promoting the present reaction will be made the subject of further study.

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The Synthesis of Hydroxylysine from the Cyanohydrin of γ-Acetamido-γ,γ-dicarbethoxybutyraldehyde[1]

BY OSCAR TOUSTER

Bergström and Lindstedt[2] and Sheehan and Bolhofer[3] have recently presented degradative evidence which establishes the structure of natural hydroxylysine as α,ϵ-diamino-δ-hydroxycaproic acid. The latter workers also synthesized this amino acid by two routes.[4] The first method was based upon the reduction and hydrolysis of methyl α,ϵ-diphthalimido-δ-keto-DL-caproate, which was originally prepared in several steps from glutamic acid.[3] The second synthesis involved the catalytic hydrogenation of the cyanohydrin of γ-acetamido-γ,γ-dicarbethoxybutyraldehyde[5] in acetic anhydride, followed by hydrolysis and decarboxylation of the reduction product. We have independently synthesized hydroxylysine from this cyanohydrin by a similar procedure, except that crystalline cyanohydrin was employed in our work and the amino acid was isolated in a different manner. The yield of crystalline hydroxylysine was 40%, based on the cyanohydrin. This initial product and material obtained from it by recrystallization in 60% yield gave similar amounts of formaldehyde on reaction with periodate. The identity of the amino acid was established by elementary analyses of its monohydrochloride, monopicrate and dipicrate, by its reaction with periodate to form formaldehyde and ammonia, by its behavior in a new modified ninhydrin test and by paper chromatography.

Experimental

Nine grams of the cyanohydrin of γ-acetamido-γ,γ-dicarbethoxybutyraldehyde[6] was dissolved in 135 ml. of a 3:1 mixture of ethyl acetate and acetic anhydride and hydrogenated for 6 hours at three atmospheres pressure and room temperature, using 0.6 g. of Adams platinum oxide as catalyst. After removal of the catalyst by filtration and removal of solvents by distillation *in vacuo*, the colorless product was dissolved in 70 ml. of concd. HCl and the solution refluxed for 15 hours. The acid was then removed under reduced pressure and an aqueous solution of the residue decolorized with charcoal. Evaporation to dryness yielded 7.2 g. of crude dihydrochloride as a yellow oil which partially crystallized on drying over phosphorus pentoxide.

Three and five-tenths grams of the crude dihydrochloride was dissolved in 60 ml. of hot 95% ethanol and treated with 1.63 ml. of aniline in 5 ml. of 95% ethanol, followed by sufficient water (10 ml.) to prevent oiling out of monohydrochloride. The solution was allowed to stand at room temperature for a short time and then overnight in the refrigerator. The first crop of hydroxylysine monohydrochloride (0.61 g.) was collected by filtration and washed with ethanol. Cooling of the combined mother liquor and washings yielded a considerable amount (0.56 g.) of additional monohydrochloride. The total yield of amino acid, based on cyanohydrin, was 40%. A slightly smaller yield was obtained when pyridine was employed in place of aniline. Recrystallization from twenty volumes of 70% ethanol gave a product which decomposed at 215–220°.[7]

Anal.[8] Calcd. for $C_6H_{15}N_2O_3Cl$: C, 36.27; H, 7.61; N, 14.10. Found: C, 36.65; H, 7.58; N, 14.62; NH_2-N, 14.3.

An orange-yellow monopicrate was prepared by reaction of hydroxylysine with one equivalent of picric acid in aqueous solution. A small amount of light yellow dipicrate also formed. This was separated manually and the monopicrate was then recrystallized from water. It melted at 224–226°.

Anal. Calcd. for $C_{12}H_{17}N_5O_{10}$: C, 36.83; H, 4.38; N, 17.90. Found: C, 37.26; H, 4.25; N, 17.62.

The dipicrate was obtained by using slightly more than two equivalents of picric acid. It melted at 123–125°[9] after recrystallization from water.

Anal. Calcd. for $C_{18}H_{20}N_8O_{17}$: C, 34.85; H, 3.25; N, 18.06. Found: C, 34.97; H, 3.47; N, 17.76.

Synthetic and natural hydroxylysine monohydrochloride showed identical behavior in a new modified ninhydrin test which distinguishes hydroxylysine from other natural amino acids.[10] Using a periodate oxidation procedure in which natural hydroxylysine has been reported to yield ammonia and a 65% yield of formaldehyde as the dimedone condensation product,[11] ammonia and a 59% yield of formaldehyde–dimedone product were obtained from the synthetic preparation. The synthetic and natural amino acids had identical R_f values on paper chromatograms run in phenol–hydrochloric acid and phenol–ammonia systems.[12]

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[1] Supported in part by The Rockefeller Foundation and Nutrition Foundation, Inc., through grants to the Division of Nutrition.

[2] Bergström and Lindstedt, *Arch. Biochem.*, **26**, 323 (1950).

[3] Sheehan and Bolhofer, THIS JOURNAL, **72**, 2469 (1950).

[4] Sheehan and Bolhofer, *ibid.*, **72**, 2472 (1950).

[5] Moe and Warner, *ibid.*, **70**, 3918 (1948).

[6] We are indebted to Dr. O. A. Moe, of General Mills, Inc., Minneapolis, Minn., for a sample of this compound.

[7] Melting points were taken with a Fisher–Johns microblock.

[8] Microanalyses by Clark Microanalytical Laboratory, Urbana, Illinois.

[9] The different melting point behavior observed by Sheehan and Bolhofer[4] was probably due to difference in proportion of racemates or different technique for determining melting point, or both.

[10] An unpublished test of Dr. Francis P. Chinard of Johns Hopkins University. We are indebted to Dr. James Weisiger of the Hospital of the Rockefeller Institute for Medical Research for information regarding this test and for a sample of natural hydroxylysine.

[11] A. P. J. Martin and R. L. M. Synge, *Biochem. J.*, **35**, 309 (1941).

[12] We are indebted to Dr. J. G. Heathcote, Cereals Research Station, St. Albans, Herts, England, for the paper chromatographic comparisons.

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The Solution Absorption Spectrum of Americium

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It has long been observed that the absorption spectra of the trivalent rare earth ions possess a unique sharpness, the structure of the peaks being discernible at room temperature and even in solutions. This phenomenon has also been observed in the case of the electronically analogous actinide elements.

The generally accepted explanation for the origin of the lines in the rare earth spectra is that they result from transitions within the 4f electron shell.

Trivalent europium, the analog of americium, has been shown by absorption spectra and magnetic susceptibility data to have a $4f^6$ electron configuration, a $7F_0$ ground state, and one or more low lying excited levels. Since americium ion probably has a $5f^6$ configuration, it also is expected to have a singlet ground state and one or more low lying excited levels. The following represents the first

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