

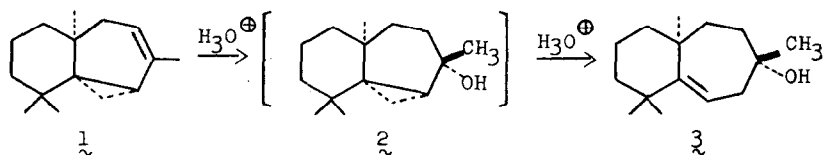
THE MECHANISM OF THE TRANSFORMATION OF  
THUJOPSENE TO WIDDROL<sup>1</sup>

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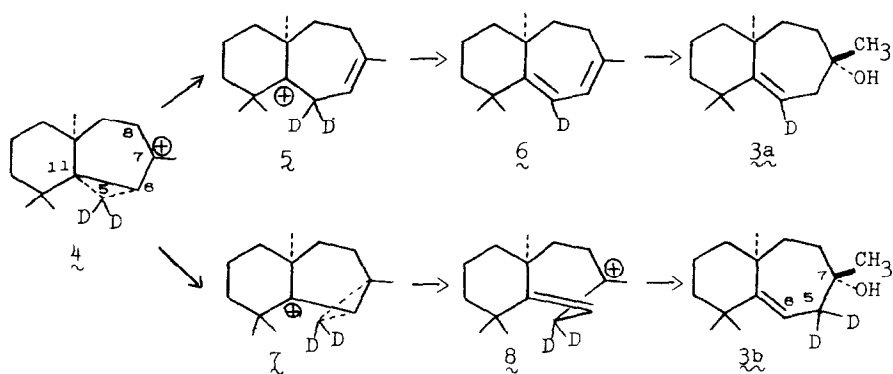
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(Received 12 June 1964)

When the tricyclic sesquiterpene thujopsene (1) is allowed to react with aqueous acid the bicyclic sesquiterpenic alcohol widdrol (3) is formed in 25% yield.<sup>3</sup> Enzell<sup>4</sup> has suggested that



this transformation proceeds by first the diaxial addition of water to form the intermediate alcohol 2 followed by an acid catalyzed cyclopropane ring opening. Such a process seems most unlikely since the attack of acid on the tertiary cyclopropyl carbinol 2 should yield the cyclopropylcarbinyl carbonium ion 4 and not the product of a simple opening of a cyclopropane ring. The carbonium ion 4, which can be formed by direct protonation of thujopsene, can rearrange to the homoallylic ion 5 and subsequently collapse to the diene 6. The hydration



of the diene to yield widdrol, however, would appear to be most unlikely. Alternatively, the ion 4 can rearrange in the well known manner<sup>5-7</sup> to yield the isomeric cyclopropylcarbinyl ion 7 and, in turn, the homoallylic ion 8. This latter ion upon hydration directly leads to widdrol.

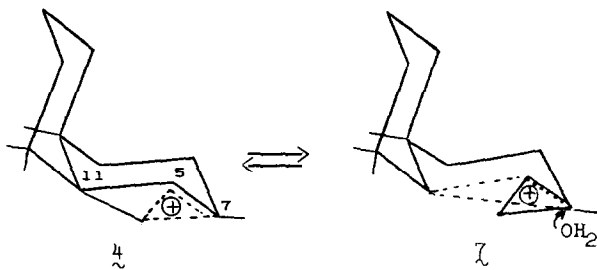
To differentiate between these several possible pathways, (+)-5,5-dideuteriothujopsene 4 was prepared by our published method<sup>8</sup> except dideuteromethylene iodide<sup>9</sup> (93% dideutero<sup>10</sup>) was employed in the synthesis. The labeled thujopsene was allowed to react with 0.02 N HClO<sub>4</sub> in 20% aqueous dioxan for 175 minutes and (+)-6,6-dideuterowiddrol (93% dideutero) was obtained in 30% yield. The NMR spectrum of the product clearly established that the dideuteromethylene group had remained intact and was located next to the double bond since the characteristic absorption of this allylic methylene group (C-5) at  $\tau = 7.3-8.2$  was not present and the vinyl proton quartet at  $\tau = 4.5$  in natural widdrol now appeared as a clean singlet. Both the deuterium content and the NMR spectral evidence rule out the involvement of the diene 6 as well as the direct opening of the cyclopropane ring in 4 and establish the correctness of

a pathway involving isomeric cyclopropylcarbinyl ions (or equivalent bicyclobutonium ions)  $\text{4}$  and  $\text{7}$ .

In agreement with the above results was the finding that when the acid catalyzed rearrangement of natural thujopsene was carried out in the presence of 99.8%  $\text{D}_2\text{O}$ , the widdrol obtained possessed no deuterium ( $0 \pm 2\%$ ) at C-6. The mass spectrum of the widdrol formed showed it possessed the following composition: 2% undeuterated, 43% monodeutero, 43% dideutero, 11% trideutero,  $\sim 0.5\%$  tetradeutero, and  $< 0.1\%$  pentadeutero. The NMR spectrum indicated that in the mono- and dideutero species, the isotope was present mainly on C-8. The slow introduction of deuterium into the methyl group on C-7 clearly showed the great preference for the endocyclic double bond in thujopsene, a feature indicated by the earlier synthesis of the hydrocarbon.<sup>8</sup>

It also was found that when widdrol was allowed to react with  $0.02 \text{ N HClO}_4$  in 20% dioxan, isolatable amounts of thujopsene were formed in the early stages of the reaction, showing the expected reversible nature of the rearrangement process involving bicyclobutonium ions. Starting with either thujopsene or widdrol the same equilibrium mixture of products was obtained.

The net rearrangement can be visualized as shown below,



the change being the rebonding of the methano carbon (C-5) from C<sub>11</sub>-C<sub>6</sub> to C<sub>6</sub>-C<sub>7</sub>. The attack by the solvent on the bicyclobutonium ion  $\lambda$  (or equivalent homoallylic ion) should occur predominantly from the side opposite the bond which breaks and the resulting widdrol should possess the hydroxyl group in a cis relationship to the angular methyl group. This same stereochemical arrangement has been assigned by Enzell<sup>4</sup> on the basis of a series of chemical transformations.

## REFERENCES

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9. Prepared by the method of S. Winstein and E. C. Friedrich, private communication.
10. The deuterium content of the material was determined by mass spectrometry. We are indebted to Prof. A. L. Burlingame for these studies.