For gas chromatography[15] a column 9 ft. long maintained at 203° and a carrier-gas inlet pressure of 20 p.s.i. were used. A major component (71%) with a retention time of 14.8 min. and a minor component (29%) with a retention time of 16.8 min. were detected.

10-Deoxyacetylandromedol-5,6-acetonide (XI), 164 mg. (19%), crystallized from ethyl acetate–cyclohexane, had m.p. 194–196°, $[\alpha]^{27}\text{D}$ +14.0° (*c* 0.5, ethanol), $\lambda_{\text{CHCl}_3}^{\text{C=O}}$ 5.71 and 5.76 μ, no ultraviolet absorption down to 190 mμ.

Anal. Calcd. for $C_{25}H_{40}O_6$: C, 68.77; H, 9.24. Found: C, 68.55; H, 9.16.

10-Deoxyacetylandromedenols (XVII), 102 mg. (13%), crystallized from ethyl acetate–cyclohexane, had m.p. 196–197°, $[\alpha]^{26}\text{D}$ +25° (*c* 0.4, ethanol), $\lambda_{\text{CHCl}_3}^{\text{C=O}}$ 5.81 μ, $\lambda_{\text{CHCl}_3}^{\text{C=C}}$ 6.02 μ, λ_{max} 203 mμ (ε 6670).

Anal. Calcd. for $C_{22}H_{34}O_4$: C, 69.81; H, 9.05. Found: C, 69.90; H, 9.02.

For gas chromatography[15] the same conditions were employed as given above for the corresponding acetonides (XV). In the present case (XVII), the minor component (26%) had the lower retention time, 12.6 min., and the major component (74%) had a retention time of 14.0 min.

Attempted Conversion of 10-Deoxyacetylandromedol-5,6-acetonide (XI) to 10-Deoxyacetylandromedol (VII).—The 10-deoxyacetonide (XI), 135 mg., was subjected to the same aqueous acetic acid treatment described above for the diene acetonides (XIV). Crystallization of the crude product from ethyl acetate gave 59 mg. of material, m.p. 264–268°, with an infrared spectrum identical with that of 10-deoxyandromedol (V). Thin layer chromatography of the mother liquor revealed the presence of approximately equal amounts of 10-deoxyacetylandromedol (VII), 10-deoxyandromedol (V), and 10-deoxyacetylandromedenols (XVII).

Ozonization of 10-Deoxyacetylandromedenols (XVII).—Under conditions described above for $\Delta^{10(18)}$-andromedenol (II), 125 mg. of XVII provided, after hydrogenolysis of the ozonides, silicic acid chromatography, and crystallization from ethyl acetate–cyclohexane, 36 mg. of **16-keto-17-nor-10-deoxyacetylandromedol (XXI)**, m.p. 202–204°, $[\alpha]^{24}\text{D}$ +18° (*c* 0.9, ethanol), $[\alpha]^{24}{}_{320}$ +490°, positive Cotton effect, $\lambda_{\text{CHCl}_3}^{\text{C=O}}$ 5.71 and 5.76 μ (sh).

Anal. Calcd. for $C_{21}H_{32}O_6$: C, 66.30; H, 8.48. Found: C, 66.14; H, 8.72.

A second peak was eluted from the column and crystallized from ethyl acetate to give 15 mg. of the 10-deoxy-15,16-seco compound (XIX), m.p. 218–221°, $\lambda_{\text{KBr}}^{\text{C=O}}$ 5.72 and 5.82 μ.

Anal. Calcd. for $C_{22}H_{34}O_7$: C, 64.37; H, 8.35. Found: C, 64.46; H, 8.42.

Heterocyclic Spirans. VI.[1]
1-Aza-3-oxaspiro[4.5]dec-1-ene

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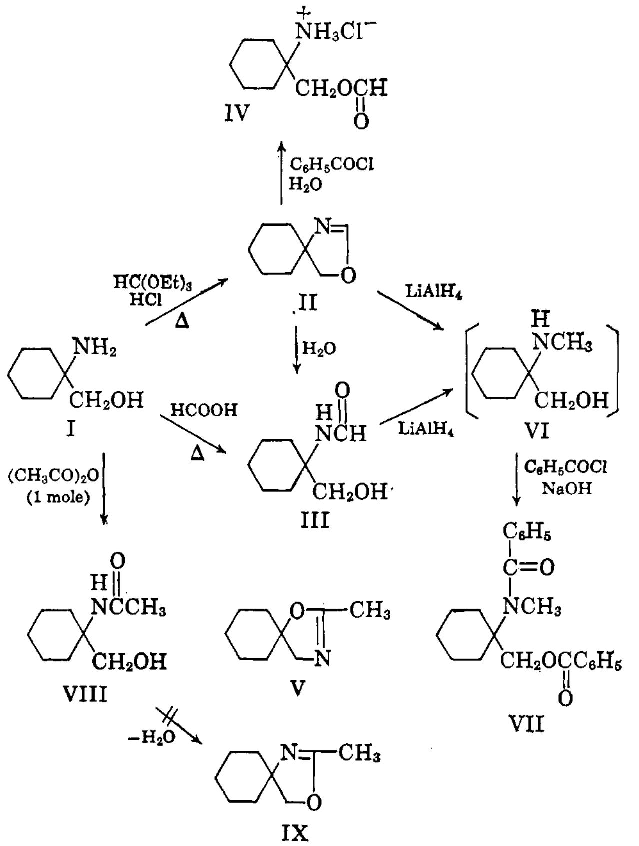
Spirooxazolidines have been prepared from the cyclic ethanolamine derivative, 1-aminocyclohexanemethanol (I), by condensation with aldehydes and cyclic ketones.[1b] Similarly, spiroimidazolones have been prepared by condensation of cyclic α-aminoamides, such as 1-aminocyclohexanecarboxamide, with triethyl orthoformate.[2] We now wish to report the synthesis of the parent unsubstituted spirooxazoline, 1-aza-3-oxaspiro[4.5]dec-1-ene (II), by acid-catalyzed condensation[3] of I with triethyl orthoformate. The spirooxazoline (II) was obtained as an oil, having a strong imine double-bond band at 1634 cm.$^{-1}$ in its infrared spectrum. The oil (II) is readily hydrolyzed, with ring opening, to the formamide III. The hydrolysis even takes place in the presence of moist air, as indicated by the gradual appearance of crystals of III in the oil. Hydrolysis of II with benzoyl chloride in moist ether gave, not the formamide III, but the formate ester hydrochloride (IV), in which protonation of the amino group has stabilized location of the formyl group on oxygen. A related spirooxazoline, 2-methyl-1-oxa-3-azaspiro[4.5]dec-2-ene[4] (V), is also reported to be hygroscopic and to undergo hydrolysis in moist air with ring opening.[4a]



Reduction of oxazoles[5a] and their intermediate reduction products, oxazolidines,[5b] with lithium aluminum hydride is reported to go all the way, with ring opening, to ethanolamine derivatives.[5c] Reduction of the spirooxazoline II with lithium aluminum hydride proceeded similarly, giving an oil (VI) having an amine odor. The oil was characterized through its crystalline dibenzoyl derivative (VII), which has no NH or OH absorption in its infrared spectrum, and was identical with a sample obtained by reduction of the formamide III with lithium aluminum hydride.

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(1) Previous papers in this series on the synthesis of heterocyclic spiranes: (a) I: W. E. Noland, J. F. Kneller, and D. E. Rice, *J. Org. Chem.*, **22**, 695 (1957); (b) II: W. E. Noland and R. A. Johnson, *ibid.*, **25**, 1155 (1960); (c) III: W. E. Noland and R. J. Sundberg, *Tetrahedron Letters*, 295 (1962); (d) IV: W. E. Noland and R. J. Sundberg, *J. Org. Chem.*, **28**, 3150 (1963); (e) V: W. E. Noland, R. J. Sundberg, and M. L. Michaelson, *ibid.*, **28**, 3576 (1963).

(2) E. Schipper and E. Chinery, *ibid.*, **26**, 4480 (1961).

(3) R. M. Roberts, *et al.*, *J. Am. Chem. Soc.*, **71**, 3848 (1949); **76**, 2411 (1954); **77**, 3801 (1955); **78**, 4778(1956); *Org. Syn.*, **35**, 65 (1955); "Organic Syntheses," Coll. Vol. IV, John Wiley and Sons, Inc., New York, N. Y., 1963; p. 464.

(4) (a) R. Schmid, *Kunststoffe-Plastics*, **3**, 165 (1956); *Chem. Abstr.*, **52**, 11,006 (1958); (b) P. B. Talukdar and P. E. Fanta, *J. Org. Chem.*, **24**, 526 (1959).

(5) (a) M. Mousseron and M. Canet, *Bull. soc. chim. France*, 247 (1952); (b) E. D. Bergmann, D. Lavie, and S. Pinchas, *J. Am. Chem. Soc.*, **73**, 5662 (1951); (c) N. G. Gaylord, "Reduction with Complex Metal Hydrides," Interscience Publishers, Inc., New York, N. Y., 1956, pp. 807-837.

Attempted dehydration[6] of N-[1-(hydroxymethyl)-cyclohexyl]acetamide (VIII) to 2-methyl-1-aza-3-oxaspiro[4.5]dec-1-ene (IX), a homolog of II (and an isomer of V), was unsuccessful. Unchanged VIII was obtained, either from attempted azeotropic removal of water with benzene in the presence or absence of a catalytic amount of hydrochloric acid, or from warming at 50° with 2,2-dimethoxypropane and acetic acid in benzene solution.

Experimental

Melting points were determined on a calibrated Fisher-Johns hot stage.

1-Aza-3-oxaspiro[4.5]dec-1-ene (II).—The procedure is adapted from that of Roberts and co-workers[3] for the reaction of aniline with triethyl orthoformate. A mixture of 1-aminocyclohexanemethanol[1a] (16.0 g., 0.124 mole) and 1-aminocyclohexanemethanol hydrochloride[1a] (0.25 g., 0.0015 mole) in freshly distilled triethyl orthoformate (41.0 g., 0.277 mole) was refluxed for 6 hr., during which time the ethanol which formed was periodically distilled (17.0 g., 97%). Distillation of the solution through a 10-cm. Vigreux column gave the following fractions: (1) triethyl orthoformate, b.p. 83–85° (110–80 mm.); (2) an intermediate fraction, b.p. 85–103° (60 mm.), assumed to be a mixture of triethyl orthoformate and product [crystals of N-[1-(hydroxymethyl)cyclohexyl]formamide (0.29 g., 1%), m.p. 124–126° (m.m.p. 125–127° with an authentic sample[1a]), formed when the liquid was kept in contact with the air]; (3) the product, as a colorless oil (9.50 g., 54%), b.p. 104–105° (60 mm.), having an infrared spectrum the same as the analytical sample; and (4) a residual brown oil (5.70 g.). Redistillation of the product yielded a sample, b.p. 104–105° (60 mm.), $n^{26}\mathrm{D}$ 1.4701, $\nu_{C=N}$ 1634 s cm.$^{-1}$ on the liquid.

Anal. Calcd. for $C_8H_{13}NO$ (139.19): C, 69.03; H, 9.41; N, 10.06. Found: C, 68.91; H, 9.65; N, 9.72.

Care must be taken to protect the product from atmospheric moisture; otherwise, crystals of N-[1-(hydroxymethyl)cyclohexyl]formamide soon appear.

Hydrolysis to N-[1-(Hydroxymethyl)cyclohexyl]formamide (III).[6]—A sample of 1-aza-3-oxaspiro[4.5]dec-1-ene, obtained as a colorless distillate in the manner described above, was kept in contact with the air for several days. During this time, large colorless crystals formed (36% yield from 1-aminocyclohexanemethanol), m.p. 124.5–128.5°, lit.[1a] m.p. 124–125.5°. There was no depression in m.m.p. 124–127° with a sample[1a] prepared from 1-aminocyclohexanemethanol and formic acid, and the infrared spectra in Nujol were identical.

Hydrolysis to 1-Aminocyclohexanemethyl Formate Hydrochloride (IV).—Benzoyl chloride was added to a solution of 1-aza-3-oxaspiro[4.5]dec-1-ene (0.50 g., 0.0036 mole) in ether and the solution was kept overnight. The colorless crystals which had slowly formed were collected, giving a gummy white solid. Recrystallization from acetone yielded white crystals (0.14 g., 20%); m.p. 164–168° (not sharp, preceded by sweating); ν_{NH} 2620 w, 2560 vw, 2530 vw, 2480 vw, 2350 w, $\nu_{C=O}$ 1721 s cm.$^{-1}$ in Nujol. The compound, a water-soluble salt, is hygroscopic and gained weight on the balance during the weighing of the analytical sample.

Anal. Calcd. for $C_8H_{16}ClNO_2$ (193.67); C, 49.61; H, 8.33; N, 7.23. Found: C, 49.05; H, 8.57; N, 7.37.

Reduction to VI, Isolated as N-[1-(Benzoyloxymethyl)cyclohexyl]-N-methylbenzamide (VII). A. From 1-Aza-3-oxaspiro-[4.5]dec-1-ene (II).—Lithium aluminum hydride (0.35 g., 0.0092 mole) was added to a solution of 1-aza-3-oxaspiro[4.5]dec-1-ene (1.0 g., 0.0072 mole) in dry ether (30 ml.), causing an initially vigorous reaction. The mixture was refluxed for 5 hr. and then the excess lithium aluminum hydride was decomposed by addition of acetone, followed by a solution of water in acetone. The ethereal layer was treated with benzoyl chloride (1.0 g., 0.0071 mole), producing within 5 min. a water-soluble, white solid (0.45 g.), m.p. 155–164°, assumed to be a hydrochloride salt (of VI or of the benzoate ester of VI), which was removed by filtration. The filtrate was treated with aqueous 20% sodium hydroxide solution (20 ml.), and the resulting mixture was warmed on a steam bath for 20 min., causing evaporation of the ether and acetone, and formation of a gummy white solid (0.65 g., 26%). Crystallization of this solid from ethanol–water gave colorless crystals, m.p. 105–107°. Two recrystallizations from ethanol–water yielded colorless flakes; m.p. 112–113°; $\nu_{OH,NH}$ none, $\nu_{C=O}$ 1700 s and 1628 s cm.$^{-1}$ in Nujol.

Anal. Calcd. for $C_{22}H_{25}NO_3$ (351.43): C, 75.18; H, 7.17; N, 3.99. Found: C, 75.20; H, 7.20; N, 3.82.

B. From N-[1-(Hydroxymethyl)cyclohexyl]formamide (III).—N-[1-(Hydroxymethyl)cyclohexyl]formamide (2.5 g., 0.0159 mole) was placed in the thimble of a Soxhlet extractor and extracted into refluxing ether containing lithium aluminum hydride (0.5 g., 0.013 mole). After 4 days of refluxing, 0.25 g. (10%) of the formamide remained in the thimble undissolved. The excess lithium aluminum hydride was then decomposed by addition of acetone, followed by a solution of water in acetone. The ethereal layer was dried over magnesium sulfate and evaporated, leaving a white solid (0.75 g., 30% recovery), m.p. 123–124°, m.m.p. 123–125° with formamide starting material, and an oil having an amine odor. The oil was washed out with ether, the ether was evaporated, and the residual oil was shaken with benzoyl chloride and aqueous sodium hydroxide solution. The white solid which formed was crystallized from ethanol–water, giving colorless crystals (0.80 g., 24% based on unrecovered formamide), m.p. 105–110°. One recrystallization from ethanol–water yielded colorless plates (0.60 g., 18%), m.p. 109–111°. There was no depression in m.m.p. 109–111° with the sample prepared from 1-aza-3-oxaspiro[4.5]dec-1-ene (A, above), and the infrared spectra in Nujol were identical.

N-[1-(Hydroxymethyl)cyclohexyl]acetamide (VIII).[6]—A solution of 1-aminocyclohexanemethanol[1a] (14.76 g., 0.114 mole) in acetic anhydride (11.65 g., 0.114 mole) was warmed on a steam bath for 1 hr. The acetic acid formed was then evaporated under reduced pressure. The residual, viscous, dark brownish red liquid was made slightly basic with dilute aqueous sodium bicarbonate solution, and extracted five times with ether. Evaporation of the ether and crystallization of the residue from 1:1 methylene chloride–petroleum ether (b.p. 60–68°) gave two crops of small white needles (3.17 g., 16%), m.p. 118–119.5°, lit.[1a] m.p. 121–123°.

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[6] Taken from the senior thesis of Thomas E. Huntley, University of Minnesota, 1960, to whom we are indebted.

Photochemical Transformations. XVII.[1] The Photochemistry of Palustric Acid[2]

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The photochemical ring scission of 1,3-cyclohexadienes to triene derivatives is now a widespread and well-documented reaction.[4] This process has, in fact, been synthetically employed as a new entry into medium-sized ring systems.[5] The behavior of cyclohexadienes is in contrast to the ring-formation reactions which commonly occur from the irradiation of the seven- and eight-membered ring analogs.[4] Although the ring cleavage reaction appears to be a fairly general phenomenon with cyclohexadienes, there exist a few exceptional compounds, namely, the pyrocalciferols[6] and

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[1] For the previous paper in this series, see W. G. Dauben and Robert M. Coates, *J. Am. Chem. Soc.*, **86**, 2490 (1964).

[2] This investigation was supported in part by PHS Grant No. A-709, National Institute of Arthritis and Metabolic Diseases, U. S. Public Health Service.

[3] National Science Foundation Cooperative Fellow, 1960–1963.

[4] For a summary of the pertinent literature, see ref. 1.

[5] E. J. Corey and A. G. Hortmann, *J. Am. Chem. Soc.*, **85**, 4033 (1963).

[6] W. G. Dauben and G. J. Fonken, *ibid.*, **81**, 4060 (1959).