activated ester (3.13 g, yield 62.8%), mp 114–117°, $[\alpha]^{26}D$ −19.1° (c 1, methanol).

Anal. Calcd for $C_{22}H_{31}N_3O_8S$ (497.6): C, 53.10; H, 6.28; N, 8.45. Found: C, 53.74; H, 6.48; N, 8.43.

Registry No.—I, 29842-94-2; II, 29842-95-3; III, 29842-96-4; IV, 29842-97-5; V, 29842-98-6; VI, 29842-99-7; VII, 29843-00-3; VIII, 28252-48-4; IX, 29843-02-5; X, 29843-03-6; XI, 29843-04-7; XII, 29843-05-8; XIII, 29843-06-9; N^{α}-*tert*-butyloxycarbonyl-N^{ϵ}-tosyllysine *N*-hydroxysuccinimide ester, 29843-07-0.

Acknowledgments.—This work was supported in part by the American Cancer Society, The Allen Foundation, and The Geffen Foundation. One of us (K.-T. W.) is a Fulbright Scholar for 1969–1971 and on leave from the Department of Chemistry, National Taiwan University, Taiwan. We wish to thank D. Chung and J. Ramachandran for helpful suggestions during the course of this work.

The Structure of Paradisiol, a New Sesquiterpene Alcohol from Grapefruit Oil

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Received December 4, 1970

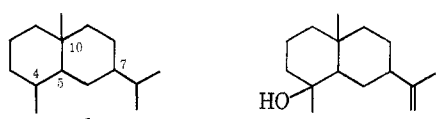
Paradisiol, a new sesquiterpene alcohol isolated from grapefruit peel oil, was shown to be 5β*H*,7β,10α-selin-11-en-4α-ol (**8**).

Previous investigations of grapefruit oil (*Citrus paradisi* Swingle) led to the detection of a bicyclic sesquiterpene ketone, nootkatone, which is considered to be the principal flavoring constituent.[1,2] Although it is the major oxygenated sesquiterpene (0.3%) in the oil, it occurs with a number of other compounds of which no detailed information is yet available.[3] Since further flavor contributors may be expected in this group, we started a composition study of a grapefruit oil fraction which was rich in nootkatone and contained a multitude of other components. In this paper we report the isolation and chemical structure of a new sesquiterpenic alcohol, named paradisiol (**8**).

Paradisiol (**8**), mp 85–86°, $C_{15}H_{26}O$, shows tertiary hydroxyl bands at 3612 and 3480 cm^{-1} and terminal methylene bands at 3090, 1635, and 890 cm^{-1}. The proton resonance spectrum shows two tertiary methyl groups at δ 0.93 (s, 3 H) and 1.04 (s, 3 H), one vinylic methyl at δ 1.74 (s, 3 H), and one methylene group at δ 4.84 (s, 2 H). On catalytic hydrogenation with palladium/C in acetic acid or with platinum/C in ethanol, 1 mol of hydrogen was consumed.

Paradisiol was readily dehydrated with phosphorus oxychloride in pyridine to give a mixture of two isomeric olefins (**9**, **10**) which could be separated by gas chromatography. Both the major (**9**) and the minor (**10**) dehydration products show bands in the infrared for terminal methylene (3080, 1642, 888 and 3090, 1640, 890 cm^{-1}, respectively). The nmr spectrum of **9** contains signals for a tertiary methyl group at δ 0.73 (s, 3 H) and a vinylic methyl group at δ 1.70 (s, 3 H). In addition, two terminal methylene groups at δ 4.37 (s, 1 H), 4.63 (s, 1 H), 4.77 (s, 1 H), and 4.85 (s, 1 H) are shown. The nmr spectrum of **10** shows a tertiary methyl group at δ 0.83 (s, 3 H) and two vinylic methyl groups at δ 1.56 (s, 3 H) and 1.71 (s, 3 H). It further shows a total of three olefinic protons at δ 4.80 (s, 2 H) and 5.22 (s, 1 H), the latter one being attached to a trisubstituted double bond.

Paradisiol is thus a bicyclic tertiary alcohol, bearing an isopropenyl group. Hydrogenation of either **9** or **10**, Pd/C in acetic acid, was shown by gas chromatography to yield an identical tetrahydro derivative. This hydrocarbon was shown to be identical with selinane (eudesmane) (**1**), prepared from β-selinene. The gross structure of paradisiol can therefore be written as selin-



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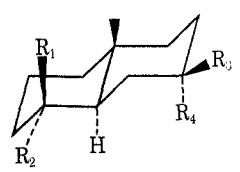
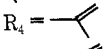


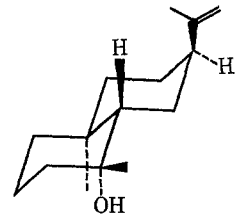
3, $R_1 = CH_3$; $R_2 = OH$; R_3 =  ; $R_4 = H$

4, $R_1 = OH$; $R_2 = CH_3$; R_3 =  ; $R_4 = H$

5, $R_1 = CH_3$; $R_2 = OH$; $R_3 = H$; R_4 = 

6, $R_1 = OH$; $R_2 = CH_3$; $R_3 = H$; R_4 = 

7, $R_1 = CH_3$; $R_2 = H$; R_3 =  ; $R_4 = H$



8

11-en-4-ol (**2**). In analogy with β- and α-selinene, "β" and "α" are used to designate the position of the double bond in **9** and **10**, respectively.

All naturally occurring compounds of the selinane family hitherto reported are *trans*-decalin derivatives. Assuming paradisiol to be trans also (*vide infra*), the discussion on the relative configuration can be confined

(1) W. D. MacLeod, Jr., and N. M. Buigues, *J. Food Sci.*, **29**, 565 (1964).
(2) W. D. MacLeod, Jr., *Tetrahedron Lett.*, 4779 (1965).
(3) H. E. Nursten and A. A. Williams, *Chem. Ind. (London)*, 486 (1967).

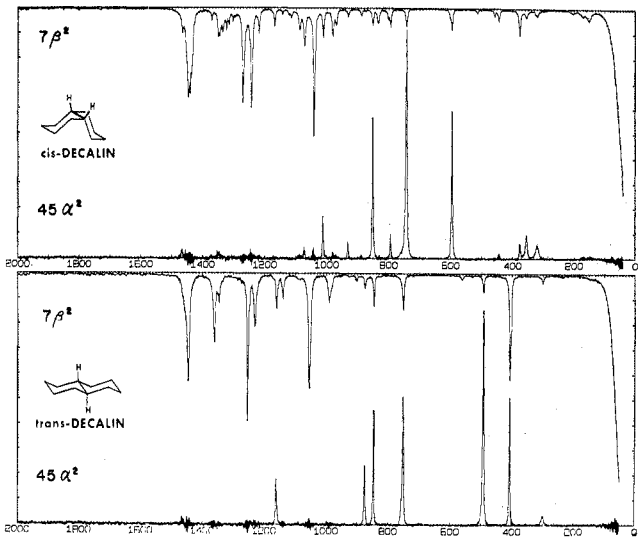


Figure 1.—Raman spectra of *cis*- and *trans*-decalin: slit 1 cm^{-1}, time constant 0.3 sec, scan rate 0.8 cm^{-1}/sec, laser power 50 mW.

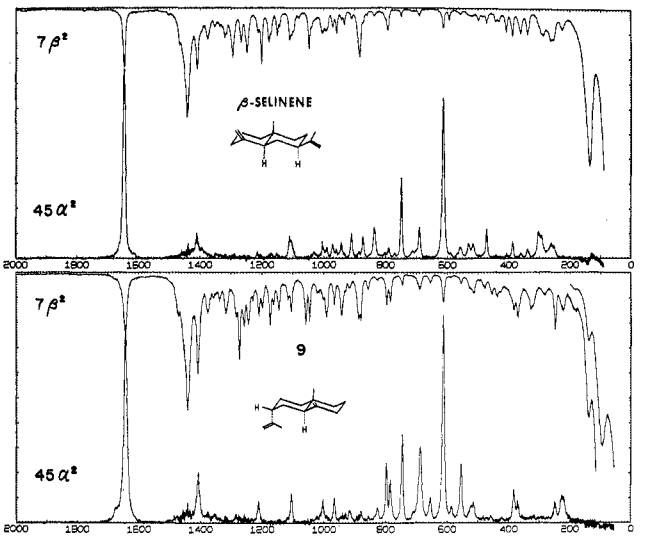


Figure 2.—Raman spectra of β-selinene and **9**: slit 2 cm^{-1}, time constant 0.3 sec, scan rate 0.8 cm^{-1}/sec, laser power 50 mW.

to the possible trans isomers of selin-11-en-4-ol. In the *trans*-decalin form, the angular substituents at C-5 and C-10 are fixed in an axial conformation; hence the structure for paradisiol is reduced to structures **3**–**6** (or their enantiomers).

Compounds **3** and **4**, bearing an equatorial isopropenyl group (as does α- and β-selinene) are both reported in the literature.[4,5] Clearly, the spectral and physical data of paradisiol do not match these data.[6] Consequently paradisiol must be either compound **5** or **6** (or their enantiomers) with an axial isopropenyl group. Since paradisiol was converted to selinane (equatorial isopropyl), isomerization at C-7 must have occurred. This is underlined by the fact that a hydrocarbon, not identical with selinane, was obtained by hydrogenation in the presence of platinum/C in ethanol. Similarly, hydrogenation of paradisiol over palladium/C (acetic acid) and over platinum/C (ethanol) gave different dihydro alcohols. These findings are readily explained by the fact that inversion of the isopropenyl group at C-7 occurred with palladium/C. Catalyst-induced inversion involves migration of the double bond which takes place only when the allylic hydrogen to be removed is sterically accessible to the catalyst and the resulting isopropylidene group can consume the incoming hydrogen from the less hindered side. This phenomenon of isomerization of axial isopropenyl groups is well documented both in the steroid field and in a structure similar to paradisiol.[7]

Until now a cis-fused ring system has not been excluded. A *cis*-decalin structure would be isomerized to a *trans*-decalin if inversion at C-5 took place. This is very unlikely to occur upon catalytic reduction of paradisiol since it would involve a shift of the double bond along three carbon atoms, for which no precedent is known.[8] In contrast, the dehydro compounds derived from paradisiol, both possessing and allylic hydrogen at C-5, might have been isomerized when reduced with palladium/C. Hydrogenation of paradisiol over palladium/C (inversion of C-7), followed by dehydration and hydrogenation over platinum/C (no isomerization), again gave selinane. Thus, inversion has only occurred at C-7 and paradisiol must be a *trans*-selin-11-en-4-ol with an axial isopropenyl group.

In accordance with the above findings, the Raman spectra give evidence for the *trans*-decalin ring structure. The stretching of C–C bonds of cyclic hydrocarbons gives rise to large contributions to the isotropic part of Raman scattering (α), and it has been found that the intensity of a polarized line is dependent on the in-phase additivity of the C–C stretching coordinates.[9] Consequently, the "isotropic Raman scattering" is quite characteristic of the C–C skeletal structure. *cis*- and *trans*-decalin are shown in Figure 1. The anisotropic part of the scattering ($7\beta^2$) is plotted downward and the isotropic part ($45\alpha^2$) in the normal upward manner. We note that, while many of the spectral lines show similarities in their anisotropic spectra (principally due to C–H deformations and antisymmetric C–C stretches), the isotropic spectra are very different, particularly in the region below 700 cm^{-1}. We should expect similar differences between the cis and trans isomers of substituted decalins.

In Figure 2 we show the isotropic and anisotropic Raman spectra of β-selinene and **9**, and, in Figure 3 (+)-selinane and **11**. It is clear from these spectra that the isotropic spectral components of each molecule in both figures are quite similar. We therefore rule out the possibility of a *cis*-decalin structure for **9** and **11**. The only remaining conclusion is that the axial orientation of the isopropenyl group is responsible for the minor deviations from the isotropic spectra exhibited by β-selinene and (+)-selinane.

In considering compounds **5** and **6**, intermedeol, the enantiomer of **5**, has been reported.[10,11] The comparison of paradisiol with intermedeol on the base of spec-

(4) R. E. Corbett and R. A. J. Smith, *Tetrahedron Lett.*, 1009 (1967).
(5) V. B. Zalkow, A. M. Shaligram, and L. H. Zalkow, *Chem. Ind. (London)*, 194 (1964).
(6) The nmr data are often given without an indication of the solvent used; hence, conclusions based on nmr data alone may not be reliable.
(7) J. B. Bream, D. C. Eaton, and H. B. Henbest, *J. Chem. Soc.*, 1974 (1957).
(8) S. Siegel and G. V. Smith, *J. Amer. Chem. Soc.*, **82**, 6087 (1960).
(9) R. G. Snyder, private communication.
(10) L. H. Zalkow, V. B. Zalkow, and D. R. Brannon, *Chem. Ind. (London)*, 38 (1963).
(11) G. L. Chetty, V. B. Zalkow, and L. H. Zalkow, *Tetrahedron Lett.*, 3223 (1968).

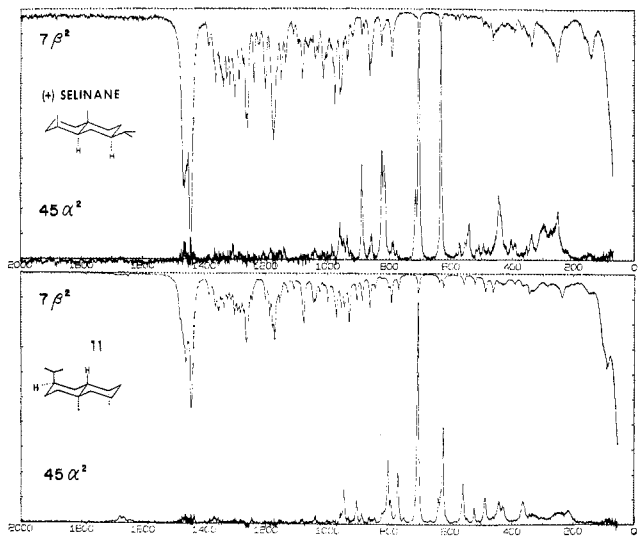
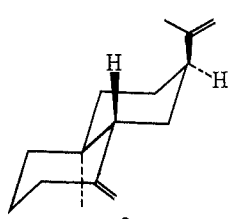


Figure 3.—Raman spectrum of (+)-selinane: slit 1 cm^{-1}, time constant 1 sec, scan rate 0.46 cm^{-1}/sec, laser power 50 mW. Raman spectrum of compound 11: slit 2 cm^{-1}, time constant 0.3 sec, scan rate 0.8 cm^{-1}/sec, laser power 50 mW.

tral data was not satisfactory, as little information on the latter compound is available. However, the melting points are different, and hydrogenation of paradisiol over palladium/C yielded a dihydro alcohol which was not the enantiomer of platinum-hydrogenated **3**, the spectral data of which are reported,[4] thus showing that paradisiol and intermedeol are not identical. Hence, paradisiol must be **6** or its enantiomer.

Compound **6**, bearing an axial hydroxyl group, is the C-4 epimer of intermedeol. Dehydration of paradisiol (**8**) (phosphorus oxychloride, pyridine) furnished, as stated earlier, a mixture of dienes **9** and **10**. Gas



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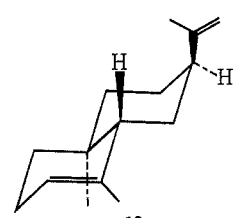
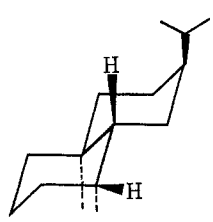
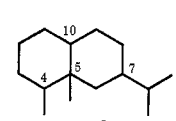


10



11



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chromatography indicated about 67% of the β isomer and 28% of the α isomer. This distribution of products is diagnostic for a hydroxyl group in an equatorial position.[12] However, normal elimination toward C-5 may be rendered difficult by the axial isopropenyl group which shields the axial C-5 hydrogen, thus making it inaccessible to the base. This may explain the relatively high amount of β isomer in the olefin mixture. This is partially substantiated by thermal dehydration of paradisiol (**8**) which gave three dehydro derivatives in about equal amounts as shown by gas chromatography.

Measurement of the pyridine-induced shifts (relative to chloroform) in the nmr spectrum often gives information on the sterical vicinity of hydroxyl groups in saturated cyclic systems.[13] In platinum-hydrogenated paradisiol a paramagnetic shift of the methyl group at C-10 of δ 0.28 was observed. Such a deshielding effect is consistent with the fact that the hydroxyl function at C-4 occupies a position 1,3 diaxial to the methyl group, thus confirming the axial conformation of the hydroxyl substituent in paradisiol.

The absolute configuration of paradisiol may be readily established. Reactions leading to selinane, including inversion of C-7, gave in all cases (−)-selinane, whereas selinane observed from β-selinene was (+)-selinane. The absolute configuration of (+)-selinane (**7**) is well established;[4,14] hence the absolute configuration of paradisiol is 5βH,7β,10α-selin-11-en-4α-ol (**8**). Correspondingly, the β dehydration product is 5βH,-7β,10α-selina-4(14),11-diene (**9**), the α isomer is 5βH,-7β,10α-selina-3,11-diene (**10**),[15] and the parent hydrocarbon is 4α,5βH,7β,10α-selinane (**11**).

Paradisiol is the first compound of the selinane group found in grapefruit. Nootkatone and valencene,[2,16] the latter one occurring in grapefruit juice, are usually looked upon as members of the same family, in which the isoprene rule is not obeyed. Biosynthetic studies on the formation of eremophilane sesquiterpenes (**12**) have not been described yet, but it was suggested long ago that the methyl group at C-10 might experience migration to C-5 by a Wagner rearrangement.[17] Thus, if a normal isoprenoid structure is assumed to be an intermediate in the biogenetic pathway, paradisiol would fit the stereochemical requirements to lead to valencene by a series of 1,2 shifts of substituents (Scheme I).[18]

It is interesting to note that compound **9** and valencene give virtually the same mass spectral pattern. This would suggest that these two compounds, upon ionization, have a common intermediate, thus lending support to the above hypothesis.

Experimental Section

Gas Chromatography.—A Perkin-Elmer[19] 226 gas chromatograph, fitted with a 75 ft × 0.01 in. Carbowax 20M column was used for all analytical runs. Temperature was programmed from 75 to 150° (2°/min) and helium gas flow held at 10-psi pressure.

For preparative purposes a 30 ft × 0.5 in. column packed with 4% SF-96 (50) silicone oil and 0.2% Carbowax 20M on 60–70 mesh Chromosorb G, and a 300 ft × 0.03 in. large-bore open

(12) D. H. R. Barton, A. S. Campos-Neves, and R. C. Cookson, *J. Chem. Soc.*, 3500 (1956).

(13) P. V. Demarco, E. Farkas, D. Doddrell, B. L. Mylari, and E. Wenkert, *J. Amer. Chem. Soc.*, **90**, 5480 (1968).

(14) W. Cocker and T. B. H. McMurry, *Tetrahedron*, **8**, 181 (1960).

(15) This compound has been reported by E. Klein and W. Rojahn, *Tetrahedron Lett.*, 279 (1970); however, the nmr data does not exactly match our data. This may possibly be due to instabilities in the 60-MHz instrument.

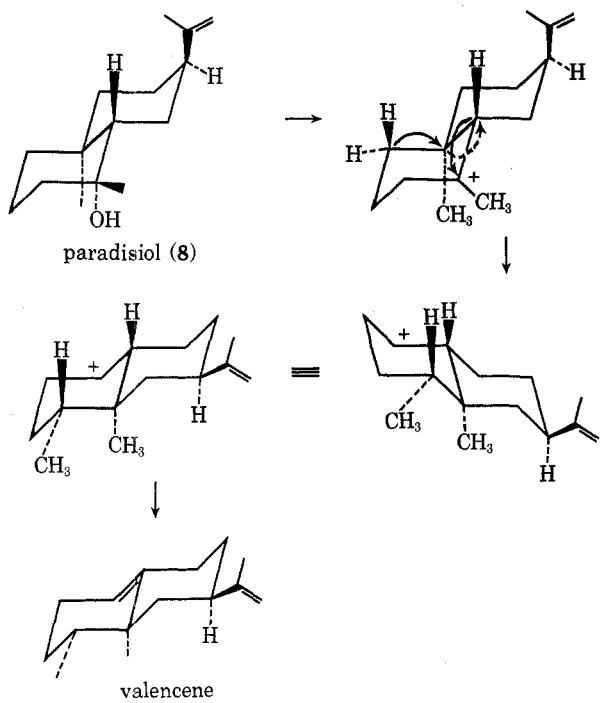
(16) G. L. K. Hunter and W. B. Brogden, Jr., *J. Food Sci.*, **30**, 383 (1965).

(17) Sir R. Robinson, cited by A. R. Penfold and J. L. Simonsen, *J. Chem. Soc.*, 87 (1939).

(18) A similar scheme has been proposed by N. H. Andersen, *Phytochemistry*, **9**, 145 (1970), in the conversion of a 2-keto-4,10-*epi*-eudesmane to α-vetivone. See also, N. H. Andersen, M. S. Falcone, and D. D. Syrdal, *Tetrahedron Lett.*, 1759 (1970).

(19) Reference to a company or product name does not imply approval or recommendation of the product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

SCHEME I



tubular column coated with OV-101 dimethylsilicone oil (Ohio Valley Specialty Chemical Co.) were used.

Infrared Spectra.—A Perkin-Elmer Model 237 infrared spectrophotometer was used. All samples were run in carbon tetrachloride.

Raman Spectra.—Spectra were obtained on submilligram quantities of material using an axial (illumination)/transverse (90° scattering) sampling technique.[20] The exciting source is a 50 mW He/Ne 6328-Å Spectra Physics laser equipped with a polarization rotator. The monochromator is a Spex 1401 with slit-shaped FW-130 photomultiplier detector and photon counting electronics. The instrumental conditions for the scans are given with each figure. The spectra shown here are not ordinary Raman scans but are scans representing "isotropic" and "anisotropic" Raman scattering. The Raman scattering experiment is described in a right-handed coordinate system in which the incident laser beam is on the z axis, the direction of observation in the y axis and the sample at the origin. The scan measuring the total scattered light intensity as a function of wavelength when the incident radiation is polarized perpendicular to the direction of observation (x) is proportional to $45\alpha^2 + 7\beta^2$ where α is the mean polarizability and β the anisotropy.[21] A second scan with the direction of laser polarization along the y axis measures $6\beta^2$. The Raman spectrometer system is on-line to a digital computer[22] which is used to calculate the scattering from the $45\alpha^2$ term. All intensities have been corrected for photomultiplier and general instrument intensity nonlinearity.[22]

Nuclear Magnetic Resonance Spectra.—A Varian HR-100 modified with an internal field frequency designed at WRRL was used. All samples were run in carbon tetrachloride (unless otherwise stated) with tetramethylsilane as an internal standard, using a microcell technique.[23]

Mass Spectra.—An EAI Model 300 quadrupole mass spectrometer and a CEC Model 110 high-resolution mass spectrometer were used.

Optical Rotation.—An NPL automatic polarimeter (Bendix Scientific Instruments), was used.

Isolation of Paradisiol (8).—Fivefold grapefruit oil was distilled at 23° and 10-μ pressure low-boiling constituents. The temperature was then raised to 55° and an intermediate fraction distilled off. The residue remaining was then distilled through a falling-film molecular still in which the pressure was held at 1 μ and the temperature of the outer jacket kept at 70°. The distillate was cooled, and crystalline nootkatone separated and filtered off. The resulting mother liquor was shown by gas chromatography to contain 30-40% nootkatone and about 5% paradisiol, and was redistilled at 3-mm pressure. The fraction boiling between 110 and 115° contained about 30% paradisiol. Further enrichment was achieved by liquid–solid chromatography on a 1 ft × 1 in. alumina (80-200 mesh) column which was charged with 1 g of distillate and developed with benzene. Elution of nootkatone was accomplished with 900 ml of benzene and paradisiol with 250 ml of benzene–ether (1:1). The latter fraction (275 mg), after evaporation of solvent, was further purified by gas chromatography on the 30-ft column. Pure paradisiol emerged in 44 min, crystallizing with mp 85–86°, optical rotation (95% EtOH) $[\alpha]^{25}D$ +14°. Spectral data:[24] ir 3612, 3480 (broad), 3090, 2940, 1635, 1452, 1383, 1261, 1168, 1090, 1063, 1053, 1038, 1022, 960, 932, 909, 890 cm^{-1}; mass spectrum m/e (rel intensity) 43 (100), 41 (54), 55 (29), 81 (26), 67 (25), 71 (25), 28 (22), 39 (18), 53 (16), 26 (15), 95 (15); mol wt molecular ion peak (determined by high-resolution mass spectrum) m/e 222.2001 (calcd for $C_{15}H_{26}O$, 222.1984).

Dihydroparadisiol, Palladium Catalyzed.—Paradisiol (58 mg, 0.26 mmol) dissolved in glacial acetic acid (20 ml) was hydrogenated at room temperature and 1 atm in the presence of 5% palladium/charcoal (45 mg) as a catalyst. The uptake of hydrogen was completed in 15 min with 1.15 equiv of hydrogen being consumed. The hydrogenation mixture was worked up in the usual manner leaving an oil which was purified by gas chromatography, using an OV-101 large-bore open tubular column and operated at 156° and 25-psi carrier gas pressure. Lack of material did not allow recrystallization of the gas chromatographically pure sample, mp 65–70°, mol wt (mass spectrum) 224. Spectral data: ir 3600, 3450 (broad), 2930, 1460, 1382, 1362, 1336, 1160, 1085, 1038, 918, 908 cm^{-1}; nmr δ 0.80 (s, 3 H), 1.13 (s, 3 H), 1.01 (d, 6 H, J = 7 Hz); mass spectrum m/e (rel intensity) 43 (100), 81 (69), 41 (54), 71 (40), 93 (40), 55 (34), 91 (33), 105 (32), 95 (31), 67 (29), 79 (29).

Dihydroparadisiol, Platinum Catalyzed.—Paradisiol (85 mg, 0.38 mmol) dissolved in 95% EtOH (35 ml) was hydrogenated after addition of 5% platinum/charcoal (55 mg) as a catalyst. After consumption of hydrogen (1.12 equiv), the dihydro derivative was purified by gas chromatography using an OV-101 silicone oil open tubular column. Lack of material did not allow recrystallization of the gas chromatographically pure sample, mp 48–55°, mol wt (mass spectrum) 224. Spectral data: ir 3615, 3480 (broad), 2930, 1460, 1386, 1366, 1336, 1178, 1166, 1092, 1063, 1044, 917, 906 cm^{-1}; nmr δ 0.92 (s, 3 H), 0.91 (d, 3 H, J = 7 Hz), 0.90 (d, 3 H, J = 7 Hz); nmr ($CDCl_3$) δ 0.94 (s, 3 H), 1.10 (s, 3 H); nmr (pyridine-d_5) δ 1.20 (s, 3 H), 1.22 (s, 3 H); mass spectrum m/e (rel intensity) 43 (100), 71 (70), 41 (56), 83 (47), 81 (46), 55 (43), 69 (40), 95 (34), 85 (32), 67 (31).

Dehydroparadisiol (9, 10).—Paradisiol (100 mg, 0.45 mmol) was dissolved in pyridine (2 ml) and phosphorous oxychloride (250 mg, 1.63 mmol) was slowly added. The mixture was held at room temperature for 16 hr, filtered, and, after addition of water, extracted with ether. The oily residue (87 mg) remaining, after drying and evaporation of the ether, was separated by gas chromatography on an OV-101 silicone oil column at 148° and 25-psi gas pressure, yielding two dehydration products emerging in 8 and 9.5 min, respectively.

β Isomer (9): mol wt (mass spectrum) 204; ir 3080, 2935, 1642, 1442, 1408, 1378, 1245, 1230, 1173, 1148, 1057, 1045, 989, 964, 942, 888, 858 cm^{-1}; mass spectrum m/e (rel intensity) 41 (100), 105 (48), 91 (46), 39 (45), 29 (43), 79 (40), 27 (38), 55 (37), 107 (34), 93 (32); mass spectrum of valencene 41 (100), 91 (45), 79 (43), 39 (42), 55 (41), 105 (41), 93 (39), 107 (38), 29 (36), 161 (35).

α Isomer (10): mol wt (mass spectrum) 204; ir 3090, 2915, 1640, 1456, 1376, 1237, 1218, 1176, 1128, 1071, 1017, 1002, 926, 890, 846 cm^{-1}; mass spectrum m/e (rel intensity) 41 (100), 122 (93), 161 (76), 107 (68), 39 (51), 29 (50), 28 (47), 91 (46), 105 (41), 55 (40).

The distribution of products obtained from thermal dehydration was determined by injecting paradisiol on a gas chromatography column at an injector temperature of 280°.

(20) G. F. Bailey, S. Kint, and J. R. Scherer, *Anal. Chem.*, **39**, 1040 (1967).

(21) E. B. Wilson, Jr., J. C. Decius, and P. C. Cross, "Molecular Vibrations," McGraw-Hill, New York, N. Y., 1955, p 43.

(22) J. R. Scherer and S. Kint, *Appl. Opt.*, **9**, 1615 (1970).

(23) R. A. Flath, N. Henderson, R. E. Lundin, and R. Teranishi, *Appl. Spectrosc.*, **21**, 183 (1967).

(24) Nmr data which were used for discussion are given there.

(+)-**Selinane (7) from β-Selinene.**—β-Selinene (131 mg, 0.64 mmol) was hydrogenated in the presence of platinum/charcoal (100 mg) in 95% EtOH (50 ml) as described above, 2.14 equiv of hydrogen being consumed. Purification by gas chromatography on the OV-101 column at 148° afforded (+)-selinane, mol wt (mass spectrum) 208, optical rotation (95% EtOH) $[\alpha]^{25}D$ +10°. Spectral data: ir 2930, 1468, 1386, 1370, 1326, 1236, 1206, 1170, 1030, 974, 934, 918, 854 cm^{-1}; nmr δ 0.88 (s, 3 H), 0.88 (d, 6 H, J 6 Hz), 0.87 (d, 3 H, J = 6 Hz); mass spectrum *m/e* (rel intensity) 43 (100), 95 (65), 109 (60), 83 (54), 81 (52), 41 (47), 55 (43), 69 (40), 67 (37), 58 (25).

(−)-**Selinane from Paradisiol. A.**—A mixture of **9** and **10** (140 mg 0.63 mmol) was hydrogenated in the presence of 5% palladium/charcoal (100 mg) in acetic acid (40 ml) with 2.20 equiv of hydrogen being consumed. Work-up of the product in the usual manner gave a saturated hydrocarbon having identical ir, nmr, and mass spectra with (+)-selinane, optical rotation (95% EtOH), $[\alpha]^{25}D$ −16°.

B.—Dihydroparadisiol (palladium-catalyzed) (45 mg, 0.20 mmol) was dehydrated as described above. The resulting mixture of olefins (36 mg) was hydrogenated over 5% platinum/charcoal (25 mg) in 95% ethanol (30 ml) with 1.09 equiv of hydrogen being consumed. Work-up in the usual manner gave a compound identical with that made by method A.

Hydrocarbon 11 from Paradisiol.—A mixture of **9** and **10** (67 mg, 0.33 mmol) was reduced catalytically with 5% platinum/charcoal (44 mg) in 95% ethanol (20 ml), 2.31 equiv of hydrogen being consumed. The crude hydrogenation mixture was purified by gas chromatography as described above, giving **11** with the following spectral data: mol wt (mass spectrum) 208; ir 2930, 1460, 1386, 1366, 1282, 1170, 1108, 1080, 1038, 998, 976, 938, 904, 854 cm^{-1}; nmr δ 0.89 (s, 3 H), 0.91 (d, 3 H = 6 Hz), 0.88 (d, 3 H, J = 6 Hz), 0.85 (d, 3 H, J = 6 Hz); mass spectrum *m/e* (rel intensity) 93 (100), 107 (98), 41 (89), 79 (85), 55 (78), 67 (69), 82 (63), 69 (61), 81 (57), 43 (47).

Registry No.—**8**, 29969-75-3; **9**, 29868-52-8; **10**, 28290-23-5; **11**, 28290-24-6; dihydroparadisiol, 29868-51-7.

Acknowledgment.—The authors wish to thank Nancy Bennett for the nmr data and W. F. Haddon for the high-resolution mass spectral data.

Conformation of Valerane

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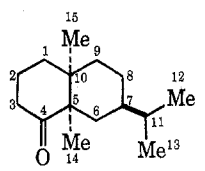
Received December 31, 1970

5β-Hydroxy-*cis*-9,10-dimethyl-2-decalone (**2**) which was shown to exist in the steroid cis conformation C was converted to 2α-acetyl-5β-hydroxy-*cis*-9,10-dimethyldecalin (**6**) and 2β-acetyl-5β-hydroxy-*cis*-9,10-dimethyldecalin (**7**). Through nmr spectral data and base equilibration, compounds **6** and **7** were assigned steroid cis conformations E and F, respectively. Through a sequence of reactions, decalin **6** was transformed to *dl*-valerane (**13**) and *dl*-7-isovalerane (**15**). The stereochemistry and conformation of the key intermediates were established by nmr studies. This investigation lends additional support for the conformation of the carbon skeleton of valeranone.

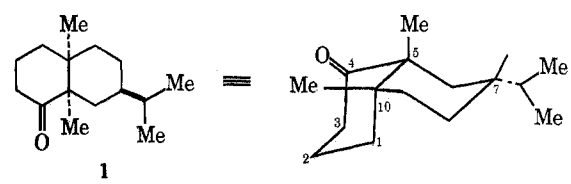
The natural product *l*-valeranone is one of the few known nonisoprenoid sesquiterpene ketones. After a great deal of experimentation by several groups of investigators its structure and absolute stereochemistry were finally established as shown in formula **1**.[1] It



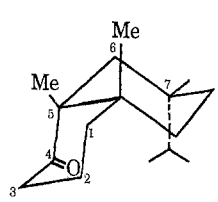
1

possesses an unusual carbon skeleton having two angular methyl groups in a cis-fused decalin ring system. The C-14 and C-15 methyl groups are α-oriented whereas the C-7 isopropyl group is β-oriented. The correctness of the proposed structure was substantiated by two different syntheses of *d*- and *l*-valeranones.[2,3] Subsequently other naturally occurring sesquiterpenoids structurally related to valeranone have been isolated from Japanese valerians.[1f] In view of the flexible nature of the cis decalin, valeranone could exist in at least two interchangeable all-chair conformations such as the "steroid" cis conformation A or the "nonsteroid" cis conformation B.

Hartshorn, *et al.*,[4] compared the optical rotatory dispersion curve of valeranone (*a*, −166) with those of 5β-



1 steroid cis A



nonsteroid cis B

methylcholestan-4-one (*a*, −75) and methyl 1-oxo-5β-etianate (*a*, −136) and suggested that the carbonyl group of valeranone is situated in the same relative en-

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