

New Macrocycles of Carbon, Nitrogen and Sulfur Atoms Incorporating 4,5-Dithio-1,3-dithiole-2-thione Units

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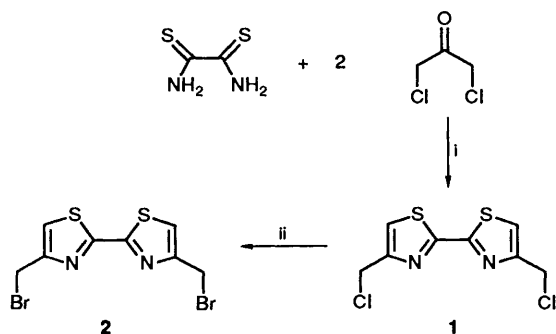
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Condensation of 2-thioxo-1,3-dithiole-4,5-dithiolate dianion, generated *in situ* from 4,5-bis-(benzoylthio)-1,3-dithiole-2-thione, with 4,4'-bis(bromomethyl)-2,2'-bi-1,3-thiol gives a mixture of macrocyclic compounds **3**, **4**, **5** and **6** while only the symmetrical product **9** was isolated using the 5,5'-bis(ethoxycarbonyl) derivative of the same bithiazole. The use of plasma desorption mass spectroscopy in analysing oligomeric reaction products, where low solubility makes the use of other conventional methods difficult is also reported.

As evidenced by the numerous citations in the literature, interest in the chemistry of macrocyclic ligands and their unique complexes with different metal ions continues apace.¹ Within a project on the preparation of new conducting molecular materials, we are interested in modified macrocyclic ligands incorporating a tetrathiofulvalene (TTF) unit, and we have recently reported novel macrocycles incorporating the 4,5-dithio-1,3-dithiole-2-thione unit and related cage macrocycles which feature non-planar tetrathiofulvalene moieties.^{2,3} Here we report the preparation of new macrocycles incorporating 4,5-dithio-1,3-dithiole-2-thione units as well as substituted and unsubstituted bithiazole units. It was expected that such macrocyclic ligands could present interesting properties both in selective metal ion complexing ability and in the electrochemical properties of their complexes.

Results and Discussion

4,4'-Bis(chloromethyl)-2,2'-bi-1,3-thiazole **1** was prepared by condensation of dithioamide and 1,3-dichloroacetone. The dibromo analogue **2** was prepared from **1** by a halogen exchange reaction using ethyl bromide, *N*-methyl-2-pyrrolidone (NMP) and a catalytic amount of sodium bromide (Scheme 1). Reaction of **1** or **2** with disodium 2-thioxo-1,3-dithiole-4,5-dithiolate, in ethanol, under nitrogen, resulted in a



Scheme 1 Reagents and conditions: i, CaCO₃, acetone, reflux; ii, NaBr(cat.), EtBr, NMP

very sparingly soluble yellow powder. The insolubility of the sample precluded conventional separation and characterization, however, it was possible to analyse the mixture by plasma desorption mass spectroscopy (PDMS)⁶ (Fig. 1).

The reaction product was shown to consist of a mixture of oligomeric macrocyclic molecules of varying ring size

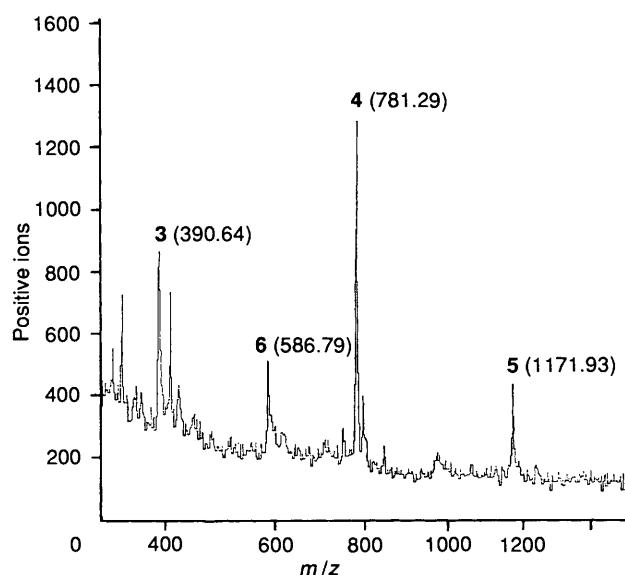


Fig. 1 PDMS of the products of the reaction shown in Scheme 2. Values in parentheses are calculated molecular masses.

depending on the ratio of bithiazole and dithiolate used in the reaction. These were the homologous products: 1:1 (**3**), 2:2 (**4**), 3:3 (**5**) and 1:2 (**6**) (Scheme 2 and Fig. 1).

In an attempt to improve the solubility of the macrocycles and thus facilitate separation and purification, we next prepared the dicarboxylate derivative **8**⁷ by bromination of diethyl 4,4'-dimethyl-2,2'-bi-1,3-thiazole-5,5'-dicarboxylate **7** with *N*-bromosuccinimide in carbon tetrachloride. Compound **7**⁸ was prepared by reaction of dithioamide with an excess of ethyl 2-chloroacetoacetate (Scheme 3). Reaction of **8** with the 2-thioxo-1,3-dithiole-4,5-dithiolate dianion under argon was carried out either by adding **8** dissolved in THF in one portion, whereupon the deep red colour of the THF solution of dithiolate disodium salt quickly disappeared, or alternatively, by adding **8** in ethanol, dropwise to the dithiolate [generated *in situ* from the 4,5-bis(thiobenzoyl)^{9,10} derivative] in ethanol. In both cases a yellow powder was isolated, which was shown to be the 2:2 macrocycle **9** (Scheme 3). There was no indication of any contamination of this product as shown by plasma desorption, electron impact or fast atom bombardment mass spectra (Fig. 2).

Unfortunately, macrocycle **9** was still only sparingly soluble

Uppsala, Sweden). The instrument and data handling procedures have been described earlier.¹² The spectra were accumulated for 500 000 fission events. A smooth background has been subtracted from all spectra. Due to the low resolution of the instrument, the measured molecular weights are isotopically averaged.

Mass spectra were recorded on a Varian MAT 311A. Infrared spectra were recorded on a Perkin-Elmer 1750 in potassium bromide discs and ¹H NMR spectra on a Bruker AC 250 FT; δ are recorded in ppm from TMS. Microanalyses were carried out by NOVO A/S Bagsvaerd, Denmark.

4,4'-Bis(chloromethyl)-2,2'-bi-1,3-dithiazole 1.—Dithiooxamide (24 g, 0.2 mol), 1,3-dichloropropan-2-one (50.8 g, 0.4 mol) and calcium carbonate (20 g, 0.2 mol) in 250 cm³ acetone were refluxed for 16 h, after which time the reaction mixture was cooled and filtered. The filtrate was evaporated *in vacuo* and the residue recrystallised from acetone to give compound **1** as needles (5.5 g, 11%), m.p., 163–165 °C (lit.,⁴ 164 °C), *m/z* 264 (M⁺, 65%), 229 (83, M⁺ – Cl) and 194, (2, M⁺ – 2Cl); $\delta_{\text{H}}(\text{CDCl}_3)$ 7.44 (2 H, s) and 4.74 (4 H, s); $\nu_{\text{max}}/\text{cm}^{-1}$ 3013, 2869, 1641, 1438 and 1336.

4,4'-Bis(bromomethyl)-2,2'-bi-1,3-dithiazole 2.—A mixture of **1** (0.5 g, 1.9 mmol), ethylbromide (2.5 cm³), sodium bromide (0.06 g) and *N*-methylpyrrolidin-2-one (NMP) (5 cm³) was heated at 65 °C for 3 d. The mixture was then cooled and poured into a 1:1 mixture of cold water and brine (8 cm³) whereupon a white solid precipitated which was filtered off and recrystallised from acetone–water (excess) to give **2** as yellow crystals (0.4 g, 60%), m.p. 180–182 °C (lit.,⁵ 180–181 °C); *m/z* 354 (M⁺, 16%) and 275 (M⁺ – Br, 76); $\nu_{\text{max}}/\text{cm}^{-1}$ 3030, 2890, 1685, 1430 and 1250; $\delta_{\text{H}}(\text{CDCl}_3)$ 7.48 (2 H, s) and 4.65 (4 H, s).

Preparation of a mixture of compounds 3, 4, 5 and 6.—To a stirred solution of disodium 2-thioxo-1,3-dithiole-4,5-dithiolate, generated *in situ* from 1.54 g of the benzoylated ester by the addition of sodium ethoxide in dry ethanol (0.17 g Na in 50 cm³ ethanol) under nitrogen, was slowly added compound **1** (1 g, 4 mmole) in ethanol (100 cm³). When the bithiazole **1** was added over 4 h the red colour of the dithiolate was discharged to light yellow. The reaction mixture was stirred overnight after which time the resulting yellow precipitate was filtered off, washed with water, ethanol, and then ether and vacuum dried at 50 °C to give a mixture of compounds (0.95 g, 66%), m.p. > 200 °C. PDMS 389.1, 585.2, 781.6 and 1172.2. Calculated masses for compounds **3**, **4**, **5** and **6** are 390, 781.3, 1172 and 586, respectively.

Diethyl 4,4'-Dimethyl-2,2'-bi-1,3-thiazole-5,5'-dicarboxylate 7.—Dithiooxamide (5.5 g, 0.046 mol) was heated overnight at 120 °C with ethyl 2-chloroacetoacetate (37.7 g, 0.23 mol).⁸ Upon being cooled, the reaction mixture became dark and crystalline. Excess of ethyl 2-chloroacetoacetate was removed by washing with ether after which the crystals became light brown. The product was recrystallised from benzene and finally from ethanol to give compound **7** as a yellow powder (9.5 g, 63%), m.p. 183–185 °C (lit.,⁸ 186 °C); *m/z* 340 (M⁺, 100%) and 295 (M⁺ – OEt, 30%); $\delta_{\text{H}}(\text{CDCl}_3)$ 4.36 (4 H, q, CH₂), 2.77 (6 H, s, Me) and 1.39 (6 H, t, CH₂ Me).

Diethyl 4,4'-Bis(bromomethyl)-2,2'-bi-1,3-thiazole-5,5'-dicarboxylate 8.—Compound **7** (2 g, 5.9 mmol) *N*-bromosuccin-

imide (2.05 g, 11.8 mmol) and benzoyl peroxide (0.07 g, 0.288 mmol) in dry carbon tetrachloride (150 cm³) were refluxed for 4 h. The reaction mixture was filtered under gravity while still hot and the filtrate was cooled. Yellow crystals precipitated on overnight refrigeration. Recrystallisation from carbon tetrachloride gave pure **8** as yellow crystals (0.8 g, 30%), m.p. 183–186 °C (lit.,⁷ 185–186 °C); *m/z* 498 (M⁺, 100%); $\delta_{\text{H}}(\text{CDCl}_3)$ 4.96 (4 H, s, CH₂Br), 4.36 (4 H, q, CH₂) and 1.42 (6 H, t, Me).

Tetraethyl 17,36-Thioxo-1,14,20,33-tetrathia[2](4,4')2,2'-bi-1,3-thiazolo[2](4,5)1,3-dithiolo[2](4,4')2,2'-bi-1,3-thiazolo[2](4,5)1,3-dithiolphane-4,10,23,29-tetracarboxylate 9.—In a typical preparation compound **8** (395 mg, 0.79 mmol) and the dithiolate (320 mg, 0.79 mmol) were mixed in THF (50 cm³) under nitrogen and stirred at room temperature. The reaction mixture went from red to yellow almost instantaneously. The NaBr which precipitated first was filtered off and the filtrate cooled. A yellow powder was collected (0.12 g, 20%) m.p. ca. 200 °C (decomp.); PDMS 1070.8 (M⁺, 1069.55); *m/z* (FAB): 1068.9 (100%), 1069.9 (65), 1070.9 (70), 1071.9 (35), 1072.9 (25) and 1073.9 (10); $\nu_{\text{max}}(\text{KBr})/\text{cm}^{-1}$ 3415, 1713 (C=O), 1511, 1333, 1270, 1046 (S=C) and 2981; $\delta_{\text{H}}(\text{CDCl}_3)$ 4.61 (8 H, S ring CH₂), 4.36 (8 H, q, CH₂CH₃) and 1.40 (12 H, t, CH₂CH₃) (Found: C, 37.75; H, 2.65; N, 5.1. Calc. for C₃₄H₂₈N₄O₈S₁₄: C, 38.18; H, 2.63; N, 5.23%).

Acknowledgements

A grant from Forskerakademiet (Denmark) to B. G. is gratefully acknowledged.

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Paper 1/03826E

Received 25th July 1991

Accepted 28th October 1991