protons, confirming its total reduction. Chromatography on alumina still did not permit crystallization, so the material was acetylated with pyridine and acetic anhydride. Prisms of **racemic O,N-diacetyldemethyldihydrogalanthamine** were obtained which were recrystallized from ethyl acetate and sublimed at 150° (0.1 mm.), m.p. 208–209.5°, $[\alpha]^{23}\mathrm{D}$ 0.00,° $[\alpha]^{23}{}_{436}$ 0.00° (*c* 0.19, chloroform). The infrared spectrum in chloroform was identical with its optically active counterpart (m.p. 177–179°). Surprisingly, the compound does not appear to depress the racemic O,N-diacetyldemethylgalanthamine, m.p. 204–205°, but fortunately its infrared spectrum (KBr) exhibits many points of difference.

Conversion of Dihydronarcissamine to Racemic Dihydrogalanthamine.—A solution of 150 mg. of the crude hydrogenation product of narcissamine in a mixture of 1 ml. of 90% formic acid and 1 ml. of 37% formalin was heated on the steam bath for 3 hr., basified, and extracted into chloroform. The product was then chromatographed over alumina with 1% ethanol in ethyl acetate and the resulting oil evaporatively distilled at 150° (0.1 mm.). The infrared spectrum of the product is identical in chloroform solution with (−)-dihydrogalanthamine and gas phase chromatography shows a retention time identical with the latter (see above). The material was purified by crystallizing its hydriodide salt from water, recovering the free base with alkali, and evaporatively distilling the product. Still an oil, the product showed $[\alpha]^{23}\mathrm{D}$ 0.0°, $[\alpha]^{23}{}_{436}$ 0.0° (*c* 0.655, chloroform).

Anal. Calcd. for $C_{17}H_{23}NO_3$: C, 70.56; H, 8.01. Found: C, 70.32; H, 7.91.

The compound formed a **methiodide** from acetone which was recrystallized from ethanol–water; m.p. 300° dec. The infrared spectrum (KBr) of the salt is very similar to, but not identical with, that of (−)-dihydrogalanthamine methiodide.

Anal. Calcd. for $C_{18}H_{26}NO_3I$: C, 50.12; H, 6.08; I, 29.43. Found: C, 50.39; H, 6.07; I, 29.34.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.]

Terpenes. XIX.[1] Synthesis of Patchouli Alcohol[2]

BY G. BÜCHI, WILLIAM D. MACLEOD, JR.,[3] AND J. PADILLA O.[4]

RECEIVED JUNE 27, 1964

(+)-Camphor was converted to (−)-homocamphor by known methods and in a short synthetic sequence the latter was transformed to the tricyclic cyclopentenone **10**. Condensation with methylmagnesium iodide or with triphenylphosphinemethylene followed by hydrogenation yielded β-patchoulene (**12**). Rearrangement of the corresponding epoxide **16** with boron fluoride furnished the desired unsaturated alcohol **18**. This key intermediate was subsequently transformed to patchoulione (**2**) and to α-patchoulene (**23**). A previously accomplished but at that time incorrectly interpreted reconversion of α-patchoulene (**23**) to patchouli alcohol (**28**) completed the synthesis. Some transformations of the natural product **28** are reinterpreted in terms of a new structure determined by the X-ray method.

Patchouli alcohol is a constituent of the East Indian shrub *Pogostemon patchouli* and a major component of commercial patchouli oil. Structure **1** was recently deduced from analytical studies[5] and this paper describes a synthesis of this sesquiterpene alcohol. The planning of our synthetic work was influenced by the finding that patchoulione (**2**), a transformation product of the alcohol, has a powerful ambergris-type odor. Consequently it seemed important to devise a synthetic sequence to the natural product in which patchoulione (**2**) figures as an intermediate. Furthermore, the construction of β-patchoulene (**12**), an olefin with rearranged skeleton, appeared simpler than a synthesis of α-patchoulene (**23**). The success of such a scheme would then depend on the ultimate transformation of β-patchoulene (**12**) to a substance with the tricyclic framework of the natural product. β-Patchoulene (**12**) contains the same bicyclo[1.2.3]-octane skeleton as (−)-homocamphor[6] (**3**) and the first phase of the synthesis was concerned with the attachment of a cyclopentane ring to this readily available starting material. Initial efforts to add a three-carbon chain by Stobbe condensations with diethyl succinate or with tetraethyl phosphonosuccinate[7] failed and addition of the sodium salt of ethyl propiolate[8] resulted in a Michael adduct rather than the desired carbinol. Realizing that the source of these difficulties may lie in the reversibility of these reactions, we turned to an irreversible process and addition of allylmagnesium chloride furnished the desired alcohol **4**. There was little doubt that the adduct had the configuration indicated and this was verified by its further transformations.[9] Treatment of the unsaturated alcohol **4** with diborane[10] followed by oxidation with Jones reagent[11,12] yielded the spirolactone **5** with infrared absorption at 1770 cm.$^{-1}$. Attempts to dehydrate this lactone with polyphosphoric acid[13] led to no useful result, but treatment with zinc chloride in a mixture of acetic acid and acetic anhydride[14] furnished a mixture of two ketones.

The minor product (10%) was optically inactive and had $\lambda_{\max}^{\mathrm{EtOH}}$ 247 mμ (ε 14,500); $\nu_{\max}^{\mathrm{CCl_4}}$ 1665 and 1615 cm.$^{-1}$; n.m.r.[15] at 4.25 (1 H, singlet) and 8.82 τ (6 H,

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[1] Part XVIII: G. Büchi, F. Greuter, and T. Tokoyorama, *Tetrahedron Letters*, **18**, 827 (1962).

[2] Announced previously: G. Büchi and W. D. MacLeod, Jr., *J. Am. Chem. Soc.*, **84**, 3205 (1962).

[3] National Institutes of Health Predoctoral Fellow 1960–1962.

[4] Pan American Union Fellow on leave from the Universidad Nacional Autonoma, Mexico, D.F.

[5] G. Büchi, R. E. Erickson, and N. Wakabayashi, *J. Am. Chem. Soc.*, **83**, 927 (1961).

[6] (−)-Homocamphor was initially prepared from commercial (+)-camphor following a published procedure [H. Favre and J.-C. Richer, *Can. J. Chem.*, **37**, 417 (1959); H. Rupe and C. Frey, *Helv. Chim. Acta*, **27**, 627 (1944)]. Later, we learned from Professor G. Quinkert, T. H. Braunschweig, that he had developed an improved synthesis of homocamphor and we are indebted to him for having made available to us his unpublished procedure.

[7] W. S. Wadsworth, Jr., and W. D. Emmons, *J. Am. Chem. Soc.*, **83**, 1733 (1961).

[8] W. E. Bachmann and E. K. Raunio, *ibid.*, **72**, 2530 (1950).

[9] The steric course of Grignard addition to substituted cyclohexanones was discussed by A. V. Kamernitzky and A. A. Akhrem, *Tetrahedron*, **18**, 705 (1962).

[10] H. C. Brown and G. Zweifel, *J. Am. Chem. Soc.*, **81**, 247 (1959).

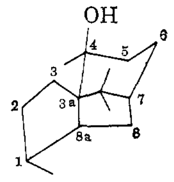
[11] A. Bowers, T. G. Halsall, E. R. H. Jones, and A. J. Lemin, *J. Chem. Soc.*, 2548 (1953).

[12] *Cf.* oxidation of secondary boranes to ketones: R. Pappo, *J. Am. Chem. Soc.*, **81**, 1010 (1959); H. C. Brown and C. P. Garg, *ibid.*, **83**, 2951 (1961).

[13] C. Rai and S. Dev, *J. Indian Chem. Soc.*, **34**, 178 (1957).

[14] D. W. Mathieson, *J. Chem. Soc.*, 177 (1951); W. S. Johnson and J. W. Petersen, *J. Am. Chem. Soc.*, **67**, 1366 (1945).

[15] N.m.r. spectra were measured in carbon tetrachloride solution on a Varian Associates A-60 instrument with tetramethylsilane as internal refer-



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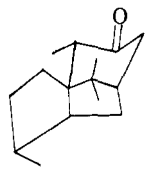

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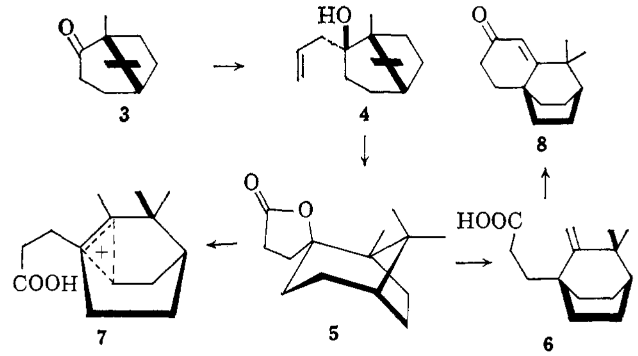
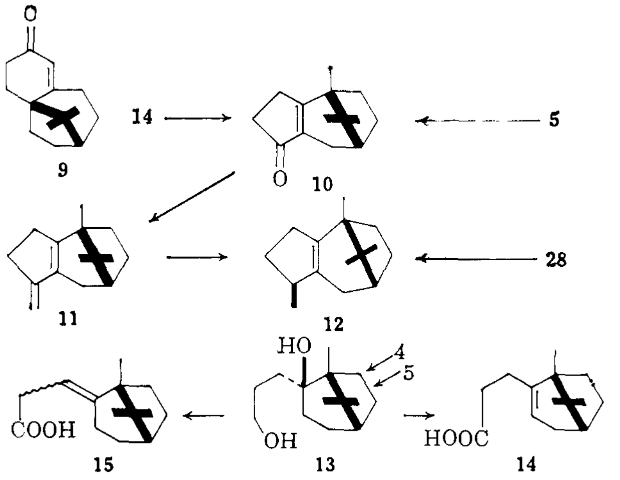


singlet). These findings agree with the symmetrical structure **8** only and exclude its isomer **9** with two nonequivalent methyl groups. The major product was the desired cyclopentenone (**10**) with the spectral characteristics: $\lambda_{\max}^{\text{EtOH}}$ 246 mμ (ϵ 13,000); $\nu_{\max}^{\text{CCl}_4}$ 1695 and 1635 cm.$^{-1}$; three methyl resonance peaks in the n.m.r. spectrum at 8.95, 9.05, and 9.15 τ. Of these, only the ultraviolet absorption ($\lambda_{\max}^{\text{calcd}}$ 238 mμ) was other than anticipated, but comparable bathochromic displacements have been observed in the spectra of other strained α,β-unsaturated ketones.[16] When the cyclopentenone **10** was condensed with triphenylphosphinemethylene[17] in peroxide-free tetrahydrofuran a liquid product was obtained whose ultraviolet absorption at 256 mμ indicated the presence of the desired diene **11**. It soon became apparent that we were dealing with a highly labile intermediate and in all subsequent preparations the crude diene **11** was hydrogenated immediately over Raney nickel W-2 catalyst. Gas chromatographic analysis of the reduction products revealed the presence of three hydrocarbons. Two of these could not be separated on a preparative scale, but a mass spectrum[18] demonstrated the presence of an isomer of β-patchoulene and a dihydro derivative. Identity of the major product (53%) with β-patchoulene (**12**) was ascertained by comparison of infrared and n.m.r. spectra and retention times in two different gas chromatographic columns. Surprisingly, the optical rotation of a synthetic sample ($[\alpha]_D - 4°$) diverged markedly from that of a sample ($[\alpha]_D - 43°$) originating from patchouli alcohol and we suspected that the cyclopentenone **10** already was largely racemic. The formation of the racemic ketone **10** can be rationalized if the two unsaturated acids **14** and **6** participate in an equilibrium prior to their irreversible dehydrations to the corresponding tricyclic ketones **10** and **8**. It must be pointed out that the nonclassical carbonium ion **7** is still asymmetric and the rearranged, classical carbonium ion leading to the unsaturated acid **6** by loss of a proton is the first symmetrical intermediate encountered. This situation emphasized the necessity of preparing the unsaturated carboxylic acid **14** by another route and of effecting its cyclization by a fast reaction in an aprotic solvent.



Hydroboration–oxidation[10] of the unsaturated alcohol **4** furnished the diol **13** identical in every respect, including optical rotation, with the product obtained by reduction of the spirolactone **5** with lithium aluminum hydride, demonstrating that no racemization had occurred in the preparation of the lactone **5**. The diol was transformed directly, in 65% yield, to the unsaturated acid **14** by successive treatments with acetic anhydride, phosphorus oxychloride in pyridine, lithium aluminum hydride, and chromium trioxide. In agreement with the structure assigned, an n.m.r. spectrum of the pure acid (**14**) had signals at -2.2 (1 H), 4.9 (1 H, broad), 9.0 (3 H), and 9.08 τ (6 H). A spectrum of the crude acid, however, revealed minor quantities of a β,γ-unsaturated isomer (**15**) descending from an isomeric unsaturated acetate produced by alternative dehydration of the diol-monoacetate. The relative amounts of isomers produced suggested axial arrangement of the tertiary hydroxyl group in the carbinol **4** and its transformation products.[19] The crude acid chloride prepared from the unsaturated acid **14** on treatment with aluminum chloride in carbon disulfide solution furnished the ketone **10** whose spectral properties were identical with those of its racemic modification. Further transformations by processes already discussed yielded the tricyclic olefin indistinguishable from β-patchoulene (**12**) *ex* patchouli alcohol. Identity was confirmed further by mixture melting point determination of the *cis*-1,2-diols prepared by oxidation of the olefins (**12**) with osmium tetroxide.[5] As expected, the cyclopentenone **10** was methylated rapidly by methylmagnesium iodide. The initially produced allylic alcohol evidently had suffered dehydration in the work-up because the reaction mixture contained hydrocarbons only. Purification of these dienes was again impracticable, but hydrogenation of the crude product furnished β-patchoulene (**12**) in an over-all yield of 52%. This key intermediate contains a third asymmetric carbon atom and if we assume catalyst approach from the more accessible α-side to its precursor **11** the resulting configuration is that

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ence. Chemical shifts are in τ-values [G. V. D. Tiers, *J. Phys. Chem.*, **62**, 1151 (1958)].

[16] Examples quoted in ref. 5.

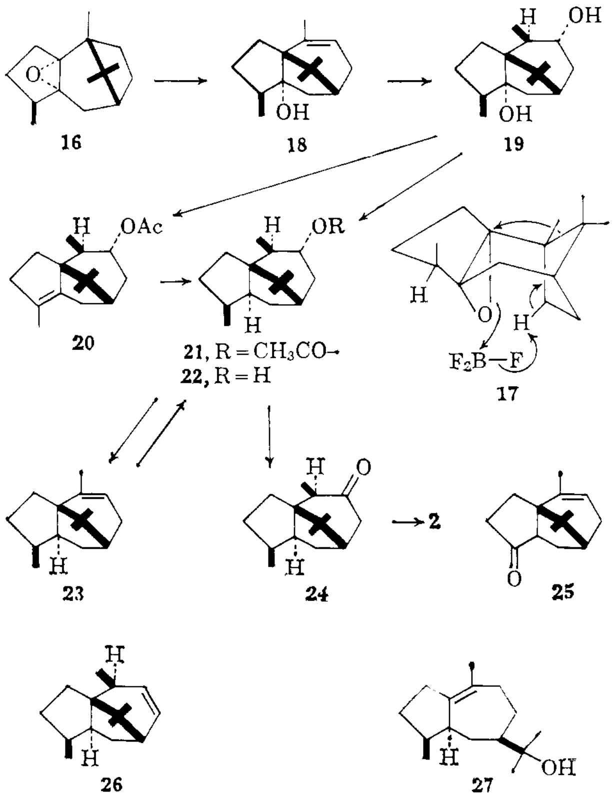
[17] U. Schöllkopf, *Angew. Chem.*, **71**, 260 (1959) (review article).

[18] Mass spectra, made available through the courtesy of Professor K. Biemann and Dr. W. Vetter, were measured on a CEC 21-103C instrument equipped with a heated inlet system (135°).

[19] D. H. R. Barton, A. da S. Campos-Neves, and R. C. Cookson, *J. Chem. Soc.*, 3500 (1956); J. D. Cocker and T. G. Halsall, *ibid.*, 4262 (1956).

shown in structure **12**. Consequently the acid-catalyzed dehydration of patchouli alcohol to the rearranged olefin **12** proceeded with retention of configuration at C-1.[5]

The second phase of the synthesis was concerned with transformations of intermediates **10** and **12** to substances with the framework of the natural product. Of the various schemes considered, two were tested experimentally. Encouraged by the light-induced Wagner–Meerwein type rearrangements observed with the two α,β-unsaturated ketones verbenone[20] and Δ^4-cholesten-3-one,[21] we investigated the photochemical behavior of the ketone **10** in a variety of solvents using mercury vapor lamps with and without Pyrex filters. Although photochemical transformations were observed, attempts to isolate the desired ketone **25** or its isomer with a cyclopropane ring failed.



We next considered the rearrangement of β-patchoulene (**12**) and its derivatives. The simplest possibility involving direct rearrangement of this olefin to its isomer **23** had to be dismissed at the outset because the equilibrium between the two olefins is quantitatively in favor of the former.[5] We were confident, however, that a suitable acidic catalyst would initiate cleavage of only one carbon–oxygen bond in the epoxide **16** and bring about migration of the favorably situated tertiary substituent.[22] β-Patchoulene (**12**), prepared by dehydration of the natural alcohol on oxidation with peracetic acid, yielded the α-epoxide **16** which on brief treatment with boron fluoride underwent the desired change to the unsaturated alcohol **18**. Apparently none of the isomer with terminal double bond was produced, and abstraction of the secondary proton may conceivably be assisted by intramolecular attack of fluoride (*cf.* **17**, arrows). The structure of the alcohol was verified by its n.m.r. spectrum: 4.57 (broad, H—C=C—); 7.73 (OH); 8.35 (CH_3—C=C—); 9.0 (doublet, J 6 c.p.s., CH_3—C—H); 9.05 and 9.14 τ (CH_3—C—CH_3). Attempts to convert alcohol **18** to α-patchoulene (**23**) through reaction with thionyl chloride and subsequent reduction of the hypothetical chloride with zinc or with lithium aluminum hydride failed. Only dienes were isolated which received no further attention. Hydroboration–oxidation[10] served in the synthesis of diol **19**, although the method was somewhat troublesome owing to the formation of unusually stable borates. Exposure of the diol **19** to a hot mixture of acetic anhydride and pyridine caused transformation to an unsaturated acetate. Elimination, possibly through a cyclic mechanism, proceeded in one direction only, as evidenced by an n.m.r. spectrum of the product **20** which showed peaks at 5.4 (doublet, 1 H, broad); 8.15 (3 H); 8.55 (3 H); 8.85 (doublet, 3 H, J 6 c.p.s.); 8.97a nd 9.20 τ (3 H each) with *no* olefinic protons. The double bond in the unsaturated acetate **20** was readily saturated with hydrogen and a platinum catalyst. The resulting acetate **21** was reduced by means of lithium aluminum hydride to the crystalline alcohol **22** identical in every respect with the substance prepared by hydroboration–oxidation[10] of α-patchoulene (**23**). If hydrogen was indeed delivered in a *cis* fashion and from the more accessible side the saturated alcohol **22** has the configuration indicated. While exploring more direct methods for the conversion of diol **19** to alcohol **22** we found that this can be accomplished in one operation using catalytic reduction in the presence of perchloric acid. To complete the synthesis of patchoulione (**2**) the secondary alcohol **22** was oxidized and the resulting ketone **24** was epimerized with alkali. The ketone **2** thus obtained was indistinguishable from a sample of authentic patchoulione.[5] Pyrolysis of the axial acetate **21** proceeded rapidly at 350° and afforded a mixture of liquid olefins. The major product (80%) with proton resonance at 4.95 (broad, —C=C—H); 8.37 (CH_3—C=C—); 9.10 (3 H doublet, J 6 c.p.s.); 9.05; and 9.11 τ (CH_3—C—CH_3) was spectroscopically and vapor chromatographically identical with α-patchoulene (**23**). Preferential formation of the trisubstituted olefin was anticipated because the transition state in ester pyrolysis seems to have a geometry approximating that of the resulting olefin.[23] It is to be noted that the minor isomer **26**, not isolated in a pure state, is less stable owing to 1,3-methyl–methyl inter-

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(20) J. J. Hurst and G. H. Whitham, *J. Chem. Soc.*, 2864 (1960).

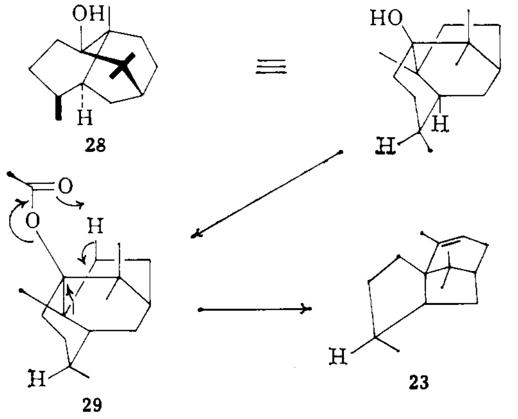
(21) W. W. Kwie, B. A. Shoulders, and P. D. Gardner, *J. Am. Chem. Soc.*, **84**, 2268 (1962).

(22) Similar acid-catalyzed epoxide rearrangements have been recorded. *E.g.*, (B. Arbusov, *Ber.*, **68**, 1430 (1935); W. Laird, F. S. Spring, and R. Stevenson, *J. Chem. Soc.*, 2638 (1961); J. D. Connolly and K. H. Overton, *ibid.*, 3366 (1961); D. Arigoni, D. H. R. Barton, E. J. Corey, O. Jeger, and their collaborators, *Experientia*, **16**, 41 (1960); I. G. Grant, J. A. Hamilton, T. A. Hamor, R. Hodges, S. G. McGeachin, R. A. Raphael, J. M. Robertson, and G. A. Sim, *Proc. Chem. Soc.*, 444 (1961); K. W. Gopinath, T. R. Govindachari, P. C. Parthasarathy, N. Viswanathan, D. Arigoni, and W. C. Wildman, *ibid.*, 446 (1961).

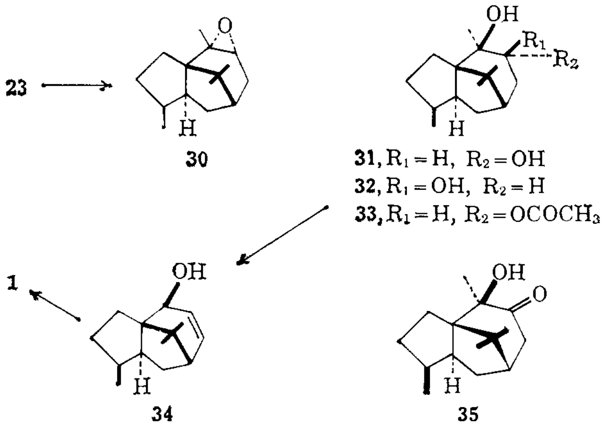
(23) C. H. DePuy and R. W. King, *Chem. Rev.*, **60**, 431 (1960).

action. A reconversion of α-patchoulene (**23**) to patchouli alcohol was described previously[5] and if early syntheses of (+)-camphor[24] are recalled the transformations outlined in this paper constitute a total synthesis of patchouli alcohol. A recently accomplished conversion of bulnesol (**27**)[25] to β-patchoulene (**12**)[26] now represents a partial synthesis of the tricyclic alcohol from bicyclic sesquiterpenes.

After this synthesis was complete and published in preliminary form[2] Professor J. D. Dunitz, ETH, Zürich, informed us that an X-ray analysis of the patchouli alcohol diester of chromic acid revealed structure **28** for patchouli alcohol.[27] The diester was reconverted to the original alcohol by base hydrolysis or by reduction with lithium aluminum hydride, thus excluding the possibility of a rearrangement in the course of esterification. Since the structure of α-patchoulene (**23**) rests secure, the pyrolysis of patchouli acetate must have been accompanied by an unprecedented rearrangement. Acetate **29** based on the new structure of patchouli alcohol (**28**) cannot lose the elements of acetic acid without rearrangement because the resulting olefin would violate Bredt's rule. The skeletal change actually observed represents a stereoelectronically favorable process allowing optimal orbital overlap throughout (arrows in **29**). An entirely analogous elimination of acetic acid results in the formation of the isomeric olefin, γ-patchoulene, containing an exocyclic methylene group. In an effort to *exclude* a rearrangement in the course of acetate pyrolysis we had previously reconverted α-patchoulene (**23**) to patchouli alcohol by a route which at that time was considered to be structurally unambiguous. Oxidation of α-patchoulene (**23**) with peracetic acid in a buffered medium at 0° afforded a mixture of the stable epoxide **30** and a diol which, although it did not react with lead tetraacetate at ambient temperature, was believed to be the *trans*-diaxial-1,2-diol (**31**). In agreement with the early structure, the diol was oxidized with chromium trioxide to a hydroxyketone (**35**) which could be reduced to α-patchoulene (**23**) by the procedure of Wolff–Kishner. The corresponding monoacetate **33** on pyrolysis produced the unsaturated alcohol **34** which was hydrogenated to the natural product. If we accept structure **28** proposed by Dunitz for patchouli alcohol, one of the four steps in the olefin–alcohol sequence must have proceeded with skeletal rearrangement.



28 **29** **23**

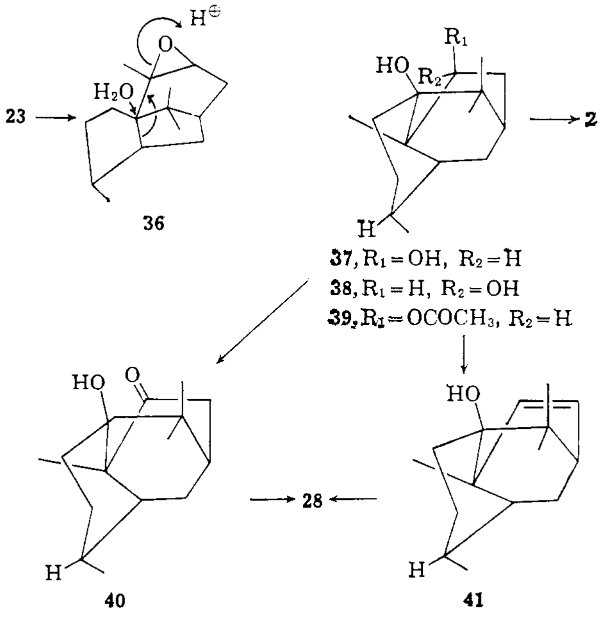


30

31, $R_1 = H$, $R_2 = OH$
32, $R_1 = OH$, $R_2 = H$
33, $R_1 = H$, $R_2 = OCOCH_3$

34 **35**

Contrary to the earlier claim,[5] reduction of the hydroxyketone did not give α-patchoulene (**23**) but an essentially quantitative yield of patchouli alcohol. This new finding strongly suggested that we were not dealing with the acyloin **35** which should have undergone elimination to yield the olefin **23**. Exposure of this hydroxyketone to lithium aluminum hydride afforded a new diol in 95% yield. It again was not cleaved by lead tetraacetate. Based on the earlier hypothesis, the new diol would be the *cis*-cyclohexane-1,2-diol (**32**) which should be oxidized readily by this reagent. "Obviously," peracid oxidation did not yield the anticipated vicinal glycol **31** and it is now clear that a rearrangement proceeding in precisely the reverse direction of that observed on pyrolysis of patchouli acetate (**29**) is taking place. This can be rationalized if it is assumed that the hypothetical β-epoxide **36**, even under the mild conditions employed for its production, rearranged to the 1,3-glycol **37** by a stereochemically favorable process. In retrospect it might be amusing to note that this type of epoxide rearrangement was used by design in our synthetic work (**16** to **18**) but never received attention in the structural



36

37, $R_1 = OH$, $R_2 = H$
38, $R_1 = H$, $R_2 = OH$
39, $R_1 = OCOCH_3$, $R_2 = H$

40 **41**

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[24] G. Komppa, *Ber.*, **36**, 4332 (1903); *Ann.*, **370**, 209 (1909).

[25] L. Dolejs, A. Mironov, and F. Sorm, *Tetrahedron Letters*, **11**, 18 (1960); E. J. Eisenbraun, T. George, B. Riniker, and C. Djerassi, *J. Am. Chem. Soc.*, **82**, 3648 (1960); H. Minato, *Tetrahedron Letters*, **8**, 280 (1961).

[26] R. B. Bates and R. C. Slagel, *J. Am. Chem. Soc.*, **84**, 1307 (1962).

[27] M. Dobler, J. D. Dunitz, and B. Gubler, H. P. Weber, G. Büchi, and J. Padilla O., *Proc. Chem. Soc.*, 383 (1963). We wish to thank Professor J. D. Dunitz for suggesting a joint announcement and for communicating his findings to us prior to publication.

studies because, for reasons already cited, we were under the impression that patchouli alcohol and the diol had identical skeletons. The previously mentioned hydroxyketone now has structure **40** and its behavior on Wolff–Kishner reduction is unexceptional. The essentially exclusive formation of an epimeric diol (**38**) on reduction with lithium aluminum hydride is justified because the hydroxy group is placed in a manner which allows internal hydride transfer to the carbonyl group within the intermediate aluminum hydride complex.[28] Both the monoacetate and the unsaturated alcohol derived from the diol **37** have to be reformulated and are now represented by structures **39** and **41**. Finally it must be pointed out that additional Wagner–Meerwein rearrangements are operating in the dehydrogenation of patchouli alcohol (**28**) to guajazulene and in the dehydration of the 1,3-diol **37** to patchoulione (**2**).

Experimental

Microanalyses were performed by Dr. S. M. Nagy and associates, M. I. T. Melting points determined on a Kofler hot-stage microscope are corrected. Infrared spectra were measured by Mrs. N. F. Alvord on a Baird Model B recording spectrophotometer and high intensity bands and others relevant to structural arguments are listed textually. Ultraviolet spectra were measured on a Cary recording spectrophotometer, Model 11. Varian Associates HR-60 and A-60 instruments were used for n.m.r. spectra. Optical rotations were determined in chloroform on a Zeiss polarimeter. Unless otherwise indicated, alumina used for chromatography was Merck acid-washed.

Unsaturated Alcohol 4.—A slurry of allylmagnesium chloride (3 moles) in ether was prepared.[29] To this was added 30.1 g. of (−)-homocamphor[6] (0.18 mole) in 200 ml. of anhydrous ether during 1 hr. with vigorous stirring and cooling. The reaction mixture was stirred overnight at room temperature and excess Grignard reagent was subsequently decomposed with dilute aqueous ammonium chloride. The phases were separated and the aqueous phase was extracted with pentane. The organic layers were washed with water, dried, and evaporated to 38.5 g. (*ca.* 95%) of crystalline alcohol **4**. Four recrystallizations from pentane at −70° afforded prisms, m.p. 36–36.5°, $[\alpha]_D$ −20°; infrared spectrum (CCl_4 and CS_2): 3550, 3080, 2950, 1635, 1480, 1455, 1385, 1365, 1250, 1232, 1125, 1010, 1000, 965, 925, and 912 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_{24}O$: C, 80.71; H, 11.61. Found: C, 80.64; H, 11.38.

Hydroboration–Oxidation of 4. A. Diol 13.—A solution of 6.62 g. of alcohol **4** (31.7 mmoles) in 60 ml. of tetrahydrofuran under an atmosphere of nitrogen was saturated with diborane at a temperature below 30°. Exhaust vapors were passed through acetone. After 2 hr. the solution was flushed with nitrogen for 15 min. and then with air for 6 hr. The solution was stirred with a mixture of 10 ml. of 10% aqueous sodium hydroxide and 20 ml. of 30% hydrogen peroxide[10] and after 6 hr. 10 ml. of additional peroxide was added and stirring continued for 3 hr. The reaction mixture was partitioned between ether and saline solution, the organic phase washed, dried, and evaporated to a crystalline residue. Two recrystallizations from ethyl acetate gave 4.80 g. (67%) of diol **13**, m.p. 138.5–139°, $[\alpha]_D$ −25°; infrared spectrum ($CHCl_3$ and KBr): 3600, 3300, 2950, 1470, 1450, 1415, 1380, 1360, 1065, 990, and 955 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_{26}O_2$: C, 74.29; H, 11.58. Found: C, 74.32; H, 11.58.

B. Lactone 5.—A solution of 1 g. (4.8 mmoles) of **4** in 10 ml. of tetrahydrofuran was treated with diborane and excess reagent was decomposed as described in part A. The reaction mixture was diluted with 100 ml. of acetone and 25 ml. of standard chromic acid[11] added dropwise with stirring over a period of 12 hr. After extraction with pentane and concentration, the residue (1.4 g.) was mixed with 10 ml. of 10% methanolic sodium hydroxide and heated on a steam bath for 30 min., cooled, and diluted with 100 ml. of 5% aqueous sodium hydroxide. Neutral material was extracted with pentane and discarded. The basic solution was acidified with hydrochloric acid and extracted with pentane. After washing with water and drying, solvent was removed *in vacuo* to leave 0.86 g. of gummy crystals. Recrystallization from ether at −15° gave 0.58 g. (54%) of lactone **5**, m.p. 84–88°. Further recrystallization afforded an analytical sample, m.p. 88–88.5°, $[\alpha]_D$ −45°; infrared spectrum (CCl_4): 2950, 1770, 1475, 1455, 1430, 1415, 1385, 1368, 1352, 1255, 1205, 1158, 1140, 1065, 1010, and 958 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_{22}O_2$: C, 75.63; H, 9.97. Found: C, 75.72; H, 9.97.

Reduction of Lactone 5.—A solution of 281 mg. of **5** (1.28 mmoles) in 20 ml. of ether was stirred with 0.5 g. of lithium aluminum hydride overnight. Excess hydride was destroyed by addition of dilute alkali until a granular precipitate formed. The ether solution was decanted and the precipitate extracted with ether. After washing with saline solution and drying, the solvent was evaporated leaving 293 mg. of crystals. Recrystallization afforded 265 mg. (93%) of a diol, identical in all respects with **13** (mixture m.p., infrared spectrum, and optical rotation).

Unsaturated Acid (**14**).—A solution of 4.21 g. of diol **13** (18.6 mmoles) in 20 ml. of pyridine and 20 ml. of acetic anhydride was allowed to react for 18 hr. at 27°. The mixture was poured into water, extracted with pentane, and the pentane phase washed, dried, and evaporated to 5.21 g. of monoacetate; ν_{max} 3600 and 1730 cm.$^{-1}$. The oil was placed in a sturdy flask with 100 ml. of pyridine, and 20 ml. of phosphorus oxychloride added, the flask stoppered tightly, and the contents heated on a steam bath for 1 hr. After cooling, the dark reaction mixture was cautiously poured onto 400 g. of cracked ice and stirred briefly. The mixture was extracted with pentane, washed with water, dried, and evaporated to yield 4.46 g. of unsaturated acetate; ν_{max} 1730, and 1650 cm.$^{-1}$. This oil was dissolved in 50 ml. of ether and excess lithium aluminum hydride (*ca.* 5 g.) was added. After stirring overnight, excess hydride was decomposed by dropwise addition of 2% aqueous sodium hydroxide until a granular, white precipitate formed. The supernatant was decanted, the precipitate extracted with ether, washed, dried, and evaporated to 3.31 g. of unsaturated alcohol; ν_{max} 3400 and 1640 cm.$^{-1}$. Dilute acid dissolved the precipitate, and additional product (0.56 g.) was extracted with pentane. The oil (3.87 g.) was taken up in 150 ml. of acetone and oxidized by dropwise addition of standard chromic acid.[11] Oxidation became slow after 20 ml. had been added and an additional 5 ml. was consumed during the following 3 hr. The reaction mixture was extracted with pentane and the extract washed with water. After partial concentration, the pentane phase was extracted with 2% aqueous sodium hydroxide and the base extract subsequently acidified with dilute hydrochloric acid. The acidified solution was extracted with ether, the ether phase washed with dilute bicarbonate and saline solutions, dried, and evaporated to yield 2.70 g. (65%) of crude acid **14** which crystallized upon cooling and scratching. Three recrystallizations from pentane at −15° afforded an analytical sample, m.p. 81–82°, $[\alpha]_D$ +19°; infrared spectrum (CCl_4): 3400–2400, 1710, 1470, 1445, 1410, 1380, 1360, 1290, 1215, and 935 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_{22}O_2$: C, 75.63; H, 9.97. Found: C, 75.60; H, 9.91.

Cyclopentenone 10. A.—Thionyl chloride (2 ml.) was added to 1.252 g. of crude acid **14** (5.64 mmoles) and the solution swirled under a vacuum of 30 mm. for 10 min. The mixture was diluted with 100 ml. of carbon disulfide and 1 g. of aluminum chloride added with rapid swirling. The flask was flushed with dry nitrogen, sealed, and shaken overnight. Slow addition of 10 ml. of acetic acid in 100 ml. of water gradually dissolved the dark gummy precipitate and the mixture was extracted with pentane and the extract washed with water, dried, and evaporated to a dark oil. Filtration of an ether solution through 10 g. of Alcoa alumina afforded a dark but crystalline residue (0.82 g.) which was sublimed at 100° (30 mm.). Thin layer chromatography of the colorless sublimate indicated a single spot when developed with 2,4-dinitrophenylhydrazine reagent. Recrystallization from pentane at −15° furnished 0.48 g. (41%) of colorless prisms, m.p. 109.5–110°. Further recrystallization afforded an analytical sample of **10**, m.p. 110°, $[\alpha]_D$ −149°, λ_{max}^{EtOH} 246 mμ (ε 13,000); infrared spectrum (CCl_4): 2950, 1690, 1635, 1475, 1445, 1405, 1390, 1375, 1365, 1300, 1270, 1240, 1190, 1055, and 1020 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_{20}O$: C, 82.30; H, 9.87. Found: C, 82.23; H, 9.72.

B.—A solution of 1 g. of zinc chloride in 25 ml. of acetic acid was mixed with 75 ml. of acetic anhydride and added under

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(28) H. B. Henbest and B. Nicholls, *J. Chem. Soc.*, 4608 (1957).

(29) M. S. Kharasch and C. F. Fuchs, *J. Org. Chem.*, **9**, 359 (1944).

nitrogen to 12.1 g. of lactone **5** (54.5 mmoles). The flask was stoppered and heated to 70° for 2 days. After cooling, the contents were poured into 250 ml. of 10% aqueous sodium hydroxide and stirred for 15 min. The buffered mixture was extracted with pentane, the pentane phase washed, dried, and evaporated to a dark oil (12 g.) which was treated with 100 ml. of hot 10% methanolic sodium hydroxide for 1 hr. Dilution with 400 ml. of 5% aqueous sodium hydroxide and extraction with pentane afforded, after evaporation, 5.5 g. of a dark, partly crystalline oil. Sublimation at 140° (20 mm.) followed by trituration with cold pentane gave 3.3 g. of colorless crystals. Thin layer chromatography revealed two spots when developed with 2,4-dinitrophenylhydrazine. This mixture of ketones was carefully chromatographed on 100 g. of alumina using mixtures of pentane and ether as eluent. Fractions containing the major product were combined to furnish 2.3 g. (20%) of the cyclopentenone (**10**). Recrystallization from ether at −70° gave 1.5 g. of a nearly racemic product, m.p. 100°, [α]D −20°. Infrared, ultraviolet, and n.m.r. spectra were identical with those of **10**, part A (previous paragraph).

Fractions containing the minor ketonic product were rechromatographed and recrystallized to afford 0.15 g. of the *meso*-cyclohexenone (**8**), m.p. 101–103°, $\lambda_{\max}^{\mathrm{EtOH}}$ 247 mμ (ε 14,500); infrared spectrum (CCl_4): 2950, 1665, 1620, 1465, 1450, 1415, 1380, 1360, 1330, 1295, 1280, 1250, 1225, 1195, 910, and 870 cm.$^{-1}$.

Anal. Calcd. for $C_{14}H_{20}O$: C, 82.30; H, 9.87. Found: C, 82.22; H, 10.04.

The basic extract was acidified with hydrochloric acid and taken up in pentane to recover 6.1 g. of a crude product which, according to its infrared spectrum, consisted mainly of lactone **5**.

β-Patchoulene (12). A.—All operations prior to addition of water were conducted under anhydrous, oxygen-free nitrogen. Anhydrous ether and tetrahydrofuran were filtered through a column of 30 g. of Woelm alumina directly into the reaction vessel. To a magnetically stirred mixture of 3.0 g. of triphenylmethylphosphonium bromide (8.0 mmoles) in 40 ml. of ether was added 4.0 ml. of 1.5 *N* *n*-butyllithium (6.0 mmoles) solution in ether. After 5 hr., a solution of 291 mg. of cyclopentenone (**10**) (1.43 mmoles) in 20 ml. of ether was added slowly and stirred overnight. The reaction was then allowed to reflux for 2 hr. Ether was then replaced with 50 ml. of tetrahydrofuran and reflux continued for 2 hr. After cooling, 10 ml. of water was added and the reaction mixture was extracted immediately with pentane. The organic phase was washed, dried, and concentrated *in vacuo* at 40° to 25 ml. Residual tetrahydrofuran was codistilled with several portions of hexane, concentrating again to 25 ml. *in vacuo*. The solution was placed on a column of alumina (30 g.) and the product eluted with 100 ml. of pentane. The eluate was concentrated to 25 ml. *in vacuo* at 40°, an equal volume of ethyl acetate added, and concentration continued to a volume of 10 ml. This was placed in a hydrogenator containing 4 g. of prereduced Raney nickel W-2 in 10 ml. of ethyl acetate. With magnetic stirring hydrogen was absorbed rapidly. The reaction was interrupted after uptake of 26 ml. of hydrogen (1.1 mmoles), the solution decanted, and the catalyst extracted with ether. After filtration through a column of 1 g. of alumina the solution was evaporated on a steam bath *in vacuo* giving 212 mg. of an oil which according to high resolution gas chromatography (20% silicone grease on base-washed firebrick) contained 53% of β-patchoulene (over-all yield 38%). A collected sample had the same gas chromatographic retention time, infrared and n.m.r. spectra as authentic β-patchoulene (**12**).[5] When starting material **10**, with [α]D −149°, was used, β-patchoulene, [α]D −42° (lit.[5] −42.3 to −43.7°), was obtained; when **10** with [α]D −20° was used, nearly racemic β-patchoulene, [α]D −4°, was forthcoming. The *cis*-glycol[5] prepared from the former had m.p. 122–123°, undepressed when mixed with authentic β-patchoulidiol.

B.—A solution of methylmagnesium iodide (5 mmoles) in ether was prepared from magnesium turnings (0.121 g., 5 mmoles) and methyl iodide (0.710 g., 5 mmoles). The cyclopentenone **10** (0.204 g., 1 mmole) in ether (5 ml.) was added during 10 min. with stirring and cooling (ice bath). This mixture was allowed to warm to room temperature and was then poured into a saturated ammonium chloride solution (10 ml.) which was extracted twice with ether (10 ml. each). The combined ether extracts were washed with water (10 ml.) and dried over sodium sulfate. After the solvents were evaporated, the residue (0.205 g.) was dissolved in ethyl acetate (4 ml.) and hydrogenated immediately using prereduced W-2 Raney nickel (3 g.) in ethyl acetate. Hydrogen uptake (1.09 mmoles) was complete in 1 hr. The solution was decanted and the catalyst washed twice with ethyl acetate (20 ml. each) and twice with ether (20 ml. each). The combined filtrates were passed through alumina (2 g.) and concentrated *in vacuo* to give a slightly yellow oil (0.168 g.). A sample (0.137 g.) was distilled at reduced pressure (0.05 mm., bath temperature 70°) in a micro-Hickman distillation flask using a trap cooled by a mixture of Dry Ice and acetone. Material collected in this way (0.115 g.) according to high resolution gas chromatography using a 20 ft. column of 30% SE-30 on 45/60 Chromosorb P at 190° contained 77% of β-patchoulene (**12**, over-all yield 52%). A sample collected from v.p.c. in the conventional manner had the same retention time and infrared spectrum as authentic β-patchoulene. The minor components in the mixture were not identified.

β-Patchoulene Oxide (16).—A solution of 26 ml. of 8 *M* peracetic acid and 2 g. of anhydrous sodium acetate in 200 ml. of chloroform was added during 20 min. to 20 g. of β-patchoulene[5] maintained at 5°. After standing in a refrigerator overnight, the mixture was washed with bicarbonate, ferrous sulfate solution, and water. The organic phase was dried and evaporated to 22.5 g. of β-patchoulene oxide. Two recrystallizations from an equal volume of pentane at −70° followed by distillation at 65° (0.3 mm.) afforded an analytical sample, n^{25}D 1.455, [α]D −8°; infrared spectrum (pure): 2980, 1460, 1440, 1380, 1368, 1310, 1090, 970, 910, 850, and 830 cm.$^{-1}$.

Anal. Calcd. for $C_{15}H_{24}O$: C, 81.76; H, 10.98. Found: C, 81.97; H, 10.99.

Unsaturated Alcohol 18.—With protection from moisture, a solution of 60 g. of β-patchoulene oxide (**16**, 0.27 mole) in 300 ml. of anhydrous ether was treated with 8 ml. of freshly distilled boron trifluoride etherate. The solution gradually turned dark red and after 10 min. the reaction was discontinued by cautious addition of 500 ml. of saturated sodium bicarbonate solution. Effervescence diminished after stirring for 1 hr. The phases were separated, the organic layer washed with water, dried, and evaporated to an oil which was chromatographed on 1 kg. of alumina. The first pentane eluate (1000 ml.) contained nonhydroxylic products, but subsequent fractions contained an alcohol which was fractionally distilled through a spinning-band column. Collection at 83–84° (0.5 mm.) afforded 34 g. of unsaturated alcohol (57%), m.p. 30–31°, [α]D −14°, after three recrystallizations from pentane at −70°. The pure compound gave an orange-yellow color reaction with tetranitromethane; infrared spectrum (pure): 3500, 2950, 1660, 1450, 1375, 1365, 1360, 1330, 1290, 1205, 1160, 1115, 1040, 1035, 965, 830, 815, and 795 cm.$^{-1}$.

Anal. Calcd. for $C_{15}H_{24}O$: C, 81.76; H, 10.98. Found: C, 81.47; H, 10.82.

Diol 19.—A 1000-ml. round-bottom three-neck flask was fitted with (a) a gas inlet tube projecting below the 100-ml. level, (b) a sturdy magnetic stirrer, (c) a gas outlet tube passing into a beaker containing acetone, and (d) a dropping funnel containing 4.32 g. of **18** (19.6 mmoles) in 500 ml. of tetrahydrofuran. Tetrahydrofuran (100 ml.) was placed in the flask and stirred vigorously while it was saturated with diborane introduced through the gas inlet. After 5 min. the solution of **18** was added dropwise over a period of 1 hr. while additional diborane was added. The flask had to be cooled with an ice bath to prevent a rise of temperature. After stirring for another hour the mixture was cautiously poured into a well stirred slurry of 200 g. of sodium bicarbonate in 2000 ml. of ice–water. After 1 hr., 100 ml. of 30% hydrogen peroxide was added and stirring continued for 2 hr. The mixture was extracted with pentane which was washed with water, dried, and concentrated to 12 g. of an oily residue which was chromatographed on 300 g. of alumina. Fractions eluted with ether and ethyl acetate afforded 2.07 g. (44%) of crystalline diol **19**. Four recrystallizations from ether–hexane at −15° gave an analytical sample, m.p. 112–113°, [α]D −2°; infrared spectrum (1% CCl_4): 3585, 3420, 3250, 2940, 1455, 1390, 1380, 1140, 1050, and 950 cm.$^{-1}$.

Anal. Calcd. for $C_{15}H_{26}O_2$: C, 75.58; H, 11.00. Found: C, 75.38; H, 10.75.

Unsaturated Acetate 20.—With protection from moisture, 198 mg. of **19** (0.83 mmole) was allowed to reflux with 1 ml. of acetic anhydride in 2 ml. of pyridine for 1 day. The reaction mixture was concentrated *in vacuo* on a steam bath and the brown residue extracted with benzene and filtered through 10 g. of alumina. The filtrate was chromatographed over 10 g. of alumina and fractions eluted with 10–20% benzene in pentane afforded 181 mg. of colorless unsaturated acetate **20** (87%), $[\alpha]_D$ +39°; infrared spectrum (pure): 2930, 1725, 1435, 1370, 1357, 1245, 1155, 1020, and 970 cm.$^{-1}$; orange color reaction with tetranitromethane.

Anal. Calcd. for $C_{17}H_{26}O_2$: C, 77.82; H, 9.99. Found: C, 77.50; H, 10.14.

Alcohol 22. **A.**—A solution containing 6.12 g. of α-patchoulene (**23**,[5] 30 mmoles) in 25 ml. of tetrahydrofuran was saturated with diborane during 2 hr. Exhaust vapors were passed into a beaker containing acetone. The reaction was cautiously poured into a stirred slurry of 25 g. of sodium bicarbonate and 250 ml. of ice-water. After 1 hr. 20 ml. of 30% hydrogen peroxide was added and stirring continued overnight. This mixture was then extracted with pentane which was washed with water, dried, and evaporated. The residue (8.21 g.) was chromatographed on 290 g. of alumina. Starting material (1.26 g.) was eluted with 10% benzene in pentane. Benzene eluates afforded 5.06 g. (91%) of alcohol **22**, m.p. 96–97.5° after recrystallization from pentane at −70°. Further recrystallization gave needles, m.p. 97–97.5°, $[\alpha]_D$ −7°; infrared spectrum (CCl_4): 3600, 3380, 2930, 1447, 1380, 1370, 1125, 1035, 985, and 967 cm.$^{-1}$.

Anal. Calcd. for $C_{15}H_{26}O$: C, 81.02; H, 11.79. Found: C, 81.14; H, 11.98.

B.—A solution of 347 mg. of diol **19** (1.46 mmoles) in 5 ml. of acetic acid containing 1 drop of perchloric acid was magnetically stirred in an atmosphere of hydrogen over 1 g. of prereduced platinum oxide at 30°. Reduction was interrupted after 1.5 hr. when 25.1 ml. of hydrogen (0.94 mmole) had been absorbed. The solution was diluted with pentane, decanted, washed with aqueous bicarbonate and water, the organic phase dried, and evaporated *in vacuo* on a steam bath. The oily residue was chromatographed in hexane on 10 g. of alumina. Unidentified hydrocarbons were eluted with hexane and further elution with benzene afforded 118 mg. (31%) of alcohol **22**. Two recrystallizations gave needles, m.p. 96–97.5°, undepressed when mixed with **22**, part A; infrared spectra of both samples were identical.

C.—A solution of 131 mg. of unsaturated acetate **20** (0.52 mmole) in 1 ml. of acetic acid was stirred magnetically with 100 mg. of prereduced platinum oxide in an atmosphere of hydrogen at 27°. Hydrogen uptake was complete within 10 hr. after 13.2 ml. (0.60 mmole) had been absorbed. The solution was diluted with pentane, decanted, washed with aqueous bicarbonate and water, and dried. Solvent was evaporated to afford 128 mg. of acetate **21** (98%), whose infrared spectrum was identical with that of **21** obtained from alcohol **22**. The oil was subsequently treated with excess lithium aluminum hydride in ether for 4 hr., excess hydride decomposed with a few drops of water, the organic phase decanted, washed with water, and dried. Solvent was evaporated and the residue chromatographed on 3 g. of alumina. Fractions eluted with 10% benzene in pentane furnished 99 mg. of crystalline alcohol **22** (87%), m.p. 96.5–97.5° after several recrystallizations from pentane at −70°. An infrared spectrum was identical with that of **22**, part A, and no mixture melting point depression was observed.

Acetate 21.—A solution of 1.40 g. of alcohol **22** (6.3 mmoles) in 5 ml. of acetic anhydride and 5 ml. of pyridine was heated on a steam cone for 2 hr. The reagents were distilled *in vacuo* and the residue filtered through a bed of alumina to furnish 1.53 g. of acetate **21** (92%). An analytical sample was distilled in a micro-Hickman still at 140° (1 mm.), $[\alpha]_D$ −3°; infrared spectrum (pure): 2950, 1730, 1450, 1380, 1370, 1360, 1245, 1010, and 965 cm.$^{-1}$.

Anal. Calcd. for $C_{17}H_{28}O_2$: C, 77.23; H, 10.67. Found: C, 76.93; H, 10.71.

α-Patchoulene (**23**).—A column (10 cm. × 1 cm.) packed with glass helices was heated to 350°. Under a slow stream of nitrogen 1.465 g. of acetate **21** (5.55 mmoles) was dropped through the column over a period of 1 hr. Hot organic vapors were condensed at −70° and the products chromatographed on 50 g. of alumina. Fractions were eluted with hexane contained 680 mg. of a mixture of olefins. Starting material (331 mg., 1.3 mmoles) was eluted with benzene. The major olefin (80%) collected from a gas chromatograph was identical in retention time, infrared and n.m.r. spectra with authentic α-patchoulene (**23**).[5] It was formed in 62% yield based on acetate (**21**) consumed and had $[\alpha]_D$ +51°, (authentic sample purified by g.l.c., $[\alpha]_D$ +56°); infrared spectrum (pure): 2960, 1640, 1470, 1444, 1377, 1370, 1358, 1340, 1295, 1200, 1140, 1020, 990, 850, and 790 cm.$^{-1}$. A minor product, apparently **26**, ν_{max} 730 cm.$^{-1}$, could not be isolated in pure form.

Epipatchoulione (**24**).—A solution of chromic acid[11] was added dropwise with stirring to 377 mg. of alcohol **22** (1.7 mmoles) in 40 ml. of acetone until a permanent yellow color was imparted to the solution. The reaction mixture was extracted with pentane, and the extract shaken with water and dried. Evaporation gave 368 mg. of **24** (97%) which crystallized upon cooling. Three recrystallizations from pentane at −70° gave prisms, m.p. 25–26°, $[\alpha]_D$ +13°; infrared spectrum (pure): 2930, 1693, 1470, 1450, 1400, 1382, 1365, 1220, 1185, 1125, 1100, and 1030 cm.$^{-1}$.

Anal. Calcd. for $C_{15}H_{24}O$: C, 81.76; H, 10.98. Found: C, 81.50; H, 11.11.

Patchoulione (**2**).—A pellet of potassium hydroxide (0.15 g.) was added to a solution of 230 mg. of epipatchoulione (**24**) in 5 ml. of absolute ethanol and the mixture warmed briefly. After 12 hr. at room temperature the mixture was diluted with pentane and washed with water. The organic phase was dried and evaporated leaving 218 mg. of crystals. Recrystallization from methanol at −70° gave 137 mg. of patchoulione (**2**, 59%), m.p. 45–49°. Further recrystallization furnished an analytical sample, m.p. 48–50°, $[\alpha]_D$ −64°. The sample melted undepressed when mixed with an authentic sample kindly provided by Dr. H. E. Eschinazi, Givaudan Corp.

Wolff–Kishner Reduction of the Hydroxyketone 40 to Patchouli Alcohol (**28**).—The hydroxyketone **40** (0.300 g., 1.27 mmoles) was suspended in a mixture of 24 ml. of triethylene glycol, 1 ml. of hydrazine hydrate (85%), and potassium hydroxide (0.600 g.) and the mixture was subsequently heated to 175° for 1.5 hr. Water and hydrazine were distilled until the pot temperature reached 220°. After 1 hr. the reaction mixture was cooled, 40 ml. of water was added, and the solution was extracted four times with 40 ml. of ether. The combined ether layers were shaken with water and dried over magnesium sulfate and the ether was evaporated to a crystalline residue (0.205 g., 73%). One recrystallization from pentane at −70° afforded a pure sample, m.p. 55–56.5°, which showed no depression on admixture of authentic patchouli alcohol, m.p. 55–56.5°. The infrared spectra of the two samples were superimposable.

Reduction of the Hydroxyketone 40 to the Diol 38.—The hydroxyketone **40** (0.080 g., 0.34 mmole) and lithium aluminum hydride (0.200 g.) were dissolved in ether (30 ml.). After stirring at room temperature for 8 hr. excess hydride was decomposed by dropwise addition of a 2% solution of sodium hydroxide in water until a white precipitate formed. The supernatant was decanted and the precipitate was rinsed three times with ether. After the dried solvent had been evaporated, the crystalline residue (0.076 g., 95% yield) was recrystallized three times from benzene. The pure product (80% yield) had m.p. 157–158°, $[\alpha]^{30}_D$ −72° ($CHCl_3$).

Anal. Calcd. for $C_{15}H_{26}O_2$: C, 75.58; H, 11.0. Found: C, 75.82; H, 10.94.

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