[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

Unsaturated Amines. VIII. Dehydrogenation and Hydroxylation of 1-Methyldecahydroquinoline by Means of Mercuric Acetate[1]

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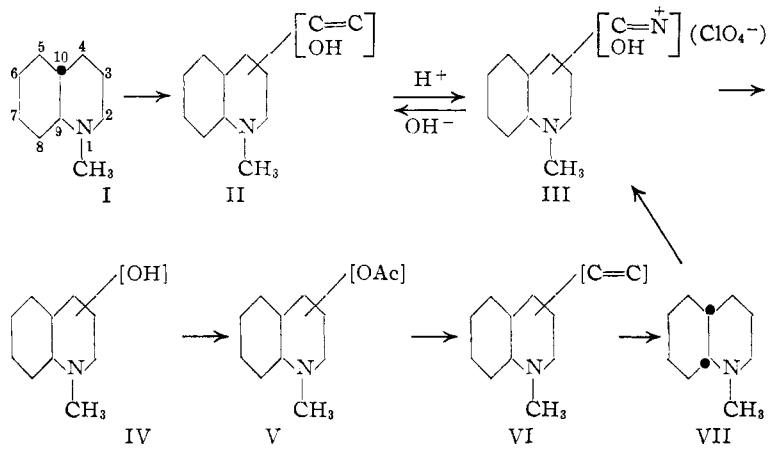
A combination of dehydrogenation and hydroxylation of a saturated tertiary amine has been realized by means of mercuric acetate. The amine which served as the model for this study was 1-methyldecahydroquinoline, which possesses two tertiary carbons alpha and beta to the nitrogen. The main product obtained by treatment of either *cis*- or *trans*-1-methyldecahydroquinoline with mercuric acetate was shown to have the structure 10-hydroxy-1-methyl-Δ^{8}-octahydroquinoline, with salts having the 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium cation. The structure proof rested first on the determination of the juxtaposition of the hydroxyl and double bond functions and ultimately on the synthesis of the unsaturated hydroxyamine and related compounds by other routes. Additional information has been obtained concerning the stereochemical course of reduction of 10-hydroxy-1-methyl-Δ^{8}-octahydroquinoline and 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium salts.

It has been shown[5-8] that one result to be expected from the action of mercuric acetate on cyclic tertiary amines is the introduction of unsaturation α,β to the amino nitrogen. The introduction of additional functionality by means of mercuric acetate offers an intriguing possibility from the point of view of both synthesis and degradation. The reaction of 1-methyldecahydroquinoline with mercuric acetate[9] offers a point of entry into the study of the oxidation of a tertiary amine beyond the initial removal of a pair of hydrogens.



Treatment of *trans*-1-methyldecahydroquinoline (I), $C_{10}H_{19}N$, with mercuric acetate in 5% acetic acid solution (95% aqueous) gave a product, $C_{10}H_{17}NO$, which contained, in addition to the expected carbon–carbon double bond,[5] a hydroxyl group. The optimum yield of this product (54%) was realized by employing a 30-minute reaction time at steam-bath temperature, and the quantity of mercurous acetate precipitated corresponded to a 62% yield on the basis of reaction of four moles of mercuric acetate with one of amine. The location of the unsaturation as α,β to the nitrogen in the new base, suggested by its instability[10] and by previous experience in this Laboratory,[5-8] was indicated by the shift toward higher infrared frequency (1643 to 1668 cm.$^{-1}$) observed in the double bond stretching region in going from the base to its perchlorate salt.[11] The presence of a hydroxyl group in the $C_{10}H_{17}NO$ product (II, assuming the ring system to be unchanged) and its derivatives was indicated by analysis and by characteristic infrared absorption in the 3 μ region; moreover, the product could be acetylated. The perchlorate salt, $C_{10}H_{17}NO\cdot HClO_4$, showed one active hydrogen in the Zerewitinoff determination, and this information, coupled with the infrared data, was consistent with the existence of hydroxyl and ternary iminium (>C=N$^+$< $\longleftrightarrow$ >C$^+$—N<) salt functions (III). The presence of the ternary iminium grouping in III was verified by the high-yield reactions[12] of the perchlorate salt with potassium cyanide to give a hydroxyaminonitrile, $C_{11}H_{18}N_2O$, and with lithium aluminum hydride to give a saturated hydroxyamine, $C_{10}H_{19}NO$.

In establishing the structure of the $C_{10}H_{17}NO$ compound and subsequent products, it was desirable to show first that the original ring system in I had been retained in the conversions described, even though such an assumption seemed reasonably safe. The acetate V of the saturated hydroxyamine IV was formed by prolonged treatment with acetic anhydride and pyridine. Pyrolysis of the acetate resulted in a mixture of unsaturated amines (VI), and catalytic reduction of this mixture gave 1-methyldecahydroquinoline, preponderantly the *cis* form (VII). Formulas II–VI therefore represent the intermediate compounds correctly as having the six–six ring system intact.

Attention was directed next to determination of the function and position of the hydroxyl group in

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(2) Eli Lilly and Co. Fellow, 1953–1954.

(3) Monsanto Chemical Co. Fellow, 1954–1955.

(4) Sinclair Refining Co. Fellow in Organic Chemistry, 1953–1954. Work done under the sponsorship of the Sinclair Research Laboratories, Inc.

(5) N. J. Leonard, A. S. Hay, R. W. Fulmer and V. W. Gash, THIS JOURNAL, **77**, 439 (1955).

(6) N. J. Leonard, P. D. Thomas and V. W. Gash, *ibid.*, **77**, 1552 (1955).

(7) N. J. Leonard, W. J. Middleton, P. D. Thomas and D. Choudhury, *J. Org. Chem.*, **21**, 344 (1956).

(8) Preceding article: N. J. Leonard, R. W. Fulmer and A. S. Hay, THIS JOURNAL, **78**, 3457 (1956).

(9) P. D. Thomas, Ph.D. Thesis, University of Illinois, 1954.

(10) See, for example: R. Adams and J. E. Mahan, THIS JOURNAL, **64**, 2588 (1942); R. Grewe and A. Mondon, *Chem. Ber.*, **81**, 279 (1948).

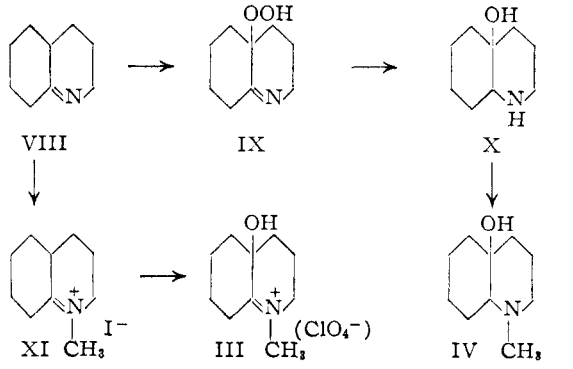
(11) N. J. Leonard and V. W. Gash, THIS JOURNAL, **76**, 2781 (1954).

(12) N. J. Leonard and A. S. Hay, *ibid.*, **78**, 1954 (1956).

II, III and IV. The failure of the saturated hydroxyamine IV to give a positive Tollens test, together with the absence of the unique properties associated with an α-hydroxyamine, ruled out the positions α to the nitrogen as possible points of attachment of the hydroxyl group. Oxidation of IV by 0.05 *M* lead tetraacetate in glacial acetic acid at 60° was taken as qualitative evidence[13] for the presence of a β-hydroxy-3°-amine grouping, which is not attacked at room temperature in the usual lead tetraacetate titration.[14] At 60°, β-hydroxy-3°-amines are oxidized by lead tetraacetate more rapidly than their γ- and δ-hydroxy analogs. The function of the hydroxyl β to the nitrogen was regarded as tertiary on the basis of 95% recovery of IV following chromic acid treatment under conditions normally successful for the oxidation of a secondary alcohol.[15] The failure of IV to form a tosylate might also be regarded as supporting evidence for a 3°-hydroxyl function, but adequate controls in the tosylation of hydroxyamines are lacking. Since there is only one position β to the nitrogen which can hold a 3°-hydroxyl group, compound IV was tentatively assigned the structure 10-hydroxyl-1-methyldecahydroquinoline.

The foregoing assignment limited the structure of the original mercuric acetate oxidation product (II) to 10-hydroxy-1-methyl-Δ^8-octahydroquinoline or 10-hydroxy-1-methyl-Δ^2-octahydroquinoline. The former structure was to be preferred because it would result from dehydrogenation at an α-3°-carbon (C-9), which has been found thus far to be preferential over dehydrogenation at an α-2°-carbon (C-2) in the same molecule,[5-8] and because C-9 is the more logical position of unsaturation to explain hydroxylation at C-10. Moreover, the assignment of the 10-hydroxy-1-methyl-Δ^8-octahydroquinoline structure provided an entirely reasonable explanation for the next experimental observation, that the same product was obtained by mercuric acetate oxidation of both *trans*- and *cis*-1-methyldecahydroquinoline (I, VII).

The structure 10-hydroxy-1-methyldecahydroquinoline assigned to IV was checked by synthesis and through the availability of authentic samples. Thus, $\Delta^{1(9)}$-octahydroquinoline (VIII)[16] was converted to the hydroperoxide IX and thence to 10-hydroxydecahydroquinoline (X), all of established structure.[17,18] The methylation of X (one of the racemates) with formaldehyde and formic acid led to the isolation of one racemate of 10-hydroxy-1-methyldecahydroquinoline (IV),[17,18] the perchlorate and picrate derivatives of which were identical with the corresponding derivatives of the compound obtained by reduction of the mercuric acetate dehydrogenation–hydroxylation product from 1-methyl-



decahydroquinoline (I and VII). Finally, the structure of the original mercuric acetate product was proved by direct synthesis. The methiodide of VIII, 1-methyl-$\Delta^{1(9)}$-octahydroquinolinium iodide (XI),[18,19] offered this unique possibility. Mercuric acetate converted XI to the same $C_{10}H_{17}NO$ product that was obtained from 1-methyldecahydroquinoline. Corresponding salts (*e.g.*, III) of the two samples of the hydroxy-enamine were also shown to be identical by direct comparison. The structures of compounds described above are thus established as: II, 10-hydroxy-1-methyl-Δ^8-octahydroquinoline; III, 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium perchlorate; IV, 10-hydroxy-1-methyldecahydroquinoline; V, 10-acetoxy-1-methyldecahydroquinoline; VI, probable mixture containing 1-methyl-Δ^9-, 1-methyl-$\Delta^{4(10)}$-, and 1-methyl-$\Delta^{5(10)}$-octahydroquinoline.

In addition, the hydroxyaminonitrile which resulted from the combination of III with potassium cyanide can now be assigned the structure 9-cyano-10-hydroxy-1-methyldecahydroquinoline[12] (XII, probably *trans*).

The perchlorate of XII is relatively stable below 35°. The picrate can be formed in ether, but attempted recrystallization from ethanol or formation in ethanol resulted in the elimination of hydrogen cyanide and the isolation of 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium picrate.[20] The unsaturated product II was also the result of attempted lithium aluminum hydride reduction[12] of XII.

The probable course of the dehydrogenation–hydroxylation of 1-methyldecahydroquinoline proceeds with intermediate formation of 1-methyl-$\Delta^{1(9)}$-octahydroquinolinium acetate (XIII). This material (undoubtedly the main organic component originating in the treatment of 1-methyl-$\Delta^{1(9)}$-octahydroquinolinium iodide (XI) with acetic acid and mercuric acetate) has been shown to undergo hy-

(13) N. J. Leonard and M. A. Rebenstorf, THIS JOURNAL, **67**, 49 (1945).

(14) D. H. R. Barton, C. J. W. Brooks and J. S. Fawcett, *J. Chem. Soc.*, 2137 (1954).

(15) *E.g.*, D. H. R. Barton, C. J. W. Brooks and P. de Mayo, *ibid.*, 3950 (1954).

(16) Details to be reported by G. Stork, R. Terrell and J. Szmuszkovicz; for Communication see THIS JOURNAL, **76**, 2029 (1954).

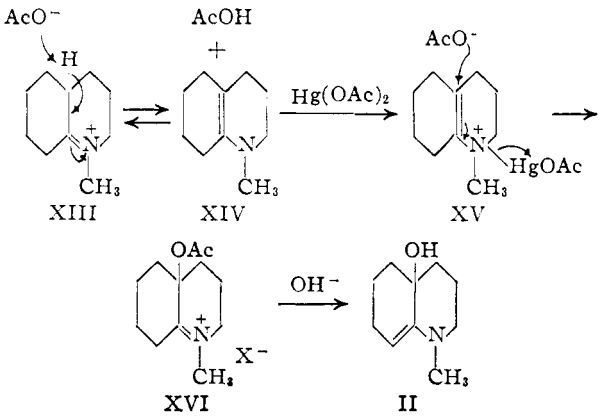
(17) B. Witkop and L. A. Cohen, Abstracts of the XIVth International Congress of Pure and Applied Chemistry, Zürich, Switzerland, July, 1955, #206.

(18) L. A. Cohen and B. Witkop, THIS JOURNAL, **77**, 6595 (1955).

(19) We are indebted to Dr. Bernhard Witkop, National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, Bethesda, Md., not only for generously providing samples of 10-hydroxydecahydroquinoline and 10-hydroxy-1-methyldecahydroquinoline picrate but also for sending us a copy of his paper with Dr. L. A. Cohen[18] in manuscript form.

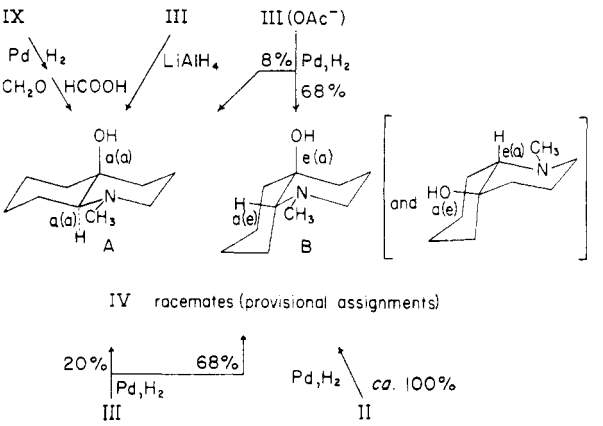
(20) N. J. Leonard and G. W. Leubner, THIS JOURNAL, **71**, 3408 (1949).

droxylation to give, on work-up, 10-hydroxy-1-methyl-Δ^8-octahydroquinoline (II; salt, III). By contrast, 10-acetoxy-1-methyldecahydroquinoline (V), with the C-10 oxygen function already in place, was found to react very sluggishly with mercuric acetate, yielding an intractable mixture. The mechanism of the conversion of 1-methyldecahydroquinoline to 1-methyl-$\Delta^{1(9)}$-octahydroquinolinium acetate (XIII) can be regarded as similar to that postulated for the dehydrogenation of quinolizidine.[5,7] The continuation of the oxidation process might involve the sequence pictured below, assuming first an equilibrium between the acetate in the weakly acidic solution and the corresponding base, 1-methyl-Δ^9-octahydroquinoline (XIV), which could be interrupted by formation of a mercurated complex (XV) through the free pair of electrons on the nitrogen. Attack of acetate at the



double bond could be a concerted process with cleavage of the nitrogen–mercury bond, which process effectuates the further oxidation of the unsaturated amine XIV and the reduction of Hg(II).[7,21] Basification of solution containing 10-acetoxy-1-methyl-$\Delta^{1(9)}$-octahydroquinoline (XVI) would lead to the abstraction of a proton from C-8 and rapid hydrolysis of the substituted allyl acetate,[22] thereby resulting in the isolation of 10-hydroxy-1-methyl-Δ^8-octahydroquinoline (II). An alternative mechanism for the hydroxylation (acetoxylation) stage, proceeding by attack of the $HgOAc^+$ moiety at the double bond, seems less favored.

The stereochemistry of the saturated compound, 10-hydroxy-1-methyldecahydroquinoline (IV, and related V) is of subsidiary interest. The racemate of IV obtained by the lithium aluminum hydride reduction of III and by the methylation of 10-hydroxydecahydroquinoline (X) (m.p. 150–151°)[23] is designated arbitrarily as form A: m.p. 38–38.5°, n^{20}D (supercooled) 1.5016; perchlorate, m.p. 105–106°; picrate, m.p. 156–156.5°. Since X was actually a mixture resulting from the palladium-on-charcoal hydrogenation of IX in ethyl acetate solution prior to the isolation of the racemate melting at 150–151° [18] and since the methylation of this racemate was not quantitative, form A of IV cannot be designated as *cis* or *trans* on this basis. Stereospecificity is recognizable in the lithium aluminum



hydride reduction of III, and axial (*trans*) addition of hydride at C-9 may be postulated since this would allow the incoming group to be further removed from the alcoholate anion, in a transition state closely resembling A (one of the enantiomers is shown), than it would be during addition *cis* to the hydroxyl. The hydrogenation of III in ethanol solution using palladium-on-charcoal resulted in the isolation of form A of IV in 20% yield, and the isolation of the geometrically isomeric form B to the extent of 68%, characterized as follows: m.p. 43–46°, n^{20}D 1.4955; perchlorate, m.p. 117.5–118°; picrate, m.p. 151–152°. The hydrogenation of 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium acetate (II in 5% aqueous acetic acid) using the same catalyst resulted in a similar mixture of IV racemates. By contrast, 10-hydroxy-1-methyl-Δ^8-octahydroquinoline (II) in ethanol was converted practically quantitatively to form B of IV. Addition of hydrogen to II under the mild conditions employed would be expected to result from the approach of the less hindered face of the unsaturated molecule toward the hydrogen-on-catalyst surface. The provisional assignment of the *cis* ring juncture to form B (the enantiomer is shown in the alternative conformation) would not be inconsistent with this argument, especially since similar catalytic reduction of VIII results mainly in *cis*-decahydroquinoline, and would be internally consistent with the assignment of form A based on the hydride reduction of III.

Experimental[24]

trans-**Decahydroquinoline.**—Made by the catalytic hydrogenation of quinoline according to the directions of Bailey and McElvain,[25] the *trans*-decahydroquinoline crystallized as colorless needles, m.p. 47.5–48.5° (reported[25,26] 48°); hydrochloride, m.p. 281–283° (reported 278–279°,[25] 286–287.5°,[27] 275°[28]).

(21) G. Schwarzenbach and G. Anderegg, *Helv. Chim. Acta*, **37**, 1289 (1954).

(22) E. Bächli and P. Karrer, *ibid.*, **38**, 1863 (1955).

(23) "Rings presumed to have a *trans* fusion,"[18] but no proof of this geometrical assignment was available. A supporting argument can be provided—as in the present work—based on the lithium aluminum hydride reduction of IX.[18]

(24) All melting points are corrected. We are indebted to Mrs. Esther Fett, Mrs. Lucy Chang, Mrs. R. Maria Benassi, Mr. Joseph Nemeth and Mr. R. J. Nesset for microanalyses and to Mrs. Louise Griffing and Mr. James Brader for determination of the infrared absorption spectra, using a Perkin-Elmer automatic recording infrared spectrometer, model 21. Zerewitinoff active hydrogen determination was performed by the Clark Microanalytical Laboratory, Urbana, Ill.

(25) C. F. Bailey and S. M. McElvain, THIS JOURNAL, **52**, 4013 (1930).

(26) B. Witkop, *Experientia*, **10**, 419 (1954).

(27) V. Prelog and S. Szpilfogel, *Helv. Chim. Acta*, **28**, 1684 (1945).

(28) W. Hückel and F. Stepf, *Ann.*, **453**, 163 (1927).

trans-**1-Methyldecahydroquinoline *p*-Toluenesulfonate Salt.**—A solution of 0.5 g. (3.6 mmoles) of *trans*-decahydroquinoline and 0.75 g. (4.0 mmoles) of methyl *p*-toluenesulfonate in 3 ml. of absolute ethanol was heated 30 minutes on the steam-bath. The solution was cooled and an excess of ether was added to precipitate the salt. Recrystallization from benzene–ethanol gave colorless platelets, m.p. 174–174.5°, yield 0.96 g. (82%).

Anal. Calcd. for $C_{17}H_{27}NO_3S$: C, 62.75; H, 8.36; N, 4.30. Found: C, 62.56; H, 8.40; N, 4.34.

trans-**1-Methyldecahydroquinoline.**—N-Methylation of *trans*-decahydroquinoline was carried out according to the directions of Ehrenstein and Bunge[29]; b.p. 206–208° (reported[29] 204–205°), $n^{20}D$ 1.4820, yield 89%.

Reaction of Mercuric Acetate with *trans*-1-Methyldecahydroquinoline.—To a stirred solution of 510 g. (1.6 moles) of mercuric acetate in 2 l. of 5% aqueous acetic acid maintained at 90–95° was added 61.2 g. (0.4 mole) of *trans*-1-methyldecahydroquinoline in one portion. After heating for 30 minutes on the steam-bath, the mixture was cooled rapidly under the tap to about 25°. The precipitated mercurous acetate was collected on the filter and washed successively with six 50-ml. portions of cold water and three 50-ml. portions of absolute ethanol. The dried salt weighed 258 g. (62% yield on the basis of reaction of four moles of mercuric acetate with one of amine). The filtrate and washings were combined and saturated with hydrogen sulfide, and the mercuric sulfide was removed by filtration. Aqueous sodium hydroxide in excess was added to the concentrated filtrate. Ether extraction followed by the usual drying and concentrating operations gave a residue which was distilled through a short Vigreux column, giving 23.4 g. of starting material, collected at 45–64° (1 mm.), and 22.5 g. (54% yield based on starting material consumed) of *10-hydroxy-1-methyl-*Δ^8*-octahydroquinoline*, 65–75° (1 mm.). The product darkened rapidly unless stored under nitrogen at Dry Ice temperature. It was redistilled under nitrogen, b.p. 80–83° (1.5 mm.), $n^{20}D$ 1.5211, infrared maxima (liquid film) 1643 (>C=C<) and 3450 cm.$^{-1}$ (O–H).

Anal. Calcd. for $C_{10}H_{17}NO$: C, 71.81; H, 10.25. Found: C, 71.92; H, 10.51.

10-Hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium Perchlorate.—Prepared in and recrystallized from absolute ethanol, the perchlorate of 10-hydroxy-1-methyl-Δ^8-octahydroquinoline formed colorless platelets, m.p. 130–131°, infrared maxima (mull) 1668 (>C=$\overset{+}{N}$<) and 3385 cm.$^{-1}$ (O–H).

Anal. Calcd. for $C_{10}H_{18}ClNO_5$: C, 44.86; H, 6.78; N, 5.23; active H, 0.37% (1). Found: C, 45.16; H, 6.69; N, 5.12; active H, 0.42% (1.13).

10-Hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium Picrate.—The picrate crystallized as yellow plates from ethanol, m.p. 141–142°.

Anal. Calcd. for $C_{16}H_{20}N_4O_8$: C, 48.48; H, 5.09; N, 14.14. Found: C, 48.52; H, 5.11; N, 14.30.

Reaction of Potassium Cyanide with 10-Hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium Perchlorate.—The mixture resulting from the combination of 2.9 g. (45 mmoles) of potassium cyanide and 4.0 g. (15 mmoles) of 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium perchlorate in 50 ml. of water was extracted with ether. Following drying and evaporation of the ether extracts, **9-cyano-10-hydroxy-1-methyldecahydroquinoline** was distilled at 103–104° (1.4 mm.) and solidified, m.p. 59–62°, yield 2.6 g. (89%), infrared maxima 2224 (C≡N) and 3475 cm.$^{-1}$ (O–H).

Anal. Calcd. for $C_{11}H_{18}N_2O$: C, 68.00; H, 9.34. Found: C, 68.26; H, 9.31.

9-Cyano-10-hydroxy-1-methyldecahydroquinoline Picrate.—The base and picric acid were combined in ether solution, from which the picrate separated as yellow prisms, m.p. 145–146°.

Anal. Calcd. for $C_{17}H_{21}N_5O_8$: C, 48.22; H, 5.00; N, 16.54. Found: C, 48.04; H, 5.25; N, 16.26.

Attempted recrystallization from ethanol or formation in ethanol resulted in the elimination of hydrogen cyanide and isolation of 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium picrate, m.p. 140–140.5°.

(29) M. Ehrenstein and W. Bunge, *Ber.*, **67**, 1715 (1934).

9-Cyano-10-hydroxy-1-methyldecahydroquinoline Perchlorate.—The perchlorate was formed in ethanol and recrystallized from ethanol–ether, the temperature being maintained below 35°, as colorless prisms, m.p. 179°, infrared maximum (mull) at 3440 cm.$^{-1}$, none detectable at 2220 cm.$^{-1}$.

Anal. Calcd. for $C_{11}H_{19}ClN_2O_5$: C, 44.82; H, 6.50; N, 9.51. Found: C, 44.63; H, 6.39; N, 9.26.

At the boiling point of ethanol, hydrogen cyanide is liberated and the perchlorate reverts to that of the unsaturated base.

Attempted lithium aluminum hydride reduction of 9-cyano-10-hydroxy-1-methyldecahydroquinoline in ether resulted in the isolation of 10-hydroxy-1-methyl-Δ^8-octahydroquinoline, identified as the picrate.

10-Acetoxy-1-methyl-Δ^8-octahydroquinoline and 10-Acetoxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium Picrate.—A mixture of 3.9 g. (23 mmoles) of 10-hydroxy-1-methyl-Δ^8-octahydroquinoline, 20 ml. of pyridine and 40 ml. of acetic anhydride was heated on the steam-bath for 15 hours, then evaporated almost to dryness *in vacuo* and basified with 40% aqueous sodium hydroxide. The basic mixture was extracted with ether, and the combined ether extracts were dried and evaporated. The residual oil was distilled under nitrogen, giving 0.3 g. of starting material, collected up to 68° (0.5 mm.), and 0.45 g. (10% yield based on starting material consumed) of **10-acetoxy-1-methyl-Δ^8-octahydroquinoline**, b.p. 68–69° (0.5 mm.), $n^{20}D$ 1.4937. The product was extremely unstable, darkening almost immediately after distillation. Conversion to the picrate gave yellow prisms from ethanol, m.p. 164–165°, formulated as **10-acetoxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium picrate.**

Anal. Calcd. for $C_{18}H_{22}N_4O_9$: C, 49.31; H, 5.06; N, 12.78. Found: C, 49.57; H, 5.38; N, 12.78.

cis-**Decahydroquinoline.**—A solution of 19.0 g. (0.138 mole) of $\Delta^{1(9)}$-octahydroquinoline,[16–18] b.p. 54–57° (1.5 mm.) $n^{19.5}D$ 1.5033, in 50 ml. of ethanol was hydrogenated at 25° and 3 atmospheres using 4 g. of palladium-on-charcoal. Distillation of the filtered solution gave 14.4 g. (77%) of *cis*-**decahydroquinoline**, b.p. 106–107° (20 mm.); **picrate**, m.p. 142–144° after two recrystallizations from ethanol (reported 142–145°,[28] 144–145°[30]). This method is superior to those previously reported for the preparation of *cis*-decahydroquinoline.

cis-**1-Methyldecahydroquinoline.**—N-Methylation of *cis*-decahydroquinoline was effected by the method of Ehrenstein and Bunge[29]; b.p. 107–108° (20 mm.), $n^{20}D$ 1.4851, yield 82%. The product was characterized by formation of the **picrate**, which melted sharply at 199–200° (reported[29] 199–200°) after one recrystallization from ethanol, yield 87%.

Reaction of Mercuric Acetate with *cis*-1-Methyldecahydroquinoline.—The same method was used for the *cis* isomer as described above for *trans*-1-methyldecahydroquinoline, with the exception that a 15-minute heating period was employed, after which the quantity of mercurous acetate collected was 93% of that required for reaction of mercuric acetate with amine in the molar ratio 4:1. The product (32% yield) was collected at 65–66° (0.4 mm.), $n^{20}D$ 1.5198, and was identical with the **10-hydroxy-1-methyl-Δ^8-octahydroquinoline** obtained from the *trans* isomer: perchlorate, m.p. 130–131°; picrate, m.p. 141–142°. The identity was based on infrared spectra and mixed melting point determinations.

10-Hydroxyl-1-methyldecahydroquinoline.—To a stirred solution of 6.6 g. (0.17 mole) of lithium aluminum hydride in 300 ml. of anhydrous ether maintained at the reflux was added 15.0 g. (0.056 mole) of 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium perchlorate over a short period of time. The reaction mixture was heated under reflux for 8 hours, dilute aqueous sodium hydroxide was added, and the ether layer was combined with further ether extracts to give 8.3 g. (87%) of product, b.p. 67° (0.6 mm.), $n^{20}D$ 1.5016. Crystallization occurred when the colorless oil was chilled in Dry Ice; colorless needles, m.p. 38–38.5°, infrared maximum 3350 cm.$^{-1}$ (broad).

Anal. Calcd. for $C_{10}H_{19}NO$: C, 70.96; H, 11.32; N, 8.28. Found: C, 70.70; H, 11.03; N, 8.16.

(30) G. R. Clemo, J. G. Cook and R. Raper, *J. Chem. Soc.*, 1183 (1938).

A Tollens test on 10-hydroxy-1-methyldecahydroquinoline was negative.

10-Hydroxy-1-methyldecahydroquinoline Perchlorate.—The perchlorate separated as colorless needles from ethanol, m.p. 105–106°, infrared maximum 3475 cm.$^{-1}$.

Anal. Calcd. for $C_{10}H_{20}ClNO_5$: C, 44.60; H, 7.10; N, 5.19. Found: C, 44.57; H, 7.39; N, 4.99.

10-Hydroxy-1-methyldecahydroquinoline Picrate.—The picrate crystallized from ethanol as yellow prisms, m.p. 156–156.5°.

Anal. Calcd. for $C_{16}H_{22}N_4O_8$: C, 48.24; H, 5.57; N, 14.07. Found: C, 48.36; H, 5.83; N, 14.07.

Reaction of Lead Tetraacetate with 10-Hydroxy-1-methyldecahydroquinoline.—Two solutions, each containing 0.5 ml. (*ca.* 3 millimoles) of 10-hydroxy-1-methyldecahydroquinoline and 80 ml. of 0.05 *M* lead tetraacetate in glacial acetic acid, were heated, together with a blank, at 60 ± 5°. The course of the reaction was followed by the withdrawal of 1.0-ml. aliquot portions which were added to 10 ml. of an aqueous solution containing 2.5% potassium iodide and 20% sodium acetate. The iodine liberated was titrated with 0.01 *M* sodium thiosulfate solution to the starch endpoint. Within 6 hours slightly over one molar equivalent of lead tetraacetate was consumed by the 10-hydroxy-1-methyldecahydroquinoline solutions, while the titration value of the blank remained constant.

Attempted Chromic Acid Oxidation of 10-Hydroxy-1-methyldecahydroquinoline.—The procedure followed was one which had been successful for the oxidation of cevadine orthoacetate acetate.[15] A solution of 10-hydroxy-1-methyldecahydroquinoline and excess chromic acid in acetic acid was maintained at 25° overnight. The organic base remained unchanged and was recovered to the extent of 95%, identified by conversion to 10-hydroxy-1-methyldecahydroquinoline perchlorate, m.p. 104–106°.

Attempted tosylation of 10-hydroxy-1-methyldecahydroquinoline using *p*-toluenesulfonyl chloride and pyridine at steam-bath temperature was unsuccessful. The original base was recovered as the perchlorate, m.p. 104–106°.

10-Acetoxy-1-methyldecahydroquinoline.—Following the heating of 2.0 g. (11.8 mmoles) of 10-hydroxy-1-methyldecahydroquinoline, 10 ml. of pyridine and 20 ml. of acetic anhydride on the steam-bath for 14 hours, the mixture was concentrated *in vacuo*, basified with dilute aqueous sodium hydroxide and extracted with ether. The residue after drying and evaporating the ether extracts was distilled through a modified Holzman column. 10-Acetoxy-1-methyldecahydroquinoline was distilled at 78–80° (1 mm.), $n^{20}D$ 1.4836, yield 1.9 g. (77%), selected infrared absorption maxima 1235 and 1733 cm.$^{-1}$.

Anal. Calcd. for $C_{12}H_{21}NO_2$: C, 68.21; H, 10.02; N, 6.63. Found: C, 67.77; H, 9.84; N, 6.85.

The picrate crystallized from absolute ethanol as yellow needles, m.p. 164.5–165°. (This picrate depressed the melting point of 10-acetoxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium picrate, m.p. 164–165°.)

Anal. Calcd. for $C_{18}H_{24}N_4O_9$: C, 49.09; H, 5.49; N, 12.72. Found: C, 49.23; H, 5.42; N, 12.73.

Pyrolysis of 10-Acetoxy-1-methyldecahydroquinoline.—The pyrolysis method was essentially that previously described,[11] with the temperature maintained at 525 ± 10°. The crude pyrolysate was treated with dilute aqueous sodium hydroxide solution, and the mixture was extracted with ether. The residue obtained from the ether extracts was distilled through a modified Holzman column, b.p. 95–98° (20 mm.), $n^{20}D$ 1.5044–1.5050, yield 59%, infrared maxima 1664(s) and 1643(w) cm.$^{-1}$. The material can be represented as a mixture of 1-methyl-Δ^{9}-octahydroquinoline, 1-methyl-Δ-$^{4(10)}$-octahydroquinoline and 1-methyl-$\Delta^{5(10)}$-octahydroquinoline. Attempts to purify the mixture through fractional crystallization of the picrates and perchlorates did not succeed. The crude mixture of perchlorates gave a very strong band in the infrared spectrum (Nujol mull) at 1668 cm.$^{-1}$.

Reduction of the Mixture of 1-Methyloctahydroquinolines.—The mixture of 1-methyloctahydroquinolines (0.25 g.) obtained from the pyrolysis of 10-acetoxy-1-methyldecahydroquinoline was dissolved in 50 ml. of ethanol and hydrogenated at 25° in a microhydrogenation apparatus, using 0.1 g. of 10% palladium-on-charcoal. After one mole equivalent of hydrogen had been taken up, the catalyst was removed by filtration and the solvent was evaporated. The picrate was formed from the residue and was recrystallized from ethanol as fine yellow needles, m.p. 193–195°, yield 0.59 g. (94%). After two further recrystallizations, the melting point was raised to 198.5–199.5°, and was undepressed on admixture with authentic *cis*-**1-methyldecahydroquinoline picrate.**

10-Hydroxy-1-methyldecahydroquinoline from 10-Hydroxydecahydroquinoline.—A sample of 10-hydroxy-1-methyldecahydroquinoline picrate, m.p. 153–154°, was kindly provided by Dr. Bernhard Witkop. A larger amount of 10-hydroxy-1-methyldecahydroquinoline was made in this Laboratory by methylation of 10-hydroxydecahydroquinoline[17,18] with formaldehyde and formic acid. A check sample of 10-hydroxydecahydroquinoline, m.p. 150–151°, was also kindly provided by Dr. Witkop. The 10-hydroxy-1-methyldecahydroquinoline obtained by methylation was converted to the **perchlorate**, m.p. 103.5–105.5° (48% over-all yield). The melting points of the 10-hydroxy-1-methyldecahydroquinoline perchlorate and picrate were not depressed when each was mixed with the corresponding derivative of the compound obtained by reduction of the mercuric acetate dehydrogenation–hydroxylation product from 1-methyldecahydroquinoline (see above). Furthermore, the infrared spectra of the corresponding derivatives were identical.

Reaction of Mercuric Acetate with $\Delta^{1(9)}$-Octahydroquinoline Methiodide.—The methiodide, prepared in benzene at 5° from 10 g. (0.072 mole) of $\Delta^{1(9)}$-octahydroquinoline[16] and 10.5 g. (0.074 mole) of methyl iodide, separated as colorless needles, m.p. 118–121° (reported[17,18] 118–122°). Since the compound was very unstable, it was assumed that the theoretical amount (20.2 g., 0.072 mole) of 1-methyl-$\Delta^{1(9)}$-octahydroquinolinium iodide had been formed. The benzene was decanted from the crystalline material and 500 ml. of 5% aqueous acetic acid was added. The benzene was removed by partial distillation on the steam-bath. The warm solution was then added to 127 g. (0.4 mole) of mercuric acetate and the resulting mixture was stirred on the steam-bath. (The same results were obtained in air or under nitrogen.) A heavy precipitation of mercurous acetate began after 10 minutes, and after 25 minutes the reaction was terminated. The product was isolated as described previously, and **10-hydroxy-1-methyl-Δ^{8}-octahydroquinoline** was collected at 65–75° (0.5 mm.), $n^{20}D$ 1.5212–1.5225, yield 3.95 g. (33%). The yield obtained was commensurate with that realized from *trans*-1-methyldecahydroquinoline with a large excess of mercuric acetate, either with or without the benefit of a nitrogen atmosphere. No trace of the organic base corresponding to the starting material was detected. The **picrate** of the product was identical with the 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium picrate described above.

Reaction of mercuric acetate with 10-acetoxy-1-methyldecahydroquinoline, conducted in the same manner, resulted in a mixed product. The mercurous acetate formed after 30 minutes amounted to only 33% of that theoretically required for reaction of two moles of mercuric acetate with one of substrate. The oily organic product was converted to the perchlorate, which could not be induced to crystallize and which had infrared absorption maxima at 3450 (O–H), 1730 (ester C=O), 1672 ($>C{=}\overset{+}{N}<$) and 1245 cm.$^{-1}$ (C–O).

The Stereochemistry of 10-Hydroxy-1-methyldecahydroquinoline. Form A.—The racemate of 10-hydroxy-1-methyldecahydroquinoline, obtained by the lithium aluminum hydride reduction of 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium perchlorate (see above) and by the methylation of 10-hydroxydecahydroquinoline,[17,18] is designated as form A: m.p. 38–38.5°, $n^{20}D$ (supercooled) 1.5016; perchlorate, colorless needles, m.p. 105–106°; picrate, yellow prisms, m.p. 156–156.5°.

Form B.—A solution of 1.0 g. (6 mmoles) of 10-hydroxy-1-methyl-Δ^{8}-octahydroquinoline in 50 ml. of absolute ethanol was reduced using 0.1 g. of 10% palladium-on-charcoal in a microhydrogenation apparatus. The theoretical volume of hydrogen (152 ml.) was absorbed within 4 hours. The product was distilled through a Holzman column, b.p. 80–81° (2 mm.), $n^{20}D$ 1.4955, yield 1.0 g. On standing at Dry Ice temperature, the distillate solidified to a colorless, pasty mass, m.p. 43–46°. This racemate, like form A, was unstable and had to be stored in the cold under nitrogen.

Anal. Calcd. for $C_{10}H_{19}NO$: C, 70.96; H, 11.32; N, 8.28. Found: C, 71.29; H, 11.35; N, 8.51.

The perchlorate of form B was prepared in ethanol and was recrystallized from ethanol–ether as colorless needles, m.p. 117.5–118°, infrared maximum 3455 cm.$^{-1}$.

Anal. Calcd. for $C_{10}H_{20}ClNO_5$: C, 44.60; H, 7.10; N, 5.19. Found: C, 44.47; H, 7.36; N, 5.24.

The picrate of form B was prepared from the pure base in absolute ethanol. After one recrystallization from ethanol, the picrate melted at 150–160°; after a second recrystallization with rapid cooling, at 151–152°; after a third recrystallization with slow cooling, at 150–160°. This behavior suggested that an ethanolate was being formed in the slow cooling process, and this idea was confirmed. Recrystallization of the material of original m.p. 151–152°, with very slow cooling, gave thick orange needles, m.p. 158.5–160°, which had the correct analysis for the picrate with one molecule of ethanol.

Anal. Calcd. for $C_{18}H_{28}N_4O_9$: C, 48.64; H, 6.35; N, 12.61. Found: C, 48.45; H, 6.35; N, 12.74.

The ethanolate of the picrate was converted to picrate by rapid cooling during crystallization as fine yellow needles, m.p. 151–152°.

Anal. Calcd. for $C_{16}H_{22}N_4O_8$: C, 48.24; H, 5.57; N, 14.07. Found: C, 48.55; H, 5.61; N, 13.97.

At no time during the recrystallization procedure was there any evidence of the presence of a trace of the isomeric picrate (form A), m.p. 156–156.5°. Form A picrate depressed the melting point of both form B picrate and form B picrate ethanolate.

Catalytic Hydrogenation of 10-Hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium Acetate.—A solution of 0.4 g. (2.4 mmoles) of 10-hydroxy-1-methyl-Δ^8-octahydroquinoline in 50 ml. of 5% aqueous acetic acid was reduced using 0.1 g. of 10% palladium-on-charcoal in a microhydrogenation apparatus. The theoretical volume of hydrogen was absorbed within 24 hours. The oily product was converted to the picrate, which, after one recrystallization from absolute ethanol, was observed to melt at 150–151°, yield 0.65 g. (68%). Admixture with 10-hydroxy-1-methyldecahydroquinoline (form B) picrate caused no depression in melting point.

Evaporation of the picrate mother liquor gave 80 mg. (8%) of the more soluble picrate of 10-hydroxy-1-methyldecahydroquinoline (form A) m.p. 156–156.5°, undepressed on admixture with this derivative.

Catalytic Hydrogenation of 10-Hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium Perchlorate.—The hydrogenation of 0.4 g. (0.5 mmole) of 10-hydroxy-1-methyl-$\Delta^{1(9)}$-octahydroquinolinium perchlorate in 50 ml. of absolute ethanol using 0.1 g. of 10% palladium-on-charcoal was completed in 10 minutes. The residue after removal of catalyst and ethanol was recrystallized from ethanol–ether, giving 0.27 g. (68%) of perchlorate, m.p. 115–116°. A second recrystallization raised the melting point to 116–118° and this salt did not depress the melting point of 10-hydroxy-1-methyldecahydroquinoline (form B) perchlorate. The mother liquor yielded 0.08 g. (20%) of 10-hydroxy-1-methyldecahydroquinoline (form A) perchlorate, m.p. 103–105°.

Acid Dehydration of 10-Hydroxy-1-methyldecahydroquinoline (Form A).—A solution of 0.1 g. (0.6 mmole) of 10-hydroxy-1-methyldecahydroquinoline (form A) in 10 ml. of concentrated hydrochloric acid was heated at the reflux temperature for 18 hours. The solution was cooled, basified with aqueous sodium hydroxide and extracted with ether. The oil remaining after removal of the ether was taken up in absolute ethanol and converted to the picrate. Recrystallization from ethanol gave fine orange needles, m.p. 123–124°, yield 0.15 g. (63%).

Anal. Calcd. for $C_{16}H_{20}N_4O_7$: C, 50.52; H, 5.30; N, 14.73. Found: C, 50.56; H, 5.62; N, 14.54.

From inspection of the 3 and 6 μ regions of the infrared spectrum of a Nujol mull of the picrate, it is indicated that this substance is most safely regarded as the derivative of a mixture of 1-methyloctahydroquinolines ($\Delta^{4(10)}$, $\Delta^{5(10)}$, Δ^9).

Catalytic Hydrogenation of 1-Methyloctahydroquinoline.—A solution of 84 mg. (0.5 mmole) of 1-methyloctahydroquinoline, prepared from 0.2 g. of the picrate described above, in 25 ml. of ethanol was hydrogenated using 0.05 g. of 10% palladium-on-charcoal. The product was converted to the picrate, m.p. 197–198°, yield 0.17 g. (85%), which was identified by direct comparison as *cis*-**1-methyldecahydroquinoline picrate.**

Acid Dehydration of 10-Hydroxy-1-methyldecahydroquinoline (Form B).—The treatment with concentrated hydrochloric acid was the same as that applied to form A. The product was converted to the picrate, orange needles, m.p. 123–124°, identical with the **1-methyloctahydroquinoline picrate** described above, yield 18%. A considerable quantity of gummy material was formed which had no counterpart in the acid treatment of form A.

Formic Acid Reduction of 10-Hydroxy-1-methyl-Δ^8-octahydroquinoline.—The procedure of de Benneville and Macartney[31] was followed[6] in the formic acid reduction of 10-hydroxy-1-methyl-Δ^8-octahydroquinoline. A mixture of products was obtained from which only the picrate of 10-hydroxy-1-methyldecahydroquinoline (form A), m.p. 155–156°, could be isolated (5% yield) and identified.

(31) P. L. de Benneville and J. H. Macartney, THIS JOURNAL, **72**, 3073 (1950).

URBANA, ILLINOIS

[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT OF NORTHWESTERN UNIVERSITY]

Elimination Reactions in Cyclic Systems. IV. *cis* and *trans* Eliminations in the Cyclohexane and Cyclopentane Series[1]

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cis-2-*p*-Tolylsulfonylcyclohexyl and *cis*-2-*p*-tolylsulfonylcyclopentyl *p*-toluenesulfonates have been synthesized. Elimination of *trans* groups on treatment with hydroxide ion was found to be favored in the cyclopentane series over the cyclohexane series by a factor of 3. This result is correlated with other data which show the greater ease of introducing a double bond into the cyclopentane ring system than into the cyclohexane ring system. The rate of *trans* elimination for the cyclohexane derivative was about 435 times as rapid as the corresponding *cis* elimination. In the cyclopentane series *trans* elimination is favored over *cis* elimination by a factor of 20. It is concluded that attainment of a planar four-centered transition state with the groups to be eliminated occupying *trans* positions is not nearly so important a factor in facilitating elimination in these systems where the hydrogen being eliminated is activated, as in some studied previously.

The much higher rates of *trans* elimination as compared to *cis* elimination observed for reactions in a number of cyclic systems[2–4] showed that the

(1) This investigation was supported by the Office of Naval Research under Contract No. N7onr-45007. The results were reported in a preliminary fashion in THIS JOURNAL, **76**, 4748 (1954).

(2) W. Hückel, W. Tappe and G. Legutke, *Ann.*, **543**, 191 (1940).

(3) S. J. Cristol, N. L. Hause and J. S. Meek, THIS JOURNAL, **73**, 674 (1951); E. D. Hughes, C. K. Ingold and R. Pasternak, *J. Chem. Soc.*, 3832 (1953).

(4) D. H. R. Barton and E. Miller, THIS JOURNAL, **72**, 1066 (1950).