The Preparation and Alkylation of Arylazopyridine 1-Oxides[1]

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The methylation of 2-(*p*-dimethylaminophenylazo)pyridine 1-oxide (I) and 2-(*p*-hydroxyphenylazo)pyridine 1-oxide (VI) with dimethyl sulfate leads to the N-methoxypyridinium compounds IX and XX, respectively. In refluxing chloroform I reacts with iodomethane in an unexpected manner to form the N-methylpyridinium triiodode compound (XI). Reaction of the phenol VI with alkali yields the diazamerocyanine (XXII), which shows positive solvatochromism.

Heterocyclic azo dyes in which the heterocyclic ring is quaternized were first described by Kiprianov[2] in 1949. During the intervening years the investigation of this class of compounds has been stimulated by the discovery of their utility for the dyeing of certain synthetic fibers such as polyacrylonitrile fibers.[3]

2-Pyridylazo compounds, and therefore their quaternary derivatives, are relatively difficult to prepare because diazotized 2-aminopyridine does not couple with aromatic amines[4] or phenols. In contrast to 2-aminopyridine, however, 2-aminopyridine 1-oxide in aqueous acid forms a stable diazonium compound[5] which then can be coupled in the usual manner with aromatic amines, phenols, etc. It was of interest to establish whether quaternary dyes could be prepared from the azo derivatives of pyridine 1-oxide.

The properties of the products obtained during the present work by coupling diazotized 2-aminopyridine 1-oxide to a number of amines and phenols are listed in Table I.

All of the pyridine 1-oxide coupling products had absorption bands in the vicinity of 8 μ, which is the region in which the N^+–O^- stretching band is believed to occur in 2-substituted pyridine 1-oxides.[6a] Whereas the products of coupling with tertiary amines are necessarily in the N-oxide form, the phenolic coupling products could exist in several tautomeric forms. Both the *para*-coupled products (VI and VII) and the *ortho*-coupled product (VIII) had broad, multiple absorption in the 3–4-μ region, indicative of strong hydrogen bonding. This observation, however, does not permit assignment of tautomeric structure. The N-oxide forms are shown throughout this paper for the sake of convenience.

Alkylation of Amine Coupling Products.—The alkylation of 2-aminopyridine 1-oxide occurs on the oxygen atom to give the 2-amino-1-methoxypyridinium salts.[5] Similarly, alkylation of *p*-(2-pyridylazo)-N,N-dimethylaniline occurs on the pyridine nitrogen rather than on the dimethylamino group.[6b]

When a suspension of red azo N-oxide I ($\lambda_{max}^{CH_3OH}$ 495 mμ) in toluene was treated with dimethyl sulfate, a marked bathochromic shift was observed and a blue solid ($\lambda_{max}^{CH_3OH}$ 555 mμ) was isolated.[7] This solid was purified as the perchlorate, shown by elemental analysis to be the monoalkylation product (Scheme I). The bathochromic shift indicates that alkylation must have occurred on the oxygen atom rather than on the dimethylamino group and the primary alkylation product is therefore assigned structure IX. Alkylation of other *p*-aminophenylazo derivatives with dimethyl sulfate also gave the O-methyl products whose properties (as the perchlorates) are listed in Table II. It is interesting that, in the alkylation of the product of coupling to *m*-toluidine (V, Table I), only the oxygen atom is alkylated; the primary amino group was retained (XVII, Table II), as it was in the alkylation of 2-aminopyridine 1-oxide itself. Alkylation with 2-bromoethanol similarly gave the O-alkylation product (XIII, Table II).

When the alkylation of I was carried out at reflux with an excess of iodomethane in chloroform, an unexpected reaction occurred. A bathochromic shift was again observed, but the violet solid product obtained gave an analysis in agreement with the N-methylpyridinium triiodide compound (XI).

Similar reactions were observed with the diethylamino (II) and bis(2-hydroxyethyl)amino (IV) analogs of I.

The structural assignment of XI is supported by the elemental analysis, by the absorption at 555 mμ (CH_3OH), and by the stability of XI at room temperature in the presence of 2 *N* sodium carbonate solution. This latter observation indicates XI to have the N-methylpyridinium structure, since the N-methoxypyridinium compounds such as IX and X are rapidly discolored by 2 *N* sodium carbonate.

An oxidation–reduction sequence has clearly occurred and an attempt was made to determine the mechanism of this reaction.

When the alkylation of I was run in chloroform at *room temperature* there was obtained a dark solid which gave a single, violet band on paper chromatography. Iodine analysis leaves no doubt that this product is iodide X (calcd per cent I, 33.0%; found, 30.9%) rather than the triiodide (calcd per cent I, 61.2%). Thus compound X is a reasonable intermediate in the formation of XI.

An analytically pure sample of iodide X was obtained by treating a cold, aqueous solution of methosulfate IX with sodium iodide; physical properties were in agreement with those of the iodide obtained by the room-temperature alkylation (above).

(1) These results were presented at the Southeastern Regional Meeting of the American Chemical Society, Charlotte, N. C., Nov 1963.

(2) A. Kiprianov and G. Oksengendler, *Acta Chim. d. Kiewer Staatl. Univ.*, **5**, 29 (1949).

(3) See, *e.g.*, R. Sureau, *Teintex*, **26**, 401 (1961).

(4) R. W. Faessinger and E. V. Brown, *J. Am. Chem. Soc.*, **73**, 4606 (1951).

(5) A. R. Katritzky, *J. Chem. Soc.*, 191 (1957).

(6) (a) A. R. Katritzky and A. R. Hands, *J. Chem. Soc.*, 2195 (1958). (b) Unpublished results; see also British Patent (Geigy) 793,587 (1958).

(7) After the presentation of this work,[1] two patents reporting the alkylation of I were issued: (a) F. Brody and W. Sydor, U. S. Patent 3,118,871 (Jan 21, 1964); (b) H. Gleinig, *et al.*, Belgian Patent 641,161 (April 1, 1964). However, no physical properties other than the shade of dyeing on polyacrylonitrile fibers were reported for the products obtained.

SCHEME I

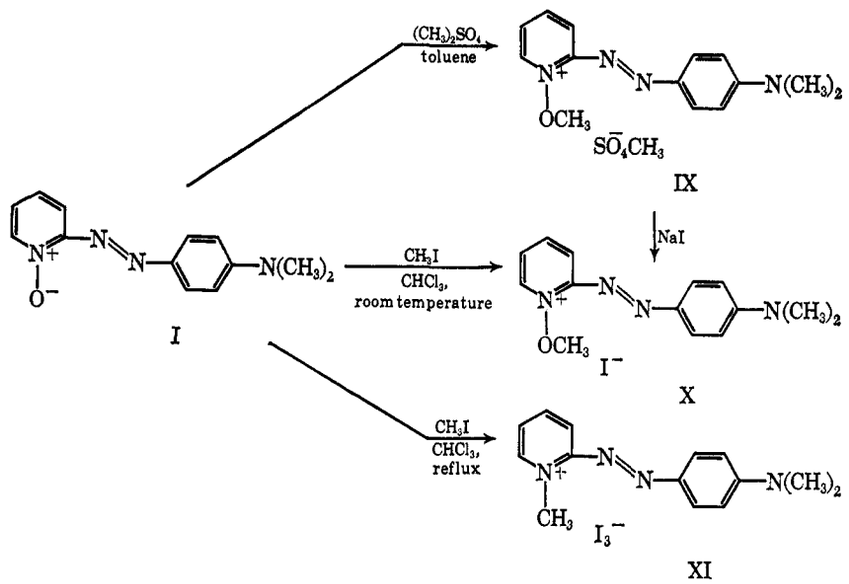
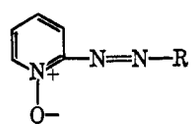


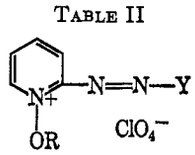
TABLE I



Compd	R	Mp, °C[a]	λ_{max}^{MeOH}, mμ	$\epsilon_{max} \times 10^{-3}$	Anal., % C Calcd	C Found	H Calcd	H Found	N Calcd	N Found
I	p-$(CH_3)_2NC_6H_4$	180–181[b]	495	32.5						
II	p-$(C_2H_5)_2NC_6H_4$	167–169	504	38.7	66.7	66.8	6.7	6.8	20.7	20.6
III	p-$(HOCH_2CH_2)CH_3NC_6H_4$	203–204	497	36.2	61.8	62.3	5.9	6.0	20.6	20.7
IV	p-$(HOCH_2CH_2)_2NC_6H_4$	202–203	496	36.3	59.6	59.8	6.0	6.0	18.5	18.3
V	4-NH_2-2-$CH_3C_6H_3$	218–220	466	31.9					24.6	24.2
VI	p-HOC_6H_4	219–220	383	21.8	61.4	61.3	4.2	4.2	19.5	19.7
VII	4-HO-2-$CH_3C_6H_3$	226–227	393	18.3					18.3	18.6
VIII	2-HO-5-$CH_3C_6H_3$	159–160			62.9	62.9	4.8	5.0	18.3	18.3

[a] All melted with decomposition. [b] Lit. value 181–182°: L. Pentimalli, *Gazz. Chim. Ital.*, **89**, 1843 (1959).

TABLE II



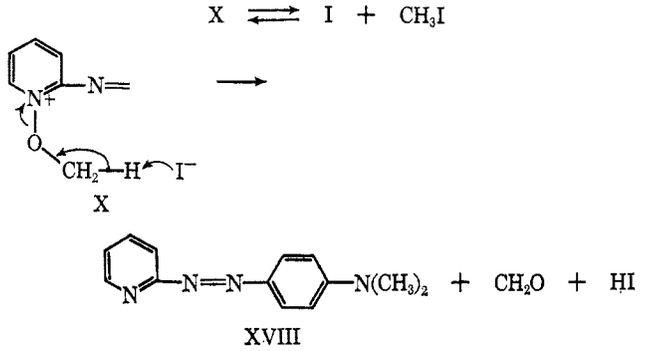
Compd	R	Y	Mp, °C	$\lambda_{max}^{CH_3OH}$, mμ	$\epsilon_{max} \times 10^{-3}$	Anal., % C Calcd	C Found	H Calcd	H Found	Cl Calcd	Cl Found	N Calcd	N Found
XII	CH_3	C_6H_4-p-$N(CH_3)_2$	186–187	566	70.5	47.1	46.9	4.8	4.7	9.9	9.9	15.7	15.8
XIII	$HOCH_2CH_2$	C_6H_4-p-$N(CH_3)_2$	168–170	565	72.4	46.6	46.6	5.0	5.1	9.2	9.2	14.5	14.4
XIV	CH_3	C_6H_4-p-$N(C_2H_5)_2$	157–158	570	68.9	49.9	50.2	5.5	5.8	9.2	9.4	14.6	14.3
XV	CH_3	C_6H_4-p-$N(CH_3)CH_2CH_2OH$		568	75.4	46.6	46.5	5.0	5.0	9.2	9.2	14.5	14.7
XVI	CH_3	C_6H_4-p-$N(CH_3)CH_2CH_2CN$	189–191	552	60.6	48.6	48.7	4.6	4.7	9.0	8.8	17.7	17.5
XVII	CH_3	C_6H_3-2-CH_3-4-NH_2	190–191	543	74.5	45.6	45.6	4.4	4.7	10.3	10.4	16.3	16.1

When iodide X was heated in refluxing chloroform for 1 hr, the original violet band (paper chromatography) disappeared and was replaced by two new bands, one yellow and one red. It was possible to separate the yellow and red solids by chromatographing the reaction mixture on an alumina column.

The red solid was obtained in larger amount and melted at 180–181°; no depression of melting point was observed on admixture with an authentic sample of N-oxide I. The alkylation of I with iodomethane to form X is thus reversible. The demethylation of X to I represents attack by iodide ion at the O-methyl group and is analogous to the reported[8] demethylation of 1-methoxypyridinium p-toluenesulfonate by nucleophilic agents such as sodium acetate, sodium benzyl mercaptide, and morpholine to give pyridine 1-oxide. A similar demethylation of iodide X occurred when an attempt was made to recrystallize it from ethanol. The perchlorate anion, in contrast to the iodide ion, is weakly nucleophilic, and the N-methoxypyridinium perchlorate salts were found to be stable in refluxing alcohol.

(8) N. A. Coats and A. R. Katritzky, *J. Org. Chem.*, **24**, 1836 (1959).

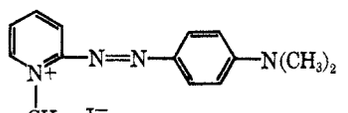
The yellow band (above) yielded in small amount a solid which was identified as *p*-(2-pyridylazo)-N,N-dimethylaniline (XVIII), by comparison with the thin layer chromatographic behavior of an authentic sample of XVIII prepared according to the method of Faessinger and Brown.[4] A reasonable path of formation of XVIII involves attack of iodide ion as a base on one of the methoxyl protons to form HI, formaldehyde, and the pyridine derivative (XVIII). This reaction is analogous to the well-known reaction of N-alkoxypyridinium compounds with alkali to form an aldehyde and the pyridine compound.[9]



X

XVIII

Under the conditions of methylation, pyridine azo compound XVIII would be methylated to give the N-methylpyridinium iodide (XIX).[10] Since this latter methylation is essentially irreversible, whereas the formation of X is reversible, it is clear that eventually all of starting N-oxide I will be converted to XIX.

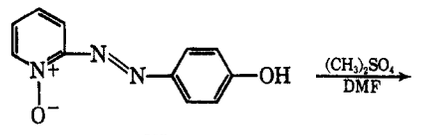


XIX

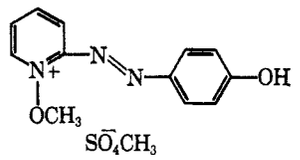
The mechanism of formation of iodine, which is necessary for formation of the triiodide observed, remains unexplained.[11]

Atmospheric oxygen does not appear to be involved in the oxidation, for triiodide XI was obtained even when the methylation was carried out under a nitrogen atmosphere.

Alkylation of Azophenol VI.—Alkylation of azophenol VI was carried out with dimethyl sulfate in N,N-dimethylformamide, from which a red monoalkylation product (XX) was precipitated by the addition of ethyl acetate. The absorption maximum undergoes a large bathochromic shift in proceeding from N-oxide VI [$\lambda_{max}^{CH_3OH}$ 383 mμ (ε 21,800)] to pyridinium



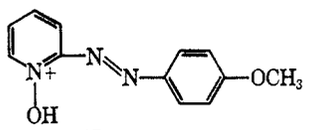
VI



XX

compound XX [$\lambda_{max}^{CH_3OH}$ 520 mμ (ε 21,000)]; this bathochromic shift of 137 mμ is nearly twice that (71 mμ) observed with the dimethylamino analog.

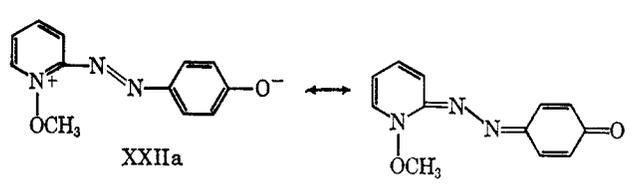
When an aqueous solution of XX was treated with 2 *N* sodium hydroxide, a red solid was formed which had lost the elements of methylsulfuric acid. This solid absorbs at about the same wavelength as XX but has a much higher molar absorptivity [$\lambda_{max}^{CH_3OH}$ 523 mμ (ε 58,000)]. This observation establishes structure XX for the alkylation product; if alternative structure XXI were correct, a significant hypsochromic shift would occur in the reaction with alkali to give 2-(*p*-methoxyphenylazo)pyridine 1-oxide.



XXI

Since quaternary salt XX has two acidic centers, base can attack in principle in either of two ways. It could extract a proton from the $NOCH_3$ group, with subsequent loss of formaldehyde and formation of *p*-(2-pyridylazo)phenol. Although this pathway is followed in the dialkylamino series, it is clearly excluded in the present instance; *p*-(2-pyridylazo)phenol is soluble in aqueous alkali, whereas a red solid, insoluble in 2 *N* sodium hydroxide, was actually obtained.

In the second pathway the base removes the more acidic phenolic hydrogen to form resonance hybrid XXII; as indicated above, elemental analysis of the red solid is in agreement with that demanded by structure XXII.



XXIIa XXIIb

A series of "pyridone azinobenzoquinones" or diazamerocyanines, of which the simplest member is represented by XXIII, was similarly prepared by Hünig and Köbrich[13] by treating the corresponding azophenol salts with sodium hydroxide solution. On the basis of the positive solvatochromism[14] shown by

(9) E. Ochiai, *J. Org. Chem.*, **18**, 534 (1953).

(10) Some iodide XIX was undoubtedly present in the reaction mixture. A paper chromatogram of the methylation mixture showed two violet bands of the same shade. This second band (in addition to the band due to triiodide XI) also was not decolorized by carbonate solution, and must therefore be due to the N-methyl compound XIX. However, because XIX was present in smaller amount, it was soluble in the reaction mixture and was not isolated.

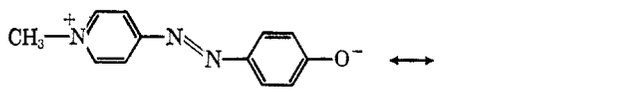
(11) Additional HI could be generated by reaction of iodomethane with ethanol, which was present in the chloroform as a preservative to the extent of about 0.75%. The presence of HI suggests the possibility that some XVIII is formed by reduction of the N-oxide by HI, with formation of I_2. The literature[12] indicates that pyridine and quinoline 1-oxides do not liberate iodine from acidified potassium iodide. No reduction was observed when II was treated with acidified aqueous potassium iodide solution at room temperature. This observation, however, does not exclude the possibility of reduction of N-oxide I by hydrogen iodide in *refluxing chloroform*.

(12) A. R. Katritzky, *Quart. Rev.* (London), **10**, 395 (1956).

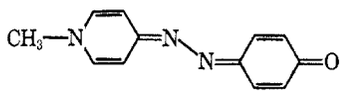
(13) S. Hünig and G. Köbrich, *Ann.*, **617**, 210 (1958).

(14) The term "positive" solvatochromism indicates a shift of absorption to longer wavelengths when the polarity of the solvent is increased. For recent discussions of the phenomenon of solvatochromism, see (a) A. I. Kiprianov, *Russ. Chem. Rev.*, **29**, 618 (1960); (b) S. Hünig, *et al.*, *Ann.*, **690**, 9 (1965).

XXIII, Hünig and co-workers[13,15] concluded that XXIII is more nearly quinoidal (*i.e.*, XXIIIb) in structure.



XXIIIa



XXIIIb

Table III compares the spectral data for XXII with those reported by Hünig and Herrmann[15] for XXIII. The solvents in Table III are listed in order of increasing polarity, as measured by the E_T value of Dimroth and co-workers.[16] Single peaks without structure were observed for XXII in water, formamide, and methanol in the range 300–800 mμ. In chloroform and benzene, a weak side band at 344 mμ (ε 6200) and 343 mμ (ε 4400), respectively, was observed in addition to the main band at the indicated wavelengths (Table III).

TABLE III

VARIATION OF ABSORPTION MAXIMUM AND MOLAR ABSORPTIVITY OF XXII AND XXIII WITH SOLVENT POLARITY

	XXII		XXIII[b]	
Solvent (E_T value)[a]	λ_{max}, mμ	ε × 10^{-3}	λ_{max}, mμ	ε × 10^{-3}
Benzene (34.5)	482	28.0	512	47.4
Chloroform (39.1)	493	29.9	522	56.4
Methanol (55.5)	523	58.0	545	67.0
Formamide (56.6)	526	58.0	550	82.3
Water (63.1)	525	60.9		

[a] Reference 16. [b] Reference 15.

The bathochromic shifts observed for XXII and XXIII as solvent polarity is increased (positive solvatochromism) are quite similar. In both cases the molar absorptivity increases with increasing solvent polarity, as is usually the case with merocyanines which show positive solvatochromism.[15] The above data indicate that quinoidal structure XXIIb is a closer approximation of the structure of resonance hybrid XXII than is zwitterionic structure XXIIa.

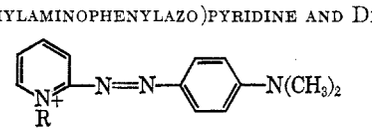
The infrared spectrum of XXII showed no absorption bands in the 5–6-μ region, but had the following bands in the 6–7-μ region (KBr): 6.20 (s), 6.30 (w), 6.47 (ms), 6.71 (m), and 7.0 (s). Since the band at 6.20 μ (6.19 μ in chloroform) is strong, it is reasonable to assign it to the carbonyl group in XXIIb.[17] The carbonyl absorption of *p*-benzoquinone occurs at about 6.0 μ ($CHCl_3$),[18] whereas there is a strong carbonyl band at 6.08 μ (KBr)[19] in the spectrum of the anil of *p*-benzoquinone. This shift in the carbonyl absorption in XXII *vs.* that for benzoquinone or benzoquinone anil indicates that although XXIIb is a better representation than XXIIa, significant interaction between the pyridine nitrogen and the carbonyl group does occur.[20]

The alternative reaction of XX with "base" mentioned above (*i.e.*, removal of a proton from the $NOCH_3$ group, with subsequent loss of formaldehyde) was observed to a small extent when a solution of XX in ethanol was refluxed and then concentrated to dryness. When the residue was taken up in water, a yellow solid separated in 15% yield. The solid was soluble in sodium carbonate solution and had an analysis in agreement with the empirical formula of the demethoxylated material, *p*-(2-pyridylazo)phenol (XXIV).

Electronic Spectra.—Table IV summarizes the absorption maxima for one series of the pyridine azo compounds. As expected, the pyridine 1-oxide compound with its semipolar N–O bond has an absorption maximum lying approximately halfway between the pyridine compound and the $NOCH_3$ pyridinium compound. The N-methoxypyridinium compound is bathochromic *vs.* the N-methylpyridinium analog by 8 mμ and also has a somewhat higher molar absorptivity. All of the N-methoxypyridinium compounds in Table II have high molar absorptivities.

TABLE IV

ABSORPTION MAXIMA FOR 2-(*p*-DIMETHYLAMINOPHENYLAZO)PYRIDINE AND DERIVATIVES



R	$\lambda_{max}^{CH_3OH}$, mμ	ε × 10^{-3}
...	432[a]	29.5
O^-	495	32.5
OCH_3[b]	563	72.9
CH_3[b]	555[c]	58.7

[a] In ethanol: L. Pentimalli, *Tetrahedron*, 9, 194 (1960). [b] Iodide anion. [c] Unpublished observation.

Nmr Spectra.—The nmr spectrum of dimethylamino salt IX was determined in D_2O. In addition to the dimethylamino hydrogens at 3.10 ppm (6 H), the spectrum showed two peaks in the methoxy region at 3.75 (3 H) and 4.19 ppm (3 H). A sample of potassium methylsulfate in D_2O gave a single peak at 3.72 ppm. Thus, the 3.75-ppm peak in IX is attributable to the methylsulfate ion, and the 4.19-ppm peak is assigned to the methoxy group attached to the pyridinium nitrogen. The aromatic region was complex, but a typical A_2B_2 pattern centered at 6.92 ppm (4 H) owing to the *para*-disubstituted benzene ring was clearly apparent.

Phenolic salt XX in D_2O similarly showed two methoxy peaks, at 4.30 (3 H) for the $NOCH_3$ and at 3.63 ppm (3 H) for the methylsulfate ion. The A_2B_2 *para*-substituted benzene ring pattern was centered at 7.04 ppm (4 H).

The nmr spectrum of diazamerocyanine XXII, determined in $CDCl_3$, was very complex. It did show a methoxy peak at 4.22 ppm (3 H), which is the same region as for pyridinium compounds IX and XX.

(15) S. Hünig and H. Herrmann, *Ann.*, **636**, 32 (1960).

(16) The E_T values are molar transition energies calculated from the position of the absorption maximum of pyridinium N-phenolbetaines in various solvents and are thus a measure of solvent polarity: (a) K. Dimroth, *et al.*, *ibid.*, **661**, 1 (1963); (b) C. Reichardt, *Angew. Chem.*, **77**, 30 (1965).

(17) As pointed out by a referee, the pyridinium ring also frequently absorbs at about 6.2 μ. This band is thus compatible with both XXIIa and XXIIb and does not serve as a basis for differentiating between these two structures.

(18) This band is actually split into a doublet occurring at 5.97 and 6.02 μ, as a result of Fermi resonance coupling: J. F. Bagli, *J. Phys. Chem.*, **65**, 1052 (1961).

(19) H. J. Teuber and W. Schmidtke, *Chem. Ber.*, **93**, 1260 (1960).

(20) The carbonyl group in N-methyl-4-pyridone absorbs at the even longer wavelength of 6.32 μ ($CHCl_3$); see L. J. Bellamy and P. E. Rogasch, *Spectrochim. Acta*, **16**, 30 (1960).

Since a different solvent had to be used for the determination of the spectrum of XXII, no conclusions about relative deshielding of the $NOCH_3$ group in the above three compounds can be drawn.

Experimental Section

All melting points are uncorrected. Infrared spectra were determined with Perkin-Elmer infrared spectrophotometers, Models 221, 521, or 631, as Nujol mulls unless otherwise indicated. The electronic spectra (usually only in the region 300–800 mμ) were measured with a Cary Model 14 recording spectrophotometer. Solvents used for spectral measurements had the following specifications: (a) methanol and benzene were Eastman Spectrograde; (b) formamide was Eastman White Label; (c) chloroform was purified according to Morgan and Lowry.[21] The nmr spectra were determined on a Varian A-60 nmr spectrophotometer using tetramethylsilane as internal standard. The paper chromatograms were run on Whatman No. 1 paper with methyl ethyl ketone saturated with water as the eluent.

The azo compounds of Table I were prepared by diazotizing 2-aminopyridine 1-oxide in aqueous hydrochloric acid,[5] followed by coupling to solutions of the amino compounds in aqueous hydrochloric acid and to solutions of the phenols in aqueous sodium hydroxide and sodium carbonate mixtures. After proper pH adjustment of the reaction mixture, the azo compounds were filtered off. The azo compounds of Table I were purified by recrystallization from the following solvents, respectively: I, chloroform; II, benzene; III, chloroform (Soxhlet);[22] IV, chloroform (Soxhlet);[22] V, aqueous hydrochloric acid, followed by alkali; VI, acetone (Soxhlet);[22] VII, methanol (Soxhlet);[22] VIII, aqueous sodium hydroxide, followed by hydrochloric acid.

Methylation of 2-(*p*-Dimethylaminophenylazo)pyridine 1-Oxide (I). A. With Dimethyl Sulfate.—A mixture of 3 g of I, 3 ml of dimethyl sulfate, and 75 ml of toluene was heated at 75–80° for 2 hr. The blue solid obtained weighed 4.1 g, mp 160–161°. To a clarified solution of this methosulfate in 100 ml of water was added dropwise a solution of 1 g of sodium perchlorate monohydrate in 5 ml of water. The needles of XII which separated weighed 3.7 g; after a recrystallization from water the solid melted at 186–187°.

Compounds XIV–XVII (Table II) were prepared in similar manner to the above, except that nitrobenzene was used as the alkylation solvent in the preparation of compounds XV–XVII.

B. With Iodomethane.—A mixture of 2 g of I and 5 ml of iodomethane in 50 ml of chloroform (contained the usual 0.75% ethanol as stabilizer) was heated at gentle reflux for 15 hr; an additional 5 ml of iodomethane was then added and refluxing was continued for 4 hr. The solid was filtered off and a second crop was obtained from the filtrate; total weight was 3.6 g (70%). After two recrystallizations (Soxhlet)[22] from methanol, the triiodide XI weighed 2.4 g (47%): mp 176–178°; $\lambda_{max}^{CH_3OH}$ 555 mμ (ε 63,900), 375 mμ (ε 6800).

Anal. Calcd for $C_{14}H_{17}I_3N_4$: C, 27.0; H, 2.8; I, 61.2; N, 9.0. Found: C, 27.4; H, 2.9; I, 61.2; N, 8.6.

Methylation of 2-(*p*-diethylaminophenylazo)pyridine 1-oxide with iodomethane was carried out similarly to that for I; the crude product (62%) was isolated by concentrating the reaction mixture to dryness. The solid was purified by two recrystallizations (Soxhlet)[22] from methanol to give the N-methyl triiodide: mp 130–131°; $\lambda_{max}^{CH_3OH}$ 563 mμ (ε 73,800), 350 mμ (ε 6700).

Anal. Calcd for $C_{16}H_{21}I_3N_4$: C, 29.6; H, 3.3; I, 58.6; N, 8.6. Found: C, 29.7; H, 3.5; I, 58.6; N, 8.5.

Reaction of I with 2-Bromoethanol.—A solution of 2 g of I and 3 ml of 2-bromoethanol in 75 ml of nitrobenzene was heated at 55–60° for 4 hr; another 3 ml of 2-bromoethanol was added and heating was continued for 14 hr. The product was precipitated by adding 200 ml of ethyl acetate, and was then slurried in ethyl acetate to remove nitrobenzene (2.35 g). This bromide was dissolved in 100 ml of water and sodium perchlorate was added to precipitate the perchlorate XIII. The perchlorate was purified by recrystallization, in order, from water, twice from methanol, slurrying with chloroform, followed by a final recrystallization from methanol, mp 168–170°.

Conversion of IX to X.—To a solution of 0.4 g of IX in 20 ml of water at 5° was added dropwise a solution of 1 g of sodium iodide in 5 ml of water. The needles of X which formed were filtered off and washed with cold water: 0.38 g, mp 119–120°, $\lambda_{max}^{CH_3OH}$ 563 mμ (ε 72,900). The paper chromatogram of X showed a single violet band.

Anal. Calcd for $C_{14}H_{17}IN_4O$: C, 43.8; H, 4.5; I, 33.0; N, 14.6. Found: C, 43.8; H, 4.4; I, 33.3; N, 14.3.

Formation of I and XVIII from X.—A mixture of 0.2 g of X and 20 ml of chloroform (contained the usual 0.75% ethanol as stabilizer) was warmed at reflux on a water bath for 1 hr. The mixture was concentrated to about 5 ml, which was then put on an alumina column and chromatographed with chloroform.

The yellow band which was eluted first gave a small amount of an oil which soon crystallized on standing. This solid was thin layer chromatographed on silica gel with ethyl acetate as eluent, and behaved identically with an authentic sample of *p*-(2-pyridylazo)-N,N-dimethylaniline (XVIII).[4]

An intermediate, yellow and red band was followed by a red band, which on concentration to dryness gave 0.06 g (48%) of a solid melting at 180–181°; a mixture melting point determination with authentic I showed no depression.

Methylation of VI.—A mixture of 3.0 g of VI, 75 ml of Spectrograde (Eastman) dimethylformamide, and 6 ml of freshly distilled dimethyl sulfate was warmed at 45–50°, under which conditions the mixture was homogeneous. An additional 2 ml of dimethyl sulfate was added after 20 hr and again after 6 hr. Total time at 45–50° was 38 hr. A small amount of solid was filtered off and to the filtrate was added dropwise 100 ml of ethyl acetate. The orange needles of XX which separated were filtered off and washed with 4:3 ethyl acetate–dimethylformamide and then with ethyl acetate: 2.3 g (48%), softened at 163°, melted at 166–168°.

Anal. Calcd for $C_{13}H_{15}N_3O_6S$: C, 45.7; H, 4.4; N, 12.3; S, 9.4. Found: C, 45.7, H, 4.4; N, 12.3; S, 9.4.

Reaction of XX with 2 *N* NaOH.—To a solution of 0.5 g of XX in 25 ml of water was added dropwise 1.5 ml of 2 *N* NaOH. The mixture was then cooled in ice; the hairlike, red needles of XXII were filtered off and washed with cold water: 0.32 g (94%); mp 154–155° dec; λ_{max}^{MeOH} 523 mμ (ε 58,000), 307 (inflection), 283 (5700), 251 (4200).

Anal. Calcd for $C_{12}H_{11}N_3O_2$: C, 62.9; H, 4.8; N, 18.3. Found: C, 62.4; H, 4.7; N, 18.0.

Formation of *p*-(2-Pyridylazo)phenol (XXIV) from XX.—A solution of 2.6 g of XX in 150 ml of ethanol was refluxed and then concentrated to dryness; the red solid residue was added to 50 ml of water. The yellow solid which did not dissolve was filtered off (0.24 g), mp 227–230°. This solid (XXIV) was recrystallized (Soxhlet)[22] twice from benzene; it was then dissolved in a solution of 1 g of sodium hydroxide and 2.1 g of sodium carbonate in 70 ml of water and then reprecipitated by the addition of 2 *N* hydrochloric acid to neutrality: 0.11 g, mp 230–232°.

Anal. Calcd for $C_{11}H_9N_3O$: C, 66.3; H, 4.6; N, 21.1. Found: C, 66.1; H, 4.8; N, 21.1.

Registry No.—I, 7687-09-4; II, 7695-57-0; III, 7687-10-7; IV, 7687-11-8; V, 7687-12-9; VI, 7687-13-0; VII, 7687-14-1; VIII, 7687-15-2; XII, 7687-05-0; XIII, 7687-06-1; XIV, 7687-07-2; XV, 7687-08-3; XVI, 7687-16-3; XVII, 7687-17-4; XXIIb, 7687-18-5; XXIIIb, 6068-47-9; 2-(*p*-dimethylaminophenylazo)pyridine derivative (R = OCH_3), 7687-20-9; 2-(*p*-dimethylaminophenylazo)pyridine derivative (R = CH_3), 7690-90-6; IX, 7687-21-0; XI, 7721-41-7; $C_{16}H_{21}N_4I_3$, 7721-42-8; XX, 7690-91-7; XXIV, 7687-22-1.

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(21) S. O. Morgan and H. H. Lowry, *J. Phys. Chem.*, **34**, 2385 (1930).

(22) The recrystallization was effected by extracting the solid with the indicated solvent in a Soxhlet apparatus; the crystals which formed in the receiver were then collected.