concentrate, after acidification with hydrochloric acid, was extracted with ether from which semi-crystalline material was obtained. Two crystallizations from hexane yielded dihydrohumulinic acid, m.p. 124.8–125.4°, identical with the hydrogenation product of humulinic acid, by mixed melting point. The distillate when treated as before and then chromatographed on silicic acid yielded two bands identified as acetone and isobutyraldehyde dinitrophenylhydrazones. Similar results were obtained with the dihydro dextrorotatory isohumulone.

Ozonization of Isohumulone Fractions.—In a typical experiment, ozonized oxygen was bubbled through a solution of 337 mg. (0.928 millimole) of levorotatory isohumulone in 30 ml. of acetic acid at 19–20° for 30 minutes. The ozonide was decomposed by addition of 100 cc. of water and 5 g. of zinc dust. The suspension was filtered and the filtrate distilled to approximately one-third its original volume. The distillate was collected in a flask containing 1 g. of 2,4-dinitrophenylhydrazine in 40 ml. of 3 *N* hydrochloric acid. The dinitrophenylhydrazones were extracted into benzene (250 ml.), which was then concentrated to 100 ml. and diluted with 200 ml. of petroleum ether. Adsorption on a silicic acid column 48 × 200 mm. followed by development with petroleum ether (60–70°)–ether (6:1) yielded a slow intense band and a fast faint band. The slow band yielded 210 mg. (93 mole %) of acetone dinitrophenylhydrazone identified by melting point 125–126°, mixed melting point and optical properties. The fast moving band yielded 12 mg. of the dinitrophenylhydrazone of methyl *n*-propyl ketone.[11] No evidence for isobutyraldehyde could be obtained. Comparable results were obtained in the ozonization of the dextrorotatory and inactive isomers. When the oily fractions B and C obtained by chromatography of isohumulone oil were ozonized, in addition to acetone dinitrophenylhydrazone, small yields of isobutyraldehyde 2,4-dinitrophenylhydrazone (9–14 mole %) were isolated and identified by mixed melting points and examination of optical properties.

Absorption Spectra.—Ultraviolet absorption spectra were determined with a Cary recording spectrophotometer and infrared spectra were obtained with a Beckman IR-3 recording spectrophotometer.

(11) Humulone, lupulone and humulinic acid have been found to yield traces of this compound on ozonization, J. F. Carson, THIS JOURNAL, **73**, 4652 (1951).

ALBANY 6, CALIFORNIA

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE UNIVERSITY OF ILLINOIS]

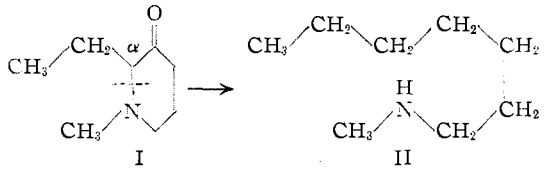
The Electrolytic Reduction of Bicyclic α-Aminoketones. A New Method for the Synthesis of Medium Rings[1] Containing Nitrogen[2,3]

BY NELSON J. LEONARD, SHERLOCK SWANN, JR., AND JOHN FIGUERAS, JR.

RECEIVED APRIL 14, 1952

A new method has been discovered for the synthesis of medium-size ring compounds containing a nitrogen atom, namely, the electrolytic reduction of bicyclic α-aminoketones at a lead cathode in 30% sulfuric acid at 60°. Certain nine- and ten-membered-ring aminoalcohols have been obtained in good yields by this method. Specifically, the electrolytic reduction of 1-ketoquinolizidine led to the monocyclic product, 5-hydroxyazacyclodecane. The presence of a secondary amine function in the product was established by N-methylation with formaldehyde-formic acid, and the size of the ring present in the product was determined by its conversion to azacyclodecane through the successive operations of dehydration and catalytic reduction. The similar electrolytic reduction of 1-ketoöctahydropyrrocoline produced 4-hydroxyazacyclononane and 8-keto-octahydropyrrocoline gave the isomeric 5-hydroxyazacyclononane. Indication of the monocyclic nature of the products was obtained from the fact that both could be methylated readily by means of formaldehyde–formic acid.

Previous work in these laboratories has shown that the reduction of 1-methyl-2-ethyl-3-piperidone (I) at a lead cathode in 30% sulfuric acid at 60° yields, as the main product, N-methylheptylamine (II).[4] On the basis of this discovery, it was anticipated that the electrolytic reduction, under the same conditions, of *bicyclic* α-aminoketones (III, XI, XV) should yield medium-size rings containing a nitrogen atom. In the past, the main factor limiting the preparation of cycles having nine or ten members has been the difficulty of closure of rings of this size. The selection of bicyclic compounds (5,6 or 6,6 rings) as precursors would circumvent this difficulty since the medium ring (9 or 10) is already existent in the external boundary of the bicyclic system. The facile scission of the C_α–N bond of α-aminoketones under electrolytic reduction conditions[4] offers a unique method for bringing about a valence-bridge cleavage which converts a bicyclic to a monocyclic compound.



I II

The electrolytic reduction of 1-ketoquinolizidine (III) at a lead cathode in a catholyte of 30% sulfuric acid at 60° gave a mixture of two products. The lower boiling fraction, obtained in 4.5% yield, was shown to be 1-azabicyclo[5.3.0]decane (IV),[5] by direct comparison of the picrate with an authentic sample.[6] The higher boiling material, obtained in 59% yield, showed a strong infrared absorption band at 3345 cm.$^{-1}$, indicating the presence of an hydroxyl (and/or NH) group. Microanalysis of the base and its picrate indicated a molecular formula, $C_9H_{19}NO$, consistent with a monocyclic aminoalcohol structure. The production of an open-chain aminoalcohol by the electrolytic reduction of 1-butyl-3-pyrrolidone[4] suggested, by analogy, that the $C_9H_{19}NO$ compound was 5-hydroxyazacyclodecane (V). In order to

(1) We are using the classification of H. C. Brown and V. Prelog (see ref. 21 in H. C. Brown, Roslyn S. Fletcher and R. B. Johannesen, THIS JOURNAL, **73**, 212 (1951)) of medium rings as those containing 8 to 12 members.

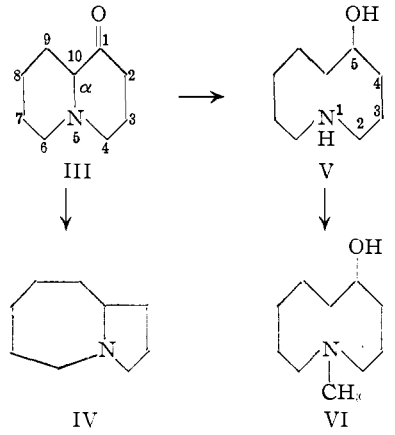
(2) This work was supported in part by a grant from E. I. du Pont de Nemours and Company, Inc.

(3) Presented at the 121st National Meeting of the American Chemical Society, Buffalo, N. Y., March 24, 1952.

(4) N. J. Leonard, S. Swann, Jr., and H. L. Dryden, Jr., THIS JOURNAL, **74**, 2871 (1952).

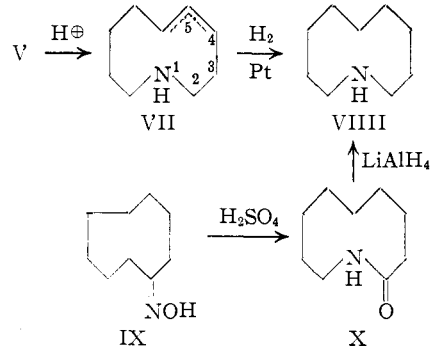
(5) V. Prelog and K. Seiwerth, *Ber.*, **72**, 1638 (1939), proved that this compound was the product of the Clemmensen reduction of 1-ketoquinolizidine.

(6) N. J. Leonard and W. C. Wildman, THIS JOURNAL, **71**, 3100 (1949).



III V IV VI

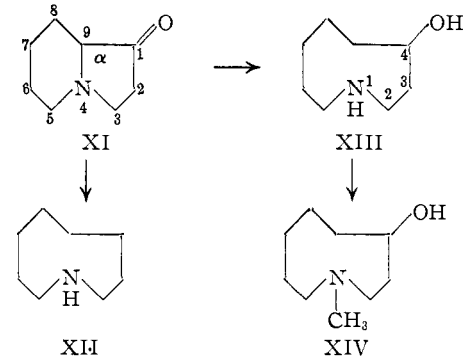
prove that the nitrogen atom was present as a secondary amine function, a methylation procedure was employed which was known to be ineffective for O-methylation but effective for N-methylation: formaldehyde–formic acid.[7] The use of this reagent with V produced a $C_{10}H_{21}NO$ compound, which had infrared absorption bands at 1376 and 3333 cm.$^{-1}$, indicative of the methyl and hydroxyl groups present in the molecule. The methylated compound was therefore assigned the structure 1-methyl-5-hydroxyazacyclodecane (VI). In order to establish directly the presence of the ten-membered ring in these compounds (V and VI), it was considered necessary to transform the $C_9H_{19}NO$ aminoalcohol to a compound known to possess the ten-membered-ring structure. Accordingly, the aminoalcohol (V) was dehydrated by heating with hydrochloric acid, and the mixture obtained, con-



VII VIII IX X

taining Δ^4- or Δ^5-unsaturated amine (VII) or both, was hydrogenated directly. The saturated amine obtained by this sequence of reactions had the composition requisite for azacyclodecane ($C_9H_{19}N$) and formed a picrate, m.p. 191–192°, which was found to be identical with an authentic sample of azacyclodecane (VIII) picrate. Authentic azacyclodecane was prepared by the method of Ruzicka, Kobelt, Häfliger and Prelog,[8] through Beckmann rearrangement of cyclononanone oxime (IX), followed by lithium aluminum hydride reduction of the resulting ten-membered-ring amide (X). Direct evidence for the position of the hydroxyl group in 5-hydroxyazacyclodecane (V) was not obtained, but in view of previous work in these laboratories,[4] there was no reason to expect that the original carbonyl group and the final hydroxyl group would occupy different relative positions.

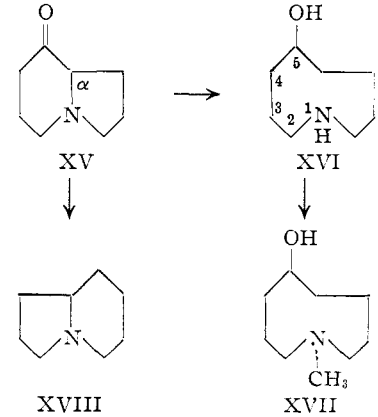
Since the electrolytic reduction of 1-ketoquinolizidine (III) was thus shown to produce 5-hydroxyazacyclodecane (V) as the main product, it was desirable to learn whether bicyclic α-aminoketones possessing six- and five-membered fused rings could be converted to nine-membered-ring aminoalcohols by similar reduction at 60° using a lead cathode. The reduction of 1-ketoöctahydropyrrocoline (XI) gave two products which were shown to possess the desired nine-membered-ring structure.



XI XIII XII XIV

The lower boiling compound, obtained in about 1% yield, had physical properties suggestive of azacyclononane (XII) and formed a picrate, m.p. 149–151°, which was identical with an authentic sample of azacyclononane[8] picrate. The major product (49% yield) had composition ($C_8H_{17}NO$) and physical properties consistent with its structural assignment as XIII, 4-hydroxyazacyclononane. The secondary function of the nitrogen and the monocyclic constitution of the aminoalcohol were established by the formation of a methylated product (1-methyl-4-hydroxyazacyclononane, XIV) on treatment with formaldehyde–formic acid. The infrared spectrum of the latter indicated the presence of a methyl group and the retention of the hydroxyl group.

The electrolytic reduction of 8-ketoöctahydropyrrocoline (XV) resulted in the formation of 5-hydroxyazacyclononane (XVI) in yields up to 73%. The establishment of the structure was based on analogy with the aminoalcohol products obtained from III and XI and on N-methylation with formaldehyde–formic acid, which provided the homol-



XV XVI XVIII XVII

(7) *Org. Syntheses*, **25**, 89 (1945).

(8) L. Ruzicka, M. Kobelt, O. Häfliger and V. Prelog, *Helv. Chim. Acta*, **32**, 544 (1949).

ogous 1-methyl-5-hydroxyazacyclononane (XVII). A second product of the electrolytic reduction of XV at 60° using a lead cathode was octahydropyrrocoline (XVIII),[9] and the yield of this material was greater, the higher the concentration of XV in the catholyte.

The products obtained from all three of the bicyclic α-aminoketones here studied (III, XI, XV) necessarily result from initial C_α–N cleavage at the cathode. This fact has already been established for the case of monocyclic α-aminoketones.[4] 5-Ketoazacyclodecane, resulting from C_α–N cleavage in 1-ketoquinolizidine (III), would serve as the intermediate for both 5-hydroxyazacyclodecane (V) and 1-azabicyclo[5.3.0]decane (IV). The yield of the bicyclic product (IV) was greater as the concentration of 1-ketoquinolizidine in the catholyte solution was increased. The apparent concentration effect was analogous to that observed in the conversion of 8-ketoöctahydropyrrocoline (XV) to monocyclic (XVI) and bicyclic (XVIII) products. In the latter case, the intermediate aminoketone resulting from C_α–N cleavage would be expected to be capable of forming a bicyclic structure (6,5 → 5,6 ring), whereas the intermediate aminoketone resulting from C_α–N scission in 1-ketoöctahydropyrrocoline (XI) would not be expected to form a bicyclic structure having one four-membered-ring (5,6 → 4,7 ring).

In conclusion, the method here devised provides a new path to ring structures of medium size possessing N–H and O–H functions, and the nine- and ten-membered-ring aminoalcohols described are representative of cyclic structures which can be made by the electrolytic reduction of bicyclic α-aminoketones.

Experimental[10,11]

Bicyclic α-Aminoketones. 1-Ketoquinolizidine (III).[12]—After alkylation of ethyl 2-piperidinecarboxylate[13] with γ-bromobutyronitrile and ethanolysis of the resulting ester nitrile, a 69% yield of diethyl piperidine-1-γ-butyrate-2-carboxylate was obtained, b.p. 95–98° (0.03 mm.), $n^{20}D$ 1.4588. The diester was cyclized in toluene using sodium ethoxide, in the usual manner.[14] The Dieckmann product was hydrolyzed and the keto acid was decarboxylated in 6 *N* hydrochloric acid to give an 85% yield of 1-ketoquinolizidine, b.p. 95° (4 mm.). The aminoketone formed a **semicarbazone**, colorless prisms, m.p. 214°.[12] **The picrate** was formed in ether and recrystallized from ethyl acetate–cyclohexane as yellow prisms, m.p. 167–168°.

Anal. Calcd. for $C_{15}H_{18}N_4O_8$: C, 47.12; H, 4.86. Found: C, 47.46; H, 5.05.

1-Ketoöctahydropyrrocoline (XI).[15,16]—Ethyl 2-piperidinecarboxylate and excess ethyl acrylate were heated in ethanol under a reflux condenser for 3.5 hours. After removal of the low boiling materials and distillation of the residue, diethyl piperidine-2-carboxylate-1-β-propionate was obtained in 68% yield, b.p. 110° (0.15 mm.). 1-Ketooctahydropyrrocoline was obtained in the usual way from this diester in 62% yield, b.p. 85° (3 mm.), $n^{20}D$ 1.4812. **The picrate** was formed in ether and recrystallized from acetone as yellow plates, m.p. 175–176°.

Anal. Calcd. for $C_{14}H_{16}N_4O_8$: C, 45.65; H, 4.38. Found: C, 45.97; H, 4.58.

8-Ketoöctahydropyrrocoline. Ethyl Pyrrolidine-1-γ-butyronitrile-2-carboxylate.—A mixture of 21 g. (0.15 mole) of crude ethyl ester of proline, 23 g. of anhydrous potassium carbonate and 22 g. (0.15 mole) of γ-bromobutyronitrile was warmed on a steam-bath for one-half hour with occasional swirling. After cooling, a sufficient quantity of water was added to dissolve the inorganic salts. The mixture was extracted with ether, the ethereal solution was dried and the ether was removed by distillation. The ester nitrile boiled at 133° (0.1 mm.), $n^{20}D$ 1.4617, d^{20}_4 1.015, yield 24.2 g. (79%).

Anal. Calcd. for $C_{11}H_{18}N_2O_2$: C, 62.83; H, 8.63; MR_D, 56.29. Found: C, 62.74; H, 8.69; MR_D, 56.94.

The picrate, formed in ether and recrystallized from ethyl acetate–cyclohexane, melted at 111–112°.

Diethyl Pyrrolidine-1-γ-butyrate-2-carboxylate.—A vigorous stream of dry hydrogen chloride was passed for 10 minutes into a well-cooled mixture of 150 ml. of absolute ethanol and 23.4 g. (0.111 mole) of ethyl pyrrolidine-1-γ-butyronitrile-2-carboxylate. The reaction mixture was heated under reflux for 1 hour. The hot solution was filtered and the filtrate was concentrated *in vacuo*. Water (*ca.* 50 ml.) was added to the concentrate, the resulting mixture was cooled and made alkaline with 40% sodium hydroxide. The product was extracted with four 50-ml. portions of ether. The ether solution was dried and the ether was removed. The residue was distilled, b.p. 104–107° (0.2 mm.), $n^{20}D$ 1.4550, d^{20}_4 1.028, yield 17.4 g. (61%).

Anal. Calcd. for $C_{13}H_{23}NO_4$: C, 60.67; H, 9.01; MR_D, 67.44. Found: C, 60.75; H, 8.78; MR_D, 67.91.

8-Ketoöctahydropyrrocoline (XV).—Diethylpyrrolidine-1-γ-butyrate-2-carboxylate was cyclized with sodium ethoxide in dry toluene and the Dieckmann product was converted to the aminoketone in the usual manner.[14] From 26.2 g. (0.112 mole) of the aminodiester was obtained 5.8 g. (41%) of 8-ketoöctahydropyrrocoline, b.p. 79–80° (5.5 mm.), $n^{20}D$ 1.4893.

Anal. Calcd. for $C_8H_{13}NO$: C, 69.08; H, 9.42. Found: C, 68.86; H, 9.59.

The picrate was obtained as small yellow needles from ether, m.p. 141.5–145°.

Anal. Calcd. for $C_{14}H_{16}N_4O_8$: C, 45.65; H, 4.38. Found: C, 45.78; H, 4.36.

8-Hydroxyoctahydropyrrocoline.—A solution of 1.0 g. (0.007 mole) of 8-ketoöctahydropyrrocoline in 10 ml. of anhydrous ether was added gradually to 0.5 g. of lithium aluminum hydride[17] in 20 ml. of ether. The mixture was allowed to stand for 10 minutes, and 1.0 ml. of water was added cautiously, followed by 0.8 ml. of 10% sodium hydroxide solution. The mixture was allowed to stand overnight. The ether solution was decanted from the precipitated salts, and the salts were washed well with ether. The combined ether solutions were dried, the ether was removed, and the residue was distilled at a bath temperature of 100° and a pressure of 0.03 mm., $n^{20}D$ 1.5000, yield 0.58 g. (58%).

Anal. Calcd. for $C_8H_{15}NO$: C, 68.04; H, 10.71; N, 9.92. Found: C, 68.17; H, 10.79; N, 9.61.

The infrared absorption spectrum of this product showed the presence of a hydroxyl group (absorption at 3333 cm.$^{-1}$) and the absence of a carbonyl group.

The picrate was formed in ether and obtained as small yellow prisms from ethyl acetate–cyclohexane, m.p. 175–176°.

Anal. Calcd. for $C_{14}H_{18}N_4O_8$: C, 45.41; H, 4.90. Found: C, 45.52; H, 4.90.

(9) N. J. Leonard and W. E. Goode, THIS JOURNAL, **72**, 5404 (1950).

(10) We wish to express our thanks to Dr. Hugh L. Dryden, Jr., and Mr. Gene C. Robinson for their kind assistance. Microanalyses were performed by Miss Emily Davis, Mrs. Jean Fortney and Mrs. Katherine Pih. We are indebted to Miss Elizabeth M. Petersen and Miss Helen Miklas for determination of infrared spectra.

(11) All melting points are corrected.

(12) G. R. Clemo and G. R. Ramage, *J. Chem. Soc.*, 437 (1931).

(13) Picolinic acid was obtained from α-picoline in 71% yield by a modification of the method of G. Black, E. Depp and B. B. Corson (*J. Org. Chem.*, **14**, 14 (1949)), and catalytic reduction followed by esterification was the sequence used to obtain ethyl 2-piperidinecarboxylate, in a modification of the procedure of A. W. Singer and S. M. McElvain (THIS JOURNAL, **57**, 1135 (1935)).

(14) N. J. Leonard and W. V. Ruyle, *ibid.*, **71**, 3094 (1949).

(15) G. R. Clemo and G. R. Ramage, *J. Chem. Soc.*, 2969 (1932).

(16) G. R. Clemo, T. P. Metcalfe and R. Raper, *ibid.*, 1129 (1936).

(17) R. F. Nystrom and W. G. Brown, THIS JOURNAL, **70**, 3738 (1948).

Electrolytic Reductions.—The lead cathode used in these experiments was cast in a graphite mold which was initially at a temperature of 25°. The cathode was anodized in perchloric acid prior to use. Its purity was 99.95% or better. The apparatus and procedure employed have been described by Swann.[18] The electrolysis cell was assembled and placed in a bath at 60°. The anolyte was preheated to 55–60° and poured into its compartment. The voltage was applied and the catholyte solution, previously heated to 55–60°, was added all at once through the condenser. The amperage was adjusted to 5.0 amp. by means of a rheostat in series with the cell. The current density was thus maintained at 0.05 amp./cm.^{2}. Current was allowed to flow until 4.5–5.0 faradays per mole had passed. All runs were made in 30% sulfuric acid at 60 ± 5°.

After completion of electrolysis, the cell was disassembled immediately. The catholyte was made strongly basic with 40% aqueous sodium hydroxide, while the temperature was maintained at 20–30° by external cooling. The solution was saturated with potassium carbonate and then filtered to remove precipitated salts. The salts and the filtrate were thoroughly extracted with ether. This method led to good recoveries and was more advantageous than steam distillation of the high-boiling aminoalcohols. The combined ether extracts were dried over anhydrous sodium sulfate and the ether was removed by distillation.

Reduction of 1-Ketoquinolizidine (III).—From 5.35 g. (0.036 mole) of 1-ketoquinolizidine in 100 ml. of 30% sulfuric acid was obtained 4.72 g. of crude product. Two colorless, liquid fractions, A and B, were collected and were identified as **1-azabicyclo[5.3.0]decane and 5-hydroxyazacyclodecane.** Fraction A, b.p. 100° (0.7 mm.), n^{20}D 1.4838, yield 0.24 g. (4.5%), formed a picrate in ether, m.p. 209–210°. One recrystallization from methanol gave yellow needles, m.p. 217–217.5°, which did not depress the melting point of an authentic sample of 1-azabicyclo[5.3.0]decane picrate[6,19] and the infrared spectra of the two picrates were identical. Fraction B, b.p. 75° (0.2 mm.), n^{20}D 1.5050, yield 3.17 g. (59%), showed a very strong, slightly unsymmetrical infrared absorption band at 3345 cm.$^{-1}$, corresponding to an OH (and/or NH) group.

Anal. Calcd. for $C_9H_{19}NO$: C, 68.74; H, 12.18; N, 8.91. Found: C, 68.98; H, 12.01; N, 8.61.

The picrate, which was formed in ether and recrystallized from ethyl acetate–cyclohexane as fine yellow needles, m.p. 149–149.5°, had a composition consistent with that found for the parent substance.

Anal. Calcd. for $C_{15}H_{22}N_4O_8$: C, 46.63; H, 5.74; N, 14.50. Found: C, 46.85; H, 5.90; N, 14.39.

Establishment of the Secondary Amine Function.—To a solution of 2.6 g. of fraction B (5-hydroxyazacyclodecane) in 25 g. of formic acid (90%) was added 9.0 g. of 40% formalin. The mixture was heated at the boiling point for 4 hours. After the addition of 1.9 ml. of 12 *N* hydrochloric acid, the mixture was concentrated to a volume of 5–10 ml. The concentrate was made alkaline with a 40% solution of sodium hydroxide, followed by enough water to dissolve any precipitated salts. The alkaline mixture was extracted with ether and the combined ether extracts were dried. The ether was removed and the residue was distilled as a colorless liquid, b.p. 102° (2.5 mm.), n^{20}D 1.4913, yield 1.52 g. (54%), with the correct composition for the N-methyl derivative.

Anal. Calcd. for $C_{10}H_{21}NO$: C, 70.12; H, 12.36. Found: C, 69.62; H, 12.26.

The product showed infrared absorption bands at 1376 and 3333 cm.$^{-1}$ corresponding to methyl and hydroxy groups present in the molecule (1-methyl-5-hydroxyazacyclodecane).

Establishment of the Ten-Membered Ring.—A solution of 0.74 g. of fraction B (5-hydroxyazacyclodecane) in 30 ml. of 12 *N* hydrochloric acid was heated on the steam-bath for 2 hours. The solution was allowed to stand overnight, diluted with 30 ml. of water, and the resulting solution was shaken for 2 hours at 25° and 3 atmospheres with hydrogen over platinum oxide. The catalyst was removed by filtration and the filtrate was basified with 40% sodium hydroxide solution. The basic mixture was extracted with ether, the ethereal extracts were dried, and the ether was removed. The residue formed a picrate, m.p. 178–179°, yield 1.27 g. (73%). Two recrystallizations from aqueous ethanol raised the melting point of the yellow needles to 191–192°.

Anal. Calcd. for $C_{15}H_{22}N_4O_7$: C, 48.64; H, 6.00; N, 15.13. Found: C, 48.66; H, 6.05; N, 14.99.

This picrate gave no melting point depression with an authentic sample of azacyclodecane picrate (see below) and the infrared spectra of the two picrates were identical.

Azacyclodecane (VIII).—This compound was prepared by the method of Ruzicka, Kobelt, Häfliger and Prelog.[8] From 97.5 g. of the diethyl ester of azelaic acid was obtained 3.0 g. of pure azacyclodecane picrate, long yellow needles, m.p. 191–192° (reported,[8] 184–185°).

Reduction of 1-Ketoöctahydropyrrocoline (XI).—The product from the reduction of 11.4 g. (0.083 mole) of 1-ketoöctahydropyrrocoline in 100 ml. of 30% sulfuric acid was distilled through a Holzman column[20] to give two colorless, liquid fractions, C and D, which were identified as **azacyclononane and 4-hydroxyazacyclononane.** The undistilled residue, after recrystallization from hexane, gave 2.0 g. of a colorless powder, m.p. 88–98°, which was not further characterized. Fraction C boiled at 44.5° (2 mm.) (92° at 24 mm. on a nomograph),[21] n^{20}D 1.4777, wt. 0.14 g. (1%). The physical properties of fraction C correspond to those reported for azacyclononane.[8] **The picrate** of fraction C was formed in ether and recrystallized from dilute ethanol as yellow needles, m.p. 150–152°.

Anal. Calcd. for $C_{14}H_{20}N_4O_7$: C, 47.19; H, 5.66. Found: C, 47.36; H, 5.69.

The derivative did not depress the melting point of the picrate, m.p. 149–151° (reported 135–136°,[8] 148–149°[22]), of authentic azacyclononane, prepared by ring expansion[8] of pure cycloöctanone.[23] The infrared absorption spectra of the two picrates were identical.

Fraction D, b.p. 70° (0.2 mm.), n^{20}D 1.5068, yield 5.68 g. (48%), showed a very strong, slightly unsymmetrical infrared absorption band in the hydroxyl region (3345 cm.$^{-1}$).

Anal. Calcd. for $C_9H_{17}NO$: C, 67.08; H, 11.97; N, 9.78. Found: C, 67.35; H, 11.82; N, 10.08.

The picrate was formed in ether and recrystallized as small yellow plates from ethyl acetate–cyclohexane, m.p. 137.5–139°.

Anal. Calcd. for $C_{14}H_{20}N_4O_8$: C, 45.16; H, 5.41. Found: C, 45.41; H, 5.56.

N-Methylation.—Fraction D (4-hydroxyazacyclononane) was N-methylated by the use of formaldehyde–formic acid, as in the case of the homologous 5-hydroxyazacyclodecane. The product was distilled *in vacuo* as a colorless liquid, b.p. 97° (4 mm.), n^{20}D 1.4897, yield 75%.

Anal. Calcd. for $C_9H_{19}NO$: C, 68.74; H, 12.18. Found: C, 68.46; H, 12.14.

The product showed infrared absorption bands at 1372 and 3339 cm.$^{-1}$ corresponding to methyl and hydroxyl groups present in the molecule (1-methyl-4-hydroxyazacyclononane). **The picrate** was formed in ether and recrystallized from absolute ethanol as fine, golden needles, m.p. 189–190°.

Anal. Calcd. for $C_{15}H_{22}N_4O_8$: C, 46.63; H, 5.74. Found: C, 47.00; H, 5.78.

Reduction of 8-Ketoöctahydropyrrocoline (XV).—The product from the reduction of 4.33 g. (0.031 mole) of 8-ketoöctahydropyrrocoline in 100 ml. of 30% sulfuric acid solution was fractionally distilled. Two colorless, liquid fractions, E and F, were obtained and were identified as **octahydropyrrocoline and 5-hydroxyazacyclononane.** Fraction E, b.p. 68° (20 mm.), n^{20}D 1.4701, yield 0.83 g. (21%), gave a picrate which crystallized from ethanol as small, yellow plates, m.p. 231–232°, and did not depress the melt-

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ing point of an authentic sample of octahydropyrrocoline picrate.[9] The infrared absorption spectra of the two samples were identical. Fraction F, b.p. 95° (0.1 mm.), yield 2.7 g. (47%), which became semi-solid on standing at room temperature, exhibited a strong infrared absorption band in the hydroxyl region (3345 cm.$^{-1}$). **The picrate** of fraction F was formed in ether and recrystallized from ethyl acetate–cyclohexane as small, yellow needles, m.p. 176–176.5°.

Anal. Calcd. for $C_{14}H_{20}N_4O_8$: C, 45.16; H, 5.41; N, 15.05. Found: C, 45.24; H, 5.64; N, 14.88.

While the analytical results were indicative of a monocyclic aminoalcohol, the melting point of the picrate was close to that of the picrate of the bicyclic aminoalcohol, 8-hydroxyoctahydropyrrocoline (see above). A mixture of the picrate of fraction F with the picrate of 8-hydroxyoctahydropyrrocoline melted at 152–158°, and the two picrates were therefore not identical. Although only small differences were detectable in the infrared spectra of the two picrates, the spectra of the corresponding free bases had well-defined differences.

N-Methylation.—Fraction F (5-hydroxyazacyclononane) was N-methylated by means of formaldehyde–formic acid as described above. The product was converted directly to the **picrate**, yellow rods from ethanol, decomposition point 285–289° after initial darkening at 258°, with an analysis consistent with that required for 1-methyl-5-hydroxyazacyclononane picrate.

Anal. Calcd. for $C_{15}H_{22}N_4O_8$: C, 46.63; H, 5.74; N, 14.50. Found: C, 46.89; H, 5.89; N, 14.63.

Concentration Effect in the Electrolytic Reductions.—As observed in pairs of runs, the following results indicate an apparent effect of concentration on the proportion of monocyclic and bicyclic products formed following initial C_α–N bond cleavage:

	1-Keto-quinolizidine		8-Ketoöcta-hydropyrrocoline	
Concn. (per 100 ml. of 30% H_2SO_4), g.	5.35	12.6	1.93	4.33
Yield bicyclic amine, %	4.5	38	None detected	21
Yield monocyclic amino-alcohol, %	59	41	73	47

1-Ketoöctahydropyrrocoline (11.4 g. per 100 ml.) gave no bicyclic amine.

URBANA, ILLINOIS

[CONTRIBUTION FROM THE LABORATOIRE DE CHIMIE PHYSIQUE, INSTITUT PASTEUR, PARIS, FRANCE]

Solubilization in Alcohol–Soap Micelles. II. Electrolytes as Additives[1]

BY H. B. KLEVENS[2]

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The addition of electrolytes to alcohol–soap systems results in an initial marked increase in hydrocarbon solubility followed by a decrease when the concentration of electrolyte is further increased. The effect of KCl > K_2SO_4 > $K_4Fe(CN)_6 \cdot 3H_2O$ for systems in which the concentrations of both alcohol and soap are low but the change in added electrolyte is minimized at higher soap and/or alcohol concentration. The apparent maxima in hydrocarbon solubility observed are probably due to the presence of micelles of a maximum solubilizing power and do not involve changes from solutions in which the hydrocarbon is dissolved to one in which water is solubilized.

Since it has been reported that the addition of electrolytes to soap solutions results in an increase in hydrocarbon solubility[3–5] and to a decrease in the amount of polar compound dissolved[3,4] and that the addition of long chain polar additives to soap solutions markedly enhances the solubility of hydrocarbons,[6] it was of some interest to determine what would be the competitive effect of these two apparently opposing additives (electrolyte and long chain alcohol). The addition of electrolyte decreases the long range coulomb repulsion forces and the polar additives tend to increase the van der Waals attraction forces with probably no effect on the forces of repulsion. These effects would tend to initially increase the micelle size and possibly the disorder in the micelle (for the micelle would be made up of C_{14} soap molecules and much shorter, C_8, alcohol molecules. This disorder will result in a marked increase in solubilizing power.[7] At higher salt and alcohol concentrations, the competitive effects should predominate.

Experimental Methods

The solubility of hydrocarbons was determined by a turbidometric method described previously.[8] The soap was prepared from a carefully fractionated methyl ester of tetradecanoic acid followed by saponification with hot alcoholic potassium hydroxide. Solutions were prepared so that there was always an excess of about 5% potassium hydroxide to decrease the amount of hydrolysis. The long chain alcohols were obtained from the Humphrey–Wilkinson Company and were purified by fractional distillation. The *n*-heptane obtained from Westvaco Chlorine Company was used without further purification since spectroscopic studies have shown it to be quite free of unsaturates and branch chain isomers.[9]

The Effect of Added Electrolyte on Solubility of *n*-Heptane in Soap–Alcohol Micelles.—The data in Fig. 1 show the effect of added electrolyte upon the solubility of *n*-heptane in potassium tetradecanoate (KC_{14})–octanol-1 solutions. For those systems with high alcohol–soap ratios, there appears to be an optimum value of hydrocarbon solubility. These apparent maxima occur at decreasing values of KCl with increasing alcohol–soap ratios, and have approximately the same solubility values for *n*-heptane of about 0.55 mole per 1000 g. of soap–alcohol solution. At higher electrolyte concentrations than those reported here, for solutions with alcohol–soap mole ratios of 1.2, 0.88, 0.635 and 0.38, the systems were initially turbid since the concentrations of added KCl were sufficient to decrease the octanol-1 solubility.

(1) Experimental work done in part at the Division of Agricultural Biochemistry, University of Minnesota, St. Paul, Minnesota.

(2) Advanced Research Scholar, Fulbright Act 1951–1952; Institut Pasteur, Paris XV, France.

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