Tetrahedron Letters No.27, pp. 2341-2344, 1970. Pergamon Press. Printed in Great Britain.

The Structure of Bamberger's Nitrosohydrazones and the Mechanism of their Rearrangement

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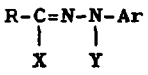
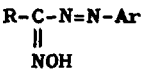
(Received in UK 8 May 1970; accepted for publication 14 May 1970)

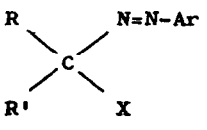
The course of the reaction between aldehyde arylhydrazones (Ia) and nitrous acid has not been satisfactorily resolved.[1-4] The final products, depending on the reaction conditions, are azo-oximes (II),



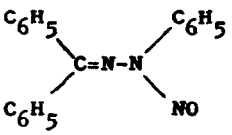


(II)

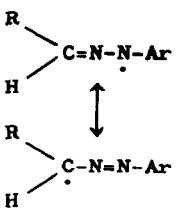
(Ia) X=Y=H
(Ib) $X=NO_2$, Y=H
(Ic) X=NO, Y=H
(Id) X=H, Y=NO
(Ie) X=H, $Y=CH_3$
(If) $X=NO_2$, $Y=CH_3$
(Ig) X=NO, $Y=CH_3$



(III)



(IV)



(V)

nitrohydrazones (Ib), compounds in which the hydrazone ring has been o,p-nitrosubstituted, and various dimers.[1,4,5]

Unstable intermediates are often isolable. According to Bamberger and Pemsel[1a] these are C-nitroso compounds (Ic), but Busch and Kunder[2] assigned them the N-nitroso structure (Id), since N-methylphenylhydrazones (Ie) do not react with nitrous acid (contrary to Bamberger and Pemsel[1d]), whereas ketone hydrazones, e.g. benzophenone phenylhydrazone, do. The

lability of the nitroso group prevents a satisfactory resolution of this question by chemical means.[1,2,4] Structure (Ic) was recently considered likely,[3] because most arylhydrazone reactions are now known to proceed via attack at carbon to give azo-intermediates (III). This mechanism would invalidate Busch's objections to the C-nitroso structure if the products from ketone arylhydrazones had the azo-structure (III, X=NO).

Reaction of benzophenone phenylhydrazone with sodium nitrite in acetic acid-dimethylsulphoxide gave the nitroso derivative[2] m.p. 80-95° (decomp.). Although bright yellow, this compound does <u>not</u> contain a phenylazo chromophore, as evidenced by its electronic absorption (EA) spectrum (Fig.1), which does not show the expected peak in the visible region.[6] The yellow

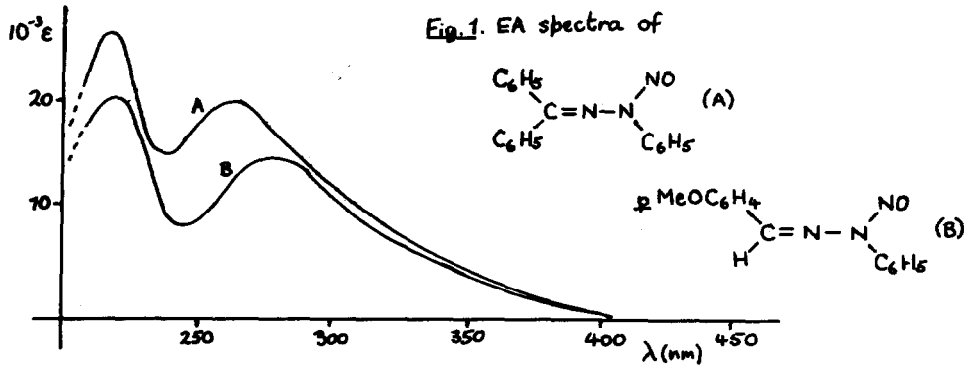


Fig.1. EA spectra of

(A)

(B)

colour is due to end-absorption. This compound cannot therefore have the azo-structure and is an N-nitrosohydrazone (IV).

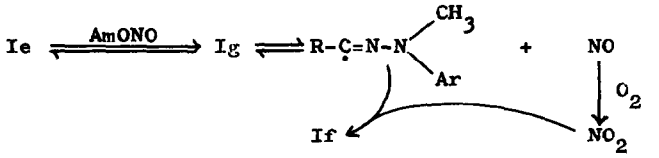
Nitrosation of anisaldehyde phenylhydrazone (Ia, R=p-MeO-C_6H_4; Ar=C_6H_5) gave the very unstable nitroso-hydrazone[1a] (homogeneous to TLC at -20°). The IR spectrum of this product shows no NH absorption and the EA spectrum of a fresh solution (Fig.1) shows clearly that it contains a similar type of chromophore to the benzophenone nitrosophenylhydrazone.[7] Since a C-nitroso structure (Ic) is impossible for the latter compound, the spectra in Fig.1 must be characteristic of the N-nitrosohydrazone chromophore and the aldehyde nitroso-hydrazones must have the N-nitroso structure (Id).

This conclusion is also supported by nmr data. The NH signal from the arylidene arylhydrazones is a sharp singlet at low field in DMSO-d_6 (anisaldehyde phenylhydrazone τ 0.12; cf. benzophenone phenylhydrazone τ 1.53), which disappears in $CDCl_3$. The CH methine proton is seen as a sharp singlet at about τ 2.4 which is virtually solvent-invariant (anisaldehyde phenylhydrazone τ 2.27 in DMSO-d_6; τ 2.55 in $CDCl_3$; cf. anisaldehyde N-methylphenylhydrazone, τ 2.43 in both solvents). Anisaldehyde N-nitrosophenylhydrazone shows a singlet at τ 1.75 in DMSO-d_6 and at τ 1.82 in $CDCl_3$. This position is consistent with a methine CH signal shifted downfield about 0.6 ppm by an N-nitroso group, and the virtual absence of a solvent effect also shows clearly that it is a CH and not an NH signal.

Formation of the C-nitrohydrazones (Ib) and the azo-oximes (II) from the N-nitrosohydrazones (Id) therefore involves a rearrangement,[8] accompanied in the case of the nitrohydrazones by oxidation.

The formation of dimers by oxidation of phenylhydrazones with various reagents including amyl nitrite, involves the intermediary of the radical species (V).[4,9] In the present case, the nitrosohydrazones (Id) must be capable of homolytic dissociation to give (V) and nitric oxide. Formation of the nitrohydrazones is then explicable on the basis of air-oxidation of nitric oxide to nitrogen dioxide and its recombination at carbon with the radical (V).[10] The early workers[1,5] often prepared these compounds by reacting hydrazones (Ia) with nitrous fumes (N_2O_3 + NO + NO_2); under these conditions nitrosation probably first occurs, and the radical (V), thus formed combines with the NO_2 present. In agreement with this hypothesis, phenylnitroformaldehyde phenylhydrazone (Ib, R=Ar=C_6H_5) can be prepared in good yield by passing NO_2 through a solution of benzaldehyde phenylhydrazone in ether containing amyl nitrite.

Further support for this mechanism came from a study of the nitrosation of anisaldehyde N-methylphenylhydrazone (Ie, R=p-$MeOC_6H_4$-, Ar=C_6H_5).[1d,2] This hydrazone reacts readily with amyl nitrite <u>in air</u> to give anisylnitroformaldehyde N-methylphenylhydrazone, (If, R=p-$MeOC_6H_4$-, Ar=C_6H_5) and another product,[1d] which is still being investigated.



Under nitrogen, the hydrazone, which is incapable of N-nitrosation, is unchanged. This appears to explain the discrepancy between the two accounts.[1e,2] An unstable C-nitrosohydrazone (Ig) is presumably formed but cannot react further in the absence of oxygen. This implies that in the case of hydrazones (Ia) lacking the N-methyl group, the C-nitrosohydrazones (Ic) are transient intermediates capable of being trapped only in the presence of base, which causes isomerisation to azo-oximes (II).[1]

Early confusion[1,5] on the course of the reaction between phenylhydrazones and nitrous acid is therefore reduced. The exact products isolated depend on the hydrazone concentration and the degree of air access, since when insufficient air is available to produce the nitrohydrazones (Ib), dimers of the radical (V) predominate.

References

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3. J. Buckingham, Quart. Revs., 1969, 23, 37.
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6. A.J. Bellamy and R.D. Guthrie, J. Chem. Soc., 1965, 2788.
7. On standing for a short time, the spectrum of the nitrosohydrazone is replaced by that of 1,2-bis(phenylazo)-1,2-bis-(p-methoxyphenyl)-ethane[4] (λ max 408 nm; isosbestic point at 376 nm).
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9. T.W. Milligan and B.C. Minor, J. Org. Chem., 1962, 27, 4663.
10. Oxidation of a C-nitroso compound by nitrogen dioxide is also possible; T.G. Bonner and R.A. Hancock, J. Chem. Soc. (B), 1970, 519.