ciable amount of the primary mercaptan formed by simple addition,[2] and secondly, conditions are favorable for the formation of free radicals, through which anti-Markownikoff addition is now assumed to proceed.[3] Dehydrocyclization of the adduct then would lead directly to the principal observed product.

It is also possible to consider styrene as a conjugated diolefin[4] which reacts with hydrogen sulfide by 1,4-addition to form an adduct and then is catalytically dehydrocyclized. In view of the lack of confirmatory data, this is highly speculative, but it has the virtue of an ultimately simpler path, especially if cyclization is effected during the addition under the influence of the catalyst. In a parallel study of the reaction of butadiene and hydrogen sulfide to form thiophene, crotyl mercaptan (which would be formed by 1,4-addition) was isolated in experiments at 400° where the dehydrogenation activity of the catalyst was not sufficiently complete to convert the reactants to thiophene. Approximately equal quantities of thiophene and crotyl mercaptan were obtained in one case. No attempt was made, however, to isolate a corresponding styrene derivative in this investigation.

(2) Barr and Keyes, *Ind. Eng. Chem.*, **26**, 1111 (1934).
(3) Mayo and Walling, *Chem. Rev.*, **27**, 351 (1940).
(4) Alder, *Die Chemie*, **55**, 53 (1942).

Summary

Catalytic dehydrocyclization of styrene and hydrogen sulfide at 600° over FeS/Al_2O_3 catalyst is described, leading to 60% mole conversion to benzothiophene.

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[CONTRIBUTION FROM THE DEPARTMENT OF AGRICULTURAL CHEMISTRY, NORTH DAKOTA AGRICULTURAL COLLEGE AND EXPERIMENT STATION]

An Improved Synthesis of the Selenium Analogs of Methionine and Homocystine[1]

BY HAROLD J. KLOSTERMAN AND EDGAR PAGE PAINTER[2]

A synthesis of amino acids with selenium substituted for sulfur in methionine and homocystine was recently described.[3] The selenium-containing amino acid from which these compounds were prepared was α-amino-γ-(benzylseleno)-butyric acid. The latter compound was prepared by reaction of sodium benzyl selenide with ethyl-α-benzamido-γ-chlorobutyrate. While these steps gave satisfactory yields, the synthesis of ethyl α-benzamido-γ-chlorobutyrate was very time consuming.

The recent paper by Livak, Britton, VanderWeele and Murray[4] describing a new synthesis of methionine from 5-(β-bromoethyl)-hydantoin suggested a better method of preparing α-amino acids with selenium in the γ-position. The compound, 5-(β-bromoethyl)-hydantoin, readily prepared from γ-butyrolactone, reacted with sodium benzyl selenide to give 5-(β-benzylselenoethyl)-hydantoin in a yield of 72%. Saponification of the hydantoin by sodium hydroxide at a temperature of 155° gave α-amino-γ-(benzylseleno)-butyric acid in 85% yield. From the latter compound the selenium analogs of methionine and homocystine were prepared as previously described.[3]

Experimental

5-(β-Bromoethyl)-hydantoin.—This compound was prepared from α-amino-γ-hydroxybutyric acid by the method of Livak, *et al.*,[4] m. p. 141° (uncor.).

Anal. Calcd. for $C_5H_7BrN_2O_2$: N, 13.53. Found: N, 12.49.

While the analysis of our compound, as well as the one of Livak, *et al.*, agrees well with that calculated for the monohydrate (12.44% N) we have been unable to remove a molecule of water by heating in vacuum or recrystallization from organic solvents.

5-(β-Benzylselenoethyl)-hydantoin.—To a solution of 69.5 g. (0.4 mole) of benzyl selenomercaptan[5] in 400 cc. of oxygen-free absolute ethanol, 9.2 g. of sodium was added in small pieces. After the sodium dissolved, a solution of 72 g. of 5-(β-bromoethyl)-hydantoin dissolved in 200 ml. of absolute ethanol was added and the mixture heated for one hour. The solution was cooled to room temperature, 25 ml. of concentrated hydrochloric acid added and then heated to boiling to ensure ring closure. The solvent was removed at reduced pressure and the salt extracted with water.

The residue was dried, then extracted with 2.5 liters of boiling toluene. After cooling in the refrigerator 75 g. of crude 5-(β-benzylselenoethyl)-hydantoin, melting at 101°, a yield of 72%, were obtained. After recrystallization by dissolving a portion of the crude product in boiling water and cooling, fine needles, melting point at 123–124°, were obtained. Recrystallization of this product from toluene did not change the melting point. The recovery by recrystallization from water was about 95% and the nitrogen content remained nearly constant.

Anal. Calcd. for $C_{12}H_{14}N_2O_2Se$: N, 9.43; Se, 26.58. Found: N, 8.95; Se, 25.0.

As is the case with 5-(β-bromoethyl)-hydantoin, the analyses agree better for the monohydrate, 8.89 nitrogen and 25.07% selenium.

α-Amino-γ-(benzylseleno)-butyric Acid.—A solution of 68 g. (0.23 mole) of crude 5-(β-benzylselenoethyl)-hydantoin in 600 cc. of 1.5 *M* sodium hydroxide was hydrolyzed by heating in an autoclave at 155° for thirty minutes. After the solution cooled to room temperature, a small amount of carbon was added and the solution filtered. The α-amino-γ-(benzylseleno)-butyric acid which precipitated when acid was added to a *p*H of 5.5

(1) Published by permission of the Director, North Dakota Agricultural Experiment Station.
(2) Present address: Division of Chemistry, College of Agriculture, University of California, Davis, California.
(3) Painter, THIS JOURNAL, **69**, 232 (1947).
(4) Livak, Britton, VanderWeele and Murray, *ibid.*, **67**, 2218 (1945).
(5) Painter, *ibid.*, **69**, 229 (1947).

contained a small amount of metallic selenium which cleaved as selenide during the hydrolysis. After cooling, the crystals were filtered off, washed with ethanol to remove any unhydrolyzed hydantoin and dried. The yield of crude product was 56 g., 90% of the theoretical.

The crude α-amino-γ-(benzylseleno)-butyric acid was dissolved in 500 ml. of hot water by adding excess hydrochloric acid, clarified with a little carbon, and filtered hot. The compound was precipitated by adjusting the *p*H to 5.5 and cooling. The yield of a compound decomposing at 250° was 52.7 g.

Anal. Calcd. for $C_{11}H_{15}NO_2Se$: N, 5.15; Se, 29.01. Found: N, 5.09; Se, 28.9.

The amino acid, α-amino-γ-(benzylseleno)-butyric acid synthesized by this method has been used to prepare the selenium analogs of methionine and homocystine.[3] By the addition of methyl iodide in the ratio of two moles to one of α-amino-γ-(benzylseleno)-butyric acid after the latter compound was reduced with sodium in liquid ammonia, the selenium analog of methionine was obtained in 80% yields.

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Summary

The compound 5-(β-bromoethyl)-hydantoin was treated with sodium benzyl selenide in ethanol to give 5-(β-benzylselenoethyl)-hydantoin. Hydrolysis of the latter with sodium hydroxide gave α-amino-γ-(benzylseleno)-butyric acid. Reduction of this amino acid with sodium in liquid ammonia yielded the selenium analog of homocysteine; by methylation of the reduced form the selenium analog of methionine is obtained.

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[CONTRIBUTION FROM THE DIVISION OF CHEMISTRY OF THE NATIONAL RESEARCH COUNCIL]

The Alkaloids of *Delphinium Consolida* L.[1]

BY LÉO MARION AND O. E. EDWARDS

As the number of investigations concerning the alkaloids of *Delphinium* species increases, it becomes evident that lycoctonine is of widespread occurrence. Lycoctonine, first found in *Aconitum lycoctonum* L.,[2] has been reported as occurring in *D. Brownii*,[3] *D. elatum* L.[4] and *D. ajacis* L.[5] and it has now been found in *D. consolida* L. in which it is one of the two major alkaloids. Although lycoctonine can be found in the free state it is generally esterified with anthranilic acid. This acid in turn is mostly always combined in the form of an amide with another acid which in the instances known is one of succinic acid,[2] methylsuccinic acid[3,4] or acetic acid.[5] In the present occurrence, however, lycoctonine itself has been isolated as well as anthranoyllycoctonine uncombined with another acid.

The seeds of *D. consolida* L. have been the subject of several contributions. Markwood[6] isolated two alkaloids which he designated delsoline and delcosine and reported the presence of a third crystalline alkaloid for which he gave no analytical figures. Recently, Cionga and Iliescu[7] confirmed the presence of delsoline and delcosine but failed to detect Markwood's third alkaloid. They rejected Markwood's empirical formulas and claimed that the two alkaloids are isomeric, putting forward the obviously incorrect formula $C_{25}H_{40}O_7N$ to represent them.

Besides delsoline and delcosine, the present investigation has revealed the presence of four more alkaloids in the seeds of *D. consolida*. These are lycoctonine, which is the most abundant, anthranoyllycoctonine and two new bases for which the names delsonine and consolidine are suggested. Although delsonine yields a crystalline perchlorate, the base itself is amorphous, but in the presence of boiling alcoholic potassium hydroxide it is converted into a crystalline, apparently isomeric, base which it is suggested to designate as isodelsonine. The last remaining base, consolidine, appears from its melting point to be probably identical with Markwood's third base.[6] When hydrolyzed, consolidine gives rise to one mole of benzoic acid and an amorphous base.

From the previously known delsoline and delcosine and from their salts, analytical figures have been obtained which do not support the claim of Cionga and Iliescu[7] that the two bases are isomeric. The analytical data are in best agreement with the empirical formulas $C_{25}H_{43}O_7N$ for delsoline and $C_{22}H_{37}O_6N$ for delcosine. The formula of delsoline can be expanded to $C_{21}H_{31}O_3N(OCH_3)_4$ and that of delcosine to $C_{19}H_{25}N(OH)_3(OCH_3)_3$. The latter differs by CH_4 from the formula suggested by Markwood[6] for delcosine. Furthermore, whereas Cionga and Iliescu[7] reported the two bases to be levorotatory, we found that although the figures expressing the optical activities are in good agreement with theirs, both delsoline and delcosine are dextrorotatory.

Delcosine absorbed one mole of bromine but the compound formed appeared to be of the nature of a perbromide. When delcosine was acetylated it gave rise to a mixture of two derivatives. The most abundant of the two yielded analytical figures in good agreement with those required by triacetyldelcosine whereas the other appeared to be a compound derived from triacetyldelcosine by

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