Amine Oxidation. Part 14.[1] Acid-catalysed Deoxygenation of Some *NN*-Dimethylaniline *N*-Oxides and Reactions of the Resultant Iminium-benzenium Dications

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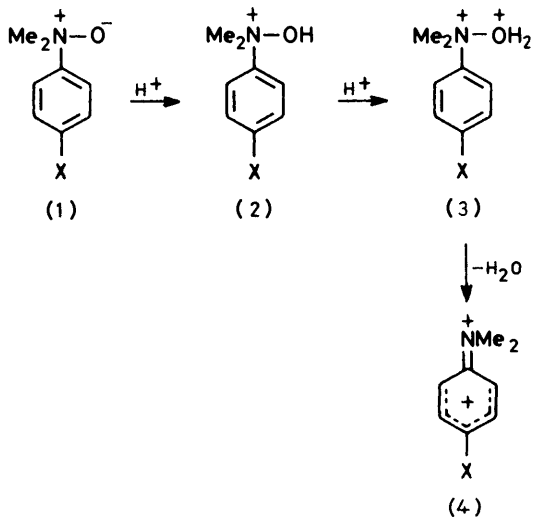
The reactions of *NN*-dimethylaniline *N*-oxide and three substituted derivatives (4-CH_3, 4-CH_3O, and 4-NO_2) in strong acids have been followed by ^1H and ^{13}C n.m.r. spectroscopy and product studies. These *N*-oxides can be deoxygenated in strong acids to give *NN*-dimethyliminium-benzenium dications. With the 4-methoxy-substituted *N*-oxide the reaction, which is helped by the electron-releasing methoxy-substituent, proceeds at room temperature in trifluoroacetic acid (TFA). By contrast the *NN*-dimethylaniline *N*-oxide with an electron-withdrawing 4-nitro-substituent is stable in TFA and requires the stronger acid fluorosulphonic acid for reaction to occur. The mechanisms of these reactions are discussed.

In an attempt to generate tertiary aminium radicals in a strongly acidic medium we investigated the reduction of solutions of amine *N*-oxides with iron(II) salts [2] in TFA † or mixtures of TFA with FSA.†[3] Although this was unsuccessful, owing to the insolubility of the iron salts in these strongly acidic media, we observed that certain of the amine *N*-oxides reacted under these conditions in the absence of added metal ions.

During the course of this investigation Okamoto and his co-workers published a series of papers on the acid-catalysed reactions of *N*-arylhydroxylamines and related compounds,[4] including some *NN*-dimethylaniline *N*-oxides.[4d,f] From these extensive studies they concluded that *N*-arylhydroxylamines and *NN*-dimethylaniline *N*-oxides can be dehydrated in strong acids to give an iminium-benzenium dication (illustrated in Scheme 1 with an *N*-oxide). The dication reacts further with nucleophiles present in the solution.

We report here our studies on the mechanisms of the reactions of a selection of *NN*-dimethylaniline *N*-oxides under strongly acidic conditions.



Scheme 1. X = H, Me, OMe, or NO_2

Results and Discussion

(a) NN-*Dimethyl-4-toluidine* N-*Oxide* (1; X = CH_3).—In TFA *NN*-dimethyl-4-toluidine *N*-oxide exists as the monoprotonated cation (2; X = CH_3) (^1H and ^{13}C n.m.r. data in Tables 1 and 2). However, in more acidic solution, typically in TFA with FSA (equimolar) or in TFSA, it reacts cleanly to give one product with the ^1H n.m.r. absorptions in Table 3. From this spectrum this species is assigned structure (5) (Scheme 2), where Y is either trifluoroacetate, fluorosulphonate, or trifluoromethanesulphonate. Consistent with this structure the *N*-methyl resonances (d, 6 H, *J* 6 Hz) move upfield and that of the methylene (s, 2 H) downfield from the positions of the resonances of the equivalent groups in the monoprotonated *N*-oxide. A calculation of the chemical shift of the methylene group for (5) from shielding constants [5] corresponds closely with the value obtained in this study. An authentic sample of 4-dimethylaminobenzyl alcohol (6) in TFA–FSA solution gives a ^1H n.m.r. spectrum identical with that from (5).

The aromatic resonances in the ^{13}C n.m.r. spectrum of the product differ little from those of the protonated *N*-oxide (2; X = CH_3) but the methylene resonance moves downfield to a chemical shift (70.9 p.p.m., triplet in off-resonance spectrum) in agreement with the value expected for a benzyl trifluoroacetate or fluorosulphonate [6] (Table 4). In a similar manner to that observed with the ^1H n.m.r. spectrum, the *N*-methyl resonance in the ^{13}C n.m.r. spectrum moves upfield, consistent with the replacement of the hydroxy in (2; X = CH_3) by a hydrogen.

From the studies of Okamoto and his co-workers [4d,f] the likely mechanism for the formation of (5) involves the acid-catalysed dehydration of the *N*-oxide (1; X = CH_3) to give

Table 1. ^1H N.m.r. data for a selection of *NN*-dimethylaniline *N*-oxides in TFA

	Chemical shifts (δ)		
4-$XC_6H_4\overset{+}{N}Me_2OH$	Ar–H	N–Me	Substituent
X = H	7.85 (m, 5 H)	4.05 (s, 6 H)	
CH_3	7.75 (d, 2 H)	4.00 (s, 6 H)	2.50 (s, 3 H)
	7.50 (d, 2 H)		
OCH_3	7.80 (d, 2 H)	4.0 (s, 9 H)	
	7.25 (d, 2 H)		
NO_2	8.65 (d, 2 H)	4.15 (s, 6 H)	
	8.25 (d, 2 H)		

† The following abbreviations are used in this paper: TFA, trifluoroacetic acid; FSA, fluorosulphonic acid; TFSA, trifluoromethanesulphonic acid.

Table 2. ^{13}C N.m.r. data for a selection of *NN*-dimethylaniline *N*-oxides in TFA

$4\text{-}XC_6H_4\overset{+}{N}Me_2OH$	Chemical shifts (δ) C_{Ar}	CH_{Ar}	CH_3–N	Substituent
X = H	149.7	133.7	61.7	
		132.3		
		120.1		
CH_3	147.2	132.6	61.6	21.1
	145.2	120.0		
OCH_3	161.3	121.1	60.7	55.9
	141.6	116.0		
NO_2	154.5	127.8	62.4	
	151.1	122.9		

Table 3. ^1H N.m.r. data for the products from the reaction of a selection of *NN*-dimethylaniline *N*-oxides with TFA, FSA, or TFA–FSA

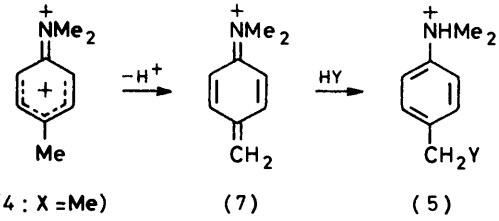
	Chemical shifts (δ) Ar–H	NMe	Substituent
Product from $4\text{-}CH_3C_6H_4\overset{+}{N}Me_2OH$ in TFA–FSA			
(5)	7.75 (s, 4 H)	3.55 (d, 6 H, *J* 6 Hz)	5.6 (s, 2 H)
Products from $Ph\overset{+}{N}Me_2OH$ in TFA–FSA			
(15) [a]	7.80 (m, 4 H)	3.55 (d, 6 H, *J* 6 Hz)	
(16)	7.40 (m, 4 H)	3.9 (d, 6 H, *J* 2 Hz)	
	6.40 (s, 1 H)		
Products from $4\text{-}CH_3OC_6H_4\overset{+}{N}Me_2OH$ in TFA			
(21)	7.90 (d, 2 H)	4.10 (s, 6 H)	
	7.05 (d, 2 H)		
(15)	7.55 (d, 2 H)	3.45 (d, 6 H, *J* 6 Hz)	
	7.20 (d, 2 H)		
Product from $4\text{-}NO_2C_6H_4\overset{+}{N}Me_2OH$ in FSA			
(23)	9.0—7.8		
	(m, 3 H)	3.65 (d, 6 H, *J* 6 Hz)	

[a] 4-Dimethylaminophenol in FSA has δ 7.8 (m, 4 H) and 3.65 (d, 6 H, *J* 6 Hz).

Table 4. ^{13}C N.m.r. data for the products from the reaction of a selection of *NN*-dimethylaniline *N*-oxides with TFA, FSA, or TFA–FSA

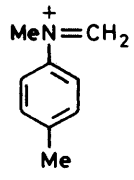
	Chemical shifts (δ) C_{Ar}	C–H_{Ar}	CH_3–N	Substituent
Product from $4\text{-}CH_3C_6H_4\overset{+}{N}Me_2OH$ in TFA–FSA				
(5)	144.2	132.9	49.6	70.9
	138.7	122.4		
Products from $Ph\overset{+}{N}Me_2OH$ in TFA–FSA				
(15)	156.4	Multiple	48.3	
	150.9	absorptions		
	140.7	128.9		
	134.6	to 121.1		
Products from $4\text{-}CH_3OC_6H_4\overset{+}{N}Me_2OH$ in TFA				
(21)	186.7	139.0	47.1	
	(164.4) [b]	129.1		
(15)	158.4	123.3	49.2	
	137.4	119.7		
Product from $4\text{-}NO_2C_6H_4\overset{+}{N}Me_2OH$ in FSA				
(23)	150.8	123.3	48.4	
	150.8	119.5		
	136.4	114.8		

[a] Complex C_{Ar} and C–H_{Ar} absorption pattern, see text. [b] This resonance is obscured by the solvent TFA. The value recorded is from a spectrum provided by Professor J. H. Ridd.



(4 : X = Me) (7) (5)

Scheme 2. Y = CF_3CO_2, FSO_3, or CF_3SO_3



(8)

the *NN*-dimethyliminium-benzenium dication (4; X = CH_3) (Scheme 1) which after loss of a proton reacts with the solvent (Scheme 2). The n.m.r. spectra do not reveal the presence of any other resonances apart from those of (5) and the mono-protonated *N*-oxide (2; X = CH_3). Thus in the reaction mixtures it has not been possible to detect either intermediates (3 or 4; X = CH_3) or (7), or an alternative product (8), that might have been expected from loss of a proton from the *N*-methyl group of (4; X = CH_3). An attempt to detect these intermediates by studying the reactions with variable-temperature n.m.r. spectroscopy (−60 °C to ambient temperature) in a manner similar to that used by Olah *et al.*[7] to look at intermediates in the benzidine and Wallach rearrangements was unsuccessful.

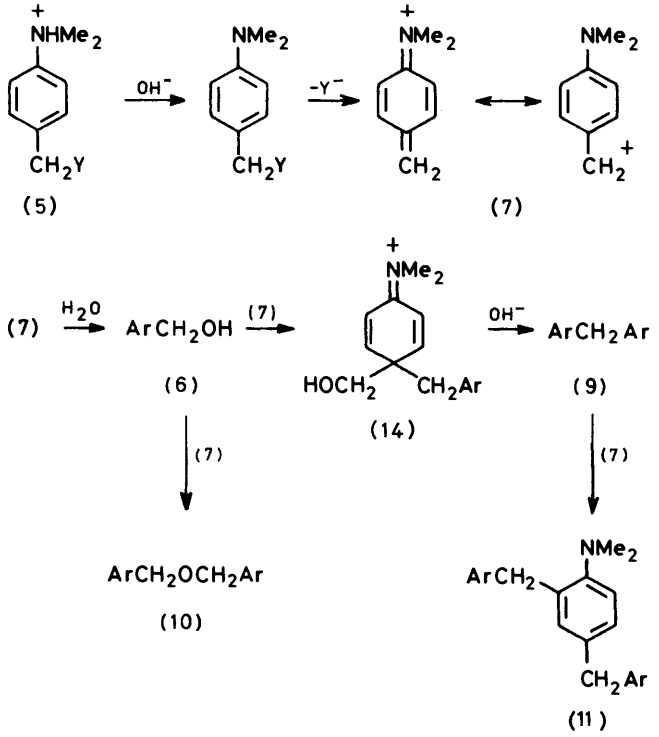
Solutions of *NN*-dimethyl-4-toluidine *N*-oxide (1; X = CH_3) in TFA–FSA (1 : 0.75, v/v), which had reacted to give the product (5) (^1H n.m.r.), were neutralised or made basic with cold aqueous base and the organic materials were extracted into diethyl ether. Chromatographic analyses (t.l.c. and h.p.l.c.) showed that the diethyl ether solutions contained two major and two minor products and traces of other materials. The products were isolated by preparative h.p.l.c. The two major components were shown, by comparison with authentic compounds, to be 4-dimethylaminobenzyl alcohol (6) and the diamine (9) and the minor components were identified by ^1H n.m.r. and mass spectroscopy as (10) and (11) (Scheme 3). The overall and relative yields of the products were very variable and depended on the work-up procedure (Table 5).

The preparation of an authentic sample of the ether (10) by heating the alcohol (6) in dimethyl sulphoxide, following the procedure of Emert *et al.*[8] for making related dibenzyl ethers, gave a mixture which contained (t.l.c. and h.p.l.c.) the required ether (10), the diamine (9), the triamine (11) and other polyamino-compounds. The four compounds (6) and (9)—(11) were also obtained when the alcohol (6) was dissolved in trifluoroacetic anhydride, in TFA, or in TFA–FSA (1 : 0.75, v/v) and worked up as described above.

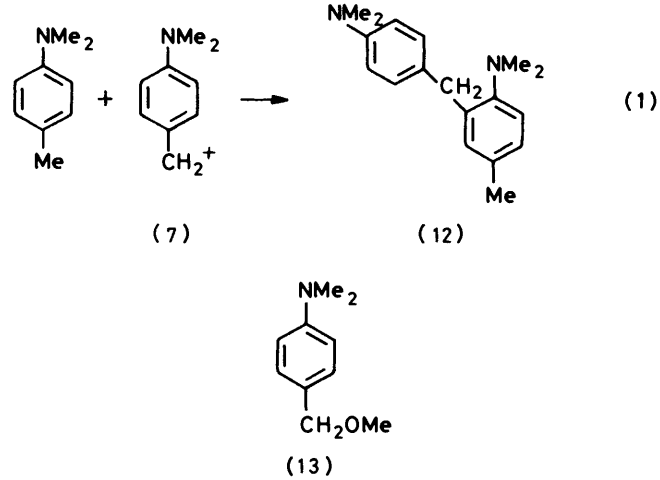
When *NN*-dimethyl-4-toluidine *N*-oxide (1; X = CH_3) containing the parent tertiary amine was treated with TFA–FSA (1 : 0.75, v/v) and worked up as described above, the product mixture contained an extra compound identified (t.l.c., h.p.l.c., ^1H n.m.r., and m.s.) as the diamine (12) [reaction (1)]. The yield of this product increased at the expense of the others on addition of further amounts of *NN*-dimethyl-4-toluidine to the reaction mixture. With an excess

Table 5. Yields of products from the reaction of *NN*-dimethyl-4-toluidine *N*-oxide in TFA–FSA after basic work-up

Basification procedure	Total product yield (%)	Product distribution (%) (6)	(9)	(10)	(11)
pH 14 with NaOH	40	76	20.5	3.5	Trace
AcOH saturated with NaOAc, then pH 8.0 with NaOH	67	54.5	40	5.5	Trace
Acetate buffer (pH 5.5), then pH 7.0 with $NaHCO_3$	54	55.5	42	2.5	Trace
Iced water followed by Na_2CO_3	70	41	59	Trace	Trace



Scheme 3. Ar = 4-dimethylaminophenyl



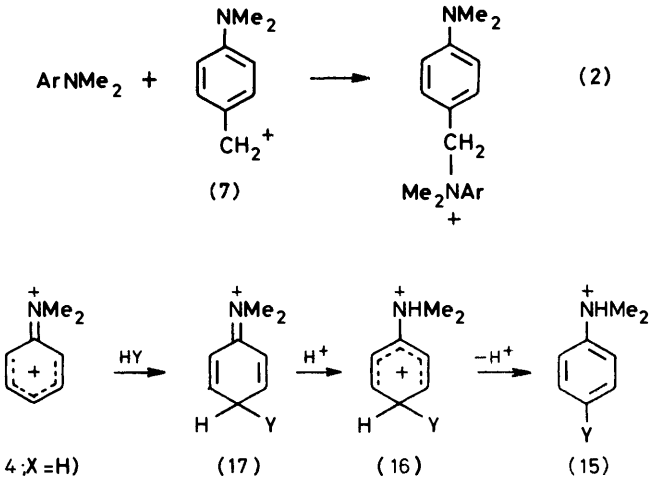
of tertiary amine over its *N*-oxide compound (12) became the major reaction product. In a similar manner the addition of the diamine (9) to the reaction of *N*-oxide (1; X = CH_3) gave an increased yield of the triamine (11).

When the acidic reaction mixture from *N*-oxide (1; X = CH_3) was worked up by pouring it into methanol and making it basic with methanolic sodium carbonate one major product was obtained (h.p.l.c.) which was identified as the ether (13) (^{1}H n.m.r. and m.s.). However, an attempt to make 4-dimethylaminobenzyl fluoride by reacting *NN*-dimethyl-4-toluidine *N*-oxide (1; X = CH_3) with anhydrous hydrogen fluoride or hydrogen fluoride–FSA was unsuccessful. The *N*-oxide was stable in anhydrous hydrogen fluoride, and in the mixed acid system gave the same products as those from reactions in TFA–FSA.

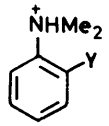
All the products above can be rationalised as arising *via* a common intermediate, the 4-dimethylaminobenzyl cation (7), which is formed in the work-up by the action of base on the anilinium ion (5) (Scheme 3). The cation (7) reacts further with the nucleophilic species present during the work-up. Thus water converts (7) into the alcohol (6) which in turn can act as a nucleophile and react with (7) to give both the diamine (9) and the diamino-ether (10). The triamine (11) and the diamine (12) arise from nucleophilic addition of compound (9) and *NN*-dimethyl-4-toluidine respectively to (7). Presumably the trace products include higher molecular weight polyamines from the further reaction of the products described above with the cation (7). The work-up using methanolic sodium carbonate not unexpectedly gives the ether (13) from nucleophilic attack by methanol.

A possible explanation for the generally poor recovery of the products is that the missing material consists of water-soluble quaternary ammonium salts arising from the tertiary amines acting as nitrogen nucleophiles [reaction (2)].

In our view the most likely route to the diamine (9) involves attack of the cation (7) at the 1-position of 4-dimethylaminobenzyl alcohol (6) to give the intermediate (14) followed by base-catalysed loss of formaldehyde (Scheme 3). Alternatively (14) loses the hydroxymethyl cation in a reaction that is equivalent to the reverse of the first step in the chloromethylation of aromatic compounds with formaldehyde and hydrogen chloride.[9]



Scheme 4. Y = CF_3CO_2 or FSO_3



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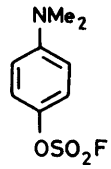


(20)

(b) NN-*Dimethylaniline* N-*Oxide* (1; X = H).—^{1}H and ^{13}C n.m.r. analyses show that *NN*-dimethylaniline *N*-oxide (1; X = H) in TFA is present entirely as the monoprotonated species (2; X = H) (Tables 1 and 2). In TFA–FSA (2; X = H) reacts *via* an observable intermediate to give a product assigned structure (15) (Scheme 4).

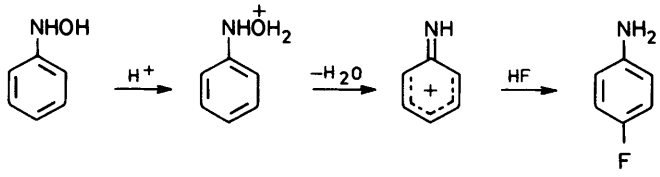
Following the mechanism proposed by Shudo *et al.*[44,f] for the acid-catalysed reaction of this *N*-oxide in the presence of benzene, we propose Scheme 4 to account for the formation of (15) from the iminium-benzenium dication (4; X = H) and identify the intermediate as (16). The preferred disposition of the charges in the iminium-benzenium dication (4; X = H) will have the two positive charges as far apart as possible with the consequence that nucleophilic attack will occur at the 4- rather than the 2-position.

The aromatic resonances in the ^{1}H and ^{13}C n.m.r. spectra of (15) are more complex than predicted for a 4-substituted dimethylanilinium ion. However, the same effect is seen in the spectra of authentic 4-dimethylaminophenol (18) for although the n.m.r. spectra of TFA solutions are normal those of FSA or TFA–FSA solutions contain unexpectedly complex aromatic absorptions. Comparison shows that the spectra of strong acid solutions of (15) and (18) are almost superimposable although there are differences in the relative intensities of some absorptions.

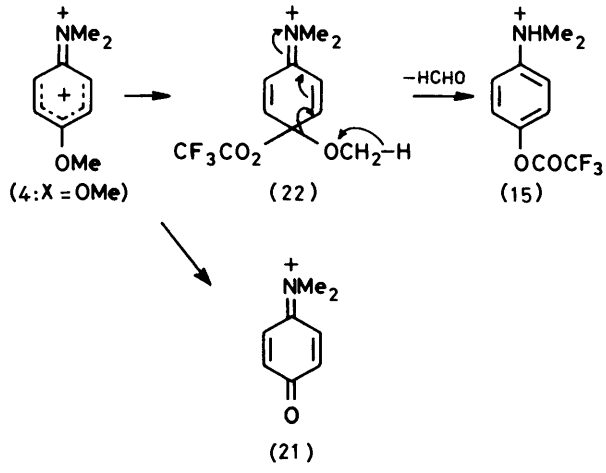
The ^{1}H n.m.r. spectrum of the intermediate is consonant with it having the dicationic structure (16). The spectrum resembles that of the product (15) with small changes in the aromatic and *N*-methyl resonances and a new absorption attributable to the hydrogen on the 4-position which appears at δ 6.4. Although we cannot find ^{1}H n.m.r. data for any compounds comparable to (16) the value of 6.4 for 4-H seems reasonable based on the chemical shifts of protonated aromatic compounds reported by Olah and Mo.[10]

In agreement with these assignments the relative proportions of the species (2; X = H), (15), and (16) in a reaction mixture at a given time is dependent on the acidity of the medium, although given sufficient time all the reactions reach the same final product (15). Thus in TFA–FSA (1 : 0.75, v/v) the reaction proceeds to (15) and the concentration of (16) is relatively low throughout the reaction. In the stronger acid TFA–FSA (1 : 2, v/v) the relative concentration of (16) increases whilst in the strongest acid TFA–FSA (1 : 3, v/v) or in pure FSA the dominant species in the early stages of the reaction is (16) which is converted slowly into (15). Thus intermediate (16) is favoured by an increase in acidity and in the strongest acid, where the concentration of basic species is very small, the final loss of a proton from (16) becomes the slow step of the overall process.

These data eliminate alternative interpretations of the n.m.r. spectra for the species assigned structures (15) and (16). Thus the two compounds are not a mixture of (15; Y = CF_3CO_2) and (15; Y = FSO_3) since the ^{1}H n.m.r. spectrum of the reaction mixture in pure FSA, where the former cannot be formed, shows the presence of both species. Furthermore changing the substituent from trifluoroacetate to fluorosulphonate would not be expected to have a very marked effect on the ^{1}H n.m.r. spectrum of (15).



Scheme 5.



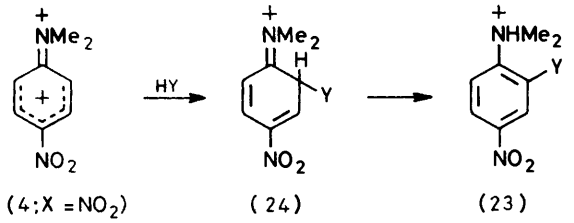
Scheme 6.

The species assigned structure (16) is not the 2-substituted product (19) because not only would 2-substitution have to be the favoured pathway in stronger acid but, since the final product is (15), the mechanism would require the unlikely rearrangement of (19) to (15).

When solutions of *NN*-dimethylaniline *N*-oxide (1; X = H) in TFA–FSA (1 : 2, v/v), which had been shown by ^{1}H n.m.r. spectroscopy to have reacted to give (15), were made basic with aqueous base and extracted with diethyl ether two products (t.l.c. and h.p.l.c.) with trace amounts of other materials were obtained. The two products were isolated by dry column chromatography and identified as 4-dimethylaminophenol (18) and 4-dimethylaminophenyl fluorosulphonate (20). The absence of 4-dimethylaminophenyl trifluoroacetate after work-up arises either from its ease of hydrolysis to the aminophenol (18) or from the lack of formation of (15; Y = CF_3CO_2) in the reaction mixture. The stability of aryl perfluorosulphonates towards hydrolysis in basic solution [11] is such that (15; Y = FSO_3) could be the sole reaction product that gives (18) and (20) on work-up.

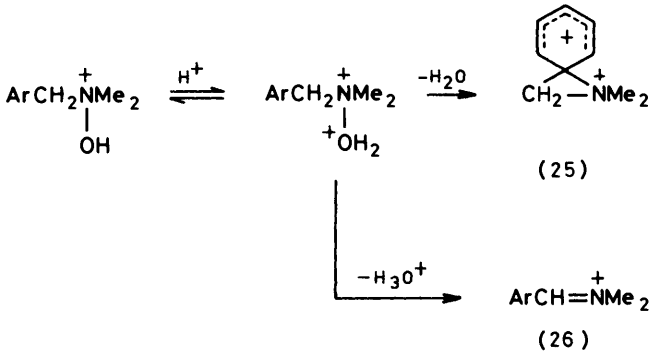
The difficulty in extracting the aminophenol from aqueous solution and also the dependence of the extent of hydrolysis on the work-up conditions led to variable yields of the two products (18) and (20). The yields were not quantified.

An attempt to make 4-dimethylaminofluorobenzene, by dissolving *N*-oxide (1; X = H) in anhydrous hydrogen fluoride followed by a basic work-up, failed to give any products (t.l.c., h.p.l.c. and comparison with authentic 4-dimethylaminofluorobenzene). When the reaction was repeated using hydrogen fluoride–FSA the products were the aminophenol (18) and aminofluorosulphonate (20). The lack of reaction of the *N*-oxide in anhydrous hydrogen fluoride is surprising since both dimethylaminoaryl *N*-oxides and *N*-arylhydroxylamines undergo acid-catalysed dehydration in strong acids,[4] and *N*-phenylhydroxylamine, under conditions comparable to those used in this study, is reported to give 4-fluoroaniline in 43% yield [12] (Scheme 5).



(4; X = NO_2) (24) (23)

Scheme 7. Y = CF_3CO_2 or FSO_3



(25)

(26)

Scheme 8.

(c) NN-*Dimethyl-4-anisidine* N-*Oxide* (1; X = OCH_3).—Solutions of *NN*-dimethyl-4-anisidine *N*-oxide in TFA are unstable and ^1H n.m.r. spectroscopy shows that the monoprotonated *N*-oxide (2; X = OCH_3) (Table 1), formed initially, reacts to give two products. The major product has been identified as the *NN*-dimethylquinone-iminium cation (21) by comparison of its ^1H and ^{13}C n.m.r. spectra with those of an authentic sample prepared by the persulphate oxidation of 4-dimethylaminophenol in TFA (Tables 3 and 4). The minor product which has identical ^1H and ^{13}C n.m.r. spectra with 4-dimethylaminophenol in TFA has been assigned structure (15). From the behaviour of the aromatic amine *N*-oxides in strong acid described above we propose the mechanism in Scheme 6 for the formation of (21) and (15). Thus the electron-releasing mesomeric effect of the methoxy-group aids the dehydration of the diprotonated *N*-oxide (3; X = OCH_3) and formation of the *NN*-dimethyliminium-benzenium dication (4; X = OCH_3) to such an extent that the reaction occurs in TFA in the absence of FSA. In further reactions (4; X = OCH_3) is partitioned (approximate proportions 1 : 3) between nucleophilic addition followed by loss of formaldehyde to give (15) and nucleophilic displacement of the methyl giving (21). The latter reaction is analogous to the mechanism proposed for the anodic oxidative demethylation of 4,4′-dimethoxydiphenylamine.[13] The products from the reaction of *NN*-dimethyl-4-anisidine *N*-oxide were not studied further.

(d) NN-*Dimethyl-4-nitroaniline* N-*Oxide* (1; X = NO_2).—^1H N.m.r. spectroscopy shows that *NN*-dimethyl-4-nitroaniline *N*-oxide (1; X = NO_2) is more resistant to acid-catalysed dehydration than (1; X = CH_3, H, or CH_3O), it is stable in TFA and TFSA at room temperature but reacts slowly in pure FSA. These strongly acidic conditions are needed to generate the *NN*-dimethyliminium-benzenium dication (4; X = NO_2) in the presence of the electron-withdrawing nitro-group. The ^1H and ^{13}C n.m.r. spectra of the reaction mixtures are consistent with the major product being a 2-substituted *NN*-dimethyl-4-nitroanilinium ion (23) (Scheme 7).

(e) N-*Oxides of Trimethylamine and Some* NN-*Dimethylbenzylamines*.—Trimethylamine *N*-oxide, *NN*-dimethylbenzylamine *N*-oxide, and the substituted *NN*-dimethylbenzylamine *N*-oxides (4-CH_3O, 4-CH_3, and 4-NO_2) were dissolved in TFA–FSA and in pure FSA. ^1H N.m.r. spectroscopy shows that in none of these solutions is there any evidence for acid-catalysed dehydration. Thus protonated trimethylamine *N*-oxide is stable in strong acids such as FSA, in agreement with Olah *et al.*,[14] even when heated to 100 °C. Likewise the substituted protonated *NN*-dimethylbenzylamine *N*-oxides, in contrast to their carbon and oxygen analogues the phenethyl alcohols,[15] and benzyl hydroperoxides,[16] respectively, are not dehydrated either with or without neighbouring group participation to give (25) or (26) or products derived from these cations (Scheme 8).

In conclusion we find that *NN*-dimethylaniline *N*-oxides can be deoxygenated in solution in strong acids. The rate at which this reaction occurs depends on the strength of the acid and the substituents on the substrate. The ease of reaction and all the products can be rationalised in terms of the formation of iminium-benzenium dications in the initial dehydration of the diprotonated *N*-oxide.

Experimental

Methods.—^1H N.m.r. spectra for deuteriochloroform, TFA, TFA–FSA, FSA, and TFSA solutions were obtained with a Varian A-60A (60 MHz), JEOL JNM-MH-100 (100 MHz), or Varian EM 360A (60 MHz) spectrometer and ^{13}C n.m.r. spectra with a JEOL JNM-FX60 or JEOL FX90Q Fourier transform spectrometer. Tetramethylsilane was used as an internal or external standard. For studies with TFA–FSA mixtures the compound (*ca.* 100 mg) was dissolved in TFA and cooled to −10 °C before the required amount of FSA was carefully added. Solutions in FSA or TFSA were prepared by solidifying the acid with liquid nitrogen before the addition of substrate, the mixture was warmed to −10 °C, and the solution became homogeneous. Samples for low-temperature studies were cooled with acetone–dry ice or liquid nitrogen. Mass spectra were measured on an A.E.I. MS 30 spectrometer. T.l.c. analyses were carried out on silica gel GF_{254} (Merck) eluted with propan-2-ol–hexane. Dry-pack columns in nylon tubing (W. Coles and Co. Ltd.) were prepared from silica gel 80—200 mesh (Fisons Scientific Apparatus Ltd.), which was deactivated to correspond with the activity of the silica gel used for t.l.c., and were eluted with propan-2-ol–hexane (1 : 20). H.p.l.c. was carried out with a Du Pont 830 chromatograph using stainless steel columns (25 × 0.4 or 25 × 0.94 cm) packed with Partisil-10 (Whatman), coupled to a Du Pont 837 variable-wavelength u.v. detector.

Materials.—All the materials were commercial reagent grade unless otherwise stated and were obtained from Aldrich Chemical Co. Ltd., Fisons Scientific Apparatus Ltd., Koch-Light Ltd., or Fluorochem Ltd. The substituted *NN*-dimethylaniline *N*-oxides were prepared following Huisgen *et al.*[17] Since the *N*-oxides are very hygroscopic they were dried in a vacuum desiccator over phosphorus pentaoxide for several days before being stored under nitrogen in the dark a −10 °C. The purities of the *N*-oxides were checked by ^1H n.m.r. spectroscopy of deuteriochloroform solutions. The substituted *NN*-dimethylbenzylamine *N*-oxides were prepared as described previously.[18] 4-Dimethylaminobenzyl alcohol (6) prepared by the method of Chaikin and Brown [19] had b.p. 123 °C at 0.8 mmHg (lit.,[20] 125 °C at 1.0 mmHg); δ ($CDCl_3$) 7.16 (2 H, d), 6.77 (2 H, d), 4.57 (2 H, s), and 2.95

(6 H, s); *m/z* 151 (M^+, 23%), 150 (15.5), 134 (38.5), 105 (56.4), 91 (100), 69 (59), 57 (77), and 55 (95); $\lambda_{max.}$ (propan-2-ol–hexane, 1 : 20) 259 nm (log ε 3.24). The alcohol was stored under nitrogen at −20 °C. 4,4′-Methylenebis-(*NN*-dimethylaniline) (9) was prepared following Vogel [21] and had m.p. 86—88 °C (lit.,[21] 89—90 °C); δ ($CDCl_3$) 7.08 (4 H, d), 6.75 (4 H, d), 3.80 (2 H, s), and 2.90 (12 H, s); *m/z* 254 (M^+, 100%), 253 (76), 210 (39.5), 134 (47.5), 105 (39.5), 91 (71), 57 (84), and 55 (97.5); $\lambda_{max.}$ (propan-2-ol–hexane, 1 : 20), 263 nm (log ε 3.53).

The preparation of 4,4′-bis(dimethylaminobenzyl) ether (10) was carried out by heating the benzyl alcohol (6) with dimethyl sulphoxide following the general procedure of Emert *et al.* for making related dibenzyl ethers.[8] Compound (10) was separated from (9), (11), and polyamino-compounds by dry column chromatography and had δ ($CDCl_3$) 7.22 (4 H, d), 6.81 (4 H, d), 4.48 (4 H, s), and 12.98 (2 H, s); *m/z* 284 (M^+, 20%), 254 (16.5), 253 (13.5), 149 (20), 148 (16.5), 135 (33.5), 134 (100), and 67 (96.5); $\lambda_{max.}$ (propan-2-ol–hexane, 1 : 20) 262 nm (log ε 3.51).

4-Dimethylaminofluorobenzene was prepared by methylation of 4-fluoroaniline following the method of Vogel [22] and had b.p. 198—200 °C (lit.,[23] 78—79.5 at 16 mmHg); δ ($CDCl_3$) 7.17—6.53 (4 H, m) and 2.88 (6 H, s); *m/z* 139 (M^+, 33%), 138 (45), 125 (100), 124 (83.5), 95 (31), 75 (19), 58 (43.5), and 56 (26).

NN-Dimethyl-1,4-benzoquinoneiminium cation (21) was prepared by stirring potassium persulphate (0.16 g) with a solution of 4-dimethylaminophenol (0.1 g) in TFA (60 cm^3). After 18 h the u.v. spectrum of the reaction mixture had $\lambda_{max.}$ 278 nm (lit.,[24] $\lambda_{max.}$ 280 nm). The reaction mixture was then concentrated and ^1H n.m.r. spectroscopy showed that the solution contained (21) with a small amount of unchanged phenol. The identity of (21) was confirmed by comparison of its ^{13}C n.m.r. spectrum with one provided by J. H. Ridd.

The Reaction of NN-*Dimethyl-4-toluidine* N-*Oxide* (1; X = CH_3) *with TFA–FSA.*—The following procedure is typical of those used to do n.m.r. studies and to isolate the products from *N*-oxide (1; X = CH_3). The *N*-oxide (0.2 g) was dissolved in TFA (0.76 cm^3), cooled to −10 °C, and FSA (0.57 cm^3) (equimolar quantities of acids) was added slowly with shaking. When the reaction had gone to completion, as assessed by the formation of (5) by ^1H n.m.r. spectroscopy, the solution was made basic with cooling. The organic compounds were extracted with diethyl ether which was dried ($MgSO_4$) and removed on a rotary evaporator. The products in the residue which were isolated by preparative h.p.l.c. were, in order of elution, 4,4′-methylenebis-(*NN*-dimethylaniline) (9), 4,4′-bis(dimethylaminobenzyl) ether (10), triamine (11), and 4-dimethylaminobenzyl alcohol (6). Compounds (6), (9), and (10) were identified by comparison of their spectra with those from authentic materials. The triamine (11) had δ ($CDCl_3$) 7.16—7.52 (11 H, m), 3.96 (2 H, s), 3.76 (2 H, s), 2.90 (12 H, s), and 2.60 (6 H, s); *m/z* 387 (M^+, 53.5%), 372 (21.5), 267 (10.5), 134 (100), and 118 (12.5); $\lambda_{max.}$ (propan-2-ol–hexane, 1 : 20) 260 nm (log ε 3.60).

For reactions in the presence of *NN*-dimethyl-4-toluidine the amine (0.09, 0.18, or 0.36 g) was added after the formation of (5) and before work-up. Preparative t.l.c. with elution by benzene followed by propan-2-ol–hexane (1 : 50) gave the diamine (12) which had δ ($CDCl_3$) 7.24–6.64 (7 H, m), 4.00 (2 H, s), 2.92 (6 H, s), 2.64 (6 H, s), and 2.20 (3 H, s); *m/z* 268 (M^+, 100%), 253 (48.5), 134 (45.5), 132 (23), 105 (31.5), 91 (48), 79 (43), and 77 (77); $\lambda_{max.}$ (propan-2-ol–hexane, 1 : 20) 256 nm (log ε 3.07).

Reactions of (1; X = CH_3) in the presence of the diamine (9) (0.08, 0.17, or 0.34 g) were carried out as described for *NN*-dimethyl-4-toluidine and yields of the triamine (11) increased with increasing amounts of (9).

Reactions of 4-*Dimethylaminobenzyl Alcohol* (6) *with TFA and TFA–FSA.*—The alcohol was dissolved in TFA or TFA–FSA and the reaction mixture was analysed by n.m.r. spectroscopy before it was worked up as described above for *N*-oxide (1; X = CH_3). Chromatographic analysis showed that the mixtures contained (6) and (9)—(11).

Quantitative Product Studies for Reactions of N-*Oxide* (1; X = CH_3) *with TFA–FSA.*—For quantitative analyses the products from the reaction of the *N*-oxide (1; X = CH_3) were extracted into diethyl ether, as described above, and were separated and estimated (254 nm) by h.p.l.c. with propan-2-ol–hexane (1 : 20) as eluant and *NN*-diethylaniline as the internal standard. The influence of the procedure used to basify the reaction mixture on product yields was studied using this method.

Preparation of 4-*Dimethylaminobenzyl Methyl Ether* (13) *from* N-*Oxide* (1; X = CH_3).—FSA (0.77 cm^3) was added to a cooled solution of the *N*-oxide (1; X = CH_3) (0.2 g) in TFA (1.07 cm^3). When the reaction had gone to completion, the solution was poured into methanol (25 cm^3) and basified with a suspension of sodium carbonate in methanol. The solution was filtered, dissolved in water (25 cm^3), extracted with diethyl ether, and the ether solution was dried ($MgSO_4$) and concentrated with a rotary evaporator. The residue consisted of one product, the methyl ether (13), which had δ ($CDCl_3$) 7.10 (2 H, d), 6.65 (2 H, d), 4.3 (2 H, s), 3.3 (3 H, s), and 2.9 (6 H, s); *m/z* 165.1150 (M^+, 35.5%) ($C_{10}H_{15}NO$ requires 165.1153), 135 (17.5), 134 (100), and 118 (10).

Attempted Reaction of N-*Oxide* (1; X = CH_3 *or* H) *with Liquid Hydrogen Fluoride.*—The *N*-oxide (1; X = CH_3 or H) (0.2 g) was added in portions to the hydrogen fluoride (2 cm^3) in a polythene reaction vessel and allowed to stand for 4 h while the solvent was lost by evaporation. The residue was cooled, made basic (pH 8), and extracted with diethyl ether. The ether solution was dried ($MgSO_4$), concentrated, and analysed by t.l.c. and h.p.l.c.

The experiment was repeated for both *N*-oxides with the addition of FSA (1.5 cm^3) to the hydrogen fluoride solution.

The Reaction of NN-*Dimethylaniline* N-*Oxide* (1; X = H) *with TFA–FSA.*—The *N*-oxide (1; X = H) (0.5 g) was dissolved in TFA (1 cm^3) before FSA (2 cm^3) was added slowly with cooling. The reaction was analysed by n.m.r. spectroscopy and when it had gone to completion it was brought to pH 6 with base and extracted with diethyl ether. The ether solution was dried ($MgSO_4$) and concentrated and the residue was separated into two products by dry column chromatography with propan-2-ol–hexane (1 : 20). The first was 4-dimethylaminophenol (18) (180 mg), *m/z* 137.0845 (M^+, 88%) ($C_8H_{11}NO$ requires 137.0841), 136 (100), and 121 (25). Although this material was shown to be pure by chromatography it consistently gave broad absorptions in its ^1H n.m.r. spectrum. The broadening was attributed to the presence of a small amount of 4-dimethylaminophenoxyl radical. Consonant with this interpretation the solutions of the product in chloroform gave an e.s.r. spectrum.

The second was 4-dimethylaminophenyl fluorosulphonate (20) (120 mg), δ ($CDCl_3$) 7.17 (2 H, d), 6.65 (2 H, d), and 2.95 (6 H, s); *m/z* 219.0363 (M^+, 31%) ($C_8H_{11}FNO_3S$ requires 219.0365), 137 (26.5), 136 (100), 108 (11), and 65 (12).

The Reaction of NN-*Dimethyl-4-anisidine* N-*Oxide* (1; X = OCH_3) *with TFA*.—The *N*-oxide (1; X = OCH_3) (0.1 g) was dissolved in TFA (1.0 cm^3), cooled to −10 °C, and this solution was allowed to warm to room temperature. The products were monitored by n.m.r. spectroscopy.

The Reaction of NN-*Dimethyl-4-nitroaniline* N-*Oxide* (1; X = NO_2) *with FSA*.—The *N*-oxide (1; X = NO_2) (0.1 g), dissolved in FSA (1.0 cm^3) and cooled to −10 °C, was warmed to room temperature. The mixture was analysed by n.m.r. spectroscopy.

The Attempted Reactions of Trimethylamine N-*Oxide and Some* NN-*Dimethylbenzylamine* N-*Oxides with TFA–FSA and FSA*.—The solutions of the *N*-oxides (0.05 g) in TFA (0.76 cm^3)–FSA (0.57 cm^3) or in FSA (0.5 cm^3) were examined by ^1H n.m.r. spectroscopy for reaction products. The ^1H n.m.r. spectrum of a solution of trimethylamine *N*-oxide in FSA at 100 °C was also studied.

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