[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, INDIANA UNIVERSITY, BLOOMINGTON, IND.]

A Hibaene Model[1]

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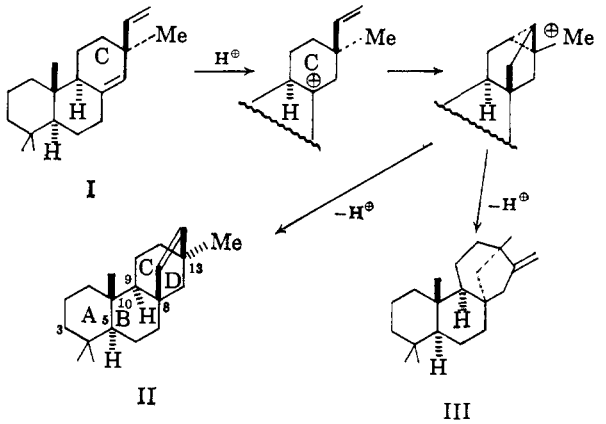
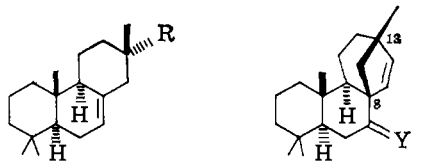
RECEIVED JANUARY 9, 1964

The partial synthesis of isohibaene from isopimaric acid is described. The stereochemistry of the synthetic intermediates is examined. The stereochemistry of the related diterpenic substances stachenone and beyerol is discussed.

An analysis of the structure patterns extant among diterpenic natural substances in 1955 led at that time to the advancement of a hypothesis concerning the possible biosynthetic relationship between the tri- and tetracarbocyclic diterpenes,[2] which in present-day terms can best be illustrated as [*e.g.*: pimaradiene (I) → hibaene (II) or kaurene (III)][3]



The kinship of the two diterpene groups aroused our interest in a study of their chemical interconversion. Compounds of hibaene (II)-like structure were our first goal of synthesis, on the assumption that they could be converted later into products of the kaurene (III) type. The present communication deals with the transformation of isopimaradiene (IVa) into isohibaene (Va).[4]



IVa, R = vinyl
b, R = $(CH_2)_2OH$

Va, Y = H_2
b, Y = O

Hydroboration of isopimaradiene (IVa), prepared from isopimaric acid,[5] followed by alkaline hydrogen peroxide oxidation, led to mixtures of an unsaturated alcohol and one or two saturated diols. The proton magnetic resonance (p.m.r.) spectrum of the monoalcohol, a minor reaction product, revealed it to be IVb, a consequence of preferential diborane attack on the exposed vinyl group of isopimaradiene (IVa). The signal characteristic of the vinyl function[5a] was missing in the p.m.r. spectrum of the alcohol, while its nuclear double bond still showed a one-proton signal of proper chemical shift. The diols, one melting at 144° and the other at 149°, were obtained in variable yields which depended on the conditions of the hydroboration. Thus the use of an excess of diborane led to a diol mixture, while limited quantities of reagent produced the 144° diol almost exclusively.

A p.m.r. investigation of the O-acetyl derivatives of the two dialcohols gave the first indication of their stereochemistry. The C_7-methine signal in the p.m.r. spectrum of the diacetate derived from the 144° diol was a multiplet at 4.72–4.90 p.p.m. [deuteriochloroform solution with tetramethylsilane (δ = 0.00 p.p.m.) as internal standard], characteristic of an equatorial hydrogen,[6] whereas that of the derivative of the 149° diol was a broad multiplet (two overlapping quartets) at 4.2–4.65 p.p.m., indicative of an axial hydrogen vicinally disposed to other axial hydrogens.[6] These data, added to the known *cis* stereochemistry of the hydroboration–oxidation process,[7] suggested structures VIa and VIIa for the 144 and 149° diols, respectively. While as yet tentative, these assignments were in consonance with the best available rationale for the variability of yields of the two diols. In the presence of a large excess of diborane the major hydroborating agent would be expected to be the sterically undemanding BH_3 species whose addition to the nuclear double bond of isopimaradiene (IVa) might take place with low discrimination of approach from the α-side *vs.* the more hindered β-side, thus leading to both diols. Contrastingly, the use of minimal quantities of diborane would be expected to make mono- and dialkylboranes (most likely formed by the initial addition of BH_3 to the vinyl function of IVa) the major hydroborating agents whose steric requirements would preclude their addition to the nuclear double bond of IVa from its β-side, thus leading predominantly to the 144° diol (VIa).[8]

(1) This work was presented at the XIXth International Congress of Pure and Applied Chemistry, London, July 10–17, 1963.

(2) E. Wenkert, *Chem. Ind.* (London), 282 (1955).

(3) For an experimental confirmation of this biosynthetic path in the case of a fungal, tetracarbocyclic, diterpenic substance see A. J. Birch, R. W. Richards, H. Smith, A. Harris, and W. B. Whalley, *Tetrahedron*, **7**, 241 (1959).

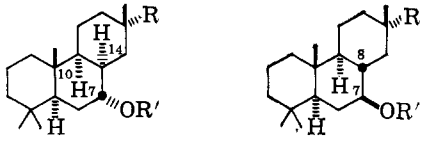
(4) It is suggested that isohibaene be the common name for 8,13-epihibaene. While at the moment it is merely the end product of our partial synthesis, it or its optical antipode (in any of a variety of states of oxidation) are likely natural products of the future.

(5) (a) E. Wenkert and P. Beak, *J. Am. Chem. Soc.*, **83**, 998 (1961), footnote 4; (b) E. Wenkert, V. I. Stenberg, and P. Beak, *ibid.*, **83**, 2320 (1961), see Experimental; (c) R. F. Church and R. E. Ireland, *Tetrahedron Letters*, 493 (1961). The diene IVa recently has been isolated from natural sources *Pinus silvestris* [H. Erdtman and L. Westfelt, *Acta Chem. Scand.*, **17**, 1826 (1963)] and *Podocarpus ferruginea* (E. Wenkert and J. D. McChesney, unpublished observations).

(6) *Cf.* R. V. Lemieux, R. K. Kullnig, H. J. Bernstein, and W. G. Schneider, *J. Am. Chem. Soc.*, **80**, 6098 (1958).

(7) H. C. Brown, "Hydroboration," W. A. Benjamin, Inc., New York, N. Y. 1962.

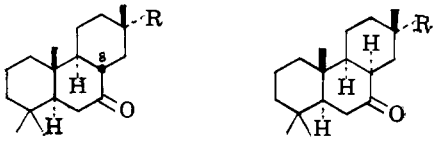
(8) On occasions there was isolated a third diol, m.p. 136°, whose p.m.r. spectrum and conversion to a noncrystalline olefinic monoacetate (containing a nuclear double bond and a CH_2OAc group) on acetylation showed it to be a primary, tertiary dicarbinol. While the irreproducibility of its formation prevented full characterization of this dialcohol, the anomaly of its partial tertiary nature is accommodated most readily by the assumption of the alco-



VI VII

a, R = $(CH_2)_2OH$, R' = H
b, R = $(CH_2)_2OAc$, R' = Ac

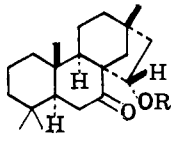
Corroboration of the configuration of the 149° diol (VIIa) came rapidly from oxidation–reduction studies. Sarett oxidation of the alcohol yielded crystalline ketoaldehyde VIIIa, whose instability in solutions exposed to air caused its transformation to ketoacid VIIIb even on purification by crystallization. Oxidation of the 149° diol VIIa by chromic acid in acetic acid yielded the same ketoacid more efficiently. Base-induced C_8-equilibration of the ketoaldehyde as well as the ketoester VIIIc, derived from the acid VIIIb by diazomethane treatment, led to the recovery of starting materials. These facts established the 8β-H configuration in the 7-keto compounds VIIIa–c. Conversion of the ketoester into the 149° diol VIIa on lithium aluminum hydride reduction indicated that this C_8-configuration had existed already in the diol precursor of the oxidation products.



VIII IX

a, R = CH_2CHO
b, R = CH_2CO_2H
c, R = CH_2CO_2Me
d, R = $(CH_2)_2OH$

Jones oxidation of the 144° diol VIa with a limited amount of chromic acid yielded a hydroxyketone whose further Jones oxidation afforded the ketoacid VIIIb while its Sarett oxidation gave the ketoaldehyde VIIIa. More intensive Jones oxidation of the 144° diol produced a mixture of ketoacid VIIIb and tetracyclic ketol Xa, whereas Sarett oxidation of the diol led to a mixture of the aforementioned hydroxyketone, ketoaldehyde VIIIa, and Xa. Structure VIIId could be assigned to the hydroxyketone on the basis of its recovery from base-catalyzed equilibration and its conversion to the 149° diol (VIIa) on lithium aluminum hydride reduction. It presumably had isomerized at C-8 on chromatography. Unfortunately its 8-epimeric precursor IXd could not be obtained in pure form.



Xa, R=H
b, R=Ac

The apparent anomaly of the nuclear, secondary carbinol moiety of the 144° diol VIa undergoing faster oxidation than the side-chain primary alcohol unit, illustrated by the formation of VIIId, seems to be a consequence of the specific steric environment at C-7 and C-8. Since the 7-hydroxy group is axial, it would be expected to be oxidized rapidly.[9] Furthermore, introduction of trigonality at C-7 should offset partly the energetically unfavorable 1,3-diaxial interaction of the C_{14}-methylene group and the angular methyl group at C-10. Complete relief from this nonbonded interaction in the resultant 7-keto-8α-H substances IX would occur upon enolization of the 7-keto function (toward C-8), a process likely to be fast both because of the strain release and of the ease of proton removal from the unhindered 8α-side. Since the enol might trap a sidechain aldehyde in an intramolecular aldol condensation, even the unusual, spontaneous ring closure of intermediate IXa (→Xa) during the oxidations of the 144° diol VIa appears to be a consequence of the initial C-8 stereochemistry.[10]

The cyclization of IXa had occurred with amazing stereospecificity, as only one tetracyclic ketol[11] was obtained. The stereochemistry of its carbinol carbon was assigned as depicted in Xa on the basis of a p.m.r. spectral analysis of the ketol and its acetate Xb, the product of exposure of the ketol to ketene. The hydroxy- and acetoxymethine signals were extraordinarily far downfield, at 4.84 and 5.55 p.p.m., respectively, characteristic of CH units held in or near the plane of proximate keto groups.[12] Pyrolysis of the ketoacetate Xb yielded 7-ketoisohibaene (Vb),[13]

(9) J. Schreiber and A. Eschenmoser, *Helv. Chim. Acta*, **38**, 1529 (1955).

(10) The ketoaldehyde VIIIa of 8β-H configuration did not undergo spontaneous cyclization, presumably because it possesses neither of the two structural factors contributing to the driving force of enolization of its 8-epimer IXa.

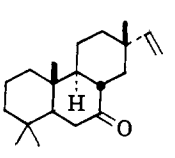
(11) The isolation of an alcohol as one of the end products of the oxidation of the 144° diol constituted yet another unpredicted observation. Presumably it reflected a low rate of oxidation of Xa. Had any of the β-diketone iv, the penultimate oxidation product, been formed, it might

iv v

not have survived the reaction work-up, since during the standard product separation by alumina chromatography it could be expected to suffer hydrolytic ring fission and the resultant ketoacid VIIIb be lost on the alumina column. The case of this ring cleavage [reminiscent of the extraordinarily facile hydrolytic ring opening of the β-diketone v (E. Wenkert, P. Beak, and D. P. Strike, unpublished observation)] was portrayed most strikingly by the observation of the conversion of crude iv [μ_{CCl_4}, C=O 5.74 (s), 5.90(s)], obtained from a 3-hr. Jones oxidation of ketol Xa, into ketoacid VIIIb on silica chromatography.

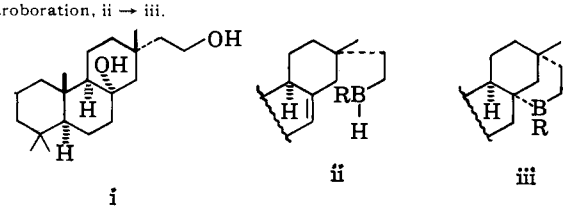
(12) *Cf.* D. H. Williams, N. S. Bhacca, and C. Djerassi, *J. Am. Chem. Soc.*, **85**, 2810 (1963).

(13) When during an early phase of our investigation the separation of the diol products of hydroboration–oxidation of isopimaradiene appeared to be an insurmountable task, Sarett oxidation of the alcohol mixture was undertaken and the resultant, presumed ketoaldehyde exposed to sodium acetate–acetic anhydride in the hope that this treatment would lead to cyclization and trapping of the tetracyclic ketol as its acetate. When the crude mixture was pyrolyzed, a low yield of 7-ketoisohibaene (Vb) indeed was realized. The only other recognizable, crystalline product was the olefinic ketone vi, m.p. 122–123°, obviously a product of acetylation of ketol VIIId and elimination of acetic acid.



vi

hol (tentative assignment i) being the end product of an intramolecular hydroboration, ii → iii.



i ii iii

whose Wolff–Kishner reduction led to isohibaene (Va), m.p. 73–75.°

Hibaene.—In the midst of our above investigation and a similar study emanating from pimaradiene (I),[14] the isolation of three hibaene (II)-like, diterpenic, natural substances—hibaene,[15] stachenone,[16] and beyerol[17]—was reported. Their possibly close stereochemical relationship with isohibaene (Va) aroused our immediate interest in these natural products.

Biosynthetic considerations, p.m.r. and optical rotatory dispersion (o.r.d.) data, and some chemical results led Kitahara and Yoshikoshi to suggest structure II for hibaene (m.p. 30°), a terpenic constituent of the essential oil of *Thujopsis dolabrata* Sieb. et Zucc. Its published p.m.r. spectrum[15] was different from that of our synthetic hydrocarbon Va (m.p. 73–75°) and incorporated a feature of stereochemical significance. The chemical shift of one of hibaene's methyl hydrogens was recorded as 44 c.p.s. (*cf.* Table I), distinctly upfield of the p.m.r. signals of methyl hydrogens surrounded by a saturated hydrocarbon environment[18] and, hence, characteristic of a methyl group shielded by a multiple bond.[19] This fact, added to the o.r.d.

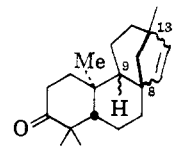
TABLE I

CHEMICAL SHIFTS

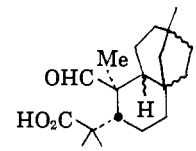
	Of methyl hydrogens (in c.p.s.)	Of olefinic hydrogens (in p.p.m.)
Phyllocladene	49, 51, 55	4.69 (broad singlet)
III[26]	49, 52, 62	4.73 (broad singlet)
II[15]	44, 49, 51, 58	
Va	48, 51, 61, 63	5.42, 5.53 (doublets) (J = 5.5 c.p.s.)
Vb	52, 52, 65, 71	5.68, 5.90 (doublets) (J = 5.5 c.p.s.)
XIIIa	54, 60, 62, 64	5.42, 5.67 (doublets) (J = 5.5 c.p.s.)
XIIIb	45, 50, 52, 59	5.46, 5.72 (doublets) (J = 5.5 c.p.s.)
XIVd	47, 61	5.81 (singlet)
XV	45, 49, 51, 102 (J = 1.5 c.p.s.)	5.42 (broad singlet)
XVI[26]	49, 52, 62, 103 (J = 1.5 c.p.s.)	5.07 (broad singlet)
XVIIa	55, 76	5.88 (singlet)
XVIIb	55, 77	5.86 (singlet)
XVIIIb	47, 61	5.59, 5.78 (doublets) (J = 5.5 c.p.s.)

data[15] which had fixed the absolute configuration of the 8,13-etheno bridge as depicted in II, was in consonance with the 10,9,8-*anti-trans* arrangement suggested for hibaene (II),[15] since only in this configuration is a methyl group, the one at C-10, within the shielding influence of the nuclear double bond.[20] Thus hibaene (II) and our synthetic hydrocarbons appeared to be 8,13-epimers.

Stachenone.—A chemical and spectral study of this ketonic constituent of the oleoresin of *Spirostachys africana* Sond. revealed it to possess structure XI whose stereochemistry was assigned only partly.[16] While its A/B junction was shown to be *trans* and of nonsteroidal, absolute configuration, no distinction was made between the four possible isomers of varying C_9 and C_8–C_{13} configurations.[16] Close inspection of the published p.m.r. data and comparison with the spectra of model compounds[18] permitted our elimination of two structural possibilities. The p.m.r. spectrum of an aldehydoacid (XII) degradation product showed an aldehyde hydrogen signal at 9.20 p.p.m. Since this chemical shift is characteristic of equatorial aldehydes,[18,21] the structure of the degradation product was limited to a *cis* arrangement of the carboxyaldehyde moiety and its neighboring C_9–H group. As a consequence, stachenone appeared to be a 3-keto derivative of hibaene (II) enantiomer or of isohibaene (Va) enantiomer.

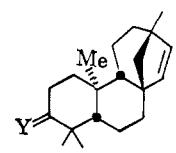


XI



XII

Differentiation between these two structures on the basis of the chemical shifts of stachenone's methyl group hydrogens was precluded, since the keto function was expected to affect the δ-value of the diagnostically important C_{10}-methyl group. Hence, the natural ketone was reduced to the olefinic hydrocarbon stachene by conversion to its semicarbazone and Wolff–Kishner reduction of the latter,[22] and the p.m.r. spectrum examined. It revealed an upfield methyl signal (δ = 45 c.p.s.) (*cf.* Table I) and, furthermore, was nearly indistinguishable from the published p.m.r. spectrum of hibaene (II). Comparison of stachene's other physical properties, m.p. 25–27°, $[\alpha]^{23}D$ +39° (c, 2.0, $CHCl_3$), with those recorded for hibaene,[15] m.p. 30°, $[\alpha]^{23}D$ −49.9°, indicated the two to be enantiomers.[23] Thus the structure of stachenone is XIIIa.[24]



XIIIa, Y = O
b, Y = H_2

(14) E. Wenkert and P. W. Jeffs, unpublished data.

(15) Y. Kitahara and A. Yoshikoshi, Abstracts of the 6th Natural Products Symposium of the Japanese Chemical Society, Pharmaceutical Society and Agricultural Chemical Society, Sapporo, Japan, July 6–7, 1962, pp. 113–119. We are most grateful to Professor D. E. White (Chemistry Department, University of Western Australia) for making us aware of the Japanese study.

(16) W. H. Baarschers, D. H. S. Horn, and L. R. Johnson, *J. Chem. Soc.*, 4046 (1962).

(17) P. R. Jefferies, R. S. Rosich, D. E. White, and M. C. Woods, *Australian J. Chem.*, **15**, 521 (1962).

(18) *Cf.* R. W. J. Carney, Ph.D. Dissertation, Iowa State University, 1962, for a composite study of the p.m.r. spectra of tricarbocyclic diterpenic substances, whose data proved to be of immense help in our present work.

(19) This phenomenon is highly reminiscent of the shielding of the C-10 angular methyl hydrogens (δ 35–38 c.p.s.) by the transannular double bond in Diels–Alder adducts of levopimaric acid [W. L. Meyer and R. B. Huffman, *Tetrahedron Letters*, 691 (1962); W. A. Ayer, C. E. McDonald, and J. B. Stothers, *Can. J. Chem.*, **41**, 1113 (1963)].

(20) Recently (letter, date June 12, 1963), Professor Kitahara kindly informed us that a direct comparison between dihydrohibaene and isostevane has shown these substances to be enantiomers. In view of the complete structure elucidation of steviol and isosteviol [E. Mosettig, U. Beglinger, F. Dolder, H. Lichti, P. Quitt, and J. A. Waters, *J. Am. Chem. Soc.*, **85**, 2305 (1963), and references cited therein] this constitutes proof of the absolute configuration II of hibaene.

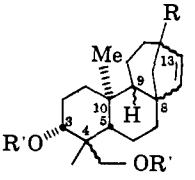
(21) *Cf.* T. J. King and J. P. Yardley, *J. Chem. Soc.*, 4308 (1961).

(22) The authors are indebted to Drs. Horn and Baarschers for a gift of a stachenone sample.

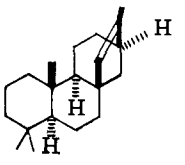
(23) In view of Professor Kitahara's inability to furnish us with a sample of hibaene, all comparisons of the physical properties of our hydrocarbons with those of hibaene were limited to collations with the recorded data in the literature.[15] The unfortunate accompanying lack of rigorous accuracy (*e.g.*, *cf.* the 1 c.p.s. deviation from identity of the methyl p.m.r. signals of stachene and hibaene, Table I) is the only factor standing in the way of the enantiomeric relationship of stachene and hibaene constituting the first complete structure proof of the latter.

(24) Recently stachene was recognized as a natural product. Our direct comparison (p.m.r. and infrared spectra, optical rotation, and gas-

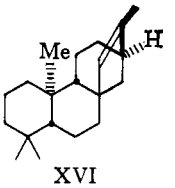
Beyerol.—Beyerol monocinnamate has been shown to be a major terpenic constituent of *Beyeria leschenaulti* (DC) Baill. *var. drummondii* (Muell. Arg.) whose alkaline hydrolysis has yielded the trihydroxyditerpene beyerol.[17] A structure analysis of this triol has revealed it to be XIVa, wherein the stereochemistry at C-4, C-9, and C-8–C-13 was left unassigned.[17] As in the cases of hibaene and stachenone, it seemed worthwhile to ascertain the δ_{Me} values of beyerol in order to obtain some insight into the relationship of the angular C_{10}-methyl group and the etheno bridge in this system. Since the triol was insoluble in deuteriochloroform, the p.m.r. spectrum of its triacetate XIVb[17] was determined.[25] However, its farthest upfield methyl signal, 47 c.p.s., lay between the values we had recorded by now for hibaene (II)-like compounds stachene (XIIIb), 45 c.p.s., and isophyllocladene (XV), 45 c.p.s., and for isohibaene systems isohibaene (Va), 48 c.p.s., and *l*-isokaurene (XVI),[26] 49 c.p.s. (*cf.* Table I). Unfortunately this anomaly could not be explained until the effect of the C_4-acetoxymethyl group, if any, on the C_{10}-methyl function had been determined. For this reason the C_4-configuration of beyerol (XIVa) had to be resolved and the p.m.r. spectra of several derivatives were inspected.



XIVa, R = CH_2OH, R' = H
b, R = CH_2OAc, R' = Ac
c, R = CO_2Me, R' = H
d, R = CO_2Me, R' = Ac

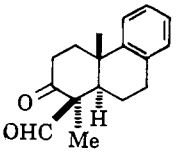


XV



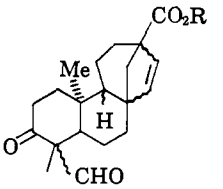
XVI

Jones oxidation of beyerol (XIVa) has yielded previously an aldehydoketoacid (XVIIa)[17] whose treatment with diazomethane now gave the ester XVIIb. The p.m.r. spectra of the acid and ester revealed aldehyde hydrogen signals characteristic of axial aldehyde functions, 9.68 and 9.65 p.p.m., respectively.[18,21,27]

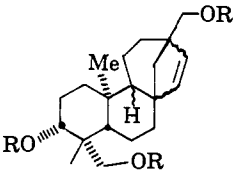


vii

Sodium borohydride reduction of the ester XVIIb yielded a dihydroxyester (XIVc) whose acetylation led to the triester XIVd. The p.m.r. spectra of the latter diacetate (XIVd) and beyerol triacetate (XIVb) were inspected for the position of the AB patterns of the acetoxymethyl hydrogens.[28] As already quoted elsewhere,[29] the two sets of two doublets each were characteristic of axial acetoxymethyl groups. Hence, two independent sets of measurements indicated an axial configuration for beyerol's C_4-oxygenated methyl function (*cf.* XVIIIa).

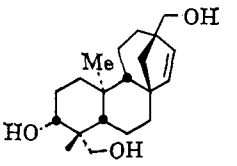


XVIIa, R = H
b, R = Me



XVIIIa, R = H
b, R = Ac

The *cis*-1,3-diaxial relationship between the C_4-acetoxymethyl and C_{10}-methyl groups in beyerol triacetate (XVIIIb) and triester XIVd and the possible perturbation of the chemical shifts of their angular methyl groups by the C_4-substituents make interpretation of the significance of the 47 c.p.s. signal for their farthest upfield methyl groups (*cf.* Table I) less meaningful. Our recent finding of a 2 c.p.s. paramagnetic shift of the methyl resonance in 1,3-diaxial methyl–methyl interacting systems upon the introduction of an acetoxy function on one of the methyl groups[30] and comparison of the 47 c.p.s. value for the methyl resonances of XVIIIb and XIVd with the 45 c.p.s. value for the methyl signals of stachene and isophyllocladene makes an assignment of a trihydroxystachene structure (XIX) to beyerol most tempting. However, in the absence of a larger amount of data substantiating the reality of this minute shift the structure assignment is premature.[31]



XIX

phase chromatographic retention time) of our desoxygenation product of stachenone and a hydrocarbon isolated from *Erythroxylon monogynum* furnished to us by Dr. K. H. Overton and R. Murray has proved their identity.

(25) The authors are most grateful to Professor D. E. White and Mr. R. S. Rosich for their generous gift of a beyerol sample.

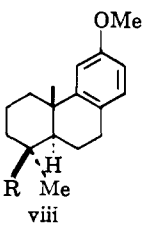
(26) *Cf.* L. H. Briggs, B. F. Cain, R. C. Cambie, B. R. Davis, P. S. Rutledge, and J. K. Wilmhurst, *J. Chem. Soc.*, 1345 (1963). Our p.m.r. data are in agreement with those recorded in this paper. We are indebted to Mr. J. F. Grove (Imperial Chemical Industries Ltd., Akers Research Laboratories) and Dr. J. M. Mellor (Universite de Strasbourg) for gifts of *l*-isokaurene and *l*-kaurene samples, respectively.

(27) *Cf.* W. R. Chan, C. Willis, M. P. Cava, and R. P. Stein, *Chem. Ind.* (London), 495 (1963); and δ_{CHO} 9.76 p.p.m. for vii (E. Wenkert and A. Afonso, unpublished observation).

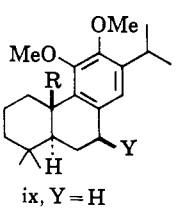
(28) *Cf.* E. Wenkert and P. Beak, *Tetrahedron Letters*, 358 (1961).

(29) A. Gaudemer, J. Polonsky, and E. Wenkert, *Bull. soc. chim. France*, in press.

(30) Three sets of models, viii,[18] ix, and x (E. Wenkert and J. D. McChesney, unpublished observation; R = Me as well as CH_2OAc) were on hand.



viii



ix, Y = H
x, Y = OAc

(31) The composite study of the stereochemistry of beyerol by White and co-workers[32] included a p.m.r. analysis of the δ_{Me} values of various beyerol derivatives. However, since the Australian workers neglected to note the closeness of the upfield signals of these substances with those of *l*-isokaurene and merely emphasized their similarity with the signals of phyllocladene derivatives, the stereochemical conclusion drawn from this phase of the work is invalid.

Further investigation on the stereochemistry of beyerol was halted in view of the continuing studies by White and his co-workers which culminated most recently in the proposal of structure XIX for beyerol.[32] Thus it would appear that the stereochemistry of our synthetic hydrocarbon (Va) is not represented by any presently known diterpenic natural product of the hibaene type.[33a,b]

Experimental[34]

Hydroboration. Oxidation of Isopimaradiene (IVa).[35] (a).—A solution of 18.0 g. of boron trifluoride etherate was added dropwise to a stirring solution of 5.53 g. of the diene IVa and 6.0 g. of sodium borohydride in 80 ml. of tetrahydrofuran maintained at 0° over nitrogen. Stirring was continued for a further 2 hr. at 0° before the destruction of the excess diborane by the addition of hydrated sodium sulfate. Sodium hydroxide, 30 ml. of 3 *N*, was added to the resulting suspension, followed by the careful addition of 20 ml. of 30% hydrogen peroxide, and the mixture refluxed gently for 14 hr. After cooling and saturating with sodium chloride, the oxidation mixture was extracted several times with ethyl acetate and then with ether. The combined extracts were washed successively with 10% ferrous sulfate solution, 5% sodium carbonate solution, and water. After drying over anhydrous sodium sulfate the solvents were removed *in vacuo* to yield 5.28 g. of a viscous oil. Chromatography of this oil over 80 g. of neutral Woelm or Merck alumina (activity II) gave the fractions: 2.13 g. of A eluted with 200 ml. of 1:1 benzene–hexane; 3.30 g. of B eluted with 1 l. of 9:1 benzene–ethyl acetate, 200 ml. of 1:1 benzene–ethyl acetate, and 1 l. of ethyl acetate. Crystallization of B from ethyl acetate afforded 2.3 g. of solid, m.p. 134–136°, which on further crystallization from ethyl acetate gave large prisms of the pure diol VIa, m.p. 136–137°, $[\alpha]^{20}D$ +29° (*c* 1.0, 95% EtOH); spectra: infrared (Nujol), OH 3.05 (s) μ; p.m.r., 3-proton singlets 0.84, 0.86, 0.89, 1.04 p.p.m. (C–Me); 2-proton triplet 3.75 p.p.m. (J = 7.5 c.p.s.) (hydroxymethyl); 1-proton singlet 3.77 p.p.m. (C_7-methine). Crystallization of the diol from benzene afforded a polymorph, m.p. 144°, as long prisms which could be reconverted to the 136–137° melting form by crystallization from ethyl acetate. The two types of crystals were not different solvates as evidenced by their identical n.m.r. spectra.

Anal. Calcd. for $C_{20}H_{32}O$: C, 77.86; H, 11.76. Found: C, 77.71; H, 11.67.

The diacetate VIb, prepared in the usual way in pyridine–acetic anhydride, was an oil, b.p. 140° (0.3 mm.); spectra: infrared (film) C=O 5.86 (s), C—O 8.08–8.10 (m) μ; p.m.r., 3-proton singlets 0.81, 0.81, 0.91, 1.05 p.p.m. (C—Me); 2.00, 2.01 p.p.m. (CH_3CO); 2-proton triplet 4.06 p.p.m. (J = 7.5 c.p.s.) (acetoxymethyl); 1-proton singlet 4.75 p.p.m. (C_7-methine).

Anal. Calcd. for $C_{24}H_{40}O_4$: C, 73.43; H, 10.27. Found: C, 73.58; H, 10.23.

Rechromatography of fraction A in 100 ml. of hexane over 60 g. of alumina (activity II) yielded the fractions: 176 mg. of diene IVa with 200 ml. of hexane, 282 mg. of an oil which on crystallization from hexane gave the unsaturated alcohol IVb, m.p. 80–82°. Two recrystallizations from hexane yielded the pure alcohol, m.p. 82°; spectra: infrared, OH 3.00 (w), C=C 6.00 (w) μ; p.m.r., 3-proton singlets 0.79, 0.84, 0.85, 0.92 p.p.m. (C—Me); 2-proton triplet 3.70 p.p.m. (J = 7.5 c.p.s.) (hydroxymethyl); 1-proton singlet 5.20 p.p.m. (broad, olefinic).

Anal. Calcd. for $C_{20}H_{34}O$: C, 82.69; H, 11.80. Found: C, 82.65; H, 11.78.

Further elution with 500 ml. of ethyl acetate gave 267 mg. of diol VIa.

(b).—A solution of 2.52 g. of isopimaradiene (IVa) in 25 ml. of tetrahydrofuran was added slowly to a stirring solution of 0.5 g. of sodium borohydride and 1.5 g. of boron trifluoride etherate at 0° for 2 hr. and then at 25° for 17 hr. After the successive addition of moist sodium sulfate, 15 ml. of water, 10 ml. of 5 *N* sodium hydroxide, and 7 ml. of 30% hydrogen peroxide to the hydroboration mixture, the solution was stirred at 25° for 20 min. and then heated at 60° for 15 min. Cooling and saturating of the solution with sodium chloride followed by extraction with ether yielded 2.73 g. of gum after drying over anhydrous sodium sulfate. Chromatography of the gum in 40 ml. of 3:1 benzene–hexane over 75 g. of neutral alumina (activity II) afforded the fractions: 814 mg. of diene IVa with 3:1 benzene–hexane and benzene, 288 mg. of unsaturated alcohol IVb with 9:1 benzene–ether, 134 mg. of solid, not investigated further, and 814 mg. of solid, m.p. 140–150°, with ethyl acetate. Acetylation of the m.p. 140–150° solid by a 1-hr. refluxing in 6 ml. of pyridine and 1 ml. of acetic anhydride and the usual work-up yielded 845 mg. of crude product. Chromatography in 25 ml. 2:1 hexane–benzene over 20 g. of neutral alumina (activity 1) gave 267 mg. of an oily acetate (VIIb) [later obtained as needles, m.p. 97–98°, on crystallization from hexane; p.m.r. spectrum: 3-proton singlets 0.84, 0.84, 0.91, 0.91 p.p.m. (C–Me); 2-proton triplet 4.09 p.p.m. (J = 7.5 c.p.s.) (acetoxymethyl); 1-proton multiplet 4.20-4.65 p.p.m. (C_7-methine)].

A solution of diacetate VIIb in 10 ml. of ether was added to a suspension of 200 mg. of lithium aluminum hydride in 30 ml. of ether and the mixture stirred for 17 hr. at 25°. Decomposition of the excess lithium aluminum hydride with water and extraction of the two-phase system with 10:1 chloroform–methanol afforded 210 mg. of solid. Crystallization from ether followed by a second crystallization from ethyl acetate gave the pure diol VIIa, m.p. 149°, $[\alpha]D$ +54° (*c* 1.04, 95% EtOH); spectra: infrared ($CHCl_3$), OH 2.70 (w), 2.90 (w) μ; p.m.r., 3-proton singlets 0.86, 0.86, 0.86, 0.89 p.p.m. (C–Me); 1-proton multiplet 2.88, 3.42 p.p.m. (C_7-methine); 2-proton triplet 3.75 (J = 7.5 c.p.s.) (hydroxymethyl).

Anal. Calcd. for $C_{20}H_{32}O_2$: C, 77.86; H, 11.76. Found: C, 77.75; H, 11.56.

The p.m.r. spectra of the remaining chromatographic fractions showed the presence of hydroxymethyl signals indicating that hydrolysis of the primary acetate group had taken place during the chromatography. These fractions were combined, reacetylated by refluxing with 2 ml. of acetic anhydride containing 80 mg. of sodium acetate, and chromatographed in hexane over 4 g. of alumina (activity I). Hexane eluted 59 mg. of an oil which was not investigated further. Elution with 4:1 and 2:1 hexane–benzene yielded 6.0 mg. of an oil whose crystallization from hexane afforded the diacetate VIIIb, m.p. 97–98. Later fractions whose p.m.r. spectra showed the presence of a primary alcohol function were combined and reduced in ether with lithium aluminum hydride. Isolation of the product in the usual manner gave 110 mg. of diol VIa.

Oxidation of Diol VIa. (a).—A solution of 730 mg. of the diol VIa was added slowly to an ice-cold solution of 1.4 g. of chromium trioxide in 20 ml. of pyridine. After allowing the reaction to come to 25° during the course of 2 hr., it was poured into 100 ml. of ether and the ether solution was washed successively with three portions of 20-ml. aliquots of 2 *N* hydrochloric acid, 10% sodium carbonate solution, and water. Work-up in the usual manner afforded 650 mg. of an oil which was dissolved in hexane and chromatographed over 20 g. of neutral alumina (activity III). Elution with hexane gave 90 mg. of an oily aldehydic material (infrared spectrum). Attempted crystallization from hexane and consequent air oxidation afforded acidic material which after several recrystallizations from ethyl acetate–methanol gave pure ketoacid VIIIb as plates, m.p. 228–230°; spectra: infrared (Nujol), OH 2.90 (w), C=O 5.88 (s) μ; p.m.r., 3-proton singlets, 0.84, 0.87, 1.01, 1.08 p.p.m. (C—Me).

Anal. Calcd. for $C_{20}H_{32}O_3$: C, 74.96; H, 10.06. Found: C, 74.83; H, 10.04.

Treatment of 60 mg. of ketoacid VIIIb with excess diazomethane in ether afforded 56 mg. of oil which solidified on standing. Three crystallizations from hexane gave 26 mg. of needles of ketoester VIIIc, m.p. 85–86°, $[\alpha]D$ +17° (*c* 4.0, 95% EtOH); spectra: infrared (CCl_4), C=O 5.74 (s) and 5.84 (s) μ; p.m.r., 3-proton singlets 0.88, 0.92, 1.00, 1.12 p.p.m. (C—Me), 3.75 p.p.m. (OMe).

Anal. Calcd. for $C_{21}H_{34}O_3$: C, 75.40; H, 10.25. Found: C, 75.17; H, 9.99.

Continued chromatography and elution with hexane and 2:1 hexane–benzene afforded a total of 300 mg. of solid which after several crystallizations from hexane gave needles of ketoalcohol

(32) P. R. Jefferies, R. S. Rosich, and D. E. White, *Tetrahedron Letters*, 1793 (1963).

(33) (a) The support of this work by the National Science Foundation is acknowledged gratefully. (b) We have just been informed by Dr. Yoshikoshi (letter, dated December 27, 1963) that his structure proof of hibaene was completed and that the hydrocarbon was shown to possess structure II.

(34) The able technical assistance by Messr. N. Cole and R. V. Stevens is acknowledged gratefully.

(35) Prepared from isopimaric acid[5] which was obtained from W W gum rosin, kindly donated by Dr. R. V. Lawrence, U. S. Department of Agriculture.

Xa, m.p. 157°; spectra: infrared (CCl_4), OH 2.85 (w), C=O 5.92 (s) μ; p.m.r., 3-proton singlets 0.86, 0.86, 0.96, 1.17 p.p.m. (C—Me); 1-proton four-line multiplet 4.70, 4.80, 4.88, 4.98 p.p.m. (C_{15}-H).

Anal. Calcd. for $C_{20}H_{32}O_2$: C, 78.89; H, 10.59. Found: C, 78.84; H, 10.55.

Elution with 1:1 benzene–ether yielded 85 mg. of gum which was identified as the acyclic ketol VIIId from its spectral properties (see below).

On one occasion the ketoalcohol Xa crystallized in 10% yield directly from the oxidation mixture prior to alumina chromatography which subsequently afforded a further quantity of ketol Xa (total 30% yield).

(**b**).—Chromic acid solution[36] (0.08 ml., 0.30 mmole) was added slowly to 104 mg. (0.30 mmole) of the diol VIa in 15 ml. of acetone at 0° for 5 min., 1.0 ml. of methanol was added, and the solvents were removed in a stream of nitrogen. Extraction of the resulting residue with four 10-ml. portions of ether and drying of the extract over anhydrous sodium sulfate afforded 102 mg. of colorless gum. This was combined with 29 mg. from a previous run and their benzene solution chromatographed over 5 g. of neutral alumina (activity II). Benzene eluted 78 mg. of gummy material, showing both aldehyde and hydroxyl absorption, which could not be induced to crystallize. Continued elution with 19:1 through 5:1 benzene–ether mixtures afforded 47 mg. of a solid which on crystallization from hexane yielded the pure ketoalcohol VIIId, m.p. 118–120°; spectra: infrared (CCl_4), OH 2.73 (w) and 2.90 (w), C=O 5.90 (s) μ; p.m.r., 3-proton singlets 0.84, 0.89, 0.89, 1.08 p.p.m. (C—Me); 2-proton triplet 3.73 p.p.m. (J = 7 c.p.s.) (hydroxymethyl); o.r.d.[37] (*c* 0.01, MeOH), $[\alpha]_{526}$ +57°, $[\alpha]_{370}$ +422°, $[\alpha]_{313}$ +237°, $[\alpha]_{263}$ +945°, $[\alpha]_{250}$ +840°.

Anal. Calcd. for $C_{20}H_{34}O_2$: C, 78.38; H, 11.18. Found: C, 78.16; H, 11.13.

(**c**).—Chromic acid reagent (1.05 ml., 3.0 mmoles) was added to a solution of 500 mg. of the diol VIa in 30 ml. of acetone at 0°. The solution was allowed to stand and worked up as above. The semisolid product, 440 mg., was partitioned into an acid fraction, 90 mg., and a neutral material, 380 mg., by carbonate extraction of the ethereal solution, followed by the usual procedure. The acid fraction was shown to be the ketoacid VIIIb from its infrared spectrum and m.p. The neutral fraction was crystallized from hexane to yield 125 mg. of the tetracyclic ketoalcohol Xa. Thin-layer chromatography (t.l.c.) on silica showed the mother liquors to contain two minor components in addition to the ketoalcohol Xa. Aluminum chromatography led to a further 50 mg. of the ketoalcohol Xa.

Oxidation of Diol VIIa. (**a**).—A solution of 105 mg. of diol VIIa in 1 ml. of pyridine was added to an ice-cold solution of 210 mg. of chromium trioxide previously dissolved in 2 ml. of pyridine. The mixture was stirred for 90 min. during which time the temperature was allowed to rise to 25°. The oxidation mixture was poured into 30 ml. of ether, filtered, and the filtrate washed with 10 ml. of 2 *N* sodium carbonate solution. After drying over anhydrous sodium sulfate and removal of the solvent and pyridine *in vacuo*, the residual material, 100 mg., was dissolved in hexane and chromatographed over 3.0 g. of alumina (activity II). Elution with benzene gave 30 mg. of solid material which crystallized from hexane as ketoaldehyde VIIIa, m.p. 105–107° (rapid heating); spectra: infrared (CCl_4), aldehyde CH 3.71 (w), C=O 5.84–5.91 (s) μ; p.m.r., 3-proton singlets 0.84, 0.89, 1.03, 1.08 p.p.m. (C—Me); 1-proton triplet 9.86 p.p.m. (J = 3.5 c.p.s.) (aldehyde hydrogen).

Anal. Calcd. for $C_{20}H_{32}O_2$: C, 78.89; H, 10.59. Found: C, 78.43; H, 10.77.

This aldehyde (VIIIa) was extremely sensitive to air oxidation and attempts at crystallization invariably led to formation of the ketoacid VIIIb. Furthermore its ready air oxidation resulted in a variation of its melting point with rate of heating owing to the ketoacid formation.

(**b**).—A solution of 6.5 mg. of chromium trioxide in 0.5 ml. of glacial acetic acid was added to a solution of 10 mg. of the diol VIIa in 0.3 ml. of acetic acid. The solution was warmed at 60° for 10 min. and then poured into water. Crystallization of the resulting precipitate from ethyl acetate afforded 7.0 mg. of the ketoacid VIIIb, m.p. 220–228°. The identity of this material with the acid obtained from the diol VIa was shown by the usual spectral comparisons and a m.m.p. determination.

Equilibration of (a) VIIa, (b) VIIIc, and (c) VIIId.—Addition of 13 mg. of ketoaldehyde VIIIa to 10 ml. of 30% aqueous methanol containing 20 mg. of potassium hydroxide was followed by heating of the mixture at 50° under nitrogen for 2 hr. Extraction of the solution with ether afforded unchanged ketoaldehyde, m.p. 105–107°.

(**b**).—Brief refluxing of 50 mg. of ketoester VIIIc with 5 ml. of methanol, to which *ca.* 50 mg. of sodium had been added previously, and addition of water resulted in the isolation of an acid. Methylation of the acid with ethereal diazomethane yielded 38 mg. of unchanged ketoester VIIc, m.p., m.m.p. 84–86°.

(**c**).—A solution of 25 mg. of the ketoalcohol VIId in 0.5 ml. of methanol was added to 5 ml. of methanol containing *ca.* 50 mg. of sodium. After refluxing the solution for 10 min., water was added and the solution extracted with ether. Drying of the ether extract over anhydrous sodium sulfate and removal of the solvent left a solid residue which crystallized from hexane to afford 17 mg. of the starting ketoalcohol, m.p. 118–120° (identified by its infrared spectrum and a m.m.p. determination).

Lithium Aluminum Hydride Reductions of (a) VIIIc and (b) VIIId. (**a**).—To a solution of 50 mg. of the ester VIIIc in 10 ml. of ether was added slowly 50 mg. of lithium aluminum hydride. The mixture was stirred at room temperature for 15 hr. The excess hydride was decomposed with water and the solution acidified and extracted with ether. The ether extracts, after drying, yielded 42 mg. of a viscous gum which crystallized on trituration with ether. Two crystallizations from ether afforded 17 mg. of diol VIIa, m.p. 147–149° (no depression on admixture with 149° diol VIIa).

(**b**).—Treatment of 20 mg. of ketoalcohol VIIId in 30 ml. of ether with 20 mg. of lithium aluminum hydride as above afforded after work-up 12 mg. of diol VII, m.p. 148–149° after two crystallizations from ethyl acetate (identified by its infrared spectrum and a m.m.p. determination).

Ketoacetate Xb.—A solution of 75 mg. of ketoalcohol Xa in dry ether was cooled to 0° and ketene passed through the solution for 15 min. After allowing it to stand for 4 hr. at room temperature, the solvent was removed *in vacuo* and the residue dissolved in hexane and passed through a short alumina column. The eluate was evaporated and the gummy residue, 74 mg., crystallized from hexane to yield a solid, m.p. 104–106°. Further crystallization of this material gave prisms of pure ketoacetate Xb, m.p. 106–107°; spectra: infrared (CCl_4), C=O 5.75 (s) and 5.86 (s) μ; 3-proton singlets 0.87, 0.87, 0.99, 1.16 p.p.m. (C—Me); 2.02 p.p.m. (CH_3CO); 1-proton multiplet 5.44, 5.52, 5.62, 5.70 p.p.m. (C_{15}-hydrogen); o.r.d. (*c* 0.02, MeOH), $[\alpha]_{435}$ +35°, $[\alpha]_{385}$ 0.0°, $[\alpha]_{303}$ −1980°, $[\alpha]_{294}$ −22°, $[\alpha]_{263}$ +3175°, $[\alpha]_{246}$ +2620°.

Anal. Calcd. for $C_{22}H_{34}O_4$: C, 76.26; H, 9.84. Found: C, 76.51; H, 9.63.

7-Ketoisohibaene (Vb).—Two passes of 60 mg. of the ketoacetate Xb in a slow stream of nitrogen through an 18-in. path of glass helices contained in a Vycor tube held at 580° gave 49 mg. of brown gum showing the absence of ester carbonyl absorption in its infrared spectrum. (Lower temperatures failed to effect pyrolysis of the ketoacetate.) Chromatography of the pyrolysis product in hexane over 1 g. of alumina (activity I) gave 20 mg. of solid, m.p. 105–110°, on elution with 10:1 benzene–ether. Two crystallizations from methanol yielded needles of ketoolefin Vb, m.p. 113–114°; spectra: infrared (CCl_4), C=O 5.81 (s), C=O 6.00 (w) μ; p.m.r., 3-proton singlets 0.85, 0.85, 1.09, 1.19 p.p.m. (C—Me); 2-proton doublets 5.68, 5.90 p.p.m. (J = 5.5 c.p.s.) (C_{15} and C_{16}-olefinic hydrogens); o.r.d. (*c* 0.016, MeOH) $[\alpha]_{435}$ +103°, $[\alpha]_{385}$ +82°, $[\alpha]_{345}$ +54°, $[\alpha]_{333}$ −17°, $[\alpha]_{303}$ −453°, $[\alpha]_{294}$ −79°, $[\alpha]_{286}$ +722°, $[\alpha]_{263}$ +1288°, $[\alpha]_{256}$ +1160°.

Anal. Calcd. for $C_{20}H_{30}O$: C, 83.86; H, 10.58. Found: C, 83.56; H, 10.50.

Isohibaene (Va).—To a solution of 14 mg. of the ketoolefin in 0.2 ml. of methanol containing *ca.* 30 mg. of sodium methoxide was added 0.1 ml. of 95% hydrazine. The reaction mixture was heated in a sealed tube at 160° for 8 hr. The product was extracted with ether and the ether extract washed with water, dried over anhydrous sodium carbonate, and the ether removed *in vacuo*, leaving 11 mg. of gum which solidified on standing. Two crystallizations from methanol gave plates of the olefin Va, m.p. 73–75°, $[\alpha]_D$ +8° (*c* 0.016, MeOH); spectra: p.m.r.,

(36) A. Bowers, T. G. Halsall, E. R. H. Jones, and A. J. Lemin, *J. Chem. Soc.*, 2548 (1953).

(37) Measured on a Bellingham and Stanley spectropolarimeter by the courtesy of Professor F. R. N. Gurd, Indiana University Medical School, Indianapolis, Ind.

3-proton singlets 0.80, 0.84, 1.02, 1.04 p.p.m. (C–Me); 2-proton doublets 5.42, 5.53 p.p.m. (J = 5.5 c.p.s.) (olefinic hydrogens).

Anal. Calcd. for $C_{20}H_{32}$: C, 88.16; H, 11.84. Found: C, 88.26; H, 11.53.

Stachene (XIIIb).—Treatment of 100 mg. of stachenone (XIIIa)[22] in 5 ml. of aqueous methanol with a solution of semicarbazide hydrochloride–sodium acetate afforded 100 mg. of solid which after several crystallizations from methanol gave plates of stachenone semicarbazone (XIII, Y = $NNHCONH_2$), m.p. 220–222°.

Anal. Calcd. for $C_{21}H_{33}N_3O$: C, 73.42; H, 9.68; N, 12.23. Found: C, 73.34; H, 9.46; N, 12.44.

A mixture of 25 mg. of the semicarbazone (XIII, Y = $NNHC(=O)NH_2$) and *ca.* 30 mg. of sodium methoxide in 1 ml. of methanol was heated at 160° in a sealed tube for 4 hr. Isolation of the product by ether extraction gave 17 mg. of a clear mobile oil which was dissolved in hexane and passed through a short column of alumina. Gas chromatography of the oily filtrate, 12 mg., on a Carbowax column (20% w.w. on Chromosorb) at 250° showed a single peak which on collection gave pure stachene (XIIIb), m.p. 25–27°, $[\alpha]^{23}D$ +39° (c 2.0, $CHCl_3$); spectra: infrared, *gem*-dimethyl 7.16 (m) and 7.27 (m) μ, olefinic H bending 13.74 (s) μ; p.m.r., 3-proton singlets 0.90, 1.00, 1.03, 1.07 p.p.m. (C–Me); 2-proton doublets 5.42, 5.67 p.p.m. (J = 5.5 c.p.s.) (olefinic hydrogens).

Anal. Calcd. or $C_{20}H_{32}$: C, 88.16; H, 11.84. Found: C, 88.32; H, 11.85.

Ester XVIIb.—The acid XVIIa, obtained from the Jones oxidation of beyerol (XIX),[25] was dissolved in ether and treated with excess ethereal diazomethane. The crude ester was crystallized from methanol to afford an 85% yield of pure ester XVIIb (prisms), m.p. 138–140°; spectra: infrared (Nujol), C=O 5.78 (s), 5.82 (s), 5.90 (s) μ; p.m.r., 3-proton singlets 0.92, 1.28 p.p.m. (C–Me) and 3.68 p.p.m. (OMe); 2-proton singlet 5.86 p.p.m. (C_{15}- and C_{16}-hydrogens); 1-proton singlet 9.65 p.p.m. (aldehyde hydrogen).

Anal. Calcd. for $C_{21}H_{28}O_4$: C, 73.22; H, 8.19. Found: C, 73.08; H, 8.23.

Diol Ester XIVc.—A solution of 150 mg. of the ester XVIIb in 15 ml. of absolute methanol was cooled to 0° and 45 mg. of sodium borohydride added slowly with stirring. After being allowed to stand at 0° for 1 hr., the solution was evaporated *in vacuo* and the residue was treated with water and extracted with ether. Removal of the ether, after drying, left 135 mg. of gum which was dissolved in benzene and chromatographed on 1 g. of alumina (activity IV). Elution with benzene and 19:1 benzene–ether gave 80 mg. of solid which on successive crystallizations from ether–hexane and ether–methanol afforded needles of pure diol ester XIVc, m.p. 148–148.5°, $[\alpha]^{20}D$ +53° (c 1.6, 95% EtOH); spectra: infrared (CCl_4), OH 2.95 (w), C=O 5.78 (s) μ.

Anal. Calcd. for $C_{21}H_{30}O_4$: C, 72.80; H, 8.73. Found: C, 72.85; H, 9.20.

Triester XVIIIb.—A mixture of 27 mg. of the diol ester XIVc and 10 mg. of anhydrous sodium acetate was refluxed in acetic anhydride for 2 hr. The solution was cooled, poured into water, and extracted with ether. The extract was worked up in the usual manner giving 21 mg. of product which on three crystallizations from hexane yielded 10 mg. of long prisms of the triester XVIIIb, m.p. 126–127.5°; spectra: infrared (CCl_4), C=O 5.75 (s) μ; p.m.r., 3-proton singlets 0.78, 1.03 p.p.m. (C—Me); 2.03, 2.05 p.p.m. (CH_3CO); 3.68 p.p.m. (OMe); 2-proton doublets 4.17, 4.35 p.p.m. (J = 7.5 c.p.s.) (acetoxymethyl); 1-proton multiplet 4.45–4.70 p.p.m. (C_3-H); 2-proton singlet 5.80 p.p.m. C_{15}- and C_{16}-hydrogens.

Anal. Calcd. for $C_{25}H_{34}O_6$: C, 69.74; H, 7.96. Found: C, 69.80; H, 8.39.

[CONTRIBUTION FROM THE GEORGE HERBERT JONES LABORATORY, UNIVERSITY OF CHICAGO, CHICAGO 37, ILL., AND THE CHEMISTRY DIVISION OF THE U. S. NAVAL ORDNANCE TEST STATION, CHINA LAKE, CALIF.]

Electrophilic Addition Reactions of 1,1-Dimethyldiazenium Bromide with 1,3-Dienes and Styrenes[1]

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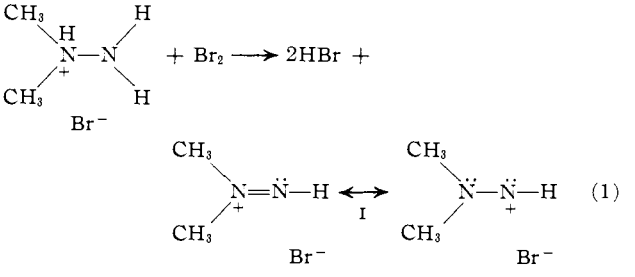
RECEIVED DECEMBER 12, 1963

1,1-Dimethyldiazenium bromide (I), prepared by the oxidation of 1,1-dimethylhydrazine with bromine in hydrobromic acid solution, reacts with conjugated olefins. For example, with 1,3-butadiene, a good yield of 1,1-dimethyl-Δ^4-tetrahydropyridazinium bromide, and, with styrene, 1,1-dimethyl-2-(2-bromo-2-phenylethyl)-hydrazinium bromide (II) is obtained. Compound II dissolves in aqueous base to give 1,1-dimethyl-4-phenyl-1,2-diazetidinium hydroxide (III), and immediate addition of sodium perchlorate gives its perchlorate IV. If the basic solution of III (pH above 8) is allowed to stand, it hydrolyzes to give 1,1-dimethyl-2-(2-hydroxy-2-phenylethyl)hydrazine (V). In weakly acidic solutions, V is also formed, but a competing decomposition of II gives styrene. With dilute acid, V gives an interesting fragmentation reaction to yield dimethylamine, ammonia, formaldehyde, and benzaldehyde, and hydrolyzes to give 1,1-dimethylhydrazine and phenylacetaldehyde.

Recent research[2–4] has shown that in the oxidation of 1,1-dialkylhydrazines in cold (0°) aqueous acidic solutions 2 equivalents of oxidizing agent (I_2, Br_2, Cl_2, and $NaBrO_3$) are consumed, and a moderately stable oxidation intermediate, the 1,1-dialkyldiazenium salt, is obtained.

The unusual structure I is supported by its unique nuclear magnetic resonance spectrum. This n.m.r. absorption (methyl singlet, 4.78 δ) appears when bromine is added to a solution of 1,1-dimethylhydrazine in hydrobromic acid (D_2O, 0°, methyl singlet of hydrazinium ion, 3.39 δ; and broad singlet due to all exchangeable hydrogen, DOH–NH, 5.92 δ). The latter absorption shifts to higher δ-values as the hydrobromic acid concentration of the sample is increased. The absorptions of I and the 1,1-dimethylhydrazinium ion, however, are quite independent of their concentrations and the acidity of the solution. When 1,1-dimethylhydrazine in deuteriotrifluoroacetic acid is oxidized with bromine, the same type of spectrum is observed (n.m.r. in deuteriotrifluoroacetic acid with TMS; hydrazinium



(1) Presented in part at the Combined Regional Meeting of the Southwest and Southeast Regions of the American Chemical Society, New Orleans, La., Dec. 7–9, 1961.

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