Supporting Information

Sulfur–Containing Amide–Based [2]Rotaxanes and Molecular Shuttles

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Contents

1. General Remarks

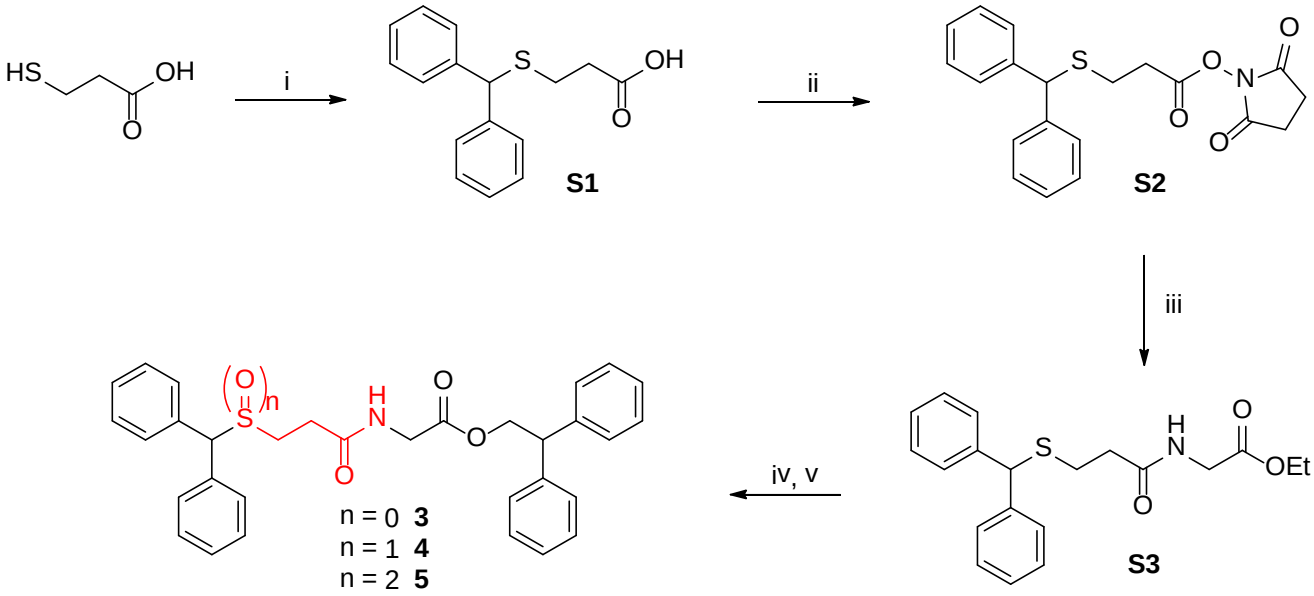
Unless stated otherwise, all reagents and anhydrous solvents were purchased for Aldrich Chemicals and used without further purification. *p*-Xylylene diamine, was distilled under reduced pressure and then recrystallised from ether. 3,3-Diphenylpropane-1-thiol was prepared as described by Wilkinson *et al*.[S1] Column chromatography was performed using Kiesegel C60 (Merck, Germany) as the stationary phase. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker AV 300 or Bruker AV 400 instrument, at a constant temperature of 25 ˚C, or at the temperature specified. Chemical shifts are reported in parts per million from low to high field and referenced to TMS. Coupling constants (*J*) are reported in hertz. Standard abbreviations indicating multiplicity are used as follows: br = broad, d = doublet, q = quadruplet, t = triplet, s = singlet.

2. General Procedure for the Preparation of [2]Rotaxanes

The sulfur-containing thread (**3**, **4** or **5**, 1.0 equiv.) and Et_3N (ten-fold excess) was dissolved in anhydrous $CHCl_3$ and stirred vigorously while solutions of the amine (five-fold excess) and the acid chloride (five-fold excess) in anhydrous $CHCl_3$ were added over 3 hours using motor-driven syringe pumps. The reaction was filtered and the solvent removed under reduced pressure. The crude material was then subjected to column chromatography (silica gel, $CHCl_3$/MeOH as eluent) to give the [2]rotaxane **6**, **7** or **8** in 12, 43 or 10% yield, respectively. Further details are given in the Supporting Information.

3. Experimental Procedures, Synthesis and Characterization

Scheme 1. Synthesis of Threads **3**–**5**.[a]



[a] Reagents and conditions: (i) bromodiphenylmethane, 100 °C, 89%; (ii) DCC, *N*-hydroxysuccinimide, THF, 0 °C, 97%; (iii) Et_3N, glycine ethyl ester hydrochloride, $CHCl_3$, RT, 61%; (iv) diphenylethanol, *bis*(chlorodibutyltin)oxide, toluene, reflux, 88%; (ii) MCPBA, $CHCl_3$, –20 °C, 90 min, 70% (**4**, 1.0 equiv. MCPBA), 98% (**5**, from **4**: 1.0 additional equiv. MCPBA).

3-Benzhydrylmercaptopropionic acid (S1). 3-Mercaptopropionic acid (1.10 g, 10.4 mmol) was slowly added to bromodiphenyl methane (2.51 g, 10.4 mmol). After the initial reaction had subsided the mixture was heated to 100 °C until there was no further evolution of HBr. The reaction mixture was then allowed to cool to room temperature and extracted with a saturated $NaHCO_3$ solution. The aqueous layer was acidified with 1M HCl and extracted with $CHCl_3$. The organic layer was dried with $MgSO_4$ and the solvent removed under reduced pressure. Recrystallization from aqueous ethanol yielded **S1** as a colorless solid 2.64 g (89 %). mp 90-91 °C (lit.[S2] 88-90 °C); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.43-7.20 (m, 10H, Ar<u>H</u>), 5.19 (s, 1H, Ar_2C<u>H</u>), 2.65 (m, 2H, C<u>H_2</u>$COOH$) and 2.56 (m, 2H, C<u>H_2</u>S); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 177.8, 141.0, 128.9, 128.5, 127.6, 54.3, 34.2, 26.8; Anal. Calc. for $C_{15}H_{14}O_2S$: C 70.6, H 5.9; found: C 70.3, H 6.1.

3-Benzhydrylsulfanylpropionic acid succinimidyl ester (S2). *N,N'*-Dicyclohexylcarbodiimide (2.32 g, 11.0 mmol) was added to a solution of **S1** (3.01 g, 11.0 mmol) and *N*-hydroxysuccinimide (1.30 g, 11.0 mmol) in THF (20 mL) at 0 °C. The reaction mixture was stirred at 0 °C for 8 h before being filtered and the solvent removed under reduced pressure. The urea by-product was removed by crystallisation from ethyl acetate and the filtrate was then evaporated to yield the product as a colorless solid 3.96 g (97 %). mp 109-110 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.45-7.21 (m, 10H, ArC<u>H</u>), 5.23 (s, 1H, $Ar_2C\underline{H}$) and 2.85-2.72 (m, 8H, 4·$C\underline{H}_2$); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 169.3, 167.5, 141.0, 129.1, 128.7, 127.8, 54.9, 31.9, 27.0, 26.0; LRMS (FAB): *m/z* = 369 $[M+H]^+$; Anal. calc. for $C_{20}H_{19}O_4SN$: C 65.0, H 5.2; found : C 65.1, H 5.4.

(3-Benzhydrylsulfanyl-propionylamino)acetic acid ethyl ester (S3). Triethylamine (0.6 mL), was added to a slurry of glycine ethyl ester hydrochloride (0.64 g, 4.59 mmol) in chloroform (10 mL) and the reaction mixture allowed to stir for 5 minutes. 3-Benzhydrylsulfanyl propionic acid *N*-hydroxysuccinimidyl ester **S2** (1.65 g, 4.47 mmol) was then added and the mixture was stirred for 30 minutes. The reaction mixture was then washed with water, dried with $MgSO_4$ and the solvent removed to give **S3** as a colorless solid 1.59 g (61 %). mp 46-47 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.49-7.28 (m, 10H, Ar<u>H</u>), 6.13 (bt, 1H, N<u>H</u>CH_2), 5.23 (s, 1H, $Ar_2C\underline{H}$), 4.22 (qt, *J* = 7.0 Hz, 2H, $C\underline{H}_2CH_3$), 4.04 (d, *J* = 7.0 Hz, 2H, NH-$C\underline{H}_2$-CO-), 2.77 (t, *J* = 7.0 Hz, 2H, $SC\underline{H}_2CH_2$), 2.45 (t, *J* = 7.0 Hz, 2H, $SCH_2C\underline{H}_2$) and 1.32 (t, *J* = 7.0 Hz, 3H, $CH_2C\underline{H}_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 171.6, 170.3, 141.6, 129.0, 128.7, 127.7, 62.0, 55.1, 41.8, 36.3, 28.3, 14.5; LRMS (FAB): *m/z* = 357 $[M]^+$; HRMS (FAB): *m/z* = 357.1406 (calc. for $C_{20}H_{23}O_3NS$, 357.1399).

(3-Benzhydrylsulfanyl-propionylamino) acetic acid 2,2-diphenyl ethyl ester (3). (3-Benzhydryl-sulfanyl-propionylamino) acetic acid ethyl ester **S3** (966 mg, 2.70 mmol), diphenylethanol (536 mg, 2.70 mmol), and *bis*(chlorodibutyltin)oxide (10 mg) in toluene (50 mL) were refluxed for 8 hours with

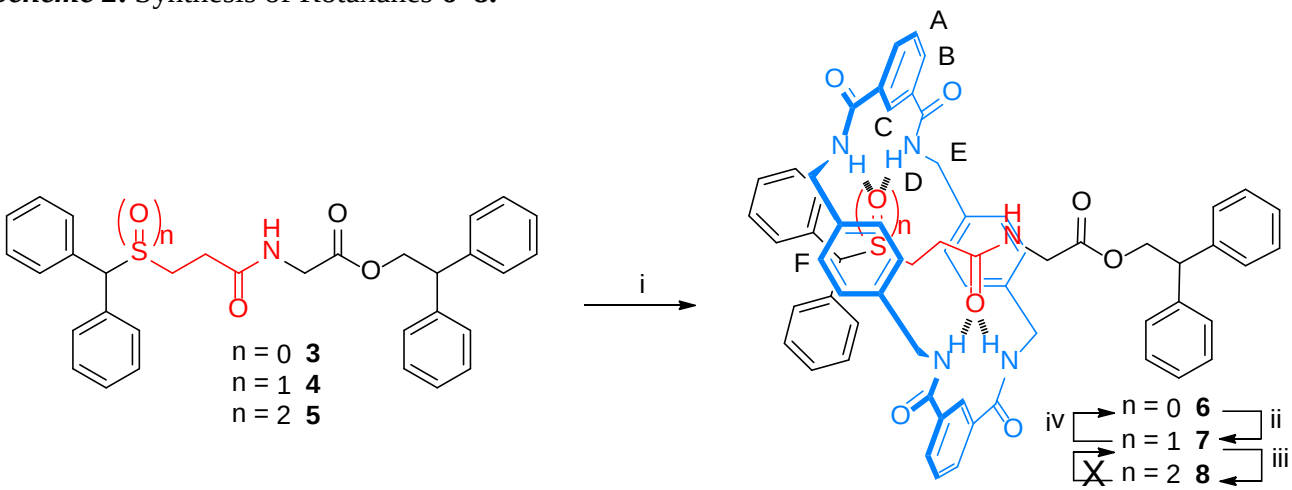
the continual distillation to remove liberated ethanol. After this time toluene was removed *in vacuo*, and the crude product was purified by column chromatography to give **1** as a colorless oil 1.21 g (88%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46-7.28 (m, 20H, ArC<u>H</u>), 6.00 (t, *J* = 7.0 Hz, 1H, N<u>H</u>CH_2), 5.21 (s, 1H, Ph_2C<u>H</u>), 4.74 (d, *J* = 7.0 Hz, 2H, C<u>H</u>$_2$$CHAr_2$), 4.40 (t, *J* = 7.0 Hz, 1H, CH_2C<u>H</u>Ar_2), 3.95 (d, *J* = 7.0 Hz, 2H, NHC<u>H</u>$_2$), 2.72 (t, *J* = 7.0 Hz, 2H, SC<u>H</u>$_2$$CH_2$) and 2.39 (t, *J* = 7.0 Hz, 2H, SCH_2C<u>H</u>$_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 170.9, 170.0, 135.6, 135.3, 129.8, 129.7, 129.4, 129.2, 129.1, 129.0, 73.2, 67.8, 50.1, 41.7, 36.2, 28.3; LRMS (FAB): *m/z* = 510 $[M+H]^+$; HRMS (FAB): *m/z* = 510.2097 (calc. for $C_{32}H_{32}NO_3S$, 510.2103).

(+,-) 3-(Benzhydrylmethanesulfinyl)propionylaminoacetic acid 2,2-diphenylethyl ester (4). To a solution of **3** (1.17 g, 2.29 mmol) in chloroform (10 mL) at -20 °C under an argon atmosphere, was added a solution of MCPBA (460 mg, 2.29 mmol) in chloroform (5 mL). The reaction mixture was stirred at -20 °C for 90 minutes then diluted with chloroform (30 mL) and allowed to warm to room temperature. The reaction mixture was washed with 5% $NaHCO_{3(aq)}$ (3 x 30 mL) and H_2O (3 x 30 mL). The organic layer was then dried with $MgSO_4$ and the solvent removed under reduced pressure to give **2** as a colorless solid 85 mg (70 %). mp 110-111 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.51-7.29 (m, 20H, Ar<u>H</u>), 6.53 (t, 1H, N<u>H</u>CH_2), 4.89 (s, 1H, Ar_2C<u>H</u>S), 4.71 (d, *J* = 7.0 Hz, 2H, C<u>H</u>$_2$$CHAr_2$), 4.38 (t, *J* = 7.0 Hz, 1H, CH_2C<u>H</u>Ar_2), 3.89 (dd, *J* = 6.0 Hz, *J* = 18.0 Hz, 2H, NHC<u>H</u>$_2$) and 2.93-2.67 (m, 4H, SC<u>H</u>$_2$C<u>H</u>$_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 170.9, 170.0, 135.6, 135.3, 129.4, 129.1, 129.0, 128.8, 128.6, 127.3, 73.2, 67.8, 50.1, 46.0, 41.7, 29.1; LRMS (FAB): *m/z* = 526 $[M+H]^+$; HRMS (FAB): *m/z* = 526.2047 (calc. for $C_{32}H_{32}O_4NS$, 526.2052).

3-(Benzhydrylmethanesulfonyl)propionylaminoaceticacid 2,2-diphenyl ethyl ester (5). To a solution of **4** (2.66 g, 5.06 mmol) in chloroform (10 mL) at –20 °C under argon, was added a solution of MCPBA (873 mg, 5.06 mmol) in chloroform (8 mL). The reaction mixture was allowed to stir at –

20 °C for 1.5 hours before being warmed to room temperature. The reaction mixture was then diluted with chloroform and washed with 5% $NaHCO_{3(aq)}$ (3 x 30 mL) and H_2O (3 x 30 mL). The organic layer was then dried with $MgSO_4$ and the solvent removed under reduced pressure to give the product as a colorless solid 2.68 g (98 %). mp 138-139 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.48-7.23 (m, 20H, ArH), 6.17 (t, *J* = 5.0 Hz, 1H, NH), 5.43 (s, 1H, Ph_2CH-SO_2-), 4.72 (d, *J* = 7.0 Hz, 2H, Ph_2CHCH_2), 4.39 (t, *J* = 7.0 Hz, 1H, Ph_2CHCH_2), 3.92 (d, *J* = 5.0 Hz, 2H, $NHCH_2$), 3.23 (t, *J* = 7.0 Hz, 2H, SCH_2CH_2) and 2.70 (t, *J* = 7.0 Hz, 2H, SCH_2CH_2); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 170.9, 170.0, 135.6, 135.3, 129.4, 129.1, 129.0, 128.8, 128.6, 127.3, 74.2, 67.0, 50.1, 47.8, 41.9, 28.1; LRMS (FAB): *m/z* = 542 $[M+H]^+$; HRMS (FAB): *m/z* = 542.2005 (calc. for $C_{32}H_{32}NO_5S$, 542.2001).

Scheme 2. Synthesis of Rotaxanes **6**–**8.**[a]



[a] Reagents and conditions: (i) isophthaloyl dichloride, *p*-xylylenediamine, Et_3N, $CHCl_3$, RT, 4 h, 12% (**6**), 43% (**7**), 10% (**8**); (ii) MCPBA (1.0 equiv.), $CHCl_3$, –20 °C to RT, 90 min., 95%; (iii) MCPBA (1.0 equiv.), $CHCl_3$, –20 °C to RT, 90 min., 97%; (iv) Lawesson's reagent (1.0 equiv.), THF, –20 °C to RT, 1 h, 87%.

[2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclohexacosane)-((3-benzhydrylsulfanyl-propionylamino)aceticacid 2,2-diphenylethyl ester)- rotaxane (6).

Method a): Rotaxane **6** was synthesized using the general procedure for the preparation of benzylic amide [2]rotaxanes from thread **3** (500 mg, 0.98 mmol). The crude obtained was subjected to column

chromatography on silica gel using $CHCl_3$ as eluent to obtain the desired compound as a colorless solid 118 mg (12%).

Method b): To a solution of rotaxane **7** (37 mg, 0.04 mmol) in THF (2 mL) at –20 °C was added Lawesson's reagent (14 mg, 0.04 mmol). The reaction mixture was allowed to stir at room temperature for 1 hour before the solvent removed under reduced pressure. The crude product was purified by column chromatography (5% MeOH/$CHCl_3$) to give the desired product as a colorless solid 32 mg (87 %). mp 115-116 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.21 (d, J = 7.0 Hz, 4H, CH_B), 8.11 (br t, 2H, CH_C), 7.67 (t, J = 7.0 Hz, 2H, CH_A), 7.31 (br t, 4H, CH_D), 7.29–7.12 (m, 28H, ArH), 6.43 (br t, 1H, $CH_2CONHCH_2COO$), 4.66 (s, 1H, Ph_2CHS), 4.57 (d, J = 7.0 Hz, 2H, $COOCH_2$), 4.53 (AA'BB' system, 4H, J = 5.0 and 14.0 Hz, 4H, CH_E), 4.27 (t, J = 7.0 Hz, 1H, Ph_2CHCH_2O), 3.31 (d, J = 6.0 Hz, 2H, CH_2COO), 1.72 (t, J = 8.0 Hz, 2H, S-CH_2-CH_2 or S-CH_2-CH_2) and 1.43 (t, J = 8.0 Hz, 2H, S-CH_2-CH_2 or S-CH_2-CH_2); LRMS (FAB): *m/z* = 1080 $[M+K]^+$; HRMS (FAB): *m/z* = 1042.4210 (calc. for $C_{64}H_{60}O_7N_5S$, 1042.4213).

(+,-) [2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclohexacosane)–((benzhydrylmethanesulfinyl)-propionylaminoaceticacid 2,2-diphenyl ethyl ester)-rotaxane (7). Method a): Rotaxane **7** was synthesized from **4** (440 mg, 0.84 mmol) using the general procedure. Column chromatography ($CHCl_3$) afforded the product as a white solid 379 mg (43 %).

Method b): To a solution of rotaxane **6** (25 mg, 0.024 mmol) in $CHCl_3$ (1 mL) under an argon atmosphere at –20 °C was added a solution of MCPBA (4.00 mg, 0.02 mmol) in $CHCl_3$ (0.5 mL). The reaction mixture was stirred at –20 °C for 90 minutes before being allowed to warm to room temperature. The reaction mixture was then diluted with $CHCl_3$ and washed with 5% $NaHCO_{3(aq)}$ (3 x 30 mL) and H_2O (3 x 30 mL). The organic layer was dried with $MgSO_4$ and the solvent removed *in vacuo* to give **5** as a colorless solid 24 mg (95 %). mp 127-128 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.22 (t, J = 8.0 Hz, 4H, ArH_B), 7.97 (s, 2H, ArH_C), 7.63 (t, J = 8.0 Hz, 4H, NH_D), 7.33-7.27 (m, 28H,

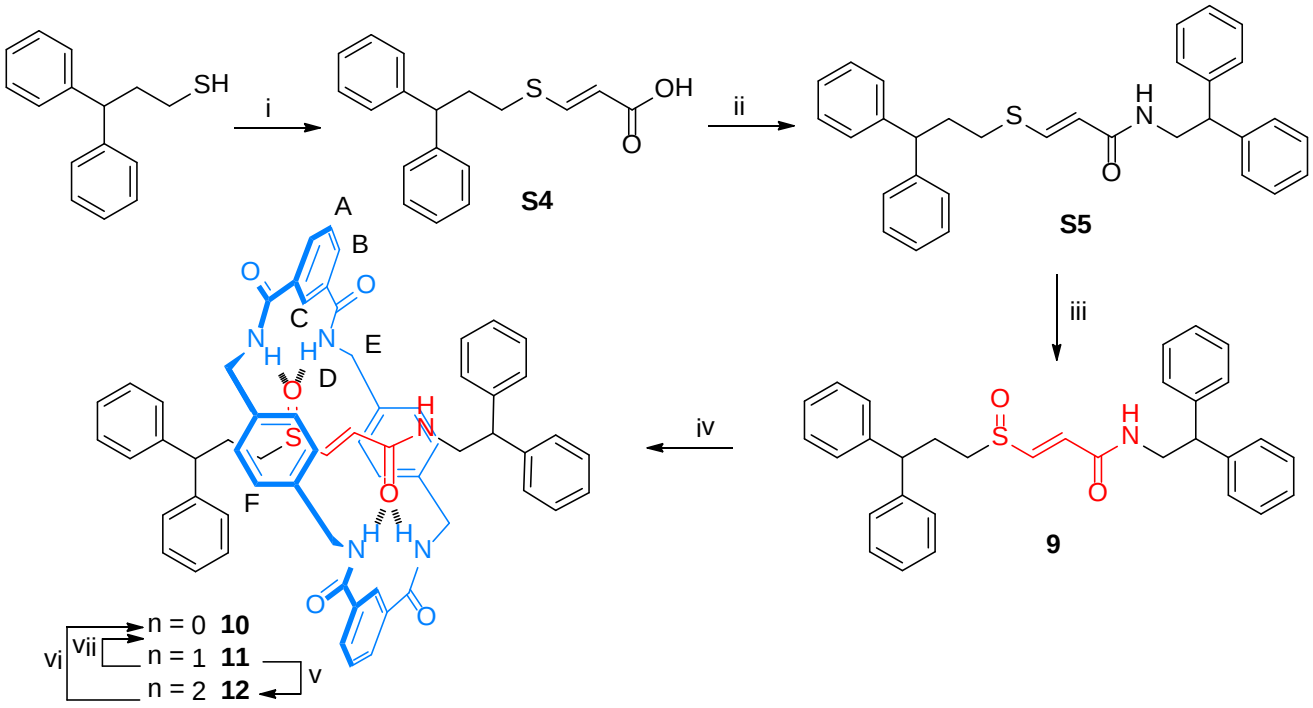
ArH), 7.24 (bt, 2H, ArH_A), 4.60 (m, 11H, $CH_2CONHCH_2COO$, CH_E and $COOCH_2$), 4.38 (s, 1H, Ph_2CH-SO), 4.30 (t, *J* = 8.0 Hz, 1H, Ph_2CH-CH_2), 3.70 (t, *J* = 5.0 Hz, 2H, CH_2COO) and 1.29-0.92 (m, 4H, SO-CH_2-CH_2); LRMS (FAB): *m/z* = 1059 $[M+H]^+$; HRMS (FAB): *m/z* = 1058.4154 (calc. for $C_{64}H_{60}O_8N_5S$, 1058.4162).

[2]-(1,4,7,14,17,20-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25–terabenzocyclohexacosane)-((3-benzhydrylsulfonyl-propionylamino) acetic acid 2,2-diphenylethyl ester)-rotaxane (8).

Method a): Rotaxane **8** was synthesized using the general procedure for the preparation of benzylic amide [2]rotaxanes from thread **5** (500 mg, 0.92 mmol). The crude material obtained was subjected to column chromatography on silica gel using $CHCl_3$ as eluent to obtain the desired compound as colorless solid 99 mg (10%).

Method b): To a solution of rotaxane **7** (100 mg, 0.09 mmol) in $CHCl_3$ (2 mL) under an Ar atmosphere at –20 °C was added a solution of MCPBA (16 mg, 0.09 mmol) in $CHCl_3$ (0.5 mL). The reaction mixture was allowed to stir at –20 °C for 90 minutes before being warmed to room temperature. The reaction mixture was diluted with chloroform and washed with 5% $NaHCO_{3(aq)}$ (3 x 30 mL) and H_2O (3 x 30 mL). The organic layer was dried with $MgSO_4$ and the solvent removed under reduced pressure to give **8** as a colorless solid 94 mg (97 %). mp 110-111 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.11 (d, *J* = 8.0 Hz, 4H, ArH_B), 7.91 (s, 2H, ArH_C), 7.62 (t, *J* = 6.0 Hz, 1H, $CH_2CONHCH_2COO$), 7.56 (bt, 2H, ArH_A), 7.42 (t, *J* = 4.0 Hz, 4H, NH_D), 7.32-7.02 (m, 28H, ArH), 4.86 (s, 1H, Ph_2CH-SO2-), 4.66 (d, *J* = 8.0 Hz, 2H, $COOCH_2$), 4.56 (m, 8H, CH_E), 4.32 (t, *J* = 8.0 Hz, 1H, Ph_2CHCH_2O), 3.57 (d, *J* = 6.0 Hz, 2H, $NHCH_2COO$), 2.00 (t, *J* = 7 Hz, 2H, $SO_2CH_2CH_2$ or $SO_2CH_2CH_2$) and 1.57 (t, *J* = 7.0 Hz, 2H, $SO_2CH_2CH_2$ or $SO_2CH_2CH_2$); LRMS (FAB): *m/z* = 1074 $[M+H]^+$; HRMS (FAB): *m/z* = 1074.4106 (calc. for $C_{64}H_{60}N_5O_9S$, 1074.4111).

Scheme 3. Synthesis of Rotaxanes **10**–**12.**[a]



[a] Reagents and conditions: (i) propiolic acid, pyridine, 3 hours, 88 %; (ii) oxalyl chloride, benzene, then 2,2-diphenylethylamine, CH_2Cl_2, 92 % over 2 steps; (iii) MCPBA, CH_2Cl_2, 90%; (iv) isophthaloyl dichloride, *p*-xylylenediamine, Et_3N, $CHCl_3$, RT, 63 % (**11**); (v) MCPBA, CH_2Cl_2, RT, 18 h, 83% (**12**); (vi) $Ph_2CHCH_2CH_2SNa$, DMF, 120 °C, 15 h, 85% (**10**); (vii) $Ph_2CHCH_2CH_2SNa$, DMF, 120 °C, 16 h, 92% (**10**).

(*E*)-3-(3,3-Diphenyl-propylsulfanyl)-acrylic acid (S4). 3,3-diphenylpropane-1-thiol (5.00 g, 22.0 mmol) was dissolved in dry pyridine (100 mL), and the solution was cooled in an ice bath. Propiolic acid (1.49 mL, 1.10 equiv) was then added dropwise and the solution was stirred at 0 °C for 3 hours. After a further 18 hours stirring at room temperature the solvent was removed *in vacuo*. The resulting black solid was then triturated with CH_2Cl_2 (300 mL), before water (250 mL) followed by 1M HCl (50 mL, 2.3 equiv.) was added. The triphasic mixture was vigorously stirred and upon complete dissolution of the solid, the aqueous layer was extracted with CH_2Cl_2 (3 x 100 mL). The combined organic layers were dried with $MgSO_4$, filtered and the solvent removed *in vacuo*. The crude residue was purified using flash column chromatography on silica gel (eluent: CH_2Cl_2 to 5% MeOH/CH_2Cl_2) to yield the corresponding pure (*E*)-acid as a colorless amorphous solid 5.75 g (88 %). ^{1}H NMR (400

MHz, $CDCl_3$): δ = 7.77 (d, *J* = 13.2 Hz, 1H, SC<u>H</u>=CH), 7.17-7.34 (m, 10H, H-Ar), 5.65 (d, 1H, SCH=C<u>H</u>), 4.07 (t, *J* = 7.8 Hz, 1H, $Ph_2C\underline{H}$), 2.72-2.77 (m, 2H, $SC\underline{H}_2CH_2$), 2.39-2.47 (m, 2H, $SCH_2C\underline{H}_2$); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 169.4, 149.6, 143.4, 128.7, 127.8, 126.7, 112.7, 50.0, 34.2, 30.3; LRMS (ESI-): *m/z* = 297 $[M-H]^-$; HRMS (FAB, NBA matrix): *m/z* = 298.1036 (calc. for $C_{18}H_{18}O_2S$, 298.1027).

(*E*)-*N*-(2,2-Diphenyl-ethyl)-3-(3,3-diphenyl-propylsulfanyl)-acrylamide (S5). Acid **S4** (940 mg, 3.15 mmol) was dissolved in dry benzene (30 mL), and the solution was cooled in an ice bath. Oxalyl chloride (555 μL, 2.00 equiv) was then added dropwise, followed by one drop of DMF. The solution was stirred at room temperature for 2 hours before the solvent was removed *in vacuo*. The resulting yellow oil was dissolved in dry CH_2Cl_2 (5 mL) and added dropwise to an ice-cold solution of 2,2-diphenylethylamine (1.43 g, 2.30 equiv) in dry CH_2Cl_2 (50 mL). The reaction mixture was then stirred at room temperature for 2 hours. After this time water (40 mL) and 1M HCl (10 mL, 3.2 equiv.) were added and the aqueous layer was extracted with CH_2Cl_2 (2 x 50 mL). The combined organic layers were dried with $MgSO_4$, filtered and the solvent removed *in vacuo*. The crude residue was then purified by column chromatography (eluent: petroleum ether/EtOAc 7/3) to yield the corresponding pure amide as a colorless solid 1.47 g (92 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.68 (d, *J* = 14.9 Hz, 1H, SC<u>H</u>=CH), 7.19-7.45 (m, 20H, H-Ar), 5.61 (t, *J* = 4.8 Hz, 1H, NH), 5.35 (d, 1H, SCH=C<u>H</u>), 4.26 (t, *J* = 8.0 Hz, 1H, $Ph_2C\underline{H}CH_2NH$), 4.08 (t, *J* = 7.7 Hz, 1H, $Ph_2C\underline{H}CH_2CH_2S$), 3.99-4.05 (m, 2H, CH_2NH), 2.85 (t, *J* = 7.5 Hz, 2H, $SC\underline{H}_2CH_2$), 2.40-2.49 (m, 2H, $SCH_2C\underline{H}_2$). ^{13}C NMR (100 MHz, $CDCl_3$)δ = 166.3, 145.6, 143.7, 141.2, 129.2, 128.8, 128.3, 128.0, 127.4, 126.6, 114.4, 50.4, 50.0, 44.4, 34.8, 30.2; LRMS (ESI+): *m/z* = 478 $[M+H]^+$; HRMS (FAB, NBA matrix): *m/z* = 477.2138 (calc. for $C_{32}H_{31}NOS$, 477.2126).

(+/-) (*E*)-*N*-(2,2-Diphenyl-ethyl)-3-(3,3-diphenyl-propane-1-sulfinyl)-acrylamide (9). Vinyl sulfide **S5** (1.47 g, 3.08 mmol) was dissolved in CH_2Cl_2 (50 mL), and the solution was cooled to -78 °C. MCPBA (530 mg, 1.00 equiv) was then added and the solution was stirred at room temperature overnight. After this time saturated $NaHCO_{3(aq)}$ (50 mL) was slowly added and the aqueous layer was extracted with CH_2Cl_2 (3 · 20 mL). The combined organic layers were dried with $MgSO_4$, filtered and the solvents removed *in vacuo*. The crude residue was then purified *via* flash column chromatography (eluent: petroleum ether/EtOAc 1:1) to yield the corresponding vinyl sulfoxide **9** as a colorless amorphous solid 1.37 g (90 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.48 (d, *J* = 14.8 Hz, 1H, SC<u>H</u>=CH), 6.99-7.25 (m, 20H, H-Ar), 5.41 (t, *J* = 4.9 Hz, 1H, NH), 5.15 (d, 1H, SCH=C<u>H</u>), 4.26 (t, *J* = 8.0 Hz, 1H, $Ph_2C\underline{H}CH_2NH$), 4.06 (t, *J* = 7.8 Hz, 1H, $Ph_2C\underline{H}CH_2CH_2S$), 3.79-3.91 (m, 2H, CH2NH), 2.55 (t, *J* = 7.7 Hz, 2H, $SC\underline{H}_2CH_2$), 2.20-2.29 (m, 2H, $SCH_2C\underline{H}_2$); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.3, 145.6, 143.7, 141.3, 128.9, 128.7, 128.0, 127.9, 127.2, 126.6, 114.4, 50.4, 50.0, 44.4, 34.8, 30.2; LRMS (ESI+): *m/z* = 494 $[M+H]^+$; HRMS (FAB, NBA matrix): *m/z* = 493.2081 (calc. for $C_{32}H_{31}NO_2S$, 493.2075).

(+,-)[2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclo hexacosane)–((*E*)-*N*-(2,2-diphenylethyl)-3-(3,3-diphenyl-propane-1-sulfinyl)-acrylamide)-rotaxane (11). Rotaxane **11** was synthesized from thread **9** (390 mg, 0.79 mmol) using the general procedure. The crude residue obtained was purified *via* flash column chromatography on silica gel (eluent gradient pet. ether/EtOAc 1 :1, EtOAc then 1% MeOH/EtOAc) to give unreacted thread **9** (95 mg, 24%) and the desired vinyl sulfoxide [2]rotaxane **11** as a colorless solid 510 mg (63%). ^{1}H NMR (400 MHz, CD_2Cl_2): δ = 8.21 (br s, 2H, CH_C), 8.05 (d, *J* = 7.8 Hz, 4H, CH_B), 7.87 (br t, 1H, $N\underline{H}CH_2CHPh_2$), 7.55 (br t, 2H, NH_D), 7.52 (t, 2H, CH_A), 7.55 (br t, 2H, $NH_{D'}$), 7.26–6.98 (m, 20H, ArH), 6.83 (d, *J* = 7.8 Hz, 4H, CH_F), 6.67 (d, *J* = 7.8 Hz, 4H, $CH_{F'}$), 6.11 (d, *J* = 14.4 Hz, 1H, SOC<u>H</u>=CH), 5.39 (d, 1H, SOCH=C<u>H</u>), 4.49-4.18 (m, 9H, CH_E, $CH_{E'}$ and $Ph_2C\underline{H}CH_2NH$), 4.00-3.89 (m, 1H, $Ph_2CHC\underline{H}_2NH$),

3.72 (m, 2H, $Ph_2C\underline{H}CH_2CH_2S$ and $Ph_2CHC\underline{H_2}NH$), 2.17-1.90 (m, 4H, $SOC\underline{H_2}C\underline{H_2}$); ^{13}C NMR (100 MHz, $CDCl_3$) : δ = 169.5, 169.4, 167.2, 146.1, 145.8, 140.6, 140.4, 137.0, 136.7, 134.9, 134.7, 132.6, 132.4, 132.3, 132.2, 131.1, 130.8, 130.7, 130.5, 130.2, 130.0, 127.2, 55.2, 53.8, 53.5, 47.2, 47.0, 32.3; HRMS (FAB, NBA matrix): *m/z* = 1025.4175 (calc. for $C_{64}H_{59}N_5O_6S$, 1025.4186).

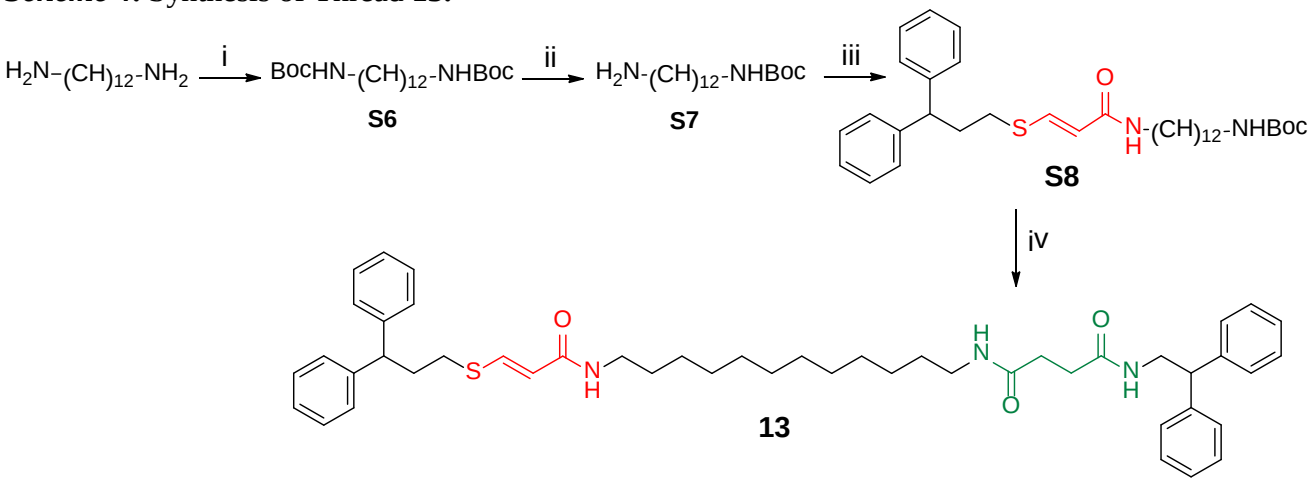
[2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclohexacosane) –((*E*)-*N*-(2,2-diphenyl-ethyl)-3-(3,3-diphenyl-propane-1-sulfonyl)-acrylamide)-rotaxane (12). Vinyl sulfoxide rotaxane **11** (50 mg, 49 μmol) was dissolved in CH_2Cl_2 (3 mL). MCPBA (16 mg, 1.5 equiv.) was then added and the solution was allowed to stir at room temperature for 18 h. A saturated $NaHSO_3$ solution (3 mL) was then slowly added, and the resulting biphasic mixture was vigorously stirred at room temperature for 15 min. The aqueous layer was extracted with CH_2Cl_2 (3 x 3 mL). The combined organic layers were then washed with a saturated sodium bicarbonate solution (3 x 2 mL), water (2 mL) and brine (2 mL), dried with magnesium sulfate and the solvent removed *in vacuo*. The resulting white solid was purified using flash column chromatography on silica gel (eluent: petroleum ether/EtOAc 1/1 to EtOAc) to yield the corresponding vinyl sulfone rotaxane **12** as a colorless solid 42 mg (83 %). ^1H NMR (400 MHz, CD_2Cl_2): δ = 7.94 (dd, $J_{A\text{-}B}$ = 7.6 Hz, $J_{B\text{-}C}$ = 1.5 Hz, 4H, CH_B), 7.88 (br s, 2H, CH_C), 7.64 (br t, 1H, $N\underline{H}CH_2CHPh_2$), 7.50 (t, 2H, CH_A), 7.23–7.00 (m, 24H, ArH and NH_D), 6.80 (m, 8H, CH_F), 5.78 (d, *J* = 15.2 Hz, 1H, $SO_2C\underline{H}$=CH), 5.39 (d, 1H, SO_2CH=C$\underline{H}$), 4.39 (dd, J_{gem} = 14.4 Hz, $J_{NH\text{-}E}$ = 5.6 Hz, 4H, CH_E), 4.22 (dd, $J_{NH\text{-}E'}$ = 5.1 Hz 4H, $CH_{E'}$), 4.05 (t, *J* = 7.6 Hz, 1H, $Ph_2C\underline{H}CH_2NH$), 3.72 (t, *J* = 7.8 Hz, 1H, $Ph_2C\underline{H}CH_2CH_2S$), 3.53 (dd, $J_{NH\text{-}CH2}$ = 5.6 Hz, 2H, $CHC\underline{H_2}NH$), 2.40-2.34 (t, *J* = 7.5 Hz, 2H, $SO_2C\underline{H_2}CH_2$), 2.06-1.98 (m, 2H, $SCH_2C\underline{H_2}$); ^{13}C NMR (100 MHz, $CDCl_3$) : δ = 167.0, 163.2, 158.8, 142.5, 141.6, 137.5, 135.2, 134.5, 130.8, 129.3, 128.9, 128.8, 128.7, 127.9, 127.5, 127.1, 127.0, 125.0, 52.6, 49.7, 49.6, 45.2, 44.2, 27.1; HRMS (FAB, NBA matrix): *m/z* = 1041.4148 (calc. for $C_{64}H_{59}N_5O_7S$, 1041.4135).

[2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclo hexacosane) –((*E*)-*N*-(2,2-diphenyl-ethyl)-3-(3,3-diphenyl-propylsulfanyl)-acrylamide)-rotaxane (10).

Method a): 3,3-Diphenylpropane-1-thiol (111 mg, 10.0 equiv) was dissolved in dry DMF (2 mL) and the solution was cooled to 0 °C. NaH (60% suspension in oil, 19.5 mg, 10.0 equiv) was then added and the resulting solution was stirred for 30 min. Vinyl sulfoxide rotaxane **11** (50 mg, 49 μmol) dissolved in dry DMF (1 mL) was then added and the solution was heated to 120 °C for 16 h. After this time the solvent was removed *in vacuo*, and the resulting residue purified *via* column chromatography (eluent: petroleum ether/EtOAc 7/3 to 1/1) to yield the vinyl sulfide rotaxane **10** as a colorless amorphous solid 42 mg (92 %).

Method b): 3,3-Diphenylpropane-1-thiol (113 mg, 10.0 equiv) was dissolved in dry DMF (2 mL) and the solution was cooled to 0 °C. NaH (60% suspension in oil, 19.7 mg, 10.0 equiv) was then added and the resulting solution was stirred for 30 min. Vinyl sulfone rotaxane **12** (52 mg, 49 μmol) dissolved in dry DMF (1 mL) was then added and the solution was heated to 120 °C for 15 h. After this time the solvent was removed *in vacuo*, and the resulting residue purified *via* column chromatography (eluent: petroleum ether/EtOAc 7/3 to 1/1) to yield the vinyl sulfide rotaxane **10** as a colorless amorphous solid 39 mg (85 %). ^{1}H NMR (400 MHz, CD_2Cl_2): δ = 8.06 (br d, $J_{A\text{-}B}$ = 7.3 Hz, 4H, CH_B), 7.97 (br s, 2H, CH_C), 7.59 (t, 2H, CH_A), 7.31–6.84 (m, 20H, ArH), 6.83 (m, 8H, CH_F), 6.79 (br t, 4H, NH_D), 6.56 (d, J = 14.7 Hz, 1H, SC<u>H</u>=CH), 6.41 (br t, 1H, N<u>H</u>CH_2CHPh_2), 4.46 (dd, J_{gem} = 14.2 Hz, $J_{NH\text{-}E}$ = 5.5 Hz, 4H, CH_E), 4.26 (dd, $J_{NH\text{-}E'}$ = 4.8 Hz, 4H, $CH_{E'}$), 4.19 (d, 1H, SCH=C<u>H</u>), 3.63 (t, J = 7.8 Hz, 1H, Ph_2C<u>H</u>CH_2NH), 3.53 (t, J = 7.8 Hz, 1H, Ph_2C<u>H</u>CH_2CH_2S), 3.14 (dd, $J_{NH\text{-}CH2}$ = 5.8 Hz, 2H, CHC<u>H_2</u>NH), 1.91-1.83 (m, 2H, SC<u>H_2</u>CH_2), 1.81-1.75 (m, 2H, SCH_2C<u>H_2</u>); HRMS (FAB, NBA matrix): m/z = 1009.4245 (calc. for $C_{64}H_{59}N_5O_5S$, 1009.4237).

Scheme 4. Synthesis of Thread **13.**[a]



[a] Reagents and conditions: (i) Boc_2O, CH_2Cl_2 100 %; (ii) HCl, Et_2O, CH_2Cl_2, 87 %; (iii) **S4**, oxalyl chloride, CH_2Cl_2, 90 %; (iv) TFA, CH_2Cl_2, then *N*-(2,2-diphenylethyl)-succinamic acid, DMAP, EDCI, CH_2Cl_2, 83% over 2 steps.

(12-*tert*-Butoxycarbonylamino-dodecyl)-carbamic acid *tert*-butyl ester (S6). 1,12-Diaminododecane (60 g, 0.3 mol) was dissolved in a 1:1 mixture of CH_2Cl_2 and MeOH (1 L). Boc_2O (130 g, 2.0 equiv) was then added and the solution was stirred at room temperature for 18 h. After this time the solvent was removed *in vacuo* to yield the dicarbamate as a colorless amorphous solid 120 g (100 %). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.62-4.42 (m, 2H, NHBoc), 3.18-3.04 (m, 4H, CH_2N), 1.53-1.39 (m, 4H, CH_2CH_2N), 1.45 (s, 18H, Me_3C), 1.33-1.25 (m, 16H, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 156.8, 79.0, 40.6, 30.1, 29.5, 29.3, 28.4, 26.8; LRMS (ESI+): *m/z* = 400.5 $[M+H]^+$.

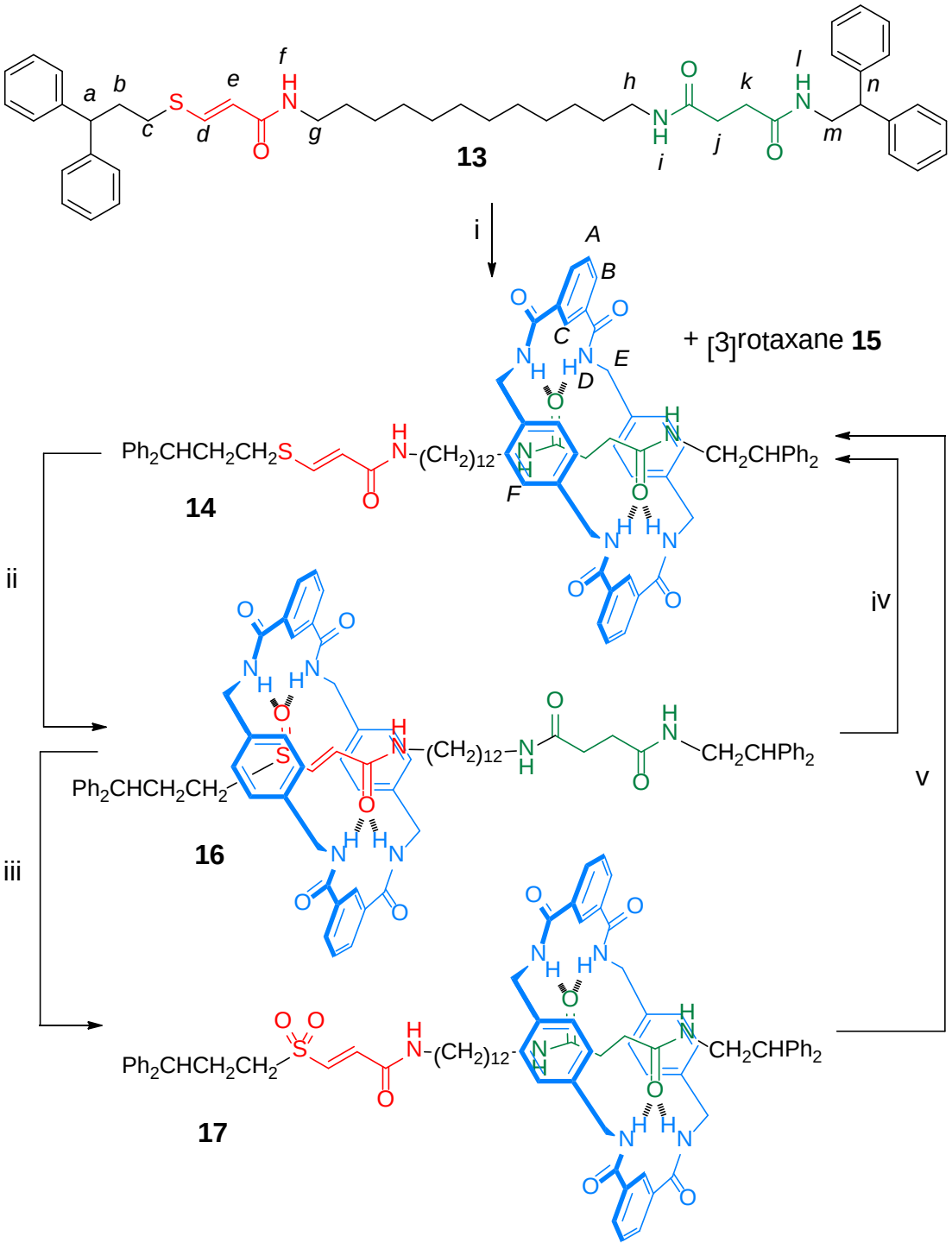
(12-Amino-dodecyl)-carbamic acid *tert*-butyl ester (S7). Di-boc derivative **S6** (70 g, 0.19 mol) was dissolved in CH_2Cl_2 (280 mL), before a solution of HCl (2M in Et_2O, 280 mL, 3 equiv.) was added over 5 min. The solution was vigorously stirred at room temperature for 22 hours. The resulting white precipitate was filtered, washed with Et_2O (3 x 200 mL) and dried under vacuum to yield the hydrochloride of the mono-Boc derivative as a colorless solid 55 g (87 %). The crude material was used in the next step without any further purification.

{12-[(*E*)-3-(3,3-Diphenylpropylsulfanyl)-acryloylamino]-dodecyl}-carbamic acid *tert*-butyl ester (S8). **S4** (940 mg, 3.15 mmol) was dissolved in dry benzene (30 mL), and the solution was cooled in an ice bath. Oxalyl chloride (555 μL, 2.00 equiv) was then added dropwise, followed by one drop of DMF. The solution was stirred at room temperature for 2 hours before the solvent was removed. The resulting yellow oil was dissolved in dry CH_2Cl_2 (5 mL) and added dropwise to an ice-cold solution of the amine **S7** (2.17 g, 2.30 equiv) in dry CH_2Cl_2 (50 mL). The reaction mixture was stirred at room temperature for 2 hours before being quenched with water (40 mL) and 1M HCl (10 mL, 3.20 equiv). The aqueous layer was extracted with CH_2Cl_2 (2 x 50 mL), and the combined organic layers were then dried with $MgSO_4$, filtered and the solvent evaporated. The crude residue was purified by column chromatography (eluent: CH_2Cl_2 to 2% MeOH/CH_2Cl_2) to yield **S8** as a colorless amorphous solid 1.64 g (90 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.51 (d, J = 14.9 Hz, 1H, SC<u>H</u>=CH), 7.35-7.18 (m, 10H, H-Ar), 5.50 (d, 1H, SCH=C<u>H</u>), 5.38 (t, J = 4.6 Hz, 1H, CH=CHCON<u>H</u>), 4.61-4.49 (m, 1H, NHBoc), 4.06 (t, J = 7.8 Hz, 1H, $Ph_2C\underline{H}CH_2CH_2S$), 3.32-3.24 (dt, J = 6.4 Hz, 2H, $C\underline{H}_2NHCOCH{=}CH$), 3.15-3.06 (m, 2H, $C\underline{H}_2NHBoc$), 2.72 (t, J = 7.8 Hz, 2H, $SC\underline{H}_2CH_2$), 2.45-2.38 (m, 2H, $SCH_2C\underline{H}_2$), 1.56-1.44 (m, 4H, CH_2), 1.46 (s, 9H, Me_3C), 1.35-1.24 (m, 18H, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 164.4, 157.9, 143.8, 141.5, 128.6, 127.9, 126.4, 116.8, 50.0, 40.6, 39.4, 34.9, 30.2, 29.7, 29.5, 29.3, 28.4, 26.9, 26.8; LRMS (ESI+): m/z = 581.5 $[M+H]^+$; HRMS (FAB, NBA matrix): m/z = 580.3694 (calc. for $C_{35}H_{52}N_2O_3S$, 580.3699).

***N*-(2,2-Diphenyl-ethyl)-*N*'-{12-[(*E*)-3-(3,3-diphenyl-propylsulfanyl)-acryloylamino]-dodecyl}-succinamide (13)**. Carbamate **S8** (950 mg, 1.63 mmol) was dissolved in CH_2Cl_2 (20 mL) and TFA (10 mL) was added dropwise. The solution was then stirred at room temperature for 3 hours before the solvent was evaporated. The crude oil was dissolved in CH_2Cl_2 (50 mL) and washed with saturated $NaHCO_3$ (50 mL) before being dried with $MgSO_4$, filtered and the solvent removed *in vacuo*. The resulting yellow solid was dissolved in dry CH_2Cl_2 (20 mL) and *N*-(2,2-diphenylethyl)-

succinamic acid (578 mg, 1.20 equiv),[S3] DMAP (314 mg, 1.50 equiv) and EDCI (471 mg, 1.50 equiv) were then added. The reaction mixture was stirred at room temperature for 20 hours before being quenched with 1M HCl (10 mL). The organic layer was then washed with 1M HCl (5mL), saturated $NaHCO_{3(aq)}$ (5 mL) and brine (5 mL), before being dried with $MgSO_4$, filtered and the solvent removed. The resulting yellow solid was purified by column chromatography (eluent: CH_2Cl_2 to 8% MeOH/CH_2Cl_2) to yield **13** as a colorless solid 1.03 g (83 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.49 (d, *J* = 14.7 Hz, 1H, SC<u>H</u>=CH), 7.33-7.16 (m, 20H, H-Ar), 5.94-5.85 (m, 2H, $CH_2NHCOCH_2$), 5.45 (d, 1H, SCH=C<u>H</u>), 5.19 (t, *J* = 4.8 Hz, 1H, CH=CHCON<u>H</u>), 4.16 (t, *J* = 8.1 Hz, 1H, $Ph_2C\underline{H}CH_2NH$), 4.04 (t, *J* = 7.8 Hz, 1H, $Ph_2C\underline{H}CH_2CH_2S$), 3.87 (dd, *J* = 5.8 Hz, 2H, $Ph_2CHC\underline{H}_2NH$), 3.32-3.24 (dt, $J_{CH2\text{-}CH2}$ = 6.6 Hz, $J_{CH2\text{-}NH}$ = 6.6 Hz, 2H, $C\underline{H}_2NHCOCH=CH$), 3.20-3.14 (m, 2H, $C\underline{H}_2NHCOCH_2CH_2$), 2.71 (t, *J* = 6.8 Hz, 2H, $SC\underline{H}_2CH_2$), 2.44-2.34 (m, 2H, $SCH_2C\underline{H}_2$), 2.38 (s, 4H, $COC\underline{H}_2C\underline{H}_2CO$), 1.54-1.40 (m, 4H, CH_2), 1.34-1.22 (m, 16H, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 172.2, 172.0, 164.4, 143.8, 141.9, 141.5, 128.7, 128.6, 128.5, 128.2, 128.0, 127.9, 126.8, 126.2, 116.8, 50.6, 50.0, 43.8, 39.6, 39.5, 34.9, 31.8, 31.7, 30.2, 29.7, 29.5, 29.4, 29.2, 26.9, 26.8; LRMS (ESI+): *m/z* = 760.5 $[M+H]^+$; HRMS (FAB, NBA matrix): *m/z* = 759.4445 (calc. for $C_{48}H_{61}N_3O_3S$, 759.4434).

Scheme 5. Synthesis of Rotaxanes **14**–**17**.[a]



[a] Reagents and conditions: (i) isophthaloyl dichloride, *p*-xylylenediamine, Et_3N, $CHCl_3$, RT, 23% (**14**) + 8% (**15**); (ii) MCPBA, CH_2Cl_2, -78 °C to RT, 2 h, 90% (**16**); (iii) MCPBA, CH_2Cl_2, -78 °C to RT, 2 h, 92% (**17**); (iv) $Ph_2CHCH_2CH_2SNa$ (10 equiv.), DMF, 120 °C, 16 h, 93% (**14**); (v) $Ph_2CHCH_2CH_2SNa$ (10 equiv.), DMF, 120 °C, 18 h, 90% (**14**).

[2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclohexaco-sane)–(*N*-(2,2-diphenylethyl)-*N*'-{12-[(*E*)-3-(3,3-diphenyl-propylsulfanyl)-acryloylamino]-do-decyl}-succinamide)-rotaxane (14). Method a): Rotaxane **14** was synthesized from thread **13** (760 mg, 1.00 mmol) using the general procedure. The crude obtained was subjected to a flash column chromatography on silica gel (eluent: petroleum ether/EtOAc 1:1, to 1% MeOH/EtOAc) to give first the [3]rotaxane **15** 144 mg (8 %) then the vinyl sulfide [2]rotaxane **14** as a colorless solid 291 mg (23%).

Method b): 3,3-Diphenylpropane-1-thiol (52 mg, 10 equiv.) was dissolved in dry DMF (2 mL) and the solution was cooled to 0 °C. NaH (60% suspension in oil, 9 mg, 10 equiv.) was added and the mixture was stirred under N_2 for 30 minutes. Vinyl sulfoxide rotaxane **16** (30 mg, 23 μmol), dissolved in 1 mL dry DMF was then added and the solution was heated to 120 °C for 16 hours. After this time, the solvent was removed *in vacuo*, and the resulting dark residue was purified *via* column chromatography (eluent: CH_2Cl_2/CH_3CN 8/2) to yield the corresponding vinyl sulfide rotaxane **14** as a colorless solid 28 mg (93 %).

Method c): 3,3-Diphenylpropane-1-thiol (88 mg, 10 equiv) was dissolved in dry DMF (2 mL) and the solution was cooled to 0 °C. NaH (60% suspension in oil, 16 mg, 10 equiv) was added and the mixture was stirred under N_2 for 30 minutes. Vinyl sulfone rotaxane **17** (50 mg, 39 μmol), dissolved in 1 mL dry DMF was then added and the solution was heated to 120 °C for 18 hours. After this time the solvent was removed *in vacuo*, and the resulting crude residue was subjected to column chromatography (eluent: CH_2Cl_2/CH_3CN 8/2) to yield the corresponding vinyl sulfide rotaxane **14** as a colorless solid 44 mg (90 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.24 (br s, 2H, CH_C), 8.07 (dd, $J_{A\text{-}B}$ = 7.8 Hz, $J_{B\text{-}C}$ = 1.5 Hz, 4H, CH_B), 7.54-7.47 (m, 6H, CH_A and NH_D), 7.25-7.06 (m, 20H, H-Ar), 6.99 (d, J = 14.7 Hz, 1H, SC<u>H</u>=CH), 6.96 (s, 8H, CH_F), 6.31 (br t, 1H, NHCO), 6.16 (br t, 1H, NHCO), 5.55 (br t, 1H, NHCO), 5.29 (d, 1H, SCH=C<u>H</u>), 4.43 (dd, J_{gem} = 14.4 Hz, $J_{NH\text{-}E}$ = 5.4 Hz, 4H, CH_E), 4.38 (dd, $J_{NH\text{-}E'}$ = 5.1 Hz, 4H, $CH_{E'}$), 4.02 (t, J = 8.1 Hz, 1H, Ph_2C<u>H</u>CH_2NH), 3.91 (t, J = 7.8 Hz, 1H,

$Ph_2CHCH_2CH_2S$), 3.64 (dd, J_{CH2-NH} = 5.6 Hz, 2H, Ph_2CHCH_2NH), 3.10-3.02 (m, 2H, $CH_2NHCOCH=CH$), 2.99-2.91 (m, 2H, $CH_2NHCOCH_2CH_2$), 2.71 (t, *J* = 7.5 Hz, 2H, SCH_2CH_2), 2.30-2.21 (m, 2H, SCH_2CH_2), 1.39-1.29 (m, 4H, CH_2), 1.24-1.02 (m, 20H, CH_2 and $COCH_2CH_2CO$); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 172.9, 172.8, 166.5, 164.6, 143.7, 141.6, 141.2, 137.6, 133.9, 131.4, 129.2, 129.1, 129.0, 128.9, 128.0, 127.9, 127.7, 127.4, 127.1, 126.6, 124.2, 116.8, 50.5, 50.0, 44.2, 44.1, 39.8, 39.6, 34.7, 30.2, 29.7, 29.5, 29.3, 29.1, 29.1, 26.8 ; HRMS (FAB, NBA matrix): *m/z* = 1291.6558 (calc. for $C_{80}H_{89}N_7O_7S$, 1291.6544).

[3]-bis-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclohexacosane)–(*N*-(2,2-diphenyl-ethyl)-*N*'-{12-[(*E*)-3-(3,3-diphenyl-propylsulfanyl)-acryloylamino]-dodecyl}-succinamide)-rotaxane (15). See the preparation of **14**, Method a). ^1H NMR (400 MHz, $CDCl_3$) δ = 8.11 (br s, 2H, CH_C), 8.07 (br s, 2H, $CH_{C'}$), 8.00 (dd, J_{A-B} = 7.8 Hz, J_{B-C} = 1.0 Hz, 4H, CH_B), 8.00 (d, $J_{A'-B'}$ = 8.3 Hz, 4H, $CH_{B'}$), 7.72-7.61 (m, 4H, NH_D), 7.46 (t, 2H, CH_A), 7.41 (t, 2H, $CH_{A'}$), 7.37-7.30 (m, 4H, $NH_{D'}$), 7.25-6.99 (m, 22H, H-Ar and 2 NHCO), 6.98 (s, 8H, CH_F), 6.96 (s, 8H, $CH_{F'}$), 6.59 (br t, 1H, NHCO), 6.37 (d, *J* = 15.2 Hz, 1H, $SCH=CH$), 4.77 (d, 1H, $SCH=CH$), 4.55-4.20 (m, 16H, CH_E and $CH_{E'}$), 4.05 (t, *J* = 8.0 Hz, 1H, Ph_2CHCH_2NH), 3.69 (t, *J* = 7.7 Hz, 1H, $Ph_2CHCH_2CH_2S$), 3.66-3.60 (m, 2H, Ph_2CHCH_2NH), 2.91-2.83 (m, 2H, $CH_2NHCOCH=CH$), 2.53-2.44 (m, 2H, $CH_2NHCOCH_2CH_2$), 2.16-2.10 (m, 2H, SCH_2CH_2), 2.05-1.96 (m, 2H, SCH_2CH_2), 1.31-0.72 (m, 24H, CH_2 and $COCH_2CH_2CO$); LRMS (ESI+): *m/z* = 1825 $[M+H]^+$; HRMS (FAB, NBA matrix): *m/z* = 1823.8721 (calc. for $C_{112}H_{117}N_{11}O_{11}S$, 1823.8655).

[2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclo hexacosane)–(*N*-(2,2-diphenyl-ethyl)-*N*'-{12-[(*E*)-3-(3,3-diphenyl-propane-1-sulfinyl)-acryloylamino]-dodecyl}-succinamide)-rotaxane (16). Vinyl sulfide shuttle **14** (25 mg, 20 μmol) was dissolved in CH_2Cl_2 (1 mL), and the solution was cooled to -78 °C. MCPBA (3.5 mg, 1.0 equiv) was then added

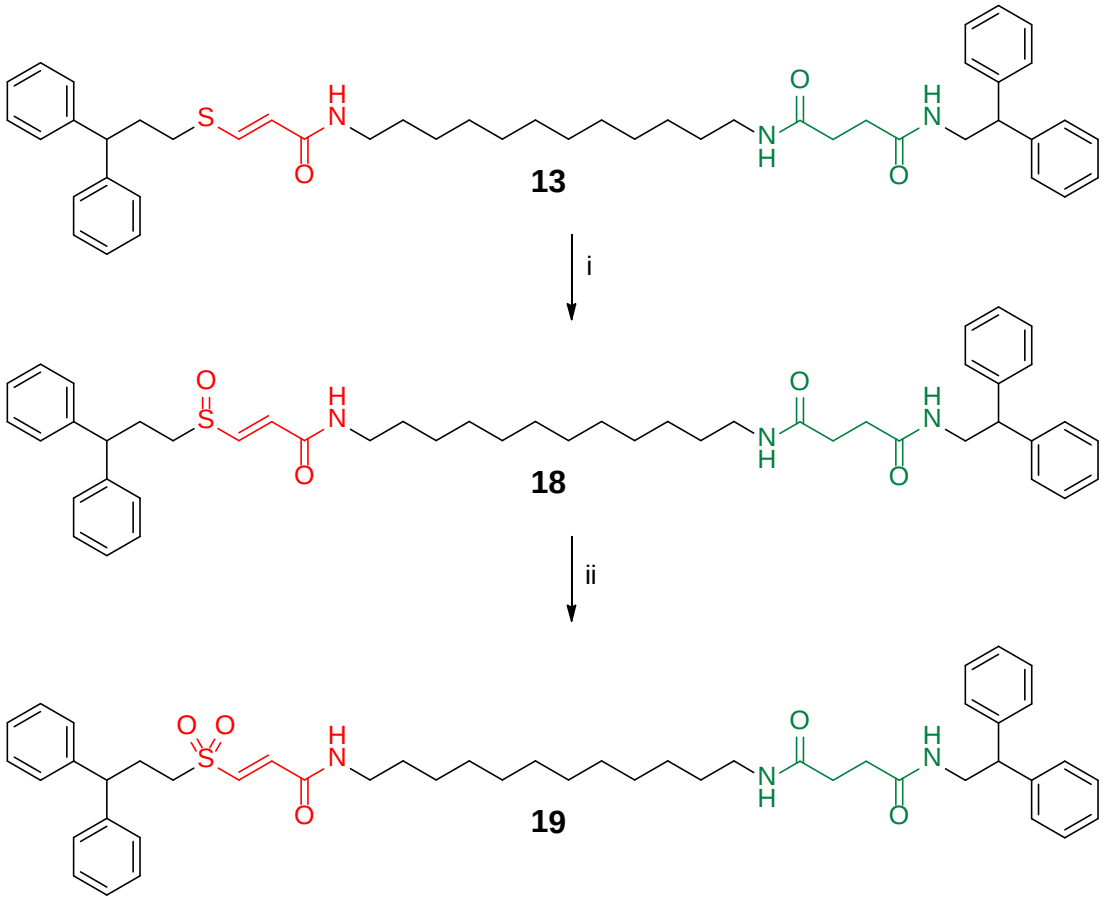
and the solution was allowed to warm to room temperature over 2 hours before being stirred overnight at room temperature. A saturated $NaHCO_3$ solution (10 mL) was then added slowly, and the aqueous layer was extracted with CH_2Cl_2 (3 x 1 mL). The combined organic layers were dried with $MgSO_4$, filtered and the solvent removed *in vacuo*. The crude residue was the purified by column chromatography (eluent: CH_2Cl_2/CH_3CN 9/1 to 9/6) to yield the corresponding vinyl sulfoxide shuttle **16** as a colorless amorphous solid 23 mg (90 %). ^{1}H NMR (400 MHz, 55°C, $CDCl_3$) δ = 8.33 (br s, 2H, CH_C), 8.08 (br d, J_{A-B} = 7.6 Hz, 4H, CH_B), 7.54-7.48 (m, 4H, NH_D), 7.47 (t, 2H, CH_A), 7.23-7.01 (m, 21H, H-Ar and NHCO), 6.96 (d, $J_{F-F'}$ = 8.0 Hz, 4H, CH_F), 6.91 (d, 4H, $CH_{F'}$), 6.59 (d, J = 14.9 Hz, 1H, S(O)C<u>H</u>=CH), 6.01 (br t, 1H, NHCO), 5.93 (d, 1H, S(O)CH=C<u>H</u>), 5.85 (br t, 1H, NHCO), 4.43-4.34 (m, 8H, CH_E and $CH_{E'}$), 4.04 (t, J = 8.1 Hz, 1H, Ph_2C<u>H</u>CH_2NH), 3.82 (t, J = 7.8 Hz, 1H, Ph_2C<u>H</u>CH_2CH_2SO), 3.70 (dd, J = 5.8 Hz, 2H, Ph_2CHC<u>H</u>$_2NH$), 3.25-3.15 (m, 1H, C<u>H</u>$_2$NHCO-CH=CH), 3.13-3.05 (m, 1H, C<u>H</u>$_2$NHCOCH=CH), 3.03-2.95 (m, 2H, C<u>H</u>$_2$NHCOCH_2CH_2), 2.33-2.15 (m, 4H, S(O)C<u>H</u>$_2$C<u>H</u>$_2$), 2.08 (s, 4H, NHCOC<u>H</u>$_2$C<u>H</u>$_2$CONH), 1.51-1.31 (m, 4H, CH_2), 1.28-1.12 (m, 16H, CH_2); ^{13}C NMR (100 MHz, DMSO-*d*6) δ 171.9, 171.6, 165.6, 162.3, 144.5, 143.9, 143.8, 142.8, 137.5, 134.4, 134.3, 130.1, 128.6, 128.5, 128.4, 128.3, 127.8, 127.7, 127.4, 127.4, 126.3, 125.7, 50.1, 49.5, 43.2, 42.9, 40.1, 39.9, 38.5, 30.1, 30.0, 29.0, 28.8, 28.7, 28.6, 26.6; HRMS (FAB, NBA matrix): *m/z* = 1307.6484 (calc. for $C_{80}H_{89}N_7O_8S$, 1307.6493).

[2]-(1,4,7,14,17,20,-Hexaaza-2,6,15,19-tetraoxo-3,5,9,12,16,18,22,25-tetrabenzocyclohexaco-sane)–(*N*-(2,2-diphenyl-ethyl)-*N*'-{12-[(*E*)-3-(3,3-diphenyl-propylsulfonyl)-acryloylamino]-dodecyl}-succinamide)-rotaxane (17). <u>Method a):</u> Vinyl sulfoxide shuttle **16** (25 mg, 20 μmol) was dissolved in CH_2Cl_2 (1 mL), and the solution was cooled to -78 °C. MCPBA (7.0 mg, 2.0 equiv) was then added and the solution was allowed to warm to room temperature over 2 hours before being stirred overnight at room temperature. A saturated $NaHSO_3$ solution (0.5 mL) was then added slowly to quench the reaction, and the aqueous layer was then extracted with CH_2Cl_2 (3 x 1 mL). The

combined organic layers were washed with saturated $NaHCO_{3(aq)}$ (3 x 1 mL), water (1 mL) and brine (1 mL), before being dried with $MgSO_4$, filtered, and the solvent evaporated. The crude residue was purified using flash column chromatography on silica gel (eluent: CH_2Cl_2/CH_3CN 9/1 to 7/3) to yield the corresponding vinyl sulfone shuttle **17** as a colorless amorphous solid 23 mg (92 %).

Method b): Identical as Method a) However starting from vinyl sulfide shuttle **14** and using a larger excess of MCPBA (3.0 equiv) to give 23 mg of product (88 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.28 (br s, 2H, CH_C), 8.07 (br d, $J_{A\text{-}B}$ = 7.8 Hz, 4H, CH_B), 7.54 (br t, 4H, NHD), 7.47 (t, $J_{A\text{-}B}$ = 7.8 Hz, 2H, CH_A), 7.26-7.16 (m, 21H, H-Ar and NHCO), 7.02 (d, J = 14.7 Hz, 1H, $SO_2C\underline{H}$=CH), 6.94 (s, 8H, CH_F), 6.67 (d, 1H, SO_2CH=C$\underline{H}$), 6.31 (br t, 1H, NHCO), 6.02 (br t, 1H, NHCO), 4.45-4.35 (m, 8H, CH_E and $CH_{E'}$), 4.02 (t, J = 8.1 Hz, 1H, $Ph_2C\underline{H}CH_2NH$), 3.88 (t, J = 7.8 Hz, 1H, $Ph_2C\underline{H}CH_2CH_2S$), 3.70-3.63 (m, 2H, $Ph_2CHC\underline{H}_2NH$), 3.29-3.20 (m, 2H, $C\underline{H}_2NHCOCH$=CH), 3.02-2.94 (m, 2H, $C\underline{H}_2NHCOCH_2CH_2$), 2.73-2.68 (m, 2H, $SO_2C\underline{H}_2CH_2$), 2.38-2.27 (m, 2H, $SO_2CH_2C\underline{H}_2$), 1.51-1.31 (m, 4H, CH_2), 1.29-1.01 (m, 20H, CH_2 and $COC\underline{H}_2C\underline{H}_2CO$); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 172.9, 172.8, 166.6, 162.6, 142.6, 141.5, 137.6, 137.1, 136.4, 133.9, 131.5, 129.2, 129.1, 128.9, 128.7, 128.0, 127.9, 127.6, 127.2, 126.9, 124.3, 53.2, 50.5, 49.8, 44.2, 44.0, 40.2, 29.7, 29.2, 29.0, 28.9, 27.6, 26.8, 22.7; HRMS (FAB, NBA matrix): *m/z* = 1323.6458 (calc. for $C_{80}H_{89}N_7O_9S$, 1323.6442).

Scheme 6. Synthesis of Threads **18** and **19**.[a]



[a] Reagents and conditions: (i) MCPBA, CH_2Cl_2, -78 °C to RT, 2 h, 90% (**18**); (vii) MCPBA, CH_2Cl_2, RT, 18 h, 94% (**19**).

(+/-)-*N*-(2,2-Diphenyl-ethyl)-*N*'-{12-[(*E*)-3-(3,3-diphenyl-propane-1-sulfinyl)-acryloylamino]-dodecyl}-succinamide (18). Vinyl sulfide thread **13** (200 mg, 0.26 mmol) was dissolved in CH_2Cl_2 (3 mL), and the solution was cooled to -78 °C. MCPBA (45 mg, 1.0 equiv) was then added and the solution was allowed to warm to room temperature over 2 hours before being stirred at room temperature overnight. A saturated $NaHCO_3$ solution (3 mL) was then slowly added and the aqueous layer was extracted with CH_2Cl_2 (3 x 3 mL). The combined organic layers were dried with $MgSO_4$, filtered and the solvent evaporated. The crude residue was purified using flash column chromatography on silica gel (eluent: petroleum ether/EtOAc 6/4 to EtOAc) to yield the corresponding vinyl sulfoxide as a colorless amorphous solid 182 mg (90 %). ^{1}H NMR (400 MHz, $CDCl_3$, 50 °C) δ = 7.32 (d, J = 14.4 Hz, 1H, SC<u>H</u>=CH), 7.27-7.09 (m, 20H, H-Ar), 6.87 (br t, 1H,

NHCO), 6.63 (d, 1H, SCH=CH), 6.20 (br t, 1H, NHCO), 6.09 (br t, 1H, NHCO), 4.09 (t, *J* = 7.8 Hz, 1H, Ph_2CHCH_2NH), 3.93 (t, *J* = 8.1 Hz, 1H, $Ph_2CHCH_2CH_2S$), 3.78 (dd, *J* = 5.8 Hz, 2H, Ph_2CHCH_2NH), 3.26-3.18 (m, 2H, $CH_2NHCOCH=CH$), 3.12-3.04 (m, 2H, $CH_2NHCOCH_2CH_2$), 2.71 (ddd, J_{gem} = 13.1 Hz, J_{CH-CHa} = 10.6 Hz, J_{CH-CHb} = 5.3 Hz, 1H, $SOCH_2CH_2$), 2.55 (ddd, J_{CH-CHa} = 10.1 Hz, J_{CH-CHb} = 5.0 Hz, 1H, $SOCH_2CH_2$), 2.50-2.33 (m, 2H, $SOCH_2CH_2$), 2.32 (s, 4H, $COCH_2CH_2CO$), 1.48-1.33 (m, 4H, CH_2), 1.28-1.12 (m, 16H, CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 172.3, 172.1, 162.4, 144.0, 143.2, 143.0, 141.9, 129.6, 128.8, 128.7, 128.6, 128.5, 128.2, 128.0, 127.9, 127.7, 127.6, 126.8, 126.5, 51.1, 50.6, 50.3, 43.9, 39.9, 39.6, 31.8, 31.7, 29.7, 29.4, 29.3, 29.2, 29.1, 29.0, 27.4, 26.8; LRMS (ESI+): *m/z* = 776.5 $[M+H]^+$.

***N*-(2,2-Diphenyl-ethyl)-*N*'-{12-[(*E*)-3-(3,3-diphenyl-propane-1-sulfonyl)-acryloylamino]-dodecyl}-succinamide (19)**. Vinyl sulfoxide **18** (80 mg, 0.10 mmol) was dissolved in CH_2Cl_2 (2 mL). MCPBA (26 mg, 1.5 equiv) was then added and the solution was allowed to stir at room temperature for 18 hours. A saturated $NaHSO_3$ solution (1 mL) was then added slowly, and the resulting biphasic mixture was vigorously stirred at room temperature for 15 minutes. The aqueous layer was then extracted with CH_2Cl_2 (3 x 2 mL). Combined organic layers were washed with a saturated sodium bicarbonate solution (3 x 1 mL), water (1 mL) and brine (1 mL), dried with magnesium sulfate, filtered and the solvent evaporated. The resulting white solid was purified using flash column chromatography on silica gel (eluent: petroleum ether/EtOAc 1/1 to pure EtOAc) to yield the corresponding vinyl sulfone **19** as a colorless amorphous solid 77 mg (94 %). ^{1}H NMR (400 MHz, $CDCl_3$) δ= 7.25-7.08 (m, 21H, SCH=CH and H-Ar), 7.02 (br t, 1H, NHCO), 6.90 (d, *J* = 14.7 Hz, 1H, SCH=CH), 6.11 (br t, 2H, NHCO), 4.09 (t, *J* = 7.8 Hz, 1H, Ph_2CHCH_2NH), 3.92 (t, *J* = 8.0 Hz, 1H, $Ph_2CHCH_2CH_2S$), 3.77 (dd, *J* = 5.7 Hz, 2H, Ph_2CHCH_2NH), 3.26-3.18 (m, 2H, $CH_2NHCOCH=CH$), 3.12-3.04 (m, 2H, $CH_2NHCOCH_2CH_2$), 2.92-2.84 (m, 2H, $SO_2CH_2CH_2$), 2.48-2.39 (m, 2H, $SO_2CH_2CH_2$), 2.32 (s, 4H, $COCH_2CH_2CO$), 1.49-1.32 (m, 4H, CH_2), 1.29-1.12 (m, 16H,

CH_2); ^{13}C NMR (100 MHz, $CDCl_3$) δ= 172.3, 172.1, 161.6, 157.9, 142.6, 141.8, 137.0, 130.1, 129.7, 128.9, 128.7, 128.5, 128.3, 128.2, 128.0, 127.6, 126.9, 126.8, 53.2, 50.5, 43.9, 40.2, 39.6, 31.9, 31.8, 29.7, 29.4, 29.1, 29.0, 28.9, 27.8, 26.7; LRMS (ESI+): *m/z* = 808.5 $[M+H]^+$.

4. X-ray Data

The structure of rotaxane **7** in the solid state was determined by X-ray crystallography. Suitable single crystals were obtained by slow diffusion of diethyl ether into a solution of the rotaxane **7** in dichloromethane. X-ray data for each of the rotaxanes is shown below.

7: $C_{65}H_{61}N_5O_{12}SCl_2$, *M*=1207.16, crystal size 0.06×0.06×0.01mm, monoclinic $P2_1/n$, *a*=18.838(1), *b*=17.343(2), *c*=19.035(4) Å, α=97.085(1), β=90.41(10),γ=98.695(1)°, *V*=6219.33(11) $Å^3$, *Z*=4, ρ_{calcd}=1.289 Mg m^{-3}; MoK_α radiation (graphite monochromator, λ=0.71073 Å), μ=0.080 mm^{-1}, *T*=180(2)K. 10380 data (3580 unique, R_{int}=0.0792, 2.18<θ<22.61°), were collected on a Siemens SMART CCD diffractometer using narrow frames (0.3° in ω), and were corrected semi-empirically for absorption and incident beam decay (transmission 0.58-1.00). The structure was solved by direct methods and refined by full-matrix least-squares on F^2 values of all data (G.M.Sheldrick, SHELXTL manual, Siemens Analytical *X*-ray Instruments, Madison WI, USA, 1994, version 5) to give $wR=\{\Sigma[w(F_O^2-F_C^2)^2]/\Sigma[w(F_O^2)^2]\}^{1/2}$=0.067**,** conventional *R*=0.067. Amide hydrogen atoms were refined isotropically subject to a distance constraint N-H = 0.98 Å, with the remainder constrained; anisotropic displacement parameters were used for all non-hydrogen atoms.

Crystallographic data for **6**,[4] **7** and **8**[4] (excluding structure factors) have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication numbers CCDC-160649 (**6**),[4] CCDC-829630 (**7**) and CCDC-161353 (**8**)[4]. Copies of the data can be obtained free of charge on application to The Director, CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: Int. code + (1223)336-033; e-mail: teched@chemcrys.cam.ac.uk).

5. References

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