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Photochemical Reactions. XXV.[1] Intramolecular Photooxidation of the Indole Ring by an Aliphatic Nitro Group

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Photolysis of ethyl α-nitro-β-(3-indolyl)propionate resulted in the formation of ethyl α-hydroxyimino-β-(2-oxindol-3-yl)propionate.

Keywords——redox reaction; photochemical rearrangement; ethyl α-nitro-β-(3-indolyl)propionate; 2-oxindole; α-hydroxyimino carboxylic acid ester; dioxazolidine intermediate

The photochemical rearrangement of 3-(2-nitroprop-1-enyl)indole (1) into 3-(2-hydroxyiminopropylidene)-2-oxindole (2) is an intriguing example of the intramolecular photooxidation of the indole ring by a conjugated nitro group.[3]

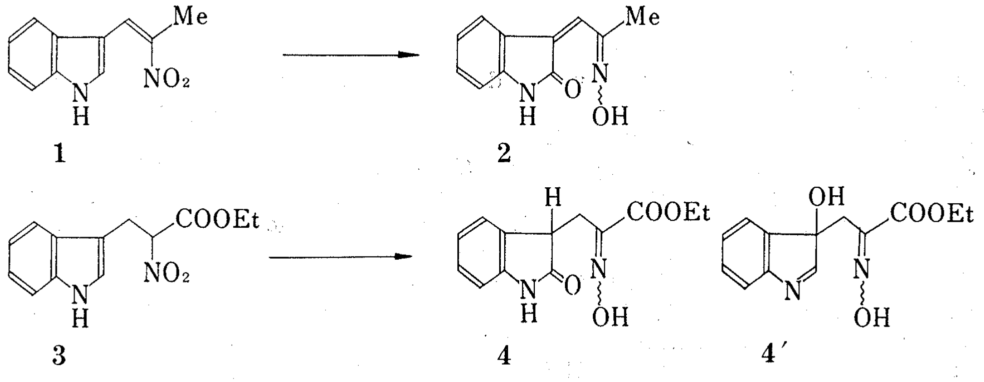

Chart 1

In the course of our investigations on the photooxidation of various organic functions[4,5] by the nitro group, we had occasion to examine the photochemical behavior of ethyl α-nitro-β-(3-indolyl)propionate (3), in which the nitro group is not conjugated. We report here that irradiation of 3 caused a rearrangement leading to ethyl α-hydroxyimino-β-(2-oxindol-3-yl)-propionate (4) rather than ethyl α-hydroxyimino-β-(3-hydroxyindolen-3-yl)propionate (4′). The present result is the first example of intramolecular photooxidation of the indole ring by an unconjugated aliphatic nitro group, and has mechanistic implications.

Ethyl α-nitro-β-(3-indolyl)propionate[6] (3) (UV $\lambda_{\max}^{\mathrm{CH_3CN}}$ nm (ε): 272 (5680), 278 (5760), 288 (4740)[7] was irradiated in acetonitrile with a high-pressure mercury arc lamp until 3 had completely disappeared. Thin-layer chromatography (TLC) of the reaction mixture showed the presence of several products. The major product (4) was isolated by silica gel chromato-

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[5] Y. Maki, T. Furuta, M. Kuzuya, and M. Suzuki, *J.C.S. Chem. Commun.*, **1975**, 616.
[6] D.A. Lyttle and D.I. Weisbalt, *J. Am. Chem. Soc.*, **69**, 2118 (1974).
[7] No charge transfer band was observed in the UV spectrum of 3. The UV spectrum of skatole (0.04 M) containing nitro ethane (0.4 M) did not indicate intermolecular interaction between two molecules in the ground state.

graphy in *ca.* 50% yield. Among the minor products, the only compound isolated was ethyl β-(3-indolyl)acrylate, which can be formed by loss of nitrous acid from **3**.

The structural proof of **4** rests upon microanalytical results and spectral data; *e.g.*, the nuclear magnetic resonance spectrum (NMR) of **4** (DMSO-d_6, δ) showed signals at 12.4 (1H, s, OH), 10.35 (1H, broad, NH), 3.75 (1H, t, J=8 Hz, C_3–H) and 2.90 (2H, d, J=8 Hz, C_β–H_2) in addition to aromatic and ethyl ester proton signals. Upon addition of deuterium oxide, the signals at 12.4 (OH), 10.35 (NH) and 3.75 (C_3–H) disappeared and the signal at 2.90 (C_β–H_2) coalesced to a sharp singlet. The ultraviolet spectrum (UV) of **4** (246 and 283 nm) was virtually superimposable on that of α-hydroxyimino-β-(2-oxindol-3-yl) propionic acid which was prepared *via* several steps from isatin in poor yield.[8] Thus, the alternative structure (**4'**) can be eliminated. The stereochemistry relating to the hydroxyimino function is not clear at present.

The present photoreaction involves an intramolecular redox reaction in which the nitro group is reduced to a nitroso group while an oxygen atom is apparently transferred to the 2-position of the indole ring. Although various possible mechanisms can be considered, at present we have no evidence as to the actual mechanism in this case.

Mechanistic studies to the present photoreaction and its extension to the intermolecular photooxidation of various indole derivaties by aliphatic nitro compounds are now in progress.

Experimental

Melting points were measured on a Yanagimoto micro-melting point apparatus (a hot-stage type) and are uncorrected. Infrared (IR) spectra were recorded on a Hitachi 215 spectrometer in KBr disks. NMR spectra were obtained on a Hitachi R20-B (60 MHz) spectrometer using DMSO-d_6 as a solvent. Mass spectra (MS) were run on a Hitachi RMU-6L instrument.

Photolysis of Ethyl α-Nitro-β-(3-indolyl)propionate (3)——The nitro compound (3) (0.5 g) in acetonitrile (200 ml) was irradiated with a 400W high-pressure mercury arc lamp through a Pyrex filter under nitrogen until **3** had completely disappeared (monitored by TLC, about 10 hr). The reaction mixture was concentrated under reduced pressure, and the residue was chromatographed on silica gel (solvent: $CHCl_3$) to isolate ethyl α-hydroxyimino-β-(2-oxindol-3-yl)propionate (**4**). Recrystallization of the crude (**4**) from ethanol–*n*-hexane (1:2) gave yellow prisms, mp 184° (0.25 g), in 50% yield. *Anal.* Calcd. for $C_{13}H_{14}N_2O_4$: C, 59.53; H, 5.38; N, 10.68. Found: C, 59.23; H, 5.23; N, 10.38. IR $\nu_{\max}^{\mathrm{KBr}}$ cm^{-1}: 3200—3250 (NH and OH), 1690 (CO). NMR (DMSO-d_6, δ): 12.4 (1H, s, O$\underline{H}$), 10.35 (1H, b, N$\underline{H}$), 7.00 (4H, m, Ar$\underline{H}$), 4.17 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 3.75 (1H, t, J=8 Hz, C_3–H), 2.90 (2H, d, J=8 Hz, $C\underline{H}_2$), 1.25 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$). MS *m/e*: 262 (M^+). Repeated silica gel chromatography permitted the isolation of a small amount of ethyl β-(3-indolyl)acrylate, which was identical in every respect with an authentic sample.

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