After the addition was finished the temperature was raised to 90° and kept at this value for 3 hr.

The mixture was then cooled to −10° and hydrolyzed with ice and H_2SO_4. The organic layer after drying was distilled. Thus were collected 3.86 g of X: bp 89.5°, n^{25}_D 1.3900, $[\alpha]^{25}_D$ −9.23° (pure liquid) (lit.[14] bp 89.7°, n^{25}_D 1.38945, $[\alpha]^{25}_{D\max}$ −11.4,[6] pure liquid).

Registry No.—II, 7492-94-6; I, 7492-89-9; V, 7540-78-5; VI, 7492-90-2; IX, 7485-44-1; X, 7485-45-2; VIII, 7485-46-3.

---

[14] F. D. Rossini, "Selected Values of Physical and Thermodynamic Properties of Hydrocarbons and Related Compounds," API Research Project 44, New York, N. Y., Oct 31, 1952, Table 8a.

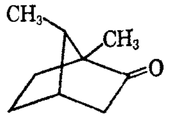
The Acid-Catalyzed Rearrangement of *cis*-2,3-Dimethyl-*endo*-2-norborneol[1]

LOWELL D. HATFIELD AND WILLIAM D. HUNTSMAN[2]

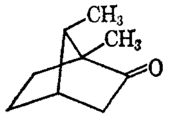
Department of Chemistry, Ohio University, Athens, Ohio 45701

Received September 16, 1966

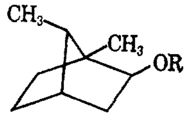
In the course of another study the need arose for samples of α- and β-santenone (**1** and **2**) and the formation of α-santenyl acetate (**3b**), reported to occur when *cis*-2,3-dimethyl-*endo*-2-norborneol (**5**) is treated with sulfuric acid in acetic acid, appeared to offer a convenient entry to the α series.[3,4] In our hands, however, this reaction furnished substantial amounts of the β isomer (**4b**), as well as the α isomer. The esters were separated by preparative vpc, and identified as described below. Actually, the formation of both isomers is not surprising since it has been shown that the rearrangement of *exo*-isosantene (**6**), *endo*-isosantene (**7**), and santene (**8**) with sulfuric acid in acetic acid gives a mixture of α- and β-santenyl acetate.



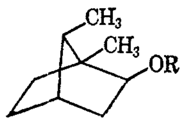
1



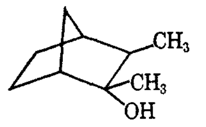
2



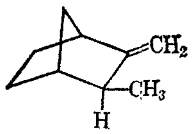
3a, R = H
b, R = Ac



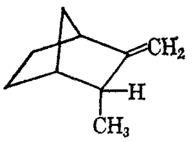
4a, R = H
b, R = Ac



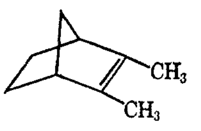
5



6



7



8

Steric interference between the *syn*-C-7 methyl group and the acetoxyl group would be expected to decrease the stability of the β isomer. This is borne out by the results presented in Table I, where it is seen that the proportion of the β acetate decreases with increasing duration of acid treatment.

TABLE I

COMPOSITION OF MIXTURE OF α- AND β-SANTENYL ACETATES FROM REARRANGEMENT OF 5[a]

	Compn of mixture,[b] %	
Time, hr	α-Santenyl acetate	β-Santenyl acetate
0.5	51	43
2	54	39
3	59	35
12	74	21
3[c]	76	19

[a] Reactions were carried out by mixing 0.25 g of **5**, 1 ml of glacial acetic acid, and 1 drop of concentrated sulfuric acid, and heating for the specified period of time at 55–60° unless noted otherwise. The mixtures were poured over ice and extracted with ether, and the extracts were washed thoroughly and dried. Analyses were performed by vpc on a 3.8-m column containing LAC-446 on Chromosorb, and operated at 150°. [b] In addition to the santenyl acetates, approximately 5% of an unidentified compound and 1% of 1-methyl-*exo*-2-norbornyl acetate were also present. Formation of the last-named compound indicates that the starting alcohol (**5**) may have contained a small amount of *exo*-2-methyl-*endo*-2-norborneol as an impurity. [c] Reaction temperature was 100°.

The isomeric santenols were obtained by saponification of the acetates, and the melting point of the α isomer and its 3-nitrophthalate ester agreed well with literature values. Correspondingly good agreement was observed for the melting point of the 3-nitrophthalate ester of β-santenol, but the melting point of the free alcohol (108–108.5°) is substantially higher than the literature value 97–98°.[5] The β-santenol used in the earlier studies was separated from the α isomer by fractional crystallization of the 3-nitrophthalate esters, and it is possible that the separation was incomplete. Analysis by vpc of the β-santenol obtained in the present study showed less than 1% of the α isomer to be present.

The nmr spectra of the acetate esters and the free alcohols substantiate the structural assignments. In the β isomers the methyl group at C-7 is more deshielded than it is in the α isomers. The proton at C-2 shows fine splitting owing to long-range coupling ($J \sim 1$ cps) with the *anti*-C-7 proton in the β isomers.[6,7]

Oxidation of the alcohols with chromium(VI) oxide in acetic acid gave the corresponding ketones. The melting points of both ketones as well as their semicarbazones agreed well with literature values. Both ketones exhibit a carbonyl stretching mode at 5.70 μ. It has been observed that the carbonyl group in camphor shields the *syn*-C-7 methyl group to a greater extent than the *anti*-C-7 methyl group.[8] The same effect is observed with the santenones; the C-7 methyl doublet is centered at τ 9.07 in α-santenone and at 9.15 in β-santenone.

---

[1] Taken from the Ph.D. Dissertation of L. D. Hatfield, Aug. 1966.

[2] To whom inquiries should be addressed.

[3] O. Diels and K. Alder, *Ann.*, **486**, 202 (1931).

[4] N. J. Toivonen and E. Wuolejoki, *Suomen Kemistilehti*, **33B**, 119 (1960); *Chem. Abstr.*, **55**, 1471 (1961).

[5] S. Beckmann and A. Durkop, *Ann.*, **594**, 205 (1955).

[6] S. I. Musher, *Mol. Phys.*, **6**, 93 (1963); F. A. L. Anet, *Can. J. Chem.*, **39**, 789 (1961).

[7] A. F. Thomas and B. Willhalm, *Tetrahedron Letters*, 1309 (1965); F. G. Bordwell and M. L. Douglass, *J. Am. Chem. Soc.*, **88**, 993 (1966).

[8] J. O. Connolly and R. McCrindle, *Chem. Ind.* (London), 379 (1965).

Experimental Section[9]

cis-2,3-Dimethyl-*endo*-2-norborneol.[3,4,10]—From 26.0 g of *exo*-3-methylnorcamphor[11] and a solution of methylmagnesium iodide prepared from 7.3 g of magnesium and 44.0 g of methyl iodide, there was obtained 27.5 g (97% yield) of *cis*-2,3-dimethyl-*endo*-2-norborneol, mp 59–61°. A sample purified by sublimation melted at 63–64° (lit.[3,4,10] mp 63–65°, 62.5–64.5°); infrared λ_{max} (CCl_4) 2.78, 2.92, 6.78, 6.83, 6.93, 7.26, 7.30, 7.67, 8.55, 8.90, 9.30, 9.68, 9.95, 10.12, 10.36, 10.68, 10.92, and 11.22 μ; nmr spectrum ($CDCl_3$) singlets at τ 7.61 (1 H) and 8.83 (3 H), a doublet with peaks at 9.06 and 9.17 (3 H, J = 6.5 cps), and a multiplet in the 7.8–8.9 region (8 H).

Rearrangement of *cis*-2,3-Dimethyl-*endo*-2-norborneol.—*cis*-2,3-Dimethyl-*endo*-2-norborneol (27.0 g, 0.193 mole) was dissolved in 75 ml of glacial acetic acid, 1.0 ml of concentrated sulfuric acid was added, and the solution was heated on a water bath at 55–60° for 1.5 hr. The yellow solution was poured over 300 g of crushed ice, 100 ml of ether was added, and the organic layer was separated. The aqueous layer was extracted with two 100-ml portions of ether and the combined extracts were washed in succession with 10% sodium hydroxide and water, and finally dried over sodium sulfate. Removal of the ether on a rotary evaporator left 30 g of a pale yellow oil which showed two major vpc peaks on a Carbowax-4000 column (170°, 50 ml of He/min). In addition, traces of low-boiling matrials and a small amount of 1-methyl-*exo*-norbornyl acetate were also present. Distillation of the acetate mixture through a spinning-band column gave 26.2 g of a colorless oil: bp 71.5–73.2° (5 mm), n^{25}_D 1.4568.

The mixture of acetates (20 g) was separated by preparative vpc on a 3-m Carbowax-4000 column operated at 175° with a helium flow of 120 ml/min.

β-Santenyl Acetate.—From the preparative vpc separation there was obtained 7.81 g of β-santenyl acetate: n^{25}_D 1.4558; infrared λ_{max} (neat) 3.41, 3.50, 5.77, 6.88, 7.24, 7.29, 7.34, 7.67, 8.10, 8.52, 9.02, 9.42, 9.53, 9.70, 9.90, 10.24, and 10.60 μ; nmr ($CDCl_3$) distorted triplet with additional fine splitting (J ~ 1 cps) centered at τ 5.32 (1 H), singlets at 7.98 (3 H) and 8.98, and a doublet (J = 6.8 cps) with peaks at 8.97 (sh) and 9.08. The area of the doublet and singlet in the τ 8.9–9.1 region corresponded to six protons. In addition, a multiplet was present in the τ 8.0–8.9 region (7.8 H). Analytical vpc of this material showed less than 1% of the α isomer.

Anal. Calcd for $C_{11}H_{18}O_2$: C, 72.49; H, 9.95. Found: C, 72.15; H, 9.82.

α-Santenyl Acetate.—From the preparative vpc separation there was obtained 5.41 g of α-santenyl acetate: n^{25}_D 1.4575; infrared λ_{max} (neat) 3.40, 3.50, 5.76 (sh), 5.79, 6.80, 6.92, 7.28, 7.30, 7.38, 8.10, 8.52, 8.80, 9.08, 9.58, 9.78, 9.90, and 10.25 μ; nmr signals ($CDCl_3$), quartet at τ 5.29 ($J_{2,exo\text{-}3}$ = 2.9 cps, $J_{2,endo\text{-}3}$ = 7.2 cps), singlets at 7.98 (3 H), and 9.05 (3 H), doublet with peaks at 9.13 and 9.25 (J = 7.0 cps), and multiplet at 8.0–8.9 (8 H). Analysis by vpc showed 1% of the β isomer.

Anal. Calcd for $C_{11}H_{18}O_2$: C, 72.49; H, 9.95. Found: C, 72.70; H, 9.72.

β-Santenol.—A solution of 7.60 g (0.042 mole) of β-santenyl acetate and 3.3 g (0.059 mole) of potassium hydroxide in 30 ml of ethanol was refluxed 2 hr. Most of the solvent was removed on a rotary evaporator, 50 ml of water was added to the residue, and the mixture was steam distilled. The distillate was extracted with ether, the ether solution was dried over sodium sulfate, and the ether was removed on a rotary evaporator. The residue (4.78 g) was a colorless, camphorlike solid, mp 108–108.5°. The melting point of the solid obtained by sublimation at 60–65° (15 mm) was unchanged (lit.[5] mp 97–98°). The 3-nitrophthalate acid ester had mp 197–198° (lit.[5] mp 195–196°). The infrared spectrum (in CCl_4) showed peaks at 2.78, 2.94, 3.40, 3.50, 6.83, 6.89, 7.24, 7.29, 7.50, 7.72, 8.42, 8.53, 9.03, 9.38, 9.72, 10.10, 10.40, 10.68, 11.02, 11.70, and 11.92 μ; the nmr spectrum ($CDCl_3$) consisted of a distorted triplet with further fine splitting (J ~ 1 cps) centered at τ 6.51 (1 H), a doublet (J = 6.5 cps) with peaks at 8.95 (sh) and 9.06. The area of the singlet at 8.93 together with the doublet corresponds to six protons. Other peaks include a singlet at τ 7.51 (1 H) and a multiplet in the 8.0–9.0 region (8 H).

Anal. Calcd for $C_9H_{16}O$: C, 77.14; H, 11.46. Found: C, 76.94; H, 11.40.

α-Santenol.—A solution containing 5.15 g (0.028 mole) of α-santenyl acetate, 2.30 g (0.041 mole) of potassium hydroxide, and 25 ml of ethanol was refluxed for 2 hr, and the solvent was removed on a rotary evaporator. The residue was steam distilled, the distillate was extracted with ether, and the ether solution was dried over sodium sulfate. Removal of the ether on a rotary evaporator gave 3.41 g of α-santenol, mp 84–85° (lit.[5] mp 86°); 3-nitrophthalate acid ester, mp 175–176° (lit.[5] mp 174–175°). A sample of the alcohol purified by sublimation at 65–70° (15 mm) melted at 84–85°; infrared λ_{max} (CCl_4) 2.78, 2.95, 6.80, 6.92, 7.25, 7.28, 7.50, 7.68, 8.08, 9.08, 9.25, 9.38, 9.48, 9.80, 9.98, 10.18, 10.37, 10.98, and 11.90 μ; nmr signals ($CDCl_3$), quartet centered at τ 6.49 ($J_{2,endo\text{-}3}$ = 7.2 cps, $J_{2,exo\text{-}3}$ = 3.0 cps) (1 H), singlets at 7.47 (1 H) and 9.02 (3 H), a three-proton doublet with peaks at 9.16 and 9.27 (J = 6.6 cps), and a multiplet (8 H) in the 8.0–9.0 region.

Anal. Calcd for $C_9H_{16}O$: C, 77.14; H, 11.46. Found: C, 76.97; H, 11.32.

β-Santenone.—A solution of 2.2 g (0.022 mole) of chromium(VI) oxide in 5 ml of glacial acetic acid and 3 ml of water was added dropwise to a cooled and stirred solution of 3.8 g (0.027 mole) of β-santenol in 12 ml of glacial acetic acid. The mixture was allowed to stand for 90 min at room temperature and then was poured into 50 ml of water, and extracted with three 75-ml portions of ether. The combined extracts were washed thoroughly with 10% sodium bicarbonate, and saturated salt solution. The solution was dried over sodium carbonate and the solvent was removed by distillation leaving 2.85 g of crude β-santenone, shown by vpc to contain 5% β-santenol and *ca.* 1% α-santenone. A sample of β-santenone obtained by preparative vpc on a 3-m Carbowax-4000 column at 175° melted at 45–46° (lit.[5] mp 48–49°); infrared λ_{max} (CCl_4) 3.37, 3.42, 5.70, 6.76, 6.80, 7.05, 7.20, 7.25, 7.48, 7.72, 7.87, 7.94, 8.55, 8.75, 9.14, 9.37, 9.52, 9.77, 9.92, 10.65, 10.80, and 11.18 μ; nmr spectrum ($CDCl_3$), a singlet at τ 8.98 (3 H), a doublet (J = 7.0 cps) with peaks at 9.09 and 9.20 (3 H), and a multiplet in the 7.5–8.8 region (8.2 H). The semicarbazone, recrystallized from methanol, melted at 240–241° (lit.[5] mp 237–238°).

Anal. Calcd for $C_{10}H_{17}N_3O$: C, 61.51; H, 8.78; N, 21.52. Found: C, 61.52; H, 8.46; N, 21.65.

α-Santenone.—A solution of 1.7 g (0.017 mole) of chromium(VI) oxide in 4 ml of glacial acetic acid and 2 ml of water was added dropwise during 25 min to a cooled and stirred solution containing 2.80 g (0.02 mole) of α-santenol in 10 ml of glacial acetic acid. The mixture was stirred at room temperature for 90 min, poured into cold water, and extracted with three 50-ml portions of ether. The combined extracts were washed thoroughly with 10% sodium bicarbonate and water, and finally dried over anhydrous sodium carbonate. The ether was removed by distillation leaving 2.02 g of crude α-santenone, shown by vpc on a LAC-446 column at 150° to contain a substantial amount of unchanged α-santenol. Treatment with an additional 0.31 g of chromium(VI) oxide in 1 ml of glacial acetic acid and 1 ml of water for 4 hr and processing as described above gave 1.45 g of material which contained only about 4% α-santenol. This material was purified by vpc on a 3-m Carbowax-4000 column at 175°, and the α-santenone obtained melted at 51–52° (lit.[5] mp 55°); infrared λ_{max} (CCl_4) 3.38, 3.48, 5.70, 6.76, 6.83, 7.08, 7.24, 7.54, 7.67, 7.73, 8.40, 8.54, 9.14, 9.25, 9.41, 9.57, 9.78, 10.62, 10.83, and 11.73 μ; nmr spectrum ($CDCl_3$), a singlet at τ 8.96 (3 H), a doublet (J = 6.5 cps) with peaks at 9.01 and 9.12 (3 H), and a multiplet (8 H) in the 7.5–8.8 region. The semicarbazone, recrystallized from methanol–ethyl acetate, melted at 133–134° (lit.[5] mp 135°).

Anal. Calcd for $C_{10}H_{17}N_3O$: C, 61.51; H, 8.78; N, 21.52. Found: C, 61.56; H, 8.33; N, 21.56.

Registry No.—**5**, 7492-78-6; **4b**, 7492-79-7; **3b**, 7492-80-0; **4a**, 509-12-6; **3a**, 509-11-5; **2**, 7492-82-2; **1**, 7492-83-3.

---

(9) Melting points and boiling points are uncorrected. Microanalyses were by Galbraith Laboratories, Knoxville, Tenn., and by Mrs. J. DeBoer of this laboratory. Infrared spectra were recorded with a Perkin-Elmer 21 spectrophotometer, and nmr spectra were determined with a Varian A-60 spectrometer, using tetramethylsilane as internal standard. Analytical vpc determinations were performed with an F & M 720 chromatograph, and preparative scale separations were carried out with an Aerograph A-700 instrument.

(10) E. E. van Tamelen and R. J. Thiede, *J. Am. Chem. Soc.*, **74**, 2615 (1952).

(11) E. J. Corey, R. Hartman, and P. A. Vatakencherry, *ibid.*, **74**, 2615 (1952).