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THE SYNTHESIS AND STEREOCHEMISTRY OF FICHTELITE

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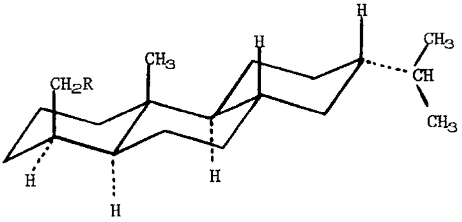
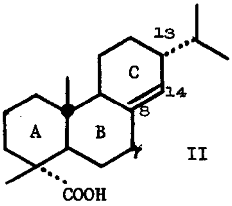
Among products of the anaerobic decomposition of abietic-type resin acids in certain decayed conifers, the saturated hydrocarbon fichtelite (Ia) has long engaged the attention of chemists (1). The structure and partial stereochemistry of fichtelite have been known since 1938 (2), but the complete configuration, particularly at C-4 and C-13 (steroid numbering), has remained speculative (3). In this report we describe the synthesis of fichtelite from the all-trans tetrahydroabietic acid IIId, and by this means have been able to establish the stereochemistry of fichtelite as that shown in Ia.

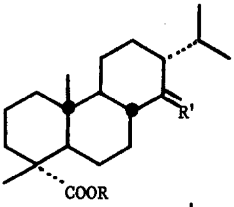


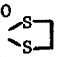
Ia: R=H
Ib: R=OH
Ic: R=OTs
Id: R=S-Bu-n

Reduction of abietic, neoabietic, or levopimaric acid by lithium in liquid ammonia (4) gave predominantly the common $\Delta^{8(14)}$-dihydroabietic acid II, m.p. 195-197°, $[\alpha]_D$ -26°, whose NMR spectrum indicated retention of about 15% of the Δ^{13}-isomer (5) even after extensive recrystallization (6). The Δ^{7}-structure proposed earlier (4) for this acid is obviously incompatible with its formation from neoabietic and levopimaric acid In addition, the close similarity of the plain positive ORD curve to that of Δ^{4}-cholestene (7), rather than to the negative one of Δ^{5}-cholestene, also supports the $\Delta^{8(14)}$-assignment.

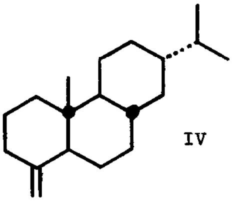


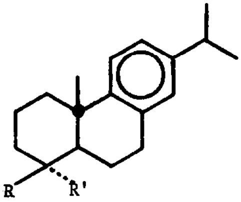
II



IIIa: R=H, R'=O
IIIb: R=CH$_3$, R'=O
IIIc: R=CH$_3$, R'=


IIId: R=H, R'=H$_2$


IV



Va: R=CH$_2$OH, R'=H
Vb: R=H, R'=CHO
Vc: R=H, R'=CH$_2$OH

Reduction and hydroboration of the acid II by lithium aluminum hydride-boron trifluoride, followed by treatment with hydrogen peroxide and base (8), gave, in 65% yield, a homogeneous diol, m.p. 172-174°, $[\alpha]_D$ +11° (9). Oxidation of this diol with Jones reagent afforded the keto acid IIIa, m.p. 253-257°, $[\alpha]_D$ +12°. This acid and its methyl ester, m.p. 78-79°, $[\alpha]_D$ + 14°, were unaffected by treatment with acid or with sodium methoxide in absolute methanol. These products must, therefore, possess the more stable equatorial α-configuration of the isopropyl group at C-13 as well as the trans-fused junction of rings B and C (10).

The keto ester IIIb (and also the keto acid IIIa) failed, apparently for steric reasons, to form a 2,4-dinitrophenylhydrazone and gave anomalous results on attempted Wolff-Kishner reduction. However, IIIb did undergo smooth conversion into the corresponding ethylenethioketal IIIc, m.p. 205.5-206.5°, $[\alpha]_D^{CHCl_3}$ -33°, by reaction with ethanedithiol and boron trifluoride etherate (11). Desulfurization of this derivative with Raney nickel and hydrolysis of the resulting oily ester furnished the desired all-trans tetrahydroabietic acid IIId, m.p. 177.5-179°, $[\alpha]_D$ +10°, whose diamylamine salt melted at 127-127.5°. Catalytic hydrogenation of abietic acid has been reported (12) to give a tetrahydro acid of similar m.p. and rotation.

Degradation of the acid IIId into the 4-methylene derivative IV was patterned after the procedure of Zeiss and Martin (13) for the conversion of dehydroabietic acid into the aromatic ring-C analog of IV. The olefin IV had $[\alpha]_D$ +66°, n_D^{25} 1.5090, and displayed infrared peaks at 6.1 and 11.3 μ characteristic of an exocyclic methylene group. Its NMR spectrum (CCl_4) showed the two olefinic protons in the expected region at 5.26 and 5.53 τ.

On hydrogenation over platinum oxide in acetic acid, IV was rapidly converted into a saturated hydrocarbon which crystallized from cold methanol only when seeded with authentic fichtelite. After several recrystallizations from methanol this product melted at 45-46° [lit. (1) 46°]; mixed m.p. with natural fichtelite, 45-46°; $[\alpha]_D$ +19° [lit. (1) +18°]. Further evidence for its identity with fichtelite came from a comparative X-ray powder diffraction pattern and a KBr pellet infrared spectrum, both of which were indistinguishable from those of the natural product.

The reduction of the olefin IV into fichtelite was also achieved by its reaction with diborane (α-side attack favored by the angular methyl group at C-10) to give a solid alkylborane, which, however, was not convertible directly into Ia by protonolysis. Treatment with alkaline hydrogen peroxide, on the other hand, smoothly afforded the primary alcohol Ib, whose *p*-toluenesulfonate (Ic), m.p. 109-109.5°, was converted into the corresponding *n*-butyl sulfide (Id) by reaction with potassium *n*-butylmercaptide in *t*-butyl alcohol. Raney nickel desulfurization of Id then gave fichtelite having the same properties as those of the product of catalytic hydrogenation.

That the methyl group at C-4 in fichtelite is actually β-oriented (axial) was shown by model studies with the aromatic ring-C analog of IV. This olefin (13,14) was transformed by hydroboration into the analogous aromatic ring-C alcohol Va. The 3,5-dinitrobenzoate of Va melted at 107-109°. Conversion of the same olefin into the 4-formyl derivative Vb (14) was then accomplished by any of three pathways: (i) formation of a glycol with osmium tetroxide, followed by pinacol rearrangement in refluxing formic acid (14); (ii) epoxidation with *m*-chloroperbenzoic acid, followed by rearrangement with boron trifluoride etherate in benzene; and (iii) hydroboration to the alcohol Va, followed by oxidation with chromium trioxide in pyridine (Sarett reagent). Reduction by lithium aluminum hydride of the aldehyde Vb prepared by any of these methods gave an epimeric alcohol (Vc), whose 3,5-dinitrobenzoate melted at 126-128° (mixed m.p. with the 3,5-dinitrobenzoate of Va, 79-85°).

Since the aldehyde Vb would be expected to enolize readily, especially under the acid conditions of the rearrangements, it is not surprising that only the more stable equatorial α-isomer could be obtained. Consequently, in the absence of any steps that could lead to epimerization at C-4 in the conversion of the olefin IV into the alcohol Ib and thence into fichtelite, the methyl group at C-4 in fichtelite must be axial (β-oriented), as shown in Ia, rather than equatorial as has been tentatively proposed (3).

The equatorial α-methyl C-4 isomer of fichtelite was synthesized by epoxidation of the olefin IV followed by rearrangement into the corresponding aldehyde and Wolff-Kishner reduction of the latter to the hydrocarbon. This product, $[\alpha]_D$ +5°, could not be induced to crystallize from methanol when seeded with authentic fichtelite.

Thus, interestingly, the production of fichtelite by anaerobic decarboxylation of abietic acid-type precursors takes place without inversion at C-4.

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