

# **Azaindenocorannulenes: Synthesis, Properties, & Chirality**

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# 1. Materials and methods

## 1.1 General and instruments

Unless otherwise stated, all commercially available reagents and solvents were used as received without further purification. Flash chromatography was performed on silica gel 100-200 m. Thin layer chromatography (TLC) was performed on glass backed plates pre-coated with silica (GF254), which were developed using standard visualizing agents. All optical measurements were performed in HPLC grade dichloromethane. UV-Vis measurements were carried out on HATACHI U-3900. Infrared spectra (IR) were recorded on a *JASCO FT/IR-4100 Fourier Transform Infrared Spectrometer*. IR frequencies are given in  $\text{cm}^{-1}$ . Signal intensities are presented as weak (w), medium (m), strong (s) and very strong (vs). NMR spectra were recorded on *Bruker AV-400/500* (400/500 MHz) instruments. The chemical shift ( $\delta$ ) is shown in ppm and referenced against the corresponding solvent peaks (for  $\text{CDCl}_3$ ,  $^1\text{H}$ -NMR: 7.26 ppm;  $^{13}\text{C}$ -NMR: 77.16 ppm). Data is reported as follows: chemical shift in ppm, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = doublet of doublet, dt = doublet of triplet), coupling constant ( $J$ ) in Hz, and integration. Fluorescence excitation/emission measurements were carried on *Edinburgh FLS980* spectrophotometer, using 450W Xenon arc lamp, with excitation and emission slit widths at 1 nm. Emission spectra were obtained by exciting at the longest wavelength excitation maximum. Fluorescence lifetimes were measured using nanosecond flash lamp with computer controlled power supply, for solutions with O.D.  $\sim$  0.1. Absolute quantum yields were measured using an integrating sphere accessory. Microwave reactions were performed in a *CEM Discover Microwave Reactor* with integrated active cooling. All cyclic voltammetry measurements were performed using a *CHI600E Electrochemical Analyzer*, *CH Instruments, Inc.* and in THF solvent with a scan rate of 0.1 V/s. THF was of HPLC grade and distilled over  $\text{CaH}_2$  prior to its use. Tetrabutylammonium hexafluorophosphate (TBAH) was used as an electrolyte. Non-Aqueous  $\text{Ag}/\text{Ag}^+$  was used as reference electrode (10 mM  $\text{AgNO}_3$  in 0.1 M  $\text{Bu}_4\text{NPF}_6$  in acetonitrile), platinum wire as counter electrode and glassy carbon as working electrode for all measurements. All  $E_{1/2}$  potentials are directly obtained from cyclic voltammetric curves as averages of the cathodic and anodic peak potentials. Ferrocene was used as an internal standard. The standard potential of ferrocinium/ferrocene couple in THF (+0.085 V) was used to calibrate all voltammetry plots. High-resolution mass spectra (HRMS) recorded for accurate mass analysis, were performed on either a Q-TOF micro (*Bruker Compass Data Analysis 4.0*) spectrometer. The ECD spectrometer was purged with nitrogen before recording each spectrum, which was baseline subtracted. The baseline was always measured for

the same solvent and in the same cell as the samples. The spectra are presented without smoothing and further data processing. VCD spectra were measured on ChiralIR-2X with 300  $\mu\text{m}$  cell,  $\text{CHBr}_3$  as solvent. The crystal structures were obtained from Rigaku XtalAB PRO MM007 DW.

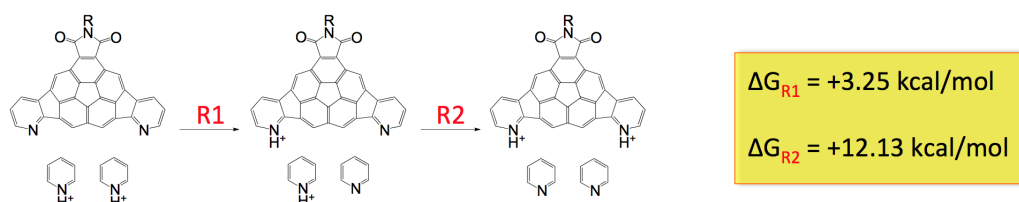
## 1.2 Computational data

Computed structure and property results were carried out using the GAMESS<sup>[1]</sup> Gaussian09<sup>[2]</sup> software packages. The B97-D<sup>[3]</sup> density functional was used in combination with the Def2-TZVP and Def2-TZVPP basis sets<sup>[4]</sup> for geometry optimizations, Hessian evaluations, and property calculations.

Inversion barriers for compounds 7 and 9 were carried out at the B97-D/Def2-TZVP//B97-D/Def2-TZVP(GP) level, with continuum solvent as per experimental studies.

Reduction potential data was determined at the B97-D/Def2-TZVPP//B97-D/Def2-TZVPP level of theory, with THF as continuum solvent, and using  $E^\circ = -\Delta H/nF$ , where  $n = 1$ ,  $F = 1 \text{ eV}$ , and referenced to Ag/AgCl. The Strumm and Morgan correction<sup>[5]</sup> for 0.1 M AgCl/Ag of 0.29 was used in combination with the value for the SHE electrode, giving  $4.73 = 4.44 \text{ (SHE)} + 0.29 \text{ (0.1 M AgCl/Ag)}$ , for the reference value.

The VCDs and pKa data were determined at the wB97X-D<sup>[6]</sup>/Def2-TZVPP//B97-D/Def2TZVP(GP) level of theory, and visualized using MatLab. The VCDs were carried out in  $\text{CHBr}_3$  solvent, and pKa data in THF solvent in accord with experimental studies, using the following bond separation reactions and including ZPE correction evaluated at  $T = 298.15\text{K}$ .



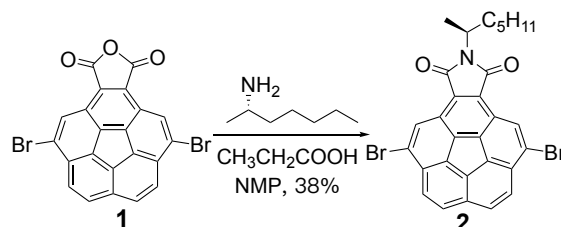
And were computed according to the relation :

$$\Delta G_{\text{reaction}} = \left( \sum_i^{\text{products}} E_i^{\text{DFT}} + \text{ZPE}_i + G_i^{298K} \right) - \left( \sum_i^{\text{reactants}} E_i^{\text{DFT}} + \text{ZPE}_i + G_i^{298K} \right)$$

The ECD spectra were obtained at the TD-CAM-B3LYP<sup>[7]</sup> (Acetonitrile)/Def2-TZVPP//B97-D/Def2TZVP(GP) level of theory, and visualized using MatLab and GaussView.

## 2. Synthetic procedures and analyses

### 2.1 Synthesis of compound 2



compound 1 (500 mg 1.05 mmol, 1 eq), (s)-(+)-2-aminoheptane (181.5 mg, 1.58 mmol, 1.5 eq) and propionic acid (0.47 mL, 6.30 mmol, 6 eq) in NMP (60 ml) was heated to 130 °C for 16 h under nitrogen atmosphere in sealed tube. After cooling to room temperature, the reaction mixture was quenched with saturated aqueous NaHCO<sub>3</sub> (60 ml). The organic layer was separated and the aqueous layer was extracted with dichloromethane (2×60 ml). The combined organic layers were dried, filtered, concentrated through rotary evaporation, and purified by silica gel chromatography (hexane : dichloromethane = 10 : 1) to give 2 as a yellow solid (228 mg, 38%).

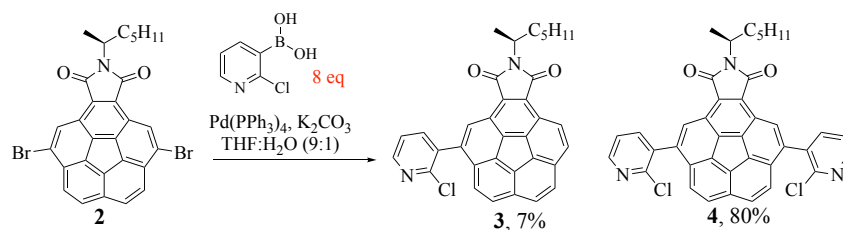
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.55 (s, 1H), 8.10 – 7.71 (m, 2H), 4.73 – 3.92 (m, 1H), 2.18 – 2.03 (m, 1H), 1.77 (m, 1H), 1.53 (d, *J* = 6.9 Hz, 3H), 1.35-1.20 (m, 6H), 0.84 (t, *J* = 6.9 Hz, 1H).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 168.77, 137.14, 134.60, 133.94, 131.33, 131.14, 130.67, 129.50, 128.04, 127.64, 125.47, 124.40, 47.70, 33.97, 31.44, 26.55, 22.50, 18.96, 13.99.

HRMS-ESI (+): Calculated for C<sub>29</sub>H<sub>22</sub>Br<sub>2</sub>NO<sub>2</sub> [M+H<sup>+</sup>] 574.00118; found 574.0018.

IR (film): 2929.3 (w), 2855.6 (w), 2378.1 (m), 2352.6 (w), 2310.9 (m), 1759.1 (m), 1702.1 (s), 1550.1 (w), 1509.3(w), 1457.1 (w), 1391.9 (w), 1362.0 (s), 1313.3 (m), 1064.9 (m), 871.2 (w), 826.7 (m), 755.5 (w), 737.7 (w), 668.7 (w).

### 2.2 Synthesis of compound 3 and 4



36.0 mg (0.0626 mmol, 1 eq) of compound 2, 78.8 mg (0.50 mmol, 8 eq) of 2-chloropyridine-3-boronic acid, 7.23 mg (0.00626 mmol, 0.1 eq) of tetrakis(triphenylphosphine)palladium, 43.3 mg (0.313 mmol, 5 eq) of potassium carbonate, 0.3 mL of THF and water (9:1) were added to a sealed tube. The reaction mixture was degassed under a nitrogen atmosphere and then heated at 100 °C for 1.5 h. When the reaction finished the reaction mixture was cooled to room temperature and add 5 ml water, 5 ml ethyl acetate then use DCM to wash the water phase (twice), collected the organic and dried over anhydrous magnesium sulfate, and concentrated to dryness under reduced pressure. The product was purified by chromatography on silica gel to give 32 mg compound 4 as a yellow solid (80%) and 2.4 mg compound 3 (7%).

#### Compound 3

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.58 (dd, *J* = 4.8, 1.9 Hz, 1H), 8.47 (d, *J* = 8.9 Hz, 1H), 8.39 (s, 1H), 7.97 (d, *J* = 8.9 Hz, 1H), 7.86 (dd, *J* = 11.3, 2.5 Hz, 2H), 7.84 (d, *J* = 8.8 Hz 1H), 7.75 (dd, *J* = 7.5, 1.8 Hz, 1H), 7.49 (d, *J* = 8.8 Hz, 1H), 7.41 (dd, *J* = 7.5, 4.8 Hz, 1H), 4.43-4.38 (m, 1H), 2.13-2.10 (m, 1H), 1.83-1.73 (m, 1H), 1.52 (d, *J* = 7.0 Hz, 3H), 1.43 – 1.15 (m, 6H), 0.83 (t, *J* = 7.0 Hz, 3H).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 169.46, 169.42, 150.81, 149.56, 140.73, 138.81, 138.63, 138.50, 135.74, 135.48, 134.81, 134.25, 131.95, 131.70, 131.25, 130.85, 130.79, 129.52, 129.02, 128.62, 127.76, 126.42, 126.36, 125.77, 125.27, 124.47, 122.54, 47.50, 33.97, 31.43, 26.54, 22.48, 18.99, 13.97.

HRMS-ESI (+): Calculated for C<sub>34</sub>H<sub>25</sub>ClNaN<sub>2</sub>O<sub>2</sub> [*M*+Na<sup>+</sup>] 551.1473; found 551.1497.

IR (film): 3742.9 (w), 2926.3 (m), 2856.3 (w), 2353.5 (w), 2310.8 (w), 1756.3 (m), 1699.6 (s), 1553.8 (w), 1511.1 (w), 1391.6 (s), 1363.4 (s), 1127.2 (w), 1089.5 (w), 1061.8 (w), 1024.2 (w), 830.2 (m), 754.7 (w), 691.6 (w), 668.1 (w).

#### Compound 4

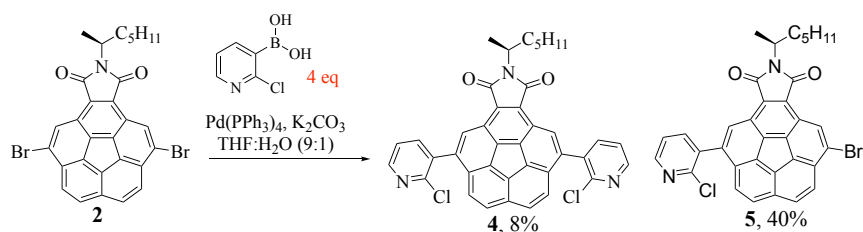
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.58 (dd, *J* = 4.8, 1.9 Hz, 2H), 8.41 (s, 2H), 7.91 (br, 1H), 7.82 (d, *J* = 8.8 Hz, 2H), 7.65 (br, 1H), 7.51 (d, *J* = 8.8 Hz, 2H), 7.43 (br, 2H), 4.44-4.36 (m, 1H), 2.15-2.16 (m, 1H), 1.85 – 1.70 (m, 1H), 1.53 (d, *J* = 6.9 Hz, 3H), 1.29 (m, 6H), 0.84 (t, *J* = 7.0 Hz, 3H).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 169.32, 150.80, 149.66, 140.71, 139.26, 138.61, 135.81, 135.29, 134.15, 131.73, 131.07, 130.87, 129.07, 126.79, 126.55, 124.84, 122.59, 47.60, 33.95, 31.42, 26.54, 22.48, 18.99, 13.98.

HRMS-ESI (+): Calculated for C<sub>39</sub>H<sub>27</sub>Cl<sub>2</sub>NaN<sub>3</sub>O<sub>2</sub> [*M*+Na<sup>+</sup>] 662.1372; found 662.1313.

IR (film): 2957.0 (m), 2924.5 (s), 1756.7 (m), 1698.9 (s), 1553.0 (w), 1511.0 (w), 1464.9 (w), 1364.1 (s), 1261.5 (w), 1064.1 (m), 1019.9 (w), 889.6 (w), 668.9 (w).

## 2.3 Synthesis of compound 4 and 5



40 mg (0.0695 mmol, 1 eq) of compound 2, 43.7 mg (0.278 mmol, 4 eq) of 2-chloropyridine-3-boronic acid, 8.0 mg (0.00695 mmol, 0.1 eq) of tetrakis(triphenylphosphine)palladium, 48.0 mg (0.348 mmol, 5 eq) of potassium carbonate, 0.5 mL of THF and water (9:1) were added to a sealed tube. The reaction mixture was degassed under a nitrogen atmosphere and then heated at 100 °C for 1.5 h. When the reaction finished the reaction mixture was cooled to room temperature and add 5 ml water, 5 ml ethyl acetate then use DCM to wash the water phase (twice), collected the organic and dried over anhydrous magnesium sulfate, and concentrated to dryness under reduced pressure. The product was purified by chromatography on silica gel to give 3.5 mg compound 4 as a yellow solid (8%) and 17 mg compound 5 (40%).

### Compound 5

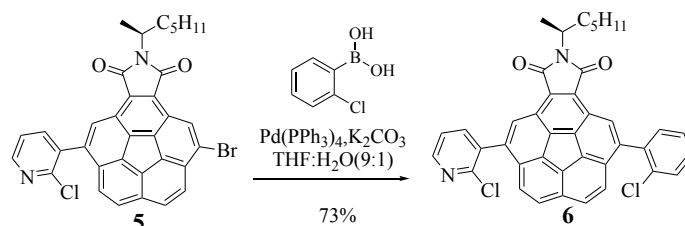
$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.66 (s, 1H), 8.58 (dd,  $J = 4.8, 1.8$  Hz, 1H), 8.35 (s, 1H), 7.92 (q,  $J = 8.8$  Hz, 2H), 7.81 (d,  $J = 8.9$  Hz, 1H), 7.75 (dd,  $J = 7.5, 1.7$  Hz, 1H), 7.50 (d,  $J = 8.8$  Hz, 1H), 7.42 (dd,  $J = 7.5, 4.8$  Hz, 1H), 4.54 – 4.22 (m, 2H), 2.18-2.05 (m, 2H), 1.80-1.73 (m, 1H), 1.52 (d,  $J = 6.9$  Hz, 3H), 1.35-1.25 (m, 6H), 0.84 (t,  $J = 6.9$  Hz, 3H).

$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  169.14, 169.04, 150.74, 149.71, 140.69, 139.10, 138.63, 137.41, 135.30, 135.02, 134.94, 134.06, 131.77, 131.54, 131.11, 131.05, 130.72, 129.65, 129.04, 128.07, 127.39, 127.16, 126.61, 126.07, 124.66, 124.51, 122.61, 47.65, 33.95, 31.43, 26.54, 22.49, 18.98, 13.99.

HRMS-ESI (+): Calculated for  $\text{C}_{34}\text{H}_{24}\text{BrClN}_2\text{NaO}_2$   $[\text{M}+\text{Na}^+]$  629.0616; found 629.0602.

IR (film): 2925.7 (w), 2855.6 (w), 2378.2 (w), 2348.3 (w), 2311.8 (w), 1758.0 (m), 1700.1 (s), 1552.3 (w), 1511.2(w), 1391.4 (w), 1362.6 (s), 1062.5 (m), 872.2 (w), 826.7 (m), 752.0 (w), 736.9 (w), 674.7 (w).

## 2.4 Synthesis of compound 6



75 mg (0.123 mmol, 1 eq) of compound 5, 38.5 mg (0.246 mmol, 2 eq) of 2-chlorophenylboronic acid, 14.2 mg (0.0123 mmol, 0.1 eq) of tetrakis(triphenylphosphine)palladium, 85.0 mg (0.615 mmol, 5 eq) of potassium carbonate, 0.7 mL of THF and water (9:1) were added to a sealed tube. The reaction mixture was degassed under a nitrogen atmosphere and then heated at 100 °C for 1.5 h. When the reaction finished the reaction mixture was cooled to room temperature and add 5 ml water, 5 ml ethyl acetate then use DCM to wash the water phase (twice), collected the organic and dried over anhydrous magnesium sulfate, and concentrated to dryness under reduced pressure. The product was purified by chromatography on silica gel to give 57 mg compound 6 as a yellow solid (73%).

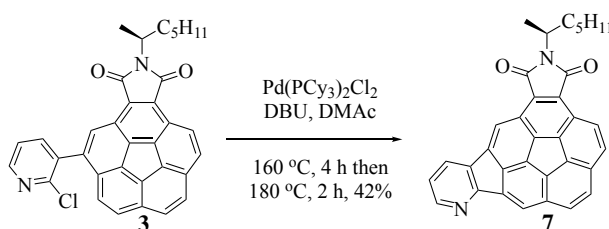
$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.58 (dd,  $J = 4.8, 1.9$  Hz, 1H), 8.41 (s, 2H), 7.80 (t,  $J = 8.4$  Hz, 2H), 7.65 (br, 2H), 7.59 – 7.32 (m, 6H), 4.44–4.38 (m, 1H), 2.20 – 2.06 (m, 1H), 1.80–1.70 (m, 1H), 1.53 (d,  $J = 6.9$  Hz, 3H), 1.34 – 1.22 (m, 6H), 0.84 (t,  $J = 6.9$  Hz, 3H).

$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  169.45, 169.37, 150.81, 149.58, 141.55, 140.73, 138.95, 138.65, 138.34, 137.46, 135.84, 135.26, 135.20, 134.26, 133.74, 132.26, 131.77, 131.57, 130.89, 130.79, 129.95, 129.74, 129.01, 128.74, 128.65, 127.38, 127.00, 126.56, 126.46, 126.09, 125.06, 124.62, 122.56, 47.53, 33.97, 31.43, 26.54, 22.48, 18.99, 13.98.

HRMS-ESI (+): Calculated for  $\text{C}_{40}\text{H}_{28}\text{Cl}_2\text{NaN}_2\text{O}_2$   $[\text{M}+\text{Na}^+]$  661.1437; found 661.1420.

IR (film): 3651.6 (m), 2924.6 (m), 2854.8 (m), 1757.5 (m), 1699.5 (s), 1553.3 (w), 1466.6 (w), 1436.2 (w), 1391.6 (w), 1363.9 (s), 1126.9 (w), 1092.3 (w), 1062.2 (w), 890.1 (w), 828.4 (m), 754.3 (w), 737.0 (w), 694.7 (w).

## 2.5 Synthesis of compound 7





A dry, sealed tube containing a magnetic stirring bar was charged with compound 3 (7.5 mg, 0.01418 mmol, 1 eq), Pd(PCy<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> (1.1 mg, 0.001418 mmol, 0.1 eq), DBU (0.013 mL, 0.085 mmol, 6 eq) and dimethylacetamide (0.65 mL). The reaction vessel was sealed, evacuated, purged with nitrogen and heated at 160 °C for 4 hours then heated to 180 °C for 2 h. The reaction mixture was allowed to cool and was then diluted with 20 mL of dichloromethane. The organic solution was washed with 10% HCl, water, and brine and was then dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was subjected to silica gel flash column chromatography to give 7 (2.9 mg, 42%).

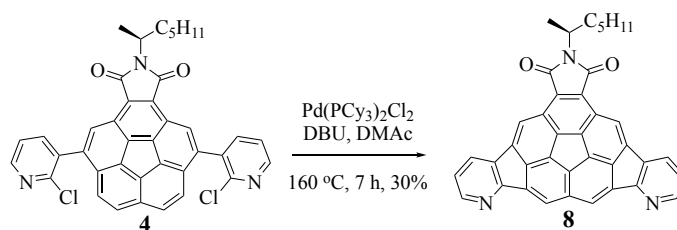
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.39 (d, *J* = 4.3 Hz, 1H), 8.31 (s, 1H), 8.16 (dd, *J* = 9.0, 1.0 Hz, 1H), 7.97 (s, 1H), 7.93 (d, *J* = 7.6 Hz, 1H), 7.69 (d, *J* = 8.8 Hz, 1H), 7.63 (d, *J* = 9.0 Hz, 1H), 7.56 (d, *J* = 8.8 Hz, 1H), 7.14 (dd, *J* = 7.6, 5.0 Hz, 1H), 4.47 – 4.06 (m, 1H), 2.16 – 1.96 (m, 1H), 1.80–1.70 (m, 1H), 1.49 (dd, *J* = 6.9, 1.2 Hz, 3H), 1.25–1.17 (m, 6H), 0.83 (t, *J* = 6.6 Hz, 3H).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 169.22, 169.11, 158.78, 149.04, 143.86, 141.25, 140.30, 140.16, 139.89, 139.02, 138.25, 137.00, 136.94, 134.03, 131.92, 131.30, 131.18, 130.98, 130.14, 129.53, 129.36, 127.47, 125.94, 125.11, 124.97, 122.67, 121.81, 47.50, 33.94, 31.44, 26.53, 22.47, 18.94, 13.99.

HRMS-ESI (+): Calculated for C<sub>34</sub>H<sub>25</sub>N<sub>2</sub>O<sub>2</sub> [M+H<sup>+</sup>] 493.1919; found 493.1911.

IR (film): 2924.0 (m), 2854.0 (m), 2378.8 (w), 2310.8 (w), 1754.6 (m), 1696.9 (s), 1553.4 (w), 1511.5(w), 1486.3 (w), 1454.8 (w), 1362.1 (s), 1304.7 (w), 1186.7 (w), 1166.0 (w), 964.9 (w), 888.3 (m), 826.0 (w), 804.5 (w), 790.8 (w).

## 2.6 Synthesis of compound 8



A dry, sealed tube containing a magnetic stirring bar was charged with compound 4 (39 mg, 0.0609 mmol, 1 eq), Pd(PCy<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> (9.0 mg, 0.0122 mmol, 0.2 eq), DBU (0.0546 mL, 0.365 mmol, 6 eq) and dimethylacetamide (3 mL). The reaction vessel was sealed, evacuated, purged with nitrogen and heated at 160 °C for 7 hours. The reaction mixture was allowed to cool and was then diluted with 20 mL of dichloromethane. The organic solution was washed with 10% HCl, water, and brine and was then dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was subjected to silica gel flash column chromatography to give 8 (10.4 mg, 30%).

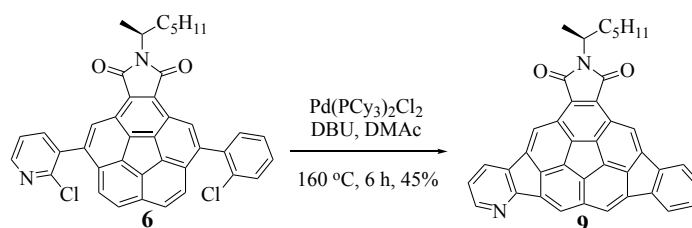
$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.40 (d,  $J = 3.9$  Hz, 2H), 8.18 (s, 2H), 7.94 (s, 2H), 7.91 (d,  $J = 7.7$  Hz, 2H), 7.14 (dd,  $J = 7.6, 5.1$  Hz, 2H), 4.36-4.30 (m, 1H), 2.07-2.01 (m, 1H), 1.80 – 1.68 (m, 1H), 1.46 (d,  $J = 6.9$  Hz, 3H), 1.28-1.20 (m, 6H), 0.82 (t,  $J = 6.7$  Hz, 3H).

$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  168.66, 158.29, 149.20, 142.74, 142.03, 141.93, 141.24, 140.12, 139.70, 138.98, 133.38, 131.94, 131.88, 129.83, 129.39, 126.75, 122.72, 121.74, 47.62, 33.95, 31.43, 26.52, 22.47, 18.83, 13.99.

HRMS-ESI (+): Calculated for  $\text{C}_{39}\text{H}_{26}\text{N}_3\text{O}_2$   $[\text{M}+\text{H}^+]$  568.2008; found 568.2020

IR (film): 2924.4 (m), 2854.9 (w), 2377.7 (m), 2353.2 (w), 2345.4 (m), 1785.1 (m), 1753.1 (w), 1699.1 (s), 1680.1 (w), 1580.3 (w), 1563.5 (m), 1553.4 (m), 1511.1 (w), 11501.8 (m), 1476.3 (w), 1361.3 (m), 890.9 (w).

## 2.7 Synthesis of compound 9



A dry, sealed tube containing a magnetic stirring bar was charged with compound 6 (20 mg 0.0313 mmol, 1 eq),  $\text{Pd}(\text{PCy}_3)_2\text{Cl}_2$  (4.6 mg, 0.00625 mmol, 0.2 eq), DBU (0.028 mL, 0.1878 mmol, 6 eq) and dimethylacetamide (1.55 mL). The reaction vessel was sealed, evacuated, purged with nitrogen and heated at 160 °C for 6 hours. The reaction mixture was allowed to cool and was then diluted with 20 mL of dichloromethane. The organic solution was washed with 10% HCl, water, and brine and was then dried over anhydrous magnesium sulfate and concentrated under reduced pressure. The residue was subjected to silica gel flash column chromatography to give 9 (8 mg, 45%).

$^1\text{H}$  NMR (400 MHz,  $\text{C}_2\text{Cl}_4\text{D}_2$ )  $\delta$  8.39 (dd,  $J = 5.0, 1.5$  Hz, 1H), 8.14 (s, 1H), 8.10 (s, 1H), 7.92-7.89 (m, 2H), 7.66 – 7.61 (m, 2H), 7.54 (s, 1H), 7.34 – 7.22 (m, 2H), 7.15 (dd,  $J = 7.7, 5.1$  Hz, 1H), 4.35-4.25 (m, 1H), 2.05-1.95 (m, 1H), 1.78-1.72 (m, 1H), 1.46 (d,  $J = 6.9$  Hz, 3H), 1.30-1.20 (m, 6H), 0.85 (t,  $J = 6.8$  Hz, 3H).

$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  168.85, 168.78, 158.39, 148.89, 143.08, 142.93, 142.55, 141.58, 141.40, 141.13, 140.89, 139.85, 139.38, 139.32, 139.30, 138.91, 138.70, 133.57, 131.97, 131.91, 131.84, 131.79, 130.02, 129.65, 129.64, 129.35, 128.99, 126.40, 124.94, 122.61, 121.94, 121.46, 120.64, 447.52, 33.96, 31.44, 26.53, 22.48, 18.84, 13.99.

HRMS-ESI (+): Calculated for  $\text{C}_{40}\text{H}_{27}\text{N}_2\text{O}_2$   $[\text{M}+\text{H}^+]$  567.2089; found 567.2067.

IR (film): 3743.2 (m), 2924.7 (m), 2854.4 (m), 2353.2 (m), 2311.0 (m), 1754.9 (m), 1698.7 (s), 1552.3 (w), 1512.0(w), 1391.1 (w), 1361.5 (m), 1261.4 (m), 1019.2 (w), 891.0 (w), 802.8 (w), 760.3 (m), 668.7 (w).

### 3. Effect of equivalents of CPB in Suzuki coupling reaction

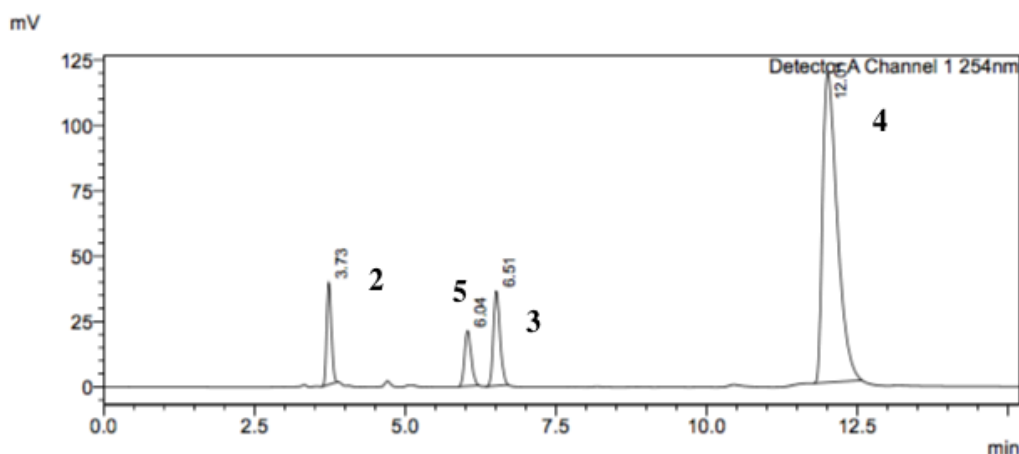
**Table S1:** The ratio of 2-5 under different equivalent of CPB

equivalent	Time	2 (%)	3 (%)	4 (%)	5 (%)
2	30 min	60	<0.5	3.5	36
4	30 min	46	<1	9	44
6	30 min	34	1	16	49
8	30 min	0	7.5	92	<0.5
10	30 min	0	6.5	93	<0.5

HPLC condition: Zorbax CN (250 x 4.6 mm), hexane / dichloromethane (80/20) as mobile phase, flow rate = 1 mL/min, UV detection at 254 nm.

Firstly, I use pure compounds **2-5** under the condition: Zorbax CN (250 x 4.6 mm), hexane / dichloromethane (80/20) as mobile phase, flow rate = 1 mL/min, UV detection at 254 nm. we got the retention time of those four compounds as 3.6-3.7 min, 6.4-6.5 min, 12.0-12.1 min, 6.0-6.1 min, respectively. Then mix those four compounds and run the HPLC again, make sure those four compounds have a good resolution under our condition.

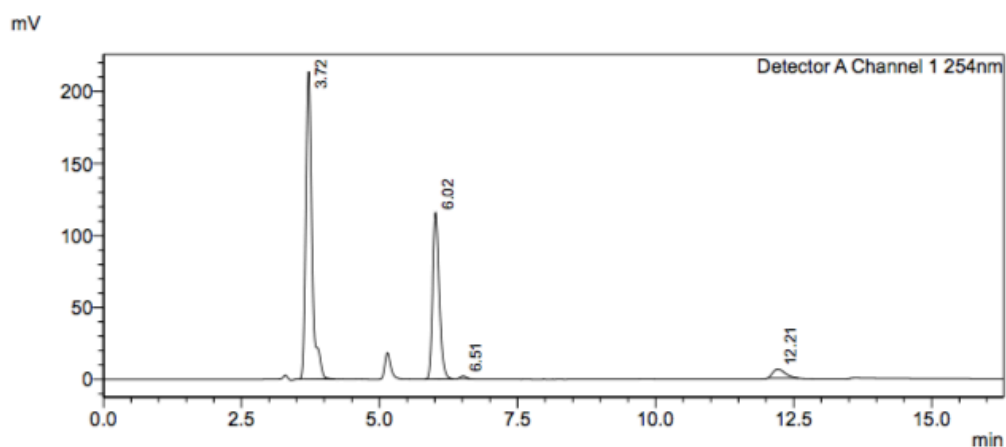
Chromatogram:



Peak Table:

Detector A Channel 1 254nm				
Peak	Ret. Time	Area	Height	Area%
1	3.73	211125	38732	7.97
2	6.04	163602	21171	6.17
3	6.51	277995	36102	10.49
4	12.01	1997010	118255	75.37
Total		2649732	214261	100.00

**Figure S1:** The HPLC trace for the mixture of 2-5



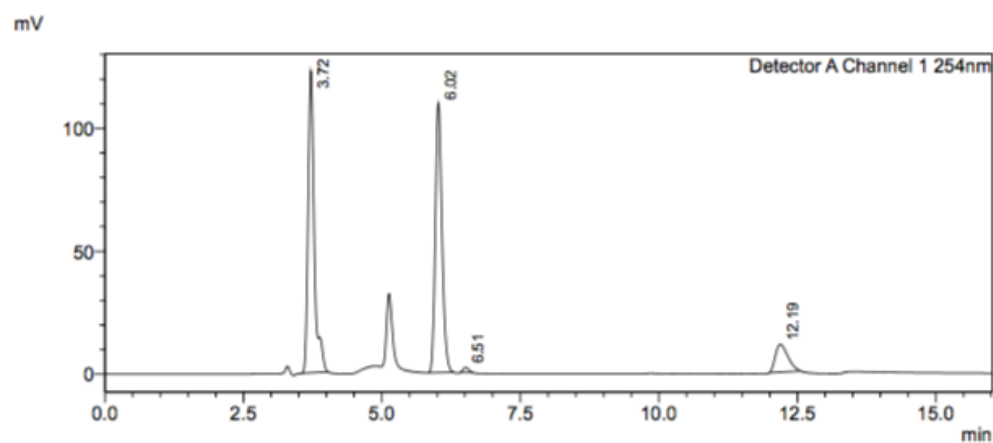
Peak Table:

Detector A Channel 1 254nm

Peak	Ret. Time	Area	Height	Area%
1	3.72	1653295	213458	60.57
2	6.02	970341	115310	35.55
3	6.51	9742	1544	0.36
4	12.21	96000	6144	3.52
Total		2729378	336457	100.00

**Figure S2:** The HPLC trace for 2 eq CPB

Chromatogram:



Peak Table:

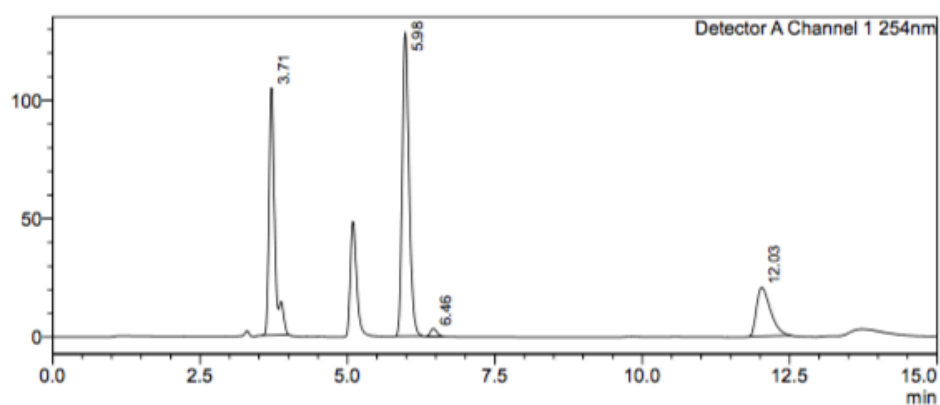
Detector A Channel 1 254nm

Peak	Ret. Time	Area	Height	Area%
1	3.72	959540	122705	46.36
2	6.02	916917	109653	44.30
3	6.51	14214	2033	0.69
4	12.19	178998	11282	8.65
Total		2069669	245673	100.00

**Figure S3:** The HPLC trace for 4 eq CPB

Chromatogram:

mV



Peak Table:

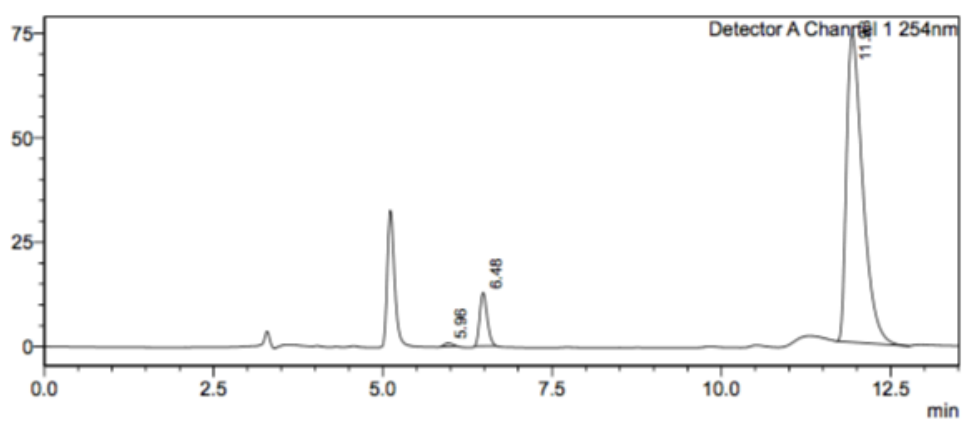
Detector A Channel 1 254nm

Peak	Ret. Time	Area	Height	Area%
1	3.71	720827	104371	34.15
2	5.98	1024172	127669	48.53
3	6.46	24193	3307	1.15
4	12.03	341307	20591	16.17
Total		2110498	255939	100.00

**Figure S4:** The HPLC trace for 6 eq CPB

Chromatogram:

mV



Peak Table:

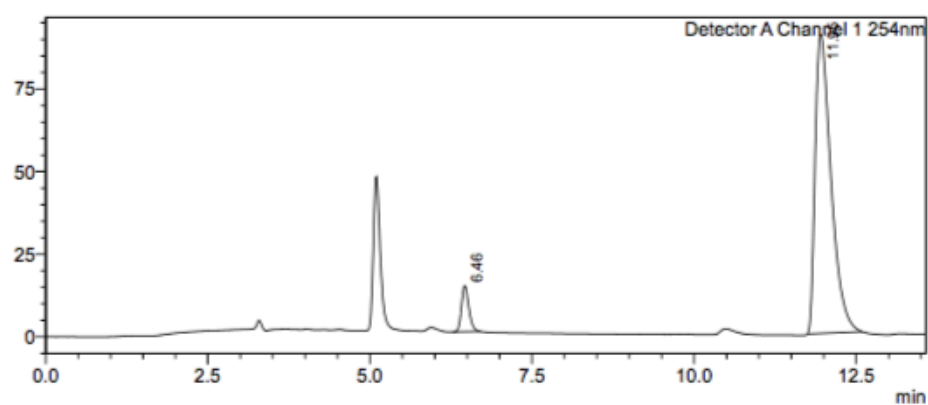
Detector A Channel 1 254nm

Peak	Ret. Time	Area	Height	Area%
1	5.96	6378	735	0.48
2	6.48	97968	12762	7.34
3	11.93	1231059	73682	92.19
Total		1335405	87179	100.00

**Figure S5:** The HPLC trace for 8 eq CPB

Chromatogram:

mV



Peak Table:

Detector A Channel 1 254nm

Peak	Ret. Time	Area	Height	Area%
1	6.46	109499	13899	6.63
2	11.95	1542015	90471	93.37
Total		1651514	104369	100.00

**Figure S6:** The HPLC trace for 10 eq CPB

## 4. Cyclic voltammetric measurements

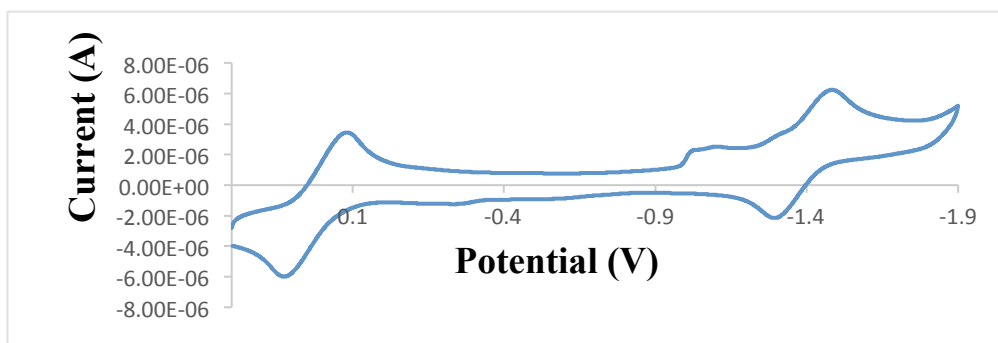


Figure S7: Reduction CV plot for 7.

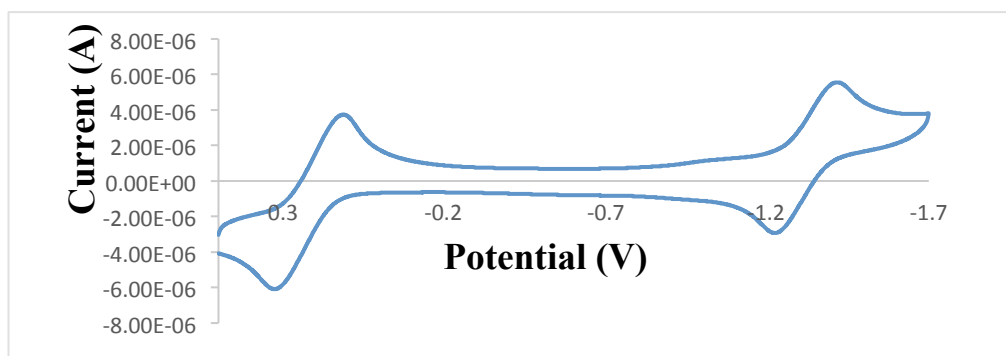


Figure S8: Reduction CV plot for 8.

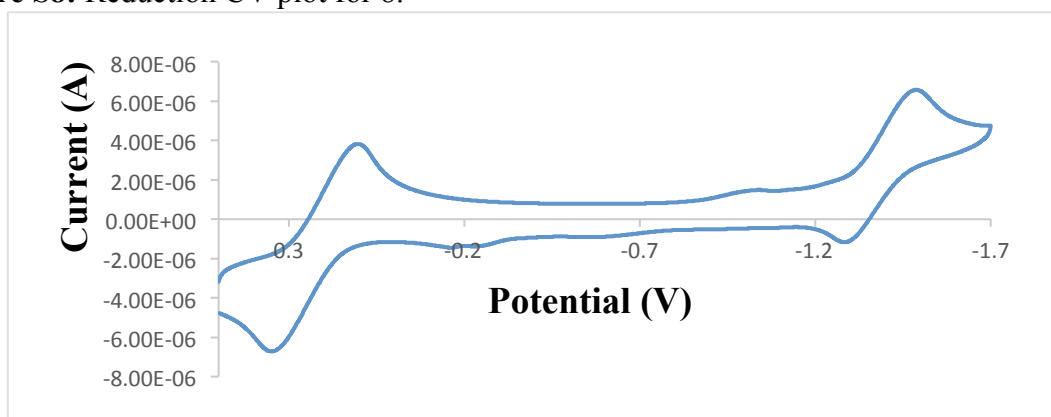
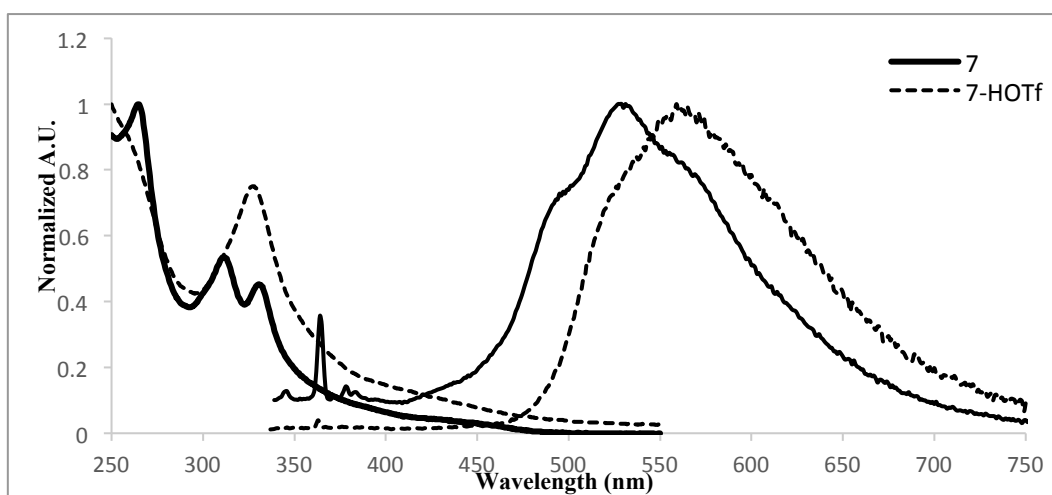


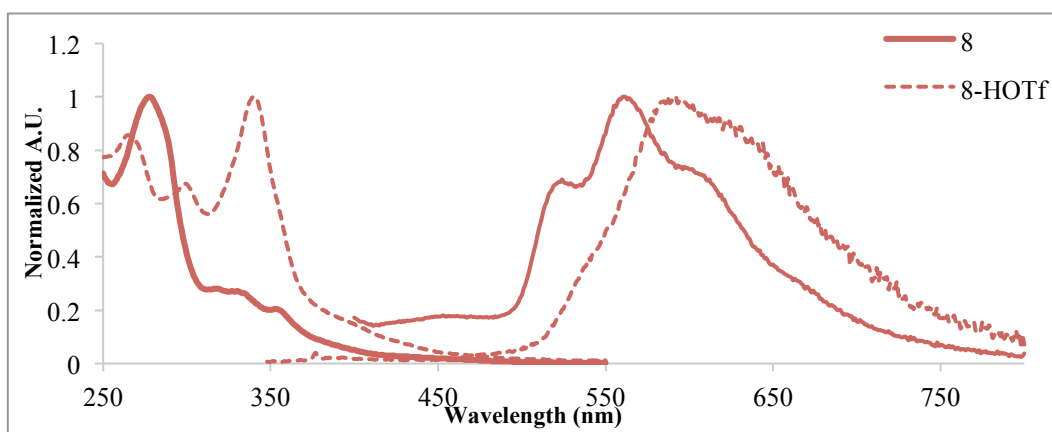
Figure S9: Reduction CV plot for 9.



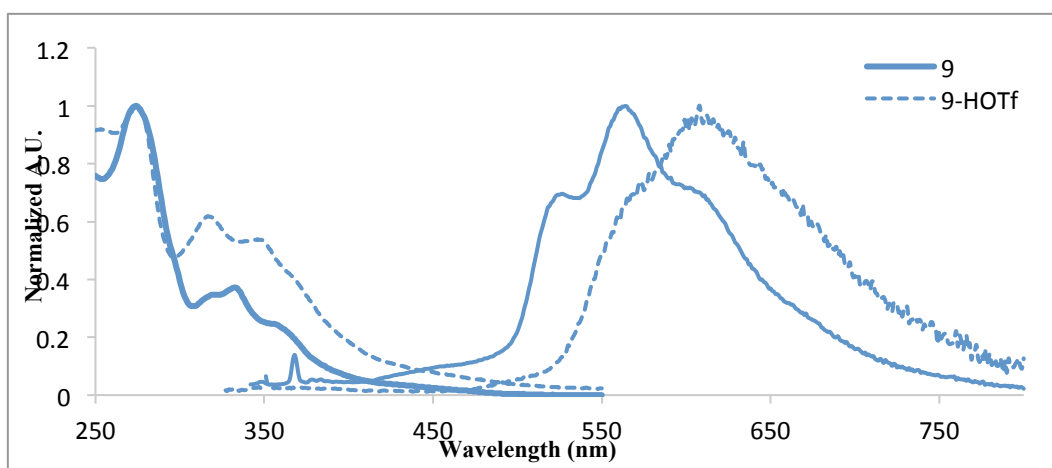
## 5. UV and fluorescence spectra of 7-9



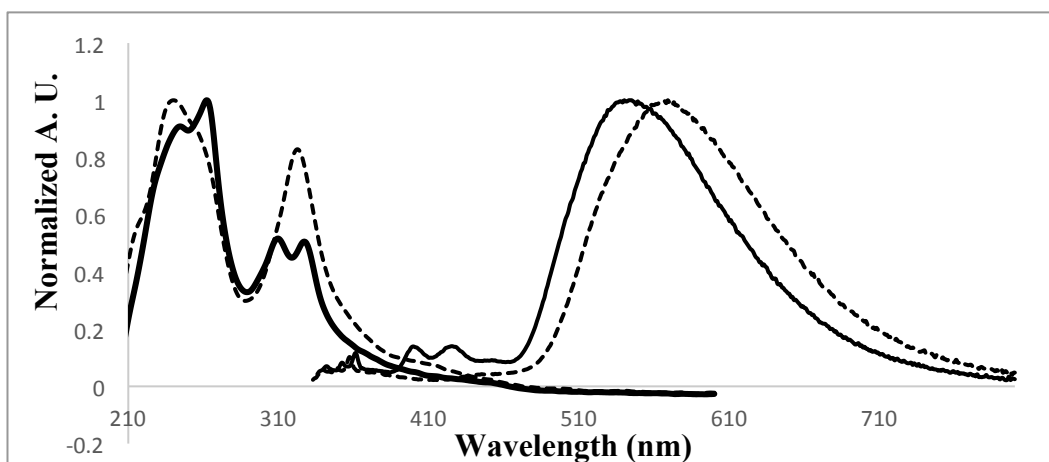
**Figure S10:** UV and fluorescence spectra of 7 (— Cyclohexane as solvent, --- DCM as solvent)



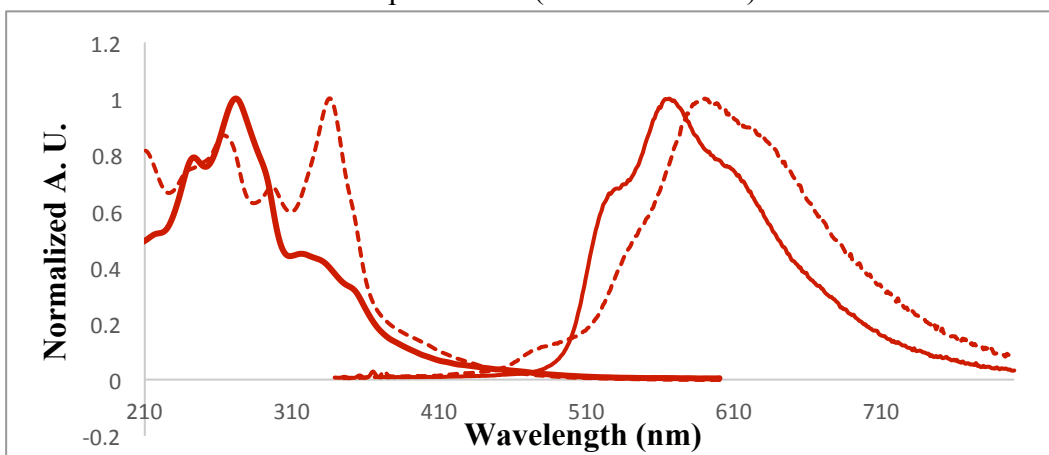
**Figure S11:** UV and fluorescence spectra of 8 (— Cyclohexane as solvent, --- DCM as solvent)



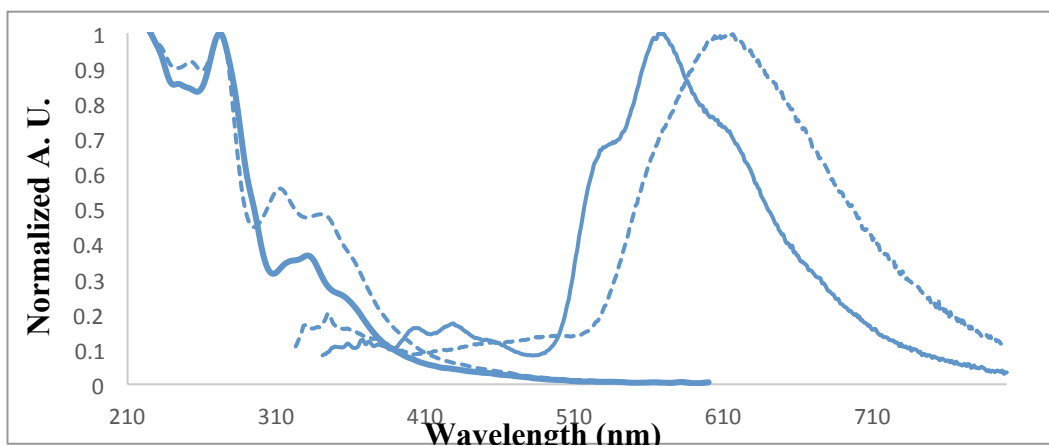
**Figure S12:** UV and fluorescence spectra of 9 (— Cyclohexane as solvent, --- DCM as solvent)



**Figure S13:** UV and fluorescence spectra of 7 (ACN as solvent)



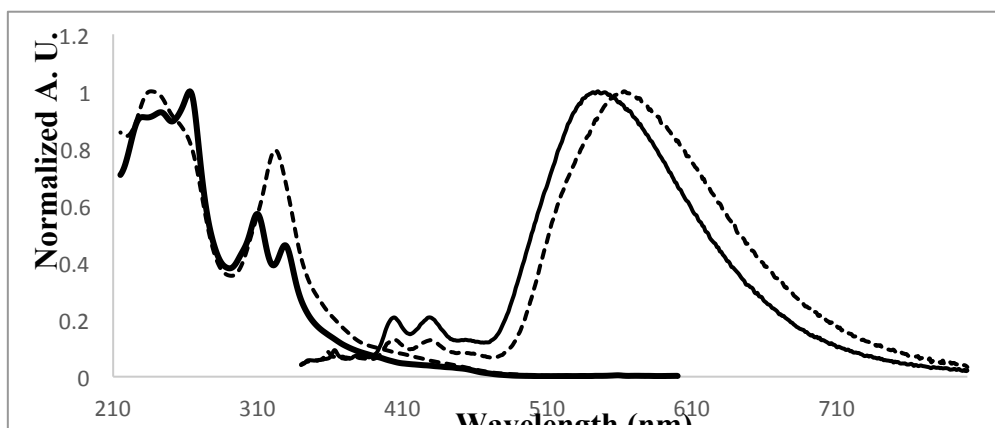
**Figure S14:** UV and fluorescence spectra of 8 (ACN as solvent)



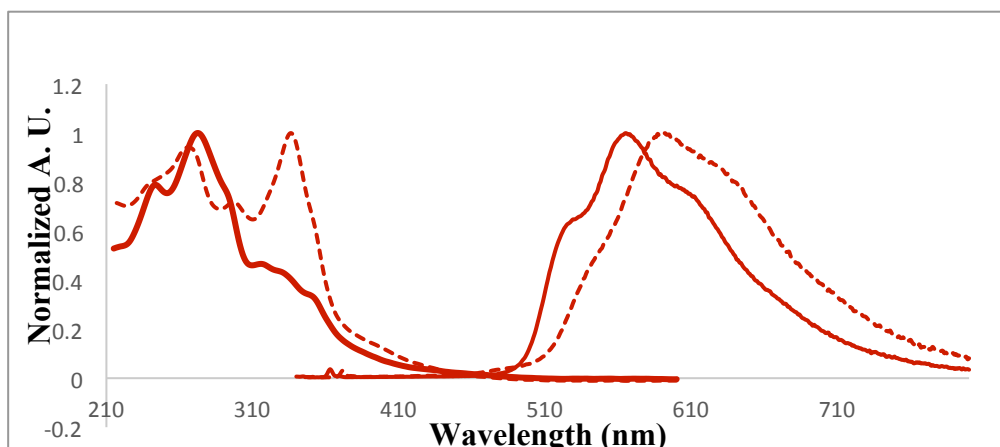
**Figure S15:** UV and fluorescence spectra of 9 (ACN as solvent)

**Table S2. Photophysical properties of 7, 8, and 9 (acetonitrile as solvent).**

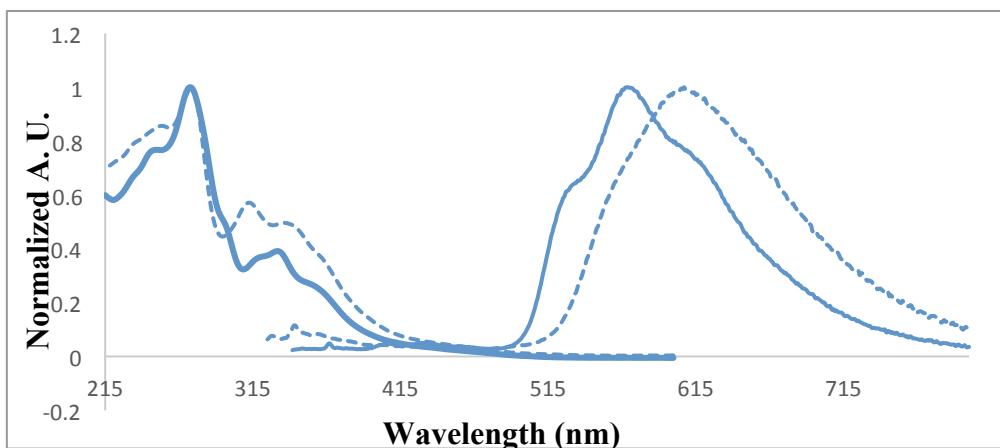
Compound	Ex (nm)	Em (nm)	$\lambda_{\text{abs}}$ (nm)
7	326	542	262, 310, 327
7-HOTf	323	567	323
8	329	525, 566	272, 329
8-HOTf	335	590	264, 296, 335
9	331	529, 568	272, 331
9-HOTf	313	611	272, 312, 340



**Figure S16:** UV and fluorescence spectra of 7 (EtOH as solvent)



**Figure S17:** UV and fluorescence spectra of 8 (EtOH as solvent)



**Figure S18:** UV and fluorescence spectra of 9 (EtOH as solvent)

**Table S3. Photophysical properties of 7, 8, and 9 (ethanol as solvent).**

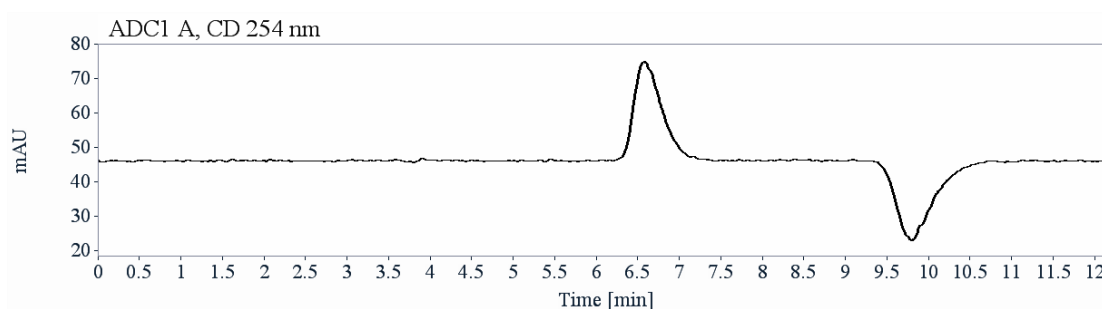
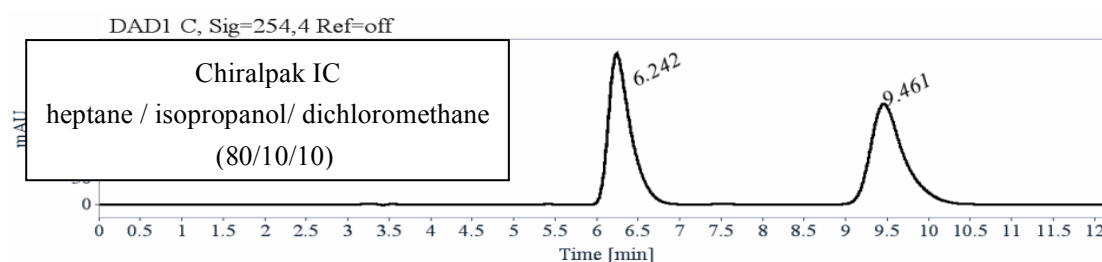
Compound	Ex (nm)	Em (nm)	$\lambda_{\text{abs}}$ (nm)
7	328	545	263, 310, 329
7-HOTf	324	563	236, 322
8	328	526, 566	272, 331
8-HOTf	335	591	266, 297, 336
9	331	528, 570	273, 332
9-HOTf	313	606	274, 313 344

## 6. Diastereomeric separation of 7a/7b

### 6.1 Analytical HPLC separation for the diastereomers 7a/7b

- A sample of **7a/7b** is dissolved in dichloromethane, injected on a Chiralpak IC column, and detected with an UV detector at 254 nm and with dichroism circular at 254 nm. The flow-rate is 1 ml/min.

Column	Mobile Phase	t1	k1	t2	k2	$\alpha$	R <sub>s</sub>
Chiralpak IC	heptane / isopropanol / dichloromethane (80/10/10)	6.24 (+)	1.12	9.46 (-)	2.21	1.98	5.48

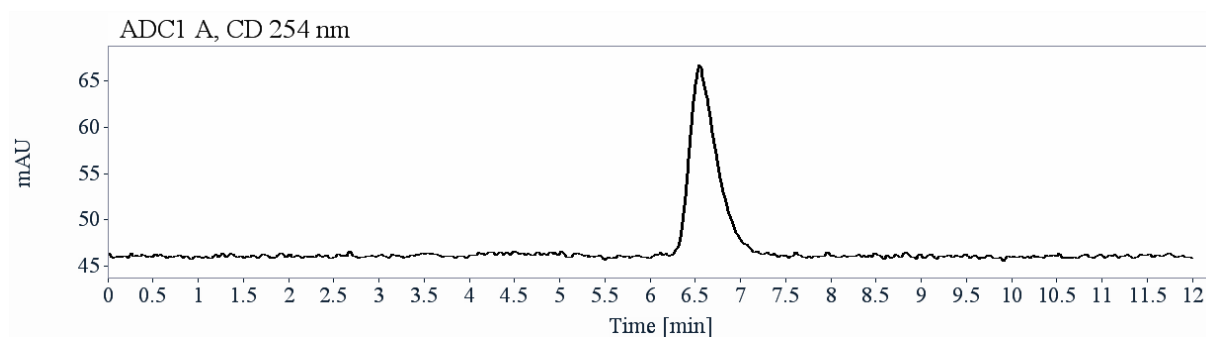
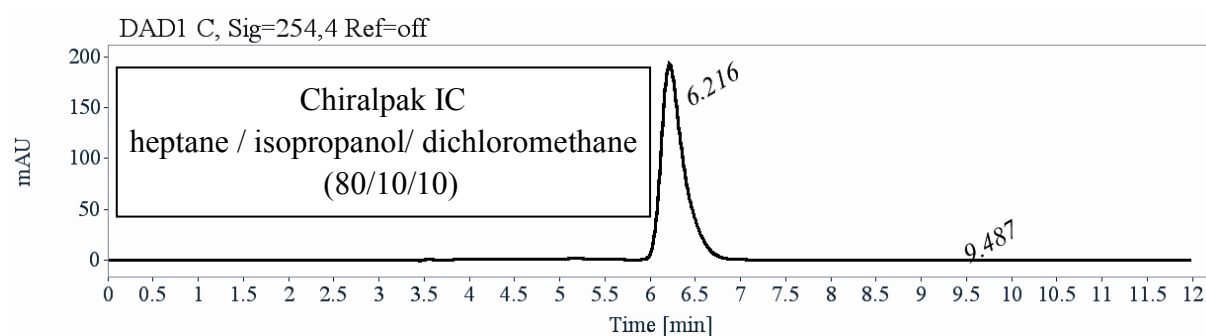


RT [min]	Area	Area%	Capacity Factor	Diastereoselectivity	Resolution (USP)
6.24	5568	50.04	1.12		
9.46	5560	50.04	2.21	1.98	5.48
Sum	11127	100.08			

### 6.2 Semi-preparative separation of diastereomers 7a/7b:

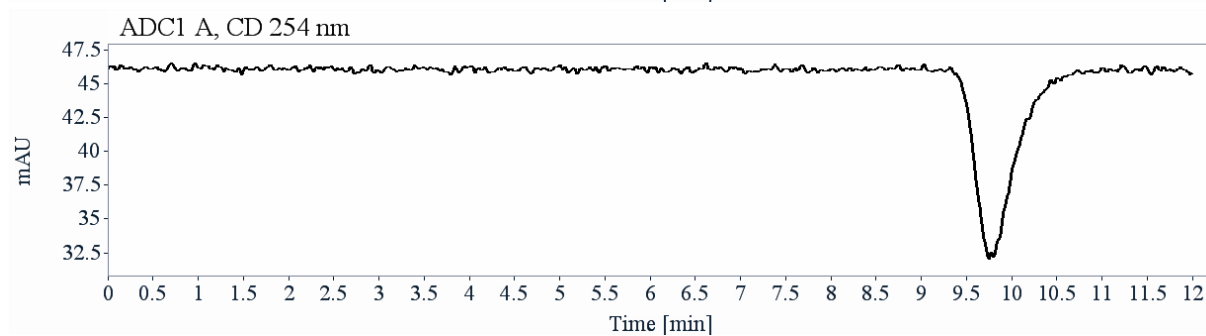
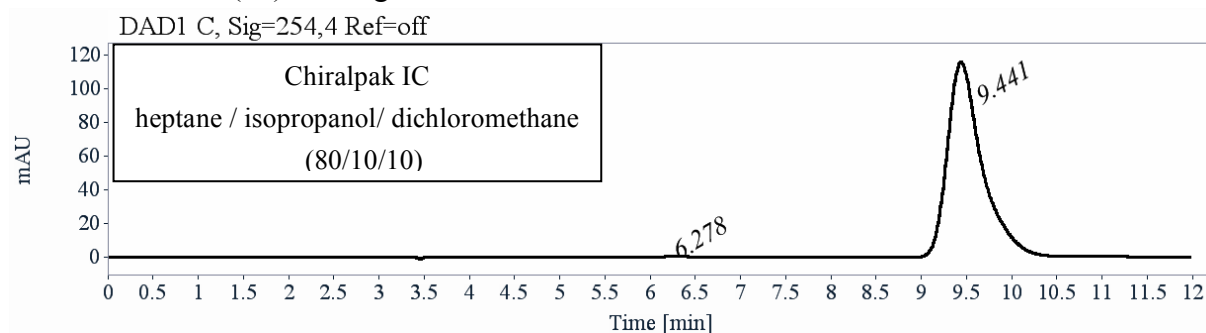
- Sample preparation: About 20 mg of compound **7a/7b** are dissolved in 7 mL of a dichloromethane.
- Chromatographic conditions: Chiralpak IC (250 x 10 mm), hexane / ethanol / dichloromethane (70/10/20) as mobile phase, flow-rate = 5 mL/min, UV detection at 280 nm.
- Injections (stacked): 10 times 0.7ml, every 8 minutes.

- First fraction(7a): 4.6 mg of the first eluted diastereomer with ee =99 %



RT [min]	Area	Area%
6.22	3389	99.51
9.49	17	0.59
Sum	3406	100.00

- Second fraction(7b): 5.0 mg of the second eluted diastereomer with de >98.5 %



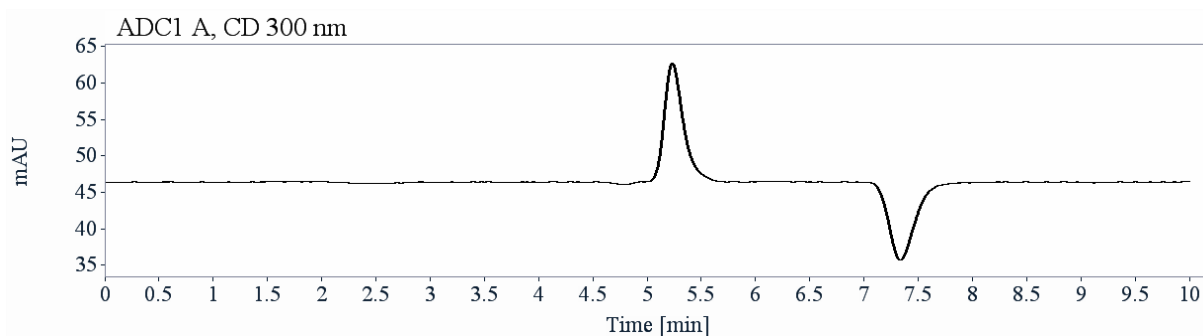
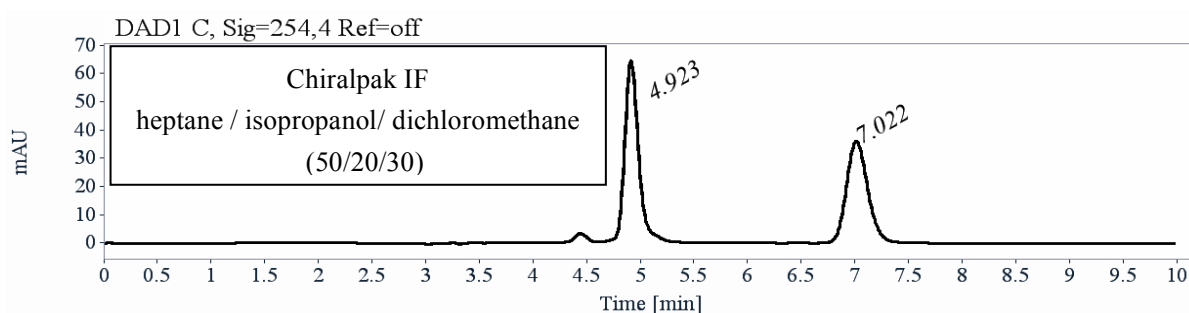
RT [min]	Area	Area%
6.28	16	0.52
9.44	3090	99.48
Sum	3106	100.00

## 7. Diastereomeric separation of 9a/9b

### 7.1 Analytical HPLC separation of the diastereomers 9a/9b

- A sample of **9a/9b** is dissolved in dichloromethane, injected on the chiral columns, and detected with an UV detector at 254 nm and with dichroism circular detector at 300 nm. The flow-rate is 1 ml/min.

Column	Mobile Phase	t1	k1	t2	k2	$\alpha$	Rs
Chiralpak IF	heptane / isopropanol / dichloromethane (50/20/30)	4.92 (+)	0.67	7.02 (-)	1.38	2.06	7.14

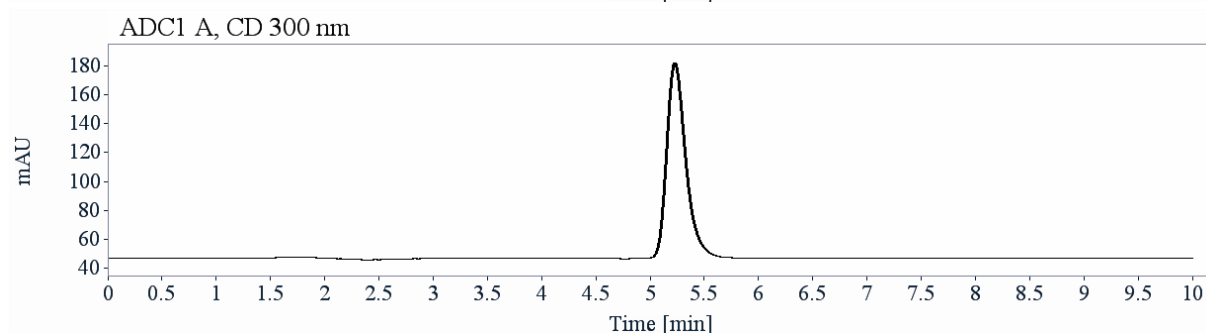
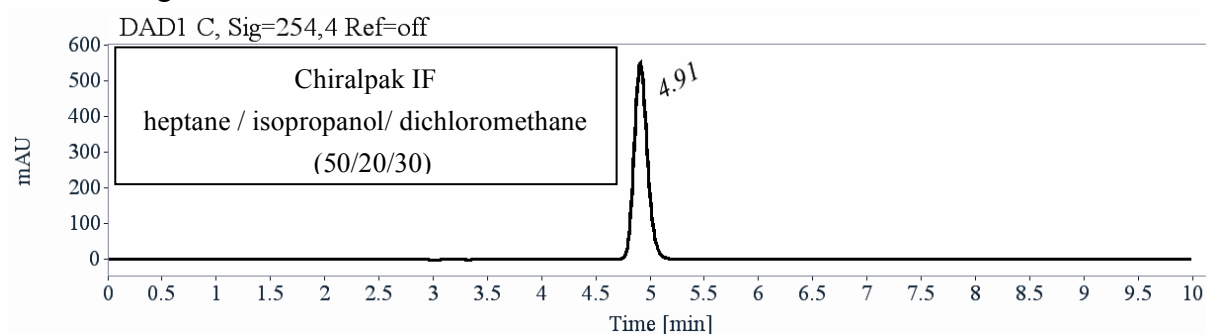


RT [min]	Area	Area%	Capacity Factor	Diastereoselectivity	Resolution (USP)
4.92	580	53.77	0.67		
7.02	498	46.23	1.38	2.06	7.14
Sum	1078	100.00			

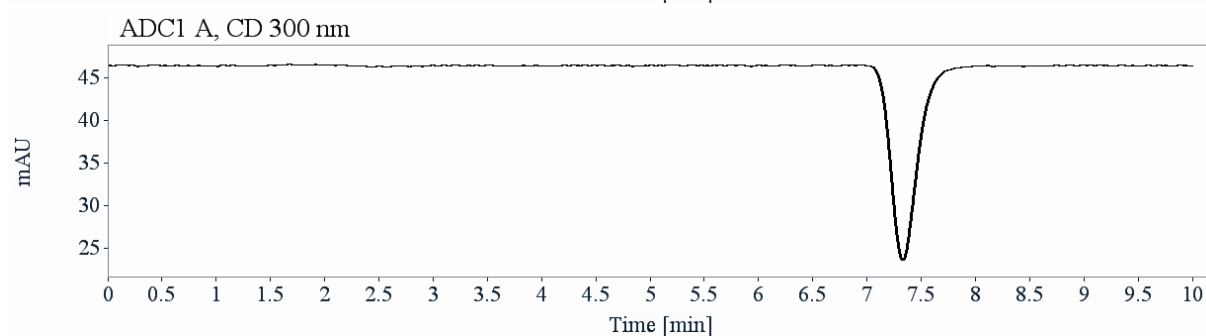
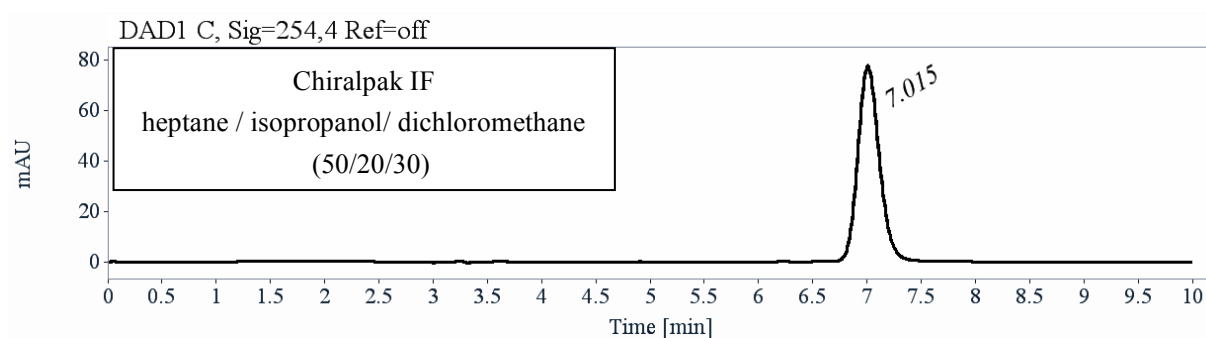
### 7.2 Semi-preparative separation of diastereomers 9a/9b

- Sample preparation: About 48 mg of compound **9a/9b** are dissolved in 12 mL of dichloromethane.
- Chromatographic conditions: Chiralpak IF (250 x 10 mm), hexane / iPrOH / dichloromethane (50/20/30) as mobile phase, flow-rate = 5 mL/min, UV detection at 254 nm.
- Injections (stacked): 60 times 200  $\mu$ L, every 8 minutes.

- First fraction(9a): 11.2mg of the first eluted ((+, CD300)-diasteomer) with de > 99.5%
- Second fraction(9b): 11.4mg of the second eluted ((-, CD300)-diastereomer) with de >99.5%
- Chromatograms of the collected fractions:



RT [min]	Area	Area%
4.91	4700	100.00
Sum	4700	100.00



RT [min]	Area	Area%
7.02	1065	100.00
Sum	1065	100.00

## 8. Optical rotations

Optical rotations were measured on a 241 Perkin-Elmer polarimeter with a sodium lamp (589 nm), a mercury lamp (578 and 546 nm) and a double-jacketed 10 cm cell at 25°C.

**Table S4:**  $[\alpha]_D^{25}$  of **7a** and **7b** at different wavelength in CH<sub>2</sub>Cl<sub>2</sub>

$\lambda$ (nm)	1 <sup>st</sup> eluted ( <b>7a</b> ) on Chiralpak IC $[\alpha]_D^{25}$ (CH <sub>2</sub> Cl <sub>2</sub> )	2 <sup>nd</sup> eluted ( <b>7b</b> ) on Chiralpak IC $[\alpha]_D^{25}$ (CH <sub>2</sub> Cl <sub>2</sub> )
589	+ 284 (c = 0.24)	- 283 (c = 0.14)
578	+ 308 (c = 0.24)	- 308 (c = 0.14)
546	+ 396 (c = 0.24)	- 308 (c = 0.14)

**Table S5:**  $[\alpha]_D^{25}$  of **9a** and **9b** at different wavelength in CH<sub>2</sub>Cl<sub>2</sub>

$\lambda$ (nm)	1 <sup>st</sup> eluted ( <b>9a</b> ) on Chiralpak IC $[\alpha]_D^{25}$ (CH <sub>2</sub> Cl <sub>2</sub> )	2 <sup>nd</sup> eluted ( <b>9b</b> ) on Chiralpak IC $[\alpha]_D^{25}$ (CH <sub>2</sub> Cl <sub>2</sub> )
589	+ 89 (c = 0.044)	- 88 (c = 0.016)
578	+ 93 (c = 0.044)	- 94 (c = 0.016)
546	+ 102 (c = 0.044)	- 100 (c = 0.016)

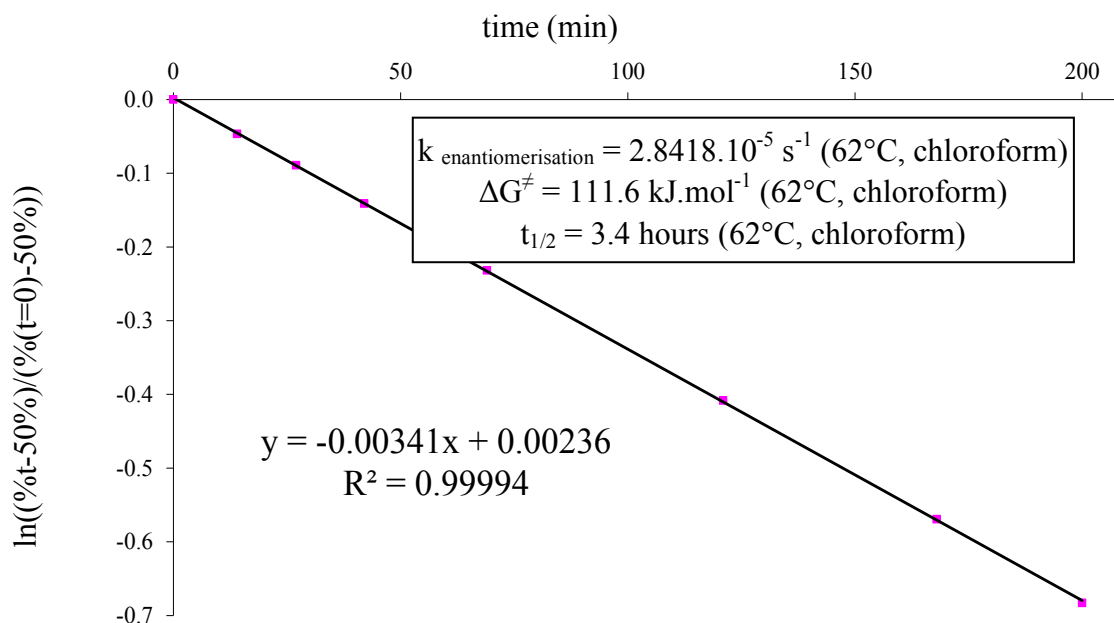


## 9. Kinetic studies of epimerization

About 0.3 mg of the 2<sup>nd</sup> eluted diastereomer **7b** is heated in about 15 mL of chloroform at 62°C. 0.02ml aliquots are taken and then injected on Chiralpak IC (80:10:10 heptane / isopropanol / dichloromethane, 1 mL/min, UV 254 nm). The percentage decrease of the 2<sup>nd</sup> eluted diastereomer (**7b**) is monitored.

**Table S6:** Percentage of **7b** at different time in CHCl<sub>3</sub>.

Time (min)	% 2 <sup>nd</sup> eluted diastereomer( <b>7b</b> )	$\ln ((\%t-50\%)/(\%(t=0)-50\%))$
0	99.19	0.0000
14	96.95	-0.0466
27	95.00	-0.0890
42	92.72	-0.1410
55	90.94	-0.1836
69	89.02	-0.2316
121	82.70	-0.4083
168	77.84	-0.5692
200	74.85	-0.6828



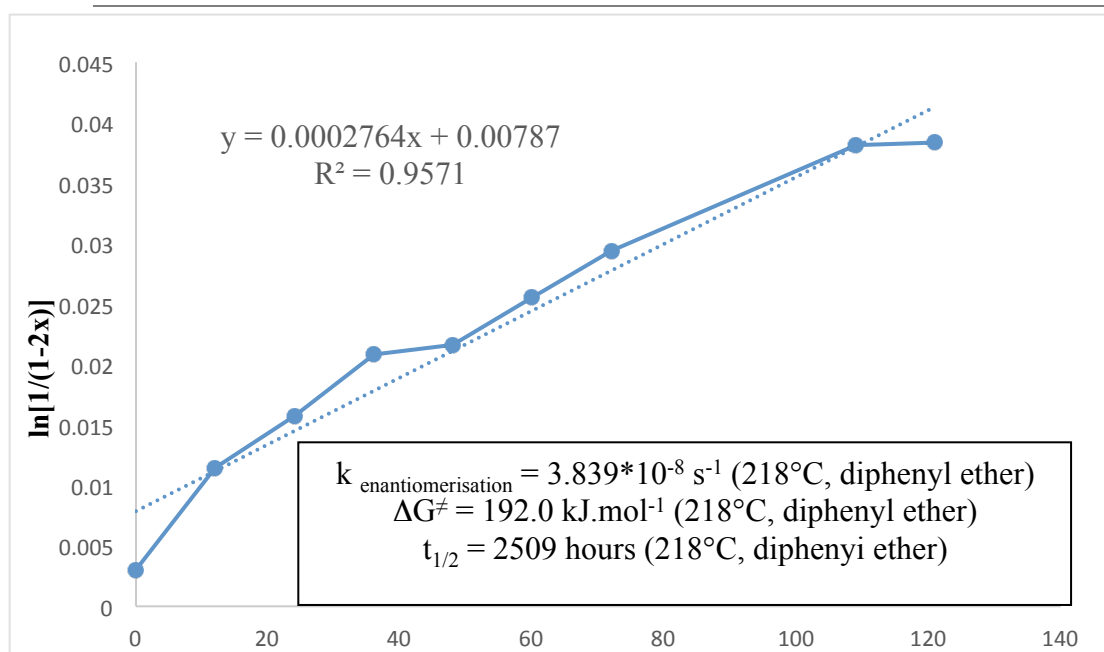
**Figure S19:** Kinetics of **7b** epimerization in cyclohexane at 62°C

About 0.3 mg of the 2<sup>nd</sup> eluted diastereomer (**9b**) is heated in about 15 mL of diphenyl ether at 218°C. 0.02ml are taken and then injected on Chiralpak IF (50:20:30 heptane / isopropanol /

dichloromethane, 1 mL/min, UV 365 nm). The percentage decrease of the second eluted diastereomer (**9b**) is monitored.

**Table S7:** Percentage of **9b** at different time in diphenyl ether.

Time (h)	% 2 <sup>nd</sup> eluted enantiomer( <b>9b</b> )	ln (1/(1-2X))
0	99.85	0.00300451
12	99.43	0.01146548
24	99.22	0.01572296
36	98.97	0.02081514
48	98.93	0.02163230
60	98.74	0.02552296
72	98.55	0.02942881
109	98.13	0.03811733
121	98.12	0.03832511



**Figure S20:** Kinetics of **9b** epimerization in diphenyl ether at 218°C

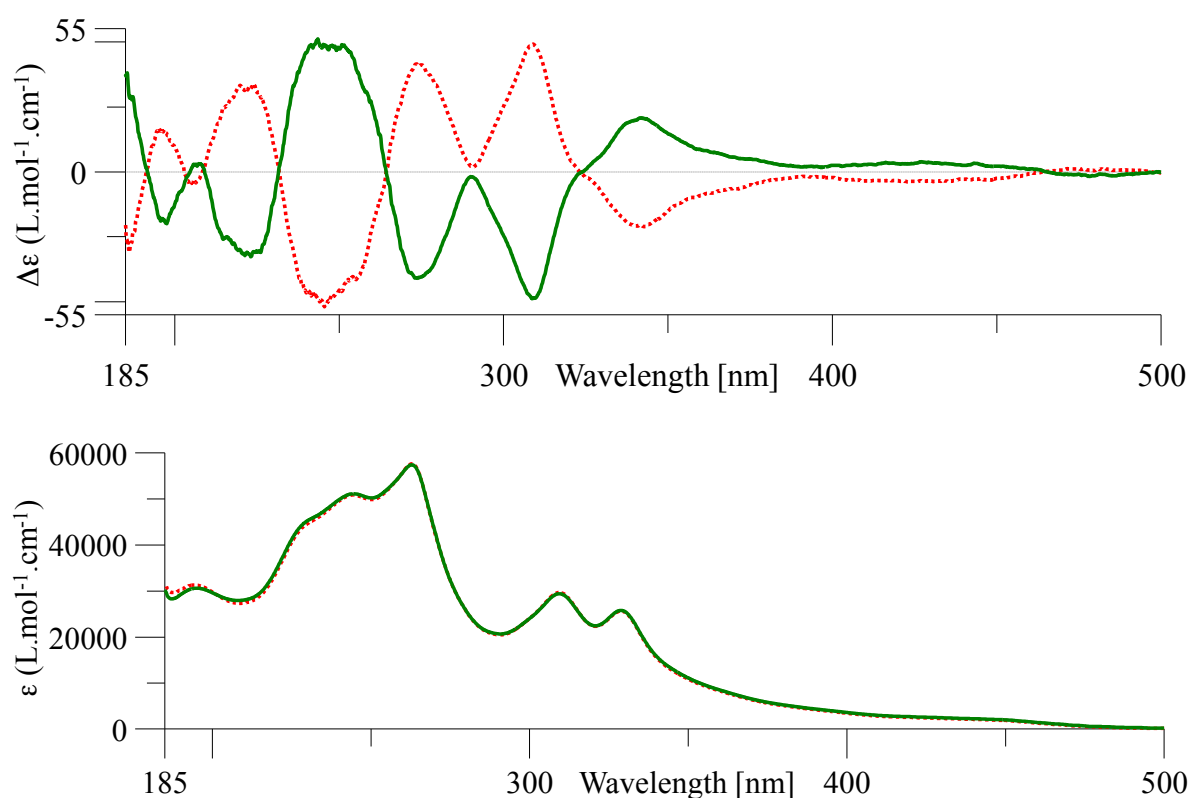
## 10. Electronic circular dichroism

ECD and UV spectra were measured on a JASCO J-815 spectrometer equipped with a JASCO Peltier cell holder PTC-423 to maintain the temperature at  $25.0 \pm 0.2^\circ\text{C}$ . A CD quartz cell of 1 mm of optical pathlength was used. The CD spectrometer was purged with nitrogen before recording each spectrum, which was baseline subtracted.

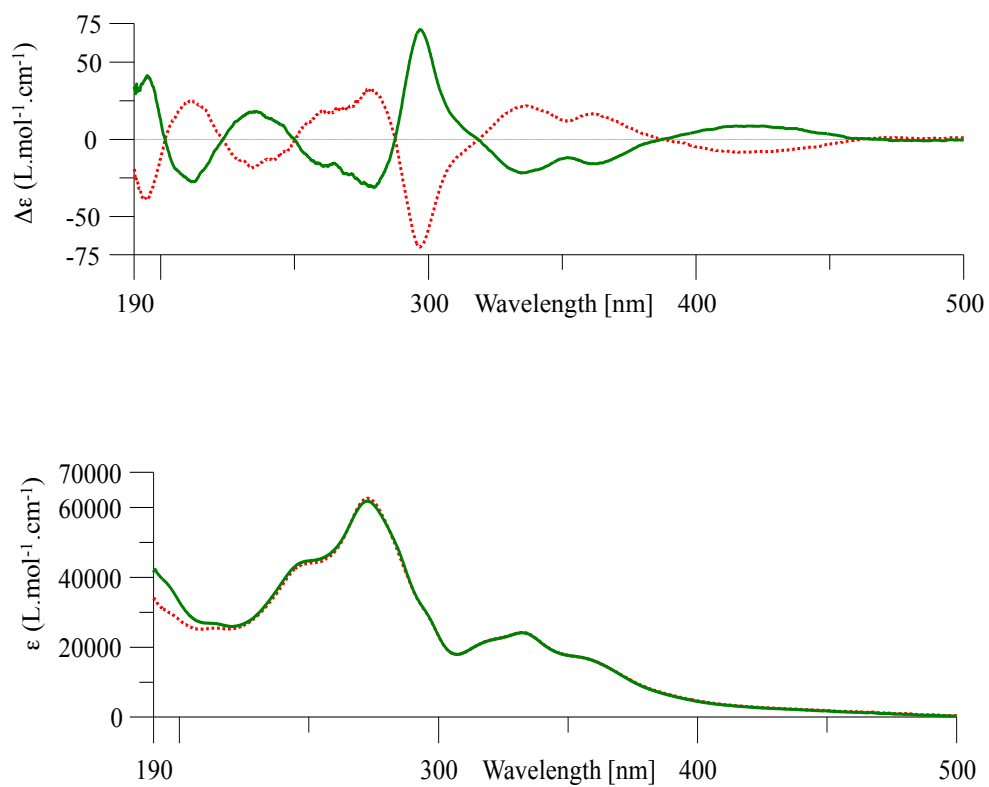
The baseline was always measured for the same solvent and in the same cell as the samples.

The spectra are presented without smoothing and further data processing.

Acquisition parameters: 0.1 nm as intervals, scanning speed 50 nm/min, band width 1 nm, and 5 accumulations per sample.



**Figure S21:** ECD and UV-vis of **7a** and **7b** in ACN (1<sup>st</sup> eluted diastereomer (**7a**): green solid line, concentration = 0.332 mmol.L<sup>-1</sup> in acetonitrile. 2<sup>nd</sup> eluted diastereomer(**7b**): red dotted line, concentration = 0.331 mmol.L<sup>-1</sup> in acetonitrile).



**Figure S22:** ECD and UV-vis of **9a** and **9b** (1<sup>st</sup> eluted diastereomer: green solid line, concentration = 0.0282 mmol. L<sup>-1</sup> in acetonitrile. 2<sup>nd</sup> eluted diastereomer: red dotted line, concentration = 0.0339 mmol. L<sup>-1</sup> in acetonitrile.).

## 11. Calculated ECD spectra of 7a and 9a

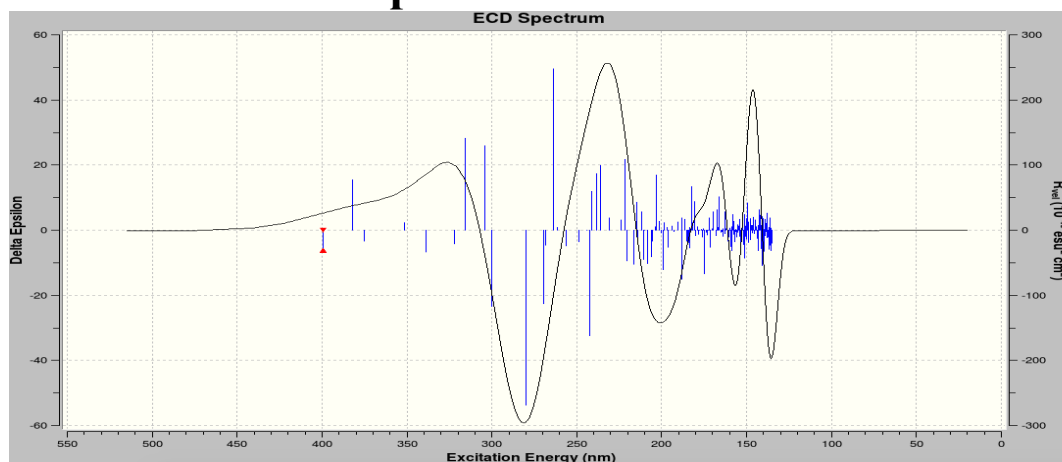


Figure S23: Calculated ECD spectrum of 7a.

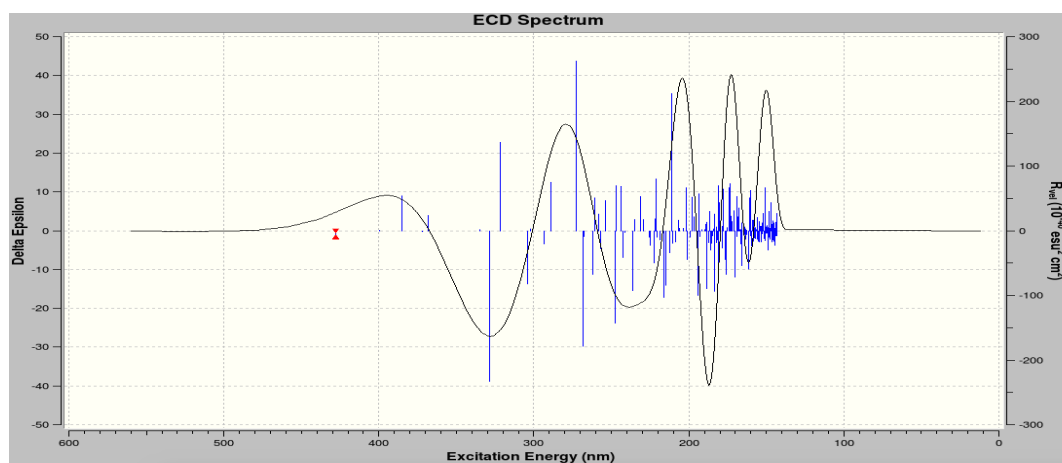
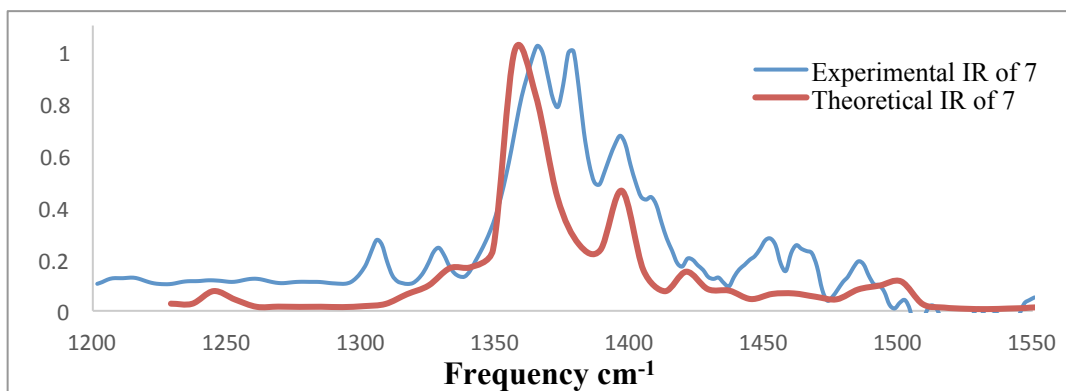
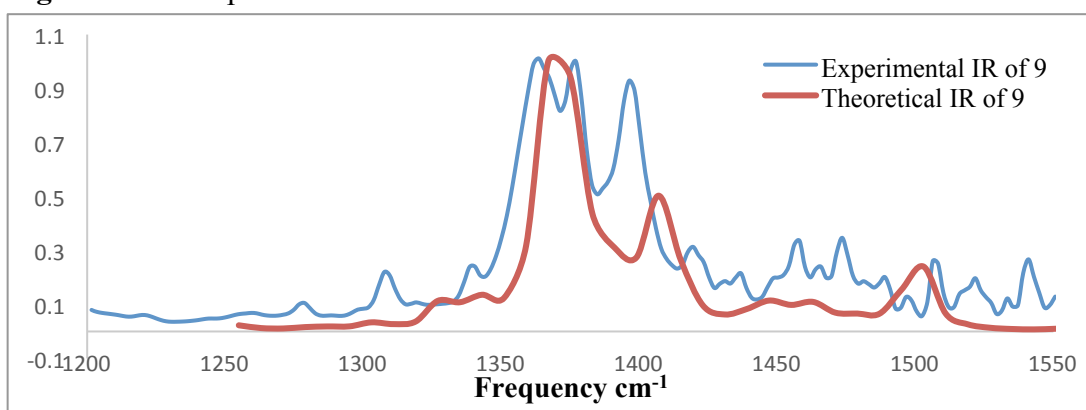


Figure S24: Calculated ECD spectrum of 9a.

## 12. IR spectra of 7 and 9



**Figure S25:** IR spectra of 7



**Figure S26:** IR spectra of 9

### 13. Vibrational circular dichroism

The VCD spectra were measured on the BioTools Chiral IR-2X (Dual PEM) with 300  $\mu\text{m}$  cell,  $\text{CHBr}_3$  as solvent.

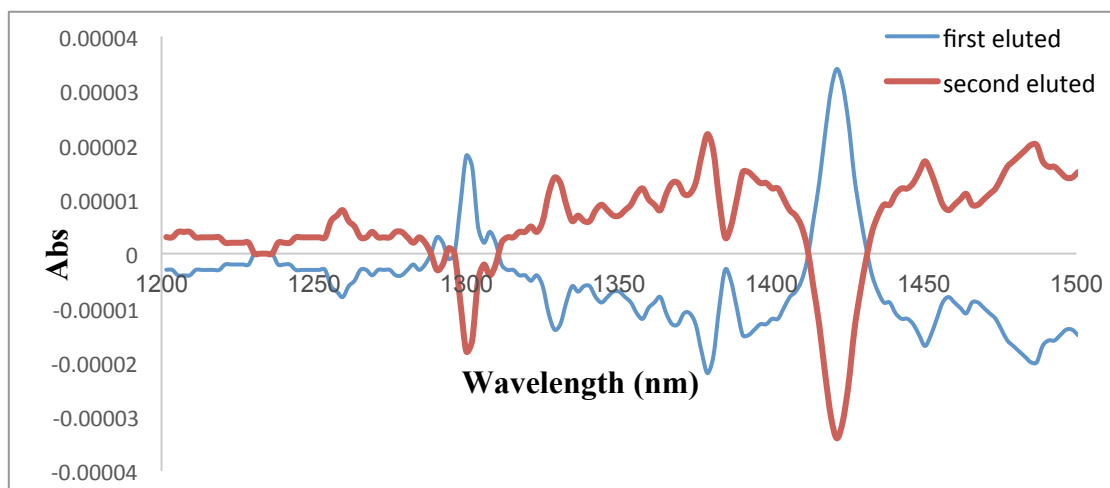


Figure S27: VCD spectra of 7

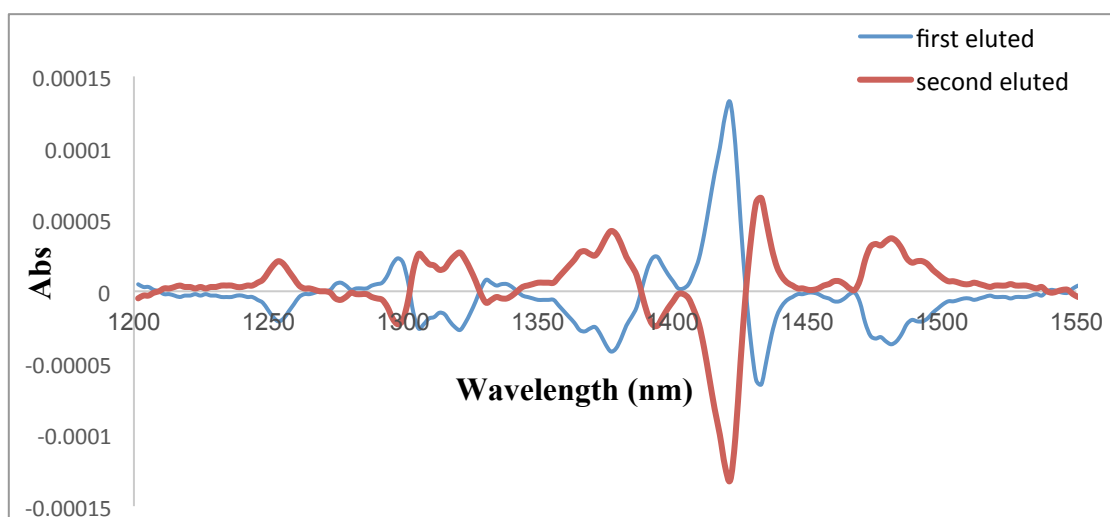


Figure S28: VCD spectra of 9

### 14. Absolute configuration of 7a and 9a

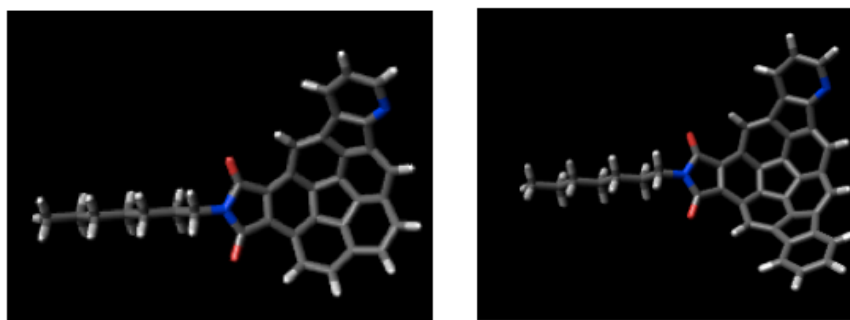
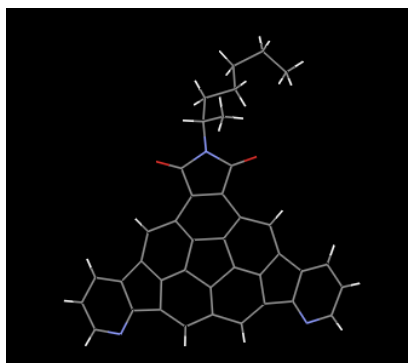


Figure S29: The absolute configuration of the first eluted (the structure we used for calculation) of 7a (left) and 9a (right)

## 15. Single crystal structure



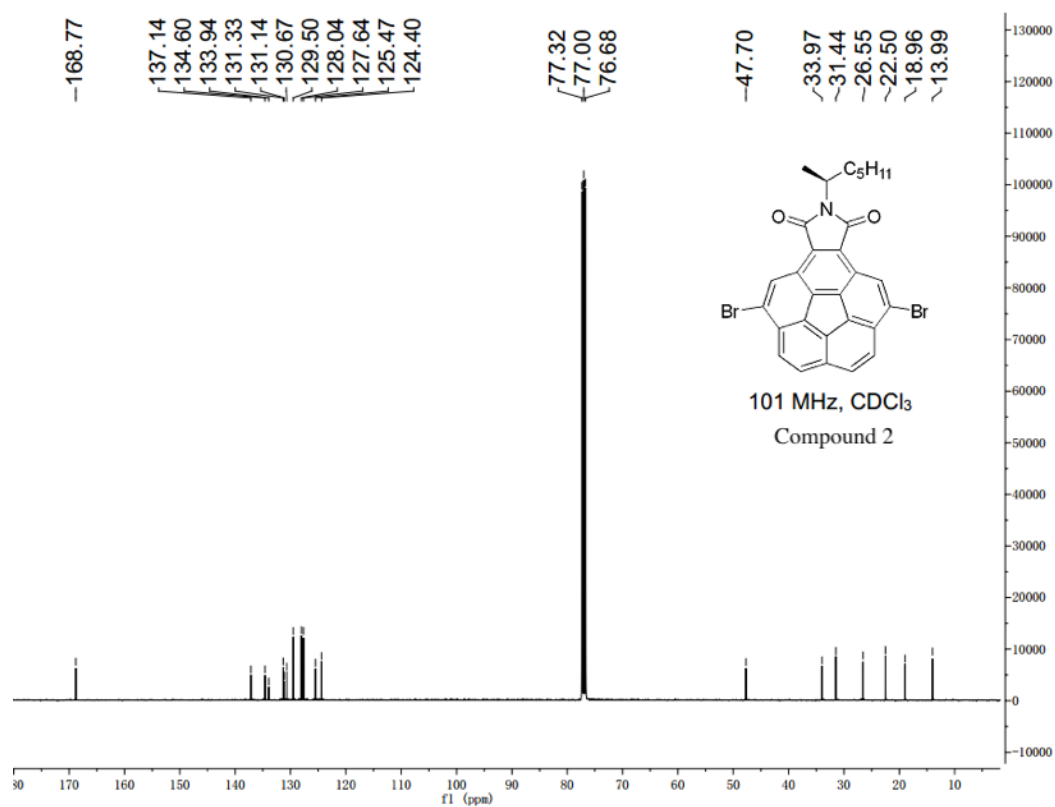
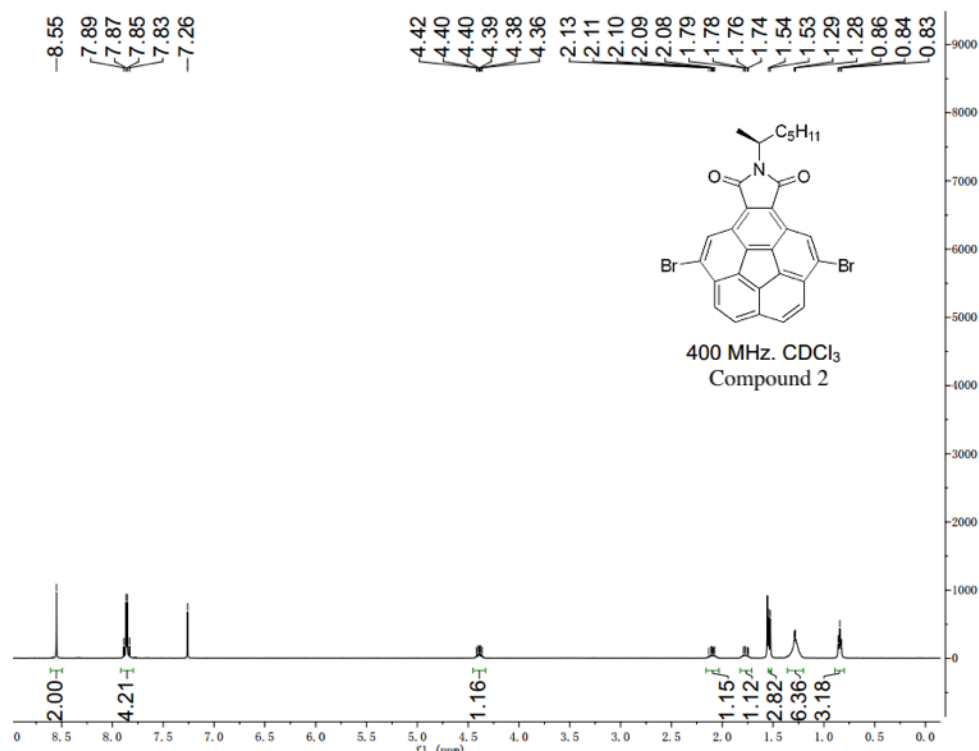
**Table S8:** Crystal data and structure refinement for **8**.

Identification code	Jay_TXQ_2_160K
Empirical formula	C <sub>156</sub> H <sub>104</sub> N <sub>12</sub> O <sub>10</sub>
Formula weight	2306.51
Temperature/K	159.99(10)
Crystal system	triclinic
Space group	<i>P</i> 1
<i>a</i> /Å	7.85160(10)
<i>b</i> /Å	16.71440(10)
<i>c</i> /Å	21.76930(10)
$\alpha$ /°	81.4450(10)
$\beta$ /°	81.2140(10)
$\gamma$ /°	78.2500(10)
Volume/Å <sup>3</sup>	2743.69(4)
<i>Z</i>	1
$\rho_{\text{calc}}$ /cm <sup>3</sup>	1.396
$\mu$ /mm <sup>-1</sup>	0.700
<i>F</i> (000)	1204.0
Crystal size/mm <sup>3</sup>	0.2 × 0.1 × 0.1
Radiation	CuK $\alpha$ ( $\lambda$ = 1.54184)
2 $\Theta$ range for data collection/°	4.138 to 149.422
Index ranges	-9 ≤ <i>h</i> ≤ 9, -20 ≤ <i>k</i> ≤ 20, -27 ≤ <i>l</i> ≤ 27
Reflections collected	119182
Independent reflections	21305 [ <i>R</i> <sub>int</sub> = 0.0405, <i>R</i> <sub>sigma</sub> = 0.0286]
Data/restraints/parameters	21305/3623/1637
Goodness-of-fit on <i>F</i> <sup>2</sup>	1.030
Final <i>R</i> indexes [ <i>I</i> ≥ 2 $\sigma$ ( <i>I</i> )]	<i>R</i> <sub>1</sub> = 0.0371, <i>wR</i> <sub>2</sub> = 0.0978
Final <i>R</i> indexes [all data]	<i>R</i> <sub>1</sub> = 0.0395, <i>wR</i> <sub>2</sub> = 0.1010
Largest diff. peak/hole / e Å <sup>-3</sup>	0.26/-0.32
Flack parameter	0.04(5)

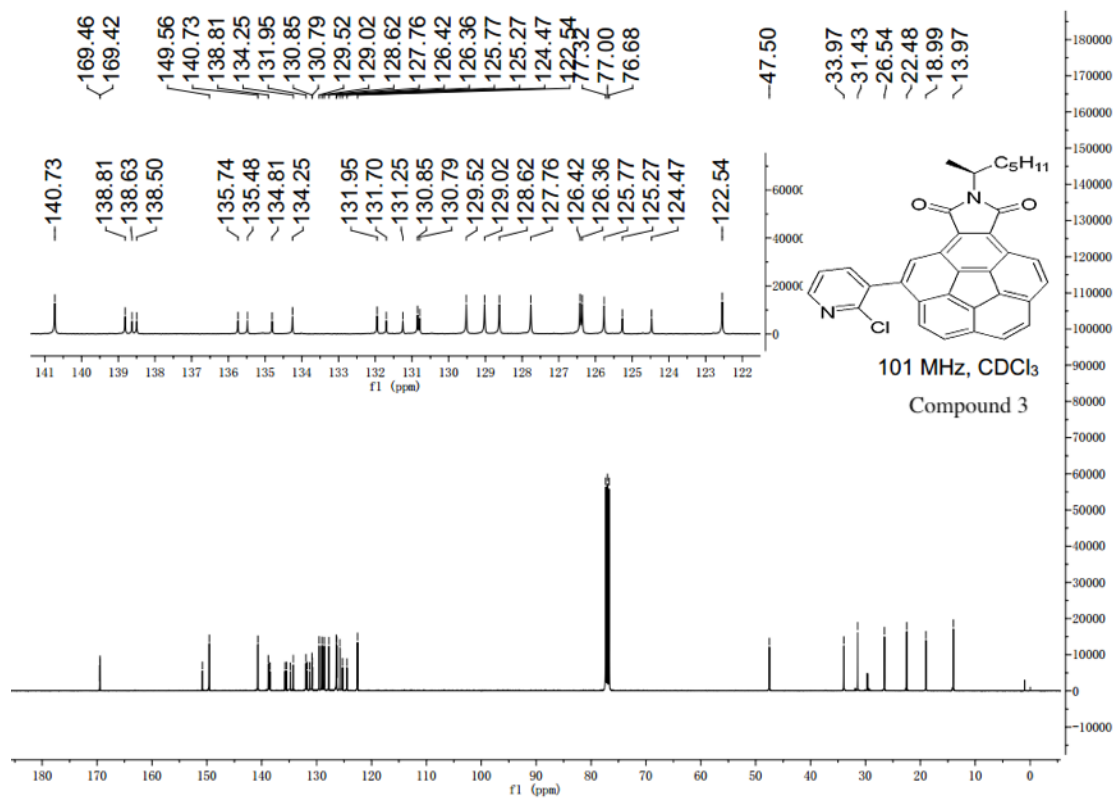
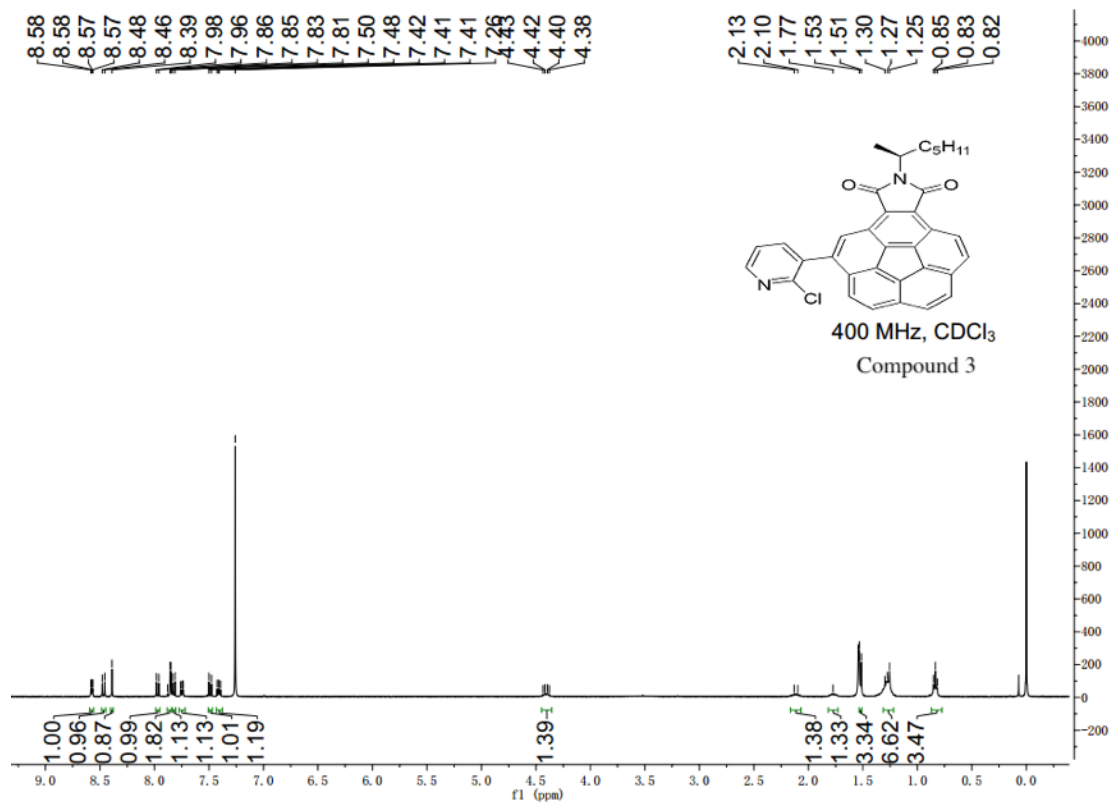


# 16. $^1\text{H}$ -NMR and $^{13}\text{C}$ -NMR

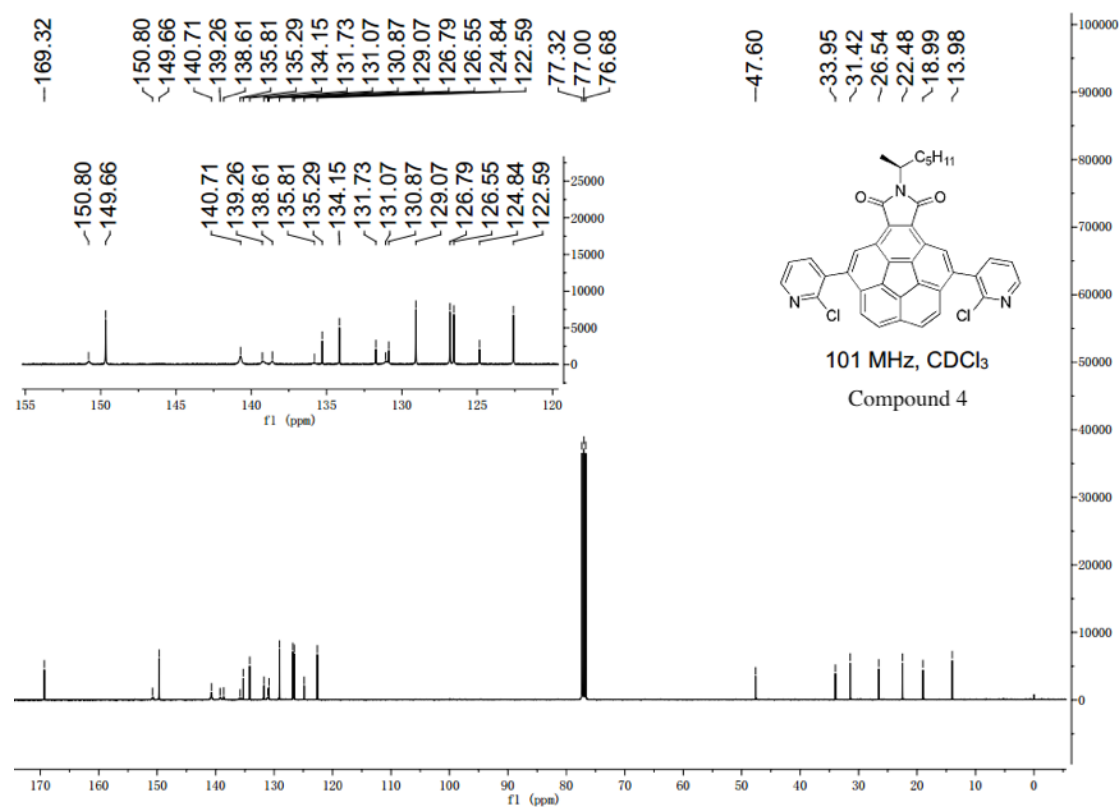
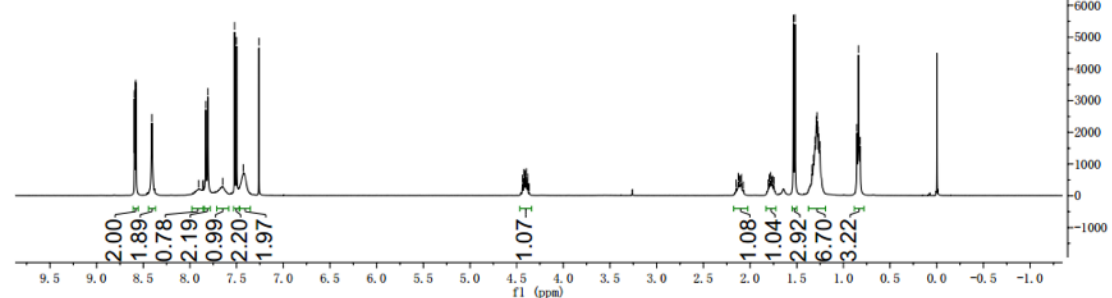
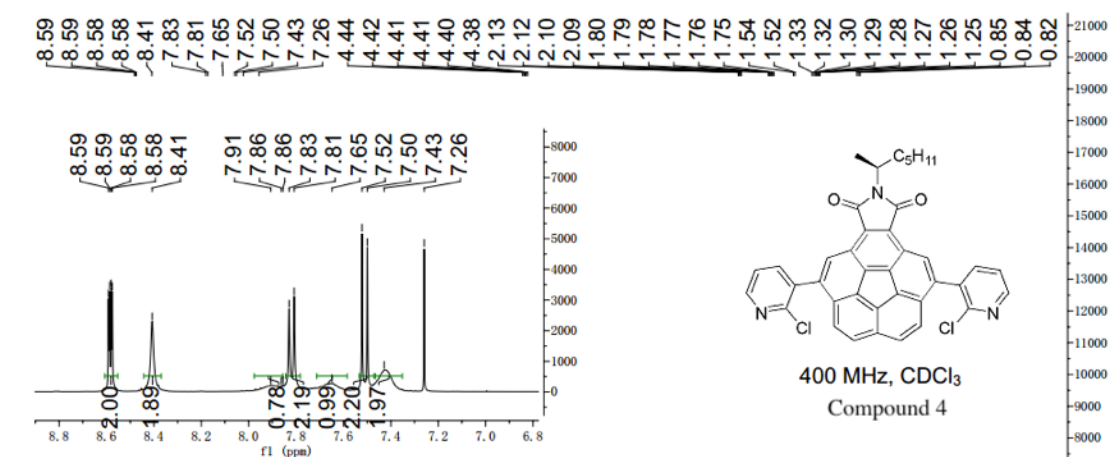
Compound 2



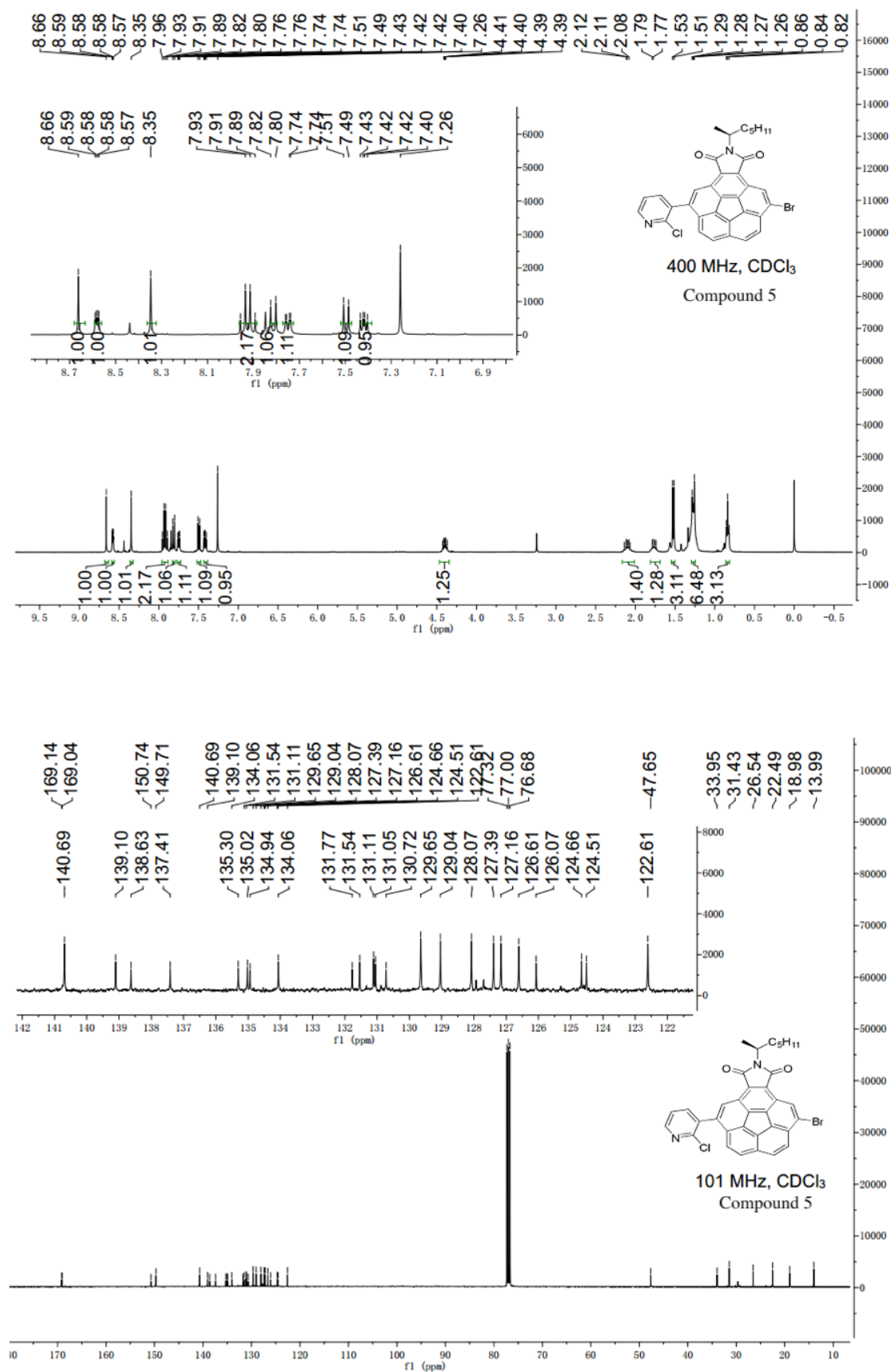
# Compound 3



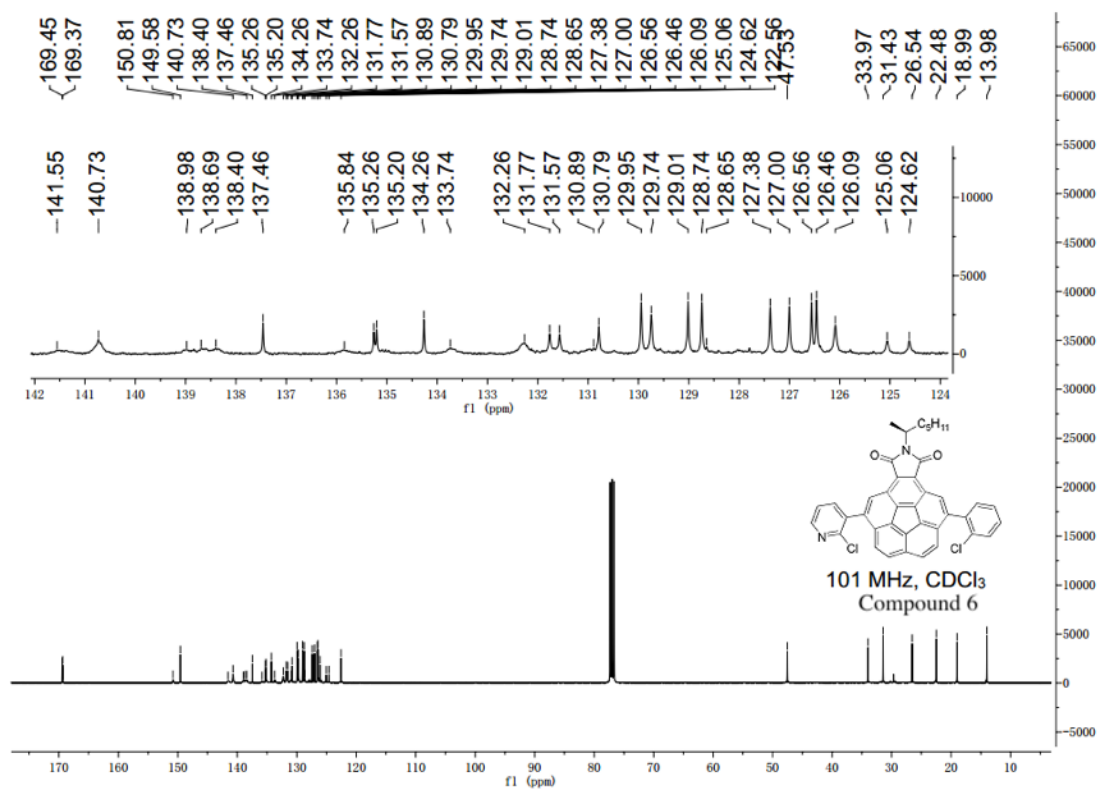
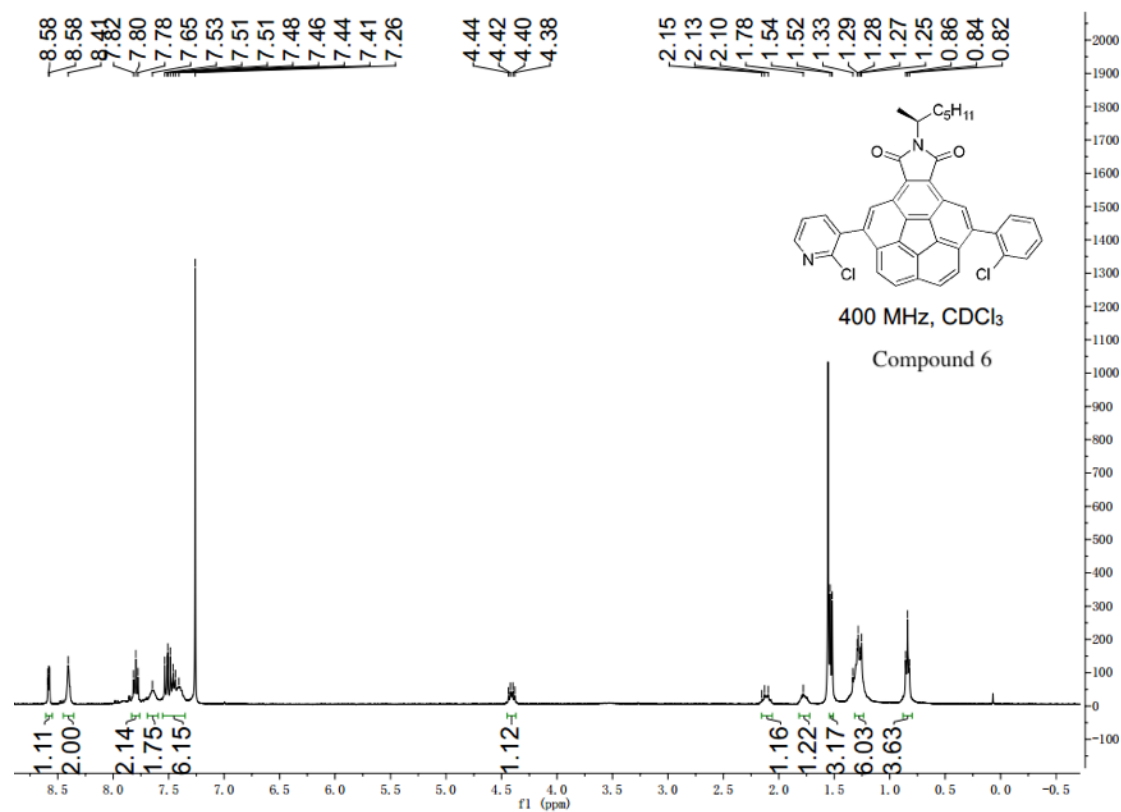
# Compound 4



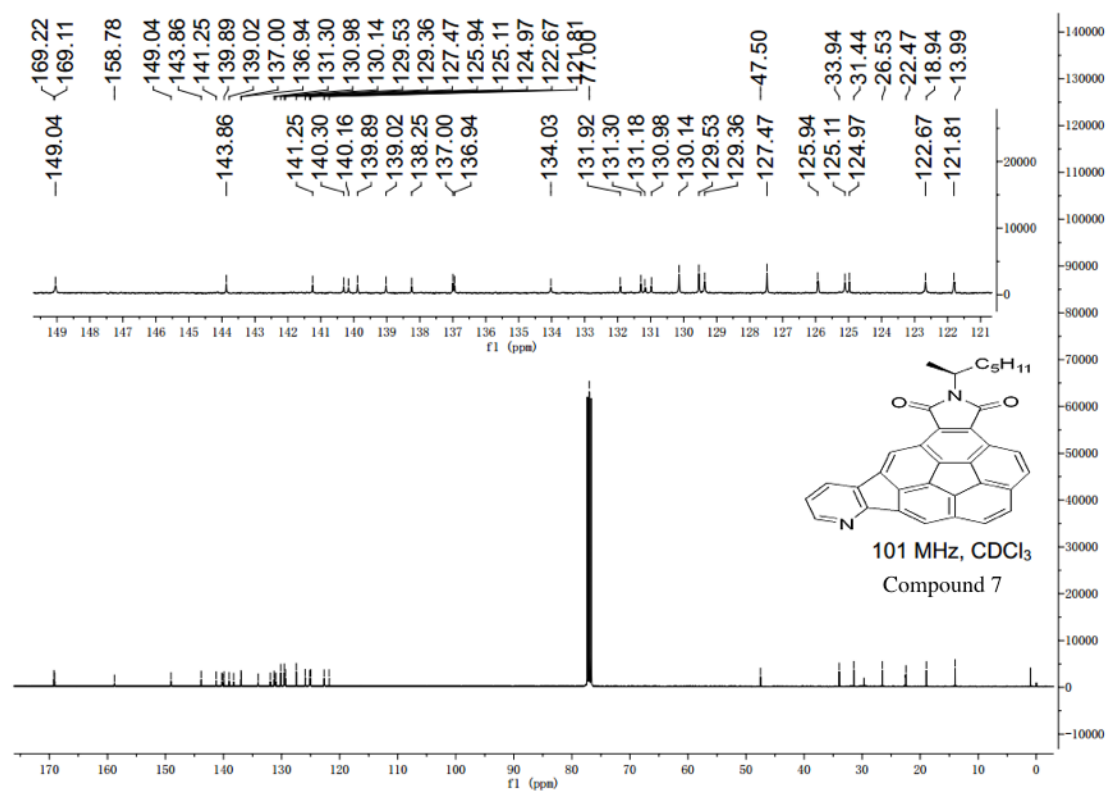
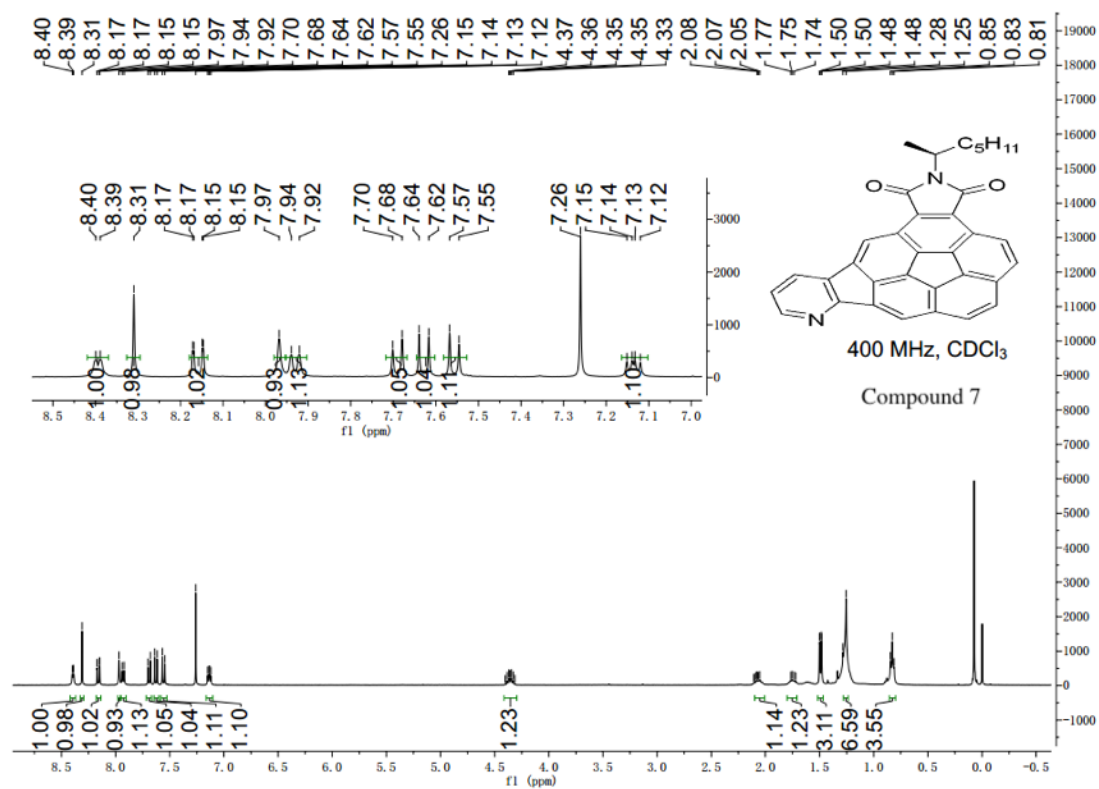
# Compound 5



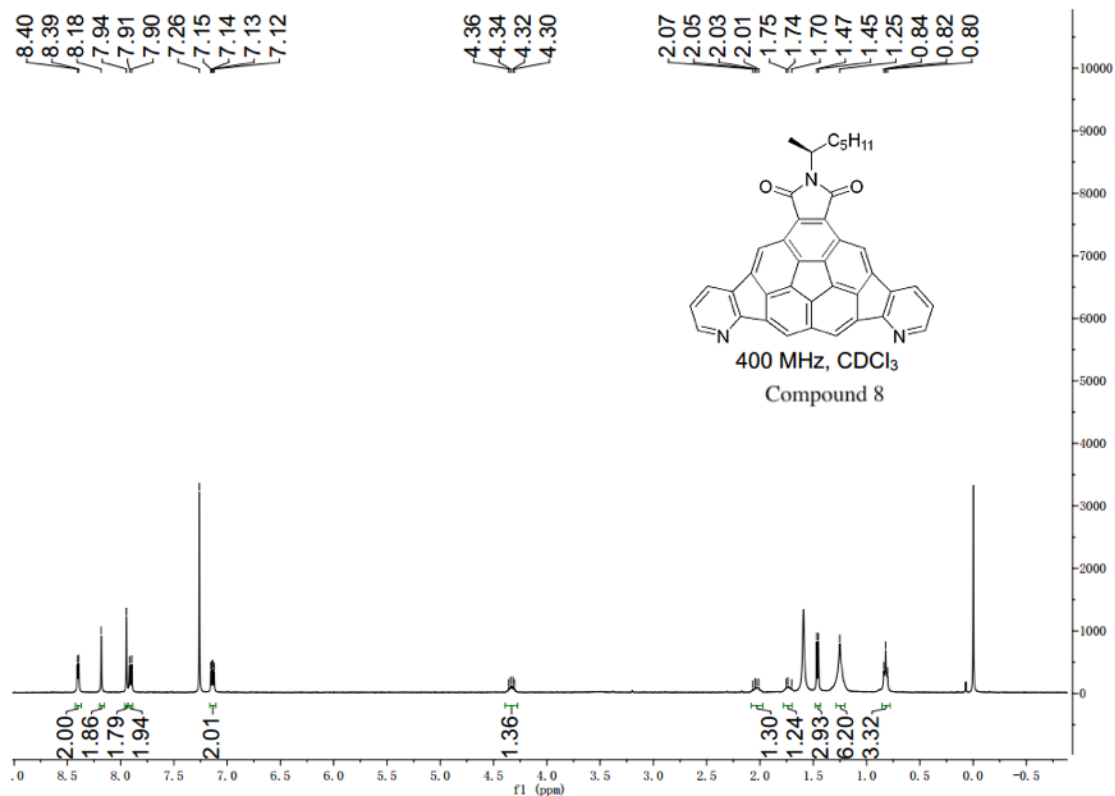
# Compound 6



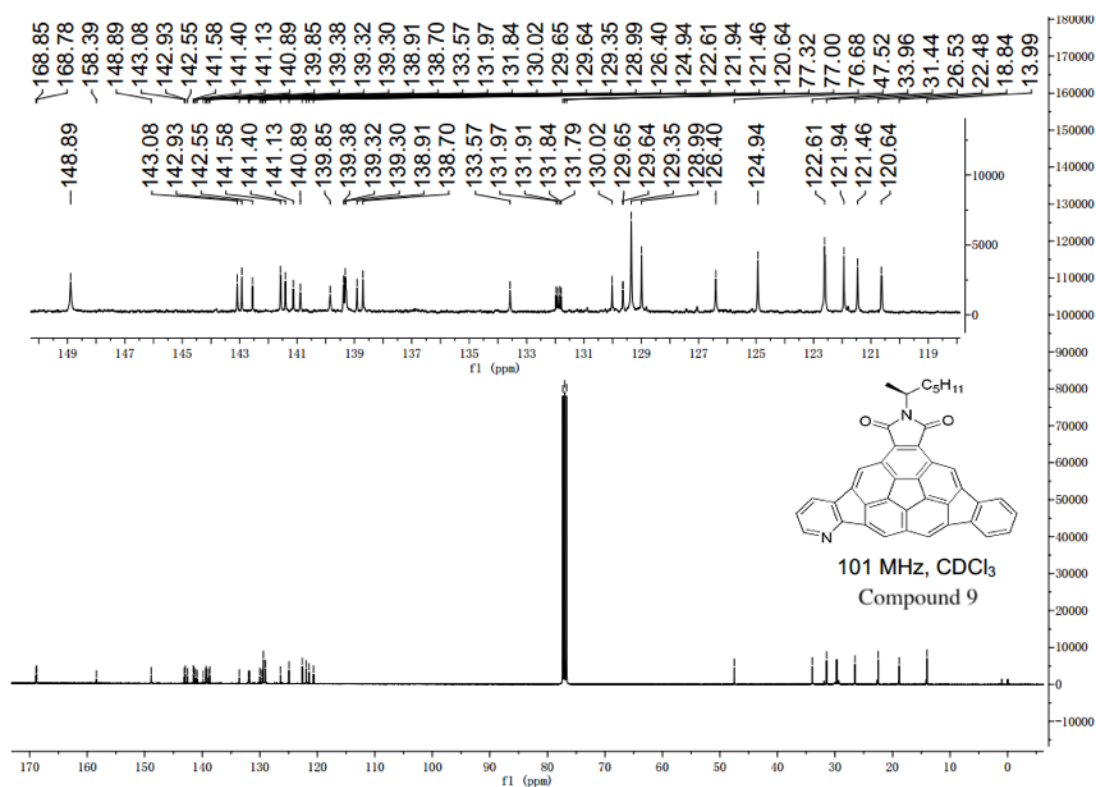
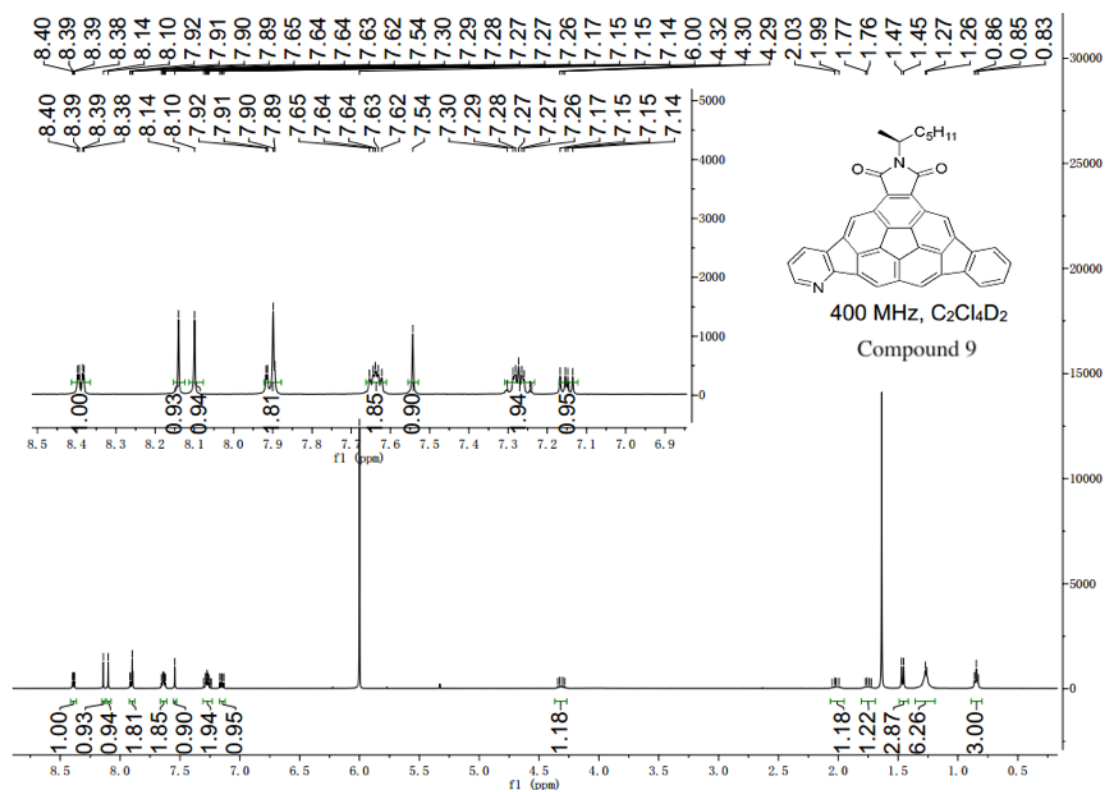
# Compound 7



# Compound 8



# Compound 9





## 17.Literature

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