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Cleavage of Some Derivatives of 2-Mercaptobenzothiazole *

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In the presence of alkali 2-hydroxyethylthiobenzothiazole is cleaved with the formation of 2-hydroxybenzothiazole and ethylene sulphide polymer. 2-Ethylthiobenzothiazole and 2-carboxymethylthiobenzothiazole are cleaved analogously, but the reactions are much slower. With ammonia 2-hydroxyethylthiobenzothiazole also yields 2-hydroxybenzothiazole, but the reaction is very slow. With hydrazine hydrate all three sulphides yield 2-hydrazinobenzothiazole and the corresponding thiols. The reaction is slowest with the ethyl compound, fastest with the carboxymethyl compound, but also in this case much slower than the alkaline cleavage of 2-hydroxyethylthiobenzothiazole. In acid solution the ethyl compound is stable, but the other two compounds are slowly cleaved to 2-hydroxybenzothiazole and the corresponding thiols.

The exceptional behaviour of 2-hydroxyethylthiobenzothiazole in alkali seems to be due to the intermediate formation of an 1,3-oxathiolane. The reaction thus is analogous to the formation of ethylene sulphide from ethylene oxide and thiocyanate.

In connection with work on corrosion inhibitors derived from 2-mercaptobenzothiazole (I) it was observed that 2-(2-hydroxyethylthio)benzothiazole (II) was cleaved by aqueous alkali with the formation of 2-hydroxybenzothiazole (III) and ethylene sulphide polymer:

(1)

II III

The stability of 2-alkylthio derivatives of benzothiazole towards alkaline reagents or acids has not been reported, so it seemed worth while to investigate, if this type of cleavage is common to various types of such compounds. Sexton [1] observed that on heating above 125°C compound II decomposed according to a similar route giving III and possibly dithian.

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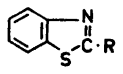


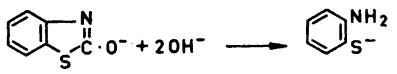
I: R = SH IV: R = SC_2H_5
II: R = SCH_2CH_2OH V: R = SCH_2COOH
III: R = OH VI: R = $NHNH_2$

As representatives of this class of compounds the following substances were chosen: 2-ethylthiobenzothiazole (IV), 2-(2-hydroxyethylthio)benzothiazole (II), and 2-carboxymethylthiobenzothiazole (V). The stability towards alkali, ammonia, and hydrazine was studied and, for comparison, also the behaviour in acid solution.

Reaction with alkali. As a working hypothesis the primary reaction was assumed to follow the scheme (Bt = 2-benzothiazolyl):

$$\underset{\text{II, IV or V}}{Bt{\cdot}SR} + 2\ OH^- \rightarrow \underset{\text{III}}{Bt{\cdot}O^-} + RS^- + H_2O \qquad (2)$$

Hydroxyl ion is consumed during the reaction with the formation of weaker bases, so an attempt was made to follow the progress of the reaction by means of potentiometric titrations of drawn samples. However, hydroxybenzothiazole (III) is not stable towards alkali, but slowly consumes hydroxyl ion with the formation of *o*-aminothiophenol and carbonate [2], so this method was not applicable:

 (3)

Also, in the presence of many bases of partly unknown strength it was difficult to determine the hydroxyl ion with any precision.

Another method is iodimetric titration of the thiol formed. In view of reaction (3) this could only give an upper estimate of the progress of reaction (2). This method was, however, used in the experiments with the ethyl and carboxymethyl compounds (IV and V). In the case of hydroxyethylthiobenzothiazole (II), it is doubtful whether the free thiol is ever formed. The corresponding solid polymer separates from the reaction mixture and was determined gravimetrically, giving a lower estimate of the progress of reaction (2).

All three sulphides were soluble in aqueous ethanol, so comparative experiments were carried out in that solvent at room temperature. Under these circumstances the ethyl and carboxymethyl compounds (IV and V) were practically stable, whereas the hydroxyethyl compound (II) was half decomposed in two hours, Fig. 1.

At higher temperatures, 70—100°, the former compounds were, however, slowly decomposed according to reaction (2). Hydroxybenzothiazole (III) was isolated in poor yield. The ethyl compound (IV) gave ethanethiol, recognised by its odour, and also a small amount of sodium carbonate according to reaction (3). The carboxymethyl compound (V) gave mercaptoacetic acid, identified as its mercaptal with benzaldehyde:

$$C_6H_5CHO + 2\ HSCH_2COOH \rightarrow C_6H_5CH(SCH_2COOH)_2 + H_2O \qquad (4)$$

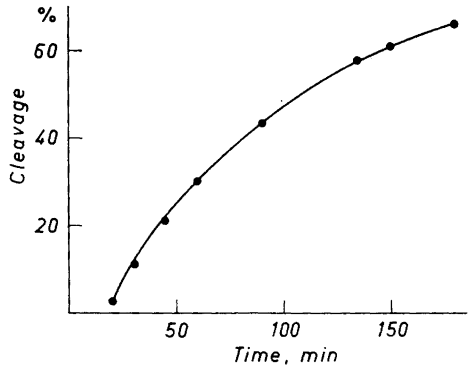


Fig. 1. Cleavage of 2-hydroxyethylthiobenzothiazole (II) by alkali at room temperature. For details see Experimental.

Reaction with ammonia. Experiments were made only with the hydroxyethyl compound (II). At room temperature no reaction was noticeable within a month. At 100° decomposition was observed with the formation of hydroxybenzothiazole (III).

Reaction with hydrazine. All three sulphides reacted analogously with the formation of 2-hydrazinobenzothiazole (VI) and the corresponding thiol:

$$\text{Bt·SR} + \text{H}_2\text{NNH}_2 \rightarrow \text{Bt·NHNH}_2 + \text{RSH} \qquad (5)$$

Comparative experiments showed, that the carboxymethyl compound (V) was cleaved most rapidly, followed by the hydroxyethyl compound (II). Table 1 presents the results of these experiments. The thiols were determined iodimetrically but not otherwise isolated or characterised. In this reaction no insoluble ethylene sulphide polymer was formed.

Reaction with acid. Hydrochloric acid was used in aqueous ethanol. Ethylthiobenzothiazole (IV) was not attacked at room temperature or at 65° whereas the other two sulphides were slowly hydrolised at 65° to hydroxybenzothiazole (III) and the corresponding thiol:

$$\underset{\text{II, V}}{\text{Bt·SR}} + \text{H}_2\text{O} \xrightarrow{\text{H}^+} \underset{\text{III}}{\text{Bt·OH}} + \text{RSH} \qquad (6)$$

Table 1. Hydrazinolysis of 2-benzothiazolyl sulphides.

Substance	Yield in %		M.p. of 2-hydrazinobenzothiazole
	2-hydrazinobenzothiazole	Thiol	
2-Ethylthiobenzothiazole (IV)	11	11	189 – 193°
2-Hydroxyethylthiobenzothiazole (II)	15	29	191 – 195°
2-Carboxymethylthiobenzothiazole (V)	26	31	190 – 192°

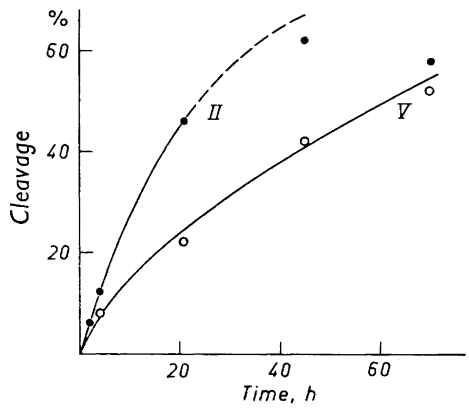


Fig. 2. Cleavage of 2-hydroxyethylthiobenzothiazole (II) and 2-carboxymethylthiobenzothiazole (V) by acid at 65°. For details see Experimental

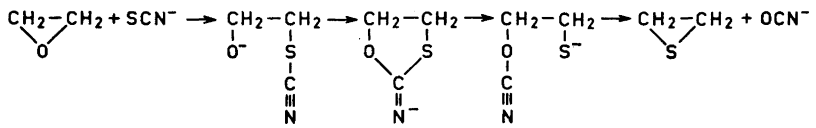
Fig. 2 shows the iodimetrically estimated progress of the reactions. It is likely that the values for the cleavage of 2-hydroxyethylthiobenzothiazole (II) during the later part of the reaction are too small. The mercaptoethanol primarily formed condenses in the acid solution decreasing the amount of titratable mercapto groups.

DISCUSSION

Aliphatic and aromatic sulphides are generally stable towards the rather weak reaction conditions used in this study. The results obtained thus give rise to two questions: (1) Why are 2-alkylthiobenzothiazoles hydrolysed and hydrazinolysed and (2) Why is the hydrolysis of 2-hydroxyethylthiobenzothiazole by alkali, and only by alkali, much faster than the corresponding reactions with 2-ethylthio- and 2-carboxymethylthiobenzothiazole?

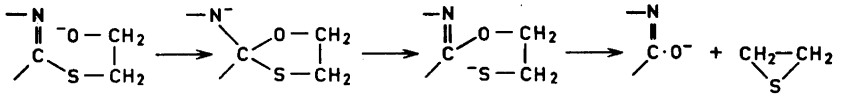
The answer to the first question seems to be that the thiazolylthio group contains a disguised dithiocarbimide group, $-N=C(S-)_2$. Very few simple dithiocarbimides have been described, but the dimethyl and diethyl esters are hydrolysed by alkali [3] just as related derivatives of carbonic acid. The relative stability of the benzothiazolyl sulphides is understandable since the dithiocarbimide group forms part of an aromatic ring system.

The answer to the second question may be found in the rather close analogy of the reaction described with the formation of ethylene sulphide from ethylene oxide and thiocyanate and various other substances containing sulphur. For this reaction the following mechanism seems well founded [4-9]:



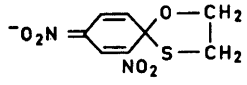
(7)

The analogous scheme is:



(8)

In the alkaline solution the ethylene sulphide is rapidly polymerised. This conclusion is supported by the fact that 2,4-dinitrothioethanol gives an exactly analogous reaction, where the cyclic intermediate is supposed to be [7]:



The rapid cleavage of 2-hydroxyethylthiobensothiazole by alkali is thus conditioned by the formation of an intermediate 1,3-oxathiolane. Ring closure is not possible in the alkaline cleavage of the other two sulphides or in the reactions of all three sulphides with hydrazine or acid and accordingly these reactions are much slower.

EXPERIMENTAL

Melting points are determined with a hot stage microscope and corrected.

2-Hydroxyethylthiobenzothiazole (II). Sexton [1] prepared the compound by alkylating the sodium salt of mercaptobenzothiazole (I) with ethylene chlorohydrin. It was found more convenient to use ethylene oxide. I (66.8 g, 0.4 mole) and sodium hydroxide (20 g, 0.5 mole) were dissolved in 250 ml of water. At 5° ethylene oxide (17.6 g, 0.4 mole) was added and the temperature kept below 25°. The solution rapidly turned turbid and an oil separated. After 30 min the upper, aqueous layer was decanted off and the lower layer was repeatedly washed with water. During this operation the oil solidified. It was crushed, washed on a filter and dried. The raw product (70 g, 83 %) melted at 48—53°. After recrystallisation from benzene-ligroin the m.p. rose to 58—59°. Sexton reports m.p. 56—58°.

2-Ethylthiobenzothiazole (IV). This compound was prepared according to Kendall and Suggate [10]. The yield of product, recrystallised from light petroleum, was 54 %. M.p. 26°. Kendall and Suggate report 26°.

2-Carboxymethylthiobenzothiazol (V). The procedure of Kucherov [11] was closely followed. I (50.1 g, 0.3 mole) was dissolved with sodium hydroxide (24 g, 0.6 mole) in 700 ml of water. Monochloroacetic acid (28.5 g, 0.3 mole) was added in portions. After two days at room temperature the solution was acidified yielding 64.5 g (95 %) of crystalline product, equiv. wt. (titration) 227.3, calc. 225.3, m.p. 154—157°. Kucherov reports 153.5—154°.

Alkaline cleavage of 2-hydroxyethylthiobenzothiazole (II). A preparative experiment was made in the manner described above from 33.4 g of I. However, the raw II was not separated, but the mixture was kept at 100° for 5 h yielding a yellow liquid with a grey-white precipitate. This was filtered off, yield 12.5 g, m.p. 161—164° (Found: S 48.7; OH 1.34. Calc. for C_2H_4S: S 53.34; the sulphur in the precipitate corresponds to 95 % of the mercapto group). Similar properties were reported for ethylene sulphide polymer obtained in other ways [12].

The filtrate on acidification yielded 22.7 g of pale-yellow crystals, recrystallised from benzene, m.p. 136.5—137.5. Hunter [13] for III reports m.p. 138°. (Found: equiv. wt. (titr.) 149.6; N 9.13; S 22.0. Calc. for C_7H_5NOS: equiv. wt. 151.2; N 9.27; S 21.2.)

In a crude *kinetic experiment* a solution 0.5 M with regard to II and 1.5 M with regard to sodium hydroxide was prepared from 5.28 g of II, 15 ml of 5 N NaOH, 5 ml of water and ethanol to a total of 50 ml. The solution was immediately parted in portions of 5 ml, which were left at room temperature. After appropriate times the polymer formed was

filtered off, washed with 80 % aqueous ethanol, dried at room temperature, and weighed. One portion was left for 19 h and yielded 166.6 mg of polymer. For a polymer containing 48.7 % sulphur the theoretical amount is 164.6 mg, so the reaction was considered complete after this time and the conversion calculated on this basis. Fig. 1 gives the results.

Alkaline cleavage of 2-ethylthiobenzothiazole (IV). Crude *kinetic experiments* were made corresponding to those mentioned previously. At room temperature no iodine was consumed by the solution after 68 h and potentiometric titration with hydrochloric acid revealed no formation of weak bases.

When a solution of the same composition was heated in a sealed glass ampoule at 100° the originally homogeneous solution parted in two liquid phases within a few hours. A small amount of crystalline material separated and was identified as sodium carbonate. Ethanethiol was formed, recognised by its odour and its reaction with iodine. Acidification of the reaction mixture yielded a small amount of crystalline material, identified as 2-hydroxybenzothiazole (III), m.p. 136—139°.

Alkaline cleavage of 2-carboxymethylthiobenzothiazole (V). In crude *kinetic experiments*, corresponding to those mentioned previously, practically no iodine was consumed by the solution after 48 h at room temperature.

A *preparative experiment* was carried out at 100°. A solution was made from 17 g (0.075 mole) of V, 60 ml of 5 N NaOH, and water to a total of 100 ml. After 23 h at 100° the solution was acidified, yielding crystals, identified as 2-hydroxybenzothiazole (III), m.p. 136—139°. Extraction of the mother liquor with ether, evaporation, and vacuum distillation of the residue yielded 2.5 g of distillate, b.p.$_{5\cdot5}$ 91—96°. The equiv. wt. on titration with alkali was 98.7, with iodine, 104, calc. for mercaptoacetic acid 92.1. A sample was mixed with an appropriate amount of benzaldehyde and a trace of conc. hydrochloric acid. A crystalline mass resulted, m.p. after recrystallisation from benzene 124—125.5°, equiv. wt. (titration) 136.7, for the mercaptal of mercaptoacetic acid with benzaldehyde calc. 136.1. The m.p. reported [14] is 126—127°.

Reaction of ammonia with 2-hydroxyethylthiobenzothiazole (II). Solutions were made from 2.11 g of II in 8 ml of conc. ammonia and 12 ml of ethanol. After a month at room temperature no change was observed. After 17 h at 100° 0.2 g of precipitate separated on cooling. On acidification the mother liquor yielded 1.2 g of crude 2-hydroxybenzothiazole (III), m.p. after recrystallisation from benzene 134—138°.

Reaction of hydrazine with 2-hydroxyethylthiobenzothiazole (II). A solutions was made from 2.11 g of II in 8 ml of hydrazine hydrate and 12 ml of ethanol. The solution was left 1 month at room temperature. The iodine consumption then corresponded to 52 % reaction. After 16 days crystals began to separate. The final yield of crystals was 0.5 g, m.p. 198—200°, efter two recrystallisations from water. Boggust and Cocker [15] report for 2-hydrazinobenzothiazole m.p. 199.5°. Titration with perchloric acid in glacial acetic acid gave the equiv. wt. 166.8, calc. 165.2.

A similar experiment carried out at 65° for 4 days yielded 0.5 g of the hydrazino compound. The iodine consumption of the mother liquor corresponded to 80 % cleavage.

Comparative experiments with hydrazine. Solutions were made with 10 mmoles of either II, IV or V in 8 ml of hydrazine hydrate and 12 ml of ethanol. After 5 h at 65° each solution was treated as follows. A sample of 1 ml was diluted with ethanol and titrated with 0.1 N iodine. The residue was diluted to 200 ml with water and acidified with 15 ml of conc. hydrochloric acid and cooled with ice water. The precipitated unchanged starting material was filtered off and the filtrate basified with 8 g of sodium hydroxide. Precipitated 2-hydrazinobenzothiazol was recovered and weighed and its m.p. determined. Results are given in Table 1.

Reactions in acid solution. In each experiment 25 mmoles of sulphide, 15 ml of 5 N HCl, 5 ml of water, and ethanol to 100 ml were mixed. The solutions were halfed, one half being kept at room temperature, the other at 65°. Samples were withdrawn at appropriate times and titrated with 0.1 N iodine. The former solutions did not consume any iodine within 8 days and the starting material was recovered unchanged. This was also observed with the solution containing the ethylthio compound (IV) at 65°. In the other two cases the consumption of iodine rose with time, as can be seen in Fig. 2. From the solutions hydroxybenzothiazole was isolated, m.p. and mixed m.p. 136—140°.

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