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N-DEMETHYLATION OF N,N-DIMETHYLANILINES BY PHOTOEXCITED 3-NITROCHLOROBENZENE[1-3)]

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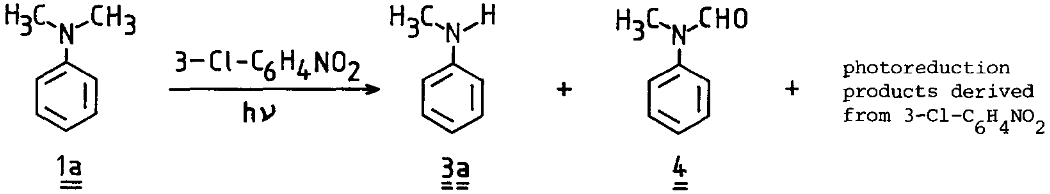
Summary - The title reaction proceeds via initial electron transfer (rather than hydrogen atom transfer) from the amine to the photoexcited nitro compound, as demonstrated by methoxy substitution in the substrate and absence of CH_3/CD_3-discrimination.

In 1974, Takami, Matsuura and Saito[4)] briefly reported the efficient demethylation of N,N-dimethylaniline (1a) by photoexcited 3-chloronitrobenzene (2) in benzene solution.



The authors suggested an initial hydrogen abstraction from a N-methyl group of 1 effected by photoexcited 2 as the first step in a sequence of reactions ultimately leading to demethylation[4)]. It had been stated in the same paper, however, that excited 1-nitronaphthalene was also effective in inducing demethylation, which is in contrast to the results of Hurley and Testa[5)], who have shown that 1-nitronaphthalene abstracts hydrogen from 2-propanol with a rate constant four powers of ten smaller than nitrobenzene.

This makes an initial hydrogen atom transfer a less likely candidate for the first step in the demethylation reaction. In view of the current interest in the photoinduced oxidative dealkylation of tertiary amines[6)], a reinvestigation of the title reaction aimed at the detection of possible substituent effects and deuterium isotope effects seemed desirable.

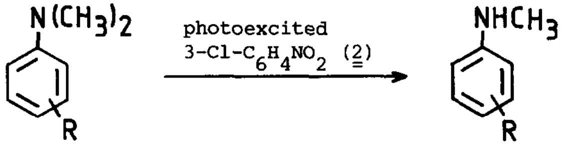
A. Demethylation of substituted N,N-dimethylanilines (1b-g) with photoexcited 2

Benzene solutions of 1a-g (0.008 M) and 2 (0.024 M) were photolyzed, worked up and analyzed for both unchanged starting material and mono-N-methylaniline 3a-g under standardized conditions[7)]. The necessary condition, that more than 95% of the incident light must be absorbed by the nitro compound 2 , is most easily met with 1a and clearly limits the number of suitable substituted N,N-dimethylanilines available for this study.

Table 1: Preparative scale demethylations of compounds 1a-g by photoexcited 2[7)]

1	R	Fraction of light absorbed by 2 [%]	Conversion of 1 [%]	Yield* of 3 [%]
a	H	99	77	49
b	p-OCH_3	83	100	92
c	m-OCH_3	97	78	40
d	p-tert-Butyl	97	55	31
e	p-Br	97	52	71
f	m-Cl	97	58	84
g	p-CN	91	54	70

*based on consumed starting material 1.



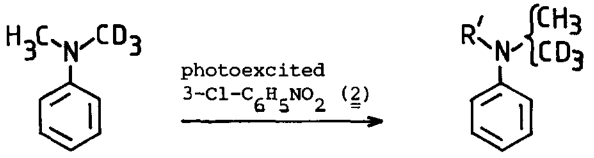
1a-g 3a-g

The following quantum yields (366 nm) for starting material disappearance (Φ_d) or product formation (Φ_p) have been determined[8)]: 1a : $\Phi_d = 5.0\ (\pm 0.5) \times 10^{-2}$; 3a : $\Phi_p = 4.5\ (\pm 0.5) \times 10^{-2}$; 1c : $\Phi_d = 28\ (\pm 2) \times 10^{-2}$; 1g : $\Phi_d = 4\ (\pm 0.5) \times 10^{-2}$.

Thus 1c is 6 - 8 times more efficiently demethylated than 1g under otherwise identical conditions, and from table 1 it is evident that monodemethylation is most efficiently achieved with 1b. Although rate constants have so far not been determined, the trends observed indicate that donor substituted N,N-dimethylanilines are more efficiently demethylated than others.

B. Deuterium labelling studies

When photoexcited 2 was allowed to react with N-trideuteriomethyl-N-methylaniline[9)] (5, 98.5% CD_3, as determined mass spectrometrically), the CH_3/CD_3-ratio in the resulting monomethylaniline 6a (isolated as its N-acetyl-derivative 6b) indicated a solvent dependent discrimination between CH_3 and CD_3 groups (table 2, entries 1 and 2). However, when a 1:1 mixture of 1 a and its perdeuterated analogue (1a-d_{11}) was subjected to the same photolysis conditions, discrimination ratios close to or even equal to unity were observed (table 2, entries 3 and 4).



6a: R' = H
6b: R' = $COCH_3$

5 6a,b

Table 2: Discrimination between CH_3 and CD_3 groups in the demethylation of N,N-dimethylaniline by photoexcited 3-chloronitrobenzene (2), as calculated from the CD_3 content of 6b.

Entry	Solvent / Substrate	k_{CH_3}/k_{CD_3} Benzene	Cyclohexane	Acetonitrile	Analytical method used
1	$C_6H_5N(CH_3)CD_3$ (5)	3.5	2.1	2.4	NMR*
2		3.5	1.97	2.55	MS**
3	1:1 mixture of 1a and 1a-d_{11}	1.0	1.1	1.0	NMR*
4		1.05	1.20	1.17	MS**

*Intensity of CH_3CO singlet used as internal reference for integration. **See footnote 10.

This suggests that a hydrogen atom transfer is not involved in the rate limiting step of the demethylation, since in this case a pronounced CH_3/CD_3-discrimination would have to be observed using the 1:1 mixture of 1a and 1a-d_{11}. The discrimination observed with 5 is not associated with the initial event but with the internal proton transfer step linking the tight ion pair 6 and the radicals 7 and 8 (see scheme below, eqn. [2]). These findings, together with the trends observed with the methoxy-N,N-dimethylanilines (see above) strongly suggest that the initial step in the title reaction is electron transfer rather than H-atom transfer.

The scheme originally proposed[4] for the mechanism of the title reaction is therefore adapted as follows (Ar = 3-Cl-C_6H_4):

$$\text{1a} + ArNO_2^* \longrightarrow \left[C_6H_5\text{-}\overset{+\bullet}{N}(CH_3)_2 + Ar\text{-}NO_2^{\bullet\,-}\right] \;(6) \qquad [1]$$

$$6 \longrightarrow C_6H_5\text{-}N(CH_3)\text{-}CH_2^{\bullet} \;(7) + Ar\text{-}N(OH)O^{\bullet} \;(8) \qquad [2]$$

$$7 + 8 \longrightarrow C_6H_5\text{-}N(CH_3)\text{-}CH_2\text{-}O\text{-}N(OH)\text{-}Ar \;(9) \qquad [3]$$

$$9 \longrightarrow ArNO + C_6H_5NHCH_3 \;(3a) + CH_2O \qquad [4]$$

$$9 \longrightarrow C_6H_5\text{-}N(CH_3)CHO \;(4) + Ar\text{-}NHOH \qquad [5]$$

$$7 \xrightarrow{-e^-} C_6H_5\text{-}\overset{+}{N}(CH_3){=}CH_2 \xrightarrow{H_2O} CH_2O + 3a \qquad [6]$$

$$8 + Ar\text{-}NO_2 \longrightarrow C_6H_5\text{-}N(CH_3)\text{-}CH_2\text{-}O\text{-}N(O)\text{-}Ar \longrightarrow 4 + Ar\text{-}NHO^{\bullet} \qquad [7]$$

Equations [3] - [7] represent several alternative product forming steps[4].

The potential general applicability of dual labelling experiments as used in this study for the discrimination between electron-transfer initation versus hydrogen atom abstraction in amine α-oxidations and related reactions is currently being investigated, as is the origin of the solvent influence on the magnitude of the isotope effects associated with the internal proton transfer step (eqn. [2]).

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[1] Photochemistry of Aromatic Nitro Compounds, XVI. - Part XV: D. Döpp, U. Arfsten-Romberg, W. Bolz, W. van Hoof and H. Kosfeld, Chem. Ber. 112, 3946 (1979).

[2] presented in part at the Xth International Conference on Photochemistry, Iraklion, Crete, Sept. 6 - 12, 1981. See J. Photochem. 17, 107 (1981) for abstract.

[3] Taken in part from the diploma thesis of J. Heufer, Duisburg 1981.

[4] M. Takami, T. Matsuura and I. Saito, Tetrahedron Lett. 1974, 661.

[5] R. Hurley and A. C. Testa, J. Am. Chem. Soc. 90, 1949 (1968).

[6] See for example the following papers and references cited therein: B. M. P. Hendriks, R. I. Walter and H. Fischer, J. Am. Chem. Soc. 101, 2378 (1979); R. S. Davidson and K. R. Trethewey, J. Chem. Soc. Perkin 2, 1977, 173; D. Griller, J. A. Howard, P. R. Mariott and J. C. Scaiano, J. Am. Chem. Soc. 103, 619 (1981); J. C. Scaiano, J. Phys. Chem. 85, 2851 (1981); S. Inbar, H. Linschitz and S. G. Cohen, J. Am. Chem. Soc. 103, 1048 (1981); C. G. Shaefer and K. S. Peters, J. Am. Chem. Soc. 102, 7566 (1980), J. D. Simon and K. S. Peters, J. Am. Chem. Soc. 103, 6403 (1981); T. Latowski and B. Zelent, J. Org. Chem. 44, 3559 (1979); F. D. Lewis, Tong-Ing Ho and J. Th. Simpson, J. Org. Chem. 46, 1077 (1981); F. D. Lewis and J. Th. Simpson, J. Am. Chem. Soc. 102, 7593 (1980).

[7] A 150 W high pressure mercury vapour source was used in connection with a water cooled Duran jacket ($\lambda \geq 280$ nm). The solution was rapidly circulated and purged with N_2 throughout the reaction. Irradiation time in all cases: 3 hr. The concentrations of 1a-g and 3a-g in the concentrated photolysate were determined by n.m.r. integration after addition of a known amount of a standard substance, the signals of which did not interfere with the signals of both 1a-g and 3a-g.

[8] A Bausch and Lomb high intensity monochromator was used to isolate the broadened 366 nm emission from a 200 W super pressure mercury source. Starting materials and products were quantitatively analyzed by HPLC. Ferrioxalate actinometry (C. G. Hatchard, C. A. Parker, Proc. Roy. Soc. A 235, 518 (1956)) was used.

[9] Prepared from N-methylaniline and dimethylsulfate-d_6.

[10] Determined with an error of ± 0.15 from the intensity ratio of the respective molecular ions. In general, the procedure given in K. Biemann, Mass Spectrometry, Organic Chemical Applications, Mc Graw Hill, New York, 1962, was followed. With the doubly focussing instrument used in this work, an ionization energy of 20 eV was needed in some experiments which caused a little preferential fragmentation of the undeuterated molecular ions, thus the discrimination ratios obtained by MS-analysis of 6b may be too high by 0.1.

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