Tetrahedron Letters,Vol.27,No.29,pp 3325-3328,1986 0040-4039/86 $3.00 + .00
Printed in Great Britain Pergamon Journals Ltd.

PHOTOLYSIS OF 3-NITROPHENYL AZIDE: TRAPPING THE REACTIVE INTERMEDIATES

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Summary: Irradiation of 3-nitrophenyl azide gives four trappable intermediates; the singlet nitrene, two isomeric dehydroazepines, and the triplet nitrene.

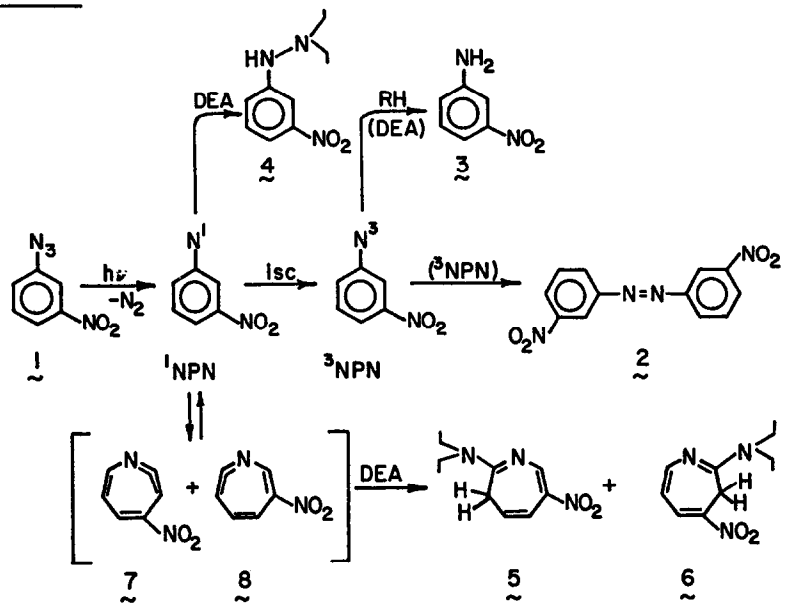
The photochemistry of aryl azides is receiving increasing attention[1] because of their importance to photoimaging[2] and photolabeling[3] technologies. The 3-nitro substituted phenyl azides in particular are among the most often chosen photolabeling agents. Despite this importance, the photochemistry of these compounds has not been studied in detail.[1a,4] Herein we report the results of the investigation of 3-nitrophenyl azide (**1**) in solvents such as cyclohexane and ethyl alcohol, and in the presence of diethylamine (**DEA**).

Irradiation of azide **1** (5×10^{-3} M) in degassed cyclohexane with the filtered output (λ=295 to 330 nm) of an Oriel 250 W lamp gives 3,3'-dinitroazobenzene (**2**) in 34% yield. The major product is intractable tar. There is only a trace of 3-nitroaniline (**3**) formed. By analogy with phenyl azide[5] and 4-nitrophenyl azide,[6] we presume that azobenzene (**2**) is formed by the dimerization of triplet 3-nitrophenyl nitrene (^{3}**NPN**), Scheme 1. In support of this suggestion, we note that the yield of **2** increases to 54% when an identical solution of azide **1** is photolyzed with a nitrogen laser (337 nm, 10 ns, 7 mJ). The high power of the laser insures a greater concentration of ^{3}**NPN** and favors dimerization.

Irradiation of **1** in ethyl alcohol with the Oriel lamp gives aniline **3** (23%) and azobenzene **2** (42%). Photolysis with the laser gives **2** in greater than 90% yield. These findings are consistent with the common proposal that anilines are formed in these reactions by a hydrogen abstraction-disproportionation sequence originating with the triplet nitrene.[1] It should be noted that neither dimerization to form **2** nor reduction to **3** are of any value in a photolabeling experiment where covalent bond formation between the probe and the target site is required.

The photolysis of azide **1** in solutions containing diethylamine is quite revealing. Irradiation leads to three new products that are formed from the covalent linkage of **DEA** to a reactive intermediate derived from the azide as well as to the previously described products. The new products were separated by careful chromatography and identified as hydrazine **4** and isomeric 2-diethylamino-3H-azepines **5** and **6**, Scheme 1.[7]

Scheme I



The yields of products 2-6 vary with DEA concentration in a curious way. Low concentrations of DEA effectively inhibit the formation of azo dimer 2 and increase the yield of aniline 3. At higher concentrations of the amine, the yield of 3 begins to decrease as the DEA incorporation products 4, 5, 6 increase. Significantly, the yields of these DEA containing products do not increase uniformly, but, at very high DEA concentration, hydrazine 4 is formed at the expense of azepines 5 and 6. This is shown graphically in Figure 1.

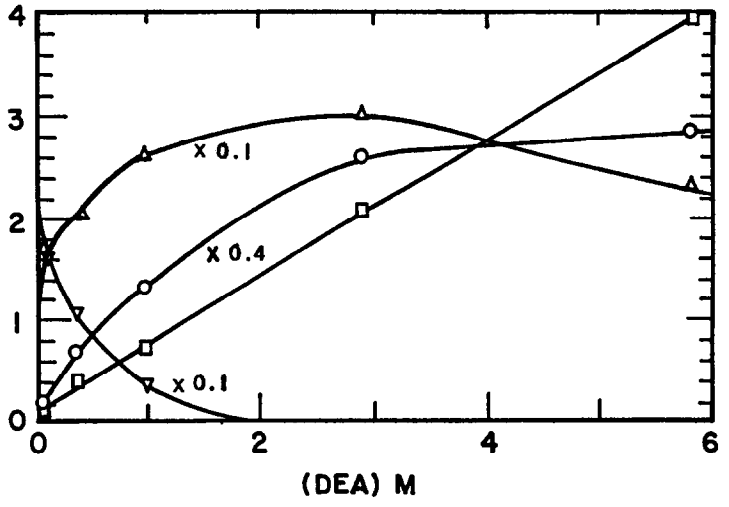


Figure 1. The relative yields of photoproducts vs [DEA] (yields of 2(∇) and 3(Δ), ratios of 4 to 5(o) and 4 to 6(□)).

These findings require the involvement of at least four different reactive intermediates. One of these is the precursor to azo dimer **2** and aniline **3**. Its formation is inhibited by **DEA**. This intermediate may be assigned without controversy to the ground state triplet nitrene,[8] Scheme 1. The second and third intermediates are the precursors to azepines **5** and **6**. In the absence of **DEA** these species, in part, isomerize to ^{3}**NPN** and then dimerize forming **2**. By analogy with the behavior of phenyl azide[5,9] it seems reasonable to assign these compounds to the isomeric dehydraoazepines **7** and **8**, Scheme 1. The dehydroazepines are trapped by the nucleophilic addition of **DEA** that give, after tautomerization,[9] isolated products **5** and **6**.

We attribute formation of hydrazine **4** to capture of the initially formed singlet nitrene by **DEA**. The evidence for this assertion rests on our observation that the relative yields of the dehydroazepine derived products (**5** and **6**) decline as that of **4** increaes. Hydrazines of this sort are not reported from photolysis of most phenyl azides,[5,9] but similar reactions have been observed for 4-cyanophenyl azide[10] and in the intramolecular capture of pyridine by some presumed electron poor nitrenes.[11] Evidently, alcohols are not effective traps for ^{1}**NPN** or **7** or **8** since irradiation in ethanol gives mainly **2** and **3**.

We provisionally associate the effect of the 3-nitro substituent with its electron withdrawing nature. This may increase the electrophilicity[4d] of ^{1}**NPN** and slow its conversion to **7** and **8**. These findings highlight an important point for the use of 3-nitrophenyl azide derivatives as photolabeling agents. They will form covalent bonds at the target site most effectively only when a nucleophilic amine residue is located therein.

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7) Irradiation through a $K_2Cr_2O_7$ filter to low conversion (ca. 40%) insures that azide **1** is the primary light absorber.

4: ^1H NMR: δ in ppm ($CDCl_3$) 1.07 (6H, t; J=7 Hz), 2.71 (4H, q; J=7 Hz), 4.51 (1H, b), 7.12 (1H, dd; J=8 and 2 Hz), 7.25 (1H, t; J=8 Hz), 7.50 (1H, dd; J=8 and 2 Hz), 7.71 (1H, t; J=2 Hz); IR: ν 1530 and 1320 cm^{-1}; MS: m/e 209 (M+, $C_{10}H_{15}H_3O_2$).

5: ^1H NMR: δ in ppm ($CDCl_3$) 1.08 (3H, t; J=7 Hz), 1.29 (3H, t; J=7 Hz), 2.80 (2H, b), 3.39 (2H, q; J=7 hz), 3.2 (2H, q; J=7 Hz), 5.20 (1H, td; J=7 and 9 Hz), 7.15 (1H, dd; J=9 and 2 Hz), 8.70 (1H,d; J=2 Hz); IR: ν 1530 and 1320 cm^{-1}; MS: m/e 209 (M^+,$C_{10}H_{15}N_3O_2$).

6: ^1H NMR: δ in ppm ($CDCl_3$) 1.05 (3H,t; J=7 Hz), 1.31 (3H, t; J=7 Hz), 3.50 (2H b), 3.52 (2H, q; J=7 Hz), 3.71 (2H, q; J=7 Hz), 5.71 (1H, t; J=7 Hz), 7.54 (1H, d; J=7 Hz), 7.82 (1H, d; J=7 Hz); IR: ν 1320, 1480 and 1580 cm^{-1}; MS: m/e 209 (M^+, $C_{10}H_{15}N_3O_2$).

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Acknowledgment: This work was supported by the National Institutes of Health.

(Received in USA 28 February 1986)