Communications to the Editor

Chem. Pharm. Bull.
30(8)3028—3031(1982)

PHOTO-DEAROMATIZATION. 1,2-PHOTOADDITION OF ALCOHOL TO N,3-DIMETHYLPHTHALIMIDE WITHOUT PHOTOENOLIZATION[1,2)]

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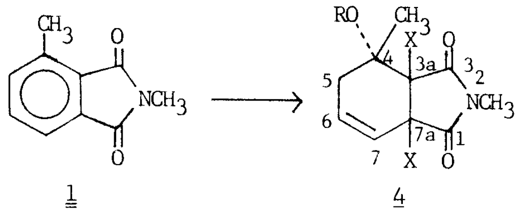
Dearomatization of N,3-dimethylphthalimide occurs upon irradiation accompanying incorporation of the solvent alcohol in the aromatic ring. The X-ray crystal structure analysis of the product revealed the complete structure of a multi-substituted cyclohexene system. No evidence for formation of the photo-enol in the phthalimide system has been found during the study of the possible course of the photodearomatization.

KEYWORDS —— photo-dearomatization; N,3-dimethylphthalimide; nucleophilic photoaddition; photoreduction; photoenolization; deuterium incorporation; X-ray analysis; 3a,4,5,7a-tetrahydro-4-alkyloxy-2,4-dimethyl-1H-isoindole-1,3(2H)-dione

One typical approach to overcome the resonance energy of benzenoids and to dearomatize them is by electronic excitation, a transformation for which there exist many precedents.3) In this way various nucleophiles such as amine,4) cyanide5) and hydride6) have been observed to add photochemically to benzenoids. Here we wish to report the photoaddition of alcohol: upon irradiation of N,3-dimethylphthalimide (1) in methanol, ethanol or isopropanol, 1,2-addition of alcohol resulted in dearomatization, without recourse to intermediate photoenolization.

In a typical example, irradiation (500 w high-pressure mercury lamp with a Pyrex filter, 8 h, N_2) of a 10 mM solution of (1) in methanol gave, besides two isomeric reduction products (2) (mixture, 27%) and addition products (3) (mixture, 30%), consistent with the general photochemical pattern of phthalimides,7,8) a third compound (4a, mp 119-120°C, 14%), which was apparently formed by the addition of methanol to the benzene moiety of (1), followed by reduction.

Similarly, irradiation of (1) in ethanol and isopropanol led to the similar products (4b, mp 103-104°C) and (4c, mp 65-66°C),[9] while no detectable amount of the product was formed in *tert*-butanol. The results are summarized in Table I. The yields of the dearomatized products (4) increase in the order of reactivity of the α-hydrogen of alcohols to hydrogen abstraction.



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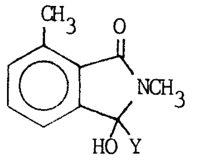
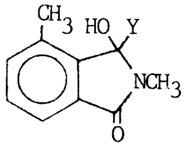


2a: Y=H
3a: Y=CH_2OH



2b: Y=H
3b: Y=CH_2OH

Table I. Yields of 4 in Various Alcohols

Solvent	Time (h)	4	R	X	Yield (%)
MeOH	8	a	CH_3	H	14
EtOH	1	b	CH_3CH_2	H	27
iso-PrOH	1	c	$(CH_3)_2CH$	H	31
tert-BuOH	8	-	-	-	-
MeOD	50	d	CH_3	D	3
EtOD	8	e	CH_3CH_2	D	5

The complete structure and the stereoconfiguration at the three new asymmetric centers of (4b) was established by X-ray analysis. The crystal structure analysis of (4b) confirmed the *cis* ring-junction and that the CH_3 group on C-4 is on the same side as the *cis* hydrogen atom on C-3a and C-7a. The name of the compound is 3aβ,4,5,7aβ-tetrahydro-2,4β-dimethyl-4α-ethoxy-1*H*-isoindole-1,3(2*H*)-dione. Bond lengths and angles are shown in Fig. 1. The conformation of the molecule has the following features: an equatorial CH_3 and an axial O-ethyl *trans* to C-3a and a dihedral angle of 135° between the planes of the two rings.[10]

The imide (1) possesses two imide carbonyls, one of which is formally photoenolizable, and the other is not. One attractive explanation for the formation of (4) could be addition of alcohol to a photo-generated enol (5→8). When (1) was thermally reduced with sodium borohydride, the isomer ratio of (2a) and (2b) was approximately equal to the value (3 : 2) observed in the above photoreaction. So there seems to be no significant intramolecular photoenolization in competition with intermolecular photoreduction.[11]

To confirm this, photolysis of (1) in CH_3OD or CH_3CH_2OD was examined (Table I). Based on pmr spectrometry, the recovered imide (1) incorporated no detectable amount of deuterium at the aromatic methyl group. By contrast, the products (4d) and (4e) were found to contain significant amounts of deuterium at the ring fused carbons: (4d) contained nearly quantitative and ca. 60% deuterium, at the 3a position and at the 7a position, respectively.

A plausible mechanism of the photo-dearomatization reaction is illustrated in Chart 1. Initial 1,2- and 1,4-addition of alcohol to an excited state benzenoid (6) including the conjugated imide carbonyls affords (7) and (8), respectively, and the latter will readily lead to its keto-form (7).[12] Photoreduction of the dienone by hydrogen abstraction from the α-H in alcohols (no α-H in *tert*-butanol) gives rise to (9), followed by the reversion of the enol (9) to the keto-form (4) resulting in partial incorporation of solvent deuterium at C-7a.

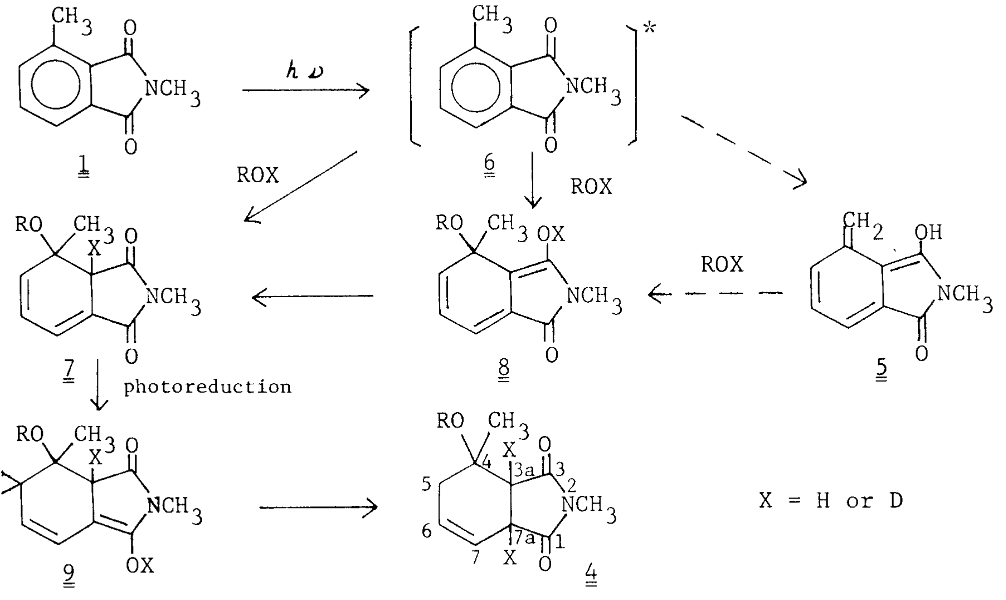


Chart 1

A number of photochemical aromatic substitutions have been reported including nucleophilic substitution with alkoxy groups.[13] Photoaddition of alcohols to double bonds in olefin[14] and enone[15] is also well known. However, nucleophilic photoaddition of alcohols to benzenoids has not been reported. It is worth noting that in a multi-substituted benzenoid system such as (1), the addition of alcohol to a benzene moiety effectively competes with the usual addition to a carbonyl. The scope and limitation of this dearomatization reaction, both with regard to substrates and addends, are under investigation.

ACKNOWLEDGEMENT This work was supported in part by a grant in aid (to Y. K.) from the International Cooperation Program of the Japan Society for the Promotion of Science, which is gratefully acknowledged.

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9) All new compounds gave satisfactory elemental analyses and spectral properties (ir, nmr, mass) consistent with the assigned structures.

10) A six-membered ring with five atoms except C-4 lies in a plane, and a five membered ring is essentially coplanar with the two carbonyl oxygens and the N-methyl carbon.

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12) If the 1,2-addition is assumed to proceed in a cis mode,[15)] the trans stereochemistry of the products (4, and therefore, 7) suggests that the 1,4-addition is predominatnt. However, both pathways are tentatively included.

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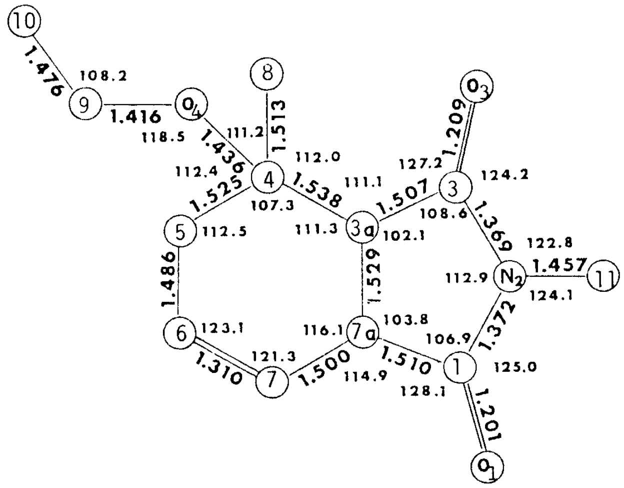

Fig. 1. Bond Lengths and Angles of 4b

(Received June 2, 1982)