

soluble in ether and alcohol. The yield was 12.5 g. or 87% of the theoretical amount. A purple-violet color was obtained with ferric chloride solution. The methyl ester has the "oil of wintergreen" odor.

Anal. Calcd. for $C_7H_8O_3F$: neut. equiv., 156. Found: neut. equiv., 157.4.

Acetyl-5-fluorosalicylic Acid.—Acetylation was effected by warming 4.5 g. of the hydroxy acid with 10 ml. of acetic anhydride and a few drops of sulfuric acid. After cooling the mixture, adding 100 ml. of water, and filtering there was obtained 3.2 g. (56% yield) of product which crystallized from benzene as fine needles melting at 130–131°

which gave no ferric chloride color test. The compound is soluble in alcohol, ether, hot benzene and insoluble in ligroin.

Anal. Calcd. for $C_9H_7O_4F$: neut. equiv., 198.1. Found: neut. equiv., 198.4.

Summary

5-Fluorosalicylic acid and its acetyl derivative have been prepared. These are more toxic than the unfluorinated compounds.

EVANSTON, ILL.

RECEIVED APRIL 24, 1939

[CONTRIBUTION FROM THE GEORGE HERBERT JONES LABORATORY, THE UNIVERSITY OF CHICAGO]

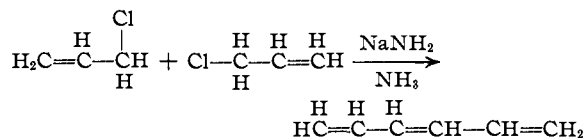
Syntheses of Polyenes. I. Hexatriene and its Polymers

BY M. S. KHARASCH AND E. STERNFELD¹

Introduction

In the course of an investigation on highly unsaturated compounds containing conjugated systems, the need of a simple and efficient method of synthesis became apparent. The general method now in use (the reduction of unsaturated carbonyl compounds to pinacols, replacement of the hydroxyl groups by halogens, and elimination of the halogens by zinc) necessitates the use of large quantities of materials, involves difficult experimental procedures, and usually the over-all yield of the polyene is poor.

Preparation of Hexatriene and its Polymers.—Ordinarily, when organic halides are treated with bases, halogen acids are eliminated and ethylene derivatives are formed. In certain cases, however, two molecules of the halide condense in the course of the reaction to form an unsaturated dimer. Specifically, 9-fluorenyl bromide reacts with potassium hydroxide in acetone solution to yield bifluorenylidene.² In our laboratory sodamide in liquid ammonia has been used successfully as a condensing agent. The equation below represents the reaction of allyl chloride with sodamide in liquid ammonia.



Our hypothesis which has now been verified in a number of cases is that halides of weakly electro-

negative radicals³ will condense when treated with sodamide in liquid ammonia if there is a hydrogen atom on the carbon atom to which the halogen atom is attached.

Since the electronegativity of the allyl radical would be decreased by substituents on the α -carbon atom and only very little affected by substituents on the β -carbon atom, this general method applies to the preparation of many substituted hexatrienes.

Our method of preparing hexatrienes has many advantages over the methods of van Romburgh, namely, the decomposition of *s*-divinylglycol diformate,⁴ or the dehydration of 1,5-hexadien-4-ol. The operations involved are simple and rapid. The sodamide used is produced preferably by the action of sodium on liquid ammonia in the presence of finely divided iron as a catalyst.⁵ It is then added to a liquid ammonia solution of allyl chloride as rapidly as the violence of the reaction permits, and the products are isolated as described in the experimental part.

It was found that the yield of hexatriene was dependent upon the order of addition; thus sodamide added to allyl chloride gave 30% hexatriene, whereas when the allyl chloride was added to sodamide only a 10% yield of hexatriene was obtained along with a proportionately greater amount of a high boiling material. This is accounted for on the basis that a concentrated solu-

(3) Kharasch and Flenner, *THIS JOURNAL*, **54**, 674 (1932); Kharasch and Swarts, *J. Org. Chem.*, **3**, 405 (1938).

(4) Van Romburgh, *J. Chem. Soc.*, **90**, 130 (1906); *Proc. Roy. Acad. Amsterdam*, **15**², 1184 (1913).

(5) Vaughn, Vogt and Nieuwland, *THIS JOURNAL*, **56**, 2120 (1934).

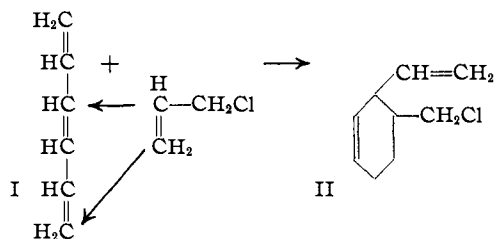
(1) Eli Lilly Fellow. The authors wish to thank the Eli Lilly Company for generous support which made this work possible.

(2) Thiele and Wahnscheidt, *Ann.*, **376**, 278 (1910).

tion of sodamide causes the hexatriene to polymerize.

We are not prepared to state whether the hexatriene made from allyl chloride in this manner is *cis* or *trans*; in our opinion there is not sufficient evidence to show that either pure *cis*- or pure *trans*-hexatriene has ever been isolated. The constants of our hexatriene are nearer to those obtained by Farmer and co-workers⁶ for the *cis*-hexatriene.

The nature of the higher boiling material obtained by the reaction of allyl chloride with sodamide in liquid ammonia is dependent upon the experimental conditions. When three moles of allyl chloride was dissolved in liquid ammonia and two moles of sodamide added, the main product (50%) was a compound boiling at 44–48° at 8 mm., containing one chlorine atom. The molecular weight of the substance was 156 and it was identified as 1-chloromethyl-2-vinyl-cyclohexene-3. The product undoubtedly is formed by the condensation of allyl chloride with hexatriene as indicated in the following schematic representation



The structure of the substance (II) was proved by hydrogenation to 1-ethyl-2-methylcyclohexane. The boiling point and index of refraction of this substance agreed with those recorded in the literature.⁷

This type of condensation has been discussed recently by Alder and Windemuth,⁸ who condensed cyclopentadiene and anthracene with a number of allyl compounds, including allyl chloride. They found that temperatures about 150–180° and fairly high pressures were necessary to bring about the condensations. Compound II is formed readily under our experimental conditions at –33° and atmospheric pressure.

(6) Farmer, Larola, Switz and Thorpe, *J. Chem. Soc.*, 2949 (1927).

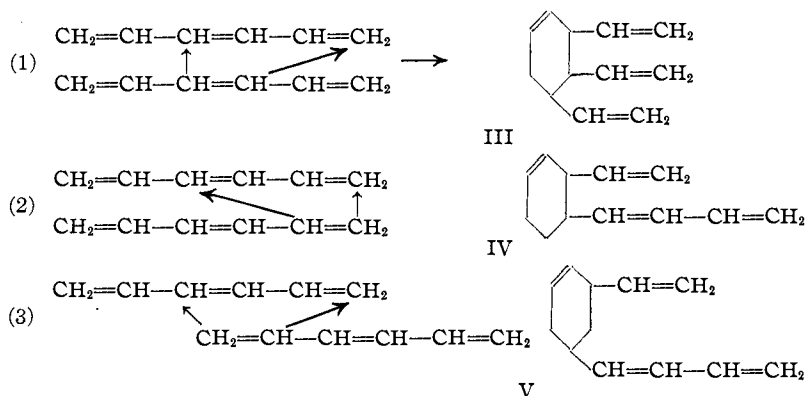
(7) Signaigo and Cramer, *THIS JOURNAL*, 55, 3326 (1933).

(8) Alder and Windemuth, *Ber.*, 71B, 1939 (1938).

However, if an excess of sodamide is employed, polymers of hexatriene can be isolated uncontaminated with halogen compounds. In particular one fraction can be isolated which boils 50–55° at 3 mm., in over 40% of the calculated yield. The only investigation of the polymers of hexatriene mentioned in the literature was conducted by van Romburgh⁴ who distilled a five-year-old sample of hexatriene and obtained a liquid which boiled at 99.5° at 16 mm. The molecular weight indicated that it was a dimer of hexatriene. Because of the density of the liquid van Romburgh assumed that a ring had been formed with the elimination of two double bonds. However, he made no attempt to establish the structure of his dimer.

Upon hydrogenation of the dimer a saturated hydrocarbon (molecular weight 168) is obtained. The fact that the substance absorbs eight hydrogen atoms corresponding to four double bonds indicates a ring structure for the molecule, since the straight chain molecule would have five double bonds. The index of refraction of the saturated dimer is much too high for a straight chain paraffin hydrocarbon but is normal for a cyclohexane derivative.

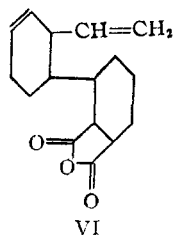
Dimerization of hexatriene to give a ring compound may take place in two ways: 1,4-addition of a medial double bond of a hexatriene molecule to another hexatriene molecule as in scheme 1, or 1,4-addition of a terminal double bond, as in scheme 2 or 3.



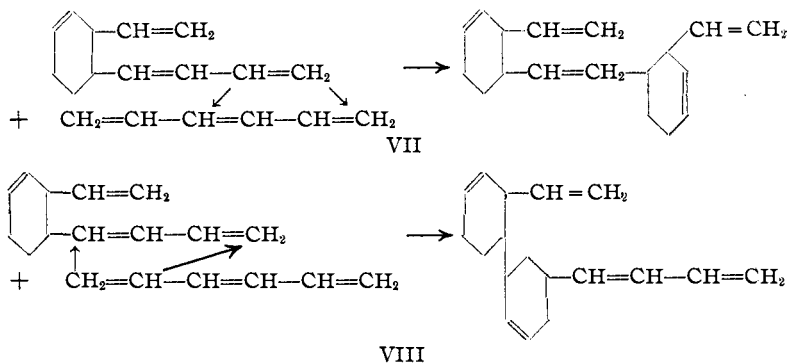
Of the three dimers, IV and V contain conjugated systems and will react with maleic anhydride. Since the dimer gives a well-defined crystalline derivative with maleic anhydride, its structure is either IV or V.

Hydrogenation of the dimer yields a liquid which is either 1-butyl-2-ethyl or 1-butyl-3-

ethylcyclohexane. Neither of these cyclohexanes is recorded in the literature. We synthesized the 1-butyl-2-ethylcyclohexane using the procedure suggested by Signaigo and Cramer.⁷ α -Ethylcyclohexanone from α -chlorocyclohexanone and ethylmagnesium bromide was added to butylmagnesium bromide and the mixture, upon hydrolysis, gave 1-butyl-2-ethylcyclohexanol. This substance was dehydrated by distillation with iodine and then hydrogenated to the saturated hydrocarbon. The constants of 1-butyl-2-ethylcyclohexane agreed with those of the saturated hexatriene dimer. The unsaturated compound is, therefore, 1-butadienyl-2-vinylcyclohexene-3 (IV) and the maleic anhydride derivative is represented by VI. The dimerization of hexatriene is analogous to the dimerization of butadiene to vinylcyclohexene, and of phenylbutadiene to phenylstyrylcyclohexene. These conjugated systems, therefore, as well as hexatriene upon condensation give rise to six-membered rings by 1,4-addition of a terminal double bond in preference to the addition of a medial double bond.



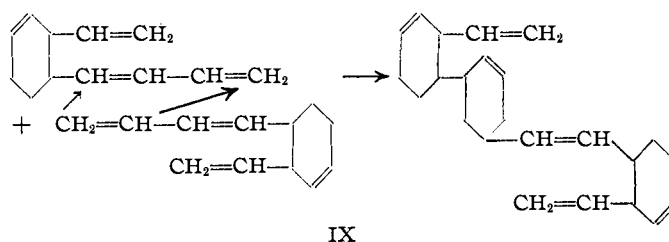
With the aid of a molecular still we isolated the trimer and tetramer of hexatriene. The structure of the trimer, which has five double bonds, may be represented by two different formulas, according to two possible reactions by which it may be formed



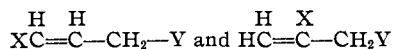
That VII is probably the correct structure is in-

dicated by the fact that the trimer does not react with maleic anhydride.

The tetramer of hexatriene was obtained as a light-yellow viscous liquid whose color became darker in air. It has six double bonds and a molecular weight of 320. It does not react with maleic anhydride. These facts, in conjunction with the observation that the tetramer is formed under conditions that favor the presence of large concentrations of the dimer, indicate that the tetramer results from the 1,4-addition between two molecules of dimer as follows.



This work is being continued. We are also engaged in an extensive study of other polyenes prepared by treating sodamide in liquid ammonia with substituted allyl compounds of the type



in which Y is a halogen atom and X is either a halogen atom, a hydrocarbon radical, or a carboxy group.

Experimental Part

Preparation of Hexatriene and Butadienylvinylcyclohexene.—The sodamide was prepared in an 800-cc. unsilvered Dewar flask (equipped with a stirrer and a dropping tube) from 23 g. of sodium in 600 cc. of liquid ammonia. About half a gram of ferric nitrate was dissolved in the ammonia and then the sodium added in 2–3 g. portions, each piece being allowed to react before the next was added. The sodamide suspension was forced over into a 3-liter Dewar, equipped with a good stirrer and containing 1 liter of liquid ammonia and 76 g. (1 mole) of allyl chloride. The flow of sodamide suspension had to be regulated carefully and only small portions added at a time as the reaction was very violent.

In later runs the sodamide was made in large quantities by the above procedure and stored, after evaporation of the ammonia, in a sealed bottle until used. It was added to the reaction mixture by means of an adapter cut short at the narrow end and connected to a glass tube of the same diameter in the

rubber stopper of the Dewar flask by a short piece of rubber tubing. This procedure allowed much greater control of the speed of the reaction and was more convenient than the earlier method in the reactions where the sodamide was added to the allyl chloride.

After all the sodamide was added the mixture was poured into a 3-liter round-bottomed flask and the ammonia evaporated on the steam-bath. Water was then added to dissolve the sodium chloride, and the mixture extracted successively with several portions of ether. The combined ether portions were washed thoroughly with water, dried over anhydrous sodium sulfate, and the ether removed. The remaining material was separated into fractions. Two different procedures were used. In the first experiments the product was fractionated with the aid of a column. The low boiling material was hexatriene (8.6 g., 24%), b. p. 76–80°, n_{20}^D 1.4330, d_{20}^{20} 0.7182. This material, dissolved in methyl alcohol, hydrogenated smoothly in the presence of platinum oxide to *n*-hexane, b. p. 68°, n_{20}^D 1.3748.

The second fraction was the dimer, 14 g. (41%), b. p. 50–55° at 3 mm., n_{20}^D 1.5137.

Anal. Calcd. for $C_{12}H_{16}$: C, 89.92; H, 10.08; mol. wt., 160. Found: C, 89.20; H, 9.75; mol. wt. (in triphenylmethane), 174.

Upon hydrogenation 0.4234 g. of liquid in absolute methyl alcohol absorbed 254.1 cc. of hydrogen (corr.). Calcd. for $C_{12}H_{16}$ and four double bonds, 264 cc. The ethylbutylcyclohexane had a b. p. 208°, n_{20}^D 1.4493.

Anal. Calcd. for $C_{12}H_{24}$: C, 85.71; H, 14.29. Found: C, 85.42; H, 14.19.

By using a column the liquid is kept at 75–80° for some time during the distillation of the hexatriene and polymerization takes place. To avoid this the product was sealed in a system containing a flask and several bomb tubes and connected to a vacuum line by a yoke. The liquid was cooled, the system evacuated to the limits of a three-stage mercury pump, degassed, and sealed off. The flask containing the liquid was allowed to come to room temperature while one of the tubes was cooled. In this way a 30% yield of hexatriene was obtained after twenty-four hours. The remaining liquid was distilled on an oil pump, yielding 33% of the dimer.

Preparation of Hexatriene Dimer, Trimer, and Tetramer.—The yield of butadienylvinylcyclohexene was increased to 50% by adding 100 g. (1.33 moles) of allyl chloride to a solution of 70 g. (2 moles) of sodamide in 2 liters of liquid ammonia and stirring the mixture for thirty to forty-five minutes after the addition of the halide. The aforementioned procedure was then followed and the ether-free product distilled in a molecular still. Twenty-seven grams of dimer distilled at 20–35° at 10^{-4} mm.

Five grams of trimer distilled at 70–80° at 10^{-4} mm., n_{20}^D 1.5232.

Anal. Calcd. for $C_{18}H_{24}$: C, 89.92; H, 10.08; mol. wt., 240. Found: C, 89.27; H, 9.84; mol. wt. (in triphenylmethane), 227. *Hydrogenation:* 0.2450 mg. in methyl alcohol absorbed 113.1 cc. of hydrogen (corr.). Calcd. for $C_{18}H_{24}$ and five double bonds, 114.3 cc.

Five grams of tetramer distilled at 120–133° at 10^{-4} mm., n_{20}^D 1.5330.

Anal. Calcd. for $C_{24}H_{32}$: C, 89.92; H, 10.08; mol. wt., 320. Found: C, 88.98; H, 9.72; mol. wt. (in triphenylmethane), 341. *Hydrogenation:* 0.2837 g. in methyl alcohol absorbed 126 cc. hydrogen (corr.). Calcd. for $C_{24}H_{32}$ and six double bonds, 119.5 cc.

Preparation of Chloromethylvinylcyclohexene.—Forty grams of sodamide was added over a period of one and one-half hours to a solution of 100 g. of allyl chloride in liquid ammonia. After the usual treatment the following fractions were obtained: 13 g., b. p. 70–85° (hexatriene contaminated with halogenated compounds) and 23 g. of chloromethylvinylcyclohexene, b. p. 44–48° at 8 mm., n_{20}^D 1.4670.

Anal. Calcd. for $C_9H_{13}Cl$: Cl, 22.66; mol. wt., 156.45. Found: Cl, 22.91; mol. wt. (in camphor), 156.

It was hydrogenated under pressure of 40 pounds (2.7 atm.) in presence of platinum oxide. The resulting liquid, after some purification, yielded a fraction b. p. 156°, n_{20}^D 1.4412, which is identical with 1,2-ethylmethylcyclohexane.

Synthesis of 1,2-Butylethylcyclohexane.—Twenty grams of ethylcyclohexanone was added to butylmagnesium bromide from 4.5 g. of magnesium and 23 g. of butyl bromide in 150 cc. of ether at 0°. The mixture was allowed to warm up to room temperature, then hydrolyzed with dilute sulfuric acid and ice. The layers were separated, the ether solution was washed with saturated sodium bisulfite and water, dried over anhydrous sodium sulfate, and distilled. The carbinol left after distillation of the ether, 20 g., was distilled immediately with 0.5 g. of iodine and gave a mixture of olefin and water boiling from 100–200°. The olefin, 15 g., was separated, dried, dissolved in glacial acetic acid and hydrogenated at an initial pressure of 36 pounds (2.5 atm.) in the presence of 0.3 g. of platinum oxide. The saturated hydrocarbon was separated by the addition of water, washed with cold concentrated sulfuric acid, dried and distilled. Upon fractionation was obtained 7 g. of pure 1,2-butylethylcyclohexane, b. p. 205–206°, n_{20}^D 1.4479.

Reaction of Hexatriene and its Dimer with Maleic Anhydride.—By heating equivalent amounts of hexatriene and maleic anhydride in benzene at 90–100° for three hours the vinyl (or ethylidene) tetrahydrophthalic anhydride, m. p. 45°, described by Farmer and Warren⁹ was obtained. The free acid, m. p. 160°, was hydrogenated; 0.2108 g. absorbed 45.64 cc. of hydrogen (corr.). Calcd. for vinyl tetrahydrophthalic acid, 47.93 cc. Ethyl hexahydrophthalic acid, m. p. 117°, was the product.

Butadienylvinylcyclohexene reacted smoothly in benzene with maleic anhydride at 90–100°. The resulting anhydride was not crystallized, but was converted to the free acid, m. p. 178°.

Anal. Calcd. for $C_{16}H_{20}O_4$: C, 69.70; H, 7.26; neut. equiv., 138. Found: C, 70.05; H, 7.65; neut. equiv., 138.

Summary

1. A simple method of obtaining hexatriene and compounds derived from hexatriene in comparatively good yields by the condensation of allyl chloride is described.

(9) Farmer and Warren, *J. Chem. Soc.*, 897 (1929).

2. The structures of the hexatriene polymers are elucidated.

3. Work is being continued on the chemistry

of these compounds and also on the synthesis of similar compounds containing substituent groups.

CHICAGO, ILLINOIS

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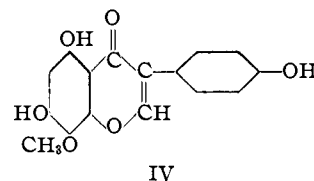
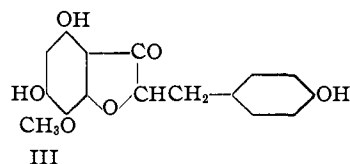
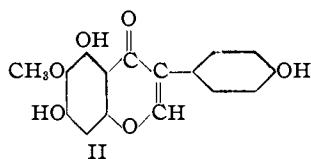
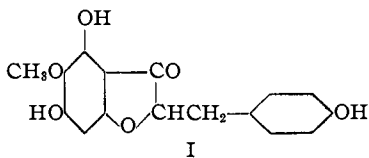
[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

Derivatives of Coumaran. IV. The Structure of Tectorigenin

BY R. L. SHRINER, EDWARD J. MATSON AND R. E. DAMSCHRODER

The glucoside, tectoridin, was isolated by Shibata¹ from the rhizomes of *Iris tectorum* Maxim. Recently Mannich, Schumann and Lin² have shown that the glucoside, shekanin, in the rhizomes of the blackberry lily, *Belamcanda chinensis* (L.) Lemn, is identical with tectoridin. Hydrolysis of tectoridin produced glucose and tectorigenin. Since the products of alkaline decomposition of tectorigenin were *p*-hydroxyphenylacetic acid, formic acid and iretol (V), Shibata first proposed the coumaran-3-one structure shown in formula I. Later, on the basis of the absorption spectrum, Asahina, Shibata and Ogawa³ suggested the isoflavone structure of formula II. It is obvious that the isomeric formulas III and IV also represent possible structures which would yield the same degradation products.

The coumaranone structures I and III have two atoms of hydrogen more than the isoflavone structures but the combustion analyses were not sufficiently accurate to distinguish between them. None of these structures has been synthesized previously. This paper reports the synthesis of the two isomeric coumaranone structures, I and III, and of their completely methylated derivatives.



The general method⁴ of synthesis used involved the preparation of the coumaranones properly substituted in the benzene nucleus, condensation of the active methylene group in the heterocyclic ring with an aldehyde followed by reduction. The necessary coumaranones are most conveniently made by treating phenols with chloroacetonitrile followed by hydrolysis and ring closure.

Application of this method to iretol (V) yielded two isomeric coumaranones which were separated by fractional crystallization. The structure of the two isomeric coumaranones produced by hydrolysis and ring closure of α -chloro-2,4,6-trihydroxy-3-methoxyacetophenimine hydrochloride (VI) was established by methylation and synthesis of each of the methylated compounds. The less soluble isomer was 4,6-dihydroxy-5-methoxycoumaran-3-one (VII); the more soluble was 4,6-dihydroxy-7-methoxycoumaran-3-one (X).

The methylated isomer, 4,5,6-trimethoxycoumaran-3-one (VIII), was prepared from antiarol (XIII), which underwent a Hoesch reaction with chloroacetonitrile to yield the α -chloroacetophenone (XIV). Ring closure gave the desired coumaranone (VIII). In a similar fashion the isomeric methylated compound, 4,6,7-trimethoxy-

(1) Shibata, *J. Pharm. Soc. Japan*, **47**, 380 (1927).

(2) Mannich, Schumann and Lin, *Arch. Pharm.*, **275**, 317 (1937).

(3) Asahina, Shibata and Ogawa, *J. Pharm. Soc. Japan*, **48**, 1087 (1928).

(4) Shriner and Damschroder, *THIS JOURNAL*, **60**, 894 (1938); Shriner and Anderson, *ibid.*, **60**, 1415 (1938).