the fact that a dynamic equilibrium is reached in this system involving abietic, palustric, and neoabietic acids. The isomerization at 200° probably involves catalysis by the carboxylic acid group. The difference in temperature (25 *vs.* 200°) and environment probably accounts for the difference in the composition of the final equilibrium mixtures. The palustric acid peak was again collected, and, based on the observed rotation, it would appear that not more than a trace of levopimaric acid is present in the final equilibrium mixture. Previous workers[7] employing a partition chromatographic analytical method at room temperature reported values of 93% abietic, 4% palustric, and 2% neoabietic acids for the acid isomerization of abietic acid under the same conditions.

The acid-induced equilibria of the four conjugated dienoic resin acids probably involve a common carbonium ion.[8,9] The results of the isomerization experiments show an interesting difference in what might be expected in terms of thermodynamic stabilities.

It is interesting to note that the half-lives of the four conjugated dienoic resin acids at 200° correlate with the absorptivity of the resin acids ($t_{1/2}$, min; absorption at λ_{max}, mμ: levopimaric acid, 15, 19; palustric 40, 31; abietic 75, 77; neoabietic 120, 80). It is generally held that the absorptivity of the resin acids is related to ring strain.

It is of further interest to note that in the case of palustric acid, protonation must occur from the α side exclusively at C-9 or else a 9-β-H abietic and neoabietic acid would be formed. No appreciable amounts of any unknown peaks were observed in the glpc analyses.

Experimental Section

All optical rotations were determined in 95% ethanol at *c* 1.

Thermal Reactions.—About 0.2 g of each acid was placed in a glass Carius tube. The air in each tube was replaced with nitrogen. The tubes were then sealed under vacuum, submerged in an oil bath, and heated at 200°.

Isomerization of Abietic Acid at 200°.—The change in acid composition with time is plotted in Figure 1. Only three peaks were observed in the glpc analysis through 10.5 hr (no disproportionation observed). These were identified as methyl abietate, palustrate, and neoabietate by means of relative retention times, infrared and ultraviolet absorption spectra, and optical rotation. The value for the methyl palustrate peak was $[\alpha]^{25}D$ +65.2 (theory +68.4).

Isomerization of Abietic Acid in the Presence of Potassium Hydroxide at 200°.—Abietic acid was dissolved in methanol containing potassium hydroxide (1:0.05 mole ratio). The solvent was removed under vacuum. The residual solid was heated at 200° in the usual manner. The system reached the equilibrium distribution in about 8 hr.

Isomerization of Palustric, Levopimaric, and Neoabietic Acids at 200°.—A final equilibrium distribution of 81% abietic, 14% palustric, and 5% neoabietic acid was obtained in all cases. Essentially no disproportionation was observed at the end of 21.5 hr in the case of neoabietic and levopimaric acids. A total of 6.1% of resin acids other than abietic, palustric, and neoabietic acids were observed to be present at the end of 24 hr in the case of palustric acid.

Acid Isomerization of Abietic, Levopimaric, Palustric, and Neoabietic Acids.—A 1% solution of each of the four conjugated dienoic resin acids was made in a 0.5 *N* ethanolic solution of hydrochloric acid. Aliquots were removed periodically and poured into water. The resin acids were immediately extracted with ether, the ether was stripped off (quantitative yield), and the residue was analyzed. The methyl palustrate peak exhibited $[\alpha]^{25}D$ +67.7° (theory for methyl palustrate is $[\alpha]^{25}D$ +68.4°). The final equilibrium distribution for all four acids (50 hr at room temperature) was 93% abietic, 4% palustric, and 3% neoabietic acids. No disproportionation was observed in any of the four acids.

Registry No.—Abietic acid, 514-10-3.

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Oxidation of 3β-Acetoxy-14α-methyl-5α-cholest-7-ene[1]

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The susceptibility of 3β-acetoxy-14α-methyl-5α-cholest-7-ene (I) to oxidation by chromium trioxide has already been noted, and this property was used as a means of removing olefin I from a reaction mixture.[2] At the time oxidation was performed on a microscale, and the products were not further investigated. Recently, it became necessary to review the reaction in more detail, and one of the products has now been found to arise by an unusual allylic oxidation.

Small-scale studies showed that oxidation (room temperature) of olefin I with chromium trioxide in aqueous acetic acid was essentially complete in 1 hr. When the reaction was carried out on a larger scale, thin layer chromatography (tlc) of the crude product showed three main spots. Preparative tlc (on silica) led to three crystalline products, each of which was subjected to further purification by the same technique. The main product was the expected 7,11-dione II.[3] A thin band close to the leading edge of the diketone (II) zone provided saturated ketone III,[4] and a third zone gave a new compound which showed an infrared band at 1670 cm^{-1}, typical of an α,β-unsaturated ketone. The latter substance was not Δ^8-7-ketone IV as anticipated. This possibility was eliminated by comparison with an authentic sample, synthesized by Jones oxidation of 8α,9α-epoxy 7α-alcohol Va to ketone Vb followed by treatment with zinc in acetic acid.[5]

A rotatory dispersion curve of the new ketone exhibited a positive Cotton effect in methanol, and in petroleum ether solution showed all the fine structure associated with a Δ^7-6-keto system[6] (Figure 1). The ultraviolet absorption curve showed a maximum at 245

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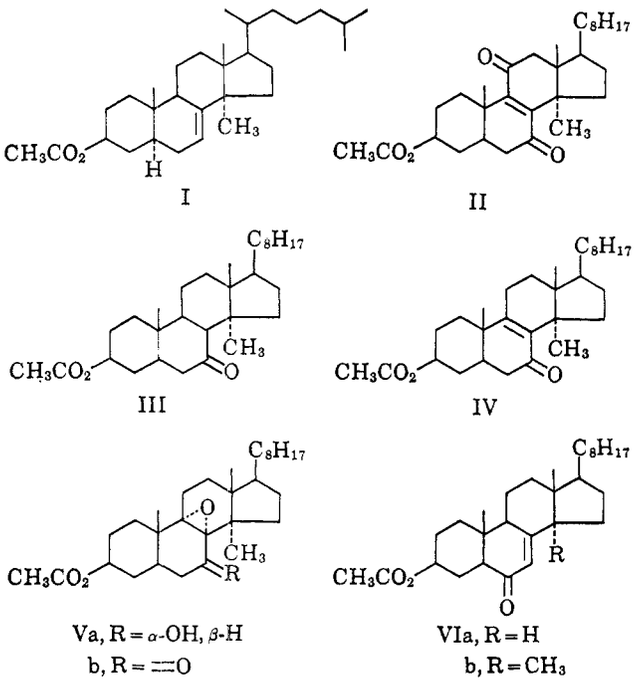
mμ (ε 13,920), and the nmr spectrum exhibited a signal at 5.78 due to the α proton of an α,β-unsaturated ketone system. These data corresponded closely with those determined for a sample of the acetate of deoxyviperidone (VIa).[6,7] Accordingly, the new ketone was formulated as 3β-acetoxy-6-oxo-14α-methyl-5α-cholest-7-ene VIb.[8]

Chromium trioxide oxidation of Δ^7 sterols and triterpenoids has not previously been reported to yield a 6-ketone,[9] presumably because sterols suffer preferential attack at the 14 hydrogen (blocked in this case by a methyl group), and the presence of a triterpenoid 4,4-dimethyl group results in increased steric hindrance at C-6. However, such allylic oxidations may be more general in scope, and before the advent of preparative tlc may have escaped detection.



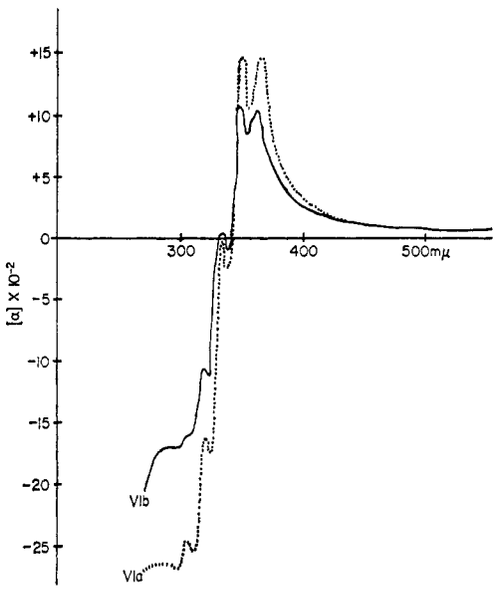


Figure 1.—Rotatory dispersion curves in ligroin solution: ———, 3β-acetoxy-6-oxo-14α-methyl-5α-cholest-7-ene (VIb); · · · ·, desoxyviperidone acetate (VIa) (3β-acetoxy-6-oxo-5α-cholest-7-ene) from *Peniocereus greggii*.[7]

Experimental Section[10]

Chromium Trioxide Oxidation of 3β-Acetoxy-14α-methyl-5α-cholest-7-ene (I).—A solution of chromium trioxide (1.0 g) in acetic acid (40 ml) containing just enough water to ensure a clear solution was added to a solution of 3β-acetoxy-14α-methyl-5α-cholest-7-ene (I, 1.0 g) in glacial acetic acid (60 ml). The mixture was allowed to stand at room temperature for 90 min (tlc showed no starting material remaining). Following dilution with water and extraction with diethyl ether, the extract was washed well with water, aqueous sodium hydrogen carbonate, and water, dried, and concentrated. The residual yellow oil was separated into three zones on four chromatoplates developed three times in ethyl acetate–ligroin (15:85). Each of the three zones was further purified in the same manner, then recrystallized from methanol to give, in order of increasing polarity, (1) 3β-acetoxy-7-oxo-14α-methyl-5α-cholestane (III) crystallizing in colorless needles [155 mg; mp 118–120° (ketone III did not depress the melting point of an authentic sample[4] prepared by peracid oxidation of olefin I, and their infrared spectra were identical)], (2) 3β-acetoxy-7,11-dioxo-14α-methyl-5α-cholest-8-ene (II) obtained as yellow needles [390 mg; mp 113–115°; λ_{max} 271 mμ (ε 8253); ν_{max} 1740, 1680 cm^{-1} (lit.[3b] mp 116–118°); λ_{max} 271 (ε 8404); ν_{max} 1739, 1681 cm^{-1})], and (3) 3β-acetoxy-6-oxo-14α-methyl-5α-cholest-7-ene (VIb) crystallizing in small colorless prisms [80 mg; mp 170–172°; nmr, 0.72 (18-Me), 0.84 (19-Me), 0.90, 0.94, 1.12, 2.06 (acetate), 4.75 (3-H), 5.78 (7-H); $[\alpha]_D$ 0°; ORD (in methanol, *c* 0.037), $[\alpha]_{550}$ +163, $[\alpha]_{500}$ +217°, $[\alpha]_{450}$ +217°, $[\alpha]_{400}$ +272°, $[\alpha]_{345}$ +1140° (peak), $[\alpha]_{326}$ 0°, $[\alpha]_{290}$ −3153 (inflexion); λ_{max} 245 mμ (ε 13,920); ν_{max} 1670, 1615, 1735, 1240 cm^{-1}].

Anal. Calcd for $C_{30}H_{48}O_3$ (456): C, 78.89; H, 10.59. Found: C, 78.76; H, 10.55; mol wt (mass spectroscopy), 456.

3β-Acetoxy-7-oxo-14α-methyl-5α-cholest-8-ene (IV).—A solution of 1.0 g of 3β-acetoxy-7α-hydroxy-8α,9α-epoxy-14α-methyl-5α-cholestane (Va was obtained as a by-product from oxidation of 3β-acetoxy-14α-methyl-5α-cholest-7-ene (I) with *m*-chloroperbenzoic acid in chloroform)[4] in acetone was treated (dropwise) with Jones reagent[11] until an orange tinge was present. The solution was diluted with water and extracted with diethyl ether; the extract was washed well with water and aqueous sodium hydrogen carbonate, dried, and concentrated. The residue was chromatographed (column) on silica gel (0.05–0.20 mm, E. Merck, Darmstadt). Elution with 19:1 ligroin–ethyl acetate gave ketone Vb as a homogeneous crystalline solid (0.8 g) which no longer showed hydroxyl absorption in the infrared spectrum, but exhibited a strong carbonyl band at 1700 cm^{-1}. Without further characterization, ketone Vb was dissolved in acetic acid (50 ml) and zinc dust (1.0 g) was added. The mixture was heated at reflux for 1 hr, cooled, filtered, and diluted with water. Extraction with diethyl ether provided (after washing and concentrating) a colorless oil which was purified by preparative layer chromatography on four plates developed in ethyl acetate–ligroin (1:4). The main zone provided 3β-acetoxy-7-oxo-

(7) Isolated from the cactus *Peniocereus greggii*, J. C. Knight and G. R. Pettit, unpublished results.

(8) Preparation of ketone VIb affords, in principle, a route to naturally occurring 14α-methyl steroids of the Macdougallin (3β,6α-dihydroxy-14α-methyl-5α-cholest-8-ene) type (*cf.* ref 3b).

(9) For examples of the oxidation of the Δ^7-sterol and triterpene series, see ref 5a and b, and also C. Djerassi, G. W. Krakower, A. J. Lemin, L. H. Liu, J. S. Mills, and R. Villotti, *J. Amer. Chem. Soc.*, **80**, 6284 (1958), and references cited therein.

(10) All solvents were redistilled, and ligroin refers to a fraction boiling at 60–70°. Extracts of aqueous solutions were dried over anhydrous magnesium sulfate. Preparative thin layer chromatography was performed using silica gel HF_{254} (E. Merck, Darmstadt) in 2-mm layers on 200 × 200 mm plates. Melting points were observed using a Fisher-Johns apparatus and are uncorrected. The ultraviolet (methanol solution, Cary spectrophotometer), infrared (KBr disks, Beckman IR-12), and nuclear magnetic resonance spectra (deuteriochloroform solution with tetramethylsilane as internal standard, Varian A-60), and optical rotatory dispersion (JASCO ORD/UV-5) measurements were determined by Miss K. Reimer. We also wish to thank John Occolowitz for the mass spectra (Atlas CH-4 spectrometer). The microanalyses were provided by Dr. A. Bernhardt, Max Planck Institut, Mülheim, Germany, and optical rotations at the sodium D line (chlorform solution at 20°) were determined by Dr. P. Demoen, Janssen Pharmaceutica, Beerse, Belgium.

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14α-methyl-5α-cholest-8-ene (IV) as a solid which crystallized from methanol as large flat needles (460 mg): mp 114–117°; λ_{max} 254 mμ, (ε 9417); ν_{max} 1745, 1660, 1583 cm^{-1}; nmr, δ 0.66 (18-Me), 0.80, 0.90, 1.18 (19-Me), 4.70; $[\alpha]_D$ +19.5° (*c* 1.30); ORD (*c* 0.06 in ligroin), $[\alpha]_{450}$ +32°, $[\alpha]_{400}$ +94°, $[\alpha]_{367}$ +160° (peak), $[\alpha]_{344}$ 0°, $[\alpha]_{300}$ −480°, $[\alpha]_{280}$ −897°, $[\alpha]_{260}$ −2180°.

Anal. Calcd for $C_{30}H_{48}O_3$: C, 78.89; H, 10.59. Found: C, 78.89; H, 10.62.

Registry No.—I, 5259-20-1; II, 5535-18-2; III, 14156-34-6; IV, 15963-76-5; VIb, 15963-75-4.

The Reaction of α,β-Unsaturated Nitriles with Concentrated Sulfuric Acid

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Ritter and coworkers[2] have shown that the reaction between nitriles and branched olefins or tertiary alcohols in the presence of concentrated sulfuric acid led to the formation of N-alkylamides. This reaction was further studied,[3-9] and the general view[3,9] is that the reaction proceeds through a carbonium ion, formed from the olefin or alcohol which attacks the nitrogen of the nitrile group. Hydrolysis and tautomerism of the intermediate product leads to formation of the N-substituted amide.

Since an unsaturated nitrile contains both a nitrile group and a double bond, there is the possibility of interaction between these groups. Ritter[2f] carried out such a reaction between acrylonitrile (AN) and sulfuric acid in the presence of acetic acid and represented the polymer obtained as polyalanine (I) in the absence of any evidence.

$$CH_2{=}CHCN \xrightarrow{H_2SO_4} CH_2{=}CHCO[NHCH(CH_3)CO]_nNHCH(CH_3)CN$$
I

Formation of I is possible if propagation of the polymerization is through the α-carbon atom of the nitrile. Magat[10] reported the formation of a soluble polymer, of unidentified structure, on reaction of methacrylonitrile with a large excess of sulfuric acid.

The reaction of α,β-unsaturated nitriles with concentrated sulfuric acid seemed therefore to be an interesting method for the preparation of amino acids.

We reinvestigated the reaction between AN and sulfuric acid in the presence of acetic acid.[2f] An insoluble polymer was formed which on acid hydrolysis gave traces of an amino acid which was not alanine.

Owing to the insolubility of the polymer formed under these conditions[2f] we decided to investigate the reaction using excess sulfuric acid to obtain soluble polymers.[10] In fact under these conditions, a water-soluble product was formed. The chromatogram of its hydrolyzate showed several spots, among them a strong one belonging to β-alanine.

The effect of various factors on the yield of β-alanine was studied. The low yields obtained prompted us to try to find out what happened to the major portion of the AN. Distillation of the dilute reaction mixture, before hydrolysis, in the presence of 40% sodium hydroxide solution, was found to evolve ammonia, which was determined quantitatively by titration. The origin of the ammonia is from ammonium salts or possibly acrylamide, formed by total or partial hydrolysis of the nitrile groups, respectively, in the presence of sulfuric acid. Under these distillation conditions β-alanine did not evolve ammonia as opposed to the behavior acrylamide. The amount of the ammonia evolved was calculated as the per cent of "labile nitrogen" obtained at the end of the reaction, out of the initial amount of acrylonitrile introduced.

Increasing the acid concentration from 92 to 98% or the molar ratio of concentrated sulfuric acid (98%) to AN, increased the yield of β-alanine (Table I). The lowering in yield of β-alanine and the increase in the per cent of "labile nitrogen" at the low sulfuric acid concentration seems to be due to the increase in the amount of water present, which leads to extensive hydrolysis.

TABLE I

EFFECT OF VARIOUS FACTORS ON THE YIELD OF β-ALANINE

$[H_2SO_4]$/[AN][a]	Acid concn, %	β-Alanine yield, %	"Labile nitrogen," %
1	98	2.5	75.0
2.5	98	13.5	78.5
6	98	14.3	77.5
11.25	98	17.5	82.0
2.5	92	5.5	
7.5	92	2.9	96.5
10	92	3.0	97.0
b		5.5	60.0
b		5.2	65.0
c		0.6	

[a] 150 mmol of AN was used. [b] AN–chlorosulfonic acid–sulfuric acid (1:3:1) was used. [c] AN–sulfuric acid–acetic acid (1:2.5:1) was used.

We investigated the reaction of AN with a mixture of sulfuric acid and chlorosulfonic acid hoping to increase the yield of β-alanine by eliminating the water present in the reaction mixture. However, the yield decreased (Table I), but there was also a decrease in the per cent of "labile nitrogen." We tried also the reaction conditions of Ritter,[2f] using a mixture of sulfuric acid and acetic acid, but in the presence of the latter a large decrease in yield of β-alanine was observed (Table I).

The results of these experiments pointed out that the maximum yield of β-alanine will be obtained using concentrated sulfuric acid or by using fuming sulfuric

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