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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Synthetic schemes and spectral data of unsymmetric rotor and rotaxane 1.

$^1$H NMR spectra of $1.0 \times 10^{-3}$ M rotaxane 1 in the presence and absence of $0.5 \times 10^{-3}$ M L-phenylalaninol in CDCl$_3$.

Enantiomeric separation of rotaxane 1 via HPLC equipped with chiral column.
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-toluenesulfonate-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 °C. The iodization and the purification of 4 were carried out according to the literature. \[ \text{Reference} \]

\[ \text{H-NMR (300 MHz, in CDCl}_3\text{), 3.26 ppm (2H, t, } J = 6.6 \text{ Hz, -OCH}_2\text{-), 3.60-3.67 (12H, -OCH}_2\text{CH}_2\text{O-), 3.75 (4H, t, } J = 6.9 \text{, ICH}_2\text{CH}_2\text{O-), 3.90 (2H, t, } J = 5.7 \text{, phthalimide-CH}_2\text{-), 7.23 (2H, m, phthalimide), 7.85 (2H, m, phthalimide).} \]


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-(tetrahydropryan-2-yloxy)-naphthalene-2-sodium hydroxyed 5 in DMF. \[ \text{H-NMR (300 MHz, in CDCl}_3\text{), 1.66-2.09 (9H, m, THP), 2.85 (2H, t, } J = 5.1 \text{, NH}_2\text{), 3.50 (2H, t, } J = 5.4 \text{, -OCH}_2\text{-), 3.60-3.70 (12H, -OCH}_2\text{-), 3.82 (2H, t, } J = 5.1 \text{, -OCH}_2\text{-), 3.96 (2H, t, } J = 4.8 \text{, -OCH}_2\text{-), 4.28 (2H, t, } J = 5.1 \text{, -OCH}_2\text{-), 5.56 (1H, t, } J = 3.0 \text{, THP), 7.17 (1H, t, Ar), 7.32 (2H, td, } J = 5.4 \text{, } J = 1.2 \text{, Ar), 7.46 (1H, s, Ar), 7.65 (1H, dd, } J = 5.4 \text{, } J = 1.2 \text{, Ar), 7.68 (1H, dd, } J = 5.4 \text{, } J = 1.2 \text{, Ar).} \]

11 : 3-(2-hydroxymethyl-allyloxy)-naphthalene-2-carboxylic acid 11 was synthesized by the deprotection and the hydrolysis of 3-{[2-tetrahdropryan-2-yloxymethyl]-allyloxy]napththalene-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-allyloxy)tetrahydropryan 9 in the presence of base. \[ \text{H-NMR (300 MHz, in CDCl}_3\text{), 4.37 ppm (2H, s, Ar-CH}_2\text{-), 4.92 (2H, s, Ar-CH}_2\text{-), 5.40 (1H, s, CH}_2\text{=C), 5.44 (1H, s, CH}_2\text{=C), 7.31 (1H, s, Ar), 7.44 (1H, td, } J = 7.4 \text{, } J = 1.2 \text{, Ar), 7.58 (1H, td, } J = 7.4 \text{, } J = 1.2 \text{, Ar), 7.75 (1H, dd, } d = 7.4 \text{, } J = 1.2 \text{, Ar), 7.89 (1H, dd, } J = 7.4 \text{, } J = 1.2 \text{, Ar).} \]
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 ppm (16H, -CH\(_2\)-), 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, \(J = 6.9, Ar\)), 7.64 (1H, d, \(J = 7.5, Ar\)), 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\(_3\)CN), 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 °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$_2$CH$_2$-), 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
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(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$^+$/Ar).

**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$^+$).
\[ ^1H \text{ NMR spectra of } 1.0 \times 10^{-3} \text{ M rotaxane I in the presence and absence of } 0.5 \times 10^{-3} \text{ M L-phenylalaninol in CDCl}_3. \]
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.