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ACID-CATALIZED REARRANGEMENT OF THUJOPSENE. I.
STRUCTURE DETERMINATION OF NEW COMPOUNDS (1)

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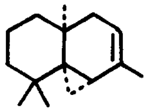
In connection with the current interest (2) on the behavior of homoallyl and cyclopropylcarbinyl ions, we have studied the acid-catalyzed reaction of thujopsene (3) in order to clarify the fate of the carbonium ion formed therefrom. We describe here our result of the investigation, since the acid-catalyzed reactions of this system were found to undergo more deep-seated rearrangements than those reported (4, 5).

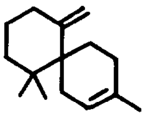
Thujopsene was heated with oxalic acid (4) under the three different conditions (cf. TABLE). The reaction mixture obtained in each reaction was separated by column (Al_2O_3, SiO_2 and SiO_2 impregnated with $AgNO_3$) chromatography and gas chromatography (GC). The result is summarized in the TABLE. Identity of the known compounds was established by comparison of their t_R in GC, IR and NMR spectra with the authentic specimens. Of the reaction products II - X, compounds thus identified were chamigrene III (6), cuparene VI (7) and widdrol X (8). The structures of the hitherto unknown compounds were determined in the following ways (9).

<u>Hydrocarbon II</u> contains three tert. methyls δ 0.78, 0.78, 0.81 (each 3H, s) and the system $-\overset{|}{C}=CH-CH_2-$ [$\nu^{liq.}$ 1673, 840-800 cm^{-1}, δ 5.22 (1H, m)]. Hydroboration of II gave the alcohol XI [m.p. 85°, ν^{KBr} 3350, 1100-1000 cm^{-1}, δ 0.75, 0.78, 0.90 (each 3H, s), 3.47 (1H, br.s)], which was oxidized with chromic oxide in pyridine to afford the ketone XII [m.p. 48°, ν^{KBr} 1712 cm^{-1}, δ 0.82, 0.85, 1.17 (each 3H, s)]. Optical rotation was nearly 0° for II, XI and XII over the range of 220-350 mμ. The structure was supported by the formation of II from III in a good yield upon acid treatment (10).

<u>Hydrocarbon IV</u> has three tert. methyls δ 0.85, 0.85, 0.93 (each 3H, s), a methyl attached to a double bond δ 1.57 (3H, d, J=2) and two vinylic protons of the type $-CH=\overset{|}{C}-$ [$\nu^{liq.}$ 1660, 840-820 cm^{-1}, δ 5.27


I


II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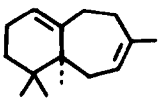
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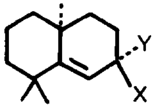
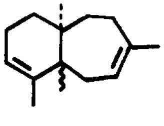
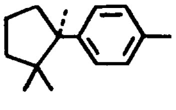
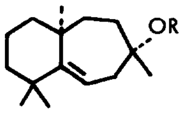
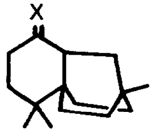
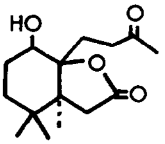

VIII: X=CH_3, Y=CH_2OH
IX: X=CH_2OH, Y=CH_3
XIV: X=CH_3, Y=CHO
XV: X=CH_3, Y=CO_2H
XVI: X=CH_3, Y=CH_2Cl
XVII: X=Y=CH_3
XVIII: X=CHO, Y=CH_3
XIX: X=CH_2Cl, Y=CH_3

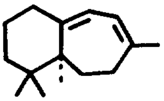

Va: α Me
Vb: β Me

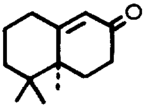

VI


VII: R=Et
X: R=H


XI: X= $\langle^{H}_{OH}$
XII: X=O


XIII


XX


XXI

(2H, m)]. The absence of a maximum in UV region and of a signal due to the grouping $\rangle C{=}\overset{|}{C}{-}CH_2{-}\overset{|}{C}{=}C\langle$ in the NMR spectrum of IV disclosed that these double bonds are at least two carbons apart. Ozonization followed by alkaline H_2O_2 oxidation of IV yielded the hydroxyketo-γ-lactone XIII (m.p. 193°, ν^{KBr} 3610, 1761, 1712, 1418 cm^{-1}), which was stable to acids and alkalis and gave a positive iodoform test.

Hydrocarbon V has two tert. methyls δ 0.87 (6H, s) and two $CH_3{-}\overset{|}{C}{=}\overset{|}{C}{-}H$ [$\nu^{liq.}$ 1635, 835 cm^{-1}, δ 1.67 (6H, m), 5.24 (2H, m)] at least two carbons apart. Thus the alternative structures Va and Vb were assigned. The mechanistic consideration (10) favors Va.

Widdrol ethyl ether VII exhibits bands at 3040, 1618, 843 (trisubst. olefine), 1095 cm^{-1} (C-OC) in its IR spectrum and signals at δ 5.40 (1H, q, AB$\underline{X}$, J_{AX}=9, J_{BX}=6), 2.34 (1H, q, $\underline{A}$BX, J_{AB}=14), 1.92 (1H, q, A$\underline{B}$X), 3.28 (2H, q, J=7), 0.90-1.19 (bump. 5 Me) in its NMR spectrum. The structure was easily assigned from these spectral observations and confirmed by synthesis from widdrol by the successive reaction of potassium and ethyl iodide.

Alcohol VIII contains four tert. methyls (δ 0.90, 1.07, 1.07, 1.15) a prim. hydroxyl [ν^{KBr} 3450, 1050-1015 cm^{-1}, δ 3.17 (2H, s)] and a vinylic proton δ 5.03 (1H, s) [tosylate, m.p. 75-77°, δ 0.93, 0.98, 1.03, 1.10 (each 3H, s), 3.61 (2H, s), 4.98 (1H, s)] (11). The chromic acid oxidation of VIII afforded the

TABLE. Product Ratio of the Acid-catalyzed Reaction of Thujopsene.

Products		I	II	III	IV	V	VI	VII	VIII	IX	X	XX
Retention time*		1.00	1.14	1.29	1.44	1.59	1.92	2.31	0.91	0.96	1.00	1.52
Reaction Conditions and Yield**	oxalic acid in EtOH, 90° 12 hrs.	47	3	6	17	4	trace	15			7	
	oxalic acid in EtOH, 125° 10 hrs.	6	9	21	37	5	6		2	1	1	
	$HClO_4$ in dioxane, 80° 2 hrs.	9	5	11	26	12					18	19

* Retention time of I was taken as standard for hydrocarbons and VII,and that of X was taken for alcohols.
** Yields of the products were calculated from gas chromatograms.

aldehyde XIV [liquid, $\nu^{\text{liq.}}$ 2804, 2694, 1723, 860 cm^{-1}, δ 1.10 (9H, s), 1.20 (3H, s), 5.10 (1H, s), 9.23 (1H, s)] and the carboxylic acid XV [m.p. 105.5°, ν^{KBr} 3000-2500, 1693 cm^{-1}, δ 1.10 (6H, s), 1.20, 1.27 (each 3H, s), 5.42 (1H, s), 11.98 (1H, br.s)]. Treatment of VIII with thionylchloride gave the chloride XVI, liquid, δ 1.03 (6H, s), 1.07 (3H, s), 1.17 (3H, s), 3.25 (2H, s), 5.08 (1H, s), which was also obtained from X by the action of thionylchloride or hydrochloric acid in acetic acid. XVI was reduced with sodium in ethanol to give the hydrocarbon XVII, liquid, δ 0.95, 0.97, 1.05, 1.08, 1.14 (each 3H, s), 5.10 (1H, s).

Alcohol IX has essentially the same structural features as VIII [ν^{KBr} 3350 cm^{-1}, δ 0.91, 1.03, 1.08, 1.13 (each 3H, s), 3.14 (1H, d, J=10), 3.24 (1H, d, J=10), 5.04 (1H, s)] and gave on chromic acid oxidation the liquid aldehyde XVIII [$\nu^{\text{liq.}}$ 2714, 1719, 890-850 cm^{-1}, δ 1.10 (9H, s), 1.18 (3H, s), 5.22 (1H, s), 9.28 (1H, s)]. The chloride XIX, liquid, δ 1.03 (6H, s), 1.08 (3H, s), 1.17 (3H, s), 3.21 (1H, d, J=11), 3.33 (1H, d, J=11), 5.10 (1H, s), obtained from IX with thionylchloride was reduced with sodium in ethanol to afford XVII.

The products and their formation ratio depend on the kind of acid used. A representative example is also listed in the TABLE. The new product XX has three tert. methyls δ 1.00, 1.13, 1.13 (each 3H, s) and the system CH_3-C=CH-CH=C- [$\nu^{\text{liq.}}$ 1650, 830 cm^{-1}, δ 1.78 (3H, m), 5.53 (1H, d, J=8), 5.67 (1H, d, J=8), λmax 254 nm (ϵ 10400), 263 (11500), 273 (7300)]. Tetrahydro compound of XX was identical with the tetrahydro derivative of IV. On ozonolysis XX gave a diketone [$\nu^{\text{liq.}}$ 1715, 1693 cm^{-1}, δ 1.00 (3H, s), 1.02 (6H, s), 2.02 (3H, s)] , which with sodium hydroxide in ethanol yielded the α,β-unsaturated ketone XXI [$\nu^{\text{liq.}}$ 1670 cm^{-1}, δ 1.15, 1.18, 1.33 (each 3H, s), 5.70 (1H, br.s), λmax 242 nm (ε 10200) : 2,4-DNP, m.p. 185-187°]. XXI was different from the trimethyloctalenone (12) obtained from widdrol.

As is clear from the present result, thujopsene is unstable toward acids and undergoes the multistep rearrangement, producing many natural congeners. Thus this kind of process might be involved in the genesis of these natural products.

References and Footnotes

1) Presented at a) The 19th Annual Meeting of Chemical Society of Japan in Tokyo on April 3, 1966. Abstract of the Papers, Vol. III, 452 (1966). b) Symposium on the Chemistry of Terpenes, Essential Oils and Aromatics in Matsuyama on October, 1967. Abstract of the Papers, 73 (1967). c) Symposium on the Chemistry of Natural Products in Fukuoka on October 29, 1970. Abstract of the Papers, 174 (1970).

2) a) W. G. Dauben and L.E. Friedrich, Tetrahedron Letters, 2675 (1964). b) Y. Hikino and P. de Mayo, Chem. Comm., 550 (1965). c) L. Birladeanu, T. Hanafusa, B. Johnson and S. Winstein, J. Am. Chem. Soc., 88, 2316 (1966). d) J. Tadanier, J. Org. Chem., 31, 2124 (1966). e) S.W. Pelletier, S. Nakamura and Y. Shimizu, Chem. Comm., 727 (1966).

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9) All the new compounds in this paper gave the satisfactory elemental analyses. The molecular weight was secured by mass spectrometry. All NMR spectra were measured at 60 Mc/s in CCl_4. Chemical shifts (δ) are expressed in ppm from internal TMS and coupling constants (J) in Hz. UV spectra were taken for MeOH solution and IR spectra in CCl_4 unless otherwise stated.

10) S. Itô, M. Yatagai, K. Endo and M. Kodama, Tetrahedron Letters, 1153 (1971).

11) This compound has also been obtained by Dauben and Friedrich (5a). The identity was confirmed by direct comparison.

12) C. Enzell, Acta Chem. Scand., 15, 1191 (1961). S. Itô, K. Endo and T. Nozoe, Chem. Pharm. Bull., 11, 132 (1963).