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RESEARCHES ON THE AROMATIC AZO COMPOUNDS

THE OXIDATION OF *p*-DIMETHYLAMINO-PHENYLAZO-PYRIDINES

L. PENTIMALLI
Istituto di Chimica degli Intermedi, Facoltá Chimica Industriale, Bologna

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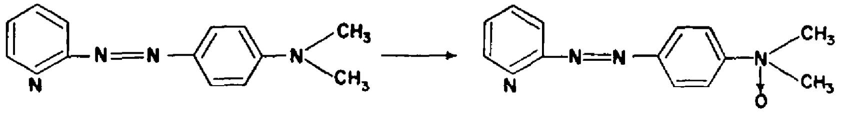
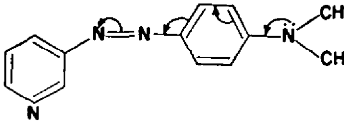
Abstract—This paper concerns the mono-oxidation of the three isomeric *p*-dimethylamino-phenylazo-pyridines by perbenzoic acid. The 2-isomer leads only to the amino-oxide; the 3-isomer yields mainly the amino-oxide, and small amounts of the 1-oxide. With the 4-isomer a mixture was obtained, from which only the 1-oxide was isolated. These results are discussed on the basis of the absorption spectra and resonance structures of the azo compounds.

THE results of the mono-oxidation of 2-(*p*-dimethylamino)-phenylazo-pyridine have previously been reported.[1] The oxidation of the dimethylamino group and not the pyridine nitrogen as might be expected on the basis of the acidity constants, suggests a revision of the concepts of resonance in the arylazo-pyridine system. It must be assumed that the conjugation of the dimethylamino group and the pyridine ring does not occur sufficiently to give the pyridine nitrogen an electron density greater than the initial value on the amino nitrogen. In order to discuss the reasons for this the behaviour of the other position isomers was investigated by mono-oxidation with organic peracids. This is a convenient method for evaluating the relative electron density on the different nitrogen atoms of the molecule. The experimental results of the mono-oxidation of 2-(*p*-dimethylamino)-phenylazo-pyridine (I) show that the first oxygen atom goes to the dimethylamino group, which suggests a similar course for the 3-isomer (III). The basicity of the amino nitrogen in the 2-isomer due to the lack of conjugation by electromeric effect via the azo group to the pyridine nitrogen, must occur in the 3-isomer where such conjugation is impossible. The pyridine nitrogen in *meta* position is not inhibited by the —M-effect of the azo group and the electron density on it can be greater than in the 2-isomer.


I II


III

Mono-oxidation of III gave a mixture from which the principal product, an orange

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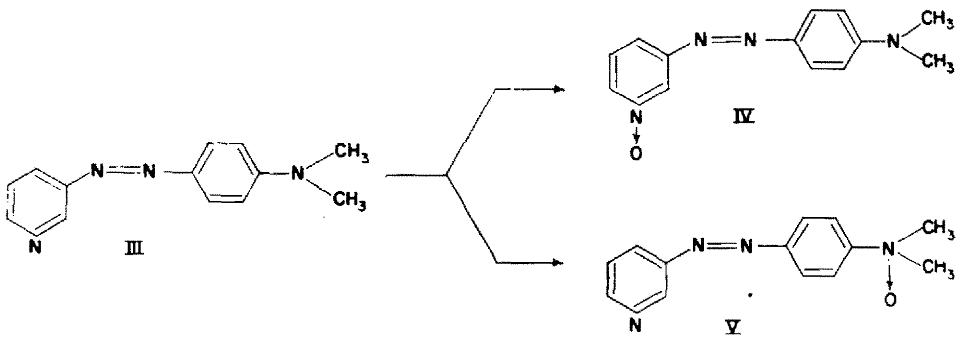
[1] L. Pentimalli, *Gazz. Chim. Ital.* 89, 1843 (1959).

coloured compound, was isolated, corresponding to the mono-oxidized azo compound with a spectrum almost identical to that of 3-phenylazo-pyridine (Figs. 1 and 2).



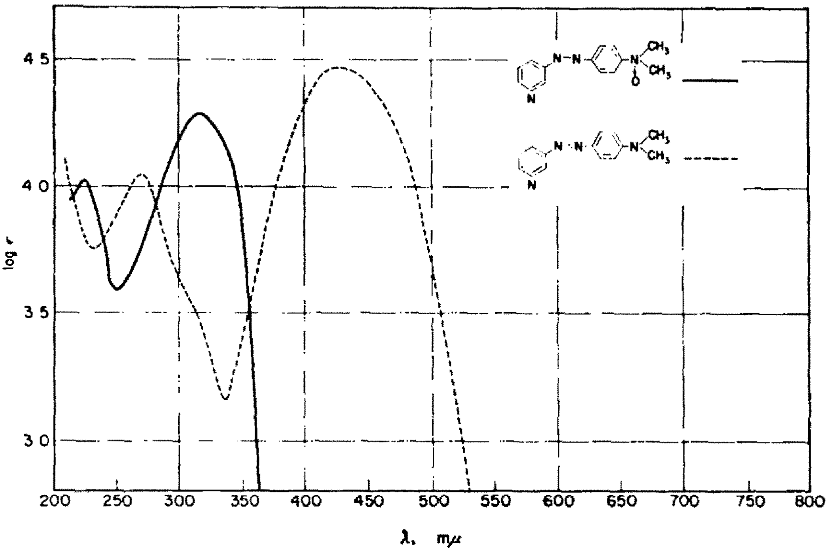


Fig. 1.

Besides the amino-oxide V it was possible to isolate a small amount of the 1-oxide IV (Fig. 3), identified by direct comparison with a sample obtained by synthesis.[2] Table 1 summarizes the spectrophotometrical data.

The first oxygen atom therefore goes preferentially to the amino nitrogen. The small amount of the 1-oxide indicates that the pyridine nitrogen in the 3-isomer has an electron density greater than in the 2-isomer.

Oxidation of this kind of molecule by organic peracids presents difficulties, especially concerning the constancy of the results. This is caused by the easy cleavage of the azo molecule since the mono-oxidation often led to low yield even when no unchanged starting material was recovered.

Comparison of spectrophotometrical data of the *p*-dimethylamino-derivatives may be useful for understanding the relative behaviour of the different isomers (Fig. 4). The characteristic data are collected in Table 2.

[2] R. W. Faessinger, P. L. Malloy and E. V. Brown, unpublished work; private communication by E. V. Brown.

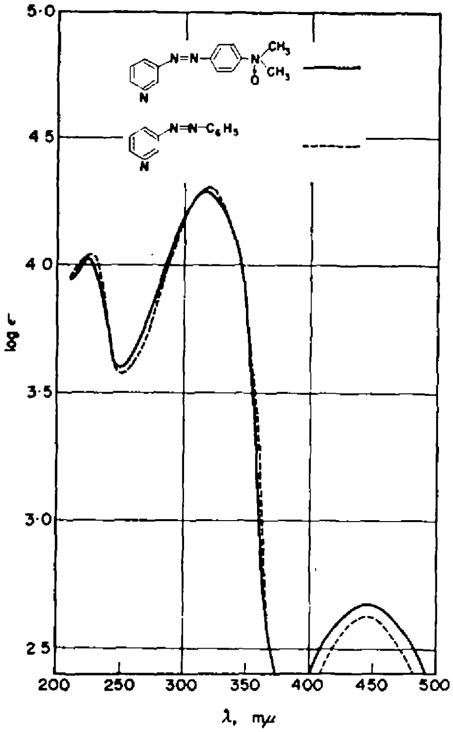
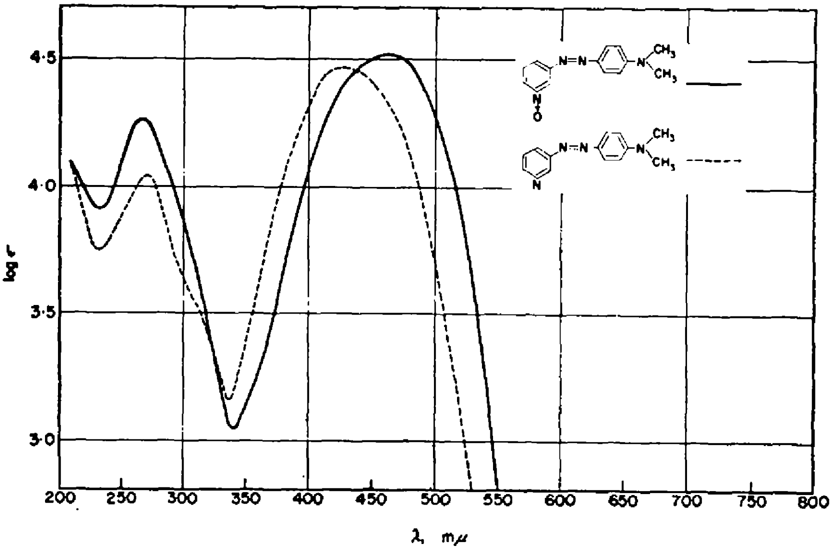

5·0
4·5
4·0
3·5
3·0
2·5
log ε
200
250
300
350
400
450
500
λ, mμ
N=N
CH₃
N
O
N=N–C₆H₅

FIG. 2.


4·5
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3·0
log ε
200
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500
550
600
650
700
750
800
λ, mμ
N=N
CH₃
N
O

FIG. 3.

TABLE 1. MAXIMA WAVELENGTH (mμ) AND CORRESPONDING INTENSITIES (LOG ε) IN THE ABSORPTION SPECTRA OF 3-(p-DIMETHYLAMINO)-PHENYLAZO-PYRIDINE AND RELATED N-OXIDES IN ETHANOL

		λ_1	λ_2*	λ_3	λ_4
3-isomer	III	272(4·03)		428(4·46)	
3-isomer 1-oxide	IV		268(4·26)	464(4·51)	
3-isomer amino-oxide	V	224(4·02)		316(4·29)	444(2·67)
3-phenylazo-pyridine		224(4·04)		318(4·30)	444(2·63)

* λ_2 indicates the λ_{max} of the pyridine-1-oxide band.

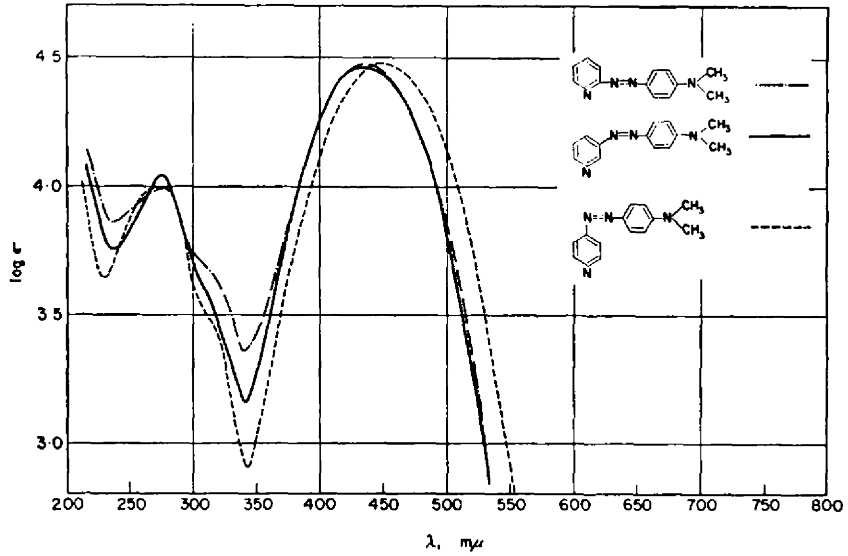
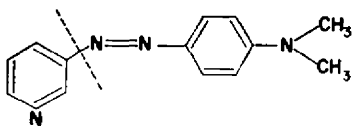


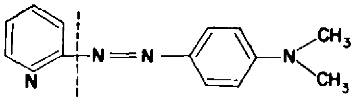
FIG. 4.

TABLE 2. MAXIMA WAVELENGTH (mμ) AND CORRESPONDING INTENSITIES (LOG ε) IN THE ABSORPTION SPECTRA OF ISOMERIC p-DIMETHYLAMINO-PHENYLAZO-PYRIDINES IN ETHANOL

	λ_1	λ_3
2-(p-dimethylamino)-phenylazo-pyridine	273(3·99)	432(4·47)
3-(p-dimethylamino)-phenylazo-pyridine	272(4·03)	428(4·46)
4-(p-dimethylamino)-phenylazo-pyridine	272(4·00)	444(4·48)

Although the curves show no marked differences, it may be observed that the curves of the 2- and 3-isomers are almost identical. The 2-isomer shows a short 4 mμ shift in comparison with the 3-isomer, while the 4-isomer shows a significant red shift of about 12 mμ in comparison with the other two. However, it is apparent that neither of the two conjugate azo compounds (2- and 4-isomers) shows major shifts with regard to the non-conjugate azo compound (3-isomer). The conjugation K band (λ_3) may therefore be related to the principal conjugation of the molecule, certainly due to the dimethylamino group but involving to a negligible extent the pyridine ring.





As in the case of the phenylazo-pyridines, the molecules must be represented with the main chromophoric system including only the azo group, since interaction between the azo group and the pyridine ring should involve substantial differences of the absorption depending on whether or not the phenylazo substituent is in a conjugate position.

Examination of absorption spectra in acidic media to observe the protonation electronic effect on the nitrogen atoms, as with the unsubstituted phenylazo-pyridines,[3] was not suitable because protonation leads to a tautomeric equilibrium[4] and serves only to complicate certain aspects of the problem.

The spectroscopic measurements in neutral medium (ethanol) show therefore for the three isomers, at the ground state in inactive media, a conjugate phenylazo structure with no significant effect of the pyridyl group: the *ortho-meta* equivalence is striking in this respect (Fig. 4); hence, in the arylazo-pyridines, in inactive media, the azo group (electron-acceptor) behaves as an insulator between the two electronic oscillators. The 2- and 4-isomers of the arylazo-pyridines, in the normal state, may therefore properly be regarded as potentially conjugate rather than conjugate azo compounds, an electromeric effect remaining where the possible mesomeric effect fails to occur.

The presence of the dimethylamino group in *para* position, affecting the azo group to a greater extent, opposes the electron pull of the azo group on the pyridyl, and the basicity of the pyridine nitrogen is increased to about the same extent for the 2- and 4-isomers.

TABLE 3. ACIDITY CONSTANTS, p*K*a, AT 25°

	Pyridinium	Azonium	Ammonium
2-phenylazo-pyridine[5]	2·0	−3·1	—
4-phenylazo-pyridine[5]	3·5	−3·1	—
2-(*p*-dimethylamino)-phenylazo-py[4]	4·5	...	2·0
4-(*p*-dimethylamino)-phenylazo-py[4]	5·8	...	3·4
pyridine	5·3	—	—
azobenzene[4]	—	−2·5	—

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[3] L. Pentimalli, unpublished work; see M. Colonna and A. Risaliti, *Gazz. Chim. Ital.* **85**, 1148 (1955).

[4] I. M. Klotz, H. A. Fiess, J. Y. Chen Ho and M. Mellody, *J. Amer. Chem. Soc.* **76**, 5136 (1954); G. Cilento,

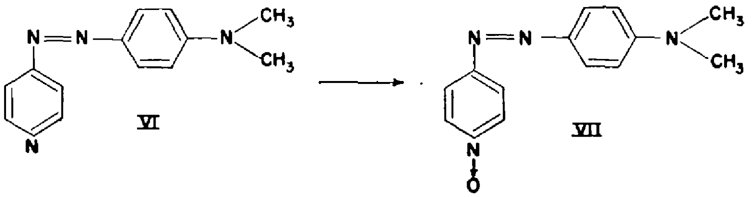
[5] E. C. Miller and J. A. Miller, *Ibid.* **78** 1718 (1956).

A. Foffani and M. R. Foffani, *Rend. Accad. Lincei* [8] **23**, 60 (1957).

Comparison of the absorption curves of the p-dimethylamino-phenyl-azo-pyridines shows no appreciable conjugation for the 2-isomer, potentially conjugate, and the first oxygen atom adds exclusively to the amino nitrogen (in contrast to the assignments of the acidity constant values). The 4-isomer, on the other hand, shows an appreciable shift (+16 mμ) with respect to the 3-isomer, which may be related to a more pronounced conjugation regarding the other members of the series. This agrees with the general case of 4-pyridine-derivatives, which always show a stronger conjugative effect than 2-derivatives.[6]

Also on the basis of the acidity constant (Table 3), markedly higher for the 4-isomer than for the 2-derivative, it may be anticipated that mono-oxidation will lead in this case to at least a mixture of oxidation products and the pyridine nitrogen atom can compete, to a greater or a lesser extent, with the amino nitrogen in accepting the first oxygen atom.

The experimental results gave a mixture from which (assuming the presence of the amino oxide) only the 1-oxide is isolated, from the pyridine nitrogen, which is not formed in the oxidation of the 2-isomer.


VI

VII

Identification of the oxidation compound was by direct comparison with the 1-oxide (VII) obtained by synthesis[2] and the absorption curves appeared to be identical (Fig. 5).

Attempts for further oxidation failed.

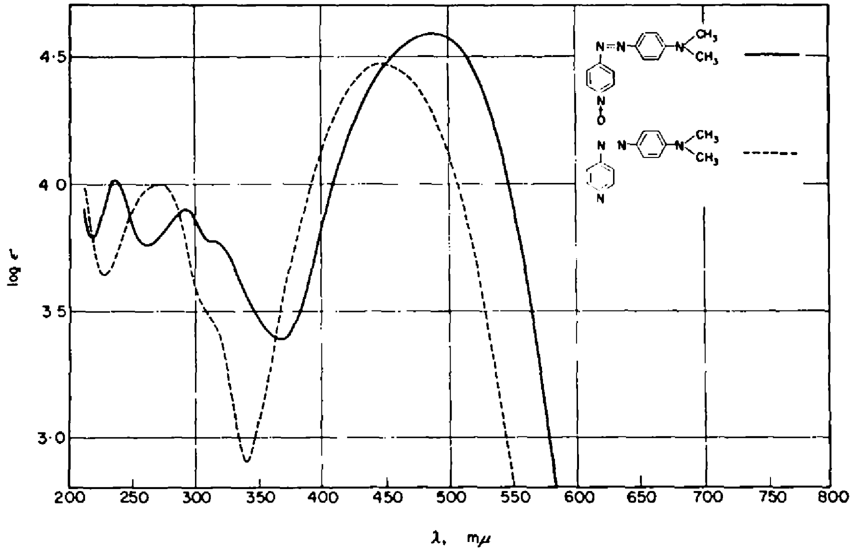


FIG. 5.

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[6] see M. Colonna, A. Risaliti and L. Pentimalli, *Gazz. Chim. Ital.* **86**, 1067 (1956).

As a result of these investigations, it may be assumed that in the arylazo-pyridines the azo group appears to be an ineffective conjugation conductor, owing to its strong electron-acceptor character. With the 3-isomer, the first oxygen atom goes preferentially to the amino group, and only to a small extent to the pyridine nitrogen. The 2-isomer, in which the azo group may decrease the electron density on the pyridine nitrogen, yields only the amino oxide. With the 4-isomer, in which resonance is more pronounced as is the case for the pyridine 4-derivatives, a mixture was obtained from which only the 1-oxide was isolated in appreciable amounts.

TABLE 4. MAXIMA WAVELENGTH (mμ) AND CORRESPONDING INTENSITIES (LOG ε) IN THE ABSORPTION SPECTRA OF 4-(p-DIMETHYLAMINO)-PHENYLAZO-PYRIDINE AND RELATED 1-OXIDE IN ETHANOL

4-(*p*-dimethylamino)-phenylazo-py (VI)	272(4·00)	292(3·90)	444(4·48)
4-*p*-dimethylamino-phenylazo 1-oxide (VII)	236(4·02)	292(3·90)	490(4·59)

EXPERIMENTAL

3-(p-*Dimethylamino)-phenylazo-pyridine* (III). 3-Amino-pyridine (4·6 g) was diazotized and coupled with dimethylaniline. The mixture, after 1 hr at 0°, was neutralized with sodium carbonate; the separated azo compound was filtered, washed with iced water and dried. Yield 4·8 g. Red fine needles (benzene or ligroin), m.p. 123° (reported[7] 121°).

3-*Amino-pyridine*-1-*oxide, hydrochloride*. To a solution of 3-amino-pyridine (20 g, 0·20 mole) in pyridine (60 ml), at 0°, benzoyl chloride (36 g, 0·26 mole) was slowly added, with stirring. After 2 hr, the suspension was poured into cold water (500 ml) and the white precipitate filtered, well washed with water and dried. Yield 37 g of 3-(N-benzoyl)-amino-pyridine, white prisms (benzene-ligroin), m.p. 118° (reported[7] 119°). This derivative (40 g) was oxidized by hydrogen peroxide and acetic acid. Yield 30 g of 3-(N-benzoyl)-amino-pyridine-1-oxide, white prisms (ethanol) m.p. 209–210°.[8] The oxide, on hydrolysis with aqueous sodium hydroxide and the resulting solution acidified with HCl, gave 3-amino-pyridine-1-oxide hydrochloride (8 g), white needles (ethanol–ether), m.p. 291–292°.[2]

3-(p-*Dimethylamino)-phenylazo-pyridine*-1-*oxide* (IV). This was obtained from the hydrochloride and dimethylaniline.[2] Purple needles (benzene), m.p. 186°.

Mono-oxidation of III. To a solution of III (2 g, 1 mole) in chloroform (150 ml), at 0°, a solution of perbenzoic acid (1·5 moles) in chloroform was slowly added. After remaining overnight the peracid had disappeared, and the mixture was shaken with saturated sodium carbonate solution, and dried (anhydrous sodium carbonate) filtered and the chloroform evaporated. The residue was washed with benzene and dissolved in hot acetone. On cooling, hemispherical clusters of 3-(*p*-dimethylamino-N-oxide)-phenylazo-pyridine (1 g), orange needles (acetone) m. p. 118–119°, were obtained (Found: N, 23·27; Calc. for $C_{13}H_{14}N_4O$: N, 23·12%). The benzene solution was poured on an alumina column. The lower orange band gave unchanged azo compound; often an upper purple band was obtained, which gave 0·2 g of purple needles (benzene), m.p. 183–186°, identical with 3-(*p*-dimethylamino)-phenylazo-pyridine-1-oxide.

3-*Phenylazo-pyridine*. Prepared by condensation of 3-amino-pyridine and nitrosobenzene in 50% KOH, according to Campbell *et al.*[8] Orange needles (petroleum ether), m.p. 50–51°.

4-(p-*Dimethylamino)-phenylazo-pyridine* (VI). Prepared by coupling diazotized 4-amino-pyridine with dimethylaniline.[8] Brick red needles (benzene–ligroin), m.p. 208°.

4-*Amino-pyridine*-1-*oxide, hydrochloride*. To a solution of 4-amino-pyridine (10 g, 1 mole) in pyridine (80 ml), at 0°, benzoyl chloride (18 g, 0·13 mole) was slowly added, with stirring. After 2 hr, the precipitate was collected, washed with ether and dried. Yield 14 g 4-(N-benzoyl)-amino-pyridine

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[7] A. Binz and C. Räth, *Liebigs Ann.* **486**, 95 (1931).

[8] N. Campbell, A. W. Henderson and D. Taylor, *J. Chem. Soc.* 1281 (1953).

hydrochloride, m.p. 250°. The hydrochloride was dissolved in hot water (300 ml), filtered, and the filtrate neutralized with $NaHCO_3$. Yield 10·2 g of 4-(N-benzoyl)-amino-pyridine, white prisms (water) m.p. 202°.[9]

4-(N-benzoyl)-amino-pyridine (10 g) was oxidized by hydrogen peroxide and acetic acid, as with the 3-derivative. 4-(N-benzoyl)-amino-pyridine-1-oxide, white needles (water) m.p. 247–250°. The crude oxide was used for the next step.

4-(N-benzoyl)-amino-pyridine-1-oxide, hydrolysed with aqueous sodium hydroxide and the resulting solution acidified with HCl, gave 4-amino-pyridine-1-oxide hydrochloride, white needles (ethanol–ether) m.p. 181°.

4-(p-*Dimethylamino)-phenylazo-pyridine*-1-*oxide* (VII). From 4-amino-pyridine-1-oxide hydrochloride and dimethylaniline.[3] Long purple needles (ethanol), m.p. 212°.

Mono-oxidation of VI. This was oxidized with perbenzoic acid, as described for the 3-isomer. The residue was dissolved in benzene and the solution poured on an alumina column. The lower orange band gave little unchanged azo compound; from the upper purple band needles (ethanol or benzene), m.p. 211°, identical with 4-(*p*-dimethylamino)-phenylazo-pyridine-1-oxide, were obtained.

Ultra-violet-visible absorption spectra. The absorption spectra were determined in 95% ethanol with a Beckman Model DU Quartz spectrophotometer.

Acknowledgement—The author is indebted to Prof. Ellis V. Brown, Seton Hall University, South Orange, N.J., U.S.A., having kindly provided experimental details of his unpublished work.

[9] E. Koenigs, G. Kinne and W. Weiss, *Ber. Dtsch. Chem. Ges.* 57, 1172 (1924).