SYNTHESIS AND STRUCTURES OF ISOMERIC BENZOBISTHIAZOLES

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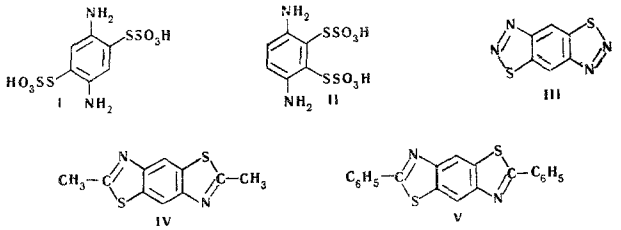
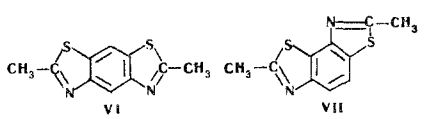
It is shown that the bases described in a number of papers and patents as 2,6-dimethyl-, 2,6-diamino-, and 2,6-dimercaptobenzo[1,2-d:4,3-d']bisthiazoles (isomers of linear structure) are actually 2,7-dimethyl-, 2,7-diamino-, and 2,7-dimercaptobenzo[1,2-d:6,5-d']bisthiazoles (isomers of angular structure). The synthesis of the hitherto unknown 2,6-dimethylbenzo[1,2-d:4,5-d']bisthiazoles is described.

In 1903 Green and Perkin [1] described diaminobenzenedithiosulfonic acid, which they prepared from p-phenylenediamine, by treating it with sodium hyposulfite and sodium dichromate. Treatment of this acid with nitrous acid gave benzobisthiadiazole, with acetic anhydride gave dimethylbenzobisthiazole, and with benzaldehyde diphenylbenzobisthiazole. This type of cyclization showed that the amino groups and thiosulfonic groups were ortho to one another. Hence, the authors ascribed to their diaminobenzenedithiosulfonic acid the structure I, and the above-mentioned derivatives structures III–V.



Green and Perkin rejected structure II for the dithiosulfonic acid, since they regarded it as improbable.

Of recent years the structure of the benzobisthiazoles has been repeatedly discussed, and sometimes reviewed. Thus Edge [2] synthesized dimethylbenzobisthiazole from m-phenylenediamine via its dithioacetyl derivative, and ascribed to the resultant product the linear structure VI. However it was subsequently shown [3,4] that this is wrong, and that Edge's base has the angular structure VII.



Regarding the dimethylbenzobisthiazole obtained by Green and Perkin, not one of the authors who repeated the synthesis [2,5,6] commented on the structure IV which the original authors had assigned to it. Its mode of preparation was considered to demonstrate its structure unequivocally [2,4].

In 1956 A. I. Kiprianov, A. I. Stetsenko, and E. D. Sych [7] effected oxidative cyclization of 2-methyl-6-thioacetylaminobenzothiazole, and ascribed to the resultant dimethylbenzobisthiazole the structure of Green and Perkin's base IV, despite the substantial difference in melting points (98–100° for Green and Perkin's compound, 121° for that of Kiprianov and coworkers).

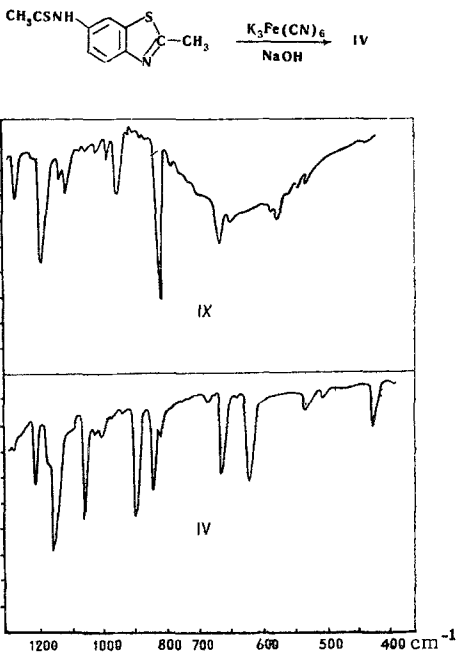
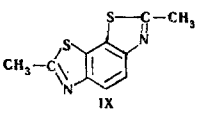


Fig. 1. IR spectra of linear (IV) and angular (IX) dimethylbenzobisthiazoles.

The linear structure for the base obtained by Kiprianov and coworkers now appears to be inadequately based. It has been shown [8] that the Skraup cyclization product of 6-aminobenzothiazole is more probably the angular thiazoloquinoline VIII than its linear isomer.

It was recently found [3] that oxidative cyclization of 2-methyl-5-thioacetylaminobenzothiazole also give an angular (VII) and not a linear dimethylbenzobisthiazole. It was natural to assume that the similar cyclization of 2-methyl-6-thioacetylaminobenzothiazole must give a dimethylbenzobisthiazole not of linear (IV) but angular (IX) structure



In the present work the primary problem was to settle the question of the actual structure of the cyclization product from 2-methyl-6-thioacetylaminobenzothiazole. For that purpose it was necessary to check whether it was identical with Green and Perkin's dimethylbenzobisthiazole.

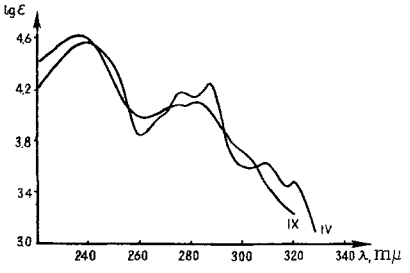
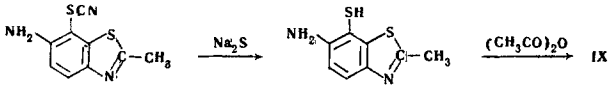


Fig. 2. UV spectra of IX and IV.

The two compounds were synthesized by the appropriate procedures, and contrary to what we expected, they proved to be identical. It was established that the difference in melting points was connected with the ability of the base to give a hydrate when crystallized from aqueous ethanol, the hydrate melting at 121°, while the same preparation, vacuum-dried at 110°, or recrystallized from benzene, melts at 101°. The two preparations obtained by the two different methods, gave an undepressed mixed melting point. Their IR and UV spectra were identical. Salts and other derivatives of the two preparations were also identical.

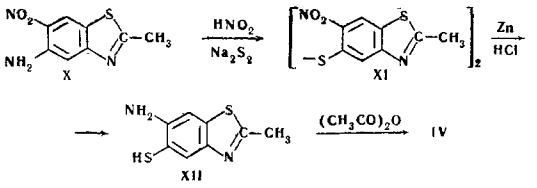
The very same dimethylbenzobisthiazole, melting point 101°, was then also obtained by yet a third method. 2-Methyl-6-amino-7-thiocyanobenzothiazole [9] was reduced to the corresponding aminomercaptan, which was then cyclized by heating with acetic anhydride. This method of synthesis more probably leads to formation of not a linear, but of an angular product, according to the equations



But then it would have to be admitted that Green and Perkin, as well as all later authors, ascribed the wrong structures to diaminobenzenedithiosulfonic acid obtained from p-phenylene diamine and all its cyclization products. The problem was solved by determining the dipole moment of the base mp 101°. A value of 2.7 D was obtained. If the base had the symmetric structure IV, its dipole moment would be zero.

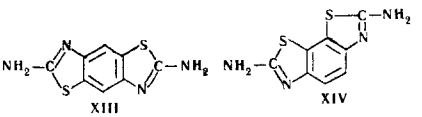
Thus it was established that the dimethylbenzobisthiazole prepared by Green and Perkin from p-phenylenediamine, and subsequently by Kiprianov, Stetsenko, and Sych from 2-methyl-6-aminobenzothiazole via the thioacetyl derivative, and now prepared by us from 2-methyl-6-amino-7-thiocyanobenzothiazole, is not the linear isomer (IV), but the angular one (IX). Furthermore it is shown that up to the present no one has ever obtained the linear isomer V.

After some unsuccessful experiments, we synthesized this linear isomer as follows:



It forms colorless needles with a melting point of 227°. As expected, its dipole moment was found to be zero*. Fig. 1 shows the IR spectra of the linear (IV) and angular (IX) dimethylbenzobisthiazoles. The spectrum of base IX has an intense absorption band at 813 cm^{-1}, corresponding to the benzene ring's containing two adjacent CH groups [10]. This band is absent from the spectrum of base IV. Fig. 2 gives the UV spectra of both bases.

In 1950 a diaminobenzobisthiazole melting above 360° was described [11], which was prepared by the action of potassium cyanide on p-phenylenediaminedithiosulfonic acid. Considering that this sulfonic acid has structure I, following Green and Perkin, the authors ascribe to the resultant diamine structure XIII. We can now confirm that actually this was the diaminobenzobisthiazole with the angular structure XIV.



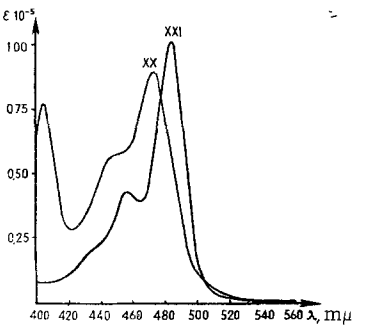
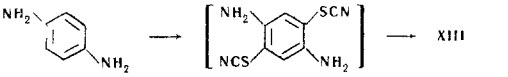


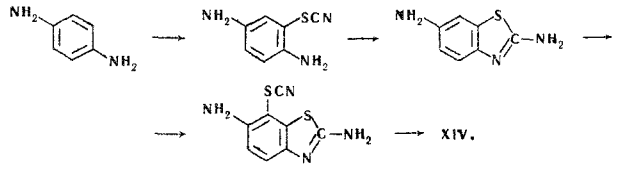
Fig. 3. UV spectra of XX and XXI.

Recently a patent [12] described another method of preparing symmetrical diaminobenzobisthiazole XIII. The authors of the patent considered that they obtained this isomer by thiocyanating p-phenylenediamine in the presence of bromine.

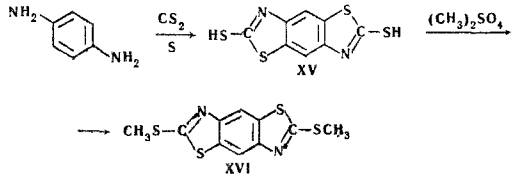


*The dipole moments were determined in the laboratory of Prof. A. E. Lutskii, to whom we are much obliged.

We confirmed this synthsis in accordance with the directions of the patent, and obtained the diamine in excellent yield. To ascertain whether it actually had structure XIII, we fused it with alkali, and treated the scission product with acetic anhydride. This gave the angular dimethylbenzobisthiazole melting point 101°. Hence thiocyanating p-phenylenediamine also gives not the linear (XIII) but the angular (XIV) diamine. Obviously the equations are:



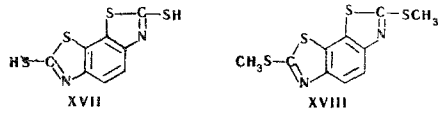
In 1940 a patent was published [13] describing a method of obtaining linear symmetrical dimercaptobenzobisthiazole XV. The method comprises heating p-phenylenediamine with sulfur and carbon disulfide at 240°. The dimercaptan was dissolved in alkali, and treated with dimethyl sulfate to give dimethylmercaptobenzobisthiazole XVI, mp 153°.



From the resultant base XVI, the authors of the patent synthesized a number of cyanine dyes [13,14].

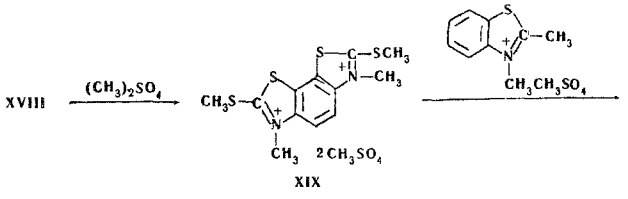
Later patents were taken out on the use of the dimercaptobenzobisthiazole of structure XV for vulcanizing rubber [15,16], and for synthesizing azo and anthraquinone dyes [17].

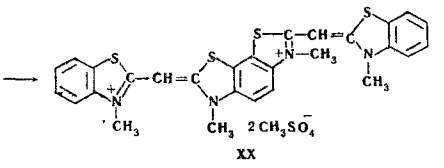
We have found that, contrary to the patent [13], reaction of p-penylenediamine with carbon disulfide and sulfur also gives not the linear (XV) but the angular (XVII) isomer.



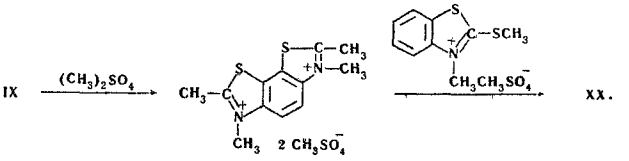
This was shown from the IR spectrum of derivative XVIII, prepared as described in the patent. The spectrum has an intense band at 810 cm^{-1}, characteristic of two adjacent CH groups in a benzene ring [10].

Direct proof was also obtained. Heating dimethylmercaptobenzobisthiazole XVIII with excess dimethyl sulfate converted it to the diquaternary salt XIX, and the biscyanine dye XX was synthesized by condensing XIX with a quaternary salt of 2-methylbenzothiazole in pyridine.

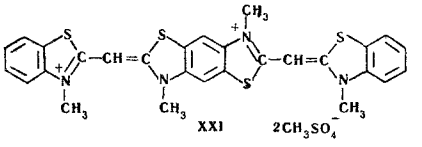




The same dye XX was obtained by synthesis from a diquaternary salt of angular dimethylbenzobisthiazole IX and a quaternary salt of 2-methylmercaptobenzothiazole, the equation being



The absorption curves of the biscyanines prepared by the different methods wholly coincides, and differ substantially from the absorption curve of the isomeric biscyanine XXI, which we obtained by condensing a quaternary salt of 2-methylmercaptobenzothiazole with a diquaternary salt of linear dimethylbenzobisthiazole IV (Fig. 3).



EXPERIMENTAL

2,7-Dimethylbenzo[1,2-d:4,3-d']bisthiazole (IX) was prepared a) from the K salt of 1,4-diamino-2,3-dithiosulfonic acid [1], b) from 2-methyl-6-thioacetylamonobenzothiazole [7], and c) from 2-methyl-6-amino-7-thiocyanobenzothiazole.

In the synthesis of IX by the latter method, 0.88 g 2-methyl-6-amino-7-thiocyanobenzothiazole [9] was added gradually to a solution of 2 g crystalline Na sulfide in 5 m*l* water at 60–70°. The solution was then filtered, 5 m*l* Ac_2O added, the whole heated for 3 hr on a boiling water bath, and then neutralized with ammonia. The precipitate was washed with water and dried. Yield 0.66 g (75%), mp 121° (ex EtOH). After vacuum-drying at 110° or recrystallizing from benzene, the compound had mp 101°. A mixed mp of specimens prepared by methods a and b, was undepressed.

The dimethylmethosulfate of base IX was prepared from a mixture of base (2.2 g) and Me_2SO_4 (2.8 g) by heating it at 120° for 20 min. The reaction product was triturated with benzene, then washed with acetone and ether. Yield of salt 3.6 g (77%).

2,6-Dimethylbenzo[1,2-d:4,5-d']bisthiazole (IV). 5 m*l* dilute HCl (1:1) was added to 12 g 2-methyl-5-amino-6-nitrobenzothiazole (X), prepared as described in [18,19]. The suspension was diazotized at -3° to -5° with a solution of 3.5 g $NaNO_2$ in 10 m*l* water. After filtering the diazo solution was added, at -5°, dropwise and with stirring, to a Na disulfide solution, prepared from 15 g crystalline Na sulfide, 2.1 g S, and 50 m*l*

water. Concentrated alkali solution was added at the same time as the diazo solution, so that the reaction mixture was alkaline at all times (in all about 9 ml 40% NaOH). The resultant mixture was left for 3 hr at 0°, then gradually heated to 70°, till evolution of N had ceased, and the precipitate of disulfide XI had coagulated. After washing with water and drying, the disulfide (11.4 g) was reduced without further purification. It was dissolved in 57 ml AcOH, the solution heated to boiling, and 14 g Zn dust and 19 ml conc. HCl added. After refluxing to 30 min, 19 ml Ac_2O and 40 ml benzene were added, and heating continued for 3 hr more, on a water-bath. The benzene was distilled off, NaOH added until the mixture was alkaline, the precipitate filtered off, dried, and extracted in a Soxhlet apparatus with $CHCl_3$. After distilling off the $CHCl_3$, the base was extracted from the residue by boiling with 50 ml HCl, the acid solution decolorized with active charcoal, and ammonia added to the filtrate. The precipitate was chromatographed in $CHCl_3$ solution on alumina. The base obtained was recrystallized from benzene. Yield 0.7 g (5.8%), needles, mp 227° (corr). Found: N 12.91; 12.91; S 28.72; 28.74%. Calculated for $C_{10}H_8N_2$: N 12.72; S 29.10%.

The dimethylmethosulfate of base IV was obtained in quantitative yield by boiling for a short time a benzene solution of base IV with excess Me_2SO_4, needles mp 270° (decomp, ex aqueous EtOH). The salt was readily soluble in water, very slightly soluble in EtOH. Found: N 6.16; 6.08; S 27.48; 27.57%. Calculated for $C_{14}H_{20}N_2O_4S_4$: N 5.94; S 27.11%.

2,7-Diaminobenzo[1,2-d:4,3-d']bisthiazole (XIV) was prepared as described in [12], the yield being almost quantitative.

Scission of base XIV, and preparation of base IX from the scission product. A mixture of 24 g NaOH and 24 g KOH with 12 g crystalline Na sulfide was melted in a silicone bath, and heated until evolution of water vapor ceased. 10 g diaminobenzobisthiazole (XIV) was added in portions to the alkali melt held at 210–220°. Each time the mixture frothed, and NH_3 was evolved. The mixture was kept at 220° for 15 min more, then dissolved in 300 ml water. 200 ml Ac_2O was added to the solution, and the whole refluxed for 20 min, then extracted with $CHCl_3$. The solvent was distilled off, the residue refluxed with 30 ml 50% H_2SO_4, and the base precipitate from the acid solution with ammonia. After recrystallizing from benzene it had mp 101°, yield 3.9 g (39%). Undepressed mixed mp with IX.

If the product obtained after boiling with Ac_2O was not heated with 50% H_2SO_4, after recrystallizing from benzene it had mp 189°. Judging by its analysis, it was 2-methyl-6-acetylamino-7-acetylmercaptobenzothiazole. Found: N 9.95; 10.05%. Calculated for $C_{12}H_{12}N_2O_2S_2$: N 10.00%.

2,7-Dimethylmercaptobenzo[1,2-d:4,3-d']bisthiazole (XVIII). Following the patent [13], a mixture of 10.8 g p-phenylenediamine, 17 g (2.2 mole) CS_2, and 6.4 S, was heated in a steel autoclave for 6 hr at 240°. The solid reaction product was extracted with 60 ml 5% NaOH. Crude dimercaptobenzobisthiazole XVII was precipitated with AcOH. The precipitate (13.7 g) was dissolved in 100 ml 10% NaOH, the solution heated to 40°, and 16.5 (2.4 mole Me_2SO_4 added with shaking. The precipitate formed was extracted with 150 ml hot benzene, the tarry solid twice washed with hot benzene, the benzene solutions concentrated to small volume, and chromatographed on alumina. The colorless eluate was evaporated to dryness, and the residue recrystallized ex benzene + EtOH. Yield 6.1 g (40%), colorless needles mp 154° (153° according to [13]).

Biscyanine dye XX. A mixture of 0.29 g XVIII and 1 g Me_2SO_4 was heated for 8 hr at 160°. The resultant bisquaternary salt of base XVIII was washed with ether and vacuum-dried. To it was added 0.8 g methylmethosulfate of 2-methylbenzothiazole, 20 ml pyridine, and the mixture refluxed for 5 min. The precipitate of dye was filtered off, washed with pyridine, hot water, and acetone. Yield 0.48 g (62%). After recrystallizing from EtOH + HCOOH, it formed brownish-yellow crystals mp 320° (decomp). Found: S 24.42; 24.32%. Calculated for $C_{30}H_{30}N_4O_8S_6$: S 25.06%.

The same dye was obtained by another route*. 0.24 g dimethylmethosulfate of base IX and 0.45 g methylmethosulfate of 2-methylmercaptobenzothiazole were dissolved in 5 ml Ac_2O, 5 drops Et_3N added, and the mixture boiled for 10 min. The precipitate of dye was filtered off, and washed, first with EtOH, then with nitromethane, and finally with ether. The absorption curve of the dye formed coincided with that of dye XX prepared by the first method.

Biscyanine dye XXI. 0.047 g dimethylmethosulfate of base IV, 0.12 g methylmethosulfate 2-methylmercaptobenzothiazole, and 2 ml pyridine, were refluxed together for 2 min. The precipitate of dye was washed with pyridine, MeOH, and ether. Yield of brownish-red crystals 0.037 g (49%), mp > 360°. Found: S 24.69; 24.55%. Calculated for $C_{30}H_{30}N_4O_8S_6$: S 25.06%.

As dyes XX and XXI were very insoluble in the usual organic solvents, their absorption curves were determined in EtOH + HCOOH (2:1).

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