forces by Butler, Thomson and Maclennan[32] holds, it would follow that the surface area of the methanol or the surface energy of mixing or both diminish with pressure. In other words, the sum of the cohesive energies of alcohol and of water seems to approximate to the adhesive energy of water and alcohol as the pressure increases.

Summary

The specific volumes and compressions of six solutions of resorcinol and fifteen solutions of methanol in water have been measured at 25° and the corresponding apparent and partial quantities computed. The apparent compression of resorcinol varies only slightly with concentration and an equation linear in the square root of its concentration expresses this variation within experimental error. The apparent volumes of resorcinol and the apparent volumes and compressions of methanol in aqueous solutions are certainly not linear functions of the square roots of their concentrations. On the other hand, the curves of the apparent compressions and the apparent volumes of water in methanol solutions against the square root of the concentration of water are S-shaped but have the region of inflection so drawn out that a linear function gives a very fair representation of the data even over the whole concentration range.

Analysis of the effect of concentration on the partial volumes of the components indicates that methanol and resorcinol promote the association of water, thereby differing from most other types of solutes. This effect is correlated with the variation with concentration of other significant properties of these solutions. It is noteworthy that the specific compressions (to 1000 bars) of all solutions of methanol from 0 to 15% are the same as the specific compression of pure water.

New values of the compressions of pure methanol at various pressures up to 1000 bars are given and it is pointed out that these do not agree with values already in the literature.

(32) *Op. cit.*, p. 683.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF ILLINOIS]

Some Reactions of δ-Aminovaleric Acid and its Derivatives

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δ-Aminovaleric acid is closely related to the physiologically important amino acids, arginine, citrulline, ornithine and proline, and seemed to us to be a suitable starting material for the synthesis of these products. However, when an attempt was made to brominate δ-benzoylaminovaleric acid according to the procedure recently described for the corresponding caproic acid derivative,[1] the product obtained was a mixture of the α-bromo-δ-benzoylaminovaleric acid which Fischer and Zemplén have obtained[2] and N-benzoyl-β,β-dibromo-α-piperidone. Likewise, bromination of α-carbomethoxyaminovaleric acid resulted in cyclization to give β,β-dibromo-α-piperidone.[3] It is interesting to note that no such cyclization was observed in the case of ε-benzoylaminocaproic acid, which would have to give a seven-membered ring if this type of reaction were to occur.

Convenient procedures for the production of δ-aminovaleric acid and its benzoyl, carboethoxy and carbomethoxy derivatives have been developed. δ-Ureidovaleric acid has also been prepared and its bromination studied. The product of this bromination has not been identified.

(1) Eck and Marvel, *J. Biol. Chem.*, **106**, 387 (1934).
(2) Fischer and Zemplén, *Ber.*, **42**, 1022 (1909).
(3) Heymons, *ibid.*, **66**, 847 (1933).

Experimental Part

δ-Aminovaleric Acid Hydrochloride.—Cyclopentanonoxime was converted to α-piperidone by the general procedure of Wallach.[4] The details of the procedure are those which have been described for the rearrangement of cyclohexanonoxime.[1] After neutralization of the acid solution, the α-piperidone was extracted with chloroform and distilled. The yields were about 60% of the theoretical amount. The α-piperidone was hydrolyzed to δ-aminovaleric acid hydrochloride by boiling with concentrated hydrochloric acid, and the amino acid hydrochloride was obtained in pure condition by decolorizing the solution with charcoal and evaporating to dryness under reduced pressure. The yield was about 80% of the theoretical amount of a product which melted at 92–94°. It is unnecessary to put the hydrolysis mixture in a sealed tube as described by Wallach.

δ-Benzoylaminovaleric Acid.—This product was obtained in 60% yields by the procedure of Wallach.[4] We

(4) Wallach, *Ann.*, **312**, 171 (1900).

found that, to obtain a product which melted at 105–106°, it was necessary first to isolate the hydrochloride of the amino acid and then benzoylate with benzoyl chloride and sodium hydroxide.

Bromination of δ-Benzoylaminovaleric Acid.—When 10.3 g. of the benzoyl derivative was mixed with 1.4 g. of red phosphorus and brominated with 30 g. of bromine in the manner described by Fischer and Zemplén[2] two products were obtained. The product which was soluble in sodium carbonate was the α-bromo acid which has been previously described and, while it did not crystallize, it did give δ-benzoylornithine, m. p. 256°, when treated with aqueous ammonia.

Another portion (about 1 g.) of the bromination product was alkali insoluble and, after recrystallization from alcohol, this portion melted at 115–116°.

Analysis for nitrogen and bromine indicated that this product was N-benzoyl-β,β-dibromo-α-piperidone.

Anal. Calcd. for $C_{12}H_{12}O_2NBr_2$: N, 3.87; Br, 44.20. Found: N, 4.04; Br, 43.67.

The structure of this product was established by its preparation from N-benzoyl-α-piperidone.[5] To 1 g. of the N-benzoyl-α-piperidone in 10 cc. of dry chloroform was added three drops of phosphorus trichloride and 1.6 g. of bromine. The mixture was allowed to stand under a bright electric light for thirty-six hours, and then worked up in the usual manner for such reactions. The product (0.2 g.) melted at 115°, and showed no depression when mixed with a sample of the material obtained in brominating δ-benzoylaminovaleric acid.

δ-Carbomethoxyaminovaleric Acid.—To a solution of 15.3 g. of δ-aminovaleric acid hydrochloride in 100 cc. of water was added 8 g. of sodium hydroxide and 8.4 g. of sodium bicarbonate. To this cold, well-stirred solution, 9.4 g. of methyl chlorocarbonate was slowly added. After about one hour, the solution was acidified with hydrochloric acid and extracted with four 25-cc. portions of chloroform. The chloroform was removed, and the residue was recrystallized by dissolving in 20 cc. of ethyl acetate. The yield was 3.5 g. (20% of the theoretical amount) of a product melting at 71–72°.

Anal. Calcd. for $C_7H_{13}O_4N$: N, 8.00. Found: N, 7.84.

The carboethoxy derivative was obtained in the same manner by the use of ethyl chlorocarbonate. This product melted at 67–68°.

Anal. Calcd. for $C_8H_{15}O_4N$: N, 7.40. Found: N, 7.98.

Bromination of δ-Carbomethoxyaminovaleric Acid.—To a solution of 2.6 g. of the above carbomethoxy derivative in 25 cc. of chloroform was added 1.34 g. of phosphorus tribromide. A solid separated in about one hour. This was apparently the imide bromide of α-piperidone. When 3 g. of bromine was added, a vigorous reaction occurred, and hydrogen bromide was evolved. At the end of thirty-six hours under a bright light the reaction appeared to be complete. Water (25 cc.) was added, and the excess bromine was destroyed by passing a little sulfur dioxide through the reaction mixture. The chloroform solution was separated, and the solvent evaporated. The residue, after crystallization from alcohol, melted at 170–171°. The yield was 1 g. This product was identical with the β,β-dibromo-α-piperidone previously described by Heymons.[3]

δ-Ureidovaleric Acid.—To a solution of 15.3 g. of δ-aminovaleric acid hydrochloride in 30 cc. of water was added 8.5 g. of potassium cyanate. After a few minutes foaming had ceased, and the mixture was evaporated to dryness on a steam-bath. The residue was then taken up in 100 cc. of hot water, acidified with hydrochloric acid and boiled with charcoal to decolorize the solution. After removing the charcoal by filtration and cooling the solution, the ureido compound separated as white crystals, melting at 178°. The yield was 5 g. (34% of the theoretical amount).

Anal. Calcd. for $C_6H_{12}O_3N_2$: N, 17.50. Found: N, 17.40.

Attempts to brominate this derivative gave an alkali-insoluble compound which was non-crystalline, and which melted, with decomposition, at about 195–215°. It was not identified.

(5) Schotten, *Ber.*, **21**, 2235 (1888).

Summary

The action of bromine and a trace of phosphorus tribromide on δ-benzoylaminovaleric acid, δ-carbomethoxyaminovaleric acid and δ-ureidovaleric acid produces ring closure and bromination to give dibrominated α-piperidone derivatives.

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