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PHOTOCHEMISTRY OF THE PHTHALIMIDE SYSTEM: REDUCTION, ADDITION, AND CYCLIZATION*

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Although photoreactions of amide groups have been well documented (1), very little is known about imide derivatives with the exception of photochemical additions to some maleimides (1). In N-substituted phthalimides the carbonyl groups as part of a strained five-membered ring system, are activated. The rigid geometrical arrangement of the polar groups allows for effective intramolecular interaction between the carbonyl and certain side chain groups whereby the symmetrical structure and the presence of two equally reactive carbonyl groups increases the probability of such interaction by a factor of two. We wish to report on the general photochemical behavior and pertinent synthetic aspects of N-substituted phthalimides.

N-Alkylphthalimides were irradiated with 1KW high pressure mercury lamp for 0.5 - 8 hr and the reaction mixtures were purified by preparative tlc or column chromatography (silica gel). When alcohol was employed as a solvent, dihydro products 1 (R = CH_3,C_2H_5)(3) with one imide carbonyl group reduced were isolated in 30 - 40% yield (4), accompanied by 2 resulting from the addition of the alcohol ($R'CH_2OH$) to the imide carbonyl (2 : R = CH_3,C_2H_5; R' = H, CH_3; 20 - 40%)(5). The formation of the hydroxyalkyl derivatives instead of corresponding ether derivatives suggests that a free-radical mechanism is operative in the addition process (6). Since reduction by, and addition of, alcohol are photoreactions common to carbonyl systems (7), the above two reactions are characteristic of phthalimides and, at least formally, underline

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* Photochemistry of the Phthalimide System. II. For Part I see ref. (1).

their resemblance with carbonyl systems. It is interesting that such a cross-conjugated carbonyl system as phthalimides behaves in the excited states like simple carbonyl compounds.

Irradiation of **3a** in ethanol, in addition to the reduced product (**1** ; R = *o*-tolyl; 20%), gave, after column chromatography, a crystalline compound **4a**: mp 220.5 - 223°(decomp); ir, 3300 (OH), 1670 cm^{-1} (amide); mass, *m/e* 237 (M^{+}), 219 (base; M-H$_2$O), an interesting ring system with a tertiary alcohol group adjacent to an nitrogen atom, resulting from intramolecular cyclization of the carbonyl carbon with the methyl carbon. This structure was confirmed by facile conversion, on acid treatment, to the dehydrated product, 6H-isoindolo[2,1a]indol-6-one **5a**; mp 153 - 154.5°; nmr (C*d*Cl$_3$), (1H, s); mass, *m/e* 219 (M^{+}). In a similar way, the homologous **3b** gave rise to the cyclized homolog **4b** (mp 234 - 236°(decomp)), which, on treatment with acid, afforded the homologous indole **5b** (mp 173 - 176°). Preliminary experiments indicate that the cyclization of **3b** (10 m*M*, *t*-butanol) is significantly quenched in the presence of 2 - 10 m*M* of isoprene, suggestive of an excited triplet state intermediate. The reaction presumably involves intramolecular hydrogen abstraction by the excited amide carbonyl to give a biradical intermediate **6** followed by coupling to **4**. Ketones containing γ-C-H bonds, on electronic excitation, undergo 1,5 - hydrogen transfer to yield both cleavage (Norrish type II photoelimination) and cyclization products (cyclobutanol formation)(7,8). However, under certain circumstances, δ-H transfer may also take place to lead to cyclopentanol. Examples of δ-H transfer have become a subject of current interest (9). The formation of **4** takes place in good yields (**4a**, 65%; **4b**, 82%, yields in *t*-butanol) in the phthalimide system **3**, in which the N atom is regarded as the α-atom and the methyl carbon is δ with respect to the imide carbonyl carbon. This tendency of phthalimide derivatives to produce cyclopentanols on photolysis, probably by way of seven-membered transition states (8), is worthy to note.

Since N-substituted phthalimides are readily accessible starting materials, the above type II photoprocesses as well as the reduction and addition processes may provide a synthetic entry to novel heterocyclic systems. In addition, the mechanistic studies would enlarge our understanding of the excited states of extended carbonyl systems in general. Scope and mechanism of these photoprocesses are under investigation.

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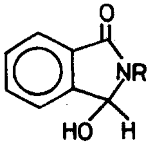

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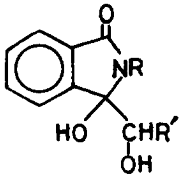

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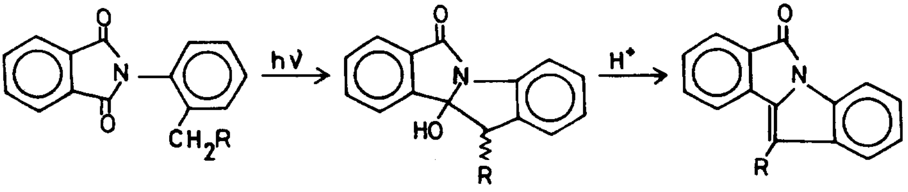
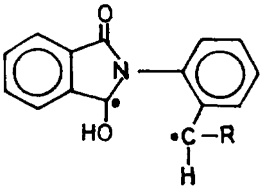


3 **4** **5**

a: R = H; b: R = CH_3



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