spectrum was identical with that of the 5α-tetrahydroisojervine obtained by the Birch reduction of VIII. The middle band yielded a crystalline product (16.8 mg.), which had m.p. 135–137° on recrystallization from aqueous ethanol. The infrared spectrum showed no absorption of a carbonyl group and was different from that of III or XII.

Alkali Treatment of Triacetyl-8,9-dihydroisojervine (XIXa).—A solution of triacetyl-8,9-dihydroisojervine (XIXa, 30 mg.) in methanol (2 ml.) containing 10% potassium hydroxide was refluxed for 2 hr. under a stream of nitrogen. The solution was evaporated *in vacuo*, diluted with water, and treated with chloroform. The chloroform solution afforded a crystalline material (XIXb, 20 mg.), which had m.p. 213–215° on recrystallization from aqueous methanol; λ_{max} 254 mμ (ε 19,000); ν_{max} 3370, 1704, 1610, and 1055 cm.$^{-1}$.

Anal. Calcd. for $C_{29}H_{43}NO_4$: C, 74.16; H, 9.23. Found: C, 74.01; H, 9.15.

The Dihydro Derivative of The Isomer (XX). A.—The compound (XX, 0.23 g.) was hydrogenated over prereduced Adams platinum (0.1 g.) in acetic acid (10 ml.) at room temperature, and after 6 hr. 13.4 ml. of hydrogen was absorbed (calculated for 1 mole, 12.7 ml.). The crystalline substance obtained after the usual work-up was recrystallized from acetone and the dihydro derivative (XXI, 0.12 g.), m.p. 230–232°, was obtained; λ_{max} 239 mμ (ε 12,800); ν_{max} 1691, 1630, and 1035 cm.$^{-1}$.

Anal. Calcd. for $C_{27}H_{41}NO_3$: C, 75.83; H, 9.66; N, 3.28. Found: C, 75.52; H, 9.76; N, 3.31.

B.—The dihydro derivative (XXI) was also obtained from 5α-dihydroisojervine (VIII); a solution of VIII (60 mg.) in methanol (8 ml.) was saturated with hydrogen chloride and allowed to stand at room temperature for 2 days. Water was added to the residue obtained on removal of the solvent under reduced pressure. The aqueous solution was made alkaline to pH 8 with 5% aqueous sodium carbonate, when a solid material (the starting material, 35 mg.) separated. After filtration, the aqueous solution was repeatedly extracted with chloroform. The chloroform solution gave a resin on removal of the solvent, which was chromatographed on paper. Five bands appeared on the chromatogram. The middle band was cut out and treated with aqueous ammonia and chloroform. The chloroform solution gave an amorphous substance which crystallized on trituration with acetone. On recrystallization from acetone, a crude sample of XXI (3.5 mg.), m.p. 220–227°, was obtained, which showed the practically same infrared spectrum and R_f value as the pure dihydro derivative mentioned above.

Acknowledgment.—The authors wish to express their appreciation to Professor S. M. Kupchan, University of Wisconsin, for providing them with an abundant amount of crude jervine, to Mr. S. Ohnishi, Toyo-rayon Company, Ltd., and to Mr. S. Shimokawa, Hokkaido University, for measurement of the n.m.r. spectra, and also to Miss A. Maeda for microanalysis.

Syntheses of Jasmone and the Related Compounds. II.[1] Preparation of *trans*-Jasmone and Allethrone

KEIITI SISIDO, SIGERU TORII, AND MITUYOSI KAWANISI

Department of Industrial Chemistry, Faculty of Engineering, Kyôto University, Kyôto, Japan

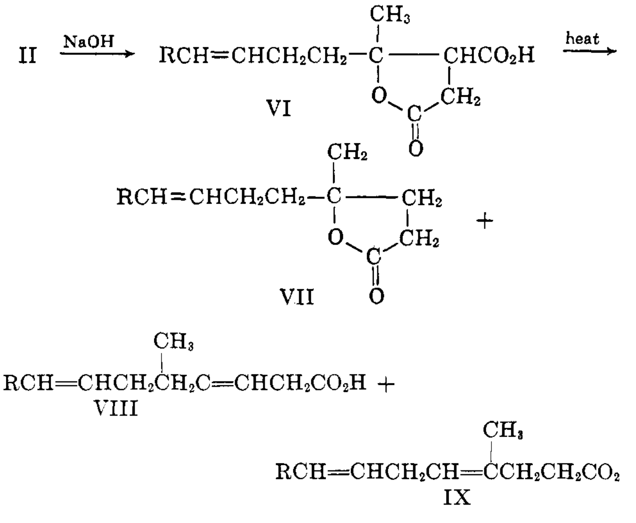
Received December 30, 1963

trans-Jasmone (Vb) and allethrone (Va) were synthesized from γ-methyl-γ-(3,4-dibromoalkyl)paraconic acids (III) by cyclodehydration with polyphosphoric acid followed by debromination with zinc. The acids III were obtained by bromination of γ-methyl-γ-alkenyl-α,β-dicarbethoxybutyrolactones (II) followed by heating with hydrochloric acid. Care was required in order to avoid the migration of and addition to the side-chain double bond.

In the previous paper,[2] a synthesis of 2,3-dialkyl-2-cyclopenten-1-ones including dihydrojasmone from γ,γ-dialkylparaconic acids was described. A synthesis of cyclopentenones (V) with an unsaturated side chain such as *trans*-jasmone[3–5] (Vb) and allethron[6] (Va) was undertaken. In order to avoid the migration of and addition to the double bond, a reaction sequence as illustrated in Scheme I was followed.

Reaction of ethyl β-methyl-β-alkenylglycidates (I) with sodium malonate afforded γ-methyl-γ-alkenyl-α,β-dicarbethoxybutyrolactones (II). Bromination of II followed by heating with hydrochloric acid gave γ-methyl-γ-(3,4-dibromoalkyl)paraconic acids (III). Treatment of III with polyphosphoric acid as described previously[2] resulted in the formation of methyldibromoalkylcyclopentenones (IV) which were subsequently debrominated with activated zinc[7] to give the expected cyclopentenones (V), including *trans*-jasmone (Vb) and allethrone (Va). The structures of these cyclopentenones were established by infrared spectra as well as conversion into the well-defined crystalline derivatives.

Saponification of II with aqueous sodium hydroxide followed by decarboxylation in glacial acetic acid[2] gave paraconic acids (VI). These were identical with the paraconic acids obtained by debromination of III, indicating that during the treatment of the lactone diesters (II) with alkali no shift of the double bond in the alkenyl group took place. Further evidence supporting the



---

[1] Part I[2] concerned the preparation of dihydrojasmone and the homologs from γ,γ-dialkyl paraconic acid.

[2] K. Sisido, S. Torii, and M. Kawanisi, *J. Org. Chem.*, **29**, 904 (1964).

[3] W. Treff and H. Werner, *Chem. Ber.*, **68**, 640 (1935).

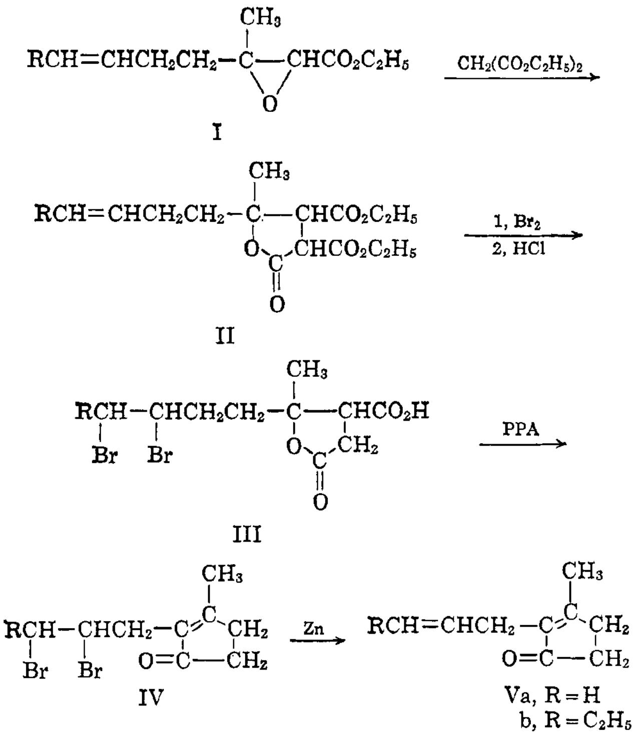
[4] H. Hunsdiecker, *ibid.*, **75**, 460 (1942).

[5] L. Crombie and S. H. Harper, *J. Chem. Soc.*, 869 (1952).

[6] L. Crombie, A. J. B. Edger, S. H. Harper, M. W. Lowe, and D. Thompson, *ibid.*, 3552 (1950).

[7] F. Bohlmann and K. Kieslich, *Chem. Ber.*, **87**, 1363 (1954).

SCHEME I



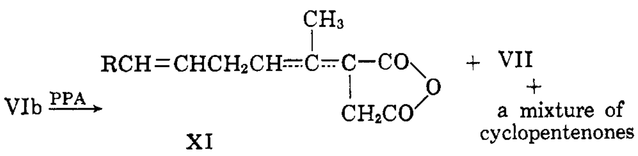
absence of the migration was obtained by ozonolysis of VI and by gas chromatography of the methyl ester of VI.

Thermal decarboxylation[8] of the paraconic acids (VI) afforded the butyrolactones (VII) and the two isomeric diunsaturated carboxylic acids (VIII and IX).

The unsaturated paraconic acids (VI) could not be prepared by the ordinary method through lactonization[2] of Stobbe half-esters[9] prepared by the reaction of methyl alkenyl ketones with diethyl succinate because of an inevitable addition of the lactonization reagent, *i.e.*, hydrogen halide, to the double bond.

For the synthesis of cyclopentenones (V) the direct cyclodehydration of γ-methyl-γ-alkenylparaconic acids (VI) or -butyrolactones (VII) would appear to be more straightforward. Due to the double bond migration, however, VI and VII did not give single products when heated with polyphosphoric acid.

This treatment of γ-methyl-γ-(3-hexenyl)paraconic acid (VIb) afforded a mixture of cyclopentenones accompanied by the corresponding acid anhydride (XI) and the butyrolactone (VII). The infrared spectra of the cyclopentenone mixture showed an absorption of an isolated double bond (1660 cm.$^{-1}$) and a conjugated double bond (1640 cm.$^{-1}$), indicating the shift of the original double bond toward the direction of the cyclopentenone ring.[10] When the mixed cyclopentenones were heated at 200° for 2 hr., the spectrum of the conjugated double bond became stronger at the expense of the band at 1660 cm.$^{-1}$. Elliott[11] described similar double bond migration by heat in the case of pyrethrone. γ-Methyl-γ-(3-butenyl)paraconic acid (VIa) gave a resinous material upon the same treatment.



Experimental[12]

Ethyl β-Methyl-β-(3-butenyl)glycidate (Ia).—To a mixture of 19.8 g. (0.2 mole) of allylacetone[13] (b.p. 131–132°, lit.[13] b.p. 127–132°) and 24.5 g. (0.2 mole) of ethyl chloroacetate, 22.4 g. of potassium *t*-butoxide in 160 ml. of dry *t*-butyl alcohol was added. The mixture was stirred at 10–15° for 1 hr. and, after addition of ice–water, the reaction mixture was extracted with ether. The product obtained on evaporation of the ethereal solution was distilled under reduced pressure to give 36.3 g. (80% based on allylacetone) of ethyl β-methyl-β-(3-butenyl) glycidate (Ia), b.p. 128.5° (30 mm.), $n^{23}\text{D}$ 1.4436; $\nu_{\max}$ (neat) 3070, 1640, 992, and 910 cm.$^{-1}$ (terminal vinyl group). Gas chromatography showed a single peak.

Anal. Calcd. for $C_{10}H_{16}O_3$: C, 65.19; H, 8.75. Found: C, 65.40; H, 8.76.

In a similar way, from 25.2 g. (0.2 mole) of *trans*-oct-5-en-2-one[5] [$\nu_{\max}$ (neat) 1710 (carbonyl) and 965 cm.$^{-1}$ (*trans* double bond); 2,4-dinitrophenylhydrazone, m.p. 55–56°, lit.[5] m.p. 56°], 33 g. (78%) of **ethyl β-methyl-β-(3-hexenyl)glycidate (Ib)** was obtained, b.p. 138° (14 mm.), $n^{20}\text{D}$ 1.4517, $\nu_{\max}$ (neat) 965 cm.$^{-1}$ (*trans* double bond).

Anal. Calcd. for $C_{12}H_{20}O_3$: C, 67.89; H, 9.50. Found: C, 68.08; H, 9.52.

Reaction of Ethyl β-Methyl-β-(3-butenyl)glycidate (Ia) with Diethyl Malonate.—To a mixture of 13.6 g. (0.2 mole) of sodium ethoxide and 37.5 g. (0.25 mole) of diethyl malonate in 120 ml. of anhydrous ethanol, 15.4 g. (0.1 mole) of ethyl β-methyl-β-(3-butenyl)glycidate (Ia) was added and refluxed for 20 hr. The mixture was acidified and taken up in ether. The ether layer was washed with sodium bicarbonate solution and, after drying over sodium sulfate, evaporated *in vacuo*. Distillation of the residue yielded 13.5 g. (45.4% based on glycidate) of γ-methyl-γ-(3-butenyl)-α,β-dicarbethoxybutyrolactone (IIa), b.p. 172° (2 mm.), $n^{23}\text{D}$ 1.4615; $\nu_{\max}$ (neat) 3080, 1640, 992, and 905 (terminal vinyl), 1790 (lactone carbonyl), and 1750 and 1740 cm.$^{-1}$ (ester carbonyls).

Anal. Calcd. for $C_{15}H_{22}O_6$: C, 60.39; H, 7.43. Found: C, 60.63; H, 7.60.

Similarly, from 15.4 g. (0.1 mole) of ethyl β-methyl-β-(3-hexenyl)glycidate (Ib), 18 g. (58%) of **γ-methyl-γ-(3-hexenyl)-α,β-dicarbethoxybutyrolactone (IIb)**, b.p. 162° (0.9 mm.), $n^{20}\text{D}$ 1.4661, was obtained; $\nu_{\max}$ (neat) 968 (*trans* double bond), 1785 (lactone carbonyl), 1750 and 1740 cm.$^{-1}$ (ester carbonyls).

Anal. Calcd. for $C_{17}H_{26}O_6$: C, 62.56; H, 8.03. Found: C, 62.72; H, 8.11.

γ-Methyl-γ-(3,4-dibromobutyl)paraconic Acid (IIIa) *via* **Dibromolactone Diesters.**—Bromination of 29.8 g. (0.1 mole) of γ-methyl-γ-(3-butenyl)-α,β-dicarbethoxybutyrolactone (IIa) was carried out in 50 ml. of carbon tetrachloride at −5° with 16 g. of bromine. The dibromide was heated vigorously with 100 ml. of concentrated hydrochloric acid for 6 hr. until the evolution of hydrogen chloride ceased and then cooled to room temperature. Precipitated solid was collected and a further amount of dibromolactone acid was extracted from the residual black material with hot water. Thus, 54.4 g. (76%) of γ-methyl-γ-(3,4-dibromobutyl)paraconic acid (IIIa) was obtained, m.p. 126°, $\nu_{\max}$ (neat) 1745 cm.$^{-1}$ (paraconic acid carbonyl).[2]

Anal. Calcd. for $C_{10}H_{14}BrO_4$: C, 33.54; H, 3.94. Found: C, 33.63; H, 3.94.

In a similar way, from 32.6 g. (0.1 mole) of γ-methyl-γ-(3-hexenyl)-α,β-dicarbethoxybutyrolactone (IIb), 38.1 g. (78%) of **γ-methyl-γ-(3,4-dibromohexyl)paraconic acid (IIIb)**, m.p. 122°, was obtained, $\nu_{\max}$ (neat) 1745 cm.$^{-1}$ (paraconic acid carbonyl).

---

(8) W. S. Johnson and R. H. Hunt, *J. Am. Chem. Soc.*, **72**, 935 (1950).

(9) W. S. Johnson and G. H. Daub, *Org. Reactions*, **6**, 26 (1951).

(10) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," Methuen and Co., London, 1958, p. 35.

(11) M. Elliott, *Chem. Ind.* (London), 1142 (1960).

(12) Microanalyses were performed by Miss Kenko Ogawa of this laboratory.

(13) M. S. Schechter, N. Green, and F. B. Laforge, *J. Am. Chem. Soc.*; **71**, 3165 (1949).

Anal. Calcd. for $C_{12}H_{18}Br_2O_4$: C, 37.33; H, 4.70. Found: C, 37.66; H, 4.93.

***trans*-Jasmone (Vb) by Dehydration of γ-Methyl-γ-(3,4-dibromohexyl)paraconic Acid (IIIb).**—A mixture of 5 ml. of polyphosphoric acid (82–83% P_2O_5) and 7.7 g. (0.021 mole) of γ-methyl-γ-(3,4-dibromohexyl)paraconic acid (IIIb) was heated at 140–145° for 30 min. to complete the decarboxylation; 30 ml. of water, 20 ml. of benzene, and 10 ml. of ether were added to this mixture. The organic layer was separated from resinous by-products and washed with sodium bicarbonate solution and saturated sodium chloride solution, dried over anhydrous sodium sulfate, and evaporated. The infrared absorption of this residue showed four bands in the carbonyl region at 1698, 1765, 1780, and 1840 cm.$^{-1}$, indicating that the residue comprised three components such as cyclopentenones (IV), lactone, and acid anhydride. The cyclopentenone and the lactone could be isolated by column chromatography on alumina using chloroform as an eluent. Repeated chromatography on alumina carried out with a mixture of carbon tetrachloride, petroleum ether (b.p. 40–60°) and chloroform (3:3:1 by volume) gave two fractions. From the first principal fraction 2.7 g. (40% based on IIIb) of 3-methyl-2-(2,3-dibromopentyl)-2-cyclopentenone-1 (IVb) was isolated, ν_{max} (neat) 1698 (carbonyl) and 1640 cm.$^{-1}$ (ethylene). The second minor fraction afforded 1.2 g. (19% based on IIIb) of γ-methyl-γ-(3,4-dibromohexyl)butyrolactone whose infrared spectrum was identical in every fine detail with that of the compound described in the subsequent paragraph.

The dibromocyclopentenone (IVb) was treated with 3 g. of activated zinc powder[7] in 3 ml. of 95% ethanol under reflux for 10–15 hr. Upon cooling to the room temperature, 5 ml. of water was added and the reaction product was extracted with ether. The ether layer was washed with saturated sodium chloride solution, dried over anhydrous sodium sulfate, and evaporated. Distillation of the residue under diminished pressure afforded 0.42 g. (31% based on IVb) of 3-methyl-2-(*trans*-2-pentenyl)-2-cyclopentenone-1, *i.e.*, *trans*-jasmone (Vb); b.p. 118° (13 mm.), $n^{20}D$ 1.4992; lit.[4] 142° (23 mm.), $n^{20}D$ 1.4974; semicarbazone m.p. 230°, lit.[4] m.p. 200–202°; 2,4-dinitrophenylhydrazone m.p. 127°, lit.[4] m.p. 128.5°; λ_{max} 258 mμ (ϵ 19,000) in ethanol. The ketone, semicarbazone, and 2,4-dinitrophenylhydrazone gave correct analyses. Infrared spectra were identical with those of the reported charts.[4]

Similarly from 3.6 g. (0.01 mole) of γ-methyl-γ-(3,4-dibromobutyl)paraconic acid (IIIa) there was obtained 0.24 g. (18.5%) of allethrone (Va); b.p. 120° (3 mm.), lit.[6] b.p. 63–70° (0.3 mm.); $n^{20}D$ 1.4501; ν_{max} (neat) 3080, 1640, 995, and 906 (terminal vinyl group), and 1698 and 1640 cm.$^{-1}$ (cyclopentenone); 2,4-dinitrophenylhydrazone m.p. 171–172°, lit.[6] m.p. 172°; λ_{max} 258 mμ (ϵ 19,250) in ethanol. These gave correct analyses for carbon and hydrogen.

Saponification of Lactone Diesters (IIa) with Sodium Hydroxide to Give Paraconic Acid (VIa).—A mixture of 15 g. (0.01 mole) of γ-methyl-γ-(3-butenyl)-α,β-dicarbethoxybutyrolactone (IIa) in 100 ml. of 1 *N* sodium hydroxide was refluxed for 4–5 hr. and neutralized to pH 6.5–7 with dilute sulfuric acid. When water was evaporated *in vacuo*, there were obtained in semisolid state lactonedicarboxylic acids, which were boiled for 30 min. of glacial acetic acid until the evolution of carbon dioxide ceased. Acetic acid was removed and 150 ml. of water was added. The precipitated light brown solid was recrystallized from a mixture of water and ethanol (10:1) to give 5.6 g. (60% based on lactone diesters) of γ-methyl-γ-(3-butenyl)paraconic acid (VIa), m.p. 135°; ν_{max} (neat) 1745 (paraconic acid), 3080, 1635, 985, and 910 cm.$^{-1}$ (terminal vinyl). The same acid was obtained from IIIa by the treatment with zinc powder.

Anal. Calcd. for $C_{10}H_{14}O_4$: C, 60.59; H, 7.12. Found: C, 60.69; H, 7.13.

Bromination of 9.9 g. (0.05 mole) of VIa was carried out with 8 g. of bromine in 30 ml. of of anhydrous chloroform at −5°. Recrystallization of the dibromide from water–ethanol (10:1) gave 17.2 g. (96%) of IIIa, m.p. and m.m.p. 126°.

Methyl γ-Methyl-γ-(3-butenyl)paraconate.—This compound (b.p. 134° at 3 mm., $n^{20}D$ 1.4688) was obtained by esterification of VIa with diazomethane. This showed a single gas chromatographic peak [6-ft. "Shimadzu Thermol-3" (silicone) column; retention time, 5.0 min. at 237°; 55 ml. of nitrogen/min.]. Infrared spectra of terminal vinyl group were the same as those of the acid VIa.

Anal. Calcd. for $C_{11}H_{16}O_4$: C, 62.25; H, 7.60. Found: C, 62.59; H, 7.78.

γ-Methyl-γ-(*trans*-3-hexenyl)paraconic Acid (VIb).—From 16.3 g. (0.05 mole) of γ-methyl-γ-(3-hexenyl)-α,β-dicarbethoxybutyrolactone (IIb), 7.3 g. (65%) of γ-methyl-γ-(*trans*-3-hexenyl)paraconic acid (VIb) was obtained, m.p. 138°, ν_{max} (neat) 965 (*trans* double bond) and 1745 cm.$^{-1}$ (carbonyl).

Anal. Calcd. for $C_{12}H_{18}O_4$: C, 63.70; H, 8.02. Found: C, 63.79; H, 7.91.

In order to confirm the position of the double bond, with 0.45 g. (2 mmoles) of γ-methyl-γ-(*trans*-3-hexenyl)paraconic acid (VIb) ozonolysis was carried out in chloroform at 0°. The ozonide was decomposed in 50 ml. of boiling water. Distilled volatile material was converted into the corresponding 2,4-dinitrophenylhydrazone, which was proved to be propionaldehyde derivative by the correct analysis for carbon and hydrogen, comparison of R_f values of the paper chromatography, and mixture melting point with an authentic compound.

Debromination of γ-Methyl-γ-(3,4-dibromohexyl)paraconic Acid (IIIb).—The treatment of 7.7 g. (0.02 mole) of IIIb with 4.5 g. of zinc powder as above gave 4.1 g. (90%) of γ-methyl-γ-(*trans*-3-hexenyl)paraconic acid (VIb), m.p. 138°. The mixture melting point with the paraconic acid obtained by hydrolysis of lactone diester (IIb) showed no depression, ν_{max} (neat) 964 cm.$^{-1}$ (*trans* double bond).

Decarboxylation of γ-Methyl-γ-(3-hexenyl)paraconic Acid (VIb).—A mixture of 4.5 g. (0.02 mole) of γ-methyl-γ-(*trans*-3-hexenyl)paraconic acid (VIb) and 0.05 g. of potassium hydrogen sulfate was treated at 230–250° for 4 hr. and there was obtained, as a neutral substance, 2.2 g. (61% based on VIb) of γ-methyl-γ-(*trans*-3-hexenyl)butyrolactone (VIIb), b.p. 136° (13 mm.), $n^{20}D$ 1.4700, ν_{max} (neat) 1760 cm.$^{-1}$ (lactone carbonyl).

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. Found: C, 72.40; H, 9.80.

Ozonolysis of VIIb gave, as a volatile fragment, only propionaldehyde, which was identified as the corresponding 2,4-dinitrophenylhydrazone.

As acidic products of pyrolysis, there was obtained 1.3 g. (37%) of a mixture of **4-methyldeca-3,7- and 4,7-dienoic acids** (**VIIIa and IXb**), b.p. 132° (2.5 mm.), $n^{20}D$ 1.4698, ν_{max} (neat) 1710 cm.$^{-1}$.

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. Found: C, 72.29; H, 9.80.

In the n.m.r. spectra of VIIIb and IXb, the methylene signal adjacent to the carboxylic acid group in structure VIIIb appeared at τ 6.9 and 7.1 as a doublet due to spin–spin coupling to the adjacent proton. Integration of the doublet signals gave area equivalent to one proton, suggesting the presence of equal amounts of each isomer.

The mixed acids VIIIb and IXb, after esterification with diazomethane followed by reaction with excess phenyl magnesium bromide[14] to produce **1,1-diphenyl-4-methyldeca-1,3,7- and 1,4,7-triene**, b.p. 145° (1.5 mm.), $n^{20}D$ 1.5928, showed an ultraviolet absorption at λ_{max} 251 mμ (ϵ 9000) in ethanol. The proportion of VIIIb and IXb was calculated[9] to exist in an equal ratio.

Anal. Calcd. for $C_{23}H_{26}$: C, 91.33; H, 8.67. Found: C, 90.48; H, 8.79.

Decarboxylation of γ-Methyl-γ-(3-butenyl)paraconic Acid (VIa).—A mixture of 9.9 g. (0.05 mole) of γ-methyl-γ-(3-butenyl)paraconic acid (VIa) and 0.03 g. of potassium hydrogen sulfate was treated at 230–250° for 4 hr. and there was obtained 5 g. (65%) of γ-methyl-γ-(3-butenyl)butyrolactone (VIIa), b.p. 119° (10 mm.), $n^{20}D$ 1.4672; ν_{max} (neat) 3080, 1640, 992, and 905 (terminal vinyl), and 1765 cm.$^{-1}$ (lactone carbonyl).

Anal. Calcd. for $C_9H_{14}O_2$: C, 70.10; H, 9.15. Found: C, 70.23; H, 9.10.

The lactone VIIa gave a single gas chromatographic peak.

As an acidic component, there was obtained 2.1 g. (28%) of a mixture of **4-methylocta-3,7- and 4,7-dienoic acids** (**VIIIa and IXa**), b.p. 105° (2 mm.), $n^{20}D$ 1.4681.

Anal. Calcd. for $C_9H_{14}O_2$: C, 70.10; H, 9.15. Found: C, 70.15; H, 9.10.

N.m.r. spectra of the mixed acids, VIIIa and IXa, exhibited a signal for the methylene adjacent to the carboxylic acid group in VIIIa similar to that of VIIIb.

Cyclodehydration of γ-Methyl-γ-(3-hexenyl)paraconic Acid (VIb).—To 2 ml. of polyphosphoric acid (82–83% P_2O_5) warmed at 100–120° was added 2.02 g. (0.01 mole) of γ-methyl-γ-(*trans*-3-hexenyl)paraconic acid (VI). The mixture was heated under 10 mm. gradually in the course of 30 min. to a final temperature

---

(14) *Cf.* L. Crombie and A. G. Jacklin, *J. Chem. Soc.*, 1622 (1957).

of 135°. During this period, vigorous evolution of carbon dioxide occurred. After the decomposition reaction subsided, the temperature was raised gradually during 3 hr. to 160°, when crude cyclopentenone together with lactone, dicarboxylic acids, and the acid anhydride[2] were distilled. From the ethereal solution of this crude cyclopentenone acidic material was removed with 5% potassium carbonate solution. The ether layer was washed with water, dried, and evaporated.

In order to separate the cyclopentenone from the mixture, Girard P reagent[15] was employed. To a boiling mixture of 1.4 g. of Girard P reagent, 16 ml. of ethanol, 2.7 ml. of methanol, and 2 g. of acetic acid, 1.2 g. of the crude cyclopentenone was added. After boiling for 1 hr., the mixture was poured into a solution of 3 g. of sodium carbonate in 100 ml. of ice–water. The neutral solution was extracted twice with ether and 12 ml. of 12 *N* sulfuric acid was added. The ether layer was washed with sodium bicarbonate solution as well as saturated sodium chloride solution, dried, and evaporated. On redistillation of the residue there was obtained 0.6 g. (32% based on VIb) of the isomer of *trans*- jasmone, b.p. 85° (1.5 mm.), n^{20}_{D} 1.5069; ν_{max} (neat) 980 (cross-conjugated *trans* double bond), 970 (*trans* double bond), 1698 (carbonyl), and 1640 and 1660 cm.$^{-1}$ (ethylenic bond).

On heating this material at 200° for 2 hr., double bond migration was noticed on an examination of the infrared spectrum.

Anal. Calcd. for $C_{11}H_{16}O$: C, 80.44; H, 9.83. Found: C, 79.77; H, 9.79.

2,4-Dinitrophenylhydrazone of the cyclopentenone melted at 213–215°.

Anal. Calcd. for $C_{17}H_{20}O_4N_4$: C, 59.29; H, 5.85. Found: C, 59.37; H, 6.15.

Similar treatment of 1.82 g. (0.01 mole) of γ-methyl-γ-(3-hexenyl)butyrolactone (VIIb) with polyphosphoric acid afforded 0.65 g. (41%) of the cyclopentenone, b.p. 90° (2 mm.). The infrared spectra were identical with those of the material prepared from VIb.

Dehydration of γ-Methyl-γ-(3-butenyl)paraconic Acid (VIa).—Reaction of γ-methyl-γ-(3-butenyl)paraconic acid (VIa) with polyphosphoric acid was examined under 10 mm. at 135–145°, but the mixture became too sticky, and no volatile material was obtained.

γ-Methyl-γ-(3,4-dibromohexyl)butyrolactone.—Bromination of 18.2 g. (0.1 mole) of γ-methyl-γ-(3-hexenyl)butyrolactone (VIIb) was carried out in 30 ml. of carbon tetrachloride at −5° with 16 g. of bromine. On removal of the solvent *in vacuo*, there was obtained 34 g. of γ-methyl-γ-(3,4-dibromohexyl)butyrolactone, n^{20}_{D} 1.5332, ν_{max} (neat) 1770 cm.$^{-1}$ (lactone carbonyl). Attempted purification failed because the substance decomposed on heating. This material, however, gave satisfactory analyses without further purification.

Anal. Calcd. for $C_{11}H_{18}Br_2O_2$: C, 38.62; H, 5.30. Found: C, 38.98; H, 4.99.

Dehydration of γ-Methyl-γ-(3,4-dibromohexyl)butyrolactone.—A mixture of 1.5 ml. of polyphosphoric acid and 3.4 g. (0.01 mole) of γ-methyl-γ-(3,4-dibromohexyl)butyrolactone was stirred at 145° for 30 min. After treating the reaction mixture in the same way as described above on the paraconic acid (IIIb), there was obtained 2.1 g. of the reaction products which contained the desired cyclopentenone IVb together with unchanged lactone. In order to separate the cyclopentenone, Girard P reagent was employed. From 2.1 g. of the mixture, 1.3 g. (40%) of IVb was obtained. The infrared spectra of the dibromocyclopentenone were superimposable in every fine detail with those of the compound obtained from the corresponding paraconic acid IIIb.

Allethrone (Va) by Dehydration of γ-Methyl-γ-(3,4-dibromobutyl)butyrolactone.—A mixture of 5 ml. of polyphosphoric acid and 6.8 g. (0.022 mole) of γ-methyl-γ-(3,4-dibromobutyl)butyrolactone (prepared from VIIa by bromination as described above) was heated at 130–145° for 30 min., and to this mixture 30 ml. of water and 10 ml. of benzene were added. On debromination of the reaction mixture in the same way as described above, there was obtained 0.6 g. (21% based on dibromobutyrolactone) of allethrone (Va), b.p. 120° (30 mm.). The infrared spectra were identical with those of the compound described in a preceding paragraph.

---

(15) A. Girard and G. Sandalesco, *Helv. Chim. Acta*, **19**, 1095 (1936).

The Structure of Carnosol

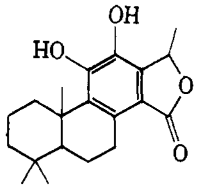
CARL HEINZ BRIESKORN,[1] ALBRECHT FUCHS,[1] J. B-SON BREDENBERG,[2]
JAMES D. MCCHESNEY,[2,3] AND ERNEST WENKERT[2]

Institut für Pharmazie und Lebensmittelchemie, Universität Würzburg, Germany, and the Department of Chemistry, Indiana University, Bloomington, Indiana

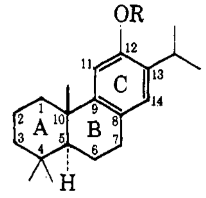
Received March 16, 1964

Carnosol is shown to be a phenolic diterpenic lactone of the ferruginol type. Its biosynthesis as well as that of the related tanshinones is discussed. A proton magnetic resonance study of the derivatives of carnosol, ferruginol, and totarol is presented.

Over 20 years ago a bitter principle was isolated from sage, *Salvia carnosa* Dougl.[4] The natural substance was named carnosol and noted to be a diphenolic, ester-containing $C_{19}H_{26}O_4$ hydrophenanthrene. While nothing further has been reported on this compound, another bitter principle, picrosalvin, was isolated recently from two other species of sage, *Salvia officinalis* L. and *Salvia triloba* L.,[5] as well as from rosemary, *Rosmarinus officinalis* L. (see Experimental), and recorded to be a $C_{20}H_{26}O_4$ *o*-diphenolic hydrophenanthrene lactone of structure I. The similarity of the physical and chemical properties of the two principles suggested that they may be the same natural product. As a consequence, a direct comparison of the two substances and their derivatives was made (see Experimental)[6] and their identity established. In view of the priority of the work of



I



IIa, R=H
b, R=Bz
c, R=Ac
d, R=Me

---

(1) Universität Würzburg.

(2) Indiana University.

(3) National Science Foundation Cooperative Predoctoral Fellow, 1962–.

(4) A. I. White and G. L. Jenkins, *J. Am. Pharm. Assoc., Sci. Ed.*, **31**, 33, 37 (1942).

(5) (a) C. H. Brieskorn and A. Fuchs, *Chem. Ber.*, **95**, 3034 (1962). (b) Undoubtedly this substance is identical with the $C_{20}H_{26}O_4$ compound isolated from *Salvia officinalis* L. by M. M. Janot, H. Pourrat, and J. LeMen [*Ann. pharm. franc.*, **10**, 433 (1952)].

(6) The authors are most grateful to Professor A. I. White for his gift of carnosol and its derivatives.