Organic Mass Spectrometry, 1970, Vol. 4, pp. 571 to 585. Heyden & Son Limited. Printed in Northern Ireland

MASS SPECTRAL FRAGMENTATIONS OF ALKYLPYRIDINE *N*-OXIDES

D. A. LIGHTNER, R. NICOLETTI,† G. B. QUISTAD‡ and E. IRWIN
Department of Chemistry,§ University of California, Los Angeles, California 90024, USA

(*Received* 13 *August* 1970; *accepted* 24 *August* 1970)

Abstract—The behavior of a series of (2-, 3- and 4-) methyl-, ethyl- and *n*-butylpyridine *N*-oxides has been investigated at 70 and 14 eV. A loss-of-OH fragmentation occurs in *all* the *N*-oxides studied but is most important for 2-methyl- and 2-ethylpyridine *N*-oxides. All isomeric *n*-butylpyridine *N*-oxides show only a very weak loss-of-OH fragmentation from the molecular ion and a much stronger loss-of-OH fragment ion from the [M − 42] fragment. The loss-of-oxygen fragmentation is relatively intense in all cases studied, however. The loss-of-alkyl and McLafferty rearrangement fragmentations characteristic of the ethyl- and butylpyridines appear in the *N*-oxide mass spectra and are manifest from the molecular [M] and [M − 16] ions.

PREVIOUSLY reported mass spectrometric data on a few pyridine *N*-oxides focused primarily on the identification[1,2] of the *N*-oxide group and the *ortho*-effect[2] which has also been observed in 2-methylquinoline and isoquinoline *N*-oxides[3] and methylbenzimidazole and quinoxaline *N*-oxides.[4] Thus, the presence of an intense [M − 17] ion (more intense than [M − 16]) in the mass spectrum was shown to be diagnostic of an alkyl group on the carbon *alpha* to the amine oxide group.[1,2,3] Moreover, an increase of the ratio of the [M − 16] to [M − 17] ion intensities was used to determine that the loss-of-OH was produced from the [M − 16] ion for quinoline and isoquinoline *N*-oxides but occurred from the molecular [M] ion in 2-methylquinoline, 1-methyl- and 3-methylisoquinoline *N*-oxides.[3] We obtained variable results and considerably larger than reported[1] [M − 16] peaks with our *N*-oxides using the MS-9 heated inlet system. Therefore, all *N*-oxide mass spectra were run in a cold source (50°C) using a direct inlet probe.

Methylpyridine N-oxides

The mass spectra of the isomeric methylpyridine *N*-oxides (Figs. 1 to 3) reveal an intense ion for loss-of-OH [M − 17] from 2-methylpyridine *N*-oxide (I) but only weakly intense [M − 17] ions from 3- and 4-methylpyridine *N*-oxides (II and III respectively). A metastable ion ($m^* = 77{\cdot}7$, $109^{+\cdot} \rightarrow 92^+ + 17$, see Table 1 for all metastable ions) is observed for I but not for II or III. Although we cannot strictly rule out their formation from the molecular ion [M], the [M − 17] ions in the mass spectra of II and III appear to originate from the much more intense [M − 16] ions by loss of hydrogen. Whether this pathway (supported by metastables, $m^* = 91{\cdot}0$, in I, II and III) also contributes substantially to the [M − 17] ion of I might be determined in part by comparing the [M − 16]/[M − 17] ratios at high and low ionizing voltages for I, II and III (see Table 2). Thus, although the ratio increases in all three cases, the increase is much less steep for I than for either II or III, and the [M − 17]

† NATO Postdoctoral Fellow on leave from the Istituto di Chimica Organica, Universita di Roma.
‡ NDEA Fellow, 1969 to present.
§ Contribution No. 2747.

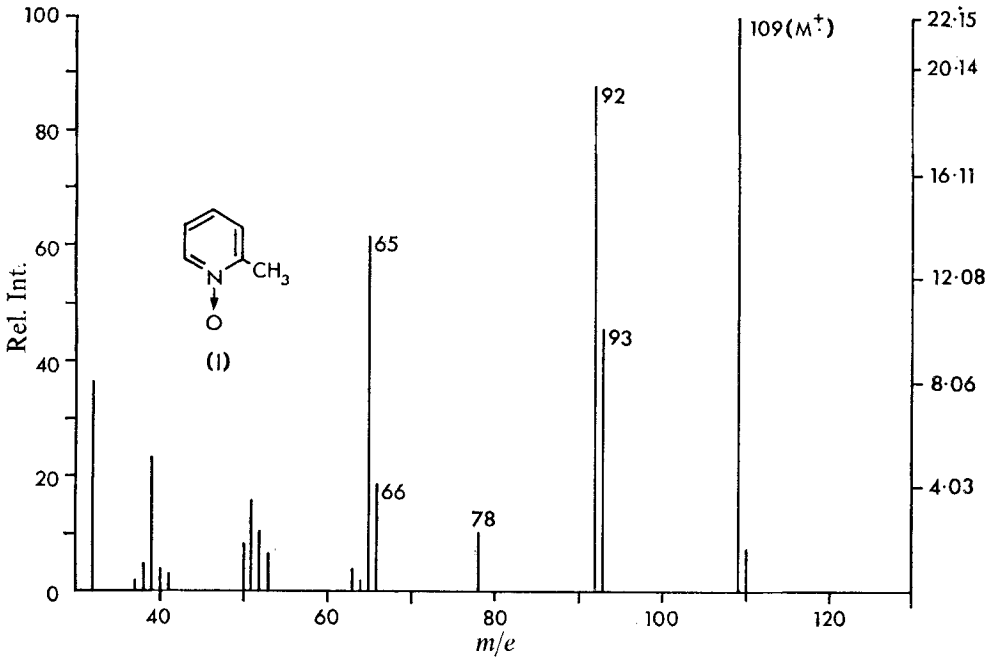


FIG. 1. Mass spectrum of 2-methylpyridine *N*-oxide, 70 eV.

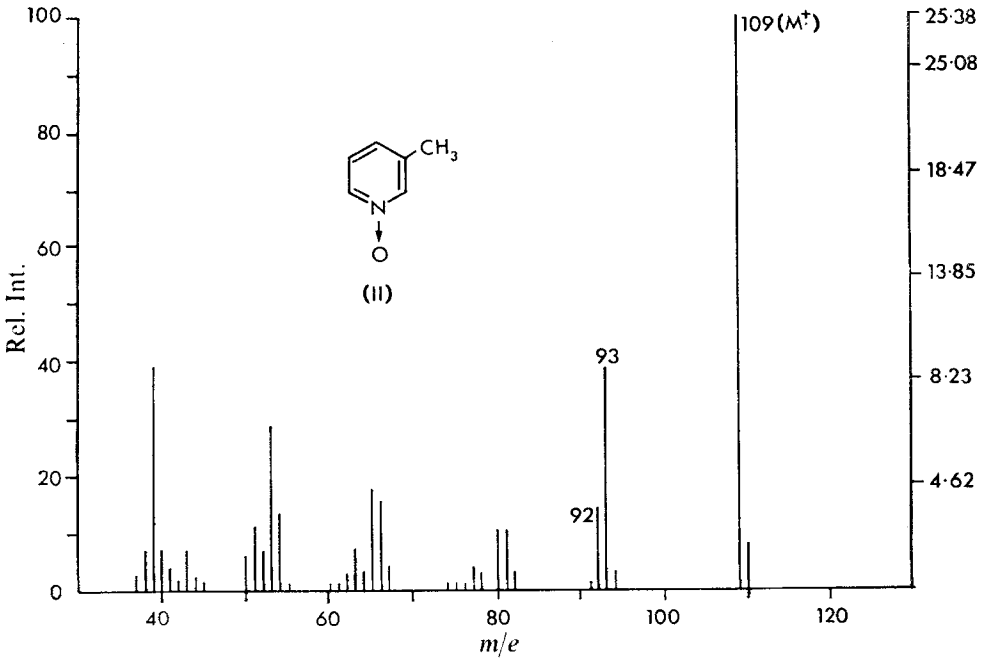


FIG. 2. Mass spectrum of 3-methylpyridine *N*-oxide, 70 eV.

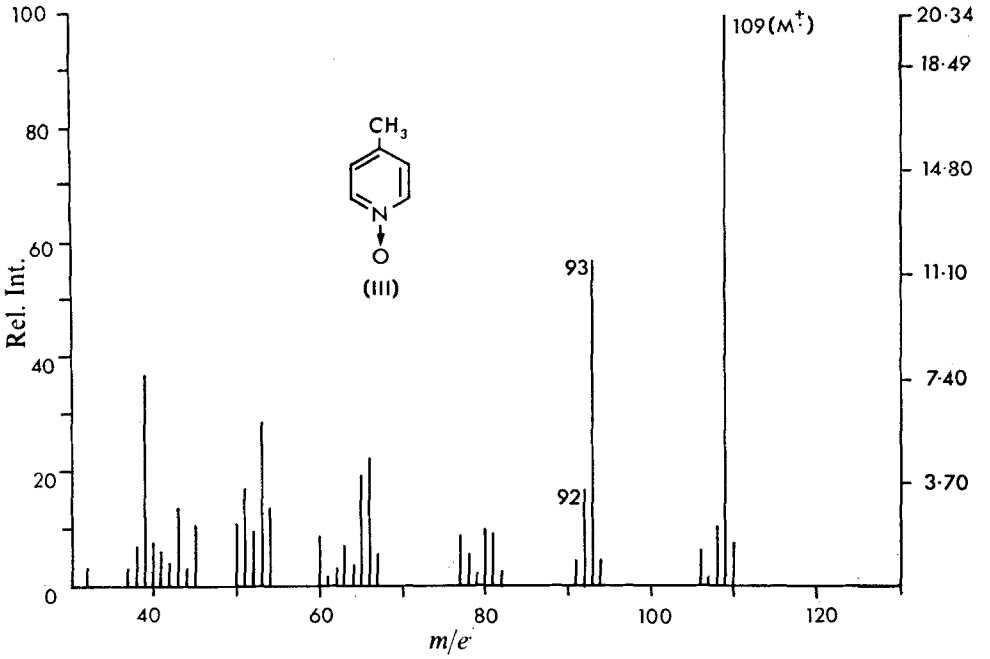


FIG. 3. Mass spectrum of 4-methylpyridine *N*-oxide, 70 eV.

intensity of I is considerably higher than that of either II or III at 14 eV. Therefore, if the arguments of Buchardt, Duffield and Shapiro[3] apply for these *N*-oxides we may conclude that the [M − 17] ion from I is formed largely from [M].

Ethylpyridine N-oxides

The loss-of-OH [M − 17] fragmentation takes place to a greater extent in all of the isomeric ethylpyridine *N*-oxides (Figs. 4 to 6) than in the methyl isomers (I to III). Again, a metastable ion ($m^* = 91{\cdot}4$, $123^{+\cdot} \rightarrow 106^+ + 17$) is observed for 2-ethylpyridine *N*-oxide (IV) but not for the isomeric 3- and 4-ethylpyridine *N*-oxides (V and VI respectively). All the isomers (IV to VI) show a metastable ion ($m^* = 105{\cdot}0$) for loss of hydrogen from [M − 16], however. The data of Table 2 show an increase in the [M − 16]/[M − 17] ratio in going from 70 to 14 eV for all the ethyl compounds; and, as explained above, this behavior is consistent with the [M − 17] ion being produced by loss of a hydrogen atom from the [M − 16] ion. The increase in the ratio for IV is quite small, however (0·4 to 0·5); in fact, it is considerably smaller than that observed for 2-methylpyridine *N*-oxide (I). As before, the data point strongly to the molecular ion [M] as the major direct precursor of [M − 17] for IV and to [M − 16] as the precursor to [M − 17] for V and VI.

Both V and VI show moderate-to-weak ions at *m/e* 92 (Figs. 5 and 6); whereas, the *m/e* 92 fragment ion is virtually absent in the mass spectrum of IV (Fig. 4). This fragment presumably arises from *m/e* 107 [M − 16] by loss of methyl; however, this could be confirmed only in the mass spectrum of V by the presence of a metastable ion at *m/e* 94·8. It may be noted, however, that the ratio of the percent total ionization

TABLE 1. METASTABLE IONS IN THE MASS SPECTRA OF ALKYLPYRIDINE AND ALKYLPYRIDINE *N*-OXIDES

Alkyl	m^* (found)	m^* (calculated)	Fragmentation process
2-, 3- and 4-Methylpyidine	91·0	91·0	$93^+ \rightarrow 92^+ + 1$
N-oxides (I, II and III)	77·7[a]	77·7	$109^+ \rightarrow 92^+ + 17$
	64·5	64·5	$92^+ \rightarrow 77^+ + 15$
	64·0	64·0	$66^+ \rightarrow 65^+ + 1$
	46·8	46·8	$93^+ \rightarrow 66^+ + 27$
	46·0	45·9	$92^+ \rightarrow 65^+ + 27$
2-, 3- and 4-Ethylpyridine	106·0[c]	106·0	$108^+ \rightarrow 107^+ + 1$
N-oxides (IV, V and VI)	105·0	105·0	$107^+ \rightarrow 106^+ + 1$
	94·8[c]	94·8	$123^+ \rightarrow 108^+ + 15$
	91·4[a,c]	91·4	$123^+ \rightarrow 106^+ + 17$
	79·0[b]	79·1	$107^+ \rightarrow 92^+ + 15$
	75·0	75·1	$79^+ \rightarrow 77^+ + 2$
	65·0[b]	65·0	$67^+ \rightarrow 66^+ + 1$
	58·8	58·9	$106^+ \rightarrow 79^+ + 27$
	58·4[b]	58·3	$107^+ \rightarrow 79^+ + 28$
	57·3	57·4	$106^+ \rightarrow 78^+ + 28$
	45·9	45·9	$92^+ \rightarrow 65^+ + 27$
2-, 3- and 4-*n*-Butylpyridine	106·0[a]	105·9	$136^+ \rightarrow 120^+ + 16$
N-oxides (VII, VIII and IX)	91·0	91·0	$93^+ \rightarrow 92^+ + 1$
	83·2[a]	83·2	$135^+ \rightarrow 106^+ + 29$
	78·8[a]	78·7	$151^+ \rightarrow 109^+ + 42$
	77·7[a]	77·7	$109^+ \rightarrow 92^+ + 17$
	70·5[a]	70·5	$120^+ \rightarrow 92^+ + 28$
	64·2[b,c]	64·1	$135^+ \rightarrow 93^+ + 42$
	57·3	57·3	$151^+ \rightarrow 93^+ + 58$
	46·9	46·8	$93^+ \rightarrow 66^+ + 27$
	45·9[a,b]	45·9	$92^+ \rightarrow 65^+ + 27$
2-, 3- and 4-*n*-Butylpyridine	105·0[a]	105·0	$107^+ \rightarrow 106^+ + 1$
(X, XI and XII)	91·0	91·0	$93^+ \rightarrow 92^+ + 1$
	78·0[a]	78·1	$106^+ \rightarrow 91^+ + 15$
	75·0[a,c]	75·0	$79^+ \rightarrow 77^+ + 2$
	70·5[a]	70·5	$120^+ \rightarrow 92^+ + 28$
	64·0	64·1	$135^+ \rightarrow 93^+ + 42$
	57·4[a]	57·4	$106^+ \rightarrow 78^+ + 28$
	46·8	46·8	$93^+ \rightarrow 66^+ + 27$

[a] Metastable ion for the 2-isomer only.
[b] Metastable ion for the 3-isomer only.
[c] Metastable ion for the 4-isomer only.

for the *m/e* 92 ions in IV, V and VI respectively is 1:10:5 which fairly closely parallels the *m/e* 92 intensities in the corresponding ethylpyridines (1:20:7).[5,6]

Interestingly, 4-ethylpyridine *N*-oxide (VI) shows a uniquely intense loss of methyl ion (*m/e* 108) from the molecular ion ($m^* = 79{\cdot}0$, $123^{+\cdot} \rightarrow 108^+ + 15$). Neither of the isomeric *N*-oxides IV and V exhibits this ion to any notable extent. This peculiarity might be best explained by assuming that the *N*-oxides show an inverse tendency to lose CH_3 as compared to the corresponding ethylpyridines[5,6] because the electronic effects determining the fragmentation behavior of the ethylpyridines[5,6] are reversed for the *N*-oxides (e.g. the π-electron density is greatest at C-3 in pyridine and greatest at C-2 and 4 in pyridine *N*-oxide[7]). The expected large [M — 15] ion intensity for

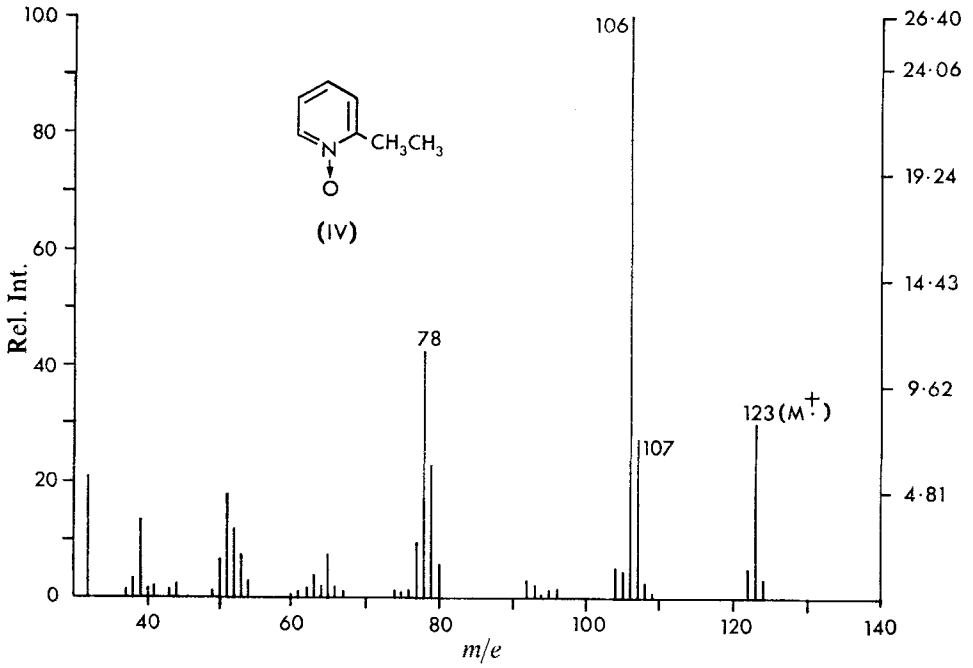


FIG. 4. Mass spectrum of 2-ethylpyridine *N*-oxide, 70 eV.

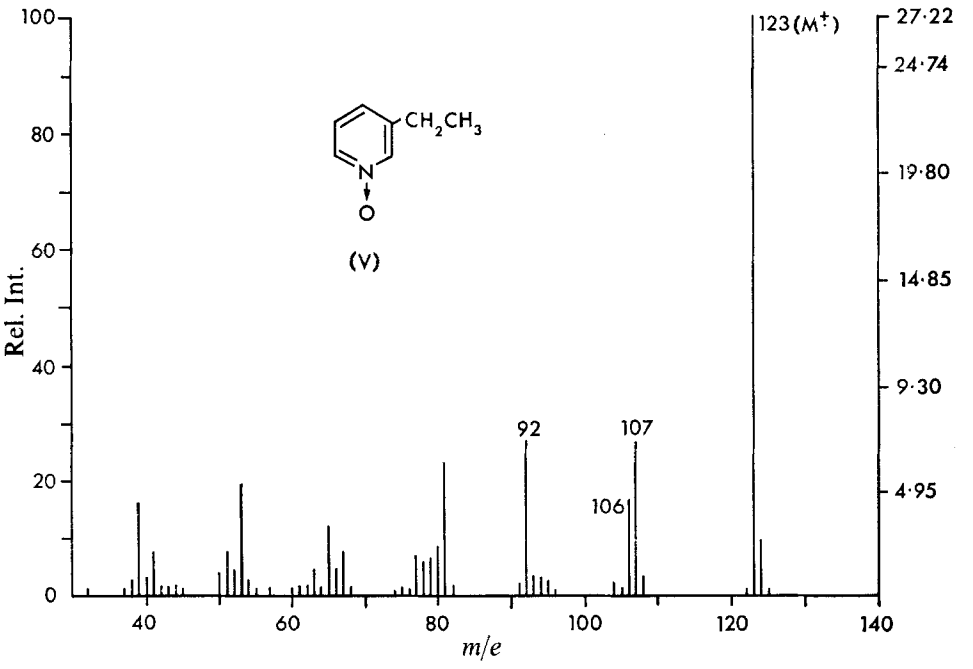


FIG. 5. Mass spectrum of 3-ethylpyridine *N*-oxide, 70 eV.

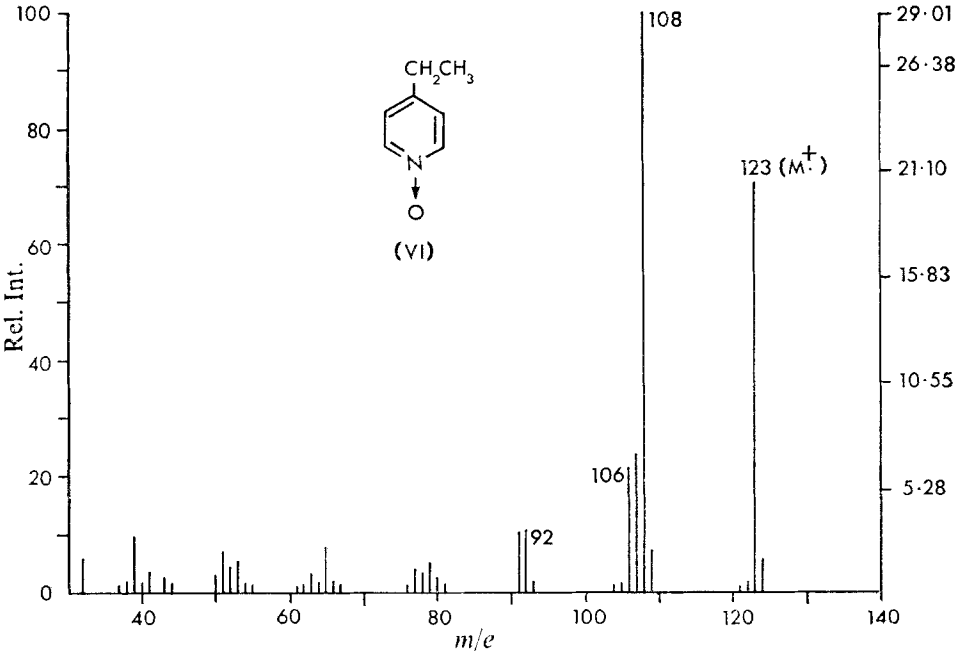


FIG. 6. Mass spectrum of 4-ethylpyridine *N*-oxide, 70 eV.

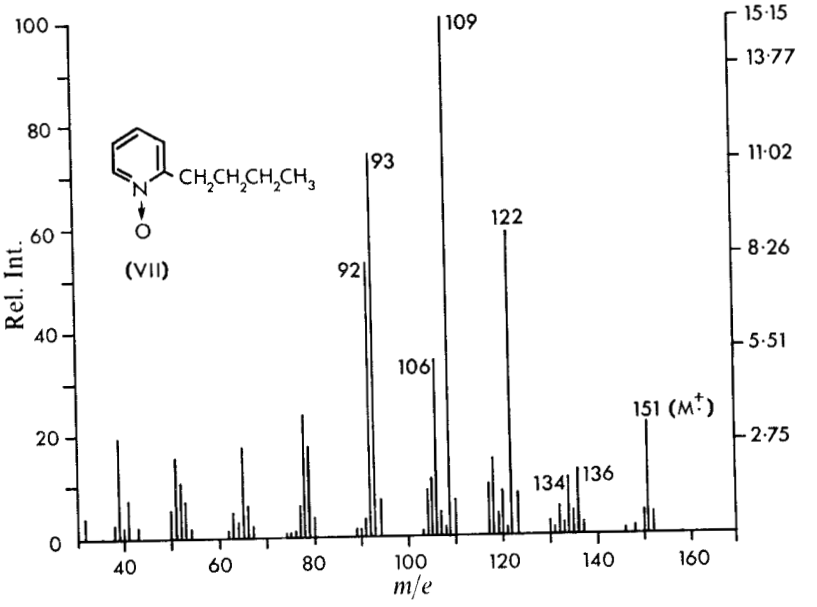
TABLE 2. PERCENT TOTAL IONIZATION OF THE [M − 16] AND [M − 17] IONS OF ALKYLPYRIDINE *N*-OXIDES

Compound	eV	[M]	[M − 16]	[M − 17]	[M − 16]/[M − 17]
2-Methylpyridine *N*-oxide (I)	70	22	10	19	0·5
	14	59	18	14	1·3
3-Methylpyridine *N*-oxide (II)	70	25	10	3·7	3
	14	77	11	0·7	16
4-Methylpyridine *N*-oxide (III)	70	20	12	3·4	3·5
	14	67	28	1·3	13
2-Ethylpyridine *N*-oxide (IV)	70	7·8	7·2	26	0·4
	14	28	19	39	0·5
3-Ethylpyridine *N*-oxide (V)	70	27	7·3	4·5	1·5
	14	66	12	2·5	5
4-Ethylpyridine *N*-oxide (VI)	70	24	7·6	7·0	1·1
	14	56	13	3·0	4·3
2-Butylpyridine *N*-oxide (VII)	70	3·3	0·7	1·8	0·3
	14	17	2·1	1·6	1·3
3-Butylpyridine *N*-oxide (VIII)	70	14	6·3	0·6	10
	14	35	12	0·5	24
4-Butylpyridine *N*-oxide (IX)	70	15	5·4	0·2	27
	14	39	13	0·3	43

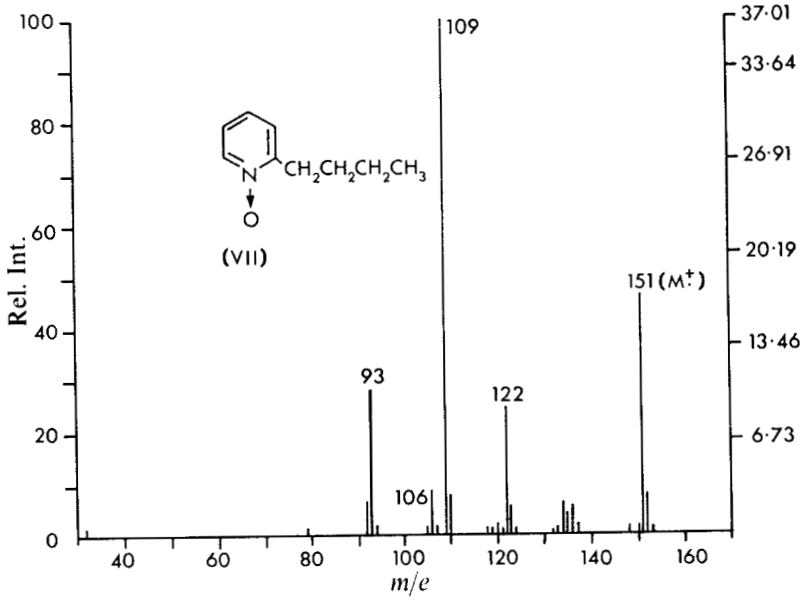
2-ethylpyridine *N*-oxide is suppressed by the lower energy pathway for loss of OH give an intense [M − 17] ion.

n-Butylpyridine N-oxides

It may be noted from Figs. 7 to 9 that the [M − 17] and [M − 16] ion intensities are weak (% Σ) in the mass spectra of 2-, 3- and 4-butylpyridine *N*-oxides (VII, VIII

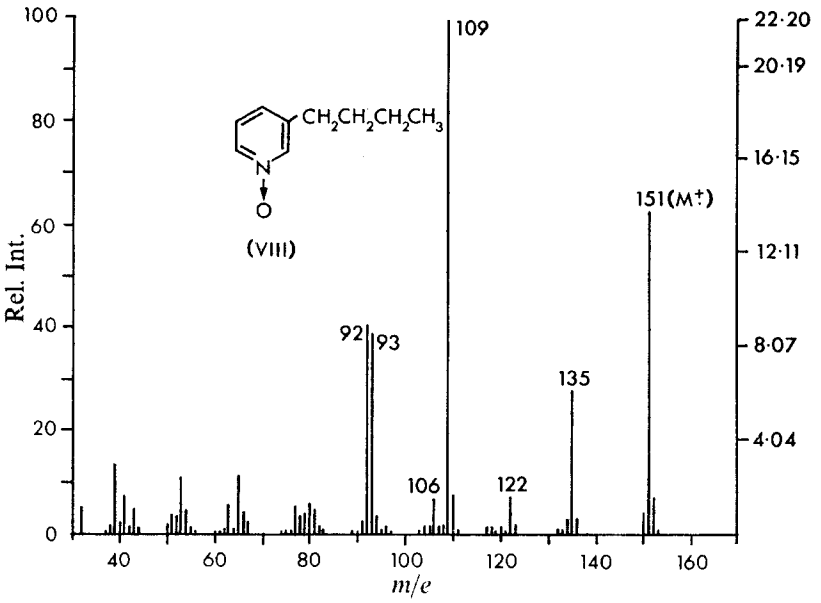


(a)

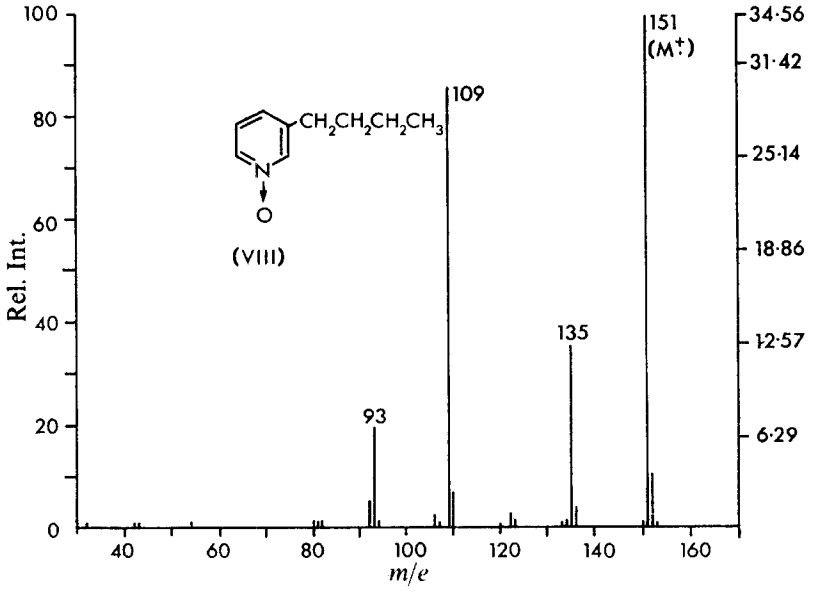


(b)

FIG. 7. Mass spectra of 2-*n*-butylpyridine *N*-oxide, (a) 70 eV, (b) 14 eV.

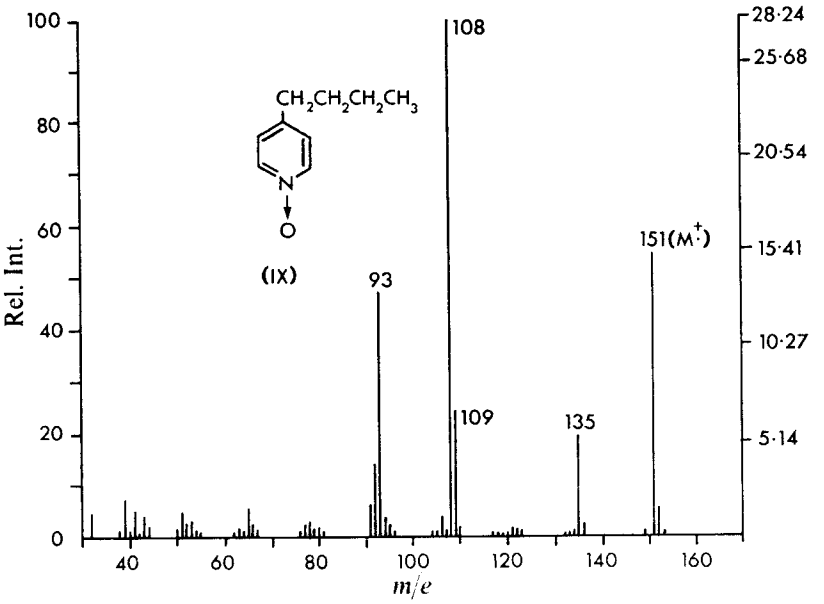


(a)

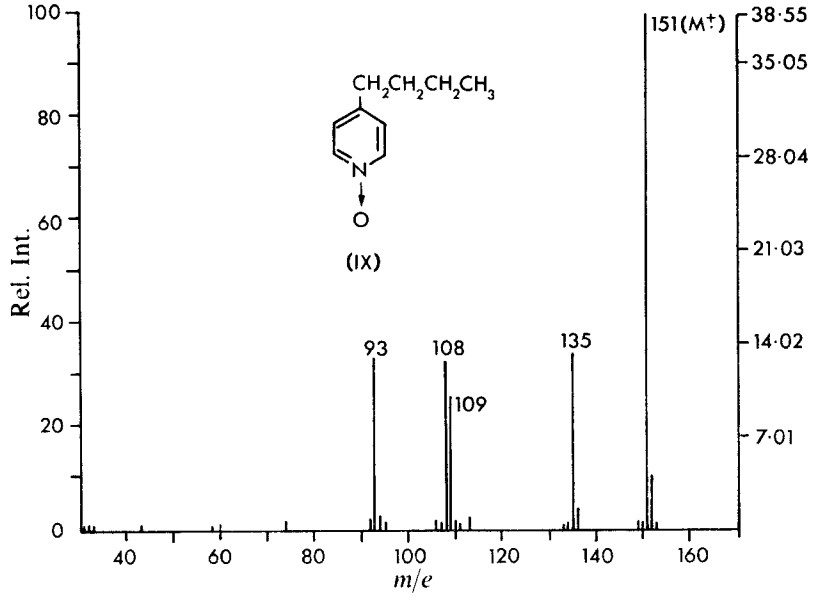


(b)

FIG. 8. Mass spectra of 3-*n*-butylpyridine *N*-oxide, (a) 70 eV, (b) 14 eV.



(a)



(b)

FIG. 9. Mass spectra of 4-*n*-butylpyridine *N*-oxide, (a) 70 eV, (b) 14 eV.

and IX respectively). The usual trend is observed, however, wherein the 2-isomer (VII) exhibits more intense [M − 17] ions than either the 3-isomer (VIII) or the 4-isomer (IX) (Table 2). In all other respects the isomeric butylpyridine *N*-oxides exhibit a unique behavior. Both the 2- and 3-butylpyridine *N*-oxides (VII and VIII) show an intense loss of 42 amu, C_3H_6 by high resolution measurements (m^* = 78·8, $151^{+\cdot} \rightarrow 109^+ + 42$) which is only a minor fragmentation in the mass spectrum of IX.

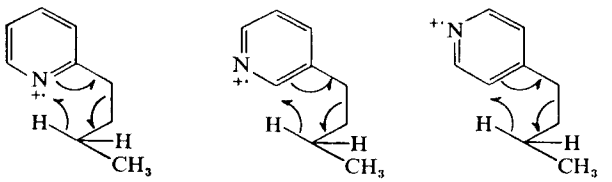
TABLE 3. PERCENT TOTAL IONIZATION OF THE [M − 42] AND [M − 43] IONS OF BUTYLPYRIDINES AND *N*-OXIDES

Fragment ion	eV	*n*-Butylpyridines 2-	3-	4-	*n*-Butylpyridine *N*-oxides 2-	3-	4-
[M − 42]	70	33[a]	22[a]	42[a]	15[b]	22[b]	6·9[b]
	14	75	13	28	37	30	9·9
[M − 43]	70	4·0	25	5·1	0·3	0·4	28
	14	0·0	2·2	0·0	0·0	0·0	12
[M − (42 + 16)]	70	—	—	—	11	8·6	13
	14	—	—	—	10	6·9	12
[M − (42 + 17)]	70	—	—	—	8·1	8·8	4·0
	14	—	—	—	2·4	1·9	0·6

[a] Supported by a metastable ion at *m/e* 64·0 for the process [M] → [M − 42].
[b] Supported by a metastable ion at *m/e* 78·8 for the process [M] → [M − 42].

At 14 eV, however, (Figs. 7b, 8b, 9b), it becomes clear that even for IX, the [M − 42] fragmentation is a low energy pathway. There is ample precedence for this type of rearrangement in the mass spectra of 2-butylpyridine[5,6,8] and butylquinolines and isoquinolines;[9,10] hence, it is particularly interesting to compare the McLafferty rearrangement found for 2-, 3- and 4-butylpyridines (X, XI and XII respectively) to that found in the corresponding *N*-oxides.

The data of Table 3 show a much less favored McLafferty rearrangement for XI than for either X or XII. Charge localization in the vicinity of the nitrogen nonbonding orbital (see Scheme 1) may account for the very low energy McLafferty



(X) (XI) (XII)

SCHEME 1

rearrangement evident in the mass spectrum of 2-butylpyridine (X) (note the *m/e* 93 intensities at 70 and 14 eV in Table 3). In going from 70 to 14 eV the McLafferty rearrangement becomes significantly less favored for the 3-butyl (XI) and 4-butyl (XII) isomers. The hydrogen transfer is presumably achieved in these cases more through excited π than through n states, although the crossing over of excited states of the radical ion leading to product is undoubtedly facile.†

† The two lowest lying ionization potentials of pyridine are 9·45 ± 0·05 and 10·06 ± 0·05 eV; see J. Momigny, J. Urbain and H. Wankenne, *Bull. Soc. Roy. Sci. Liege* **34**, 337 (1965).

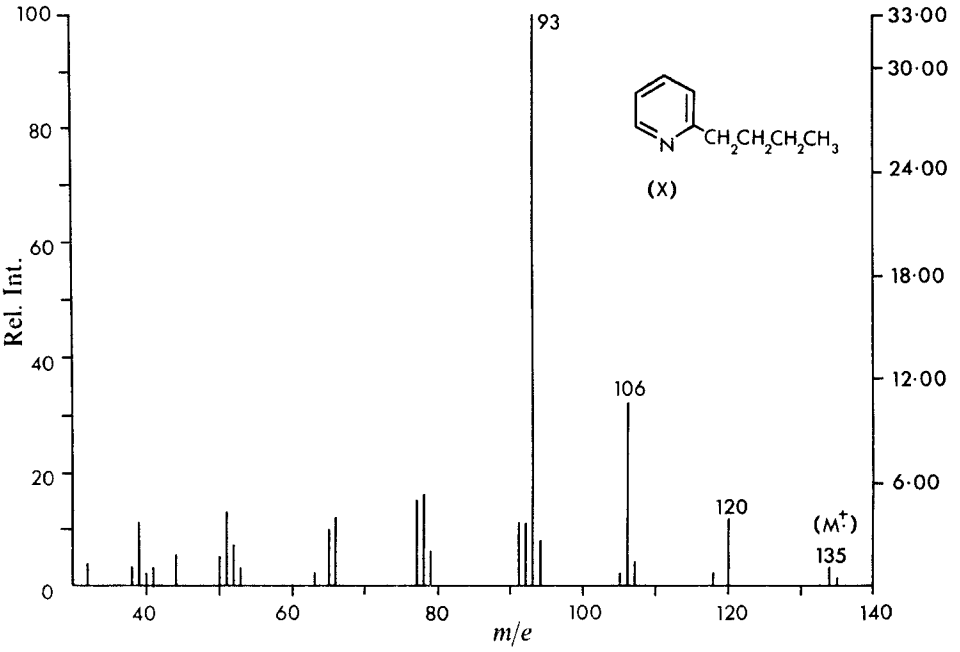


FIG. 10. Mass spectrum of 2-*n*-butylpyridine, 70 eV.

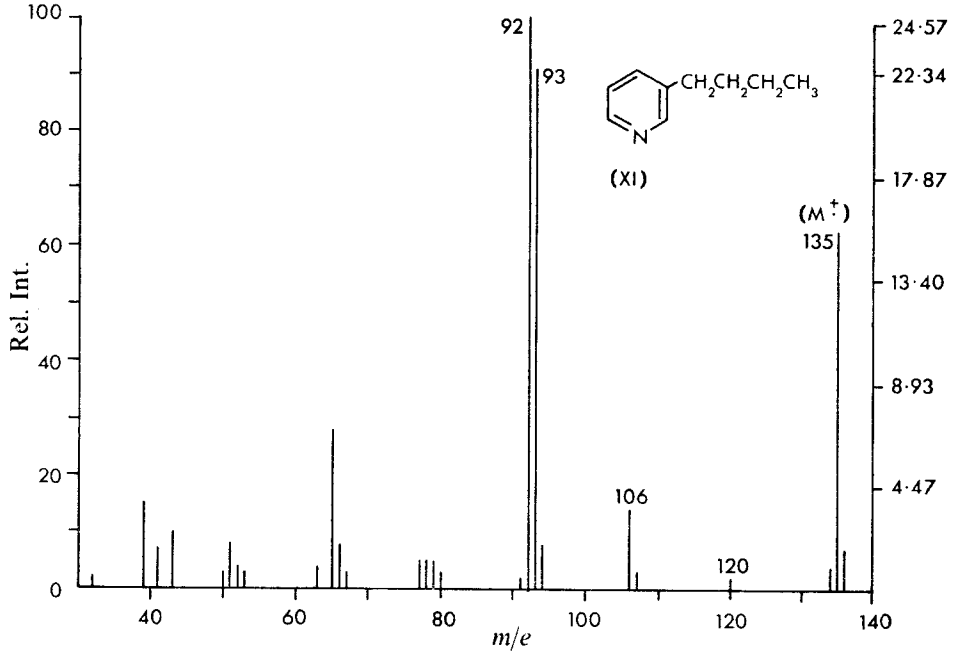


FIG. 11. Mass spectrum of 3-*n*-butylpyridine, 70 eV.

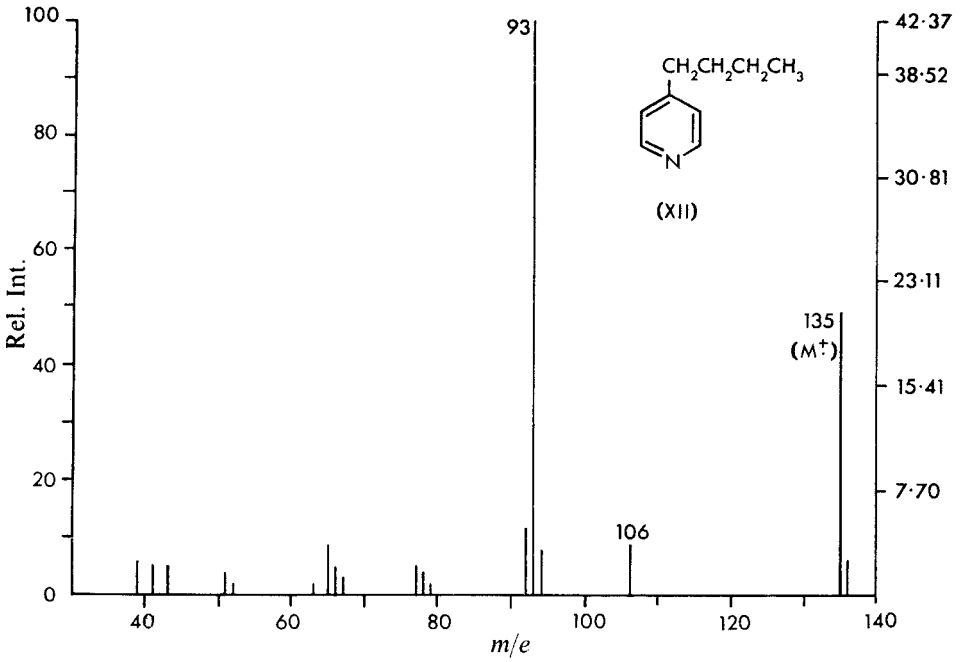


FIG. 12. Mass spectrum of 4-*n*-butylpyridine, 70 eV.

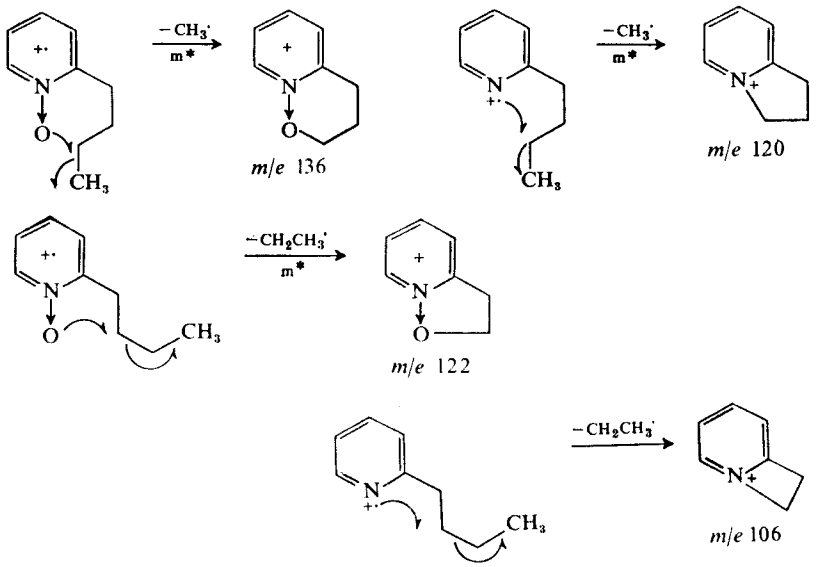
The *N*-oxide (VII, VIII and IX) behavior, on the other hand, is akin to that of *n*-butylbenzene† in which only π excitation is the low energy process. Namely, the [M − 42] intensity increases in going from 70 to 14 eV (see Table 3); however, the [M − 42] intensity of 4-butylpyridine *N*-oxide (IX) is apparently lower than that of either the 2- or 3-isomer. As is evident from the [M − 43] intensities, a competing low energy fragmentation process intervenes in the mass spectrum of IX but not in either VII or VIII. This behavior is reminiscent of the [M − 15] fragmentation of the ethylpyridine *N*-oxides (*vide supra*) in which the 4-isomer exhibits a uniquely strong propensity toward an α-cleavage fragmentation which is essentially non-evident in the 2- and 3-isomers. The electronic effect of the free amine group in distributing radical character or positive charge to the transfer sites is expected to be reversed for the *N*-oxides;[7] hence, the increase in [M − 42] intensity of VIII compared to XI and the decrease in intensity of VII and IX to X and XII is somewhat more understandable. This superficial way of interpreting the observed behavior awaits an explanation based on a quasi-equilibrium theory treatment[11,12], however, when the nature of the excited states leading to product is more fully characterized.

The moderately intense *m/e* 92 and 93 ions in the *N*-oxide mass spectra (Figs. 7 to 9) might arise in a stepwise fashion by loss of 16 and 17 amu respectively from *m/e* 109 or by loss of 42 and/or 43 amu from the very weakly intense loss-of-OH (*m/e* 134), and/or loss-of-oxygen (*m/e* 135) fragment ions. The metastable ion data (Table 1) confirm that *m/e* 92 arises from *m/e* 93 in all cases and from *m/e* 120 and 109 in 2-*n*-butylpyridine *N*-oxide (VII). Other routes are not excluded, however. The ion at

† At 70 eV the % Σ of [M − 42] ion of *n*-butylbenzene is 25 and at 14 eV it is 37. Similarly, at 70 eV the [M − 43] value is 63 and at 14 eV it is 25.

m/e 93 arises at least in part by a McLafferty rearrangement from the [M − 16] ions which are moderately intense in the mass spectra of 3-*n*-butylpyridine *N*-oxide (VIII) and 4-*n*-butylpyridine *N*-oxide (IX), $m^* = 64{\cdot}2$ for $135^{+\cdot} \rightarrow 93^{+\cdot} + 42$. Moreover, the ratio of the [M − (42 + 16)] intensities (1·3:1:1·5) of the *N*-oxides (VII, VIII and IX respectively) correlates fairly well with the ratio of the [M − 42] intensities (1·5:1:2) of the corresponding free amines (X, XI and XII respectively). Surprisingly, a metastable ion ($m^* = 57{\cdot}3$) is also found in the mass spectra of VII, VIII and IX and this correlates with the formation of *m/e* 93 directly from the molecular ion [M], $151^{+\cdot} \rightarrow 93^{+\cdot} + 58$.

The proximity of the *N*-oxide group to the alkyl group of 2-*n*-butylpyridine *N*-oxide is sufficient to allow for oxygen participation in formation of the [M − 15] and [M − 29] ions as shown in Scheme 2. The isomeric butylpyridine *N*-oxides (VIII and



SCHEME 2

IX) have only very weak [M − 15] and [M − 29] ions. A similar type of participation (by nitrogen)[8,9] is also characteristic of the 2-*n*-butylpyridine (X) fragmentations leading to relatively more intense [M − 15] and [M − 29] ions here than in the spectra of the isomeric butylpyridines (XI and XII). Thus, the moderately intense ion at *m/e* 106 in the mass spectrum of VII arises from the [M − 16] ion, $m^* = 83{\cdot}2$ for $135^{+\cdot} \rightarrow 106^{+} + 29$.

EXPERIMENTAL

The methyl and ethylpyridines used were commercial samples (K & K Laboratories, Inc). The purity of all pyridines was checked by gas-liquid chromatography (Varian Aerograph 1200 instrument with flame ionization detector), using two different stationary phases (carbowax 20 M and SE 30 on Chromosorb W, 60-80 Mesh) in ⅛ in. diam. 6-ft columns. The purity of all samples was greater than 99·5%. The purity of all pyridine *N*-oxides was checked by thin layer chromatography using chloroform–ethyl acetate–ethanol (5·5:3·5:1) as eluent and observing the spots after exposure of the plates to iodine vapor. The mass spectra were measured on an AEI MS-9 mass spectrometer using an ion current of 20 μa. All microanalyses were determined by Miss Heather King in the UCLA chemistry department microanalytical laboratory.

2-Butylpyridine (X).[13] The lithium derivative of the 2-picoline (23·0 g, 0·25 mole), was prepared in ether using phenyl lithium.[14] Propyl bromide (31·0 g, 0·25 mole) was added during 10 mins. with stirring and the mixture was treated to reflux for 30 mins. The reaction mixture was poured into water, and the organic layer was separated and washed with water. Removal of the solvents on a rotory evaporator, after drying over anhydrous sodium sulfate, was followed by a fractional distillation of the residue to give 2-butylpyridine, 12 g (36%), b.p. 82 to 83°/25 torr.

3-Butyl-(XI)[15] *and 4-butylpyridine* (XII).[16] Sodium amide was prepared in 400 ml of liquid ammonia using 4·6 g (0·2 mole) of sodium. To this suspension, the appropriate picoline (18·6 g, 0·2 mole) was added during 10 mins.[17] After 30 mins. of stirring, propyl iodide (34 g, 0·2 mole) was added dropwise during 30 mins. Stirring was continued for 10 mins. and then the ammonia was allowed to evaporate. Water was added to the residue, and the resulting mixture was extracted twice with ether (75 ml portions). After drying over anhydrous sodium sulfate followed by evaporation of the solvent, fractional distillation gave the pure product:

3-butylpyridine, b.p. 90·5 to 91·5/20 torr; yield 16 g (94%).
4-butylpyridine, b.p. 92 to 93/20 torr; yield 15 g (88%).

2-, 3- and 4-*Picoline N-oxides* and *2-ethylpyridine N-oxide* were prepared as reported previously.[18] The other *N*-oxides were obtained from the corresponding pyridines by using the following general procedure.[19]

The appropriate pyridine (1·5 g) was dissolved in 10 ml of acetic acid containing 0·5 ml of acetic anhydride and 1·5 ml of hydrogen peroxide (30%) and the mixture was heated at 70° for 3 hrs. An additional 1 ml of hydrogen peroxide was added and the heating continued for 9 hrs. Volatile materials were removed at 60° using a rotory evaporator, and the residue was dissolved in 10 ml of chloroform to which was added anhydrous potassium carbonate. Filtration and removal of solvent gave crude *N*-oxide. All the amine-oxides prepared are hygroscopic. In order to remove water from analytical sample, the following technique was used:

Before the distillation or sublimation of the sample, the latter was heated under vacuum at 20 or 30°C below its boiling point, or its sublimation temperature for 8 to 12 hrs. in the same distilling or sublimating apparatus. Then, by raising the temperature of the oil bath, the compound was distilled (or sublimed). In this way, it was possible to obtain appropriate analytically pure samples.

3-Ethylpyridine *N*-oxide, b.p. 80/0·2 torr (Found: C, 68·08%; H, 7·36%. C_7H_9N requires: C, 68·27%; H, 7·37%). 4-Ethylpyridine *N*-oxide, sublimed at 95/0·1 torr, m.p. 120° (Found: C, 67·9%; H, 7·60%. C_7H_9N requires: C, 68·27%; H, 7·37%). 2-Butylpyridine *N*-oxide, b.p. 90/0·2 torr (Found: C, 71·71%; H, 8·58%. $C_9H_{13}N$ requires: C, 71·49%; H, 8·67%). 3-Butylpyridine *N*-oxide, b.p. 95/0·2 torr (Found: C, 71·26%; H, 8·76%. $C_9H_{13}N$ requires: C, 71·49%; H, 8·67%). 4-Butylpyridine *N*-oxide, b.p. 100/0·1 torr (Found: C, 71·24%; H, 8·29%. $C_9H_{13}N$ requires: C, 71·49%; H, 8·67%).

Acknowledgement—We wish to thank the National Institutes of Health (USPHS AM-11193) and Eli Lilly and Company for support of this work. The mass spectrometer used in this study was purchased with funds made available by the National Science Foundation (GP-3672).

REFERENCES

1. T. A. Bryce and J. R. Maxwell, *Chem. Commun.* 206 (1965).
2. R. Grigg and B. G. Odell, *J. Chem. Soc.* (*B*) 218 (1966).
3. O. Buchardt, A. M. Duffield and R. H. Shapiro, *Tetrahedron* **24**, 3193 (1968).
4. A. Tatematsu, H. Yoshizumi, E. Hayashi and H. Nakata, *Tetrahedron Letters* No. 31, 2985 (1967).
5. K. Biemann, *Mass Spectrometry, Organic Chemical Applications*, McGraw-Hill, New York, 1962, p. 134.
6. See also H. Budzikiewicz, C. Djerassi, and D. H. Williams, *Mass Spectrometry of Organic Compounds*, Holden-Day, Inc, San Francisco, 1967, Chapter 20.
7. K. Schofield, *Hetero-Aromatic Nitrogen Compounds*, Plenum Press, New York, 1967, Chapter 5.
8. G. Spiteller, *Massenspektrometrische Strukturanalyse Organischer Verbindungen*, Verlag Chemie, Weinheim, 1966, p. 172.
9. S. D. Sample, D. A. Lightner, O. Buchardt and C. Djerassi, *J. Org. Chem.* **32**, 997 (1967).

10. P. M. Draper and D. B. MacLean, *Can. J. Chem.* **46,** 1487 (1968).
11. H. M. Rosenstock and M. Kraus in F. W. McLafferty (Ed), *Mass Spectrometry of Organic Ions*, Academic Press, New York, 1963, Chapter 1.
12. R. G. Cooks, I. Howe and D. H. Williams, *Org. Mass Spectrom.* **2,** 137 (1969).
13. C. Osuch and R. Levine, *J. Am. Chem. Soc.* **78,** 1723 (1956).
14. R. B. Woodward and E. C. Kornfeld, *Org. Syn.* Coll. Vol. 3, 413 (1955).
15. R. L. Frank and C. Weatherbee, *J. Am. Chem. Soc.* **70,** 3482 (1948).
16. J. F. Areus and J. P. Wibout, *Rec. Trav. Chim. Pay-Bas* **61,** 59 (1942).
17. It has been shown 3-picoline can be alkylated as well as the 2- and 4-isomer. H. C. Brown and W. A. Murphey, *J. Am. Chem. Soc.* **73,** 3308 (1951).
18. E. Klingsberg, *The Chemistry of Heterocyclic Compounds*—"Pyridine and Its Derivative," part II, Interscience, New York, 1961, p. 98, and references cited therein.
19. E. Ochiai, *J. Org. Chem.* **18,** 534 (1953).