Synthesis of bis[1,2]dithiolo[1,4]thiazine imines from Hünig's base

Stanislav A. Amelichev,[a] Susana Barriga,[b] Lidia S. Konstantinova,[a] Tatjana B. Markova,[a] Oleg A. Rakitin,[a] Charles W. Rees[c] and Tomás Torroba[d]

[a] *N. D. Zelinsky Institute of Organic Chemistry, Academy of Sciences, Leninsky Prospect, 47, 117913 Moscow, Russia*
[b] *Departamento de Química Orgánica, Facultad de Veterinaria, Universidad de Extremadura, 10071 Cáceres, Spain*
[c] *Department of Chemistry, Imperial College of Science, Technology and Medicine, London, UK SW7 2AY*
[d] *Departamento de Química, Facultad de Ciencias, Universidad de Burgos, 09001 Burgos, Spain*

Received (in Cambridge, UK) 14th June 2001, Accepted 2nd August 2001
First published as an Advance Article on the web 13th September 2001

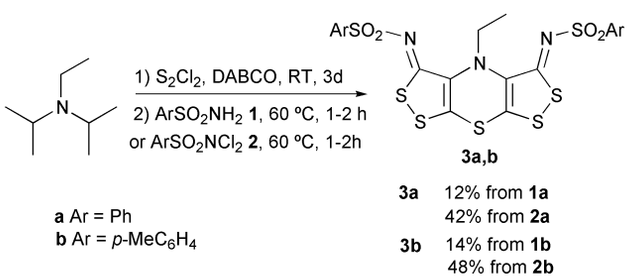
N-Ethyldiisopropylamine, S_2Cl_2 and DABCO in chloroform at room temperature form intermediate salts which react with nucleophiles to give tricyclic bis[1,2]dithiolo[1,4]thiazine derivatives. The reactions of some representative amino compounds as the nucleophiles are now described. With arenesulfonamides **1a**,**b** and their *N*,*N*-dichloro derivatives **2a**,**b**, the *N*,*N*′-bis(arylsulfonyl)dithiolothiazinediimines **3a**,**b** are formed in modest yields. With toluene-*p*-sulfonohydrazide and aniline the more complex reactions give only the monohydrazone **7** and the bicyclic anilino derivative **8**, respectively, in very low yields. The diimines **3a**,**b** are also produced, in better yield, from the bis(1,2-dithiole-3-thione) **4** with chloramine B and T; similarly the analogous monothione **12** gives the monoimines **13a**,**b**. The reaction rates and yields (up to 93%) in the conversion of **12** to **13** are greatly increased by scandium triflate. Possible reaction mechanisms are considered.

Introduction

We have recently reported the striking one-pot conversion of *N*-alkyldiisopropylamines into bis[1,2]dithiolo[1,4]thiazinedithiones and bis[1,2]dithiolopyrroledithiones by the action of disulfur dichloride (S_2Cl_2).[1–3] We also found that the addition of oxygen donors to the reaction permitted the preparation of ketothione and diketo derivatives of these heterocycles by interception of the expected reaction intermediates by the oxygen nucleophiles. We considered that this three-component reaction could provide a versatile preparation of complex heterocyclic systems from readily available tertiary amines and commercial reagents, by the careful selection of reaction components and conditions.[4–8] In this paper we report the one-pot preparation of mono- and diimine derivatives of bisdithiolothiazines from *N*-ethyldiisopropylamine (Hünig's base), disulfur dichloride and sulfonamides, as a new example of this useful multicomponent reaction.

Results and discussion

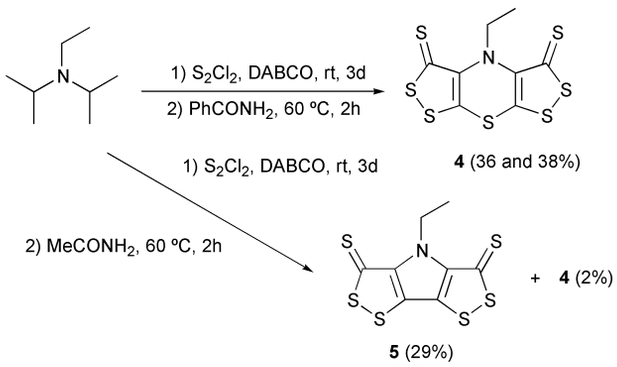
In a typical experiment, we stirred Hünig's base (1 equiv.), 1,4-diazabicyclo[2.2.2]octane (DABCO) (7 equiv.) and S_2Cl_2 (10 equiv.) for 3 d at rt in chloroform, then added a primary amide or amine (10 equiv.) and stirred again for 1–2 h at 60 °C before chromatography of the reaction mixture. The outcome depended critically upon on the nature of the amide or amine used as the last component. Thus, the reaction of Hünig's base, S_2Cl_2, DABCO and benzene- (**1a**) or toluene-*p*-sulfonamide (**1b**) under these conditions gave products **3a**, a yellow solid, mp 203–205 °C (12%) and **3b**, a yellow solid, mp 213–214 °C (14%), characterised by the usual spectroscopic and analytical techniques (Scheme 1). Both compounds showed in their ^{1}H-NMR spectra two equivalent aryl rings and one ethyl group, confirmed by the number of aromatic and aliphatic signals in the ^{13}C-NMR spectra. Mass spectra (FAB$^+$) and microanalyses also confirmed the symmetrical *N*,*N*′-bis(phenylsulfonyl)- or



Scheme 1

N,*N*′-bis(*p*-tolylsulfonyl)-bis[1,2]dithiolo[1,4]thiazine-3,5-diimine structures assigned to **3a**,**b**. Much better yields of **3a**,**b** (42 and 48%) were obtained by using the *N*,*N*-dichloroarenesulfonamides **2**. *N*,*N*-Dichlorosulfonamides have been used in reactions with preformed monocyclic 1,2-dithiolium salts to give analogous iminodithioles.[9]

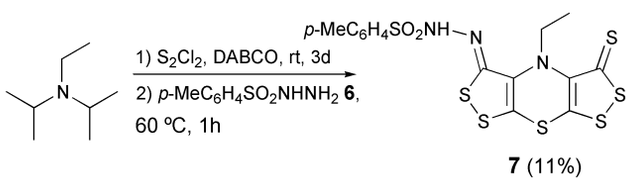
However, the reaction of Hünig's base, S_2Cl_2, DABCO and carboxamides under the same conditions did not give similar results. With benzamide we obtained bis[1,2]dithiolo[1,4]-thiazine-3,5-dithione **4**[3] (36 and 38%) as the only product and with acetamide, we obtained bis[1,2]dithiolopyrrole-3,5-dithione **5**[3] (29%) as the major product together with only a minor amount of **4** (2%) (Scheme 2). Compounds **4** and **5** were identical with authentic specimens obtained by previously reported methods.[1–3] Benzamide has played little or no part in the reaction; the yield of **4** was reproducible and very similar to that obtained without benzamide. Acetamide, however, does alter the reaction pathway; it causes loss of sulfur to give the fused pyrrole **5** as the major product. Pyrrole **5** is not seen in the benzamide reaction. Control experiments (TLC) showed that treatment of **4** with acetamide (or benzamide) in boiling chloroform for 2 h gave no reaction; thus, the influence of acetamide presumably depends on its reaction with S_2Cl_2 and DABCO, possibly to generate a reactive species which reduces an intermediate salt to pyrrole **5** in competition with cyclisation to give



Scheme 2

thiazine **4**. Other control experiments (TLC) showed that acetamide was more reactive towards S_2Cl_2 on treatment of the amides (1 mmol) with S_2Cl_2 (10 mmol) and DABCO (10 mmol) in chloroform at room temperature. The contrast between the sulfonamides and the carboxamides is also striking; the former, but not the latter, react with the intermediate dithiolium salt to become incorporated into the product. This suggests that the sulfonamides may be reacting through the small equilibrium amount of their anions generated by DABCO.

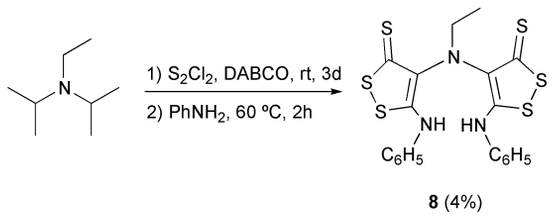
We then performed the reaction of Hünig's base, S_2Cl_2, DABCO with toluene-*p*-sulfonohydrazide **6** under the same conditions and obtained a low yield of compound **7** as yellow crystals, mp 178–180 °C (11%) (Scheme 3). Mass spectrometry,



Scheme 3

HRMS and microanalysis gave a molecular formula $C_{15}H_{13}N_3O_2S_7$ for **7**, indicating the formation of the monohydrazone derivative of the dithione. The ^{1}H-NMR spectrum showed one ethyl and one methyl group together with two pairs of aromatic protons. The ^{13}C-NMR spectrum showed a thiocarbonyl group at δ 201 (supported by IR), five other sp^2-tertiary carbon atoms and the aryl ring and the ethyl group signals in accord with the unsymmetrical structure 4-ethyl-3-thioxobis[1,2]dithiolo[3,4-*b*:4′,3′-*e*][1,4]thiazin-5-one [*N*-(*p*-tolylsulfonyl)]hydrazone **7**.

An even more unexpected result was obtained in the reaction of Hünig's base, S_2Cl_2, DABCO and aniline under the same reaction conditions. In this case, after chromatography of the complex reaction mixture we obtained yellow crystals, mp 214–216 °C, in very low yield (4%) (Scheme 4), for which mass



Scheme 4

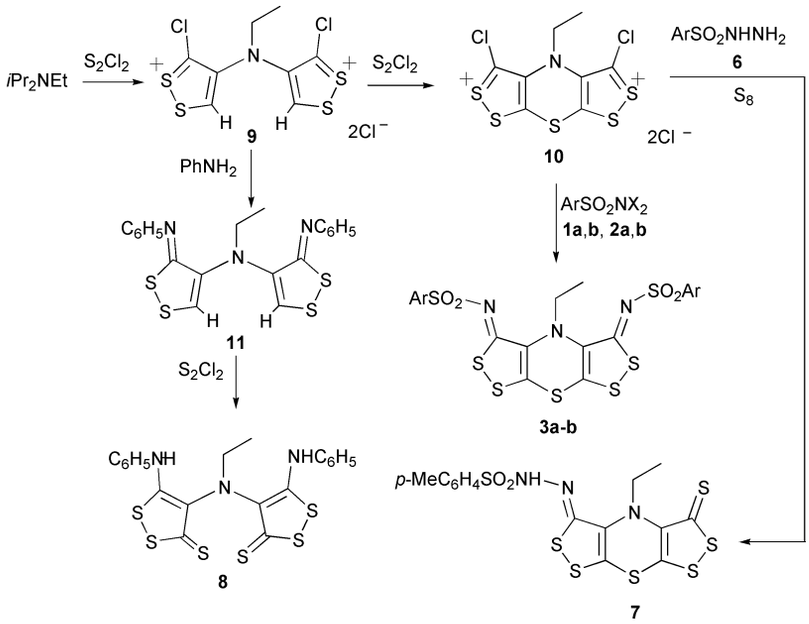
spectrometry, HRMS and microanalysis gave the molecular formula $C_{20}H_{17}N_3S_6$. The ^{1}H-NMR spectrum showed one ethyl group, two identical phenyl and NH groups. The ^{13}C-NMR spectrum showed a thiocarbonyl signal at δ 195 (supported by IR) and two other sp^2-tertiary carbon atoms together with the phenyl and the ethyl group signals. All spectral data pointed to a symmetrical structure, tentatively assigned as *N*,*N*-bis(5-phenylamino-3-thioxo-1,2-dithiol-4-yl)ethylamine **8**. Addition of the much less nucleophilic *p*-nitroaniline in place of aniline resulted in very little reaction, and the nitroaniline was largely recovered.

These results can be rationalised by considering the most likely intermediates, the 1,2-dithiolium salts **9** and **10**, which have been proposed before.[1,3] These intermediates are expected to react readily with the nucleophiles added or formed in the last stage of the reaction (Scheme 5). Thus, intermediate **9** could be intercepted by aniline to form the diimine **11**, which could react with S_2Cl_2 to give the dithione **8**. Intermediate **9** is likely to be rapidly converted into the more stable tricyclic intermediate **10** (Scheme 5) thus explaining the very low yield of the bicyclic product **8**. Reaction of **10** with sulfonamides **1a**,**b** and (in combination with sulfur or some nucleophilic sulfur species) with **2a**,**b** could explain the formation of products **3a**,**b** and **7**.

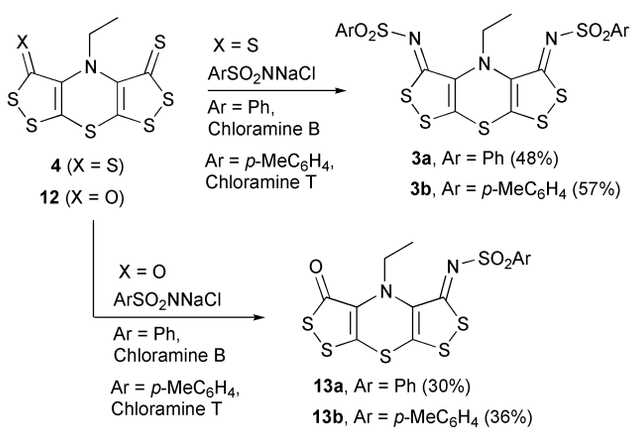
Searching for a better yield of the anilino derivative **8**, we performed the reaction of Hünig's base (1 equiv.), S_2Cl_2 (10 equiv.) and aniline (10 equiv.) with less DABCO (5 equiv.), conditions which favour the formation of more chlorinated intermediates,[7] but we obtained only traces of **8**. Furthermore, *N*,*N*-bis(5-chloro-3-oxo-1,2-dithiol-4-yl)ethylamine[7] did not react with aniline in refluxing chloroform, suggesting that a more plausible route to **8** is trapping of the more reactive intermediate 1,2-dithiolium salt **9** by aniline before the sulfuration step.

Further confirmation of the structures of **3a**,**b** was obtained by their independent synthesis from the preformed tricyclic dithione **4** (Scheme 6). The reaction of monocyclic 1,2-dithiole-3-thiones with nitrenes or nitrene precursors is known,[10] including their reactions with chloramine B and T.[11] Treatment of bis[1,2]dithiolo[1,4]thiazine-3,5-dithione **4** (1 equiv.) with chloramine B or T (10 equiv.) and acetic acid in refluxing benzene for 1.5 h gave **3a**,**b** (48 and 57%) respectively (Scheme 6). These yields are considerably higher than those from the reaction of Hünig's base with S_2Cl_2 and the sulfonamide, but are comparable with the yields (42 and 48%) from the *N*,*N*-dichlorosulfonamide **2a**,**b** reactions (Scheme 1). The products from both sources gave superimposable IR, ^{1}H- and ^{13}C-NMR and mass spectra. A similar reaction of chloramine B or T (10 equiv.) with 3-oxo-bis[1,2]dithiolo[1,4]thiazine-5-thione **12**[3] (1 equiv.) and acetic acid in refluxing benzene for 1.5 h gave the *N*-arylsulfonyl imines **13a**,**b** (30 and 36%) respectively (Scheme 6), which were characterised by standard spectroscopic and analytical techniques. Only the thione, and not the keto group, had reacted. Compounds **13a**,**b** were not isolated from the Hünig's base reactions already described and, at present, these chloramine B and T reactions provide the only route to the unsymmetrical compounds **13a**,**b**. The relatively high yielding reactions of chloramine B and T with thiones **4** and **12** probably involve chlorination of the thione sulfur followed by nucleophilic attack by the sulfonamide anion. It seemed possible that these reactions could be catalysed by Lewis acids and so we investigated the influence of scandium triflate on the reactions of **12**. The reaction rate and the yields were dramatically increased. Treatment of **12** with chloramine T in the presence of scandium triflate (25 mol%), in DCM at room temperature for 7 minutes, gave the sulfonyl imine **13b** in 93% yield. (The effect of more or less catalyst is shown in Table 3.) The same reaction with only 5 mol% catalyst in DCM at room temperature overnight also gave a high yield of **13b** (80%). Similarly the reaction of chloramine B with **12** and scandium triflate (50 mol%) gave the analogous product **13a** in 73% yield in 10 minutes.

The scandium triflate reactions clearly provide an excellent route to the imino derivatives of the bisdithiolothiazine ring system which are now readily available from Hünig's base in two steps *via* the fused dithiolothiones. By analogy with earlier work,[5] these reactions can reasonably be expected to extend to other *N*-substituted diisopropylamines. The scope of the



Scheme 5



Scheme 6

catalysed reaction has not yet been determined but even the lower yielding thermal processes are synthetically useful, given the simplicity of the one-pot procedure and the ready availability of the cheap starting materials.

Experimental

Melting points were determined on a Köfler hot-stage apparatus and are uncorrected. IR spectra were recorded on a Perkin-Elmer 298 instrument in KBr pellets. ^{1}H-NMR and ^{13}C-NMR spectra were recorded on a Bruker DRX 400. CH_3, CH_2 and CH groups were identified by DEPT experiments. *J*-values are given in Hz. Mass spectra were recorded on VG7070E and VG-AutoSpec instruments using electron impact or FAB ionisation. Light petroleum refers to the fraction with bp 40–60 °C.

Preparation of bis[1,2]dithiolo[1,4]thiazine imines from Hünig's base

Disulfur dichloride (2.0 ml, 25 mmol) was added dropwise at −15–−20 °C to a stirred solution of *N*-ethyldiisopropylamine **1** (0.44 ml, 2.5 mmol) and DABCO (1.96 g, 17.5 mmol) dissolved in chloroform (100 ml). Then the mixture was stirred at −20 °C for 15 min and at room temperature for 72 h. Then the amine derivative (25 mmol) was added, the mixture was refluxed for the time given in Table 1, filtered and the solvent was removed under reduced pressure. The residue was separated by column chromatography (silica gel Merck 60, light petroleum, and then light petroleum–CH_2Cl_2 mixtures). Reaction details and product yields are given in Table 1.

Table 1 Preparation of bisdithiolothiazines from *N*-ethyldiisopropylamine and S_2Cl_2; reaction conditions for the second stage

Reagent	Reaction time/h	Product (yield, %)
$PhSO_2NH_2$	2	**3a** (12)
$PhSO_2NCl_2$	1	**3a** (42)
4-$MeC_6H_4SO_2NH_2$	1	**3b** (14)
4-$MeC_6H_4SO_2NCl_2$	1	**3b** (48)
4-$MeC_6H_4SO_2NHNH_2$	1	**7** (11)
$PhNH_2$	2	**8** (4)
4-$H_2NC_6H_4NO_2$	2	—
$PhCONH_2$	2	**4**[3] (36 and 38)
$MeCONH_2$	2	**5**[3] (29) + **4** (2)

Reaction of bisdithiolothiazinethiones 4 and 12 with chloramines B and T

Acetic acid (0.15 ml, 5 drops) was added dropwise to a stirred mixture of 4-ethylbis[1,2]dithiolo[3,4-*b*:4′,3′-*e*][1,4]thiazine-3,5-dithione **4**[3] (0.15 mmol) or 4-ethyl-3-oxobis[1,2]dithiolo[3,4-*b*:4′, 3′-*e*][1,4]thiazine-5-thione **12**[3] (0.3 mmol) and chloramine B or T (1.5 mmol) in benzene (20 ml). The mixture was refluxed for 1.5 h, filtered and the solvent was removed under reduced pressure. The residue was separated by column chromatography (silica gel Merck 60, light petroleum, and then light petroleum–CH_2Cl_2 mixtures). Reaction details and product yields are given in Table 2.

Reaction of bisdithiolothiazinethione 12 with chloramines B and T in the presence of scandium triflate

A mixture of 4-ethyl-3-oxobis[1,2]dithiolo[3,4-*b*:4′,3′-*e*][1,4]-thiazine-5-thione **12**[3] (0.3 mmol), chloramine B or T (0.6 mmol) and scandium triflate (see Table 3) in benzene (20 ml) was stirred at room temperature for the time given in Table 3, filtered and the solvent was removed under reduced pressure. The residue was separated by column chromatography (silica gel Merck 60, light petroleum, and then light petroleum–CH_2Cl_2 mixtures). Reaction details and product yields are given in Table 3.

***N*,*N*′-Bis(phenylsulfonyl)-4-ethyl-3*H*,4*H*,5*H*-bis[1,2]dithiolo-[3,4-*b*:4′,3′-*e*][1,4]thiazine-3,5-diimine 3a.** Orange crystals (from light petroleum–$CHCl_3$), mp 203–205 °C (Found

Table 2 Reaction of bisdithiolothiazinethiones **4** and **12** with chloramines B and T

Starting material	Reagent	Product (yield, %)
4	Chloramine B	**3a** (48)
4	Chloramine T	**3b** (57)
12	Chloramine B	**13a** (30)
12	Chloramine T	**13b** (36)

Table 3 Reaction of bisdithiolothiazinethione **12** with chloramines B and T in the presence of scandium triflate

Reagent	Mol% $Sc(OTf)_3$	Reaction time	Product (yield, %)
Chloramine B	50	15 min	**13a** (73)
Chloramine T	1	15 min	**13b** (48)
Chloramine T	5	12 min	**13b** (52)
Chloramine T	5	12 hours	**13b** (80)
Chloramine T	10	10 min	**13b** (80)
Chloramine T	25	7 min	**13b** (93)
Chloramine T	50	5 min	**13b** (89)
Chloramine T	100	5 min	**13b** (85)

$M^+ + 1$, 585.9191. $C_{20}H_{16}N_3O_4S_7$ requires *M*, 585.9186) (Found: C, 41.1; H, 2.6; N, 7.1. $C_{20}H_{15}N_3O_4S_7$ requires C, 41.0; H, 2.6; N, 7.2%); δ_H ($CDCl_3$) 1.12 (3H, t, *J* 7.2, CH_3), 3.75 (2H, q, *J* 7.2, CH_2), 7.46 (4H, m, Ph), 7.56 (2H, m, Ph), 7.90 (4H, m, Ph); δ_C ($CDCl_3$) 168.56, 148.29, 140.08 and 139.86 (4 × sp^2-tertiary C), 133.16, 128.98 and 126.74 (3 C–H), 44.54 (CH_2), 14.27 (CH_3); ν_{max}/cm^{-1} 1480, 1430, 1300, 1240, 1080, 970, 880, 770, 740; *m*/*z* 586 ($M^+ + 1$, 11%), 551 (2), 533 (3), 516 (3), 401 (2), 290 (7), 207 (9), 152 (22), 135 (23), 123 (31), 105 (32), 95 (51), 77 (56), 69 (78), 55 (100); *m*/*z* (FAB^+) 586 ($M^+ + 1$, 53%).

***N*,*N*′-Bis(*p*-tolylsulfonyl)-4-ethyl-3*H*,4*H*,5*H*-bis[1,2]dithiolo-[3,4-*b*:4′,3′-*e*][1,4]thiazine-3,5-diimine 3b.** Orange crystals (from light petroleum–$CHCl_3$), mp 213–214 °C (Found $M^+ + 1$, 613.9522. $C_{22}H_{20}N_3O_4S_7$ requires *M*, 613.9499) (Found: C, 43.2; H, 3.1; N, 6.7. $C_{22}H_{19}N_3O_4S_7$ requires C, 43.1; H, 3.1; N, 6.8%); δ_H ($CDCl_3$) 1.13 (3H, m, CH_3), 2.43 (6H, s, $2CH_3$), 3.75 (2H, br s, CH_2), 7.29 (4H, m, Ph), 7.76 (4H, m, Ph); δ_C ($CDCl_3$) 168.27, 148.00, 144.09, 140.11 and 136.94 (5 × sp^2-tertiary C), 129.71 and 126.91 (2 C–H), 44.59 (CH_2), 21.76 and 14.38 (2 × CH_3); ν_{max}/cm^{-1} 1490, 1280, 1140, 1080, 750; *m*/*z* 614 ($M^+ + 1$, 15%), 447 (3), 290 (2), 165 (7), 123 (20), 95 (45), 69 (80), 55 (100).

4-Ethyl-3-thioxo-3*H*,4*H*,5*H*-bis[1,2]dithiolo[3,4-*b*:4′,3′-*e*]-[1,4]thiazin-5-one [*N*-(*p*-tolylsulfonyl)]hydrazone 7. Orange crystals (from light petroleum–$CHCl_3$), mp 178–180 °C (Found $M^+ + 1$, 491.9143. $C_{15}H_{14}N_3O_2S_7$ requires *M*, 491.9131) (Found: C, 36.7; H, 2.8; N, 8.5. $C_{22}H_{19}N_3O_4S_7$ requires C, 36.6; H, 2.7; N, 8.55%); δ_H ($CDCl_3$) 1.33 (3H, t, *J* 6.9, CH_3), 2.43 (3H, s, CH_3), 4.12 (2H, q, *J* 6.9, CH_2), 7.33 (2H, d, *J* 7.5, Ar), 7.87 (2H, d, *J* 7.6, Ar); δ_C ($CDCl_3$) 201.96 (C=S), 157.03, 156.77, 148.61, 144.79, 136.61, 135.98 and 133.90 (7 × sp^2-tertiary C), 129.75 and 128.69 (2 C–H), 43.23 (CH_2), 21.75 and 14.68 (2 × CH_3); ν_{max}/cm^{-1} 3150 (NH), 1560, 1510, 1480, 1340, 1300 (C=S), 1170, 1080, 1040; *m*/*z* 492 ($M^+ + 1$, 15%), 281 (6), 207 (11), 147 (26), 120 (28), 105 (31), 91 (56), 73 (81), 55 (100).

***N*,*N*-Bis(5-phenylamino-3-thioxo-1,2-dithiol-4-yl)ethylamine 8 (tentative structure).** Yellow crystals (from light petroleum–$CHCl_3$), mp 214–216 °C (Found M^+, 490.9767. $C_{20}H_{17}N_3S_6$ requires *M*, 490.9747) (Found: C, 48.7; H, 3.5; N, 8.5. $C_{20}H_{17}N_3S_6$ requires C, 48.8; H, 3.5; N, 8.55%); δ_H ($CDCl_3$) 1.23 (3H, t, *J* 7.1, CH_3), 3.24 (1H, m, ½CH_2), 4.46 (1H, m, ½CH_2), 7.30 (2H, m, Ph), 7.44 (8H, m, Ph), 11.29 (2H, br s, 2NH); δ_C ($CDCl_3$) 195.62 (C=S), 174.81, 137.82 and 131.24 (3 × sp^2-tertiary C), 129.90, 127.35 and 122.57 (3 × C–H), 44.22 (CH_2), 14.57 (CH_3); ν_{max}/cm^{-1} 3090, 2970 and 2940 (NH), 1590, 1540, 1420, 1370, 1320 (C=S), 1200, 980; *m*/*z* 491 (M^+, 31%), 458 (59), 428 (21), 365 (29), 251 (31), 233 (33), 192 (21), 160 (23), 135 (17), 104 (15), 89 (30), 77 (80), 45 (100).

***N*-Phenylsulfonyl-4-ethyl-3-oxo-3*H*,4*H*,5*H*-bis[1,2]dithiolo-[3,4-*b*:4′,3′-*e*][1,4]thiazin-5-imine 13a.** Orange crystals (from light petroleum–$CHCl_3$), mp 189–190 °C (Found M^+, 445.9025. $C_{14}H_{10}N_2O_3S_6$ requires *M*, 445.9016) (Found: C, 37.7; H, 2.2; N, 6.2. $C_{14}H_{10}N_2O_3S_6$ requires C, 37.7; H, 2.3; N, 6.3%); δ_H ($CDCl_3$) 1.22 (3H, t, *J* 7.1, CH_3), 3.77 (2H, q, *J* 7.1, CH_2), 7.51 (2H, dt, *J* 8.6, *J* 1.0 Ph), 7.58 (1H, t, *J* 6.6, Ph), 7.96 (2H, dd, *J* 8.6, *J* 1.0, Ph); δ_C ($CDCl_3$) 182.27 (C=O), 168.34, 147.57, 147.30, 139.89, 139.66 and 137.27 (6 × sp^2-tertiary C), 133.06, 129.09 and 126.97 (3 × C–H), 43.65 (CH_2), 14.42 (CH_3); ν_{max}/cm^{-1} 1650 (C=O), 1510, 1450, 1300, 1080, 820, 740; *m*/*z* 446 (M^+, 15%), 414 (100), 350 (44), 305 (89), 273 (100), 245 (62), 209 (36), 181 (27), 141 (77).

***N*-(*p*-Tolylsulfonyl)-4-ethyl-3-oxo-3*H*,4*H*,5*H*-bis[1,2]di-thiolo[3,4-*b*:4′,3′-*e*][1,4]thiazin-5-imine 13b.** Orange crystals (from light petroleum–$CHCl_3$), mp 164–165 °C (Found M^+, 459.9169. $C_{15}H_{12}N_2O_3S_6$ requires *M*, 459.9172) (Found: C, 39.4; H, 2.6; N, 5.9. $C_{15}H_{12}N_2O_3S_6$ requires C, 39.1; H, 2.6; N, 6.1%); δ_H ($CDCl_3$) 1.23 (3H, t, *J* 7.2, CH_3), 2.43 (3H, s, CH_3), 3.77 (2H, q, *J* 7.2, CH_2), 7.32 (2H, d, *J* 8.2, Ph), 7.86 (2H, d, *J* 8.2, Ph); δ_C ($CDCl_3$) 182.22 (C=O), 167.91, 147.57, 147.14, 144.23, 139.48, 137.18 and 136.81 (7 × sp^2-tertiary C), 129.62 and 126.95 (2 × C–H), 43.55 (CH_2), 21.60 and 14.34 (2 × CH_3); ν_{max}/cm^{-1} 1660 (C=O), 1520, 1460, 1300, 1280, 1140, 1080, 1030, 880; *m*/*z* 460 (M^+, 1%), 428 (8), 364 (8), 305 (17), 155 (37), 91 (100).

Acknowledgements

We gratefully acknowledge financial support from the Dirección General de Enseñanza Superior of Spain (grant no. FP97–08858491), the Junta de Castilla y León, Consejería de Educación y Cultura, y Fondo Social Europeo (Project ref. BU07/00B), the Russian Foundation for Basic Research (grant no. 99–03–32984a and no. 01–03–061967), the Royal Society, an RSC Journals Grant to O.A.R., MDL Information Systems (UK) Ltd, and we thank the Wolfson Foundation for establishing the Wolfson Centre for Organic Chemistry in Medical Science at Imperial College.

References

1 C. F. Marcos, C. Polo, O. A. Rakitin, C. W. Rees and T. Torroba, *Angew. Chem., Int. Ed. Engl.*, 1997, **36**, 281.
2 C. F. Marcos, C. Polo, O. A. Rakitin, C. W. Rees and T. Torroba, *Chem. Commun.*, 1997, 879.
3 C. W. Rees, A. J. P. White, D. J. Williams, O. A. Rakitin, C. F. Marcos, C. Polo and T. Torroba, *J. Org. Chem.*, 1998, **63**, 2189.
4 C. F. Marcos, O. A. Rakitin, C. W. Rees, L. I. Souvorova, T. Torroba, A. J. P. White and D. J. Williams, *Chem. Commun.*, 1998, 453.
5 C. W. Rees, A. J. P. White, D. J. Williams, O. A. Rakitin, C. F. Marcos and T. Torroba, *J. Org. Chem.*, 1999, **64**, 5010.
6 C. F. Marcos, O. A. Rakitin, C. W. Rees, T. Torroba, A. J. P. White and D. J. Williams, *Chem. Commun.*, 1999, 29.
7 S. Barriga, L. S. Konstantinova, C. F. Marcos, O. A. Rakitin, C. W. Rees, T. Torroba, A. J. P. White and D. J. Williams, *J. Chem. Soc., Perkin Trans. 1*, 1999, 2237.
8 L. S. Konstantinova, N. V. Obruchnikova, O. A. Rakitin, C. W. Rees and T. Torroba, *J. Chem. Soc., Perkin Trans. 1*, 2000, 3421.
9 F. Boberg and R. Wiedermann, *Liebigs Ann. Chem.*, 1969, **728**, 36.
10 (*a*) D. M. McKinnon, in *Comprehensive Heterocyclic Chemistry*, ed. A. R. Katritzky and C. W. Rees, Pergamon, Oxford, 1984, vol. 4, ch. 31, p. 783; (*b*) D. M. McKinnon, in *Comprehensive Heterocyclic Chemistry II*, ed. A. R. Katritzky, C. W. Rees and E. F. V. Scriven, Elsevier, Oxford, 1996, vol. 3, ch. 3.11, p. 569.
11 S. Tamagaki and S. Oae, *Tetrahedron Lett.*, 1972, 1159.