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Terpenoids. X.[1] Natural Autoxidation of Thujopsene

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Synopsis. The natural autoxidation of thujopsene **1** afforded three dimeric peroxides (**14**, **15**, and **16**) as the major products. 9α,10-Epoxy-8α-thujopsanol **17** was separated as a minor product besides other known compounds, allylic alcohols **2** and **3**, mayurone **7**, thujopsane-8α,9α-diol **11**, and thujopsan-9-ones **19** and **20**.

Kawamura[2] described in his first report the instability of thujopsene **1** towards exposure to air or sunlight; i.e., **1** suffers autoxidation very easily. The photosensitized[3,4] and catalytic[5] autoxidations were examined extensively; however, the oxidation occuring naturally with atmospheric oxygen has not been studied so far, in which the reaction can proceed under extremely mild conditions. In this paper, we will show the products from the natural autoxidation of **1**, as analyzed by chromatographic separation.

Results and Discussion

Three crystalline bis(Δ^9-thujopsen-8-yl) peroxides were separated by repeated alumina chromatography in the order of elution: **14** mp 100—102 °C, **15** mp 62—68 °C, and **16** mp 136—138 °C. Upon the reduction by LiAlH$_4$, the peroxide **14** gave only Δ^9-thujopsen-8β-ol[1] **2**, whearas the peroxide **16** gave Δ^9-thujopsen-8α-ol[1] **3**. The peroxide **15** gave a 1 : 1 mixture of **2** and **3**. The gas chromatography of peroxides showed a broad peak accompanied with the peaks of thujopsadiene[1] **6** and mayurone[1] **7** as decomposition products.

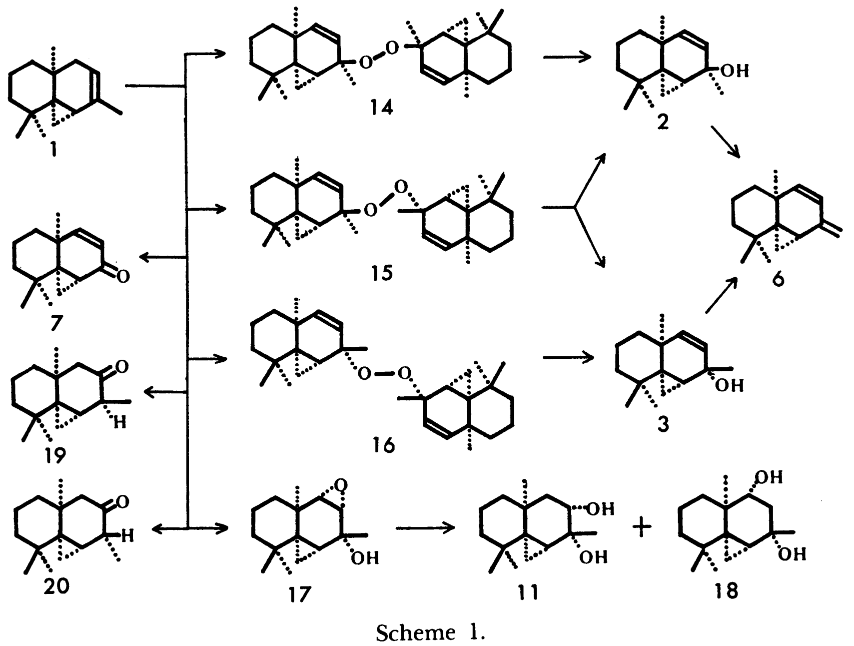
A crystalline compound **17** mp 106—107 °C was isolated as a minor product. The IR spectrum of **17** showed the presence of an OH group. The ^{1}H NMR spectrum showed two protons on an epoxy ring, one of which showed a long-range coupling constant of 1.8 Hz. The reductive cleavage of the epoxy ring in **17** with LiAlH$_4$ resulted in the formation of thujopsane-8α,9α-diol[1] **11** as a minor product. Thus, 9α,10-epoxy-8α-thujopsanol was assigned to **17**. The major reduction product was 8α,10α-diol **18**.

As the known compounds, **2**, **3**, thujopsan-9-ones[6] **19** and **20**, **7** and **11** were also separated from the natural autoxidation products.

Experimental

A thujopsene fraction (23.8 g) obtained by spinning band column distillation of Hiba wood neutral oil was allowed to stand for 6 years. The viscous oil afforded by repeated chromatography on alumina following fractions: hydrocarbons 24%, peroxides (**14**—**16**) 25%, a 1 : 1 mixture of thujopsan-9-ones (**19** and **20**) 6%, allylic alcohols **2** and **3**, 2%, mayurone **7**, 6%, epoxy alcohol **17**, 5% and 8α,9α-diol **11**, 0.6%. The structures of the known compounds, **2**, **3**, **7**, **11**, **19**, and **20**, were confirmed by the comparison of their ^{1}H NMR and IR spectra with those reported earlier.[1,6] **17**: Mp 106—107 °C. IR (KBr) 3500 (OH), 3050, 2970, 2930, 1459, 1378, 1306, 1177, 1159, 1129, 1074, 1040, 1022, 1004, 922, 919, 910, 864, 830, and 809 cm^{-1}. ^{1}H NMR (CDCl$_3$) δ=0.18 (1H, dd, J=8.8, 4.0 Hz), 0.54 (3H, s), 1.00 (3H, s), 1.34 (3H, s), 1.41 (3H, s), 0.93—1.81 (8H, m), 2.05 (1H, broad), 2.74 (1H, d, J=4.0 Hz), and 3.02 (1H, dd, J=4.0, 1.8 Hz).

Separation of 14, 15, and 16: A later part of the peroxide fraction obtained above crystallized. Recrystallization from hexane gave peroxide **16** (1.05 g) mp 136—138 °C. Found: C, 81.73; H, 10.51%. Calcd for$C_{30}H_{46}O_2$: C, 81.63; H, 10.87%. IR (KBr) 3080, 2950, 1389, 1371, 1360, 1159, 1103, 1082, 770, 756,



Scheme 1.

and 740 cm^{-1}. ^{1}H NMR ($CDCl_3$) δ=0.33—0.72 (4H, m), 0.65 (6H, s), 1.06 (6H, s), 1.15 (6H, s), 1.44 (6H, s), 1.0—1.7 (14H, m), 5.02 (2H, d, J=10.4 Hz), and 5.42 (2H, dd, J=10.4, 1.8 Hz).

The intermediate fraction between hydrocarbons and **16** was re-chromatographed. The fast-running fraction crystallized and afforded peroxide **14** (0.15 g) mp 100—102 °C (from hexane). IR (KBr) 3055, 3010, 1466, 1381, 1371, 1160, 1100, 1091, 1080, 901, 882, 764, and 741 cm^{-1}. ^{1}H NMR ($CDCl_3$) δ=−0.03 (2H, dd, J=5.6, 4.6 Hz), 0.39 (2H, dd, J=9.6, 4.6 Hz), 0.63 (6H, s), 1.04 (6H, s), 1.13 (6H, s), 1.28 (6H, s), 1.1—1.7 (14H, m), and 4.93—5.38 (4H, m).

Repeated chromatography of the middle fractions of **14** and **16** finally gave crystalline peroxide **15** (0.11 g) mp 62—68 °C. IR (neat) 3060, 2920, 1386, 1371, 1360, 1158, 1171, 1132, 1083, 1032, 952, 903, 881, 770, 751, and 740 cm^{-1}. ^{1}H NMR ($CDCl_3$) δ=0.00 (1H, dd, J=5.4, 4.6 Hz), 0.29—0.70 (3H, m), 0.64 (6H, s), 1.05 (6H, s), 1.14 (6H, s), 1.31 (3H, s), 1.44 (3H, s), 1.0—1.7 (14H, m), 5.08 (1H, d, J=10.4 Hz), 5.16 (2H, s), and 5.52 (1H, dd, J=10.4, 1.8 Hz).

Reduction of Peroxides 14—16: Peroxide **14** (120 mg) dissolved in 2 ml of dioxane was refluxed for 10 hrs with excess $LiAlH_4$. The usual work-up gave an oil (85.7 mg), identical to **2**, obtained by $KMnO_4$ oxidation of thujopsene.[1] Peroxide **16** (157 mg) was reduced as above, and gave 128 mg of **3**. The similar reduction product of peroxide **15** was a 1 : 1 mixture of **2** and **3** by gas chromatography.

Reductive Cleavage of Epoxy Ring in 17: Epoxy alcohol **17** (283 mg) in 10 ml dioxane was refluxed with $LiAlH_4$ for 1 day. The product (290 mg) was recrystallized from ether-hexane gave diol **18** mp 128—129.5 °C (98 mg). The residue from the mother liquor (160 mg) was chromatographed on an alumina column (6 g) and eluted with ether. **18** (54 mg) was recovered and 8α,9α-diol **11** (28 mg) was obtained. **18**: IR (KBr) 3260(broad, OH), 3010, 1370, 1252, 1141, 1091, 1048, 1002, 911, 888, 859, 838, and 741 cm^{-1}. ^{1}H NMR ($CDCl_3$) δ=0.43 (1H, dd, J=10.6, 5.0 Hz), 0.57 (3H, s), 1.01 (3H, s), 1.26 (3H, s), 1.42 (3H, s), 0.80—1.8 (8H, m), 1.69 (2H, d, J=3.4 Hz), 2.79 (1H, broad), 2.96 (1H, d, J=5.2 Hz), and 3.30 (1H, dt, J=5.2, 3.4 Hz).

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