from the measurements of Drude [3] and those for acetone-dioxan and acetone-tetrahydrofuran mixtures from a recent communication of Lindberg [4]. It is seen that in acetone-benzene mixtures the plots are linear within the limits of experimental error over the whole range of the mixtures. In acetone-dioxan mixtures there is at 25° a weak deviation from the rectilinear course in the range from pure acetone to 12 % dioxan, but from the values of the rate constant one can conclude that this deviation disappears at 40° and higher temperatures. In acetone-tetrahydrofuran mixtures the number of kinetic data is too small for definite conclusions, but it seems probable that in this solvent system the plot is also linear over the whole range of mixtures.

The slope of the plots shows that in eqn. (1) the last term in the brackets is greater than the sum of the first two terms. This is quite natural, since the final products of the reaction are ionized and, accordingly, it is reasonable to assume that the dipole moment of the transition complex is large. The different slopes of the plots show that the term in brackets has different values for the three solvent systems.

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The Structure and Synthesis of *Cyclo*alliin Isolated from *Allium cepa*

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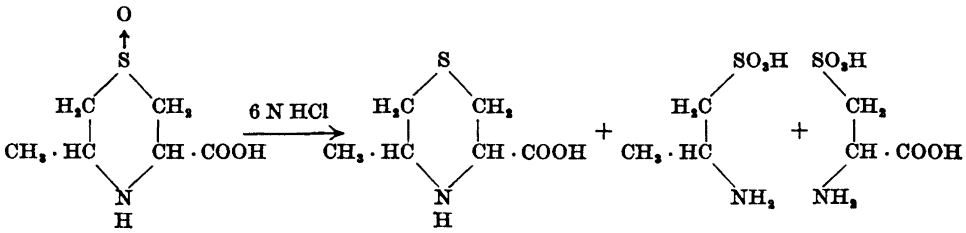
Some years ago we [1] isolated from a 70 % ethanol extract of onion after hydrolysis with 6 N HCl the crystalline hydrochloride of a sulphur-containing amino acid $C_6H_{11}O_3NS \cdot HCl$. Before hydrolysis it was not found in onion. This amino acid could be oxidized by 30 % hydrogen peroxide in glacial acetic acid to the corresponding sulphoxide which was isolated as the crystalline hydrochloride $C_6H_{11}O_4NS \cdot HCl \cdot H_2O$ (Virtanen and Bramesfeld). Because the sulphoxide could be reduced with Raney nickel back to $C_6H_{11}O_3NS$ it was clear that an amino acid sulphoxide and its thioether were in question.

Later on the sulphoxide was found as an original amino acid in onion [2]. The first isolated S-amino acid was obviously formed from the sulphoxide on treatment with strong hydrochloric acid. The amino acid sulphoxide was isolated from a 70 % ethanol extract of onion. The elementary composition of the isolated and recrystallized amino acid hydrochloride corresponded to the formula $C_6H_{11}O_4NS \cdot HCl \cdot H_2O$. (Found: C 31.31 ; H 6.37 ; N 5.90 ; S 13.60 ; Cl 15.20. Calc. C 31.09 ; H 6.09 ; N 6.04 ; S 13.84 ; Cl 15.31.) On spraying with ninhydrin it gives a greenish blue spot, its reduced S-compound a violet one, on the paper chromatogram. The sensitiveness of of the colour reaction of the sulphoxide is about 1/20, and that of the S-compound about 1/10, of that of alanine. R_F-values for the sulphoxide: 0.85 in phenol-NH_3, 0.15 in butanol-acetic acid-water, and for the S-compound: 0.90 in phenol-NH_3, 0.48 in butanol acetic acid-water [2]. Sulphoxide $[\alpha]_D^{20} -17.4°$ (in water).

There is no double bond and also no primary amino group in either of the amino acids. The nitrogen belongs to an imino group. On the basis of these facts and the elementary composition of the substance it should contain a heterocyclic ring.

Detailed investigations of the products formed by heating of the sulphoxide with 6 N HCl at 105°C for 43 h elucidated the structure of this compound. As reduction products the corresponding thioether (II) and as oxidation products 2-aminopropane-1-sulphonic acid (2-methyltaurine) (III) and cysteic acid (IV) were formed. In addition a small spot in the solvent front (phenol), probably an amine, was found on the paper chromatogram (Fig. 1). These results led to structure I for the sulphoxide and structure II for the thioether [3,4].

The elementary composition of compound III corresponded to the formula $C_3H_9O_3NS$. Paper chromatographically it was identical with synthetic 2-methyltauri-



I II III IV

3-Methyl-1,4-thiazane-5-carboxylic acid-1-oxide (*Cyclo*alliin)

3-Methyl-1,4-thiazane-5-carboxylic acid (Thioether of *cyclo*alliin)

2-Aminopropane-1-sulphonic acid (2-Methyltaurine)

Cysteic acid

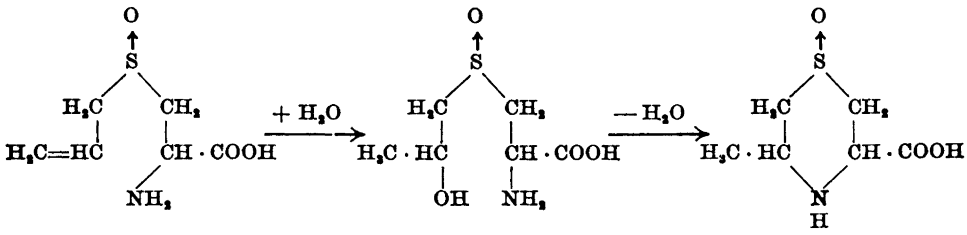
ne which was synthesized from allylamine by the method of Rumpf [4] and separated from salts in an Amberlite IR-120 column. The IR-spectra of the synthetic product and substance III were identical, and hence the formation of 2-methyltaurine as an oxidation product of amino acid I was confirmed.

Cysteic acid was characterized by paper chromatography. Beside these products a red pigment was formed which could be divided into two spots on the paper chromatogram. The chemical nature of these substances is not known yet. Since the oxidation products 2-methyltaurine and cysteic acid do not by far correspond quantitatively to the reduction product, thioether, it is probable that the coloured compounds in question are also oxidation products from *cyclo*alliin.

Because the new amino acid (3-methyl-1,4-thiazane-5-carboxylic acid-1-oxide) which occurs in onion originally has the same elementary composition as alliin, the name *cyclo*alliin is proposed for it [5]. In addition, the biosynthesis of *cyclo*alliin from alliin (V), is possible *e.g.*

The structure of *cyclo*alliin could also be confirmed through the synthesis of 3-methyl-1,4-thiazane-5-carboxylic acid. The way of the synthesis was the following (p. 625).

L-Cystein was used in the synthesis of S-allylcystein. 3 g of S-allylcystein was added to 200 ml of glacial acetic acid and the suspension, saturated with HBr at 0°C, was allowed to stay for 3 1/2 days in a sealed tube. S-Allylcystein then dissolved almost completely. Glacial acetic acid and HBr were distilled off *in vacuo* and pyridine was added to the residue, after which the mixture in a bottle with a reflux condenser was allowed to stay for 4 h in a boiling water bath. Pyridine was removed *in vacuo* and the residue was dissolved into 2.5 N HCl. The amino acids in the solution were then fractionated in a 4.3 × 61 cm column filled with Dowex 50 (200—400 mesh). The resin was in the H-form, in equilibrium with 2.5 N HCl. The dropping rate was about 1 ml/min. Fractions 1 480—2 180 ml contained an unknown amino acid, probably some hydroxyamino acid, which paper-chromatographically differed completely from the thioether of *cyclo*alliin. Fractions 2 530—3 240



V I

$$CH_2{=}CH \cdot CHBr + HS \cdot CH_2 \cdot CH(NH_2) \cdot COOH \rightarrow CH_2{=}CH \cdot CH_2 \cdot S \cdot CH_2 \cdot CH(NH_2) \cdot$$

$$COOH \xrightarrow{HBr} CH_3 \cdot CHBr \cdot CH_2 \cdot S \cdot CH_2 \cdot CH(NH_2) \cdot COOH \xrightarrow{pyridine}$$

$$\underbrace{CH_3 \cdot CH \cdot CH_2 \cdot S \cdot CH_2 \cdot CH}_{NH} \cdot COOH \xrightarrow{H_2O_2} \underbrace{CH_3 \cdot CH \cdot CH_2 \cdot SO \cdot CH_2 \cdot CH}_{NH} \cdot COOH$$

ml contained a compound (RS I) which gave with ninhydrin the same colour as the thioether of *cyclo*alliin. On the paper chromatogram both travelled approximately similarly in butanol-acetic acid-water and phenol-NH_3. These fractions were evaporated to dryness *in vacuo*, the residue was dissolved in water, and HCl was removed in an Amberlite IR-120 column by eluting the amino acid with 500 ml of 1 N ammonia. After evaporation *in vacuo* the amino acid was crystallized for several times from an acetone-water mixture. The yield was 190 mg. Fractions 3 860—5 420 ml again contained a ninhydrin-positive substance (RS II). It was isolated and crystallized in the same way as the former one. The yield was 360 mg. This fraction was coloured with ninhydrin much more strongly than RS I. On the paper chromatogram the substance separated into two spots, when water saturated benzylalcohol-*n*-butanol (1:1) or *tert.*butanol-methylethylketone-formic acid-water (160:160:1:39) were used as solvents. Substance RS II was fractionated in a cellulose powder column (4.5 cm × 70 cm) with water-saturated benzylalcohol-*n*-butanol (1:1). First appeared an amino acid (RS III) which was paper chromatographically in all of the four solvents used identical with the thioether of *cyclo*alliin, and then a somewhat slower travelling amino acid (RS IV). RS III and RS IV were separated from benzylalcohol in an Amberlite IR-120 column by elution with 1 N ammonia and crystallized several times from an acetone-water mixture. RS III in water $[\alpha]_D^{20}$ —50.9°, thioether of *cyclo*alliin —41.3°.

Amino acids RS I, RS III, and RS IV, formed in the synthesis and isolated in crystalline form, had the same elementary composition, $C_6H_{11}O_2NS$ as the thioether of *cyclo*alliin (RS I: Found: C 44.83; H 6.83; S 19.72; N 8.59. RS II (mixture of RS III and RS IV): Found: C 44.71; H 6.90: S 19.43. Calc. C 44.70; H 6.88; S 19.89; N 8.69). When RS III, which on the paper chromatogram behaved exactly as the

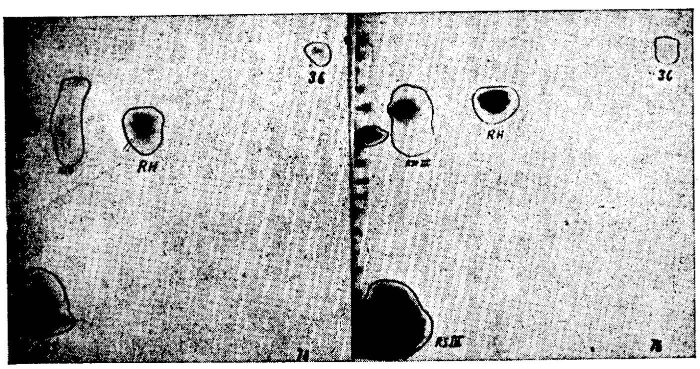


Fig. 1. Two-dimensional paper chromatogram of the products formed from *cyclo*alliin (left) and the sulphoxide of synthetic RS III (right) with 6 N HCl at 105°C for 43 h. Solvents: butanol-acetic acid-water and phenol-NH_3. RSO unchanged *cyclo*alliin, RSO III unchanged sulphoxide of RS III. 36 cysteic acid, RH 2-methyltaurine, RS and RS III thioethers of *cyclo*alliin and the sulphoxide RSO III, respectively. The small spot in the solvent front (phenol + NH_3) near RSO is probably an amine.

thioether of *cyclo*alliin, was oxidized with hydrogen peroxide into the corresponding sulphoxide this gave the same products both quantitatively and qualitatively as *cyclo*alliin with 6 N HCl at 105°C (Fig. 1). Their IR-spectra resembled each other, but were not identical, however.

As mentioned before, RS I travelled somewhat slower than the thioether of *cyclo*alliin on the paper chromatogram. Both were coloured with ninhydrin in the same way. Oxidized into the sulphoxide RS I gave the same products with 6 N HCl in 105°C as *cyclo*alliin. The IR-spectra differed more from each other than did those of *cyclo*alliin and RS III. Also RS IV travelled slower on the paper chromatogram than RS III, its spot was coloured more strongly with ninhydrin than were those of RS I, RS III, and the thioether of *cyclo*alliin. Also RS III is coloured with ninhydrin somewhat stronger than the natural compound. Although a compound which would have had identical IR-spectra with natural *cyclo*alliin resp. its thioether could not be separated from the synthetical products, all the known facts suggest that the three compounds RS I, RS III and RS IV are stereoisomers of the natural compound. The properties of synthetic RS III and the thioether of *cyclo*alliin are in all respects closest in resemblance.

*Cyclo*alliin represents a new type of natural amino acids. It could been found in all parts of the *Allium* species investigated (*A.cepa*, *A.sativum*, *A. porrum*). The highest content of *cyclo*alliin was found in onion imported from Hungary (3.2 g hydrochloride per kg). From a batch of onions cultivated in Finland 1.4 g per kg was isolated.

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