TABLE III

PAPER CHROMATOGRAMS OF 3-BUTENYLTHIOUREA

	Unknown sample	3-Butenylthiourea
R_{Ph} in chloroform–water	0.61	0.61
R_{Ph} in benzene–ethanol–water (5:1:2)	.59	.58
R_f in heptane–butanol–formic acid (1:1:1)	.17	.18

reported previously.[2,3] By collecting eluates of the R_{Ph} 0.61 spot from a number of chloroform–water chromatograms, it was possible to obtain a quantity sufficient for rechromatography in other solvent systems. Eight 25-μl. spots of a solution of 24.6 mg. of the water-extracted unknown mixture (from 70 mg. of unextracted material) in 1 cc. of ethanol were chromatographed in a chloroform–water system, and the spots at R_{Ph} 0.61 were eluted by the method described above. The concentration, calculated[14] from an ultraviolet spectrum of the combined eluates which showed the characteristic maxima at 243 mμ, indicated that 16.2 μg. of 3-butenylthiourea had been eluted, equivalent to 0.86 mg. per 100 lb. of cabbage. For rechromatography in other solvent systems, portions of the eluate corresponding to 8 μg. of 3-butenylthiourea were concentrated and spotted, as described for 3-methylthiopropylthiourea. The chromatographic evidence for 3-butenylthiourea in three systems is shown in Table III.

Evidence for 3-Methylsulfinylpropylthiourea.—In order to study the spot that remained at the origin in the chloroform–water paper chromatogram, a chromatogram was run in a butanol–toluene–water (3:1:1) system.[17] It gave a new blue spot at R_{Ph} 0.35, which was close to that of 3-methylsulfinylpropylthiourea. With the identification of 3-methylthiopropylthiourea, this tentative assignment became more reasonable. 3-Methylsulfinylpropyl isothiocyanate[25,26] might have some volatility under the conditions employed in the vacuum steam distillation, or the sulfoxide could be formed as an artifact subsequent to the steam distillation.

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NATICK, MASS.

[CONTRIBUTION FROM THE RESEARCH LABORATORIUM DR. C. JANSSEN]

The Synthesis of 2-R-3,3-Diphenyl-Δ^1-pyrrolines from 2,2-Diphenyl-4-bromobutyronitrile

BY PAUL J. A. DEMOEN AND PAUL A. J. JANSSEN

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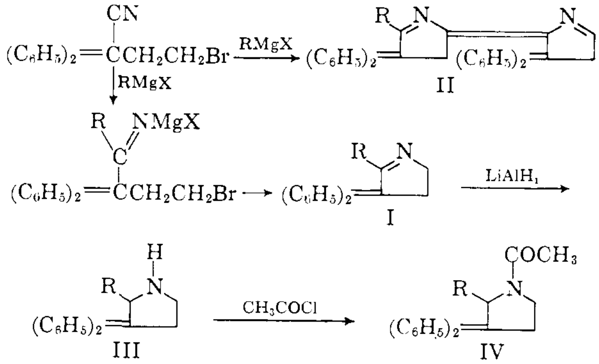
Different types of reaction products are obtained when an alkyl-, aryl- or aralkylmagnesium halide is allowed to react with 2,2-diphenyl-4-bromobutyronitrile under the conditions described. One series of reaction products consists of 2-substituted-3,3-diphenyl-Δ^1-pyrrolines, whereas the other series consists of higher melting products whose structure is discussed.

The most widely accepted method of synthesis of pyrrolines undoubtedly is the Grignard reaction between 4-chlorobutyronitriles and alkyl-, aryl- or aralkylmagnesium halides.[1-10] Little is known however about 3,3-disubstituted-Δ^1-pyrrolines.

Murray and Cloke[5] synthesized four (methyl-, ethyl-, *n*-propyl- and *n*-butyl-)2-phenyl-3-alkyl-3-phenyl-Δ^1-pyrrolines from 4-chloro-2-alkyl-2-phenylbutyronitriles and phenylmagnesium bromide. As a rule, they refluxed the Grignard reagent and the nitrile for eight hours in ether, and added the cooled mixture to liquid ammonia. After evaporation of the ammonia, the Δ^1-pyrrolines were isolated from the residue. Yields were: CH_3, 78%; C_2H_5, 70%; n-C_3H_7, 58%; n-C_4H_9, 35%. Except for the *n*-butylpyrroline, the compounds were solids. After a 6 months storage in a desiccator over phosphorus pentoxide, they changed to yellow resinous masses.



In this paper the products formed by the action of different alkyl-, aryl- or aralkylmagnesium halides on 2,2-diphenyl-4-bromo-butyronitrile are described. A typical general method was adopted,[2,3] and after suitable processing, the residual oily product was subjected to vacuum distillation. The phenomena described were observed on distillation: 1. In two cases (R = C_2H_5, n-C_3H_7) the distillate consisted of the expected substituted Δ^1-pyrroline I in yields between 22 and 65%, and the distillation residue after crystallization gave a pure compound with a higher melting point than the corresponding Δ^1-pyrroline. The yields were relatively low

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(8 to 24%) and inversely proportional to the yields of the corresponding Δ^1-pyrrolines. 2. In four cases (R = CH_3, C_6H_5, 4-$CH_3C_6H_4$, 4-ClC_6H_4) the expected Δ^1-pyrroline distilled, but a higher melting product could not be isolated from the residue. The yields for the Δ^1-pyrrolines were from 42 to 64%. 3. In one case (R = benzyl) no Δ^1-pyrroline was obtained, but the residue gave the high melting fraction in 47% yield. 4. Finally, in two other cases (R = *n*-C_4H_9, *i*-C_3H_7) pure reaction products could not be obtained.

In Table I are given the halides (RX), and the yields and melting points of the corresponding Δ^1-pyrrolines (I) and high melting fractions (II).

TABLE I

RX	Δ^1-Pyrrolines (I) Yield, %	M.p., °C.	High-melting fractions (II) Yield, %	M.p., °C.
Methyl iodide	53	50.4–52.0	0	
Ethyl bromide	65	81.2–82.0	8	193.0–194.4
n-Propyl bromide	(22)	Oil (impure)	24	177.0–179.6
n-Butyl bromide	..	Oil (impure)	0	....
Isopropyl bromide	..	Oil (impure)	0	....
Bromobenzene	58	125.5–127.0	0	....
4-Methylbromobenzene	64	129.8–131.4	0	....
4-Chlorobromobenzene	42	121.5–122.0	0	....
Benzyl chloride	0	....	47	226.0–227.0

Although Craig, *et al.*,[3] obtained 55, 46 and 13% yields for 2-phenyl-, 2-ethyl- and 2-benzyl-Δ^1-pyrroline, resp., "in the reverse order of the order of reactivity of the Grignard reagents from which they are derived," the substituting group (R) seems to exert little or no influence on the yields of the Δ^1-pyrrolines in the present work. A ranking correlation, however, between the order of reactivity of the Grignard reagents and the yields is found for the high-melting products (II): 8, 24 and 47% for 2-ethyl, 2-*n*-propyl and 2-benzyl, resp.

The Δ^1-Pyrrolines (I).—The Δ^1-pyrrolines, after crystallization from petroleum ether or alcohol, are crystalline or micro-crystalline white or slightly yellow, stable products. They could be stored in brown snap-caps for over three years without visible or measurable (melting point, titration, ultraviolet and infrared spectrum) decomposition. The great stability is in contrast with the behavior of the 2-phenyl-3-alkyl-3-phenyl-Δ^1-pyrrolines described by Murray and Cloke[5] which resinify after several months in a vacuum desiccator over phosphorus pentoxide.

The ultraviolet absorption of the 2-alkyl-3,3-diphenyl-Δ^1-pyrrolines in isopropyl alcohol shows an intense end-absorption toward short wave lengths. This results in an important qualitative change of the characteristic phenyl absorption (3 maxima in the neighborhood of 260 mμ). Only one absorption maximum is found at about 260 mμ, with an ϵ-value of approximately 520. Compounds containing non-conjugated phenyl substituents as the only chromophoric groups are expected to show maximum absorption at about 260 mμ, ϵ approx. 230, for each phenyl group.[11–14]

The intense end-absorption toward shorter wave lengths is to be ascribed to the double bond in the pyrroline ring system. This is confirmed by the absorption spectrum of the corresponding pyrrolidines (III, IV) which do not show end absorption, but the normal phenyl spectrum with 3 maxima around 260 mμ. Cymerman and Gilbert[13] likewise noted appreciable end absorption for the spectra of 5-methyl- and 1,5-dimethyl-2-imino-3,3-diphenylpyrrolidine.

When measured in a solvent containing 10% 0.1 *N* hydrochloric acid plus 90% isopropyl alcohol, the 2-alkyl-Δ^1-pyrrolines show absorption without maximum below 300 mμ, increasing sharply below approximately 225 mμ. This spectrum has a molar absorptivity of about 2200 at 260 mμ and about 4000 at 230 mμ. As mentioned above, this should be interpreted as an α-C═N effect. The corresponding pyrrolidines indeed show normal absorption in this solvent.

2-Phenyl-, 2-*p*-tolyl- and 2-*p*-chlorophenyl-3,3-diphenyl-Δ^1-pyrrolines show an intense ultraviolet absorption in isopropyl alcohol: ϵ_{max} 12,000, 14,000 and 16,300 at 249, 256.5 and 256 mμ, resp. These intensities and wave lengths of maximum absorption are characteristic for a double bond conjugated to a phenyl group[15–17] and are further evidence for the Δ^1-unsaturation in pyrrolines obtained from 4-halobutyronitrile and Grignard reagents. Prototropic isomerization giving the corresponding Δ^5-pyrrolines is therefore excluded. This is in agreement with the opinion of Murray and Cloke.[5] On acidifying the solution, the absorption maxima are displaced to longer wave lengths.

In agreement with the reported infrared spectra of various substituted Δ^1-pyrrolines[7–10,18,19] the pyrrolines described herein do not show NH-absorption at about 3 μ, but they all show intense absorption at 6.13 μ, the region of absorption of the characteristic C═N band in compounds having the azomethine system. This C═N band is displaced to 6.01 μ in the hydrochloride salt of the Δ^1-pyrroline (I, R = C_2H_5), whereas the broad ammonium band at 3.80–3.96 μ and the immonium band at 5.16 μ were found to occur. Both ammonium and immonium bands are of low intensity when measured in potassium bromide disks.

Under the experimental conditions described herein, the Δ^1-pyrrolines could not be reduced with tin in concentrated hydrochloric acid, nor

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with zinc powder in the same acid or in sodium hydroxide solution. Craig[3] and Gabriel and Coleman,[20] however, described the quantitative reduction of 2-phenylpyrroline with tin in concentrated hydrochloric acid, but LaForge[21] was unable to confirm these results.

Catalytic reduction with platinum oxide between 25 and 60° (1 atmosphere) in ethanol likewise did not reduce the pyrrolines. Reduction with lithium aluminum hydride, on the other hand, gave the corresponding pyrrolidines (III) in all cases and in good yields. One pyrrolidine (III, R = CH_3) was converted with acetyl chloride to the N-acetylpyrrolidine (IV, R = CH_3).

The High-melting Fractions (II).—The high-melting products which were obtained in variable amounts (<10 to about 50% yield) are white to clear yellow, amorphous or micro-crystalline stable compounds which are nearly insoluble in water, alcohol and benzene, but very soluble in chloroform and in carbon tetrachloride.

The products were titrated potentiometrically with acetous perchloric acid. They show an equivalent weight twice that of the corresponding Δ^1-pyrrolines, minus the formula weight of the substituent R. Total nitrogen determination (Kjeldahl and micro-Dumas) revealed the presence of two nitrogen atoms per basic equivalent. The compounds thus contain two atoms of nitrogen per molecule, of which only one behaves like a base in glacial acetic acid.

The ultraviolet spectra of the compounds show an unusual intense absorption (Table II). Both the intensity and the wave length of maximum absorption indicate a highly conjugated system. In a recent paper, Sugasawa and Ushioda[22] found maximum absorption at 293 mμ, log ε 4.37, for 2-phenyl-3-benzal-Δ^1-pyrroline.

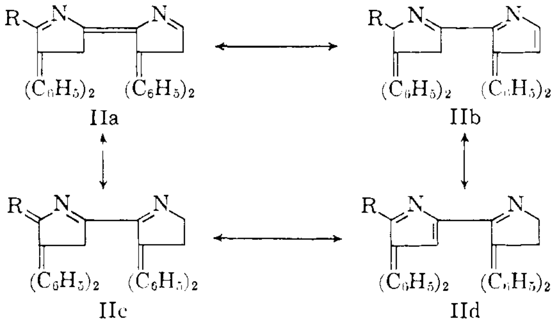
Acidification of the solvent resulted in a hyperchromic and bathochromic effect. In this solvent, the high-melting fraction resulting from benzylmagnesium halogenide (II, R = benzyl) shows a second absorption band with maximum near 246 mμ (ε 36,800). This band resembles qualitatively the absorption of the system C_6H_5-$CR_1{=}CR_2R_3$. Its absorption, however, is more than twice as intense as for this chromophore.

TABLE II

ULTRAVIOLET ABSORPTION OF HIGH-MELTING FRACTIONS (II)

	In *i*-PrOH + 0.5% $CHCl_3$		In 0.01 *N* HCl–90% *i*-PrOH			
RX	λ, mμ	ε	λ, mμ	ε	λ, mμ	ε
Ethyl bromide	336	14,700	371	18,600	..	....
n-Propyl bromide	333	14,200	375	21,500	..	....
Benzyl chloride	332	17,400	368	23,200	246	36,800

If one considers the basic equivalent, the total nitrogen content and the ultraviolet absorption suggesting several conjugated double bonds, structural formula II may be postulated for the high-melting products. It corresponds to the condensation of two moles of Δ^1-pyrroline, where one R-substituent is split off and an additional double bond arises. As described for the methylene-azomethine system,[5,23,24] tautomeric structures IIa–IId likewise should be possible.



The infrared spectra of the high-melting products resemble those of the corresponding Δ^1-pyrrolines. The high melting products, however, show only negligible background absorption in the C=N—region, where the Δ^1-pyrrolines show a strong maximum (6.13 μ). On the other hand, they have a marked double peak between 6.65 and 6.75 μ, whereas the Δ^1-pyrrolines show only one isolated peak at 6.74 μ. As concluded by Bellamy[25] and Weissberger,[26] the characteristic C=N vibrations can be displaced and even completely disappear under the influence of conjugation.

Under the experimental conditions described, the high melting products could not be reduced with lithium aluminum hydride, the starting material (II, R = C_2H_5) being recovered in 60% yield. This probably is to be ascribed to the hyperconjugated structure. Catalytic reduction with platinum oxide as described for the Δ^1-pyrrolines likewise was unsuccessful.

Experimental

Reaction Products from 2,2-Diphenyl-4-bromobutyronitrile and Ethylmagnesium Bromide.—Magnesium (9.54 g.) was allowed to react with 64 g. (0.59 mole) of ethyl bromide in 100 ml. of ether. After the addition of 60 g. (0.2 mole) of 2,2-diphenyl-4-bromobutyronitrile in 110 ml. of xylene, the ether was removed by warming and the mixture was refluxed for 8 hours. After cooling, a saturated aqueous solution of ammonium chloride was added at 0°. The organic layer was extracted with diluted hydrochloric acid. The aqueous extract was made alkaline with an excess of sodium hydroxide and extracted with ether. The ether was evaporated and the remaining oil was distilled *in vacuo*, b.p. 168–170° (2 mm.), giving 32.5 g. (0.13 mole, 65%) of yellowish oil which solidified on standing. After recrystallization from ether, 27.0 g. of 2-ethyl-3,3-diphenyl-Δ^1-pyrroline (I, R = C_2H_5) was obtained as white crystals, m.p. 81.2–82.0°. Calcd.: for $C_{18}H_{19}N$: neut. equiv., 249.34: C, 86.70; H, 7.68; N, 5.62. Found: neut. equiv., 249.0; C, 86.5; H, 7.71; N, 5.65. Ultraviolet absorption in isopropyl alcohol: λ_{max} 259.5 mμ (ε 535), λ_{min} 258.5 mμ (ε 530); ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: no absorption maximum between 210 and 300 mμ; ϵ_{260} mμ 2300.

An oily residue remained in the distillation flask. This residue was dissolved in ether and crystallized from benzene, yielding 3.6 g. (0.008 mole, 7.6%) of amorphous powder, m.p. 185–188°. After recrystallization from acetone, 2.4 g. of slightly yellow crystalline powder was obtained, m.p.

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193.0–194.4° (II, R = C_2H_5). Calcd. for $C_{34}H_{30}N_2$: neut. equiv., 466.60; C, 87.51; H, 6.48; N, 6.00. Found: neut. equiv., 471.4; C, 87.3; H, 6.55; N, 5.94. Ultraviolet absorption in isopropyl alcohol containing 0.5% chloroform: λ_{max} 336 (ϵ 14,700) and 253 mμ (shoulder, ϵ 3100); λ_{min} 281 mμ (ϵ 2300); the absorption rises sharply below 240 mμ; ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 371 mμ (ϵ 18,600), λ_{min} 303 mμ (ϵ 500); the absorption rises sharply below 225 mμ.

In another experiment, 66.4 g. of magnesium, 448 g. of ethyl bromide and 420 g. (1.4 moles) of 2,2-diphenyl-4-bromobutyronitrile were refluxed for 6 hours in 600 ml. of xylene. The reaction products were extracted as described above, the ethereal extract was evaporated and the residue was dissolved in petroleum ether: 24.5 g. (0.053 mole, 7.6%) of the high melting product crystallized in the refrigerator, m.p. 188–190° (II, R = C_2H_5). The filtrate was evaporated and distilled, b.p. 170–190° (2 mm.), yielding 111.5 g. (0.45 mole, 31.9%) of 2-ethyl-3,3-diphenyl-Δ^1-pyrroline (I, R = C_2H_5).

2-Methyl-3,3-diphenyl-Δ^1-pyrroline (I, R = CH_3).—Magnesium (9.54 g.) was allowed to react with 85 g. (0.60 mole) of methyl iodide in 100 ml. of ether; 60 g. (0.2 mole) of 2,2-diphenyl-4-bromobutyronitrile in 120 ml. of xylene was added, and the reaction was processed as above, but refluxing was continued for 10 hours; b.p. 170–180° (3–5 mm.), yielding 25 g. (0.106 mole, 53%) of product, m.p. 46–48°. After recrystallization from petroleum ether 18.3 g. of 2-methyl-3,3-diphenyl-Δ^1-pyrroline (I, R = CH_3) was obtained, m.p. 50.4–52.0°. Calcd. for $C_{17}H_{17}N$: neut. equiv., 235.31; C, 86.77; H, 7.28; N, 5.95. Found: neut. equiv., 237.0; C, 86.7; H, 7.22; N, 5.88. Ultraviolet absorption in isopropyl alcohol: λ_{max} 260.0 mμ (ϵ 530); λ_{min} 255.0 mμ (ϵ 515).

2-Phenyl-3,3-diphenyl-Δ^1-pyrroline (I, R = C_6H_5) was prepared as described for (I, R = C_2H_5), substituting 92 g. (0.59 mole) of bromobenzene for the ethyl bromide. The product had b.p. 210–220° (4 mm.), yield 34.5 g. (0.116 mole, 58%), m.p. 126–128°. After recrystallization from petroleum ether, 23.4 g. of 2-phenyl-3,3-diphenyl-Δ^1-pyrroline (I, R = C_6H_5) was obtained, m.p. 125.5–127.0°. Calcd. for $C_{22}H_{19}N$: neut. equiv., 297.38; C, 88.85; H, 6.44; N, 4.71. Found: neut. equiv., 301.1; C, 89.0; H, 6.66; N, 4.85. Ultraviolet absorption in isopropyl alcohol: λ_{max} 249 mμ (ϵ 12,000), λ_{min} 230.5 mμ (ϵ 7300); ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 271.4 mμ (ϵ 10,500), λ_{min} 233 mμ (ϵ 5800).

2-*p*-Tolyl-3,3-diphenyl-Δ^1-pyrroline (I, R = 4-$CH_3C_6H_4$) was prepared from 11 g. of magnesium, 85.1 g. (0.5 mole) of 4-bromotoluene and 60 g. (0.2 mole) of 2,2-diphenyl-4-bromobutyronitrile in 125 ml. of xylene by refluxing for 17 hours. After decomposition of the complex and evaporation as above, 40 g. (64%) of a viscous, brown oil was collected which decomposed slightly on distillation, b.p. 195–210° (3.5 mm.). The oil was dissolved in ether and dry hydrogen chloride was passed through the solution: a small amount of crystalline material was obtained, and was converted to the base and crystallized from ether, yielding 4.0 g. (0.013 mole, 6.4%) of 2-*p*-tolyl-3,3-diphenyl-Δ^1-pyrroline (I, R = 4-CH_3-C_6H_4). Calcd. for $C_{23}H_{21}N$: neut. equiv., 311.41; C, 88.70; H, 6.80; N, 4.50. Found: neut. equiv., 316.4; C, 88.7; H, 6.88; N, 4.36. Ultraviolet absorption in isopropyl alcohol: λ_{max} 256.5 mμ (ϵ 14,000), λ_{min} 230.5 mμ (ϵ 5700); ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 297 mμ (ϵ 10,000), λ_{min} 239 mμ (ϵ 2200).

2-*p*-Chlorophenyl-3,3-diphenyl-Δ^1-pyrroline (I, R = 4-ClC_6H_4) was prepared as described above from 19 g. of magnesium, 229 g. (1.2 moles) of 4-chlorobromobenzene and 120 g. (0.4 mole) of 2,2-diphenyl-4-bromobutyronitrile in 200 ml. of xylene. Refluxing was continued for 16 hours. After decomposition and evaporation, 56.5 g. (0.17 mole, 42%) of distillate was collected, b.p. 214–219° (1 mm.), which was crystallized from methanol at −15°, yielding 35.6 g. of 2-*p*-chlorophenyl-3,3-diphenyl-Δ^1-pyrroline (I, R = 4-ClC_6H_4) as a crystalline powder, m.p. 121.5–122.0°. Calcd. for $C_{22}H_{18}ClN$: neut. equiv., 331.83; C, 79.63; H, 5.47; N, 4.22; Cl, 10.69. Found: neut. equiv., 332.7; C, 79.7; H, 5.41; N, 4.08; Cl, 10.3. Ultraviolet absorption in isopropyl alcohol: λ_{max} 256 mμ (ϵ 16,300), λ_{min} 231 mμ (ϵ 6700); ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 260.5 mμ (ϵ 11,600), 298 mμ (shoulder, ϵ 6500), λ_{min} 235.5 mμ (ϵ 4800).

Reaction Products from 2,2-Diphenyl-4-bromobutyronitrile and *n*-Propylmagnesium Bromide.—Magnesium (9.6 g., 0.4 mole) in 100 ml. of ether and 55.2 g. (0.45 mole) of *n*-propyl bromide in 100 ml. of ether were allowed to react for one hour; 60 g. (0.2 mole) of 2,2-diphenyl-4-bromo-butyronitrile in 100 ml. of xylene was added. The ether was evaporated and the mixture was refluxed for 8 hours. After 6.5 hours a precipitate was formed and 150 ml. of xylene was added to redissolve it. The mixture was cooled and decomposed with 200 ml. of saturated ammonium chloride solution. A negligible amount of precipitate (0.3 g.) appeared in the organic layer, and was identified as 2,2-diphenyl-4-bromobutyronitrile. The organic layer was evaporated, yielding 44.8 g. (about 93%) of brownish oil. After the addition of 30 ml. of petroleum ether, a precipitate formed in the refrigerator: 11.5 g. (0.024 mole, 24%) of the high-melting fraction (II, R = *n*-C_3H_7), m.p. 170–173°. After recrystallization from petroleum ether, 8.4 g. of slightly yellow, amorphous powder was obtained, m.p. 177.0–179.6°, Calcd. for $C_{35}H_{32}N_2$: neut. equiv., 480.62; C, 87.46; H, 6.71; N, 5.83. Found: neut. equiv., 470.8; C, 87.3; H, 6.74; N, 5.79. Ultraviolet absorption in isopropyl alcohol containing 0.5% chloroform: λ_{max} 333 mμ (ϵ 14,200), λ_{min} 282.3 mμ (ϵ 1900); ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 375 mμ (ϵ 21,500), λ_{min} 304 mμ (ϵ < 1000).

The filtrate from which the high melting fraction (11.5 g.) first was isolated, was evaporated and distilled, b.p. 147–160° (1 mm.), yielding 11.6 g. (0.044 mole, 22%) of a brownish oil. After redistillation, b.p. 153–160° (1 mm.), 7.3 g. of a yellowish oily product was obtained, which was identified as impure 2-*n*-propyl-3,3-diphenyl-Δ^1-pyrroline (I, R = *n*-C_3H_7). Calcd. for $C_{19}H_{21}N$: neut. equiv., 263.37. Found: neut. equiv., 317.4. Ultraviolet absorption in isopropyl alcohol: ϵ_{259} mμ 650; shape and intensity closely resembling the 2-methyl and 2-ethyl homologs.

Reaction Product from 2,2-Diphenyl-4-bromobutyronitrile and Benzylmagnesium Chloride.—The Grignard reagent was prepared from 6.25 g. (0.26 mole) of magnesium and 44 g. (0.35 mole) of benzyl chloride in 150 ml. of ether. 2,2-Diphenyl-4-bromobutyronitrile (60 g., 0.2 mole) in 100 ml. of xylene was added, the ether was evaporated and the mixture was refluxed for 13 hours. After decomposition with 200 ml. of cold saturated ammonium chloride solution, the organic layer was washed with water and evaporated. The residue was washed with ether and dried, yielding 25 g. (0.047 mole, 47%) of the high-melting fraction (II, R = benzyl), m.p. 224–226°. After recrystallization from methyl isobutyl ketone, 18.4 g. was obtained, m.p. 226.0–227.0°. Calcd. for $C_{39}H_{32}N_2$: neut. equiv., 528.66; C, 88.60; H, 6.10; N, 5.30. Found: neut. equiv., 530.7; C, 88.1; H, 6.49; N, 5.25. Ultraviolet absorption in isopropyl alcohol containing 0.5% chloroform: λ_{max} 332 mμ (ϵ 17,400), λ_{min} 284 mμ (ϵ 3300); ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 246 (ϵ 36,800) and 368 mμ (ϵ 23,200), λ_{min} 228.5 (ϵ 24,100) and 311 mμ (ϵ 1300).

Reaction between 2,2-Diphenyl-4-bromobutyronitrile and Isopropylmagnesium Bromide.—From 9.5 g. of magnesium, 58.2 g. (0.47 mole) of isopropyl bromide and 60 g. (0.2 mole) of 2,2-diphenyl-4-bromobutyronitrile in 150 ml. of xylene, refluxed for 15 hours, there was obtained 15.8 g. (about 30%) of a yellow oil, b. p. 145–185° (1 mm.) The product had a neutralization equivalent of 1800 and contained 5.8% bromine. Ultraviolet absorption in isopropyl alcohol resembled the starting nitrile. In another experiment, after 8.5 hours of refluxing, 23.2 g. (±44%) of an oil was obtained, b.p. 188–192° (6 mm.). The oil was not basic and contained 8.6% bromine.

Reaction between 2,2-Diphenyl-4-bromobutyronitrile and *n*-Butylmagnesium Bromide.—Magnesium (6 g.), 37 g. (0.27 mole) of *n*-butyl bromide and 60 g. (0.2 mole) of 2,2-diphenyl-4-bromobutyronitrile were refluxed for 8 hours in 150 ml. of xylene. After decomposition and evaporation, 19.3 g. (about 35%) was recovered as an oil, b.p. 160–162° (1 mm.). Calcd. for $C_{20}H_{23}N$: neut. equiv., 277.39. Found: neut. equiv., 462; Br, 4.5.

After redistillation, b.p. 155–157° (1 mm.), 8.6 g. of oily product was obtained, containing 4.4% bromine, neutralization equivalent 403. The material showed maximum absorption at 328 mμ, ϵ 140 (for mol. wt. 277.4), indicating the presence of a negligible amount of the high melting product.

2-Methyl-3,3-diphenylpyrrolidine Hydrochloride (III, R = CH_3).—A mixture of 3.8 g. (0.1 mole) of lithium aluminum hydride and 17 g. (0.072 mole) of 2-methyl-3,3-diphenyl-Δ^1-pyrroline (I, R = CH_3) was refluxed for 48 hours under stirring in 300 ml. of ether in an atmosphere of nitrogen. The mixture was decomposed with a cold saturated ammonium chloride solution, washed with water and concentrated. The resulting oil (16 g., 0.068 mole, 93.6%) was dissolved in ether and precipitated as the hydrochloride. The salt was recrystallized from isopropyl alcohol, yielding 16.5 g. (0.060 mole, 83.3%) of 2-methyl-3,3-diphenylpyrrolidine (III, R = CH_3), m.p. 192.0–193.5%. Calcd. for $C_{17}H_{19}N \cdot HCl$: neut. equiv., 273.80; C, 74.57; H, 7.36; N, 5.12; Cl, 12.95. Found: neut. equiv., 276.4; C, 74.6; H, 7.58; N, 5.00; Cl, 12.9. Ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 256 (ϵ 420), 261.5 (ϵ 495), 265.5 (ϵ 465), 272.5 mμ (ϵ 345); λ_{min} 246.5 (ϵ 260), 257.5 (ϵ 415), 264.5 (ϵ 445), 271 mμ (ϵ 290).

After stirring 10 g. (0.042 mole) of 2-methyl-3,3-diphenyl-Δ^1-pyrroline (I, R = CH_3) with an excess of zinc powder in diluted hydrochloric acid for 5 hours, extraction from the alkalized solution with ether and precipitation with hydrochloric acid, there was obtained 5.5 g. (0.020 mole, 48%) of a product, m.p. 153–154.5°, which was identified (melting point and ultraviolet spectrum) as the hydrochloride of the starting material (I, R = CH_3).

2-Ethyl-3,3-diphenylpyrrolidine (III, R = C_2H_5).—Lithium aluminum hydride (8.81 g., 0.23 mole) and 29 g. (0.116 mole) of 2-ethyl-3,3-diphenyl-Δ^1-pyrroline (I, R = C_2H_5) were refluxed for 25 hours in 250 ml. of ether in an atmosphere of nitrogen. The mixture was decomposed as above, washed and evaporated. The resulting oil was kept for 4 days in a refrigerator at −15° and solidified, giving 22 g. (0.088 mole, 75.4%) of a white, curdy powder, m.p. 51–53°. Calcd. for $C_{18}H_{21}N$: neut. equiv., 251.36. Found: neut. equiv., 256.7.

A portion (9 g.) of the product was dissolved in ether and transformed to the hydrochloride, giving 9.2 g. (89.3%) of 2-ethyl-3,3-diphenylpyrrolidine hydrochloride (III, R = C_2H_5), m.p. 219–220°. Calcd. for $C_{18}H_{21}N \cdot HCl$: neut. equiv., 287.83; C, 75.11; H, 7.70; N, 4.87; Cl, 12.31. Found: neut. equiv., 293.0; C, 75.6; H, 7.62; N, 4.69; Cl, 12.3. Ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 255.5 (ϵ 410), 261.5 (ϵ 475), 265 (ϵ 455), 272.5 mμ (ϵ 355); λ_{min} 242 (ϵ 230), 256.5 (ϵ 405), 264 (ϵ 435), 270.5 mμ (ϵ 300).

In another attempt 10 g. of 2-ethyl-3,3-diphenyl-Δ^1-pyrroline (I, R = C_2H_5) and 10 g. of tin were kept in 75 ml. of hydrochloric acid for 2 hours at room temperature, and for 3 hours in a boiling water-bath. After cooling and addition of excess sodium hydroxide, the base was extracted with ether, and the solvent was evaporated. The residue was washed with petroleum ether and dried, yielding 3.5 g. (35%) of a white solid, m.p. 79–80°, which was identified (melting point and ultraviolet spectrum) as the starting material. Finally, 10 g. of 2-ethyl-3,3-diphenyl-Δ^1-pyrroline, 10 g. of zinc powder and 10 g. of sodium hydroxide were stirred with 500 ml. of ether for 2 hours in a water-bath. The base was extracted with diluted hydrochloric acid, and alkalized. After extraction with ether and evaporation, the residue was crystallized from petroleum ether, yielding 2.2 g. (22%) of an amorphous solid, m.p. 80–81°, which was identified as above, as the starting material (I, R = C_2H_5).

2-Phenyl-3,3-diphenylpyrrolidine Hydrochloride (III, R = C_6H_5).—Lithium aluminum hydride (4.85 g., 0.13 mole) and 19 g. (0.064 mole) of 2-phenyl-3,3-diphenyl-Δ^1-pyrroline (I, R = C_6H_5) were refluxed for 26 hours in 250 ml. of ether in an atmosphere of nitrogen, and processed as described above; yield 16.6 g. (0.055 mole, 86.6%) of oily product, which was transformed to the hydrochloride, giving 18 g. (0.054 mole, 84%) of 2-phenyl-3,3-diphenylpyrrolidine hydrochloride (III, R = C_6H_5), m.p. 253–258°. After recrystallization from isopropyl alcohol, it had m.p. 262.0–264.0° with slight decomposition. Calcd. for $C_{22}H_{21}N \cdot HCl$: neut. equiv., 335.87; C, 78.67; H, 6.60; N, 4.17; Cl, 10.56. Found: neut. equiv., 338.3; C, 79.0; H, 6.55; N, 4.08; Cl, 10.4. Ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 256 mμ (shoulder, ϵ 560), 261 (ϵ 680), 265.5 (ϵ 660), 272.5 mμ (ϵ 465); λ_{min} 242.5 (ϵ 285), 264 (ϵ 630), 271 mμ (ϵ 435).

2-*p*-Chlorophenyl-3,3-diphenylpyrrolidine Hydrochloride (III, R = 4-ClC_6H_4).—Lithium aluminum hydride (5.32 g., 0.14 mole) and 33.2 g. (0.1 mole) of 2-*p*-chlorophenyl-3,3-diphenyl-Δ^1-pyrroline (I, R = 4-ClC_6H_4) were refluxed in an atmosphere of nitrogen for 15 hours in 350 ml. of ether, and stirred thereafter for 12 hours at room temperature. The mixture was decomposed with a solution of 120 g. of sodium–potassium tartrate in 400 ml. of water. The ethereal layer was dried with potassium carbonate and saturated with hydrochloric acid, yielding 33.9 g. (0.091 mole, 91.5%) of grayish-white solid, m.p. 242–250°. After recrystallization from isopropyl alcohol, 25.4 g. of white 2-*p*-chlorophenyl-3,3-diphenylpyrrolidine hydrochloride (III, R = 4-Cl-C_6H_4) was obtained, m.p. 271.0–272.5°. Calcd. for $C_{22}H_{20}ClN \cdot HCl$: neut. equiv., 370.31; C, 71.35; H, 5.72; N, 3.78; chloride, 9.58; total chlorine, 19.15. Found: neut. equiv., 373.7; C, 71.3; H, 5.82; N, 3.71; chloride, 9.7; total chlorine, 18.9. Ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 261.5 (ϵ 725), 266.5 mμ (ϵ 710); minima at 246.5 (ϵ 390), 264.5 mμ (ϵ 690).

Action of Lithium Aluminum Hydride on the High-melting Fraction (II, R = C_2H_5).—Lithium aluminum hydride (7.6 g., 0.2 mole) and 15 g. (0.032 mole) of the high-melting fraction (II, R = C_2H_5) in 200 ml. of ether were refluxed for 24 hours in an atmosphere of nitrogen. Benzene was added, the ether was removed, the mixture was refluxed again for 25 hours, and then processed with ammonium chloride as above. The residue was washed with ether, yielding 10.5 g. (60%) of slightly yellow powder, which was identified as the starting material (m.p. 192–194°) through its ultraviolet spectrum and mixed melting point.

2-Methyl-3,3-diphenyl-N-acetylpyrrolidine (IV, R = CH_3).—From 4 g. (0.014 mole) of 2-methyl-3,3-diphenylpyrrolidine hydrochloride, the base was liberated and acetylated with 5 ml. of acetyl chloride in ether. After evaporation and crystallization from isopropyl alcohol, 2 g. (0.007 mole, 50%) of 2-methyl-3,3-diphenyl-N-acetylpyrrolidine (IV, R = CH_3) resulted, m.p. 124.0–126.0°. The product was not basic in glacial acetic acid. Calcd. for $C_{19}H_{21}NO$: C, 81.67; H, 7.57; N, 5.01. Found: C, 81.5; H, 7.70; N, 4.80. Ultraviolet absorption in 0.01 *N* HCl–90% isopropyl alcohol: λ_{max} 245.1 (ϵ 290), 256.5 (ϵ 460), 262 mμ (ϵ 525), 266 (ϵ 530), 273 mμ (ϵ 420); λ_{min} 243.5 (ϵ 285), 247 (ϵ 280), 264 (ϵ 495), 271 mμ (ϵ 310).

Melting points are uncorrected. They were determined on a Hershberg–Tottoli apparatus (Büchi). Titrations were performed in glacial acetic acid–perchloric acid in the same solvent as a titrant. The titrations were followed potentiometrically using glass–calomel electrodes connected to a Metrohm–Titriskop (Metrohm). Mercuric acetate was added to titrate the hydrochlorides.[27] Chloride was determined according to Volhard. Total chlorine and bromine were determined according to Volhard, after mineralization in a Wurzschmitt bomb with sodium peroxide and ethylene glycol.[28] Ultraviolet spectra were measured with a Beckman DK2-ratio recording spectrophotometer. Infrared spectra were measured in potassium bromide pellets with a Perkin–Elmer sodium chloride Infracord.

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BEERSE, ANTWERP, BELGIUM

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