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PHOTOCHEMICAL DECOMPOSITION OF N-NITROSAMINES

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A search for further synthetically useful reactions involving substitution of a saturated carbon atom through intramolecular hydrogen abstraction(1) by a photochemically generated radical held in spacial proximity has led us to examine the photochemical decomposition of N-nitrosamines.

N-Dibutylnitrosamine when irradiated neat or in hydrocarbon solvents with ultraviolet light above 3000Å (Hanovia A 550 watt lamp, PYREX filter) was essentially inert; the only product isolated was a trace of dibutylamine. Under the same conditions N-dibenzylnitrosamine, I, was slowly converted to a 1:1 mixture of N-benzylidenebenzylamine, II, and dibenzylamine, III, isolated by gas chromatography and identified by comparison with authentic samples. A similiar result has been reported for N-dimethylnitrosamine in the gas phase.(2) This bimolecular disproportionation reaction could be effected thermally by the vapor phase pyrolysis of the nitrosamine at

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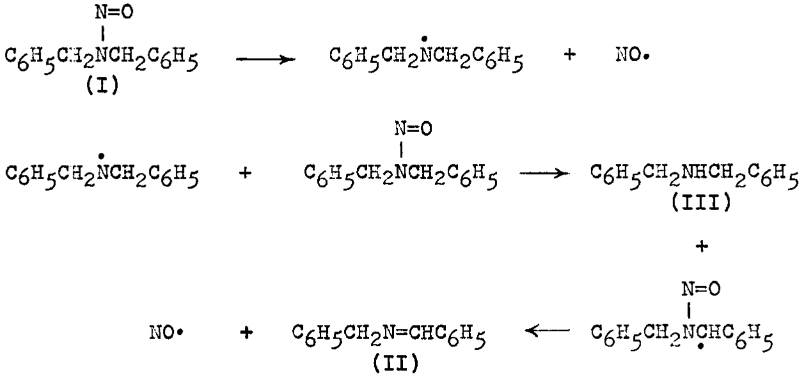
325° which afforded quantitatively the same 1:1 mixture of liquid products. In analogy with the previously reported(3) thermal decomposition of alkyl nitrites we visualize the following radical intermolecular abstraction mechanism as responsible for both the thermal and photochemical decomposition. Recombination within the solvent cage of the radical pair resulting from the primary step may be responsible for the low yield observed photochemically.



$$\underset{(I)}{C_6H_5CH_2\overset{N=O}{\overset{|}{N}}CH_2C_6H_5} \longrightarrow C_6H_5CH_2\dot{N}CH_2C_6H_5 + NO\cdot$$

$$C_6H_5CH_2\dot{N}CH_2C_6H_5 + C_6H_5CH_2\overset{N=O}{\overset{|}{N}}CH_2C_6H_5 \longrightarrow \underset{(III)}{C_6H_5CH_2NHCH_2C_6H_5} + C_6H_5CH_2\overset{N=O}{\overset{|}{N}}\underset{\bullet}{C}HC_6H_5$$

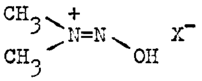
$$C_6H_5CH_2\overset{N=O}{\overset{|}{N}}\underset{\bullet}{C}HC_6H_5 \longrightarrow NO\cdot + \underset{(II)}{C_6H_5CH_2N{=}CHC_6H_5}$$

However, the mode of decomposition was remarkably changed with the inclusion of a proton donor. Irradiation of N-dibutylnitrosamine under the same condition but with one equivalent of trifluoroacetic acid added leads in 40% yield after neutralization to a liquid isomer isolated by gas chromatography and possessing ν_{max}^{neat}: 3400, 3200, 1603 and 940 $cm.^{-1}$ The nuclear magnetic resonance spectrum displayed singlets at 4.68τ (broad, 1H), 0.5τ (broad, 1H), 6.89τ (broad, 2H) and a triplet centered at 7.85τ (2H). Hydrolysis with aqueous base furnished N-butylbutyrlamide identified by comparison with an authentic sample. These observations suggest that the photoisomer is N-butylbutyramidoxime, XI ($R_1=CH_3CH_2CH_2CH_2$-, R_2=H, $R_3=CH_3CH_2CH_2$-). N-Dibenzylnitrosamine undergoes an analogous photoisomerization to yield 5% III and 90% of the corresponding amidoxime, m.p. 114°, which was hydrolyzed to N-benzylbenzamide. In this case the authencity of the product was established by its identity with a sample prepared from the condensation$^{(4)}$ of phenylhydroxamyl chloride with benzylamine.

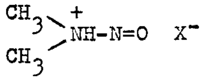
Symmetrical N-(α,α'-disubstituted)nitrosamines such as N-dicyclohexylnitrosamine are denitroxylated by irradiation under these conditions: the major (96%) liquid product isolated by gas chromatography was the corresponding imine, identified by infrared comparison with an authentic sample and hydrolysis which furnished cyclohexanone (isolated as its 2,4-dinitrophenylhydrazone).

Unsymmetrical nitrosamines rearrange with selective orientation, for example, N-(α-methylbenzyl)benzylnitrosamine furnishes N-(α-methylbenzyl)benzamidoxime unaccompanied by N-(α-methylbenzylidene)benzylamine. N-(Methyl)benzylnitrosamine gives only N-methylbenzamidoxime. Both amidoximes exhibit consistent nuclear magnetic resonance and infrared spectra. In order to ascertain if this orientation is due to an intermediate imine through which extensive equilibration of the α-hydrogens might occur prior to final product formation, both I and N-(α-methylbenzyl)benzylnitrosamine were photochemically transformed in the presence of deuteriotrifluoroacetic acid in benzene. Analysis by nuclear magnetic spectroscopy failed to indicate any significant exchange.

Of the ground state spectroscopic species present, the entity undergoing excitation is the hydrogen bonded nitrosamine/acid complex, IV, λ_{max} 340 mμ.; ε 100, described previously$^{(5)}$ and not the nitrosamine conjungate acid present in low concentrations. Structure V rather than VI may be assigned to this conjungate acid as indicated by the nuclear magnetic resonance spectrum (in 9M H_2SO_4) of a representative base, N-dimethylnitrosamine. Singlets appeared at 5.29τ (3H) and 5.57τ (3H, relative to the CH_3COOH methyl) consistent only with V. In 9M H_2SO_4 N-dibutylnitrosamine was present entirely as the conjungate acid (no absorption above 300 mμ.) and failed to undergo any amidoxime formation upon prolonged irradiation.


$\mathrm{(CH_3)_2\overset{+}{N}{=}N{-}OH\ \ X^-}$

(V)


$\mathrm{(CH_3)_2\overset{+}{N}H{-}N{=}O\ \ X^-}$

(VI)

The product appears as a result of the unimolecular rearrangement of this nitrosamine/acid complex (1:1) since the quantum yield[*], Φ=0.75, in benzene and remains essentially invariant in water or ethanol as a solvent. A small acid dependence of quantum efficency was noted at low concentrations, i.e., Φ=0.63 with two equivalents of trifluoroacetic acid. However, the addition of a small amount (0.01M) of nitric oxide to the complex (0.1M) causes a significant decrease in

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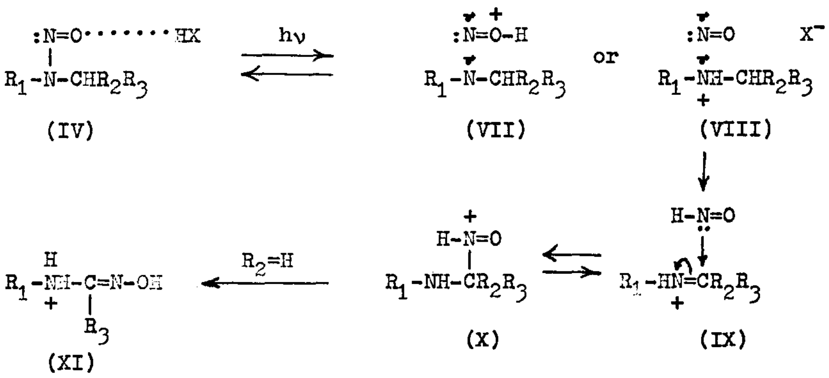
[*] Measured relative to the benzophenone (0.1M)/benzhydrol (0.375M) system where Φ=0.39 in benzene at 366 mμ.$^{(6)}$

overall rearrangement rate ($\Phi=0.55$). The following mechanism is consistent with but not a necessary result of these observations.



The long wavelength transition in nitrosamines has been assigned to the local symmetry allowed but overlap forbidden nitrogen $n\rightarrow\pi^*$ promotion.(7,8) The excited molecule resulting from such a transition has a weakened N-N bond and increased electron localization on both the amino-nitrogen and oxygen. Protonation of the excited triplet state before or after N-N bond breaking may lead to the triplet radical ion π-complex(9,10) VII or VIII which collapses to the imine and nitroxyl within the solvent cage. Spin inversion caused by the added paramagnetic species (•N=O) might provide a singlet π-complex which would result in recombination (sequence VII or VIII→IV) and a reduced quantum yield. Dissociation of the radical complex occurs in the presence of electron transfer agents and the addition of excess hydroquinone to the reacting system resulted in a quantitative conversion to the <u>sec</u>-amine.

Phenol was less efficient and reduction occured only to the extent of 43%.

Sequence IX→X must possess restrictive steric or electronic requirements with addition occuring only with the less hindered more electrophilic imines where R_3=H. The orientation observed in unsymmetrical nitrosamines may be determined by the preferred ground state configuration(11) about the N-N bond. A similiar effect in the photochemical decomposition of alkyl nitrites has been noted.(12)

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