with the specimen obtained by manganese dioxide oxidation (Table I, no. 10) was demonstrated by mixture melting point determination and infrared comparison.

Reaction of Δ^5-Pregnene-3,17-dione with Manganese Dioxide.—A solution of 0.20 g. of Δ^5-pregnene-3,17-dione (m.p. 163–165°, no high intensity absorption in the ultraviolet, quantitatively converted to progesterone with a trace of acid)[9] in 20 cc. of benzene was shaken at room temperature with 2 g. of manganese dioxide for 1 hour. The total product exhibited λ_{max} 284 mμ, log ϵ 4.41, and 6-dehydroprogesterone with m.p. 143–145° could easily be isolated after one crystallization.

MEXICO CITY, D. F.

[CONTRIBUTION NO. 1135 FROM STERLING CHEMISTRY LABORATORY, YALE UNIVERSITY]

Synthesis and Stereochemistry of the 3-Keto-Δ^4-steroidal System from Diterpenic Acids[1a,b]

BY HAROLD H. ZEISS AND WILLIAM B. MARTIN, JR.[1c]

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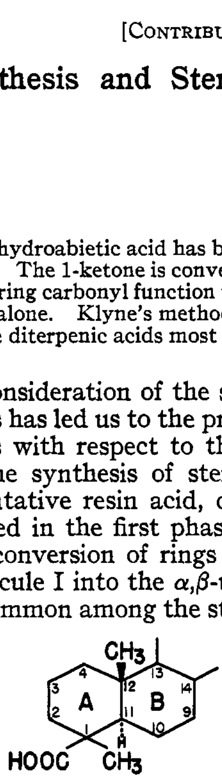
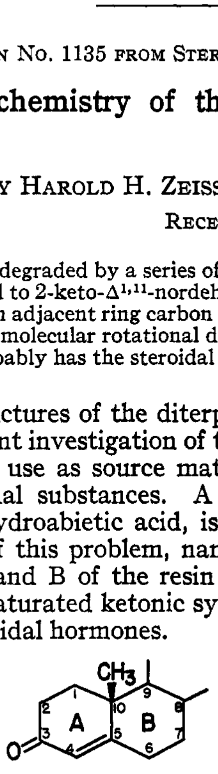
Dehydroabietic acid has been degraded by a series of reactions, including Hofmann elimination, to 1-ketonordehydroabietane. The 1-ketone is converted to 2-keto-$\Delta^{1,11}$-nordehydroabietene, a 3-keto-Δ^4-steroidal system, by a new method of moving a ring carbonyl function to an adjacent ring carbon atom. This method is applied also in the conversion of α-decalone to β-decalone. Klyne's method of molecular rotational differences is used to demonstrate that the C-12 angular methyl group of the diterpenic acids most probably has the steroidal β-configuration.

Consideration of the structures of the diterpenic acids has led us to the present investigation of these acids with respect to their use as source material in the synthesis of steroidal substances. A representative resin acid, dehydroabietic acid, is employed in the first phase of this problem, namely, the conversion of rings A and B of the resin acid molecule I into the α,β-unsaturated ketonic system II common among the steroidal hormones.



I



II

The degradation of dehydroabietic acid (III) at C-1 to 1-ketonordehydroabietane (IV),[2] previously believed to have been achieved by chromic acid oxidation of diphenyl-*t*-dehydroabietinol[3] and subsequently shown to be erroneous,[4] has been accomplished by a series of reactions including Hofmann elimination. In the course of this present work Jeger, *et al.*,[4] reported the preparation of IV by treatment of dehydroabietinol with phosphorus pentachloride followed by ozonolysis of the olefinic mixture containing the desired exocyclic olefin. Stork and Burgstahler[5] subsequently have synthesized *dl*-IV.

The acid chloride of III, by reaction with sodium azide followed by decomposition and rearrangement of the acid azide in xylene at 90°, is converted smoothly into dehydroabietane-1-isocyanate (V). The infrared spectrum of V is characterized by an intense band at 2220 cm.$^{-1}$ (4.5 μ) and the lack of the carbonyl band of III at 1680 cm.$^{-1}$ (5.9 μ). Treatment of V with mineral acid to obtain the corresponding primary amine is unsatisfactory; but reduction of V with lithium aluminum hydride[6] yields N-methyldehydroabietane-1-amine (VI). Reductive methylation of VI with formalin in formic acid gives rise to N,N-dimethyldehydroabietane-1-amine (VIII), which on further methylation with methyl iodide eliminates trimethylamine spontaneously, although slowly, at room temperature. The three β-carbon atoms, having one, two and three hydrogen atoms, may compete in this elimination. The Hofmann elimination rule leads to the prediction of predominant elimination at the C-1 methyl group, and this is found to be the case by the isolation of $\Delta^{1\text{-exo}}$-dehydroabietene (VIII). Alternately, the solid, unstable quaternary iodide from VII may be isolated, treated with silver oxide and thermally decomposed to VIII. Or, VI may be quaternized directly with methyl iodide and decomposed to VIII with equally satisfactory results.[7] The exocyclic nature of the double bond in VIII is substantiated by the appearance of absorption bands at 1650 cm.$^{-1}$ (6.1 μ) and at 880 cm.$^{-1}$ (11.3 μ) in the infrared spectrum of the olefin. From the ozonolysis of VIII at low temperature, ketone IV is obtained whose infrared spectrum (Fig. 1) is the same as that of Jeger's ketone and of the synthetic *dl*-ketone.[5] The 2,4-dinitrophenylhydrazone of IV melts between 85–86° in agreement with that derivative reported by Jeger.[4,8]

Of the several methods known for moving a ring carbonyl function to an adjacent ring carbon atom

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[1] (a) Taken from the dissertation submitted by W. B. Martin, Jr., to the Faculty of the Graduate School, Yale University, 1953, in candidacy for the degree of Doctor of Philosophy. (b) Presented in part at Buffalo, N. Y., March 26, 1952; Abstr. 121st Meeting, Amer. Chem. Soc., p. 41K; (c) E. I. du Pont de Nemours Fellow, 1951–1952.

[2] Nomenclatural usage in this paper follows the suggestion of J. L. Simonsen and D. H. R. Barton, "The Terpenes," Vol. III, Cambridge Univ. Press, 1952, p. 391, by which dehydroabietic acid becomes dehydroabietane-1-carboxylic acid.

[3] H. H. Zeiss, THIS JOURNAL, **70**, 858 (1948).

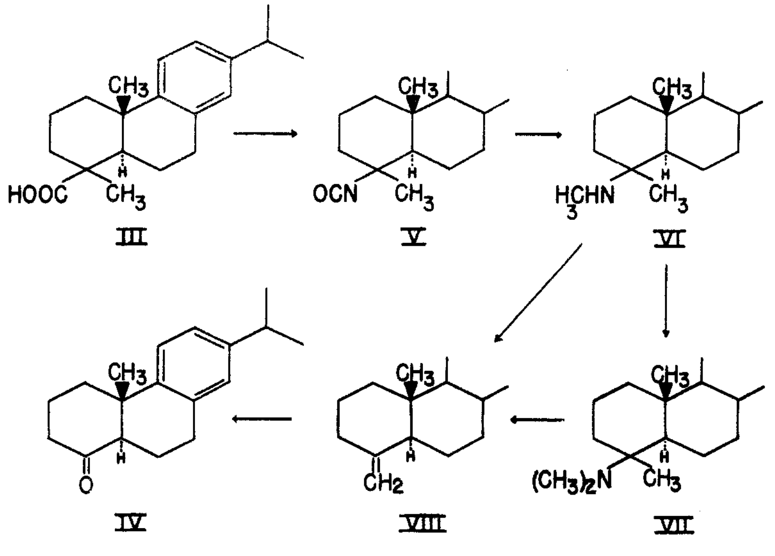
[4] A. Brossi, H. Gutmann and O. Jeger, *Helv. Chim. Acta*, **33**, 1730 (1950); H. H. Zeiss, THIS JOURNAL, **73**, 497 (1951).

[5] G. Stork and A. Burgstahler, *ibid.*, **73**, 3544 (1951).

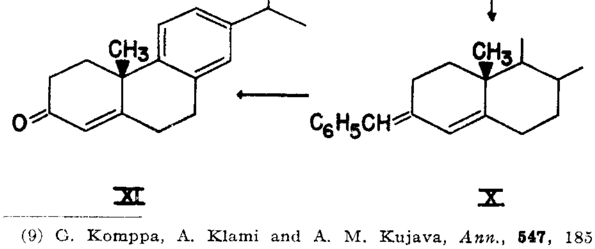
[6] The reduction of an isocyanate to a methylamine, with lithium aluminum hydride, hithertofore unreported, to our knowledge was first performed by W. von E. Doering and K. B. Wiberg (unpublished results).

[7] The facile elimination is attributed to the excessive steric strain obtaining in the quaternary salt.

[8] The ketone itself, on standing for several months, crystallized, m.p. 50.5–51°; semicarbazone, m.p. 216–216.5°. Jeger has reported 30–32° and 204–205°, respectively, for these compounds. NOTE ADDED IN PROOF.—The isolation of a new C-1 ketone by R. P. Jacobsen, THIS JOURNAL, **75**, 4709 (1953), allows the presumption that Jeger's ketone is a *cis-trans* mixture.



that employed by Komppa, Klami and Kujava[9] in the conversion of verbanone to pinocamphone is typical. A new method of achieving such a transformation has been developed which has the sole advantage of greater convenience. The ketone IV is condensed with benzaldehyde in aqueous, alcoholic sodium hydroxide from which the 1-keto-2-benzilidene derivative (IX) is obtained. The conjugated nature of this ketone is shown by its λ_{max} 292 mμ, log ϵ 4.19, λ(C=O) 5.97 μ. Reduction of IX with aluminum isopropoxide in boiling xylene is accompanied by elimination to yield the 2-benzilidene-$\Delta^{1,11}$ product (X), λ_{max} 288 mμ, log ϵ 4.5, infrared carbonyl region clear. From the selective ozonolysis of X in ethyl acetate at $-60°$ there is isolated the desired steroidal analog, 2-keto-$\Delta^{1,11}$-nordehydroabietene (XI), λ_{max} 236 mμ, log ϵ 4.31, λ (C=O) 6.01 μ. Application of the same reaction series just described to the model compound, *cis*-α-decalone, leads to the known 2-keto-$\Delta^{1,9}$-octalin, which on catalytic hydrogenation yields a mixture of *cis*- and *trans*-β-decalones.



The ketones IV and XI are structurally related through reduction to the $C_{18}H_{26}$ hydrocarbon (XII), nordehydroabietane. Since IV is optically stable in boiling alcoholic potassium hydroxide, the fusion of rings A/B of IV is probably *trans*,[10] in agreement with the conclusion of Barton and Schmeidler[11] regarding the resin acids themselves. The reduction of IV by zinc amalgam in hydrochloric acid, acetic acid and toluene leads, therefore, to *trans*-XII. Catalytic hydrogenation of XI over palladium black in ethanol gives the saturated 2-keto product (XIII), λ (C=O) 5.84 μ, which is further reduced by the modified Clemmensen method to the $C_{18}H_{26}$ hydrocarbon (XIIIa). The optical rotations and infrared spectra of *trans*-XII and XIIa (Fig. 5) indicate that hydrocarbon XIIa is either the *cis* isomer or, more probably, a mixture of *cis* and *trans* forms, arising originally from hydrogenation of XI.

The conversion of diterpenic acids to steroidal substances must depend inevitably upon the stereochemical configuration of the C-12 angular methyl group. Inasmuch as this position is not subject to stereochemical control, an α-configuration of this methyl group would impose a most difficult obstacle. Fortunately, there now exists considerable evidence pointing to a correct β-configuration. Klyne[12] has correlated the stereochemistry of rings A/B of the triterpenes with that of the steroids by a method of molecular rotational differences which suggests that if the difference between the molecular rotations of a ring A ketonic compound and its corresponding saturated derivative is positive, then the A/B angular group is β. Since this positive shift of rotation has been observed with a large number of steroids and triterpenoid ketones, as well as the 2-keto-$\Delta^{1,6}$ product prepared from lanostadienol by Ruzicka and co-workers,[13] a mirror-image relationship at the rings A/B angular methyl group between the triterpenes and the steroids becomes unacceptable. From the establishment of the stereochemical identity of rings A and B of abietic acid and manoöl[14] and of manoöl and the triterpenes[15] the diterpenic angular methyl group would appear to be beta also. The preparation of the diterpenoid ketones and their corresponding hydrocarbons reported in this paper allows a direct application of Klyne's method to the diterpenes.

Comparison of the molecular rotations of IV and XI (Table I) with that of *trans*-XII gives Δ

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[9] G. Komppa, A. Klami and A. M. Kujava, *Ann.*, **547**, 185 (1941). Verbanone is treated with sodamide and then carbonated to the β-keto acid. The β-hydroxy acid is obtained on electrolytic reduction of the keto acid, followed by acetic anhydride dehydration to the α,β-unsaturated acid. The corresponding acid chloride is treated with sodium azide and then hydrolyzed to pinocamphone. See also J. Bredt and W. H. Perkin, Jr., *J. Chem. Soc.*, **103**, 2182 (1913); J. Bredt and M. Bredt-Savelsberg, *Ber.*, **62**, 2214 (1924).

[10] This conclusion presupposes, of course, that no configurational changes have occurred at C-11 during the conversion of dehydroabietic acid to 1-ketonordehydroabietane.

[11] D. H. R. Barton and G. A. Schmeidler, *J. Chem. Soc.*, 1197 (1948).

[12] W. Klyne, *ibid.*, 2916 (1952).

[13] W. Voser, D. E. White, H. Heusser, O. Jeger and L. Ruzicka, *Helv. Chim. Acta*, **35**, 830 (1952).

[14] O. Jeger, O. Dürst and G. Büchi, *ibid.*, **30**, 1853 (1947).

[15] L. Ruzicka, O. Dürst and O. Jeger, *ibid.*, **30**, 353 (1947).

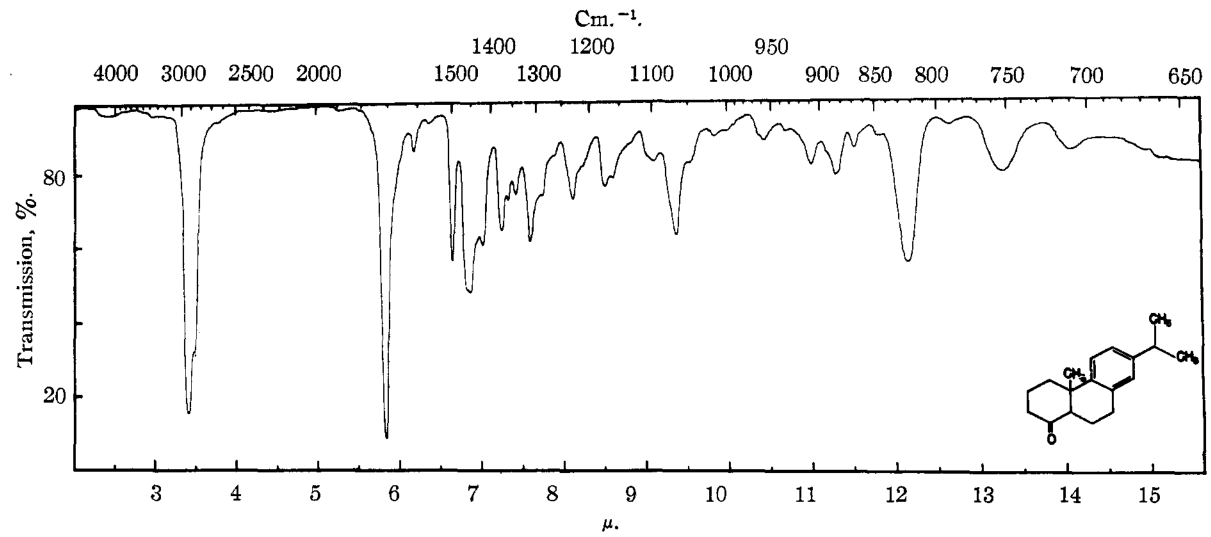

Fig. 1.

(C=O) and Δ (C=C—C=O) values of +199° and +580°, respectively, and the Δ (C=O) of XIII and XIIa is +77°. These large positive Δ values lend support, therefore, to the tentative conclusion that the C-12 methyl group of the diterpenic acids is stereochemically related to the A/B angular methyl group of the steroids.

Table I

Table of Molecular Rotations[a]

	Compound	$[\alpha]_D$	$[M]_D$	Δ
XII	*trans*-Nordehydroabietane	+52.2°	+127°	0
IV	1-Ketonordehydroabietane	+127	+326	+199 (IV–XII)
XI	2-Keto-$\Delta^{1,11}$-nordehydroabietene	+278	+707	+580 (XI–XII)
XIIa	Nordehydroabietane	+27.1	+65.7	0
XIII	2-Ketonordehydroabietane	+55.7	+143	+77 (XIII–XIIa) +16 (XIII–XII)

[a] All rotations were measured in absolute ether at temperatures ranging between 25–28° in a 1-dm. tube.

Acknowledgment.—We wish to express our appreciation for the kind and generous support of this work by the Research Corporation of New York and for the fellowship aid to one of us (W. B. M.) by the du Pont Company.

Experimental

Dehydroabietane-1-isocyanate.—Dehydroabietic acid, m.p. 172–173.5°, $[\alpha]^{26}_D$ +62.7°, 63.2 g., was dissolved in 550 ml. of dry ether to which 28 g. of freshly distilled thionyl chloride and a few drops of pyridine were added. The solution was refluxed for 22 hours and then extracted with 1% sodium hydroxide. The ether layer was washed with water to neutrality, dried and the ether removed at 70° *in vacuo*. The crude acid chloride, weighing 66.2 g. and showing strong carbonyl absorption at 5.5 μ in its infrared spectrum, was dissolved in 525 ml. of cold acetone, and a solution of 13.6 g. of sodium azide in 38.5 ml. of water was added with vigorous stirring. After 20 minutes of agitation the oily mixture was poured into 1 l. of water and the oil extracted with xylene. At room temperature a slow evolution of nitrogen from the dried xylene solution was noted and at 90° gas evolution continued smoothly. After this reaction had subsided, the solution was heated to reflux, a total of about 85% of nitrogen being obtained. A small portion of the xylene solution was freed of xylene and the residue was evaporatively distilled at 50–60° (0.01 mm.) to give the clear, colorless dehydroabietane-1-isocyanate as a liquid distillate, $[\alpha]^{24}_D$ +58.6° (α 1.74°, c 2.97 in benzene).

Anal. Calcd. for $C_{20}H_{27}ON$: C, 80.76; H, 9.15; N, 4.71. Found: C, 80.62; H, 9.14; N, 4.66.

The infrared spectrum of this substance shows intense absorption at 4.5 μ, characteristic of the —N=C=O group and no C=O absorption at 5.5 or 5.85 μ. On standing, the liquid isocyanate decomposed to an amorphous solid which, after chromatography and crystallization from benzene, melted between 215–221.5° (uncor.). It analyzed approximately the same as the isocyanate but contained no band at 4.5 μ. Its spectrum, showing strong bands at 6.1 and 6.5 μ, was not comparable with that of dehydroabietoyl amide. This solid may be N,N′-didehydroabietylurea, but it was not characterized further.

N-Methyldehydroabietane-1-amine.—The xylene solution from the Curtius reaction on 63.2 g. of dehydroabietic acid (less *ca.* 5% for isocyanate isolation) was slowly added with stirring to 45.7 g. of lithium aluminum hydride in absolute ether. The temperature was maintained at or below 35° during most of the addition and was later allowed to rise to 42°. After completion of reaction 154 ml. of ethyl acetate was added followed by water until the mixture became cream-colored. The inorganic salt was centrifuged and washed with ether. Removal of solvents *in vacuo* left 61 g. of a viscous yellow oil which, after evaporative distillation between 95–100° (0.01 mm.), yielded 43.9 g. of a strongly basic, colorless distillate. Treatment of its ether solution with dry hydrogen chloride produced 45.4 g. of the amine hydrochloride. The free amine was liberated by dissolving the salt in water and treating with potassium hydroxide. The resultant oil was redissolved in ether and reprecipitated as the hydrochloride twice more, after which 38.4 g. (57% from dehydroabietic acid) of pure amine salt was obtained, m.p. 199–202° dec.

Anal. Calcd. for $C_{20}H_{32}NCl$: C, 74.61; H, 10.02; N, 4.35. Found: C, 75.00; H, 10.23; N, 4.50.

This hydrochloride (3.15 g.) was converted to the free amine and the amine was evaporatively distilled at 45–50° (0.01 mm.) to yield 2.7 g. of colorless distillate, n^{25}_D 1.5471, $[\alpha]^{27}_D$ +26.5° (α 0.13, c 0.49 in absolute ether).

Anal. Calcd. for $C_{20}H_{31}N$: C, 84.14; H, 10.95; N, 4.91. Found: C, 84.07; H, 10.87; N, 5.03.

Two characterizing absorption bands at 3.1 and 8.8 μ were observed in its infrared spectrum.

N,N-Dimethyldehydroabietane-1-amine.—N-Methyldehydroabietane-1-amine (2.40 g.) was dissolved in 90% formic acid, 1.5 g. of formalin was added and the solution was refluxed under nitrogen for 24 hours. This was next concentrated *in vacuo*, and the residual yellow liquid was poured into water, made alkaline with potassium hydroxide and extracted with ether. Removal of the ether left 2.64 g. of crude tertiary amine which, after evaporative distillation between 83–89° (0.01 mm.) and several precipitations as the hydrochloride from dry ether, gave the salt, m.p. 230–231°. Alternatively, the hydrochloride can be recrystallized from water.

Anal. Calcd. for $C_{21}H_{34}NCl$: C, 75.08; H, 10.20; N, 4.17. Found: C, 74.02; H, 10.18; N, 4.01.

Regeneration of the free amine with base and evaporative distillation between 78–82° (0.01 mm.) yielded 2.0 g. (78%) of N,N-dimethyldehydroabietane-1-amine. The alkylation of 28.8 g. of N-methyldehydroabietane-1-amine gave 19.7 g. (65%) of the dimethylamine which crystallized on standing, m.p. 39–40°, $[\alpha]^{28}\text{D}$ +3.5° (α 0.51°, *c* 14.45 in absolute ether).

Anal. Calcd. for $C_{21}H_{33}N$: C, 84.22; H, 11.11; N, 4.68. Found: C, 84.39; H, 11.10; N, 4.85.

The spectrum of the tertiary amine lacked the N–H stretching band at 3.1 μ. Its hydrochloride melted between 231–232°.

Anal. Found: C, 74.57; H, 9.85; N, 4.21.

$\Delta^{1\text{-exo}}$-Dehydroabietene. (a) From N-Methyl-dehydroabietane-1-amine.—The secondary amine (3.1 g.) was dissolved in 150 ml. of absolute ethanol to which 25 g. of anhydrous potassium carbonate and 25 g. of freshly distilled methyl iodide were added. After refluxing the dry system for 50 hours, the mixture was filtered, the solid washed with chloroform and the combined filtrates and washings concentrated *in vacuo* at 35–40°, leaving 2.8 g. of yellow oil. This oil, neutral, water-insoluble and free of halide ion, was evaporatively distilled at 73–78° (0.01 mm.) to give 2.37 g. (86%) of olefin, $n^{25}\text{D}$ 1.5500, $[\alpha]^{24}\text{D}$ + 195.5 (α 30.07, *c* 15.38 in 1,1-dichloroethane). The terminal methylene group in this olefin is shown clearly by bands at 6.1 and at 11.3 μ (very strong) in its infrared spectrum.

Anal. Calcd. for $C_{19}H_{26}$: C, 89.70; H, 10.30. Found: C, 89.44; H, 10.33.

(b) **From N,N-Dimethyldehydroabietane-1-amine.**—The dimethylamine (1.56 g.) was treated with 24 g. of methyl iodide in 20 ml. of ether and refrigerated for six days, after which 0.15 g. of solid quaternary iodide was obtained. However, when 8 g. of additional methyl iodide was added and the mixture allowed to stand for five hours at room temperature, it became almost solid. Removal of excess of methyl iodide at the aspirator pump and extraction of the solid with ether left 1.82 g. of the quaternary salt. The combined solids were dissolved in methanol (immediate odor of amine) and freshly prepared silver oxide was added. After stirring for 2.5 hours the silver salts were filtered and washed with fresh methanol. Solvent methanol was removed at the aspirator between 55–60° and the vapors were collected in a cold trap. This distillate was very basic and was titrated with picric acid to neutrality. Removal of methanol from the distillate left 0.44 g. of yellow, solid picrate, which, after recrystallization from ethanol, melted at 223–224 dec. Mixed m.p. with the picrate of authentic trimethylamine gave no depression.

The oil remaining from the original methanol distillation was evaporatively distilled between 85–110° (0.1 mm.), yielding 1.1 g. (87%) of the olefin. Subsequent reactions on larger amounts of the dimethylamine (4.2 and 14.5 g. lots) gave almost quantitative yields of the olefin.

1-Ketonordehydroabietane.—A number of ozonizations of $\Delta^{1\text{ exo}}$-dehydroabietene were performed in either ethyl acetate or 1,1-dichloroethane at temperatures between −60 and −70°. Yields of the desired ketone ranging between 45–58% were obtained in the former solvent and about 30% in the latter. The general procedure involved passing just under the theoretical quantity of ozone through the cold solution of the olefin, removal of the solvent under reduced pressure and refluxing the ozonide with zinc dust in water. The organic material was extracted next with ether. In one experiment the water–zinc dust mixture was filtered and the water was treated with an ethanolic solution of 2,4-dinitrophenylhydrazine containing a trace of hydrochloric acid. After heating on the steam-bath, the solution was cooled to give a solid which, after recrystallization from ethanol melted between 164.5–165.5°. These orange needles proved to be the 2,4-dinitrophenylhydrazone of formaldehyde and melted undepressed when mixed with an authentic sample.

The ether solution of the decomposed ozonide was washed with base to remove small amounts of unidentified acidic material. Girard T reagent was then used in the usual manner to separate ketonic and non-ketonic fractions. The latter fraction was always found to contain substantial quantities of unreacted olefin which were reozonized to produce additional amounts of ketone. The ketonic fraction was further purified by chromatographing through a column of alumina using benzene both as solvent and as eluant. The benzene eluant was evaporatively distilled at 80–97° (0.01 mm.) to give a colorless and very viscous distillate. After standing for several months in the refrigerator, this material slowly crystallized, the crystallizate obtained melting between 38–39° without further purification. A later preparation, seeded with these crystals, slowly deposited well-formed prisms, which, after centrifuging from its sirup, melted between 50–51°. The extreme solubility of these crystals prevented recrystallization from solvent. However, the crystalline as well as the sirupy ketone analyzes correctly for *d*-1-ketonordehydroabietane. The infrared spectra, showing carbonyl absorption at 5.8 μ, are identical with each other as well as with the spectrum of the synthetic *dl*-1-ketonordehydroabietane obtained by Stork and Burgstahler[5] and the rotations[4] are also in close agreement: $[\alpha]^{29}\text{D}$ +124.7° (α 3.48, *c* 2.79 in 95% ethanol). The ultraviolet spectrum of the ketone showed no conjugated chromophoric system.

Anal. Calcd. for $C_{18}H_{24}O$: C, 84.32; H, 9.44. Found (crystalline): C, 84.36; H, 9.31; (sirupy) C, 84.65; H, 9.69.

The 2,4-dinitrophenylhydrazone of 1-ketonordehydroabietane was prepared using a trace of concentrated hydrochloric acid. The derivative obtained, m.p. 83–87°, was chromatographed through alumina using benzene as solvent and eluant. After recrystallization from aqueous methanol material was obtained melting between 94–96°.

Anal. Calcd. for $C_{24}H_{28}O_4N_4$: C, 66.03; H, 6.47; N, 12.84. Found: C, 66.05; H, 6.62; N, 14.08.

The same derivative was prepared using sulfuric acid as catalyst. After chromatographing and recrystallizing as before, material was obtained melting between 85–86°.

Anal. Found: C, 64.08; H, 6.51; N, 12.01.

The semicarbazone of 1-ketonordehydroabietane was prepared in the usual manner and was purified by chromatographing through alumina using benzene as the solvent and methanol as the eluant. Recrystallization from aqueous methanol gave material melting between 216–216.5° dec.

Anal. Calcd. for $C_{19}H_{27}ON_3$: C, 72.80; H, 8.68; N, 13.41. Found: C, 73.39; H, 8.91; N, 12.99.

1-Ketonordehydroabietane (0.94 g.) was dissolved in 30 ml. of 95% ethanol containing 0.7 g. of potassium hydroxide and 1 ml. of water. The solution was refluxed for one hour during which the solution turned red. After cooling it was poured into 600 ml. of water and the orange-red liquid was extracted with ether. After decolorizing with Norit and removal of the ether, the ketone was chromatographed through alumina with benzene. Evaporative distillation between 85–93° (0.01 mm.) gave 0.86 g. (91%) of the colorless ketone. The infrared spectrum and the rotation, $[\alpha]^{29}\text{D}$ +123° (in 95% ethanol), of the ketone were unchanged.

***trans*-Nordehydroabietane.**—1-Ketonordehydroabietane (0.62 g.) was dissolved in 3 ml. of toluene to which 5.5 g. of amalgamated mossy zinc, 6.6 ml. of concentrated hydrochloric acid and 11 ml. of acetic acid were added. The mixture was refluxed for one day with occasional additions of 3-ml. portions of hydrochloric acid totaling 15 ml. After dilution with 300 ml. of water the solution was extracted with ether. Washing, drying and removal of the solvent ether left 0.59 g. of liquid. This impure hydrocarbon was treated with Girard T reagent and the non-ketonic fraction was chromatographed through alumina with petroleum ether. Evaporative distillation of the eluted hydrocarbon between 78–82° (0.1–1 mm.) gave 0.44 g. (75%) of colorless liquid hydrocarbon, $n^{25}\text{D}$ 1.5403, $[\alpha]^{27}\text{D}$ +52.2° (α 3.78, *c* 7.24 in ether).

Anal. Calcd. for $C_{18}H_{26}$: C, 89.19; H, 10.81. Found: C, 88.98; H, 11.06.

The ultraviolet spectrum of nordehydroabietane showed slightly modified absorption for the aromatic system of dehydroabietic acid, $\lambda_{\max}$ 267 mμ, log ϵ 3.05; $\lambda_{\max}$ 276 mμ, log ϵ 3.05.

The 6,8-dinitro derivative of nordehydroabietane was prepared by adding nordehydroabietane (0.35 g.) to an ice-cooled solution of 2 ml. of concentrated nitric acid in 3 ml. of sulfuric acid. This was stirred vigorously during the addition and for 15 minutes thereafter. After coming to room temperature the mixture was poured into 200 ml. of icewater and the resultant tan precipitate was filtered, dissolved in a mixture of ether and benzene and washed well with water. Removal of the solvents left 0.45 g. of crude nitrated product which was chromatographed through alumina with benzene and pentane. The eluate was recrystallized from ethanol to a constant m.p. of 141–141.5°.

Anal. Calcd. for $C_{18}H_{24}O_4N_2$: C, 65.04; H, 7.28; N, 8.43. Found: C, 65.36; H, 7.57; N, 8.24.

2-Keto-$\Delta^{1,11}$-nordehydroabietene.—1-Ketonordehydroabietane (4.9 g.) was condensed with 2.42 ml. of freshly distilled benzaldehyde in 38 ml. of 95% ethanol to which 1.15 g. of sodium hydroxide in 1.15 g. of water was added. After standing at room temperature for four days followed by an additional five days at 0°, the solution had separated into a pale yellow oily layer and a supernatant alcoholic layer. The oily layer was removed, dissolved in ether, washed with water and dried. Removal of the ether left 4.7 g. of a viscous orange liquid. Concentration of the decanted upper layer at reduced pressure with mild warming, extraction with ether and washing of the ether with water was followed by removal of the ether from the dried solution, leaving an additional 2.64 g. of the orange liquid. The ultraviolet absorption of the liquid, $\lambda_{\max}$ 292 mμ, log ϵ 4.2, indicated the presence of the expected **1-keto-2-benzylidenenordehydroabietane**. All attempts to secure this derivative in the crystalline state at room temperature failed. Partial purification was effected by chromatographing through alumina using mixtures of benzene and petroleum ether as eluants.

Anal. Calcd. for $C_{25}H_{28}O$: C, 87.16; H, 8.19. Found: C, 86.52; H, 8.81.

This material, $[\alpha]^{26}\mathrm{D}$ $-52.3°$ (α 0.51°, *c* 0.975 in benzene), underwent change on standing as evidenced by loss of absorption at 292 mμ and was used without delay in the next step.

The 2-benzylidene derivative prepared above (1.86 g.) was dissolved in dry xylene and 15 ml. of a 1 *M* solution of aluminum isopropoxide in isopropyl alcohol was added. After refluxing for four days a consistent negative acetone test was obtained. The reaction flask was cooled, diluted with 10 ml. of water and the contents filtered. The alumina was washed with ether and the combined xylene–ether filtrates were concentrated and passed through an alumina column. Using pentane as the eluant, fractions containing **2-benzylidene-$\Delta^{1,11}$-nordehydroabietene** were obtained. This material showed absorption at 288 mμ, log ϵ 4.5 and showed no carbonyl absorption in its infrared spectrum. From the reduction and dehydration of 4 g. of the 2-benzylidene compound a yield of 1.71 g. (45%) was obtained, $[\alpha]^{29}\mathrm{D}$ +353° (α 3.78°, *c* 1.07 in ether). This phenylbutadiene system is unstable and was used in the impure state.

With ethyl acetate as solvent at −60° 2-benzylidene-$\Delta^{1,11}$-nordehydroabietene (1.45 g.) was treated with ozone until the exhaust gases tested for ozone. The excess ozone was blown out with oxygen, and 1 g. of zinc dust was added. After removal of the solvent, water was added and the mixture was refluxed under nitrogen for one hour during which the odor of benzaldehyde was noted. Ether extraction yielded 1.4 g. of a brown oil which was chromatographed through a column of alumina using 2:1 benzene–petroleum ether as solvent and benzene as eluant. In this manner 0.29 g. (26%) of the desired unsaturated ketone was obtained. Rechromatographing of 0.24 g. of this material using pentane as solvent and 1:1 pentane–benzene as eluant gave 0.19 g. (17%) of pure liquid 2-keto-$\Delta^{1,11}$-nordehydroabietene, $n^{25}\mathrm{D}$ 1.5682, $[\alpha]^{27}\mathrm{D}$ +264° (α 0.95, *c* 0.36 in 95% ethanol). Its ultraviolet spectrum showed two absorption peaks, $\lambda_{\max}$ 225 mμ and 236 mμ (log ϵ of 4.28 and 4.31, respectively). In the infrared range it showed unsaturated carbonyl absorption at 6.01 μ.

Anal. Calcd. for $C_{18}H_{22}O$: C, 84.99; H, 8.72. Found: C, 84.50; H, 8.73.

The semicarbazone was prepared and, after recrystallization from aqueous ethanol, melted constantly between 208–209° and absorbed at 269 mμ (log ϵ 4.74).

Anal. Calcd. for $C_{19}H_{25}ON_3$: C, 73.28; H, 8.03; N, 13.49. Found: C, 73.34; H, 8.13; N, 13.10.

2-Ketonordehydroabietane.—Hydrogenation at 28° and under one atmosphere of 175 mg. of 2-keto-$\Delta^{1,11}$-nordehydroabietene with palladium black in absolute ethanol resulted in the uptake of one mole equivalent of hydrogen within 30 minutes. After removal of the catalyst and the solvent, the residual liquid was treated with Girard T reagent and thereby separated into two fractions, one of which was extractable with Girard T and was identified as unhydrogenated material (28 mg.). The other fraction (136 mg.) showed no absorption maxima in the ultraviolet region between 220 and 250 mμ and showed strong carbonyl absorption at 5.8 μ and no hydroxyl band in the infrared. This fraction was purified further by chromatographing through alumina using petroleum ether as solvent and 1:1 petroleum ether–benzene as eluant. The eluted, colorless 2-ketonordehydroabietane was evaporatively distilled at 70° (0.05 mm.) to give 116 mg. (66%) of product whose ultraviolet spectrum contained typical absorptions of dehydroabietic acid, $\lambda_{\max}$ 267 mμ (log ϵ 3.20) and $\lambda_{\max}$ 276 mμ (log ϵ 3.23), $n^{25}\mathrm{D}$ 1.5480, $[\alpha]^{25}\mathrm{D}$ +55.7° (α 0.34°, *c* 0.61 in ether).

Anal. Calcd. for $C_{18}H_{24}O$: C, 84.32; H, 9.44. Found: C, 84.36; H, 9.47.

The semicarbazone of the saturated 2-ketone was prepared and recrystallized from aqueous ethanol, m.p. 186–187°. A mixture of this semicarbazone with that of 1-ketonordehydroabietane gave a depressed melting point.

Anal. Calcd. for $C_{19}H_{27}ON_3$: C, 72.80; H, 8.68; N, 13.41. Found: C, 73.09; H, 8.68; N, 13.82.

2-Ketonordehydroabietane (0.33 mg.) is reduced by the modified Clemmensen method described earlier for 1-ketonordehydroabietane, and the hydrocarbon product, nordehydroabietane, purified also in the same way. This material has essentially the same infrared spectrum as that of *trans*-nordehydroabietane excepting the lack of weak absorption bands at 8.2, 10.1 and 11.2 μ. The ultraviolet spectra of the two hydrocarbons are in close agreement. However, its rotation is lower than that of the *trans*-nordehydroabietane, the inference of this fact being that it is either a mixture of *cis* and *trans* isomers or the *cis* isomer: $[\alpha]^{27}\mathrm{D}$ +27.1° (α 0.45°, *c* 1.66 in ether).

Anal. Calcd. for $C_{18}H_{26}$: C, 89.19; H, 10.81. Found: C, 89.01; H, 11.03.

2-Benzylidene-α-decanol.—*cis*-α-Decalone (26.7 g.) was condensed with benzaldehyde according to the procedure of Johnson[16] from which 27 g. (64%) of **2-benzylidene-α-decalone**, m.p. 92–93.5°, was obtained.

Anal. Calcd. for $C_{17}H_{20}O$: C, 84.96; H, 8.39. Found: C, 85.16; H, 8.38.

This substance shows a $\lambda_{\max}$ 285 mμ, log ϵ 4.22, in the ultraviolet and strong carbonyl absorption at 5.95 μ in the infrared regions.

Five grams of the 2-benzilidene ketone[17] was reduced with 5 g. of aluminum isopropoxide in 100 ml. of isopropyl alcohol over a period of three days, after which acetone formation had ceased. The isopropyl alcohol was removed *in vacuo* and 20 ml. of water was added. Ether extraction of the product was followed by crystallization of the carbinol from aqueous ethanol to give 4.0 g. (79%) of 2-benzylidene-α-decalol, m.p. 97–98°.

Anal. Calcd. for $C_{17}H_{22}O$: C, 84.25; H, 9.15. Found: C, 84.00; H, 9.25.

Its spectra (ultraviolet and unfrared) contained absorption bands at 245 mμ, log ϵ 4.16, 2.8 and 3.0μ (O–H) and 9.8μ (C–O, α, β-unsaturated secondary hydroxyl).

The acetate of this carbinol was prepared with acetic anhydride and pyridine and melted between 56.5-57.5° after crystallization from aqueous ethanol.

Anal. Calcd. for $C_{19}H_{24}O_2$; C, 80.24; H, 8.51. Found: C, 80.38; H, 7.96.

2-Benzylidene-$\Delta^{1,9}$-octalin. **(a) From 2-Benzylidene-α-decalone.**—The 2-benzylidene ketone (5.7 g.) was dissolved in xylene and added to 50 ml. of a 1 *M* solution of aluminum isopropoxide in isopropyl alcohol. The solution was heated to boiling and the isopropyl alcohol and acetone were allowed to distil. After eight days the reaction mixture was cooled, treated with water and filtered. The xylene was removed and the residue crystallized from ether in a Dry Ice-bath. Recrystallization in the same manner yielded 2.4 g. (45%) of pure 2-benzylidene-$\Delta^{1,9}$-octalin, m.p. 76–77°.

Anal. Calcd. for $C_{17}H_{20}$: C, 91.01; H, 8.99. Found: C, 90.75; H, 9.08.

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[16] W. S. Johnson, THIS JOURNAL, **65**, 1317 (1943).

[17] Wolff–Kishner reduction of this ketone failed to give any isolable product.

Its ultraviolet spectrum shows one strong absorption peak at 285 mμ, log ε 4.48.

(b) **From 2-Benzylidene-α-decalol.**—Many dehydration experiments were performed using acetic anhydride, tosyl chloride, potassium hydrogen sulfate, boric acid and oxide, iodine, formic acid, Shaw solution, thionyl chloride in pyridine and conditions for xanthate preparation and decomposition. These methods either failed or gave the desired product in very poor yield. Of these the use of acetic anhydride is described. Three grams of 2-benzylidenecarbinol was refluxed in 200 ml. of acetic anhydride for 19 hours, then cooled and poured into 200 ml. of iced water. The oily layer was separated by decantation of the supernatant aqueous layer, taken up in ether and isolated by ether evaporation: 2.84 g. This was chromatographed through alumina using petroleum ether as solvent and eluant, from which 1.39 g. of semi-solid eluate was obtained having ultraviolet absorption in the 280 mμ region. This was rechromatographed with pentane from which 0.54 g. of crystalline product was secured in the first eluates. Recrystallization of this material gave a total of 0.33 g. (12%) of the pure 2-benzylidene-$\Delta^{1,9}$-octalin.

2-Keto-$\Delta^{1,9}$-octalin.—2-Benzylidene-$\Delta^{1,9}$-octalin (2.33 g.) was ozonized in 150 ml. of ethyl acetate at −60° for approximately three-quarters of the theoretical time. Zinc dust (1 g.) was added and the solution was concentrated *in vacuo*. Water was added next and the mixture refluxed for one hour. Ether extraction removed an oil which was treated directly with Girard T reagent. About 0.6 g. of ketonic material was isolated which upon evaporative distillation between 85–100° (0.1 to 1 mm.) yielded a total of 0.32 g. (20%) of 2-keto-$\Delta^{1,9}$-octalin, n^{26}D 1.5213.[18] This substance absorbed at 238 mμ, log ε 4.15, in the ultraviolet region and had carbonyl absorption at 6.02 μ in its infrared spectrum.

The semicarbazone of the unsaturated ketone was prepared and crystallized from ethanol, m.p. 207–208°.

Anal. Calcd. for $C_{11}H_{17}ON_3$: C, 63.74; H, 8.27; N, 20.27. Found: C, 63.34; H, 8.40; N, 20.17.

Its ultraviolet spectrum displays a very intense maximum at 269 mμ, log ε 4.59.

Its 2,4-dinitrophenylhydrazone was also prepared and crystallized from ethyl acetate, m.p. 168–169°.

Anal. Calcd. for $C_{16}H_{18}O_4N_4$: C, 58.17; H, 5.49; N, 16.96. Found: C, 58.10; H, 5.52; N, 16.95.

β-Decalone.—2-Keto-$\Delta^{1,9}$-octalin (226 mg.) was hydrogenated at atmospheric pressure in ethyl acetate with platinum. After a 10% excess of an equimolar amount of hydrogen had been absorbed, the solvent and catalyst were removed leaving a colorless oil which was evaporatively distilled between 45–60° (35 mm.); 84 mg. (37%), n^{27}D 1.4863.[19] The infrared spectrum of this material showed strong carbonyl absorption at 5.85 μ and none at 6.0 μ. Continued distillation between 70–120° (0.1 mm.) yielded 73 mg. (32%) of additional distillate, n^{27}D 1.5099, having the same carbonyl absorption as above, but which was apparently contaminated with β-decalol.

A 2,4-dinitrophenylhydrazone derivative was prepared from the latter fraction. A small portion of this derivative was recrystallized to a m.p. of 164.5–166°. However, recrystallization of the main fraction from ethanol was accompanied by upward and downward fluctuations in m.p.'s after each subsequent recrystallization and by a concurrent appearance of yellow and orange crystals. Finally, a sample melting between 111–114° was analyzed. This erratic behavior is believed to be due to the non-homogeneity of a *cis*-*trans* mixture.

Anal. Calcd. for $C_{16}H_{20}O_4N_4$: C, 57.82; H, 6.07; N, 16.86. Found: C, 57.78; H, 6.46; N, 16.67.

The semicarbazone of this fraction was also prepared and crystallized from absolute ethanol, m.p. 175.5–176.5°.

Anal. Calcd. for $C_{11}H_{19}ON_3$: C, 63.12; H, 9.15; N, 20.08. Found: C, 62.95; H, 9.15; N, 19.99.

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(18) E. C. du Feu, F. J. McQuillin and R. Robinson, *J. Chem. Soc.*, 53 (1937); report the following values: 2-keto-Δ^{19}-octalin, n^{18}D 1.5238; semicarbazone, m.p. 208°; 2,4-dinitrophenylhydrazone, m.p. 168°.

(19) The authors of ref. 17 report the following values for what they consider to be *cis*-β-decalone, arising from the palladium-on-strontium carbonate hydrogenation of 2-keto-$\Delta^{1,9}$-octalin, n^{20}D 1.4888; semicarbazone, m.p. 182–183°. C. Mannich, W. Koch and F. Borkowski, *Ber.*, **70**, 355 (1937), give a m.p. of 192° for the semicarbazone of *trans*-β-decalone; W. Hückel, *Ann.*, **441**, 28 (1925), lists the following constants: *cis*-β-decalone, n^{20}D 1.49265 and *trans*-β-decalone, n^{19}D 1.48088.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF WAYNE UNIVERSITY]

Terpenoids. III.[1] The Isolation of Erythrodiol, Oleanolic Acid and a New Triterpene Triol, Longispinogenin, from the Cactus *Lemaireocereus longispinus*[2]

BY CARL DJERASSI, R. M. McDONALD AND A. J. LEMIN[3]

RECEIVED JULY 15, 1953

The Guatemalan cactus *Lemaireocereus longispinus*, although devoid of alkaloids, has proved to be a rich source of triterpenoid glycosides. Acid hydrolysis of the mixed glycosides produced oleanolic acid, previously isolated from another cactus, erythrodiol and a new triterpene, termed longispinogenin, which has been characterized as Δ^{12}-oleanene-3β,16β-*x*-triol.

In a recent communication[4] there was described an investigation of the triterpenoid constituents of the cactus *Lemaireocereus thurberi* and it was shown that oleanolic acid and a new triterpenoid lactone, thurberogenin, could be isolated. Prompted by this observation, we have undertaken an extensive investigation of certain other members of the *Cactaceae* family, particularly those of the subtribe *Cereanae*, and the present note concerns such an examination of the triterpenoid constituents of the cactus *Lemaireocereus longispinus*. This cactus is apparently restricted to Guatemala[5] and the plants used in the present study were obtained through the courtesy of Srta. Elizabeth Berlin from the gardens of Don Mariano Pacheco H. in Guatemala City.[6]

In contrast to the abundance of alkaloids in certain related genera,[7] *L. longispinus* proved to be devoid of alkaloids as had earlier been found to be

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(1) Paper II, C. Djerassi, E. Wilfred, L. J. Visco and A. J. Lemin, *J. Org. Chem.*, **18**, 1449 (1953).

(2) This investigation was supported by a research grant (G-3863) from the National Institutes of Health, Public Health Service, Department of Health, Education and Welfare.

(3) Postdoctorate Research Fellow, 1953, on funds supplied by the U. S. Public Health Service.

(4) C. Djerassi, L. E. Geller and A. J. Lemin, THIS JOURNAL, **75**, 2254 (1953).

(5) N. L. Britton and J. N. Rose, "The Cactaceae," Vol. II, Carnegie Institution of Washington, Washington, D. C., 1920, p. 89.

(6) It is noteworthy that another Guatemalan cactus, *Nyctocereus guatemalensis*, which was obtained from the same source, has been found to be devoid of glycosides.

(7) C. Djerassi, N. Frick and L. E. Geller, THIS JOURNAL, **75**, 3632 (1953), and subsequent papers to be published from this Laboratory.