of this substance clearly differed from that of its alleged synthetic counterpart **12a** and the isomers thereof (**12b** and **c**).

Reduction of (−)-β-vetivone with lithium in ammonia–ethanol afforded principally a new dihydro alcohol [40% yield, λ_{max}^{film} 3.00 (OH), 9.71, 10.38, and 11.05 μ] along with one of the previously obtained *meso* dihydro alcohols (15% yield) and recovered starting material. Degradation of this new dihydro alcohol along the lines described above for the *meso* compound afforded a new desisopropylidenedihydro-β-vetivone [λ_{max}^{film} 5.81 (CO), 8.64, and 9.6 μ] whose infrared spectrum bore no close resemblance to that of its supposed racemic counterpart **12b** or the synthetic *meso* compounds **12a** and **c**.

In view of the nonidentity of our naturally derived and synthetic ketones we must conclude that β-vetivone cannot be represented by I or a stereoisomer thereof. Evidence which supports a spiro[4.5]decane skeleton for this substance and its relatives is presented in the following paper.

Acknowledgments. We thank the Public Health Service for supporting this work through a research grant (AI04965, Division of Allergy and Infectious Diseases) and predoctoral fellowships. We are indebted to Dr. S. K. Freeman (International Flavors and Fragrances, Inc., New York, N. Y.) for generous samples of vetivert acetate.

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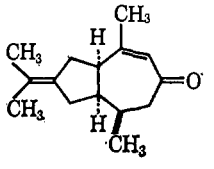
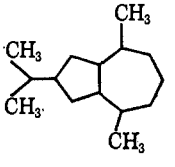
The Structure of β-Vetivone and Related Vetivane Sesquiterpenes

Sir:

The preceding report[1] summarizes synthetic and degradative work refuting the previously proposed structure (I) for β-vetivone[2] and those related sesquiterpenes whose carbon skeletons hinge on their correlation with "isovetivane" (II).[3] In this earlier work we noted



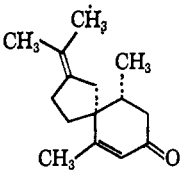
I



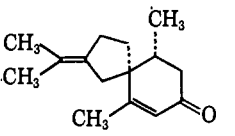
II

that the carbonyl absorption (λ_{max} 5.81 μ) of dihydro-β-vetivone and desisopropylidenedihydro-β-vetivone seemed better accommodated by a cyclohexanone than a cycloheptanone as previously formulated.[1] We therefore sought alternative structures for these substances based on cyclohexanone. With this in mind and after considering the wealth of chemical and physical data recorded for β-vetivone,[1,2] we decided on the spiro[4.5]decanes III and IV as likely possibilities.

Chart I summarizes the transformations which verify this proposal and allow us to choose III as the correct structure.

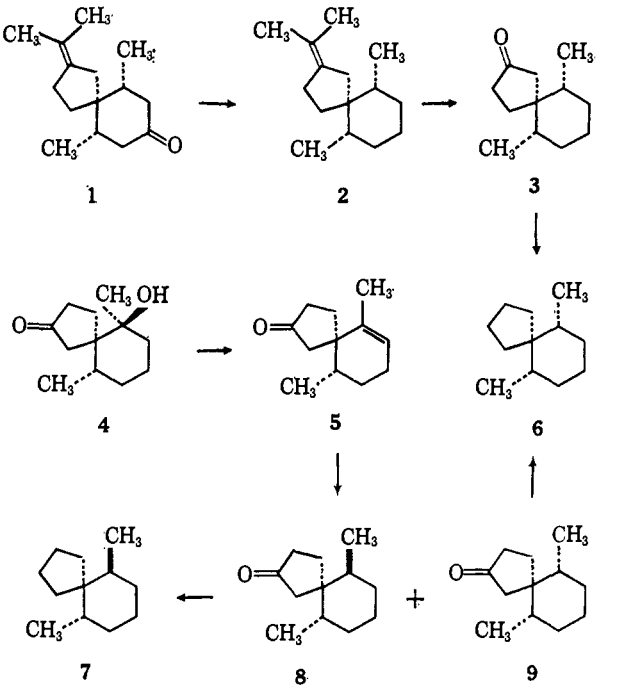


III



IV

Chart I



The known *meso*-dihydro-β-vetivone (**1**)[4] yielded the corresponding unsaturated hydrocarbon **2** [λ_{max}^{film} 7.25, 8.71, 9.06, 9.46, 10.23, and 10.59 μ; $\delta_{TMS}^{CCl_4}$ = 1.60 (vinyl CH_3), 1.25 (ring H envelope), and 0.80 ppm ($CHCH_3$ doublet, J = 5 Hz)] upon Wolff–Kishner reduction[5] of the semicarbazone derivative, mp 192–193°. Ozonolysis[4] afforded the cyclopentanone **3** [λ_{max}^{film} 5.75 (CO), 7.11, 7.24, 8.42, 8.61, 9.44, 10.60, and 11.29 μ] which in turn gave the hydrocarbon **6** [λ_{max}^{film} 7.24, 8.68, 9.42, 10.29, 11.00, 11.10, and 11.20 μ] after conversion to the ethylene thioketal derivative and desulfurization with W-2 Raney nickel[6] in refluxing ethanol.

We secured an authentic sample of the spiro[4.5]-decane **6** from hydroxy ketone **4**,[7] a known photochemical transformation product of *trans*-4a,8-dimethyl-5,6,7,8-tetrahydro-2(4aH)-naphthalenone. Dehydration with thionyl chloride in pyridine led to a mixture of olefins [λ_{max}^{film} 5.75 (CO), 7.11, 7.24, 8.6, 10.12, 10.25, 10.36, 11.06, 11.79, and 12.42 μ], mainly **5** along with a minor amount of the exocyclic double bond isomer. Hydrogenation over palladium on carbon in ethanol afforded a mixture of ketones **8** [λ_{max}^{film} 5.75 (CO), 7.11, 7.24, 8.53, 8.67, 10.20, 10.50, 10.74, and 11.25 μ] and **9** [λ_{max}^{film} 5.75, 7.11, 7.24, 8.53, 8.67,

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(2) J. Simonsen and D. H. R. Barton, "The Terpenes," Vol. III, Cambridge University Press, London, 1952, pp 224–232.
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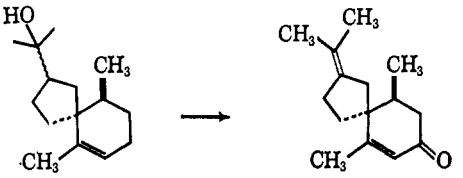
(7) P. J. Kropp and W. F. Erman, *J. Am. Chem. Soc.*, **85**, 2456 (1963).

9.90, 10.16, 10.48, 10.70, and 11.27 μ] in the ratio 2:3 as judged by the gas chromatogram. The major component of this mixture should be the *meso* isomer **9** since the double bond in unsaturated ketone **5** appears from models to be somewhat hindered by the proximate methyl group.[8] Ketones **8** and **9** differed from **3** according to the infrared spectra and gas chromatographic behavior. However, desulfurization of the thioketal derivative of ketone **9** afforded the same hydrocarbon **6** previously obtained from β-vetivone. Ketones **3** and **9** must therefore be epimeric at the spiro ring junction. Ketone **8**, when similarly treated, afforded hydrocarbon **7** [λ_{max}^{film} 7.24, 8.63, 9.42, 10.25, 10.75, 10.95, and 11.33 μ] which closely resembled **6**. These hydrocarbons could be cleanly separated by gas chromatography.

The above transformations require that β-vetivone be formulated as III, or the mirror image. The choice of III can be made from Yosioka and Kimura's work in which hinesol (now formulated as V) was converted to (+)-β-vetivone (VI).[9] The absolute configuration of hinesol (V) follows from its degradation to (+)-α-



V VI

methylglutaric acid by Šorm and co-workers.[10]

In view of the findings recorded above and in our previous report,[1] the list of sesquiterpenes containing a spiro[4.5]decane ring system which previously contained only the acrorones[11] and agarospirol[12] must now be expanded to include β-vetivone, hinesol[10] (a close relative of agarospirol[12]), bicyclovetivenol,[13] α-isovetivenene, and β-isovetivenene.[3]

Acknowledgments. We thank the Public Health Service for supporting this work through a research grant (AI04965, Division of Allergy and Infectious Diseases) and predoctoral fellowships. We are indebted to Dr. S. K. Freeman (International Flavors and Fragrances, Inc., New York, N. Y.) for generous samples of vetivert acetate and Dr. P. J. Kropp (Procter and Gamble Company, Cincinnati, Ohio) for a supply of the tetrahydronaphthalenone.

(8) This methyl group probably prefers an axial conformation to avoid *gauche* butane interactions with the adjacent spiro methylenes. Such an orientation may be particularly favored with olefin **5** because the double bond alleviates or removes the unfavorable *gauche* interactions normally associated with an axial methylcyclohexane: *Cf.* E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis," Interscience Publishers, Inc., New York, N. Y., 1965, pp 42ff, 109ff.

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(13) G. Chiurdoglu and J. Decot, *ibid.*, **4**, 1 (1958).

(14) (a) Alfred P. Sloan Foundation Fellow; (b) Public Health Service Fellow of the National Institute of General Medical Sciences.

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The Acidities of Weak Acids in Dimethyl Sulfoxide (DMSO) Solutions. III. Comments on the H_- Acidity Scales

Sir:

There has been some apparent disparity between the acidity scale in cyclohexylamine solvent developed by Streitwieser[1] and his co-workers and one which we reported earlier[2] for DMSO, aqueous DMSO, and methanolic DMSO. We present here some recent results which bring the two scales into better over-all agreement but which indicate a significant difficulty in basing the scales satisfactorily on the aqueous reference state.

In our previous communication[2] we reported a ΔpK between fluorene (FH) and 9-phenylxanthene (PXH) of 3.7–3.8. Subsequent work showed that the actual ΔpK was too great to relate the indicators directly, and an intermediate indicator, 1,1,3-triphenylpropene (TPH), has now been used. The result is that the pK of indicators less acidic than fluorene must be increased by about 1.6 units. This gives a pK span of 9.7 units between FH and our least acidic indicator, diphenylmethane (DH), as compared to Streitwieser's span of 10.4. This is surprisingly good agreement considering the vast difference in the acidities involved and the difference in solvent systems.

A second point of inconsistency is the assignment of absolute pK values. We based our scale on 4-nitroaniline (NAH), the pK of which was reported to be 18.4 by Stewart and O'Donnell,[3] a valued based on the aqueous reference state. Streitwieser's scale is based on 9-phenylfluorene (PFH), the pK of which is reported to be 18.5 by Langford and Burwell[4] and 18.6 by Bowden and Stewart.[5] We have related FH to NAH, FH to PFH, and PFH to NAH, and find that PFH is significantly more acidic than previously reported. Ritchie has also found this to be the case.[6] With these results our ΔpK between PFH and DH is 13.6 while Streitwieser's is 14.6—still excellent agreement. Furthermore, if both scales are based on the same reference compound the absolute pK values are within 1 pK unit throughout.

Absolute pK values have been avoided intentionally in the above discussion. The reason is that large deviations have been found between the hydrocarbon indicators, PFH and FH, and the nitroanilines in aqueous DMSO, and this causes uncertainties in basing the acidity scale on the aqueous reference state. This is shown graphically in Figure 1 where the H_- of 10 mM KOH solutions in aqueous DMSO is plotted against $-\log [H_2O]$ using the different indicators. Values calculated from the data of Stewart, O'Donnell, and Dolman[7] are also included. They used Me_4N^+ as the cation. The pK values of the nitroanilines are assumed to be those reported by Stewart and O'Donnell.[3]

(1) (a) A. Streitwieser, Jr., J. H. Hammons, E. Ciuffarin, and J. I. Brauman, *J. Am. Chem. Soc.*, **89**, 59 (1967); (b) A. Streitwieser, Jr., E. Ciuffarin, and J. H. Hammons, *ibid.*, **89**, 63 (1967).

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(3) R. Stewart and J. P. O'Donnell, *ibid.*, **84**, 493 (1962).

(4) C. H. Langford and R. L. Burwell, *ibid.*, **82**, 1503 (1960).

(5) K. Bowden and R. Stewart, *Tetrahedron*, **21**, 261 (1965).

(6) C. D. Ritchie and R. E. Uschold, *J. Am. Chem. Soc.*, **89**, 2752 (1967).

(7) (a) R. Stewart and J. P. O'Donnell, *Can. J. Chem.*, **42**, 1694 (1964); (b) R. Stewart and D. Dolman as presented in a review by K. Bowden, *Chem. Rev.*, **66**, 119 (1966).