

Supporting Information

Asymmetric [3+3] Annulation of Copper–Allenylidenes with Pyrazolones:

Synthesis of Chiral 1,4-Dihydropyrano[2,3-c]pyrazoles

Feng Jiang,[†] Xinping Feng,[†] Rou Wang,[†] Xing Gao,[†] Hao Jia,[†] Yumei Xiao,[†] Cheng Zhang,^{*,†} and Hongchao Guo^{*,†,‡}

[†] Department of Applied Chemistry, China Agricultural University, Beijing 100193, China

[‡] Key Laboratory of Green Pesticide and Agricultural Bioengineering, Ministry of Education, Guizhou University, Guiyang 550025, China

Email: hchgao@cau.edu.cn, zhangc9711@cau.edu.cn

CONTENTS

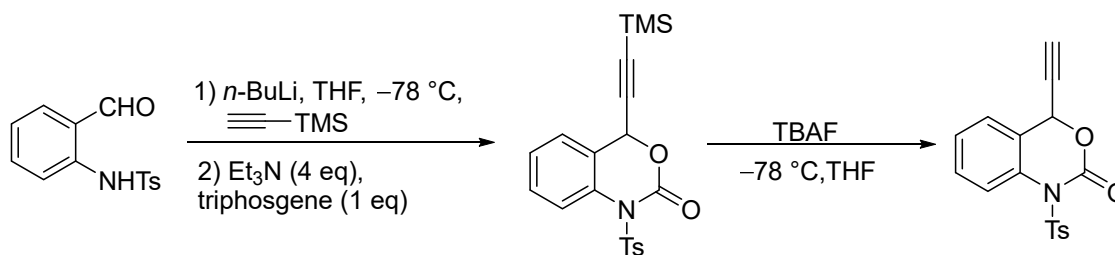
General Information	S2
Preparation of Starting Materials	S3
General Procedure for the [3+3] Annulation	S4
Scaled-up Synthesis and Synthetic Transformation	S5
Characterization Data for Products	S6
¹ H and ¹³ C NMR Spectra of All Products 3 , 4	S20
HPLC Chromatograms of the Products 3 , 4	S48
X-Ray Crystallographic Data	S76

General Information

All reactions were performed under Ar atmospheres in glassware with magnetic stirring. Unless otherwise stated, all reagents were purchased from commercial suppliers and used without further purification. All solvents were purified and dried according to standard methods prior to use. Organic solutions were concentrated under reduced pressure on a rotary evaporator or an oil pump. Reactions were monitored through thin layer chromatography (TLC) on silica gel–precoated glass plates. Chromatograms were visualized by fluorescence quenching with UV light at 254 nm. Flash column chromatography was performed using Qingdao Haiyang flash silica gel (200-300 mesh). ^1H and ^{13}C NMR spectra were recorded in CDCl_3 using a 300MHz NMR instrument (referenced internally to Me_4Si). Chemical shifts (δ , ppm) are relative to tetramethylsilane (TMS) with the resonance of the non-deuterated solvent or TMS as the internal standard. ^1H NMR data are reported as follows: chemical shift, multiplicity (s = singlet; d = doublet; q = quartet; m = multiplet; br = broad), coupling constant (Hz), and integral. Data for ^{13}C NMR spectra are reported in terms of chemical shift. Optical rotation was obtained on an Autopol V Plus polarimeter. Accurate mass measurements were performed using an Agilent instrument with the ESI-MS technique. HPLC analysis was performed on Agilent 1100 series and Agilent 1260 series, UV detection monitored at 254 nm, using a IA, OOG-4457-EO, R&C, IBN5 column with hexane and *i*-PrOH as solvents. X-ray crystallographic data were collected using a Gemini E Rigak.

Preparation of Starting Materials

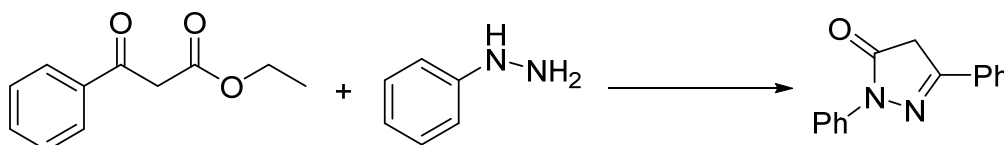
Representative Procedure for the Preparation of Ethynyl Benzoxazinanones¹



Trimethylsilylacetylene (24 mmol, 3.4 mL) was dissolved into 50 mL THF and cooled to $0\text{ }^{\circ}\text{C}$, then *n*-BuLi (22 mmol) was added via syringe. After stirred at this temperature for 15 min under argon atmosphere, N-(2-formylphenyl)-4-methylbenzenesulfonamide (10 mmol, 2.75 g) was added. After the starting material was consumed, the mixture was then cooled to $-78\text{ }^{\circ}\text{C}$. And Et_3N (40 mmol, 5.58 mL) was added followed by a THF solution of triphosgene (10 mmol, 2.96 g in 20 mL THF). After the mixture was stirring at $-78\text{ }^{\circ}\text{C}$ for 30 min, water (100 mL) was added to quench the reaction. After extracted with DCM and dried with Na_2SO_4 , the solvent was removed under vacuum. The crude product was used directly without further purification.

Then product of last step was redissolved in THF (50 mL). After the mixture was cooled to $-78\text{ }^{\circ}\text{C}$, TBAF (10 mmol, 1.0 N in THF) was added dropwise. The mixture was allowed to stirring at this temperature for further 10 min before quenched with aq. NH_4Cl . The mixture was extracted with DCM and purified by column chromatography (PE/EtOAc = 7:1) to give the product as white solid (2.59 g, 79% yield over two steps).

Representative Procedure for the Preparation of Pyrazolone²

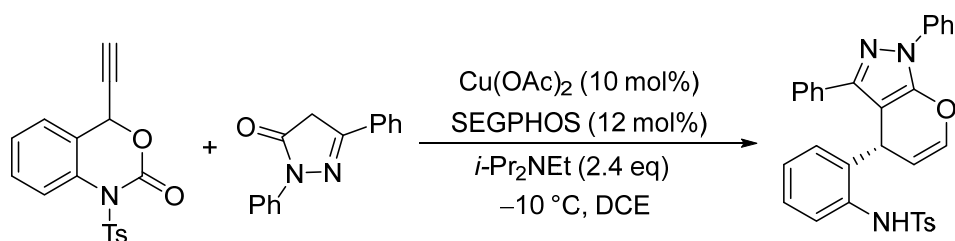


To 1 eq. (0.035 mol) of β -ketoester in 50 ml of acetic acid was added 1 eq. of substituted phenylhydrazine (for HCl salt 1 eq. of triethylamine was added). The content was refluxed for 24–36 h, the contents cooled, and solvent was removed in vacuo. To the precipitate in flask was added ethylacetate to suspend the product and was then filtered to obtain pure compound. Thus obtained product was dried to yield substituted pyrazolone.

¹ Li, T. R.; Cheng, B. Y.; Wang, Y. N.; Zhang, M. M.; Lu, L. Q.; Xiao, W. J. A. *Angew Chem Int Ed.* **2016**, 55, 12422.

² Kumar, V.; Chang, C. K.; Tan, K. P.; Jung, Y. S.; Chen, S. H.; Cheng, Y. S.; Liang, P. H. *Org. Lett.* **2014**, 16, 5060.

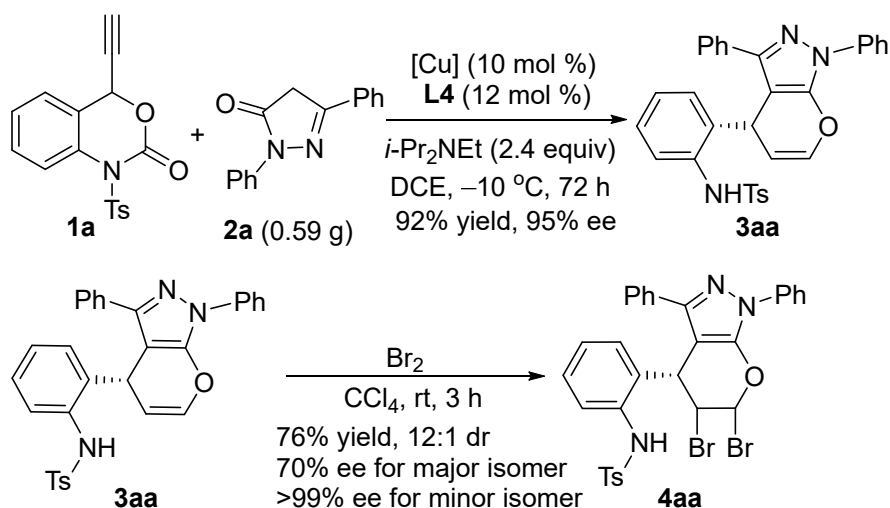
General Procedure for the [3+3] Annulation



Cu(OAc)₂ (0.01 mmol, 1.8 mg) and (*S*)-SEGPhos (0.012 mmol, 14.1 mg) were mixed in 2.0 mL DCE and stirred at -10 °C for 15 min under argon atmosphere. Then *i*-Pr₂NEt (0.24 mmol, 36 μL) and Ethynyl Benzoxazinanes (0.12 mmol) were added and stirred for 15 min. Then pyrazolone (0.1 mmol) was added. The reaction mixture was stirred at -10 °C until the pyrazolone fully disappeared (determined by TLC). The mixture was purified by flash column chromatography.

Scaled-up Synthesis and Synthetic Transformation

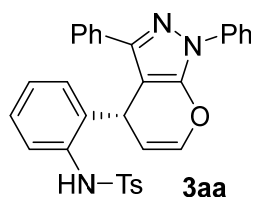
Cu(OAc)₂ (0.25 mmol, 45 mg) and (*S*)-SEGPhos (0.3 mmol, 352.5 mg) were mixed in 50 mL of DCE and the resulting mixture was stirred at -10 °C for 30 min under argon atmosphere. Then *i*-Pr₂NEt (6 mmol, 0.9 mL) and ethynyl benzoxazinanes (3 mmol, 0.98 g) were added and stirred for 30 min. Then pyrazolone (2.5 mmol, 0.59 g) was added. The reaction mixture was stirred at -10 °C until the pyrazolone was fully consumed (determined by TLC). The mixture was purified by flash column chromatography to give the corresponding product.



The CCl₄ solution (1 mL) of Br₂ (5 eq) was slowly added to the solution (1 mL) of **3aa** (0.1 mmol). The reaction mixture was stirred at rt until the compound **3aa** was fully consumed (determined by TLC). Then, NaHSO₃ (sat. aq.) was added to quench the reaction. The mixture was extracted with DCM and the organic phase was dried with Na₂SO₄. After removal of the solvent, the residue was purified by flash column chromatography to give the derivative.

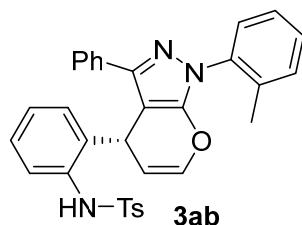
Characterization Data for Products

(*R*)-*N*-(2-(1,3-diphenyl-1,4-dihydropyrano[2,3-*c*]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide (**3aa**)



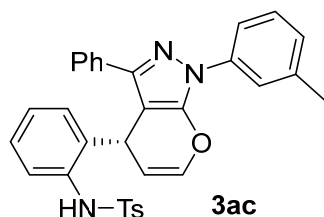
The title compound **3aa** was prepared according to the general procedure as described above in 90% yield (46.8 mg). It was purified by flash column chromatography (Petroleum ether:EtOAc=5:1) to afford yellow solid. mp = 56 – 58 °C; $[\alpha]_D^{25} = -75.2$ (*c* 0.33, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.94 – 7.87 (m, 2H), 7.66 – 7.58 (m, 2H), 7.54 – 7.46 (m, 2H), 7.44 – 7.37 (m, 2H), 7.36 – 7.29 (m, 1H), 7.26 – 7.23 (m, 1H), 7.23 – 7.17 (m, 5H), 7.11 (dd, *J* = 7.4, 1.4 Hz, 1H), 7.02 – 6.93 (m, 1H), 6.73 (d, *J* = 7.9 Hz, 1H), 6.65 – 6.59 (m, 1H), 6.51 (brs, 1H), 5.41 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.16 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.39 (s, 3H); ¹³C NMR (75 MHz, CDCl₃) δ 148.12, 146.81, 143.58, 137.85, 136.00, 132.71, 132.44, 130.45, 129.32, 128.76, 127.71, 127.57, 127.37, 127.16, 127.10, 126.87, 126.11, 125.60, 120.80, 106.61, 96.98, 21.18; HRMS (ESI): *m/z* for C₃₁H₂₅N₃O₃SH⁺ [M+H]⁺ calcd.: 520.1689, found: 520.1694; HPLC analysis: 92% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 17.51 min (minor), 22.65 min (major).

(*R*)-4-methyl-*N*-(2-(3-phenyl-1-(*o*-tolyl)-1,4-dihydropyrano[2,3-*c*]pyrazol-4-yl)phenyl)benzenesulfonamide



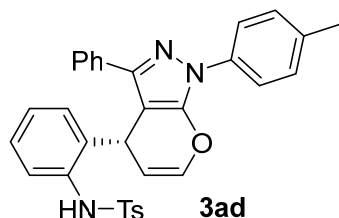
The title compound **3ab** was prepared according to the general procedure as described above in 90% yield (47.9 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 78 – 80 °C; $[\alpha]_D^{25} = -37.3$ (*c* 0.93, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.66 – 7.57 (m, 2H), 7.47 (dt, *J* = 6.7, 1.5 Hz, 1H), 7.43 – 7.33 (m, 5H), 7.23 – 7.19 (m, 2H), 7.19 – 7.15 (m, 3H), 7.09 (td, *J* = 7.5, 1.4 Hz, 1H), 6.99 (td, *J* = 7.6, 1.8 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 6.55 (s, 1H), 6.47 (dd, *J* = 6.1, 1.7 Hz, 1H), 5.40 (dd, *J* = 3.8, 1.7 Hz, 1H), 5.06 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.37 (s, 3H), 2.33 (s, 3H); ¹³C NMR (75 MHz, CDCl₃) δ 147.99, 147.45, 143.57, 137.91, 135.97, 135.78, 135.24, 132.81, 130.75, 130.29, 129.30, 128.85, 127.69, 127.41, 127.26, 127.21, 127.17, 127.07, 126.75, 126.26, 125.06, 106.46, 95.08, 21.19, 17.56. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₃SH⁺ [M+H]⁺ calcd.: 534.1846, found: 534.1844; HPLC analysis: 98% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 16.00 min (minor), 26.03 min (major).

(R)-4-methyl-N-(2-(3-phenyl-1-(m-tolyl)-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)benzenesulfonamide



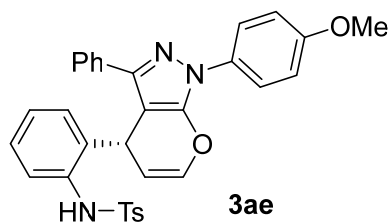
The title compound **3ac** was prepared according to the general procedure as described above in 87% yield (46.2 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 48 – 50 °C; $[\alpha]_D^{25} = -62.2$ (c 0.78, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.72 – 7.64 (m, 2H), 7.64 – 7.58 (m, 2H), 7.42 – 7.37 (m, 2H), 7.37 – 7.33 (m, 1H), 7.24 – 7.22 (m, 1H), 7.21 – 7.17 (m, 3H), 7.16 – 7.10 (m, 1H), 7.10 – 7.03 (m, 1H), 7.00 – 6.90 (m, 1H), 6.71 (d, *J* = 7.9 Hz, 1H), 6.62 – 6.58 (m, 1H), 6.57 (s, 1H), 5.39 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.14 (ddd, *J* = 6.1, 3.9, 1.3 Hz, 1H), 2.44 (s, 2H), 2.37 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.01, 146.80, 143.56, 138.82, 137.85, 137.74, 136.02, 132.74, 130.44, 129.32, 128.54, 127.71, 127.52, 127.35, 127.17, 127.07, 126.99, 126.87, 125.65, 125.60, 121.57, 118.01, 106.58, 96.90, 21.19. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₃SH⁺ [M+H]⁺ calcd.: 534.1846, found: 534.1844; HPLC analysis: 95% ee (OOG-4457-EO, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 16.73min (minor), 22.69 min (major).

(R)-4-methyl-N-(2-(3-phenyl-1-(p-tolyl)-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)benzenesulfonamide



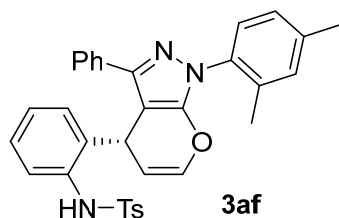
The title compound **3ad** was prepared according to the general procedure as described above in 48% yield (25.5 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 58 – 60 °C; $[\alpha]_D^{25} = -55.1$ (c 0.22, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.92 – 7.84 (m, 2H), 7.66 – 7.59 (m, 2H), 7.52 – 7.43 (m, 4H), 7.34 – 7.29 (m, 1H), 7.27 (d, *J* = 1.0 Hz, 1H), 7.26 – 7.18 (m, 4H), 6.72 – 6.64 (m, 1H), 6.58 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.47 – 6.41 (m, 2H), 6.19 (s, 1H), 5.47 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.18 (dd, *J* = 6.1, 3.9 Hz, 1H), 3.60 (s, 3H), 2.42 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 159.13, 148.08, 146.93, 144.31, 143.47, 137.94, 137.69, 136.09, 132.90, 129.29, 128.72, 128.60, 127.74, 127.60, 127.31, 126.93, 126.00, 124.59, 120.70, 115.56, 112.22, 106.84, 97.11, 54.96, 32.27, 21.21. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₃SH⁺ [M+H]⁺ calcd.: 534.1846, found: 534.1847; HPLC analysis: 94% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 18.55 min (minor), 65.11 min (major).

(R)-N-(2-(1-(4-methoxyphenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



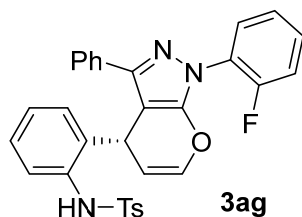
The title compound **3ae** was prepared according to the general procedure as described above in 67% yield (36.9 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 57 – 59 °C; $[\alpha]_D^{25} = -49.4$ (c 0.82, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.78 – 7.71 (m, 2H), 7.64 – 7.57 (m, 2H), 7.41 – 7.34 (m, 2H), 7.24 – 7.13 (m, 7H), 7.11 – 7.03 (m, 1H), 7.03 – 6.92 (m, 3H), 6.74 (d, *J* = 7.9 Hz, 1H), 6.60 – 6.52 (m, 2H), 5.37 (dd, *J* = 4.0, 1.7 Hz, 1H), 5.11 (dd, *J* = 6.1, 3.8 Hz, 1H), 3.85 (s, 3H), 2.37 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 157.93, 147.66, 146.52, 143.54, 137.87, 136.04, 132.79, 132.57, 131.08, 130.42, 129.31, 127.70, 127.44, 127.22, 127.15, 127.10, 126.82, 125.38, 122.72, 113.95, 106.51, 96.46, 55.21, 21.17. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₄SH⁺ [M+H]⁺ calcd.: 550.1795, found: 550.1792; HPLC analysis: 92% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 29.16 min (minor), 96.33 min (major).

(R)-N-(2-(1-(2,4-dimethylphenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



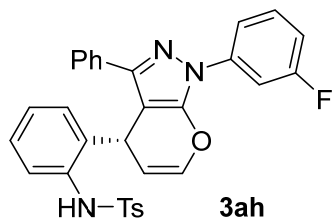
The title compound **3af** was prepared according to the general procedure as described above in 46% yield (18.7 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 58 – 60 °C; $[\alpha]_D^{25} = -51.9$ (c 0.32, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.66 – 7.58 (m, 2H), 7.45 – 7.32 (m, 4H), 7.22 (s, 1H), 7.20 (s, 1H), 7.19 – 7.17 (m, 2H), 7.16 (d, *J* = 2.2 Hz, 3H), 7.09 (s, 1H), 6.98 (td, *J* = 7.6, 1.8 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 6.64 (s, 1H), 6.46 (dd, *J* = 6.1, 1.7 Hz, 1H), 5.40 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.05 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.40 (s, 3H), 2.37 (s, 3H), 2.27 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 147.81, 147.46, 143.53, 138.87, 137.93, 136.04, 134.95, 133.24, 132.90, 131.35, 130.28, 129.29, 127.66, 127.34, 127.20, 127.15, 127.05, 127.00, 126.91, 126.75, 124.94, 106.39, 94.93, 21.17, 20.85, 17.39. HRMS (ESI): *m/z* for C₃₃H₂₉N₃O₃SH⁺ [M+H]⁺ calcd.: 548.2002, found: 548.2004; HPLC analysis: 96% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 15.34 min (minor), 59.22 min (major).

(R)-N-(2-(1-(2-fluorophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



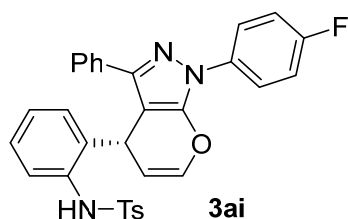
The title compound **3ag** was prepared according to the general procedure as described above in 48% yield (26.0 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 82 – 84 °C; $[\alpha]_D^{25} = -47.3$ (c 0.28, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.70 – 7.65 (m, 1H), 7.64 – 7.57 (m, 2H), 7.48 – 7.28 (m, 5H), 7.25 – 7.22 (m, 1H), 7.19 (m, *J* = 7.8, 2.7, 1.2 Hz, 5H), 7.10 (d, *J* = 1.4 Hz, 1H), 6.98 (d, *J* = 1.7 Hz, 1H), 6.75 (d, *J* = 7.9 Hz, 1H), 6.55 – 6.48 (m, 2H), 5.38 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.09 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.37 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 155.99 (d, *J* = 253.5 Hz), 149.32, 147.80, 143.57, 137.93, 135.99, 132.56, 130.47, 129.67 (d, *J* = 7.7 Hz), 129.31, 127.71, 127.63, 127.50 (d, *J* = 52.2 Hz), 127.29, 127.19, 126.87, 125.40, 124.93 (d, *J* = 11.8 Hz), 124.31, 124.26, 116.50, 116.24, 106.46, 95.94, 21.17. HRMS (ESI): *m/z* for C₃₁H₂₄FN₃O₃SH⁺ [M+H]⁺ calcd.: 538.1595, found: 538.1595; HPLC analysis: >99% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 29.27 min.

(R)-N-(2-(1-(3-fluorophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



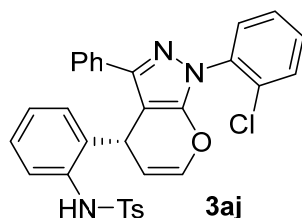
The title compound **3ah** was prepared according to the general procedure as described above in 75% yield (40.1 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 54 – 56 °C; $[\alpha]_D^{25} = -49.7$ (c 0.36, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.75 – 7.60 (m, 4H), 7.46 – 7.36 (m, 3H), 7.26 – 7.13 (m, 6H), 7.08 (d, *J* = 1.3 Hz, 0H), 7.03 – 6.90 (m, 2H), 6.65 (d, *J* = 7.9 Hz, 1H), 6.61 – 6.55 (m, 2H), 5.46 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.19 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.39 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 162.64 (d, *J* = 242.3 Hz), 148.44, 147.07, 143.64, 139.31 (d, *J* = 10.6 Hz), 137.66, 136.02, 132.43, 132.26, 130.39, 129.98 (d, *J* C-F = 9.0 Hz), 129.35, 127.76, 127.62, 127.17, 127.10, 126.83, 125.92, 115.65, 115.61, 112.72, 112.44, 107.80 (d, *J* = 26.4 Hz), 106.82, 97.40, 21.20. HRMS (ESI): *m/z* for C₃₁H₂₄FN₃O₃SH⁺ [M+H]⁺ calcd.: 538.1595, found: 538.1642; HPLC analysis: >99% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 14.89 min.

(R)-N-(2-(1-(4-fluorophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



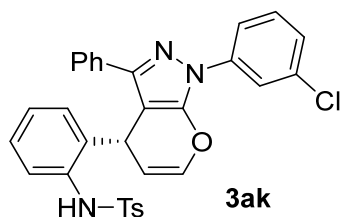
The title compound **3ai** was prepared according to the general procedure as described above in 52% yield (27.7 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 57 – 59 °C; $[\alpha]_D^{25} = -32.7$ (c 0.82, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.86 – 7.80 (m, 2H), 7.64 – 7.58 (m, 2H), 7.42 – 7.37 (m, 2H), 7.25 – 7.22 (m, 1H), 7.22 – 7.17 (m, 4H), 7.17 – 7.12 (m, 2H), 7.08 (td, *J* = 7.5, 1.3 Hz, 1H), 6.95 (td, *J* = 7.6, 1.7 Hz, 1H), 6.68 (d, *J* = 7.9 Hz, 1H), 6.57 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.52 (s, 1H), 5.42 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.16 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.38 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 160.66(d, *J* = 249.1Hz), 159.03, 148.15, 146.70, 143.60, 137.75, 136.01, 134.02 (d, *J* = 2.7 Hz), 132.57, 132.43, 130.39, 129.33, 127.73, 127.62, 127.43, 127.17, 127.12, 126.82, 125.68, 122.56 (d, *J* = 8.4 Hz), 115.55 (d, *J* = 22.9 Hz), 106.73, 96.93, 21.19. HRMS (ESI): *m/z* for C₃₁H₂₄FN₃O₃SH⁺ [M+H]⁺ calcd.: 538.1595, found: 538.7597; HPLC analysis: 92% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 17.89 min (minor), 30.08 min (major).

(R)-N-(2-(1-(2-chlorophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



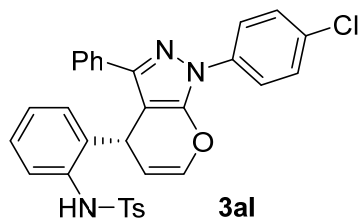
The title compound **3aj** was prepared according to the general procedure as described above in 46% yield (25.4 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 58 – 60 °C; $[\alpha]_D^{25} = -49.0$ (c 0.44, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.68 – 7.60 (m, 3H), 7.57 (dd, *J* = 5.9, 3.5 Hz, 1H), 7.47 – 7.36 (m, 4H), 7.23 (s, 1H), 7.22 – 7.14 (m, 5H), 7.10 (td, *J* = 7.5, 1.3 Hz, 1H), 6.98 (td, *J* = 7.6, 1.7 Hz, 1H), 6.77 (d, *J* = 8.0 Hz, 1H), 6.60 (s, 1H), 6.48 (dd, *J* = 6.1, 1.7 Hz, 1H), 5.42 (dd, *J* = 4.0, 1.7 Hz, 1H), 5.08 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.37 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.89, 147.96, 143.56, 137.86, 136.05, 134.65, 132.59, 131.67, 130.41, 130.01, 129.31, 129.26, 127.70, 127.57, 127.22, 127.15, 126.84, 125.22, 106.50, 95.50, 21.17. HRMS (ESI): *m/z* for C₃₁H₂₄ClN₃O₃SH⁺ [M+H]⁺ calcd.: 554.1300, found: 554.1302; HPLC analysis: 99% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 21.48 min (minor), 34.16 min (major).

(R)-N-(2-(1-(3-chlorophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



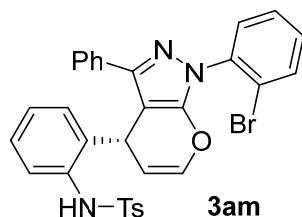
The title compound **3ak** was prepared according to the general procedure as described above in 75% yield (41.2 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 56 – 58 °C; $[\alpha]_D^{25} = -66.8$ (c 0.36, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.94 (t, *J* = 2.1 Hz, 1H), 7.81 (ddd, *J* = 8.2, 2.1, 1.0 Hz, 1H), 7.63 (d, *J* = 8.1 Hz, 2H), 7.46 – 7.34 (m, 3H), 7.26 – 7.13 (m, 8H), 7.08 (td, *J* = 7.5, 1.3 Hz, 1H), 6.94 (td, *J* = 7.6, 1.7 Hz, 1H), 6.68 – 6.54 (m, 3H), 5.46 (dd, *J* = 3.8, 1.7 Hz, 1H), 5.19 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.40 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.52, 147.06, 143.63, 138.95, 137.66, 136.04, 134.48, 132.41, 132.25, 130.38, 129.75, 129.36, 127.77, 127.64, 127.17, 127.09, 126.83, 125.95, 125.84, 120.45, 118.26, 106.82, 97.40, 21.21. HRMS (ESI): *m/z* for C₃₁H₂₄ClN₃O₃SH⁺ [M+H]⁺ calcd.: 544.1300, found: 544.1303; HPLC analysis: >99% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 14.90 min.

(R)-N-(2-(1-(4-chlorophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



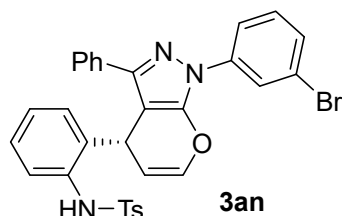
The title compound **3al** was prepared according to the general procedure as described above in 59% yield (32.6 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 68 – 70 °C; $[\alpha]_D^{25} = -26.7$ (c 0.50, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.89 – 7.80 (m, 2H), 7.64 – 7.58 (m, 2H), 7.48 – 7.41 (m, 1H), 7.41 – 7.36 (m, 2H), 7.25 – 7.23 (m, 7H), 7.23 – 7.18 (m, 4H), 7.16 (d, *J* = 1.7 Hz, 1H), 7.09 (td, *J* = 7.5, 1.3 Hz, 1H), 6.95 (ddd, *J* = 8.9, 7.3, 1.7 Hz, 1H), 6.70 – 6.63 (m, 1H), 6.60 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.44 (s, 1H), 5.43 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.18 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.39 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.39, 146.86, 143.61, 137.71, 136.48, 135.99, 132.47, 132.34, 131.41, 130.41, 129.33, 128.83, 127.75, 127.71, 127.54, 127.17, 127.12, 126.83, 125.83, 121.65, 106.77, 97.27, 21.20. HRMS (ESI): *m/z* for C₃₁H₂₄ClN₃O₃SH⁺ [M+H]⁺ calcd.: 554.1300, found: 554.1300; HPLC analysis: 91% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 19.72 min (minor), 45.60 min (major).

(R)-N-(2-(1-(2-bromophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



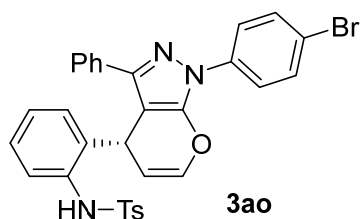
The title compound **3am** was prepared according to the general procedure as described above in 79% yield (47.1 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 60 – 62 °C; $[\alpha]_D^{25} = -33.2$ (c 0.33, CH₂Cl₂); ¹H NMR (300 MHz, DMSO-*d*₆) δ 7.75 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.65 – 7.58 (m, 3H), 7.47 (td, *J* = 7.6, 1.5 Hz, 1H), 7.42 – 7.32 (m, 3H), 7.24 – 7.15 (m, 6H), 7.13 – 7.06 (m, 1H), 6.98 (td, *J* = 7.6, 1.7 Hz, 1H), 6.77 (d, *J* = 7.8 Hz, 1H), 6.48 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.45 (s, 1H), 5.40 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.07 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.37 (s, 3H); ¹³C NMR (75 MHz, CDCl₃) δ 148.70, 147.79, 143.56, 137.82, 136.27, 136.06, 133.13, 132.59, 130.43, 130.37, 129.52, 129.31, 127.89, 127.70, 127.55, 127.23, 127.13, 126.84, 121.58, 106.55, 95.51, 21.18. HRMS (ESI): *m/z* for C₃₁H₂₄BrN₃O₃SN⁺ [M+Na]⁺ calcd.: 622.0598, found: 622.0599; HPLC analysis: 96% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 21.03. min (minor), 33.30 min (major).

(R)-N-(2-(1-(3-bromophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



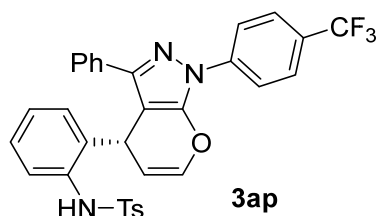
The title compound **3an** was prepared according to the general procedure as described above in 69% yield (41.4 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 68 – 70 °C; $[\alpha]_D^{25} = -28.7$ (c 0.93, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 8.12 – 8.07 (m, 1H), 7.91 – 7.81 (m, 1H), 7.68 – 7.59 (m, 2H), 7.45 – 7.37 (m, 3H), 7.36 – 7.29 (m, 1H), 7.25 – 7.24 (m, 1H), 7.23 – 7.13 (m, 4H), 7.08 (d, *J* = 1.3 Hz, 1H), 6.95 (dd, *J* = 7.8, 1.8 Hz, 1H), 6.64 (d, *J* = 8.1 Hz, 1H), 6.59 (dd, *J* = 6.0, 1.6 Hz, 1H), 6.51 (s, 1H), 5.45 (dd, *J* = 4.0, 1.8 Hz, 1H), 5.19 (d, 1H), 2.40 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.57, 147.03, 143.63, 139.02, 137.68, 136.02, 132.38, 132.25, 130.39, 130.02, 129.35, 128.81, 127.76, 127.63, 127.18, 127.10, 126.84, 125.95, 123.31, 122.39, 118.77, 106.82, 97.42, 21.21. HRMS (ESI): *m/z* for C₃₁H₂₄BrN₃O₃SN⁺ [M+Na]⁺ calcd.: 622.0598, found: 622.0597. HPLC analysis: 93% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 15.06 min (major), 16.98 min (minor).

(R)-N-(2-(1-(4-bromophenyl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



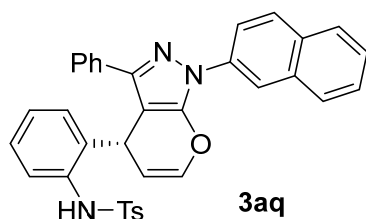
The title compound **3ao** was prepared according to the general procedure as described above in 77% yield (46.0 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford white solid. mp = 206 – 208 °C; $[\alpha]_D^{25} = -29.5$ (c .90, CH₂Cl₂); ¹H NMR (300 MHz, DMSO-*d*₆) δ 7.81 – 7.75 (m, 2H), 7.63 – 7.55 (m, 4H), 7.42 – 7.36 (m, 2H), 7.25 – 7.17 (m, 5H), 7.15 (d, *J* = 1.7 Hz, 1H), 7.08 (td, *J* = 7.5, 1.3 Hz, 1H), 6.94 (td, *J* = 7.6, 1.7 Hz, 1H), 6.65 (d, *J* = 7.9 Hz, 1H), 6.58 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.43 (s, 1H), 5.43 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.18 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.39 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.40, 146.93, 143.60, 137.65, 137.00, 136.05, 132.46, 132.35, 131.78, 130.37, 129.34, 127.76, 127.70, 127.56, 127.17, 127.10, 126.81, 125.88, 121.90, 119.21, 106.81, 97.30, 21.20. HRMS (ESI): *m/z* for C₃₁H₂₄BrN₃O₃SH⁺ [M+H]⁺ calcd.: 600.0778, found: 600.0781; HPLC analysis: 95% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 20.05 min (minor), 52.96 min (major).

(R)-4-methyl-N-(2-(3-phenyl-1-(4-(trifluoromethyl)phenyl)-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)benzenesulfonamide



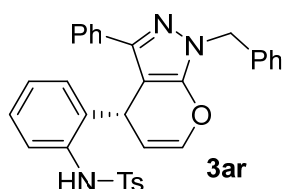
The title compound **3ap** was prepared according to the general procedure as described above in 90% yield (52.8 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 60 – 63 °C; $[\alpha]_D^{25} = -31.4$ (c 0.40, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 8.08 – 8.01 (m, 2H), 7.75 – 7.59 (m, 4H), 7.48 – 7.37 (m, 2H), 7.25 – 7.14 (m, 6H), 7.09 (td, *J* = 7.5, 1.3 Hz, 1H), 6.94 (ddd, *J* = 9.0, 7.3, 1.7 Hz, 1H), 6.65 – 6.56 (m, 2H), 6.54 (s, 1H), 5.49 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.23 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.40 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.94, 147.31, 143.66, 140.69, 137.62, 136.01, 132.29, 132.24, 129.36, 128.76 (d, *J* = 245.3 Hz), 127.75 (d, *J* = 56.1 Hz), 127.80, 127.72, 126.85, 126.95 (q, *J* = 3.8 Hz), 125.78 (d, *J* = 43.6 Hz), 119.94, 106.94, 97.72, 21.21. HRMS (ESI): *m/z* for C₃₂H₂₄F₃N₃O₃SH⁺ [M+H]⁺ calcd.: 588.1563, found: 588.1565; HPLC analysis: 92% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 153.84 min (minor), 33.04 min (major).

(R)-4-methyl-N-(2-(1-(naphthalen-2-yl)-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)benzenesulfonamide



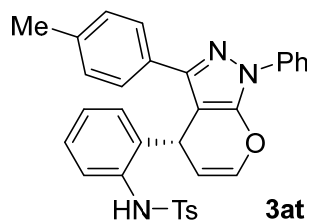
The title compound **3aq** was prepared according to the general procedure as described above in 62% yield (35.3 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 61 – 63 °C; $[\alpha]_D^{25} = -32.7$ (c 0.83, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 8.34 – 8.28 (m, 1H), 8.14 – 8.05 (m, 1H), 7.97 – 7.85 (m, 4H), 7.64 – 7.59 (m, 2H), 7.51 (ddd, *J* = 7.1, 4.9, 1.7 Hz, 2H), 7.46 – 7.40 (m, 2H), 7.24 – 7.18 (m, 7H), 7.09 (td, *J* = 7.5, 1.4 Hz, 1H), 6.97 (td, *J* = 7.6, 1.7 Hz, 1H), 6.72 (d, *J* = 7.9 Hz, 1H), 6.64 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.49 (s, 1H), 5.42 (dt, *J* = 3.7, 1.8 Hz, 1H), 5.17 (dd, 1H), 2.38 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.32, 147.06, 143.58, 137.89, 136.05, 135.40, 133.14, 132.71, 132.40, 131.42, 130.49, 129.33, 128.71, 127.83, 127.76, 127.63, 127.45, 127.39, 127.17, 127.11, 126.93, 126.36, 125.59, 119.81, 118.15, 106.67, 97.23, 21.19. HRMS (ESI): *m/z* for C₃₅H₂₇N₃O₃SH⁺ [M+H]⁺ calcd.: 570.1846, found: 570.1849; HPLC analysis: 92% ee (OOG-4457-EO, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 26.05 min (minor), 31.52 min (major).

(R)-N-(2-(1-benzyl-3-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



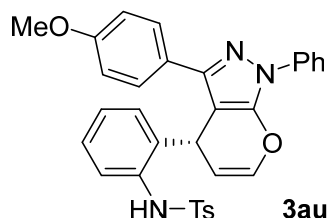
The title compound **3ar** was prepared according to the general procedure as described above in 29% yield (15.2 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 52 – 54 °C; $[\alpha]_D^{25} = -65.7$ (c 0.40, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.59 – 7.51 (m, 2H), 7.36 (dd, *J* = 6.2, 1.2 Hz, 4H), 7.33 – 7.27 (m, 2H), 7.22 – 7.09 (m, 5H), 7.08 – 7.00 (m, 2H), 6.96 (td, *J* = 7.4, 6.9, 2.1 Hz, 1H), 6.78 (d, *J* = 7.9 Hz, 1H), 6.51 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.45 (s, 1H), 5.31 (s, 2H), 5.28 (dd, *J* = 3.8, 1.8 Hz, 1H), 4.99 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.36 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 147.07, 143.48, 137.86, 136.13, 136.05, 133.02, 132.65, 130.33, 129.26, 128.38, 127.63, 127.43, 127.21, 127.15, 127.05, 127.00, 126.70, 125.08, 106.43, 50.81, 21.16. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₃SH⁺ [M+H]⁺ calcd.: 534.1846, found: 534.1846; HPLC analysis: >99% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 26.19.

(R)-4-methyl-N-(2-(1-phenyl-3-(p-tolyl)-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)benzenesulfonamide



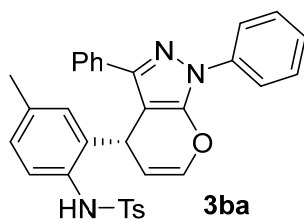
The title compound **3at** was prepared according to the general procedure as described above in 62% yield (33.0 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp =78–80 °C; $[\alpha]_D^{25} = -43.6$ (c 0.41, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.92 – 7.84 (m, 2H), 7.66 – 7.58 (m, 2H), 7.48 (dd, *J* = 8.6, 7.2 Hz, 2H), 7.34 – 7.30 (m, 2H), 7.28 (s, 1H), 7.25 – 7.14 (m, 3H), 7.09 (td, *J* = 7.5, 1.3 Hz, 1H), 7.04 – 6.94 (m, 3H), 6.80 – 6.73 (m, 1H), 6.58 (dd, *J* = 6.1, 1.6 Hz, 1H), 6.51 (s, 1H), 5.36 (dd, *J* = 3.9, 1.6 Hz, 1H), 5.10 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.38 (s, 3H), 2.27 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.09, 146.79, 143.56, 137.90, 137.80, 137.35, 136.06, 132.42, 130.44, 129.84, 129.33, 128.75, 128.47, 127.35, 127.16, 127.11, 126.65, 126.03, 125.54, 120.79, 106.58, 96.73, 21.19, 20.89. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₃SH⁺ [M+H]⁺ calcd.:534.1846, found:534.1843; HPLC analysis: 87% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 19.88 min (minor), 58.04 min (major).

(R)-N-(2-(3-(4-methoxyphenyl)-1-phenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



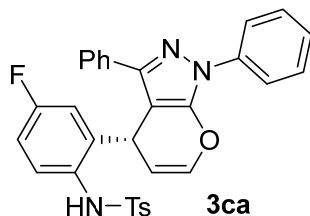
The title compound **3au** was prepared according to the general procedure as described above in 76% yield (41.6 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 66 - 68 °C; $[\alpha]_D^{25} = -33.6$ (c 0.38, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.91 – 7.82 (m, 2H), 7.62 (d, *J* = 8.2 Hz, 2H), 7.53 – 7.42 (m, 2H), 7.37 – 7.28 (m, 3H), 7.25 – 7.14 (m, 3H), 7.13 – 7.04 (m, 1H), 6.99 – 6.92 (m, 1H), 6.76 – 6.68 (m, 3H), 6.63 (s, 1H), 6.57 (dd, *J* = 6.1, 1.6 Hz, 1H), 5.38 (dd, *J* = 4.1, 1.7 Hz, 1H), 5.12 (dd, *J* = 6.1, 3.9 Hz, 1H), 3.73 (s, 3H), 2.38 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 159.02, 147.91, 146.80, 143.59, 137.90, 137.76, 135.99, 132.40, 130.43, 129.34, 128.75, 128.08, 127.41, 127.17, 127.08, 125.97, 125.61, 125.35, 120.73, 113.19, 106.60, 96.53, 54.87, 21.21. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₄SH⁺ [M+H]⁺ calcd.:550.1795, found:550.1795; HPLC analysis: 80% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 34.72 min (minor), 61.51 min (major).

(R)-N-(2-(1,3-diphenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)-4-methylphenyl)-4-methylbenzenesulfonamide



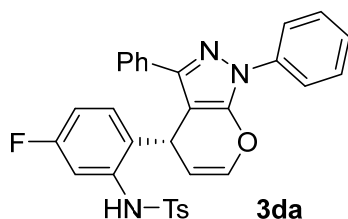
The title compound **3ba** was prepared according to the general procedure as described above in 79% yield (42 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 65 – 67 °C; $[\alpha]_D^{25} = -37.0$ (c 0.52, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.94 – 7.87 (m, 2H), 7.67 – 7.59 (m, 2H), 7.52 – 7.45 (m, 2H), 7.44 – 7.39 (m, 1H), 7.32 (d, *J* = 7.3 Hz, 1H), 7.25 – 7.17 (m, 5H), 6.96 (d, *J* = 2.1 Hz, 1H), 6.75 (dd, *J* = 8.1, 2.1 Hz, 1H), 6.59 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.53 (d, *J* = 8.1 Hz, 1H), 6.35 (s, 1H), 5.39 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.15 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.40 (s, 3H), 2.15 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.11, 146.90, 143.47, 137.96, 137.72, 137.67, 136.11, 132.82, 130.93, 129.51, 129.30, 128.75, 127.81, 127.72, 127.55, 127.22, 126.90, 126.19, 126.00, 120.66, 106.91, 97.25, 21.20, 20.68. HRMS (ESI): *m/z* for C₃₂H₂₇N₃O₃SH⁺ [M+H]⁺ calcd.: 534.1846, found: 534.1842; HPLC analysis: 91% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 17.42 min (minor), 21.15 min (major).

(R)-N-(2-(1,3-diphenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)-4-fluorophenyl)-4-methylbenzenesulfonamide



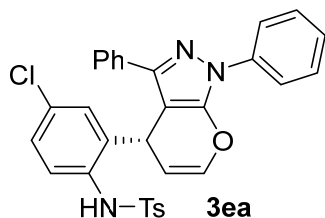
The title compound **3ca** was prepared according to the general procedure as described above in 82% yield (44.1 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 76 – 78 °C; $[\alpha]_D^{25} = -36.6$ (c 0.95, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.94 – 7.83 (m, 2H), 7.68 – 7.58 (m, 2H), 7.52 – 7.43 (m, 4H), 7.34 – 7.27 (m, 2H), 7.26 – 7.16 (m, 3H), 6.87 (dd, *J* = 9.5, 2.9 Hz, 1H), 6.65 – 6.56 (m, 2H), 6.53 (d, *J* = 5.2 Hz, 1H), 6.45 (s, 1H), 5.49 (dt, *J* = 3.6, 1.6 Hz, 1H), 5.16 (dd, *J* = 6.1, 3.9 Hz, 1H), 2.42 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 161.84 (d, *J* = 248.7 Hz), 147.92, 146.84, 143.80, 138.02, 137.80, 135.77, 132.67, 129.43, 128.76, 128.61 (d, *J* = 8.8 Hz), 127.82, 127.70, 127.25, 126.81, 126.15, 120.78, δ 117.04 (d, *J* = 23.4 Hz), 114.09 (d, *J* = 22.7 Hz), 106.21, 96.71, 21.23, 17.56. HRMS (ESI): *m/z* for C₃₁H₂₄FN₃O₃SH⁺ [M+H]⁺ calcd.: 538.1595, found: 538.1591; HPLC analysis: 91% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 16.19 min (minor), 19.90 min (major).

(R)-N-(2-(1,3-diphenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)-5-fluorophenyl)-4-methylbenzenesulfonamide



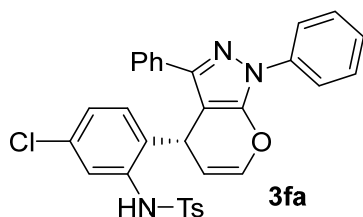
The title compound **3da** was prepared according to the general procedure as described above in 68% yield (33.1 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 96 – 98 °C; $[\alpha]_D^{25} = -37.4$ (c 0.24, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.91 – 7.83 (m, 2H), 7.66 – 7.58 (m, 2H), 7.53 – 7.44 (m, 2H), 7.38 – 7.28 (m, 3H), 7.25 – 7.16 (m, 5H), 7.09 (dd, *J* = 8.7, 6.2 Hz, 1H), 6.80 – 6.69 (m, 2H), 6.69 – 6.62 (m, 1H), 6.60 (dd, *J* = 6.1, 1.7 Hz, 1H), 5.25 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.03 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.37 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 160.93(d, *J* = 245.3), 148.05, 146.64, 143.95, 138.14, δ 136.69 (d, *J* = 155.0 Hz), 134.07(m), 132.49, 131.63 (d, *J* = 9.1 Hz), 129.50, 128.82, 127.78, 127.71, 127.03, 126.82, 126.28, 120.87, 106.09, 96.38, 21.18. HRMS (ESI): *m/z* for C₃₁H₂₄FN₃O₃SH⁺ [M+H]⁺ calcd.: 538.1595, found: 538.1591; HPLC analysis: 96% ee (R&C, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 17.92 min (minor), 23.10 min (major).

(R)-N-(4-chloro-2-(1,3-diphenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



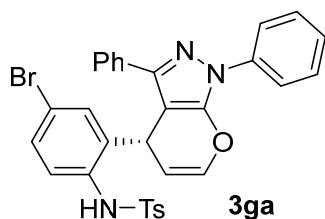
The title compound **3ea** was prepared according to the general procedure as described above in 78% yield (43.1 mg). It was purified by flash column chromatography (Petroleum ether:EtOAc=5:1) to afford yellow solid. mp = 62 – 64 °C; $[\alpha]_D^{25} = -89.5$ (c 0.21, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.92 – 7.84 (m, 2H), 7.64 – 7.57 (m, 2H), 7.52 – 7.44 (m, 2H), 7.44 – 7.38 (m, 2H), 7.33 (d, *J* = 7.4 Hz, 1H), 7.27 – 7.19 (m, 6H), 7.13 (d, *J* = 2.5 Hz, 1H), 6.91 (dd, *J* = 8.5, 2.5 Hz, 1H), 6.64 – 6.58 (m, 2H), 6.54 (s, 1H), 5.38 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.08 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.40 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.00, 146.71, 143.85, 138.25, 137.76, 135.72, 133.29, 132.59, 130.89, 130.49, 129.46, 128.79, 127.83, 127.75, 127.30, 127.16, 126.88, 126.21, 120.81, 105.98, 96.53, 21.22. HRMS (ESI): *m/z* for C₃₁H₂₄ClN₃O₃SH⁺ [M+H]⁺ calcd.: 554.1300, found: 554.1306; HPLC analysis: 91% ee (IA, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t*_R = 16.41 min (minor), 19.60 min (major).

(R)-N-(5-chloro-2-(1,3-diphenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



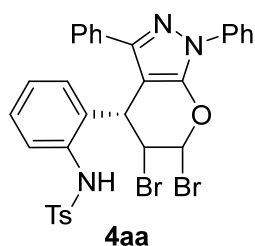
The title compound **3fa** was prepared according to the general procedure as described above in 68% yield (37.6 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 102 – 104 °C; $[\alpha]_D^{25} = -78.3$ (c 0.41, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.91 – 7.83 (m, 2H), 7.64 – 7.58 (m, 2H), 7.53 – 7.45 (m, 2H), 7.41 – 7.26 (m, 4H), 7.26 – 7.18 (m, 4H), 7.12 – 7.00 (m, 2H), 6.81 (d, *J* = 2.0 Hz, 1H), 6.60 (dd, *J* = 6.1, 1.7 Hz, 1H), 6.56 (s, 1H), 5.30 (dd, *J* = 3.9, 1.7 Hz, 1H), 5.05 (dd, *J* = 6.1, 3.8 Hz, 1H), 2.39 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 147.99, 146.70, 144.00, 138.20, 137.73, 135.57, 133.71, 132.52, 132.43, 131.44, 129.48, 128.80, 127.84, 127.76, 127.14, 127.09, 126.79, 126.26, 124.89, 120.84, 105.97, 96.31, 21.19. HRMS (ESI): *m/z* for C₃₁H₂₄ClN₃O₃SH⁺ [M+H]⁺ calcd.: 554.1300, found: 554.1304; HPLC analysis: 97% ee (R&C, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 26.48 min (minor), 29.64 min (major).

(R)-N-(4-bromo-2-(1,3-diphenyl-1,4-dihydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide



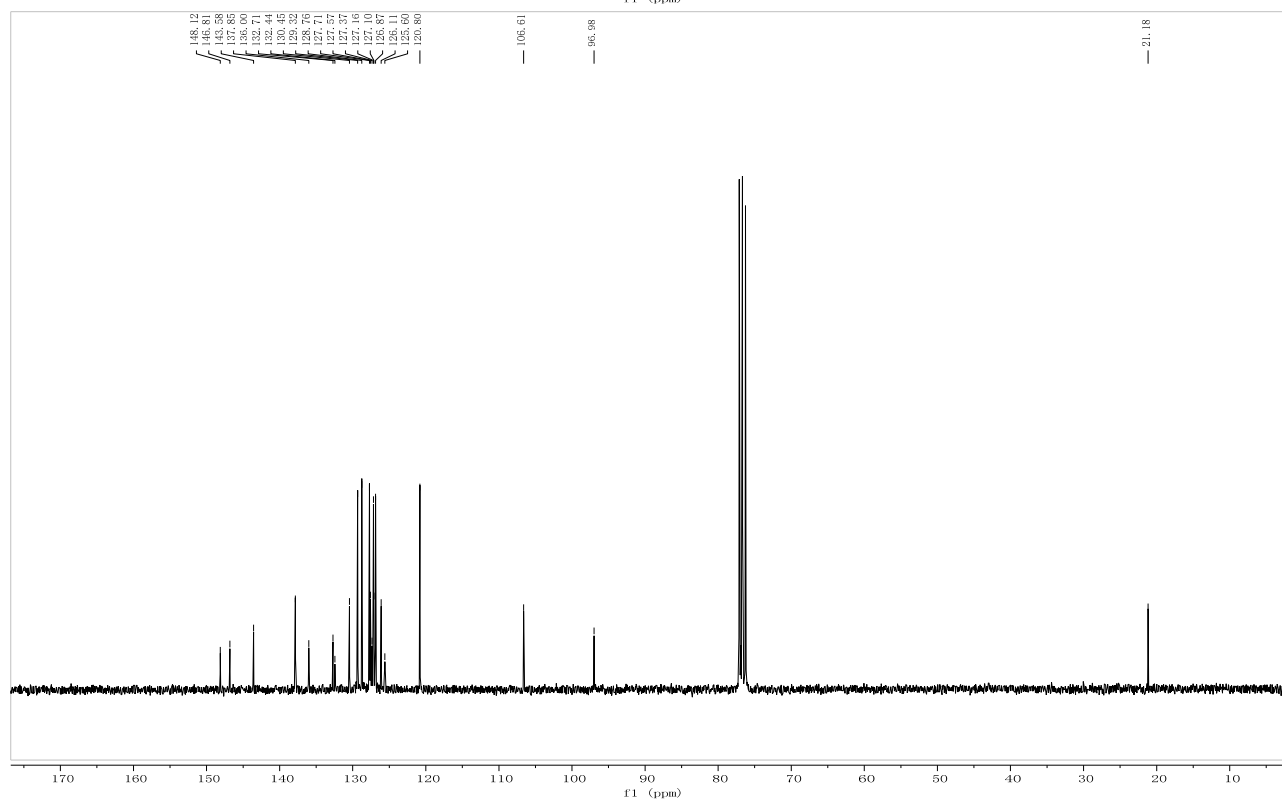
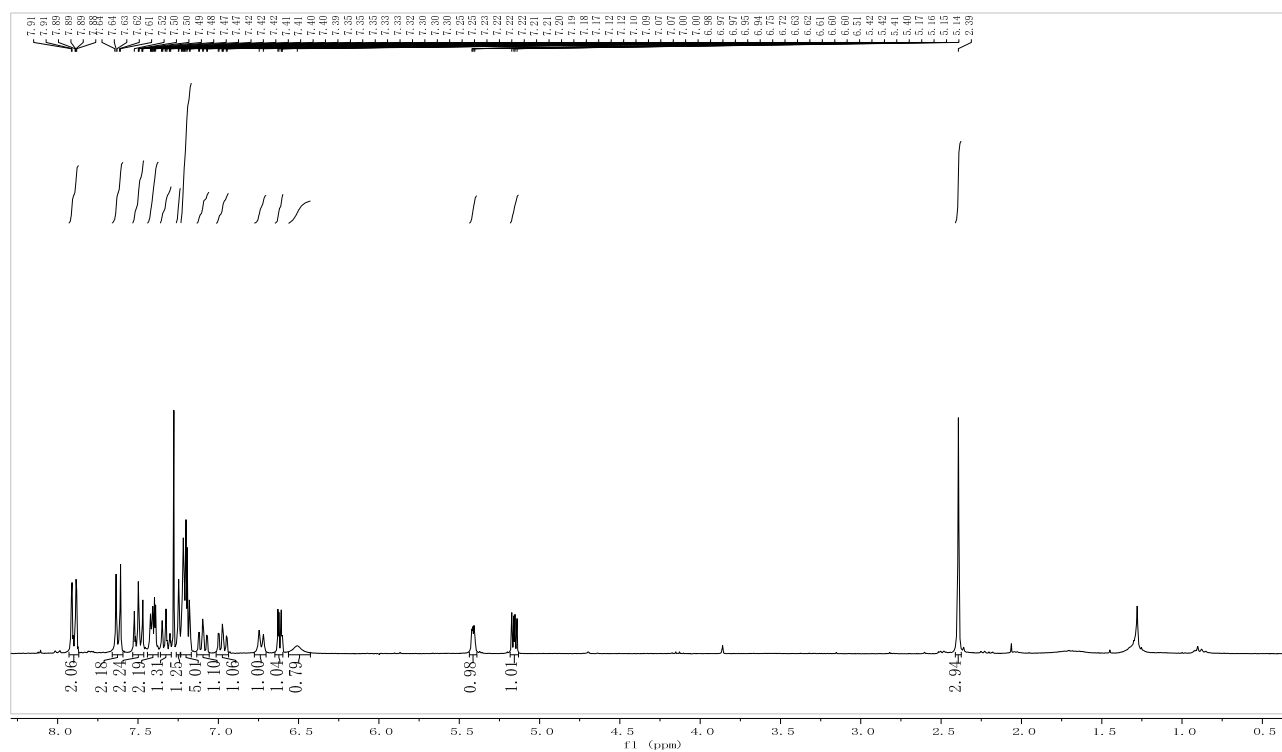
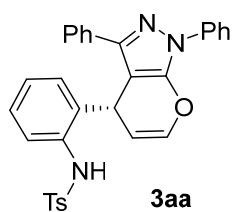
The title compound **3ga** was prepared according to the general procedure as described above in 76% yield (45.1 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 106 – 108 °C; $[\alpha]_D^{25} = -26.7$ (c 0.50, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.91 – 7.85 (m, 3H), 7.64 – 7.56 (m, 3H), 7.53 – 7.44 (m, 2H), 7.43 – 7.28 (m, 3H), 7.26 – 7.19 (m, 5H), 7.07 (dd, *J* = 8.5, 2.4 Hz, 1H), 6.65 – 6.54 (m, 2H), 6.50 (s, 1H), 5.07 (dd, 1H), 2.39 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.05, 146.67, 143.87, 138.32, 137.75, 135.69, 133.46, 132.57, 131.56, 130.30, 129.47, 128.79, 127.83, 127.77, 127.13, 126.92, 126.23, 120.83, 105.91, 96.48, 21.21. HRMS (ESI): *m/z* for C₃₁H₂₄BrN₃O₃SSNa⁺ [M+Na]⁺ calcd.: 622.0598, found: 622.0594; HPLC analysis: 94% ee (R&C, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), *t_R* = 29.05 min (minor), 34.77 min (major).

N-(2-(5,6-dibromo-1,3-diphenyl-1,4,5,6-tetrahydropyrano[2,3-c]pyrazol-4-yl)phenyl)-4-methylbenzenesulfonamide

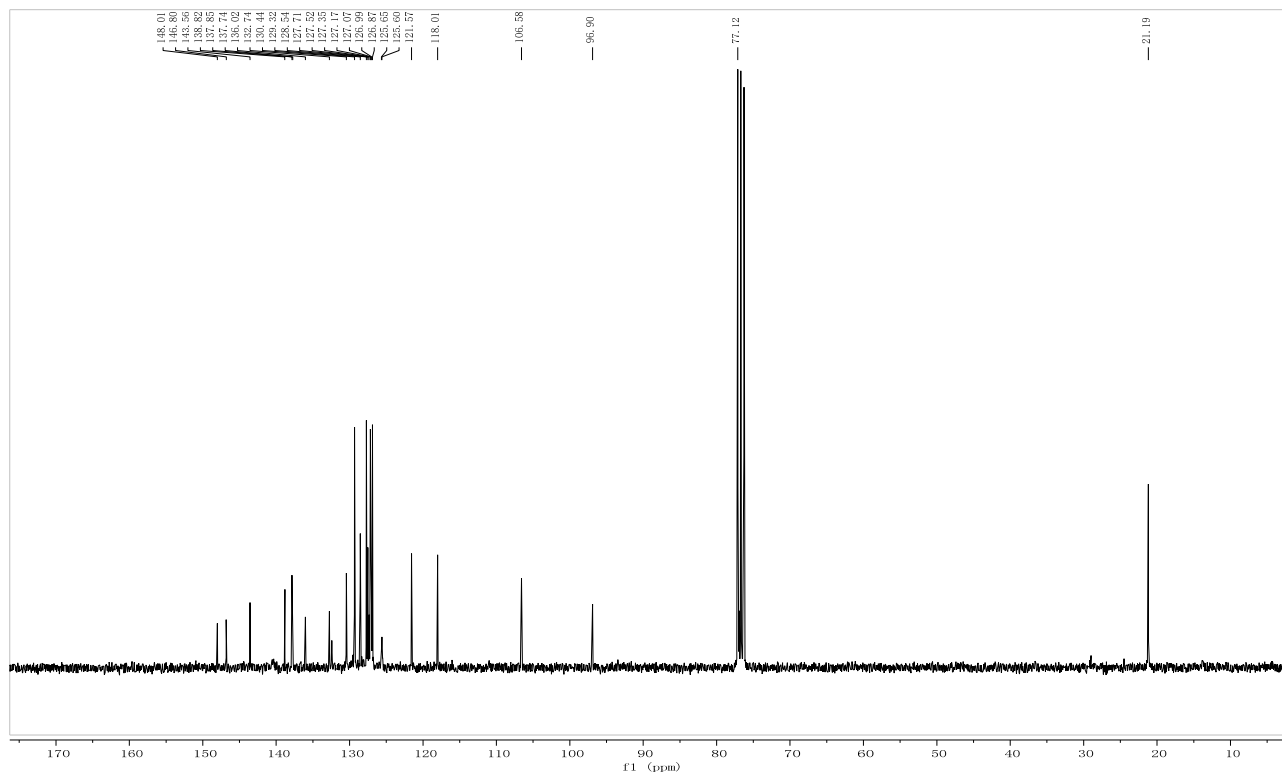
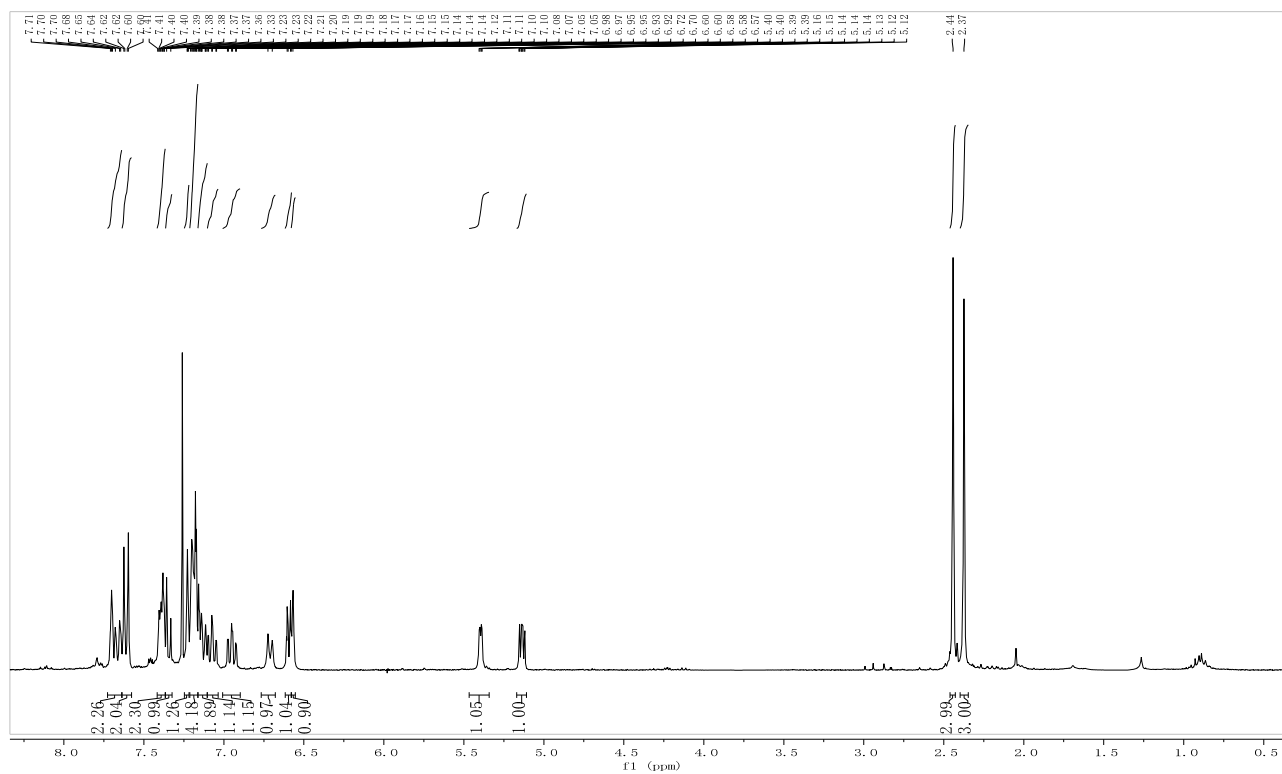
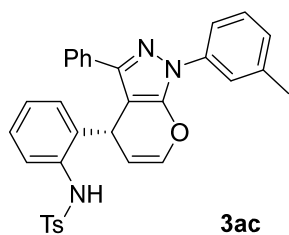


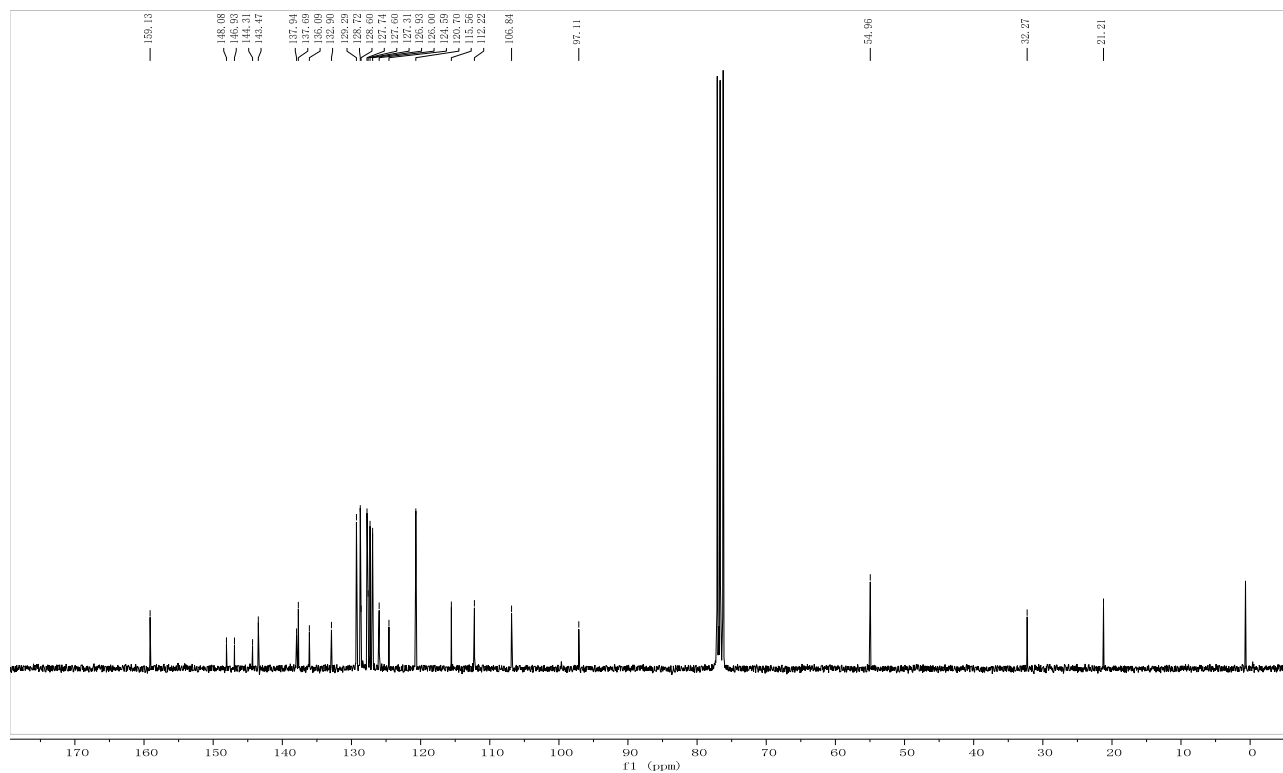
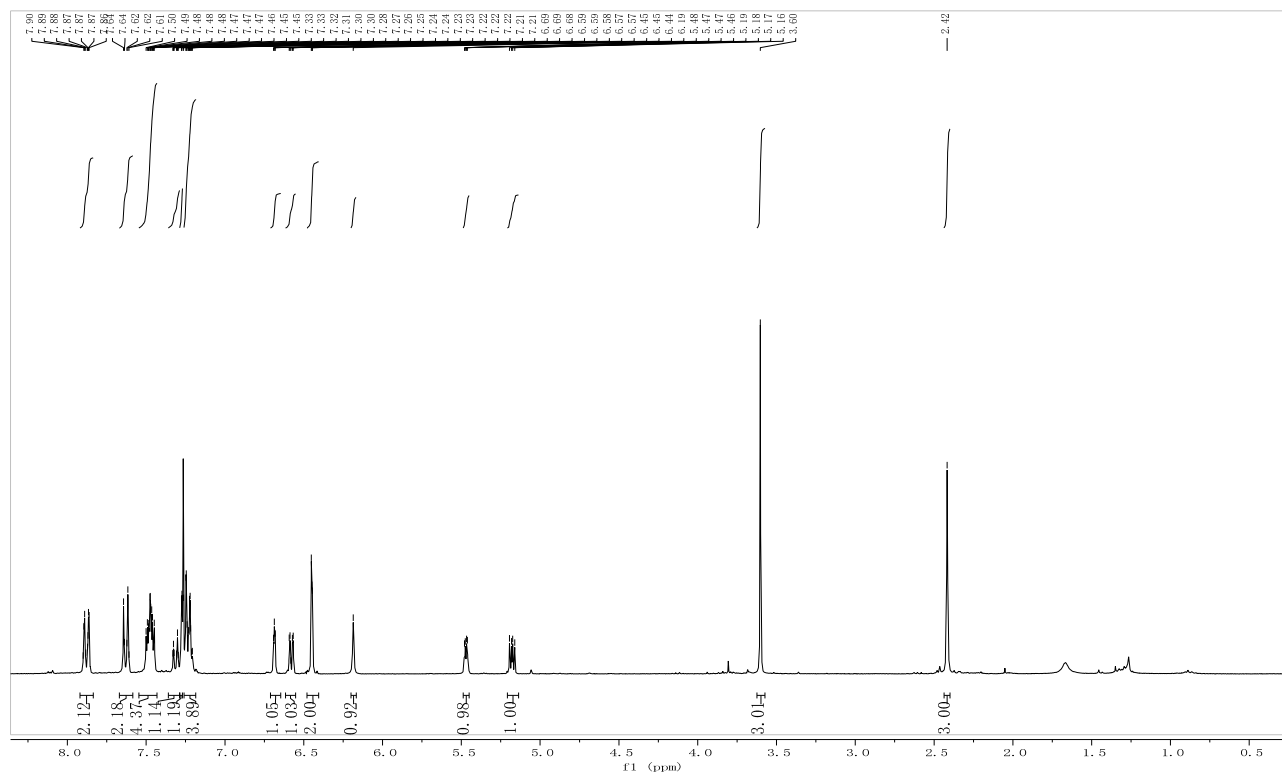
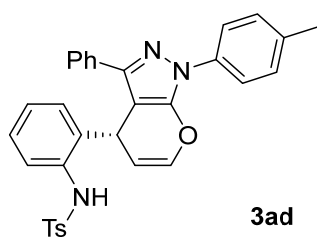
The title compound **4aa** was prepared according to the general procedure as described above in 76% yield (51.7 mg). It was purified by flash column chromatography (Petroleum ether :EtOAc=5:1) to afford yellow solid. mp = 104 – 106 °C; $[\alpha]_D^{25} = -66.2$ (c 0.36, CH₂Cl₂); ¹H NMR (300 MHz, Chloroform-*d*) δ 7.92 – 7.87 (m, 2H), 7.75 (m, 2H), 7.73 – 7.69 (m, 2H), 7.55 – 7.48 (m, 2H), 7.34 (d, *J* = 3.9 Hz, 2H), 7.30 (m, 2H), 7.26 – 7.20 (m, 2H), 7.09 (dd, *J* = 4.9, 1.9 Hz, 1H), 7.01 – 6.95 (m, 2H), 6.73 – 6.68 (m, 2H), 6.67 – 6.62 (m, 1H), 5.82 (s, 1H), 5.14 (t, *J* = 1.3 Hz, 1H), 2.44 (s, 3H). ¹³C NMR (75 MHz, CDCl₃) δ 148.66, 144.80, 144.02, 137.85, 137.62, 135.47, 133.23, 132.29, 132.03, 129.47, 128.82, 128.79, 127.98, 127.93, 127.70, 127.58, 127.46, 127.27, 127.25, 126.48, 126.35, 121.27, 121.21, 92.62, 78.73, 48.21, 41.49, 21.29. HRMS (ESI): *m/z* for C₃₁H₂₅Br₂N₃O₃SH⁺ [M+H]⁺ calcd.: 680.0036, found: 680.0037; HPLC analysis: 12:1 dr; 70% ee for major diastereomer, >99% ee for minor diastereomer (IBN5, isopropanol: hexane=85:15, 1.0 mL/min, UV: 254 nm), major diastereomer: *t*_R = 25.64 min (minor), 27.77 min (major); minor diastereomer: 38.91 min (major).

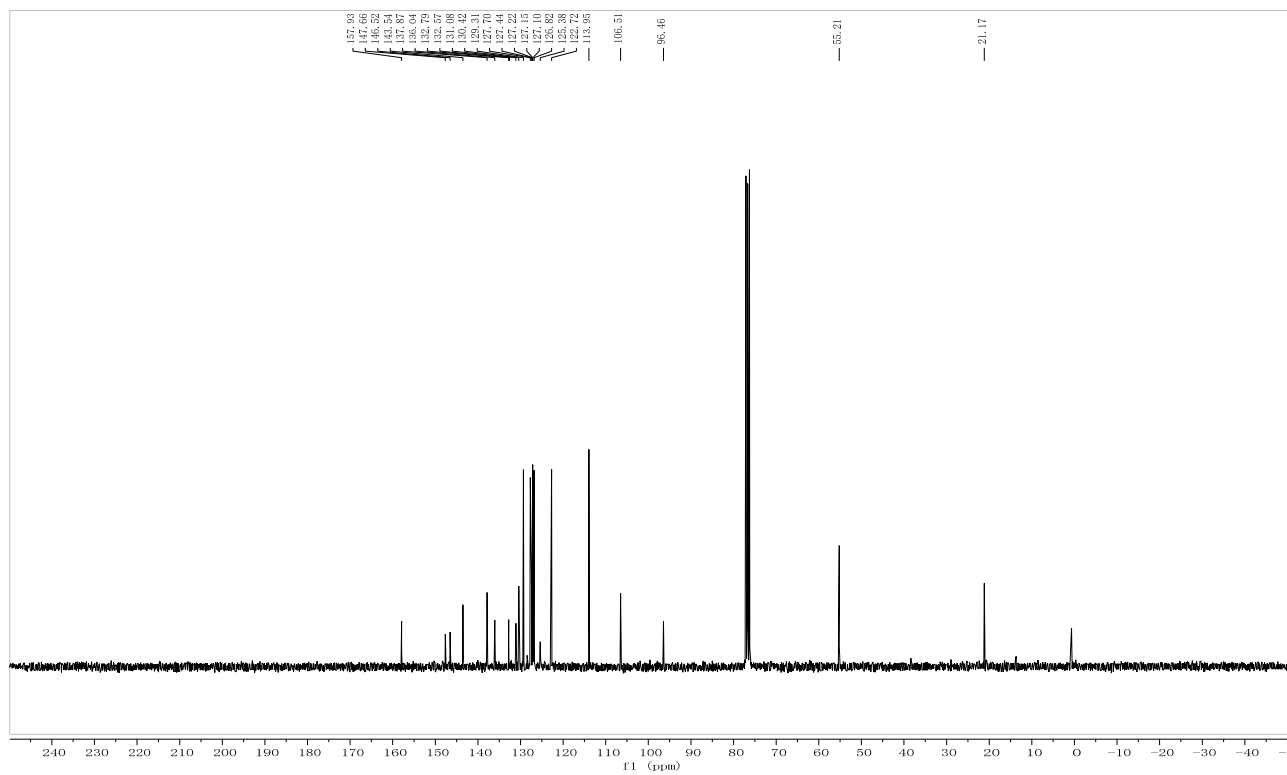
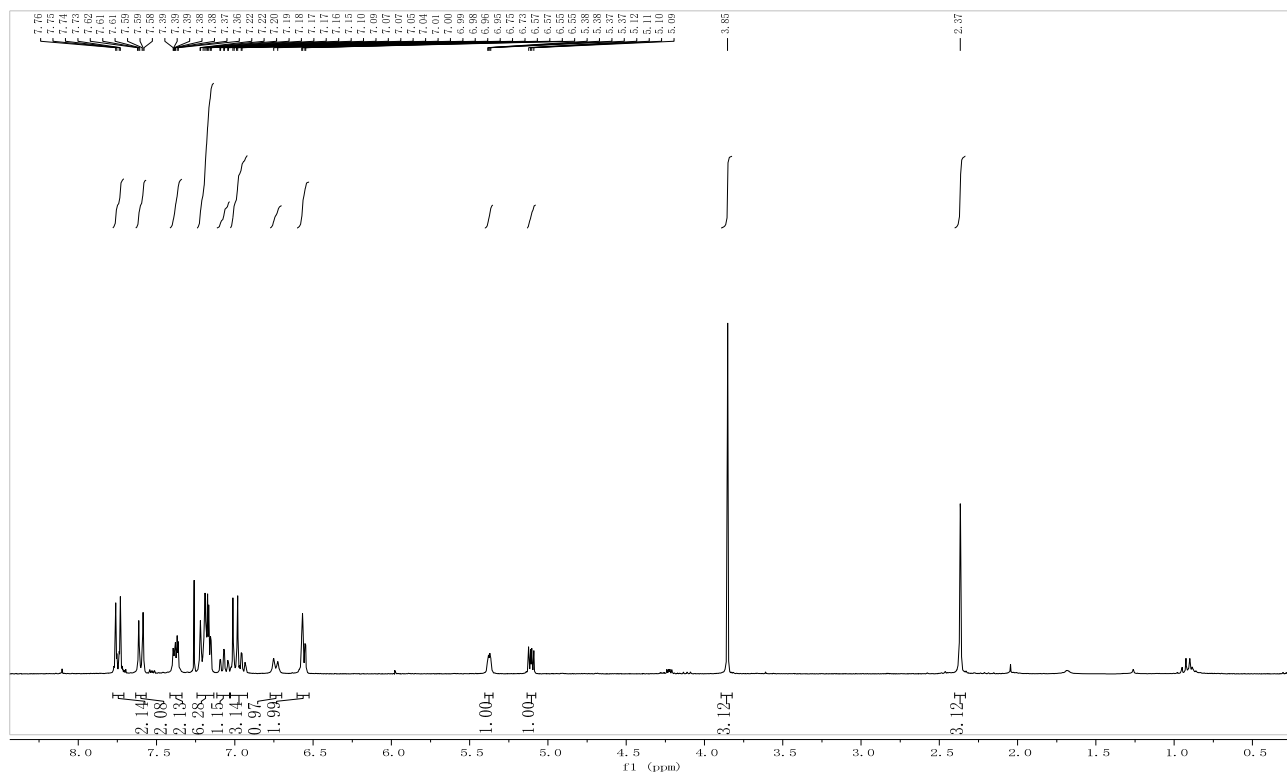
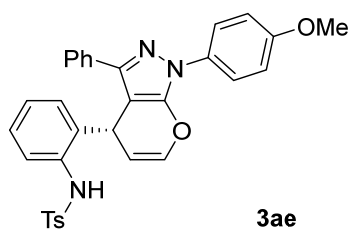
¹H and ¹³C NMR Spectra of All Products 3, 4

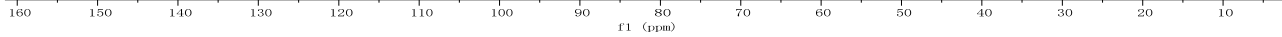
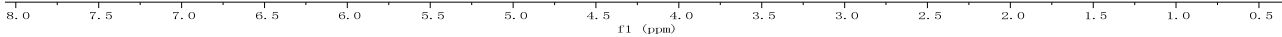




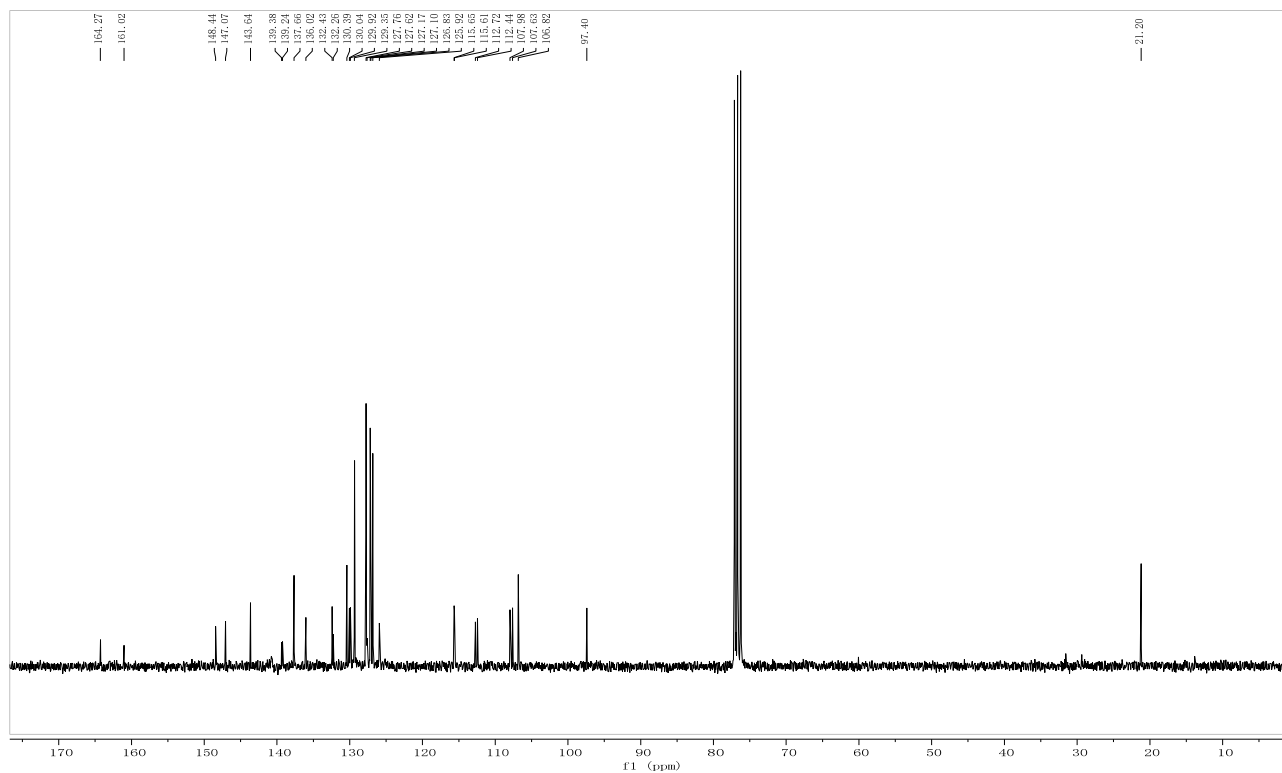
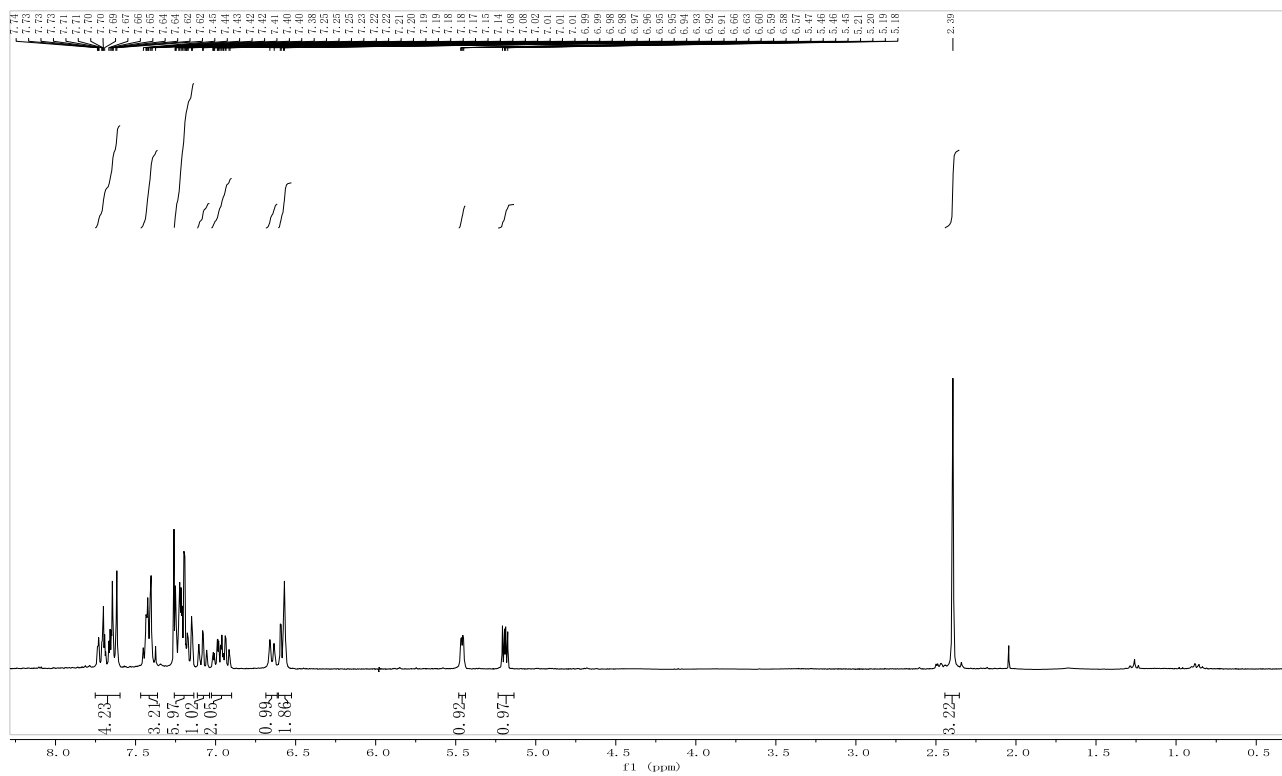
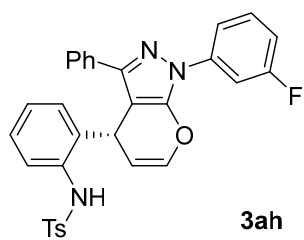


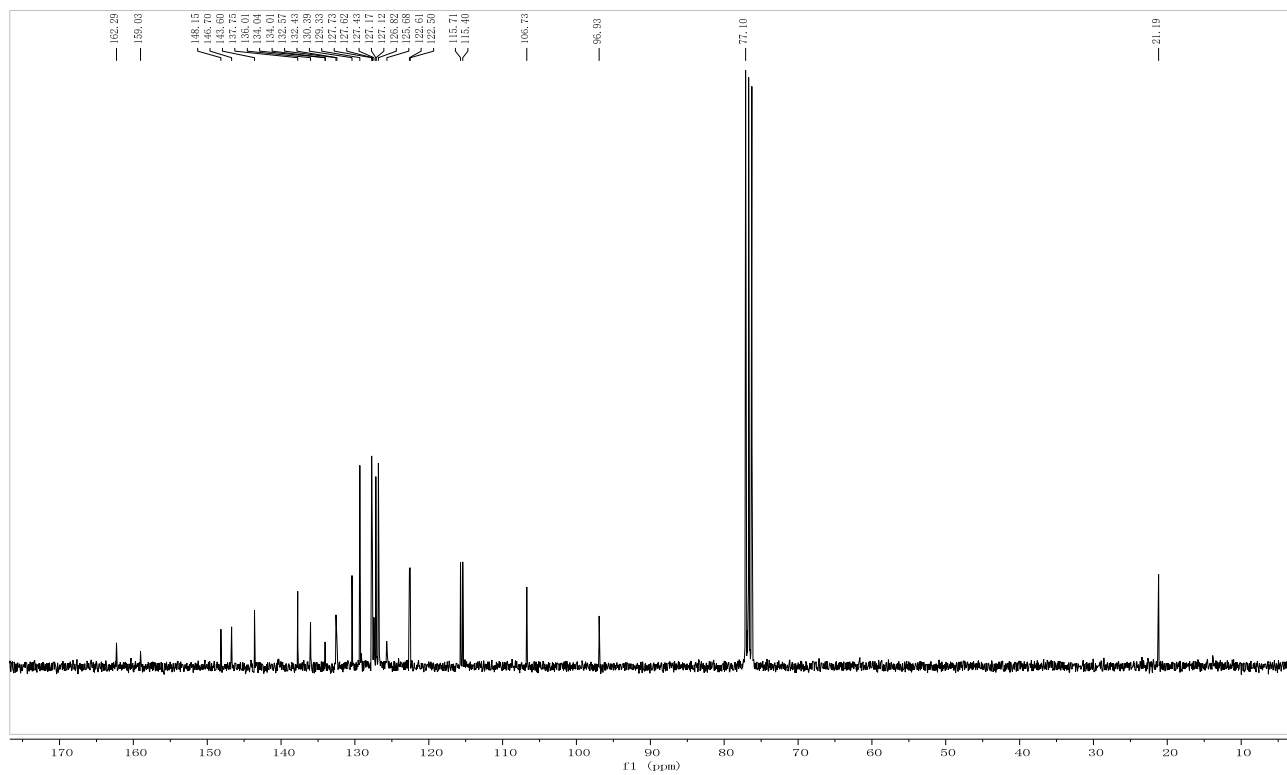
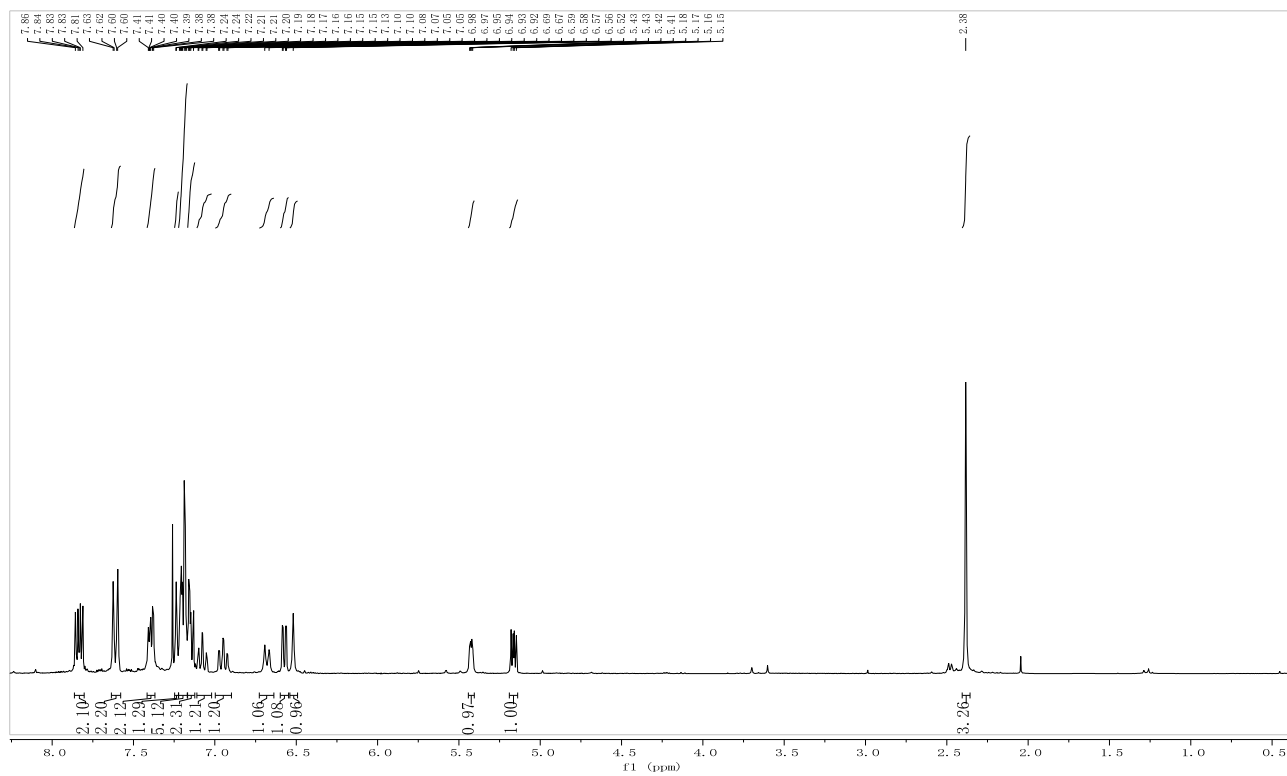
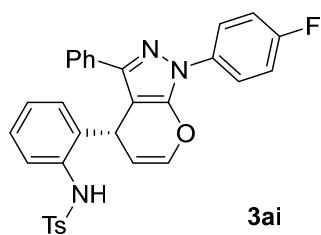


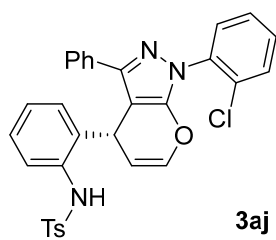




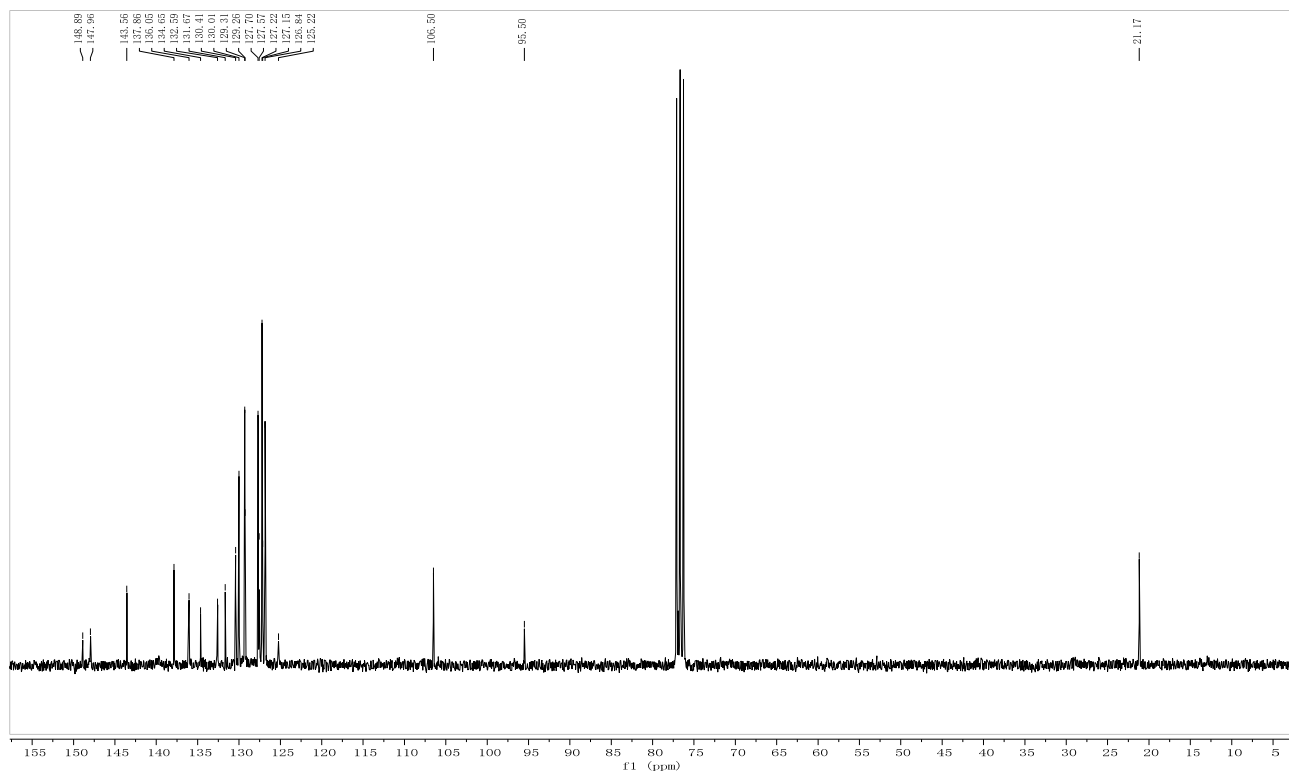
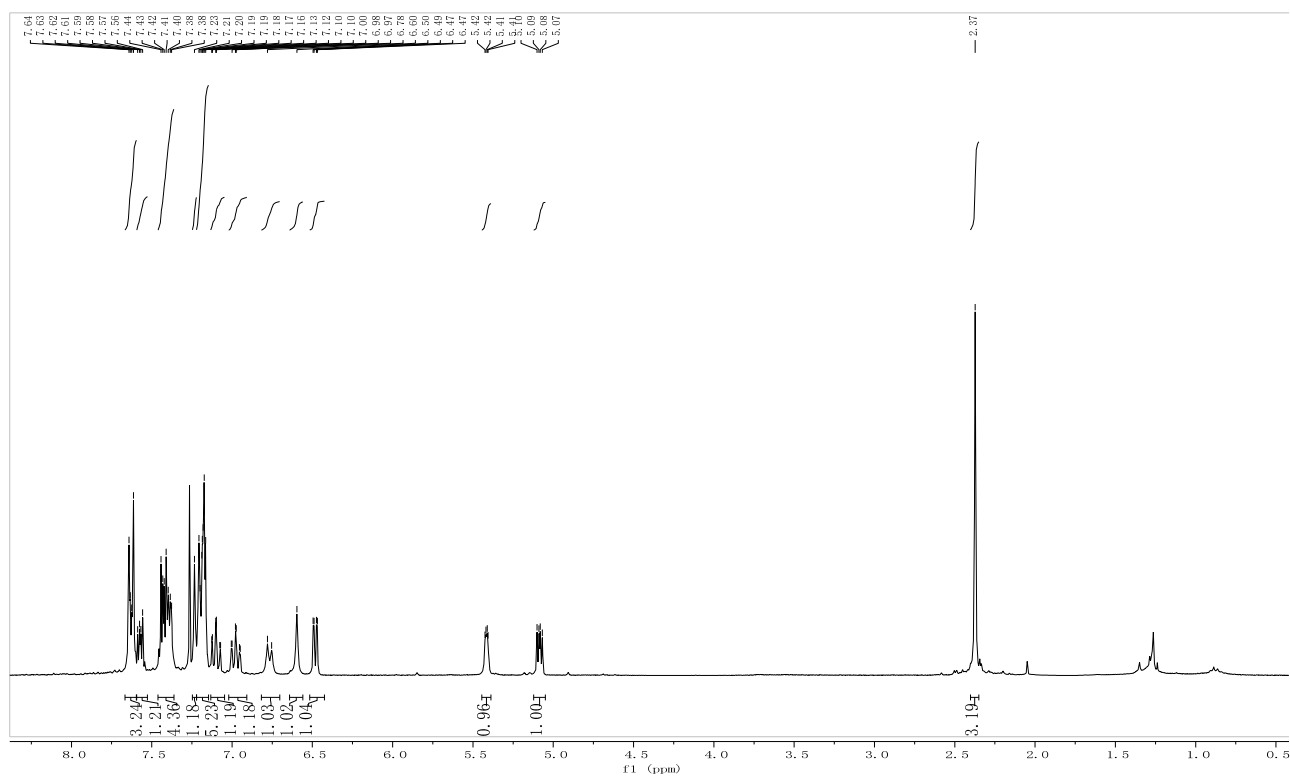


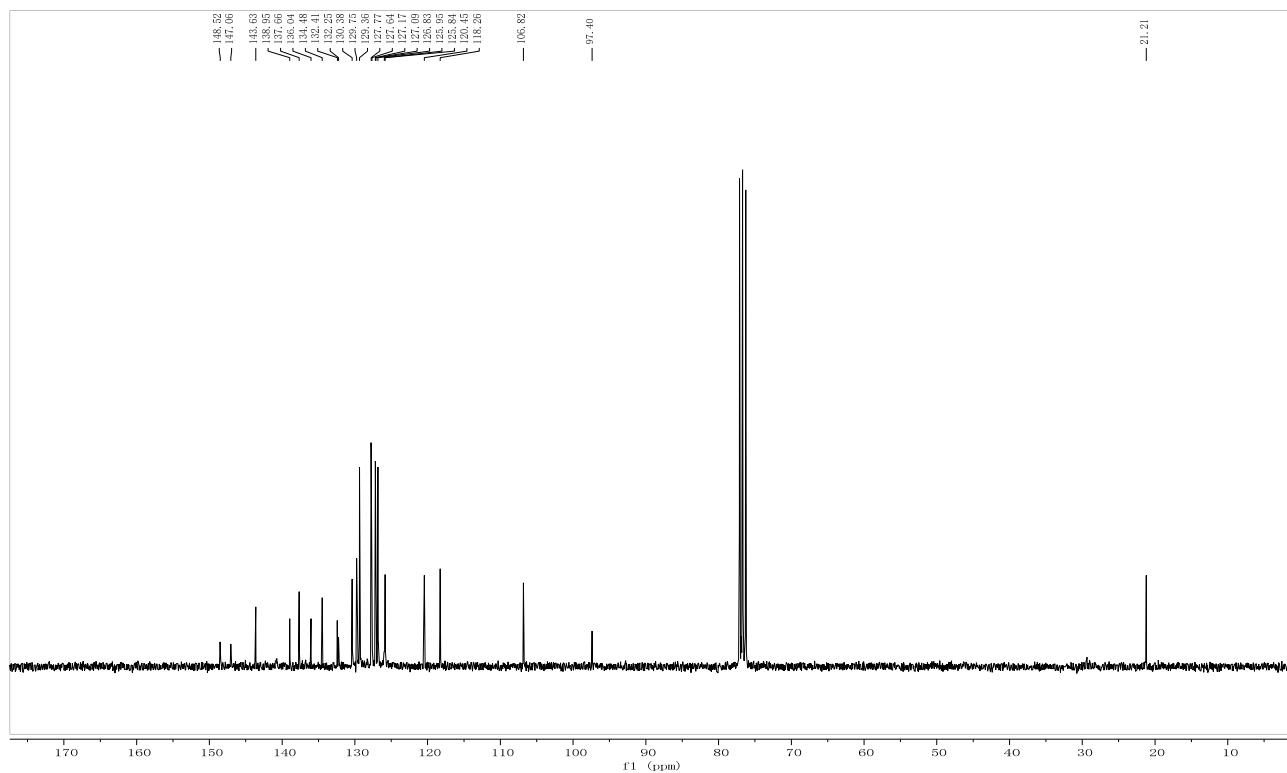
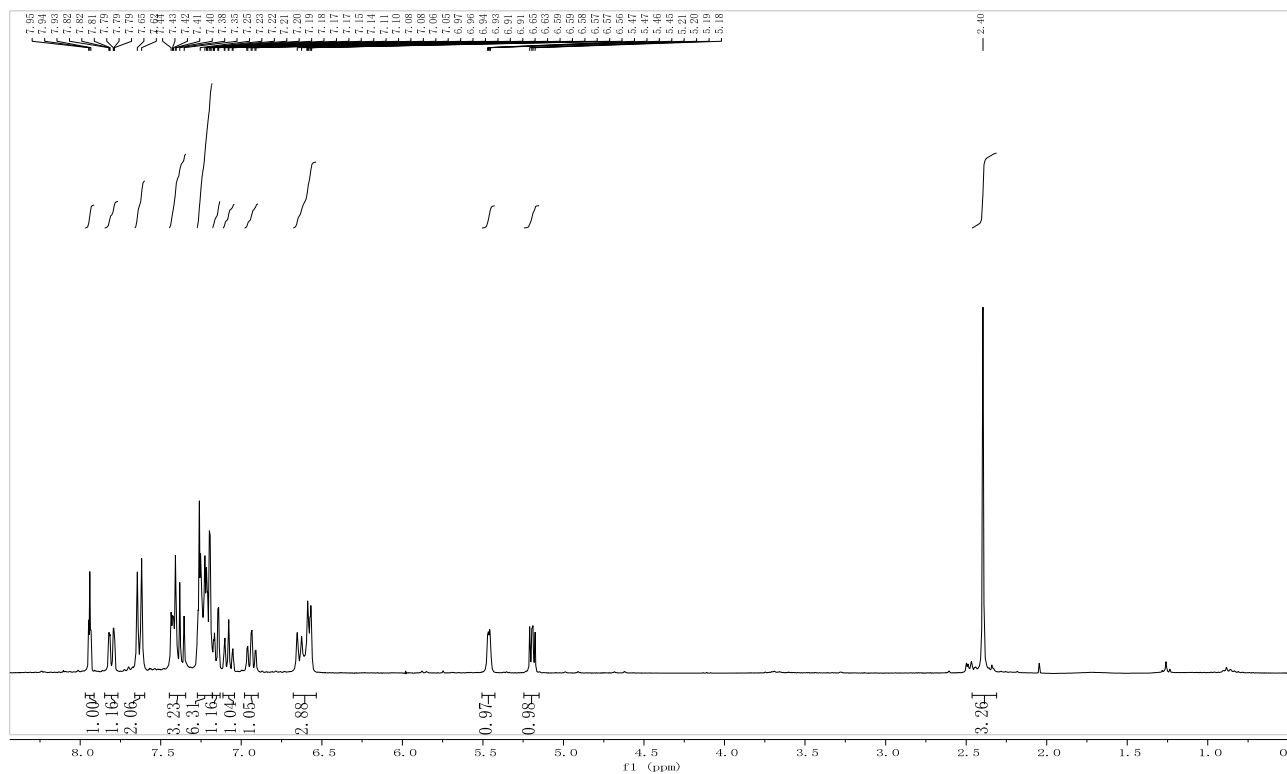
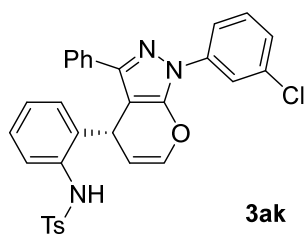


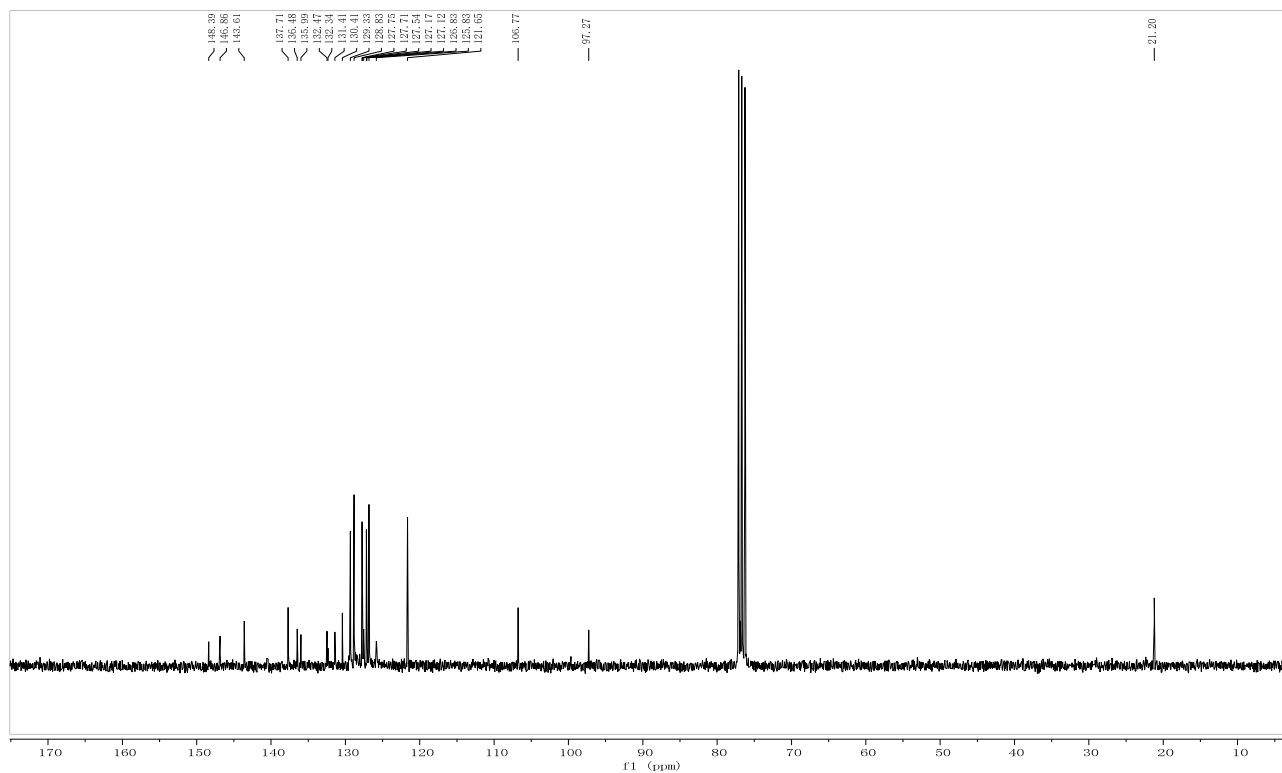
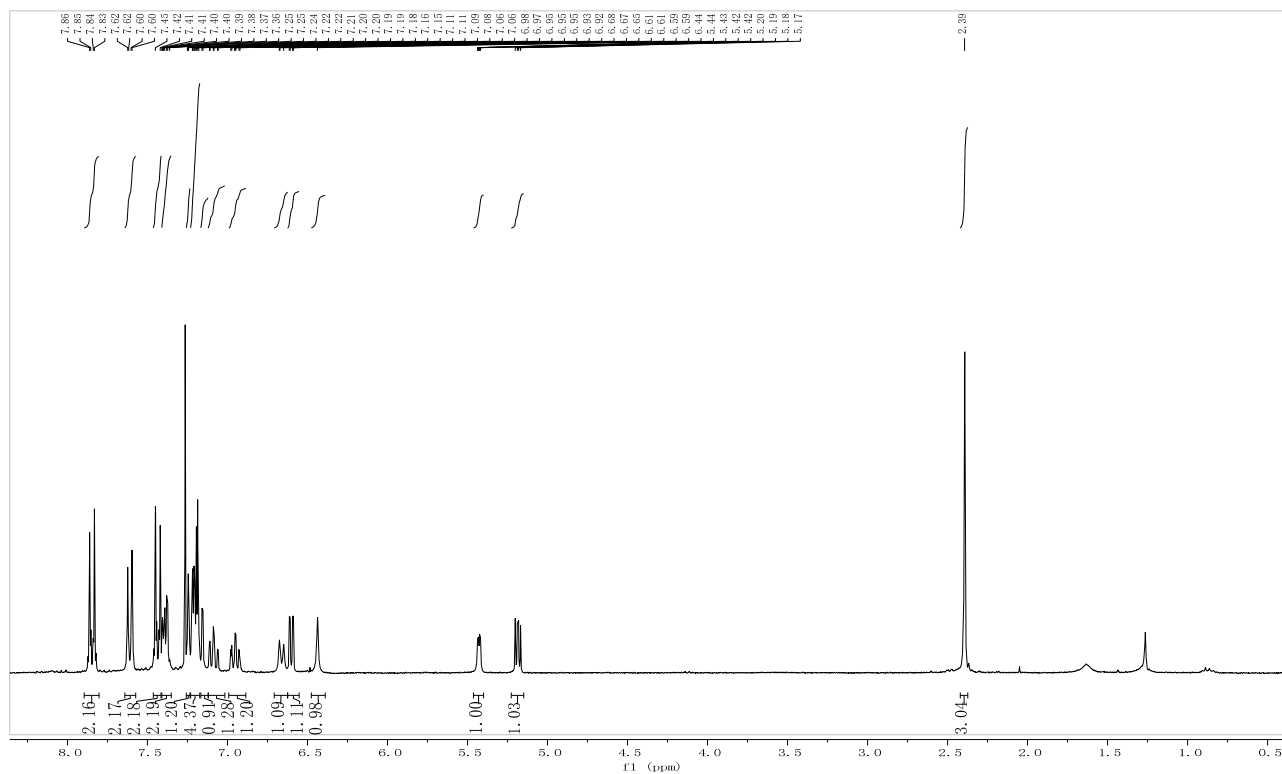
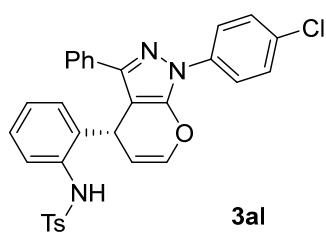


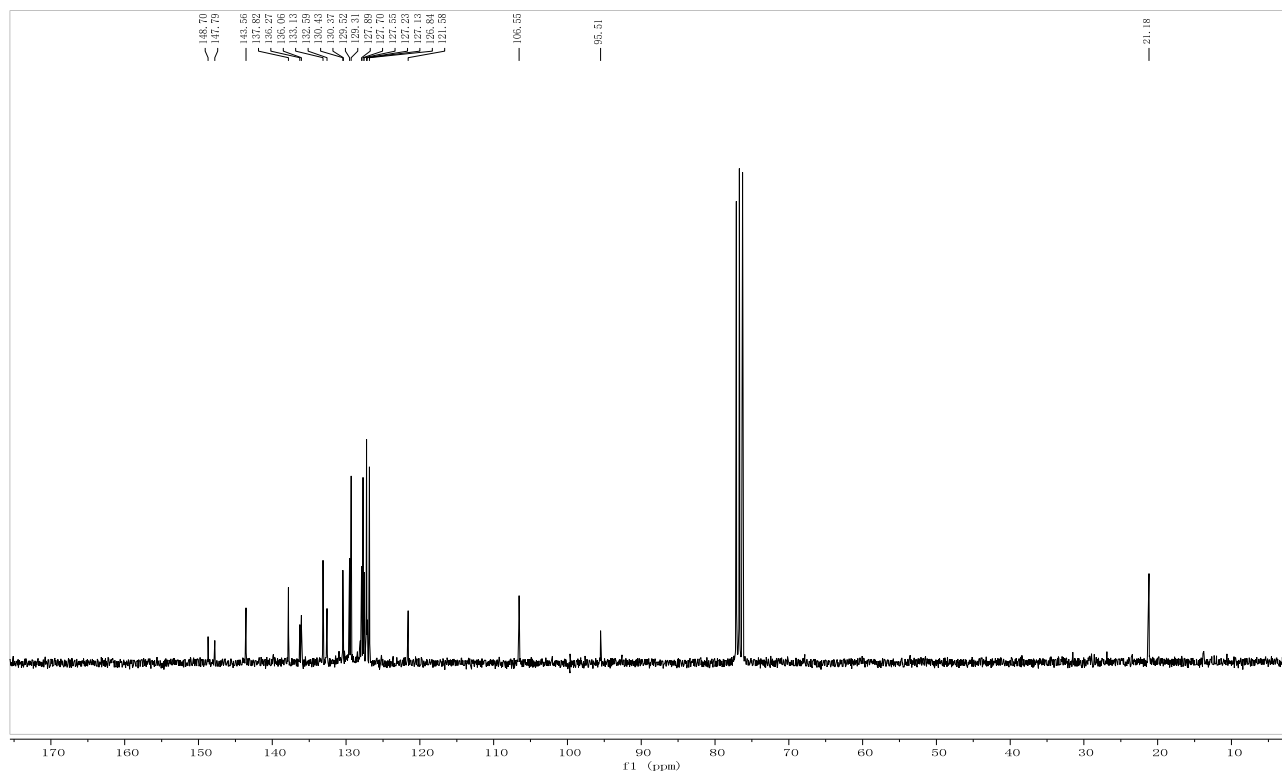
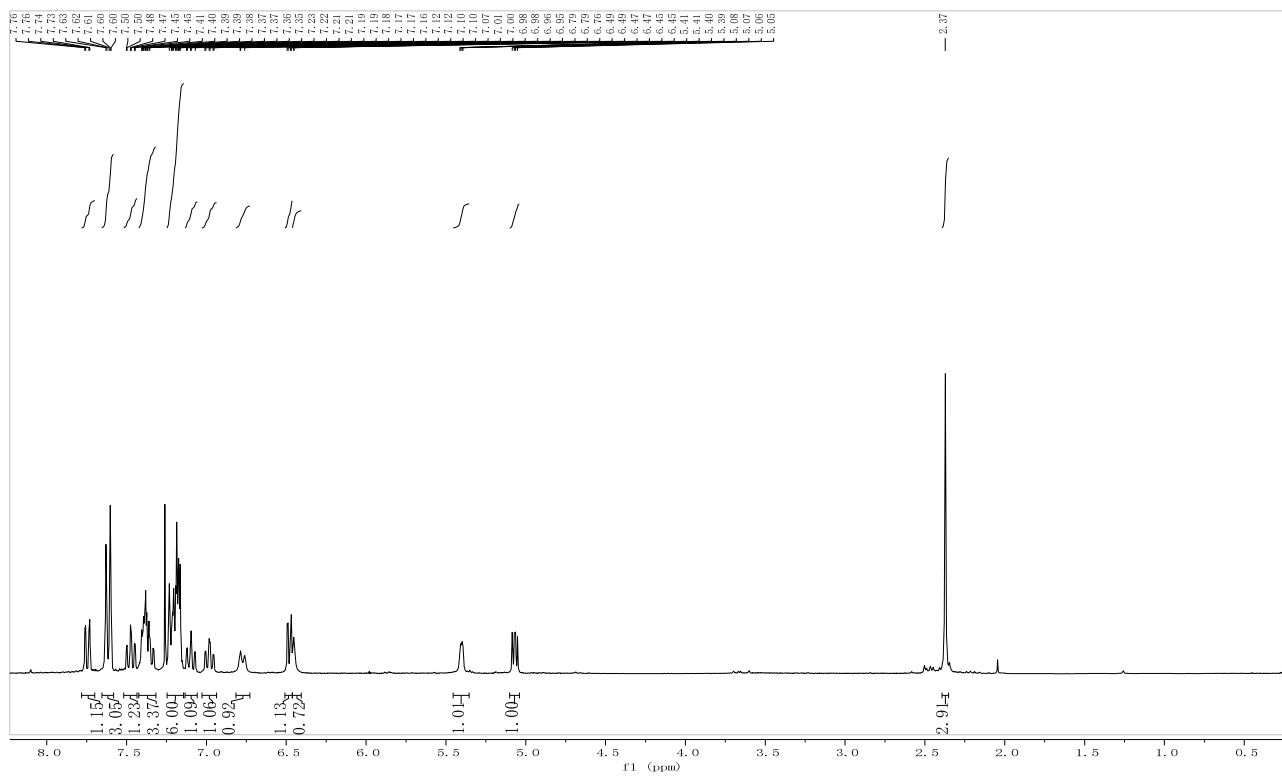
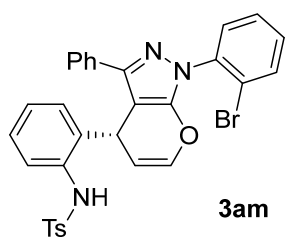


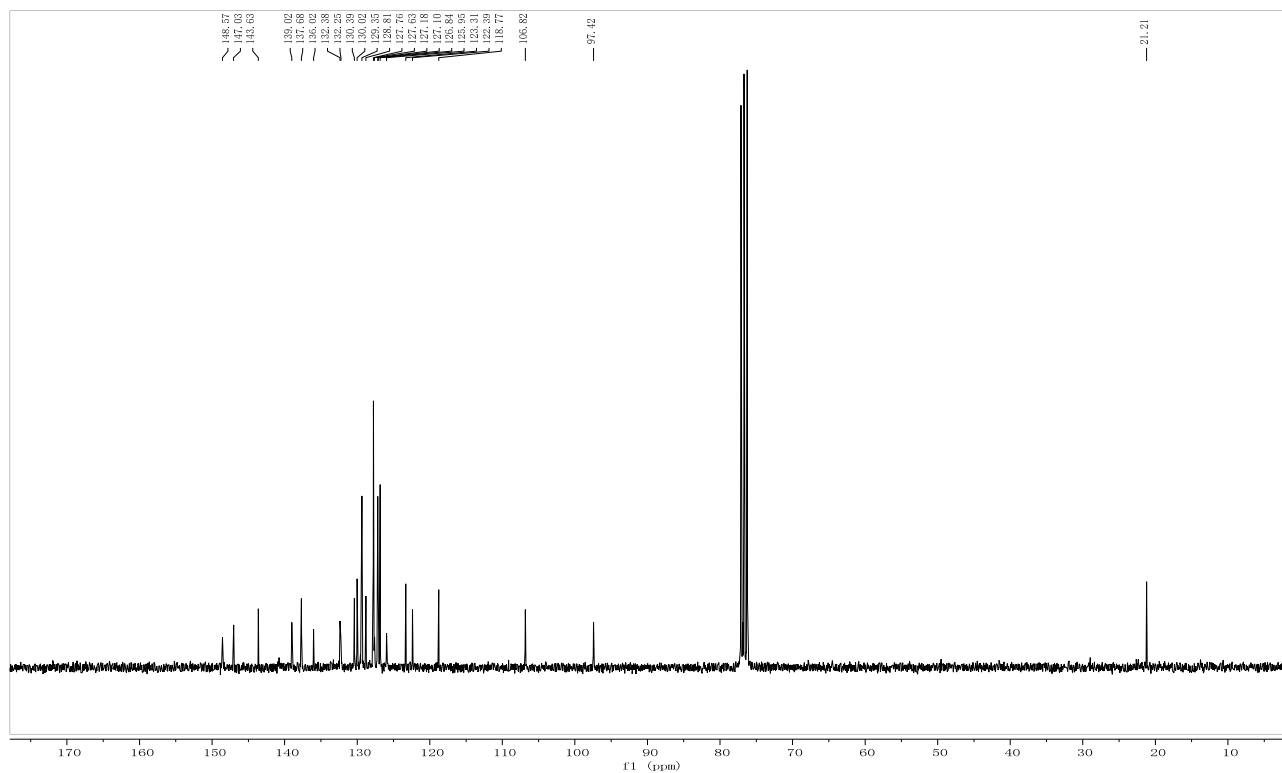
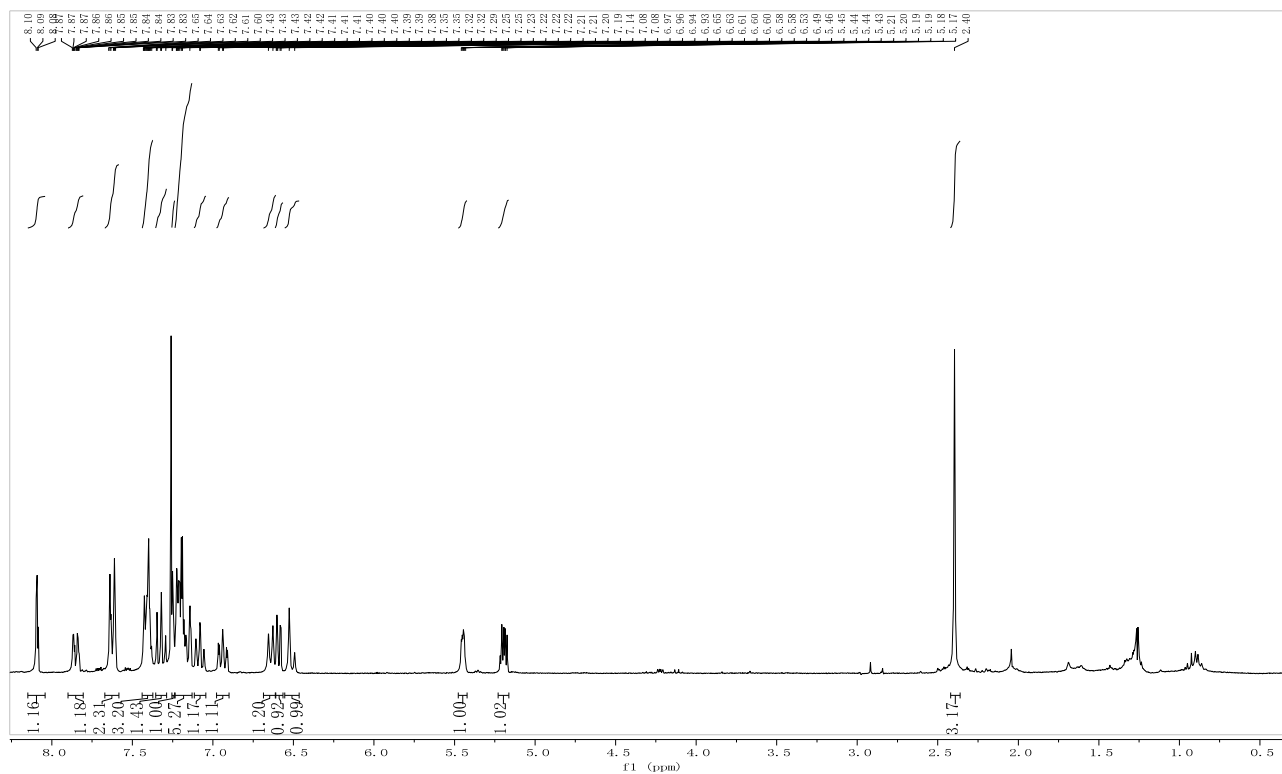
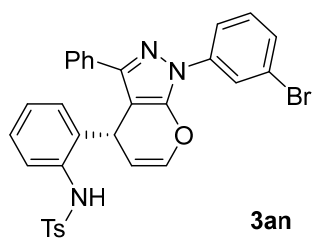
3aj

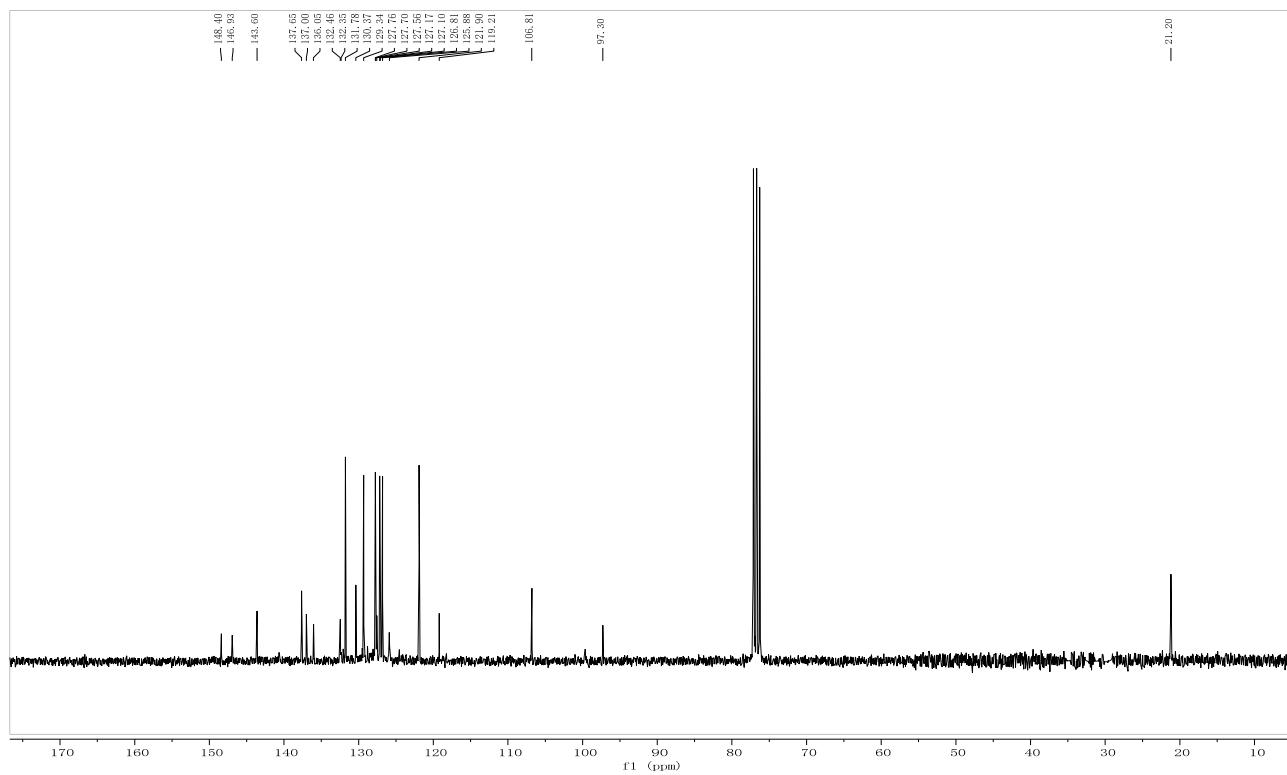
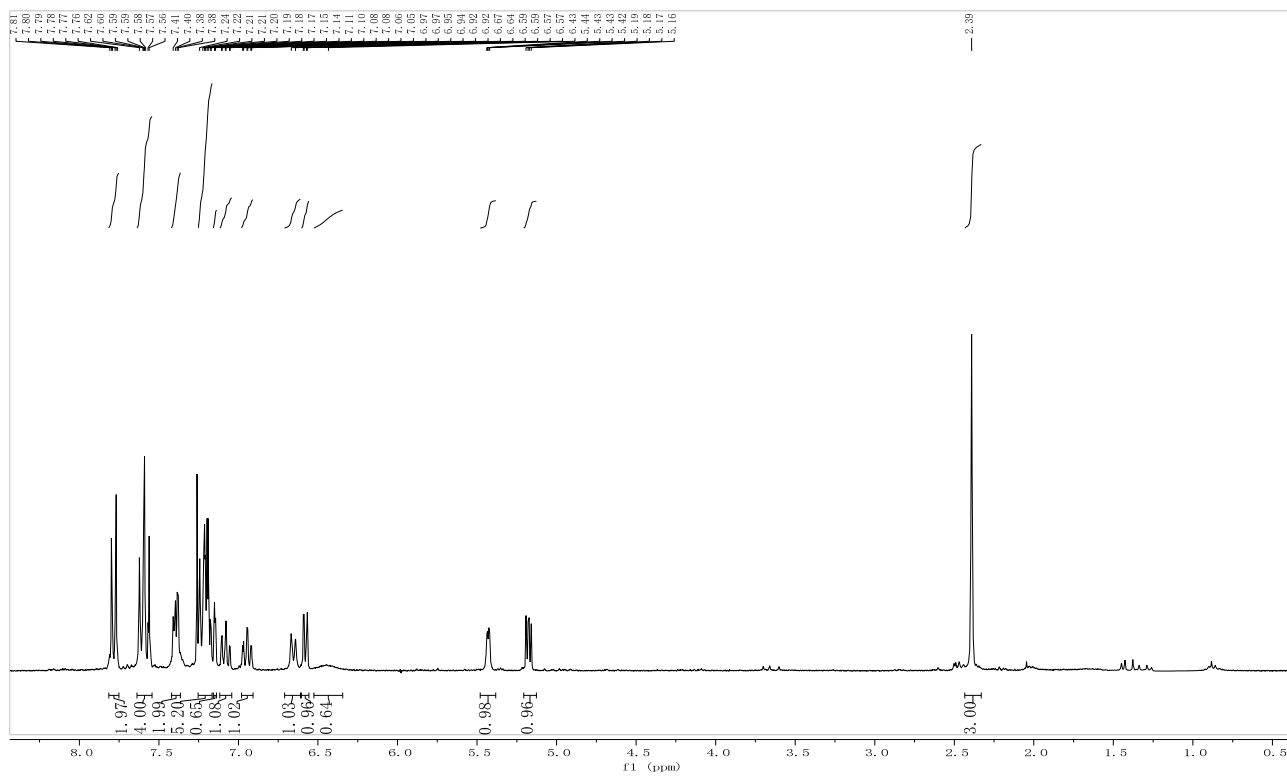
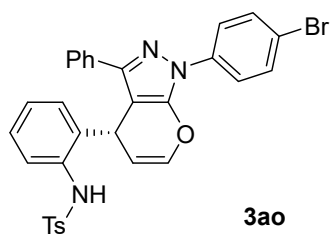


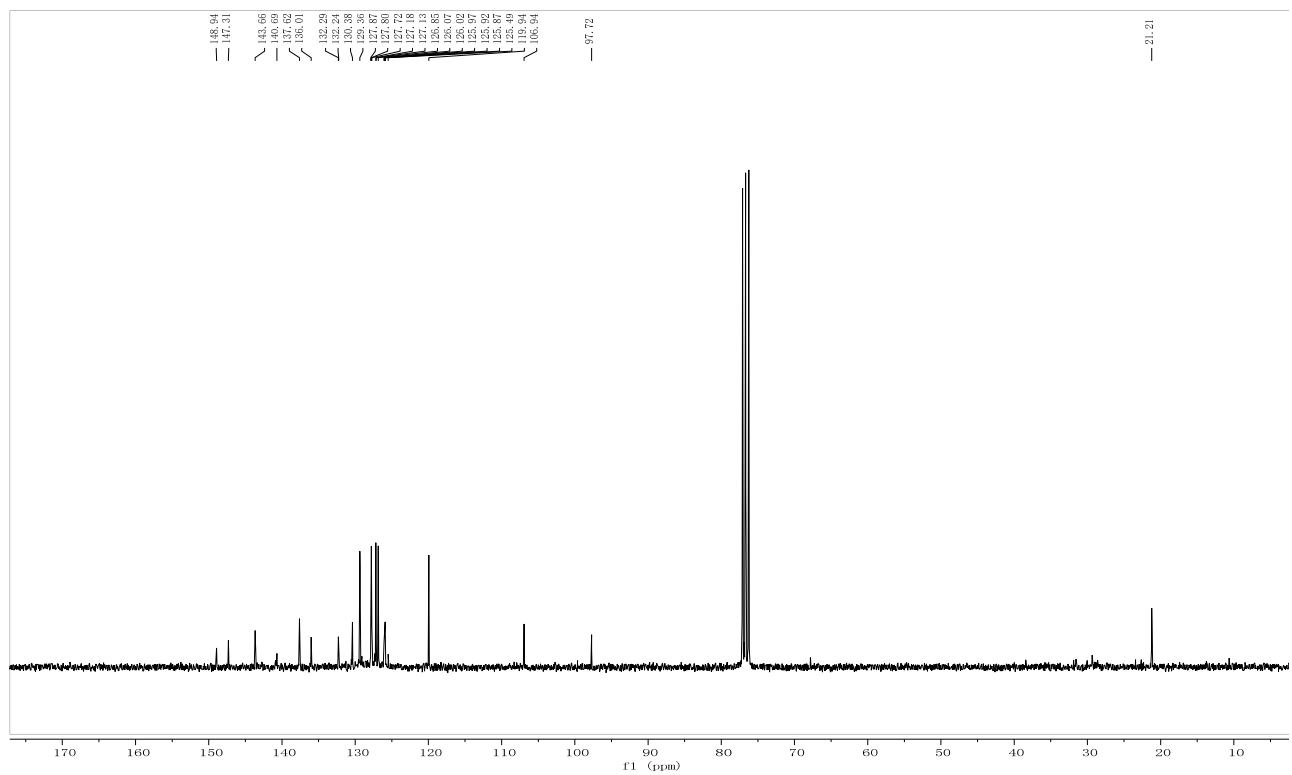
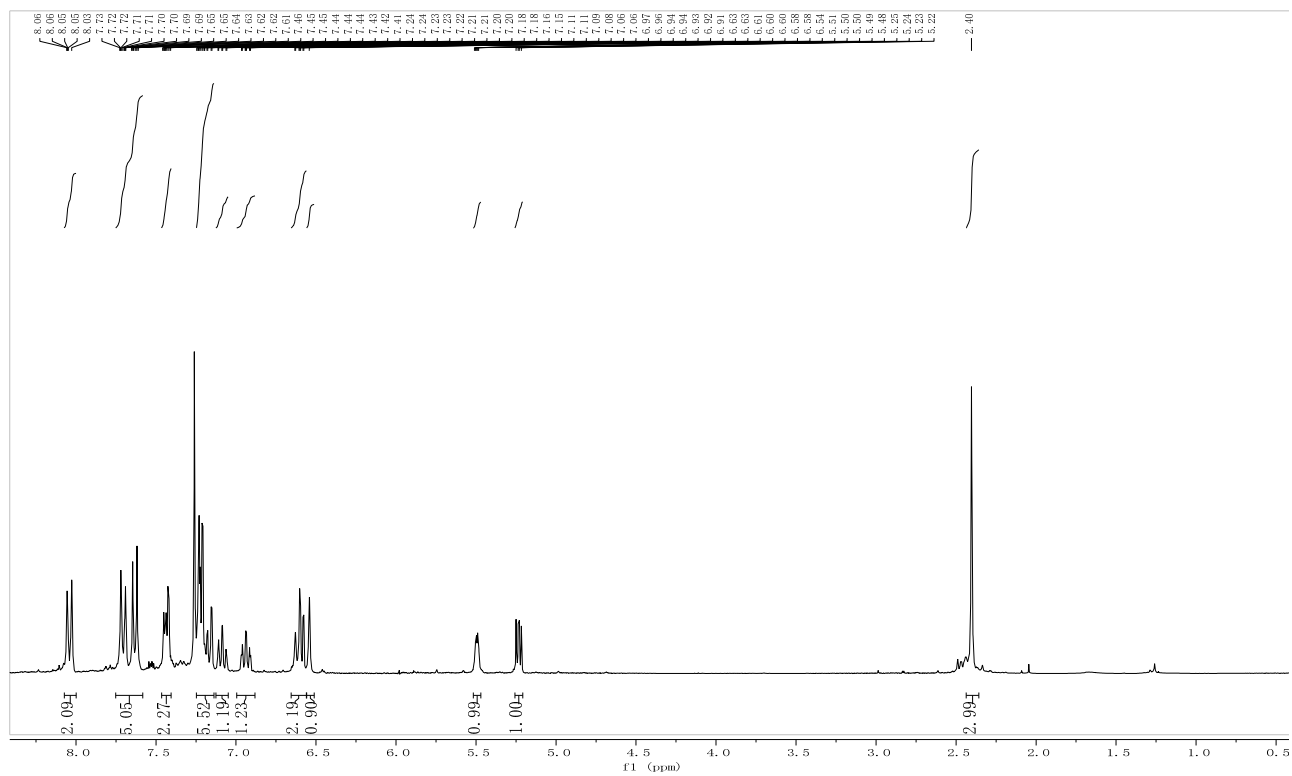
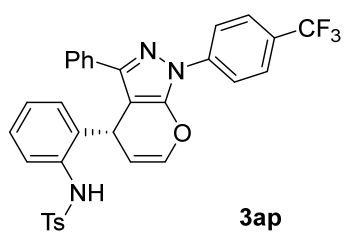


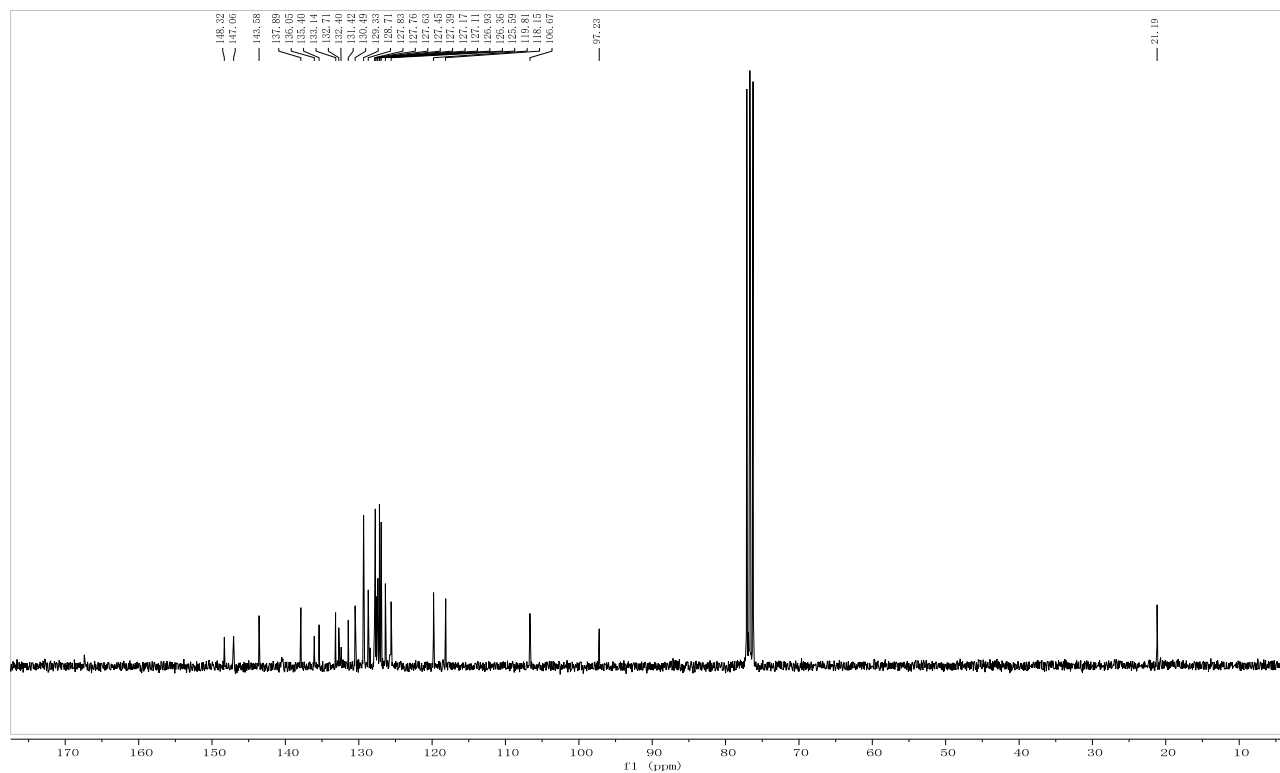
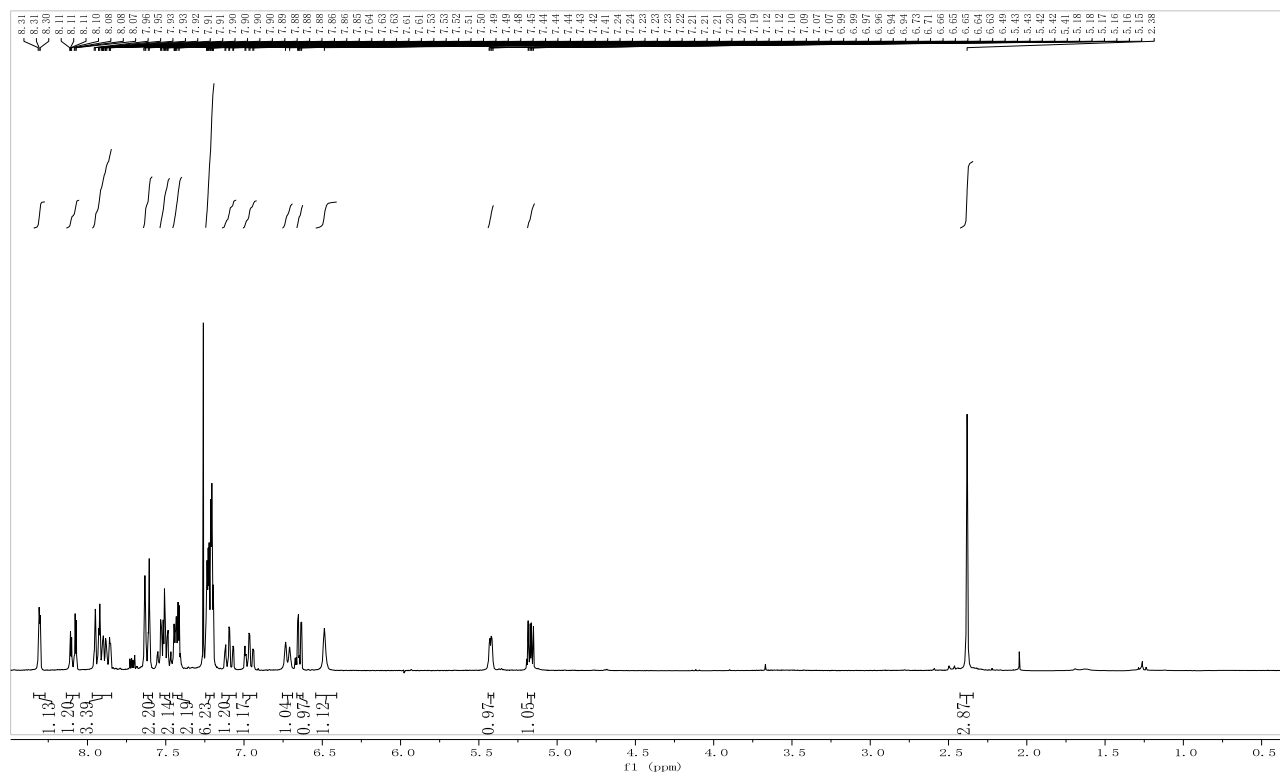
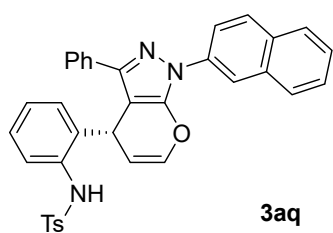


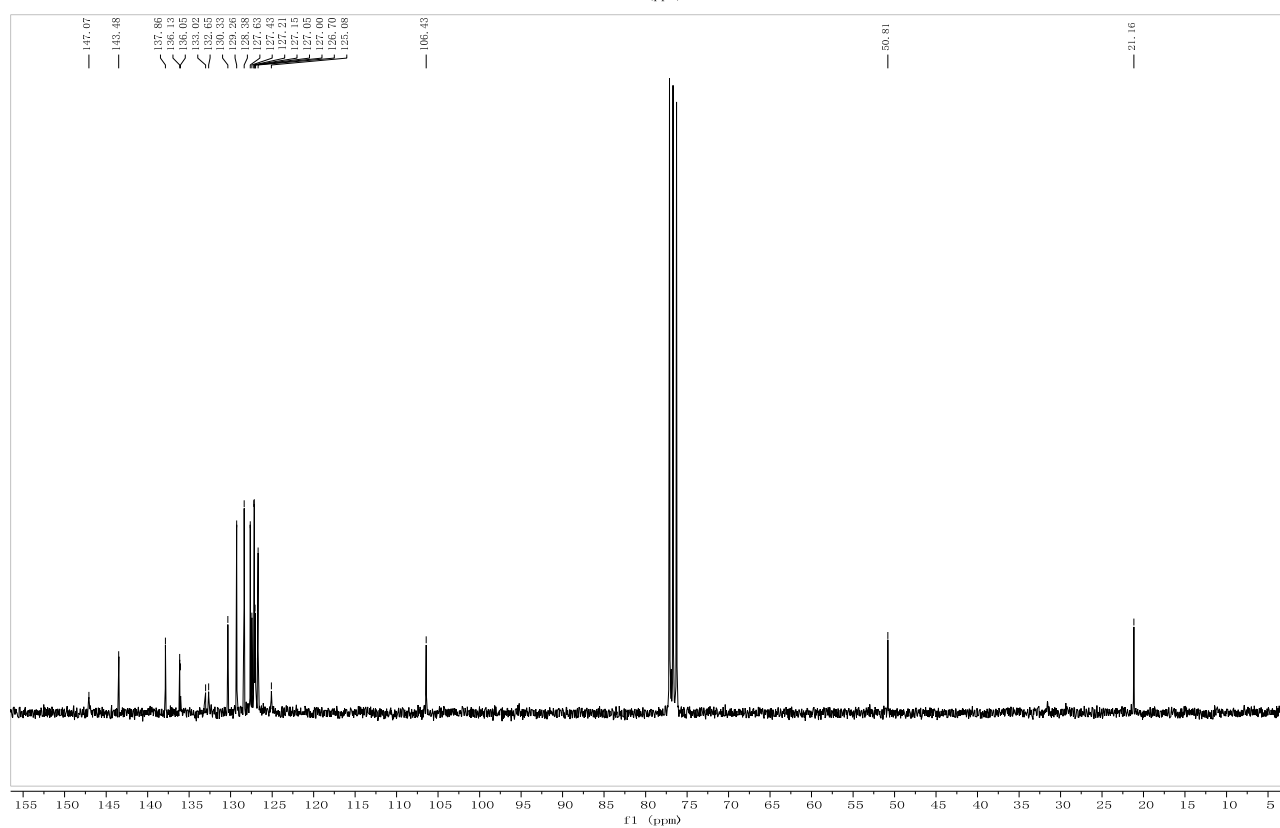
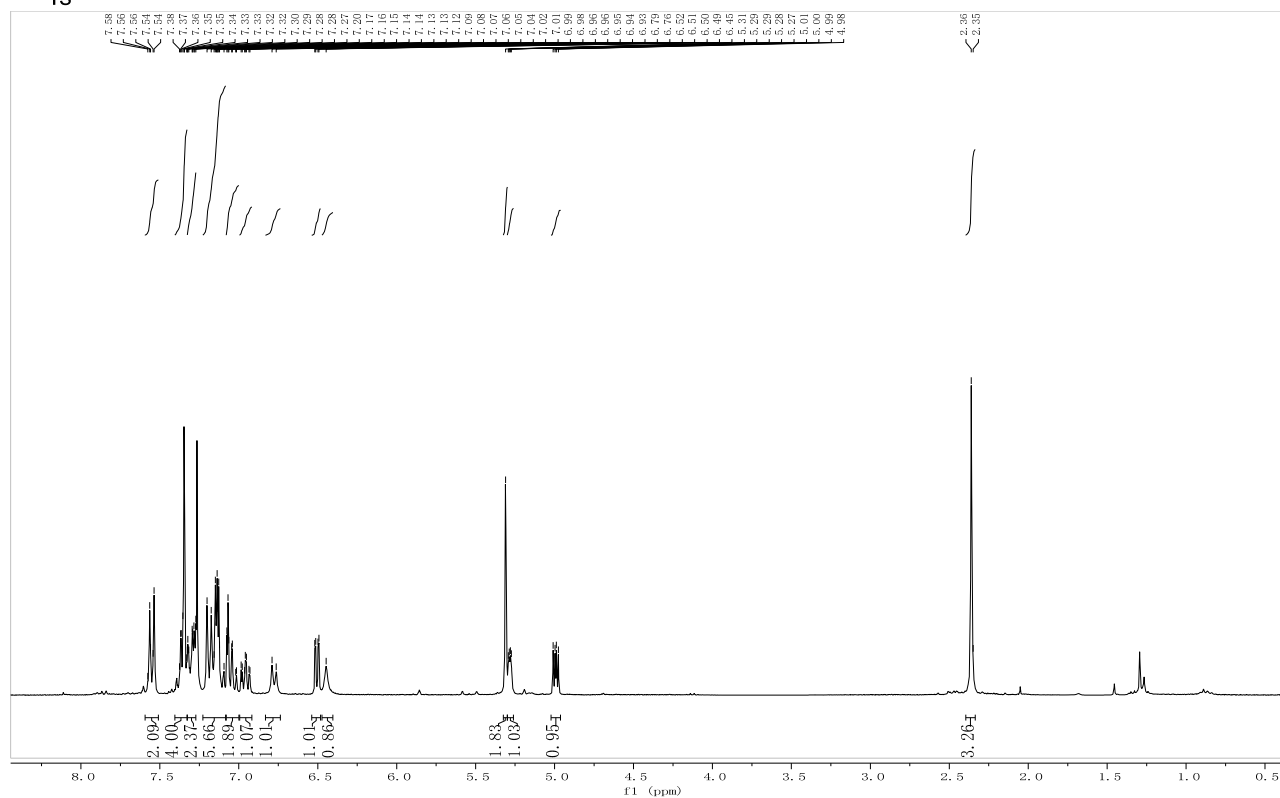
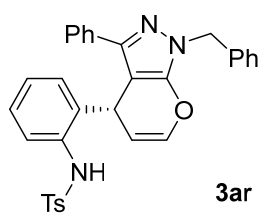


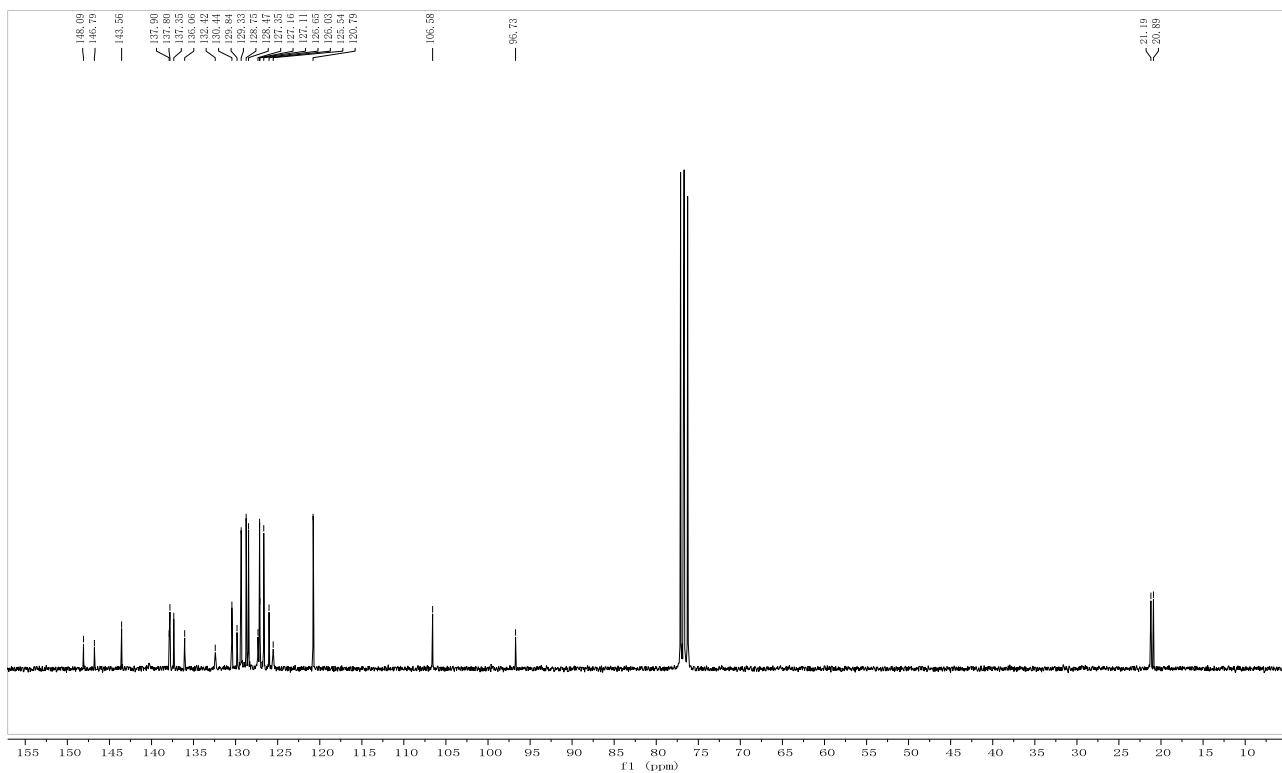
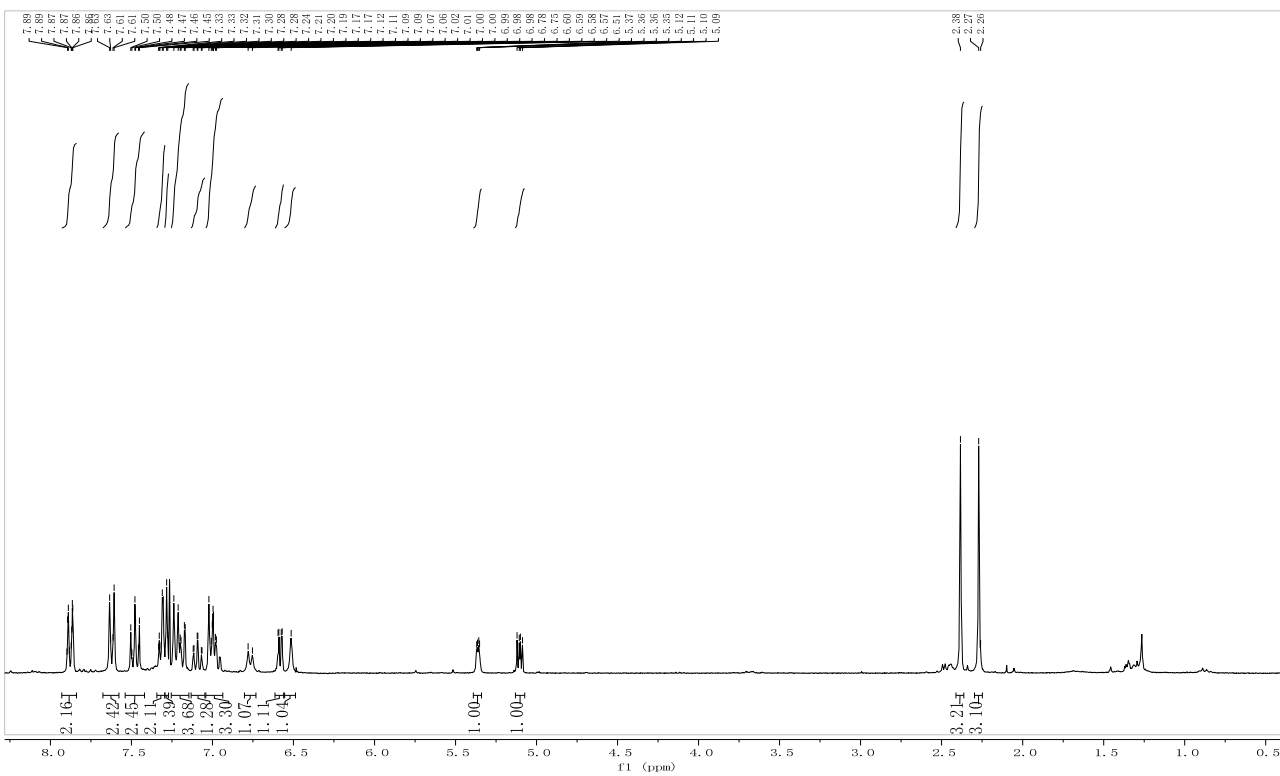


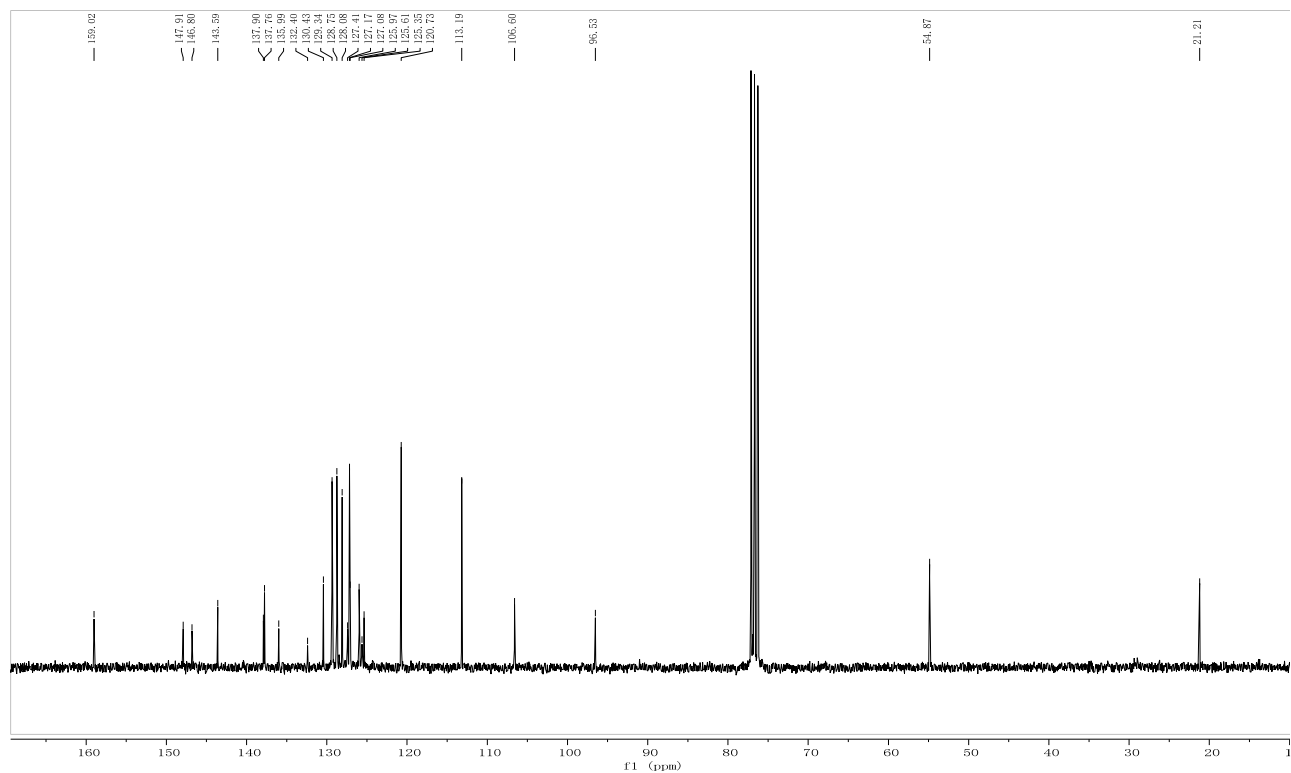
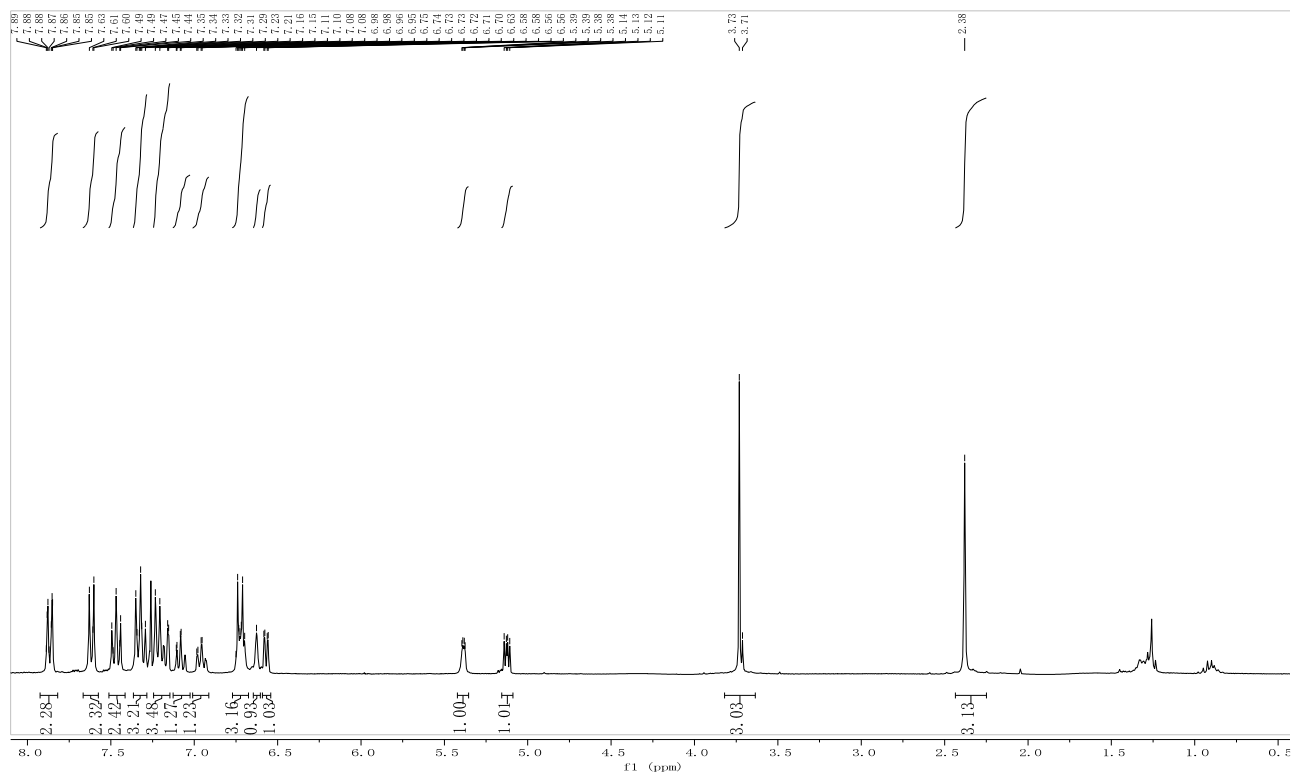
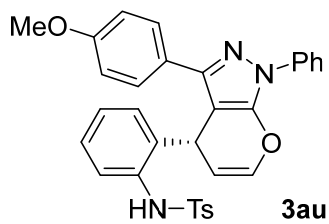


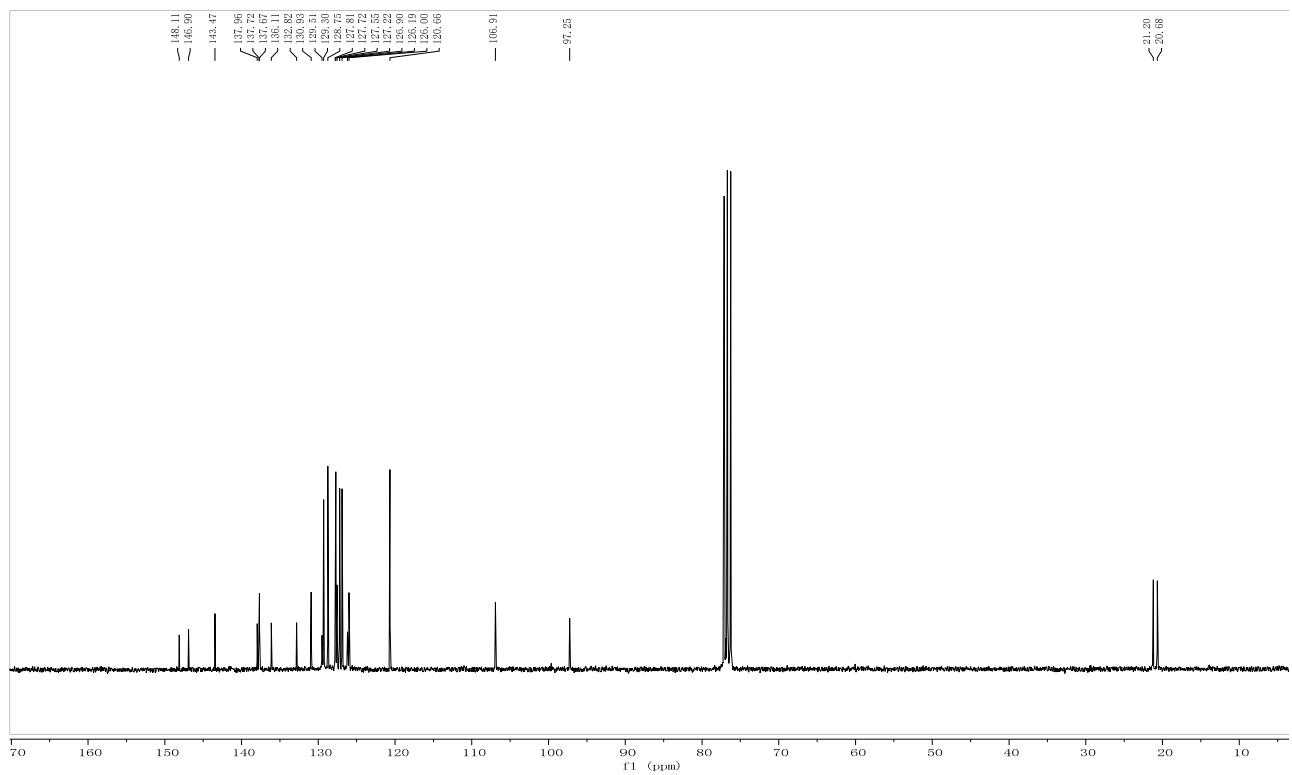
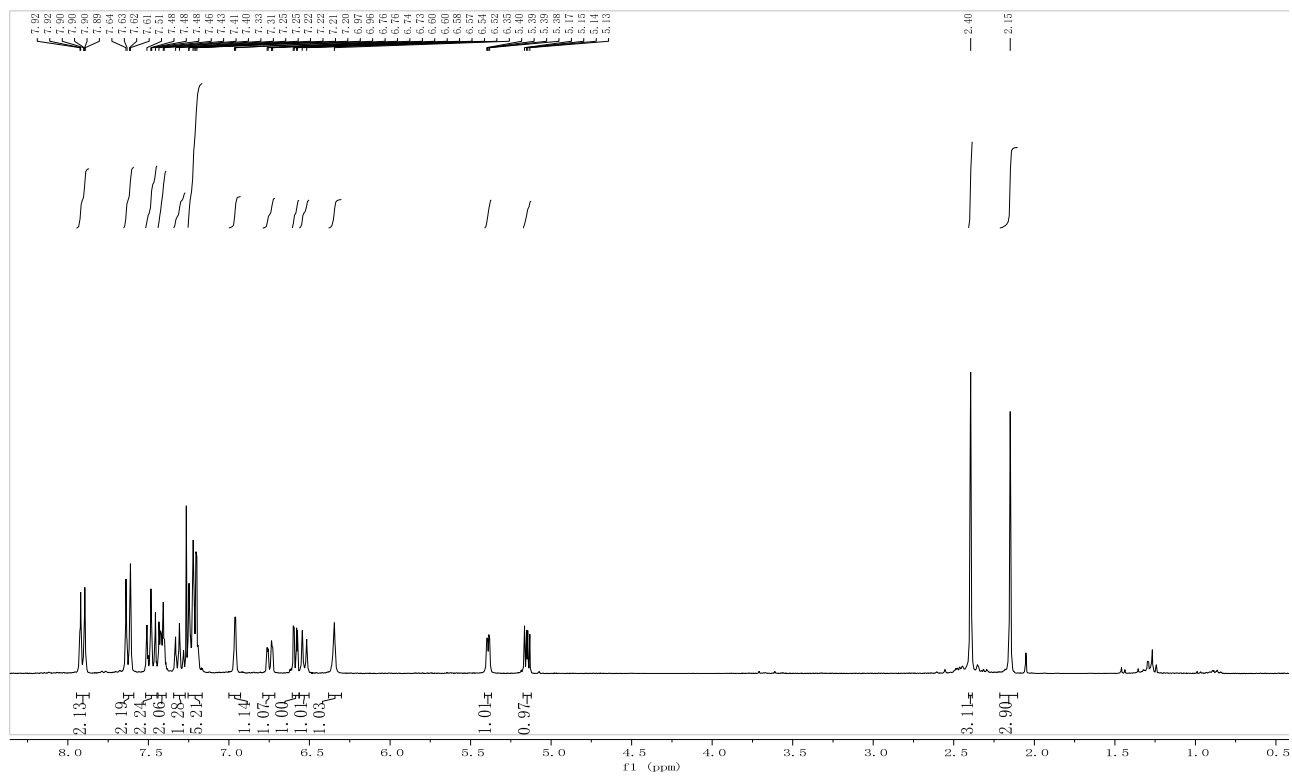
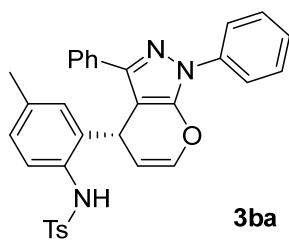


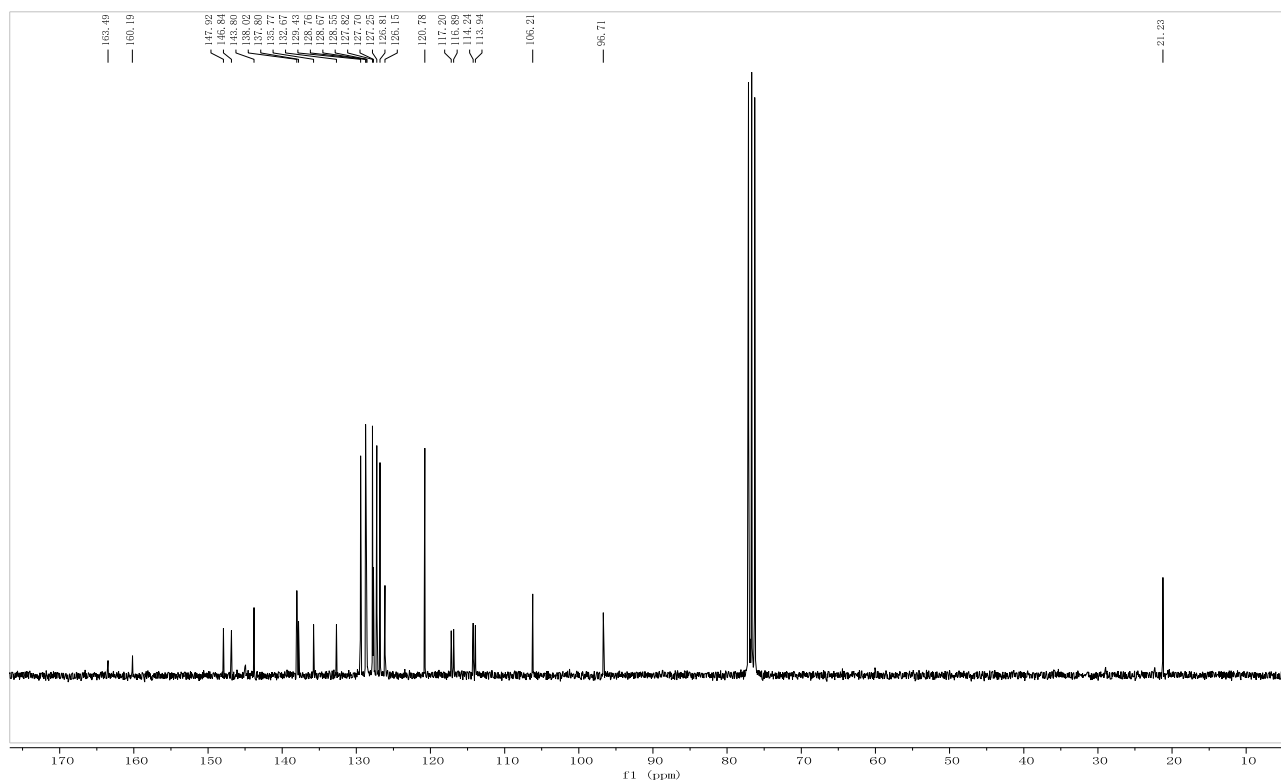
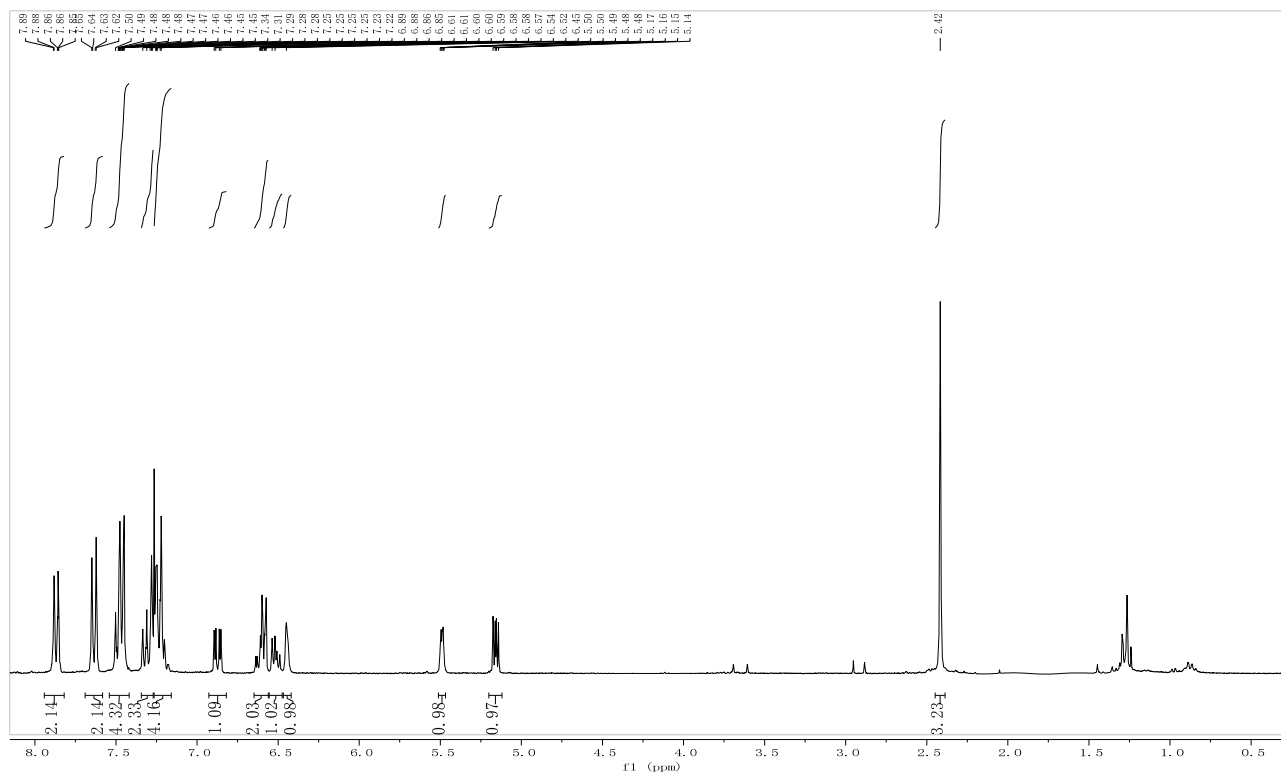
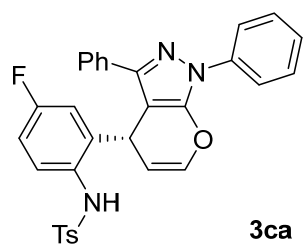


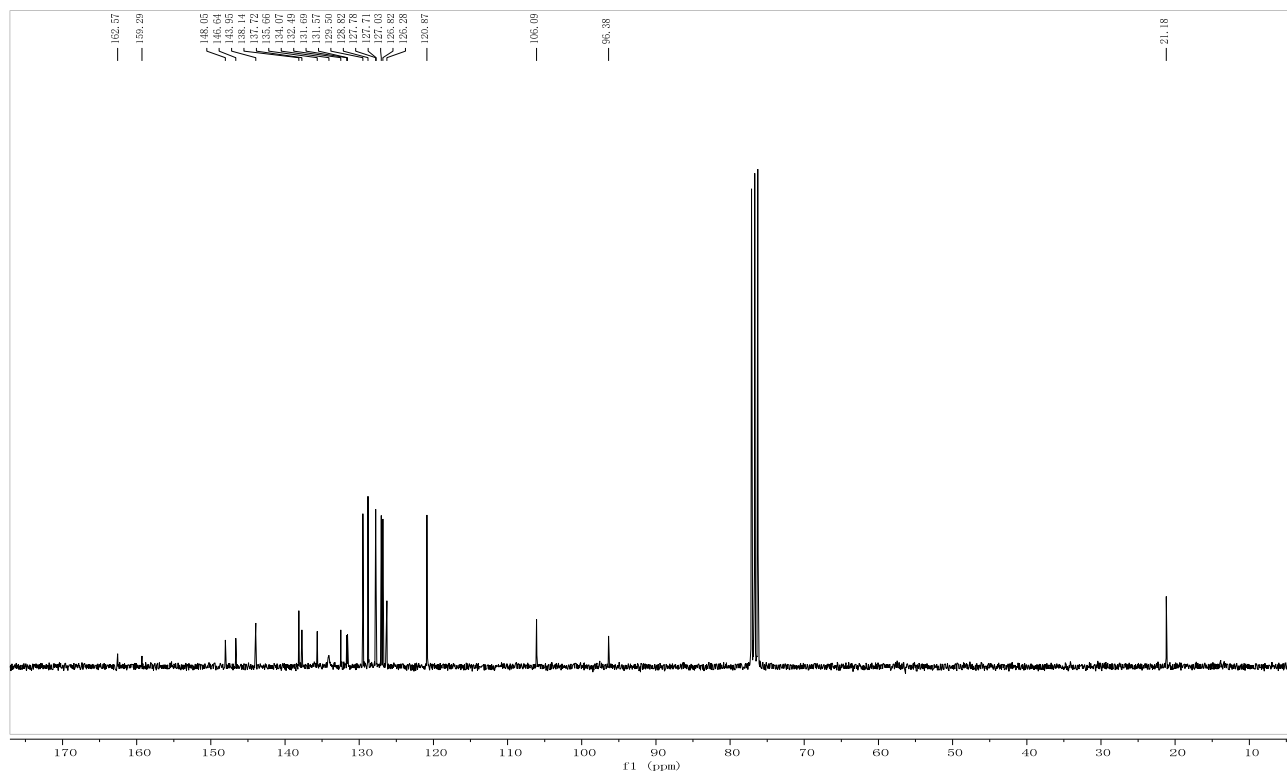
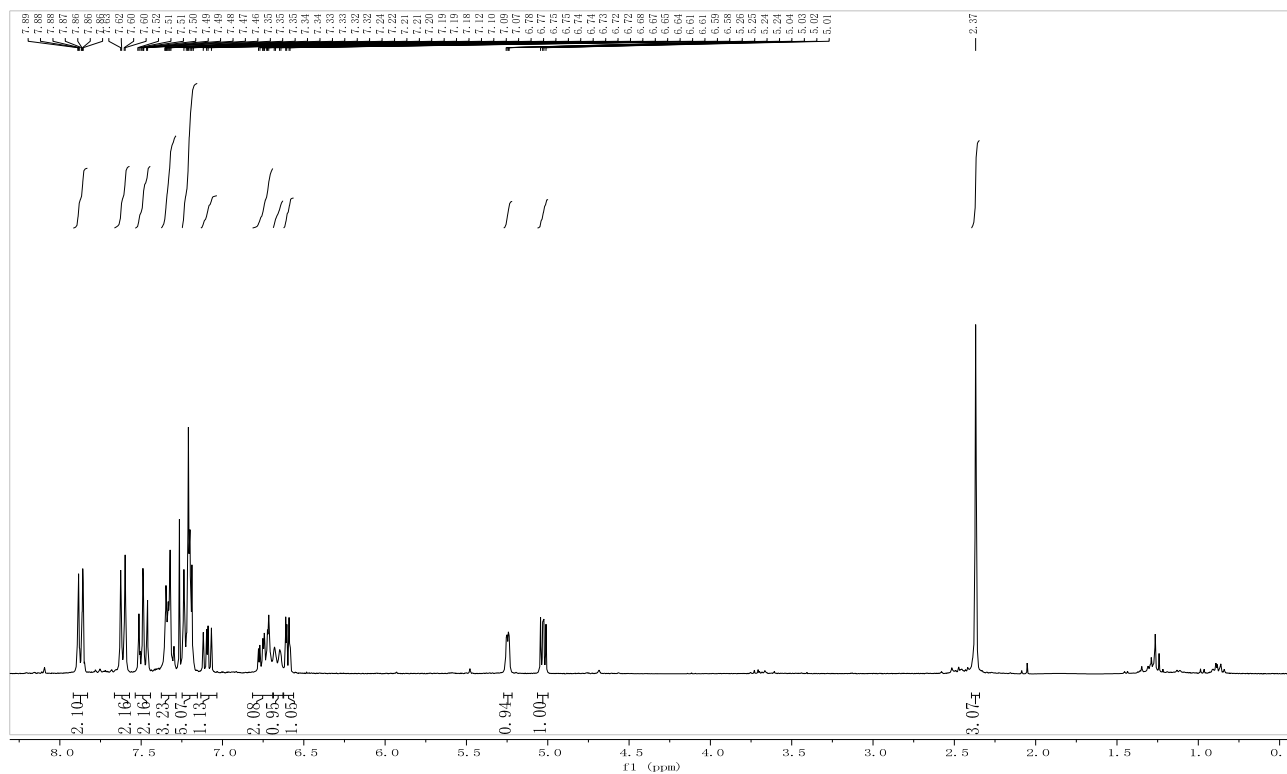
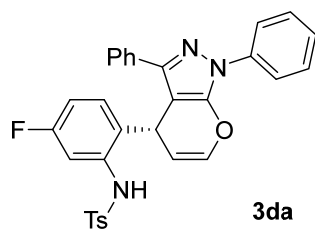


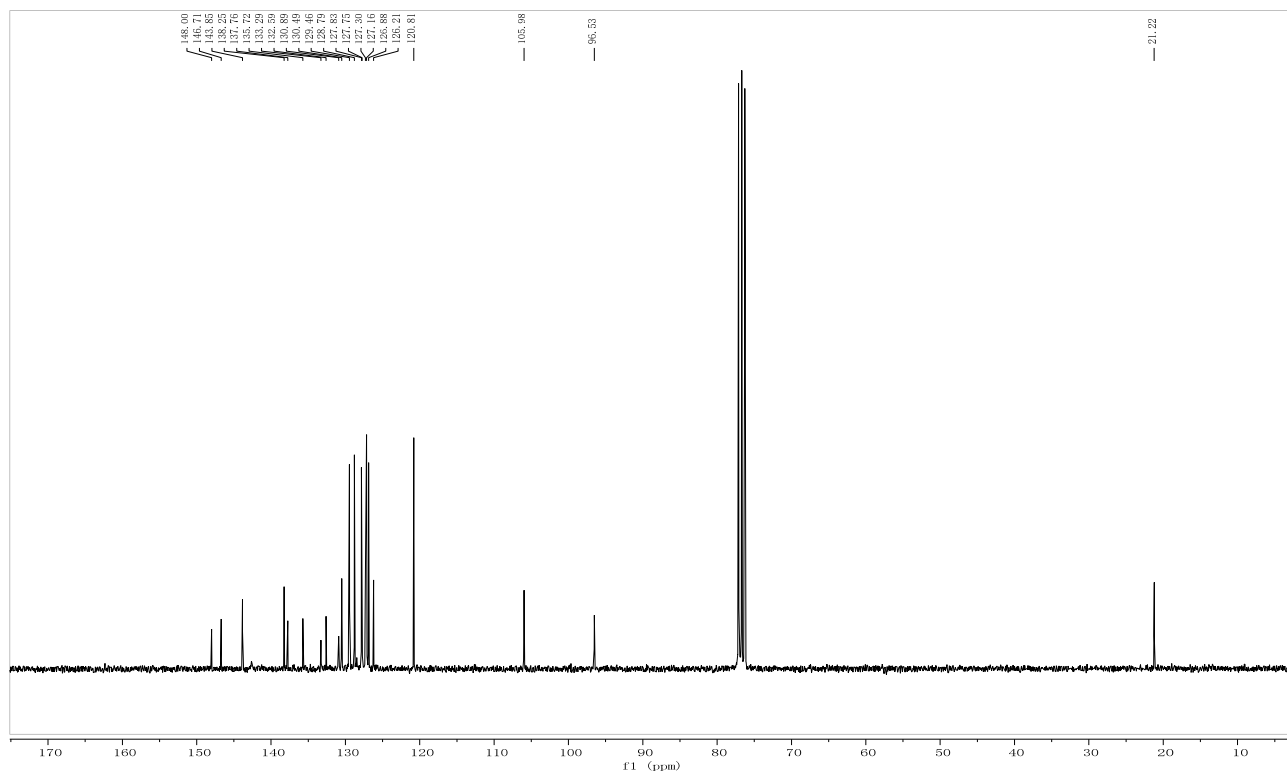
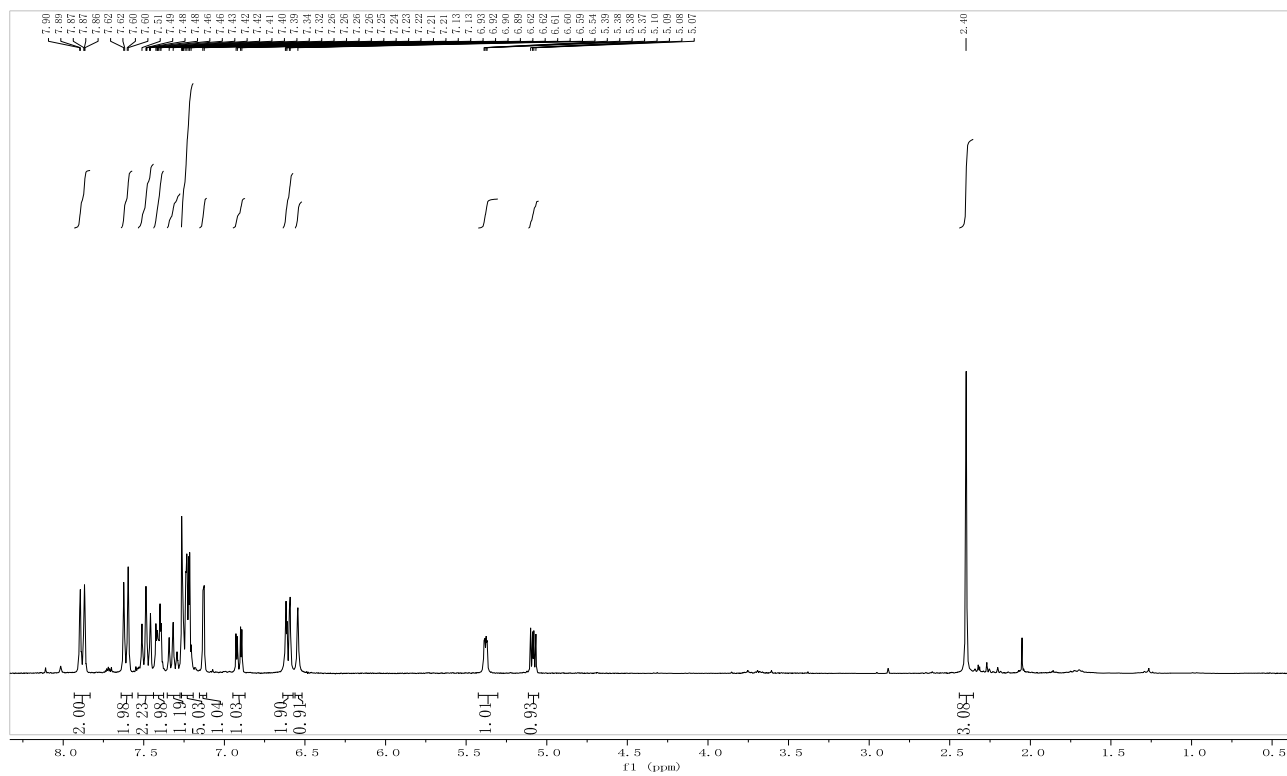
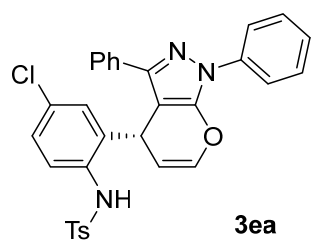


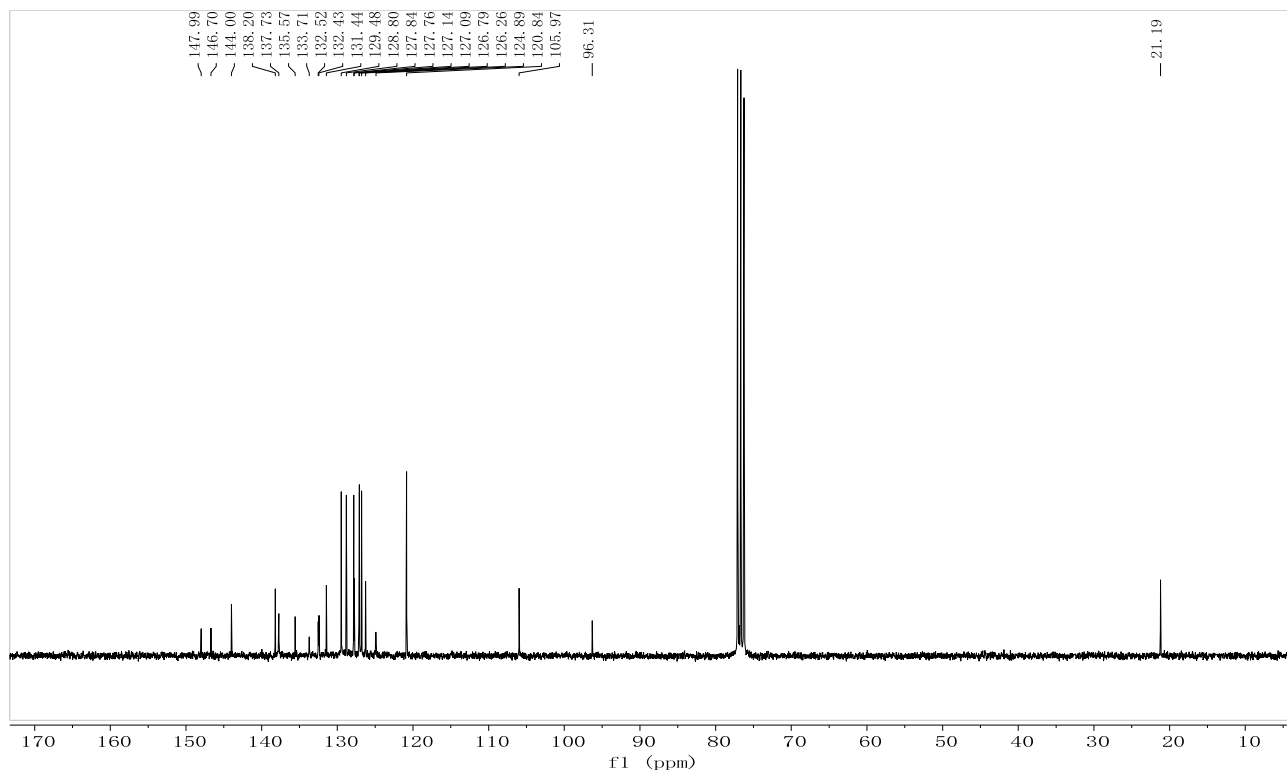
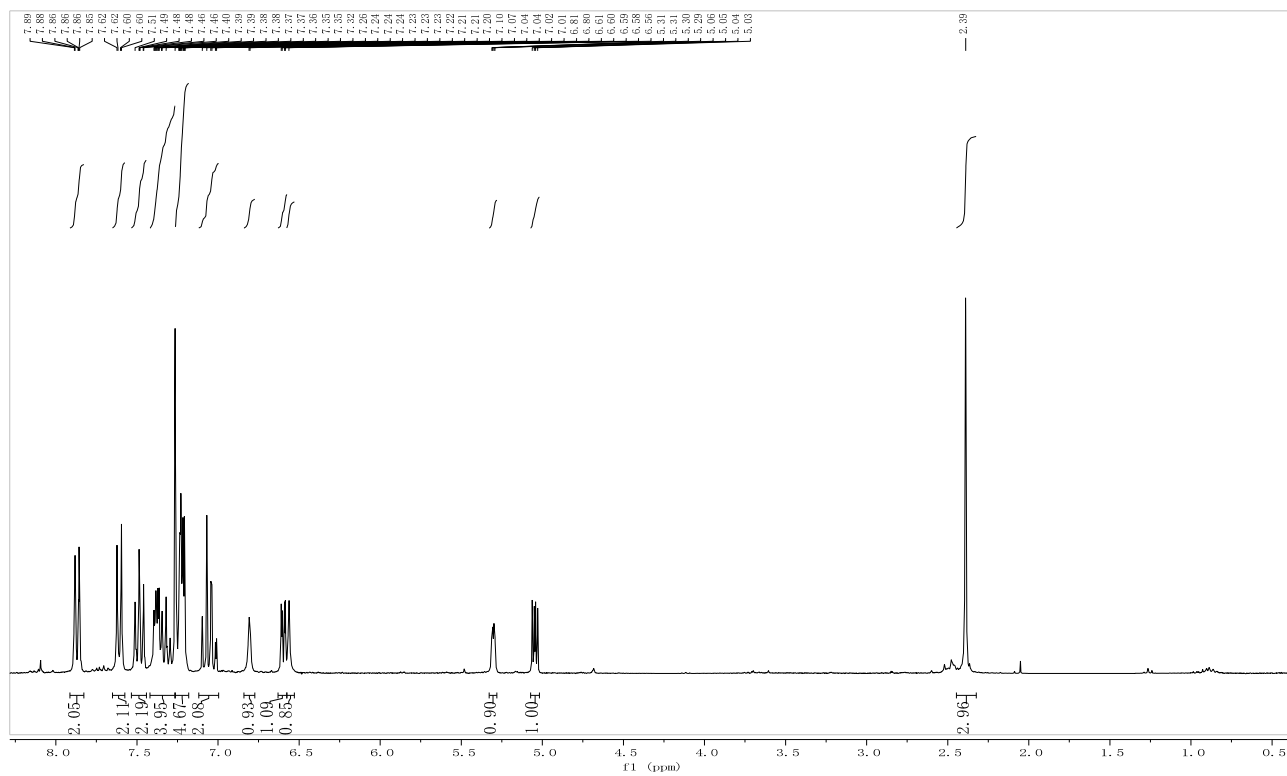
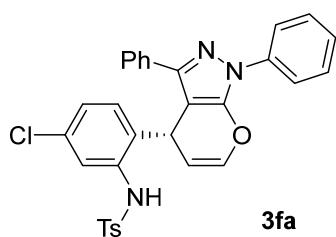


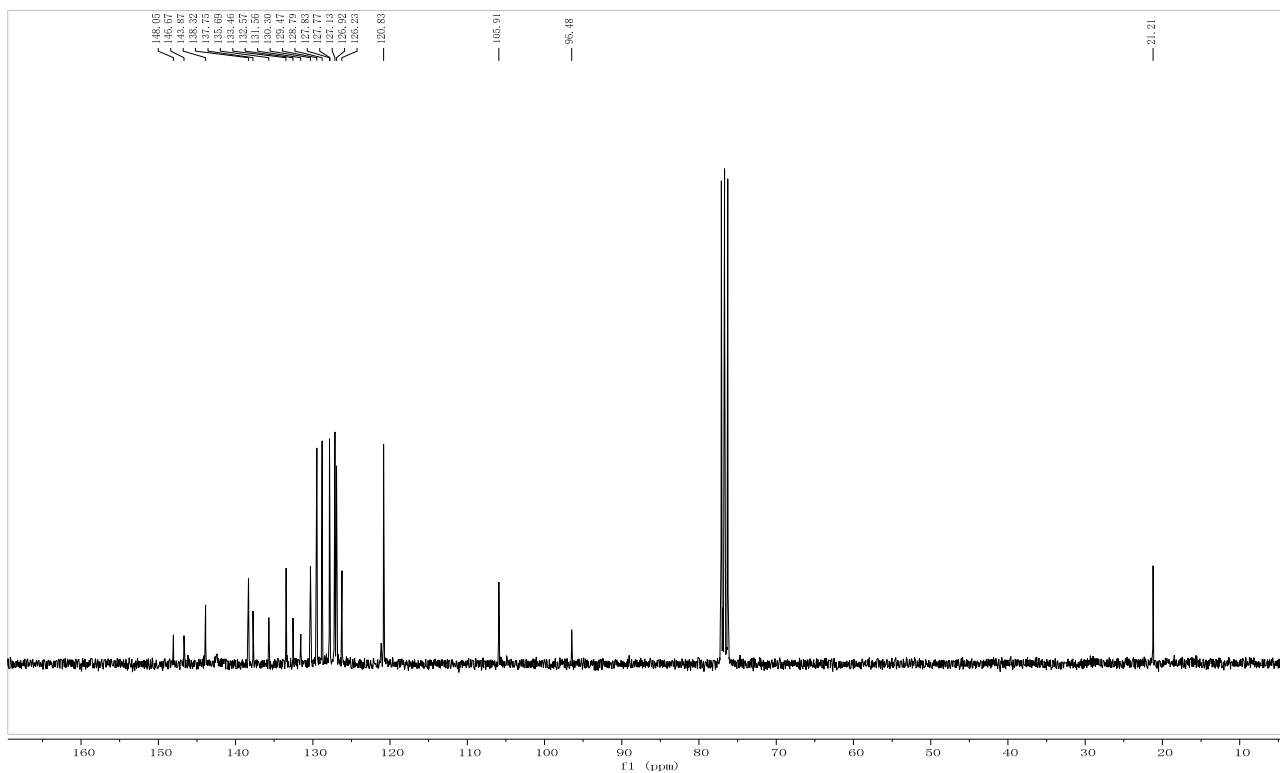
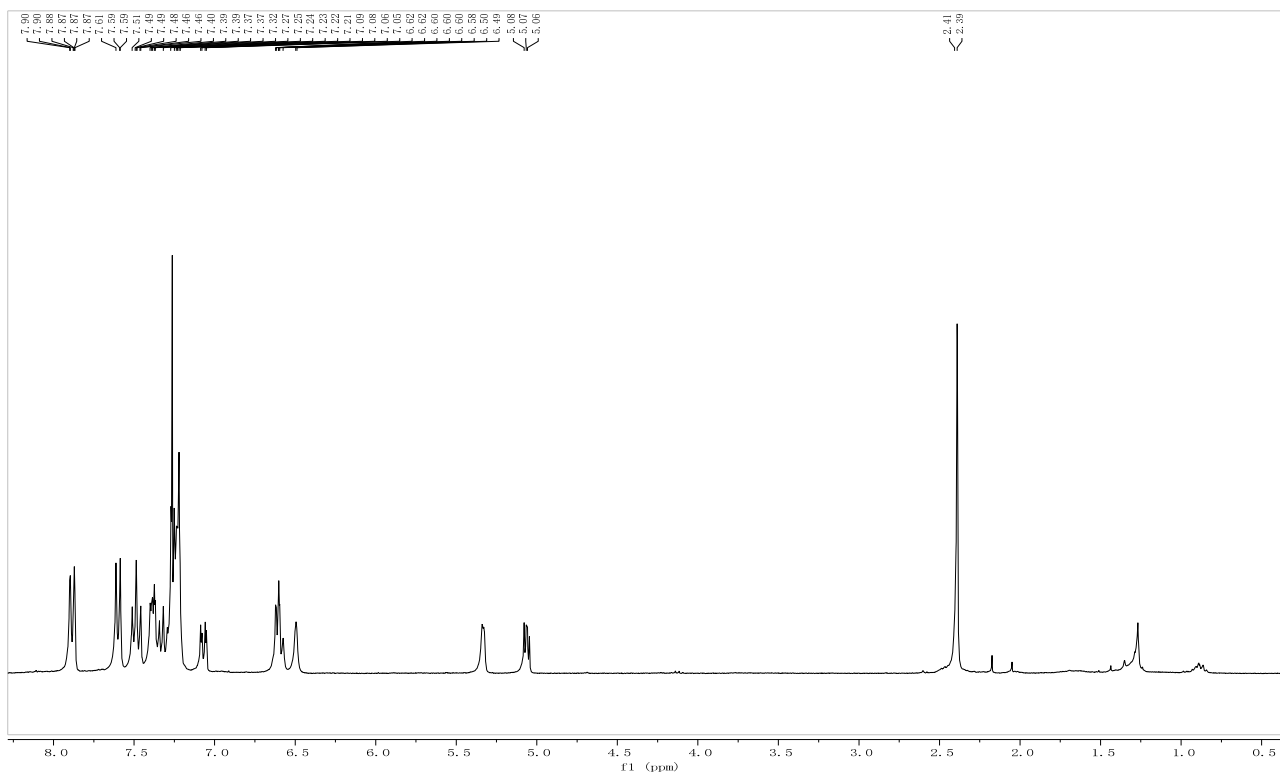
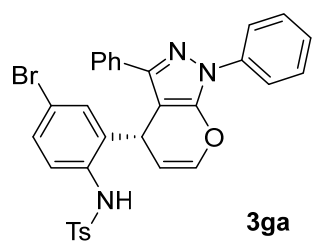


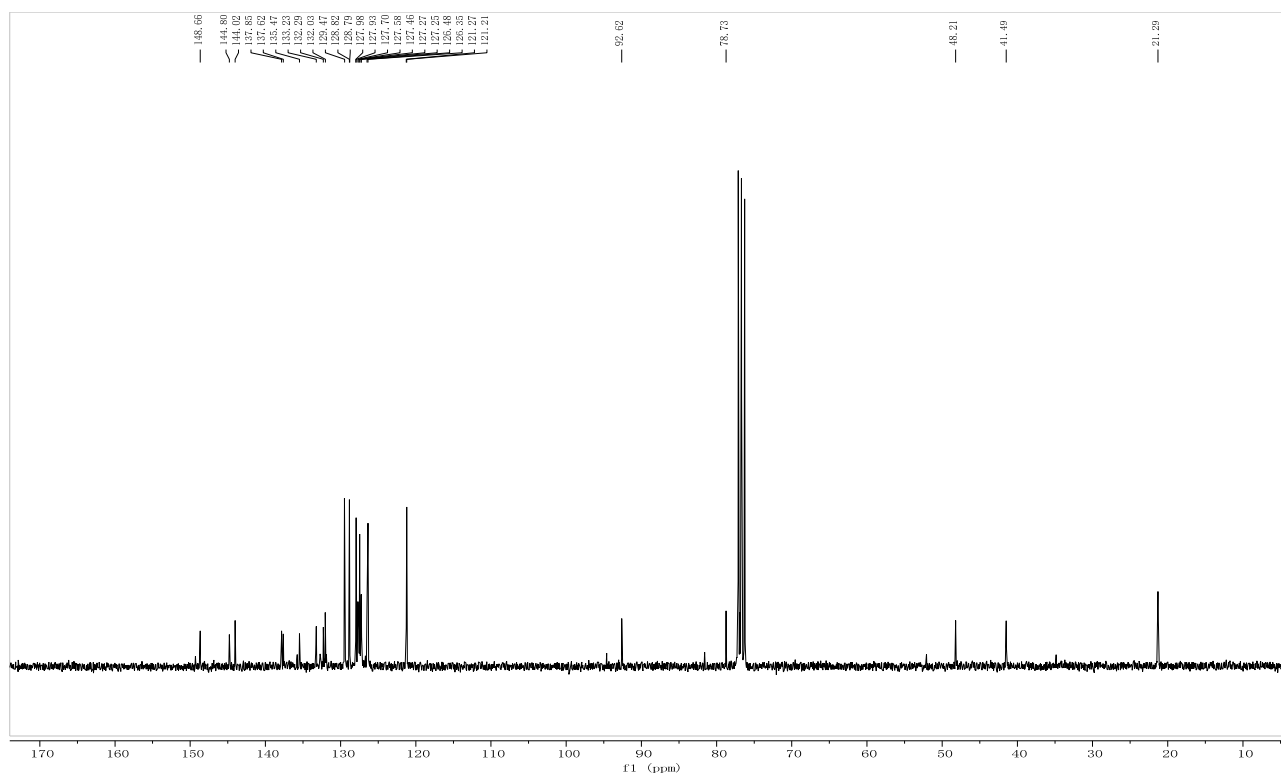
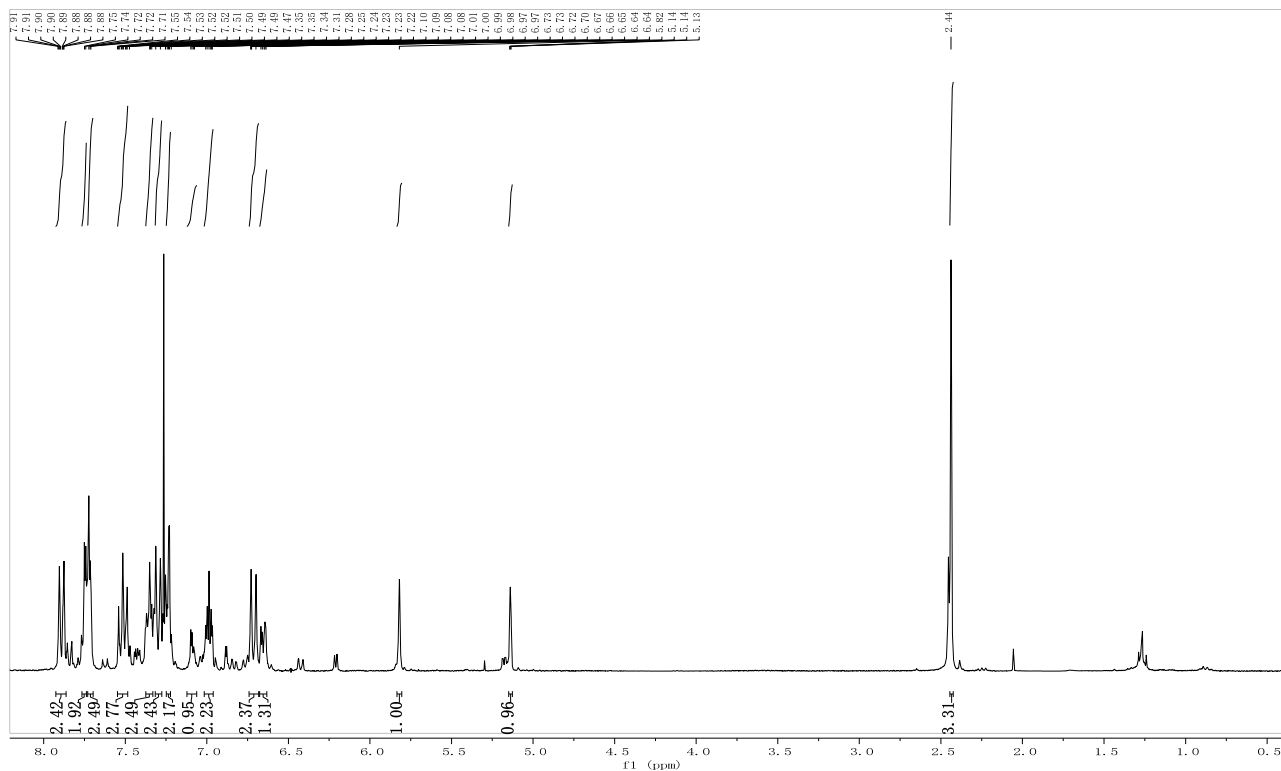
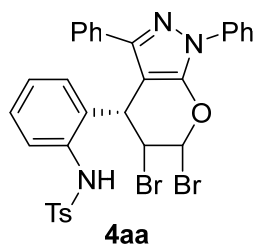






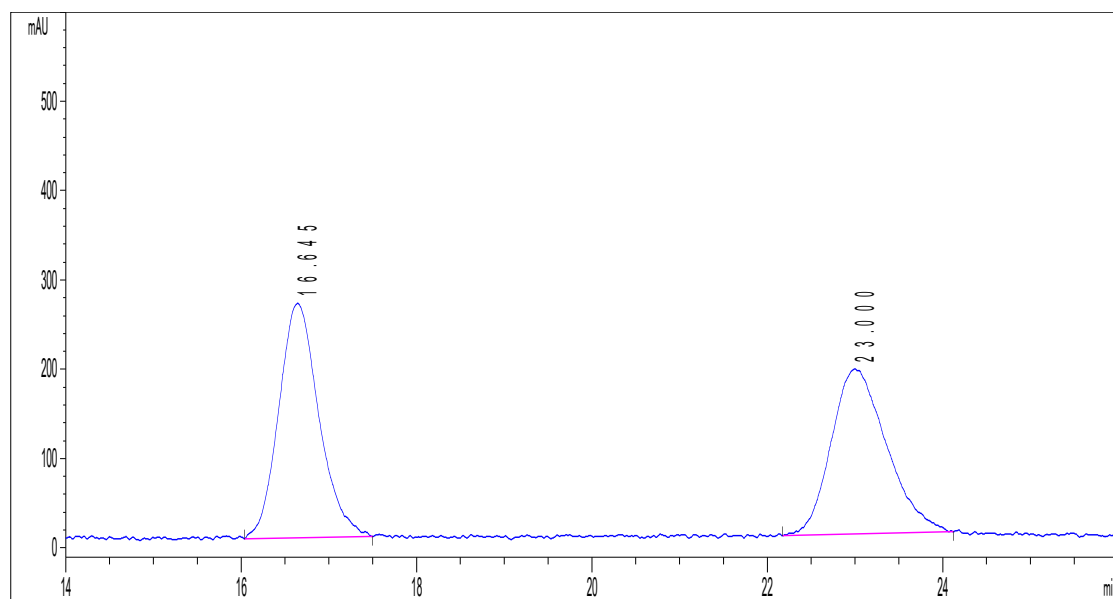






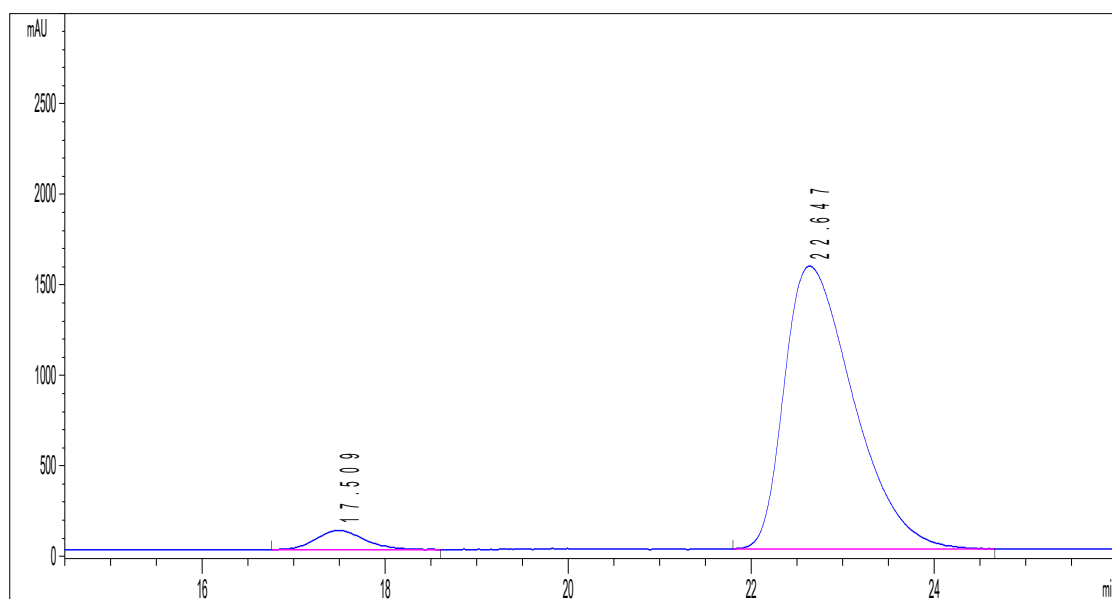
HPLC Chromatograms of the Products 3, 4

HPLC chromatogram of racemic 3aa



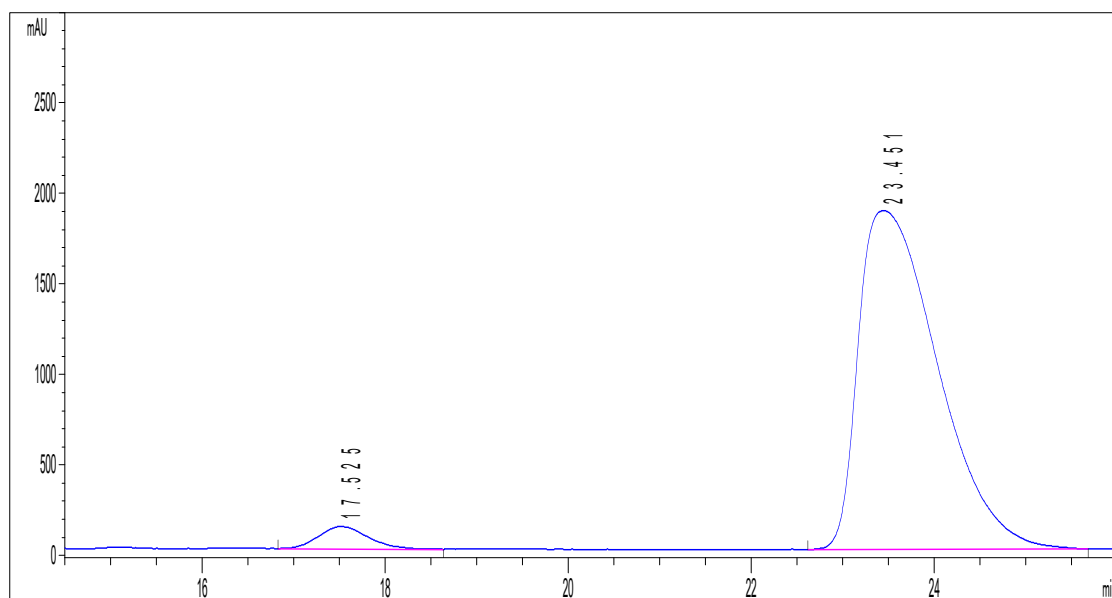
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	16.645	BB	0.4598	8344.725	262.4132	50.7681
2	23	BB	0.5372	8.09E+03	184.7405	49.2319

HPLC chromatogram of chiral 3aa



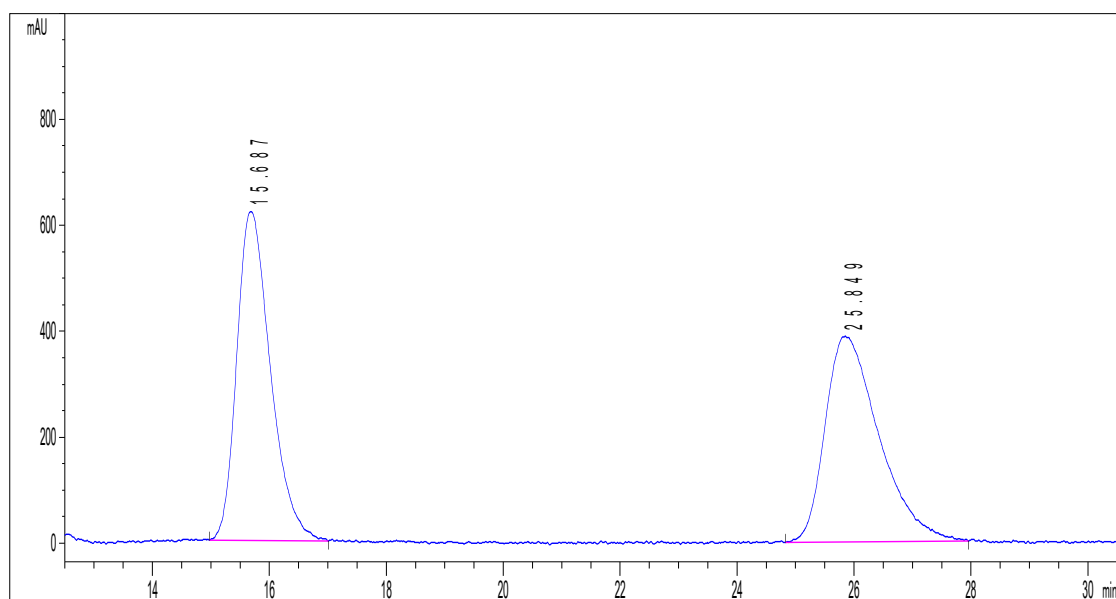
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	17.509	BB	0.4707	4058.179	106.5103	4.7136
2	22.647	BB	0.8059	8.20E+04	1563.355	95.2864

HPLC chromatogram of chiral 3aa (gram-scale)



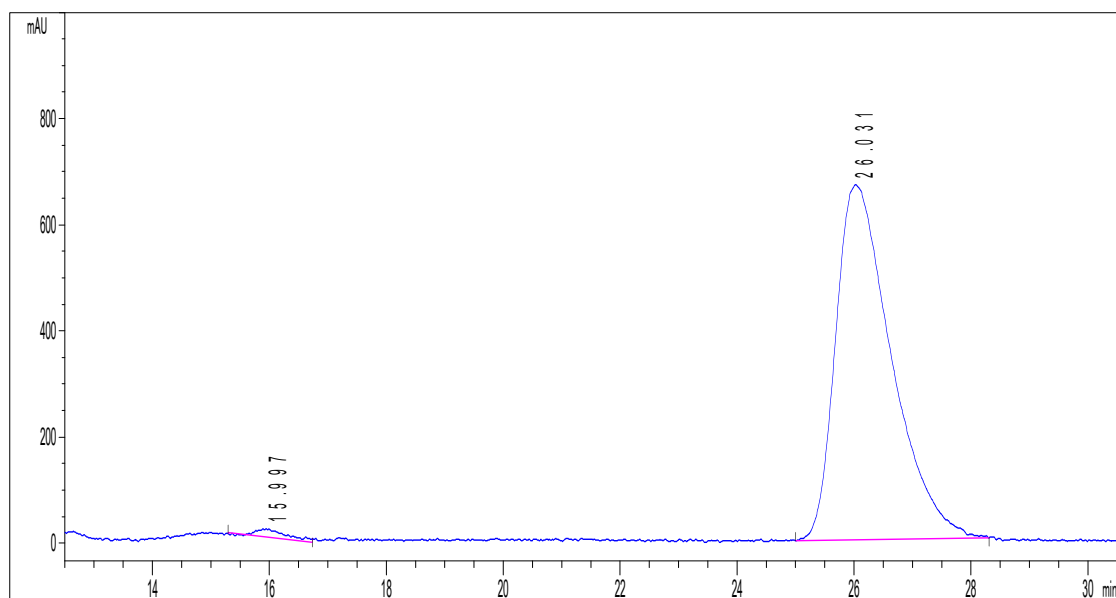
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	17.525	BB	0.4514	4665.269	123.3735	3.9785
2	23.451	BB	0.8881	1.13E+05	1872.108	96.0215

HPLC chromatogram of racemic 3ab



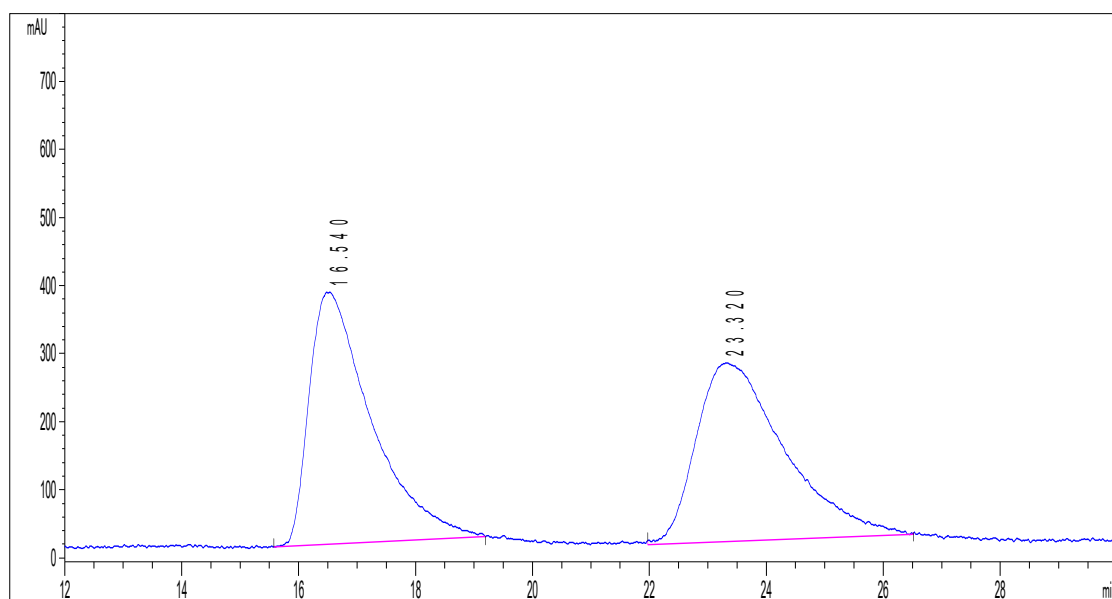
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.687	BB	0.5807	2.48E+04	620.2633	50.008
2	25.849	BB	0.7555	2.48E+04	387.9114	49.992

HPLC chromatogram of chiral 3ab



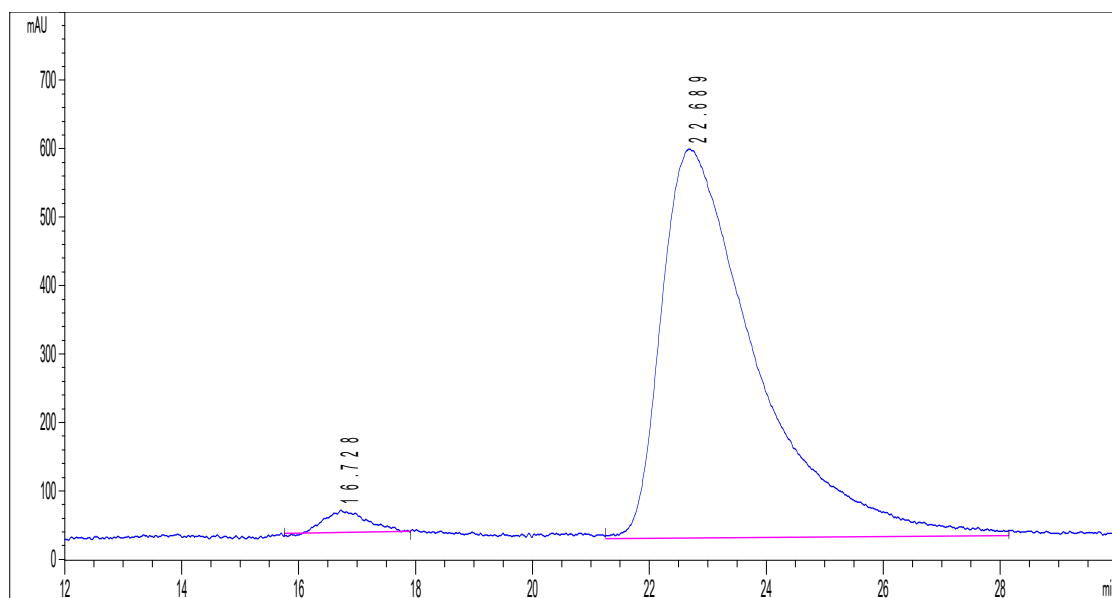
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.997	MM T	0.4739	409.8574	14.41535	0.9061
2	26.032	BB	0.9136	4.48E+04	670.7097	99.0939

HPLC chromatogram of racemic 3ac



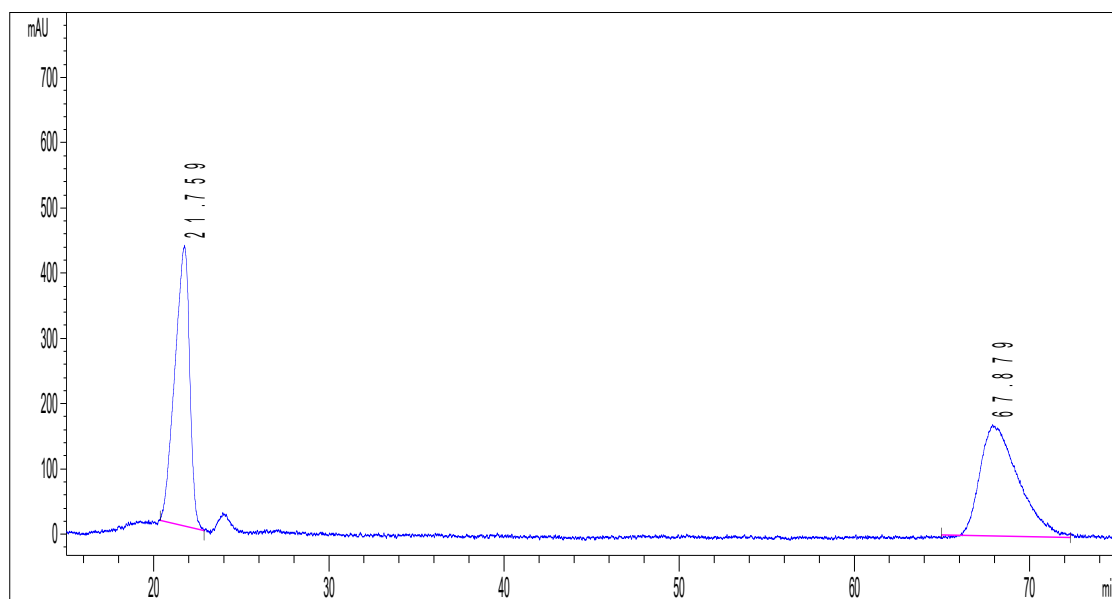
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	16.54	BB	0.9016	27285	370.4039	49.8226
2	23.32	MM R	1.7476	2.75E+04	262.0618	50.1774

HPLC chromatogram of chiral 3ac



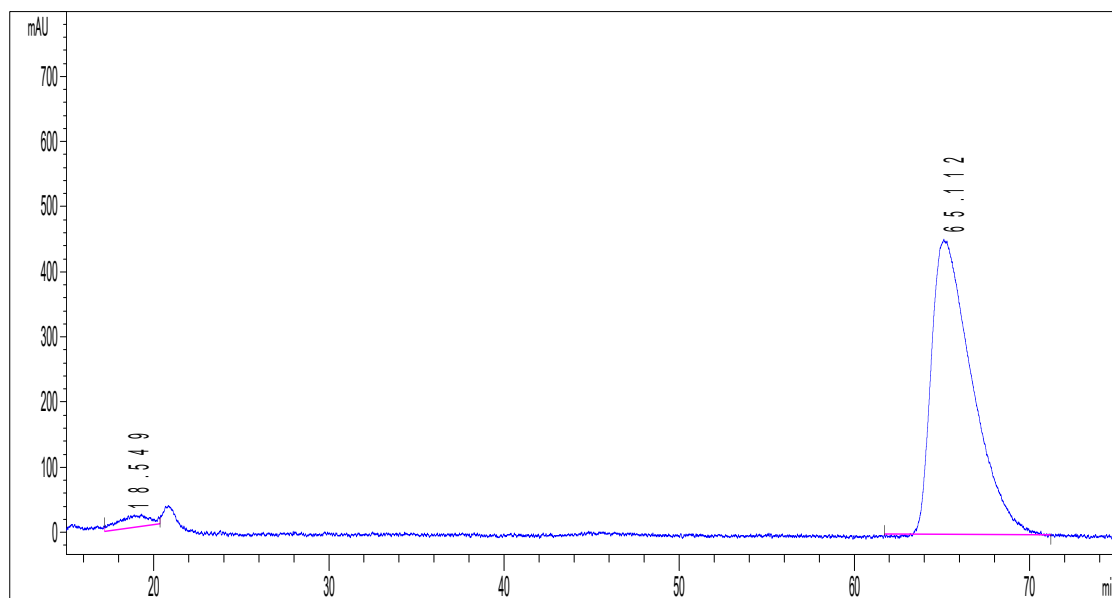
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	16.728	MM R	0.8417	1650.477	32.68291	2.5121
2	22.689	MM R	1.8773	6.41E+04	568.6545	97.4879

HPLC chromatogram of racemic 3ad



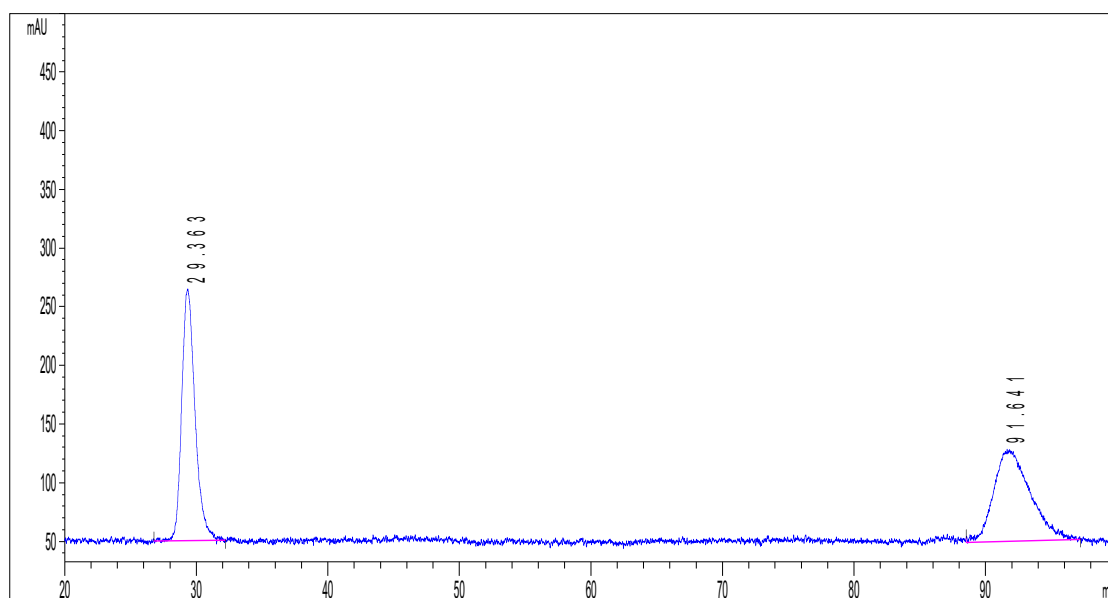
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	21.759	BB	0.7061	25250	429.624	49.6726
2	67.879	MM R	2.5105	2.56E+04	169.8412	50.3274

HPLC chromatogram of chiral 3ad



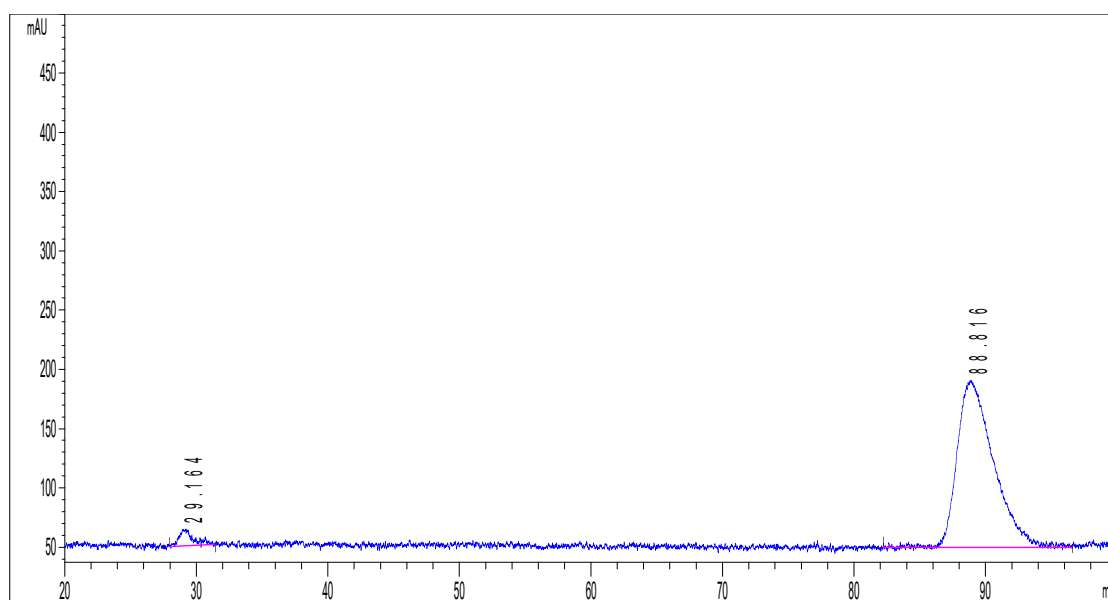
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	18.549	MM R	2.0475	2275.194	18.52021	3.0416
2	65.112	MM R	2.6717	7.25E+04	452.4279	96.9584

HPLC chromatogram of racemic 3ae



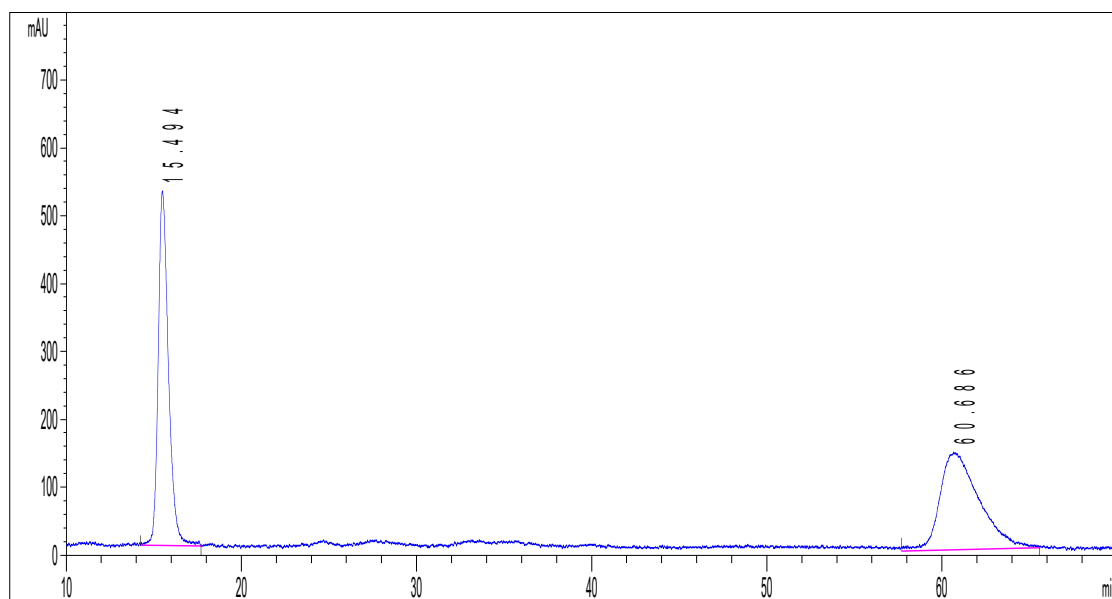
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	29.363	MM R	1.1754	15130	214.5392	50.2246
2	91.641	MM R	3.18	1.50E+04	78.58865	49.7754

HPLC chromatogram of chiral 3ae



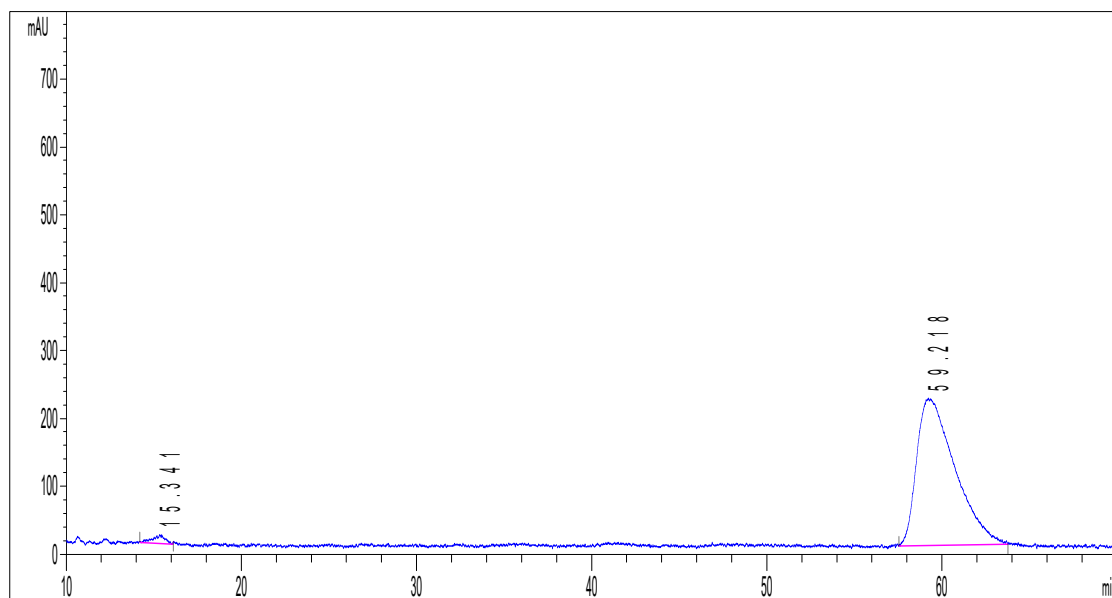
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	29.164	MM R	1.23	1042.923	14.13123	3.6695
2	88.816	MM R	3.2346	2.74E+04	141.0745	96.3305

HPLC chromatogram of racemic 3af



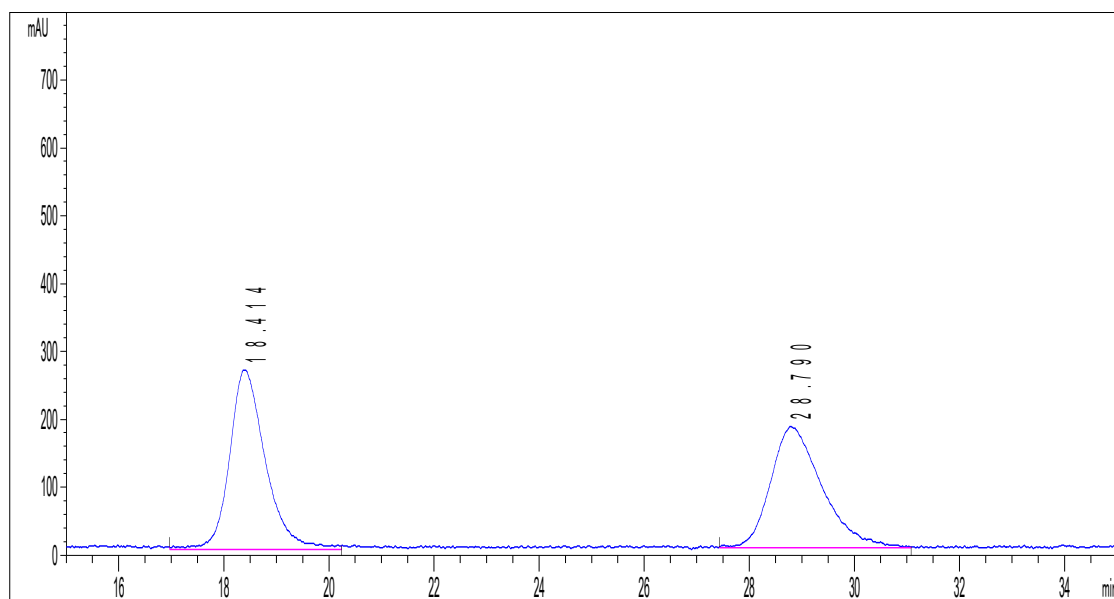
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.494	BB	0.5152	19736.6	510.4416	50.8645
2	60.681	MM R	2.6074	1.91E+04	136.1269	49.1355

HPLC chromatogram of chiral 3af



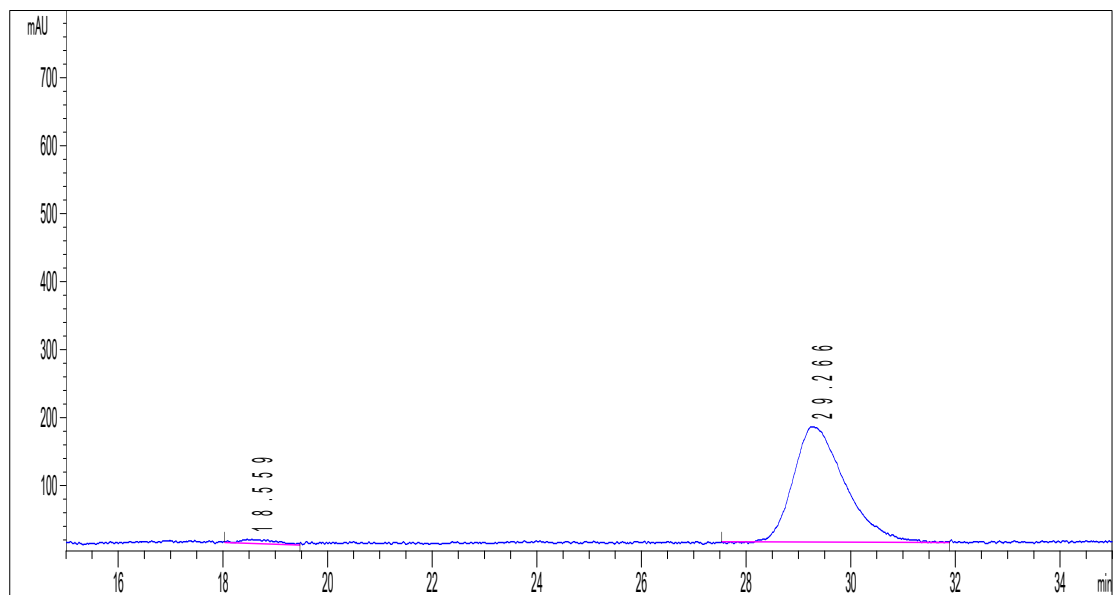
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.341	MM R	0.8076	627.3428	12.94665	1.8685
2	59.218	BB	1.7925	3.29E+04	216.5586	98.1315

HPLC chromatogram of racemic 3ag



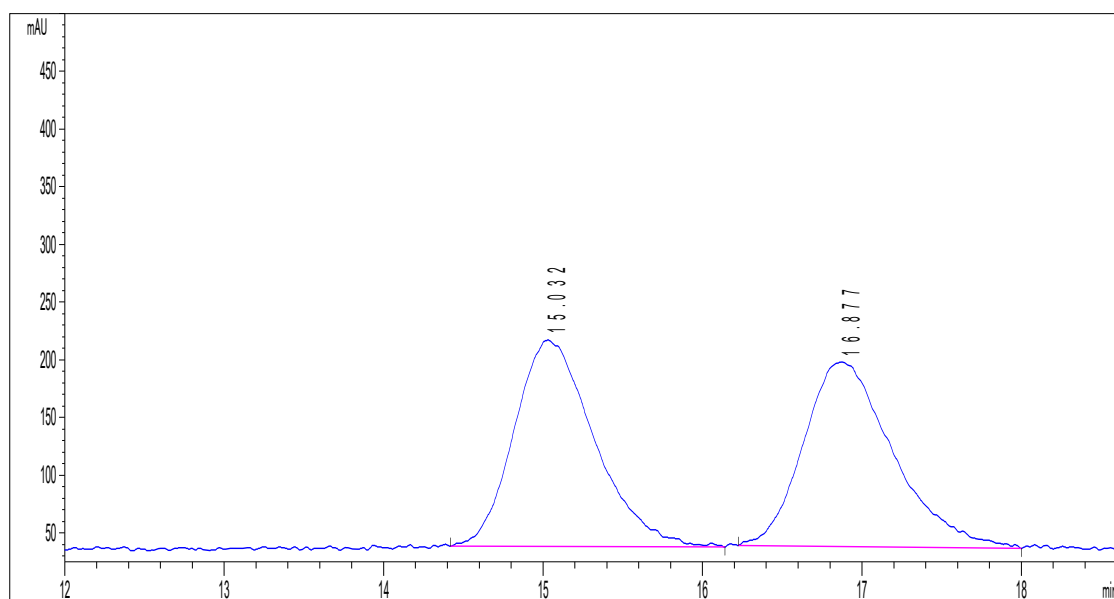
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	18.414	MM R	0.7886	12491.7	263.9965	50.9173
2	28.79	MM R	1.1244	1.20E+04	178.4845	49.0827

HPLC chromatogram of chiral 3ag



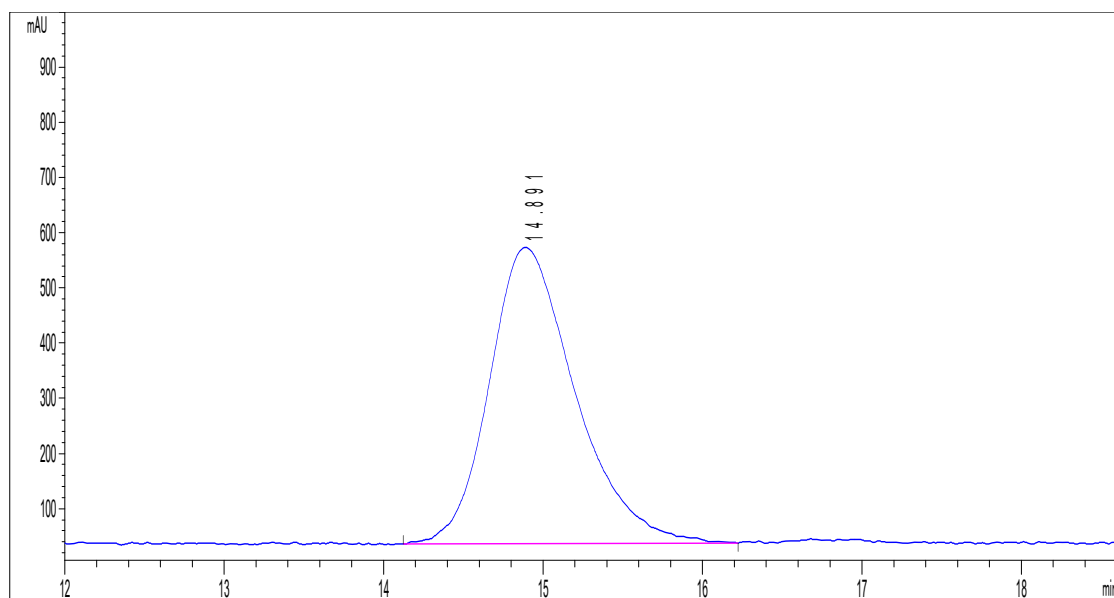
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	18.559	MM R	0.7354	316.0303	6.39541	2.6273
2	29.266	MM R	1.1463	1.17E+04	170.2992	97.3727

HPLC chromatogram of racemic 3ah



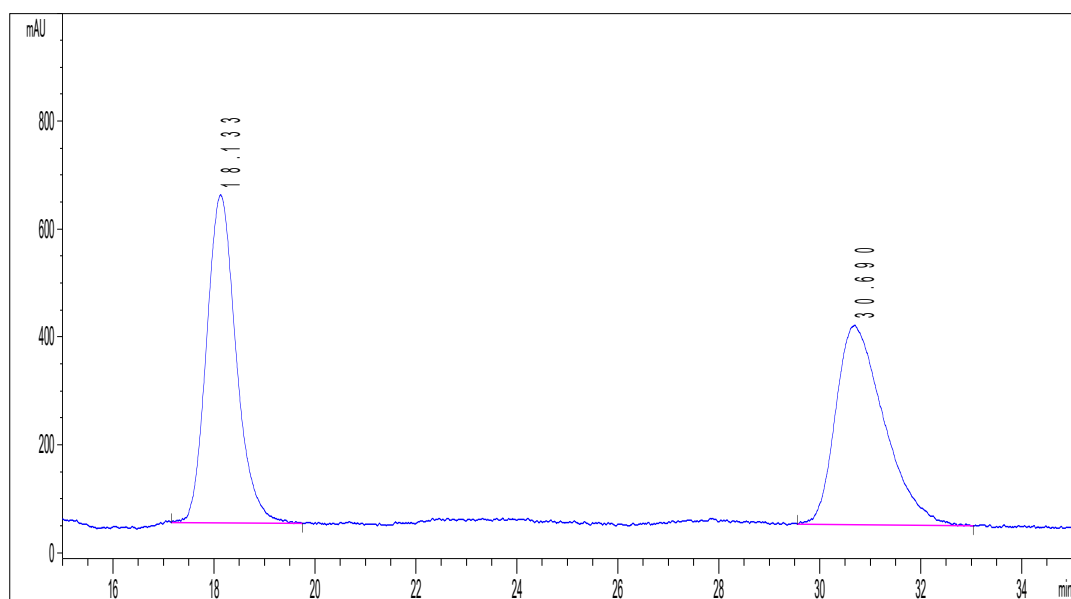
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.032	BB	0.43	6252.532	178.6987	50.0744
2	16.877	BB	0.4965	6.23E+03	159.5951	49.9256

HPLC chromatogram of chiral 3ah



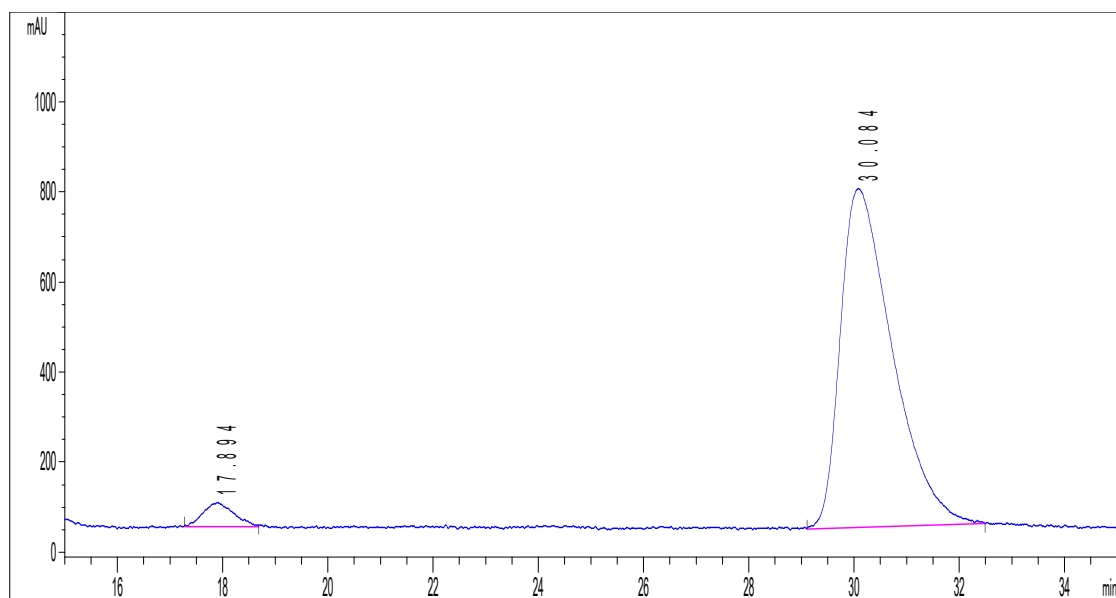
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	14.892	BB	0.5545	20181.8	537.5012	100

HPLC chromatogram of racemic 3ai



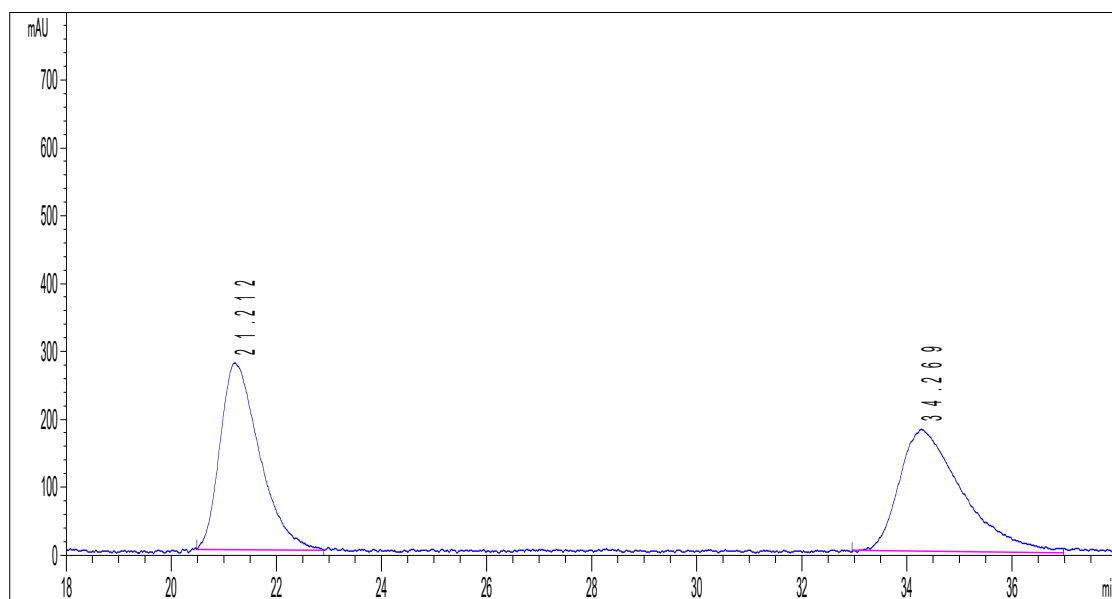
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	18.133	BB	0.5496	24449.6	605.5986	50.1338
2	30.693	BB	0.7954	2.43E+04	368.1497	49.8662

HPLC chromatogram of chiral 3ai



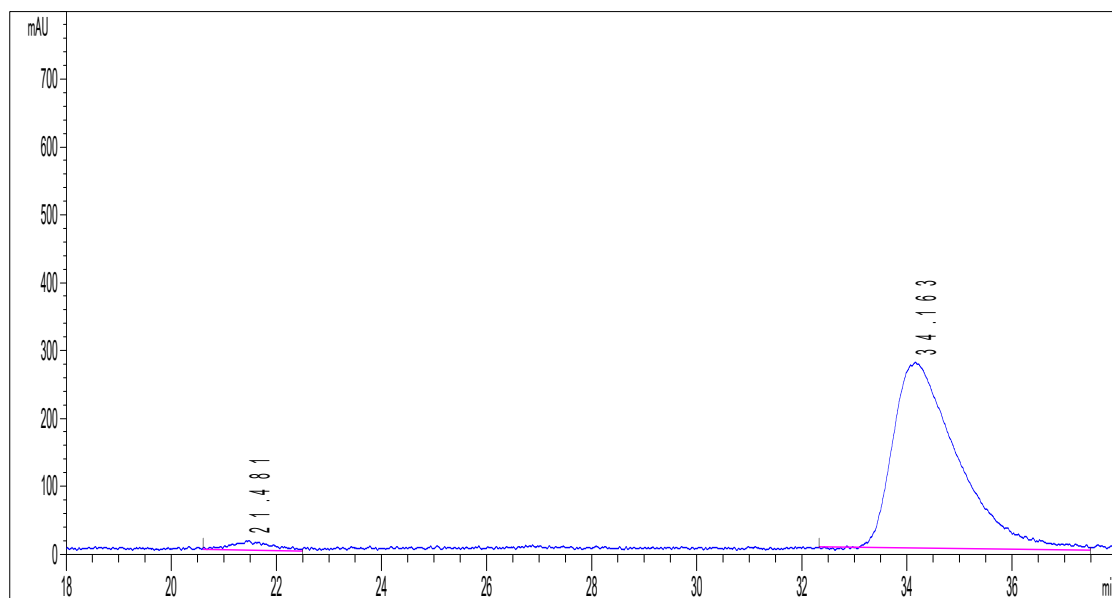
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	17.894	MM R	0.6839	2239.423	54.5756	4.1633
2	30.084	BB	0.8216	5.16E+04	751.9864	95.8367

HPLC chromatogram of racemic 3aj



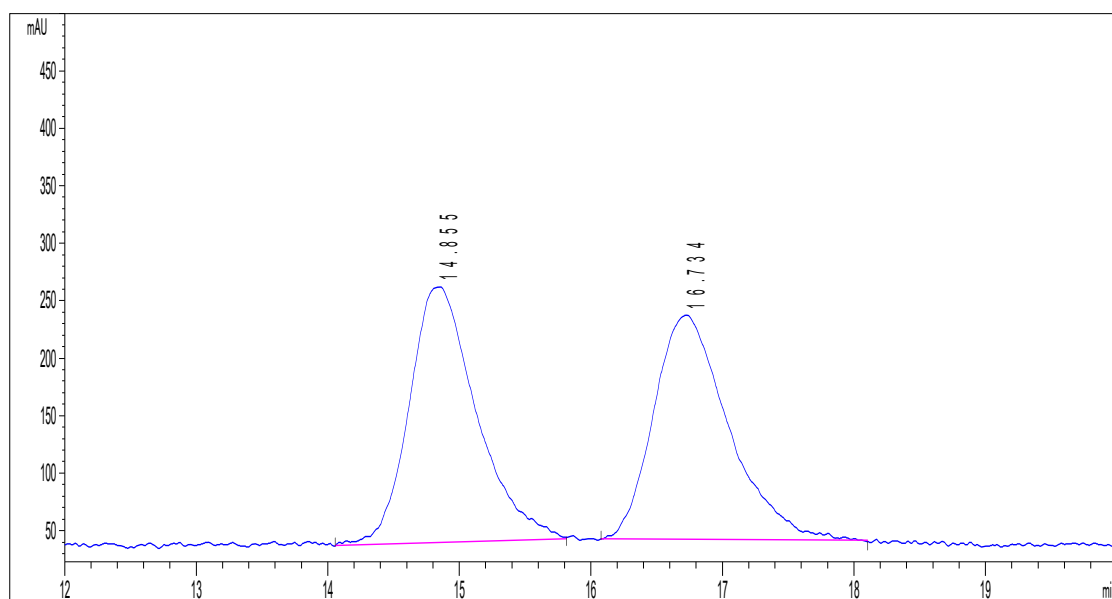
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	21.212	BB	0.6525	14323.1	275.1282	49.2851
2	34.269	MM R	1.3726	1.47E+04	178.958	50.7149

HPLC chromatogram of chiral 3aj



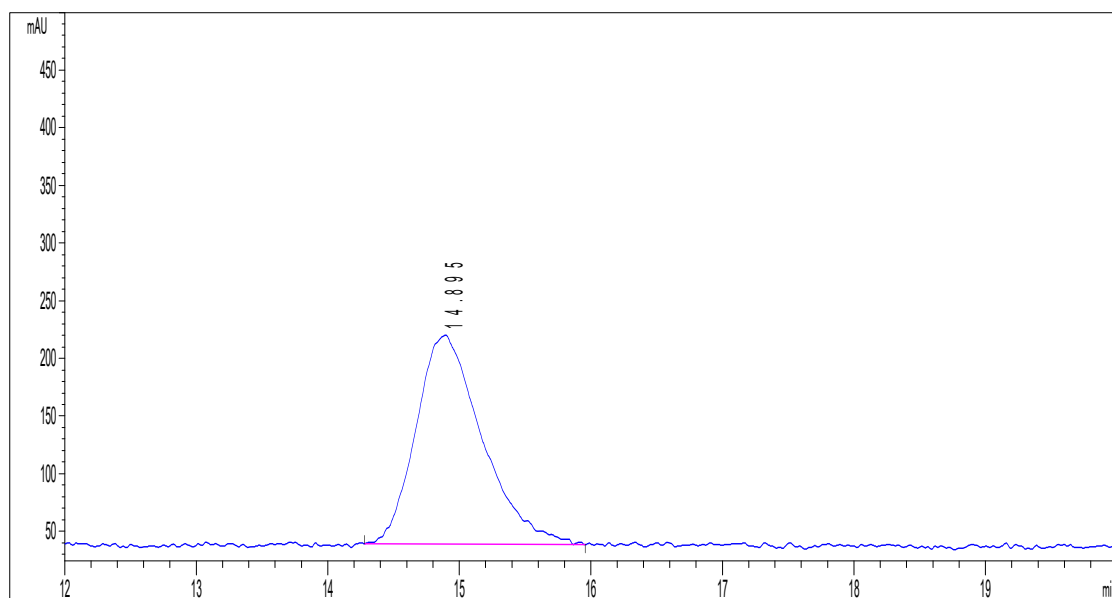
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	21.481	MM R	0.8168	673.3596	13.739	2.7922
2	34.163	MM R	1.5523	2.34E+04	273.9848	97.2078

HPLC chromatogram of racemic 3ak



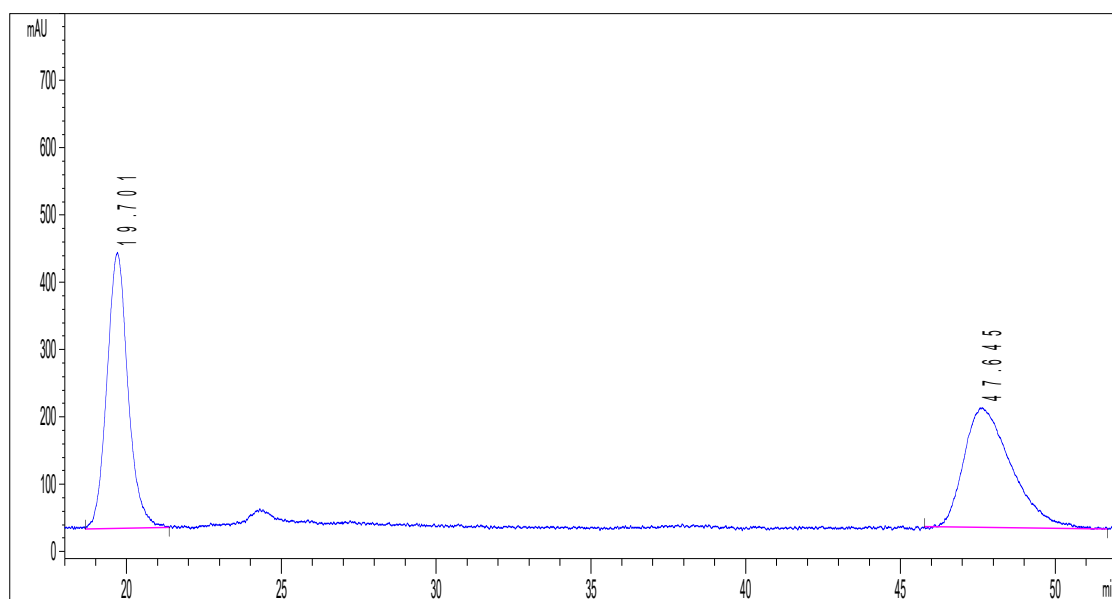
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	14.855	MM R	0.5921	7900.764	222.3894	50.6676
2	16.734	MM R	0.6577	7.69E+03	194.9267	49.3324

HPLC chromatogram of chiral 3ak



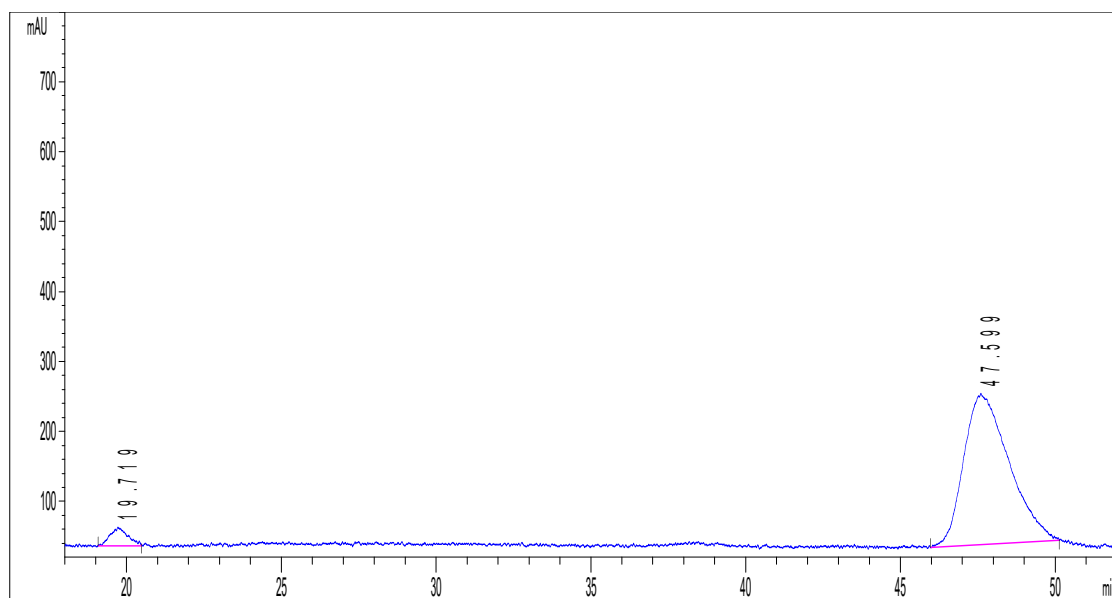
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	14.895	BB	0.4298	6.32E+03	181.2608	100

HPLC chromatogram of racemic 3al



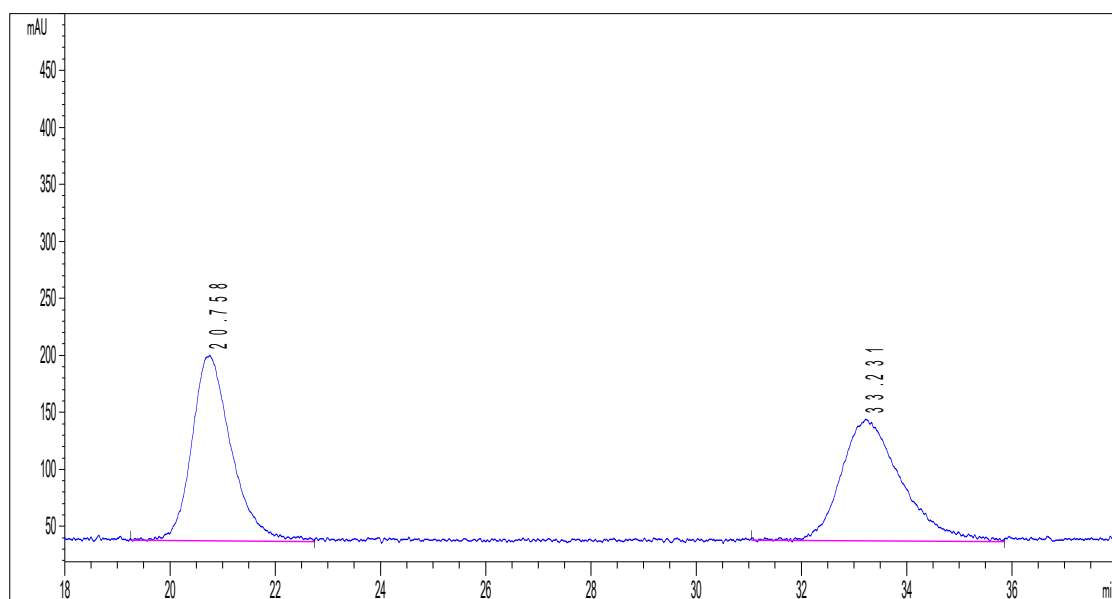
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	19.705	BB	0.6236	18887.8	406.4862	49.9417
2	47.645	MM T	1.775	1.89E+04	177.7626	50.0583

HPLC chromatogram of chiral 3al



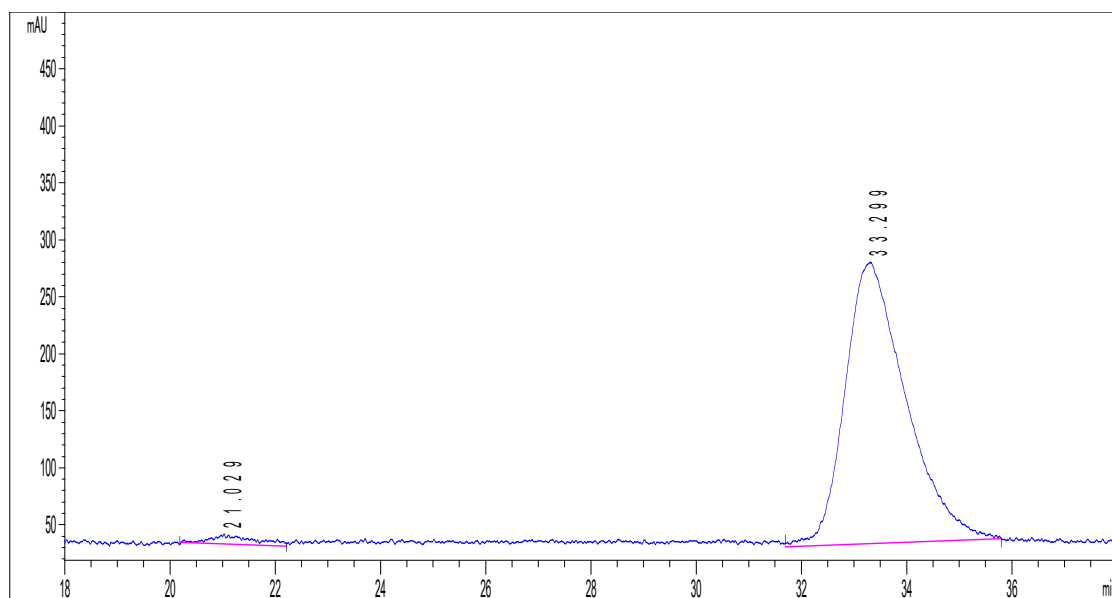
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	19.719	MM R	0.6574	1014.886	25.73114	4.4225
2	47.599	BB	1.1957	2.19E+04	216.6426	95.5775

HPLC chromatogram of racemic 3am



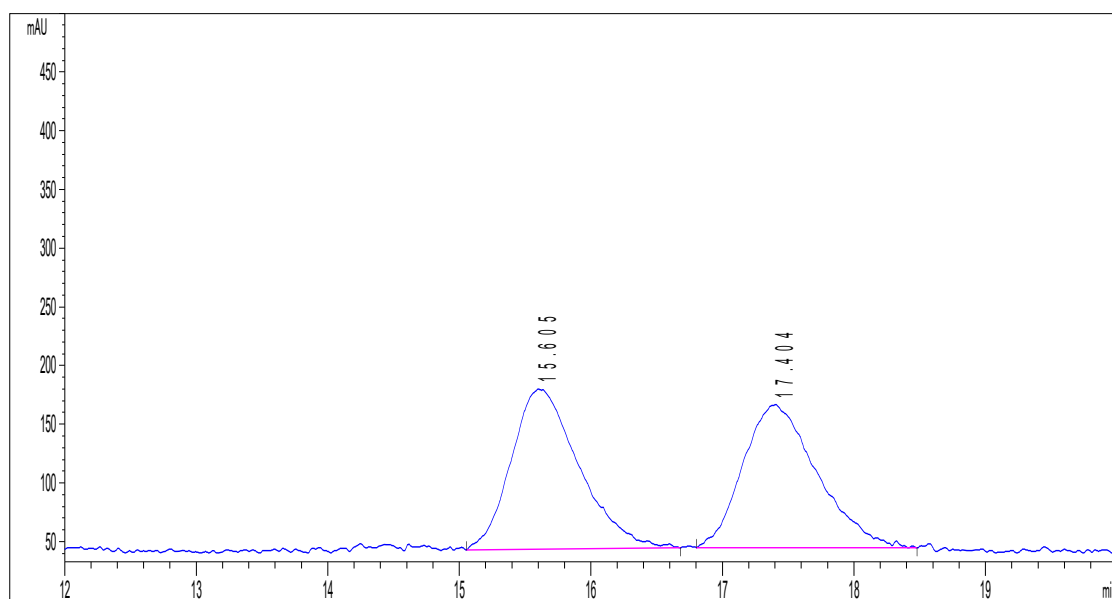
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	20.758	MM R	1.0656	8458.605	162.1644	50.1066
2	33.231	MM R	1.322	8.42E+03	106.185	49.8934

HPLC chromatogram of chiral 3am



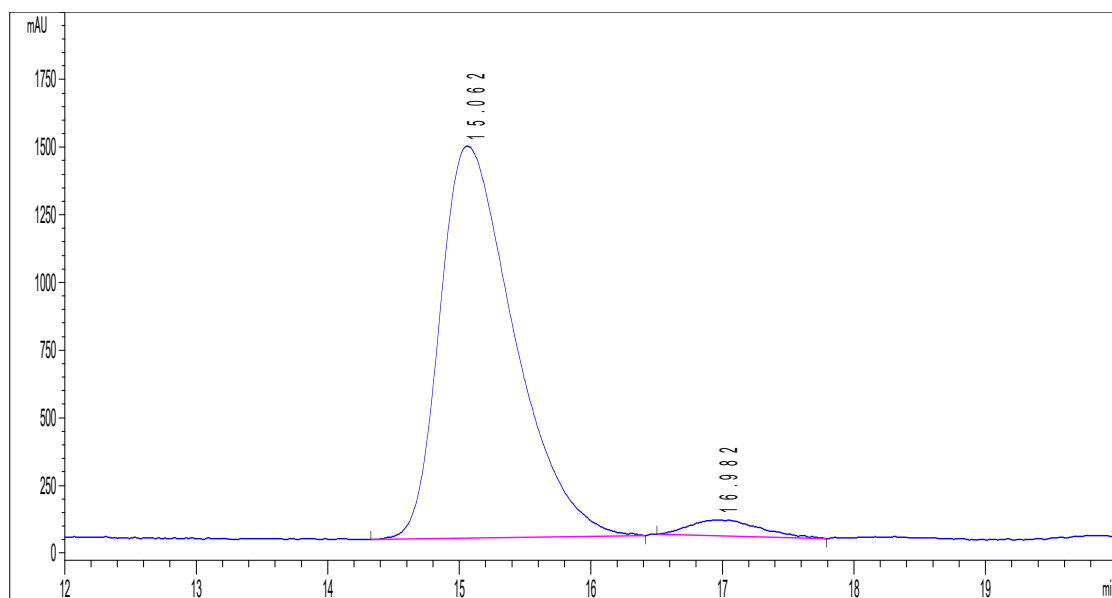
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	21.029	MM R	0.9102	461.6728	8.45368	2.2782
2	33.299	MM R	1.3384	1.98E+04	246.5938	97.7218

HPLC chromatogram of racemic 3an



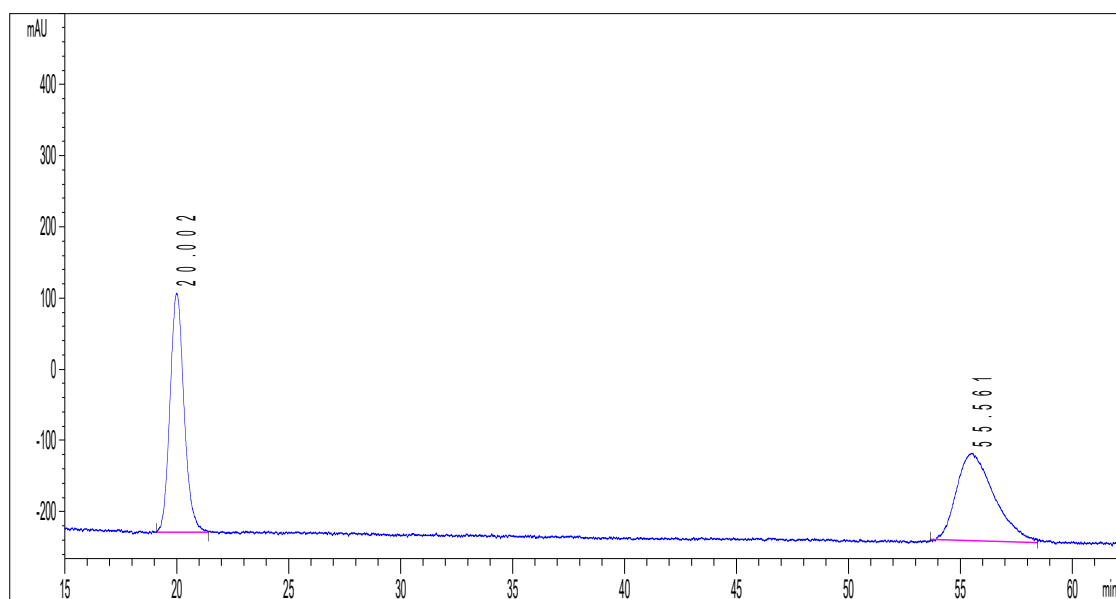
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.612	BV	0.5343	5056.906	137.3689	49.6364
2	17.398	VB	0.5453	5.13E+03	124.4014	50.3636

HPLC chromatogram of chiral 3an



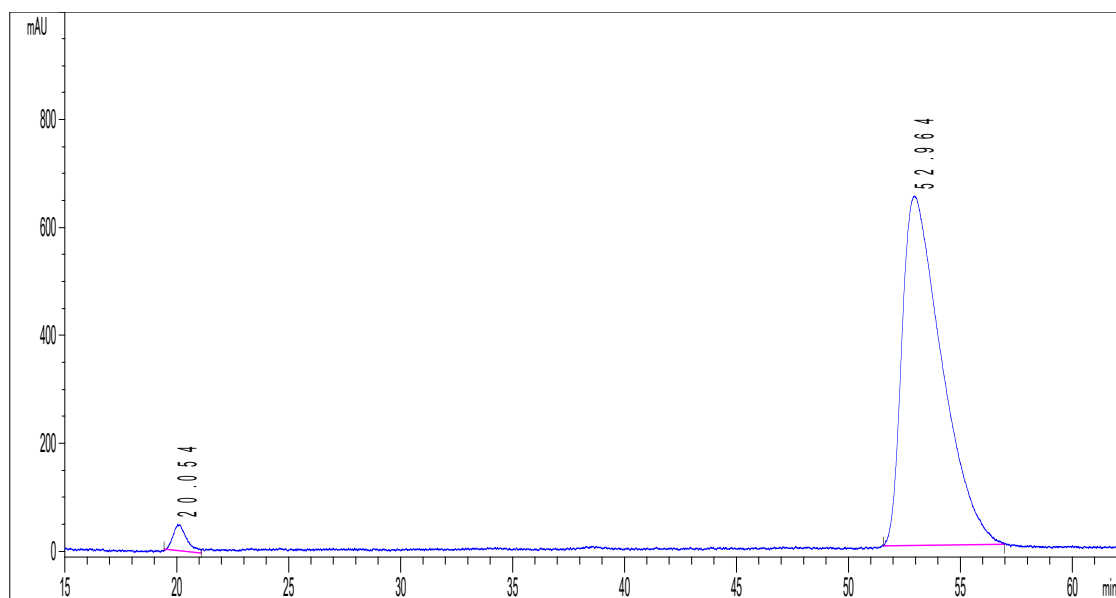
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.062	BB	0.5779	56811.3	1450.113	96.2751
2	16.982	BB	0.4385	2.20E+03	59.87788	3.7249

HPLC chromatogram of racemic 3ao



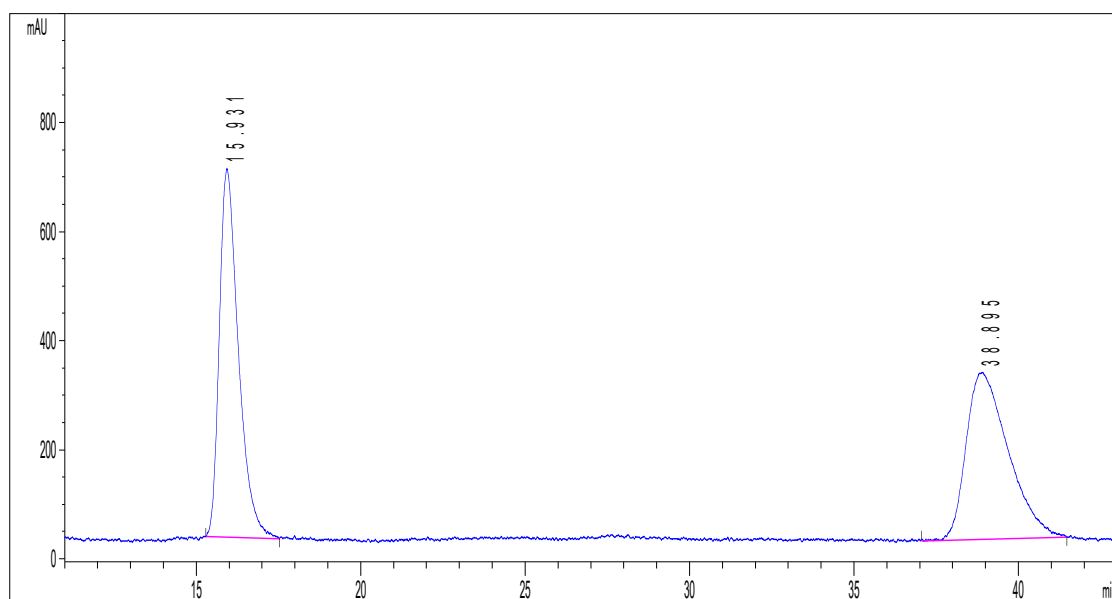
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	20.002	BB	0.5649	14627.2	334.9099	50.5232
2	55.561	MM R	1.9464	1.43E+04	122.6565	49.4768

HPLC chromatogram of chiral 3ao



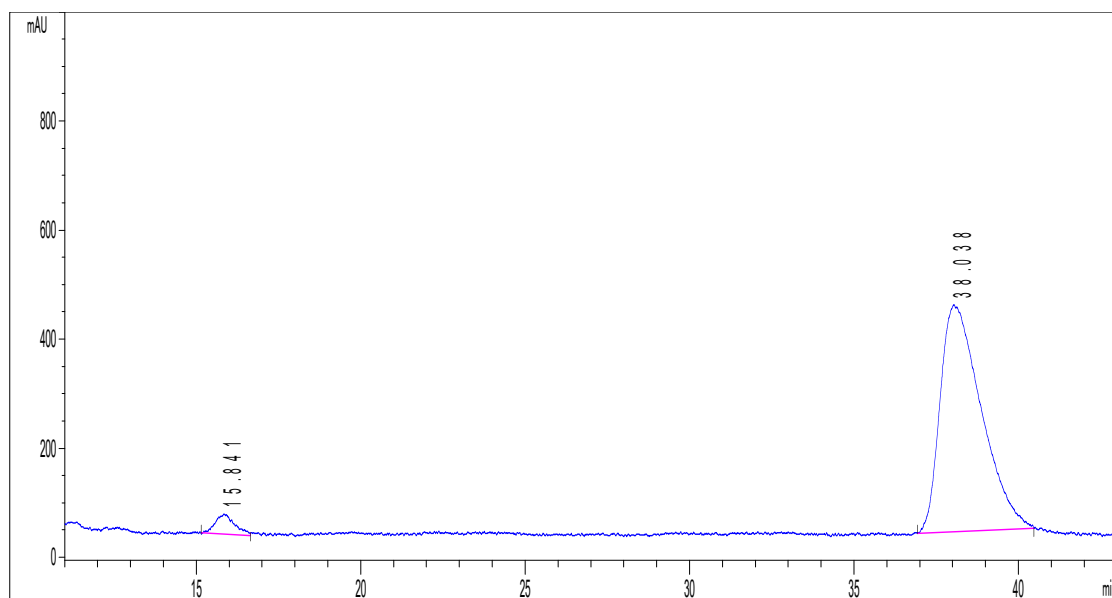
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	20.054	MM R	0.7057	2031.562	47.97674	2.4825
2	52.964	BB	1.458	7.98E+04	646.9656	97.5175

HPLC chromatogram of racemic 3ap



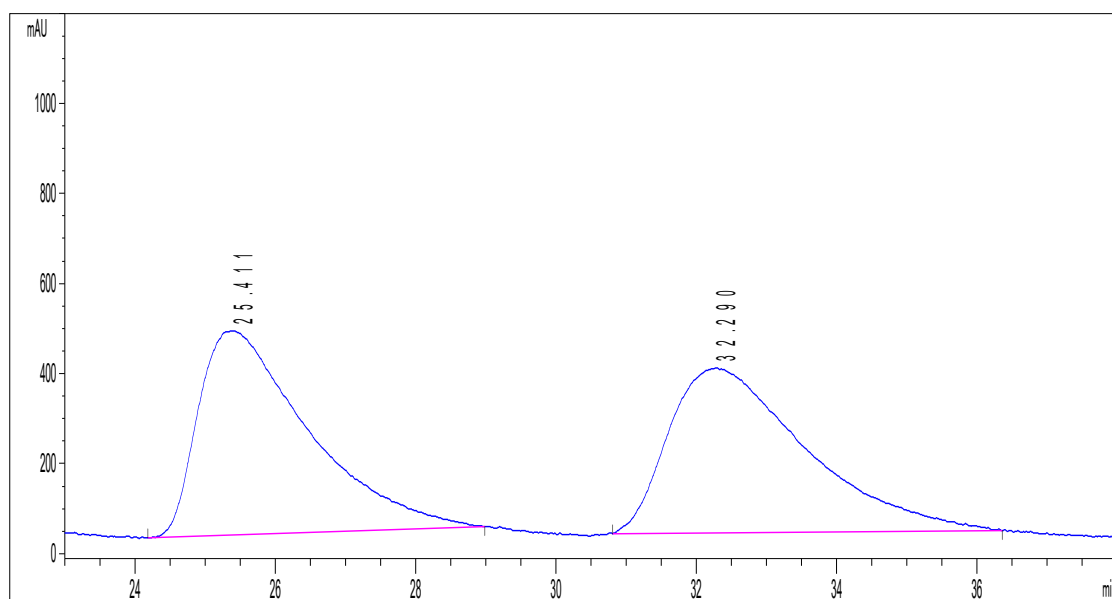
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.931	BB	0.5397	27194.6	675.2951	50.0154
2	38.895	MM R	1.4823	2.72E+04	305.5822	49.9846

HPLC chromatogram of chiral 3ap



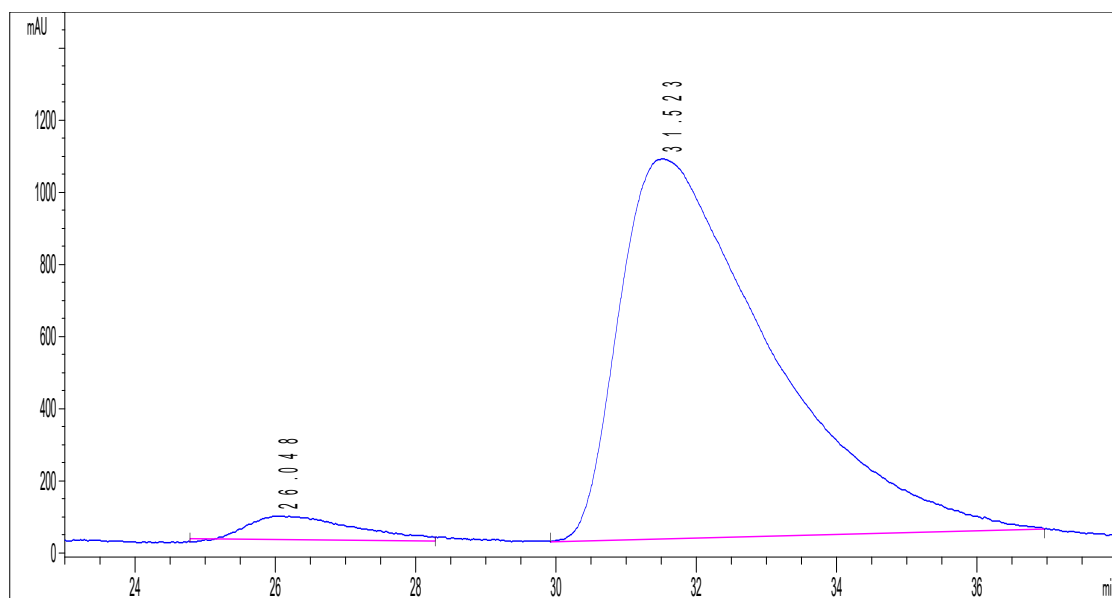
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.841	MM R	0.6922	1535.373	36.96819	4.0815
2	38.038	BB	1.0287	3.61E+04	416.2723	95.9185

HPLC chromatogram of racemic 3aq



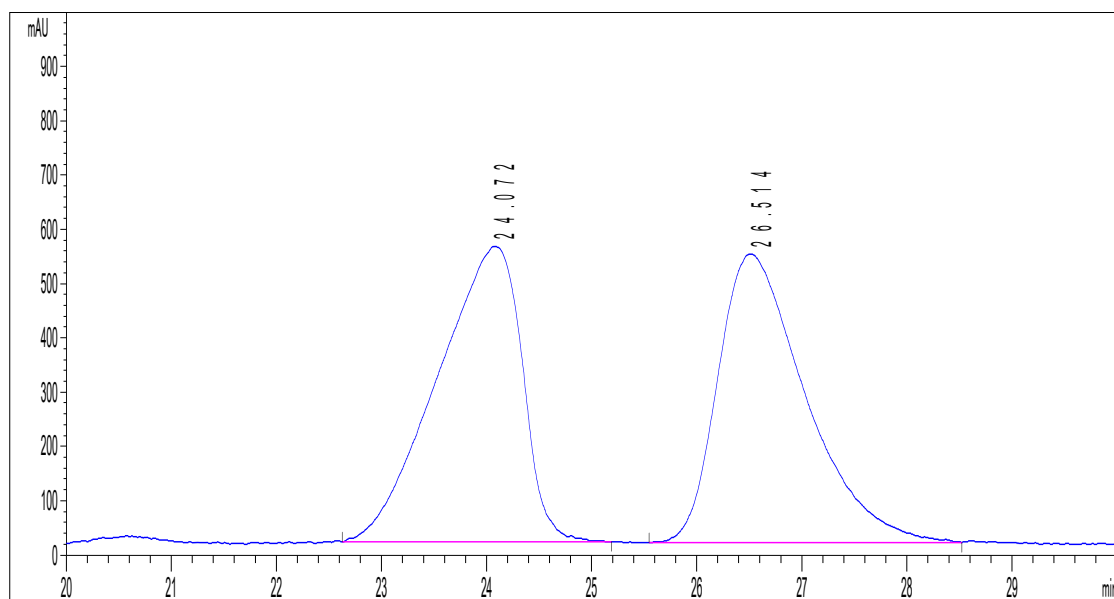
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	25.411	BB	1.2831	49456.8	453.2865	49.9576
2	32.29	BB	1.5908	4.95E+04	366.3361	50.0424

HPLC chromatogram of chiral 3aq



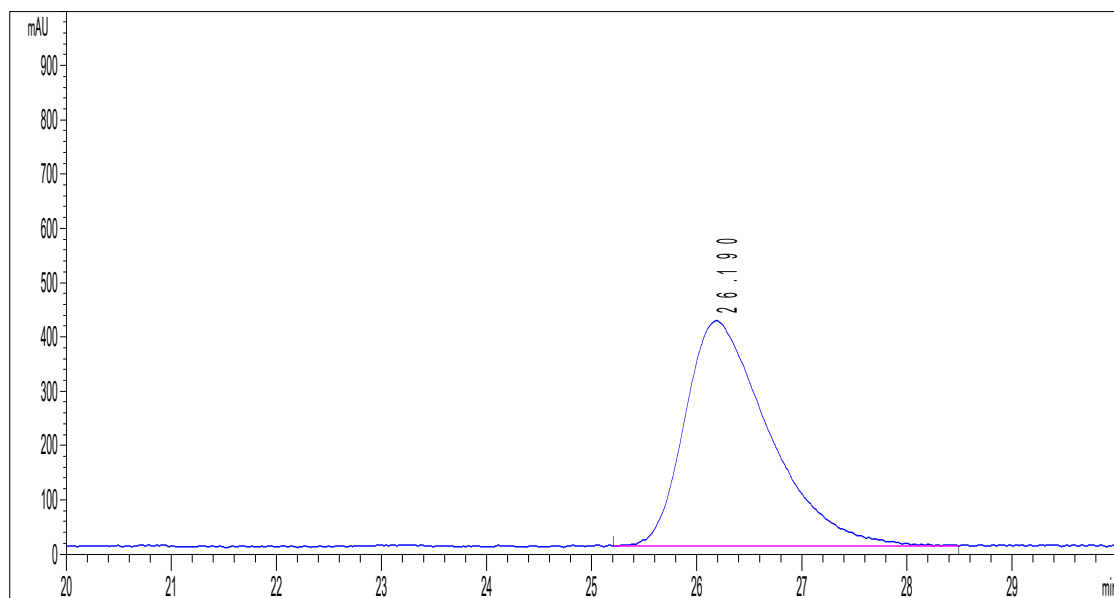
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	26.048	MM R	1.7665	6914.127	65.23291	4.2149
2	31.523	BB	1.7548	1.57E+05	1053.354	95.7851

HPLC chromatogram of racemic 3ar



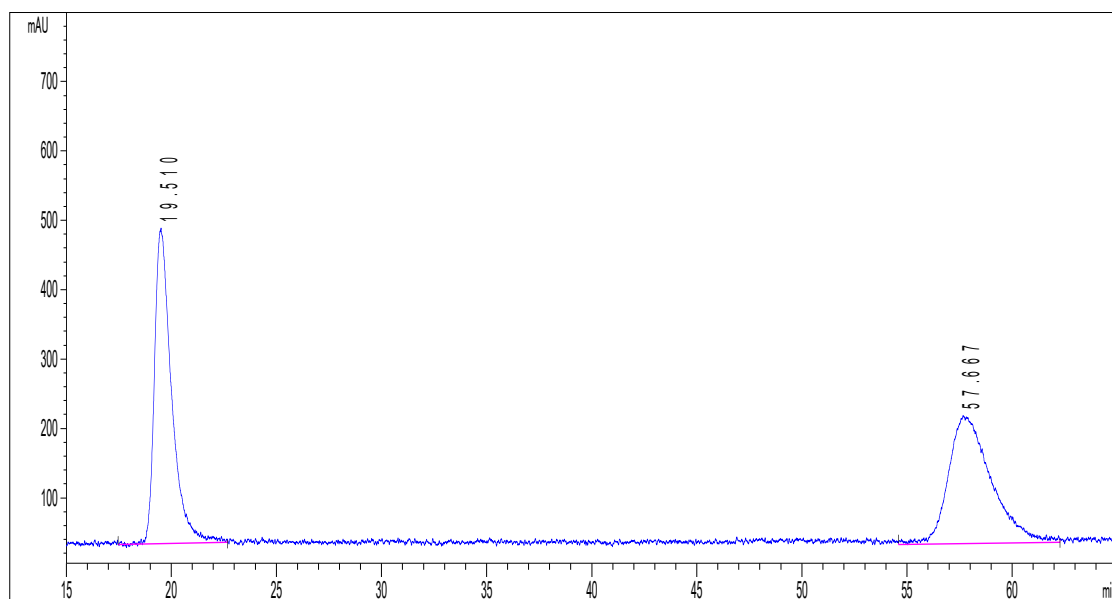
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	24.072	BB	0.6677	30506.3	544.9537	49.8378
2	26.514	BB	0.7538	3.07E+04	531.726	50.1622

HPLC chromatogram of chiral 3ar



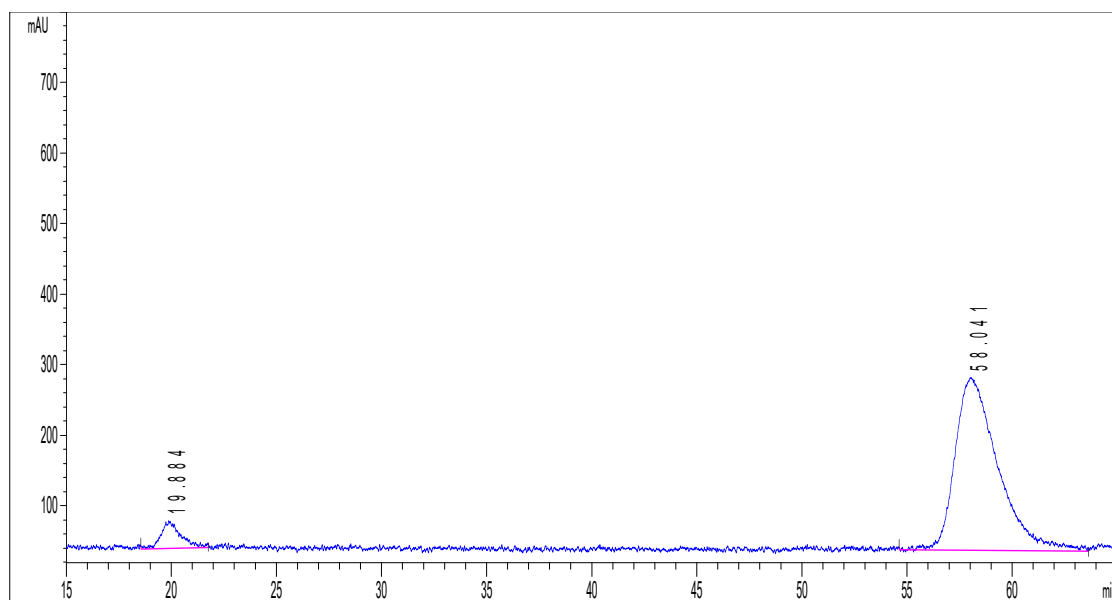
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	26.19	BB	0.7565	23016.8	415.7895	100

HPLC chromatogram of racemic 3at



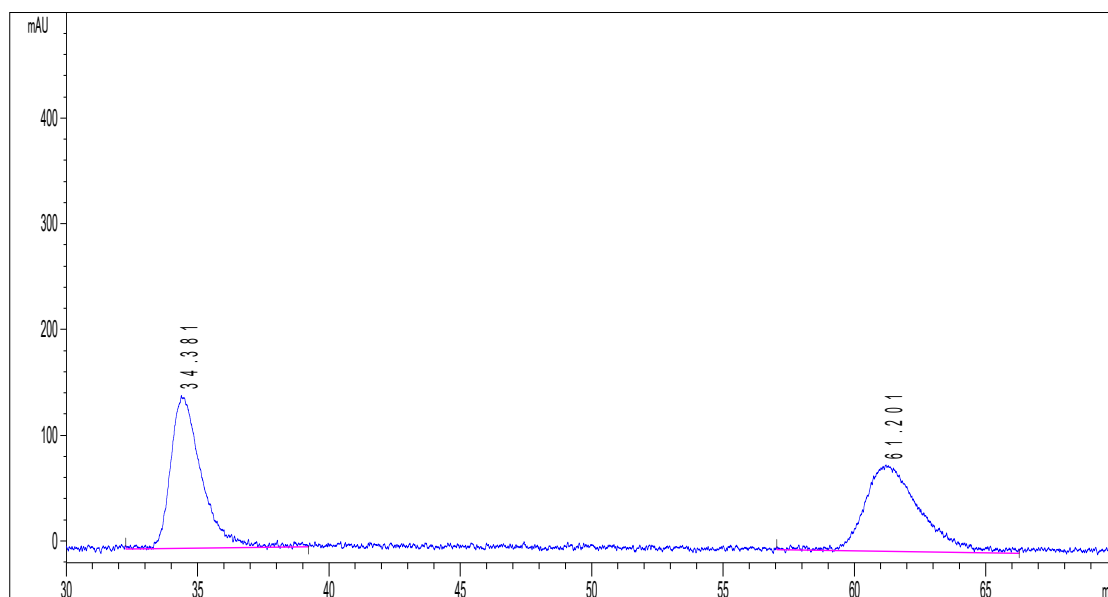
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	19.51	MM R	1.2708	25619	454.1058	49.6629
2	57.667	MM R	2.3502	2.60E+04	184.1482	50.3371

HPLC chromatogram of chiral 3at



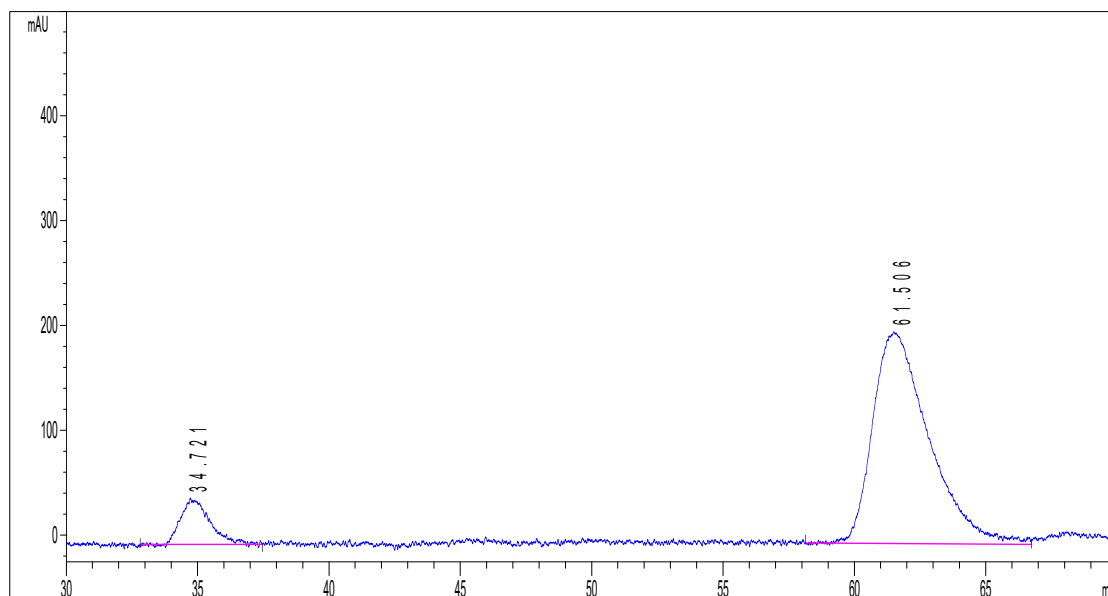
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	19.884	MM R	1.156	2491.5	38.59672	6.7206
2	58.041	MM R	2.6891	3.46E+04	244.3776	93.2794

HPLC chromatogram of racemic 3au



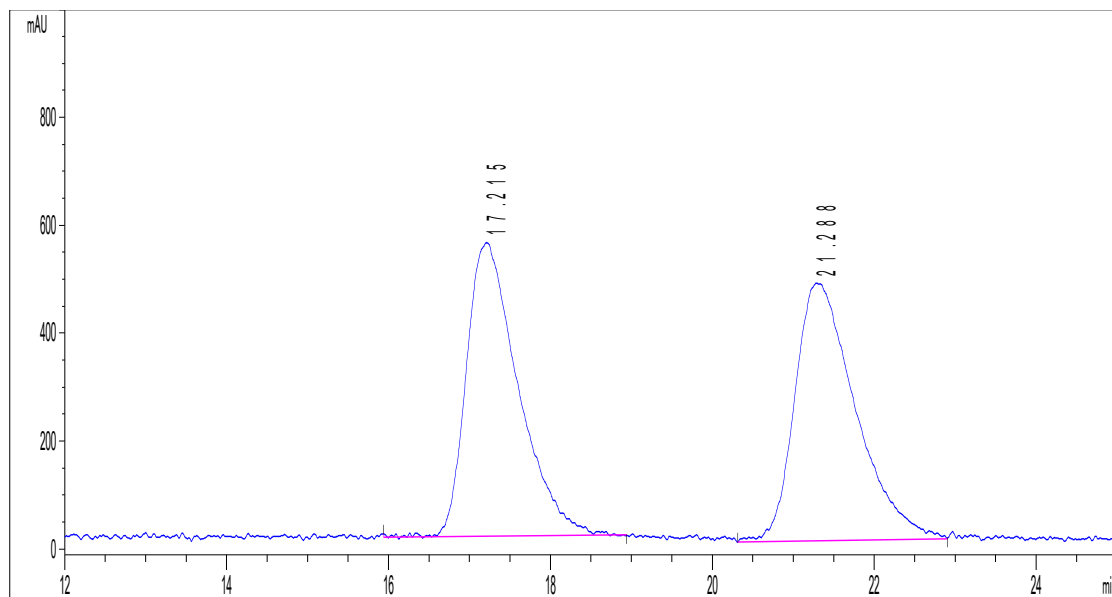
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	34.381	MM R	1.3699	11858.3	144.2679	49.7689
2	61.201	MM R	2.4448	1.20E+04	81.59193	50.2311

HPLC chromatogram of chiral 3au



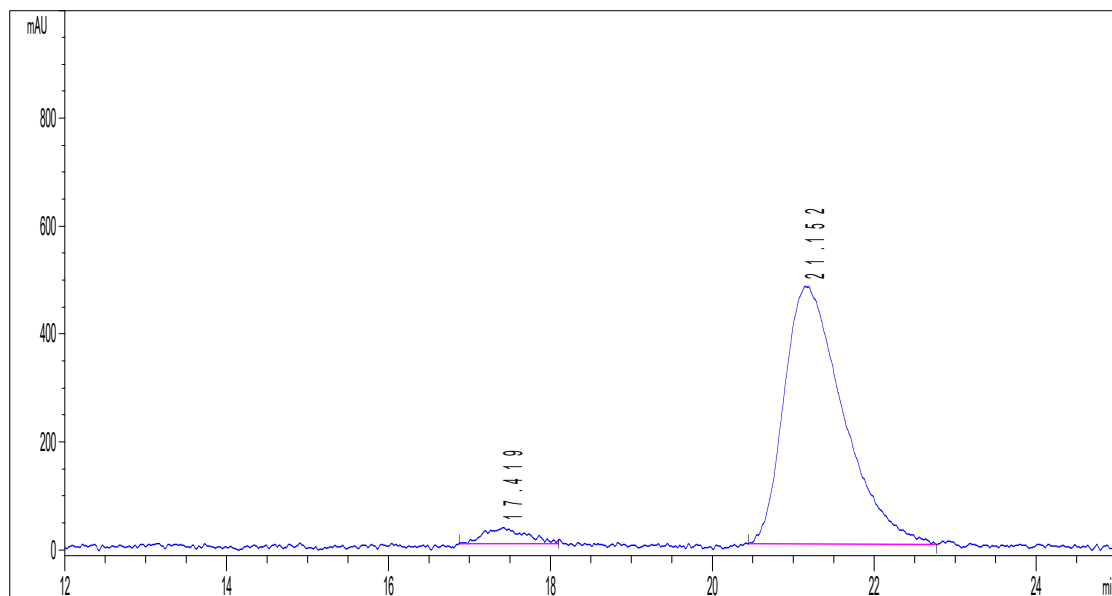
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	34.721	MM R	1.2623	3321.589	43.85478	9.9766
2	61.506	MM R	2.7397	3.00E+04	202.2507	90.0234

HPLC chromatogram of racemic 3ba



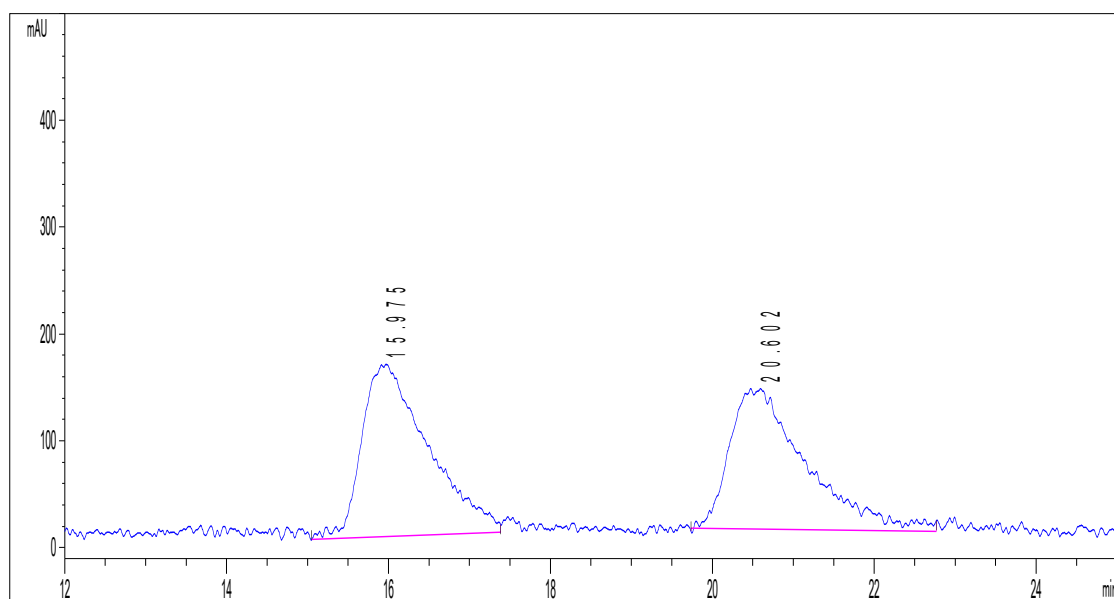
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	17.215	MM R	0.909	24310.1	544.7188	49.4351
2	21.288	BV	0.6204	2.49E+04	477.6762	50.5649

HPLC chromatogram of chiral 3ba



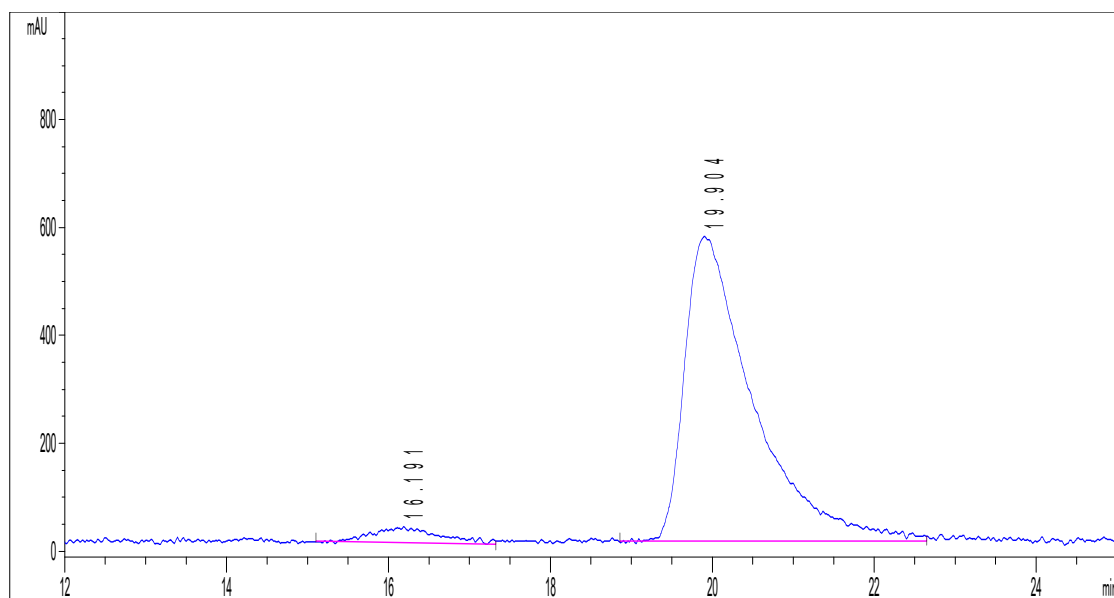
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	17.419	MM R	0.603	1085.873	30.01415	4.3013
2	21.152	BB	0.6034	2.42E+04	477.5192	95.6987

HPLC chromatogram of racemic 3ca



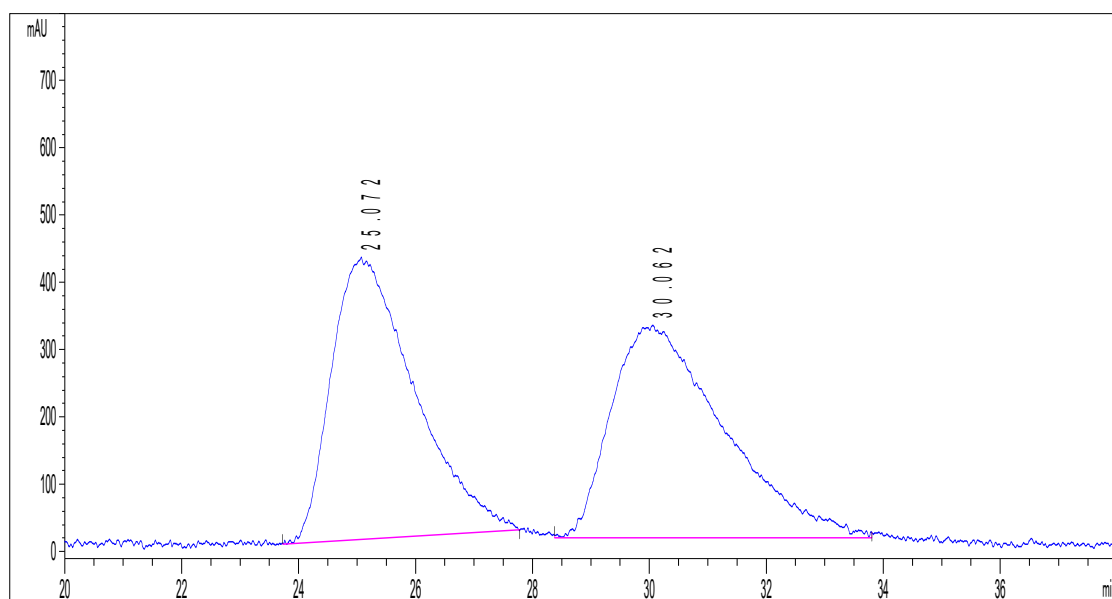
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.972	MM R	0.9334	8792.812	157.0089	50.2856
2	20.476	MM R	1.0278	8.69E+03	135.8795	49.7144

HPLC chromatogram of chiral 3ca



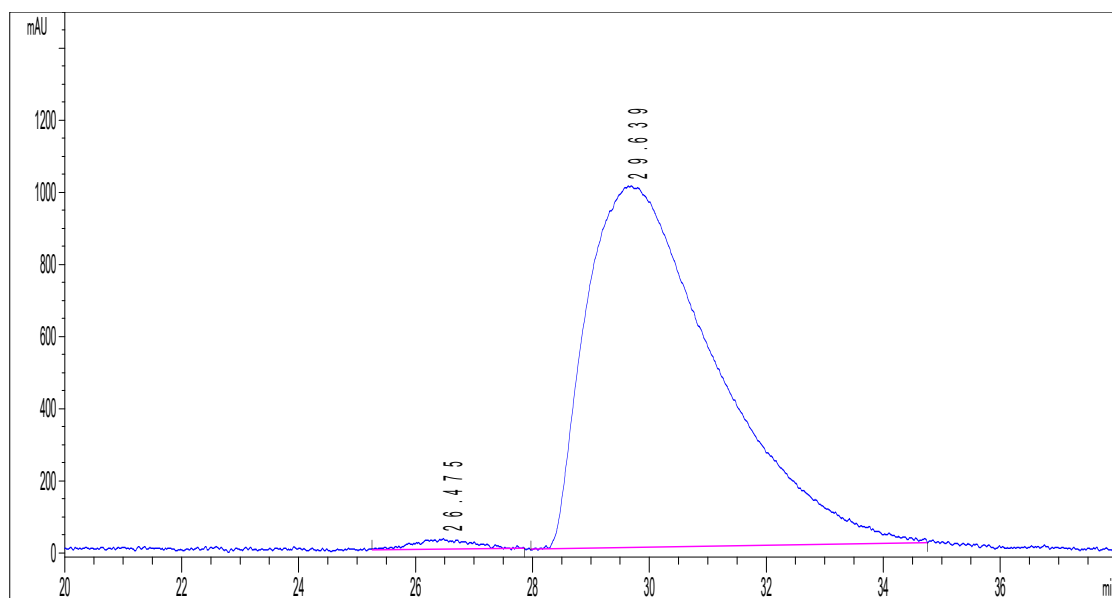
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	16.191	MM R	0.904	1591.06	29.33439	4.5851
2	19.904	MM R	1.003	3.31E+04	564.2089	95.4149

HPLC chromatogram of racemic 3da



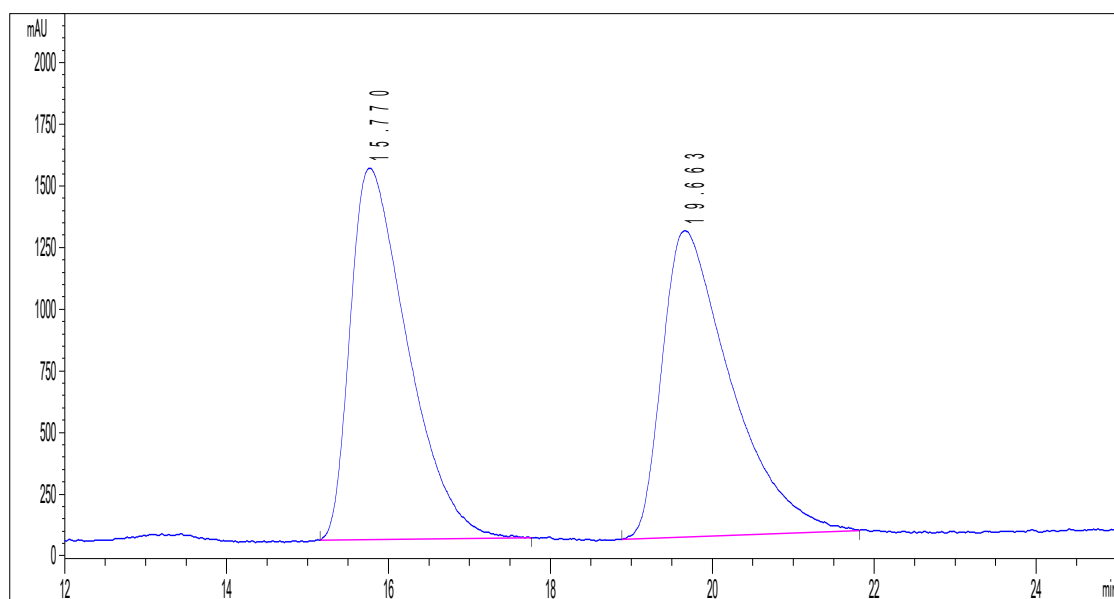
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	25.072	MM R	1.5602	41381.9	419.4415	49.5552
2	30.062	MM R	2.0723	4.21E+04	315.3093	50.4448

HPLC chromatogram of chiral 3da



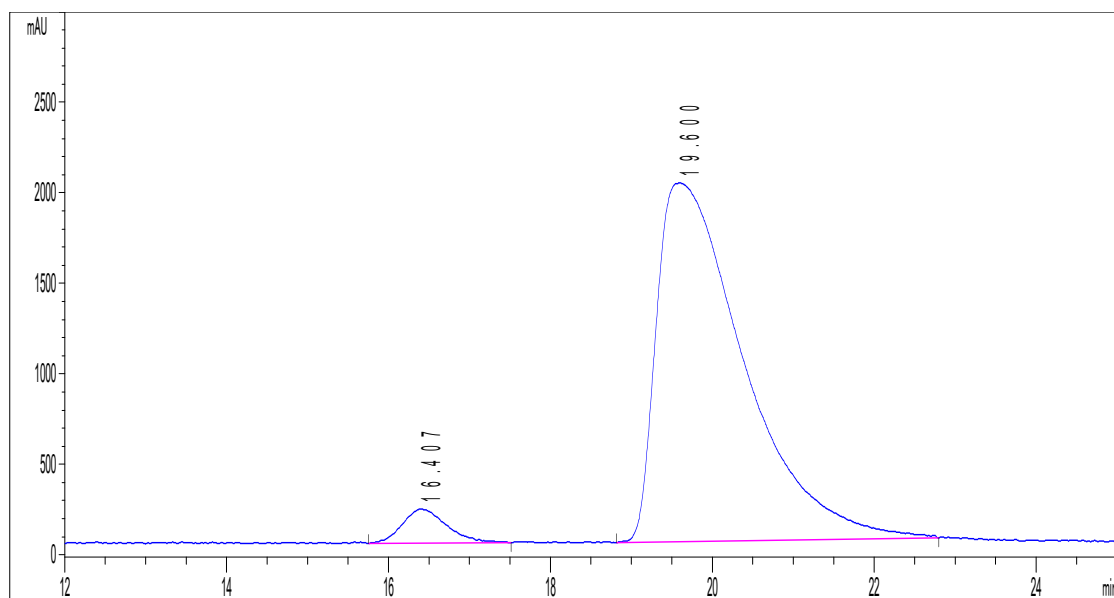
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	26.475	MM R	1.1547	1916.768	28.45984	1.2273
2	29.639	MM R	2.5693	1.54E+05	1000.651	98.7727

HPLC chromatogram of racemic 3ea



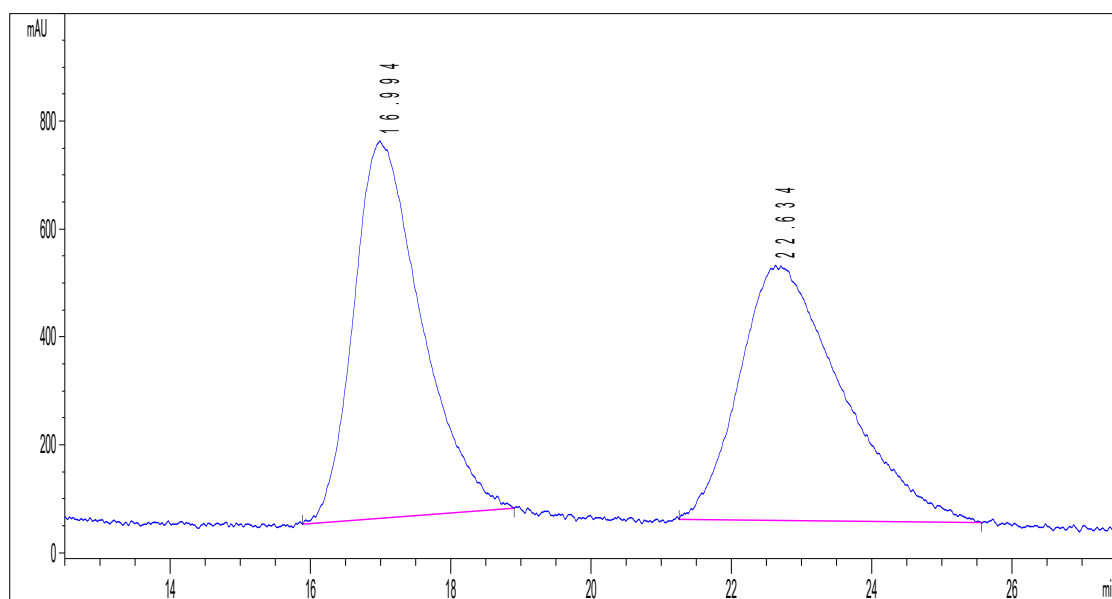
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	15.77	BB	0.6946	74327.3	1507.649	50.3748
2	19.663	BB	0.7852	7.32E+04	1242.192	49.6252

HPLC chromatogram of chiral 3ea



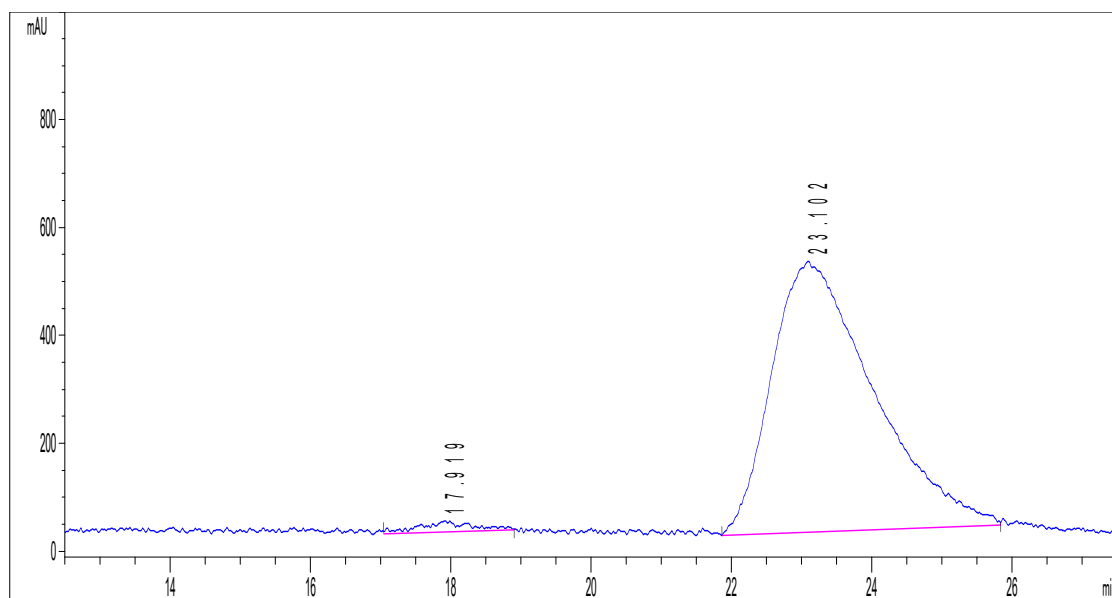
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	16.407	BB	0.4702	7167.419	188.3161	4.6015
2	19.6	BB	0.886	1.49E+05	1982.838	95.3985

HPLC chromatogram of racemic 3fa



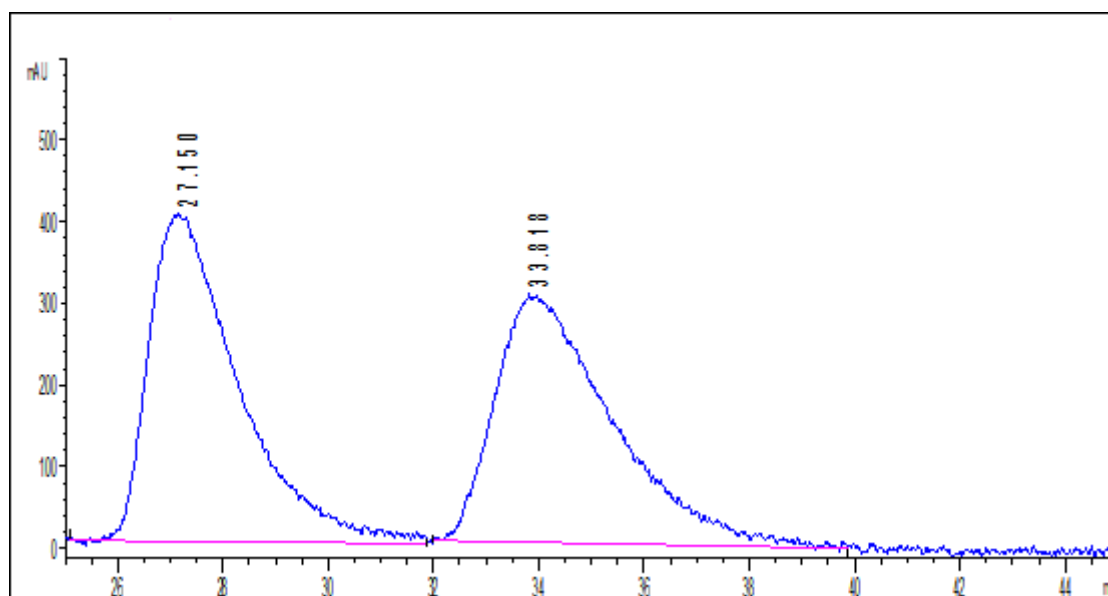
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	16.994	BB	0.8182	47111.1	699.1375	49.5786
2	22.634	BB	1.1971	4.79E+04	471.5129	50.4214

HPLC chromatogram of chiral 3fa



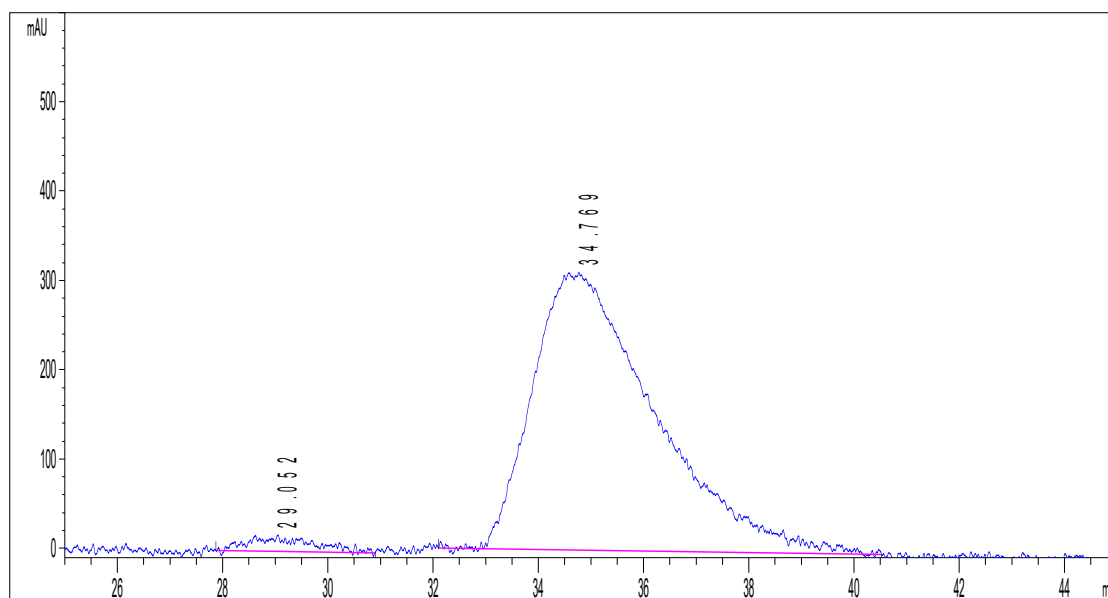
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	17.919	MM R	0.842	1065.223	21.08589	2.062
2	23.102	BV	1.1952	5.06E+04	503.0544	97.938

HPLC chromatogram of racemic 3ga



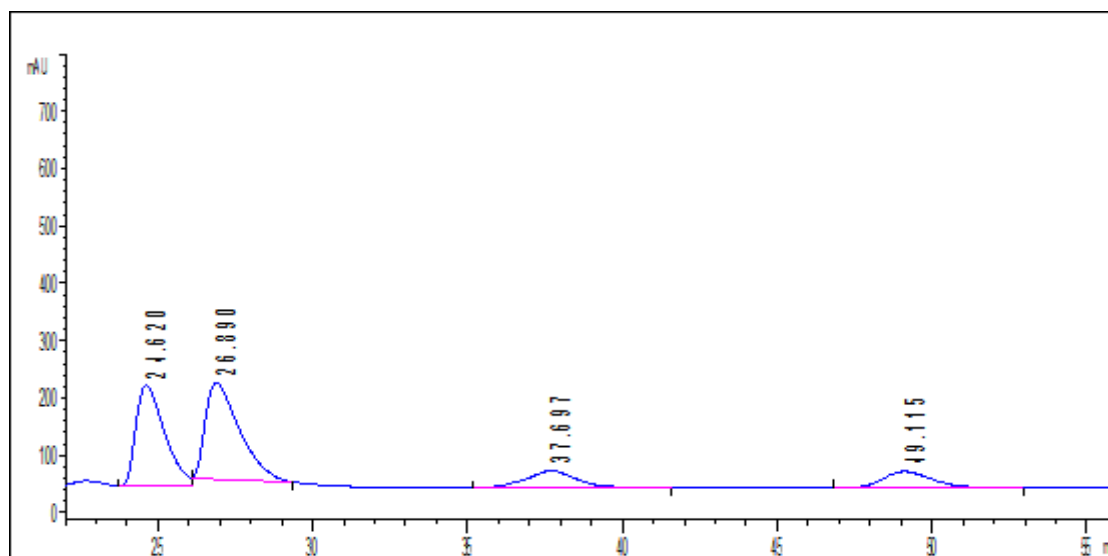
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	27.15	MM R	1.9684	47306.5	400.5403	50.3306
2	33.818	MM R	2.5576	4.67E+04	304.2303	49.6694

HPLC chromatogram of chiral 3ga



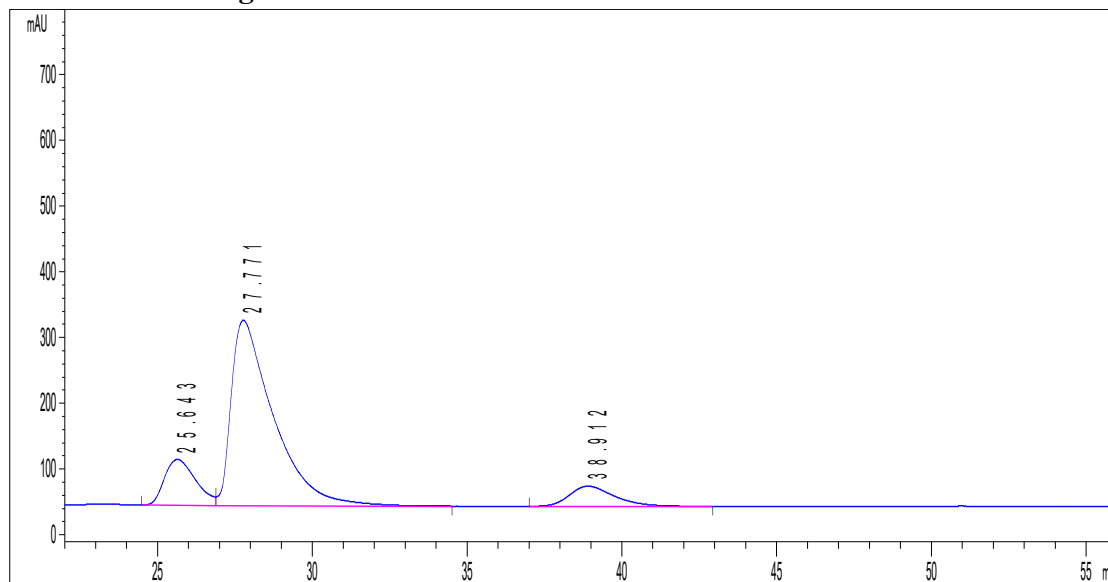
Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	29.052	MM R	1.2404	1392.096	18.44998	2.7107
2	34.769	MM R	2.6804	5.00E+04	310.6745	97.2893

HPLC chromatogram of chiral 4aa



Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	24.616	MM R	1.0382	1.08E+04	172.8521	37.6611
2	26.89	MM R	1.1791	1.13E+04	159.0261	39.3504
3	37.697	BB	1.4728	3319.939	29.31306	11.6118
4	49.115	BB	1.3476	3252.689	28.59166	11.3766

HPLC chromatogram of chiral 4aa



Peak #	RetTime [min]	Type	Width [min]	Area mAU*s	Height [mAU]	Area %
1	25.643	BV	1.0881	4874.011	69.57838	14.0672
2	27.771	VB	1.3526	2.67E+04	281.7252	77.0209
3	38.912	BB	1.4308	3087.82	30.59454	8.9119

X-Ray Crystallographic Data

Crystallographic data for **3aa** has been deposited with the Cambridge Crystallographic Data Centre as deposition number CCDC 1844053. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif, or by emailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12, Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033.

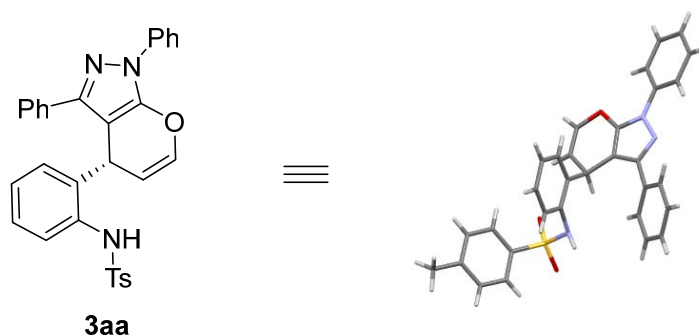


Table S1. Crystal data and structure refinement for **3aa**.

Identification code	3aa	
Empirical formula	C ₃₁ H ₂₅ N ₃ O ₃ S	
Formula weight	519.60	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group	P -1	
Unit cell dimensions	a = 10.369(2) Å	= 79.86(3)°.
	b = 12.959(3) Å	= 69.61(3)°.
	c = 13.156(3) Å	= 84.09(3)°.
Volume	1629.5(7) Å ³	
Z	2	
Density (calculated)	1.059 Mg/m ³	
Absorption coefficient	0.130 mm ⁻¹	

F(000)	544
Theta range for data collection	1.670 to 27.476°.
Index ranges	-13<= <i>h</i> <=13, -16<= <i>k</i> <=16, -17<= <i>l</i> <=17
Reflections collected	23056
Independent reflections	7420 [R(int) = 0.0413]
Completeness to theta = 25.242°	99.3 %
Absorption correction	None
Refinement method	Full-matrix least-squares on F ²
Data / restraints / parameters	7420 / 0 / 344
Goodness-of-fit on F ²	1.105
Final R indices [I>2sigma(I)]	R1 = 0.0701, wR2 = 0.2099
R indices (all data)	R1 = 0.0740, wR2 = 0.2171
Extinction coefficient	n/a
Largest diff. peak and hole	0.482 and -0.457 e.Å ⁻³

Table S2. Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for **3aa**. U(eq) is defined as one third of the trace of the orthogonalized U_{ij} tensor.

	x	y	z	U(eq)
S1	1494(1)	9426(1)	1346(1)	28(1)
O1	447(2)	10196(1)	1200(2)	40(1)
O2	2923(2)	9648(1)	823(2)	38(1)
O3	6646(2)	7592(1)	-2530(1)	31(1)
N1	1247(2)	8385(1)	892(2)	24(1)

N2	4115(2)	6282(2)	-2974(2)	25(1)
N3	5442(2)	6570(2)	-3211(2)	24(1)
C1	480(4)	8013(3)	6184(2)	50(1)
C2	731(3)	8385(2)	4981(2)	34(1)
C3	-321(3)	8895(2)	4627(2)	34(1)
C4	-97(2)	9228(2)	3517(2)	30(1)
C5	1197(2)	9064(2)	2764(2)	27(1)
C6	2261(3)	8564(2)	3103(2)	37(1)
C7	2010(3)	8219(2)	4212(2)	40(1)
C8	2078(2)	7447(2)	1046(2)	22(1)
C9	1600(2)	6742(2)	2009(2)	29(1)
C10	2399(3)	5855(2)	2205(2)	35(1)
C11	3684(3)	5673(2)	1445(2)	37(1)
C12	4138(3)	6369(2)	478(2)	31(1)
C13	3342(2)	7263(2)	252(2)	23(1)
C14	3868(2)	7967(2)	-852(2)	23(1)
C15	5212(2)	8440(2)	-994(2)	26(1)
C16	6421(2)	8249(2)	-1739(2)	29(1)
C17	5460(2)	7208(2)	-2496(2)	23(1)
C18	4156(2)	7359(2)	-1788(2)	22(1)
C19	3353(2)	6753(2)	-2127(2)	23(1)
C20	1853(2)	6589(2)	-1662(2)	24(1)
C21	915(2)	7370(2)	-1199(2)	28(1)
C22	-482(3)	7205(2)	-803(2)	34(1)
C23	-963(3)	6259(2)	-863(2)	39(1)
C24	-29(3)	5483(2)	-1323(2)	41(1)
C25	1364(3)	5640(2)	-1717(2)	33(1)

C26	6531(2)	6142(2)	-4052(2)	24(1)
C27	6257(2)	5309(2)	-4478(2)	29(1)
C28	7302(3)	4876(2)	-5295(2)	34(1)
C29	8621(3)	5242(2)	-5672(2)	33(1)
C30	8881(3)	6071(2)	-5245(2)	33(1)
C31	7846(2)	6528(2)	-4441(2)	29(1)

Table S3. Bond lengths [Å] and angles [°] for **3aa**.

S1-O1	1.437(2)
S1-O2	1.4355(19)
S1-N1	1.6439(19)
S1-C5	1.765(2)
O3-C16	1.401(3)
O3-C17	1.356(3)
N1-H1	0.8601
N1-C8	1.442(3)
N2-N3	1.377(3)
N2-C19	1.328(3)
N3-C17	1.363(3)
N3-C26	1.423(3)
C1-H1A	0.9600
C1-H1B	0.9600
C1-H1C	0.9600
C1-C2	1.508(4)
C2-C3	1.394(4)

C2-C7	1.382(4)
C3-H3	0.9300
C3-C4	1.391(4)
C4-H4	0.9300
C4-C5	1.384(3)
C5-C6	1.389(4)
C6-H6	0.9300
C6-C7	1.388(4)
C7-H7	0.9300
C8-C9	1.390(3)
C8-C13	1.391(3)
C9-H9	0.9300
C9-C10	1.386(3)
C10-H10	0.9300
C10-C11	1.386(4)
C11-H11	0.9300
C11-C12	1.385(4)
C12-H12	0.9300
C12-C13	1.402(3)
C13-C14	1.525(3)
C14-H14	0.9800
C14-C15	1.519(3)
C14-C18	1.504(3)
C15-H15	0.9300
C15-C16	1.326(3)
C16-H16	0.9300
C17-C18	1.366(3)

C18-C19	1.423(3)
C19-C20	1.482(3)
C20-C21	1.393(3)
C20-C25	1.401(3)
C21-H21	0.9300
C21-C22	1.384(3)
C22-H22	0.9300
C22-C23	1.395(4)
C23-H23	0.9300
C23-C24	1.386(4)
C24-H24	0.9300
C24-C25	1.378(4)
C25-H25	0.9300
C26-C27	1.395(3)
C26-C31	1.392(3)
C27-H27	0.9300
C27-C28	1.386(3)
C28-H28	0.9300
C28-C29	1.385(4)
C29-H29	0.9300
C29-C30	1.385(4)
C30-H30	0.9300
C30-C31	1.386(3)
C31-H31	0.9300
O1-S1-N1	105.89(11)
O1-S1-C5	108.63(12)

O2-S1-O1	120.23(12)
O2-S1-N1	106.86(11)
O2-S1-C5	107.61(12)
N1-S1-C5	106.92(10)
C17-O3-C16	112.26(17)
S1-N1-H1	111.7
C8-N1-S1	117.44(14)
C8-N1-H1	111.7
C19-N2-N3	105.59(18)
N2-N3-C26	119.33(18)
C17-N3-N2	109.45(17)
C17-N3-C26	131.09(19)
H1A-C1-H1B	109.5
H1A-C1-H1C	109.5
H1B-C1-H1C	109.5
C2-C1-H1A	109.5
C2-C1-H1B	109.5
C2-C1-H1C	109.5
C3-C2-C1	120.6(3)
C7-C2-C1	120.4(3)
C7-C2-C3	119.0(2)
C2-C3-H3	119.6
C4-C3-C2	120.8(2)
C4-C3-H3	119.6
C3-C4-H4	120.4
C5-C4-C3	119.2(2)
C5-C4-H4	120.4

C4-C5-S1	120.22(19)
C4-C5-C6	120.8(2)
C6-C5-S1	118.85(18)
C5-C6-H6	120.4
C7-C6-C5	119.2(2)
C7-C6-H6	120.4
C2-C7-C6	121.1(3)
C2-C7-H7	119.5
C6-C7-H7	119.5
C9-C8-N1	118.7(2)
C9-C8-C13	120.9(2)
C13-C8-N1	120.40(19)
C8-C9-H9	119.9
C10-C9-C8	120.2(2)
C10-C9-H9	119.9
C9-C10-H10	120.0
C9-C10-C11	120.0(2)
C11-C10-H10	120.0
C10-C11-H11	120.4
C12-C11-C10	119.2(2)
C12-C11-H11	120.4
C11-C12-H12	119.1
C11-C12-C13	121.9(2)
C13-C12-H12	119.1
C8-C13-C12	117.7(2)
C8-C13-C14	123.06(19)
C12-C13-C14	119.2(2)

C13-C14-H14	109.3
C15-C14-C13	110.94(18)
C15-C14-H14	109.3
C18-C14-C13	111.37(17)
C18-C14-H14	109.3
C18-C14-C15	106.71(18)
C14-C15-H15	117.3
C16-C15-C14	125.4(2)
C16-C15-H15	117.3
O3-C16-H16	117.5
C15-C16-O3	125.0(2)
C15-C16-H16	117.5
O3-C17-N3	121.89(19)
O3-C17-C18	128.4(2)
N3-C17-C18	109.68(19)
C17-C18-C14	121.77(19)
C17-C18-C19	103.26(19)
C19-C18-C14	134.7(2)
N2-C19-C18	112.01(19)
N2-C19-C20	118.95(19)
C18-C19-C20	129.0(2)
C21-C20-C19	121.5(2)
C21-C20-C25	119.2(2)
C25-C20-C19	119.3(2)
C20-C21-H21	119.9
C22-C21-C20	120.1(2)
C22-C21-H21	119.9

C21-C22-H22	119.8
C21-C22-C23	120.4(2)
C23-C22-H22	119.8
C22-C23-H23	120.3
C24-C23-C22	119.5(2)
C24-C23-H23	120.3
C23-C24-H24	119.8
C25-C24-C23	120.5(2)
C25-C24-H24	119.8
C20-C25-H25	119.8
C24-C25-C20	120.3(2)
C24-C25-H25	119.8
C27-C26-N3	118.4(2)
C31-C26-N3	121.4(2)
C31-C26-C27	120.2(2)
C26-C27-H27	120.3
C28-C27-C26	119.5(2)
C28-C27-H27	120.3
C27-C28-H28	119.6
C29-C28-C27	120.8(2)
C29-C28-H28	119.6
C28-C29-H29	120.4
C30-C29-C28	119.3(2)
C30-C29-H29	120.4
C29-C30-H30	119.5
C29-C30-C31	120.9(2)
C31-C30-H30	119.5

C26-C31-H31	120.3
C30-C31-C26	119.3(2)
C30-C31-H31	120.3

Symmetry transformations used to generate equivalent atoms:

Table S4. Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for **3aa**. The anisotropic displacement factor exponent takes the form: $-2 \left[h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12} \right]$

	U ¹¹	U ²²	U ³³	U ²³	U ¹³	U ¹²
S1	30(1)	23(1)	28(1)	-7(1)	-5(1)	-3(1)
O1	51(1)	28(1)	40(1)	-7(1)	-13(1)	9(1)
O2	37(1)	36(1)	36(1)	-10(1)	0(1)	-16(1)
O3	23(1)	38(1)	32(1)	-15(1)	-4(1)	-7(1)
N1	22(1)	23(1)	28(1)	-6(1)	-9(1)	2(1)
N2	22(1)	28(1)	25(1)	-7(1)	-6(1)	-4(1)
N3	22(1)	28(1)	22(1)	-6(1)	-4(1)	-4(1)
C1	65(2)	52(2)	33(1)	-5(1)	-16(1)	-10(2)
C2	38(1)	33(1)	32(1)	-9(1)	-11(1)	-8(1)
C3	30(1)	36(1)	32(1)	-11(1)	-1(1)	-3(1)
C4	26(1)	28(1)	34(1)	-10(1)	-7(1)	2(1)
C5	26(1)	28(1)	28(1)	-10(1)	-7(1)	-3(1)
C6	23(1)	55(2)	34(1)	-15(1)	-8(1)	1(1)
C7	34(1)	52(2)	39(1)	-13(1)	-17(1)	3(1)

C8	23(1)	20(1)	26(1)	-5(1)	-10(1)	-2(1)
C9	29(1)	30(1)	26(1)	-3(1)	-6(1)	-6(1)
C10	41(1)	32(1)	30(1)	5(1)	-12(1)	-5(1)
C11	44(1)	28(1)	38(1)	-2(1)	-17(1)	8(1)
C12	32(1)	29(1)	31(1)	-7(1)	-9(1)	4(1)
C13	25(1)	21(1)	24(1)	-6(1)	-10(1)	-3(1)
C14	24(1)	22(1)	22(1)	-7(1)	-7(1)	-1(1)
C15	27(1)	27(1)	26(1)	-9(1)	-8(1)	-4(1)
C16	28(1)	31(1)	31(1)	-10(1)	-9(1)	-7(1)
C17	24(1)	23(1)	22(1)	-4(1)	-7(1)	-4(1)
C18	24(1)	23(1)	20(1)	-4(1)	-7(1)	-3(1)
C19	24(1)	22(1)	22(1)	-4(1)	-8(1)	-2(1)
C20	24(1)	28(1)	22(1)	-4(1)	-7(1)	-4(1)
C21	29(1)	30(1)	28(1)	-8(1)	-9(1)	-3(1)
C22	25(1)	40(1)	36(1)	-11(1)	-10(1)	3(1)
C23	23(1)	53(2)	40(1)	-7(1)	-6(1)	-10(1)
C24	37(1)	40(1)	49(2)	-14(1)	-9(1)	-14(1)
C25	30(1)	32(1)	38(1)	-12(1)	-6(1)	-5(1)
C26	25(1)	25(1)	19(1)	-4(1)	-5(1)	0(1)
C27	28(1)	31(1)	28(1)	-10(1)	-8(1)	-1(1)
C28	36(1)	36(1)	31(1)	-15(1)	-9(1)	2(1)
C29	31(1)	38(1)	27(1)	-10(1)	-7(1)	8(1)
C30	25(1)	41(1)	29(1)	-5(1)	-3(1)	0(1)
C31	28(1)	32(1)	25(1)	-5(1)	-4(1)	-5(1)

Table S5. Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$) for **3aa**.

	x	y	z	U(eq)
H1	388	8258	1105	29
H1A	584	7261	6310	75
H1B	-437	8230	6604	75
H1C	1133	8310	6405	75
H3	-1183	9014	5138	41
H4	-808	9556	3284	36
H6	3130	8462	2593	44
H7	2714	7871	4441	48
H9	742	6866	2523	35
H10	2072	5382	2847	42
H11	4235	5090	1582	44
H12	4994	6239	-35	37
H14	3177	8532	-898	27
H15	5185	8902	-519	31
H16	7177	8576	-1737	35
H21	1228	8002	-1155	34
H22	-1105	7729	-496	40
H23	-1902	6149	-595	47
H24	-345	4851	-1366	49

H25	1983	5113	-2020	40
H27	5380	5046	-4215	35
H28	7116	4333	-5595	41
H29	9324	4934	-6205	40
H30	9762	6324	-5502	40
H31	8028	7088	-4164	35

Table S6. Torsion angles [°] for **3aa**.

S1-N1-C8-C9	89.2(2)
S1-N1-C8-C13	-89.8(2)
S1-C5-C6-C7	-176.0(2)
O1-S1-N1-C8	-173.77(16)
O1-S1-C5-C4	21.2(2)
O1-S1-C5-C6	-162.2(2)
O2-S1-N1-C8	56.94(19)
O2-S1-C5-C4	152.86(19)
O2-S1-C5-C6	-30.6(2)
O3-C17-C18-C14	-3.6(4)
O3-C17-C18-C19	-178.6(2)
N1-S1-C5-C4	-92.6(2)
N1-S1-C5-C6	83.9(2)
N1-C8-C9-C10	-177.2(2)
N1-C8-C13-C12	176.35(19)
N1-C8-C13-C14	-5.6(3)

N2-N3-C17-O3	178.62(19)
N2-N3-C17-C18	-0.6(2)
N2-N3-C26-C27	-11.0(3)
N2-N3-C26-C31	169.7(2)
N2-C19-C20-C21	-148.1(2)
N2-C19-C20-C25	30.2(3)
N3-N2-C19-C18	0.0(2)
N3-N2-C19-C20	-179.45(18)
N3-C17-C18-C14	175.51(18)
N3-C17-C18-C19	0.5(2)
N3-C26-C27-C28	-179.8(2)
N3-C26-C31-C30	178.6(2)
C1-C2-C3-C4	-179.2(2)
C1-C2-C7-C6	-179.5(3)
C2-C3-C4-C5	-1.2(4)
C3-C2-C7-C6	0.9(4)
C3-C4-C5-S1	177.21(18)
C3-C4-C5-C6	0.7(4)
C4-C5-C6-C7	0.5(4)
C5-S1-N1-C8	-58.07(18)
C5-C6-C7-C2	-1.3(4)
C7-C2-C3-C4	0.4(4)
C8-C9-C10-C11	0.6(4)
C8-C13-C14-C15	119.5(2)
C8-C13-C14-C18	-121.8(2)
C9-C8-C13-C12	-2.6(3)
C9-C8-C13-C14	175.4(2)
C9-C10-C11-C12	-1.9(4)

C10-C11-C12-C13	1.0(4)
C11-C12-C13-C8	1.3(3)
C11-C12-C13-C14	-176.8(2)
C12-C13-C14-C15	-62.5(3)
C12-C13-C14-C18	56.2(3)
C13-C8-C9-C10	1.7(3)
C13-C14-C15-C16	115.1(3)
C13-C14-C18-C17	-113.9(2)
C13-C14-C18-C19	59.2(3)
C14-C15-C16-O3	1.2(4)
C14-C18-C19-N2	-174.3(2)
C14-C18-C19-C20	5.0(4)
C15-C14-C18-C17	7.3(3)
C15-C14-C18-C19	-179.6(2)
C16-O3-C17-N3	178.6(2)
C16-O3-C17-C18	-2.4(3)
C17-O3-C16-C15	3.6(3)
C17-N3-C26-C27	164.3(2)
C17-N3-C26-C31	-15.0(4)
C17-C18-C19-N2	-0.3(2)
C17-C18-C19-C20	179.1(2)
C18-C14-C15-C16	-6.4(3)
C18-C19-C20-C21	32.6(3)
C18-C19-C20-C25	-149.1(2)
C19-N2-N3-C17	0.3(2)
C19-N2-N3-C26	176.57(19)
C19-C20-C21-C22	177.9(2)
C19-C20-C25-C24	-177.8(2)

C20-C21-C22-C23	0.2(4)
C21-C20-C25-C24	0.4(4)
C21-C22-C23-C24	-0.1(4)
C22-C23-C24-C25	0.2(4)
C23-C24-C25-C20	-0.4(4)
C25-C20-C21-C22	-0.3(4)
C26-N3-C17-O3	3.0(4)
C26-N3-C17-C18	-176.2(2)
C26-C27-C28-C29	1.8(4)
C27-C26-C31-C30	-0.7(3)
C27-C28-C29-C30	-1.9(4)
C28-C29-C30-C31	0.7(4)
C29-C30-C31-C26	0.5(4)
C31-C26-C27-C28	-0.5(4)

Symmetry transformations used to generate equivalent atoms:

Table S7. Hydrogen bonds for **3aa** [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
---------	--------	----------	----------	--------
