Lead Salt of 7-Carboxy-1-indanacetic Acid.—A solution of 110 g. (0.5 mole) of the dibasic acid XV in 270 ml. of ethanol was adjusted to *p*H 7.5 with 1 *N* aqueous sodium hydroxide and to it a warm solution of 277 g. (0.84 mole) of lead nitrate in two liters of water was added over the course of four hours with rapid stirring. The finely divided, precipitated lead salt was removed by filtration, washed with water (3 × 200 ml.) and ethanol (2 × 500 ml.), and dried to constant weight at 100° and 20 mm. pressure. The yield was quantitative.

Anal. Calcd. for $C_{12}H_{10}O_4Pb$: C, 33.9; H, 2.4; Pb, 48.6. Found: C, 34.0; H, 2.5; Pb, 48.4.

2,2a,3,4-Tetrahydro-1-keto-1H-cyclopent[cd]indene (XVI).—Pyrolysis of not more than 0.25″ thick layers of the lead salt of 7-carboxy-1-indanacetic acid at 350–380° (20 mm.) gave yields of 40 to 50% of ketone as a crystalline sublimate. This was resublimed at 60° (20 mm.) to give diamond-shaped crystals, m.p. 63°.

Anal. Calcd. for $C_{11}H_{10}O$: C, 83.5; H, 6.6; mol. wt., 158. Found: C, 83.6; H, 6.6; mol. wt. (Rast), 148.

The 2,4-dinitrophenylhydrazone of XVI was prepared in the usual manner and was recrystallized from ethanol; m.p. 255–257° dec.

Anal. Calcd. for $C_{17}H_{14}O_4N_4$: C, 60.4; H, 4.2; N, 16.6. Found: C, 61.0; H, 4.6; N, 16.5.

2,2a,3,4-Tetrahydro-1H-cyclopent[cd]indene (I).—Application of the modified Wolff–Kishner procedure of Anderson and Wade[13] to 3.96 g. (0.025 mole) of 2,2a,3,4-tetrahydro-1-keto-1H-cyclopent[cd]indene, resulted in an 80% yield, 2.9 g., of the hydrocarbon, b.p. 91° (10 mm.), $n^{20}D$ 1.5629.

Anal. Calcd. for $C_{11}H_{12}$: C, 91.6; H, 8.4. Found: C, 91.7; H, 8.5.

2a,3,4,5-Tetrahydroacenaphthene was prepared in a similar manner from 2a,3,4,5-tetrahydro-5-acenaphthenone in 84% yield and it boiled at 114–115° (10 mm.), $n^{20}D$ 1.5607 (reported[20] b.p. 115–116° (10 mm.), $n^{25}D$ 1.5582).

Oxidation Experiments.—Following the directions of Anderson and Greef,[6] potassium permanganate oxidations were performed on 2,2a,3,4-tetrahydro-1-keto-1H-cyclopent[cd]indene (XVI), 2,2a,3,4-tetrahydro-1H-cyclopent[cd]indene (I) and 2a,3,4,5-tetrahydroacenaphthene. In each case, after esterification, trimethyl hemimellitate of m.p. 100–101° was obtained (reported[21] m.p. 100–101). From the ketone, a 15% yield was obtained; however, the two hydrocarbons gave yields of 1 and 4%, respectively.

Hydrogenation of 2,2a,3,4-Tetrahydro-1H-cyclopent[cd]indene (I).—A solution of 2 g. (14 mmoles) of I in 20 ml. of absolute ethanol was hydrogenated at room temperature and atmospheric pressure using 0.4 g. of 5% palladized carbon as catalyst. After two hours and the consumption of 300 mole % of hydrogen, hydrogen absorption ceased and the mixture was filtered. Evaporation of the filtrate gave an 85% yield of **perhydrocyclopent[cd]indene** which sublimed easily on the steam-bath at atmospheric pressure, m.p. 50°.

Anal. Calcd. for $C_{11}H_{18}$: C, 88.0; H, 12.0. Found: C, 87.8; H, 12.0.

Application of the same conditions, even in the presence of perchloric acid, resulted in no hydrogenation of 2a,3,4,5-tetrahydroacenaphthene.

4-Nitroso-5-acenaphthenol (XI).—5-Acenaphthenol[12] (5 g., 0.03 mole) was dissolved in a warm solution of 1.2 g. (0.03 mole) of sodium hydroxide in 30 ml. of water. To the cooled (6–7°) solution, 2.2 g. (0.031 mole) of sodium nitrite was added and then 12 ml. of 6 *N* sulfuric acid was added over a 15-minute period with stirring. After being stirred for another 15 minutes, the mixture was filtered and the washed and dried precipitate was digested with ten 25-ml. portions of boiling cyclohexane. Concentration to 35 ml. and cooling gave material of m.p. 172–174° dec.

Anal. Calcd. for $C_{12}H_9O_2N$: C, 72.4; H, 4.6; N, 7.0. Found: C, 72.2; H, 4.4; N, 6.7.

Hydrogenation of 5-Acenaphthenol (X).—5-Acenaphthenol[12] (6.8 g., 0.04 mole) was dissolved in 75 ml. of absolute ethanol, 3 g. of Raney nickel[22] was added, and the mixture was hydrogenated at 25° and a pressure of 40 p.s.i. until 110 mole % of hydrogen was absorbed. The mixture was then filtered, the ethanol was flash-distilled from the filtrate, and the residue was dissolved in 300 ml. of ether. Thorough extraction with 0.5 *N* aqueous sodium hydroxide solution removed phenolic material (50% recovery) after which the ether was evaporated and the residue was distilled to yield 2a,3,4,5-tetrahydroacenaphthene (see above) (15%) and 2a,3,4,5-tetrahydro-5-acenaphthenol, b.p. 158–160° (18 mm.)[1] (35%).

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[20] J. v. Braun and G. Kirschbaum, *Ber.*, **55**, 1680 (1922).

[21] L. Schmid and F. Tadros, *Monatsh.*, **63**, 210 (1933).

[22] R. Mozingo, *Org. Syntheses*, **21**, 15 (1941).

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The Isolation of Piperitone Oxide from *Mentha sylvestris*

BY ROBERT H. REITSEMA AND VERNERS J. VARNIS

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From a species of mint, *Mentha sylvestris*, there has been obtained a ketone corresponding to the formula $C_{10}H_{16}O_2$. Through conversion to diosphenol and progressive degradation studies, the structure of this material has been shown to be *l*-piperitone oxide.

Essential oils from the mint species generally contain predominantly monocyclic terpenes. The oxygenated constituents appear to have oxygen in either the 2-position (the spearmints) or the 3-position (the peppermints) of the *p*-menthane ring. One of the few mint oils which appeared to be distinct from this generalization was the oil from *Mentha sylvestris*. Chromatography indicated that a ketone was present in rather high concentration which was different from the common mint constituents.[1] Since *M. sylvestris* was of interest in a hybridizing program, the structure of this new ketone was investigated.

Analysis of the ketone and the semicarbazone indicated the empirical formula to be $C_{10}H_{16}O_2$. Steam distillation of the ketone or the semicarbazone from an acid media gave diosphenol (I). This and the general infrared spectrum[2] indicated the presence of a *p*-menthane carbon skeleton. The second oxygen was probably not present as a hydroxyl or ester group on the basis of the infrared spectrum and the failure to obtain hydroxyl group derivatives. A possibility was an ether group which would be cyclic since all ten carbons are used in the menthane structure. The formation of diosphenol showed the location of oxygen functions at carbons 2 and 3. The isolation of diosphenol and not a ma-

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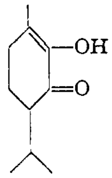
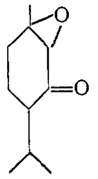
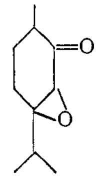
[1] R. H. Reitsema, *J. Am. Pharm. Assoc.* (*Sci. Ed.*), **43**, 414 (1954).

[2] A. T. O'Connor and L. A. Goldblatt, *Anal. Chem.*, **26**, 1726 (1954).

terial with a new isolated double bond or an aromatic ring suggested a 1,2-epoxy ketone structure such as in piperitone oxide (II) or carvenone oxide (III).

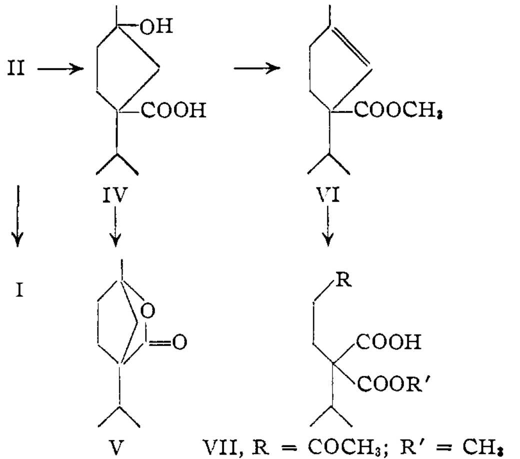

I


II


III

Either of these would be expected to cleave in the observed manner and the actual formation of diosphenol from II with acid has been reported.[3,4] Autoxidation can give the epoxides from the well known corresponding unsaturated ketones,[5] so that their occcurrence in mint oils would not be unexpected. Comparison of the physical constants indicated piperitone oxide to be the more likely structure.

The naturally occurring material was shown to be piperitone oxide by comparison with a readily available, though stereoisomeric, piperitone oxide. Physical properties of piperitone oxide prepared from *l*-piperitone compared well with the naturally occurring material with the exception of optical activity. For direct comparison, the oxides from the two sources were carried through the degradation scheme described by Treibs.[6] The hydroxy acid IV melted at 112–113° as reported, whereas the corresponding material from *M. sylvestris* melted at 86–87°. Since the latter was not stable to boiling solvents, was the lower melting and gave the lactone V more readily, it seemed likely that it was the *cis* isomer predominantly.



VII, R = $COCH_3$; R′ = CH_3
VIII, R = COOH; R′ = H

The two hydroxy acids gave the piperitolenic acids (VI) which still differed in optical activity. However, the boiling points, the refractive indices and the specific gravities were in good agreement and the infrared spectra were identical. The partially racemic character of the material derived from *l*-piperitone was evident still by comparison of rotations. Finally, the two tricarboxylic acids (VIII) obtained were identical in all respects and the melting point of the mixture was not depressed.

This is apparently not the first time that piperidone oxide has been isolated from an essential oil. The ketone, designated X_1, which has been isolated from *Lippia turbinata* oil,[7] corresponds in properties to the material from the present work. It is also possible that the lactone reported in peppermint only by Power and Kleber[8] was a derivative of piperitone oxide, since the conditions for its isolation are the same as for the production of IV and V from II.

The original interest in this ketone was to evaluate its place in a biosynthetic scheme. Although the compound has oxygens on both the 2- and 3-carbons, it does not appear likely from its structure that it is the anticipated intermediate[9] in the formation of the constituents of the mint oils.

Acknowledgments.—The technical assistance of Mr. Wm. Faas and the permission of the A. M. Todd Company to publish this material are gratefully acknowledged.

Experimental[10]

Mentha sylvestris **Oil.**—The characteristics of this silvery leaf plant have been described previously. It has been known by other names. Two strains were studied in the present work and no differences were found.[11] The greatest care was taken to ensure that only authentic plants were used as the source of the oil for the work.

Freshly cut plants of *M. sylvestris* were steam distilled through carefully cleaned equipment, and the oil of musty odor was quickly separated from the condensate water. It was stored under nitrogen in a refrigerator. The ketone content, measured by cold oximation, was 31–36% calcd. as $C_{10}H_{16}O_2$, although samples with 68% ketone were observed. Average values for the physical constants were n^{20}_D 1.475, d^{25}_{25} 0.96, α_D −85°. Although the diploid form was used for the present work, the oil from diploid and tetraploid plants did not vary appreciably.

M. sylvestris **Ketone.**—The oil was distilled under vacuum through a 600 × 13 mm. Podbielniak Heli-Grid column. Fractions boiling around 91° (3 mm.) gave on cooling to 0–4° a white solid, recrystallized from hexane, m.p. 14.5–15.5°, n^{20}_D 1.4624, d^{25}_{25} 1.008, $[\alpha]^{22}_D$ −177.0° (*c* 0.96, EtOH), α_D −176.92°, λ^{EtOH}_{max} 296 mμ (ϵ about 50). The material showed carbonyl absorption in the infrared near 1700 cm.$^{-1}$. It gave a positive test with Fehling solution, silver nitrate and, after a slight delay, with periodate.

Anal. Calcd. for $C_{10}H_{16}O_2$: C, 71.39; H, 9.56. Found: C, 71.60; H, 9.43.

The semicarbazone was isolated readily in the cold from either a fraction rich in the ketone or from the whole oil directly. A fraction from *M sylvestris*, b.p. 99–100° (5 mm.) (1.99 g.), in 20 ml. of ethanol was stirred with a solution of 2.54 g. of sodium acetate and 3.2 g. of semicarbazide hydrochloride in 40 ml. of water at room temperature for 1 hr. The mixture was cooled and filtered, giving 2.24 g. of white crystals, m.p. 199–200°, $[\alpha]^{25}_D$ 213° (*c* 0.29, 95%

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(3) H. Rupe and M. Refardt, *Helv. Chim. Acta*, **25**, 836 (1942).

(4) W. Treibs, *Ber.*, **66B**, 610 (1933).

(5) W. Treibs, *Ber.*, **64B**, 2178 (1931).

(6) W. Treibs, *Ber.*, **64B**, 2545 (1931).

(7) G. A. Fester, E. A. Martinuzzi and A. I. Riccardi, *Rec. fac. ing. quim.* (*Sante Fe, Argentina*), **20**, 43 (1951).

(8) E. B. Power and C. Kleber, *Pharm. Rund.*, **12**, 157 (1894).

(9) M. J. Murray and R. H. Reitsema, *J. Am. Pharm. Assoc.* (*Sci. Ed.*), **43**, 612 (1954); A. G. Rooth and R. Hegnauer, *Pharm. Weekblad*, **90**, 33 (1955).

(10) Melting points are corrected. Unbracketed α_D indicates observed rotations on the homogeneous material without solvent, taken at room temperature in a 1-dm. tube. Ultraviolet absorption measurements were taken on a Beckman DU spectrophotometer in 95% alcohol. Infrared analyses by Anderson Physical Laboratories, Champaign, Ill. Microanalyses by Micro-Tech Laboratories, Skokie, Ill., and Clark Microanalytical Laboratory, Urbana, Ill.

(11) The taxonomy, formation of polyploids and cultivation are the result of work by M. J. Murray of these laboratories. Specimens have been deposited at the St. Louis Botanical Garden and the Cornell University Herbarium.

EtOH). Recrystallization gave two forms of the semicarbazone. The less soluble form melted at 203–203.5° after numerous recrystallizations from methanol.

Anal. Calcd. for $C_{11}H_{19}O_2N_3$: C, 58.64; H, 8.50. Found: C, 58.89; H, 8.49.

The more soluble form, m.p. 180.5–181.5°, was the usual product from recrystallization from aqueous ethanol, $\lambda_{\max}^{\mathrm{EtOH}}$ 226 mμ (ε 9,200) and 242 mμ (ε 10,100) [reported[7] m.p. about 186–187°, $\lambda_{\max}^{\mathrm{EtOH}}$ 222 mμ (ε 10,150) and 242 mμ (ε 11,300)].

Anal. Calcd. for $C_{11}H_{19}O_2N_3$: C, 58.64; H, 8.50; N, 18.66. Found: C, 58.90; H, 8.73; N, 18.45.

The 2,4-dinitrophenylhydrazone, m.p. 115–117°, was prepared from the ketone fractions and also from the semicarbazone, but could not be brought to constant melting point due to decomposition. No phenylurethan could be obtained and the oxime was an oil which was not obtained crystalline.

Diosphenol from the Semicarbazone.—Steam distillation of the semicarbazone from 5% oxalic acid or 5–10% sulfuric acid gave about 25% of the theoretical amount of crystals. These melted at 83–84° after recrystallization from water and sublimation at atmospheric pressure from a bath at 80°. The material did not depress the melting point of diosphenol prepared from menthone.[12] The phenylurethan, m.p. 109–110.5°, did not depress the melting point of diosphenol phenylurethan. The infrared spectrum showed no variation from that reported for diosphenol.[13] The ultraviolet absorption, $\lambda_{\max}^{\mathrm{EtOH}}$ 272.5 mμ (ε 9,500), compared well with that of diosphenol from menthone at the same degree of purity (reported[14] $\lambda_{\max}^{\mathrm{EtOH}}$ 272.5 mμ (ε 11,000)). Acid treatment of authentic piperitone oxide gave a similar product.

From the still pot liquors through continuous extraction with ether was obtained a solid, m.p. 113–114°, $\lambda_{\max}^{\mathrm{EtOH}}$ 296 mμ (ε 50.5).

Anal. Calcd. for $C_{10}H_{18}O_3$: C, 64.55; H, 9.53. Found: C, 64.32; H, 9.90.

Since the amount of material available was small, the structure of this material has not been determined as yet, although the analysis would be satisfied by 1,2-dihydroxymenthone. The material depressed the melting point of the hydroxy acid IV obtained from authentic piperitone oxide.

Piperitone Oxide Rearrangement.—A fraction of *M. sylvestris* oil, b.p. 99° (8 mm.), $n^{20}\mathrm{D}$ 1.4632 (2.0 g.), in methanol was added to a boiling methanolic potassium hydroxide solution according to the method of Treibs[6] and gave a 42% yield of white needles, m.p. 83–90°. Recrystallization failed to give a product of consistent melting point. A sample recrystallized four times alternately from benzene and methylcyclohexane, m.p. 86–87°, $[\alpha]^{25}\mathrm{D}$ −33.3° (*c* 1.8, EtOH), was not completely pure hydroxy acid. The microanalysis indicated the probable presence of some lactone V, which is more soluble and has a lower melting point. The same material was obtained in 22% yield when whole oil of *M. sylvestris* was used in place of the fraction.

Authentic *d*-piperitone oxide (α_{D} 21.0°) was prepared from *l*-piperitone (α_{D} −46°) from *Eucalyptus dives* oil.[4] The hydroxy acid IV corresponding to the above, obtained in 47.5% yield, was recrystallized from benzene to give a product, m.p. 112–113° (113–114° reported[15]), $[\alpha]_{\mathrm{D}}$ 0 ± 0.1°, which was stable to boiling solvents.

Methyl Ester of Piperitolenic Acid (VI).—Fifteen grams of the once-crystallized acid IV from the alkaline rearrangement of *M. sylvestris* ketone was dissolved in a solution of 60 ml. of methanol and 6.0 ml. of concentrated sulfuric acid. The observed rotation of the mixture was −7.5° initially, −6.25° after 15 hours at room temperature and 7.5° after boiling under reflux for 15 hours. Distillation of the crude product (13.4 g.) at atmospheric pressure gave a center cut of 7.49 g., b.p. 210–212°, which was redistilled giving predominantly a fraction boiling at 100–101° (22 mm.), $n^{20}\mathrm{D}$ 1.4579, $\alpha^{23}\mathrm{D}$ 49.12°, $d^{20}{}_{20}$ 0.9662.

The acid prepared from *d*-piperitone oxide gave a fraction, b.p. 208–209°, $n^{20}\mathrm{D}$ 1.4567, which on redistillation gave a product boiling at 100–101° (22 mm.), $n^{20}\mathrm{D}$ 1.4567, $\alpha^{24}\mathrm{D}$ −1.5°, $d^{25}{}_{25}$ 0.965. These products from *M. sylvestris* ketone and *d*-piperitone gave identical infrared spectra.

α-Carboxy-α-isopropylglutaric Acid (VIII).—Methyl piperitolenate (5.0 g.) prepared from *M. sylvestris* ketone was stirred with 2 ml. of water and oxidized with a slurry of 8.0 g. of potassium permanganate moistened with 2 ml. of water as described.[6] There were obtained 1.13 g. of alkali-insoluble product and 3.05 g. of the desired keto acid ester VII. The latter gave a positive iodoform test.

The above crude VII was saponified as before[6] with 5 ml. of boiling 40% aqueous potassium hydroxide for one minute and oxidized with bromine in aqueous sodium hydroxide to give 1.92 g. of very viscous oil. A portion of this oil was placed on a porous plate and after standing overnight, a white solid was present which could be recrystallized from ether–petroleum ether to give white crystals, m.p. 162–163° (with foaming).

The same sequence of reactions was successful in producing a comparable yield of crystals, m.p. 162–164° (with foaming) (160–162° reported[6]), from VI derived from piperitone oxide. These two tricarboxylic acids, from *M. sylvestris* ketone and from authentic piperitone oxide melted without depression at 162–163°.

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[12] A. K. Macbeth and W. G. P. Robertson, *J. Chem. Soc.*, 3512 (1953).

[13] R. J. W. LeFevre, F. Maramba and R. L. Werner, *ibid.*, 2496 (1953).

[14] J. Walker and J. Read, *ibid.*, 238 (1934).

[15] W. Treibs, *Ber.*, **63B**, 2423 (1930).