ALKYLATION OF PHENOL WITH 2,5-DICHLORO-2,5-DIMETHYLHEXANE

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This is to certify that the

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2,5-Dichloro-2,5-dimethylhexane

presented by

Harold Everett Dodds, Jr.

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of the requirements for

Ph.D. degree in Organic Chemistry

Harold Hart
Major professor

Date January 11, 1966

ABSTRACT

ALKYLATION OF PHENOL WITH 2,5-DICHLORO-2,5-DIMETHYLHEXANE

By Harold E. Dodds, Jr.

Hart, Corbin, Wagner, and Wu (1) found that phenol reacted with 5-chloro-2-methyl-2-pentene in the absence of a Friedel-Crafts catalyst to give as products 5,5-dimethylhomochroman, 1,1-dimethyl-5-tetralol, and 4,4-dimethyl-6-tetralol. The formation of these products and the results of deuterium labeling experiments were rationalized by a mechanism which involved reaction of the primary carbon of a dimethylcyclopropylcarbonium ion with either the oxygen, or the ortho or para positions of phenol, followed by cyclization. This homoallylic chloride is similar to 2,5-dichloro-2-methylpentane, which is a primary-tertiary dichloride. Both compounds would be expected to give the same products by similar mechanisms.

It seemed of interest to extend this study to 2,5-dichloro-2,5-dimethylhexane, a tertiary-tertiary dichloride, to determine whether the reaction proceeds via a homoallylic-cyclopropylcarbinyl cation, or ordinary tertiary carbonium ions. Accordingly, the non-catalyzed reaction between phenol and 2,5-dichloro-2,5-dimethylhexane was carried out. Eight product fractions were detected by gas chromatography. Samples of these fractions were isolated and the infrared, ultraviolet, mass, and NMR spectra for each fraction were obtained. By analyzing each of these spectra it was determined that these fractions contained the compounds 2,2-dimethyl-4-isopropylchroman (I), 1,1-dimethyl-3-isopropyl-5-indanol (II), 3,3-dimethyl-1-isopropyl-4-indanol (III),

1,1,4,4-tetramethyl-5-tetralol (IV), 1,1,4,4-tetramethyl-6-tetralol (V), 4,4,6,6-tetramethyl-2,8-diisopropyl-3,4-dihydroindano [5,6-b] pyran (VI), 2,2,6,6,9,9-hexamethyl-4-isopropyl-3,4,6,7,8,9-hexahydronaphtho [2,3-b] pyran (VII), 4,4,6,6,9,9-hexamethyl-2-isopropyl-3,4,6,7,8,9-hexahydronaphtho[2,3-b] pyran (VIII), 1,1,4,4,5,5,8,8-octamethyl-1,2,3,4,5,6,7,8-octahydro-9-anthrol (IX), and 1,1,4,4,5,5,8,8-octamethyl-1,2,3,4,5,6,7,8-octahydro-9-phenanthrol (X).

The sulfuric acid catalyzed reaction between phenol and 2,5-dichloro-2,5-dimethylhexane was run according to the procedure of Bruson and Kroeger (2). From this reaction were isolated fractions having identical gas chromatographic retention times to those fractions of the non-catalyzed reaction containing compounds I and V-X. There was no fraction detected containing compound II which Bruson and Kroeger (2) claimed was the major product of this reaction.

The products from both the non-catalyzed and the sulfuric acid catalyzed reactions can be rationalized by similar mechanisms. The bis chloride first ionized to a tertiary carbonium ion and a chloride ion. The carbonium ion attacked phenol at either the oxygen, or at the ortho or para positions. The attack was followed by a second ionization and either immediate cyclization to a tetralol, or rearrangement to a secondary carbonium ion and cyclization to either a chroman (in the case of initial attack at oxygen) or to an indanol (in the case of initial attack at one of the aromatic ring positions). In the formation of products VI-X this sequence was repeated a second time.

The mass spectra of several model compounds were taken. These spectra aided the elucidation of the structure of products I-X, and in the interpretation of their mass spectra.

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1. Hart, H., J. L. Corbin, C. R. Wagner, and C-Y. Wu, J. Am. Chem. Soc., 85, 3267 (1963).

2. Bruson, H. A. and J. W. Kroeger, J. Am. Chem. Soc., 62, 36 (1940).

ALKYLATION OF PHENOL WITH 2,5-DICHLORO-2,5-DIMETHYLHEXANE

By

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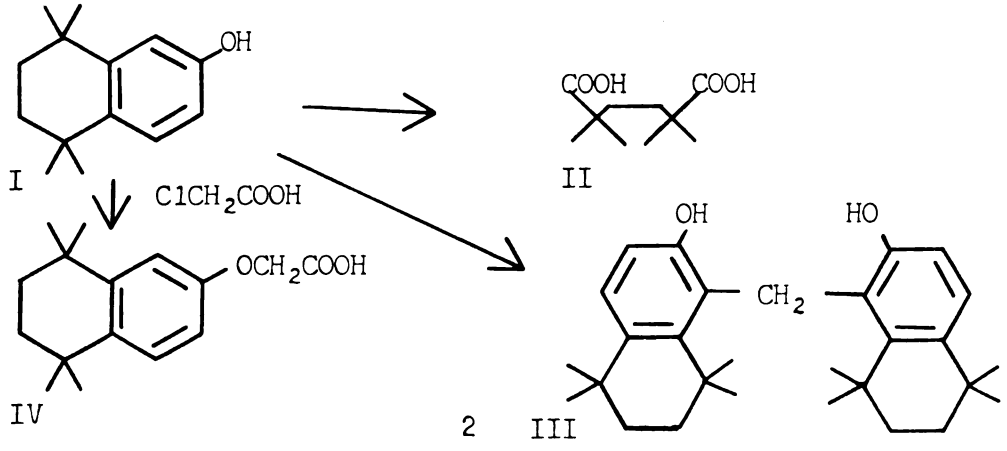
INTRODUCTION

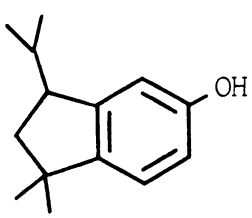
INTRODUCTION

Reactive alkyl halides such as those with a tertiary, allylic, benzylic, or homoallylic group, can alkylate an activated aromatic nucleus (i.e., phenol) without the use of a Friedel-Crafts catalyst (1-5). Such compounds as t-butyl chloride (2), α-phenethyl chloride (3), triphenylmethyl chloride (4), and 5-chloro-2-methyl-2-pentene (5) have reacted with phenol to evolve hydrogen chloride and have yielded nuclearly alkylated products.

Bruson and Kroeger (6) used 2,5-dichloro-2,5-dimethylhexane to alkylate phenol with various Friedel-Crafts catalysts. When aluminum chloride was used as the catalyst the product isolated was 1,1,4,4-tetramethyl-6-tetralol (I), m.p. 145.0-145.2°. The structure was based on the following evidence. Oxidation with potassium permanganate yielded 1,1,4,4-tetramethyladipic acid (II). Like β-naphthol, the condensation of the tetralol with formaldehyde in acid solution yielded a crystalline methylene dinaphthol derivative (III), m.p. 232°. Reaction of the tetralol with chloroacetic acid gave a derivative (IV), m.p. 164-165°.



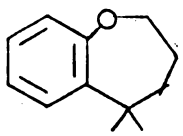
When either sulfuric acid or boron trifluoride was used as the Friedel-Crafts catalyst a different phenolic product, m.p. 97-98° (6) was obtained. This compound gave an oxyacetic acid derivative, m.p. 112-113°, but did not yield a crystalline derivative with formaldehyde nor did it yield any identifiable acid upon oxidation with permanganate. It was claimed (6) that the phenol was not 1,1,4,4-dimethyl-5-tetralol because the authors were also able to obtain two different products when 2,6-dimethylphenol was reacted with 2,5-dichloro-2,5-dimethylhexane with different catalysts. [With an aluminum chloride catalyst they obtained a product melting at 165°, but with a sulfuric acid catalyst the product obtained distilled at 156°/6 mm.] The phenol melting at 97-98° was recovered without any rearrangement when it was heated with aluminum chloride. Since there was no rearrangement it was concluded that this phenol did not contain an open chain. Having eliminated the possibility of an acyclic phenol and a phenol substituted in the 2 position, Bruson and Kroeger concluded that the phenol melting at 97-98° was probably 1,1-dimethyl-3-isopropyl-5-indanol (V).



V

Whereas 2,5-dichloro-2,5-dimethylhexane is a tertiary-tertiary dihalide, a system analogous to a primary-tertiary dihalide was studied by Hart, Corbin, Wagner, and Wu (5). They showed that the reaction of 5-chloro-2-methyl-2-pentene and phenol without a

Friedel-Crafts catalyst gave as products 5,5-dimethylhomochroman (VI), 1,1-dimethyl-5-tetralol (VIII), and 4,4-dimethyl-6-tetralol (VIII).



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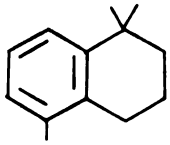
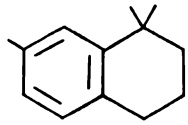
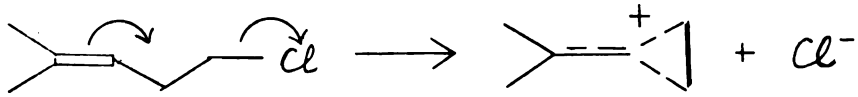


VII



VIII

The formation of these products and the results of deuterium labeling experiments were rationalized in terms of the dimethylcyclopropyl carbonium ion (IX). The ion was formed in the following manner:



IX

The products were formed by reaction of a primary site of the carbonium ion with either the oxygen or the ortho or para positions of the phenol and subsequent cyclization.

The purpose of this thesis was to study the non-catalyzed reaction between 2,5-dichloro-2,5-dimethylhexane and phenol and to determine whether it would be necessary to invoke such an ion or an intermediate, or whether the products might be accounted for via ordinary tertiary carbonium ions. When the non-catalyzed reaction between phenol and 2,5-dichloro-2,5-dimethylhexane was carried out eight product factions were detected by gas chromatography. In order to find out whether one of these eight products was the phenol melting at 97-98° reported by Bruson and Kroeger (6) the sulfuric acid catalyzed reaction between phenol and the bis chloride was also run.

Six product fractions were produced in this reaction which had identical retention times on the gas chromatograph to six of the eight product fractions of the non-catalyzed reaction. The structure determination of all these products forms the main body of this thesis.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Part I. General Description of the Reactions

The non-catalyzed reaction of phenol with 2,5-dichloro-2,5-dimethylhexane was run without using a solvent. The bis chloride (0.55 mole) and a four-fold excess of phenol (2.12 moles) were heated at 85-90° for 4 hours at which time the evolution of hydrogen chloride had ceased. This reaction mixture was dissolved in ether and extracted with a portion of 10% aqueous potassium hydroxide and two portions of Claisen's alkali. The basic extracts were neutralized and extracted with ether. The four ether solutions were dried, filtered, concentrated, and weighed.

The sulfuric acid catalyzed reaction was carried out by a procedure similar to that reported by Bruson and Kroeger (6). Equimolar amounts of the bis chloride and phenol (0.14 mole each) were added dropwise as a melt to a 79% sulfuric acid solution at 10°. After stirring the reaction mixture for 22 hours at room temperature and for 1 hour at 90°, the mixture was poured into ice-water. The aqueous mixture was extracted with ether and the combined ether extracts were extracted with 10% aqueous potassium hydroxide and with Claisen's alkali. The basic extracts were neutralized and extracted with ether. The three ether solutions were dried, filtered, concentrated, and weighed.

The extracts from the non-catalyzed reaction contained eight product fractions which were detected by gas chromatography. These

fractions shall henceforth be designated as fractions A-H. The extracts from the sulfuric acid catalyzed reaction contained six product fractions. These six fractions had identical retention times on the gas chromatograph to fractions A and D-H of the non-catalyzed reaction. Fractions A and E-H were found largely in the neutral extracts of both reactions. The recovered bis chloride was found only in the neutral extract of the sulfuric acid catalyzed reaction. Recovered phenol and fractions B-D were found largely in the basic extracts of the non-catalyzed reaction. Recovered phenol and D were found largely in the basic extracts of the sulfuric acid catalyzed reaction. A complete separation was not effected by extraction. Therefore, smaller amounts of the neutral products were found in the basic extracts and vice versa. In addition to the recovered reactants and products A-H a considerable amount of polymer was detected in the first Claisen's alkali extract of the non-catalyzed reaction.

In order to obtain samples of fractions A-C and E-H additional separations had to be made. Pure D was obtained by recrystallizing the Claisen's alkali extract of the sulfuric acid catalyzed reaction from aqueous ethanol. Fractions A, C, and E-H were obtained by elution and gas chromatography. The neutral extract of the non-catalyzed reaction, when eluted on a column containing acid-washed alumina gave several fractions. Among these were two which contained better than 90% A, a third which contained about 99% C, and another which contained a mixture of E-H only. The fraction containing C was recrystallized from petroleum ether. Pure A was collected when the enriched fractions of A were injected into a gas chromatograph. Fractions E

and H were collected when the fraction containing E-H only was injected into a gas chromatograph. Fractions F and G were obtained by eluting the neutral extract of the sulfuric acid catalyzed reaction through a column containing acid-washed alumina. The sample of B was obtained by distilling the first Claisen's alkali extract of the non-catalyzed reaction through a spinning band column.

The main product of the non-catalyzed reaction was C which was obtained in a 40.7% yield. The yields of the other products in this reaction were: A, 6.5%; B, 4.2%; D, 5.1%; E, 2.7%; F, 2.0%; G, 2.9%; and H, 0.9%. The main product of the sulfuric acid catalyzed reaction was D which was obtained in a 33% yield. The yields of the other products in this reaction were: A, a trace amount; E, 0.30%; F, 1.34%; G, 4.0%; and H, 0.28%. A considerable amount of both reactants was recovered from the sulfuric acid catalyzed reaction.

When a sample of each fraction had been obtained the infrared, ultraviolet, mass, and NMR* spectra for each fraction were run. By the interpretation of these spectra, the structures of the ten compounds in fractions A-H were determined.

Part II. Identification of the Reaction Products

A. Fraction A

Fraction A had the molecular formula $C_{14}H_{20}O$. Its infrared spectrum (Figure 1) showed no bands at either 3500 $cm.^{-1}$ or 3400 $cm.^{-1}$, but had intense bands at both 1200 $cm.^{-1}$ and 1140 $cm.^{-1}$. The presence

*Nuclear magnetic resonance.

of the latter bands and the absence of the former ones suggested that this compound was an ether. Bands at 1385 cm.$^{-1}$ and 1370 cm.$^{-1}$ indicated geminal dimethyl groups.

The ultraviolet spectrum of A in isooctane (Figure 2) had maxima at 286.5 mμ (log ϵ = 3.48) and 279 mμ (log ϵ = 3.47). Table 1 shows the ultraviolet spectrum of A and the spectra of several model compounds.

Table 1. Ultraviolet spectra of several ethers

Compound (solvent)	$\lambda_{max.}$ (mμ)	log ϵ	Reference
A (isooctane)	286.5, 279	3.48, 3.47	Figure 2
anisole (ethanol)	277, 270	3.15, 3.20	(7)
chroman (ethanol)	279, 274	3.21, 3.23	(8)
2,2-dimethylchroman (cyclohexane)	285, 279	2.45, 2.22	(9)
coumaran (isooctane)	290, 282, 279	3.48, 3.48, 3.47	(10)

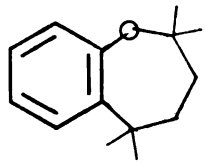
The spectrum was most consistent with a chroman and was inconsistent with either an acyclic aromatic ether or a coumaran.

The mass spectrum of A (Figure 3) showed a parent peak at m/e 204 and a base peak at 161 (M-43). The base peak represents the loss of a C_3H_7 fragment, probably an isopropyl group. Strong peaks at 43, 41, and 39 were probably due to an isopropyl group and to that group less two and four hydrogens, respectively. The peak at 189 (M-15) was only 1% of the base peak showing that the loss of a methyl group was a relatively more difficult occurrence. This suggested

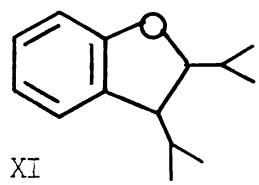
that an isopropyl group was on a carbon alpha to an aromatic ring, and that no methyl group was similarly placed. This fragmentation phenomenon will be discussed in more detail in a later section of this thesis.

The NMR spectrum of A (Figure 4), taken neat, was complex, but all twenty hydrogens could be accounted for. Four sharp peaks at τ 9.40, τ 9.28, τ 9.02, and τ 8.90 represented 1.5 hydrogens each and were assigned to the six methyl hydrogens of an isopropyl group. The splitting of the first two peaks and the last two peaks was 6.7 c.p.s.. This was due to the methine hydrogen of the isopropyl group. The different magnetic environment of the two methyls could be due to the asymmetry of the carbon atom to which the isopropyl group is attached. Two unsplit peaks at τ 8.87 and τ 8.61 represented 3.0 hydrogens each and were assigned to a geminal dimethyl group attached to the aliphatic ring. The different magnetic environment of these two methyl groups is similarly related to the asymmetry of the molecule. Two peaks at τ 8.49 and τ 8.33 and two multiplets centered at τ 7.59 and τ 7.16 represented 4.0 hydrogens as a unit and were due to an ABCD system which contained the methylene and methine hydrogens. The multiplet at τ 2.9-3.4 represented 4.0 hydrogens and was due to a complex pattern of four aromatic hydrogens.

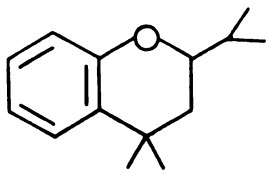
Among the several structures which could be written for compound A structures X, XI, XII, and XIII are the most likely.



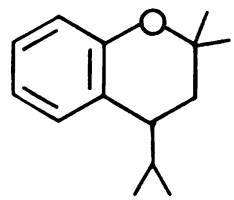
X



XI



XII



XIII

Structures X, XI, and XII can be eliminated by the evidence presented above. Structure X does not contain an isopropyl group which was necessary to explain the NMR and mass spectra of A. Structure XI is contrary to both the ultraviolet and NMR spectra. The positions of the maxima in the ultraviolet spectrum are lower than those reported for coumaran, but are quite close to the positions of the maxima for 2,2-dimethylchroman. Structure XI likewise lacks the geminal dimethyl group on an aliphatic ring observed in the NMR spectrum.

Structure XII is eliminated by both the NMR and mass spectra. The mass spectrum which has an intense peak at 161 and a weak peak at 189 requires that the isopropyl group be alpha to the aromatic ring. If the structure were XII the peak at 189 would be much greater than 1% of the base peak.

The NMR spectrum of A can best be interpreted by assuming structure XIII rather than XII. This distinction can be seen in an enlargement of the region containing the methylene and methine hydrogens (Figure 5). In this ABCD system the signals for protons A and D are multiplets at τ 7.16 and τ 7.59, respectively. Protons B and C are represented in part by the peaks at τ 8.49 and τ 8.33. Protons A-D are assigned as shown on the diagram of XIII in Figure 5. The signal

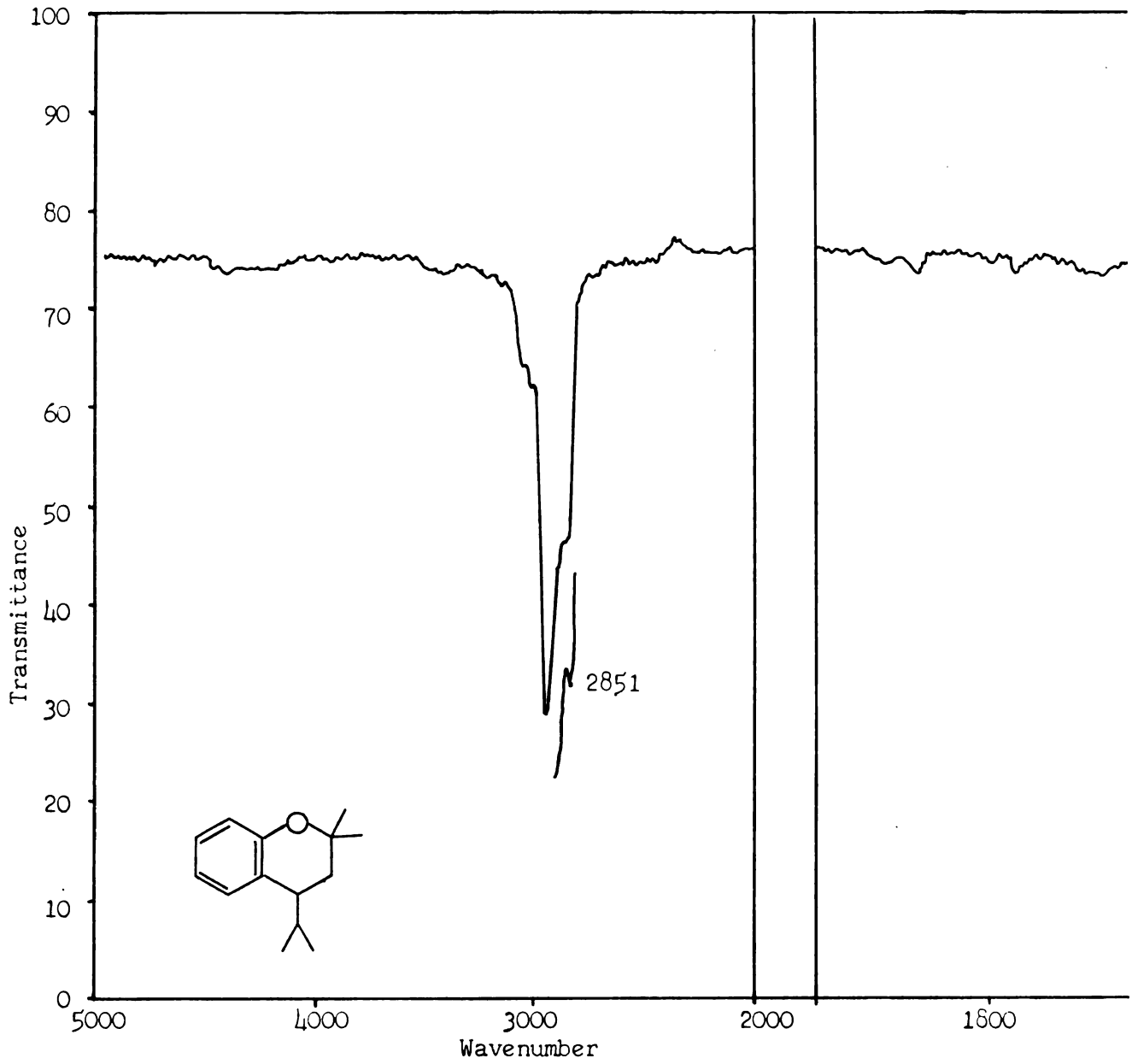
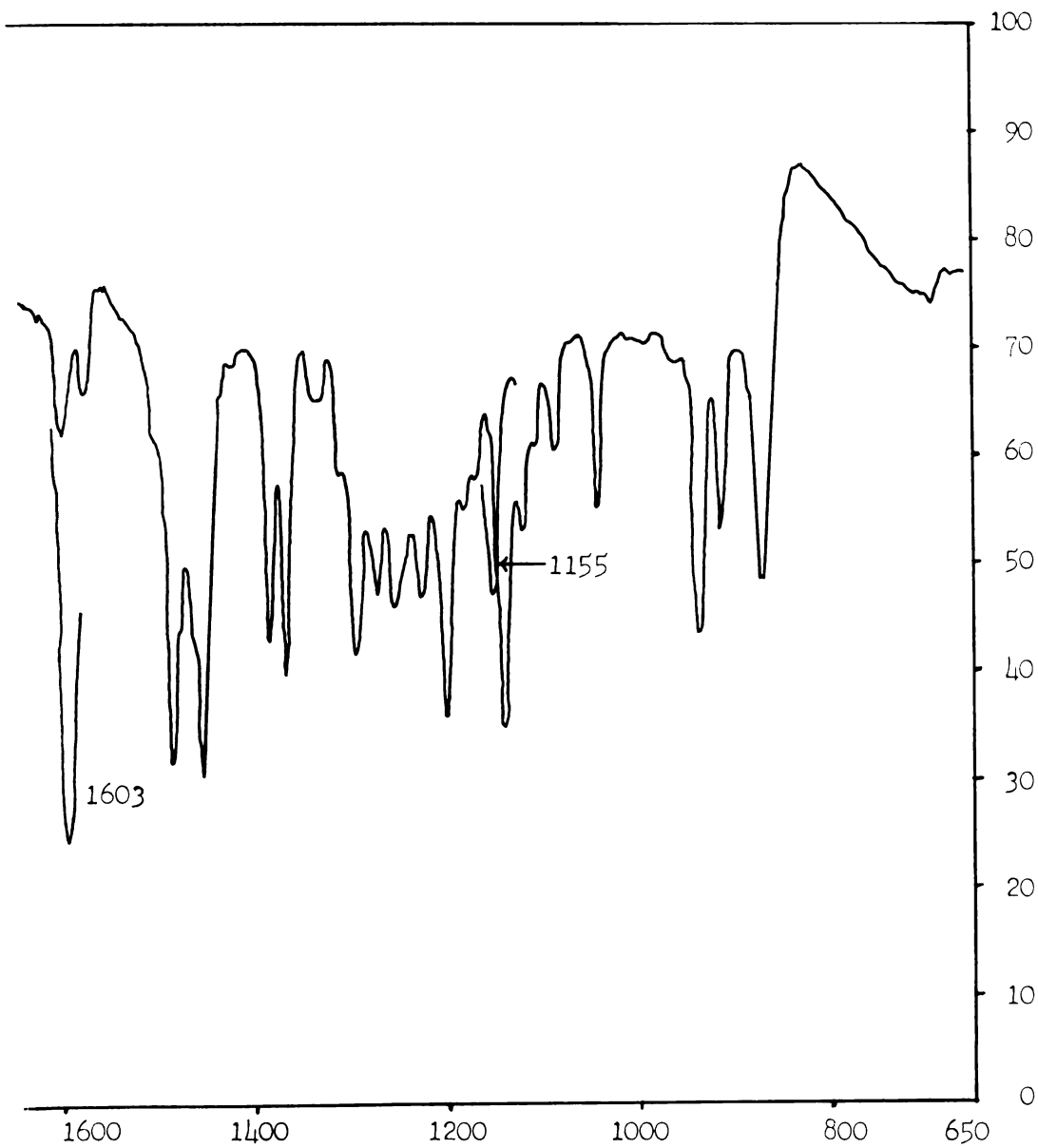


Figure 1. Infrared spectrum of fraction A.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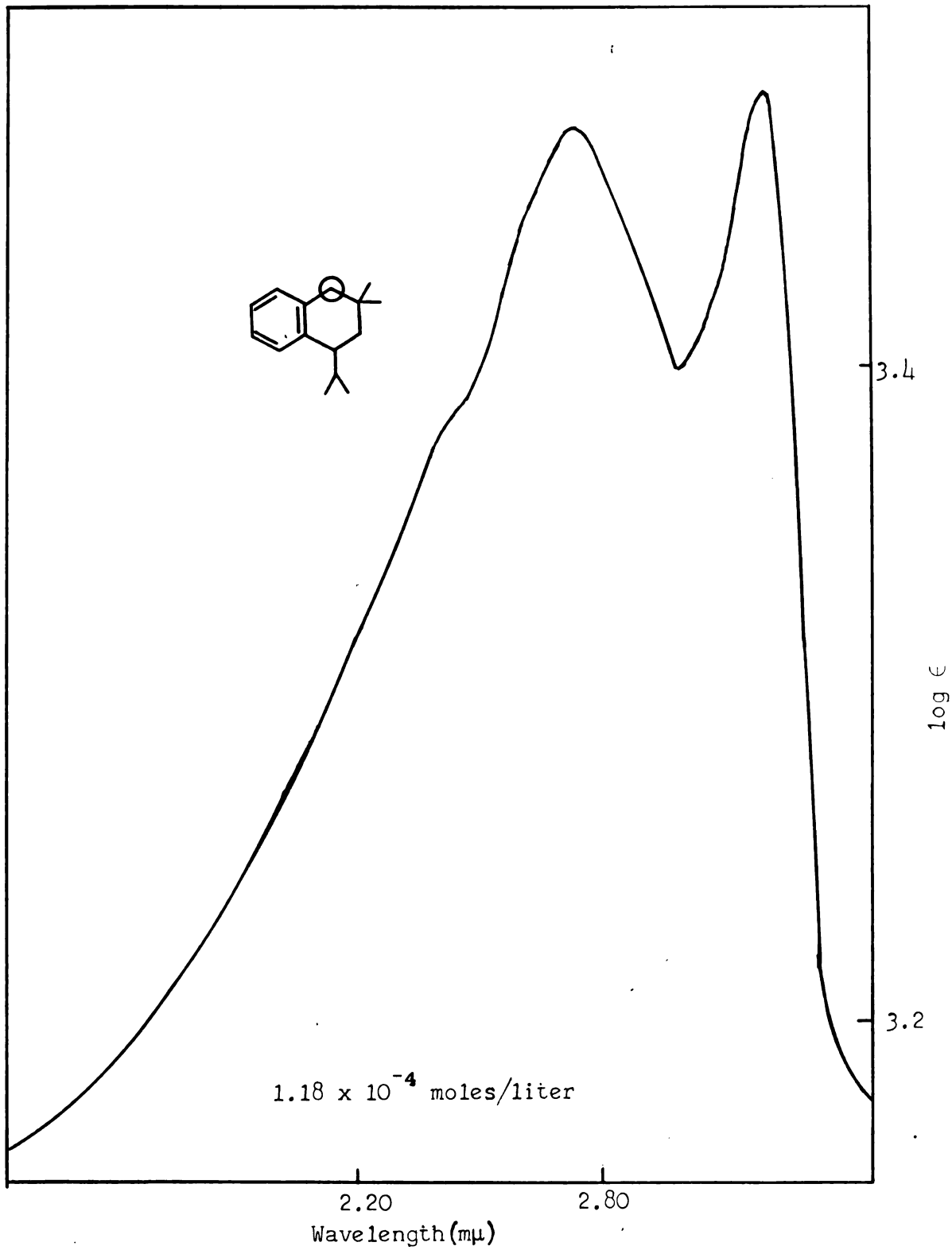


Figure 2. Ultraviolet spectrum of fraction A in isooctane.

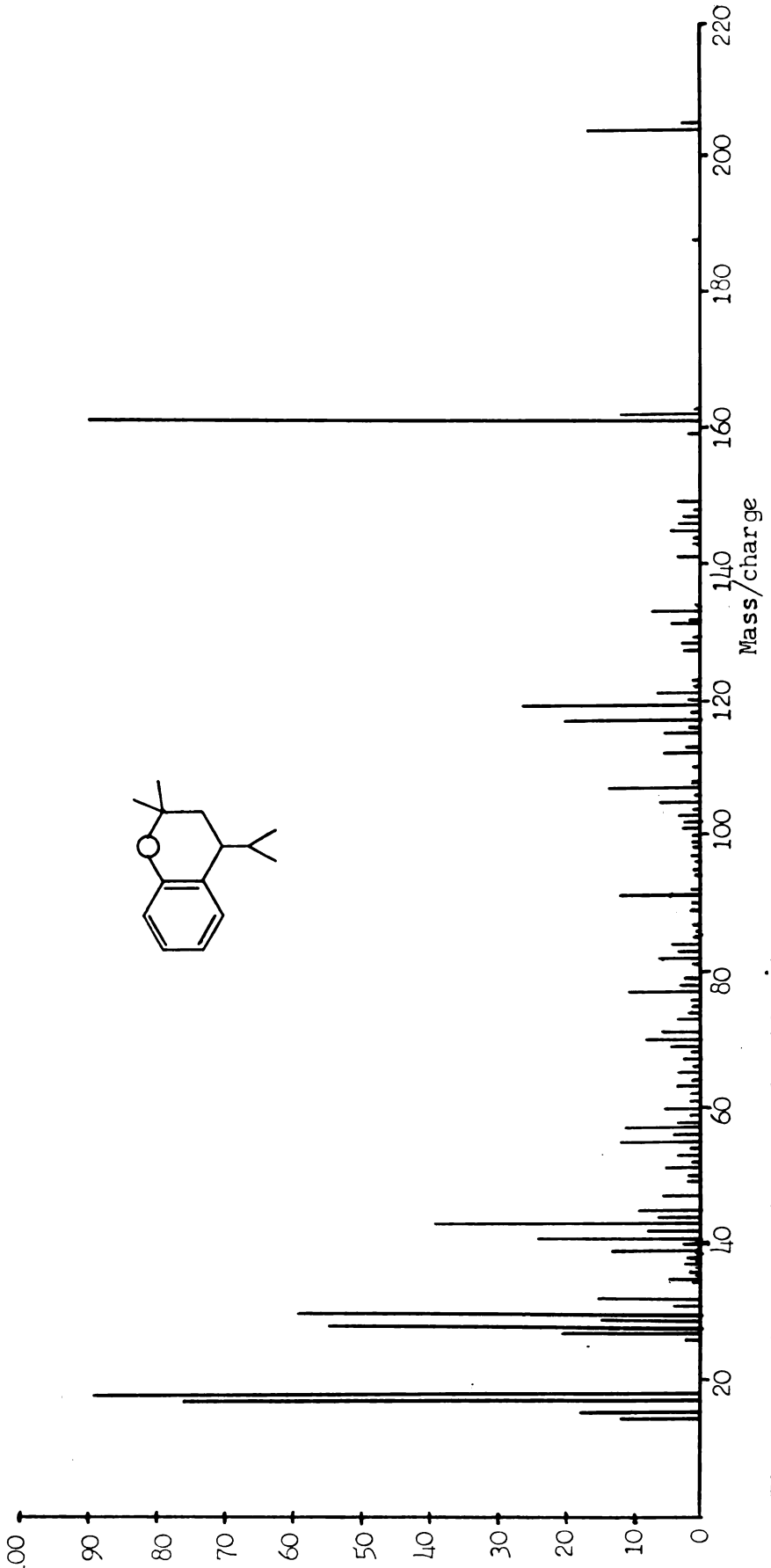
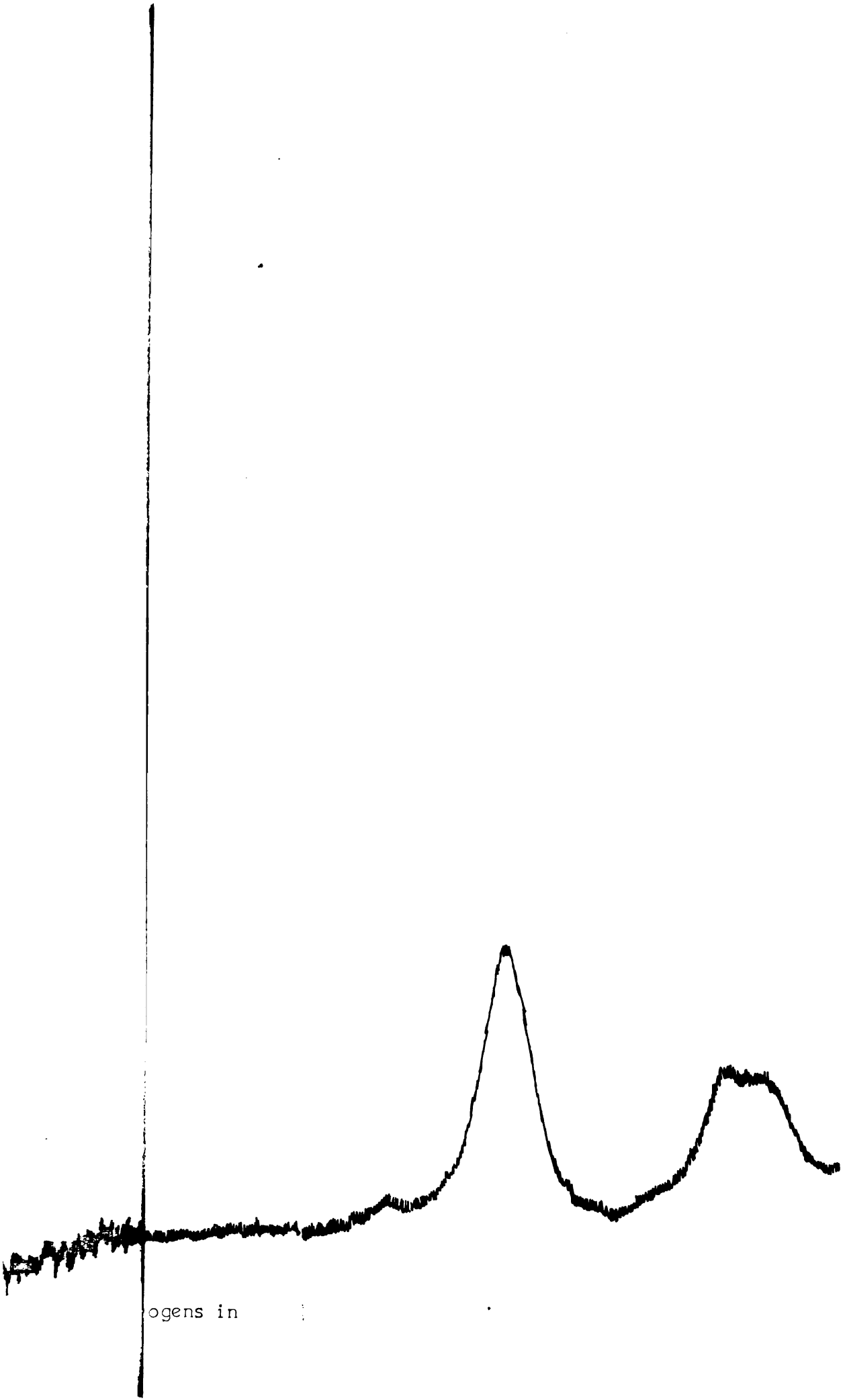


Figure 3. Mass spectrum of fraction A



ogens in

for D, the methine hydrogen on the isopropyl group, is split into 14 parts. It is split into a septet (J = 6.7 c.p.s.) by the six primary isopropyl hydrogens and each of these signals is split into a doublet (J_{DA} = 2.8 c.p.s.) by proton A. The remaining peaks in this region are due to an ABC pattern in which the signal due to proton A is also split by proton D ($J_{AD_{app.}}$ = 3.6 c.p.s.). Since a normal ABC pattern without additional splitting has 15 lines the complete interpretation of this system would be difficult. However, from inspection of this spectrum a combination of constants can be obtained which is 1/2 (J_{AB} + J_{AC}) = 9.2 c.p.s. The position of the multiplet for proton A centered at τ 7.16 is that which would be expected for a methine hydrogen alpha to a phenyl ring and would be much too low for a methine hydrogen alpha to an oxygen as would be required by structure XII.

Since all of the above data are consistent with structure XIII and are inconsistent with any other structure, compound A has the formula represented by structure XIII.

B. Fraction B

Fraction B was shown by gas chromatography to contain about 15.5% of C and trace amounts of phenol and A. Its infrared spectrum (Figure 6) had a sharp band at 3600 $cm.^{-1}$ and a broad band at 3400 $cm.^{-1}$. These bands indicated that the fraction was either an alcohol or a phenol. There were also bands at 1385 $cm.^{-1}$ and 1370 $cm.^{-1}$ due to geminal dimethyl groups.

The ultraviolet spectrum of B in cyclohexane (Figure 7) had maxima at 285 mμ (log ε = 3.56), 279 mμ (log ε = 3.61), and 272 mμ (log ε = 3.52). These maxima were not typical either of a phenol substituted in the 2 and 3 positions or of one substituted in the 3 and 4 positions. These maxima suggested that B was probably a mixture of both kinds of phenols. Part of this spectrum was not due to the presence of C, since the solution used in the reference cell contained the same concentration of C estimated to be in the sample cell. Table 2. lists the ultraviolet spectra of fractions B, C, and D and some model compounds. The spectra of B and the model compounds were taken in cyclohexane. The spectra of C and D were taken in isooctane.

Table 2. Ultraviolet spectra of several phenols

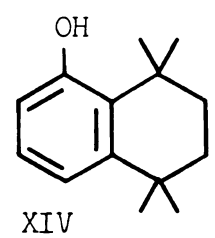
Compound	$\lambda_{max.}$ (mμ)	log ε	Reference
B	285, 279, 272	3.51, 2.61, 3.52	Figure 7
C	280, 273	3.41, 3.38	Figure 11
D	286, 278	3.34, 3.32	Figure 15
4-indanol	277, 268	2.91, 28.3	(11a)
5-indanol	286, 282	3.43, 3.49	(11b)
5-tetralol	279, 272	3.14, 3.13	(11c)
6-tetralol	288, 279	3.30, 3.30	(11d)

The mass spectrum of B (Figure 8) had distinctive peaks at m/e 204 (parent), 189, 161, and 147 (base peak). The peak at 147 (M-57) could not be explained by a simple fragmentation of a C_4H_9 group from any reasonable structure which could be drawn. The origin of this

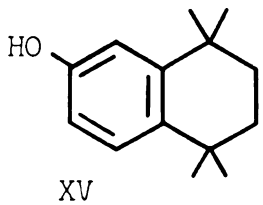
peak will be discussed in a later section of this thesis. The peaks at 189 (M-15) and 161 (M-43) had relative intensities of 3.7 and 79, respectively. The peak at 189 was due to the loss of a methyl group. The peak at 161 was due to the loss of a C_3H_7 fragment which probably was an isopropyl group. There were also intense peaks at 43, 41, and 39 which were probably caused by the same type of fragmentation pattern postulated for the peaks at the same mass units found in the mass spectrum of XIII.

The NMR spectrum of B in carbon tetrachloride (Figure 9) was complex and no electronic integration of the several peaks was possible. The spectrum had peaks at τ 9.34, τ 9.23, τ 9.15, τ 9.11, and τ 9.08 which were probably due to isopropyl hydrogens. It had peaks at τ 8.97, τ 8.78, and τ 8.49 which were probably due to geminal dimethyl groups on an aliphatic ring. Peaks at τ 8.33, τ 8.23, τ 7.87, τ 7.75, τ 6.93, and τ 6.83 were probably due to methylene and methine hydrogens. A sharp peak at τ 8.01 which had an intensity that varied considerably in the several NMR spectra taken was due to a trace of acetone in the solution. Peaks at τ 5.28 and τ 5.20 were in the region normally occupied by a phenolic hydrogen. A multiplet at τ 2.7-3.5 represented the aromatic hydrogens of B.

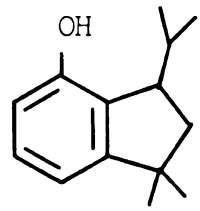
The complexity of this spectrum, especially in the isopropyl and phenolic hydrogen regions, supported the evidence from the ultraviolet spectrum that B was actually a mixture of two compounds which had nearly identical retention times on the gas chromatograph under the conditions used for the detection of the products. A series of possible structures is listed for the two compounds in fraction B.



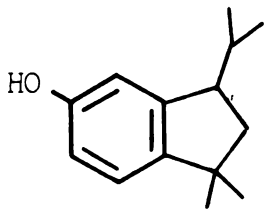
XIV



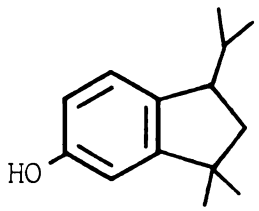
XV



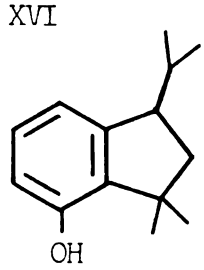
XVI



XVII

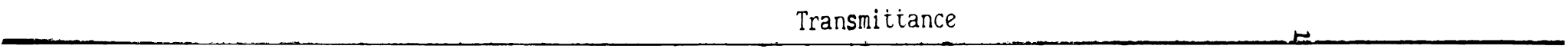


XVIII



XIX

Two of the above compounds must be the phenols having a molecular formula of $C_{14}H_{20}O$ which are found in fraction B since no other reasonable structures can be drawn. Structures XIV and XV do not contain any isopropyl groups. Thus, both are inconsistent with the NMR and particularly the mass spectra of B. The infrared spectrum showed that at least one of the components had a hydroxyl group which participated in intermolecular bonding. The ultraviolet spectrum suggested that one of these phenols was substituted in the 2 and 3 positions whereas the other was substituted in the 3 and 4 positions. These data show that one of the compounds must be either XVI or XIX and the other must be either XVII or XVIII. In another section of this thesis it will be shown that structures XVII and XIX are favored from mechanistic considerations. Structures XVII and XIX will be designated henceforth as compounds B-1 and B-2, respectively.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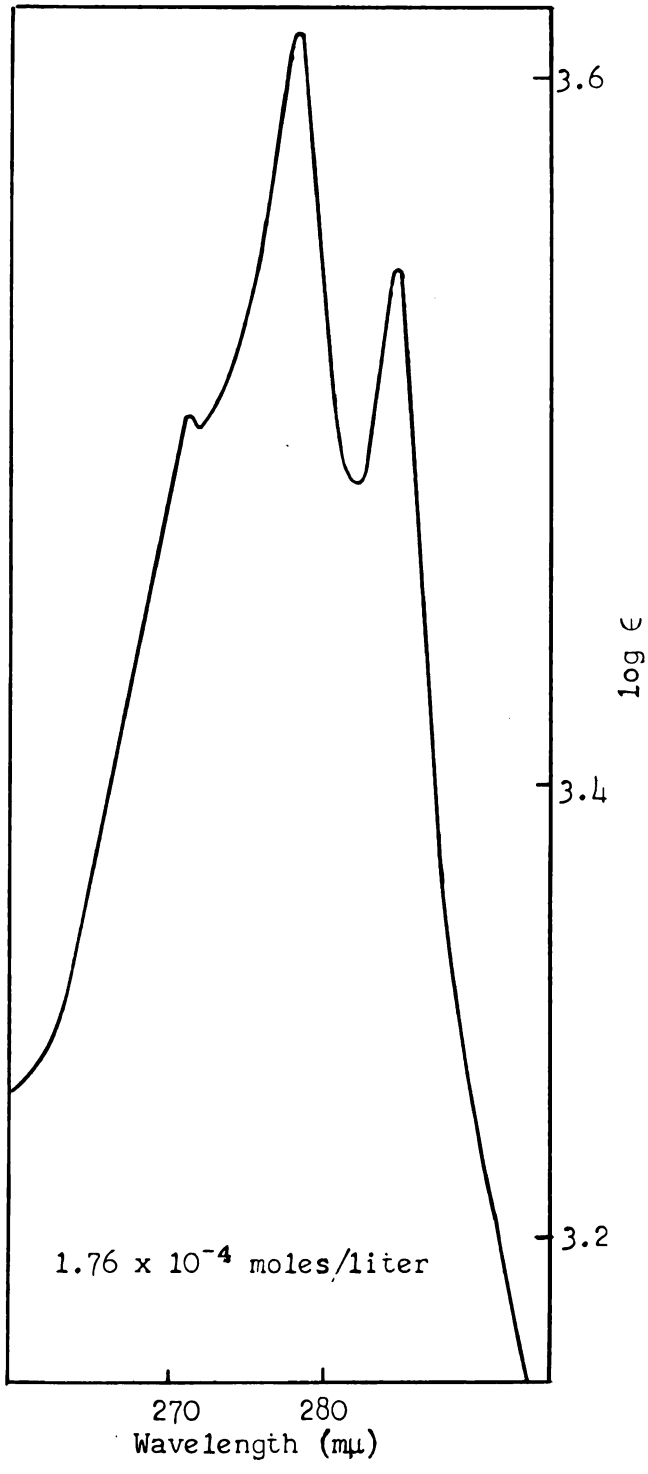

Figure 7. Ultraviolet spectrum of fraction B in cyclohexane

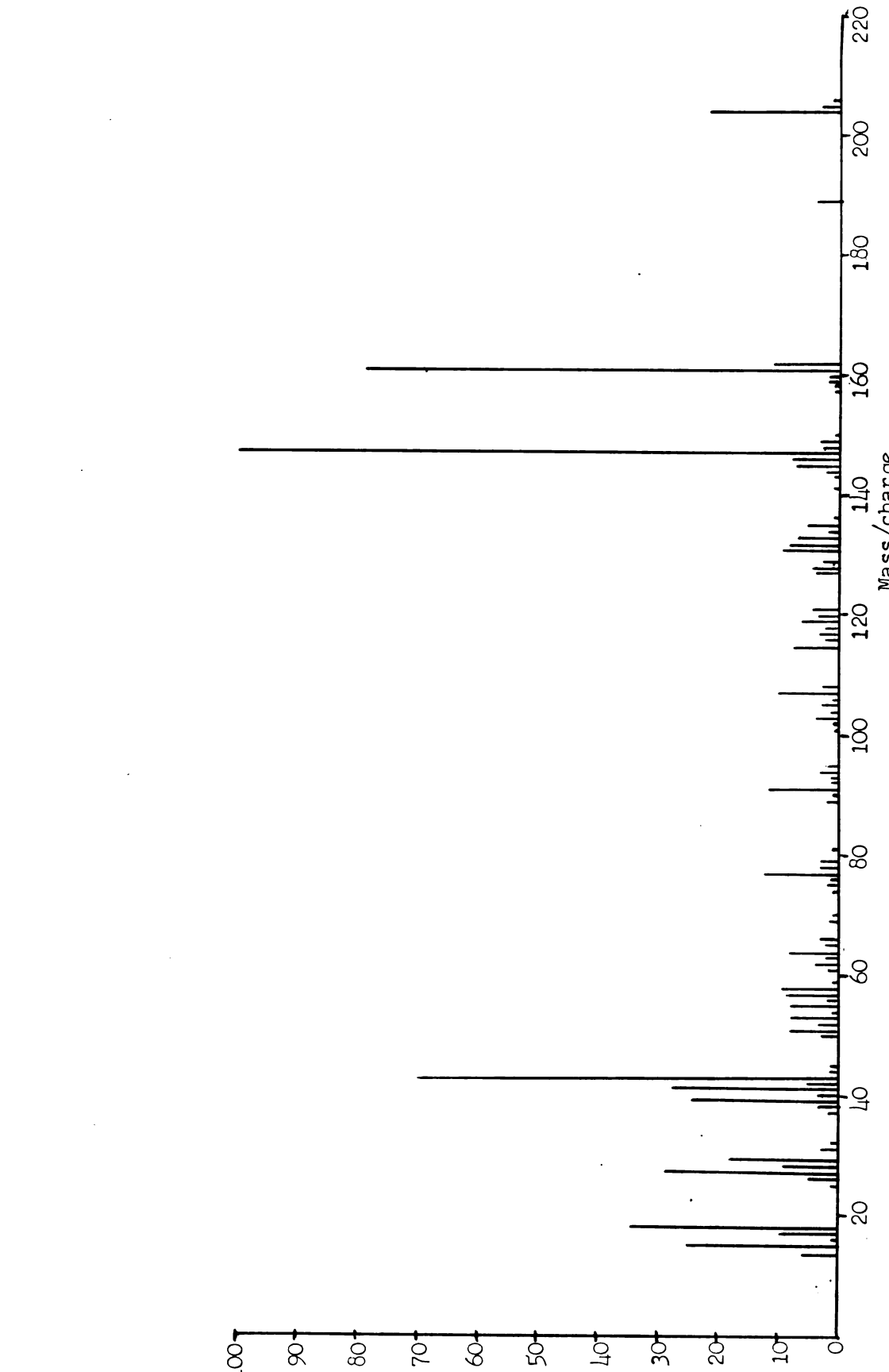

Figure 8. Mass spectrum of fraction B.

C. Fraction C

Fraction C was the major product of the non-catalyzed reaction. Its infrared spectrum (Figure 10) had a sharp band at 3600 $cm.^{-1}$ and a weak band at approximately 3500 $cm.^{-1}$. It also had two bands at 1380 $cm.^{-1}$ and 1360 $cm.^{-1}$. The first two bands were typical for an alcohol or a phenol and the latter two were typical for geminal dimethyl groups.

The ultraviolet spectrum of C in isooctane (Figure 11) had maxima at 280 mμ ($\log \epsilon = 3.41$) and 273 mμ ($\log \epsilon = 3.38$). These maxima were typical of a phenol substituted in the 2 and 3 positions (see Table 2 on page 18).

The mass spectrum of C (Figure 12) showed a parent peak at m/e 204 and a base peak at 189 (M-15). A large metastable peak at 176 was due to this transformation from mass 204 to mass 189. The peak at 161 (M-43) was only 5% of the base peak. The low intensity of this peak suggested that there was no isopropyl group on the molecule which could be easily lost.

The NMR spectrum of C (Figure 13) was easily interpreted. The peaks in this spectrum were at τ 8.75 and τ 8.60, each representing 6.0 hydrogens; τ 8.37, representing 4.0 hydrogens; τ 5.58, representing 1.0 hydrogen; and multiplets at τ 3.75 and τ 3.20, representing the remaining 3.0 hydrogens. The peaks at τ 8.75 and τ 8.60 corresponded to twelve geminal dimethyl hydrogens; and at τ 8.37 to four methylene hydrogens; that at τ 5.58 to the phenolic hydrogen; and the two multiplets corresponded to the three aromatic hydrogens.

Evidence for the presence of a methyl group and the absence of an isopropyl group, which was shown in the mass and NMR spectra, eliminated structures XVI-XIX as possibilities for compound C. The decision between structures XIV and XV can be made on the basis of the NMR, ultraviolet, and infrared spectra. The NMR showed that the magnetic environment of two of the methyl groups was different than that of the other two. A difference of this magnitude would be expected for structure XIV, but not for structure XV. The ultraviolet spectrum of C supported the choice of structure XIV because it showed that C was a phenol substituted in the 2 and 3 positions. The absorption due to the phenol group in the infrared spectrum showed that there was little intermolecular hydrogen bonding. This lack of intermolecular hydrogen bonding suggested that the phenol was hindered. All of the above considerations show that C has spectral properties consistent with structure XIV but inconsistent with structures XV-XIX.

D. Fraction D

Fraction D was the only phenolic product of molecular weight 204 detected among the products of the sulfuric acid catalyzed reaction. It was also found in a lesser amount among the products of the non-catalyzed reaction. Its infrared spectrum (Figure 14) had a sharp band at 3600 $cm.^{-1}$ and a shorter broad band at 3450 $cm.^{-1}$. These bands were caused by an alcohol or a phenol which participated in considerable intermolecular hydrogen bonding. Bands at 1365 $cm.^{-1}$ and 1390 $cm.^{-1}$, characteristic of a geminal dimethyl group, were also present.

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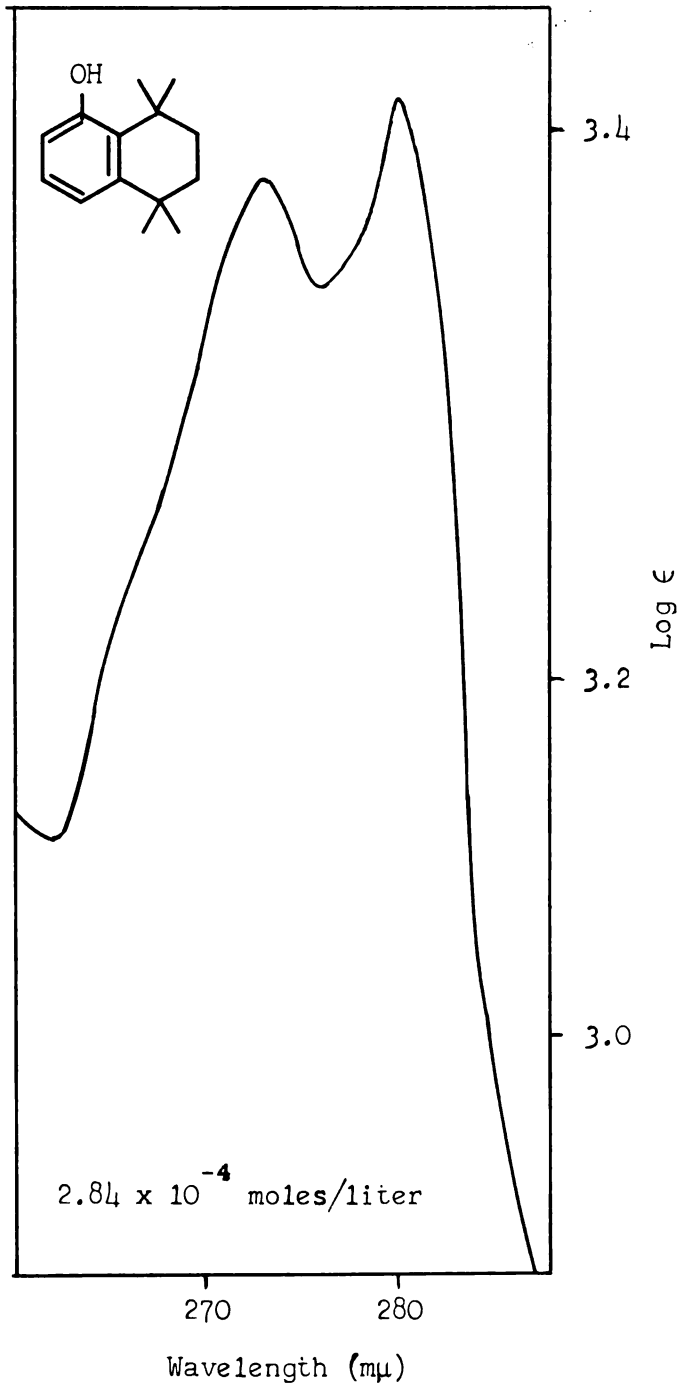

Figure 11. Ultraviolet spectrum of fraction C in isooctane.

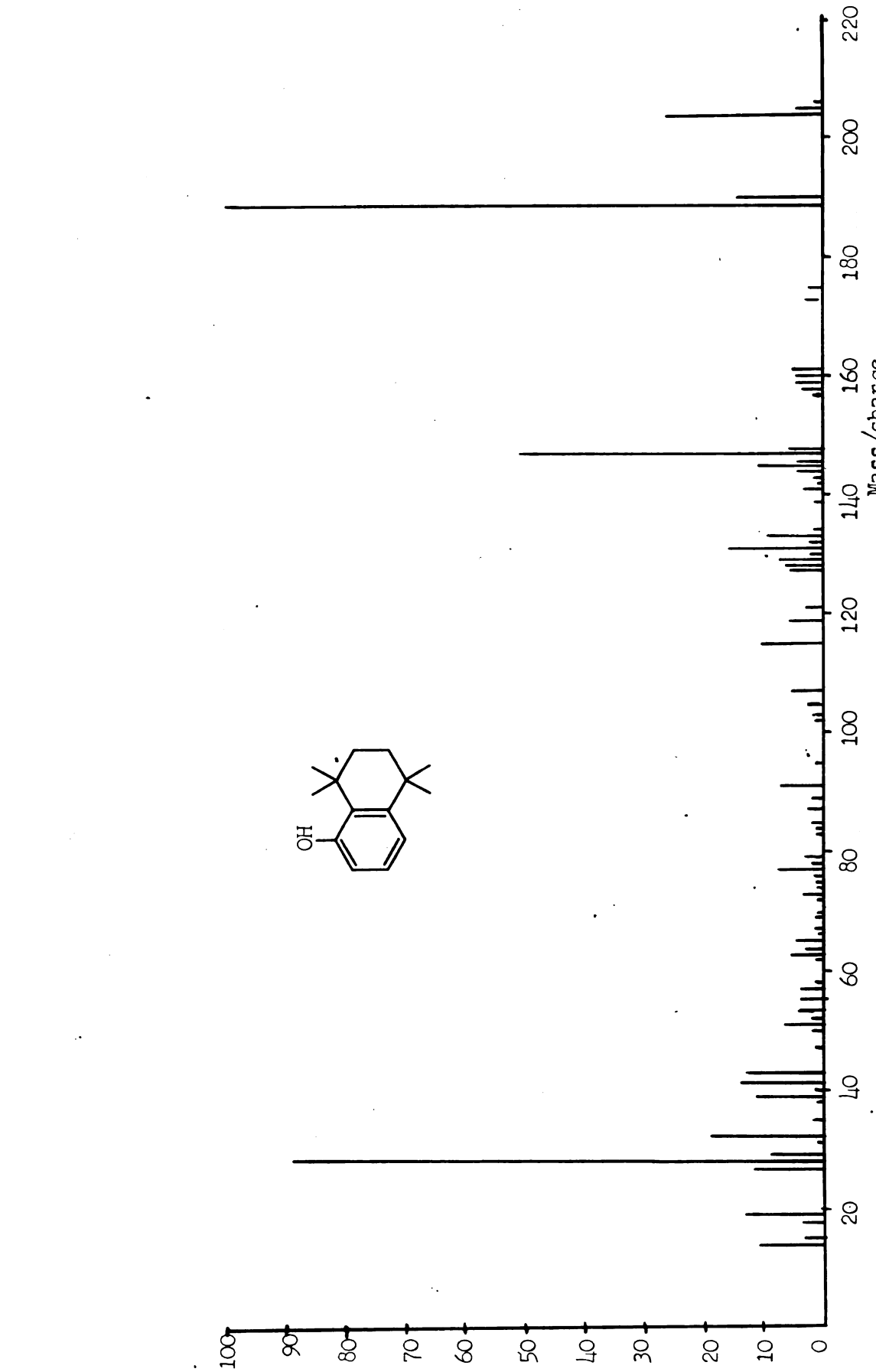

Figure 12. Mass spectrum of fraction C.

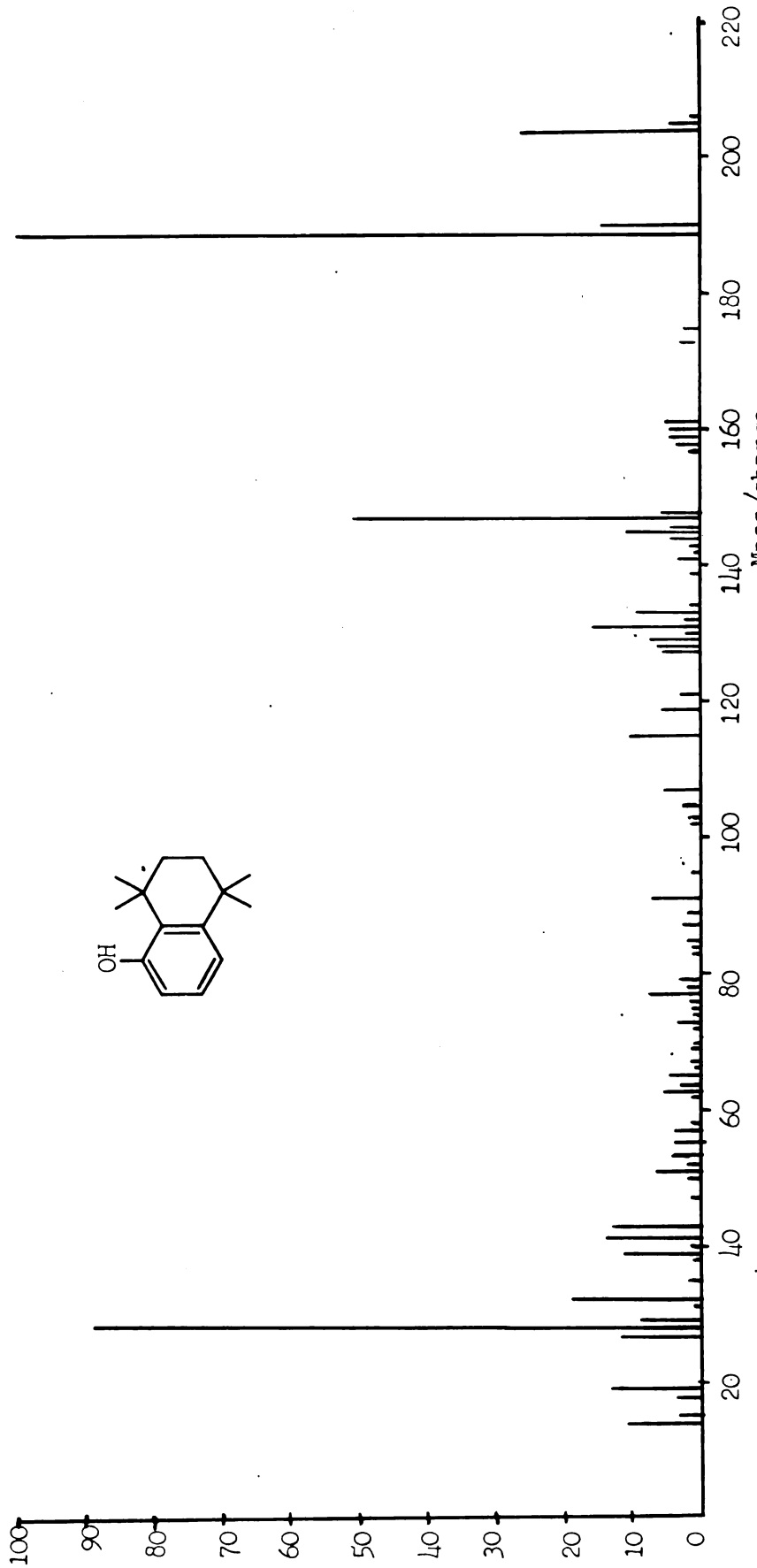

Figure 12. Mass spectrum of fraction C.

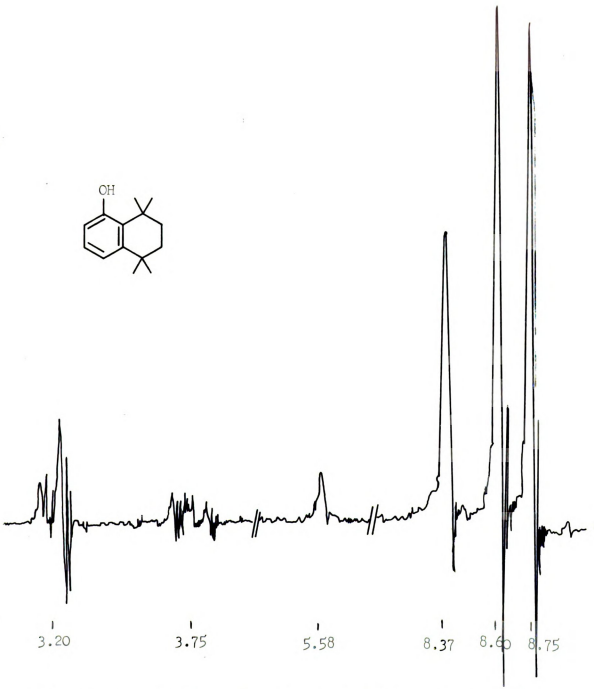

Figure 13. NMR spectrum of fraction C in carbon tetrachloride.

The ultraviolet spectrum of D in isooctane (Figure 15) had maxima at 286 mμ (log ϵ = 3.34) and 278 mμ (log ϵ = 3.32). This spectrum was typical of a phenol substituted in the 3 and 4 positions (see Table 2 on page 18).

The mass spectrum of D (Figure 16) showed a parent peak at m/e 204 and a base peak at 189 (M-15). A metastable peak at 176 was due to the transition from mass 204 to mass 189. The peak at 189 represented the loss of a methyl group from a compound having the formula $C_{14}H_{20}O$. The peak at 161 (M-43) was only 6% of the base peak. The low intensity of this peak suggested that there was no easily lost isopropyl group on the molecule.

The NMR spectrum of compound D in acetone-d_6 (Figure 17) was easily interpreted. Two peaks at τ 8.77 and τ 8.38 represented 12.0 and 4.0 hydrogens, respectively; a multiplet at τ 2.8-3.5 represented 3.0 hydrogens; and a peak at τ 2.32 represented the remaining hydrogen. The peak at τ 8.77 was due to two pairs of geminal dimethyl hydrogens; the peak at τ 8.34 to four methylene hydrogens; the multiplet to the aromatic hydrogens; and the remaining peak at τ 2.32 to the phenolic hydrogen. This last peak is quite low for a phenolic hydrogen. Its position was probably due to proton interchange with a trace of water in the acetone-d_6 solvent. Since all of the other NMR spectra were run either neat or using carbon tetrachloride as a solvent this was the only spectrum where the peak for the phenolic hydrogen was found at such a low position.

The evidence for the presence of only methyl groups shown in both the mass and NMR spectra eliminated structures XVI-XIX as possible

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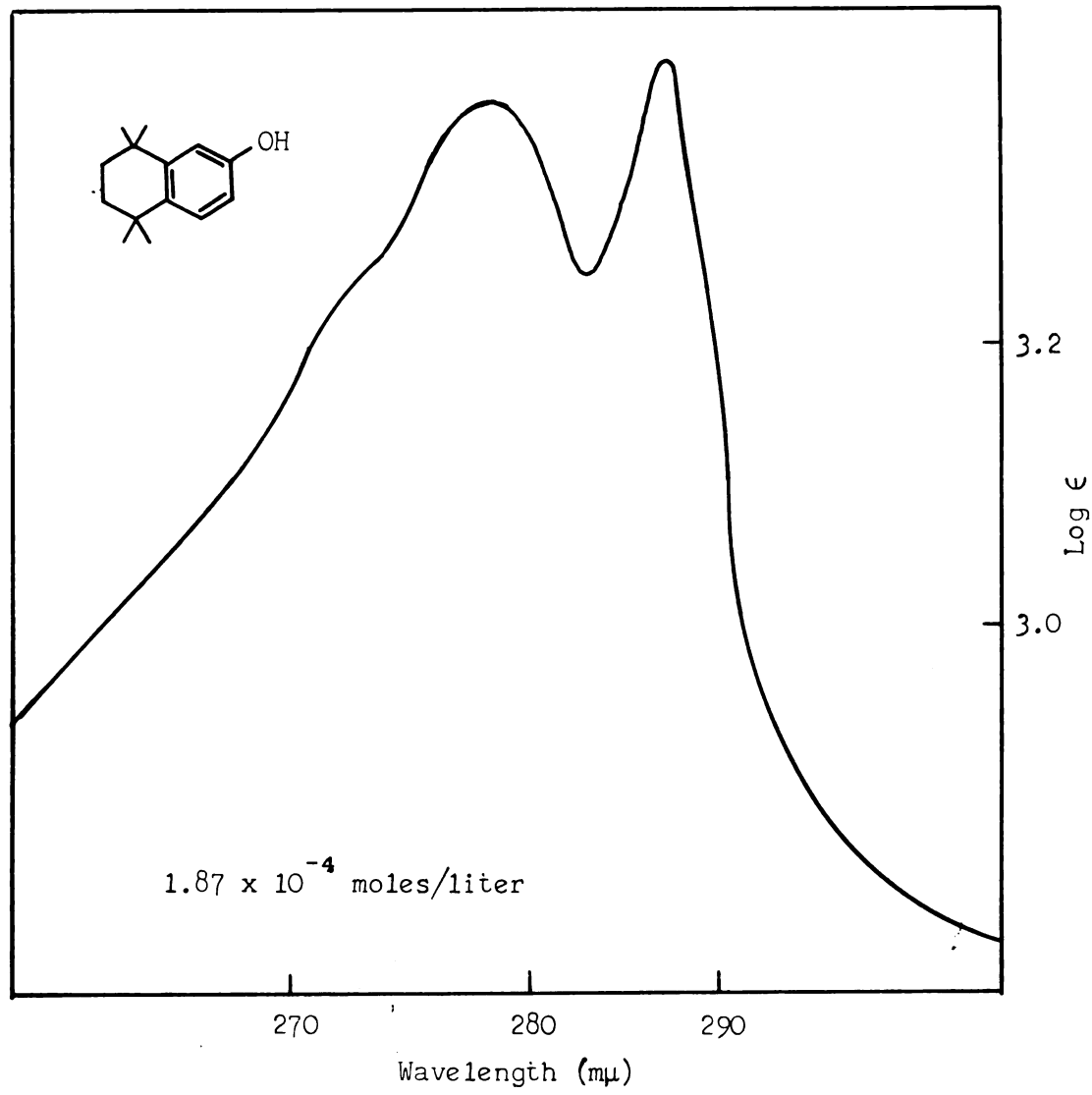


Figure 15. Ultraviolet spectrum of fraction D in isooctane.

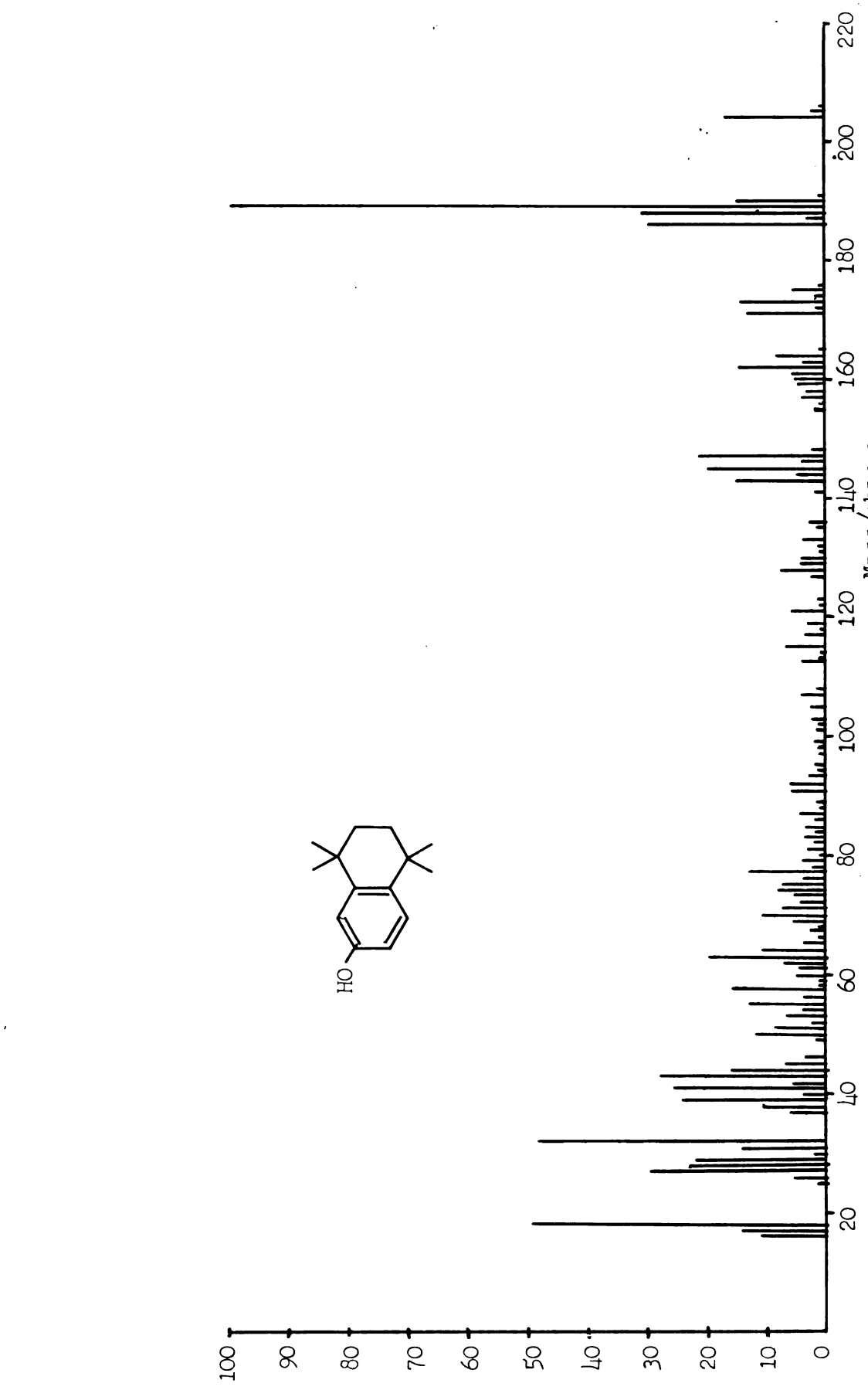


Figure 16. Mass spectrum of fraction D.

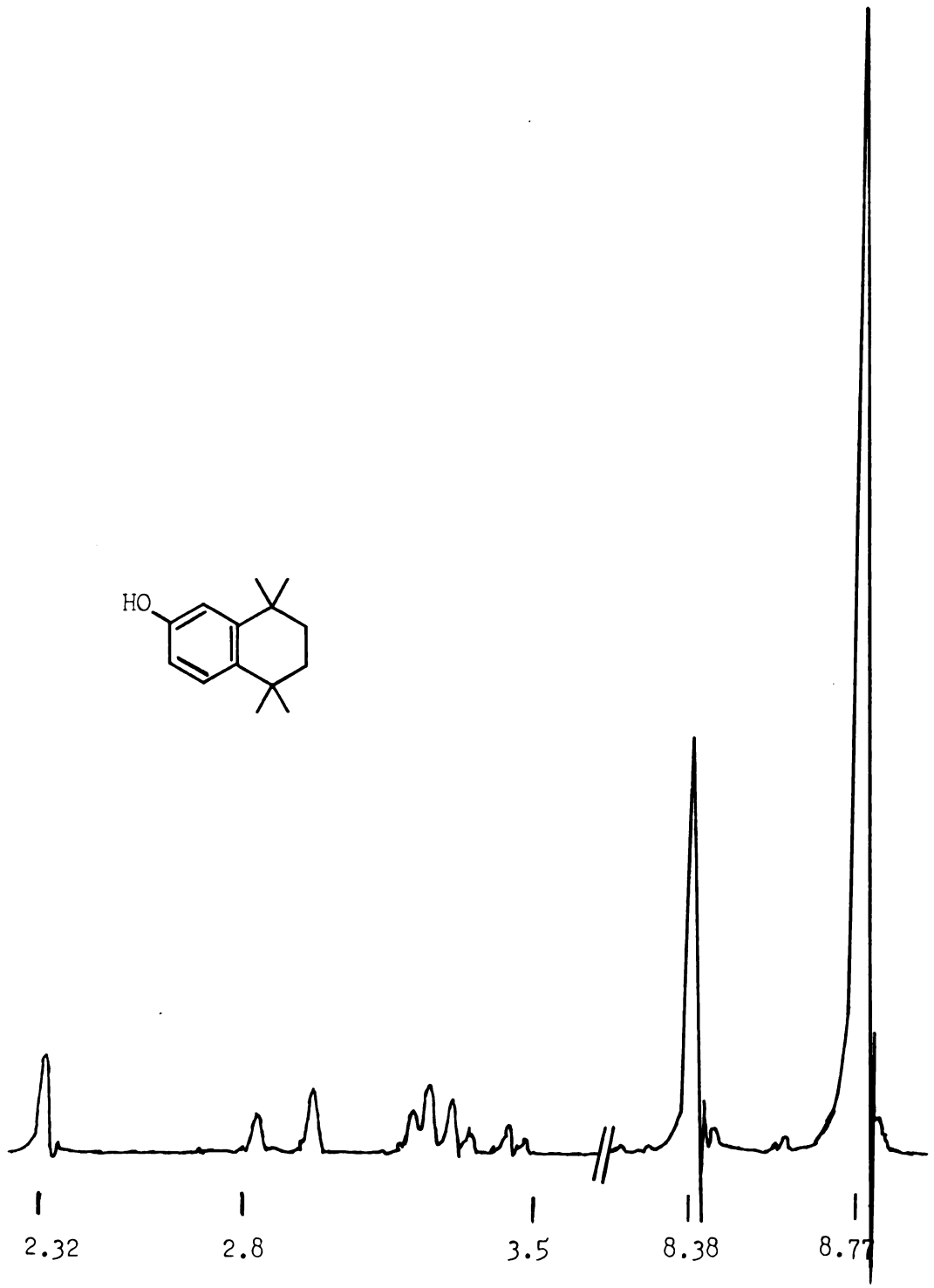


Figure 17. NMR spectrum of fraction D in acetone-d_6.

structures for D. The decision between structures XIV and XV can be made on the basis of the NMR, ultraviolet, and infrared spectra. The NMR spectrum showed that both sets of geminal dimethyl groups had equivalent magnetic environments. The ultraviolet spectrum was consistent with a phenol substituted in the 3 and 4 positions. The infrared spectrum showed that there was considerable intermolecular hydrogen bonding in a solution of D. This meant that the phenol was probably not hindered. All of the above considerations show that compound D has spectral properties only consistent with XV. Compound D melted at 142-143° and was probably identical to the compound melting at 145° reported earlier by Bruson and Kroeger (6), who showed chemically that their compound had structure XV (see Introduction).

E. Fraction E

Fraction E was found in small amounts in the neutral extracts of both the non-catalyzed and the sulfuric acid catalyzed reactions. Its infrared spectrum (Figure 18) had no bands in the region from 3600 $cm.^{-1}$ to 3400 $cm.^{-1}$. There was an intense band at 1190 $cm.^{-1}$ and many other sharp bands in the region from 1200 $cm.^{-1}$ to 1050 $cm.^{-1}$. The lack of bands in the former region and the presence of a strong band at 1190 $cm.^{-1}$ suggested that compound E was an ether. Bands at 1390 $cm.^{-1}$ and 1370 $cm.^{-1}$ suggested that E had geminal dimethyl groups.

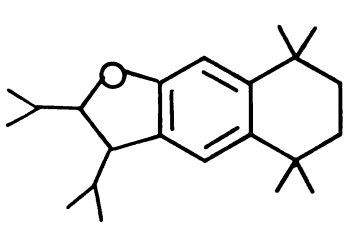
The ultraviolet spectrum of E in cyclohexane (Figure 19) had maxima at 298 mμ ($\log \epsilon = 3.03$), 292 mμ ($\log \epsilon = 3.04$), and 288 mμ ($\log \epsilon$ 3.06). This ultraviolet spectrum showed that E had a different ring system than any of the previously isolated compounds.

The mass spectrum of E (Figure 20) had a parent peak at m/e 314 and a base peak at 271 (M-43). The base peak represented the facile loss of a C_3H_7 fragment, probably an isopropyl group. None of the other peaks were greater than 10% of the base peak except the peaks at 43 and 41 which have been previously cited as probably being associated with an isopropyl fragment.

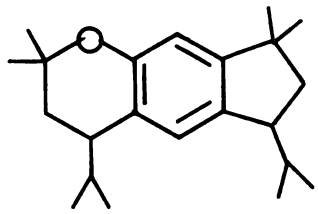
The NMR spectrum of E (Figure 21) was complex. Electronic integration of part of the spectrum was possible. Peaks at τ 9.40, τ 9.33, τ 9.27, τ 9.19, τ 9.04, and τ 9.00, each representing 1.5 hydrogens, together with two peaks hidden under a peak at τ 8.87 constituted the eight peaks of two isopropyl groups. The peak at τ 8.87 less the two hidden peaks and peaks at τ 8.82, τ 8.69, and τ 8.62 each represented 3.0 hydrogens. These peaks were associated with four magnetically unequivalent methyl groups which were not split by any protons on adjacent carbons. The areas under peaks at τ 8.33 and τ 8.13 and multiplets centered at τ 7.7 and τ 7.0 could not be integrated electronically. These peaks were in the region of the spectrum usually associated with methylene and methine hydrogens. Peaks at τ 3.60 and τ3.10 each represented 1.0 hydrogen. These two peaks in the region of aromatic protons split each other by less than 1 c.p.s.. Jackman (12) stated that mutual splitting is 7-10 c.p.s. for ortho protons, 2-3 c.p.s for meta protons, and 1 c.p.s. for para protons. The two aromatic protons of E must therefore be para to each other.

The information already presented limits consideration to structures XX-XXIV. Structure XX can be eliminated immediately. The NMR

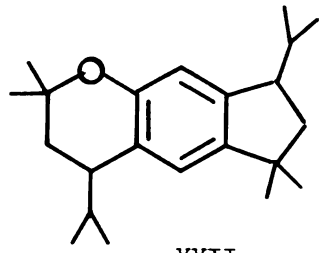
spectrum of XX would not show four separate unsplit methyl groups as are found in the NMR spectrum of E. The choice between the remaining structures can be made by comparing the NMR spectrum of E



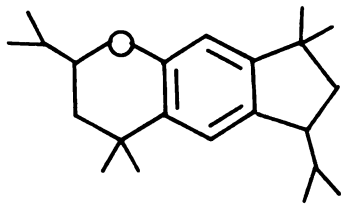
XX



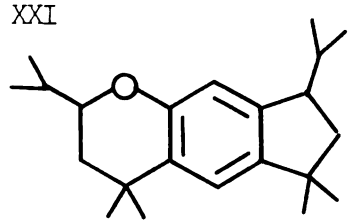
XXI



XXII



XXIII



XXIV

with the NMR spectra of A and B. If the oxygen-containing aliphatic ring of E were similar to the corresponding ring in A, the NMR spectra of the two compounds would be similar in the isopropyl proton region. Since these spectra are not similar in that region those structures which propose an oxygen-containing aliphatic ring for E similar to that in A can be eliminated. A section comparing the isopropyl region of the NMR spectra of several compounds is included later in this thesis. Part of the NMR spectrum of E in the isopropyl region is similar to the corresponding part of the one for B. This indicates that the non-oxygen-containing aliphatic ring in E is probably similar to the aliphatic ring of B. On the basis of this evidence structure XXIV is therefore favored. The choice of XXIV rather than the other structure will be discussed in more detail in the section of the thesis covering the mechanism of these reactions.

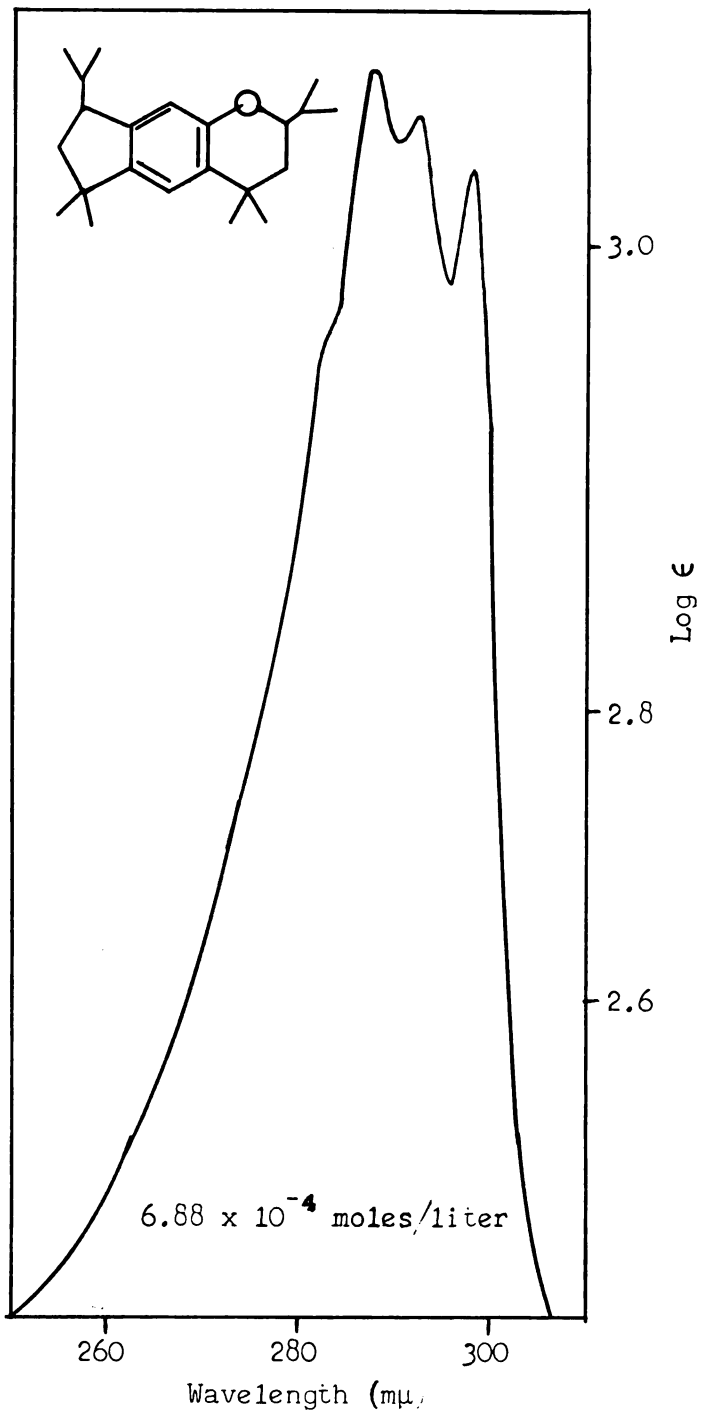


Figure 19. Ultraviolet spectrum of fraction E in cyclohexane.

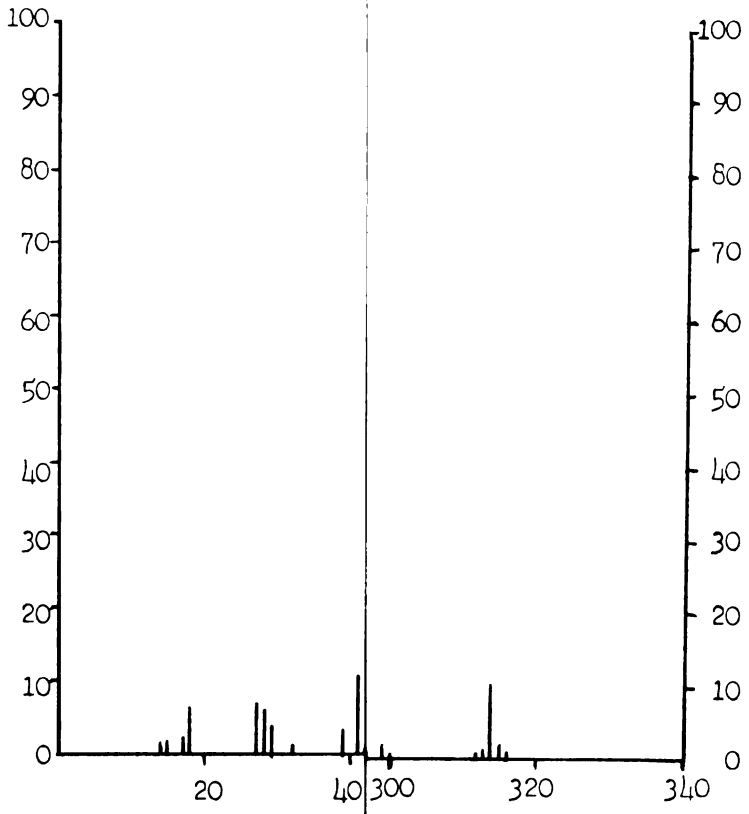


Figure 20. Mass spe

Fig

F. Fraction F

Fraction F was found chiefly in the neutral extracts of both the non-catalyzed and the sulfuric acid catalyzed reactions. Trace amounts were also found in the second Claisen's alkali extract of the non-catalyzed reaction. The infrared spectrum of F (Figure 22) had no bands in the region from 3600 $cm.^{-1}$ to 3400 $cm.^{-1}$ and it had two intense bands at 1200 $cm.^{-1}$ and 1140 $cm.^{-1}$. The absence of bands in the 3600 $cm.^{-1}$ to 3400 $cm.^{-1}$ region and the presence of the two intense bands indicated that F was an ether. Strong bands at 1385 $cm.^{-1}$ and 1370 $c.^{-1}$ were due to the presence of geminal dimethyl groups.

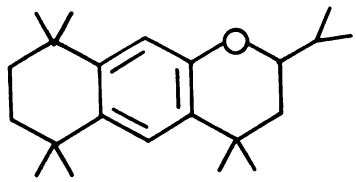
The ultraviolet spectrum of F in isooctane (Figure 23) had maxima at 293 mμ ($\log \epsilon = 3.55$) and 284 mμ ($\log \epsilon = 3.51$). This spectrum was not similar to any of the previously mentioned spectra and therefore must have been due to a different ring system.

The mass spectrum of F (Figure 24) had a parent peak at m/e 314 and a base peak at 271 (M-43) which was due to the loss of a C_3H_7 fragment, probably an isopropyl group. A peak at 299 had an intensity of 65% of the base peak and was due to the loss of a methyl group. There were strong peaks at 43, 41, and 39 which are generally associated with a strong M-43 peak. There was a peak at 45 which had an intensity of 19.2% of the base peak. An attempt to rationalize the existence of this peak will be made in a later part of this thesis.

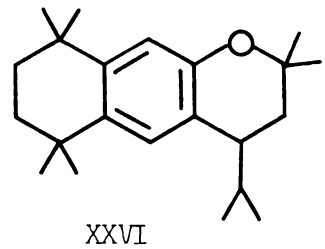
The NMR spectrum of F in carbon tetrachloride (Figure 25) was complex, but electronic integration of part of the spectrum was possible. Four peaks at τ 9.38, τ 9.25, τ 9.00, and τ 8.87, representing 1.5 hydrogens each, were assigned to an isopropyl group.

Peaks at τ 8.80, τ 8.73, and τ 8.62 represented 3, 12, and 3 protons, respectively. The two smaller peaks represented a geminal dimethyl group on the ring containing the isopropyl group. The single peak at τ 8.73 was due to the four methyl groups on the other ring. The peak at τ 8.33 was due to four methylene hydrogens. The remaining peaks in that region represented part of the ABCD system composed of the methylene and methine hydrogens in the ring containing the isopropyl group. Peaks at τ 3.27 and τ 2.80 were due to aromatic hydrogens. These two protons must have been para to each other since they split each other by less than 1.0 c.p.s. (12).

There are two possible structures which are reasonable for F.



XXV



XXVI

The choice between XXV and XXVI can be made by comparing the NMR spectra of compounds A and F. A comparison of these two spectra in the isopropyl and geminal dimethyl regions showed that part of this region for the spectrum of F was superimposable on the spectrum of A. Compound F must have therefore the same structure as A in the ring containing the isopropyl group. According to this evidence structure XXVI is correct for compound F.

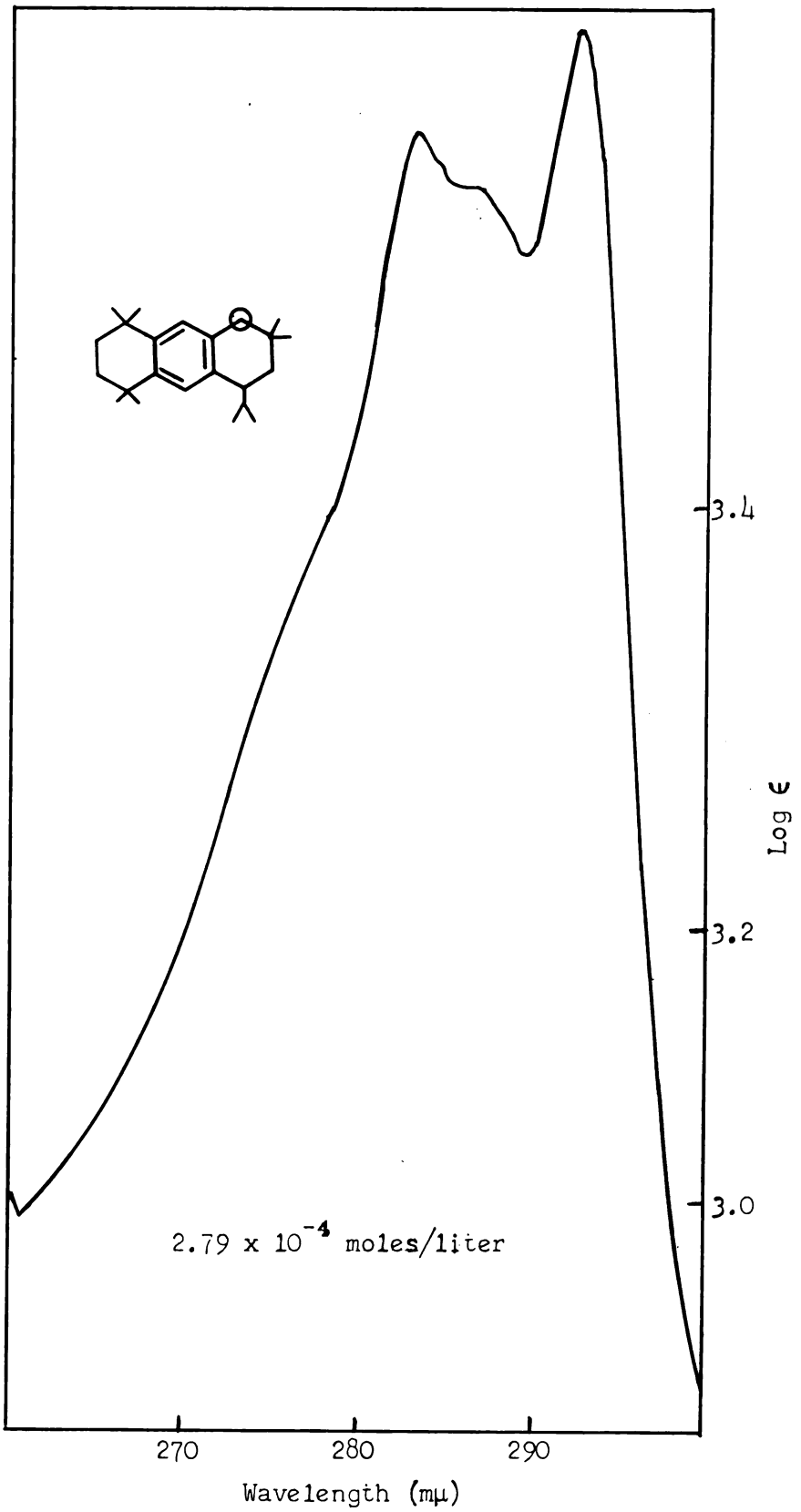


Figure 23. Ultraviolet spectrum of fraction F in isooctane.

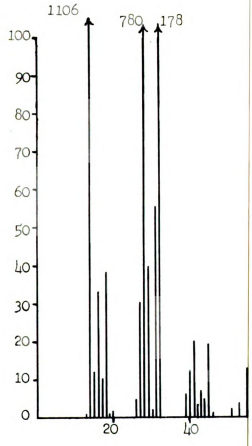


Figure 24. Mass spectrum o

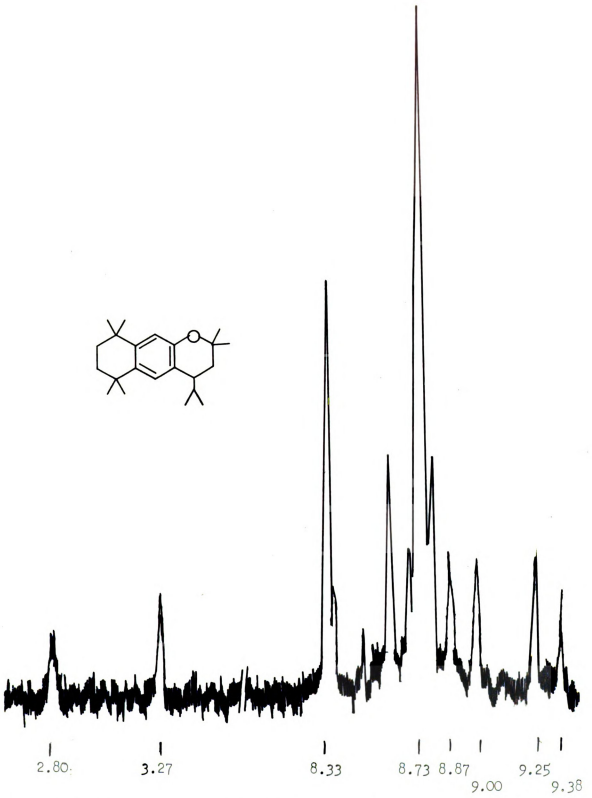


Figure 25. NMR spectrum of fraction F in carbon tetrachloride.

G. Fraction G

Fraction G was found in the neutral extracts of both the non-catalyzed and the sulfuric acid catalyzed reactions. A small amount of G was also found in the second Claisen's alkali extract of the non-catalyzed reaction. The infrared spectrum of G (Figure 26) had no bands from 3600 $cm.^{-1}$ to 3400 $cm.^{-1}$. The absence of any bands in this region and the presence of a moderately strong band at 1185 $cm.^{-1}$ indicated that this compound was an ether. The presence of strong bands at 1385 $cm.^{-1}$ and 1365 $cm.^{-1}$ indicated that G had geminal dimethyl groups.

The ultraviolet spectrum of G in isooctane (Figure 27) had maxima at 291 mμ ($\log \epsilon = 3.46$) and 282 mμ ($\log \epsilon = 3.44$). This was similar to the ultraviolet spectrum of F and indicated that products F and G probably had similar ring systems.

The mass spectrum of G (Figure 28) showed a parent peak at m/e 314 and a base peak at 271 (M-43) which was due to the loss of a C_3H_7 fragment, probably an isopropyl group. A large peak at 299 (M-15) had an intensity of 61.5% of the base peak. This was due to the loss of a methyl group. Large peaks at 43, 41, and 39 were present as in the other cases when there was a strong M-43 peak. The strong peaks at 69 and 55 will be discussed in a later section of this thesis.

The NMR spectrum of G (Figure 29) was complex. Electronic integration of part of the spectrum was possible. Four peaks at τ 9.04, τ 9.01, τ 8.94, and τ 8.91, each representing 1.5 hydrogens, were assigned to an isopropyl group. Peaks at τ 8.80, τ 8.75, and

τ 8.70 were assigned to six unsplit methyl groups. Two of these methyl groups had a magnetic environment slightly different from each other and different from the other four. The peak at τ 8.37 was assigned to four methylene hydrogens. The other peaks in that region were assigned to part of an ABCD system. The two remaining peaks a τ 3.47 and τ 3.02 each represented 1.0 protons. These two peaks, which were due to aromatic hydrogens, showed a mutual splitting of less than 1.0 c.p.s.. These were therefore two hydrogens in the para positions on an aromatic ring (12).

The only reasonable structures which can be drawn for this compound are structures XXV and XXVI. Since compound F has already been assigned structure XXVI and compounds F and G are different compounds, then compound G must have structure XXV. A comparison of the isopropyl regions of the NMR spectra of compounds E and G showed that the peaks due to the isopropyl hydrogens in the spectrum for G can be superimposed on one of the two sets of isopropyl hydrogens in the spectrum for E. This means that compounds E and G must have similar structures in the oxygen-containing aliphatic ring. This comparison serves as additional evidence for the correct assignment of structures for both compounds E and G.

H. Fraction H

Fraction H was found in small amounts in the neutral extracts of both the non-catalyzed and the sulfuric acid catalyzed reactions. A trace amount was present in the second Claisen's alkali extract of the non-catalyzed reaction. The infrared spectrum of H (Figure 30)

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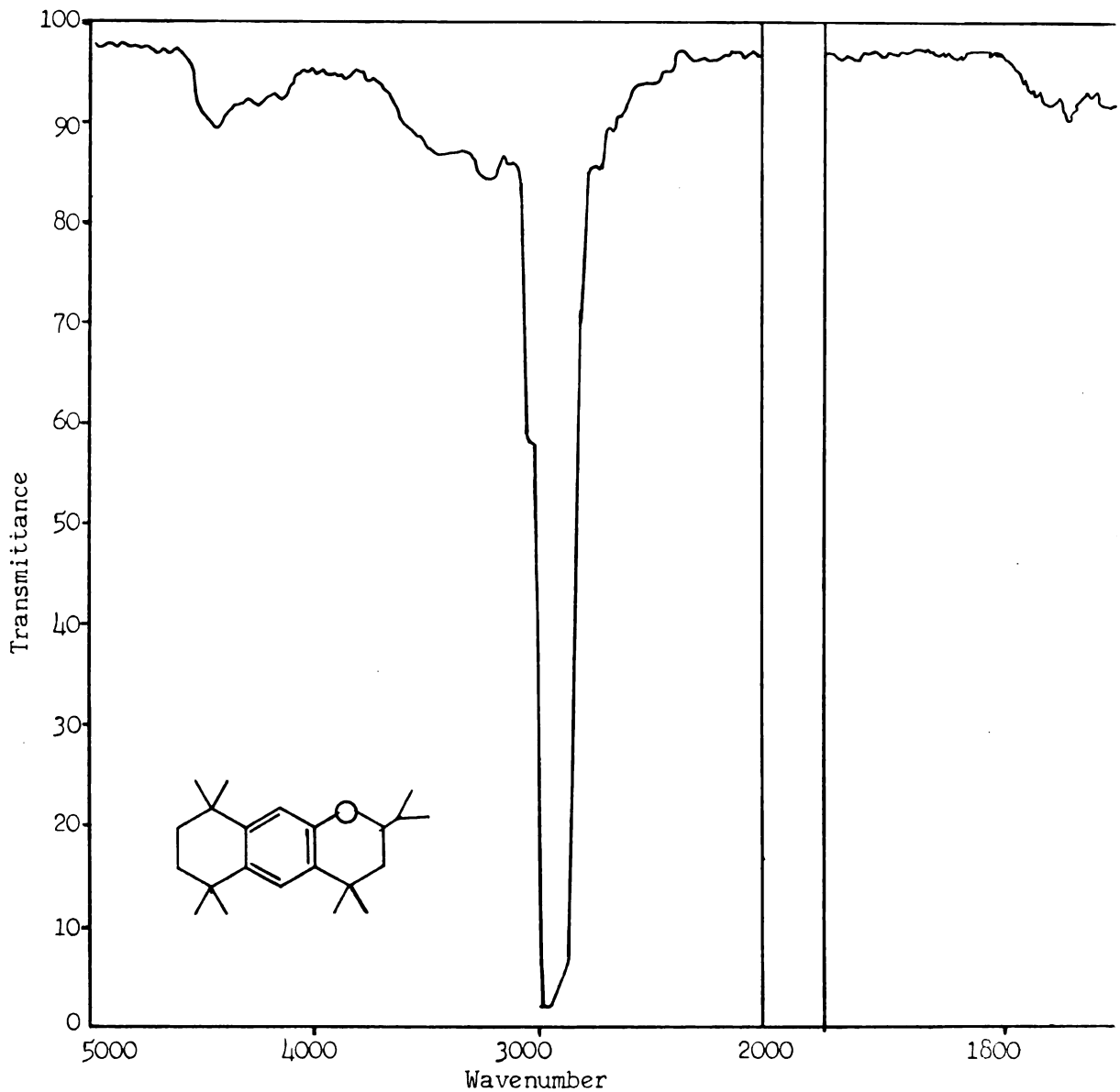
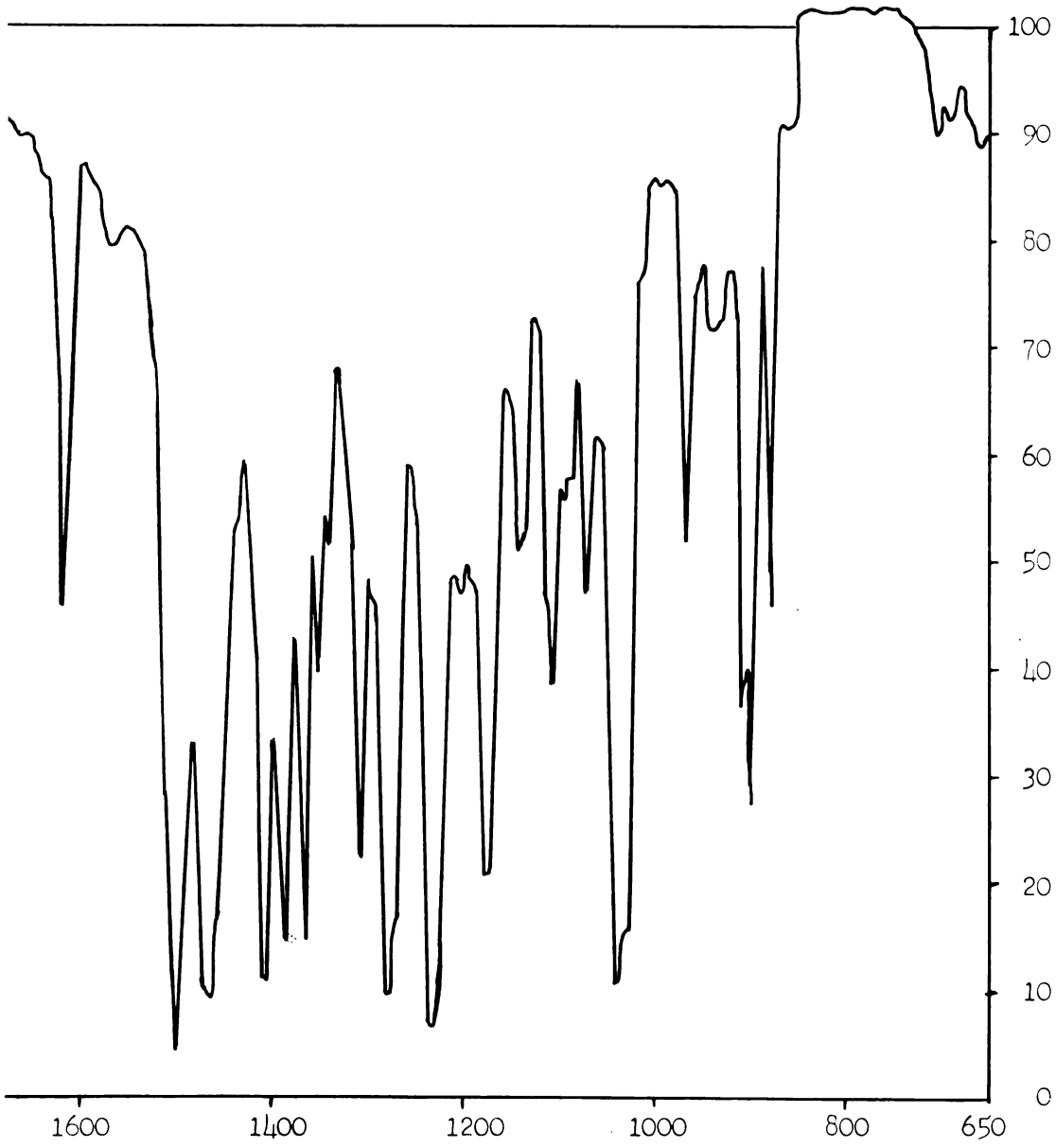


Figure 26. Infrared spectrum of fraction G.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0
1600
1400
1200
1000
800
650

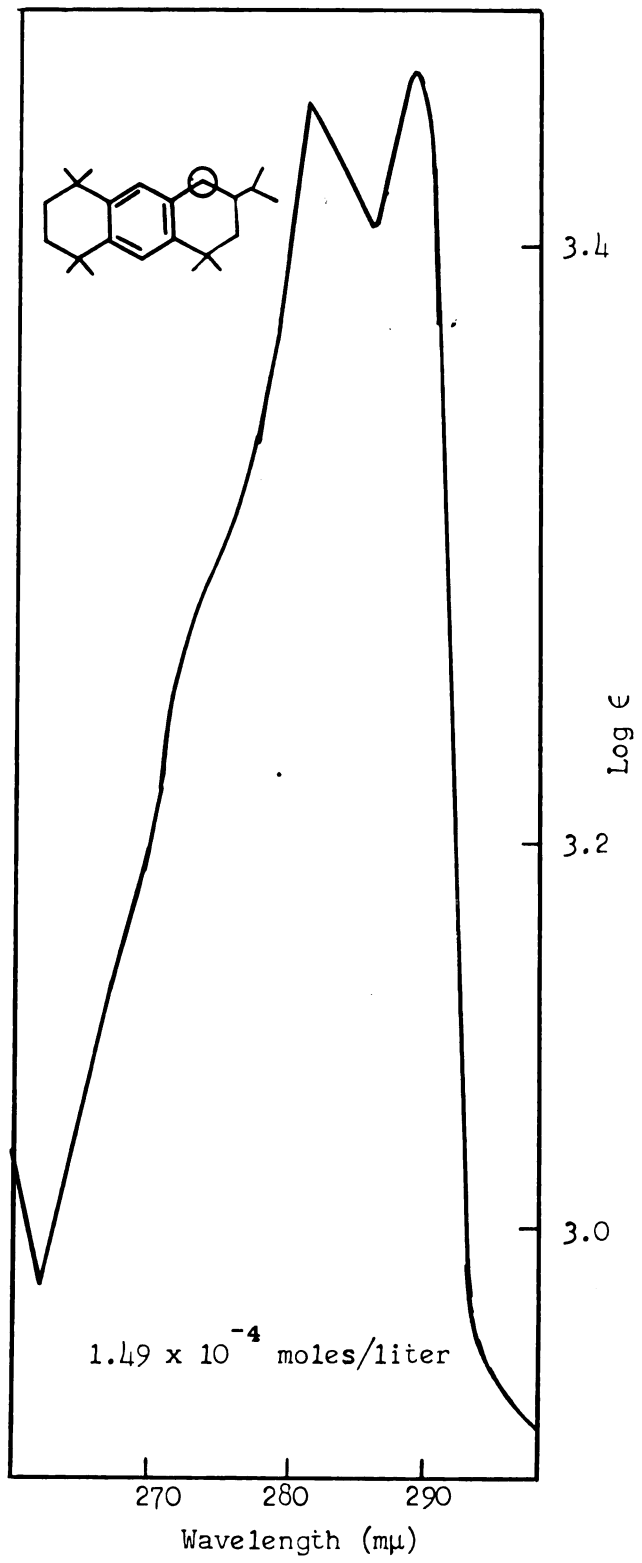
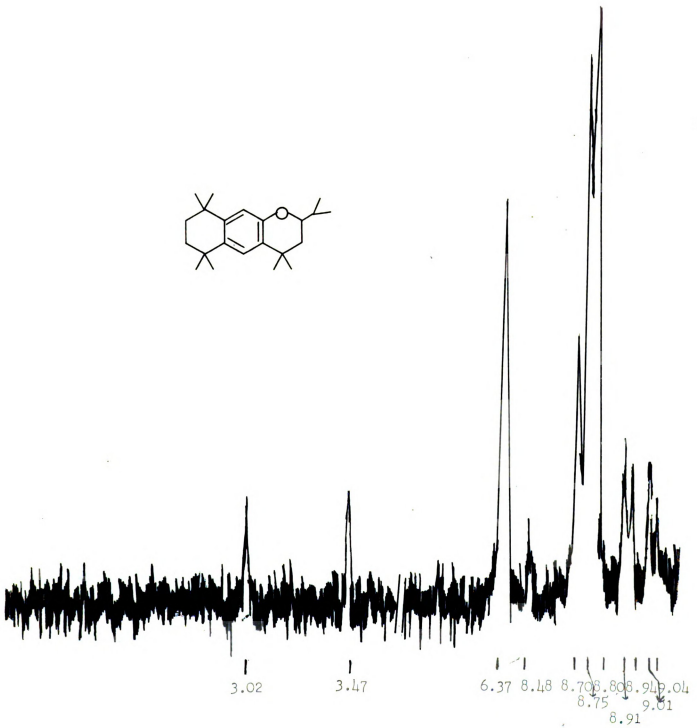


Figure 27. Ultraviolet spectrum of fraction G in isooctane.

Figure 29. NMR spectrum of fraction G in carbon tetrachloride.



had a sharp band at 3650 $cm.^{-1}$ and no band at 3400 $cm.^{-1}$. This indicated that the fraction contained an alcohol or a phenol which was unable to participate in intermolecular hydrogen bonding. A medium strength sharp band at 1650 $cm.^{-1}$ was probably due to a keto group, perhaps belonging to a minor impurity in fraction H. Bands at 1395 $cm.^{-1}$ and 1365 $cm.^{-1}$ were probably due to geminal dimethyl groups.

The ultraviolet spectrum of H in cyclohexane (Figure 31) had maxima at 298 mμ ($\log \epsilon = 2.86$), 275 mμ ($\log \epsilon = 3.54$), and 269 mμ ($\log \epsilon = 3.51$). This spectrum was different than any of the spectra for the other compounds isolated from these reactions and must belong to a different ring system.

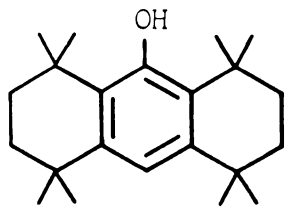
The mass spectrum of H (Figure 32) had a parent peak at m/e 314 and a base peak at 271 (M-43) which was due to the loss of a C_3H_7 fragment. There were peaks at 299 (M-15) and 328 (M+14) which had intensities relative to the base peak of 28.9% and 2.1%, respectively. The former peak was due to the loss of a methyl group and the latter one to an impourity which probably had a molecular weight of 328. Strong peaks at 43, 41, and 39 which are normally present when there is an intense M-43 peak were also found in this spectrum.

The NMR spectrum of H (Figure 33) showed splitting only in the methylene region where it was poorly defined. The peaks in the aliphatic region at τ 8.77, τ 8.74, τ 8.59, τ 8.53, and τ 8.40 had relative intensities of 9, 6, 9, 2, and 8, respectively. The first four peaks were all due to geminal dimethyl groups. The peak at τ 8.40 was broad and was due to all of the methylene hydrogens.

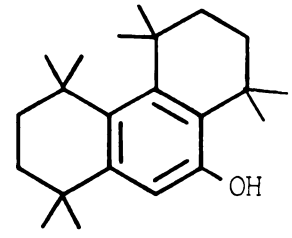
Two peaks at τ 5.10 and τ 3.23 were barely observable above the noise level of the spectrum. The former peak was assigned to a phenolic hydrogen and the latter one to an aromatic hydrogen.

The compound or compounds in fraction H must have either structure XXVII or XXVIII, or there must be a mixture of both structures.

The NMR spectrum of H can best be explained by assuming that H is a mixture of these compounds in a ratio of 70 to 30, with XXVII as the major component. The peaks at τ 8.77 and τ 8.59 would be due to XXVII and those at τ 8.74 and τ 8.53 would be due to XXVIII. The last peak in each set would be due to the geminal



XXVII



XXVIII

dimethyl groups closest to the hydroxyl group. The first peak in each set would be due to the remaining geminal dimethyl groups. Compounds XXVII and XXVIII will henceforth be designated as compounds H-1 and H-2, respectively.

The ketonic impurity observed in both the infrared and mass spectra of fraction H probably was a compound having either structure XXIX or XXX. These two compounds are quinones which would come from the oxidation of H-1 and H-2.

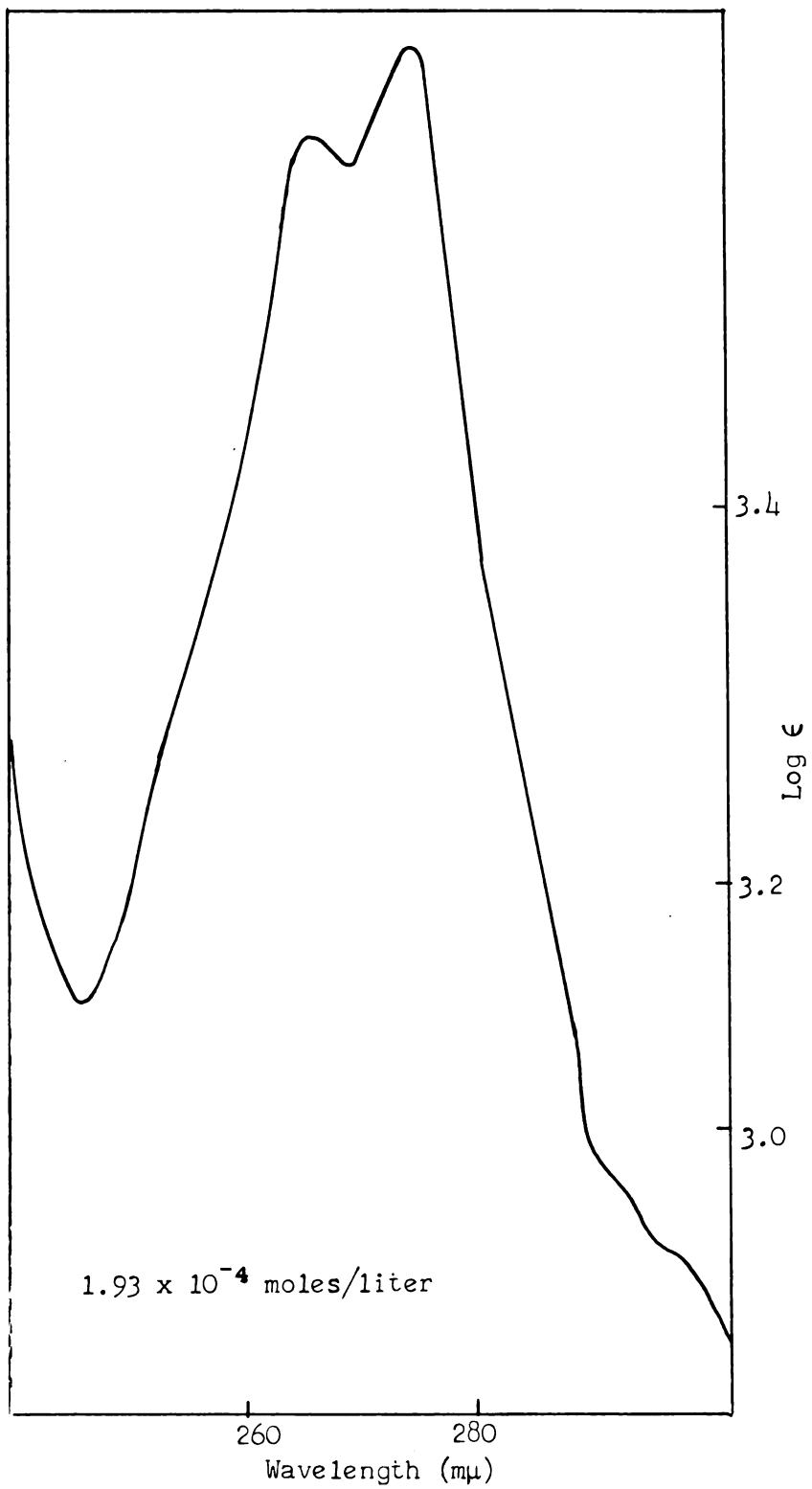


Figure 31. Ultraviolet spectrum of fraction H in cyclohexane.

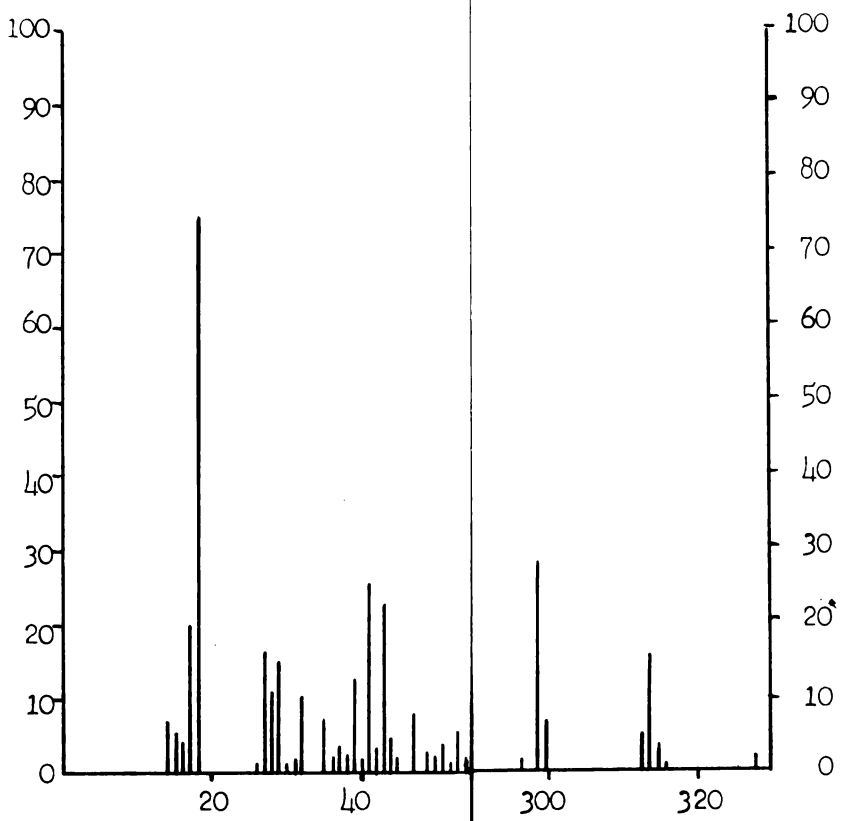


Figure 32. Mass spectrum

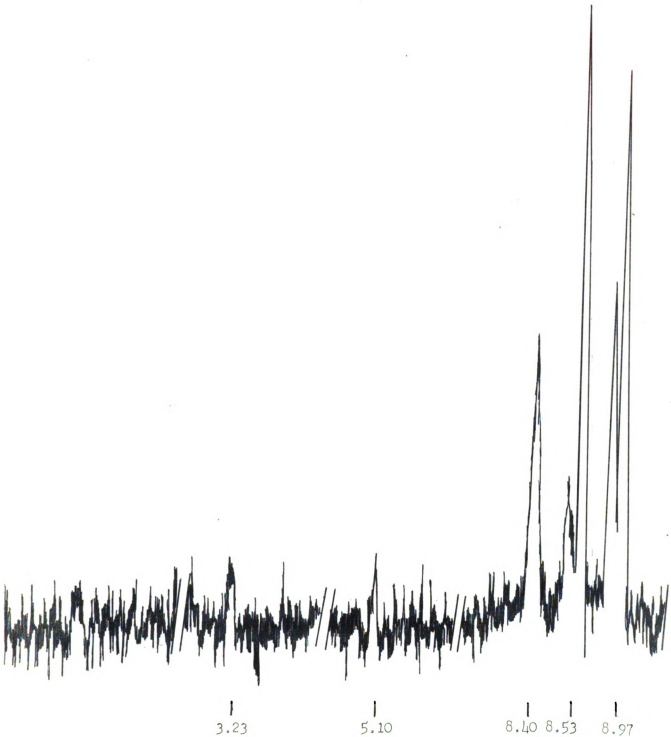
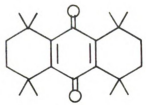
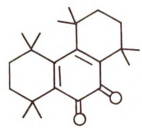


Figure 33. NMR spectrum of fraction H in carbon tetrachloride.



XXIX



XXX

I. Comparison of isopropyl regions of NMR spectra of several comounds

The primary hydrogens of an isopropyl group in an aliphatic ring gave a distinct NMR pattern which depended on the type of ring and the position of the isopropyl group on that ring. The spectra in this region of compounds XIII, XVII, XIX, XXIV, XXV, and XXVI from this thesis and 1,1-dimethyl-4-isopropyltetralin (XXXI), prepared by Barclay, Ginn, and Milligan (13), are shown in Table 3. In this table all peak positions are shown in τ units.

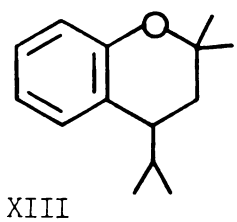
The origin of the quartet in this region is due to two factors. If the isopropyl group is in an asymmetric molecule the two methyl groups in the isopropyl group will be in different magnetic environments. The signals for each of these methyl groups will be split in two by approximately 6.7 c.p.s. by the methine hydrogen of the isopropyl group. Whereas the splitting by the methine hydrogen tends to be constant, the difference in magnetic environment of each methyl group varies considerably from compound to compound. In the cases presented in Table 3, type I shows little difference in environment, but type II shows considerable difference. The difference in magnetic environment of types III and IV comes between these two extremes.

Table 3. Isopropyl regions of NMR spectra of several compounds

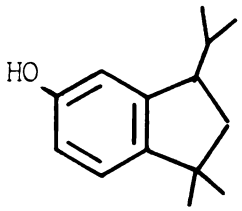
Compound	Type I	Type II	Type III	Type IV
XIII		9.40, 9.28, 9.02, 8.90		
XVII and XIX (mixture)			9.34, 9.23, 9.15, 9.11, 9.08*	
XXIV	9.04, (8.87)** 9.00		9.40, 9.27, 9.33, 9.19	
XXV	9.04, 8.94, 9.01, 8.91			
XXVI		9.38, 9.25, 9.00, 8.87		
XXXI				9.31, 9.19, 9.03, 8.93

*These are the positions of the five distinguishable peaks in this region which probably contains eight peaks.

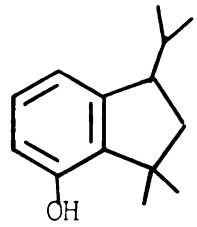
**This is the position of a large peak which hid the two peaks required to complete this quartet.



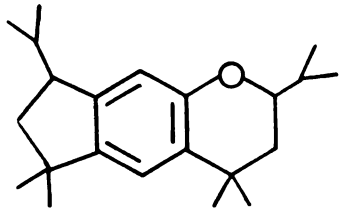
XIII



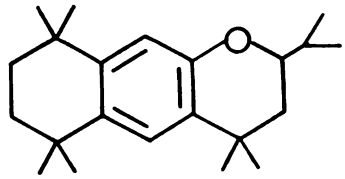
XVII



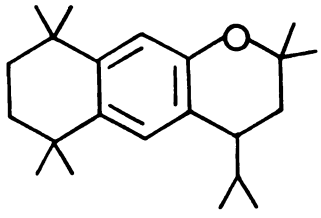
XIX



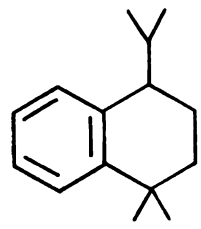
XXIV



XXV



XXVI



XXXI

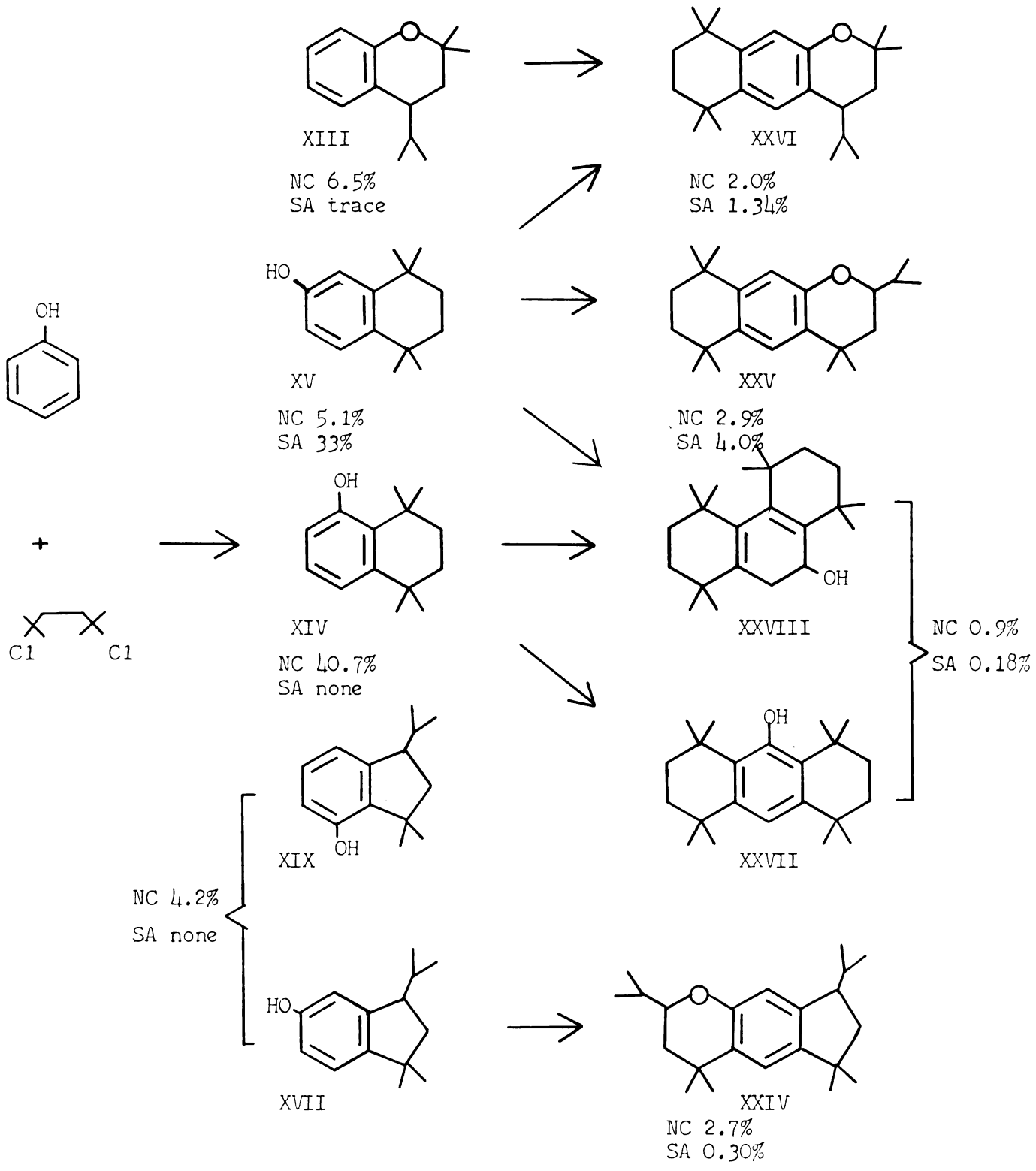
The closeness of the positions of the peaks within each type permits easy determination of the position of an isopropyl group by examination of a NMR spectrum.

Part III. Mechanism of the Reaction

The eight product fractions detected from the non-catalyzed reaction between 2,5-dichloro-2,5-dimethylhexane and phenol contained ten compounds. These were 2,2-dimethyl-4-isopropylchroman (XIII), 1,1,4,4-tetramethyl-5-tetralol (XIV), 1,1,4,4-tetramethyl-6-tetralol (XV), 1,1-dimethyl-3-isopropyl-5-indanol (XVII), 3,3-dimethyl-1-isopropyl-4-indanol (XIX), 4,4,6,6-tetramethyl-2,8-diisopropyl-3,4-dihydroindano [5,6-b]pyran (XXIV), 4,4,6,6,9,9-hexamethyl-2-isopropyl-3,4,6,7,8,9-hexahydronaphtho[2,3-b]pyran (XXV), 2,2,6,6,9,9-hexamethyl-4-isopropyl-3,4,6,7,8,9-hexahydronaphtho[2,3-b]pyran (XXVI), 1,1,4,4,5,5,8,8-octamethyl-1,2,3,4,5,6,7,8-octahydro-9-anthrol (XXVII), and 1,1,4,4,5,5,8,8-octamethyl-1,2,3,4,5,6,7,8-octahydro-9-phenanthrol (XXVIII).

The six product fractions detected in the sulfuric acid catalyzed reaction had identical retention times on the gas chromatograph to those fractions of the non-catalyzed reaction containing compounds XIII, XV, and XXIV-XXVII. However, XVII, which would correspond to the product previously isolated by Bruson and Kroeger (see Introduction), was not detected.

Compounds XIII-XV, XVII, and XIX had molecular formulas $C_{14}H_{20}O$ and were formed by the cyclialkylation of phenol by the bis chloride. Compounds XXIV-XXVIII had molecular formulas $C_{22}H_{34}O$ and were formed by the second cyclialkylation of one of the $C_{14}H_{20}O$ products by the

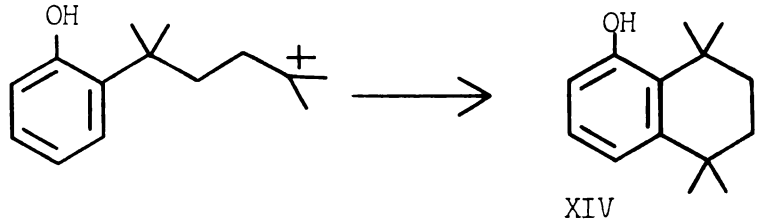

XIII
NC 6.5%
SA trace
XXVI
NC 2.0%
SA 1.34%
HO
XV
NC 5.1%
SA 33%
XXV
NC 2.9%
SA 4.0%
OH
+
C1
C1
XIV
NC 40.7%
SA none
XXVIII
NC 0.9%
SA 0.18%
XIX
OH
NC 4.2%
SA none
XXVII
HO
XVII
XXIV
NC 2.7%
SA 0.30%

bis chloride. A scheme of all the products gives the $C_{14}H_{20}O$ product from which each of the $C_{22}H_{34}O$ products could be made. Included in this scheme are the relative yields of all the products from both reactions.

Since the formation of the $C_{22}H_{34}O$ products can be explained by a two step process in which a $C_{14}H_{20}O$ product is formed followed by a cyclialkylation of this product similar to the cyclialkylation of phenol, it is only necessary to describe the reaction mechanism for the formation of the $C_{14}H_{20}O$ products. The reaction products can be rationalized in terms of a carbonium ion mechanism. It can be explained without invoking a non-classical carbonium ion species such as that postulated by Hart, Corbin, Wagner, and Wu in a similar reaction (see Introduction). In the first step, the bis chloride probably dissociates into a tertiary carbonium ion and a chloride ion.

This carbonium ion could react with the phenol at either the oxygen, or at the ortho or para positions. This step would be followed by the formation of a second carbonium ion which in turn would attack the same aromatic ring or another phenol molecule. All of the fractions isolated were due to this second attack being intramolecular; however, a considerable amount of polymer (27% of total product weight) obtained from the non-catalyzed reaction was probably due to this second step being intermolecular.

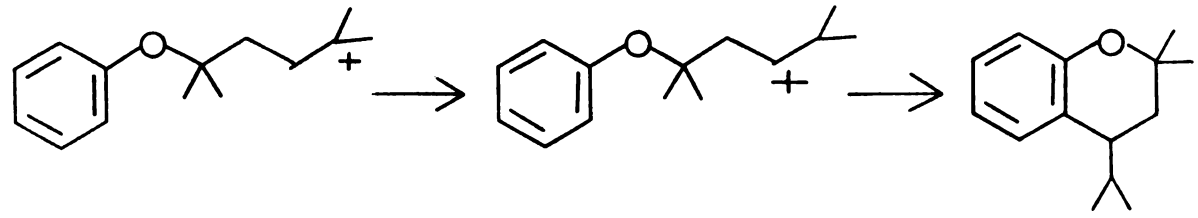
Compounds XIV and XV were produced by attack of the tertiary carbonium ion of the bis chloride at the ortho and para positions of phenol, respectively. Initial attack was followed by the formation of a second tertiary carbonium ion which then cyclized to a tetralol. This sequence of events is shown for the formation of XIV.



XIV

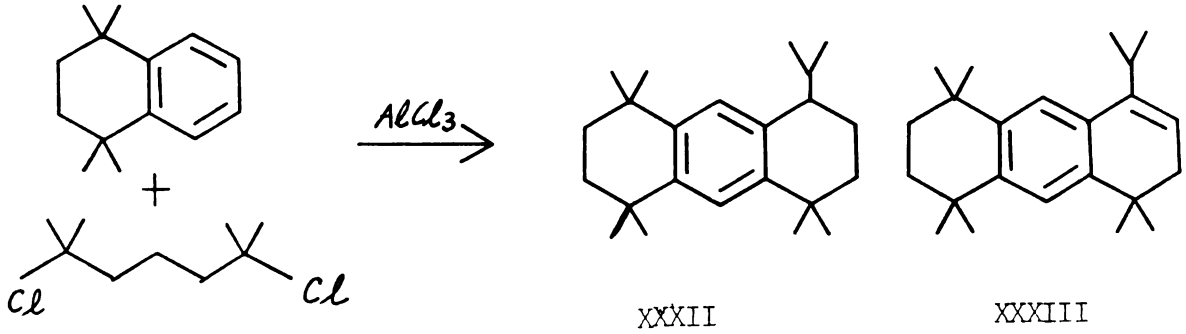
This is a familiar type of cyclialkylation for which there are many cases cited in the literature (14). Bruson and Kroeger (6) used 2,5-dichloro-2,5-dimethylhexane with phenol in the presence of aluminum chloride to produce 1,1,4,4-tetramethyl-6-tetralol. Reppe and co-workers (15) used 1,4-dichlorobutane with benzene in the presence of aluminum chloride to produce a mixture containing tetralin, octahydroanthracene, octahydrophenanthrene, and dodecahydrotriphenylene.

XIII probably was formed by attack of the tertiary carbonium ion of the bis chloride on the phenolic oxygen. A second ionization, followed by rearrangement to a secondary carbonium ion and cyclization leads to the product.



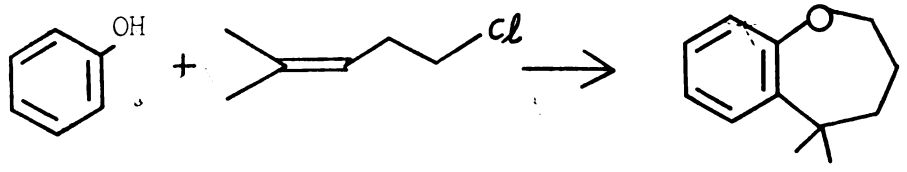
XIII

Hydride shifts of this type, even though they involve conversion of a tertiary to a secondary carbonium ion, are quite common in cyclialkylations, probably because they lead to six- rather than seven-membered rings. For example, Barclay, Ginn, and Milligan (13) found that the reaction of 1,1,4,4-tetramethyltetralin with 2,6-dichloro-2,6-dimethylheptane in the presence of aluminum chloride yielded a mixture of XXXII and XXXIII.



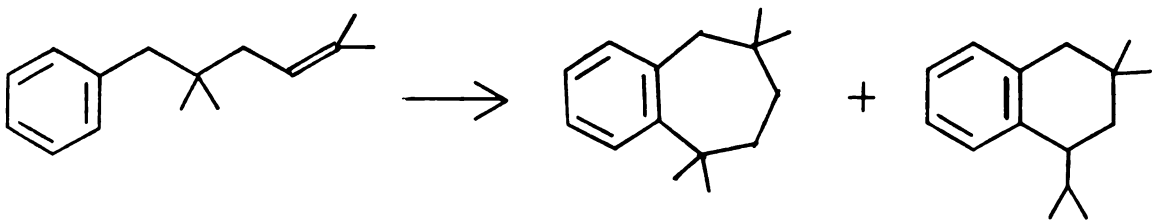
XXXII XXXIII

Hart, Corbin, Wagner, and Wu (5) found that the non-catalyzed addition of 5-chloro-2-methyl-2-pentene to phenol gave 5,5-dimethylhomochroman as the neutral product. This reaction was an exception to the rule that cyclization to a seven-membered ring is not usually favored. In this case, the reaction proceeds via the dimethylcyclopropylcarbonium ion (see Introduction).



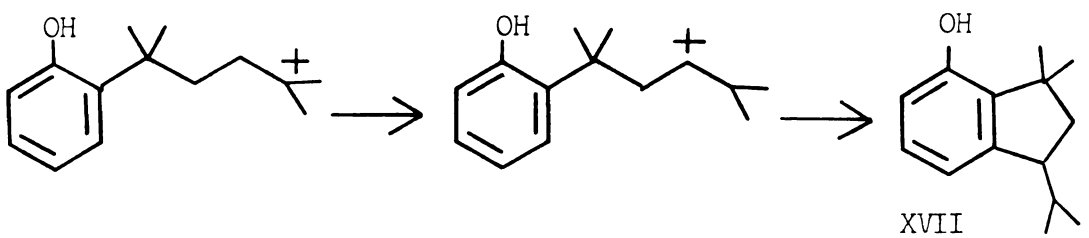
Hart and Corbin (16) used several Friedel-Crafts catalysts for the attempted synthesis of 1,1,4,4-tetramethyl-6,7-benzocycloheptene (XXXIV) from 2,5,5-trimethyl-7-phenyl-2-heptene. With aluminum

chloride at 0° the only product isolated was 3,3-dimethyl-1-isopropyltetralin (XXXV). With boron trifluoride at 0° or with ferric chloride a mixture of products was obtained containing 33% XXXIV and 67% XXXV. There was no product obtained when stannic chloride was used as the catalyst. This study showed that ring closure to a seven-membered ring occurred only under the mildest Friedel-Crafts conditions.



XXXIV XXXV

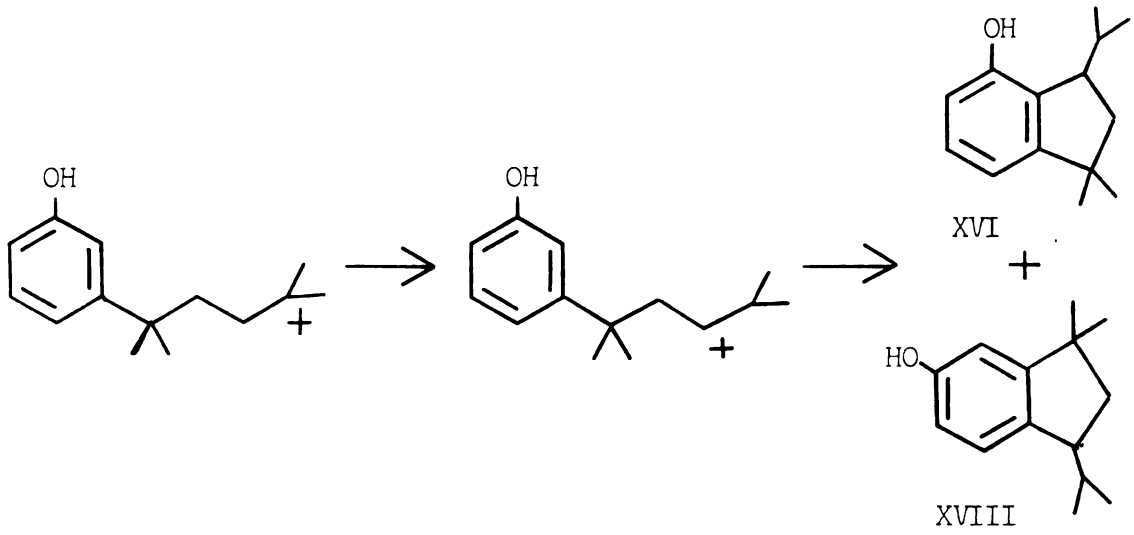
Compounds XVII and XIX would be formed by a process similar to the mechanism cited for the formation of XIII. In this case initial attack would be at an ortho or para position of phenol. This sequence for the formation of XVII is shown below.



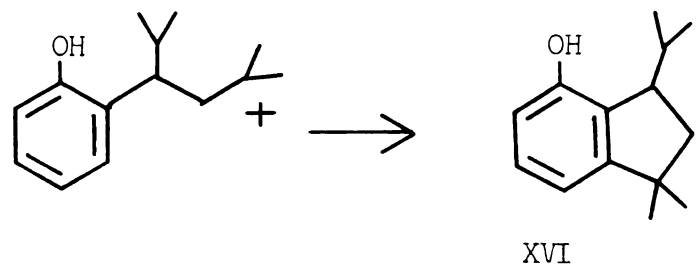
XVII

Whereas the determination of the structure of the two components in fraction B could not be made on the basis of spectral evidence alone, it should now be clear that formation of structures XVII and XIX can easily be explained by the above mechanism. In order for one of the two components to be either structure XVI or XVIII, one of two less favored reaction paths would have to be

followed. Attack of the tertiary carbonium ion at the meta position of phenol followed by a hydride shift and cyclization would produce a mixture of XVI and XVIII. An even poorer path would involve rear-



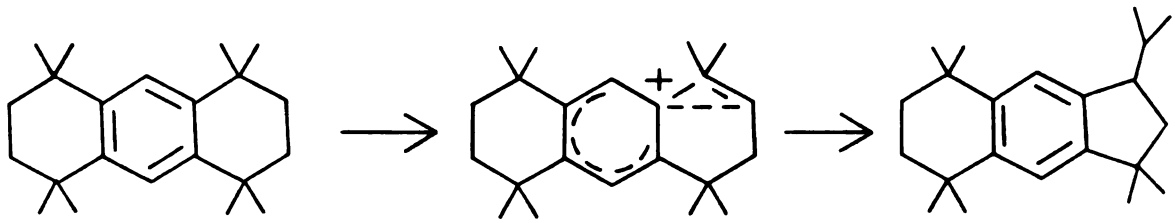
rangement of the first-formed tertiary carbonium ion prior to the attack on the aromatic ring. This path would be considered poorer because it requires that the attack of the carbonium ion be the slow step. According to the reaction scheme carbonium ion rearrangements can occur only during the slow step of the reaction. Attack of the carbonium ion at an electron rich position of phenol should be the fast step of this reaction. This sequence is given for the formation of XVI.



XVI

Similar mechanistic considerations explain why structure XXIV was favored over structure XXIII when deciding which was correct for E.

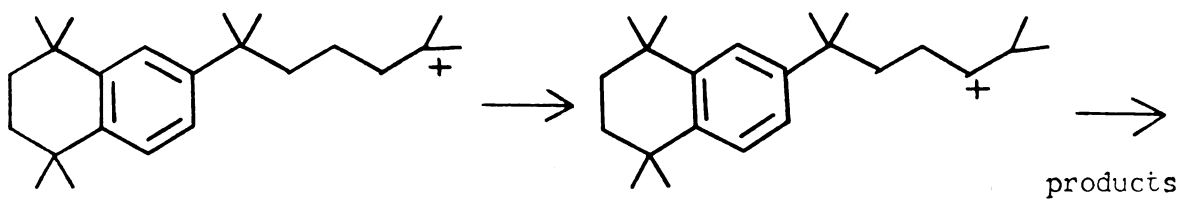
Barclay, Gray, and Milligan (17) found that 1,1,4,4,5,5,8,8-octamethyl-1,2,3,4,5,6,7,8-octahydroanthracene rearranged in the presence of aluminum chloride to give XXXVI. They suggested that this rearrangement proceeded through a benzenonium ion intermediate.



XXXVI

The non-catalyzed reaction reported in this thesis could not have had a benzenonium ion intermediate because its formation requires the loss of a hydride ion. Since there is no species in the reaction mixture capable of transferring a hydride ion such an intermediate would be prevented from forming.

In a later paper, Barclay, Ginn, and Milligan (13) suggested that the reaction of 1,1,4,4-tetramethyltetralin with 2,6-dichloro-2,6-dimethylheptane in the presence of aluminum chloride went through a mechanism similar to the one proposed in this thesis.



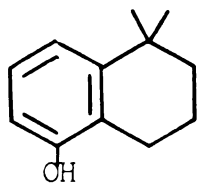
It is difficult to explain why production of the 5-tetralol is favored by the non-catalyzed reaction whereas the 6-tetralol is favored by the sulfuric acid catalyzed reaction. In fact, no products formed by initial attack at the ortho position of phenol in the sulfuric acid catalyzed reaction were even detected. Further experiments would be necessary to discover the true cause or causes of this preference. The absence of the 5-tetralol (XIV) among the products detected was not due to formation of the 5-tetralol (XIV) followed by rearrangement to the 6-tetralol (XV) under reaction conditions, since no rearrangement occurred when a mixture of XIV in 79% sulfuric acid was heated on a steam bath for 30 minutes. Likewise, there was no XVII even detected in the products of the sulfuric acid catalyzed reaction although the presence of a small amount of XXIV suggests that some XVII could have been present at some time during the reaction. Further experiments would be required to discover what conditions if any favored the formation of an indanol (XVII) over a tetralol (XV).

Part IV. Use of Mass Spectrometry in the Elucidation of Molecular Structures of Chromans, Indanols, and Tetralols

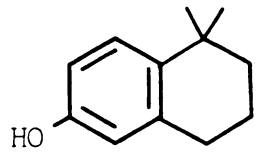
Mass spectrometry has been used extensively to elucidate the structures of complex molecules. Two excellent books which describe this technique have recently been written by Biemann (18) and Budzikiewicz, Djerassi, and Williams (19).

In order to use mass spectrometry to elucidate the structures of the compounds isolated from the reaction of phenol with 2,5-dichloro-2,5-dimethylhexane, the mass spectra of several reference compounds

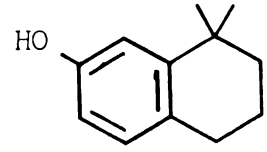
were run. These compounds are 1,1-dimethyl-5-tetralol (XXXVII), 1,1-dimethyl-6-tetralol (XXXVIII), 4,4-dimethyl-6-tetralol (XXXIX), 1,1,3-trimethyl-4-indanol (XL), and 1-isopropyl-5-indanol (XLI), all prepared by Corbin (20).



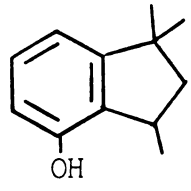
XXXVII



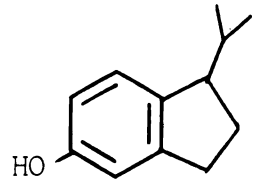
XXXVIII



XXIX



XL



XLI

A comparison of the mass spectra of compounds XXXVII, XXXVIII, and XXXIX shows that there is little difference between them. Since these compounds differed only in the position of the hydroxyl group on the aromatic ring, one concludes that this variation of structure between compounds does not seem to have a large effect on their mass spectra. These data indicate that mass specrometry probably would not be useful in distinguishing between structures XVI-XIX. A similar effect was observed by Biemann (18a), who showed that there was little difference between the mass spectra of the three ethyl-toluenes. A much greater difference between the mass spectra of compounds XIV and XV was observed. The origin of some of these peaks will be discussed later.

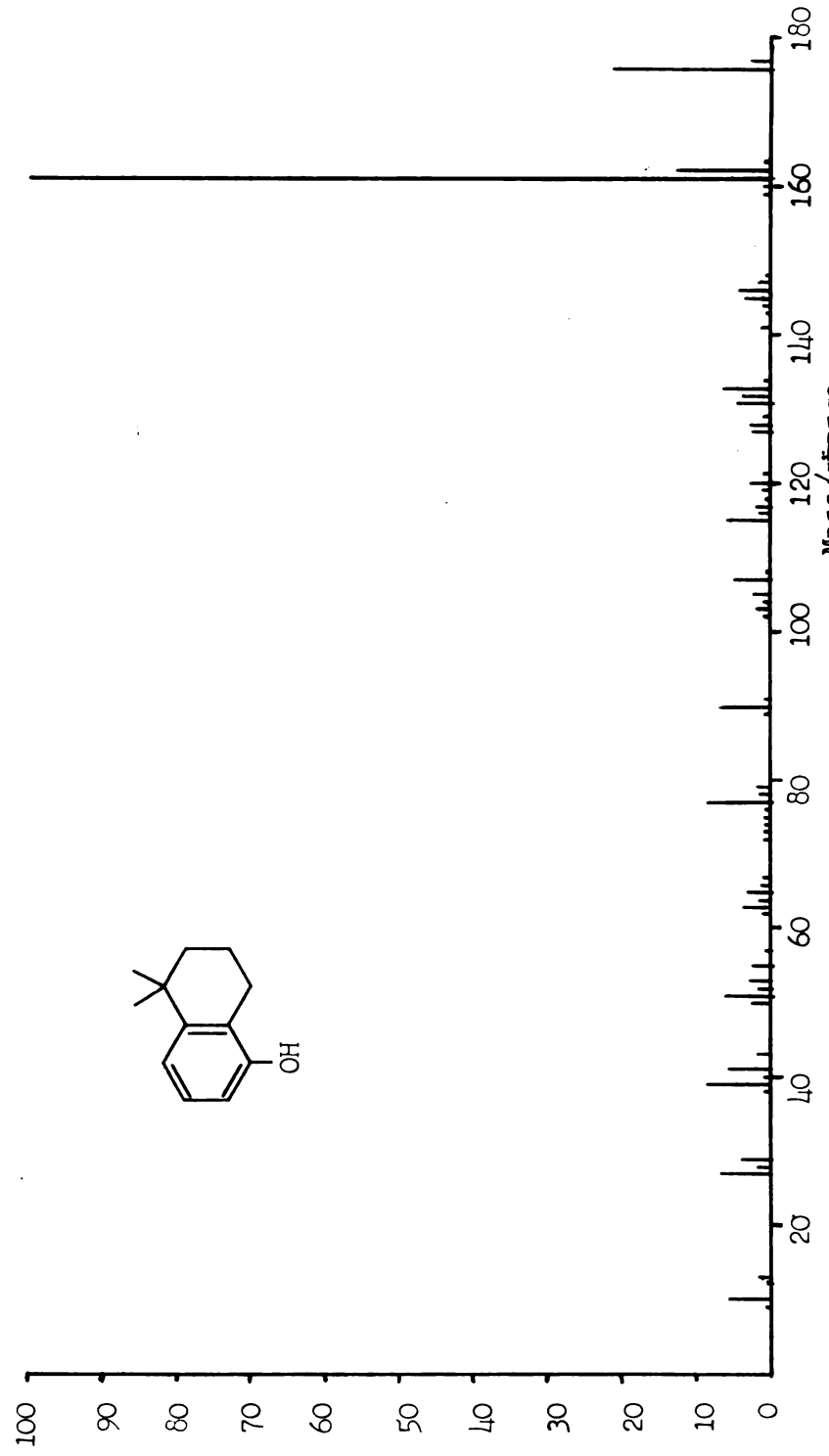


Figure 34. Mass spectrum of 1,1-dimethyl-5-tetralol (XXXVII).

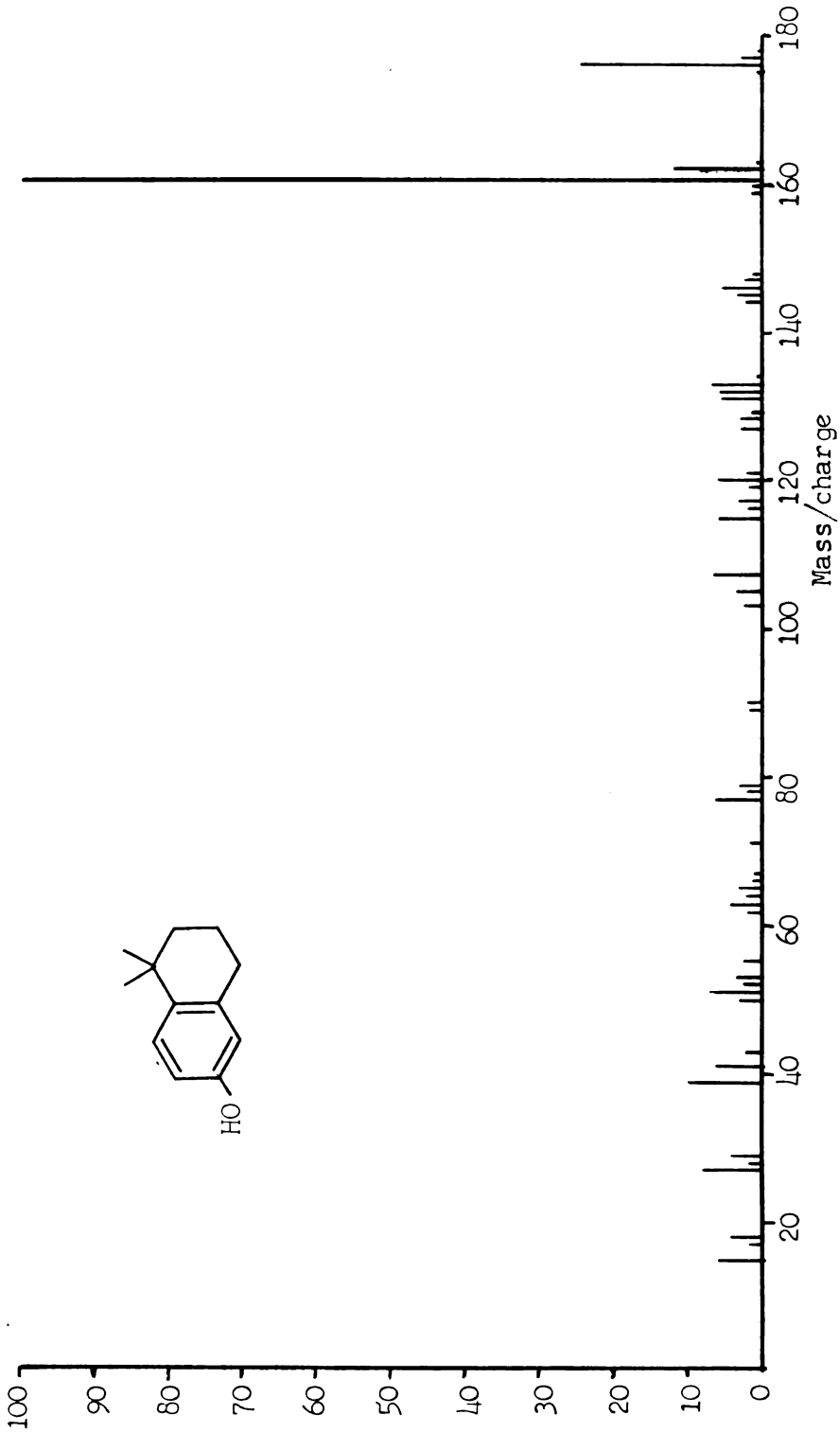


Figure 35. Mass spectrum of 1,1-dimethyl-6-tetralol (XXXVIII).

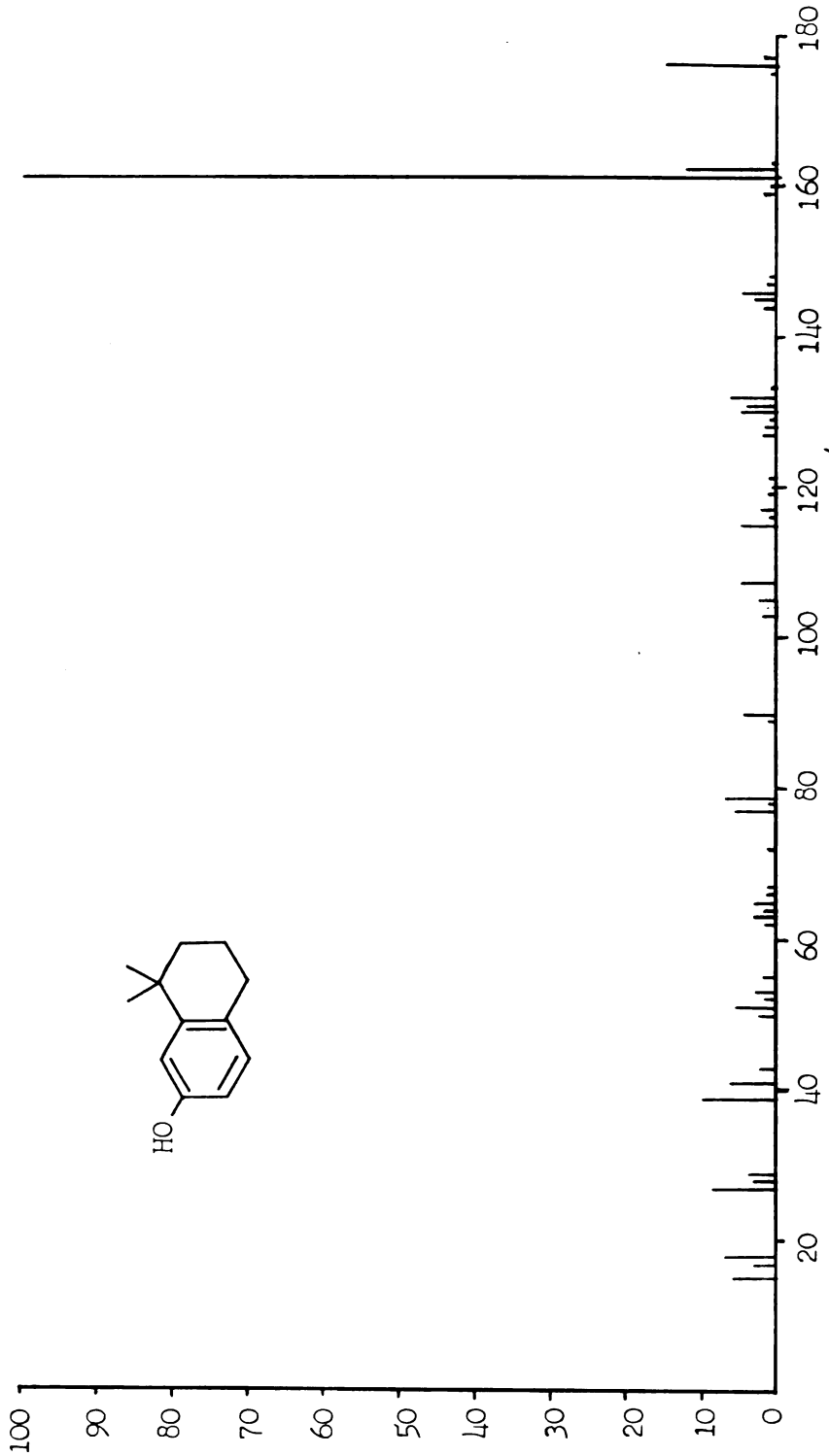


Figure 36. Mass spectrum of 4,4-dimethy1-6-tetra1o1 (XXXIX).

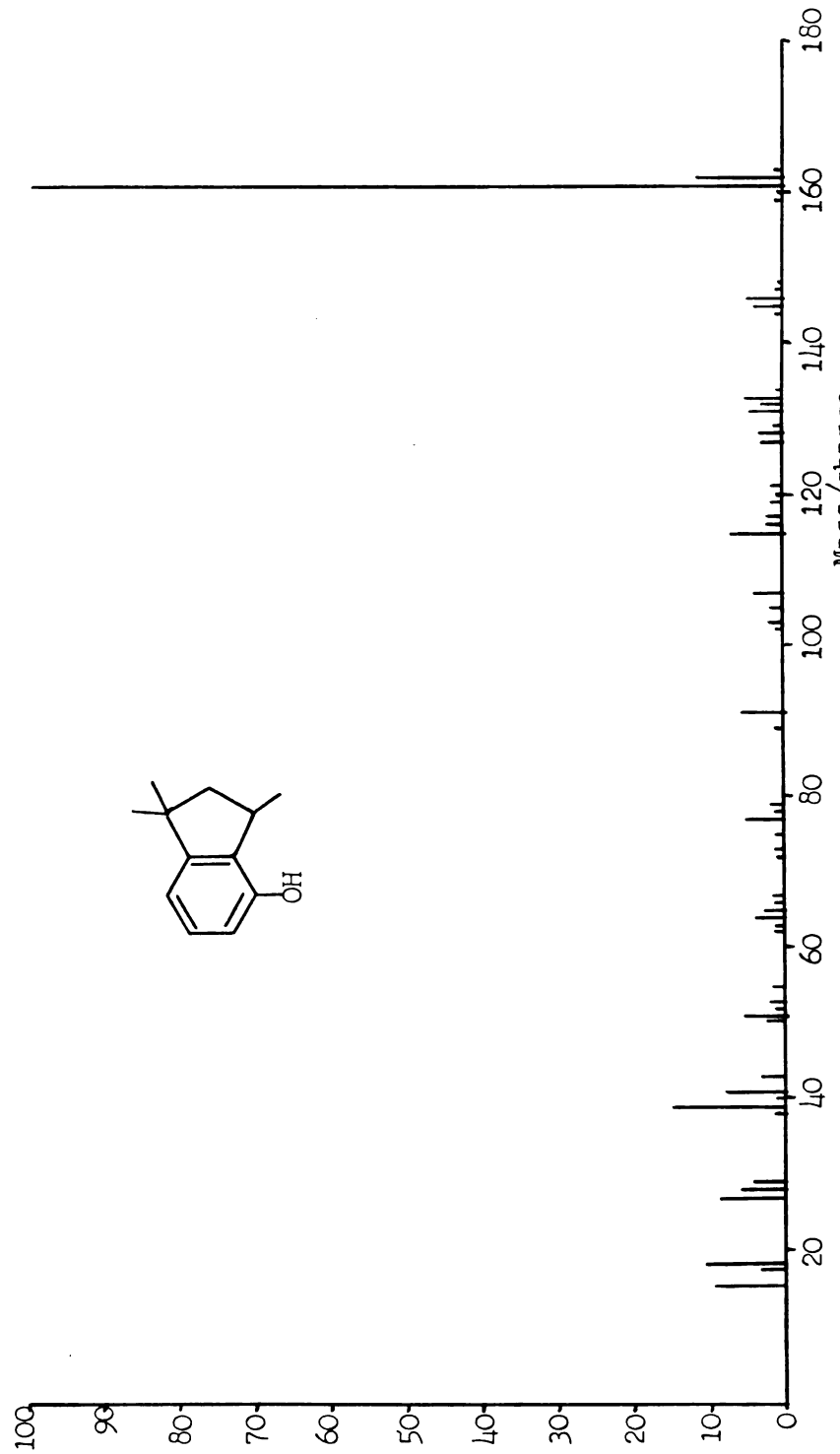


Figure 37. Mass spectrum of 1,1,3-trimethyl-4-indanol (XL).

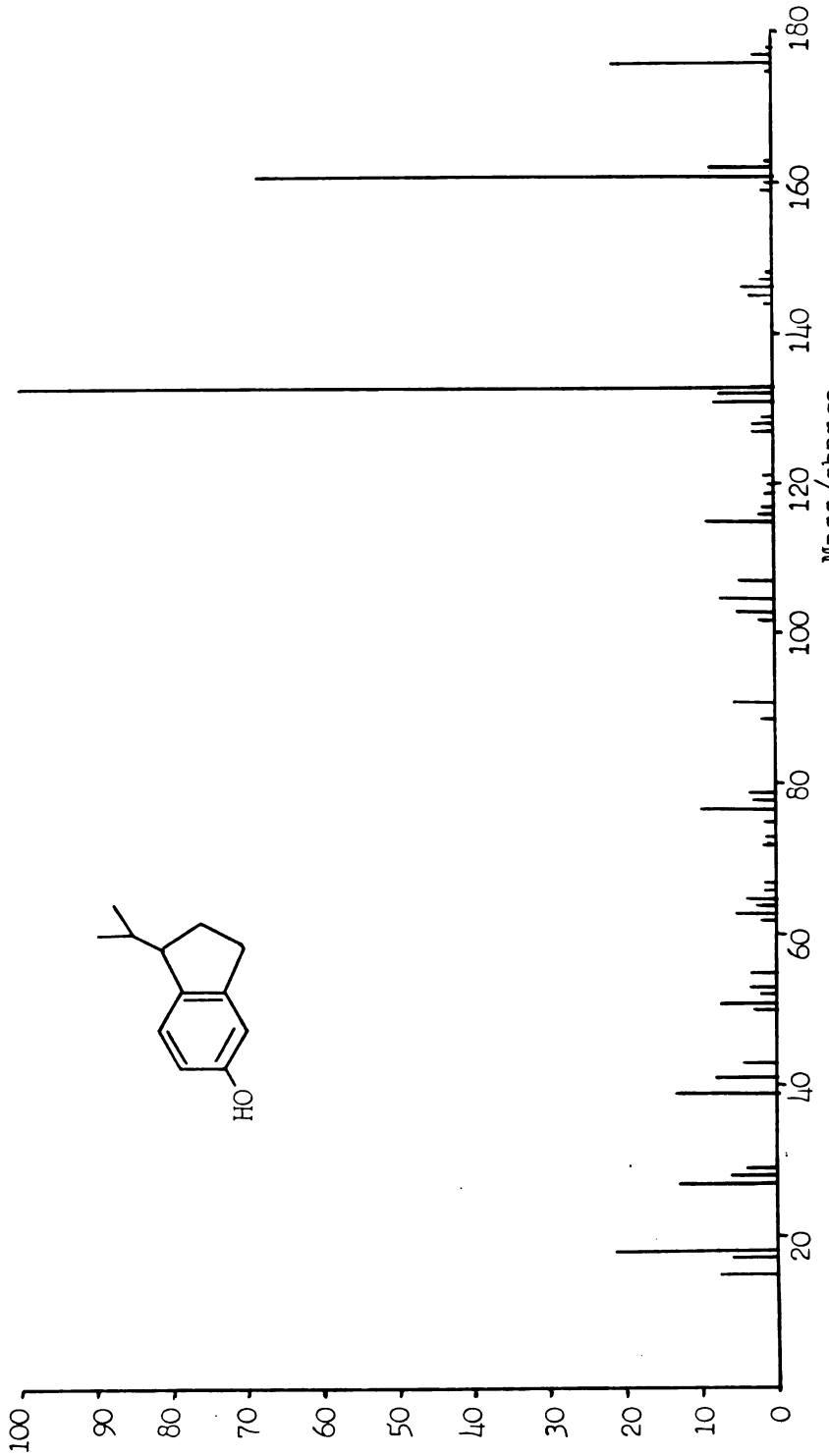
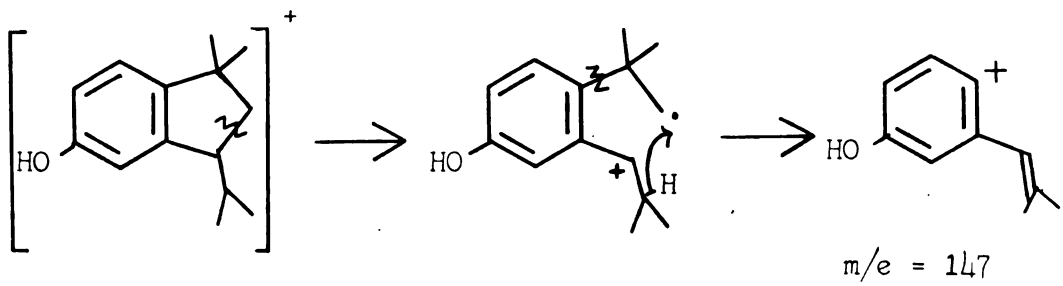


Figure 38. Mass spectrum of 1-isopropyl-5-indanol (XLI)

In all the mass spectra studied, the molecular weight was easily obtained because the parent peak due to the molecular ion generally had an intensity of 10-20% of that of the base peak.

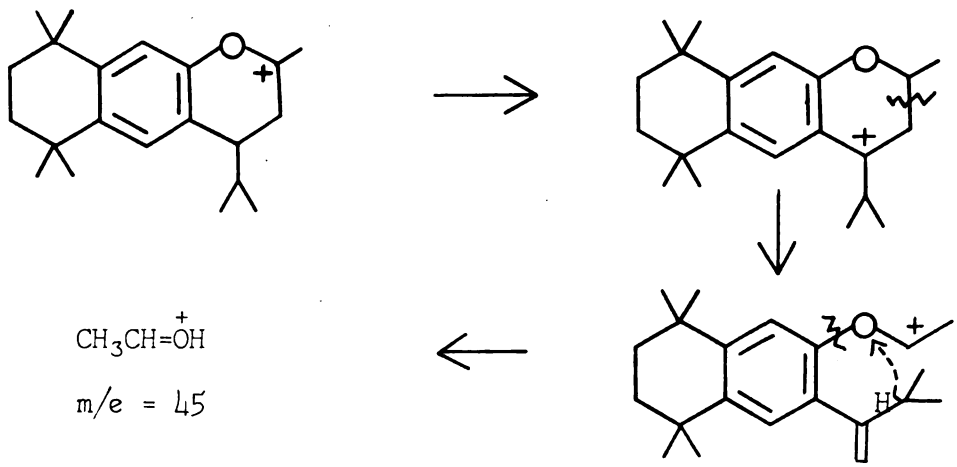
The origin of the base peak, the most intense peak due to the fragmentation of the compound, was important to the interpretation of the spectra studied. In the spectra of model compounds XXXVII-XLI, the base peak was due to the loss of an alkyl group from a carbon alpha to the aromatic ring. This type of fragmentation probably explains the source of the base peaks in compounds XIII-XV, XXIV, and XXVI. Both Biemann (182) and Budzikiewicz, Djerassi, and Williams (19a) cite examples where this type of fragmentation is the source of the base peaks.

The origin of the base peak in the spectra of compounds XVII, XIX, XXVII, and XXVIII is due to a closely related type of fragmentation, which may be considered a three step process. For example, in the case of XVII this fragmentation would result from the breaking of the aliphatic ring bond of the carbon alpha to the aromatic ring, hydrogen atom transfer, and cleavage of t-butyl radical from the aromatic ring.



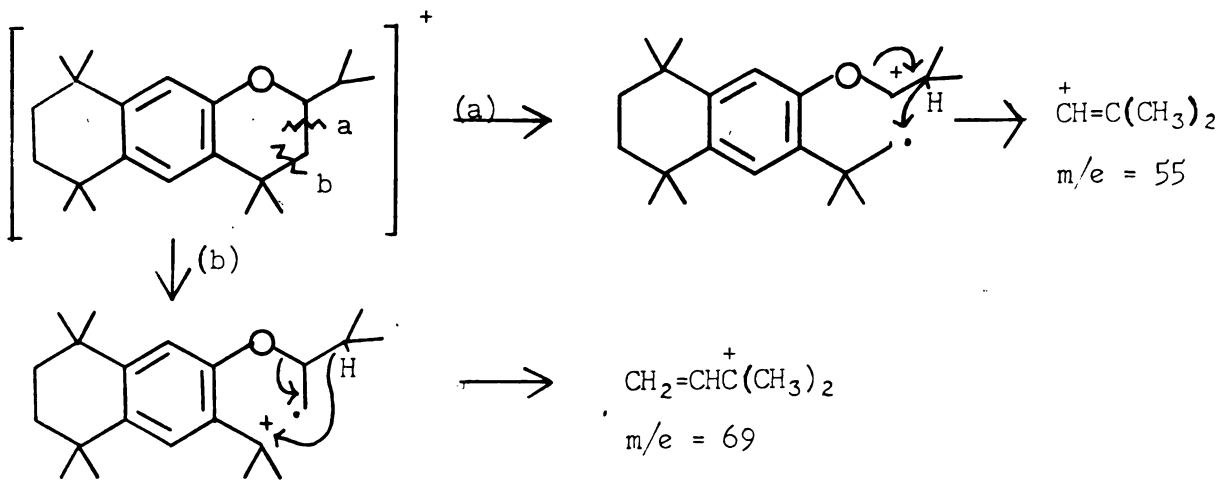
A similar fragmentation pattern would be responsible for the base peaks of XIX, XXVII, and XXVIII. In fact, this type of fragmentation explains the origin of several peaks in the mass spectra shown in this thesis. This type of fragmentation is probably responsible for the peak at m/e 147 in the mass spectrum of XIV.

The base peak in the mass spectrum of XXV is probably due to the loss of an isopropyl group from a carbon attached to oxygen. This type of fragmentation was shown by McLafferty (21) in the mass spectrum of ethyl sec-butyl ether. Several of the peaks observed in this spectrum were due to the loss of alkyl groups from a carbon attached to oxygen. However, the base peak in the mass spectrum of ethyl sec-butyl ether was not due to such a fragment, but rather to a fragment with m/e 45 for which McLafferty (21) gave the formula C_2H_5O. Since the peak at 45 was also the base peak in the mass spectra of methyl n-propyl ether, methyl n-butyl ether, methyl iso-butyl ether, and diisopropyl ether he concluded that this carbonium ion was the result of alpha and beta cleavage with hydrogen rearrangement. In the mass spectrum of XXVI there was a strong peak at 45 (19.2%) which probably also had a similar origin. In the mass



spectrum of XIII there was a peak at m/e 45 (9.0%) which probably had the same origin as the corresponding peak for XXVI.

The peaks at m/e 55 and 69 in the mass spectrum of XXV could possibly have had the following origins:



Certain artifacts which do not have anything to do with the fragmentation pattern of the compound being examined often appear in mass spectra. The causes of these artifacts are usually air, water, and mercury. Peaks due to mercury are found at 204, 202, 201, 200, 199, and 198. Air peaks are found at 40, 32, 28, 16, and 14. Peaks at 18 and 17 are often due to a trace of water in the system. The inclusion of small amounts of these materials which cause such artifacts does not seem to have any detectable effect on the other peaks in the spectra.

The problem of the structure of fraction A may now be discussed in greater detail. In the proof of structure for A it was stated that the low intensity of the M-15 peak (1%) compared to that of the M-43 peak (100%) suggested that an isopropyl group was probably lost

from a carbon alpha to the aromatic ring. Whereas, no direct comparison between the loss of an alkyl group from a carbon alpha to an aromatic ring versus that of the same group being lost from a carbon alpha to oxygen has been presented, there are data on the relative leaving abilities of a methyl versus an isopropyl. In the mass spectrum for fraction B such a case is presented. In this spectrum the M-15 peak has an intensity relative to the base peak of 3.7% whereas the M-43 peak has an intensity of 79%. The intensity ratio of the M-15 peak to the M-43 peak is therefore 1 to 21. However, in the mass spectrum for A this ratio is 1 to 100. In addition to this evidence, the spectra of the model compounds presented and those of similar cases cited from the literature indicated that the loss of an alkyl group from a carbon alpha to an aromatic ring would be favored over the loss of the same group from a carbon alpha to oxygen. Thus, if VII were the correct structure for fraction A, the M-43 and M-15 peaks would be expected to be much closer in intensities than was observed. The facile loss of the C_3H_7 fragment from the molecular ion of A under the conditions of mass spectrometry therefore allows a clear choice between structures VII and VIII.

EXPERIMENTAL

EXPERIMENTAL

Elution chromatography

The columns for elution chromatography were packed with either acid-washed aluminum oxide from Merck and Company or 120-500/μ mesh polycaprolactam from L. Light Company.

Gas chromatography

Gas chromatography was done on either an Aerograph Model 202 or an aerograph Model A-90-P instrument. The columns were either silicone (SE-30) on Chromasorb W, 20% by weight; Apiezon-L on Chromasorb W, 10% by weight; or Carbowax on Firebrick, 20% by weight. All columns had a 1/4 in. external diameter.

Thin-layer chromatography

Plates for thin-layer chromatography were prepared on 1 x 3 in. microscope slides using Aluminum Oxide G from Research Specialties Company. The plates were developed in an iodine chamber.

Infrared spectra

The infrared spectra were obtained on either a Perkin-Elmer Model 21 or a Unicam Model SP200 instrument using carbon tetrachloride solutions in sodium chloride cells.

Ultraviolet spectra

The ultraviolet spectra were obtained on a Beckman DB Spectrophotometer. Extinction coefficients were calulcated assuming Beer's law valid.

Mass spectra

The mass spectra were obtained on a Consolidated Electrodynamics Model 21-103C Mass Spectrometer. The mass spectra were run by Dr. M. E. Russell, H. H. Harris, and J. F. Wettaw. The intensities of all peaks were assigned values relative to that of the most intense peak of the compound's spectrum which was assigned the value of 100.

NMR spectra

The NMR spectra were obtained on a Varian Model A-60 instrument using tetramethylsilane as an internal standard. The band positions were recorded in τ units. The relative peak areas were obtained by electronic integration.

Microanalyses

All microanalytical data were obtained from the Spang Microanalytical Laboratory, Ann Arbor, Michigan.

Melting Points

All melting points are uncorrected.

Part I The Alkylation Reaction

A. Preparation of 2,5-dichloro-2,5-dimethylhexane

The procedure of Bruson and Kroeger (6) was followed. A reaction mixture containing 250 g. (1.71 moles) of 2,5-dimethyl-2,5-hexandiol in 700 ml. of concentrated hydrochloric acid was heated and stirred until all the diol had melted. Hydrogen chloride gas was passed through the solution for 20 minutes. The solid which formed upon cooling was collected on a sintered glass filter. The product was recrystallized from 95% ethanol to give 205 g. (1.11 moles, 65.0%) of white needles melting at 64-66°. Bruson and Kroeger (6) reported a melting point of 63-64°.

B. Non-catalyzed reaction of 2,5-dichloro-2,5-dimethylhexane with phenol

A mixture of 100 g. (0.55 mole) of 2,5-dichloro-2,5-dimethylhexane and 200 g. (2.12 moles) of phenol was heated with stirring at 85-90° for 4 hours. At the end of that period the evolution of hydrogen chloride had ceased. The mixture was dissolved in ether and extracted with a 200-ml. portion of 10% aqueous potassium hydroxide and two 300-ml. portions of Claisen's alkali. The Claisen's alkali was prepared by dissolving 175 g. of potassium hydroxide in 125 ml. of water, cooling, and slowly adding 500 ml. of methanol. The basic extracts were acidified with hydrochloric acid, then neutralized by addition of small portions of solid potassium carbonate. The neutralized extracts were extracted with ether, dried over calcium

chloride, filtered, and concentrated by passing a stream of air over the solution. The amounts of reactants and products recovered from the neutral fraction, the 10% aqueous potassium hydroxide extract, and the two Claisen's alkali extracts were 39.90 g., 20.17 g., 64.61 g., and 51.54 g., respectively. Eight product fractions and phenol were detected by thin-layer chromatography and by injecting ether solutions of the extracts through a gas chromatograph with a 10 ft. 20% silicone column at 180° and 215°. These products were designated in the order of their retention times on the column as fractions A-H. The material balance will be discussed in a later part of this thesis.

C. Sulfuric acid catalyzed reaction of 2,5-dichloro-2,5-dimethylhexane with phenol

A melt containing 26.0 g. (0.14 mole) of 2,5-dichloro-2,5-dimethylhexane and 13.3 g. (0.14 mole) of phenol was added dropwise over a 1-hour period to 100 ml. of a mechanically stirred solution of 79% sulfuric acid at 10°. The reaction mixture was stirred for 22 hours at room temperature followed by 1 hour at 90°. The mixture was poured into ice-water. This was extracted with ether. The ether solution was extracted with a 50-ml. portion of 10% aqueous potassium hydroxide and a 50-ml. portion of Claisen's alkali. The basic extracts were acidified with hydrochloric acid and neutralized by addition of small portions of solid potassium carbonate. The neutralized solutions were extracted with ether, dried over calcium chloride, filtered, and concentrated by passing an air stream over the solution. The amounts of the reactants and products obtained from the neutral, 10% aqueous potassium hydroxide, and Claisen's alkali extracts were

9.12 g., 6.11 g., and 3.47 g., respectively. Six product fractions, phenol, and 2,5-dichloro-2,5-dimethylhexane were detected by thin-layer chromatography and by injecting ether solutions of the above extracts into a gas chromatograph with a 10 ft. 20% silicone column at 180° and 215°. The products had identical retention times to those of fractions A and D-H obtained in the non-catalyzed reaction. The material balance will be discussed in a later part of this thesis.

Part II. Product Isolation

A. Fraction A

Fraction A was found largely in the neutral extract of the non-catalyzed reaction where its estimated amount was 6.8 g. (16.8 %). A smaller amount was found in the second Claisen's alkali extract of the non-catalyzed reaction. Trace amounts of A were found in the remaining extracts of the non-catalyzed reaction and the neutral extract of the sulfuric acid catalyzed reaction.

A 19.81 g. portion of the neutral extract from the non-catalyzed reaction was eluted on a column containing 495 g. of acid-washed alumina using petroleum ether, benzene, ether, 95% ethanol, and methanol as eluents. Fractions A and E-H were left after concentration of the petroleum ether fractions. Fraction A tended to stay on the column slightly longer than the other four fractions. The seventh and eighth 100-ml. fractions containing 92% and 97% of A, respectively, were dissolved in ether and several 50-100 µl. portions of this solution were injected into a gas chromatograph with a 10 ft.

20% silicone column at 210° and a helium flow rate of 120 ml. per minute. Pure A was collected at 4.5 minutes after injection. Sufficient material was collected to run a neat NMR spectrum.

Anal. Calc'd. for $C_{14}H_{20}O$: C, 82.30; H, 9.86.

Found: C, 82.32; H, 9.87.

The infrared, ultraviolet, mass, and NMR spectra of A are shown on pages 12-15.

B. Fraction B

Fraction B was detected by gas chromatography in all extracts of the non-catalyzed reaction. Its retention time on all columns used was very close to the retention times of fractions C and D which were always found in the extracts containing B. Fraction B comprised approximately 3.7 g. (5.7%) of the first and 0.8 g. (1.5%) of the second Claisen's alkali extract of this reaction. The remaining two extracts from the non-catalyzed reaction had only trace amounts of B. There was no B detected among the products of the sulfuric acid catalyzed reaction.

A 28.75 g. portion of the first Claisen's alkali extract from the non-catalyzed reaction was distilled through a spinning band column. From this distillation the following fractions were obtained: 12.05 g. of phenol at 45-65°/4.5 mm., 0.5 ml. of fraction B at 65-80°/0.75 mm., and 15.20 g. of residue. This fraction of B contained some phenol. The fraction was poured onto a watch glass which glass which was placed in a vacuum desiccator. The pressure in this desiccator was maintained at 0.1 mm. for 3 hours. The sample

of B now contained trace amounts of phenol and fraction A and it contained 15.5% of fraction C. The relative amounts of impurities were determined by injecting an ether solution of this sample of B into a gas chromatograph with a 20 ft. 20% silicone column at 215°.

The infrared, ultraviolet, mass, and NMR spectra of this sample of B are shown on pages 21-24.

C. Fraction C

Fraction C was detected by gas chromatography in all of the extracts from the non-catalyzed reaction. It comprised approximately 4.7 g. (7.3%) of the first and 15.8 g. (36.6%) of the second Claisen's alkali extracts and about 26 g. (67.7%) of the neutral extract from this reaction. A trace of C was found in the aqueous potassium hydroxide extract of the non-catalyzed reaction. No C was detected in any of the extracts from the sulfuric acid catalyzed reaction.

A 19.81 g. portion of the neutral extract from the non-catalyzed reaction was eluted on a column containing 495 g. of acid-washed alumina using petroleum ether, benzene, ether, 95% ethanol, and methanol as eluents. Fraction C was recovered from the ether and 95% ethanol fractions. A 3.00-g. fraction recovered from ether was found to be more than 99% pure by injecting an ether solution of part of this fraction into a gas chromatograph with a 20 ft. 20% silicone column at 215°. A portion of this fraction was recrystallized from petroleum ether yielding 0.77 g. of white needles melting at 134-135°.

Anal. Calc'd. for $C_{14}H_{20}O$: C, 82.30; H, 9.86.

Found: C, 82.48; H, 9.83.

The infrared, ultraviolet, mass, and NMR spectra of C are shown on pages 27-30.

D. Fraction D

Fraction D was detected in all of the extracts from both the non-catalyzed and sulfuric acid catalyzed reactions. The Claisen's alkali extract of the sulfuric acid catalyzed reaction was more than 99% pure D.

The Claisen's alkali extract from the sulfuric acid catalyzed reaction was recrystallized from ethanol-water yielding white crystals of D melting at 142-143°.

The infrared, ultraviolet, mass, and NMR spectra of D are shown on pages 32-35.

E. Fractions E-H

Fractions E-H were found chiefly in the neutral extracts of both the non-catalyzed and sulfuric acid catalyzed reactions. Trace amounts of these compounds were also present in the second Claisen's alkali extract of the non-catalyzed reaction.

A 19.81 g. portion of the neutral extract from the non-catalyzed reaction was eluted on a column containing 495 g. of acid-washed alumina using petroleum ether, benzene, ether, 95% ethanol, and methanol as eluents. The fifth 100-ml. fraction recovered from petroleum ether weighed 1.50 g. and was shown by gas chromatography to contain a mixture of E-H only. This fraction was redissolved in a small amount of pentane and 100-µl. portions of this solution were injected into a gas chromatograph with a 20 ft. 20% silicone column at 215° with a helium flow rate of 85 ml. per minute. Small amounts of E melting at 86-88° and H subliming at 215° were collected from

these injections. The peaks corresponding to fractions F and G overlapped considerably making it impossible to isolate either of these fractions by this method.

A 1.46 g. portion of the neutral extract from the sulfuric acid catalyzed reaction was eluted on a column containing acid-washed alumina using petroleum ether, cyclohexane, benzene, ether, and 95% ethanol as eluents. The material recovered from the first 50-ml. petroleum ether fraction, weighing 0.14 g., contained fraction G melting at 109-112°. The material recovered from the first 50-ml. cyclohexane fraction, weighing 0.02 g., contained fraction F melting at 101-105°. A check on the purity of these fractions by gas chromatography showed that the sample of F contained about 8% G. The sample of G was greater than 99% pure.

Part III. Estimated Yields of Products A through H in the Non-catalyzed and Sulfuric Acid Catalyzed Reactions

The yields of products A-H were estimated using several techniques. Products B-D and phenol were separated from the other products and 2,5-dichloro-2,5-dimethylhexane by elution chromatography on acid-washed alumina. The weight of phenol in the first Claisen's alkali extract of the non-catalyzed reaction was obtained by weighing the amount of phenol recovered by distilling this extract through a spinning band column. Ether solutions of the extracts and fractions obtained by elution chromatography were injected into a gas chromatograph. The relative areas under the peaks on the chromatograms obtained from these injections were determined either by electronic integration

or by using a planimeter. Whenever there was incomplete separation of the peaks on these chromatograms the relative areas were estimated by comparing the heights of the peaks. The amount of polymer was estimated from the discrepancy between the amount of phenol recovered from distilling the first Claisen's alkali extract of the non-catalyzed reaction through the spinning band column and the amount of phenol estimated by gas chromatography.

Products A-H were assigned a letter corresponding to the order of their retention time on gas chromatography columns. The column and conditions which gave maximum separation was the 20 ft., 1/4 in. diameter, 20% silicone column at 215° and a helium flow rate of 85 ml. per minute. The retention times of the various fractions under these conditions were: solvents and 2,5-dichloro-2,5-dimethylhexane at 2 minutes, phenol at 3.7 minutes, A at 6.3 minutes, B at 38 minutes, C at 41.3 minutes, D at 44.3 minutes, E at 58.3 minutes, F at 69.3 minutes, G at 76.7 minutes, and H at 91 minutes. The peaks for fractions B, C, and D overlapped. The peaks for F and G likewise overlapped slightly. The polymer did not come off as a peak, but temporarily altered the base line of the gas chromatogram.

The amounts of the reactants used for both reactions are given in Table 4.

The estimated amounts of reactants recovered and products obtained for both reactions are listed in Table 5. In the non-catalyzed reaction 88% of the 2,5-dichloro-2,5-dimethylhexane was accounted for by these products. Phenol was used in large excess in that reaction. The amounts of products and reactants isolated in the sulfuric acid

Table 4. Amounts of reactants

Compound	Non-catalyzed	Sulfuric Acid Catalyzed
Phenol	2.12 moles	0.14 mole
Bis chloride	0.55 mole	0.14 mole

Table 5. Estimated amounts of reactants recovered and products obtained

Fraction	Non-catalyzed	Sulfuric Acid Catalyzed
Phenol	830 mmoles (39%)	59 mmoles (42%)
Bis chloride	none	14 mmoles (10%)
A	36 mmoles (6.5%)	trace amount
B	23 mmoles (4.2%)	none
C	224 mmoles (40.7%)	none
D	28 mmoles (5.1%)	46 mmoles (33%)
E	7.3 mmoles (2.7%)	0.21 mmole (0.30%)
F	5.4 mmoles (2.0%)	0.93 mmole (1.34%)
G	8.0 mmoles (2.9%)	2.8 mmoles (4.0%)
H	2.5 mmoles (0.9%)	0.19 mmole (0.28%)
Polymer	23 %*	none

*Based on a monomer unit weight of 204.

catalyzed reaction accounted for 49% of the 2,5-dichloro-2,5-dimethylhexane and 78% of the phenol. Phenol was lost during the extractions because of its great solubility in water. The bis chloride was lost because of its high volatility. The bis chloride had a strong sweet odor at room temperature. When heated to a melt a noticeable amount collected on the sides of the container. A considerable amount of the unreacted bis chloride was lost by evaporation during the concentration of the neutral extract from the sulfuric acid catalyzed reaction. Besides being volatile itself, the bis chloride could decompose into a gaseous alkene and hydrogen chloride when heated. The bis chloride also could hydrolyze to a glycol in the aqueous sulfuric acid solution and this glycol would remain in the aqueous layer during an extraction.

Slight alterations in experimental procedure for both reactions, especially the sulfuric acid catalyzed reaction might give a much better material balance.

SUMMARY

SUMMARY

The non-catalyzed aklylation of phenol with 2,5-dichloro-2,5-dimethylhexane yielded eight fractions, designated A-H. The sulfuric acid catalyzed reaction between the same two compounds yielded six fractions which had identical retention times on the gas chromatograph to those of fractions A and D-H. Samples of each of these fractions were isolated by using one or more separation methods and structures were assigned to the compounds in the several fractions. Fraction A was assigned the structure of 2,2-dimethyl-4-isopropyl-chroman. The two compounds in fraction B were assigned the structures of 1,1-dimethyl-3-isopropyl-5-indanol and 3,3-dimethyl-1-isopropyl-4-indanol. Fractions C and D were assigned the structures of 1,1,4,4-tetramethyl-5-tetralol and 1,1,4,4-tetramethyl-6-tetralol, respectively. Fraction E was assigned the structure of 4,4,6,6-tetramethyl-2,8-diisopropyl-3,4-dihydroindano[5,6-b]pyran. Fractions F and G were assigned the structures of 2,2,6,6,9,9-hexamethyl-4-isopropyl-3,4,6,7,8,9-hexahydronaphtho[2,3-b]pyran and 4,4,6,6,9,9-hexamethyl-2-isopropyl-3,4,6,7,8,9-hexahydronaphtho[2,3-b]pyran, respectively. The two compounds in H were assigned the structures of 1,1,4,4,5,5,8,8-octamethyl-1,2,3,4,5,6,7,8-octahydro-9-anthrol and 1,1,4,4,5,5,8,8-octamethyl-1,2,3,4,5,6,7,8-octahydro-9-phenanthrol. The main compound isolated from the sulfuric acid catalyzed reaction was not 1,1-dimethyl-3-isopropyl-5-indanol as postulated by Bruson and Kroeger (6), but was 1,1,4,4-tetramethyl-6-tetralol. In fact,

none of the compounds which they had postulated for the main product was even detected in the reaction mixture.

The mechanisms of both reactions were postulated to involve the attack of the tertiary carbonium ion from the bis chloride on either the oxygen or the ortho or para positions of the phenol. A second ionization, followed either by attack on the aromatic ring forming a six-membered ring, or by rearrangement to a secondary carbonium ion which then attacked the aromatic ring to form a five-membered ring (in the case of an indanol) or a six-membered ring (in the case of a chroman). This sequence of events was followed in the formation of compounds having the formula $C_{14}H_{20}O$ in fractions A-D. The remainder of the compounds produced had the formula $C_{22}H_{34}O$ and had a mechanism of formation due to two successive cyclialkylations of phenol by the bis chloride.

Mass spectrometry was a useful tool in the elucidation of the several structures. In most cases it totally supported the evidence obtained from the other spectra. In those cases where there were apparent contradictions, the sources of the major peaks on the mass spectra could be explained from the designated structures in a straightforward manner.

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LITERATURE CITED

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