subjected to desulfurization with deactivated Raney nickel (two level teaspoonfuls)[15] in acetone solution (100 ml) as described above. Purification of **15** through short-path distillation at 2.5 mm, bath temperature 105°, gave analytically pure product (187 mg): $\nu_{\text{max}}^{\text{CHCl}_3}$ 2940, 2880, 1520, 1500, 1400, and 1380 cm^{-1}; $\delta_{\text{TMS}}^{\text{CCl}_4}$ 0.87 (s, CH_3), 0.85 (d, J = 5 Hz, isopropyl), and 0.82 (s, CH_3) ppm.

Natural Valerane from *l*-Valeranone.—This product was prepared from natural valeranone (120 mg) essentially as described by Hikino, *et al.*,[1f] and the identity of the product prepared in our laboratories was established by comparison of infrared and nmr spectra of material prepared in Japan.[16]

Registry No.—**3**, 29969-74-2; **5**, 29863-73-8; **6**, 29863-74-9; **7**, 29863-75-0; **8**, 29862-76-1; **9**, 29863-77-2; **10**, 29863-78-3; **11**, 29863-79-4; **12**, 29863-80-7; **12** 2,4-DNP, 29863-81-8; **13**, 29863-82-9; **14**, 30008-94-7; **14** 2,4-DNP, 29863-83-0; **15**, 29863-84-1.

Acknowledgment.—We sincerely thank Dr. H. Hikino for helping us with natural valeranone and for providing us with the copies of his infrared and nmr spectra of valerane, Professor Edward Piers for providing us with his experimental details for the preparation of **3** from **4**, Dr. David H. Buss for gas chromatograms, Mr. Melvin C. Seffel for infrared spectra, and Mr. David B. Holland for technical assistance. The interest and encouragement of Dr. Leonard R. Axelrod are gratefully acknowledged. This investigation was supported in part by a research grant from the Southwest Foundation for Research and Education for preparing compounds of medicinal value, and Grant A-03270-12 from the National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, Bethesda, Md.

Acetylation of Pinane

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When pinane was treated with acetyl chloride and aluminum chloride under Friedel–Crafts conditions, an unstable product, 2-acetyl-1-chloro-4-isopropyl-1-methylcyclohexane, was formed. This product was transformed to a mixture of acetyl-4-isopropyl-1-methylcyclohexenes by loss of HCl. The stereochemistry of the products and its bearing on the mechanism of the Kondakov reaction is discussed.

Although the chemistry of the pinenes has been extensively studied,[1] relatively little has been learned about the saturated hydrocarbon, pinane. The pinane molecule is quite stable and its potentially labile cyclobutane ring is resistant to most oxidizing agents and mineral acids. It reacts only slowly with hydrogen bromide at 230°.[2]

Whereas free-radical type reactions of pinane have been reported,[3-8] reactions of pinane by ionic mechanisms have not. However, the acetylation of saturated hydrocarbons with acetyl chloride in the presence of aluminum chloride is known[9-11] and offers a feasible route toward functionalizing pinane. We have investigated this reaction and present here the results of our work.

When an ethylene dichloride solution of the complex formed between acetyl chloride and aluminum chloride was added to pinane (**1**), a mixture of chloro ketones **5** was produced. The chloro ketones lost HCl slowly on standing. Upon heating, HCl was evolved more rapidly and the product formed was the α,β-unsaturated ketone **8**. When submitted to glc analysis, HCl was again lost but the products eluted were the β,γ-unsaturated ketones **6** and **7** plus a small amount of **8**.

That the chloro ketones formed are 2-acetyl-1-chloro-4-isopropyl-1-methylcyclohexanes (**5**) was supported by the fact the same products were formed by adding acetyl chloride to 1-*p*-menthene. Also, the unsaturated ketones eluted from the glc were identical with those prepared by the acetylation of 1-*p*-menthene with acetic anhydride.

The nmr spectra of crude and distilled fractions of the β-chloro ketone **5** revealed that it was a mixture of at least two principal isomers **5a** and **5b**. One isomer (which dominated the earlier fractions of the distilled crude) showed a broad multiplet at τ 6.83 (*ca.* 12-Hz wide, $>CHCOCH_3$), sharp singlets at τ 7.82 (CH_3CO) and 8.35 [$>C(Cl)CH_3$], and a doublet at τ 9.22 $\left(J = 5.5\ \text{Hz}, -\!<\begin{matrix}CH_3\\ CH_3\end{matrix}\right)$. The nmr of later fractions showed additional peaks at τ 7.30 (*ca.* 17-Hz wide, $>CHCOCH_3$), a sharp singlet at τ 7.77 (CH_3CO), and a doublet at τ 9.26 $\left(J = 5.5\ \text{Hz}, -\!<\begin{matrix}CH_3\\ CH_3\end{matrix}\right)$ assigned to a second isomer. The signals for the methine protons α to the carbonyl indicated that this proton was equatorial in the lower boiling isomer **5a** (less broad and further downfield from TMS) and was axial in the higher boiling isomer **5b** (signal at higher field and broader due to diaxial coupling).[12]

In accord with the above, it was found that **5a** decomposed on glc to a β,γ-unsaturated ketone **6** in which the acetyl group is quasiaxial while isomer **5b** decomposed to a β,γ-unsaturated ketone **7** in which the acetyl

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(1) (a) B. D. Sully, *Chem. Ind. (London)*, 263 (1964). (b) D. V. Banthorpe and D. Whittaker, *Chem. Rev.*, **66**, 643 (1966); *Quart. Rev. Chem. Soc.*, 373 (1966). (c) C. Bordenca, *Amer. Perfum. Cosmet.*, **80**, (7), 19 (1965).

(2) B. T. Brooks, "The Chemistry of the Nonbenzenoid Hydrocarbons," 2nd ed, Reinhold, New York, N. Y., 1950, p 533.

(3) (a) G. Bonnet, *Bull. Inst. Pin.*, 217, 241 (1938); 1 (1939). (b) A. Gandini, *Gazz. Chim. Ital.*, **70**, 254 (1940); **71**, 722 (1941).

(4) (a) C. Fillatre and R. Lalande, *Bull. Soc. Chim. Fr.*, 4141 (1968); (b) G. S. Fisher, J. S. Stinson, and L. A. Goldblatt, *J. Amer. Chem. Soc.*, **75**, 3675 (1953).

(5) E. Muller and G. Fiedler, *Chem. Ber.*, **98**, 3493 (1965).

(6) G. A. Schmidt and G. S. Fisher, *J. Amer. Chem. Soc.*, **76**, 5426 (1954).

(7) G. A. Schmidt and G. S. Fisher, *ibid.*, **81**, 445 (1959).

(8) C. Fillatre and R. Lalande, *Bull. Soc. Chim. Fr.*, 1575 (1966).

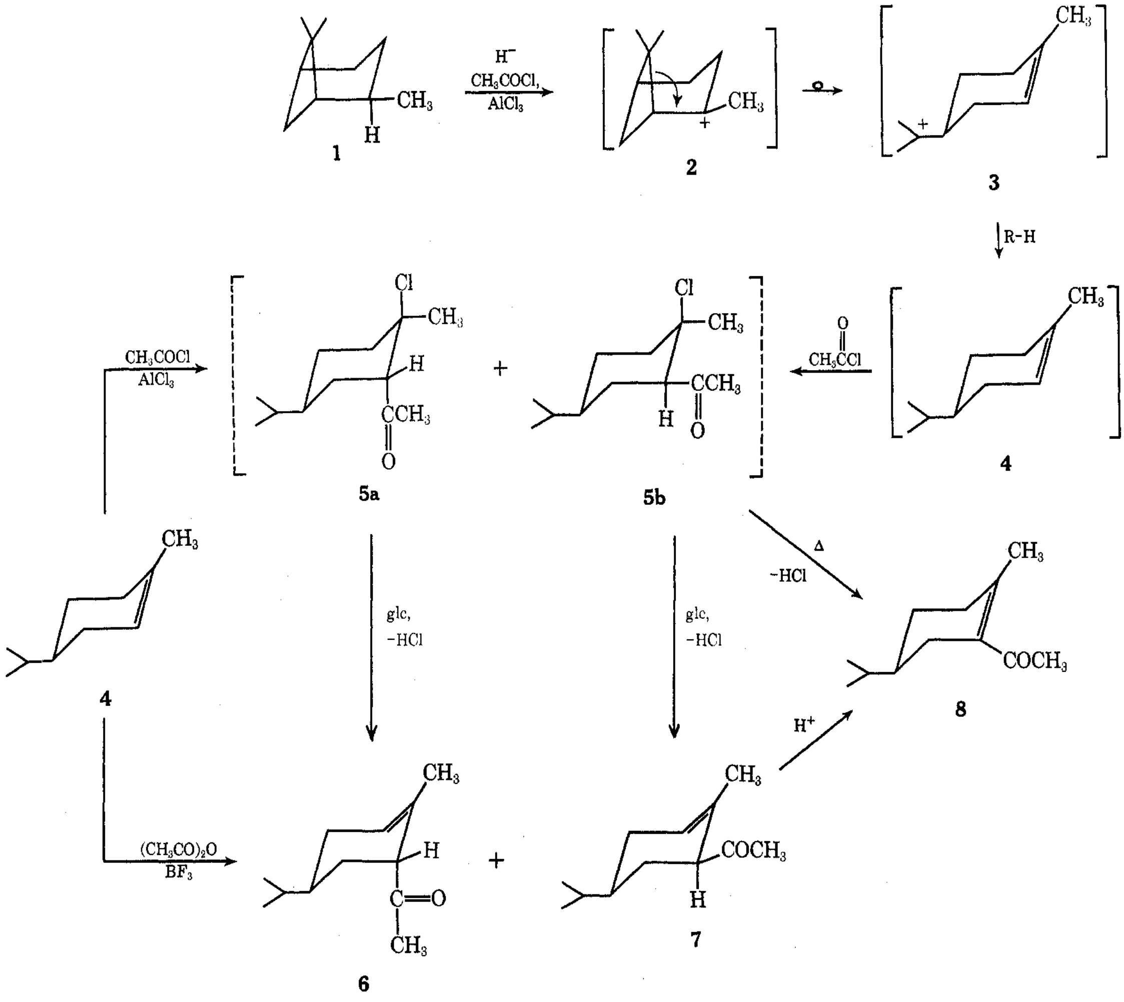
(9) G. A. Olah, ed., "Friedel-Crafts and Related Reactions," Vol. I, Interscience, New York, N. Y., 1964, p 135; Vol. III, pp 1069–1077.

(10) I. Tabushi, K. Fujita, and R. Oda, *Tetrahedron Lett.*, 4247 (1968); 5455 (1968).

(11) G. Baddeley, B. G. Heaton, and J. W. Rasburn, *J. Chem. Soc.*, 4713 (1960).

(12) L. M. Jackman, "Application of Nuclear Magnetic Resonance Spectroscopy to Organic Chemistry," Pergamon Press, Elmsford, N. Y., 1959, p 116.

SCHEME I

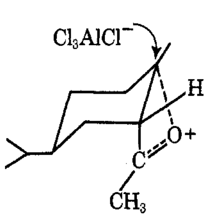


group is quasiequatorial plus an α,β-unsaturated ketone **8**. The structures of the β,γ-unsaturated ketones were based on the observation that the proton α to the carbonyl in isomer **6** gave an nmr signal which was only half as broad as the corresponding proton of isomer **7** indicating that the former was quasiequatorial and the latter quasiaxial.[13]

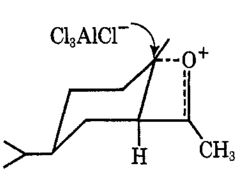
Recent evidence on the ir spectra of 4-alkyl-1-methylcyclohexyl chlorides[14] indicates that those compounds in which the chlorine is axial have carbon–chlorine stretching bands at 560 ± 20 cm^{-1} and those in which the chlorine is equatorial have bands at 650 ± 20 cm^{-1}. The presence of a strong band at 540 cm^{-1} (and no evidence of any in the 650-cm^{-1} region) for both **5a** and **5b** clearly suggest that the chlorine is axial in both isomers as indicated in Scheme I. It is not surprising, therefore, that the higher boiling fractions decompose more rapidly since they are enriched in **5b** which can decompose to **8** *via* a trans diaxial elimination.

Scheme I suggests a mechanism to explain the products formed. The acetyl chloride–aluminum chloride complex can abstract a hydride ion from *cis*-pinane to produce a carbonium ion **2** which can rearrange and abstract a hydride ion to form 1-*p*-menthene (**4**). The source of the hydride ion could be **1** or some other hydrocarbon species in the medium.[9] An alternative mechanism involving α-pinene, formed by the loss of a proton from **2**, is not likely since α-pinene produced only residue under these reaction conditions while **4** produced the β-chloro ketones **5a** and **5b**.

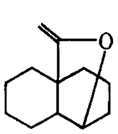
That only axial chloro compounds were detected can be rationalized from either kinetic or thermodynamic considerations. A four-membered transition state such as **10a** can be considered in which the oxygen stabilizes the carbonium ion and requires that the chlorine attack from the least hindered side leading to **5a**. Such a four-centered transition state was first proposed by Cope.[15] More recently they have been considered by



10a



10b



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[13] (a) F. Camps, J. Coll, and J. Pascual, *J. Org. Chem.*, **32**, 2563 (1967). (b) A possible anomaly appears in that the equatorial methine proton of **6** (τ 6.94) appears at higher, not lower, field than the axial proton of **7** (τ 6.82). This reversal could be due to the shielding effects of the carbonyl in much the same manner as occurs in cyclohexanone. See K. M. Wellman and F. G. Bordwell, *Tetrahedron Lett.*, 1073 (1963).

[14] C. Altona, H. J. Hageman, and E. Havinga, *Rel. Trav. Chim. Pays-Bas*, **87**, 353 (1968); C. Altona, *Tetrahedron Lett.*, 2325 (1968).

[15] A. C. Cope, T. A. Liss, and D. S. Smith, *J. Amer. Chem. Soc.*, **79**, 240 (1957).

TABLE I

Fraction	Bp, °C	Wt, g	$n^{20}D$	Analysis by glc[a] % **6**	% **7**	% **8**
1	40–80	63.0	1.4572	0.0	0.0	0.0
2	92	25.0	1.4764	56.6	4.3	5.6
3	97	22.0	1.4775	68.9	7.4	5.9
4	97	27.5	1.4785	64.2	14.6	7.2
5	97	27.0	1.4792	53.2	14.5	18.8
6	107	20.0	1.4802	41.3	17.3	34.0
7	107	6.5	1.4802	38.5	21.3	32.9
8	107	3.5	1.4805	35.3	24.3	33.1
Residue		101.0				

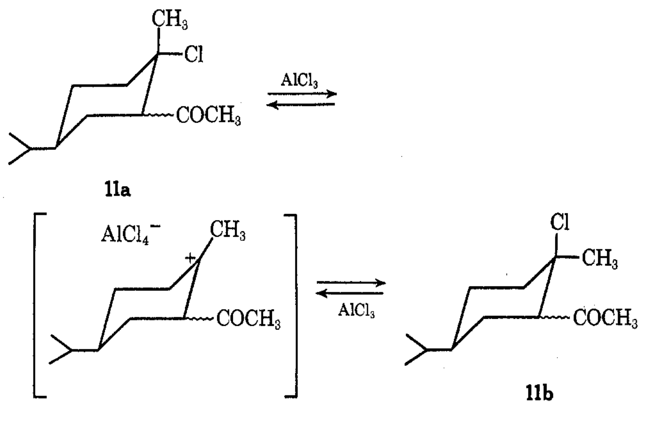
[a] glc shows only decomposition products of **5**.

TABLE II
SPECTRAL DATA

Compd	Ir, cm^{-1} >=O	C—Cl	Nmr, τ $\overset{COCH_3}{-C-H}$	$\overset{O}{\|\|}$ CCH$_3$	$\overset{CH_3}{-\|-Cl}$	CH$_3$–C=	H–C=	$-<^{CH_3}_{CH_3}$
6	1710		6.94	7.81		8.34	4.33	9.12
7	1710		6.82	7.88		8.40	4.33	9.10
8	1685			7.77		8.13		9.08
5a	1715	540	6.83	7.82	8.35			9.22
5b	1715	540	7.30	7.77	8.35			9.26

others[9,16] as the initially formed species to explain acylation results which led to the vinyl ether **9** from cis decalin and to a mixture of β-, γ-, and δ-chlorocyclohexyl methyl ketones from cyclohexene. The formation of **5b** could result either from epimerization of **5a** or from **10b**.

However, since both **5a** and **5b** are tertiary chlorides, it is not unreasonable that a process involving epimerization *via* chloride exchange could conceivably occur under the reaction conditions as illustrated below.



11a

11b

If all other factors are considered negligible, the compound having an axial chlorine (**11b**) is favored by about 1.4 kcal/mol over the epimer (**11a**).[17] Such an energy difference between isomers would require that a true equilibrium would be composed of about 93% **12b**. Hence, the observed result could be rationalized on both kinetic and thermodynamic considerations.

Experimental Section[18]

2-Acetyl-1-chloro-4-isopropyl-1-methylcyclohexane (5). A.—To a mixture of 200 g (1.5 mol) of $AlCl_3$ in 450 ml of ethylene dichloride was added 235 g (3.0 mol) of acetyl chloride while maintaining a temperature of 15°. After the dark brown solution was stirred for an additional 20 min, it was added over a 2-hr period to a solution of 276 g (2.0 mol) of pinane (90% cis) and 100 ml of ethylene dichloride at −5°. Stirring was continued for an additional 1 hr at −5° and then the reaction mixture was poured onto 2.5 l. of ice and water and the layers were allowed to separate. The aqueous layer was extracted with 200 ml of ethylene dichloride. The organic layers were combined and washed twice with 200-ml portions of HCl, twice with 200-ml portions of 10% NaOH, and then with water until neutral to litmus. The ethylene dichloride was removed at atmospheric pressure and the batch distilled under vacuum (1.0 mm) (see Table I).

By preparative glc, the major peaks were collected. The first sample contained a mixture of the first two major peaks (60.2% **6** and 37.1% **7**) and the second was primarily the third major peak (98.9% **8**). The structures were identified by comparison of the nmr and ir with authentic samples prepared by an independent syntheses described later. Spectral data are included in Table II.

B.—According to the procedure described above (A), a solution composed of 133.5 g (1 mol) of $AlCl_3$, 300 ml of ethylene dichloride, and 80 g (1.02 mol) of acetyl chloride was added to a solution of 150 g (1.1 mol) of 1-*p*-menthene in 75 ml of ethylene dichloride. The product was distilled under vacuum (4.0 mm) (Table III).

TABLE III

Fraction	Bp, °C	Wt, g	$n^{20}D$	Analysis by glc % **6**	% **7**	% **8**
1	63–93	21.0	1.4640	Mostly lights		
2	100	4.7	1.4732			
3	105	8.7	1.4755	66.9	15.9	6.5
4	105	4.8	1.4762	74.7	13.5	5.3
5	110	5.1	1.4765	63.0	20.8	7.1
6	112	16.5	1.4782	50.3 (39.2)[a]	32.8 (35.6)	9.4 (19.6)
7	112	15.0	1.4792	36.6 (29.0)	39.8 (35.7)	18.2 (31.3)
8	112	4.8	1.4805	30.5 (28.0)	32.4 (26.9)	32.6 (41.4)
9	112	5.1	1.4848	Some heavies		
Residue		76.0				

[a] Figures in parentheses are those which represent the glc analysis after samples stood for 5 days.

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[16] M. S. Ahmad, G. Baddeley, B. G. Heaton, and J. W. Rasburn, *Proc. Chem. Soc., London*, 395 (1959).

[17] M. Hanack, "Conformation Theory," Academic Press, New York, N. Y., 1965, p 103.

[18] The spinning-band distillation was done on an NFA-100 Nester-Faust auto annular Teflon spinning-band column. All glc analyses were obtained from an F & M Model 720 using a 4-ft column of 0.25-in. diameter packed with 25% SE 30 on Gas-Chrom P. Infrared spectra were obtained neat on a Perkin-Elmer Model 457 grating infrared spectrometer utilizing KBr demountable cells, and nmr spectra were obtained from a Varian Associates A-60A spectrometer utilizing TMS as internal standard.

C.—Samples of crude **5** showed large increases in the amount of **8** (by glc and nmr analysis) when subjected to the following conditions: (1) refluxed for 3 hr in 20% NaOH; (2) heated to 150° for 5 hr; and (3) a solution of **5** in ethylene dichloride is stirred overnight at room temperature in the presence of stannic chloride.

The products from procedures A and B gave similar ir and nmr spectra as described in the text. The presence of some **8** in the higher boiling fractions could be determined by the presence of an ir band at 1685 cm^{-1} and a peak in the nmr at τ 8.13 (see Table II).

6-Acetyl-4-isopropyl-1-methylcyclohexene (6 and 7).—1-*p*-Menthene (100 g, 0.72 mol) was added to a mixture of 98 g (0.96 mol) of acetic anhydride and 8.0 ml of $BF_3 \cdot O(C_2H_5)_2$ over a 40-min period at 36°. After an additional stirring period of 2 hr, 150 ml of H_2O was added and the mixture stirred for 2 hr. The layers were separated, washed with 10% NaOH, and then made neutral to litmus with water. Distillation yielded a main fraction, 25.2 g (19% theory), bp 95–96° (7 mm), which was composed of 5.1% hydrocarbons, 52.0% **6**, 32.7% **7**, and 10.2% **8**. These glc retention times were identical (peak enhancement) with those produced in the glc of **5**. Spinning band distillation of the above yielded purified samples of **6** (98.5% by glc) and **7** (95.2% by glc).

Registry No.—**1**, 6876-13-7; **5a**, 30338-42-2; **5b**, 30338-43-3; **6**, 30338-44-4; **7**, 30338-45-5; **8**, 30338-46-6.

Acknowledgment.—We are indebted to Professors J. A. Marshall and W. G. Dauben for valuable discussions, Mr. P. Porcaro for spectroscopic determinations, and Dr. H. U. Daeniker for his support and encouragement during this project.

A Synthesis of *N*-Methyl-1,9-ethenophenothiazine, a Bridged *syn*-Metacyclophane[1,2]

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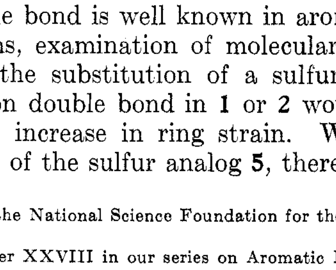
Received February 1, 1971

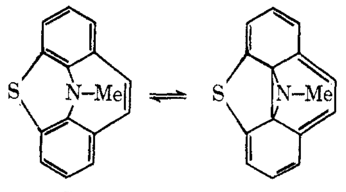
A synthesis of *N*-methyl-1,9-ethenophenothiazine (**5**) is described. Analogously to the two other known examples of bridged *syn*-metacyclophanes, **5** undergoes thermal extrusion of the methylamino bridge to give **19**.

As part of our studies of 15,16-dihydropyrene derivatives,[4] we have been concerned with the synthesis of such derivatives in which the internal substituents at the 15 and 16 positions are oriented cis to each other.[5] In particular we have studied those examples where a bridging heteroatom, as part of a three-membered ring, constitutes the cis substituents.[6,7] In the approach employed, the synthesis of the bridged *syn*-[2.2]metacyclophane-1,9-dienes (**1** and **2**) was first accomplished and then their possible valence tautomerization to the corresponding pyrene *cis*-15,16-epoxide (**3**) and pyrene *cis*-15,16-imine (**4**) was studied.



1, X = O **3**, X = O
2, X = N,R **4**, X = N,R

Although substitution of a sulfur atom for a carbon–carbon double bond is well known in aromatic heterocyclic systems, examination of molecular models suggested that the substitution of a sulfur atom for a carbon–carbon double bond in **1** or **2** would lead to a very marked increase in ring strain. We undertook the synthesis of the sulfur analog **5**, therefore, both to see whether it could exist and, if so, what effect the additional ring strain might have on the equilibrium between the valence tautomers **5** and **6**.[8]



5 **6**

The synthesis of **5** was modeled after that employed for the synthesis of 8,16-imino[2.2]metacyclophane-1,9-diene.[7] Treatment of phenothiazine (**7**) with oxalyl chloride and aluminum chloride, following the Stollé isatin procedure,[9] gave **8** in 75% yield. Hydrolysis of **8** with aqueous base followed by addition of hydrogen peroxide gave the corresponding acid **9**, which was converted by reaction with diazomethane to the methyl ester **10** for isolation and purification. The overall yield for these three steps was 65%.

When **10** was subjected to the Stollé isatin synthesis followed by a repetition of the above sequence, the diester **12** was readily formed. The nmr spectrum of **12** exhibited three types of aromatic protons: a pair of doublets at τ 2.33 (J = 7.5, J = 2 Hz), a pair of doublets at τ 3.03 (J = 7.5, J = 2 Hz), and a triplet at τ 3.29 (J = 7.5, J = 7.5 Hz), each of equivalent integrated area, as would be expected for **12**.

Treatment of **12** with sodium hydride followed by an excess of methyl iodide gave the *N*-methyl derivative **13** in 95% yield. Lithium aluminum hydride reduction of **13** led to the corresponding diol **14** in 96% yield. This, on reaction with phosphorus tribromide in ben-

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(1) We thank the National Science Foundation for their support of this work.

(2) This is paper XXVIII in our series on Aromatic Molecules Bearing Substituents within the Cavity of the π-Electron Cloud. For the preceding communication, see V. Boekelheide and J. Lawson, *Chem. Commun.*, 1558 (1970).

(3) NDEA Fellow, 1967–1970.

(4) For a review, see V. Boekelheide, *Proc. Welch Foundation*, **12**, 83 (1968).

(5) R. H. Mitchell and V. Boekelheide, *Chem. Commun.*, 1555 (1970).

(6) B. A. Hess, Jr., A. S. Bailey, B. Bartusek, and V. Boekelheide, *J. Amer. Chem. Soc.*, **91**, 1665 (1969).

(7) B. A. Hess, Jr., and V. Boekelheide, *ibid.*, **91**, 1672 (1969).

(8) Because of the importance of physiologically active phenothiazine derivatives, it was also of interest in this regard to prepare a phenothiazine derivative having a rigid, butterfly geometry.

(9) R. Stollé, *Ber.*, **46**, 3915 (1913).