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The synthesis of nine macrocyclic polyether- and polythioether-diesters **9-13** and dithioesters **14-17** derived from 1,10-phenanthroline-2,9-dicarboxylic acid are reported. The macrocycles were prepared under conditions of high dilution in the absence of metal templates in consistently good yields and their structures were confirmed by ^1H and ^{13}C nmr spectroscopy. A macrocyclic phenanthroline-pyridine tetraester **18** is also recorded.

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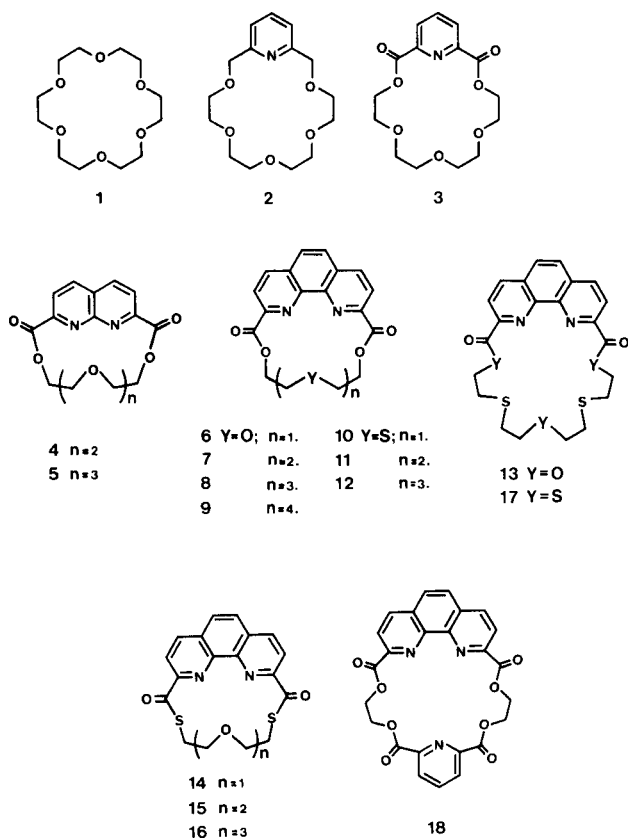
In recent years, there has been considerable interest in the use of macrocyclic ionophores incorporating heterocyclic subunits as cation selective ligands [1]. Of particular interest to us are structures which incorporate nitrogen heterocycles into the macrocyclic ring. For example, the pyridyl-18-crown-6 **2** [2] was observed to form a markedly more stable 1:1 complex with Ag^+ than did 18-crown-6 **1** [3], and to complex Cu^{2+} as well [4]. The presence of the heterocyclic nitrogen also enabled compound **2** to form a more stable complex with alkyl ammonium ions than did **1** [5]. These macrocyclic ligands and their chiral analogues have been studied as models for enzyme substrate binding [6].

The incorporation of ester linkages into these macrocycles further modifies their complexing abilities. The pyridyl diester **3** [7,8] is particularly interesting because of its affinity for K^+ over Ba^{2+} [9,10]. We have previously reported the synthesis of the 1,8-naphthyridine polyether diesters **4** and **5**, and also the phenanthroline polyether diesters **6-8** [11]. We record here the synthesis, characterization, and nmr spectral properties of the phenanthroline polyether- and polythioether-diesters **9-13**, the dithioesters **14-17**, and the phenanthroline-pyridine tetraester **18**. The cation-binding studies of these ionophores will be reported elsewhere.

Synthesis of the Polyether and Polythioether Bridges.

Compounds **19**, **20** and **23** were obtained commercially and compounds **21** [12], **24** [13] and **25** [13] were prepared using literature methods. Bennett and Whincop [14] reported the synthesis of the diol **22** from 2-mercaptoethanol and the vesicant 1,5-dichloro-3-thiapentane (mustard gas) and Sloan [15] prepared the same compound from 2-mercaptoethanol and divinyl sulfide. However, we found it more convenient to prepare **22** from 3-thiapentane-1,5-dithiol and 2-bromoethanol in methanol under basic conditions which provided a 73% yield of the desired product.

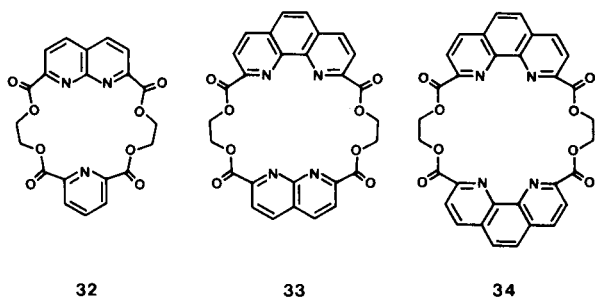
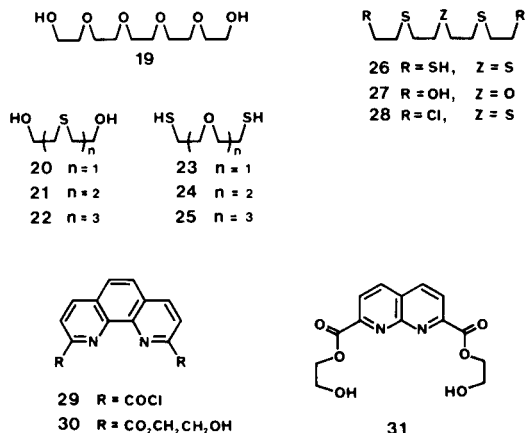
Several attempts to repeat the procedure of Weber and Vögtle [16] for the direct conversion of the diol **22** to a bis-isothiuronium salt and subsequent hydrolysis to the dithiol **26** were unsuccessful. However, treatment of the diol **22** with thionyl chloride at room temperature gave the corresponding dichloro compound **28** which was easily converted into **26** by the method of Speziale [17]. A satisfactory alternative route to **28** (63%) was devised by reacting the dipotassium salt of 3-thiapentane-1,5-dithiol with 1,2-dichloroethane at room temperature for 24 hours. 6-Oxa-3,9-dithiaundecane-1,11-diol (**27**) was prepared by the method of Maas *et al* [18]. In all cases, ^1H and ^{13}C nmr spectra were consistent with the structures of the products obtained.



Synthesis of the Macrocycles.

Macrocyclic formation was achieved by the slow addition of the appropriate bridging diol (or dithiol) into a refluxing solution of 1,10-phenanthroline-2,9-dicarbonyl chloride (**29**) [11] in a large volume of solvent and then to maintain the reflux for 16 hours, *i.e.*, overnight, although good yields could be obtained after only 4 hours of reaction. The vigorous reflux provided enough agitation and stirring of the reaction mixture was unnecessary. The reaction times were, in general, much shorter than those times quoted for the preparation of the analogous pyridine containing macrocycles [7,8]. Both toluene and benzene, dried by the azeotropic distillation of water, were suitable solvents for the preparation of most of the macrocycles. However, dichloromethane, which provided better solubility for the bridging diols **21**, **22** and **27**, was used in the synthesis of compounds **11**, **12** and **13**. Isolation of the product was achieved by filtration of the hot reaction mixture which removed any polymer, and then concentration of the filtrate and crystallization.

The structure of all new compounds was confirmed by microanalysis, ^1H and ^{13}C nmr and mass spectroscopy. The yields obtained for these bridged phenanthrolines **6-17** having macrocyclic cavities of 15, 18, 21 or 24-members ranged from 33 to 72% (average 51%). By



comparison, the yields reported by Bradshaw [8] for the synthesis of four corresponding pyridine analogues having the same macrocycle size varied greatly (9, 24, 28, 75%). The consistently higher yields we obtained is in part due to the inclusion of the larger planar 1,10-phenanthroline residue into the cyclic framework. Pedersen [19] first noticed similar effects in the synthesis of dibenzo-18-crown-6 in improved yield over that of 18-crown-6 (**1**).

Esterification of 1,10-phenanthroline-2,9-dicarbonyl chloride with excess ethane-1,2-diol gave **30** as a monohydrate. Reaction of the diol **30** with pyridine-2,6-dicarbonyl chloride in benzene under the high dilution conditions gave the tetraester **18** in high yield. A similar approach yielded the 2,7-bis[2'-hydroxy-carboethoxy]-1,8-naphthyridine **31**, however, attempts to produce other macrocycles such as **32-34** from **30** and **31**, surprisingly, were all unsuccessful.

d2

NMR Spectra.

The ^1H nmr spectra of these macrocycles are relatively simple due to their symmetry. In general, they showed the expected singlet (δ , ~ 7.9) and AB quartet (~ 8.3 and ~ 8.4 , $J = 9$ Hz) for the aromatic protons of the phenanthroline. The methylene protons of the bridges gave rise to a series of broad triplets with the exception of the γ -methylene resonances of **11** and **15** and the ϵ -methylene resonance of **9**, which were observed as singlets. For the polyether diesters **6-9**, the chemical shifts of these resonances decreased with increasing distance of the methylene from the aromatic moiety [11]. The incorporation of sulfur into the macrocyclic framework of compounds **10-17** altered this trend with the resonances of the adjacent methylene groups undergoing upfield shifts. The complete assignment of these compounds was readily made, however, by comparisons of chemical shifts within homologous series and to those observed for their all-oxa analogues.

Assignment of the ^{13}C nmr spectra could be made by comparison with spectra of several 2,9-disubstituted 1,10-phenanthrolines [20,21]. Single frequency decoupling (SFD) experiments of specific proton resonances while observing the carbon resonances enabled a complete assignment of the carbon nmr to be made [22,23]. As we noted previously, for the polyethers **6-9**, the order of the carbon methylene resonances is opposite to that of the corresponding protons in that their chemical shifts increase with increasing distance from the aromatic nucleus [11]. All the chemical shift data are included in the Experimental.

EXPERIMENTAL

Melting points are uncorrected. The ^1H nmr spectra were recorded on a Perkin-Elmer R-32 spectrometer at 90 MHz or a JEOL JNM FX-200

spectrometer at 199.5 MHz. The ^{13}C nmr spectra were determined on this latter machine at 50.1 MHz. The chemical shifts are reported in ppm (δ) from tetramethylsilane as an internal standard. Mass spectra were recorded on a VG Micromass 7070F mass spectrometer at 70eV (Mr. F. Shanks, Monash University, Victoria). Elemental analyses were performed by the Australian Microanalytical Service, AMDEL, Melbourne.

Bridging Groups.

3,6,9,12-Tetraoxatetradecane-1,14-diol (**19**) (Fairfield Chemical Company) was azeotroped with benzene under Dean Stark conditions, distilled and stored over 4 Å molecular sieves. 3-Thiapentane-1,5-diol (**20**), 3-oxapentane-1,5-dithiol (**23**), 3-thiapentane-1,5-dithiol, 2,6-pyridinedicarbonyl chloride, ethanolamine and ethane-1,2-diol were obtained from the Aldrich Chemical Co. and used without further purification.

3,6,9-Trithiaundecane-1,11-diol (**22**).

3-Thiapentane-1,5-dithiol (2.0 g, 13 mmoles) in 3% potassium hydroxide in methanol (50 ml) was heated at reflux for 1 hour, and then 2-bromoethanol (3.3 g, 26 mmoles) was added in one portion and the reflux continued for a further 2 hours. The reaction mixture was concentrated, *in vacuo*, and the residue triturated with hot dichloromethane. Removal of the solvent yielded **22** (2.3 g, 73%) as an amorphous white solid, mp 88-89° (acetone) (lit [14] mp 91-92°).

3,6,9-Trithiaundecane-1,11-dichloride (**28**).

3-Thiapentane-1,5-dithiol (10.0 g, 65 mmoles) in 8% potassium hydroxide in methanol (100 ml) was added to excess 1,2-dichloroethane (100 ml) and stirred at 20° for 18 hours. The mixture was concentrated, *in vacuo*, and the residue triturated with hot acetone. Removal of the solvent yielded the dichloride **28** (11.5 g, 63%), mp 72-75° (carbon tetrachloride) (lit [24] mp 72-75°).

General Method for the Macrocylic Diesters.

Except where indicated, the bridging group was dissolved in dry toluene (or benzene) (200 ml) and added dropwise over 1 hour to a refluxing solution of 1,10-phenanthroline-2,9-dicarbonyl chloride [1] (0.5 g, 1.6 mmoles) in dry toluene (or benzene) (1.5 l). The solution was maintained at reflux for the specified time and then filtered while hot. The filtrate was concentrated, *in vacuo*, and the residue crystallized to give the macrocycle.

3,6,9,12,15,18-Hexaoxa-29,32-diazatetracyclo[18.8.4.0^{23,31}.0^{26,30}]dotriaconta-20,22,23,26,28(1),29,31-heptaene-2,19-dione (**9**).

3,6,9,12-Tetraoxatetradecane-1,14-diol (**19**) (0.39 g, 1.6 mmoles) gave **9** (0.35 g, 45%) after 5 hours reflux as white needles, mp 137-138° (water); ^1H nmr (deuteriochloroform): 90 MHz, δ 3.60 (s, 4H, CH₂-10,11), 3.70 (m, 4H, CH₂-8, 13), 3.80 (m, 4H, CH₂-7, 14), 4.05 (m, 4H, CH₂-5, 16), 4.65 (m, 4H, CH₂-4, 17), 7.80 (s, 2H, H-24, 25), 8.25 (d, 2H, J = 9 Hz, H-21, 28), 8.37 (d, 2H, J = 9 Hz, H-22, 27); ^{13}C nmr (deuteriochloroform): δ 65.5 (C-4, 17), 68.8 (C-5, 16), 70.68 and 70.82 (C-7, 8, 10, 11, 13, 14), 123.9 (C-21, 28), 128.2 (C-24, 25), 130.6 (C-23, 26), 137.3 (C-22, 27), 145.5 (C-30, 31), 148.0 (C-1, 20), 165.5 (C-2, 19); ms: m/e (%) 471 (21), 470 (M⁺, 81), 427 (15), 339 (28), 222 (29), 180 (50), 179 (57), 178 (64), 177 (23), 125 (85), 89 (100).

Anal. Calcd. for C₂₄H₂₆N₂O₈: C, 61.3; H, 5.6; N, 6.0. Found: C, 60.9; H, 5.7; N, 5.8.

3,9-Dioxa-6-thia-20,23-diazatetracyclo[9.8.4.0^{14,22}.0^{17,21}]tricoso-11,13,15,17,19(1),20,22-heptaene-2,10-dione (**10**).

3-Thiapentane-1,5-diol (**20**) (0.2 g, 1.6 mmoles) gave **10** (0.35 g, 60%) after 18 hours reflux as fawn plates, mp 239-241° dec (toluene); ^1H nmr (deuteriochloroform): 90 MHz, δ 3.40 (m, 4H, CH₂-5, 7), 4.65 (m, 4H, CH₂-4, 8), 7.90 (s, 2H, H-15, 16), 8.34 (d, 2H, J = 9 Hz, H-12, 19), 8.46 (d, 2H, J = 9 Hz, H-13, 18); ^{13}C nmr (deuteriochloroform): δ 34.7 (C-5, 7), 63.5 (C-4, 8), 122.5 (C-12, 19), 127.7 (C-15, 16), 129.5 (C-14, 17), 136.7 (C-13, 18), 145.2 (C-21, 22), 147.5 (C-1, 11), 164.9 (C-2, 10); ms: m/e (%) 354 (M⁺, 3), 296 (3), 295 (7), 269 (33), 223 (14), 179 (11), 178 (21), 89 (21),

86 (100).

Anal. Calcd. for C₁₈H₁₄N₂O₈S: C, 61.0; H, 4.0; N, 7.9; S, 9.1. Found: C, 61.3; H, 4.1; N, 7.7; S, 9.3.

3,12-Dioxa-6,9-dithia-23,26-diazatetracyclo[12.8.4.0^{17,25}.0^{20,24}]hexacos-14,16,18,20,22(1),23,25-heptaene-2,13-dione (**11**).

3,6-Dithiaoctane-1,8-diol (**21**) [12] (0.30 g, 1.6 mmoles) (in 1:1 dichloromethane/toluene) gave **11** (0.49 g, 72%) after 18 hours reflux as fawn needles, mp 209-210° (toluene); ^1H nmr (deuteriochloroform): 90 MHz, δ 3.15 (t, 4H, J = 5 Hz, CH₂-5, 10), 3.50 (s, 4H, CH₂-7, 8), 4.80 (t, 4H, J = 5 Hz, CH₂-4, 11), 7.90 (s, 2H, H-18, 19), 8.37 (d, 2H, J = 9 Hz, H-15, 22), 8.49 (d, 2H, J = 9 Hz, H-16, 21); ^{13}C nmr (deuteriochloroform): δ 29.4 (C-5, 10), 32.8 (C-7, 8), 69.8 (C-4, 11), 124.0 (C-15, 22), 128.4 (C-18, 19), 130.8 (C-17, 20), 137.3 (C-16, 21), 145.7 (C-24, 25), 148.0 (C-1, 14), 165.6 (C-2, 13); ms: m/e (%) 414 (M⁺, 7), 329 (26), 328 (74), 269 (46), 256 (10), 223 (18), 179 (16), 178 (22), 125 (17), 89 (31), 87 (100).

Anal. Calcd. for C₂₀H₁₆N₂O₈S₂: C, 58.0; H, 4.4; N, 6.8; S, 15.5. Found: C, 57.6; H, 4.4; N, 6.5; S, 15.2.

3,15-Dioxa-6,9,12-trithia-26,29-diazatetracyclo[15.8.4.0^{20,28}.0^{23,27}]nonacos-17,19,21,23,25(1),26,28-heptaene-2,16-dione (**12**).

3,6,9-Trithiaundecane-1,11-diol (**22**) [14] (0.40 g, 1.6 mmoles) (in dichloromethane) gave **12** (0.54 g, 69%) after 18 hours reflux as white crystals, mp 171-172° (benzene); ^1H nmr (deuteriochloroform): 90 MHz, δ 2.95 (s, 8H, CH₂-7, 8, 10, 11), 3.20 (t, 4H, J = 8 Hz, CH₂-5, 13), 4.70 (t, 4H, J = 8 Hz, CH₂-4, 14), 7.95 (s, 2H, H-21, 22), 8.43 (d, 2H, J = 9 Hz, H-18, 25), 8.51 (d, 2H, J = 9 Hz, H-19, 24); ^{13}C nmr (deuteriochloroform): δ 29.7 (C-5, 13), 32.7 (C-7, 11), 33.0 (C-8, 10), 64.8 (C-4, 14), 124.0 (C-18, 25), 128.4 (C-21, 22), 130.1 (C-20, 23), 137.5 (C-19, 24), 145.5 (C-27, 28), 147.9 (C-1, 17), 165.1 (C-2, 16); ms: m/e (%) 474 (M⁺, <1), 415 (2), 328 (17), 269 (16), 180 (22), 179 (16), 89 (16), 87 (50), 44 (100).

Anal. Calcd. for C₂₂H₂₂N₂O₈S₃: C, 55.7; H, 4.7; N, 5.9; S, 20.3. Found: C, 55.4; H, 4.9; N, 6.0; S, 20.0.

3,9,15-Trioxa-6,12-dithia-26,29-diazatetracyclo[15.8.4.0^{20,28}.0^{23,27}]nonacos-17,19,21,23,25(1),26,28-heptaene-2,16-dione (**13**).

6-Oxa-3,9-dithiaundecane-1,11-diol (**27**) (0.37 g, 1.6 mmoles) gave **13** (0.35 g, 47%) after 24 hours reflux as yellow needles, mp 174-175° (toluene); ^1H nmr (deuteriochloroform): 90 MHz, δ 2.85 (t, 4H, J = 6 Hz, CH₂-7, 11), 3.25 (t, 4H, J = 8 Hz, CH₂-5, 13), 3.78 (t, 4H, J = 6 Hz, CH₂-8, 10), 4.68 (t, 4H, J = 8 Hz, CH₂-4, 14), 7.90 (s, 2H, H-21, 22), 8.28 (d, 2H, J = 9 Hz, H-18, 25), 8.32 (d, 2H, J = 9 Hz, H-19, 24); ^{13}C nmr (deuteriochloroform): δ 30.8 (C-5, 13), 32.1 (C-7, 11), 65.2 (C-4, 14), 71.8 (C-8, 10),

123.9 (C-18, 25), 128.3 (C-21, 22), 130.8 (C-20, 23), 137.5 (C-19, 24), 145.5 (C-27, 28), 148.1 (C-1, 17), 165.3 (C-2, 16); ms: m/e (%) 458 (M⁺, 2), 440 (16), 269 (74), 179 (26), 178 (28), 125 (22), 89 (39), 87 (76), 86 (100).

Anal. Calcd. for C₂₂H₂₂N₂O₈S₂: C, 57.6; H, 4.8; N, 6.1; S, 14.0. Found: C, 58.0; H, 5.0; N, 6.0; S, 14.2.

6-Oxa-3,9-dithia-20,23-diazatetracyclo[9.8.4.0^{14,22}.0^{17,21}]tricoso-11,13,15,17,19(1),20,22-heptaene-2,10-dione (**14**).

3-Oxapentane-1,5-dithiol (**23**) (0.23 g, 1.6 mmoles) gave **14** (0.35 g, 58%) after 20 hours reflux as a yellow solid, mp 213-214° (acetonitrile); ^1H nmr (deuteriochloroform): 90 MHz, δ 3.75 (t, 4H, J = 6 Hz, CH₂-4, 8), 3.95 (t, 4H, J = 6 Hz, CH₂-5, 7), 7.90 (s, 2H, H-15, 16), 8.06 (d, 2H, J = 9 Hz, H-12, 19), 8.34 (d, 2H, J = 9 Hz, H-13, 18); ^{13}C nmr (deuteriochloroform): δ 31.1 (C-4, 8), 71.8 (C-5, 7), 118.6 (C-12, 19), 127.8 (C-16, 17), 130.1 (C-14, 17), 137.0 (C-13, 18), 143.9 (C-21, 22), 152.4 (C-1, 11), 194.9 (C-2, 20); ms: m/e (%) 370 (M⁺, 18), 342 (16), 297 (70), 238 (28), 237 (23), 222 (29), 180 (21), 179 (39), 178 (100), 151 (28), 103 (26), 89 (67). A satisfactory elemental analysis could not be obtained.

6,9-Dioxa-3,12-dithia-23,26-diazatetracyclo[12.8.4.0^{17,25}.0^{20,24}]hexacos-14,16,18,20,22(1),23,25-heptaene-2,13-dione (**15**).

3,6-Dioxaoctane-1,8-dithiol (**24**) [13] (0.30 g, 1.6 mmoles) gave **15** (0.35 g, 51%) after 24 hours reflux as yellow needles, mp 250-252° (carbon tetrachloride); ^1H nmr (deuteriochloroform): 90 MHz, δ 3.35 (t, 4H, J = 6

Hz, CH₂-4, 11), 3.65 (s, 4H, CH₂-7, 8), 3.85 (t, 4H, J = 6 Hz, CH₂-5, 10), 7.70 (s, 2H, H-18, 19), 8.02 (d, 2H, J = 9 Hz, H-15, 22), 8.18 (d, 2H, J = 9 Hz, H-16, 21); ¹³C nmr (deuteriochloroform): δ 29.9 (C-4, 11), 68.9 (C-5, 10), 70.2 (C-7, 8), 118.4 (C-15, 22), 128.0 (C-18, 19), 131.0 (C-17, 20), 137.2 (C-16, 21), 144.5 (C-24, 25), 151.3 (C-1, 14), 195.1 (C-2, 13); ms: m/e (%) 414 (M⁺, 23), 297 (54), 256 (34), 238 (42), 222 (23), 180 (26), 179 (40), 178 (100), 103 (35), 89 (69).

Anal. Calcd. for C₂₀H₁₈N₂O₄S₂: C, 57.7; H, 4.4; N, 6.7; S, 15.5. Found: C, 57.8; H, 4.3; N, 6.5; S, 15.6.

6,9,12-Trioxa-3,15-dithia-26,29-diazatetracyclo[15.8.4.0^{20,28}.0^{23,27}]nonacosia-17,19,21,23,25(1),26,28-heptaene-2,16-dione (**16**).

3,6,9-Trioxaundecane-1,11-dithiol (**25**) [13] (0.37 g, 1.6 mmoles) gave **16** (0.25 g, 33%) after 18 hours reflux as yellow crystals, mp 183-184° (dichloromethane/hexane); ¹H nmr (deuteriochloroform): 90 MHz, δ 3.55 (t, 4H, J = 6 Hz, CH₂-4, 14), 3.80 (s, 8H, CH₂-7, 8, 10, 11), 3.90 (t, 4H, J = 6 Hz, CH₂-5, 13), 7.95 (s, 2H, H-21, 22), 8.33 (d, 2H, J = 9 Hz, H-18, 25), 8.43 (d, 2H, J = 9 Hz, H-19, 24); ¹³C nmr (deuteriochloroform): δ 29.6 (C-4, 14), 70.6 (C-5, 13), 70.7 and 70.9 (C-7, 8, 10, 11), 119.2 (C-18, 25), 128.2 (C-21, 22), 131.2 (C-20, 23), 137.4 (C-19, 24), 144.9 (C-27, 28), 151.6 (C-1, 17), 194.1 (C-2, 16); ms: m/e (%) 458 (M⁺, 27), 425 (17), 397 (21), 297 (37), 238 (36), 222 (27), 180 (43), 179 (51), 178 (100), 133 (32), 103 (42), 89 (70).

Anal. Calcd. for C₂₂H₂₂N₂O₅S₂: C, 57.6; H, 4.8; N, 6.1; S, 14.0. Found: C, 57.6; H, 5.0; N, 5.8; S, 13.6.

3,6,9,12,15-Pentathia-26,29-diazatetracyclo[15.8.4.0^{20,28}.0^{23,27}]nonacosia-17,19,21,23,25(1),26,28-heptaene-2,16-dione (**17**).

3,6,9-Trithiaundecane-1,11-dithiol (**26**) [17] (0.45 g, 1.6 mmoles) (in dichloromethane) gave **17** (0.28 g, 34%) after 18 hours reflux as pale yellow crystals, mp 197-198° (benzene); ¹H nmr (deuteriochloroform): 90 MHz, δ 2.85 (s, 8H, CH₂-7, 8, 10, 11), 3.00 (t, 4H, J = 7 Hz, CH₂-5, 13), 3.40 (t, 4H, J = 7 Hz, CH₂-4, 14), 7.93 (s, 2H, H-21, 22), 8.25 (d, 2H, J = 9 Hz, H-18, 25), 8.40 (d, 2H, J = 9 Hz, H-19, 24); ¹³C nmr (deuteriochloroform): δ 28.7 (C-4, 14), 31.9 (C-5, 13), 32.2 and 32.4 (C-7, 8, 10, 11), 119.0 (C-18, 25), 128.3 (C-21, 22), 131.3 (C-20, 23), 137.5 (C-19, 24), 144.7 (C-27, 28), 151.2 (C-1, 17), 193.7 (C-2, 16); ms: m/e (%) 506 (M⁺, 2), 447 (5), 446 (5), 266 (13), 238 (23), 180 (17), 179 (24), 178 (45), 151 (12), 119 (23), 89 (18), 40 (100).

Anal. Calcd. for C₂₂H₂₂N₂O₅S₃: C, 52.1; H, 4.4; N, 5.5; S, 31.6. Found: C, 51.6; H, 4.7; N, 5.3; S, 31.9.

2,9-Bis[2'-hydroxy-carboethoxy]-1,10-phenanthroline Monohydrate (**30**).

1,10-Phenanthroline-2,9-dicarbonyl chloride [11] (**29**) (0.2 g, 0.7 mmole) was added in one portion to ethane-1,2-diol (5 ml). The mixture was then heated at 100° for 1 hour, allowed to cool, and then poured onto cracked ice precipitating the diol **30** (0.2 g, 85%) as the monohydrate, mp 234-235° (methanol); ¹H nmr (DMSO-d₆): 90 MHz, δ 3.40 (s, 2H, H₂O), 3.85 (dt, 4H, J = 6 and 6 Hz, CH₂OH), 4.40 (t, 4H, J = 6 Hz, CO₂CH₂), 5.05 (t, 2H, J = 6 Hz, OH), 8.20 (s, 2H, H-5, 6), 8.45 (d, 2H, J = 9 Hz, H-3, 8), 8.75 (d, 2H, J = 9 Hz, H-4, 7); ¹³C nmr (DMSO-d₆): δ 58.9 (CH₂OH), 67.3 (CO₂CH₂), 123.8 (C-3, 8), 128.4 (C-5, 6), 130.5 (C-4a, 6a), 138.0 (C-4, 7), 145 (C-10a, b), 147.9 (C-2, 9), 164.9 (C=O); ms: m/e (%) 355 (M⁺-1, 10), 326 (29), 313 (48), 296 (16), 269 (18), 268 (100), 180 (29), 179 (24), 178 (38), 177 (18), 89 (16).

Anal. Calcd. for C₁₈H₁₆N₂O₆·H₂O: C, 57.8; H, 4.8; N, 7.5. Found: C, 57.8; H, 5.0; N, 7.6.

2,7-Bis[2'-hydroxy-carboethoxy]-1,8-naphthyridine (**31**).

By the method described for the synthesis of the diol **30**, 1,8-naphthyridine-2,7-dicarbonyl chloride [11] (0.8 g, 3 mmoles) was treated with excess ethane-1,2-diol. This gave the diol **31** (0.8 g, 83%) as white needles, mp 229-230° (ethanol); ¹H nmr (DMSO-d₆): 90 MHz, δ 3.75 (dt, 4H, J = 6 and 6 Hz, CH₂OH), 4.38 (t, 4H, J = 6 Hz, CO₂CH₂), 4.95 (t, 2H, J = 6 Hz, OH), 8.20 (d, 2H, J = 9 Hz, H-3, 6), 8.65 (d, 2H, J = 9 Hz, H-4, 5); ¹³C nmr (DMSO-d₆): δ 58.8 (CH₂OH), 67.6 (CO₂CH₂), 123.1 (C-3, 6), 125.2 (C-4a), 139.5 (C-4, 5), 151.7 (C-2, 7), 153.6 (C-8a), 164.4 (C=O); ms: m/e (%) 305 (M⁺-1, 6), 275 (25), 263 (38), 246 (29), 218 (100), 217 (33), 174 (18), 156 (26), 128 (41).

Anal. Calcd. for C₁₄H₁₄N₂O₆: C, 54.9; H, 4.6; N, 9.2. Found: C, 55.1; H, 4.7; N, 9.0.

3,6,14,17-Tetraoxa-28,31,32-triazapentacyclo[17.8.4.1^{8,12}.0^{21,30}.0^{25,29}]dotriaconta-8,10,12(32),19,21,23,25,27(1),28,30-decaene-2,7,13,18-tetraene Monohydrate (**18**).

A solution of 2,9-bis[2'-hydroxy-carboethoxy]-1,10-phenanthroline (**30**) (0.50 g, 1.4 mmoles) in benzene (1 l) was refluxed for 2 hours under Dean-Stark conditions. To this was added, dropwise over 1 hour, a solution of 2,6-pyridinedicarbonyl chloride (0.28 g, 1.4 mmoles) in benzene (200 ml). The mixture was maintained at reflux for 24 hours, filtered and the solvent removed, *in vacuo*, to yield **18** (0.5 g, 76%) as the monohydrate, mp 298-300° dec (acetonitrile); ¹H nmr (199.5 MHz, deuteriochloroform): δ 3.38 (s, 2H, H₂O), 4.73 and 5.10 (m's, 8H, CH₂-4, 5, 15, 16), 7.90 (s, 2H, H-23, 24), 7.95 (t, 1H, J = 8 Hz, H-10), 8.30 (d, 2H, J = 8 Hz, H-9, 10), 8.39 (d, 2H, J = 9 Hz, H-20, 27), 8.52 (d, 2H, J = 9 Hz, H-21, 26); ¹³C nmr (deuteriochloroform): δ 63.3 and 65.3 (C-4, 5, 15, 16), 124.3 (C-20, 27), 128.4 (C-9, 11, 23, 24), 130.8 (C-22, 25), 137.4 (C-21, 26), 138.3 (C-10), 145.5 (C-29, 30), 147.6 and 147.8 (C-1, 8, 12, 19), 164.9 and 165.7 (C-2, 7, 13, 18); ms: m/e (%) 487 (M⁺, 2), 459 (3), 373 (27), 372 (100), 180 (20), 179 (23), 178 (23), 150 (12), 128 (12), 89 (22).

Anal. Calcd. for C₂₈H₁₇N₃O₈·H₂O: C, 59.4; H, 3.6; N, 8.4. Found: C, 59.7; H, 3.6; N, 8.4.

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