THE ACETYLATION OF NORTRICYCLENE
SOME CHEMISTRY OF
1-SUBSTITUTED NORTRICYCLENES

By

Robert A. Martin

A THESIS

Submitted to the School of Advanced Graduate Studies
of Michigan State University of Agriculture and
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* * *

To Jan, My Wife, for Her Patience
and Understanding

VITA

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AN ABSTRACT

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ABSTRACT

The acylation of cyclopropane and certain substituted cyclopropanes led to an unusual rearrangement, giving predominantly β-chloroketones and their related α,β-unsaturated ketones rather than the anticipated γ-chloroketones. The rearranged β-chloroketones are formally produced by migration of a hydrogen from the carbon of the cyclopropane ring to which the acyl group becomes attached to one of the two remaining ring carbons, the chlorine becoming bound to the third.

Because both planes of the three-membered ring might be necessary for the rearrangement which accompanies acylation reaction, it was deemed desirable to acylate a cyclopropane ring, one side of which was blocked by a cage.

Nortricyclene seemed well suited to this purpose and was subsequently shown to react with a 1:1 complex of acetyl chloride-aluminum chloride to give 69% of 2-chloro-6-acetylnorbornane. No other chloroketone was detected. Dehydrohalogenation of 2-chloro-6-acetylnorbornane afforded a 40-50% yield of 1-acetylnortricyclene and thus provided a rather convenient synthetic route to several previously inaccessible 1-substituted nortricyclenes. The structure of 1-acetylnortricyclene was proved by conversion to the known 1-methylnortricyclene.

Several 1-substituted nortricyclenes were prepared and their infrared and near-infrared spectra studied for possible correlations. All of the 1-substituted nortricyclenes examined absorbed in the 11.7

and 12.7 µ regions. The band at 12.75 ± 0.06 µ was found to be particularly characteristic for nortricyclenes substituted only on the cyclopropane ring. The near-infrared spectra contained bands at 1.669 ± 0.007 µ and 1.149 ± 0.003 µ characteristic of the nortricyclene system.

The hydrochloride of 1-aminonortricyclene reacted with sodium nitrite in glacial acetic acid to give only 1-acetoxynortricyclene, obtained in 55% yield. The structure of this acetate was proved by degradation to norcamphor 2,4-dinitrophenylhydrazone and comparison of its melting point and mixed melting point with an authentic sample. Authentic 1-acetoxynortricyclene was synthesized by a Baeyer-Villiger reaction of 1-acetylnortricyclene and its infrared and near-infrared spectra shown to be identical with the acetate obtained from the nitrous acid reaction.

The reaction of nitrous acid with the hydrochloride of 1-aminomethylnortricyclene in glacial acetic acid gave a mixture of acetates obtained in 52% yield. The mixture was subsequently characterized by preparative and infrared techniques as being composed of 91-92% 1-nortricyclylcarbinyl acetate (the unrearranged acetate), about 5% of an acetate with an exocyclic methylene group (probably 6-acetoxynorcamphene), and less than 5% of an unknown unsaturated acetate with infrared bands at 6.10 and 8.90 µ.

The mechanisms of the acylation and of the amine-nitrous acid reactions are discussed.

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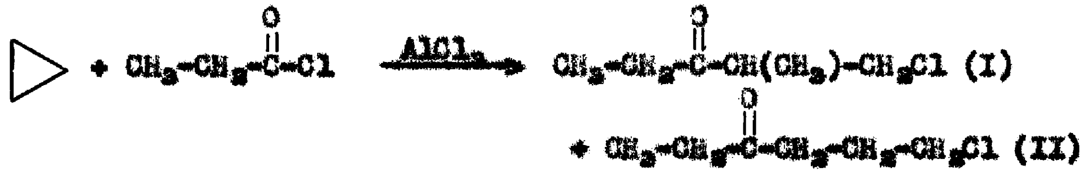
INTRODUCTION

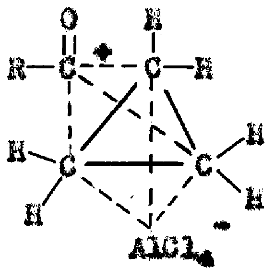
The acylation of cyclopropane (1,2) and certain substituted cyclopropanes (3,4) led to an unusual rearrangement, giving predominantly β-chloroketones and their related α,β-unsaturated ketones rather than the anticipated -chloroketones. Thus, when Hart and Curtis (1,2) treated a chloroform solution of the 1:1 complex of propionyl chloride and aluminum chloride with cyclopropane, they obtained 1-chloro-2-methyl-3-pentanone (I) and 6-chloro-3-hexanone (II) in a 2:1 ratio.



$$\triangleright + CH_3-CH_2-\overset{O}{\overset{\|}{C}}-Cl \xrightarrow{AlCl_3} CH_3-CH_2-\overset{O}{\overset{\|}{C}}-CH(CH_3)-CH_2Cl \ (I) + CH_3-CH_2-\overset{O}{\overset{\|}{C}}-CH_2-CH_2-CH_2Cl \ (II)$$

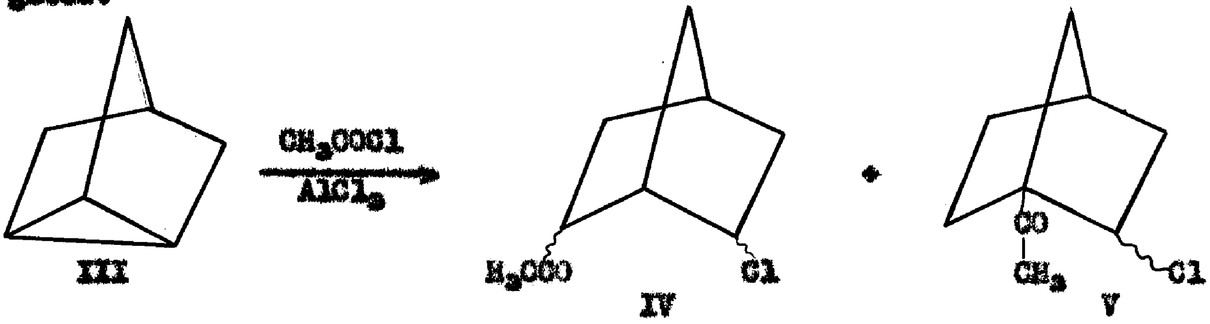
The rearranged product, I, is formally produced by migration of a hydrogen from the carbon of the cyclopropane ring to which the acyl group becomes attached to one of the two remaining ring carbons, the chlorine becoming bound to the third.

Because both planes of the three-membered ring might be necessary for this rearrangement of bonds, perhaps in a "sandwich-type aggregate" consisting of a cyclopropane ring between the ions of the acyl chloride-aluminum chloride complex (4),



it seemed desirable to acylate a cyclopropane ring, one side of which was blocked by a cage.

Nortricyclene (III) is well suited to this purpose, and in addition, its acylation might give some insight into the stereochemistry of additions to three-membered rings, a problem which had not been investigated.



Thus, if acetylation of nortricyclene (III) proceeded as in the acylation of other cyclopropanes, normal addition would give 2-chloro-6-acetylnorbornanes (IV), and rearrangement would be expected to give 1-acetyl-2-chloronorbornanes (V).

This thesis describes the acetylation of nortricyclene and the characterization of the reaction product. It happened that the acetylation led to the previously unknown 1-acetylnortricyclene, thus providing a rather convenient starting material for the preparation of several previously inaccessible 1-substituted nortricyclenes, among them the hydrochlorides of 1-amino and 1-aminomethylnortricyclene. Correlation of the infrared and near-infrared spectra of these 1-substituted nortricyclenes and the reactions of 1-amino and 1-aminomethylnortricyclene with nitrous acid comprise a significant portion of this thesis.

EXPERIMENTAL

I. Acetylation Experiments

A. 3-Bromonortricyclene

The procedure of Roberts, Trumbell, Bennett, and Armstrong was followed (5).

In a one-liter flask, equipped with "Trubore" stirrer and an efficient condenser was placed 50.0 g. (0.53 mole) of norbornene, 95.0 g. (0.53 mole) of N-bromosuccinimide, 1.0 g. of benzoyl peroxide, and 250 ml. of carbon tetrachloride. The mixture was refluxed, stirred, and irradiated with a "GE Sunlamp," 275 W., for approximately one hour, after which time a vigorous reaction commenced and the mixture quickly darkened. It was refluxed, stirred, and irradiated for a total of four hours, cooled, and filtered. The residue remaining after removal of the carbon tetrachloride was distilled (no column, Claisen head) to give 33.0 g. (40.0%) of 3-bromonortricyclene, b.p. 67-68° (16 mm.), n_D^{25} 1.5275.

B. Nortricyclene (5)

In a 500-ml., three-necked flask, equipped with "Trubore" stirrer, bulb condenser, addition funnel, and under an atmosphere of dry nitrogen, was placed 6.0 g. (0.25 mole) of magnesium turnings, and 100 ml. of anhydrous ether. A solution of 30.0 g. (0.17 mole) of 3-bromonortricyclene and 6.5 g. (0.06 mole) of ethyl bromide in 100 ml. anhydrous ether was added over 45 minutes, and the mixture refluxed for two hours after completion of the addition. It was then cooled, hydrolyzed with an excess of 3 N hydrochloric acid and allowed to stand overnight. The layers were separated, the ether layer washed with two 50 ml. portions of water, and dried over anhydrous magnesium sulfate. After removal of the ether, using a glass-helices packed column, distillation of the remaining residue gave 10.4 g. (65%) of nortricyclene, b.p. 99-100° (atm.).

C. Acetylation of Nortricyclene

To 100 ml. of methylene chloride contained in a 500-ml., three-necked flask, equipped with "Trubore" stirrer, addition funnel, and parallel adapter fitted with thermometer and calcium chloride drying tube, was added 40.2 g. (0.30 mole) of anhydrous aluminum chloride. The flask was cooled to 5°, and 31.4 g. (0.40 mole) of acetyl chloride in 50 ml. of methylene chloride added over 1.5 hours. The mixture was allowed to stir overnight, or until a clear yellow solution was obtained. To this solution, maintained at 5°, was added 23.5 g. (0.25 mole) of nortricyclene (4) in 70 ml. of methylene chloride (1.5 hours). The solution was stirred for 15 minutes at 5° after addition was complete, and for 1.25 hours while warming to room temperature. The reaction mixture was cooled to 0° and hydrolyzed by dropwise addition of 200 ml. of 20% hydrochloric acid. The layers were separated, and the water layer extracted with two 50-ml. portions of methylene chloride. The combined organic layers were then successively washed twice with

50 ml. of water, twice with 50 ml. of sodium bicarbonate, once with 50 ml. of water and dried over anhydrous sodium sulfate. Alternate procedures were then followed, depending upon whether 2-chloro-6-acetylnorbornane or 1-acetylnortricyclene was the desired product.

1. 2-Chloro-6-acetylnorbornane

The methylene chloride was removed *in vacuo* at room temperature or below, and the residue distilled (no column) under reduced pressure to yield 30.1 g. (69.6%) of 2-chloro-6-acetylnorbornane, b.p. 76-80° (0.8 mm.), n_D^{25} 1.4963, infrared carbonyl band at 5.85 μ with a shoulder at 5.95 μ. In addition to 2-chloro-6-acetylnorbornane, a residue of about 7 g., which boiled above 125° (0.8 mm.), was obtained. Its structure was not investigated.

Anal. Calc'd for $C_9H_{13}OCl$: Cl, 20.6.
Found: Cl, 18.9.

a. *Preparation of 2-Chloro-6-(1-hydroxyethyl)norbornane*

To a slurry of 3.7 g. (0.10 mole) of lithium aluminum hydride in 250 ml. of anhydrous ether, in a one-liter, three-necked flask, equipped with "Trubore" stirrer, condenser, and addition funnel ($CaCl_2$ tubes), there was added over 2 hours, a solution of 26.0 g. (0.15 mole) of crude 2-chloro-6-acetylnorbornane, as obtained from the acetylation of nortricyclene, in 250 ml. of anhydrous ether. After one hour of reflux, the mixture was cooled in an ice bath and hydrolysed with H_2O and dilute hydrochloric acid. "Celite" was added, the mixture stirred vigorously, filtered, and ether extracts of the "celite"-hydroxide residue combined with the organic layer and dried over anhydrous sodium sulfate. The ether was distilled, and the residual oil fractionated to give two main products, 6.8 g. (26%) of 1-(1-hydroxyethyl)nortricyclene, b.p. 55-57° (0.9 mm.), n_D^{25} 1.4858-1.4864 and 13.8 g. (53%) of 2-chloro-6-(1-hydroxyethyl)norbornane, b.p. 72-77° (0.4 mm.) n_D^{25} 1.5006-1.5040. The latter showed characteristic hydroxyl absorption (2.75 and 2.95 μ), and did not have the characteristic nortricyclene bands at 11.7 and 12.7 μ. An analytical sample (b.p. 101° at 1.8 mm., n_D^{25} 1.5047) gave the following data:

Anal. Calc'd for $C_9H_{15}OCl$: C, 61.88; H, 8.66; Cl, 20.30.

Found: C, 62.00; H, 8.63; Cl, 20.35.

b. *Attempted Dehydrohalogenation of 2-Chloro-6-(1-hydroxyethyl)-norbornane*

Several attempts to convert this chlorohydrin to a tetrahydrofuran with powdered potassium hydroxide in ether at room temperature, and the following attempt in refluxing ether were unsuccessful.

In a 300-ml., three-necked flask, equipped with "Trubore" stirrer, condenser, and Erlenmeyer flask arranged for addition of a solid (13), was placed a solution of 7.5 g. (0.04 mole) of chlorohydrin in 100 ml. of anhydrous ether. Powdered potassium hydroxide, 22.4 g. (0.4 mole), was then added over 30 minutes, and the mixture refluxed and vigorously stirred for 4.5 additional hours. The mixture was filtered, ether distilled, and the residue fractionated. Infrared examination of the distillates showed only 2.0 g. (0.015 mole) of 1-(1-hydroxyethyl)-nortricyclene (b.p. 55-57° at 0.9 mm.) and 2.5 g. (0.014 mole) of recovered chlorohydrin (b.p. 72-77° at 4 mm.), accounting for 68% of the starting chlorohydrin.

2. 1-Acetylnortricyclene

a. Dehydrohalogenation of 2-Chloro-6-acetylnorbornane with Base

After removal of the methylene chloride from the acetylation of nortricyclene reaction mixture *in vacuo*, the residue was added (30 minutes) to a refluxing solution of 60.0 g. sodium carbonate monohydrate in 300 ml. of water contained in a 500-ml., three-necked flask, equipped with stirrer, reflux condenser, and addition funnel. The mixture was stirred and refluxed for 15 minutes after completion of addition, cooled, layers separated, and the water layer extracted with two 50-ml. portions of ether. The combined organic layers were dried over anhydrous sodium sulfate. After removal of the ether (distillation), the residue was distilled under reduced pressure to yield 13.5-17.0 g. (40-50%) of 1-acetylnortricyclene, b.p. 50-52° (2 mm.) n_D^{25} 1.4926, carbonyl band at 5.95 µ.

Anal. Calc'd for $C_9H_{12}O$: C, 79.37; H, 8.89.
Found: C, 79.26; H, 8.92.

b. Thermal Dehydrohalogenation of 2-Chloro-6-acetylnorbornane

After distillation of the methylene chloride from the acetylation reaction mixture at atmospheric pressure, the residue was destructively distilled at 14 mm. using a water aspirator. Distillate collected between 85-95° was refractionated through a 1 by 30 cm. glass-helices packed column giving 13.5 g. (40%) of 1-acetylnortricyclene, b.p. 50-52° (2 mm.) n_D^{25} 1.4926.

Two derivatives, the 2,4-dinitrophenylhydrazone and oxime, of 1-acetylnortricyclene were prepared. The 2,4-dinitrophenylhydrazone, obtained as red plates from 95% ethanol containing a little ethyl acetate, was converted by recrystallization from carbon disulfide or isooctane to orange needles. Both crystalline forms melted at 169.5-171° and showed $\lambda_{max.}$ in 95% ethanol at 378 mμ (log ϵ, 4.36), 260 mμ (log ϵ, 4.00), 2.38 mμ (log ϵ, 4.15). Their infrared spectra (chloroform solvent) were identical.

Anal. Calc'd for $C_{15}H_{16}N_4O_4$: C, 56.95; H, 5.11; N, 17.71.

Found (red): C, 56.91; H, 4.96; N, 17.84.

(orange): C, 56.80; H, 5.15; N, 17.61.

The oxime, white plates from 95% ethanol, melted at 122.5-123.5°.

Anal. Calc'd for $C_9H_{13}NO$: C, 71.48; H, 8.67; N, 9.26.

Found: C, 71.47; H, 8.65; N, 9.20.

D. Acetylation of Norbornene

Into a 500-ml., three-necked flask, equipped as for the acetylation of nortricyclene, was placed 53.4 g. (0.40 mole) of anhydrous aluminum chloride and 120 ml. of methylene chloride. A solution of 31.4 g. (0.40 mole) of acetyl chloride in 60 ml. of methylene chloride was added over 1.5 hours, keeping the temperature below 10°. The mixture was allowed to stir overnight, or until a clear yellow solution was obtained. To this solution, cooled in ice, was added a solution of 35.3 g. (0.375 mole) of norbornene (previously distilled from sodium) in 80 ml. of methylene chloride, at such a rate as to maintain the temperature below 10° (about 1.5 hours). The solution was stirred for 15 minutes, the ice bath removed, and stirring continued for 1.25 hours. The reaction mixture was hydrolyzed by pouring it slowly, with stirring, onto a mixture of ice and 75 ml. of concentrated hydrochloric acid. The layers were separated, and the water layer washed with two 50-ml. portions of methylene chloride. The combined methylene chloride layers were then washed successively with three 50-ml. portions of water, two 50-ml. portions of 10% sodium carbonate solution, one 50-ml. portion of water, and dried over anhydrous sodium sulfate. The residue remaining after distillation of the methylene chloride was fractionated to give 26.0 g. (40%) of product, b.p. 70-71° (1 mm.) n_D^{25} 1.4929-1.4943.

Attempted Dehydrohalogenation of the Norbornene Acetylation Product

Into a 500-ml., three-necked flask, fitted with "Trubore" stirrer, condenser, and addition funnel, was placed a solution of 60 g. (0.48 mole) of sodium carbonate monohydrate in 300 ml. of water. The solution was heated to reflux and 15.0 g. (0.087 mole) of chloroketone from the acetylation of norbornene (freshly distilled) was added over 0.5 hours. The mixture was stirred and refluxed for 15 minutes after addition was complete, cooled, extracted with four 50-ml. portions of ether, and the combined ether extracts dried over anhydrous sodium sulfate. Fractionation (Vigreux column) of the residue remaining after the ether had been distilled, afforded an 80% recovery of starting material (b.p. 70-71° at mm.) n_D^{25} 1.4929-1.4943). No dehydrohalogenated product was obtained.

E. Preparation of Equilibrium Mixture of Nortricyclene and Norbornene

The method of Schleyer was employed (6).

A 1-liter distilling flask, equipped with an air condenser and thermometer, was charged with 500 g. of norbornene (previously distilled from sodium), and 10 g. of powdered Houdry synthetic silica-alumina catalyst, type S-90. The system was flushed with dry nitrogen, and a balloon filled with dry nitrogen was fitted to the top of the condenser. The pot temperature was adjusted to maintain gentle reflux (usually 94-95°). Gentle reflux was maintained, with occasional swirling, for 2.5 hours, and the mixture distilled from the catalyst (approximately 1.5 hours), into an ice-cooled receiver to give 450 g. of hydrocarbon mixture. Comparison of the infrared spectrum of this material, between 11.0 and 13.0 μ, with spectra of mixtures of known nortricyclene content, indicated about 30% nortricyclene. The material was isomerized once more for 2.5 hours, keeping the pot temperature below 100°. Distillation provided 375 g. of material of 70-75% nortricyclene content.

F. Acetylation of the Nortricyclene-Norbornene Equilibrium Mixture (6)

To 300 ml. of methylene chloride contained in a 1-liter, three-necked flask, equipped as for the acetylation of pure nortricyclene, was added 77.4 g. (0.58 mole) of aluminum chloride. A solution of

50.2 g. (0.64 mole) of acetyl chloride in 50 ml. of methylene chloride was added (1 hour), and the mixture allowed to stir until a clear, yellow solution was obtained. The solution was cooled in an ice bath, and 54.5 g. of nortricyclene-norbornene equilibrium mixture in 150 ml. of methylene chloride added while maintaining the reaction temperature below 7°. Work-up as in the acetylation of nortricyclene, followed by destructive distillation at aspirator pressure and refractionation through a 1 by 30 cm. glass-helices packed column, gave 23.6-26.6 g. (40-45%) of 1-acetylnortricyclene, b.p. 50-52° (2 mm.) together with 11.0 g. (44%) of chloroketone, b.p. 83-85° (2 mm.), n_D^{25} 1.4950, obtained from addition of acetyl chloride to norbornene. Since the equilibrium mixture of nortricyclene-norbornene is obtained in about 75% yield from norbornene (some polymer is produced during the isomerization), the overall yield of 1-acetylnortricyclene from norbornene is about 30-35%.

II. Proof of Structure of 1-Acetylnortricyclene

A. 1-Nortricyclenecarboxylic Acid

To 5.0 g. (0.037 mole) of 1-acetylnortricyclene contained in a 300-ml. flask equipped with stirrer and addition funnel and cooled in an ice bath, was added (1.5 hours) a solution of sodium hypobromite prepared by adding 17.8 g. (0.11 mole) of bromine to an ice cold solution of 15 g. of sodium hydroxide in 100 ml. of water. A small amount of detergent was added and the mixture vigorously stirred at 0° until the color disappeared (usually 0.5 hours after completion of addition) and then for three hours at room temperature. The bromoform layer was separated, and the aqueous layer extracted with two 50-ml. portions of ether. The aqueous layer was then acidified with hydrochloric acid, excess bromine destroyed with sodium bisulfite, and extracted with several portions of ether. The combined ether layers were extracted with several portions of cold 10% sodium hydroxide, the alkaline layers acidified with hydrochloric acid, and the crude acid removed by filtration. Recrystallization from water or sublimation at 70° (1 mm.) gave 4.0 g. (79%) of 1-nortricyclenecarboxylic acid, m.p. 119-120°, neutralization equivalent 135.6 (theoretical, 138.2).

Anal. Calc'd for $C_8H_{10}O_2$: C, 69.53; H, 7.30.

Found: C, 69.65; H, 7.37.

B. 3-Carboxynortricyclene (5)

To a Grignard reagent prepared from 20.8 g. (0.12 mole) of 3-bromonortricyclene, and 3.64 g. (0.15 mole) of magnesium turnings and cooled in an ice-salt bath, was added gaseous carbon dioxide for a period of two hours. The reaction mixture was hydrolyzed with 3 N hydrochloric acid and the layers separated. The water layer was extracted with two small portions of ether, and the combined ether layers extracted with five 10-ml. portions of 10% sodium carbonate solution. The combined sodium carbonate extracts were acidified with hydrochloric acid, extracted with several small portions of ether and the combined ether extracts dried over calcium sulfate. The residue, after stripping the ether, was distilled at 5 mm. (trap to trap) and recrystallized from pentane, to give 8.5 g. (50%) of 3-carboxynortricyclene, m.p. 49-50°.

C. 1-Hydroxymethylnortricyclene

To a suspension of 8.0 g. (0.21 mole) of lithium aluminum hydride in 650 ml. of anhydrous ether, was added (two hours) a solution of 12.5 g. (0.0907 mole) of 1-nortricyclenecarboxylic acid in 100 ml. of anhydrous ether. Stirring was continued for two hours after addition was complete. The mixture was hydrolyzed with 10% sulfuric acid, layers separated, and the aqueous layer extracted with two 50-ml. portions of ether. The combined ether layers were washed successively with water, 10% sodium carbonate, water, and dried over anhydrous magnesium sulfate. After distillation of solvent, there was obtained 8.81 g. (78.7%) of 1-hydroxymethylnortricyclene, b.p. 50-54° (0.8 mm.), n_D^{25} 1.4941.

<u>Anal</u>. Calc'd for $C_8H_{12}O$: C, 77.37; H, 9.75.

Found: C, 77.15; H, 9.61.

The phenylurethan, recrystallized from ligroin (90-120°), melted at 117.5-118°.

<u>Anal</u>. Calc'd for $C_{15}H_{17}NO_2$: C, 74.05; H, 7.04; N, 5.76.

Found: C, 74.08; H, 7.24; N, 5.78.

D. Preparation of the Tosylate of 1-Hydroxymethylnortricyclene

A solution of 2.5 g. (0.020 mole) of 1-hydroxymethylnortricyclene in 100 ml. of dry ether was placed in a 300-ml. flask, fitted with a "Trubore" stirrer and condenser ($CaCl_2$ tube), and treated with 0.48 g. (0.020 mole) of sodium hydride. The white flocculent alkoxide was evident after about 1.5 hours and stirring was continued for a total of six hours. A solution of 4.13 g. (0.020 mole) of tosyl chloride in

75 ml. of dry ether was added over 10 minutes to the alkoxide suspension cooled in an ice bath. After an additional five hours of stirring, the mixture was filtered, and the filtrate evaporated. The infrared spectrum of the remaining oil showed no hydroxyl bands (2.75 or 3.0 µ) and was presumably the tosylate.

E. Lithium Aluminum Hydride Reduction of the Tosylate of 1-Hydroxymethylnortricyclene

A solution of the previously prepared tosylate in 50 ml. of anhydrous ether was added to a suspension of 2.0 g. (0.053 mole) of lithium aluminum hydride in 100 ml. of anhydrous ether and allowed to stir overnight. The mixture was hydrolyzed with water and base (7), and the ethereal solution dried over anhydrous magnesium sulfate. Distillation of the ether through a 36 cm. Vigreux column left a residual oil whose infrared spectrum was essentially identical with 1-hydroxymethylnortricyclene.

F. 1-Formylnortricyclene

The procedure was analogous to that used by Lipp for the preparation of tricyclal (8).

A solution of 5.0 g. (0.04 mole) of 1-hydroxymethylnortricyclene in 100 ml. of 10% acetic acid was treated portionwise (10 minutes) with 2.7 g. (0.041 mole) of chromic oxide. The mixture was heated on the steam bath for 30 minutes, made alkaline with potassium carbonate, and steam distilled. The distillate layers were separated, and the aqueous layer extracted with two small portions of ether. The organic layer and ether extracts were combined and dried over anhydrous magnesium sulfate, and the solvent removed through a six-inch Vigreux column. The residue, which distilled at 83-87° (14 mm.), weighed 2.5 g. (50%) and was predominately 1-formylnortricyclene, carbonyl band at 5.95 μ, but was contaminated with some unchanged 1-hydroxymethylnortricyclene. The red 2,4-dinitrophenylhydrazone, recrystallized from 95% ethanol containing some ethyl acetate, had a melting point of 218-219.5°.

<u>Anal</u>. Calc'd for $C_{14}H_{14}N_4O_4$: C, 55.62; H, 4.67; N, 18.50.

Found: C, 55.71; H, 4.77; N, 18.64.

G. <u>1-Methylnortricyclene</u>

A mixture of 20 ml. of diethyleneglycol, 1.9 g. of crude aldehyde, 3 ml. of 85% hydrazine hydrate and 3.5 g. of potassium hydroxide was refluxed for one hour, then distilled until the pot temperature reached 177°. The organic layer of the distillate, after drying over anhydrous magnesium sulfate, gave a single peak in a Perkin-Elmer Vapor Fractometer, preparative column with didecyl phthalate on firebrick, column temperature 76°. An authentic sample* showed identical retention time, and samples thus purified had identical infrared spectra, except for a band at 12.5 μ in the authentic sample, previously attributed to an impurity (9).

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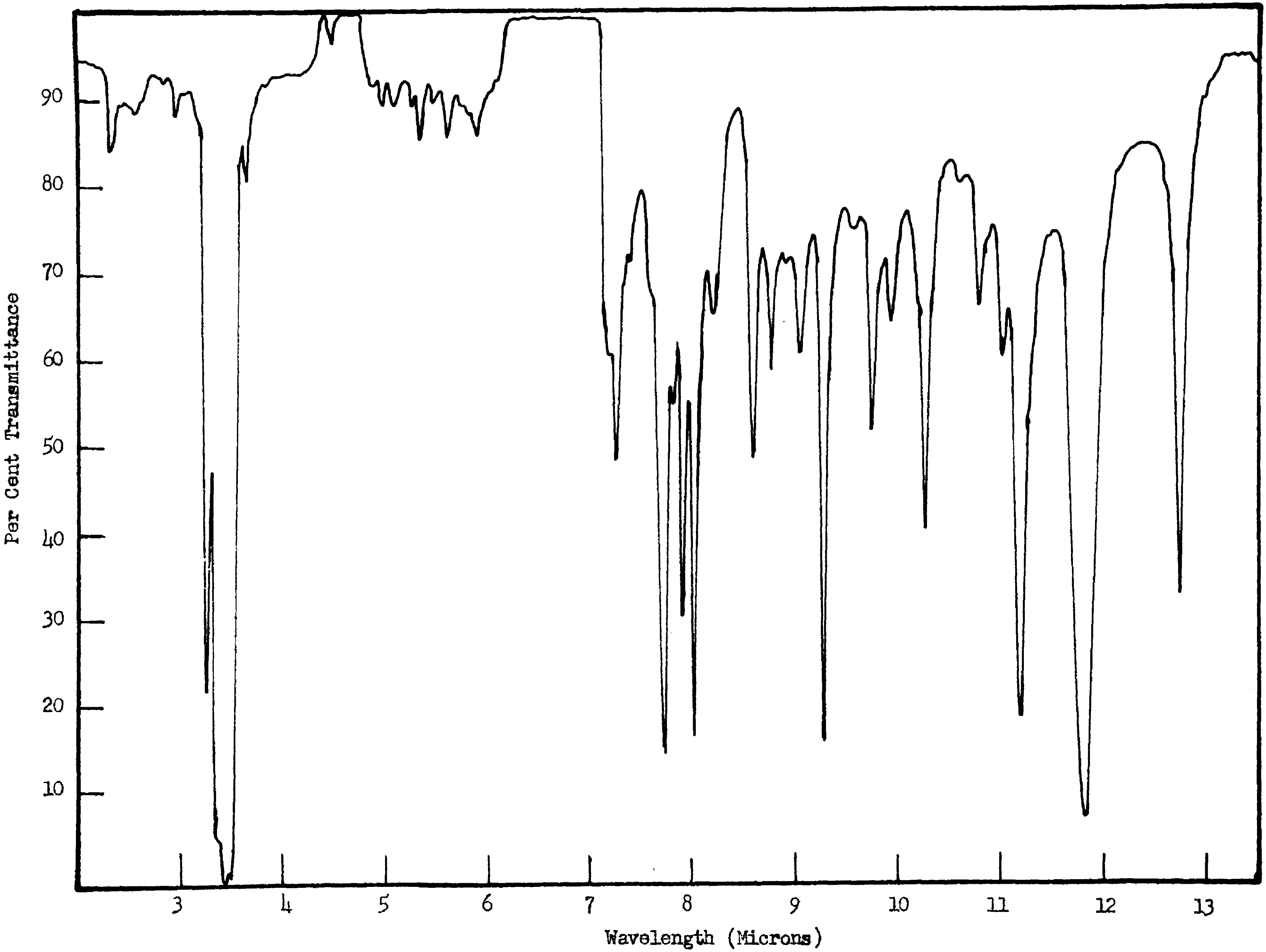
*The author is indebted to Professor Paul von R. Schleyer, Princeton University, for an authentic sample of 1-methylnortricyclene and for communications on the infrared spectra of nortricyclenes.



1-Methylnortricyclene (CS_2)

III. Preparation of Various 1-Substituted Nortricyclenes

A. Endo-2-Carbomethoxynorbornene-5

The method of Roberts, Trumbull, Bennett, and Armstrong was used (5).

To a solution of 90.0 g. (1.0 mole) of methyl acrylate (stabilized with methylhydroquinone) in 90 ml. of anhydrous ether contained in a 500-ml., three-necked flask, fitted with "Trubore" stirrer, condenser, addition funnel, and contained in an ice bath, was added (1.75 hours) 66.0 g. (1.0 mole) of freshly distilled cyclopentadiene. The mixture was stirred for an additional 30 minutes in an ice bath, the ice bath removed, a small amount of hydroquinone added, and allowed to stand overnight.

The residue remaining after removal of the ether was distilled to give 124.3 g. (82%) of the desired ester, b.p. 60-63° at 3.3 mm.

Attempted Isomerization of *endo*-2-Carbomethoxy-norbornene-5

Into a 500-ml. flask, equipped with a bulb condenser ($CaCl_2$ tube) was placed 63.7 g. (0.42 mole) of ester, 150 ml. of hexane (washed with sulfuric acid and distilled from sodium), and one gram of powdered Houdry synthetic silica-alumina catalyst, type S-90. The mixture was gently refluxed (83°) in an oil bath for 12 hours, cooled, and filtered. The residue remaining after removal of the hexane was distilled to give 90% recovery of ester, b.p. 62-63° (2 mm.). The infrared spectrum of the distillate was identical with the starting ester.

The isomerization was attempted once more, under more vigorous conditions.

Into a 300-ml. flask, equipped with "Trubore" stirrer and condenser ($CaCl_2$ tube), was placed 57.3 g. (0.38 mole) of ester and one gram of powdered catalyst. The mixture was heated in an oil bath (100°) and stirred for 15 hours, cooled, and filtered. Distillation afforded 90% recovery of material which again showed no change in the infrared spectrum.

B. 1-(1-hydroxyethyl)nortricyclene

To a slurry of 3.8 g. (0.10 mole) of lithium aluminum hydride and 50 ml. of anhydrous ether in a 300-ml., three-necked flask, fitted with stirrer, addition funnel, and condenser, was added (15 minutes) a solution of 8.0 g. (0.059 mole) 1-acetylnortricyclene in 100 ml. of anhydrous ether. The mixture was stirred for two additional hours at room temperature, cooled, and hydrolyzed with water and 20% sodium hydroxide according to Gaylord (7). The mixture was filtered and dried over anhydrous magnesium sulfate. After removal of solvent, distillation (Vigreux column) afforded 6.6 g. (82%) of 1-(1-hydroxyethyl)nortricyclene, b.p. 63-64° (1 mm.), n_D^{25} 1.4838.

Anal. Calc'd for $C_9H_{14}O$: C, 78.21; H, 10.21.

Found: C, 78.04; H, 10.21.

C. 1-Nortricyclenecarboxamide

To 3.0 g. (0.22 mole) of 1-nortricyclenecarboxylic acid in a 100-ml. flask fitted with an addition funnel, condenser, and magnetic stirrer, was added (10 minutes) 2.4 ml. (0.033 mole) of thionyl chloride. After the initial exothermic reaction had subsided (45 minutes), the mixture was stirred for two additional hours at room temperature, and finally for 30 minutes on the steam bath. After cooling, 45 ml. of anhydrous ether was added and then anhydrous ammonia was introduced over the vigorously stirred reaction mixture for 20 minutes. The reaction mixture was filtered and the residue washed with cold water. Recrystallization from benzene gave 2.7 g. (90%) of white, lustrous needles, m.p. 219-222° (decomposition).

Anal. Calc'd for $C_8H_{11}NO$: C, 69.99; H, 8.08; N, 10.26.

Found: C, 70.07; H, 8.14; N, 10.19.

D. The Hydrochloride of 1-Aminonortricyclene

Three methods for the preparation of this compound were investigated. Method 3 afforded the highest yield and purest product.

1. Modified Beckmann Rearrangement of Nortricyclyl Methyl Ketoxime

The oxime was obtained in essentially quantitative yield according to the method used by Roberts and Chambers to prepare cyclopropyl methyl ketoxime (10).

In a 25-ml., one-necked flask, equipped with a condenser, was placed 2.0 g. (0.015 mole) of 1-acetylnortricyclene, 1.5 g. (0.019 mole) of hydroxylamine hydrochloride, 0.8 g. (0.0075 mole) of sodium carbonate, 8 ml. of water and 14 ml. of 95% ethanol. The mixture was refluxed for one hour and then allowed to cool to precipitate the oxime, which was then recrystallized from ethanol-water.

The rearrangement was effected by placing into a 50-ml. flask, equipped with condenser, addition funnel, and magnetic stirrer, 1.35 g. (0.009 mole) of oxime, 2.3 g. of sodium carbonate, 8 ml. of water and 4 ml. of dioxane. The mixture was heated to gentle reflux, 1.8 g. benzenesulfonyl chloride added over 20-25 minutes, and refluxed for 10 additional minutes. The flask was cooled, whereupon the amide mixture crystallized. The mixture was filtered and the solid washed with cold water and cold 10% sodium carbonate solution. The yield of amide mixture was 1.10 g. (81%), m.p. 104-125°.

Attempted saponification of these amides with potassium hydroxide in water-ethylene glycol solvent gave only an oily solid with an infrared carbonyl absorption at 5.68 μ, probably norcamphor (11).

2. Modified Hofmann Rearrangement of 1-Nortricyclenecarboxamide

The method was that used by Lipp and Padberg to prepare apotricyclylamine hydrochloride (11).

Into a 25-ml. flask, equipped with condenser, addition funnel, and magnetic stirrer, was placed 1.0 g. (0.0073 mole) of 1-nortricyclenecarboxamide and 3 ml. of anhydrous methanol. A sodium methylate solution prepared from 0.24 g. (0.011 mole) of sodium and 7 ml. of anhydrous methanol was added to the ice-cooled suspension over 15 minutes. To this mixture 0.77 g. (0.0048 mole) of bromine was added and the mixture refluxed for one hour. The methanol was evaporated and the urethan taken up in hot pentane. The pentane-insoluble portion, unreacted amide, amounted to 230 mg. The pentane was evaporated to yield 580 mg. (75%

based on unrecovered amide) of methyl urethan, m.p. 86.5-87.5°.

Anal. Calc'd for $C_9H_{13}O_2N$: C, 64.64; H, 7.83; N, 8.37.

Found: C, 64.61; H, 7.77; N, 8.44.

The urethan thus obtained (580 mg., 0.0035 mole) was mixed with 1.2 g. (0.021 mole) of powdered potassium hydroxide, heated for approximately eight minutes in an oil bath at 160°, and immediately steam distilled into dilute hydrochloric acid. Evaporation of the distillate yielded about 100 mg. (19%) of amine hydrochloride, m.p. above 250° (decomposition).

3. Hofmann Rearrangement of 1-Nortricyclenecarboxamide

The following procedure was suggested by the work of Magnien and Baltzly (12).

Into a 300-ml. flask, equipped with condenser, thermometer, and magnetic stirrer, was placed 6.0 g. (0.044 mole) of amide, 72 ml. of sodium hypochlorite solution (12), and 24 ml. of dioxane (previously purified by refluxing and distilling over sodium (12). The mixture was gradually heated (0.5 hour) until the pot temperature reached 50° at which time no solid remained. Stirring was continued without heating for one hour, the pot temperature adjusted to 45-50°, and the solution stirred for 1.25 additional hours. The mixture was immediately steam distilled into dilute hydrochloric acid until the distillate was no longer basic (about 600 ml.). The distillate was carefully evaporated to dryness at about 40° with a rotary evaporator, the residue taken up in anhydrous methanol and filtered. Treatment of the filtrate with anhydrous ether deposited white needles, 4.0 g. (61%), melting point above 250° (decomposition). The residue from steam distillation deposited 1.05 g. of unreacted amide, and the yield of amine hydrochloride based on unrecovered amide was 75%.

<u>Anal</u>. Calc'd for $C_7H_{12}NCl$: C, 57.73; H, 8.31; N, 9.62.

Found: C, 57.76; H, 8.32; N, 9.61.

E. <u>Benzamide of 1-Aminonortricyclene</u>

A solution of 200 mg. of the hydrochloride of 1-aminonortricyclene in 20 ml. of water was cooled in an ice bath and made basic (pH about 11) by dropwise addition of cold 10% sodium hydroxide solution. To this solution was slowly added with vigorous stirring 0.25 ml. of benzoyl chloride. The mixture was filtered, the residue washed with sodium bicarbonate solution and recrystallized from ethyl alcohol-water to give white needles, m.p. 223.5-224°.

<u>Anal</u>. Calc'd for $C_{14}H_{15}NO$: C, 78.84; H, 7.09; N, 6.57.

Found: C, 78.73; H, 7.14; N, 6.50.

F. <u>The Hydrochloride of 1-Aminomethylnortricyclene</u>

To a slurry of 4.1 g. (0.111 mole) of lithium aluminum hydride in 500 ml. of anhydrous ether in a two liter, three-necked flask, equipped with "Trubore" stirrer, condenser, and Erlenmeyer flask arranged for addition of a solid (13), was added, (1.5 hours) 5.0 g. (0.037 mole) of 1-nortricyclenecarboxamide. The mixture was stirred for two hours, refluxed and stirred for one additional hour, and then hydrolyzed with water and 15% sodium hydroxide according to Gaylord (7). The ether layer was decanted and dried overnight (barium oxide), and then treated with anhydrous hydrogen chloride to precipitate the white hydrochloride. Recrystallization from 15% n-propanol-85% benzene afforded white needles, 5.25 g. (90%), m.p. 238-239.5° (decomposition).

<u>Anal</u>. Calc'd for $C_8H_{14}NCl$: C, 60.19; H, 8.84; N, 8.77, Cl, 22.27.
Found: C, 60.21; H, 8.76; N, 8.74; Cl, 22.39.

IV. Amine-Nitrous Acid Reactions

A. Nitrous Acid Reaction of the Hydrochloride of 1-Aminonortricyclene

Into a 50-ml. flask, equipped with condenser ($CaCl_2$ tube), solid addition funnel, and magnetic stirrer, was placed 2.0 g. (0.014 mole) of amine hydrochloride, 30 ml. of glacial acetic acid, and 2 ml. of acetic anhydride. The resulting solution was treated with 2.0 g. (0.30 mole) of sodium nitrite over one hour, stirred an additional hour, treated similarly with another 2.0 g. of sodium nitrite, and stirred for one more hour at which time gas evolution had stopped. The solution was neutralized with a saturated solution of sodium bicarbonate and extracted with several small portions of pentane. The pentane extracts were combined and washed successively with water, sodium bicarbonate solution, water, dilute hydrochloric acid, and finally again with water, and dried over anhydrous magnesium sulfate. After the pentane was removed (distillation), the residue was distilled to give 1.14 g. (55%) of acetate, b.p. 41-42° (2 mm.). An unidentified residue of approximately 175 mg. with an infrared absorption at 6.08 μ was also obtained.

It was not further investigated. Vapor chromatographic analysis of the distillate resulted in one large band (didecyl phthalate on firebrick column, 115°, 7 lbs. helium) after one hour. Material purified by gas chromatography (silicone-column, 113-114°, 10 lbs. nitrogen) showed bands in the infrared at 11.82 and 12.81 µ, carbonyl absorption at 5.68 µ and C-H absorption at 3.23 µ.

<u>Anal</u>. Calc'd for $C_9H_{12}O_2$: C, 71.02; H, 7.94.

Found: C, 70.81; H, 7.81.

1. <u>3-Acetoxynortricyclene</u>

The procedure outlined in U. K. Patent Specification No. 717,010 was followed (14).

Into a 500-ml. flask fitted with a condenser, was combined 46.0 g. (0.50 mole) of freshly distilled bicycloheptadiene, 120 g. (2.0 mole) of glacial acetic acid, and 1.6 ml. of 40% (volume) sulfuric acid. The mixture was heated at 100° for three hours, poured over ice, and extracted several times with pentane. The combined pentane layers were washed with water and 10% sodium carbonate solution and dried over anhydrous magnesium sulfate. The pentane was evaporated in a rotary evaporator and the residue distilled to give 51.0 g. (67.2%) of 3-acetoxynortricyclene (together with some unsaturated material), b.p. 81-83° (15 mm.), n_D^{25} 1.4689.

2. <u>Baeyer-Villiger (15) Reaction of 3-Acetylnortricyclene</u>

The general procedure of Emmons and Lucas (16) was used. Trifluoroacetic anhydride was prepared according to Bourne and Stacey (17).

To prepare the trifluoroacetic anhydride, 100 g. of trifluoroacetic acid was added to 87 g. of phosphorus pentoxide contained in a 500-ml. flask equipped with an eight-inch Vigreux column and distillation head. Gentle application of heat afforded the anhydride, b.p. 38-41° (atm).

Trifluoroacetic anhydride, 2.3 g. (0.018 mole), prepared as above, was added dropwise to an ice-cooled suspension of 0.4 ml. of 90% hydrogen peroxide in 5 ml. of methylene chloride, contained in a 25-ml. flask, equipped with condenser ($CaSO_4$ tube), dropping funnel, and magnetic stirrer. The mixture was allowed to warm to room temperature, and then added (15 minutes) to an ice-cooled mixture of 1.0 g. (0.0074 mole) 1-acetylnortricyclene, 5.26 g. of dry disodium hydrogen phosphate and 10 ml. of methylene chloride, in a 50-ml. flask, fitted with condenser ($CaSO_4$ tube), addition funnel, and magnetic stirrer. After addition was complete, the mixture was stirred for 0.5 hours in the ice bath, 1.5 hours while warming to room temperature, and finally refluxed and stirred for an additional 1.5 hours. It was then cooled, decanted, and the mixed salts washed with several small portions of methylene chloride. The combined methylene chloride extracts were washed with water and 10% sodium carbonate and dried over anhydrous magnesium sulfate. The methylene chloride was stripped and the residue distilled at 41° (2 mm.) to give 300 mg. of nearly pure acetate. A residue of 250 mg. was shown by infrared to be a mixture of acetate and starting ketone.

Further purification of the distillate (silicone vapor chromatography column, 113°, 10 lbs. nitrogen), gave material whose infrared spectrum was identical with the acetate obtained from the hydrochloride of 1-aminonortricyclene.

3. Hydrolysis of 1-Acetoxynortricyclene

Into a 25-ml. flask, equipped with a condenser and magnetic stirrer, was added a solution of 200 mg. (0.0013 mole) of 1-acetoxynortricyclene in 2 ml. of carbon tetrachloride and 10 ml. of 10% hydrochloric acid. The mixture was refluxed and stirred for 12 hours, layers separated, and the water layer extracted with several small portions of carbon tetrachloride. The combined carbon tetrachloride extracts were dried over anhydrous magnesium sulfate and then evaporated to give a solid with an intense carbonyl absorption at 5.65 μ, presumably norcamphor. The 2,4-dinitrophenylhydrazone, prepared according to Shriner and Fuson (18) and recrystallized from 95% ethanol, melted 129-130°; literature value (19), 130°.

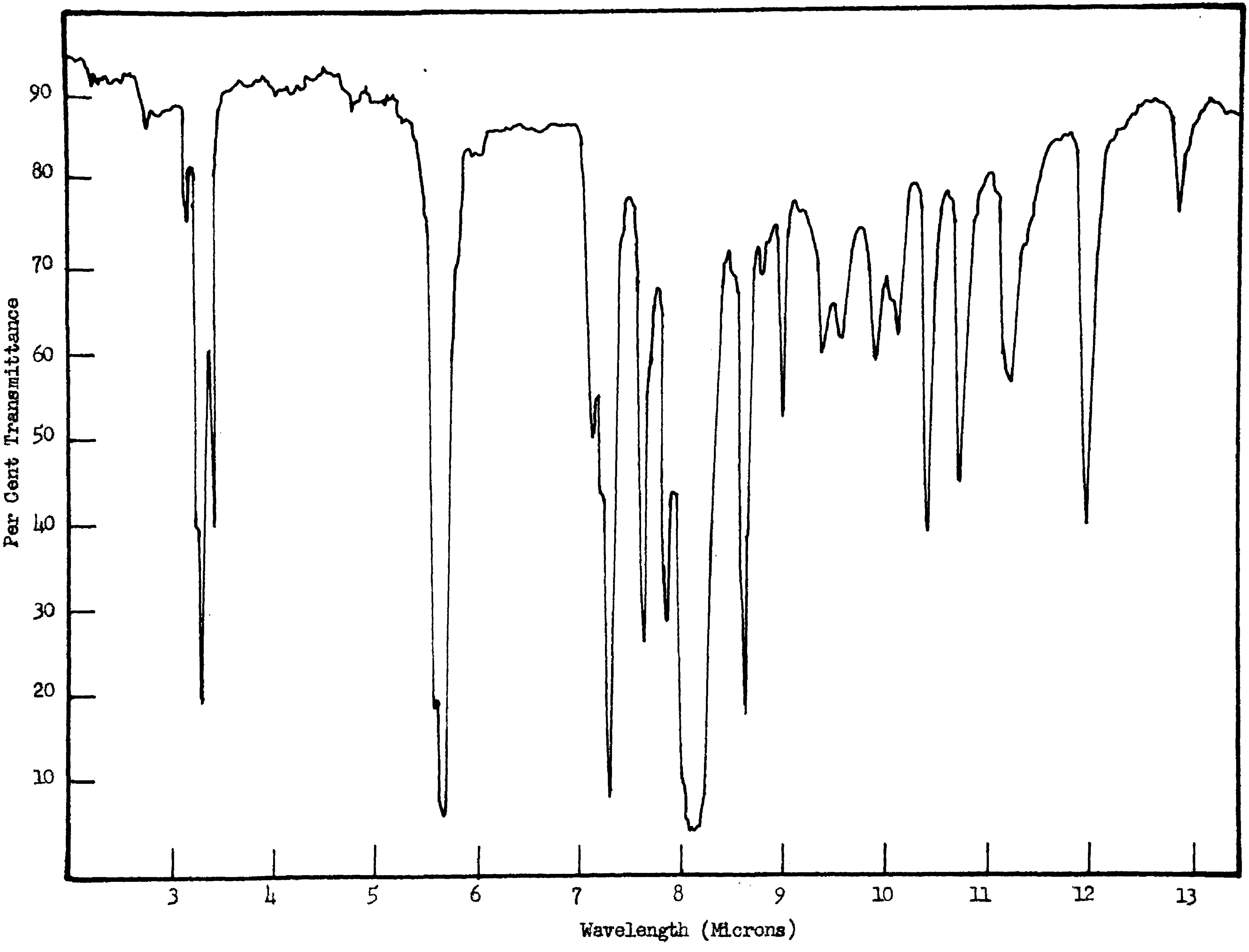
4. 2-Acetoxynorbornene-5

The procedure of Alder and Rickert was followed (20).

A 200-ml. steel bomb was charged with 45.0 (0.68 mole) of freshly distilled cyclopentadiene and 70.0 g. (0.81 mole) of vinyl acetate. The mixture was heated with occasional stirring at 185-190° for ten hours, allowed to cool, and distilled to give 42.4 g. (41.0%) of ester, b.p. 74-78° (14 mm.), n_D^{25} 1.4672 (lit. value 73-77° at 14 mm., n_D^{25} 1.4668 (5)).

5. 2-Acetoxynorbornane

Into a 250-ml. hydrogenation bottle was placed 25.0 g. (0.16 mole) of 2-acetoxynorbornene-5, 150 ml. of glacial acetic acid, and 0.5 g. of



1-Acetoxynortricyclene (CS_2)

platinum oxide hydrogenation catalyst. The mixture was hydrogenated at room temperature with 50 lbs. hydrogen pressure. Hydrogenation proceeded very quickly, a stable pressure being reached in about 20 minutes. The mixture was filtered, the filtrate poured into 500 ml. of water, and the aqueous solution extracted with five 75-ml. portions of pentane. The combined pentane extracts were then successively washed, three times with small portions of water, twice with 10% sodium carbonate solution, once again with water and dried over anhydrous magnesium sulfate. After the pentane was stripped, the colorless residue was distilled to give 22.5 g. (90%) of acetate, b.p. 76-78° (13 mm.) n_D^{28} 1.4572 (lit. value 81-83° at 12 mm. n_D^{28} 1.4578). The infrared spectrum confirmed the hydrogenation of the carbon-carbon double bond.

6. 2-Hydroxynorbornane

Into a 300-ml., three-necked flask, fitted with condenser, "Trubore" stirrer, and addition funnel, was placed 125 ml. of anhydrous ether and 2.1 g. (0.055 mole) of lithium aluminum hydride. A solution of 15.4 g. (0.10 mole) of 2-acetoxynorbornane in 50 ml. of anhydrous ether was then added at such a rate as to maintain gentle reflux (about one hour). The mixture was refluxed and stirred for one hour after addition was complete, and then stirred at room temperature for an additional hour. Hydrolysis was accomplished with water and 15% sodium hydroxide solution (7), and the ether solution decanted. The residue was thoroughly washed with two 75-ml. portions of ether, the ether portions combined and dried over anhydrous magnesium sulfate. The ether was evaporated to give an oily solid the infrared spectrum of which indicated that the alcohol was contaminated with a small amount of unreacted ester. The material was not further purified, but a portion of it was used in the following preparation.

7. Norcamphor 2,4-Dinitrophenylhydrazone

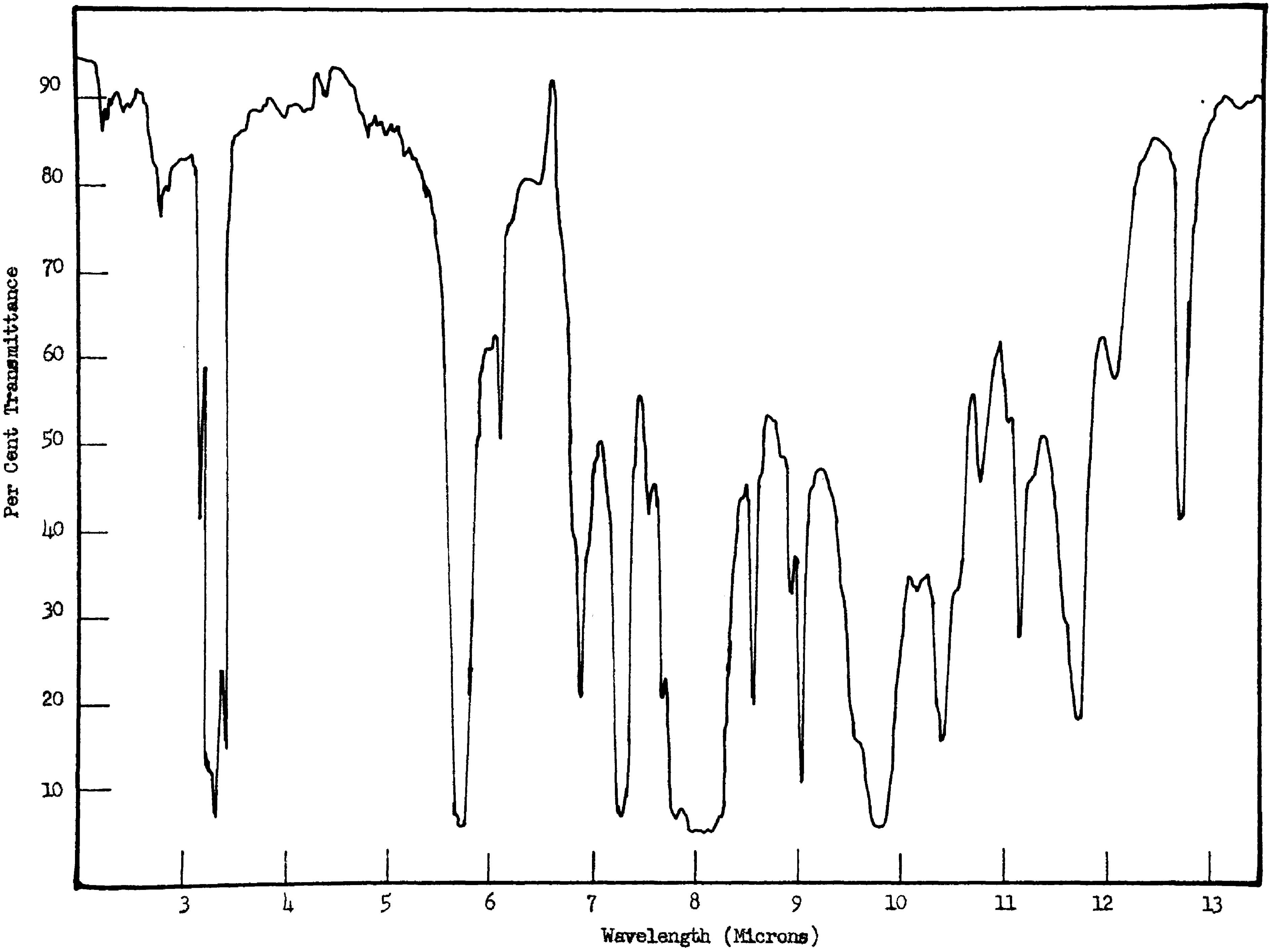
A solution of 1.12 g. (0.01 mole) of crude 2-hydroxynorbornane was dissolved in 5 ml. of glacial acetic acid. To this solution was added, in small portions over 15 minutes, 0.6 g. (0.006 mole) of chromic anhydride in 5 ml. of 80% acetic acid. The solution was heated for one hour on the steam bath, neutralized with 10% sodium carbonate solution, and steam distilled until no more oil separated in the distillate. The distillate was extracted twice with ether and the combined ether layers evaporated. The oily residue was converted directly to its 2,4-dinitrophenylhydrazone, and the latter was filtered and recrystallized from 95% ethanol. This material melted 129-130.5° (lit. value 130° (19)) and did not depress the melting point of the 2,4-dinitrophenylhydrazone of the product obtained from hydrolysis of 1-acetoxynortricyclene.

8. Nitrous Acid Reaction of the Hydrochloride of 1-Aminomethylnortricyclene

Into a 50-ml. flask, equipped with solid addition funnel, condenser ($CaCl_2$ tube), and magnetic stirrer, was placed 3.0 g. (0.019 mole) of amine hydrochloride, 30 ml. of glacial acetic acid and 2 ml. of acetic anhydride. The resulting solution was treated over one hour with 3.0 g. (0.043 mole) of sodium nitrite and allowed to stir for one additional hour. After similar treatment with another 3.0 g. of sodium nitrite and further stirring for one hour, gas evolution had stopped and the mixture was neutralized by pouring it slowly into excess sodium bicarbonate solution. The mixture was extracted several times with small portions of pentane and the combined pentane extracts washed successively with water, sodium bicarbonate solution, water, 3 N hydrochloric acid, finally with water and dried over anhydrous magnesium sulfate. The pentane was stripped and the residue distilled to yield 1.6 g. (52%) of acetates, b.p. 58-61° (2.2 mm.). The infrared spectrum of this material indicated that it was mainly nortricyclylcarbinyl acetate (bands at 11.73 and 12.73 μ) together with small amounts of an exocyclic methylene compound (doublet at 5.97 and 6.02 μ, shoulder at 11.30 μ), and another unsaturated compound with a band at 6.10 μ. Vapor chromatographic analysis of this mixture over a didecyl phthalate on firebrick column led to inconclusive results, the mixture composition varying considerably with variations in temperature and carrier gas pressure. The residues remaining from this run and another run of 2.7 g. (0.017 mole) were combined and distilled to give 1.2 g. of material, b.p. 110-130° (0.7 mm.) with an intense doublet at 5.97 and 6.02 μ but no band at 11.30 μ. Apparently this material was composed of higher molecular weight acetates containing an exocyclic carbon-carbon double bond, but no terminal methylene groups. It was not further investigated.

1. <u>1-Nortricyclylcarbinyl acetate</u>

Into a 300-ml. flask, equipped with condenser, addition funnel ($CaCl_2$ tubes), and magnetic stirrer was added 100 ml. of anhydrous ether



Acetate Mixture (CS_2 except from 6.2 to 7.2 µ where CCl_4 was used) and 1.54 g. (0.065 mole) of sodium hydride. To this suspension was added over 30 minutes a solution of 8.0 g. (0.065 mole) of 1-hydroxymethylnortricyclene in 50 ml. of anhydrous ether, and the mixture allowed to stir for 24 hours. To the alkoxide suspension was then added (one hour) a solution of 5.06 g. (0.065 mole) of acetyl chloride in 50 ml. of anhydrous ether and the mixture allowed to stir for 24 hours. After filtration of the mixture, the residual salts were washed thoroughly with ether, the ether layers combined and washed successively, twice with water, three times with sodium bicarbonate solution, once with water, and dried over anhydrous magnesium sulfate. After stripping the ether, the residue was distilled to give 8.3 g. (77.5%) of acetate, b.p. 58-60° (2 mm.). The infrared spectrum of this material contained nortricyclyl bands at 11.73 and 12.73 μ.

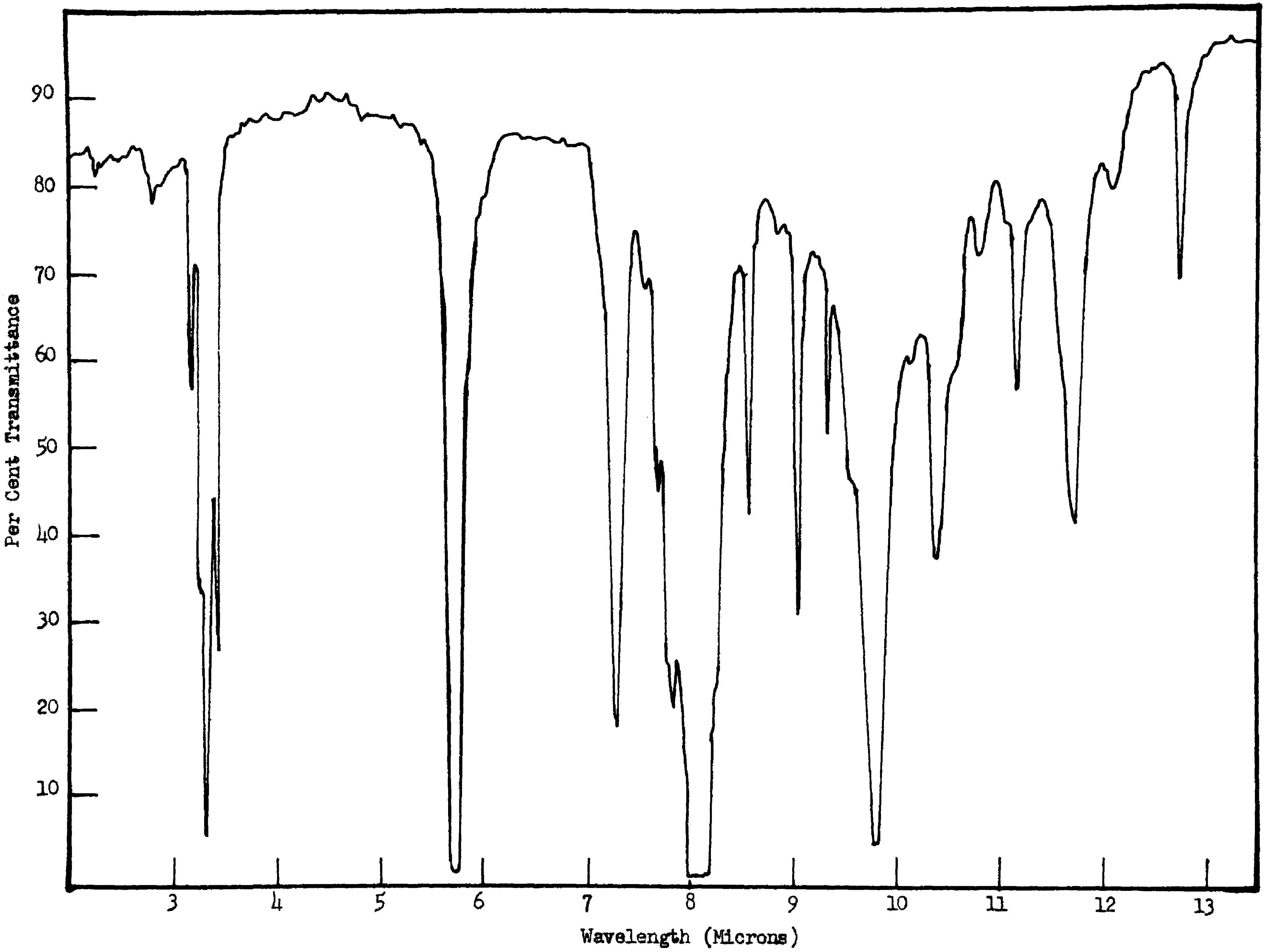
<u>Anal.</u> Calc'd for $C_{10}H_{14}O_2$: C, 72.25; H, 8.49.

Found: C, 72.27; H, 8.50.

A 0.25-ml. sample of 1-nortricyclylcarbinyl acetate was passed through a preparative scale silicone gas chromatographic column (132°; 7 lbs. H_2 carrier). Infrared analysis of the resulting material (band from 43 to 60 minutes after injection of the sample) showed almost complete absence of the nortricyclyl bands at 11.73 and 12.73 μ, and new bands at 5.97, 6.02 and 11.30 μ (very intense). This acetate is probably 6-acetoxynorcamphene.

<u>Anal.</u> Calc'd for $C_{10}H_{14}O_2$: C, 72.25; H, 8.49.

Found: C, 72.09; H, 8.44.



1-Nortricyclylcarbinyl Acetate (CS_2)

2. Solvolysis of 1-Nortricyclylcarbinyl Trifluoroacetate

This trifluoroacetate was prepared by James A. Wrede (21).

A 2.6 g. (0.012 mole) sample of trifluoroacetate was stirred at room temperature with 10 ml. of 10% sodium hydroxide for 24 hours, extracted with ether and the combined ether extracts dried over anhydrous magnesium sulfate. After removal of the ether, the residue was distilled to give 1.2 g. (80%) of alcohol, b.p. 53-55° (0.8 mm.). The infrared spectrum of this material showed bands at 5.97, 6.02, and 11.30 μ (very intense). There were no nortricyclyl bands evident at 11.78 and 12.74 μ, eliminating the possibility of the presence of 1-hydroxymethylnortricyclene.

This alcohol was converted to the corresponding acetate by the same general procedure used for the synthesis of 1-nortricyclylcarbinyl acetate.

Into a 100-ml. flask, equipped with condenser, addition funnel ($CaCl_2$ tubes), and magnetic stirrer was placed 25 ml. of anhydrous ether and 0.23 g. (0.0097 mole) of sodium hydride. A solution of 1.20 g. (0.0096 mole) of alcohol, as obtained above, in 25 ml. of anhydrous ether was added over ten minutes and the mixture allowed to stir for 24 hours. A solution of 0.75 g. (0.0097 mole) of acetyl chloride in 25 ml. of anhydrous ether was added (ten minutes) and the mixture stirred for an additional 24 hours. After filtration, the residual salts were washed thoroughly with ether, the combined ether extracts washed with water and sodium bicarbonate solution and dried over anhydrous magnesium sulfate. After removal of the ether, the residue was distilled to give 0.9 g.

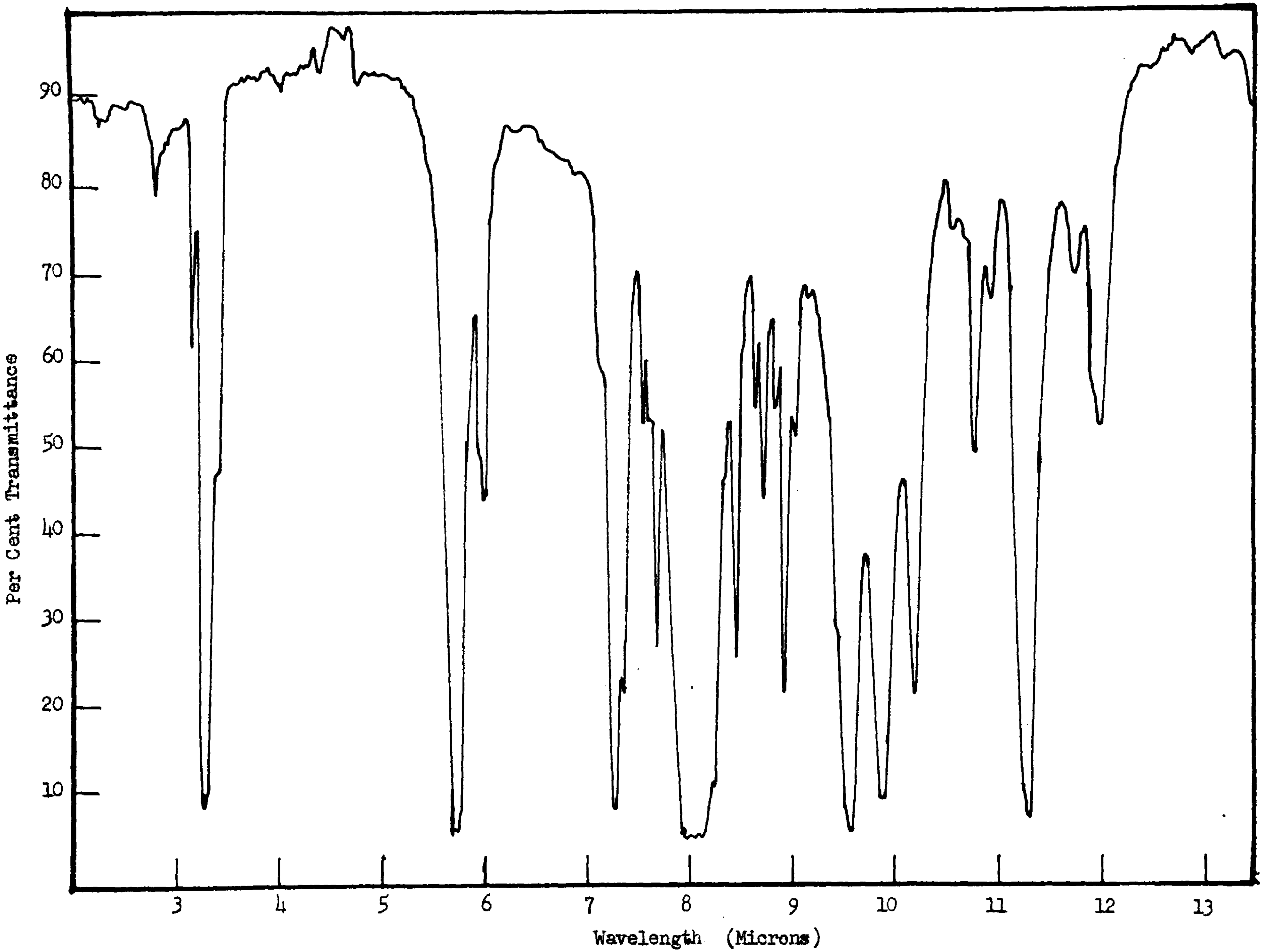
(56%) of acetate, b.p. 51-52.5 (1.8 mm.). The infrared spectrum of this material was identical with the rearranged acetate obtained from the gas chromatographic treatment of 1-nortricyclylcarbinyl acetate, except for a trace band at about 12.7 μ in the latter material, apparently due to unrearranged 1-nortricyclylcarbinyl acetate.

3. Potassium Permanganate Treatment of Acetate Mixture

In a 50-ml. flask, cooled in an ice bath, was placed a solution of 500 mg. of acetate mixture in 5 ml. of ether, 10 ml. of 2% aqueous potassium permanganate, and a small amount of detergent. During the course of eight hours stirring in the ice bath, an additional 15 ml. of 2% potassium permanganate solution was added in 5-ml. portions. The mixture was filtered, layers separated, the aqueous layer extracted with ether, and the combined ether layers dried over anhydrous magnesium sulfate. Distillation of the residue remaining after removal of the ether resulted in material the infrared spectrum of which was identical with authentic 1-nortricyclylcarbinyl acetate, except for faint bands at 5.97; 6.02, 6.10 and 8.90 μ all attributable to unsaturated acetates, and much diminished in intensity when compared with the starting acetate mixture.

4. Bromine in Acetic Acid Titration of the Acetate Mixture

The procedure of Reid and Beddard (22), suggested for the determination of small amounts of unsaturates in large quantities of saturated material, was employed.



Acetate Believed to be 2-Acetoxynorcamphene (CS_2)

A 0.01155 N solution of bromine in acetic acid was prepared by diluting 0.3 ml. of bromine to one liter with glacial acetic acid, and standardizing it with 0.01134 N sodium thiosulfate to a starch end point. Accurately weighed 0.1 g. samples were placed into one dram vials and each dissolved in 25 ml. of methyl alcohol contained in 500-ml. iodine flasks. The solutions were thoroughly mixed and placed in an ice bath for 30 minutes. Each sample was then treated with 10 ml. of standard bromine solution, mixed thoroughly, and replaced in the ice bath for three minutes. After removal from the ice bath, and dilution with 100 ml. of water, 10 ml. of 10% potassium iodide was added, and the solution titrated with standard 0.01 N sodium thiosulfate to a starch end point.

Samples titrated by this method indicate 10.3-10.5% unsaturation. A "blank" of pure 1-nortricyclylcarbinyl acetate, titrated in the same way, permits a correction to 8.2-8.4% unsaturation in the acetate mixture.

5. Infrared Analysis of the Acetate Mixture

The infrared spectrum of the acetate mixture indicated a preponderance of unrearranged acetate, identified by nortricyclyl bands at 11.73 and 12.73 μ. Two unsaturates were also present (8.2-8.4%), identified by weak bands at 5.97, 6.02, 6.10, 8.90 and 11.30 μ. One of these unsaturates, which accounts for the bands at 5.97, 6.02, 11.30 μ and a portion of the 8.90 μ band, is probably 6-acetoxynorcamphene (vide infra) as obtained by isomerization of 1-nortricyclylcarbinyl acetate (vapor chromatograph), and from the alcohol resulting from hydrolysis of

1-nortricyclylcarbinyl trifluoroacetate. Accordingly, mixtures of known concentration of 1-nortricyclylcarbinyl acetate and 6-acetoxynorcamphene were analyzed by infrared and compared with the mixture of acetates from the nitrous acid reaction of the hydrochloride of 1-aminomethylnortricyclene. The infrared spectrum obtained by placing a carbon disulfide solution of acetate mixture in the "reference" beam and a mixture of identical concentration composed of 5% 6-acetoxynorcamphene and 95% 1-nortricyclylcarbinyl acetate in the "sample" beam, showed two main deflections due to the mixture from the nitrous acid reaction, one at 6.10 μ and a second at 8.90 μ, both apparently due to an unknown acetate present to the extent of 4-5%. The bands at 5.97, 6.02, and 11.30 μ were nearly balanced, indicating the presence of 6-acetoxynorcamphene to the extent of about 5% in the acetate mixture.

6. Analyses and Melting Points

The method of Umhoefer (23) was used for the chlorine analysis of 2-chloro-6-acetylnorbornane. Two grams of sodium, cut into four or five pieces, was placed in a 250-ml. flask containing 25 ml. of isopropyl alcohol. A 0.5 g. sample of 2-chloro-6-acetylnorbornane was added and the mixture refluxed for 2.5 hours. The excess sodium was decomposed by cautiously adding water through the condenser. After addition of 50 ml. of water, the solution was neutralized to congo red paper with 6 N nitric acid. The chloride ion was titrated by the Volhard method.

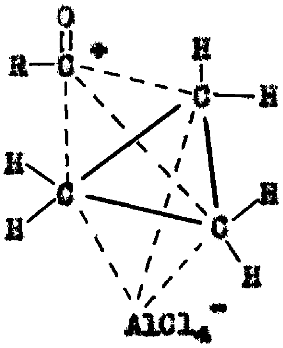
The other analyses were done by Spang Microanalytical Laboratory, Ann Arbor, Michigan.

Melting points were determined in a capillary in an efficiently stirred oil bath using a thermometer calibrated against a Bureau of Standards thermometer. Stem corrections were not made.

DISCUSSION

I. Mechanism of the Acetylation

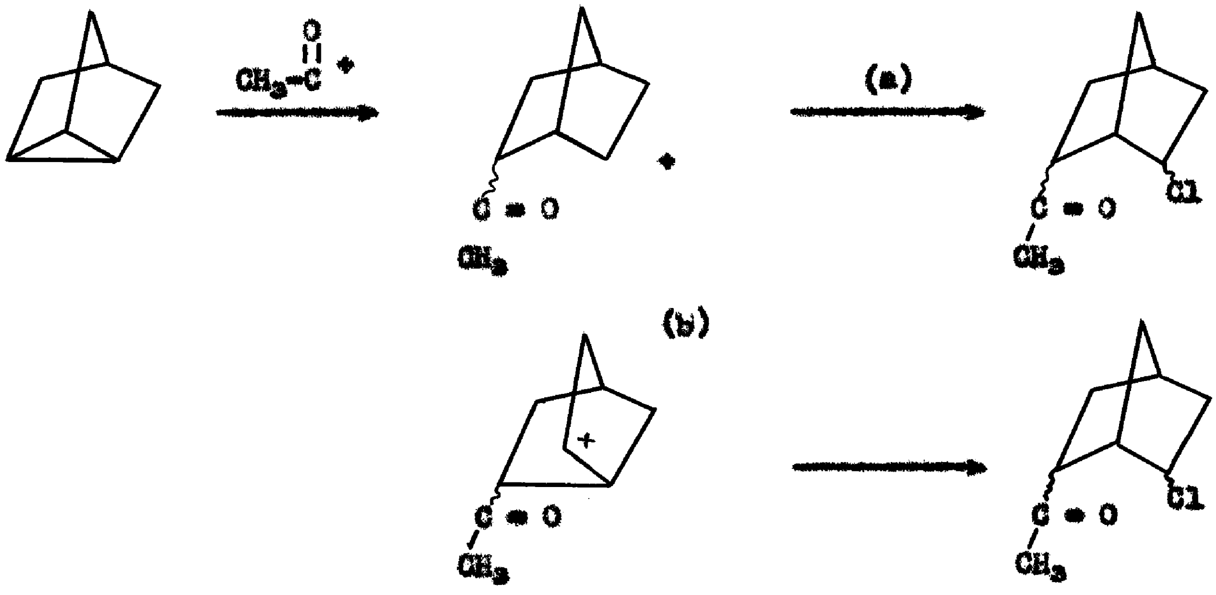
The acetylation of cyclopropanes apparently proceeds through an electrophilic attack by the acylonium ion on the cyclopropane ring. The electrophilic nature of the attack in these acylations is pointed out by the work of Levitt (34) on substituted cyclopropanes, where the reaction rate decreased markedly as electron withdrawing groups were placed on the ring. Thus, much 1,1-dichlorocyclopropane was recovered from an acetylation in refluxing chloroform, monochlorocyclopropane required several hours at room temperature, while cyclopropane and dimethylcyclopropane reacted rapidly at 0°. The unsuccessful attempts to acylate cyclopropane and dimethylcyclopropane using acetyl perchlorate as a source of acylonium ions (3,4), indicates that a simple attack by the acylonium ion is not an entirely satisfactory representation of the reaction. Levitt (4) proposed a "sandwich type aggregate" consisting of a cyclopropane ring between the ions of the acetyl chloride-aluminum chloride complex as a possible explanation for the acylation reaction, and the rearrangement which accompanies it.



Such an aggregate demands that both faces of the cyclopropane ring be available for complexation and, hence, that nortricyclene would not be expected to react. Since the acetylation of nortricyclene was found to proceed readily at 0-7° to yield 69% of 2-chloro-6-acetylnorbornane it must be concluded that such an aggregate is not necessary for reaction, at least in this case.

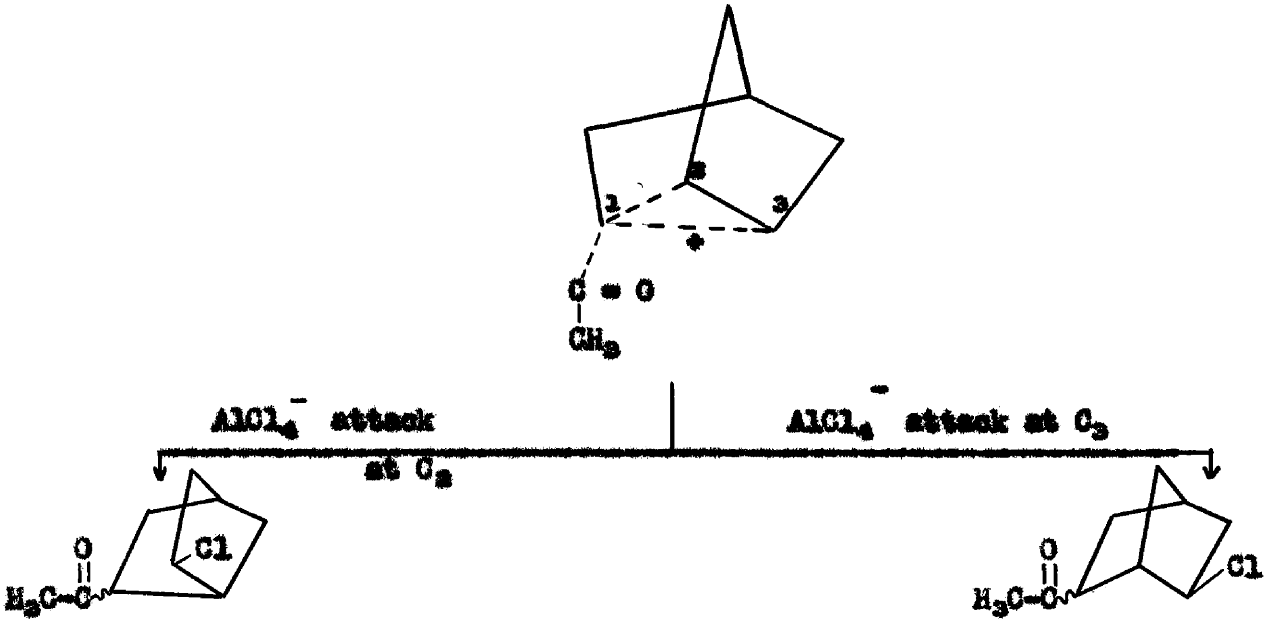
Two possible mechanisms can be proposed for the acetylation of nortricyclene. The first, illustrated in Chart I, involves a "classical" carbonium ion formed after initial attack by the acylonium ion.

Chart I

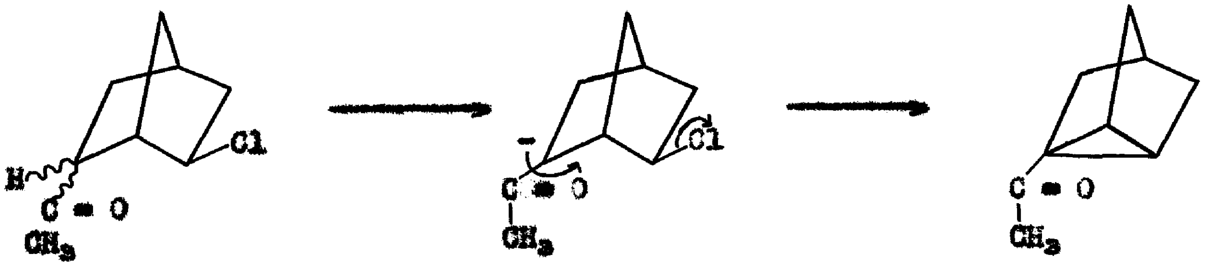


This carbonium ion can proceed directly to product (path a) or can first rearrange (path b), since both paths lead to the observed 2-chloro-6-acetylnorbornane of unspecified stereochemistry. Alternately, the acetylation can proceed through a "non-classical" carbonium ion (Chart II) of the general type often proposed in this system (5,24).

Chart II



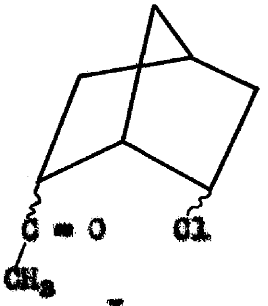
After initial attack by the acylonium ion on any one of the equivalent three-membered ring carbons, attack by the aluminum tetrachloride ion on one of the two remaining carbon atoms would lead to the observed product, with *exo* configuration of the chlorine. The *exo* configuration is in agreement with the observed facile dehydrohalogenation of the chloroketone to 1-acetylnortricyclene.



After removal of the α-hydrogen under dehydrohalogenation conditions as a proton, the *exo* chlorine is the correct configuration to be displaced by the electron pair of the carbanion. It is not possible to distinguish between these mechanisms with the information available at this writing.

II. Structure of the Chloroketone from the Acetylation of Nortricyclene

The chloroketone from the acetylation of nortricyclene was obtained, though never pure (indicated by a 5.95 μ shoulder on the 5.85 μ carbonyl band, and by the low chlorine analysis), by a careful, rapid distillation at a pressure less than 1 mm. That this ketone is a 2-chloro-6-acetylnorbornane (I)



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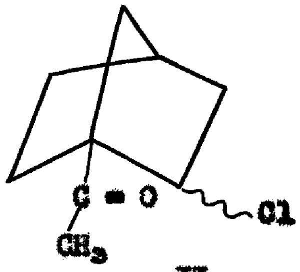
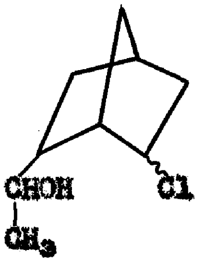


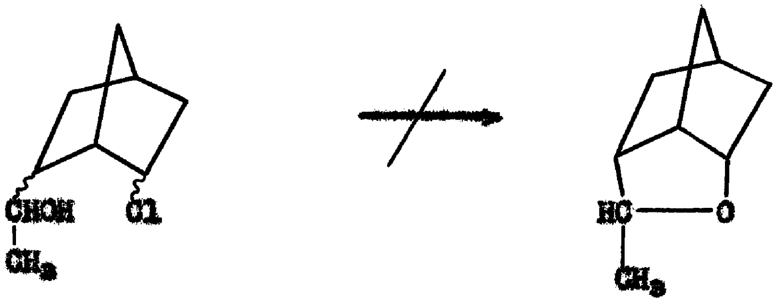
II

rather than a 1-acetyl-2-chloronorbornane (II), is apparent from its facile dehydrohalogenation to 1-acetylnortricyclene. It was possible to convert the chloroketone to the corresponding chlorohydrin (III) with lithium aluminum hydride,



with only partial dehydrohalogenation to 1-(1-hydroxyethyl)nortricyclene.

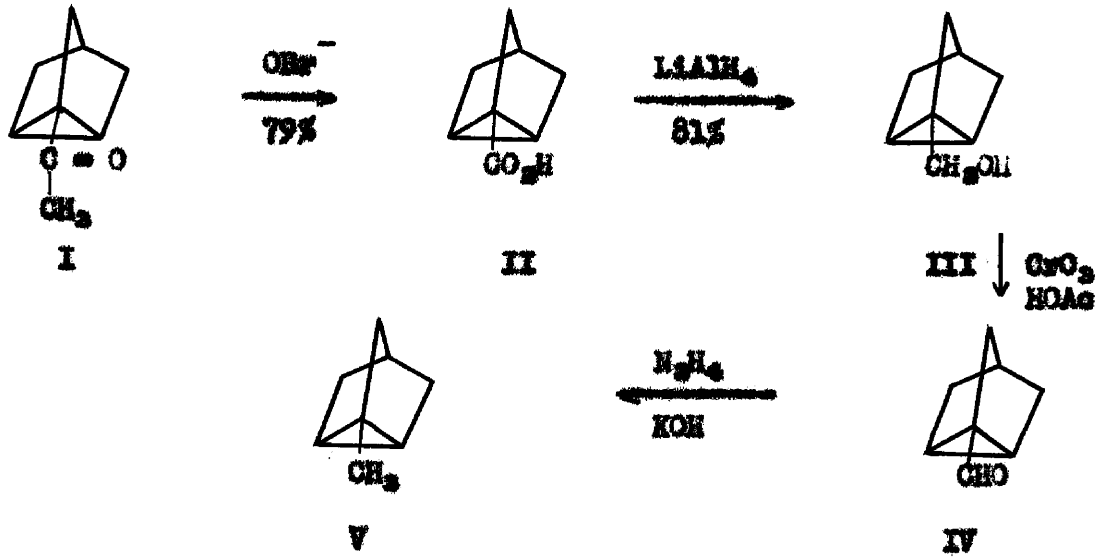
Several experiments, including refluxing the chlorohydrin in an ether suspension of powdered potassium hydroxide, designed to convert the chlorohydrin to the corresponding tetrahydrofuran were unsuccessful, indicating, perhaps, that



the acetyl group in the chloroketone is predominantly *exo*.

III. Proof of Structure of 1-Acetylnortricyclene

The absence of a carbon-carbon double bond in the infrared spectrum of the dehydrohalogenated ketone from the acetylation of nortricyclene, together with cyclopropyl carbon-hydrogen stretch bands at 3.26 μ (25,26), and 1.666 μ (27) and a carbonyl absorption at 5.95 μ indicated a cyclopropyl ring conjugated with a carbonyl group. The 2,4-dinitrophenylhydrazone, obtained either as red plates or orange needles, had a λ max. at 378 mμ (log ε, 4.36), also characteristic of cyclopropyl conjugation (28,29). The structure was proved chemically by conversion to the known 1-methylnortricyclene (Chart I).



Sodium hypobromite oxidation of 1-acetylnortricyclene (I) afforded 1-carboxynortricyclene (II) (m.p. 119-120°) in 79% yield. This acid was different from the only other known nortricyclenecarboxylic acid, the 3-isomer, m.p. 49-50°, prepared according to Roberts and co-workers (5). Lithium aluminum hydride reduction of 1-carboxynortricyclene gave 1-hydroxymethylnortricyclene (III) in 81% yield. Attempts to reduce the tosylate of this alcohol with lithium aluminum hydride resulted only in the recovery of the starting alcohol. The conversion to 1-methylnortricyclene was then accomplished by oxidation to 1-formylnortricyclene (IV) (carbonyl absorption at 5.95 μ, red 2,4-dinitrophenylhydrazone) which was not isolated pure, but converted by a Wolff-Kishner reduction to the hydrocarbon. The 1-methylnortricyclene obtained in this way was purified by vapor chromatography (silicone column), and had a retention time and infrared spectrum identical with an authentic sample, except for a band at 12.53 μ previously attributed to an impurity in the authentic material, and absent in the material from the Wolff-Kishner reaction.

IV. Infrared and Near-Infrared Spectra of Nortricyclenes

A. Infrared Spectra

Nortricyclene itself and several 3-substituted nortricyclenes absorb in the 12.4-12.5 μ region. Lippincott (30) in his careful infrared and Raman work on the structure of nortricyclene, attributed this band (doublet in the 3-substituted nortricyclenes) to a doubly-degenerate cage-breathing frequency. Another correlation at about 11.7 μ has been [illegible] in an early application of infrared techniques, used a band at 11.83 μ'

in an early application of infrared techniques, used a band at 11.83 μ

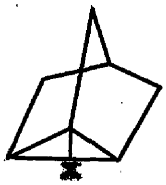
to follow the catalytic isomerization of camphene (I) to tricyclene (II) (32).

I II

Schleyer and O'Connor (33) have pointed out that a band in the 11.7 μ region is characteristic of 1-substituted nortricyclenes, and that there is no peak of significant intensity in any nortricyclene which does not possess this structural feature. All of the 1-substituted nortricyclenes investigated in the present work were found to have bands in the 11.7 μ region and in the 12.7 μ region (Table I). The band at 12.75 μ ± .06 μ is quite constant and independent of the 1-substituent. This band varies widely (12.1-12.7μ) in position, when the 1-substituent is maintained

TABLE I

CHARACTERISTIC INFRARED ABSORPTION OF SOME 1-SUBSTITUTED NORTRICYCLENES



X =	11.7μ Region	12.7μ Region
$-COCH_3$	11.77	12.72
$-C(NOH)CH_3$	11.85	12.70
$-CH(OH)CH_3$	11.94	12.73
$-CO_2H$	11.60	12.74
$-CONH_2$	11.65	12.70
$-CH_2OH$	11.78	12.74
$-CH_2OCONHC_6H_5$	11.74	12.75
$-CH_2NH_3^+Cl^-$	11.74	12.75
$-CH_3$	11.77	12.74
$-OCOCH_3$	11.82	12.81
$-NH_3^+Cl^-$	11.72	12.78
$-CH_2OCOCH_3$	11.73	12.73

constant (methyl) and other groups are placed elsewhere (especially in the 3-position) on the nortricyclene ring system (33). It would seem, then, that the band in the 12.7 μ region is particularly characteristic for a 1-substituted nortricyclene which is otherwise unsubstituted.

The band in the 11.7 μ region is somewhat more intense and is a bit more variable (11.60-11.95 μ) when the 1-substituent is varied, but remains constant at about 11.75 μ when the 1-substituent is constant (methyl) (33). Its position is relatively independent of groups in the 3-position of the nortricyclene ring system. In summary, both bands seem characteristic of nortricyclenes substituted on the cyclopropane ring; the 11.7 μ region band is relatively independent of other substituents, but varies somewhat in position depending upon the nature of the 1-substituent, whereas the 12.7 μ region band is quite constant for nortricyclenes substituted *only* on the cyclopropane ring, but is quite variable when substituents are placed in the 3-position on the nortricyclene ring system. In closing this discussion it should be pointed out that only nortricyclenes monosubstituted on the three-membered ring have been examined. It is quite possible that multiple substitution on the cyclopropane ring may alter these correlations.

B. Near-Infrared Spectra

Cyclopropyl compounds exhibit a fundamental carbon-hydrogen stretching frequency at about 3.25 μ (25,26). Two bands in the near infrared at 1.63-1.65 and at 2.24 μ have been considered characteristic of cyclopropyl compounds, when the presence of terminal methylene groups which also absorb in this region, can be excluded (27). The first of these bands (1.63-1.65 µ) has been attributed to an overtone of the cyclopropyl carbon-hydrogen stretching frequency, while the second band (2.24 µ) apparently is a combination band.

Nortricyclene may be considered as a 1,2,3-trisubstituted cyclopropane. All of the compounds examined in the present work exhibited the fundamental carbon-hydrogen stretching frequency from 3.24 to 3.26 µ (25,26). The near-infrared spectra contain two regions of interest for correlation of bands arising from carbon-hydrogen stretching frequencies; the first overtone region from about 1.65 to 1.75 µ and the second overtone region from 1.10 to 1.20 µ (Table II). In the first overtone region the band from 1.66 to 1.67 µ seems to be characteristic of the three-membered ring in nortricyclenes. Its position is such that a strong contribution must come from a fundamental carbon-hydrogen stretching frequency of 3.3 µ or less (34), and it diminishes in intensity by about one-third when the three-membered ring is substituted. This band is probably an overtone of the 3.24-3.26 µ fundamental. In the second overtone region the band from 1.14 to 1.15 µ also appears to be characteristic of cyclopropane ring in nortricyclene, its intensity diminishing upon substitution in the 1-position.

It should be pointed out that these correlations for nortricyclene are applicable only in the absence of carbon-carbon double bonds. Norbornene and norbornadiene, for instance, both exhibit bands in the 1.66-1.67 and 1.14-1.15 µ regions. Fortunately, the presence of carbon-carbon double bonds can usually be established by examination of the 2-15 µ region.

TABLE II

CHARACTERISTIC NEAR-INFRARED ABSORPTION OF SUBSTITUTED NORTRICYCLENES

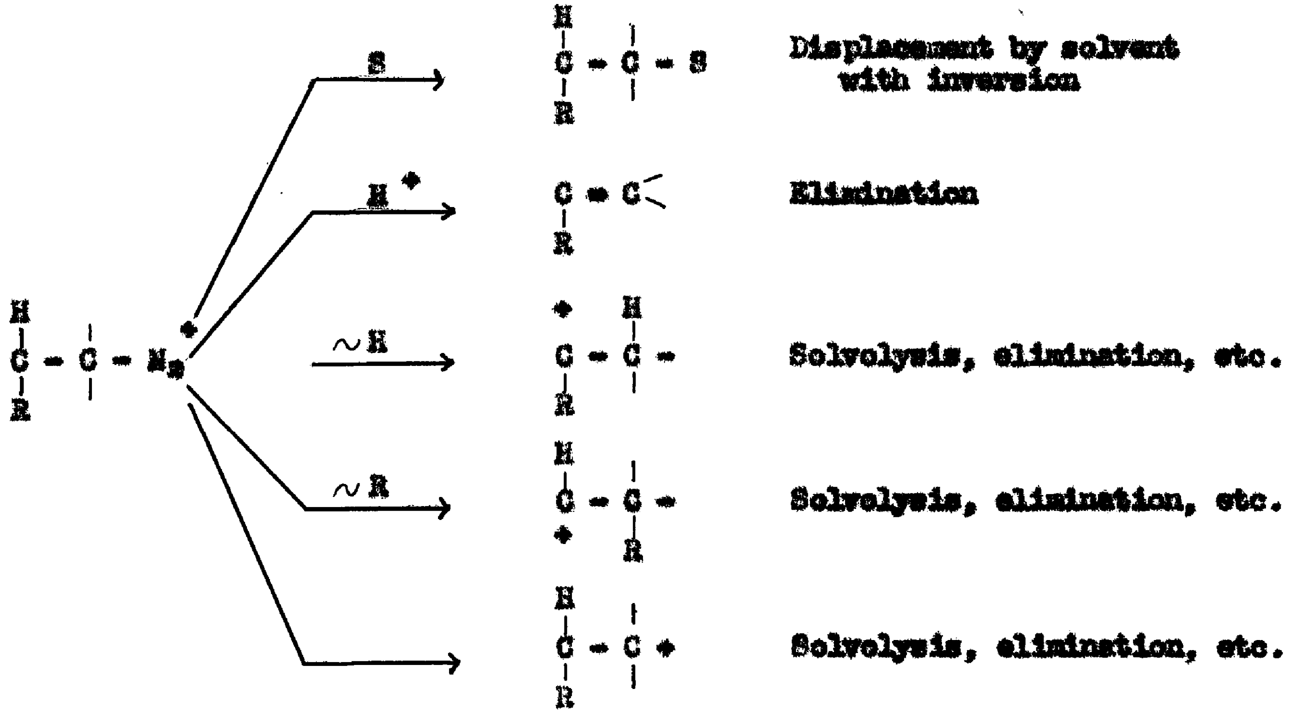
Substituent	1.66 µ Region	1.14 µ Region
	<u>1-Substituted Compounds</u>	
$-COCH_3$	1.668	1.146
$-C(NOH)CH_3$	1.672	1.148
$-CH(OH)CH_3$	1.675	1.149
$-CO_2H$	1.662	1.146
$-CH_2OH$	1.674	1.151
$-OCOCH_3$	1.668	1.147
$-CH_2OCOCH_3$	1.672	1.149
	<u>Compounds Not Substituted on the Cyclopropane Ring</u>	
Nortricyclene	1.673	1.149
3-Carboxy-nortricyclene	1.668	1.149
3-Chloro-5-acetylnortricyclene	1.666	1.143

V. Amine Reactions with Nitrous Acid

A. General

The reaction of aliphatic and alicyclic amines with nitrous acid has long been known to yield a variety of products. The mechanism usually given for the reaction (35,36) proposes that the diazonium ion which is first formed decomposes with loss of nitrogen to a carbonium ion which can subsequently react with solvent, eliminate a proton, or rearrange to account for the products most frequently found in this type of reaction. A competing direct displacement (S_N2 type) of the diazonium salt by solvent accounts for partial inversion observed in the case of optically active amines (37).

Streitwieser (38) has proposed that the diazonium ion, rather than the carbonium ion, is the "branching point" of the competing reactions. The diazonium ion could then react according to the following scheme.



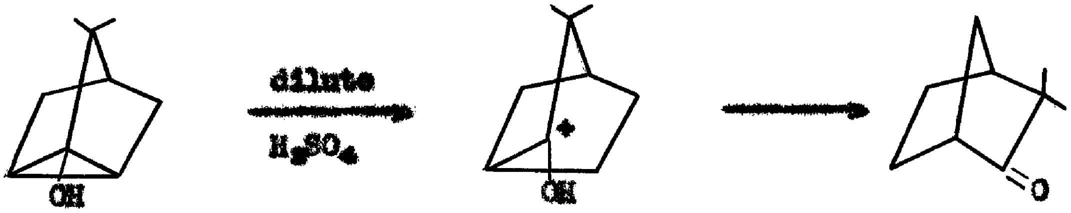
This proposal offers an attractive explanation for many of the reactions found in the literature that are difficultly explainable by a "free" carbonium ion intermediate.

B. The Hydrochloride of 1-Aminonortricyclene

Lipp and Padberg have reported (11) that apotricyclylamine hydrochloride (I), when treated with sodium nitrite and dilute hydrochloric acid, afforded a 50-55% yield of apotricyclol (II).

I　　　　II

The structure of the apotricyclol was inferred from its ready conversion to the known camphenilone (III).



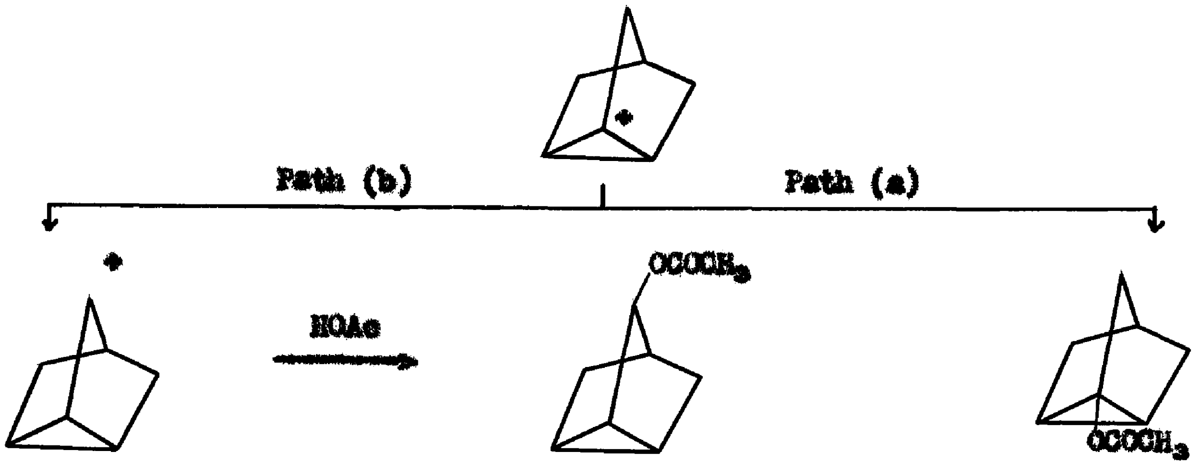
III

No other products were reported.

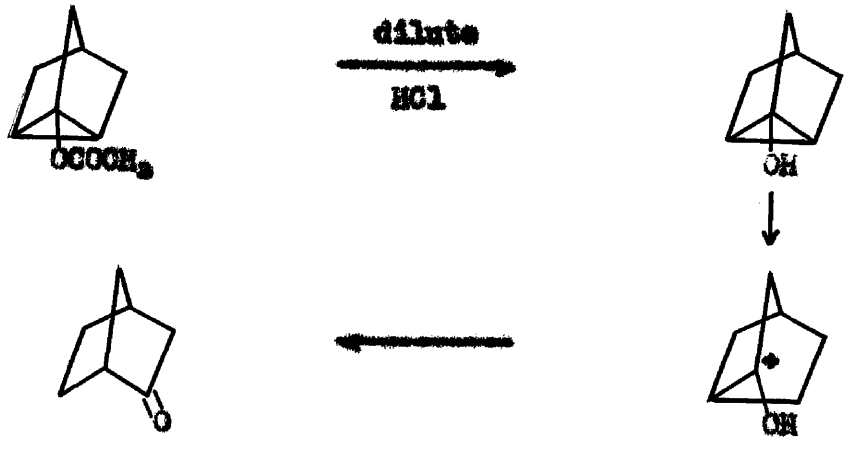
In the present work, the nitrous acid deamination reaction of the analogous hydrochloride of 1-aminonortricyclene was run in glacial acetic acid (yielding acetates) rather than in dilute aqueous media (which would give the corresponding alcohols) for two main reasons. First, Lipp and Padberg reported that apotricyclol (II) was unstable in air and could be kept at room temperature only under an atmosphere of hydrogen. There is no a priori reason to expect any 1-hydroxynortricyclene formed from 1-aminonortricyclene to be any more stable, since the structures differ only in that apotricyclol contains a gem-dimethyl group on the 7-carbon. Secondly, the acetates from this reaction would be expected to have lower boiling points and viscosities than the corresponding alcohols, facilitating use of sensitive vapor chromatographic analytical and preparative techniques.

When the hydrochloride of 1-aminonortricyclene was treated in glacial acetic acid with sodium nitrite, only one acetate, as shown by a single peak on the vapor chromatograph, was obtained. The infrared spectrum of this material had a carbon-hydrogen stretch band at 3.25 μ (25,26) and no carbon-carbon double bond stretching band in the 6.0-6.3 μ region. This infrared evidence indicates a nortricyclene structure. If a carbonium ion were formed in this reaction, although expected to be highly strained due to its bridgehead location and its position on a three-membered ring, it could lead to two nortricyclyl acetates (Chart I).

Chart I

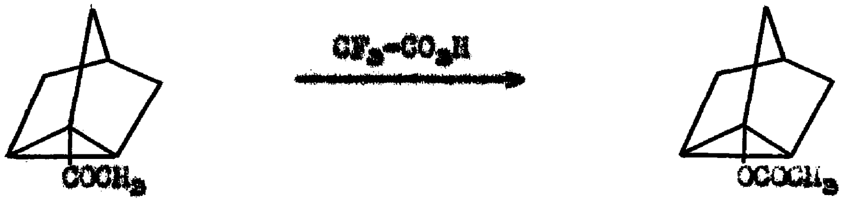


Path (a) involves an attack on the carbonium ion by an acetic acid molecule to lead to 1-acetoxynortricyclene. Path (b) leads first to a considerably less strained carbonium ion and then to 3-acetoxynortricyclene. Comparison of the infrared spectrum of authentic 3-acetoxynortricyclene with the unknown acetate offered conclusive proof that the acetate in question was not 3-acetoxynortricyclene. That this acetate was 1-acetoxynortricyclene was shown both by degradation and by synthesis. By refluxing the acetate in dilute hydrochloric acid and allowing the solid thus produced to react with 2,4-dinitrophenylhydrazine, a 2,4-dinitrophenylhydrazone, m.p. 129-130°, was formed. This experiment is analogous to Lipp and Padberg's conversion of apotricyclol (II) to camphenilone (III), and would be expected to result in norcamphor (IV).



IV

The 2,4-dinitrophenylhydrazone prepared from an authentic sample of norcamphor, m.p. 129-130.5°, did not depress the melting point of the sample from the hydrolysis of 1-acetoxynortricyclene. A sample of authentic 1-acetoxynortricyclene (VI) was synthesized by the Baeyer-Villiger (15) reaction of 1-acetylnortricyclene (V).



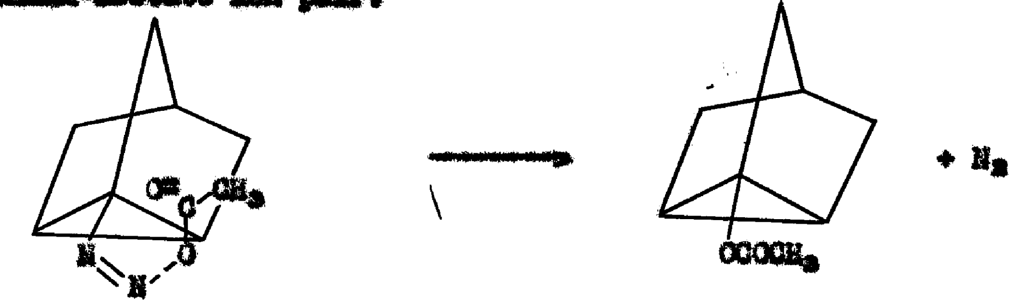
V

VI

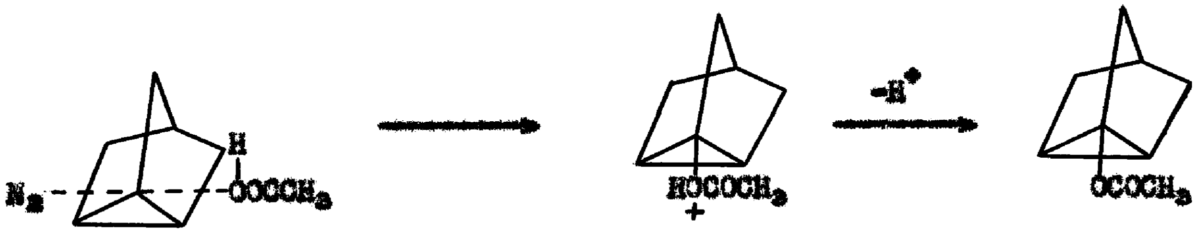
The infrared spectrum of material synthesized in this manner was identical with the acetate from the nitrous acid reaction.

Considering the evidence available, both from the strain expected and the fact the no 3-acetoxynortricyclene is formed, it is doubtful that a free carbonium ion is actually produced during the reaction.

A much more likely path is available directly through the diazonium ion. In this case the hydrogens on carbon seven of the nortricyclene molecule are in a *gauche* conformation relative to the diazo linkage. Because of the rigidity of the tricyclic system they could not assume the planarity necessary for displacement of nitrogen from the diazonium salt to form the carbonium ion leading to 3-acetoxynortricyclene. The 1-acetoxynortricyclene formed in this reaction could arise from the breakdown of a diazonium-acetate ion pair.



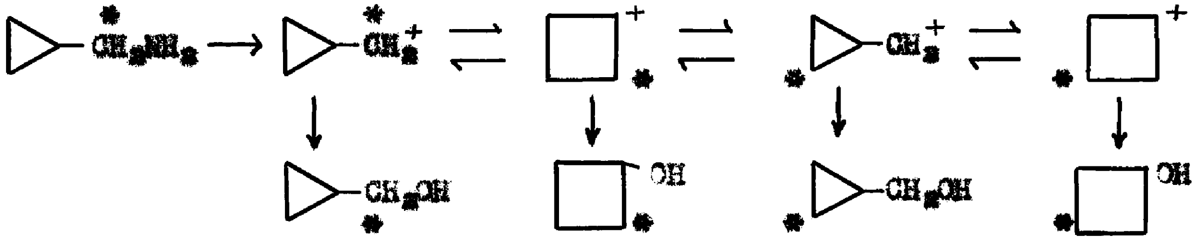
The possibility of breakdown of this general type has been suggested for deamination reactions in non-polar solvents (38). Another, though perhaps unlikely, possibility for the formation of the 1-ester is the direct displacement of nitrogen by an acetic acid molecule.



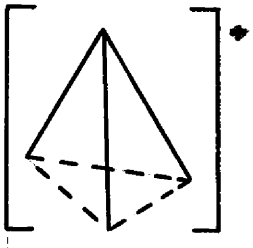
Such an attack would presumably come from the "side" or "front."

C. The Hydrochloride of 1-Aminomethylnortricyclene

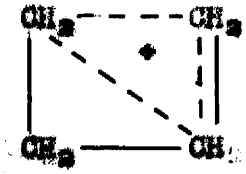
Roberts and his students (39) have reported that the reaction of cyclopropylcarbinylamine with nitrous acid leads to a mixture of 56% cyclopropylcarbinol, 40% cyclobutanol, and 4% allylcarbinol. Cyclobutylamine leads to a similar mixture composed of 51% cyclopropylcarbinol, 45% cyclobutanol, and 4% allylcarbinol. When cyclopropylcarbinylamine labeled with C^{14} at the carbon carrying the amine group was treated with nitrous acid, the resulting cyclopropylcarbinol had 53.2% of the label at the carbon carrying the alcohol group, 48.3% at the two equivalent methylene carbons, and no C^{14} at the tertiary carbon. The cyclobutanol obtained had 21% of the C^{14} at C_3, 71.6% at C_2 and C_4, and no C^{14} at C_1. Several suggestions have been made to account for these results. A sequence of equilibrating "classical" carbonium ions



could account for the isotopic tracer results, but does not account for the ease of interconversion of the ions nor for the abnormal solvolytic reactivities of the corresponding chlorides (cyclopropylcarbinylchloride 63, cyclobutylchloride 3, and allylcarbinylchloride 0.005, all in 50% ethanol), reactions which lead to approximately the same mixture of alcohols. Another possible intermediate is the "nonclassical" tricyclobutonium ion

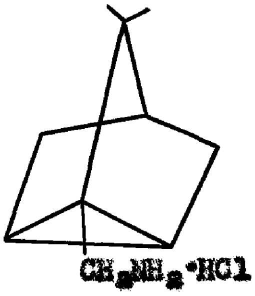


but if this were the sole intermediate, complete equivalence of the methylene carbons in the cyclobutanol and cyclopropylcarbinol would be required. Since this is not observed, other intermediates must be operative. A third suggestion involves a series of equilibria between "nonclassical" bicyclobutonium ions of the type



which can account for the C^{14} scrambling and gives some justification for the accelerated solvolysis rates.

Lipp reported (8) that Ω-aminotricyclene hydrochloride (I),



I

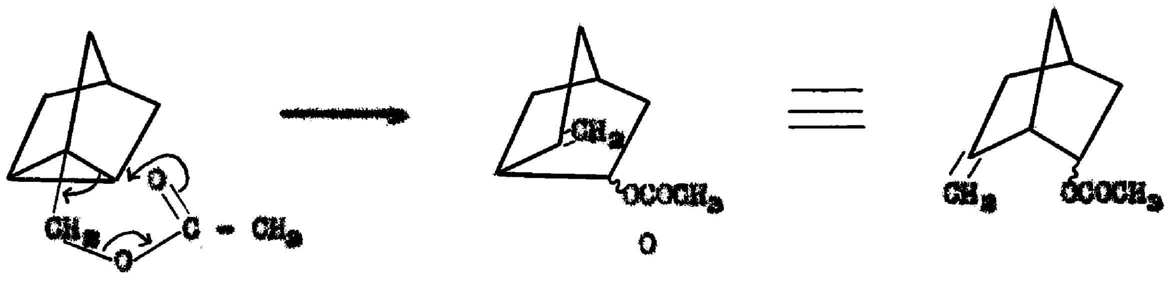
when treated in dilute hydrochloric acid with sodium nitrite gave an unknown mixture of products.

When the hydrochloride of 1-aminomethylnortricyclene (II),

II

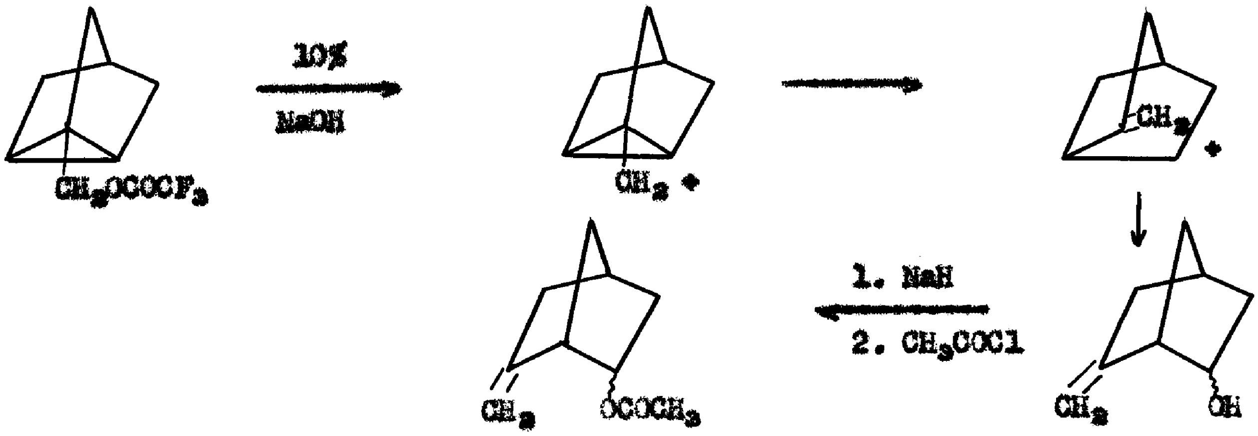
a compound analogous to Ω -aminotricyclene hydrochloride, was treated in glacial acetic acid with sodium nitrite, a mixture of acetates was obtained in 52% yield. The infrared spectrum of this material indicated that it was predominantly a 1-substituted nortricyclene (bands at 11.73 and 12.73 μ), probably 1-nortricyclylcarbinyl acetate. Smaller amounts of unsaturated material were also evident from carbon-carbon stretch bands at 5.97, 6.02 and 6.10 μ, a band at 8.90 μ, and a terminal methylene deformation band at 11.30 μ (41). Several attempts to analyse this mixture by vapor chromatography were unsuccessful. Complete separation of bands could not be achieved, and their relative intensities appeared to vary with differences in column temperature and carrier gas pressure. It seemed plausible that isomerisation of the mixture was taking place on the column, and to test this premise authentic 1-nortricyclylcarbinyl acetate was prepared and passed through a preparative scale vapor chromatographic column. The infrared spectrum of the resulting material had strong carbon-carbon double bond stretch bands at 5.97 and 6.02 μ and a very intense terminal methylene deformation band at

11.30 μ (41). The short wavelength of the carbon-carbon double bond stretch bands is indicative of an *exocyclic* double bond attached to a strained ring system (41) and the 11.30 μ band is very good evidence that this double bond incorporates a terminal methylene group. In all probability this acetate is 6-acetoxynorcamphene, perhaps formed by interaction of the acetate group with the three-membered nortricyclene ring.

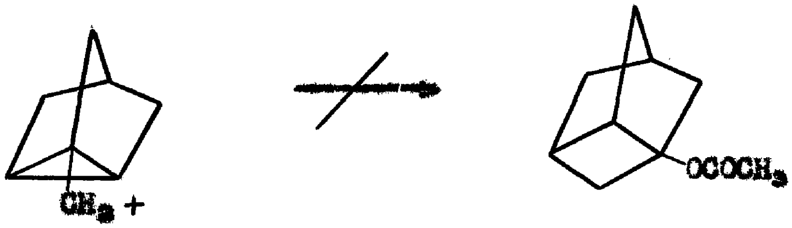


Further evidence for the structure of this acetate is afforded by synthesis of an apparently identical acetate from the alcohol obtained by the solvolysis of 1-nortricyclylcarbinyl trifluoroacetate (Chart II).

Chart II



Alkyl oxygen fission of the trifluoroacetate must occur leading to the carbonium ions indicated and subsequently to the rearranged alcohol. The infrared spectrum of this alcohol had carbon-carbon double bond stretch bands at 5.97 and 6.02 μ, and a terminal methylene deformation band at 11.30 μ. The acetate synthesized from this alcohol had an infrared spectrum identical with the acetate obtained by isomerization of 1-nortricyclylcarbinyl acetate, except for a very weak band around 12.7 μ in the latter material, probably due to a trace of unrearranged 1-nortricyclylcarbinyl acetate. Oxidation of the acetate mixture with cold dilute potassium permanganate solution resulted in an acetate the infrared spectrum of which was identical with authentic 1-nortricyclylcarbinyl acetate except for bands, much diminished in intensity when compared with starting material, attributable to traces of unsaturates. This rules out the possibility of any four-membered ring acetate, analogous to the formation of cyclobutanol from cyclopropylcarbinylamine, since it would be expected to survive these mild oxidation conditions.

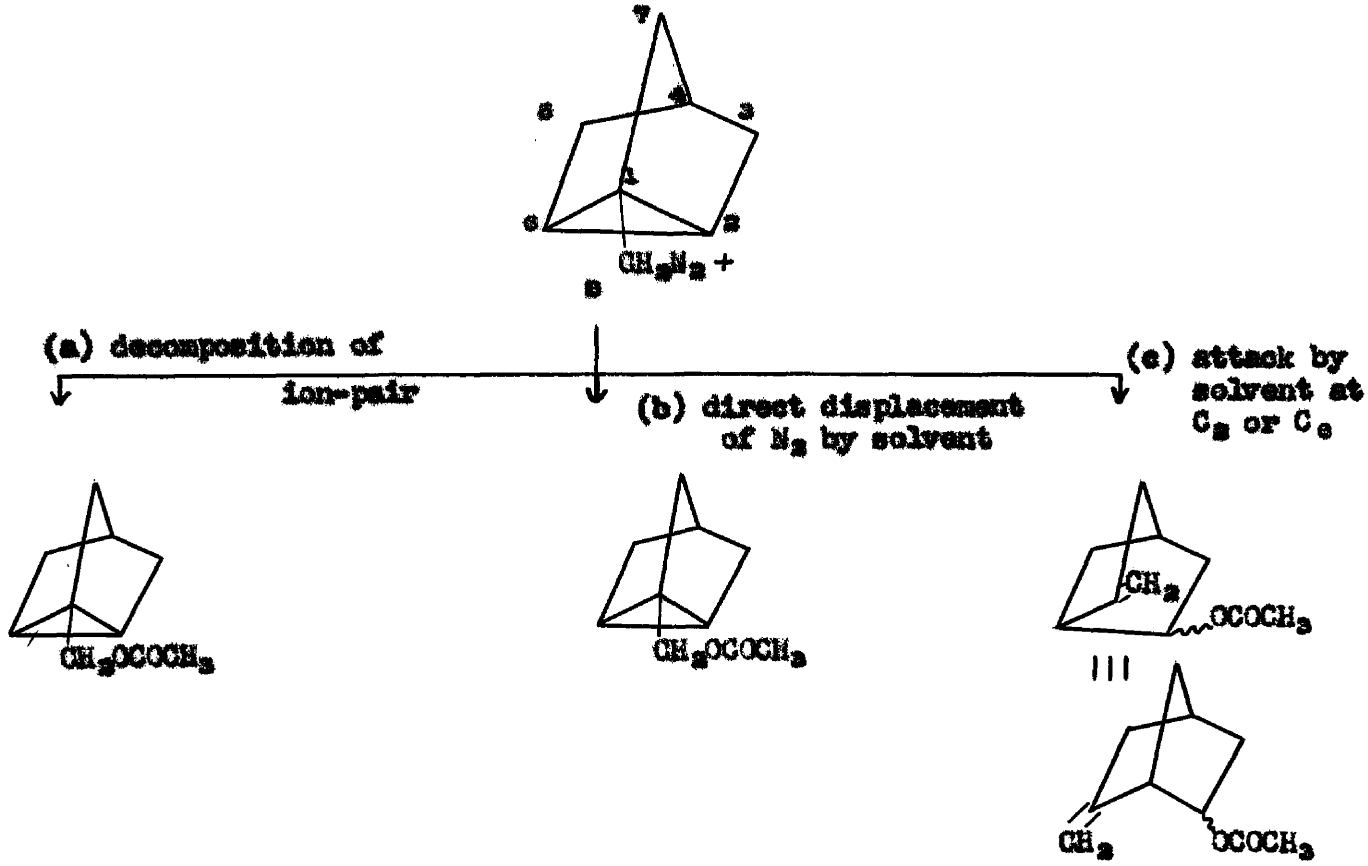


Titration with bromine in acetic acid (22) indicates the presence of unsaturates to the extent of 8.2-8.4% in the acetate mixture. That most of this unsaturated material (about 5% of the acetate mixture) was 6-acetoxynorcamphene was established by employing differential infrared techniques, using a known concentration of acetate mixture and an identical concentration of mixtures of authentic 1-nortricyclylcarbinyl acetate and 6-acetoxynorcamphene.

In summary, the nitrous acid reaction of the hydrochloride of 1-aminomethylnortricyclene leads to 91-92% of 1-nortricyclylcarbinyl acetate, the unrearranged acetate, about 5% of an unsaturated acetate, probably 6-acetoxynorcamphene, and less than 5% of an unknown unsaturated compound with infrared absorption bands at 6.10 and 8.90 μ.

The acetates observed in this deamination could arise directly from the diazonium salt (Chart III).

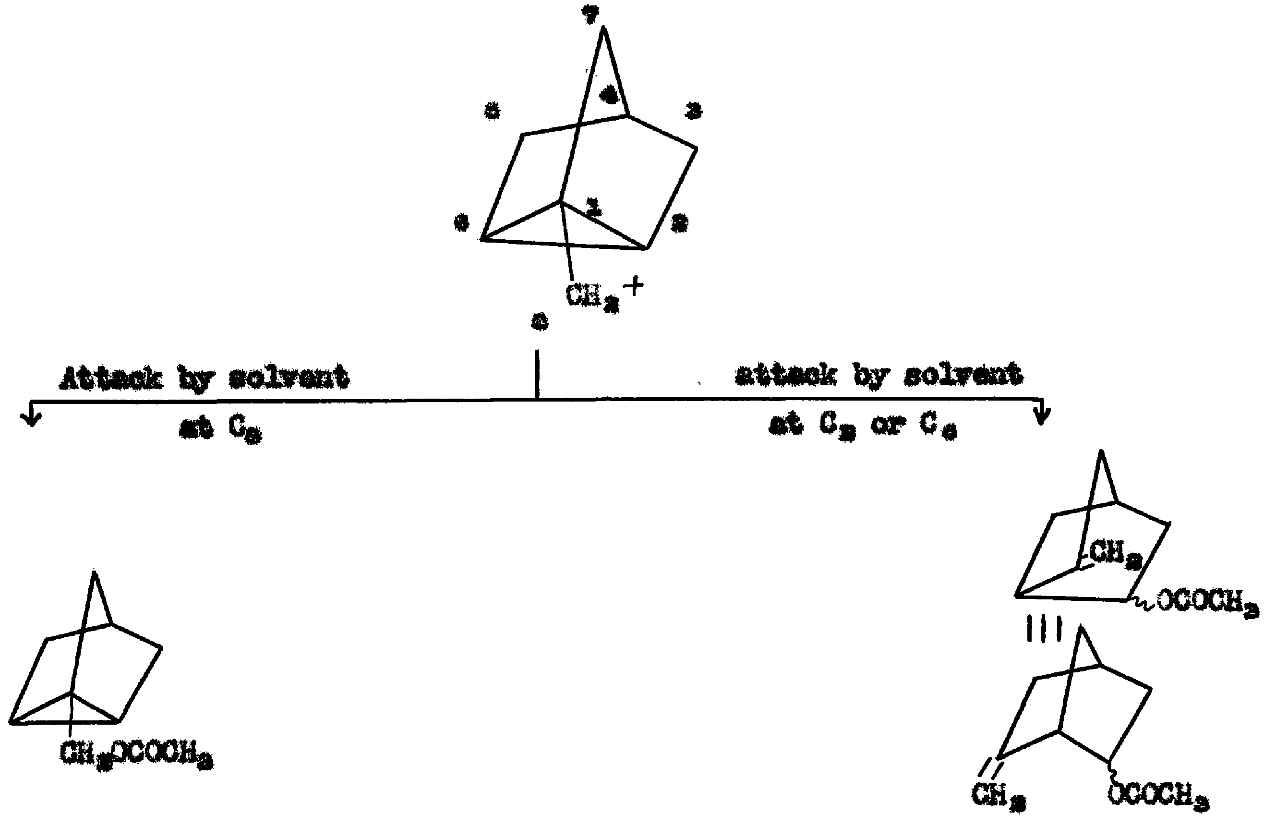
Chart III



Path (a) involves the breakdown of a diazonium-acetate ion-pair as has been suggested in the case of 1-aminonortricyclene. Path (b) is a direct displacement of nitrogen by solvent (S_N2 type) leading to unrearranged acetate. Path (c) involves a concerted attack by solvent at carbon 2 or 6 and elimination of nitrogen to form 6-acetoxynorcamphene.

Alternately, formation of the free carbonium ion could also lead to the observed products by routes similar to paths (a) and (c) described above (Chart IV).

Chart IV



It is not possible to decide from the facts available in the present work and in the literature whether the diazonium salt or the carbonium ion serves as the intermediate in this reaction. It is entirely possible that both species are present.

SUMMARY

1. Nortricyclene was shown to react with a 1:1 complex of acetyl chloride-aluminum chloride to give 69% of 2-chloro-6-acetylnorbornane. No other chloroketone was detected.

2. Dehydrohalogenation of 2-chloro-6-acetylnorbornane afforded a 40-50% yield of 1-acetylnortricyclene.

3. Several previously inaccessible 1-substituted nortricyclenes were prepared and their infrared and near-infrared spectra studied for possible correlations. All of the 1-substituted nortricyclenes examined in this work absorbed in the 11.7 and 12.7μ regions. The band at 12.75 ± 0.06μ was found to be particularly characteristic for nortricyclenes substituted only on the cyclopropane ring. The near-infrared spectra showed bands at 1.669 ± 0.007μ and 1.149 ± 0.003μ characteristic of the nortricyclene system.

4. The hydrochloride of 1-aminonortricyclene reacted with sodium nitrite in glacial acetic acid to give only 1-acetoxynortricyclene, obtained in 55% yield. The structure of this acetate was proved by degradation to norcamphor 2,4-dinitrophenylhydrazone and comparison of its melting point and mixed melting point with an authentic sample. Authentic 1-acetoxynortricyclene was synthesized by a Baeyer-Villiger reaction of 1-acetylnortricyclene.

5. The nitrous acid reaction of the hydrochloride of 1-aminomethylnortricyclene in glacial acetic acid gave a mixture of acetates obtained in 52% yield. The mixture was subsequently characterized by preparative and infrared techniques as being composed of 91-92% 1-nortricyclylcarbinyl acetate (the unrearranged acetate), about 5% of an acetate incorporating an exocyclic methylene group (probably 6-acetoxynorcamphene), and less than 5% of an unknown unsaturated acetate with infrared bands at 6.10 and 8.90 μ.

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APPENDIX

The infrared spectra appearing in the APPENDIX and in the EXPERIMENTAL were recorded on a Perkin-Elmer Model 21 spectrophotometer.

The near-infrared spectra were recorded on a Beckman Model DK-2 spectrophotometer.

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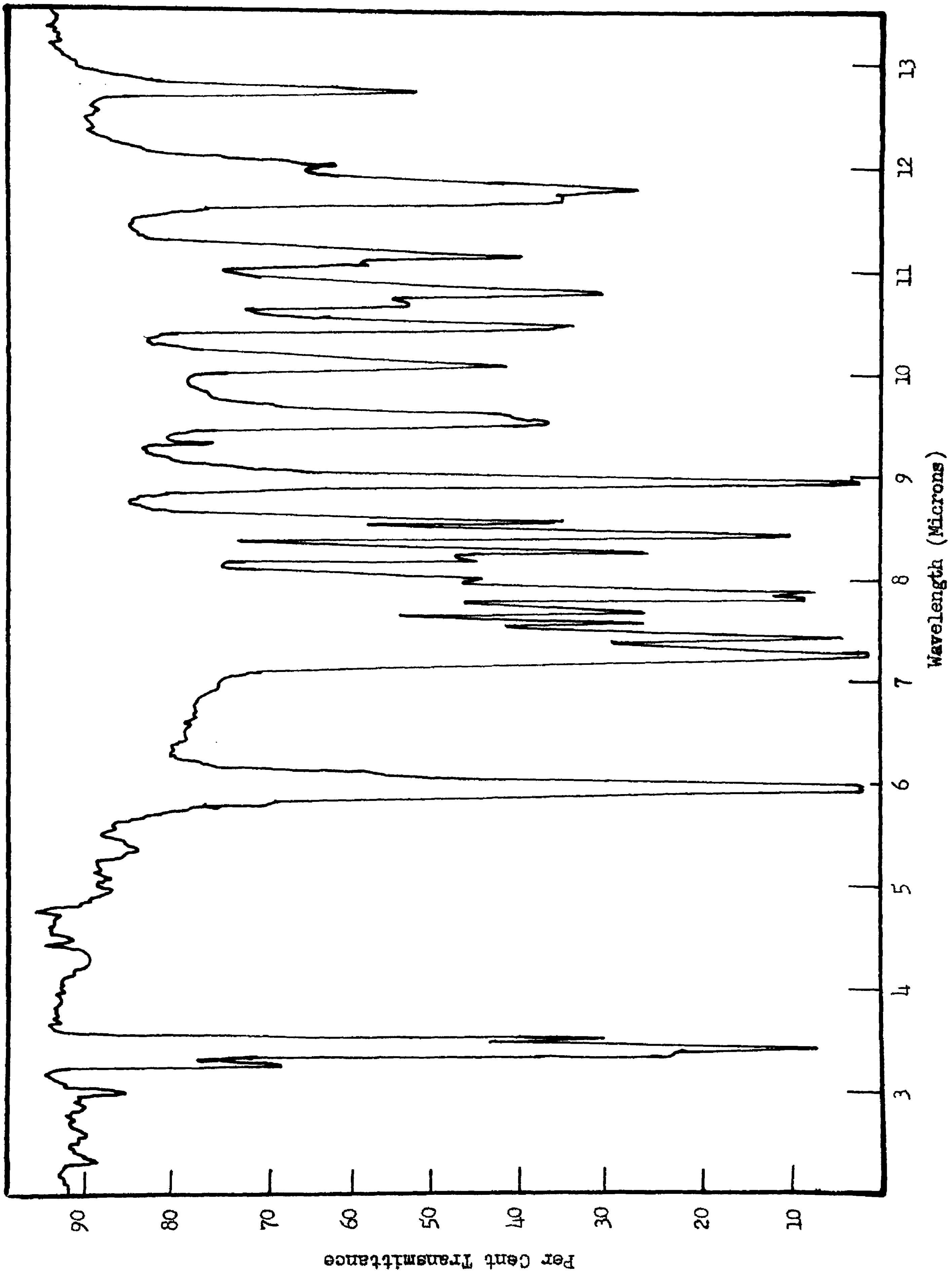
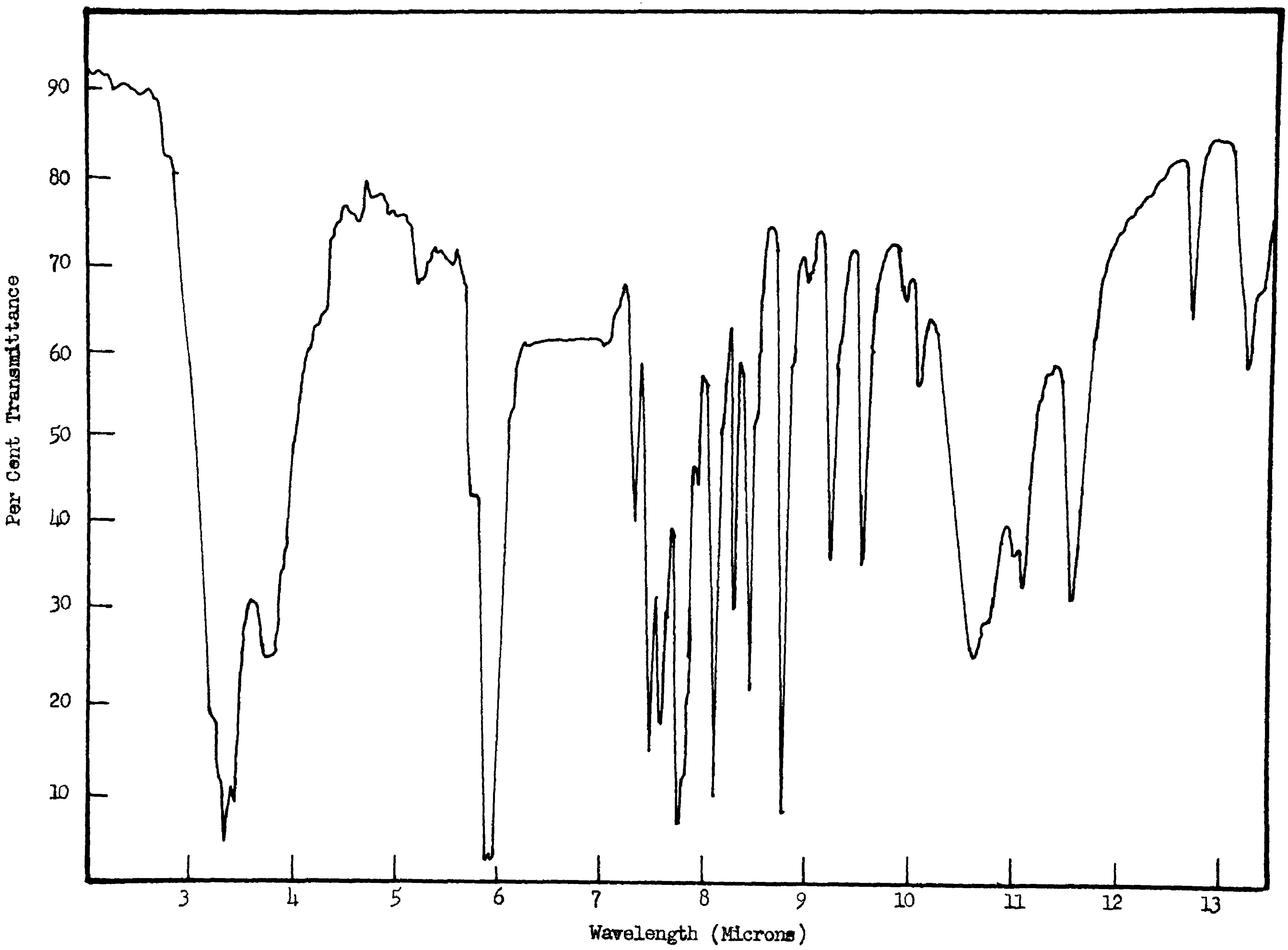
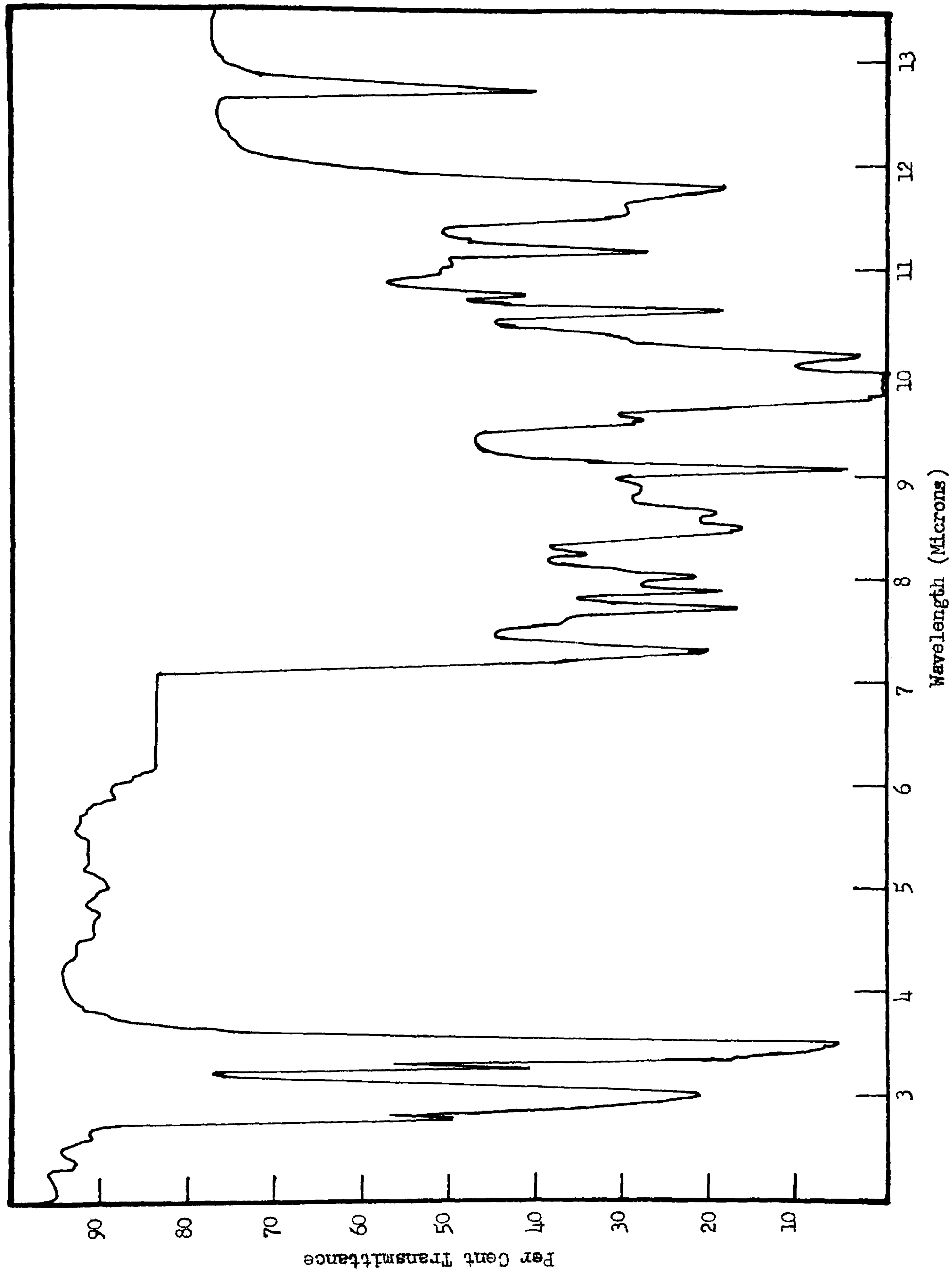
I. INFRARED SPECTRA



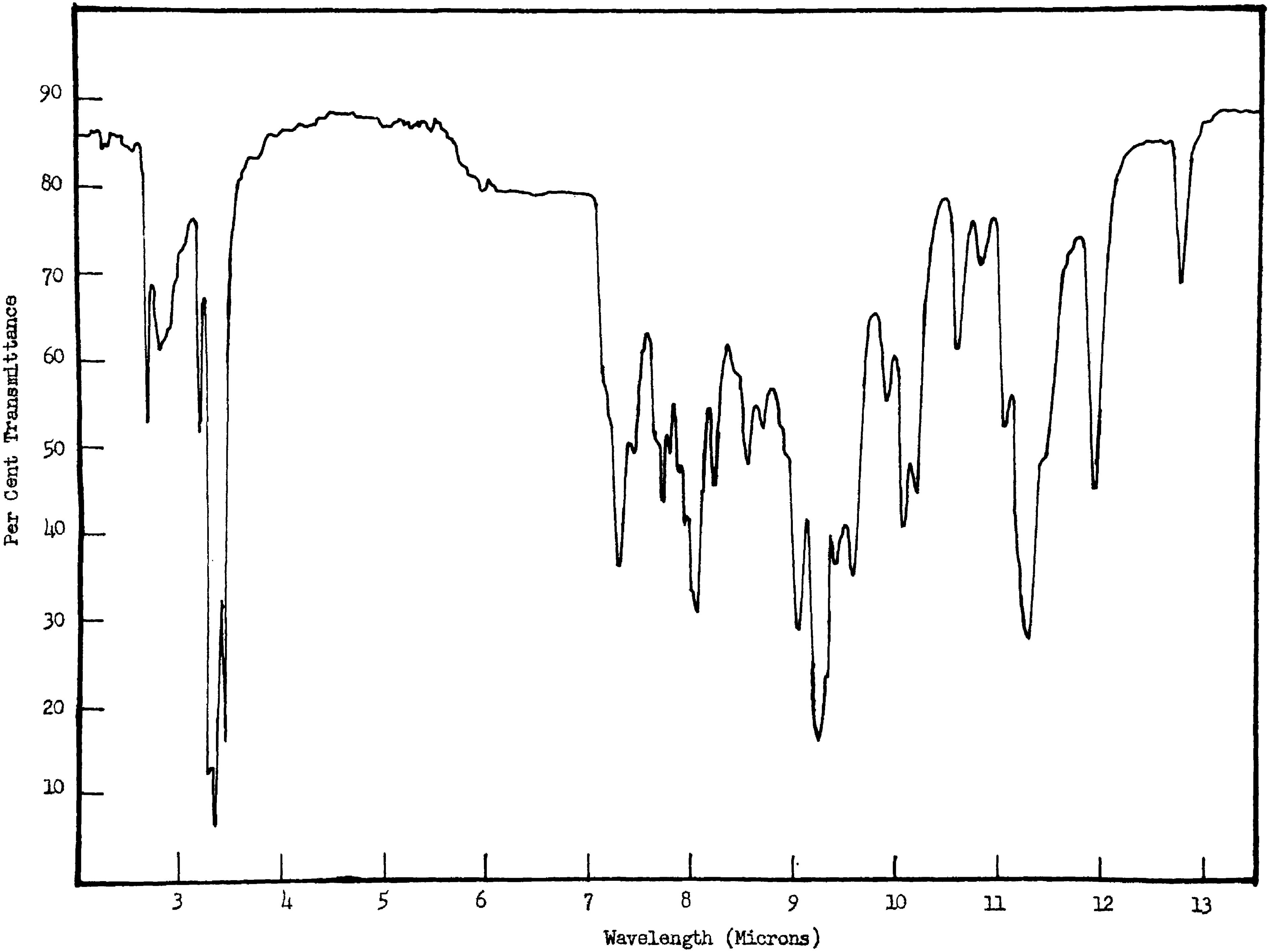
1-Acetylnortricyclene (CS$_2$)



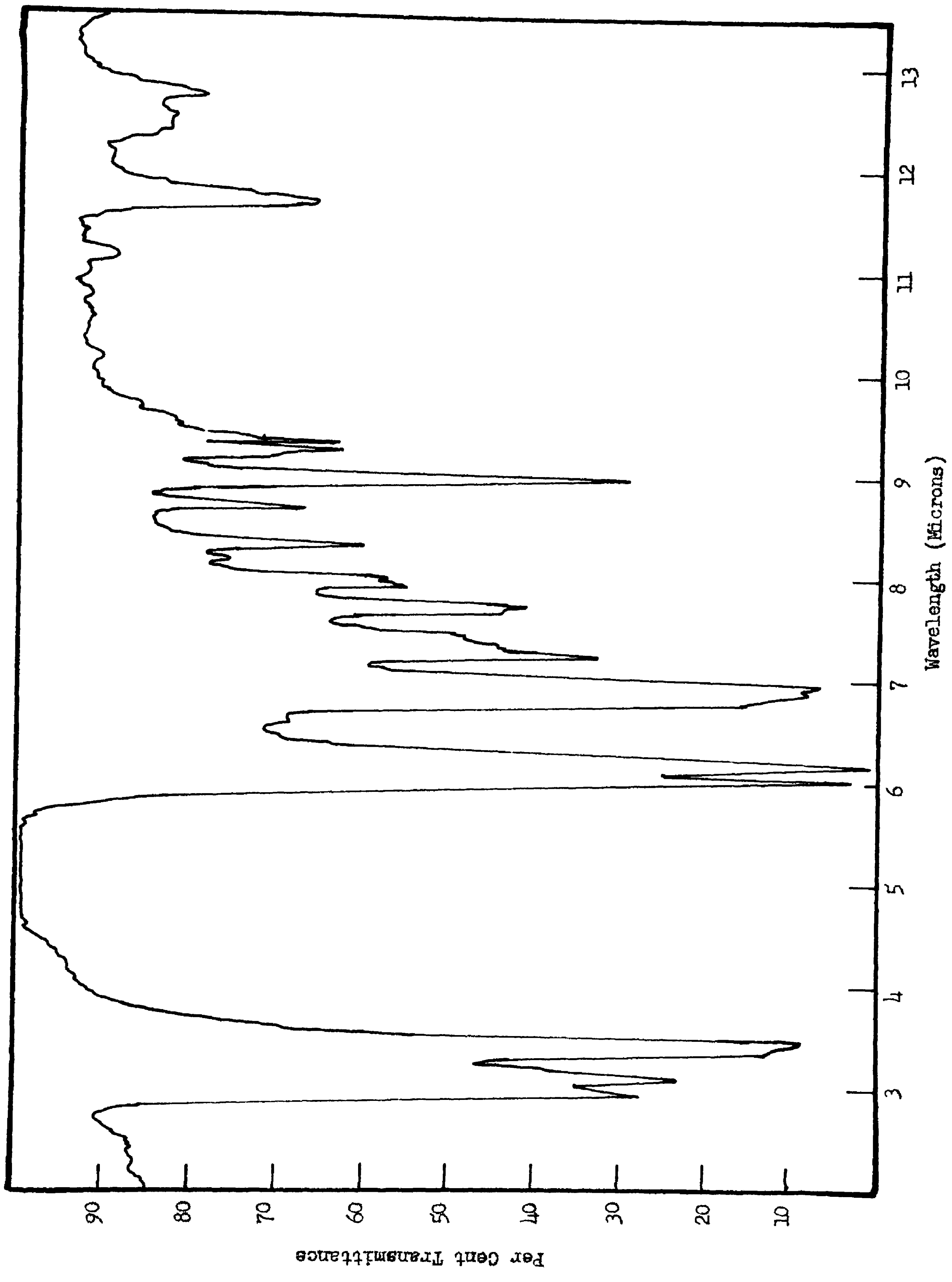
1-Nortricyclenecarboxylic acid (CS_2)



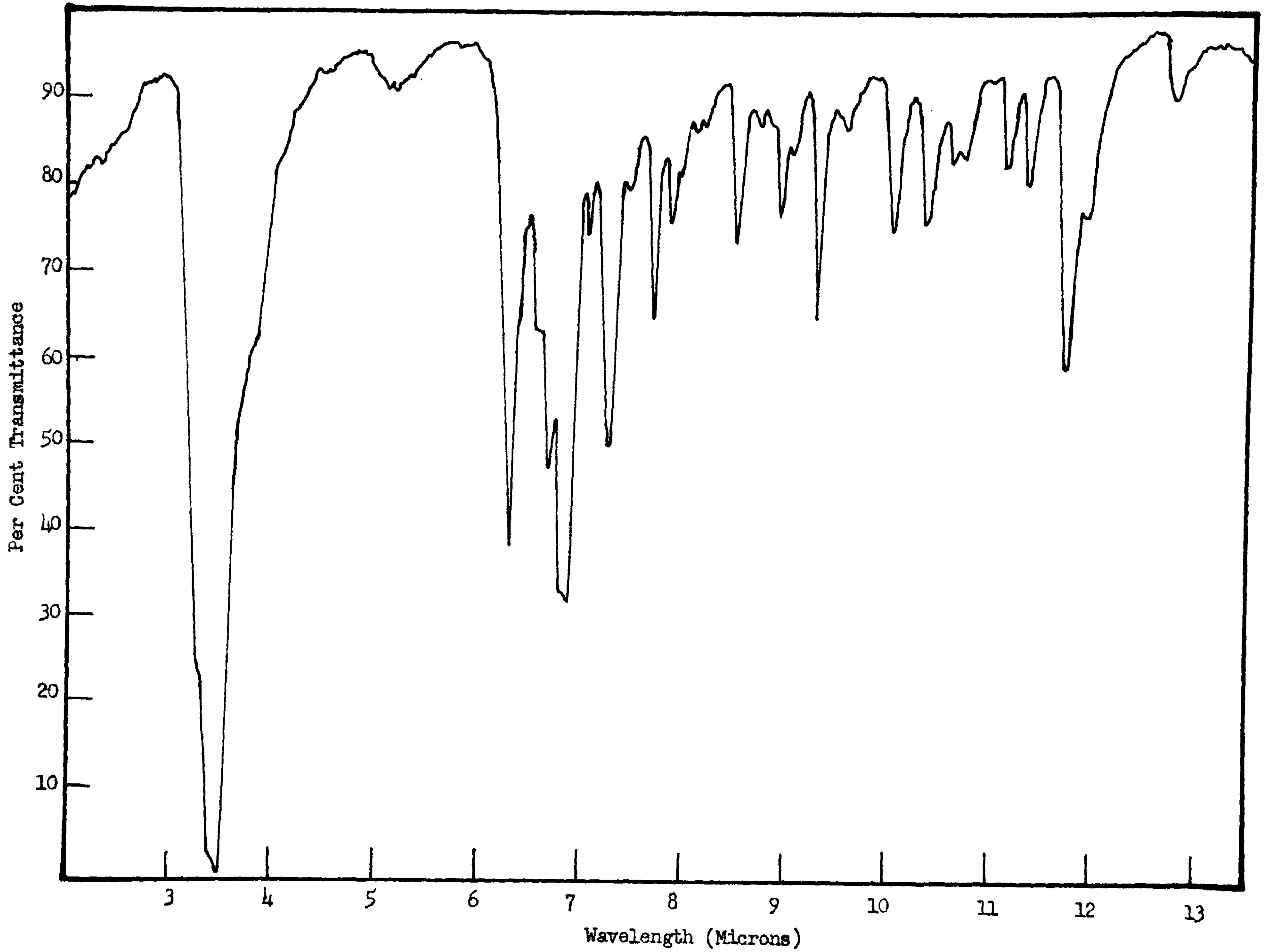
1-Hydroxymethylnortricyclene (CS_2)



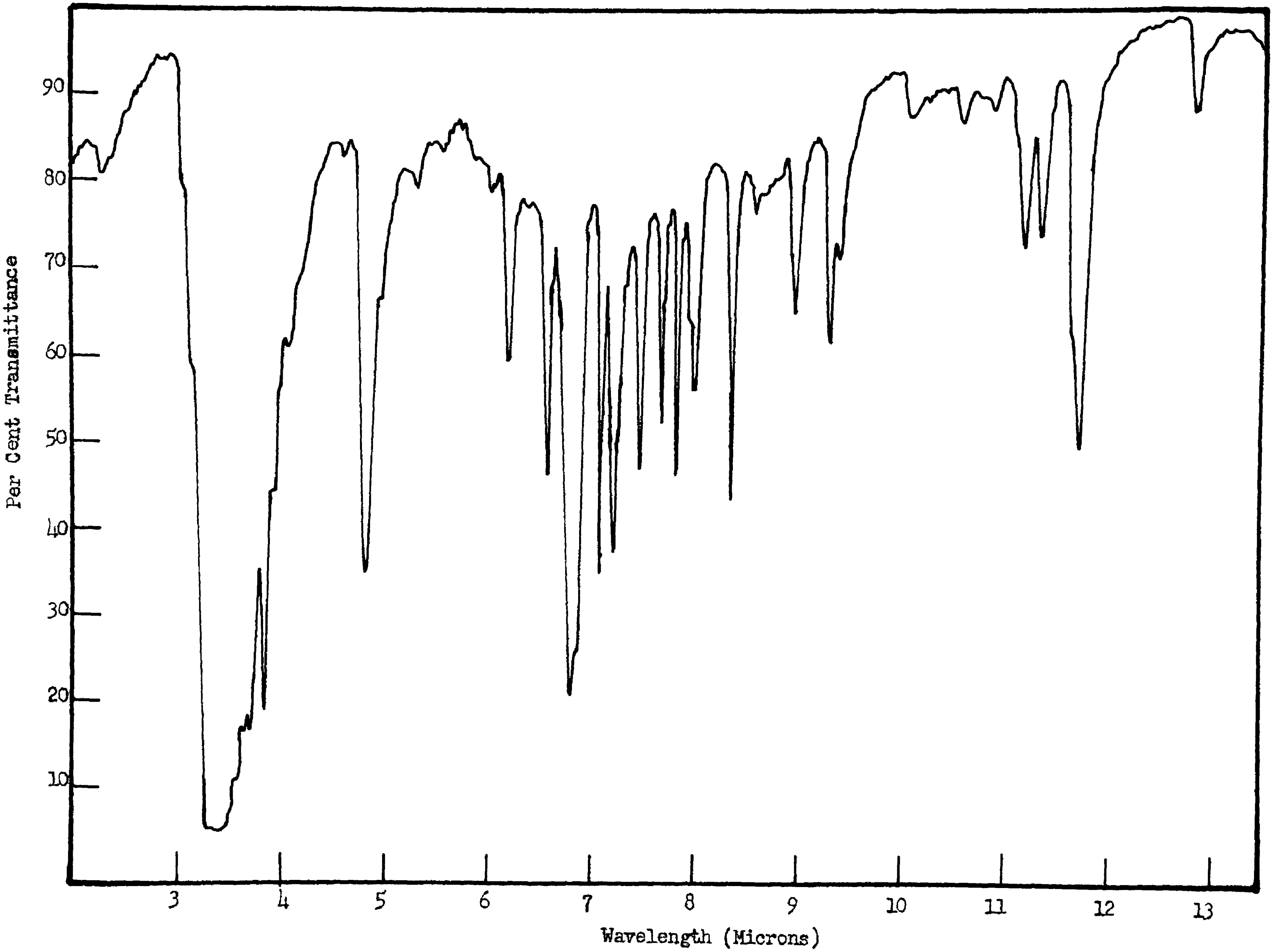
1-(1-Hydroxyethyl)nortricyclene (CS_2)



1-Nortricyclenecarboxamide ("Nujol" Mull)

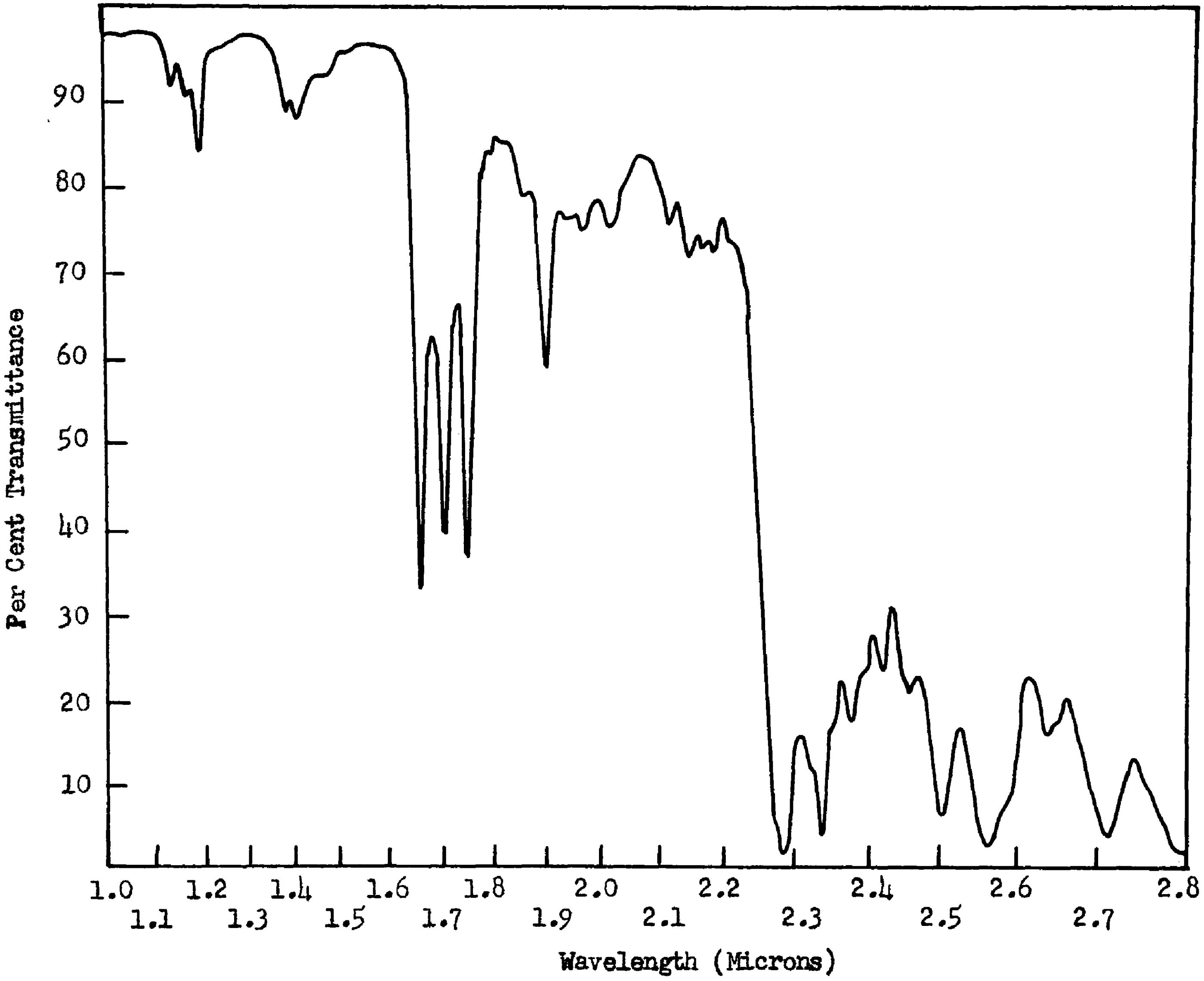


Hydrochloride of 1-Aminomethylnortricyclene ("Nujol" Mull)

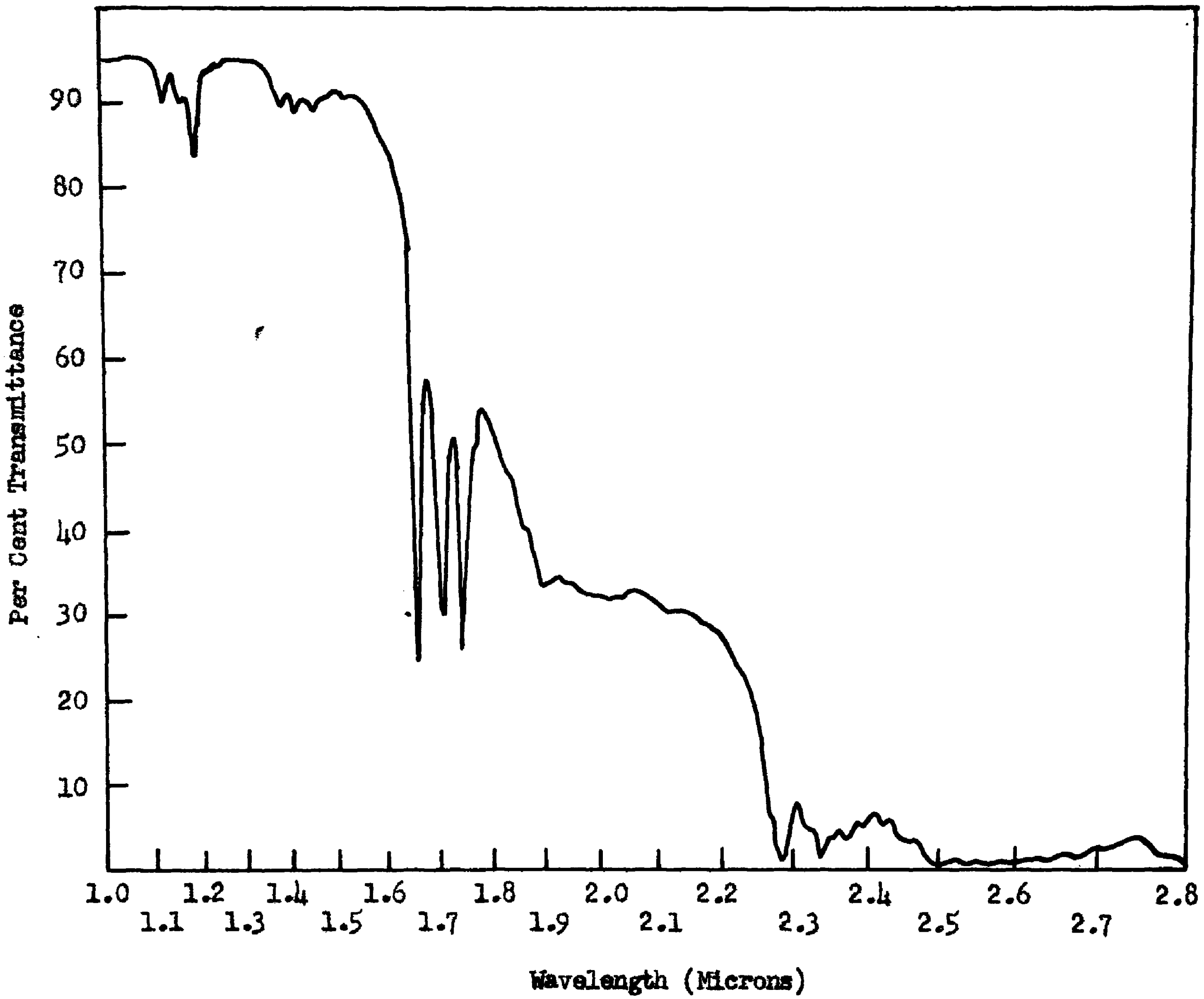


Hydrochloride of 1-Aminonortricyclene ("Nujol" Mull)

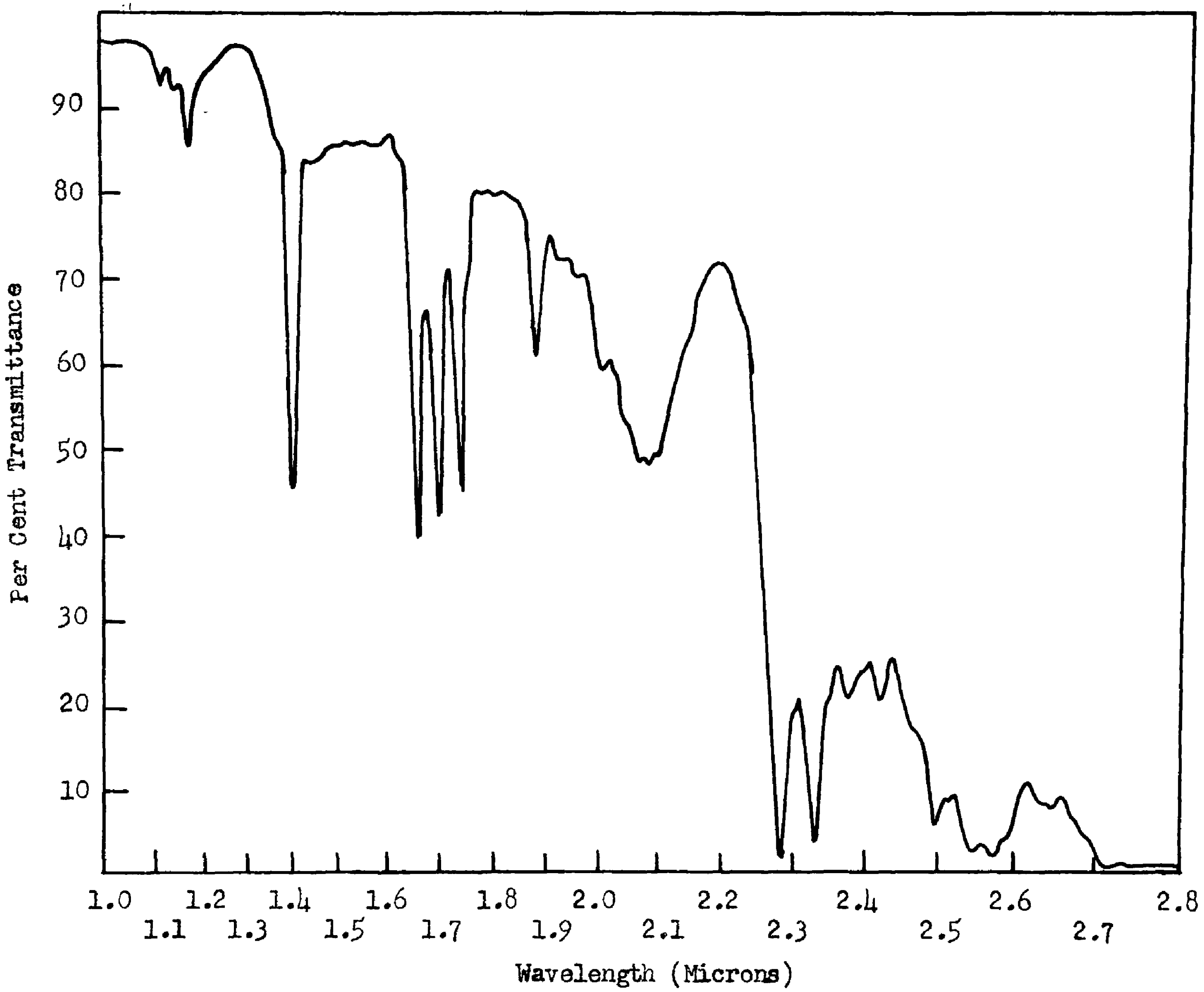
II. NEAR-INFRARED SPECTRA



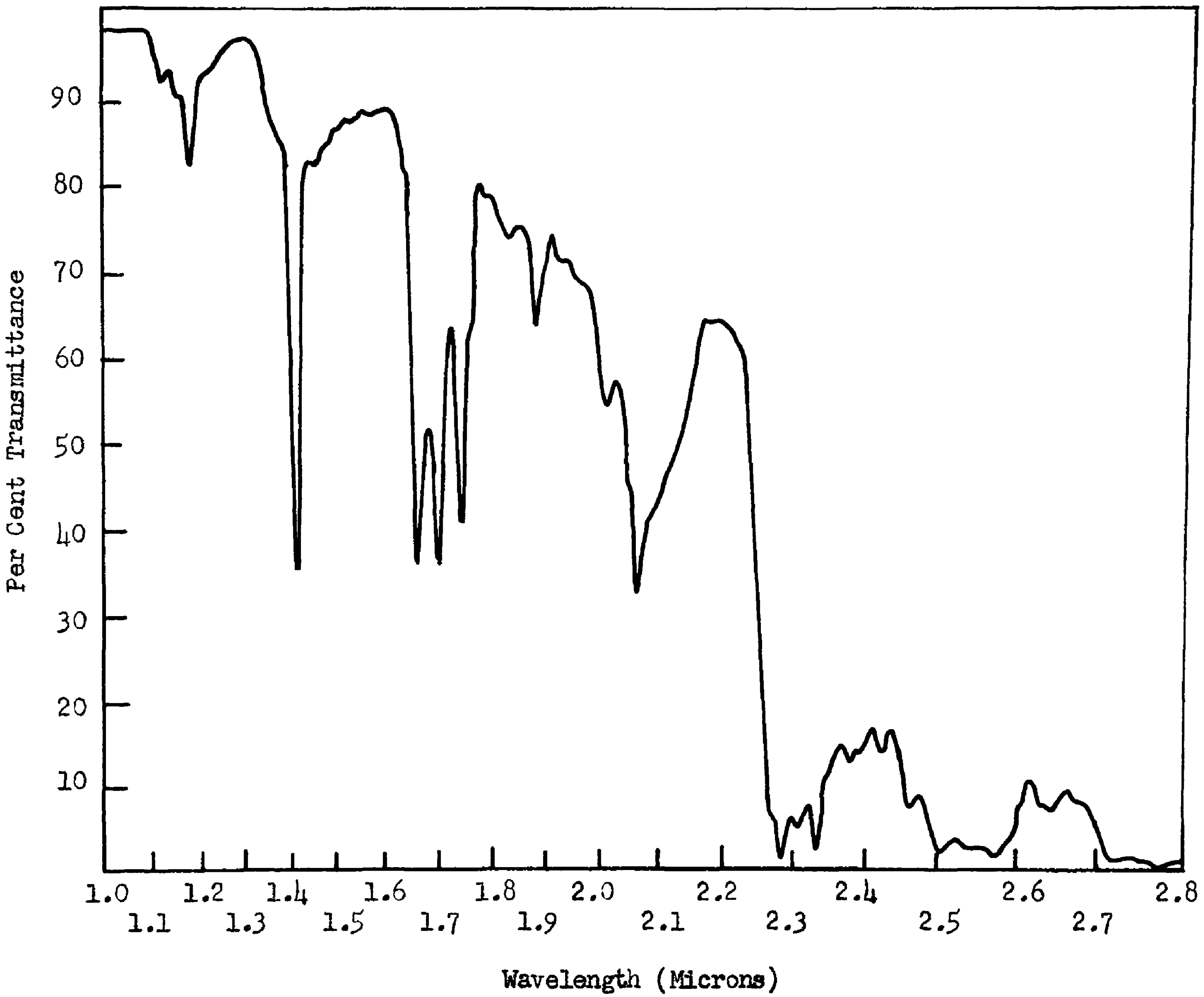
1-Acetylnortricyclene (CCl_4)



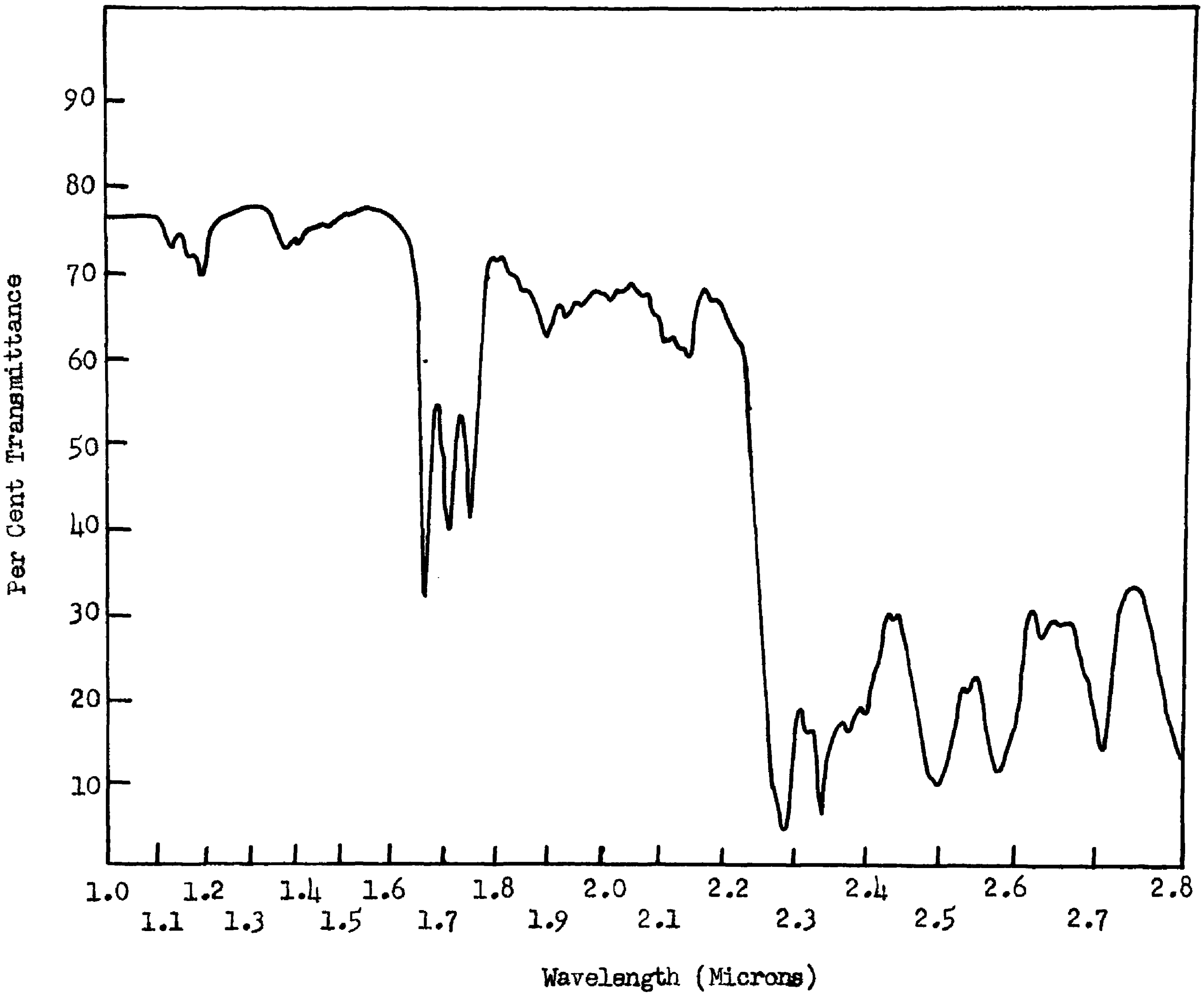
1-Nortricyclenecarboxylic Acid (CCl_4)



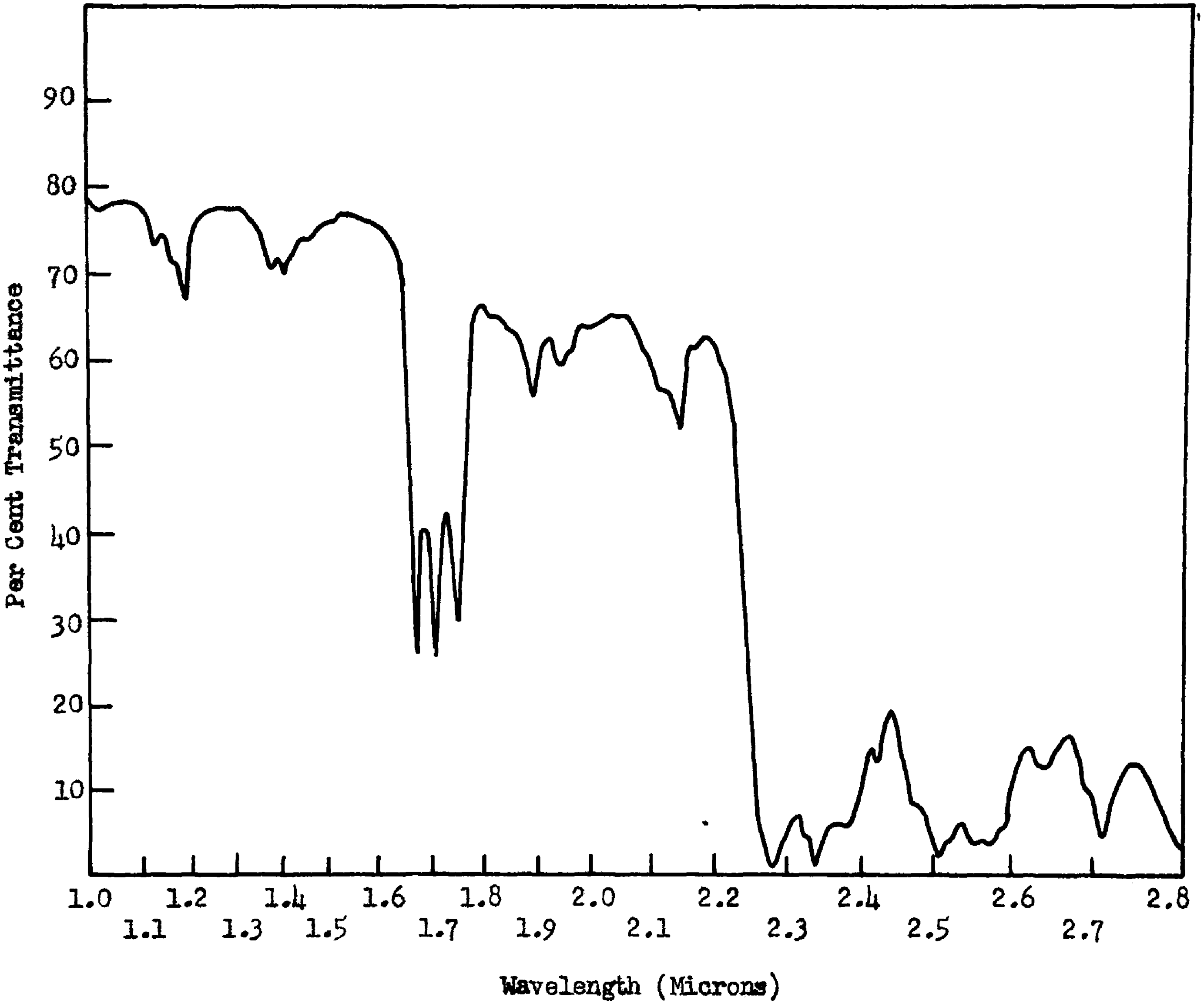
1-Hydroxymethylnortricyclene (CCl_4)



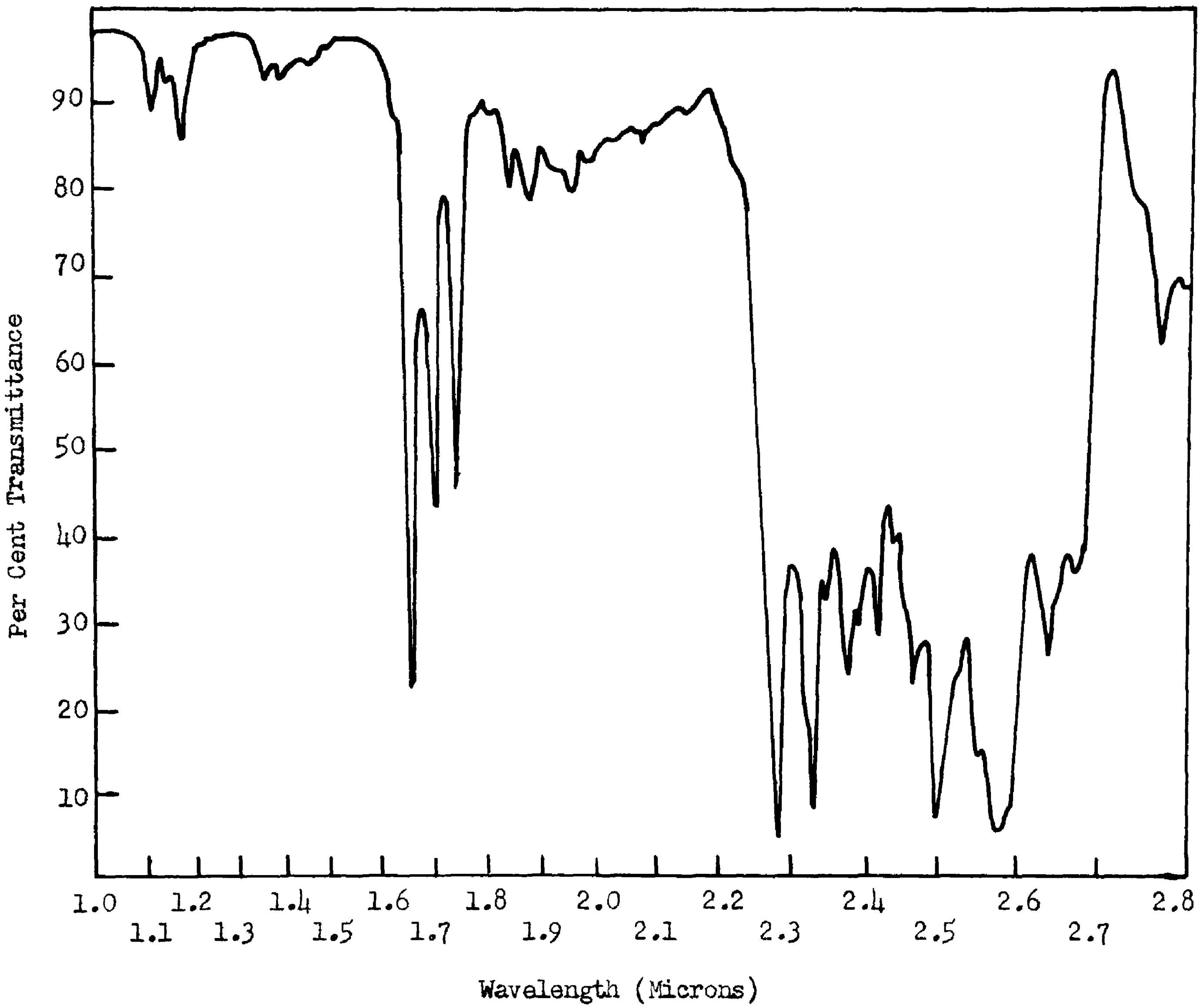
1-(1-Hydroxyethyl)nortricyclene (CCl_4)



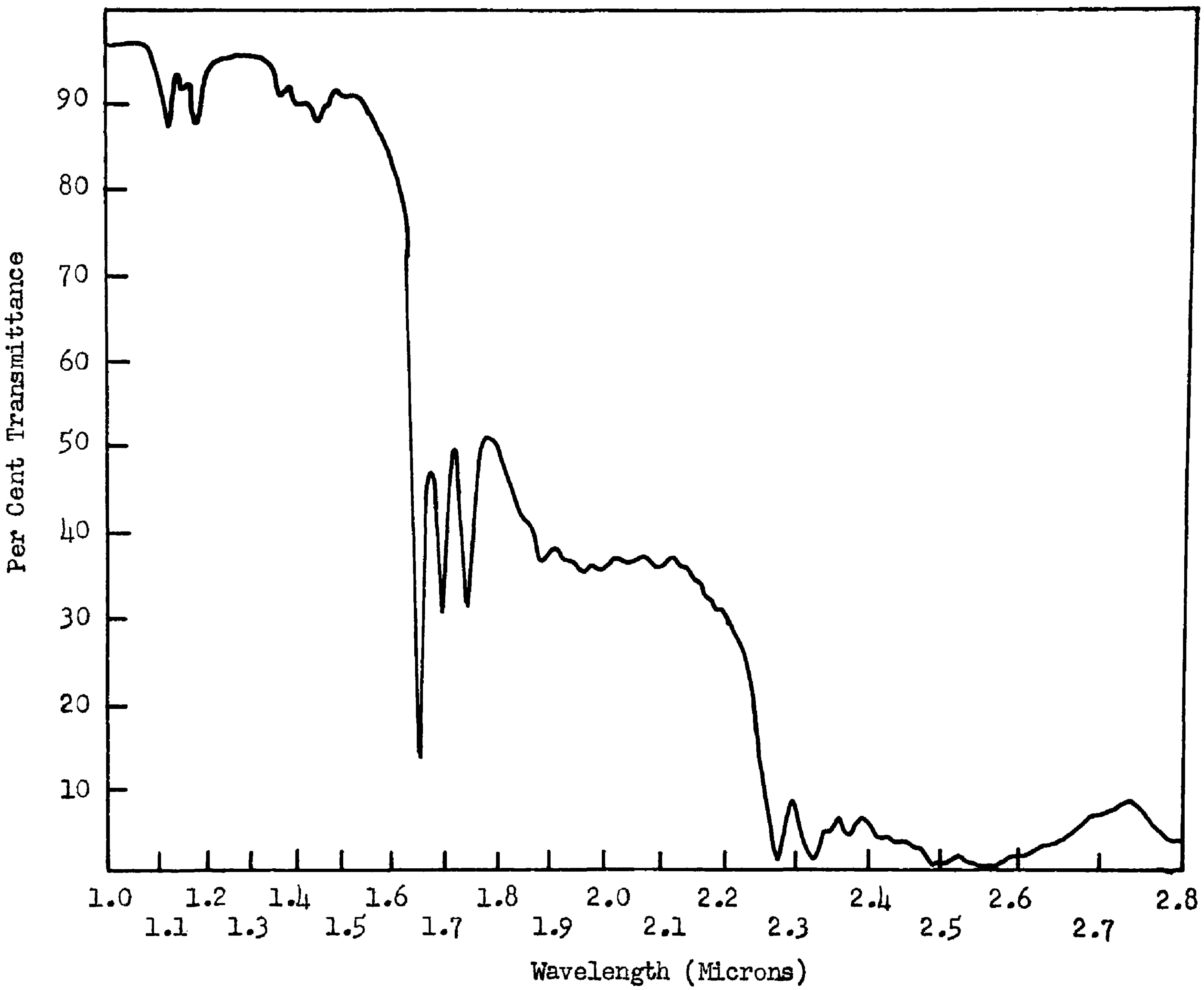
1-Acetoxynortricyclene (CCl_4)



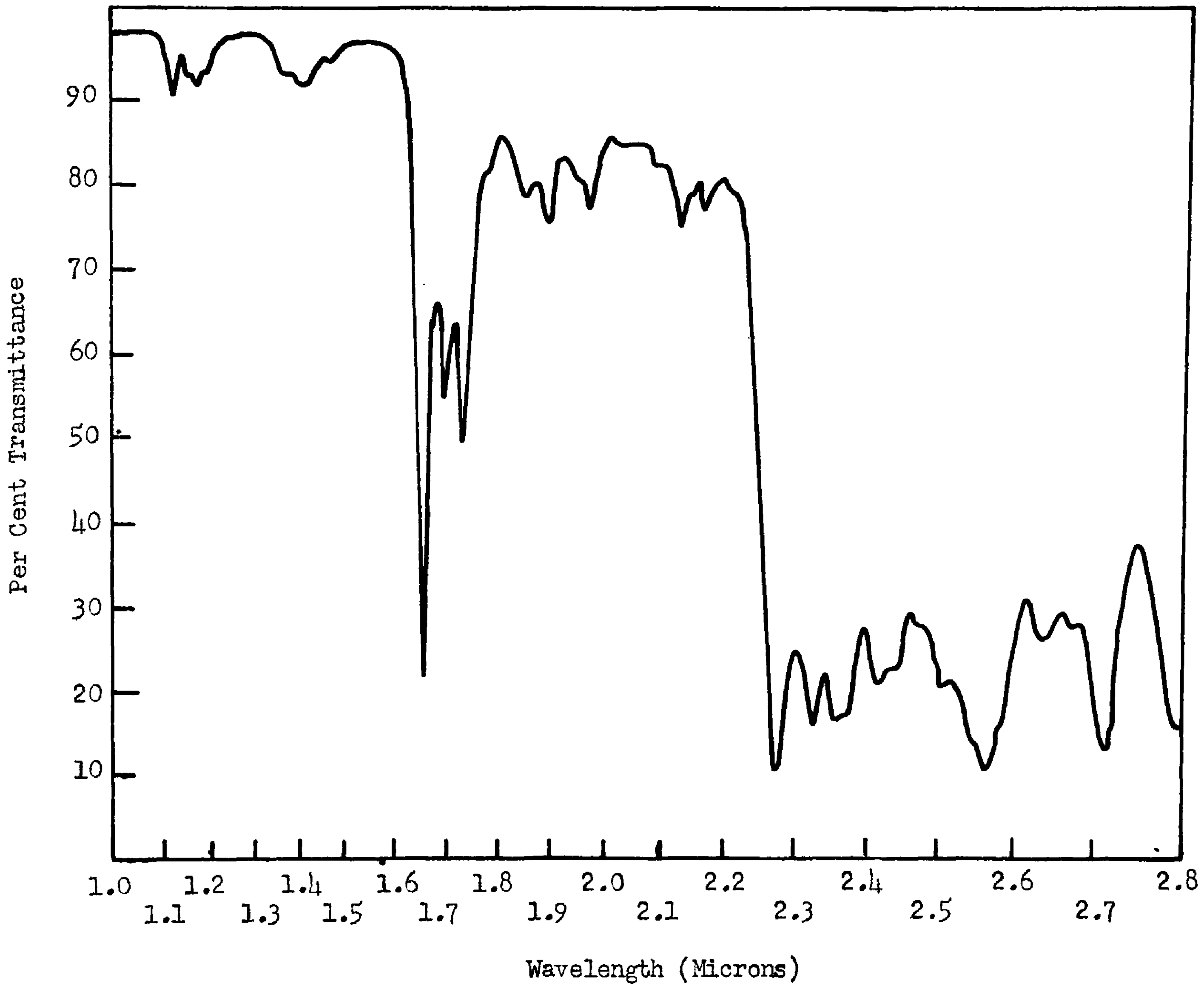
1-Nortricyclylcarbinyl Acetate (CCl_4)



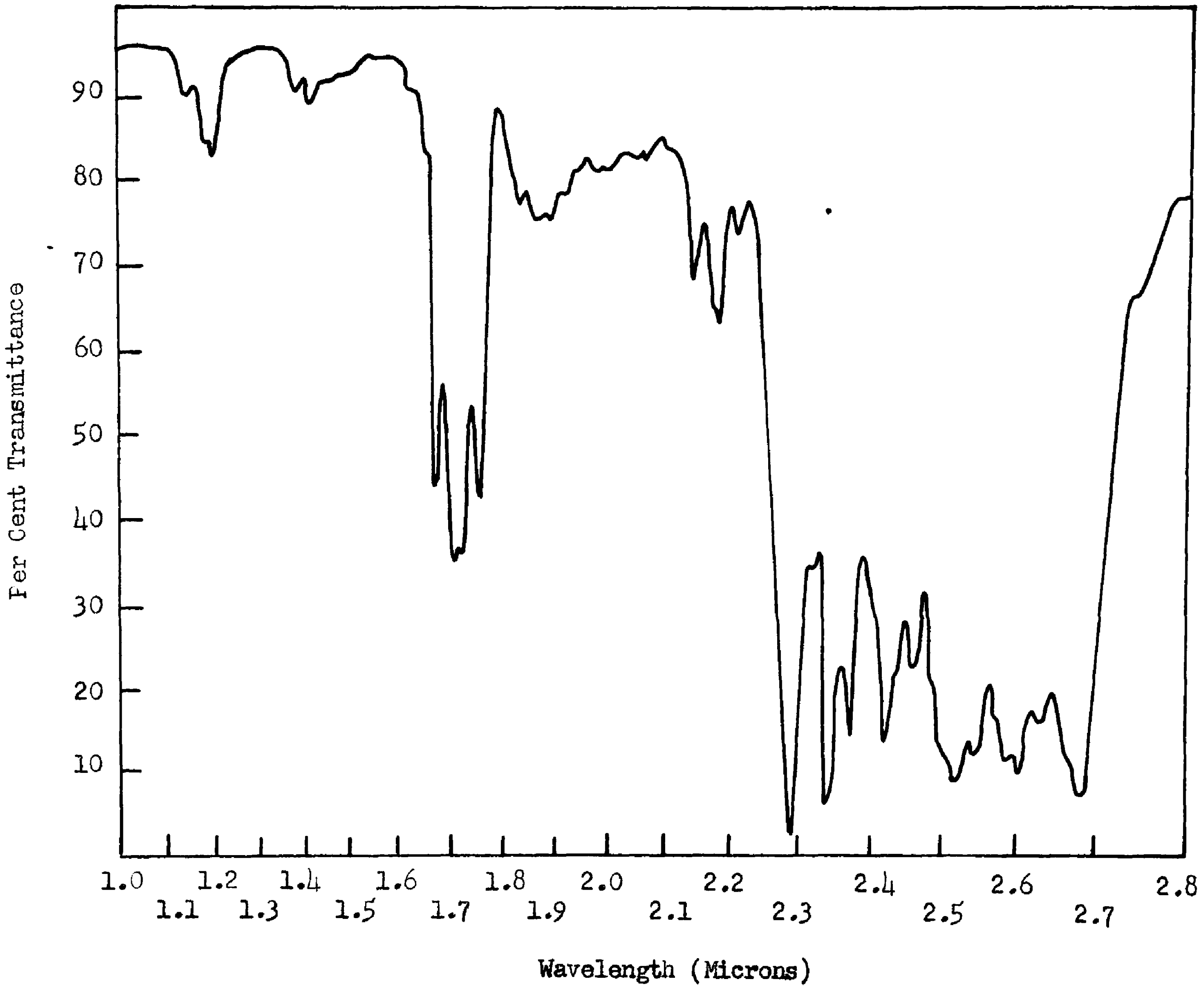
Nortricyclene (CCl_4)



3-Nortricyclenecarboxylic Acid (CCl_4)



3-Chloro-5-acetylnortricyclene (CCl_4)



Norbornene (CCl_4)