375. *The Action of Heat on Heterocyclic Bases Containing an Alkylthio-grouping. Part I. 2-Alkylthiobenzothiazoles and 2-Alkylthiobenzoxazoles.*

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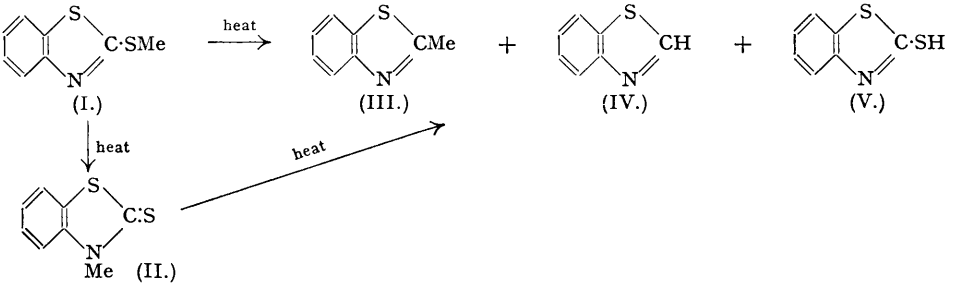
2-Methylthiobenzothiazole and 2 : 3-dihydro-3-methylbenzothiazole-2-thione on boiling undergo pyrolysis to give, amongst other products, benzothiazole and 2-methylbenzothiazole. Pyrolysis of 2-ethylthiobenzothiazole also gives benzothiazole and 2-methylbenzothiazole, but no detectable amount of 2-ethylbenzothiazole. The last can be readily identified by condensation with 2-methylthiobenzothiazole and methyl toluene-*p*-sulphonate, not only the expected 3 : 3′ : 8-trimethylthiacyanine but also the 3 : 3′-dimethylthiacyanine being obtained.

2-Methylthio- and 2-ethylthio-benzoxazoles on boiling yield the isomeric thiones but no benzoxazole or 2-methylbenzoxazole.

During experiments involving the preparation of 2-methylthiobenzothiazole methotoluene-*p*-sulphonate from 2-methylthiobenzothiazole (I) and methyl toluene-*p*-sulphonate by fusion at temperatures from 140° to 180°, it was noted that the fusion mixture became yellow. From the melt, in one experiment, a minute quantity of a 3 : 3′-dimethylthiacyanine (VII) was isolated. This dye was not obtained from pure 2 : 3-dihydro-3-methylbenzothiazole-2-thione (II) or from (I) which had been purified either by distillation under reduced pressure or by recrystallisation from light petroleum. It was assumed, therefore, that dye formation was due to traces of 2-methylbenzothiazole (III) formed in the distillation of (I) at normal pressures and that prolonged boiling of purified (I) would yield larger quantities of (III).

When (I) was boiled it was observed that the boiling point rose gradually until it approached that of (II), and after 30 hours the liquid was found to consist mainly of (II) with small quantities of (III), benzothiazole (IV), and 2-mercaptobenzothiazole (V). The thione (II) on pyrolysis also gave (III), (IV), and (V), but no (I).



(I.) (III.) (IV.) (V.) (II.)

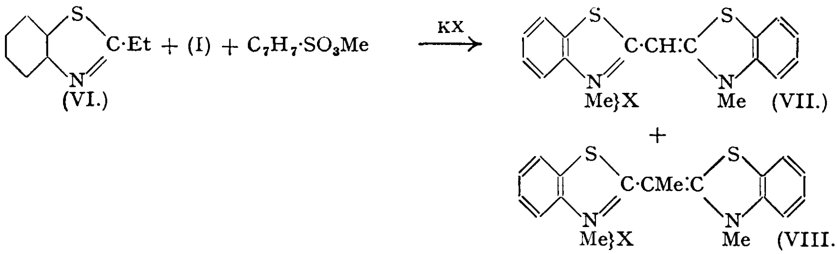
Of these compounds, only (III) gives a thiacyanine dye on fusion with (I) and methyl toluene-*p*-sulphonate. Reed, Robertson, and Sexton (*J.*, **1939**, 473) recorded the isomerisation of (I) to (II) when the thioether was heated in the presence of traces of iodine or methyl iodide, but apparently obtained no other compounds.

The formation of the thione (II) from (I), and of (III), (IV), and (V) from both (I) and (II) by heating, is remarkable and permits of no simple explanation. It is suggested that (II) is formed as the primary product from (I), possibly by a free-radical mechanism, and that the other compounds are pyrolytic products of (II). Möhlau and Krohn (*Ber.*, 1888, **21**, 60), by boiling dimethylaniline with sulphur, were the first to prepare (II) although they assigned an incorrect structure to it (see Mills, Clark, and Aeschlimann, *J.*, 1923, **123**, 2362). They also obtained (IV) in the same reaction and, since (IV) was produced by boiling (II) with sulphur, assumed that (II) was formed initially from dimethylaniline and sulphur and converted into (IV) by subsequent heating with more sulphur. From our experiments, sulphur appears unnecessary for the conversion of the thione into benzothiazole. A re-examination of Möhlau and Krohn's reaction also showed that the benzothiazole fraction obtained contained both (III) and (V).

The pyrolysis of purified 2-ethylthiobenzothiazole occurred more readily than that of (I), but the products were not all clearly defined. After 12 hours' boiling, in addition to appreciable quantities of (IV) and (V), small amounts of 3-ethyl-2 : 3-dihydrobenzothiazole-2-thione and

(III) were obtained. No unchanged thioether was recovered, nor was any 2-ethylbenzothiazole (VI) detectable *via* the thiacyanine condensation below, which experiments showed would reveal traces of (VI) in the presence of (III) and (IV).

When purified (VI) was fused with (I) and methyl toluene-*p*-sulphonate the melt became orange and when heated with pyridine gave a mixture of two cyanine dyes. One, formed in lower yield, gives a pale yellow ethanolic solution, whilst the other, which is more soluble, gives a deep yellow solution. The former was identified, *via* its bromide, as 3 : 3′-dimethylthiacyanine bromide (VII; X = Br), and the latter *via* its iodide as 3 : 3′ : 8-trimethylthiacyanine iodide (VIII; X = I).



Although other authors (Brooker, B.P. 439,857; Götze, *Z. angew. Chem.*, 1936, **49**, 563; Kiprianov and Grigor'eva, *Chem. Abs.*, 1940, **34**, 3274) have prepared cyanine dyes from (VI), and in some cases have obtained two dyes, the isolation of an unsubstituted monomethincyanine has not been reported.

The formation of the 3 : 3′-dimethylthiacyanine dyes from 2-ethylbenzothiazole is surprising, and a fuller investigation of the reactions of 2-ethylbenzothiazole and related compounds will be the subject of a subsequent communication.

Comparative experiments on the action of heat on 2-methylthiobenzoxazole and 2-ethylthiobenzoxazole indicated that the oxazole ring was more sensitive than the thiazole ring. Some thione was obtained in each case, but no benzoxazole or 2-methylbenzoxazole. There was also much decomposition product which could not be identified.

EXPERIMENTAL.

3 : 3′-Dimethylthiacyanine Iodide from Redistilled 2-Methylthiobenzothiazole.—Pure 2-methylthiobenzothiazole, m. p. 46°, redistilled at normal pressures, had b. p. 291—300°. A portion (15 g.) and methyl toluene-*p*-sulphonate (16 g.) were heated together at 185° for 6 hours. The yellowish melt was dissolved in hot ethanol (400 c.c.), and triethylamine (22 c.c.) added. After boiling for 1 hour the solution was diluted with water, and potassium iodide (22 g.) was added. The solution was extracted with chloroform, which was then distilled off, and the residue diluted with benzene, giving a yellowish-brown solid, which, after being washed with methanol, left yellow crystals (0·01 g.). The sensitising action of these crystals on a gelatino-silver chloride emulsion was identical with that of authentic 3 : 3′-dimethylthiacyanine iodide.

Pure 2-methylthiobenzothiazole and methyl toluene-*p*-sulphonate gave no dye under the same conditions.

Pyrolysis of 2-Methylthiobenzothiazole.—The compound (25 g.; b. p. 140—144°/6 mm.) was heated for different periods. (1) 12 *Hours' gentle boiling.* The liquid, which slowly darkened, consisted mainly of unchanged 2-methylthiobenzothiazole (15·54 g.), b. p. 112—118°/2 mm., and the isomeric thione, b. p. 118—165°/2 mm. (5·75 g.), m. p. 90° (pale yellow blades from methanol).

(2) 20 *Hours' gentle boiling.* Two fractions were collected: (i) b. p. 60—150°/1 mm., (ii) b. p. 155—65°/1 mm. The former (3·6 g.) was dissolved in ether and extracted with N-hydrochloric acid (3 × 20 c.c.), and the acid extracts were basified, to give an oil (1·45 g.), b. p. 226°/760 mm., identified as benzothiazole *via* its sulphate, m. p. 157°, and picrate, m. p. 167° (Found: C, 42·9; H, 2·2; S, 8·75. Calc. for $C_7H_5NS,C_6H_3O_7N_3$: C, 42·8; H, 2·2; S, 8·8%). Cocker (*J. Soc. Chem. Ind.*, 1936, **55**, 228T) gives sulphate, m. p. 157°, and picrate, m. p. 176°. Ochiai and Nishizawa (*J. Pharm. Soc. Japan*, 1940, **60**, 132) give picrate, m. p. 168°. Although the oil gave pure derivatives of benzothiazole it contained a trace of 2-methylbenzothiazole (see below). The ethereal solution on evaporation left 2-methylthiobenzothiazole (1·42 g.), m. p. 45°.

Fraction (ii) (14·25 g.) which solidified on cooling was separated by 2·5N-sodium hydroxide (20 c.c.) into 2 : 3-dihydro-3-methylbenzothiazole-2-thione (13·22 g.) and 2-mercaptobenzothiazole (0·46 g.), m. p. 178°.

(3) 30 *Hours' vigorous boiling.* The dark viscous liquid on distillation at 1 mm. gave benzothiazole (7·49 g.), the thione (8·22 g.), 2-mercaptobenzothiazole (0·75 g.), and a large amount of tarry residue.

Detection of 2-Methylbenzothiazole in the Benzothiazole Fraction from the Pyrolysis of 2-Methylthiobenzothiazole.—1·8 G. of the fraction, b. p. 226°/760 mm., obtained in (2) above were mixed with 2-methylthiobenzothiazole (2·16 g.) and methyl toluene-*p*-sulphonate (4·7 g.), and the mixture was heated at 130—140° for 3 hours. The yellow melt was dissolved in pyridine (30 c.c.), and the solution boiled (30 minutes) and poured into a warm solution of potassium bromide (12 g.) in 50% aqueous methanol (60 c.c.). The solid (0·08 g.) which separated on cooling was collected, washed with ethanol, hot benzene, and ether, and recrystallised from methanol (10 c.c.), to give yellow needles (0·06 g.), m. p. 293—294° (decomp.) alone or admixed with authentic 3 : 3′-dimethylthiacyanine bromide. The absorption and photographic sensitising spectra of the dye in ethanol solution were also identical with that of the thiacyanine.

Pyrolysis of 2 : 3-*Dihydro*-3-*methylbenzothiazole*-2-*thione*.—2 : 3-Dihydro-3-methylbenzothiazole-2-thione (20 g.) was boiled for 10 hours, the liquid rapidly darkening, and methanethiol and hydrogen sulphide were evolved. Distillation at 25 mm. gave two fractions, (i) an oil (12·17 g.), b. p. 110—200°, which partly solidified, and (ii) a solid (4·7 g.), b. p. 200—220°. From (i) by the procedure outlined above, a benzothiazole fraction (2·72 g.) and the thione were isolated, whilst (ii) gave the thione and 2-mercaptobenzothiazole (0·52 g.).

Tests for the Presence of 2-*Methylbenzothiazole in the Benzothiazole Fraction*.—The benzothiazole fraction (0·32 g.), 2-methylthiobenzothiazole (0·38 g.), and methyl toluene-*p*-sulphonate (0·85 g.) were heated together at 140° for 3½ hours. The yellow melt was dissolved in pyridine (5 c.c.), and the solution boiled for 15 minutes and poured into a solution of potassium bromide (2 g.) in water (60 c.c.), to give yellow needles (0·02 g.) of 3 : 3′-dimethylthiacyanine bromide, m. p. 293—294° (decomp.).

Under the same experimental conditions, 2-methylbenzothiazole (0·32 g.) gave 0·54 g. (79%) of 3 : 3′-dimethylthiacyanine bromide, indicating that the benzothiazole fraction from the thione pyrolysis contained at least 4% of 2-methylbenzothiazole.

Reaction between Dimethylaniline and Sulphur.—Dimethylaniline (100 g.) and sulphur (130 g.) were boiled together for 12 hours, and the reaction mixture worked up as described by Möhlau and Krohn (*loc. cit.*). From the crude thione alkali-soluble 2-mercaptobenzothiazole (0·5 g.) was isolated. A portion (1·35 g.) of the benzothiazole fraction obtained (b. p. 228°) was treated with 2-methylthiobenzothiazole (1·81 g.) and methyl toluene-*p*-sulphonate (3·72 g.) to give 3 : 3′-dimethylthiacyanine bromide (0·03 g.).

Pyrolysis of 2-*Ethylthiobenzothiazole*.—Redistilled 2-ethylthiobenzothiazole (25 g.; b. p. 148—50°/6 mm.) was boiled for 12 hours. The solution rapidly darkened and the dark viscous liquid (which smelled of hydrogen sulphide) was distilled, to yield (i) (5·6 g.), b. p. 162—170°/20 mm., (ii) (0·93 g.), b. p. 170—220°/20 mm., (iii) (2·15 g.), b. p. 200—215°/3 mm. (solidified), and a dark pitch-like residue. This residue consisted of alkali-soluble 2-mercaptobenzothiazole (2·7 g.) and an insoluble unidentified black solid (4·8 g.).

From (i) and (ii) a colourless oil (5 g.), b. p. 91°/3 mm., 227°/760 mm., was obtained which, with picric acid gave an excellent yield of benzothiazole picrate, whilst (iii) yielded 3-ethyl-2 : 3-dihydrobenzothiazole-2-thione (0·76 g., after crystallisation), m. p. 75—76°, and 2-mercaptobenzothiazole (0·6 g.).

Similar results were also obtained when the pyrolysis was carried out for 5 hours except that a larger amount of mercaptobenzothiazole (4·6 g.) was isolated and some unchanged thioether (4·5 g.) was recovered from the distillate by extraction of its benzene solution with concentrated hydrochloric acid (2-ethylthiobenzothiazole is soluble in concentrated but not in dilute mineral acids; cf. 2-methylthiobenzothiazole, Hofmann, *Ber.*, 1887, **20**, 1791).

Detection of 2-*Methylbenzothiazole in the Benzothiazole Fraction*.—The fraction (2·44 g.), b. p. 227°/760 mm., from the pyrolysis of 2-ethylthiobenzothiazole was fused at 130—140° for 3½ hours with 2-methylthiobenzothiazole (2·7 g.) and methyl toluene-*p*-sulphonate (5·6 g.). From the *yellow* melt, by the procedure already described, a dye (0·19 g.) was obtained identical in all respects with authentic 3 : 3′-dimethylthiacyanine bromide.

3 : 3′-*Dimethyl- and* 3 : 3′ : 8-*Trimethylthiacyanine Dyes from* 2-*Ethylbenzothiazole*.—2-Ethylbenzothiazole (1·63 g.), b. p. 254° (purified *via* the picrate, m. p. 136°; Clarke, *J.*, 1928, 2320, gives m. p. 138°), 2-methylthiobenzothiazole (1·81 g.), and methyl toluene-*p*-sulphonate (3·72 g.) were fused together at 140° for 3 hours. The *orange* melt was dissolved in hot pyridine (10 c.c.), boiled for 30 minutes, and poured into a warm solution of potassium bromide (4 g.) in water (40 c.c.). On cooling, yellow needles (0·15 g.) separated, which after crystallisation from methanol gave yellow needles, m. p. 293—294° (decomp.), identical with authentic 3 : 3′-dimethylthiacyanine bromide (Found : C, 52·15; H, 4·2; S, 16·6. Calc. for $C_{17}H_{15}N_2BrS_2$: C, 52·15; H, 3·9; S, 16·4. Calc. for $C_{18}H_{17}N_2BrS_2$: C, 53·3; H, 4·2; S, 15·8%). Addition of potassium iodide (4 g. in 40 c.c. of water) to the filtrate gave slowly an ochre-yellow precipitate of 3 : 3′ : 8-trimethylthiacyanine iodide (0·5 g.), m. p. 247° (decomp.), which crystallised from methanol as orange prisms (0·29 g.), m. p. 252° (decomp.) (Found : C, 48·05; H, 3·8; S, 14·2; I, 27·8. Calc. for $C_{18}H_{17}N_2IS_2$: C, 47·8; H, 3·5; S, 14·2; I, 28·05%). Kiprianov and Ushenko (*Chem. Abs.*, 1950, **44**, 5733) give m. p. 237° (decomp.). A solution of the dye in ethanol was deep yellow and had an absorption maximum at 4675 A., $\varepsilon = 51{,}000$ (cf. 3 : 3′-dimethylthiacyanine iodide, absorption maximum at 4200 A., $\varepsilon = 66{,}400$). Incorporated in a gelatino-silver chloride emulsion the dye gave a zone of extra spectral sensitivity with a maximum at 4900 A. Unlike solid 3 : 3′-dimethylthiacyanine iodide which exhibits a green fluorescence when exposed to ultra-violet light and a bright blue fluorescence when absorbed on filter paper, 3 : 3′ : 8-trimethylthiacyanine iodide exhibits no fluorescence.

From a mixture of benzothiazole with 5% of 2-ethylbenzothiazole, both 3 : 3′-dimethyl- and 3 : 3′ : 8-trimethyl-thiacyanines dyes were also isolated.

Pyrolysis of 2-*Methylthiobenzoxazole*.—2-Methylthiobenzoxazole (25 g.) was boiled for 20 hours. The product, on distillation under diminished pressure, gave unchanged 2-methylthiobenzoxazole (13·6 g.), b. p. 148—52°/20 mm., and impure 2 : 3-dihydro-3-methylbenzoxazole-2-thione (5·92 g.), b. p. 200—

210°/20 mm., which crystallised from ethanol (100 c.c.) as colourless needles (3·98 g.), m. p. 130° (Seidel, *J. pr. Chem.*, 1890, **42**, 452, gives m. p. 128°).

Pyrolysis of 2-Ethylthiobenzoxazole.—2-Ethylthiobenzoxazole (25 g.) was boiled for 20 hours. The thick black liquid was distilled at 1 mm. pressure. Fractions collected were : (i) an oil (0·04 g.), b. p. 60—100°, (ii) an oil (3·22 g.), b. p. 100—140°, (iii) a solid (3·63 g.), b. p. 140—160°, and (iv) a resin (6·2 g.), b. p. 160—220°. From (i), (ii), and (iii) unchanged 2-ethylthiobenzoxazole (0·66 g.), b. p. 230—240°, and 3-ethyl-2 : 3-dihydrobenzoxazole-2-thione (2·42 g.) were isolated. From (iv) a phenolic compound, m. p. 160—162°, soluble in hot aqueous ethanol (1 part of water; 2 parts of ethanol) and an insoluble neutral compound, m. p. 192°, were obtained. These compounds were not identified.

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