New tertiary amine-derived C_2-symmetric chiral pyridine-*N*,*N*′-dioxide ligands and their applications in asymmetric catalysis

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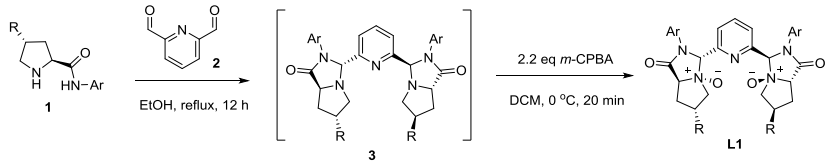
1. General information

Reactions were monitored by thin layer chromatography using UV light to visualize the course of reaction. Purification of reaction products was carried out by flash chromatography. ^{1}H and ^{13}CNMR spectra were obtained using a Bruker DPX-400 spectrometer. ^{1}H NMR chemical shifts are reported in ppm (δ) relative to tetramethylsilane (TMS) with the solvent resonance employed as the internal standard. Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet), coupling constants (Hz) and integration. ^{13}C NMR chemical shifts are reported in ppm (δ) from tetramethylsilane (TMS) with the solvent resonance as the internal standard. Melting points were measured on an electrothermal digital melting point apparatus.

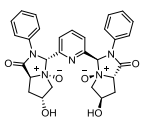
2. General procedure for preparation of chiral Py-2NO ligands L1



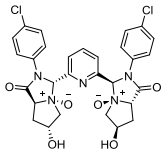
In a sealed tube equipped with a magnetic stirring bar, pyridine-2,6-dicarbaldehyde **2** (1.0 mmol) and optically pure 4-hydroxyprolinamide or prolinamide **1** (2.4 mmol, 2.4 equiv) were added. Then, anhydrous ethanol (6.0 mL) was added and the reaction was heated with stirring at reflux for 12 h. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to give the intermediate **3**.

For the oxidation step, see: X. Liu, L. Lin and X. Feng, Chiral *N,N'*-dioxide ligands: synthesis, coordination chemistry and asymmetric catalysis, *Org. Chem. Front.*, 2014, **1**, 298-302. In a sealed tube equipped with a magnetic stirring bar, to the intermediate **3** was added 3.0 mL of DCM and *m*-CPBA (2.2 eq). The reaction mixture was stirred at 0 ^{o}C for 20 min. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to furnish the Py-2NO ligand **L1**.

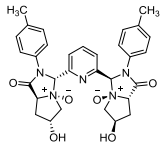
3. Characterization data of Py-2NO ligands L1



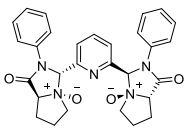
L1a: White solid, m.p. 249.1-249.3 ^{o}C; yield 61%, >20:1 dr; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.53-2.60 (m, 4H), 3.80-3.84 (m, 2H), 3.96 (d, J = 10.8 Hz, 2H), 4.14-4.17 (m, 2H), 4.51-4.53 (m, 2H), 6.05 (s, 2H), 7.19-7.25 (m, 8H), 7.68 (d, J = 7.6 Hz, 2H), 7.89-7.92 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 35.7, 70.2, 73.5, 75.0, 86.0, 122.3, 127.5, 128.6, 131.6, 132.4, 136.7, 148.5, 167.0; HRMS (ESI-TOF) m/z: Calcd. for $C_{29}H_{29}N_5NaO_6$ $[M+Na]^+$: 566.2008; Found: 566.2002.



L1b: White solid, m.p. 245.3-245.6 ^{o}C; yield 59%, >20:1 dr; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.50-2.61 (m, 4H), 3.80-3.84 (m, 2H), 3.96 (d, J = 10.8 Hz, 2H), 4.14-4.17 (m, 2H), 4.51-4.53 (m, 2H), 6.05 (s, 2H), 7.19-7.24 (m, 8H), 7.68 (d, J = 7.6 Hz, 2H), 7.89-7.92 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 35.7, 70.2, 73.5, 75.0, 86.0, 122.3, 127.5, 128.6, 131.6, 132.4, 136.7, 148.5, 167.0; HRMS (ESI-TOF) m/z: Calcd. for $C_{29}H_{27}Cl_2N_5NaO_6$ $[M+Na]^+$: 634.1228; Found: 634.1220.

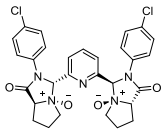


L1c: White solid, m.p. 248.6-249.5 ^{o}C; yield 60%, 18:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.23 (s, 6H), 2.31-2.36 (m, 2H), 2.43-2.48 (m, 2H), 3.72 (d, J = 8.4 Hz, 2H), 4.14-4.18 (m, 2H), 4.35-4.39 (m, 2H), 4.44 (s, 2H), 6.79 (s, 2H), 7.10 (d, J = 8.4 Hz, 4H), 7.36 (d, J = 8.4 Hz, 4H), 7.59 (d, J = 8.0 Hz, 2H), 7.84-7.88 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 20.9, 36.4, 70.9, 74.9, 76.7, 86.8, 124.5, 128.7, 129.9, 133.4, 136.9, 151.1, 168.8; HRMS (ESI-TOF) m/z: Calcd. for $C_{31}H_{33}N_5NaO_6$ $[M+Na]^+$: 594.2323; Found: 594.2325.

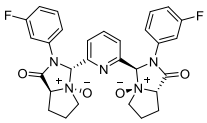


L1d: White solid, m.p. 223.5-224.0 ^{o}C; yield 62%, >20:1 dr; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 1.97-2.03 (m, 2H), 2.25-2.36 (m, 4H), 2.46-2.54 (m, 2H), 3.80-3.85 (m, 6H), 6.08 (s, 2H), 7.06-7.10 (m, 2H), 7.19-7.23 (m, 4H), 7.31-7.33 (m, 4H), 7.67 (d, J = 7.6 Hz, 2H), 7.75-7.79 (m,

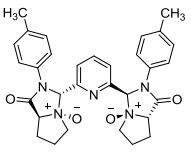
1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 21.7, 23.7, 70.4, 86.8, 120.8, 125.6, 127.2, 128.4, 134.5, 136.6, 149.3, 167.5; HRMS (ESI-TOF) m/z: Calcd. for $C_{29}H_{29}N_5NaO_4$ $[M+Na]^+$: 534.2112; Found: 534.2107.



L1e: White solid, m.p. 260.5-260.9 ^{o}C; yield 60%, 18:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 1.99-2.02 (m, 2H), 2.12-2.15 (m, 2H), 2.23-2.33 (m, 4H), 3.62-3.66 (m, 2H), 3.86 (d, J = 6.0 Hz, 2H), 3.96-4.04 (m, 2H), 6.81 (s, 2H), 7.36-7.38 (m, 4H), 7.54-7.57 (m, 4H), 7.61 (d, J = 7.6 Hz, 2H), 7.83-7.87 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 22.9, 24.7, 71.7, 77.4, 86.8, 125.2, 128.7, 129.4, 130.9, 135.1, 137.0, 151.1, 169.5; HRMS (ESI-TOF) m/z: Calcd. for $C_{29}H_{27}Cl_2N_5NaO_4$ $[M+Na]^+$: 602.1332; Found: 602.1330.

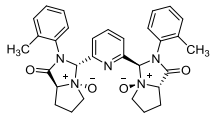


L1f: White solid, m.p. m.p. 272.5-273.4 ^{o}C; yield 27%, 12:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 1.98-2.00 (m, 2H), 2.12-2.20 (m, 4H), 2.25-2.30 (m, 2H), 3.62-3.66 (m, 4H), 3.93-4.01 (m, 2H), 6.89 (s, 2H), 7.00-7.04 (m, 2H), 7.30-7.37 (m, 4H), 7.59 (d, J = 7.2 Hz, 2H), 7.65 (d, J = 7.6 Hz, 2H), 7.85-7.89 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 22.8, 24.5, 71.4, 77.3, 86.4, 109.9 (d, J_{CF} = 26.2 Hz), 113.3 (d, J_{CF} = 21.1 Hz), 118.5, 129.0, 131.1 (d, J_{CF} = 9.0 Hz), 136.8, 137.9 (d, J_{CF} = 10.1 Hz), 150.5, 162.7 (d, J_{CF} = 242.3 Hz), 169.3; HRMS (ESI-TOF) m/z: Calcd. for $C_{29}H_{27}F_2N_5NaO_4$ $[M+Na]^+$: 570.1923; Found: 570.1918.

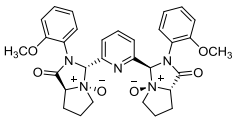


L1g: White solid, m.p. 268.2-268.9 ^{o}C; yield 60%, >20:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 1.97-1.99 (m, 2H), 2.13-2.33 (m, 12H), 3.65-3.69 (m, 2H), 3.94-4.03 (m, 4H), 6.75 (s, 2H), 7.06 (d, J = 8.8 Hz, 4H), 7.39 (d, J = 8.4 Hz, 4H), 7.57 (d, J = 7.6 Hz, 2H), 7.76-7.79 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 21.0, 22.9, 24.6, 71.6, 77.4, 87.4, 123.9, 128.4, 129.9, 133.6, 136.4,

136.9, 151.5, 169.2; HRMS (ESI-TOF) m/z: Calcd. for $C_{31}H_{33}N_5NaO_4$ $[M+Na]^+$: 562.2425; Found: 562.2418.

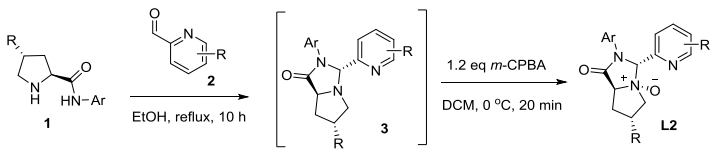


L1h: White solid, m.p. m.p. 240.5-241.7 ^oC; yield 42%, >20:1 dr; ^1H NMR (DMSO-d_6, 400 MHz) δ: 2.07-2.15 (m, 4H), 2.29 (s, 6H), 2.34-2.37 (m, 4H), 3.80 (s, 2H), 4.10-4.17 (m, 2H), 4.55 (s, 2H), 6.54 (s, 2H), 6.86-6.89 (m, 2H), 7.14-7.25 (m, 6H), 7.42 (d, J = 7.6 Hz, 2H), 7.70-7.74 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 18.5, 23.5, 25.6, 72.9, 77.7, 88.4, 127.6, 127.7, 129.2, 131.1, 133.9, 136.8, 137.6, 153.0, 170.4; HRMS (ESI-TOF) m/z: Calcd. for $C_{31}H_{33}N_5NaO_4$ $[M+Na]^+$: 562.2425; Found: 562.2419.



L1i: White solid, m.p. m.p. 243.1-241.4 ^oC; yield 45%, >20:1 dr; ^1H NMR (DMSO-d_6, 400 MHz) δ: 2.06-2.12 (m, 4H), 2.34-2.36 (m, 4H), 3.78-3.82 (m, 2H), 3.84 (s, 6H), 4.20-4.26 (m, 2H), 4.54-4.55 (m, 2H), 6.31 (s, 2H), 6.67-6.71 (m, 2H), 7.08-7.10 (m, 2H), 7.13 (s, 2H), 7.25-7.29 (m, 2H), 7.50 (d, J = 3.6 Hz, 2H), 7.68-7.72 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 23.0, 25.3, 56.4, 72.2, 77.4, 87.7, 112.5, 121.3, 122.8, 127.6, 130.6, 131.0, 137.4, 152.6, 155.8, 170.2; HRMS (ESI-TOF) m/z: Calcd. for $C_{31}H_{33}N_5NaO_6$ $[M+Na]^+$: 594.2323; Found: 594.2331.

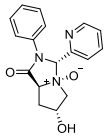
4. General procedure for preparation of chiral Py-NO ligands L2



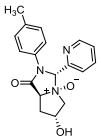
In a sealed tube equipped with a magnetic stirring bar, pyridine-2-carbaldehyde **2** (1.0 mmol) and optically pure 4-hydroxyprolinamide or prolinamide **1** (1.2 mmol, 1.2 equiv) were added. Then, anhydrous ethanol (6.0 mL) was added and the reaction was heated with stirring at reflux for 12 h. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to give the intermediate **3**.

For the oxidation step, see: X. Liu, L. Lin and X. Feng, Chiral *N,N′*-dioxide ligands: synthesis, coordination chemistry and asymmetric catalysis, *Org. Chem. Front.*, 2014, **1**, 298-302. In a sealed tube equipped with a magnetic stirring bar, to the intermediate **3** was added 3.0 mL of DCM and *m*-CPBA (1.2 eq). The reaction mixture was stirred at 0 ^{o}C for 20 min. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to furnish the Py-NO ligand **L2**.

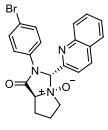
5. Characterization data of Py-NO ligands L2



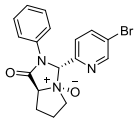
L2a: Light yellow solid, m.p. 145.7-146.6 ^{o}C; yield 68%, >20:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.50-2.54 (m, 2H), 3.74 (d, J = 9.2 Hz, 1H), 4.13-4.17 (m, 1H), 4.46 (d, J = 3.2 Hz, 1H), 4.76-4.80 (m, 1H), 6.75 (br s, 1H), 6.86 (s, 1H), 7.15-7.19 (m, 1H), 7.31-7.35 (m, 2H), 7.38-7.42 (m, 1H), 7.47-7.49 (m, 2H), 7.68 (d, J = 7.6 Hz, 1H), 7.83-7.87 (m, 1H), 8.60-8.61 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 36.9, 71.1, 75.0, 76.8, 86.6, 122.5, 125.1, 126.5, 127.8, 129.4, 136.3, 137.0, 149.7, 151.6, 169.2; HRMS (ESI-TOF) m/z: Calcd. for $C_{17}H_{17}N_3NaO_3$ $[M+Na]^+$: 334.1162; Found: 334.1166.



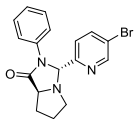
L2b: Light yellow solid, m.p. 152.5-153.1 ^{o}C; yield 65%, >20:1 dr; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.19 (s, 3H), 2.65-2.68 (m, 2H), 3.84-3.88 (m, 1H), 3.95 (d, J = 9.2 Hz, 1H), 4.51 (s, 1H), 4.95-4.98 (m, 1H), 5.97 (s, 1H), 7.01 (d, J = 8.0 Hz, 2H), 7.10 (d, J = 8.8 Hz, 2H), 7.27-7.30 (m, 1H), 7.46 (d, J = 7.6 Hz, 1H), 7.67-7.71 (m, 1H), 8.61-8.63 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 21.0, 36.9, 71.5, 74.3, 76.5, 88.4, 122.7, 125.2, 126.4, 130.0, 132.6, 136.8, 137.2, 150.1, 150.2, 168.6; HRMS (ESI-TOF) m/z: Calcd. for $C_{18}H_{19}N_3NaO_3$ $[M+Na]^+$: 348.1319; Found: 348.1317.



L2c: Light yellow solid, m.p. 154.3-154.7 °C; yield 64%, 18:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.09-2.13 (m, 1H), 2.24-2.31 (m, 1H), 2.40-2.53 (m, 2H), 3.77-3.81 (m, 1H), 4.06-4.13 (m, 1H), 4.52-4.55 (m, 1H), 7.07 (s, 1H), 7.52-7.65 (m, 5H), 7.74-7.79 (m, 1H), 7.84 (d, J = 8.4 Hz, 1H), 7.97-8.00 (m, 2H), 8.39 (d, J = 8.4 Hz, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 23.1, 25.0, 71.7, 77.6, 87.0, 118.7, 124.4, 124.7, 127.8, 128.3, 128.5, 129.5, 130.4, 132.3, 136.0, 136.4, 147.1, 153.0, 169.9; HRMS (ESI-TOF) m/z: Calcd. for $C_{21}H_{18}BrN_3NaO_2$ $[M+Na]^+$: 446.0475; Found: 446.0476.

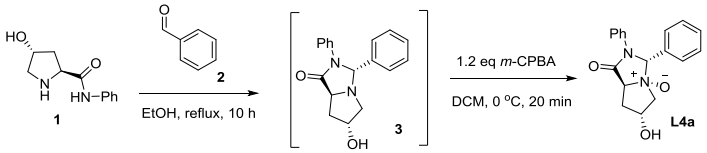


L2d: Light yellow solid, m.p. 143.5-143.9 °C; yield 64%, >20:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.04-2.07 (m, 1H), 2.17-2.23 (m, 1H), 2.35-2.44 (m, 2H), 3.66-3.70 (m, 1H), 3.96-4.03 (m, 1H), 4.31-4.34 (m, 1H), 6.83 (s, 1H), 7.16-7.20 (m, 1H), 7.32-7.36 (m, 2H), 7.49 (d, J = 7.6 Hz, 2H), 7.65 (d, J = 8.4 Hz, 1H), 8.10-8.12 (m, 1H), 8.71 (d, J = 2.4 Hz, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 23.0, 24.9, 71.7, 77.5, 86.5, 121.5, 122.4, 126.5, 129.4, 129.5, 136.5, 139.4, 150.3, 151.4, 169.8; HRMS (ESI-TOF) m/z: Calcd. for $C_{17}H_{16}BrN_3NaO_2$ $[M+Na]^+$: 396.0318; Found: 396.0322.



3d: Light yellow solid, m.p. 182.0-182.8 °C; yield 88%, >20:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.09-2.12 (m, 1H), 2.22-2.28 (m, 1H), 2.39-2.50 (m, 2H), 3.71-3.75 (m, 1H), 4.01-4.08 (m, 1H), 4.36-4.39 (m, 1H), 6.87 (s, 1H), 7.21-7.25 (m, 1H), 7.37-7.41 (m, 2H), 7.53-7.56 (m, 2H), 7.70 (d, J = 8.0 Hz, 1H), 8.15-8.17 (m, 1H), 8.76 (d, J = 2.4 Hz, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 24.9, 27.9, 56.0, 64.6, 82.5, 120.0, 121.2, 124.1, 125.1, 129.2, 137.9, 140.3, 150.5, 157.7, 175.1; HRMS (ESI-TOF) m/z: Calcd. for $C_{17}H_{16}BrN_3NaO$ $[M+Na]^+$: 380.0369; Found: 380.0375.

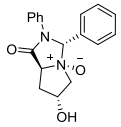
6. General procedure for preparation of chiral ligand L4a



In a sealed tube equipped with a magnetic stirring bar, benzaldehyde **2** (1.0 mmol) and optically pure 4-hydroxyprolinamide **1** (1.2 mmol, 1.2 equiv) were added. Then, anhydrous ethanol (6.0 mL) was added and the reaction was heated with stirring at reflux for 12 h. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to give the intermediate **3**.

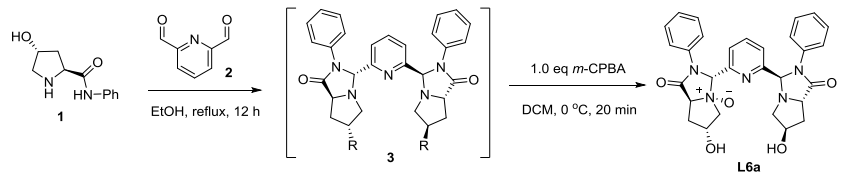
For the oxidation step, see: X. Liu, L. Lin and X. Feng, Chiral *N,N'*-dioxide ligands: synthesis, coordination chemistry and asymmetric catalysis, *Org. Chem. Front.*, 2014, **1**, 298-302. In a sealed tube equipped with a magnetic stirring bar, to the intermediate **3** was added 3.0 mL of DCM and *m*-CPBA (1.2 eq). The reaction mixture was stirred at 0 ^{o}C for 20 min. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to furnish the ligand **L4a**.

7. Characterization data of chiral ligand L4a



L4a: white solid; yield 75%, >20:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.45-2.57 (m, 2H), 3.69 (d, J = 11.6 Hz, 1H), 4.07-4.11 (m, 1H), 4.48 (s, 1H), 4.77-4.80 (m, 1H), 6.80 (s, 1H), 7.16-7.19 (m, 1H), 7.32-7.38 (m, 5H), 7.50-7.53 (m, 4H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 36.7, 70.8, 75.4, 76.5, 87.7, 123.1, 126.7, 128.5, 129.5, 130.3, 130.4, 131.7, 136.2, 168.1; HRMS (ESI-TOF) m/z: Calcd. for $C_{18}H_{18}N_2NaO_3$ $[M+Na]^+$: 333.1210; Found: 333.1206.

8. General procedure for preparation of chiral ligand L6a

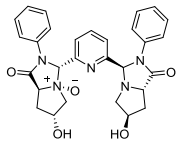


In a sealed tube equipped with a magnetic stirring bar, pyridine-2,6-dicarbaldehyde **2** (1.0 mmol) and optically pure 4-hydroxyprolinamide or prolinamide **1** (2.4 mmol, 2.4 equiv) were added. Then, anhydrous ethanol (6.0 mL) was added and the reaction was heated with stirring at reflux for 12 h. After completion of the reaction, as indicated by TLC, the aftertreatment residue was

purified by flash column chromatography to give the intermediate **3**.

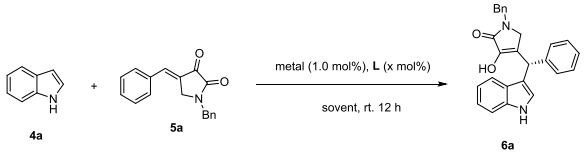
For the oxidation step, see: X. Liu, L. Lin and X. Feng, Chiral *N,N'*-dioxide ligands: synthesis, coordination chemistry and asymmetric catalysis, *Org. Chem. Front.*, 2014, **1**, 298-302. In a sealed tube equipped with a magnetic stirring bar, to the intermediate **3** was added 3.0 mL of DCM and *m*-CPBA (1.0 eq). The reaction mixture was stirred at 0 ^{o}C for 20 min. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to furnish the chiral ligand **L6a**.

9. Characterization data of chiral ligand L6a



L6a: White solid, m.p. 222.1-223.4 ^{o}C; yield 41%, >20:1 dr; ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 1.84-1.90 (m, 1H), 2.15-2.26 (m, 2H), 2.41-2.44 (m, 1H), 2.95-2.98 (m, 1H), 3.21 (d, J = 10.0 Hz, 1H), 3.64 (d, J = 11.2 Hz, 1H), 3.77-3.80 (m, 1H), 3.98-4.06 (m, 2H), 4.25 (s, 1 H), 4.38 (s, 1H), 4.92 (br s, 1H), 6.13 (s, 1H), 6.69 (br s, 1H), 6.82 (s, 1H), 7.03-7.07 (m, 1H), 7.14-7.24 (m, 3H), 7.28-7.32 (m, 2H), 7.48-7.56 (m, 6H), 7.79-7.83 (m, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 36.5, 37.1, 63.3, 63.7, 70.0, 70.9, 74.7, 76.4, 82.4, 86.1, 121.5, 122.9, 123.8, 125.0, 126.6, 127.5, 129.1, 129.4, 136.3, 137.9, 138.1, 150.5, 158.0, 168.7, 174.9; HRMS (ESI-TOF) m/z: Calcd. for $C_{29}H_{29}N_5NaO_5$ $[M+Na]^+$: 550.2061; Found: 550.2059.

10. Table S1: optimization of reaction conditions for synthesis of compound 6a[a]

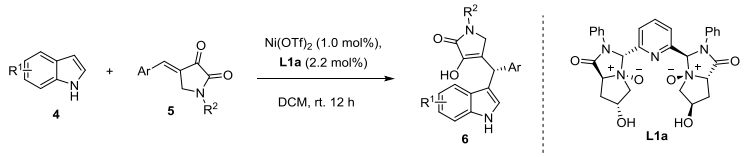


Entry	Metal	Ligand	Ligand/metal	Sovent	Yield[b] (%)	Ee[c]
1	$Ni(OTf)_2$	**L1a**	1.0	DCM	88	77(+)
2	$Ni(OTf)_2$	**L1a**	2.0	DCM	87	91(+)
3	$Ni(OTf)_2$	**L1a**	3.0	DCM	90	93(+)
4	$Ni(OTf)_2$	**L1a**	2.2	DCM	92	94(+)
5	$Co(OTf)_2$	**L1a**	2.2	DCM	91	88(+)
6	$Zn(OTf)_2$	**L1a**	2.2	DCM	90	92(+)
7	$Yb(OTf)_2$	**L1a**	2.2	DCM	88	37(-)

8	$Ho(OTf)_2$	**L1a**	2.2	DCM	89	43(-)
9	$Tb(OTf)_2$	**L1a**	2.2	DCM	90	37(-)
10	$Ni(OTf)_2$	**L1b**	2.2	DCM	87	80(+)
11	$Ni(OTf)_2$	**L1c**	2.2	DCM	85	61(+)
12	$Ni(OTf)_2$	**L1d**	2.2	DCM	65	17(-)
13	$Ni(OTf)_2$	**L1e**	2.2	DCM	85	72(-)
14	$Ni(OTf)_2$	**L1f**	2.2	DCM	87	84(-)
15	$Ni(OTf)_2$	**L1g**	2.2	DCM	88	71(-)
16	$Ni(OTf)_2$	**L1h**	2.2	DCM	83	30(-)
17	$Ni(OTf)_2$	**L1i**	2.2	DCM	88	71(-)
18	$Ni(OTf)_2$	**L1a**	2.2	$CHCl_3$	91	92(+)
19	$Ni(OTf)_2$	**L1a**	2.2	DCE	91	91(+)
20	$Ni(OTf)_2$	**L1a**	2.2	THF	84	92(+)
21	$Ni(OTf)_2$	**L1a**	2.2	CH_3CN	88	92(+)
22	$Ni(OTf)_2$	**L1a**	2.2	CH_3OH	<10%	-
23	$Ni(OTf)_2$	**L1a**	2.2	AcOEt	<10%	-
24[d]	$Ni(OTf)_2$	**L1a**	2.2	DCM	81	90(+)
25[e]	$Ni(OTf)_2$	**L1a**	2.2	DCM	85	89(+)

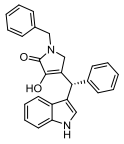
[a] Reaction conditions: metal (1.0 mol %), ligand (x mol %), **4a** (0.30 mmol), and **5a** (0.20 mmol) in 3.0 mL of CH_2Cl_2 at 25 ℃.
[b] Isolated yield after flash chromatography.
[c] Determined by HPLC analysis.
[d] Run at -5 ℃.
[e] $Ni(OTf)_2$ (0.5 mol %), **L1a** (1.1 mol %).

11. Catalytic asymmetric synthesis of compounds 6

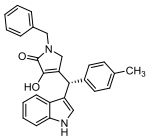


In a sealed tube equipped with a magnetic stirring bar, to the mixture of $Ni(OTf)_2$ (1.0 mol %), **L1a** (2.2 mol %) in 3.0 mL of CH_2Cl_2 was added **4** (0.30 mmol), and **5** (0.20 mmol). The reaction mixture was stirred at room temperature for 12 h and was directly loaded onto a silica gel and purified by flash chromatography to give the desired product **6**, using hexane/EtOAc (10/1, v/v) as the eluent.

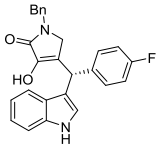
12. Characterization data of compounds 6



6a: Light yellow solid, m.p. 193.2-195.4 ^{o}C; yield 89%, 94% ee, $[\alpha]_D^{20}$ = -18.7 (*c* 1.2, $CHCl_3$); The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 19.86 min; τ_{minor} = 10.81 min); ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 3.54-3.67 (m, 2H), 4.51 (s, 2H), 5.58 (s, 1H), 6.86-6.90 (m, 1H), 6.96 (s, 1H), 7.02-7.06 (m, 1H), 7.11-7.35 (m, 12H), 9.52 (br s, 1H), 10.92 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 39.0, 45.9, 48.1, 112.0, 115.6, 118.9, 119.1, 121.6, 123.4, 123.8, 126.8, 126.9, 127.7, 128.5, 128.8, 129.1, 136.9, 138.2, 142.5, 142.8, 167.3; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{22}N_2NaO_2$ $[M+Na]^+$: 417.1573; Found: 417.1568.

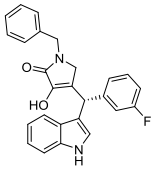


6b: Light yellow solid, m.p. 221.1-222.5 ^{o}C; yield 85%, 91% ee, $[\alpha]_D^{20}$ = -4.1 (*c* 0.41, $CHCl_3$); The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 17.46 min; τ_{minor} = 9.40 min); ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.24 (s, 3H), 3.52-3.66 (m, 2H), 4.51 (s, 2H), 5.54 (d, *J* = 2.8 Hz, 1H), 6.85-6.89 (m, 1H), 6.94 (s, 1H), 7.02 (d, *J* = 7.6 Hz, 1H), 7.07 (d, *J* = 8.0 Hz, 2H), 7.11-7.15 (m, 4H), 7.22-7.35 (m, 5H), 9.49 (br s, 1H), 10.91 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 21.1, 38.6, 45.9, 48.1, 112.0, 115.7, 118.9, 119.1, 121.5, 123.7, 123.8, 126.9, 127.7, 127.8, 128.4, 128.8, 129.1, 129.4, 135.7, 137.0, 138.2, 139.8, 142.4, 167.4; HRMS (ESI-TOF) m/z: Calcd. for $C_{27}H_{24}N_2NaO_2$ $[M+Na]^+$: 431.1730; Found: 431.1733.

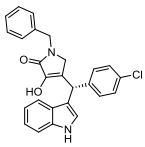


6c: Light yellow solid, m.p. 167.4-168.8 ^{o}C; yield 90%, 91% ee; The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 17.51 min; τ_{minor} = 9.30 min); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 3.45-3.55 (m, 2H), 4.40-4.51 (m, 2H), 5.50 (s, 1H), 6.87 (d, *J* = 1.6 Hz, 1H), 6.82-6.92 (m, 3H), 7.03-7.24 (m, 11H), 8.14 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 38.7, 46.8, 48.7, 111.3, 115.3 (d, J_{CF} = 21.2 Hz), 116.2, 119.5 (d, J_{CF} = 23.1 Hz), 122.3, 123.0, 126.5, 127.7, 128.8, 129.7 (d, J_{CF} = 8.1 Hz), 136.6

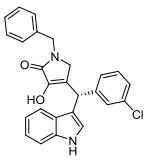
(d, J_{CF} = 9.0 Hz), 141.8, 161.6 (d, J_{CF} = 242.3 Hz), 167.8; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{21}FN_2NaO_2$ $[M+Na]^+$: 435.1479; Found: 435.1479.



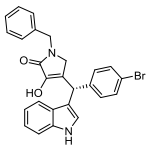
6d: Light yellow solid, m.p. 115.4-115.9 ^oC; yield 90%, 94% ee; The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 9.09 min; τ_{minor} = 15.45 min); ^1H NMR (DMSO-d_6, 400 MHz) δ: 3.58-3.69 (m, 2H), 4.47-4.57 (m, 2H), 5.59 (s, 1H), 6.88-6.92 (m, 1H), 7.01-7.05 (m, 4H), 7.10-7.14 (m, 3H), 7.17 (d, J = 8.0 Hz, 1H), 7.24 (d, J = 7.2 Hz, 1H), 7.28-7.36 (m, 4H), 9.58 (br s, 1H), 10.98 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 38.8, 46.0, 48.2, 112.1, 113.6 (d, J_{CF} = 21.0 Hz), 114.9, 115.1 (d, J_{CF} = 22.2 Hz), 119.0 (d, J_{CF} = 8.1 Hz), 121.7, 122.6, 124.0, 124.6, 126.7, 127.7, 129.1, 130.6 (d, J_{CF} = 7.2 Hz), 136.9, 138.1, 142.8, 145.8 (d, J_{CF} = 7.2 Hz), 162.8 (d, J_{CF} = 241.2 Hz), 167.3; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{21}FN_2NaO_2$ $[M+Na]^+$: 435.1479; Found: 435.1484.



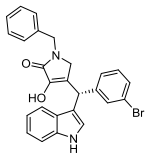
6e: Light yellow solid, m.p. 240.2-241.3 ^oC; yield 91%, 93% ee, $[\alpha]_D^{20}$ = -60.7 (*c* 1.2, $CHCl_3$); The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 17.35 min; τ_{minor} = 9.40 min); ^1H NMR (DMSO-d_6, 400 MHz) δ: 3.55-3.67 (m, 2H), 4.46-4.57 (m, 2H), 5.57 (s, 1H), 6.87-6.91 (m, 1H), 6.99 (s, 1H), 7.03-7.07 (m, 1H), 7.12-7.16 (m, 2H), 7.23-7.36 (m, 9H), 9.56 (br s, 1H), 10.96 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 38.5, 46.0, 48.2, 112.1, 115.1, 119.0, 121.7, 122.7, 124.0, 126.7, 127.7, 128.7, 129.1, 130.3, 131.3, 137.0, 138.1, 141.9, 142.7, 167.3; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{21}ClN_2NaO_2$ $[M+Na]^+$: 451.1184; Found: 451.1185.



6f: Light yellow solid, m.p. 238.2-239.9 ^{o}C; yield 90%, 97% ee; The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 8.57 min; τ_{minor} = 6.43 min); ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 3.43-3.47 (m, 1H), 3.68-3.73 (m, 1H), 4.48-4.58 (m, 2H), 5.88 (d, J = 8.8 Hz, 1H), 6.87-6.96 (m, 2H), 7.04-7.25 (m, 8H), 7.29-7.32 (m, 2H), 7.35-7.39 (m, 1H), 7.43-7.46 (m, 1H), 9.53-9.56 (m, 1H), 10.98 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 36.3, 46.0, 48.6, 112.1, 114.6, 118.8, 119.1, 121.3, 121.7, 124.2, 126.7, 127.5, 127.7, 128.6, 129.1, 129.8, 130.3, 133.3, 137.0, 138.1, 140.1, 143.2, 167.4; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{21}ClN_2NaO_2$ [M+Na]$^{+}$: 451.1184; Found: 451.1185.

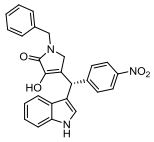


6g: Light yellow solid, m.p. 222.1-223.4 ^{o}C; yield 91%, 91% ee, $[\alpha]_D^{20}$ = -39.1 (*c* 0.9, $CHCl_3$); The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 16.95 min; τ_{minor} = 9.67 min); ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 3.55-3.66 (m, 2H), 4.46-4.56 (m, 2H), 5.54 (s, 1H), 6.87-6.91 (m, 1H), 6.98 (d, *J* = 2.4 Hz, 1H), 7.02-7.06 (m, 1H), 7.12-7.16 (m, 3H), 7.19-7.25 (m, 3H), 7.28-7.30 (m, 2H), 7.32-7.35 (m, 1H), 7.38 (d, *J* = 4.4 Hz, 1H), 7.45 (d, *J* = 12.0 Hz, 1H), 9.56 (br s, 1H), 10.96 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 38.5, 46.0, 48.2, 112.1, 115.0, 119.0, 119.1, 120.0, 121.7, 122.7, 124.0, 126.7, 127.7, 128.4, 129.1, 129.2, 130.7, 131.6, 136.9, 138.1, 142.3, 142.7, 167.3; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{21}BrN_2NaO_2$ [M+Na]$^{+}$: 495.0679; Found: 495.0682.

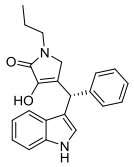


6h: Light yellow solid, m.p. 113.6-114.8 ^{o}C; yield 90%, 94% ee; The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 17.37 min; τ_{minor} = 9.13 min); ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 3.57-3.68 (m, 2H), 4.48-4.56 (m, 2H), 5.57 (s, 1H), 6.88-6.92 (m, 1H), 7.01 (s, 1H), 7.04-7.07 (m, 1H), 7.12-7.41 (m, 11H), 9.58 (br s, 1H), 10.98 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 38.7, 45.9, 48.2, 112.1, 114.8, 118.9, 119.1, 121.7, 122.1, 122.5, 124.1, 126.7, 127.6, 127.7, 129.1,

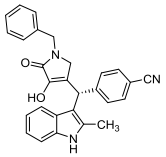
129.7, 131.0, 131.1, 136.9, 138.1, 142.9, 145.7, 167.2; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{21}BrN_2NaO_2$ $[M+Na]^+$: 495.0679; Found: 495.0678.



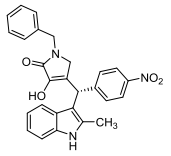
6i: Light yellow solid, m.p. 110.2-115.1 ^oC; yield 92%, 98% ee, $[\alpha]_D^{20}$ = -12.0 (*c* 0.4, $CHCl_3$); The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 16.96 min; τ_{minor} = 9.85 min); ^1H NMR ($CDCl_3$, 400 MHz) *δ*: 3.49-3.59 (m, 2H), 4.43-4.53 (m, 2H), 5.58 (s, 1H), 6.77 (d, *J* = 1.6 Hz, 1H), 6.91-6.95 (m, 1H), 7.05-7.08 (m, 2H), 7.10 (d, *J* = 7.6 Hz, 2H), 7.17-7.20 (m, 4H), 7.27 (d, *J* = 8.0 Hz, 1H), 7.32 (d, *J* = 8.8 Hz, 2H), 8.02 (d, *J* = 8.4 Hz, 2H), 8.17 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) *δ*: 38.3, 45.8, 47.7, 110.5, 113.8, 118.1, 118.9, 121.5, 122.2, 122.7, 125.2, 126.7, 126.8, 127.8, 128.1, 135.3, 135.6, 141.5, 145.7, 148.1, 166.6; HRMS (ESI-TOF) m/z: Calcd. for$C_{26}H_{21}N_3NaO_4$ $[M+Na]^+$: 462.1424; Found: 462.1424.



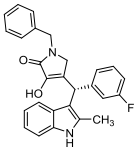
6j: Light yellow solid, m.p. 92.3-94.1 ^oC; yield 90%, 96% ee, $[\alpha]_D^{20}$ = -6.0 (*c* 1.1, $CHCl_3$); The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 18.49 min; τ_{minor} = 12.59 min); ^1H NMR (DMSO-d_6, 400 MHz) *δ*: 0.74-0.78 (m, 3H), 1.40-1.46 (m, 2H), 3.22-3.25 (m, 2H), 3.60-3.74 (m, 2H), 5.58 (s, 1H), 6.87-6.91 (m, 1H), 7.03-7.07 (m, 2H), 7.17-7.23 (m, 2H), 7.28-7.30 (m, 4H), 7.36 (d, *J* = 8.0 Hz, 1H), 9.37 (br s, 1H), 10.95 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) *δ*: 11.6, 21.6, 39.0, 43.9, 48.3, 112.0, 115.7, 118.9, 119.1, 121.6, 122.7, 123.9, 126.7, 126.9, 128.5, 128.8, 137.0, 142.6, 143.0, 167.1; HRMS (ESI-TOF) m/z: Calcd. for $C_{22}H_{22}N_2NaO_2$ $[M+Na]^+$: 369.1573; Found: 369.1570.



6k: Light yellow solid, m.p. 133.1-134.4 ^{o}C; yield 91%, 95% ee; The ee was determined by HPLC analysis using a Chiralpak ID column (80/20 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 17.23 min; τ_{minor} = 20.69 min); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.25 (s, 3H), 3.39 (d, *J* = 10.4 Hz, 1H), 3.65 (d, *J* = 10.4 Hz, 1H), 4.32-4.36 (m, 1H), 4.52 (d, *J* = 15.2 Hz, 1H), 5.63 (s, 1H), 6.76-6.83 (m, 2H), 6.97-7.01 (m, 1H), 7.04 (d, *J* = 8.0 Hz, 2H), 7.18-7.23 (m, 7H), 7.41-7.43 (m, 2H), 8.08-8.14 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 11.0, 36.8, 45.8, 47.6, 108.8, 109.0, 109.7, 117.8, 118.5, 120.2, 126.7, 126.8, 127.8, 131.1, 135.4, 141.6, 145.6, 166.7; HRMS (ESI-TOF) m/z: Calcd. for $C_{28}H_{23}N_3NaO_2$ $[M+Na]^+$: 456.1682; Found: 456.1678.

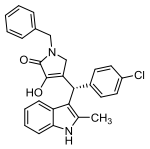


6l: Light yellow solid, m.p. 136.7-137.4 ^{o}C; yield 90%, 99% ee; The ee was determined by HPLC analysis using a Chiralpak ID column (85/15 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 23.06 min; τ_{minor} = 28.40 min); ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.29 (s, 3H), 3.44 (d, *J* = 16.4 Hz, 1H), 3.74 (d, *J* = 16.4 Hz, 1H), 4.45 (d, *J* = 15.2 Hz, 1H), 4.56 (d, *J* = 15.2 Hz, 1H), 5.70 (s, 1H), 6.76-6.80 (m, 1H), 6.90-6.97 (m, 2H), 7.13 (d, *J* = 7.2 Hz, 2H), 7.22-7.31 (m, 4H), 7.42 (d, *J* = 8.0 Hz, 1H), 8.13 (d, *J* = 8.8 Hz, 2H), 9.59 (br s, 1H), 11.00 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 16.8, 42.9, 50.7, 53.2, 114.4, 116.0, 123.3, 123.8, 125.4, 126.1, 128.5, 132.1, 132.4, 132.5, 133.8, 134.3, 138.5, 140.5, 142.9, 148.0, 151.1, 155.3, 171.9; HRMS (ESI-TOF) m/z: Calcd. for $C_{27}H_{23}N_3O_4$ $[M+Na]^+$: 453.1689; Found: 453.1694.

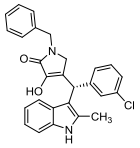


6m: Light yellow solid, m.p. 144.1-145.0 ^{o}C; yield 88%, 90% ee; The ee was determined by HPLC analysis using a Chiralpak IB column (90/10 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 16.31 min; τ_{minor} = 13.83 min); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.21 (s, 3H), 3.39 (d, *J* = 18.4 Hz, 1H), 3.70 (d, *J* = 18.4 Hz, 1H), 4.31 (d, *J* = 15.2 Hz, 1H), 4.54 (d, *J* = 15.2 Hz, 1H), 5.63 (s, 1H), 6.78-6.85 (m, 4H), 6.89 (d, *J* = 7.6 Hz, 1H), 6.94-6.98 (m, 1H), 7.03-7.05 (m, 2H), 7.08-7.10 (m, 1H), 7.14-7.20 (m, 5H), 8.03 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 10.4,

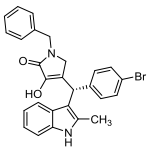
35.6, 45.0, 46.9, 108.8, 108.9, 111.5 (d, J_{CF} = 21.2 Hz), 113.3 (d, J_{CF} = 22.2 Hz), 117.4, 117.7, 119.3, 121.3, 121.9, 125.6, 125.9, 127.1, 127.9 (d, J_{CF} = 8.1 Hz), 131.3, 133.7, 134.9, 140.5, 141.9 (d, J_{CF} = 7.3 Hz), 161.8 (d, J_{CF} = 243.4 Hz), 166.1; HRMS (ESI-TOF) m/z: Calcd. for $C_{27}H_{23}FN_2NaO_2$ $[M+Na]^+$: 449.1636; Found: 449.1633.



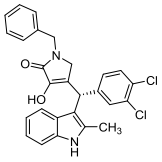
6n: Light yellow solid, m.p. 136.9-137.4 ^oC; yield 91%, 92% ee; The ee was determined by HPLC analysis using a Chiralpak ID column (85/15 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 11.58 min; τ_{minor} = 13.85 min); ^1H NMR ($CDCl_3$, 400 MHz) δ: 2.19 (s, 3H), 3.36 (d, J = 18.4 Hz, 1H), 3.65 (d, J = 18.4 Hz, 1H), 4.25 (d, J = 15.6 Hz, 1H), 4.52 (d, J = 15.6 Hz, 1H), 5.59 (s, 1H), 6.76-6.82 (m, 2H), 6.92-6.96 (m, 1H), 7.01 (d, J = 8.0 Hz, 4H), 7.07 (d, J = 8.4 Hz, 2H), 7.13-7.16 (m, 5H), 8.07 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 9.9, 34.8, 44.6, 46.5, 108.4, 117.0, 117.2, 118.9, 121.2, 125.1, 125.5, 125.6, 126.2, 126.6, 127.2, 129.9, 130.9, 133.2, 134.4, 137.2, 140.1, 165.7; HRMS (ESI-TOF) m/z: Calcd. for $C_{27}H_{23}ClN_2NaO_2$ $[M+Na]^+$: 465.1340; Found: 465.1343.



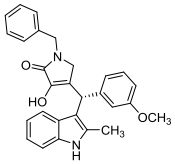
6o: Light yellow solid, m.p. 127.8-127.9 ^oC; yield 90%, 92% ee; The ee was determined by HPLC analysis using a Chiralpak IC column (80/20 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 23.90 min; τ_{minor} = 10.55 min); ^1H NMR ($CDCl_3$, 400 MHz) δ: 2.09 (s, 3H), 3.49 (s, 2H), 4.36 (d, J = 15.2 Hz, 1H), 4.51 (d, J = 15.2 Hz, 1H), 5.59 (s, 1H), 6.81-6.85 (m, 1H), 6.94-6.97 (m, 1H), 6.99-7.04 (m, 4H), 7.09-7.17 (m, 7H), 7.22-7.24 (m, 1H), 8.06 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 12.1, 37.2, 46.6, 49.8, 109.6, 110.6, 118.5, 119.6, 121.0, 121.4, 126.7, 127.6, 128.0, 128.8, 129.6, 129.9, 132.7, 134.1, 135.2, 136.7, 139.0, 141.9, 167.9; HRMS (ESI-TOF) m/z: Calcd. for $C_{27}H_{23}ClN_2NaO_2$ $[M+Na]^+$: 465.1340; Found: 465.1345.



6p: Light yellow solid, m.p. 137.4-138.6 ^{o}C; yield 91%, 94% ee; The ee was determined by HPLC analysis using a Chiralpak ID column (90/10 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 20.29 min; τ_{minor} = 25.61 min); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.21 (s, 3H), 3.36 (d, *J* = 15.2 Hz, 1H), 3.65 (d, *J* = 15.2 Hz, 1H), 4.28 (d, *J* = 15.2 Hz, 1H), 4.53 (d, *J* = 15.2 Hz, 1H), 5.57 (s, 1H), 6.77-6.83 (m, 2H), 6.95-6.98 (m, 3H), 7.02-7.04 (m, 2H), 7.14-7.18 (m, 5H), 7.23 (d, *J* = 8.4 Hz, 2H), 8.02 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 12.1, 37.1, 46.8, 48.6, 110.6, 119.2, 119.4, 120.2, 121.1, 123.2, 127.3, 127.7, 128.6, 128.8, 129.8, 131.3, 133.1, 135.4, 136.6, 139.9, 142.3, 167.9; HRMS (ESI-TOF) m/z: Calcd. for $C_{27}H_{23}BrN_2NaO_2$ $[M+Na]^+$: 509.0835; Found: 509.0831.

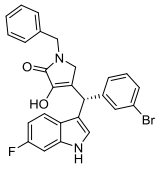


6q: Light yellow solid, m.p. 154.1-155.2 ^{o}C; yield 91%, 96% ee; The ee was determined by HPLC analysis using a Chiralpak IC column (90/10 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 11.03 min; τ_{minor} = 12.46 min); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.23 (s, 3H), 3.39 (d, *J* = 18.4 Hz, 1H), 3.68 (d, *J* = 18.4 Hz, 1H), 4.34 (d, *J* = 15.2 Hz, 1H), 4.54 (d, *J* = 15.2 Hz, 1H), 5.56 (s, 1H), 6.82-6.85 (m, 2H), 6.92-6.95 (m, 1H), 6.96-7.00 (m, 1H), 7.03-7.05 (m, 2H), 7.15-7.20 (m, 7H), 7.99 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 12.1, 36.9, 46.8, 48.6, 110.1, 110.6, 119.0, 119.6, 121.2, 127.1, 127.6, 127.7, 128.8, 129.9, 130.2, 130.3, 132.4, 133.1, 135.4, 136.5, 141.3, 142.4, 167.7; HRMS (ESI-TOF) m/z: Calcd. for $C_{27}H_{22}Cl_2N_2NaO_2$ $[M+Na]^+$: 499.0951; Found: 499.0950.

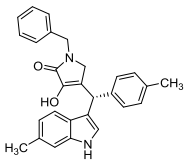


6r: Light yellow solid, m.p. 128.1-128.7 ^{o}C; yield 89%, 90% ee; The ee was determined by HPLC analysis using a Chiralpak ID column (90/10 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ =

254 nm; τ_{major} = 38.07 min; τ_{minor} = 47.28 min); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 2.18 (s, 3H), 3.40 (d, J = 18.4 Hz, 1H), 3.56 (s, 3H), 3.71 (d, J = 18.4 Hz, 1H), 4.27 (d, J = 15.2 Hz, 1H), 4.54 (d, J = 15.2 Hz, 1H), 5.62 (s, 1H), 6.62-6.65 (m, 1H), 6.67-6.71 (m, 2H), 6.76-6.80 (m, 1H), 6.89 (d, J = 8.0 Hz, 1H), 6.92-6.96 (m, 1H), 7.02-7.04 (m, 3H), 7.12-7.18 (m, 5H), 8.04 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 12.1, 37.6, 46.7, 48.8, 55.1, 110.5, 110.9, 111.6, 114.0, 119.3, 120.6, 120.9, 123.8, 127.6, 127.7, 128.8, 129.3, 133.0, 135.4, 136.8, 142.0, 142.5, 159.7, 167.9; HRMS (ESI-TOF) m/z: Calcd. for $C_{28}H_{26}N_2NaO_3$ $[M+Na]^+$: 461.1836; Found: 461.1839.



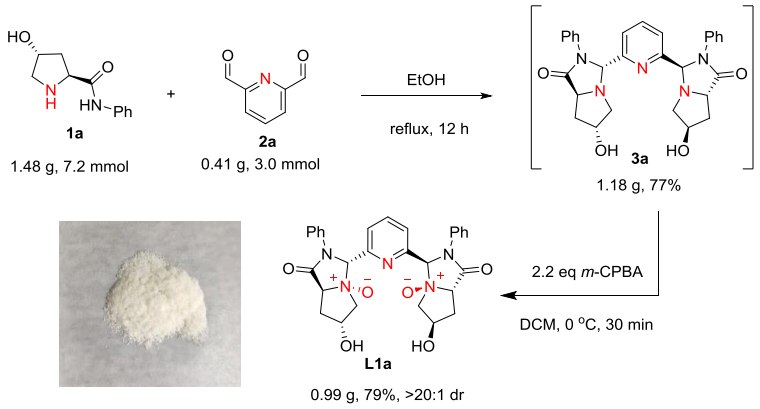
6s: Light yellow solid, m.p. 134.5-134.9 ^{o}C; yield 91%, 95% ee; The ee was determined by HPLC analysis using a Chiralpak IA column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 13.74 min; τ_{minor} = 7.51 min); ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 3.51 (s, 2H), 4.50 (s, 2H), 5.45 (s, 1H), 6.69-6.72 (m, 2H), 6.92-6.95 (m, 1H), 7.03-7.08 (m, 5H), 7.18-7.24 (m, 4H), 7.27-7.32 (m, 2H), 8.11 (br s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 38.0, 45.7, 47.5, 96.5 (d, J_{CF} = 26.2 Hz), 107.5 (d, J_{CF} = 25.3 Hz), 114.8, 119.0 (d, J_{CF} = 9.5 Hz), 120.9, 121.7, 125.9, 126.6, 126.7, 127.8, 129.0, 129.1, 130.2, 135.4, 141.1, 142.6, 158.9 (d, J_{CF} = 247.0 Hz), 166.6; HRMS (ESI-TOF) m/z: Calcd. for $C_{26}H_{20}BrFN_2NaO_2$ $[M+Na]^+$: 513.0584; Found: 513.0582.



6t: Light yellow solid, m.p. 112.1-112.7 ^{o}C; yield 92%, 99% ee; The ee was determined by HPLC analysis using a Chiralpak IC column (60/40 hexane/*i*-PrOH; flow rate: 1.0 mL/min; λ = 254 nm; τ_{major} = 6.44 min; τ_{minor} = 7.41 min); ^{1}H NMR (DMSO-d_6, 400 MHz) δ: 2.26 (s, 3H), 2.36 (s, 3H), 3.53-3.66 (m, 2H), 4.52 (s, 2H), 5.53 (s, 1H), 6.72 (d, J = 8.0 Hz, 1H), 6.86 (s, 1H), 7.02 (d, J = 8.0 Hz, 1H), 7.07-7.14 (m, 7H), 7.25 (d, J = 7.2 Hz, 1H), 7.29-7.33 (m, 2H), 9.50 (br s, 1H), 10.75 (br s, 1H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ: 21.0, 21.8, 38.6, 45.9, 48.1, 111.8, 115.5, 118.9, 120.7, 123.1, 123.8, 124.8, 127.6, 127.7, 128.3, 129.1, 129.3, 130.6, 135.7, 137.4, 138.2, 139.8, 142.3, 167.4; HRMS (ESI-TOF) m/z: Calcd. for $C_{28}H_{26}N_2NaO_2$ $[M+Na]^+$: 445.1886; Found:

445.1887.

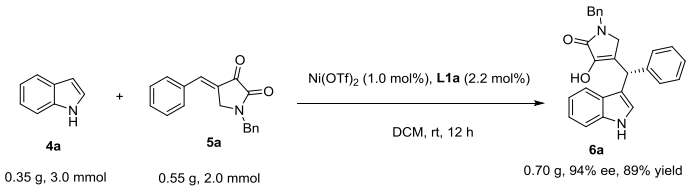
13. The gram scale synthesis of the ligand L1a



In a sealed tube equipped with a magnetic stirring bar, pyridine-2,6-dicarbaldehyde **2a** (0.41 g, 3.0 mmol) and optically pure 4-hydroxyprolinamide **1** (1.48 g, 7.2 mmol) were added. Then, anhydrous ethanol (30.0 mL) was added and the reaction was heated with stirring at reflux for 12 h. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to give the intermediate **3a**.

For the oxidation step, see: X. Liu, L. Lin and X. Feng, Chiral *N,N′*-dioxide ligands: synthesis, coordination chemistry and asymmetric catalysis, *Org. Chem. Front.*, 2014, **1**, 298-302. In a sealed tube equipped with a magnetic stirring bar, to the intermediate **3** was added 20.0 mL of DCM and *m*-CPBA (2.2 eq). The reaction mixture was stirred at 0 ^{o}C for 30 min. After completion of the reaction, as indicated by TLC, the aftertreatment residue was purified by flash column chromatography to furnish the Py-2NO ligand **L1a** (0.99 g, 79%, >20:1 dr).

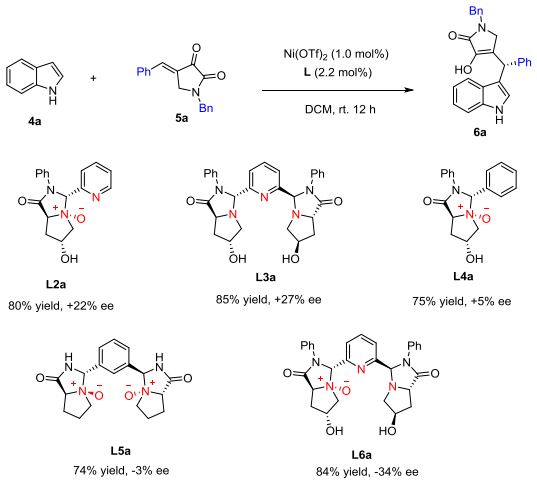
14. The preparative gram scale asymmetric synthesis of the product 6a



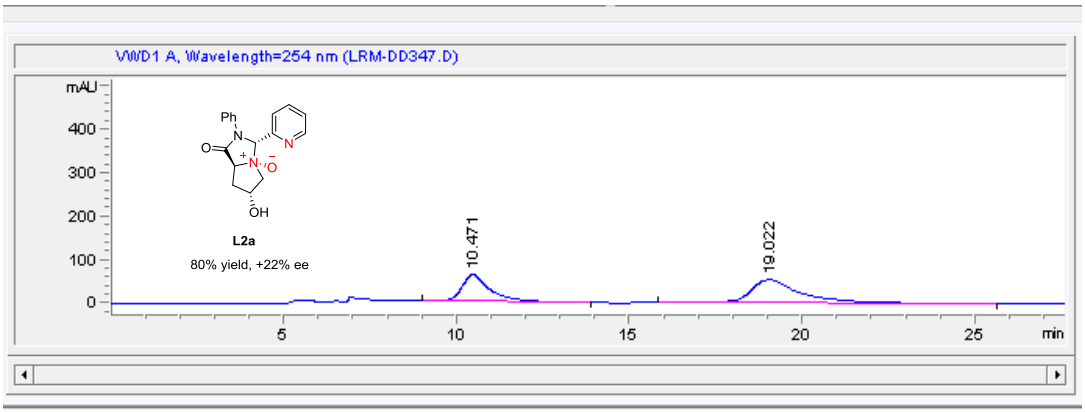
In a sealed tube equipped with a magnetic stirring bar, to the mixture of $Ni(OTf)_2$ (1.0 mol %), **L1a** (2.2 mol %) in 30 mL of CH_2Cl_2 was added **4a** (3.0 mmol), and **5a** (2.0 mmol). The reaction mixture was stirred at room temperature for 12 h and was directly loaded onto a silica gel and purified by flash chromatography to give the desired product **6a** (0.70 g, 94% ee, 89% yield),

using hexane/EtOAc (10/1, v/v) as the eluent.

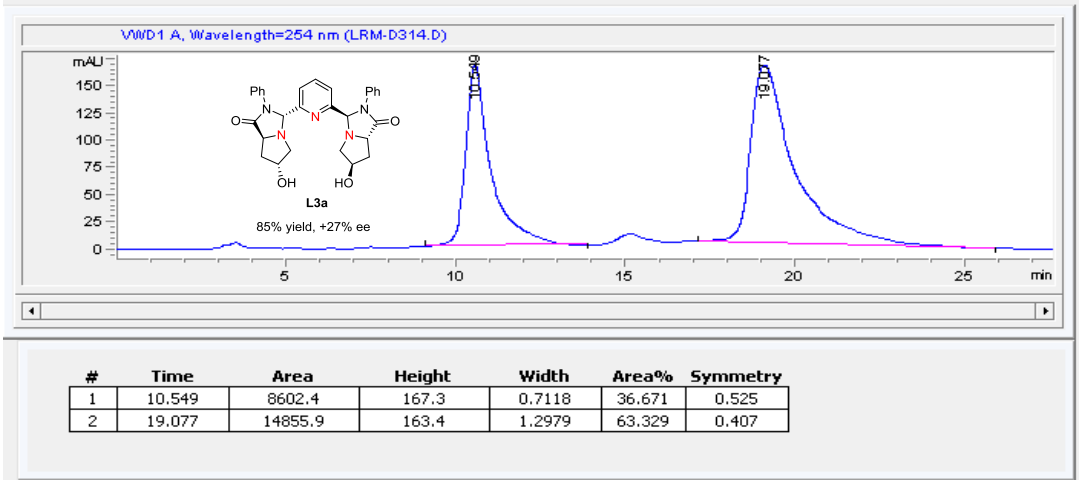
15. Control experiments and HPLC spectra for compound 6a



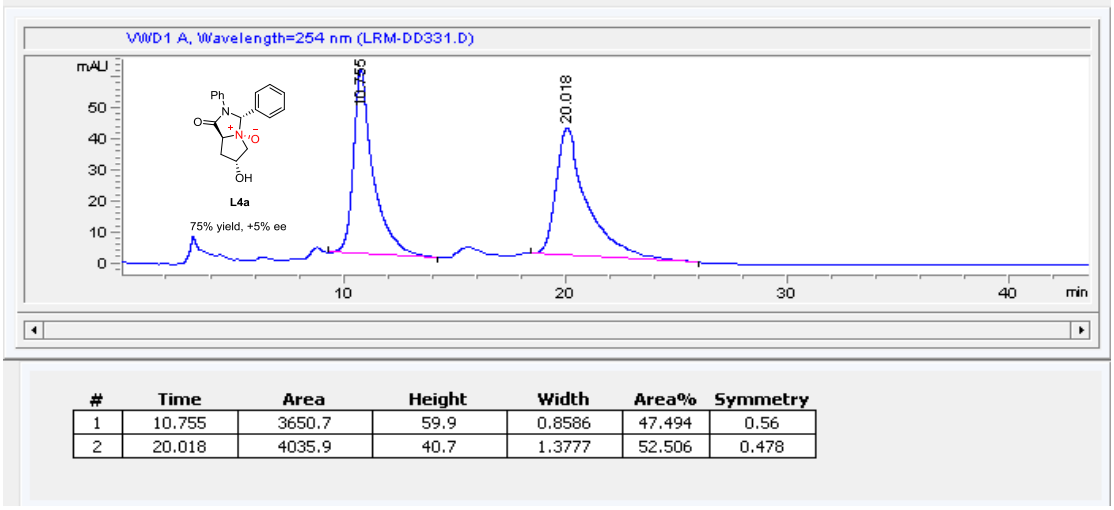
In a sealed tube equipped with a magnetic stirring bar, to the mixture of $Ni(OTf)_2$ (1.0 mol %), **L** (2.2 mol %) in 30 mL of CH_2Cl_2 was added **4a** (0.3 mmol), and **5a** (0.2 mmol). The reaction mixture was stirred at room temperature for 12 h and was directly loaded onto a silica gel and purified by flash chromatography to give the desired product **6a**, using hexane/EtOAc (10/1, v/v) as the eluent.



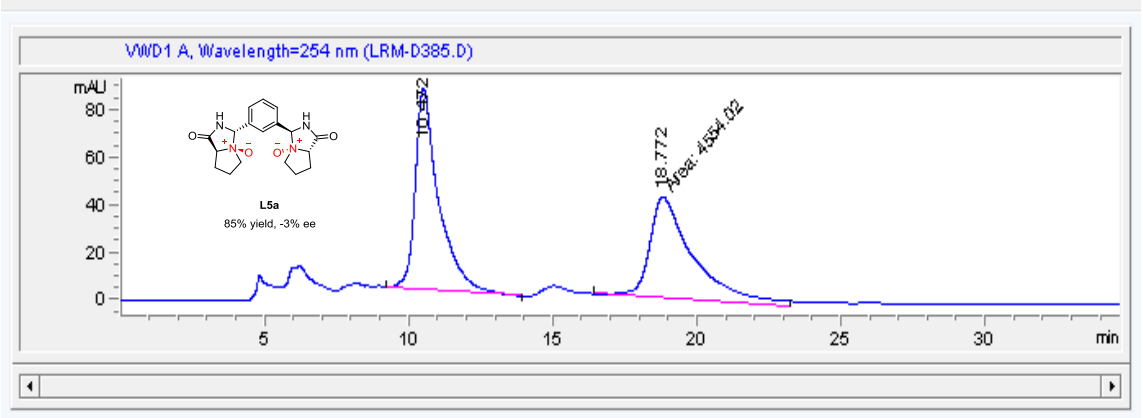
#	Time	Area	Height	Width	Area%	Symmetry
1	10.471	3605.8	62.3	0.8158	38.821	0.633
2	19.022	5682.4	54	1.4553	61.179	0.558



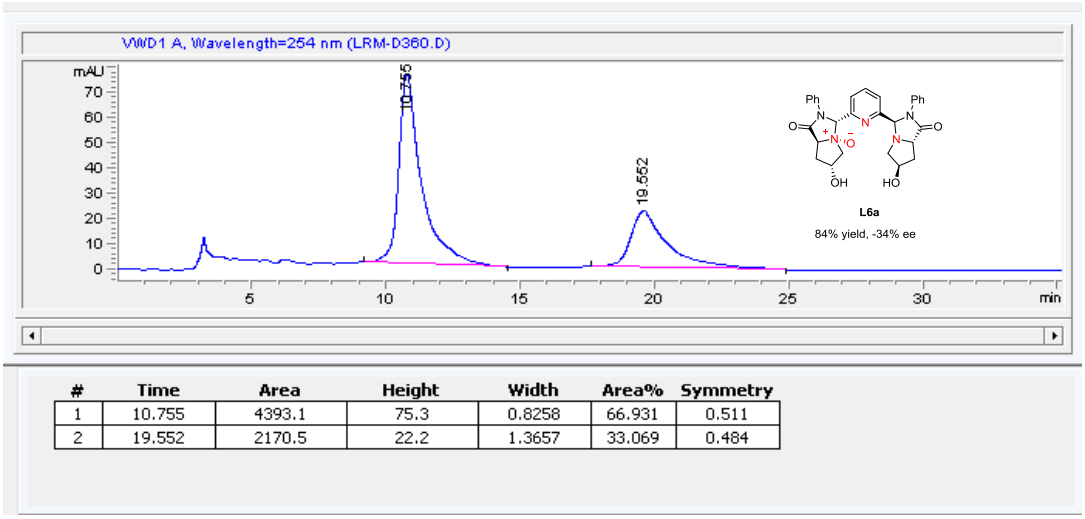
#	Time	Area	Height	Width	Area%	Symmetry
1	10.549	8602.4	167.3	0.7118	36.671	0.525
2	19.077	14855.9	163.4	1.2979	63.329	0.407



#	Time	Area	Height	Width	Area%	Symmetry
1	10.755	3650.7	59.9	0.8586	47.494	0.56
2	20.018	4035.9	40.7	1.3777	52.506	0.478

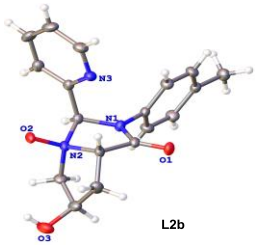


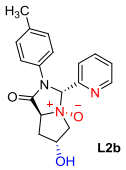
#	Time	Area	Height	Width	Area%	Symmetry
1	10.472	4805.4	84.9	0.8012	51.343	0.501
2	18.772	4554	42.9	1.7703	48.657	0.435



#	Time	Area	Height	Width	Area%	Symmetry
1	10.755	4393.1	75.3	0.8258	66.931	0.511
2	19.552	2170.5	22.2	1.3657	33.069	0.484

16. X-ray crystal data for compounds L2b, L2c and 3d



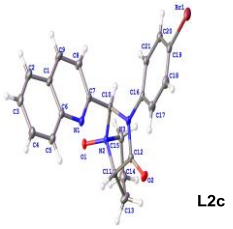


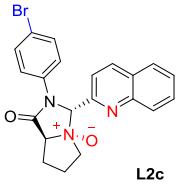
CCDC 2206523

Table S2 Crystal data and structure refinement for L2b

Identification code	**L2b**
Empirical formula	$C_{18}H_{23}N_3O_5$
Formula weight	361.39
Temperature/K	169.99(10)
Crystal system	monoclinic
Space group	$P2_1$
a/Å, b/Å, c/Å	7.9392(2), 6.15070(10), 17.6593(3)
α/°, β/°, γ/°,	90, 93.002(2), 90
Volume/Å^3	861.15(3)
Z	2
ρ_{calc}g/cm^3	1.323
μ/mm^{-1}	0.853
F(000)	384.0
Radiation	Cu Kα (λ = 1.54184)
Crystal size/mm^3	0.15 × 0.13 × 0.1
2Θ range for data collection/°	5.01 to 133.19
Index ranges	-9 ≤ h ≤ 9, -7 ≤ k ≤ 7, -20 ≤ l ≤ 20
Reflections collected	6299
Independent reflections	2954 [R_{int} = 0.0339, R_{sigma} = 0.0366]
Data/restraints/parameters	2954/1/244
Goodness-of-fit on F^2	1.127
Final R indexes [I>=2σ (I)]	R_1 = 0.0462, wR_2 = 0.1377
Final R indexes [all data]	R_1 = 0.0467, wR_2 = 0.1387
Largest diff. peak/hole / e Å^{-3}	0.34/-0.32

Crystal Data for $C_{18}H_{23}N_3O_5$ (*M* =361.39 g/mol): monoclinic, space group $P2_1$ (no. 4), *a* = 7.9392(2) Å, *b* = 6.15070(10) Å, *c* = 17.6593(3) Å, *β* = 93.002(2) °, *V* = 861.15(3) Å^3, *Z* = 2, *T* = 169.99(10) K, μ(Cu Kα) = 0.853 mm^{-1}, *Dcalc* = 1.394 g/cm^3, 6299 reflections measured (5.01° ≤ 2Θ ≤ 133.19°), 2954 unique (R_{int} = 0.0339, R_{sigma} = 0.0366) which were used in all calculations. The final R_1 was 0.0462 (I > 2σ(I)) and wR_2 was 0.1387 (all data).



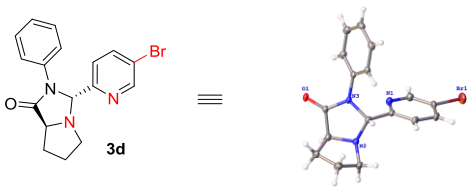


CCDC 2206524

Table S3 Crystal data and structure refinement for L2c

Identification code	**L2c**
Empirical formula	$C_{21}H_{20}BrN_3O_3$
Formula weight	442.31
Temperature/K	220.00(12)
Crystal system	monoclinic
Space group	$P2_1$
a/Å, b/Å, c/Å	10.83288(12), 7.10591(8), 12.90956(17)
α/°, β/°, γ/°,	90, 107.1505(13), 90
Volume/Å^3	949.56(2)
Z	2
ρ_{calc}g/cm^3	1.547
μ/mm^{-1}	3.187
F(000)	452.0
Radiation	Cu Kα (λ = 1.54184)
Crystal size/mm^3	0.14 × 0.12 × 0.11
2Θ range for data collection/°	7.166 to 142.432
Index ranges	-13 ≤ h ≤ 11, -7 ≤ k ≤ 8, -11 ≤ l ≤ 15
Reflections collected	7086
Independent reflections	3209 [R_{int} = 0.0173, R_{sigma} = 0.0166]
Data/restraints/parameters	3209/1/257
Goodness-of-fit on F^2	1.038
Final R indexes [I>=2σ (I)]	R_1 = 0.0353, wR_2 = 0.0936
Final R indexes [all data]	R_1 = 0.0354, wR_2 = 0.0937
Largest diff. peak/hole / e Å^{-3}	0.46/-0.56
Flack parameter	-0.02(2)/-0.01(3)

Crystal Data for $C_{21}H_{20}BrN_3O_3$ (*M* =442.31 g/mol): monoclinic, space group $P2_1$ (no. 4), *a* = 10.83288(12) Å, *b* = 7.10591(8) Å, *c* = 12.90956(17) Å, *β* = 107.1505(13) °, *V* = 949.56(2) Å^3, *Z* = 2, *T* = 220.00(12) K, μ(Cu Kα) = 3.187 mm^{-1}, *Dcalc* = 1.547 g/cm^3, 7086 reflections measured (7.166° ≤ 2Θ ≤ 142.432°), 3209 unique (R_{int} = 0.0173, R_{sigma} = 0.0166) which were used in all calculations. The final R_1 was 0.0353 (I > 2σ(I)) and wR_2 was 0.0937 (all data).



CCDC 2208260

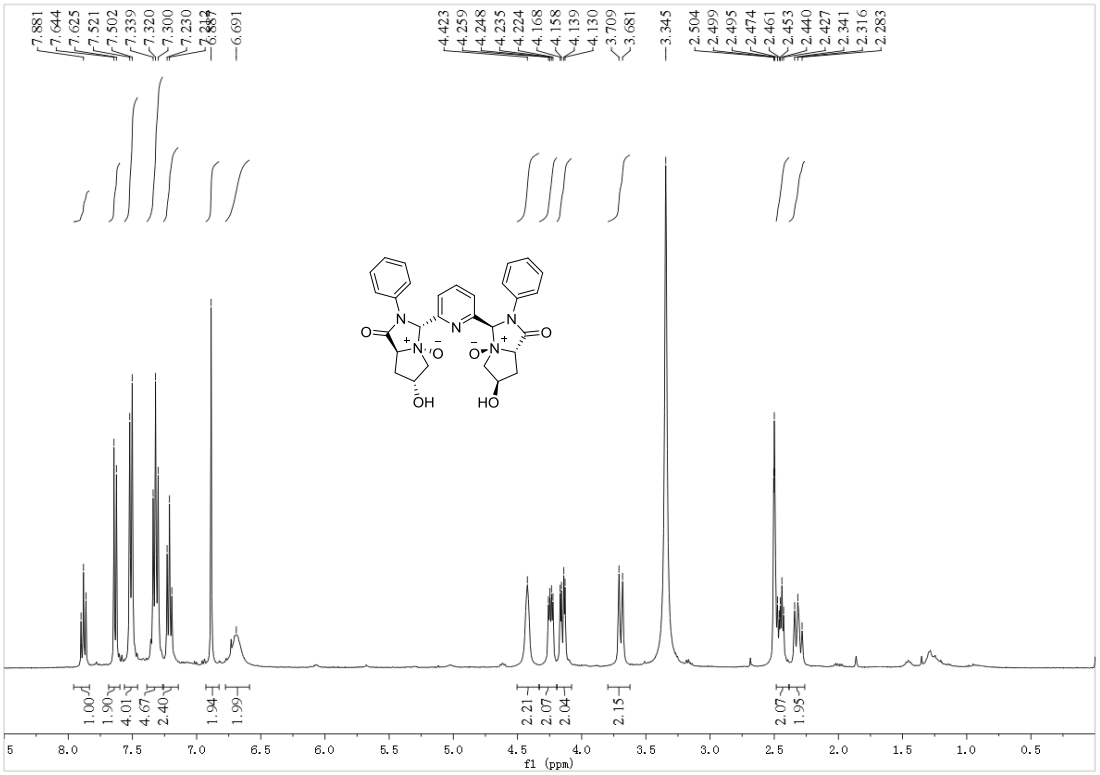
Table S4 Crystal data and structure refinement for 3d

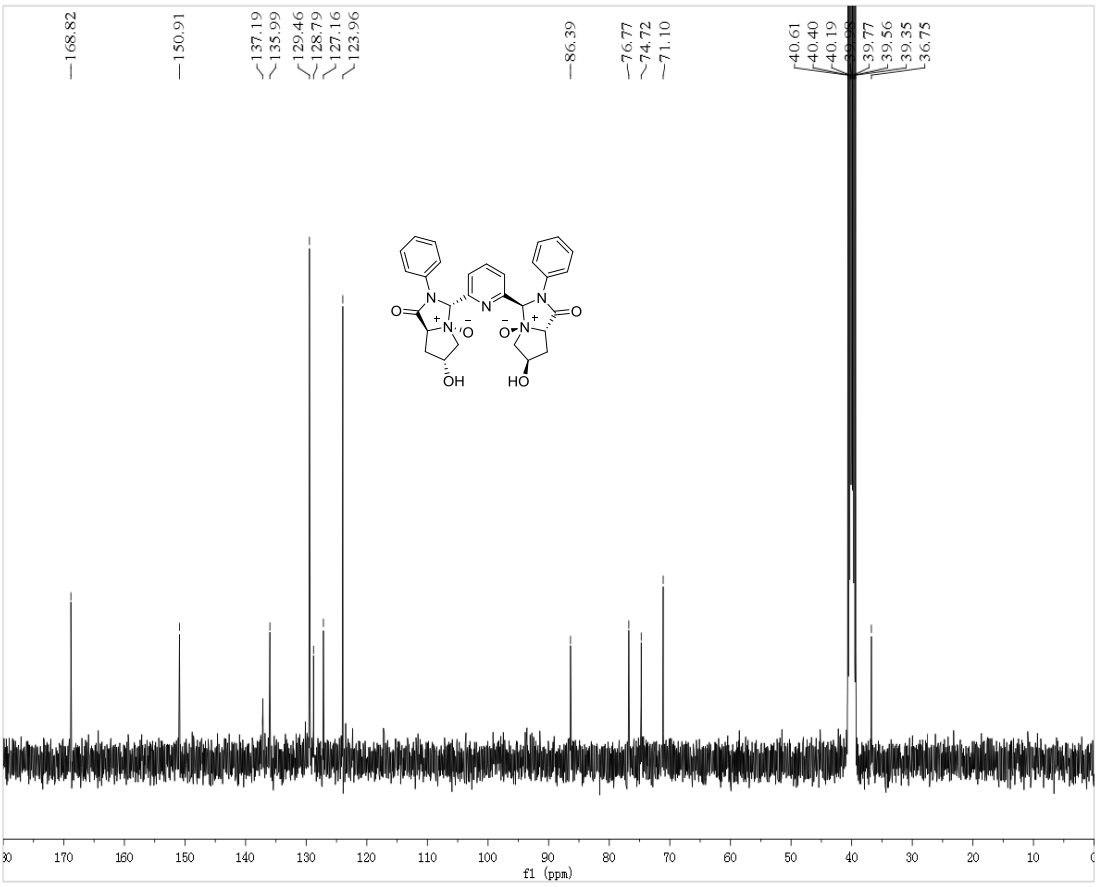
Identification code	**3d**
Empirical formula	$C_{17}H_{16}BrN_3O$
Formula weight	358.24
Temperature/K	150.00(10)
Crystal system	orthorhombic
Space group	$P2_12_12_1$
a/Å, b/Å, c/Å	7.79020(10), 9.7405(2), 19.9339(3)
α/°, β/°, γ/°,	90, 90, 90
Volume/Å^3	1512.59(4)
Z	4
ρ_{calc}g/cm^3	1.573
μ/mm^{-1}	3.745
F(000)	728.0
Radiation	Cu Kα (λ = 1.54184)
Crystal size/mm^3	0.14 × 0.12 × 0.1
2Θ range for data collection/°	8.872 to 147.76
Index ranges	$-9 \le h \le 9$, $-10 \le k \le 11$, $-24 \le l \le 24$
Reflections collected	11359
Independent reflections	3026 [R_{int} = 0.0498, R_{sigma} = 0.0330]
Data/restraints/parameters	3026/0/199
Goodness-of-fit on F^2	1.034
Final R indexes [I>=2σ (I)]	R_1 = 0.0356, wR_2 = 0.0899
Final R indexes [all data]	R_1 = 0.0366, wR_2 = 0.0911
Largest diff. peak/hole / e Å^{-3}	0.53/-0.73
Flack parameter	-0.032(12)/-0.021(10)

Crystal Data for $C_{17}H_{16}BrN_3O$ (*M* =358.24 g/mol): orthorhombic, space group $P2_12_12_1$ (no. 19), *a* = 7.79020(10) Å, *b* = 9.7405(2) Å, *c* = 19.9339(3) Å, *V* = 1512.59(4) Å^3, *Z* = 4, *T* = 150.00(10) K, μ(Cu Kα) = 3.745 mm^{-1}, *Dcalc* = 1.573 g/cm^3, 11359 reflections measured (8.872 ° ≤ 2Θ ≤ 147.76°), 3026 unique (R_{int} = 0.0498, R_{sigma} = 0.0330) which were used in all calculations. The final R_1 was 0.0356 (I > 2σ(I)) and wR_2 was 0.0911 (all data).

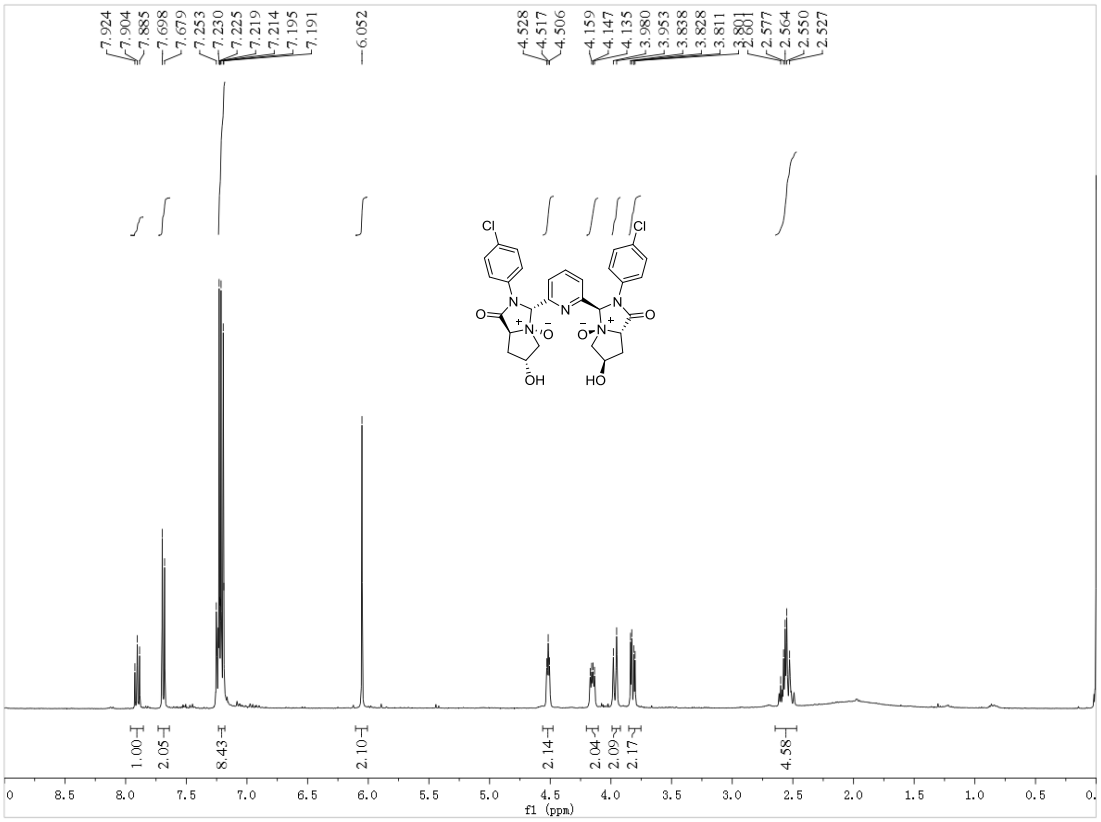
17. The copies of ^{1}H NMR, ^{13}C NMR and HPLC spectra for compounds **L** and **6**

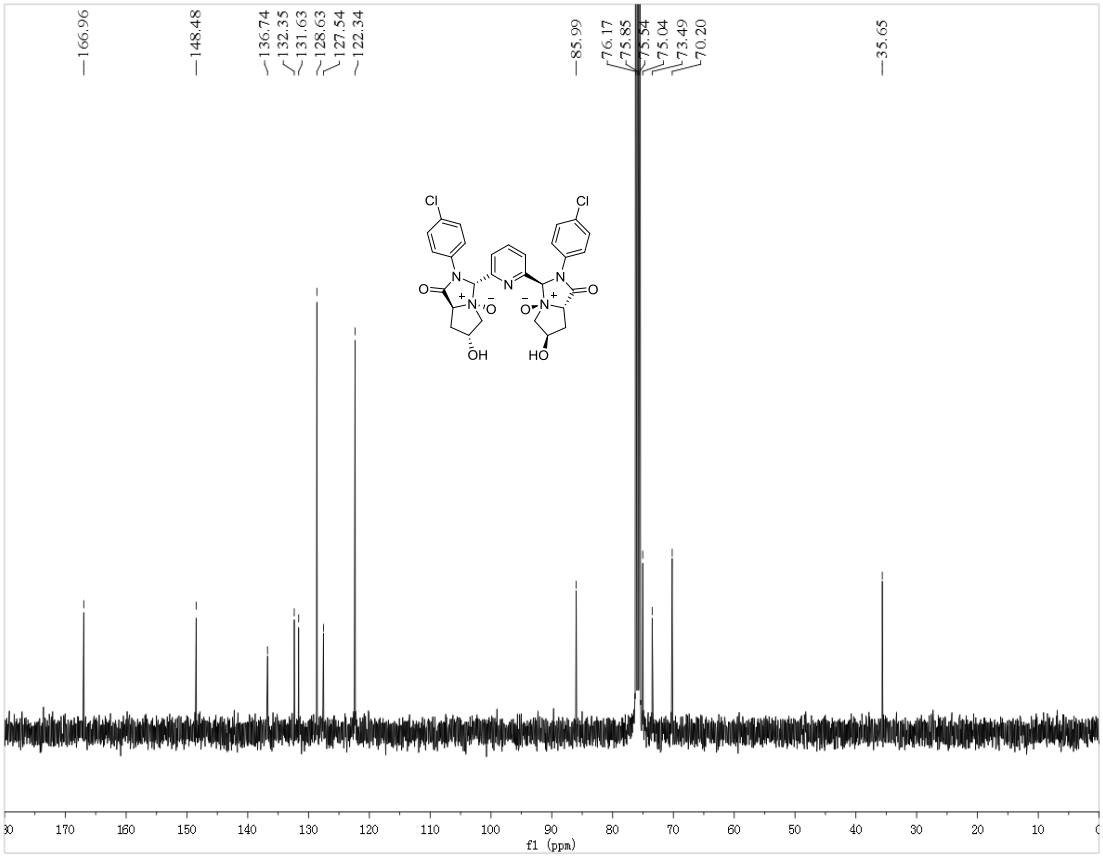
^{1}H and ^{13}C NMR of L1a



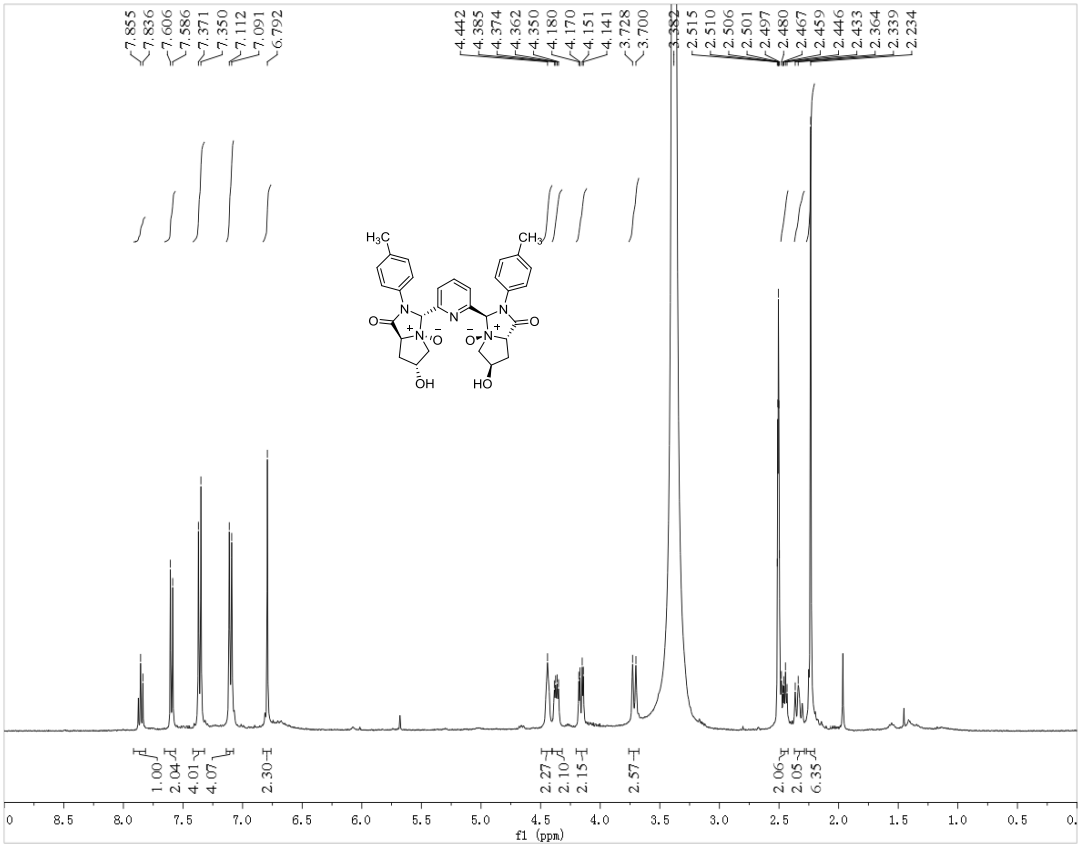


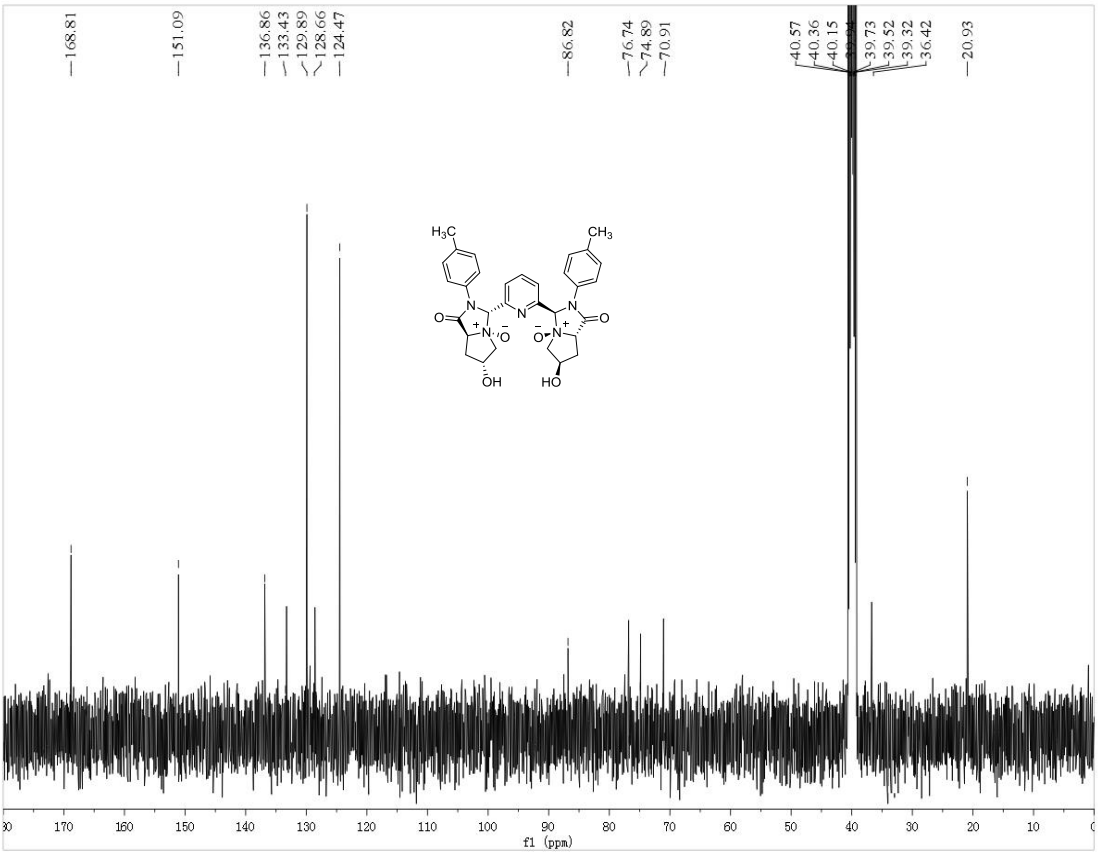
^{1}H and ^{13}C NMR of L1b



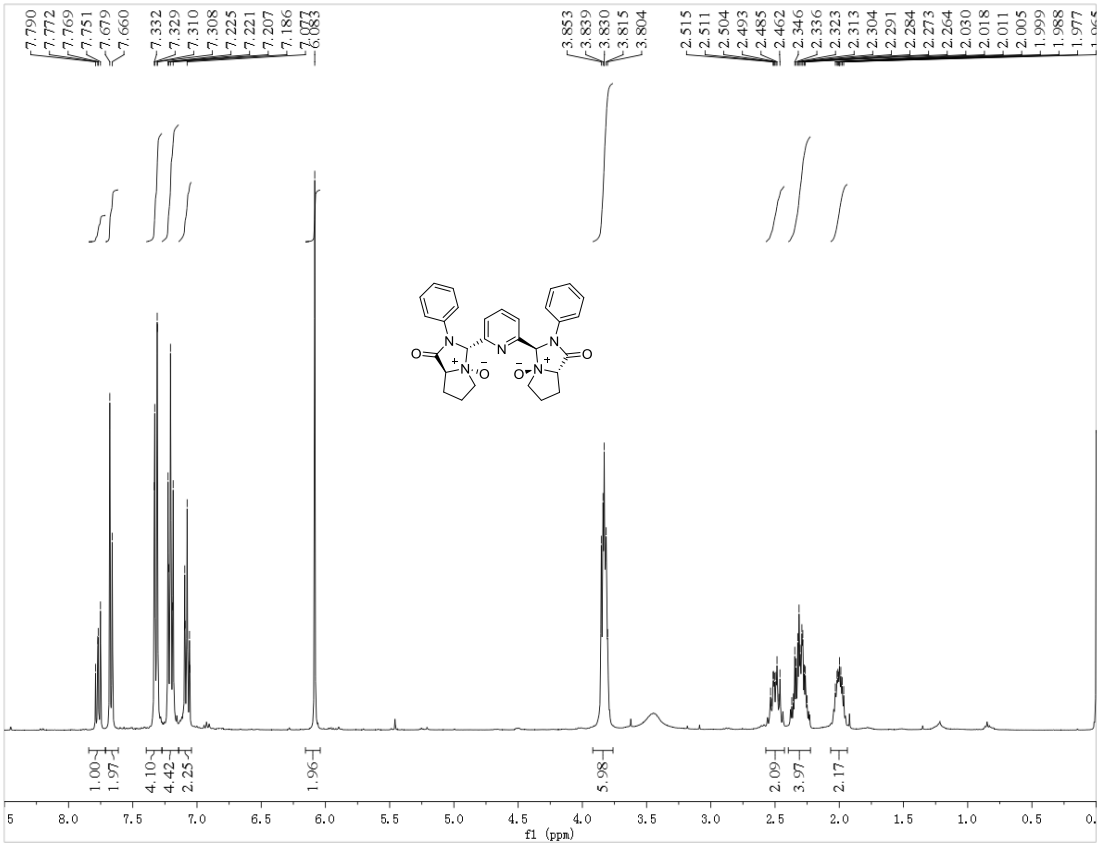


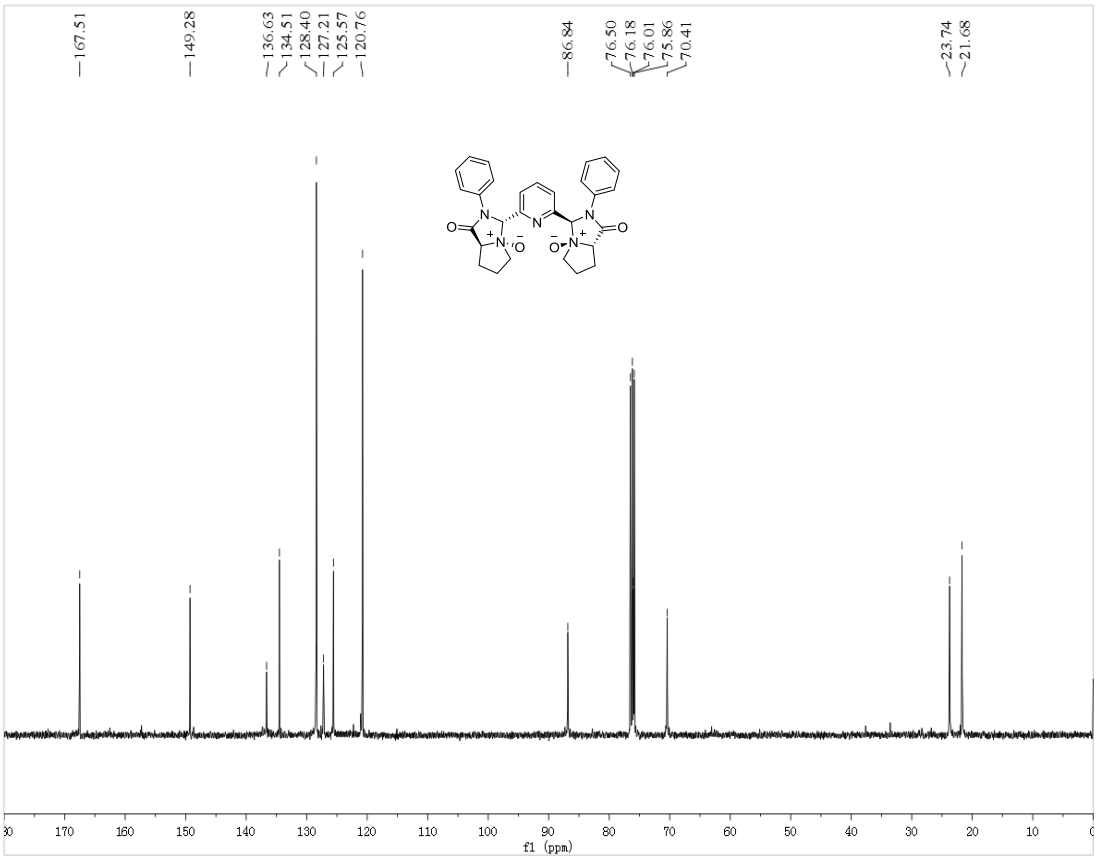
^{1}H and ^{13}C NMR of L1c



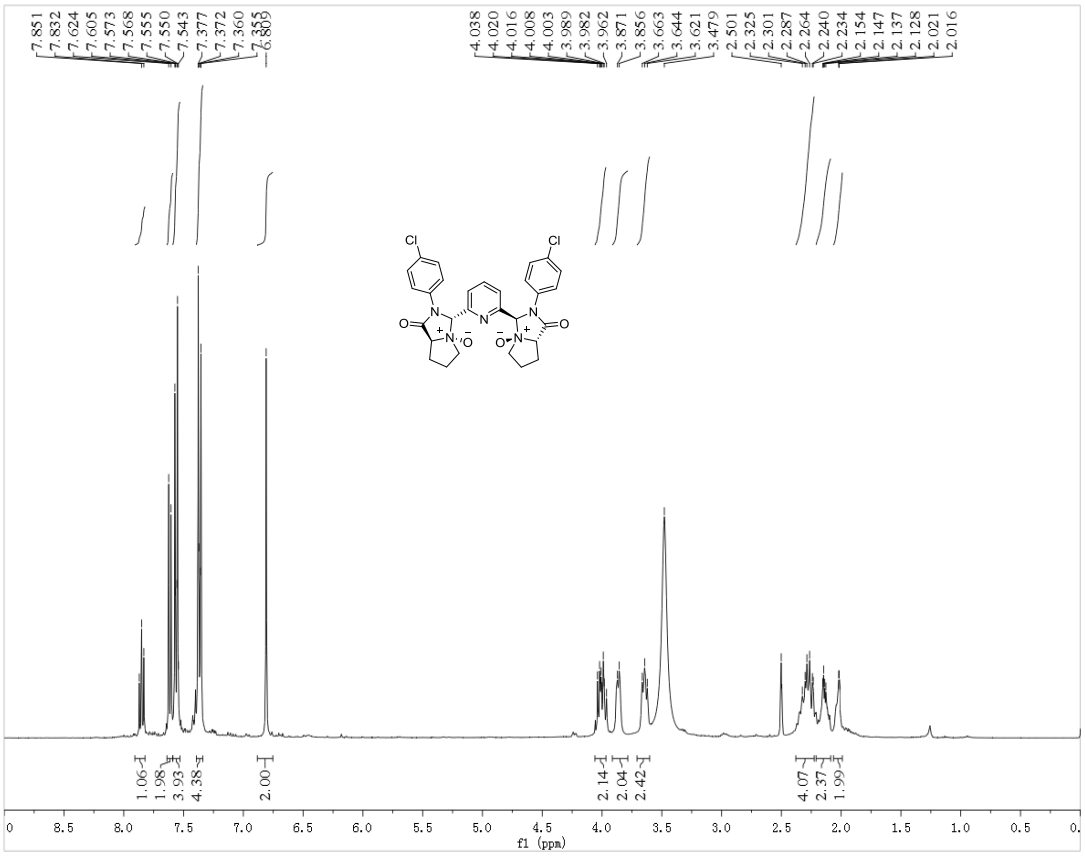


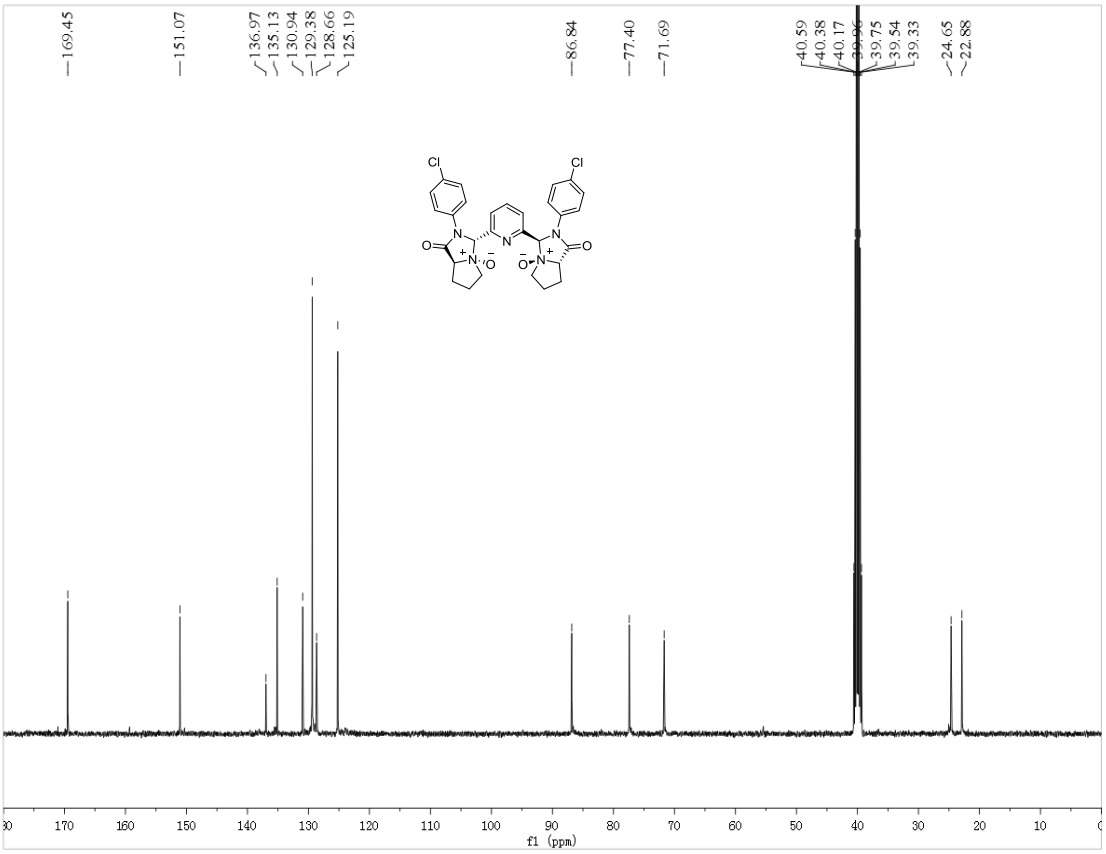
^{1}H and ^{13}C NMR of L1d



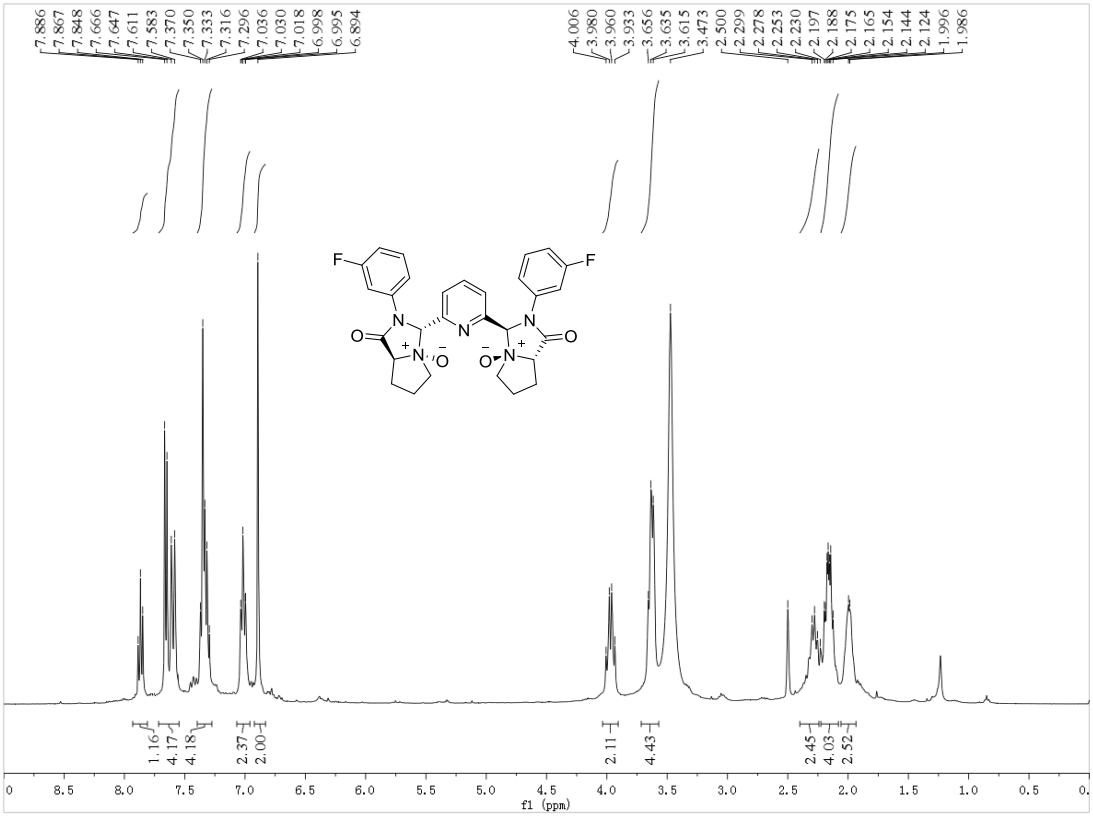


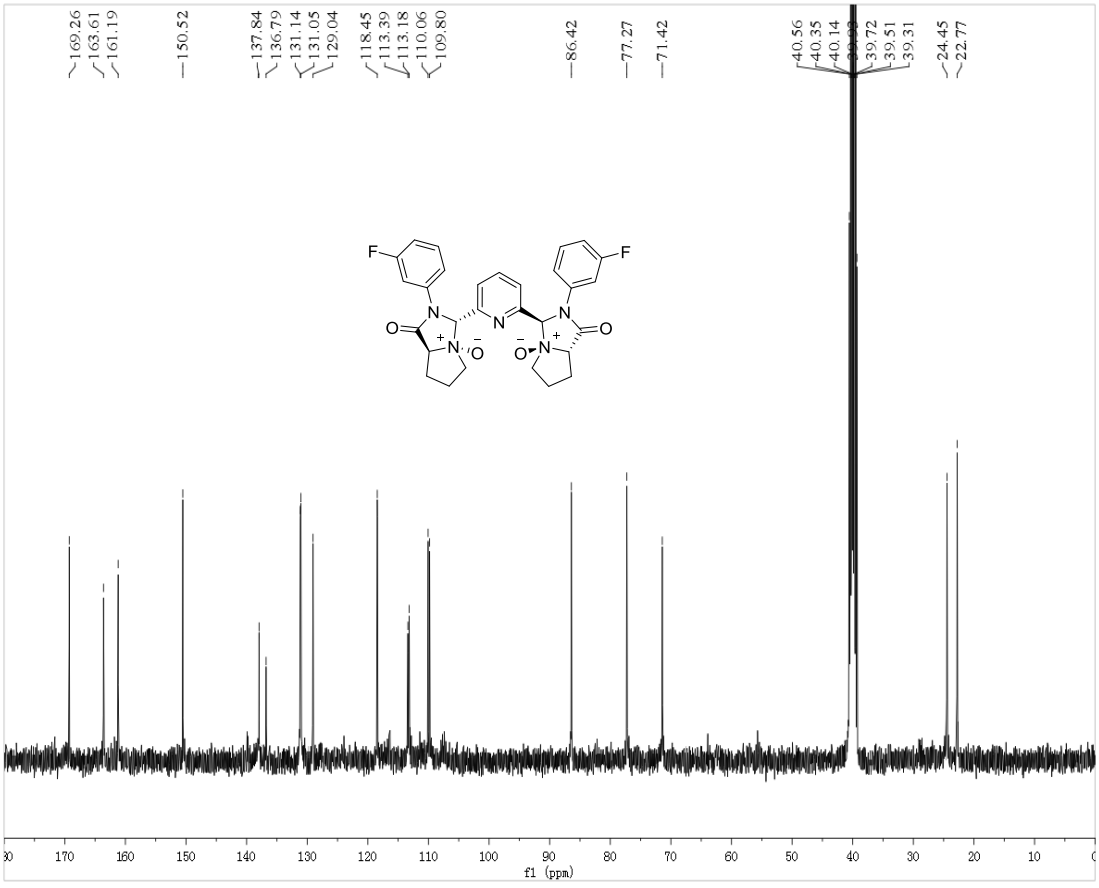
^{1}H and ^{13}C NMR of L1e



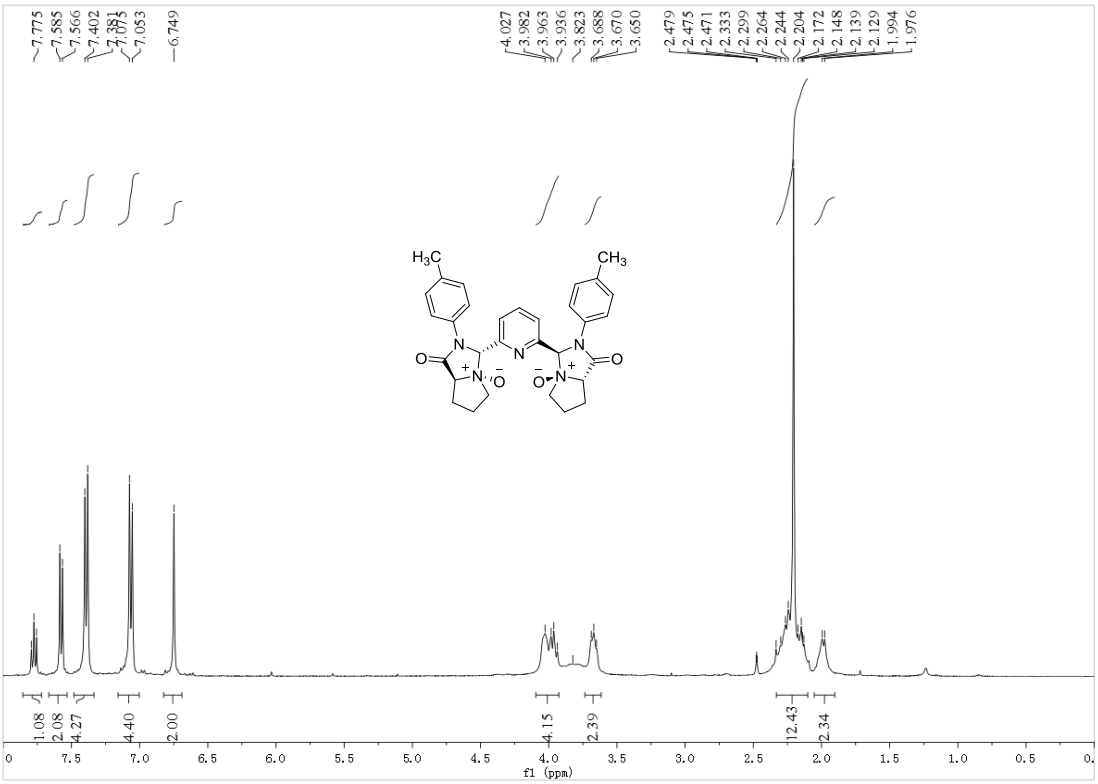


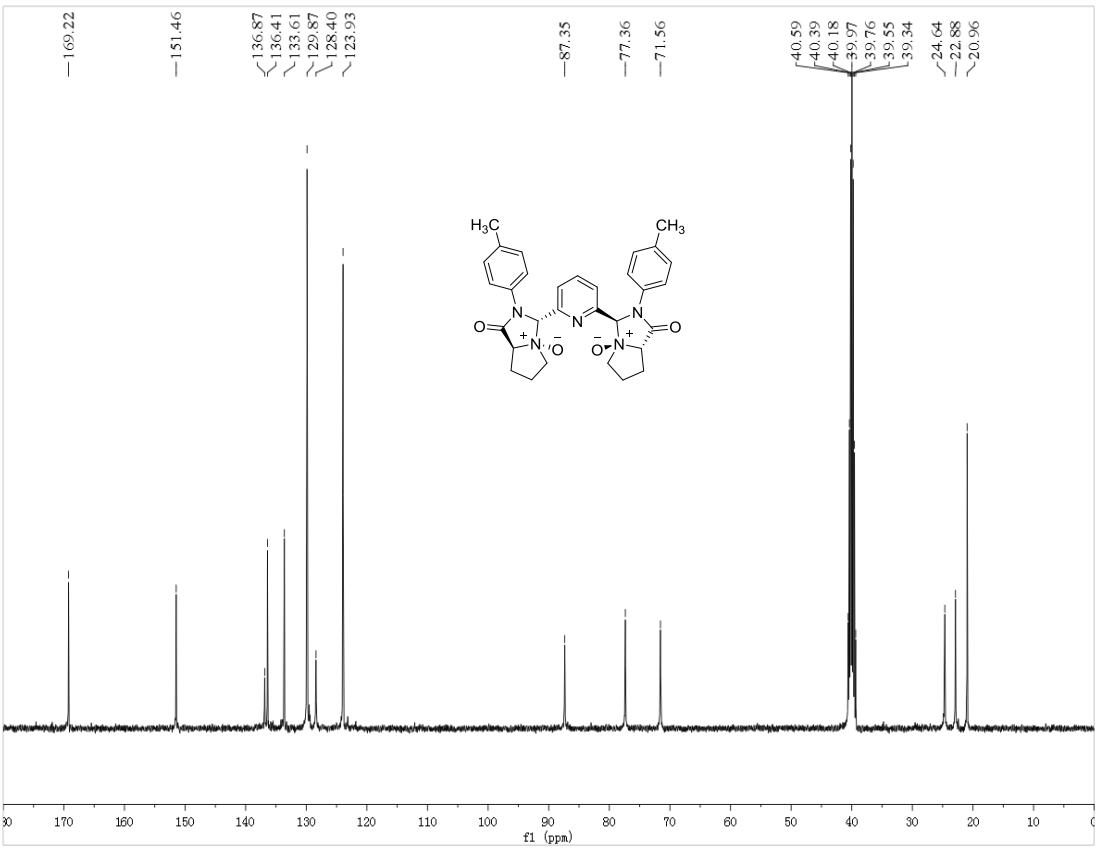
^{1}H and ^{13}C NMR of L1f



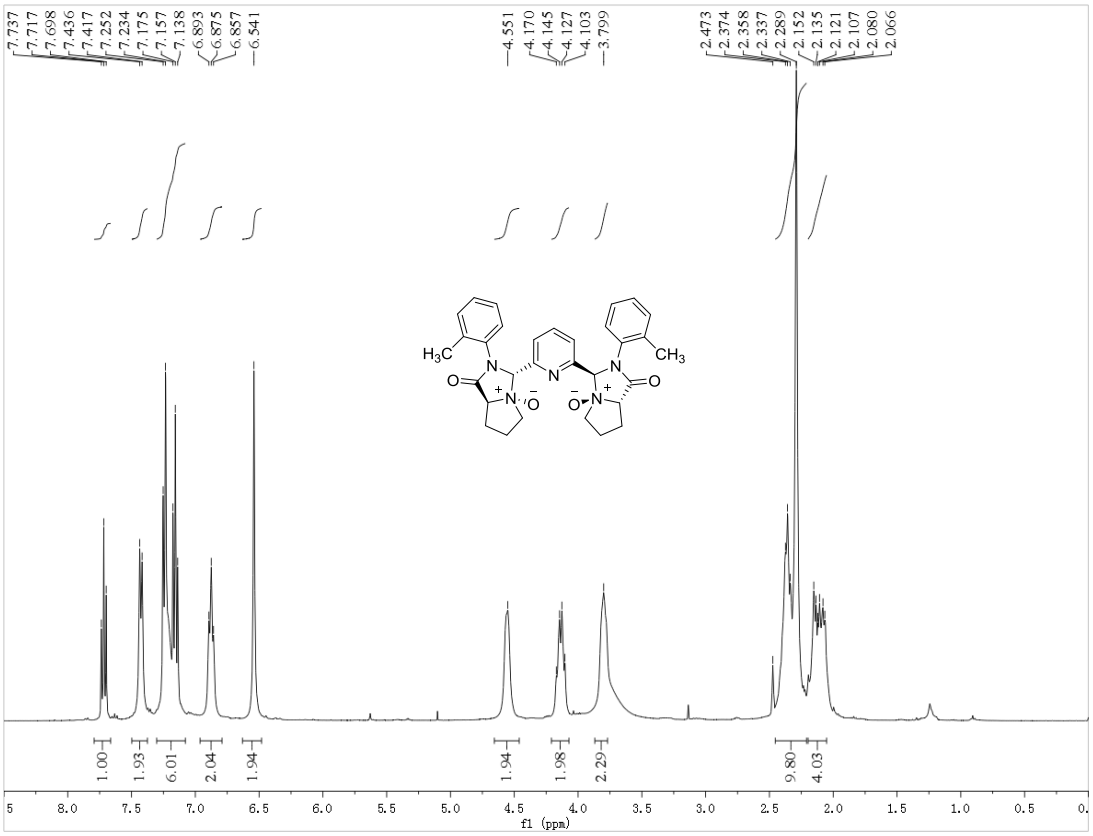


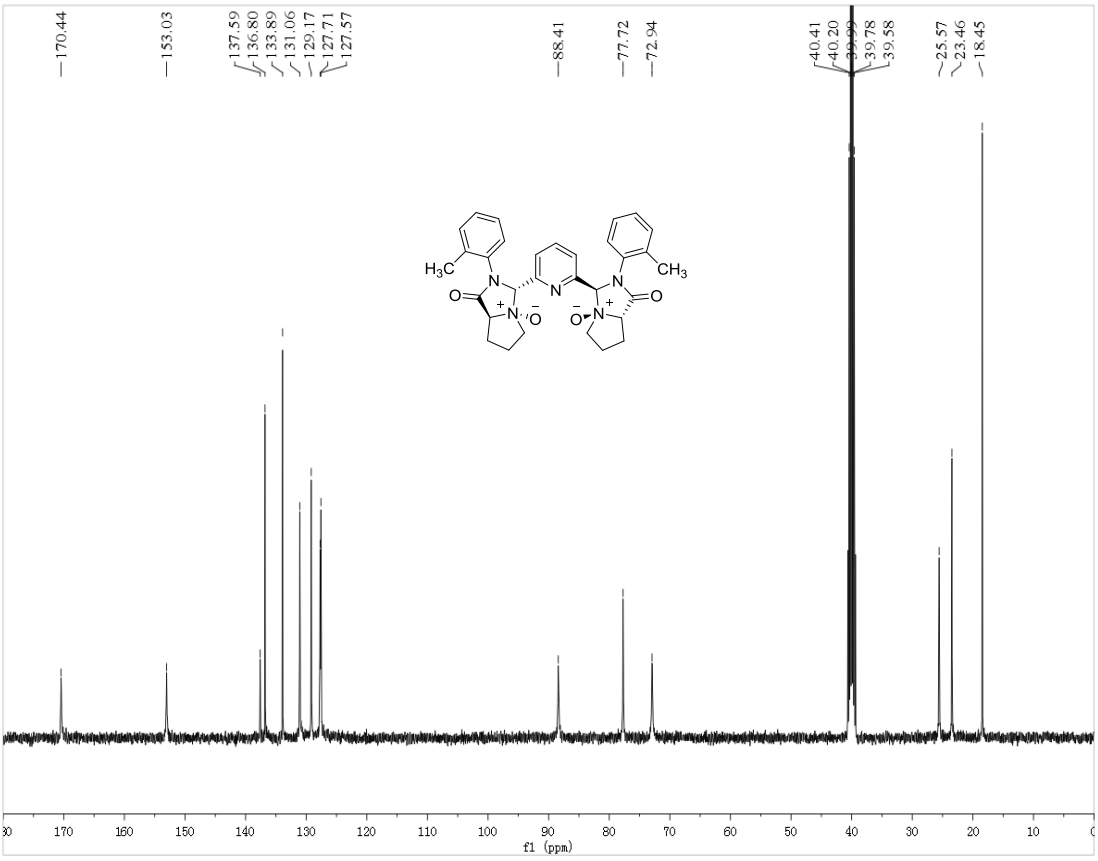
^{1}H and ^{13}C NMR of L1g



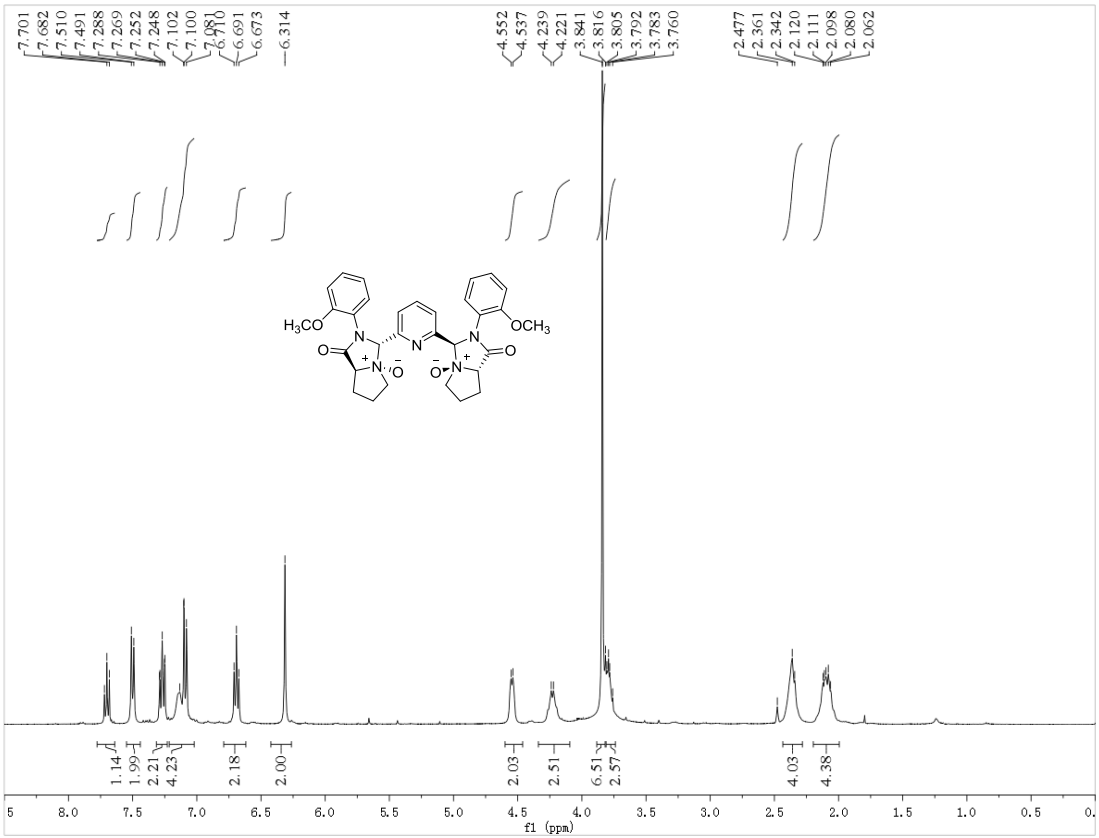


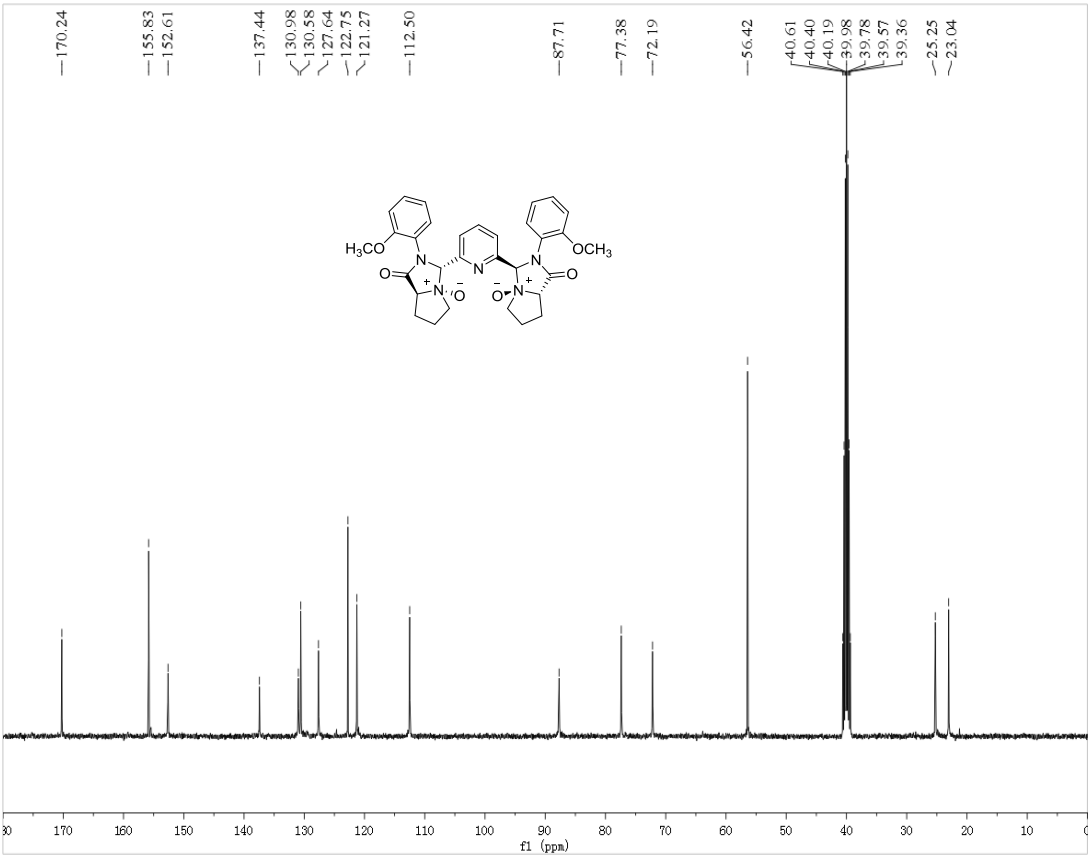
^{1}H and ^{13}C NMR of L1h



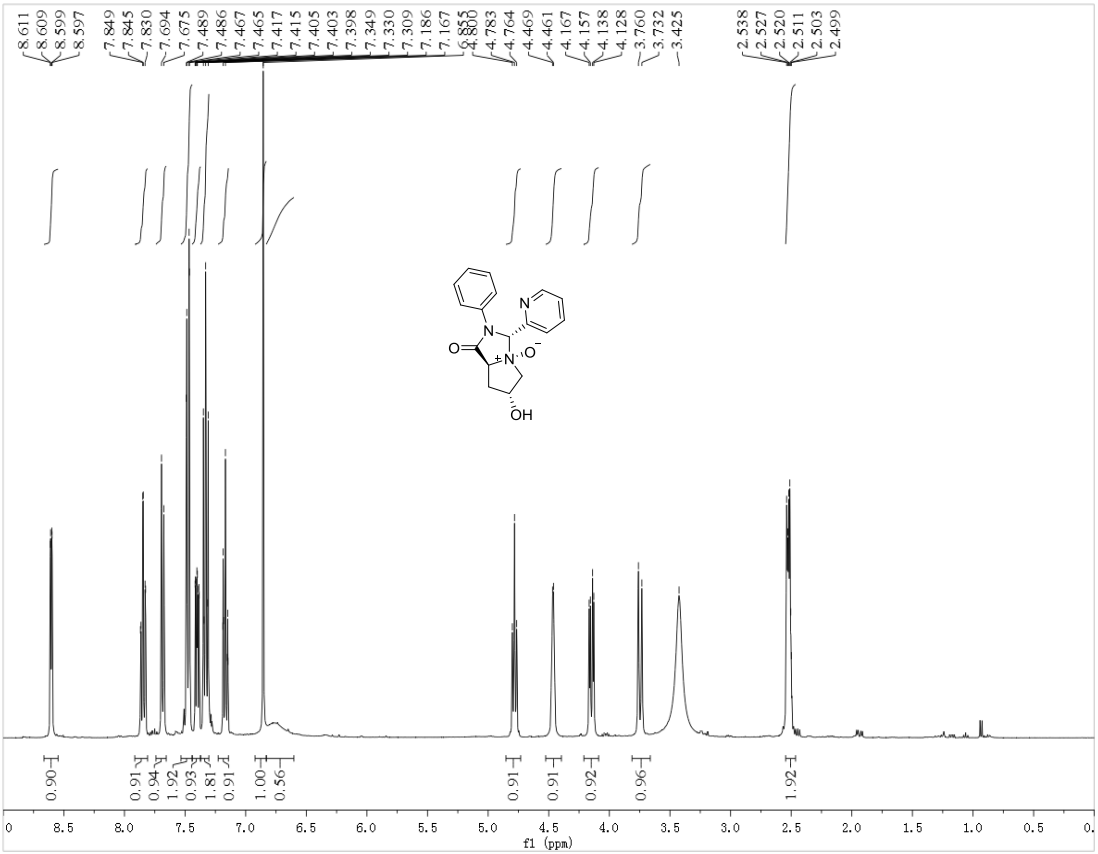


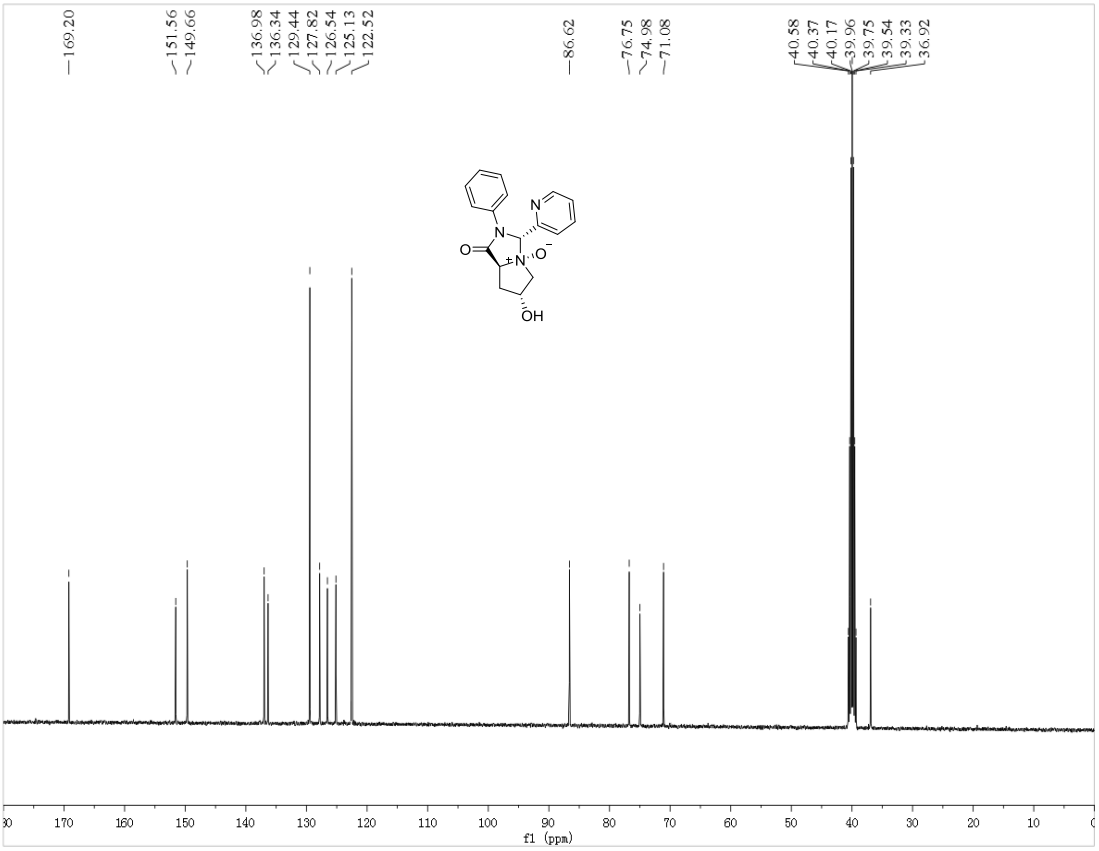
^{1}H and ^{13}C NMR of L1i



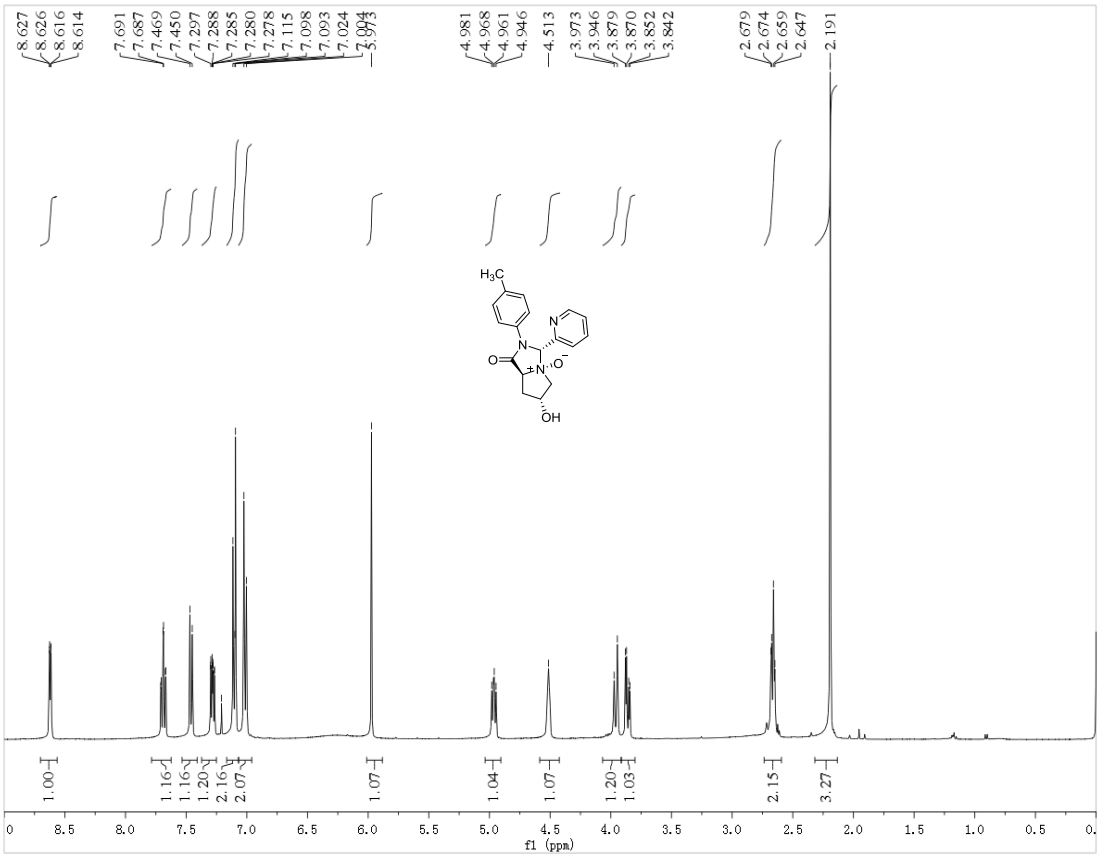


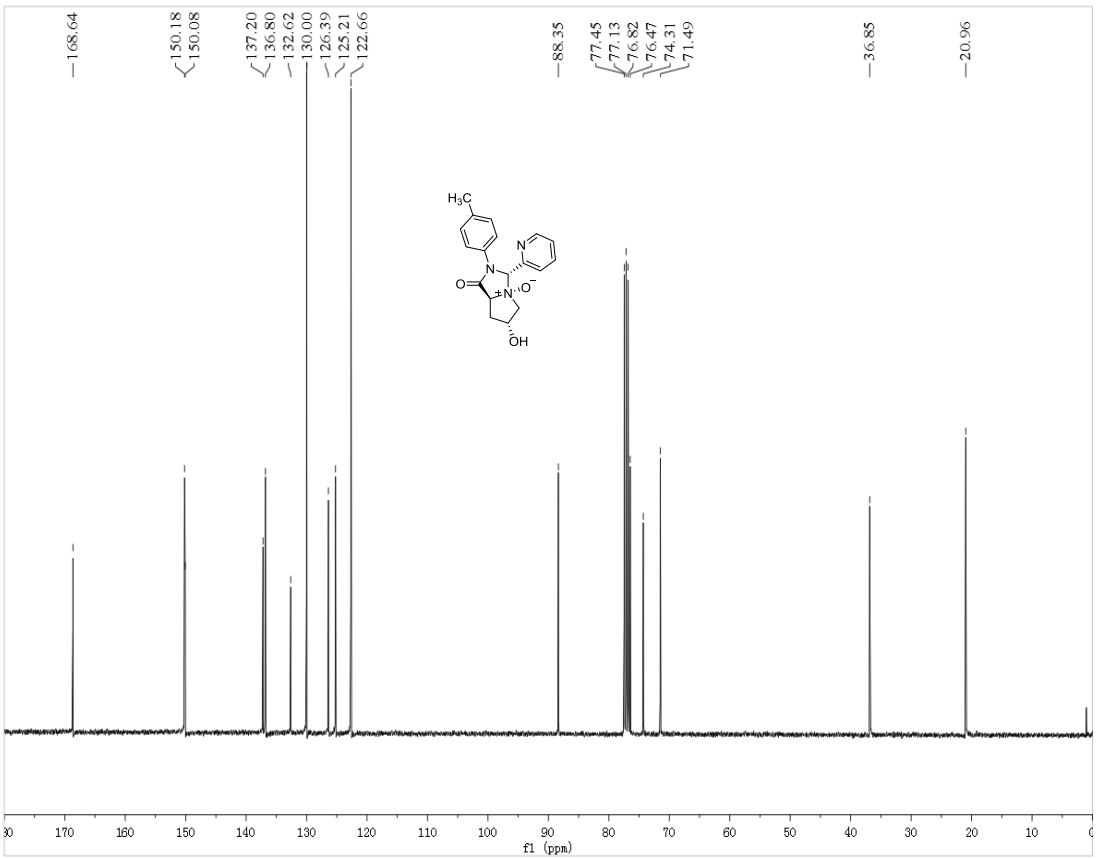
^{1}H and ^{13}C NMR of L2a



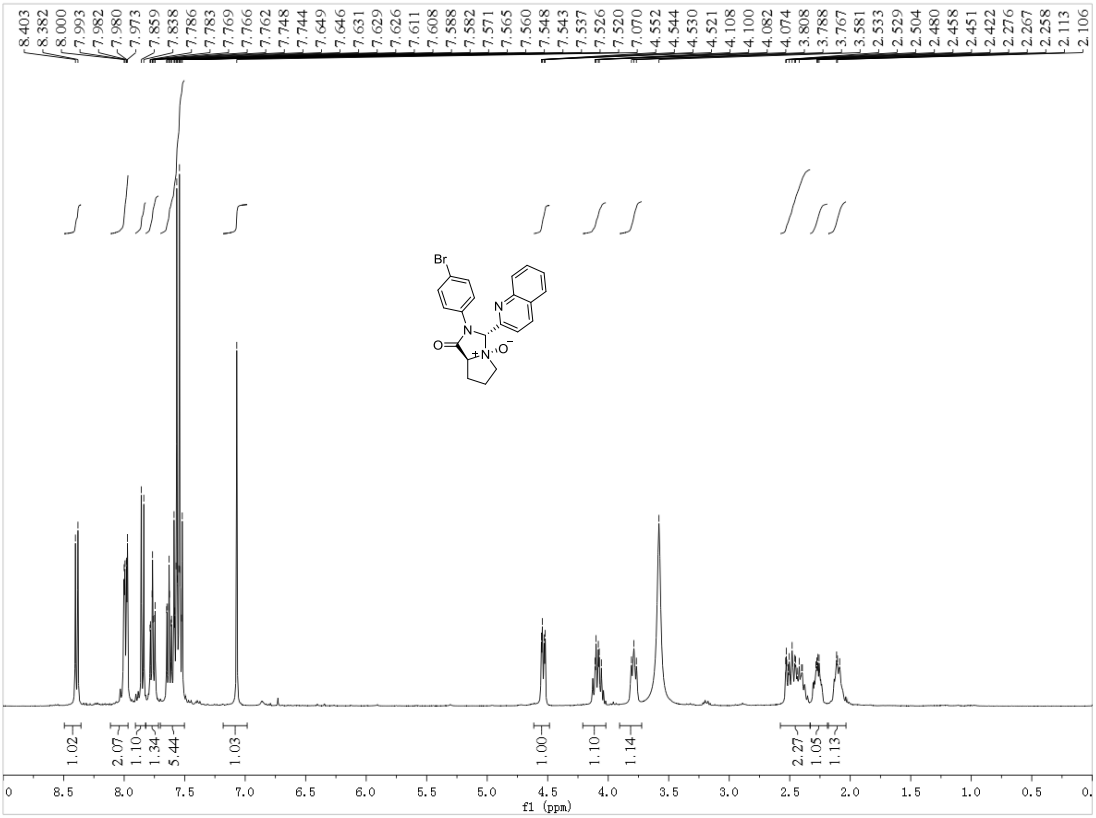


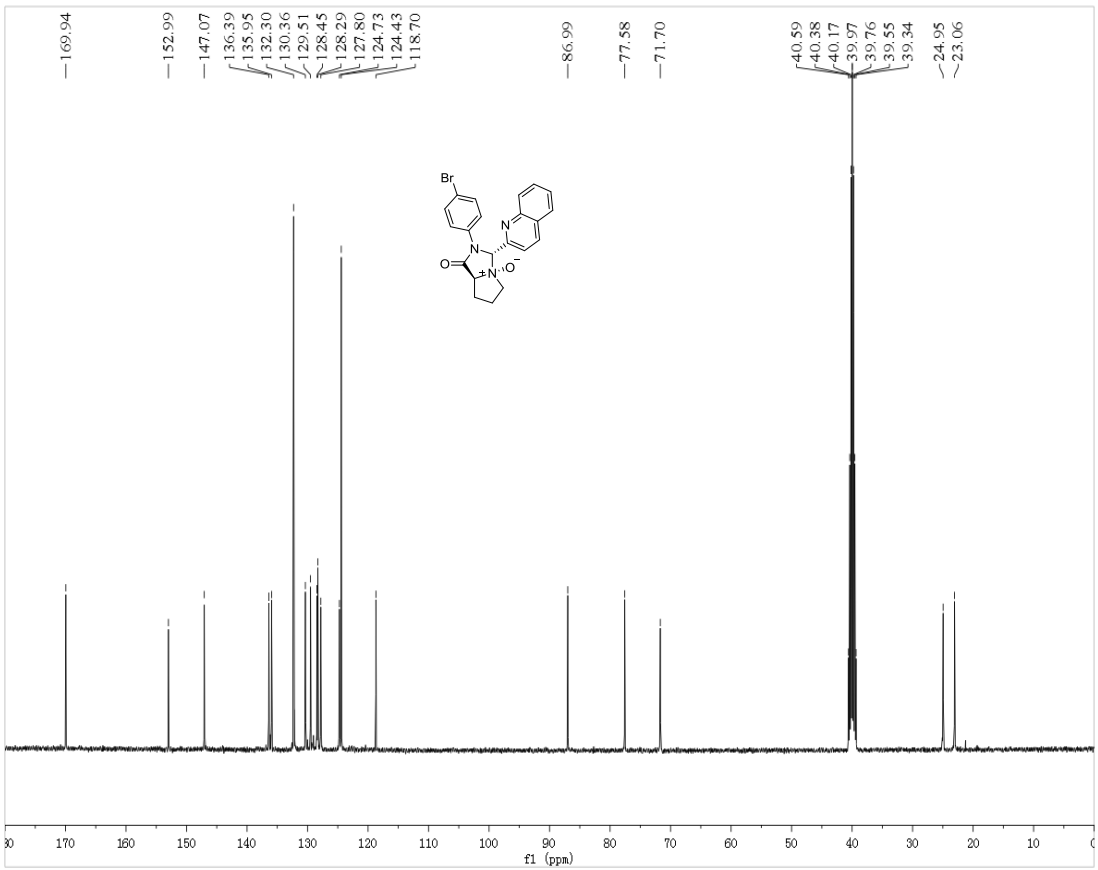
^{1}H and ^{13}C NMR of L2b



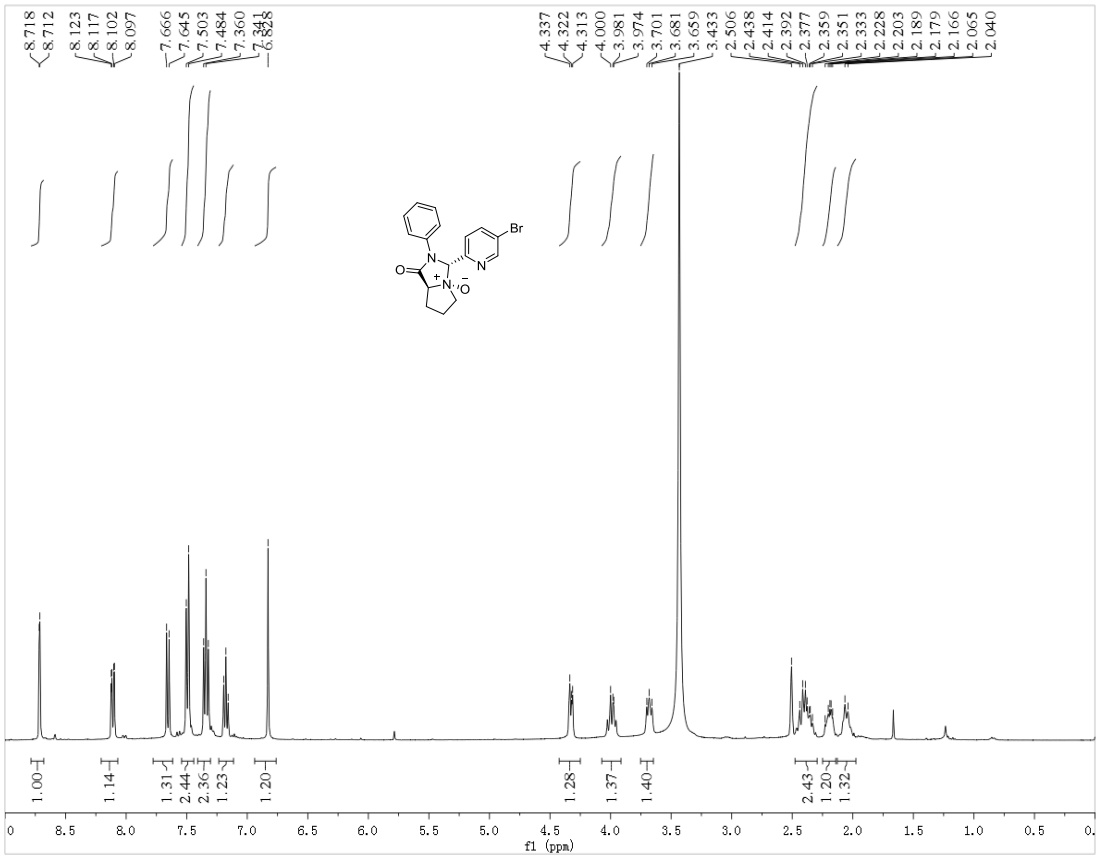


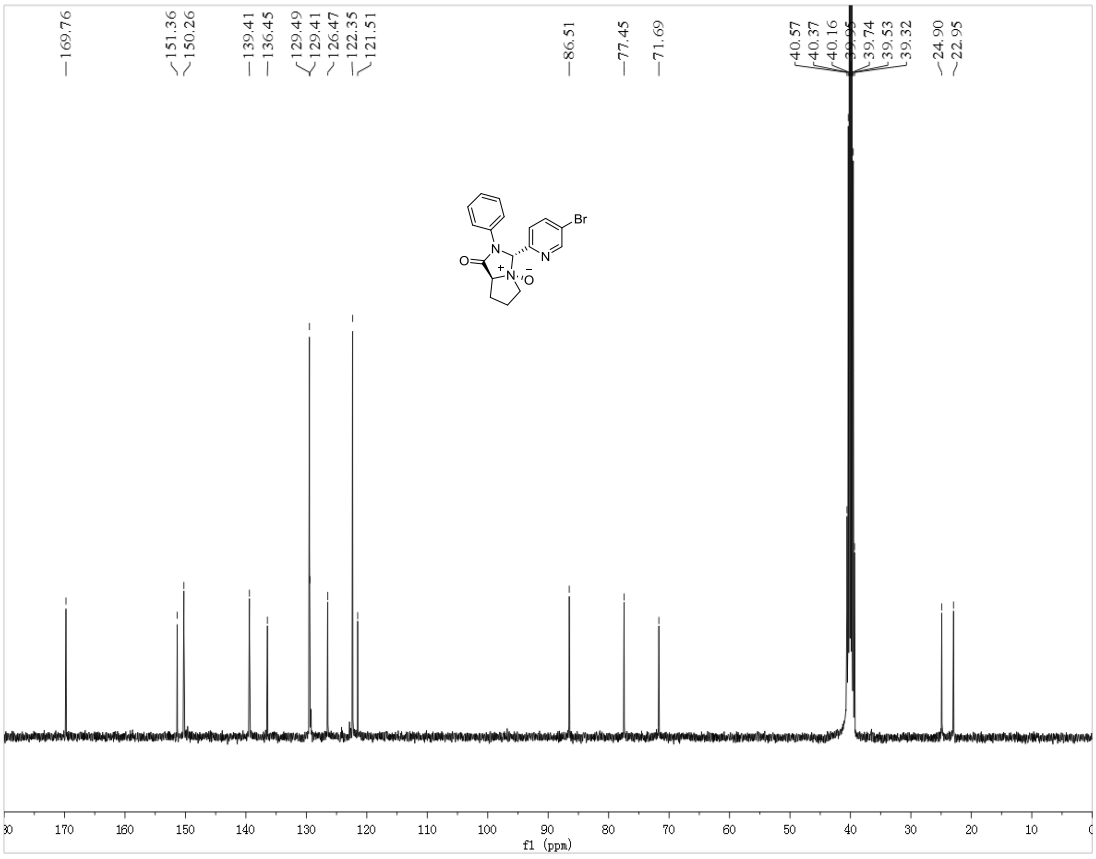
^{1}H and ^{13}C NMR of L2c



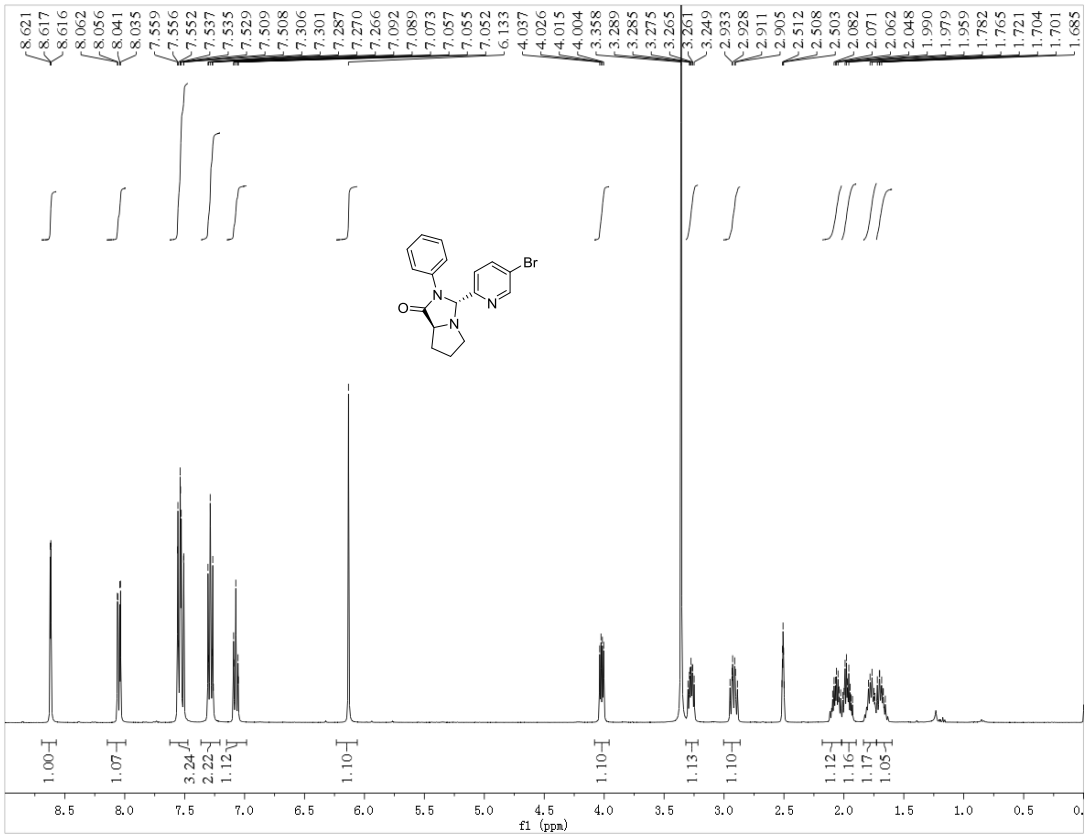


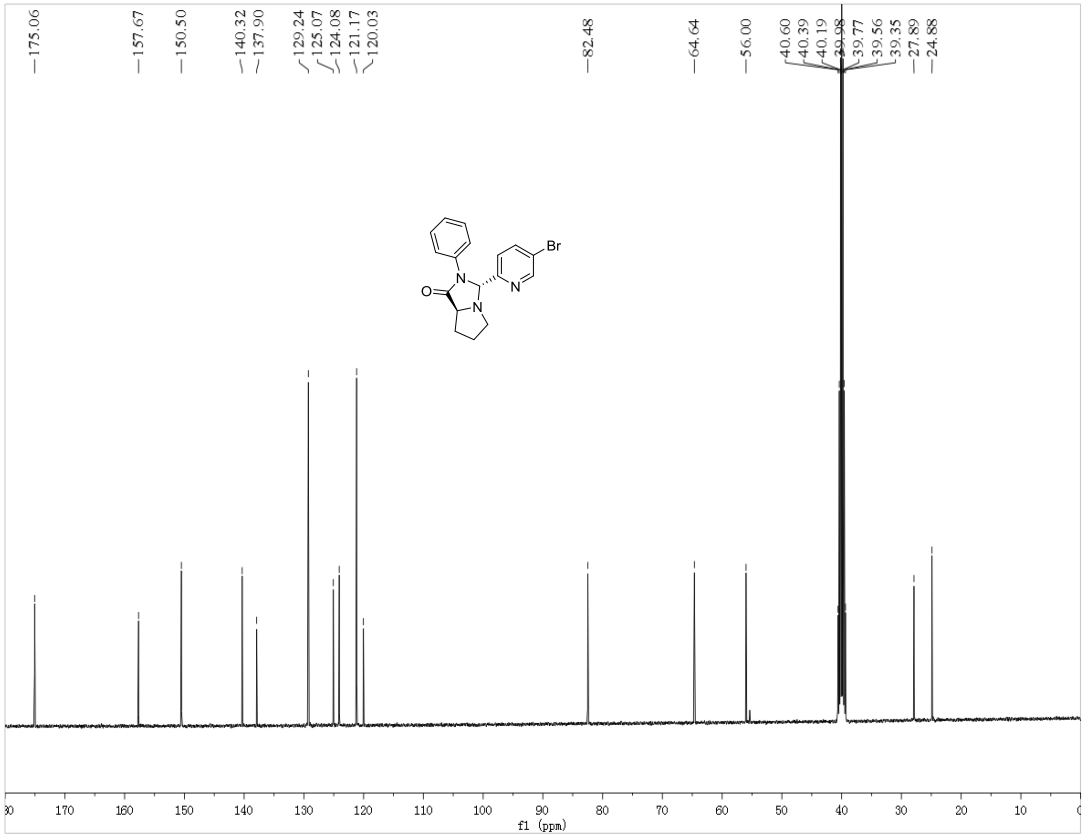
^{1}H and ^{13}C NMR of L2d



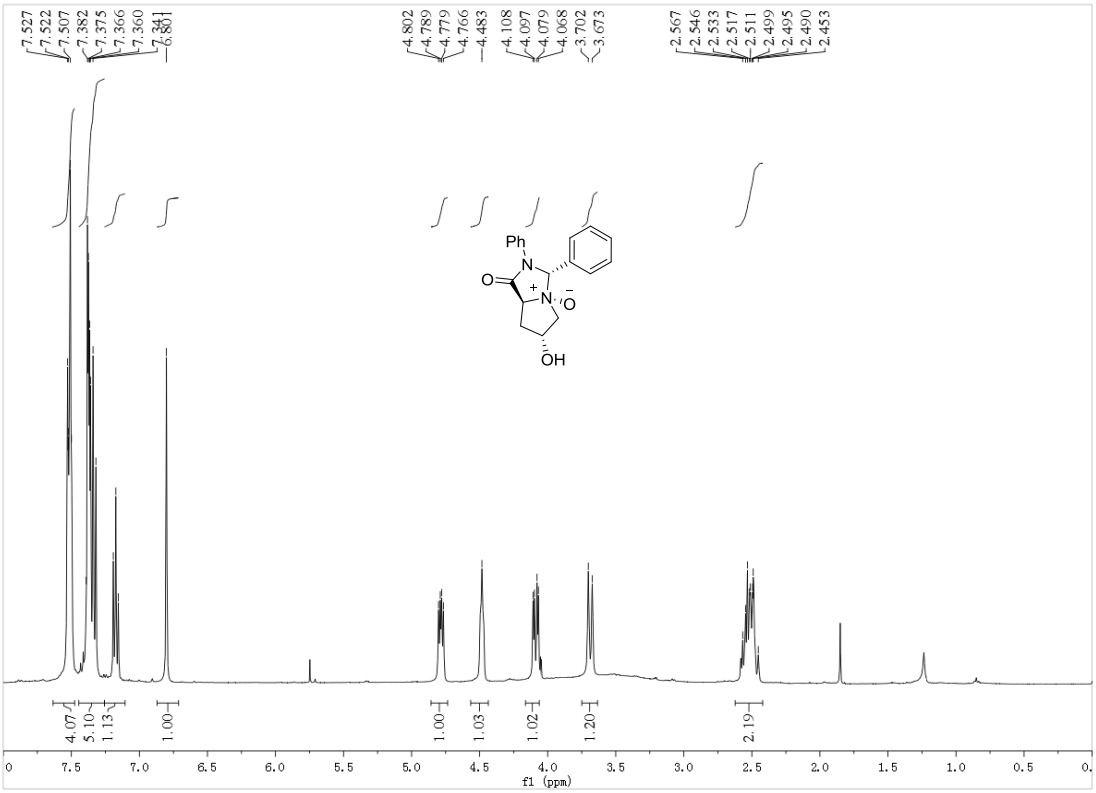


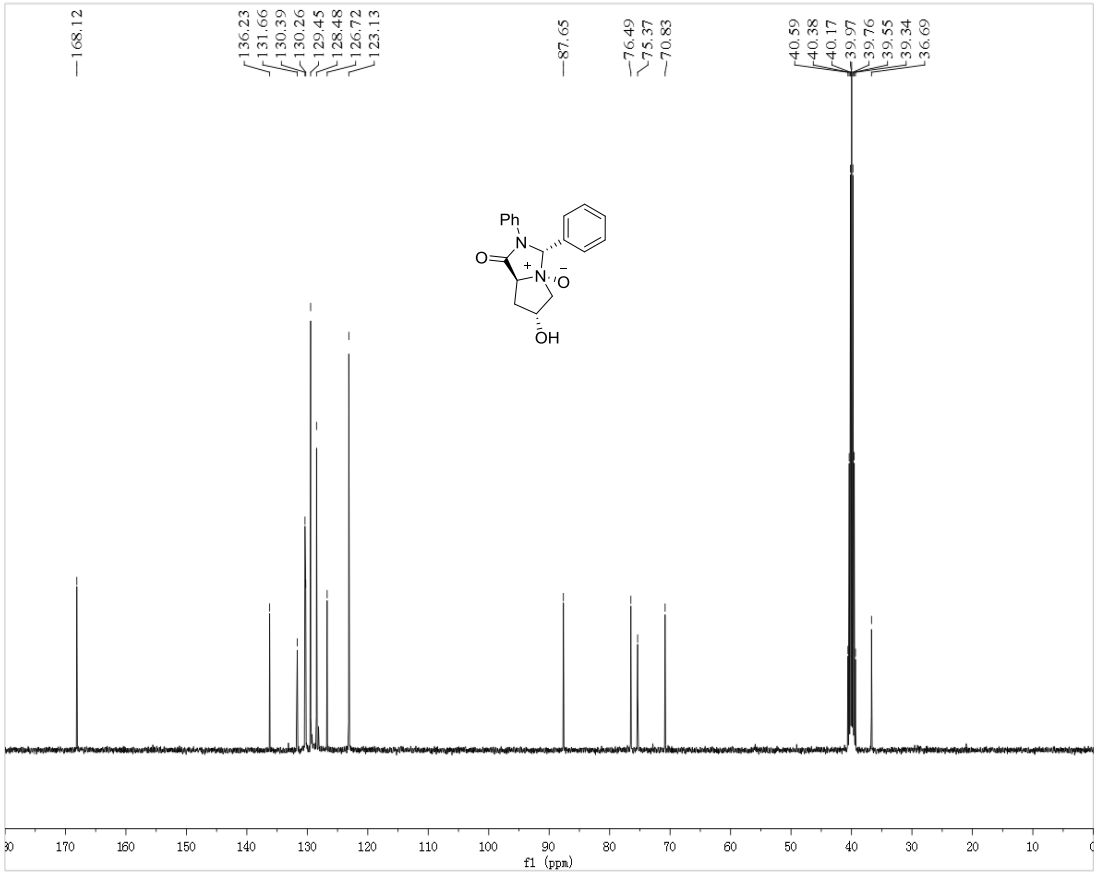
^{1}H and ^{13}C NMR of 3d



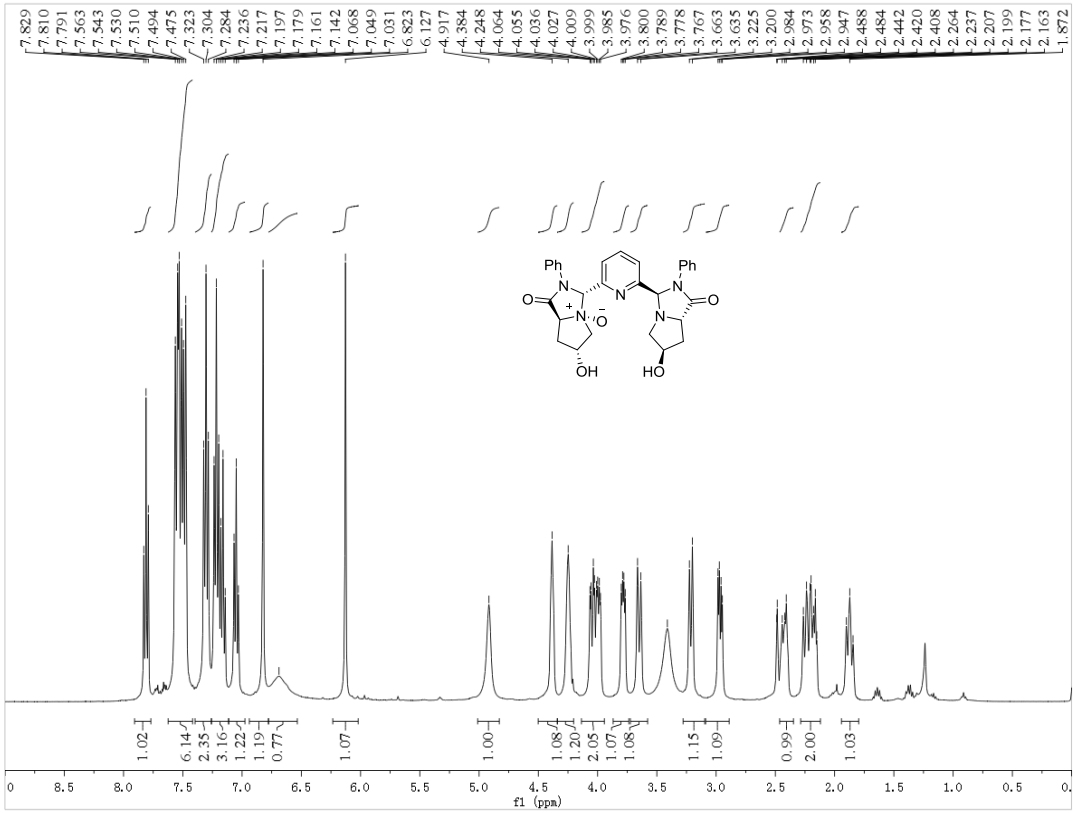


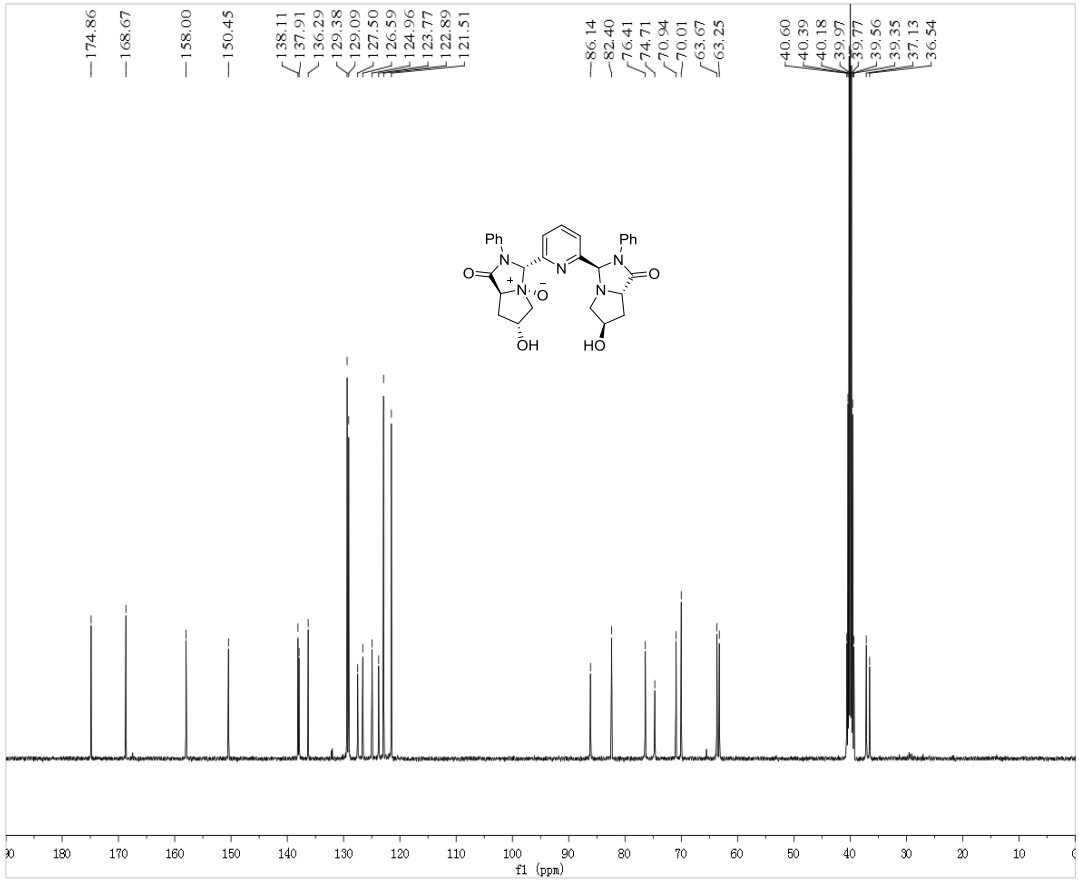
^{1}H and ^{13}C NMR of L4a



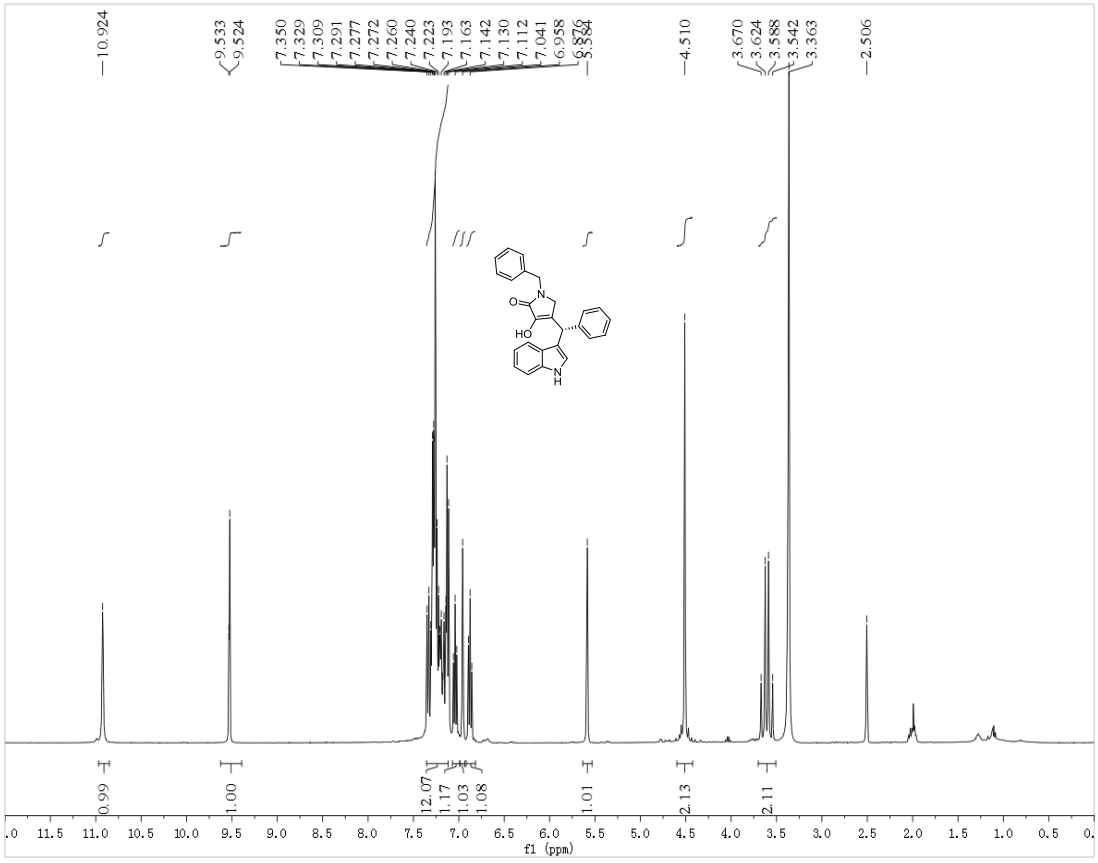


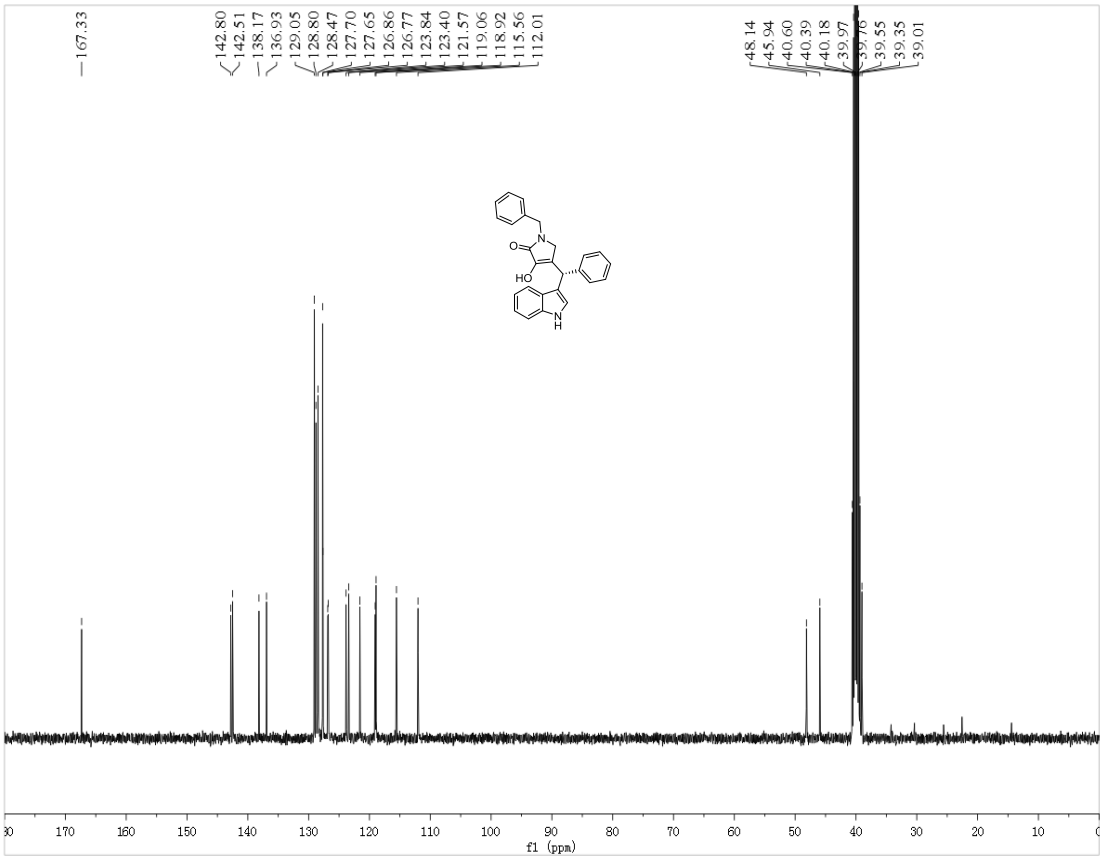
^{1}H and ^{13}C NMR of L6a



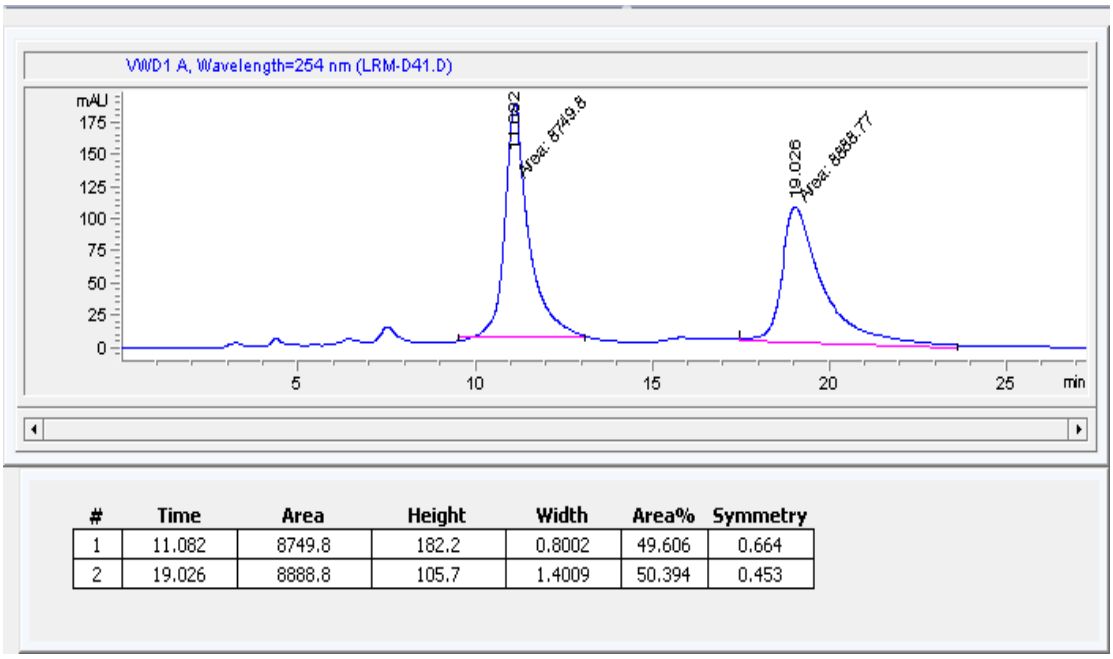


^{1}H and ^{13}C NMR of 6a

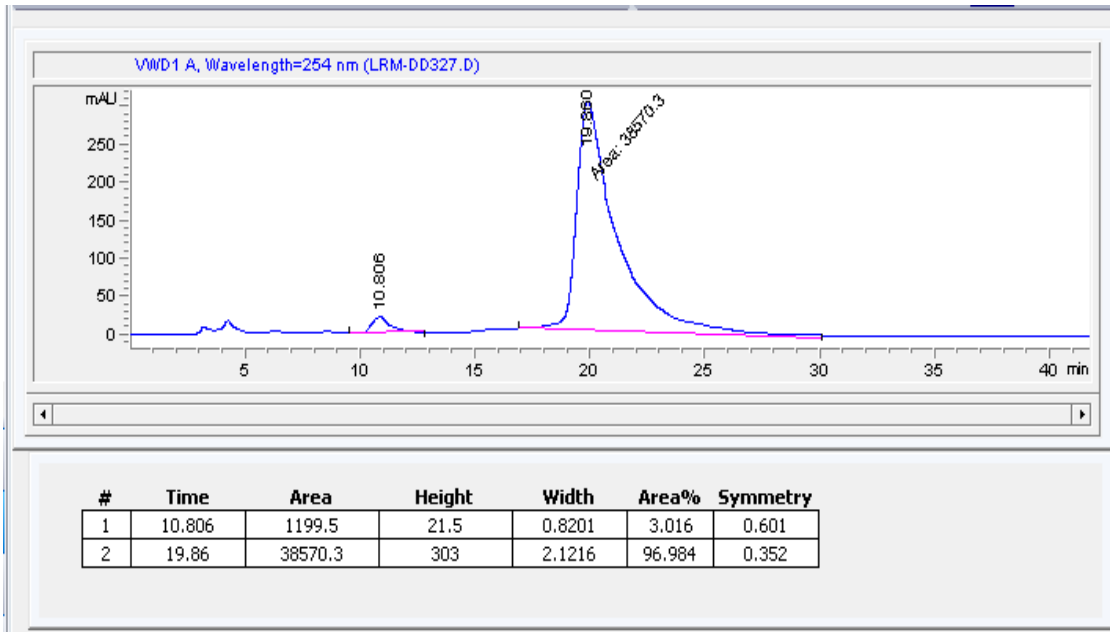




HPLC of **6a**

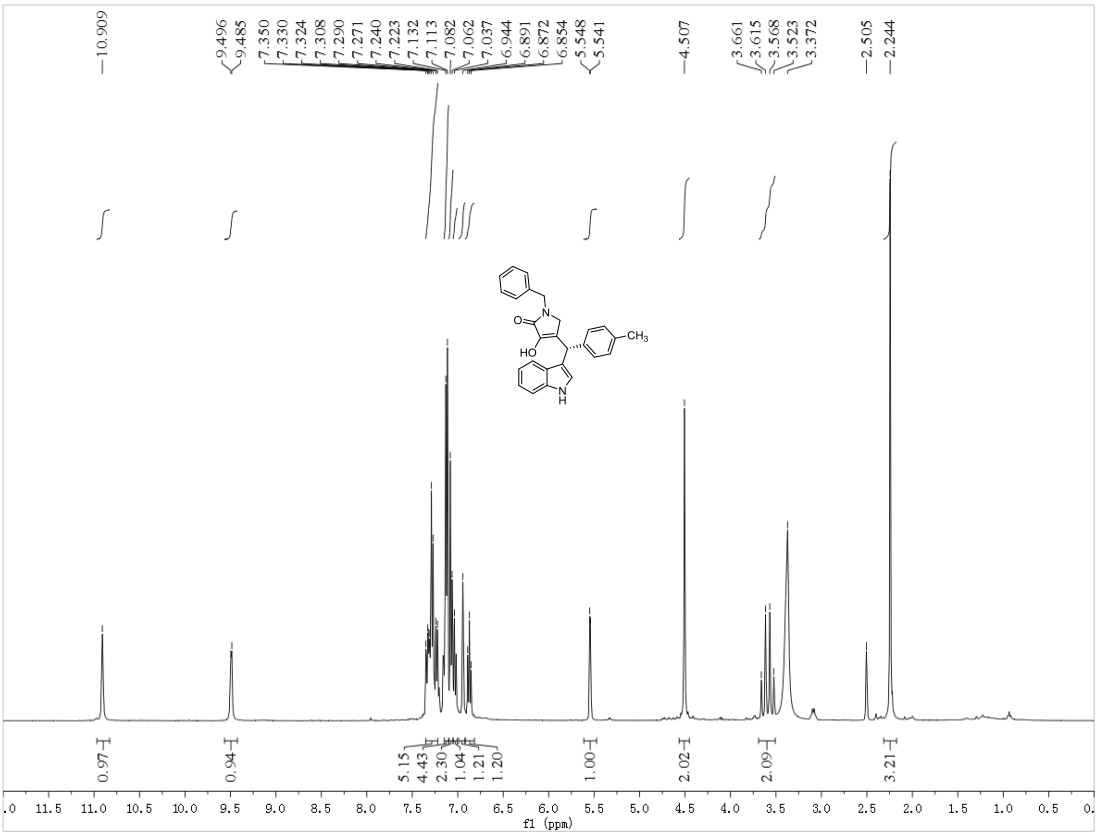


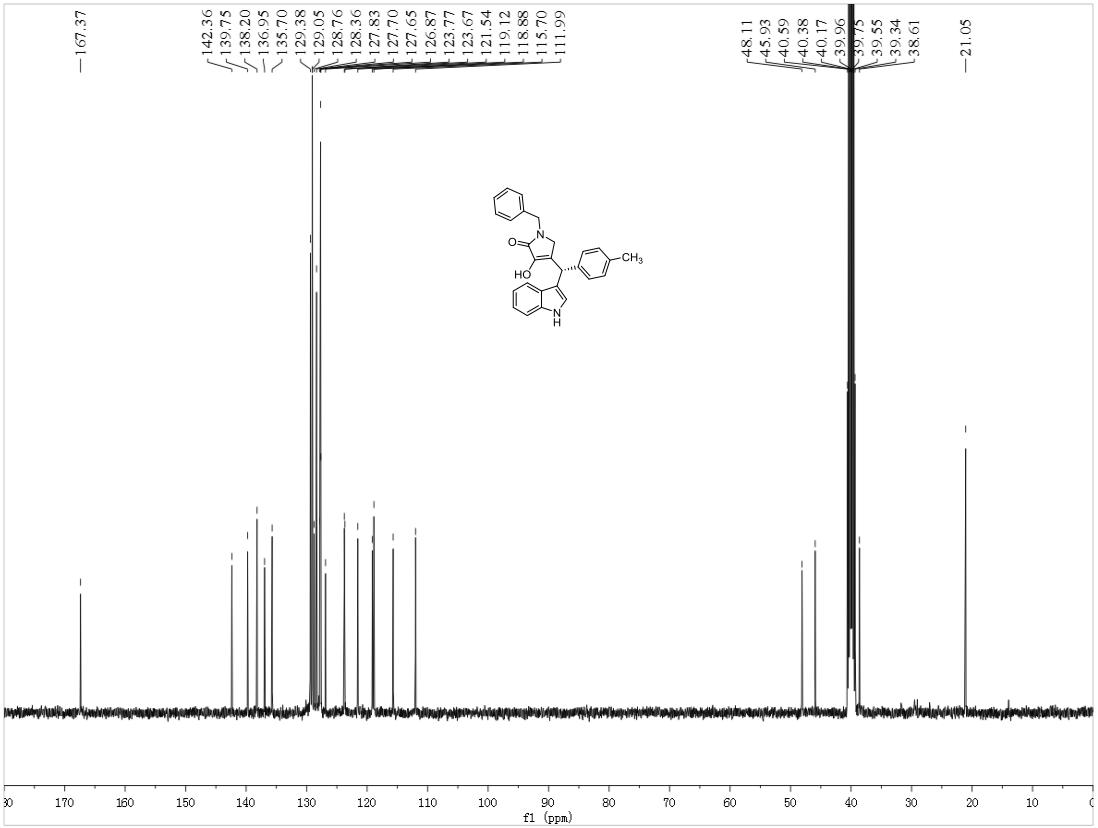
#	Time	Area	Height	Width	Area%	Symmetry
1	11.082	8749.8	182.2	0.8002	49.606	0.664
2	19.026	8888.8	105.7	1.4009	50.394	0.453



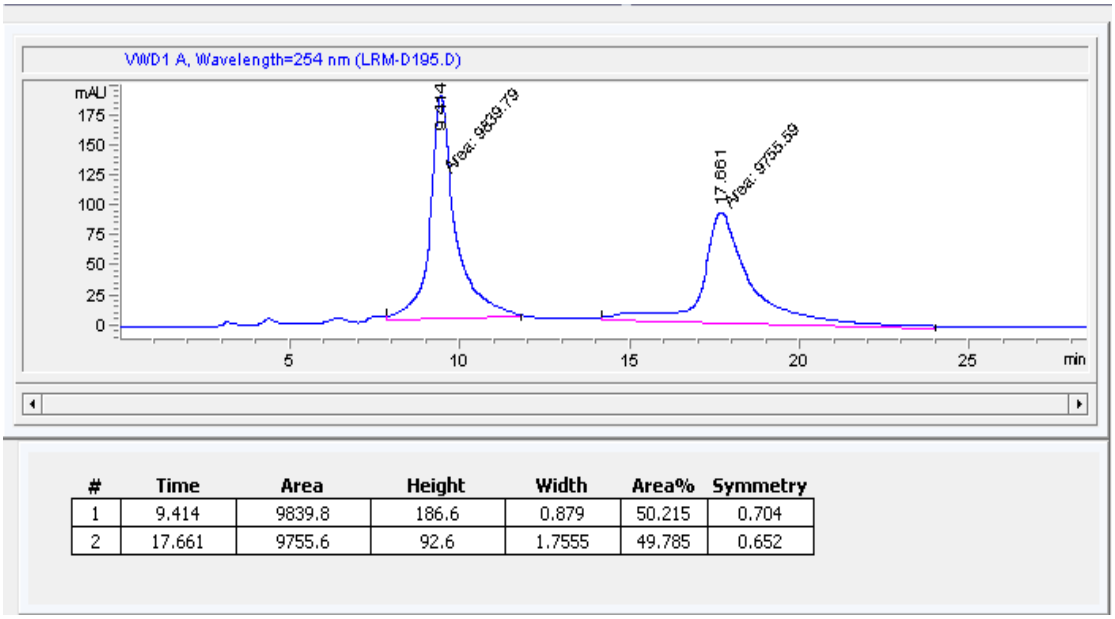
#	Time	Area	Height	Width	Area%	Symmetry
1	10.806	1199.5	21.5	0.8201	3.016	0.601
2	19.86	38570.3	303	2.1216	96.984	0.352

^{1}H and ^{13}C NMR of 6b

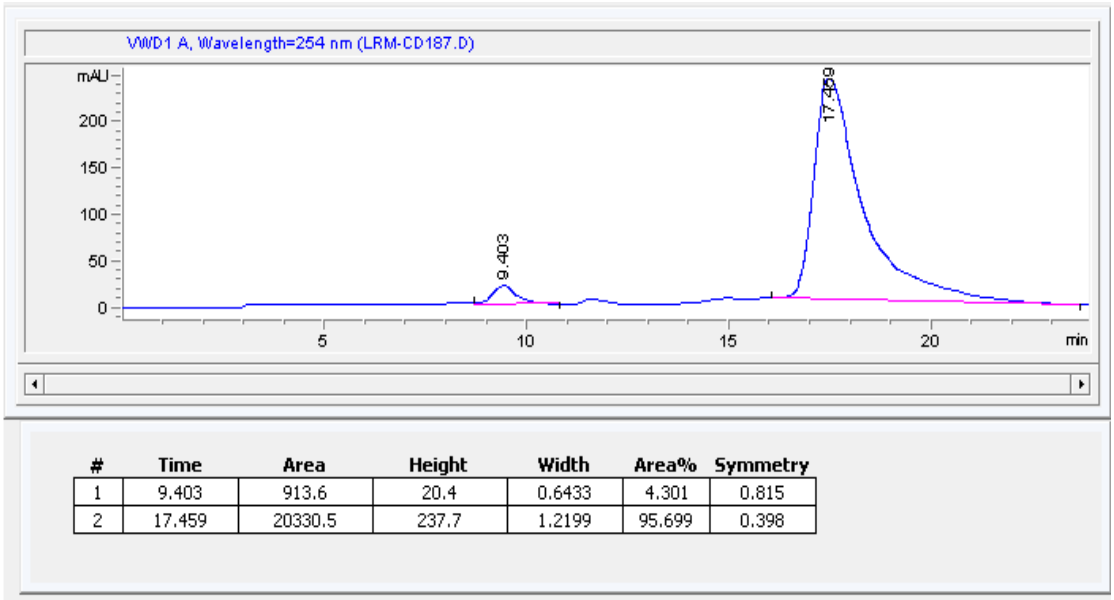




HPLC of **6b**

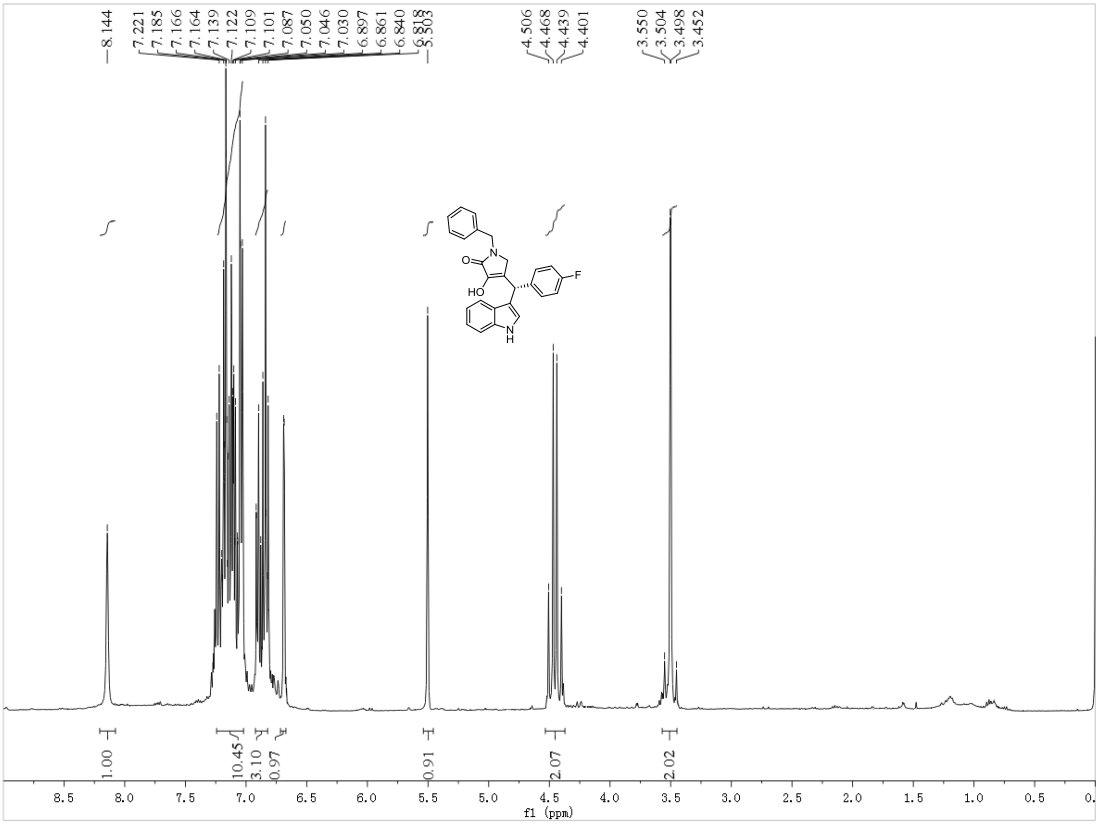


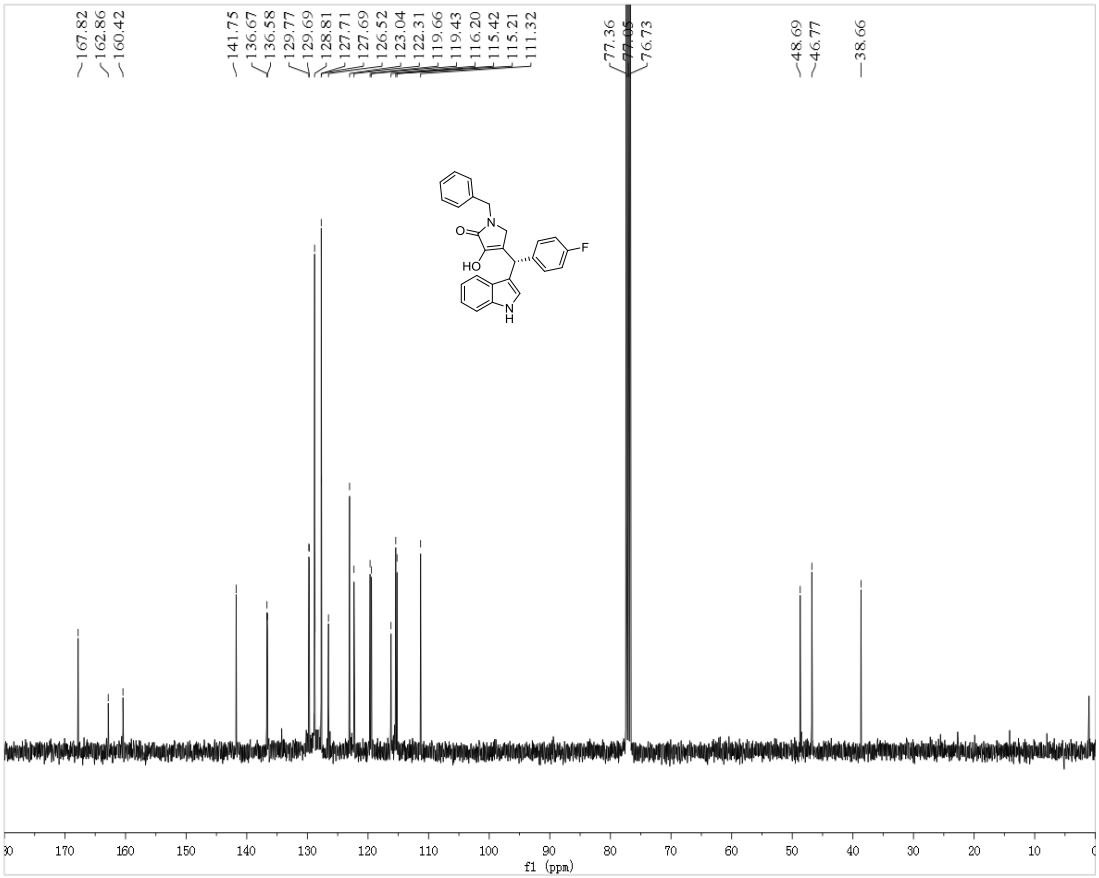
#	Time	Area	Height	Width	Area%	Symmetry
1	9.414	9839.8	186.6	0.879	50.215	0.704
2	17.661	9755.6	92.6	1.7555	49.785	0.652



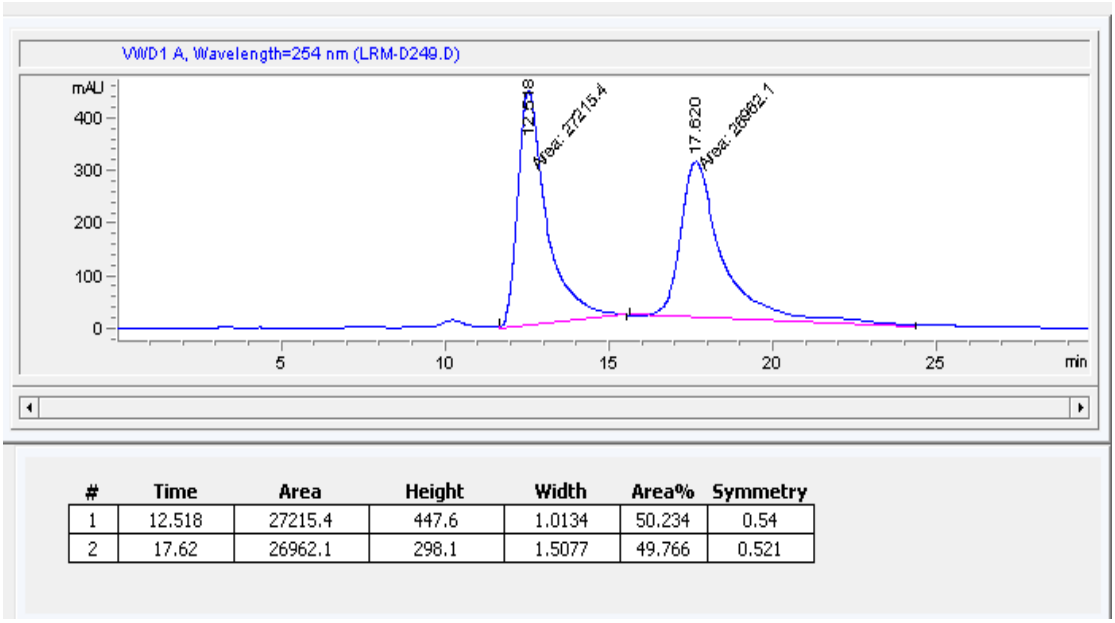
#	Time	Area	Height	Width	Area%	Symmetry
1	9.403	913.6	20.4	0.6433	4.301	0.815
2	17.459	20330.5	237.7	1.2199	95.699	0.398

^{1}H and ^{13}C NMR of 6c

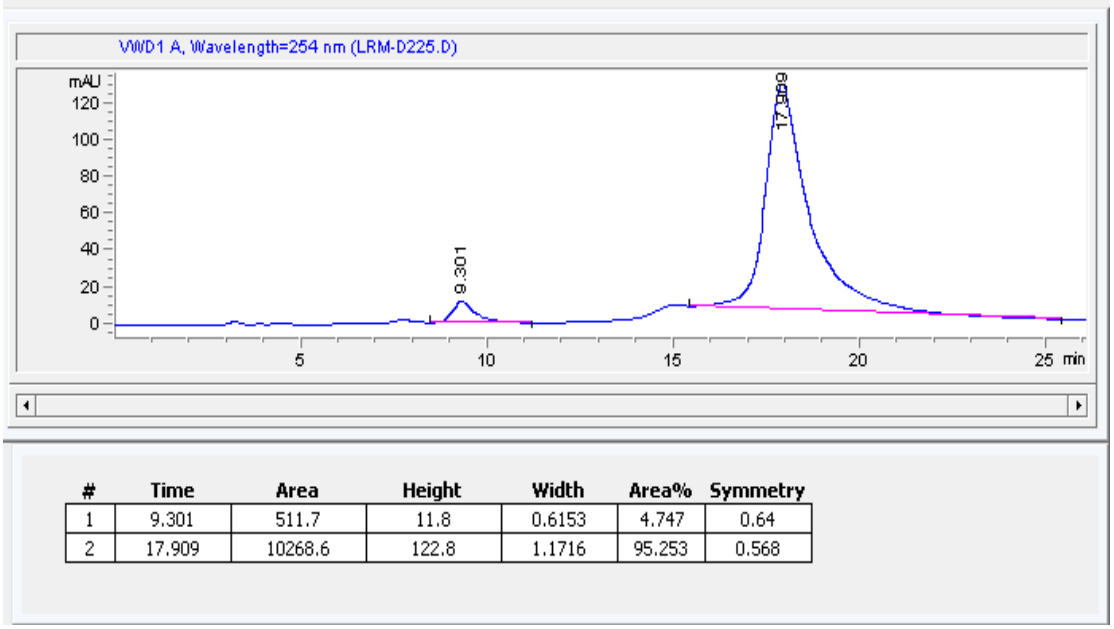




HPLC of **6c**

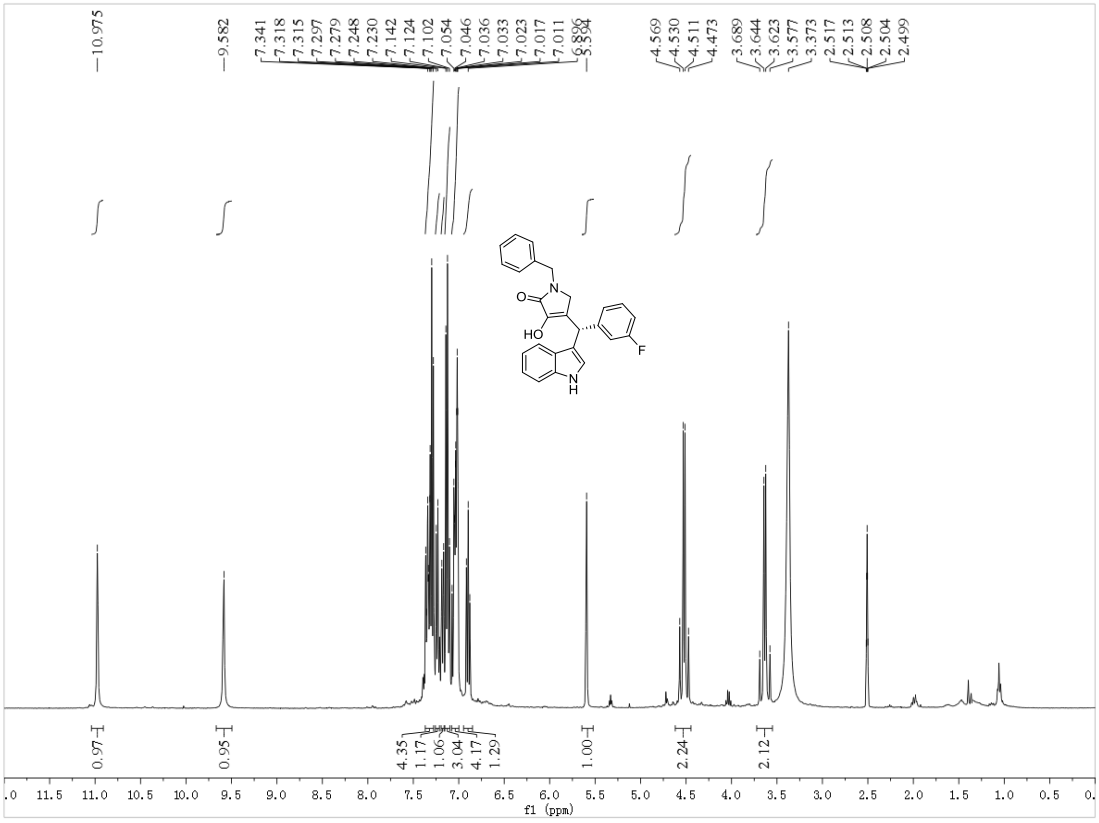


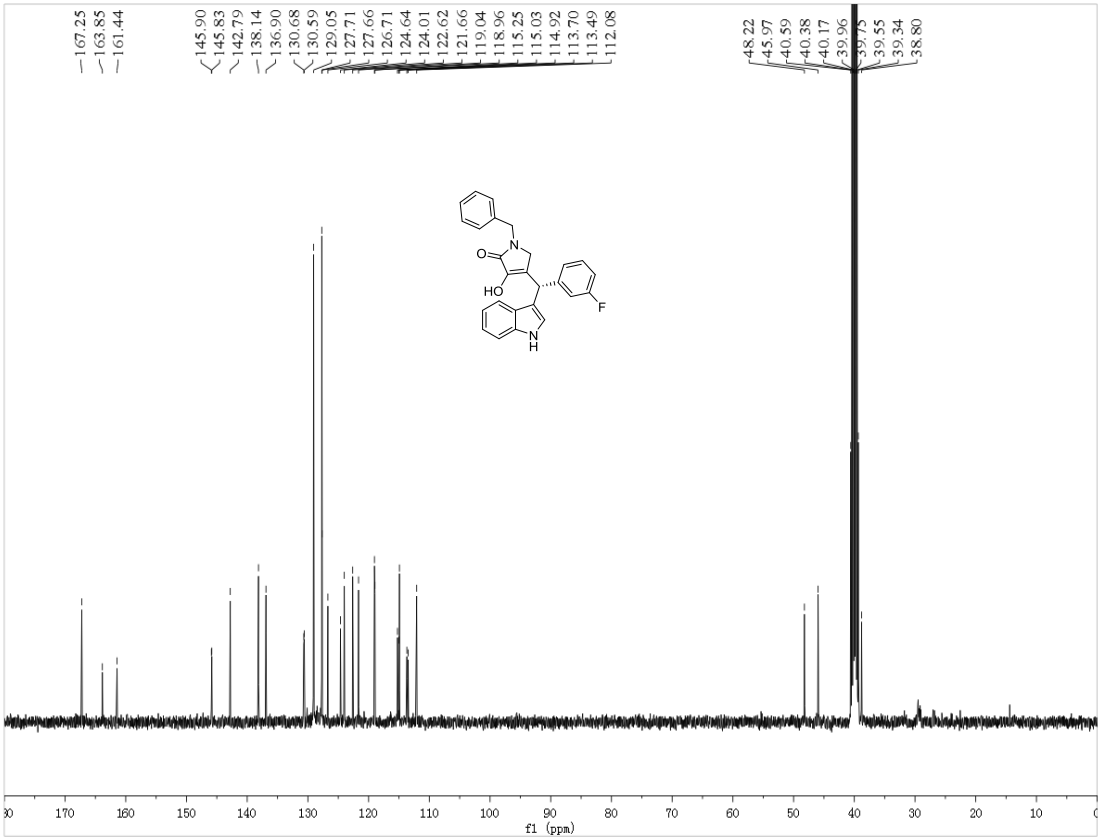
#	Time	Area	Height	Width	Area%	Symmetry
1	12.518	27215.4	447.6	1.0134	50.234	0.54
2	17.62	26962.1	298.1	1.5077	49.766	0.521



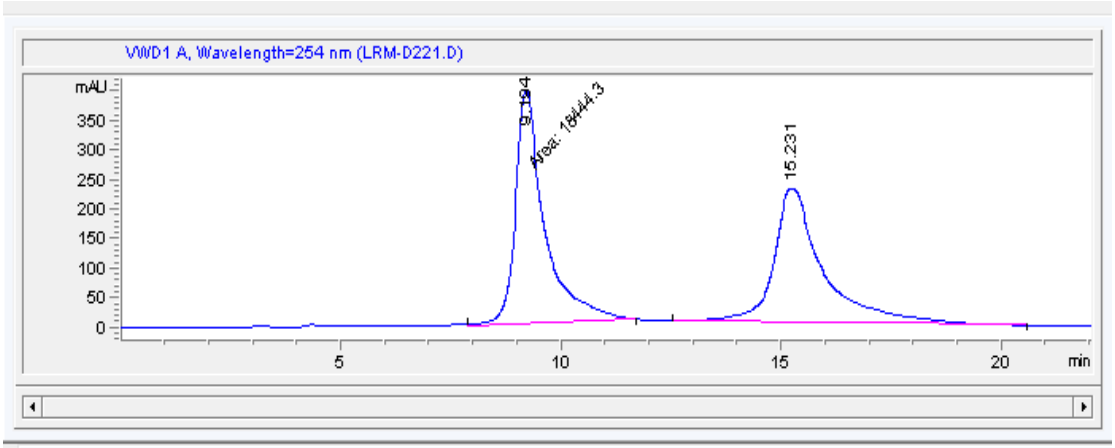
#	Time	Area	Height	Width	Area%	Symmetry
1	9.301	511.7	11.8	0.6153	4.747	0.64
2	17.909	10268.6	122.8	1.1716	95.253	0.568

^{1}H and ^{13}C NMR of 6d

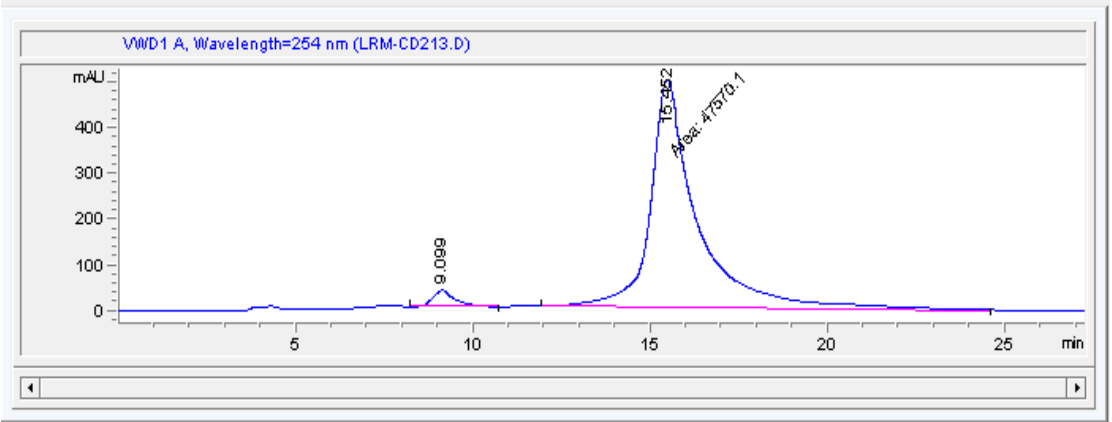




HPLC of **6d**

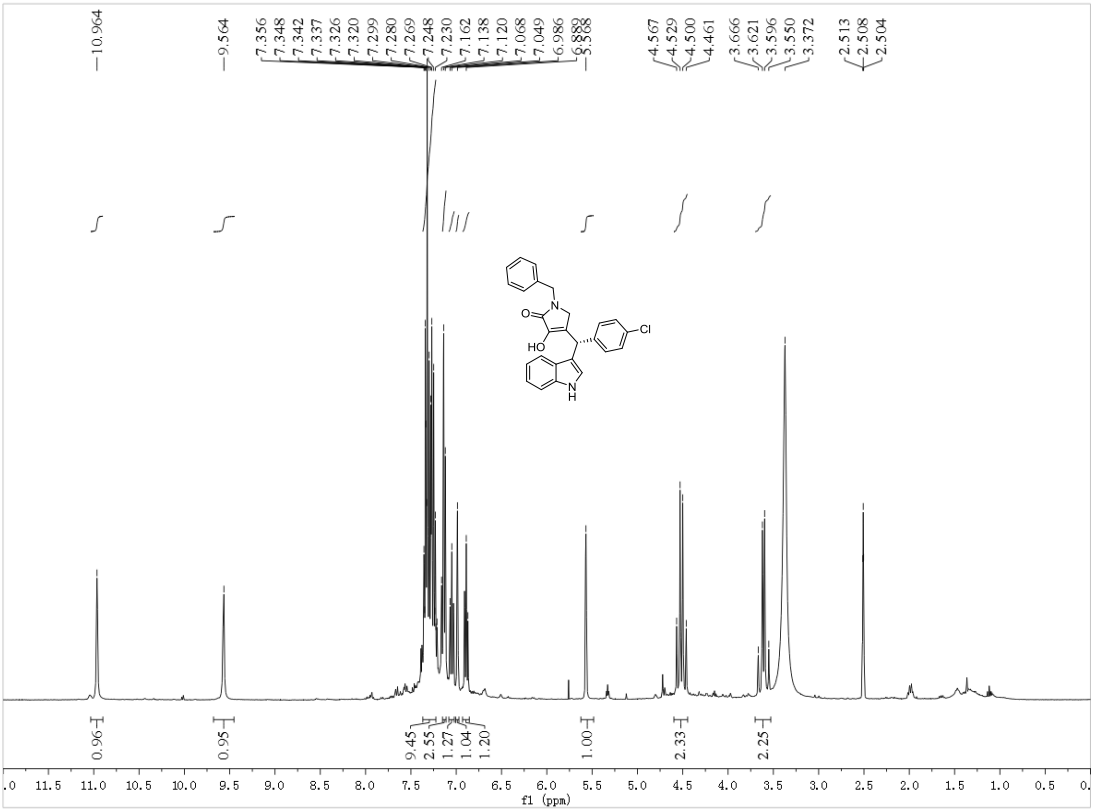


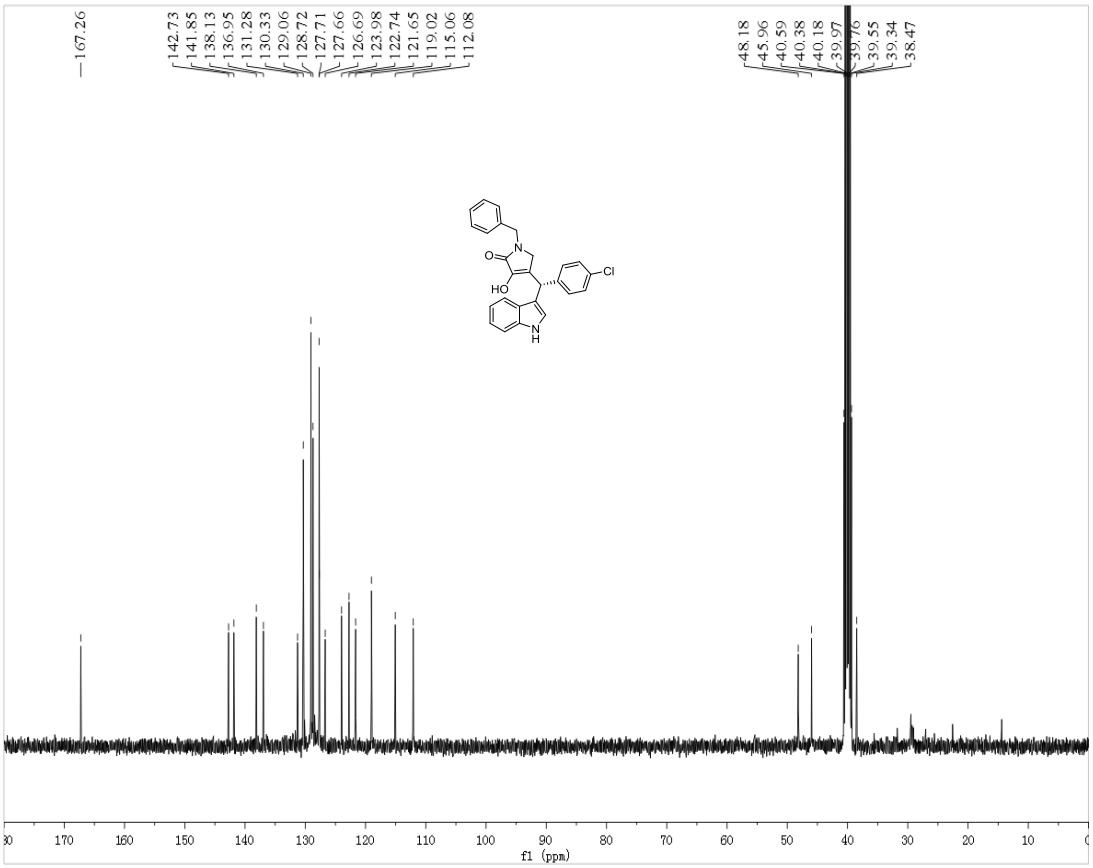
#	Time	Area	Height	Width	Area%	Symmetry
1	9.194	18444.3	397.2	0.7739	50.785	0.548
2	15.231	17874.1	227.5	1.0938	49.215	0.558



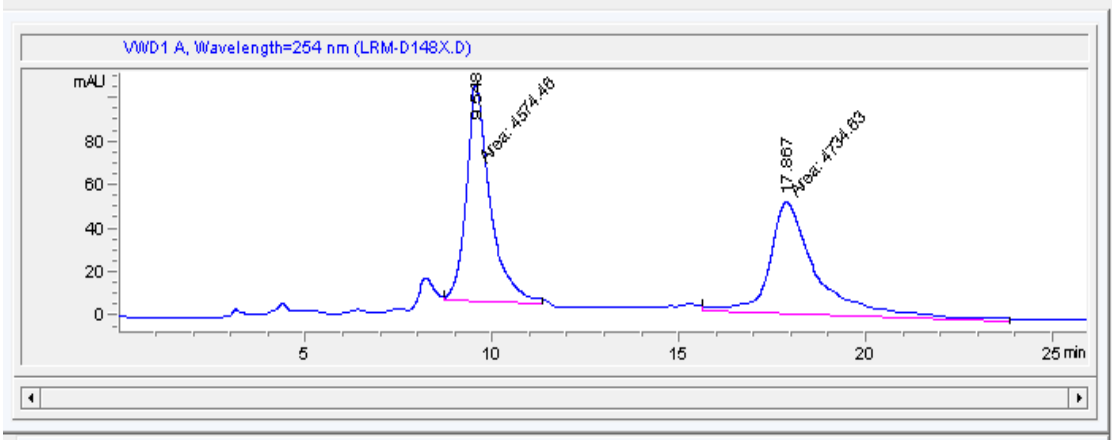
#	Time	Area	Height	Width	Area%	Symmetry
1	9.099	1556.2	36	0.6092	3.168	0.635
2	15.452	47570.1	498.9	1.5892	96.832	0.509

^{1}H and ^{13}C NMR of 6e

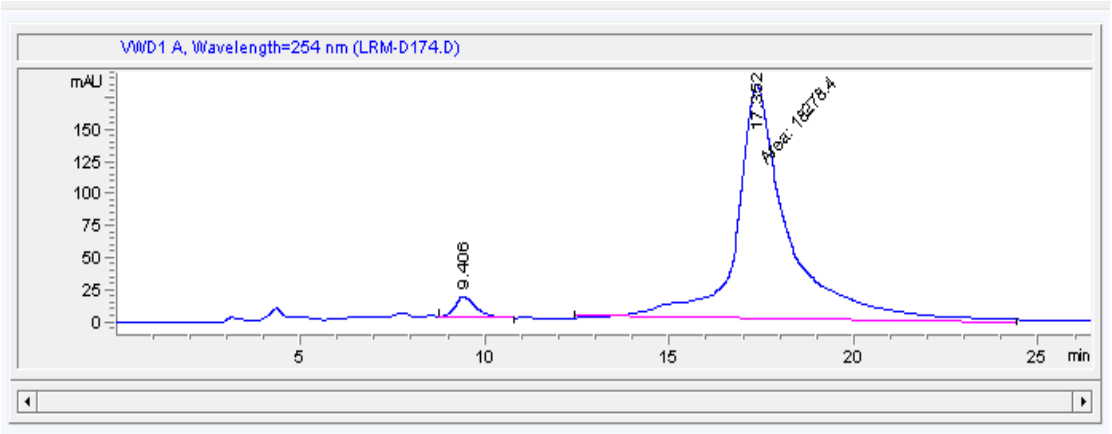




HPLC of **6e**

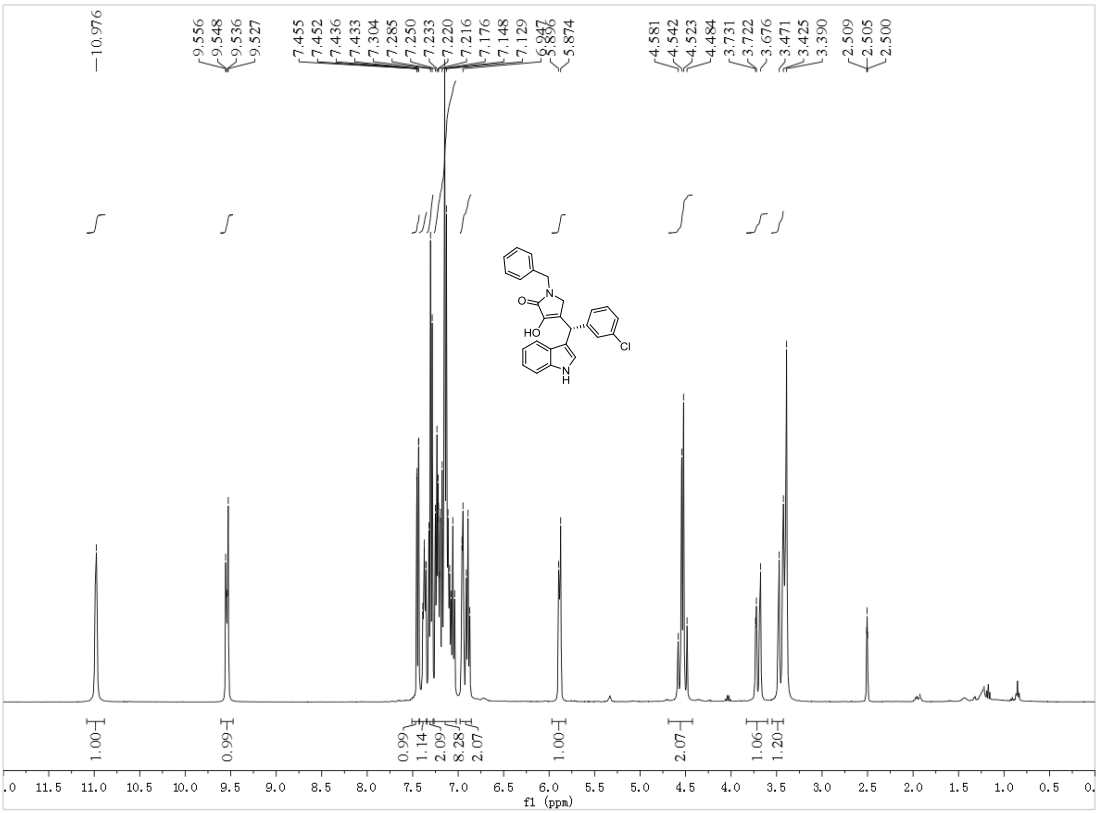


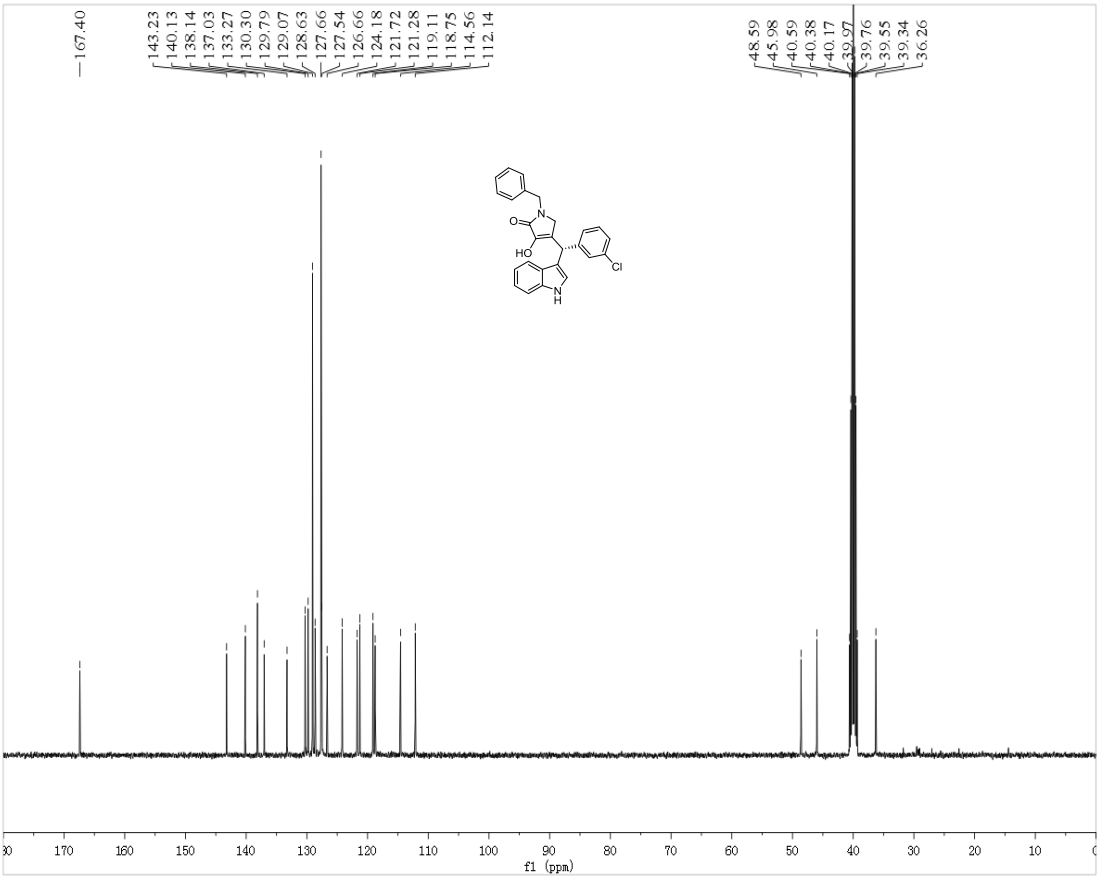
#	Time	Area	Height	Width	Area%	Symmetry
1	9.548	4574.5	100.6	0.7577	49.140	0.664
2	17.867	4734.6	51.6	1.5286	50.860	0.533



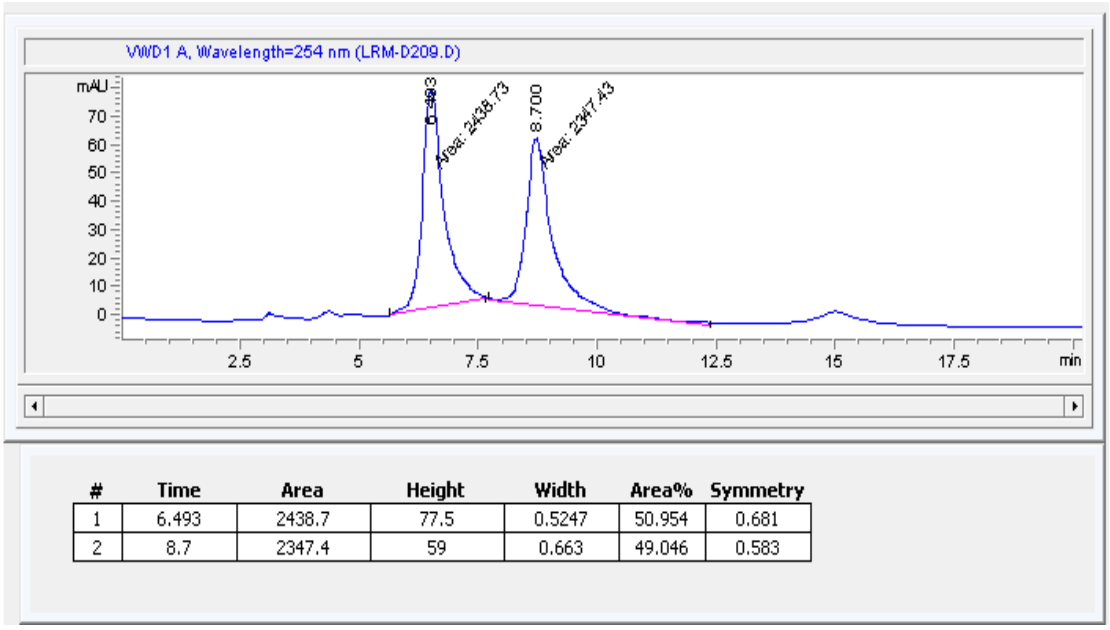
#	Time	Area	Height	Width	Area%	Symmetry
1	9.406	664.2	16.5	0.5925	3.506	0.72
2	17.352	18278.4	183.4	1.6614	96.494	0.647

^{1}H and ^{13}C NMR of 6f

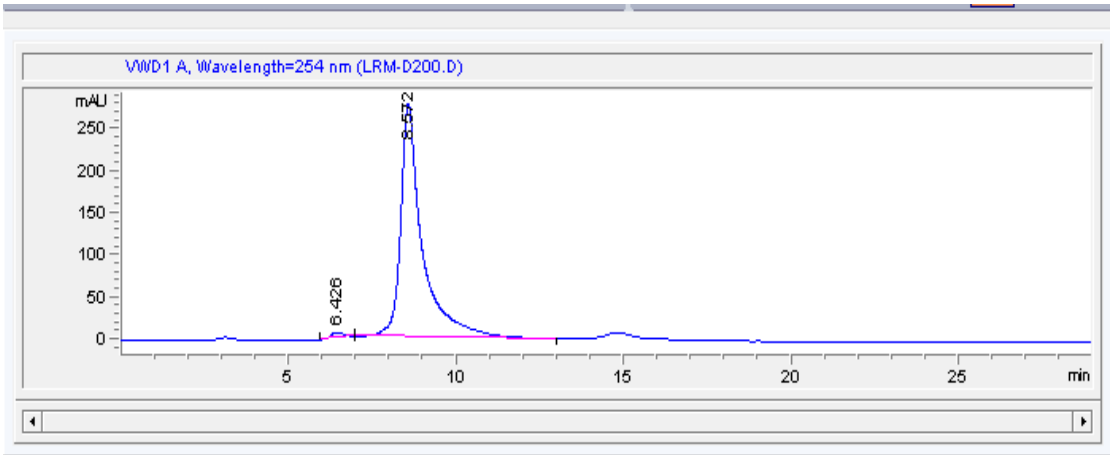




HPLC of **6f**

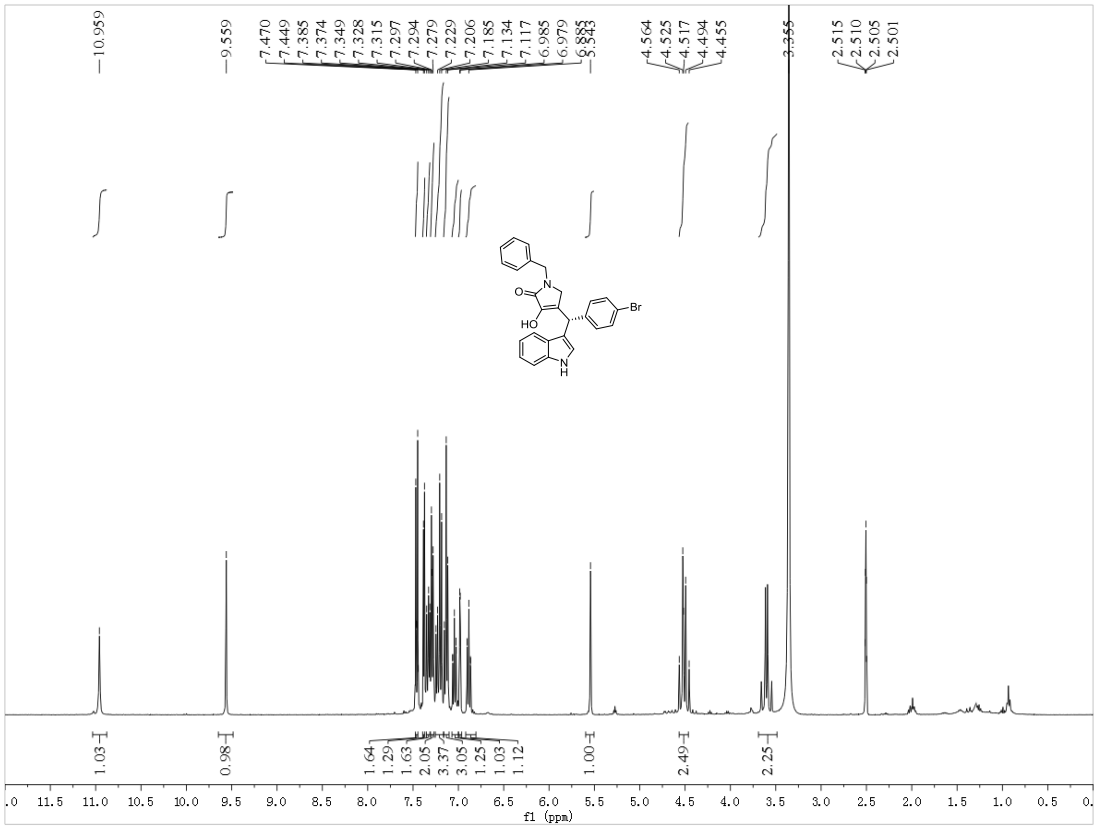


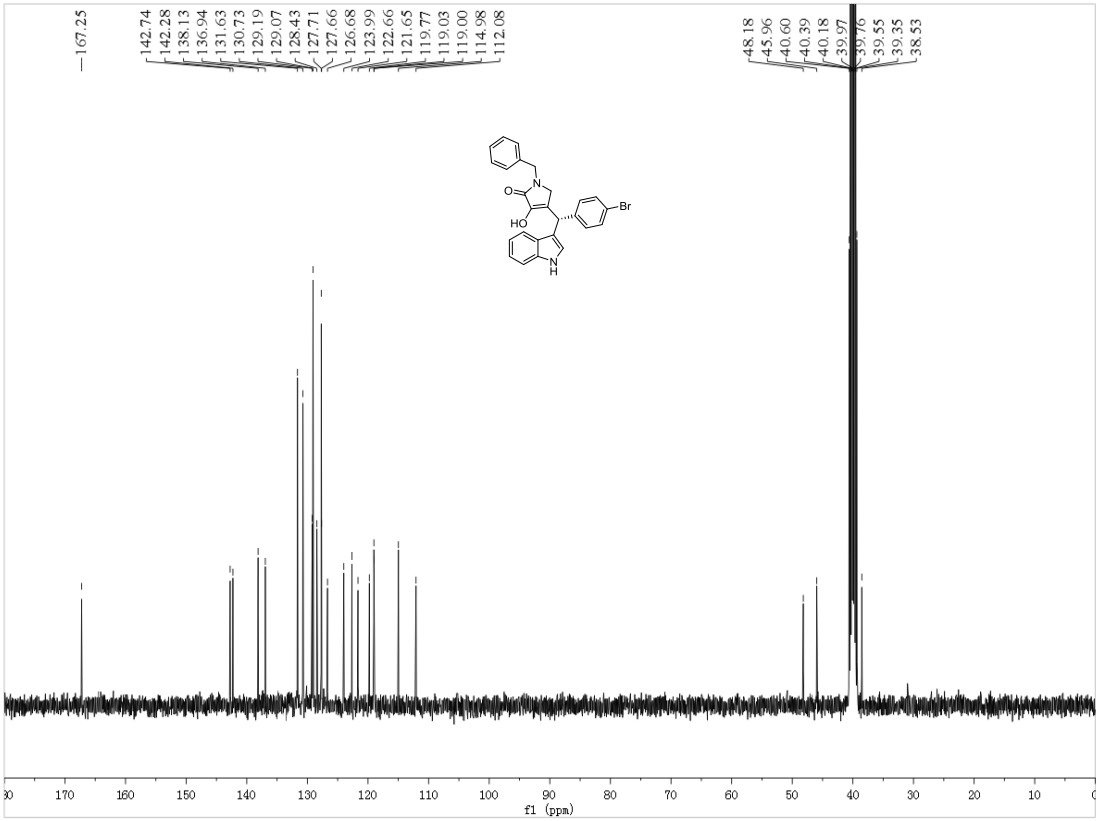
#	Time	Area	Height	Width	Area%	Symmetry
1	6.493	2438.7	77.5	0.5247	50.954	0.681
2	8.7	2347.4	59	0.663	49.046	0.583



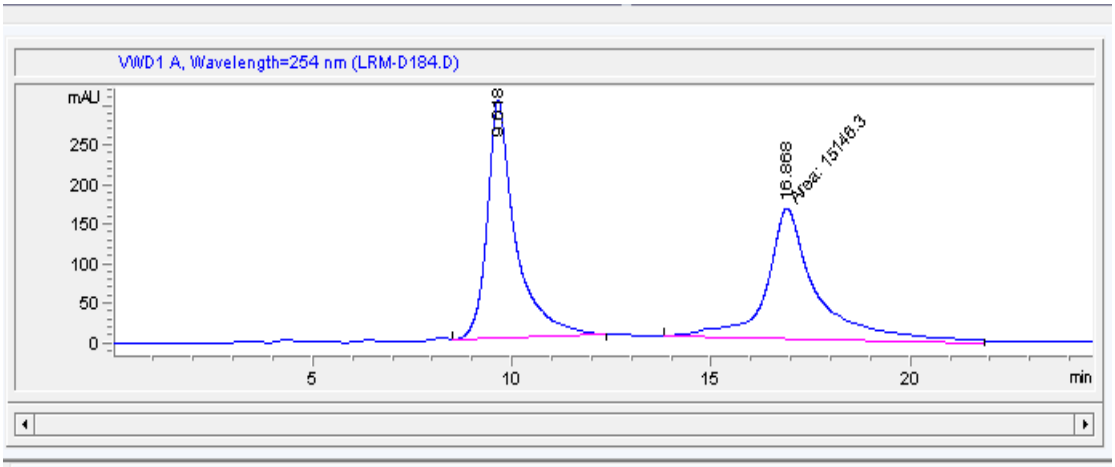
#	Time	Area	Height	Width	Area%	Symmetry
1	6.426	173.7	6.9	0.3683	1.381	0.818
2	8.572	12401.4	278.1	0.6173	98.619	0.505

^{1}H and ^{13}C NMR of 6g

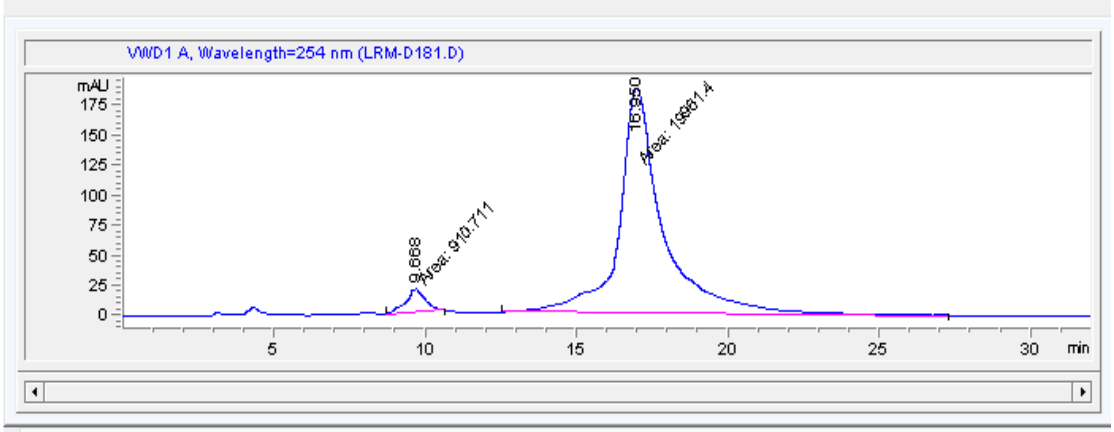




HPLC of **6g**

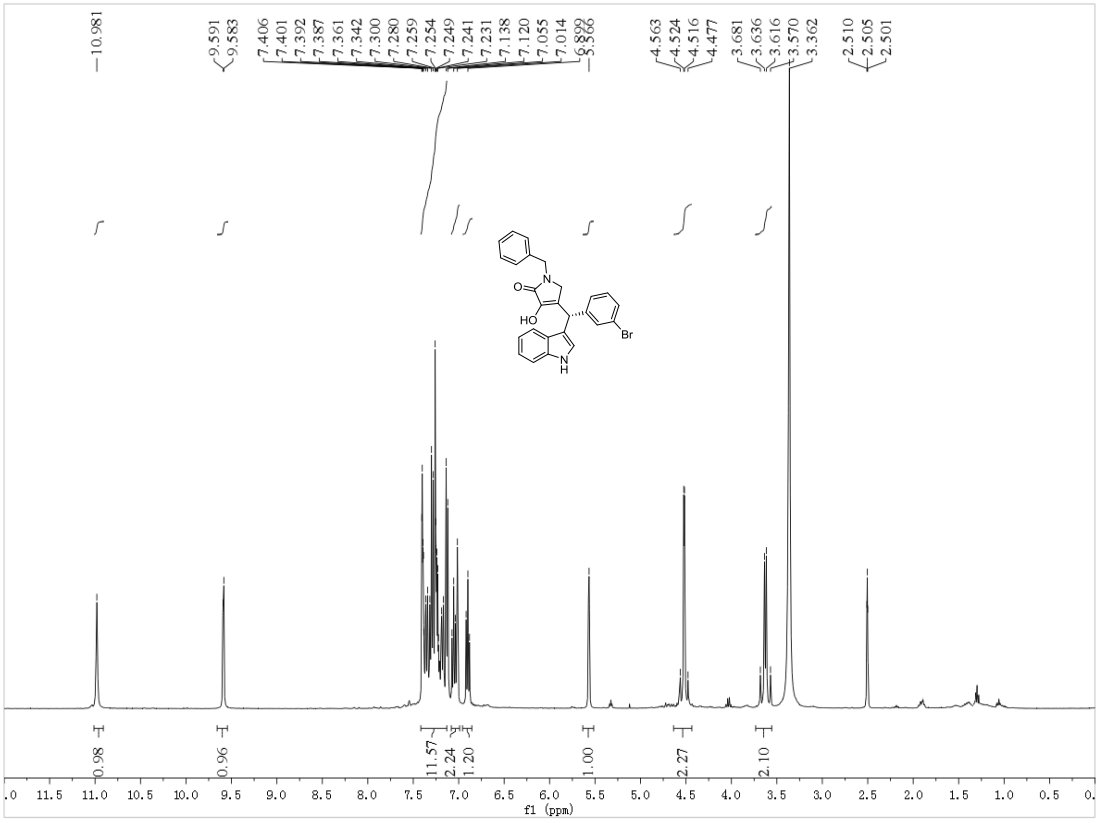


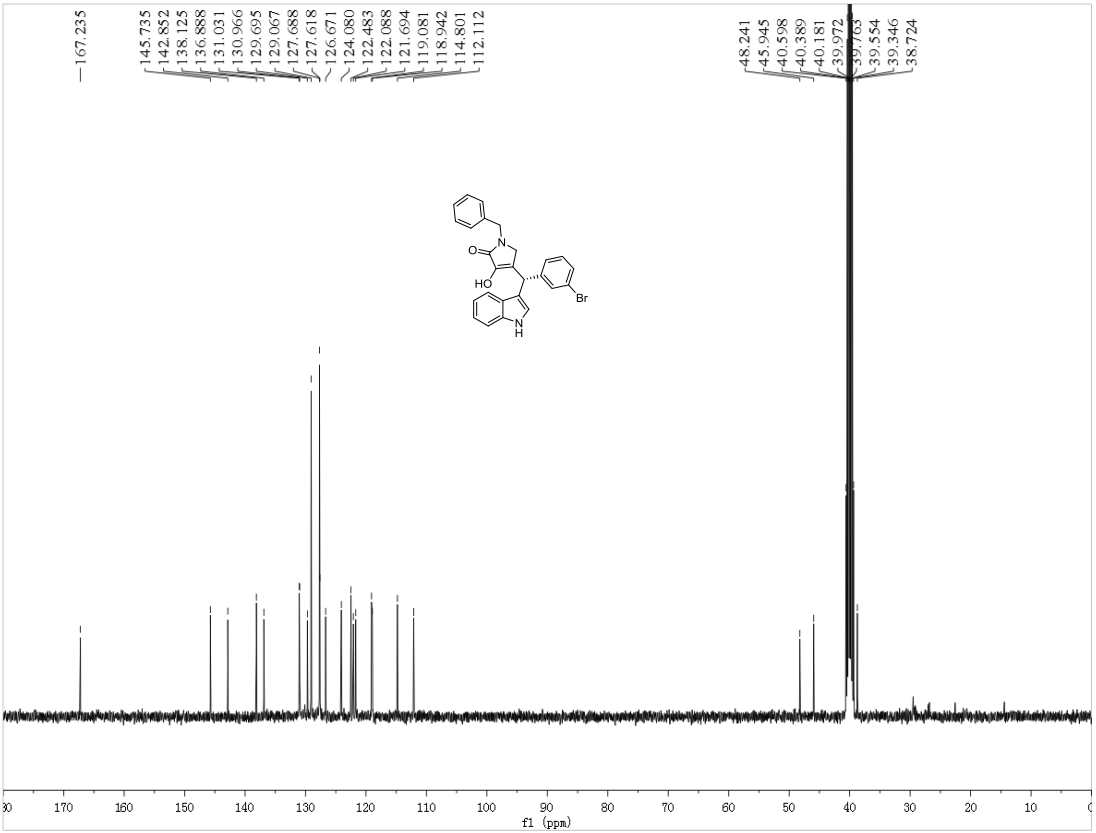
#	Time	Area	Height	Width	Area%	Symmetry
1	9.618	14966.2	301.8	0.6955	49.701	0.575
2	16.868	15146.3	165.8	1.5223	50.299	0.645



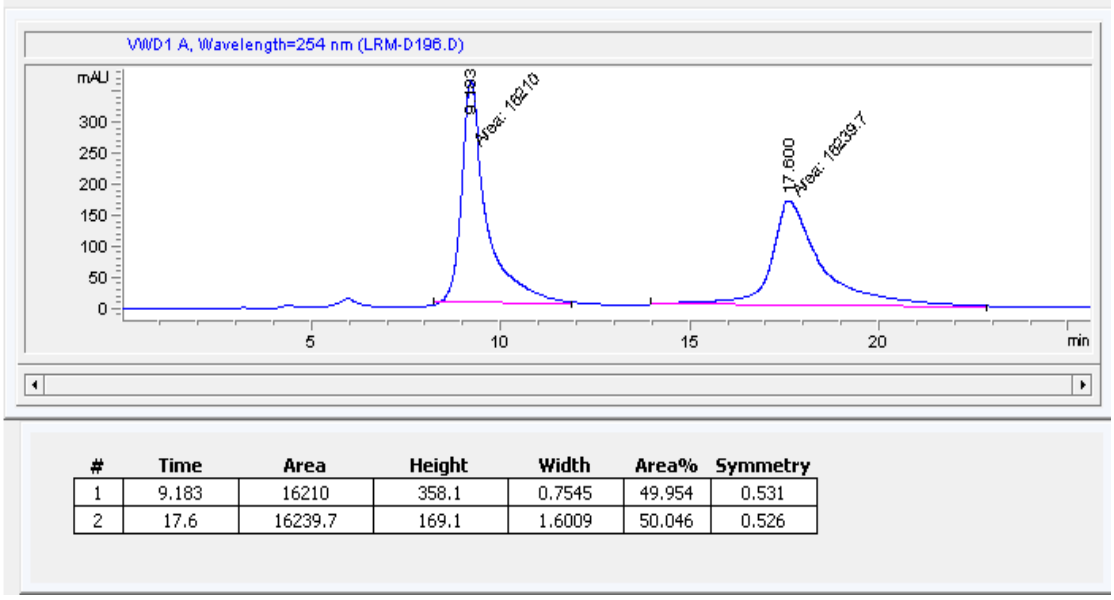
#	Time	Area	Height	Width	Area%	Symmetry
1	9.668	910.7	19.6	0.7742	4.363	1.071
2	16.95	19961.4	188	1.7695	95.637	0.614

^{1}H and ^{13}C NMR of 6h

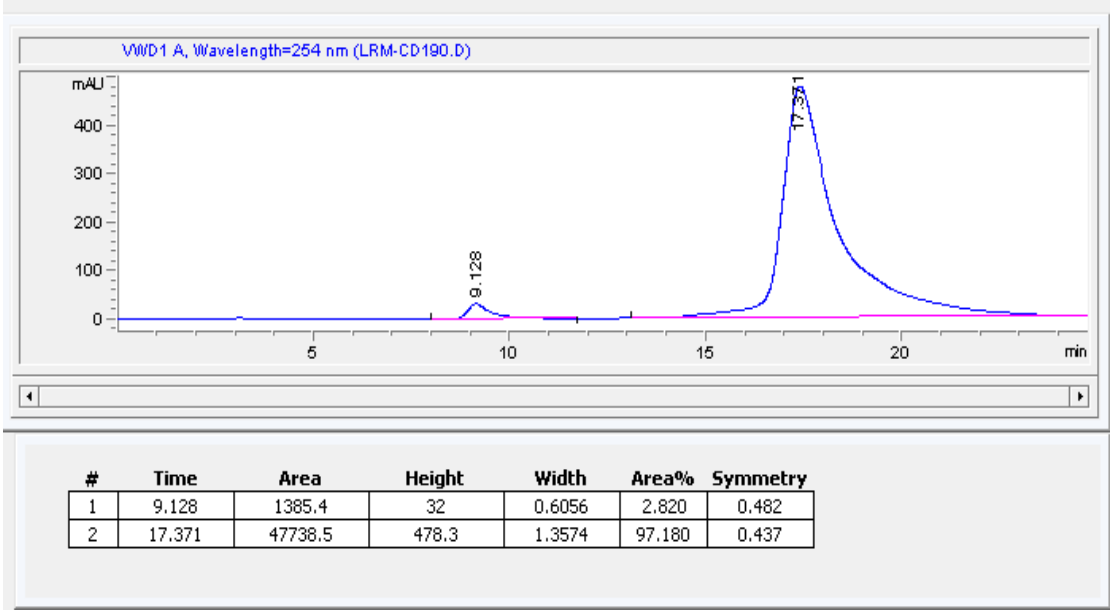




HPLC of **6h**

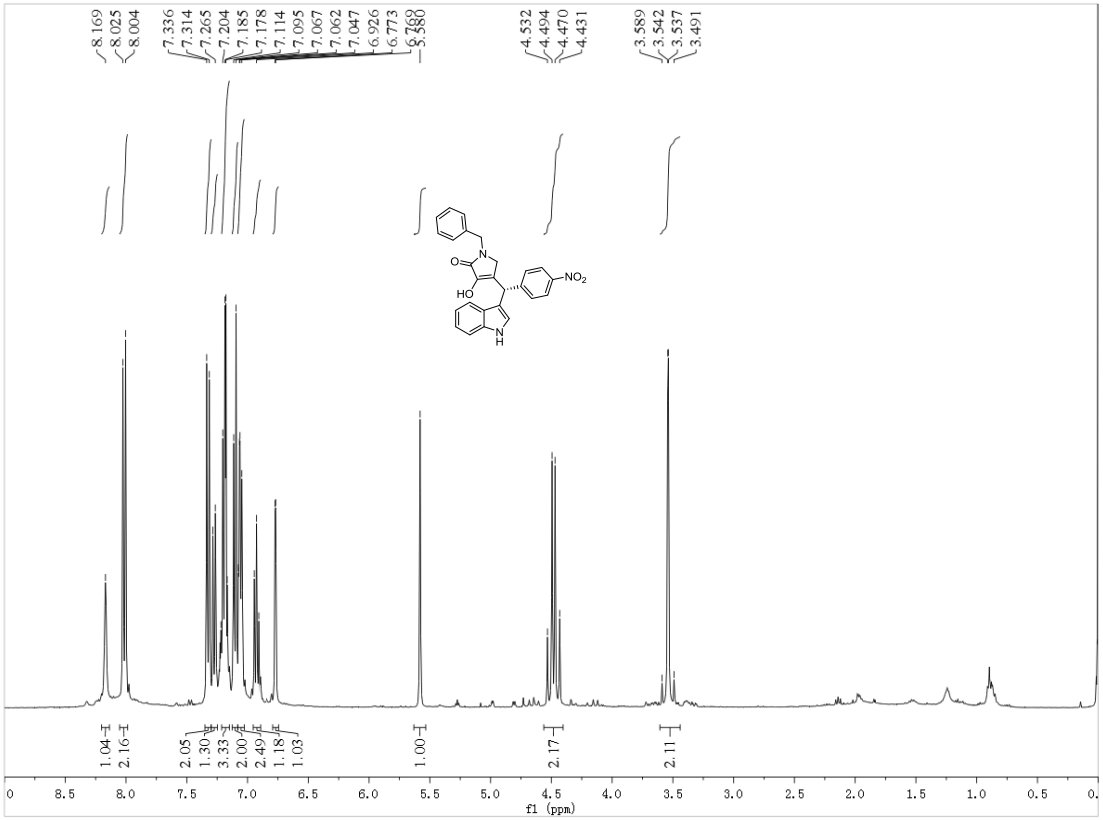


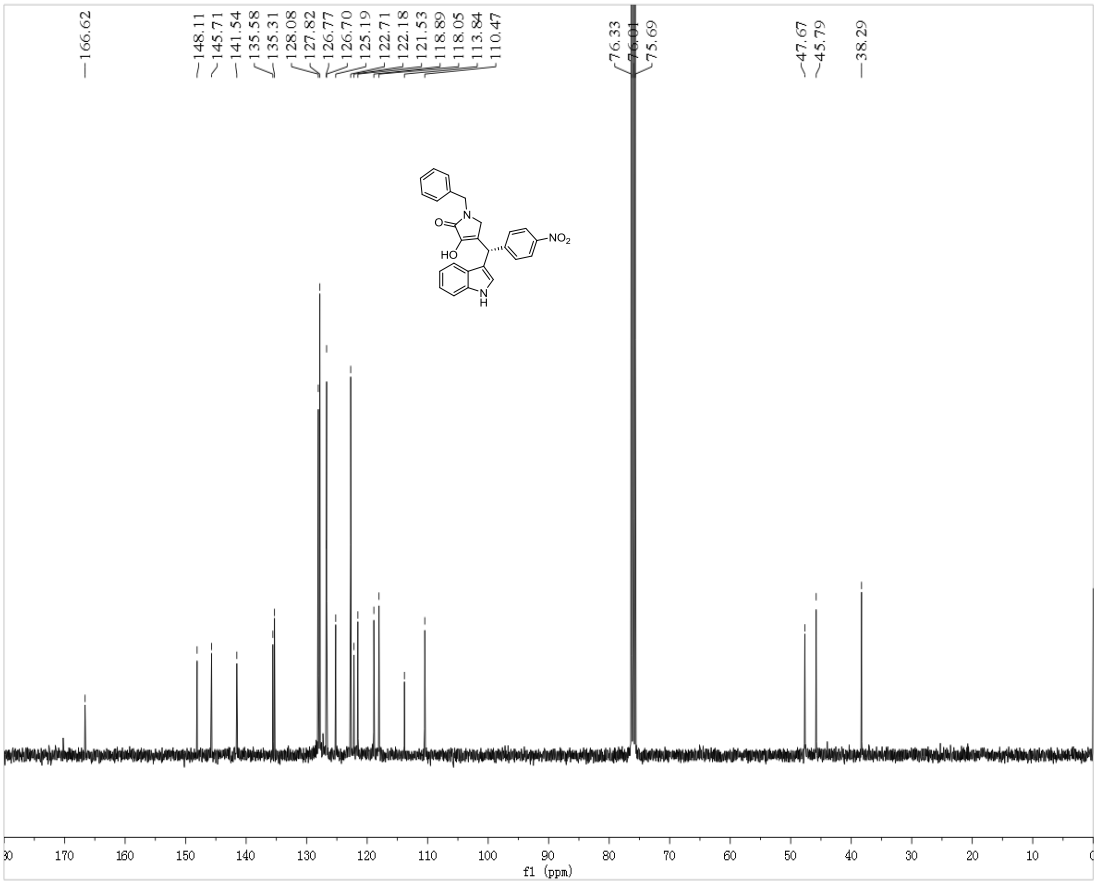
#	Time	Area	Height	Width	Area%	Symmetry
1	9.183	16210	358.1	0.7545	49.954	0.531
2	17.6	16239.7	169.1	1.6009	50.046	0.526



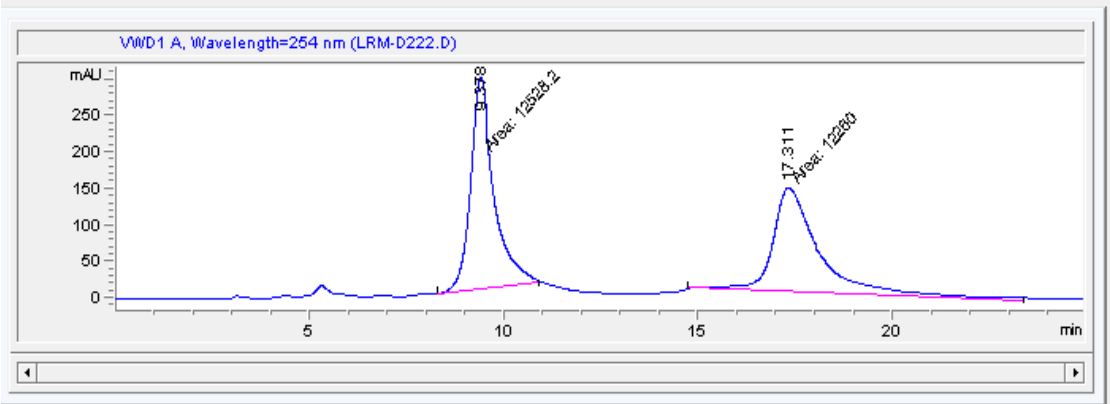
#	Time	Area	Height	Width	Area%	Symmetry
1	9.128	1385.4	32	0.6056	2.820	0.482
2	17.371	47738.5	478.3	1.3574	97.180	0.437

^{1}H and ^{13}C NMR of 6i

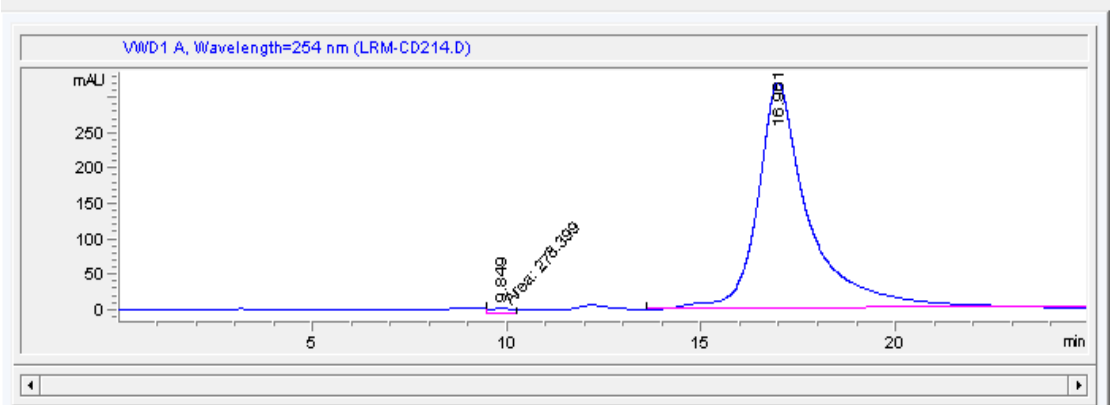




HPLC of **6i**

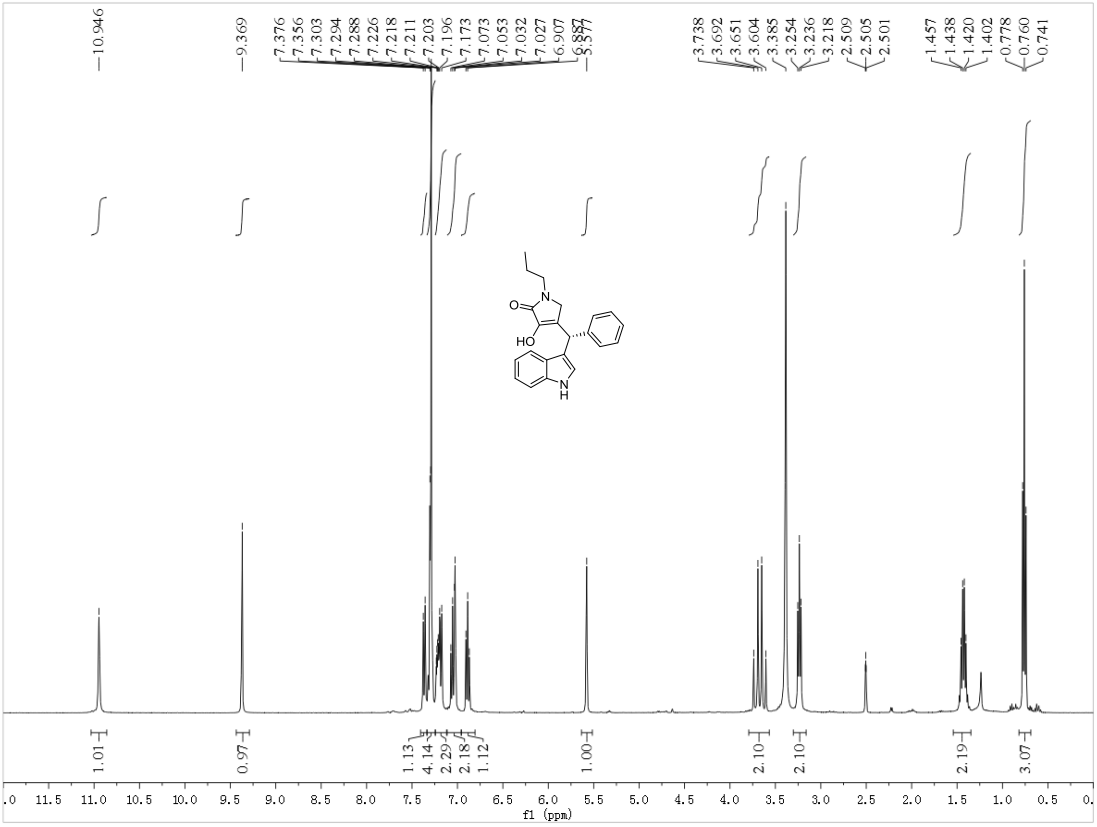


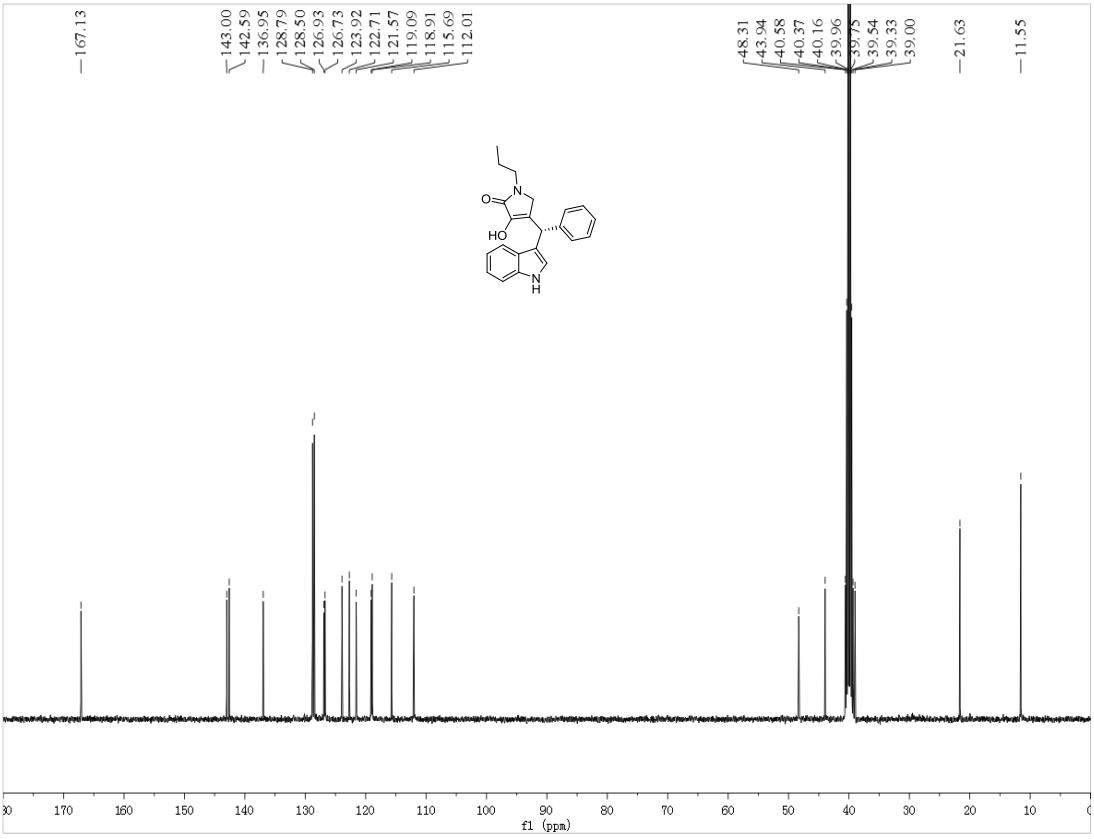
#	Time	Area	Height	Width	Area%	Symmetry
1	9.378	12528.2	291.9	0.7152	50.541	0.711
2	17.311	12260	143.7	1.4223	49.459	0.518



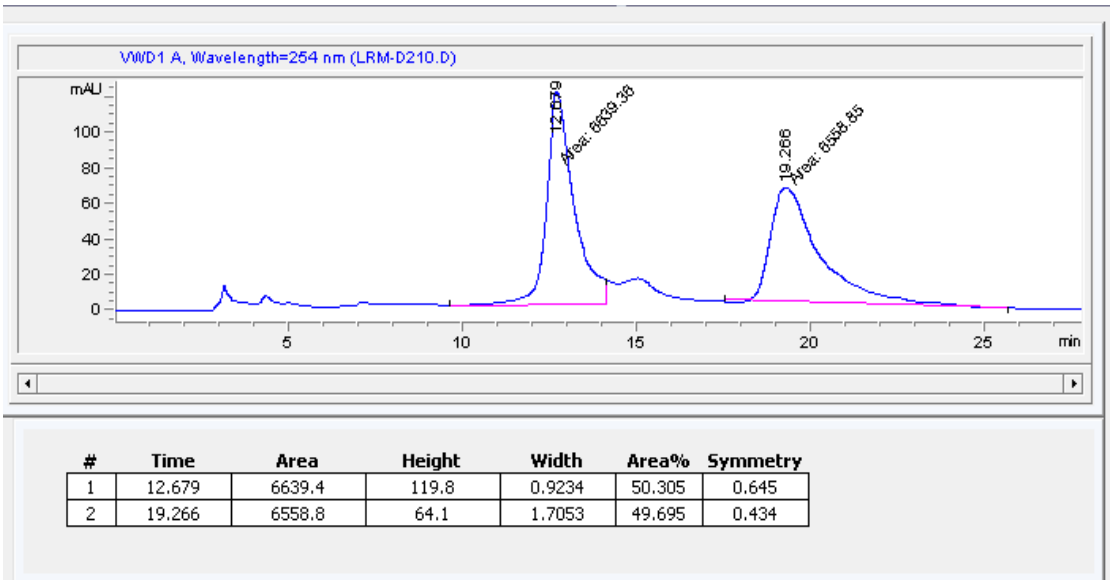
#	Time	Area	Height	Width	Area%	Symmetry
1	9.849	278.4	6.3	0.7395	0.926	0.842
2	16.961	29799.3	320.3	1.2906	99.074	0.608

^{1}H and ^{13}C NMR of 6j

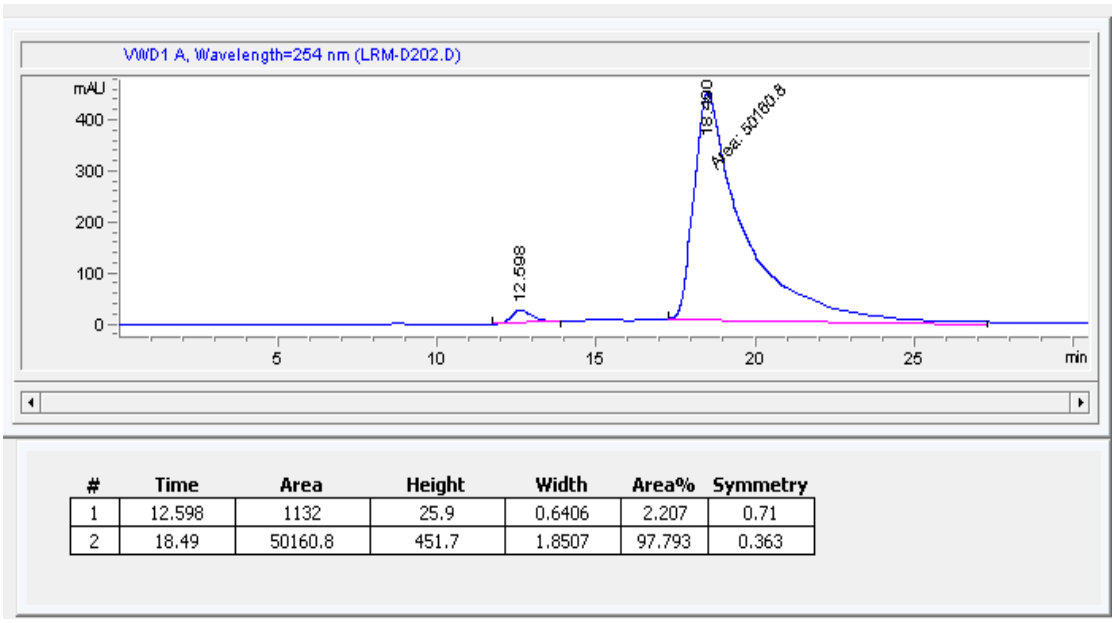




HPLC of **6j**

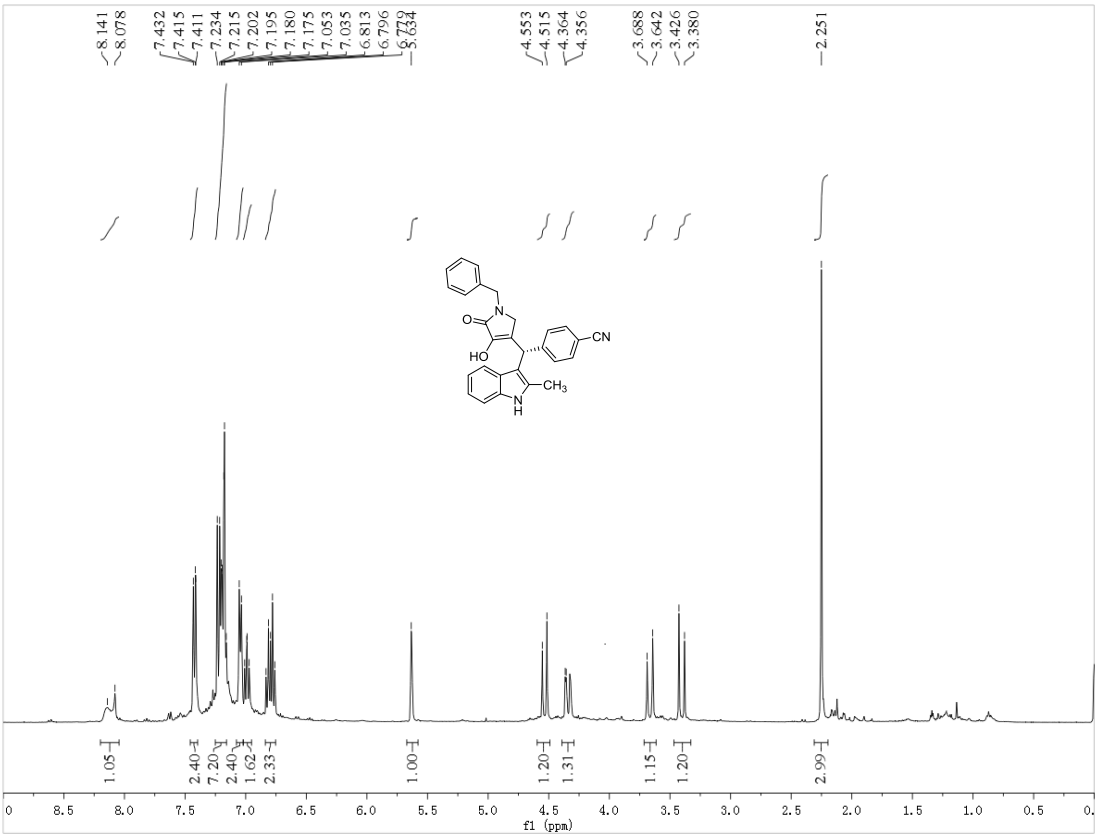


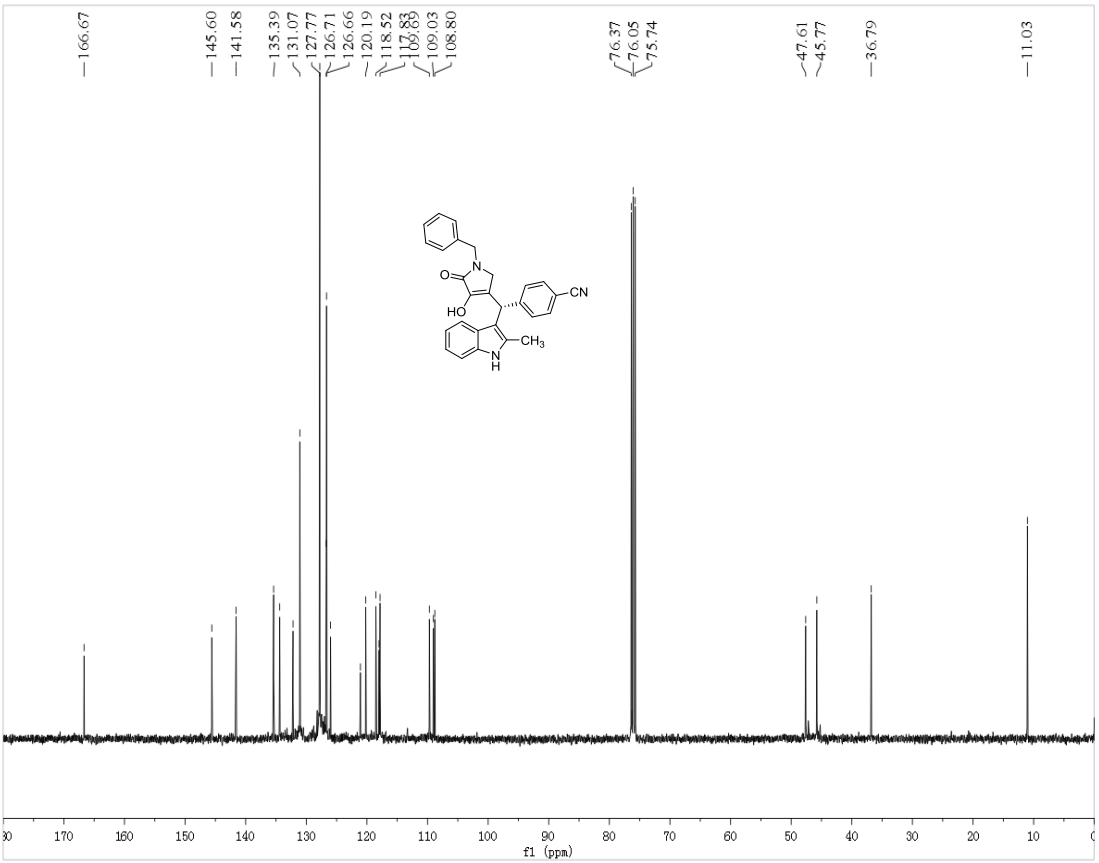
#	Time	Area	Height	Width	Area%	Symmetry
1	12.679	6639.4	119.8	0.9234	50.305	0.645
2	19.266	6558.8	64.1	1.7053	49.695	0.434



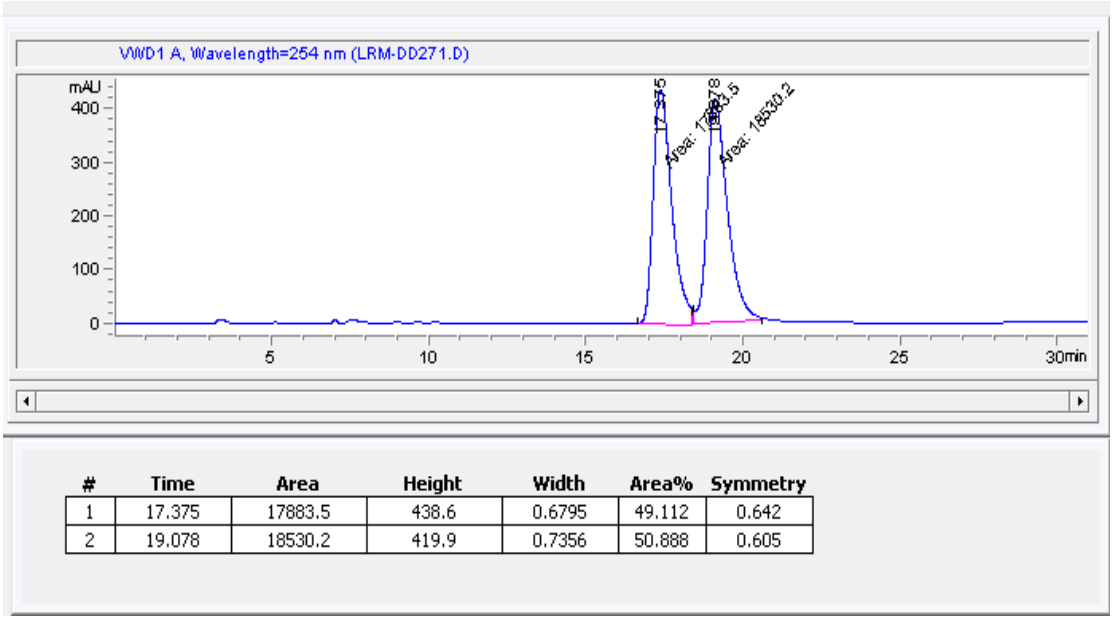
#	Time	Area	Height	Width	Area%	Symmetry
1	12.598	1132	25.9	0.6406	2.207	0.71
2	18.49	50160.8	451.7	1.8507	97.793	0.363

^{1}H and ^{13}C NMR of 6k

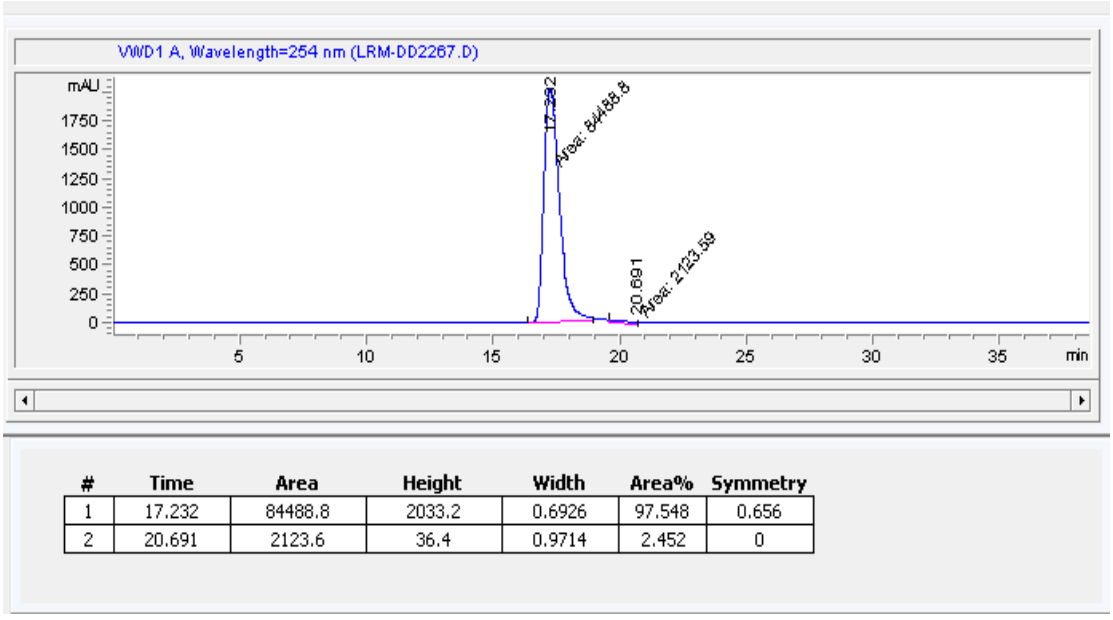




HPLC of **6k**

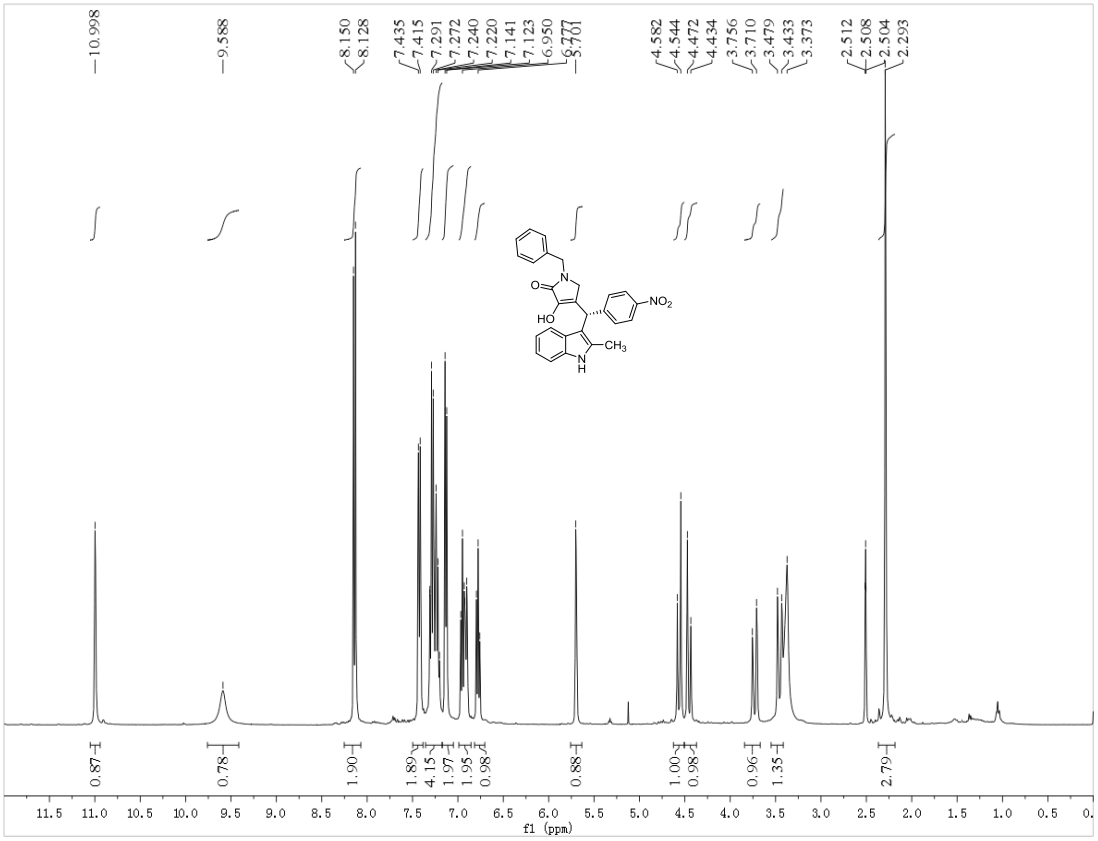


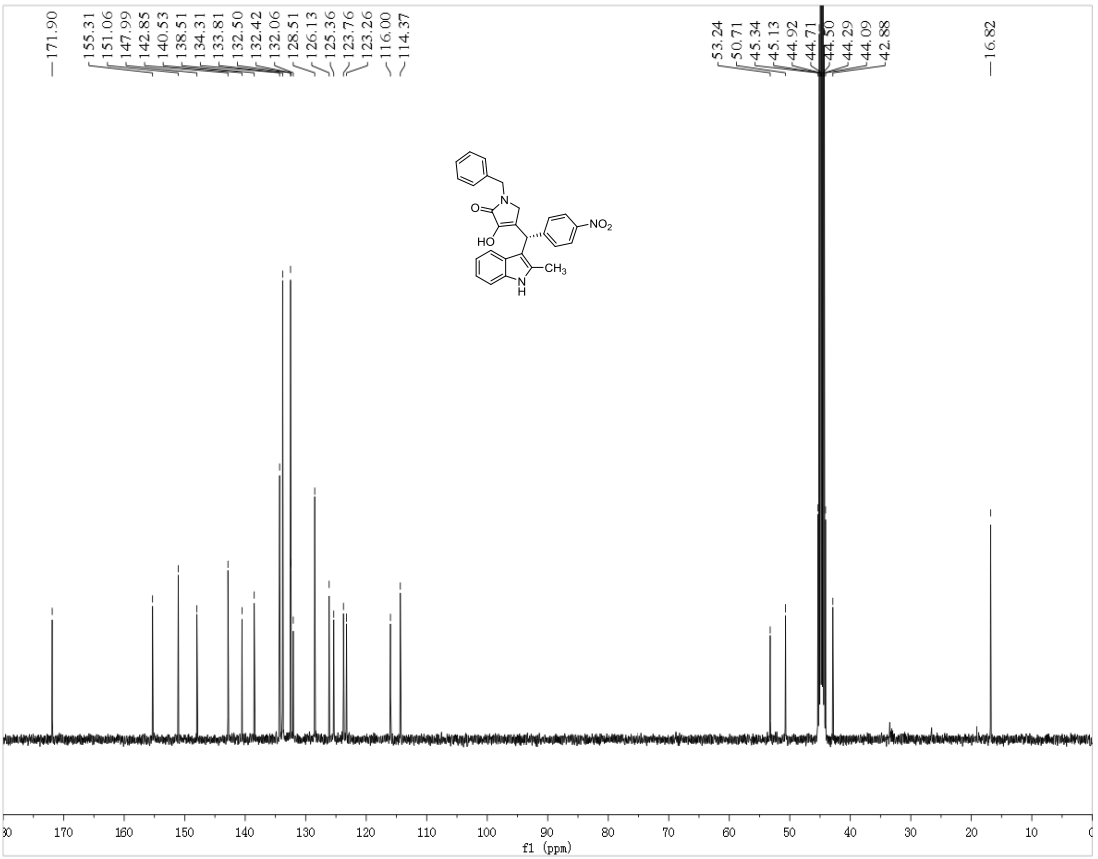
#	Time	Area	Height	Width	Area%	Symmetry
1	17.375	17883.5	438.6	0.6795	49.112	0.642
2	19.078	18530.2	419.9	0.7356	50.888	0.605



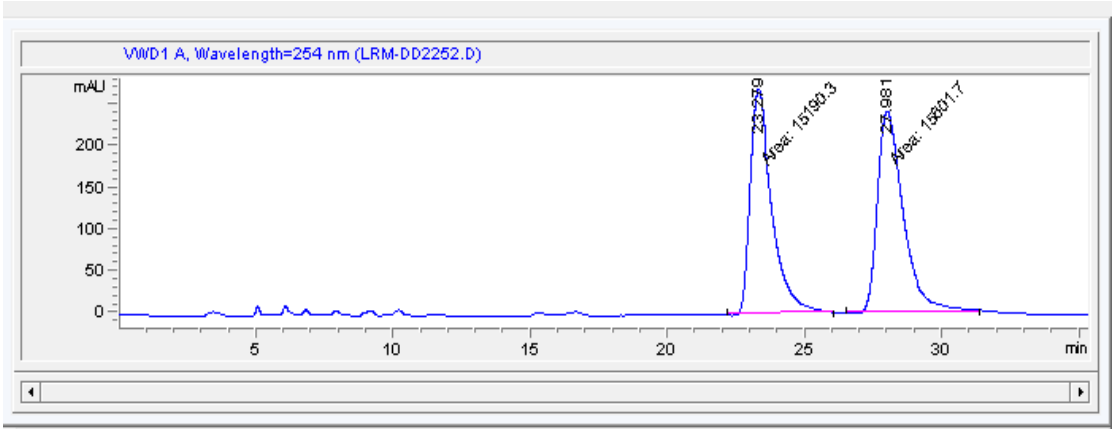
#	Time	Area	Height	Width	Area%	Symmetry
1	17.232	84488.8	2033.2	0.6926	97.548	0.656
2	20.691	2123.6	36.4	0.9714	2.452	0

^{1}H and ^{13}C NMR of 6l

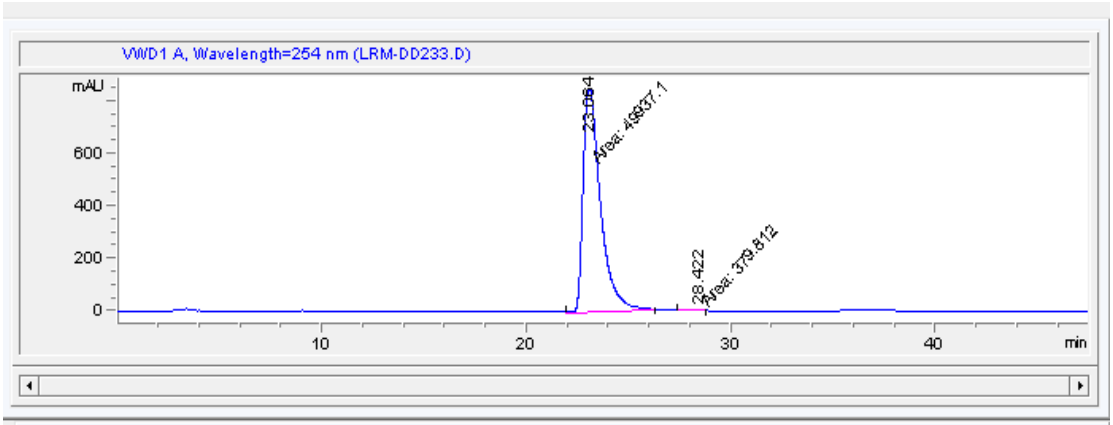




HPLC of **6l**

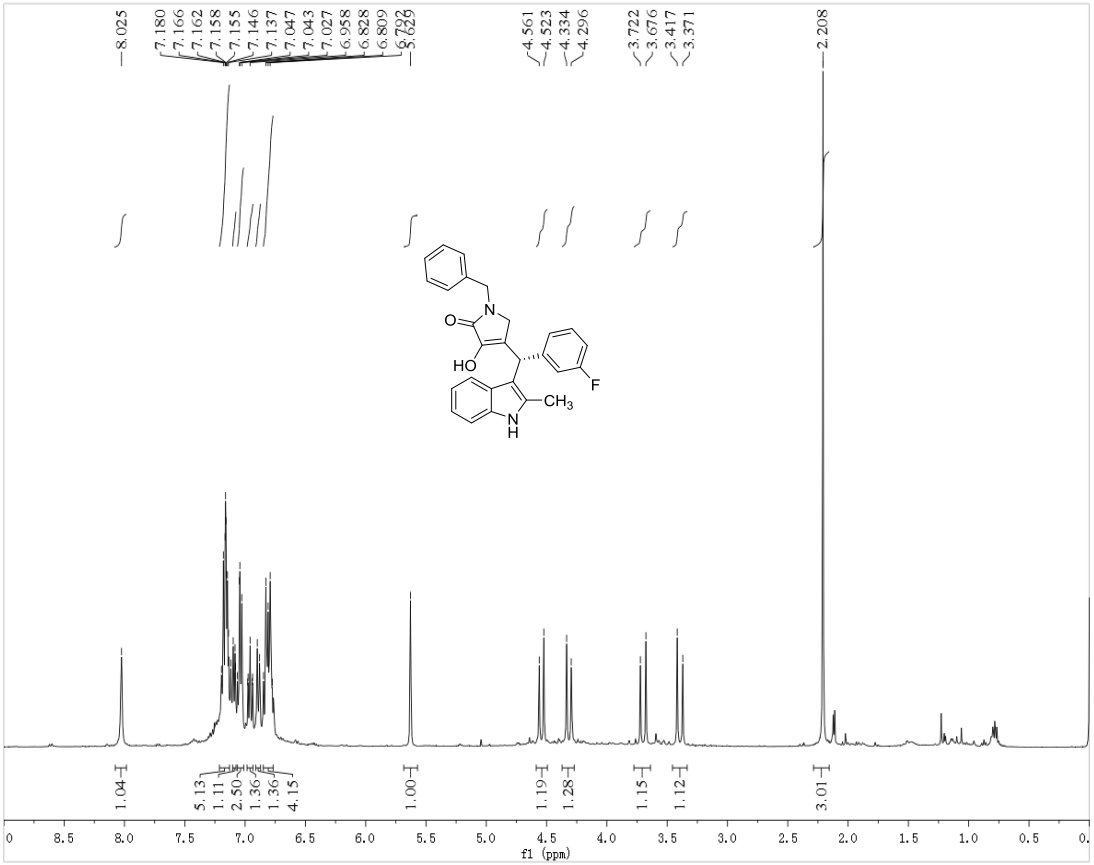


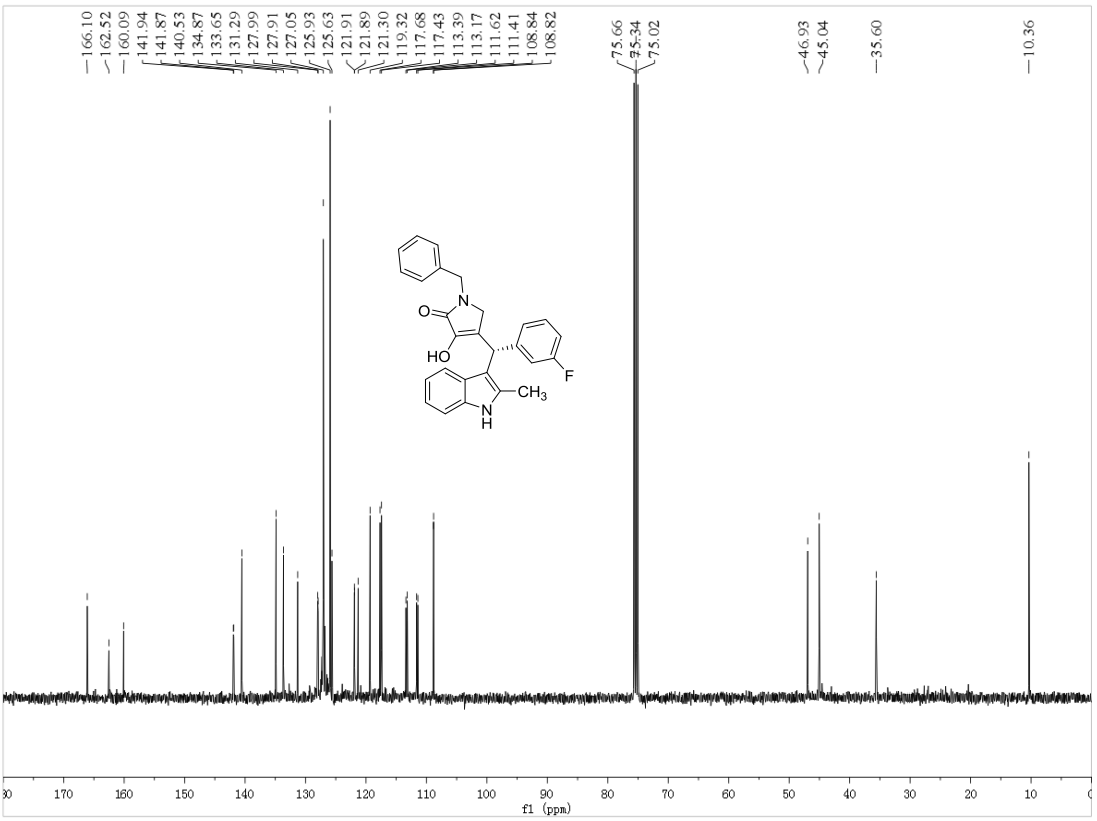
#	Time	Area	Height	Width	Area%	Symmetry
1	23.279	15190.3	270	0.9378	49.332	0.565
2	27.981	15601.7	241.2	1.0782	50.668	0.572



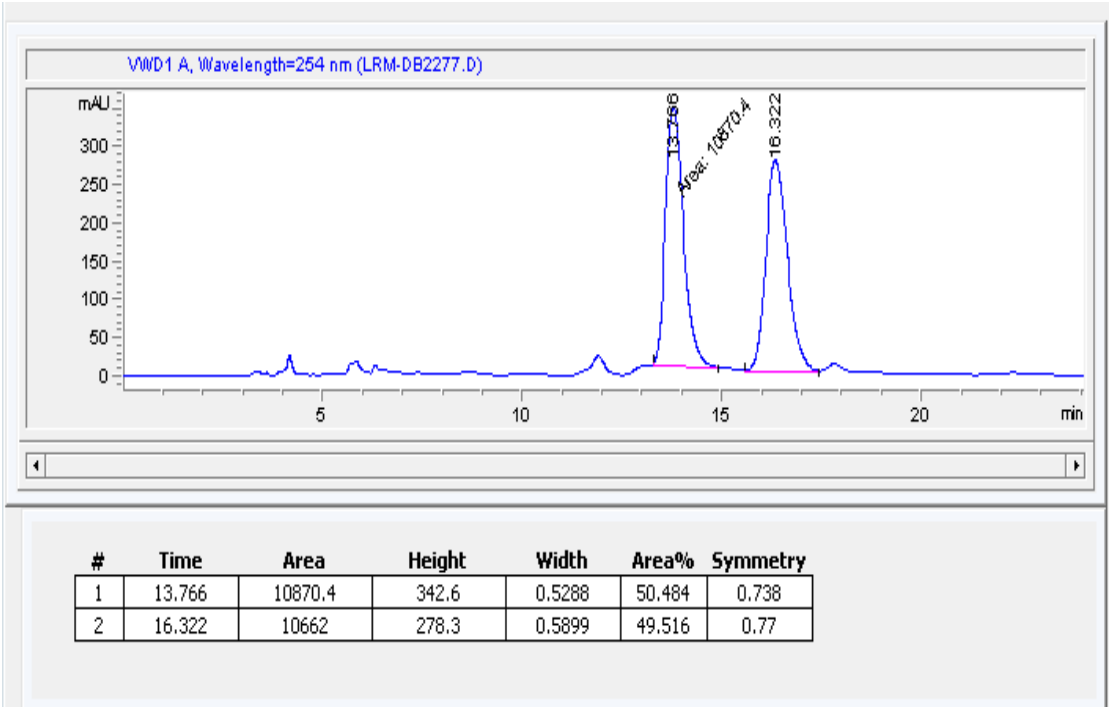
#	Time	Area	Height	Width	Area%	Symmetry
1	23.064	49937.1	853.3	0.9754	99.245	0.553
2	28.422	379.8	4.9	1.2889	0.755	2.706

^{1}H and ^{13}C NMR of 6m

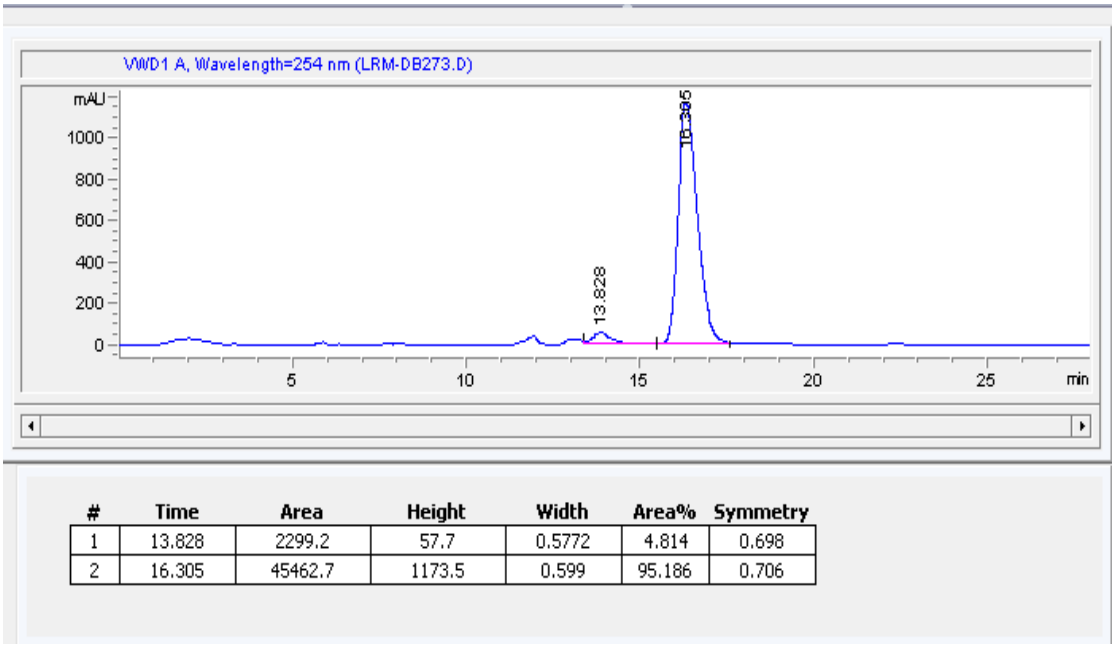




HPLC of **6m**

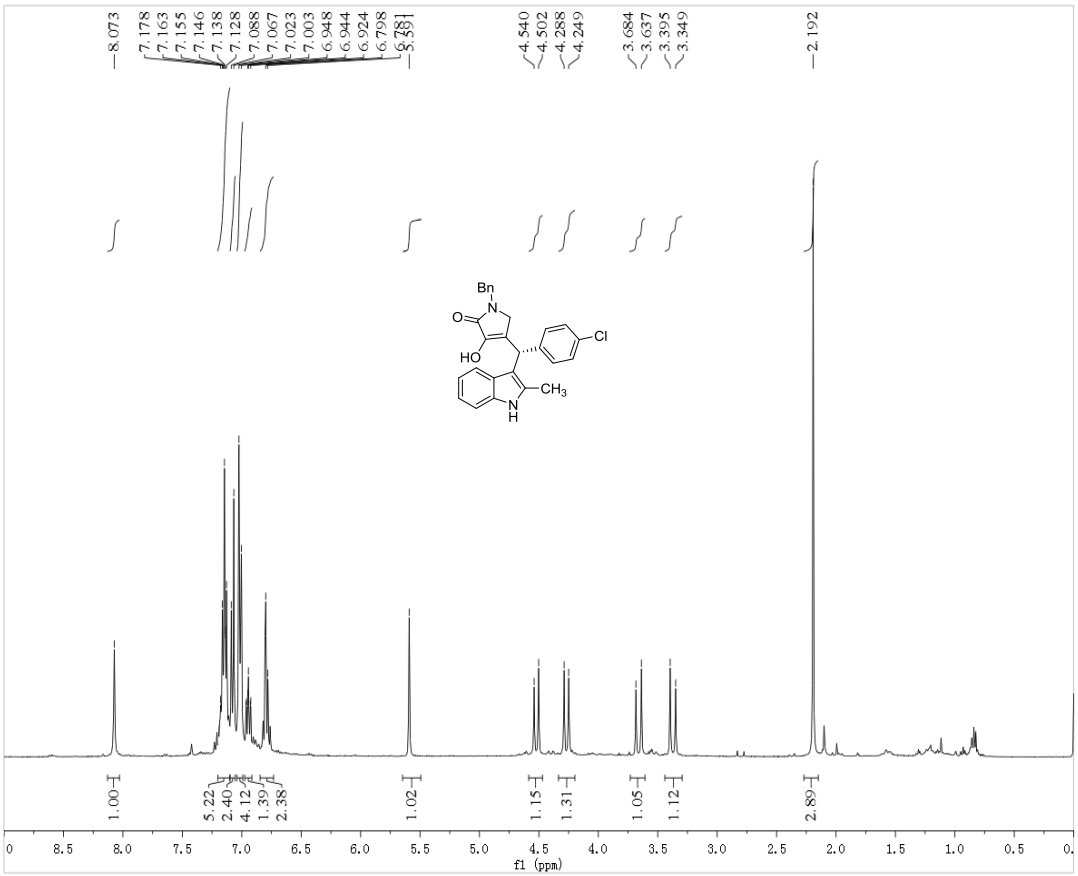


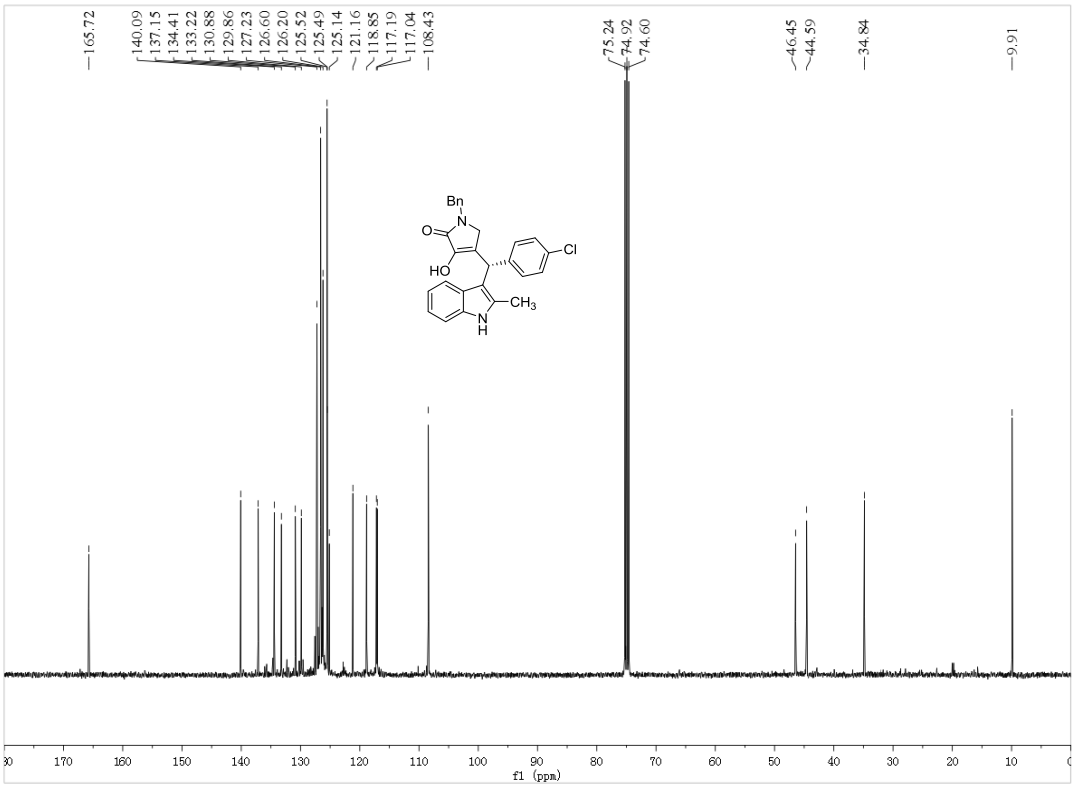
#	Time	Area	Height	Width	Area%	Symmetry
1	13.766	10870.4	342.6	0.5288	50.484	0.738
2	16.322	10662	278.3	0.5899	49.516	0.77



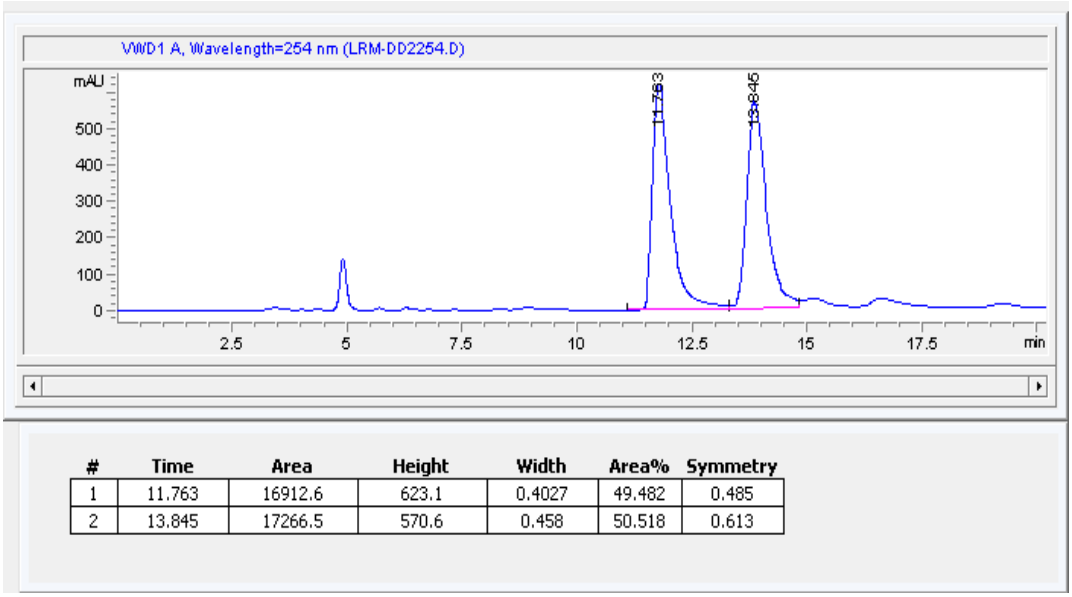
#	Time	Area	Height	Width	Area%	Symmetry
1	13.828	2299.2	57.7	0.5772	4.814	0.698
2	16.305	45462.7	1173.5	0.599	95.186	0.706

^{1}H and ^{13}C NMR of 6n

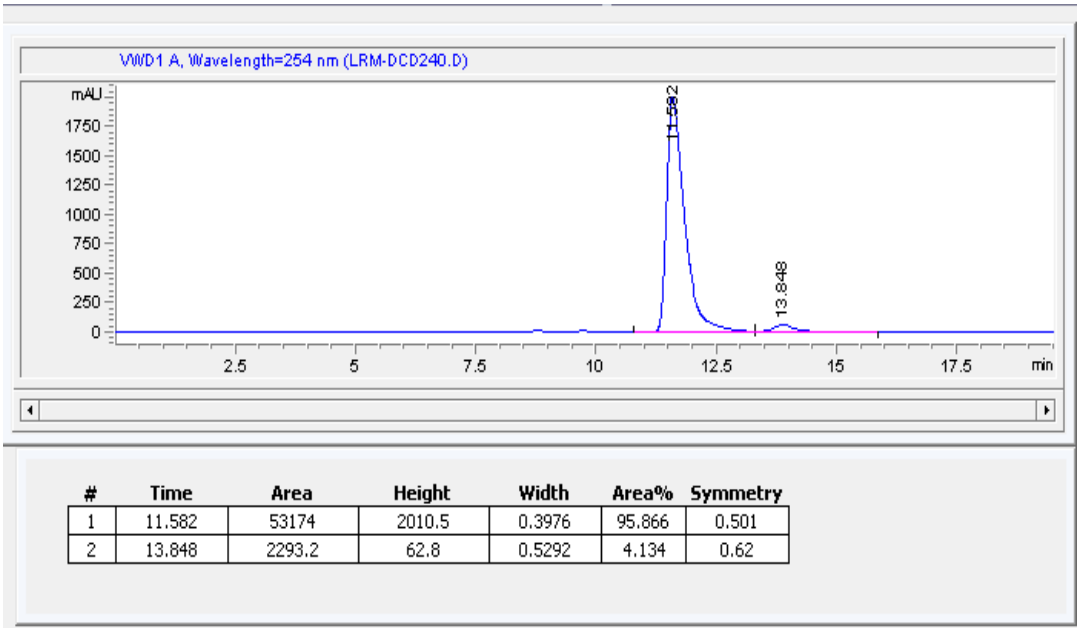




HPLC of **6n**

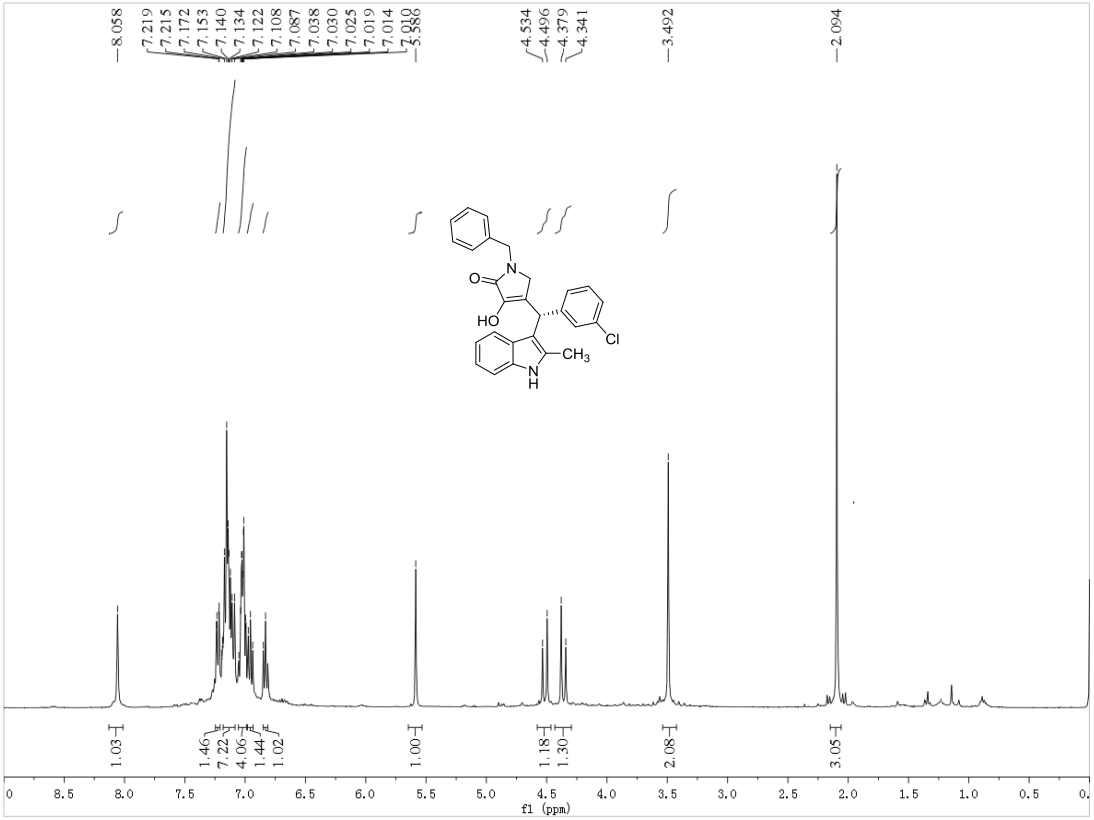


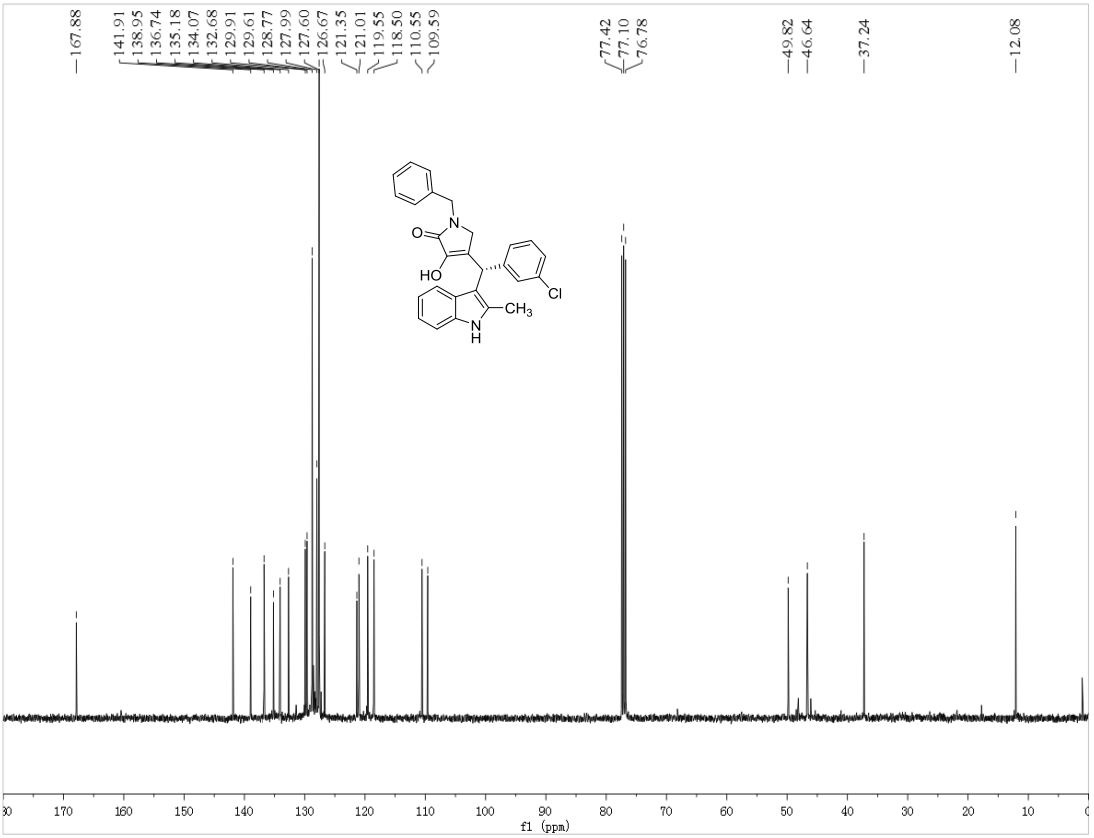
#	Time	Area	Height	Width	Area%	Symmetry
1	11.763	16912.6	623.1	0.4027	49.482	0.485
2	13.845	17266.5	570.6	0.458	50.518	0.613



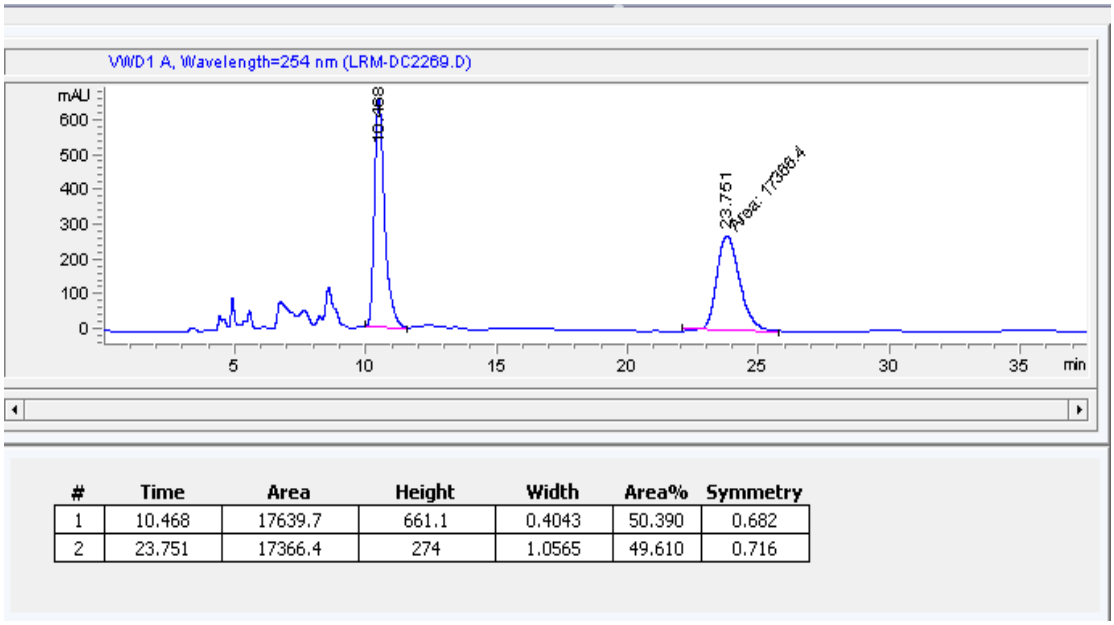
#	Time	Area	Height	Width	Area%	Symmetry
1	11.582	53174	2010.5	0.3976	95.866	0.501
2	13.848	2293.2	62.8	0.5292	4.134	0.62

^{1}H and ^{13}C NMR of 6o

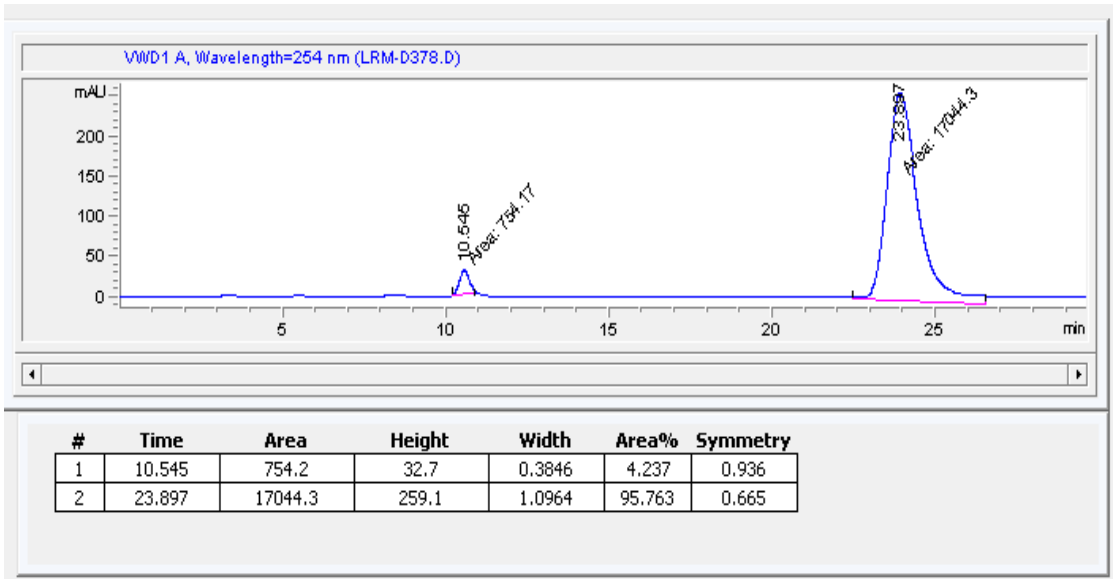




HPLC of **6o**

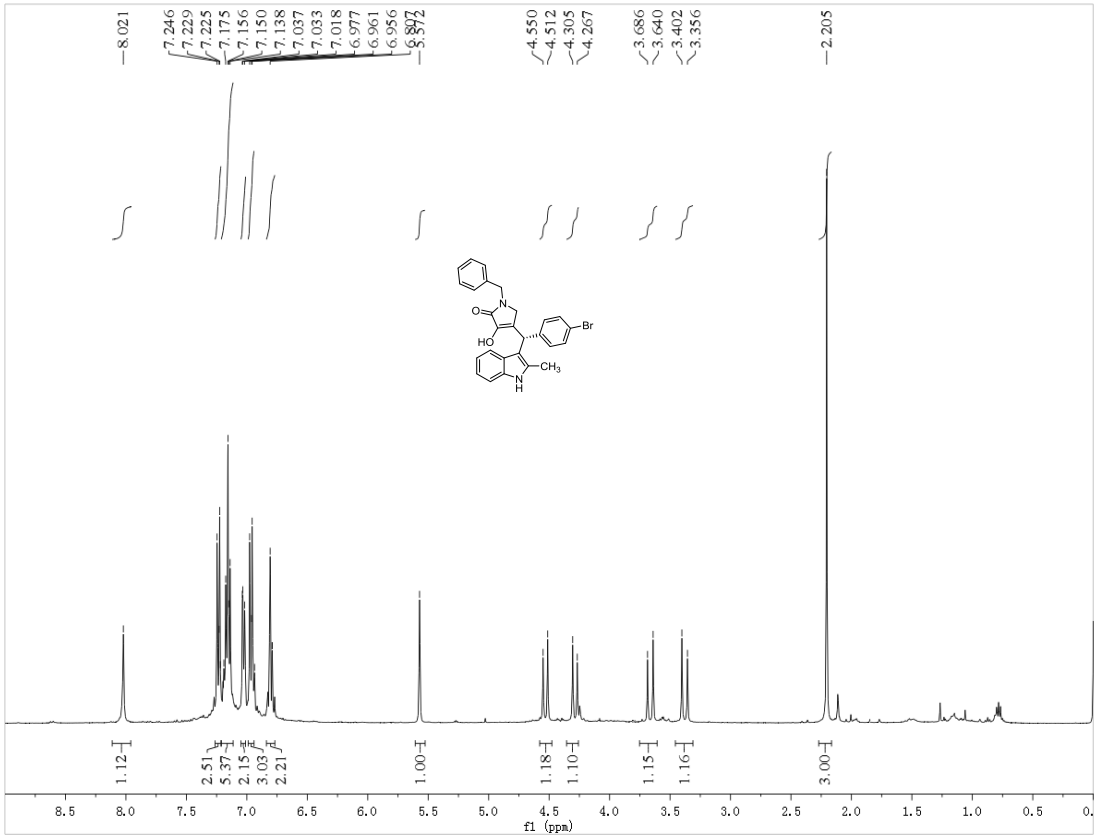


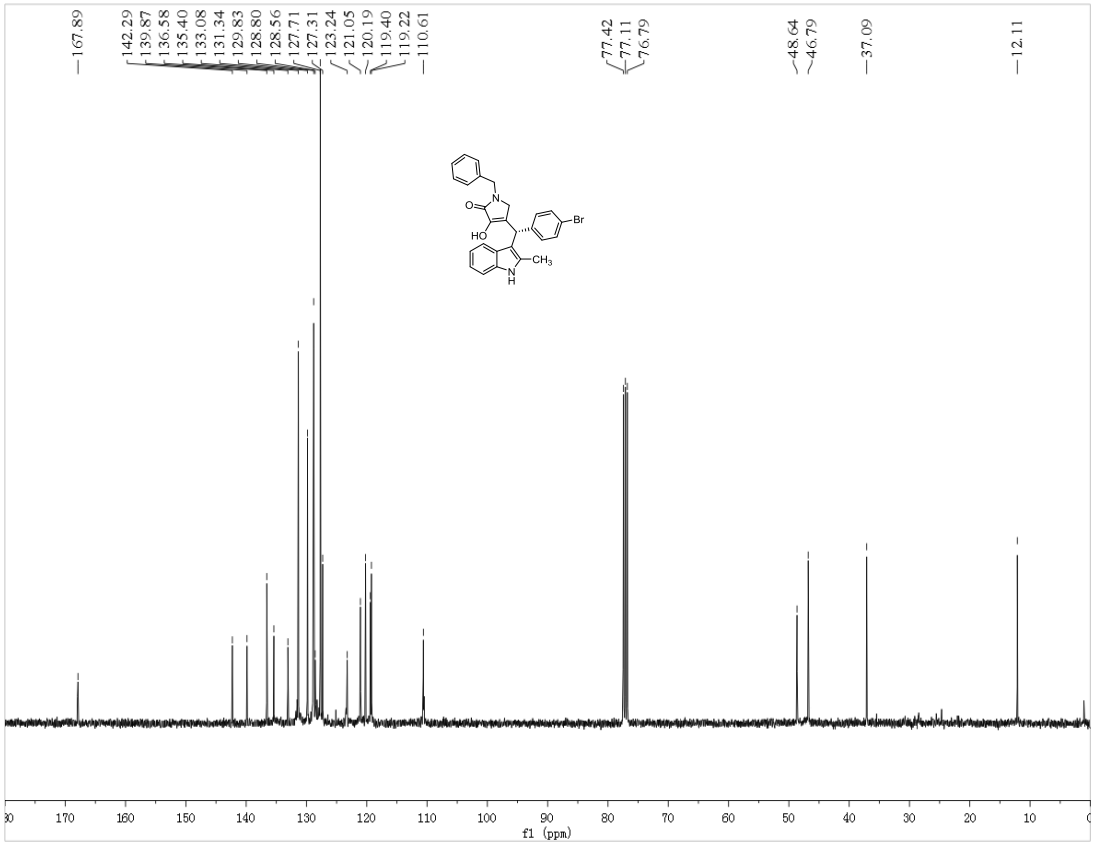
#	Time	Area	Height	Width	Area%	Symmetry
1	10.468	17639.7	661.1	0.4043	50.390	0.682
2	23.751	17366.4	274	1.0565	49.610	0.716



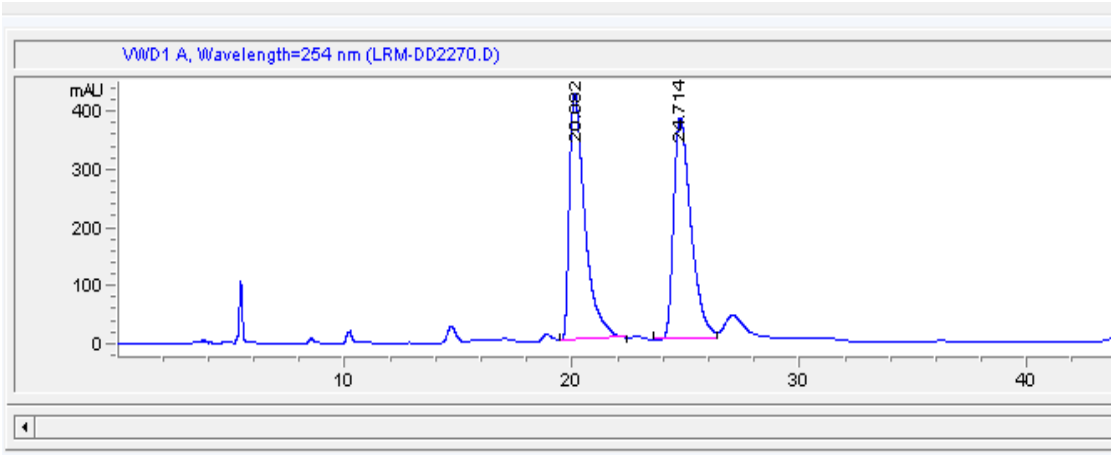
#	Time	Area	Height	Width	Area%	Symmetry
1	10.545	754.2	32.7	0.3846	4.237	0.936
2	23.897	17044.3	259.1	1.0964	95.763	0.665

^{1}H and ^{13}C NMR of 6p

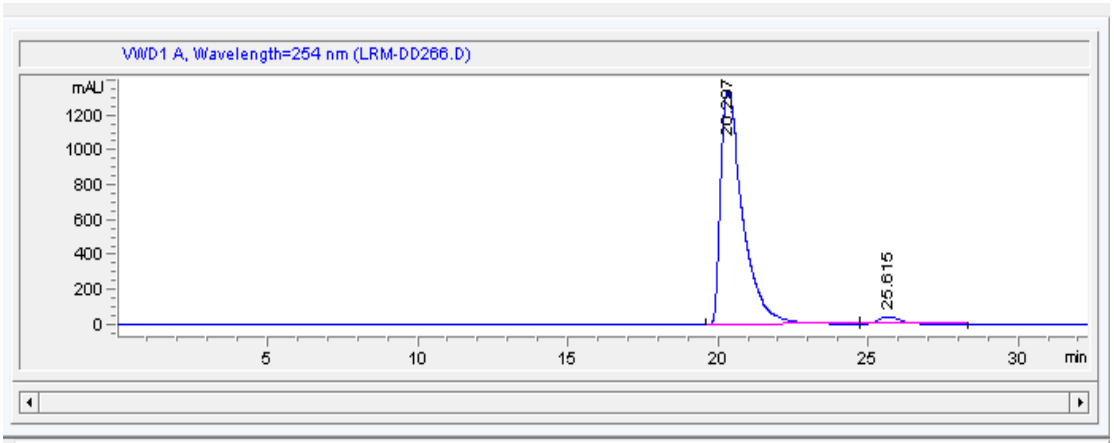




HPLC of **6p**

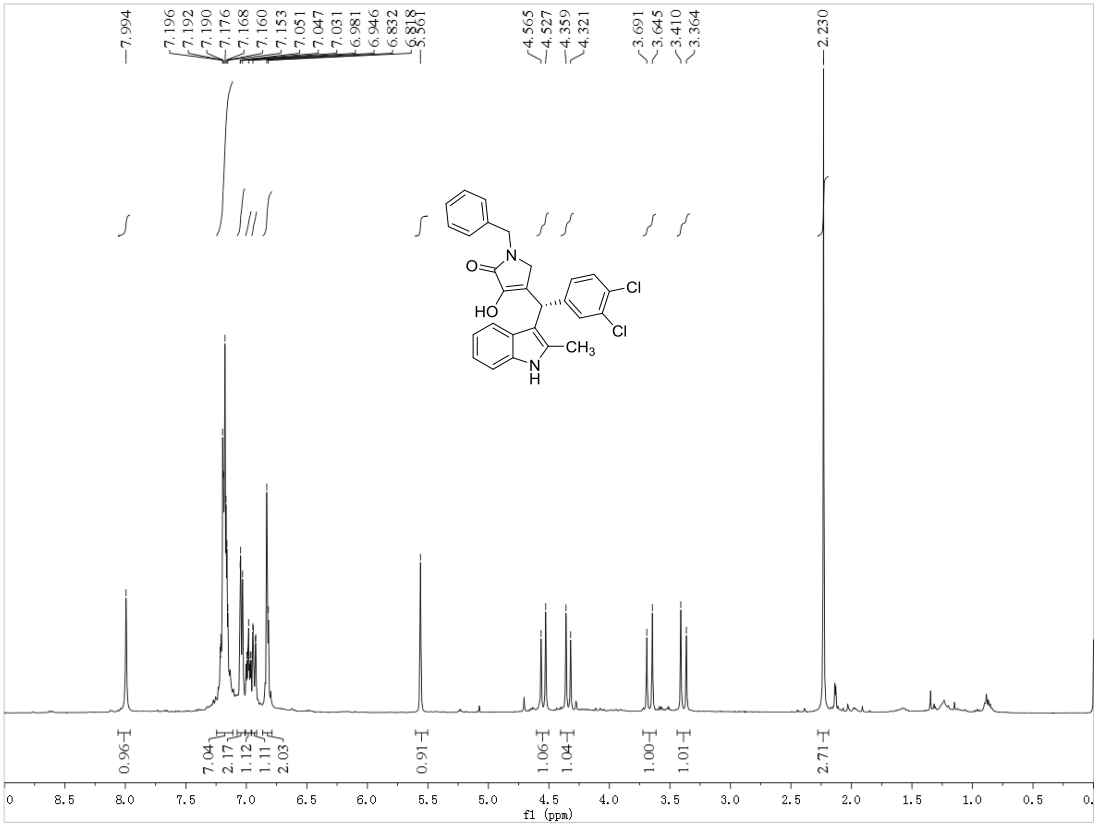


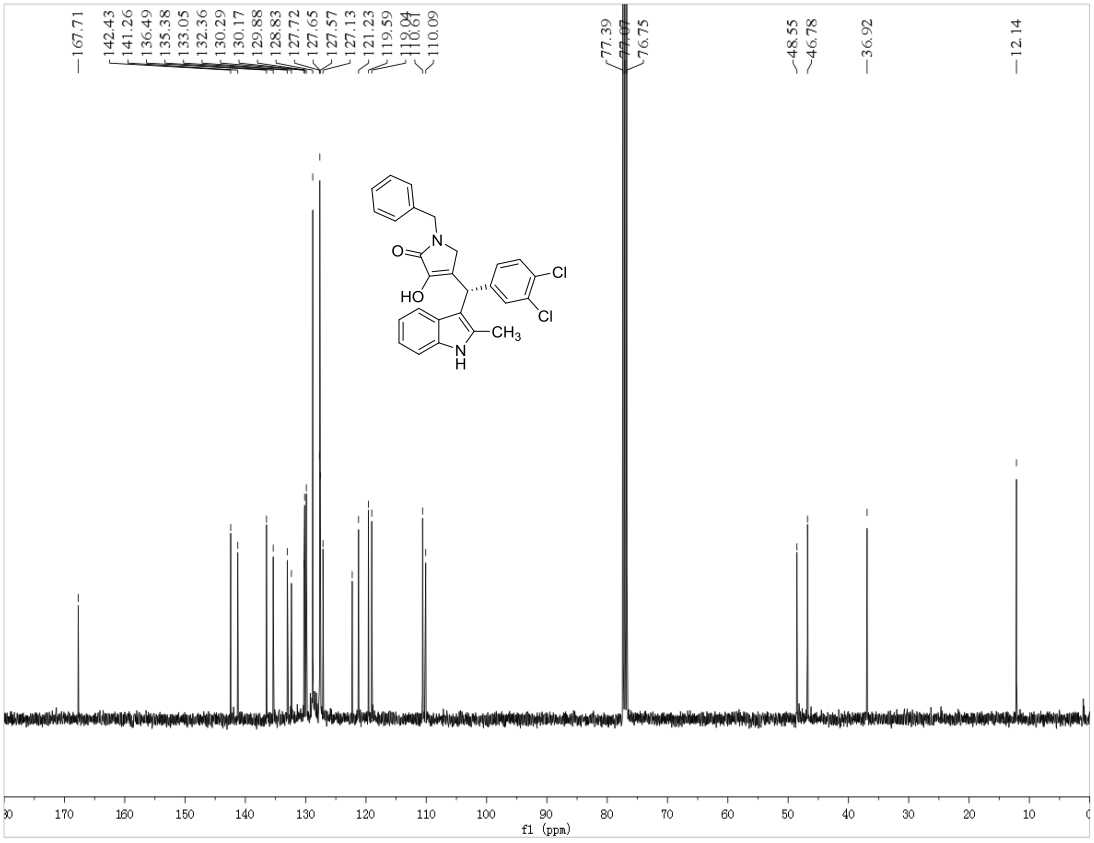
#	Time	Area	Height	Width	Area%	Symmetry
1	20.082	20179.8	425.1	0.7128	49.761	0.456
2	24.714	20373.5	381.8	0.8245	50.239	0.559



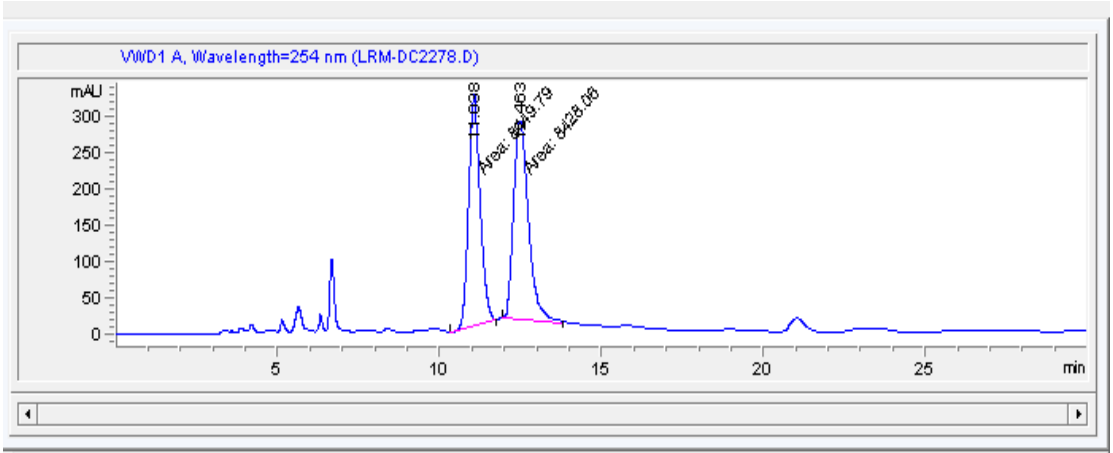
#	Time	Area	Height	Width	Area%	Symmetry
1	20.297	68643.9	1346.8	0.7626	97.034	0.411
2	25.615	2098.2	40.8	0.7804	2.966	0.675

^{1}H and ^{13}C NMR of 6q

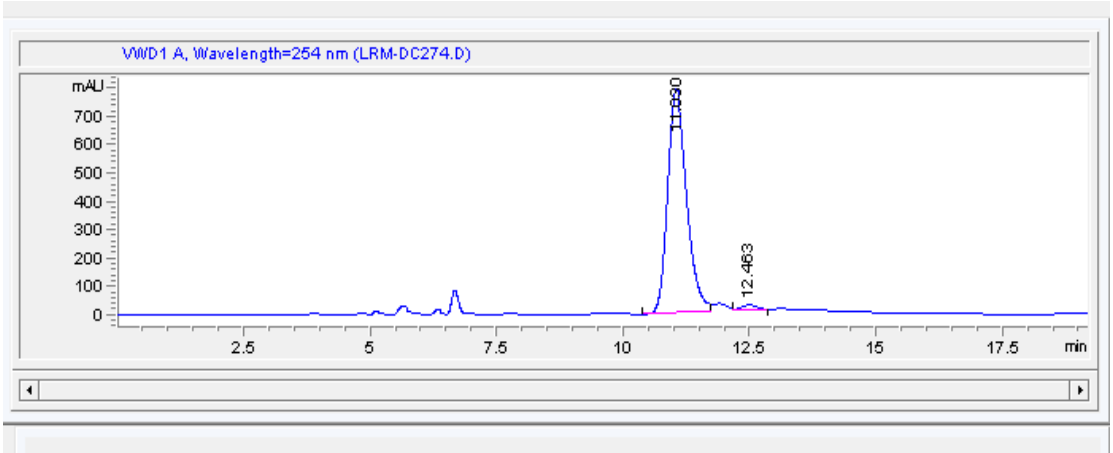




HPLC of **6q**

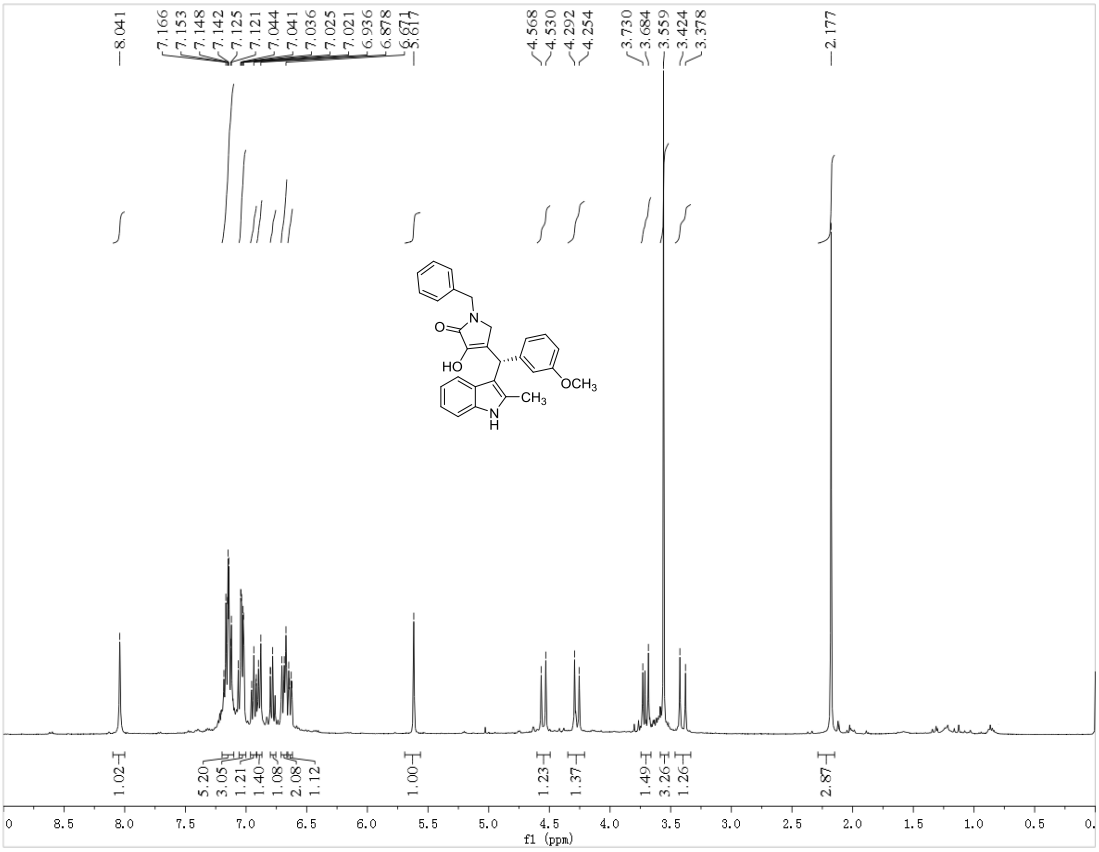


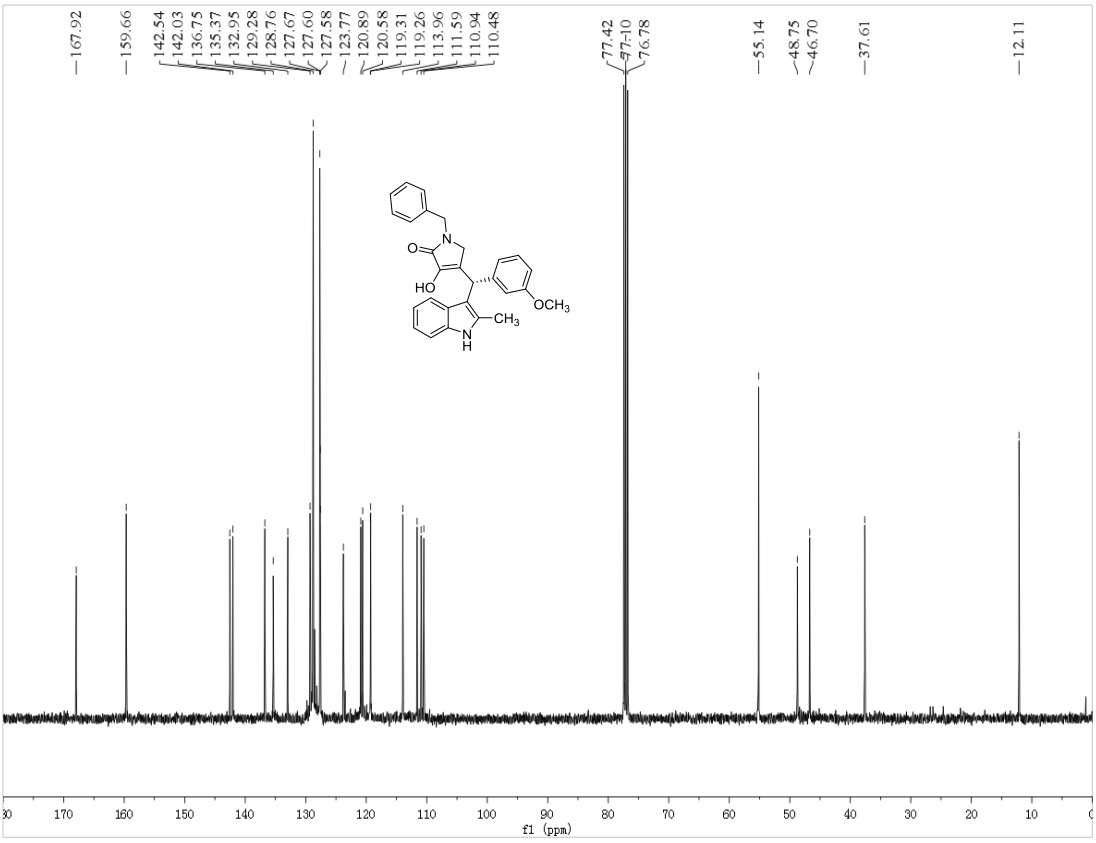
#	Time	Area	Height	Width	Area%	Symmetry
1	11.038	8449.8	321.4	0.4381	50.064	0.833
2	12.463	8428.1	273.4	0.5138	49.936	0.718



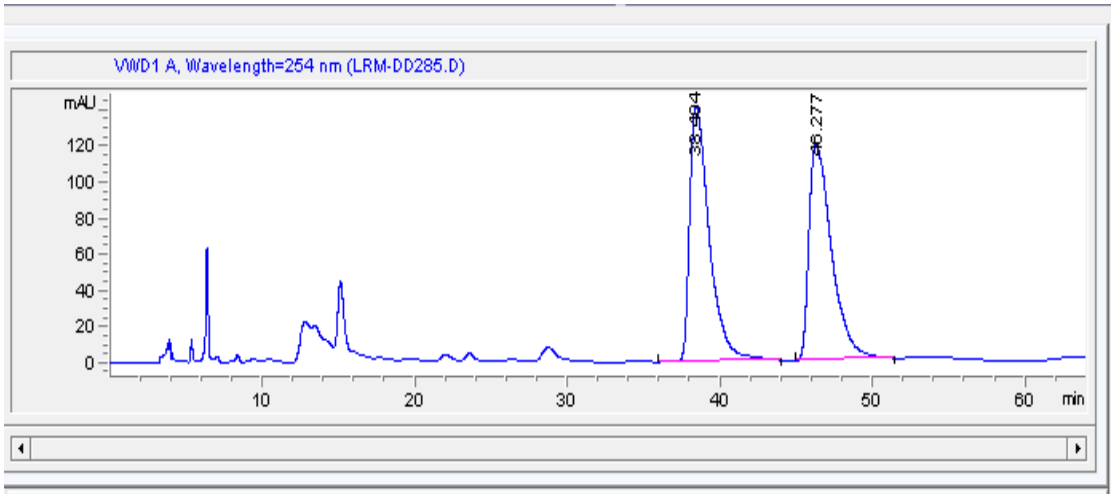
#	Time	Area	Height	Width	Area%	Symmetry
1	11.03	21013	794	0.4098	97.863	0.737
2	12.463	458.8	19.9	0.3685	2.137	1.037

^{1}H and ^{13}C NMR of 6r

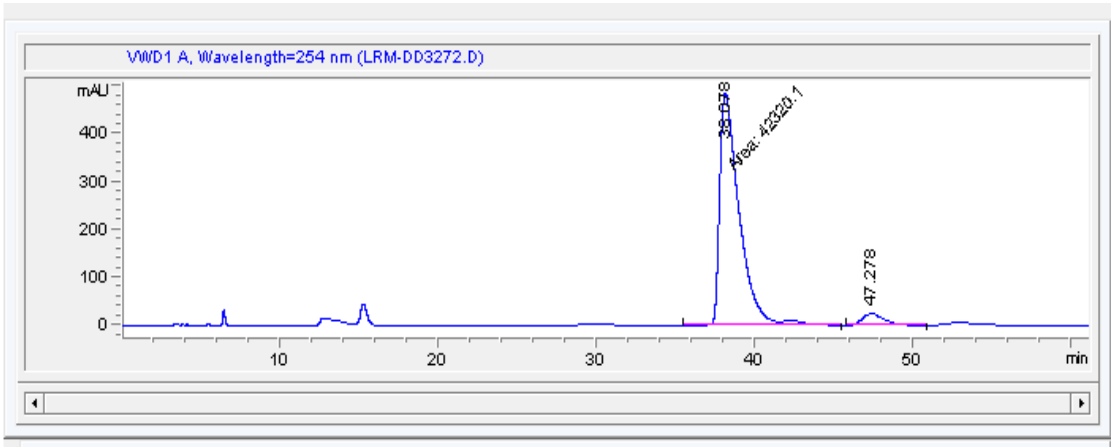




HPLC of **6r**

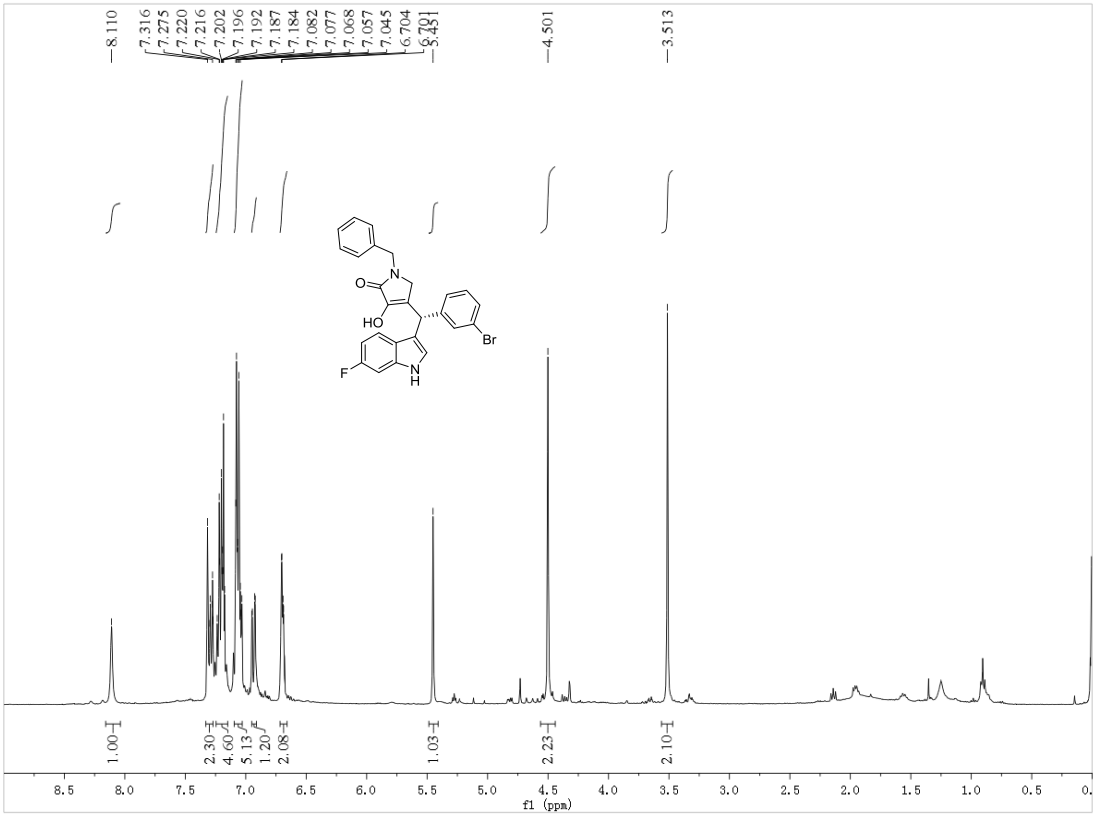


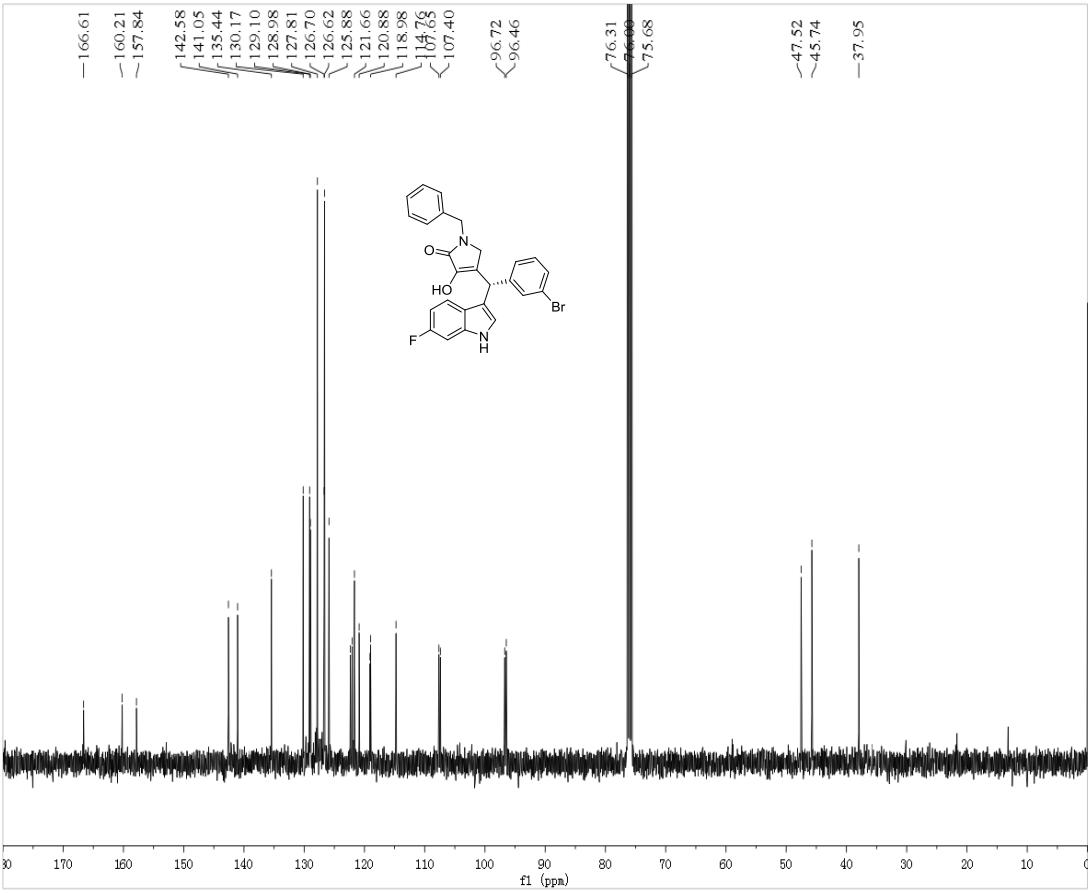
#	Time	Area	Height	Width	Area%	Symmetry
1	38.404	12559.8	141.7	1.3324	50.704	0.432
2	46.277	12211	119.6	1.4043	49.296	0.42



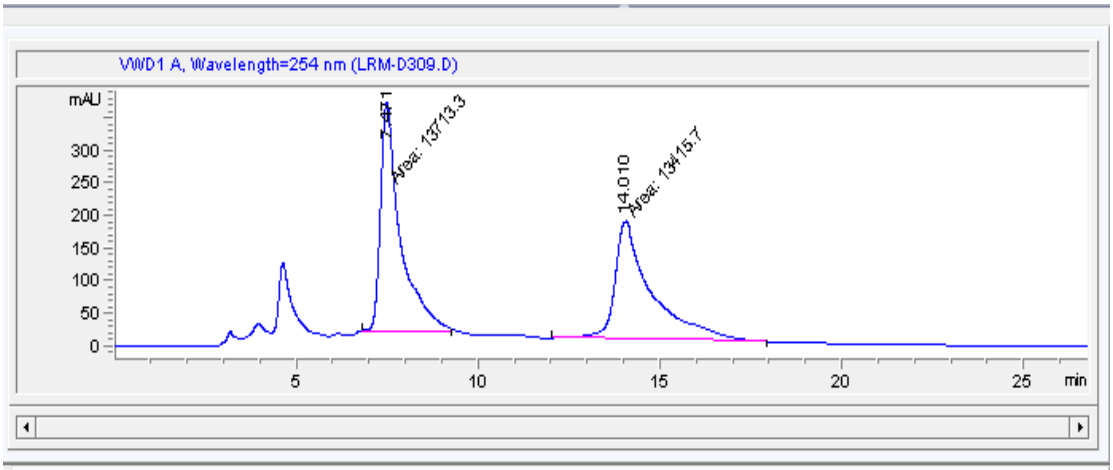
#	Time	Area	Height	Width	Area%	Symmetry
1	38.078	42320.1	486.7	1.4492	94.813	0.385
2	47.278	2315.1	24.8	1.3901	5.187	0.643

^{1}H and ^{13}C NMR of 6s

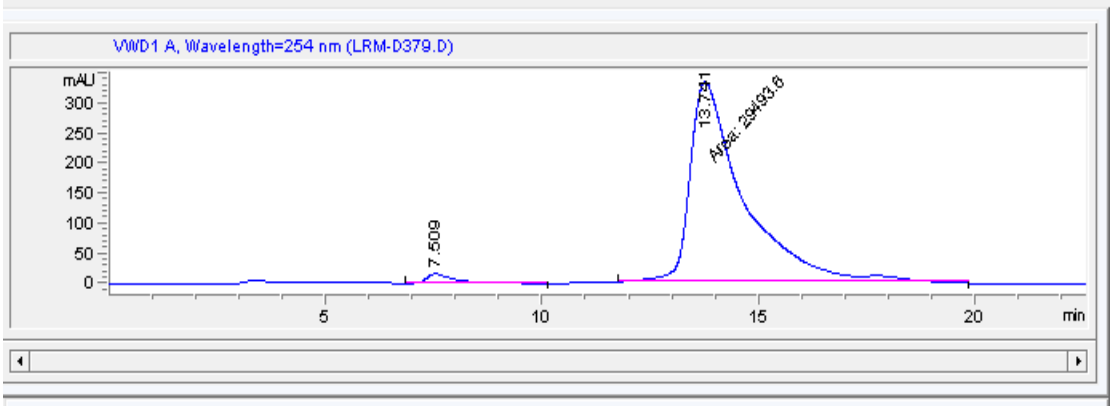




HPLC of **6s**

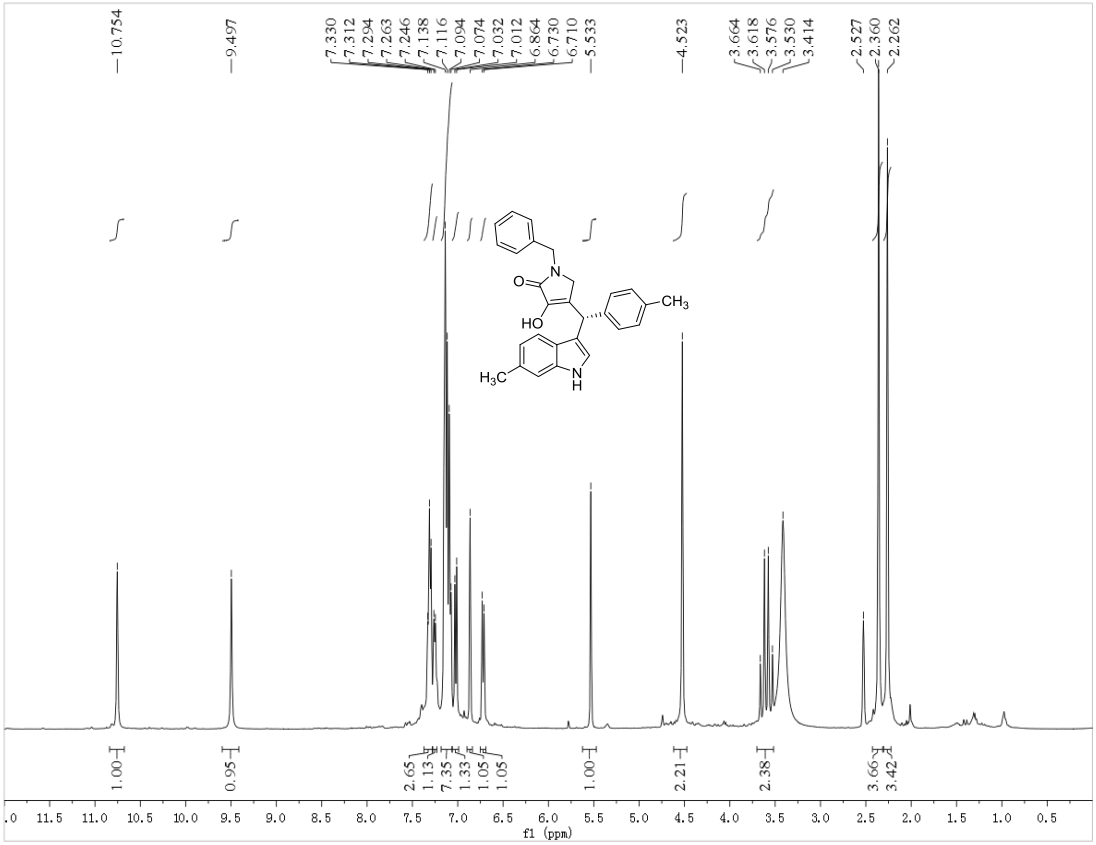


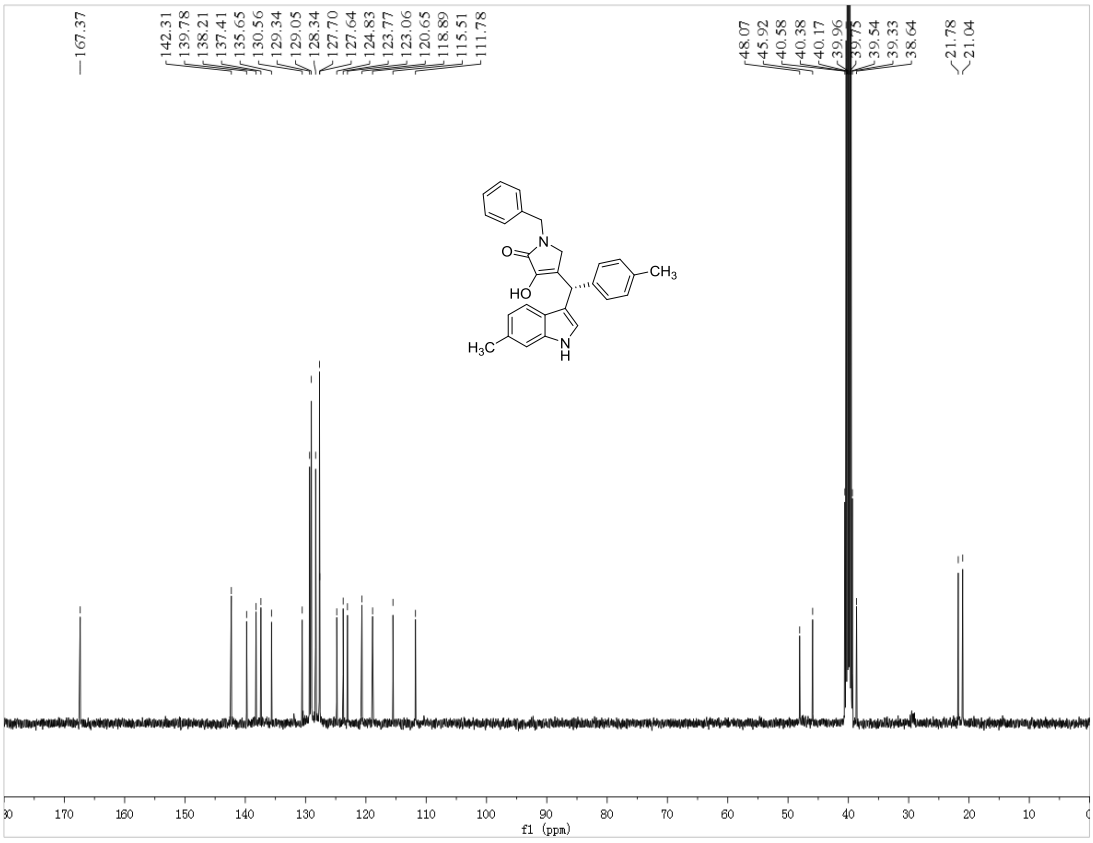
#	Time	Area	Height	Width	Area%	Symmetry
1	7.471	13713.3	351.9	0.6494	50.549	0.409
2	14.01	13415.7	182.5	1.225	49.451	0.393



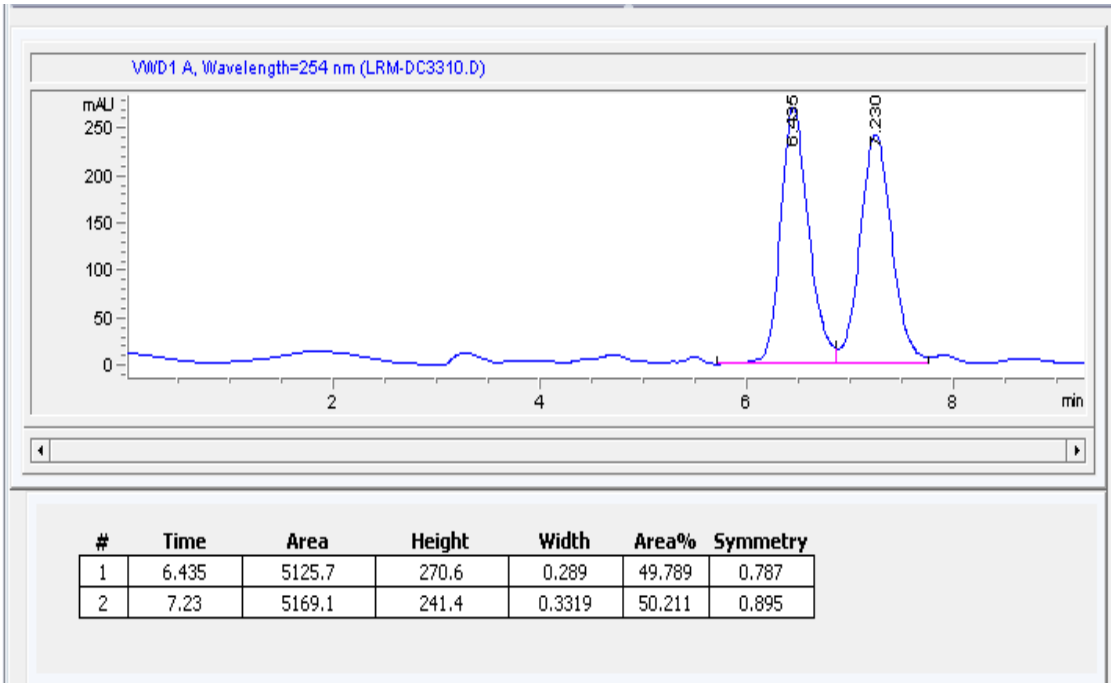
#	Time	Area	Height	Width	Area%	Symmetry
1	7.509	707	15.6	0.6374	2.341	0.406
2	13.741	29493.6	335	1.4673	97.659	0.394

^{1}H and ^{13}C NMR of 6t

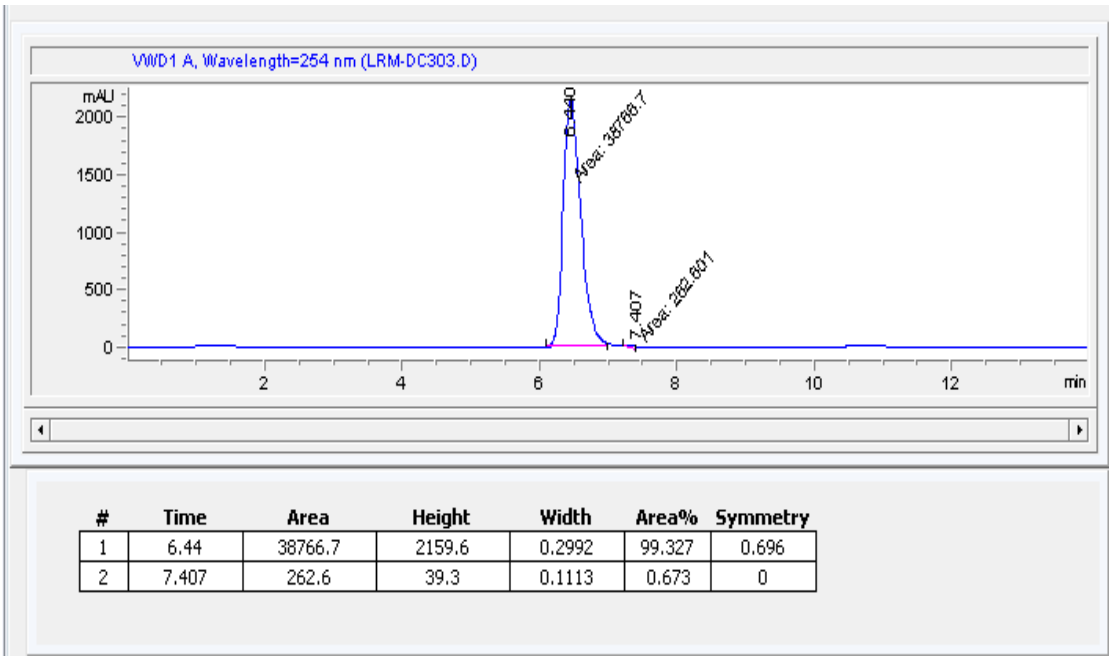




HPLC of **6t**



#	Time	Area	Height	Width	Area%	Symmetry
1	6.435	5125.7	270.6	0.289	49.789	0.787
2	7.23	5169.1	241.4	0.3319	50.211	0.895



#	Time	Area	Height	Width	Area%	Symmetry
1	6.44	38766.7	2159.6	0.2992	99.327	0.696
2	7.407	262.6	39.3	0.1113	0.673	0