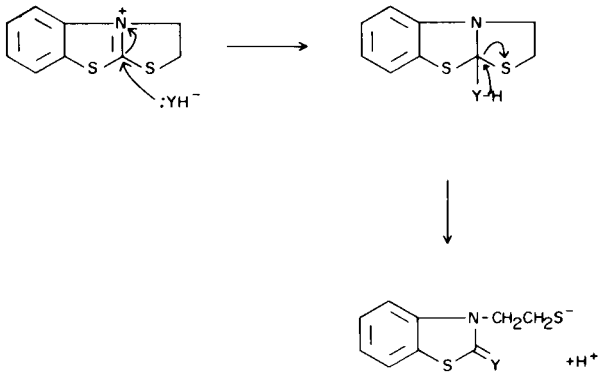
Benzothiazolium Derivatives. III. Nucleophilic Substitution Reactions of Benzothiazolium Salts (1)

Paul Sohar, George H. Denny, Jr., and Robert D. Babson

Merck Sharp & Dohme Research Laboratories, Division of Merck & Co., Inc.

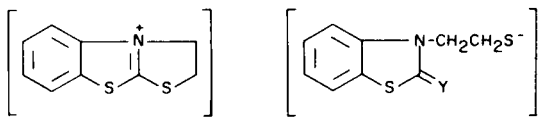
The reactions of 2,3-dihydrothiazolo[2,3-*b*]benzothiazolium bromide **1** (A^-=Br^-) with certain nucleophilic reagents have been performed for the purpose of ascertaining the reaction pathways and identifying the group that is displaced from the central carbon atom of the dithiocarbamate system. The nature of complex salt-like intermediates formed initially from **1** (A^-=Br^-) has been studied and confirmed. For comparison, a number of nucleophilic substitution reactions of 2-methylthio-3-methylbenzothiazolium iodide **17** and 2-dimethylamino-3-methylbenzothiazolium perchlorate **18** have been examined.

Nucleophilic substitution reactions of *N,S*-dialkylbenzothiazolium salts have been studied by Sexton (2), Riemschneider, *et al.* (3), and more recently by Kuznetsova, *et al.* (4). The latter workers studied such displacements using benzothiazolium salts in which the substituents attached to the nitrogen and exocyclic sulfur atoms are connected by a chain of carbon atoms, as in the example shown below (:YH$^-$ is a nucleophile):



Disulfides such as **3** were formed when the reactions were performed in basic solutions in the presence of oxygen, while in acidic media the free mercaptans were obtained.

In a previous publication the present authors (5) obtained similar results by treating 2,3-dihydrothiazolo-[2,3-*b*]benzothiazolium bromide **1** (A^-=Br^-) with either sodium hydroxide or sodium sulfide. In addition, it was found that the proper adjustment of reaction conditions permitted the isolation of water-insoluble intermediates having salt-like structures (shown below) themselves capable of conversion to the corresponding disulfides under continued treatment in pyridine-water.



It has now been found that brief treatment of **1** (A^-=Br^-) with aqueous ammonia gives the corresponding salt structure **2**, analogous to the two previously reported structures **8** and **10** (5). In accord with expectation, **2** was converted to the disulfide **3** on further treatment with ammonia in pyridine-water. Furthermore, the starting salt **1** (A^-=Br^-) was regenerated when **2** was treated with hydrobromic acid in dimethylformamide solution. The presence of the 2,3-dihydrothiazolo[2,3-*b*]benzothiazolium cation as part of the structure of **2** was recognized by the presence of characteristic uv absorption peaks at 253, 258 and 305 mμ (5).

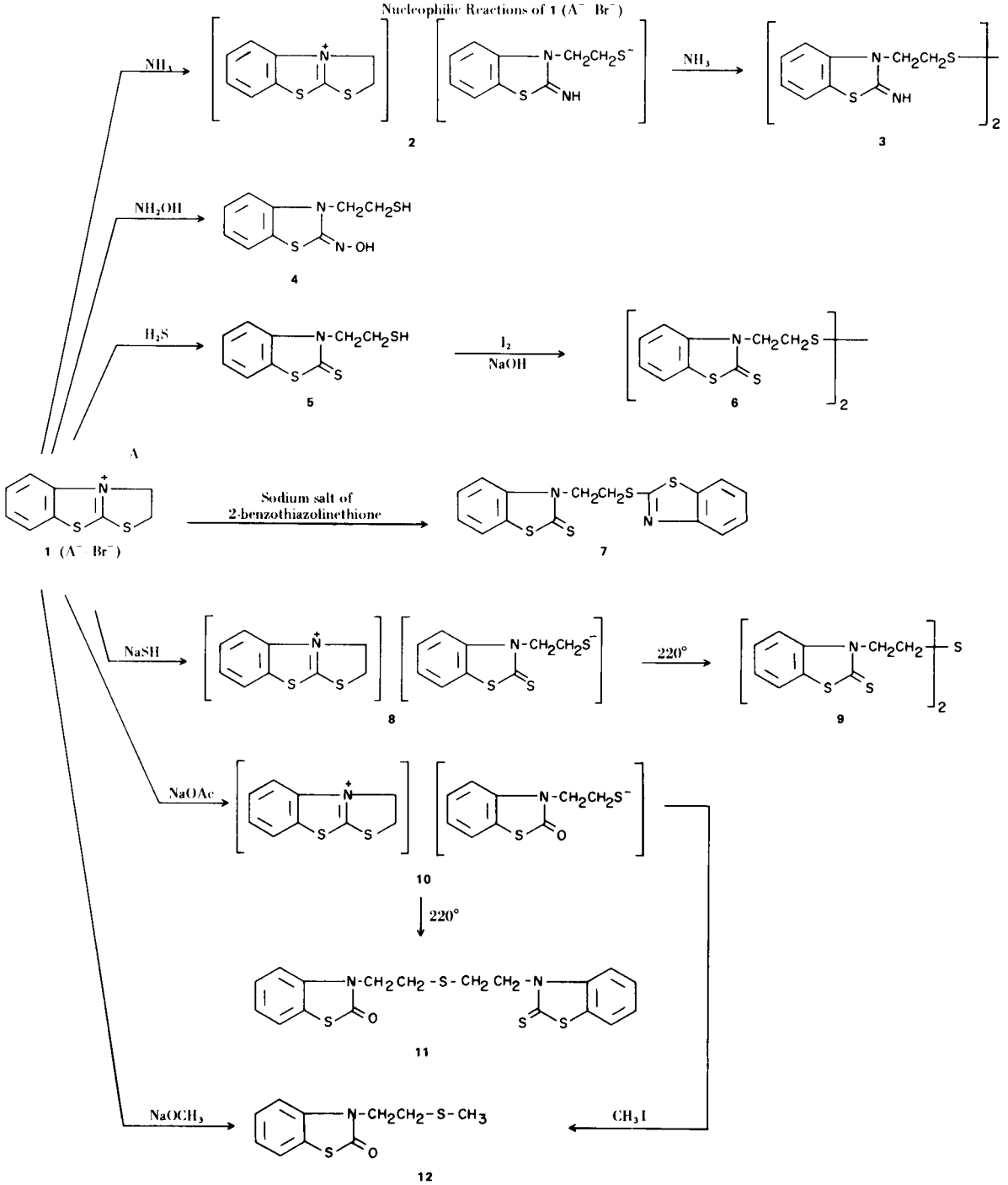
Treatment of **1** (A^-=Br^-) with hydroxylamine in a weakly acidic reaction medium (excess of hydroxylamine hydrochloride) resulted in the expected displacement to give **4**. Here the negatively charged sulfur atom was neutralized to the mercapto group without the formation of the intermediate adduct or the disulfide. The oxime function was detected in the infrared spectrum at 2.8 μ (OH stretch) and 6.2 μ (C=N stretch). In addition, the nmr spectrum showed exchangeable protons at τ 0.9 (NO*H*) and 8.1 ppm (S*H*).

Another example of nucleophilic attack upon structure **1** (A^-=Br^-) under mildly acidic conditions was provided by aqueous hydrogen sulfide. Here the mercaptan **5** was formed (uv peak at 325 mμ) and neither the intermediate adduct nor the disulfide **6** was isolated. Compound **5** could, however, be readily converted to **6** by the action of an alkaline solution of iodine in chloroform.

Nucleophilic attack on **1** (A^-=Br^-) by the anion from

SCHEME I

Nucleophilic Reactions of 1 (A^- Br^-)

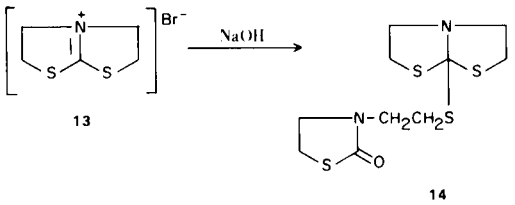


the sodium salt of 2-benzothiazolinethione also resulted in the opening of the dihydrothiazolo ring with the introduction of a thione group at position 2 to give the *thioether* **7**. The uv spectrum of **7** shows an array of peaks formed by the superposition of patterns from typical *N*- and *S*-substituted alkyl derivatives of 2-benzothiazolinethione (5). In this case, the benzothiazolyl moiety became attached to the incipient mercaptoethyl group formed during dihydrothiazolo ring opening, possibly *via* a rearrangement, or through initial attack at the methylene group directly adjacent to sulfur in **1** (A^-=Br^-). The possibility of opening the dihydrothiazolo ring to yield a product having a *monosulfide* linkage in the product was first inferred from mass spectrometry data

obtained for compound **8**. Thus the mass spectrum of the adduct **8** was found to be identical with that of compound **9**, which was prepared from **8** by heating for 2 minutes under nitrogen at the temperature of the mass spectrometer probe (220°). Here the anionic portion of the salt acted as a nucleophile in opening the dihydrothiazolo ring (probably by attack at the *S*-methylene) with the formation of a thione function within the framework of the former cation and a thioether linkage between the two now identical components. The resultant monosulfide **9** is isomeric with **8**, which explains why compound **8** was found to have a molecular ion peak at m/e 420, the salt having undergone the reaction described above before becoming ionized as a single fragment under electron bombardment. An exactly similar set of circumstances was observed with compounds **10** and **11**, with **10** being converted to **11** by heating at 220°, and the observation of identical fragmentation patterns for **10** and **11** in the mass spectrometer (see Scheme II).

Another instance of monosulfide formation resultant from nucleophilic attack upon **1** ($A^-=Br^-$) was the observation that **1** ($A^-=Br^-$) was converted by methanolic sodium methoxide to compound **12**. Here it may be inferred that the initial attachment of methoxyl to the carbon atom common to both heterocyclic rings must be followed by ring opening and methyl group rearrangement. The structure of **12** is supported by its ultraviolet absorption spectrum (λ max at 215 mμ) and by the presence of mass spectral peaks at m/e 225 (M^+), 151 [$(M-74)^+$], and 74 [$(M-151)^+$], the latter being assignable to a methyl vinyl sulfide fragment, the result of a McLafferty rearrangement similar to those outlined in Scheme II. Compound **12** was also obtained by treatment of the salt **10** with methyl iodide in chloroform. This reaction was accompanied by the precipitation of the salt **1** ($A^-=I^-$) from the solution.

In view of the unusual nature of the salt structures **2**, **8**, and **10** these compounds were subjected to further study. This was thought to be especially encumbent upon the present authors in view of the fact that two other groups of investigators (6,7) proposed a fundamentally different structure for the analogous compound **14** obtained under similar conditions. Thus, treatment of **13** with cold aqueous sodium hydroxide was reported to give **14** in 75% yield, as shown below.



In the indicated structure partial dihydrothiazolo ring opening was followed by the formation of a covalent bond between the incipient sulfur anion and the central carbon atom of the unopened but now neutralized fused ring moiety. Evidence cited for the covalent structure **14** included molecular weight determinations by the Rast and cryoscopic (in dioxane) methods, and the absence of a C=N stretching vibration in the vicinity of 6.3 μ in the infrared spectrum. Spectroscopic data for our products (**2**, **8**, and **10**) do not contradict the ionic structures nor do they support them exclusively. Each exhibits absorption peaks in the 6.3-6.4 μ region, but these could be assigned to functions other than the critical C=N stretches. The observed ultraviolet absorption peaks (252, 258, and 310 mμ) are known to be characteristic of benzothiazolium salts (5), and therefore lend support to the proposed ionic structures. As explained earlier, molecular weight determinations by mass spectrometry involve heating of the samples, and are therefore capable of causing combi-

SCHEME II

Mass Spectral Fragmentation Patterns for Compounds 9 and 11
(McL. McLafferty Rearrangement)

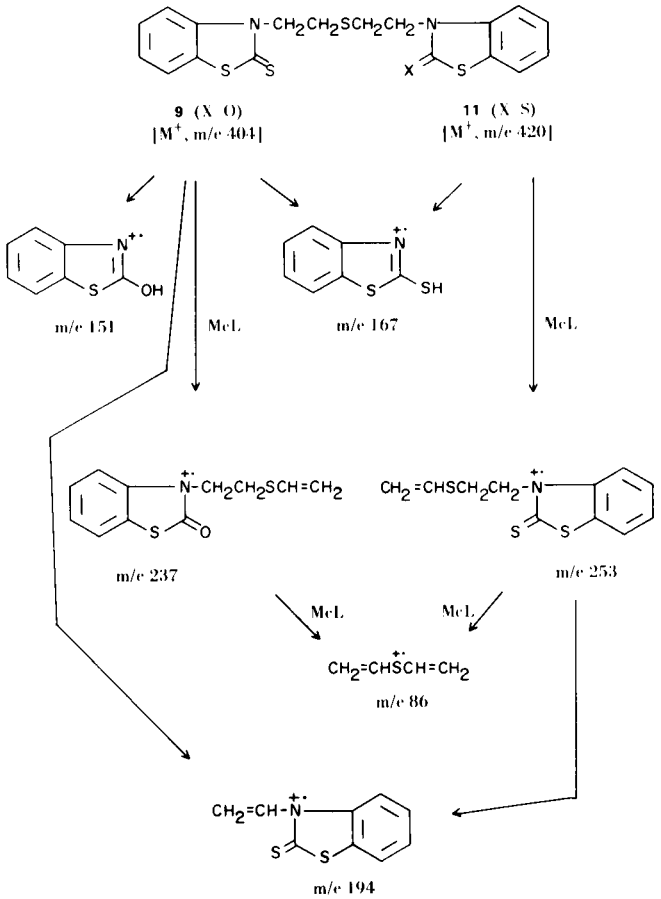


TABLE I

No.	M.p.	Formula	Analysis Calcd. C	H	N	S	Found C	H	N	S	Ultraviolet Absorption Spectrum (in Methanol) λ max (mμ)	ε x 10^{-3}
1 (A^-=picrate ion)	182-184	$C_{15}H_{10}N_4O_7S_2$	42.65	2.38	13.27	15.18	42.57	2.34	13.34	15.27	313	20.1
											257.5	13.2
											250	14.3
2	137-139	$C_{18}H_{17}N_3S_4$	53.60	4.25	10.42	31.73	53.26	4.27	10.31	31.75	307	10.1
											297.5	10.0
											266	10.0
											258	12.0
											253	10.0
											222.5	55.5
4	130-132	$C_9H_{10}N_2OS_2$	47.79	4.46	12.38	28.32	47.51	4.70	12.33	28.45	307	4.6
											267.5	8.5
											226	27.8
5	147-149	$C_9H_9NS_3$	47.58	3.99	6.17	42.26	47.62	3.91	6.16	42.20	325	25.6
											230	15.2
											207	18.3
7	147-149	$C_{16}H_{12}N_2S_4$	53.34	3.36	7.78	35.53	53.20	3.33	7.86	35.67	326	32.6
											302	14.0
											291	13.1
											281	13.5
											263	24.0
											226	45.8
9	178-181	$C_{18}H_{16}N_2S_5$	51.39	3.83	6.66	38.11	51.37	3.81	6.48	37.96	324	58.0
											230	39.0
											207.5	45.0
11	152-154	$C_{18}H_{16}N_2OS_4$	53.44	3.99	6.92	31.70	53.08	4.08	6.91	31.88	326	23.8
											290	5.3
											282.5	4.9
											237.5	18.2
											212.5	51.0

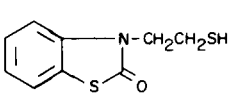
12	oil	$C_{10}H_{11}NOS_2$	53.30	4.92	6.22	28.46	53.53	4.61	6.36	28.29	290	2.7		
											282.5	2.6		
											245	5.7		
											215	38.0		
20	187-189	$C_8H_8N_2OS$	53.33	4.48	15.55	17.79	53.27	4.47	15.51	17.50	307.5	5.0		
											268	8.6		
											226	27.4		
21	120-122 (a)	$C_8H_8N_2S$	58.53	4.91	17.06	19.49	58.39	4.89	16.82	19.40	299	4.6		
											295	4.7		
											290	4.3		
											262	9.0		
											222	40.3		

(a) Lit., m.p. 123°, E. Besthorn, *Ber.*, **43**, 1519 (1910).

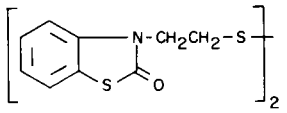
nation of the ionic particles prior to electron bombardment, thereby giving erroneous results.

The possibility of covalent structures as opposed to the ionic forms in the benzothiazolium series was further tested by means of thin-layer electrophoresis. For purposes of comparison the picrate salt **1** (A^-=picrate ion) was prepared and subjected to an electric field side by side with **8** and **10** (8). All three samples showed two spots each, with those on the anode side traveling the same distance (~ 3 cm.), suggesting the presence of the same cation in each sample. On the cathode side the anionic parts of **8** and **10** moved a shorter distance from the origin (~ 1 cm.) while the picrate ion traveled about 12 cm. From this experiment it is concluded that the ionic structures given herein are a reasonable representation of the intermediates isolated in our experiments.

Chemical evidence, while not capable of discriminating clearly between the ionic and covalent extremes, is in support of our general structural assignments. For example, it was found that treatment of the salt **10** with hydrobromic acid resulted in the formation of two products, **1** (A^-=Br^-) and the free mercapto compound **15** (4). However, one would expect the covalently bound structure corresponding to **10** to be similarly converted. More indicative of the salt structure was the reaction of **10** with aqueous silver nitrate solution. This gave the 2,3-dihydrothiazolo[2,3-*b*]benzothiazolium cation (isolated as its picrate) and a silver mercaptide which was identical with material obtained directly from **15** and silver nitrate. Furthermore, iodine oxidation of **10** in chloroform gave **1** (A^-=I^-) and the disulfide **16** (9), in accordance with the expected behavior of mercaptide salts.



15

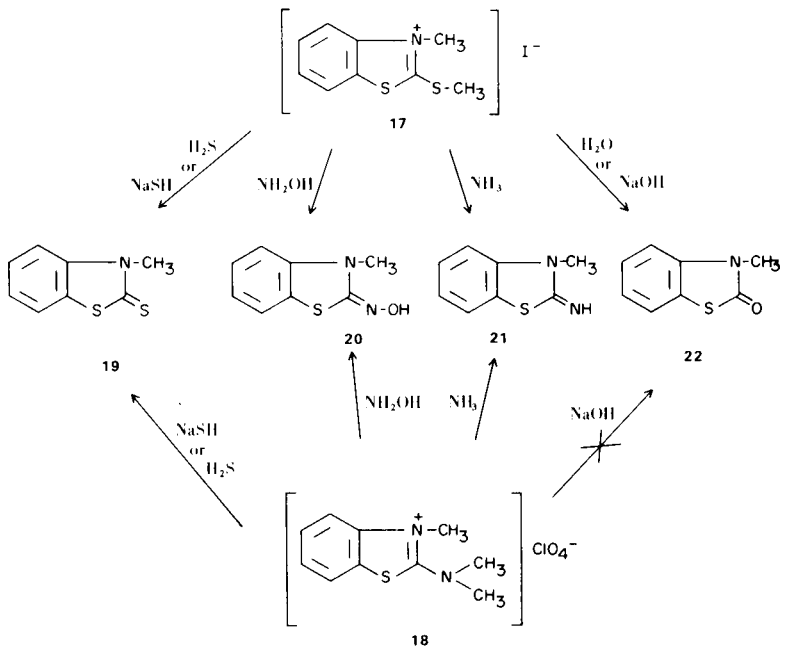


16

An attempt was made to prepare adducts similar to **2**, **8**, and **10** by direct precipitation from aqueous solutions of **1** (A^-=Br^-) and sodium ethyl sulfide. However, the resulting gummy material resisted purification due to instability which was evidenced by a strong mercaptan odor. The uv spectrum of this unpurified material was superimposable upon that of **1** (A^-=picrate ion), and on heating a new peak appeared at 325 mμ, indicating a thermal transofrmation similar to the conversion of **8** to **9**.

For comparison with the above results the two previously known benzothiazolium salts **17** (2) and **18** (10) were treated with representative nucleophiles (ammonia, hydroxylamine, hydrogen sulfide, sodium hydroxide) and

SCHEME III



found to give products similar to those obtained by analogous reactions of the dihydrothiazolo structure **1** (A^-=Br^-) (see Scheme III). The single exception in reactivity was the failure of **18** to yield **22** upon hydroxide treatment, probably the result of ring opening of the product *via* thiourethane cleavage. However, formation of **22** from **17** was effected by previous workers using either sodium hydroxide solution (2) or boiling water (3).

The reactions described herein provide further evidence that introducing a positive charge into the benzothiazolium nucleus provides enhanced nucleophilic reactivity to substitution into this particular heterocyclic system.

EXPERIMENTAL (11)

Nucleophilic Reactions of Benzothiazolium Salts (12).

A. With Hydrogen Sulfide.

Hydrogen sulfide gas was passed through dilute aqueous solutions of **1** (A^-=Br^-), **17**, and **18** at the temperature of a steam bath for 5-6 hours. The precipitated products were collected on a funnel, washed with water and air-dried; thus 0.5 g. (1.6 mmoles) of **17** gave 0.25 g. (89%) of 3-methyl-2-benzothiazolinethione **19**, while **18** gave only 24% of **19**. The latter transformation was also accomplished with sodium hydrosulfide in 77% yield.

Compound **1** (A^-=Br^-) (25 g., 81 mmoles) in 1.5 l. of water gave 11.2 g. of crude product. Crystallization from 750 ml. of ethanol gave 9.0 g. (44%) of 3-(2-mercaptoethyl)-2-benzothiazolinethione **5**; nmr (deuteriochloroform) τ 2.3-2.9 (multiplet, 4-H, C_6H_4), 5.2-5.5 (multiplet, 2-H, NCH_2), 6.8-7.2 (multiplet, 2-H, CH_2S) and 8.38 ppm (triplet, J = 8.5 Hz, 1-H, SH). Oxidation of **5** (50 mg., 0.22 mmoles) in chloroform (20 ml.) was performed by continuously shaking the chloroform solution with 20 ml. of 1 *N* sodium hydroxide solution while adding sufficient iodine (in chloroform) to give a persistent coloration. The organic layer was separated, washed with water, dried over sodium sulfate, concentrated to a small volume and diluted with hexane to give 30 mg. (60%) of a yellow solid, shown by comparison of its infrared spectrum with that of an authentic sample to be bis[2-(benzothiazolinethion-3-yl)ethyl]disulfide **6** (5).

B. With Hydroxylamine.

To aqueous solutions of **1** (A^-=Br^-), **17**, and **18** each containing three equivalents of hydroxylamine hydrochloride was added one equivalent of sodium hydroxide solution, and the mixtures heated on a steam bath for 10 minutes. After having been cooled, the white crystals were collected, washed with water, air-dried and crystallized from ether. In this manner **1** (A^-=Br^-) (2.0 g., 7.3 mmoles) gave 0.4 g. (25%) of 3-(2-mercaptoethyl)-2-benzothiazolinoxime **4**; compound **17** (0.5 g., 1.6 mmoles) gave 0.23 g. (82%) of 3-methyl-2-benzothiazolinoxime **20**; and **18** (1.0 g., 3.4 mmoles) gave 0.35 g. (57%) of **20**.

C. With Ammonia.

Dilute aqueous solutions of **17** and **18** were combined with 2 volumes of concentrated aqueous ammonium hydroxide. The solutions stood overnight, after which they were made strongly alkaline with dilute aqueous sodium hydroxide solution and the precipitated products collected by filtration and air-dried. Pure compounds were obtained by crystallization from ether-hexane. Thus 450 mg. (1.4 mmoles) of **17** gave 60 mg. (26%) of 3-methyl-2-benzothiazolinimine **21**, and 1.0 g. (3.4 mmoles) of **18** gave 150 mg. (27%) of the same imine.

Similarly, to 7.0 g. (25.6 mmoles) of **1** (A^-=Br^-) in 140 ml. of water was added 70 ml. of ammonium hydroxide. After having been stirred for 0.5 hour, the solid was collected by filtration, washed with water, and air-dried. Crystallization of the crude material (5.1 g.) from a mixture of 50 ml. of chloroform and

150 ml. of ether gave 3.5 g. (68%) of 2,3-dihydrothiazolo[2,3-*b*]-benzothiazolium 2-(2-benzothiazolinimin-3-yl)ethyl sulfide **2**. The salt-like nature of this compound was inferred by reconverting it to **1** ($A^-=Br^-$) by treating its solution in dimethylformamide with a few drops of 57% hydrobromic acid. Also, compound **2** (2.5 g., 6.2 mmoles) was further treated with ammonium hydroxide (20 ml.) in 40 ml. of pyridine on the steam bath for 0.5 hour. Upon dilution with water a precipitate was obtained. After being washed with water, air-dried, and crystallized from 300 ml. of ethanol, 1.4 g. (54%) of bis[2-(2-benzothiazolinimin-3-yl)ethyl]-disulfide **3** was obtained; m.p. 156-158°, lit. (4), m.p., 163-164°.

D. With Sodium Acetate.

An aqueous solution of 2.0 g. (7.3 mmoles) of **1** ($A^-=Br^-$) and 10 g. of sodium acetate was allowed to stand for 1 week at room temperature. The precipitate was collected, washed with water and air-dried to give 0.7 g. (48%) of 2,3-dihydrothiazolo[2,3-*b*]-benzothiazolium 2-(2-benzothiazolinon-3-yl)ethyl sulfide **10**. The clear mother liquors gave a second crop of precipitate on heating at steam bath temperature for 0.5 hours. This was similarly isolated and crystallization from ethanol gave 0.3 g. (20%) of **16**.

E. With the Sodium Salt of 2-Benzothiazolinethione.

A solution of 2.5 g. (9.1 mmoles) of **1** ($A^-=Br^-$), 0.8 g. (4.7 mmoles) of 2-benzothiazolinethione, and 0.2 g. (4.7 mmoles) of sodium hydroxide in 100 ml. of water was heated on the steam bath for 0.5 hour. The resulting precipitate was collected, washed with water and air-dried. Crystallization of the product from acetone gave 0.3 g. (18%) of 3-[2-(benzothiazol-2-ylthio)ethyl]-2-benzothiazolinethione **7**; nmr (pyridine-d_5), τ 1.8-2.9 (multiplet, 8-H, C_6H_4) and 4.8-6.3 ppm (A_2B_2 multiplet, 4-H, CH_2CH_2).

F. With Methanolic Sodium Methoxide [Preparation of 3-(2-Methylthioethyl)-2-benzothiazolinone **12**].

Solid sodium methoxide (0.8 g., 15 mmoles) was added all at once to a stirred slurry of 4.0 g. (15 mmoles) of **1** ($A^-=Br^-$) in 100 ml. of anhydrous methanol. After a few minutes the solution became clear, after which it was heated under reflux for two hours and then evaporated to dryness *in vacuo*. The residue was next partitioned between 100 ml. each of water and methylene chloride. The organic layer, after being washed with water, dried (magnesium sulfate), and evaporated to dryness, yielded 3.0 g. (92%) of **12** as a thick oil; homogeneous by thin-layer chromatography (silica gel G, hexane); nmr (deuteriochloroform) τ 2.5-3.1 (multiplet, 4-H, C_6H_4), 5.84 (multiplet, 2-H, NCH_2), 7.2 (multiplet, 2-H, SCH_2), and 7.82 ppm (singlet, 3-H, CH_3). The infrared spectrum showed a strong carbonyl absorption at 6.0 μ.

Reactions of 2,3-Dihydrothiazolo[2,3-*b*]benzothiazolium 2-(2-benzothiazolinon-3-yl)ethyl Sulfide (**10**).

A. With Iodine.

To a magnetically stirred solution of 2.0 g. (5.0 mmoles) of **10** in 50 ml. of chloroform was added dropwise 0.63 g. (2.5 mmoles) of iodine in 50 ml. of chloroform. The white crystals that formed were collected, washed with chloroform, and air-dried to give 1.2 g. (75%) of **1** ($A^-=I^-$) m.p., 241-244°. This material was further identified by conversion to the picrate **1** (A^-=picrate ion). The mother liquors from the reaction mixture were concentrated, and the gummy residue triturated with ethanol to give a crude solid which was dissolved in chloroform (250 ml.) and passed through 25 g. of alumina (sintered-glass funnel). The combined eluates were concentrated and the residue on trituration with ethanol gave 0.8 g. (76%) of bis[2-(2-benzothiazolinon-3-yl)ethyl]disulfide **16**, m.p., 125-127°, lit. (5), m.p. 124-126°.

B. With Hydrobromic Acid.

To a suspension of 300 mg. (0.74 mmoles) of **10** in 1 ml. of water was added 5 drops of 57% aqueous hydrobromic acid and the mixture was stirred for 1 hour. Dilution of the filtered reaction mixture with 25 ml. of acetone gave a white precipitate which was collected, washed with acetone, and found to be identical with an authentic sample of **1** ($A^-=Br^-$) (mixture melting point and comparison of infrared spectra). The solid portion from the original filtration was washed thoroughly with water and air-dried. This gave 135 mg. (86%) of 3-(2-mercaptoethyl)-2-benzothiazolinone **15**, m.p., 54-56°, lit. (4), m.p., 48-49°.

C. With Silver Nitrate.

A solution of 0.2 g. (0.5 mmoles) of **10** in 50 ml. of chloroform was stirred with a solution of 0.1 g. (0.6 mmoles) of aqueous silver nitrate solution for 1 hour. The mixture was filtered and the solid washed with 100 ml. of water. After air-drying 150 mg. (95%) of the silver salt of 15 was obtained, identical with a sample prepared in the same manner directly from **15**. The filtrate from the reaction was placed in a separatory funnel and the aqueous portion separated and filtered with Darco KB. To the filtrate was added 400 mg. of picric acid as a saturated aqueous solution. After a few minutes yellow crystals formed which were isolated by filtration and washed with water. After air-drying 100 mg. (48%) of **1** (A^-=picrate ion) was obtained. Similar results were observed when aqueous solutions of neutral lead acetate were used in place of silver nitrate.

D. With Methyl Iodide.

Compound **10** (100 mg., 0.25 mmole) in 4 ml. of chloroform was combined with 4.6 g. (32 mmoles) of methyl iodide and heated under reflux for 10 minutes. After having stood for 4 hours at room temperature the precipitate which had formed was collected, washed with chloroform, and identified as the salt **1** ($A^-=I^-$) by means of its melting point and infrared spectrum. Solvent removal *in vacuo* provided a quantitative yield of **12**, the infrared spectrum of which was identical with that of a sample obtained previously by an alternative method.

Bis[2-(2-benzothiazolinethion-3-yl)ethyl Sulfide (**9**).

A sample (0.5 g., 1.43 mmoles) of 2,3-dihydrothiazolo[2,3-*b*]-benzothiazolium 2-(2-benzothiazolinethion-3-yl)ethyl sulfide **8** was placed in a test tube which was then purged with nitrogen and stoppered with a wad of cotton. The tube was immersed in an oil bath at 220° for 2 minutes. After having been cooled, the glassy solid was triturated with ethanol and the resulting crude solid was crystallized from acetone to yield 360 mg. (72%) of **9**; nmr (pyridine-d_5) τ 2.3-2.8 (multiplet, 8-H, C_6H_4), 5.22 (multiplet, 4-H, NCH_2); the ultraviolet spectrum of **8** (5) differed markedly from that of the product **9**, as did the corresponding infrared spectra; however, the mass spectra of **8** and **9** were identical.

2-(2-Benzothiazolinon-3-yl)-2′-(2-benzothiazolinethion-3-yl)diethyl Sulfide (**11**).

A test tube containing 80 mg. of 2,3-dihydrothiazolo[2,3-*b*]-benzothiazolium 2-(2-benzothiazolinon-3-yl)ethyl sulfide (**10**) was heated in the same manner as described above for compound **8**. The glassy solid was triturated with ether to give a quantitative amount of **11**; nmr (pyridine-d_5) τ 2.3-2.9 (multiplet, 8-H, C_6H_4), 5.28 [multiplet, 2-H, NCH_2 (thione portion)], 5.72 [multiplet, 2-H, NCH_2 (oxo portion)] and 6.9 ppm (multiplet, 4-H, SCH_2). Compounds **10** (5) and **11** showed different ultraviolet and infrared spectra, but identical mass spectra (see above), with a peak at m/e 86 being assigned to the divinyl sulfide

fragment, also present in the mass spectra of **8** and **9** but not in those of the disulfides **6** and **16**.

In contrast to the starting materials **8** and **10**, the products **9** and **11** were stable to treatment with both acid and base.

REFERENCES

(1) Supported by Contract PH-43-62-479, Cancer Chemotherapy National Service Center, National Institutes of Health, U. S. Public Health Service.

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(8) Thin-layer electrophoresis was performed on a flat-bed apparatus (E-C Apparatus Company, Swarthmore, Pennsylvania) using a gradient of 15 volts/cm. for one hour at ambient temperature. The paper strip was immersed in a solution of 0.2 *M* sodium bromide in methanol/dimethylformamide (1:1) for one hour. Visualization of the resultant spots was facilitated by means of uv light. As a stability test, **10** was allowed to stand in the solution for one hour and then recovered unchanged by water precipitation.

(9) The preparation of the disulfide **16** from **1** (A^-=Br^-) in 26% yield using aqueous sodium hydroxide was described in reference 5. In subsequent experiments it was found that this conversion may also be effected by heating with *n*-butyl alcohol (steam bath, overnight; yield, 59%).

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(11) All melting points were determined on a Thomas-Hoover Unimelt apparatus and are uncorrected. The infrared spectra were obtained as nujol mulls between sodium chloride discs using a Perkin-Elmer Model 137 Infracord spectrophotometer. Ultraviolet spectra were obtained by A. Kalowsky using a Cary Model 11 spectrophotometer and the nuclear magnetic resonance spectra by R. C. Zerfing with a Varian Associates A-60A instrument (TMS standard). Mass spectra were obtained by J. L. Smith on a Consolidated Electrodynamics Model 21-110 mass spectrometer using a 100 μa ionizing current, 70 eV ionizing voltage and 8 KV accelerating voltage; the samples were introduced directly into the source, which was heated to 200-220°. Elemental analyses were performed by R. N. Boos and associates. We thank Dr. E. J. J. Grabowski for helpful discussions.

(12) The dilute aqueous solutions referred to were of approximately 2% (by weight) concentration. Known compounds obtained as reaction products were identified by comparison of their infrared and ultraviolet spectra and melting points with those of authentic samples (reference 5).

Received July 27, 1970 Rahway, New Jersey 07065