

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

The Electrolytic Reduction of α -Aminoketones^{1,2}

BY NELSON J. LEONARD, SHERLOCK SWANN, JR., AND HUGH L. DRYDEN, JR.

The electrolytic reduction of aminoketones has been studied systematically to determine the influence of (a) the structure (α - and β -aminoketones) and ring size (acyclic and five- and six-membered rings) of the aminoketone, (b) the cathode material (cadmium, lead, copper and tin), (c) the temperature of reduction (60 and 20°). Of special interest was our finding that the electrolytic reduction of 1-methyl-2-ethyl-3-piperidone at 60° in sulfuric acid at a cadmium cathode proceeds with rearrangement to give 1-methyl-2-propylpyrrolidine. The same reduction-rearrangement product was obtained previously under Clemmensen conditions. By contrast, electrolytic reduction of the same α -aminoketone at 20° using a cadmium or lead cathode gave N-methylheptylamine. "Chemical" reduction at 20° using amalgamated zinc and hydrochloric acid also yielded N-methylheptylamine. A consideration of the products obtained in our electrolytic reduction studies indicates that the initial step of reductions leading to ring opening and/or rearrangement is cleavage of the C α -N bond. The nature of the reduction products isolated can be related to the structure of the intermediate obtained by the initial C α -N cleavage, the reduction temperature, and the relative activities of the electrodes for the reduction of simple aliphatic ketones as previously observed.

Introduction

It has been shown in recent studies³ on the Clemmensen reduction of cyclic α -aminoketones that ring size is one factor which determines whether an open-chain 2°-amine or a rearranged 3°-amine is produced. Since it is known^{4,4a} that simple aliphatic ketones can be reduced to hydrocarbons electrolytically, a reaction which is analogous to "chemical" reduction by the Clemmensen method, and since it was to be expected that selective reductions, involving only the carbonyl group or the C α -N bond of the α -aminoketone, could be effected by a choice of suitable cathodes, we have studied the electrolytic reduction of representative cyclic α -aminoketones with the hope of elucidating further³ the course of these reductions.

The reduction of 1-methyl-2-ethyl-3-piperidone (I) was studied at cathodes of cadmium, copper, lead and tin at temperatures of 60 and 20°. Reduction of 1-butyl-3-pyrrolidone (VIII) was studied at a cadmium cathode at 60 and 20°, and dimethylaminoacetone and 1-methyl-4-piperidone were reduced at the same cathode at 60°. All reductions were carried out in 30% sulfuric acid as the catholyte and at cathodic current densities in the range 0.053-0.073 amp. per cm.². The quantity of current allowed to pass through the electrolysis cell wherever possible was equivalent to six faradays per mole of aminoketone, which is the theoretical current for scission of the C α -N bond and reduction of the carbonyl group to methylene. After completion of the reduction, the catholyte was made

TABLE I
ELECTROLYTIC REDUCTION OF AMINOKETONES

Compound	Cathode	Temp., °C.	Products	Yield, %
1-Methyl-2-ethyl-3-piperidone (I)	Cadmium	60	1-Methyl-2-propylpyrrolidine (VI)	41
		20	1-Methyl-2-ethyl-3-hydroxypiperidine (VII)	10
		20	N-Methylheptylamine (III)	36
	Lead	60	N-Methylheptylamine (III)	36
		20	1-Methyl-2-propylpyrrolidine (VI)	20
		20	N-Methylheptylamine (III)	54
	Copper	60	1-Methyl-2-propyl- Δ^2 -pyrroline (V)	27
		20 ^a	1-Methyl-2-propylpyrrolidine (VI)	11
		20 ^c		
Tin	60 ^b			
	20 ^c			
	20 ^c			
1-Butyl-3-pyrrolidone (VIII)	Cadmium	60	Dibutylamine (X)	64
		60	1-Butyl-3-hydroxypyrrolidine (XI) + } 1-Butylamino-3-butanol (XII)	21 ^d
		20	Dibutylamine (X)	37
	20	1-Butyl-3-hydroxypyrrolidine (XI) + } 1-Butylamino-3-butanol (XII)	39 ^d	
	20	1-Methylpiperidine	59	
	20	Dimethylamine ^e	25	

^a 94% of starting material recovered. ^b 78% of starting material recovered. ^c 85% of starting material recovered. ^d Total yield of both compounds. ^e Isolation of the hydrocarbon product was not attempted.

(1) Reported at the Twelfth National Organic Symposium of the American Chemical Society, Denver, Colorado, June 14, 1951.

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

(3) For leading reference, see N. J. Leonard and R. C. Sentz, THIS JOURNAL, **74**, 1704 (1952).

(4) S. Swann, Jr., and J. Feldman, *Trans. Electrochem. Soc.*, **67**, 195 (1935).

(4a) S. Swann, Jr., and E. W. Field, *ibid.*, **72**, 327 (1937).

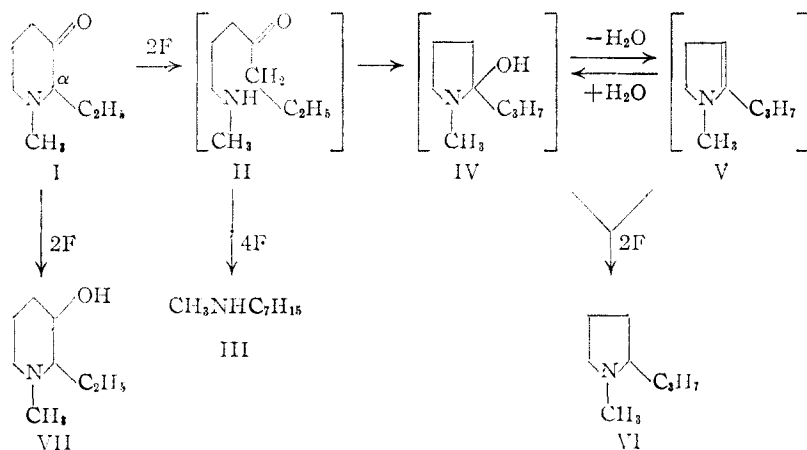
strongly alkaline and the reduction products were separated by extraction with ether or by steam distillation. Identification of the products was made by means of their physical properties and by comparison of derivatives with authentic samples. The results of the electrolytic reductions are assembled in Table I.

Discussion of Results

It was possible to duplicate the Clemmensen reduction-rearrangement⁵ of the six-membered-ring α -aminoketone, 1-methyl-2-ethyl-3-piperidone (I) to 1-methyl-2-propylpyrrolidine (VI) by carrying out the electrolytic reduction at 60° using a cadmium cathode. Under these electrolytic conditions, 1-methyl-2-ethyl-3-hydroxypiperidine (VII) was isolated as a minor product (10% yield) from the reduction of I.

The reduction-rearrangement (I \rightarrow VI) was also brought about, although less effectively, at a lead cathode (20% yield as compared with 41% yield at cadmium), and at a copper cathode (10% yield), both at 60°. The low activity of the copper cathode compared with the activities of cadmium and lead has also been observed by Swann and Feldman⁴ for the reduction of methyl *n*-propyl ketone to *n*-pentane. The failure of a tin cathode to bring about reduction of I is of interest since it indicates that a high hydrogen overvoltage at the cathode is not the sole factor in effecting reduction. Tin is a cathode of high hydrogen overvoltage as are cadmium and lead, whereas copper is a cathode of low hydrogen overvoltage.⁶ A tin cathode has been shown to be only slightly active for the reduction of methyl *n*-propyl ketone⁴ and *n*-valeraldehyde.^{4*}

A reasonable explanation for the products obtained by the electrolytic reduction of I is indicated in the accompanying diagram. The initial intermediate (II) in the reduction sequence results from



the cleavage⁷ of the C_α -N bond of the aminoketone I at the cathode surface. That such a cleavage is possible during electrolytic reduction was indicated by the fact that, in a preliminary experiment, the reduction of dimethylaminoacetone at 60° at a cadmium cathode gave dimethylamine as the only isolable basic reduction product (see Table I).³

(5) N. J. Leonard and W. V. Ruyle, *THIS JOURNAL*, **71**, 3094 (1949).

(6) J. O'M. Bokris, *Nature*, **159**, 539 (1947).

(7) For postulates of the mechanism of C_α -N cleavage under Clemmensen reduction conditions, see (a) G. R. Clemo, R. Raper and H. J. Vipond, *J. Chem. Soc.*, 2095 (1949), and (b) J. H. Brewster, Abstracts of Papers, 12th International Congress of Pure and Applied Chemistry, New York, N. Y., September, 1951, p. 466.

(8) The cleavage of several quaternary benzylammonium salts to yield toluene at lead and platinum cathodes has been reported by H. Klinz, "Über die Elektrolyse quaterer ammonium Salze," Dissertation, Würzburg, 1924.

Direct reduction of the carbonyl group of II would lead to N-methylheptylamine (III), whereas cyclization to an intermediate such as IV or the pyrroline V⁹ followed by reduction would lead to the formation of the rearrangement product VI.¹⁰ The formation of 1-methyl-2-propyl- Δ^2 -pyrroline (V) (in 24% yield together with 10% of 1-methyl-2-propylpyrrolidine (VI)) at a copper cathode at 60° is in accord with this reaction scheme. Apparently a copper cathode is relatively inactive for the reduction of intermediates such as IV and V even though it can effect the cleavage of the C_α -N bond. Since it is known⁴ that a copper cathode is only slightly active for carbonyl reductions, conversion of the intermediate ketone (II) to III would not be expected to occur. Hence the ketone II must remain in the catholyte as a salt or be converted to IV and/or V which are reduced only partially at copper. Treatment of the catholyte solution with strong alkali followed by steam distillation would be expected to convert II or IV to 1-methyl-2-propyl- Δ^2 -pyrroline (V) as well as to liberate any of the latter already present in the catholyte as the salt.

Apparently cyclization of the intermediate II is favored only at elevated temperatures, since 1-methyl-2-propylpyrrolidine (VI) was obtained from 1-methyl-2-ethyl-3-piperidone (I) only when the electrolytic reductions (at cadmium, lead, or copper) were carried out at 60°, whereas N-methylheptylamine (III) was the sole product at 20° (at the cadmium or lead cathode). Since both cadmium and lead cathodes are known to be active

for the reduction of methyl *n*-propyl ketone to *n*-pentane,⁴ the conversion of II to III at these cathodes is to be expected. The novelty of the observed conversions lies in their temperature dependency. The lead cathode used was more effective than the cadmium cathode in producing the open chain product, N-methylheptylamine (III), as is shown by the relative yields of III at the two cathodes at 20° (54% at lead and 36% at cadmium) and by the formation of a substantial quantity (36%) of III at the lead cathode at 60°. At 20° the copper cathode was ap-

parently inactive for the initial C_α -N bond cleavage since I was recovered unchanged.

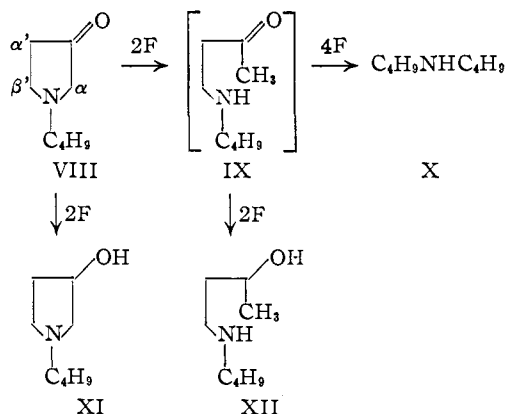
Normally Clemmensen reductions are carried out with zinc amalgam and concentrated hydrochloric acid at the reflux temperature. The observed temperature-dependence of the electrolytic reduction of I at cadmium led us to examine the "chemical" reduction of I for a similar influence of temperature upon the product obtained. Indeed, when 1-methyl-2-ethyl-3-piperidone (I) was reduced with zinc amalgam and hydrochloric acid and maintained at 20° rather than the usual reflux

(9) The isomeric structure with the exocyclic 2, α -double bond is not precluded.

(10) L. C. Craig (*THIS JOURNAL*, **55**, 2543 (1933)) has reported the electrolytic reduction of several 2-alkyl-1-methyl- Δ^2 -pyrrolines to the corresponding pyrrolidines at a lead cathode in yields of 45-92%.

temperature, N-methylheptylamine (III) resulted instead of the ring-contracted product VI.

The electrolytic reduction of the five-membered ring α -aminoketone, 1-butyl-3-pyrrolidone (VIII), at a cadmium cathode at 60 and 20° yielded dibutylamine (X) together with a mixture of 1-butyl-3-hydroxypyrrolidine (XI) and 1-butylamino-3-butanol (XII). The yield of dibutylamine (X) was higher at 60 than 20°; the yield of mixed alcohols was lower at 60° (see Table I). In both cases, the mixture of alcohols contained approximately 90% of the open chain alcohol XII. An



authentic sample of 1-butyl-3-hydroxypyrrolidine (XI) was prepared by the reduction of VIII with lithium aluminum hydride. The addition of butylamine to methyl vinyl ketone followed by reduction of the crude 1-butylamino-3-butanone with lithium aluminum hydride yielded a sample of 1-butylamino-3-butanol (XII).

The results of the reduction of VIII support the hypothesis that cleavage of the C_{α} -N bond is the first step in the reduction. In this case the intermediate 2°-aminoketone IX cannot cyclize, even at 60°, and instead undergoes reduction either to X or to the corresponding alcohol XII. Reduction to X is favored at the higher reaction temperature. Some five-membered ring alcohol (XI) is formed in a competitive reaction but the major component of the alcoholic reduction products is XII, indicating that ring opening is the dominant course of the reduction. That the initial ring opening did not occur by a β -elimination giving 1-butylamino-2-butanone as a reaction intermediate is shown by the identification of the open chain alcohol as 1-butylamino-3-butanol (XII) rather than 1-butylamino-2-butanol, and by the fact that 1-methyl-4-piperidone, which could theoretically undergo a β -elimination, is converted to 1-methylpiperidine when reduced at a cadmium cathode at 60° (see Table I).

Experimental¹¹

α -Aminoketones.—1-Methyl-2-ethyl-3-piperidone,⁵ 1-butyl-3-pyrrolidone¹² and dimethylaminoacetone¹³ were prepared as described in the literature. We are indebted to

(11) Melting points are corrected and boiling points are uncorrected. Microanalyses were performed by Mrs. Jean Fortney, Mrs. Katherine Pih and Miss Emily Davis. We are indebted to Miss Elizabeth M. Petersen for determination of infrared spectra.

(12) N. J. Leonard, F. E. Fischer, E. Barthel, Jr., J. Figueras, Jr., and W. C. Wildman, *THIS JOURNAL*, **73**, 2371 (1951).

(13) J. W. Magee and H. R. Henze, *ibid.*, **60**, 2148 (1938).

Eli Lilly and Company for a sample of 1-methyl-4-piperidone.

Electrolytic Reductions.—The cathodes of cadmium, lead and tin were cast in graphite molds which were initially at temperatures of 270, 25 and 70°, respectively. The lead cathode was etched in perchloric acid prior to use. Several lengths of extruded copper rod were used for the copper cathode. All of the metals had a purity of 99.95% or better. The apparatus¹⁴ and procedure employed have been described by Swann.¹⁵ A cold water-bath was placed around the electrolysis cell during the reductions at 20°. In carrying out the reductions at 60°, the electrolysis cell was assembled except for the catholyte solution and was then heated to 60° in a water-bath. The voltage was applied and the catholyte solution, previously heated to 60°, was added all at once through the condenser. The reduction temperatures were maintained to within 5° of the desired values. The current through the cell was 5.3 to 7.3 amperes, depending upon the current density desired, and was allowed to flow until the theoretical current (see Introduction) equivalent to 6 faradays per mole of aminoketone had passed. In the cases of the reductions of I at cadmium and lead cathodes at 20° and lead at 60° only the equivalent of 4 to 5 faradays per mole of aminoketone could be passed due to foaming of the catholyte.

(1) **Reduction of 1-Methyl-2-ethyl-3-piperidone (I) (a) Cadmium Cathode at 60°.**—The catholyte solution obtained from the reduction of 0.071 mole of I was made alkaline by the addition of excess 50% sodium hydroxide. A large excess of alkali was avoided and the temperature of the solution was kept above 10° to prevent separation of sodium sulfate which interfered with the extractions. The product was extracted with methylene chloride. The combined extracts were dried and the solvent was removed. The portion of the residue which was ether-soluble was distilled through a semimicro column¹⁶ to give 3.70 g. (41%) of product; b.p. 72–74° (55 mm.); n_D^{20} 1.4371–1.4378 (reported for 1-methyl-2-propylpyrrolidine,⁵ b.p. 146–147° (742 mm.); n_D^{20} 1.4380). The picolonate after recrystallization from ethanol melted at 169.6–171.6° (dec.) and admixture with an authentic sample of the picolonate of 1-methyl-2-propylpyrrolidine (m.p. 169.5–171°)⁵ caused no depression in the melting point. A picrate was prepared from the amine obtained in a similar reduction. After recrystallization from ethyl acetate the picrate melted at 122.5–124°. Admixture with the picrate of 1-methyl-2-propylpyrrolidine (m.p. 123–124°)⁵ caused no depression in the melting point.

Distillation of the pot residue gave 7 fractions of material boiling at 47–84° (3.7 mm.); yield 1.95 g. Two fractions (b.p. 69–80°; n_D^{20} 1.4678–1.4734; weight 1.0 g.) were treated with an excess of picric acid in ethanol giving 2.60 g. of a picrate, m.p. 107–109° after three recrystallizations from ethanol (literature⁵ for 1-methyl-2-ethyl-3-hydroxypiperidine (VII), b.p. 73–77° (4 mm.); n_D^{20} 1.4800; picrate m.p. 107–109.5°). A mixture with the picrate of 1-methyl-2-ethyl-3-hydroxypiperidine (m.p. 108–110.5°) melted at 108–111.5°. The weight of the picrate obtained corresponds to a 10% yield of the alcohol.

(b) **Cadmium Cathode at 20°.**—The catholyte solution obtained from the reduction of 0.071 mole of I was cooled in an ice-bath and was treated with 30% sodium hydroxide solution until it was just alkaline. Sufficient 6 *N* hydrochloric acid was added to bring the pH to 6. The solution was cooled to 5° and then was filtered to remove sodium sulfate. The filtrate was made strongly alkaline and was treated with 20 ml. of benzoyl chloride. A heavy oil separated and was extracted with ether. The combined ether extracts were shaken with anhydrous sodium sulfate and extracted with 40 ml. of 3 *N* hydrochloric acid followed by 40 ml. of water. When the combined aqueous extracts were made alkaline and steam distilled, only a few drops of organic distillate was obtained thus indicating the absence of any appreciable quantity of VI. The solvent was removed from the ether solution and the residual benzoyl derivative was hydrolyzed by heating under reflux with 50

(14) Reference 15, p. 155, Fig. 3(A).

(15) S. Swann, Jr., "Electrolytic Reactions," in A. Weissberger, editor, "Technique of Organic Reactions," Vol. II. Interscience Publishers, Inc., New York, N. Y., 1948.

(16) G. W. Gould, Jr., G. Holzman and C. Niemann, *Anal. Chem.*, **20**, 361 (1948).

ml. of concentrated hydrochloric acid for 20 hours. The reaction mixture was concentrated to a small volume under reduced pressure, the residue was made strongly alkaline by the addition of 50% sodium hydroxide solution, and the amine was distilled in steam. When the steam distillate (250 ml.) was treated with potassium carbonate (60 g.) the *N*-methylheptylamine (III) separated and was isolated by extraction with ether followed by distillation through a semimicro column; b.p. 106–112° (138 mm.); yield 3.31 g. (36%); n_D^{20} 1.4247–1.4268. A sample of *N*-methylheptylamine prepared from methylamine and heptyl iodide¹⁷ had b.p. 164–166°; n_D^{20} 1.4232.

The product from a similar reduction in which the benzoylation procedure was omitted was distilled from sodium; b.p. 110–111° (139 mm.); n_D^{20} 1.4257. The picrate after recrystallization from ethanol–water mixture melted at 96.2–97.2° and admixture with an authentic sample of the picrate of *N*-methylheptylamine¹⁷ (m.p. 96.5–97.0°) caused no depression in the melting point. The picronate after recrystallization from ethanol melted at 174–174.8° (dec.); literature,^{7a} m.p. 174–175°.

(c) **Lead Cathode**¹⁸ at 60°.—The catholyte solution obtained from 0.07 mole of I was made strongly alkaline with sodium hydroxide and the reduction products were distilled in steam. Potassium carbonate was added to the distillate to salt out the product which was then extracted with ether. Distillation yielded 6.31 g. of material boiling at 108–116° (150 mm.); n_D^{20} 1.4286–1.4310. The distillate was benzoylated as described in part (b) in order to separate the secondary from the tertiary amines. From the hydrochloric acid extract there was obtained 1.83 g. (20%) of VI; b.p. 94–95° (138 mm.); n_D^{20} 1.4351–1.4368. The picronate after recrystallization from ethanol melted at 169.6–171.6° (dec.) and did not depress the melting point of 1-methyl-2-propylpyrrolidine picronate.

The amine obtained from the benzoylated material was distilled from barium oxide; b.p. 117–118° (156 mm.); n_D^{20} 1.4227–1.4229; yield 3.22 g. (36%). The picronate after recrystallization from ethanol melted at 175.5–176.5° (dec.) and did not depress the melting point of the picronate of *N*-methylheptylamine obtained in part (b).

(d) **Lead Cathode** at 20°.—The products obtained from 0.06 mole of I were isolated from the catholyte by steam distillation as in part (c). The steam distillate (300 ml.) was treated with 8 g. of sodium hydroxide and 12 ml. of benzoyl chloride and the mixture was treated from this point as in part (b). The *N*-methylheptylamine obtained was distilled from barium oxide; b.p. 116–118° (154 mm.); n_D^{20} 1.4239–1.4250; yield 4.21 g. (54%). The picronate melted at 174.3–176.3° (dec.) and did not depress the melting point of the picronate obtained in (b). The hydrochloric acid extract obtained during the purification of the secondary amine was made strongly alkaline, the organic material was extracted with ether, and the solvent removed from the combined extracts. Distillation of the residue from sodium metal yielded only a few drops of material boiling below 185° (154 mm.).

(e) **Copper Cathode** at 60°.—The products obtained from 0.0784 mole of I were isolated from the catholyte by steam distillation as described in (c). Distillation gave four fractions of material; b.p. 109–121° (154 mm.); n_D^{20} 1.4517–1.4687; weight 4.69 g. The liquid foamed severely during the distillation thus preventing a satisfactory fractionation. The infrared spectrum of a sample of the distillate contained absorption peaks at 1665 cm^{-1} and 1698 cm^{-1} . Similar peaks (1665 cm^{-1} and 1701 cm^{-1}) were present in the spectrum of an authentic sample of 1-methyl-2-propyl- Δ^2 -pyrrolidine (V) (see below). Distillation of the pot residue gave an additional five fractions of material; b.p. up to 112° (17 mm.) (bath temperature 200°); n_D^{20} 1.4739–1.4631; weight 1.82 g. The first of the last five fractions was combined with the material collected at 154 mm. for the hydrogenation experiment described below but the composition of the higher boiling fractions was not investigated.

A portion (1.31 g.) of the material which distilled at 154 mm. was treated with an excess of picronic acid in ethanol solution. The solution was seeded with the picronate of

VI and was kept in a refrigerator overnight. The picronate which separated was recrystallized from ethanol; weight 0.75 g. (equivalent to a 9.7% yield of VI). After a second recrystallization from ethanol the picronate melted at 167.5–169.5°, and a mixture with the picronate of 1-methyl-2-propylpyrrolidine melted at 168–170°.

The mother liquors remaining after the separation of the picronate of VI were concentrated to one-half of the original volume and ether was added until a permanent turbidity appeared. The mixture was allowed to stand at room temperature for several hours and then was kept in a refrigerator overnight. A picronate (1.48 g.) separated. Re-working of the mother liquors yielded an additional quantity of picronate. The total weight of crude material (1.85 g.) corresponded to a 24% yield of V. After several recrystallizations from ethyl acetate–hexane solution, the product melted at 95.5–97.0° (dec.) when placed in a melting point bath previously heated to 93°. When the sample was heated in the bath from room temperature, the solid melted at 93–94° (dec.). The picronate could not be obtained analytically pure. A mixture with the picronate of 1-methyl-2-propyl- Δ^2 -pyrrolidine (V) (see below) melted at 96–97° (dec.) when placed in the melting point bath at 94°. The infrared spectrum of the picronate of the reaction product was similar to but not completely identical with the spectrum of the authentic sample of the picronate of V.

In order to obtain a further estimate of the quantities of V and VI produced in the reduction, a portion (3.38 g.) of the reduction product was dissolved in a mixture of 15 ml. of absolute ethanol and 3 ml. of concentrated hydrochloric acid and was hydrogenated at 1 atmosphere pressure using 0.4 g. of platinum oxide as the catalyst. The hydrogen absorption (0.0137 mole) corresponded to a 27% yield of V based on I assuming that the hydrogen absorbed was utilized only for the reduction of V to VI. The catalyst and solvent were removed from the hydrogenation product, the residue was made alkaline, and the product was extracted with ether. Distillation from barium oxide gave 2.43 g. (71%) of VI; b.p. 100.5–101.0° (154 mm.); n_D^{20} 1.4360–1.4366. Assuming that the VI present in the hydrogenation mixture was recovered quantitatively, the amount of VI present prior to the hydrogenation corresponded to an 11% yield based on I. A portion of the hydrogenation product was converted to its picronate; m.p. 169.6–171.0°. Admixture with an authentic sample of the picronate of VI caused no depression of the melting point.

(f) **Other Reductions.**—When I was electrolyzed at a copper cathode at 20° or at a tin cathode at 20 or 60°, hydrogen was evolved at the cathode during the entire reduction period. In contrast to this behavior, no hydrogen evolution was observed during the reductions described previously until near the completion of the runs. The 1-methyl-2-ethyl-3-piperidone was recovered to the extent of 94, 85 and 78%, respectively. No material boiling below 96° (34 mm.) was obtained in these attempted reductions.

(2) **Reduction of 1-Butyl-3-pyrrolidone (VIII) (a) Cadmium Cathode** at 60°.—The reduction products obtained from 0.032 mole of VIII were separated from the catholyte by the steam distillation procedure described in 1(c). Distillation gave 2.66 g. (64%) of dibutylamine (X) (b.p. 84–85° (59 mm.); n_D^{20} 1.4186–1.4189) (literature,¹⁹ b.p. 159° (761 mm.); n_D^{20} 1.4177) and 0.98 g. (21%) of a mixture (see below) of XI and XII (b.p. 110.5–111.5° (17 mm.); n_D^{20} 1.4409–1.4458). A portion of the dibutylamine was converted to its phenylthiourea which, after recrystallization from ethanol–water mixture followed by drying at 0.1 mm., melted at 84.0–85.5° (literature,²⁰ m.p. 85.5–86°). Admixture with an authentic sample (m.p. 84.3–85.6°) did not depress the melting point.

(b) **Cadmium Cathode** at 20°.—The reaction products were isolated as described in (a). From 0.032 mole of VIII there was obtained 1.54 g. (37%) of dibutylamine (X); b.p. 83–86° (62 mm.); n_D^{20} 1.4180–1.4191. Further distillation of the pot residue remaining from the distillation of the dibutylamine gave 1.82 g. (39%) of a product boiling at 112–115° (20 mm.); n_D^{20} 1.4359–1.4491. The infrared spectrum of the latter material was almost identical with that of 1-butylamino-3-butanol (XII) (see below). A por-

[17] N. J. Leonard and E. Bartlett, Jr., unpublished work.

[18] Although several investigators have reported the formation of organo-lead compounds during the reduction of ketones at a lead cathode (see ref. 4 for example), the formation of such compounds was never observed in the course of our work.

[19] A. I. Vogel, *J. Chem. Soc.*, 1825 (1948).

[20] J. W. Suggitt and G. F. Wright, *THIS JOURNAL*, 69, 2073 (1947).

tion (0.995 g.) of this material was treated with 5 ml. of acetic anhydride and was allowed to stand for 10 minutes. A drop of concentrated sulfuric acid was then added and the mixture was allowed to stand for two hours. Water (30 ml.) was added, the mixture was treated with an excess of sodium carbonate, and the oil which separated was taken up in ether. The ether solution (A) was extracted with 10 ml. of 3 N hydrochloric acid and was washed with 10 ml. of saturated sodium chloride solution. The combined aqueous extracts were treated with an excess of sodium carbonate, 10 g. of potassium hydroxide dissolved in 10 ml. of water was added, and the mixture was warmed on a steam-bath for one hour. The organic material was extracted with ether, the solution was dried, and the ether was removed. Treatment of the residue with an excess of picronic acid in ethanol yielded a picrolonate which after recrystallization from ethanol melted at 166.5–168.5° (dec.). Admixture with the picrolonate of 1-butyl-3-hydroxypyrrolidine (XI) (see below) did not depress the melting point of the latter.

The solvent was removed from the ether solution (A) and the residue was heated under reflux overnight with a solution of 15 g. of potassium hydroxide in 40 ml. of water. The organic product was extracted with ether and converted to its picrolonate. After recrystallization from ethanol the picrolonate melted at 204–206° (dec.) and admixture with the picrolonate of 1-butylamino-3-butanol (XII) (see below) did not depress the melting point of the latter. On the basis of refractive index it was judged that the mixture of alcohols contained approximately 90% of XII.

(3) **Reduction of 1-Methyl-4-piperidone at a Cadmium Cathode at 60°.**—The reduction product was isolated from the catholyte by procedure 1(a) using ether as the extractant. From 0.054 mole of the piperidone there was obtained 3.15 g. (59%) of 1-methylpiperidine; b.p. 105–106° (750 mm.); n_D^{20} 1.4370 (literature,²¹ b.p. 105.9° (760 mm.); n_D^{20} 1.4378). The picrate after recrystallization from ethanol melted at 222–225° (dec.). A mixture with an authentic sample prepared from amine obtained by the Wolff-Kishner reduction of the piperidone (see below) showed no depression of the melting point.

(4) **Reduction of Dimethylaminoacetone at a Cadmium Cathode at 60°.**—An ether solution of the reduction product was obtained from the catholyte using the procedure in 1(a). A picrate was prepared from a portion of the solution. The crude material melted at 156–157°²² and did not depress the melting point of a crude authentic sample (m.p. 156–157°) prepared from 25% aqueous dimethylamine solution. Recrystallization of each sample of the picrate raised the melting point to 157–158°.²³ Analysis of an aliquot of the ether extract by conversion to the picrate indicated that the yield of dimethylamine obtained from 0.1 mole of aminoketone was 25%. The recovery of dimethylamine was probably low because of its high volatility and water solubility.

Picrolonate of 1-Methyl-2-propyl- Δ^2 -pyrroline.—The pyrroline (V) was prepared by the method of Craig²⁴; b.p. 119° (148 mm.); n_D^{20} 1.4733 (literature,²⁴ b.p. 176–177°). The picrolonate was prepared in ethyl acetate and was induced to crystallize by the addition of hexane. Recrystallization of the crude material from ethyl acetate–hexane solution gave a first crop of material which was impure (m.p. 96–120° dec.) but the remainder of the product separated in a relatively pure state (m.p. 96–97° dec.). Recrystallization of the latter gave material melting at 96.5–97.5° (dec.) when placed in the bath at 94°. This material failed to analyze correctly. Several recrystallizations followed by drying over phosphorus pentoxide at 1 mm. for two days also failed to yield a sample which was analytically pure.

1-Butyl-3-hydroxypyrrolidine (XI).—A solution of 4.14 g. (0.0293 mole) of 1-butyl-3-pyrrolidone (VIII) in 25 ml. of

ether was added to a stirred suspension of 0.48 g. (0.0127 mole) of lithium aluminum hydride in 200 ml. of dry ether during a period of five minutes. Thirty milliliters of 10% sulfuric acid was added cautiously to the mixture, the acid layer was separated, and the product was liberated from the acid solution by the addition of a solution of 25 g. of sodium hydroxide in 30 ml. of water and extraction with ether. The product was distilled; b.p. 119.8–120° (22 mm.); yield 3.34 g. (80%). A center fraction (b.p. 120°, n_D^{20} 1.4659) was submitted for analysis.

Anal. Calcd. for $C_8H_{17}NO$: C, 67.08; H, 11.97; N, 9.78. Found: C, 66.84; H, 11.98; N, 9.80.

A picrolonate was prepared in and recrystallized from ethanol; m.p. 167.5–169.5° (dec.).

Anal. Calcd. for $C_{13}H_{25}N_2O_6$: C, 53.06; H, 6.19; N, 17.19. Found: C, 53.14; H, 6.20; N, 17.39.

1-Butylamino-3-butanol Picrolonate.—Freshly distilled methyl vinyl ketone (9.6 g., 0.137 mole) was dissolved in 30 ml. of dry ether and 10.0 g. (0.137 mole) of freshly distilled butylamine was added, the mixture being cooled in an ice-bath. The mixture was kept at 5° for 30 minutes and then was added to a stirred suspension of 5.2 g. (0.137 mole) of lithium aluminum hydride in 400 ml. of dry ether during a period of 45 minutes. The excess hydride was decomposed by the addition of 20 ml. of water followed by 100 ml. of 30% sodium hydroxide solution. The ether layer containing the product was separated. Removal of the ether and distillation of the residue gave 8.8 g. (44%) of product (XII); b.p. 115–119° (23 mm.); n_D^{20} 1.4435–1.4442. This material could not be obtained analytically pure. The picrolonate was prepared in ethanol and after three recrystallizations from ethanol it melted at 203–204° (dec.).

Anal. Calcd. for $C_{13}H_{27}N_2O_6$: C, 52.80; H, 6.65; N, 17.11. Found: C, 52.86; H, 6.89; N, 17.17.

Wolff-Kishner Reduction of 1-Methyl-4-piperidone.—A mixture of 3.3 g. (0.029 mole) of 1-methyl-4-piperidone, 50 ml. of triethylene glycol, 4.6 ml. of 85% hydrazine hydrate and 6.4 g. of potassium hydroxide was heated at 145° for one hour. The temperature was raised to 225° during one hour and maintained at this temperature until no more material distilled (2.5 hours). The distillate was saturated with potassium carbonate and the amine was extracted with ether. Removal of the ether and distillation of the residue afforded 1.68 g. (58%) of 1-methylpiperidine; b.p. 104–105°; n_D^{20} 1.4378. The picrate after one recrystallization from ethanol melted partially at 146–148° and became clear at 187°. When this material was recrystallized from ethanol in the presence of a slight excess of the amine, the melting point rose to 221–223° (dec.).²⁵

Reduction of 1-Methyl-2-ethyl-3-piperidone (I) at 20° with Zinc Amalgam and Hydrochloric Acid.—Mossy zinc (50 g.) was amalgamated in the usual manner⁶ and was covered with 40 ml. of concentrated hydrochloric acid. A solution of 5.0 g. (0.0354 mole) of I in 40 ml. of concentrated hydrochloric acid was added and the mixture was stirred at 20 ± 5° for 38 hours. The reduction product was isolated as described previously⁶ and was distilled giving four fractions of material boiling at 103–114° (93 mm.); n_D^{20} 1.4304–1.4319; yield 1.88 g. The N-methylheptylamine (III) was purified through its benzoyl derivative as described above giving 1.12 g. (24% yield based on I) of material boiling at 112–114° (145 mm.); n_D^{20} 1.4211–1.4218. The picrate melted at 97.0–98.5° and a mixture with the picrate of N-methylheptylamine melted at 98.0–99.0°. The picrolonate melted at 175–176° (dec.) and admixture with the picrolonate of III obtained in 1(b) did not depress the melting point.

URBANA, ILLINOIS

RECEIVED NOVEMBER 29, 1951

(21) H. W. Magnusson and E. R. Scheirz, *Univ. Wyoming Pub.*, **7**, 1 (1940); *C. A.*, **34**, 6867 (1940).

(22) The melting points of the picrates of dimethylpropylamine and dimethylisopropylamine, the other possible reduction products, are reported to be 108–109° and 240–241° (dec.), respectively (W. McMeeking and T. Stevens, *J. Chem. Soc.*, 347 (1933)).

(23) The melting point of dimethylamine picrate is reported to be 155–156° (M. Delepine, *Ann. chim. phys.*, [7] **8**, 457 (1896), and 158–159° (G. Jerusalem, *J. Chem. Soc.*, **95**, 1275 (1909)).

(24) L. C. Craig, *This Journal*, **55**, 293 (1933).

(25) The melting point of the picrate of 1-methylpiperidine has been reported as 149–151° (G. Wittig, M. Heintzler and M. Wetterling, *Ann.*, **557**, 201 (1947)), 145–150° with clearing at 180° (F. Krohnke, *Ber.*, **67B**, 656 (1934)), and values ranging from 222° (J. von Braun, M. Kuhn and O. Goll, *Ber.*, **59**, 2330 (1926)) to 226° (ref. 14). The lower melting samples apparently contained an excess of picric acid over that required for a monopicate. A sample prepared in this Laboratory (ref. 17) which melted partially at 146–149° and became clear at 184° was found upon analysis to have a molar ratio of picric acid to amine of approximately 1.5.