of VIa; m.p. 192.5–194° with previous softening. From the mother liquor by concentration and addition of water there was obtained an additional 161 mg., m.p. 189–192°, bubbles in melt, clear at 199°; 91% yield (two fractions). Crystallization of the first fraction from methanol gave 199 mg., m.p. 193.5–194.5°; infrared, λ_{max} 3460, 1092 cm.$^{-1}$; $[\alpha]^{24}D$ −7° (18.8 mg., αD −0.07°), [M]D −30.

Anal. Calcd. for $C_{25}H_{38}O_6$ (434.55): C, 69.09; H, 8.81. Found: C, 68.99; H, 8.55.

$\Delta^{5,7,9(11)}$-Pregnatriene-17α,21-diol-3,20-dione 21-Acetate 3,20-Bisethylene Ketal (VII).—A solution of IIIb (0.3 g.) in chloroform (1 ml., dried over anhydrous potassium carbonate) was treated with a solution of mercuric acetate (0.4 g.) in glacial acetic acid (8 ml.) and acetic anhydride (0.1 ml.). The mixture was shaken at 5° overnight, and was then filtered for removal of mercurous acetate. Evaporation at reduced pressure of the filtrate gave an orange solid. Six crystallizations from methanol gave 52 mg. (17% yield) of VII; m.p. 205–207.5°; λ_{max} 312 mμ (ϵ 8100), 325 mμ (ϵ 9200) and 340–341 mμ (ϵ 5800), inflection at 296–297 mμ; infrared, λ_{max} 3530, 1750, 1630, 1230, 1215, 1090 cm.$^{-1}$; $[\alpha]^{27}D$ +190° (10.2 mg., αD +0.97°), [M]D +897.

Anal. Calcd. for $C_{27}H_{36}O_7$ (472.56): C, 68.62; H, 7.68. Found: C, 68.53; H, 8.11.

Δ^7-Allopregnene-17α,21-diol-3,20-dione (VIII).—Compound VIa (215 mg.) in methanol (10 ml.) and 8% (v./v.) sulfuric acid (1 ml.) was refluxed for 40 minutes. Water was added; the mixture was cooled, and the crystals were collected; 157 mg. (91% "crude" yield). Two crystallizations from acetone (petroleum ether wash) gave pure VIII; 111 mg., m.p. 245–247.5° with previous softening; infrared, λ_{max} 3380, 3290, 1730, 1705, 1104 cm.$^{-1}$; $[\alpha]^{24}D$ −10° (17.45 mg., αD −0.09°), [M]D −35.

Anal. Calcd. for $C_{21}H_{30}O_4$ (346.45): C, 72.80; H, 8.73. Found: C, 72.58; H, 8.91.

Maleic Anhydride Adduct (IX) of $\Delta^{5,7,9(11)}$-Pregnatriene-17α,21-diol-3,20-dione 21-Acetate 3,20-Bisethylene Ketal.—A mixture of VII (28 mg.), maleic anhydride (11 mg.) and benzene (3 ml.) was refluxed for 17 hours, and evaporated at reduced pressure. The residue was triturated with ether, and the solid was collected; 20 mg., m.p. 233–240° with previous softening (brown melt). Four crystallizations from acetone–petroleum ether gave 13 mg. of IX; m.p. 247–249.5° (brown melt); λ_{max} none; infrared, λ_{max} 3470 1866, 1850, 1785, 1750, 1242, 1228, 1094 cm.$^{-1}$.

Anal. Calcd. for $C_{31}H_{38}O_{10}$ (570.61): C, 65.25; H, 6.71. Found: C, 65.01; H, 6.92.

PEARL RIVER, NEW YORK

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, COLUMBIA UNIVERSITY]

Poison Ivy "Urushiol"

BY WILLIAM F. SYMES[1] AND CHARLES R. DAWSON

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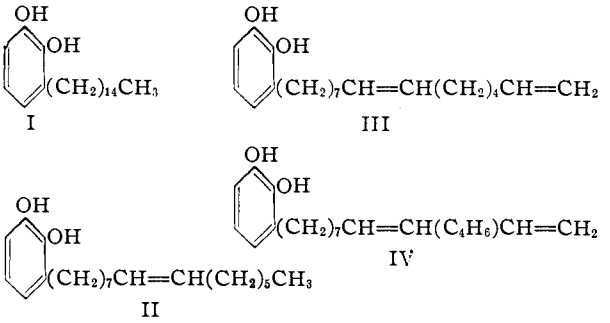
The toxic principle of poison ivy has an olefinic unsaturation of about two double bonds and possesses the carbon skeleton of 3-pentadecylcatechol. It has been found that the dimethyl ether can be separated by chromatography on alumina into four pure components which vary only in their degree of unsaturation in the side chain. One of the components has a completely reduced side chain. The other three contain one, two and three olefinic bonds, respectively. The structures proposed for the olefinic components on the basis of ozonolysis and oxidative degradation experiments are as follows: a monoolefin, 1,2-dihydroxy-3-(pentadecenyl-8′)-benzene; a diolefin, 1,2-dihydroxy-3-(pentadecadienyl-8′,11′)-benzene and a triolefin, 1,2-dihydroxy-3-(pentadecatrienyl-8′,11′,14′)-benzene.

The poison ivy plant (*Rhus toxicodendron radicans*) and the related species poison oak (*R. toxicodendron diversilobum*) and poison sumac (*R. toxicodendron vernix*) probably cause more human suffering annually than any other North American plants. For this reason there has long been interest in establishing the chemical structure of the vesicant principle of *Rhus toxicodendron*.[2] Although McNair concluded in 1921 that the active principle of the poison oak is a catechol compound, he could not further identify it structurally.[3] Thirteen years later the carbon skeleton of the poison ivy principle was first revealed as the result of the work of Hill and his students.[4] They found that hydrogenation of the poison ivy principle gave a compound identical to that obtained on hydrogenation of urushiol, the vesicant oil occurring in the sap of the Japanese lac tree (*Rhus verniciflora*). Majima had established earlier that the structure of hydrourushiol is that of 3-pentadecylcatechol.[5]

Majima's investigation of Japanese lac urushiol extended over a period of 15 years and he finally concluded that it was a mixture of olefinic catechols which could not be separated by distillation. The vesicant oil had an unsaturation equivalent to about two olefinic bonds and on hydrogenation gave the single substance hydrourushiol. Ozonolysis and other oxidative degradations, carried out on dimethylurushiol, led to a variety of products including small amounts of dimethylhydrourushiol. Although his attempts to separate pure ozonides were unsuccessful, the ozonolysis products seemed best accounted for in terms of four components differing only in the number of double bonds in the alkenyl side chain of urushiol. Majima postulated the following structures for the components of urushiol and indicated some uncertainty about the existence of the diolefinic component.[6]



(1) This paper is based on a portion of the thesis submitted by William F. Symes in 1951 to Columbia University in partial fulfillment of the requirements for the Ph.D. degree in chemistry.

(2) R. Khittel, *Am. J. Pharm.*, **6** [3], 542 (1858); L. Maisch, *ibid.*, **14** [3], 4 (1866); H. Pfaff, *J. Exp. Med.*, **2**, 181 (1897); S. F. Acree and W. A. Syme, *J. Biol. Chem.*, **2**, 547 (1906).

(3) J. B. McNair, THIS JOURNAL, **43**, 159 (1921).

(4) G. A. Hill, V. Mattacotti and W. D. Graham, *ibid.*, **56**, 2736 (1934).

(5) R. Majima, *Ber.*, **48**, 1593 (1915).

(6) R. Majima, *ibid.*, **55B**, 172 (1922).

Prior to the present investigation there was no information concerning the olefinic composition of the poison ivy principle except that it possesses an unsaturation equivalent to about two olefinic bonds.[4,7] Although Hill's work has led to the widespread impression that the poison ivy principle and Japanese lac urushiol are identical,[8-10] such a conclusion is not justified, for only the hydrogenated forms of the two oils were shown to be the same. Mason and Schwartz[11] chromatographed a sample of poison ivy oil on a column of alumina and obtained six bands. They concluded that at least three toxic components were present in the oil. However, they were not able to recover the components in a form suitable for structural identification, and therefore gave no information concerning the unsaturation or structural skeleton of the toxic components.

It is the purpose of this article to report that four components of common structural skeleton, but differing in degree of unsaturation, constitute the poison ivy principle. The components have been chromatographically separated and purified in the form of their dimethyl ethers prior to their structural identification as a monoölefin, a diolefin, a triolefin and the saturated analog, 3-pentadecylcatechol (hydrourushiol). The structures of the di- and triolefinic components have been shown to be different from those proposed by Majima (III and IV) for the corresponding components of the lac urushiol. The poison ivy principle and the lac urushiol are not identical. They are the same only in the structures of their saturated and monoölefinic components (I and II).[12]

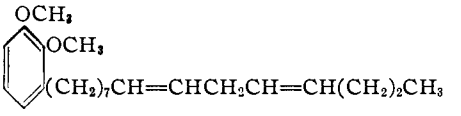
The allergenic properties of the poison ivy oil, its marked susceptibility to autoxidation, and previous experience with the chromatographic separation of similar systems,[13] made it advisable to work with the relatively more stable and non-toxic dimethyl ether rather than the free catechol. The dimethyl ether was obtained essentially free of non-"urushiol" contaminants, for on catalytic hydrogenation it absorbed approximately two moles of hydrogen and gave practically a quantitative yield of pure dimethylhydrourushiol of sharp melting point. However, the fact that the dimethyl ether was not a homogeneous diolefin became readily apparent when it was chromatographed on a column of activated alumina. The fractions of oily liquid, obtained either by fractional elution or extrusion and sectioning of the column as previously described,[13] showed a parallel increase in double bond value and refractive index with increasing adsorbability.

Several of the least strongly adsorbed fractions were combined and treated with 30% performic acid[14] in an attempt to obtain glycol derivatives of the olefins. Two crystalline compounds were isolated by chromatography. One proved to be dimethylhydrourushiol, thereby establishing the presence of a saturated component, 3-pentadecylcatechol (I) in the poison ivy principle. The other crystalline compound proved to be a monoglycol which on periodic acid oxidation yielded heptaldehyde. The monoölefin from which the glycol was obtained was therefore 3-(pentadecenyl-8′)-veratrole, the dimethyl ether of II. The glycols corresponding to the higher olefinic components could not be isolated readily in pure form.

The olefinic components of the dimethyl ether were separated by repeated chromatography. Fractions of similar refractive indices were combined and rechromatographed. In this way a monoölefin, $n^{25}D$ 1.4932, and a diolefin, $n^{25}D$ 1.5030, were isolated as fractions of constant refractive index. A triolefin also was obtained by combining fractions varying over a range of $n^{25}D$ 1.5145–1.5175. Each of these olefinic components absorbed the calculated amount of hydrogen on catalytic reduction to give pure I. No fraction with a double bond value exceeding 3.0 was obtained from any of the chromatograms. It may be concluded, therefore, that no component with more than three double bonds is present in the toxic principle of poison ivy.

The ultraviolet absorption spectra revealed that the reduction product I and the di- and triolefinic components were almost identical in regard to position and magnitude of their absorption maxima and minima. This fact, as pointed out elsewhere,[13] precludes the existence of conjugation in the di- and triolefinic components.

The structure of the diolefin was established by ozonolysis as 1,2-dimethoxy-3-(pentadecadienyl-8′,11′)-benzene

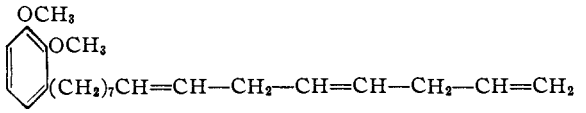
V 

n-Butyraldehyde was isolated in 58% yield and identified as the dimedon derivative. The aldehydic fragment containing the aromatic nucleus was oxidized to the corresponding acid and isolated in 40% over-all yield as the amide. It proved to be identical to a synthetic sample of ω-(2,3-dimethoxyphenyl)-caprylic acid amide. The structure of the diolefin was therefore satisfactorily established without isolating the intermediate dialdehyde fragment; presumably malondialdehyde. In particular, it should be noted that the diolefinic component V of poison ivy "urushiol" has a different structure from that (III) proposed by Majima for the diolefinic component of lac urushiol.

The structure of the triolefin also was revealed by ozonolysis and by consideration of the ultraviolet absorption data. Catalytic reduction of the ozonide produced a 42% yield of formaldehyde, isolated and identified as the dimedon derivative. Oxidation of the aromatic fragment gave the same substituted caprylic acid as obtained from the diolefin; isolated in 33% yield as the amide. These degradation products placed the position of two of the double bonds; one in the 14′-position and the

(7) D. Wasserman and C. R. Dawson, *J. Org. Chem.*, **8**, 73 (1943).
(8) F. A. Stevens, *J. Am. Med. Assoc.*, **127**, 912 (1945).
(9) C. E. Prokesch, *Arch. Pediatrics*, **67**, 267 (1950).
(10) W. M. Harlow, "Poisonivy and Poisonsumac," New York State College of Forestry at Syracuse, Vol. XXII, No. 4 (1949).
(11) H. S. Mason and L. Schwartz, THIS JOURNAL, **64**, 3058 (1942).
(12) S. V. Sunthankar and C. R. Dawson, to be published.
(13) W. F. Symes and C. R. Dawson, THIS JOURNAL, **75**, 4952 (1953).
(14) D. Swern, G. N. Billen, T. W. Findley and J. T. Scanlan, *ibid.*, **67**, 1786 (1945).

other in the 8′-position. The position of the third double bond now became apparent. It had to be between the 8′ and 14′ position, yet not be conjugated with either (ultraviolet spectra). Only the 11′-position meets this requirement. The structure of the triolefin is therefore 1,2-dimethoxy-3-(pentadecatrienyl-8′,11′,14′)-benzene



VI

It is of interest to note that the side chain structures of the mono-, di- and triolefinic components of the poison ivy principle are the same as those of the corresponding olefins of cardanol and cardol in cashew nut shell liquid.[15]

Experimental[16,17]

The poison ivy "urushiol" used in this investigation was provided by the Lederle Laboratories Division of the American Cyanamid Company. It was a dark brown viscous oil that had been obtained by originally extracting the leaves and twigs of poison ivy plants with alcohol and then processing for the removal of fats, waxes and chlorophyll.

Preparation of Dimethyl "Urushiol."—An attempt was made originally to methylate the above oil using an excess of diazomethane in absolute ether. The product, however, proved to be mainly the monomethyl ether which was then converted into the dimethyl ether by dimethyl sulfate in methanolic sodium hydroxide. A superior yield of the dimethyl ether was obtained by methylating the crude "urushiol" *via* the reaction of its sodium salt with methyl iodide. In a typical experiment, 11.0 g. of metallic sodium was dissolved in 350 ml. of absolute ethanol and the resulting solution was treated with 47.5 g. of "urushiol" and 150 g. of methyl iodide. A voluminous curdy precipitate separated but disappeared on refluxing the solution for 7 hours on the steam-bath. After adding 200 ml. of absolute ethanol, containing 6.0 g. of dissolved sodium, and another 150 g. of methyl iodide, the refluxing was continued for an additional 14 hours.[18] The excess methyl iodide and about 400 ml. of ethanol were then removed by distillation and 500 ml. of water was added to the residue to dissolve the sodium iodide. The red oil which separated was extracted exhaustively with diethyl ether and the ethereal extract was washed with water, dried and concentrated. The residual viscous red oil (32 g.) was refluxed for 1 hour with 150 ml. of 3 *N* KOH in 70% aqueous ethanol to saponify the fatty acid esters, diluted with 500 ml. of water, and extracted exhaustively with 800 ml. of ligroin (b.p. 60–90°). The ligroin was removed by distillation and the residue of 16 g. (31%) of reddish oil was dried by the addition and distillation of benzene until a clear distillate was obtained. Using a short, vacuum-jacketed Vigreux column, the oil was distilled at 0.5 mm. under an atmosphere of nitrogen. After a forerun of 5 g. of a light yellow oil distilling at 80–170°, 8.2 g. of a pale yellow oil, $n^{25}D$ 1.5032, distilling at 170–180° was collected as the dimethyl "urushiol."

A small sample of the dimethyl ether on catalytic hydrogenation[13] absorbed hydrogen equivalent to 2.0 double bonds. After removal of the catalyst and solvent the residual colorless oil solidified on chilling, m.p. 33–35°. One recrystallization from methanol produced fine needles of m.p. 35.5–36.5°; not depressed when mixed with an authentic sample of 3-pentadecylveratrole (dimethylhydrourushiol) of m.p. 36–37°.[4]

(15) W. F. Symes and C. R. Dawson, *Nature*, **171**, 841 (1953).

(16) All melting points are corrected.

(17) Microanalyses were performed by Clark Microanalytical Laboratories, Urbana, Ill., and Schwarzkopf Microanalytical Laboratory, Middle Village, L. I., N. Y.

(18) It seems probable that the methylation can be accomplished in considerably shorter time. Recent work on the methylation of Japanese Lac urushiol by a similar procedure employing excess methyl iodide indicates that the methylation is complete in about 3 hours.[12]

Chromatography of Dimethyl "Urushiol."—A 13.5-g. sample of dimethyl "urushiol," obtained as described above, was dissolved in 50 ml. of ligroin and chromatographed on a 9.5 × 45 cm. column of 1600 g. of activated alumina.[19] A pressure of 5 lb. of nitrogen allowed for a flow rate of about 8 l. per hour. The adsorbed material was then completely eluted in fractions as shown in Table I.

TABLE I

Fraction	Solvent, vol. in liters		Amount, g.	$n^{27}D$
1	Ligroin	5.0	2.88	1.4951
2	Ligroin	3.5	1.80	1.4982
3	Ligroin	1.0	0.90	1.4982
4	Ligroin	0.8	0.25	1.5000
5	Ligroin	3.0	1.08	1.4987
6	Ligroin	5.0	1.50	1.5001
7	Ligroin	6.0	1.31	1.5013
8	Ether	2.0	2.65	1.5120
9	Ether	1.0	0.30	1.5150

Isolation of the Diolefin.—Fractions 2 through 7 of Table I were combined, 6.84 g., and rechromatographed on a 5.5 × 40 cm. column of 650 g. of alumina using 9.5 l. of ligroin to develop the column under 5 lb. pressure of nitrogen at a flow rate of 2.5–3 l. per hour until a non-volatile oil was first detected in the effluent. The column was then extruded, cut into 14 equal sections which were extracted exhaustively with diethyl ether. Removal of the ether by distillation gave 14 fractions of colorless oil (total weight, 6.29 g.) varying in refractive index from $n^{25}D$ 1.4955 to $n^{25}D$ 1.5088. Fractions 6–10 ($n^{25}D$ 1.5030–1.5032) were combined to give 2.88 g. of diolefin, $n^{25}D$ 1.5030. A small sample on catalytic hydrogenation absorbed an amount of hydrogen equivalent to 2.0 double bonds to give a quantitative yield of 3-pentadecylveratrole, m.p. 34–36°. After one recrystallization from methanol the melting point was 36–37°.

Isolation of the Triolefin.—Fraction 8, 2.65 g., from Table I was rechromatographed on a 4 × 25 cm. column of 250 g. of alumina. Seven liters of ligroin was required to develop the column under 4–5 lb. pressure of nitrogen at a flow rate of 4–5 l. per hour. The alumina was then extruded, sectioned, and worked up in the usual way to give 1.61 g. of colorless oil in 11 fractions varying in refractive index from $n^{25}D$ 1.5018 to $n^{25}D$ 1.5190.

Fractions 5–9 ($n^{25}D$ 1.5145–1.5175) were combined to give 0.76 g. of triolefin, $n^{25}D$ 1.5160. A small sample on catalytic hydrogenation absorbed an amount of hydrogen equivalent to 3.0 double bonds to give a quantitative yield of 3-pentadecylveratrole, m.p. 35–36° without recrystallization.

Isolation of the Monoölefin.—Fraction 1 of Table I, 2.88 g., was rechromatographed on a 4 × 25 cm. column of 250 g. of alumina using 4.5 l. of ligroin to develop the column. The alumina was then extruded, sectioned, and worked up in the usual way to give 2.55 g. of colorless oil in 15 fractions varying in refractive index from $n^{25}D$ 1.4925 to $n^{25}D$ 1.4987.

Fractions 7–11 ($n^{25}D$ 1.4932–1.4935) were combined to give 0.84 g. of monoölefin, $n^{25}D$ 1.4932. A small sample on catalytic hydrogenation absorbed an amount of hydrogen equivalent to 1.0 double bonds and the reduced material melted at 35–36.5° without recrystallization. A sample of this monoölefin was oxidized with osmium tetroxide to give a crystalline glycol, m.p. 94–95°.[20]

Fractions 1 (0.45 g.) and 6 (0.15 g.) both had a refractive index of 1.4925, but the intermediate fractions, each of about 0.08 g., contained material of unexpectedly high refractive index, *i.e.*, $n^{25}D$ 1.4960–1.5018.

These high values were found to be due to the presence of an impurity, a contaminant of non-urushiol skeleton, in fractions 2–5. A sample of these combined fractions on catalytic hydrogenation absorbed less than the theoretical

(19) The activated alumina was prepared by heating aluminum hydroxide (Mallinckrodt) for 4 hours at 275-300° with slow stirring. The alumina used in this particular experiment had become partially deactivated on storage; other experimental details previously described.[14]

(20) B. Loev and C. R. Dawson, to be published.

quantity of hydrogen for one double bond to give an oil which could not be crystallized. The saturated component, hydrourushiol, which was undoubtedly present in fractions 1 and 6 and probably 2–5, but which could not be readily separated from the contaminant present in these fractions, was obtained as described below.

Isolation of the Saturated Component and a Crystalline Monoglycol.—A 5.1-g. sample of dimethyl "urushiol" was dissolved in 25 ml. of ligroin and chromatographed on a 2.5 × 50 cm. column of activated alumina. The first four fractions eluted with ligroin gave colorless oils varying in $n^{25}D$ from 1.4915 to 1.5011. These were combined, 1.8 g., and treated with 7.0 ml. of 98–100% formic acid and 1.1 g. of 30% H_2O_2. The non-homogeneous reaction mixture was stirred vigorously for 4 hours at 40° during which it turned dark brown. The addition of 20 ml. of water caused an amber oil to separate which was extracted with ether. The ethereal extract was washed several times with water to remove the formic acid, and evaporated. The residue was taken up in 30 ml. of a solution of 3 *N* NaOH in 70% ethanol and refluxed one hour. About 10 ml. was then removed by distillation, 15 ml. of water was added, and the solution was acidified to *p*H 2 with 6 *M* H_2SO_4. The dark brown sticky suspension was extracted exhaustively with boiling petroleum ether (b.p. 35–60°) to give on evaporation 1.0 g. of a pale reddish semi-solid. About 0.6 g. was soluble in 25 ml. of cold petroleum ether and the resulting solution was passed through a small column of 20 g. of activated alumina (A). The residual 0.4 g. was dissolved in 10 ml. of diethyl ether and passed through a 25-g. column of alumina (B). The columns were then eluted with benzene, etc., as shown below.

Fraction	Elution solvent, ml.		Amount eluted, g.
A1	Benzene	250	0.15 solid, m.p. 31–34°
2	2% Methanol in benzene	150	.30 viscous oil
3	6% Methanol in benzene	200	.08 solid, m.p. 57–59°
B1	Benzene	200	.10 semi-solid
2	Diethyl ether	50	.26 viscous oil

Fraction A-1 was recrystallized twice from methanol to give a colorless solid of m.p. 35.5–36.5°. When mixed with a sample of the catalytically reduced dimethyl "urushiol" of m.p. 35.5–36.5° no depression in melting point was observed. Analysis was correct for hydrourushiol (3-pentadecylveratrole).

Anal. Calcd. for $C_{23}H_{40}O_2$: C, 79.25; H, 11.55. Found: C, 79.45; H, 11.37.

Fraction B-1 was rechromatographed on 25 g. of alumina to give 0.030 g. of solid of m.p. 62–64°. Fraction B-2 was chilled in the refrigerator to form a semi-solid which on the addition of 5 ml. of cold petroleum ether gave 0.075 g. of white solid of m.p. 63–65.5°. These two fractions of solid material were combined with A-3 and recrystallized from petroleum ether to give about 150 mg. of a crystalline solid of m.p. 63–65°. On further recrystallization from ligroin the material melted constantly at 66.8–68.2°. Analysis was correct for a monoglycol of dimethyl "urushiol."

Anal. Calcd. for $C_{23}H_{40}O_4$: C, 72.59; H, 10.60. Found: C, 72.47, 72.50; H, 10.48, 10.29.

Cleavage of the Monoglycol with Periodic Acid. Isolation of the 2,4-Dinitrophenylhydrazone of Heptaldehyde.—The monoglycol, 0.120 g., was dissolved in 6 ml. of absolute methanol and treated with 0.100 g. of paraperiodic acid. Heat was evolved and the solution became a pale yellow. After allowing it to stand at room temperature (*ca.* 26°) for two hours, 10 ml. of water was added to the solution and the resulting cloudy mixture was extracted with two 10-ml. portions of diethyl ether. The ether was removed by evaporation and the residue steam distilled. The distillate (5 ml.) was extracted with 5 ml. of diethyl ether and the ether evaporated. The residue was taken up in 10 ml. of 95% ethanol containing 50 mg. of 2,4-dinitrophenylhydrazine and refluxed for five minutes. On the addition of five drops of 12 *M* hydrochloric acid, the solution changed from a deep orange to a bright yellow, and 35 mg. (39% of theory) of yellow needles of m.p. 100–101.5° were obtained on chilling. Fine hair-like crystals of constant melting point, 103.5–104.5°, were obtained on four recrystallizations from aqueous ethanol. When mixed with an authentic sample of heptaldehyde 2,4-dinitrophenylhydrazone of m.p. 104–105° no depression in melting point was observed.

Anal. Calcd. for $C_{13}H_{18}N_4O_4$: N, 19.10. Found: N, 18.98.

Ozonolysis of the Diolefin.—A 0.50-g. (0.0014 mole) sample of the chromatographically pure diolefin ($n^{25}D$ 1.5030) was dissolved in 20 ml. of ethyl acetate, treated with ozone, the ozonide catalytically reduced, and the volatile aldehyde fraction converted into the dimedon derivative as previously described.[13] A yield of 0.278 g. (58%) of a colorless crystalline solid of m.p. 126–129° was obtained. After three recrystallizations from aqueous ethanol the mica-like crystals melted at 132.5–133.5°. When mixed with an authentic sample of *n*-butyraldehyde dimedon of m.p. 133–134° no depression in melting point was observed.

Anal. Calcd. for $C_{20}H_{30}O_4$: C, 71.82; H, 9.04. Found: C, 71.82; H, 9.26, 9.18.

The oil remaining after distillation of the solvent and volatile aldehyde from the reduced ozonide was taken up in 50 ml. of acetone and oxidized by the portionwise addition of 1.5 g. of $KMnO_4$ at 40–45°. The oily acid, 0.250 g. (65%) obtained on working up the reaction mixture in the usual way,[13] could not be crystallized. It was, therefore, dissolved in 3 ml. of thionyl chloride, refluxed for 30 minutes on the steam-bath, and the reddish solution then poured into 25 ml. of concentrated NH_4OH chilled to −10° in an ice–salt mixture. After a vigorous reaction subsided, the resulting gummy precipitate was extracted exhaustively with ether, the ether removed by evaporation, and the glassy residue extracted with three 25-ml. portions of boiling ligroin. On concentrating to 25 ml. and chilling in an ice–salt-bath, 0.160 g. (40% of theory, based on diolefin) of a white crystalline solid of m.p. 88–92° was obtained. One recrystallization from aqueous ethanol gave long silky needles which on further recrystallization melted constantly at 96.5–97.5°. When mixed with an authentic sample of ω-(2,3-dimethoxyphenyl)-caprylamide of m.p. 97–98° no depression in melting point was observed.

Anal. Calcd. for $C_{16}H_{25}O_3N$: C, 68.78; H, 9.01. Found: C, 68.44; H, 8.98.

Ozonolysis of the Triolefin.—A 0.45-g. (0.0013 mole) sample of the chromatographically purified triolefin ($n^{25}D$ 1.5160) was dissolved in 20 ml. of ethyl acetate, ozonized, and the dimedon derivative of the volatile aldehyde was obtained as described previously. A yield of 0.160 g. (42%) of a colorless solid of m.p. 185–187° resulted. One recrystallization from 95% ethanol gave needles of m.p. 189–190.5°; not depressed when mixed with an authentic sample of formaldehyde dimedon of m.p. 189–190°.

Anal. Calcd. for $C_{17}H_{24}O_4$: C, 69.83; H, 8.27. Found: C, 70.06; H, 8.47.

The non-volatile aldehyde residue from the reduced ozonide was oxidized, as described for the diolefin, with $KMnO_4$ to give 0.230 g. (65%) of a pale yellow oily acid. The amide was prepared as described above and amounted to 0.120 g. (33% based on triolefin) of a colorless crystalline solid of m.p. 89–92°. One recrystallization from aqueous ethanol gave silky needles of m.p. 96.5–97.5°. When mixed with an authentic sample of ω-(2,3-dimethoxyphenyl)-caprylamide of m.p. 97–98° no depression in melting point was observed.

Anal. Calcd. for $C_{16}H_{25}O_3N$: C, 68.78; H, 9.01. Found: C, 68.46, 68.72; H, 8.90, 9.05.

ω-(2,3-Dimethoxyphenyl)-caprylamide.—A Grignard reagent was prepared from 0.40 g. (0.017 mole) of magnesium turnings covered with 10 ml. of absolute diethyl ether in a 200-ml. 3-neck flask fitted with a mercury seal stirrer, a 50-ml. separatory funnel and a reflux condenser by adding 4.3 g. (0.014 mole) of 3-(7′-bromoheptyl)-veratrole[7] dissolved in 10 ml. of absolute ether dropwise over a period of 35 minutes. The reaction mixture was stirred for an additional 30 minutes, after which it was cooled in an ice–salt-bath and dry carbon dioxide was passed over the surface of the vigorously stirred sticky reaction mixture for a period of 40 minutes. The mixture changed to a stiff white paste during the course of the carbonation. Upon hydrolysis with ice and dilute sulfuric acid, a pale yellow oil separated. This was exhaustively extracted with diethyl ether and the ether extract was in turn washed with 10% sodium hydroxide to remove the organic acid. Acidification of the basic extract

gave 1.1 g. (29%) of a pale yellow oily acid which could not be crystallized.

The amide was prepared by the procedure given for the amide of the acid obtained from the diolefin. A 0.250-g. sample of the acid gave 0.140 g. of impure amide of m.p. 87–92°. On two recrystallizations from aqueous ethanol the silky needles melted at 97–98°. Analysis was correct for ω-(2,3-dimethoxyphenyl)-caprylamide.

Anal. Calcd. for $C_{16}H_{25}O_3N$: C, 68.78; H, 9.01. Found: C, 68.71; H, 8.94.

Ultraviolet Absorption Spectra.—The ultraviolet spectra of the saturated, diolefinic and triolefinic components of dimethyl "urushiol" were determined using a Cary recording photoelectric spectrophotometer with 0.00010 *M* solutions in 95% ethanol. Very similar spectra for the corresponding components of methylcardanol have been presented elsewhere.[13]

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Terpenes. I. Structure and Synthesis of the $C_{17}H_{20}$ Hydrocarbon Obtained by Dehydrogenation of Agathic Acid

BY G. BÜCHI AND JAMES J. PAPPAS

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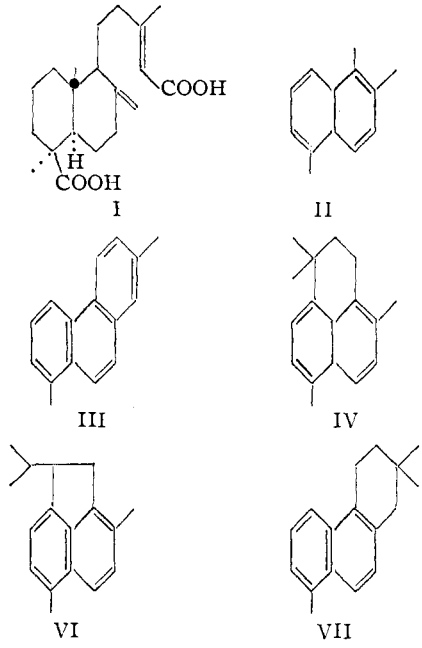
1,1,4,7-Tetramethylphenalan has been synthesized and shown to be identical with the hydrocarbon $C_{17}H_{20}$ obtained by dehydrogenation of agathic acid.

The structure of agathic acid (I) has been established through the researches of Ruzicka and his co-workers.[1] The carbon skeleton of this compound was determined from the structures of the aromatic hydrocarbons formed in the dehydrogenation of agathic acid. The detailed structure was deduced from results obtained in a study of oxidative degradation. The *trans*-locking of the two rings was demonstrated by conversion of agathic acid (I) to a degradation product of manoöl[2] which in turn had been related to abietic acid,[3] the structure of which is known in all details.[4]

Dehydrogenation of agathic acid with either sulfur or selenium gave agathalene (1,2,5-trimethylnaphthalene) (II), pimanthrene (1,7-dimethylphenanthrene) (III) and a hydrocarbon $C_{17}H_{20}$ (IV).[1a] When tetrahydroagathic acid was dehydrogenated, agathalene and the $C_{17}H_{20}$ hydrocarbon (IV) were isolated but pimanthrene (III) could not be detected.

The hydrocarbon $C_{17}H_{20}$ (IV) was resistant to further dehydrogenation and readily absorbed two equivalents of hydrogen when hydrogenated over Adams platinum catalyst. Exhaustive oxidation of IV with potassium ferricyanide in aqueous potassium hydroxide solution gave a ketodicarboxylic acid $C_{16}H_{12}O_5$ (V). The ultraviolet absorption spectrum of IV was similar to the spectrum of naphthalene and Ruzicka and Rey[5] assumed that IV was 3,6-dimethyl-1-isopropylacenaphthene (VI). When they synthesized VI they found it to be different from the hydrocarbon obtained from agathic acid. Fieser and Fieser[4] suggested 2,2,8-trimethyl-1,2,3,4-tetrahydrophenanthrene (VII) as an expression for the $C_{17}H_{20}$ hydrocarbon. However, this structure can be ruled out because it would not give a ketodicarboxylic acid ($C_{16}H_{12}O_5$) an oxidation with potassium ferricyanide, and in addition VII should give pimanthrene on further dehydrogenation. It is worthy of note that the structure of this important product of dehydrogenation, in which more carbon atoms of agathic acid are retained than in any other one, was, until the present investigation, still unknown. The knowledge of its structure would certainly have facilitated the efforts to arrive at a structural expression for agathic acid (I). In this paper we report work on the structure and a synthesis of the hydrocarbon $C_{17}H_{20}$ (IV).



We turn first to a discussion of a possible mecha-

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