Tetrahedron. Vol. 29, pp. 3929 to 3931. Pergamon Press 1973. Printed in Great Britain

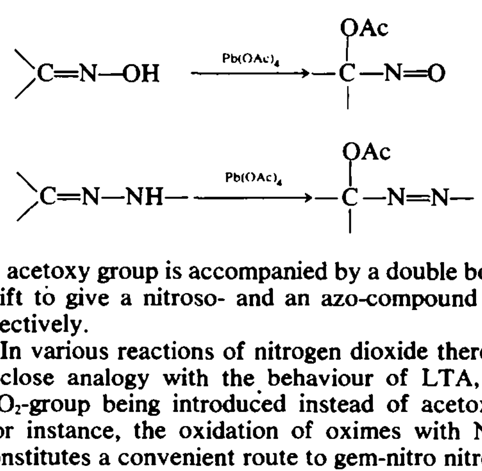
OXIDATION OF 2,4-DINITROPHENYLHYDRAZONES BY NITROGEN DIOXIDE

TH. A. B. M. BOLSMAN and TH. J. DE BOER*
Laboratory for Organic Chemistry, University of Amsterdam, Nieuwe Achtergracht 129, Amsterdam, The Netherlands

(*Received in the UK* 29 *May* 1973; *Accepted for publication June* 1973)

Abstract—2,4-Dinitrophenylhydrazones are rapidly oxidised by nitrogen dioxide to gem-nitroazo compounds **2**, in yields ranging from 60–85%. The nitration products of aldohydrazones **3** undergo spontaneous rearrangement to hydrazones **5**. An addition-elimination mechanism is proposed, in accordance with the observed kinetic deuterium-isotope effect.

The oxidation of oximes and hydrazones by lead tetraacetate (LTA) is well documented in the literature.[1,2,3] With both substrates, the introduction of

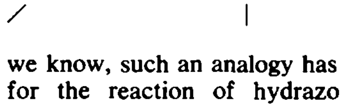


$$>C{=}N{-}OH \xrightarrow{Pb(OAc)_4} -\overset{OAc}{\underset{|}{C}}-N{=}O$$

$$>C{=}N{-}NH{-} \xrightarrow{Pb(OAc)_4} -\overset{OAc}{\underset{|}{C}}-N{=}N{-}$$

an acetoxy group is accompanied by a double bond shift to give a nitroso- and an azo-compound respectively.

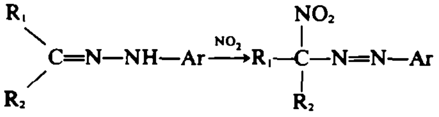
In various reactions of nitrogen dioxide there is a close analogy with the behaviour of LTA, an NO_2-group being introduced instead of acetoxyl. For instance, the oxidation of oximes with NO_2 constitutes a convenient route to gem-nitro nitroso compounds.[4]



$$>C{=}N{-}OH \xrightarrow{NO_2} -\overset{NO_2}{\underset{|}{C}}-N{=}O$$

As far as we know, such an analogy has not been reported for the reaction of hydrazones with nitrogen dioxide.

We have now found that NO_2 is an effective oxidizing agent for ketohydrazones **1** resulting in the formation of nitro-substituted azo-compounds **2**.



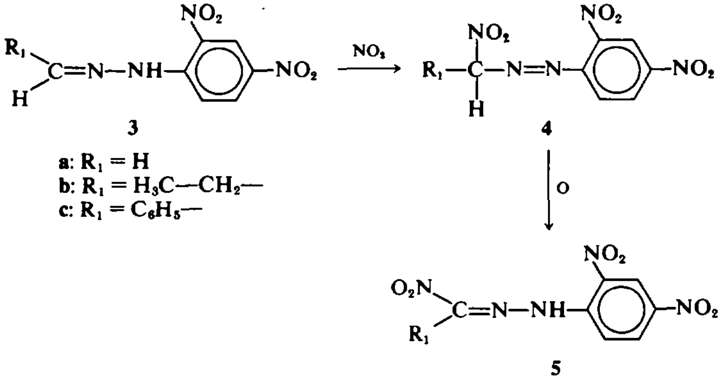
$$R_1R_2C{=}N{-}NH{-}Ar \xrightarrow{NO_2} R_1{-}\overset{NO_2}{\underset{R_2}{C}}{-}N{=}N{-}Ar$$

1 **2**

When Ar = phenyl and R_1 and R_2 are alkyl, aralkyl or aryl a complex mixture of azo-derivatives is formed,[5] because the aromatic nucleus (Ar) is simultaneously attacked by NO_2. Thus a phenyl hydrazone **1** ($Ar = -C_6H_5$) yields three azo-compounds of type **2**, ($Ar = -C_6H_5$, $4NO_2C_6H_4-$ and $2,4\text{-}diNO_2C_6H_3-$). The product ratio depends on R_1 and R_2 and much less so on reaction conditions. A much cleaner reaction takes place when 2,4-dinitrophenyl hydrazones are treated with NO_2: there is no further aromatic nitration and only one nitro group is introduced in the "aliphatic part" of the molecule, thus leading to the corresponding (tri-)nitro substituted azo-compounds in yields of 60–85%. NMR spectra suggest that only one isomer is formed, and in accordance with literature[6] we expect this to be the trans compound. Hitherto such compounds have been synthesized only by coupling a diazonium salt with an *aci*-nitro compound, albeit in less favorable yields.[7]

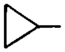
When $R_2 = H$, as in 2,4-dinitrophenylaldohydrazones **3**, thermodynamically more stable tautomers **5** are formed. These are formally the 2,4-dinitrophenylhydrazones of carbonyl compounds with an NO_2-group directly attached to CO, as such a non-existent class of compounds.

The tautomerization (**4**→**5**) is rapid in a protic solvent like water. Under aprotic circumstances some unchanged **4** can be isolated. By means of ^{13}C NMR, it was shown that **5b**, derived from propionaldehyde, exists in a syn- and an anti-form, formed in approximately equimolar amounts, as shown by ^1H NMR (see Fig. 1). Each of the compounds **5a** and **5c** is only present as one isomer, presumably anti for steric reasons. As to the mechanism of these NO_2 oxidations, it seems likely (*vide infra*) that the reaction starts with the addition of NO_2 to the C═N bond. Apparently only a nitrogroup (not nitrite) becomes attached to carbon (not



a: $R_1 = H$
b: $R_1 = H_3C—CH_2—$
c: $R_1 = C_6H_5—$

Table 1. Products derived from ketohydrazones with $Ar = 2,4\text{-diNO}_2C_6H_3—$
$R_1R_2C{=}N—NHAr + NO_2 \rightarrow R_1R_2C(NO_2)N = NAr$

R_1	R_2	yield %	m.p. °C	UV nm (log ε) ($CHCl_3$)	Analysis
$H_3C—$	$H_3C—$	80	63–65	403 (2·52)	Calc. C: 38·17 H: 3·20 N: 24·73 Found C: 38·22 H: 3·24 N: 24·89
$—(CH_2)_5—$		61	111–114	410 (2·54)	Calc. C: 44·58 H: 4·05 N: 21·67 Found C: 44·25 H: 4·20 N: 21·80
$C_6H_5—CH_2—$	$H_3C—$	83	oil	410 (2·53)	Calc. C: 50·14 H: 3·65 N: 19·49 Found C: 50·07 H: 3·84 N: 19·57
$C_6H_5—$	$H_3C—$	85	108	418 (2·64)	Calc. C: 48·70 H: 3·21 N: 20·29 Found C: 48·83 H: 3·28 N: 20·45
	$H_3C—$	70	oil	403 (2·62)	Calc. C: 42·87 H: 3·59 N: 22·65 Found C: 43·01 H: 3·67 N: 22·71

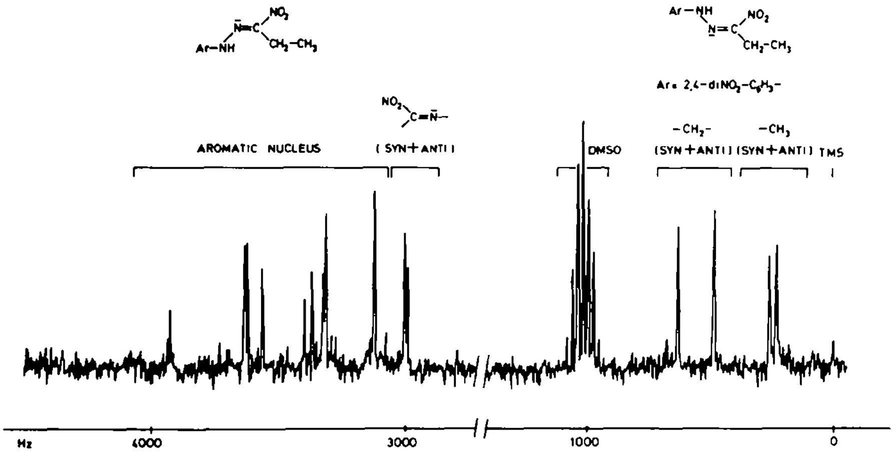
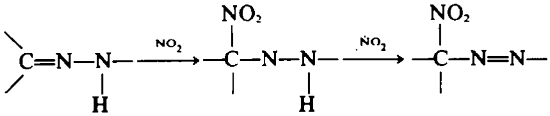


Fig 1. ^{13}C NMR spectrum of the approximately 1 : 1 mixture of syn- and anti-**5b**.

Table 2. Products derived from aldohydrazones with Ar = 2,4-diNO$_2$C$_6$H$_3$—
$R_1CH{=}N{-}NHAr + NO_2 \rightarrow R_1C(NO_2){=}N{-}NHAr$

	yield %	m.p. °C	UV nm (log ε) (CHCl$_3$)	Analysis
5a	80	156–157	349 (4·2) 378 (sh)	Calc. C: 32·95 H: 1·98 N: 27·45 Found C: 33·20 H: 1·76 N: 27·27
5b	68	132–135	350 (4·28) 378 (sh)	Calc. C: 38·17 H: 3·20 N: 24·73 Found C: 38·22 H: 3·17 N: 24·81
5c	76	138–140	356 (4·3) 386 (sh)	Calc. C: 47·14 H: 2·74 N: 21·14 Found C: 47·06 H: 2·86 N: 21·28

nitrogen) of the C=N bond. Subsequent elimination of a hydrogen atom, possibly assisted by simultaneous combination with another molecule of NO$_2$, leads to products (**2** and **4**):



$$>C{=}N{-}\underset{H}{N}{-}\xrightarrow{NO_2}{-}\overset{NO_2}{C}{-}N{-}\underset{H}{N}{-}\xrightarrow{NO_2}{-}\overset{NO_2}{C}{-}N{=}N{-}$$

Reversal of these addition-elimination steps is less probable. We have supported this assumption by measuring the kinetic deuterium isotope effect. The deuterated hydrazone is easily obtainable by exchange of the NH in an excess of methanol-O-d.[8] Initial elimination (abstraction) of hydrogen (deuterium) by NO$_2$ would lead to a relatively large (primary) isotope effect,[9] whereas initial addition of NO$_2$ to the double bond and hydrogen-loss afterwards would lead to a small (secondary) isotope effect, assuming that this second step is not (or hardly) rate determining. In fact we have found $k_H/k_D = 1{\cdot}25 \pm 0{\cdot}05$ which falls in the range usually observed for secondary isotope effects. The results are consistent with a reaction of the type $AH + 2NO_2 \rightarrow ANO_2 + HNO_2$ and fit the kinetic equation (up to 80% conversion): $kt = 1/(2a - b) \ln b(a - x)/a(b - x)$ (a = initial conc. hydrazone, b = initial conc. NO$_2$, *cf* Experimental).

It is noteworthy that compounds of type **2** and **5** can be reduced easily to benz-1,2,4-triazines.[7]

EXPERIMENTAL

Melting points are uncorrected. ^{1}H NMR spectra were determined using a Varian HA-100 spectrometer and ^{13}C NMR was measured on a Varian XL-100 Fourier transform NMR spectrometer. All hydrazones are synthesized according to literature procedures,[10] in acidic methanol. Commercial nitrogen dioxide (J. T. Baker) was distilled on a vacuum line immediately before use.

General method for synthesis

333 ml of a 3 M solution of NO$_2$ in methylene chloride was added slowly to a 0·1 M solution of the hydrazone in 500 ml of methylene chloride. After half an hour the solution was washed with sat NaHCO$_3$. After drying (MgSO$_4$) and evaporation of the solvent a crude crystalline product was obtained. The purification was effected by crystallisation from CHCl$_3$/cyclohexane (1:1) or by column chromatography (silica gel/CHCl$_3$). Specific data are summarised in tables.

Kinetic measurements

The kinetics were measured on a Cary 14 spectrophotometer at 450 nm and 20°C. The initial concentration of hydrazone (derived from acetone) was $0{\cdot}5 \times 10^{-3}$ M and that of nitrogen dioxide was $7{\cdot}5 \times 10^{-3}$ M, both in methylene chloride. Extinction coefficients of product ($1{\cdot}8 \times 10^2\,M^{-1}\,cm^{-1}$) and starting material ($4{\cdot}1 \times 10^3\,M^{-1}\,cm^{-1}$) at 450 nm differ by a factor of twenty.

The extinction coefficient for nitrogen dioxide is almost negligible at this wavelength. The rate of the reaction can therefore easily be determined by means of multicomponent analysis, as described earlier.[11]

REFERENCES

[1] D. C. Iffland, R. Salisbury and W. R. Schafer, *J. Am. Chem. Soc.* **83**, 747 (1961)

[2] R. N. Butler, *Chem. Ind.* 437 (1968)

[3] D. C. Iffland and G. X. Criner, *Chem. Ind.* 176 (1956)

[4] R. Scholl, *Chem. Ber.* **21**, 507 (1888). For the reaction of NO$_2$ with hydrocarbons *cf.* A. I. Titov, *Tetrahedron* **19**, 557 (1963)

[5] M. Busch and H. Kemder, *Chem. Ber.* **49**, 324 (1916)

[6] D. L. Webb and H. H. Jaffé, *J. Am. Chem. Soc.* **86**, 2419 (1964)

[7] R. Fusco and G. Bianchetti, *Gazz. Chim. Ital.* **90**, 1113 (1960)

[8] C. Asselineau, H. Montrozur and J. C. Promé, *Bull. Soc. Chim. Fr.* 1911 (1969)

[9] A. F. Trotman-Dickinson, *Adv. Free Rad. Chem.*, Vol. 1, 1 (1965). Primary k_H/k_D isotope effects for homolytic NH(ND) bond rupture have been reported as high as 6·2

[10] G. D. Johnson, *J. Am. Chem. Soc.* **73**, 5888 (1951)

[11] I. S. Herschberg, *Z. anal. Chem.* **205**, 180 (1964)