The electron density at the carbon to nitrogen bond decreases in the order given and so does the yield of methyl esters decrease in the same order. In the formation of the methyl esters from the same acids the yields seem to increase with decrease in electron density.

Sudborough and Lloyd[5] performed a series of experiments (acid and alcohol) similar to the first series mentioned except that ethyl alcohol was used in place of methyl alcohol; they found the opposite order of yield of ester. By repeating a few similar experiments with ethyl alcohol we were able to confirm their work. They used their data to correlate steric hindrance. Their conclusion was that steric hindrance played the most important part in controlling the yield of ester. If steric hindrance plays such an important part then phenylacetic and monochloroacetic acids should give about the same yield of ester since they occupy about the same space. Likewise, phenylacetamide and chloroacetamide should give practically the same yield of ester. The results in the present study far from confirm this point of view; they differ by 13% in the latter case and 20% in the former case.

It might be stated that the quantity of ester formed is more or less independent of the degree of ionization of the acid. It might also be stated that steric hindrance apparently plays only a minor part in the esterification of the substituted acetic

acid derivatives considered in this study. A more important factor, which might be considered a division of steric hindrance, is the inductive effects of the substituent or, in other words, the electron density at the carbonyl carbon atom.

The esterifying agent did not change the order of yields of esters of methyl alcohol, while ethyl alcohol gave the reverse order of yields of the esters studied.

Summary

A study was made of the reaction between acids and alcohols and between amides and alcohols using boron fluoride as the esterifying agent. The same esterifications were also carried out in the presence of hydrochloric acid and sulfuric acid and without an esterifying agent.

The order of increasing yields of methyl esters from acids was propionic, acetic, chloroacetic, dichloroacetic, trichloroacetic, and phenylacetic acids. This order was reversed when the corresponding amides were used and also when ethyl alcohol reacted with the acids. The esterifying agent did not change the order of yield of methyl esters.

There seems to be no direct relationship between the ionization constant and the quantity of ester formed.

The spacial requirement of a substituent in acetic acid is less important than the inductive effect of the substituent upon the yield of ester.

(5) Sudborough and Lloyd, *J. Chem. Soc.*, **75**, 467 (1899).

Studies in the Pyrrole Series. III. The Relation of Tripyrrylmethane Cleavage to Methene Synthesis[1,2]

BY ALSOPH H. CORWIN AND JOHN S. ANDREWS[3]

Our previous studies of the mechanism of the aldehyde synthesis of dipyrrylmethenes[4] have shown that definite structures can no longer be assigned to methenes on the basis of the simple carbinol mechanism. The possibility of the presence of a tripyrrylmethane intermediate led to the prediction that mixtures of three methenes may result.

More recently Metzger and Fischer[5] have announced an aldehyde synthesis which gives the mixture of three methenes predicted by our tripyrrylmethane mechanism. They prefer to disregard the significance of our predictions, however, and to explain their results by returning to the old mechanism of Fischer and Ernst.[6a]

We are now extending our studies to the synthesis of an unsymmetrical dipyrrylmethene (IV, Chart I) which does not owe its lack of symmetry to the presence of an N-methyl group. This re-

(1) The major portion of this paper is from the doctoral dissertation of John S. Andrews, The Johns Hopkins University, 1935.

(2) Presented at the Pittsburgh meeting of the American Chemical Society, September, 1936.

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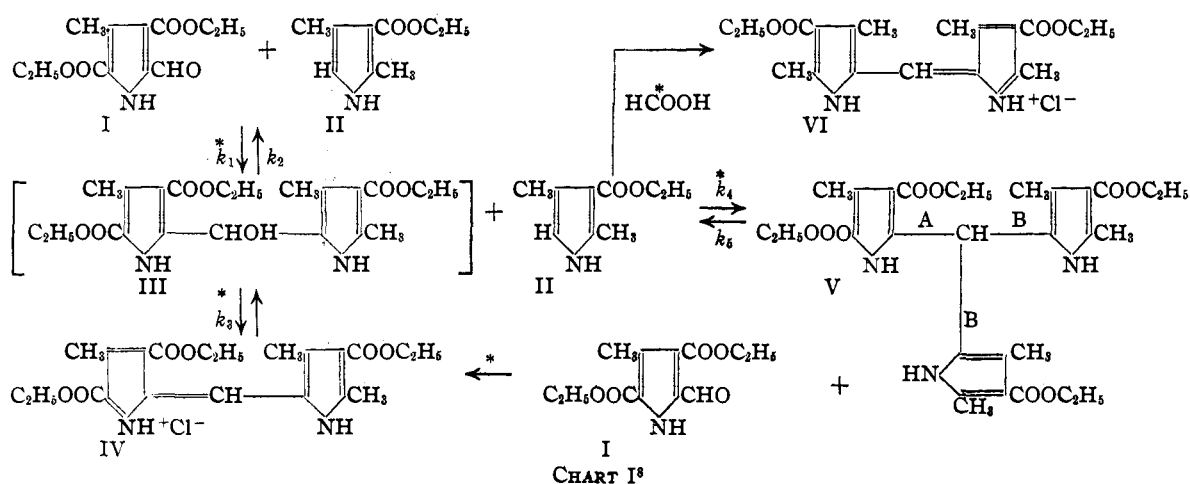(4) Corwin and Andrews, THIS JOURNAL, **58**, 1087 (1936).

(5) Metzger and Fischer, *Ann.*, **327**, 1 (1936).

(6) Fischer and Ernst, (a) *ibid.*, **447**, 146 (1926): (b) *ibid.*, **139**; (c) *ibid.*, **141**.

action is of particular interest because the corresponding tripyrrylmethane (V) has been prepared by Fischer and Ernst[6c] and found to be entirely stable to the cleavage which our mechanism requires. We now find not only that the stability of this substance is an illusion but also that, under certain conditions, the synthesis of methene IV can proceed through a reaction involving this tripyrrylmethane as an intermediate. Under other conditions the tripyrrylmethane may occur as a by-product and it was the impurity observed by Corwin and Quattlebaum[7] in their first preparation of methene IV. Chart I presents the reactions which led to our conclusions.

ture of tripyrrylmethane V and aldehyde I, when treated with hydrogen chloride, gives a high yield of methene IV, which must result from cleavage at bond B.

Whether or not the tripyrrylmethane is actually an intermediate depends on the relative magnitudes of k_1 and k_4. If $k_1 > k_4$, the pyrryl aldehyde I will remove pyrrole II from the solution faster than the tripyrrylmethane can form. These velocity relationships define one set of conditions under which a tripyrrylmethane will not be an intermediate in the methene synthesis. If, on the other hand, $k_4 > k_1$, tripyrrylmethane formation will remove the pyrrole, and cleavage by

CHART I[8]

When equimolecular quantities of aldehyde I and pyrrole II are employed, methene IV is obtained in high yield. When twice the amount of pyrrole II is used, tripyrrylmethane V is produced, practically quantitatively. When treated with hydrogen chloride this compound undergoes no apparent reaction but when formic acid is added to the reaction mixture methene VI is obtained in an amount equivalent to that formed from one-half mole of pyrrole II. We interpret this as indicating cleavage at bond B.

The formation of tripyrrylmethane by reaction 4 shows that $k_4 > k_3$.[9] Knowing that $k_4 > k_3$, the high yields of methene IV obtained from the equimolar condensation would be paradoxical unless aldehyde I, like formic acid, were a reagent for the cleavage of tripyrrylmethane V. Experiment shows that it is such a reagent. The mix-

the excess aldehyde will follow. Our current data do not permit a decision between these possibilities.

Many tripyrrylmethanes are readily cleaved by acid and the contrasting behavior exhibited by methane V led Fischer and Ernst[6b] and later Fischer, Doyle and Gleim[10] to certain assumptions relating negative substituents to the relative ease of dipyrrylmethene and tripyrrylmethane formation. These authors offer an explanation which is essentially thermodynamic, saying that negative groups decrease the tendency of the pyrrole ring to transition into the pyrrolenine form. However, they offer no experimental measure of this tendency. The experiments cited above indicate that the decisive factors tending to change the course of the reactions are kinetic rather than thermodynamic and involve reaction velocities rather than free energies. These studies have brought to light the fallacy in the assumption that negative groups in a single pyrrole ring can

(7) Corwin and Quattlebaum, THIS JOURNAL, **58**, 1084 (1936).

(8) The arrows which are starred indicate reactions which we have performed. The bracketed compounds are those which were not isolated in the reactions indicated.

(9) The notation $k_a > k_b$ should be interpreted as indicating that the velocity constant k_a is many times as large as the constant k_b.

(10) Fischer, Doyle and Gleim, Ann., **525**, 28 (1936).

stabilize all three pyrryl-methyl bonds in the tripyrrylmethane V.

Direct evidence with regard to the velocities of these competing reactions could be secured from the postulated carbinols. Our attempts to prepare these have not been successful[11] but we have succeeded in isolating the methyl and ethyl ethers of carbinol III, using a modification of the method of Baeyer and Villiger.[12] The reactions of these ethers given in Chart II, follow exactly those assumed for the free carbinols.

that the tripyrrylmethane cannot be an intermediate in the formation of methene IV in this reaction. Taken together, these facts demonstrate that $k_6 > k_8$. But since $k_7 > k_6$, we conclude that $k_7 > k_8$, or in other words that the N-methyl group hinders the condensation to a tripyrrylmethane.

This observation concerning the effect of an N-methyl group is significant in that it bears on the conclusions of Fischer and Heyse[13] with respect to the exclusive cleavage of unsymmetrical tri-
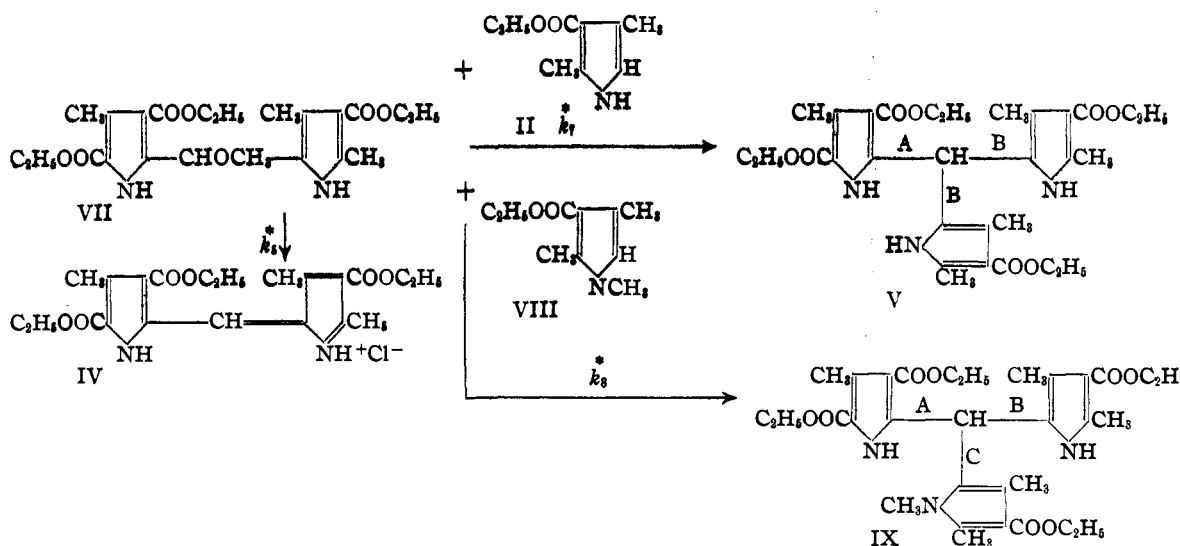

CHART II[8]

In the presence of acid methene IV is formed rapidly from the carbinol ether VII but when pyrrole II is also present condensation to the tripyrrylmethane takes place and no methene is formed. Thus, $k_7 > k_6$, a close analogy to the conclusion that $k_4 > k_3$.

It was observed, however, that substitution of the pyrrole by its N-methyl homolog (VIII) gave an entirely different result. Here methene formation is predominant. The tripyrrylmethane IX was prepared by the fusion method, however, and is the first completely unsymmetrical tripyrrylmethane to be reported. Considerations given below led us to predict that acid would cleave it to methene IV and pyrrole VIII. Experiment fully justified this prediction. The cleavage of tripyrrylmethane IX to methene IV proceeds much less rapidly than the formation of methene IV from carbinol ether VII in the presence of the N-methylpyrrole VIII, showing

pyrrylmethanes at a single point. The isolation of a single pair of reaction products can be explained equally well by assuming that cleavage occurs at all possible points, as was proved in the case of the di-N-methyltripyrrylmethane,[4] and that rates of subsequent competitive reactions account for the apparent course of the total reaction. An example of this reasoning is given in Chart III.

In the cleavage of the mono-N-methyltripyrrylmethane X, an explanation of the type advanced by Fischer and Heyse would involve the simplest assumptions, namely, that $k_9 > 0$ and that $k_{12} = 0$, since the methene VI and the N-methyl pyrrole VIII are the sole products and are isolated in quantitative yield. The alternative assumptions which are capable of explaining these experimental facts are that $k_9 > 0$, $k_{12} > 0$, $k_{11} > k_{10}$, and $k_{13} > k_{14}$. The assumptions are entirely in accord with the analogies given above and with the observations reported for the corre-

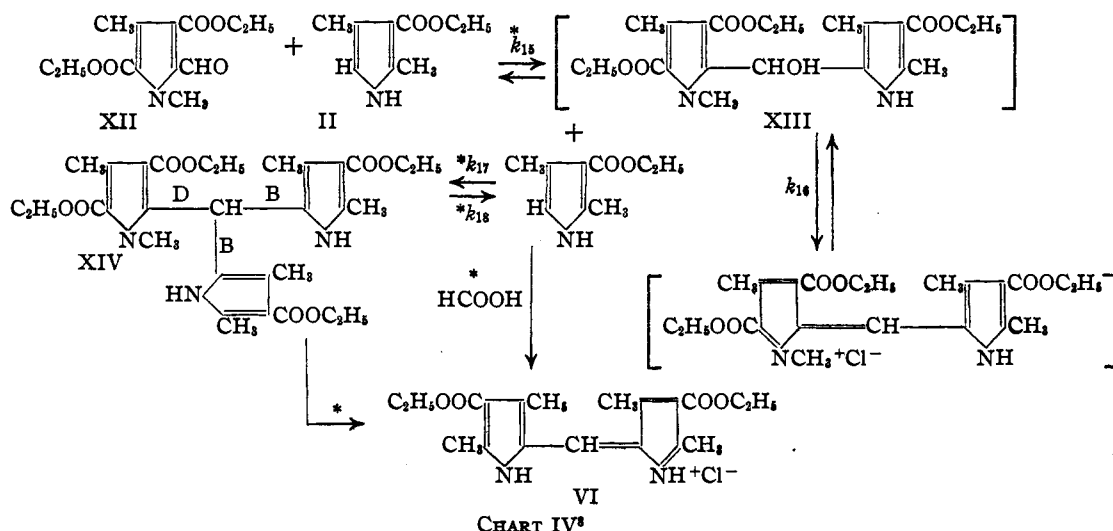(11) Compare Fischer and Fries, Z. physiol. Chem., 231, 244 and 248 (1925).

(12) Baeyer and Villiger, Ber., 37, 2873 (1904).

(13) Fischer and Heyse, Ann., 439, 240 (1924).

CHART III[8]

CHART IV[8]
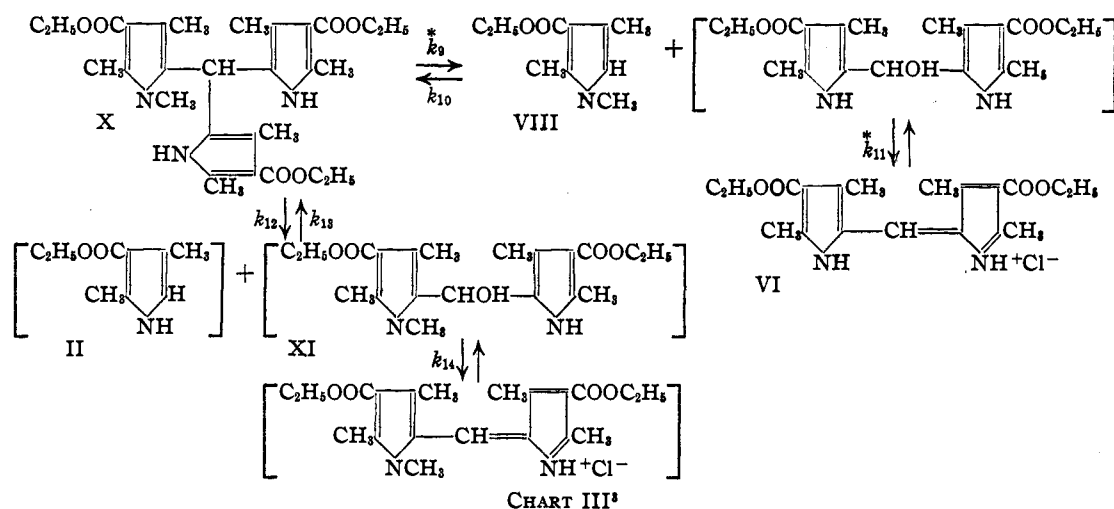
sponding di-N-methyltripyrrylmethane,[4] cleavage of which gave a methene unpredictable on the basis of the assumptions of Fischer and Heyse. These are the considerations which led us to predict that tripyrrylmethane IX would appear to cleave exclusively at bond C.

In order to combine the influences of the "negative" and N-methyl groups a second methene synthesis has also been studied. Chart IV presents the several reactions which must be considered.

small amounts of Piloty's methene (VI), demonstrating the profound influence of the N-methyl substituent. Less drastic conditions gave tripyrrylmethane XIV in good yield. When subjected to acid cleavage this methane gave low yields of Piloty's methene, suggesting slow cleavage at bond D. In contrast to this, when formic acid was added to the mixture, the methene was formed rapidly and in good yield for one-half mole of pyrrole II, which we interpret as indicating rapid cleavage at bond B. It seems probable that

In view of the results of the previous synthesis (Chart I) it was expected that the primary objective of our studies, the synthesis of an unsymmetrical N-methylmethene, would be accomplished, since in the absence of the N-methyl group methene formation takes place readily. Drastic condensation, however, yielded only

this cleavage actually gives an N-methylmethene but its isolation has not yet been accomplished.

To decide upon the effect of the N-methyl group in this cleavage it will be necessary to know the exact course of the cleavage of the lower homolog, tripyrrylmethane V. If it is true that no cleavage takes place at bond A (Chart), I

a new effect of the N-methyl group will develop, namely, the weakening of a pyrryl–methyl bond. If, however, cleavage does take place at bond A, the only effect of the N-methyl group will be that already noted of hindering the back condensation.

In many of these condensations it has been noted that still other side reactions complicate the results. This is strikingly illustrated by the condensation of the aldehyde I with the N-methyl pyrrole VII. The condensation in acid led to a variety of colorless substances which have been characterized but not identified. In an effort to identify the tripyrrylmethane the Feist fusion method was used. This led to a mixture of substances. It is thought that the study of these various compounds may furnish the clues to the other reactions which sometimes complicate the aldehyde synthesis of dipyrrylmethenes.

When the N-methyl aldehyde XII was condensed with the N-methyl pyrrole VII by either the Feist fusion method or by our method using hydrogen chloride the tripyrrylmethane was formed. We have not yet been able to devise a method for demonstrating cleavages of this compound.

Experimental Part

Isolation of 3,5,4'-Tricarbethoxy-4,3',5'-trimethyl-2,2'-dipyrrylmethene Hydrochloride (IV) and 3,5,4',4"-Tetracarbethoxy-4,3',5',3",5"-pentamethyltripyrrylmethane (V) from the Same Reaction Mixture.—One gram of 2-formyl-3,5-dicarbethoxy-4-methylpyrrole and 0.66 g. of 2,4-dimethyl-3-carbethoxy-pyrrole were dissolved in 250 cc. of hot hexane. Dry hydrogen chloride gas was introduced for fifteen to twenty seconds. An initially appearing precipitate gave way to a red crystalline deposit of the methene hydrochloride. Filtration and washing with dry ether yielded 1.35 g. or 78% of the methene salt. The filtrate was evaporated in a current of air and the resulting tarry residue dissolved in 15 cc. of methanol. Crystallization was induced by chilling in dry ice–alcohol. Without filtering, the solution was poured into water and allowed to stand for several hours. Filtration yielded 0.25 g. of crude, pink tripyrrylmethane, or 11% based upon the aldehyde used: recrystallized from alcohol–water, m. p. 194°; no depression of mixed m. p. with methane prepared by the Feist fusion method. NOTE: The success of this experiment depends upon having the relation between temperature and speed of addition of hydrogen chloride such that the first addition of hydrogen chloride precipitates some aldehyde as noted. The proportion of tripyrrylmethane may be increased by decreasing the amount of aldehyde.

Free Base of Methene IV.—The methene salt was ground to a paste with water in a mortar. An excess of 10% ammonia solution was added dropwise and grinding

was continued until the contact was intimate. The base was filtered off, washed with water and dried. The base is not stable in alcohol or solvents containing water but it may be crystallized from a small amount of benzene or carbon tetrachloride or from a large amount of hexane. Like Piloty's methene, this material does not melt reversibly[4,14] but melts with decomposition at 137°.

Anal. Calcd. for $C_{21}H_{26}O_6N_2$: C, 62.67; H, 6.51. Found: C, 62.63; H, 6.53.

Copper Complex of Methene IV.—The methene free base was dissolved in an excess of carbon tetrachloride with gentle warming. An ammoniacal solution of copper acetate was boiled until cupric oxide began to precipitate and then added to the methene solution. The solutions were shaken vigorously overnight, separated and the crude complex obtained by evaporating the carbon tetrachloride in an air stream. The unreacted base could not be removed by repeated recrystallizations from hexane. For the purification, advantage was taken of the fact that the methene is unstable in aqueous solutions while the copper complex is stable. The crude crystals were dissolved in boiling alcohol and water was added dropwise until the complex precipitated. After cooling, the crystals were filtered off, dried and recrystallized from hexane.

Anal. Calcd. for $C_{42}H_{50}O_{12}N_4Cu$: C, 58.22; H, 5.82. Found: C, 58.28; H, 5.78.

Identification of Methene IV.—Since the melting point method is not satisfactory for purposes of comparison, an attempt was made to characterize this substance by hydrogenation to the corresponding methane, as was done with Piloty's methene. One gram of the methene salt was dissolved in 25 cc. of methanol and shaken with Adams catalyst and hydrogen for an hour. The colorless precipitate was filtered off, separated from admixed catalyst by dissolving in hot alcohol and filtering and allowed to crystallize; yield 0.4 g., m. p. 245–246°. The original filtrate from the reduction was evaporated to dryness in a vacuum, the residue extracted with petroleum ether, washed with ether and crystallized from alcohol–water; yield 0.15 g., m. p. 157–158°. Mixed m. p. with 3,5,4'-tricarbethoxy-4,3',5'-trimethyldipyrrylmethane prepared by the method of Fischer and Halbig[15] showed a depression. To avoid the decomposing action of methanol, a reduction was attempted in purified hexane. This was not successful. Addition of a few drops of methanol, however, caused the reduction to take place rapidly and the same two compounds were isolated. The nature of these compounds will be the subject of further study.

A satisfactory method for the identification of methene IV was finally achieved by means of its crystallographic properties. The refractive indices were determined by the Becke method and by oblique illumination. The immersion liquids used were water, ethylene glycol, glycerol, solutions of KI and $KHgI_3$ in glycerol and various mixtures of these. White light was used. The values obtained were: N_α, 1.445; N_β, 1.545; $N_\gamma > 1.698$. Dispersion was observable in sections perpendicular to or slightly oblique to an optic axis. Red is greater than violet. Pleochroism: α, bright yellow; β, orange; γ,

(14) Fischer and Heidelmann, *Ann.*, **527**, 115 (1937).

(15) Fischer and Halbig, *ibid.*, **447**, 132 (1926).

red. Habit: lath-like crystals, up to 1 cm. long, tabular on a side giving an optical section perpendicular or slightly oblique to an optic axis. Comparison of pleochroism and indices was used for the identification of the samples obtained by the cleavages cited below. Occasional samples were obtained which had another methene as an impurity but this was not Piloty's methene. This phenomenon will be subjected to further investigation. The authors are indebted to Dr. J. D. H. Donnay of the Department of Geology for suggesting this means of identification and for his collaboration in the work, and to Mr. W. J. Kirkpatrick for making the measurements cited above.

Preparation of Tripyrrylmethane V. (a) **By Fusion.**[6c]—Two grams of 2-formyl-3,5-dicarbethoxy-4-methylpyrrole and 2.7 g. of 2,4-dimethyl-3-carbethoxypyrrole were ground together in a mortar and then heated for ten minutes in a Pyrex tube at 190–200°. The crude methane was recrystallized from 30 cc. of toluene. The crystals were filtered off, washed with hexane and ether and recrystallized from alcohol–water; m. p. 194°; yield 83%.

(b) **By Acid Condensation.**—One gram of the aldehyde and 1.35 g. of the α-free pyrrole were dissolved in 250 cc. of hot hexane and hydrogen chloride gas bubbled in for fifteen seconds. A red oily mass was deposited. The solution was decanted and cooled. The resultant precipitate was filtered off, dissolved in hot toluene, decolorized with carbon and precipitated with hexane. The red mass from the reaction mixture was dissolved in methanol and then poured into ice water. The precipitate was filtered off, washed with ether and dried. Recrystallization of each of these fractions from alcohol–water gave products melting at 194°. No depression with tripyrrylmethane obtained by fusion, yield 78%.

Cleavages of Tripyrrylmethane V. (a) **With Formic Acid.**—Two-tenths gram of the tripyrrylmethane and 1 cc. of anhydrous formic acid were dissolved in 5 cc. of dry ether, chilled in ice and saturated with dry hydrogen chloride. The solution reddened slowly. It was allowed to stand at room temperature overnight. Long needles of Piloty's methene (VI) were deposited; yield 0.05 g. or 80%. Reduced in methanol with hydrogen and Adams catalyst to give colorless dipyrrylmethane, m. p. 230°; no depression with methane obtained by reduction of Piloty's methene.

In the foregoing experiment a separation from methene IV, which should precipitate at the same time in the cleavage, is obtained by taking advantage of the ready decomposition of this substance.[7] This was demonstrated by adding methene equivalent to that formed in the reaction (0.15 g.) to the same amount of formic acid and ether and saturating with hydrogen chloride. Although originally insoluble, solution was complete in ten to fifteen minutes. When the formic acid was omitted the process of solution took about one day.

As a control experiment, Piloty's methene was prepared from 2,4-dimethyl-3-carbethoxypyrrole under the same conditions: 0.1 g. of the pyrrole, 1 cc. of anhydrous formic acid and 5 cc. of dry ether were mixed, chilled and saturated with dry hydrogen chloride. After ten to fifteen minutes long needles of the methene began to separate. These were allowed to stand overnight at room temperature, filtered off and washed; yield 0.092 g. or 80%.

(b) **With 2-Formyl-3,5-dicarbethoxy-4-methylpyrrole, I.**—One-tenth gram of tripyrrylmethane V and 0.045 g. of aldehyde I were dissolved in 10 cc. of dry ether. The solution was chilled in ice and saturated with dry hydrogen chloride. Precipitation of orange-yellow needles of methene IV occurred very rapidly. The solution was allowed to stand in ice for one hour and then centrifuged; yield, 0.125 g. or 81%. Identified by conversion into base and crystallographic comparison with methene IV base as described above.

3,5,4'-Tricarbethoxy-4,3',5'-trimethyldipyrrylcarbinolmethylether, VII.—Fifty cc. of 2% potassium hydroxide solution was poured on 50 g. of ice. Then 0.5 g. of potassium hydroxide was dissolved in 25 cc. of anhydrous methanol and 1 g. of the salt of methene IV (or an equivalent quantity of the free base) dissolved as quickly as possible without heating. After one minute the alcoholic solution was poured into the ice–potassium hydroxide solution to precipitate the crude carbinol ether. The gummy mass was centrifuged and the alkali decanted. The mass was kneaded with hexane and distilled water repeatedly until the colored tar had all been removed. The residue was then extracted with wet, boiling hexane and the solution was decanted and allowed to crystallize in an ice-box. One recrystallization yielded a colorless product. This substance was first obtained in crystalline form by Mr. William A. Bailey, Jr.

Anal. Calcd. for $C_{22}H_{30}O_7N_2$: C, 60.81; H, 6.96. Found: C, 60.89, 60.76; H, 7.01, 7.02.

Carbinol Ethyl Ether.—The preparation was identical with that given above except for the substitution of anhydrous ethanol for methanol.

Anal. Calcd. for $C_{23}H_{32}O_7N_2$: C, 61.59; H, 7.10. Found: C, 61.57; H, 7.29.

Reactions of the Carbinol Methyl Ether, VII. (a) **With Hydrogen Chloride.**—One-tenth gram of the carbinol methyl ether was dissolved in hexane and dry hydrogen chloride gas introduced for a few seconds. An immediate precipitation of methene IV occurred. This precipitate showed no tendency to dissolve upon the addition of excess hydrogen chloride. Filtration and washing with dry ether yielded 0.09 g. of this substance.

(b) **With Hydrogen Chloride and 2,4-Dimethyl-3-carbethoxypyrrole.**—One gram of the carbinol ether and 0.4 g. of the α-free pyrrole were dissolved in hexane. Dry hydrogen chloride gas was added and a colorless solid precipitated immediately. This rapidly changed to a tarry material which adhered to the walls of the vessel. The solution was decanted and the tar dissolved in 5 cc. of ether. Upon scratching a granular precipitate formed. This was filtered off, washed with ether and recrystallized from alcohol–water, m. p. 194°; no depression with tripyrrylmethane V, yield 89%.

(c) **With Hydrogen Chloride and 1,2,4-Trimethyl-3-carbethoxypyrrole.**—Following the procedure outlined above but substituting the N-methyl α-free pyrrole, no tripyrrylmethane was obtained. Methene IV was isolated instead. Precipitation was as rapid as in (a).

(d) **With Hydrogen.**—One gram of the carbinol methyl ether was dissolved in 50 cc. of methanol, Adams catalyst added and the mixture shaken for eighteen hours with hydrogen at a pressure of two atmospheres. No hydrogen

was absorbed. Filtration and evaporation of the solvent yielded a yellow oil which, when dissolved in ether and treated with gaseous hydrogen chloride, gave a precipitate of methene IV.

3, 5, 4′, 4″ - Tetracarbethoxy - 4, 3′, 5′, 1″, 3″, 5″ - hexamethyltripyrrylmethane, IX.—Two-tenths gram of the carbinol ether VII and 0.08 g. of 1,2,4-trimethyl-3-carbethoxypyrrole were ground together, placed in a testtube, immersed in an oil-bath and the latter heated rapidly to 145–50°. The mixture melted at 110° and bubbled slowly. After five minutes at 150° bubbling ceased and then a pinch of finely ground potassium bisulfate was added, causing rapid bubbling. The liquid congealed and the bath was then allowed to cool to 100°, the fusion mass dissolved in 2–3 cc. of toluene and crystallized; 5–10 cc. of hexane was added, the crystals filtered off, washed with hexane and recrystallized from methanol–water. Alternate warming and scratching was necessary to obtain crystals; yield, 0.25 g. or 93% of the recrystallized product. For analysis, it was recrystallized three times.

Anal. Calcd. for $C_{31}H_{41}O_8N_3$: C, 63.79; H, 7.08. Found: C, 63.69; H, 7.07.

Cleavage of Tripyrrylmethane, IX.—One-tenth gram of the tripyrrylmethane was suspended in 5 cc. of dry ether, chilled in an ice-bath and saturated with dry hydrogen chloride. A red color developed slowly and after two hours at 0–5° the solution was thick with a precipitate of fine yellow needles of methene IV. These were centrifuged off and the mother liquor decanted. Upon standing for an hour the mother liquor deposited an additional crop of crystals which was combined with the first crop and the whole was washed with ether; yield, 0.035 g. or 48%. The salt was converted into free base and identified crystallographically. The residue from the evaporation of the mother liquor had the characteristic odor of 1,2,4-trimethyl-3-carbethoxypyrrole but impurities prevented its isolation.

3, 5, 4′, 4″ - Tetracarbethoxy - 1, 4, 3′, 5′, 3″, 5″ - hexa - methyltripyrrylmethane, XIV. (a) By Fusion.—One gram of 1,4-dimethyl-2-formyl-3,5-carbethoxypyrrole and 1.25 g. of 2,4-dimethyl-3-carbethoxypyrrole were ground together and heated at 190–200° for ten minutes. When cool the mass was extracted with hot hexane and the residue dissolved in hot methanol and chilled in dry ice-alcohol. After crystallization had begun an equal volume of water was added to complete the precipitation. The crystals were filtered off, dissolved in hot toluene, decolorized with carbon and precipitated with two volumes of hexane; m. p. of precipitate, 158–159°. The material was recrystallized from alcohol–water and then extracted rapidly with boiling ethanol. The residue from the ethanol extraction is a by-product which chars without melting at 240–250° and which will be subjected to further investigation. The alcohol extract was fractionally crystallized to remove more of this product. The crystals were tripyrrylmethane melting sharply at 169°. The yield of crude material was 55%.

Anal. Calcd. for $C_{31}H_{41}O_8N_3$: C, 63.79; H, 7.08. Found: C, 63.90, 63.95; H, 7.21, 7.23.

(b) With Hydrogen Chloride.—One gram of the N-methyl aldehyde and 1.25 g. of the α-free pyrrole were dissolved in 50 cc. of hexane and dry hydrogen chloride gas

introduced for ten to fifteen seconds. The cloudy solution was decanted from a small amount of oily material and then cooled by partial evaporation in a stream of air. Filtration yielded 2.15 g. (98%) of the tripyrrylmethane as a red solid. This was recrystallized slowly from alcohol–water to yield a colorless, beautifully crystalline compound: m. p. 169–70°; mixed m. p. with the product from the fusion, no depression. No by-product was obtained.

Cleavages of Tripyrrylmethane, XIV. (a) With Hydrogen Chloride Alone.—One and four-tenths grams of the tripyrrylmethane was dissolved in 425 cc. of dry ether and the solution saturated at 5–10° with hydrogen chloride gas. After standing overnight long red needles of Piloty's methene hydrochloride melting at 215° with decomposition were deposited; yield 0.22 g. or 24%; identified in the usual manner by reduction.

(b) With Hydrogen Chloride and Formic Acid.—One-tenth gram of the tripyrrylmethane and 0.5 cc. of formic acid were dissolved in 5 cc. of dry ether and the solution was chilled and saturated with hydrogen chloride. Crystals of Piloty's methene slowly separated. The solution was allowed to stand overnight and then filtered; yield 0.042 g. or 82%; identified as Piloty's methene by reduction.

Condensations of 2-Formyl-3,5-dicarbethoxy-4-methylpyrrole and 1,2,4-Trimethyl-3-carbethoxypyrrole. (a) With Hydrogen Chloride.—One and one-tenth grams of the N-methyl α-free pyrrole and 1.55 g. of the pyrrole aldehyde were dissolved in 75 cc. of dry ether and the solution introduced into a flask designed to permit the replacement of air with an atmosphere of hydrogen. The solution was then chilled in an ice-bath and, after sweeping thoroughly with a stream of hydrogen, hydrogen chloride gas was allowed to pass in for several minutes. The solution slowly became red and was allowed to stand for eighteen hours. The solvent was then evaporated to a small volume in a stream of hydrogen. This resulted in the formation of a nearly colorless precipitate which was filtered off, thoroughly extracted with ether and suspended in boiling methanol. Filtration yielded a material melting between 185 and 205°. About half of this residue dissolved when treated with a small amount of toluene. The insoluble portion melted at 216–226° and chilling the filtrate yielded a small amount of crystalline material melting at 188°. Concentration of the methanol mother liquor gave more of this compound and still further amounts were obtained by adding several volumes of methanol to this filtrate and allowing to stand several days in the ice-box. The residue from the toluene extraction was purified further by repeated rapid extraction with boiling ethanol. The residue melted at 228–234° and the soluble portion obtained by cooling the ethanol extracts melted at 185°. On treatment with hydrogen chloride and lead dioxide the high-melting substance gave a slight brown discoloration accompanied by a trace of purple. The low-melting substance gave a deep lavender coloration. Neither appeared to cleave with hydrogen chloride.

(b) By Fusion.—Two grams of the pyrrole aldehyde and 2.8 g. of the N-methyl α-free pyrrole were ground together at 210° for twenty minutes. After cooling, the mass was dissolved in 50 cc. of methanol, chilled in dry ice–alcohol and the crystals filtered off; 2.3 g. of a sub-

stance melting at 126–32° was obtained. Further chilling of the filtrate yielded a very small amount of a material melting at 158–159°. The low-melting fraction was recrystallized from methanol and then from ethanol–water, m. p. 141°. The mother liquors from the recrystallization yielded the high melting material, m. p. 161°. When potassium bisulfate was used as a condensing agent, small amounts of the material melting at 185° which was obtained from the hydrogen chloride condensation could be isolated. All these substances will be subjected to further study.

1,4,1′,3′,5′,1″,3″,5″-Octamethyl-3,5,4′,4″-tetracarbethoxytripyrrylmethane. (a) **Hydrogen Chloride Method.** —One gram of 1,4-dimethyl-2-formyl-3,5-carbethoxypyrrole and 1.56 g. of 1,2,4-trimethyl-3-carbethoxypyrrole were dissolved in 30 cc. of dry ether, 5 cc. of ether saturated with hydrogen chloride at 0° was added and the mixture allowed to stand for twenty hours. The precipitate was filtered off, washed with ether, dissolved in chloroform and chilled in dry ice. When crystallization had started several volumes of ether were added and the solution chilled in dry ice. The colorless crystals were recrystallized from alcohol–water; m. p. 178°, yield 1.3 g. Lead dioxide and hydrogen chloride or hydrogen chloride in air gave a lavender color but hydrogen chloride in an inert atmosphere produced no color change.

(b) **Fusion Method.**—Two grams of the N-methyl aldehyde and 2.7 g. of the N-methyl α-free pyrrole were ground together and fused at 210° for twelve minutes. After cooling 50 cc. of methanol was added. Solution took place followed by rapid deposition of colorless crystals. These were filtered off, and washed with methanol; m. p. 175°, yield 1.6 g. An additional 0.9 g. was obtained by chilling the mother liquors in dry ice. Recrystallization from alcohol–water raised the m. p. to 178°; no m. p. depression with the material from acid condensation.

Anal. Calcd. for $C_{33}H_{45}O_8N_3$: C, 64.79; H, 7.41. Found: C, 64.86, 64.91; H, 7.58, 7.55.

Summary

1. A tripyrrylmethane has been isolated as a by-product in the aldehyde synthesis of a dipyrrylmethene.

2. The stability of one "negatively substituted" tripyrrylmethane has been shown to be illusory.

3. It has been demonstrated that varying courses of dipyrrylmethene and tripyrrylmethane syntheses can be accounted for on the basis of varying reaction velocities.

4. Conditions have been defined under which the aldehyde synthesis may proceed directly without an intervening tripyrrylmethane.

5. A hindering action of N-methyl groups has been discovered.

6. By-products have been observed in the Feist fusion for tripyrrylmethanes.

2,5,5-Trimethyl-1,3-hexadiene and its Hydrogen Bromide Addition Product
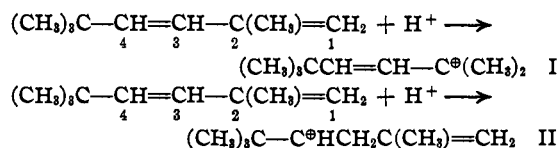
BY KENNETH N. CAMPBELL[1]

During work in this Laboratory on the rearrangements of compounds containing a neopentyl system[2] it was considered of interest to study the addition reactions of a conjugated hydrocarbon containing such a system. The hydrocarbon chosen for study was 2, 5, 5 - trimethyl- 1, 3-hexadiene, one of the simplest compounds fulfilling the requirements.

The addition of one molecule of hydrogen bromide to this hydrocarbon could take place in several ways. Applying the theory current in this Laboratory,[3] addition of a proton would be most likely to occur at carbon atom (1) or carbon atom (3) of the conjugated system, giving the two positive fragments, I and II.

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(2) Whitmore and Laughlin, THIS JOURNAL, **55**, 3732 (1933); Whitmore and Meunier, *ibid.*, **55**, 1106, 3721 (1933).

(3) Whitmore, *ibid.*, **54**, 3274 (1932).

$$(CH_3)_3C—\underset{4}{C}H=\underset{3}{C}H—\underset{2}{C}(CH_3)=\underset{1}{C}H_2 + H^+ \longrightarrow$$
$$(CH_3)_3CCH=CH—C^{\oplus}(CH_3)_2 \quad I$$

$$(CH_3)_3C—\underset{4}{C}H=\underset{3}{C}H—\underset{2}{C}(CH_3)=\underset{1}{C}H_2 + H^+ \longrightarrow$$
$$(CH_3)_3C—C^{\oplus}HCH_2C(CH_3)=CH_2 \quad II$$

Fragment I could become stabilized by the addition of a bromide ion, giving the 1,2-hydrobromide, III, $(CH_3)_3CCH=CH—C(CH_3)_2Br$, or a shift of an electron pair could occur, resulting in fragment IV, $(CH_3)_3C—C^{\oplus}H—CH=CH(CH_3)_2$. This then could add a bromide ion to give the 1,4-hydrobromide, V, $(CH_3)_3C—CHBr—CH=CH(CH_3)_2$, or it could appropriate an electron pair, together with the attached methyl group from the adjacent carbon atom, and addition of a bromide ion to the resulting fragment would yield the rearranged bromide, VI, $(CH_3)_2CBr—CH(CH_3)—CH=C(CH_3)_2$. Such a rearrangement would be analogous to that of *t*-butylethylene to