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PHOTOCHEMICAL REACTIONS OF 1,2,3,3a,4,5-HEXAHYDRO-N-PHENYLACETYLINDOL-6-ONES

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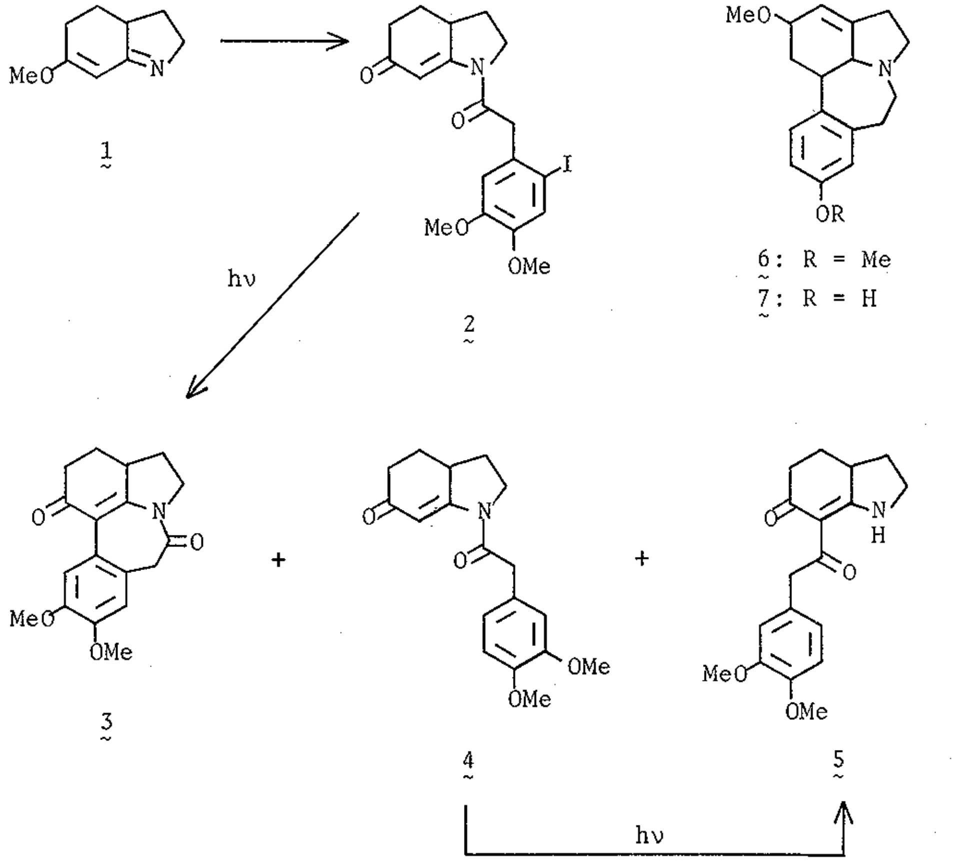
Upon irradiation, 1,2,3,3a,4,5-hexahydro-N-(2-iodo-4,5-dimethoxyphenylacetyl)indol-6-one (2) underwent photocyclization to the indolo[1,7-ab][3]benzazepine derivative (3) and deiodination followed by nonaromatic photo-Fries rearrangement to 1,2,3,3a,4,5-hexahydro-7-(3,4-dimethoxyphenylacetyl)indol-6-one (5), which, upon further irradiation, gave rise to the bibenzyl (11), aldehyde (12), and carboxylic acid (13). The production of these compounds (11 to 13) was accounted for by a mechanism involving an α-cleavage and subsequent ketene formation. The latter process was demonstrated by experiments using several nucleophiles as trapping agents.

We recently described that N-benzoyl-1,2,3,3a,4,5-hexahydroindol-6-one derivatives can be succesfully photocyclized to the pyrrolo[3,2,1-de]phenanthridine ring system.[1] In connection with this, it was of some interest to examine the photochemical behavior of N-phenylacetyl analogs. The present paper reports the results of our investigation on the photochemical reactions of the enamido ketones which involve a new intramolecular cyclization and formation of some products accounted for by a mechanism involving rearrangement followed by photolytic C–C bond cleavage.

Our investigation was initiated by irradiation of the enamido ketone (2) in anticipation of ring closure to the indolobenzazepine system, which is the fundamental skeleton of new structure 6 and 7 recently proposed for alkaloids, cocculine and cocculidine, respectively.[2]

Treatment of the iminoenol ether (1)[3] with 2-iodo-4,5-dimethoxyphenylacetyl chloride in chloroform in the presence of aqueous potassium carbonate resulted in N-acylation with C–O bond cleavage *in situ* to give the enamido ketone (2), mp 213–214°, in 89% yield. The presence of an enamido ketone function in 2 was characterized by ir absorption bands at 1685, 1640, 1600 cm^{-1} and the nmr data for the olefinic proton which appeared as doublet (J = 2 Hz) at δ 6.69, due to allylic coupling with C-3a proton. Irradiation[4] of 2 in dioxane in the presence of triethylamine for 95 hr afforded the desired cyclized product (3) (10%), mp 196.5–197°, together with the deiodinated product (4) (23%), mp 142–143°, and the rearranged product (5) (14%), mp 92–93°. The structure of the cyclized product (3) was confirmed by its nmr spectrum, in which no olefinic proton was observed and one of two aromatic proton singlets observed appeared at lower field (δ 7.16) than usual, indicating that it is forced into the deshielding zone of 1-oxo group owing to the ring formation. The ir spectrum [ν_{max} ($CHCl_3$) 1685sh, 1675sh, 1650, and 1605 cm^{-1}] gave evidence for ketone and amide groups and unsaturation.

The deiodinated product (4) was identified by direct comparison with an authentic sample prepared from the iminoenol ether (1)



1

2

6: R = Me
7: R = H

3

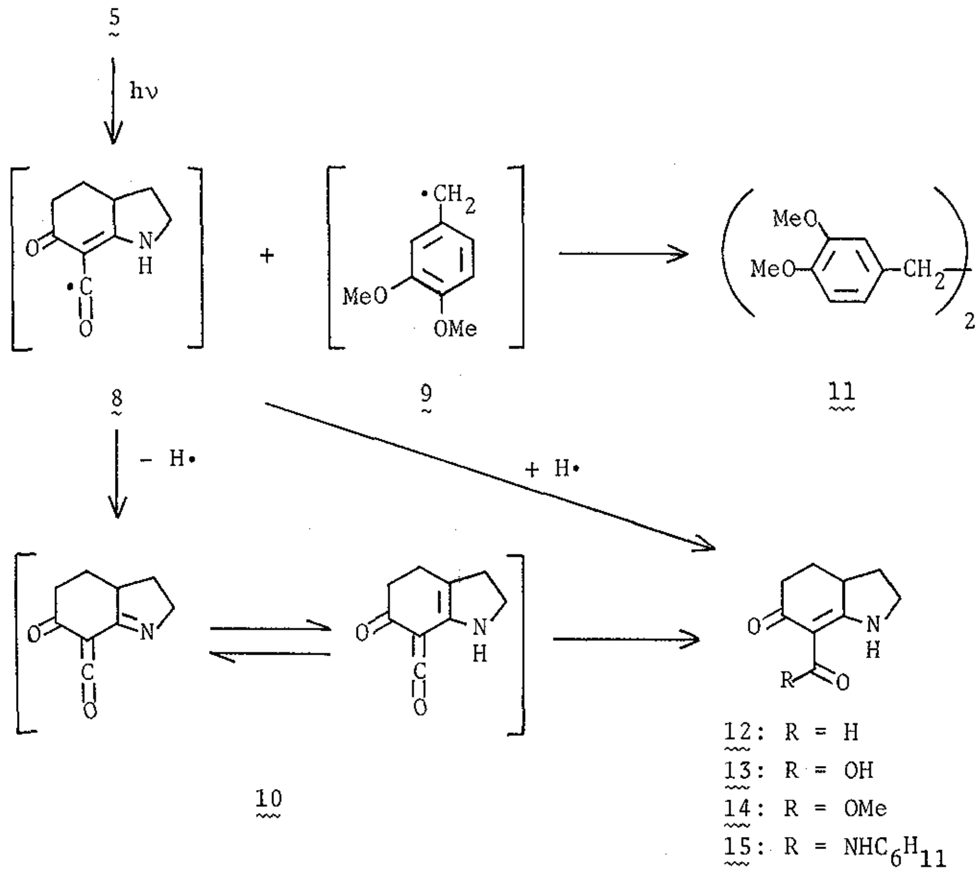
4

5

and 3,4-dimethoxyphenylacetyl chloride in a similar manner for 2. Finally, the structural evidence for the rearranged product (5) was provided by its nmr spectrum whose absorption pattern in the region about δ 1.5–4.0 (9H) was closely similar to that of 4, indicating the presence of the 1,2,3,3a,4,5-hexahydroindol-6-one moiety as a common structural unit. Furthermore, the spectrum showed a one-proton broad singlet at δ 10.49 attributable to the imine hydrogen exchangeable with deuterium and there was no olefinic signal expected at around δ 6.7. Additional evidence for the above assignment was obtained from the ir spectrum [ν_{max} ($CHCl_3$) 3250 (NH) and 1600 (C=O and C=C) cm^{-1}].

It is postulated that during the photolysis of 2, hydrogen transfer occurs competitively with cyclization, yielding 4, and the product (4) undergoes a nonaromatic photo-Fries rearrangement. The result compatible with the latter postulation was obtained from the following experiment: irradiation of the deiodinated product (4) (practically synthesized from 1 as mentioned above) itself in dioxane for 110 hr gave the expected rearranged product (5) (27%), accompanied by the unexpected bibenzyl (11) (16%), mp 110.5–111° (lit.[5] 109–110°), and an acidic product (5%), mp 177–179° (sublimed at about 165°). The last product was formulated as the carboxylic acid (13) on the basis of the following evidence. The nmr spectral pattern in the aliphatic region (δ 1.5–4.0, 9H) being closely similar to those for both 4 and 5 indicated the presence of the 1,2,3,3a,4,5-hexahydroindol-6-one moiety. In addition, the spectrum exhibited two low-field singlets at δ 9.44

(broad) and 14.99, suggestive of hydrogen bondings of the NH to the C-7 carbonyl group and the OH to the 6-oxo group. The most likely mechanism for the formation of these unexpected compounds (11 and 13) is shown below, involving an α-cleavage producing the acyl and the benzyl radicals, followed by ketene formation and dimerization, respectively. The carboxylic acid may arise by



subsequent chemical process, nucleophilic attack on the intermediate ketene (10) with a trace amount of water included in the solvent. Following trapping experiments gave indication of the intermediacy of the ketene. Thus the rearranged product (5) was irradiated in an acetonitrile–water (1 : 1) solution with a 100 W high pressure mercury arc lamp for 48 hr to give the carboxylic acid (13) (33%), the bibenzyl (11) (28%), and the aldehyde (12) (15%), mp 143–144°. Irradiation of 5 in methanol in the same manner gave the corresponding ester (14) (40%), mp 94–95°, 11 (18%), and 12 (14%). The competition between the aldehyde and ketene formation may be explicable in terms of a pathway concerning the acyl radical (8), which abstracts a hydrogen from the solvent to yield the aldehyde or loses it to yield the ketene.

It was expected that when a more powerful nucleophile was used, the intermediate ketene would be efficiently trapped during irradiation. Accordingly, 5 was irradiated in benzene containing cyclohexylamine for 46 hr to give the corresponding amide (15) (82%), mp 165–166°, and the bibenzyl (11) (35%).

REFERENCES AND NOTES

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3 The former conjugated diene structure[1a] for this compound pre-

pared by the Birch reduction of 6-methoxyindoline was revised to its tautomeric form represented by **1** on a spectral and chemical basis.[1b]

4 All irradiations were carried out under a nitrogen atmosphere at room temperature, unless otherwise stated, using a low pressure mercury arc lamp.

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