The Kinetics of *syn–anti*-Isomerism of 2,4-Dinitrophenylhydrazones

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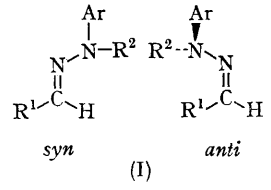
2,4-DINITROPHENYLHYDRAZINE (DNP) has been widely used as a reagent to characterise carbonyl compounds but its use for simple aldehydes has been limited because of the wide variation in m.p. found for such derivatives in the literature.[1] There has been much speculation as to the origin of these m.p. differences and the existence of hydrazone isomers (geometric and tautomeric) has been suggested. We now report a study of the bromination of such hydrazones, the results of which are relevant to this problem.

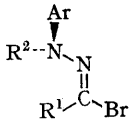
Although the bromination of a large number of arylidene arylhydrazines (I; R^1 = Ar, R^2 = H) has been reported[2,3] in which the methine hydrogen is replaced by bromine, giving hydrazidic bromides (II; R^1 = Ar, R^2 = H), the bromination of the alkylidene analogues has not been recorded. In acetic acid solution we have now found that such hydrazidic bromides are formed on treatment of alkylidene DNPs (Ia) with bromine. That the products are hydrazidic bromides is consistent with spectroscopic data and is demonstrated by their conversion, in aqueous acetone at reflux, into *C*-alkyl-*N*-(2,4-dinitrophenyl)hydrazides.

The kinetics of bromination of eight alkylidene DNPs (Ia; R^1 = alkyl) were studied in 70% acetic acid containing 0·1M-potassium bromide, using an electrometric technique.[3] Under these conditions, the alkylhydrazidic bromides [II; R^2 = H, Ar = 2,4-$(NO_2)_2C_6H_3$] were formed. However, unlike the reaction of bromine with arylidene arylhydrazines[3,4] studied under the same conditions, which was a second-order process, first-order each in bromine and hydrazone, the reaction with alkylidene DNPs was independent of the concentration of bromine used. With one of the compounds (Ic) variation in the halogenating species was studied. For compound (Ic) the rate constant obtained for bromination ($k = 1{\cdot}6 \times 10^{-3}$ sec.$^{-1}$) was the same as for chlorination of the hydrazone, and also it did not vary when the bromine : tribromide ion ratio in the solution was varied by a factor of ten, adding support to the view that the rate-determining step in the reaction does not involve the halogenating species. For the eight alkylidene DNPs studied, the k-values were excellently correlated by the reduced form of the Taft equation,[5] $\log k = \delta E_S + \log k_0$, with $\delta = +0{\cdot}49$ [$r = 0{\cdot}996$, $k_0(CH_3) = 3 \times 10^{-3}$ sec.$^{-1}$]. This implies that the reaction being measured is sensitive only to the size of R, the group involved, and not to its electronic effect.

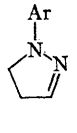


syn *anti*

(I)



(II)



(III)

(Ia) R^2 = H, Ar = 2,4-$(NO_2)\cdot C_6H_3$

(Ib) $R^2 = CH_3$, $R^1 = XC_6H_4$, Ar = 4-$NO_2\cdot C_6H_4$

(Ic) R^2 = H, $R^1 = CHMe_2$, Ar = 2,4-$(NO_2)_2\cdot C_6H_3$

The data are consistent with a rate-determining conversion of the *syn*-isomer of the hydrazone (I), present in excess, into the reactive *anti*-isomer (a *cis*-configuration). The bromination of 1-(2′,4′-dinitrophenyl)-2-pyrazoline [III; Ar = 2,4-$(NO_2)_2$-C_6H_3] which is a model for the *anti*-isomer of (I), we have found was a rapid reaction with a second-order rate constant of 10 l.mole^{-1} sec.$^{-1}$, the rate-determining step involving both bromine and the pyrazoline. Karabatsos and his co-workers[6] have shown from n.m.r. measurements that alkylidene

DNPs, present when solid as the *syn*-isomer, isomerise in solution to mixtures of *syn*- and *anti*-isomers. Our results are consistent with these data, the large R groups which reduced the amount of the *anti*-isomer at equilibrium also producing the smaller rate constants for bromination. Spectroscopic studies also showed[7] that when the amino-nitrogen of the hydrazone (I) was disubstituted, the *anti*-isomer could not be detected. We have found that such disubstituted hydrazones [I; R^2 = Me, Ar = 2,4-$(NO_2)_2$·C_6H_3] are brominated approximately twenty times less rapidly than the unmethylated analogues (Ia).

Hydrazones can also, in theory, tautomerise to an ene-hydrazine (IV) or azo-alkane (V) and, although this has been reported not to occur in nonpolar solvents,[8] the question as to the existence of these isomers in polar solvents is still controversial.[9] Ene-hydrazine (IV) formation is not the process being measured by our rate constants for bromination of alkylidene DNPs since the bromination of one such hydrazone (Ia; R^1 =MeEtCH) with an asymmetric carbon α to the

$$-\overset{|}{C}=CH-NH-NH- \leftrightharpoons -\overset{|}{C}H-CH=N-NH- \leftrightharpoons$$

(IV)

$$-\overset{|}{C}H-CH_2-N=N-$$

(V)

bromination site occurred with complete retention of configuration. Moreover, the rate data for trimethylacetaldehyde DNP (Ia; R^1 = CMe_3), which cannot form the ene-hydrazine (IV), and trimethylacetaldehyde *N*-MeDNP [I; R^1 = CMe_3, R^2 = Me, Ar = 2,4-$(NO_2)_2$.C_6H_3] which can form neither (IV) or (V) are correlated with the data for other hydrazones which could theoretically form both (IV) and (V). It is, furthermore, unlikely that the rate constants for a tautomeric change of the type indicated would be correlated by steric (as observed) rather than electronic parameters or both.

NN-Disubstituted hydrazones have been reported to fail to react with electrophiles such as diazonium ion,[10] lead tetra-acetate,[11] halogen,[12] nitrosobis-sulphate,[13] and α-carbonylazo-compounds.[14] Our present kinetic results suggested that, in fact, the bromination of such hydrazones does occur, even if at a very much reduced rate. In support of this we have isolated for the first time an *NN*-disubstituted hydrazidic bromide [II; R^1 = CMe_3, R^2 = Me, Ar = 2,4-$(NO_2)_2$·C_6H_3], m.p. 108°, from the bromination of trimethylacetaldehyde *N*-MeDNP. This hydrazidic bromide is readily converted on hydrolysis into the corresponding hydrazide. The bromination of other *NN*-disubstituted hydrazones (Ib) was also zero-order in bromine and the results obtained for substituent variation parallel those for the bromination of alkylidene DNPs, *e.g.*, the rate of bromination of compounds (Ib) was independent of the nature of the *m*- or *p*-substituents (X) in the arylidene ring, while *o*-substituents in this ring have a simple steric effect (correlated by the Taft equation).

The similarity in the behaviour towards bromination of both alkylidene DNPs and arylidene and alkylidene *NN*-disubstituted hydrazones is presumably due to their sharing a similar mechanism. That is, in both types of compound preliminary attack of the electrophile is followed by loss of a C–H proton, rather than an N–H (with the formation of an azo-compound[15]). We have n.m.r. evidence that the N–H of such alkylidene DNPs is in fact tightly hydrogen-bonded to the *ortho*-nitro-group. Without this *o*-NO_2 group, as for example in alkylidene-*p*-nitrophenylhydrazines, the bromination reaction is again second-order.

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