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INTERACTION OF TERMINAL EPOXIDES OF α-GERANYL AND α-FARNESYL ACETATES WITH FLUOROSULFONIC ACID

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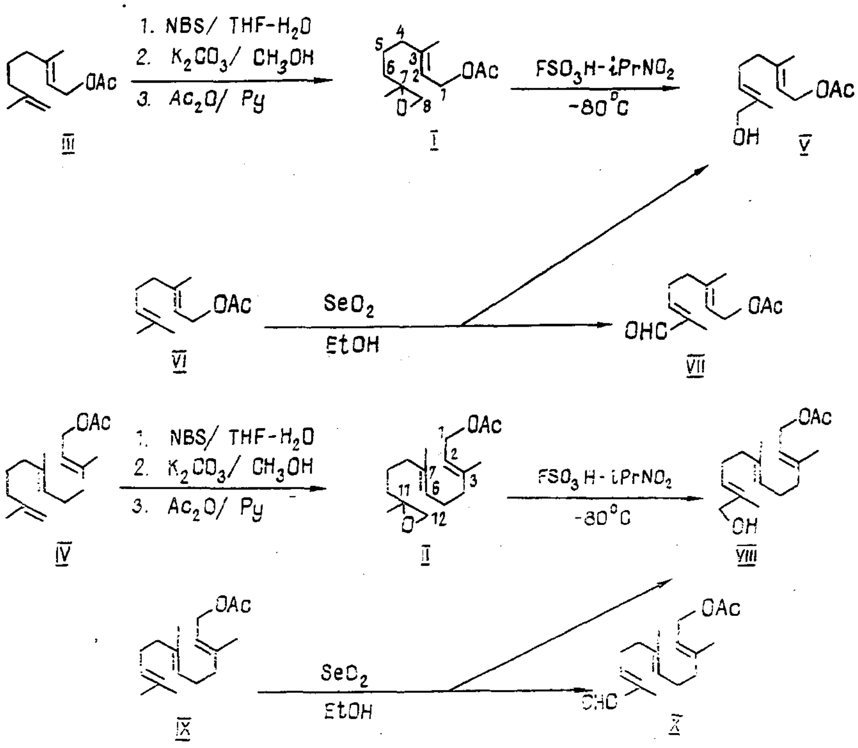
The interaction of 7,8-epoxygeranyl acetate and of 11,12-epoxy-E,E-farnesyl acetate with fluorosulfonic acid forms products of the opening of the epoxide ring.

We have previously [1] shown that on the interaction of terminal epoxides of β-terpenyl acetates with a superacid at low temperatures products of the opening and isomerization of the oxide ring are formed. In the present communication we give the results obtained in the reaction of the acetates of 7,8-epoxygeraniol (I) and of 11,12-epoxy-E,E-farnesol (II) with fluorosulfonic acid.

The epoxyacetates (I) and (II) were synthesized by the method of [2] from α-geranyl acetate (III) and E,E-farnesyl acetate (IV), respectively [3]. On the interaction of 7,8-epoxygeranyl acetate (I) with FSO_3H in 2-nitropropane (molar ratio of substrate to FSO_3H = 1:1, −78 to −80°C, 30 min) the only reaction product was trans-8-hydroxygeranyl acetate (V) (yield 55%). At the same time, 25-30% of unchanged initial epoxide (I) remained, and 15-20% of a polymeric product was formed. Performing the reaction at the higher molar ratio of (I):FSO_3H = 1:5 (−78 to −80°C) led to the complete resinification of the substrate even with a relatively short reaction time (5 min). When the amount of cyclizing agent was reduced to 0.5 mole per 1 mole of substrate (−80 to −85°C, 1 h), the epoxygeranyl acetate (I) did not react.

The structure of the hydroxyacetate (V) was shown by spectral methods, and also by comparing it with a sample obtained from geranyl acetate (VI) on its oxidation with selenium dioxide [4]. In the latter case, a small amount of the acetoxyaldehyde (VII) was also formed, its structure following from its spectral characteristics and the results of elementary analysis



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11,12-Epoxy-E,E-farnesyl acetate (II) reacted with fluorosulfonic acid (molar ratio of (II) to FSO_3H = 1:10, 30 min) at the same temperature (−78 to −80°C) with the formation of a single product — E,E,E-farnesene-1,12-diol 1-monoacetate (VIII) (yield 50%). At the same time, 38% of the initial epoxide (II) was recovered. The structure of hydroxyacetate (VIII) was confirmed by its spectral characteristics and by its formation on the oxidation of E,E-farnesyl acetate (IX) with selenium dioxide. In this case, as well, in addition to compound (IX), a small amount (15%) of the acetoxyaldehyde (X), identified on the basis of the results of spectral and elementary analyses, was isolated from the reaction product.

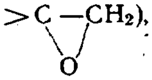
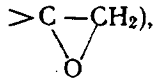
It must be mentioned that compound (II) entered into reaction with the superacid with some difficulty, and even at a ratio of substrate to cyclizing agent of 1:1 no reaction took place.

As is known [4], selenium dioxide oxidizes only a methyl group in the trans- position relative to an aliphatic chain and, therefore, the terminal double bonds in the hydroxyacetates (V) and (VIII) had the trans- configuration, which was also confirmed by their PMR spectra.

Consequently, on the interaction of the epoxyacetates (I) and (II) with a superacid, the main direction of the reaction is the opening of the epoxide ring, which takes place stereospecifically with the formation of the allyl hydroxyacetates (V) and (VIII). No formation of carbocyclization products was detected.

EXPERIMENTAL

For the general experimental part, see [1].

Synthesis of 7,8-Epoxy-α-geranyl Acetate (I). With stirring, 9.56 g of N-bromosuccinimide was added to a solution of 9.35 g of α-geranyl acetate (III) in 290 ml of tetrahydrofuran and 90 ml of H_2O cooled to 0°C. The mixture was stirred at the same temperature for 1 h and was then left to assume room temperature. The bulk (170 ml) of the solvent was distilled off in vacuum, and the residue was extracted with ether. The ethereal extract was washed with water, with saturated $NaHCO_3$ solution, and with water again, and it was then dried and the solvent was distilled off. The residue (13.6 g) was dissolved in 140 ml of methanol, and 11.5 g of K_2CO_3 was added. The resulting mixture was stirred at room temperature for 15 h, the solid matter was filtered off, and the solvent was distilled off in vacuum. The residue (8.9 g) was dissolved in 60 ml of pyridine, 6 ml of acetic anhydride was added, and the resulting mixture was kept at room temperature for 15 h. The solvent was distilled off in vacuum, and the residue was diluted with water (60 ml) and was extracted three times with ether. The ethereal extract was washed successively with 10% H_2SO_4 solution, water, saturated $NaHCO_3$ solution, and water again, and was dried, and the solvent was distilled off. The residue (9.3 g) was chromatographed on a column containing 120 g of SiO_2. Petroleun ether−ethyl acetate (97:3) eluted from the column 4.7 g of 7,8-epoxy-α-geranyl acetate (I), a colorless viscous liquid. IR spectrum (cm^{-1}): 1215, 1720 ($OCOCH_3$), 940, 1010 ( $>\underset{\diagdown O \diagup}{C - CH_2}$), 1657 (>C=C<H). PMR spectrum (ppm): 1.27 (s, 3H, CH_3 at C-7), 1.72 (s, 3H, CH_3 at C-3), 1.95 (s, 3H, $OCOCH_3$), 4.53 (d, J = 7 Hz, 2H, CH_2-O-), 4.81 (br.s, 2H,  $>\underset{\diagdown O \diagup}{C - CH_2}$), 5.36 (t, J = 7 Hz, 1H, 2-H). Calculated %: C 67.63; H 9.37. $C_{12}H_{20}O_3$. Found %: C 67.89; H 9.50.

Then a mixture of the same solvents in a ratio of 4:1 eluted from the column 3.3 g of a mixture of more polar substances, which was not investigated.

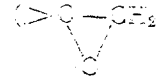
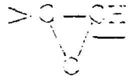
Interaction of 7,8-Epoxy-α-geranyl Acetate (I) with Fluorosulfonic Acid. With stirring, a solution of 200 mg of 7,8-epoxy-α-geranyl acetate (I) in 1 ml of 2-nitropropane cooled to −78 to −80°C was added to a solution of 95 mg of FSO_3H in 3 ml of 2-nitropropane cooled to the same temperature. The mixture was stirred at this temperature for 30 min, and then 2 ml of a 1:1 solution of Et_3N in petroleum ether was added. The resulting solution was treated with 5 ml of H_2O and was extracted with ether. The ethereal extract was worked up in the usual way, giving 187 mg of a reaction product which was chromatographed on a column containing 6 g of SiO_2. Petroleum ether−ethyl acetate (97:3) eluted 65.5 mg of unchanged initial 7,8-epoxy-α-geranyl acetate (I), and a 9:1 mixture of the same solvents eluted 102.8 mg (76.4% yield, taking the recovered initial epoxide (I) into account) of gerane-1,8-diol (V), a colorless viscous liquid. IR spectrum (cm^{-1}): 1225, 1733 ($OCOCH_3$), 1020, 3472, 3605 (OH group), 1645, 1667 (>C=C<H). PMR spectrum ($CDCl_3$, ppm): 1.70 (s, 3H) and 1.76 (s, 3H) (CH_3 at C-3 and C-7), 2.05 (s, 3H, $OCOCH_3$), 3.98 (br.s, 2-H, CH_2-OH), 4.58 (d, J = 7 Hz, 2H, CH_2-OAc), 5.36 (t, J = 7 Hz, 2H, 2-H and 6-H). Calculated %: C 67.68; H 9.42. $C_{12}H_{20}O_3$. Found %: C 67.89; H 9.50.

Oxidation of Geranyl Acetate (VI) with Selenium Dioxide. A solution of 780 mg of geranyl acetate (VI) in 2 ml of ethanol was treated with 180 mg of selenium dioxide, and the mixture was boiled under reflux for 1 h; it was then diluted with water (5 ml) and extracted with ether (3 × 5 ml). The ethereal extract was washed with saturated $(NH_4)_2S$ solution and with water and was dried, and the solvent was distilled off in vacuum. The residue (774 mg) was chromatographed on a column containing 17 g of SiO_2. Petroleum ether–ethyl acetate (19:1) eluted 361 mg of the unchanged initial geranyl acetate (VI).

A 9:1 mixture of the same solvents eluted 51 mg (12.4%, taking the recovered geranyl acetate (VI) into account) of the acetoxyaldehyde (VII), a viscous yellowish liquid. IR spectrum (cm^{-1}): 1220, 1730 ($OCOCH_3$), 1675, 2705 (CHO), 1648 (>C=C<H). PMR spectrum ($CDCl_3$, ppm): 1.74 (s, 6H, CH_3 at C-3 and C-7), 2.05 (s, 3H, $OCOCH_3$), 4.59 (d, J = 7 Hz, 2H, CH_2-O-), 5.39 (t, J = 7 Hz, 1H, 2-H), 6.45 (t, J = 7 Hz, 1H, 6-H), 9.39 (s, 1H, CHO). Calculated %: C 68.63; H 8.49. $C_{12}H_{18}O_3$. Found %: C 68.54; H 8.63.

A 4:1 mixture of the same solvents eluted 346 mg (yield 82.6%, taking the recovered geranyl acetate (VI) into account) of the hydroxyacetate (V), identical in its chromatographic and spectral characteristics with the sample obtained from epoxide (I).

Synthesis of 11,12-Epoxy-α-E,E-farnesyl Acetate (II). With stirring, 650 mg of N-bromosuccinimide was added to a solution of 718 mg of α-E,E-farnesyl acetate (IV) in 9 ml of tetrahydrofuran and 2 ml of H_2O cooled to 0°C. The mixture was stirred at the same temperature for 2 h and then it was warmed to room temperature over 1 h and was worked up as described above. The reaction product (856 mg) was dissolved in 15 ml of methanol, 1.0 g of K_2SO_4 was added, the mixture was stirred at room temperature for 3 h, the solid matter was filtered off, and the solvent was distilled off in vacuum.

The residue (0.63 g) was dissolved in 4 ml of pyridine, 4 ml of acetic acid was added, and the mixture was left at room temperature for 16 h. It was worked up in the usual way, to give 0.69 g of reaction product, which was chromatographed on a column containing 15 g of SiO_2. Petroleum ether–ethyl acetate (9:1) eluted 121 mg of the initial α-E,E-farnesyl acetate (IV). Then a 93:7 mixture of the same solvents eluted 106 mg of 11,12-epoxy-α-farnesyl acetate (II), a colorless viscous liquid. IR spectrum (cm^{-1}): 1225, 1734 ($OCOCH_3$), 950, 1018, 1112 ( $>\underset{O}{C-CH_2}$), 1668 – (>C=C<H). PMR spectrum ($CDCl_3$, ppm): 1.28 (s, 3H, CH_3 at C-11), 1.65 (s, 3H) and 1.68 (s, 3H)(CH_3 at C-3 and C-7), 2.01 (s, 3H, $OCOCH_3$), 4.51 (d, J = 7 Hz, CH_2-OAc), 4.70 (br.s, 2H,  $>\underset{O}{C-\underline{CH_2}}$), 5.36 (m, 2H, 2-H, 6-H). Calculated %: C 72.63; H 10.14. $C_{17}H_{28}O_3$. Found %: C 72.82; H 10.06.

After this, a 3:1 mixture of the same solvents eluted 320 mg of a more polar substance, which we did not investigate.

The Interaction of 11,12-Epoxy-α-E,E-farnesyl Acetate (II) with Fluorosulfonic Acid. With stirring, a solution of 100 mg of 11,12-epoxy-α-E,E-farnesyl acetate (II) in 1 ml of 2-nitropropane cooled to −78 to −80°C was added to a solution of 360 mg of FSO_3H in 2 ml of 2-nitropropane cooled to the same temperature. The solution was stirred at this temperature for 30 min, and was then worked up as described above. The reaction product (97 mg) was chromatographed on a column containing 2.5 g of SiO_2. Petroleum ether–ethyl acetate (97:3) eluted 38 mg of the unchanged initial epoxyacetate (II), and a 9:1 mixture of the same solvents eluted 49.4 mg (yield 79.7%, allowing for the epoxide (II) recovered) of E,E,E-farnesene-1,12-diol 1-monoacetate (III), a colorless viscous liquid. IR spectrum (cm^{-1}): 1226, 1730 ($OCOCH_3$), 1018, 3500, 3600 (OH group), 1665 (>C=C<H). PMR spectrum (ppm): 1.58 (s, 3H), 1.61 (s, 3H), and 1.70 (s, 3H) (CH_3 at C-3 and C-11), 1.97 (s, 3H, $OCOCH_3$), 3.40 (br.s, 1H, OH), 3.88 (br.s, 2H, $\underline{CH_2}-OH$), 4.46 (d, J = 7 Hz, 2H, $\underline{CH_2}-OAc$), 5, C-7, 17 (m, 3H, 2-H, 6-H and 10-H). Calculated %: C 72.73; H 10.18. $C_{17}H_{28}O_3$. Found %: C 72.82; H 10.06.

Oxidation of E,E-Farnesyl Acetate (IX) with Selenium Dioxide. A solution of 590 mg of E,E-farnesyl acetate (IX) in 8 ml of ethanol was treated with 180 mg of selenium dioxide, and the mixture was boiled under reflux for 3 h and was then worked up as described above, giving 540 mg of a reaction product, which was chromatogrphed on a column containing 11 g of SiO_2. Petroleum ether–ethyl acetate (19:1) eluted 320 mg of the unchanged initial geranyl acetate (IX).

Then a 9: 1 mixture of the same solvents elüted 35 mg (15%, allowing for the farnesyl acetate (IX) recovered) of the acetoxyaldehyde (X), a viscous yellowish liquid. IR spectrum (cm^{-1}): 1226, 1732 ($OCOCH_3$), 1687, 2704 (CHO), 1645 (>C=C<H). PMR spectrum (ppm): 1.61 (s, 3H), 1.66 (s, 6H) (CH_3 at C-3, C-7, and C-11), 1.93 (s, 3H, $OCOCH_3$), 4.45 (d, J = 7 Hz, 2H, CH_2-O-), 5.07 (m, 2H, 2-H, and 6-H), 6.26 (m, 1H, 10-H), 9.20 (s, 1H, CHO). Calculated %: C 73.23; H 9.49. $C_{17}H_{26}O_3$. Found %: C 73.35; H 9.41.

A 4:1 mixture of the same solvents eluted 87 mg (37%, taking the farnesyl acetate (IX) recovered into account) of the hydroxyacetate (VIII), identical in its chromatographic and spectral characteristics with the sample obtained from epoxide (II).

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