Electronic Supplementary Information

Title : Chiral Sensing for Amino-Acid Derivative Based on [2]Rotaxane Composed of Unsymmetric Rotor and Unsymmetric Axle

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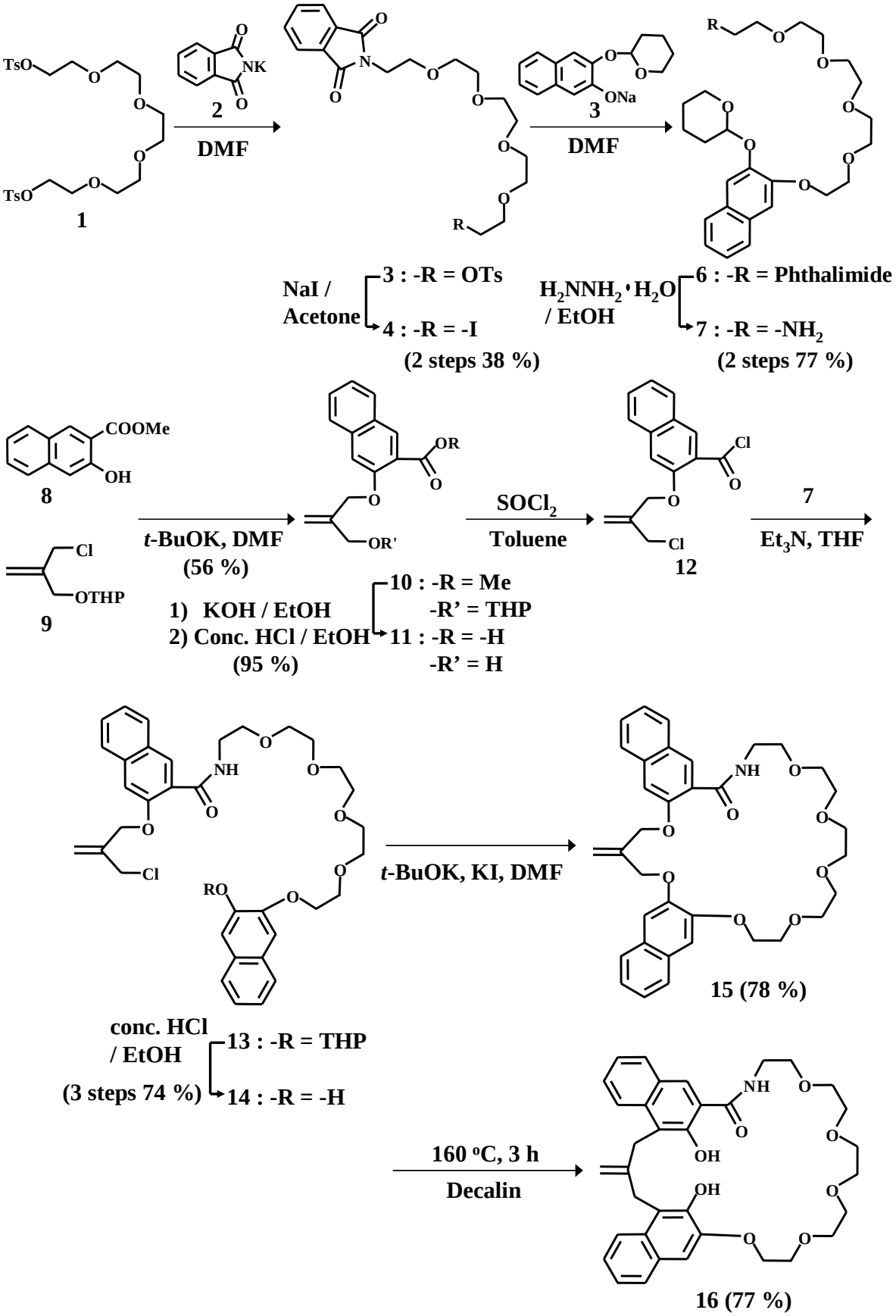
Contents

Supplementary Material (ESI) for Chemical Communications



Synthesis of unsymmetric rotor having two hydroxy groups.

4 : 1-phthalimide-14-iodo-3,6,9,10-tetraoxatetradecane **4** was synthesized by the iodization of 1-phthalimide-14-*p*-toluenesufonate-3,6,9,10-tetraoxatetradecane **3** which was obtained from the reaction between excess amount of pentaethylene glycol di-*p*-toluenesulfonate **1** and potassium phthalimide **2** in N,N-dimethylformamide (DMF) at 50 ^{o}C. The iodization and the purification of **4** were carried out according to the literature.[Reference] ^{1}H-NMR (300 MHz, in $CDCl_3$), 3.26 ppm (2H, t, J = 6.6 Hz, -OCH_2-), 3.60-3.67 (12H, -OCH_2CH_2O-), 3.75 (4H, t, J = 6.9, ICH_2CH_2O-), 3.90 (2H, t, J = 5.7, phtalimide-CH_2-), 7.23 (2H, m, phtalimide), 7.85 (2H, m, phtalimide).

[Reference] D. Parker, *Macrocycle Synthesis*, Oxford University, 1996.

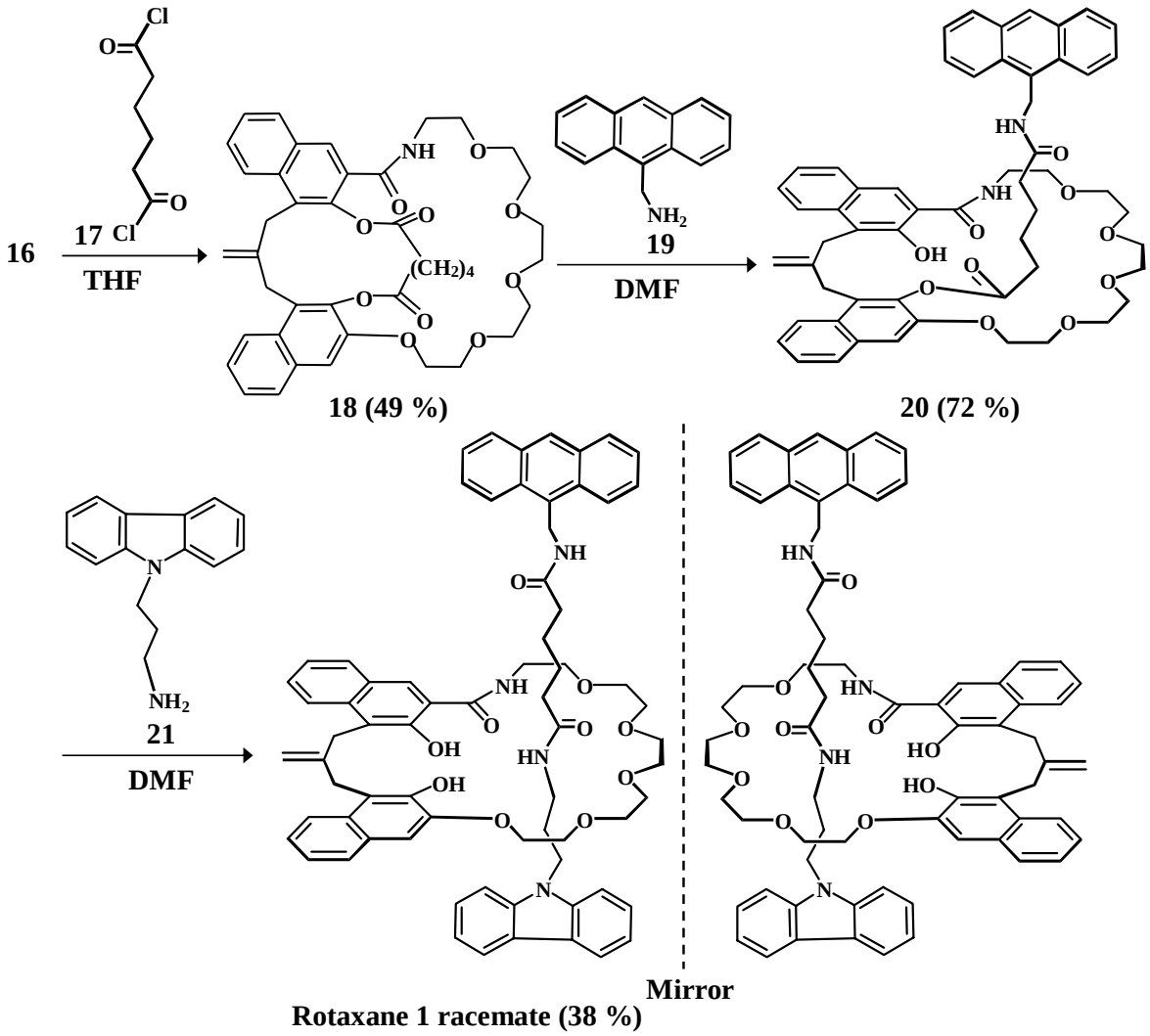
7 : 1-amino-14-[3-(tetrahydropyran-2-yloxy)-naphthalene]-3,6,9,10-tetraoxatetradecane **7** was synthesized by the hydrazine reduction (in EtOH) of 1-phthalimide-14-(3-(tetrahydropyran-2-yloxy)-naphthalene)-3,6,9,10-tetraoxatetradecane **6** which was obtained from the reaction between **4** and 3-(tetrahydropyran-2-yloxy)-naphthalene-2-sodium hydroxyed **5** in DMF. ^{1}H-NMR (300 MHz, in $CDCl_3$), 1.66-2.09 (9H, m, THP), 2.85 (2H, t, J = 5.1, NH_2), 3.50 (2H, t, J = 5.4, -OCH_2-), 3.60-3.70 (12H, -OCH_2-), 3.82 (2H, t, J = 5.1, -OCH_2-), 3.96 (2H, t, J = 4.8, -OCH_2-), 4.28 (2H, t, J = 5.1, -OCH_2-), 5.56 (1H, t, J = 3.0, THP), 7.17 (1H, t, Ar), 7.32 (2H, td, J = 5.4, J = 1.2, Ar), 7.46 (1H, s, Ar), 7.65 (1H, dd, J = 5.4, J = 1.2, Ar), 7.68 (1H, dd, J = 5.4, J = 1.2, Ar).

11 : 3-(2-hydroxymethyl-allyloxy)-naphthalene-2-carboxylic acid **11** was synthesized by the deprotection and the hydrolysis of 3-[(2-tetrahydropyran-2-yloxymethyl)-allyloxy]-naphthalene-2-carboxylic acid methyl ester **10** which was obtained from the reaction between 3-hydroxy-naphthalene-2-carboxylic acid methyl ester **8** and 2-(2-chloromethyl-allyoxy)-tetrahydropyran **9** in the presence of base. ^{1}H-NMR (300 MHz, in $CDCl_3$), 4.37 ppm (2H, s, Ar-CH_2-), 4.92 (2H, s, Ar-CH_2-), 5.40 (1H, s, CH_2=C), 5.44 (1H, s, CH_2=C), 7.31 (1H, s, Ar), 7.44 (1H, td, J = 7.4, J = 1.2, Ar), 7.58 (1H, td, J = 7.4, J = 1.2, Ar), 7.75 (1H, dd, d = 7.4, J = 1.2, Ar), 7.89 (1H, dd, J = 7.4, J = 1.2, Ar).

14 : Noncyclic compound **14** was synthesized by the amide formation between the amine **7** and the acid chloride **12** prepared from the corresponding carboxylic acid **11**, and then the deprotection of the obtained **13**. ^{1}H-NMR (300 MHz, in $CDCl_3$), 3.60-3.75 pm (16H, -CH2-), 3.84 (2H, t, J = 4.5, -CH_2-), 4.22 (2H, t, J = 4.5, -CH_2-), 4.23 (2H, s, Ar-CH_2-), 4.82 (2H, s, Ar-CH_2-), 5.42 (1H, s, CH_2=C), 5.45 (1H, s, CH_2=C), 7.08 (1H, s, Ar), 7.18 (1H, s, Ar), 7.19 (1H, s, Ar), 7.23-7.30 (2H, Ar), 7.38 (1H, t, J = 7.5, Ar), 7.50 (1H, t, J = 7.5, Ar), 7.56-7.65 (2H, Ar), 7.69 (1H, d, J = 8.1, Ar), 7.86 (1H, d, J = 8.1, Ar). 1645 cm^{-1} (O=CNH).

Macrocyclic Compound 15 : Macrocyclic compound **15** was synthesized by the intramolecular cyclization of **14** in the presence of base under the high dilution condition. ^{1}H-NMR (300 MHz, in $CDCl_3$), 3.53-3.71 ppm (16H, -CH_2-), 3.94 (2H, t, J = 4.5, -CH_2-), 4.30 (2H, t, J = 4.5, -CH_2-), 4.87 (2H, s, Ar-CH_2-), 5.03 (2H, s, Ar-CH_2-), 5.52 (1H, s, CH_2=C), 5.63 (1H, s, CH_2=C), 7.16 (1H, s, Ar), 7.20 (1H, s, Ar), 7.29 (1H, s, Ar), 7.32-7.41 (2H, Ar), 7.39 (1H, t, J = 7.8, Ar), 7.45 (1H, t, J = 7.8, Ar), 7.60 (1H, d, J = 9.0, Ar), 7.64 (1H, d, J = 6.9, Ar), 7.69 (1H, d, J = 7.5, Ar), 7.90 (1H, d, J = 7.5, Ar), 8.38 (1H, s, NH), 8.75 (1H, s, Ar). 1649 cm^{-1} (O=CNH). ESI-MS (Cationic mode, in CH_3CN), m / z = 602.4 (H^+).

Rotor 16 : Two hydroxy groups were introduced into the macrocyclic compound by using tandem Claisen rearrangement. The thermal reaction toward **15** was performed in decalin at 160 ^{o}C for 3 h. ^{1}H-NMR (300 MHz, in $CDCl_3$), 3.44 ppm (2H, m, -CH_2-), 3.50 (2H, m, -CH_2-), 3.56 (2H, m, -CH_2-), 3.61-3.85 (12H, m, -CH_2-), 3.85 (2H, s, Ar-CH_2-), 3.99 (2H, s, Ar-CH_2-), 4.17 (2H, m, -CH_2-), 4.62 (1H, s, CH_2=C), 4.91 (1H, s, CH_2=C), 7.05 (1H, s, Ar), 7.28 (1H, t, J = 7.5, Ar), 7.29 (1H, t, J = 7.5, Ar), 7.38 (1H, t, J = 8.4, Ar), 7.40 (1H, t, J = 8.4, Ar), 7.49 (1H, s, OH), 7.63 (1H, d, J = 7.5, Ar), 7.78 (1H, d, J = 7.5, Ar), 7.84 (1H, d, J = 8.4, Ar), 7.94 (1H, d, J = 8.4, Ar), 7.96 (1H, s, NH), 10.62 (1H, s, OH). 3533 cm^{-1} (O-H), 1648 (O=CNH). m / z = 602.4 (H^+).



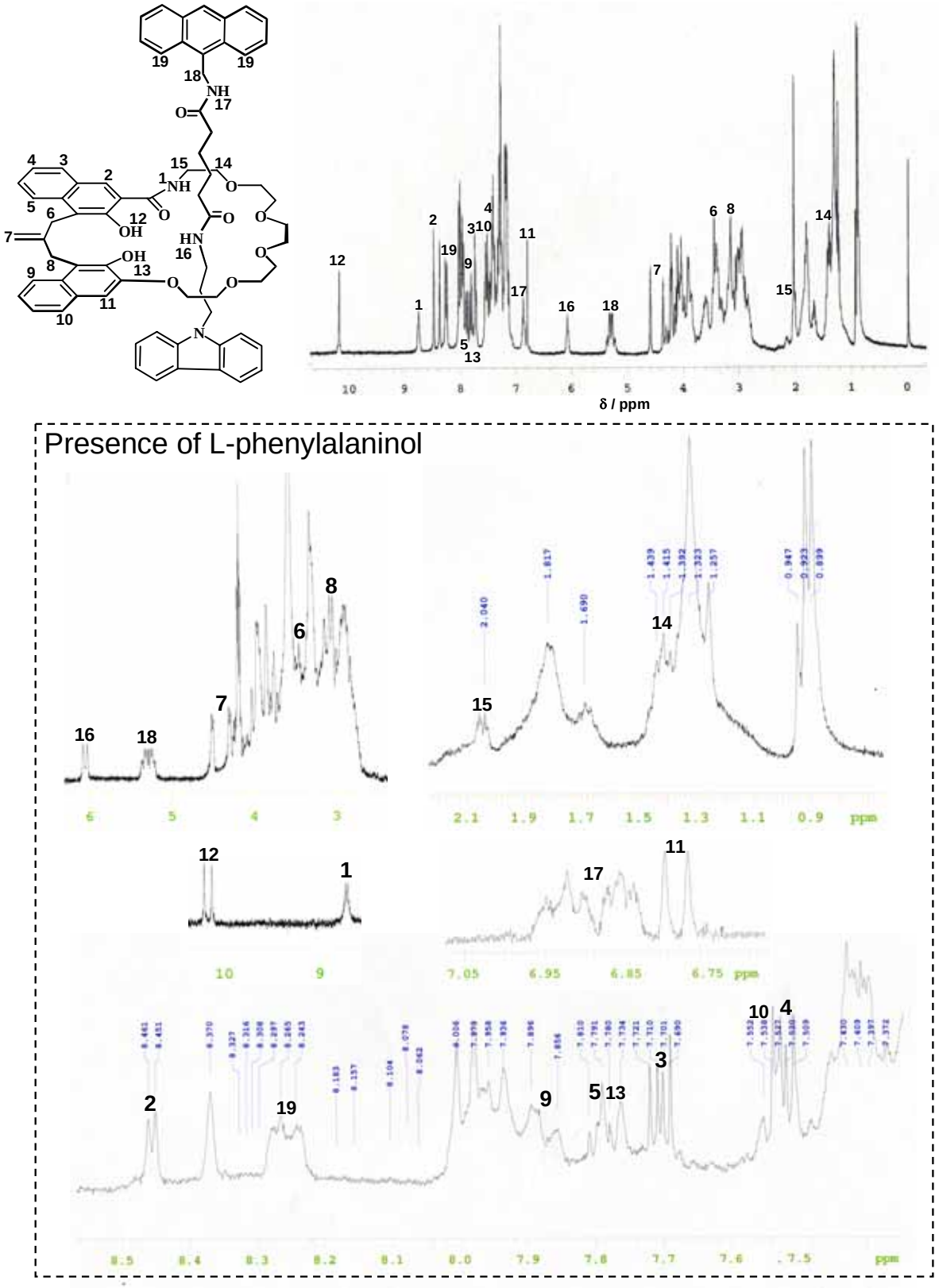
Synthesis of rotaxane **1** racemate via covalent bond formation such as esterification and aminolysis.

Diester 18 : Diester compound **18** was synthesized by the diesterification of rotor **16** having two hydroxy groups with adipoyl chloride **17** in the presence of base. ^{1}H-NMR (300 MHz, in $CDCl_3$), 2.18 ppm (4H, br, -CH_2CH_2-), 2.78 (4H, br, -COO-CH_2-), 3.63-3.70 (16H, br, -CH_2-), 3.87 (2H, s, Ar-CH_2-), 3.88 (2H, s, Ar-CH_2-), 4.20-4.26 (4H, br, -CH_2-, CH_2=C), 6.94 (1H, br, NH), 7.15 (1H, s, Ar), 7.43-7.47 (2H, Ar), 7.51 (1H, t, J = 6.9, Ar), 7.60 (1H, t, J = 6.9, Ar), 7.73 (1H, d, J = 7.5, Ar), 7.89-7.94 (3H, Ar), 8.33 (1H, s, Ar). 1748 cm^{-1} (O=COAr) 1640 (O=CNH). m / z = 734.4 (Na^{+}).

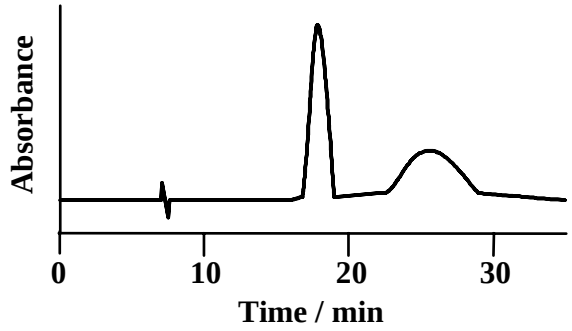
Monoester 20 : Monoester compound **20** was synthesized by the monoaminolysis of diester **18** with same equivalent amount of amino-methyl anthracene **19** at room temperature for 5 days. ^{1}H-NMR

(300 MHz, in $CDCl_3$), 1.21 ppm (2H, br, -CH_2-), 1.52 (4H, br, -CH_2-), 2.14 (2H, br, -COO-CH_2-), 3.34-4.08 (20H, br, -CH_2-), 3.62 (2H, s, Ar-CH_2-), 3.64 (2H, s, Ar-CH_2-), 4.41 (1H, s, CH_2=C), 5.07 (1H, s, CH_2=C), 5.47 (2H, d, J = 4.5, Anthracene-CH_2-), 6.38 (1H, br, NH), 6.88 (1H, s, Ar), 7.19-7.27 (2H, Ar), 7.38 (1H, t, J = 7.8, Ar), 7.40 (2H, t, J = 8.4, Anthracene), 7.49 (2H, t, J = 8.4, Anthracene), 7.57 (1H, t, J = 7.8, Ar), 7.62 (1H, d, J = 7.8, Ar), 7.75 (1H, d, J = 7.8, Ar), 7.92 (1H, d, J = 7.8, Ar), 7.96 (1H, d, J = 7.8, Ar), 8.02 (2H, d, J = 8.4, Anthracene), 8.17 (1H, br, NH), 8.33 (2H, d, J = 8.4, Anthracene), 8.44 (1H, s, Anthracene), 11.8 (1H, br, OH). 1746 cm^{-1} (O=COAr), 1644 (O=CNH), 1631 (O=CNH). m / z = 919.5 (H^+).

Rotaxane 1 : Rotaxane **1** was synthesized by the second monoaminolysis of the monoester **20** with amino-propyl carbazole **21**. ^{1}H-NMR (300 MHz, in $CDCl_3$), 0.92 ppm (4H, -CH_2-), 1.24-1.46 (8H, -CH_2-), 1.82 (2H, -CH_2-), 2.80-4.22 (20H, -CH_2-), 3.16 (2H, s, Ar-CH_2-), 3.45 (2H, s, Ar-CH_2-), 4.36 (1H, s, CH_2=C), 4.59 (1H, s, CH_2=C), 5.31 (2H, m, Anthracene-CH_2-), 6.06 (1H, br, NH), 6.78 (1H, s, Ar), 6.87 (1H, br, NH), 7.12-7.31 (3H, t, Ar, 4H, d, Carbazole), 7.28 (2H, t, J = 7.8, Anthracene), 7.39 (2H, t, J = 7.8, Anthracene), 7.50 (1H, d, J = 7.80, Ar), 7.53 (1H, t, J = 7.8, Ar), 7.70 (1H, d, J = 7.8, Ar), 7.73 (1H, s, OH), 7.80 (1H, d, J = 7.8, Ar), 7.87 (1H, d, J = 7.8, Ar), 7.93 (2H, d, J = 7.8, Anthracene), 7.95 (2H, d, J = 7.8, Carbazole), 8.00 (2H, d, J = 7.8, Carbazole), 8.24 (2H, d, J = 7.8, Anthracene), 8.36 (1H, s, Anthracene), 8.46 (1H, s, Ar), 8.74 (1H, br, NH), 10.15 (1H, s, OH). 3311 cm^{-1} (O-H), 1643 (O=CNH), 1630 (O=CNH). m / z = 1165.6 (Na^+).



^{1}H NMR spectra of 1.0×10^{-3} M rotaxane **1** in the presence and absence of 0.5×10^{-3} M *L*-phenylalaninol in $CDCl_3$.



Chromatograms of the enantiomeric separation. Two peaks were corresponded to each enantiomers which were identified by ESI-MS measurements of each corrected fractions. Column, Chiralcel OC (0.46 cm i.d. × 25 cm, Daicel Co.); Mobile Phase, Hexane / EtOH (30 / 70); Flow rate, 0.7 ml /min; Detection wavelength, 285 nm.