150 cc. of sodium-dried xylene and boiled under reflux for one and one-half hours. On cooling, there was deposited 13.2 g. of a gray powder.

On boiling the decomposition product with alcohol, 4 g. of a gray powder, softening at about 259°, remained undissolved. A similar by-product was noted in the preparation of the aniline derivative of phthalaldehyde acid by Fuson's procedure.

The alcoholic solution, after treatment with Norite, on cooling, deposited almost microscopic, colorless needles; m. p., 178°. The aniline derivative of phthalaldehyde acid melted at 176–177°. A mixed melting point showed no depression.

Anal. Subs., 0.3770, 0.3320: 30.35, 30.20 cc. of 0.1016 *N* HCl; 11.10, 12.00 cc. of 0.1328 *N* NaOH. Calcd. for $C_{14}H_{11}O_2N$: N, 6.22. Found: 5.98, 5.94.

Preparation of Phthalaldehyde Acid.—For the preparation of phthalaldehyde acid, 44 g. of the aniline derivative of phthalonic acid, obtained from α-nitronaphthalene, was decomposed as described above. The xylene was decanted as completely as possible, and the residue boiled under reflux with 350 cc. of 10% hydrochloric acid for one and one-half hours. After cooling, the solution was filtered from a small amount of insoluble material and extracted with ether. The ether was evaporated and the residue dissolved in water. After treatment with Norite, the solution was evaporated to dryness, as the attempt to induce crystallization failed. The residue melted at 96° and showed no depression in melting point when mixed with phthalaldehyde acid. The product was free from nitrogen.

Neutral equivalent. Subs., 0.4277, 0.4177: 20.95, 20.59 cc. of 0.1328 *N* NaOH. Calcd. for $C_8H_6O_3$: neut. equiv., 150. Found: 153.7, 152.8.

Summary

It has been shown that in the oxidation of α-nitronaphthalene by potassium permanganate in an alkaline medium, the nitrated ring is attacked.

MORGANTOWN, WEST VIRGINIA

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

A SYNTHESIS OF TAURINE

BY C. S. MARVEL, C. F. BAILEY AND M. S. SPARBERG

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Taurine, 2-amino-ethylsulfonic acid, is of considerable interest to the physiological chemist since it occurs in the tissues of various lower animals and in secretions of the higher animals. In the bile it is found combined with cholic acid as taurocholic acid. The probable source of natural taurine is the amino acid, cystine. This conversion of cystine to taurine has been carried out in the laboratory by Friedmann[1] but it does not furnish a practical method of preparation.

At present the common sources for taurine are ox bile[2] and the large muscle of the abalone.[3] The first source gives a very low yield of the

[1] Friedmann, *Beitr. Phys. Path.*, **3**, 38 (1903).

[2] (a) Hammersten, *Z. physiol. Chem.*, **32**, 456 (1901); (b) Tauber, *Beitr. Phys Path.*, **4**, 324 (1904).

[3] Schmidt and Watson, *J. Biol. Chem.*, **33**, 499 (1918).

product, and large amounts of the starting material must be available if any considerable amount of taurine is needed. The second source is said to be very satisfactory and 74 kg. of the muscles will yield 362 g. of taurine.

Taurine has been synthesized by several methods. Kolbe[4] converted isethionic acid, $HOCH_2CH_2SO_3H$, to 2-chloro-ethylsulfonyl chloride, hydrolyzed this product to 2-chloro-ethylsulfonic acid and obtained taurine from this by the action of aqueous ammonia. However, he was troubled with the separation of the taurine from the ammonium chloride. Anschütz[5] has also used this general method.

Gabriel[6] prepared taurine from ethylene imine and sulfur dioxide and from 2-mercaptothiazoline[7] by oxidation with bromine water. More recently Reychler[8] obtained taurine from bromo-ethylamine and ammonium sulfite. All of these methods require 2-bromo-ethylamine as a starting material and are not really useful for the preparation of any large amount of product.

Auzies[9] reports the preparation of taurine by sulfonation of acetaldehyde with chlorosulfonic acid, followed by the formation first of the aldehyde ammonia, then of the imido compound and finally by reduction to the amino compound. The reactions are quite complex.

Some time ago Kohler[10] mentioned that the sodium salt of 2-bromo-ethylsulfonic acid was easily obtained from ethylene bromide and sodium sulfite. No details of the reaction were given but a statement was made that the compound would be described later. However, a search of the literature has not revealed any further information concerning this compound. This seemed to be a suitable starting point for the synthesis of taurine, so the preparation was studied and found to run very smoothly and in yields of about 80%.

In the first attempts to convert sodium 2-bromo-ethylsulfonate into taurine a method very much like that described by Kolbe[4] was used. 2-Bromo-ethylsulfonyl chloride was prepared and then hydrolyzed to the acid. The sulfonic acid was then treated with aqueous ammonia and after the reaction was complete the taurine separated by crystallization from dilute alcohol which readily held in solution the ammonium bromide produced in the reaction. The yields by this procedure were very low.

It was then found that the sodium salt or the 2-bromo-ethylsulfonic acid could be treated directly with aqueous ammonia to give a mixture

[4] Kolbe, *Ann.*, **122**, 42 (1862).
[5] Anschütz, *Ann.*, **415**, 97 (1918).
[6] Gabriel, *Ber.*, **21**, 2667 (1888).
[7] Gabriel, *Ber.*, **22**, 1153 (1889).
[8] Reychler, *Bull. soc. chim. Belg.*, **32**, 247 (1923).
[9] Auzies, *Chem. Zentr.*, **82** [II], 1433 (1911).
[10] Kohler, *Am. Chem. J.*, **20**, 692 (1898).

of taurine and sodium bromide from which pure taurine could be easily obtained by crystallization from about 80% alcohol. The yield of product is about 40–50%. Undoubtedly, a considerable loss occurs in the separation from the sodium bromide.

The reaction between aqueous ammonia and sodium 2-bromo-ethylsulfonate is much slower than might be predicted from the relative positions of the bromine and the sulfur atoms. Several days are required for the complete conversion of the bromo to the amino compound. This is in accord with the results of Helfrich and Reid,[11] who have shown that oxidation of dichloro-ethyl sulfide to the sulfoxide and sulfone produces compounds with less active chlorine.

Experimental Part

Sodium 2-Bromo-ethylsulfonate.—In a 5-liter flask fitted with a reflux condenser, mechanical stirrer and separatory funnel were placed 615 g. of ethylene dibromide, 1250 cc. of 95% alcohol and 450 cc. of water. The stirrer was started and the mixture was heated to boiling. To the well-stirred, boiling mixture a solution of 125 g. of sodium sulfite (anhydrous salt) in about 450 cc. of water was added through the separatory funnel over a period of about two hours. The solution was boiled under a reflux condenser for two hours after all of the sulfite solution had been added and then the condenser was set for distillation and the alcohol and ethylene bromide were distilled. The remaining water solution was poured into a large evaporating dish and evaporated to dryness on the water-bath. The sodium 2-bromo-ethylsulfonate was extracted from the sodium bromide and unchanged sodium sulfite with 2 liters of boiling 95% alcohol. On cooling the solution, most of the salt crystallized and the mother liquor was used for a second extraction of the residue. The product after one crystallization from alcohol was dried in an oven at 110°; yield, 165–190 g., or 78–90%.

This product may contain as much as 5–8% of sodium bromide, but this does no harm in the subsequent reactions. The amount of sodium bromide can be estimated by titrating a sample of the salt with standard silver nitrate solution.

The concentration of alcohol seems to be fairly important and poorer yields were obtained when it was changed in either direction. The large excess of ethylene bromide is necessary to avoid the formation of the disulfonic acid. By diluting the alcoholic solution distilled after the reaction is finished, it is possible to recover nearly 400 g. of ethylene bromide. The salt is slightly hygroscopic and should be dried in an oven in order to remove the last of the water.

2-Bromo-ethylsulfonyl Chloride.—In a 1-liter round-bottomed flask fitted with a stopper carrying a calcium chloride tube were placed 100 g. of sodium 2-bromo-ethylsulfonate and 100 g. of phosphorus pentachloride. The reaction proceeded quietly and the contents of the flask became semi-fluid. After the reaction seemed to have stopped, the mixture was heated on a steam-bath for about two or three hours to insure complete reaction. It was then cooled thoroughly in an ice-salt mixture and treated with about 500 cc. of ice water to dissolve the salts and decompose any excess of phosphorus pentachloride. The oily layer, consisting of the sulfonyl chloride and considerable phosphorus oxychloride, was separated and distilled under reduced pressure. The yield of light straw-colored product, b. p. 119–121° at 25 mm., was 62–70 g., or 64–71%.

Anal. (Stepanow). Subs., 0.4157: 39.59 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_2H_4O_2ClBrS$: 40.06 cc. D_{20}^{20}, 1.921; n_D^{20}, 1.5242.

[11] Helfrich and Reid, THIS JOURNAL, **42**, 1208 (1920).

The product has a disagreeable odor and is a lachrymator. It hydrolyzes rather easily in the presence of water.

Taurine from 2-Bromo-ethylsulfonyl Chloride.—Thirty-seven g. of the sulfonyl chloride was added to 600 cc. of cold water and allowed to stand until the oily layer disappeared. It was then evaporated under reduced pressure to remove the water and hydrogen chloride. The residue (usually about 25 cc.) was treated with 150 cc. of aqueous ammonia (d., 0.9) and allowed to stand for several days. Then the dark colored solution was boiled with decolorizing carbon (Norite), filtered and evaporated to 10–15 cc., until no odor of ammonia was perceptible. On the addition of 95% alcohol, taurine crystallized; yield, about 3.5 g., or 16%.

Anal. (Kjeldahl). Subs., 1.3706: 10.77 cc. of 1 *N* acid. Calcd. for $C_2H_7O_3NS$: N, 11.2. Found: 11.0.

The Reaction between Sodium 2-Bromo-ethylsulfonate and Aqueous Ammonia.—In order to find out the approximate rate of reaction between sodium 2-bromo-ethylsulfonate and aqueous ammonia, a weighed sample of the dry salt was dissolved in a large excess of aqueous ammonia and from time to time aliquot portions were titrated with standard silver nitrate solution to determine the amount of bromide ion. These experiments indicated that the reaction was about 25% complete in five hours, 60% complete in thirty hours and 90% complete in five days. The reaction did not seem to have proceeded further at nine days, so in subsequent experiments five days were allowed for this reaction.

The reaction between sodium 2-bromo-ethylsulfonate and ammonia might produce taurine and sodium bromide, or the sodium salt of taurine and ammonium bromide. In order to determine which products were produced, some samples of the sulfonic acid salt and ammonia were allowed to stand for five days and then evaporated to dryness. When all of the excess of ammonia had been driven off, the residue was analyzed by the Kjeldahl method. This residue would contain twice as much nitrogen if the sodium salt of taurine and ammonium bromide were formed as it would if taurine and sodium bromide were formed. The actual amount of nitrogen was always somewhat less than that required for the second reaction.

Taurine from Sodium 2-Bromo-ethylsulfonate.—A solution of 110 g. of sodium 2-bromo-ethylsulfonate (containing 5–6% of sodium bromide) in about 2 liters of concd. aqueous ammonia (d., 0.9) was allowed to stand for five to seven days and then evaporated to dryness. The last of the water was removed by heating on a steam-bath. The residue was dissolved in the minimum amount of hot water and, if necessary, treated with decolorizing carbon (Norite). The colorless solution was concentrated to 65–70 cc. and about four volumes of 95% alcohol were added. In a short time taurine mixed with some sodium bromide separated. When crystallization was complete, the crude taurine was collected on a filter and recrystallized by dissolving in hot water and then adding to the solution enough 95% alcohol to give a final concentration of 80% of alcohol. The taurine which then separated was usually free from bromides. However, occasional runs had to be recrystallized four or five times to remove all of the sodium bromide. The yield of pure taurine was 31 to 36 g., or 44–51%.

Summary

Taurine, 2-amino-ethylsulfonic acid, has been prepared in fair yields by converting ethylene bromide to sodium 2-bromo-ethylsulfonate and treating this product with aqueous ammonia.

URBANA, ILLINOIS

[CONTRIBUTION FROM THE DEPARTMENT OF PHARMACOLOGY OF JOHNS HOPKINS UNIVERSITY]

THE INFRA-RED ABSORPTION SPECTRA OF ORGANIC DERIVATIVES OF AMMONIA. V. PRIMARY, SECONDARY AND TERTIARY ALKYL AMINES

BY FREDERICK K. BELL[1]

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Introduction

All of the ammonia derivatives thus far examined in this series of studies[2] contained the aryl group and, with the exception of the phenyl amines and naphthylamine, were of the mixed aryl-alkyl type.

The present communication is concerned with the examination of the purely aliphatic amines. It was hoped that the results of this investigation, in conjunction with those already obtained in the case of the pure aryl amines, would be of assistance in the interpretation of the absorption spectra of the mixed amines previously examined. This expectation has been at least partially fulfilled.

The absorption spectra, between 1.0 and 12.0μ, of three series (*n*-propyl, *n*-butyl and *iso*-amyl) of primary, secondary and tertiary amines are presented and discussed in this communication.

Experimental Part

The same experimental procedure as previously described has been followed in the present work. Since all of the substances examined are liquids, the measurements were made at room temperature. In this connection it appears desirable to mention a precaution which should be taken in the examination of liquids in the open type of absorption cell as employed in this work. Considerable evaporation of the liquid may take place depending, of course, on the boiling point of the liquid in question, and liquid must be added from time to time in the course of the examination. This procedure was found to be necessary in the case of several compounds in the present study.

The specimens of mono-, di- and tri-*n*-propylamine, mono-, di- and tri-*n*-butylamine and mono-, di- and tri-*iso*-amylamine were obtained from

[1] E. R. Squibb and Sons Fellow.

[2] Bell, THIS JOURNAL, (a) **47**, 2192, 3039 (1925); (b) **48**, 813, 818 (1926).