Cyclisation chemistry of 4*H*-1,2,6-thiadiazines

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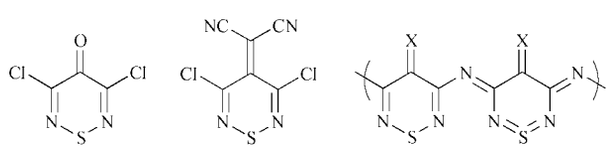
Received (in Cambridge, UK) 23rd May 2000, Accepted 22nd June 2000
Published on the Web 28th July 2000

3,5-Dichloro-4*H*-1,2,6-thiadiazin-4-one **1** condenses rapidly at room temperature with 1,2-diaminobenzene, 2-aminothiophenol and sodium 2-aminophenoxide to give, respectively, the purple thiadiazinoquinoxaline **4a**, red thiadiazinobenzothiazine **4b** and orange thiadiazinobenzoxazine **4c** in almost quantitative yield. The 10*H* tautomer **4a** is spectroscopically almost identical with the purple 10-methyl derivative **11** formed by condensation of **1** with *N*-methyl-1,2-diaminobenzene and by the methylation of **4a**. The chlorine substituent in these tricyclic thiadiazino compounds is readily displaced by nucleophiles, to give the 4-ethoxy **13** and 4-piperidino derivative **21**. The dicyanomethylene compound **2**, analogous to **1**, reacts in the same way as **1** with 2-aminothiophenol to give **4b** (87%), but its reaction with 1,2-diaminobenzene is more complex since, in addition to the analogous formation of **4a**, there is now the possibility of another cyclisation in the intermediate **16** which leads to the tetracyclic compound **14** and its substitution product **15**. This difference in reaction pathway between **1** and **2** is further illustrated by their condensation with 1,8-diaminonaphthalene: **1** is converted into **19** by simple displacement of chlorine, whilst **2** gives, almost quantitatively, the product **20** of cyclisation onto the neighbouring cyano group.

We have recently described some chemistry of the readily available 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** [1,2] and the related



1 **2** **3**

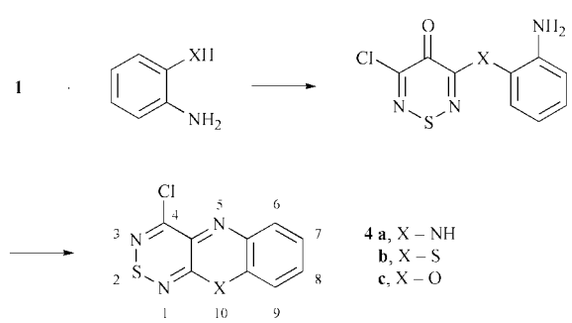
new thiadiazine **2** [2,3] directed towards the synthesis of their amino derivatives required as monomers for conjugated polymers incorporating the repeat unit **3**. The chlorine atoms in **1** and **2** are readily displaced by nucleophiles such as thiophenols and amines.[1,2] We now describe the reactions of **1** and **2** with 1,4- and 1,5-bis-nucleophiles which provide a ready source of new, colourful polycyclic ring systems.

Results and discussion

Cyclisations with 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one 1

Thiadiazinone **1** reacted smoothly with ethanolic solutions of 1,2-diaminobenzene and 2-aminothiophenol at room temperature to give purple 4-chloro-10*H*-[1,2,6]thiadiazino[3,4-*b*]quinoxaline **4a** [λ_{max} 548 nm (log ε 3.58)], and the red 4-chloro[1,2,6]thiadiazino[3,4-*b*][1,4]benzothiazine **4b** [λ_{max} 463 nm (log ε 3.66)] respectively. The reactions were rapid and at relatively high concentrations (1 mmol of **1** and 2 mmol of the amine in *ca.* 10 ml EtOH) were complete within one hour; the new tricyclic products separated from the reaction mixture and recrystallisation gave analytically pure **4a** (96%) and **4b** (95%) in very high yields.

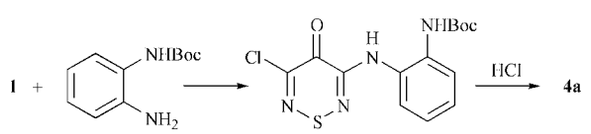
In view of the earlier work [1,2] we propose that the first step is nucleophilic displacement of chlorine followed by cyclodehydration as shown in Scheme 1. This is supported by treatment of thiadiazinone **1** with the mono-Boc derivative **5** [4] of 1,2-diaminobenzene, under the same conditions, to give the analogous first product **6** in good yield (76%); deprotection of



4 a, X – NH
b, X – S
c, X – O

Scheme 1

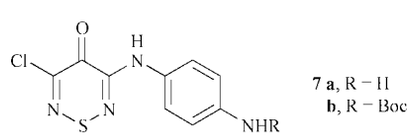
6 with 3 M HCl in ethyl acetate [5] gave the cyclised product **4a** (72%) directly (Scheme 2). The ready cyclisation appears to



5 **6**

Scheme 2

drive the reactions cleanly to completion since the analogous reaction of thiadiazinone **1** with 1,4-diaminobenzene, and its mono-Boc derivative,[6] gave the secondary amines **7a** (20%) and **7b** (38%) respectively in much lower yield. The Boc derivative **7b** was hydrolysed with HCl as before to give **7a** (93%).



7 a, R = H
b, R = Boc

Thiadiazinone **1** reacted slowly with 2-aminophenol (2 equiv. in boiling EtOH) to give the analogous secondary amine **8** (86%), where the amino group had preferentially displaced

DOI: 10.1039/b004113k

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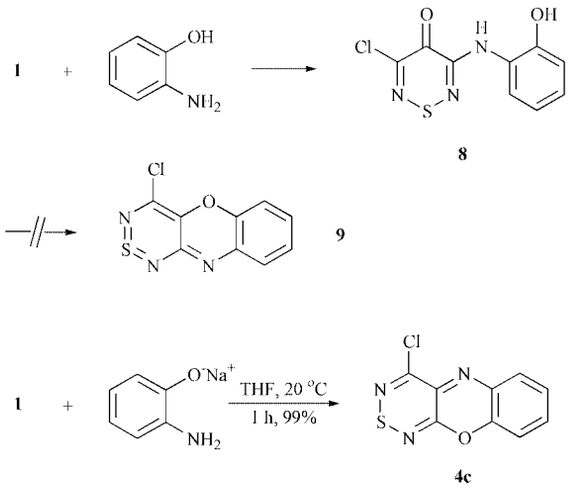
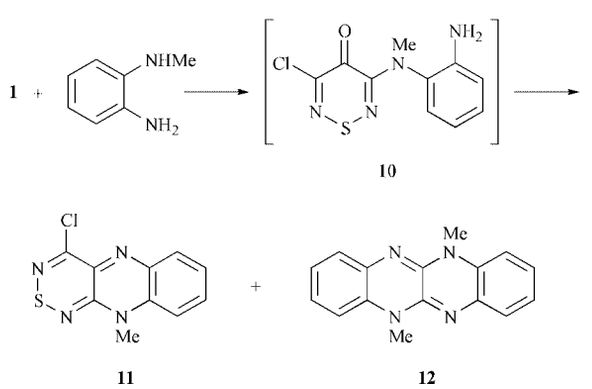


Scheme 3

chlorine (Scheme 3). It is notable that even in boiling EtOH the uncyclised product **8** gave no sign of cyclodehydrating to give the thiadiazinobenzoxazine **9** with its higher energy S^{IV} sulfurdiimide structure. However thiadiazinone **1** reacted rapidly and virtually quantitatively with the sodium salt of 2-aminophenol, in THF at room temperature in one hour, to give orange 4-chloro[1,2,6]thiadiazino[3,4-*b*][1,4]benzoxazine **4c** (99%) exactly analogous to **4a** and **b**.

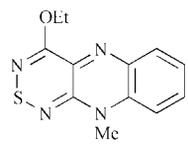
The spectral data of the three tricyclic compounds **4** are in good agreement with the proposed structures with sulfur in the S^{II} oxidation state though, in principle, there is another regioisomer possible in each case with S^{IV} sulfur, such as **9**. In the formation of **4b** and **4c** the reagents 2-aminothiophenol and sodium 2-aminophenoxide would be expected to effect displacement of chlorine through the more nucleophilic sulfur and oxygen functions. However a further ambiguity arises in the 1,2-diaminobenzene reaction; by analogy with structures **4b** and **c**, **4a** is written with the amino hydrogen located at N-10 rather than N-1 or N-5, though delocalisation around the tricyclic system could possibly reduce the energy difference between these tautomers. Structure **4a** was shown to be correct for the major tautomer (the only one observed) by comparison with the *N*-methylated derivative, 4-chloro-10-methyl-10*H*-[1,2,6]thiadiazino[3,4-*b*]quinoxaline **11** which was prepared in two ways. The first involved reacting thiadiazinone **1** with *N*-methyl-1,2-diaminobenzene, where it was expected that the greater nucleophilicity of the secondary amine would result in formation of isomer **10** which would cyclise to the N-10 methylated derivative **11** (Scheme 4). This reaction gave a



Scheme 4

monomethylated purple product (70%) whose spectral data supported structure **11**. No other isomeric product was observed, but a small amount (15%) of a yellow, highly fluorescent compound was obtained and identified as the tetracyclic 5,11-dimethyl-5*H*,11*H*-quinoxalino[2,3-*b*]quinoxaline **12** by comparison with the mp and spectral data in the literature.[7] The scope and mechanism of the unexpected and intriguing formation of **12** in this reaction is being investigated.

The second route to compound **11** was methylation of **4a** with iodomethane in DMSO and aqueous sodium hydroxide at room temperature, in 95% yield. When EtOH was used in place of DMSO the sodium ethoxide generated displaced chloride to give 4-ethoxy-10-methyl-10*H*-[1,2,6]thiadiazino[3,4-*b*]quinoxaline **13** (59%) as the major product. The two *N*-methyl compounds **11** were identical.



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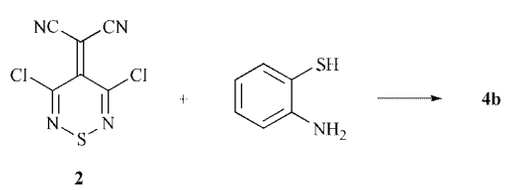
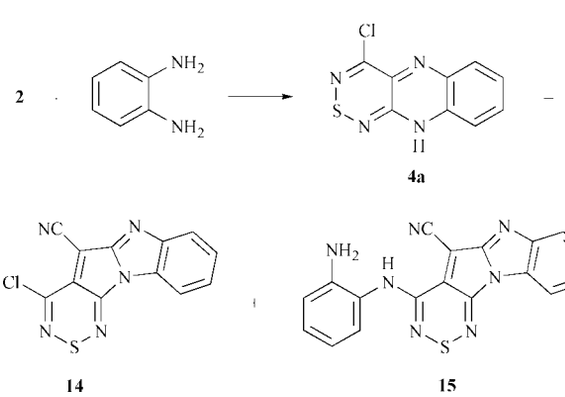
A comparison of the spectral data, particularly the UV and ^{13}C NMR spectra, for compound **4a** and its methylated derivative **11** showed that they were almost identical, in agreement with the 10*H* structure **4a** being the tautomer isolated.

Cyclisations with 3,5-dichloro-4-dicyanomethylene-1,2,6-thiadiazine 2

An ethanolic solution of the dicyanomethylene compound **2** and 2-aminothiophenol gave the tricyclic thiadiazine **4b** (87%), identical with the product from thiadiazinone **1**, presumably by the same mechanism but with the expulsion of malononitrile upon cyclisation (Scheme 5). The reaction of **2** with 1,2-diaminobenzene was more complex however (Scheme 6,



Scheme 5



Scheme 6

Table 1). Two major products, thiadiazinoquinoxaline **4a** and 4-chloro-5-cyano[1,2,6]thiadiazino[3′,4′ : 5,4]pyrrolo[1,2-*a*]-benzimidazole **14**, and a minor product **15** were isolated. Compound **4a** was identical with that described above (Scheme 1). Attempts to improve the yields (Table 1) of **4a** and **14** were unsuccessful, though we noted that an excess of 1,2-diaminobenzene reduced the yield of **14** whilst one equiv. actually improved the yield; this suggests that cyclisation onto the nitrile to yield **14** is acid catalysed.

Compound **14** was obtained as bright red needles (the kinetic polymorph from rapid crystallisation from 1,2-dichloroethane)

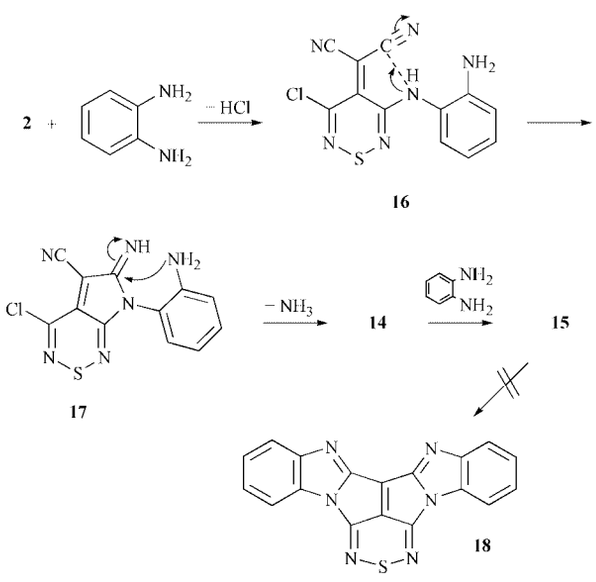
Table 1 Treatment of 3,5-dichloro-4-dicyanomethylene-1,2,6-thiadiazine **2** with 1,2-diaminobenzene in ethanol (5 ml) at 20 °C (see Scheme 6)

Compound **2**/ mmol	1,2-Diamino-benzene (equiv.)	Reaction time/h	Product yield (%)			
			2	**4a**[a]	**14**	**15**
0.24	1	48	22	36[b]	34[b]	Trace
0.22	2	12	—	42	19	—
0.26	3	36	—	23	Trace	—

[a] Yields calculated assuming 2 equiv. of amine required for the formation of **4a**. [b] Yields take into account the recovered starting material **2**.

or as deep red prisms (the thermodynamic polymorph from slow crystallisation from 1,2-dichloroethane), both with mp 254–256 °C. The bright red needles darkened in colour on heating above 145 °C. Microanalysis and HRMS gave the molecular formula as $C_{12}H_4ClN_5S$, indicating the loss of the elements of NH_4Cl in its formation. The ^{13}C NMR spectra showed twelve separate resonances indicating an unsymmetrical molecule, and the signal at 112.3 ppm supported the presence of a cyanide indicated by IR stretching at 2230 cm^{-1}; no amine stretching was observed. On this basis structure **14** was proposed and this was confirmed by X-ray crystallography.[8] An attempted independent synthesis of **14** from thiadiazinone **1** and 2-benzimidazolylacetonitrile gave only a trace (TLC) of the desired compound.

A probable route to the tetracyclic compound **14** is shown in Scheme 7. After displacement of chlorine by 1,2-diamino-



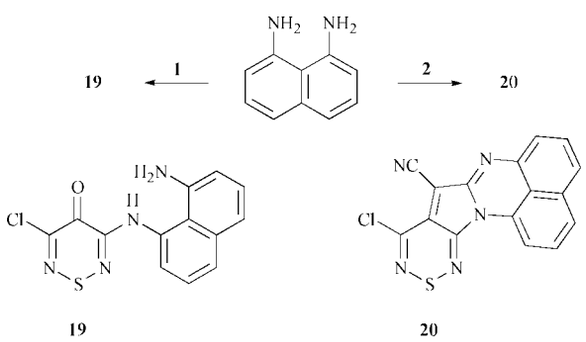
Scheme 7

benzene to give the expected secondary amine **16** there are two possible cyclisation pathways. The primary amino group can attack the thiadiazine ring at C-4 to displace malononitrile to form **4a**, exactly analogous to the cyclodehydration of Scheme 1. Alternatively the secondary amino group can cyclise onto the neighbouring nitrile carbon (*cf.* refs. 2 and 3) to give the iminopyrrole **17** which is intercepted in a second cyclisation with loss of ammonia; the two cyclisation steps could be acid catalysed. Finally the chlorine in **14** could be displaced by more 1,2-diaminobenzene to give the minor product **15**; that this was the probable source of **15** was shown by its independent formation, as a major product (83%), from **14** and 4 equiv. of 1,2-diaminobenzene in hot ethanol.

Just as the secondary amino group in **16** cyclised onto the neighbouring nitrile to give **17**, and hence **14**, (Scheme 7) so, in principle, could the secondary amine in **15** cyclise similarly to give the symmetrical heptacyclic system **18**, though this would presumably be more strained with its four contiguous 5-membered rings. Attempts to enforce this second cyclisation by heating **15** in ethanol, in acetic acid and in polyphosphoric acid were unsuccessful.

Cyclisations with 1,8-diaminonaphthalene

With these mechanisms in mind, we decided to treat the thiadiazines **1** and **2** with a bis-amine that could not form a 6-membered cyclic intermediate necessary for generation of the very stable products like **4a**; we chose 1,8-diaminonaphthalene which would have to form a less favourable 7-membered ring when cyclising onto C-4 of the thiadiazine ring. Reaction of the thiadiazinone **1** with 1,8-diaminonaphthalene gave only the initial product **19** in moderate yield (46%), with no sign of cyclodehydration (Scheme 8). Since the analogous cyclisation



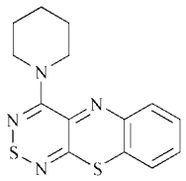
Scheme 8

will also be disfavoured in the reaction of dicyanomethylene-thiadiazine **2** with 1,8-diaminonaphthalene, it is reasonable to assume that the alternative cyclisation onto the cyano group (*cf.* Scheme 7) to give a product analogous to **14** would be favoured. Indeed, addition of 1,8-diaminonaphthalene to an ethanolic solution of **2** gave the green, pentacyclic 9-chloro-8-cyano-[1,2,6]thiadiazino[3′,4′:5,4]pyrrolo[1,2-*a*]perimidine **20** [λ_{max} 662 nm (log ε 3.77)] in up to 96% yield. This poorly soluble product separated from the reaction solution, and recrystallisation gave analytically pure material. Structure **20** is based on HRMS, microanalysis, IR and UV spectra and by analogy with the closely related product **14**; in particular a doubly charged ion, M^{++}, was observed in the HRMS, but low solubility prevented the collection of the NMR data. The conversion of **2** into **20** compared with that of **1** into **19**, by 1,8-diaminonaphthalene, provides another example (*cf.* ref. 2) of the additional reactivity exhibited by the dicyanomethylene compound **2** over the simpler compound **1**.

We saw above an example of the ready displacement of chlorine from 4-chlorothiadiazine **4a**, during its methylation, to give the 4-ethoxy compound **13**. We assumed that such reactivity would extend to the chloro derivatives of related compounds like **4b**, **c** and **11**. This was supported by the virtually quantitative displacement of chlorine in **4b** by piperidine in refluxing DCM in one hour to give **21**.

Conclusion

We have shown that a variety of highly coloured, stable polycyclic 1,2,6-thiadiazines can be readily prepared from the



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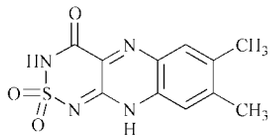

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monocyclic thiadiazines **1** and **2**. By variation of the C-4 substituent and the heteroatom at position 10 of the tricyclic compounds **4** a wide range of potential new chromophores could be produced. Whilst the highly coloured compounds are not suitable for use as non-linear optical materials, simple oxidation of the sulfur to its dioxide would give compounds similar to the sulfone **22**, the only other reported example of these ring systems, which has been investigated as an optical dye.[9]

Experimental

General experimental details have been described before.[2,3] Compounds **1** and **2** were prepared by the literature methods.[1,3] Additionally 250 MHz ^{1}H NMR and 62.9 MHz ^{13}C NMR were recorded on a Bruker WM250 machine.

4-Chloro-10*H*-[1,2,6]thiadiazino[3,4-*b*]quinoxaline 4a

Method 1. To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (182 mg, 1.0 mmol) in EtOH (7 ml) at *ca.* 20 °C 1,2-diaminobenzene (216 mg, 2.0 mmol) was added in one portion. The mixture became purple and after 1 h a deep purple precipitate had formed. This was filtered off (215 mg, 91%) and the addition of a little water to the filtrate gave a second purple precipitate (12 mg, 5%). The precipitates (identical by TLC) were combined and crystallisation gave the *title compound* **4a** (227 mg, 96%) as purple–red needles, mp 310 °C subl. (from EtOH) (Found: C, 45.7; H, 1.9; N, 23.8. Calc. for $C_9H_5ClN_4S$: C, 45.8; H, 2.1; N, 23.7%); λ_{max}(DCM)/nm 262 inf (inflection) (log ε 4.21), 267 (4.22), 283 (4.15), 291 inf (4.08), 326 (3.99), 341 inf (3.90), 366 (3.80), 385 (3.85), 407 (3.68), 485 inf (3.43), 522 (3.58), 548 (3.58), 595 inf (3.31); ν_{max}(Nujol)/cm^{-1} 3228m (NH), 3188m, 3140m, 3072m and 3052m (Ar CH), 1608s, 1568w, 1514m, 1471s, 1415s, 1380s, 1275m, 1221m, 1117m, 957m, 925s, 879m, 803s, 768m, 743s, 721s, 620s, 604s; δ_H(400 MHz; DMSO-d_6) 10.18 (1H, s, N*H*), 6.90 (1H, ddd, *J* 1.6, 7.7, 7.7 Hz, Ar *H*), 6.87 (1H, dd, *J* 1.4, 6.4 Hz, Ar *H*), 6.66 (1H, ddd, *J* 1.4, 7.7, 7.7 Hz, Ar *H*), 6.37 (1H, dd, *J* 1.2, 7.8 Hz, Ar *H*); δ_C(100 MHz; DMSO-d_6) 150.0, 142.3, 139.7, 136.5, 135.9, 130.6 (Ar *C*H), 128.3 (Ar *C*H), 123.2 (Ar *C*H), 113.6 (Ar *C*H); *m*/*z* (EI) 236 (M$^+$, 100%), 201 (M$^+$ − Cl, 32), 174 (M$^+$ − CHClN, 8), 168 (7), 162 (4), 154 (6), 149 (6), 143 (M$^+$ − CClNS, 21), 131 (6), 118 (6), 102 (5), 90 (9), 76 ($C_6H_4^+$, 4), 69 (11) (Found: M$^+$, 235.9922. $C_9H_5ClN_4S$ requires *M*, 235.9923).

Method 2. (i) To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (22 mg, 0.12 mmol) in EtOH (2 ml) at *ca.* 20 °C 2-(*N*-*tert*-butoxycarbonylamino)aniline **5**[4] (50 mg, 0.24 mmol) was added in one portion. After 3 h the mixture was poured into ice–water and the yellow–orange precipitate was collected, washed (H_2O), dried and recrystallisation gave the *3-[2-(N-tert-butoxycarbonylamino)anilino]-5-chloro-4H-1,2,6-thiadiazin-4-one* **6** (32 mg, 76%) as yellow crystals, mp >280 °C dec. (from EtOH); λ_{max}(EtOH)/nm 305 (log ε 4.11), 318 (4.12), 391 (3.64); ν_{max}($CHCl_3$)/cm^{-1} 3425w and 3340w (NH), 3155w (Ar CH), 1712m, 1634m, 1596m, 1541s, 1480m, 1371m, 1181m, 1157s, 916s, 833m, 651s; δ_H(250 MHz; $CDCl_3$) 9.07 (1H, br, N*H*), 7.76 (1H, m, Ar *H*), 7.43 (1H, m, Ar *H*), 7.26–7.19 (2H, m, Ar *H*), 6.49 (1H, br, N*H*), 1.54 (9H, s, *^{t}Bu*); *m*/*z* (EI) 354 (M$^+$, 6%), 298 (M$^+$ − ^{t}Bu, 17), 280 (26), 254 (21), 237 (36), 219 (18), 201 (7), 165 (15), 159 (17), 152 (8), 149 (8), 134 (14), 118 (7), 108 (14), 93 (CClNS$^+$, 11), 78 (7), 57 (^{t}Bu$^+$, 100) (Found: M$^+$, 354.0550. $C_{14}H_{15}ClN_4O_3S$ requires *M*, 354.0553). (ii) To a stirred solution of 3-[2-(*N*-*tert*-butoxycarbonylamino)anilino]-5-chloro-1,2,6-thiadiazin-4-one **6** (21 mg, 0.06 mmol) in ethyl acetate (1 ml) at *ca.* 20 °C, was added 3 M HCl. After 6 h the mixture was diluted with ethyl acetate (5 ml), treated with aqueous sodium bicarbonate and the organic layer was separated, dried and the volatiles were removed. Flash chromatography (Et_2O) of the residue gave the title compound **4a** (10 mg, 72%) identical with that prepared above.

4-Chloro[1,2,6]thiadiazino[3,4-*b*][1,4]benzothiazine 4b

Method 1. To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (546 mg, 3 mmol) in EtOH (35 ml) at *ca.* 20 °C 2-aminothiophenol (640 µl, 6 mmol) was added in one portion. The mixture rapidly became red and after 1 h a red precipitate had formed. This was filtered off and crystallisation gave the *title compound* **4b** (645 mg, 85%) as orange–red needles, mp 149–152 °C (from EtOH) (Found: C, 42.6; H, 1.3; N, 16.5. Calc. for $C_9H_4ClN_3S_2$: C, 42.7; H, 1.6; N, 16.6%); λ_{max}(DCM)/nm 271 (log ε 4.33), 277 (4.33), 332 inf (3.87), 343 (3.93), 360 inf (3.84), 400 (3.80), 422 inf (3.74), 463 (3.66); ν_{max}(Nujol)/cm^{-1} 3045w (Ar CH), 1590s, 1569w, 1562w, 1546m, 1531m, 1515m, 1434m, 1300m, 1282s, 1274s, 1261s, 1227m, 1121m, 1086m, 1060s, 841m, 813m, 772s, 765s, 726m, 715m, 704s, 679m, 609s; δ_H(400 MHz; DMSO-d_6) 7.23–7.20 (1H, m, Ar *H*), 7.19–7.13 (2H, m, Ar *H*), 7.08–7.04 (1H, m, Ar *H*); δ_C(100 MHz; DMSO-d_6) 153.5, 144.9, 138.9, 136.0, 131.2 (Ar *C*H), 130.01 (Ar *C*H), 128.6 (Ar *C*H), 126.7, 125.6 (Ar *C*H); *m*/*z* (EI) 253 (M$^+$, 100%), 227 (M$^+$ − CN, 7), 218 (M$^+$ − Cl, 13), 192 (M$^+$ − CClN, 20), 160 (M$^+$ − CClNS, 33), 151 (8), 134 (8), 113 (7), 108 ($C_6H_4S^+$, 14), 93 (CClNS$^+$, 8), 82 (5), 69 (25) (Found: M$^+$, 252.9556. $C_9H_4ClN_3S_2$ requires *M*, 252.9567). The addition of a little water to the filtrate gave a second red precipitate (76 mg) of slightly less pure product.

Method 2. To a stirred solution of (3,5-dichloro-4*H*-1,2,6-thiadiazin-4-ylidene)propanedinitrile **2** (48 mg, 0.21 mmol) in EtOH (5 ml) at *ca.* 20 °C 2-aminothiophenol (32 µl, 0.30 mmol) was added in one portion. After 2 h a red precipitate was produced, filtration and crystallisation of which gave the title compound **4b** (33 mg, 87%) as orange–red needles, mp 149–152 °C (from EtOH), spectroscopically identical to the above specimen.

4-Chloro[1,2,6]thiadiazino[3,4-*b*][1,4]benzoxazine 4c

To a solution of 2-aminophenol (981 mg, 9 mmol) in THF (60 ml) at *ca.* 20 °C, under nitrogen, excess of NaH (380 mg of 60% mineral suspension) was added. This solution (0.15 M, 8 ml, 1.20 mmol) was added slowly to a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (211 mg, 1.16 mmol) in THF (5 ml) at *ca.* 20 °C, under nitrogen. The mixture became orange and after 1 h no starting material remained (TLC). The mixture was diluted with DCM (30 ml) and washed with water (5 × 10 ml). The organic fraction was dried, filtered and the volatiles were removed. Crystallisation of the residue gave the *title compound* **4c** (272 mg, 99%) as orange prisms, mp 158–163 °C (from EtOH) (Found: C, 45.3; H, 1.6; N, 17.6. $C_9H_4ClN_3OS$ requires C, 45.6; H, 1.7; N, 17.7%); λ_{max}(DCM)/nm 249 inf (log ε 4.04), 256 (4.08), 264 inf (4.00), 273 inf (3.77), 317 inf (3.78), 327 (3.83), 342 inf (3.77), 370 (3.66), 394 (3.65), 446 (3.85); ν_{max}(Nujol)/cm^{-1} 3105w and 3050w (Ar CH), 1615m, 1587w, 1547m, 1519m, 1456s, 1332s, 1308m, 1295m, 1283m, 1244m, 1207m, 1185m, 1107m, 969m, 903s, 877s, 802s, 767s, 750s, 720s, 617s; δ_H(400 MHz; DMSO-d_6) 7.24 (1H, dd, *J* 1.6, 7.6 Hz, Ar *H*), 7.18 (1H, ddd, *J* 1.65, 7.8, 7.7 Hz, Ar *H*), 7.04 (1H, ddd, *J* 1.3, 7.6, 7.6 Hz, Ar *H*), 6.88 (1H, dd, *J* 1.3, 8.1 Hz, Ar *H*); δ_C(100 MHz; DMSO-d_6) 151.0, 148.1, 145.8, 138.4,

133.9, 130.6 (Ar *C*H), 128.5 (Ar *C*H), 125.7 (Ar *C*H), 115.2 (Ar *C*H); *m*/*z* (EI) 237 (M^+, 100%), 202 ($M^+ - Cl$, 5), 176 ($M^+ - CClN$, 9), 144 ($M^+ - CClNS$, 11), 118 (5), 93 ($CClNS^+$, 11), 64 (6) (Found: M^+, 236.9764. $C_9H_4ClN_3OS$ requires *M*, 236.9763).

3-(4-Aminoanilino)-5-chloro-4*H*-1,2,6-thiadiazin-4-one 7a

Method 1. (i) To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (419 mg, 2.29 mmol) in DCM (20 ml) at *ca.* 20 °C 4-(*N*-*tert*-butoxycarbonylamino)aniline[6] (478 mg, 2.29 mmol) was added in one portion and after 2 h pyridine (186 µl, 2.30 mmol) was added. After a further 1 h the orange coloured mixture was adsorbed onto silica and flash chromatography (DCM) followed by recrystallisation gave the *3-[4-(N-tert-butoxycarbonylamino)anilino]-5-chloro-4H-1,2,6-thiadiazin-4-one* **7b** (310 mg, 38%) as orange crystals, mp 184–185 °C (from EtOH); λ_{max}(EtOH)/nm 245 (log ε 2.97), 319 (3.16), 336 (3.16); ν_{max}(Nujol)/cm^{-1} 3386m and 3300m (NH), 1728m, 1632m, 1596m, 1557m, 1525s, 1508s, 1318m, 1244m, 1229m, 1178m, 1159m, 889m, 837m; δ_H(250 MHz; $CDCl_3$) 8.62 (1H, br, N*H*), 7.56 (2H, d, *J* 8.8 Hz, Ar *H*), 7.40 (2H, d, *J* 8.8 Hz, Ar *H*), 6.51 (1H, br, N*H*), 1.53 (9H, s, *'Bu*); δ_H(62.9 MHz; $CDCl_3$) 156.7, 152.7, 149.9, 141.8, 135.8, 132.0, 120.9, 119.4, 80.8 [*C*(CH_3)$_3$], 28.4 (*C*H_3); *m*/*z* (EI) 354 (M^+, 2%), 298 ($M^+ - {}^t$Bu, 3), 280 (12), 254 (24), 234 (3), 208 (5), 196 (38), 178 (13), 165 (4), 160 (11), 152 (43), 134 (32), 118 (5), 108 (50), 91 (5), 80 (16), 57 (^{t}Bu, 88) (Found: M^+, 354.0550. $C_{14}H_{15}ClN_4O_3S$ requires *M*, 354.0553). (ii) To a stirred solution of 3-[4-(*N*-*tert*-butoxycarbonylamino)anilino]-5-chloro-4*H*-1,2,6-thiadiazin-4-one **7b** (52 mg, 0.15 mmol) in ethyl acetate (5 ml) at *ca.* 20 °C, was added 3 M HCl. After consumption of the starting material (TLC) the volatiles were removed. Flash chromatography (Et_2O) of the residue gave the *title compound* **7a** (35 mg, 93%) as a red solid, mp 214–215 °C; λ_{max}(EtOH)/nm 240 (log ε 3.74), 322 (3.92), 340 (3.92); ν_{max}(Nujol)/cm^{-1} 3462w, 3365w and 3304s (NH), 1616s, 1596s, 1568m, 1505w, 1175m; δ_H(270 MHz; DMSO-d_6) 7.33 (2H, d, *J* 8.6 Hz, Ar *H*), 6.54 (2H, d, *J* 8.6 Hz, Ar *H*), 5.04 (2H, br, NH_2); *m*/*z* (EI) 254 (M^+, 100%), 165 (24), 160 (7), 133 (64), 132 (9), 118 (22), 107 (38), 80 (13), 65 (7) (Found: M^+, 254.00014. $C_9H_7ClN_4OS$ requires *M*, 254.0029).

Method 2. To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (102 mg, 0.56 mmol) in EtOH (10 ml) at *ca.* 20 °C 1,4-diaminobenzene (30 mg, 0.28 mmol) was added in one portion and after 6 h pyridine (45 µl, 0.56 mmol) was added. After 1 h the volatiles were removed and flash chromatography (Et_2O) of the residue gave 3-(4-aminoanilino)-5-chloro-4*H*-1,2,6-thiadiazin-4-one **7a** (14 mg, 20%) identical to that prepared above.

3-Chloro-5-(2-hydroxyanilino)-4*H*-1,2,6-thiadiazin-4-one 8

To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (523 mg, 2.86 mmol) in EtOH (10 ml) at 20 °C 2-aminophenol (625 mg, 5.73 mmol) was added in one portion. The mixture was heated at reflux for 72 h and then cooled to *ca.* 20 °C. The volatiles were removed and flash chromatography (DCM–light petroleum, bp 60–80 °C) of the residue gave the *title compound* **8** (626 mg, 86%) as orange crystals, mp 230–231 °C (from MeOH) (Found: C, 42.2; H, 2.2; N, 16.1. $C_9H_6ClN_3O_2S$ requires C, 42.3; H, 2.4; N, 16.4%); ν_{max}(Nujol)/cm^{-1} 3400–3200br (Ar OH), 3346m (Ar NH), 3019w (Ar CH), 1607m, 1557w; δ_H(500 MHz; DMSO-d_6) 10.30 (1H, br, O*H*), 9.25 (1H, br, N*H*), 8.03 (1H, dd, *J* 1.4, 8.0 Hz, Ar *H*), 7.00–6.97 (1H, m, Ar *H*), 6.93 (1H, dd, *J* 1.5, 8.0 Hz, Ar *H*), 6.84 (1H, ddd, *J* 1.5, 7.8, 7.8 Hz, Ar *H*); δ_C(126 MHz; DMSO-d_6) 157.1, 149.6, 147.3, 140.4, 125.4, 124.7, 119.23, 119.20, 114.9; *m*/*z* (EI) 255 (M^+, 94%), 238 ($M^+ - OH$, 11), 220 ($M^+ - Cl$, 15), 173 (18), 166 (100), 146 (21), 134 (49), 120 (11), 93 ($CClNS^+$, 22).

4-Chloro-10-methyl-10*H*-[1,2,6]thiadiazino[3,4-*b*]quinoxaline 11

Method 1. To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (91 mg, 0.50 mmol) in EtOH (5 ml) at 0 °C *N*-methyl-1,2-diaminobenzene (115 µl, 1.01 mmol) was added in one portion. The mixture became brown and was allowed to warm to *ca.* 20 °C. After 5 h a black precipitate was formed, filtration of which gave the *title compound* **11** (83 mg, 70%) as purple needles, mp 207–216 °C (from EtOH) (Found: C, 48.15; H, 2.7; N, 22.25. $C_{10}H_7ClN_4S$ requires C, 48.0; H, 2.8; N, 22.4%); λ_{max}(DCM)/nm 269 (log ε 4.21), 280 inf (4.15), 291 inf (4.07), 322 (4.01), 335 inf (3.91), 367 (3.77), 386 (3.84), 407 (3.67), 496 inf (3.36), 530 inf (3.50), 556 (3.51), 606 inf (3.21); ν_{max}(Nujol)/cm^{-1} 3068w and 3019w (Ar CH), 1607w, 1586m, 1559w, 1516s, 1497m, 1336m, 1118m, 1050m, 1039m, 854m, 813m, 763m, 748s, 715m, 607s; δ_H(400 MHz; DMSO-d_6) 7.07 (1H, ddd, *J* 1.5, 7.6, 7.7 Hz, Ar *H*), 6.99 (1H, dd, *J* 1.5, 7.8 Hz, Ar *H*), 6.81 (1H, ddd, *J* 1.2, 7.6, 7.7 Hz, Ar *H*), 6.71 (1H, dd, *J* 1.1, 8.2 Hz, Ar *H*), 2.84 (3H, s, CH_3N); δ_C(100 MHz; DMSO-d_6) 149.2, 142.9, 139.1, 137.4, 135.8, 130.8 (Ar *C*H), 128.9 (Ar *C*H), 123.7 (Ar *C*H), 113.2 (Ar *C*H), 28.9 (*C*H_3N); *m*/*z* (EI) 250 (M^+, 100%), 235 ($M^+ - CH_3$, 36), 184 (13), 174 ($M^+ - C_2H_3ClN$, 14), 162 (12), 142 ($M^+ - C_2H_3ClNS$, 14), 129 (8), 113 (8), 102 (10), 90 (8), 77 (9), 70 (8) (Found: M^+, 250.0077. $C_{10}H_7ClN_4S$ requires *M*, 250.0080). Addition of a little water to the filtrate gave 5,11-dimethyl-5*H*,11*H*-quinoxalino[2,3-*b*]-quinoxaline **12** (20 mg, 15%) as a yellow–green precipitate, mp 235–242 °C (lit.,[7] 242 °C); ν_{max}(Nujol)/cm^{-1} 1679w, 1633w, 1600m, 1579s, 1549s, 1417m, 1343m, 1313m, 1300m, 1245m, 1111m, 743s; *m*/*z* (EI) 262 (M^+, 100%), 247 ($M^+ - CH_3$, 80), 232 [$M^+ - 2(CH_3)$, 17], 131 (M^{++}, 15), 124 (4), 102 (6), 90 (4), 77 (5).

Method 2. To a stirred solution of 4-chloro-10*H*-[1,2,6]-thiadiazino[3,4-*b*]quinoxaline **4a** (50 mg, 0.21 mmol) in DMSO (15 ml) at *ca.* 20 °C saturated aqueous NaOH (0.5 ml) was added. The mixture became green and iodomethane (0.5 ml) was added in one portion and the solution gradually became purple. After 6 h the mixture was diluted with DCM (50 ml), extracted with water (5 × 20 ml) and the organic fraction was dried, filtered and the volatiles were removed. Crystallisation of the residue gave the title compound **11** (50 mg, 95%) as purple needles, mp 207–216 °C (from EtOH), identical to that described above. If EtOH was used as solvent instead of DMSO then the same procedure gave *4-ethoxy-10-methyl-10H-[1,2,6]thiadiazino[3,4-b]quinoxaline* **13** (32 mg, 59%) as purple needles, mp 210–220 °C (from EtOH); λ_{max}(Nujol)/cm^{-1} 3140w and 3074w (Ar CH), 1626m, 1603s, 1585m, 1554s, 1505s, 1466s, 1407m, 1379s, 1363s, 1340s, 1314m, 1271m, 1194s, 1160m, 1118m, 1039s, 1037m, 925m, 913m, 751s, 721m, 635m; *m*/*z* (EI) 260 (M^+, 100%), 232 ($M^+ - C_2H_4$, 75), 217 ($M^+ - C_2H_3O$, 25), 203 (15), 189 (18), 170 (9), 162 (14), 143 (21), 129 (8), 113 (6), 102 (8), 90 ($C_6H_4N^+$, 9), 77 ($C_6H_5^+$, 5), 63 (4) (Found: M^+, 260.0734. $C_{12}H_{12}N_4OS$ requires *M*, 260.0731).

4-Chloro-5-cyano[1,2,6]thiadiazino[3′,4′:5,4]pyrrolo[1,2-*a*]-benzimidazole 14

Method 1 (see Table 1). To a stirred solution of (3,5-dichloro-4*H*-1,2,6-thiadiazin-4-ylidene)propanedinitrile **2** (51 mg, 0.22 mmol) in EtOH (5 ml) at *ca.* 20 °C 1,2-diaminobenzene (47.5 mg, 0.44 mmol) was added in one portion. After 12 h no starting material remained (TLC). The mixture was adsorbed onto silica and chromatography (DCM) gave 4-chloro-10*H*-[1,2,6]thiadiazino[3,4-*b*]quinoxaline **4a** (22 mg, 42%) as a purple solid, mp >310 °C (from EtOH), identical to that described above. Further elution (DCM) gave the *title compound* **14** (12 mg, 19%) as bright red needles or dark red prisms, mp 254–256 °C (from 1,2-dichloroethane) (Found: C, 50.3; H, 1.5; N, 24.35. $C_{12}H_4ClN_5S$ requires C, 50.5; H, 1.4; N,

24.6%); λ_{max}(DCM)/nm 235 (log ε 3.77), 267 (4.29), 285 inf (4.37), 289 (4.38), 295 inf (4.35), 343 inf (3.90), 356 (4.03), 423 (3.85), 450 inf (3.98), 475 (4.04), 503 inf (3.98), 539 inf (3.61); ν_{max}(Nujol)/cm^{-1} 3085w (Ar CH), 2230s (CN), 1618m, 1559s, 1531s, 1480m, 1451s, 1436s, 1413s, 1299m, 1218m, 1161s, 1131m, 941s, 825s, 792s, 766s, 750s, 737m, 646m, 623s; δ_H(400 MHz; DMSO-d_6) 8.09–8.05 (1H, m, Ar *H*), 7.97–7.93 (1H, m, Ar *H*), 7.60–7.54 (2H, m, Ar *H*); δ_C(100 MHz; DMSO-d_6) 152.8, 148.5, 142.8, 142.0, 128.1, 126.0 (Ar *C*H), 125.53 (Ar *C*H), 125.47, 121.0 (Ar *C*H), 112.5 (Ar *C*H), 112.3 (*C*N), 88.0 [=*C*(CN)]; *m*/*z* (EI) 285 (M^+, 100%), 250 ($M^+ - Cl$, 15), 239 ($M^+ - NS$, 3), 219 (14), 146 (6), 142 (6), 122 (9), 102 (9), 90 ($C_6H_4N^+$, 11), 76 ($C_6H_4^+$, 9), 63 (11), 57 (5) (Found: M^+, 284.9878. $C_{12}H_4ClN_5S$ requires *M*, 284.9876). Further elution (DCM–ether, 1:1) gave *4-(2-aminoanilino)-5-cyano[1,2,6]-thiadiazino[3′,4′:5,4]pyrrolo[1,2-a]benzimidazole* **15** (1 mg, 1%) as a red solid, mp >300 °C (from 1,2-dichloroethane) (Found: C, 60.5; H, 3.15; N, 27.55. $C_{18}H_{11}N_7S$ requires C, 60.5; H, 3.1; N, 27.45%); λ_{max}(DCM)/nm 262 (log ε 4.68), 280 (4.66), 301 inf (4.48), 353 inf (4.31), 495 inf (4.39), 525 (4.40), 563 inf (4.17); ν_{max}(Nujol)/cm^{-1} 3393w and 3316w (NH and NH_2), 3085w (Ar CH), 2215m (CN), 1621m, 1601m, 1555s, 1508s, 1455s, 1445s, 1414s, 1192m, 1170m, 832m, 756m, 741m, 668m, 600s; δ_H(400 MHz; DCM-d_2) 8.08–8.04 (1H, m, Ar *H*), 7.91–7.87 (1H, m, Ar *H*), 7.70 (1H, br s, N*H*), 7.52–7.45 (3H, m, Ar *H*), 7.19 (1H, ddd, *J* 1.4, 7.7, 7.7 Hz, Ar *H*), 6.93 (1H, dd, *J* 1.3, 8.0 Hz, Ar *H*), 6.88 (1H, ddd, *J* 1.2, 7.6, 7.6 Hz, Ar *H*), 3.89 (2H, br s, NH_2); δ_C(100 MHz; DMSO-d_6) 152.8, 149.5, 148.5, 143.6, 141.0, 128.2, 127.3 (Ar *C*H), 126.4 (Ar *C*H), 124.9 (Ar *C*H), 124.1 (Ar *C*H), 121.7, 120.3 (Ar *C*H), 118.3, 116.0 (Ar *C*H), 115.7 (Ar *C*H), 114.0 (*C*N), 112.1 (Ar *C*H), 82.8 [=*C*(CN)]; δ_C(100 MHz; DMSO-d_6 DEPT 135) 127.3 (Ar *C*H), 126.4 (Ar *C*H), 124.9 (Ar *C*H), 124.1 (Ar *C*H), 120.3 (Ar *C*H), 116.0 (Ar *C*H), 115.7 (Ar *C*H), 112.1 (Ar *C*H); *m*/*z* (EI) 357 (M^+, 100%), 341 ($M^+ - NH_2$, 49), 311 ($M^+ - NS$, 56), 284 ($M^+ - CHN_2S$, 49), 178.5 (M^{++}, 12), 162 (4), 107 (5), 91 (4), 80 (5), 69 (28) (Found: M^+, 357.0819. $C_{18}H_{11}N_7S$ requires *M*, 357.0797).

Method 2. To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (91 mg, 0.50 mmol) in EtOH (5 ml) at *ca.* 20 °C 2-benzimidazolylacetonitrile (78.5 mg, 0.50 mmol) was added in one portion. The mixture was refluxed at 80 °C for 12 h and only a trace of the title compound **14** was observed by TLC comparison with an authentic sample under several solvent systems.

4-(2-Aminoanilino)-5-cyano[1,2,6]thiadiazino[3′,4′:5,4]-pyrrolo[1,2-*a*]benzimidazole 15

To a stirred suspension of 4-chloro-5-cyano[1,2,6]thiadiazino-[3′,4′:5,4]pyrrolo[1,2-*a*]benzimidazole **14** (23 mg, 0.08 mmol) in EtOH (3 ml) 1,2-diaminobenzene (37 mg, 0.34 mmol) was added. The mixture was refluxed for 8 h, allowed to cool to *ca.* 20 °C and filtered to give a deep red precipitate, crystallisation of which gave the title compound **15** (24 mg, 83%) as deep red prisms, mp >300 °C (from 1,2-dichloroethane), identical to that described above.

3-(8-Aminonaphthalen-1-ylamino)-5-chloro-1,2,6-thiadiazin-4-one 19

To a stirred solution of 3,5-dichloro-4*H*-1,2,6-thiadiazin-4-one **1** (184 mg, 1.01 mmol) in DCM (10 ml) at 20 °C 1,8-diaminonaphthalene (317 mg, 2.01 mmol) was added in one portion. The mixture was heated at reflux for 18 h and then cooled to *ca.* 20 °C. The volatiles were removed and flash chromatography (DCM–light petroleum) of the residue gave the *title compound* **19** (134 mg, 46%) as brick-red needles, mp 219–220 °C decomp. (from ethyl acetate) (Found: C, 51.1; H, 2.9; N, 18.0. $C_{13}H_9ClN_4OS$ requires C, 51.2; H, 3.0; N, 18.4%); ν_{max}($CHCl_3$)/cm^{-1} 3357w and 3280m (Ar NH), 1631m (C=O), 1602m, 1555m, 1516m, 753m; δ_H(500 MHz; DMSO-d_6) 11.02–10.93 (1H, br, N*H*), 7.98–6.90 (6H, m, Ar *H*), 6.70–6.55 (2H, br, N*H*); δ_C(126 MHz; DMSO-d_6) 157.4, 146.0, 136.0, 135.0, 126.72, 126.66, 126.4, 125.6, 125.2, 123.1, 121.9, 116.5, 114.8; *m*/*z* (EI) 304 (M^+, 27%), 286 (49), 221 (43), 215 (51), 193 (25), 168 (44), 166 (100), 155 (28), 140 (36), 139 (27), 130 (23), 115 (24), 93 ($CClNS^+$, 22).

9-Chloro-8-cyano[1,2,6]thiadiazino[3′,4′:5,4]pyrrolo[1,2-*a*]-perimidine 20

To a stirred solution of (3,5-dichloro-4*H*-1,2,6-thiadiazin-4-ylidene)propanedinitrile **2** (57.5 mg, 0.25 mmol) in EtOH (4 ml) at *ca.* 20 °C 1,8-diaminonaphthalene (39.5 mg, 0.25 mmol) was added in one portion. After 12 h at *ca.* 20 °C filtration gave a black precipitate which on crystallisation gave the *title compound* **20** (68 mg, 81%) as deep green needles, mp >300 °C (from glacial acetic acid) (Found: C, 57.1; H, 2.1; N, 20.7. $C_{16}H_6ClN_5S$ requires C, 57.3; H, 1.8; N, 20.9%); λ_{max}(DCM)/nm 274 (log ε 4.84), 326 (4.00), 387 (4.35), 406 (4.37), 431 (3.94), 457 inf (3.86), 491 inf (3.60), 568 inf (3.60), 609 (3.75), 662 (3.77), 722 (3.54); ν_{max}(Nujol)/cm^{-1} 3103w and 3062w (Ar CH), 2231m (CN), 1653w, 1623s, 1583s, 1570s, 1527s, 1494s, 1455s, 1417s, 1387s, 1235s, 1221m, 1184m, 1166s, 1132s, 1124m, 1058m, 1005m, 904s, 827s, 801m, 793m, 770s, 708s, 663m, 622s; *m*/*z* (EI) 335 (M^+, 100%), 299 ($M^+ - HCl$, 29), 267 (6), 212 (5), 167.5 (M^{++}, 8), 162 (12), 151 (10), 140 (7), 113 (8), 91 (4), 69 (55) (Found: M^+, 335.0027. $C_{16}H_6ClN_5S$ requires *M*, 335.0032). The use of two equivalents of 1,8-diaminonaphthalene, under similar conditions, gave the title compound **20** in 96% yield.

4-Piperidino[1,2,6]thiadiazino[3,4-*b*][1,4]benzothiazine 21

To a solution of 4-chloro[1,2,6]thiadiazino[3,4-*b*][1,4]benzothiazine **4b** (126.5 mg, 0.50 mmol) in DCM (5 ml) at *ca.* 20 °C piperidine (99 µl, 1 mmol) was added in one portion. The mixture was refluxed for 1 h after which time TLC indicated a new product and no starting material. The mixture was diluted with DCM (20 ml), washed with water (3 × 5 ml) and the organic fraction was dried, filtered and the volatiles were removed. Crystallisation of the residue gave the *title compound* **21** (149 mg, 99%) as red prisms, mp 101–103 °C (from EtOH–water); λ_{max}(DCM)/nm 240 (log ε 4.24), 269 (3.93), 389 inf (4.14), 382 (3.82), 492 (3.90); ν_{max}(Nujol)/cm^{-1} 3030w (Ar CH), 1588m, 1558m, 1515s, 1505s, 1461s, 1435s, 1417m, 1370s, 1351m, 1299s, 1285s, 1275s, 1257m, 1237m, 1227m, 1203m, 1133m, 1125m, 1036m, 1026m, 968m, 955m, 916s, 883m, 855m, 815s, 804m, 790m, 760s, 739m, 721s, 625s, 601s; δ_H(300 MHz; DCM-d_2) 7.25–7.21 (1H, m, Ar *H*), 7.15–7.09 (2H, m, Ar *H*), 6.92–6.89 (1H, m, Ar *H*), 3.57 [4H, br s, 2(CH_2N)], 1.69 [6H, br s, 3(CH_2)]; δ_C(76 MHz; DCM-d_2) 149.3 (*C*=N), 144.4 (*C*=N), 139.9 (*C*=N), 135.7, 130.2 (Ar *C*H), 129.7, 128.2 (Ar *C*H), 127.5 (Ar *C*H), 125.4 (Ar *C*H), 48.0 (*C*H_2N), 25.7 (*C*H_2CH$_2$N), 24.8 (CH$_2$*C*H$_2$CH$_2$); *m*/*z* (EI) 302 (M^+, 41%), 267 (4), 236 (3), 220 (6), 186 (3), 161 (26), 134 (2), 108 (6), 84 ($C_5H_{10}N^+$, 100) (Found: M^+, 302.0650. $C_{14}H_{14}N_4S_2$ requires *M*, 302.0660).

Acknowledgements

We thank the EPSRC for a Research Studentship (P. A. K.), Professor D. J. Williams and Dr A. J. P. White for X-ray crystallography, Mr R. Sheppard for expert help with NMR spectroscopy, Dr M. A. Gray for the preparation of **4a** and **7a** and Dr M.-H. Wang for the preparation of **8** and **19**, MDL Information Systems (UK) Ltd for financial support and the Wolfson Foundation for establishing the Wolfson Centre for Organic Chemistry in Medical Science at Imperial College.

References

1 J. Geevers and W. P. Trompen, *Recl. Trav. Chim. Pays-Bas*, 1974, **93**, 270.
2 P. A. Koutentis and C. W. Rees, *J. Chem. Soc.*, *Perkin Trans. 1*, 2000, 1081.
3 P. A. Koutentis and C. W. Rees, *J. Chem. Soc.*, *Perkin Trans. 1*, 2000, 1089.
4 C. T. Seto, J. P. Mathias and G. M. Whitesides, *J. Am. Chem. Soc.*, 1993, **115**, 1321.
5 G. L. Stahl, R. Walter and C. W. Smith, *J. Org. Chem.*, 1978, **43**, 2285.
6 E. H. F. Escher, H. Robert and G. Guillemette, *Helv. Chim. Acta*, 1979, **62**, 1217.
7 W. Ried and D. P. Schäfer, *Chem. Ber.*, 1970, **103**, 2225; S. Hünig and H. Pütter, *Chem. Ber.*, 1977, **110**, 2532; E. Tauer and K.-H. Grellmann, *Chem. Ber.*, 1990, **123**, 1149.
8 A. J. P. White and D. J. Williams, unpublished work.
9 J. Dusemund and T. Schurreit, *Arch. Pharm.* (*Weinheim*, *Ger*.), 1986, **319**, 79.