Synthesis of Annelated 1,3,4,6-Thiatriazepines from Reaction of Cyclic Thioureas with 1,4-Dichloro-2,3-diazabutadienes

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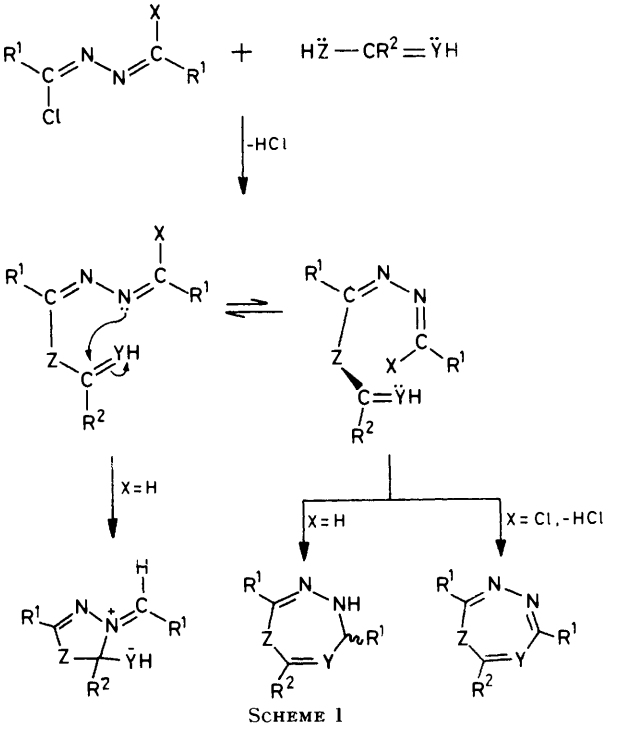
Acyclic thioureas react with 1,4-dichloro-1,4-diphenyl-2,3-diazabutadiene in the presence of triethylamine or sodium hydride to give mainly 2,5-diphenyl-1,3,4-thiadiazole. By contrast, the cyclic thioureas imidazoline-2-thione, dihydropyrimidine-2-thione, 4-oxopyrimidine-2-thione, 6-methyl-4-oxopyrimidine-2-thione, and benzimidazole-2-thiol, react with 1,4-dichloro-1,4-diphenyl-2,3-diazabutadiene, and, in the case of imidazoline-2-thione, also with 1,4-dichloro-1,4-bis(4-chlorophenyl)-2,3-diazabutadiene, in the presence of a two-molar proportion of sodium hydride, to give the series of 2,5-diphenyl-[1,2-*f*]-1,3,4,6-thiatriazepines: (7a) (35%), (7b) (63%), (9a) (36%), (9b) (26%), (8) (49%), and (7c) (29%), respectively. Formation of the thiatriazepines is accompanied by variable amounts of 2,5-diaryl-1,3,4-thiadiazoles (2a,b). Acid hydrolysis of the diarylthiatriazepines yields a mixture of breakdown products, of which the principal components are the diphenylthiadiazole (2a) (12—90%), 2,5-diphenyl-1,3,4-oxadiazole [12% from compound (7b)], the corresponding thione (21—22%), and, from the thiatriazepinones (9a and b), the corresponding pyrimidinediones (15a and b) (81—95%). The thiatriazepine (7a) reacts with sodium ethoxide to give a ring-opened product, believed to be 1-ethoxy-4-(2-thioxoimidazolin-1-yl)-1,4-diphenyl-2,3-diazabutadiene (18) (77%).

For several years we have been concerned with the development of new methods for the synthesis of *SN*-heterocycles based upon the reactions of 1-chloro-2,3-diazabutadienes [1,2] and the corresponding 1,4-dichloro-diazabutadienes [3] with *S*-nucleophiles. These researches had as one of their objectives the 1,4-addition–cyclization of 1,3-bis-nucleophiles across the diazabutadiene system, which should afford novel seven-membered heterocycles (Scheme 1). For some time this objective was thwarted by a general tendency for initial substitution to be followed by an *exo*-trigonal cyclization to give, for example when Z = S, thiadiazolines or thiadiazoles; indeed such a ring closure occurs very readily if the 3-nitrogen of the 2,3-diazabutadiene residue has access to a polarised π-bond in the bis-nucleophile.[4,5] Such closures to five-membered rings are evidently favoured by the normally *S-trans*-configuration of 2,3-diazabutadienes (azines),[6,7] which makes the desired 7-*endo*-trigonal ring closure [7] particularly difficult. Nevertheless, we are now able to report that when the bis-nucleophile is the sodium salt of a cyclic thiourea, such 1,4-dichloro-2,3-diazabutadienes (1a and b) are indeed converted into 1,3,4,6-thiatriazepines, provided that cyclization in the desired sense is encouraged by the addition of sufficient sodium hydride to ensure the formation of an intermediate anion. The spectroscopic properties and behaviour towards acids and bases of these novel heterocycles have also been studied.



Scheme 1

Reaction of 1,4-*Dichloro*-1,4-*diaryl*-2,3-*diazabutadienes with Thioureas*

(*a*) *Acylic Thioureas.*—As reported in an earlier account of the reactions of the dichlorodiazabutadiene (1a) with *S*-nucleophiles,[3] thiourea reacts rapidly with the dichloride (1a) in refluxing ethanol, but the product is the five-membered 2,5-diphenyl-1,3,4-thiadiazole (2a) (75%). Reasoning that the second addition–elimination required for the formation of a seven-membered ring would be impeded by the initial formation of a hydrochloride (3), which must facilitate the unwanted 5-*exo*-trigonal closure, we tried unsuccessfully to promote thiatriazepine formation by the addition to the reaction mixture of various bases, including triethylamine. In the case of triethylamine, its hydrochloride (57%) was formed but the unwanted thiadiazole (2a) was still the main product (89%) (Scheme 2).

In order to make ring-closure to a thiatriazepine more likely, it was decided to increase the nucleophilicity of the thiourea; accordingly, compound (1a) was treated

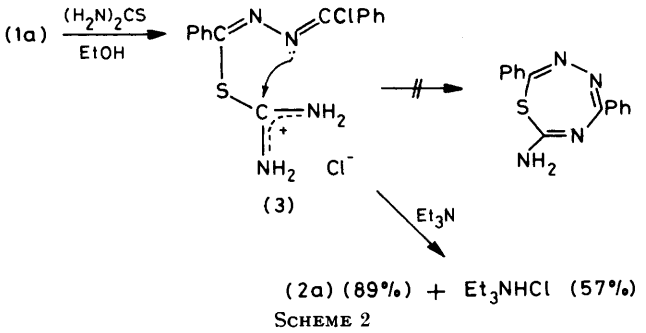
with the sodium salt of *NN'*-dimethylthiourea, generated *in situ* from the thiourea and sodium hydride in anhydrous dimethylformamide (DMF). To promote further the *N*-nucleophilicity essential for 7-*endo*-closure (Scheme 1), a second molar proportion of sodium hydride was added after the initial reaction had subsided. Hydrogen was evolved and this was taken to indicate that the

(1) (2)

a; Ar = Ph a; Ar = Ph

b; Ar = 4-ClC_6H_4 b; Ar = 4-ClC_6H_4

sodium salt of an intermediate isothiourea (4) had been produced (Scheme 3); generation of such an anionic centre in the nucleophile should have the secondary effect of making the attack by the 3-nitrogen upon the C=N bond of the isothiourea very unlikely. However, the thiadiazole (2a), although obtained in lower yield than before (46%), was still the only organic product isolated from the resulting mixture.



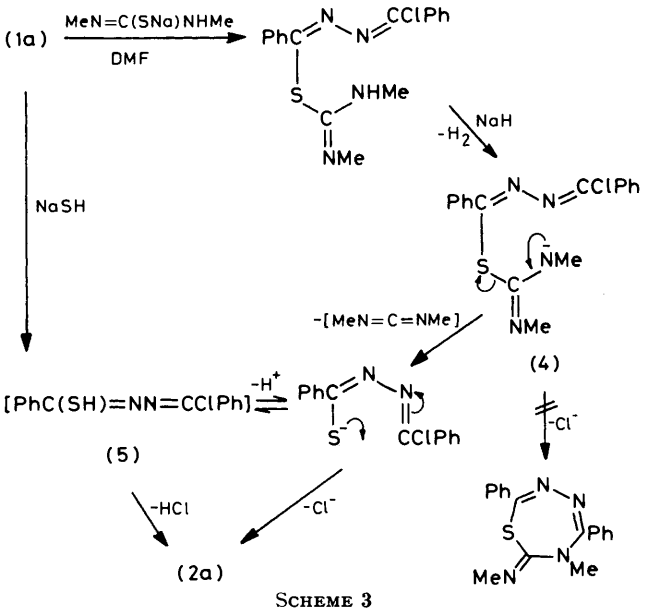
(2a) (89%) + Et_3NHCl (57%)

SCHEME 2

Continued production of the thiadiazole under these conditions is rationalised by the mechanism shown in Scheme 3, in which elimination of *NN'*-dimethylcarbodi-imide leads to the anion of the thiohydrazide (5). This mechanism is supported by an earlier observation [3] that the dichloride (1a) reacts with sodium hydrogen sulphide to give a high yield of the thiadiazole (2a) (84%), a reaction which seems certain to proceed *via* the thiohydrazide (5) or its anion, and by the discovery that such thiohydrazides spontaneously cyclise to Δ^2-1,3,4-thiadiazolines.[8]

Treatment of the dichloride (1a) with the sodium salts of thioacetamide and acetylthiourea gave similar yields (76% and 82%, respectively) of the thiadiazole, and a new initiative was clearly required to prevent the unwanted elimination of carbodi-imide in the intermediate stages of the reaction.

(*b*) *Cyclic Thioureas.*—Three-atom linear structural units such as allenes [9] and carbodi-imides [10] are well known to be difficult to accommodate even in a seven-membered ring, and we therefore argued that the elimination proposed in Scheme 3 might be prevented by the use of suitable cyclic five- or six-membered thioureas. Significantly, treatment of the dichloride (1a) with imidazoline-2-thione (6a) (ethylenethiourea) in the presence of triethylamine gave rather a low yield (35%) of the thiadiazole. Accordingly, compound (1a) was next treated with the sodium salt of imidazolinethione in DMF: at first, only low yields of any component other than the thiadiazole were detected by t.l.c., but the addition of a second molar proportion of sodium hydride proved effective, and a yellow solid, m.p. 177—179 °C, which gave microanalytical results compatible with its formulation as $C_{17}H_{14}N_4S$, was isolated in 35% yield.



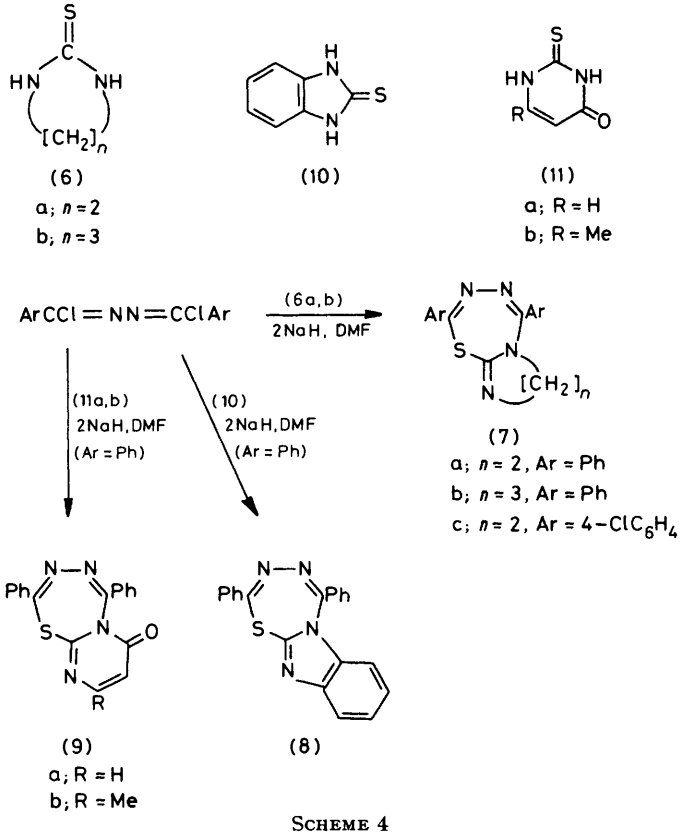
SCHEME 3

The ^1H n.m.r. spectrum of this product confirmed that two phenyl groups and two non-equivalent methylene-groups were present, and its ^{13}C n.m.r. spectrum showed in addition that three different C=N bonds were present in accord with the thiatriazepine structure (7a). A literature search failed to reveal any previous examples of annelated thiatriazepines, and in view of the novelty of the ring system, an *X*-ray crystallographic analysis was undertaken.[11] It showed conclusively that an annelated diphenylthiatriazepine (7a) had been obtained, the seven-membered ring being extensively puckered with one C=N bond (133 pm) being somewhat longer than the other two (126 pm).

The general nature of this method of thiatriazepine synthesis was then demonstrated by the preparation of a series of analogous compounds (7b) (63%), (8) (49%), and (9a and b) (36 and 26%) from the sodium salts of, respectively, dihydropyrimidine-2-thione (6b), benzimidazole-2-thiol (10), and 4-oxo- and 6-methyl-4-oxopyrimidine-2-thiones (11a and b) (Scheme 4). In a single experiment with 1,4-dichloro-1,4-bis(4-chlorophenyl)-2,3-diazabutadiene (1b),[12] the corresponding thiatriazepine (7c) (29%) was also obtained from imidazoline-2-thione. The structures proposed for these thia-

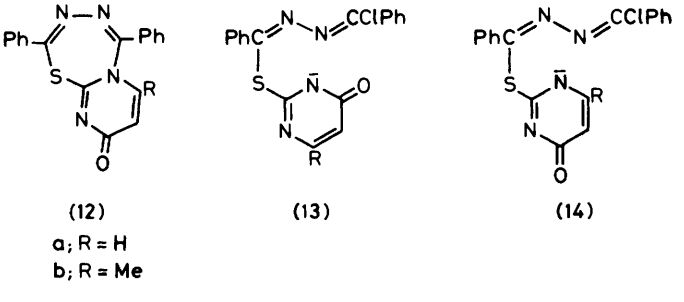
triazepines follow from comparison of their spectroscopic data, especially their u.v. and ^{13}C n.m.r. spectra, with those of the first example (7a).

The most difficult of the structural assignments are those for the 4-oxopyrimidine-2-thione adducts (9a,b), for which alternative structures (12a,b) are possible on the basis of a different orientation of addition. Discrimination between these two possibilities was made on the basis of their i.r. spectra, since the carbonyl stretching absorption of the adduct (9a) (ν_{CO} 1 688 cm^{-1}) is more consistent with its being a 2,3-disubstituted pyrimidin-4-one (ν_{CO} expected to lie in the range 1 655—1 690 cm^{-1}) than with a 2,3-disubstituted pyrimidin-6-one (ν_{CO} in the range 1 630—1 650 cm^{-1}).[13-15] The carbonyl stretching frequency of the adduct (9b) (ν_{CO} 1 692 cm^{-1}) is close enough to that of the adduct (9a) to indicate that methyl substitution does not lead to a change of orientation in its formation. Such an orientation is also more likely on mechanistic grounds, since structure (9) would arise *via* the intermediate anion (13), whereas structure (12) would have to arise from the vinylogous and less nucleophilic amide anion (14).



SCHEME 4

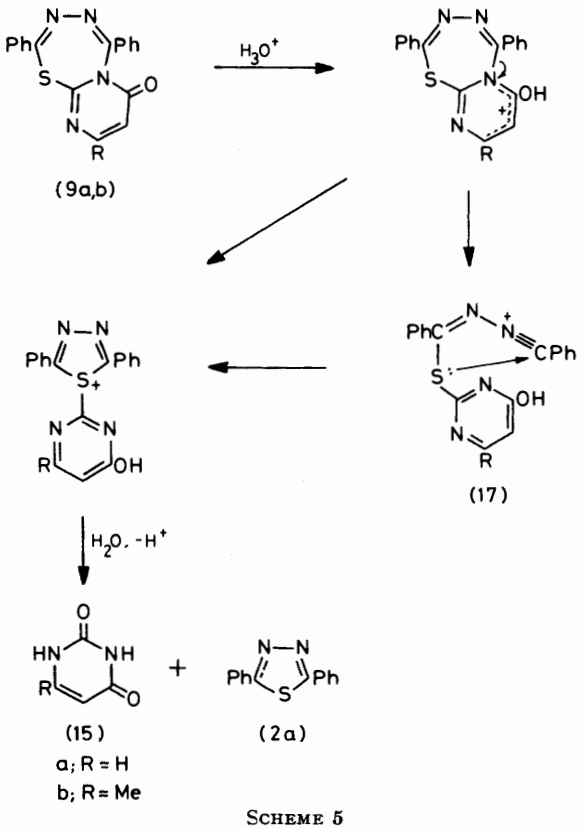
In each of the reactions leading to the thiatriazepines (7)—(9), a baseline spot was observed by t.l.c. analysis of the crude product. In the case of the reaction product from the dichloride (1a) and 4-oxopyrimidinethione (11a) an attempt was made to isolate this material by flash chromatography; however, only 2,5-diphenyl-1,3,4-thiadiazole (2a) (8%) (R_F = 0.7) was isolated. Its formation is attributed to the decomposition of the unidentified material which gives rise to the baseline spot in the t.l.c. analysis, since diphenylthiadiazole was not detected in the initial product. The corresponding bis(4-chlorophenyl)thiadiazole (2b) was also isolated from the



reaction of compound (1b) with imidazolinethione (36% yield).

Reactions of Annelated Thiatriazepines

(*a*) *Acid Hydrolysis.*—The thiatriazepine (7a) was examined first and proved to be quite susceptible to acid hydrolysis, since it completely decomposed within 45 min. Two major products were detected by t.l.c. of

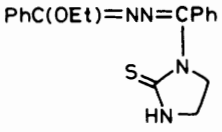


SCHEME 5

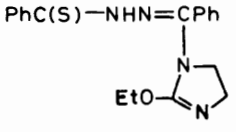
which one appeared to be the thiadiazole (2a). It was isolated (12%) with difficulty, but the other component was very strongly retained on chromatographic silica gel and was not identified.

The related thiatriazepine (7b) was next investigated, and also decomposed readily in methanolic aqueous acid. Three products were isolated from the mixture formed in this case, and were identified by comparison with authentic samples as the thiadiazole (2a) (19%), the corresponding 2,5-diphenyl-1,3,4-oxadiazole (12%), and pyrimidine-2-thione (6b) (21%). Comparable hydrolysis of the tricyclic thiatriazepine (8) gave as the only isolated product a low yield (22%) of the benzimidazole-2-thiol (10) from which it had been prepared.

Acid hydrolysis of either of the thiatriazepin-7-ones (9a,b) is a much cleaner reaction, and in both cases only two products could be detected. Those formed from compound (9a) proved to be the diphenylthiadiazole (2a) (64%) and the uracil (15a) (81%); similarly, compound (9b) afforded the homologous methyluracil (15b) (95%) and the same thiadiazole (90%). The smoothness of the hydrolytic decomposition of these two thiatriazepines is attributed to the presence of their 7-carbonyl group which, when protonated, will assist a uniform hydrolysis pathway during fission of the thiatriazepine ring (Scheme 5). Transannular attack by sulphur across the puckered ring may occur directly after protonation, or could be preceded by an S_N1-like ionization to a nitrilium ion (17). Such S_N1 pathways have been convincingly demonstrated for solvolysis of halogenodiazabutadienes.[16]



(18)

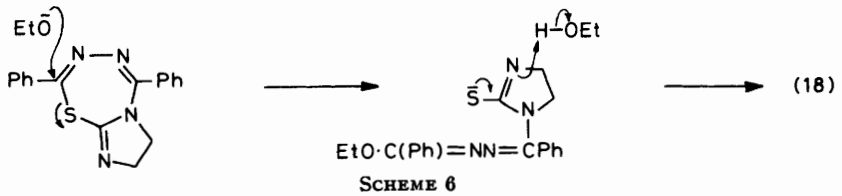


(19)

None of these thiatriazepines appears to form stable salts with mineral acids, or display any of the basic properties which characterise the Δ^2-thiadiazoline-4-carboxmidines prepared from 1-chloro-1,4-diphenyl-2,3-diazabutadienes and thioureas.[4,5]

(*b*) *With Sodium Ethoxide.*—Very rapid decomposition occurred when the thiatriazepine (7a) was heated with ethanolic sodium ethoxide. A pale-yellow solid, m.p. 162—164 °C, separated out in high yield (77%) on cooling, and its colour and u.v. spectrum [$\lambda_{max.}$ (EtOH) 292 (ε 17 950) and 236 nm (27 700)] suggested that it was an acyclic diazabutadiene. Its ^{1}H n.m.r. spectrum revealed the presence of an ethoxy-group (δ 4.42 and 1.42, $^3J_{HH}$ *ca.* 7 Hz), an exchangeable NH (δ 7.15), and a 4H-multiplet (centred around δ 3.88) ascribed to the two methylene groups of an imidazoline ring. These assignments were confirmed by the ^{13}C n.m.r. spectrum, which is in general accord with the structure, (18), proposed.

The isomeric thiobenzoylhydrazone (19) would fit with the analytical data and with the ^{1}H n.m.r., but is rejected on the following grounds. Firstly, the ^{13}C n.m.r. spectrum of compound (19) would be expected to display a thiocarbonyl resonance at *ca.* δ_C 192—193 p.p.m. (*cf.* PhCSNHNHCH$_2$Ph, $\delta_{C=S}$ 192.6 p.p.m.[4]). The observed



SCHEME 6

value for compound (18) is $\delta_{C=S}$ 183.5 p.p.m. (*cf.* dihydropyrimidine-2-thione, $\delta_{C=S}$ 177 p.p.m.), and the C=N resonance of compound (18) ($\delta_{C=N}$ 163.7 p.p.m.) is also encouragingly close to that of ethyl benzimidate ($\delta_{C=N}$ 166.0 p.p.m.). Secondly, the facile ring closure of thiabenzoylhydrazones to Δ^2-1,3,4-thiadiazolines [8] would lead us to expect compound (19) to be unstable, decomposing readily to diphenylthiadiazole (2a) and 2-ethoxyimidazoline (Scheme 6).

However, since we have not yet studied the ethoxide-initiated ring opening reactions of any of the other thiatriazepines, nor investigated the chemical properties of compound (18) beyond showing that it decomposes in acid, this identification should be regarded as provisional.

EXPERIMENTAL

Chromatographic and spectroscopic techniques have been described previously.[4] N.m.r. spectra were obtained in deuteriochloroform solutions unless otherwise stated, and u.v. spectra are for ethanolic solutions. *NN*-Dimethylformamide (DMF) was dried by distillation from phosphorus pentaoxide and stored over B.D.H. 4A molecular sieve. Commercial sodium hydride (50% dispersion in oil) was washed with anhydrous light petroleum (b.p. 40—60 °C) immediately before use. 1,4-Dichloro-1,4-diphenyl-2,3-diazabutadiene was prepared by slow chlorination of benzaldehyde azine in glacial acetic acid at room temperature (75% yield), m.p. (from EtOH) 122—123 °C (lit.,[17] m.p. 123 °C). 1,4-Bis(4-chlorophenyl)-2,3-diazabutadiene was prepared (61%) by the reaction of hydrazine hydrate with 4-chlorobenzaldehyde in ethanol, m.p. (from EtOH) 202—203 °C (lit.,[18] m.p. 208 °C), and was chlorinated at 50 °C for 4 h in glacial acetic acid, giving 1,4-dichloro-1,4-bis(4-chlorophenyl)-2,3-diazabutadiene (1b) (83%), m.p. 102—103 °C (Found: C, 48.9; H, 2.2; Cl, 41.2; N, 8.0%; M^+, 344, 346, 348. $C_{14}H_8Cl_4N_2$ requires C, 48.6; H, 2.3; Cl, 41.0; N, 8.1%; *M*, for ^{35}Cl, 344), δ_H (90 MHz) 8.1—7.4 (2 × ArH); $\nu_{max.}$ (Nujol) 1 630 (C=N) and 828 cm^{-1} (Ar CH def.). The thioureas were commercial samples or were prepared by standard methods.

I.r. and mass spectral results for compounds (7a), (7b), (7c), (8), (9a), (9b) and (18) are given in Supplementary publication SUP No. 23314 (8 pages).*

Reactions of 1,4-*Dichloro*-1,4-*diphenyl*-2,3-*diazabutadiene* (1a).—(a) *With thiourea*. A suspension of the dichloride (1.00 g, 3.6 mmol) and thiourea (280 mg, 3.7 mmol) in ethanol (25 cm^3) and triethylamine (1 cm^3, 7 mmol) was heated under reflux for 24 h. The solvent was evaporated and the residue was then taken up in chloroform (20 cm^3) and washed with water (20 cm^3). The organic layer was dried and evaporated, giving 2,5-diphenyl-1,3,4-thiadiazole (2a) (750 mg, 3.2 mmol, 89%), m.p. and mixed m.p. 140—141 °C (lit.,[19] m.p. 141—142 °C) with an authentic sample prepared by the reaction of 1-chloro-1,4-diphenyl-2,3-diazabutadiene with thiobenzamide (74%).[20] Triethylamine hydrochloride (560 mg, 4.1 mmol, 57%), m.p. and mixed m.p. 254—255 °C (lit.,[21] m.p. 253—254 °C), was isolated from the aqueous extract.

(b) *With* NN′-*dimethylthiourea*. Sodium hydride (345 mg of 50% dispersion, *ca.* 7 mmol) was added to a solution of the thiourea (0.73 g, 7.1 mmol) in anhydrous DMF (40 cm^3). When evolution of hydrogen had subsided, the solution was added during 45 min, to a stirred solution of the dichloride (1a) (2.0 g, 7.2 mmol) in dry DMF (70 cm^3) at room temperature. After 30 min, a further portion of sodium hydride (345 mg) was added, and stirring was continued for 30 min. The solution was filtered (Kieselguhr) and the filtrate evaporated to give, after addition of ethanol, cooling, and filtering, 2,5-diphenyl-1,3,4-thiadiazole (2a) (46%).

(c) *With* N-*acetylthiourea*. From a similar experiment using *N*-acetylthiourea (0.84 g, 7.1 mmol), the yield of thiadiazole (2a) was 82%.

(d) *With thioacetamide*. From a similar experiment using thioacetamide (0.53 g, 7.1 mmol) the yield of thiadiazole (2a) was 76%.

(e) *With imidazoline*-2-*thione* (6a). In an experiment similar to (a) (above) using imidazoline-2-thione (370 mg, 3.6 mmol) and triethylamine (1.5 cm^3, 10.8 mmol), the dichloride (1a) (1.0 g, 3.6 mmol) was converted only into the thiadiazole (2a) [35% based on dichloride consumed (86%)]. In an experiment similar to (b) (above), sodium hydride (50% dispersion 1.73 g, *ca.* 36 mmol) was added to a solution of imidazoline-2-thione (3.67 g, 36.0 mmol) in dry DMF (100 cm^3), and the resulting solution was then added to the dichloride (1a) (10.0 g, 36.1 mmol) in DMF (230 cm^3). After 1.5 h at room temperature, with stirring, the mixture was treated with a further portion of sodium hydride (36 mmol) and stirred at room temperature for a further 3 h. The solution was filtered (Kieselguhr) and the filtrate was shown by t.l.c. (EtOAc–$CHCl_3$ 1 : 3) to contain two components (R_F 0 and 0.30). The latter component was isolated by evaporation of the solvent under reduced pressure and stirring of the residue with acetone (30 cm^3) for 2 h; the acetone extract was then cooled and filtered, to give a pale yellow solid which was identified spectroscopically and by *X*-ray crystallography [11] as 7,8-*dihydro*-2,5-*diphenylimidazo*[1,2-f]-1,3,4,6-*thiatriazepine* (7a) (3.90 g, 12.7 mmol, 35% based on dichlorodiazabutadiene), m.p. (from EtOH) 177—179 °C (with decomp.) (Found: C, 66.3; H, 4.6; N, 18.2; S, 10.6%; M^+, 306. $C_{17}H_{14}N_4S$ requires C, 66.6; H, 4.6; N, 18.3; S, 10.5%; *M*, 306); δ_H (90 MHz) 8.23—7.3 (10 H, m, 2 × Ph) and 3.76 (4 H, m, CH_2CH_2); δ_C (20.1 MHz) 159.0, 147.2, and 143.9 (C=N × 3), 135.1—128.1 (Ar), and 53.0 and 47.9 p.p.m. (both t, 2 × CH_2); $\lambda_{max.}$ (ε) 251 nm (23 750), $\lambda_{min.}$ 277 nm (14 800), $\lambda_{inf.}$ 326 (5 600) and 283 nm (13 350); i.r. and mass spectral data in the Supplementary publication.

(f) *With dihydropyrimidine*-2-*thione* (6b). In a similar experiment to (e), above, using sodium hydride (1.78 g × 2), the dichlorodiazabutadiene (1a) (10 g, 36 mmol), and dihydropyrimidine-2-thione (6b) (4.19 g, 36 mmol) in DMF (330 cm^3), the filtrate (through Kieselguhr) was shown by t.l.c. (chloroform–methanol, 30 : 1) to contain two components (R_F 0 and 0.58). A similar procedure to that described before gave a white solid identified spectroscopically as 8,9-*dihydro*-2,5-*diphenyl*-7H-*pyrimido*[1,2-f]-1,3,4,6-*thiatriazepine* (7b) (7.28 g, 22.7 mmol, 63%), m.p. (from EtOH) 180—182 °C (with decomp.) (Found: C, 67.5; H, 4.9; N, 17.4; S, 9.8%; M^+, 320. $C_{18}H_{16}N_4S$ requires C, 67.5; H, 5.0; N, 17.5; S, 10.0%; *M*, 320); δ_H (60 MHz) 8.48—7.28 (10 H, m, 2 × Ph), 3.75—2.95 (2 × NCH_2), and 2.10—1.56 (CH_2); δ_C (20.1 MHz) 151.0, 149.3, 148.5 (3 × C=N), 139.5—127.5 (Ar), 46.7 and 45.7 (both t, 2 × NCH_2), and

* For details of the Supplementary publications scheme, see Notice to Authors No. 7, *J. Chem. Soc., Perkin Trans. 1*, 1981, Index issue.

20.5 p.p.m. (t, CH_2); $\lambda_{max.}$ (ε) 253 nm (21 150); $\lambda_{min.}$ 228 nm (17 600); $\lambda_{inf.}$ 312 (10 950), 290 (12 450), and 240 nm (19 350); mass spectral and i.r. data in the Supplementary publication.

(g) *With 4-oxopyrimidine-2-thione* (11a). In a similar experiment using sodium hydride (1.81 g × 2), the dichlorodiazabutadiene (1a) (10 g, 36 mmol), and 4-oxopyrimidine-2-thione (11a) (4.85 g, 27.8 mmol) in DMF (325 cm^3), the filtrate was shown by t.l.c. [EtOAc–light petroleum (b.p. 40—60 °C) 1 : 1] to contain a baseline spot and another component (R_F 0.69) which was isolated as above and identified spectroscopically as *2,5-diphenylpyrimido*[1,2-f]-*1,3,4,6-thiatriazepin-7-one* (9a) (4.31 g, 13.0 mmol, 36% based on dichlorodiazabutadiene), m.p. (from EtOH) 234—236 °C (with decomp.) (Found: C, 64.7; H, 3.3; N, 16.6; S, 9.7%; M^+, 332. $C_{18}H_{12}N_4OS$ requires C, 65.0; H, 3.6; N, 16.9; S, 9.7%; *M*, 332); δ_H (60 MHz) 8.34—7.25 (10 H, m, 2 × Ph), 7.82 (d, $|J|$7 Hz, NCH=), and 6.44 (d, =CHCO); δ_C (20.1 MHz) 160.0 (C=O), 158.8, 146.9, and 146.2 (3 × C=N), 152.7 (NCH=), 134.6—127.0 (Ar), and 116.8 p.p.m. (CO*C*H=); $\lambda_{max.}$ (ε) 296.5 nm (27 950); $\lambda_{min.}$ 238 nm (12 650); $\lambda_{inf.}$ 258 nm (16 400); mass spectral and i.r. data in the Supplementary publication.

The combined mother-liquors from the isolation of compound (9a) were evaporated and the residue was separated by flash chromatography (55 mm o.d. column, $CHCl_3$–MeOH 50 : 9) to yield 2,5-diphenyl-1,3,4-thiadiazole (2a) (650 mg, 2.7 mmol, 8% based on dichlorodiazabutadiene; R_F 0.7), m.p. and mixed m.p. with authentic material 140—141 °C. A baseline spot was observed but was not investigated further.

(h) *With 6-methyl-4-oxopyrimidine-2-thione* (11b). In a similar experiment using sodium hydride (1.74 g × 2), the dichlorodiazabutadiene (1a) (10 g, 36 mmol), and 6-methyl-4-oxopyridimidine-2-thione (11b) (5.13 g, 36.1 mmol) in DMF (330 cm^3), the filtrate was shown by t.l.c. [eluant as in (g)] to contain a baseline spot and a component (R_F 0.43) which was isolated by flash chromatography (35 mm o.d. column, chloroform) and identified spectroscopically as *9-methyl-2,5-diphenylpyrimido*[1,2-f]-*1,3,4,6-thiatriazepin-7-one* (9b) (3.2 g, 9.2 mmol, 26% based on the dichloride), m.p. (from Me_2CO) 226 °C (with decomp.) (Found: C, 66.0; H, 4.0; N, 16.2; S, 9.3%; M^+, 346. $C_{19}H_{14}N_4OS$ requires C, 65.9; H, 4.1; N, 16.2; S, 9.3%; *M*, 346); δ_H (60 MHz) 8.37—7.32 (10 H, m, 2 × Ph), 6.26 (s, CO*CH*=), and 2.31 p.p.m. (Me); δ_C (20.1 MHz) 164.0 (NCMe), 160.3 (C=O), 157.2, 146.7, and 146.3 (3 × C=N), 134.7—126.2 (Ar), 113.6 (d, CH=) and 23.4 p.p.m. (q, Me); $\lambda_{max.}$ (ε) 294 nm (24 100), $\lambda_{min.}$ 233 nm (11 350), $\lambda_{inf.}$ 255 nm (14 300); i.r. and mass spectral data in the Supplementary publication.

(i) *With benzimidazole-2-thiol* (10). In a similar experiment using sodium hydride (1.39 g × 2), the dichloride (1a) (8.50 g, 28.9 mmol) and benzimidazole-2-thiol (10) (4.34 g, 28.9 mmol) in DMF (300 cm^3), the filtrate was shown by t.l.c. to contain a baseline spot and a component [R_F 0.30, (eluant as before)] which was isolated as in (e) and identified spectroscopically as *2,5-diphenylbenzimidazo*[1,2-f]-*1,3,4,6-thiatriazepine* (8) (5.0 g, 14.1 mmol, 49% based on dichloride), m.p. (from toluene) 203—204 °C (Found: C, 71.1; H, 3.7; N, 16.0; S, 9.0%; M^+, 354. $C_{21}H_{14}N_4S$ requires C, 71.2; H, 4.0; N, 15.8; S, 9.1%; *M*, 354); δ_H (60 MHz) 8.35—6.0 (Ar); δ_C (20.1 MHz) 148.3, 143.4, 142.4 (3 × C=N) and 134.6—112.9 p.p.m. (Ar); $\lambda_{max.}$ (ε) 271 nm (33 300), $\lambda_{min.}$ 231 nm (13 350), $\lambda_{inf.}$ 311 nm (12 450); i.r. and mass spectral data in the Supplementary publication.

Reaction of 1,4-Dichloro-1,4-bis(4-chlorophenyl)-2,3-diazabutadiene (1b) *with Imidazoline-2-thione* (6a).—In a similar experiment to (e) (above) using the dichlorodiazabutadiene (1b) (6.25 g, 18.0 mmol), sodium hydride (0.86 × 2 g, 36 mmol), and imidazoline-2-thione (1.84 g, 18.0 mmol) in DMF (150 cm^3), the filtrate was evaporated under reduced pressure and eluted ($CHCl_3$–EtOAc, 3 : 1) through silica gel to give, as the first component eluted, 2,5-bis(4-chlorophenyl)-1,3,4-thiadiazole (2b) (2.0 g, 6.51 mmol, 36%), m.p. 223—224 °C (lit.,[22] 225 °C) (Found: C, 54.9; H, 2.4; N, 9.0%; M^+, 306. Calc. for $C_{14}H_8Cl_2N_2S$: C, 54.7; H, 2.6; H, 8.9%; *M* for ^{35}Cl, 306); δ_H (90 MHz) 8.1—7.6 p.p.m. (dd, 1,4-disub. Ar), and a cream-coloured second component, identified spectroscopically as *7,8-dihydro-2,5-bis(4 chlorophenyl)imidazo*[1,2-f]-*1,3,4,6-thiatriazepine* (7c) (2.0 g, 5.3 mmol, 29%), m.p. 166—168 °C (Found: C, 54.2; H, 3.0; N, 15.0; Cl, 19.1%; M^+, 374. $C_{17}H_{12}Cl_2N_4S$ requires C, 54.4; H, 3.2; N, 14.9; Cl, 18.9%; *M* for ^{35}Cl, 374); δ_H (90 MHz) 8.15—7.35 (dd, 2 × 1,4 disub. Ar), and 3.85 (4 H, m, CH_2CH_2); δ_C (20.1 MHz) 159.0, 146.9, and 143.3 (3 × C=N), 137.6—127.9 (Ar), and 53.5 and 48.5 p.p.m. (CH_2CH_2); mass spectral and i.r. data in the Supplementary publication.

Acid Hydrolysis of Thiatriazepines.—(a) *7,8 Dihydro-2,5-diphenyl*[1,2-f]-*1,3,4,6-thiatriazepine* (7a). A solution of the thiatriazepine (7a) (500 mg, 1.6 mmol) in ethanol (20 cm^3) and concentrated hydrochloric acid (2.2 cm^3) was heated under reflux for 45 min, after which time t.l.c. (EtOAc–$CHCl_3$ 1 : 3) indicated complete conversion of starting material into two products (R_F 0 and 0.7). The mixture was neutralised with 1M aqueous sodium hydroxide and evaporated under reduced pressure; the oily residue was then dissolved in chloroform (25 cm^3) and extracted with an equal volume of water. The organic layer was dried and evaporated, and the oil was shown to contain both components. The less polar component (R_F 0.7) was isolated by flash chromatography ($CHCl_3$–MeOH 50 : 9, 35 mm o.d. column) and identified as 2,5-diphenyl-1,3,4-thiadiazole (2a) (45 mg, 0.2 mmol, 12%) by mixed m.p. (139—141°C) with an authentic sample, but the other component could not be eluted.

(b) *8,9-Dihydro-2,5-diphenyl-7H-pyrimido*[1,2-f]-*1,3,4,6-thiatriazepine* (7b). In a similar experiment using the thiatriazepine (7b) (710 mg, 2.2 mmol) in ethanol (20 cm^3), methanol (10 cm^3), and hydrochloric acid (2.2 cm^3), neutralisation after 45 min was followed by addition of water (50 cm^3); 2,5-diphenyl-1,3,4-thiadiazole (2a) (100 mg, 0.4 mmol, 19%) crystallized, m.p. and mixed m.p. 140—142 °C. The filtrate was chilled, and a precipitate formed which was recrystallized from ethanol and identified as 2,5-diphenyl-1,3,4-oxadiazole (57 mg, 0.3 mmol, 12%) by m.p. and mixed m.p. 132 °C (lit.,[23] m.p. 136—137 °C) with an authentic sample. The filtrate was evaporated and a component (R_F 0.56, $CHCl_3$–MeOH 4 : 1), isolated by flash chromatography, was identified as dihydropyrimidine-2-thione (6b) (53 mg, 0.5 mmol, 21%), mixed m.p. with an authentic sample 210—212 °C (lit.,[24] m.p. 211 °C).

(c) *2,5-Diphenylpyrimido*[1,2-f]-*1,3,4,6-thiatriazepin-7-one* (9a). A similar experiment using the thiatriazepine (9a) (220 mg, 0.7 mmol) in methanol (15 cm^3) containing concentrated hydrochloric acid (1.8 cm^3) gave, after 1 h under reflux, a solution which on cooling yielded 2,5-diphenyl-1,3,4-thiadiazole (2a) (100 mg, 0.4 mmol, 64%), m.p. 140—142 °C. Evaporation of the filtrate under reduced pressure gave a solid which was washed with ethanol and identified as pyrimidine-2,4-dione (60 mg, 0.5 mmol, 81%), mixed

m.p. with authentic material 325 °C (with decomp.) (lit.,[25] m.p. 335 °C).

(d) 9-*Methyl*-2,5-*diphenylpyrimido*[1,2-f]-1,3,4,6-*thiatriazepin*-7-*one* (9b). The solution obtained by refluxing the thiatriazepinone (9b) (400 mg, 1.2 mmol) and concentrated hydrochloric acid (2.2 cm^3) in ethanol (20 cm^3) for 25 min was cooled and diluted with water (20 cm^3), giving 2,5-diphenyl-1,3,4-thiadiazole (2a) (245 mg, 1.0 mmol, 90%) m.p. 138—139 °C. The filtrate was evaporated under reduced pressure, and the residue recrystallized from glacial acetic acid, to give 6-methylpyrimidine-2,4-dione (138 mg, 1.1 mmol, 95%) mixed m.p. with authentic material 314 °C (with decomp.) (lit.,[26] m.p. 300 °C with decomp.).

(e) 2,5-*Diphenylbenzimidazo*[1,2-f]-1,3,4,6-*thiatriazepine* (8). The solution obtained by refluxing the thiatriazepine (8) (750 mg, 2.1 mmol) and concentrated hydrochloric acid (2.2 cm^3) in methanol (20 cm^3) for 30 min was neutralised and diluted with water (25 cm^3), and extracted with chloroform (3 × 25 cm^3). The dried extracts were evaporated under reduced pressure and a component, R_F 0.5 (EtOAc–$CHCl_3$ 1 : 3) was isolated by flash chromatography and identified as benzimidazole-2-thiol (10) (70 mg, 0.5 mg, 0.5 mmol, 22%), m.p. and mixed m.p. with authentic material 298 °C (lit.,[27] m.p. 301—302 °C).

Reaction of Thiatriazepine (7a) *with Sodium Ethoxide.*—The thiatriazepine (7a) (310 mg, 1.0 mmol) was heated to reflux for 10 min with a solution of sodium ethoxide (from 25 mg, 1.1 g-atom of sodium) in anhydrous ethanol (10 cm^3), The volume of the solution was reduced to *ca.* 5 cm^3 by evaporation under reduced pressure and cooled. A pale yellow solid was recrystallized from ethanol and identified spectroscopically as 1-*ethoxy*-1,4-*diphenyl*-4-(2-*thioxoimidazolin*-1-*yl*)-2,3-*diazabutadiene* (18) (270 mg, 0.8 mmol, 77%), m.p. 162—164 °C (Found: C, 64.6; H, 5.5; N, 16.1; S, 8.9%; M^+, 352. $C_{19}H_{20}N_4OS$ requires C, 64.8; H, 5.7; N, 15.9; S, 9.1%; *M*, 352), δ_H (90 MHz) 8.05—7.63 (4 H, m, *m*-H of 2 × Ph), 7.53—7.23 (6 H, m, *o*/*p*-H of 2 × Ph), 7.15 br D_2O-labile, N*H*), 4.42 (2 H, q, 1 |*J*| 17 Hz, CH_2Me), 3.88 (4 H, m, CH_2CH_2), and 1.42 (3 H, t, Me); δ_C (20.1 MHz) 183.5 (C=S), 163.7 (O*C*=N), 149.4 (NC=N), 133.5—127.2 (Ar), 62.9 (t, CH_2), 48.9 (t, N=CN*C*H_2), 42.9 (t, S=CNH*C*H_2), and 14.0 p.p.m. (Me); $\lambda_{max.}$ (ε) 292 (17 950) and 236 nm (27 700); $\lambda_{min.}$ 262 (14 150) and 218 nm (22 700); $\lambda_{inf.}$ 280 nm (16 700); i.r. and mass spectral data in the Supplementary publication.

We are indebted to Reckitt and Colman Pharmaceutical Division, Hull, for financial support (to S. F. M.) and for helpful discussions.

[1/2012 *Received*, 31*st December*, 1981]

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