

190–192°) and recrystallized from ethanol–water, m.p. 192–193°.

*Anal.* Calcd. for  $C_{15}H_{27}N_3O$ : C, 67.88; H, 10.25; N, 15.83. Found: C, 67.64; H, 10.36; N, 15.57.

*Reduction of 9-Butyl-cis-2-decalone (X) and 9-Butyl-1-decalone (IXb) to 9-Butyl-cis-decalin (XI).* A solution of 5 g. of 9-butyl-cis-2-decalone, 10 ml. of ethanedithiol, 10 ml. of boron trifluoride etherate, and 10 ml. of glacial acetic acid was allowed to stand 16 hr. Water (100 ml.) was added, and the mixture was extracted three times with methylene chloride, dried, and evaporated. The excess ethanedithiol was distilled off under reduced pressure, leaving a residue of 6.5 g. of the thioketal. This was combined with 75 ml. of diethylene glycol, 28 ml. of 95% hydrazine, and 14 g. of potassium hydroxide. The solution was heated from 90 to 165° during 2 hr. (gas began evolving at 110°) and held at 165° for 6 hr. The mixture was cooled, 400

ml. of water was added, and the solution was extracted four times with ether. The combined ethereal extract was washed with saturated salt water, dried, and evaporated. The residue was distilled to afford 2.5 g. (53%) of 9-butyl-cis-decalin, b.p. 135–138° at 20 mm., as well as a 2.1-g. residue which was largely unreacted thioketal. The butyldecalin was indicated to be a single isomer by v.p.c. on a 5-ft. and a 20-ft. silicone gum rubber column.

*Anal.* Calcd. for  $C_{14}H_{26}$ : C, 86.51; H, 13.49. Found: C, 86.65; H, 13.33.

Reduction of 9-butyl-cis-1-decalone (5.0 g.) was effected in the same manner to afford 2.4 g. (50%) of 9-butyl-cis-decalin and a 2.0-g. residue of thioketal. The infrared spectrum and v.p.c. retention times of the two samples of butyldecalin were identical, indicating that the dicarbanion reaction had produced exclusively the *cis* isomer.

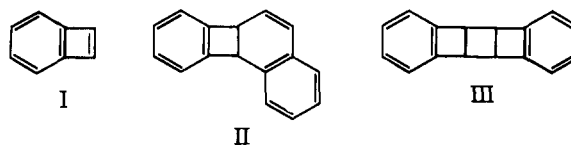
## Studies Concerned with the Synthesis of 1-Methyl-2-Phenylbenzocyclobutadiene<sup>1,2</sup>

A. T. Blomquist and Charles G. Bottomley<sup>3,4</sup>

*Contributed from the Baker Laboratory of Chemistry, Cornell University, Ithaca, New York. Received August 20, 1964*

*Light-catalyzed bromination of trans-1-methyl-2-phenylbenzocyclobutene can be controlled to give either 2-bromo-1-methyl-2-phenylbenzocyclobutene or 1,2-dibromo-1-methyl-2-phenylbenzocyclobutene. Reaction of the monobromo compound with alkoxides (sodium methoxide, sodium ethoxide, and sodium *t*-butoxide) fails to effect dehydrobromination and affords only the corresponding 2-alkoxy derivatives. Debromination of the dibromo compound with zinc, various amalgams, and sodium iodide gives 3,4-dimethyl-7,8-diphenyl-1,2,5,6-dibenzocyclooctatetraene as the only isolable, stable product. The experimental evidence obtained suggests that in these debrominations 1-methyl-2-phenylbenzocyclobutadiene may not be formed as a transient intermediate but instead there is formed, as a metastable intermediate via a succession of coupling reactions, a linear syn-dibenzotricyclooctadiene that rearranges rapidly to the cyclooctatetraene derivative. Nickel carbonyl debromination leads to a dimer of methylphenylbenzocyclobutadiene that is not a cyclooctatetraene but may be a stable anti form of a linear dibenzotricyclooctadiene.*

The chemistry of benzocyclobutadiene (I) and its possible precursors has received considerable attention in recent years. Stimulation for these studies is derived in part from molecular orbital calculations which suggest that the cyclobutadiene I should possess considerable resonance energy and exist in a singlet state.<sup>5</sup> The short-lived existence of the hydrocarbon has in fact been demonstrated by trapping experiments<sup>6</sup> and by the isolation of the dihydrobiphenylene II<sup>6a,7</sup> and the dibenzotricyclooctadiene III,<sup>8</sup> both of which are dimers of I.



In view of the fact that Roberts has suggested that greater stability is to be expected in simple 1,2-disubstituted cyclobutadienes in which one substituent

(1) For closely related preceding papers, see A. T. Blomquist and C. G. Bottomley, *Ann.*, **653**, 67 (1962); *Trans. N. Y. Acad. Sci.*, [2] **3**, 823 (1962).

(2) This study was supported in part by the National Science Foundation Grant NSF-G5923.

(3) American Viscose Summer Fellow, 1959; Procter and Gamble Predoctoral Research Fellow, 1959–1960; National Science Foundation Fellow, 1960; National Science Foundation Fellow, Jan.–April 1961.

(4) The work reported here was abstracted from part of the dissertation presented by C. G. Bottomley, June 1961, to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

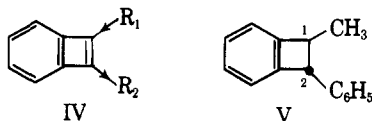
(5) J. D. Roberts, A. Streitwieser, Jr., and C. M. Regan, *J. Am. Chem. Soc.*, **74**, 4579 (1952).

(6) (a) C. D. Nenitzescu, A. Avram, and D. Dinu, *Ber.*, **90**, 2541 (1957); (b) M. P. Cava and M. J. Mitchell, *J. Am. Chem. Soc.*, **81**, 5409 (1959); M. P. Cava and R. Pohlke, *J. Org. Chem.*, **27**, 1564 (1962); (d) M. Avram, C. D. Matuscu, D. Dinu, I. G. Dinulescu, and C. D. Nenitzescu, *Acad. Rep. Populare Romine, Studii Cercetari Chim.*, **9**, 435 (1961); (e) M. P. Cava and R. Pohlke, *J. Org. Chem.*, **28**, 1012 (1963).

(7) M. P. Cava and D. R. Napier, *J. Am. Chem. Soc.*, **78**, 500 (1956); **79**, 1701 (1957); **80**, 2255 (1958).

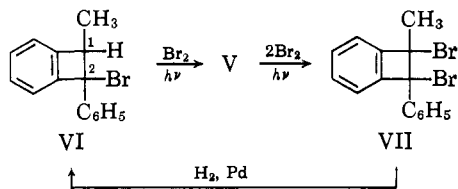
(8) (a) A. Avram, D. Dinu, and C. D. Nenitzescu, *Chem. Ind. (London)*, 257 (1959); (b) A. Avram, D. Dinu, G. Matuscu, and C. D. Nenitzescu, *Ber.*, **93**, 1789 (1960).

is electron releasing and the other electron attracting,<sup>9</sup> it is reasonable to suppose that increased stability should also obtain for similarly disubstituted benzocyclobutadienes of type IV.

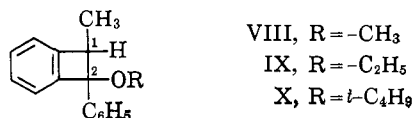


To test the above hypothesis, it was of interest to attempt the preparation of 1-methyl-2-phenylbenzocyclobutadiene (IV with  $R_1 = \text{CH}_3$ ,  $R_2 = \text{C}_6\text{H}_5$ ) from the available precursor *trans*-1-methyl-2-phenylbenzocyclobutene (V)<sup>1</sup> via the appropriate mono and dibromo derivatives of the hydrocarbon V. The remainder of this report presents the results obtained pertinent to the foregoing.

Bromination of the hydrocarbon V in the presence of light can be controlled to give either the metastable liquid 2-bromo-1-methyl-2-phenylbenzocyclobutene (VI) or the stable solid, 1,2-dibromo-1-methyl-2-phenylbenzocyclobutene (VII). The ultraviolet spectra of the two bromo compounds VI and VII are typical of substituted benzocyclobutenes (see Experimental part) and show the expected slight bathochromic shifts relative to the hydrocarbon V. Analysis of the n.m.r. spectrum of VI (Experimental part) clearly indicates that the monobromo derivative is actually the compound represented by VI and comprises roughly an equimolar mixture of the two possible stereoisomers.



Attempted dehydrohalogenation of the monobromo compound VI with alkoxides, *i.e.*, sodium methoxide, sodium ethoxide, and potassium *t*-butoxide, affords only the corresponding ethers VIII, IX, and X, and there is no evidence of the occurrence of dehydrobromination.

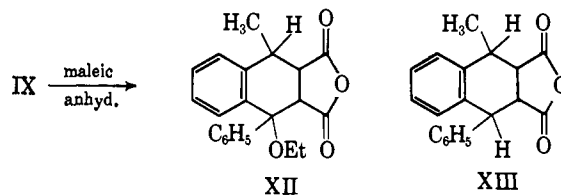


The ultraviolet spectra of the three ethers were similar to that of the bromide VI except that the methyl and ethyl ethers (VIII and IX) showed strong absorption maxima at longer wave lengths, 290 and 300  $m\mu$ , not observed in the initial bromo compound VI (Experimental part). Since similar long-wave absorption was observed for the model compound *o*-ethylbenzohydroxy ethyl ether (XI), it would appear that the absorption above 280  $m\mu$  is perhaps a consequence of interaction of the methoxide and ethoxide groups, in the ethers VIII and IX, with the benzene chromophore.

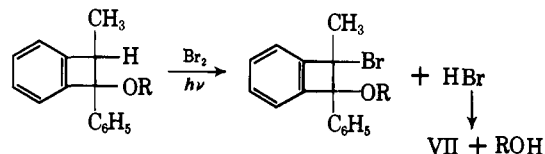
(9) J. D. Roberts, Special Publication No. 12, The Chemical Society, London, 1958, p. 111.

The n.m.r. spectra of the three ethers were as expected with the exception that the ethyl ether IX showed an octet for the methylene hydrogens instead of a quartet. Apparently, this fine splitting is due to a long range effect.

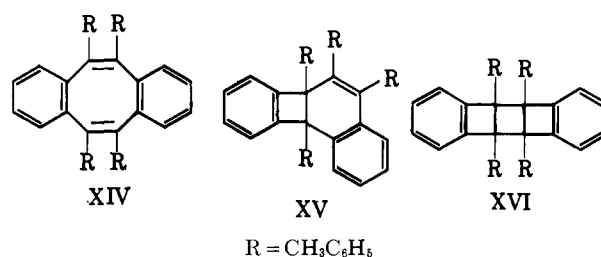
Some chemical evidence was obtained in support of the structural assignments for the ethers. Reaction of the ethyl ether IX with maleic anhydride afforded a Diels-Alder adduct (XII) as expected. The ultraviolet spectrum of this adduct was similar to the adduct XIII obtained earlier from the hydrocarbon V.<sup>1</sup> Treatment of the ether IX with acetyl bromide<sup>10</sup>



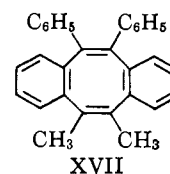
gave one isomer of the monobromide VI (91%) while light-catalyzed bromination (1 molar equiv.) of each of the three ethers gave the known dibromide VII. In the latter bromination presumably the initially liberated hydrogen bromide cleaves the ether function as shown.



Dehalogenation of the dibromo compound VII was effected with several reagents to give, as the only *isolable* product, a crystalline hydrocarbon, m.p. 215–216°, a dimer of the desired 1-methyl-2-phenylcyclobutadiene. Reagents effective for this debromination (yields in parentheses) were activated zinc dust in ether (85%), sodium amalgam (56%), lithium amalgam (45%), and sodium iodide (20%). In general terms the possible structures for the dimer are given in the formulations XIV, XV, and XVI. The physical



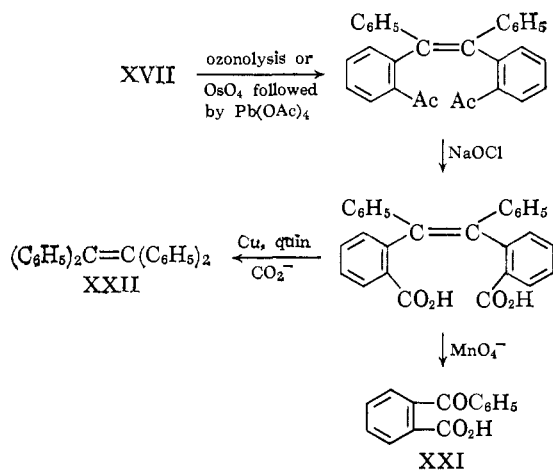
and chemical properties of the dimer are in accord with the cyclooctatetraene structure XIV with the methyl and phenyl groups disposed as shown in structure XVII. The ultraviolet spectrum of the dimer



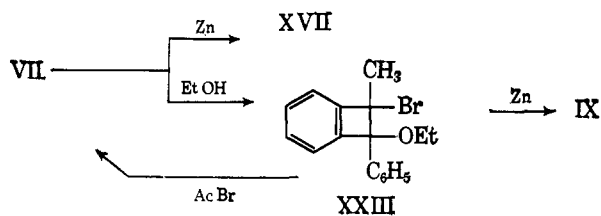
(10) R. L. Burwell, Jr., L. M. Elkin, and L. G. Maury, *J. Am. Chem. Soc.*, 73, 2428 (1951).

( $\lambda_{\max}$  285  $m\mu$ ,  $\log \epsilon$  3.50) indicates the absence of a benzocyclobutene chromophore, present in structures XV and XVI. It is unreactive toward bromine at room temperature, fails to decolorize permanganate, gives only a faint yellow color with tetranitromethane, and cannot be hydrogenated at room temperature with Pt in ethyl acetate or Pd-C in dioxane.

In accord with the postulated structure XVII, the dimeric hydrocarbon can be degraded to either *o*-benzoylbenzoic acid (XXI) or tetraphenylethylene (XXII) via the paths shown.

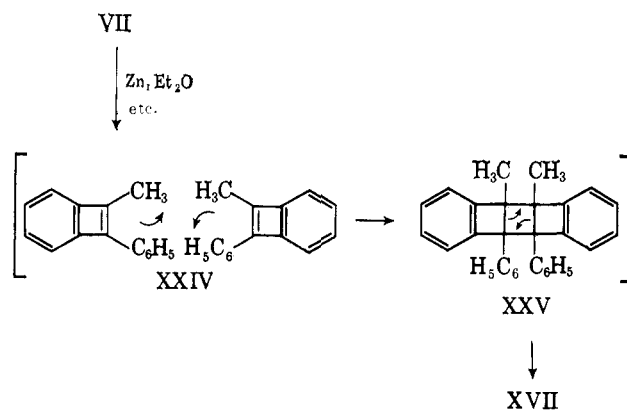


Zinc debromination of the dibromo compound VII in ethanol solution produced the dimer XVII (10%) together with the ethyl ether IX (31%). Since it was observed that solvolysis of the compound VII in ethanol gives a bromoether (XXIII, 90%) and the latter on reaction with zinc in methanol forms the ethyl ether IX (30%), the following relationships are indicated.



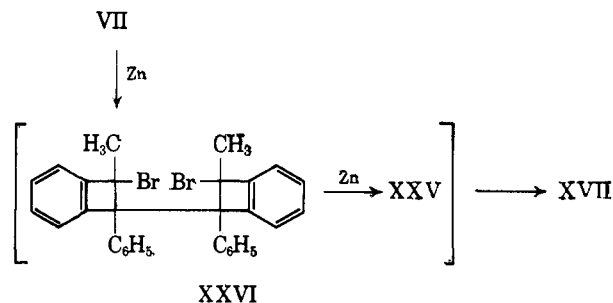
Formation of the cyclooctatetraene dimer XVII from the dibromide VII is formally analogous to the debromination of 1,2-dibromobenzocyclobutene that affords the isolable linear dimer III which rearranges, on heating, to 1,2,5,6-dibenzocyclooctatetraene. Accordingly, as a first hypothesis, formation of the dimer XVII can be considered to occur as shown in Scheme I. Attempts were made therefore to demonstrate the transient existence of the intermediates XXIV and XXV. Zinc debromination of VII in ether was done at 0°, the solvent removed, and the organic residue taken up in isooctane at 0°. Initially the resulting solution showed strong ultraviolet absorption at 274, 282, and 297  $m\mu$ , together with broad weak peaks at 325 and 343  $m\mu$ . As time passed all of these peaks diminished, some of the dimer XVII precipitated, and, finally, after 3 hr. at room temperature, the ultraviolet absorption of the isooctane solution was essentially that of the dimer XVII,  $\lambda_{\max}$  285  $m\mu$ .

Scheme I

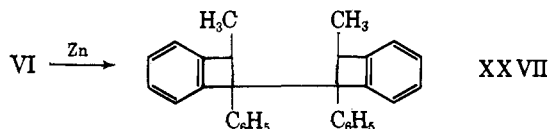


All efforts to trap the intermediate butadiene XXIV with various dienophiles and dienes failed; only the dimer XVII could be isolated. This contrasts markedly with the successful trapping of benzocyclobutadiene, as Diels-Alder adducts, in the debromination of 1,2-dibromobenzocyclobutene.<sup>6</sup> The lack of evidence for the formation of benzocyclobutadiene intermediate XXIV can be explained on the basis of a second path to the dimer XVII (Scheme II).

Scheme II



Support for this sequence of two successive coupling reactions is provided by (a) the observed greater reactivity of one bromine over the other in the dibromide VII, and (b) reaction of the monobromide VI with Zn to produce the coupled hydrocarbon product XXVII in 67% yield. In accord with (a) above is the observed solvolysis of the dibromide VII in ethanol which



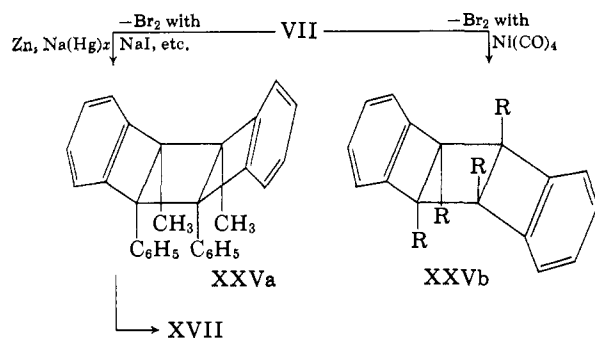
produces the bromoether XXIII. To date it has not been possible to verify the second coupling step (XXVI  $\rightarrow$  XXVII) since attempts to brominate the compound XXVII to XXVI have not been successful.

Nickel carbonyl debromination of the dibromide VII also gives a dimeric hydrocarbon, m.p. 165–166°, that is not identical with the hydrocarbon XVII, m.p. 215–216°. This second dimer is unreactive toward bromine, ethanolic permanganate solution, and ozone at 0°; it gives no yellow color with tetranitromethane. Its ultraviolet spectrum resembles closely the spectra of the compound XXVII (Experimental part) and the transient intermediate formed in the low temperature debromination of the dibromide VII (*supra vide*). The principal absorption maxima are

(log  $\epsilon$  values in parentheses): 269.7 (3.77), 275.5 (3.72), and 299.3  $m\mu$  (2.39).

The foregoing observations indicate that this second dimer is a "linear" type as formulated by structure XVI. This postulation would be in accord with the observed nickel carbonyl debromination of 1,2-dibromocyclobutene that gives the linear dimer III.<sup>8</sup> Unlike the dimer III, which isomerizes thermally to a dibenzocyclooctatetraene, the second dimer forms only polymeric material on heating.

On the basis of the available data the following scheme is suggested for the debromination of the dibromide VII.



The metastable intermediate formed in debrominations with Zn, etc., is the *syn* isomer XXVa which readily isomerizes without inversion to the *syn*-cyclooctatetraene XVII. Nickel carbonyl debromination of VII produces an *anti* isomer XXVb (disposition of methyl and phenyl groups, R, unknown) which is not prone to isomerize because of the unfavorable electronic configuration<sup>11</sup> of the *anti*-dibenzocyclooctatetraene that would result.

Further study is necessary in order to establish the structure of the dimeric hydrocarbon formed in the nickel carbonyl debromination of VII and to elucidate the reaction paths leading to the two dimers of 1-methyl-2-phenylcyclobutadiene.

### Experimental<sup>12</sup>

**2-Bromo-1-methyl-2-phenylbenzocyclobutene (VI).** A solution of 2.00 g. (10.3 mmoles) of *trans*-1-methyl-2-phenylbenzocyclobutene (V)<sup>1</sup> and 1.65 g. (10.3 mmoles) of bromine in 20 ml. of carbon tetrachloride was irradiated with ultraviolet light until the solution became colorless,<sup>13</sup> *ca.* 2 min. After removal of solvent, distillation of the residual oil through a 4-in. Vigreux column at 0.07 mm. gave five fractions: (1) 0.07 g., b.p. up to 102°,  $n_{26.5}^{20}D$  1.6072; (2) 0.20 g., b.p. 102–103°,  $n_{26.5}^{20}D$  1.6108; (3) 0.34 g., b.p. 103–104°,  $n_{26.5}^{20}D$  1.6141; (4) 1.37 g., b.p. 104°,  $n_{26.5}^{20}D$  1.6158; (5) 0.62 g., b.p. above 104°,  $n_{26.5}^{20}D$  1.6174. Fraction 3 was analyzed.

*Anal.* Calcd. for C<sub>15</sub>H<sub>13</sub>Br: C, 65.95; H, 4.80; Br, 29.25. Found: C, 65.75; H, 4.92; Br, 29.20.

The ultraviolet spectrum of the bromo compound VI in isooctane solution showed the maxima (log  $\epsilon$

values in parentheses): 267.5 sh (3.55), 273.5 (3.61), and 279.4  $m\mu$  (3.55). The n.m.r. spectrum of VI indicates the bromo compound to be a mixture of the two possible *cis* and *trans* isomers. In carbon tetrachloride solution, VI showed a broad multiplet at 7.80 p.p.m. (aromatic H's), two quartets at 4.78 and 4.12 p.p.m. (CH<sub>3</sub>CH), and a pair of doublets at 1.81 and 0.99 p.p.m. (CH<sub>3</sub>CH) with  $J_{CH_3CH} = 8$  c.p.s.

Upon catalytic reduction over a prerduced 10% palladium-on-charcoal catalyst the monobromo compound VI, in ethyl acetate, absorbed 63% of the amount of hydrogen required for complete hydrogenolysis. The product of reduction, after a conventional work-up including a final molecular distillation, was obtained as a clear liquid that still contained halogen.

**1,2-Dibromo-1-methyl-2-phenylbenzocyclobutene (VII).** A solution of 1.00 g. (5.15 mmoles) of the hydrocarbon V and 1.65 g. (13 mmoles) of bromine in 10 ml. of carbon tetrachloride was irradiated with ultraviolet light until it became colorless,<sup>13</sup> *ca.* 5 min. Removal of the solvent *in vacuo* afforded 1.85 g. (100%) of the impure dibromide VII, m.p. 115–117°. Two recrystallizations of this product from petroleum ether (b.p. 60–70°) gave pure VII as clear prisms, m.p. 119.5–120.0°;  $\lambda_{max}^{isooctane}$  (log  $\epsilon$  values in parentheses) 271.0 sh (3.60), 277.0 (3.65), and 283.0  $m\mu$  (3.60).

*Anal.* Calcd. for C<sub>15</sub>H<sub>12</sub>Br<sub>2</sub>: C, 51.17; H, 3.44; Br, 45.44. Found: C, 51.12; H, 3.67; Br, 45.47.

Upon catalytic reduction over a prerduced 10% palladium-on-charcoal catalyst a solution of the dibromide VII in ethyl acetate absorbed 105% of the amount of hydrogen required for the hydrogenolysis of one bromine. Conventional work-up of the hydrogenolysis product, including a final molecular distillation, gave a colorless liquid (70%) having  $n_{19}^{20}D$  1.6150 and an infrared spectrum identical with that of the monobromide VI. Treatment of the liquid with sodium ethoxide afforded the ethyl ether IX, m.p. 55.0–55.5°, described below.

**Reaction of the Bromide VI with Potassium *t*-Butoxide. 2-*t*-Butoxy-1-methyl-2-phenylbenzocyclobutene (X).** A solution of 1.00 g. (3.66 mmoles) of the bromo compound VI in 25 ml. of *t*-butyl alcohol, to which had been added 0.30 g. (7.7 g.-atoms) of potassium, was refluxed 3 hr. The cloudy solution was poured into 80 ml. of cold water and the aqueous solution extracted with three 15-ml. portions of petroleum ether (b.p. 30–60°). The yellow oil obtained from the washed and dried extracts was chromatographed over 50 g. of neutral alumina (Merck no. 71707) using petroleum ether as an eluent. The first 200-ml. fraction collected gave 0.41 g. (42%) of the ether X which after sublimation at 40° (0.05 mm.) was isolated as white prisms, m.p. 49.5–50.0°;  $\lambda_{max}^{isooctane}$  (log  $\epsilon$  values in parentheses) 255 sh (2.90), 261.5 (3.17), 267.8 (3.32), and 274.4  $m\mu$  (3.29).

*Anal.* Calcd. for C<sub>19</sub>H<sub>22</sub>O: C, 85.67; H, 8.33; mol. wt., 266. Found: C, 85.49; H, 8.35; mol. wt. (Rast), 195.

The n.m.r. spectrum of the ether X in carbon tetrachloride solution showed a broad multiplet at 7.86 (aromatic H's), a quartet at 4.15 (CH<sub>3</sub>CH), a singlet at 1.28 (C–CH<sub>3</sub>), and a doublet at 0.78 p.p.m. (CH<sub>3</sub>CH) with  $J_{CH_3CH} = 8$  c.p.s.

(11) G. Wittig, G. Koenig, and K. Clauss, *Ann.*, **593**, 127 (1955).

(12) All melting points and boiling points are uncorrected. Chemical shifts for n.m.r. spectra are given in p.p.m. downfield from tetramethylsilane and done at 60 Mc. unless otherwise stated.

(13) The ultraviolet irradiation apparatus used for the hydrocarbon brominations was identical with that described by J. Meinwald and P. Gassman, *J. Am. Chem. Soc.*, **82**, 2857 (1960).

*2-Ethoxy-1-methyl-2-phenylbenzocyclobutene (IX).*

This ether was prepared by a procedure similar to that used for the preparation of the *t*-butyl ether X. From 1.85 g. (6.8 mmoles) of the bromide VI and sodium ethoxide (10 mmoles) there was obtained 1.55 g. (97%) of the crude ether IX as an oily solid, after chromatography on alumina. Sublimation of this crude product gave the crystalline ether IX, m.p. 55.5–56.0°;  $\lambda_{\text{max}}^{\text{isooctane}}$  (log  $\epsilon$  values in parentheses) 248 sh (2.83), 254 sh (3.01), 260.7 (3.20), 267.1 (3.34), 273.5 (3.30), 291.2 (1.97), and 300 m $\mu$  (2.00).

*Anal.* Calcd. for  $\text{C}_{17}\text{H}_{18}\text{O}$ : C, 85.67; H, 7.61; mol. wt., 238. Found: C, 85.50, 85.48; H, 7.66, 7.50; mol. wt. (Rast), 234.

The n.m.r. spectrum of the ether IX in carbon tetrachloride solution showed a broad multiplet at 7.15 (aromatic H's), a quadruplet at 3.75 ( $\text{CH}_3\text{CH}$ ), an octet at 3.45 ( $\text{CH}_3\text{CH}_2\text{-O-}$ ), a triplet at 1.10 ( $\text{CH}_3\text{-CH}_2\text{-O-}$ ), and a doublet at 0.79 p.p.m. ( $\text{CH}_3\text{CH}$ ) with  $J_{\text{CH}_3\text{CH}} = 7$  c.p.s. and  $J_{\text{CH}_3\text{CH}_2} = 7$  c.p.s.

*Reaction of the Ether IX with Maleic Anhydride.*

A solution of 0.30 g. (1.26 mmoles) of the ether IX and 0.17 g. (1.9 mmoles) of maleic anhydride in 7 ml. of dry carbon tetrachloride was refluxed 6 hr. Removal of the solvent gave a white solid residue that was recrystallized from benzene–petroleum ether (b.p. 30–60°) to give 0.33 g. (78%) of the adduct 1,2,3,4-tetrahydro-4-ethoxy-1-methyl-4-phenyl-2,3-naphthalenedicarboxylic acid anhydride (XII), m.p. 178.0–179.0°;  $\lambda_{\text{max}}^{\text{isooctane}}$  (log  $\epsilon$  values in parentheses) 244 sh (2.55), 250 sh (2.58), 254.7 (2.64), 260.6 (2.69), 264.1 (2.67), and 270.6 m $\mu$  (2.51).

*Anal.* Calcd. for  $\text{C}_{21}\text{H}_{20}\text{O}_4$ : C, 74.98; H, 5.99. Found: C, 74.90; H, 6.09.

*Reaction of the Ether IX with Acetyl Bromide.*<sup>10</sup>

Acetyl bromide (0.37 g., 3 mmoles) was added to 0.50 g. (2.1 mmoles) of the ether IX and the mixture was allowed to stand at room temperature for 20 hr. Excess acetyl bromide was removed with a stream of dry nitrogen and the brown residual oil was distilled through a modified Hickman still giving 0.52 g. (91%) of the monobromide VI,  $n_{\text{D}}^{24.5}$  1.6183, which had an infrared spectrum identical with an authentic specimen.

*2-Methoxy-1-methyl-2-phenylbenzocyclobutene (VIII).*

This ether was obtained by the procedure used in the preparation of the ethyl and *t*-butyl ethers IX and X. From 0.69 g. of the bromo compound VI there was obtained 0.45 g. (87%) of distilled pure ether VIII, b.p. 77° (0.07 mm.);  $n_{\text{D}}^{21.0}$  1.5699;  $\lambda_{\text{max}}^{\text{isooctane}}$  (log  $\epsilon$  values in parentheses) 250 sh (2.81), 255 sh (3.00), 260.9 (3.20), 267.4 (3.35), 273.0 (3.33), 290.1 (1.88), and 300.0 m $\mu$  (1.86).

*Anal.* Calcd. for  $\text{C}_{16}\text{H}_{16}\text{O}$ : C, 85.68; H, 7.19. Found: C, 85.67; H, 7.25.

The n.m.r. spectrum of the ether VIII in carbon tetrachloride solution at 56.4 Mc. showed a broad multiplet at 7.20 (aromatic H's), a quartet at 3.79 ( $\text{CH}_3\text{CH}$ ), a singlet at 3.25 ( $-\text{OCH}_3$ ), and a doublet at 0.81 p.p.m. ( $\text{CH}_3\text{CH}$ ).

*Light-Catalyzed Reaction of the Ethers VIII, IX, and X with Bromine.* Carbon tetrachloride solutions of equimolar quantities of bromine and the ether (VIII, IX, or X) were irradiated with ultraviolet light for 1–2 hr. The crystalline product obtained in each of the

three cases proved to be the dibromo compound VII (*via* mixture melting point determination with authentic dibromide VII). The yield of dibromide VII was 58% from the ethyl ether IX, 56% from the methyl ether VIII, and 35% from the *t*-butyl ether X.

*o-Ethylbenzohydrol Ethyl Ether (XI).* This ether was obtained *via* the procedure used to prepare the benzocyclobutene ethers VII, IX, and X. From 3.80 g. of *o*-ethyldiphenylmethyl bromide<sup>1</sup> there was obtained, after a final distillation, 2.19 g. (95%) of the ether XI, b.p. 89.91° (0.01 mm.);  $n_{\text{D}}^{24.5}$  1.5495;  $\lambda_{\text{max}}^{\text{isooctane}}$  (log  $\epsilon$  values in parentheses) 250 sh (2.50), 254 sh (2.61), 260.0 (2.71), 265.5 (2.69), 269 sh (2.55), 272.6 (2.47), 307.5 (1.10), and 320.0 m $\mu$  (0.90).

*Anal.* Calcd. for  $\text{C}_{17}\text{H}_{20}\text{O}$ : C, 84.95; H, 8.39. Found: C, 85.22; H, 8.41.

*Debromination of the Dibromo Compound VII. 3,4-Dimethyl-7,8-diphenyl-1,2,5,6-dibenzocyclooctatetraene (XVII).*

*A. With Lithium Amalgam.* A solution of 1.90 g. (5.15 mmoles) of the crude dibromide VII and 75 ml. of ether was placed in a thick-walled 250-ml. Pyrex bottle. Lithium amalgam (29 g., containing 0.5% lithium) was added, and the bottle was purged with nitrogen and shaken mechanically for 20 hr. The solution was filtered and the ether evaporated to give 1.46 g. of orange solid. The solid was boiled in petroleum ether (30–60°) to give 0.75 g. of orange residue. From the petroleum ether extract only an intractable semisolid was obtained. The orange residue was then boiled in ethanol to leave 0.45 g. (45%) of the cyclooctatetraene XVII, m.p. 207.0–207.5°;  $\lambda_{\text{max}}$  285 m $\mu$  (log  $\epsilon$  3.50).

*Anal.* Calcd. for  $\text{C}_{30}\text{H}_{24}$ : C, 93.71; H, 6.29; mol. wt., 384. Found: C, 93.71; H, 6.39; mol. wt. (Rast), 310.

*B. With Sodium Amalgam.* The procedure for lithium amalgam debromination was followed. Reaction of 1.90 g. (5.15 mmoles) of compound VII with 50 g. of mercury containing 0.50 g. of sodium gave as the only isolable product the dimer XVII, 0.56 g. (56%), m.p. 205–207°. The remainder of the product, 0.34 g., was an uncharacterizable, yellow semisolid.

*C. With Sodium Iodide.* A solution of 1.90 g. (5.15 mmoles) of the crude dibromide VII and 15 ml. of dry dimethylformamide (DMF) was added to a solution of 4.50 g. (30 mmoles) of sodium iodide in 60 ml. of dry DMF. After stirring at room temperature for 25 hr., the violet solution was poured into 300 ml. of water, the iodine destroyed with dilute aqueous sodium bisulfite solution, and the mixture extracted with three 50-ml. portions of ether. From the combined washed and dried ether extracts there was obtained 1.0 g. of the yellow semisolid which was extracted with petroleum ether (b.p. 30–60°). The petroleum ether extracts gave 0.30 g. of an orange bromine-containing oil. Trituration of the petroleum ether insolubles afforded 0.20 g. (20%) of the crude cyclooctatetraene XVII, m.p. 195–200°. No characterizable products could be obtained from the ethanol extracts.

*D. With Zinc-Ether.*—Reagent grade zinc dust (90–95%) was activated according to the method of Baer–Buchnea.<sup>14</sup> To a vigorously stirred suspension of activated zinc (from 60 g. of zinc dust) in 1 l. of

(14) E. Baer and D. Buchnea, *J. Biol. Chem.*, 230, 447 (1958).

anhydrous ether, under an atmosphere of nitrogen, a solution of 3.94 g. (10.3 mmoles) of crude dibromide VII in 500 ml. of ether was added over a 3-hr. period. The deep gold color which developed during the addition slowly faded. After stirring an additional 4 hr., the light yellow solution was filtered through kieselguhr and the ether removed to give, after further washing with ether, 1.71 g. (85.5%) of the cyclooctatetraene XVII, m.p. 210–211°.

*E. With Zinc-Ethanol.* Repetition of the zinc debromination according to the preceding procedure using 1.90 g. (5.15 mmoles) of compound VII and ethanol as solvent gave 0.10 g. (10%) of the dimer XVII, m.p. 205–207°. The remainder of the product, 0.38 g., was a yellow halogen-containing oil, b.p. 83° (0.03 mm.),  $n_D^{25}$  1.5560. This material later crystallized, m.p. 54.5–55.5°, and had an infrared spectrum identical with that of the ethyl ether IX.

Repetition of the above reaction in which 1.90 g. of the dibromide VII was added as a solid to the zinc suspension gave, after the usual work-up, 0.45 g. (45%) of the dimer XVII.

*Ozonolysis of the Cyclooctatetraene XVII.* A solution of 2.00 g. (5.20 mmoles) of the hydrocarbon XVII in 125 ml. of chloroform and 25 ml. of ethanol was ozonized with a 3% stream of ozone in dry air for 1 hr. at 0°. The solution was poured into a vigorously stirred mixture of 20 g. of sodium iodide, 80 ml. of ethanol, and 20 ml. of acetic acid cooled at 0°. After stirring for 2 hr., the reaction mixture was poured into 500 ml. of water, the iodine destroyed with sodium bisulfite, and the solution extracted with three 50-ml. portions of ether. From the combined washed and dried organic solutions there was obtained, after recrystallization in methanol, 1.30 g. (59%) of *cis-sym-o,o'*-diacetyltetraphenylethylene (XIX), m.p. 176.0–176.5°.

*Anal.* Calcd. for  $C_{30}H_{24}O_2$ : C, 86.61; H, 5.81. Found: C, 86.46; H, 5.93.

*Hypochlorite Oxidation of the Ketone XIX to cis-sym-Tetraphenylethylene-sym-o,o'-dicarboxylic Acid (XX).* A mixture of 1.00 g. (2.40 mmoles) of the ketone XIX in 50 ml. of dioxane and 36 ml. of 5% sodium hypochlorite, containing 1.0 g. of sodium hydroxide, was stirred at room temperature for 24 hr. Sodium bisulfite, 0.5 g., was added to destroy excess sodium hypochlorite, the aqueous layer separated, and the latter extracted with two 50-ml. portions of ether. Acidification of the aqueous layer with dilute hydrochloric acid gave 1.00 g. (100%) of the diacid XX, m.p. 285–290°, which after recrystallization from acetic acid showed m.p. 295.0–297.0°.

*Anal.* Calcd. for  $C_{28}H_{20}O_4$ : C, 79.98; H, 4.76; neut. equiv., 210.2. Found: C, 79.84; H, 4.86; neut. equiv., 205.8.

*Decarboxylation of the Acid XX. Tetraphenylethylene (XXII).* A solution of 0.20 g. (0.48 mmole) of the acid XX in 6 ml. of quinoline, containing 0.8 g. of copper powder, was refluxed for 1 hr.<sup>15</sup> This solution was poured into 25 ml. of benzene and the benzene solution washed successively with water, concentrated hydrochloric acid, water, 10% aqueous sodium carbo-

nate, and water. From the dried organic layer there was obtained, after recrystallization from benzene-ethanol, 0.10 g. (62%) of the hydrocarbon XXII, m.p. 220.0–221.5°; m.m.p., with authentic hydrocarbon XXII 220.0–221.5°.

*Permanganate Oxidation of the Acid XX.* A solution of 0.50 g. of the acid XX in 50 ml. of water containing 5 ml. of 10% aqueous potassium hydroxide and 10 g. of potassium permanganate was refluxed for 3 hr.<sup>16</sup> The reaction mixture was acidified with sulfuric acid, and then sodium bisulfite was added to destroy manganese dioxide and excess permanganate. The solution was filtered and the collected solid, after drying, was extracted with boiling benzene to afford 0.10 g. of unchanged acid XX. The aqueous filtrate was extracted with three 50-ml. portions of ether, and the ether solutions were combined with the benzene extracts and evaporated to dryness. Sublimation of the residue thus obtained gave 0.15 g. (34%) of *o*-benzoylbenzoic acid (XXI), m.p. 123.5–125°, whose melting point was not depressed upon admixture with an authentic specimen of the acid.

*Osmium Tetroxide Oxidation of the Dimer XVII.* To a solution of 1.50 g. (3.90 mmoles) of the dimer XVII in 15 ml. of pyridine 1.00 g. (3.94 mmoles) or osmium tetroxide was added.<sup>17</sup> The mixture was stirred at room temperature for 20 hr., and, since the osmate ester could not be hydrolyzed in the usual manner, the solvent was removed and the brown solid dissolved in dioxane. Addition of aqueous sodium sulfide gave a black precipitate which was filtered. The tan residue obtained after evaporation of the filtrate was recrystallized in carbon tetrachloride to give 0.21 g. (16.5%) of the diol 3,4-dihydroxy-3,4-dimethyl-7,8-diphenyl-1,2,5,6-dibenzocyclooctatriene (XVIII), m.p. 222.0–223°.

*Lead Tetraacetate Cleavage of the Diol XVIII to the Diketone XIX.* A suspension of 0.15 g. (0.38 mmole) of the diol XVIII and 0.23 g. (0.52 mmole) of lead tetraacetate in 10 ml. of dry benzene was stirred for 10 hr. at room temperature and then refluxed for 0.5 hr.<sup>18</sup> The mixture was poured into 25 ml. of water, the benzene layer separated, and the aqueous layer extracted with 15 ml. of benzene. From the combined benzene fractions there was obtained 0.15 g. (100%) of the diketone XIX, m.p. 172–174°. After recrystallization from petroleum ether (b.p. 60–70°), the diketone product proved to be identical with the previously prepared sample of the diketone XIX (see above).

*Solvolysis of the Dibromo Compound VII in Ethanol. 1-Bromo-2-ethoxy-1-methyl-2-phenylbenzocyclobutene (XXIII).* A solution of 1.33 g. (3.8 mmoles) of the dibromide VII and 75 ml. of ethanol was stirred for 4 hr. The solid residue obtained after removal of the ethanol was taken up in ether. From the washed and dried ether solution there was obtained 1.07 g. (90%) of an orange solid. Recrystallization of this solid from petroleum ether (b.p. 60–70°) gave the bromo ether XXIII as white prisms, m.p. 106.5–107.5°;

(16) R. L. Shriner, R. C. Fuson, and D. Y. Curtin, "The Systematic Identification of Organic Compounds," 4th Ed., John Wiley and Sons, Inc., New York, N. Y., 1956, p. 250.

(17) J. S. Baran, *J. Org. Chem.*, **25**, 257 (1960).

(18) B. Bannister and B. Elsner, *J. Chem. Soc.*, 1061 (1951).

(15) L. F. Fieser and M. M. Peckel, *J. Am. Chem. Soc.*, **68**, 2577 (1946).

$\lambda_{\text{max}}^{\text{isooctane}}$  (log  $\epsilon$  values in parentheses) 256 sh (3.02), 263.8 (3.26), 270.0 (3.40), and 277.1 m $\mu$  (3.36).

*Anal.* Calcd. for C<sub>17</sub>H<sub>17</sub>OBr: C, 64.36; H, 5.41; Br, 25.16. Found: C, 64.15; H, 5.34; Br, 25.23.

*Debromination of the Bromo Ether XXIII.* A solution of 0.60 g. (1.9 mmoles) of the bromo ether XXIII in 100 ml. of ethanol was added over a 1-hr. period to a stirred suspension of activated zinc (from 30 g. of 95% zinc)<sup>14</sup> in 200 ml. of ethanol under an atmosphere of dry nitrogen. After stirring an additional 3 hr., the solution was filtered and the ethanol removed *in vacuo*. From a washed and dried ethereal solution of the residue there was obtained, after distillation through a short-path Vigreux column, 0.12 g. (30%) of the ether IX, b.p. 81° (0.03 mm.),  $n_{\text{D}}^{24.8}$  1.5578. The material crystallized on cooling, m.p. 54.5–55.5°, and showed no depression of melting point on admixture with an authentic sample.

*Bromination of the Bromo Ether XXIII.* A mixture of 0.33 g. (1.0 mmole) of the bromo ether XXIII and 0.18 g. (1.5 mmoles) of acetyl bromide was allowed to stand at room temperature for 20 hr. Removal of the volatile materials *in vacuo* gave 0.37 g. (100%) of the dibromide VII as white crystals, m.p. 119.5–120.0°, whose melting point was not depressed on admixture with an authentic sample.

*Low-Temperature Zinc Debromination of the Dibromide VII.* *A.* Zinc debromination of 1.90 g. (5.15 mmoles) of the dibromide VII was carried out as previously described (see above section D on Debromination Studies of VII), except that the temperature was maintained at 0°. The zinc dust was filtered under nitrogen and the ether removed at 0°. To the residue was added 200 ml. of cold petroleum ether (b.p. 30–60°), the solution stirred for 2 hr., and the precipitated dimer XVII, 0.12 g., filtered. The solvent was removed from the clear solution at 0°, and 50 ml. of isooctane was immediately added to the tan residue (most of the residue was insoluble). An aliquot of the isooctane solution was used for the ultraviolet studies described below. The remainder of the isooctane slurry was evaporated to give 0.54 g. of the dimer XVII.

*Ultraviolet Studies of the Isooctane Solution.* The ultraviolet studies of the isooctane solution were made as rapidly as possible. Initially the solution showed strong absorption at 274 and 282 m $\mu$  with a shoulder at 297 m $\mu$  and possibly very weak absorption at 325 and 343 m $\mu$ . After 30 min. the base line had increased and the shoulder at 297 m $\mu$  was weak, while the broad peak at 325 m $\mu$  was no longer discernible; the peak at 343 m $\mu$  was very weak. After 60 min., the spectrum showed only diminished absorption at 274 and 282 m $\mu$  with a very weak shoulder at 297 m $\mu$ . After 180 min. even the peaks at 274 and 282 m $\mu$  had all but disappeared. The spectrum was essentially that of the dimer XVII with a maximum at 285 m $\mu$ .

*B.* Activated zinc dust from 30 g. of zinc was mixed with 5 g. of Celite and packed in a jacketed column (1 × 15 in.). A solution of 1.90 g. (5.15 mmoles) of the dibromide VII in 125 ml. of ether was passed through the column over a 1.5-hr. period, while maintaining column jacket temperature at 8–10° with water. Both the column and the solution collected in the iced receiver became golden in color. After all the di-

bromide solution had been added, ether was passed through the column until the effluent was colorless. The receiver was warmed to room temperature and, although the gold color did not dissipate, only starting material or the dimer XVII could be isolated.

*Debromination of the Dibromo Compound VII in the Presence of Trapping Reagents.* *A. Dienophiles.* (1) Zinc debromination in ether of 1.90 g. (5.15 mmoles) of the dibromide VII was carried out as previously described (see above section D, Debromination of Compound VII) in the presence of 10 mmoles of tetracyanoethylene (TCNE). After the usual work-up, only TCNE could be recovered from the viscous dark oils. (2) The above procedure was repeated using 10 mmoles of N-phenylmaleimide. After the usual work-up, a small amount of the dimer XVII as well as starting materials were isolated. (3) The zinc debromination of 5.15 mmoles of the dibromide VII was carried out as described in section B (Low-Temperature Bromination of the Dibromide VII) with 10 mmoles of TCNE in the receiver. Removal of the solvent gave a yellow solid from which 0.76 g. (76%) of the dimer XVII was obtained upon trituration with a few milliliters of ether. From the yellow ether filtrate, TCNE was isolated.

*B. Dienes.* Zinc debromination of 1.90 g. (5.15 mmoles) of the dibromide VII was carried out as before, but in the presence of 7.5 ml. of freshly prepared cyclopentadiene. After half of the dibromide had been added, an additional 5 ml. of cyclopentadiene was added. The usual work-up afforded 0.65 g. (65%) of the dimer XVII. A similar result was obtained when the debromination was carried out at 0°.

*The Coupling of the Monobromo Compound VI with Zinc.* A solution of 1.72 g. (6.3 mmoles) of the monobromide VI in 100 ml. of ether was added over a 1-hr. period to a suspension of activated zinc (from 30 g. of zinc) in 250 ml. of ether under an atmosphere of dry nitrogen. After stirring for an additional period of 3 hr., the solution was filtered and the ether removed. Evaporation of the washed and dried ethereal solution of the residue gave a yellow glass. The latter was chromatographed over 50 g. of alumina (Merck no. 71707) using petroleum ether (b.p. 30–60°) as eluent. The glass obtained in the first ether collected from the column was recrystallized in 95% ethanol to give 0.81 g. (67%) of the dimer XXVII as white cubes, m.p. 155.5–156.0°;  $\lambda_{\text{max}}^{\text{isooctane}}$  (log  $\epsilon$  values in parentheses) 256 sh (3.39), 261.2 (3.52), 267.4 (3.66), 273.5 (3.62), 289.4 (2.37), and 297.7 m $\mu$  (2.43).

*Anal.* Calcd. for C<sub>30</sub>H<sub>26</sub>: C, 93.22; H, 6.78; mol. wt., 384. Found: C, 93.46; H, 6.88; mol. wt. (Rast). 378.

*Nickel Carbonyl Debromination of the Dibromide VII.* A solution of the dibromide VII, from 2.00 g. (10 mmoles) of the compound V, in 50 ml. of anhydrous benzene was cooled in Dry Ice, and 2.0 ml. of nickel carbonyl was condensed in the flask. The solution was slowly heated to reflux in nitrogen and, after refluxing for 6 hr., the dark green precipitate, 2.55 g., was filtered from the golden solution. All but 0.20 g., a water-insoluble polymeric material, of the dark green precipitate dissolved in water. Assuming all water-soluble material to be nickel bromide, 2.35 g. (95%) of nickel

bromide was obtained. The gold benzene solution was evaporated and the yellow oil, 2.28 g., chromatographed over 75 g. of neutral alumina (Merck 71707). Elution with 20% carbon tetrachloride in petroleum ether (b.p. 30–60°) gave 0.65 g. (32.5%) of a crystalline material: m.p. 158–162°, raised to 165.0–166° dec. on recrystallization from hexane;  $\lambda_{\text{max}}^{\text{isooctane}}$  (log  $\epsilon$  values in parentheses) 258 sh, (3.47), 262 sh (3.64), 269.7 (3.77), 275.5 (3.72), 279 sh, (3.56), 292 sh (2.53), and 299.3  $\mu$  (2.39).

*Anal.* Found: C, 93.63, 93.50; H, 6.48, 6.42; mol. wt. (Rast), 388.

Further elution of the column with 30–40% carbon tetrachloride in petroleum ether (b.p. 30–60°) gave 0.90 g. (45%) of a halogen-free solid. From 95% ethanol the latter crystallized into a tan powder.

*Anal.* Found: C, 89.62; H, 6.27; mol. wt. (Rast), 364.

Final elution of the column with ether gave 0.70 g. of a halogen-free glass which could not be obtained crystalline on attempted crystallization from either polar or nonpolar solvents. At room temperature no reaction occurred between the dibromide VII and nickel carbonyl in either benzene or ether.

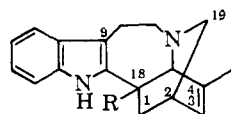
## Vinca Alkaloids. XVII. Chemistry of Catharanthine<sup>2,3</sup>

Marvin Gorman, Norbert Neuss, and Nancy J. Cone

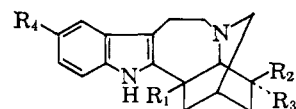
Contribution from the Lilly Research Laboratories, Indianapolis 6, Indiana.  
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*Catharanthine (I), a major alkaloid of the isoquinuclidine type in the leaves of Vinca rosea Linn. (Catharanthus roseus G. Don.), undergoes a number of interesting transformations under acidic conditions. These reactions appear to proceed via tetracyclic immonium intermediates of the type XVI or XXVI. The products of these transformations are related to the naturally occurring alkaloid quebrachamine (XIII) and are represented by cleavamine (XI) and its derivatives.*

Catharanthine (I),  $C_{21}H_{24}O_2N_2$ , one of the major alkaloids in the leaves of *Vinca rosea* Linn., has been shown to be closely related to the indole moiety of the dimeric oncolytic alkaloids, vinblastine and vincristine, also found in this plant.<sup>4</sup> Spectral data indicate that the alkaloid is a simple 2,3-substituted pentacyclic indole containing an ester group and closely related to the isoquinuclidine alkaloid coronaridine (II),  $C_{21}H_{26}O_2N_2$ .<sup>5,6</sup> The n.m.r. spectra (Figure 1) confirm the above assignments and indicate that the alkaloid contains a double bond with one vinyl proton at  $\delta$  5.3, a C-ethyl group characterized by a methyl triplet at  $\delta$  1.1, and an allylic methylene quartet at  $\delta$  1.9. These data clearly suggested structure I for catharanthine. Supporting evidence for the position of the double bond was obtained from decoupling experiments performed on the vinyl proton of the alkaloid.<sup>7</sup> Satu-



I, R = COOCH<sub>3</sub>  
X, R = H



II, R<sub>1</sub> = COOCH<sub>3</sub>; R<sub>2</sub> = C<sub>2</sub>H<sub>5</sub>; R<sub>3</sub> = H; R<sub>4</sub> = H; coronaridine  
III, R<sub>1</sub> = COOCH<sub>3</sub>; R<sub>2</sub> = C<sub>2</sub>H<sub>5</sub>; R<sub>3</sub> = H; R<sub>4</sub> = OCH<sub>3</sub>; voacangine  
IV, R<sub>1</sub> = COOCH<sub>3</sub>; R<sub>2</sub> = H; R<sub>3</sub> = C<sub>2</sub>H<sub>5</sub>; R<sub>4</sub> = H; dihydrocatharanthine  
VII, R<sub>1</sub> = H; R<sub>2</sub> = H; R<sub>3</sub> = C<sub>2</sub>H<sub>5</sub>; R<sub>4</sub> = H; epi-ibogamine  
VIII, R<sub>1</sub> = H; R<sub>2</sub> = C<sub>2</sub>H<sub>5</sub>; R<sub>3</sub> = H; R<sub>4</sub> = H; ibogamine

ration of this proton led to changes in the shape of the C-2 proton at  $\delta$  2.62, and, in addition, small decoupling effects were seen on the protons at  $\delta$  4.18 (C-5 proton) and 1.9 (methylene of ethyl group). As expected, dehydrogenation of catharanthine with palladium on carbon yielded 3-ethylpyridine by the cleavage of the allylic C-1–C-2 bond. In the isoquinuclidine Iboga alkaloids which do not have a double bond at C-3–C-4 (*viz.*, voacangine (III) and dihydrocatharanthine (IV) (*vide supra*)), the C-1–C-18 bond is broken to afford 3-methyl-5-ethylpyridine.<sup>8</sup>

Hydrogenation of I afforded only one isomer, dihydrocatharanthine (IV). Its infrared spectrum is strikingly similar to that of coronaridine (II). The differences in these compounds could be explained by examining Dreiding models which showed that the hydrogens most likely entered the molecule from the side nearest to N<sub>10</sub> to give an axial ethyl group in dihydrocatharanthine. The ethyl group in the Iboga

(1) Presented in part at the 144th National Meeting of the American Chemical Society, Los Angeles, Calif., April 1–4, 1963, Abstracts, p. 38M.

(2) *Vinca Alkaloids. XVI*: M. Gorman, G. H. Svoboda, I. S. Johnson, H. F. Wright, and N. Neuss, *ref. 1*, p. 40L.

(3) N. Neuss and M. Gorman, *Tetrahedron Letters*, 206 (1961).

(4) N. Neuss, M. Gorman, W. Hargrove, N. J. Cone, K. Biemann, G. Büchi, and R. E. Manning, *J. Am. Chem. Soc.*, **86**, 1440 (1964).

(5) M. Gorman, N. Neuss, N. J. Cone, and J. A. Deyrup, *ibid.*, **82**, 1142 (1960).

(6) The correlation of isoquinuclidine alkaloids (with no aromatic methoxyl groups) is readily found by the observance of a triplet centered at 6.8  $\mu$  in the infrared spectrum: N. Neuss, "Lilly Collection of Physical Data on Indole and Dihydroindole Alkaloids," Eli Lilly and Co., Indianapolis, Ind., 1964.

(7) The decoupling experiments described herein were carried out by Mr. P. Landis from these laboratories on a proton-proton de-

coupler patterned after that described by Mr. L. F. Johnson, Varian Associates, Palo Alto, Calif.

(8) F. Walls, O. Collera, and A. Sandoval, *Tetrahedron*, **2**, 173 (1958).