

Synthesis of Condensed Heterocyclic Systems V (I):  
11H-Indeno[1,2-b]quinolines from Photochemical and Acid-Catalyzed  
Rearrangements of *trans*-2-(2-Aminobenzylidene)-1-indanones

David C. Lankin (2) and Hans Zimmer (3)

Department of Chemistry, University of Cincinnati, Cincinnati, Ohio 45221

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Previous studies from this and other laboratories have concerned themselves with various aspects of the facile photoinduced ring annelation reaction of  $\alpha$ -(2-hydroxy and 2-aminobenzylidene)carbonyl compounds, (1). Such suitably substituted compounds, upon irradiation, have been shown to undergo a rearrangement which leads to the formation of substituted coumarins (2) (4) ( $X = O$ ), carbostyrils (3) (5) and/or condensed quinolines (4) (5,6) ( $X = NH$ ); the photochemical reaction sequence is outlined in Figure 1.

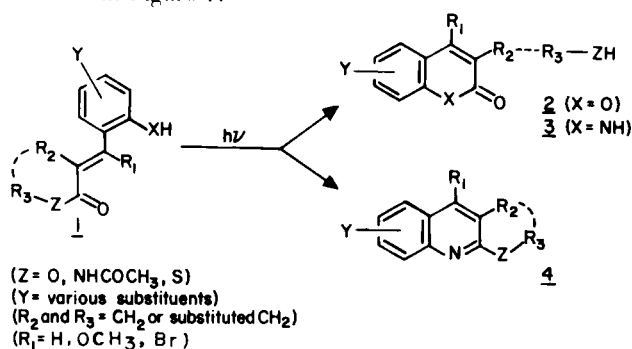


Figure 1

In the present study, we wish to describe a further application of this photochemical reaction to the synthesis of several representative 11H-indeno[1,2-b]quinolines. The synthesis of this ring system has previously been reported (7), though on a rather involved preparative route. The synthetic sequence used in this work is outlined in Figure 2.

Stannous chloride reduction of the nitro compounds (5a) (7a,8) and (5b) (7a) gives the amines (6a) and (6b), respectively. Irradiation of (6a) in methanol for 4 1/3 hours provides an essentially quantitative yield of (7a) (7) as the only photoproduct. The reaction proceeds very smoothly, as shown by the ultraviolet spectra in Figure 3, which displays three isosbestic points at 269 nm, 323 nm and 346 nm. Similarly, irradiation of (6b) in methanol leads to formation of (7b) (7a,7b,9). The rearrangement could also be affected by refluxing (6a) and (6b) in glacial acetic acid, giving (7a) and (7b), respectively, (10).

The structure of the amines (6a,b) was established on the basis of their (I) mode of formation, (II) elemental analysis, (III) spectral properties, and (IV) subsequent chemical and photochemical transformations to (7a) and (7b). Of particular value for identification is the nmr

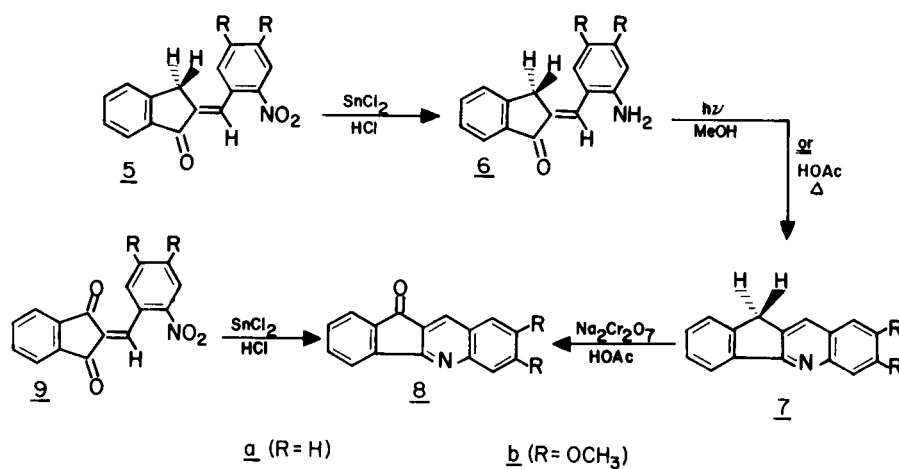


Figure 2

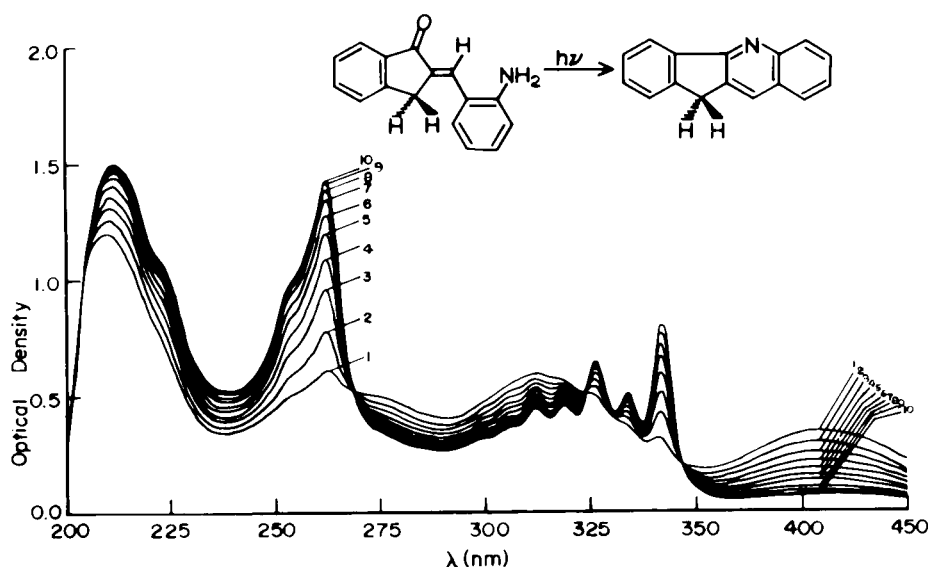
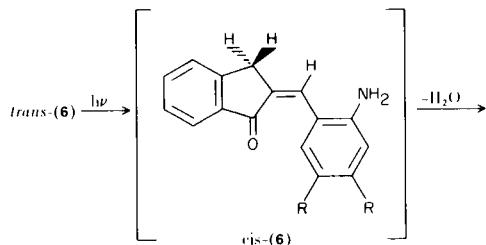


Figure 3. Course of the photolysis of *trans*-2-(2-aminobenzylidene)-1-indanone (**6a**), ( $4.37 \times 10^{-5} M$  in methanol); curve (irradiation time in seconds): 1(0), 2(15), 3(31), 4(45), 5(60), 6(75), 7(90), 8(105), 9(120), 10(135).

spectrum of the amines. The chemical shift for the allyl  $\text{CH}_2$  in (**6a**) was  $5.98 \delta$  (d) while the vinyl H was  $2.62 \delta$  (t); the splitting for  $-\text{CH}_2-\text{CH}=\text{CH}-$  was 1.5 Hz. The corresponding values for **6b** were  $6.04 \delta$  (d),  $2.25 \delta$  (t), and 1.5 Hz. In addition **6a** and **6b** showed typical amine peaks at 3350, 3250 and 3350, 3240 respectively, in their ir spectrum (11). That (**7a**) and (**7b**) were indeed the observed rearrangement products was unequivocally confirmed by their oxidation to (**8a**) and (**8b**), respectively, with sodium dichromate in acetic acid. Spectral comparison of the oxidation products to that of pure samples of (**8a,b**), obtained from an independent synthesis from (**9a,b**) (12), showed them to be identical.

Several points related to the work described are noteworthy. First of all, the photochemical transformation (**6**)  $\rightarrow$  (**7**) may be viewed as involving an initial light-catalyzed *trans*  $\rightarrow$  *cis* isomerization to *cis*-(**6**), which then undergoes a thermal cyclodehydration reaction to (**7**).



This is consistent with the mechanistic interpretation, proposed by us (4a,b,d,5a) earlier and others (4c) to explain the general course of these types of rearrangements. Secondly, it is of interest to note that in an earlier report, which describes the zinc/acetic acid reduction of (**5a,b**)

(**7a**), only the heterocyclics (**7a,b**) were obtained. At that time, the intermediacy of the amines (**6a,b**), which were considered to be unstable under the conditions of the reduction and which cyclized to (**7a,b**), was postulated. The results of the acetic acid catalyzed transformation of (**6a,b**)  $\rightarrow$  (**7a,b**) provide strong evidence for the involvement of (**6a,b**) in the reductive cyclization reaction (**7a**) of (**5a,b**) to (**7a,b**). Therefore **6b**, according to the occurrence of sharp isosbestic points, never will occur in any appreciable concentration during the course of the reaction. Further applications of this reaction to the synthesis of other condensed nitrogen heterocyclic systems is currently in progress.

#### EXPERIMENTAL

##### General Procedures.

Spectra were determined as follows: ir, chloroform solution, Perkin Elmer 700; uv, methanol solution, Unicam SP-800A; nmr, deuteriochloroform solution, Bruker HFX-10; mass spectra, Hitachi-Perkin Elmer RMU-7A operating at 70 v. Analyses by thin layer chromatography (tlc) involved Eastman Kodak pre-coated silica gel with fluorescent indicator as the adsorbent, eluted with chloroform and developed with iodine and/or detected by ultraviolet light. Elemental analyses were performed by Galbraith Laboratories, Knoxville, Tennessee; all melting points are uncorrected.

##### *trans*-2-(Nitrobenzylidene)-1-indanones. General Procedure.

To a solution of substituted 2-nitrobenzaldehydes (0.05 mole) in 80% sulfuric acid was slowly added 1-indanone (0.05 mole). The solution was stirred at room temperature for 24-36 hours after which the reaction mixture was slowly poured into 400 ml. of water and the resulting precipitate filtered. The crude 2-(2-nitrobenzylidene)-1-indanones were recrystallized from the appropriate solvent.

**trans-2-(2-Nitrobenzylidene)-1-indanone (5a).**

Obtained as a pale yellow solid m.p. 166-168° from 95% ethanol (Lit. (6a,b,7) 169-170°, 95% ethanol),  $R_f = 0.52$ , in 68% yield.

**trans-2-(4,5-Dimethoxy-2-nitrobenzylidene)-1-indanone (5b).**

Obtained as a yellow solid m.p. 208-210° from 95% ethanol (Lit. (6a) 210° from acetic acid),  $R_f = 0.41$ , in 90% yield.

**Reduction of 5a.**

To a solution of 20 g. of stannous chloride dihydrate in 70 ml. of concentrated hydrochloric acid was added 5.0 g. (0.019 mole) of **5a**. After stirring the reaction mixture at room temperature for 12-18 hours, it was cooled to 0° and with constant stirring neutralized by slow addition of ammonium hydroxide solution to pH 8-9. Care was taken to maintain the temperature at between 0-5°. The basic solution was stirred for an additional 1.5 hours in the cold and then filtered. The collected residue was dried, combined with sand and extracted with chloroform in a Soxhlet apparatus for 6 days. The chloroform was evaporated and the resulting solid was recrystallized from methanol, providing 1.3 g. (37%) of *trans*-2-(2-aminobenzylidene)-1-indanone (**6a**) as a deep yellow solid m.p. 155-157° with decomposition,  $R_f = 0.22$ . The mass spectrum of **6a** showed a molecular ion at  $m/e$  235.

*Anal.* Calcd. for  $C_{16}H_{13}NO$ : N, 5.95. Found: N, 5.55.

**Reduction of 5b.**

To a solution of 15 g. of stannous chloride dihydrate in 175 ml. of concentrated hydrochloric acid was added 5.0 g. (0.015 mole) of **5b**. After stirring the reaction mixture at room temperature for 12-24 hours, it was cooled to 0° and, with constant stirring, neutralized as in the case of **5a**. The collected residue dried, being careful to protect the filter cake from light, and then combined with sand and extracted with chloroform for 5-6 days in a Soxhlet apparatus. Solutions of the product were periodically removed to prevent the product from being heated for extended periods of time. The combined chloroform extracts were evaporated providing 1.7 g. (37.5%) of *trans*-2-(2-amino-4,5-dimethoxybenzylidene)-1-indanone (**6b**) as small red needles m.p. 165-166° dec.,  $R_f = 0.11$ . The mass spectrum for **6b** showed a molecular ion at  $m/e$  295.

*Anal.* Calcd. for  $C_{18}H_{17}NO_3$ : N, 4.74. Found: N, 4.97.

**General Photolysis Procedure.**

All preparative irradiations were conducted using a Hanovia Type L 450 watt mercury arc lamp. The solutions to be irradiated were placed in Pyrex test tubes (25 mm x 200 mm), which held an effective volume of 50 ml. Each tube was sealed with a serum cap and attached to the Hanovia quartz immersion well, 5-10 mm away from the light source. The entire apparatus was immersed in a water filled Dewar flask which was used as a cooling bath. The temperature was maintained at 10-15° by periodic addition of crushed ice. Spectroscopic scale irradiations were conducted on solutions (approx.  $5 \times 10^{-5} M$ ) which were placed in a cuvette. The cuvette was then attached to the Hanovia quartz immersion well. The time intervals which were chosen, depended on the rate of photolysis. In both preparative and spectroscopic irradiations, a Pyrex filter, which was fitted between the lamp and the quartz jacket, was employed. Control experiments on all compounds which were irradiated showed them to be totally unreactive in the dark in the solvents in which they were irradiated.

**Irradiation of 6a.**

A solution of **6a** (0.5 g., 2.13 mmoles) in 50 ml. anhydrous

methanol was irradiated for a total of 4 1/3 hours, the course of the photolysis being followed by tlc. Evaporation of the solvent gave a tan solid, which was homogeneous to tlc. Recrystallization from aqueous methanol gave 0.450 g. (97.5%) of 11*H*-indeno[1,2-*b*]quinoline, (**7a**) m.p. 167-168° (Lit. (6a) 168-170°)  $R_f = 0.47$ .

**Irradiation of 6b.**

A solution of **6b** (0.5 g., 1.69 mmoles) in 100 ml. of anhydrous methanol was irradiated for a total of 40 hours, the reaction being followed as above. The solvent was evaporated and the residue recrystallized from methanol. In addition to some tar which was formed in the reaction, 55 mg. of a solid, which was homogeneous to tlc, was shown to be 7,8-dimethoxy-11*H*-indeno[1,2-*b*]quinoline (**7b**) as pale reddish crystals, m.p. 196-197.5° (Lit. (6c) 197°),  $R_f = 0.54$ .

**Acid-Catalyzed Rearrangement of 6a.**

A solution of **6a** (0.5 g., 2.13 mmoles) in 12 ml. of glacial acetic acid was refluxed for 4 hours. The acetic acid solution was diluted with 50 ml. of water and extracted with methylene chloride (4 x 50 ml.). The combined methylene chloride extracts were back extracted with water (3 x 75 ml.) and the organic phase dried (anhydrous sodium sulfate) and evaporated. The resulting residue was recrystallized from aqueous methanol affording 0.206 g. (56.5%) of **7a**. Spectral comparison of **7a** obtained from the photolysis and from the acid-catalyzed rearrangement of (**6a**) showed them to be identical.

**Acid-Catalyzed Rearrangement of (6b).**

A solution of **6b** (0.3 g., 1.02 mmoles) in 15 ml. of acetic acid was refluxed for 4 hours. After the workup as described for **6a**, the resulting residue was recrystallized from aqueous ethanol providing 0.14 g. (50%) of **7b**. Spectral and tlc comparison of **7b**, obtained from the photolysis and the acid-catalyzed rearrangement of **6b** showed them to be identical.

**Oxidation of 7a (6c).**

A solution of **7a** (0.32 g., 1.55 mmoles) and sodium dichromate (0.32 g.) was refluxed for 3.5 hours. The resulting green solution was diluted with water and the precipitated solid was filtered and recrystallized from aqueous methanol giving 0.2 g. (56%) of 11*H*-indeno[1,2-*b*]quinolin-11-one, (**8a**) m.p. 173-174°. Comparison of the oxidation product with that of a pure sample of **8a**, prepared by an independent route (12), showed them to be identical.

**Oxidation of 7b.**

A solution of (0.049 g., 0.177 mmole) and sodium dichromate (0.56 g.) in 10 ml. of glacial acetic acid was refluxed for 1.5 hours. After a similar workup as for **7a**, there was obtained 0.25 g. (48.5%) of 11*H*-indeno[1,2-*b*]quinolin-11-one; **8b**, m.p. 287-289°. Comparison of this oxidation product with that of a pure sample of **8b**, prepared by an independent route (12), showed them to be identical.

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(9a) In this case, compound **7b** underwent a subsequent photochemical reaction at a rate which was comparable to its formation from **6b**. Compound **7b** could be isolated from the photolysis, however, after evaporation of the methanol, in which it was irradiated, followed by heating (50-70°) of the residue. The observed photochemical reaction of **7b** possibly involves addition of the solvent to **7b**, a reaction which has recently been examined in the case of simple quinolines (**9b**). Indeed, if either **7a** or **7b** are irradiated separately in methanol, both undergo a photochemical reaction, **7a** reacting slower than **7b**. The exact nature of this photochemical reaction is being explored in more detail and the results will be the subject of a subsequent publication. (b) For some examples of solvent addition to nitrogen heterocycles, see e.g., F. R. Stermitz, C. C. Wei and C. M. O'Donnell, *J. Am. Chem. Soc.*, 92, 2745 (1970) and references cited therein.

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