20 ft coiled aluminum column containing 20% silicone gum rubber (SE-30) on Chromosorb W (40–60 mesh), unless stated otherwise. By selecting a power setting of "50" during these separations, the column was heated using a nonlinear temperature program. The samples were collected at room temperature. Retention times (rt) are quoted for a particular run and the composition of the mixture is expressed in mole per cent. The yield of sulfides in Table I are based on the starting *N*-oxide.

C_4H_9S); pmr ($CDCl_3$) δ 6.53 (H-6), 5.94 (H-2), 5.59 (H-5), 5.40 (H-3) ($J_{2,3}$ = 2.9, $J_{2,6}$ = 1.2, $J_{3,5}$ = 1.5, $J_{5,6}$ = 8.0, $J_{5,7}$ = $J_{5,7'}$, ~ 1.0, $J_{6,7'}$ ~ 1.0 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 283 (5), 195 (6), 194 (40), 182 (3), 153 (8), 152 (88), 142 (3), 135 (4), 126 (3), 125 (12), 124 (4), 111 (7), 110 (100), 109 (5), 93 (19), 92 (9), 80 (8), 65 (4), 57 (12), 43 (35), 41 (10), 39 (5); the primary fragmentation at 8.5 eV was *m/e* 283, 194 (base peak) 181, 135; at 10 eV, in addition to these ions, *m/e* 224, 152, 125, an 93 became prominent; the metastable ion at *m/e* 133.0 also appeared as a broad peak for the transition *m/e* 283 → 194 (m* 133.0). *Anal.* Calcd for $C_{14}H_{21}NO_3S$: C, 59.35; H, 7.47; N, 4.94; S, 11.29. Found: C, 59.22; H, 7.48; N, 4.88; S, 11.26.

D. 4-*n*-Propylpyridine 1-Oxide.—Reaction of the *N*-oxide on three times the (molar) scale as A yielded a fraction (37.3 g), bp 90–98° (0.01 mm), which was separated by gc[14] but this time using 5% DEGS on Chromosorb (injection temperature 80°).

3-Acetoxy-4-*n*-propylpyridine (3.1%, rt 43.3 min): pmr ($CDCl_3$) δ 8.35 (H-6), 8.28 (H-2), 7.18 (H-5), 2.50 ($CH_2CH_2CH_3$), 2.28 ($OCOCH_3$), 1.52 ($CH_2CH_2CH_3$), 0.93 ($CH_2CH_2CH_3$). *Anal.* Calcd for $C_{10}H_{13}NO_2$: N, 7.82. Found: N, 8.04.

4-(1-Acetoxypropyl)pyridine (3.0%, rt 45.6 min): pmr ($CDCl_3$) δ 8.60 (H-2, H-6), 7.26 (H-3, H-5), 5.67 ($CHOCOCH_3$), 2.10 ($OCOCH_3$), 1.81 (CH_2CH_3), 0.89 (CH_2CH_3). *Anal.* Calcd for $C_{10}H_{13}NO_2$: N, 7.82; Found: N, 8.04.

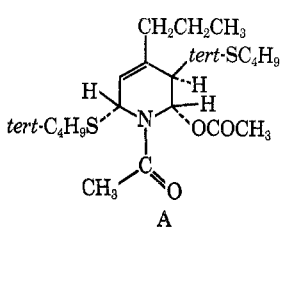
2-*tert*-Butylthio-4-*n*-propylpyridine (43.0%, rt 35.8 min): pmr ($CDCl_3$) δ 8.43 (H-6), 7.17 (H-3), 6.88 (H-5), 2.50 ($CH_2CH_2CH_3$), 1.60 ($CH_2CH_2CH_3$), 1.51 (*tert*-C_4H_9), 0.93 ($CH_2CH_2CH_3$). *Anal.* Calcd for $C_{12}H_{19}NS$: C, 68.87; H, 9.15; N, 6.69. Found: C, 68.64; H, 9.13; N, 6.64.

3-*tert*-Butylthio-4-*n*-propylpyridine (6.2%, rt 37.5 min): pmr ($CDCl_3$) δ 8.72 (H-2), 8.47 (H-6), 7.20 (H-5), 2.92 ($CH_2CH_2CH_3$), 1.62 ($CH_2CH_2CH_3$), 1.28 (*tert*-C_4H_9), 0.97 ($CH_2CH_2CH_3$). *Anal.* Calcd for $C_{12}H_{19}NS$: C, 68.87; H, 9.15; N, 6.69. Found: C, 68.96; H, 9.29; N, 6.77.

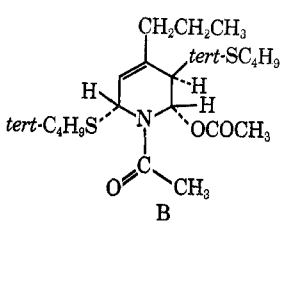
4-(1-*tert*-Butylthiopropyl)pyridine (1.2%, rt 40.8 min): pmr ($CDCl_3$) δ 8.55 (H-2, H-6), 7.32 (H-3, H-5), 3.68 (CHS), 1.84 (CH_3CH_2), 1.20 (*tert*-C_4H_9), 0.90 (CH_3). *Anal.* Calcd for $C_{12}H_{19}NS$: N, 6.69. Found: N, 6.82.

Chromatography of the nonvolatile fraction and elution with benzene afforded initially some 2-*tert*-butylthio-4-*n*-propylpyridine and their fractions enriched in **5e**. The pure solid was obtained by removing benzene and crystallizing the residue from petroleum ether (bp 30–60°) at −60°: mp 67–69° (2.2 g, 2.4%); pmr ($CDCl_3$) δ 6.53 (H-6), 5.96 (H-2), 5.79 (H-5), 5.34 (H-3), 5.64 (H-7), 2.24 ($NCOCH_3$), 2.00 ($OCOCH_3$), 1.42 (*tert*-C_4H_9), 2.24 (CH_2CH_3), 1.06 (CH_2CH_3); pmr (C_5D_5N) δ 6.84 (H-6), 6.41 (H-2), 5.92 (H-5), 5.63 (H-3), 5.71 (H-7), 2.23 ($NCOCH_3$), 1.92 ($OCOCH_3$), 1.47 (*tert*-C_4H_9), 2.10–2.25 (CH_2CH_3), 0.94 (CH_2CH_3) ($J_{2,3}$ = 3.0, $J_{2,6}$ = 1.2, $J_{3,5}$ = 1.6, $J_{5,6}$ = 8.0, $J_{5,7}$ = 1.1, $J_{6,7}$ = 1.2, J_{7,CH_2} = 7.4, J_{CH_2,CH_3} = 7.4 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 311 (2), 252 (2), 223 (6), 222 (4), 210 (3), 181 (11), 180 (100), 164 (2), 163 (12), 162 (6), 154 (3), 153 (9), 152 (8), 139 (7), 138 (68), 137 (3), 136 (6), 125 (9), 124 (2), 123 (5), 121 (22), 120 (25), 119 (5), 118 (7), 117 (2), 110 (6), 109 (2), 108 (4), 107 (4), 106 (55), 93 (8), 92 (10), 57 (19), 43 (62). *Anal.* Calcd for $C_{16}H_{25}NO_3S$: C, 61.72; H, 8.09; N, 4.50. Found: C, 61.94; H, 8.16; N, 4.38.

The mother liquor contained some **4e** but this compound was obtained more readily in a cognate reaction (0.1 mol of *N*-oxide) in which triethylamine was omitted. The nonvolatile material was chromatographed as above and elution with benzene yielded a fraction which, when crystallized from petroleum ether at −60° produced 1-acetyl-2-acetoxy-3,6-di(*tert*-butylthio)-4-*n*-propyl-1,-2,3,6-tetrahydropyridine (**4e**) (0.3 g, 0.75%), mp 96–97°. The structure of **4e** was established in a fashion quite analogous to that described for the lower homologs.[5,6] Its pmr spectrum (30°) showed the two rotamers, A and B, in the ratio of 55:45:



A



B

for A, (C_5D_5N) δ 6.64 (H-2), 5.48 (H-3), 5.98 (H-5), 5.68 (H-6), 2.44 ($NCOCH_3$), 2.02 ($OCOCH_3$), 1.46, 1.42 (*tert*-C_4H_9), 0.88 ($CH_2CH_2CH_3$); for B, (C_5D_5N) δ 5.54 (H-2), 5.44 (H-3), 5.98 (H-5), 6.35 (H-6), 2.25 ($NCOCH_3$), 2.06 ($OCOCH_3$), 1.48, 1.42 (*tert*-C_4H_9), 0.88 ($CH_2CH_2CH_3$) ($J_{2,3}$ = 2.2, $J_{5,6}$ = 3.7, J_{6,CH_2} = 1.7, J_{5,CH_2} = 1.2, J_{CH_2,CH_3} = 7.2 Hz) (at 115–120°, signals due to H-2 and H-6 broadened into the base line); mass spectrum (70 eV) *m/e* (rel intensity) 401 (0.1), 312 (15), 252 (12), 223 (2), 222 (15), 212 (2), 211 (4), 210 (22), 209 (13), 196 (3), 181 (5), 180 (38), 163 (7), 155 (7), 154 (28), 153 (57), 152 (11), 139 (4), 138 (38), 132 (7), 126 (3), 125 (36), 124 (7), 57 (100), 56 (11), 41 (52); at 12.5 eV, ion *m/e* 312 (base peak), 252 (40), 222 (85), 209 (54), and 153 (70) are most prominent. *Anal.* Calcd for $C_{20}H_{35}NO_3S_2$: C, 59.83; H, 8.73; N, 3.49. Found: C, 59.94; H, 8.82; N, 3.35.

E. 4-Isopropylpyridine 1-Oxide.—The reaction using 0.3 mol of the *N*-oxide produced 38.6 g [bp 90–110° (0.01 mm)] which was separated on a 5% DEGS column.[14]

2-*tert*-Butylthio-4-isopropylpyridine (44.5%, rt 38.8 min): pmr ($CDCl_3$) δ 8.42 (H-6), 7.20 (H-3), 6.94 (H-5), 2.83 [$CH(CH_3)_2$], 1.50 (*tert*-C_4H_9), 1.22 [$CH(CH_3)_2$]. *Anal.* Calcd for $C_{12}H_{19}NS$: N, 6.69. Found: N, 6.45.

3-*tert*-Butylthio-4-isopropylpyridine (4.3%, rt 41.7 min): pmr ($CDCl_3$) δ 8.70 (H-2), 8.51 (H-6), 7.27 (H-5), 3.86 [$CH(CH_3)_2$], 1.28 (*tert*-C_4H_9), 1.21 [$CH(CH_3)_2$]. *Anal.* Calcd for $C_{12}H_{19}NS$: N, 6.69. Found: N, 6.72.

Benzene eluted **5b** from alumina (0.95 g, 1%). It was recrystallized from petroleum ether (bp 30–60°) at −60°: mp 107–108.5°; pmr (C_5D_5N) δ 6.71 (H-6), 6.43 (H-2), 5.96 (H-5), 6.19 (H-3), 1.86, 1.78 (C-7 CH_3's), 2.20 ($NCOCH_3$), 1.96 ($OCOCH_3$), 1.50 (*tert*-C_4H_9) ($J_{2,3}$ = 3.1, $J_{2,6}$ = 1.4, $J_{3,5}$ = 1.6, $J_{5,6}$ = 8.0 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 311 (6), 252 (2), 223 (7), 222 (51), 181 (11), 180 (100), 164 (4), 163 (30), 162 (11), 153 (8), 152 (12), 138 (24), 137 (3), 136 (5), 125 (6), 124 (3), 122 (7), 121 (57), 120 (75), 119 (6), 118 (7), 110 (11), 108 (7), 107 (5) 106 (37), 92 (10), 79 (10), 32 (99), 41 (69). *Anal.* Calcd for $C_{16}H_{25}NO_3S$: C, 61.72; H, 8.09; N, 4.50. Found: C, 61.97; H, 8.05; N, 4.41.

There were indications that the mother liquor contained some **4b**, but a purer product (**4b**) was obtained when the above reaction was carried out omitting triethylamine. Using 0.1 mol of *N*-oxide and an identical work-up, the solid (0.5 g, 1.2%) from the column, crystallized from petroleum ether (bp 30–60°) at −60°, mp 89–90°. The pmr data in C_5D_5N at 30° is given for rotamers A and B (85:15), analogous to those described in section D: for A, δ 6.53 (H-2), 5.49 (H-3), 5.93 (H-5), 5.66 (H-6), 2.20 ($NCOCH_3$), 1.98 ($OCOCH_3$), 1.21 (*tert*-C_4H_9), 1.00, 1.03 [$(CH_3)_2CH$]; for B, δ 5.43 (H-2), 5.43 (H-3), 5.93 (H-5), 6.29 (H-6), 2.10 ($NCOCH_3$), 2.01 ($OCOCH_3$), 1.21, 1.23 (*tert*-C_4H_9), 1.00, 1.03 [$(CH_3)_2CH$] ($J_{2,3}$ = 2.4, $J_{5,6}$ = 3.7, $J_{6,CH}$ = 1.0, J_{CH,CH_3} = 7.0 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 401 (1), 342 (1), 314 (5), 313 (12), 312 (64), 254 (2), 253 (5), 252 (33), 223 (5), 222 (33), 212 (2), 211 (6), 210 (41), 209 (13), 196 (11), 181 (10), 180 (79), 164 (9), 163 (35), 156 (3), 155 (11), 154 (49), 153 (46), 152 (11), 139 (5), 138 (35), 137 (4), 136 (5), 132 (10), 125 (25), 123 (5), 122 (42), 121 (27), 120 (24), 112 (5), 107 (12), 106 (15), 99 (7), 90 (12), 57 (100), 56 (11), 55 (8), 45 (10), 43 (49), 42 (5), 41 (55), 39 (14), 32 (9), 29 (25), 28 (27); at 13 eV, ion *m/e* 312 (base peak), 252 (34), 222 (29), 209 (15), and 153 (26) are most prominent. *Anal.* Calcd for $C_{20}H_{35}NO_3S_2$: C. 59.83; H, 8.79; N, 3.49. Found: C, 60.14; H, 8.98; N, 3.52.

F. 4-Picoline 1-Oxide and Propionic Anhydride.—The reaction (0.3 mol, *N*-oxide) yielded 2- and 3-*tert*-butylthio-4-picoline (30%, ratio 91:9). Chromatography of the nonvolatile fraction produced a mixture of tetrahydropyridines which were separated as follows. Crystallization of the residues from the benzene eluates, from petroleum ether (bp 30–60°) afforded 1-propionyl-2-propionoxy-3,6-di-(*tert*-butylthio)-4-methyl-1,2,3,6-tetrahydropyridine (**11**) (1.8 g, mp 111–113°) shown to exist as two rotamers, A and B, *analogous* to those in section D: for A, (C_5D_5N) δ 6.65 (H-2), 5.43 (H-3), 5.97 (H-5), 5.66 (H-6), 2.74 ($NCOCH_2CH_3$), 1.23 ($NCOCH_2CH_3$), 2.32 ($OCOCH_2CH_3$), 1.08 ($OCOCH_2CH_3$), 1.45 (*tert*-C_4H_9S), 1.79 (4-CH_3); for B, δ 5.62 (H-2), 5.37 (H-3), 5.97 (H-5), 6.31 (H-6), 2.81 ($NCOCH_2CH_3$), 1.25 ($NCOCH_2CH_3$), 2.37 ($OCOCH_2CH_3$), 1.10 ($OCOCH_2CH_3$), 1.45 (*tert*-C_4H_9S), 1.81 (4-CH_3) ($J_{2,3}$ = 2.2, $J_{5,6}$ = 3.7, J_{6,CH_3} = 2.0, J_{5,CH_3} = 1.8, $J_{CH_2,CH_3(OCO)}$ = 7.6, $J_{CH_3,CH_2(NCO)}$ = 7.1 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 401 (1), 327 (1), 313 (2), 312 (7), 311 (33), 256 (4),

240 (1), 239 (4), 238 (24), 222 (8), 214 (1), 200 (2), 184 (5), 183 (13), 182 (100), 181 (3), 167 (4), 166 (41), 150 (6) 145 (4), 141 (4), 128 (3), 127 (9), 126 (72), 125 (25), 124 (3), 111 (4), 110 (56), 95 (6), 94 (78), 93 (20), 92 (9), 90 (5), 57 (90), 41 (52), 39 (2), 32 (12), 29 (75), 29 (4), 27 (21). *Anal.* Calcd for $C_{20}H_{35}NO_3S_2$: C, 59.83; H, 8.79; N, 3.49. Found: C, 59.95; H, 8.87; N, 3.29.

Distillation of the mother liquors of **11** yielded a viscous oil, bp 140–160° (0.01 mm), which crystallized on being triturated with petroleum ether (bp 30–60°) to produce 1-propionyl-2-propionoxy-3-*tert*-butylthio-4-methylene-1,2,3,4-tetrahydropyridine (**10**) (0.5 g): mp 64–65°; pmr ($CDCl_3$) δ 6.58 (H-6), 5.99 (H-2), 5.44 (H-3), 5.63 (H-5), 5.27, 5.22 (H-7,7′), 2.50 ($NCOCH_2CH_3$), 1.21 ($NCOCH_2CH_3$), 2.26 ($OCOCH_2CH_3$), 1.11 ($OCOCH_2CH_3$), 1.45 (*tert*-C_4H_9S); mass spectrum (70 EV) *m/e* (rel intensity) 311 (3), 238 (1), 223 (3), 222 (27), 208 (1), 198 (5), 167 (10), 166 (94), 149 (3), 142 (4), 126 (3), 125 (10), 124 (5), 111 (7), 110 (100), 109 (4), 97 (4), 94 (3), 93 (35), 92 (8), 80 (8), 57 (45), 41 (15), 39 (6), 29 (47), 28 (15), 27 (9). *Anal.* Calcd for $C_{16}H_{25}NO_3S$: C, 61.72; H, 8.09; N, 4.50. Found: C, 61.82; H, 8.15; N, 4.56.

G. Pyridine 1-Oxide.—From the reaction (0.1 mol, *N*-oxide) as described in section A, there were isolated, in the benzene eluate, 1-acetyl-2-*tert*-butylthio-3,4-diacetoxy-1,2,3,4-tetrahydropyridine (**12a**) (2.5 g): mp 91–93°; uv max (hexane) 237 mμ (log ϵ 4.23), 199 (4.02); ir (CCl_4) 1752 (ester C=O), 1700 (amide C=O), 1655 cm^{-1} (C=C); pmr (C_5D_5N) δ 1.38 (*tert*-C_4H_9), 1.88, 2.02 ($OCOCH_3$), 2.18 ($NCOCH_3$), 6.13 (H-2), 5.49 (H-3), 5.11 (H-4), 5.24 (H-5), 6.95 (H-6), ($J_{2,3}$ = 3.0, $J_{3,4}$ = 1.4, $J_{4,5}$ = 4.4, $J_{5,6}$ = 8.2, $J_{2,4}$ = 1.2, $J_{2,6}$ = 1.2, $J_{3,5}$ = 1.8, $J_{4,6}$ = 1.2, $J_{3,6}$ = 0.4 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 329 (8), 240 (5), 210 (5), 198 (12), 181 (5), 180 (40), 170 (4), 168 (4), 139 (9), 138 (100), 128 (12), 114 (4), 113 (4), 112 (12), 111 (7), 97 (6), 96 (87), 80 (17), 79 (5), 68 (5), 57 (20), 43 (65), 41 (14), 39 (4), 29 (7); mass spectrum (10 eV) *m/e* (rel intensity) 331 (11), 330 (21), 329 (100), 269 (5), 241 (16), 240 (63), 239 (11), 210 (32), 181 (16), 180 (95) 167 (11), 91 (5). *Anal.* Calcd for $C_{15}H_{23}NO_5S$: C, 54.71; H, 6.99; N, 4.25; S, 9.72. Found: C, 54.87; H, 7.00; N, 4.22; S, 9.78.

Pyrolysis of **12a** at 200° for 50 min yielded a dark liquid on distillation at 0.2 mm; gc separation[14] proved to contain (enrichment method) 2-*tert*-butylthiopyridine (66%), acetic anhydride (16%), 3-*tert*-butylthiopyridine (13%), and acetic acid (6%). The ratio of 2- to 3-sulfide is 85:15.

Pyridine-2,6-d_2 1-oxide[5] yielded the 2,6-d_2 analog of **12a**: pmr (C_5D_5N) δ within 0.05 ppm of **12a** listed above; mass spectrum (10 eV) *m/e* (rel intensity) 332 (9), 331 (33), 270 (2), 243 (7), 242 (35), 241 (7.3) 212 (9), 211 (7), 183 (15), 182 (100), 191 (9), 109 (11). In this fragmentation, *m/e* 331 → 270 loses CH_3CO_2D while at 10 eV **12a**, *m/e* 329 → 269, involves the loss of CH_3CO_2H.

H. 3-Picoline 1-Oxide.—The solid, on elution from alumina, proved to be **12c**: mp 123–124° (1% yield, based on *N*-oxide); uv max (hexane) 239 mμ (log ϵ 4.25), 200 (3.96); ir (CCl_4) 1760 (ester C=O), 1702 (amide C=O), 1680 cm^{-1} (C=C); pmr (C_5D_5N) δ 1.40 (*tert*-C_4H_9), 1.88, 2.08 ($OCOCH_3$) 2.20 ($NCOCH_3$), 1.78 (CH_3), 6.40 (H-2), 5.57 (H-3), 5.27 (H-4), 6.85 (H-6) ($J_{2,3}$ = 2.7, $J_{2,4}$ = 1.2, $J_{2,6}$ = 1.2, $J_{3,4}$ = 1.3, $J_{4,6}$ = 1.2 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 344 (3), 343 (11), 284 (3), 254 (12), 224 (7), 212 (8), 195 (6), 194 (43), 182 (8), 153 (9), 152 (97), 142 (11), 126 (20), 125 (8), 111 (8), 110 (100), 100 (12), 94 (28), 93 (8), 92 (6), 82 (8), 81 (6), 57 (37), 55 (8), 43 (93), 41 (28), 39 (9), 32 (16), 29 (19). The mass spectrum of the 2,6-d_2 analog at 10 eV gave ions *m/e* (rel intensity) 345 (100), 286 (2), 256 (25), 228 (10), and 196 (95) indicating that the two deuterium atoms are retained. *Anal.* Calcd for $C_{16}H_{25}NO_5S$: C, 55.97; H, 7.29; N, 4.08; S, 9.32. Found: C, 56.02; H, 7.36; N, 4.04; S, 9.43.

When **12c** (290 mg) was pyrolyzed at 200 ± 5° for 0.5 hr, a dark liquid was distilled (0.2 mm) which was revealed to be (by pmr) 2-*tert*-butylthio-5-picoline (75%) and 3-*tert*-butylthio-5-picoline (25%) as well as acetic anhydride and acetic acid.

Omission of triethylamine from this reaction changed the sulfide ratio (Table I) but actually improved the yield of **12c** slightly.

I. Pyridine 1-Oxide and *n*-Butyl Mercaptan.—Using method A, and neglecting an analysis of the sulfide fraction, the nonvolatile residue was chromatographed. Elution of **12b** was accomplished by benzene–dichloromethane (1:1) and dichloromethane. The solid crystallized from petroleum ether (bp 30–60°) at −60°, mp 58–59° (0.8% yield based on the *N*-oxide). Its pmr spectrum was compatible with the proposed structure, the most significant feature being the downfield doublet ($CDCl_3$) at δ 6.87 (H-6, $J_{5,6}$ = 8.0 Hz); mass spectrum (70 eV) *m/e* (rel intensity) 329 (4), 270 (1), 269 (1), 240 (9), 211 (2), 210 (16), 199 (1), 198 (13), 181 (4), 180 (37), 169 (3), 168 (17), 167 (3), 139 (9), 138 (100), 112 (6), 96 (94), 80 (20), 79 (13), 43 (87). *Anal.* Calcd for $C_{15}H_{23}NO_5S$: C, 54.70; H, 7.04; N, 4.25. Found: C, 54.76; H, 6.91; N, 4.42.

J. 3-Picoline 1-Oxide and *n*-Butyl Mercaptan.—Using the procedure outlined in A and I, a solid, mp 117.5–118.5°, was isolated which proved to be **12d**: mass spectrum (70 eV) *m/e* (rel intensity) 343 (0.8), 284 (0.8), 283 (0.8), 255 (2), 254 (11), 224 (6), 213 (4), 212 (31), 195 (2), 194 (16), 182 (11), 153 (3), 152 (30), 111 (8), 110 (100), 109 (4), 94 (17), 93 (11), 92 (7), 84 (3), 82 (9), 65 (4), 57 (7), 56 (5), 55 (5), 45 (5), 43 (54), 41 (9), 39 (5), 32 (11), 29 (6). *Anal.* Calcd for $C_{16}H_{25}NO_5S$: C, 54.35; H, 7.37; H, 4.88. Found: C, 54.38; H, 7.44; N, 4.97.

Registry No.—**4b**, 31579-80-3; **4e**, 31579-81-4; **5a**, 31579-82-5; **5b**, 31579-83-6; **5c**, 31579-84-7; **5c′**, 31579-85-8; **5d**, 31579-86-9; **5d′**, 31579-87-0; **5e**, 31579-88-1; **10**, 31579-89-2; **11**, 31579-90-5; **12a**, 31579-91-6; **12** 2,6-d_2 analog, 31571-03-6; **12b**, 31571-04-7; **12c**, 31571-05-8; **12d**, 31571-06-9; triethylamine, 121-44-8; 4-ethylpyridine 1-oxide, 14906-55-9; 4-*n*-propylpyridine 1-oxide, 25813-87-0; 4-isopropylpyridine 1-oxide, 22581-87-9; 4-(1-acetoxyethyl)pyridine, 2555-02-4; 3-acetoxy-4-ethylpyridine, 31571-11-6; 2-*tert*-butylthio-4-ethylpyridine, 31579-73-4; 3-*tert*-butylthio-4-ethylpyridine, 31579-74-5; 3-acetoxy-4-*n*-propylpyridine, 31579-75-6; 2-*tert*-butylthio-4-*n*-propylpyridine, 31579-76-7; 3-*tert*-butylthio-4-*n*-propylpyridine, 31615-27-7; 4-(1-*tert*-butylthiopropyl)pyridine, 31579-77-8; 2-*tert*-butylthio-4-isopropylpyridine, 31579-78-9; 3-*tert*-butylthio-4-isopropylpyridine, 31579-79-0.

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