colorless crystals of the desired product, mp 149–150° (0.42 g). The chloroacetate was characterized by infrared absorption bands (Nujol mull) at 3.04 (NH), 5.78–5.90 (C=O), 7.51, 7.70, 7.88, 7.95, 8.05, 8.75, 9.58, 10.38, and 12.40–12.45 μ.

Anal. Calcd for $C_{17}H_{24}ClNO_5$: C, 57.1; H, 6.7; Cl, 9.9. Found: C, 57.2; H, 6.6; Cl, 9.9.

Oxidation of XVII. (ψ)-α-Epiisocycloheximide Chloroacetate XVIII.—A solution of XVII (2 g) was oxidized by the method described for the preparation of XV (R′ = $COCH_2Cl$). The crude keto chloroacetate thus obtained (1.66 g) was crystallized first from methylene chloride–ether, and then from aqueous methanol giving flaky colorless crystals of pure XVIII, mp 108–109°. XVIII showed characteristic infrared bands at 3.06 (NH), 5.77–5.90 (C=O), 7.71, 8.00, 8.75, 10.20, and 10.51 μ.

Anal. Calcd for $C_{17}H_{24}ClNO_5$: C, 57.1; H, 6.7; Cl, 9.9; N, 3.9. Found: C, 56.5; H, 6.4; Cl, 9.0; N, 4.0.

dl-α-Epiisocycloheximide (III).—XV (R′ = $COCH_2Cl$, 0.32 g) in 15 ml of methanol was treated at room temperature with a solution of 0.5 g of potassium bicarbonate in 5 ml of water. After stirring overnight, the methanol was removed *in vacuo*, and the resulting aqueous mixture was extracted with methylene chloride. Evaporation of the methylene chloride extract previously washed with water and dried over anhydrous sodium sulfate gave a glassy material which was dissolved in 10 ml of methylene chloride and adsorbed on a column of silica gel (8 g). After washing the column with 100 ml of methylene chloride and 100 ml of 10% ethyl acetate in methylene chloride (this eluted about 40 mg of the starting material), crude III (80 mg) was obtained by elution with 200 ml of 20% ethyl acetate in methylene chloride. After recrystallization from methylene chloride, III appeared as colorless crystals, mp 153–153.5°. It was soluble in alcohol and acetone and sparingly soluble in water and ether. Its characteristic infrared bands (Nujol mull) were at 2.90 (OH), 3.11 and 3.24 (NH), 5.77, 5.85, and 5.99 (C=O), 7.78, 7.88, 8.00, 8.62, 9.30, 10.82, and 11.51 μ.

Anal. Calcd for $C_{15}H_{23}NO_4$: C, 64.0; H, 8.2; N, 5.0. Found: C, 64.0; H, 8.2; N, 5.1.

Acetylation of III with acetic anhydride in pyridine for 24 hr at room temperature gave *dl*-α-epiisocycloheximide acetate (XIV, R′ = Ac), mp 165–167°, which was identical with the specimen obtained previously (mmp 165–167°).

dl-Dihydro-α-Epiisocycloheximide (XXIV). Reduction of dl-α-Epiisocycloheximide.—A mixture of lithium aluminum hydride (132 mg) in 15 ml of dry tetrahydrofuran was treated, slowly, with 770 mg of dry *t*-butyl alcohol, and the mixture was stirred at 0° for 30 min. It was then treated dropwise, with external cooling and efficient stirring, with a solution of III (300 mg) in 10 ml of tetrahydrofuran. After stirring for 2 hr at 0–5°, the mixture was treated dropwise with 5 ml of cold water and 5 ml of 20% acetic acid. The mixture was stirred for a few minutes longer and filtered from the precipitated inorganic salts, and the filtrate was freed from tetrahydrofuran *in vacuo*. The residual aqueous mixture was extracted with five 50-ml portions of methylene chloride. Evaporation of the combined organic extracts (washed with water and sodium bicarbonate solution and dried over anhydrous sodium sulfate) gave a white solid which was crystallized from ethyl acetate to give crystalline XXIV, mp 214–216° (about 100 mg). XXIV was very sparingly soluble in methylene chloride, chloroform, and water, and practically insoluble in ether. Its infrared spectrum showed characteristic bands (Nujol mull) at 2.90 (OH), 3.10 and 3.23 (NH), 5.73 and 5.99 (C=O), 7.74, 7.93, 8.59, 8.94, 9.32, 9.42, and 9.54 μ, and its solution spectrum (in acetonitrile, 2.5 mg/ml) was characterized by bands at 2.78 (OH), 2.94 (NH), 5.85 (C=O), and 8.68 μ.

Anal. Calcd for $C_{15}H_{25}NO_4$: C, 63.6; H, 8.9; N, 4.9. Found: C, 63.8; H, 8.8; N, 5.3.

Acetonide of Diol XIII.—The diol XIII (0.2 g) was refluxed in acetone (20 ml) in the presence of anydrous copper sulfate (1.0 g) for 16 hr. After filtration to remove copper sulfate and evaporation of the solvent the residue was crystallized from aqueous alcohol to give the acetonide XXV quantitatively, mp 102°. The infrared spectrum of this material showed significant absorption at 3.12, 3.22, 5.79, 5.81, 7.74, 7.90, 8.30, 8.54, and 8.72 μ, while its nmr spectrum in deuteriochloroform exhibited peaks at 81.8 and 83.9 (acetonide methyls), at 54.3 (J = 5.4 cps) and 54.9 (J = 4.5 cps) for the cyclohexane methyl groups, and at 226 (sharp) and 237 cps (broad) for C*H*–O protons. In pyridine solution these peaks occurred at 83.6, 85.4, 58.2, 58.1, 216 (sharp), and 230 (broad) cps, respectively.

Anal. Calcd for $C_{18}H_{29}NO_4$: C, 66.9; H, 9.0; N, 4.3. Found: C, 66.8, H, 9.1; N, 4.4.

Under the same conditions as described above diol XXIV was recovered unchanged.

Acknowledgment.—We are grateful to Dr. T. Okuda (Tanabe Seiyaku Company, Tokyo) who supplied us with an optically active synthetic sample of α-epiisocycloheximide acetate for comparison purposes.

The Formation of a Cyclopropane Ring by Hydride Reduction of a Bridged Imidate[1]

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Treatment of the bridged imidates Ia and Ib with lithium aluminum hydride in refluxing 1,2-dimethoxyethane results in fragmentation of the molecule with production of the cyclopropane derivative II in 47 and 43% yields, respectively. At the same time the cyclopropane ring originally present in Ia is opened and the cleaved fragment appears in the product as N-methyl-*n*-propylamine. The cyclization is limited in scope and apparently depends on the coincidence of several structural features in the imidates I. These are partially defined.

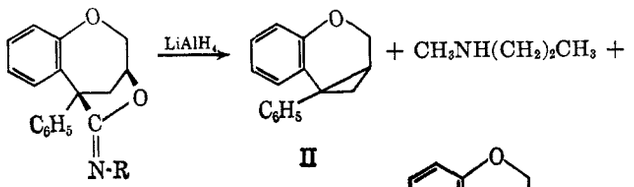
The bridged cyclic imidates I[2] were treated with excess lithium aluminum hydride in refluxing 1,2-dimethoxyethane in an effort to secure the corresponding amino alcohol III for pharmacological testing. Although a poor yield (24%) of III was formed from Ib, the main product obtained from both imidates was a neutral substance lacking nitrogen. The elemental analysis combined with the presence of absorption at 1.63 μ in its near-infrared spectrum, characteristic of a CH_2-group in a three-membered ring,[3] suggested assignment of structure II to this product. This was confirmed by its nmr spectrum (Table I). The possibility that II was formed spontaneously as a result of some structural instability in the cyclic imidates was ruled out by the observation that Ia is unaffected by heat (225°) and by ultraviolet irradiation. Likewise, Ia was inert to lithium aluminum hydride in refluxing ether.

(1) Paper XIII in the series, "Neighboring Group Reactions."

(2) H. E. Zaugg and R. J. Michaels, *J. Org. Chem.*, **28**, 1801 (1963).

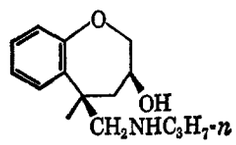
(3) W. H. Washburn and M. J. Mahoney, *J. Am. Chem. Soc.*, **80**, 450 (1958); P. G. Gassman, *Chem. Ind.* (London), 740 (1962); H. Weitkamp and F. Korte, *Tetrahedron*, **20**, 2125 (1964).

The basic cleavage product from the hydride reduction of Ia proved to be N-methyl-*n*-propylamine (isolated as the fumarate) rather than N-methylcyclopropylamine. Thus we have encountered a curious reaction in which the net result is the closure of one cyclopropane ring and the rupture of another.



Ia, R = cyclopropropyl
b, R = *n*-propyl

II



III

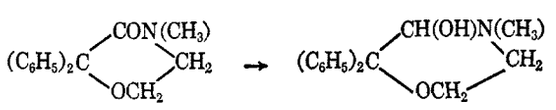
To examine the scope of the cyclization, the bridged lactone IV[2] was reduced with lithium aluminum hydride under the same conditions. In this case, however, the normal reduction product, V, was the only one formed (97% yield).

IV V

Likewise, the bridged lactam VI,[4] isomeric with the imidate Ia, gave none of the cyclopropane derivative II with lithium aluminum hydride. This reaction, however, was not entirely normal either. The expected bridged amine VIII was formed in very poor yield after prolonged hydride treatment in refluxing 1,2-dimethoxyethane, but the bulk of the reaction stopped at the intermediate carbinolamine stage VII. This stable product (see the Experimental Section for its structure proof) could be obtained in 97% yield from the lactam VI when the 1,2-dimethoxyethane was replaced by ether as solvent. Further reduction of VII in 1,2-dimethoxyethane also gave the amine VIII but still in poor yield (18%).[5] The bridged amine VIII was

(4) H. E. Zaugg, R. J. Michaels, A. D. Schaefer, A. M. Wenthe, and W.H. Washburn, *Tetrahedron*, in press.

(5) The partial hydride reduction of dicarboximides to stable carbinolamides[6] and of lactams to aminoaldehydes[7] is fairly well known. However, in relatively few cases of the latter type has the cyclic carbinolamine structure been favored over the open-chain aminoaldehyde form. Morrison, Long, and Königstein[8] found that hydride reduction of the lactam A gave the carbinolamine B as one of the products. It is probably significant in this connection that both B and VII contain diphenylcarbinyl systems attached to the carbinol carbon atoms.

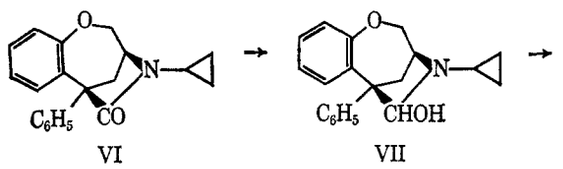


A B

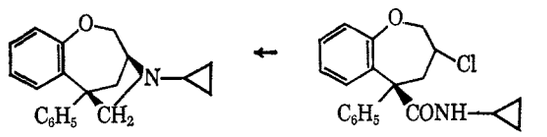
(6) (a) E. Tagmann, E. Sury, and K. Hoffmann, *Helv. Chim. Acta*, **37**, 185 (1954); (b) Z. Horii, C. Iwata, and Y. Tamura, *J. Org. Chem.*, **26**, 2273 (1961).

(7) (a) F. Galinovsky and R. Weiser, *Experientia*, **6**, 377 (1950); (b) F. Galinovsky, A. Wagner, and R. Weiser, *Monatsh. Chem.*, **82**, 551 (1951); (c) F. Galinovsky, O. Vogl, and R. Weiser, *ibid.*, **83**, 114 (1952); (d) E. E. Van Tamelen and G. C. Knapp, *J. Am. Chem. Soc.*, **77**, 1860 (1955).

(8) A. L. Morrison, R. F. Long, and M. Königstein, *J. Chem. Soc.*, 952 (1951).



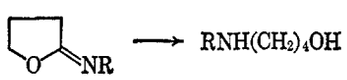
VI VII



VIII IX

obtainable, however, in good yield (94%) by hydride reduction of the chloroamide IX.[4]

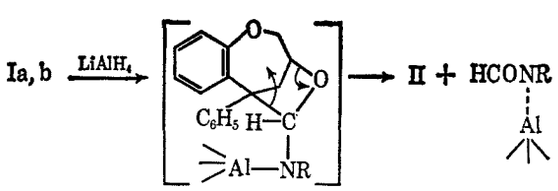
A recently reported[9] general entry to simple cyclic imidates of type X provided the opportunity for further examination of the scope of the cyclopropane ring-closure reaction. Both the cyclopropyl and the phenyl derivatives (X, R = cyclopropyl and C_6H_5) were prepared and treated in the usual manner with lithium aluminum hydride. In neither case was any cyclopropane formed and from the phenyl derivative an 88% yield of the amino alcohol XI (R = C_6H_5) was isolated.[10]



X XI

Discussion

The abnormal cyclization, I → II, can be represented formally by the sequence shown. Foregoing results



C

clearly show that the scope of the reaction is extremely limited and is probably defined by the coincidence of several features peculiar to the bridged imidate structure I. Because of the admittedly incomplete nature of the present work, these features can only be roughly outlined.

The diphenylcarbinyl system in I undoubtedly contributes to the ease of cleavage of the carbon–carbon bond.[12] However, in the absence of information concerning the course of hydride reduction of a bridged imidate without the diphenylcarbinyl group, the relative importance of its contribution to the cyclization cannot be assessed. Neither can anything be said about sequential *vs.* concerted bond breaking in intermediate C, nor about the stereochemistry of the cyclization.

(9) T. Mukaiyama and K. Sato, *Bull. Chem. Soc. Japan*, **36**, 99 (1963).

(10) These reductions are, therefore, no different from the corresponding reaction of the cyclohexyl analog (X, R = cyclohexyl). This imidate with lithium aluminum hydride produced N-(4-hydroxybutyl)cyclohexylamine (XI, R = cyclohexyl) in 45% yield.[11]

(11) C. J. M. Stirling, *J. Chem. Soc.*, 255 (1960).

(12) Susceptibility to hydride cleavage of carbon–carbon bonds that are highly substituted by electronegative groups is well known.[13]

(13) A. Dornow and K. J. Fust, *Chem. Ber.*, **90**, 1769, 1774 (1957).

A second obvious structural requirement for this cyclization is the presence of a reasonably stable leaving group at the β position. However, the smooth hydride reduction of the chloroamide IX to the bridged amine VIII shows that a good leaving group (*i.e.*, chloride ion) is, by itself, insufficient to cause cyclization to II. That a bond must connect the leaving group to the center of hydride attack may be a necessary condition for cyclization; but it, too, is not a sufficient one, because the lactone IV, which satisfies all of the obvious requirements for cyclization, undergoes *normal* hydride reduction. One must, therefore, look to the nature of the complex formed by hydride attack of the imidate I if the reason for its abnormal behavior is to be found.

The hydride-induced rupture of the cyclopropane ring in Ia is consistent with previous observations and probably occurs in the presence of a proton donor during the work up.[14] The preservation of the cyclopropane ring in the conversion, IX → VIII, further supports this view.

Experimental Section[17]

4,5-Benzo-7-*n*-propylimino-3,8-dioxa-6-phenylbicyclo[4.2.1]nonane (Ib).—Treatment of **3-(2′,3′-dibromopropyl)-3-phenyl-2-benzofuranone**, mp 137–138° (36 g, 0.088 mole), with *n*-propylamine (11.8 g, 0.2 mole) according to the procedure described[2] for the same reaction with cyclopropylamine yielded 8.1 g of a crude basic oil and 24 g of a neutral solid, mp 86–88°. Conversion of the base to its solid hydrochloride (ethereal hydrogen chloride) followed by recrystallization from an ethanol–ether mixture gave 4.8 g (13%) of ***cis*-5-bromomethyl-N-*n*-propyl-3-(*o*-hydroxyphenyl)-3-phenyl-2-tetrahydrofuranoneimine hydrochloride**, mp 207–208° (*Anal.* Calcd for $C_{20}H_{23}BrClNO_2$: C, 56.54; H, 5.46; N, 3.30. Found: C, 56.67; H, 5.47; N, 3.39.).

When this hydrochloride, suspended in 60 ml of 1,2-dimethoxyethane, was treated with sodium methoxide (1.4 g) in the usual way,[2] there was obtained 3.2 g (91%) of the bridged imidate Ib, mp 124–125°, $\lambda_{max}^{CCl_4}$ (μ) 5.89.

Anal. Calcd for $C_{20}H_{21}NO_2$: C, 78.16; H, 6.86; N, 4.56. Found: C, 78.06; H, 6.90; N, 4.65.

4,5-Benzo-3-oxa-6-phenylbicyclo[4.1.0]heptane (II) and 3-Hydroxy-5-phenyl-5-*n*-propylaminomethyl-2,3,4,5-tetrahydro-1-benzoxepin (III).—A mixture of 15.3 g (0.05 mole) of 4,5-benzo-7-cyclopropylimino-3,8-dioxa-6-phenylbicyclo[4.2.1]nonane (Ia),[2] 3.8 g (0.1 mole) of lithium aluminum hydride, and 200 ml of dry 1,2-dimethoxyethane was stirred and refluxed for 72 hr. The mixture was then treated successively with water (25 ml added dropwise) and 50% aqueous sodium hydroxide (10 ml). The organic layer was decanted from gelatinous material which was washed with a 50-ml portion of 1,2-dimethoxyethane. Combined solutions were dried over anhydrous magnesium sulfate. The drying agent was removed by filtration and the filtrate was treated with a solution of oxalic acid (4.5 g) in dry ether. The crude oxalate (3.8 g) that precipitated was collected at the filter and dried. The free base was released from the oxalate by treating it with 10 ml of 50% sodium hydroxide solution followed by several extractions with ether. The combined and dried extracts were then distilled at atmospheric pressure through a 16-in. helix-packed column (less than 0.2 g of an oil remained undistilled). The ethereal distillate containing the unknown amine was then submitted to gas chromatographic analysis. Ethereal solutions of cyclopropylamine, N-methylcyclopropylamine, and N-methyl-*n*-propylamine were used for comparison. Under identical conditions, the unknown amine and N-methyl-*n*-propylamine each gave a single peak with a retention time of 1.75 min, whereas the other two amines were maintained in the column for more than 2 min.

By treating the solution of the unknown and the solution of N-methyl-*n*-propylamine each with a solution of fumaric acid in methanol, and recrystallizing the resulting precipitate from a 2-butanone–ethanol mixture, identical (mixture melting point) fumaric acid salts (mp 112–113°) were obtained. Neither one could be secured in a state of analytical purity.

Anal. Calcd for $C_8H_{15}NO_4$: C, 50.8; H, 8.0; N, 7.4. Found: C, 50.0; H, 8.0; N, 6.5 (authentic salt); C, 49.7; H, 7.4; N, 6.4 (unknown salt).

The filtrate from the 3.8 g of oxalic acid salt was concentrated to dryness, the residue was taken up in ether, washed with water, and dried. Removal of the drying agent by filtration and the ether by distillation gave an oil which was distilled *in vacuo* to give two fractions: 5.3 g (47%), bp 116–126° (0.4 mm), $n^{25}D$ 1.6035; and 4.9 g, bp 176–206° (0.4 mm). Although the infrared spectrum of the second fraction indicated the presence in it of an amino alcohol (*i.e.*, the expected product from the reduction of Ia), the only pure substance that could be isolated from it was unreacted Ia (0.6 g). The first fraction (5.3 g) solidified (mp 58–60°) and was recrystallized twice from absolute ethanol to give pure II: mp 61–62°; $\lambda_{max}^{CHCl_3}$ (μ) 1.63 (cyclopropyl–CH_2), no NH, OH, or >C=O absorption; $\lambda_{max}^{C_2H_5OH}$ (mμ) 230 (sh ϵ 7400), 273 (ϵ 1530), 280 (ϵ 1450); for the nmr spectrum see Table I.

Anal. Calcd for $C_{16}H_{14}O$: C, 86.45; H, 6.35; O, 7.20. Found: C, 86.50; H, 6.49; O, 7.40.

When the foregoing procedure was repeated, but with the addition of 1.45 ml (0.08 mole) of water to the reaction mixture prior to the 72-hr reflux period, the yield (23%) of II was reduced by half and a 40% yield of basic oil, bp 210–213° (1.5 mm), was obtained. However, vpc analysis indicated that it was a complex mixture of at least four components (including Ia). A pure hydrochloride could not be isolated from it. When Ia was treated under reflux in ether for 96 hr with a 2:1 molar excess of lithium aluminum hydride, 98% of it was recovered unchanged.

Two attempts to obtain II from Ia by other means failed. After heating Ia at 225° for 4 hr, 80% of it was recovered unchanged, and after an alcoholic solution of Ia was irradiated for 7 hr with a 100-w Hanovia immersion-type mercury lamp, 97% of it was recovered. In neither case did infrared examination of the residues indicate the presence of any II.

Application of essentially the foregoing hydride reduction to the *n*-propylimino compound Ib gave, in addition to 10% of recovered starting material, a 43% yield of the cyclopropane derivative II, and a 24% yield of the hydroxyamine III, isolated as the hydrochloride: mp 178–181°; λ_{max}^{Nujol} (μ) 2.94 (OH).

Anal. Calcd for $C_{20}H_{26}ClNO_2$: C, 69.04; H, 7.53; N, 4.03. Found: C, 69.13; H, 7.78; N, 4.07.

Nmr Spectrum of II.—Table I summarizes the data. Cyclopropyl protons normally resonate in the 10–40-cps range. The shift to distinctly lower field in the present case is caused by deshielding by the adjacent phenyl rings.[18]

TABLE I

NMR SPECTRUM OF II IN CARBON TETRACHLORIDE (60 Mc *vs.* TMS)

Multiplet centers, cps	Assignment (*cf.* II)	Relative area[a]
440, 410	Aromatic H	9
264, 242[b]	$-CH_2-O-$	2
107, 89[c]	Cyclopropyl H	3

[a] Assuming the presence of 9 aromatic protons. [b] The $-CH_2O-$ signal consists of a quartet with split peaks. [c] The cyclopropyl proton signal is a complex octet.

3-Hydroxy-5-hydroxymethyl-5-phenyl-2,3,4,5-tetrahydrobenzoxepin (V).—A solution of 10.7 g (0.04 mole) of 3-hydroxy-

(14) C. Kaiser, A. Burger, L. Zirngibl, C. S. Davis, and C. L. Zirkle, *J. Org. Chem.*, **27**, 768 (1962), found that reduction of *trans*-N-(2-phenylcyclopropyl)formamide with lithium aluminum hydride gave a 95% yield of N-methyl-3-phenyl-*n*-propylamine. Other observations by these workers and by us[15] have demonstrated that hydride cleavage of cyclopropylamine derivatives is restricted to those having a replaceable hydrogen atom on nitrogen (*i.e.*, potential anion generators). According to expectation, furthermore, ring rupture always leads to *n*-propylamine derivatives.[16]

(15) H. E. Zaugg, R. W. DeNet, and R. J. Michaels, *ibid.*, **28**, 1795 (1963).

(16) C. H. DePuy and F. W. Breitbeil, *J. Am. Chem. Soc.*, **85**, 2176 (1963), and C. H. DePuy and L. R. Mahoney, *ibid.*, **86**, 2653 (1964), found that similar considerations apply to the base-catalyzed cleavages of cyclopropanols.

(17) Melting points and boiling points are uncorrected.

(18) C. L. Bumgardner [*J. Am. Chem. Soc.*, **83**, 4420 (1961)] found that in 1,1-diphenylcyclopropane the cyclopropyl protons give a signal at 92 cps (60 Mc *vs.* TMS).

5-phenyl-2,3,4,5-tetrahydro-1-benzoxepin-5-carboxylic acid γ-lactone (IV)[2] in 200 ml of 1,2-dimethoxyethane was refluxed and stirred with 3.0 g (0.08 mole) of lithium aluminum hydride for 66 hr. The product was isolated exactly as described in the foregoing procedure for the neutral fraction. There are obtained 10.5 g (97%) of distilled glycol V, bp 210–211° (0.9 mm), which solidified. Recrystallization from benzene gave pure V (8.2 g): mp 132–133°; $\lambda_{max}^{CHCl_3}$ (μ) 2.80 (w), 2.91 (w), no carbonyl absorption.

Anal. Calcd for $C_{17}H_{18}O_3$: C, 75.54; H, 6.71; O, 17.75. Found: C, 75.63; H, 6.51; O, 18.16.

An attempt to prepare II from IV by thermal elimination of carbon dioxide failed. The lactone IV could be heated to its distillation temperature at atmospheric pressure without showing loss of carbon dioxide.

8-Aza-4,5-benzo-8-cyclopropyl-7-hydroxy-3-oxa-6-phenylbicyclo[4.2.1]nonane (VII).—A mixture of 20 g (0.0655 mole) of **8-aza-4,5-benzo-8-cyclopropyl-7-keto-3-oxa-6-phenylbicyclo[4.2.1]-nonane (VI)**,[4] 1.5 g (0.04 mole) of lithium aluminum hydride, and 700 ml of dry ether was stirred and refluxed for 47 hr. To the cooled reaction mixture was added dropwise with stirring 2 ml of water, 2 ml of 15% sodium hydroxide solution, and 6 ml of water in that order. After stirring for 30 min at room temperature, inorganic salts were removed by filtration and washed with ether. The combined filtrate and washings were extracted with two portions of dilute (1:4) hydrochloric acid. From the neutral fraction only 0.3 g (1.5%) of starting material was recovered. The combined acid extracts were cooled in ice and treated with excess cold 40% sodium hydroxide solution. The liberated base was taken up in ether and dried over anhydrous magnesium sulfate. Filtration and removal of the ether by distillation gave 19.5 g (97%) of crude product, mp 118–125°. Two recrystallizations from cyclohexane gave pure VII (12.9 g, 64%): mp 125–126°; $\lambda_{max}^{CCl_4}$ (μ) 1.44 (OH), 1.63 (cyclopropyl-CH_2), no NH absorption; $\lambda_{max}^{CHCl_3}$ 2.83 (OH), no carbonyl absorption; for the nmr spectrum, see Table II.

Anal. Calcd for $C_{20}H_{21}NO_2$: C, 78.14; H, 6.89; N, 4.56; O, 10.41. Found: C, 77.92; H, 7.18; N, 4.51; O, 10.30.

Nmr Spectrum of VII.—Table II summarizes the data. Of particular significance is the spin–spin splitting observed for the two protons of the CHOH system. The hydroxyl absorption occurs as two peaks (J = 13 cps) at 139 and 152 cps and the CH proton absorbs at 308 and 321 cps (J = 13 cps). When the hydroxyl peaks are obliterated by deuterium exchange, the CH peaks coalesce to a singlet at 315 cps. Apparently, the proton of the hydroxyl group exchanges sufficiently slowly to allow time for spin–spin interaction with the adjacent CH proton.

TABLE II

NMR SPECTRUM[a] OF VII IN DEUTERIOCHLOROFORM

Chemical shift,[b] cps	Assignment	Relative area[c]
20–40	Cyclopropyl CH_2CH_2	4
40–110	Cyclopropyl CH	1
120–180	CCH_2CHN and OH	4
202–250	OCH_2	2
305–325	CHO	1
377–458	Aromatic H	9[c]

[a] 60 Mc. [b] Tetramethylsilane as internal standard. Numbers denote range of frequencies of absorption. [c] Assuming 9 aromatic protons.

Infrared Examination of VII in Acid Solution.—A 10% solution of VII in methanol (BaF_2 cell) shows no absorption in the carbonyl region. In 0.418 N methanolic hydrochloric acid, however, a peak appears at 6.03 μ. Protonation of the nitrogen atom of VII followed by opening of the carbinolamine ring to give a hydrogen-bonded aldehyde group could account for the appearance of this peak in acid solution.

4,5-Benzo-8-cyclopropylaza-3-oxa-6-phenylbicyclo[4.2.1]nonane (VIII). A. From the Carbinolamine VII.—A mixture of 4.0 g (0.013 mole) of the carbinolamine VII, 1.5 g (0.039 mole) of lithium aluminum hydride, and 45 ml of 1,2-dimethoxyethane was stirred and refluxed for 48 hr. Work-up of the reaction mixture in the usual way gave a crude semisolid product (4.2 g) which was recrystallized once from cyclohexane and twice from 95% ethanol to give pure VIII (0.7 g, 18%): mp 146–147°; $\lambda_{max}^{CCl_4}$ (μ) 1.63 (cyclopropyl-CH_2), no NH, OH or C=O absorption; 60-Mc chemical shifts (cycles per second) from tetramethylsilane in $CDCl_3$ solution with relative areas in parentheses, assuming 9 aromatic protons, 20–35 (4), 120–160 (3), 200–240 (4), 260–285 (1), 360–440 (9, assumed) (total area corresponds to 21 protons).

Anal. Calcd for $C_{20}H_{21}NO$: C, 82.43; H, 7.26; N, 4.81. Found: C, 82.43; H, 7.12; N, 4.92.

The infrared spectrum of the residual product indicated that it consisted of a mixture of VII and VIII together with at least one other component. When the lactam VI was treated under reflux for 70 hr with a 2:1 molar excess of lithium aluminum hydride in 1,2-dimethoxyethane, a 23% yield of VII and a 9% yield of VIII was isolated.

B. From the Chloroamide IX.—Treatment of 5.0 g (0.0146 mole) of the chloroamide IX[4] with 1.1 g (0.0292 mole) of lithium aluminum hydride in the foregoing manner followed by work up in the usual way gave 4.0 g (94%) of crude VIII, mp 143–146°. Two recrystallizations from 2-butanone gave pure VIII (3.7 g), mp 146–147°, identical in every way with the product obtained by procedure A: **VIII hydrochloride**, mp 200–201° (from 2-butanone–ether).

Anal. Calcd for $C_{20}H_{22}ClNO$: C, 73.21; H, 6.76; N, 4.27. Found: C, 73.16; H, 6.73; N, 4.45.

Reduction of N-Phenyltetrahydro-2-furanonimine (X, R = C_6H_5) with Lithium Aluminum Hydride.—A mixture of 3.3 g (0.0205 mole) of X (R = C_6H_5),[9] 1.6 g (0.041 mole) of lithium aluminum hydride, and 20 ml of 1,2-dimethoxyethane was refluxed and stirred for 50 hr. The condenser was connected to a trap containing 1,2-dimethoxyethane so that any exit gases (*i.e.*, cyclopropane) would be caught. The reaction mixture was treated as in the foregoing procedure except that the acid extraction was omitted. The filtrate from the inorganic salts was distilled to dryness. The distillate was combined with the dimethoxyethane from the condenser trap and subjected to vpc analysis. No detectable quantity of cyclopropane was formed in the reaction. The residue from the solvent distillation was distilled under reduced pressure to give 3.0 g (88%) of N-(4-hydroxybutyl)aniline (XI, R = C_6H_5): bp 138–139° (1 mm); $n^{25}D$ 1.5596;[19] $\lambda_{max}^{CCl_4}$ (μ) 1.41 (OH), 1.49 (NH); $\lambda_{max}^{CHCl_3}$ (μ) 2.77 (OH), 2.94 (NH).

Anal. Calcd for $C_{10}H_{15}NO$: C, 72.70; H, 9.15; N, 8.48. Found: C, 72.81; H, 8.96; N, 8.70.

This compound (XI, R = C_6H_5) was converted to its oxalic acid salt, mp 122–123° (from ethanol) (lit.[19] mp 124–125°).

Reduction of N-Cyclopropyltetrahydro-2-furanonimine (X, R = cyclopropyl) with Lithium Aluminum Hydride.—A pure sample of this imidate (X, R = cyclopropyl) could not be obtained by the method of Mukaiyama and Sato.[9] Elemental and infrared analyses implicated γ-butyrolactone as a persistent contaminant even in the best fraction (bp 50–52° (0.6 mm), $n^{25}D$ 1.4655) obtained. Nevertheless, this mixture was treated with lithium aluminum hydride according to the foregoing procedure. Again, no cyclopropane could be detected among the products.

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(19) O. Wichterle and J. Vogel [*Collection Czech. Chem. Commun.*, **14**, 209 (1949)] reported bp 157 (3 mm), $n^{20}D$ 1.5629, for this compound.