

Photolysis of 1-Benzoyl- and 1- and 3-*o*-Iodobenzoyl-indole

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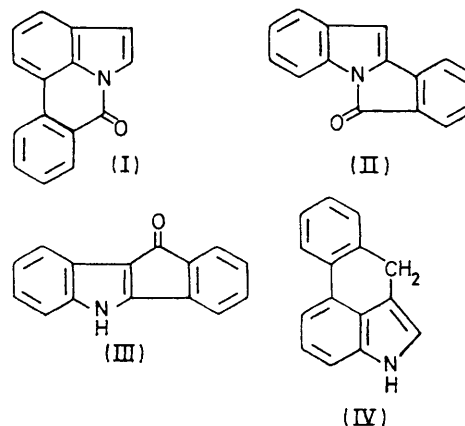
Irradiation of 1-benzoylindole in ethanol gave mainly 3-benzoylindole and a small amount of indole. 1-*o*-Iodobenzoylindole in benzene gave a mixture of isoindolo[2,1-*a*]indol-6-one (II) and indeno[1,2-*b*]indol-10(5*H*)-one (III); the latter was also obtained by irradiation of 3-*o*-iodobenzoylindole. Irradiation of 1-*o*-iodobenzoylindole gave pyrrolo[3,2,1-*de*]phenanthridin-7-one (I) in small yield.

SOMEI AND NATSUME have reported¹ that irradiation of a number of 1-acylindoles affords mainly 3-acylindoles together with smaller amounts of the 4- and 6-acyl derivatives. We record here results obtained with some related compounds.

In accord with the published work¹ irradiation of 1-benzoylindole in ethanol led mainly to migration of the benzoyl group to the 3-position. Smaller amounts of indole were also formed, but no derivatives resulting from migration of the benzoyl group into the six-membered ring were detected, although their presence among the minor products is not precluded. It has been suggested¹ that the products formed on irradiation of 1-acylindoles may arise by concerted sigmatropic rearrangement. It seems equally feasible, in the absence of evidence to the contrary, that the formation of 3-benzoylindole in the present experiments takes place by initial homolysis of the amide bond followed by recombination of radicals within a solvent cage either at nitrogen or at C-3. Alternatively, abstraction of a hydrogen atom from the solvent by the indolyl radical would give indole. This course would be in accord with the accepted mechanism for the photo-Fries rearrangement of acetanilide.²

Photocyclisation of iodo-aromatic compounds has been used to prepare a variety of polycyclic structures;^{3,4} we examined the irradiation of 1-*o*-iodobenzoylindole in the hope of obtaining the pyrrolophenanthridinone (I). However, the main product (23% yield) appeared to be isoindolo[2,1-*a*]indol-6-one (II), formed by cyclisation at C-2 of the indole nucleus. The n.m.r. spectrum shows a singlet due to the indole C-3 proton at τ 3.13 but no signal corresponding to the C-2 proton.⁵ In the spectrum

of 1-benzoylindole also the signal due to the C-2 proton is not distinguishable, being obscured by the other aromatic proton signals, but in this case the C-3 proton signal is a doublet (J ca. 4 Hz).



The second product from the irradiation of 1-*o*-iodobenzoylindole was indeno[1,2-*b*]indol-10(5*H*)-one (III), presumably formed by migration of the *o*-iodobenzoyl group from nitrogen to C-3, followed by cyclisation at C-2, since the yellow compound (II) itself is not isomerised to (III) on irradiation. In agreement, compound (III) is also produced by irradiation of 3-*o*-iodobenzoylindole. Its n.m.r. spectrum shows no signal at τ 3.0—3.3 characteristic of the C-2 proton of an indole;⁵ however neither 3-acetyl- nor 3-benzoyl-indole shows a signal at this position either, presumably because of the deshielding effect of the carbonyl group. Reduction of compound (III) with lithium aluminium hydride afforded a product with properties in agreement with those

¹ M. Somei and M. Natsume, *Tetrahedron Letters*, 1973, 2451.

² H. Shizuka and I. Tanaka, *Bull. Chem. Soc. Japan*, 1968, **41**, 2345; H. Shizuka, *ibid.*, 1969, **42**, 52, 57, 909; H. J. Hagemann, *Rec. Trav. chim.*, 1972, **91**, 1447.

³ Cf. R. K. Sharma and N. Kharasch, *Angew. Chem. Internat. Edn.*, 1968, **7**, 36.

⁴ Cf. S. M. Kupchan, J. L. Moniat, R. M. Kanojia, and J. B. O'Brien, *J. Org. Chem.*, 1971, **36**, 2413.

⁵ J.-Y. Lallemand and T. Bernath, *Bull. Soc. chim. France*, 1970, **11**, 4091; J. Hutton and W. A. Waters, *J. Chem. Soc.*, 1965, 4253.

reported for 5,10-dihydroindeno[1,2-*b*]indole ⁶ (III; CH₂ for CO) and which showed no n.m.r. signal for an indole C-2 proton, thus eliminating the alternative structure (IV).

Irradiation of 1-benzoylindoline in ethanol gave a complex mixture from which no pure product was isolated. The pyrrolophenanthridine (I) was however obtained by irradiation of *o*-iodobenzoylindoline in benzene. This gave mainly polymeric material but preparative layer chromatography afforded the product (I) in 10% yield. This structure is suggested by the molecular weight (mass spectrometry), the elemental composition, and the n.m.r. spectrum which shows the indole C-3 proton signal as a doublet at τ 3.16. The C-2 proton signal is assumed to be included in the aromatic multiplet at τ 2.20, as it is in the spectrum of 1-benzoylindole.

The iodo-compounds were irradiated in boiling benzene because the compounds were too insoluble in the cold. In ethanol, in which the compounds are more soluble, irradiation resulted in replacement of iodine by hydrogen.³ As observed by other workers,⁴ the addition of sodium thiosulphate solution to the reaction mixture to trap the released iodine decreased the reaction time and increased the yield of cyclisation product.

EXPERIMENTAL

U.v. spectra were measured with a Unicam SP 800 spectrometer for solutions in methanol unless otherwise stated. Routine i.r. spectra were measured with a Perkin-Elmer Infracord and high resolution spectra with a Hilger-Watts H 900 instrument. Mass spectra were recorded with a Hitachi RMU 60 instrument and ¹H n.m.r. spectra with a Perkin-Elmer R10 spectrometer at 60 MHz or a JEOL MH-100 instrument at 100 MHz for solutions in deuteriochloroform or [²H₆]dimethyl sulphoxide, with tetramethylsilane as internal reference.

Two light sources were used in the irradiation experiments, a Phillips HPK BA 15D type 57203B/00 high-pressure mercury vapour lamp and a Hanovia 125 W medium-pressure mercury vapour lamp. The Phillips lamp was usually mounted vertically and externally to the Pyrex reaction vessel, and the solution was maintained at 30–35 °C by a cold finger immersed in the liquid. Alternatively, the lamp was mounted horizontally beneath the vessel and the solution was maintained at reflux by the heat generated by the lamp. The Hanovia lamp was inserted directly into the reaction vessel. An efficient water jacket (of quartz or Pyrex) maintained the solution at 18–20 °C.

1-o-Iodobenzoylindole.—To a solution of sodio-indole [from sodium hydride (0.96 g) and indole (4.1 g) in dimethylformamide (70 ml) at room temperature for 1 h under nitrogen], a solution of *o*-iodobenzoyl chloride (11.1 g) in dimethylformamide (30 ml) was added dropwise and the mixture was stirred at 70 °C for 20 h. Dimethylformamide was evaporated off under reduced pressure, and the resulting red gum chromatographed on alumina. Elution with petroleum containing an increasing proportion of benzene afforded 1-*o*-iodobenzoylindole (3.6 g), which formed prisms, m.p. 92–93° (from light petroleum-ethanol) (Found: C,

52.0; H, 2.8; N, 3.9%; *M*⁺, 347. C₁₅H₁₀INO requires C, 51.9; H, 2.9; N, 4.0%; *M*, 347); ν_{\max} (KBr) 1686 cm⁻¹; λ_{\max} 245, 296, and 302 nm (log ϵ 4.63, 4.02, and 4.04); τ 3.39 (d, *J* 4.0 Hz, 3-H) and 3.05 (d, *J* 4.0 Hz, 2-H); the latter signal was separated from the aromatic multiplet presumably because of the steric effect of the iodine atom on the interaction of the carbonyl group with the five-membered ring (*cf.* 1-benzoylindole).

3-o-Iodobenzoylindole.—A solution of *o*-iodobenzoyl chloride (11.4 g) in ether (50 ml) was added dropwise to a vigorously stirred suspension of indolylmagnesium bromide [from ethylmagnesium bromide (0.045 mol) and indole (5.15 g)] in ether (70 ml) at 0 °C. The mixture was boiled for 1 h then cooled, and the complex was decomposed with aqueous ammonium chloride. The precipitated product was filtered off, washed with ether, and crystallised from methanol, giving *needles*, m.p. 185–186° (Found: C, 52.0; H, 2.85; N, 3.9%; *M*⁺, 347. C₁₅H₁₀INO requires C, 51.9; H, 2.9; N, 4.0%; *M*, 347); ν_{\max} (KBr) 3255 and 1605 cm⁻¹; λ_{\max} 210, 246, 263, and 309.5 nm (log ϵ 4.56, 4.23, 4.09, and 4.17); τ 1.5–2.6 (m, aromatic and 2-H).

1-o-Iodobenzoylindoline.—*o*-Iodobenzoyl chloride (9.2 g) was added dropwise to a stirred solution of indoline (3.5 g) in pyridine (15 ml). After 2.5 h the mixture was poured into water (100 ml), ether was added, and the mixture was vigorously stirred. The precipitate was filtered off, washed with ether and water, and crystallised from light petroleum-ether to give *prisms* (7.9 g), m.p. 124–125° (Found: C, 51.7; H, 3.8; N, 3.9%; *M*⁺, 349. C₁₅H₁₂INO requires C, 51.7; H, 3.5; N, 4.0%; *M*, 349); λ_{\max} 233, 257, 267, 283, and 291.5 nm (log ϵ 4.15, 4.12, 4.11, 3.91, and 3.86); τ 5.75 (t) and 6.28 (t) (N·CH₂) [*cf.* *N*-benzoylindoline, τ 5.98 (t, N·CH₂)].

Photolysis of 1-Benzoylindole.—A stirred solution of 1-benzoylindole (150 mg) in ethanol (160 ml) was irradiated at room temperature, through quartz, with light from the Hanovia medium-pressure lamp. After 3 h the recovered product was chromatographed on alumina and gave 3-benzoylindole (59 mg) as pale yellow crystals from methanol, m.p. and mixed m.p. 240–241°. T.l.c. and g.l.c. (135 °C; 2.5% SE30 on Chromosorb W) of the crude product showed the presence of about 7% of indole.

*Indeno[1,2-*b*]indol-10(5H)-one* (III).—A mixture of 3-*o*-iodobenzoylindole (165 mg), sodium thiosulphate (200 mg),⁴ benzene (190 ml), and water (2 ml) was irradiated through Pyrex at reflux with light from the Phillips high-pressure lamp. The reaction was monitored by t.l.c. and u.v. spectroscopy. After 15 h the solvent was evaporated off and the crude product was chromatographed on silica gel. Elution with benzene-chloroform mixtures gave a red solid (100 mg); crystallisation from methanol gave red *prisms*, m.p. 326° (Found: C, 81.9; H, 4.2; N, 6.5%; *M*⁺, 219. C₁₅H₉NO requires C, 82.2; H, 4.1; N, 6.4%; *M*, 219); ν_{\max} (KBr) 3230 and 1668 cm⁻¹; λ_{\max} 219, 222infl, 229, 233, 262infl, 267, 276, 289, 302, 313, 349, and 439.5 nm (log ϵ 4.30, 4.27, 4.22, 4.21, 4.27, 5.59, 4.69, 4.03, 4.04, 4.01, 3.40, and 289).

Reduction of this compound (29 mg) with lithium aluminium hydride (30 mg) in boiling ether (30 ml) for 3.5 h gave 5,10-dihydroindeno[1,2-*b*]indole (10.9 mg) as *needles*, m.p. 226–227° (lit.,⁶ 227–228°); λ_{\max} 228infl,

⁶ Y. Kanaoka, Y. Ban, K. Miyashita, K. Irie, and O. Yonemitsu, *Chem. and Pharm. Bull. (Japan)*, 1966, **14**, 934; Y. Kanaoka, Y. Ban, O. Yonemitsu, K. Irie, and K. Miyashita, *Chem. and Ind.*, 1966, 473; R. Huisgen and I. Ugi, *Annalen*, 1957, **610**, 57.

241inf, 246, 255inf, 264inf, 322, and 336 nm ($\log \epsilon$ 4.17, 4.30, 4.33, 4.10, 3.86, 4.38, and 4.19); τ 6.30 (s, 2-H).

Isoindolo[2,1-a]indol-6-one (II).—A mixture of 1-*o*-iodobenzoylindole (165 mg), sodium thiosulphate⁴ (250 mg), benzene (190 ml), and water (5 ml) was irradiated through Pyrex at reflux with light from the Phillips high-pressure lamp. After 8 h the recovered product was separated by preparative layer chromatography, with benzene as eluant. The fastest running band contained starting material (13 mg); the intermediate band gave yellow *needles* (35 mg), m.p. 150–151°, after further purification by t.l.c. and sublimation at 110° and 0.05 mmHg (Found: C, 82.25; H, 4.2; N, 6.1%; M^+ , 219. $C_{15}H_9NO$ requires C, 82.2; H, 4.1; N, 6.4%; M , 219); λ_{max} 231, 235.5, 241inf, 270inf, 275, 288, 301, and 354 nm ($\log \epsilon$ 4.33, 4.33, 4.23, 4.40, 4.47, 4.08, 4.14, and 3.83). A third band gave

indeno[1,2-*b*]indol-10(5*H*)-one (III) (10.2 mg) as red *needles*, m.p. and mixed m.p. 324°.

Pyrrolo[3,2,1-de]phenanthridin-7-one (I).—A mixture of 1-*o*-iodobenzoylindoline (250 mg) and sodium thiosulphate (200 mg) in benzene (190 ml) and water (10 ml) was irradiated (9 h) as described above. Preparative layer chromatography of the crude product (eluant benzene–chloroform, 1 : 1) gave pale yellow *flakes* (24 mg), m.p. 144–145° (from light petroleum–ethanol) (Found: C, 81.8; H, 4.15; N, 6.3%; M^+ , 219. $C_{15}H_9NO$ requires C, 82.2; H, 4.1; N, 6.4%; M , 219); λ_{max} 223.5, 229, 248, 261, 280, 291, 331, 342, and 358 nm ($\log \epsilon$ 4.70, 4.73, 4.02, 3.91, 3.95, 4.00, 4.12, and 4.05).

We thank the S.R.C. for a studentship to N. E.

[4/315 Received, 18th February, 1974