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Studies of Thioacids and Their Derivatives

VII. On 2-Phenyl-4(5H)-Thiazolone

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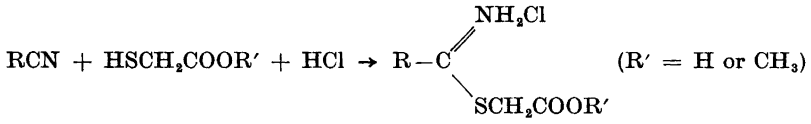
The previously unknown and rather unstable 2-phenyl-4(5H)-thiazolone (I) has been prepared by treatment of carboxymethyl thiobenzimidate hydrochloride or hydrobromide (II) with pyridine. The infrared spectrum of this substance excludes the possibility that it is the isomeric 4-hydroxythiazole. The thiazolone has an unusually high dipole moment (4.1 D). It easily polymerises to a product (III) hitherto considered as the thiazolone. On solution in alkali this polymer depolymerises and therefore gives many of the reactions expected for the monomeric thiazolone. Some remarkable reactions of the thiazolone, expecially the formation of an anhydride (IV) and a condensation product with acetone (V), are described.

As mentioned in paper No. II [1] we have tried to prepare carboxymethyl dithioates from nitriles, *via* the thioimidates formed from nitriles and thioglycollic acid [2] (or methyl thioglycollate):



Several unsuccessful attempts were made to prepare the desired dithioates from these thioimidates by reaction with hydrogen sulfide, at different pH-values, in different solvents and also with liquid hydrogen sulfide. It was found that this lack of success was in part due to the fact that these carboxymethyl thioimidates easily cyclise to thiazolones, so that the dithioates were then successfully prepared from the analogous thioimidates with no hydrogens on the nitrogen atom (*cf.* paper No. II). In connection with this investigation, however, we were able to solve some controversial problems concerning the structures of the substances formed by ring-closure of the thioimidates.

The synthesis of 2-phenyl-4(5H)-thiazolone (I) has been claimed several times in the literature.

Holmberg [3], in 1945, synthesised a product having the same composition as the thiazolone (I), C_9H_7NOS, by treating carboxymethyl thiobenzimidate hydrobromide (II) with hydrochloric acid. The reaction is an intramolecular dehydration, provided the constitution is that of the simple thiazolone (I) as the author assumes. This assumption was based on acid hydrolysis of the thiazolone to benzamide, benzoylthioglycollic acid and thioglycollic acid, and on alkaline degradation to benzonitrile and undefined products.

In 1949 Chabrier, Renard and Smarzewska [4] reported the preparation of what they considered to be the thiazolone (I) from chloroacetic acid and thiobenzamide in toluene at reflux temperature. The product, however, can not be identical with the thiazolone of Holmberg, which was not quoted by the French authors, because the melting points differ by approximately 100°C. We have not been able to confirm the only data given in support of this structure (analyses of N, S).

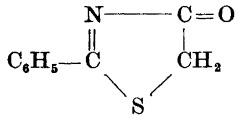
Beyer and Lässig [5] studied the reaction between chloroacetylcyanoacetate and thiobenzamide and obtained a substance which they formulated as the thiazolone (I). For the purpose of identification chloroacetic acid and thiobenzamide were heated together at 100°C and on addition of acetone a hydrochloride was obtained. This was hydrolysed by water, giving a product believed by the German authors to be identical with the product obtained from chloroacetylcyanoacetate and thiobenzamide. When the reaction between chloroacetic acid and thiobenzamide took place at higher temperature a product with the composition $C_{18}H_{12}N_2OS_2$ and m.p. 255—257°C was obtained. Beyer and Lässig formulated this as an ether (IVb) formed from two molecules of the thiazolone. No reference was given to previous work and the products were not compared with the products obtained by Holmberg and Chabrier *et al.* From the melting points it seemed, however, plausible that Beyer and Lässig had obtained the same two compounds as Holmberg and Chabrier *et al.*, respectively.

During our experiments, carried out in 1953, it soon became obvious that the simple thiazolone (I) is not identical with any of the products mentioned in the literature, and we came to the following conclusions:

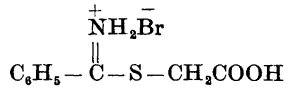
The product of Holmberg is a polymer of the simple thiazolone. Beyer and Lässig may have obtained the same product from thiobenzamide and chloroacetic acid, but this is not certain since the acetone-treatment used by these authors easily results in the formation of a condensation product (V) of acetone with two molecules of the thiazolone, having almost the same melting point as the polymeric thiazolone. In fact, a sample, obtained from Professor Beyer, of a product considered to be the thiazolone (I) was found to have approximately the same composition and infrared spectrum as our acetone derivative. The product of Chabrier *et al.* has the composition $C_{18}H_{12}N_2OS_2$ and is identical with the second product of Beyer and Lässig. We also found that the product of Holmberg is formed when the reaction between thiobenzamide and chloroacetic acid in toluene is carried out at lower concentrations than those used by Chabrier *et al.*

Stepanov [6] in a paper which appeared after the completion of our work came to the same conclusion concerning the composition of the product of Chabrier *et al.* However, in this paper — again without citing Holmberg — a

I. 2-Phenyl-4(5H)-thiazolone: (C_9H_7NOS)

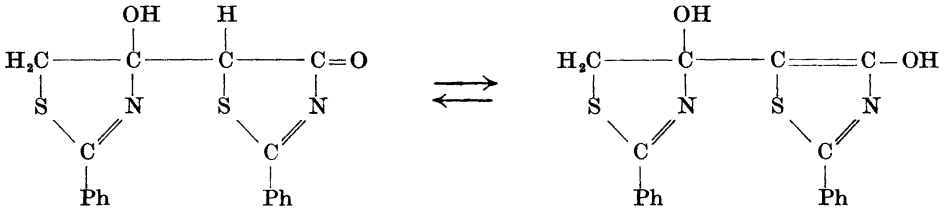


II. Carboxymethyl thiobenzimidate hydrobromide

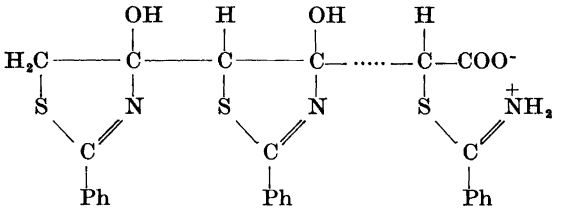


III. "Holmberg's thiazolone": $(C_9H_7NOS)_2$ or $nC_9H_7NOS \cdot H_2O$

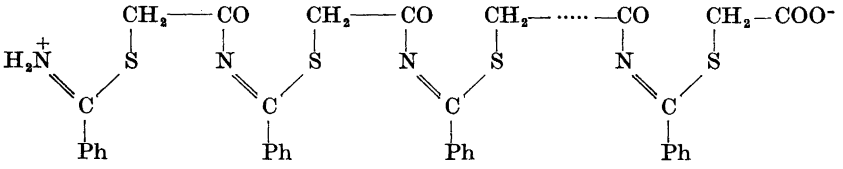
III a.



III b.

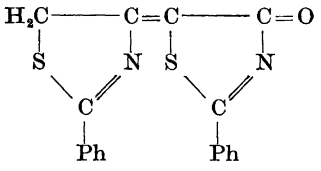


III c.

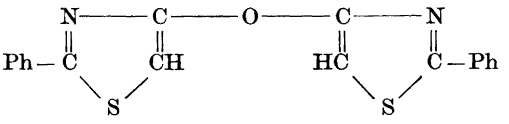


IV "Chabrier's thiazolone": $C_{18}H_{12}N_2OS_2$.

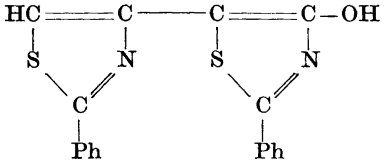
IV a.



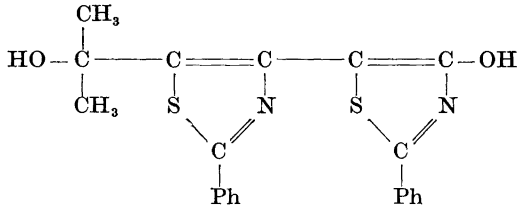
IV b.



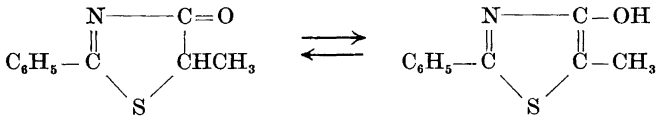
IV c.



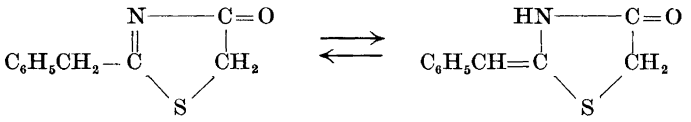
V. "Beyer's thiazolone": $C_{21}H_{18}N_2O_2S_2$.



VI. 2-Phenyl-5-methyl-4(5H)-thiazolone ($C_{10}H_9NOS$).



VII. 2-Benzyl-4(5H)-thiazolone ($C_{10}H_9NOS$).



product with m.p. 160°C, obtained from thiobenzamide and chloroacetic acid or from carboxymethyl thiobenzimidate hydrochloride, was described as a new compound and formulated as the simple thiazolone.

In the following we summarise the evidence for the structure of these compounds.

2-Phenyl-4(5H)-thiazolone

The monomeric thiazolone (I) was first isolated from a crude product formed by melting a mixture of chloroacetic acid and thiobenzamide and stirring the reaction product into water. The solid, which separated, was filtered and extracted with acetone; when the acetone solution was diluted with water a substance separated which yielded analytical values required by the formula C_9H_7NOS, but which in contrast to "Holmberg's thiazolone" was easily soluble in most organic solvents. The compound was then prepared in the pure state in the following way: Carboxymethyl thiobenzimidate hydrobromide or hydrochloride was dissolved in pyridine and after a few minutes the solution was diluted with water. A crystalline product separated and was recrystallised from ethanol. The substance forms well developed yellow crystals and has a rather sharp m.p. 106—108°C. It is easily soluble in organic solvents (ether, benzene, ethanol, chloroform, *etc.*), except light petroleum. A cryoscopical determination of the molecular weight gave figures around 200 (theoretical value 177).

The infrared spectrum of this monomer (*cf.* Table 1 and Fig. 1) shows a very pronounced difference from that of the polymer: It has no bands indicating the presence of hydroxyl groups, but shows the presence both of a C=N

Table 1. Infrared spectra of 2-phenyl-4(5H)-thiazolone and related compounds.

I. 2-Phenyl-4(5H)-thiazolone	3080 w, 2960 w, 2910 w, 1715 s, 1685 vs, 1590 s, 1505 vs, 1500 vs, 1475 vs, 1440 s, 1385 m, 1373 s, 1312 m, 1270 m, 1250 s, 1237 s, 1197 m, 1180 s, 1165 sh, 1120 vw, 1095 vw, 1070 w, 1022 w, 995 w, 952 m, 942 m, 927 w, 880 w, 873 w, 852 m, 792 m, 770 s, 705 w, 685 s, 652 m.
„ hydrochloride	3330 s, 3080 w, 3000 w, 25—2700 br, 1760 vw, 1670 s, 1595 vs, 1495 m, 1485 m, 1440 m, 1400 sh, 1340 w, 1300 sh, 1255 m, 1235 vw, 1170 w br, 995 w, 950 vw, 900 vw, 870 m, 768 s, 750 s, 715 m, 685 s.
„ acetyl derivative	3130 m, 3020 m, 2980 w, 1770 vs, 1710 m, 1650 sh, 1595 vw, 1510 sh, 1495 s, 1458 m, 1440 m, 1365 s, 1320 s, 1305 w, 1245 s, 1190 vs br, 1130 s, 1070 vw, 1020 s, 1005 s, 955 s, 915 m, 880 m, 860 vw, 740 s, 685 s.
„ benzylidene derivative	3000 m, 1710 s, 1600 s, 1575 w, 1530 vs, 1490 m, 1440 m, 1310 m, 1250 s, 1235 m, 1150 vs, 1090 vw, 1065 vw, 1025 vw, 995 w, 930 w, 915 w, 765 vs, 730 w, 705 m, 675 vs.
II. Carboxymethyl thiobenzimidate hydrochloride	3260 m, 3000 s, 2860 s, 2620 w, 2560 w, 2500 m, 2430 m, 1715 s, 1680 m br, 1595 s, 1575 sh, 1500 w, 1480 w, 1445 m, 1410 s, 1380 m, 1325 w, 1305 m, 1275 s, 1202 s, 1160 s, 1120 vw, 1090 vw, 1025 vw, 1000 w, 930 w, 900 m, 860 m, 845 vw, 830 m, 780 s, 705 s, 635 m.
III. "Holmberg's thiazolone"	3160 m, 3060 m, 2940 w, 2600 m br, 1673 vs, 1595 vw, 1565 m, 1510 m, 1485 m, 1440 s, 1410 m br, 1360 w, 1315 w, 1250 m, 1218 w, 1165 m, 1095 vw, 1070 vw, 1055 vw, 1025 vw, 992 w, 975 w, 890 w, 840 w, 790 w, 760 s, 745 s, 710 w, 685 s, 655 sh.
"Holmberg's thiazolone" acetyl derivative	3130 m, 3000 m, 2800 w, 1775 s, 1690 vs, 1630 sh, 1525 s, 1495 w, 1440 m, 1400 sh, 1360 m, 1310 s, 1175 vs, 1050 s, 1000 w, 965 w, 900 w, 860 m, 762 s, 750 s, 715 m, 685 s.
IV. "Chabrier's thiazolone"	3060 w, 2940 m, 2600 br, 1585 s, 1570 sh, 1510 s, 1460 w sh, 1440 s, 1420 s, 1330 vw, 1310 vw, 1270 w, 1237 w, 1180 w, 1155 vw, 1065 s, 1030 w, 1000 w, 975 m, 915 w, 877 w, 815 m, 757 s, 732 m, 685 s, 645 w.
„ acetyl derivative	3090 w, 3030 w, 1765 s, 1620 w, 1595 vw, 1562 m, 1500 w, 1490 s, 1462 m, 1430 m, 1365 m, 1325 m, 1305 vw, 1295 w, 1212 vs, 1190 vs, 1062 s, 1035 w, 1005 w, 975 m, 915 w, 895 vw, 875 m, 820 m, 765 s, 715 m, 685 s.
V. "Beyer's thiazolone"	3060 m, 2940 m, 2600 br, 1715 m, 1590 sh, 1565 s, 1510 s, 1485 w, 1440 sh, 1410 s br, 1365 w, 1312 w, 1245 m, 1200 w, 1170 m br, 1070 m, 1000 w, 965 w, 910 w, 755 s, 712 w, 685 s, 652 w.
VI. 2-Phenyl-5-methyl-4(5H)-thiazolone	3000 w, 2900 w, 2600 m br, 1725 s, 1655 m, 1585 m, 1540 vw, 1505 s, 1490 s, 1440 s, 1398 m, 1370 m, 1310 w, 1250 s, 1175 m, 1125 s, 1100 sh, 1040 vw, 1025 vw. 1000 w, 980 w, 940 m, 770 sh, 765 s, 715 m, 685 s.
VII. 2-Benzyl-4(5H)-thiazolone	3270 w, 3130 w, 3040 m, 2900 m, 2800 m, 1715 vs, 1690 w sh, 1635 s, 1603 w, 1575 vw, 1530 m, 1515 m, 1497 m, 1470 vw, 1455 vw, 1355 s, 1335 sh, 1292 vw, 1235 vw, 1217 m, 1172 w, 1150 m, 1075 vw, 1030 vw, 1010 vw, 990 w, 910 vw, 890 vw, 830 s, 795 w, 740 w, 720 w, 692 w, 680 m.

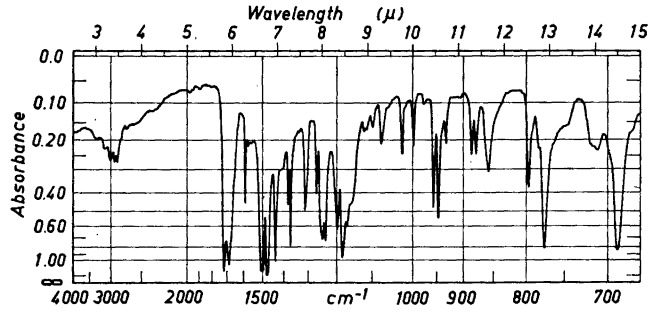


Fig. 1. Infrared spectrum of 2-phenyl-4(5H)-thiazolone.

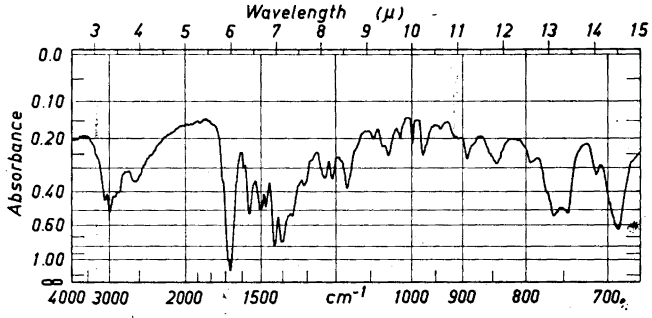


Fig. 2. Infrared spectrum of "Holmberg's thiazolone".

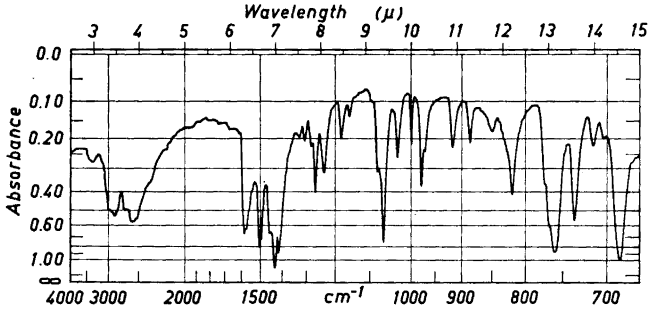


Fig. 3. Infrared spectrum of "Chabrier's thiazolone".

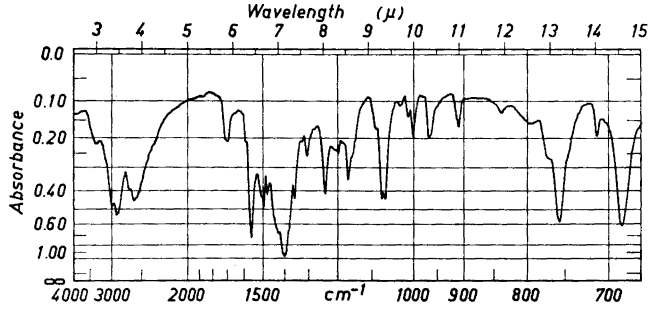
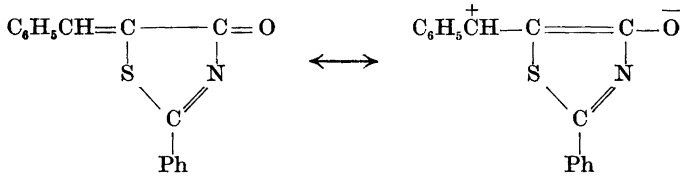


Fig. 4. Infrared spectrum of "Beyer's thiazolone".

group (at 1685 cm^{-1}) and a C=O group (at 1715 cm^{-1}). The assignment of the strong band at 1685 cm^{-1} to a C=N link is strengthened by the fact that oxazolones have C=N bands in almost the same place. Possibly this band is not due specifically to the C=N link, but to the whole conjugated system C=N—C=O. Accordingly the infrared spectrum is in full agreement with the structural formula (I) and excludes the possibility that the thiazolone is the tautomeric 4-hydroxythiazole. However, as discussed below, the compound behaves as a tautomeric substance in alkaline solution.

Small amounts of the thiazolone (I) are obtained by the procedure of Holmberg and of Beyer and Lässig and can be removed by extraction with ether.

The thiazolone diplays methylene reactivity; with benzaldehyde it forms a benzylidene derivative. The infrared spectrum of this compound still shows the C=O band at 1710 cm^{-1}, but the C=N band is missing and there is a strong band at 1530 cm^{-1}, which is thought to be due to a thiazole-ring vibration. This would seem to indicate that the resonance structure with an aromatic thiazole ring is significant for the structure of this compound:



Two bands at 1375 cm^{-1} and 1385 cm^{-1}, found in the spectrum of the thiazolone, are missing in the spectrum of the benzylidene derivative. Therefore these bands are assigned to the CH_2 group. A strong band near 1480 cm^{-1}, on the other hand, is common for the thiazolone and its benzylidene derivative and therefore is not due to the CH_2 group.

By treatment with acetic anhydride the thiazolone forms an acetyl derivative. In contrast to the solid acetates of "Holmberg's thiazolone" and "Chabrier's thiazolone", to be described below, this acetate is a destillable liquid. Its infrared spectrum shows strong acetate bands at almost the same place as the two other acetates (1770 cm^{-1} and 1190 cm^{-1}) and it is therefore certainly an enolacetate and not a C-acetyl derivative. The 1685 cm^{-1} band of the thiazolone has completely disappeared in the spectrum of the acetate (except a shoulder at 1650 cm^{-1}), but the band at 1710 cm^{-1} still persists, although weakened. This is difficult to account for, unless it is assumed that some hydrolysis to the thiazolone has taken place during the recording of the infrared spectrum. Like "Chabrier's thiazolone", which is a thiazole derivative, the acetate of the thiazolone (I) has a strong infrared band at 1510 cm^{-1}, which is assigned to the thiazole ring. Accordingly it seems reasonable to formulate this acetate as the acetate of the tautomeric 4-hydroxythiazole.

The thiazolone is a very weak base, but forms a crystalline hydrochloride; this is formed when hydrogen chloride is led into a solution of the thiazolone in ether. As proved by identity of the infrared spectra the same hydrochloride is also formed by addition of concentrated hydrochloric acid to solutions of the thiazolone in ether, ethanol or acetone; accordingly the presence of water does

not cause ring-opening. On the contrary, carboxymethyl thiobenzimidate hydrochloride or hydrobromide is rapidly transformed at room temperature into the hydrochloride or hydrobromide of the thiazolone. The product formed by melting chloroacetic acid and thiobenzamide together according to Beyer and Lässig is in fact the hydrochloride of the thiazolone, as shown by comparison of the infrared spectra. Whereas the salts of the thiobenzimidate yield a clear solution in water the salts of the thiazolone are hydrolysed almost completely by water and a precipate consisting of the thiazolone and its polymer separates. The simplest way to prepare the thiazolone is probably to melt chloroacetic acid and thiobenzamide together, stir the reaction product into water and extract the thiazolone with ether.

The infrared spectra of the thiobenzimidate hydrochloride or hydrobromide (II) and thiazolone hydrochloride or hydrobromide are very different. The former have a strong band at 1410 cm^{-1}, assigned to the carboxyl group, and a series of rather sharp "amino-acid bands" between 2400 and 2800 cm^{-1}. These bands are missing in the spectra of the thiazolone salts. These show on the other hand a broad band near 2600 cm^{-1}, which is also found in the "thiazolones" (III), (IV) and (V). Its presence in the spectrum of the hydrochloride of the monomeric thiazolone and its disappearance when "Holmberg's thiazolone" or "Chabrier's thiazolone" are converted into acetates clearly indicate that it is due to strong hydrogen bonds of the type $=C=O\cdots H-N<$ or $\gtrless C-O-H\cdots N\lessgtr$. In the spectra of the thiazolone salts the C=O band has almost disappeared, whereas the intensity of the C=N band is undiminished. This might be explained by assuming that the proton is attached to the oxygen atom rather than to the nitrogen atom. This supposition is borne out by the disappearance of the strong 1180 cm^{-1} band when the thiazolone is converted into its hydrochloride. This band is tentatively assigned to C—O stretching. The presence of the C=N band proves that the addition of HCl has not caused isomerisation to the 4-hydroxythiazole.

The thiazolone is rather unstable. After a few days it is only partly soluble in ether; with a moist substance the transformation is even more rapid. The beginning of the transformation is indicated by a depression of the melting point, sintering beginning at about 80°C. Older preparations melt with decomposition in the temperature range 150—165°C. When the freshly prepared, pure thiazolone is treated with boiling water it first melts, and then re-solidifies to a yellow solid, the infrared spectrum of which is indistinguishable from that of "Holmberg's thiazolone".

Accordingly the monomeric thiazolone is easily transformed into "Holmberg's thiazolone", and the reverse reaction has also been experimentally verified. The ultraviolet spectrum of (I) in ethanolic solution exhibits a bathochromic shift by addition of sodium hydroxide, a property displayed by all the substances (I), (III), (IV) and (V), indicating an acid function of these substances (*cf.* Figs. 5, 6, and 7). In alkaline solution the spectra of (I) and (III) are identical, indicating very fast transformation of the polymer into the monomer. At room temperature this reaction is shown to proceed even in neutral solution, at spectroscopical concentrations, as inferred from the ultraviolet spectra (Fig. 8). Upon heating the reaction rate is immensely increased. When an alkaline solution of the polymer is acidified, the substance which

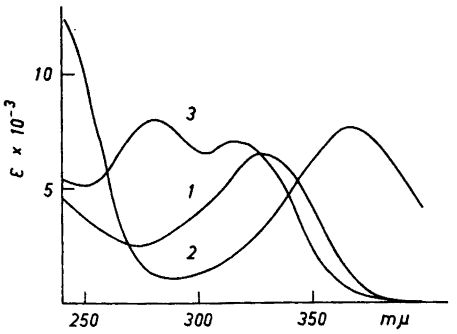


Fig. 5. The depolymerisation of the polymeric thiazolone (III) by alkali in ethanol illustrated by the ultraviolet absorption curves. 1: The polymer; 2: after addition of aqueous KOH; 3: after subsequent addition of HCl in excess.

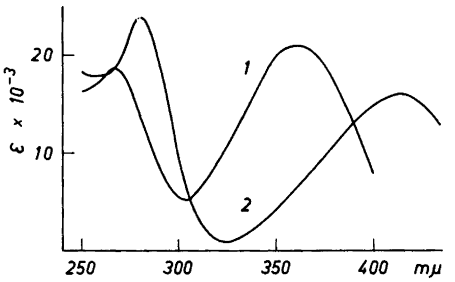


Fig. 6. The bathochromic effect of alkali on "Chabrier's thiazolone" (IV); 1: the ultraviolet absorption curve of IV dissolved in ethanol; 2: after addition of aqueous KOH.

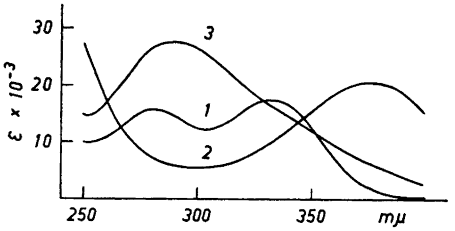


Fig. 7. The disintegration of the acetone adduct (V) by alkali, illustrated by the ultraviolet absorption curves. 1: Acetone adduct (V) in ethanol; 2: after addition of aqueous KOH; 3: after subsequent neutralization with HCl (pH~3).

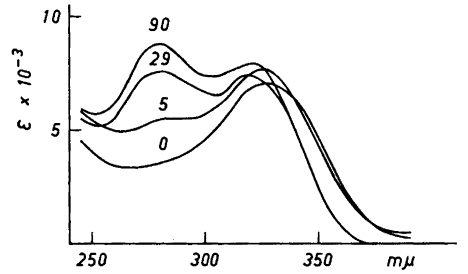


Fig. 8. The depolymerisation of the polymeric thiazolone ("Holmberg's thiazolone") (III) in 96 % ethanol, illustrated by the ultraviolet absorption curves of the polymer 0: immediately after dissolution. 5, 29 and 90: 5 h, 29 h, and 90 h after dissolution. Concentration 10^{-4} M as based on totally depolymerised thiazolone.

separates can be extracted with ether; when the dried ether solution is evaporated *in vacuo* or precipitated with petroleum ether the monomer can be isolated. By evaporation of an moist ether solution at room temperature much of the monomer is again transformed into the ether-insoluble polymer.

The thiazolone has a rather high dipole moment (4.1 Debye), and this may explain the ease with which it undergoes polymerisation. The dipole moment was measured in benzene solution; on standing the clear, yellow benzene solution became turbid because of transformation to the polymer, which is insoluble in benzene.

By addition of ammonia to an alcoholic solution of the thiazolone the compound decomposed with formation of benzonitrile and thioglycollic acid.

No other compounds could be isolated. It should perhaps be mentioned that carboxymethyl thiobenzimidate in aqueous solution rapidly decomposes into benzonitrile and thioglycollic acid, a reaction already studied by Holmberg.

As would be expected the thiazolone does not react as a ketone, *e.g.* towards phenylhydrazine. A characteristic chemical difference between the thiazolone (I) and the "thiazolones" (III), (IV) and (V) is that only the first gives an orange-red colour with diazotised aniline, turning dark red on addition of NaOH. All these compounds couple, however, with diazotised aniline in alkaline solution, the "thiazolones" of Holmberg and Beyer giving dark red solutions whereas "Chabrier's thiazolone" gives a dark green solution. With iron(III) chloride an alcoholic solution of (I) is coloured dark brown and immediately thereafter a yellow-brown precipitate is formed. The only other of the compounds described here, which gives any colour reaction with iron(III) chloride, is 2-phenyl-5-methyl-4-thiazolone, which gives a stable green colour (see later). Both the thiazolone (I) and Holmberg's "thiazolone" give highly coloured yellow solutions by addition of silver nitrate to their alkaline alcoholic solutions; on addition of nitric acid a yellow precipitate, insoluble in excess nitric acid, separates. The "thiazolones" (IV) and (V) and the 5-methylthiazolone give no reaction with silver nitrate. The benzylidene derivative of the thiazolone (I) and carboxymethyl thiobenzimidate give neither of these reactions. The hydrochloride of the thiazolone gives the same reactions as the free thiazolone.

The meaning of the coupling-reactions is clear: Only the thiazolone, which contains a methylene group, couples directly, but all the compounds capable of enolisation couple in alkaline solution. The nature of the compounds formed with silver nitrate have, however, not been cleared up, and the structural implications of this reaction are unclear.

"Holmberg's thiazolone"

The formation of the acetone condensation product and of a benzaldehyde condensation product described by Stepanov [6] is in agreement with the assumption that the substance with m.p. ca. 160°C actually is a thiazolone. From analogy considerations of similar ring systems, *e.g.* 2-phenyl-5-imidazolone [7], a substance possessing the structure (I) would be expected to display methylene reactivity. But the properties of Holmberg's thiazolone are not those to be expected for a simple micromolecular substance. It is practically insoluble in all organic solvents except those exhibiting basic properties, *e.g.* pyridine. It is precipitated by addition of ethanol to a concentrated solution in pyridine and can be purified in this way. It is thus obtained as an amorphous or microcrystalline yellow powder; on dilution of the pyridine solution with water it is often precipitated in a colloidal state. Stepanov recrystallised his substance from boiling nitrobenzene, in which it also is only slightly soluble. The identity of the product prepared according to Holmberg and products prepared according to Stepanov was shown by infrared spectra. The same substance is also obtained by the procedure of Beyer and Lässig when the hydrochloride formed from thiobenzamide and chloroacetic acid and precipitated with acetone is filtered at once, hydrolysed with water, dissolved in pyridine and precipitated

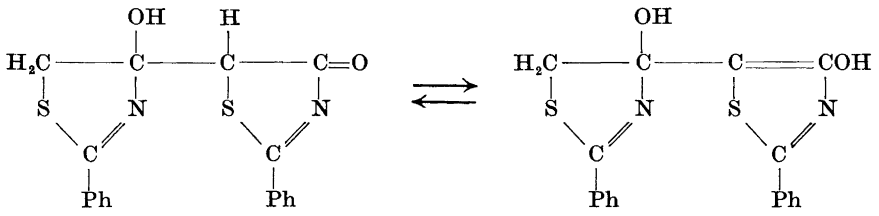
by addition of ethanol. The identity of this product with Holmberg's product, obtained from carboxymethyl thiobenzimidate hydrobromide, was shown both by infrared and ultraviolet spectra. Stepanov gives the melting point 162°, as if the substance had a sharp melting point; in fact destruction points are obtained in the temperature range 157—167°C, usually accompanied by discoloration at lower temperature, depending on the rate of heating (Holmberg: 158—160; Beyer and Lässig: 165—167).

The insolubility and the unsharp melting point strongly suggest that Holmbergs's thiazolone is a polymeric substance, but it has not been possible to determine its molecular weight by melting point depression. In camphor, tetrabromomethane and phenol it was destroyed, and in *p*-toluidine the solubility was insufficient at the melting point. The analyses (C,H,N,S) often show a significant deviation from the formula C_9H_7ONS and are in accord with the formula $nC_9H_7NOS + H_2O$, if $n = 10$ or more. In one of the preparations a value of n as low as 4 accounts for the analyses. Holmberg obtained a product of the composition $C_9H_7NOS \cdot 1/4H_2O$ by dissolving the imidoester hydrobromide in water. The water is not split off upon drying over phosphorus pentoxide.

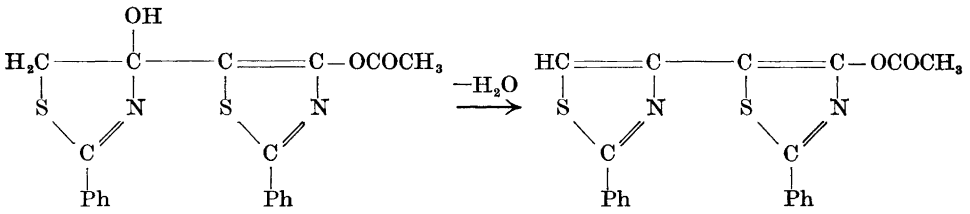
These data are in accord with the assumption that "Holmberg's thiazolone" is a polymer. Several formulae for such a product are possible; it might be an open chain-polymer, a sort of polypeptide (III c), directly derived from the thiobenzimidate, or it might be a polymerisation product derived from the thiazolone (I), either analogous to aldol (III a) or to paraformaldehyde. The infrared spectrum (*cf.* Table 1 and Fig. 2) seems, however, to exclude the latter possibility, since the spectrum shows only weak bands in the C—O—C range, 1100—1300 cm^{-1}; nor does it explain that the compound behaves chemically as a hydroxyl compound. Against the first possibility there are several arguments: The polymer is formed *via* the thiazolone and not directly from the thiobenzimidate, and this formula does not explain the formation of the monomeric thiazolone simply by dissolving the polymer into alkali and acidifying; nor does it explain the close relationship between "Holmberg's thiazolone" and "Chabrier's thiazolone" (see later). The infrared spectrum and the chemical properties of (III) are, however, in agreement with the assumption that (III) is formed by an aldol condensation, if it is assumed that this process is completely reversible. The compound (III) is a hydroxyl compound: Its infrared spectrum has hydroxyl bands at 1410 cm^{-1} and 1250 cm^{-1} and a characteristic broad band near 2600 cm^{-1}, which is also found in the spectra of the compounds (IV) and (V) and of the hydrochloride of the monomeric thiazolone. As mentioned above this band must be due to hydroxyl groups forming strong hydrogen bands, probably between O and N. This band disappears when compound (III) is acetylated. The acetyl derivative has the composition of a monoacetate of the dimer $(C_9H_7NOS)_2$. Stepanov prepared an acetate of (III) and considered it to be identical with the acetate of "Chabrier's thiazolone". However, the two acetates differ both analytically and in their reaction with diazotised aniline, giving a red and a green azo-compound, respectively. The two compounds have, however, the same m.p., because the acetate of (III) gives off water on heating and is converted into the acetate of (IV).

The polymerisation is accompanied by a disappearance of the C=O band in the infrared spectrum with retention of the C=N band; some preparations still show a weak C=O absorption, indicated as a shoulder on the C=N band.

The simplest formula which explain these data is that of the dimer (III a), provided that this enolises to a hydroxythiazole:



The acetate would then be derived from the latter formula and the relationship between the acetates of (III) and (VI) would be the following:



These formulae seem to describe the structure of the acetates correctly. However, the variable and ill-defined character of "Holmberg's thiazolone" suggests that the polymerisation may proceed further than to a dimer. The disappearance of the infrared bands ascribed to the CH_2-group (1385 and 1373 cm^{-1}) when the monomeric thiazolone polymerises points in the same direction. There is some indication that the polymerisation is stopped by addition of water to a terminal thiazolone ring, by which carboxylate and $=NH_2^+$ groups are formed (formula III b). The pronounced absorption bands at 1565 cm^{-1} and 1410 cm^{-1} may, of course, be due to a carboxylate group and the weak band at 3170 cm^{-1} might be due to a $= NH_2^+$ group. This would also account for the deviations from the stoichiometrical formula C_9H_7NOS. That the deviations from this formula are perceptible shows that the polymerisation does not proceed to form molecules with very high molecular weight.

Since the ultraviolet spectra (Figs. 5 and 8) show that the polymer is rapidly depolymerised in solution there is no difficulty in explaining that derivatives of the monomer, such as the benzylidene derivative, or of the dimer, such as the acetate, may be formed with the polymer as starting material.

However, it can not be excluded that "Holmberg's thiazolone" actually is the dimer. Its slight solubility would then be due to strong intermolecular bonds and the infrared band at 1410 cm^{-1} could be ascribed to hydroxyl groups and the band at 1565 cm^{-1} to a thiazole ring. The colloidal nature of some of the preparations obtained from aqueous solution might be explained by a

certain content of highpolymers of the type III b or III c, and the deviations from the stoichiometric formula could be explained by a content of very firmly, but not chemically bond water.

"Chabrier's thiazolone"

The identity of the substances with m.p. ca. 250°C prepared following the procedures of Chabrier *et al.* [4] and of Beyer and Lässig [5] was established by mixed melting points, analyses, infrared spectra and ultraviolet spectra in neutral and alkaline solution. Analyses (C,H,N,S) indicate the composition $C_{18}H_{12}N_2OS_2$, a condensation product of two molecules of the thiazolone (I), as also found by Stepanov [6]. The infrared spectrum (Table 1; Fig. 3) excludes any carbonyl group, no absorption occurring in the range 1600—1800 cm^{-1}, and therefore this compound can not have the structure proposed by Stepanov (IV a). The ether formula (IV b) suggested by Beyer and Lässig is also excluded since the infrared spectrum exhibits absorption at 2600 cm^{-1} and also because the compound is soluble in sodium hydroxide. The infrared spectrum shows a strong band at 1065 cm^{-1}, but this is assigned to a C—H deformation either of the phenyl group or of the thiazole ring and not to a C—O stretching vibration (*cf.* that furan, pyridine and other heterocyclics have strong C—H deformation bands in the same region). The simplest formula compatible with these data seems to be IV c. According to this formula the compound contains a hydroxyl group, which as mentioned above may give rise to the absorption at 2600 cm^{-1}. The compound should further contain two aromatic thiazole rings in which the individual C=C and C=N vibrations have disappeared. Instead, absorptions due to the thiazole ring in the range 1500—1600 cm^{-1}, overlapping the phenyl bands, would be expected. The infrared spectrum shows two strong bands at 1580 cm^{-1} and 1510 cm^{-1}. That the compound contains thiazole rings is also indicated by the absence of the bands ascribed to the CH_2 group in the spectrum of 2-phenyl-4-thiazolone.

In accordance with formula IV c Chabrier's thiazolone forms a monoacetate. The same acetate is formed by elimination of water from the acetate of compound (III). The conditions under which "Chabrier's thiazolone" is formed also suggests that it is formed by elimination of water from "Holmberg's thiazolone". As shown by Stepanov it can be formed by treatment of the latter with concentrated sulfuric acid. On melting, "Holmberg's thiazolone" gives off water, but this is accompanied by a more radical decomposition and only a very small amount of (IV) could be isolated from the melt. Nevertheless, these reactions show that there is a close relation between the two compounds (III) and (IV) and provide strong evidence against the polypeptide formula (III c) for "Holmberg's thiazolone".

The possibility has also been considered that "Chabrier's thiazolone" might be a macromolecular substance. This would be in accordance with the formation of (IV) from "Holmberg's thiazolone" and with its high melting point and slight solubility. The ultraviolet spectra of various preparations also show small differences which might be ascribed to different molecular weights. The analyses, however, agree well with the formula $C_{18}H_{12}N_2OS_2$ and not with a formula $n C_9H_7NS - H_2O$, where n may be higher than 2. Determination of the

molecular weight of "Chabrier's thiazolone" by melting point depression in camphor have given values around 500, which indicate that the compound is strongly associated, but not macromolecular.

Although perhaps not quite conclusive the available evidence strongly supports formula IV c for "Chabrier's thiazolone". No structural evidence could be obtained from degradation experiments.

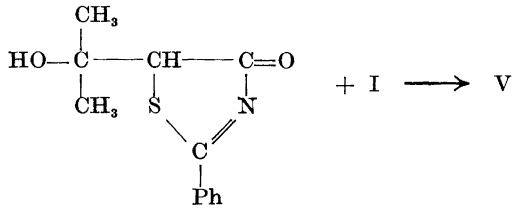
"Beyer's thiazolone"

When the product obtained by melting a mixture of chloroacetic acid and thiobenzamide was treated with acetone according to Beyer and Lässig a substance was isolated which had almost the same m.p. as "Holmberg's thiazolone", but analyses showed it to have the formula $C_{21}H_{18}N_2O_2S_2 = 2C_9H_7NOS + CH_3COCH_3 - H_2O$, strongly indicating the condensation of two molecules of the thiazolone with one molecule of acetone. On hydrolysis with dilute acid it yielded acetone, isolated and identified as the 2,4-dinitrophenylhydrazone. As mentioned, the product formed in the reaction between chloroacetic acid and thiobenzamide at 100°C is the hydrochloride of 2-phenyl-4-thiazolone. The reaction of this with acetone is not rapid; it can even be recrystallised from acetone. On standing with acetone overnight or longer, however, the hydrochloride dissolves and from the solution the acetone-product can be isolated.

The "thiazolone" of Beyer resembles very much the "thiazolone" of Holmberg. It is an amorphous yellow powder, very slightly soluble in most solvents, with unsharp melting point and variable composition. Sometimes the analytical values lie nearer to a formula derived from 3 thiazolone and 1 acetone than to the above mentioned. It must therefore be a more or less polymeric compound similar to (III); it can, however, not be a ketal derived from the polymer (III b) since it behaves chemically as a hydroxyl compound and its infrared spectrum shows no ether bands.

Although very similar to (III) it can easily be distinguished from this because it does not give any reaction with silver nitrate. It also differs from (III) in that the intense band at 1673 cm^{-1} is missing in its infrared spectrum; instead there is a rather weak band at 1715 cm^{-1}. Otherwise its infrared spectrum (*cf.* Table 1 and Fig. 4) is very similar to the spectra of (III) and (IV), especially it shows the characteristic broad band near 2600 cm^{-1}, indicating the presence of hydroxyl groups forming strong hydrogen bands.

These data are in accordance with the structure (V) for "Beyer's thiazolone". The first step in its formation must be an aldol condensation of the thiazolone with acetone giving the following compound, which then reacts with a second molecule of the thiazolone:



Instead of giving a compound analogous to "Holmberg's thiazolone" — which would be expected to exhibit the intense band near 1670 cm^{-1} — a molecule of water is eliminated spontaneously so that a compound analogous with "Chabrier's thiazolone" is formed. The only way to explain the absence of the 1670 cm^{-1} band seems to be to assume that water is eliminated to give a thiazole ring and not an isopropylidene group. It has also been assumed that an isopropylidene group does not link two thiazolone molecules together, since such a compound could hardly give acetone again on hydrolysis, and also because such a structure would exclude further condensation, whereas the analytical values make it plausible that compounds derived from more than two moles of the thiazolone per mole of acetone may be formed. The infrared band at 1715 cm^{-1} may be explained by the presence of such higher condensed compounds (which would contain one or more thiazoline rings) or otherwise by incomplete enolisation of the terminal ring.

We have considered a dozen other possible structural formulae for this compound, but find formula (V) the most plausible. The illdefined nature of this compound makes it very difficult to obtain more definite proof of its structure.

Other 4-thiazolones

Chabrier *et al.* have described some other compounds which they consider to be 4-thiazolones, but their products were high-melting, slightly soluble substances and therefore can not be the true thiazolones. For example 2-benzyl-4-thiazolone is described as a compound with m.p. 229°C, insoluble in organic solvents, but we have prepared 2-benzyl-4-thiazolone (VII) in the same way as the phenylthiazolone and find it to have m.p. 144°C and to be easily soluble in ether, benzene, etc. In a similar way 2-phenyl-5-methyl-4(5H)-thiazolone (VI) was prepared from the thiobenzimidate formed from thiobenzamide and α-bromopropionic acid.

Both these substances show a remarkable difference from the thiazolone (I). Neither of them forms a compound corresponding to "Holmberg's thiazolone". The benzyl derivative is hydrolysed to phenylacetamide by treatment with boiling water, whereas the methyl derivative (VII) is left unchanged by this treatment. The infrared spectrum of (VI) shows the band at 2600 cm^{-1}, ascribed to a thiazole hydroxyl group, and its ethanolic solution is coloured green by iron(III) chloride. This shows that the compound behaves as a hydroxythiazole; but its infrared spectrum still shows the C=O and C=N bands so that it seems that we have to deal with a mixture of tautomers. In the infrared spectrum of the benzyl compound, on the other hand, the C=N band is missing, but there is a band at 1635 cm^{-1}, which may be assigned to a C=C double bond, and a sharp band at 3270 cm^{-1}, which may be due to an NH-group. Accordingly it would seem that this compound has the constitution of a 2-benzylidene-4-thiazolidone rather than that of a 2-benzyl-4-thiazolone.

It has not been possible to prepare thiazolidones with aliphatic substituents in the 2-position. Several attempts were made to cyclise carboxymethyl thioacetimidate hydrochloride or hydrobromide or carboxymethyl thiopropionimidate hydrochloride, both with pyridine and with triethylamine as condensing agents and in the presence of water-binding substances. The reaction was also

carried out under ether, so that any thiazolone formed might at once be removed from the reaction mixture. The only solid substances we were able to isolate were acetamide and propionamide; in addition extensive cleavage of the thiobenzimidate to the nitrile and thioglycollic acid took place.

The carboxymethyl thioimidates are rather unstable. Whereas, however, the thiobenzimidate is transformed into the hydrochloride of 2-phenylthiazolone, the aliphatic thioimidates form highpolymeric substances. They can be kept in a refrigerator for several weeks, but at room temperature they are transformed in a few days into substances which are only partly soluble in water. The solution foams on shaking, indicating the presence of highpolymers. On neutralisation a white solid separates which has approximately the compositions C_4H_5NOS and C_5H_7NOS, respectively. The infrared spectra of the products show a very intense band at 1680 cm^{-1}, which can be ascribed to O=C—C=N groups, but the band at 2600 cm^{-1} is missing. Accordingly these compounds are definitely different from "Holmberg's thiazolone". There is little doubt that in this case we have to do with polymers of the type III c. The compounds are soluble in alkali because of enolisation and these solutions give an intense yellow colour with diazotised aniline. With silver nitrate they give a yellow precipitate, insoluble in nitric acid, just as the thiazolone (I).

In conclusion it may be said that the 4(5H)-thiazolone structure is particularly labile. The corresponding 4(5H)-oxazolones might be expected to be even less stable. No member of this class has so far been reported, and attempts to prepare 2-phenyl-4(5H)-oxazolone in the same way as we prepared the thiazolone (I) were unsuccessful.

EXPERIMENTAL

Carboxymethyl thiobenzimidate hydrobromide (S-Carboxymethyl thiobenzamidium bromide, II). A solution of thiobenzamide (14 g) in hot benzene (150 ml) was mixed with a solution of monobromoacetic acid (14 g) in benzene (50 ml). The crystalline bromide began at once to separate and after 24 h it was filtered and washed with ether. Yield 25 g = 89 %. M.p. 139—142°C (Holmberg: 134—136°C). (Found: Br 28.94; N 5.01. Calc. for $C_9H_{10}BrNO_2S$: Br 28.98; N 5.07).

Instead of benzene, ethyl acetate could be used as the solvent; 17 g of pure product separated directly on cooling and 8 g more could be obtained by concentration of the solution so that the total yield in this case was also about 90 %.

In the same way were prepared:

α-Carboxyethyl thiobenzimidate hydrobromide from thiobenzamide and α-bromopropionic acid in benzene. M.p. 180—182°C after recrystallisation from acetic acid. (Found: Br 28.04; N 5.30. Calc. for $C_{10}H_{12}BrNO_2S$: Br 27.54; N 4.83).

Carboxymethyl thiophenylacetimidate hydrobromide from phenylacethioamide and bromoacetic acid in ethyl acetate. M.p. 155—156°C. (Found: N 4.88. Calc. for $C_{10}H_{12}BrNO_2S$: N 4.83).

Carboxymethyl thioacetimidate hydrobromide from thioacetamide and bromoacetic acid in ether. M.p. 124—125°C. (Found: C 22.22; H 3.83. Calc. for $C_4H_8BrNO_2S$: C 22.44; H 3.76).

From thiobenzamide and α-bromoisobutyric acid only unchanged thiobenzamide could be isolated, confirming the observation by Chabrier *et al.* [4] that thiobenzamide and α-bromoisobutyric acid do not react even on heating.

The hydrochlorides of the carboxymethyl thiobenzimidic esters were prepared from nitriles (benzonitrile, phenylacetonitrile, acetonitrile, propionitrile) and thioglycollic acid [2] since chloroacetic acid reacts very slowly with thioamides.

2-Phenyl-4(5H)-thiazolone (I). 2 g of II was stirred into 5 ml of pyridine; it dissolved with slight heat evolution. After 10 min. the solution was diluted with 25 ml of cold water; an oil separated which soon crystallised. The product was filtered, washed with water, dried at room temperature (yield 1.2 g; 95 %) and recrystallised from 5 ml of ethanol, avoiding prolonged heating. The solution was opalescent, indicating that polymerisation was beginning, and addition of activated carbon was necessary to get a clear solution. On cooling the thiazolone separated as sulfur-yellow leaflets. The yield was only 0.6 g because the compound is rather soluble in ethanol. M.p. 106–108°C. (Found: C 61.05; H 4.07; N 7.83; S 18.19. Calc. for C_9H_7NOS: C 61.00; H 4.00; N 7.91; S 18.07).

This compound has been prepared several times in this way with approximately the same yield. It may also be prepared directly from thiobenzamide and chloroacetic acid:

A mixture of 20.4 g of thiobenzamide and 14.1 g of chloroacetic acid was slowly heated to 100°C and kept at this temperature for 5 min. After cooling the melt was dissolved in 90 ml of acetone; on rubbing light yellow crystals of the hydrochloride of the thiazolone separated. These were filtered, suspended into 500 ml of water and extracted with 3 × 250 ml of ether. Most of the solid dissolved in the ether. The ether solution was dried with Na_2SO_4 and partly evaporated *in vacuo* until crystals began to separate. Then the solution was heated to boiling, filtered and to the filtrate the same volume of light petroleum was added. On standing in a refrigerator the thiazolone crystallised as light yellow crystals. Yield 9.7 g of almost pure thiazolone (m.p. 102–104°C). The filtrate was evaporated to dryness *in vacuo* and left 7 g of the compound III (m.p. 160°C), which was insoluble in ether, *i.e.* polymerisation had taken place during the evaporation.

The polymer may be transformed into the monomer by solution in ethanolic alkali and subsequent acidification, dilution with water and extraction with ether.

The hydrochloride of the thiazolone may be prepared as described above from thiobenzamide and chloroacetic acid. The crystals are dried from acetone *in vacuo* or by washing with ether and recrystallised from acetic acid or dioxan (10–20 ml/g). During recrystallisation the solution should just be heated to boiling. The product obtained is then soluble in acetone. When a solution of the hydrochloride in acetic acid was boiled for 5 min the resulting product was almost insoluble in acetone, having polymerised. On addition of water it gave only "Holmberg's thiazolone", whereas the "acetone-soluble product" as mentioned above gives the monomer as the main product.

Under the microscope the hydrochloride melts at about 105°C with evolution of HCl, solidifies again and then melts at 160–163°C, having been transformed into (III). In a tube the m.p. is found to be somewhat higher (Beyer and Lässig give 123°C, but the m.p. is not well-defined). The hydrochloride is also slowly formed by boiling a solution of thiobenzamide and chloroacetic acid in ethyl acetate or directly from the thiazolone by leading gaseous hydrogen chloride (or simply by adding concentrated hydrochloric acid) to a solution of the thiazolone in ether. It then separates almost quantitatively as light yellow crystals. The identity of all these preparations was shown by identity of their infrared spectra. (Found: N 6.40; Cl 16.59 (and similar values for other preparations). Calc. for C_9H_8ClNOS: N 6.55; Cl 16.60).

The *acetyl derivative* (2-phenyl-4-acetoxythiazole) was prepared by boiling a solution of the thiazolone (2 g) in acetic anhydride (10 ml) for 1 h. No crystallisation took place on cooling as in the case of the compounds (III) and (IV), and after removal of excess acetic anhydride in vacuo a liquid remained. It was distilled *in vacuo* at 15 mm Hg. B.p. 187–189°C. (Found: C 60.10; H 4.11. Calc. for $C_{11}H_9NO_2S$: C 60.25; H 4.14).

The *benzylidene derivative* (2-phenyl-5-benzylidene-4(5H)-thiazolone) was prepared by dissolving 0.5 g of the thiazolone and 0.3 g of benzaldehyde in 10 ml of ethanol and adding a few drops of hydrochloric acid. After one hour the solution was diluted with water and the benzylidene derivative, which separated, was filtered and recrystallised from light petroleum. Yield 0.4 g (50 %). The substance has an intense yellow colour. M.p. 148–150°C. (Found: C 72.20; H 3.94; N 5.27. Calc. for $C_{16}H_{11}NOS$: C 72.44; H 4.18; N 5.28).

The dipole moment was determined by measuring the dielectric constant of a 0.057 M solution of the thiazolone in benzene at 25°C (apparatus: Dipolmeter DM 01 from the Wissenschaftlich-Technische Werkstätten, Weilheim). $\Delta\varepsilon = 0.116$; $\mu = 4.1$ Debye.

"*Holmberg's thiazolone*" (III) was obtained according to Holmberg as a yellow powder by shaking II (1.5 g) with 2 N hydrochloric acid (20 ml) for 3 h. It was washed with warm

acetone and dried *in vacuo*. M.p. 161–164°C (decomp. beginning at 155°C). (Found: C 61.07; H 4.12; N 7.90; S 18.01. Calc. for C_9H_7ONS: C 61.00; H 4.00; N 7.91; S 18.11).

The same substance was formed when a solution of thiobenzamide (5 g) and monochloroacetic acid (3.5 g) in toluene (100 ml) was refluxed for 3 h. The solution was filtered hot and yielded after cooling 1.7 g of a yellow solid which was purified by dissolution in pyridine and precipitation by addition of ethanol, or by recrystallisation from nitrobenzene. The same substance was further obtained when the thiazolone (I; 0.5 g) was suspended in boiling water, in which it melted and soon solidified again. The resulting amorphous yellow solid was filtered and washed with water and ethanol and dried *in vacuo* over over P_2O_5. In contrast to the starting material it was almost insoluble in the usual organic solvents. The identity of these two products with the authentic "Holmberg's thiazolone" was shown both by ultraviolet and infrared spectra.

When the crude product of "Holmberg's thiazolone" is extracted with boiling acetone a yellow solution is obtained; on dilution with water this yields an amorphous yellow product which is insoluble in acetone. The product was isolated by centrifugation, washed with water and acetone and dried over P_2O_5. The ultraviolet spectrum of this product was indistinguishable from the spectrum of "Holmberg's thiazolone", but the analyses corresponded to a formula $nC_9H_8NOS + H_2O$, where $n = 4-6$. (Found: C 59.86; 59.73. H 4.02; 3.95. N 7.48; 7.58).

The acetate of (III) was prepared by dissolving 1 g of (III) in 5 ml of acetic anhydride (warming) and boiling the solution for 1 min. On cooling of the solution in ice and rubbing the acetate separated as light yellow crystals, which were filtered and washed with acetic anhydride and then with ether. M.p. 162–163°C. (Found: C 60.00; H 4.11; N 7.10. Calc. for $C_{20}H_{16}N_2O_3S_2$: C 60.60; H 4.07; N 7.07). In contrast to the acetate of (IV) its ethanolic solution gives a red colour with diazotised aniline.

"*Chabrier's thiazolone*" (IV). A mixture of thiobenzamide (3 g), chloroacetic acid (3 g) and toluene (20 ml) was refluxed for 3 h. Hydrogen chloride and water were formed but the solid did not dissolve completely. The mixture was cooled in a refrigerator for some hours, the solution was decanted off and the solid extracted with boiling toluene (20 ml) and the substance which separated on cooling was recrystallised from toluene. M.p. 238–248°C (decomp.). (Found: C 63.90; H 3.53; N 8.50).

Another product which was purified by dissolution in pyridine and precipitation with ethanol had m.p. 235–250°C and gave the values: C 64.55; H 3.83; N 8.55; S 19.13. Calc. for $C_{18}H_{12}N_2OS_2$: C 64.28; H 3.60; N 8.33; S 19.03.

The same compound (identity proved by infrared spectra) is also obtained when a mixture of thiobenzamide and chloroacetic acid is heated at 130–140°C for ca. 1 h. The reaction product is dissolved in pyridine and precipitated with ethanol. M.p. 248–255°C. (Found: N 8.21; S 19.00).

The acetate of (IV) was prepared by dissolving 1 g of (IV) in 10 ml of acetic anhydride and boiling the solution for 6 min. The crystals which separated on cooling were filtered, washed with ether and recrystallised from acetic anhydride. M.p. 165–166°C. (Found: C 63.20; H 3.86. Calc. for $C_{20}H_{14}N_2O_2S_2$: C 63.30; H 3.70). In contrast to the acetate of (III) its ethanolic solution gives a green colour with diazotised aniline.

"*Beyer's thiazolone*" (*V*). When the reaction product of thiobenzamide and chloroacetic acid was left overnight after addition of acetone, the crystals of the hydrochloride dissolved again. On addition of water an oily product separated which slowly solidified. It was purified by repeated dissolutions in pyridine and precipitation by addition of ethanol. Yield 26 %. Yellow powder which melts unsharply with decomposition at 165–180°C. (Analyses on three preparations: C 64.10; 63.83; 63.83; H 4.63; 4.82; 4.63. N 7.11; 7.13; 7.07. S 16.22; 16.50; 16.05. Calc. for $C_{21}H_{16}N_2O_2S_2$: C 63.95; H 4.60; N 7.10; S 16.24).

2-Phenyl-5-methyl-4(5H)-thiazolone (VI) was prepared in the same manner as (I) with the exception that more ethanol (50 ml to 1 g) had to be used for recrystallisation. The compound has a lighter yellow colour than (I). It is soluble in sodium hydroxide with intense yellow colour. When precipitated from this solution by addition of acid it is almost white; however, as shown by its infrared spectrum it was unchanged. The compound is easily soluble in ether, but on the whole less soluble in organic solvents than (I). M.p. 190–191°C. (Found: C 62.83; H 4.91; N 7.23. Calc. for $C_{10}H_9NOS$: C 62.82; H 4.75; N 7.33).

The compound was not changed on treatment with boiling water.

2-Benzyl-4(5H)-thiazolone (VII). 2.2 g of the corresponding thiobenzimidate hydrobromide were dissolved in 5 ml of pyridine by warming to 40–50°C. After 10 min. the solution was diluted with 50 ml of ice-cold water. The crystalline precipitate was filtered at once and dried in a desiccator. Yield 1 g (70 %). Recrystallised twice from dioxan + light petroleum (1:1). M.p. 142–144°C. (Found: C 62.80; H 4.77; N 7.32. Calc. for $C_{10}H_9NOS$: C 62.82; H 4.75; N 7.33).

On treatment with boiling water the compound is hydrolysed to phenylacetamide.

Infrared spectra.

The spectra were originally recorded on a Beckman IR 2 spectrophotometer but the measurements have later been repeated and extended by use of a Perkin-Elmer model 21 double beam infrared spectrophotometer with NaCl optics and the Perkin-Elmer "Infracord" spectrophotometer – the latter instrument mainly being used for comparison and identification of different samples. The KBr disc technique was used (300 mg of KBr mixed with about 1 mg of the sample), except in the case of the liquid acetate of the thiazolone (I) which was measured in a 10 % solution in carbon tetrachloride.

The spectra display a number of strong or medium strong bands which can be assigned to the phenyl group, for example for the thiazolone (I) the bands at 3040, 1590, 1500, 1440, 1180, 852, 770, 685, and 652 cm^{-1}. The bands which are relevant for the structural problems have been discussed in the text.

The main part of this investigation was completed in 1953. We thank Dr. A. Kjær for valuable help during this part of the work. Before publication most of the experimental work has been checked and in certain respects extended, *i.a.* by the preparation of pure 2-phenyl-4(5H)-thiazolone and the other monomeric thiazolones. We thank Mr. Hans Härter for competent technical assistance during this work. Especially the infrared spectroscopical work has been much extended by means of more modern equipment and has served to corroborate (and on a few points to change) our original conclusions.

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