dimethyl azelate. The distillate was redistilled on a spinning band Podbielniak column without further condensation. The main fraction boiled at 107–109° (4.5 mm.), $n^{30}D$ 1.4434, and contained 98.6% cracked product.

Anal. Calcd. for $C_{11}H_{20}O_3$: C, 66.05; H, 10.08; hydroxylamine value, 200.2 g./equiv. Found: C, 66.14, H, 10.06; hydroxylamine value, 205.0 g./equiv.

G.l.c. analyses of the mixture during the cracking step showed two new peaks, believed to be the isomeric-substituted enol ether VII. Attempts to separate the isomers by fractional distillation were unsuccessful although *cis*- and *trans*-methyl propenyl ether have been successfully separated by this means.[24]

Methyl 9-Methoxynonanoate.—The enol ether VII (11.50 g. of 90.6% cracked products) was dissolved in 100 ml. of diethyl ether. Hydrogenation over 0.2 g. of platinum oxide was carried out at ambient temperature and 40 p.s.i. in a Parr low-pressure hydrogenation apparatus. The product was distilled through a spinning band Podbielniak column. The main fraction boiled from 109–110° (5.5 mm.), $n^{30}D$ 1.4282. The purity was 98% calculated from g.l.c. data.

Anal. Calcd. for $C_{11}H_{22}O_3$: C, 65.30; H, 10.90; sapon. equiv., 202.3. Found: C, 65.15; H, 10.87; sapon equiv., 201.3.

Acknowledgment.—We express our appreciation to Mrs. Clara E. McGrew for carbon and hydrogen microanalyses, to Mrs. Helen Ven Horst Peters for infrared spectra, to Mr. G. L. Fullington for the preparation of pure methyl azelaaldehydate and its dimethyl acetal, and to Dr. R. B. Bates for criticism and helpful suggestions. The mention of firm names or trade products does not constitute endorsement by the Department of Agriculture over other firms or similar products not mentioned.

(24) W. L. Howard, E. C. Jacobsen, and R. A. Newton, *J. Org. Chem.*, **26**, 3574 (1961).

Synthesis of 5-Substituted Derivatives of 3-Acetamido-1-methyl-2,4-dioxopyrrolidine[1]

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Received June 4, 1962

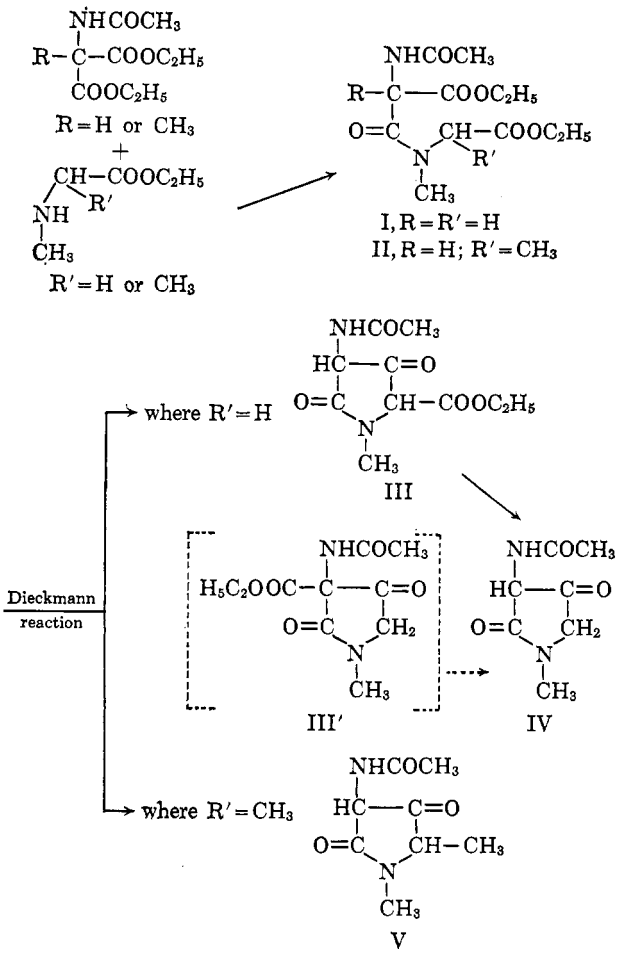
The structures of thiolutin and aureothricin, both yellow crystalline sulfur-containing antibiotics, were elucidated by Celmer and Solmons,[2] respectively, as 3-acetamido and 3-propionamido derivatives of 3-amino-5-methylpyrrolin-4-oxo[4,3-*d*]-1,2-dithiol (Ic). It is of interest that they are the first recognized examples of microbiologically active unsaturated lactams.

As part of investigation on the synthesis of thiolutin, the Dieckmann reaction of some N-(α-acetamido-α-ethoxycarbonylacetyl)-N-methylamino acid ethyl esters (I, R = R′ = H; II, R = H, R′ = CH_3) was carried out.

First, N-(α-acetamido-α-ethoxycarbonylacetyl)-N-methyl derivatives of glycine and alanine ethyl esters (I and II) were prepared from the corresponding amino acid esters and diethyl acetamidomalonates. Some 5-substituted 3-acetamido-1-methyl-2,4-dioxopyrrolidines (III, IV, and V) were prepared by the Dieckmann cyclization of the above ester derivatives. The product of this Dieckmann reaction of N-(α-acetamido-α-ethoxycarbonylacetyl)-N-methylglycine ethyl ester (I) was found to be 3-acetamido-5-ethoxycarbonyl-1-methyl-2,4-dioxopyrrolidine (III) and not 3-acetamido-3-ethoxycarbonyl-1-methyl-2,4-dioxopyrrolidine (III′), which is also a possibility. In this connection, compound III was found to be a useful intermediate for the preparation of α-amino-α'-methylamino-β-hydroxyglutaric acid. These 2,4-dioxopyrrolidines form a tautomeric system and derivatives of both ketonic and enolic tautomers were also prepared.

The sequence of reactions leading to 5-substituted derivatives of 3-acetamido-1-methyl-2,4-dioxopyrrolidine is shown in Scheme I.

SCHEME I



The starting materials, N-methylamino acid esters, were prepared *via* the α-methylamino derivatives of acetonitrile from formaldehyde or of propionitrile from acetaldehyde. In the case of the N-methylalanine ethyl ester, isolation of the intermediate, α-methylaminopropionitrile, was necessary in order to reduce the by-product formation to a minimum during esterification of the nitrile.

The condensation of N-methylamino acid ethyl esters and diethyl acetamidomalonates was effected in xylene at a refluxing temperature by the dropwise addition of the ester into the boiling xylene solution of the acetamidomalonate so as to avoid the formation of diketopiperazines by self-condensation. Completion of the reaction required more than 24 hr. of heating. The

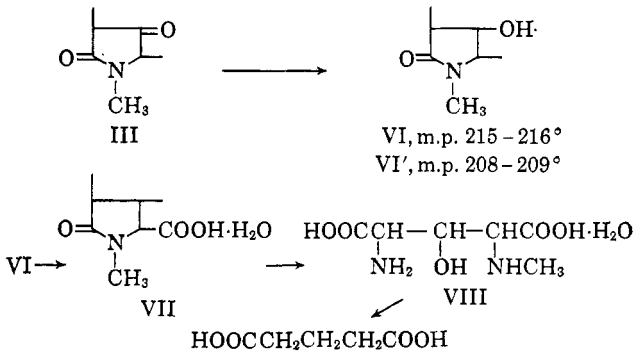
(1) Part of this paper was read at the 11th Annual Meeting of the Chemical Society of Japan, Tokyo, April, 1958.

(2) W. D. Celmer and I. A. Solmons, *J. Am. Chem. Soc.*, **77**, 2861 (1955).

products were highly viscous oils, distillable under high vacuum. The condensation failed with methyl derivatives of diethyl acetamidomalonate, possibly due to the steric effect.

Cyclization of the condensation products (I, II) progressed smoothly in an inert solvent in the presence of sodium ethoxide at room temperature. Cyclization of N-(α-acetamido-α-ethoxycarbonylacetyl)-N-methylalanine ethyl ester (II, R = H; R′ = CH_3) was attended with decarboxylation and the product thereby obtained was 3-acetamido-1,5-dimethyl-2,4-dioxopyrrolidine (V).

Similar treatment of N-(α-acetamido-α-ethoxycarbonylacetyl)-N-methylglycine ethyl ester (I, R = R′ = H) gave only one compound with an ethoxycarbonyl group, $C_{10}H_{14}N_2O_5$, which was one of the two isomers (III and III′). In order to determine which of these two alternative structures was correct, the following experiment was carried out.



Catalytic hydrogenation of III over Raney nickel at 1500 lb./in.^{2} afforded two diastereoisomeric dihydro compounds, $C_{10}H_{16}N_2O_5$, one (VI) of m.p. 215–216° and the other (VI′) of m.p. 208–209°. The former, produced in a larger amount, was converted by mild alkaline hydrolysis into a free acid (VII), which was further hydrolyzed with 6 *N* hydrochloric acid to α-amino-α′-methylamino-β-hydroxyglutaric acid (VIII). Thin layer chromatography of VIII on silica gel gave a spot near that of serine by development with water saturated with phenol. The chromatogram gave a positive reaction to the Ninhydrin reagent and to the Nessler reagent for hydroxyamino acid. Reduction[3] of this diaminodicarboxylic acid with hydriodic acid (sp. gr. 1.7) at 200° gave a straight-chain dibasic acid which was identified by infrared spectrum with authentic glutaric acid, and also by a mixture melting point test.

From the other possible structure (III′), glutaric acid could never be derived by the same procedure. These experiments leave no doubt that the Dieckmann reaction product of I (R = R′ = H) is 3-acetamido-5-ethoxycarbonyl-1-methyl-2,4-dioxopyrrolidine (III).

III is easily decarboxylated by treatment with dilute alkali and forms 3-acetamido-1-methyl-2,4-dioxopyrrolidine (IV), which was also obtained in a small amount, together with III, by the Dieckmann reaction of I. In view of the fact that the cyclization of II (R = H, R′ = CH_3) is always attended with decarboxylation, it seems reasonable to assume that IV in the Dieckmann reaction mixture may have been derived from the unstable isomer (III′) by decarboxylation. It may be possible that the two substituents, $-COOC_2H_5$ and $-NHCOCH_3$, cannot occupy the same 3-position owing to steric hindrance.

These 5-substituted 3-acetamido-1-methyl-2,4-dioxopyrrolidines (III, IV, and V) are acidic and decompose sodium hydrogen carbonate. They all show an intense blue coloration with ferric chloride solution. To confirm further their enolic character, these compounds were treated with diazomethane and the formation of enol ethers, along with the formation of 2,4-dinitrophenylhydrazones, indicated that they form tautomeric systems. The ultraviolet spectra (in water) of III, IV, and V, respectively, show absorption maxima at 274 mμ (log ε 3.84), 266 (3.85), and 268 (3.76). These spectral data provide strong evidence for the presence of the chromophor $-\overset{\alpha}{C}=\overset{\beta}{C}-\overset{R}{\underset{|}{C}}=O$ in these molecules in spite of the weak activating effect of the lactam carbonyl [α = OH, β = $NHCOCH_3$, R = $N(CH_3)$—].

Presence of the chromophor in these compounds was also suggested by their infrared spectra, carbonyl bands of which are shown in Table I.

TABLE I

CARBONYL BANDS OF III, IV, V, VI, AND VI′ (CM.$^{-1}$)

Compound	Bands A	B	C
IV		1661	1630
V		1674	1630
III	1740	1675	1635
VI	1742	1691	1638
VI′	1734	1700	1640

It is seen that the B-band of III shows a shift from those of VI and VI′ which show the normal γ-lactam carbonyl absorption near 1700 cm.$^{-1}$.[4] If III, IV, and V have an α,β-unsaturated carbonyl as their structural unit, this shift of a lactam carbonyl band will be expected. It seems reasonable, therefore, to assume that the B-band is associated with the γ-lactam carbonyl absorption. Since the infrared spectra of III, IV, and V lack normal carbonyl absorption in the 1725–1705-cm.$^{-1}$ range, the 4-oxo group in these compounds must be largely in the enolic form. As the A-band is an ester carbonyl band, the C-band is assigned to the 3-acetamido group.

Experimental

N-(α-Acetamido-α-ethoxycarbonylacetyl)-N-methylglycine Ethyl Ester (I).—A mixture of 76.2 g. (0.351 mole) of diethyl acetamidomalonate and 163 ml. of xylene was heated in an oil bath at 150°. A solution of 20.6 g. (0.176 mole) of N-methylglycine ethyl ester[5] in 40.8 ml. of xylene was added dropwise during 2.5 hr., and the mixture was heated for a further 20 hr. Most of the unchanged diethyl acetamidomalonate, which crystallized upon cooling the clear, slightly yellow solution, was filtered off, and the xylene was then distilled. The residue was distilled under high vacuum, and 32.5 g. (64.1%) of the main distillate was obtained as a very viscous yellow oil of b.p. 156–158° (0.02 mm.). The total amount of diethyl acetamidomalonate recovered as crystals and as the first distillate amounted to 43.3 g. (0.199 mole). Several redistillations produced an almost colorless viscous oil, b.p. 150–151° (0.01 mm.), $n^{23}D$ 1.4765.

(3) G. Hüfner, *J. prakt. Chem.*, **109**, 6 (1870).

(4) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," John Wiley and Sons, Inc., New York, N. Y., 1954, p. 176.

(5) S. M. McElvain and P. M. Laughton, *J. Am. Chem. Soc.*, **73**, 449 (1951).

Anal. Calcd. for $C_{12}H_{20}N_2O_6$: C, 49.99; H, 6.99; N, 9.72. Found: C, 49.95; H, 6.91; N, 10.03.

3-Acetamido-5-ethoxycarbonyl-1-methyl-2,4-dioxopyrrolidine (III).—To a solution of sodium ethoxide, prepared from 1.78 g. (0.077 g.-atom) of sodium and 22.5 ml. of absolute ethanol and diluted with 30 ml. of benzene, a solution of 22.3 g. (0.077 mole) of I in 50 ml. of benzene was added dropwise during 1 hr. During this time, a yellowish white solid of the sodio derivative of the reaction product gradually formed in the orange-yellow solution. After completion of the addition, the reaction mixture was left overnight and then distilled to dryness. The residue was dissolved in a small amount of water, and the solution was acidified with 10% hydrochloric acid. Crude crystals usually began to precipitate at once and amounted to 12.9 g., m.p. 146–157°.

Recrystallization from absolute alcohol gave 8.2 g. (43.8%) of 3-acetamido-5-ethoxycarbonyl-1-methyl-2,4-dioxopyrrolidine (III), m.p. 156–158°. It gave an intense blue coloration with ferric chloride solution. Further recrystallization from benzene raised the melting point to 160–161°; ν_{max}^{KBr} 3285, 1740, 1675, 1635, 1401, and 1205 cm.$^{-1}$; $\lambda_{max}^{H_2O}$ 274 mμ (log ε 3.84).

Anal. Calcd. for $C_{10}H_{14}N_2O_5$: C, 49.58; H, 5.85; N, 11.57; mol. wt., 242.23. Found: C, 49.43; H, 5.77; N, 11.45; mol. wt., 266.1.

An effort was made to find another isomer from the ethanolic mother liquid of recrystallization, by fractional crystallization. A compound with m.p. 195–200° was found besides the additional crops of III. Recrystallization of the compound from absolute ethanol raised the melting point to 206–208°, undepressed on admixture with the decarboxylated III, 3-acetamido-1-methyl-2,4-dioxopyrrolidine (IV).

The 2,4-dinitrophenylhydrazone of III was prepared by treating the compound with Baeyer's reagent. Recrystallization from 99% ethanol produced orange-yellow needles, m.p. 212–213°.

Anal. Calcd. for $C_{16}H_{18}N_6O_8$: C, 45.50; H, 4.30; N, 19.90. Found: C, 45.45; H, 4.49; N, 19.87.

3-Acetamido-5-carbethoxy-4-methoxy-1-methyl-2-oxo-3(or 4)-pyrroline.—The enol ether of III was prepared by the use of an ether solution of diazomethane[6] prepared from nitrosomethylurethan and distilled before use. To a suspension of 200 mg. of III in 10 ml. of ether, the solution of diazomethane was added in small portions with stirring, to a slight excess. Stirring was continued for an additional 0.5 hr. Excess diazomethane was decomposed by adding a few drops of acetic acid and the mixture was allowed to stand in a refrigerator. The crystals amounted to 70 mg., m.p. 107–110°. Recrystallization from carbon tetrachloride produced colorless prisms, m.p. 108–110°.

Anal. Calcd. for $C_{11}H_{16}N_2O_6$: C, 51.56; H, 6.29; N, 10.93. Found: C, 51.68; H, 6.26; N, 10.78.

3-Acetamido-1-methyl-2,4-dioxopyrrolidine (IV).—One gram (0.0041 mole) of III was added to a solution of 0.46 g. (0.0082 mole) of potassium hydroxide in 0.82 ml. of water. The mixture was heated on a water bath for 0.5 hr. After cooling, the resultant solution was acidified with 1.5 ml. of 10% hydrochloric acid. After several hours, the crude deposit of 3-acetamido-1-methyl-2,4-dioxopyrrolidine (IV) amounted to 0.53 g. Recrystallization from ethanol gave 0.42 g. (59.7 %) of IV as white needles, m.p. 204–206°. Further recrystallization from benzene raised the melting point to 206–208°. It gave an intense blue coloration with the ferric chloride solution; ν_{max}^{KBr} 3285, 1661, 1630, and 1330 cm.$^{-1}$; $\lambda_{max}^{H_2O}$ 266 mμ (log ε 3.85).

Anal. Calcd. for $C_7H_{10}N_2O_3$: C, 49.40; H, 5.92; N, 16.46; mol. wt., 170.17. Found: C, 49.77; H, 6.10; N, 16.42; mol. wt., 181.1.

The 2,4-dinitrophenylhydrazone of IV was prepared by the standard procedure. The crude brown product was recrystallized from tetrahydrofuran as orange-yellow prisms, m.p. 224–225° dec.

Anal. Calcd. for $C_{13}H_{14}N_6O_6$: C, 44.57; H, 4.03; N, 23.99. Found: C, 44.56; H, 3.94; N, 23.69.

3-Acetamido-4-methoxy-1-methyl-2-oxo-3-pyrroline.—From 200 mg. of IV and an excess of an ether solution of diazomethane, 200 mg. (92.4%) of crude 3-acetamido-4-methoxy-1-methyl-2-oxo-3-pyrroline, m.p. 203–212°, was obtained. Crystallization from chloroform–carbon tetrachloride gave colorless prisms, m.p. 209–211°.

Anal. Calcd. for $C_8H_{12}N_2O_3$: C, 52.16; H, 6.57; N, 15.21. Found: C, 52.34; H, 6.14; N, 15.22.

Acetaldehyde cyanohydrin was prepared by the conventional method.[7] The yield was 60%, b.p. 75–77° (7 mm.), lit.[8] b.p. 79° (25 mm.).

α-Methylaminopropionitrile was prepared by a method similar to that for methylaminoacetonitrile.[9] The yield was 77.3%, b.p. 73–75° (52 mm.).

N-Methylalanine Ethyl Ester.—The hydrochloride of N-methylalanine ethyl ester was prepared by introduction of dry hydrogen chloride below 10°, with vigorous stirring, into a solution of 60.8 g. of α-methylaminopropionitrile in 400 ml. of absolute ethanol until the precipitate of the hydrochloride of α-methylaminopropionitrile initially formed disappeared to give a saturated solution of hydrogen chloride. After removal of ammonium chloride, the reaction mixture was evaporated to dryness under reduced pressure, leaving a light yellow sirup, which crystallized very slowly. Unpurified sirup was converted immediately to a free amino acid ethyl ester. A suspension of the hydrochloride in dry ether was treated with dry ammonia gas until all of the hydrochloride appeared to be replaced by the precipitate of ammonium chloride. After removal of ammonium chloride, the ether solution was evaporated at room temperature and the residue was fractionally distilled to yield 35.7 g. (37.5%) of a colorless liquid, b.p. 79–81° (70 mm.).

N-(α-Acetamido-α-ethoxycarbonylacetyl)-N-methylalanine Ethyl Ester (II).—A solution of 14.3 g. (0.109 mole) of N-methylalanine ethyl ester in 28 ml. of xylene was allowed to react with 47.4 g. (0.218 mole) of diethyl acetamidomalonate in 100 ml. of xylene for 24 hr., as described for I. After completion of the reaction, unchanged diethyl acetamidomalonate was removed by filtration and xylene was distilled. The residual oil was distilled to yield 21.9 g. (66.5%) of a light yellow oil, b.p. 143–145° (0.01 mm.). Redistillation gave an almost colorless oil, b.p. 143° (0.01 mm.), $n^{23}D$ 1.4790.

Anal. Calcd. for $C_{13}H_{22}N_2O_6$: C, 51.64; H, 7.34; N, 9.27. Found: C, 51.83; H, 7.37; N, 9.27.

3-Acetamido-1,5-dimethyl-2,4-dioxopyrrolidine (V).—Cyclization of II was carried out as for the preparation of III. A solution of 0.93 g. (0.040 g.-atom) of sodium and 11.5 ml. of absolute ethanol in 22.4 ml. of dry benzene was treated with a solution of 12.2 g. (0.040 mole) of N-(α-acetamido-α-ethoxycarbonylacetyl)-N-methylalanine ethyl ester in 36.6 ml. of dry benzene. The crude product of V amounted to 6.5 g. Recrystallization from absolute ethanol yielded 4.7 g. (66.2%) of colorless needles, m.p. 186–187°. It gave an intense blue coloration with ferric chloride solution; ν_{max}^{KBr} 3285, 1674, 1630, 1433, 1401, and 1357 cm.$^{-1}$; $\lambda_{max}^{H_2O}$ 268 mμ (log ε 3.76).

Anal. Calcd. for $C_8H_{12}N_2O_3$: C, 52.16; H, 6.57; N, 15.21; mol. wt., 184.19. Found: C, 52.47; H, 6.47; N, 15.32; mol. wt., 221.8.

The 2,4-dinitrophenylhydrazone of V, as orange-red prisms, had m.p. 265–267° dec.

Anal. Calcd. for $C_{14}H_{16}N_6O_6$: C, 46.15; H, 4.43; N, 23.07. Found: C, 46.50; H, 4.21; N, 22.85.

3-Acetamido-1,5-dimethyl-4-methoxy-2-oxo-3-pyrroline.—This was prepared from 500 mg. of V to give 300 mg. of a crystalline product, m.p. 125–145°. Recrystallization from carbon tetrachloride yielded colorless prisms, m.p. 144–145°.

Anal. Calcd. for $C_9H_{14}N_2O_3$: C, 54.53; H, 7.12; N, 14.13. Found: C, 54.35; H, 6.95; N, 14.29.

3-Acetamido-5-carbethoxy-4-hydroxy-1-methyl-2-pyrrolidone (VI, VI').—A solution of 500 mg. (0.00206 mole) of III in 50 ml. of 50% ethanol was shaken with 2.0 g. of Raney nickel at 70° in a hydrogen stream at 1500 lb./in.$^{-2}$ in an autoclave for 1 hr. After cooling, the reaction mixture was diluted with absolute ethanol to 400 ml. and filtered while hot from Raney nickel. The filtrate was evaporated to dryness under reduced pressure. The crystalline residue amounted to 450 mg. and melted at 150–185°. By fractional crystallization from absolute alcohol, 110 mg. of pure white needles (VI), m.p. 215–216°, was obtained; ν_{max}^{KBr} 3315, 1742, 1691, 1638, and 1196 cm.$^{-1}$.

(6) W. D. McPhee and E. Klingsberg, "Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 119.

(7) R. Gaudy, *Org. Syn.*, **27**, 41 (1947).

(8) J. Timmermans and T. J. F. Mattaar, *Bull. soc. chim. Belges*, **30**, 218 (1921).

(9) A. H. Cook and S. F. Cox, *J. Chem. Soc.*, 2336 (1949).

Anal. Calcd. for $C_{10}H_{16}N_2O_5$: C, 49.17; H, 6.60; N, 11.47. Found: C, 48.77; H, 6.81; N, 11.30.

The residue from the combined mother liquor, which amounted to 320 mg., was further fractionally crystallized from chloroform. From a slightly soluble portion, 90 mg. more of VI was obtained. An insoluble portion which mainly consisted of the hydrolyzed product (VII) of VI was not purified. The remaining 170 mg. of a very soluble substance was submitted to fractional crystallization from tetrahydrofuran, which yielded 10 mg. of VI and 100 mg. of its diastereoisomer (VI′), m.p. 208–209°, depressed to 185–195° on admixture with the isomer of m.p. 215–216°; ν_{max}^{KBr} 3315, 1734, 1700, 1640, and 1205 cm.$^{-1}$.

Anal. Calcd. for $C_{10}H_{16}N_2O_5$: C, 49.17; H, 6.60; N, 11.47. Found: C, 49.28; H, 6.85; N, 11.28.

The total yield of VI was 210 mg. and that of VI′ was 100 mg. Thin layer chromatography of VI and VI′ on silica gel was carried out with ethanol–chloroform (1:1 v./v.) as the solvent. The chromatograms were chlorinated by the action of chlorine gas and detected with starch–iodide reagent as violet spots which appeared near each other.

3-Acetamido-4-hydroxy-1-methyl-2-oxo-5-pyrrolidinecarboxylic Acid (VII).—To a suspension of 200 mg. (0.00082 mole) of VI in 0.5 ml. of ethanol, 0.4 ml. of 2 *N* potassium hydroxide solution was added dropwise with agitation. After leaving the solution for 1 day at room temperature, the reaction mixture was diluted with water to 5 ml. and the solution was passed through a column of 10 ml. of Dowex-50 (X2). The column was washed with water until the washings were neutral. The effluent was collected while it was acid. This solution was evaporated to dryness under reduced pressure, leaving 170 mg. of a white crystalline mass. Recrystallization from acetone yielded 100 mg. (47.9%) of colorless plates, m.p. 203–204° dec.

Anal. Calcd. for $C_8H_{12}N_2O_5 \cdot H_2O$: C, 41.02; H, 6.03; N, 11.96. Found: C, 41.37; H, 5.92; N, 12.04.

The anhydrous substance was a hygroscopic solid.

Anal. Calcd. for $C_8H_{12}N_2O_5$: N, 12.96. Found: N, 12.84.

α-Amino-α′-methylamino-β-hydroxyglutaric Acid (VIII).—A solution of 150 mg. of VII in 5 ml. of 6 *N* hydrochloric acid was refluxed for 4 hr. After cooling, the reaction mixture was evaporated to dryness under reduced pressure, leaving a white crystalline mass. The yield, almost quantitative, amounted to 130 mg. By adding excess ethanol to a saturated solution in water and allowing it to stand in a refrigerator, colorless plates, m.p. 228–230° dec., crystallized slowly. Thin-layer chromatography of the derivative on silica gel was carried out with water saturated with phenol as the solvent. The reddish purple spot appeared near the spot of serine with ninhydrin reagent and the reddish orange positive coloration with the Nessler reagent for hydroxyamino acids. These results indicate that the product is a β-hydroxyamino acid.

Anal. Calcd. for $C_6H_{12}N_2O_5 \cdot H_2O$: C, 34.28; H, 6.71; N, 13.33. Found: C, 34.62; H, 6.29; N, 13.03.

The anhydrous substance is hygroscopic.

Anal. Calcd. for $C_6H_{12}N_2O_5$: N, 14.58. Found: N, 14.70.

Reduction of VIII to Glutaric Acid.—A mixture of 140 mg. of VIII and 5 ml. of hydriodic acid (sp. gr. 1.7) was heated at 200–220° in a sealed tube for 4 hr. After cooling, the reaction mixture was diluted with water to 25 ml. The solution was extracted twice with 50 ml. of ether. The ether layer was shaken with a minimum amount of a saturated solution of sodium thiosulfate to remove the dissolved iodine and then washed several times with a small amount of water until the pH of the last washing was about 3. The ether solution was dried over sodium sulfate and evaporated to dryness; the residue was dissolved in a minimum amount of absolute ether. On addition of petroleum ether (b.p. 40–60°) resinous products separated. The decanted solution was evaporated to dryness and the residue was recrystallized from petroleum ether. The yield of the reduction product, m.p. 97–98°, amounted to 5 mg. The melting point of this derivative was not depressed by admixture with authentic glutaric acid. The infrared spectra (KBr) of the two substances were identical and exhibited characteristic peaks at 1702, 1308, and 1210 cm.$^{-1}$.

Acknowledgment.—The author wishes to thank Mrs. Muneo Hiura for the elemental analyses.

Spectral Solvent Shifts. Substituent Effects

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Received September 30, 1963

A number of workers have observed that polar solvents cause shifts of the ultraviolet absorption maxima of aromatic molecules as compared to nonpolar solvents. This effect has been explained on the basis of various solute–solvent interactions in both the ground state and the excited state. Ungnade,[2] Nagakura and Baba,[3] and Baba and Suzuki[4] have emphasized hydrogen bonding and dipole–dipole interactions of the ground state. Bayliss and McRae[5] have considered the importance of dipole moment transitions of the solute molecule in going from ground to excited state, along with orientations of the solvent cage in the ground state and the excited state. Schubert and coworkers[6] also believe that solvation of ground state and excited states is important. They believe red shifts to be caused by greater solvation of excited states than ground states with a resultant increase in dipole moments of the solute molecule. Blue shifts would be caused by highly solvated ground states which tend to hinder excitation. Ungnade[2] has proposed a similar type of solvation to explain these shifts. McRae,[7] Semba,[8] and others have attempted to relate solvent shifts to dielectric constant and index of refraction. However, some solvents, especially dioxane, do not fit the proposed equations.

The present study is an attempt to relate the solvent shifts of substituted benzenes to known proprerties of the solute molecule, in order to evaluate the importance of hydrogen bonding and polarization effects. We have studied a series of *ortho*-, *meta*-, and *para*-substituted nitrobenzenes and have observed the effect of the substituent on the solvent shifts for the ^1L_a and ^1L_b[9] bands of nitrobenzene (primary and secondary bands of Doub and Vandenbelt),[10] when polar solvents are compared to cyclohexane. The polar solvents chosen on the basis of their proton donor–acceptor properties and dielectric constants were dioxane, a proton acceptor of low dielectric constant (2.209); methanol, a proton donor of high dielectric constant (37.5); and 2-propanol, a proton donor of intermediate dielectric constant (15.7). Of the two alcohols, methanol is the stronger acid[11] and hence the stronger proton donor. Substituent groups were chosen on the basis of their potential hydrogen-bonding properties. For the nitrobenzenes, the ^1L_a and ^1L_b bands were found to be symmetrical about the peak and band shapes did

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