Exchange, Elimination, and Ring Opening Reactions of 2,3-Dihydrobenzimidazo[1,2-*d*][1,2,4]thiadiazoles and 3*H*-Benzimidazo[2,1-*c*][1,2,4]dithiazoles

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The reactions of benzimidazo[1,2-*d*][1,2,4]thiadiazol-3(2*H*)-ones (**1**) with isocyanates, isothiocyanates, carbon disulphide, aryl cyanates, acetylenedicarboxylates, and enamines, with exchange of the isocyanate component of (**1**), to give the corresponding condensed benzimidazole derivatives (**1**)—(**6**) are described. Under more severe conditions the 1-benzothiazol-2-yl-1,3-dihydrobenzimidazole-2-thiones (**7**) were obtained from aromatic isothiocyanates. Thermolysis of the thiadiazoles (**1**) led to the triazine derivative (**12**) with elimination of isocyanate and sulphur, and in the presence of phenols to the 2-aryloxybenzimidazoles (**13**). With amines and CH-acidic compounds, the S,N bond in compound (**1**) was cleaved to give benzimidazol-2-ylsulphenamides (**14**), and the ω-substituted methylthiobenzimidazoles (**17**) and (**18**). With cyanide ion, insertion into the S,N bond of compound (**1**) to furnish the thiadiazine (**22**) took place. The dithiazoles (**2**) were fragmented by amines to give 1,3-dihydrobenzimidazole-2-thione and guanidine with loss of sulphur; reaction with cyanide ion then gave the dibenzimidazothiadiazine (**25**).

Recently we reported the synthesis of the benzimidazo[1,2-*d*][1,2,4]thiadiazol-3(2*H*)-ones (**1**) by oxidative ring closure of 1-carbamoyl-1,3-dihydrobenzimidazole-2-thiones.[1] We also mentioned the ready exchange of the isocyanate component, contained in compounds (**1**), with other isocyanates to give a differently substituted compound (**1**), with isothiocyanates to give 3*H*-benzimidazo[2,1-*c*][1,2,4]dithiazol-3-imines (**2**), and with carbon disulphide to give 3*H*-benzimidazo[2,1-*c*][1,2,4]-dithiazole-3-thione (**3**) These reactions are reversible (see Scheme 1). We report here a more detailed investigation of this exchange reaction, and of the elimination and ring opening reactions of compound (**1**).

Exchange Reactions with Compounds Containing π-Bonds.—The exchange of the alkyl or aryl isocyanate component in compounds (**1**) (R = alkyl, aryl) by other alkyl or aryl isothiocyanates is clearly not affected by structural considerations, and takes place both at room temperature in methylene dichloride (method A) and on heating (method B) with yields up to 98%. Further examples, not reported in ref. 1 are summarised in Table 1.

Dicyclohexylcarbodi-imide (DCC) could not displace the isocyanate component in the thiadiazoles (**1**) at room temperature. At 130 °C the thiadiazole (**1e**) was obtained exclusively; this probably results from the reaction of the liberated isocyanate and DCC to give the intermediate cyclohexyl isocyanate, which then reacts with the starting thiadiazole (**1**).

The exchange reaction is not confined to heterocumulenes. Electron deficient nitriles and acetylenes such as cyanic acid esters, trichloroacetonitrile, and dimethyl acetylenedicarboxylate are also suitable partners for exchange with the isocyanate (see Scheme 1 and Table 1). These reactions likewise occur under mild conditions to give the benzimidazo[1,2-*d*][1,2,4]-thiadiazoles (**4**), in practically quantitative yields, and to give dimethyl benzimidazo[2,1-*b*][1,3]thiazole-2,3-dicarboxylate (**5**), respectively. In contrast to the reactions with heterocumulenes, these are not reversible, although the reaction of the thiadiazole (**4f**) with 4-methoxyphenyl cyanate to give (**4l**) is possible.

Cyanamide, azobenzene, and dimethyl azodicarboxylate do not react with the thiadiazoles (**1**), but surprisingly, the reaction with cyclohexenylmorpholine was successful. We assigned structure (**6**) to the product on the basis of the analytical data and comparison with the product from the reaction of 1,3-dihydrobenzimidazole-2-thione and 2-bromocyclohexanone.[2]

While the exchange of the thiadiazoles (**1**) with aromatic isothiocyanates proceeds selectively to furnish the 3-aryliminodithiazoles (**2h**) and (**2k**) at room temperature, isomers were obtained at higher temperatures. The isomers show a C=S signal in the ^{13}C n.m.r. spectrum [(**7a**): 167.5 p.p.m.] and can be acetylated to compounds of type (**8**) (Scheme 2) in which the C=S group signal is retained [(**8a**): 171.9 p.p.m.]. The structure of the isomer (**7**), 1-benzothiazol-2-yl-1,3-dihydrobenzimidazole-2-thiones, follows unequivocally from an independent synthesis from 1,3-dihydrobenzimidazole-2-thione and 2-chlorobenzothiazole; this disproves the structure previously proposed,[3] 2-phenylbenzimidazo[1,2-*d*][1,2,4]thiadiazole-3(2*H*)-thione.
As expected, the rearrangement of compounds (**2**) into the isomers (**7**) proceeds more easily, the more nucleophilic the aromatic radical. Thus, with phenyl isothiocyanate a temperature of 180 °C is required, whereas with *p*-tolyl isothiocyanate the reaction takes place in boiling ethanol.

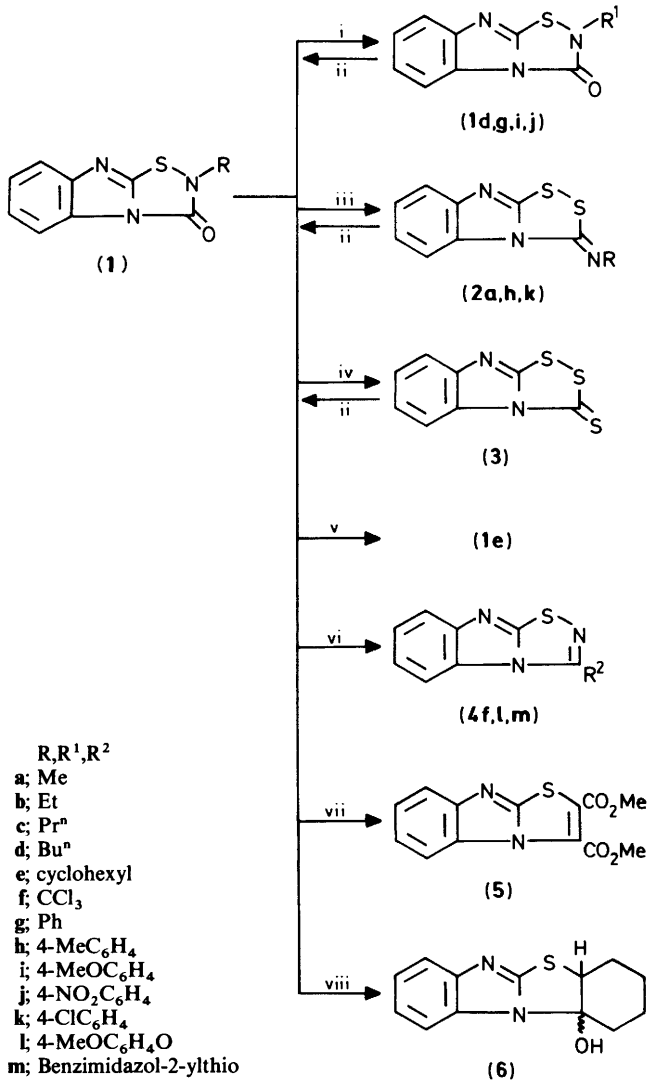
We assume that the exchange reactions do not proceed *via* the 1,3-dipole (**9**), which is formed by predissociation, but through a λ^4-thia-azapentalene-like intermediate (**10**) (Scheme 3). The reasons for this proposal are as follows.

1. In the absence of exchange partners, no isocyanate can be detected by i.r. spectroscopy of the thiadiazoles (**1**) at room temperature. Decomposition begins only above *ca.* 160 °C, with simultaneous elimination of sulphur.

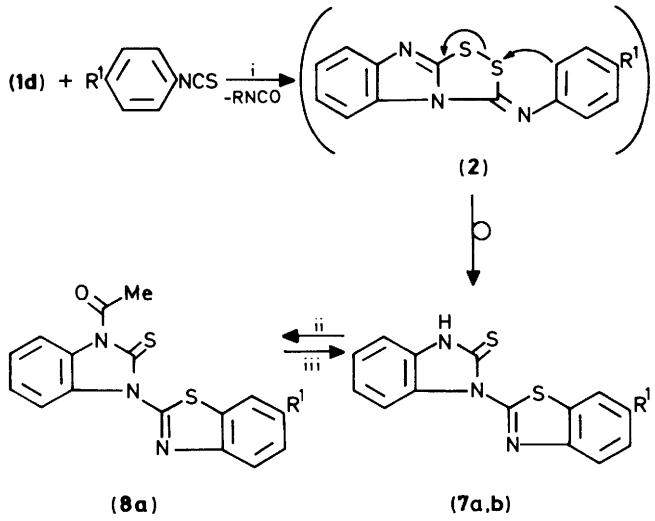
2. Analogous ring transformations were also observed for the 1,2,4-thiadiazole and dithiazole systems for example, in which heteropentalene-like intermediates were detected for particular cases.[4–6] The existence of compounds such as 1,6-dioxa-6aλ^4-thia-3,4-diazapentalenes, 1,3,4,6-tetra-aza-6aλ^4-thiapentalenes, and other types of thiapentalenes has been experimentally confirmed by Beer[7,8] and L'abbé.[9,10]

However, we did not succeed in detecting (by ^{13}C n.m.r. spectroscopy) an intermediate (**10**) in the reaction with the thiadiazole (**1d**) and A=B = BuNCO.

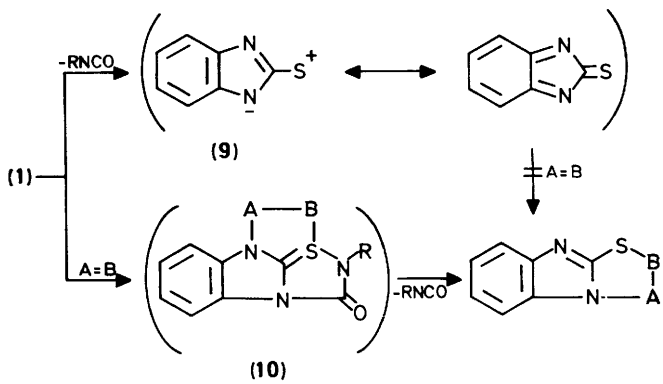
Elimination Reactions.—On heating the thiadiazoles (**1**) in high-boiling inert solvents, elimination of isocyanate occurred



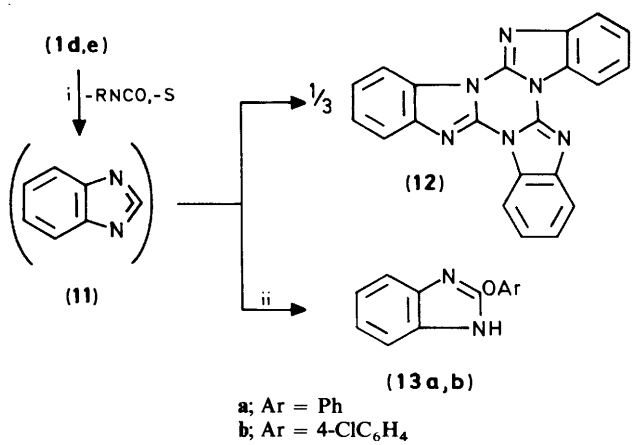
Scheme 1. *Reagents*: i, R^1NCO; ii, RNCO; iii, RNCS; iv, CS_2; v, DCC; vi, R^2CN; vii, $(CCO_2Me)_2$; viii, 1-morpholinocyclohexene



Scheme 2. *Reagents*: i, heat; ii, Ac_2O; iii, MeOH, MeONa



Scheme 3.



Scheme 4. *Reagents*: i, > 160 °C; ii, ArOH

at *ca.* 160 °C, with simultaneous elimination of sulphur. A product precipitated out which had a m.p. near 380 °C. This thermolytic behaviour is the same as that observed for the thiadiazoles (**1**). After melting, new crystals formed again with a m.p. near 380 °C. A comparison of the spectra showed the high-melting product to be identical with the triazine derivative (**12**), already reported in the literature and obtained by a different route.[11,12] We believe that the formation of the triazine (**12**) by trimerisation proceeds *via* the unisolable cyclic carbodi-imide (**11**) (Scheme 4). Cyclic carbodi-imides with different numbers of ring atoms ranging from fourteen to below eight were recently made accessible[13] by the rearrangement of cyclic amidoxime-*O*-methane sulphonates and by dehydro-sulphurisation of cyclic thioureas. Seven-membered cyclic carbodi-imides were only detected on flash vacuum pyrolysis of heteroaromatic azides and by separation on an argon matrix.[14,15] Conventional preparations afforded dimers and trimers of type (**12**).[13] Attempts to trap six-membered cyclic carbodi-imides, *e.g.* 1,3-diazacyclohexa-1,2-diene, as cycloadducts failed.

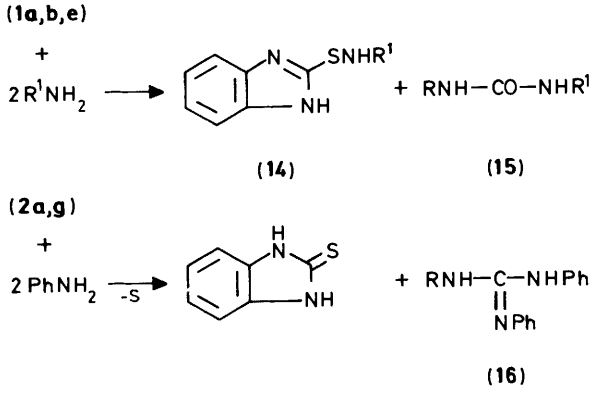
The thermolysis of the thiazoles (**1**) in the presence of phenols gave the 2-aryloxybenzimidazoles (**13**), again supporting the existence of an intermediate carbodi-imide (**11**). Phenols do not react with compounds (**1**) at room temperature; however, in the presence of alkoxide ion, alcohols reductively open the 1,2,4-thiadiazole ring in compounds (**1**) forming 1-carbamoyl-1,3-dihydrobenzimidazole-2-thiones [the reverse of the formation of (**1**)[1]].

Table 1. Examples of exchange reactions of the thiadiazoles (**1**) and (**4**) and the dithiazoles (**2**) with heterocumulenes

Compound (Formula)	Prepared from	Method (yield, %)	M.p. (°C) (Recrystallisation solvent)	Found (%) (Required) C	H	N
(**1d**) ($C_{12}H_{13}N_3OS$)	(**1g**) + Bu^{n}NCO	B (97)	156—157 (Me_2CO)	see ref. 1		
	(**2g**) + Bu^{n}NCO	B (77)				
	(**3**) + Bu^{n}NCO	B (98)				
(**1g**) ($C_{14}H_9N_3OS$)	(**2c**) + PhNCO	A (92)	235 C_6H_5Cl)	see ref. 1		
(**1i**) ($C_{15}H_{11}N_3O_2S$)	(**1b**) + 4-$MeOC_6H_4NCO$	A (95)	310—335[a] (C_6H_5Cl)	60.8 (60.60)	3.7 (3.75)	14.4 (14.15)
(**1j**) ($C_{14}H_8N_4O_3S$)	(**1e**) + 4-$NO_2C_6H_4NCO$	A (100)	300[b]	53.3 (53.85)	2.95 (2.6)	17.5 (17.95)
(**2a**) ($C_9H_7N_3S_2$)	(**1d**) + MeNCS	A (25)	195—211 (DMSO)	see ref. 1		
(**2h**) ($C_{15}H_{11}N_3S_2$)	(**1d**) + 4-MeC_6H_4NCS	A (90)	135 (EtOH)	60.65 (60.60)	3.3 (3.75)	14.15 (14.15)
(**2k**) ($C_{12}H_{13}N_3S_2$)	(**1d**) + 4-ClC_6H_4NCS	A (97)	200 (Pr^{n}OH)	52.85 (52.9)	2.45 (2.55)	13.15 (13.2)
(**4f**) ($C_9H_4Cl_3N_3S$)	(**1d**) + Cl_3CCN	A (98)	229 (Toluene)	37.25 (36.95)	1.1 (1.4)	14.45 (14.35)
(**4l**) ($C_{15}H_{11}N_3OS$)	(**1d**) + 4-MeC_6H_4OCN	A (79)	195 (EtOH)	see ref. 26		
	(**4f**) + 4-MeC_6H_4OCN	B[c] (90)				

[a] On fast heating, m.p. 235—240 °C. [b] Poorly soluble, washed with acetone, melts with decomposition. [c] Reaction at room temperature.

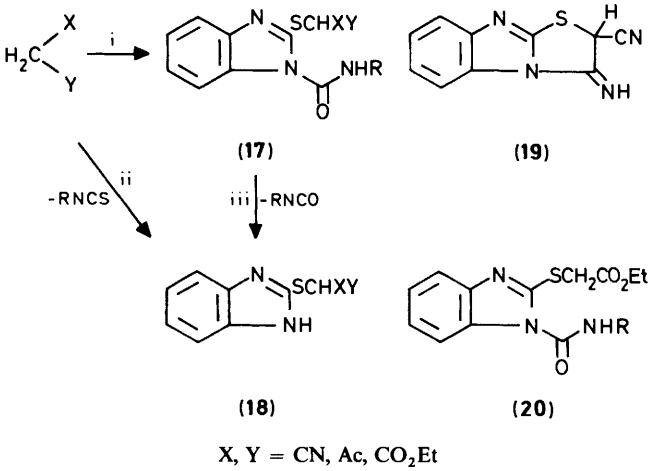
Ring Opening Reactions.—With N- and C-nucleophiles the thiadiazoles (**1**) behave as cyclic sulphenamides reacting with fission of the S,N bond analogously to the open chained sulphenamides.[16] With an excess of amine, the sulphenamides (**14**) are formed, and the liberated isocyanate is trapped as the urea (**15**) (Scheme 5). The reaction does not reach completion



Scheme 5.

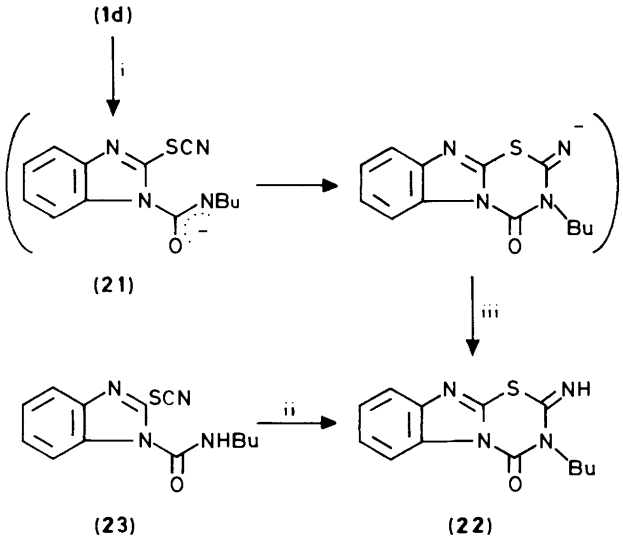
with a molar ratio of 1:1 of starting reagents, since some of the amine is removed from the reaction mixture by the quicker formation of the urea. In contrast with the 3-imino-3*H*-benzimidazo[2,1-*c*][1,2,4]dithiazoles (**2**) the nucleophilic attack takes place at the iminocarbonyl group (see ref. 17) with elimination of sulphur and subsequent aminolysis to 1,3-dihydrobenzimidazole-2-thione and the corresponding substituted guanidine (**16**). Analogously, the dithiazolethione (**3**) reacts with amines to furnish the corresponding thioureas.

C,H-Acidic compounds also cleave the S,N bond of the thiadiazoles (**1**) during the formation of compound (**17**) (Scheme 6). Analogous examples with isothiazolinones[18] and open chained



Scheme 6. *Reagents*: i, +(**1**); ii, +(**2**); iii, heat

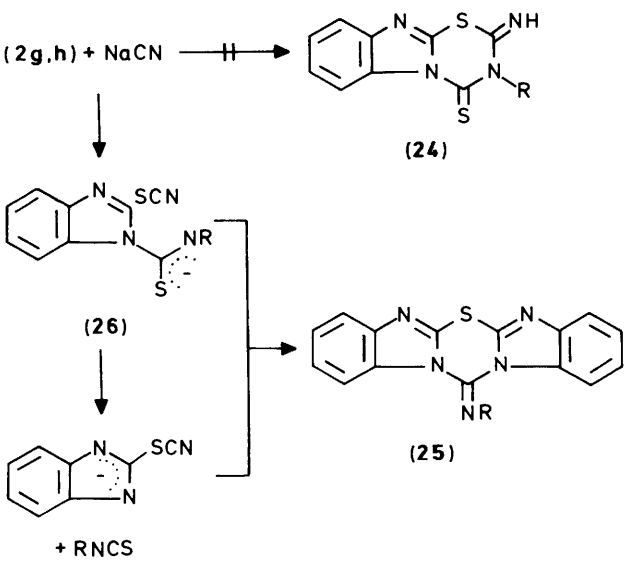
sulphenamides[19] are known. At higher temperatures, the isocyanate moiety is removed to give compound (**18**). The dithiazoles (**2**) and (**3**) react similarly, although an intermediate comparable with the carbamoyl derivatives (**17**) was not isolated. The reaction is widely applicable.[20] However, the functional groups X and Y may result in subsequent reactions which must be taken into account. For example, at 90 °C with malononitrile, the thiadiazole (**1d**) affords the iminothiazole (**19**) by cyclisation, with elimination of isocyanate, while with monoethyl malonate simultaneous decarboxylation takes place to give the acetic acid derivative (**20**). For comparison, we prepared compound (**20**) independently from 1,3-dihydrobenzimidazole-2-thione and ethyl chloroacetate and subsequent reaction with isocyanate. The cyanide ion inserts into the S,N bond of the thiadiazoles (**1**), probably *via* the intermediate (**21**) which immediately recyclises to give the thiadiazinone (**22**) (Scheme 7). Facile ring-closure of 1-carbamoyl-2-thiocy-



Scheme 7. *Reagents*: i, NaCN; ii, Et_3N; iii, H^+

anatobenzimidazole (**23**) to give the thiadiazinone (**22**)[21] in the presence of triethylamine confirms this assumption. Similar insertion reactions were observed for ring enlargements of isothiazolium compounds to yield 2-imino-1,3-thiazine derivatives.[22]

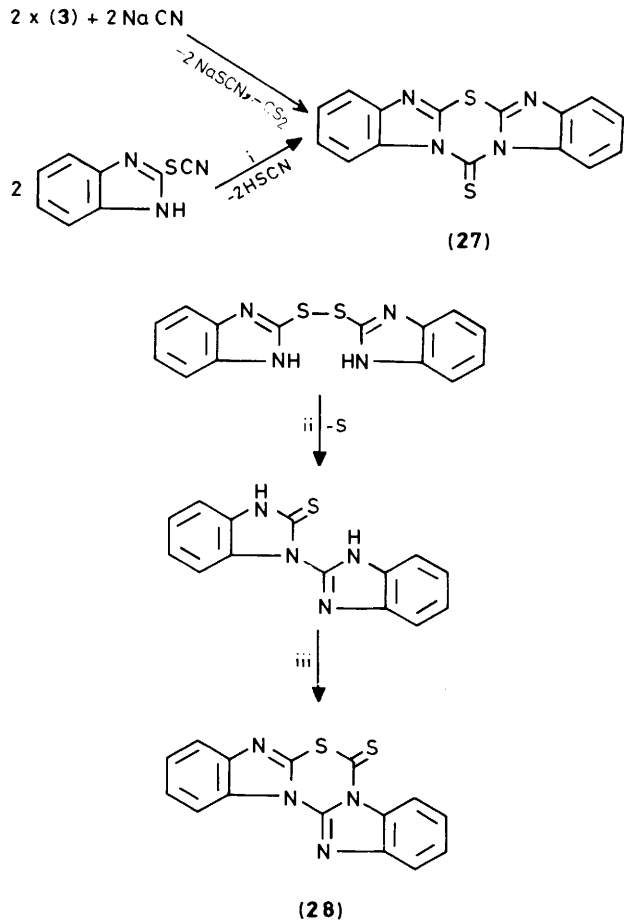
The dithiazoles (**2**) and (**3**) do not react with cyanide ion to give the analogous thiadiazine derivatives (**24**), accessible by a different pathway.[21] However, they form the 13-imino-13*H*-dibenzimidazo[2,1-*b*:1′2′-*e*][1,3,5]thiadiazine (**25**) (Scheme 8). It



Scheme 8.

is thought that the reaction begins with the fission of the S,S bond by the thiophilic cyanide ion,[23] yielding the intermediate (**26**); this then decomposes into isothiocyanate and 2-thiocyanatobenzimidazole which undergoes cyclisation to furnish the pentacyclic derivative (**25**) with the removal of the thiocyanate ion. The instability of the thioamide bonds, *e.g.* of 1-thiocarbamoyl-1,3-dihydrobenzimidazole-2-thiones, is well known.[24] The 4-iminothiadiazine (**25**) may also be obtained from 2-thiocyanatobenzimidazole and isothiocyanates in the presence of triethylamine.

For comparison, the dithiazolethione (**3**) also reacted with sodium cyanide to give the thiadiazine-4-thione (**27**) (Scheme 9),



Scheme 9. *Reagents*: i, CS_2; ii, DMF, heat; iii, $CSCl_2$

which was synthesized independently from 2-thiocyanatobenzimidazole and carbon disulphide by Haugwitz and Narayan.[25] The isomeric thiadiazine-2-thione (**28**) was not formed, as shown by an independent preparation[21] from bisbenzimidazolyl disulphide and subsequent cyclisation with thiophosgene.

Experimental

^1H N.m.r. (100 MHz) spectra were determined with a Tesla BS 567 instrument using Me_4Si as internal standard. ^{13}C N.m.r. spectra were recorded with a Varian CFT-20 (hexamethyldisilazane as internal standard). M.p.s are uncorrected.

Exchange Reactions of the Benzimidazo[1,2-d][1,2,4]*thiadiazol*-3(2H)-*ones* (**1**), 3H-*Benzimidazo*[2,1-c][1,2,4]*dithiazol*-3-*imines* (**2**) *and* -3-*thiones* (**3**), *and Benzimidazo*[1,2-d][1,2,4]*thiadiazoles* (**4**). *General Procedure.—Method A.* The benzimidazo-condensed thiadiazole or dithiazole derivative (**1**)—(**4**) (10 mmol) was dissolved or suspended in methylene dichloride (10 ml), and the heterocumulene or activated nitrile (20 mmol) was added. After 24 h at room temperature either the separated reaction product was filtered off or the solvent was distilled off under reduced pressure and the residue washed with hexane or recrystallised from an appropriate solvent.

Method B. The condensed benzimidazo derivative (**1**)—(**4**) was heated to boiling with an excess of the heterocumulene or activated nitrile. On cooling, the reaction product crystallised out. If the reaction was incomplete, the recrystallisation from the heterocumulene was repeated. The results are given in Table 1.

2-*Cyclohexylbenzimidazo*[1,2-d][1,2,4]*thiadiazol*-3(2H)-*one* (**1e**) *from* 2-*Butylbenzimidazo*[1,2-d][1,2,4]*thiadiazol*-3(2H)-*one* (**1d**) *and DCC.*—A mixture of the thiadiazole (**1d**) (2.47 g, 10 mmol) and DCC (10 g, 48.5 mmol) was heated to 100 °C for 1 h and a weak stream of N_2 was passed through the melt. The mixture was then cooled, dissolved in an excess of DCC in methanol (10 ml), and the residue was recrystallised from propanol to give a colourless material (1.50 g, 55%), m.p. 205 °C (lit.,[1] 205 °C).

Dimethyl Benzimidazo[2,1-b][1,3]*thiazole*-2,3-*dicarboxylate* (**5**).—The thiadiazole (**1d**) (2.47 g, 10 mmol) was suspended in dimethyl acetylenedicarboxylate (5.0 g, 35.2 mmol) and heated to 60 °C for 5 min. The yellow suspension was cooled off and stirred with methanol (15 ml). The solid was filtered off and recrystallised from methanol, yielding the dicarboxylate (**5**) (2.02 g, 70%), m.p. 167—168 °C (lit.,[27] 166—167 °C) (Found: C, 53.55; H, 3.75; N, 9.45. Calc. for $C_{13}H_{10}N_2O_4S$: C, 53.8; H, 3.45; N, 9.65%); $\delta_H(CDCl_3)$ 3.86 (3 H, s, OCH_3), 4.08 (3 H, s, OCH_3), and 7.0—7.8 (4 H, m, phenylene); $\delta_C(CDCl_3)$ 53.2, 54.0 (2 OCH_3), 111.8, 119.7, 122.1, 125.5 (4 aromatic CH), 129.3, 148.6 (2 aromatic C), 118.6, 128.8 (2 olefinic C), 154.4 (C-9a), and 159.7, 160.4 (2 CO_2Me).

10a-*Hydroxy*-6a,7,8,9,10,10a-*hexahydrobenzimidazo*[2,1-b]-[1,3]*benzothiazole* (**6**).—The thiadiazole (**1d**) (2.47 g, 10 mmol) and 4-cyclohex-1-enylmorpholine (5.0 g, 29.9 mmol) was dissolved in $CHCl_3$ (15 ml). The solvent was evaporated off in an open reaction vessel at room temperature, and the residue crystallised by triturating with acetonitrile (5 ml), to give a colourless compound (**6**) (1.8 g, 74%), m.p. 159—160 °C (MeCN) (lit.,[2] 136—138 °C) (Found: C, 63.4; H, 5.5; N, 11.45%; M^+, 246. Calc. for $C_{13}H_{14}N_2OS$: C, 63.4; H, 5.75; N, 11.35%; *M*, 246); $\delta_H[(CD_3)_2SO]$ 1.20—2.60 [8 H, m, $(CH_2)_4$], 4.18 [1 H, t, C*H*(OH)], 7.0 (1 H, s, OH), and 6.8—7.62 (4 H, m, phenylene); $\delta_C[(CD_3)_2SO]$ 20.8, 21.7, 28.8, 32.8 [$(CH_2)_4$], 57.6 (C-6a), 90.0 (C-10a), 109.6, 117.9, 121.2, 121.5 (aromat. CH), 132.5, 148.6 (aromat. C), and 155.2 (C-5a).

1-*Benzothiazol*-2-*yl*-1,3-*dihydrobenzimidazole*-2-*thione* (**7a**).—(*a*) The thiadiazole (**1d**) (2.47 g, 10 mmol) was heated to 180—200 °C in phenyl isothiocyanate (5.0 ml, 41.7 mmol) for 1 h. After cooling the mixture was suspended in ethanol (20 ml), and the residue filtered off and recrystallised from chlorobenzene to give fine needles of *compound* (**7a**) (1.7 g, 60%), m.p. 320—325 °C (Found: C, 59.6; H, 3.2; N, 14.75%; M^+, 283. $C_{14}H_9N_3S_2$ requires C, 59.35; H, 3.2; N, 14.85%; *M*, 283); $\delta_C[(CD_3)_2SO]$ 109.9, 115.2, 121.7, 121.7, 123.4, 125.1, 125.5, 126.5 (aromat. CH), 130.9, 131.8, 133.5, 147.3 (aromat. C), 156.2 (C-2'), and 167.5 (C=S).

(*b*) 2-Chlorobenzothiazole (1.7 g, 10 mmol) and 1,3-dihydrobenzimidazole-2-thione (1.7 g, 11.3 mmol) were heated to 200 °C for 1 h. After being cooled the mixture was finely powdered, boiled with ethanol (50 ml), and the residue was recrystallised from chlorobenzene yielding fine colourless needles (1.9 g, 67%), (mixed m.p., t.l.c., and i.r.) identical with the compound obtained by method (*a*).

3-*Acetyl*-1-*benzothiazol*-2-*yl*-1,3-*dihydrobenzimidazole*-2-*thione* (**8a**).—The 1,3-dihydrobenzimidazole-2-thione (**7a**) (1 g, 3.53 mmol) was boiled in acetic anhydride (20 ml, 212 mmol) for 4 h. On cooling, colourless *crystals* were obtained (0.8 g, 76%), m.p. 180 °C (the melt crystallised and remelted at 310—320 °C) (Found: C, 59.3; H, 3.25; N, 12.9%; M^+, 325. $C_{16}H_{11}N_3OS_2$ requires C, 59.05; H, 3.4; N, 12.9%; *M*, 325); $\delta_C(CDCl_3)$ 171.9 (C=S). The compound may be deacylated to give (**7a**) by dissolution in MeOH–MeONa and by precipitation with acetic acid.

1-(6-*Methylbenzothiazol*-2-*yl*)-1,3-*dihydrobenzimidazole*-2-*thione* (**7b**).—The thiadiazole (**1d**) (2.47 g, 10 mmol) and *p*-tolyl isothiocyanate (5.0 ml, 36.4 mmol) were boiled in ethanol (75 ml) for 1 h. At first a clear solution formed from which a colourless precipitate separated. The mixture was filtered after being cooled and the residue was recrystallised from chlorobenzene or toluene to give *compound* (**7b**) (2.85 g, 96%), m.p. 320—325 °C (Found: C, 60.4; H, 3.3; N, 14.1%; M^+, 297. $C_{15}H_{11}N_3S_2$ requires C, 60.6; H, 3.75; N, 14.15%; *M*, 297).

Tribenzimidazo[1,2-a:1',2'-c:1'',2''-e][1,3,5]*triazine* (**12**).—The thiadiazole (**1d**) (1 g, 4.05 mmol) was heated to boiling in mesitylene (25 ml). In 15 min *ca.* 10 ml of mesitylene had been distilled off containing the eliminated butyl isocyanate. Cyclohexane (30 ml) was added to the distillation residue, and the solid was filtered off, dried, and liberated from sulphur with CS_2 to give the product (**12**) (10 ml), m.p. 380 °C (DMF or toluene) (lit.,[11] 391—393 °C, lit.,[12] 353—356 °C) (Found: C, 72.55; H, 3.35; N, 24.05%; M^+, 348. Calc. for $C_{21}H_{12}N_6$: C, 72.4; H, 3.45; N, 24.1%; *M*, 348).

2-*Aryloxybenzimidazoles* (**13**).—The thiadiazole (**1d**) (1 g, 4.05 mmol) was heated to 160—170 °C in the corresponding phenol (2 g) for 15 min. The cooled melt was dissolved in methanol, precipitated with water and recrystallised. The following were obtained. (a) 2-Phenoxybenzimidazole (**13a**) (0.5 g, 59%), m.p. 227—230 °C (MeOH–H_2O) (lit.,[28] 228—229 °C). (b) 2-(p-*Chlorophenoxy*)*benzimidazole* (**13b**) (0.5 g, 50%), m.p. 228—229 °C (MeCN) (Found: C, 63.75; H, 3.05; N, 11.3%; M^+, 244. $C_{13}H_9ClN_2O$ requires C, 63.8; H, 3.7; N, 11.45%; *M*, 244).

1-*Ethylcarbamoyl*-1,3-*dihydrobenzimidazole*-2-*thione from* 2-*Ethylbenzimidazo*[1,2-d][1,2,4]*thiadiazol*-3(2H)-*one* (**1b**) *and Sodium Methoxide.*—The thiadiazole (**1b**) (2.19 g, 10 mmol) was suspended in a solution of sodium methoxide (1 g) in methanol (40 ml), and stirred at room temperature until a clear solution was obtained. After neutralisation with hydrochloric acid, water (50 ml) was added, and the carbamoyl derivative was filtered off (1 g, 45%), m.p. 305 °C (m.p. of 1,3-dihydrobenzimidazole-2-thione which is formed on heating). The compound was identical with material prepared from 1,3-dihydrobenzimidazole-2-thione and ethyl isocyanate.

N-*Substituted Benzimidazol*-2-*ylsulphenamides* (**14**).—*General procedure.* The thiadiazole (**1**) (10 mmol) was suspended in acetonitrile (40 ml) and the corresponding amine (20 mmol) was added dropwise with stirring at room temperature. After 48 h with occasional stirring the precipitated urea (**15**) was filtered off. The sulphenamide (**14**) was separated with water and recrystallised.

(a) N-*Cyclohexylbenzimidazol*-2-*ylsulphenamide* (**14**; R^1 = cyclohexyl). The thiadiazole (**1e**) and cyclohexylamine gave *compound* (**14**; R^1 = cyclohexyl) (2.17 g, 88%), m.p. 145—150 °C (benzene–hexane). The same compound was formed from the thiadiazole (**1b**) and cyclohexylamine, yield 38%, m.p. 145—150 °C (benzene–hexane) (Found: C, 62.65; H, 6.95; N, 16.8. $C_{13}H_{17}N_3S$ requires C, 63.1; H, 6.95; N, 17.0%); $\delta_C(CDCl_3)$ 24.7, 25.6, 33.3, 59.8 (cyclohexyl), 114.2 (C-4,C-7), 122.0 (C-5,C-6), 139.6 (C-3a,C-7a), and 156.0 (C-2).

Table 2. Analytical data for the ω-disubstituted 1-carbamoyl-2-methylthiobenzimidazoles (**17**)[a]

Compound (**17**)			Yield	M.p.		Found (%) (Required)			(M^+)
R	X	Y	(%)	(°C)	Formula	C	H	N	(*M*)
Me	COMe	COMe	100	180—187	$C_{14}H_{15}N_3O_3S$	54.4 (55.1)	4.9 (5.0)	13.25 (13.75)	305 (305)
Bu^n	COMe	COMe	92	180—185[b]	$C_{17}H_{21}N_3O_3S$	58.75 (58.8)	6.1 (6.15)	12.1 (12.1)	(347)
cyclo-C_6H_{11}	COMe	COMe	100	184—188	$C_{19}H_{23}N_3O_3S$	61.0 (61.1)	6.35 (6.2)	11.1 (11.25)	373 (373)
Me	CO_2Et	COMe	100	138—143[c]	$C_{15}H_{17}N_3O_4S$	53.85 (53.7)	5.05 (5.1)	12.4 (12.55)	335 (335)
Bu^n	CO_2Et	COMe	100	120—130[d]	$C_{18}H_{23}N_3O_4S$	57.05 (57.3)	6.15 (6.15)	11.15 (11.15)	377 (377)
cyclohexyl	CO_2Et	COMe	100	144—146[e]	$C_{20}H_{25}N_3O_4S$	59.35 (59.55)	6.35 (6.25)	10.45 (10.4)	403 (403)
cyclohexyl	CO_2Et	CO_2Et	63	147—148	$C_{21}H_{27}N_3O_5S$	58.05 (58.2)	6.05 (6.3)	9.5 (9.7)	308[f] (433)
Bu^n	CN	CN	23	283—285	$C_{15}H_{15}N_5OS$	57.55 (57.5)	4.65 (4.8)	22.05 (22.35)	214[f] (313)

[a] Representative example of the ^{13}C n.m.r. spectra; compound (**17**; R = cyclohexyl, X = Y = CO_2Et) ($C_{21}H_{27}N_3O_5S$): $\delta_C(CDCl_3)$ 14.0, 62.7 (OEt), 25.4, 25.7, 32.8, 50.5 (cyclohexyl), 53.8 [*S*CH(CO_2Et)$_2$], 111.5 (C-7), 119.2 (C-4), 123.5, 123.8 (C-5, C-6), 133.4 (C-7a), 143.5 (C-3a), 149.3, 150.2 (C=O,C-2), 165.9 (*C*O_2Et). [b] Fast heating, m.p. 140 °C. [c] Fast heating, m.p. 110 °C. [d] Fast heating, m.p. 95 °C. [e] Fast heating, m.p. 135 °C. [f] M^+ − RNCO.

(b) N-*Phenylbenzimidazol*-2-*ylsulphenamide* (**14**; R^1 = Ph). The thiadiazole (**1e**) and aniline gave compound (**14**; R^1 = Ph)[29] (1.32 g, 55%), m.p. 140—145 °C (MeOH–H_2O) (Found: C, 64.6; H, 5.35; N, 17.3%; M^+, 241. Calc. for $C_{13}H_{11}N_3S$: C, 64.7; H, 4.6; N, 17.4%; *M*, 241); δ_C[$(CD_3)_2SO$] 114.1, 114.9 (C-4,C-7;C-2′, C-6′), 120.0 (C-4′), 121.4 (C-5,C-6), 128.9 (C-3′,C-5′), 139.4 (C-3a,C-7a), 146.9 (C-1′), and 153.5 (C-2).

1,3-*Dihydrobenzimidazole*-2-*thione and* N,N′,N″-*Triphenylguanidine from* 3-*Phenylimino*-3H-*benzimidazo*[2,1-c][1,2,4]-*dithiazole and Aniline*.—A mixture of the dithiazole (**2g**) (500 mg, 1.76 mmol) and aniline (5.0 ml, 55 mmol) was heated to 90 °C for 1 h. After being cooled, the mixture was diluted with $CHCl_3$ (10 ml), and the precipitated 1,3-dihydrobenzimidazole-2-thione was filtered off. The filtrate was extracted with aqueous NaOH (10 ml; 2%), and washed with water (10 ml). The aqueous layers were combined and neutralised, and the precipitated 1,3-dihydrobenzimidazole-2-thione was filtered off (280 mg, 91%), m.p. 305 °C.

The $CHCl_3$ layer was evaporated off under reduced pressure, the liquid residue was diluted with methanol (20 ml), and the separated sulphur was filtered off. Water was added to the mother-liquor to give *N*,*N*′,*N*″-triphenylguanidine (440 mg, 87%), m.p. 144 °C (EtOH–H_2O).

ω-*Disubstituted* 2-*Methylthiobenzimidazoles* (**17**) *and* (**18**).—*General procedure*. The thiadiazole (**1**) and the dithiazole (**2**) were suspended in the CH-acidic compound (2 ml) (solid CH-acidic compounds are dissolved in the minimum amount of MeCN). During the reaction, which was occasionally exothermic, the reaction mixture solidified. After 24 h the mixture was triturated with hexane (10 ml) and the remaining solid was filtered off. In general, the products were obtained as pure compounds. If recrystallisation is necessary, *e.g.* acetone–water are appropriate for the carbamoyl derivatives (**17**), extended heating should be avoided because of possible isocyanate elimination.

The analytical data of the carbamoyl derivatives (**17**) from the thiadiazoles (**1**) and CH-acidic compounds are given in Table 2. The following ω-disubstituted 2-methylthiobenzimidazoles (**18**) were also obtained, from the dithiazoles (**2**) and CH-acidic compounds: (i) 2-diacetylmethylthiobenzimidazole (18, X = Y = Ac), from the dithiazole (**2a**) and acetylacetone, yield 85%, m.p. 185—186 °C (EtOH) (lit.,[30] 185—186 °C). The same compound was formed from the dithiazole (**2g**) and acetylacetone, yield 91%.

(ii) 2-[Acetyl(ethoxycarbonyl)methylthio]benzimidazole (**18**; X = Ac, Y = EtO_2C) from the dithiazole (**2a**) and ethyl acetoacetate, yield 100%, m.p. 149—150 °C (EtOH) (lit.,[30] 149—150 °C). The same compound was formed from the dithiazole (**2g**) and methyl acetoacetate in a yield of 87%.

3-*Imino*-2,3-*dihydrobenzimidazo*[2,1-b][1,3]*thiazole*-2-*carbonitrile* (**19**).—The thiadiazole (**1d**) (2.47 g, 10 mmol) was melted with malononitrile at 90 °C and kept at this temperature for 15 min. After the mixture had been cooled, ethanol (15 ml) was added and the solid was filtered off, recrystallised from DMF and affords the *thiazole* (**19**) (0.99 g, 46%), m.p. 285 °C (Found: C, 56.15; H, 2.35; N, 25.6%; M^+, 214. $C_{10}H_6N_4S$ requires C, 56.05; H, 2.8; N, 26.15%; *M*, 214); δ_C[$(CD_3)_2SO$] 58.7 (C-2), 148.3 (C-3), 112.2 (C-5), 118.4 (C-8), 121.3, 124.3 (C-7,C-6), 129.3 (C-4a), 146.8 (C-8a), 152.4 (C-9a), and 115.0 (CN).

Ethyl α-(1-*Alkylcarbamoylbenzimidazol*-2-*ylthio*)*acetates* (**20**).—The thiadiazole (**1**) (10 mmol) was suspended in monoethyl malonate (3.0 g, 22.7 mmol) at room temperature. Within a short time carbon dioxide was expelled exothermically. After several hours the mixture was dissolved in warm MeCN (30 ml) and precipitated with water. The compounds obtained were sufficiently pure for characterisation. They could be further purified by recrystallisation from EtOH or MeCN; however extended heating should be avoided because of the facile elimination of isocyanate.

(i) *Ethyl* α-(1-*ethylcarbamoylbenzimidazol*-2-*ylthio*)*acetate* (**20**; R = Et) (2.1 g, 68%), m.p. 133—134 °C (Found: C, 54.85; H, 5.55; N, 13.1%; M^+, 307. $C_{14}H_{17}N_3O_3S$ requires C, 54.7; H, 5.55; N, 13.65%; *M*, 307); $\delta_C(CDCl_3)$ 14.1, 61.9 (OEt), 14.7, 36.2 (NEt), 35.3 (SCH_2), 111.8 (C-7), 119.0 (C-4), 123.4, 123.8 (C-6,C-5), 133.7 (C-7a), 143.6 (C-3a), 150.2, 151.0 (C=O,C-2), and 169.0 (CO_2Et).

(ii) *Ethyl α-(1-cyclohexylcarbamoylbenzimidazol-2-ylthio)-acetate* (**20**; R = cyclohexyl) (3.4 g, 94%), m.p. 153—155 °C (Found: C, 59.7; H, 6.65; N, 11.65%; M^+, 361. $C_{18}H_{23}N_3O_3S$ requires C, 59.8; H, 6.4; N, 11.65%; *M*, 361); $\delta_C(CDCl_3)$ 14.1, 61.9 (Et), 24.7, 25.4, 32.8, 50.4 (cyclohexyl), 35.5 (SCH_2), 111.8 (C-7), 119.0 (C-4), 123.4, 123.7 (C-6,C-5), 133.8 (C-7a), 143.5 (C-3a), 149.3, 150.8 (C=O,C-2), and 168.9 (CO_2Et).

3-*Butyl*-2-*imino*-2,3-*dihydrobenzimidazo*[2,1-d][1,3,5]*thiadiazin*-4-*one* (**22**).—To a suspension of the thiadiazole (**1d**) (2.47 g, 10 mmol) in MeCN (50 ml), NaCN (0.49 g, 10 mmol) was added at room temperature and the mixture stirred for 1 h, then filtered and the filtrate neutralised with acetic acid. The precipitated solid (0.77 g) was filtered off and consisted mainly of 1-butylcarbamoyl-1,2-dihydrobenzimidazole-2-thione. Water was added to the mother-liquor, and the thiadiazine (**22**) (1.5 g, 55%) was obtained, m.p. 138 °C (EtOH–H_2O) (lit.,[21] 138 °C).

13H-bis-*Benzimidazo*[2,1-b:1′,2′-e][1,3,5]*thiadiazine*-13-*arylimine* (**25**) *and* -13-*thione* (**27**) *from Dithiazoles* (**2**) *and* (**3**), *respectively*.—NaCN (0.49 g, 10 mmol) was added to a suspension of dithiazole (**2**) or (**3**) (10 mmol) in MeCN (40 ml) with stirring at room temperature. After 1—2 h a clear solution is formed from which the thiadiazine (**25**) or (**27**), respectively, precipitates.

(i) 13-*Phenylimino*-13H-*dibenzimidazo*[2,1-b:1′,2′-e][1,3,5]-*thiadiazine* (**25**; R = Ph) (1.5 g, 82%), m.p. 195 °C (MeCN) (Found: C, 68.25; H, 3.05; N, 18.85%; M^+, 367. $C_{21}H_{13}N_5S$ requires C, 68.65; H, 3.55; N, 19.05%; *M*, 367); $\delta_C(CDCl_3)$ 114.5 (C-1,C-11), 119.3 (C-4,C-8), 121.7, 123.8, 124.8, 125.6, 129.3 (C-2′,C-6′;C-3,C-9;C-2,C-10;C-4′;C-3′,C-5′*), 131.8 (C-11a, C-14a), 141.8, 141.8, 143.5, 143.6 (C-13;C-5a,C-6a;C-4a,C-7a; C-1′*).

(ii) 13-p-*Tolylimino*-13H-*dibenzimidazo*[2,1-b:1′,2′-e][1,3,5]-*thiadiazine* (**25**; R = *p*-tolyl) (1.3 g, 69%), m.p. 179—180 °C (MeCN–H_2O) (Found: C, 68.95; H, 3.9; N, 18.15%; M^+, 381. $C_{22}H_{15}N_5S$ requires C, 69.25; H, 3.95; N, 18.35%; *M*, 381). $\delta_C(CDCl_3)$ 20.9 (CH_3), 114.6 (C-1,C-11), 119.2 (C-4,C-8), 121.6, 123.7, 124.6, 128.6, 129.8 (C-2′,C-6′;C-3,C-9;C-2,C-10;C-4′; C-3′,C-5′*), 131.8 (C-11a,C-14a), 135.4 (C-1′), and 140.9, 141.8, 143.4 (C-13;C-5a,C-6a;C-4a,C-7a*).

(iii) 13H-*Dibenzimidazo*[2,1-b:1′,2′-e][1,3,5]*thiadiazine*-13-*thione* (**27**) (0.74 g, 48%), m.p. 184—186 °C (lit.,[25] 184—185 °C, lit.,[31] 189—190 °C), identical (n.m.r., mixed m.p.) with a sample prepared according to Hull.[31]

13-*Phenylimino*-13H-*dibenzimidazo*[2,1-b:1′,2′-e][1,3,5]*thiadiazine* (**25**; R = Ph) *from* 2-*Thiocyanatobenzimidazole and Phenyl Isothiocyanate*.—To 2-thiocyanatobenzimidazole (1.75 g, 10 mmol) in MeCN (35 ml) was added triethylamine (2 ml), and the suspension dissolved. The thiadiazine (**25**; R = Ph) precipitated after the mixture had been concentrated in an open vessel to a volume of *ca.* 15 ml, yield 19%, m.p. 195 °C (MeCN), identical with the compound described above.

* Assignments may be reversed.

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