lactams using tlc was positive for one of these spots (R_f 0.45). The infrared spectrum of the mixture showed a band at 1760 cm^{-1}.

t-**Butyl α-Phthalimidopropionate-3-imino-N-γ-thiolactone (11).**—To a solution of 1.54 g (0.01 mole) of homocysteine thiolactone hydrochloride[15] (10) was added 31 ml (0.015 mole) of 0.5 *N* sodium hydroxide. To this solution (pH 8.0) was added a hot solution (70°) of 2.89 g (0.01 mole) of 1 in 38 ml of absolute ethanol. After cooling, the reaction mixture was aerated with nitrogen and the flask sealed. Storage at room temperature for 14 days produced a solid (11) which was collected by filtration; 2.44 g (63%). Recrystallization from 95% ethanol produced a very pale yellow solid; mp 178–180°. The infrared spectrum had absorption at 1780, 1750, 1720, 1700, and 1650 cm^{-1}.

Anal. Calcd for $C_{19}H_{20}N_2O_5S$: C, 58.76; H, 5.16; N, 7.22; S, 8.20. Found: C, 58.97; H, 5.26; N, 7.41; S, 8.14.

(15) Purchased from Nutritional Biochemicals Corp.

The Reaction of α-Chloro-α,α-diphenylacetanilide with Sodium Hydride. II.[1] The Identification of a Dimeric Product

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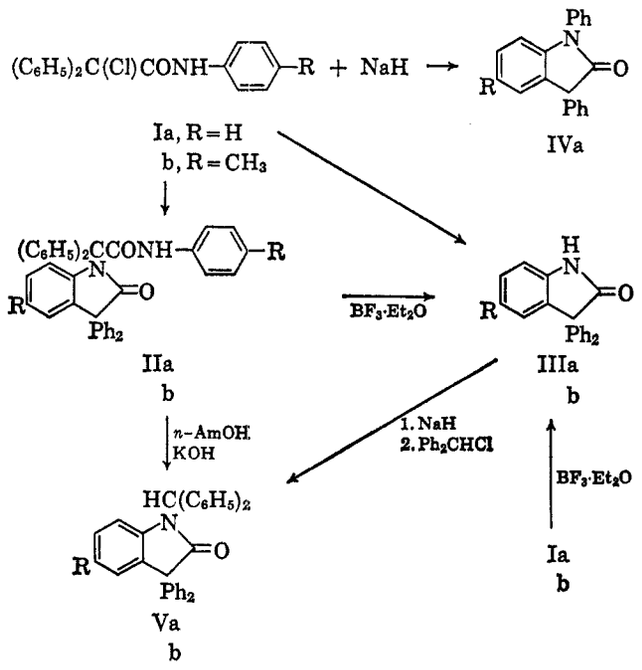
A previous investigation in this laboratory has shown that the reaction of α-chloro-α,α-diphenylacetanilide (Ia) (Scheme I) with sodium hydride gives three

SCHEME I

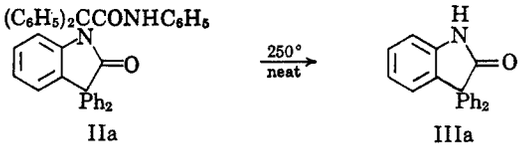


products. Two of the products were previously identified as 3,3-diphenyloxindole (IIIa) and 1,3-diphenyloxindole (IVa).[1] Subsequent investigation has shown the identity of the third and major product to be 2-[1′-(3′,3′-diphenyloxindolyl)]-2,2-diphenylacetanilide (IIa).[2] This compound is also now established as the major product obtained from the photochemical reaction of diphenyldiazomethane with phenyl isocyanate.[3]

While earlier attempts to establish the molecular weight of IIa by cryoscopic and mass spectrometric methods gave misleading values,[1,3] vapor pressure osmometry gave a molecular weight of 598 (570 calculated for $C_{40}N_{30}N_2O_2$). Saponification of IIa gave 1-(diphenylmethyl)-3,3-diphenyloxindole (Va).[2a,4] The structure of Va has now been confirmed in this laboratory by an independent and unambiguous synthesis utilizing the sodium hydride promoted alkylation of 3,3-diphenyloxindole (IIIa) with benzhydryl chloride. The previously reported quantitative conversion of IIa to IIIa by refluxing boron fluoride etherate has been confirmed.[1]

The reaction of α-chloro-α,α-diphenyl-N-*p*-tolylacetamide (Ib) with sodium hydride yields IIb and IIIb. The nmr spectrum of IIb shows the presence of two distinct methyl groups while the spectrum of IIIb shows a single methyl absorption. 5-Methyl-3,3-diphenyloxindole could be obtained in good yield by the treatment of Ib with refluxing boron fluoride etherate. The dimer was saponified giving 1-(diphenylmethyl)-5-methyl-3,3-diphenyloxindole (Vb) which was synthesized from 5-methyl-3,3-diphenyloxindole (IIIb) by treatment with sodium hydride and benzhydryl chloride.

Previous mass spectra of Ia taken on instruments utilizing a heated inlet system exhibit a molecular ion peak at *m/e* 285.[3] This is explained by the pyrolysis of IIa at 250° which gives 3,3-diphenyloxindole (IIIa) as the only isolable crystalline product. A high-



resolution mass spectrum, however, obtained utilizing a direct inlet system, shows several peaks characteristic of Ia.[5] The spectrum exhibits peaks corresponding to ions VI–XI, with *m/e* 119.0363, 120.0428, 167.0856, 284.1105, 286.1194, 450.1870, and 451.1963, respectively.

Experimental Section

Reaction of α-Chloro-α,α-diphenylacetanilide (Ia) with Sodium Hydride.[1]—The previously described procedure was followed and IIa was isolated: mp 214–215° (Kofler) (from acetone).

Anal. Calcd for $C_{40}H_{30}N_2O_2$: mol wt, 570.66. Found (vapor pressure osmometer,[7] benzene): mol wt, 598.

(1) Part I: J. C. Sheehan and J. W. Frankenfeld, *J. Am. Chem. Soc.*, **83**, 4792 (1961).

(2) (a) This structure was recently proposed by S. Sarel, J. T. Klug, E. Breuer, and F. D'Angeli [*Tetrahedron Letters*, **No. 24**, 1553 (1964)]. (b) The product of the reaction between α-chloro-α,α-diphenylacetanilide and sodium hydride was originally assigned an α-lactam structure, 1,3,3-triphenylaziridinone [S. Sarel and H. Leader, *J. Am. Chem. Soc.*, **82**, 4752 (1960)]. In ref 1 and 3, IIa was incorrectly identified as 2,2-diphenylindoxyl.

(3) J. C. Sheehan and I. Lengyel, *J. Org. Chem.*, **28**, 3252 (1963).

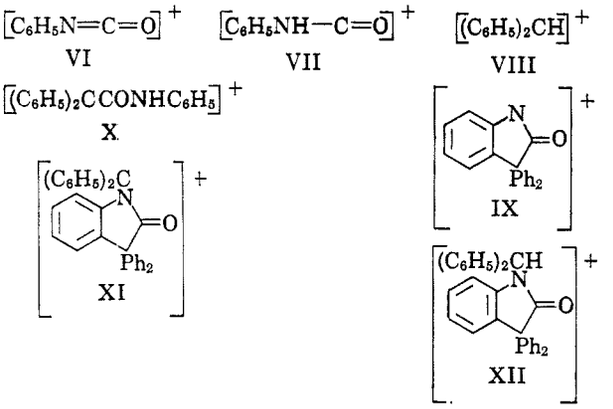
(4) C. H. Hassall and A. E. Lippman, *J. Chem. Soc.*, 1059 (1953).

(5) The high-resolution mass spectrum was determined on a CEC Type 21-110-A-1 mass spectrometer at 170° by the courtesy of Professor K. Biemann and Mr. P. Fennessy.

(6) Ultraviolet spectra were determined on a Cary Model 14 spectrophotometer; infrared spectra were determined on a Perkin-Elmer 237 spectrophotometer, and the nmr spectra were determined on a Varian A-60 spectrometer.

(7) Mechrolab vapor-pressure osmometer Model 310A.

SCHEME II



Reaction of α-Chloro-α,α-diphenyl-N-p-tolylacetamide (Ib)[8] with Sodium Hydride.—The previously described procedure was followed.[1] Recrystallization of the crude reaction product from ethyl acetate gave 5-methyl-3,3-diphenyloxindole (IIIb) (12%): mp 283–283.5° (Kofler); infrared spectrum (Nujol), 3225, 3050, 1710, and 1670 cm^{-1}; ultraviolet spectrum, $\lambda_{max}^{CHCl_3}$ 283 and 260 mμ (log ε 3.27 and 3.75, respectively); nmr spectrum (CF_3COOH), 2.25 ppm (singlet, 3 H), 7.3 ppm (singlet, 3 H), and 7.5 ppm (singlet, 10 H).

Anal. Calcd for $C_{21}H_{17}NO$: C, 84.25; H, 5.72; N, 4.68. Found: C, 84.10; H, 5.82; N, 4.63.

Evaporation of the mother liquor from the isolation of IIIb and recrystallization of the residue from acetone gave IIb (23%): mp 249–251° (Kofler); infrared spectrum (Nujol), 3390, 3050, 1725, 1705, 1600, and 1515 cm^{-1}; ultraviolet spectrum ($CHCl_3$), complicated absorption between 300 and 240 mμ with no definite maximum; nmr spectrum ($CDCl_3$), 2.19 ppm (singlet, 3 H), 2.25 ppm (singlet, 3 H), and 6.8–7.8 ppm (complex, 28 H).

Anal. Calcd for $C_{42}H_{34}N_2O_2$: C, 84.25; H, 5.72; N, 4.68. Found: C, 84.01; H, 5.63; N, 4.70.

Synthesis of 5-Methyl-3,3-diphenyloxindole (IIIb).—Boron fluoride etherate (30 ml) was added to 1.5 g (4.5 mmoles) of α-chloro-α,α-diphenyl-N-p-tolylacetamide, and the resulting solution was refluxed for 45 min. The solution was then poured into water, and the product was extracted with methylene chloride. Evaporation of the methylene chloride solution gave 1.36 g (98.5%) of 5-methyl-3,3-diphenyloxindole which was recrystallized from ethyl acetate, mp 283–284° (Kofler). The infrared and ultraviolet spectra were identical with those of IIIb.

Saponification of IIa.[2a]—To a solution of 0.2 g (3.5 mmoles) of potassium hydroxide in 10 ml of *n*-amyl alcohol was added 1.0 g (1.75 mmoles) of IIa. The resulting mixture was refluxed for 24 hr, cooled, and poured into benzene. The resulting benzene solution was washed with 1*N* hydrochloric acid and water, dried over magnesium sulfate, and evaporated under reduced pressure. The residue was recrystallized from ethyl acetate affording 577 mg (73%) of Va: mp 224–226° (Kofler); infrared spectrum (Nujol), 3050, 1710, and 1605 cm^{-1}; ultraviolet spectrum, λ_{max}^{EtOH} 260 mμ (log ε 3.8).

Synthesis of 1-(Diphenylmethyl)-3,3-diphenyloxindole (Va). — To a suspension of 2.0 g (7.03 mmoles) of 3,3-diphenyloxindole in 20 ml of dry benzene was added 7.03 mmoles of sodium hydride, and the resulting suspension was refluxed under a nitrogen atmosphere with stirring for 30 min. Benzhydryl chloride (7 mmoles) was added, and refluxing was continued for 3 hr. Water was added cautiously, and the layers were separated. The benzene solution was dried over magnesium sulfate and evaporated under reduced pressure. The residue was recrystallized from ethyl acetate giving 1.08 g (34%) of Va, mp 224° (Kofler) (not depressed on admixture with the saponification product). The infrared and ultraviolet spectra were identical with those of Va.

Anal. Calcd for $C_{33}H_{25}NO$: C, 87.77; H, 5.58; N, 3.10. Found: C, 87.69; H, 5.75; N, 2.97.

Saponification of IIb.—The procedure for the saponification of IIa was followed yielding 55% of 1-(diphenylmethyl)-5-methyl-3,3-diphenyloxindole: mp 211–214° (Kofler) (from ethyl acetate); infrared spectrum (Nujol), 3025, 1705, and 1600 cm^{-1}; ultraviolet spectrum, λ_{max}^{EtOH} 262 mμ (log ε 3.8).

(8) C. L. Stevens and J. C. French, *J. Am. Chem. Soc.*, **75**, 657 (1953).

Synthesis of 1-(Diphenylmethyl)-5-methyl-3,3-diphenyloxindole (Vb).—The synthesis was performed in a manner identical with the synthesis of Va yielding 54% of Vb: mp 210–212° (Kofler) (from ethyl acetate); nmr spectrum ($CDCl_3$), 2.25 ppm (singlet, 3H), 7.41 ppm (singlet, 23 H), and 5.5 ppm (Br, 1 H). The infrared and ultraviolet spectra were identical with those of the saponification product of IIb.

Anal. Calcd for $C_{34}H_{27}NO$: C, 87.71; H, 5.85; N, 3.01. Found: C, 87.74; H, 5.94; N, 2.98.

Acknowledgments.—J. H. B. gratefully acknowledges financial support from Public Health Service Predoctoral Fellowship 5-F1-GM-21, 126-02. We are indebted to Dr. S. M. Nagy for the microanalyses, to Mrs. N. Alvord for the ultraviolet spectra, and to Dr. D. Ben-Ishai for many invaluable discussions during the course of this work.

Synthesis of Coenzyme Q Analogs by Alkylation of Fumigatin[1a]

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The existence of fumigatin (I) in nature and its structural relationship to coenzyme Q provided the initial interest for the synthesis of isoprenoid derivatives of fumigatin by alkylation. Two appropriate coenzyme Q analogs (II) have been synthesized with isoprenoid side chains which are prominent in the coenzyme Q, vitamin E, and vitamin K groups. They are 2-hydroxy-3-methoxy-6-methyl-5-solanesyl-1,4-benzoquinone (III) and 2-hydroxy-3-methoxy-6-methyl-5-phytyl-1,4-benzoquinone (IV). (See Chart I.)

The first structure (V) proposed[2a] for rhodoquinone also supported the interest in the synthetic analogs, III and IV, until very recently when the structure of rhodoquinone was established[2b] as VI.

There is biological interest in the synthetic hydroxyquinones, III–V, etc., since Morimoto and Imada[3,4] and Lester and Fleischer[5] have found that succinoxidase activity is restored to acetone-extracted mitochondria by the photolytic demethylation "product" of coenzyme Q_7. This "product" was presumed to be the hydroxyquinone analog, VII, but new studies have revealed[6] that the "product" is about a 50:50 mixture of both isomers, VIII.

The generic 2-isoprenoidphenols have been reported[7] as precursors to members of the coenzyme Q group. On this basis and other evidence,[8] the biosynthesis of coenzyme Q appears to involve three methylation steps, *i.e.*, the two methoxy groups and the 6-methyl group. The order in these methylations is unknown.

(1) (a) Coenzyme Q. LXIX. (b)Stanford Research Institute, Menlo Park, Calif.

(2) (a) J. Glover and D. R. Threlfall, *Biochem. J.*, **85**, 14P (1962); (b) H. W. Moore and K. Folkers, *J. Am. Chem. Soc.*, **88**, 567 (1966).

(3) H. Morimoto and I. Imada, *Chem. Pharm. Bull.* (Tokyo), **12**, 739 (1964).

(4) I. Imada and H. Morimoto, *ibid.*, **13**, 136 (1965).

(5) R. L. Lester and S. Fleischer, *Biochim. Biophys. Acta*, **47**, 358 (1961).

(6) H. W. Moore and K. Folkers, *J. Am. Chem. Soc.*, **88**, 564 (1966).

(7) R. K. Olsen, J. L. Smith, G. D. Daves, Jr., H. W. Moore, K. Folkers, W. W. Parson, and H. Rudney, *ibid.*, **88**, 564 (1966).

(8) R. Olson, *Federation Proc.*, **23**, 3393 (1964).