Molecular Rearrangements. VIII. The Equilibration of 3,3-Dimethyl-2-phenyl- and 2,3-Dimethyl-3-phenyl-3*H*-indoles[1]

FRANCIS J. EVANS,[2a] GLORIA G. LYLE, JAMES WATKINS,[2b] AND ROBERT E. LYLE[2c]

Department of Chemistry of the University of New Hampshire, Durham, N. H.

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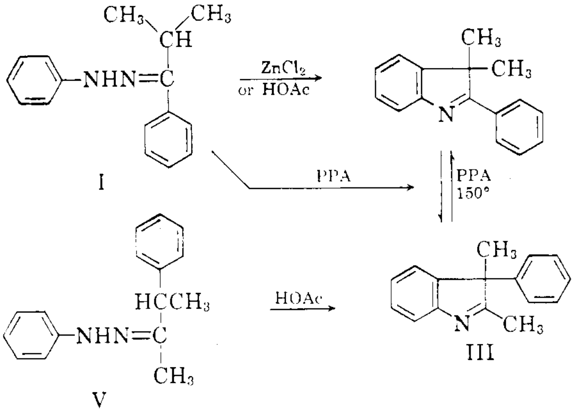
The reaction of isobutyrophenone phenylhydrazone or 3-phenyl-2-butanone phenylhydrazone with polyphosphoric acid gave an equilibrium mixture of 3,3-dimethyl-2-phenyl-3*H*-indole and 2,3-dimethyl-3-phenyl-3*H*-indole contrary to previous reports. The preparation of the 3*H*-indoles from the phenylhydrazones can be accomplished without equilibration in acetic acid. Some features of the equilibration have been investigated. The spectroscopic properties of the 3*H*-indoles are reported.

The acid-catalyzed conversion of phenylhydrazones to indoles or 3*H*-indoles (pseudoindoles) has been investigated extensively since the initial description of the reaction by Fischer.[3] The rearrangements of oxindoles,[4] indoxyls,[4] and some 2-unsubstituted 3*H*-indoles to indoles[5] by reaction with acid catalysts are also well known. The interconversion or equilibration of 3*H*-indoles by acids had not been described prior to the preliminary communication of this work[1] and the recent publications by Nakazaki and co-workers.[6] The Plancher rearrangement, which may now be considered to be such a reaction, was observed previously only with 3*H*-indole quaternary salts.[7]

The investigation of the reaction mixture from the treatment of isobutyrophenone phenylhydrazone (I) with polyphosphoric acid at 180°, following the reaction procedure of Kissman, Farnsworth, and Witkop,[8] showed it to be a mixture of two basic products subsequently identified as 3,3-dimethyl-2-phenyl-3*H*-indole (II) and 2,3-dimethyl-3-phenyl-3*H*-indole (III). This mixture of products may not have been obtained by Kissman, Farnsworth, and Witkop,[8] for lower temperatures do not cause the conversion of II to III.



The first attempts to form II from isobutyrophenone phenylhydrazone (I) gave complex mixtures of 1-acetylphenylhydrazide (IV),[9] acetanilide, and the two 3*H*-indoles (II and III).

The reaction mixture of pure isobutyrophenone phenylhydrazone (I) with polyphosphoric acid formed two picrates. The picrate (IIP), more soluble in ethanol, melted at the temperature reported for 3,3-dimethyl-2-phenyl-3*H*-indole picrate by Kissman, Farnsworth, and Witkop[8] and Leuchs[12] and was identical with the only picrate isolated from the reaction mixture of I with acetic acid or zinc chloride.[12] The second picrate (IIIP) from the reaction mixture of I with PPA was higher melting and less soluble than IIP. The picrate IIIP was identical with this derivative formed from the product of the reaction of 3-phenyl-2-butanone phenylhydrazone (V) with acetic acid.

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(1) This material was presented in part before the Division of Organic Chemistry at the 136th American Chemical Society in Atlantic City, N. J., September 13–18, 1959, and in a preliminary communication, F. J. Evans and R. E. Lyle, *Chem. & Ind.*, 497 (1960).

(2) (a) Taken in part from the thesis to be presented by F. J. E. to the Graduate Faculty of the University of New Hampshire in partial fulfillment of the Ph.D. degree. Public Health Service Predoctoral Fellow 1959–; (b) Taken in part from the Bachelor's thesis of J. W.; (c) The author to whom inquiries should be addressed.

(3) E. Fischer and T. Schmidt, *Ber.*, **21**, 1072 (1888).

(4) B. Witkop, *J. Am. Chem. Soc.*, **72**, 614 (1950), and B. Witkop and J. B. Patrick, *J. Am. Chem. Soc.*, **73**, 558 (1951).

(5) R. Robinson and H. Suginome, *J. Chem. Soc.*, 298 (1932); J. Harley-Mason and A. H. Jackson, *J. Chem. Soc.*, 374 (1955); G. Jones and T. S. Stevens, *J. Chem. Soc.*, 2344 (1953); and I. Brunner, *Monatsh.*, **16**, 850 (1895).

(6) S. Isoe and M. Nakazaki, *Chem. & Ind.*, 1574 (1959); M. Nakazaki, *Bull. Chem. Soc. Japan*, **33**, 461 (1960); M. Nakazaki, K. Yamamoto, and K. Yomagami, *Bull. Chem. Soc. Japan*, **33**, 466 (1960); and M. Nakazaki, *Bull. Chem. Soc. Japan*, **33**, 472 (1960).

(7) G. Plancher and Bonavia, *Gazz. chim. ital.*, **28**, 333, 405 (1898); *Gazz. chim. ital.*, **32**, 409, 414 (1902); and H. S. Boyd-Barrett, *J. Chem. Soc.*, 321 (1932).

(8) H. M. Kissman, D. W. Farnsworth, and B. Witkop, *J. Am. Chem. Soc.*, **74**, 3948 (1952), and B. Witkop, J. B. Patrick, and H. M. Kissman, *Chem. Ber.*, **85**, 949 (1952).

(9) This is formed by the reaction of phenylhydrazine and acetic acid during the preparation of isobutyrophenone phenylhydrazone (I). This further led to the discovery that the melting point listed for I in the standard references[10] is a perpetuating error (the original reference[11] is to isobutyrophenone semicarbazone), and that the melting points listed for many phenylhydrazones of sterically hindered ketones are suspiciously similar to the melting point of acetylphenylhydrazide (m.p. 128°). The correct melting point of the phenylhydrazone of isobutyrophenone is 29–30° and of the phenylhydrazone of 3-phenyl-2-butanone (*vide infra*) is 73–74°.

(10) For example, Huntress and Mullikan, "Identification of Pure Organic Compounds," Order 1, J. Wiley and Sons, Inc., New York, 1941, p. 391.

(11) A. Claus, *J. prakt. Chem.*, **46**, 480 (1892).

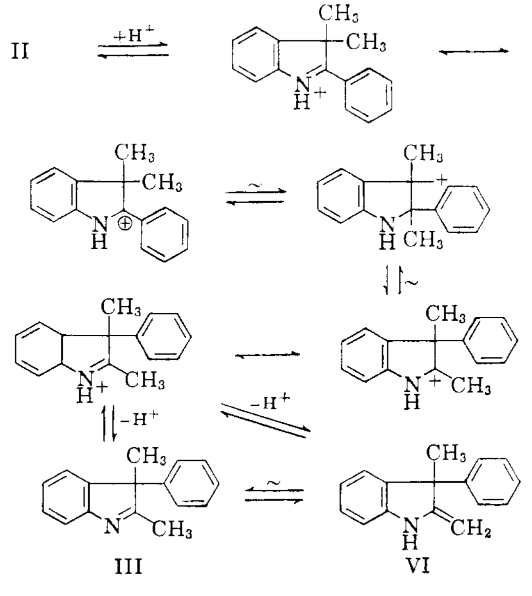
(12) H. Leuchs, A. Heller, and A. Hoffmann, *Ber.*, **62**, 877 (1929).

The bases (II and III) were prepared from the picrates (IIP and IIIP) by passing a solution of the picrates over Dowex or basic alumina. The ultraviolet ($\lambda_{\max}^{C_2H_5OH}$ 227, 233, 244, 305 mμ; log $\epsilon_{\max}$ 4.10, 4.09, 3.99, 4.15) and infrared absorption spectra of the base II were identical with those reported for 3,3-dimethyl-2-phenyl-3*H*-indole (II)[8,12] and were in accord with the properties predicted for this structure. The base (III) of IIIP was unstable and appeared to absorb oxygen from the air rapidly, for the elemental analyses for carbon, hydrogen, and nitrogen consistently accounted for only 98%. After standing for several months, one sample of 2,3-dimethyl-3-phenyl-3*H*-indole (III) crystallized. This solid effected the crystallization of all the other samples of III and, after purification, gave correct elemental analyses for III. The derivatives of the base III, picrate (IIIP), methiodide (IIIM), and dihydro compound gave the anticipated analytical values for carbon and hydrogen. The ultraviolet absorption spectrum of III was weaker than that of II ($\lambda_{\max}^{C_2H_5OH}$ 260 mμ; log $\epsilon_{\max}$ 3.72) and was consistent with the structure 2,3-dimethyl-3-phenyl-3*H*-indole (III). The infrared spectrum of III was decidedly different from that of II showing a strong band at 1588 cm.$^{-1}$, which could be used to detect small amounts of III mixed with II. A qualitative ultraviolet absorption spectrum of such a mixture was so similar to the spectrum of II that the presence of III could not be detected. The proton magnetic resonance spectra of II and III were in agreement with the assigned 3*H*-indole structures (*vide infra*).

The melting point of the methiodide of III was identical with that reported by Boyd-Barrett[7] for the product of the reaction of methyl iodide with 2-phenylindole, which was proved by these authors to be the methiodide of 2,3-dimethyl-3-phenyl-3*H*-indole (III). These data show that 2,3-dimethyl-3-phenyl-3*H*-indole (III) was the structure of III and that III resulted from a rearrangement of 3,3-dimethyl-2-phenyl-3*H*-indole (II) caused by polyphosphoric acid.

This rearrangement is unexpected, for 3,3-dimethyl-2-phenyl-3*H*-indole (II) would be considered to be the thermodynamically favored isomer and result from the rearrangement of III rather than the reverse. This assumption in conjunction with the experimental difficulties in distinguishing III from II recently led to the erroneous conclusions concerning this reaction reported by Nakazaki and co-workers.[6] These authors reported that the phenylhydrazone of 3-phenyl-2-butanone (V) on reaction with zinc chloride, boron trifluoride, or hydrochloric acid produced 3,3-dimethyl-2-phenyl-3*H*-indole (II), therefore eliminating the consideration of the mechanism proposed by Julian[13] for the "Plancher" rearrangement (equation 1), the formation of 1,2,3-trimethyl-3-phenylindolenium iodide (IIIM) from the methylation of 2-phenylindole with methyl iodide. Nakazaki and co-workers, however, assigned the structure II to the product obtained from 3-phenyl-2-butanone phenylhydrazone (V) on the basis of the melting point (170–172°) of the picrate. This value corresponds to the melting point (168–170°) previously reported from this laboratory[1] for the picrate of 2,3-dimethyl-3-phenyl-3*H*-indole (III) and is eleven to twelve degrees higher than the melting point of authentic II picrate. Nakazaki and co-workers[6] confirmed the identity of the 3*H*-indole picrate from V with the picrate of the product from the reaction of isobutyrophenone phenylhydrazone (I) with polyphosphoric acid by a mixture melting point. This indicates that Nakazaki and co-workers obtained the same mixture of II and III from the reaction of isobutyrophenone phenylhydrazone (I) as reported from this laboratory and that the picrate isolated from this mixture was the more insoluble picrate, 2,3-dimethyl-3-phenyl-3*H*-indole picrate (IIIP). These results invalidate the conclusions drawn by Nakazaki and co-workers,[6] for the purity of their starting 3*H*-indole (II) and the characterization of their products is in doubt in each reaction they ran.

The acidic conditions necessary for these rearrangements require that the reactive species be the conjugate acid of the indole or 3*H*-indole. The development of the positive charge in this salt, of course, would promote the twofold Wagner-Meerwein type rearrangement proposed by Nakazaki and co-workers; however, a more complex pathway including ring-chain tautomerism cannot be ignored.



The PMR spectra of the 3*H*-indoles are shown in Fig. 1, and it will be noted that there is no absorp-

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(13) P. L. Julian, E. W. Meyer, and H. C. Pring, "Heterocyclic Compounds," Vol. 3, R. C. Elderfield, ed., J. Wiley and Sons, Inc., New York, 1952, p. 106.

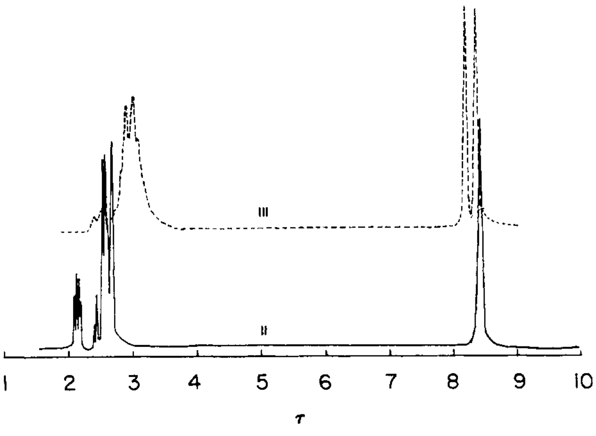

Fig. 1.—The PMR spectra of 3,3-dimethyl-2-phenyl-3*H*-indole (II) and 2,3-dimethyl-3-phenyl-3*H*-indole (III)

tion which can be attributed to a vinyl hydrogen as would be contained in the tautomer VI. The presence of the two different methyl groups is indicated by the peaks at 8.41 τ and 8.18 τ. The peak at 8.41 τ results from the 3-methyl substituent as indicated by a comparison with the PMR spectrum of 2-phenyl-3,3-dimethyl-3*H*-indole (II) shown in Fig. 1. The methyl absorption peak in this compound is also at 8.41 τ. The absorption due to the 2-methyl substituent in 2,3-dimethyl-3-phenyl-3*H*-indole evidently must be the peak at 8.18 τ. These values are in good agreement with those given by Witkop and co-workers for methylindoles.[14] Lack of evidence for the exocyclic double bond tautomer VI or the open chain ketoamine in dilute solutions in nonpolar solvents, however, does not eliminate these compounds as intermediates in the rearrangement in polyphosphoric acid.

In an effort to determine the conditions necessary for the rearrangement of 3*H*-indoles, the reactions of 3,3-dimethyl-2-phenyl-3*H*-indole (II) with a number of acidic reagents at varying temperatures were determined. The products in each case were analyzed by infrared spectroscopy and the detection of molecular rearrangement to the 2,3-dimethyl-3-phenyl-3*H*-indole (III) was determined by the presence of absorption at 1585 cm.$^{-1}$ and 1375 cm.$^{-1}$. With polyphosphoric acid no significant rearrangement was observed at temperatures below 150°. At 150° an equilibration occurred with the composition of the reaction mixture remaining constant after about two hours of heating. The composition of the equilibrium mixture was shown to be approximately 70% 2,3-dimethyl-3-phenyl-3*H*-indole (III) and 30% 3,3-dimethyl-2-phenyl-3*H*-indole (II) by ultraviolet spectroscopic analyses.[15] Approaching the equilibrium by reaction of 2,3-dimethyl-3-phenyl-3*H*-indole (III) with polyphosphoric acid at 150° gave an equilibrium mixture of similar composition. The rearrangement of 3,3-dimethyl-2-phenyl-3*H*-indole (II) was also observed on treatment with 48% hydrobromic acid at the reflux temperature of the solution and by heating the Lewis acid salt of the 3*H*-indole with boron trifluoride, aluminum chloride, ferric chloride, or zinc chloride in the inert solvent tetralin. No rearrangement of these salts was observed at temperatures below 100°; however, reaction did occur at temperatures in the region of 150°. The salts of the 3*H*-indole with *p*-toluenesulfonic acid or *p*-nitrobenzoic acid gave no rearrangement on heating in tetralin even at 150° for two hours. The experimental conditions which cause the equilibration of the 3*H*-indoles II and III are similar to the conditions used for the Plancher rearrangement.[7] Thus the rearrangement which accompanies the methylation of 2-phenylindole with methyl iodide may occur by rearrangement of 3,3-dimethyl-2-phenyl-3*H*-indole (II) hydroiodide as proposed by Julian and co-authors[13] or by rearrangement of II methiodide as proposed by Nakazaki and co-workers.[6]

Experimental

3-Phenyl-2-butanone Phenylhydrazone (V).—Mixing 10.5 g. of phenylhydrazine and 9.1 g. of 3-phenyl-2-butanone caused an exothermic reaction with the evolution of water. After the initial reaction ceased, 50 ml. of benzene and a catalytic amount of acetic acid were added, and benzene was allowed to distil from the reaction mixture, removing the water by azeotropic action. The final traces of benzene and acetic acid were removed by heating under reduced pressure, and the residue crystallized on cooling at 5° overnight giving a quantitative yield of 3-phenyl-2-butanone phenylhydrazone, m.p. 70–72°. Recrystallization from diethyl ether gave an analytical sample of V, m.p. 73–74°.

Anal. Calcd. for $C_{16}H_{18}N_2$: C, 80.67; H, 7.56. Found: C, 80.41; H, 7.56.

Isobutyrophenone Phenylhydrazone (I).—Following the procedure described above, a mixture of equimolar quantities of isobutyrophenone and phenylhydrazine was converted quantitatively to the phenylhydrazone. The isobutyrophenone phenylhydrazone was partially purified by distillation under reduced pressure and purified by crystallization from petroleum ether and ether mixture at −70° to give a white solid, m.p. 29.5–30.0°. On standing at 23° the solid slowly liquified over a period of a week. The resulting oil, however, could be resolidified to a crystalline solid having the same melting point as before liquefaction. These changes in physical state may represent the equilibration of the *syn*- and *anti*-phenylhydrazones.

Anal. Calcd. for $C_{16}H_{18}N_2$: C, 80.67; H, 7.56. Found: C, 80.86; H, 7.67.

3,3-Dimethyl-2-phenyl-3*H*-indole (II).—A solution of 8.2 g. of isobutyrophenone phenylhydrazone (I) in 50 ml. of acetic acid was heated under reflux for 4 hr. After cooling, the solution was diluted with water, made basic with potassium carbonate, and extracted two times with ether. The ether extracts were dried over potassium carbonate, and the solvent was removed by distillation. The residue was distilled under reduced pressure giving 5.0 g. (66%) of 3,3-dimethyl-2-phenyl-3*H*-indole (II), b.p. 140–146° at 1.5 mm., 152–156° at 4 mm., n^{26}D 1.6281.

Anal. Calcd. for $C_{16}H_{15}N$: C, 86.84; H, 6.83. Found: C, 86.52; H, 6.71.

Hydrobromide of II.—Dissolution of 1.3 g. of 3,3-dimethyl-2-phenyl-3*H*-indole (II) in 25 ml. of 48% hydrobromic acid produced a bright green solution which de-

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(14) L. A. Cohen, J. W. Daly, H. Kny, and B. Witkop, *J. Am. Chem. Soc.*, **82**, 2184 (1960).

(15) M. Jak-Shalom, J. D. Fitzpatrick, and M. Orchin, *J. Chem. Educ.*, **34**, 496 (1957).

posited white crystals of a low-melting solid, m.p. 60–90°. Attempts to purify this solid or determine its ultraviolet or infrared spectra converted it to the hydrobromide of 3,3-dimethyl-2-phenyl-3*H*-indole (IIB). Thus the low-melting solid readily dissolved in water but immediately precipitated as IIb, m.p. 213–215°. The ultraviolet absorption spectrum of the low-melting solid or the solution from which it came showed an absorption maximum at 332 mμ which shifted to shorter wave lengths on dilution. A total of 1.69 g. of IIB, m.p. 209–211°, was obtained from this reaction.

Anal. Calcd. for $C_{16}H_{16}BrN$; C, 63.58; H, 5.34. Found: C, 63.85; H, 5.63.

The methiodide of 3,3-dimethyl-2-phenyl-3*H*-indole (II) was prepared in ether at room temperature to give 1,3,3-trimethyl-2-phenylindoleninium iodide (IIM), m.p. 187–188° dec. (λ_{max}^{CH3OH} 227 and 279 mμ, log ϵ_{max} 4.29 and 4.00). This melting point is in contrast to that reported by Leuchs[12] m.p. 203°, for the derivative prepared at 100°. The derivative prepared by Leuchs may have been contaminated with 1,2,3-trimethyl-3-phenylindoleninium iodide (IIIM).

Anal. Calcd. for $C_{17}H_{12}IN$:C, 56.21; H, 4.99. Found: C, 56.17; H, 5.23.

2,3-Dimethyl-3-phenyl-3*H*-indole (III.)—A solution of 4.0 g. of 3-phenyl-2-butanone phenylhydrazone (IV) in 25 ml. of acetic acid was allowed to stand 12 hr. at room temperature and was heated under reflux for 3 hr. The acetic acid was removed under reduced pressure, and the oil was added to water and neutralized with base. The aqueous layer was extracted with ether, and the ether solution was extracted with dilute hydrochloric acid. The acidic extracts were neutralized with sodium hydroxide and extracted with ether. Removal of the ether gave 1.97 g. (53%) of crude 2,3-dimethyl-3-phenyl-3*H*-indole which was purified in 80% recovery by elution from a Florisil column with benzene.

Anal. Calcd. for $C_{16}H_{15}N$: C, 86.84; H, 6.83; N, 6.33. Found: C, 84.49, 84.69, 84.95, 84.85; H, 6.99, 7.12, 7.06, 6.94; N, 6.40.

One sample of III crystallized on standing for several months. The solid was triturated with petroleum ether to give an analytical sample of 2,3-dimethyl-3-phenyl-3*H*-indole (III), m.p. 77–78°.

Anal. Calcd. for $C_{16}H_{15}N$: C, 86.84; H, 6.83; N, 6.33. Found: 86.97; H, 6.80; N, 6.04.

The picrate of III, m.p. 170–171°, was prepared in ethanol to give a derivative identical to that from the polyphosphoric acid rearrangement of isobutyrophenone phenylhydrazone (I) (*vide infra*).

The methiodide of III was prepared in ether and recrystallized from ethanol–ether to give IIIM, m.p. 220–221° dec. (λ_{max}^{C2H5OH} 227 mμ; log ϵ_{max} 3.85).

Anal. Calcd. for $C_{16}H_{18}IN$: C, 56.21; H, 4.99. Found: C, 55.72; H, 5.08.

Reaction of Isobutyrophenone Phenylhydrazone (I) **with Polyphosphoric Acid.**—A mixture of 14.2 g. of isobutyrophenone and 10.8 g. of phenylhydrazine (or an equivalent quantity of the preformed phenylhydrazone I) in 30 g. of polyphosphoric acid was stirred and cooled until the initial exothermic reaction subsided. The mixture was then heated in an oil bath at 150° for 10 min. After cooling, the semisolid mass was dissolved in water and neutralized with sodium bicarbonate. The mixture was extracted with ether, and the extracts were dried over potassium carbonate. Fractional distillation of the extracts gave, after the solvent fraction, 4.7 g. of recovered ketone and phenylhydrazine, b.p. 120° at 1 mm., and 11.4 g. (50%) of a mixture of 3*H*-indoles, b.p. 120–150° at 1 mm. The analysis of the mixture by ultraviolet absorption spectroscopy indicated its composition to be 57–62% 3,3-dimethyl-2-phenyl-3*H*-indole (II) ($\lambda_{max}^{95\%\ C2H5OH}$ 227, 233, 244, 305 mμ; log ϵ_{max} 4.10, 4.09, 3.99, 4.15) and 38–43% 2,3-dimethyl-3-phenyl-3H-indole (III) ($\lambda_{max}^{95\%\ C2H5OH}$ 220, 259 mμ; log ϵ_{max} 4.32, 3.80).

Attempts to Separate the 3*H*-indoles.—Fractional distillation of the mixture of 3*H*-indoles concentrated III in the lower boiling fractions but failed to achieve complete separation.

The picrates prepared from the mixture of 3*H*-indoles were separated readily by recrystallization from ethanol. 2,3-Dimethyl-3-phenyl-3*H*-indole picrate (IIIP), m.p. 169–170°, crystallized as the first crop.

Anal. Calcd. for $C_{22}H_{18}N_4O_7$: C, 58.66; H, 4.03. Found: C, 58.78; H, 3.87.

The 3-phenyl-2,3-dimethyl-3*H*-indole picrate (IIIP) was converted to the base by passing an acetone solution of IIIP through a 2 × 28 cm. column of Dowex 2, in the bicarbonate form. The acetone solution of III was concentrated, and the residue was distilled under reduced pressure to give an oil, b.p. 133–135° at 3 mm., identical in infrared and ultraviolet absorption spectra and melting points of salts with the 3*H*-indole from the rearrangement of 3-phenyl-2-butanone phenylhydrazone (V).

From the mother liquors from the crystallization of IIIP was obtained 3,3-dimethyl-2-phenyl-3*H*-indole picrate (IIP), m.p. 157–159°, lit. m.p. 152–153°,[8] 158–160°.[11] This picrate was identical with the picrate prepared from II formed by the reaction of isobutyrophenone phenylhydrazone (I) and acetic acid.

Rearrangement of 3,3-Dimethyl-2-phenyl-3-*H*-indole (II) with Polyphosphoric Acid.—3,3-Dimethyl-2-phenyl-3*H*-indole (II) (8.15 g.) was poured slowly with stirring into 25 g. of polyphosphoric acid. The mixture was stirred until a uniform consistency was attained, and no attempt was made to moderate the exothermic reaction which took place. After the initial reaction subsided, the flask was placed in a hot air bath, and the bath temperature was raised to 150°. The reaction mixture was heated at this temperature for 0.25, 0.50, 0.75, 1.0, 1.5, 2.3, and 5 hr., and without cooling the reaction mixture was poured into 250 ml. of cold water. The solution was neutralized with solid potassium carbonate, and the tar-like material which separated was taken up in ether. The ether solution was washed with water, dried over anhydrous potassium carbonate, and concentrated by distillation. All volatile solvents were removed from the residue by heating under reduced pressure, and recoveries of 80–90% of 3*H*-indoles II and III were obtained from this reaction. The composition of the mixture of 3*H*-indoles was determined by ultraviolet absorption spectral analysis following the procedure described by Shalom, Fitzpatrick, and Orchin.[15] The composition of the equilibrium mixture approached the limiting values of approximately 70% III and 30% II at 3 hr. Reaction times as long as 5 hr. did not change the composition. The quantitative determination of these mixtures was not attempted by isolation studies; however, the components were separated by chromatographing on Florisil and identified by infrared and ultraviolet absorption spectra and preparation of solid derivatives.

The Rearrangement of 2,3-Dimethyl-3-phenyl-3*H*-indole (III) with Polyphosphoric Acid.—Samples of 1.85 g. of III were treated with polyphosphoric acid in a manner similar to that described for the reaction of II. The composition of the product mixture from III was found to remain constant after a reaction time of 2 hr. The recovery of the 3*H*-indole mixture was about 90%, and the ultraviolet absorption spectrum of this mixture was nearly superimpossible on the spectrum of the equilibrium mixture from II, giving a calculated composition of 70% III and 30% II.

Rearrangement of 3,3-Dimethyl-2-phenyl-3*H*-indole (II) **with Lewis acids.**—To solutions of 1 g. of II in 5 ml. of tetralin was added 1 g. of anhydrous aluminum chloride, anhydrous ferric chloride, or anhydrous zinc chloride. The reaction mixtures were placed in a hot air bath and heated at a temperature of 150° for 2 hr. The samples were then removed and extracted with dilute hydrochloric acid. The acid extracts were neutralized with potassium carbonate and in each case the tarry material which separated was taken up in ether. The ether solution was washed with water and dried over anhydrous potassium carbonate. The ether was removed under reduced pressure and the oil that was obtained was analyzed qualitatively by infrared spectroscopy. In each case partial rearrangement to III was found to have occurred as evidenced by the presence of absorption bands at 1585 cm.$^{-1}$ and 1375 cm.$^{-1}$.

No rearrangement took place upon similar treatment with *p*-nitrobenzoic acid or with *p*-toluenesulfonic acid.

Rearrangement of 3,3-Dimethyl-2-phenyl-3*H*-indole (II) with Boron Trifluoride.—The addition of 1 g. of II to 10 ml. of boron trifluoride in ethyl ether caused the precipitation of the Lewis salt which was collected by filtration and added to 5 ml. of tetralin. This mixture was placed in a hot air bath and heated at 150° for 2 hr. The reaction was worked up as the other Lewis acid rearrangements to give 0.75 g. (75%) of an oil which by infrared spectroscopy was shown to consist of a mixture of II and III. No attempt was made to analyze quantitatively or separate the mixture.

Rearrangement of 1,3,3-Trimethyl-2-phenyl-indoleninium Iodide (IIM).—A solution of 0.5 g. of IIM was dissolved in 6 ml. of methanol and heated in a sealed tube at 150° for 3 hr. in the manner described by Nakazaki and co-workers.[6] The tube was cooled and opened and the solvent was removed from the red-brown solution. Ether was added causing the precipitation of 0.4 g. of a violet solid, which was recrystallized from ethanol–ether to give a light brown solid, m.p. 216–218° dec. The infrared and ultraviolet absorption spectra showed this compound to be 1,2,3-trimethyl-3-phenylindoleninium iodide (IIIM). No trace of IIM was detected.

The Rearrangement of 3,3-Dimethyl-2-phenyl-3*H*-indole (II) with Hydrobromic Acid.—A solution of 1 g. of II in 15 ml. of 48% hydrobromic acid was heated under reflux for 2 hr. After cooling, the solution was neutralized with solid potassium carbonate, and the oil which separated was taken up in ether. The ether solution was washed with water and dried over anhydrous potassium carbonate. Removal of the ether gave 0.67 g. (67%) of an oil which was shown to consist of a mixture of II and III by infrared absorption spectroscopy. No resolution of the mixture was attempted.

Reduction of 3,3-Dimethyl-2-phenyl-3*H*-indole (II) with Sodium Borohydride.—A solution of 1.0 g. of II in 10 ml. of methanol was treated with an excess of sodium borohydride. The solution was maintained at room temperature, being cooled only when violent effervescence occurred. After completion of the reaction, the methanol solution was stirred gently for 5 min. and was poured into dilute hydrochloric acid. The acidic solution was neutralized with potassium carbonate, and the indoline separated as a white solid which was separated by filtration. Recrystallization of the solid from an ethanol–water mixture gave 0.95 g. (95%) of the 3,3-dimethyl-2-phenylindoline, m.p. 89–91°, lit.,[8] m.p. 95°, in the form of white needles.

The picrate was prepared in ethanol and melted at 200° dec. The picrate prepared from 0.1 *N* hydrochloric acid solution melted at 121–123°, lit.,[8] m.p. 123–124°.

Reduction of 2,3-Dimethyl-3-phenyl-3*H*-indole (III) with Sodium Borohydride.—A solution of 2 g. of III in methanol was treated with an excess of sodium borohydride in the manner described above to give 1.6 g. of an oil. The infrared spectrum of this oil was consistent with the structure 2,3-dimethyl-3-phenylindoline. The picrate was prepared in 0.1 *N* hydrochloric acid to give a derivative, m.p. 169–171° dec.

Anal. Calcd. for $C_{22}H_{20}N_4O_7$: C, 58.41; H, 4.45. Found: C, 58.72; H, 4.14.

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Diels-Alder Reactions of 3,3,4,4-Tetrafluorocyclobutene. Syntheses of Some Fluorinated Benzocyclobutenes

Raymond J. Shozda and Robert E. Putnam

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3,3,4,4-Tetrafluorocyclobutene is an active dienophile. The adducts with butadienes are catalytically converted to 7,7,8,8-tetrafluorobenzocyclobutenes, while basic treatment of the dibromide from the butadiene adduct leads to 7,7,8-trifluorobenzocyclobutene. The adduct with cyclopentadiene consists of the *endo* and *exo* isomers. Adducts with furans and certain of their reactions are described.

In recent years there has been considerable interest shown in the benzocyclobutenes.[1] We wish to report studies of some Diels-Alder reactions of 3,3,4,4-tetrafluorocyclobutene (TFCB)[2] and conversion of certain of the adducts to fluorinated benzocyclobutenes.

Adducts with Butadienes.—Reaction of TFCB with butadiene at 100–150° gives the Diels-Alder adduct (Ia) in 75% yield.[3] When this adduct is refluxed with palladium-on-carbon catalyst, disproportionation occurs to give a mixture of the aromatic compound (IIa) and the reduced compound (IIIa). Separation was achieved by gas chromatog-

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[1] See (a) M. P. Cava, R. L. Little, and D. R. Napier, *J. Am. Chem. Soc.*, **80**, 2255 (1958); (b) H. Hart and R. W. Fish, *ibid.*, **82**, 749 (1960); (c) M. P. Cava, A. A. Deana, and K. Muth, *ibid.*, **82**, 2524 (1960); and (d) W. Baker, J. F. W. McOmie, and D. R. Preston, *J. Chem. Soc.*, 2971 (1961).

[2] J. L. Anderson, R. E. Putnam, and W. H. Sharkey, *J. Am. Chem. Soc.*, **83**, 382 (1961).

[3] An isomer of this compound was prepared by the cycloaddition reaction of tetrafluoroethylene and 1,3-cyclohexadiene. D. D. Coffman, P. L. Barrick, R. C. Cramer, and M. S. Raasch, *ibid.*, **71**, 490 (1949).