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Synthesis and Crystal Structures of Macrocycles Containing 2-Imino-5-mercapto-3*H*-1,3,4-thiadiazolines†

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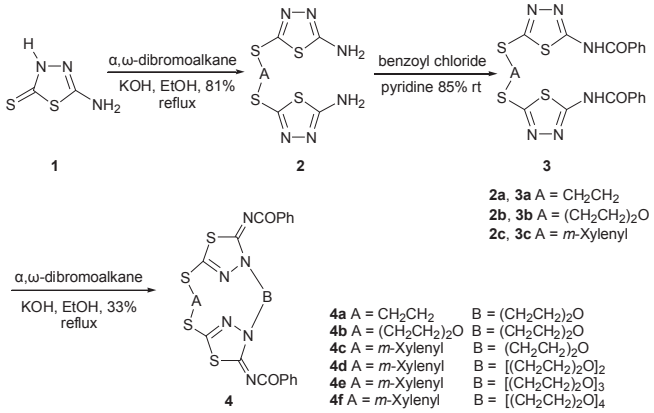
The design and synthesis of new class of macrocycles with novel shapes and heterocyclic moiety continue to be the topics of current interest,[1] because they can act as a ligand in asymmetric catalysis[2] and as a host molecule for the incorporation of guest molecule or ions.[3]

While 1,3,4-thiadizoles have received attention as a sulfur donor subunit,[4] very little is known about the corporation of heterocylic compounds into macrocyclic compounds.[1a,5] As part of our systematic efforts1[6] aimed at the synthesis of new macrocyclic ligands fused with 1,3,4-thiadiazoles, we reported[6e] our attempt to synthesize novel macrocycles that incorporate 2-imino-5-mercapto-3*H*-1,3,4-thiadiazolines. Imino group and mercapto group of 2-imino-5-mercapto-3*H*-1,3,4-thiadiazoline might show novel role when the molecule works as a host for the corporation of a guest molecule.

As part of the ongoing study of heterocycles containing 2-imino-5-mercapto-3*H*-1,3,4-thiadiazolines, we report here the synthesis of macrocycles (**4a**, **4b**, **4c**, **4d**, **4e**, and **4f**) containing two 2-imino-5-mercapto-3*H*-1,3,4-thiadizoline subunits linked at the 3- and 5-positions of the heterocyclic unit. The macrocycles were prepared from **1**, as shown in Scheme 1. The spacers between 5 and 5' are CH_2CH_2, $(CH_2CH_2)_2O$, and *m*-xylene, respectively, and the 3-3' spacer is $(CH_2CH_2)_2O$, $[(CH_2CH_2)_2O]_2$, $[(CH_2CH_2)_2O]_3$ and $[(CH_2CH_2)_2O]_4$, respectively. The crystal structures of the two compounds (**4b** and **4d**) were determined by interpreting X-ray diffraction patterns.



Compound (**1**) was regiospecifically *S*-alkylated under basic conditions, to give 5-amino-2-alkylthio-1,3,4-thiadiazole (**2**).[6e,7] In addition, 5-substituted 2-acylamino-1,3,4-thiadiazoles (**3**) were also regiospecifically alkylated at the N(3) position under basic conditions to yield a single 3-alkylated *endo*-product.[6e,8] These reactions were used for macrocycle ring formation.

Compound **2** was synthesized from **1** according the above procedure with an appropriate α,ω-dibromoalkane in the presence of KOH in ethanol to yield the *S*-alkylated dimer (**2**). Benzolylation of the amino group of **2** (7.2 - 7.3 ppm) was performed to create **3**. As evidenced by spectroscopic data, this reaction regiospecifically alkyalted the N(3) position of **3** at the NH_2 (*endo*-product), as has been observed in the benzoylation of 2-amino-5-alkylthio-1,3,4-thiadiazoles.[6e,8] In **3b**, the NH_2 signals characteristic of compound **2b** were replaced by typical NHCOPh signals appearing at 13.12 and at 8.12-7.54, 165.2, 133.0, 131.2, 128.6, and at 128.3 ppm in the ^{1}H and ^{13}C NMR spectra, respectively. In the ^{13}C NMR spectrum, the chemical shifts of C(2) and C(5) in the 1,3,4-thiadiazole of **2b** (150.0 and 169.5 ppm) changed to those of **3b** (159.5 and 159.0 ppm), as observed for 2-amino-5-alkylthio-1,3,4-thiadizole and 2-benzoylamino-5-alkylthio-1,3,4-thiadiazole. Furthermore, a characteristic carbonyl band was observed in the IR spectrum at 1661 cm^{-1} and in the ^{13}C NMR spectrum at 165.2 ppm. As expected, the cyclization reaction, which was facilitated by *N*,*N*-bisalkylation between the benzolylated compound (**3**) and the appropriate α,ω-dibromoalkane, proceeded regiospecifically at the position 3 nitrogen (*endo*-product), as in 5-substituted 2-benzoylamino-1,3,4-thiadiazoles.[6e,8] The structures of the macrocycles were firmly established by ^{1}H and ^{13}C NMR, IR, MS, and elemental analyses. The successful macrocyclization of **3b** to **4b** was supported by evidence of *N*-alkylation, provided by the appearance of a NCH_2 shift replacing that of NH at 4.57 and 50.9 ppm in the ^{1}H and ^{13}C NMR spectra, respectively. *N*-Alkylation at the 3 position was clearly shown by the ^{13}C NMR spectrum; the chemical shifts of C(2) and C(5) in 1,3,4-thiadiazole and the carbonyl carbon of **4b** appeared at 154.6, 165.9, and 174.0 ppm, respectively. The chemical shift change between **3b** and **4b** is exactly the same as that observed between 2-benzoylamino-5-alkylthio-1,3,4-thiadiazole and 2-benzoylimno-3-alkyl-5-alkylthio-3*H*-1,3,4-thiadiazole.[6e,8] In addition to this evidence, a strong imido band at 1603 cm^{-1} was seen in the IR spectrum, representing a shift to a shorter wavenumber than that of the amide (1661 cm^{-1}) of **3b**. The molecular ion peak (*m*/*z* 571) and microanalytical data support the molecular formula $C_{26}H_{26}N_6O_4S_4$. Macrocycle **4b** was derived from **1** with an overall yield of 15 - 18% after recrystallization. The

†This paper is dedicated to the memory of Prof. Chi-Sun Hahn.

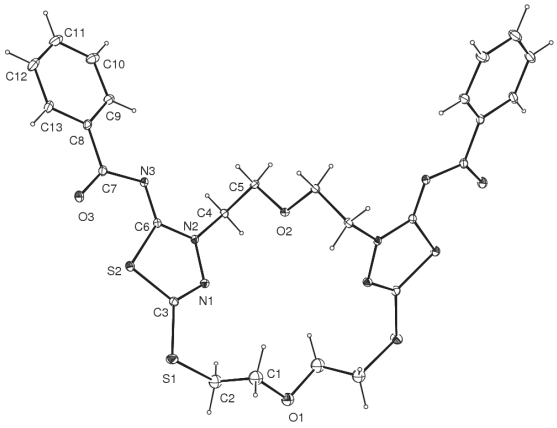


Figure 1. ORTEP diagram of macrocycle **4b** showing the atom numbering scheme with 30% probability ellipsoids. The C_2-axis passes through atoms O1 and O2: S1-C3 1.742(5); S2-C3 1.744(5); S2-C6 1.756(5); N1-C3 1.288(6); N1-N2 1.377(6); N2-C4 1.465(6); N2-C6 1.339(6); N3-C6 1.304(6); O3-C7 1.231(6); N3-C7 1.378(6); C3-S2-C6 87.6(2); C3-N1-N2 109.9(4); N1-N2-C6 118.1(4); N2-C6-S2 108.8(4).

structure of macrocycle **4b**, determined by X-ray diffraction, is shown in Figure 1.

The ORTEP diagrams of macrocyles **4b** and **4d** including the atomic numbering scheme are shown in Figures 1 and 2, respectively. The crystallographic data was as follows:

4b; $C_{26}H_{26}N_6O_4S_4$, M_w = 614.77, Monoclinic, *C*2/*c*, a = 20.252(3) Å, b = 9.7506(9) Å, c = 14.740(3) Å, ß = 99.35(2)°, V = 2872.0(8) Å^3, Z = 4 , D_{calc} = 1.422 Mg/m^3, θ_{max} = 25.0°, 2517 reflections (R_{int} = 0.0196), 169 parameters refined. Goodness of Fit = 1.104, Final R indices [$I > 2\sigma(I)$]: R_1 = 0.0772, wR_2 = 0.1894, all data: R_1 = 0.1154, wR_2 = 0.2137.

4d; $C_{31}H_{27}Cl_3N_6O_3S_4$, Monoclinic, *P*2$_1$/n, a = 13.895(3) Å, b = 17.117(5) Å, c = 15.498(3) Å, ß= 108.21(2)°, V = 3501.4 (15) Å^3, Z = 4 , D_{calc} = 1.453 Mg/m^3, θ_{max} = 27.5°. Goodness of Fit = 1.021, Final R indices [$I > 2\sigma(I)$]: R_1 = 0.0852, wR_2 = 0.2195, all data: R_1 = 0.1770, wR_2 = 0.2837.

As shown in Figure 1, the X-ray single crystal structure of **4b** shows an 18-membered macrocycle composed of the C-N-N atoms of 1,3,4-thiadiazoline rings, one *syn*-ethyl ether, one *anti* ethyl ether, and one *S-anti* conformation within the ethylene. Two of the 1,3,4-thiadiazoline rings are planar. Compound **4b** crystallizes in the centrosymmetric space group *C*2/*c*. Both O1 and O2 atoms are situated on a crystallographic two-fold rotation axis. In the 1,3,4-thiadiazoline subunits, the bond distances of N1-C3(1.288(6) Å) and N3-C6(1.304(6) Å) are shorter than other bond distances (N1-N2; 1.377(6) Å, N2-C6; 1.339(6) Å, N2-C4; 1.465(6) Å), which indicates double bond character. The S-C bond distances [1.742(2)-1.756(5) Å] are within the normal range reported for analogous macrocyclic compounds.[9] The single crystal structure of **4d** is shown in Figure 2. This macrocycle also forms an 18-membered ring. The bond distances and angles are almost identical to those of **4b**. As shown in (b), a pseudo-mirror plane exists through the middle of the molecule (the plane involving O3, C14, and C25 atoms). Each of the subunits containing a 5-membered thiadiazoline ring and

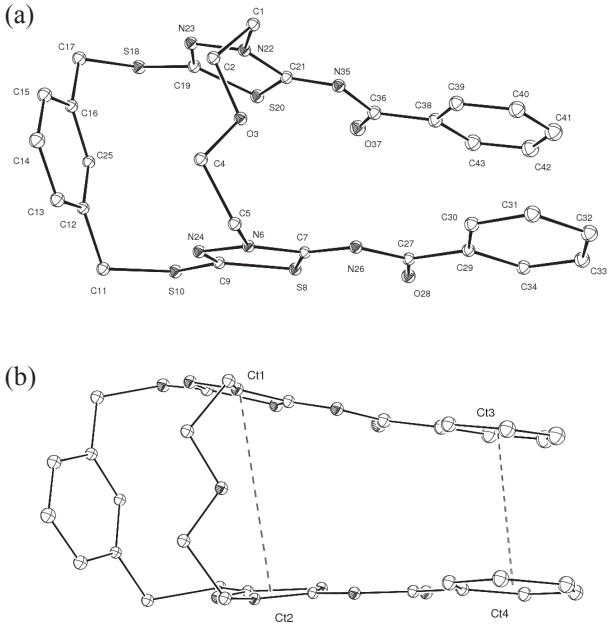


Figure 2. (a) ORTEP diagram of macrocycle **4d** showing the atom numbering scheme with 30% probability ellipsoids. H atoms and solvent $CHCl_3$ molecules are omitted for clarity: S10-C9 1.739(4); S8-C9 1.752(5); S8-C7 1.752(4); N6-C7 1.346(5); N6-N24 1.383(5); N6-C5 1.461(5); N24-C9 1.286(6); C7-N26 1.310(5); O28-C27 1.248 (5); N26-C27 1.372(5); C7-S8-C9 88.1(2); C9-N24-N6 109.3(3); C7-N6-N24 117.9(3); N6-C7-S8 108.6(3). (b) ORTEP diagram showing the relationship of rings and subunits (Ct1-Ct2 4.788 Å; Ct3-Ct4 4.247 Å, Ct refers to the centroid of ring). There is a pseudo-mirror plane passing through the middle of molecule.

phenyl ring is one conjugated system forming a single plane. The planes are tilted such that the rings approach each other as they extend from the macrocycle. The distances between these subunits are 4.788 Å and 4.247 Å for Ct1-Ct2 and Ct3-Ct4, respectively. These distances are too long for intramolecular π-π overlap between delocalized π electrons.[10]

Experimental Section

The synthesis of 5-amino-3*H*-1,3,4-thiadiazoline-5-thione (1)[11] 1,2-bis[(5-amino-1,3,4-thiadiazol-2-yl)thio]ethane (**2a**),[6e] 1,5-bis[(5-amino-1,3,4-thiadiazol-2-yl)thio]-3-oxa-pentane (**2b**),[6e] α,α'-bis[(5-amino-1,3,4-thiadiazol-2-yl)thio]-*m*-xylene (**2c**),[6e] and di(ethylene glycol) dimethanesulfonate[12] were followed the previous procedures.

1,2-Bis[(5-benzoylamino-1,3,4-thiadiazol-2-yl)thio]ethane (3a). To a solution of 1,2-bis[(5-amino-1,3,4-thiadiazol-2-yl) thio]ethane (**2a**) (2 g, 6.84 mmole) in dry pyridine (50 mL) was added benzoyl chloride (2.84 g, 20.52 mmole), in one portion. The reaction mixture was stirred at room temperature for 4 hours. The pyridine was evaporated under reduced pressure to afford solid residue, which was collected by filtration and washed with acetone and water. The product was dried under high vacuum to give 2.97 g (5.95 mmole 87%) of colorless powder. The crude product was recrystallized from DMSO.

mp 292 - 293 °C (dec.). IR (KBr, cm^{-1}) 3171, 1670 (C=O), 1529, 1293. ^{1}H NMR (300 MHz, DMSO-d_6) δ 12.81 (2H, br,

2NH), 8.11-8.08 (4H, m, Ph), 7.67-7.51 (6H, m, Ph), 3.66 (4H, s, SCH_2). ^{13}C NMR (75 MHz, DMSO-d_6) δ 165.0 (C=O), 159.6 (N-C=N), 157.4 (S-C-S), 132.4, 131.1, 128.0, 127.9 (Ph), 33.3 (SCH_2).

1,5-Bis[(5-benzoylamino-1,3,4-thiadiazol-2-yl)thio]-3-oxapentane (3b). The synthesis of **3b** followed the same procedure of preparation of **3a**.

Yield 71%, mp 232 - 233 °C. R_f 0.66 (*n*-hexane : ethyl acetate : ethanol = 5 : 3 : 1). IR (KBr, cm^{-1}) 3162, 2921, 1661 (C=O), 1532, 1297. ^1H NMR (400 MHz, DMSO-d_6) δ 13.12 (2H, br, 2NH), 8.12-8.10 (4H, m, Ph), 7.68-7.65 (2H, m, Ph), 7.58-7.54 (4H, m, Ph), 3.80 (4H, t, OCH_2, J = 6 Hz), 3.48 (4H, t, SCH_2, J = 6 Hz). ^{13}C NMR (100 MHz, DMSO-d_6) δ 165.3 (C=O), 159.5 (N-C=N), 159.0 (S-C-S), 133.0, 131.2, 128.6, 128.3 (Ph), 69.6 (OCH_2), 33.1 (SCH_2).

α,α'-Bis[(5-benzoylamino-1,3,4-thiadiazol-2-yl)thio]-*m*-xylene (3c). The synthesis of **3c** followed the same procedure of preparation of **3a**.

Yield 97 %, mp 265 - 266 °C (recrystallization from DMF). R_f 0.63 (*n*-hexane : ethyl acetate : ethanol = 5 : 3 : 1). IR (KBr, cm^{-1}) 3167, 2914, 1695 (C=O), 1559, 1308. ^1H NMR (600 MHz, DMSO-d_6) δ 13.08 (2H, br, 2NH), 8.09-8.07 (4H, dd, benzoyl), 7.66-7.64 (2H, td, benzoyl), 7.56-7.53 (4H, t, benzoyl), 7.47 (1H, br, Ph), 7.35-7.32 (3H, m, Ph), 4.50 (4H, s, $2SC\underline{H}_2Ph$). ^{13}C NMR (150 MHz, DMSO-d_6) δ 165.1 (C=O), 159.8 (N-C=N), 158.3 (S-C-S), 137.0, 133.0, 131.2, 129.6, 128.8, 128.6, 128.4, 128.3 (Ph), 37.4 ($S\underline{C}H_2Ph$).

Tri(ethylene glycol) dimethanesulfonate. The synthesis of tri(ethylene glycol) dimethanesulfonate followed the same procedure of preparation of di(ethylene glycol) dimethanesulfonate[10]

Yield 90%, oil, IR (neat, cm^{-1}) 3026, 2939, 1349, 1173. ^1H NMR (400 MHz, $CDCl_3$) δ 4.37-4.35 (4H, m, $2OCH_2$), 3.77-3.76 (4H, m, $2OCH_2$), 3.69 (4H, s, $2OCH_2$), 3.08 (6H, s, $2CH_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 70.1, 69.1, 68.6 (OCH_2), 37.2 (CH_3).

Tetra(ethylene glycol) dimethanesulfonate. Yield 89%, oil. IR (neat, cm^{-1}) 3023, 2874, 1349, 1173. ^1H NMR (400 MHz, $CDCl_3$) δ 4.36-4.35 (4H, m, $2OCH_2$), 3.76-3.75 (4H, m, $2OCH_2$), 3.66-3.63 (8H, m, $4OCH_2$), 3.08 (6H, s, $2CH_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 69.9, 69.7, 69.1, 68.3 (OCH_2), 36.9 (CH_3).

Penta(ethylene glycol) dimethanesulfonate. Yield 85%, oil. IR (neat, cm^{-1}) 3024, 2875, 1349, 1173. ^1H NMR (400 MHz, $CDCl_3$) δ 4.38-4.36 (4H, m, $2OCH_2$), 3.78-3.75 (4H, m, $2OCH_2$), 3.67-3.62 (12H, m, $6OCH_2$), 3.09 (6H, s, $2CH_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 70.0, 70.0, 69.9, 69.1, 68.4 (OCH_2), 37.1 (CH_3).

1,5-Bis[(2,2'-ethylenedithio)-5-benzoylimino-1,3,4-thiadiazolin-4-yl]-3-oxa-pentane (4a). 1,2-Bis[(5-benzoylamino-1,3,4-thiadiazol-2-yl)thio]ethane (**3a**) (0.5 g, 1 mmole) was dissolved in KOH (0.17 g, 3 mmole)-ethanol (200 mL) solution. 2-Bromoethyl ether (0.23 g, 1 mmole)-ethanol (50 mL) was slowly added to the solution. The reaction mixture was heated under reflux for 24 hours. The solvent was evaporated under reduced pressure. The residue was dissolved in methylene chloride to filter off the undissolved materials. Methylene chloride was evaporated under reduced pressure and the crude product was crystallized from methanol to give 0.21 g (0.37 mmole, 37%) of pale yellow crystal.

mp 176 - 178 °C. R_f 0.41 (*n*-hexane : ethyl acetate = 7 : 3). IR (KBr, cm^{-1}) 1605, 1570, 1514, 1471.^1H NMR (400 MHz, $CDCl_3$) δ 8.28-8.26 (4H, m, Ph), 7.53-7.42 (6H, m, Ph), 4.60 (4H, t, OCH_2, J = 5.0 Hz), 3.98 (4H, t, NCH_2, J = 5.0 Hz), 3.60 (4H, s, SCH_2). ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.1 (C=O), 165.9 (N-C=N), 153.2 (S-C-S), 135.7, 132.2, 129.4, 128.1 (Ph), 67.8 (OCH_2), 51.5 (NCH_2), 33.88 (SCH_2). FAB-MS ($CHCl_3$) m/z 571 ($[M+1]^+$), 570 ($C_{24}H_{22}N_6O_3S_4$, M^+). Anal. Calcd. for $C_{24}H_{22}N_6O_3S_4$: C, 50.50; H, 3.84; N, 14.73; S, 22.48. Found: C, 55.52; H, 3.80; N, 14.70; S, 22.50.

1,5-Bis[2,2'-(3-oxa-pentylenedithio)-5-benzoylimino-1,3,4-thiadiazolin-4-yl]-3-oxa-pentane (4b). Yield 36 %, mp 249 - 251 °C (recrystallization from chloroform/methanol (1 : 1, v/v)). R_f 0.71 (*n*-hexane : ethyl acetate : ethanol = 5 : 3 : 1).IR (KBr, cm^{-1}) 1603, 1568, 1509, 1486. ^1H NMR (300 MHz, $CDCl_3$) δ 8.26-8.23 (4H, m, Ph), 7.51-7.38 (6H, m, Ph), 4.57 (4H, t, $OC\underline{H}_2CH_2N$, J = 5.0 Hz), 4.00 (4H, s, $OCH_2C\underline{H}_2N$, J = 5.0 Hz), 3.89 (4H, t, $OC\underline{H}_2CH_2S$, J = 6.9 Hz), 3.33 (4H, t, $OCH_2C\underline{H}_2S$, J = 6.93 Hz). ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.0 (C=O), 165.9 (N-C=N), 154.6 (S-C-S), 135.6, 132.1, 129.4, 128.1 (Ph), 68.9 ($O\underline{C}H_2CH_2N$), 67.7 ($OCH_2\underline{C}H_2N$), 50.9 ($O\underline{C}H_2CH_2S$), 31.8 ($OCH_2\underline{C}H_2S$). FAB-MS m/z 615 ($[M+1]^+$), 614 ($C_{26}H_{26}N_6O_4S_4$, M^+, Anal. Calcd for $C_{26}H_{26}N_6O_4S_4$: C, 50.86; H, 4.27; N, 13.69; S, 20.89. Found: C, 50.90; H, 4.25; N, 13.70; S, 20.90.

1,5-Bis[2,2'-(1,3-phenylenedimethylenedithio)-5-benzoylimino-1.3.4-thiadiazolin-4-yl]-3-oxa-pentane (4c). Yield 31%, mp 183 - 185 °C (recrystallization from CH_2Cl_2/*n*-hexane (1 : 1, v/v)). R_f 0.63 (*n*-hexane : ethyl acetate : ethanol = 5 : 3 : 1). IR (KBr, cm^{-1}) 1605, 1570, 1509, 1468. ^1H NMR (600 MHz, $CDCl_3$) δ 8.16 (4H, d, benzoyl), 7.63 (1H, s, Ph), 7.41 (2H, t, benzoyl), 7.33 (2H, t, benzoyl), 7.26-7.23 (3H, m, Ph), 4.46 (4H, t, OCH_2), 4.32 (4H, s, $SC\underline{H}_2Ph$), 3.75 (4H, t, NCH_2). ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.9 (C=O), 166.2 (N-C=N), 154.0 (S-C-S), 137.3, 135.6, 131.9, 129.3, 128.5, 128.3, 127.9 (Ph), 67.5 (OCH_2), 50.2 (NCH_2), 36.8 ($S\underline{C}H_2Ph$). FAB-MS ($CHCl_3$) m/z 647 ($[M+1]^+$), 646 ($C_{30}H_{26}N_6O_3S_4$, M^+). Anal. Calcd for $C_{30}H_{26}N_6O_3S_4$: C, 55.70; H, 4.05; N, 12.99; S, 19.83. Found: C, 55.65; H, 3.98; N, 13.01; S, 19.90.

1,5-Bis[2,2'-(1,3-phenylenedimethylenedithio)-5-benzoylimino-1.3.4-thiadiazolin-4-yl]-3,6-dioxa-octane (4d). Yield 52%, mp 195 - 196 °C. R_f 0.66 (*n*-hexane : ethyl acetate : ethanol = 5 : 3 : 1). IR (KBr, cm^{-1}) 1605, 1570, 1509, 1468. ^1H NMR (600 MHz, $CDCl_3$) δ 8.29-8.25 (4H, d, benzoyl), 7.52-7.50 (3H, m, Ph and benzoyl), 7.45-7.41 (4H, m, benzoyl), 7.31-7.29 (3H, m, Ph), 4.60 (4H, t, $OC\underline{H}_2CH_2N$, J = 5.5 Hz), 4.37 (4H, s, $SC\underline{H}_2Ph$), 3.93 (4H, t, $OCH_2C\underline{H}_2N$, J = 5.5 Hz), 3.58 (4H, s, OCH_2CH_2O). ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.1 (C=O), 166.2 (N-C=N), 154.3 (S-C-S), 136.5, 135.8, 132.1, 130.6, 129.4, 129.2, 128.3, 128.1 (Ph), 70.3 (OCH_2CH_2O), 67.9 ($O\underline{C}H_2CH_2N$), 50.1($OCH_2\underline{C}H_2N$), 37.1 ($S\underline{C}H_2Ph$). FAB-MS ($CHCl_3$) m/z 691 ($[M+1]^+$), 690 ($C_{32}H_{30}N_6O_4S_4$, M^+). Anal. Calcd for $C_{32}H_{30}N_6O_4S_4$: C, 55.62; H, 4.38; N, 12.17; S, 18.57. Found: C, 55.60; H, 4.40; N, 13.00; S, 18.54.

1,5-Bis[2,2'-(1,3-phenylenedimethylenedithio)-5-benzoylimino-1,3,4-thiadiazolin-4-yl]-3,6,9-trioxa-undecane (4e). Yield, 27%, mp 163 - 164 °C. R_f 0.65 (*n*-hexane : ethyl acetate : ethanol = 5 : 3 : 1). IR (KBr, cm^{-1}) 1603, 1568, 1509, 1472. ^1H NMR (600 MHz, $CDCl_3$) δ 8.30-8.28 (4H, d, benzoyl), 7.53-

7.50 (2H, m, benzoyl), 7.46-7.43 (5H, m, Ph and benzoyl), 7.33-7.31 (3H, m, Ph), 4.63 (4H, t, OCH_2CH_2N, J = 5.6 Hz), 4.37 (4H, s, SCH_2Ph), 3.96 (4H, t, OCH_2CH_2N, J = 5.6 Hz), 3.58-3.56 (4H, m, OCH_2CH_2O), 3.52-3.50 (4H, m, OCH_2CH_2O). ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.1 (C=O), 166.1 (N-C=N), 154.3 (S-C-S), 136.5, 135.8, 132.1, 129.9, 129.5, 129.3, 128.5, 128.1 (Ph), 70.7 (OCH_2CH_2O), 70.6 (OCH_2CH_2O), 67.8 (OCH_2CH_2N), 50.5(OCH_2CH_2N), 37.3 (SCH_2Ph). FAB-MS ($CHCl_3$) m/z 735 ($[M+1]^+$), 734 ($C_{34}H_{34}N_6O_5S_4$, M^+). Anal. Calcd for $C_{34}H_{34}N_6O_5S_4$: C, 55.56; H, 4.66; N, 11.44; S, 17.45. Found: C, 55.57; H, 4.64; N, 11.40; S, 17.50.

1,5-Bis[2,2'-(1,3-phenylenedimethylenedithio)-5-benzoylimino-1,3,4-thiadiazolin-4-yl]-3,6,9,12-tetraoxa-tetradecane (4f). Yield 13%, mp 152 - 154 °C. R_f 0.57 (*n*-hexane : ethyl acetate : ethanol = 5 : 3 : 1). IR (KBr, cm^{-1}) 1603, 1568, 1499, 1481. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.30-8.28 (4H, d, benzoyl), 7.53-7.50 (2H, m, benzoyl), 7.46-7.43 (5H, m, Ph and benzoyl), 7.32-7.31 (3H, m, Ph), 4.63 (4H, t, OCH_2CH_2N, J = 5.6 Hz), 4.37 (4H, s, SCH_2Ph), 3.97 (4H, t, OCH_2CH_2N, J = 5.6 Hz), 3.60-3.59 (4H, m, OCH_2CH_2O), 3.55-3.53 (4H, m, OCH_2CH_2O), 3.51 (4H, s, OCH_2CH_2O). ^{13}C NMR (150 MHz, $CDCl_3$) δ 174.1 (C=O), 166.1 (N-C=N), 154.2 (S-C-S), 136.6, 135.7, 132.1, 129.8, 129.4, 129.2, 128.5, 128.1 (Ph), 70.7(OCH_2CH_2O), 70.5 (OCH_2CH_2O), 70.5 (OCH_2CH_2O), 67.7 (OCH_2CH_2N), 50.4 (OCH_2CH_2N), 37.2 (SCH_2Ph). FAB-MS ($CHCl_3$) m/z 779 ($[M+1]^+$), 778 ($C_{36}H_{38}N_6O_6S_4$, M^+). Anal. Calcd for $C_{36}H_{38}N_6O_6S_4$: C, 55.50; H, 4.92; N, 10.79; S, 16.47. Found: C, 55.03; H, 4.90; N, 10.82; S, 16.50.

X-Ray data of macrocycles (4b and 4d). Colorless crystals were obtained by slow evaporation from CH_2Cl_2/*n*-hexane (1:1, v/v) and CH_3Cl/*n*-hexane (1:1, v/v) for **4b** and **4d**, respectively. X-ray intensity data were collected on a CAD-4 diffractometer equipped with graphite monochromated Mo Kα radiation (λ = 0.71073 Å) at 295 K. The unit cell dimensions were determined on the basis of 25 reflections in the range of $11.41^o < \theta < 13.73^o$ for **4b** and $1.82^o < \theta < 27.51^o$ for **4d**. The data was collected by the $\omega/2\theta$ scan mode. Structure was solved by applying the direct method using a SHELXS-97 and refined by a full-matrix least-squares calculation on F^2 using SHELXL-97.[13] All non-hydrogen atoms were refined anisotropically. Hydrogen atoms were added in calculated positions.

Crystallographic data for the structures reported here have been deposited with the Cambridge Crystallographic Data Centre (Deposition No. CCDC-759400). The data can be obtained free of charge via www.ccdc.cam.ac.uk/deposit (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; Fax: +44-1223 336033; E-mail: deposit@ccdc.cam.ac.uk).

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