$[\alpha]^{20}_{D}$ 96.6 in water (0.244 g. of substance in 25 cc. of chloroform solution rotated 1.73 to the right in a 2-dm. tube). Successive recrystallizations gave the values 97.1, 96.8 and 96.7 and the value 96.8 is accepted for pure alpha-methylcellobioside. The pure substance melts at 144–145°, tastes faintly sweet and does not reduce Fehling's solution. The crystals which had been dried in a desiccator at room temperature did not lose weight appreciably when kept at 110° in vacuo for four hours.

Anal. Subs., 0.155: CO_2, 0.249; H_2O, 0.096. Calcd. for $C_{13}H_{24}O_{11}$: C, 43.79; H, 6.79. Found: C, 43.5; H, 6.93.

The author expresses his thanks to the International Education Board for the grant of a fellowship which enabled him to carry out this investigation. He also thanks Dr. C. S. Hudson for helpful suggestions.

Summary

Alpha-methylcellobioside has been synthesized through the transformation of the known beta-methylcellobioside hepta-acetate to its new alpha isomer by the action of titanium tetrachloride, followed by de-acetylation. The rotations of the various substances agree in first approximation with the values predicted by Hudson's rules of isorotation and the results indicate that the primary ring in all of them is of the 1,5 type. The titanium tetrachloride transformation yielded along with alpha-methylcellobioside hepta-acetate a second crystalline substance which showed in a pure condition $[\alpha]_D$ 23.8 in chloroform and m. p. 174; it is being studied further.

WASHINGTON, D. C.

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

A SYNTHESIS OF METHIONINE

BY WALLACE WINDUS AND C. S. MARVEL

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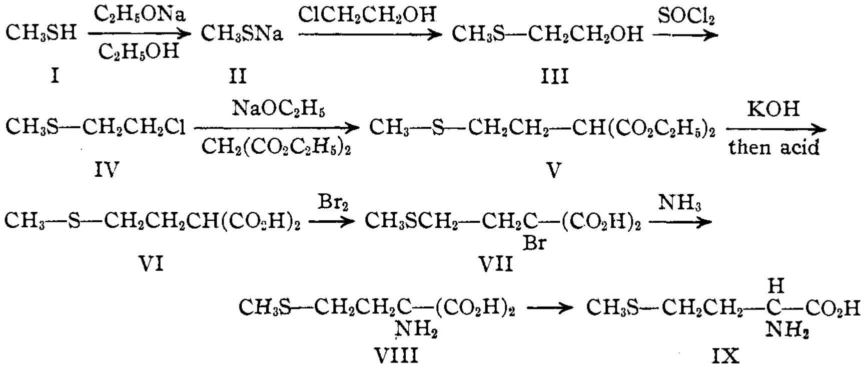
Several years ago Mueller[1] isolated from the hydrolytic products of casein a new amino acid which contained sulfur. He determined its composition and prepared some derivatives. More recently Barger and Coyne[2] have demonstrated that this amino acid was γ-methylthiol-α-amino-*n*-butyric acid and succeeded in synthesizing the racemic compound from methylthiolpropionaldehyde by use of the Zelinsky–Stadnikoff modification of the Strecker method. The yields were not very satisfactory and the starting materials are not readily available.

A new synthesis of this interesting amino acid has been accomplished which seems to be more satisfactory as a method of preparation than the original method of Barger and Coyne. The reactions involved are represented by the following outline

[1] Mueller, *J. Biol. Chem.*, **56**, 157 (1923).

[2] Barger and Coyne, *Biochem. J.*, **22**, 1417 (1928).



$$\underset{\text{I}}{CH_3SH} \xrightarrow[C_2H_5OH]{C_2H_5ONa} \underset{\text{II}}{CH_3SNa} \xrightarrow{ClCH_2CH_2OH} \underset{\text{III}}{CH_3S{-}CH_2CH_2OH} \xrightarrow{SOCl_2}$$

$$\underset{\text{IV}}{CH_3S{-}CH_2CH_2Cl} \xrightarrow[CH_2(CO_2C_2H_5)_2]{NaOC_2H_5} \underset{\text{V}}{CH_3{-}S{-}CH_2CH_2{-}CH(CO_2C_2H_5)_2} \xrightarrow[\text{then acid}]{KOH}$$

$$\underset{\text{VI}}{CH_3{-}S{-}CH_2CH_2CH(CO_2H)_2} \xrightarrow{Br_2} \underset{\text{VII}}{CH_3SCH_2{-}CH_2\underset{Br}{C}{-}(CO_2H)_2} \xrightarrow{NH_3}$$

$$\underset{\text{VIII}}{CH_3S{-}CH_2CH_2\underset{NH_2}{C}{-}(CO_2H)_2} \longrightarrow \underset{\text{IX}}{CH_3S{-}CH_2CH_2{-}\overset{H}{\underset{NH_2}{C}}{-}CO_2H}$$

The preparation of methylthiolethyl chloride (IV) has recently been described by Kirner.[3] It was found more convenient to work with absolute alcohol solutions of sodium methyl mercaptide than to use the ether suspension which Kirner recommended, even though the yields of methylthiolethyl alcohol (III) were somewhat lower when alcohol was used as the solvent. The malonic ester reaction gave a 45% yield. The saponification of the ester and isolation of the dibasic acid ran smoothly and the yields were about 72–73% of the theoretical amount. The dibasic acid was brominated in dry ether and immediately treated with ammonia to reduce to a minimum the chance for addition of the bromo compound to the sulfur atom of the same or another molecule to give complex sulfonium salts. No intermediate products were isolated between the methylthiolethylmalonic acid (VI) and the final methionine (IX). The yield of methionine based on this malonic acid derivative was about 24%.

The product which was obtained agreed in its properties with those reported by Barger and Coyne[2] for their synthetic product.

Experimental Part

Methylthiolethyl Chloride.—Methyl isothiourea sulfate was prepared in 90–95% yield by the method of Arndt.[4] This was hydrolyzed by aqueous alkali[4] and the methyl mercaptan was absorbed in alcoholic sodium ethylate solution. The methyl mercaptan obtained by the hydrolysis of 1120 g. of methyl isothiourea sulfate was absorbed in a solution of 138 g. of sodium in 3 liters of absolute alcohol. The solution was heated to boiling and 524 g. of ethylene chlorohydrin was added from a separatory funnel at such a rate that the solution continued to reflux gently. The mixture was boiled overnight after the ethylene chlorohydrin had been added. Most of the alcohol was distilled and the concentrated solution was centrifuged to remove the sodium chloride. The salt was washed with alcohol and the washings were combined. The alcohol was removed and the methylthiolethyl alcohol was distilled under reduced pressure. The yield was about 221 g. (40% of the theoretical amount) of a product which boiled at 58–68° at 15 mm.

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[3] Kirner, This Journal, **50**, 2446 (1928).

[4] Arndt, *Ber.*, **54**, 2236 (1921).

The alcohol was converted to the chloride by the method described by Kirner[3] in yields of about 60% of the theoretical amount.

Diethyl β-Methylthiolethylmalonate (V).—In a 2-liter three-necked flask fitted with a separatory funnel, a reflux condenser and a mechanical stirrer was placed 600 cc. of absolute alcohol (dried over magnesium methylate) and 30 g. of sodium was added in portions. To the slightly cooled solution of sodium ethylate was added 185 g. of diethyl malonate. Then 145 g. of methylthiolethyl chloride was added from the separatory funnel over a period of three hours. The mixture was boiled under a reflux condenser overnight to complete the reaction. The reaction mixture was then worked up in the usual manner and the malonic ester derivative was distilled under reduced pressure. The yield was 136 g. (45% of the theoretical amount) of a product which boiled at 166–167° at 30 mm. At atmospheric pressure (745 mm.) the product boiled at 275–280°; d_4^{20} 1.081; n_D^{20} 1.4675; M_D, calcd., 59.67; found, 60.57.

Anal. Subs., 0.2012, 0.1656, 0.2028: $BaSO_4$, 0.2064, 0.1686, 0.2063. Calcd. for $C_{10}H_{18}O_4S$: S, 13.67. Found: S, 14.08, 13.98, 13.97.

β-Methylthiolethylmalonic Acid (VI).—Twenty grams of the above ester were added dropwise to a boiling solution of 20 g. of potassium hydroxide in 80 cc. of 90% alcohol. The mixture was boiled under a reflux condenser for three hours. Then 100 cc. of water was added and the alcohol was distilled as completely as possible. The solution was cooled to 0° and made acid to Congo paper by the careful addition of hydrochloric acid. The water solution was extracted with ether several times. The ether layers were evaporated under reduced pressure and the residue dried in a desiccator over phosphorus pentoxide. The dried product was then purified by dissolving it in hot chloroform and adding sufficient petroleum ether to make the solution slightly turbid. On cooling the malonic acid crystallized. It was filtered and dried. There was thus obtained 11 g. (73% of the theoretical amount) of a product which melted at 92–93°. The product began to lose carbon dioxide at about 128°. Titration gave a neutral equivalent of 87 instead of the theoretical 89.

Methionine (IX).—In a three-necked 300-cc. flask fitted with a reflux condenser, a separatory funnel and a mechanical stirrer, was placed a solution of 10 g. of β-methylthiolethylmalonic acid in 100 cc. of anhydrous ether. The stirrer was started and a solution of 9 g. of bromine in 50 cc. of anhydrous ether was added dropwise. The bromination started immediately and proceeded rapidly so that the color of free bromine had disappeared within a few minutes after the last of the solution had been added.

As soon as the bromine color had disappeared, the solution was poured into ten times the theoretical amount of aqueous ammonia in a glass-stoppered bottle. The mixture became warm and was cooled in ice. The mixture was shaken thoroughly to extract all of the bromo acid from the ether layer and was then allowed to stand at ordinary temperature overnight. Longer standing did not improve the yields. The ether layer was separated and discarded as it contained no valuable product. The aqueous solution was evaporated on a steam cone under reduced pressure to a volume of about 50 cc. in order to remove most of the ammonia. The residue was neutralized with a very slight excess of hydrobromic acid and evaporated to dryness. Excess hydrobromic acid had to be avoided as it seemed to destroy the methionine. When no hydrobromic acid was added a very poor yield was obtained.

The residue, which consisted of ammonium bromide and the hydrobromide of the aminomalonic acid derivative, was heated in an oil-bath held at 140° for about three hours. The residue was taken up in water and filtered to remove a little insoluble material. To the solution was added 5 cc. of pyridine and three volumes of hot alcohol. On cooling the methionine separated as white crystals. It was recrystallized by dissolving in water and precipitating with alcohol. By working over the mother liquors there was obtained a total of 2 g. (24% of the theoretical amount) of the desired amino acid. The product melted at 272° (uncorr.) and the picrolonate darkened at 176–179° and melted at 179–180°. Barger and Coyne report the two melting points as 281° and 178°, respectively.

Anal. Subs., 0.1584, 0.1080: $BaSO_4$, 0.2521, 0.1692. Calcd. for $C_5H_{11}O_2NS$ S, 21.5. Found: S, 21.84, 21.51.

Summary

A new synthesis of methionine, γ-methylthiol-α-amino-*n*-butyric acid, has been described.

URBANA, ILLINOIS

COMMUNICATIONS TO THE EDITOR

THE SPECTROSCOPIC DETERMINATION OF THE DECOMPOSITION PRODUCTS OF ORGANIC COMPOUNDS. BENZENE IN THE ELECTRODELESS DISCHARGE

Sir:

An interesting and beautiful phenomenon is observed if benzene vapor at about 0.1-mm. pressure is subjected to the electrodeless discharge. At first a greenish glow appears near the walls of the flask adjacent to the wires. Almost immediately this spreads through the entire flask, turns red, and is extinguished by the resultant decomposition and recombination to form a solid hydrocarbon. This stops the discharge by lowering the pressure. After 40 discharges of this type the walls of the flask are found to be covered by a thin, transparent, amber-colored deposit.

However, if benzene vapor is admitted at just the rate to keep the pressure at a value suitable for the discharge, the glow persists and the accompanying decomposition and synthesis proceed continuously for an hour or more. Thus several thousand liters of the vapor are completely decomposed and quantitatively converted into a reddish-brown flaky powder. This has the same composition as benzene, according to the analysis of Dr. I. E. Muskat, but a much higher molecular weight. The formula is thus $(CH)_n$.

The spectrum, (Fig. 1) indicates that the benzene molecules rapidly decompose into molecules of C_2 and CH, and atoms of C^+ and H. Thus the 5 groups of Swan bands, and a considerable number of the other C_2 bands, as discovered by Deslandres and D'Azambuja, were found, as well as the λ4300 and λ3900 bands of CH. In addition the first four lines of the Balmer series of hydrogen, and the line spectrum of C^+ appeared.

The C_2, CH, C^+ and H seem to combine completely to form the reddish-brown hydrocarbon, as evidenced by the fact that several thousand liters of benzene vapor decompose without giving enough gaseous residue to raise the pressure sufficiently to extinguish the discharge.

The spectra were photographed by Hilger quartz spectrographs, and a