One-step syntheses of pyrrolo- and indolo-1,2,5-thiadiazoles and pyrrolobis[1,2,5]thiadiazoles

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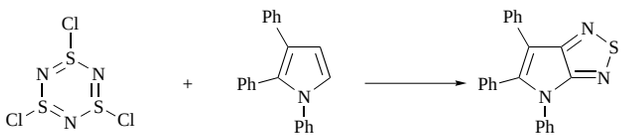
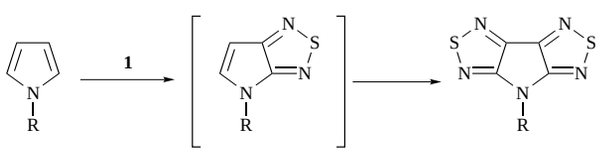
Treatment of the 2,3-unsubstituted pyrrole 2 and indoles 7 with trithiazyl trichloride 1 in hot tetrachloromethane gives the 2,3-fused 1,2,5-thiadiazolo derivatives 3 and 8. 2,3,4,5-Unsubstituted pyrroles 4 are similarly converted directly into the pyrrolobis(thiadiazoles) 6, without detection of the presumed, highly reactive, bicyclic intermediate 5. This ring fusion process is not prevented by the presence of bromine, chlorine, a carboxylic acid or carboxylic ester group at the α- or β-positions; indeed prior substitution by bromine or chlorine results in faster and cleaner reactions with trithiazyl trichloride to give the fused systems 3, 6 and 8 in high yield. Possible mechanisms are proposed to explain these results.

In previous papers we have reported the ready conversion by trithiazyl trichloride **1** of alkenes and alkynes into 1,2,5-thiadiazoles[1] and of 2,5-disubstituted furans and thiophenes into isothiazoles.[2] We proposed that the former reaction, transfer of an N–S–N unit, involved addition of the intact trimer **1** to the double or triple bond. For the latter reaction, the necessary transfer of the S–N unit probably involved attack of the furan or thiophene ring by the monomeric species, NSCl, which could occur by Diels–Alder cycloaddition or by electrophilic substitution. Although we have some evidence in favour of the electrophilic substitution mechanism,[3] we thought it of interest to extend the trithiazyl trichloride reactions to pyrroles where the enhanced sensitivity of the ring to electrophilic attack might be expected to favour that mechanism over cycloaddition, and where there is an extra mechanistic probe available in variation of the *N*-substituent.



1 **2** **3**



4 **5** **6**

Reaction of 2,3-unsubstituted pyrroles and indoles with $(NSCl)_3$

Heterocycles which formally contain activated and unsubstituted carbon–carbon 'double bonds' might react with trimer **1** in a similar manner to alkenes.[1] 1,2,3-Triphenylpyrrole **2**, with one such double bond, was therefore synthesised[4] and treated with 1 equiv. of $(NSCl)_3$ in refluxing tetrachloromethane under nitrogen. One product was cleanly formed in high yield (77%) as pale yellow crystals which are highly fluorescent (green) in solution; this was assigned the structure 4,5,6-triphenyl-4*H*-pyrrolo[2,3-*c*][1,2,5]thiadiazole **3** from its spectroscopic and analytical properties. Thus, in this new and very simple reaction the reagent has fused a thiadiazole ring across the unsubstituted 2,3-positions of the pyrrole to give a bicyclic system which would normally require a very sensitive diaminopyrrole as its synthetic precursor.

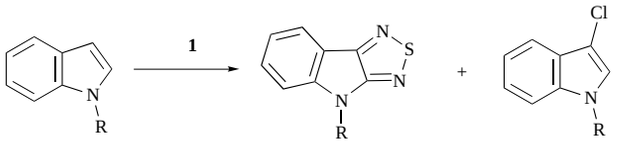
1-Phenylpyrrole **4**, R = Ph, was then treated with 2 equiv. of $(NSCl)_3$ under the same conditions. The reaction was slow but after 15 h the starting material had disappeared and the only low molecular weight product (TLC) was identified as 7-phenylpyrrolo[2,3-*c*:4,5-*c*′]bis[1,2,5]thiadiazole **6**, R = Ph (43%). NMR spectra showed the presence of a phenyl group and of six different carbon atoms, and elemental analysis and mass spectrometry gave the molecular formular $C_{10}H_5N_5S_2$. Thus the reagent has added across the pyrrole 2,3- and 4,5-positions to form, in a simple one-pot reaction, a new tricyclic system which would be very difficult to make by the standard methods of 1,2,5-thiadiazole synthesis. Indeed, given the known reduction of 1,2,5-thiadiazoles to diamino compounds,[5] the pyrrolothiadiazoles, such as **3** and **6**, could possibly provide an attractive source of the very delicate polyamino pyrroles. We did not isolate, nor see any sign of the bicyclic system **5**, R = Ph, with one thiadiazole ring (see below).

1-Methylpyrrole gave the analogous product **6**, R = Me, in slightly lower yield (31%) under the same conditions. We then turned our attention to the synthesis of the parent ring system 7*H*-pyrrolo[2,3-*c*:4,5-*c*′]bis[1,2,5]thiadiazole **6**, R = H. Pyrrole itself with the trimer gave complex reaction mixtures from which no pure products could be isolated; pyrrole is presumably highly reactive towards the reagent and sensitive to the acidic conditions which develop in its reactions. We treated various *N*-protected pyrroles with the trimer under the above conditions. The reaction of *N*-benzylpyrrole[6] was complex; *N*-phenylsulfonylpyrrole[7] was inert to the reagent even when refluxed in toluene, as might be expected if the initial attack on the ring is electrophilic in nature.

N-Triisopropylsilylpyrrole **4**, R = $SiPr^i_3$,[8] reacted rapidly to give a black insoluble precipitate, but a small amount of a low molecular weight product (TLC) could be isolated by column chromatography and purified by preparative layer chromatography; this was identified as the parent compound **6**, R = H, in very low yield (8%). Similarly the reaction of *N*-methoxycarbonylpyrrole **4**, R = CO_2Me,[9] was complex giving only a very small amount of **6**, R = CO_2Me, (4%) and a trace of the parent compound **6**, R = H. We later discovered how to prepare these tricyclic compounds **6** in much better yield (see below).

Since 2,3-unsubstituted pyrroles react with the trimer **1** to give fused 1,2,5-thiadiazoles, we studied the same reaction with a few simple indoles **7** (Table 1). The indoles were more reactive

Table 1 Reaction of 2,3-unsubstituted indoles with $(NSCl)_3$ **1** (1 equiv.) in refluxing tetrachloromethane overnight



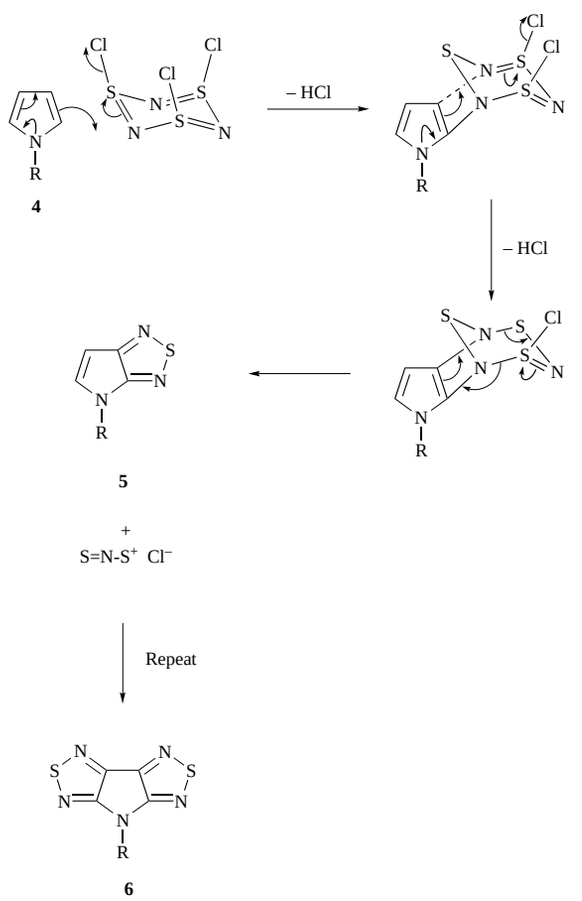
7 **8** **9**

R	Yield (%)	Yield (%)
H	23	—
Me	56	10
Ph	60	21
$PhSO_2$	38	16

than the corresponding pyrroles and gave higher yields of the fused thiadiazoles **8**, as was to be expected. Some 3-chlorinated indoles **9** were also isolated; further examples of electrophilic chlorination by the trimer will be described in later papers. The parent compound **8**, R = H, was obtained from indole in 23% yield as a fawn crystalline solid identical with the product formed in 'poor yield' from oxindole and tetrasulfur tetranitride.[10] Somewhat surprisingly, benzofuran and benzothiophene did not react with $(NSCl)_3$ under the standard conditions, nor in refluxing toluene; presumably they are insufficiently nucleophilic.

Reaction of chloro- and bromo-pyrroles and indoles with $(NSCl)_3$

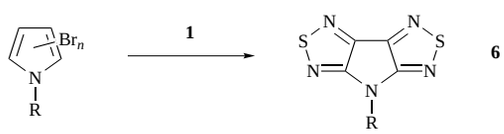
These 1,2,5-thiadiazole fusing reactions could proceed by a concerted cycloaddition mechanism similar to that proposed for the analogous alkene reaction,[1] but all the above results tend to suggest that there is a strong electrophilic component in the initial attack on the electron-rich pyrroles and indoles, and a mechanism is proposed for this (Scheme 1). This mechanism



4 **5** **6**

Scheme 1

Table 2 Reaction of bromopyrroles with $(NSCl)_3$ **1** (2 equiv.) in refluxing tetrachloromethane



R	Pyrrole	*t*/h	Yield (%)
Ph	2-Bromo[a]	2	42
Ph	2-Bromo	4	75
Ph	2,5-Dibromo	4	71
Ph	2,3,5-Tribromo	12	70
Ph	2,3,4,5-Tetrabromo	12	62
Me	2,5-Dibromo	4	74

[a] 1 Equiv. $(NSCl)_3$.

makes the reasonable assumption that the bicyclic species **5** is an intermediate on the way to the tricyclic species **6**, although **5** was not observed; presumably the remaining carbon–carbon double bond in **5** now has more enamine character and is more reactive towards $(NSCl)_3$ than the starting pyrrole.

We hoped to be able to suppress the second thiadiazole ring-fusing process by bromination of the starting pyrrole in the 2-position. However we found that a 2-bromo substituent does not block thiadiazole formation across the pyrrole 2,3-bond but, to our initial surprise, it actually accelerates the process. Thus the trimer reaction was faster and cleaner with 2-bromo-1-phenylpyrrole than with 1-phenylpyrrole, and gave the same tricyclic product **6**, R = Ph, in considerably higher yield (75%). To test the generality of this, other brominated pyrroles[11] were treated with the trimer, for shorter reaction times, and higher yields of the bis(thiadiazoles) **6** were obtained (Table 2). The mono-, di- and tri-bromo compounds are not very stable and were used immediately after being made. Treatment of 2-bromo-1-phenylpyrrole with only one equivalent of $(NSCl)_3$ still gave only the bis(thiadiazole) **6**, R = Ph, in reduced yield. Even 2,3,4,5-tetrabromo-1-phenylpyrrole gave the same product, in 62% yield. With 2,5-dibromo-1-methylpyrrole the yield of **6**, R = Me, was similarly increased to 74% (from 31%). The tricyclic compounds **6** can thus be made in good yield in a one-pot reaction of trimer with the readily formed bromopyrroles.

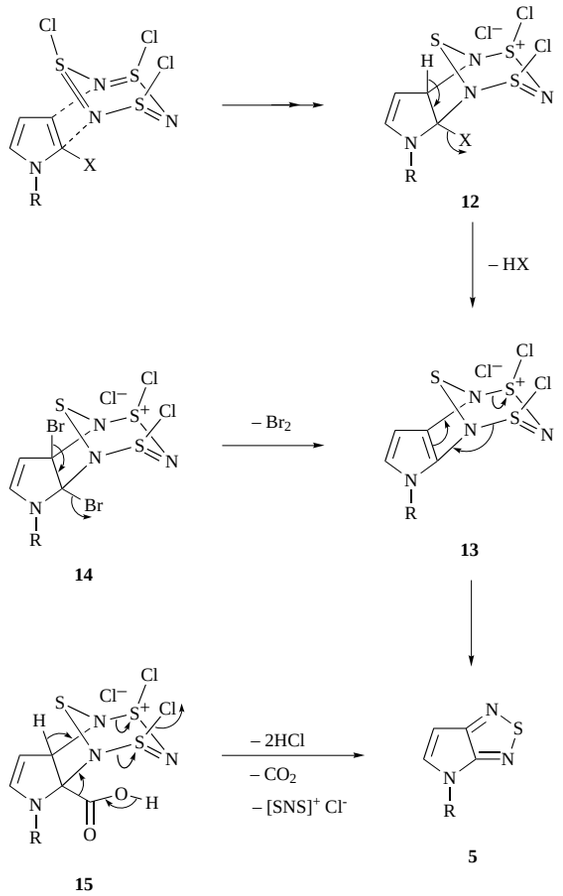
We saw above (Table 1) that when indoles **7** were treated with one equivalent of $(NSCl)_3$, besides the fused thiadiazoles **8**, some 3-chloroindoles **9** were also isolated. In view of the reactivity of the bromopyrroles just demonstrated, it was obviously of interest to see if these chloroindoles behaved similarly. The 3-chloro derivatives of indole, 1-methyl- and 1-phenylindole were prepared in high yield by chlorination with sulfuryl chloride in diethyl ether at 0 °C,[12] and treated with one equivalent of $(NSCl)_3$ in refluxing tetrachloromethane (Table 3). Compared with the results in Table 1 for the unchlorinated indoles, the yields of the fused thiadiazoles **8** were increased, the reaction times were reduced and the reactions were cleaner. Thus the 3-chloroindoles **9** could have been intermediates in the conversion of indoles **7** into **8**. 1-Phenylindole was therefore treated with an excess of the reagent **1** (3 equiv.) in tetrachloromethane for 12 h; the thiadiazole **8**, R = Ph, was obtained in higher yield (72%) and none of the 3-chloro compound was isolated. This suggests that $(NSCl)_3$ does, at least in part, chlorinate the indoles and then converts the chloro derivatives into the fused thiadiazoles, exactly as with the bromopyrroles.

Finally, since we found that neither bromine nor chlorine could be used as 'blocking groups' to prevent attack by $(NSCl)_3$, we considered the use of a carboxylic ester group in this role. Several reactions between methyl 1-methylpyrrole-2-carboxylate **10**, R = Me, and $(NSCl)_3$ under different conditions were examined but no monothiadiazole derivative was obtained. Somewhat surprisingly the bis(thiadiazole) **6**,

R = Me, was formed in yields of up to 22%, with 2 equiv. of **1** in refluxing tetrachloromethane, the annelation reaction being accompanied by demethoxycarbonylation. Methyl 1,4,5-triphenylpyrrole-3-carboxylate **11**, R = Me, with a β-ester group, and the corresponding carboxylic acids **10** and **11**, R = H, were also treated with $(NSCl)_3$ (Table 4). All gave modest yields of the corresponding fused thiadiazoles **3** and **6** with the yields from the carboxylic acids, requiring decarboxylation only, being higher than from the esters. Thus these attempts to make the mono-thiadiazoles **5** by the introduction (and subsequent removal) of relatively labile substituents on the pyrrole ring have failed. Bromine atoms activate the pyrrole ring towards attack by $(NSCl)_3$, as does a 3-chlorine atom in indole, and α- and β-carboxylic acid and ester groups are also removed during the trimer reaction.

Reaction mechanisms

All of these observations can be reasonably, although speculatively, accommodated by slight variations (Scheme 2) on the

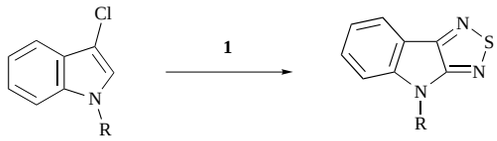


12 **13** **14** **15** **5**

Scheme 2

mechanism proposed earlier (Scheme 1). If a proton is not present at the pyrrole site being attacked (α or β or both) then HCl cannot be lost as it is in Scheme 1. The second, cyclisation step can proceed to give the 'cycloadducts' **12** (or its isomer with the H and X interchanged), **14** or **15**. If X = Br or Cl the intermediate can aromatise more rapidly than when X = H, as shown (arrows in **12**) to give **13** which can then dissociate directly to stable products. If both α- and β-positions are brominated the intermediate **14** can lose Br_2 or BrCl to give **13**, and if X = CO_2H (or CO_2Me) then decarboxylation (or demethoxycarbonylation) could proceed as shown (arrows in **15**), to give S=N–S^+Cl^- rather than Cl–S^+=N–S–Cl Cl^- as the other sulfur–nitrogen product.

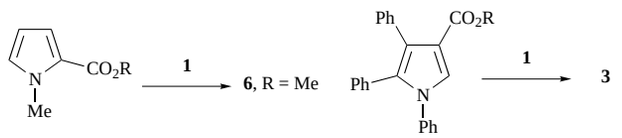
Table 3 Reaction of 3-chloroindoles with $(NSCl)_3$ **1** (1 equiv.) in refluxing tetrachloromethane



9 **8**

R	*t*/h	Yield (%)
H	8	57
Me	8	67
Ph	4	84

Table 4 Reaction of pyrrolecarboxylic acids and esters with $(NSCl)_3$ **1** in refluxing tetrachloromethane overnight



10 **11**

Pyrrole	**1** (Equiv.)	Product	Yield (%)
10, R = H	2	**6**, R = Me	32
10, R = Me	2	**6**, R = Me	22
11, R = H	1	**3**	37
11, R = Me	1	**3**	20

It is worth noting that in all of these pyrrole–trimer reactions, fusion of the 1,2,5-thiadiazole rings always occurs at the 2,3- and 4,5-bonds and none of the analogous 3,4-fused products have been observed. 1,2,5-Triphenylpyrrole, for example, reacts entirely differently to 1,2,3-triphenylpyrrole with the trimer **1**.[13] This is, of course, in complete agreement with the influence of the ring π-bond orders on pyrrole chemistry in general.

Experimental

For general details see earlier parts of this series.[2]

The following compounds were prepared by literature methods and had properties in agreement with those reported: methyl 1,4,5-triphenylpyrrole-3-carboxylate **11**, R = Me, mp 98–99 °C;[4] 1,4,5-triphenylpyrrole-3-carboxylic acid **11**, R = H, mp 274 °C (decomp.);[4] 1,2,3-triphenylpyrrole **2**, mp 180–181 °C;[4] 1-benzylpyrrole, bp 140–145 °C (30 mmHg);[6] 1-phenylsulfonylpyrrole, mp 90–92 °C;[7] 1-triisopropylsilylpyrrole, bp 100 °C (8 mmHg);[8] methyl pyrrole-1-carboxylate, bp 82–84 °C (30 mmHg);[9] 1-phenylindole, bp 143–147 °C (5 mmHg);[14] 1-phenylsulfonylindole, mp 78–79 °C;[15] the bromo-*N*-phenyl- and bromo-*N*-methyl-pyrroles;[11] 3-chloroindole **9**, R = H, mp 95–96 °C;[12] 3-chloro-1-methylindole **9**, R = Me, bp 106–110 °C (5 mmHg);[16] 3-chloro-1-phenylindole **9**,[12] R = Ph, as a colourless oil, δ_H(270 MHz, $CDCl_3$) 7.27–7.35 (2H, m, ArH), 7.39 (1H, s, indole H), 7.47–7.57 (6H, m, ArH) and 7.70–7.75 (1H, m, ArH); *m/z* 229 ($M^+ + 2$, 32%), 227 (M^+, 100), 192 ($M^+ - Cl$, 54), 165 (28), 124 (9), 95 (10), 89 (33) and 77 (Ph^+, 11).

Reactions of trithiazyl trichloride 1

Except where noted, the following general procedure was used. A mixture of the organic substrate and trithiazyl trichloride in tetrachloromethane (25 ml per mmol of substrate) was heated at reflux under nitrogen overnight. The reaction mixture was cooled to room temperature and filtered through a pad of silica

gel which was washed with dichloromethane. The combined organic solution was evaporated *in vacuo* and the residue was separated by medium pressure chromatography on silica gel, eluting with dichloromethane in light petroleum, bp 60–80 °C.

With 1,2,3-triphenylpyrrole 2. 1,2,3-Triphenylpyrrole (590 mg, 2 mmol) and trithiazyl trichloride (448 mg, 2 mmol) gave 4,5,6-*triphenyl*-4H-*pyrrolo*[2,3-c][1,2,5]*thiadiazole* **3** (544 mg, 77%), mp 203–205 °C (Found: C, 74.6; H, 4.2; N, 11.6. $C_{22}H_{15}N_3S$ requires C, 74.8; H, 4.25; N, 11.9%); $\nu_{max}(CHCl_3)$/cm^{-1} 3066, 3011, 2927, 1600, 1562, 1500, 1470, 1438, 1410, 1374, 1290, 1125, 1075, 1029 and 862; δ_H(270 MHz, $CDCl_3$) 7.22–7.36 (2H, m) and 7.51–7.56 (13H, m); *m/z* 353 (M^+, 100%), 294 ($M^+ - N_2S$, 43), 203 (11), 190 (13), 180 (18), 165 (10) and 77 (Ph^+, 53).

With 1-phenylpyrrole 4, R = Ph. 1-Phenylpyrrole (286 mg, 2 mmol) and trithiazyl trichloride (976 mg, 4 mmol) gave 7-*phenyl*-7H-*pyrrolo*[2,3-c:4,5-c′]*bis*[1,2,5]*thiadiazole* **6**, R = Ph (225 mg, 43%). One recrystallisation from hexane gave colourless needles, mp 150–151 °C (Found: C, 46.2; H, 1.8; N, 26.85. $C_{10}H_5N_5S_2$ requires C, 46.3; H, 1.9; N, 26.85%); $\nu_{max}(CHCl_3)$/cm^{-1} 3014, 1593, 1533, 1509, 1461, 1414, 1298, 1219, 1199, 1113, 807 and 791; δ_H(270 MHz, $CDCl_3$) 7.32–7.37 (1H, m, PhH), 7.54–7.61 (2H, m, PhH) and 8.44–8.48 (2H, m, PhH); δ_C(67.5 MHz, $CDCl_3$) 162.94 (ArC), 139.85 (ArC), 135.97 (PhC), 129.38 (PhC), 126.02 (PhC) and 118.85 (PhC); *m/z* 259 (M^+, 100%), 232 ($M^+ - N_2$, 9), 201 ($M^+ - N_2S$, 13), 175 (8), 143 (8) and 77 (Ph^+, 36).

With 1-methylpyrrole 4, R = Me. 1-Methylpyrrole (162 mg, 2 mmol) and trithiazyl trichloride (976 mg, 4 mmol) gave 7-*methyl*-7H-*pyrrolo*[2,3-c:4,5-c′]*bis*[1,2,5]*thiadiazole* **6**, R = Me (122 mg, 31%) as colourless needles, mp 175–176 °C (Found: C, 30.6; H, 1.3; N, 35.5. $C_5H_3N_5S_2$ requires C, 30.5; H, 1.5; N, 35.5%); $\nu_{max}(CHCl_3)$/cm^{-1} 3015, 1605, 1545, 1521, 1407, 1307, 811 and 791; δ_H(270 MHz, $CDCl_3$) 3.82 (3H, s, NMe); δ_C(67.5 MHz, $CDCl_3$) 165.23 (ArC), 139.01 (ArC) and 30.70 (Me); *m/z* 197 (M^+, 100%), 164 ($M^+ - S$, 3.3), 138 ($M^+ - N_2S$, 11) and 46 (NS^+, 43).

With 1-triisopropylsilylpyrrole 4, R = SiPr$^i_3$. 1-Triisopropylsilylpyrrole (470 mg, 2 mmol) and trithiazyl trichloride (976 mg, 4 mmol) gave 7H-*pyrrolo*[2,3-c:4,5-c′]*bis*[1,2,5]*thiadiazole* **6**, R = H (29 mg, 8%), mp 190–192 °C (Found: M^+, 182.9673. $C_4HN_5S_2$ requires *M*, 182.9673); $\nu_{max}(CHCl_3)$/cm^{-1} 3446 (NH), 3182, 2926, 1560, 1503, 1328, 1283, 1256 and 803; δ_H(270 MHz, $CDCl_3$) 8.5 (1H, s, NH); *m/z* 183 (M^+, 100%), 137 ($M^+ - NS$, 26) and 46 (NS^+, 34).

With methyl pyrrole-1-carboxylate 4, R = CO_2Me. Methyl pyrrole-1-carboxylate (250 mg, 2 mmol) and trithiazyl trichloride (976 mg, 4 mmol) gave *methyl* 7H-*pyrrolo*[2,3-c:4,5-c′]*bis*[1,2,5]*thiadiazole*-7-*carboxylate* **6**, R = CO_2Me (20 mg, 4%), mp 214–216 °C; $\nu_{max}(CHCl_3)$/cm^{-1} 3032, 2927, 1764 (C=O), 1546, 1495, 1443, 1400, 1301, 1278, 1232, 1177, 818 and 689; δ_H(270 MHz, $CDCl_3$) 4.21 (3H, s, Me); *m/z* 241 (M^+, 42%), 197 ($M^+ - CO_2$, 35), 164 ($M^+ - CO_2 - S$, 18), 156 (9), 151 (12), 138 (16), 111 (8), 67 (12), 59 (51) and 44 (CO_2^+, 100).

With indole 7, R = H. Indole (234 mg, 2 mmol) and trithiazyl trichloride (448 mg, 2 mmol) gave 4*H*-[1,2,5]thiadiazolo[3,4-*b*]-indole **8**, R = H (81 mg, 23%), mp 158–159 °C (lit.,[10] 159–160 °C) (Found: C, 55.0; H, 2.7; N, 23.7. Calc. for $C_8H_5N_3S$: C, 54.9; H, 2.9; N, 24.0%); $\nu_{max}(CHCl_3)$/cm^{-1} 3463 (NH), 3011, 1625, 1590, 1573, 1465, 1443, 1394, 1347, 1343, 1220, 820, 800 and 776; δ_H(270 MHz, $CDCl_3$) 7.24–7.30 (1H, td, ArH), 7.36–7.39 (1H, d, ArH), 7.47–7.53 (1H, td, ArH), 8.06–8.09 (1H, d, ArH) and 8.50 (1H, s, NH); δ_C(67.5 MHz, $CDCl_3$) 112.49, 115.60, 121.46, 122.65, 129.61, 149.33, 150.33 and 156.49; *m/z* 175 (M^+, 100%), 129 ($M^+ - NS$, 56), 102 ($M^+ - N_2S$, 15), 90 (14), 76 (8) and 46 (NS^+, 14).

With 1-methylindole 7, R = Me. 1-Methylindole (262 mg, 2 mmol) and trithiazyl trichloride (448 mg, 2 mmol) gave 3-chloro-1-methylindole **9** R = Me (33 mg, 10%), identical with an authentic sample and 4-*methyl*-4H-[1,2,5]*thiadiazolo*[3,4-b]-*indole* **8**, R = Me (212 mg, 56%), mp 80–81 °C (Found: C, 56.9; H, 3.6; N, 21.9. $C_9H_7N_3S$ requires C, 57.1; H, 3.7; N, 22.2%); $\nu_{max}(CHCl_3)$/cm^{-1} 3068, 3011, 2940, 1625, 1580, 1515, 1471, 1445, 1394, 1322, 1254, 1166, 1152, 1125, 1069, 1022, 876 and 800; δ_H(270 MHz, $CDCl_3$) 3.82 (3H, s, Me), 7.24–7.29 (1H, m, ArH), 7.30–7.33 (1H, d, ArH), 7.52–7.55 (1H, m, ArH) and 8.06–8.09 (1H, d, ArH); *m/z* 189 (M^+, 100%), 174 ($M^+ - Me$, 9), 161 ($M^+ - N_2$, 6), 156 (6), 143 (6), 129 ($M^+ - N_2S$, 10), 116 (8), 102 (15), 94 (14) and 46 (NS^+, 99).

With 1-phenylindole 7, R = Ph. 1-Phenylindole (386 mg, 2 mmol) and trithiazyl trichloride (448 mg, 2 mmol) gave 3-chloro-1-phenylindole **9**, R = Ph (95 mg, 21%), identical with an authentic sample and 4-*phenyl*-4H-[1,2,5]*thiadiazolo*[3,4-b]-*indole* **8**, R = Ph (301 mg, 60%), mp 105–106 °C (Found: C, 66.75; H, 3.6; N, 16.6. $C_{14}H_9N_3S$ requires C, 66.9; H, 3.6; N, 16.7%); $\nu_{max}(CHCl_3)$/cm^{-1} 3066, 3012, 1621, 1600, 1554, 1510, 1462, 1442, 1397, 1320, 1305, 1262, 1226, 1220, 1166, 1156, 802, 777 and 696; δ_H(270 MHz, $CDCl_3$) 7.30–7.40 (1H, m, ArH), 7.42–7.46 (1H, m, ArH), 7.47–7.56 (1H, m, ArH), 7.57–7.65 (3H, m, ArH), 7.70–7.75 (2H, m, ArH) and 8.15–8.20 (1H, m, ArH); *m/z* 251 (M^+, 100%), 219 ($M^+ - S$, 6), 192 (9) and 77 (Ph^+, 20).

With 1-phenylsulfonylindole 7, R = SO_2Ph. 1-Phenylsulfonylindole (257 mg, 1 mmol) and trithiazyl trichloride (244 mg, 1 mmol) gave 3-chloro-1-phenylsulfonylindole **9**, R = SO_2Ph (47 mg, 16%), mp 119–120 °C (lit.,[17] 120–121 °C); δ_H(270 MHz, $CDCl_3$) 7.30–8.02 (9H, m, ArH) and 7.56 (1H, s, indole-H); *m/z* 291 (M^+, 73%), 150 ($M^+ - PhSO_2$, 100), 141 ($PhSO_2^+$, 41), 77 (Ph^+, 81) and 4-*phenylsulfonyl*-4H-[1,2,5]*thiadiazolo*[3,4-b]-*indole* **8**, R = SO_2Ph (120 mg, 38%), mp 72–74 °C (Found: M^+, 315.0136. $C_{14}H_9N_3O_2S_2$ requires *M*, 315.0136); $\nu_{max}(CHCl_3)$/cm^{-1} 3034, 3011, 1618, 1449, 1381, 1281, 1265, 1177, 1130, 1111, 1092, 1019, 945, 909, 781, 700 and 685; δ_H(270 MHz, $CDCl_3$) 7.38–7.59 (6H, m, ArH) and 7.91–8.09 (3H, m, ArH); *m/z* 315 (M^+, 28%), 175 ($M^+ - PhSO_2$, 12), 141 ($PhSO_2^+$, 50), 110 (24), 109 (10) and 77 (Ph^+, 100).

With bromopyrroles (Table 2). The bromo-1-phenylpyrroles and 2,5-dibromo-1-methylpyrrole were treated with trithiazyl trichloride as shown in Table 2 to give 7-phenyl-7*H*-pyrrolo-[2,3-*c*:4,5-*c*′]bis[1,2,5]thiadiazole **6**, R = Ph, and 7-methyl-7*H*-pyrrolo[2,3-*c*:4,5-*c*′]bis[1,2,5]thiadiazole **6**, R = Me, respectively, identical with the compounds described above, in the yields shown.

With 3-chloroindoles 9 (Table 3). The 3-chloroindoles **9**, R = H, Me, Ph, were treated with trithiazyl trichloride as shown in Table 3 to give the 4*H*-[1,2,5]thiadiazolo[3,4-*b*]indoles **8**, R = H, Me, Ph, respectively, identical with the compounds described above, in the yields shown.

With pyrrolecarboxylic acids and esters (Table 4). The pyrrolecarboxylic acids **10** and **11** (R = H) and esters **10** and **11** (R = Me) were treated with trithiazyl trichloride as shown in Table 4 to give the thiazolopyrroles **6**, R = Me, and **3** respectively, identical with the compounds described above, in the yields shown.

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References

1 X.-G. Duan, X.-L. Duan, C. W. Rees and T.-Y. Yue, *J. Chem. Soc., Perkin Trans. 1*, 1997, 2597.
2 X.-L. Duan, R. Perrins and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1997, 1617.
3 C. W. Rees and T.-Y. Yue, *J. Chem. Soc., Perkin Trans. 1*, 1997, 2247.
4 D. S. James and P. E. Fanta, *J. Org. Chem.*, 1962, **27**, 3346.

5 L. M. Weinstock and I. Shinkai, in *Comprehensive Heterocyclic Chemistry*, ed. A. R. Katritzky and C. W. Rees, Pergamon Press, Oxford, 1984, vol. 6, p. 528; I. Shinkai and P. J. Reider, in *Comprehensive Heterocyclic Chemistry II*, ed. A. R. Katritzky, C. W. Rees and E. F. V. Scriven, Pergamon Press, Oxford, 1996, vol. 4, p. 363.
6 C. F. Hobbs, C. K. McMillin, E. P. Papadopoulos and C. A. VanderWerf, *J. Am. Chem. Soc.*, 1962, **84**, 43.
7 E. P. Papadopoulos and N. F. Haidar, *Tetrahedron Lett.*, 1968, 1721.
8 B. L. Bray, P. H. Mathies, R. Naef, D. R. Solas, T. T. Tidwell, D. R. Artis and J. M. Muchowski, *J. Org. Chem.*, 1990, **55**, 6317.
9 N. W. Gabel, *J. Org. Chem.*, 1962, **27**, 301.
10 S. Mataka, A. Hosoki, K. Takahashi and M. Tashiro, *J. Heterocycl. Chem.*, 1980, **17**, 1681.
11 H. M. Gilow and D. E. Burton, *J. Org. Chem.*, 1981, **46**, 2221.
12 G. Pappalardo and T. Vitali, *Gazz. Chim. Ital.*, 1958, **88**, 1147.
13 X.-G. Duan, X.-L. Duan, C. W. Rees and T.-Y. Yue, *J. Heterocycl. Chem.*, 1996, **33**, 1419.
14 A. F. Pozharskii, W. Martsokha and P. Simonov, *Zh. Obshch. Khim.*, 1963, **33**, 1005 (*J. Gen. Chem. USSR*, 1963, **33**, 994).
15 R. J. Sundberg and H. F. Russell, *J. Org. Chem.*, 1973, **38**, 3324.
16 D. L. Comins and M. O. Killpack, *Tetrahedron Lett.*, 1989, **30**, 4337.
17 E. Wenkert, P. D. R. Moeller, S. R. Piettre and A. T. McPhail, *J. Org. Chem.*, 1987, **52**, 3404.

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