A Convenient General Method for the Synthesis of Pyrrole-2,5-dicarbaldehydes

Silvano Cadamuro, Iacopo Degani, Rita Fochi, Antonella Gatti and Laura Piscopo
Istituto di Chimica Organica dell' Università, Via P. Giuria 7, I-10125 Torino, Italy

A new general method for the synthesis of pyrrole-2,5-dicarbaldehyde and its 3-mono- and 3,4-disubstituted derivatives is reported. It involves the intermediate formation of the corresponding 2,5-bis(1,3-benzodithiol-2-yl)pyrroles followed by hydrolysis with HgO–35% aq. HBF_4–DMSO. Pyrrole-2,5-dicarbaldehyde was obtained in overall yields of 43–65%, whilst that of the derivatives was 32–90%. Moreover the methylation of the corresponding dithiolic intermediate with further hydrolysis resulted in the formation of 1-methylpyrrole-2,5-dicarbaldehyde in 90% overall yield.

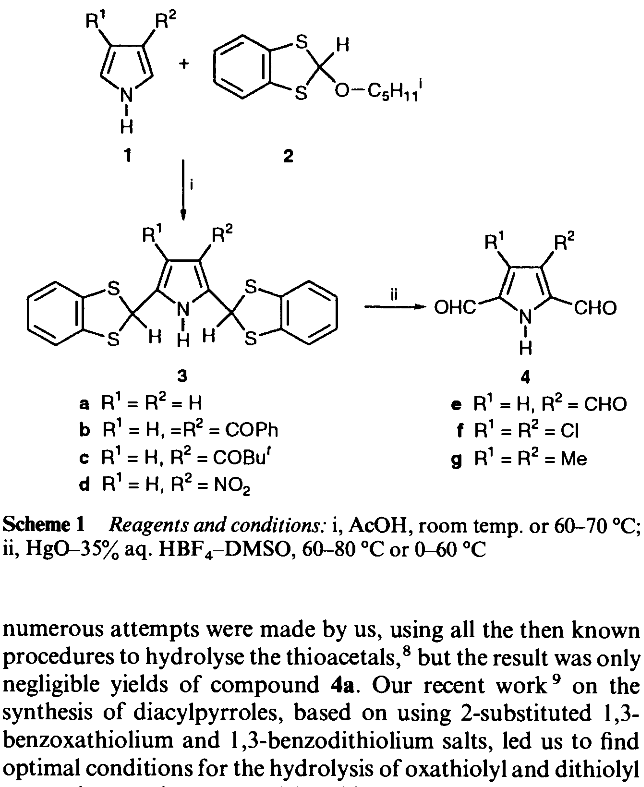
Pyrrole-2,5-dicarbaldehyde **4** ($R^1 = R^2 = H$) and its derivatives bearing various groups at the 1 and/or 3 and 4 positions are irreplaceable intermediates utilized, mainly in recent years, for the synthesis of biologically active compounds,[1] organic conductors[2] and several macrocycles.[1a,3] The greatest difficulty in synthesizing these intermediates lies in the known impossibility of introducing two formyl groups, one after the other, at positions 2 and 5 of the pyrrole. In fact, the first formyl group, introduced at position 2, not only deactivates the next formylation, but also predominantly directs it to position 4, instead of to position 5. Thus, the Vilsmeier–Haack method for the formylation of pyrrole leads to only 0.3% yield of pyrrole-2,5-dicarbaldehyde.[3d]

In an effort to overcome this difficulty two different synthetic approaches have been proposed. The first proposal is a multistep approach: (*i*) preparation of the pyrrole-2-carbaldehydes; (*ii*) conversion of the formyl group into an appropriately masked formyl group able to orientate the attack of a successive formylation at position 5; (*iii*) formylation at position 5; (*iv*) deprotection of the masked formyl group situated at position 2. The various procedures outlined in this synthetic scheme have led to 11–38% yields of pyrrole-2,5-dicarbaldehyde[3d,4] and comparable yields of its derivatives.[3a,5]

The second approach is simpler in that it involves only two steps: (*i*) reaction of the pyrrole with reagents able to supply 2,5-disubstituted pyrroles, where the introduced substituents are masked formyl groups; (*ii*) conversion of the introduced groups into formyl groups. The only known example that can be considered as following this approach is the synthesis of pyrrole-2,5-dicarbaldehyde obtained by allowing the pyrrole to react with benzimidazole in Ac_2O, followed by hydrolysis of the 2,5-bis(1,3-diacetyl-1,2-dihydrobenzimidazol-2-yl)pyrrole intermediate.[6] It was thought that such a procedure could be generalized for the synthesis of more complex pyrrole-2,5-dicarbaldehydes. In reality, when the method was applied by other authors[4c] to the synthesis of the pyrrole-2,5-dicarbaldehyde the yield was 10% instead of the 38% reported in the original work. Attempts to extend it to the synthesis of the 3-methylpyrrole-2,5-dicarbaldehyde resulted in only 6% yield.[1c]

Herein, we report a new procedure of general validity for the synthesis of pyrrole-2,5-dicarbaldehydes, in line with the second approach and based on Scheme 1.

In connection with this route, in the past a high yield (90%) synthesis of 2,5-bis(1,3-benzodithiol-2-yl)pyrrole **3a** by the simple reaction of pyrrole with 2-isopentyloxy-1,3-benzodithiole **2** in AcOH was reported.[7] It was hypothesized that by using **3a** as the starting compound, pyrrole-2,5-dicarbaldehyde **4a** could easily be obtained by hydrolysis. On the contrary,



Scheme 1 *Reagents and conditions:* i, AcOH, room temp. or 60–70 °C; ii, HgO–35% aq. HBF_4–DMSO, 60–80 °C or 0–60 °C

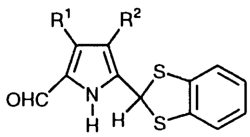
numerous attempts were made by us, using all the then known procedures to hydrolyse the thioacetals,[8] but the result was only negligible yields of compound **4a**. Our recent work[9] on the synthesis of diacylpyrroles, based on using 2-substituted 1,3-benzoxathiolium and 1,3-benzodithiolium salts, led us to find optimal conditions for the hydrolysis of oxathiolyl and dithiolyl groups in pyrrole systems. After this experience we again faced, following Scheme 1, the problem of obtaining pyrrole-2,5-dicarbaldehyde and extending the procedure to the synthesis of pyrrole-2,5-dicarbaldehydes substituted at positions 3 and 4. In the event, almost quantitative yields of 2,5-bis(1,3-benzodithiol-2-yl)pyrrole **3a** were obtained under conditions that had only been slightly modified with regard to those reported earlier, *i.e.* by allowing the pyrrole to react with compound **2** in the molar ratio of 1 : 2.2 in AcOH at room temperature for 7 h. In the same way, by appropriately varying the temperature and the reaction time, the pyrrole derivatives **1b–g** led to compounds **3b–g** in excellent yields, the only exception being **3d** (Table 1).

In the second stage, the greatest difficulties were encountered in the hydrolysis of **3a** and **3g**, where electron-withdrawing groups are absent. In fact, operating under conditions similar to those we used earlier to obtain diacylpyrroles from the corresponding benzodithiolyl derivatives,[9a] *i.e.* carrying out the hydrolysis of **3a** and **3g** in one step with HgO–35% aq. HBF_4–dimethyl sulfoxide (DMSO) at 60–70 °C, **4a** was obtained repeatedly in low and not very reproducible yields, and

Table 1 Yields and m.p.s of the products

Compound 3, 6, 8	Yield[a] (%)	M.p. (°C) (solvent)[b]	Compound 4, 7, 9	Yield[a] (%)	M.p. (°C) (solvent)[b]	Lit. data	Overall yield (%) of 4, 7, 9 from 1
3a	100	163–164[c] (B–LP)	**4a**	43–50	124–124.5 (CT–H)	124–125[6]	43–50
			4a				65[d]
3b	97	136 (E)	**4b**	86	136–137 (B)		83
3c	95	155 (E)	**4c**	95	102–103 (CT–LP)		90
3d	40	198–199 (E)	**4d**	81	140–141 (A–P)		32
3e	90	200–201 (E)	**4e**	60	186–187 (A–H)	185–187[5c], *e*	54
3f	90	175–176 (E)	**4f**	86	185–186 (B)[f]	220–223, *g*, *h*	77
3g	100	177 (E)	**4g**	70	156 (B)[i]	157–158[5b], *j*, *k*	70
6	93	152–153 (C–E)	**7**	80	124–125 (B–LP)		74
8	100	157–158 (B–LP)	**9**	90	97 (B–LP)	96–97[5c], *l*	90

[a] Yields of pure products. [b] B = benzene; E = EtOH; C = $CHCl_3$; CT = CCl_4; H = hexane; A = MeCOMe; P = pentane. [c] Lit.,[7] m.p. 163–164 °C. [d] **1a**→**3a**→**6**→**7**→**4a**. [e] The reported[5c] overall yield from pyrrole-2,4-dicarbaldehyde is 35%. [f] After sublimation (140 °C/0.8 mmHg), the product had the same m.p. (see Experimental section). [g] P. Hodge and R. W. Rickards, *J. Chem. Soc.*, 1965, 459; the reported overall yield from 2,5-dimethylpyrrole is 3%. [h] U. Colacicchi, *Atti Accad. Lincei*, 1910, **19**, 645 (*Chem. Abstr.*, 1911, **6**, 1280): the product was obtained in traces starting from 2,5-dimethylpyrrole and had m.p. 228 °C. [i] Unchanged after sublimation (140 °C/0.8 mmHg). [j] M.p. reported in ref. 14 is 137–138 °C; it is probably a misprint. [k] The reported yields starting from ethyl (ref. 5*b* and H. Fischer and H. Hofelmann, *Justus Liebigs Ann. Chem.*, 1938, **533**, 216) and *tert*-butyl (ref. 15) 3,4,5-trimethylpyrrole-2-carboxylate and 1-chloro-2,3-dimethylpent-2-en-4-yne (ref. 14) are 6–19, 11 and 23%, respectively. [l] The product was obtained by methylation of **4a**.



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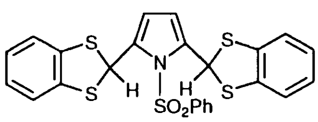
a $R^1 = R^2 = H$

b $R^1 = R^2 = Me$



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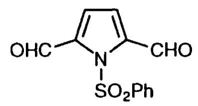

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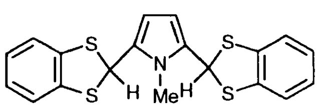

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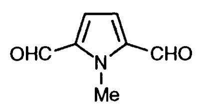

9

4g was not obtained. However, the best results came from doing the hydrolysis in two steps. Thus, first **3a** was treated at 0–5 °C with a portion of the hydrolysis reagent to transform it into the intermediate 5-(1,3-benzodithiol-2-yl)pyrrole-2-carbaldehyde **5a**. In the second step a second portion of the hydrolysis reagent was added and the reaction was carried out at 70–75 °C until the intermediate was converted into the pyrrole-2,5-dicarbaldehyde **4a**. Yields varied between 43 and 50%. Similarly, **4g** was obtained from **3g** in 70% yield, carrying out the first step at 0–5 °C and the second at room temperature. Moreover, a fairly good increase in the yield of **4a** was obtained by protecting the nitrogen of **3a** with a phenylsulfonyl group before the hydrolysis of the dithiolyl groups and deprotecting it after the hydrolysis, *i.e. via* 2,5-bis(1,3-benzodithiol-2-yl)-1-phenylsulfonylpyrrole **6** and then 1-phenylsulfonylpyrrole-2,5-dicarbaldehyde **7**. Thus, **4a** was obtained easily in a reproducible overall yield of 65% (based on pyrrole). In the other cases, where electron-withdrawing groups are present, the hydrolyses were carried out without any difficulty and **4b–f** were obtained from **3b–f** in good to excellent yields (Table 1).

Furthermore, we have demonstrated (taking into consideration only one example although there appears no foreseeable impediment to making a generalization) that the new procedure can be exploited for the synthesis of 1-methylpyrrole-2,5-dicarbaldehydes. Thus, the methylation of **3a** with Me_2SO_4 under conditions of phase-transfer catalysis led to the 1-methyl derivative **8**, which gave the corresponding dialdehyde in high yield (Table 1), by the two-step hydrolysis.

In conclusion, the described approach appears to have a general validity, is completely reproducible, easy to carry out and, in the case of known derivatives, results in distinctly higher yields of pyrrole-2,5-dicarbaldehydes than do other literature methods.

Experimental

General Details.—^1H and ^{13}C NMR spectra were recorded on a Bruker WP 80 SY spectrometer for solutions in deuteriochloroform unless otherwise noted. The chemical shifts are expressed in ppm (δ) relative to internal tetramethylsilane and J values are given in Hz. Mass spectra were recorded on a double-focusing Kratos MS 80 instrument, operating with a direct-inlet system at 70 eV, for compounds **3a–g**, **6**, **7** and **8** and on an HP 5970 B mass-selective detector connected to an HP 5890 GC, cross-linked methyl silicone capillary column (70 eV), for compounds **4a–g**, **5a**, **b** and **9**. IR spectra were recorded on a Perkin-Elmer 599 B spectrophotometer for solutions in tetrachloromethane. Column chromatography and TLC were performed on Merck silica gel 60 (70–230 mesh ASTM) and GF 254, respectively. Satisfactory elemental analysis were obtained for all the new compounds. Light petroleum refers to the fraction boiling in the range 40–70 °C and is abbreviated as LP.

3-Benzoylpyrrole **1b**,[9a] 3-pivaloylpyrrole **1c**,[9a] 3-nitropyrrole **1d**,[10] 3-formylpyrrole **1e**,[10] 3,4-dichloropyrrole **1f**,[11] 3,4-dimethylpyrrole **1g**[12] and 2-isopentyloxy-1,3-benzodithiole **2**[13] were prepared as described in the literature.

2,5-Bis(1,3-*benzodithiol*-2-*yl*)*pyrroles* **3a–g**.—*General procedures.* The conditions previously reported[7] for the preparation of **3a** were slightly modified as follows. A mixture of pyrrole **1** (10 mmol) and 2-isopentyloxy-1,3-benzodithiole **2** (5.29 g, 22 mmol) in glacial AcOH (30–50 cm^3) was set aside at room temp. or heated at 60–70 °C on an oil-bath, with stirring, for a few hours, until completion of the reaction (TLC test).

Procedure A. The reaction mixture was poured onto ice–water (200 cm^3) and the precipitate was filtered off and dissolved in $CHCl_3$ (200 cm^3). The organic layer was separated, washed successively with 5% aq. $NaHCO_3$ (2 × 100 cm^3) and water (2 × 100 cm^3), dried and then evaporated under reduced pressure. The residue was washed with MeOH (3–5 cm^3). Compounds **3a**, **3f** and **3g** were obtained in a practically pure form and were used directly in the next step without any further purification. Compound **3e** was purified by column chromatography using $CHCl_3$–LP (7:3) as eluent.

Procedure B. The reaction mixture was poured onto ice–water (200 cm^3) and the product was extracted with $CHCl_3$ (2 × 100 cm^3). The combined extracts were repeatedly washed as above. The crude residue obtained after evaporation of the solvent was chromatographed using the following eluents: LP–Et_2O (7:3) for **3b** and **3c** and $CHCl_3$–LP (7:3) for **3d**.

Reaction times and reaction temperatures are reported below together with the analytical and spectral data of all the products.

2,5-*Bis*(1,3-*benzodithiol-2-yl*)*pyrrole* **3a**. 7 h at room temp.; $\delta_H(CD_3COCD_3)$ 6.11 (2 H, d, *J* 2.59, 3- and 4-H), 6.40 (2 H, s, 2 × CH), 6.95–7.30 (8 H, m, ArH) and 10.37 (1 H, m, NH); δ_C 49.93 (d, SCHS), 108.52 (d, C-3 and C-4), 121.97 and 125.77 (d, ArC), 130.00 (s, C-2 and C-5) and 137.03 (s, ArCS).

2,5-*Bis*(1,3-*benzodithiol-2-yl*)-3-*benzoylpyrrole* **3b**. 2.5 h at 60 °C (Found: C, 63.05; H, 3.65; N, 3.0; S, 27.1%; M^+, 475. $C_{25}H_{17}NOS_4$ requires C, 63.1; H, 3.6; N, 2.9; S, 26.9%; *M*, 475); $\nu_{max}(CCl_4)/cm^{-1}$ 1640 (CO); δ_H 5.97 and 6.64 (2 H, 2 s, 1:1, 2 CH), 6.39 (1 H, d, *J* 2.50, 4-H), 6.90–7.24 (8 H, m, ArH), 7.34–7.54 and 7.64–7.84 (5 H, 2 m, 3:2, Ph) and 9.41 (1 H, m, NH); δ_C 47.35 and 49.04 (2 d, 2 SCHS), 111.59 (d, *J* 175, C-4), 100.00, 118.25 and 128.95 (s, C-2, C-3 and C-5), 122.27, 125.87 and 126.06 (d, ArCH), 128.16, 128.95 and 131.68 (d, CH of Ph), 136.42 (s, ArCS) and 211.46 (s, CO).

2,5-*Bis*(1,3-*benzodithiol-2-yl*)-3-*pivaloylpyrrole* **3c**. 2 h at 60 °C (Found: C, 60.7; H, 4.6; N, 3.1; S, 28.25%; M^+, 455. $C_{23}H_{21}NOS_4$ requires C, 60.6; H, 4.65; N, 3.1; S, 28.1%; *M*, 455); $\nu_{max}(CCl_4)/cm^{-1}$ 1645 (CO); δ_H 1.31 (9 H, s, Bu^t), 6.06 and 6.64 (2 H, 2 s, 1:1, 2 CH), 6.56 (1 H, d, *J* 2.80, 4-H), 6.95–7.27 (8 H, m, ArH) and 9.20 (1 H, m, NH); δ_C 27.75 (q, CH_3), 44.10 (s, C of Bu^t), 48.00 and 49.23 (2 d, 2 SCHS), 109.83 (d, C-4), 100.00, 116.50 and 128.07 (s, C-2, C-3 and C-5), 122.24, 122.28, 125.73 and 126.07 (d, ArCH), 136.47 and 139.39 (s, ArCS) and 202.68 (s, CO).

2,5-*Bis*(1,3-*benzodithiol-2-yl*)-3-*nitropyrrole* **3d**. 4 h at 70 °C (Found: C, 52.0; H, 3.0; N, 6.8; S, 30.85%; M^+, 416. $C_{18}H_{12}N_2O_2S_4$ requires C, 51.9; H, 2.9; N, 6.7; S, 30.7%; *M*, 416); δ_H 5.82 and 6.52 (2 H, 2 s, 1:1, 2 CH), 6.71 (1 H, d, *J* 2.70, 4-H), 6.87–7.30 (8 H, m, ArH) and 9.16 (1 H, m, NH); δ_C 46.53 and 48.28 (2 d, 2 SCHS), 105.23 (d, C-4), 117.04, 123.56 and 129.65 (s, C-2, C-3 and C-5), 122.62 and 126.41 (d, ArCH), 135.64 and 135.88 (s, ArCS).

2,5-*Bis*(1,3-*benzodithiol-2-yl*)-3-*formylpyrrole* **3e**. 2 h at 70 °C. In this case two further portions (each of 0.8 g, 3 mmol) of **2** were added, after 1 and 1.5 h respectively, to complete the reaction (Found: C, 57.2; H, 3.35; N, 3.6; S, 32.2%; M^+, 399. $C_{19}H_{13}NOS_4$ requires C, 57.1; H, 3.3; N, 3.5; S, 32.1%; *M*, 399); $\nu_{max}(CCl_4)/cm^{-1}$ 1660 (CO); δ_H([$^2H_6$]DMSO) 6.30 (1 H, d, *J* 2.70, 4-H), 6.00 and 6.80 (2 H, 2 s, 1:1, 2 CH), 6.85–7.25 (8 H, m, ArH) 9.65 (1 H, s, CHO) and 11.83 (1 H, m, NH); δ_C([$^2H_6$]DMSO) 45.47 and 47.11 (2 d, 2 SCHS), 108.14 (d, C-4), 120.07, 127.14 and 133.93 (s, C-2, C-3 and C-5), 121.93, 122.25, 125.73 and 125.87 (d, ArCH), 136.19 and 136.37 (s, ArCS) and 185.49 (d, CHO).

2,5-*Bis*(1,3-*benzodithiol-2-yl*)-3,4-*dichloropyrrole* **3f**. 2 h at 60 °C (Found: C, 49.2; H, 2.6; N, 3.2; S, 29.2; Cl, 16.1%; M^+, 439. $C_{18}H_{11}NS_4Cl_2$ requires C, 49.1; H, 2.5; N, 3.2; S, 29.1; Cl, 16.15%; *M*, 440); δ_H 6.12 (2 H, s, 2 × CH), 6.87–7.34 (8 H, m, ArH) and 8.75 (1 H, m, NH); δ_C 46.50 (d, 2 SCHS), 108.94 (s, C-3 and C-4), 125.34 (s, C-2 and C-5), 122.27 and 126.13 (d, ArCH) and 136.00 (s, ArCS).

2,5-*Bis*(1,3-*benzodithiol-2-yl*)-3,4-*dimethylpyrrole* **3g**. 5 h at room temp. (Found: C, 60.2; H, 4.35; N, 3.6; S, 32.15%; M^+, 399. $C_{20}H_{17}NS_4$ requires C, 60.1; H, 4.3; N, 3.5; S, 32.1%; *M*, 399); δ_H 1.45 and 1.50 (6 H, 2 s, 1:1, 2 Me), 5.90 (2 H, s, 2 × CH), 6.40–6.70 (8 H, m, ArH) and 8.15 (1 H, m, NH); δ_C 8.90 (q, Me), 48.79 (d, 2 SCHS), 117.35 (s, C-3 and C-4), 123.50 (s, C-2 and C-5), 122.01 and 125.79 (d, ArCH) and 137.33 (s, ArCS).

Hydrolysis of 2,5-*Bis*(1,3-*benzodithiol-2-yl*)*pyrroles* **3** *to Pyrrole-2,5-dicarbaldehydes* **4**: *Typical Procedures.—Pyrrole-2,5-dicarbaldehyde* **4a**. The hydrolysis reagent, red HgO (5.42 g, 25 mmol) and 35% aq. HBF_4 (12.5 cm^3) in DMSO (15 cm^3), was cooled at 0–5 °C in an ice-bath, with stirring. A solution of **3a** (3.71 g, 10 mmol) in DMSO (15 cm^3) was added dropwise, over a period of 20 min, and stirring and cooling was maintained for 1 h, until a TLC test ($CHCl_3$) showed the complete disappearance of the starting compound **3a** and the presence of the intermediate 5-(1,3-benzodithiol-2-yl)pyrrole-2-carbaldehyde **5a**. It is noteworthy that the TLC test must be made on portions of reaction mixture previously treated with KI, otherwise **4a** is masked in the presence of the hydrolysis reagent, probably due to complex formation. Then the ice-bath was removed and a second portion of the hydrolysis reagent, HgO (8.66 g, 40 mmol) and 35% aq. HBF_4 (20 cm^3) in DMSO (24 cm^3), was added, and the reaction mixture was heated in an oil-bath until 70–75 °C. This temperature was maintained until the intermediate **5a** had disappeared (3.5–4 h). After cooling to room temp., KI (21.58 g, 130 mmol) was added. After stirring for 5–10 min, the reaction mixture was diluted with hot benzene (30 cm^3) and the organic layer was decanted. Then the mixture was exhaustively extracted, with stirring and heating, with the same solvent (10 × 30 cm^3). The combined extracts were ice-cooled and washed successively with ice-cooled 10% aq. KI (20 cm^3) and saturated aq. NaCl (2 × 20 cm^3), the pH of the solution being checked to see that it did not exceed *ca.* 4.5. The solution was then dried and evaporated under reduced pressure and the residue was purified by chromatography, using CH_2Cl_2 containing slowly increasing amounts of $CHCl_3$ (to separate the last traces of DMSO and by-products) and then $CHCl_3$–AcOEt (9.5:0.5) as eluents. In repeated tests pure *title compound* **4a** was obtained in yields varying between 43 and 50% (0.53–0.62 g); $\nu_{max}(CCl_4)/cm^{-1}$ 1658 and 1675 (CHO); the ^1H NMR spectrum was identical with that reported;[4d] δ_C 119.32 (d, *J* 175, C-3 and C-4), 135.81 (s, C-2 and C-5) and 184.40 (d, *J* 180, CHO).

The intermediate 5-(1,3-*benzodithiol-2-yl*)*pyrrole-2-carbaldehyde* **5a** could be isolated in 86% yield (2.12 g), after addition of KI (8.30 g, 50 mmol) and work-up as above; m.p. 184–185 °C (from benzene–LP) (Found: C, 58.4; H, 3.75; N, 5.7; S, 26.0%; M^+, 247. $C_{12}H_9NOS_2$ requires C, 58.3; H, 3.7; N, 5.7; S, 25.9%; *M*, 247); $\nu_{max}(CCl_4)/cm^{-1}$ 1650 (CHO); δ_H 6.15 (1 H, s, CH), 6.35 (1 H, dd, $J_{1,4}$ 2.40, $J_{3,4}$ 3.80, 4-H), 6.85 (1 H, dd, $J_{1,3}$ 2.40, $J_{3,4}$ 3.80, 3-H), 7.05–7.44 (4 H, m, Ar-H), 9.44 (1 H, s, CHO) and 9.81 (1 H, m, NH); δ_C 48.25 (d, *J* 157, SCHS), 110.26 and 121.53 (d, *J* 172, C-3 and C-4), 122.35 and 126.14 (d, *J* 160, ArCH), 128.26 and 132.83 (s, C-2 and C-5), 136.36 (s, ArCS) and 179.15 (d, *J* 172, CHO). The next hydrolysis was carried out as above. Pure compound **4a** was obtained in comparable overall yields.

3,4-*Dimethylpyrrole-2,5-dicarbaldehyde* **4g**. A solution of **3g** (3.99 g, 10 mmol) in DMSO (30 cm^3) was cooled at 0–5 °C in an ice-bath, and the hydrolysis reagent, HgO (8.66 g, 40 mmol) and 35% aq. HBF_4 (20 cm^3) in DMSO (24 cm^3), was added dropwise, over a period of 1 h, cooling being maintained. After the addition was complete, the temperature was left to rise to room temp., and stirring was continued until a TLC test ($CHCl_3$) showed the complete disappearance of the hydrolysis intermediate 5-(1,3-benzodithiol-2-yl)-3,4-dimethylpyrrole-2-carbaldehyde **5b** (1.5 h). After addition of KI (13.28 g, 80 mmol), the reaction mixture was worked up as above to afford pure *title compound* **4g**; $\nu_{max}(CCl_4)/cm^{-1}$ 1655 and 1670 (CHO) (lit.,[14] IR disagrees); ^1H[14,15] and ^{13}C NMR[15] were identical to those reported.

The intermediate 5-(1,3-*benzodithiol*-2-*yl*)-3,4-*dimethylpyrrole*-2-*carbaldehyde* **5b** could be isolated when the hydrolysis reagent, HgO (4.77 g, 22 mmol) and 35% aq. HBF_4 (11 cm^3) in DMSO (20 cm^3), was added dropwise, over a period of 30 min, to a solution of **3g** (3.99 g, 10 mmol) in DMSO (30 cm^3), the reaction temperature being maintained at 0–5 °C. After the addition was complete, the starting compound disappeared. The above work-up afforded **5b** in 65% yield (1.79 g); m.p. 194–195 °C (from benzene–LP) (Found: C, 61.1; H, 4.8; N, 5.15; S, 26.0%; M^+, 275. $C_{14}H_{13}NOS_2$ requires C, 61.1; H, 4.8; N, 5.1; S, 23.25%; *M*, 275); $\nu_{max}(CCl_4)/cm^{21}$ 1655 (CHO); δ_H 1.92 and 2.19 (6 H, 2 s, 1:1, 2 Me), 6.19 (1 H, s, CH), 6.95–7.36 (4 H, m, ArH), 9.21 (1 H, m, NH) and 9.57 (1 H, s, CHO); δ_C 8.30 and 8.40 (2 q, 2 Me), 46.77 (d, SCHS), 121.98 and 125.92 (d, ArCH), 126.07, 126.98, 128.10 and 128.43 (s, C of pyrrole), 136.28 (s, ArCS) and 177 (d, CHO). Compound **4g** was also isolated in an 11% yield (0.17 g).

3-*Benzoylpyrrole*-2,5-*dicarbaldehyde* **4b**. A mixture of **3b** (4.75 g, 10 mmol) HgO (13 g, 60 mmol), 35% aq. HBF_4 (30 cm^3) and DMSO (120 cm^3) was heated at ~60 °C and stirred until the starting compound **3b** was no longer present and the intermediates 5-(1,3-benzodithiol-2-yl)-3-benzoylpyrrole-2-carbaldehyde and 5-(1,3-benzodithiol-2-yl)-4-benzoylpyrrole-2-carbaldehyde formed during the hydrolysis had disappeared (TLC; $CHCl_3$–AcOEt, 9.8:0.2). Hydrolysis was complete after 2 h. The reaction mixture was worked up as described above for **4a** with the only differences that the solvent for the extractions was $CHCl_3$ and the eluent for the chromatography was $CHCl_3$–AcOEt (9.6:0.4). Pure *title compound* **4b** was obtained (Found: C, 68.8; H, 4.05; N, 6.25%; M^+, 227. $C_{13}H_9NO_3$ requires C, 68.7; H, 4.0; N, 6.2%; *M*, 227); $\nu_{max}(CCl_4)/cm^{-1}$ 1678 and 1688 (CHO); δ_H 7.26 (1 H, d, *J* 2.40, 4-H), 7.52–7.70 and 7.84–8.00 (5 H, 2 m, 3:2, Ph), 9.80 and 10.22 (2 H, 2 s, 1:1, 2 CHO) and 10.40 (1 H, m, NH); $\delta_C(CD_3COCD_3)$ 120.55 (d, *J* 170, C-4), 129.13, 129.96 and 133.44 (d, *J* 160, CH of Ph), 132.50, 134.79 and 137.16 (s, C-2, C-3 and C-5), 138.82 (s, C-1 of Ph), 181.99 (d, *J* 174, CHO), 182.94 (d, *J* 187, CHO) and 190.81 (s, CO).

Compounds **4c–f** were also prepared according with the above procedure. Reaction times, reaction temperatures and chromatographic solvents are reported below together with the analytical and spectral data of all the compounds.

3-*Pivaloylpyrrole*-2,5-*dicarbaldehyde* **4c**. 2 h at 60 °C; $CHCl_3$; (Found: C, 63.85; H, 6.4; N, 6.8%; M^+, 207. $C_{11}H_{13}NO_3$ requires C, 63.8; H, 6.3; N, 6.8%; *M*, 207); $\nu_{max}(CCl_4)/cm^{-1}$ 1668 and 1688 (CHO); δ_H 1.40 (9 H, s, Bu^t), 7.40 (1 H, d, *J* 2.40, 4-H), 9.86 and 10.21 (2 H, 2 s, 1:1, 2 CHO) and 11.10 (1 H, m, NH); δ_C 27.33 (q, *J* 133, Me), 44.29 (s, C of Bu^t), 119.05 (d, *J* 175, C-4), 128.04, 133.08 and 136.94 (s, C-2, C-3 and C-5), 181.17 (d, *J* 183, CHO), 183.92 (d, *J* 194, CHO) and 202.84 (s, CO).

3-*Nitropyrrole*-2,5-*dicarbaldehyde* **4d**. 3 h at 60 °C and 4 h at 80 °C; $CHCl_3$–AcOEt (7:3) (Found: C, 42.95; H, 2.3; N, 16.7%; M^+, 168. $C_6H_4N_2O_4$ requires C, 42.9; H, 2.4; N, 16.7%; *M*, 168); $\nu_{max}(CCl_4)/cm^{-1}$ 1680 and 1695 (CHO); $\delta_H(CD_3COCD_3)$ 7.59 (1 H, br s, 4-H), 10.35 and 10.88 (2 H, 2 s, 1:1, 2 CHO) and 12.50 (1 H, m, NH); $\delta_C(CD_3COCD_3)$ 113.77 (d, *J* 181, C-4), 129.34, 130.69 and 132.69 (s, C-2, C-3 and C-5), 181.65 (d, *J* 196, CHO) and 181.91 (d, *J* 185, CHO).

Pyrrole-2,3,5-*tricarbaldehyde* **4e**. 4 h at 60 °C; $CHCl_3$–AcOEt (7:3); $\nu_{max}(CCl_4)/cm^{-1}$ 1675 and 1682 (CHO); ^1H NMR was identical to that reported;[5a] $\delta_C(CD_3COCD_3)$ 118.93 (d, *J* 174, C-4), 123.25, 125.31 and 130.81 (s, C-2, C-3 and C-5), 182.34 (d, *J* 180, CHO), 182.94 (d, *J* 186, CHO) and 187.51 (d, *J* 180, CHO).

3,4-*Dichloropyrrole*-2,5-*dicarbaldehyde* **4f**. 4 h at 60 °C; $CHCl_3$ (Found: C, 37.6; H, 1.65; N, 7.4; Cl, 37.0%; M^+, 191. $C_6H_3NCl_2O_2$ requires C, 37.5; H, 1.6; N, 7.3; Cl, 36.9%; *M*, 192); $\nu_{max}(CCl_4)/cm^{-1}$ 1670 and 1685 (CHO); δ_H 9.80 (2 H, s, 2 × CHO); δ_C 121.16 (s, C-3 and C-4), 129.15 (s, C-2 and C-5) and 178.60 (d, *J* 178, 2 CHO). Compound **4f** had been prepared before in very low yields, but it was not adequately purified and characterized; in fact the only physical data reported is a m.p. which does not coincide with that reported by us (see footnotes *g*, *h* of Table 1).

2,5-*Bis*(1,3-*benzodithiol*-2-*yl*)-1-*phenylsulfonylpyrrole* **6**.—According to the procedure previously reported for the synthesis of 1-phenylsulfonylpyrrole,[16] a solution of phenylsulfonyl chloride (3.08 g, 17.5 mmol) in CH_2Cl_2 (5 cm^3) was added dropwise at room temp., during 10 min, to a vigorously stirred mixture of **3a** (3.71 g, 10 mmol), CH_2Cl_2 (50 cm^3), tetrabutylammonium hydrogen sulfate (0.34 g, 1 mmol) and 50% aq. NaOH (5 cm^3, 90 mmol). A mildly exothermic reaction occurred and the starting compound disappeared at once (TLC; LP–MeCOMe, 9:1). The crude residue obtained after the usual work-up, was used directly in the next step. However, pure *title compound* **6** could be isolated by flash chromatography on SiO_2 (Merck, 230–400 mesh) using CCl_4–$CHCl_3$ (9.8:0.2) as eluent (Found: C, 56.4; H, 3.4; N, 2.8; S, 31.7%; M^+, 511. $C_{24}H_{17}NO_2S_5$ requires C, 56.4; H, 3.35; N, 2.7; S, 31.3%; *M*, 511); δ_H 6.37 (2 H, s, 2 × CH), 6.49 (2 H, s, 3-H and 4-H), 6.90–7.20 (8 H, m, ArH), 7.56–7.67 and 7.67–7.85 (5 H, 2 m, 2:3, Ph); δ_C 44.87 (d, *J* 160, SCHS), 114.81 (d, *J* 175, C-3 and C-4), 122.09 and 125.57 (d, *J* 165, ArCH), 126.14, 129.63 and 134.26 (d, *J* 165, CH of Ph), 136.51 (s, C-2 and C-5), 138.08 (s, ArCS) and 139.54 (s, C-1 of Ph).

1-*Phenylsulfonylpyrrole*-2,5-*dicarbaldehyde* **7**.—The reaction was carried out as previously described for the hydrolysis of compound **3b**, starting from crude **6**. By chromatography with $CHCl_3$ as eluent, pure *title compound* **7** was obtained in 80% overall yield (from **3a**) (Found: C, 54.75; H, 3.5; N, 5.4; S, 12.3%; M^+, 263. $C_{12}H_9NO_4S$ requires C, 54.75; H, 3.45; N, 5.3; S, 12.2%; *M*, 263); $\nu_{max}(CCl_4)/cm^{-1}$ 1675 and 1702 (CHO); δ_H 7.16 (2 H, s, 3-H and 4-H), 7.54–7.80 and 7.80–8.04 (5 H, 2 m, 3:2, Ph) and 10.20 (2 H, s, 2 × CHO); δ_C 120.72 (d, *J* 175, C-3 and C-4), 126.81, 129.73 and 135.02 (d, *J* 165, CH of Ph), 137.61 (s, C-2 and C-5), 137.84 (s, C-1 of Ph) and 180.69 (d, *J* 187.5, CHO).

Preparation of Pyrrole-2,5-*dicarbaldehyde* **4a** *from* **7**.—Under conditions similar to those reported,[16] a mixture of **6** (1.32 g, 5 mmol) and a 10% KOH solution in EtOH (16.6 cm^3, 30 mmol) was heated at 50 °C, with stirring, until the starting compound had disappeared (5 h; TLC; $CHCl_3$). After ice-cooling, the solution was acidified to pH 4.5–5 by addition of concentrated HCl, diluted with $CHCl_3$ (50 cm^3), and washed with ice-cooled saturated aq. NaCl (2 × 10 cm^3). The *title compound*, purified as described above, was obtained in 81% yield (0.50 g; 65% overall yield from **3a**); physical and spectroscopic data were identical with those reported above.

2,5-*Bis*(1,3-*benzodithiol*-2-*yl*)-1-*methylpyrrole* **8**.—A solution of Me_2SO_4 (1.39 g, 11 mmol) in CH_2Cl_2 (1 cm^3) was added dropwise to a vigorously stirred mixture of **3a** (3.71 g, 10 mmol), TEBA (tetraethylammonium bromide, 0.15 g) and 50% aq. NaOH (5 cm^3) in CH_2Cl_2 (10 cm^3). The reaction was exothermic and the mixture refluxed gently. When the addition was complete, the mixture was stirred for a further 15 min until **3a** had disappeared (TLC; LP–MeCOMe, 9:1). The crude residue, obtained after the usual work-up, was washed with EtOH (5–6 cm^3) to afford virtually pure (TLC, NMR) *title compound* **8** (Found: C, 59.3; H, 4.0; N, 3.7; S, 33.35%; M^+, 385. $C_{19}H_{15}NS_4$ requires C, 59.2; H, 3.9; N, 3.6; S, 33.2%; *M*, 385);

δ_H 3.75 (3 H, s, Me), 6.27 (2 H, s, 2 × CH), 6.39 (2 H, s, 3- and 4-H) and 6.97–7.24 (8 H, m, ArH); δ_C 31.94 (q, *J* 132, Me), 49.10 (d, *J* 156, SCHS), 109.10 (d, *J* 174, C-3 and C-4), 122.09 and 125.68 (d, *J* 160, ArCH), 130.77 (s, C-2 and C-5) and 137.39 (s, ArCS).

1-*Methylpyrrole*-2,5-*dicarbaldehyde* **9**.—Prepared according to the procedure described for **4g**, starting from **8** (3.83 g, 10 mmol) in DMSO (30 cm^3) and HgO (9.75 g, 45 mmol) and 35% aq. HBF_4 (22.5 cm^3) in DMSO (27 cm^3). After the addition of the hydrolysis reagent at 0–5 °C, the ice-bath was removed and the reaction mixture was heated on an oil-bath at 50 °C. After 1 h at this temperature the reaction was complete. The crude residue obtained after the above work-up was chromatographed, using LP–$CHCl_3$ (7:3) and then $CHCl_3$ as eluent, to afford pure *title compound* **9**; $\nu_{max}(CCl_4)/cm^{-1}$ 1668 and 1685 (CHO); ^{1}H NMR spectrum identical to that reported;[5c] δ_C 34.15 (q, *J* 140, CH_3), 121.35 (d, *J* 174, C-3 and C-4), 136.20 (s, C-2 and C-5) and 182.01 (d, *J* 172, CHO).

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