

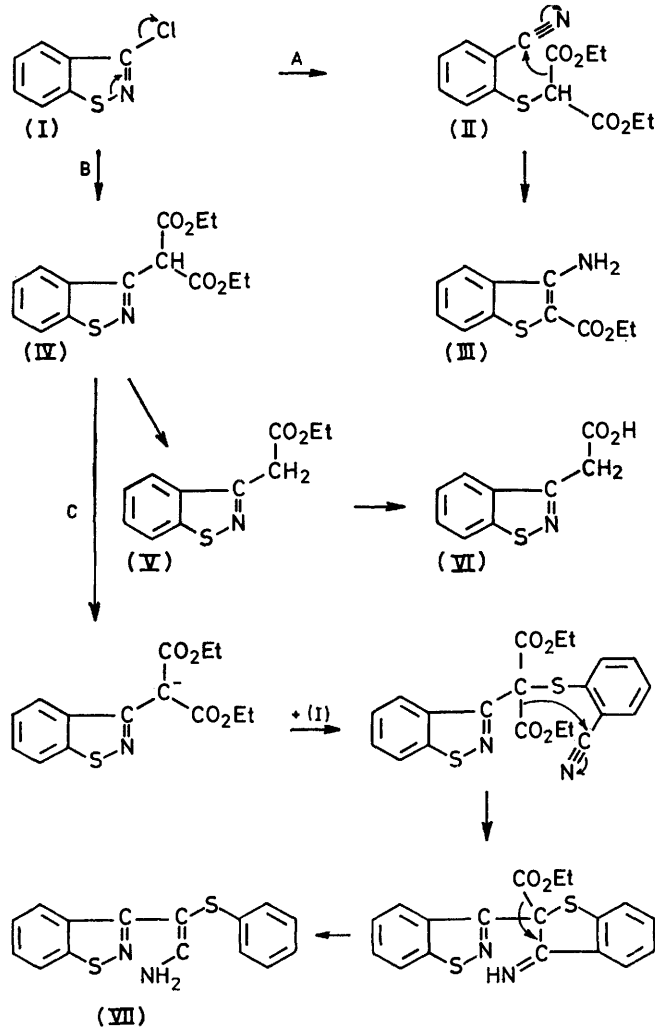
## Reaction of 3-Chloro-1,2-benzisothiazole with Diethyl Malonate in the Presence of Tetra-alkylammonium Salts. Properties and X-Ray Crystal Structure Analysis of 3-(3-Aminobenzo[*b*]thiophen-2-yl)-1,2-benzisothiazole

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3-Chloro-1,2-benzisothiazole (I) reacts with diethyl malonate, in the presence of quaternary ammonium bases, under conditions of phase-transfer catalysis to give products such as, in the reaction with diethyl sodiomalonate, diethyl 1,2-benzisothiazol-3-ylmalonate (IV) and ethyl 1,2-benzisothiazol-3-ylacetate (V), formed by normal nucleophilic substitution at the 3-position, and diethyl (2-cyanophenylthio)malonate (II) and ethyl 3-aminobenzo[*b*]thiophen-2-carboxylate (III), produced by scission of the isothiazole ring. However, in one case the reaction, carried out according to Makosza, is more complex and mainly proceeds towards the 3-(3-aminobenzo[*b*]thiophen-2-yl)-1,2-benzisothiazole (VII), a product which was not previously identified and whose structure we have now established from chemical and spectral properties and X-ray crystal structure analysis. The structure of (VII) was determined from X-ray diffractometer data by direct methods and refined by least-squares to  $R$  0.055 for 1 150 independent reflections.

It is known that the reaction of 3-chloro-1,2-benzisothiazole (I) with diethyl sodiomalonate, in dry ethanol, gives ethyl 3-aminobenzo[*b*]thiophen-2-carboxylate (III)



SCHEME

and ethyl (1,2-benzisothiazol-3-yl)acetate (V) as main products (see Scheme).<sup>1</sup>

We have re-examined the behaviour of (I) towards the anion from diethyl malonate, in order to test an alternative synthetic pathway for (V) and for the corresponding benzisothiazol-3-ylacetic acid (VI), which represent a class of substances with marked phytocidal properties.<sup>1-3</sup> To this aim, we applied phase-transfer catalysis which takes advantage of the properties of quaternary ammonium salts in nucleophilic substitutions. There are many examples of such reactions with various substrates and alkylating agents,<sup>4,5</sup> but nothing is reported about the applications of the same kind of catalysis in substitutions on heterocycles.

Preliminary investigations, carried out by the extractive alkylation of Braendstroem<sup>6,7</sup> and the catalytic alkylation of Makosza<sup>8-10</sup> showed that in both cases derivatives having benzisothiazole and thionaphthene structure are obtained. Moreover from the Makosza-type conditions the compound (VII) was isolated as principal product for the first time.

This paper reports the results of chemical and physico-chemical experiments carried out to elucidate the courses of these reactions.

In phase-transfer catalysis reactions 3-chloro-1,2-benzisothiazole (I) reacts with diethyl malonate in ways other than would be expected for a 2-chloropyridine. The results, summarised in Table I, show that essentially the same products are formed as from (I) and diethyl sodiomalonate.<sup>1,11</sup> The product ratios depend on the method (Braendstroem or Makosza) and solvent, rather than on the ammonium salt. In particular, according to the Braendstroem method,<sup>6,7</sup> diethyl (2-cyanophenylthio)malonate (II) and ethyl 3-aminobenzo[*b*]thiophen-2-carboxylate (III), formed by scission of the isothiazole ring (pathway A, Scheme), predominate over diethyl 1,2-benzisothiazol-3-ylmalonate or ethyl 1,2-benzisothiazol-3-ylacetate, derived from attack at the 3-chloro-substituent (pathway B, Scheme). On the other

TABLE I  
Distribution (%) of compounds (obtained by h.p.l.c.)

Solvent	Reaction time/ h	Compounds						
		(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
(a) By extractive alkylation (Braendstroem)								
CH <sub>2</sub> Cl <sub>2</sub> <sup>a</sup>	3	15.0	1.0	81.0	2.0	1.0		
CH <sub>2</sub> Cl <sub>2</sub> <sup>a</sup>	2	17.0	1.0	74.0	6.0	2.0		
CH <sub>2</sub> Cl <sub>2</sub> <sup>a,b</sup>	16	10.0		87.0	3.0			
Xylene <sup>a</sup>	3	41.0	40.0	14.0	4.0	1.0		
Xylene <sup>a</sup>	16		66.0	28.0	5.0	1.0		
Xylene <sup>a,b</sup>	4		68.0	27.0		5.0		
Diethyl malonate <sup>a</sup>	3	13.0		17.0	59.0	11.0		
AcOEt <sup>a,b</sup>	4	18.0	72.0		3.0	7.0		
Hexane <sup>a</sup>	24			92.0		8.0		
CH <sub>2</sub> Cl <sub>2</sub> <sup>c</sup>	24		65.0	25.0	9.0		1.0	
Xylene <sup>c</sup>	24		75.0	24.0			1.0	
(b) By catalytic alkylation (Makosza)								
No solvent <sup>a</sup>				23.0 <sup>d</sup>		1.0 <sup>d</sup>	9.0 <sup>d</sup>	67.0

<sup>a</sup> With tetrabutylammonium bromide. <sup>b</sup> Isolated ion-pair weighing.

<sup>c</sup> With trimethylbenzylammonium chloride. <sup>d</sup> By g.l.c. <sup>e</sup> By

hand in the Makosza-type reaction,<sup>8-10</sup> mainly 3-(3-aminobenzo[*b*]thiophen-2-yl)-1,2-benzisothiazole (VII) is formed, a product which was not previously identified. Carrington *et al.*<sup>11</sup> postulated that nucleophilic attack on 3-chlorobenzisothiazole can occur at either the 3-position (substitution) or the sulphur atom (ring scission). Thus it is suggested that the benzisothiazolylmalonate (IV), which is more acidic than diethyl malonate, would, as the anion, attack the sulphur atom of a second molecule of (I) to produce the new compound (VII) (pathway C, Scheme), whose structure we have now determined.

#### EXPERIMENTAL

*Physical Measurements.*—M.p.s were determined on a Buechi apparatus (Tottoli).

U.v. spectra were determined for solutions in EtOH *ca.* 10<sup>-5</sup>M (Beckman DK 2); i.r. spectra for KBr (Beckman IR 5); n.m.r. spectra for solutions in CDCl<sub>3</sub> (Varian XL 100); mass spectra were recorded with a Varian MAT CH 5 spectrometer.

Retention times, referred to phenanthrene (*t*<sub>rel</sub>), were determined by means of a Fractovap P AID/f (Erba) gas chromatograph equipped with a flame ionization detector (H<sub>2</sub> 0.40 Kg cm<sup>-2</sup>; air 1.0 Kg cm<sup>-2</sup>) under the following operational conditions: the steel column (100 × 0.25 cm) was filled with 4% fluoroalkylsiloxane (QF 1; Erba) on Chromosorb W (silanized, 30–60 mesh; Erba) with column temperature 178 °C, and nitrogen carrier gas (flow rate: 20 ml min<sup>-1</sup>). Under these conditions, *t*<sub>rel</sub> (min) were: (VI) (as 3-methylbenzisothiazole) 0.63, (V) 4.17, and (III) 8.58.

Elemental analyses were carried out by use of a Perkin-Elmer 240 analyser (C, H, N), and by the Schoeniger method (S).

For the h.p.l.c. analysis of reaction adducts, the following conditions were used: Varian 4 000 liquid chromatograph, equipped with fixed-wavelength (254 nm) detector, column (50 × 0.2 cm), filled with Permaphase ODS (Dupont), mobile phase H<sub>2</sub>O : MeOH 80 : 20, temperature 45 °C, flow rate 0.8 ml min<sup>-1</sup>, pressure: 500 p.s.i., and retention times (min): (V) 1.0, (IV) 1.4, (I) 4.0, (II) 4.8, and (III) 6.4.

*Materials.*—3-Chlorobenzisothiazole was prepared according to ref. 12. Standard samples (for comparison) of diethyl benzisothiazolylmalonate (IV), ethyl benzisothiazolylacetate (V), diethyl 2-cyanophenylthiomalonate (II),

and ethyl 3-aminobenzothiophencarboxylate (III) were prepared as previously reported.<sup>1,11</sup> Ammonium salts (Pfaltz-Bauer) employed were: trimethylbenzylammonium chloride, tetrabutylammonium bromide, triethylbenzylammonium chloride, tetrabutylammonium bromide, and tricaprylmethylammonium chloride.

*Extractive Alkylation (Braendstroem).*—The reaction was carried out by use of molar equivalents of substrate, diethyl malonate, and catalyst, in the presence of a water-immiscible solvent.

Sodium hydroxide (5 × 10<sup>-3</sup> mol) and the appropriate ammonium salt (2.5 × 10<sup>-3</sup> mol), dissolved in water (3 ml) were added to a solution, in the chosen solvent (3 ml), of diethyl malonate (2.5 × 10<sup>-3</sup> mol) and 3-chlorobenzisothiazole (1.25 × 10<sup>-3</sup> mol). The reaction mixture was heated under reflux, under stirring, until the concentration of 3-chlorobenzisothiazole was constant.

The tetrabutylammonium malonate ion-pair is extractable, with CH<sub>2</sub>Cl<sub>2</sub>, from alkaline solution, in almost quantitative yield; concentration of the organic phase gives a stable ammonium salt. In some experiments the isolated ion-pair was employed. Table I reports the results, obtained by h.p.l.c., of some reactions carried out in different solvents.

*Catalytic Alkylation (Makosza).*—The reactions were performed with molar equivalents of substrate and diethyl malonate, and catalytic amounts of ammonium salt, in the presence of concentrated sodium hydroxide and, when possible, without solvent.

A mixture of diethyl malonate (5 × 10<sup>-3</sup> mol), 3-chlorobenzisothiazole (6 × 10<sup>-3</sup> mol), tetrabutylammonium bromide (5 × 10<sup>-5</sup> mol), and 50% aqueous sodium hydroxide (2 ml) was stirred vigorously at 50–60 °C. The reaction is strongly exothermic and after 5 min boils spontaneously to give a yellow bulky mass. In 10–15 min the reaction is complete. After dilution with water, the resulting yellow solid was washed two or three times with small portions of diethyl ether, to remove (III) and (V) from (VII) which was then dried. The aqueous filtrate was acidified with concentrated hydrochloric acid and extracted with diethyl ether. The ethereal extracts contain (III), (V), and benzisothiazolylacetic acid (VI), formed by saponification of (V).

In a typical experiment, starting with 3-chlorobenzisothiazole (2 g), gas-chromatographic analysis of ethereal extracts gave the following composition (%): (V) 1, (VI) 9, (III) 23, and (VII) 67% (by weight).

*Chemical Properties of (VII).*—Compound (VII) crystallizes from ethanol as thin yellow needles, m.p. 179–180 °C (Found: C, 63.75; H, 3.60; N, 10.05; S, 22.35.  $C_{15}H_{10}N_2S_2$  requires C, 63.80; H, 3.57; N, 9.92; S, 22.71%);  $\lambda_{\max}$  (log  $\epsilon$ ) 250 (4.30), 273 (4.34), 295 (4.27), 313 (4.13), 327 (4.13), and 385 (4.32) nm;  $\nu_{\max}$  3 300 and 3 400  $cm^{-1}$ ;  $\delta$  7.2–8.8 (8 H, aromatic H) and 6–6.2 (2 H, exchangeable,  $NH_2$ );  $m/e$  283 (24%), 282  $M^+$  (100), 281 (47), 180 (9), 146 (11), 136 (12), 121 (14), 103 (17), 77 (16), and 76 (17). It is insoluble in water, acids, and bases, sparingly soluble in most organic solvents, and soluble in dimethylformamide. Prolonged boiling either in 10% sodium hydroxide or in 6N hydrochloric acid gave no modification. Product (VII) can be diazotized in 6N hydrochloric acid and coupled with  $\beta$ -naphthol.

#### Crystal Structure Analysis of Compound (VII)

*Crystal Data.*— $M = 282.39$ . Orthorhombic,  $a = 14.09(1)$ ,  $b = 22.62(2)$ ,  $c = 3.965(2)$  Å,  $U = 1 263.7$  Å<sup>3</sup>,  $Z = 4$ ,  $D_c = 1.48$  g  $cm^{-3}$ ,  $F(000) = 584$ . Cu- $K\alpha$  radiation,  $\lambda = 1.541 78$  Å,  $\mu(Cu-K\alpha) = 35.5$   $cm^{-1}$ . Space group  $P2_12_12_1$  (from systematic absences and subsequent success of structural analysis).

Preliminary lattice constants and symmetry information were deduced from rotation and Weissenberg photographs. Accurate lattice parameters were obtained by least-squares calculations based on 2 $\theta$  values for 13 strong reflections measured by single-crystal diffractometry.

*Data Collection.*—Intensity data were collected on an online Siemens AED single-crystal diffractometer ( $\omega$ —2 $\theta$  scan technique) from a slightly pleochroic tabular crystal, of size 0.25  $\times$  0.04  $\times$  0.30 mm, aligned with its  $c$  axis parallel to the  $\phi$  axis of the diffractometer, by use of Cu- $K\alpha$  radiation. The intensities of 1 300 independent reflections were measured to 2  $\theta_{\max}$ , 138° for  $l = 0, 1$  and to 2  $\theta_{\max}$ , 122° for  $l = 2-4$ , as reflections affected by spurious diffraction effects due to the metal of the goniometer head were disregarded. Only 150 reflections, having a net intensity  $I < 2\sigma(I)$ , were considered unobserved and excluded from the analysis. The intensity of a standard reflection, monitored at regular intervals to check crystal alignment and/or decomposition, showed only statistical variations and no evidence of crystal decay. After correction for Lorentz and polarization effects, structure amplitudes were put on an

TABLE 2

Fractional atomic co-ordinates ( $\times 10^4$ ) for (VII), with estimated standard deviations in parentheses for non-hydrogen atoms

	$x/a$	$y/b$	$z/c$
S(1)	1 323(1)	2 939(1)	6 325(6)
S(2)	4 910(1)	3 588(1)	5 246(5)
N(1)	2 065(4)	3 465(2)	4 919(19)
N(2)	2 702(4)	4 473(2)	1 700(18)
C(1)	2 195(5)	2 467(3)	7 775(20)
C(2)	2 120(5)	1 925(3)	9 296(22)
C(3)	2 932(6)	1 616(3)	10 143(23)
C(4)	3 827(5)	1 866(3)	9 484(21)
C(5)	3 909(5)	2 409(3)	8 003(20)
C(6)	3 094(5)	2 731(3)	7 060(19)
C(7)	2 970(4)	3 297(3)	5 414(20)
C(8)	3 698(4)	3 717(3)	4 312(18)
C(9)	3 569(5)	4 242(3)	2 783(19)
C(10)	5 225(5)	4 258(3)	3 558(21)
C(11)	6 145(5)	4 494(3)	3 267(22)
C(12)	6 250(5)	5 043(3)	1 870(24)
C(13)	5 473(6)	5 370(3)	653(23)
C(14)	4 560(5)	5 134(3)	888(21)
C(15)	4 439(5)	4 571(3)	2 244(20)

TABLE 3

Fractional atomic co-ordinates ( $\times 10^3$ ) for (VII), with estimated standard deviations in parentheses for hydrogen atoms

	$x/a$	$y/b$	$z/c$
H(1)	152(5)	176(3)	949(23)
H(2)	293(4)	112(3)	1 064(19)
H(3)	445(5)	156(3)	1 000(21)
H(4)	449(6)	263(4)	808(25)
H(5)	665(6)	428(3)	363(24)
H(6)	683(6)	528(4)	246(28)
H(7)	553(5)	583(3)	71(21)
H(8)	396(5)	540(3)	75(23)
H(9)	268(7)	491(4)	60(34)
H(10)	229(5)	420(3)	187(22)

absolute scale, first by correlating observed and calculated values, then by refining the scale factors for  $F_o$  values as a variable parameter in the least-squares procedure. Absorption effects were disregarded in view of the low absorbance of the sample.

*Structure Determination and Refinement.*—The structure was solved by direct methods, by use of the MULTAN program.<sup>13</sup> The 450 reflections with  $E \geq 1.01$  and the most significant 2 000 phase relationships were considered. The  $E$  map obtained from the set having the highest absolute figure-of-merit clearly indicated the positions of 17 out of the 19 non-hydrogen atoms; the two remaining atoms were found on a subsequent electron-density map. Block-diagonal least-squares refinement, using isotropic temperature factors, converged to  $R$  10.1%. Refinement was continued with anisotropic temperature factors which further reduced  $R$  to 7.3%. All hydrogen atoms were located on a difference map and their contributions allowed for in the calculations, assuming isotropic thermal parameters. Final  $R$  values were 5.5% for the observed reflections only and 6.1% for all reflections. At the termination of refinement the shifts of the positional parameters were not  $> 0.25\sigma$ . The function minimized was  $\Sigma w(\Delta F)^2$ , in which the weight for each reflection was unity. A final difference-Fourier synthesis showed no peak with electron density  $> 0.4$  eÅ<sup>-3</sup>. Final atomic co-ordinates are listed in Tables 2 and 3. Observed and calculated structure factors and thermal parameters are listed in Supplementary Publication No. SUP: 22570 (8 pp.).\*

Atom scattering factors were taken from ref. 14 for non-hydrogen atoms and from ref. 15 for hydrogen. All calculations were carried out on the Cyber 76 Computer of Consorzio per la gestione del Centro di Calcolo Elettronico Interuniversitario dell'Italia Nord-Orientale, Casalecchio, Bologna, with the financial support of the University of Parma.

#### RESULTS AND DISCUSSION

Table 4 gives bond distances and angles involving non-hydrogen atoms. As can be seen from the Figure, the molecule consists of two binuclear systems, connected by a C–C bond. Both these parts are strictly planar, the largest displacement from the least-square plane being 0.02 Å, while the molecule as a whole shows a small, but significant, deviation from exact planarity, the benzisothiazole and benzothiophen moieties being mutually tilted by 5.9°. As a consequence of the strain

\* See Notice to Authors No. 7 in *J.C.S. Perkin II*, 1978, Index issue.

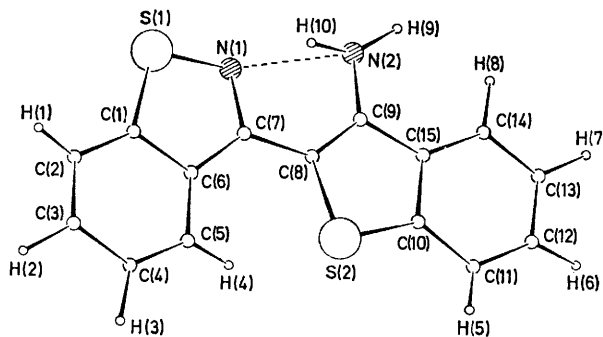
TABLE 4  
Bond lengths (Å) and angles (°) in (VII)

(a) Distances			
S(1)—N(1)	1.679(6)	S(2)—C(18)	1.772(6)
S(1)—C(1)	1.726(7)	S(2)—C(10)	1.715(7)
C(1)—C(2)	1.370(11)	C(10)—C(11)	1.407(10)
C(2)—C(3)	1.382(11)	C(11)—C(12)	1.368(11)
C(3)—C(4)	1.406(11)	C(12)—C(13)	1.407(11)
C(4)—C(5)	1.366(10)	C(13)—C(14)	1.396(11)
C(5)—C(6)	1.410(10)	C(14)—C(15)	1.393(10)
C(6)—C(1)	1.429(10)	C(15)—C(10)	1.414(9)
C(6)—C(7)	1.448(10)	C(15)—C(9)	1.450(10)
C(7)—N(1)	1.345(8)	C(9)—N(2)	1.396(9)
C(7)—C(8)	1.465(9)	C(9)—C(8)	1.346(9)
(b) Angles			
N(1)—S(1)—C(1)	96.1(3)	C(8)—S(2)—C(10)	91.3(3)
S(1)—C(1)—C(2)	130.2(6)	S(2)—C(10)—C(11)	127.3(5)
S(1)—C(1)—C(6)	107.8(5)	S(2)—C(10)—C(15)	112.6(5)
C(2)—C(1)—C(6)	122.0(7)	C(11)—C(10)—C(15)	120.1(6)
C(3)—C(2)—C(1)	119.7(7)	C(12)—C(11)—C(10)	118.5(7)
C(4)—C(3)—C(2)	119.6(7)	C(13)—C(12)—C(11)	122.1(7)
C(5)—C(4)—C(3)	121.7(7)	C(14)—C(13)—C(12)	119.6(7)
C(6)—C(5)—C(4)	120.6(6)	C(15)—C(14)—C(13)	119.2(7)
C(1)—C(6)—C(5)	117.0(6)	C(10)—C(15)—C(14)	120.3(6)
C(7)—C(6)—C(5)	132.4(6)	C(9)—C(15)—C(14)	129.0(6)
C(1)—C(6)—C(7)	110.6(6)	C(9)—C(15)—C(10)	110.5(6)
C(6)—C(7)—N(1)	115.5(6)	N(2)—C(9)—C(15)	120.1(6)
C(6)—C(7)—C(8)	128.6(6)	N(2)—C(9)—C(8)	125.9(6)
N(1)—C(7)—C(8)	115.9(6)	C(15)—C(9)—C(8)	113.9(6)
S(1)—N(1)—C(7)	110.0(5)	C(9)—C(8)—S(2)	111.7(5)
C(7)—C(8)—S(2)	120.4(5)	C(7)—C(8)—C(9)	127.8(6)

caused by the fusion of the six- and five-membered rings, angles S(1)—C(1)—C(6) and S(2)—C(10)—C(15) are reduced to *ca.* 110°, while angles S(1)—C(1)—C(2) and S(2)—C(10)—C(11) are increased to *ca.* 130°. There are small differences in the bond lengths and angles in the two six-membered rings, 1.37—1.43 Å and 117.0—122.1° being the respective ranges. Larger variations have been

observed for the two five-membered rings, which are chemically dissimilar.

The relevant structural parameters of the isothiazole system in its 1,2-derivatives examined by X-ray diffraction are listed in Table 5. Inspection of the data shows that, with a very few exceptions, bond lengths and angles show a small deal of scatter about the average values.



Projection of the structure of compound (VII)

Moreover the bonds at sulphur are shorter than the corresponding single bonds, so that some double-bond character can be assigned to them. The two S—C bonds in the thiophen ring are significantly different ( $\Delta/\sigma$  6.2): S(2)—C(8) corresponds to a S—C( $sp^2$ ) single bond, while S(2)—C(10) has some double-bond character.

The nitrogen atom of the amino-group is involved in two different interactions with adjacent nitrogen atoms, one intramolecular [N(2)  $\cdots$  N(1) 2.76(1) Å] and the other intermolecular [N(2)  $\cdots$  N(2) at  $(\frac{1}{2} - x, 1 - y,$

TABLE 5

A comparison between S—C, S—N, and N—C bond lengths (Å) and N—S—C and S—N—C angles (°) in compound (VII) and in other 1,2-isothiazoles of known structure

Compound	S—C	S—N	N—C	N—S—C	S—N—C	R(%)
3-(Di-isopropylamino)benzothiazole 1,1-dioxide <sup>a</sup>	1.753(2)	1.616(2)	1.320(3)	96.5(1)	111.8(2)	4.6
7-Chloro-1,2-benzisothiazolin-3-one <sup>b</sup>	1.72(1)	1.68(1)	1.34(1)	88.9(3)	118.4(6)	7.5
1,2-Benzisothiazolin-3-one <sup>c</sup>	1.734(5)	1.706(5)	1.36(1)	90.5(3)	115.5(3)	9.2
3-(2-Diethylammoniummethoxy)-1,2-benzisothiazole tetrachlorocuprate <sup>d</sup>	1.750(5)	1.705(5)	1.36(1)	90.6(2)	116.1(3)	
3-(2-Diethylammoniummethoxy)-1,2-benzisothiazole tetrachlorocobaltate <sup>e</sup>	1.714(5)	1.675(5)	1.31(1)	95.3(2)	109.1(3)	8.5
3-(2-Diethylammoniummethoxy)-1,2-benzisothiazole tetrachlorocobaltate <sup>e</sup>	1.77(1)	1.65(1)	1.29(1)	94.8(4)	110.3(7)	8.7
2,4-Bis-(1,2-benzisothiazol-3-yl)-3-aminocrotonitrile dimethylformamide <sup>f</sup>	1.73(1)	1.67(1)	1.30(1)	95.1(5)	109.5(8)	
1,2-Benzisothiazol-3-yl methyl ketoxime <sup>g</sup>	1.727(7)	1.664(6)	1.33(1)	94.5(3)	112.1(5)	8.2
3-(1-Phenyl-5-methoxypyrazol-3-yl)-1,2-benzisothiazole <sup>h</sup>	1.738(8)	1.679(7)	1.32(1)	93.1(3)	110.4(5)	
<i>p</i> -Nitrobenzaldehyde-1,2-benzisothiazol-3-yl hydrazone <sup>i</sup>	1.725(4)	1.664(3)	1.324(4)	94.7(2)	111.9(2)	4.3
3-Hydroxy-5-(methylsulphonyl)-4-phenylisothiazole <sup>j</sup>	1.723(4)	1.673(3)	1.318(4)	94.5(2)	111.5(2)	
3-{3-Aminobenzothiazol-2-yl}-1,2-benzisothiazole <sup>k</sup>	1.725(3)	1.671(3)	1.318(4)	94.9(3)	110.5(3)	4.1
Weighted mean <sup>l</sup>	1.731(3)	1.677(4)	1.310(4)	93.7(1)	111.6(2)	4.3
	1.715(8)	1.661(7)	1.316(10)	93.3(5)	109.2(7)	7.3
	1.726(7)	1.679(6)	1.345(8)	96.1(3)	110.0(5)	5.5
	1.736(4)	1.658(7)	1.320(4)	94.4(5)	112.0(5)	

<sup>a</sup> W. Saenger and H. Hettler, *Chem. Ber.*, 1969, **102**, 1468. <sup>b</sup> L. Cavalca, G. Fava Gasparri, A. Mangia, and G. Pelizzi, *Acta Cryst.*, 1969, **B25**, 2349. <sup>c</sup> L. Cavalca, A. Gaetani, A. Mangia, and G. Pelizzi, *Gazzetta*, 1970, **100**, 629. <sup>d</sup> A. Corradi Bonamartini, M. Nardelli, C. Palmieri, and C. Pelizzi, *Acta Cryst.*, 1971, **B27**, 1775. <sup>e</sup> A. Corradi Bonamartini, M. Nardelli, and C. Palmieri, *Acta Cryst.*, 1972, **B28**, 1207. <sup>f</sup> E. Gaetani, T. Vitali, A. Mangia, M. Nardelli, and G. Pelizzi, *J.C.S. Perkin II*, 1972, 2125. <sup>g</sup> A. Braibanti, M. A. Pellinghelli, A. Tiripicchio, and M. Tiripicchio Camellini, *Acta Cryst.*, 1973, **B29**, 43. <sup>h</sup> M. A. Pellinghelli, A. Tiripicchio, and M. Tiripicchio Camellini, *Cryst. Struct. Comm.*, 1974, **3**, 535. <sup>i</sup> M. T. Lugari Mangia and G. Pelizzi, *Gazzetta*, 1976, **106**, 769. <sup>j</sup> J. L. McVicars, M. F. Mackay, and M. Davis, *J.C.S. Perkin II*, 1977, 1332. <sup>k</sup> Present work. <sup>l</sup> To calculate the standard

deviations of the mean the formula  $\sigma = (\sigma_{ic}^2 + \sigma_{ec}^2)^{\frac{1}{2}}$  was used, where  $\sigma_{ic} = \left[ \sum_{i=1}^N \sigma_i^{-2} \right]^{-\frac{1}{2}}$  and  $\sigma_{ec} = \left\{ \left[ \sum_{i=1}^N (x_i - x_m)^2 \sigma_i^{-2} \right] / (N-1) \sum \sigma_i^{-2} \right\}^{\frac{1}{2}}$  give the internal and the external consistency respectively, and  $x_m = \sum_{i=1}^N x_i \sigma_i^{-2} / \sum_{i=1}^N \sigma_i^{-2}$ .

TABLE 6

Some significant non-bonded contacts (Å)

S(2) ··· C(5)	3.209(7)	C(1) ··· C(2 <sup>II</sup> )	3.58(1)
S(1) ··· N(1)	3.758(8)	C(5) ··· C(4 <sup>III</sup> )	3.60(1)
S(2) ··· C(10 <sup>I</sup> )	3.654(8)	C(7) ··· C(6 <sup>II</sup> )	3.56(1)
S(2) ··· C(15 <sup>I</sup> )	3.617(8)	C(9) ··· C(8 <sup>II</sup> )	3.57(1)
S(1) ··· C(1 <sup>II</sup> )	3.761(8)	N(2) ··· N(1 <sup>III</sup> )	3.64(1)

Roman numerals as superscripts refer to the following equivalent positions relative to the reference molecule at  $x, y, z$ :

I  $x, y, z + 1$ II  $x, y, z - 1$ 

$\frac{1}{2} - z$  3.15(1) Å]. The first of these interactions can be considered as a hydrogen bond [N(2)-H(10) ··· N(1) 137°]. Other relevant contacts responsible for packing in the structure (Table 6) correspond to van der Waals interactions.

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## REFERENCES

- <sup>1</sup> T. Vitali, F. Mossini, M. R. Mingiardi, E. Gaetani, and P. V. Plazzi, *L'Ateneo Parmense, Acta Naturalia*, 1971, **7**, 71.
- <sup>2</sup> T. Vitali, M. R. Mingiardi, and A. Maggiali, *Il Farmaco (Ed. Sci.)*, 1973, **28**, 8.
- <sup>3</sup> Ger. P. 1,950,370; *Chem. Abs.*, 1970, **73**, 130,991.
- <sup>4</sup> J. Dockx, *Synthesis*, 1973, 441.
- <sup>5</sup> E. V. Dehmlow, *Angew. Chem. Internat. Edn.*, 1974, **13**, 170; 1977, **16**, 493.
- <sup>6</sup> A. Braendstroem and U. Junggren, *Acta Chem. Scand.*, 1969, **23**, 2202, 2203, 2204.
- <sup>7</sup> A. Braendstroem and U. Junggren, *Tetrahedron Letters*, 1972, 473.
- <sup>8</sup> M. Makosza and B. Serafinowa, *Roczniki Chem.*, 1965, **39**, pp. 1223, 1401, 1595, 1799, 1805; *Chem. Abs.*, 1966, **64**, 17,475.
- <sup>9</sup> M. Makosza and B. Serafinowa, *Roczniki Chem.*, 1966, **40**, 1647, 1839; *Chem. Abs.*, 1967, **66**, 94,792.
- <sup>10</sup> M. Makosza, *Tetrahedron Letters*, 1969, 673, 677.
- <sup>11</sup> D. E. L. Carrington, K. Clarke, and R. M. Scrowston, *J. Chem. Soc. (C)*, 1971, 3903.
- <sup>12</sup> T. Vitali, F. Mossini, G. Bertaccini, and M. Impicciatore, *Il Farmaco (Ed. Sci.)*, 1968, **23**, 1081.
- <sup>13</sup> G. Germain, P. Main, and M. M. Woolfson, *Acta Cryst.*, 1970, **B26**, 274.
- <sup>14</sup> D. T. Cromer and J. B. Mann, *Acta Cryst.*, 1968, **A24**, 321.
- <sup>15</sup> R. F. Stewart, E. R. Davidson, and W. T. Simpson, *J. Chem. Phys.*, 1965, **42**, 3175.