VI

VII

sible recondensation of initial scission products, are therefore factors which must be simultaneously considered during research in the oxy-starch and oxy-cellulose field.

The authors are indebted to Drs. E. J. Crane, L. T. Capell and A. M. Patterson for help in naming the acetals II to V.

Summary

1. The distillation, at 3–4 mm., of the chloroform soluble products from the methanolysis of starch oxidized by periodate gave two fractions, b. p. 116–119° and 195–205°, in yields of about 18% and 24%, respectively.

2. Detailed chemical study showed that the higher-boiling fraction was probably a mixture of isomers in which a methylerythroside unit was combined in a dioxane ring with a glyoxal unit, to which in turn a methoxyl group and a second methylerythroside group were attached. These isomers were hexahydro-3,5-dimethoxy-2-(1-methyl-3, or 2-erythrofuranosyloxy)furo[3,4]-p-dioxins.

3. The low-boiling fraction was considered to be a mixture of isomers containing a methylerythroside residue condensed in a dioxane ring with a glyoxal residue to which two methoxyl groups were attached. The structures were those of the isomeric hexahydro-2,3,5-trimethoxyfuro[3,4]-p-dioxins and one isomer was isolated in a pure condition, m. p. 97–98°, $[\alpha]^{20}D$ −59° in water.

4. When the higher boiling fraction was partially degraded by methanolysis, a 36% yield of a lower boiling fraction resulted and the properties of this fraction were those described in section (3).

5. The methanolysis of periodate oxidized cellulose took a course similar to that described in sections (1) to (3) for starch.

6. The data were consistent with the assumption that the acetal links in long, uniform chains of the oxidized starch underwent methanolysis in random order while dioxane rings resulted from the formation of new hemiacetal bonds. If, however, the data depended on the recondensation of glyoxal and erythrose in acid methanol, five-membered cyclic acetal structures were not excluded for the substances described in (2) to (5). Preference was given to the former alternative.

7. The suggestion was made that glyoxal and erythrose recondensed to an unknown extent in the presence of aqueous acid.

Steric Influences on the Aromaticity of Dipyrrylmethenes. The Synthesis and Study of the Properties of a Di-N-methyldipyrrylmethene[1]

BY KARL J. BRUNINGS AND ALSOPH H. CORWIN

The preparation of N-methyl pyrroles and N-methyl dipyrrylmethanes as the first step in the synthesis of N-methylated porphyrins has been described in the first paper of this series.[2] The condensation of these compounds according to standard methods failed to provide the expected dipyrrylmethenes, which are intermediates in the proposed porphyrin synthesis. In those cases where the expected methene was to have both nitrogens occupied by methyl groups, red oils were obtained which could not be identified and the reactions which should have yielded unsymmetrical mono-N-methylmethenes provided instead totally unsubstituted dipyrrylmethenes.[3,4,5] The subsequent study of these reactions suggested that methylated methenes were unstable.

By a change in the technique of isolation we have been able to prepare 1,3,5,1′,3′,5′-hexa-

(1) Studies in the Pyrrole Series VI. Paper V, Corwin and Krieble, THIS JOURNAL, **63**, 1829 (1941).

(2) Corwin and Quattlebaum, ibid., **58**, 1081 (1936).

(3) Corwin and Andrews, ibid., **58**, 1086 (1936).

(4) Corwin and Andrews, ibid., **59**, 1973 (1937).

(5) Paden, Corwin and Bailey, ibid., **62**, 418 (1940).

methyl-4,4'-dicarbethoxydipyrrylmethene salts by means of three standard methene condensations (Chart I).

If an aqueous solution of methene chloride IV at pH 1.5–2.0 is carefully neutralized to a pH of 3.5–4.0, the solution loses its characteristic

CHART I
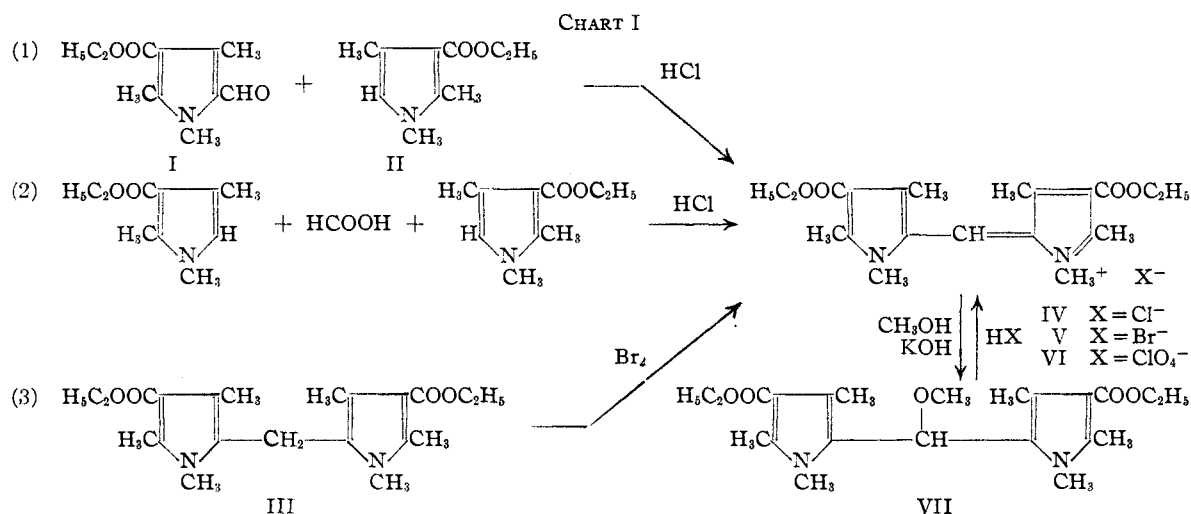
The success of reaction 1 is significant, since it precludes the mechanism often suggested[6] which requires the pyrrolenine form of the α-free pyrrole. In this instance, the presence of the N-methyl group prevents the formation of such a compound.

red color and precipitates a sticky, amorphous, colorless mass which slowly goes over into a colorless solid material. This precipitate could be isolated and purified and shown to be a dipyrryl carbinol (VIII, Chart II).

CHART II
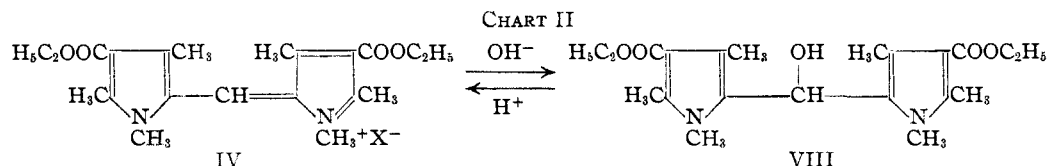
The methene salts IV and V are deep red oils and, as we might expect from their similarity to tetraalkylammonium halides, are soluble in dilute aqueous acids. Such solutions are unstable and the methene decomposes gradually on standing. The di-N-methylmethene, however, may be precipitated in the form of its perchlorate (VI) and recrystallization from toluene–chloroform yields typically long red needles of dipyrrylmethene.

The structure of the methene (VI) is proved by catalytic reduction to the dipyrrylmethane (III) and by conversion into the stable carbinol ether (VII) by means of methyl alcohol–potassium hydroxide. By acidification of hexane or ether solutions with a dry hydrogen halide, the carbinol ether is converted back to the methene. The dipyrrylcarbinol ether may be purified easily and the whole procedure serves as a method for obtaining pure dipyrrylmethene.

On reacidification the carbinol goes into solution with the reappearance of the red methene color. Addition of perchloric acid to this solution precipitates the methene (VI). The existence of dipyrryl carbinols has been suggested before[3,4,7] but the present compound is the first example in the pyrrole series which has been purified and completely characterized. The stability of the colorless carbinol in acidic solution and its ready conversion to colored methene salts at lower pH values demonstrate a strong resemblance to certain triphenylcarbinol color bases.[8]

The resistance of the methene halides to crystallization, the ease of carbinol ether formation and the stability of the carbinol in acidic solution are highly unusual properties and are not encountered in the corresponding di-NH-methene. This anomalous behavior of the di-N-methyl-

(6) Sidgwick, "Organic Chemistry of Nitrogen," Oxford University Press, London, 1937, pp. 482–490.

(7) Fischer and Fries, Z. physiol. Chem., 231, 231 (1935).

(8) Hammett, "Physical Organic Chemistry," McGraw-Hill Book Co., New York, N. Y., 1940, pp. 53–56.

methene indicates that the introduction of methyl groups on the nitrogens has affected the character of the methene more strongly than is usual in the substitution of methyl groups in pyrrole systems.

Because of their stability and color, ordinary dipyrrylmethene salts are assigned a coplanar resonating structure (A, Fig. 1). If such a structure is drawn for a di-N-methylmethene using bond angles and distances which are in approximate agreement with Robertson's,[9] obtained from the crystallographic study of phthalocyanine, the van der Waals radii of the methyl groups are observed to overlap almost completely (C, Fig. 1). A smaller but definite interference is also observed between the hydrogens of a normal unmethylated methene, but it is not likely that this small overlapping would greatly affect the coplanar configuration of the resonating molecule. However, the amount of overlapping in the case of the di-N-methyl system is so great that a profound effect must be anticipated even if the van der Waals radius of 2.0 Å. is somewhat exaggerated in this particular case.

A   B

It should be mentioned that the steric interference cannot be avoided by converting the molecule into a *trans* configuration since the 3 positions of the pyrrole rings are also occupied by methyl groups.

If complete coplanarity is a necessary condition of a resonating system and if the bond angles are assumed to be rigidly fixed, the di-N-methylmethene must have the covalent non-planar configuration (B, Fig. 1). Alternatively the resonating model can be made compatible with modern structural theory in the following ways: (1) assuming coplanarity to be a necessary condition of resonance, the angles 1, 2, 2', 3 and 3' may be increased to reduce interference of the methyl groups; (2) the van der Waals radii of the methyl groups may be penetrated; (3) the molecule may be allowed to deviate from coplanarity. Each of these accommodations requires energy which must be subtracted from that of resonance. These methods represent different approaches to the same problem and the actual structure is probably one in which all three modifications appear.

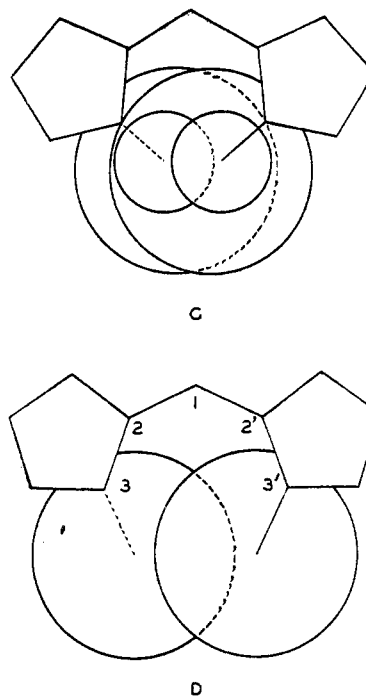(9) Robertson, *J. Chem. Soc.*, 1195 (1936).

Fig. 1.—C, Space model for di-NH-dipyrrylmethene (XI) and di-N-methyldipyrrylmethene (VI); van der Waals radius for hydrogen, 1.0 Å., for methyl groups, 2.0 Å.; D, di-N-methyldipyrrylmethene (VI), normal angles 1,2,2',3,3' increased 10° each.

Structure D, (Fig. 1) shows how the interference may be reduced to about the same degree encountered in normal unmethylated methene systems by bending angles 1, 2, 2', 3 and 3' ten degrees each. Using the force constant for bending a C—C—C angle in the plane of a resonating system, the energy involved in the bending amounts to from 15 to 20 kcal. If the N-methyl bond is bent out of the plane of the system, instead of in the plane, this energy of bending may be reduced to from 10 to 15 kcal. It is, of course, unreasonable to suppose that the angles will take so much bending while the molecule retains complete coplanarity and the van der Waals radii remain unpenetrated. By introducing these other factors the energy of accommodation may be further reduced. However, accurate quantitative data are necessary to determine how much each of these factors will modify the resonating structure, and hence it can only be predicted with certainty that the difference in energy of the covalent and the resonating planar configuration will be reduced greatly as a result of the steric hindrance of the methyl groups. It will thus be necessary to consider the chemical and physical properties of

the di-N-methylmethene in order to determine whether the molecule has the coplanar resonating structure (A), the covalent non-planar structure (B) or exists in both forms.

The stability and color of the di-N-methylmethene perchlorate support the aromatic coplanar form (A) to which these well-known methene characteristics have been ascribed. A comparison of the absorption curve (Fig. 2) in the visible of the di-N-methylmethene perchlorate with that of the corresponding unsubstituted 3,5,3',5'-tetramethyl-4,4'-dicarbethoxydipyrrylmethene (XI) perchlorate shows that the area under the curves is approximately the same. The whole curve of the methylated compound is shifted toward the visible. This shift is in agreement with the predicted lowering of the resonance energy due to the interference of the methyl groups. On the other hand, a comparison of the two curves does not indicate a radical change in structure and therefore substantiates the conclusion drawn from other properties that the perchlorate (VI) has the resonating structure A.
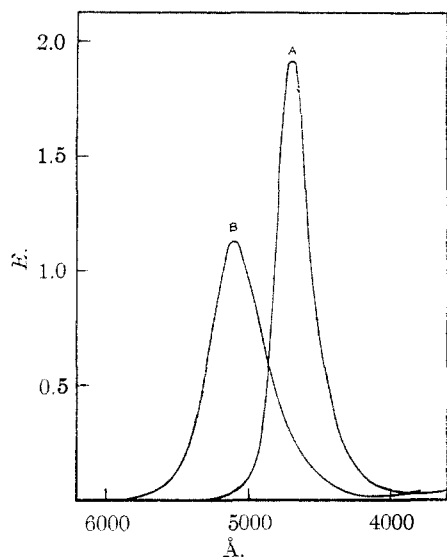

Fig. 2.—A, Di-NH-dipyrrylmethene perchlorate (XI), 1.3 × 10⁻⁵ M in chloroform λ_{max} 4700 Å.; B, di-N-methyldipyrrylmethene perchlorate (VI), 1.3 × 10⁻⁵ M in chloroform λ_{max} 5100 Å.

In contrast to the methene perchlorate, the methene bromide and chloride fail to crystallize at temperatures as low as −60° and are unstable in most organic solvents and in aqueous solutions as well. Moreover, as will be shown, these methene salts are reactive, and are subject to cleavage in which the bond between the pyrrole ring

and the center carbon atom is broken. This instability represents a decrease in the aromatic character of the methene and suggests that the structure of these compounds differs from that of the normal methene systems. These observations can be most easily explained on the assumption that the methene exists at least partially in the covalent form (B).

In preparing the methene bromide by bromination of the dipyrrylmethane it was found that one mole of bromine gave a maximum yield of 50%. On further investigation, N-methylpyrrole aldehyde (I), N-methyl-α-bromopyrrole (X) and unreacted starting methane were isolated from the mother liquor of the reaction. The compound (I) may be assumed to result from hydrolysis of α-dibromomethylpyrrole (IX). When two moles of bromine were employed no water-soluble methene was obtained and only N-methyl-α-bromopyrrole and aldehyde I could be isolated.

From these experiments it is clear that in the bromination of the methene the C–C bond linking the pyrrole ring to the bridge carbon atom has been broken. That the methene reacts with bromine could be shown by adding bromine to acidified carbon tetrachloride solutions of the carbinol ether, in which case the pyrrole aldehyde (I) and α-bromopyrrole were again obtained. However, the cleavage of the methene is extremely slow and incomplete and it was, therefore, obvious that in the case of the cleavage of the dipyrrylmethane an intermediate in the formation of the methene had reacted with bromine to give the products obtained. On the basis of the considerations respecting the structure of the methene salt summarized above, the covalent dipyrrylmethyl bromide is suggested as an energetically feasible intermediate in the reaction (Chart III).

The formation of the covalent dipyrrylmethyl bromide as first step in the bromination is a logical assumption in normal methane bromination. In the case of the di-N-methyl system, however, the ionization of this intermediate to the methene would be accompanied by a definite activation energy which would include among other things the energy of ionization of the C–Br bond and the energy necessary to force the pyrrole rings into a plane. This activation energy results in a finite rate of transformation into the ionic methene salt. The intermediate dipyrryl bromide (B) may then react with bromine directly to give the prod-

CHART III
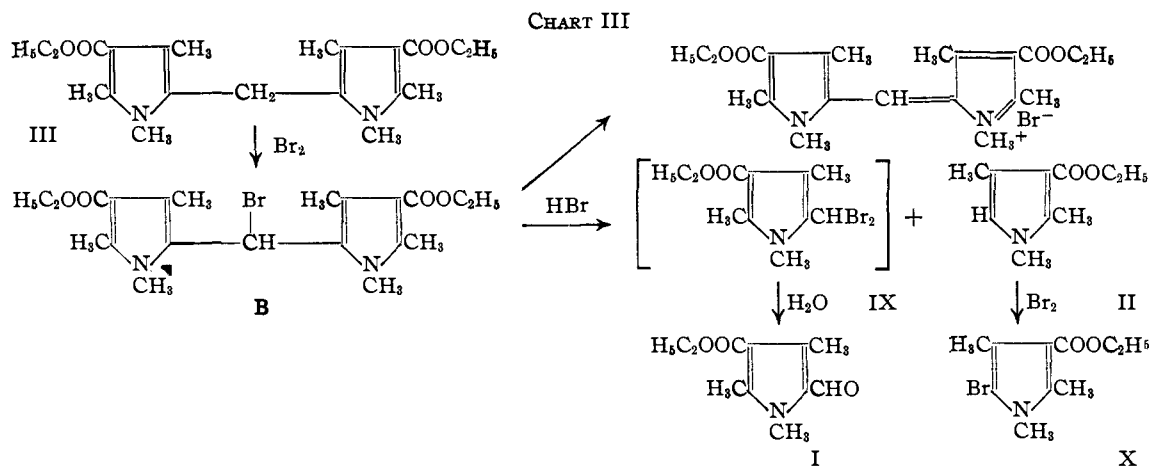
ucts found or cleave under the influence of hydrogen bromide to give the α-dibromomethylpyrrole (IX) and N-methyl α-free pyrrole (II). In the latter case the α-free pyrrole would react with bromine to give α-bromopyrrole with extreme rapidity. By the same token, the reaction between bromine and the methene would take place only after the methene had been converted to the covalent state or some activated form of the non-planar molecule. This conversion would require an activation which would be equal to the energy due to resonance stabilization. In the case of methane systems with unsubstituted nitrogen, the activation energy of conversion from the hypothetical covalent dipyrrylmethyl bromide intermediate to the planar ionic methene does not exist, thus allowing the methane bromination to provide the methene in good yields even when bromine is used in excess. Moreover, the difference in energy between the reactive covalent form and the aromatic methene salt is so great that the molecule does not react with bromine under ordinary conditions.

These arguments in favor of the participation of the covalent form of the methene halides receive strong support from the existence of the stable covalent carbinol (VIII) cited earlier in the paper. In addition, it was discovered that when sodium fluoride was added to a methene chloride solution at pH 1.5 in which the chloride is not hydrolyzed, the solution rapidly lost its red color and produced a colorless precipitate. Although the product could not be isolated and purified, the decolorizing action of the fluoride ion may be interpreted by assuming the formation of a dipyrrylmethyl fluoride. These observations stress the similarity of this system to cer-

tain triphenylmethyl halides[8] which are colorless crystalline covalent compounds capable of being converted into colored ionic triphenylmethene dyes by the action of strong acids.

The stability of the carbinol ether, the formation of the carbinol in acidic solution, the decolorizing action of the fluoride ion, the instability of the methene chloride and bromide and, finally, the aromatic character of the perchlorate salt adequately show that the structure of the methene is profoundly affected by the negative ion. Thus as we move from the perchlorate to more basic anions the increasing strength of the C-anion bond increases the stability of the covalent form, until we reach a point where the covalent form actually represents the structure of the methene. A similar series of anions and their effect on tetraalkylammonium systems has been discussed by Ingold and his co-workers.[10]

We believe that the anomalous behavior of the di-N-methylmethene can be explained entirely by steric interference and that the introduction of methyl groups on the nitrogens in methene systems results in a steric stabilization of a covalent bond. The inductive effect of the methyl groups has been neglected since the electrophobic character of the methyl group relative to hydrogen would be expected to decrease the stability of the covalent form. On the other hand, electrophilic groups, such as the carbethoxy, would be expected to stabilize the covalent form and thus to exert an effect similar in direction to the steric hindrance of alkyl groups on the nitrogens. By a combination of both effects the synthesis of entirely covalent dipyrrylmethyl halides

(10) Hanhart and Ingold, *ibid.*, 997 (1927); Hughes and Ingold, *ibid.*, **68**, 526 (1933).

similar to the triphenylmethyl halides appears promising. Work in this direction is now in progress.

The authors are indebted to the Rockefeller Foundation for a research grant which has made this investigation possible.

Acknowledgment is also made of the helpful suggestions of Dr. R. C. Lord, Jr., during the course of the work.

Experimental Section

Preparation of 1,3,5,1',3',5'-Hexamethyl-4,4'-dicarbethoxydipyrrylmethene Perchlorate (VI). A. **Bromination of 1,3,5,1',3',5'-Hexamethyl-4,4'-dicarbethoxydipyrrylmethane (III).**—A solution of 8.8 g. of the methane in 500 cc. of warm, dry carbon tetrachloride is placed in a one-liter Erlenmeyer flask. The solution is brought to room temperature and 37.6 cc. (1 mole) of bromine–carbon tetrachloride solution (25 g. of bromine per 250 cc. of carbon tetrachloride) is quickly run in while the flask is twirled. The reaction mixture is allowed to stand one-half hour and then extracted with 250 cc. of water. After extraction, the aqueous solution is filtered and 6 cc. of 70–75% perchloric acid dissolved in 20 cc. of water added in small portions. Since the methene bromide decomposes in aqueous solution, the addition of perchloric acid must take place as soon as possible after extraction. The walls of the flask are vigorously scratched during the addition of the acid; 5.5 g. of a red microcrystalline material is obtained, yield, 50%. Recrystallization from toluene–chloroform mixtures yields beautiful long red needles. The crystalline material decomposed in a range from 160–170° with explosive violence. Due to the explosive nature of this material, the analysis was carried out on the carbinol ether (see below).

B. **Condensation of 1,3,5-Trimethyl-2-formyl-4-carbethoxypyrrole (I) and 1,3,5-Trimethyl-4-carbethoxypyrrole (II).**—A mixture of 0.29 g. of aldehyde (I) and 0.5 g. of α-free pyrrole (II) is dissolved in 75 cc. of dry carbon tetrachloride in a 125-cc. Erlenmeyer flask. Gaseous hydrogen chloride is passed through the solution until saturated. After standing overnight, the solution is extracted with 100 cc. of water. The aqueous layer is then filtered and 0.1 cc. of concentrated perchloric acid (70–75%) dissolved in 15 cc. of water is added to the solution in small portions. Patient scratching of the side walls of the flask yields a crop of micro-crystalline methene perchlorate, yield 0.47 g., 73%. Note: This experiment was originally designed to synthesize the tri-N-methyl tripyrrylmethane (1 mole of aldehyde and 2 moles of α-free pyrrole). No tripyrrylmethane could be isolated. However, the use of less than 2 moles of α-free pyrrole lowers the yield of methene considerably. Excess α-free pyrrole may be isolated from the mother liquor.

C. **Condensation of 1,3,5-Trimethyl-4-carbethoxypyrrole (II) with Formic Acid.**—To a solution of 4 g. of the α-free pyrrole (II) in 20 cc. of commercial ether is added 10 cc. of 98% formic acid and 16 cc. of concentrated hydrochloric acid. After allowing the mixture to stand at room temperature overnight, the deep red solution is extracted with 200 cc. of water. The aqueous layer is washed twice

with 50 cc. of ether, and the original ether layer washed once with 50 cc. of water. Perchloric acid is then added to the aqueous layer and the methene isolated as in A; yield, 1.95 g., 38%. The ether fractions are then combined, dried over anhydrous potassium carbonate and evaporated; 1.9 g. of unreacted α-free pyrrole or 72% is retrieved. By keeping the reaction mixture close to 50° for twelve hours the yield was increased to 54%. About 75% of the unreacted pyrrole was retrieved.

Preparation of the Carbinol Ether (VII) from Di-N-methylmethene Perchlorate (VI).—After grinding to a fine powder in a mortar, 1 g. of methene perchlorate is placed in a 125-cc. Erlenmeyer flask and 55.4 cc. of alcoholic potassium hydroxide (2.5 g. of potassium hydroxide in 100 cc. of methyl alcohol) is poured over the solid. The mixture is shaken until all of the colored material has disappeared, and then filtered. The clear solution is poured into 200 cc. of ice water and allowed to stand until the precipitate has settled. The product is filtered and dried; 700 mg. is obtained, which on recrystallization from hexane–benzene gives pearly plates melting at 113–114°; yield, 82%. *Anal.* Calcd. for $C_{22}H_{32}N_2O_5$: C, 65.32; H, 7.95. Found: C, 65.28; H, 7.94.

Preparation of Methene Perchlorate (VI) from the Carbinol Ether (VII).—The carbinol ether (0.5 g.) is dissolved in 25 cc. of hexane. Gaseous hydrogen chloride is passed into the reaction flask until precipitation of the red oil is complete. The hexene is decanted and the remainder evaporated off. The clear red oil is then dissolved in water and 0.5 cc. of 70% perchloric acid added. A red amorphous solid immediately precipitates out which on recrystallization from chloroform–hexane yields crystalline methene; yield of crude product, 80–85%.

Reduction of Di-N-methylmethene Perchlorate (VI).—To a solution of 0.25 g. of the methene perchlorate in 50 cc. of methyl alcohol, 0.5 g. of Norite A (Pfanstiehl) and 2–4 drops of 10% palladium chloride are added and the flask is placed on a hydrogenation shaker. The calculated amount of hydrogen is taken up after four hours. After evaporating off the alcohol, a good yield of a crystalline compound is obtained which melts at 154–155°; mixed melt with di-N-methylmethane (III) is 154–155°.

Preparation of 1,3,5,1',3',5'-Hexamethyl-4,4'-dicarbethoxydipyrrylcarbinol. (VIII.) A. **From Di-N-methyl-dipyrrylmethane (III).**—The dipyrrylmethane (1 g.) is dissolved in 100 cc. of carbon tetrachloride and brominated according to the directions given for the preparation of methene perchlorate (A). After extraction, the aqueous solution is filtered and diluted to 100 cc. To this solution 0.25 g. of sodium hydroxide dissolved in 10 cc. of water is added. The red color of the solution disappears and a yellowish amorphous mass begins to separate. The mixture is then allowed to stand in the ice box for at least twenty-four hours. During this time the precipitate becomes solid. Filtration yields 475 mg. of dipyrrylcarbinol or 42% of the theoretical. The crude material is crystallized from hexane–benzene solutions; m. p., 142–143°. *Anal.* Calcd. for $C_{21}H_{30}N_2O_5$: C, 64.59; H, 7.75. Found: C, 64.61; H, 7.85.

B. **From Carbinol Ether (VII).**—Pure carbinol ether (500 mg.) is dissolved in 75 cc. of purified hexane in a 125-cc. filter flask. Dry gaseous hydrogen chloride is then

passed through the solution until no more oil precipitates from the supernatant liquid. The hexane is then evaporated off and the red oily residue dissolved in 50 cc. of water. The solution is placed in a 60-cc. beaker and the pH read using a glass electrode. The initial pH is 1.5; 0.2 N sodium hydroxide is then added with stirring and the pH checked with each 0.5-cc. portion added. At a pH of 3.0 the intense red color of the solution diminishes rapidly and a yellow slimy precipitate is formed. The addition of sodium hydroxide is continued until a pH of 4.0 is reached, and the mixture then removed from the electrodes and allowed to stand overnight. During this time the oily precipitate is transformed into a solid mass which can be easily filtered; yield, 420 mg. or 88%. The material is dried and recrystallized from hexane–benzene mixtures, m. p., 141–142°; mixed melt with pure carbinol, 142–143°.

Isolation of 1,3,5-Trimethyl-2-formyl-4-carbethoxypyrrole (I) and Starting Material from the Mother Liquor of Di-N-methylmethane (III) Bromination (Reaction A).—The di-N-methylmethane (III) (5 g.) dissolved in 500 cc. of dry carbon tetrachloride is brominated according to the directions above (A). After extraction with water, the carbon tetrachloride layer is dried over anhydrous potassium carbonate and evaporated to dryness at room temperature. The red viscous oil remaining after evaporation is covered with 100 cc. of 50% alcohol–water and the mixture allowed to stand several days. During this time most of the red color passes into the supernatant liquid and the residue slowly becomes solid. On filtration 1.65 g. of slightly colored solid is recovered. From this material 130 mg. of di-N-methylmethane, melting at 153–154°, is obtained by repeated recrystallizations from alcohol–water. Mixed melt with pure di-N-methyldipyrrylmethane (III) is 156–157°. The accompanying product, which clings tenaciously to the di-N-methylmethane through many recrystallizations, could not be identified. This material is believed to be N-methyl-α-hydroxymethylpyrrole obtained by the brominating action of the dibromomethylpyrrole (IX) on oxidizable substances in the reaction mixture. The 50% alcohol solution which is saved from the above filtration is evaporated down to one-half volume and allowed to stand in the cold. Semicrystalline material is filtered from the solution and dissolved in an excess of hot water. On cooling 180 mg. of very pure crystalline pyrrole aldehyde (I) is obtained, m. p. 97–98°.

Isolation of 1,3,5-Trimethyl-4-carbethoxy-2-bromopyrrole (X) from the Di-N-methylmethane (III) Bromination. —The di-N-methyldipyrrylmethane (III) (3 g.) is brominated according to the above directions, and the 300 cc. of carbon tetrachloride solution from which the methene has been extracted is dried over anhydrous potassium carbonate. A chromatographic apparatus is set up using a column of activated alumina (commercial, less than 80 mesh) about 6 inches in height in a glass tube of one-half inch diameter and developed by pressure instead of suction. The dried reddish-colored carbon tetrachloride solution is run through at a rate of about one drop per second. After all the solution has passed through, the column, which contains a broad band of red material at the top, is washed with four 100-cc. portions of dry carbon tetrachloride. Each 100-cc. fraction is caught in a separate container and

evaporated to dryness. From the first fraction, 290 mg. of very pure crystalline α-bromopyrrole (X) is obtained, m. p. 57–58°; mixed melt with α-free pyrrole (II)—room temperature; mixed melt with α-bromopyrrole (X), 57–58°. Fraction II contains 300 mg. of less pure α-bromopyrrole (Beilstein test, positive); Fraction III contains 150 mg. of pyrrole aldehyde (I) in a rather impure state (see above).

Two Molar Bromination of Di-N-methylmethane (III).— Di-N-methylmethane (III) (0.5 g.) is dissolved in 75 cc. of dry hot carbon tetrachloride. The solution is brought to room temperature and 4.7 cc. (2 moles) of bromine-carbon tetrachloride solution (25 g. of bromine in 250 cc. of carbon tetrachloride) is quickly run in; 25 cc. of water is added and the mixture placed on a shaker. After shaking for six hours the color obtained immediately after bromination of the methane has faded to a light pink. The two layers are separated and the orange colored carbon tetrachloride solution is dried over anhydrous potassium carbonate. A chromatograph column is prepared as above and the dried solution run through. The column is washed with 150 cc. of carbon tetrachloride, then a second portion of 200 cc. and a third portion of 300 cc. Each of these washings is collected separately and evaporated to dryness: Fraction I (150 cc.), 120 mg. of very pure crystalline α-bromopyrrole (X), m. p. 57–58°; Fraction II (200 cc.), 120 mg. of crystalline residue which turned red on standing, m. p., 45–48°, mixed melt with α-bromopyrrole, 48–50°; Fraction III, 90 mg. of long needle-like crystals of pyrrole aldehyde (I), m. p. 94–95°, recrystallized from hot water, m. p. 97–98°; total recovery, 330 mg. or 45% of the theoretical. The column retains a broad red band. This dye and the low yield may be explained on the basis of reactions which each of the products is known to undergo. The condensation of the corresponding N-free α-bromopyrrole in acid has been studied in this Laboratory by Corwin and Viohl.[11] The total weight of the material remaining in the carbon tetrachloride was checked in an independent experiment without chromatographing and found to contain 500 mg. of product or 80% of the theoretical. The two-molar bromination was also run omitting the water added to the reaction. In this case 20% yield was obtained after one-half hour standing. When allowed to stand for twelve hours the yield of methene became negligible. Isolation of by-products in this reaction is quite difficult and a considerable amount of unidentifiable dye is formed. However, by examining the carbon tetrachloride solution chromatographically as described above, small amounts of the α-bromopyrrole (X) and pyrrole aldehyde (I) could be isolated. The α-dibromopyrrole (IX) which is postulated as the intermediate in the formation of the pyrrole aldehyde should be highly reactive both in condensation and oxidation reactions. In this way the mixture of dyes obtained in the reaction would be explained. The water used on two-molar reactions prevents further reaction of this precursor with other products in the system by converting it to the corresponding aldehyde and thus permits isolation of the two pyrrole derivatives.

Bromination of 1,3,5,1',3',5'-Hexamethyl-4,4'-dicarbethoxydipyrrylmethene Bromide (V).—Di-N-methylcarbinol ether (0.5 g.) is dissolved in 75 cc. of dry carbon tetra-

(11) Corwin and Viohl, unpublished work.

chloride. After cooling to room temperature, dry gaseous hydrogen bromide is passed through the solution until a red oil coagulates on the side walls of the flask. To this solution 2.2 cc. (1 mole) of bromine–carbon tetrachloride solution (25 g. of bromine in 250 cc. of carbon tetrachloride) is added and the flask allowed to shake overnight. The mixture is then extracted with 50 cc. of water and 0.2 cc. of 70% perchloric acid is added to the aqueous layer. Patient scratching of the flask yields 50 mg. of methene perchlorate or about 10% of the methene which would have been recovered if bromine had not been added. A chromatographic investigation of the carbon tetrachloride layer proved the presence of α-bromopyrrole (X) and pyrrole aldehyde (I).

Methene Bromination in the Presence of Water.—By carrying out the above bromination and adding 20 cc. of water to the reaction mixture, the methene in the water layer completely disappeared after shaking the mixture for about six hours. The presence of methene was tested from time to time by addition of perchloric acid to small samples of the water layer. Chromatographic treatment of the carbon tetrachloride layer according to the technique described above yielded α-bromopyrrole (X) and pyrrole aldehyde (I).

Preparation of 1,3,5-Trimethyl-2-bromo-4-carbethoxypyrrole (X).—N-Methyl α-free pyrrole (II) (12 g.) is dissolved in 400 cc. of methyl alcohol in a 500-cc. Erlenmeyer flask. In a separate 50-cc. flask, 3.8 cc. of bromine (1 mole plus 10% excess) is run into 25 cc. of methyl alcohol which has been previously cooled in dry-ice–acetone mixture. The flask containing the α-free pyrrole is also cooled to $-50°$ in dry-ice–acetone mixture. Care must be exercised to prevent crystallization of the pyrrole from the solution. The bromine–methyl alcohol solution is then run in from a buret with constant stirring. Several times during the reaction it is necessary to cool the reaction flask again. The time of bromine addition should not exceed five minutes. After this time the solution is poured into one-half liter of ice water containing 6 g. of potassium hydroxide. A white voluminous precipitate separates out and the beaker is set aside for one hour in order to ensure complete precipitation. The solid is collected on a filter and dried; yield, 13.5 g. or 78%. The white material is dissolved in a small amount of purified hexane and allowed to crystallize. The crystals are long needles melting at 54–55° and decomposing at 145–150° with strong evolution of gas; mixed melt with N-methyl α-free pyrrole, below room temperature. *Anal.* Calcd. for $C_{10}H_{14}NO_2Br$: C, 47.2; H, 5.39. Found: C, 47.4; H, 5.38.

Decolorization of Aqueous Di-N-methylmethene Chloride Solutions by Means of Sodium Fluoride.—Di-N-

methylcarbinol ether (VII) (250 mg.) is dissolved in 75 cc. of purified hexane in a 125-cc. filter flask. The solution is saturated with dry gaseous hydrogen chloride until no more red oil precipitates from the supernatant solvent. After evaporating off the hexane and excess hydrogen chloride, the red oil is dissolved in 50 cc. of water and filtered. The pH of the solution is 1.5; 25 mg. of sodium fluoride is then added to the highly colored methene solution. Shortly after addition of the fluoride, the color of the methene solution begins to fade and a white solid settles to the bottom of the beaker. This process continues on standing until the liquid retains only a pink color. After standing overnight, the solution is filtered and 200 mg. of a substance with m. p. 130–135° is obtained. Recrystallization from benzene–hexane resulted in raising the melting point to 139–140°; mixed melt with carbinol, 140–141°.

When a large excess of sodium fluoride (4–5 moles) is added to the methene chloride solution, the color disappears very rapidly and the solution is filled with a colorless precipitate. The solid which is retained on the filter paper is quite unstable and turns into a tarry mass. Attempts to purify the compound failed. This material is believed to be the covalent dipyrrylmethyl fluoride.

Summary

1. The first example of a di-N-methylated dipyrrylmethene has been synthesized and its properties studied.

2. A dipyrrylcarbinol, representing the first compound of this type in the pyrrole series to be purified and completely characterized, has been prepared.

3. On the basis of molecular models steric influences in dipyrrylmethene systems have been discussed.

4. The steric interference of methyl groups on the nitrogens of a dipyrrylmethene was shown to reduce the stability of the methene salt and to stabilize covalent dipyrrylmethyl derivatives.

5. Di-N-methyldipyrrylmethane and its corresponding methene bromide were shown to cleave by the action of bromine.

6. A mechanism was proposed for the oxidative cleavage of di-N-methyldipyrrylmethane.