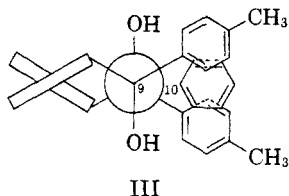


and electron-donor:electron-acceptor complexes.<sup>41</sup>

Monomolecular inclusion compounds however hold the enclosed guest molecule in a cage-like space in the center of the host component without the formation of any additional bonding other than the normally weak van der Waals forces.<sup>35-37</sup> A possible structural arrangement for I is suggested in III where the benzene moiety is confined between the equatorial *p*-tolyl substituents. The *p*-methyl groups accomplish a "locking effect" comparable to the caging effect of a cyclic host component.



### EXPERIMENTAL

Melting points are uncorrected. The microanalyses were performed by Dr. F. B. Strauss and Dr. G. Weiler Micro-analytical Laboratory, Mr. J. Alicino, E. R. Squibb and Sons, New Brunswick, N. J., and Schwartzkopf Micro-analytical Laboratory, Woodside, N. Y. Hydroxyl absorption measurements were made with a Perkin-Elmer Model

(39) See however ref. 31.

(40) We are indebted to Dr. Lester P. Kuhn, Ballistics Research Laboratory, Aberdeen Proving Ground, Md., for these infrared measurements.

(41) Although benzene can be considered a weak electron donor, there should be little difference between *trans*-II and *cis*-II diols as electron acceptors. Yet the latter does not form a molecular compound with benzene. Further, the electron acceptor complexes with benzene involve such electronegative atoms, groups, and molecules as the halogens,<sup>3-5</sup> nitro groups,<sup>6-8,18,19,21</sup> oxalyl chloride,<sup>17,18</sup> and dienophiles.<sup>20</sup> A general discussion of molecular complexes of this type, and theories as to the precise nature of the union between electron-attracting compounds and aromatics is available in G. M. Badger, *The Structures and Reactions of the Aromatic Compounds*, University Press, Cambridge, 1954, pp. 79-87.

12 B spectrometer equipped with a LiF prism; concn., 10 mg./ml., cell thickness, 0.1 mm., CHCl<sub>3</sub> solvent.<sup>40</sup> Thermo-analytical data were obtained with a Stanton milligram thermobalance.<sup>33</sup>

*trans*-9,10-Di(*p*-tolyl)-9,10-dihydro-9,10-phenanthrenediol (*trans*-II), m.p. 140-142° from ethanol.<sup>27</sup>

Molecular compound (I), m.p. 103-104°, was obtained simply by recrystallizing *trans*-II from warm benzene.

*Anal.* Calcd. for C<sub>28</sub>H<sub>24</sub>O<sub>2</sub>:C<sub>6</sub>H<sub>6</sub>: C, 86.77; H, 6.43. Mol. wt. 470. Found: C, 86.63; H, 6.52. Mol. wt., 232, 268.<sup>42</sup> A mixed m.p. of *trans*-II and I is depressed.

I (2-yr. old sample).

*Anal.* Calcd. for C<sub>28</sub>H<sub>24</sub>O<sub>2</sub>:0.5C<sub>6</sub>H<sub>6</sub>: C, 86.28; H, 6.30. Found: C, 86.02; H, 6.39.

*Recrystallizing solvent study.* Approximately 100 mg. of I or *trans*-II was dissolved in the minimum amount of boiling solvent. If a solid had not crystallized after cooling within 24 hr., the solvent was removed *in vacuo*, and the m.p. of the residue was taken. The m.p. of *trans*-II from all solvents except benzene ranged from 138 to 141°.

*Microdistillation of I.* One g. of I was slowly heated at atmospheric pressure in a microdistillation flask of conventional design. At 102-104°, I melted and almost simultaneously the benzene was distilled (105-108°) and collected into a previously weighed side arm trap immersed in a Dry Ice-acetone bath.

*m*-Dinitrobenzene. The benzene distillate was added to 1 ml. of conc. H<sub>2</sub>SO<sub>4</sub> followed by dropwise addition of 1 ml. of conc. HNO<sub>3</sub> with vigorous stirring. After cooling the test tube in a beaker of water, the acid solution was poured onto 20 g. of ice. The precipitate was collected on a filter and recrystallized from alcohol, m.p. 88-89°<sup>34</sup>; admixture of the latter with an authentic sample showed no depression.

*Acknowledgment.* The authors are most grateful for many helpful discussions with Dr. N. O. Smith, Dr. I. M. Hunsberger, and Dr. P. Gentile, of Fordham University. This research was supported in part by a grant from the Research Corporation and, in part by a grant from the U. S. Public Health Service, National Cancer Institute (C-3325). Grateful acknowledgment is hereby made to the donors of said funds.

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(42) Rast molecular weights in camphor for these molecular compounds are generally low.<sup>9</sup>

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, FLORIDA STATE UNIVERSITY]

## Pyrroles. XIII. Structure and Reactivity of N-Methyl-2-pyrrolealdehyde<sup>1</sup>

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Received April 28, 1958

On the basis of its similarity to 2-pyrrolealdehyde in chemical behavior and physical properties, *N*-methyl-2-pyrrolealdehyde is assigned a structure to which a dipolar form contributes materially.

A number of explanations have been advanced to account for the physical properties of 2-pyrrolealdehyde

and to explain its failure to undergo many of the ordinary aldehyde reactions.<sup>3,4</sup> There seems to

(1) Paper XII. W. Herz and J. Brasch, *J. Org. Chem.*, **23**, 711 (1958). This work was supported in part by the Office of Ordnance Research, U. S. Army, under Contract No. DA-01-009-ORD-436.

(2) Abstracted from the M.S. thesis of Jay Brasch, August 1957.

be no doubt that the substance is associated to some extent depending on solvent<sup>5-8</sup> or temperature,<sup>9</sup> but recent infrared measurements<sup>10,11</sup> indicate that, at least in dilute solution, there is no evidence for a dimer of the type suggested by Emmert.<sup>5,12</sup> A reinterpretation of the results of Emmert and coworkers<sup>5</sup> who presented evidence for the existence of such a dimer has recently been given by Treibs and Kolm.<sup>13</sup>

Spectra which purport to furnish evidence for the so-called hydroxymethylene form of 2-pyrrolealdehyde<sup>14</sup> do not resemble the curves given by later workers.<sup>15</sup> At the present time it seems to be generally agreed<sup>2,10,13</sup> that a resonance hybrid of the type shown below accounts satisfactorily for



the physical properties (solubility in polar solvents, high molecular weight, high polarographic reduction potential, unusually low carbonyl frequencies in the infrared)<sup>16</sup> as well as for the relatively small tendency of the carbonyl carbon to react with nu-

(3) H. Fischer and H. Orth, *Die Chemie des Pyrrols*, Akademische Verlagsgesellschaft, Leipzig, Vol. 1, p. 150 (1934).

(4) B. Oddo, *Pyrrole et Composés Pyrroliques*, *Traité de Chimie Organique*, Masson et Cie., Paris, Vol. 19, 1942.

(5) B. Emmert, K. Diehl, and F. Gollwitzer, *Ber.*, **62**, 1733 (1929); B. Emmert and K. Diehl, *Ber.*, **64**, 130 (1931).

(6) P. Pratesi and V. Berti, *Boll. Sci. Fac. Chim. Ind. Univ. Bologna*, 188 (1940). It appears that phenol is sufficiently acidic to form a hydrogen bond with the carbonyl group of 2-pyrrolealdehyde, whereas ethanol cannot compete with the aldehyde itself.

(7) M. T. Sardina and C. Bonino, Jr., *Boll. Sci. Fac. Chim. Ind. Univ. Bologna*, **12**, 155 (1954); A. Marinangeli and C. Bonino, Jr., *Ann. Chim.*, **44**, 219, 949 (1954).

(8) P. Chiorboli, *Gazz. chim. ital.*, **81**, 906 (1951).

(9) P. Pratesi and V. Berti, *Atti X<sup>o</sup> Congr. intern. Chem.*, **3**, 313 (1939).

(10) U. Eisner and R. L. Erskine, *J. Chem. Soc.*, 971 (1958), and earlier references cited therein.

(11) P. Mirone and V. Lorenzelli, *Ann. Chim.*, **48**, 72 (1958).

(12) The situation in the more concentrated solutions or in the solid state may, however, be quite different; the infrared spectra indicate a considerable degree of association.

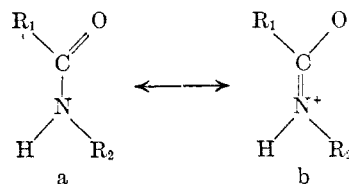
(13) A. Treibs and H. G. Kolm, *Ann.*, **606**, 166 (1957).

(14) G. Rastelli and A. Mingozi, *Gazz. chim. ital.*, **55**, 549 (1925).

(15) R. Andrisano, G. Pappalardo and L. Bolognari, *Gazz. chim. ital.*, **85**, 1430 (1955); G. B. Bonino and A. M. Marinangeli, *Atti. accad. Lincei*, **19**, 222 (1953). Our own measurements on 2-pyrrolealdehyde in 95% ethanol, containing sodium hydroxide in up to 0.05 M concentration, did not reveal the band at 310 m $\mu$  claimed by Rastelli and Mingozi and indeed differed not at all from the spectrum of 2-pyrrolealdehyde in ethanol alone. However, we wish to draw attention to the fact, not commented upon by others, that solutions of 2-pyrrolealdehyde deviate from Beer's law in a manner which is indicative of association at increasing concentration.

(16) A similar structure has been advanced to account for the properties of 3-indolealdehyde, J. Thesing, *Ber.*, **87**, 507 (1954).

cleophilic species. Thus, 2-pyrrolealdehyde may be considered as a vinylog of an amide or an  $\alpha$ -aminoaldehyde and indeed, the infrared carbonyl absorption peaks of pyrrolicarboxaldehydes and acylpyrroles are to be found<sup>10,11</sup> in the range of amide rather than aldehyde absorption. X-ray studies of amides<sup>17</sup> indicate that there is an appreciable contribution from forms (b) as well as (a), which explains the relatively low reactivity of the amide car-



bonyl; the failure of 2-pyrrolealdehyde, *p*-dimethylamino-, *p*-hydroxy-, and *p*-methoxybenzaldehyde to undergo the Cannizzaro or benzoin condensation is undoubtedly due to a similar cause.

If the existence of a dimer or the hydroxymethylene formula were responsible for the chemical behavior of 2-pyrrolealdehyde (I), one would expect *N*-methyl-2-pyrrolealdehyde (II) which does not form a dimer<sup>6</sup> to exhibit a more normal reactivity. Since little is known about the behavior of this substance we undertook a study of the more common aldehyde reactions. It may be stated at the outset that *N*-substitution was not expected to produce a marked enhancement in the activity of the carbonyl group, since the available information on reduction potential<sup>18</sup> and Raman spectra<sup>8</sup> had demonstrated that there was little difference between I and II. This was corroborated by the infrared spectrum of II; the carbonyl group (peak at 1672 cm.<sup>-1</sup>, CCl<sub>4</sub> solution) is only slightly less perturbed than that of I<sup>11</sup> (1665 cm.<sup>-1</sup>). The ultraviolet spectrum of II ( $\lambda_{\max}$  260, 289 m $\mu$ , log  $\epsilon$  3.83, 4.11, see also ref. 15) was unaffected by acid or by base.<sup>19</sup>

The failure of II to give Schiff's, Fehling's, or Tollen's test, its inability to add hydrogen cyanide or to undergo the Cannizzaro, benzoin, or Perkin condensation parallels the behavior of I and 3-indolealdehyde (III). Similarly, II could not be induced to condense with nitromethane and malonic acid. This suggests that II exists in a zwitterion-like form analogous to the formula postulated for I and III. The charge separation should not be so great as in 2-pyrrolealdehyde, due to the electron-donating effect of the methyl group. Therefore the structure of II should resemble the true aldehyde formula more than I, a conclusion which is corroborated to some degree by its physical properties.

(17) L. Pauling, R. B. Corey, and H. Branson, *Proc. Natl. Acad. Sci., U.S.A.*, **37**, 205 (1951).

(18) G. B. Bonino and G. Scaramelli, *Ber.*, **75**, 1948 (1942).

(19) For the implications of this, see ref. 13. We were also unable to observe any significant changes in the ultraviolet absorption maxima of I when run in 95% ethanol solutions containing up to one mole per l. of mineral acid.

This may also be responsible for the fact that II, in contrast to I and III, forms hydroxamic acids<sup>20</sup> and that the yields in condensations with active methylene compounds are generally higher under comparable conditions (*vide infra*). The failure of the Cannizzaro reaction may be due either to negligible attack by hydroxyl ion or inability of the postulated intermediate<sup>21</sup> to transfer a hydroxide ion to another molecule of II. On the other hand, the success of the "crossed" Cannizzaro reaction<sup>22</sup> indicates that the intermediate formed by attack of hydroxyl ion on formaldehyde can transfer a hydride ion to II.

2-Pyrrolealdehyde is reported<sup>23</sup> to undergo a normal aldol-type condensation with acetone, methyl ethyl ketone and acetophenone. This work was confirmed, although the properties of some of the products differed somewhat from those reported earlier. Analogously, *N*-methyl-2-pyrrolealdehyde gave well defined condensation products with these ketones. The compounds resulting from the reaction with methyl ethyl ketone apparently are formed from reaction at the methyl rather than the methylene group (negative iodoform test). On the other hand, just as I does not condense with acetaldehyde and crotonaldehyde,<sup>24</sup> II proved to be resistant to the carbanions prepared from these aldehydes.

Since 2-pyrrolealdehyde undergoes the modified Perkin condensation with hippuric acid,<sup>25</sup> rhodanine,<sup>25</sup> and hydantoin,<sup>26,27</sup> the behavior of *N*-methyl-2-pyrrolealdehyde toward these and related compounds was of interest. In addition, such condensation products were envisioned as possible intermediates in a projected synthesis of *N*-methyl- $\beta$ -2-pyrrolealanine, a substance which may be expected to be an antimetabolite.<sup>28</sup>

Condensation of II with hippuric acid gave 70–85% yields of the expected azlactone, only one geometrical isomer being produced. Direct hydrogenation of the azlactone could not be effected.<sup>30</sup> Therefore, recourse was had to alkaline hydrolysis which in this instance was not expected to be complicated by intramolecular condensations of the type

(20) A. Angeli and L. Alessandri, *Atti. accad. Lincei*, **23**, II, 93 (1914).

(21) J. Hine, *Physical Organic Chemistry*, McGraw-Hill Book Co., Inc., New York, 1956, pp. 259–261.

(22) E. E. Ryskiewicz and R. M. Silverstein, *J. Am. Chem. Soc.*, **76**, 5802 (1954).

(23) E. Lubrzynska, *J. Chem. Soc.*, 1118 (1916).

(24) M. Strell and F. Kreis, *Ber.*, **87**, 1011 (1954).

(25) W. Herz, *J. Am. Chem. Soc.*, **71**, 3982 (1949).

(26) K. Dittmer and W. Herz, **70**, 503 (1948).

(27) D. G. Harvey, *J. Chem. Soc.*, 1638 (1950).

(28) W. Herz, K. Dittmer, and S. J. Cristol, *J. Am. Chem. Soc.*, **70**, 504 (1948). Attempts to prepare this substance from the Mannich base<sup>29</sup> of *N*-methylpyrrole have not been successful (unpublished observations by J. L. Rogers).

(29) W. Herz and J. L. Rogers, *J. Am. Chem. Soc.*, **73**, 4021 (1951).

(30) See H. Fischer and H. S. Hofmann, *Z. Physiol. Chem.*, **245**, 139 (1936) for similar observations.

encountered earlier.<sup>25</sup> The resulting 2-benzamido-3-(*N*-methyl-2-pyrrole)acrylic acid was hydrogenated smoothly to give the *N*-benzoyl derivative of the desired amino acid. However, attempts to remove the benzoyl group did not yield a homogeneous compound. The crude fractions gave a positive ninhydrin test and inhibited the growth of *S. cerevisiae* (Fleischman's strain 139) at concentrations of 0.5 mg./ml. of medium but could not be freed of inorganic material, as has also been observed in the course of attempts to prepare  $\beta$ -2-pyrrolealanine.<sup>28,31</sup>

Condensation of II with rhodanine gave the expected product in 84% yield, but attempts to hydrolyze this to a stable thioketoacid failed. Results of condensations with acetyl glycine, hydantoin, diketopiperazine and creatinine are described in the Experimental section.

#### EXPERIMENTAL<sup>32</sup>

*2-Pyrrolalacetone and 2-dipyrrolalacetone.* The condensation of 2.8 g. of 2-pyrrolealdehyde<sup>33</sup> with 6 ml. of acetone in 100 ml. of water and 6 ml. of *N* potassium hydroxide solution furnished, after standing overnight, 2.0 g. (50%) of crude pyrrolalacetone, m.p. 102–104°, and 0.13 g. (4%) of dipyrrolalacetone, m.p. 178–180°. Recrystallization of the former from benzene gave orange crystals, m.p. 117–120° (lit.<sup>23</sup> 112–113°), soluble in acetone, hot chloroform, ethyl acetate, and benzene; insoluble in water, petroleum ether, and cold ethyl acetate. The infrared spectrum (CHCl<sub>3</sub>) had bands at 3450 and 3300 cm.<sup>-1</sup> (nonbonded and bonded —NH), 1660 (nonbonded conjugated carbonyl) and a very strong doublet at 1615 and 1600 cm.<sup>-1</sup> The dipyrrolal derivative was recrystallized from ethyl acetate, orange crystals, m.p. 187–188° (lit.<sup>23</sup> 185–186°). The infrared spectrum (nujol) had bands at 3350 and 3250 cm.<sup>-1</sup> (—NH), 1640 (conjugated C=O), 1620 (C=C?) and 1575 cm.<sup>-1</sup>

*1-(2-Pyrrole)-1-penten-3-one.* A mixture of 0.95 g. of 2-pyrrolealdehyde, 10 ml. of water, 5 ml. of ethanol, 3 ml. of *N* potassium hydroxide solution, and 9 ml. of methyl ethyl ketone was warmed on the steam bath for 10 min. After standing overnight, 30 ml. of water and 10 ml. of ethanol was added to effect solution of the liquid layer which had separated. On standing there separated 1.35 g. (90%) of yellow product, m.p. 94–96°, which was recrystallized from benzene, m.p. 121° (lit.<sup>23</sup> 98–99°), and gave a negative iodoform test. The infrared spectrum (CHCl<sub>3</sub>) had bands at 3455 and 3300 cm.<sup>-1</sup>, a very strong doublet at 1620 and 1600 cm.<sup>-1</sup> (shoulders 1670 and 1640 cm.<sup>-1</sup>) and a broad medium intensity band near 1550 cm.<sup>-1</sup>

*Anal.* Calcd. for C<sub>9</sub>H<sub>11</sub>NO: C, 72.45; H, 7.43; N, 9.38. Found: C, 72.40; H, 7.18; N, 9.05.

*2-Pyrrolalacetophenone.* In the same way, 0.9 g. of 2-pyrrolealdehyde and 3 ml. of acetophenone yielded 2.2 g. of crude yellow condensation product, m.p. 131–132°. Recrystallization from benzene and ethanol raised the m.p. to 133–134° (lit.<sup>23</sup> 138–139°). The infrared spectrum (CCl<sub>4</sub>) had bands at 3480, 3320 (—NH), 1650 (C=O, shoulder at 1665 cm.<sup>-1</sup>), and a very strong band centered at 1600 cm.<sup>-1</sup>

(31) H. Behringer and H. Taul, *Ber.*, **90**, 1398 (1957).

(32) M.p.'s and b.p.'s are uncorrected. Analyses by Drs. Weiler and Strauss, Oxford, England. Infrared spectra were run by Miss M. T. Esquivel on a Perkin-Elmer Model 21 double-beam recording spectrometer.

(33) R. M. Silverstein, E. E. Ryskiewicz, C. Willard and R. Koehler, *J. Org. Chem.*, **20**, 668 (1955).

*1,5-Di(N-methyl-2-pyrrole)-1,4-pentadien-3-one.* Condensation of 3.25 g. of II<sup>33</sup> with 6 ml. of acetone furnished 1.6 g. (45%) of yellow needles, m.p. 139–140°. Recrystallization from ethanol raised the m.p. to 141°. The iodoform test was negative. The analysis indicated that a dipyrrolal derivative had been formed. The monopyrrolal derivative could not be found. The infrared spectrum (CHCl<sub>3</sub>) exhibited a weak band at 1635, a strong band at 1605 and a medium intensity band at 1565 cm.<sup>-1</sup>

*Anal.* Calcd. for C<sub>15</sub>H<sub>16</sub>N<sub>2</sub>O: C, 74.97; H, 6.71; N, 11.7. Found: C, 74.73; H, 6.77; N, 11.6.

Reaction of this substance with dinitrophenylhydrazine yielded what appeared to be a hydrate or the product of 1,4-addition, m.p. 122–123° after recrystallization from methanol-water.

*Anal.* Calcd. for C<sub>21</sub>H<sub>22</sub>N<sub>6</sub>O<sub>5</sub>: C, 57.48; H, 5.06. Found: C, 57.79; H, 5.12.

*1-(N-methyl-2-pyrrole)-1-penten-3-one.* No crystals separated on mixing 2.2 g. of II with 18 ml. of methyl ethyl ketone in the usual manner and allowing to stand. The solution was diluted with water, thoroughly extracted with ether, and the ether layers were dried and distilled. After a small forerun, there was collected 1.42 g. of a yellow oil, b.p. 143–145° (8 mm.), which solidified on standing at 5°. The product melted at 29° and gave a negative iodoform test. The infrared spectrum (CHCl<sub>3</sub>) had bands at 160 cm.<sup>-1</sup> (C=O, shoulder at 1670) and a very strong doublet at 1605 and 1595 cm.<sup>-1</sup> (shoulders at 1565 and 1550 cm.<sup>-1</sup>).

*Anal.* Calcd. for C<sub>10</sub>H<sub>13</sub>NO: C, 73.59; H, 8.03; N, 8.58. Found: C, 73.42; H, 7.87; N, 8.70.

*1-(N-methyl-2-pyrrole)β-phenyl-1-propen-3-one.* Condensation of 1.7 g. of II with 1.8 g. of acetophenone in the usual fashion afforded 0.8 g. of product which was crystallized from ethanol, m.p. 85°. An additional 0.1 g. of product was deposited on standing from the mother liquors which consisted largely of acetophenone. The infrared spectrum (CHCl<sub>3</sub>) exhibited bands at 1645 (weak), 1613 (strong), and 1580 cm.<sup>-1</sup> (medium).

*Anal.* Calcd. for C<sub>14</sub>H<sub>13</sub>NO: C, 79.59; H, 6.20; N, 6.63. Found: C, 79.38; H, 6.38; N, 6.45.

*2-Phenyl-4-(N-methyl-2-pyrrolal)-5-oxazolone.* A mixture of 2.2 g. of II, 3.6 g. of hippuric acid, 3.6 g. of anhydrous sodium acetate and 9 ml. of water was heated on the steam bath for one hour, cooled, and diluted with water. The solid was filtered and washed thoroughly with cold water, yield of crude product 4.0 g. (87%). Recrystallization from ethanol furnished yellow woolly needles, m.p. 185°, whose infrared spectrum exhibited bands at 1770 (lactone, broad), 1655 (C=N), 1608 (weak), 1592 (weak), and 1565 cm.<sup>-1</sup> (weak).<sup>34</sup>

*Anal.* Calcd. for C<sub>15</sub>H<sub>12</sub>N<sub>2</sub>O<sub>2</sub>: C, 71.36; H, 4.80; N, 11.2. Found: C, 71.15; H, 4.70; N, 11.2.

*2-Benzamido-3-(N-methyl-2-pyrrole)acrylic acid.* A mixture of 1.5 g. of the azlactone, 40 ml. of water, 160 ml. of methanol, and 4 g. of sodium hydroxide was heated on the steam-bath for 3 hr., cooled, and acidified. Recrystallization from ethanol furnished 1.3 g. of the acid, m.p. 224°, infrared bands (CHCl<sub>3</sub>) at 3475 (amide—NH), 3050 (carboxyl—OH), 1720 (medium), 1660 (amide), 1605, and 1582 cm.<sup>-1</sup> (probably phenyl).

*Anal.* Calcd. for C<sub>15</sub>H<sub>14</sub>N<sub>2</sub>O<sub>3</sub>: C, 66.65; H, 5.22; N, 10.4. Found: C, 65.96; H, 5.23; N, 10.3.

Hydrolysis of the azlactone with methanolic potassium carbonate on the steambath furnished 3.5 g. (52%) of the methyl ester, m.p. 185–186° after recrystallization from ethyl acetate, infrared bands at 3425 (amide—NH), 1710 (conjugated ester), 1670 (amide), and 1635 cm.<sup>-1</sup> (C=C).

*Anal.* Calcd. for C<sub>16</sub>H<sub>16</sub>N<sub>2</sub>O<sub>3</sub>: C, 67.59; H, 5.67; N, 9.85. Found: C, 67.77; H, 5.33; N, 9.85.

The mother liquors of the methanol-potassium carbonate hydrolysis were concentrated to dryness. The residue was dissolved in water and acidified with dilute acid. The pre-

cipitate was recrystallized from ethanol-water, yield 1.65 g. (29%) of the acrylic acid.

*2-Benzamido-3-(N-methyl-2-pyrrole)propionic acid.* A solution of 2.0 g. of the acrylic acid in 150 ml. of ethyl acetate was reduced at 3–4 atmospheres (catalyst 10% palladium-on-charcoal) until the hydrogen uptake ceased. The solvent was removed at reduced pressure and the residue crystallized first from benzene-ligroin, then reprecipitated from sodium bicarbonate solution. There was obtained 0.57 g. of colorless crystals, m.p. 153–154°, and 0.9 g., m.p. 150–151°, total yield 75%. The infrared spectrum (CHCl<sub>3</sub>) had bands at 3425 (NH), broad carboxyl OH, 1730 (acid), 1660 (amide), and 1605 and 1582 cm.<sup>-1</sup> (phenyl).

*Anal.* Calcd. for C<sub>16</sub>H<sub>16</sub>N<sub>2</sub>O<sub>3</sub>: C, 66.13; H, 5.90; N, 10.3. Found: C, 65.86; H, 5.79; N, 10.2.

Reduction of the methyl ester furnished methyl 2-benzamido-3-(N-methyl-2-pyrrole)propionate, m.p. 117–118° from benzene-ligroin, infrared bands at 3420 (NH), 1738 (ester), 1660 (amide), and 1605 and 1582 cm.<sup>-1</sup> (phenyl).

*Anal.* Calcd. for C<sub>16</sub>H<sub>18</sub>N<sub>2</sub>O<sub>3</sub>: C, 67.11; H, 6.34; N, 9.78. Found: C, 67.76; H, 6.57; N, 9.35.

*Condensation of II with rhodanine.* A mixture of 1.0 g. of II, 1.3 g. of rhodanine, 1 g. of anhydrous sodium acetate and 5 ml. of acetic acid was refluxed for 20 min., cooled, and diluted with water. The crude product, wt. 1.78 (84%), was thoroughly washed with water. Recrystallization from ethanol afforded 1.52 g. of red-brown crystals, m.p. 158–159°. The infrared spectrum had bands at 3350 (NH), 1700 (strong), and 1592 cm.<sup>-1</sup> (very strong).

*Anal.* Calcd. for C<sub>9</sub>H<sub>8</sub>N<sub>2</sub>O<sub>2</sub>S<sub>2</sub>: C, 48.19; H, 3.59; N, 12.5. Found: C, 48.03; H, 3.82; N, 12.7.

Hydrolysis of this substance with barium hydroxide did not furnish tractable material from the acid fraction.

*Condensation of II with hydantoin.* A mixture of 2.2 g. of II, 2.4 g. of hydantoin, 2 ml. of anhydrous pyridine, 1 ml. of piperidine, and 40 ml. of absolute ethanol was refluxed for 0.5 hr. On standing at 5° overnight there precipitated 2.9 g. (96%) of yellow product. Recrystallization from ethanol-water-pyridine gave crystals, m.p. 234–235° (shrinks at 231°). The substance was insoluble in chloroform and carbon tetrachloride, infrared bands (nujol) at 3200 (bonded NH), 1745, 1700, and 1645 cm.<sup>-1</sup>

*Anal.* Calcd. for C<sub>9</sub>H<sub>9</sub>N<sub>3</sub>O<sub>2</sub>: C, 56.54; H, 4.75; N, 22.0. Found: C, 56.91; H, 4.82; N, 21.8.

Attempts to condense II with acetylglycine gave a 55% recovery of II and no condensation product. Attempts to condense II with diketopiperazine and creatinine resulted in recovery of small amounts of II and intractable material. Other condensations or tests which failed are referred to in the Discussion section.

Attempts to condense II with HCN or to subject it to the Cannizzaro, benzoin, or Perkin condensation were carried out under standard conditions described in Organic Syntheses. It was recovered in yields of 60–95%. Attempted condensations with malonic acid were carried out in the presence of various bases<sup>35</sup> without evidence of reaction. In the presence of α-picoline as a solvent and catalyst, there was a 65% recovery of II and no condensation product could be isolated. The reaction with nitromethane was carried out under conditions which were successful with 2-methoxy-5-thienylaldehyde;<sup>36</sup> the only solid which could be isolated was the sodium salt of nitromethane.

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(35) Ref. 3, p. 240.

(36) W. Herz and L. Tsai, *J. Am. Chem. Soc.*, **77**, 3529 (1955).

(34) For comparison with other azlactones, see F. Micheel and B. Schlepplinghoff, *Ber.*, **88**, 763 (1955).