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STEREOCHEMISTRY OF NONOXIDATIVE PHOTOCYCLIZATION OF INDOLE-2-CARBOXANILIDES TO AN INDOLO[2,3-c]QUINOLINE SYSTEM[1]

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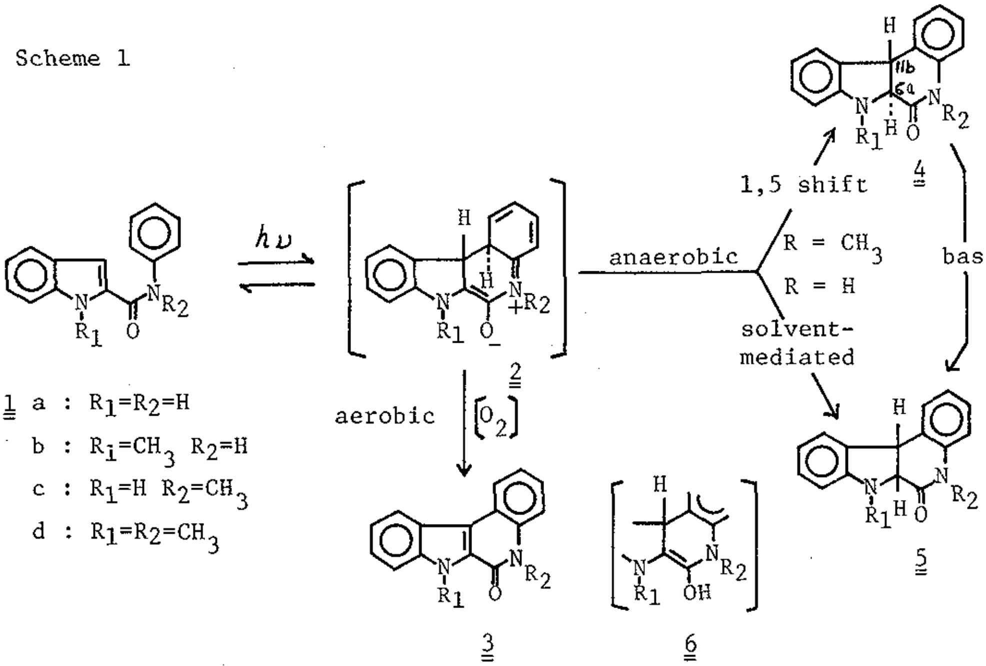
Nonoxidative photocyclization of indole-2-carboxanilides (**1a** and **1b**) yielded mainly the 6_a-11_b cis isomers of indolo[2,3-c]quinolin-6-one **5**. By contrast, from the N-methyl homologs (**1c** and **1d**) only the trans isomers **4** were obtained. The mechanism was explained in terms of the dual pathways involving a sigmatropic 1,5-hydrogen shift and a competing "solvent-mediated" course.

Heterocyclic anilides such as indole-2-carboxanilide (**1a**) undergo oxidative photocyclization in the presence of dissolved oxygen to afford the heterocyclic-condensed quinolones (**3a** etc.).[2] Chapman et al. observed nonoxidative photocyclization of arylenamines,[3] while Ninomiya et al.[4] have studied nonoxidative reactions of enamides and acrylamides. We have recently reported stereochemistry of nonoxidative photocyclization of benzo[b]thiophene-2-carboxanilides.[1a] In an extension of the work the present communication describes the nonoxidative photocyclization of indole-2-carboxanilides and delineates the general implication of the stereochemical course in the overall synthetic photochemistry of this system.

Scheme 1



As in the case of 1a, on irradiation[5] 1b cyclized oxidatively to 3b, which was accompanied by a minor product (5b). When the reaction was performed in a solvent free of oxygen, 5b was obtained as a major product along with a small amount of 3b. Under the anaerobic conditions 1a afforded two nonoxidative products, 4a and 5a, together with the oxidized quinolone (3a). Under the aerobic conditions, 1c afforded the oxidatively cyclized product (3c) with a minor product (4c), while under the anaerobic conditions, as expected, the yield of 4c increased, thus making it as major product. In a similar fashion, nonoxidative photocyclization of 1d gave mainly 4d. Neither of 5c nor 5d was isolated from the reactions of 1c and 1d.

The properties of the anilides and the quinolones, and the product distribution of the photocyclization are given in Table 1 and 2, respectively.[6] The nmr spectra of 4a,c,d showed a AB coupling (J = 22 Hz) for H_{6a} and H_{11b}. By contrast, 5a,b had J = 11 Hz suggesting the existence of two clearly different configuration series. The magnitude of J is strong-

Table 1 Properties of the Anilides (1) and the Quinolones (4, 5)

	mp(°C)		mp(°C)	NMR $J(H_{6a},H_{11b})$		mp(°C)	NMR $J(H_{6a},H_{11b})$
1a	200-201.5	4a	222-225.5	22 Hz	5a	243-250	11 Hz
1b	166.5-169	4b	-	-	5b	233.5-236.5	11
1c	199-200	4c	180-182	22	5c	219-221.5	11
1d	101-102.5	4d	160-166	22	5d	-	-

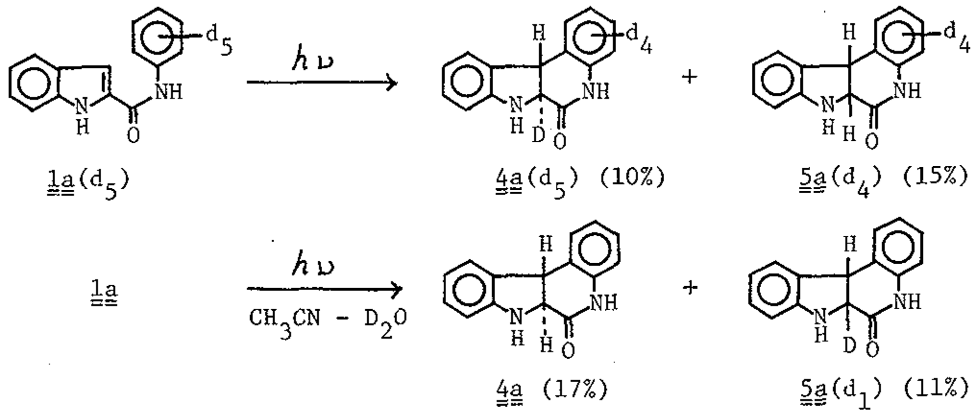
Table 2 Products of Photocyclization

Anilides	oxidative					nonoxidative						
	time(hr)	yield(%)				time(hr)	yield(%)					
1a	1	3a	(77)		–	2 1/2	3a	(22)	4a	(29)	5a	(25)
1b	1 1/3	3b	(71)	5b	(17)	2/3	3b	(26)		–	5b	(58)
1c	2 1/4	3c	(46)	4c	(9)	5	3c	(14)	4c	(26)		–
1d	9	3d	(35)	4d	(20)	2	3d	(17)	4d	(58)		–

ly indicative of a trans and a cis ring fusion for 4 and 5, respectively.[1a,3,4] When treated with a base (NaOH in EtOH), 4a and 4c were converted into 5a, and 5c, respectively, indicating that the cis compounds are more stable than the trans in this series as in the benzothiophenes, in which the stereochemical relation is unambiguously established by X-ray analysis.[1a]

The reaction courses were further examined by an isotope technique as shown in Scheme 2. Anaerobic irradiation of the anilide-2,3,4,5,6-d_5 (1a-(d_5)) gave 5a(d_4), and 4a(d_5) which contains trans 6_a-D in support of the intramolecular 1,5-shift of hydrogen, while the reaction of 1a in acetonitrile containing D_2O afforded 4a and 5a(d_1) demonstrating that, in consistent with the formation of 5a(d_4) from 1a(d_5), the cis-6_aH comes exclusively from protons of the medium.

Scheme 2



A reasonable mechanism which accounts for all these observations is presented in Scheme 1. Photochemically-allowed conrotatory electrocyclic reaction involving the 6π-arylanilide system initially forms an intermediate (**2**) which subsequently undergoes sigmatropic suprafacial 1,5-hydrogen shift to give the trans product (**4**).[1a] When R = H, rapid deprotonation from **2**, for example, may result in intervention of enol (**6**), which would lead preferably to the more stable cis isomer (**5**). This reaction of the five-membered heterocyclic anilide system thus provides a typical example of a solvent-mediated pathway in competition with an intramolecular sigmatropic reaction.[7] Applications of the reaction to synthesizing novel heterocyclic systems are in progress.

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5 Irradiation was performed with a 100 watt high-pressure mercury lamp in a solution of 1 (200 mg) in benzene:ethanol (9:1 v/v 200ml). For anaerobic experiments a solvent was purged with a stream of nitrogen for 30 min.

6 The structures of all the new compounds were supported by elemental analyses and their spectral (uv, ir, nmr, and mass) properties.

7 A similar dual mechanism was invoked by Ninomiya *et al*. in an enamide system.[4b,c]

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