mately 24-hr intervals) of 25-ml aliquots, which were worked up and examined by glpc as described below for the total reaction mixture. After 122 hr, the mixture was cooled and acidified with 100 ml of 6 *N* hydrochloric acid, then shaken in a separatory funnel. The layers were separated, and the xylene layer was extracted with four 100-ml portions of 6 *N* acid. The aqueous layers were combined, warmed, then treated with charcoal, filtered, and concentrated under reduced pressure to about 75 ml. This solution was cooled, treated with excess concentrated sodium hydroxide solution, and extracted with six 50-ml portions of chloroform, which were combined, dried over calcium sulfate, filtered, and concentrated under reduced pressure. The residual oil was distilled at 0.3 mm to give 0.3 g of a forerun (bp 55–83°), plus 5.0 g of 2-hydroxypyrrolizidine (bp 83–87°), obtained as a 60–40% A–B mixture. The forerun was found to be an anomalous $C_{10}H_{19}N$ reaction product that consisted, apparently, of a mixture of two isomers to which we are unable to give unequivocal structure assignments. The alcohol product mixture was twice fractionated through an 8-in. spinning-band column (Nester-Faust) to give 0.6-g and 1.1-g fractions of epimer A as the first two final cuts, 95 and 90% epimerically pure, respectively. These fractions solidified to waxy solids on standing in the refrigerator, and both melted at 36–40°. Epimer A (fraction two) formed a picrate in ether, mp 170–171°, unchanged on recrystallization from acetone–ether.

Anal. Calcd for $C_{13}H_{16}N_4O_8$: C, 43.82; H, 4.53; O, 35.92. Found: C, 43.7; H, 4.7; O, 35.5.

Acknowledgment.—We thank Messrs. G. E. Dudley, R. L. Young, Jr., and C. A. Andreasen for some experimental assistance; C. P. Ferguson (infrared), H. Klapper (nuclear magnetic resonance), and L. W. Daasch (mass spectrometry) for some instrumental data; C. E. Rush and staff for elemental analyses; C. Feit, Regis Chemical Company, for some experimental data (as indicated); and Professor R. K. Hill, Princeton University, for samples of (±)-isosedridine and a (±)-sedridine–isosedridine mixture.

Monocyclic Terpene Alcohols. II.[1] *p*-Menthan-7-ols, *p*-Menthan-9-ols, and *p*-Menth-3-en-9-ol

JUAN ALBAIGÉS, JOSÉ CASTELLS, AND JOSÉ PASCUAL

Departamento de Química Orgánica, Patronato de Investigación Científica y Técnica "Juan de la Cierva" (C.S.I.C.), Universidad de Barcelona, Barcelona, Spain

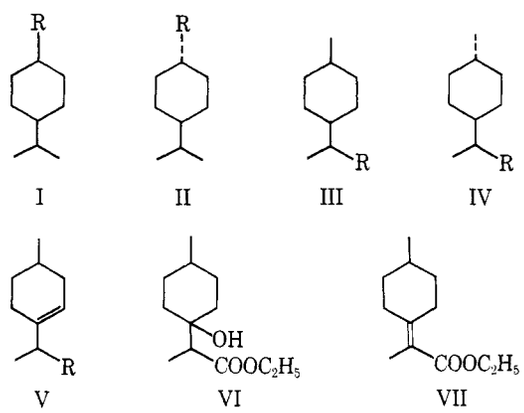
Received May 18, 1966

The preparation of several 7- and 9-derivatives of *cis*- and *trans*-*p*-menthane, and *p*-menth-3-ene, is described. Comments are made on the nmr spectra of stereoisomeric pairs.

The present paper gives an account of the work done with the final aim of preparing pure specimens of *cis*- (I, R = CH_2OH) and *trans*-*p*-menthan-7-ol (II, R = CH_2OH) and *cis*- (III, R = CH_2OH) and *trans*-*p*-menthan-9-ol (IV, R = CH_2OH), which were needed in connection with an extensive project on terpene alcohols in progress in this laboratory.[2]

***cis*- and *trans*-*p*-Menthan-7-ol.**—The *p*-menthan-7-ols have been obtained in a state of purity by Verkade, *et al.*,[3] by means of a reaction sequence the key step of which was reduction of cuminic acid and resolution of the resulting stereoisomeric *p*-menthan-7-oic acids by treatment with thiourea. In the present work a modified procedure was used involving catalytic hydrogenation of methyl cuminate followed by preparative vpc of the stereoisomeric mixture of saturated esters. In this way, pure (vpc) samples of the previously undescribed methyl *cis*- (I, R = COOMe) and methyl *trans*-*p*-menthan-7-oate (II, R = COOMe) were obtained, steric assignments being based on the identity of the melting points of the *p*-tosylates and 3,5-dinitrobenzoates of the related alcohols (*vide infra*) with those given in the literature.

Lithium aluminium hydride reduction of the esters afforded the corresponding alcohols, *cis*- (I, R = CH_2OH) and *trans*-*p*-menthan-7-ol (II, R = CH_2OH), which were purified *via* the 3,5-dinitrobenzoates.[4,5]



It is of interest that reduction of the *cis* ester was more difficult than that of the *trans* isomer, and, even after 24 hr of treatment with excess hydride, the resulting alcohol was contaminated by some starting material. As it is known that an axial carbomethoxy group reacts more slowly than an equatorial one,[6] a possible explanation rests on the "partial" axial character of the carbomethoxy group in the *cis* ester.

Pure specimens of *cis*- (I, R = Me) and *trans*-*p*-menthane (II, R = Me) were prepared by lithium aluminum hydride reduction of the *p*-tosylates obtained from stereochemically pure samples of alcohols.[3]

***cis*- and *trans*-*p*-Menthan-9-ol.**—A stereoisomeric mixture of menthan-9-ols was prepared by Frank and Berry[7] by high-pressure hydrogenation of ethyl *p*-menth-3-en-9-oate (V, R = COOEt), and Gollnick

(1) Part I, to be presented at the XXXVI^e, Congress International de Chimie Industrielle, Brussels, 1966.

(2) Research Project sponsored by the U. S. Department of Agriculture, Grant FG-Sp-135.

(3) H. van Bekkum, A. A. B. Kleis, D. Medema, P. E. Verkade, and B. M. Wepster, *Rec. Trav. Chim.*, **81**, 833 (1962).

(4) Throughout the paper "purification *via* the 3,5-dinitrobenzoate" means preparation of this derivative on a very pure condition by repeated (if necessary) crystallization and subsequent alkaline alumina saponification.[5]

(5) J. Castells and G. A. Fletcher, *J. Chem. Soc.*, 3245 (1956).

(6) E. L. Eliel, N. L. Allinger, S. I. Angyal, and G. A. Morrison, "Conformational Analysis," Interscience Publishers, Inc., New York, N. Y., 1965, p 72.

(7) R. L. Frank and R. E. Berry, *J. Am. Chem. Soc.*, **72**, 2985 (1950).

and Schade[8] have described the isolation of the *cis* and *trans* isomers from the mixture obtained by catalytic hydrogenation of *p*-menthen-9-ol. However, in light of the present work, the reported refractive indices of the alcohols and the melting point of the *cis*-3,5-dinitrobenzoate seem to cast some doubt on the steric purity of their samples.

Frank and Berry's preparation of ethyl *p*-menth-3-en-9-oate by a Reformatsky reaction between 4-methylcyclohexanone and ethyl α-bromopropionate and subsequent dehydration of the resulting hydroxy ester (VI) has been repeated. The resulting product was submitted to a careful analysis which, confirming previous assumptions,[7,9] failed to show the presence of the conjugated ester (VII). Thus, even in this case, dehydration takes place exclusively with formation of the thermodynamically more stable *endo* double bond.[10]

Mild catalytic hydrogenation of ethyl *p*-menth-3-en-9-oate leads to *cis–trans* mixtures of ethyl *p*-menthan-9-oate, with isomer ratios very dependent on the catalyst and medium employed. In agreement with current knowledge,[11] extreme results are obtained by using platinum in alcohol, which gives a *cis*:*trans* ratio of about 2:1, and palladized charcoal in alcohol containing traces of perchloric acid, which gives a *cis*:*trans* ratio of about 1:2.5 (configurational assignments based on subsequent work). Accordingly, Pt and Pd hydrogenation mixtures were used, respectively, to isolate (preparative vpc) pure ethyl *cis*-*p*-menthan-9-oate (III, COOEt) and pure ethyl *trans*-*p*-menthan-9-oate (IV, R = COOEt), from which the (liquid) acids and *p*-toluides were prepared.

cis-*p*-Menthan-9-ol (III, R = CH_2OH) and *trans*-*p*-menthan-9-ol (IV, R = CH_2OH) were obtained by lithium aluminium hydride reduction of the related esters or, alternatively, by reduction of *cis*:*trans* mixtures of ethyl *p*-menthan-9-oate followed by preparative vpc; final purification was always effected *via* the 3,5-dinitrobenzoates. The alcohols were reduced, through their *p*-tosylates, to the parent *p*-menthanes, this being the basis for stereochemical assignments in this series.

***p*-Menth-3-ene Derivatives.**—Lithium aluminum hydride reduction of ethyl *p*-menth-3-en-9-oate afforded the new terpene alcohol, *p*-menth-3-en-9-ol (V, R = CH_2OH) which structure is fully defined by its origin and its spectral properties, particularly the nmr spectrum. This alcohol, as the parent ester, has two asymmetric centers and, consequently, two (racemic) stereoisomers are possible.[12] Their presence in *p*-menth-3-en-9-ol and ethyl *p*-menth-3-en-9-oate has been explored but no conclusive results have been obtained. Both ester and alcohol behave as single isomers when submitted to tlc vpc, and spectral analysis whereas solid derivatives as the anilide (prepared from the ester) and the 3,5-dinitrobenzoate (from the alcohol) show rather broad melting points, pointing to the presence of two stereoisomers. In the case of the latter derivative, it was even possible to isolate two types of crystals with different melting points (85–8.5° and 68–72°), but the infrared and nmr spectra of both samples showed no observable differences (dimorphism ?).

Nmr Spectral Comments.—During the present work, the nmr spectra of the *cis* and *trans* isomers of the following compounds have been obtained: *p*-menthane, *p*-menthan-7-ol, *p*-menthan-9-ol, methyl *p*-menthan-7-oate, *p*-menthan-9-oic acid, and ethyl *p*-menthan-9-oate.

Comparative consideration of the ring-proton absorption patterns (τ 8–9 region) of any pair of isomers, provides practically unequivocal evidence for configurational diagnosis, *cis* isomers showing a more acute envelope than *trans* isomers. The rationale of this rests on the greater flexibility of the ring in *cis* isomers (rapid flipping between two energetically almost equivalent conformations) which lead to magnetic equivalence of ring protons.[14] Furthermore, it has been observed that, as a rule, the 1-methyl group shows a clearer splitting in *cis* than in *trans* isomers, in agreement with the "partial" axial character of this substituent in the former.[15]

In the 9-substituted series the C_8 center is asymmetric and because of this the C_9 methylene absorption can be complex.[16] Particularly in *trans*-*p*-menthan-9-ol, this methylene gives rise to a multiplet which can be easily interpreted as an AB system (from the nonequivalence of the two methylene protons) with each peak split in doublet (by coupling with the C_8 proton).

Finally, it may be worth mentioning that bands due to hydroxyl protons have been routinely identified by their diamagnetic shift with increasing dilution.

Experimental Section

Melting points were determined on a Kofler microscope and are corrected. Infrared spectra have been routinely registered for purity control, structural diagnosis, and identification purposes, but no data are given in the text. Nmr spectra were determined on a Perkin-Elmer Model R10 spectrometer (60 Mc/sec) using solutions *ca.* 5 to 10% in carbon tetrachloride, unless otherwise stated; peak positions are given in the τ scale. Preparative vpc separations were performed on an Aerograph Model Autoprep A-700 apparatus. Vpc analyses were carried out on a Barber–Colman 61-C apparatus with β-ionization detection and fitted with a silicone 550 Golay column.

Starting Materials.—Cuminic acid was prepared from commercial (Fluka) cuminaldehyde by hydrogen peroxide oxidation[17] or by a Cannizzaro reaction; cumilic alcohol, obtained as a by-product in this latter preparation, was converted to acid by dichromate oxidation. Methyl cuminate was prepared from the acid by a conventional procedure employing absolute methanol, methylene chloride, and concentrated sulfuric acid as catalyst.

Methyl *cis*- and *trans*-Menthan-7-oate.—A mixture of methyl cuminate (17.5 g), acetic acid (100 ml), and platinum oxide (300 mg) was hydrogenated at atmospheric pressure and room temperature, until no more hydrogen was being taken up (about 5 days). The crude hydrogenated product (16.8 g) was distilled [bp 47° (0.2 mm)] to give an approximately 2:1 *cis*:*trans* mixture (vpc) of saturated ester which was resolved by preparative vpc [6-m XF-1150 (30%) cyanosilicone column at 180°;

(8) K. Gollnick and G. Schade, *Tetrahedron*, **22**, 123 (1966).
(9) O. Wallach, *Ann.*, **365**, 255 (1909).
(10) *Cf.*, for example, A. C. Cope, D. Ambros, E. Ciganek, C. F. Howell, and Z. Jacura, *J. Am. Chem. Soc.*, **82**, 1750 (1960).
(11) *Cf.*, for example, R. L. Agustine, "Catalytic Hydrogenation," Marcel Dekker, Inc., New York, N. Y., 1965, p 59.
(12) From the literature, there seems to have been overlooked that a similar situation obtains in *p*-menth-1-en-9-ol (*cf.* ref 13). *p*-Menth-1-en-9-ol is presently being studied in this laboratory from this point of view.
(13) H. C. Brown and G. Zweifel, *J. Am. Chem. Soc.*, **83**, 1241 (1961).
(14) E. L. Eliel, *et al.*, ref 6, p 152.
(15) Y. R. Naves, *Helv. Chim. Acta*, **47**, 1617 (1964).
(16) J. A. Elvidge and R. G. Foster, *J. Chem. Soc.*, 981 (1964).
(17) R. G. Cooke and A. K. Macbeth, *ibid.*, 1245 (1939).

the *cis* isomer had the shorter retention time]. Both isomers were finally purified by distillation.

Methyl *cis*-*p*-menthan-7-oate had bp 47° (0.2 mm); $n^{25}D$ 1.4518; nmr 6.32 (OCH_3), 9.09–9.18 [$(CH_3)_2C$], and absorptions with ill-defined structure at 7.45, 8.00, and 8.3–9.0 ppm.

Anal. Calcd for $C_{11}H_{20}O_2$: C, 71.70; H, 10.94. Found: C, 71.90; H, 11.01.

Methyl *trans*-*p*-menthan-7-oate had bp 49–50° (0.35 mm); $n^{25}D$ 1.4492; nmr 6.38 (OCH_3), 9.07–9.17 [$(CH_3)_2C$], and ill-defined absorptions between 7.6 and 9.0 ppm.

Anal. Calcd for $C_{11}H_{20}O_2$: C, 71.70; H, 10.94. Found: C, 71.35; H, 11.13.

***cis*-*p*-Menthan-7-ol and *trans*-*p*-Menthan-7-ol.**—Methyl *cis*-*p*-menthan-7-oate (5.1 g) dissolved in dry ether (30 ml) was added dropwise to a stirred suspension of lithium aluminium hydride (2.0 g) in dry ether (50 ml) and the mixture was refluxed for 24 hr. Conventional working up and distillation [bp 121–122° (178 mm)] afforded crude *cis*-*p*-menthan-7-ol (4.1 g), containing about 4% (vpc) starting material, from which the 3,5-dinitrobenzoate, mp 72.5–73.5° (lit.[17] mp 72°), and the *p*-tosylate, mp 44.5–45.0° (lit.[3] mp 44.5°), were prepared by standard procedures.

The 3,5-dinitrobenzoate (1.5 g) was saponified on alkaline alumina[5] (30 g), using a 2:1 hexane–benzene mixture as solvent and eluent. Removal of solvents gave an oil (0.7 g) which was distilled [bp 122° (18 mm)] to give pure (vpc) *cis*-*p*-menthan-7-ol. The nmr spectrum showed 6.46–6.58 (CH_2O), 6.84 (OH), 9.07–9.14 [$(CH_3)_2C$], and a narrow envelope at 8.1–9 ppm.

The *p*-tosylate was reduced (lithium aluminium hydride)[3] to *cis*-*p*-menthane, bp 170–171° (760 mm). The nmr spectrum showed 9.04–9.14 (1 CH_3), 9.09–9.19 [$(CH_3)_2C$], and a narrow envelope at 8–9 ppm.

Treatment of methyl *trans*-*p*-menthan-7-oate by a procedure identical with that described above for the *cis* isomer, afforded *trans*-*p*-menth-7-ol, free from starting material, from which the 3,5-dinitrobenzoate, mp 94–95° (lit.[17] mp 95°), and the *p*-tosylate, mp 54.0–45.5° (lit.[3] mp 54°), were prepared.

Alkaline alumina saponification of the 3,5-dinitrobenzoate gave pure (vpc) *trans*-*p*-menthan-7-ol, bp 122–123° (18 mm). The nmr spectrum gave 6.61–6.70 (CH_2O), 6.8 (OH), 9.09–9.18 [$(CH_3)_2C$)], and a broad envelope at 8–9 ppm.

The *p*-tosylate was reduced (lithium aluminum hydride)[3] to *trans*-*p*-menthane, bp 170° (760 mm). The nmr spectrum showed 9.1 and 9.2 (methyl groups), and broad absorption at 8–9 ppm.

***p*-Menth-3-ene Derivatives.**—Ethyl *p*-menth-3-en-9-oate[7] was saponified to the (liquid) acid, from which the *p*-bromophenacyl ester, bp 145–150° (0.02 mm), was prepared.

Anal. Calcd for $C_{18}H_{21}BrO_3$: C, 59.21; H, 5.80; Br, 21.85. Found: C, 59.15; H, 5.90; Br, 21.71.

Reaction of ethyl *p*-menth-3-en-9-oate with the Grignard reagent, prepared from ethylmagnesium bromide and aniline, afforded the anilide, the sharpest melting point of which, after repeated crystallization, was 82–85.5° (from ethanol–water).

Anal. Calcd for $C_{16}H_{21}NO$: C, 78.97; H, 8.70; N, 5.76. Found: C, 78.80; H, 9.08; N, 5.67.

Ethyl *p*-menth-3-en-9-oate (15.0 g) dissolved in dry ether (75 ml) was added dropwise to a stirred suspension of lithium aluminum hydride (7.0 g) in dry ether (40 ml), and the mixture was refluxed for 15 hr. Conventional working up and distillation afforded *p*-menth-3-en-9-ol: bp 113–114° (18 mm) [60–61° (0.4 mm)]; $n^{25}D$ 1.4767; ν_{max} (film) 1660 cm^{-1} (w) (C=C); nmr 4.50 (1 H; ethylenic H), 6.54–6.65 (2 H; CH_2O), broad absorption at 7.5–8.8, and peaks at 8.95, 9.0, and 9.07 ppm.

Anal. Calcd for $C_{10}H_{18}O$: C, 77.87; H, 11.76. Found: C, 77.60; H, 11.84.

The 3,5-dinitrobenzoate had mp 64–74°; nmr 0.8–1 (aromatic H), 4.5 (ethylenic H), 5.61–5.72 (CH_2O), multiplet centered at 7.40 (8 H), broad absorption at 7.6–8.6, 8.80–8.91 (8 CH_3), and 9.0–9.1 ppm (incipient doublet) (1 CH_3).

Anal. Calcd for $C_{17}H_{20}N_2O_6$: C, 58.61; H, 5.79; N, 7.04. Found: C, 58.41; H, 5.99; N, 7.06.

Repeated crystallization of the 3,5-dinitrobenzoyl derivative from absolute ethanol, led to the isolation of two types of crystals, mp 85–88.5° and 68–72°, but both had identical infrared (CS_2 solution) and nmr spectra.

Ethyl *cis*- and *trans*-*p*-Menthan-9-oate. A.—A mixture of ethyl *p*-menth-3-en-9-oate (6.5 g), absolute alcohol (50 ml), and platinum oxide (200 mg) was hydrogenated at atmospheric pressure and room temperature during 4 hr (810 ml of hydrogen had been taken up). The crude hydrogenated product (6.4 g) was distilled [bp 122–124° (17 mm)] to give a 2:1 *cis*:*trans* mixture (vpc) of saturated ester.

B.—A mixture of ethyl *p*-menth-3-en-9-oate (12 g), absolute alcohol (100 ml, containing a few drops of perchloric acid), and palladized charcoal (600 mg) was hydrogenated at atmospheric pressure and room temperature, until no more hydrogen was being taken up (about 3 days). After filtering off the catalyst and removing part of the solvent, ether (25 ml) was added and the ethereal solution was washed with aqueous sodium bicarbonate and water, and dried (magnesium sulfate). After elimination of solvent the hydrogenated product (11.8 g) was distilled [bp 122–124° (18 mm)] to give a 1:2.5 *cis*:*trans* mixture of saturated ester.

The stereoisomeric mixtures were resolved by preparative vpc [6-m XF-1150 (30%) cyanosilicone column at 180°; the *trans* isomer had the shorter retention time]. Both isomers were finally purified by distillation.

Ethyl *cis*-*p*-menthan-9-oate had bp 124–125° (18 mm); $n^{25}D$ 1.4475; nmr (in $CDCl_3$) quadruplet centered at 5.85 and triplet centered at 8.75 (ethyl group), 8.82–8.94 (8–CH_3), 9.02–9.13 (1 CH_3), ill-defined weak absorption at 7.3–8.0, and an acute envelope centered at 8.56 ppm.

Anal. Calcd for $C_{12}H_{22}O_2$: C, 72.68; H, 11.18. Found: C, 72.51; H, 11.14.

Alkaline saponification (potassium hydroxide in dioxane–water) of the *cis* ester gave *cis*-*p*-menthan-9-oic acid: bp 108° (1 mm); $n^{25}D$ 1.4643; nmr −0.16 (carboxyl proton), 8.80–8.91 (8 CH_3), 9.02–9.12 (1 CH_3), ill-defined weak absorption at 7.3–8.0, and an acute envelope centered at 8.5 ppm.

Anal. Calcd for $C_{10}H_{18}O_2$: C, 70.55; H, 10.66. Found: C, 70.82; H, 10.60.

Reaction of the *cis* ester with the Grignard reagent, prepared from ethylmagnesium bromide and *p*-toluidine, afforded *cis*-*p*-toluide, mp 152.5–153°.

Anal. Calcd for $C_{17}H_{25}NO$: C, 78.72; H, 9.71; N, 5.40. Found: C, 79.00; H, 9.71; N, 5.69.

The *cis* acid was also obtained by acid hydrolysis (refluxing 70% sulfuric acid, 30 min) of the *cis*-*p*-toluide.

The ethyl *trans*-*p*-menthan-9-oate had bp 120–121° (15 mm); $n^{25}D$ 1.4448; nmr (in $CDCl_3$) quadruplet centered at 5.87 and triplet centered at 8.75 (ethyl group), 8.84–8.96 (8 CH_3), 9.10 and shoulder at 9.15 (1 CH_3), and ill-defined broad absorption at 7.6–8.8 ppm.

Anal. Calcd for $C_{12}H_{22}O_2$: C, 72.68; H, 11.18. Found: C, 72.65; H, 11.40.

Alkaline saponification (potassium hydroxide in dioxane–water) of the *trans* ester gave *trans*-*p*-menthan-9-oic acid: bp 97–98° (0.5 mm); $n^{25}D$ 1.4603; nmr −1.2 (carboxyl proton), 8.81–8.93 (8 CH_3), 9.08 and shoulder at 9.15 (1 CH_3), and ill-defined broad absorption at 7.6–8.8 ppm.

Anal. Calcd for $C_{10}H_{18}O_2$: C, 70.55; H, 10.66. Found: C, 70.43; H, 10.75.

Reaction of *trans* ester with the Grignard reagent, prepared from ethylmagnesium bromide and *p*-toluidine, afforded *trans*-*p*-toluide, mp 194.5–195°.

Anal. Calcd for $C_{17}H_{25}NO$: C, 78.72; H, 9.71; N, 5.40. Found: C, 78.53; H, 9.71; N, 5.70.

The *trans* acid was also obtained by acid hydrolysis (refluxing 70% sulfuric acid, 30 min) of the *trans*-*p*-toluide.

***cis*-*p*-Menthan-9-ol.**—Ethyl *cis*-*p*-menthan-9-oate (4 g) dissolved in dry ether (30 ml) was added dropwise to a stirred suspension of lithium aluminum hydride (2 g) in dry ether (30 ml) and the mixture was refluxed for 24 hr. Conventional working up and distillation [bp 61–62° (0.5 mm)] afforded crude *cis*-*p*-menthan-9-ol. The 3,5-dinitrobenzoate had mp 52–52.5° (lit.[8] mp 45–46°).

Anal. Calcd for $C_{17}H_{22}N_2O_6$: C, 58.28; H, 6.33; N, 8.00. Found: C, 58.40; H, 6.70; N, 8.03.

The *p*-tosylate (purified by preparative tlc in silica gel; benzene–hexane eluent, 1:1) had $n^{25}D$ 1.5124.

Anal. Calcd for $C_{17}H_{26}O_3S$: C, 65.77; H, 8.44; S, 10.33. Found: C, 65.79; H, 8.64; S, 10.14.

The 3,5-dinitrobenzoate (2 g) was saponified in alkaline alumina (40 g), using a 1:1 hexane–benzene mixture as solvent and eluent. Removal of solvents gave an oil (1.0 g) which was distilled [bp 127–128° (22 mm)] to give pure (vpc) *cis*-*p*-menthan-9-ol: $n^{25}D$ 1.4689 (lit.[8] $n^{25}D$ 1.4663); nmr complex absorption centered at 6.47 (CH_2O), 7.92 (hydroxyl H), 9.02 and 9.14 (methyl groups), and a narrow envelope centered at 8.6 ppm.

Anal. Calcd for $C_{10}H_{20}O$: C, 76.86; H, 12.90. Found: C, 76.87; H, 13.26.

The *p*-tosylate was reduced (lithium aluminium hydride)[8] to *cis*-*p*-menthane, identified by comparison with an authentic specimen.

trans-*p*-**Menthan-9-ol.**—Ethyl *trans*-*p*-menthan-9-oate (1.2 g) dissolved in dry ether (10 ml) was added dropwise to a stirred suspension of lithium aluminium hydride (0.6 g) in dry ether (10 ml) and the mixture was refluxed for 20 hr. Conventional working up and distillation [bp 60–61° (0.4 mm)] afforded crude *trans*-*p*-menthan-9-ol. The 3,5-dinitrobenzoate had mp 77–78.5° (lit.[8] mp 78–80°).

Anal. Calcd for $C_{17}H_{22}N_2O_6$: C, 58.28; H, 6.33; N, 8.00. Found: C, 58.30; H, 6.69; N, 7.87.

The *p*-tosylate (purified by preparative tlc in silica gel; benzene–hexane eluent, 1:1) had $n^{25}D$ 1.5104.

Anal. Calcd for $C_{17}H_{26}SO_3$: C, 65.77; H, 8.44; S, 10.33. Found: C, 65.85; H, 8.81; S, 10.29.

The 3,5-dinitrobenzoate (3 g) was saponified in alkaline alumina (50 g) using a 1:1 hexane–benzene mixture as solvent and eluent. Removal of solvents gave an oil (1.5 g) which was distilled [bp 114–115° (13 mm)] to give pure (vpc) *trans*-*p*-menthan-9-ol: $n^{25}D$ 1.4630 (lit.[8] $n^{25}D$ 1.4660); nmr double quadruplet centered at 6.43 (CH_2O), 7.75 (hydroxyl H), 9.05 and 9.15 (methyl groups), and broad envelope at 8–9 ppm.

Anal. Calcd for $C_{10}H_{20}O$: C, 76.86; H, 12.90. Found: C, 76.87; H, 13.26.

The *p*-tosylate was reduced (lithium aluminium hydride)[8] to *trans*-*p*-menthane, identified by comparison with an authentic specimen.

Alternative Procedure for the Preparation of *cis*- and *trans*-*p*-Menthan-9-ol.—Stereoisomeric mixtures of ethyl *p*-menthan-9-oate (from platinum and palladium hydrogenations; see above) were reduced by means of lithium aluminium hydride and the resulting stereoisomeric mixtures of *p*-menthan-9-ols were resolved by preparative vpc [6-m (30%) Carbowax 20 M column at 210°; the *trans* isomer had the shorter retention time]. After distillation, the alcohols had infrared spectra identical with those of the purest specimens.

Monocyclic Terpene Alcohols. III.[1] *p*-Menth-4(8)-en-9-ol and *trans*- and *cis*-*p*-Menth-8(10)-en-9-ol

FRANCISCO CAMPS, JOSÉ CASTELLS, AND JOSÉ PASCUAL

Departamento de Química Orgánica, Patronato de Investigatión Científica y Técnica "Juan de la Cierva" (C.S.I.C.), Universidad de Barcelona, Barcelona, Spain

Received May 1, 1966

Preparation of the title compounds starting from 4-methylcyclohexanone is described. Configurational assignments in the *p*-menth-8 (10)-en-9-ols are based on chemical and spectral (nmr) evidence.

As part of the research program,[2] undertaken in this laboratory, devoted to the synthesis of monocyclic terpene alcohols, the present paper describes the preparation, purification, and full characterization of the previously unknown *p*-menth-4(8)-en-9-ol (VIIa), and that of *trans*- and *cis*-*p*-menth-8(10)-en-9-ol, (XIa and XIIa). Preparation of a mixture of the latter two isomers by sensitized photooxidation of a *trans*/*cis* *p*-menth-8-ene mixture has been reported very recently in a short communication by Klein and Rojahn.[3]

***p*-Menth-4(8)-en-9-ol.**—This alcohol has been synthesized by the series of reactions outlined in Chart I.

The easily available glycidic ester (I)[4] was rearranged to the unsaturated hydroxy ester (II) by the action of diluted aqueous acid. Reduction of unsaturated hydroxy ester II with lithium aluminium hydride, avoiding the presence of acid in the working up, afforded crystalline *p*-menth-3-en-8,9-diol (III), which upon 3,5-dinitrobenzoylation yields a mono derivative, and a bis derivative.

An interesting AB system is exhibited by the nmr spectrum of III, owing to the magnetic nonequivalence between both CH_2O protons which give a quartet centered at τ 6.67, J = 10 cps.[5] Other features of this spectrum confirm the assigned structure.

The diol (III) treated with *p*-toluenesulfonic acid in refluxing benzene, gave a mixture of three main components (as detected by analytical tlc). Nmr, infrared, and ultraviolet spectra of this mixture pointed to the presence of two aldehyde compounds (IV and V, see below) in a 3:1 ratio (nmr). The conjugated aldehyde could be isolated from the mixture as the semicarbazone. The third component, separated by preparative tlc, showed no selective absorption (ultraviolet) and no hydroxyl or carbonyl bands (infrared), and on this basis structure VI is tentatively assigned to it, although no correct analysis could be secured.

The acid rearrangement of diol III can be rationalized by the initial formation of a tertiary carbonium ion (XVI), followed by C-proton removal from the hydroxymethyl group (pathway a of Chart II) to give an enol (XVII), which isomerizes to a mixture of both aldehydes IV and V, in a proportion that reflects their relative stability. Direct hydroxyl attack on the positive center (pathway b) would lead to structure (VI), which is the one proposed for the third component of the mixture.

Lithium aluminum hydride reduction of the aldehyde mixture afforded an oil with strong hydroxyl absorption (infrared), from which a pure 3,5-dinitrobenzoate derivative was obtained. Hydrolysis on alkaline aluminium oxide[6] gave the parent alcohol. The spectral data prove unequivocally that the alcohol is *p*-menth-4(8)-en-9-ol (VIIa), as expected from the assigned structure, (IV), to the main aldehyde component of the starting mixture. This menthenol is rather unstable, being oxidized in the presence of air and giving no reproducible vpc analysis under a variety of conditions.

From the mother liquor of dinitrobenzoate (VIIb), a second 3,5-dinitrobenzoate derivative, was isolated to which structure VIIIb is assigned by comparison with an authentic specimen.[1] This fact establishes that the second aldehyde formed in the acid isomerization of diol III is V.

(1) Part II, see previous paper.
(2) Sponsored by the U. S. Department of Agriculture, Grant FG-Sp-135.
(3) E. Klein and W. Rojahn, *Dragoco Rep.*, **11**, 123 (1964).
(4) G. Darzens, *Compt. Rend.*, **144**, 1123 (1907).
(5) *Cf.* J. A. Elvidge and R. G. Foster, *J. Chem. Soc.*, 981 (1964).
(6) *Cf.* J. Castells and G. A. Fletcher, *ibid.*, 3245 (1956).