# The Synthesis of 4-Methyl-2-pyrrolidones and 3-Methyl-1-pyrrolidines and Their Mass Spectral Study



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A number of 1-alkyl-4-methyl-2-pyrrolidones have been prepared from methyl 4-alkylamino-3-methyl butenoates. The corresponding 1-alkyl-3-methyl-pyrrolidines are obtainable by the reduction of the pyrrolidones with lithium aluminum hydride. The mass spectra of pyrrolidones and pyrrolidines have been studied. Three different mechanisms which lead to the base peak have been proposed.

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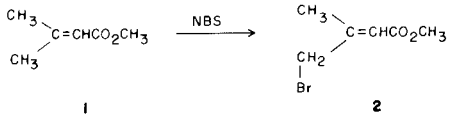
In previous publications, we reported a ring expansion of a substituted azetidine leading to a 2-pyrrolidone [2] and on thermolysis of a substituted aziridine leading to a pyrrolidine [3]. We now wish to report in detail the reaction of methyl 4-bromo-3-methyl-2-butenoate with several primary amines to form pyrrolidones and then pyrrolidines. Stereochemical assignment of the cycloadducts was made on the basis of pmr spectrosopy [4].

Results and Discussion.

I) The Chemistry of Some 2-Pyrrolidone and Pyrrolidine Derivatives.

Although bromination of *p*-phenylcrotonophenone and *p*-phenylseneciophenone at the γ-position failed [5], the corresponding methyl esters of the same general structure could be brominated in the γ-position in high yields with *N*-bromosuccinimide (NBS) [6].




1 2

Methyl 4-bromo-3-methyl-2-butenoate (**2**) was allowed to react with two molar equivalents of amine in acetonitrile for 5-7 days. Removal of the solvent and by-product (amine hydrobromide) gave an orange oil as the crude product which was clearly identified by its ir and nmr spectra as the desired normal substitution product. Since the product was very difficult to purify, an etherial solution of the crude product was treated with dry hydrogen chloride gas to precipitate the product as the corresponding hydrochloride salts. The salt proved to be easily purified by crystallization, and a 38-55% yield was thus obtained of methyl 4-alkylamino-3-methyl-butenoate hydrochloride (**3**), the structural assignment of which was confirmed by ir and nmr spectral data as well as elemental analysis.

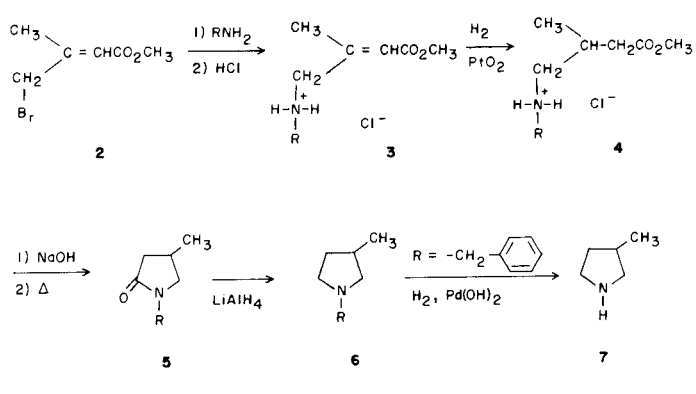
Methyl 4-alkylamino-3-methylbutenoate hydrochloride (**3**) was found to undergo facile catalytic hydrogenation over platinum oxide (Adams catalyst) to the corresponding saturated analog **4**.

Neither reduction of the carbonyl group nor hydrogenolysis of the alkylamino group appeared to be serious side reactions under the conditions utilized. Thus, methyl 4-alkylamino-3-methylbutenoate hydrochloride (**4**) was readily obtained in good yield and purified by crystallization. The saturated nature of **4** was indicated by its proton absorption in nmr spectrum in the normal region for aliphatic protons as well as the observed increase (10-20 $cm^{-1}$) in the carbonyl stretching frequency in the ir spectrum relative to that of the unsaturated precursor.

The formation of 3-methyl-2-pyrrolidone was achieved by heating the corresponding free base of the aminobutenoate followed by vacuum distillation. These compounds were identified by their proton nmr spectrum, which showed in the absence of the methoxy group, as well as by the observed decrease (from 1735 $cm^{-1}$ to 1690 $cm^{-1}$) in the carbonyl stretching frequency in the ir spectrum relative to that of the precursor. It was found that benzyl- or cyclohexylamino esters are easy to cyclize, however, the *t*-butyl- or isopropylamino esters cannot be completely cyclized even under very vigorous conditions (reflux for a few hours over a Bunsen burner). This is undoubtedly a steric effect.

The 1-alkyl-3-methyl-2-pyrrolidines **5** were obtained by the reduction of the corresponding 1-alkyl-4-methyl-2-pyrrolidones **5** with lithium aluminum hydride. The formation of these compounds **6** was strongly supported by the

SCHEME I



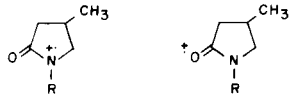

R = t-butyl, benzyl, cyclohexyl, isopropyl

absence of carbonyl stretching in the ir spectrum relative to that of the pyrrolidone as well as the additional absorption in the nmr spectrum in the normal region for aliphatic protons. Also, reduction of 1-benzyl-3-methyl-1-pyrrrolidine (**6b**) with 20% palladium hydroxide (Pearlman catalyst) leads to 3-methyl-1-pyrrolidine (**7**).

II) Mass Spectral Studies.

A) 2-Pyrrolidone.

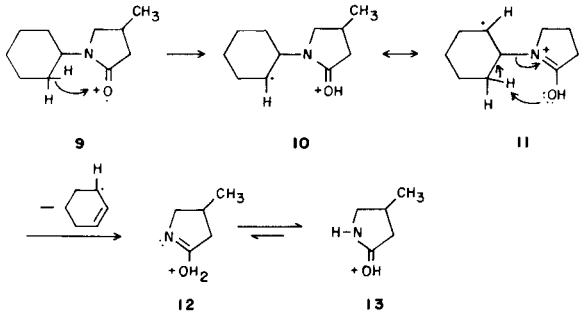
The mass spectra of several 2-pyrrolidones are shown in Table I. The odd mass molecular ions indicate the presence of a nitrogen atom in each compound. The high abundances of these molecular ions are consistent with the ions' cyclic structures. The parent peak of the 2-pyrrolidones is the molecular ion formed by loss of a nonbonding electron from either nitrogen (**8**) or oxygen (**9**).



**8** **9**

It is very interesting to point out that there are three different types of base peaks present in the various fragmentations. The most stable ion products are abundant because the stability of the particular ion enhances the rate of its formation. Since the benzyl group can stabilize the molecular ion, it is not surprising that the parent ion of 1-benzyl-3-methyl-2-pyrrolidone is also the base peak.

For the 1-cyclohexyl-3-methyl-2-pyrrolidone, it is assumed that after the formation of the molecular ion, a McLafferty rearrangement follows to form ion **10** which is stabilized by resonance (*cf.* **10, 11**). The ion(s) **10** and/or **11** then undergo(es) a hydrogen rearrangement and simultaneously the bond between nitrogen and the cyclohexyl group is cleaved which leads to ion **12** and **13**. These ions are the base peak in the mass spectrum.

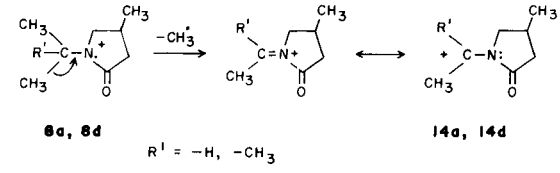


**9** **10** **11**

**12** **13**

The cyclic structures are generally more stable, under electron bombardment, than the corresponding straight chain compounds. Hence, the molecular ion **8a** or **8d** readily loses a neutral methyl group to form the daughter ion **14a**, or **14d**. The C-C bonds next to a heteroatom are most frequently cleaved, leaving the charge on the fragment containing the heteroatom whose nonbonding electrons provide resonance stabilization.

Since only a small amount of benzyl- or cyclohexylpyrrolidones $(M\text{-}CH_3)^+$ have been found, it can be assumed that the cleavage involves the neutral $CH_3$ at the alpha position of the *t*-butyl or the isopropyl group rather than the $\text{-}CH_3$ which is attached to C-4.



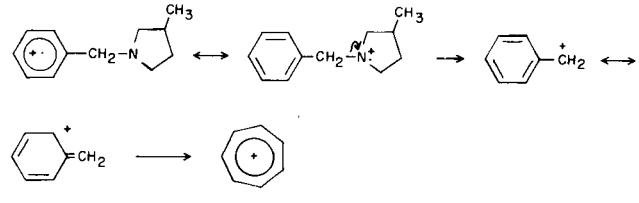
**8a, 8d** **14a, 14d**

$R' = -H, -CH_3$

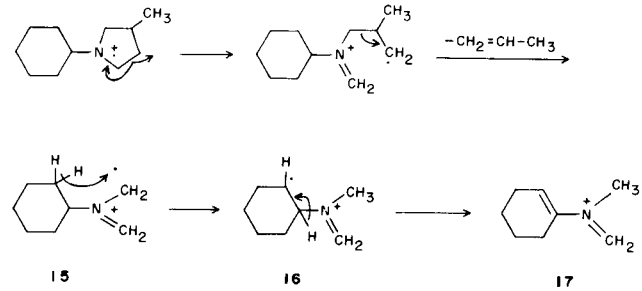
B) Pyrrolidines.

As with the other saturated cyclic amines, the parent peak of the 3-methylpyrrolidines is readily detected. Loss of a hydrogen atom from the parent ion is a favored type of fragmentation. This appears to be one of the cases where loss of a substituent (a hydrogen in this case) beta to the nitrogen atom is favored because a stable ion results.

The base peak of 1-benzyl-3-methyl-pyrrolidine can be easily explained by benzylic cleavage to form the very stable tropylium ion $(C_7H_7)^+$.



For 1-cyclohexyl-3-methylpyrrolidine, it is assumed that the neutral molecule, 1-propene, was eliminated following the cleavage of C4-C5 bond, to form ion **15**. Proton transfer from the $\beta$-carbon of cyclohexyl of **15** to form ion **16** which is followed by the loss of hydrogen leads to the formation of base peak ion **17**.



**15** **16** **17**

The base peak of 1-*t*-butyl-, and 1-isopropyl-3-methylpyrrolidine are formed by the loss of a neutral methyl

group. No $(M\text{-}CH_3)^+$ peaks have been found in the mass spectrum of 1-benzyl-, or 1-cyclohexyl-3-methylpyrrolidine. This is strong evidence to support the above discussion concerning the alpha methyl group cleavage.

Table I

The Molecular Ion Intensities of Selected Pyrrolodones, Pyrrolidines

| Molecule | $M^+$ [7] | $(M\text{-}CH_3)^+$ [7] | Base peak |
|---|---|---|---|
| **5a** | 10.66 | 100 | $C_8H_{14}NO$ |
| **5b** | 100.0 | 5.25 | $C_{12}H_{15}NO$ |
| **5c** | 28.59 | 1.93 | $C_9H_{10}NO$ |
| **5d** | 14.73 | 100 | $C_7H_{12}NO$ |
| **6a** | 6.68 | 100 | $C_8H_{16}N$ |
| **6b** | 47.42 | none | $C_7H_7$ |
| **6c** | 9.70 | none | $C_8H_{14}N$ |
| **6d** | 8.46 | 100 | $C_7H_{14}N$ |
| **7** | 100 | 3.75 | $C_5H_{11}N$ |

## EXPERIMENTAL

Melting points were determined with a Mel-Temp capillary melting point apparatus and are uncorrected. Boiling points were determined at pressures recorded on a standard VirTis gauge and are uncorrected.

Elemental analyses were performed by the Micro Tech Laboratory, Skokie, Illinois.

Spectra were obtained in either reagent grade chloroform-d employing tetramethylsilane or reagent grade deuterium oxide employing sodium 2,2-dimethyl-2-silapentane-5-sulfonate as an internal standard. The recording instrument was a Varian EM-390 or Nicolet WB-360 spectrometer. The nitrogen-15 magnetic resonance spectra were determined in acetone-$d_6$ solutions employing a Nicolet WB-360 spectrometer. Chemical shifts are referenced to nitromethane as internal standard.

Infrared spectra were obtained on a Beckman model Acculab 4 grating spectrophotometer or a Perkin-Elmer model 283 grating instrument. The high resolution mass spectra were determined by an AEI Mass Spectrometer Model 50-76 equipped with a DS-30 data system. The mode of analysis was electron impact by direct insertion of sample.

General Procedure for the Preparation of Methyl 4-Alkylamino-3-methyl-2-butenoate Hydrochloride (**3**).

To a stirred suspension containing 2.1 molar equivalents of amine in acetonitrile was added dropwise 1.0 molar equivalent of methyl 4-bromo-3-methyl-2-butenoate (**2**). After the addition was completed the reaction mixture was stirred magnetically for 5-7 days. After removing the precipitated amine hydrobromide and evaporation of the acetonitrile, an appropriate amount of ethyl ether was added to precipitate the amine hydrobromide which had become supersaturated in acetonitrile. The resulting ethyl ether solution was cooled to 0° and then exposed to a stream of dry hydrogen chloride for 5 minutes. The resulting white precipitate was collected and washed with ethyl ether. The crude product was dissolved in methanol and the solution treated with ethyl ether to a slightly turbid appearance. Cooling gave the white product. Concentration of the mother liquor and adding ethyl ether gave a second crop.

Methyl 4-*t*-Butylamino-3-methyl-2-butenoate Hydrochloride (**3a**).

An 80.0 g sample (0.41 mole) of *t*-butylamine was added dropwise into a solution which contained 38.6 g (0.2 mole) of **2** in 800 ml of acetonitrile. At the completion of the stirring period, it was worked-up following the general procedure described above to give 17.8 g (40%) of **3a** as a white product, mp 228-229° (sealed tube); ir (potassium bromide): 1730 $cm^{-1}$ (C=O); nmr (deuterium oxide): δ 5.93 (m, 1, vinyl), 3.73 (s, 5, -O-$CH_3$, -$CH_2$), 2.29 (d, 3, -$CH_3$), 1.43 (s, 9, *t*-butyl); ms: (70 eV), m/e Calcd. for $C_{10}H_{19}NO_2$: 185.1572, Found: 185.1574.

*Anal.* Calcd. for $C_{10}H_{19}NO_2$·HCl: C, 53.68; H, 9.91; N, 6.26; Cl, 15.84. Found: C, 53.33; H, 9.91; N, 6.16; Cl, 15.40.

Methyl 4-Benzylamino-3-methyl-2-butenoate Hydrochloride (**3b**).

From a 88.0 g sample (0.82 mole) of benzylamine was obtained 54.2 g (53%) of **3b** as white crystals, mp 188-189°; ir (potassium bromide): 1720 $cm^{-1}$ (-C=O); nmr (deuterium oxide): δ 7.46 (s, 5, Ph), 5.95 (m, 10, vinyl), 4.5 (s, 2, -N-$CH_2$-), 3.78 (s, 2, =C-$CH_2$), 3.75 (s, 3, -O-$CH_3$), 2.17 (s, 3, -C-$CH_3$); ms: (70 eV), m/e Calcd. for $C_{13}H_{17}NO_2$: 219.1259, Found: 219.1263.

*Anal.* Calcd. for $C_{13}H_{17}NO_2$·HCl: C, 61.05; H, 7.09; N, 5.48; Cl, 13.86. Found: C, 61.00; H, 6.97; N, 5.41; Cl, 13.81.

Methyl 4-Cyclohexylamino-3-methyl-2-butenoate Hydrochloride (**3c**).

From a 44.0 g sample of cyclohexylamine was obtained 21.9 g (44%) of **3c** as white crystals, mp 207-208°; ir (potassium bromide): 1724 $cm^{-1}$ (-C=O); nmr (deuterium oxide): δ 5.98 (m, 1, vinyl proton), 3.83 (s, 2, -$CH_2$-), 3.78 (s, 3, -$OCH_3$), 3.15 (b, 1, -N-CH-), 2.22 (b, 3, -$CH_3$), 1.28-1.93 (b, 10, cyclohexyl); ms: (70 eV), m/e Calcd. for $C_{12}H_{21}NO_2$: 211.1572, Found: 211.1574.

*Anal.* Calcd. for $C_{12}H_{21}NO_2$·HCl: C, 58.17; H, 8.95; N, 5.65; Cl, 14.31. Found: C, 58.09; H, 8.91; N, 5.56; Cl, 14.14.

Methyl 4-Isopropylamino-3-methyl-2-butenoate Hydrochloride (**3d**).

From a 64.0 g sample (1.09 mole) of isopropylamine was obtained 34.0 g (41%) of **3d** as white crystals, mp 156-158°; ir (potassium bromide): 1728 $cm^{-1}$ (-C=O); nmr (deuterium oxide): δ 6.0 (m, 1, vinyl proton), 3.75 (s, 2, -N-$CH_2$-), 3.73 (s, 3, -$OCH_3$), 3.33-3.60 (m, 1, -N-CH-), 2.33-2.40 (d, 6, -C-$(CH_3)_2$), 2.2 (s, 3, -$CH_3$); ms: (70 eV), m/e Calcd. for $C_9H_{17}NO_2$: 171.1259, Found: 171.1261.

*Anal.* Calcd. for $C_9H_{17}NO_2$·HCl: C, 52.05; H, 8.73; N, 6.74; Cl, 17.07. Found: C, 51.87; H, 8.63; N, 6.50; Cl, 17.23.

General Procedure for the Preparation of Methyl 4-Alkylamino-3-methylbutenoate Hydrochloride (**4**).

A solution of 0.03 mole equivalent of methyl 4-alkylamino-3-methyl-2-butenoate hydrochloride (**3**) in 60 ml of methanol was added to 0.064 g of platinum oxide (Adams catalyst). The mixture was hydrogenated in a Parr shaker at 45 psi. After 2 hours, the catalyst was removed by filtration through celite. The filtrate was concentrated to a small volume by evaporation under reduced pressure and dry ethyl ether was added to the solution until a few crystals appeared. Cooling provided white crystals which were recrystallized from methanol and ethyl ether solution.

Methyl 4-*t*-Butylamino-3-methylbutenoate Hydrochloride (**4a**).

From a 6.0 g sample (0.03 mole) of **3a** was obtained 4.94 g (82%) of **4a** as white platelets, mp 145-146°; ir (potassium bromide): 1738 $cm^{-1}$ (-C=O); nmr (deuterium oxide): δ 3.70 (s, 3, -$OCH_3$), 2.88-3.20 (b, 2, -N-$CH_2$), 2.05-2.60 (b, 3, -$CH_2$CH-), 1.37 (s, 9, *t*-butyl), 1.03-1.13 (d, 3, -$CH_3$); ms: (70 eV), m/e Calcd. for $C_{10}H_{19}NO_2$: 185.1572, Found: 185.1574.

*Anal.* Calcd. for $C_{10}H_{19}NO_2$·HCl: C, 53.68; H, 9.91; N, 6.26; Cl, 15.84. Found: C, 53.33; H, 9.79; N, 6.16; Cl, 15.40.

Methyl 4-Benzylamino-3-methylbutenoate Hydrochloride (**4b**).

From a 9.05 g sample (0.035 mole) of **3b** was obtained 6.80 g (75%) of **4b** as white crystals, mp 110°; ir (potassium bromide): 1742 $cm^{-1}$ (-C=O); nmr (deuterium oxide): δ 7.50 (s, 5, Ph), 4.23 (s, 2, -N-$CH_2$-), 3.67 (s, 3, -$OCH_3$), 2.95-3.20 (b, 2, -$CH_2$-N-), 2.40-2.60 (b, 3, -CH-$CH_2$-), 2.03-2.13 (s, 3, -$CH_3$); ms: (70 eV), m/e Calcd. for $C_{13}H_{19}NO_2$: 221.1416, Found: 221.1412.

*Anal.* Calcd. for $C_{13}H_{19}NO_2$·HCl: C, 60.58; H, 7.82; N, 5.43; Cl, 13.75. Found: C, 60.34; H, 7.68; N, 5.55; Cl, 14.39.

Methyl 4-Cyclohexylamino-3-methylbutenoate Hydrochloride (**4c**).

From a 7.68 g sample (0.031 mole) of **3c** was obtained 6.04 g (78%) as a white product, mp 135-136°; ir (potassium bromide): 1736 $cm^{-1}$ (-C=O); nmr (deuterium oxide): δ 3.73 (s, 3, -$OCH_3$), 2.90-3.20 (m, 3, -$CH_2$-N-CH-), 2.40-2.60 (m, 3, -CH-$CH_2$-), 1.20-2.20 (m, 10, cyclohexyl), 1.02-1.12 (d, 3, -$CH_3$); ms: (70 eV), m/e Calcd. for $C_{12}H_{23}NO_2$: 213.1728, Found: 213.1727.

*Anal.* Calcd. for $C_{12}H_{23}NO_2$·HCl: C, 57.70; H, 9.69; N, 5.61; Cl, 14.19.

Found: C, 57.63; H, 9.64; N, 5.50; Cl, 14.01.

Methyl 4-Isopropylamino-3-methylbutenoate Hydrochloride (**4d**).

From a 60.0 g sample (0.0313 mole) of **3d** was obtained 5.40 g (89%) of **4d** as white crystals, mp 108°; ir (potassium bromide): 1740 $cm^{-1}$ (-C=O); nmr (deuterium oxide): δ 3.67 (s, 3, $-OCH_3$), 3.38-3.57 (q, 1, -N-CH-), 2.93-3.06 (m, 2, $-N-CH_2-$), 2.20-2.60 (m, 3, $-CH-CH_2-$), 1.28-1.35 (d, 6, $-C(CH_3)_2-$), 1.04-1.13 (d, 3, $-CH_3$); ms: (70 eV), m/e Calcd. for $C_9H_{19}NO_2$: 173.1416, Found: 173.1412.

*Anal.* Calcd. for $C_9H_{19}NO_2 \cdot HCl$: C, 51.55; H, 9.61; N, 6.74; Cl, 17.07. Found: C, 51.23; H, 9.51; N, 6.64; Cl, 16.96.

*N*-*t*-Butyl-4-methyl-2-pyrrolidone (**5a**).

A 11.5 g (0.052 mole) sample of methyl 4-*t*-butylamino-3-methylbutenoate hydrochloride (**4a**) was dissolved in 50 ml of water. After the addition of 100 ml of ethyl ether, excess solid sodium hydroxide was added. Several ethyl ether extractions of the aqueous solution were combined. This solution was dried over magnesium sulfate and the solvent evaporated under reduced pressure yielding a light yellow oil. The crude product of methyl 4-*t*-butylamino-3-methylbutenoate was refluxed by using a Bunsen burner with a gentle flame for 12 hours. To remove the traces of unreacted methyl 4-*t*-butylamino-3-methylbutenoate, the crude product of pyrrolidone was added dropwise into a magnetically stirred solution wihch contained 3.0 g (0.01 mole) of barium hydroxide octahydrate in 50 ml of water heated to boiling. After 30 minutes, 15 ml of water was added and carbon dioxide gas passed through the reaction mixture until precipitation of barium carbonate ceased. The hot suspension was filtered through a sintered-glass funnel. The filter cake was washed twice with 10 ml portions of hot water. The aqueous solution was cooled down and extracted three times with 50 ml of ethyl ether. These combined ethyl ether solutions were dried over magnesium sulfate and the solvent evaporated under reduced pressure yielding a light yellow oil. This crude pyrrolidone was vacuum distilled and a colorless product was obtained, 5.73 g (71%) of **5a**, bp 60°/0.32 mm; ir (carbon tetrachloride): 1690 $cm^{-1}$ (-C=O); nmr (deuteriochloroform): δ 3.00-3.60 (q, 2, $-N-CH_2-$), 2.10-2.50 (b, 2, $-CH_2-$), 1.80-2.00 (q, 1, -CH-), 1.40 (s, 9, *t*-butyl), 1.10 (d, 3, $-CH_3$); $^{15}N$ nmr (acetone-$d_6$): −245.524 ppm; ms: (70 eV), m/e Calcd. for $C_9H_{17}NO$: 155.1310, Found: 155.1314.

*Anal.* Calcd. for $C_9H_{17}NO$: C, 69.63; H, 11.04; N, 9.02. Found: C, 69.36; H, 11.01; N, 8.85.

*N*-Benzyl-4-methyl-2-pyrrolidone (**5b**).

A 20.7 g (0.08 mole) sample of methyl 4-benzylamino-3-methylbutenoate hydrochloride (**4b**) was dissolved in 70 ml of water. After the addition of 100 ml of ethyl ether, excess solid sodium hydroxide was added. Several ethyl ether extractions of the aqueous solution were combined. Drying this solution over magnesium sulfate and evaporating the solvent under reduced pressure yielded a light yellow oil. Vacuum distillation of the crude product of methyl 4-benzylamino-3-methylbutenoate was accomplished and a colorless product was obtained, 11.5 g (76%) of **5b**, bp 146°/1.3 mm; ir (carbon tetrachloride): 1700 $cm^{-1}$ (-C=O); nmr (deuteriochloroform): δ 7.20 (s, 5, Ph), 4.35 (s, 2, $-N-CH_2-$), 2.75-3.25 (q, 2, $-N-CH_2-$), 2.10-2.60 (b, 2, $-CH_2-$), 1.80-2.10 (q, 1, -CH-), 0.90-1.00 (d, 3, $-CH_3$); $^{15}N$ nmr (acetone-$d_6$): −257.061 ppm; ms: (70 eV), m/e Calcd. for $C_{12}H_{15}NO$: 189.1154, Found: 189.1151.

*Anal.* Calcd. for $C_{12}H_{15}NO$: C, 76.16; H, 7.99; N, 7.40. Found: C, 75.86; H, 8.32; N, 7.36.

*N*-Cyclohexyl-4-methyl-2-pyrrolidone (**5c**).

A mixture which contained 20.5 g of **4c** in 70 ml of water was given the same procedure as the synthesis of **5b** to obtain a colorless product, 11.2 g (76%) of **5c**, mp 116°/0.7 mm; ir (carbon tetrachloride): 1678 $cm^{-1}$ (-C=O); nmr (deuteriochloroform): δ 2.80-3.35 (q, 2, $-N-CH_2-$), 2.15-2.50 (b, 2, $-CH_2-$), 1.80-1.90 (q, 1, -C-CH-), 1.20-1.75 (b, 11, cyclohexyl), 1.00-1.10 (d, 3, $-CH_3$); ms: (70 eV), m/e Calcd. for $C_{11}H_{19}NO$: 181.1467, Found: 181.1466.

*Anal.* Calcd. for $C_{11}H_{19}NO$: C, 72.88; H, 10.56; N, 7.73. Found: C, 72.68; H, 10.53; N, 7.58.

*N*-Isopropyl-4-methyl-2-pyrrolidone (**5d**).

A mixture which contained 12.3 g (0.056 mole) of **4d** in 50 ml of water was given the same procedure as the synthesis of **5a** to obtain a colorless product 6.0 g (73%) of **5d**, bp 73°/0.55 mm; ir (carbon tetrachloride): 1685 $cm^{-1}$ (-C=O); nmr (deuteriochloroform): δ 4.25 (m, 1, -N-CH-), 2.90, 3.45 (q, 2, $-N-CH_2-$), 2.35 (m, 2, $-CH_2-$), 1.90 (m, 1, -C-CH-), 1.15 (d, 9, $-C(CH_3)_2$, $-CH_3$); ms: (70 eV), m/e Calcd. for $C_8H_{15}NO$: 141.1154, Found: 141.1155.

*Anal.* Calcd. for $C_8H_{15}NO$: C, 68.04; H, 10.71; N, 9.92. Found: C, 68.04; H, 10.78; N, 9.77.

General Procedure for the Preparation of 1-Alkyl-3-methyl-1-pyrrolidine (**6**).

In a one liter three-neck flask equipped with a reflux condenser and a dropping funnel, both protected by drying tubes, was placed a suspension of 1.1 molar equivalent of lithium aluminium hydride in a suitable amount of anhydrous ethyl ether. The mixture was stirred with a magnetic stirrer using a teflon-covered stirring bar. A solution of 1.0 molar equivalent of 1-alkyl-4-methyl-2-pyrrolidone (**5**) in a suitable amount of anhydrous ethyl ether was added at such a rate as to maintain gentle reflux. The flask was then placed in an electric heating mantle, and the mixture stirred and heated under reflux for 15 hours. The heating mantle was then replaced by an ice bath, and the mixture solution cooled to about zero degrees. A suitable amount of water was added slowly with vigorous stirring (sometimes a sealed mechanical stirrer was required). After the addition of water was complete, the stirring was continued for 30 minutes. A quantity of 30% cold sodium hydroxide solution was added at once, and the flask fitted for steam-distillation which contained an ice-bath acceptor. The mixture was steam distilled until the distillate was neutral. The two layer solution was separated, and the aqueous phase extracted with three portions of 50 ml of ethyl ether. The combined organic layers were dried over potassium hydroxide by decantion, and the solvent evaporated under reduced pressure. The residue, on distillation under reduced pressure, yielded the needed pyrrolidine.

*N*-*t*-Butyl-3-methyl-1-pyrrolidine (**6a**).

A solution of 6.50 g (0.042 mole) of *N*-*t*-butyl-4-methyl-2-pyrrolidone (**5a**) in 30 ml of anhydrous ethyl ether was added as described above in the general procedure to a suspension of 1.75 g (0.046 mole) of lithium aluminium hydride in 150 ml of anhydrous ethyl ether. At the completion of the reflux period, 9 ml of water was added slowly with vigorous stirring. The resulting solution was worked up following the general procedure described above to obtain 4.90 g (83%) of **6a**, bp 157°; mm; ir (carbon tetrachloride): 2860 $cm^{-1}$ (amine $-CH_2$ stretching), 1440 $cm^{-1}$ (amine $-CH_2-$ vibration); nmr (deuteriochloroform): δ 2.95, 2.15 (t, 2, $-N-CH_2-$), 2.75, 2.65 (m, 2, $-N-CH_2-$), 2.20 (h, 1, -CH-), 1.95, 1.30 (m, 2, $-CH_2-$), 1.07 (s, 9, *t*-butyl), 1.01 (d, 3, $-CH_3$); $^{15}N$ nmr (acetone-$d_6$): −318.404 ppm; ms: (70 eV), m/e Calcd. for $C_9H_{19}N$: 141.1517, Found: 141.1520.

*Anal.* Calcd. for $C_9H_{19}N$: C, 76.53; H, 13.56; N, 9.92. Found: C, 76.56; H, 13.58; N, 9.74.

*N*-Benzyl-3-methyl-1-pyrrolidine (**6b**).

A solution of 17.5 g sample (0.092 mole) of **5b** in 50 ml of anhydrous ethyl ether was added as described above in the general procedure to a suspension of 3.87 g (0.102 mole) of lithium aluminium hydride in 150 ml of anhydrous ethyl ether. At the completion of the reflux period, 11 ml of water was added slowly with vigorous stirring. The resulting solution was worked up following the general procedure described above to obtain 13.8 g (85%) of **6b**, bp 67-68°/0.6 mm; ir (carbon tetrachloride): 2861 $cm^{-1}$ (amine $-CH_2-$ stretching), 1454 $cm^{-1}$ (amine $-CH_2-$ vibration); nmr (deuteriochloroform): δ 7.15 (s, 5, Ph), 3.60 (s, 2, $-N-CH_2-$), 2.85, 1.35 (t, 2, $-N-CH_2-$), 2.70, 2.45 (m, 2, $-N-CH_2-$), 2.25, 1.35 (m, 2, $-CH_2-$), 2.05 (h, 1, -CH-), 1.02 (d, 3, $-CH_3$); $^{15}N$ nmr (acetone-$d_6$): −324.901 ppm; ms: (70 eV), m/e Calcd. for $C_{12}H_{17}N$: 175.1361, Found: 175.1359.

*Anal.* Calcd. for $C_{12}H_{17}N$: C, 82.23; H, 9.78; N, 7.99. Found: C, 82.01; H, 9.81; N, 7.83.

*N*-Cyclohexyl-3-methyl-1-pyrrolidine (**6c**).

A solution of 12.50 g sample (0.069 mole) of **6c** in 35 ml of anhydrous ethyl ether was added as described above in the general procedure to a suspension of 2.88 g (0.076 mole) of lithium aluminium hydride in 150 ml of anhydrous ethyl ether. At the completion of the reflux period, 12 ml of water was added slowly with vigorous stirring. The resulting solution was worked up following the general procedure described above to obtain 9.42 g (82%) of **6c** bp 72°/1.3 mm; ir (carbon tetrachloride): 2859 $cm^{-1}$ (amine -$CH_2$- stretching), 1454 $cm^{-1}$ (amine -$CH_2$- vibration); nmr (deuteriochloroform): δ 2.90, 1.95 (t, 2, -N-$CH_2$-), 2.80, 2.45 (m, 2, -N-$CH_2$-), 2.20 (h, 1, -CH-), 1.20, 1.35 (m, 2, -$CH_2$-), 1.15-2.05 (b, 11, cyclohexyl), 1.00 (d, 3,-$CH_3$); ms: (70 eV), m/e Calcd. for $C_{11}H_{21}N$: 167.1674. Found: 167.1673.

*Anal.* Calcd. for $C_{11}H_{21}N$: C, 78.97; H, 1.265; N, 8.37. Found: C, 78.75; H, 12.45; N, 8.28.

*N*-Isopropyl-3-methyl-1-pyrrolidine (**6d**).

This compound was reported by Elderfield and coworkers [8] in 1950, however no evidence was given to support their discovery.

A solution of 5.5 g (0.039 mole) of **5d** in 30 ml of anhydrous ethyl ether was added as described above in the general procedure to a suspension of 1.63 g (0.043 mole) of lithium aluminium hydride in 150 ml of anhydrous ethyl ether. At the completion of the reflux period, 9 ml of water was added slowly with vigorous stirring. The resulting solution was worked up following the general procedure described above to obtain 4.0 g (81%) of **6d**, bp 138-139°; mm; ir (carbon tetrachloride): 2858 $cm^{-1}$ (amine -$CH_2$- stretching), 1460 $cm^{-1}$ (amine -$CH_2$- vibration); nmr (deuteriochloroform): δ 2.90, 1.95 (t, 2, -N-$CH_2$-), 2.77, 2.44 (m, 2, -N-$CH_2$-), 2.30 (h, 1, -CH-), 2.10 (m, 1, -N-CH-), 2.05, 1.35 (m, 2, -$CH_2$-), 1.08 (d, 5, -$C(CH_3)_2$), 1.02 (d, 3, -$CH_3$); ms: (70 eV), m/e Calcd. for $C_8H_{17}N$: 127.1361, Found: 127.1359.

*Anal.* Calcd. for $C_8H_{17}N$: C, 75.52; H, 13.47; N, 11.01. Found: C, 75.37; H, 13.66; N, 10.95.

Preparation of 3-Methyl-1-pyrrolidine (**7**).

Compound **7** has been known since early in 1900. The following process is totally different from all other procedures.

A sample of 6.0 g (0.034 mole) of **6b**, dissolved in 60 ml of methanol, was hydrogenated in a Parr shaker under the pressure of 45 psi in the presence of 20% of palladium hydroxide as catalyst. After 24 hours the absorption of hydrogen was complete. An excess amount of glacial acetic acid was added to acidify the solution. The solvent was evaporated and the residue dissolved in water, made alkaline with sodium hydroxide and extracted with ethyl ether. Fractional distillation of the resulting solution gave 1.90 g (65%) of product, bp 104°; ir (neat): 3250 $cm^{-1}$ (amine -NH), 2820 $cm^{-1}$ (amine -$CH_2$- stretching), 1440 $cm^{-1}$ (amine -$CH_2$- vibration); nmr (deuteriochloroform): δ 2.97, 2.30 (q, 2, -N-$CH_2$-), 2.90, 2.80 (m, 2, -N-$CH_2$-), 2.57 (s b, 1, -NH), 2.05 (m, 1, -CH-), 1.85, 1.20 (m, 2, -$CH_2$-), 0.95 (d, 3, -$CH_3$).

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