Electronic Supplementary Information

Dinuclear Zinc Catalyzed Asymmetric Friedel-Crafts Amido-alkylation of Indoles with Aryl Aldimines

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General information

Unless otherwise stated, all reagents were purchased from commercial suppliers and used without further purification. All solvents employed in the reactions were distilled from appropriate drying agent prior to use. Organic solutions were concentrated under reduced pressure on an EYELA N-1001 rotary evaporator. Reactions were monitored by thin-layer chromatography (TLC) on silica gel precoated glass plates (0.2±0.03 mm thickness, GF-254, particle size 0.01–0.04 mm) from Yantai Chemical Industry Research Institute, P. R. China. Chromatograms were visualized by fluorescence quenching with UV light at 254 nm. Flash column chromatography was performed using silica gel (particle size 0.04–0.05 mm) from Yantai Chemical Industry Research Institute, P. R. China.

^{1}H (400 MHz) and ^{13}C (101 MHz) spectra were recorded in DMSO-d_6 on Varian Inova-400 NMR spectometer. Chemical shifts (δ ppm) are relative to the resonance of the deuterated solvent as the internal standard (DMSO-d_6, δ 2.50 ppm for proton NMR, δ 39.51 ppm for carbon NMR). ^{1}H NMR data are reported as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), coupling constants (J) and assignment. Data for ^{13}C NMR are reported in terms of chemical shift (δ, ppm). High-resolution mass spectra (HRMS) for all the compounds were determined on Micromass GCT-TOF mass spertrometer with ESI resource.

High performance liquid chromatography (HPLC) analysis was performed on a Waters 2695 and

Agilent Technologies 1200 Series instrument equipped with a quaternary pump, using a Daicel Chiralcel OD-H Column (250 x 4.6 mm). UV absorption was monitored at 210 nm to 254 nm. Optical rotations were measured on an Autopol IV polarimeter, and $[\alpha]_D$ values are reported in 10^{-1} dg cm^2 g^{-1}; concentration (c) is reported in g/100 mL.

Experimental section

General procedure for the preparation of aldimines 3a-q[1]:

N-sulfonyl imines **3a-q** described in this paper were prepared by condensation of the corresponding aldehydes with *p*-toluenesulfonamide according to the reported procedure with minor modification: the aldehyde (25.0 mmol), *p*-toluenesulfonamide (25.0 mmol), and $Si(OEt)_4$ (27.5 mmol, 1.1 equiv.) were combined into a flask equipped with an oil-water separator and heated at 160°C for 10 hours. The produced EtOH was collected in the oil-water separator and released it at regular intervals. After cooling down, the residue of the reaction was directly recrystallized from ethyl acetate and hexanes to provide N-sulfonyl imines **3a-q**. It should be noted that, in order to avoid the trace impurities affecting the reaction, the N-sulfonyl aryl aldimines were recrystallized at least for two times before they were utilized as starting materials for asymmetric Friedel-Crafts amidoalkylation.

Procedure for the preparation of aldimine 3r[2]

A mixture of aldehyde (10 mmol), phenylsulfonamide (10 mmol) and sodium benzenesulfinate (1.82 g, 11 mmol) in formic acid (15 mL) and H_2O (15 mL) was stirred for 12 h at rt. The resulting white precipitate was filtered off, washed with H_2O (2 x 10 mL), then pentane (10 mL), and dissolved in CH_2Cl_2 (100 mL). Sat. aq $NaHCO_3$ or Na_2CO_3 (70 mL) was added and the solution was well stirred for 2 h at rt. The organic phase was decanted, and the aqueous phase was extracted with CH_2Cl_2 (2 x 35 mL). The combined organic layers was washed by H_2O (30 mL), brine (30 mL) and dried over anhydrous Na_2SO_4. The solvent was removed under reduced pressure to yield the crude product. Crystallization from ethyl acetate and hexanes gave pure N-sulfonyl imine **3r**.

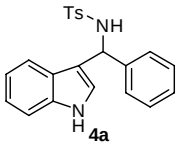
General procedure and spectroscopic data for dinuclear zinc catalyzed asymmetric

Friedel-Crafts amidoalkylation of indoles with aryl Aldimines:

Under an argon atmosphere, a solution of diethylzinc (50 μL, 1.0 M in toluene, 0.05 mmol) was added to a stirred and cooled solution of **L4** (16 mg, 0.025 mmol) in toluene (0.5 mL) at 0°C. After the addition, the cold bath was removed and the resulting solution was allowed to stir at rt for 30 min. Then a solution of N-sulfonyl imines **3a** (65 mg, 0.25 mmol) and indole **2a** (146 mg, 1.25 mmol) in 1.0 mL toluene were added. The corresponding mixture was allowed to be stirred for another 2h at rt. After the reaction was complete (monitored by TLC), 10% $NaHCO_3$ (3 mL) was added. The mixture was extracted with ethyl acetate (3×10 mL). The organic layer was washed by H_2O (5 mL), brine (5 mL) and dried over anhydrous Na_2SO_4. The solvent was evaporated *in vacuo* and the residue was purified by flash chromatography to afford the desired product **4a**.

The reaction procedures for the preparation of **4b**-**v** are identical with the above described for the preparation of **4a**. In order to demonstrate the reproducibility of the reaction, the crystals of the N-sulfonyl aryl aldimines (**3c**, **3d** and **3p**) were used to repeat the reaction under otherwise identical conditions. The results of control experiments showed that the reactions could be well reproduced in terms of yields and enantioselectivities (**4c**: 95% yield, 73:27 er *vs* 98% yield, 74:26 er; **4d**: 98% yield, 84:16 er *vs* 98% yield, 86:14 er; **4p**: 88% yield, 76:24 er *vs* 90% yield, 78:22 er).

N-[Indol-3-yl-phenylmethyl]-4-methylbenzenesulfonamide (4a)



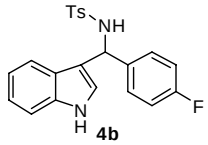
4a

Colorless solid; 95% yield, 92:8 er, [Daicel Chiralcel OD-H, Hexanes/IPA = 75/25, flow rate: 1.0 mL·min^{-1}, λ = 210.5 nm, t (major) = 10.451, t (minor) = 19.229]; $[\alpha]_D^{20}$ = +12.8 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.87 (s, 1H) , 8.49 (d, *J* = 8.8 Hz, 1H), 7.50 (d, *J* = 8.1 Hz, 2H), 7.33 – 7.24 (m, 4H), 7.20 – 7.09 (m, 5H), 7.04 (t, *J* = 7.6 Hz, 1H), 6.88 (t, *J* = 7.5 Hz, 1H), 6.78 (d, *J* = 2.1 Hz, 1H), 5.74 (d, *J* = 8.9 Hz, 1H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 141.83, 141.73, 138.86, 136.35, 128.93, 127.87, 127.06, 126.38, 123.67, 121.21, 120.86, 118.88, 118.75, 118.53, 115.70, 111.43, 54.46, 20.90; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{22}H_{20}N_2O_2SNa$: 399.1143; found: 399.1130.

N-[Indol-3-yl-(4- fluorophenyl)methyl]-4-methylbenzenesulfonamide (4b)

Colorless solid; 97% yield, 90:10 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 210.5 nm, t (major) = 11.224, t (minor) = 19.474]; $[\alpha]_D^{20}$ = +11.7 (c 0.5,

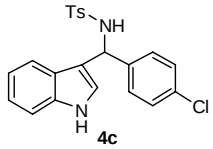
Acetone); ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.49 (d, *J* = 8.9 Hz, 1H), 7.49 (d, *J* = 8.2 Hz, 2H),



4b

7.29 (dt, *J* = 8.4, 7.1 Hz, 4H), 7.13 (d, *J* = 8.1 Hz, 2H), 7.05 (t, *J* = 7.5 Hz, 1H), 6.97 (t, *J* = 8.8 Hz, 2H), 6.90 (t, *J* = 7.5 Hz, 1H), 6.76 (d, *J* = 1.7 Hz, 1H), 5.75 (d, *J* = 8.9 Hz, 1H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 147.32, 144.08, 143.21, 143.18, 141.80, 134.45, 134.35, 131.81, 130.77, 129.08, 126.70, 124.29, 123.99, 120.95, 120.03, 119.82, 116.87, 59.22, 26.27; ESI–MS: m/z [M + Na]$^{+}$ calcd for $C_{22}H_{19}FN_2O_2SNa$: 417.1047; found: 417.1061.

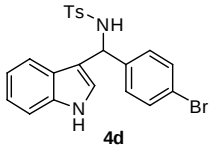
N-[Indol-3-yl-(4-chlorophenyl)methyl]-4-methylbenzenesulfonamide (4c)



4c

Colorless solid; 98% yield, 74:26 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 11.734, t (minor) = 21.264]; $[\alpha]_D^{20}$ = +5.2 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.91 (d, *J* = 25.7 Hz, 1H), 8.50 (t, *J* = 8.0 Hz, 1H), 7.48 (d, *J* = 7.8 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 8.3 Hz, 2H), 7.20 (d, *J* = 8.2 Hz, 2H), 7.13 (d, *J* = 4.0 Hz, 2H), 6.94 (t, *J* = 7.3 Hz, 1H), 6.90 (t, *J* = 7.5 Hz, 1H), 6.77 (s, 1H), 5.73 (d, *J* = 8.7 Hz, 1H), 2.29 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ143.02, 141.53, 139.56, 137.39, 132.26, 129.98, 129.96, 128.79, 127.44, 126.34, 124.76, 122.34, 119.84, 119.63, 116.16, 112.49, 54.86, 21.88; ESI–MS: m/z [M + Na]$^{+}$ calcd for $C_{22}H_{19}ClN_2O_2SNa$: 433.0793; found: 433.0760.

N-[Indol-3-yl-(4-bromophenyl)methyl]-4-methylbenzenesulfonamide (4d)



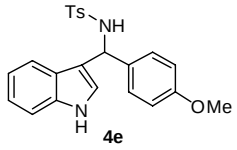
4d

Colorless solid; 98% yield, 86:14 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 210.5 nm, t (major) = 11.896, t (minor) = 20.941]; $[\alpha]_D^{20}$ = +10.8 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.93 (s, 1H), 8.51 (d, *J* = 8.7 Hz, 1H), 7.49 (d, J = 7.9 Hz, 2H), 7.32 (dd, *J* = 11.5, 5.7 Hz, 4H), 7.20 (d, *J* = 8.1 Hz, 2H), 7.14 (d, *J* = 7.7 Hz, 2H), 7.06 (t, *J* = 7.5 Hz, 1H), 6.91 (t, *J* = 7.4 Hz, 1H), 6.79 (s, 1H), 5.73 (d, *J* = 8.7 Hz, 1H), 2.31 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 147.41, 146.31, 143.92, 141.76, 136.09, 134.72, 134.37, 131.82, 130.72, 129.15, 126.72, 125.16, 124.22, 124.02, 120.45, 116.87, 59.31, 26.30; ESI–MS: m/z [M + Na]$^{+}$ calcd for $C_{22}H_{19}BrN_2O_2SNa$: 477.0248; found: 477.0245.

N-[Indol-3-yl-(4-Methoxyphenyl)methyl]-4-methylbenzenesulfonamide (4e)

Colorless solid, 90% yield, 92:8 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 221.3 nm, t (major) = 13.924, t (minor) = 27.338]; $[\alpha]_D^{20}$ = +7.5 (c 0.5,

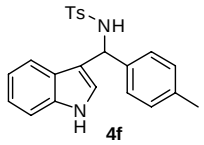
Acetone); ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.86 (d, *J* = 52.5 Hz, 1H), 8.41 (t, *J* = 8.0 Hz, 1H),



4e

7.72 (d, *J* = 7.4 Hz, 1H), 7.49 (d, *J* = 7.4 Hz, 1H), 7.36 (d, *J* = 7.4 Hz, 1H), 7.30 (d, *J* = 7.7 Hz, 2H), 7.13 (t, *J* = 7.4 Hz, 3H), 7.04 (t, *J* = 8.0 Hz, 3H), 6.89 (t, *J* = 7.1 Hz, 1H), 6.81 (s, 1H), 6.71 (d, *J* = 7.7 Hz, 1H), 5.69 (d, *J* = 8.6 Hz, 1H), 3.68 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 158.04, 141.80, 138.93, 136.46, 133.76, 132.72, 129.37, 128.97, 128.31, 126.45, 123.56, 121.20, 118.52, 116.03, 113.28, 111.46, 55.05, 54.10, 20.93; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{23}H_{22}N_2O_3SNa$: 429.1249; found: 429.1243.

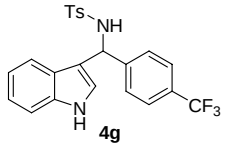
N-[Indol-3-yl-(4-Methylphenyl)methyl]-4-methylbenzenesulfonamide (4f)



4f

Colorless solid; 98% yield, 78:22 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 210 nm, t (major) = 9.660, t (minor) = 18.179]; $[\alpha]_D^{20}$ = +8.4 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.86 (s, 1H), 8.42 (d, *J* = 8.7 Hz, 1H), 7.50 (d, *J* = 7.8 Hz, 2H), 7.34 – 7.26 (m, 2H), 7.13 (d, *J* = 4.6 Hz, 4H), 7.04 (t, *J* = 7.5 Hz, 1H), 6.97 (d, *J* = 7.6 Hz, 2H), 6.87 (t, *J* = 7.4 Hz, 1H), 6.82 (s, 1H), 5.70 (d, *J* = 8.7 Hz, 1H), 2.28 (s, 3H), 2.22 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 141.86, 138.89, 138.78, 136.43, 135.75, 128.96, 128.45, 127.07, 126.44, 125.51, 123.66, 121.23, 118.96, 118.55, 115.85, 111.46, 54.34, 20.93, 20.67; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{23}H_{22}N_2O_2SNa$: 413.1300; found: 413.1299.

N-[Indol-3-yl-(4-trifloroMethylphenyl)methyl]-4-methylbenzenesulfonamide (4g)



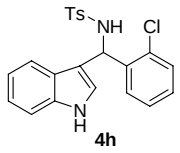
4g

Colorless solid; 98% yield, 94:6 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 11.219, t (minor) = 20.622]; $[\alpha]^{20}_D$ = +28.2 (c 1, Acetone);^{1}H NMR (400 MHz, DMSO-d_6) δ 10.95 (s, 1H), 8.58 (d, *J* = 8.0 Hz, 1H), 7.72 (d, *J* = 6.6 Hz, 1H), 7.47 (s, 3H), 7.42 – 7.26 (m, 4H), 7.09 (d, *J* = 6.3 Hz, 2H), 6.93 (t, *J* = 6.5 Hz, 1H), 6.78 (s, 1H), 5.83 (d, *J* = 8.3 Hz, 1H), 2.25 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 146.01, 142.05, 138.40, 136.43, 129.36, 128.99, 127.93, 126.51, 125.67, 124.85, 124.81, 124.76, 124.72, 123.91, 121.49, 118.83, 118.79, 114.79, 111.61, 109.39, 54.21, 20.95; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{23}H_{19}F_3N_2O_2SNa$: 467.1107; found: 467.1024.

N-[Indol-3-yl-(2-chlorophenyl)methyl]-4-methylbenzenesulfonamide (4h)

Colorless solid; 98% yield, 92:8 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate:

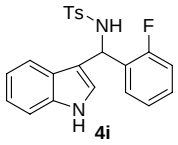
1.0 mL·min^{-1}, λ = 210.5 nm, t (major) = 8.153, t (minor) =20.030]; $[\alpha]^{20}_{D}$ = +51.2 (c 0.5, Acetone);



4h

^{1}H NMR (400 MHz, DMSO-d_6): δ 8.58 (d, *J* = 8.6 Hz, 1H), 7.59 – 7.55 (m, 1H), 7.52 (d, *J* = 8.2 Hz, 2H), 7.35 (d, *J* = 8.2 Hz, 1H), 7.34 – 7.27 (m, 2H), 7.19 – 7.16 (m, 4H), 7.08 (t, *J* = 7.6 Hz, 1H), 6.93 (t, *J* = 7.5 Hz, 1H), 6.55 (s, 1H), 6.17 (d, *J* = 8.6 Hz, 1H), 2.30 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 142.20, 138.79, 138.31, 136.40, 131.44, 129.11, 128.84, 128.80, 128.34, 126.98, 126.37, 125.65, 124.18, 121.49, 118.81, 118.50, 114.08, 111.64, 50.63, 20.93; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{22}H_{19}ClN_2O_2SNa$: 433.0748; found: 433.0751.

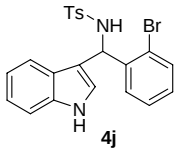
N-[Indol-3-yl-(2- fluorophenyl)methyl]-4-methylbenzenesulfonamide (4i)



4i

Colorless solid; 96% yield, 82:18 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 9.792, t (minor) = 22.034]; $[\alpha]^{20}_{D}$ = +43.2 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.93 (s, 1H), 8.55 (d, *J* = 7.5 Hz, 1H), 7.50 (d, *J* = 8.0 Hz, 2H), 7.45 (d, *J* = 4.0 Hz, 1H), 7.31 (t, *J* = 8.0 Hz, 2H), 7.15 (d, *J* = 8.0 Hz, 2H), 7.07 (t, *J* = 8.0 Hz, 1H), 7.02 – 6.96 (m, 3H), 6.94 (t, *J* = 8.0 Hz, 1H), 6.73(s, 3H), 6.02(d, *J* = 8.0 Hz, 1H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 142.18, 138.34, 136.39, 129.10, 128.88, 128.84, 128.79, 128.67, 126.37, 125.43, 124.16, 123.75, 121.49, 118.82, 118.40, 114.97, 114.77, 114.44, 114.40, 114.37, 111.67, 111.65, 47.18, 47.16, 20.93; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{22}H_{19}FN_2O_2SNa$: 417.1047; found: 417.1057.

N-[Indol-3-yl-(2-bromophenyl)methyl]-4-methylbenzenesulfonamide (4j)



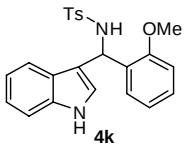
4j

Colorless solid; 97% yield, 84:16 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 8.553, t (minor) = 22.330]; $[\alpha]^{20}_{D}$ = +43.2 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.94 (s, 1H), 8.59 (d, *J* = 8.5 Hz, 1H), 7.57 (d, *J* = 7.7 Hz, 1H), 7.54 (d, *J* = 8.0 Hz, 2H), 7.45 (d, *J* = 7.9 Hz, 1H), 7.34 (t, *J* = 8.0 Hz, 2H), 7.24-7.16 (m, 3H), 7.09 (t, *J* = 7.5 Hz, 2H), 6.95 (t, *J* = 7.4 Hz, 1H), 6.50 (s, 1H), 6.16 (d, *J* = 8.4 Hz, 1H), 2.30 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 142.30, 140.39, 138.34, 136.48, 132.16, 129.19, 129.03, 128.67, 127.58, 126.47, 125.78, 124.40, 122.40, 121.59, 118.89, 118.67, 114.17, 111.72, 53.35, 21.00; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{22}H_{19}BrN_2O_2SNa$: 477.0248, 479.0228; found: 477.0243, 479.0225.

N-[Indol-3-yl-(2-Methoxyphenyl)methyl]-4-methylbenzenesulfonamide (4k)

Colorless solid; 98% yield, 90:10 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate:

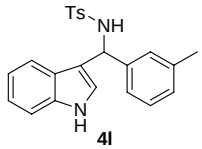
1.0 mL·min^{-1}, λ = 254 nm, t (major) = 9.967, t (minor) = 22.403]; $[\alpha]^{20}_{D}$ = +46.3 (c 1, Acetone); ^{1}H



4k

NMR (400 MHz, DMSO-d_6): δ 10.80 (s, 1H), 8.29 (d, *J* = 8.0 Hz, 1H), 7.45 (d, *J* = 8.0 Hz, 2H), 7.28 – 7.39 (m, 3H), 7.10 (d, *J* = 8.0 Hz, 2H), 7.04 (d, *J* = 8.0 Hz, 1H), 6.91 (t, *J* = 8.0 Hz, 1H), 6.75 (dd, *J* = 12.0, 8.0 Hz, 1H), 6.65 (d, *J* = 8.0 Hz, 1H), 6.16 (d, *J* = 12.0 Hz, 1H), 3.63 (s, 3H), 2.27 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 156.00, 142.44, 139.20, 137.01, 130.06, 129.43, 128.55, 128.47, 126.97, 124.18, 121.87, 120.66, 119.45, 119.17, 116.42, 112.09, 111.07, 109.99, 55.93, 48.01, 21.53; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{23}H_{22}N_2O_3SNa$:429.1249; found: 429.1253.

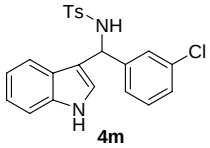
N-[Indol-3-yl-(3-methylphenyl)methyl]-4-methylbenzenesulfonamide (4l)



4l

Colorless solid; 92% yield, 88:12 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 242.8 nm, t (major) = 9.764, t (minor) = 14.796]; $[\alpha]^{20}_{D}$ = +10.4 (c 0.5, Acetone);^{1}H NMR (400 MHz, DMSO-d_6): δ 8.42 (d, *J* = 12.0 Hz, 1H), 7.48 (d, *J* = 7.9 Hz, 2H), 7.38 – 7.25 (m, 2H), 7.12 (d, *J* = 7.9 Hz, 3H), 7.05 (d, *J* = 4.7 Hz, 2H), 6.91 (m, 3H), 6.80 (s, 1H), 5.69 (d, *J* = 12.0 Hz, 1H), 2.28 (s, 3H), 2.14 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 147.18, 146.78, 144.18, 142.20, 141.74, 134.24, 133.16, 133.10, 131.78, 130.87, 129.62, 129.07, 126.59, 124.26, 123.92, 121.08, 116.82, 114.74, 59.89, 26.33, 26.27; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{23}H_{22}N_2O_2SNa$: 413.1300; found: 413.1299.

N-[Indol-3-yl-(3-chlorophenyl)methyl]-4-methylbenzenesulfonamide (4m)



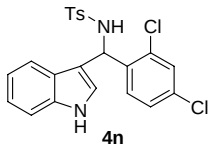
4m

Colorless solid; 98% yield, 76:24 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 12.988, t (minor) = 16.128]; $[\alpha]^{20}_{D}$ = +10.57 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.93 (s, 1H), 8.52 (d, *J* = 8.0 Hz, 1H), 7.50 (d, *J* = 7.8 Hz, 2H), 7.37 – 7.30 (m, 2H), 7.23 (s, 2H), 7.17 – 7.12 (m, 4H), 7.06 (t, *J* = 7.2 Hz, 1H), 6.91 (t, *J* = 7.2 Hz, 1H), 6.78 (s, 1H), 5.75 (d, *J* = 8.0 Hz, 1H), 2.29 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 143.94, 142.12, 138.48, 136.40, 132.70, 129.77, 129.02, 126.92, 126.60, 126.42, 125.90, 125.35, 123.80, 121.42, 118.87, 118.72, 115.10, 111.57, 53.99, 20.95; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{22}H_{19}ClN_2O_2SNa$: 433.0753; found: 433.0751.

N-[Indol-3-yl-(2,4-Dichlorophenyl)methyl]-4-methylbenzenesulfonamide (4n)

Colorless solid; 98% yield, 95:5 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate:

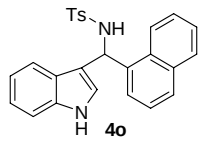
1.0 mL·min^{-1}, λ = 254 nm, t (major) = 8.139, t (minor) = 21.301]; $[\alpha]^{20}_{D}$ = +68.6 (c 0.5, Acetone);



4n

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.98 (d, *J* = 9.4 Hz, 1H), 8.59 (t, *J* = 8.3 Hz, 1H), 7.50 (d, *J* = 5.0 Hz, 1H), 7.33 (d, *J* = 8.2 Hz, 1H), 7.29 (d, *J* = 7.9 Hz, 1H), 7.23 (d, *J* = 8.4 Hz, 1H), 7.19 (d, *J* = 7.9 Hz, 2H), 7.08 (t, J = 7.5 Hz, 1H), 6.93 (dd, *J* = 13.2, 5.8 Hz, 1H), 6.56 (d, *J* = 8.0 Hz, 1H), 6.08 (d, *J* = 8.4 Hz, 1H), 2.32 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 141.91, 137.72, 132.37, 132.11, 130.24, 129.34, 128.20, 127.23, 126.41, 125.67, 124.28, 121.61, 118.93, 118.46, 113.42, 111.72, 109.39, 54.92, 20.96; ESI-MS: m/z $[M + Na]^+$ calcd for $C_{22}H_{18}Cl_2N_2O_2SNa$: 467.0364; found: 467.0367.

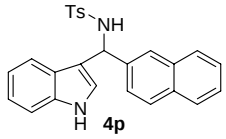
N-[Indol-3-yl-(1-Naphthyl)methyl]-4-methylbenzenesulfonamide (4o)



4o

Colorless solid; 96% yield, 85:15 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 210.5 nm, t (major) = 10.563, t (minor) = 21.070]; $[\alpha]^{20}_{D}$ = +62.4 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.85 (s, 1H), 8.59 (d, *J* = 7.8 Hz, 1H), 7.95 (d, *J* = 7.9 Hz, 1H), 7.89 (d, *J* = 7.6 Hz, 1H), 7.78 (d, *J* = 7.9 Hz, 1H), 7.62 (d, *J* = 6.7 Hz, 1H), 7.50 – 7.36 (m, 5H), 7.30 (d, *J* = 7.9 Hz, 1H), 7.22 (d, *J* = 7.6 Hz, 1H), 7.07 (dd, *J* = 14.3, 7.7 Hz, 3H), 6.88 (t, *J* = 7.0 Hz, 1H), 6.60 (s, 1H), 6.53 (d, *J* = 8.0 Hz, 1H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 141.97, 138.70, 137.05 136.35, 133.24, 130.19, 128.94, 128.56, 127.39, 126.36, 126.09, 125.62, 125.44, 125.14, 124.80, 124.63, 123.12, 121.32, 118.73, 118.54, 114.94, 111.56, 50.66, 20.93. HRMS–FAB: m/z $[M + Na]^+$ calcd for $C_{26}H_{22}N_2O_2SNa$:449.1402; found: 449.1307.

N-[Indol-3-yl-(2-Naphthyl)methyl]-4-methylbenzenesulfonamide (4p)

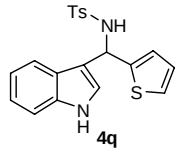


4p

Primrose yellow solid; 90% yield, 78:22 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 213.4 nm, t (major) = 13.919, t (minor) = 20.976]; $[\alpha]^{20}_{D}$ = +14.6 (c 0.5, Acetone) ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.92 (s, 1H), 8.54 (d, *J* = 8.0 Hz, 1H), 7.90 – 7.64 (m, 4H), 7.28 – 7.54 (m, 7H), 7.12 – 6.96 (m, 3H), 6.88 (d, *J* = 7.6 Hz, 2H), 5.89 (d, *J* = 8.4 Hz, 1H), 2.11 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 141.89, 138.87, 138.64, 136.40, 132.55, 131.99, 128.86, 127.69, 127.56, 127.37, 126.42, 125.98, 125.68, 125.61, 125.50, 125.46, 123.82, 121.29, 118.85, 118.61, 115.44, 111.50, 54.72, 20.74; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{26}H_{22}N_2O_2SNa$: 449.1300; found: 449.1307.

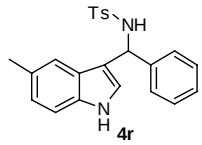
N-[Indol-3-yl-(2-Thiophenyl)methyl]-4-methylbenzenesulfonamide (4q)

Primrose yellow solid; 85% yield, 81:19 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 210.5 nm, t (major) = 10.257, t (minor) = 17.196]; $[\alpha]^{20}_D$ = +7.4 (c 0.215, Acetone); ^{1}H NMR (400 MHz, DMSO-d$_6$) δ10.91 (s, 1H), 8.62 (d, *J* = 8.4 Hz, 1H), 7.53 (d, *J* = 7.7 Hz, 2H), 7.31 (t, *J* = 7.2 Hz, 3H), 7.12 (d, *J* = 7.7 Hz, 2H), 7.04 (t, *J* = 7.2 Hz, 1H), 6.89 – 6.75 (m, 4H), 5.99 (d, *J* = 8.4 Hz, 1H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d$_6$): δ 151.16, 146.33, 146.14, 136.27, 129.03, 128.97, 126.47, 126.37, 125.15, 125.10, 125.05, 123.74, 121.22, 118.59, 111.45, 109.36, 50.15, 20.95; ESI–MS: m/z [M + Na]$^+$ calcd for $C_{20}H_{18}N_2O_2S_2Na$: 405.0702; found: 405.0714.



4q

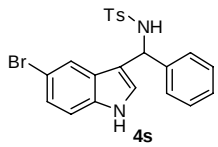
N-[5-Methylindol-3-yl-phenylmethyl]-4-methylbenzenesulfonamide (4r)



4r

Colorless solid; 94% yield, 72:28 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 9.403, t (minor) = 28.043]; $[\alpha]^{20}_D$ = +16.57 (c 1.0, Acetone); ^{1}H NMR (400 MHz, DMSO-d$_6$): δ 10.75 (s, 1H), 8.43 (d, *J* = 8.1 Hz, 1H), 7.55 (d, *J* = 7.5 Hz, 2H), 7.29 (d, *J* = 6.4 Hz, 2H), 7.24 – 7.15 (m, 6H), 6.92 (s, 1H), 6.86 (d, *J* = 7.8 Hz, 1H), 6.67 (s, 1H), 5.68 (d, *J* = 8.0 Hz, 1H), 2.30 (s, 3H), 2.25 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d$_6$): δ 142.17, 141.99, 138.85, 134.71, 129.10, 127.94, 127.07, 126.99, 126.52, 125.78, 124.03, 122.88, 118.29, 115.16, 111.19, 104.65, 54.29, 21.29, 21.00; ESI–MS: m/z [M + Na]$^+$ calcd for $C_{23}H_{22}N_2O_2SNa$: 413.1300; found: 413.1303.

N-[5-Bromoindol-3-yl-phenylmethyl]-4-methylbenzenesulfonamide (4s)



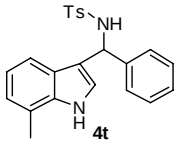
4s

Colorless solid; 98% yield, 70:30 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 7.780, t (minor) = 21.050]; $[\alpha]^{20}_D$ = +17.37 (c 1.0, Acetone); ^{1}H NMR (400 MHz, DMSO-d$_6$) δ 11.10 (s, 1H), 8.52 (d, *J* = 8.4 Hz, 1H), 7.52 (d, *J* = 7.6 Hz, 2H), 7.37 (s, 1H), 7.28 (t, *J* = 7.4 Hz, 3H), 7.24 – 7.11 (m, 5H), 6.81 (s, 1H), 5.71 (d, *J* = 8.4 Hz, 1H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d$_6$): δ 142.08, 141.58, 139.83, 138.58, 135.10, 129.08, 128.03, 127.07, 126.42, 125.68, 123.77, 121.19, 115.43, 113.56, 113.53, 111.39, 104.65, 54.02, 21.06; ESI–MS: m/z [M + Na]$^+$ calcd for $C_{22}H_{19}BrN_2O_2SNa$: 477.0248, 479.0228; found: 477.0246, 479.0225.

N-[7-Methylindol-3-yl-phenylmethyl]-4-methylbenzenesulfonamide (4t)

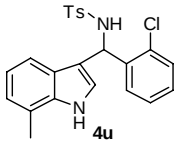
Colorless solid; 90% yield, 85:15 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 24.772, t (minor) =29.161]; $[\alpha]^{20}_D$ = +17.63 (c 1.0, Acetone); ^{1}H NMR (400 MHz, DMSO-d$_6$) δ 10.86 (s, 1H), 8.48 (d, *J* = 8.7 Hz, 1H), 7.50 (d, *J* = 7.8 Hz, 2H),

7.26 (d, *J* = 6.8 Hz, 2H), 7.20 – 7.14 (m, 2H), 7.12 (d, *J* = 7.8 Hz, 3H), 6.85 – 6.75 (m, 3H), 5.72 (d, *J* = 8.7 Hz, 1H), 2.39 (s, 3H), 2.27 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 141.88, 138.83, 135.89, 128.98, 127.93, 127.11, 126.68, 126.41, 125.15, 123.36, 121.73, 120.52, 118.82, 116.58, 116.15, 104.65, 54.59, 20.95, 16.76; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{23}H_{22}N_2O_2SNa$: 413.1300; found: 413.1302.



4t

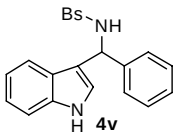
N-[7-Methylindol-3-yl-(2-chlorophenyl)methyl]-4-methylbenzenesulfonamide (4u)



4u

Colorless solid; 91% yield, 87:13 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 9.185, t (minor) =13.311]; $[\alpha]^{20}_D$ = +54.6 (c 0. 5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.19 (s, 1H), 8.64 (d, *J* = 6.4 Hz, 1H), 7.65 (s, 1H), 7.58 (d, *J* = 6.0 Hz, 2H), 7.15-7.33 (m, 7H), 6.58 (s, 1H), 6.05 (d, *J* = 6.3 Hz, 1H), 5.76 (s, 1H), 3.42 (s, 3H), 2.33 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6): δ 142.59, 138.82, 137.93, 135.10, 131.47, 129.40, 129.00, 128.71, 128.53, 127.47, 127.16, 126.44, 126.09, 124.07, 120.51, 113.80, 113.55, 111.68, 54.99, 50.31, 21.18; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{23}H_{21}ClN_2O_2SNa$: 447.0910; found: 447.0113.

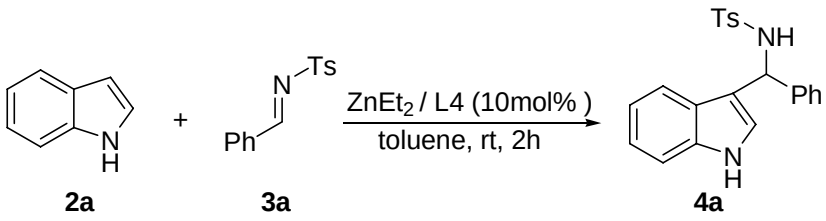
N-[Indol-3-yl-phenylmethyl]-benzenesulfonamide (4v)



4v

Colorless solid; 87% yield, 85:15 er, [Daicel Chiralcel OD-H, Hexanes / IPA = 75 / 25, flow rate: 1.0 mL·min^{-1}, λ = 254 nm, t (major) = 11.234, t (minor) = 19.982]; $[\alpha]^{20}_D$ = +12.5 (c 0.5, Acetone); ^{1}H NMR (400 MHz, DMSO-d_6)δ 10.93 (s, 1H), 8.18 (s, 1H), 8.06 (d, *J* = 8.0 Hz, 1H), 7.83 (d, *J* = 7.5 Hz, 1H), 7.57 (t, *J* = 7.9 Hz, 1H), 7.38 (d, *J* = 8.1 Hz, 2H), 7.31 (d, *J* = 7.9 Hz, 2H), 7.06 (t, *J* = 7.4 Hz, 2H), 6.93 – 6.86 (m, 4H), 6.07 (s, 1H).; ^{13}C NMR (101 MHz, DMSO-d_6): δ 147.83, 147.42, 136.65, 135.17, 129.62, 127.08, 126.39, 125.35, 123.92, 121.17, 119.25, 118.97, 118.47, 116.99, 111.65, 56.55; ESI–MS: m/z $[M + Na]^+$ calcd for $C_{21}H_{18}N_2O_2SNa$: 385.0987; found: 385.0968.

Table 4 Investigating the effect of the concentration:



2a **3a** **4a**

Entry[a]	Toluene (mL)	Yield (%)[b]	er (%)[c]
1	0.5	91	79:21
2	1	93	76:24
3	1.5	94	92:8
4	2	94	80:20

[a]The reactions were performed with 5 equiv of **2a**, in toluene under N_2 at the room temperature for two hours ($ZnEt_2$, 1.0 M in toluene). [b]Isolated yields. [c]The enantiomeric ratio was determined by chiral HPLC analysis of the corresponding products on a chiralcel OD-H column.

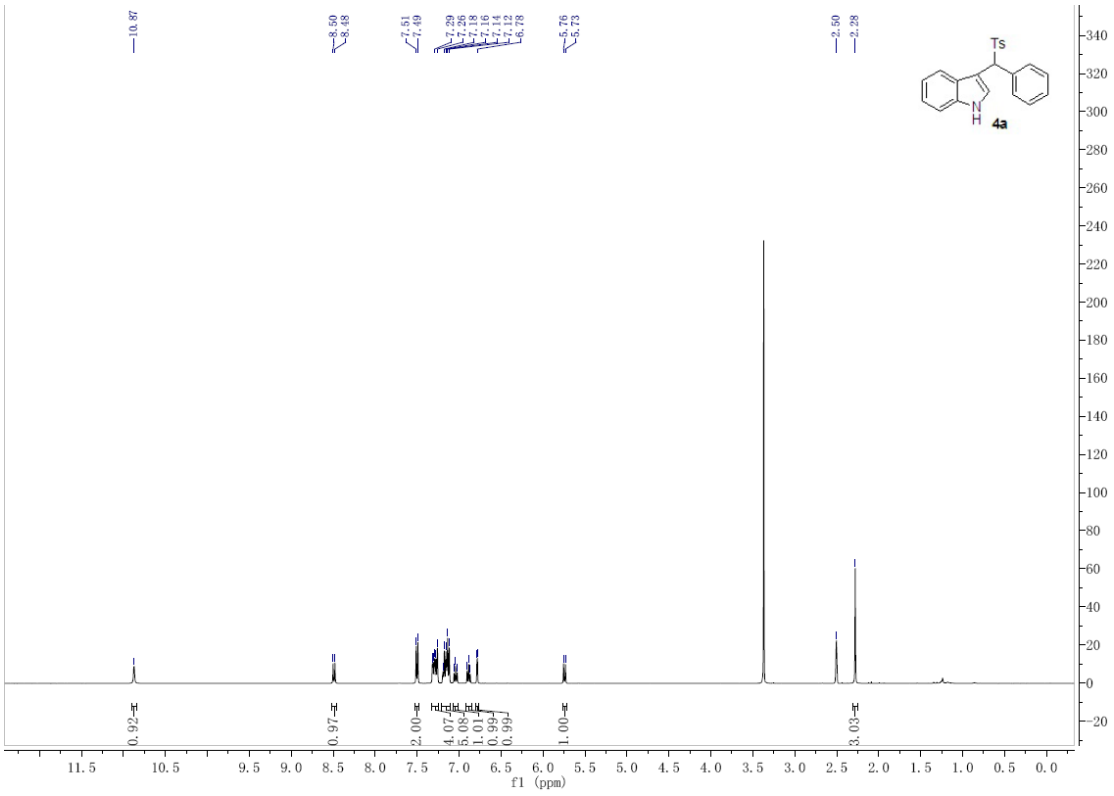
References:

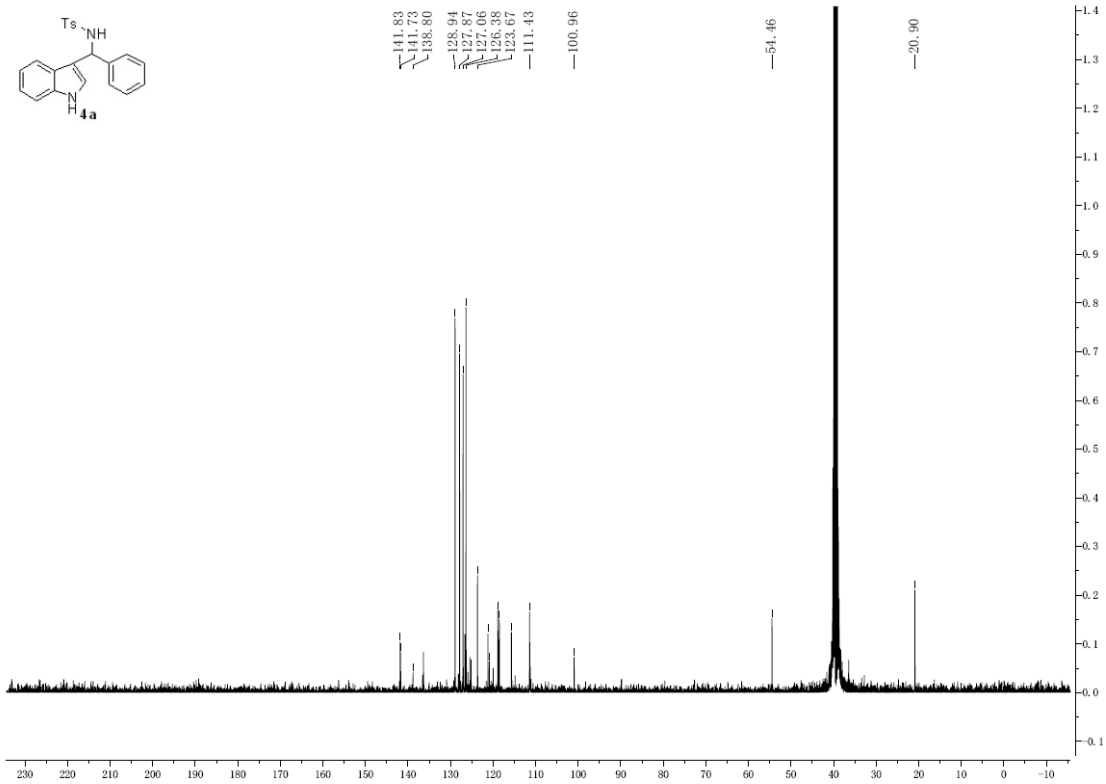
1. B. E. Love, P. S. Raje, T. C. II Williams, *Synlett*, 1994, 493-494.

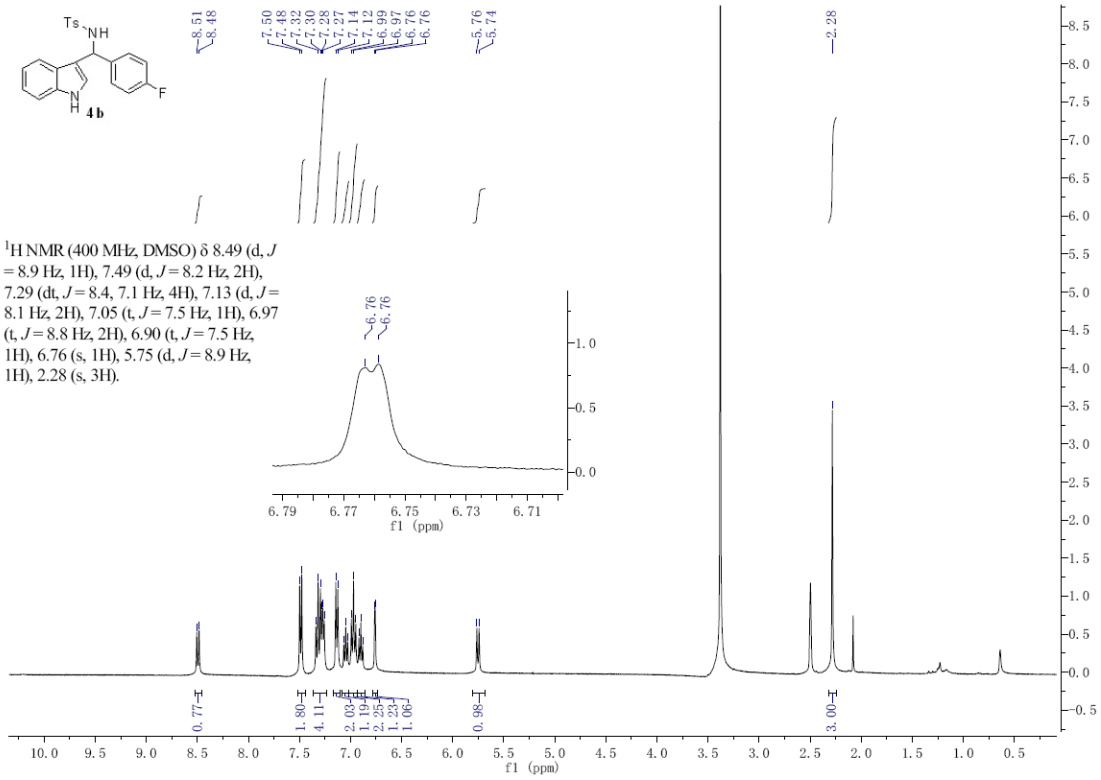
2. F. Chemla, V. Hebbe, J. -F. Normant, *Synthesis*, 2000, **1**, 75–77.

3. B. M. Trost, V. S. C. Yeh, *Org. Lett.*, 2002, **4**, 3513 –3516.

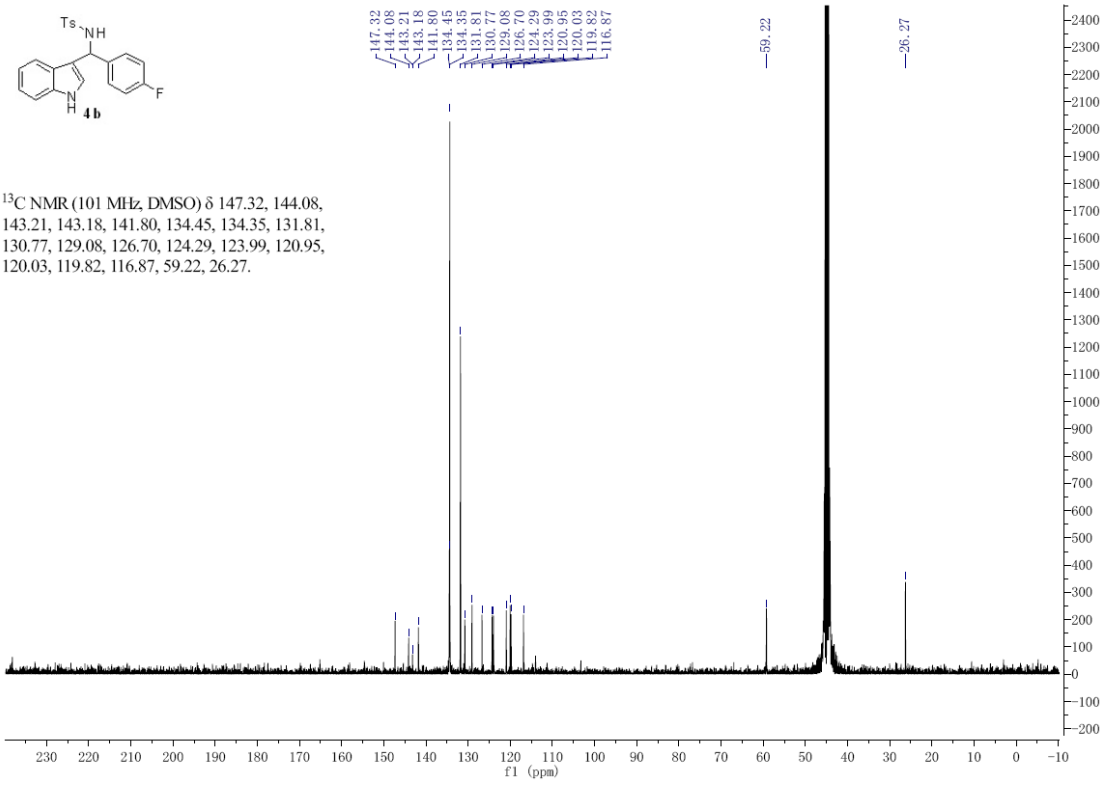
^{1}H and ^{13}C NMR spectra for 4a-v:



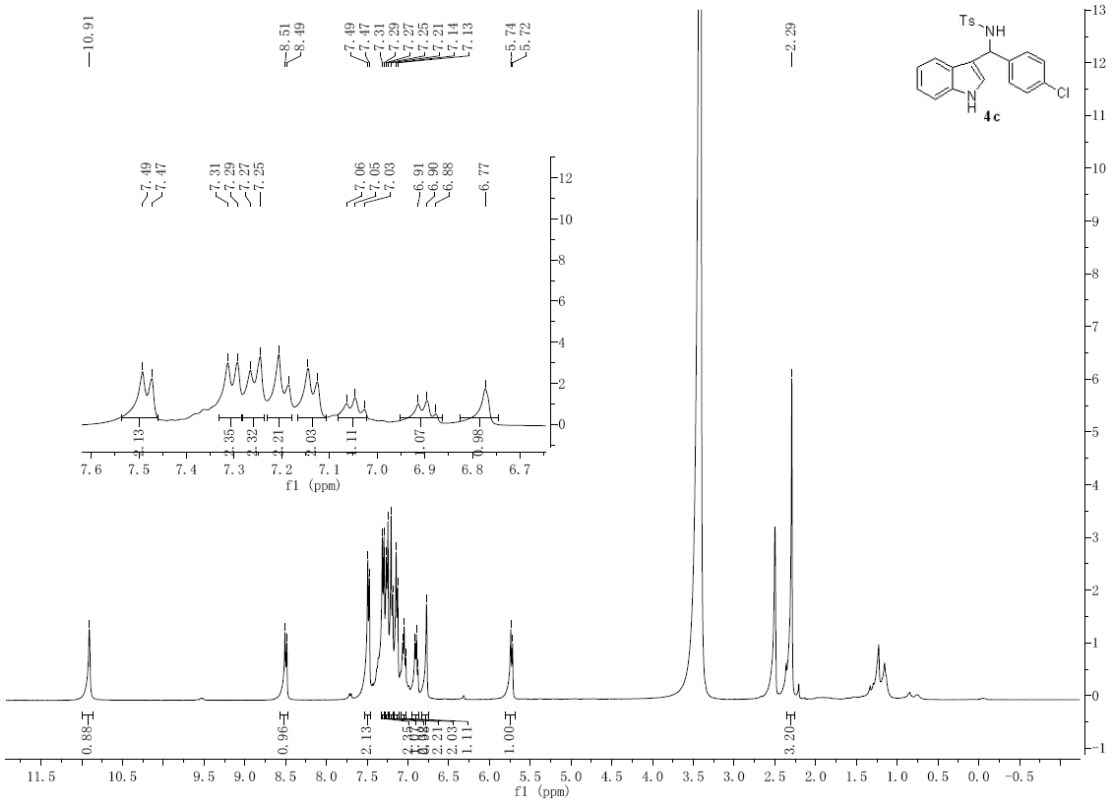


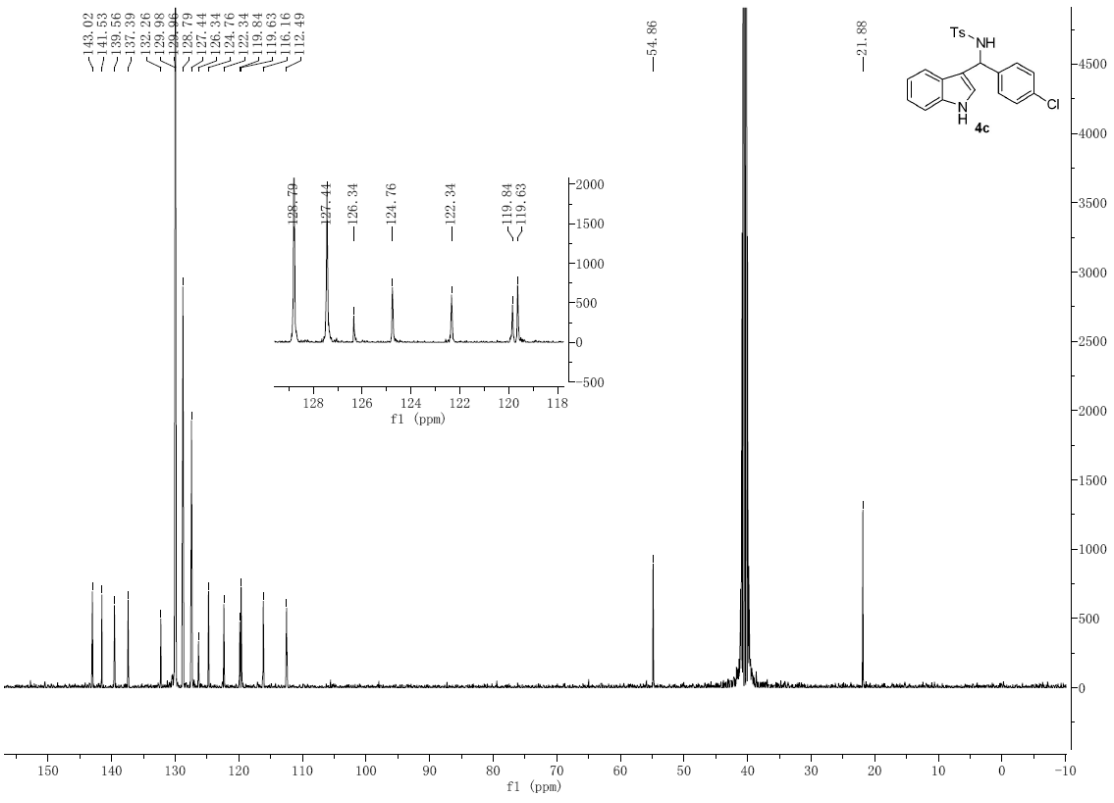


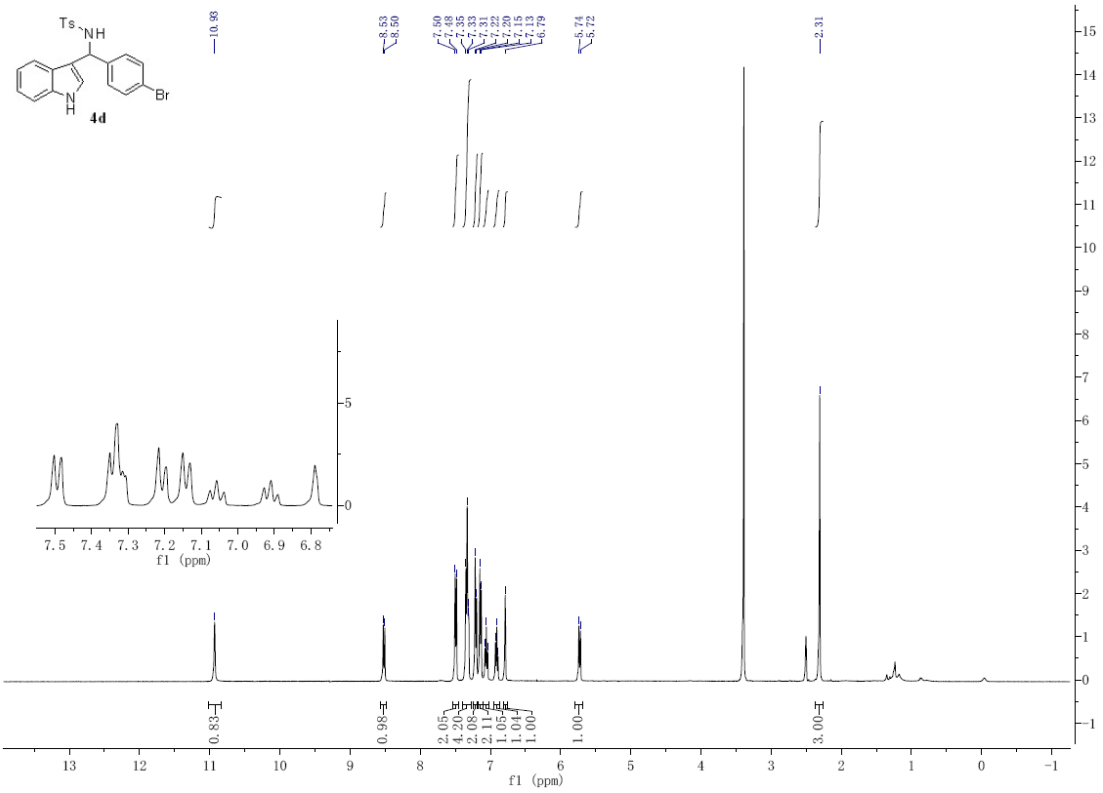
^{1}H NMR (400 MHz, DMSO) δ 8.49 (d, *J* = 8.9 Hz, 1H), 7.49 (d, *J* = 8.2 Hz, 2H), 7.29 (dt, *J* = 8.4, 7.1 Hz, 4H), 7.13 (d, *J* = 8.1 Hz, 2H), 7.05 (t, *J* = 7.5 Hz, 1H), 6.97 (t, *J* = 8.8 Hz, 2H), 6.90 (t, *J* = 7.5 Hz, 1H), 6.76 (s, 1H), 5.75 (d, *J* = 8.9 Hz, 1H), 2.28 (s, 3H).



^{13}C NMR (101 MHz, DMSO) δ 147.32, 144.08, 143.21, 143.18, 141.80, 134.45, 134.35, 131.81, 130.77, 129.08, 126.70, 124.29, 123.99, 120.95, 120.03, 119.82, 116.87, 59.22, 26.27.


10.91
8.51
8.49
7.49
7.47
7.31
7.29
7.27
7.25
7.21
7.14
7.13
5.74
5.72
2.29
Ts
NH
Cl
4c
6.77
6.91
6.90
6.88
7.06
7.05
7.03
0.88
0.96
2.13
1.00
3.20
f1 (ppm)


143.02
141.53
139.56
137.39
132.26
129.98
128.79
127.44
126.34
124.76
122.34
119.84
119.63
116.16
112.49
54.86
21.88
Ts
NH
Cl
4c
f1 (ppm)


Ts
NH
N
H
Br
4d
10.99
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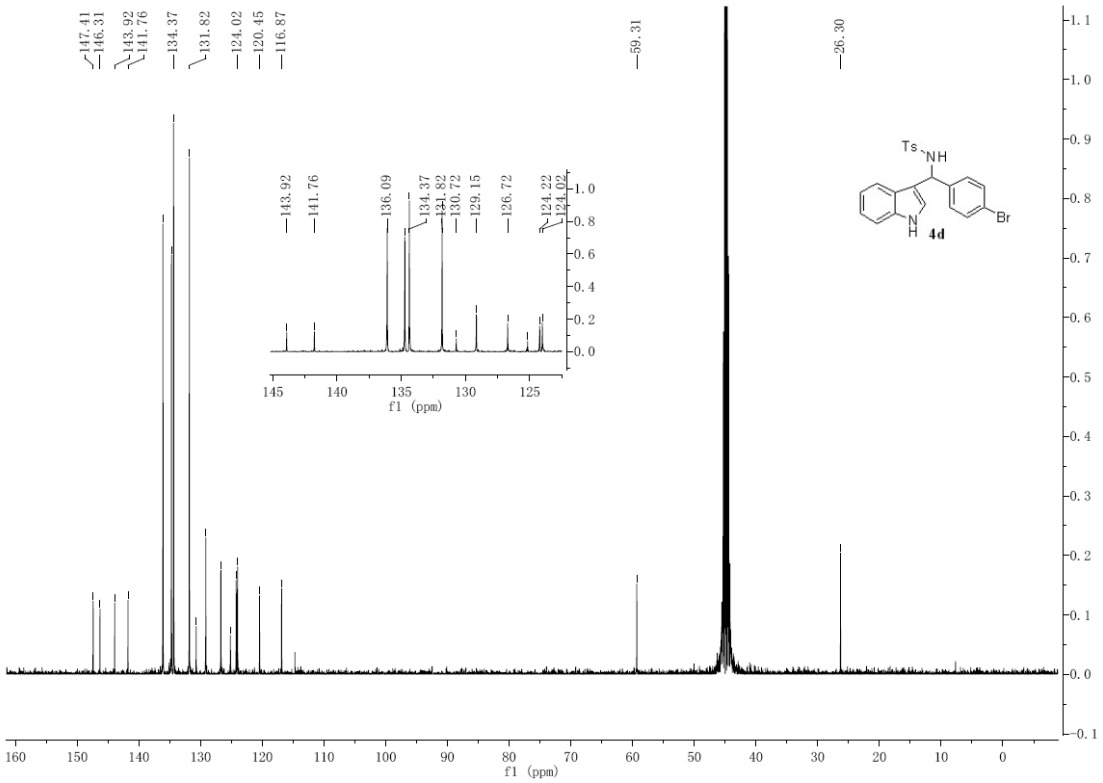
8.50
7.80
7.48
7.35
7.33
7.31
7.22
7.20
7.15
7.13
6.79
5.74
5.72
2.31
0.83
0.98
2.05
4.20
2.08
2.11
1.05
1.04
1.00
1.00
3.00
f1 (ppm)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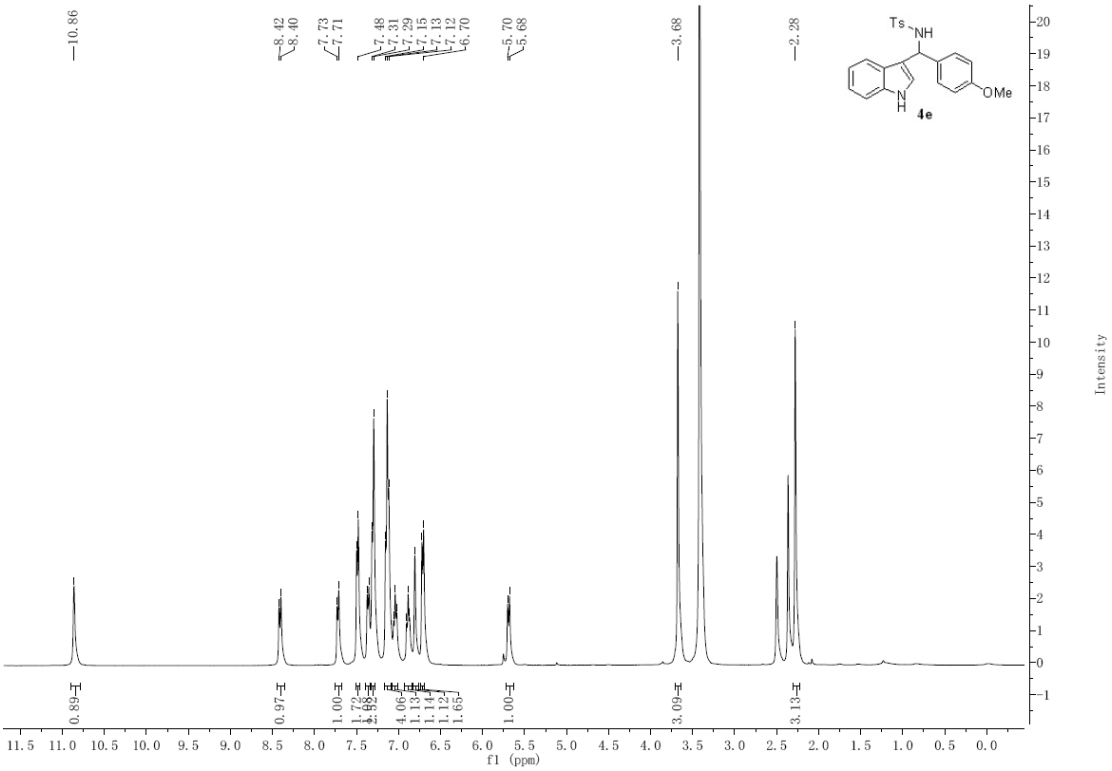
146.31
143.92
141.76
134.37
131.82
124.02
120.45
116.87
59.31
26.30
136.09
130.72
129.15
126.72
124.22
124.02
Ts
NH
N
H
Br
4d
f1 (ppm)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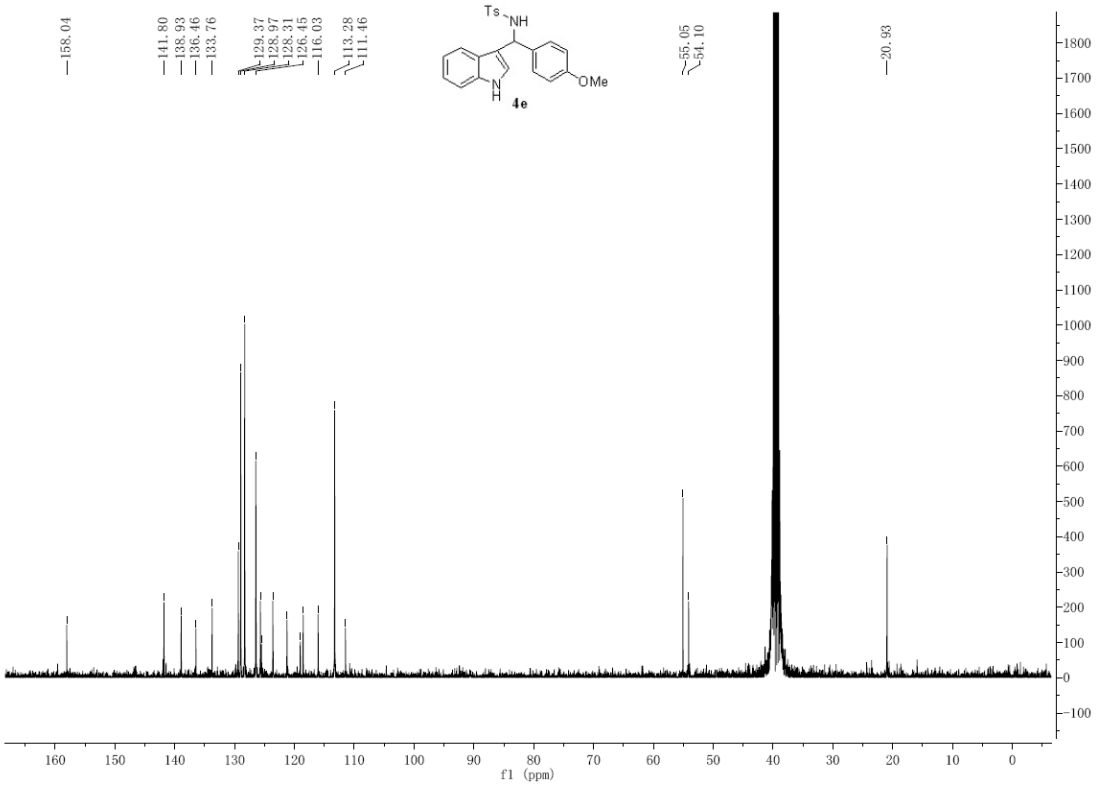
8.42
8.40
7.73
7.71
7.48
7.31
7.29
7.15
7.13
7.12
6.70
5.70
5.68
3.68
2.28
Ts
NH
OMe
4e
Intensity
f1 (ppm)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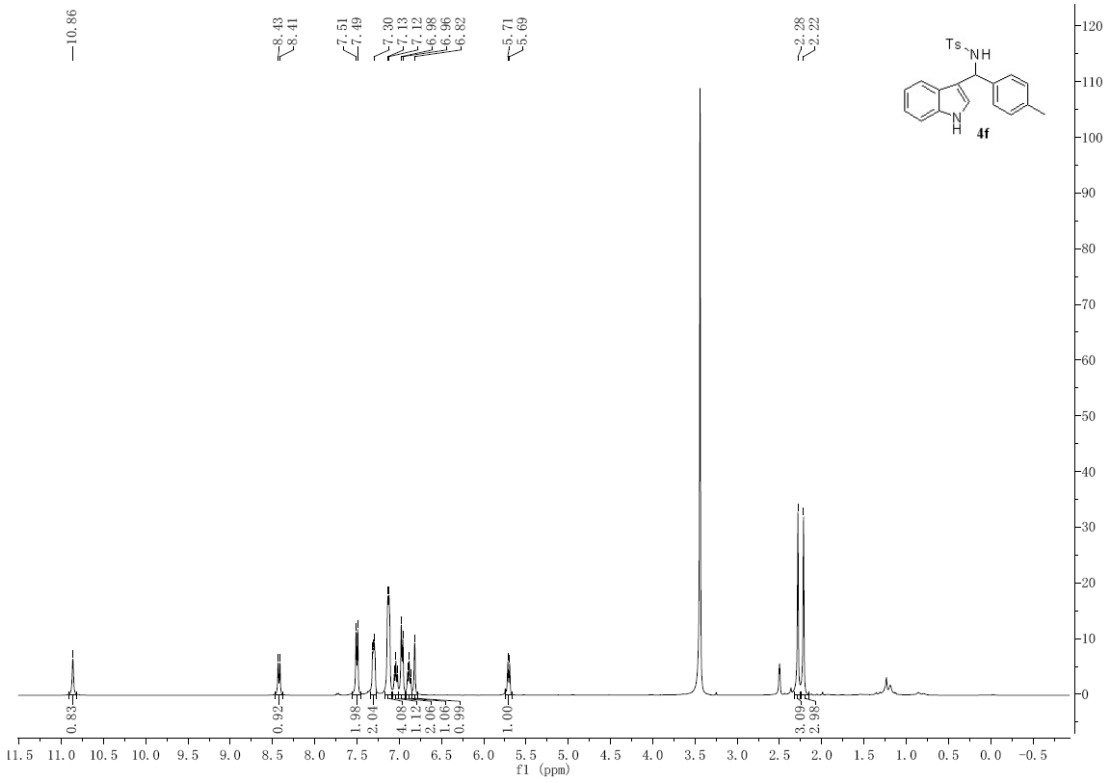
133.76
129.37
128.97
128.31
126.45
116.03
113.28
111.46
55.05
54.10
20.93
Ts
NH
OMe
4e
f1 (ppm)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8.43
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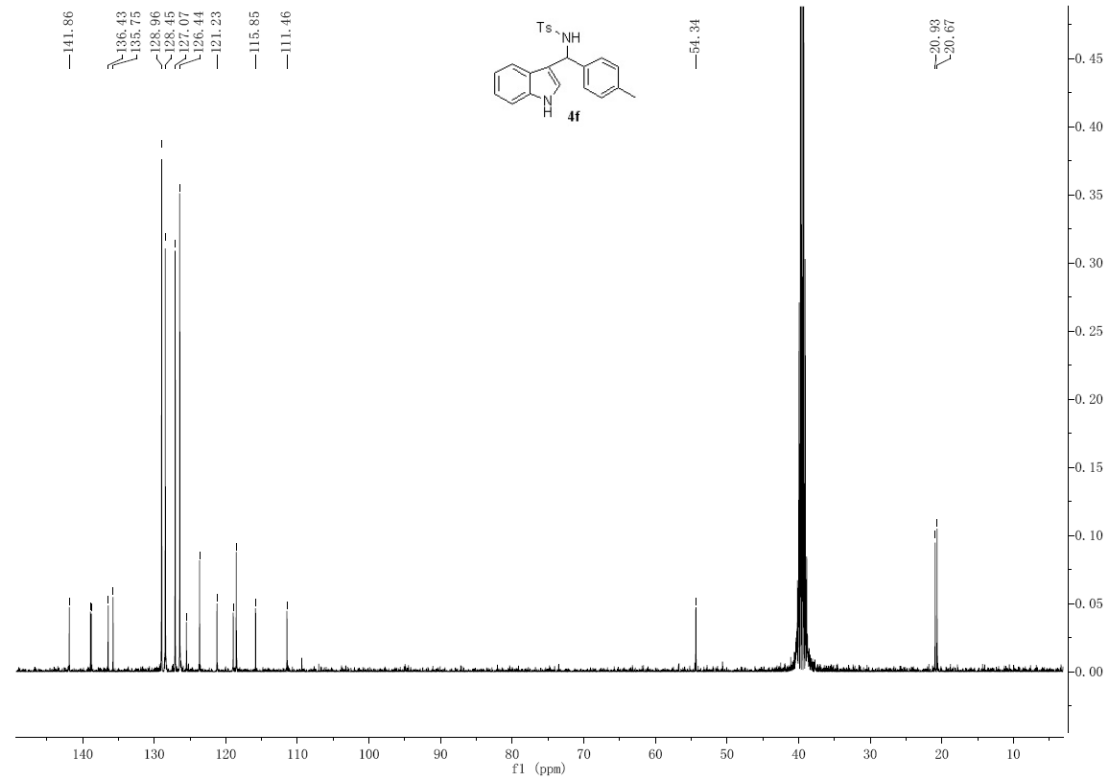
7.49
7.30
7.13
7.12
6.98
6.96
6.82
5.71
5.69
2.28
2.22
Ts
NH
4f
0.83
0.92
1.98
2.04
4.08
1.12
2.06
1.06
0.99
1.00
3.09
2.98
f1 (ppm)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136.43
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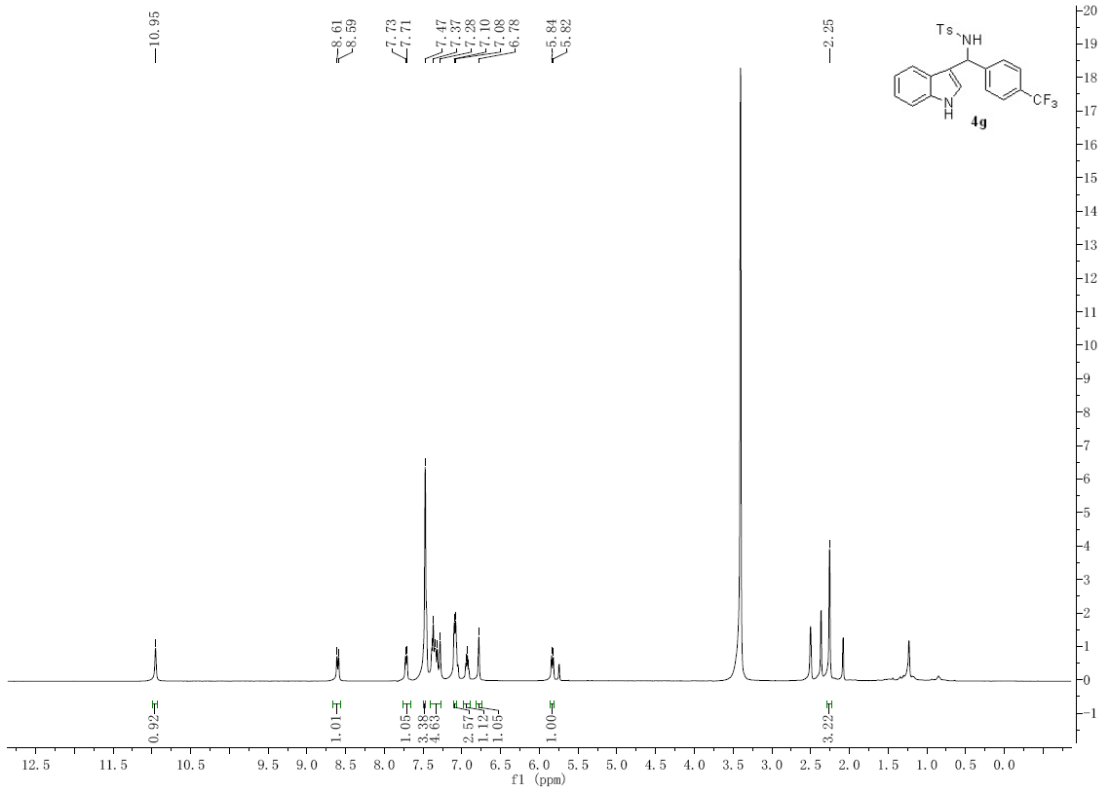
128.96
128.45
127.07
126.44
121.23
115.85
111.46
54.34
20.93
20.67
Ts
NH
4f
f1 (ppm)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8.61
8.59
7.73
7.71
7.47
7.37
7.28
7.10
7.08
6.78
5.84
5.82
2.25
Ts
NH
CF3
4g
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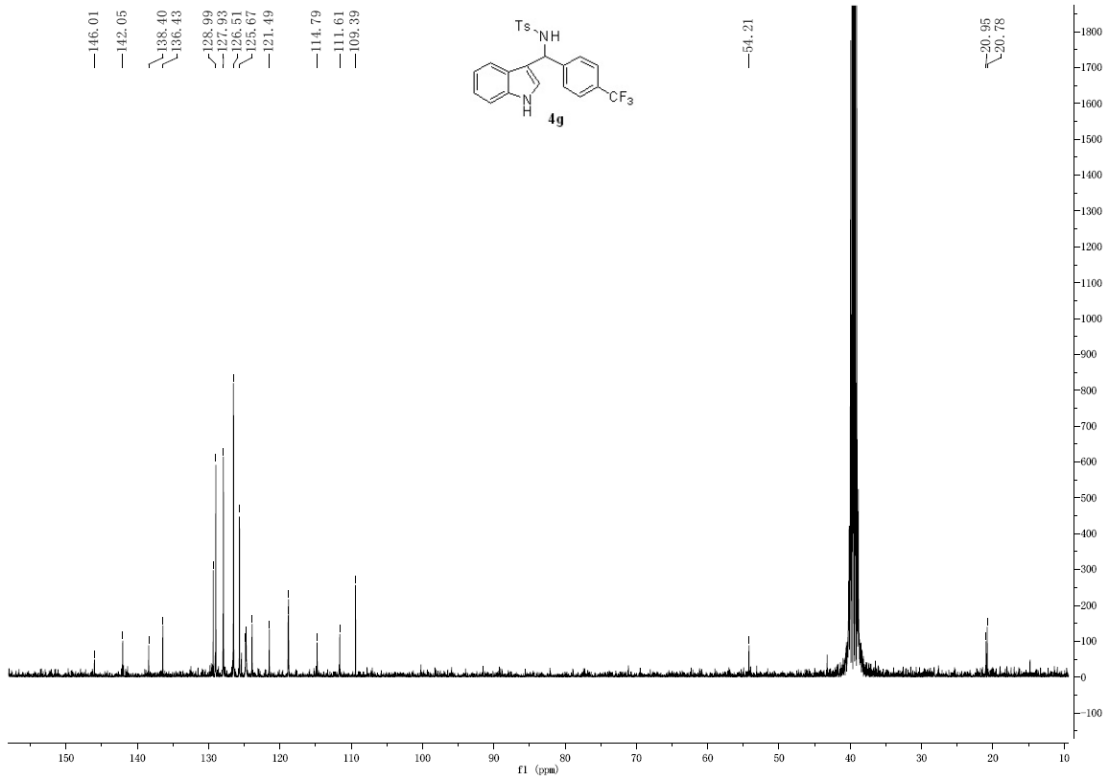
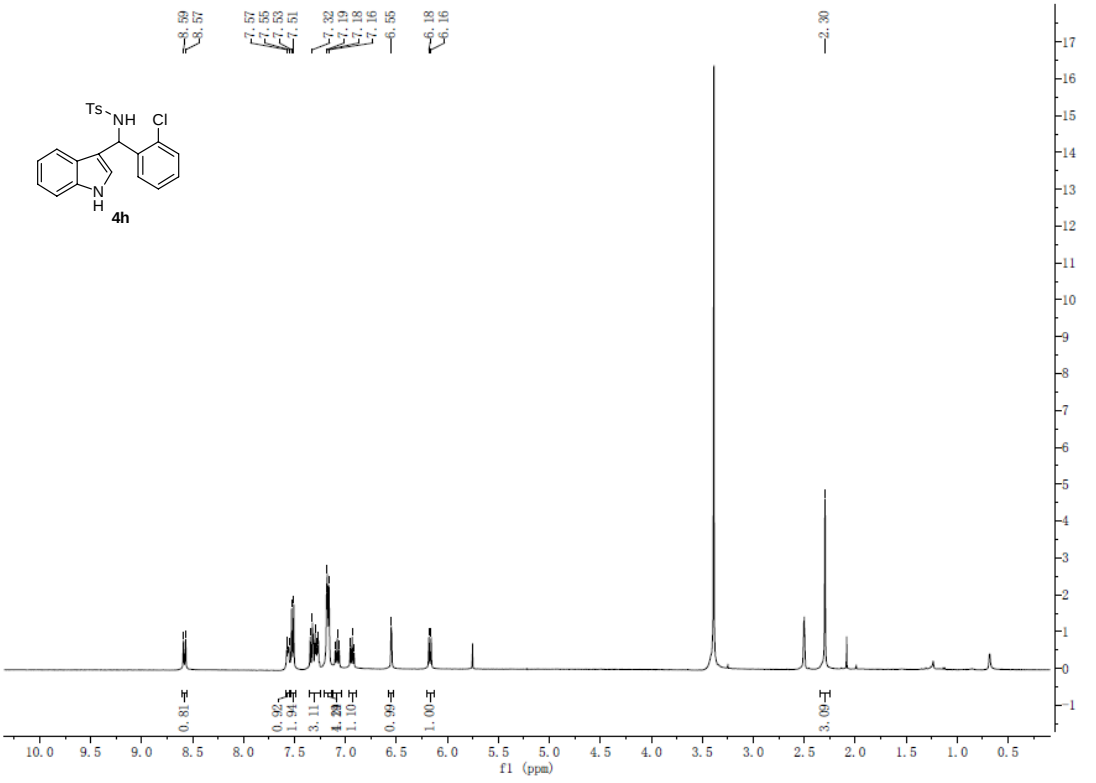
1.05
3.38
4.63
2.57
1.12
1.05
1.00
3.22
f1 (ppm)


146.01
142.05
138.40
136.43
128.99
127.93
126.51
125.67
121.49
114.79
111.61
109.39
54.21
20.95
20.78
Ts
NH
CF3
4g
f1 (ppm)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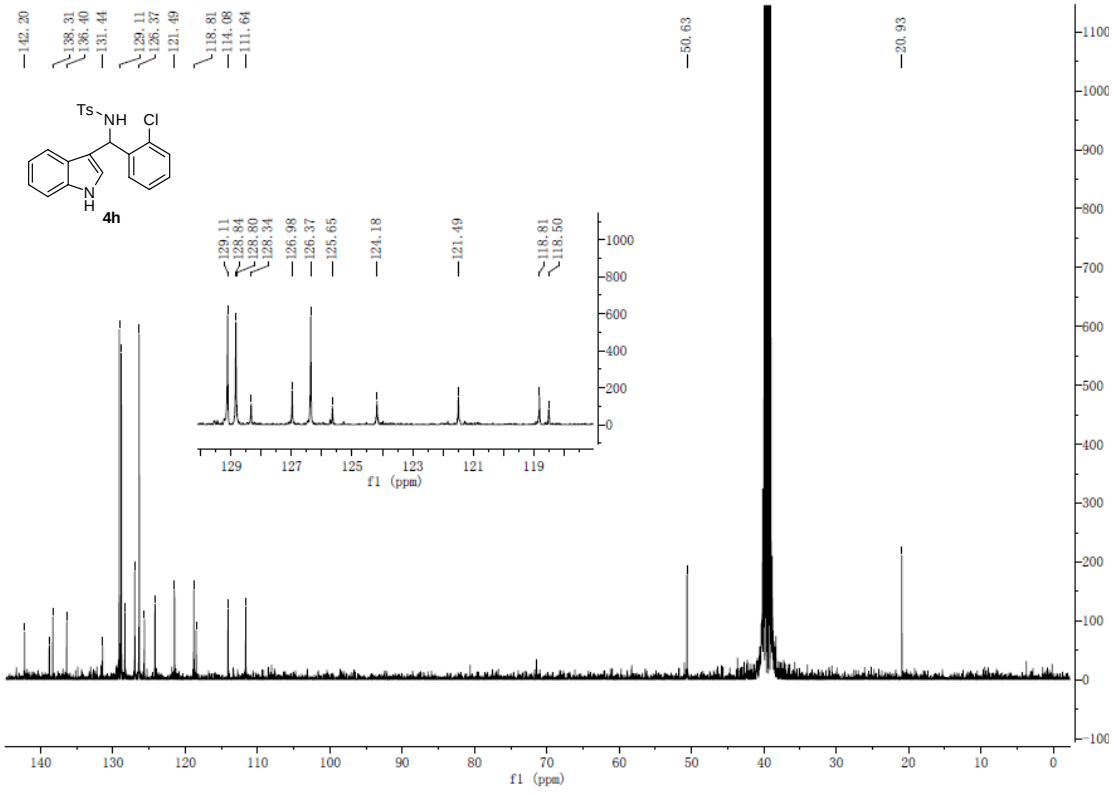
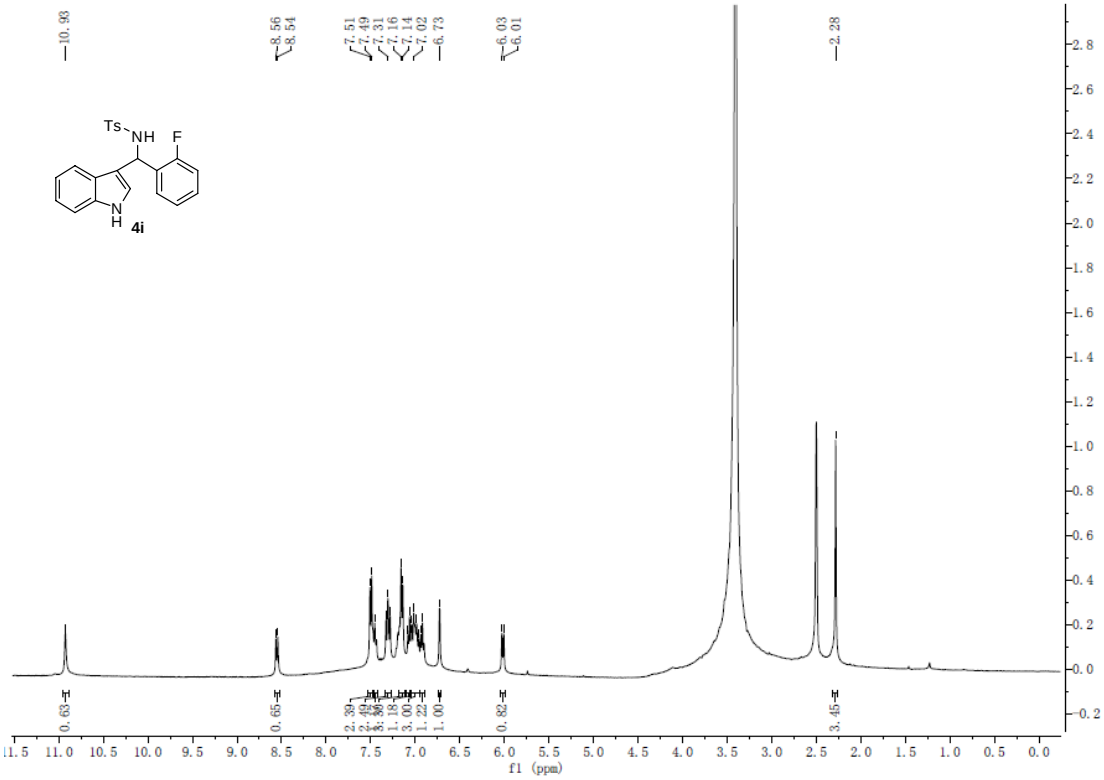
8.57
7.57
7.55
7.53
7.51
7.32
7.19
7.18
7.16
6.55
6.18
6.16
2.30
Ts
NH
Cl
N
H
4h
0.81
0.92
1.94
3.11
1.10
0.99
1.00
3.09
f1 (ppm)


142.20
138.31
136.40
131.44
129.11
126.37
121.49
118.81
114.08
111.64
50.63
20.93
Ts
NH
Cl
N
H
4h
129.11
128.84
128.80
128.34
126.98
126.37
125.65
124.18
121.49
118.81
118.50
f1 (ppm)


10.93
8.56
8.54
7.51
7.49
7.31
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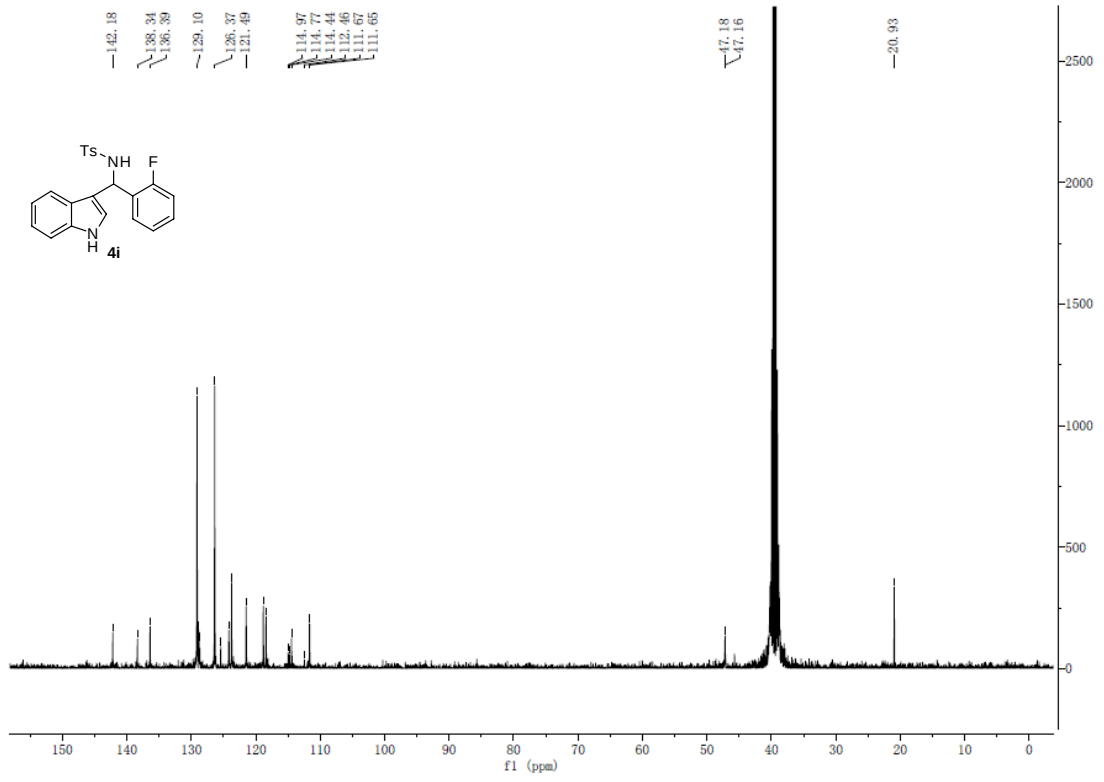
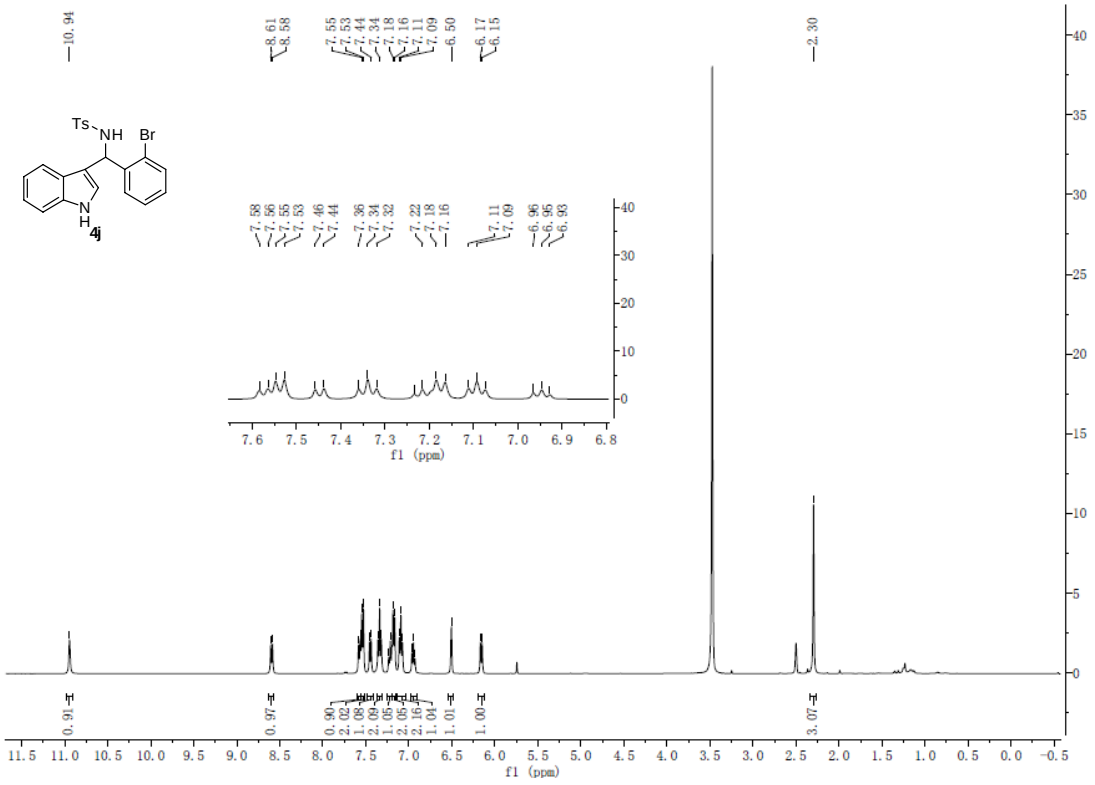
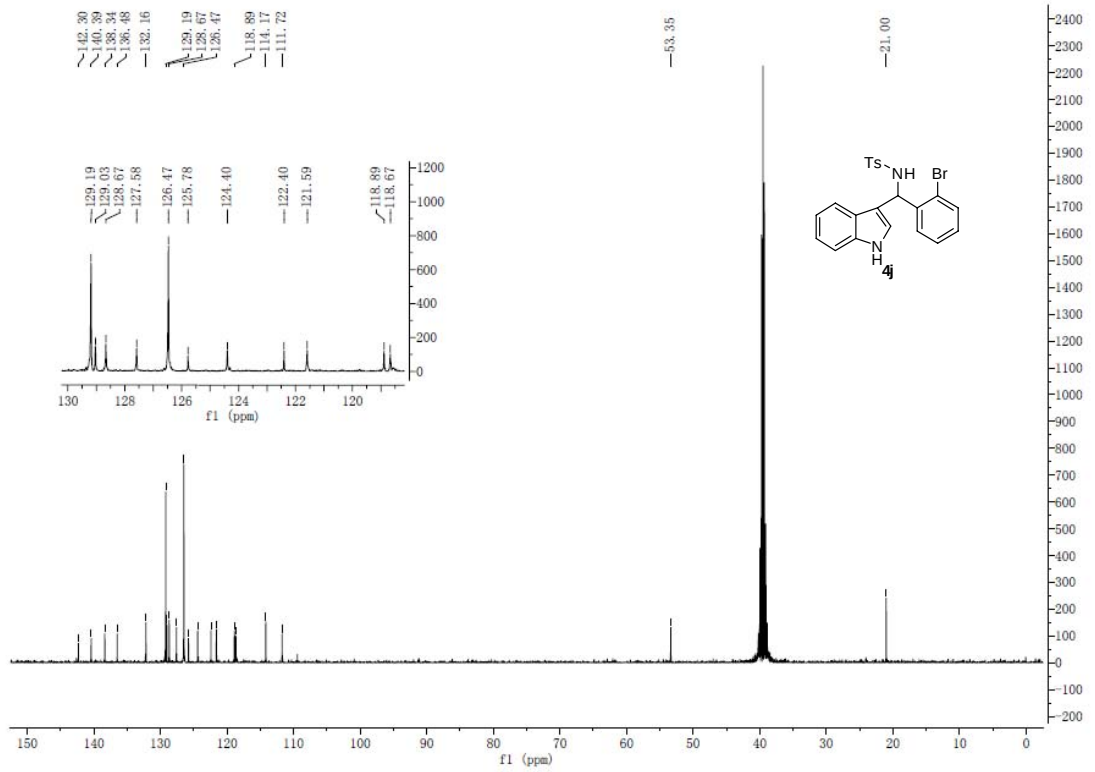
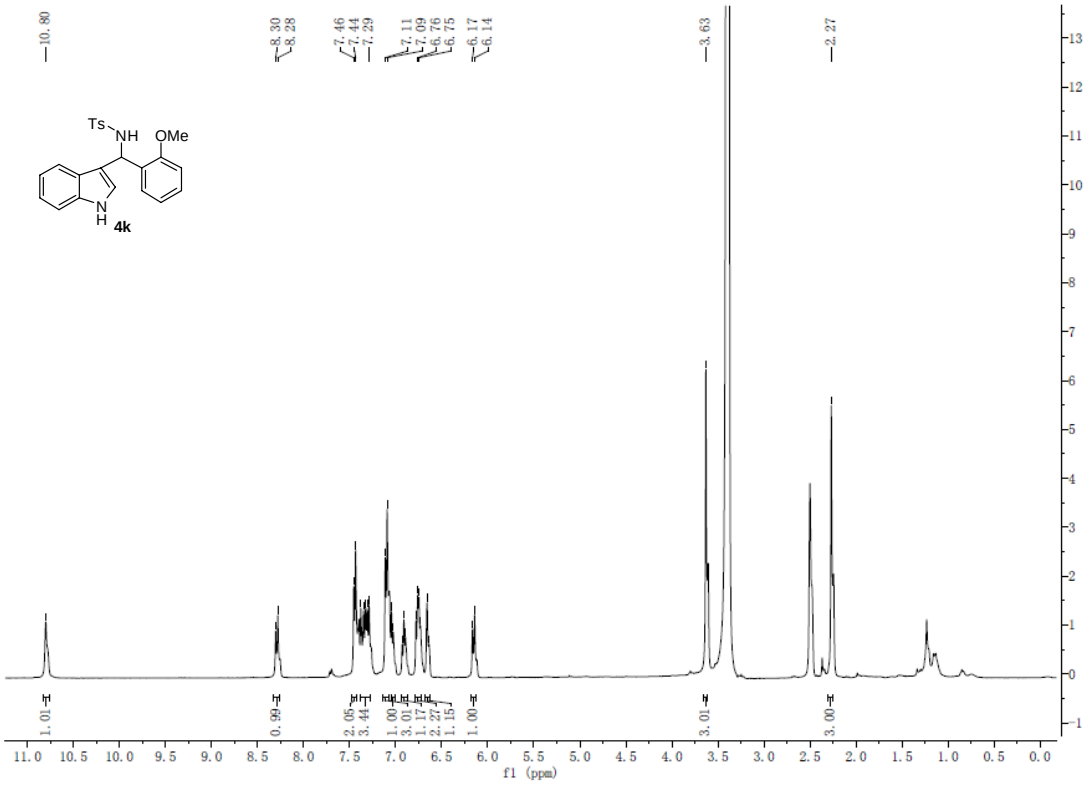
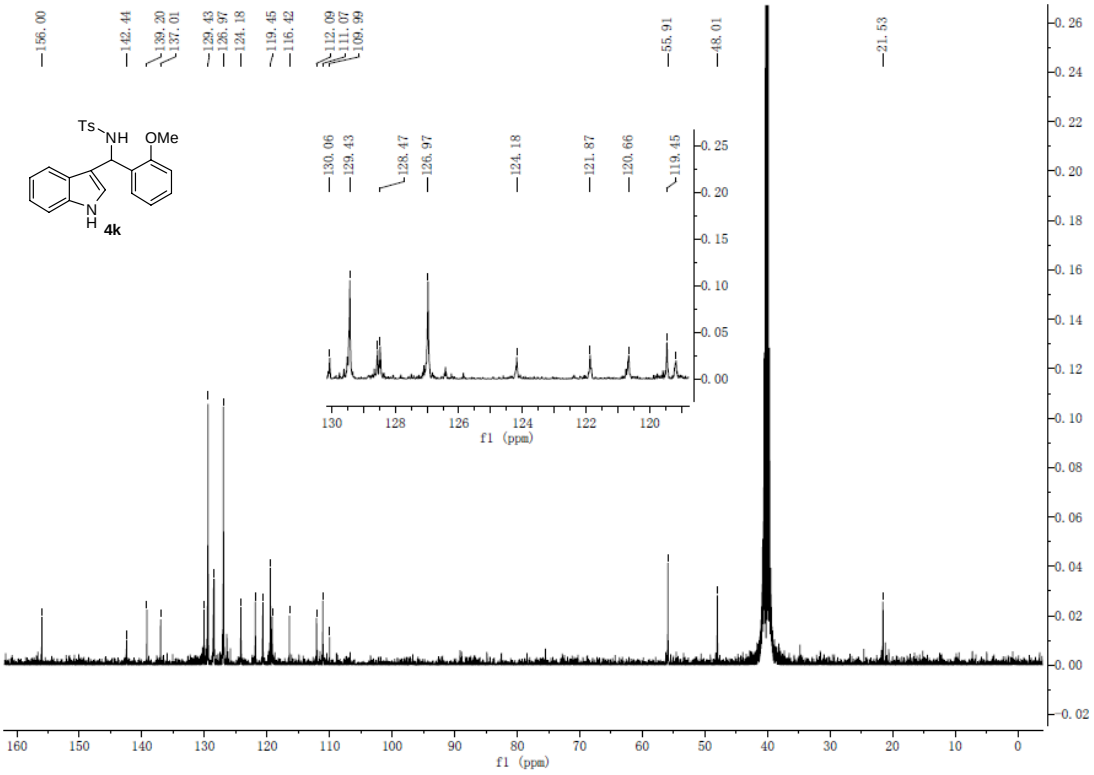
7.14
7.02
6.73
6.03
6.01
2.28
Ts
NH
F
N
H
4i
f1 (ppm)

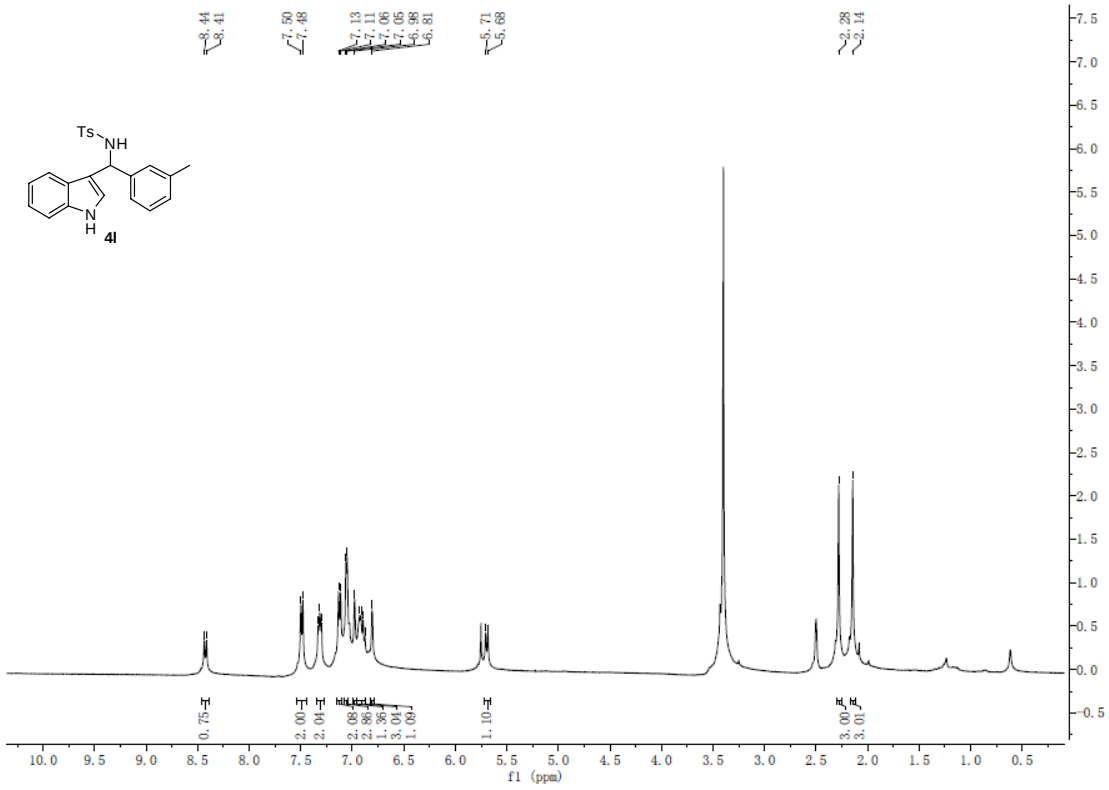

142.18
136.34
136.39
129.10
126.37
121.49
114.97
114.77
114.44
112.46
111.67
111.65
47.18
47.16
20.93
Ts
NH
F
N
H
4i
f1 (ppm)


10.94
8.61
8.58
7.55
7.53
7.44
7.34
7.18
7.16
7.11
7.09
6.50
6.17
6.15
2.30
Ts
NH
Br
N
H
4j
f1 (ppm)
0.91
0.97
3.07


142.30
140.39
138.34
136.48
132.16
129.19
128.67
128.47
118.89
114.17
111.72
53.35
21.00
129.19
129.03
128.67
127.58
126.47
125.78
124.40
122.40
121.59
118.89
118.67
Ts
NH
Br
N
H
4j
f1 (ppm)



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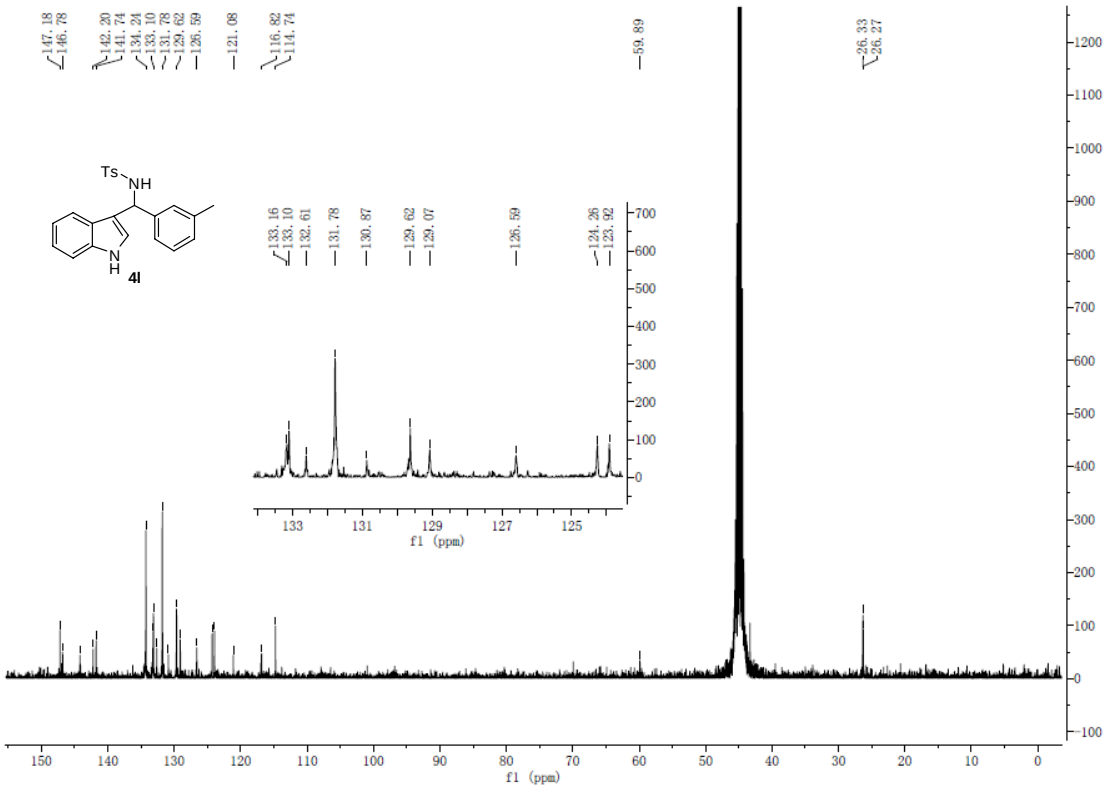
8.41
7.50
7.48
7.13
7.11
7.06
7.05
6.98
6.81
5.71
5.68
2.28
2.14
Ts
NH
N
H
4l
0.75
2.00
2.04
2.08
2.86
1.36
3.04
1.09
1.10
3.00
3.01
f1 (ppm)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141.74
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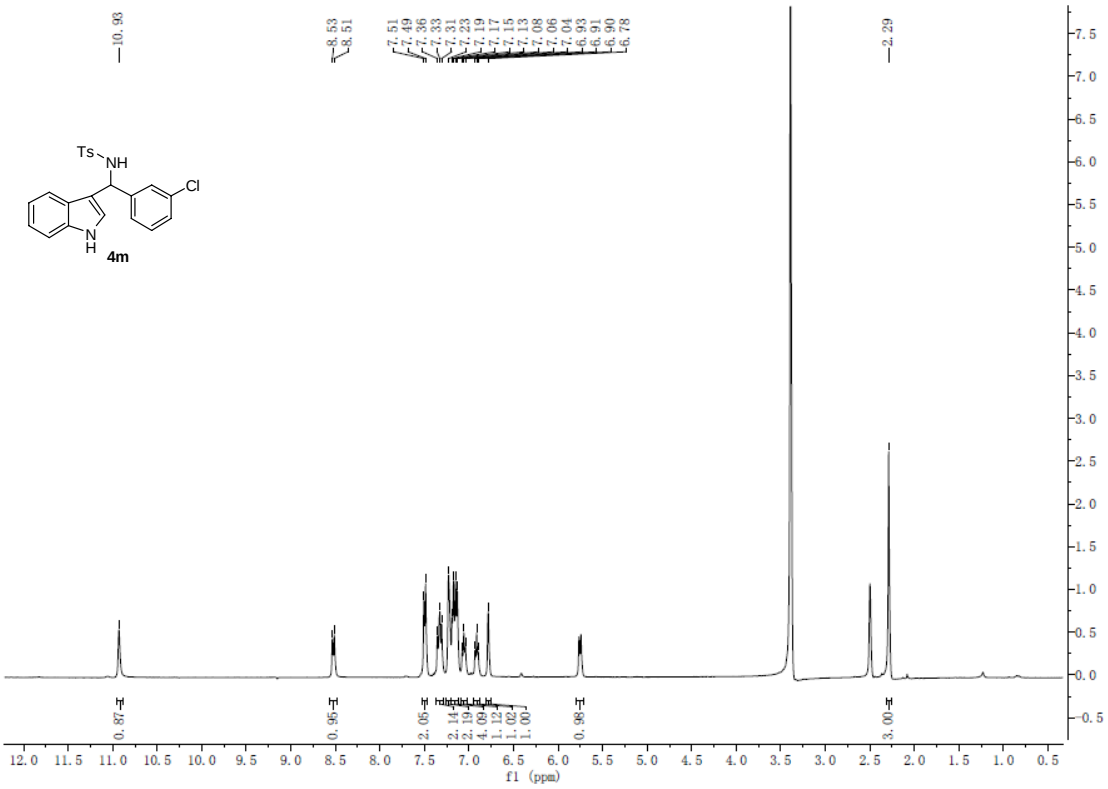
133.10
131.78
129.62
126.59
121.08
116.82
114.74
59.89
26.33
26.27
Ts
NH
N
H
4l
133.16
133.10
132.61
131.78
130.87
129.62
129.07
126.59
124.26
123.92
f1 (ppm)
f1 (ppm)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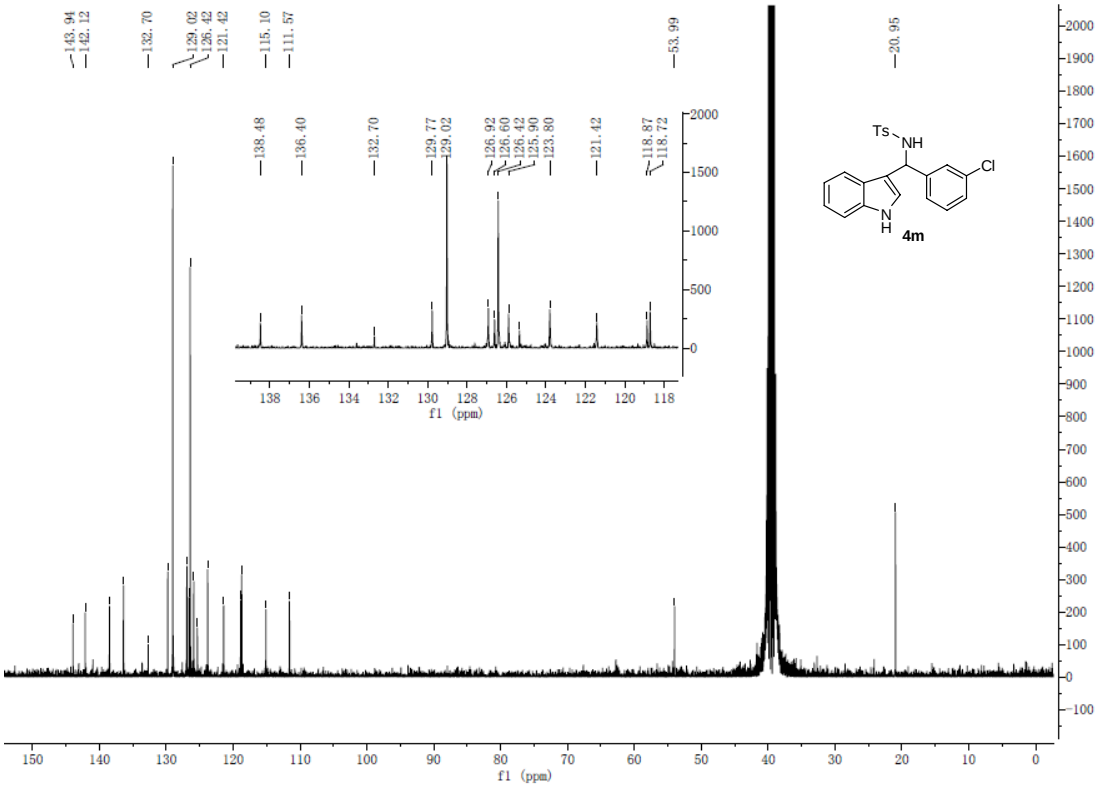
7.49
7.36
7.33
7.31
7.23
7.19
7.17
7.15
7.13
7.08
7.06
7.04
6.93
6.91
6.90
6.78
2.29
Ts
NH
Cl
N
H
4m
0.87
0.95
2.05
2.14
2.19
4.09
1.12
1.02
1.00
0.98
3.00
f1 (ppm)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126.42
121.42
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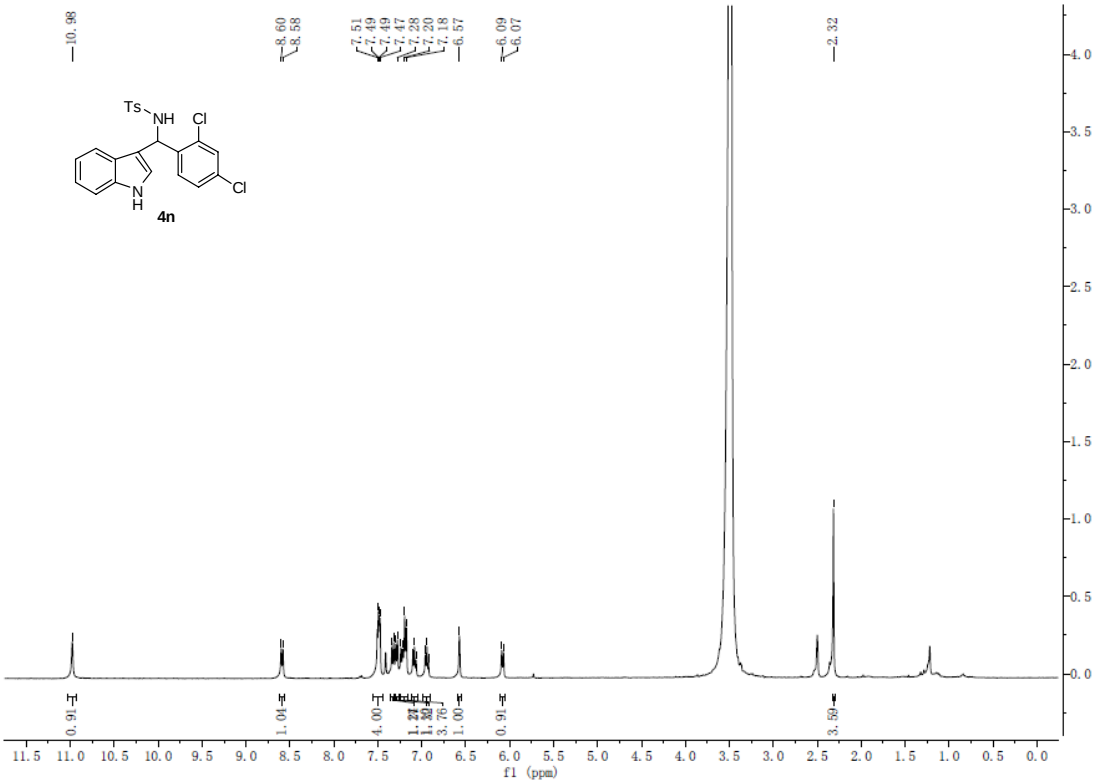
111.57
53.99
20.95
138.48
136.40
132.70
129.77
129.02
126.92
126.66
126.42
125.90
123.80
121.42
118.87
118.72
Ts
NH
Cl
N
H
4m
f1 (ppm)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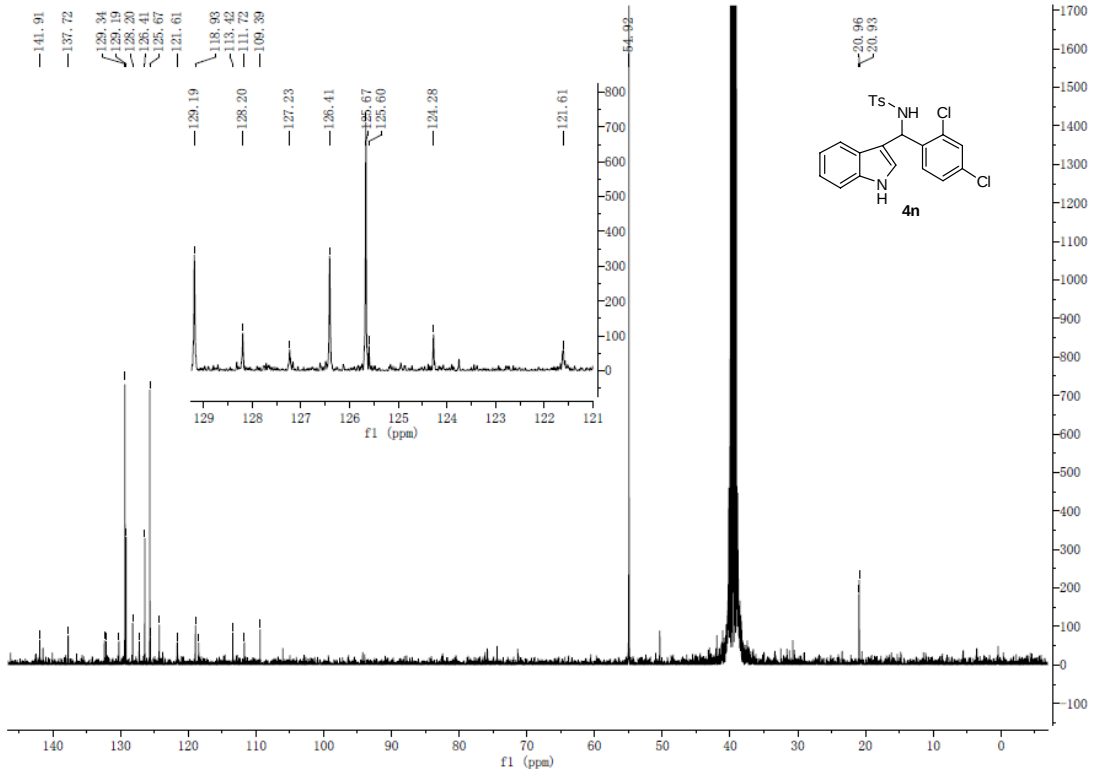
7.51
7.49
7.49
7.47
7.28
7.20
7.18
6.57
6.09
6.07
2.32
Ts
NH
Cl
Cl
N
H
4n
f1 (ppm)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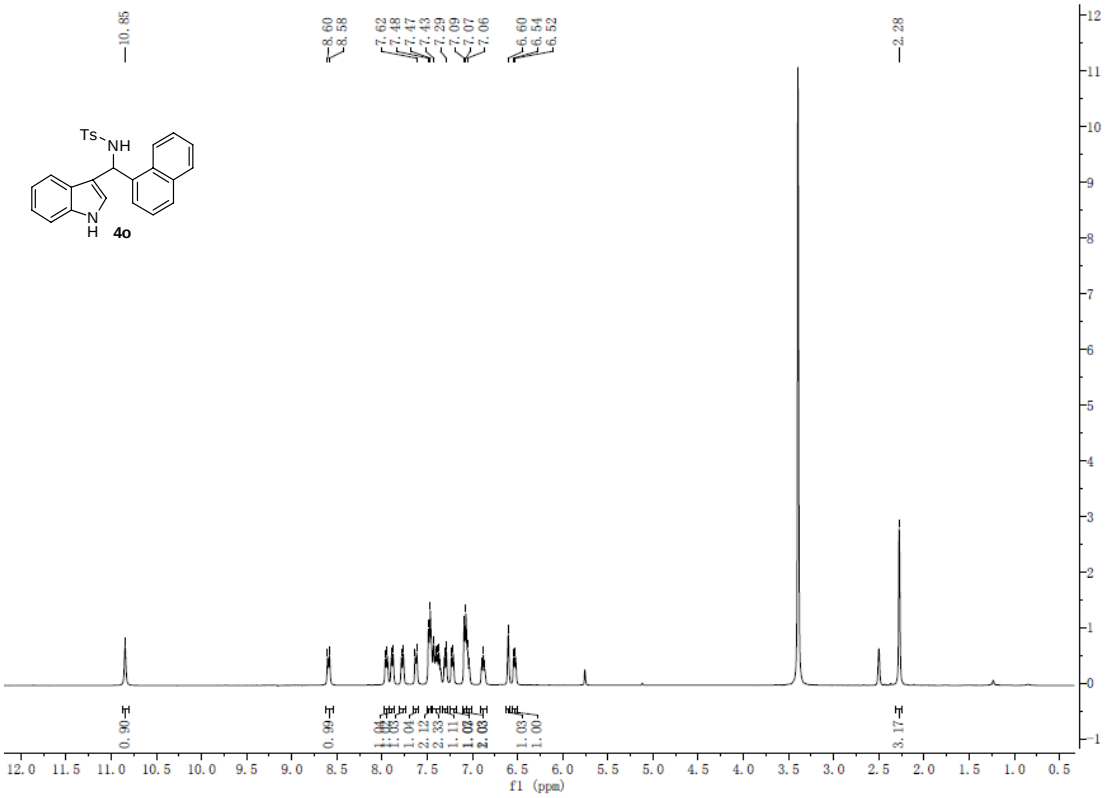
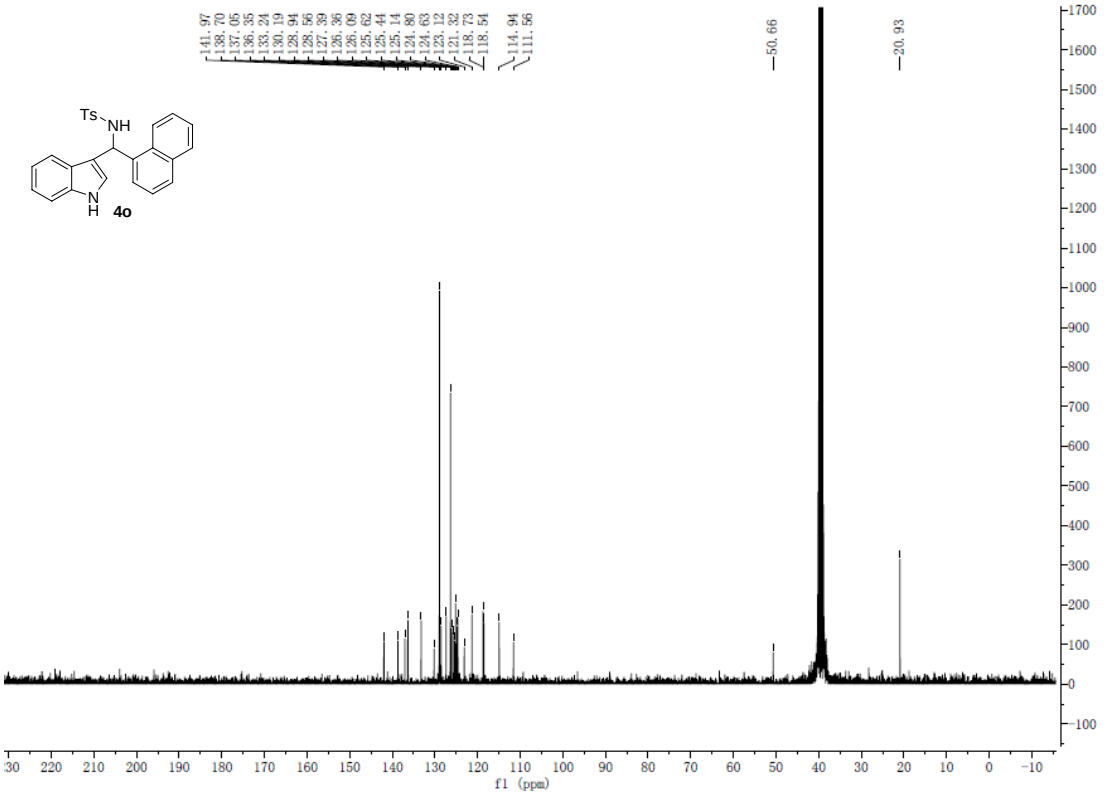
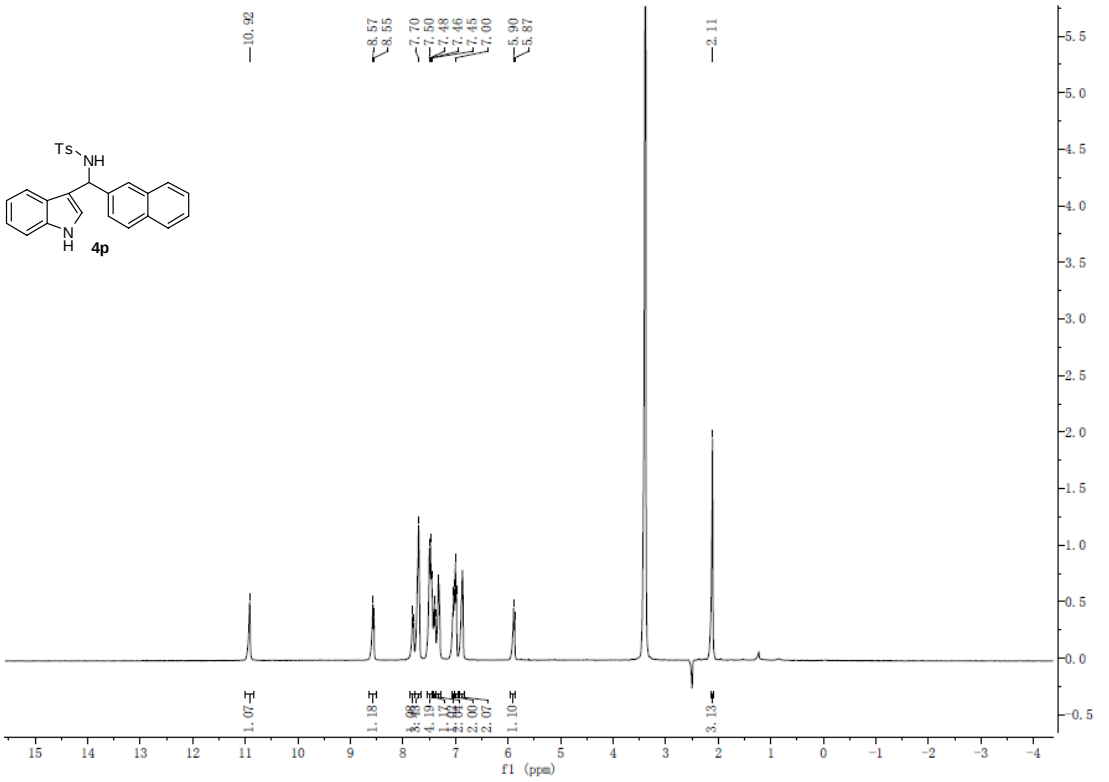
129.19
128.20
126.41
125.67
121.61
118.93
113.42
111.72
109.39
54.92
20.96
20.93
129.19
128.20
127.23
126.41
125.67
125.60
124.28
121.61
Ts
NH
Cl
Cl
N
H
4n
f1 (ppm)
f1 (ppm)






Ts
NH
N
H
4p
10.92
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8.55
7.70
7.50
7.48
7.46
7.45
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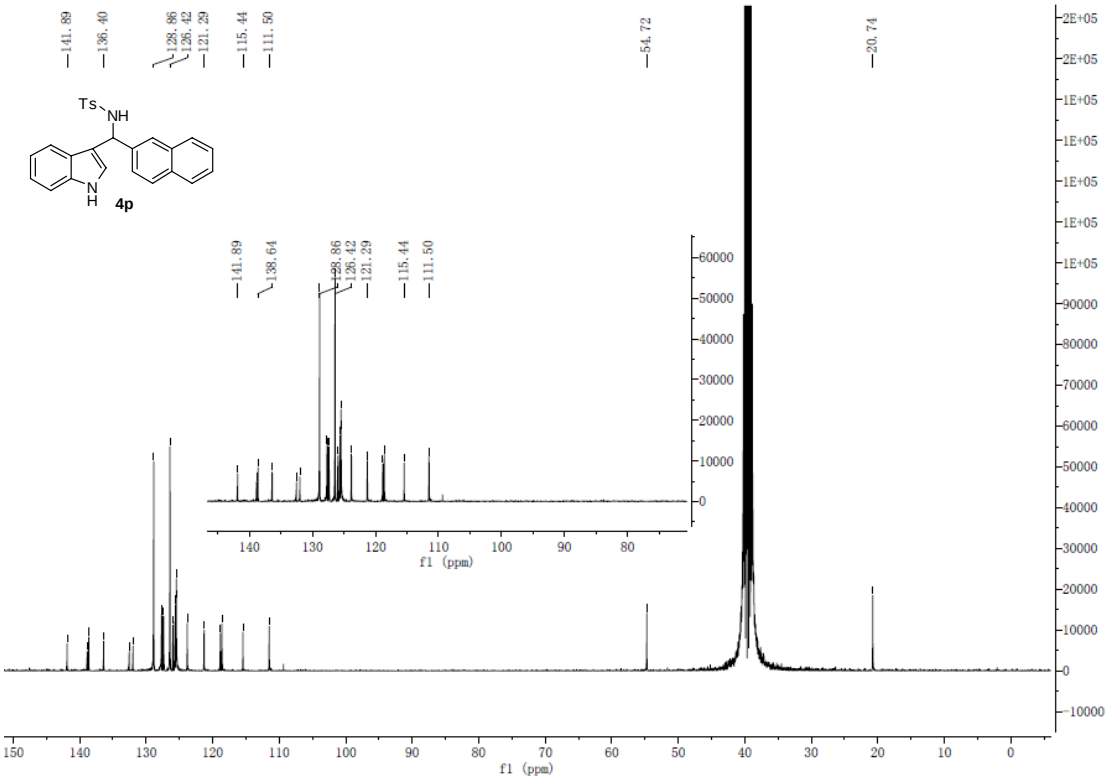
1.07
1.18
1.10
3.13
f1 (ppm)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N
H
4p
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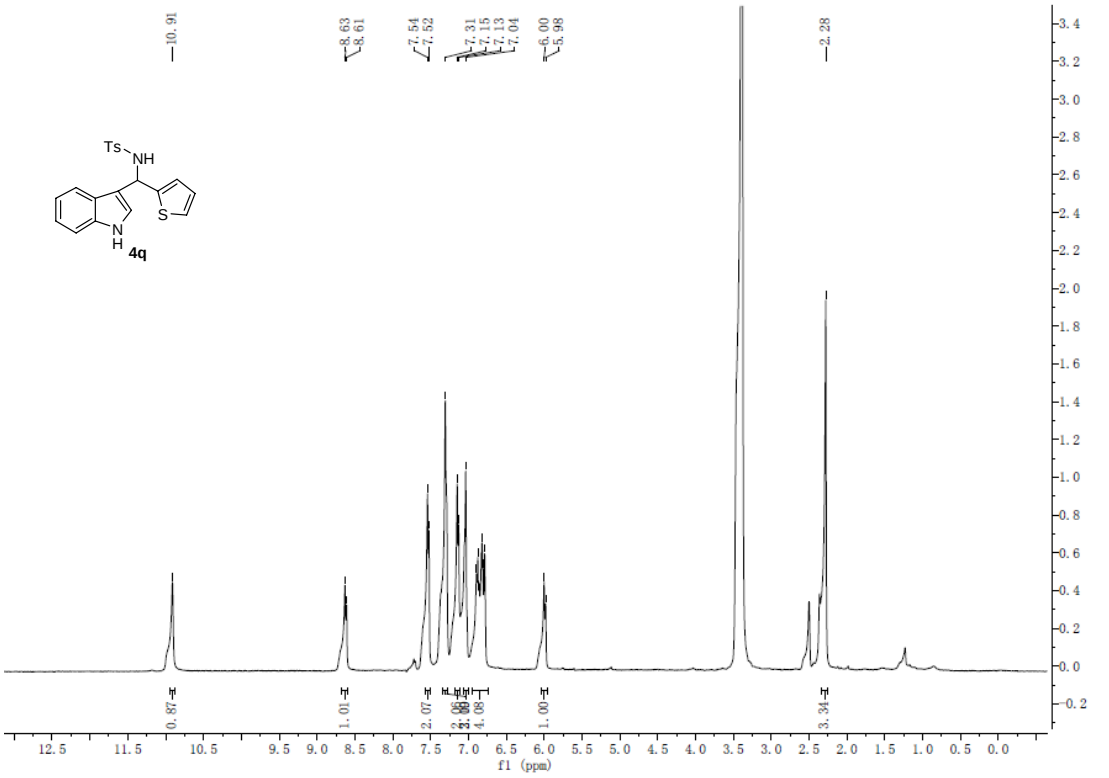
121.29
115.44
111.50
54.72
20.74
138.64
f1 (ppm)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8.63
8.61
7.54
7.52
7.31
7.15
7.13
7.04
6.00
5.98
2.28
Ts
NH
S
N
H
4q
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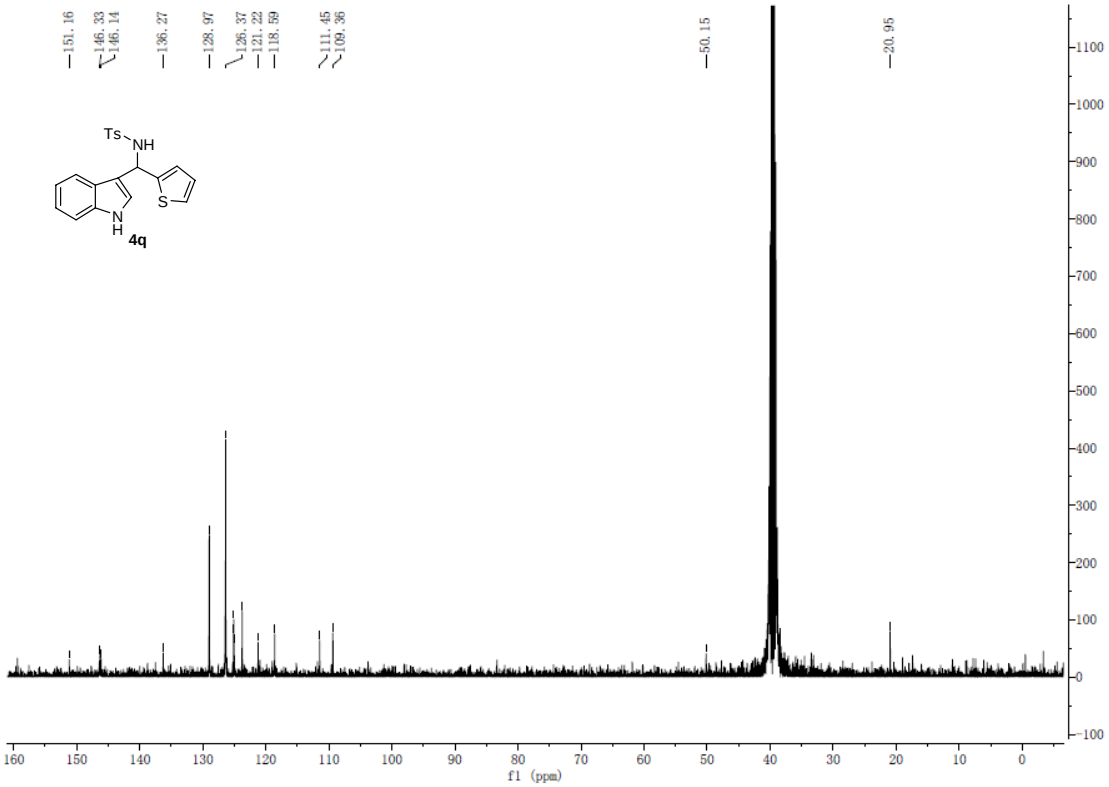
1.01
2.07
4.08
1.00
3.34
f1 (ppm)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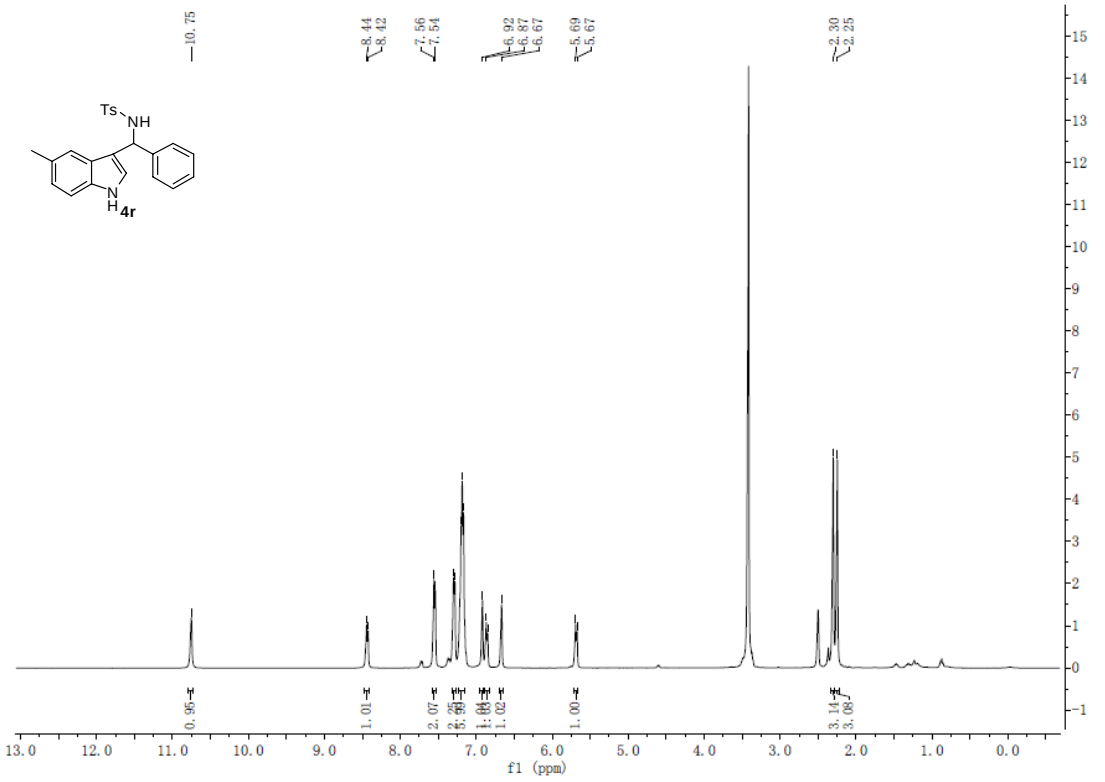
136.27
128.97
126.37
121.22
118.59
111.45
109.36
50.15
20.95
Ts
NH
S
N
H
4q
f1 (ppm)


Ts
NH
N
H
4r
10.75
8.44
8.42
7.56
7.54
6.92
6.87
6.67
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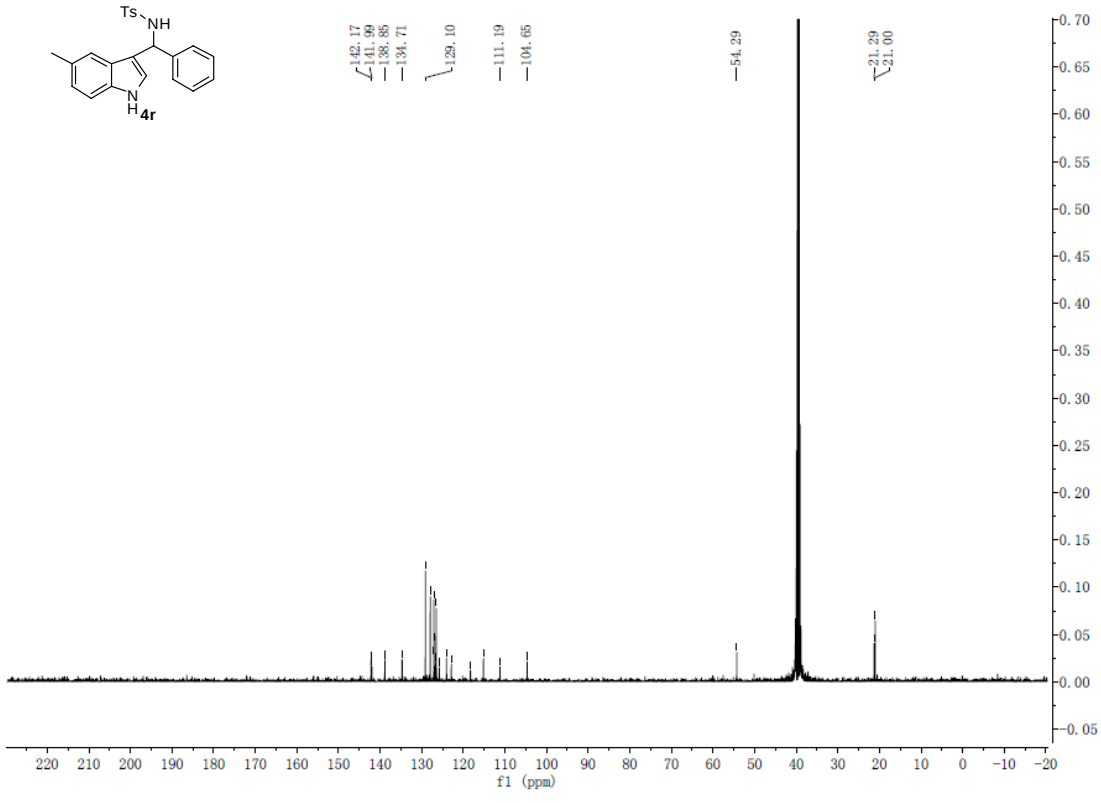
5.67
2.30
2.25
0.95
1.01
2.07
1.02
1.00
3.14
3.08
f1 (ppm)


Ts
NH
N
H
4r
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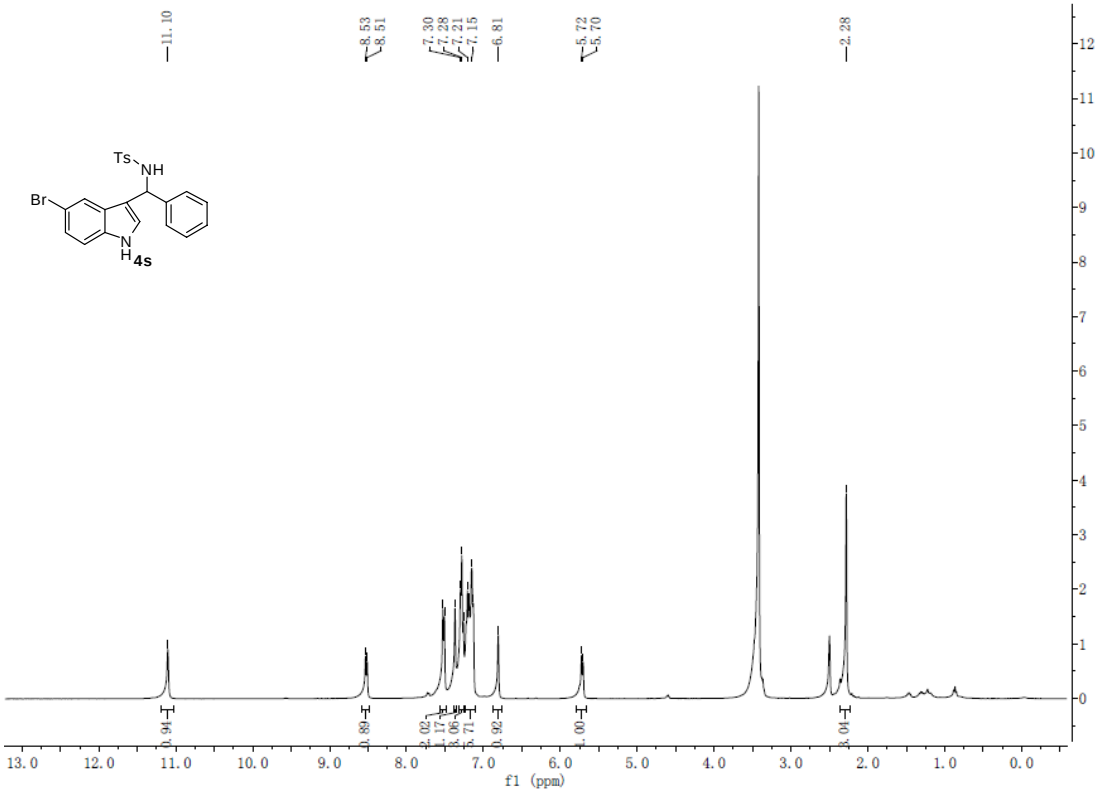
134.71
129.10
111.19
104.65
54.29
21.29
21.00
f1 (ppm)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8.53
8.51
7.30
7.28
7.21
7.15
6.81
5.72
5.70
2.28
Ts
NH
Br
N
H
4s
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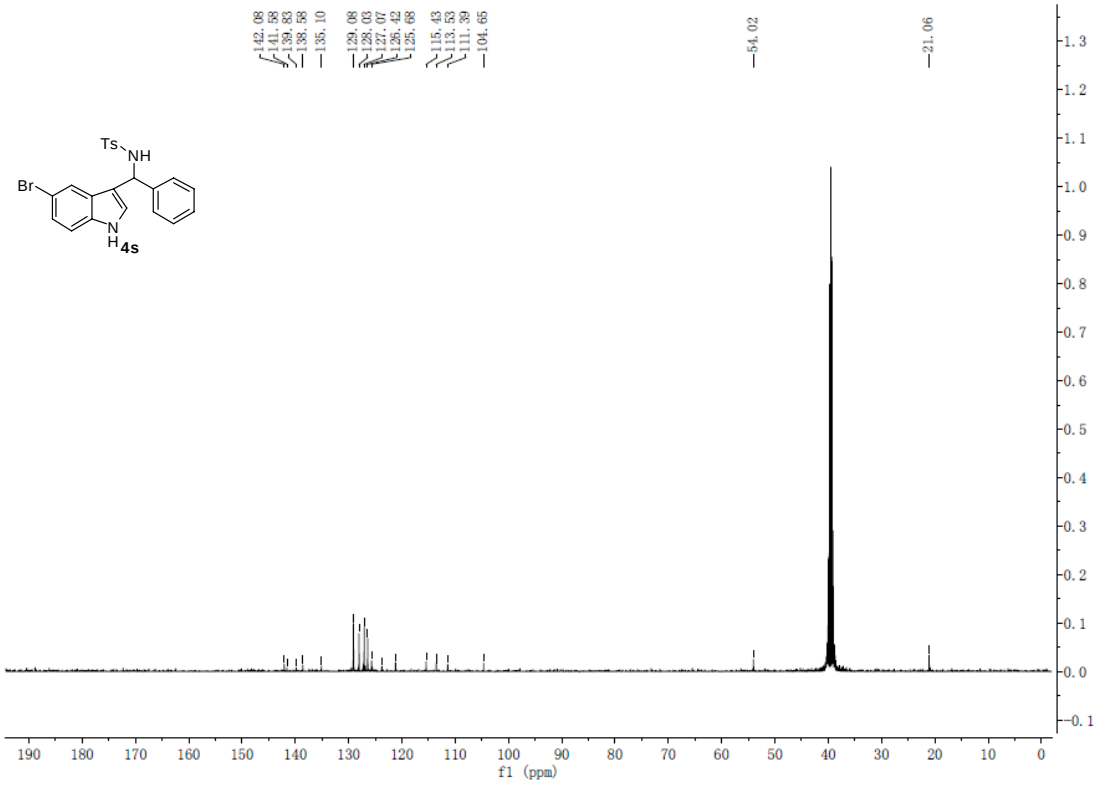
0.89
2.02
1.17
3.06
5.71
0.92
4.00
3.04
f1 (ppm)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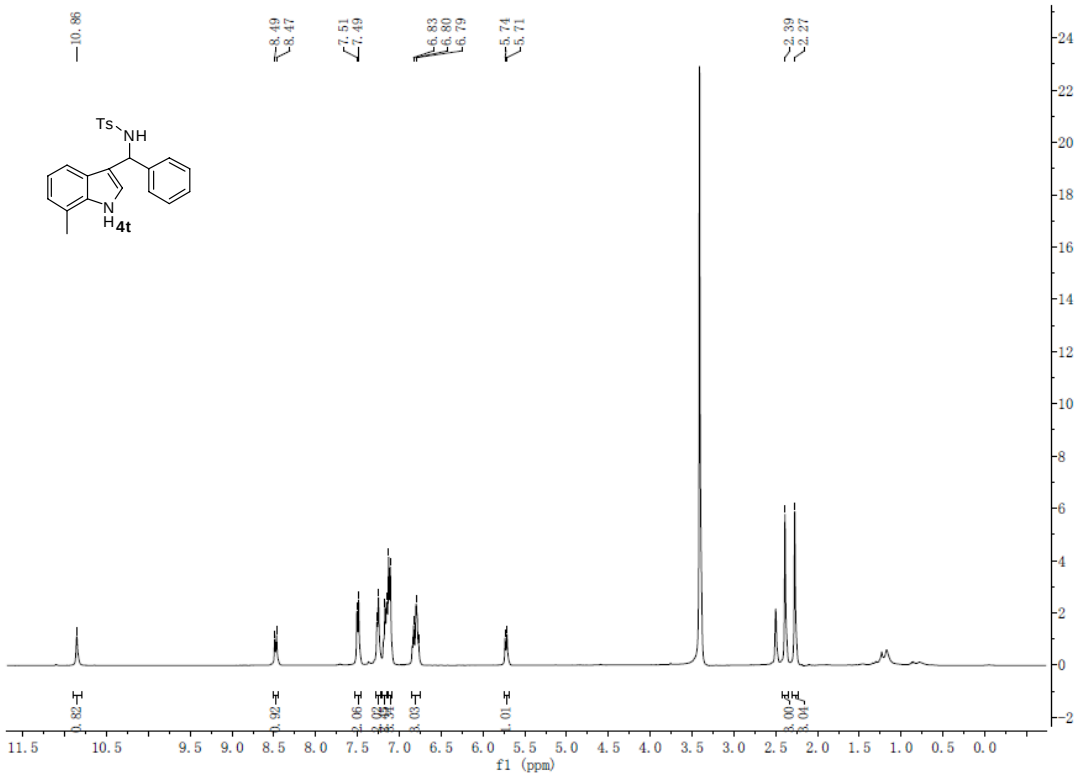
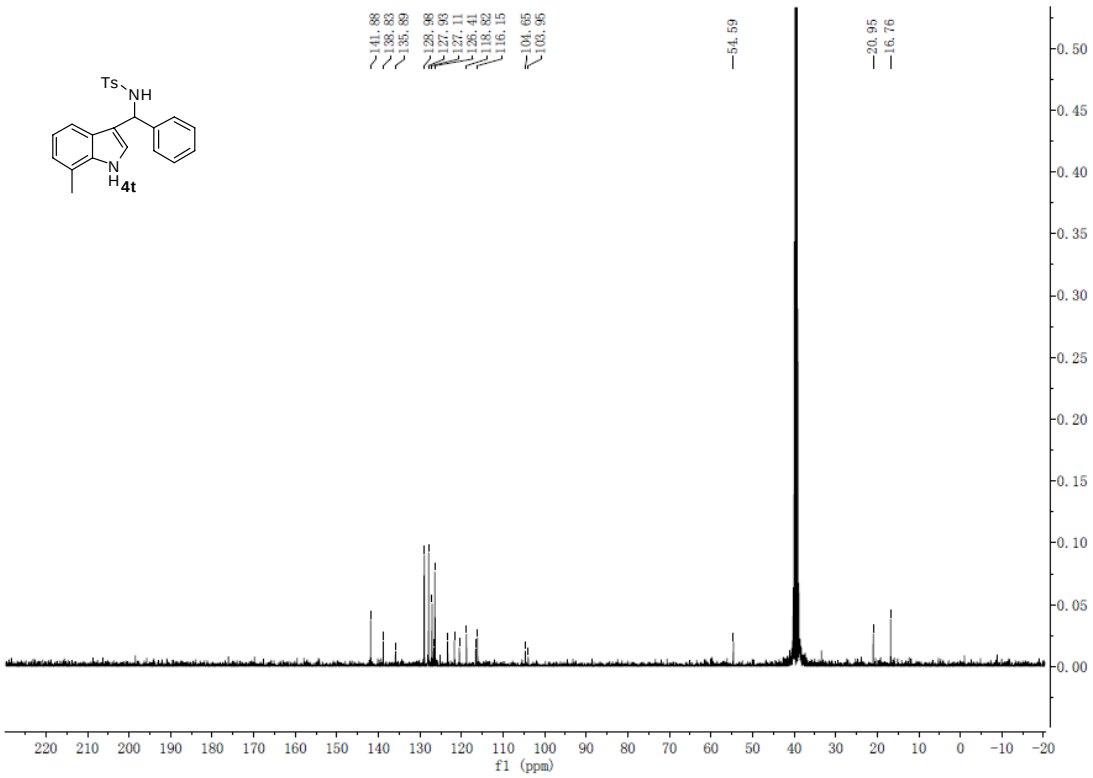
139.83
138.58
135.10
129.08
128.03
127.07
126.42
125.68
115.43
113.53
111.39
104.65
54.02
21.06
Ts
NH
Br
N
H
4s
f1 (ppm)


10.86
8.49
8.47
7.51
7.49
6.83
6.80
6.79
5.74
5.71
2.39
2.27
Ts
NH
N
H
4t
f1 (ppm)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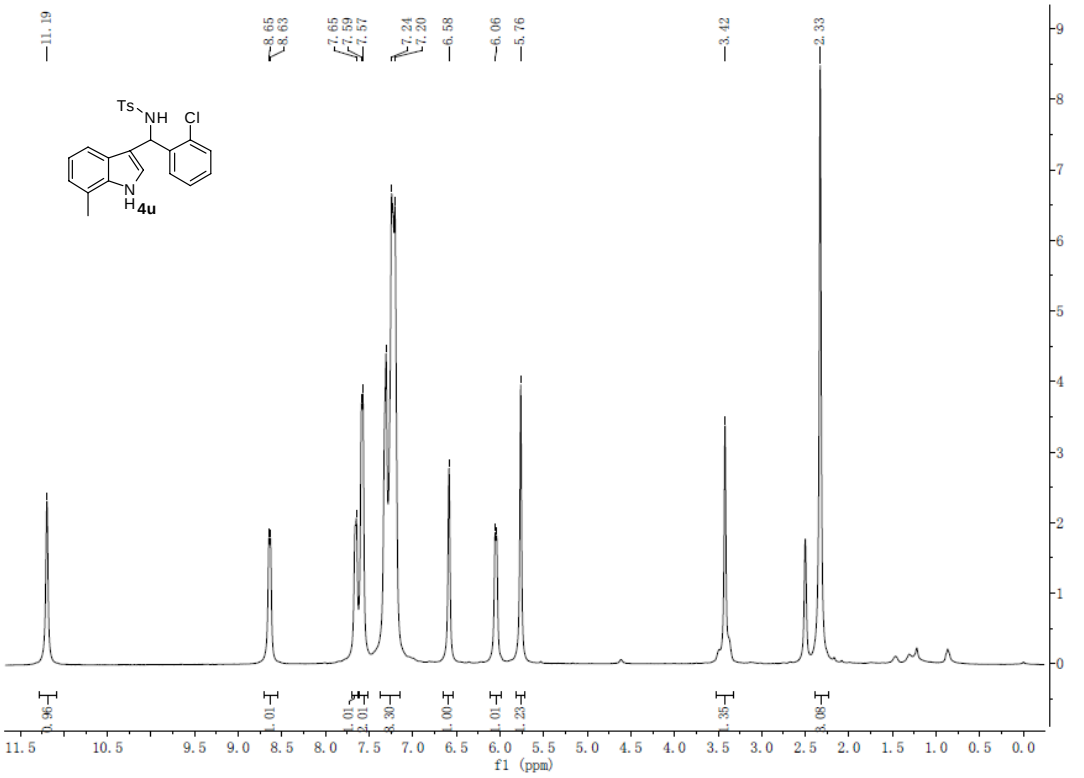
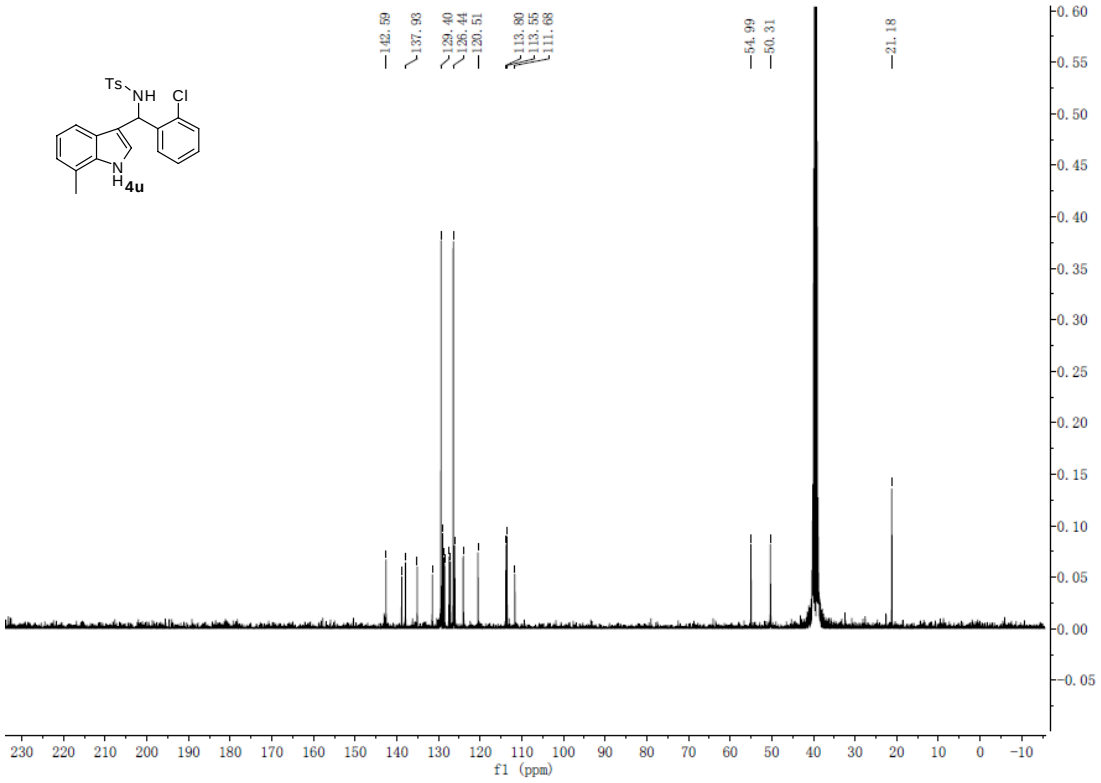
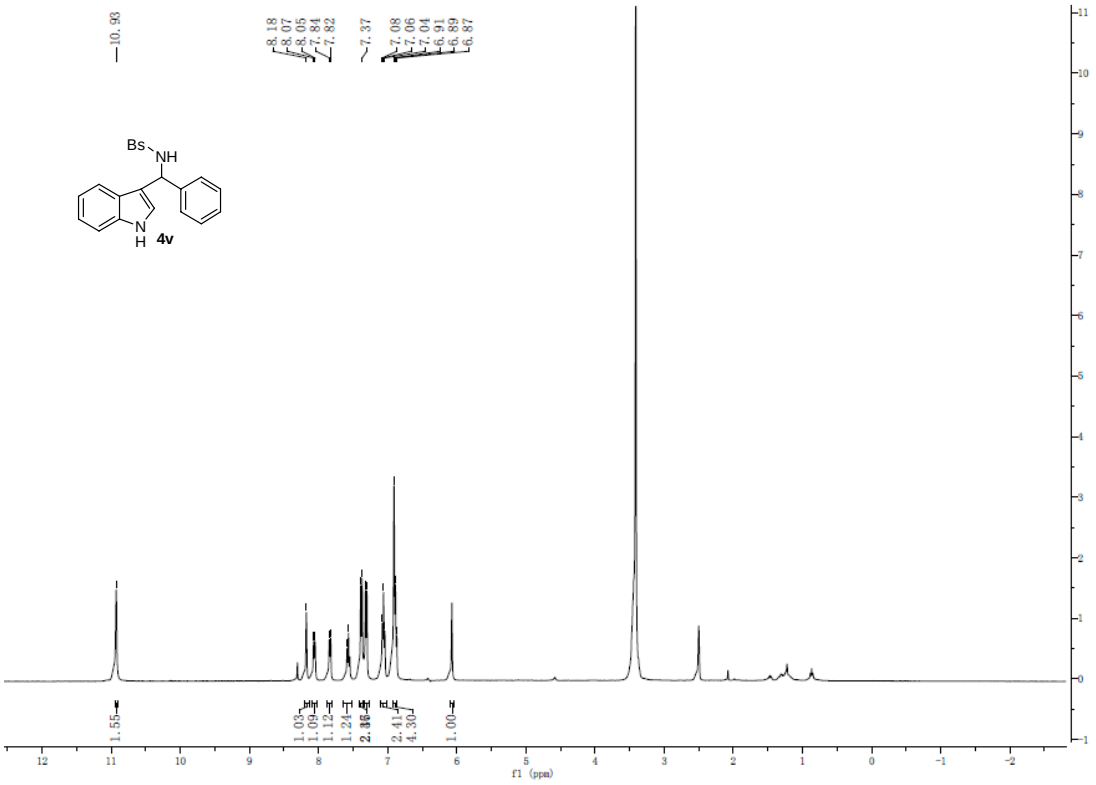
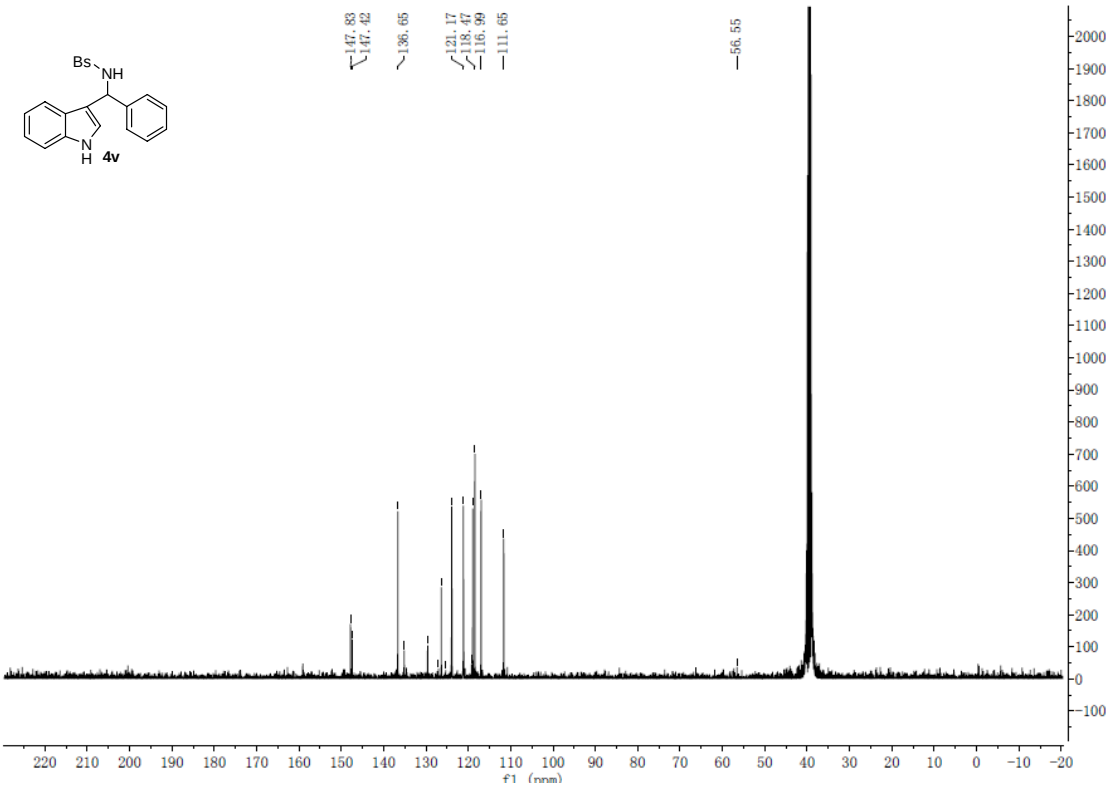
138.83
135.89
128.98
127.93
127.11
126.41
118.82
116.15
104.65
103.96
54.59
20.95
16.76
Ts
NH
N
H
4t
f1 (ppm)

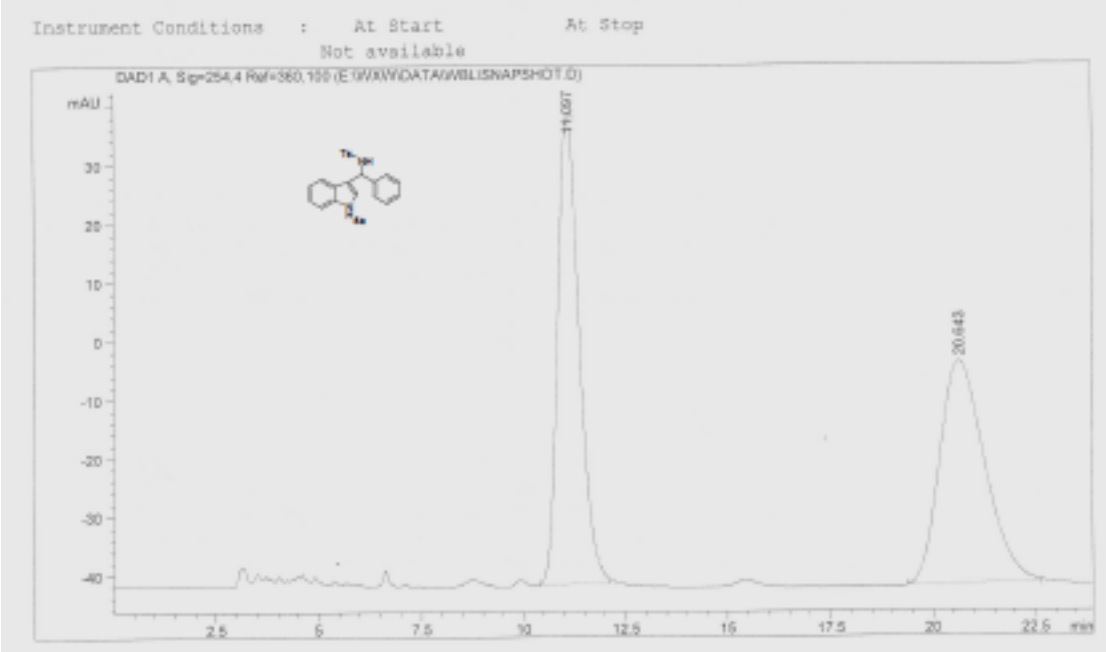





10.93
8.18
8.07
8.05
7.84
7.82
7.37
7.08
7.06
7.04
6.91
6.89
6.87
Bs
NH
N
H
4v
1.55
1.03
1.09
1.12
1.24
2.41
4.30
1.00
f1 (ppm)

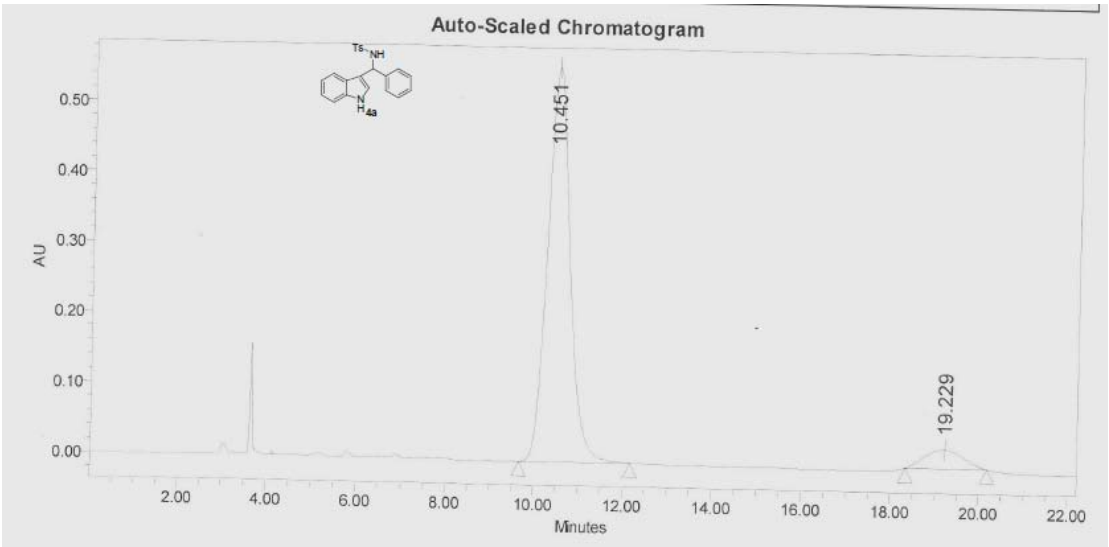

147.83
147.42
136.65
121.17
118.47
116.99
111.65
56.55
Bs
NH
N
H
4v
f1 (ppm)

HPLC spectra for 4a-v:



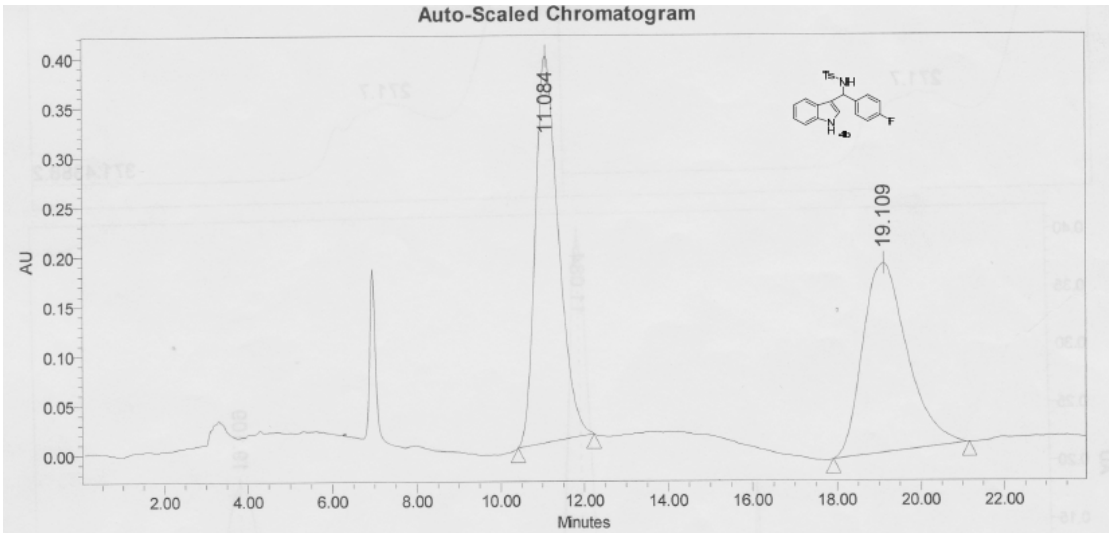
Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.097	BB	0.5673	2930.96729	80.02396	50.4683
2	20.643	BB	1.1609	2876.57886	37.84190	49.5317



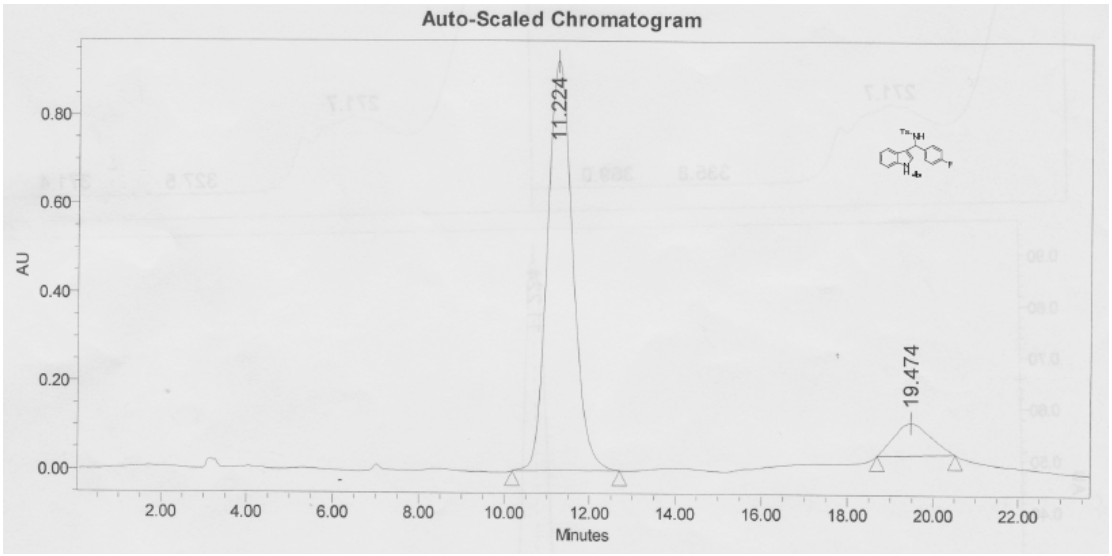
Peak Results

	Name	RT	Area	% Area	Height (µV)	Amount	Units
1		10.451	19788725	92.41	559737		
2		19.229	1625757	7.59	27046		



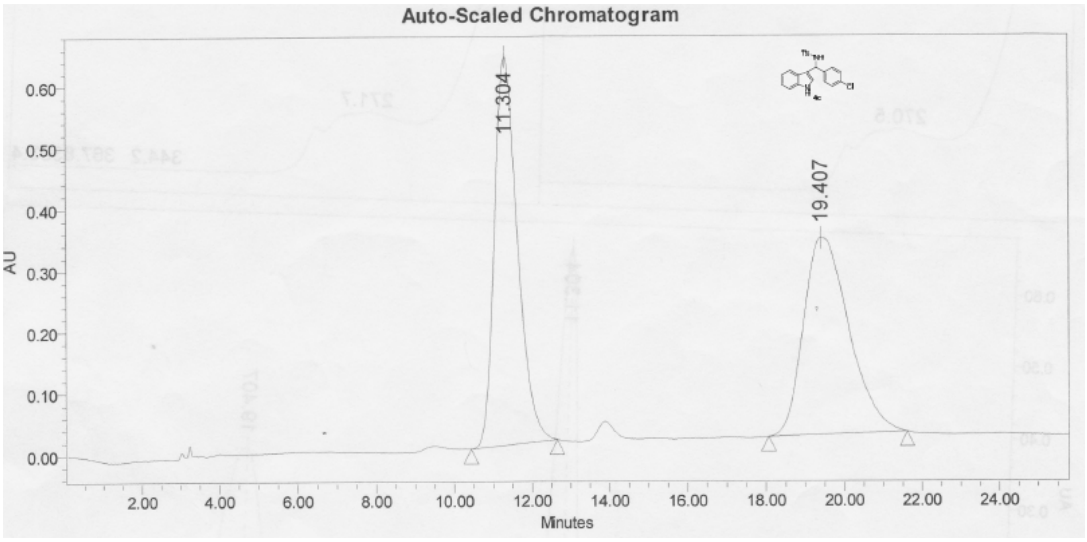
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		11.084	15041987	51.64	389399		
2		19.109	14086879	48.36	190528		



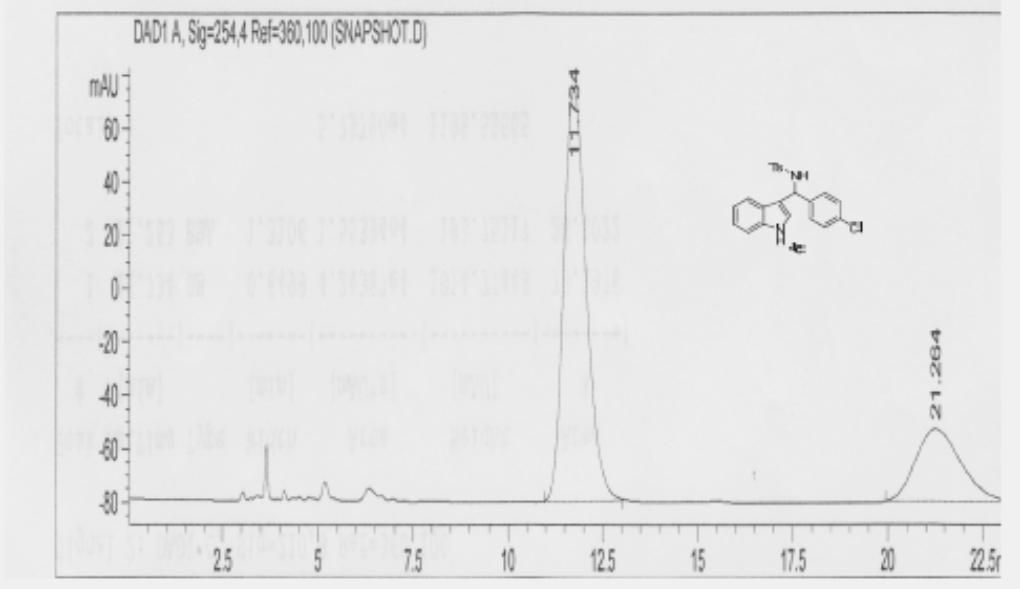
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		11.224	38074034	89.86	922904		
2		19.474	4298315	10.14	72808		



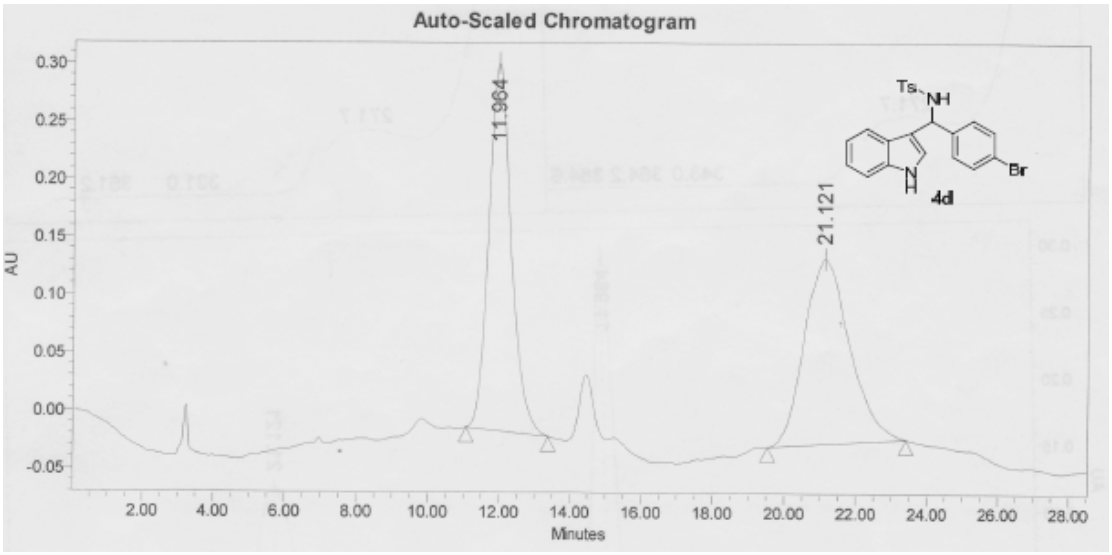
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		11.304	26065372	50.36	631986		
2		19.407	25689703	49.64	318917		



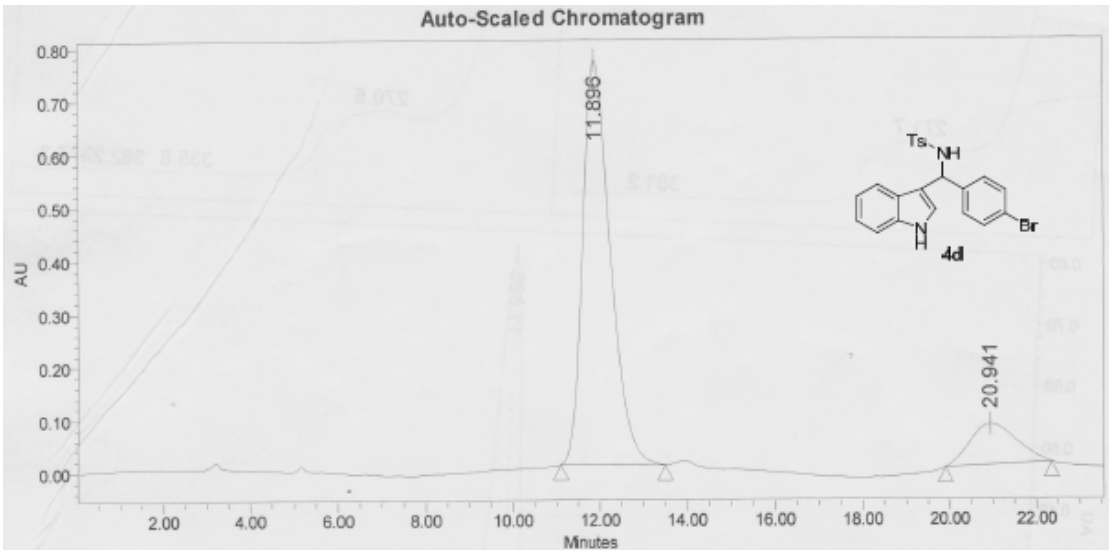
Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.734	BB	0.6388	6392.87451	155.12595	73.9909
2	21.264	BB	1.2775	2247.21143	27.32549	26.0091
Totals :				8640.08594	182.45144	



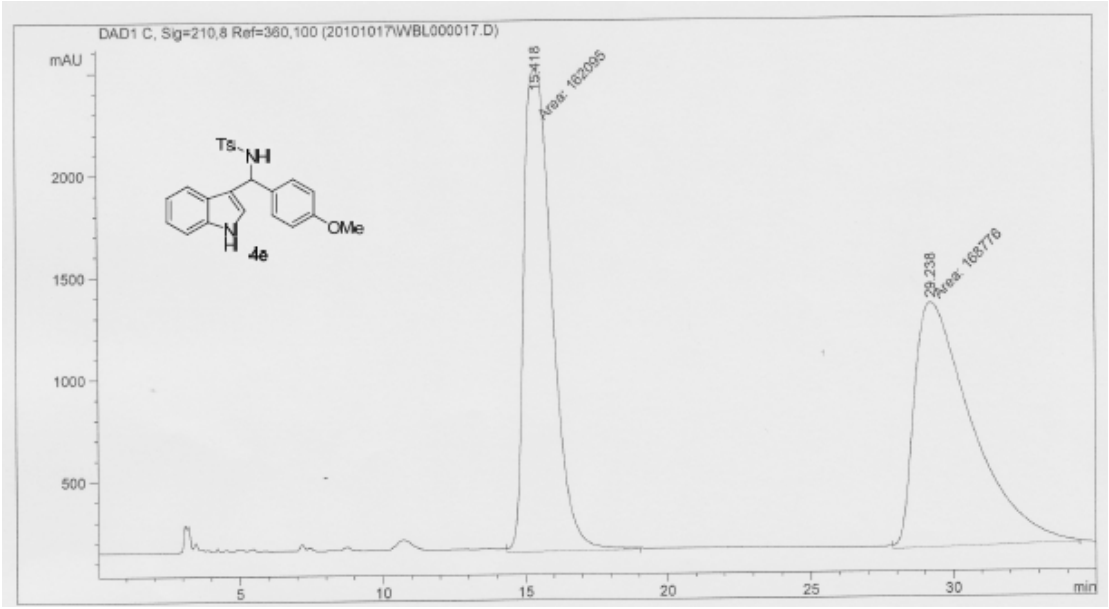
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		11.964	13944399	49.76	317495		
2		21.121	14076166	50.24	159222		



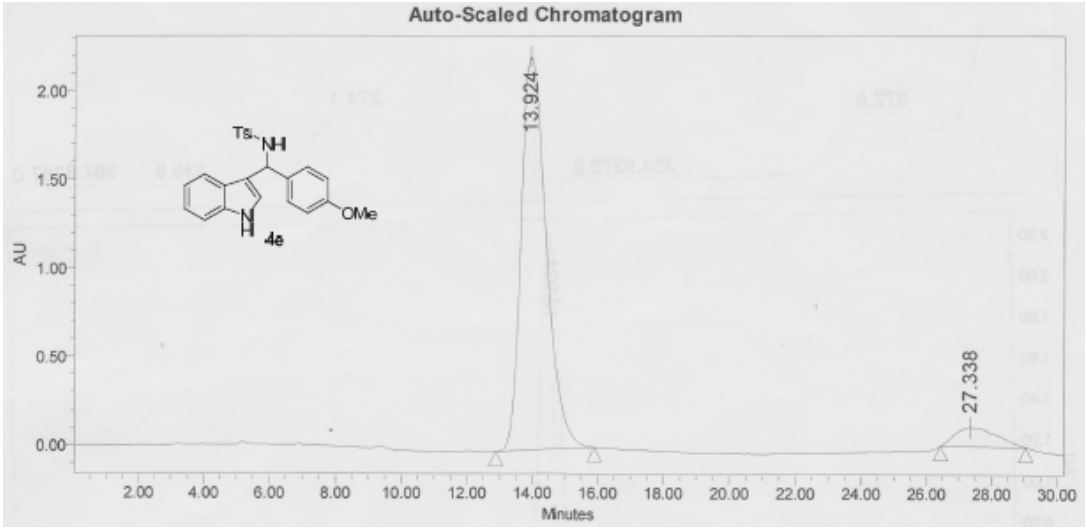
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		11.896	33694463	85.51	761337		
2		20.941	5707367	14.49	76482		



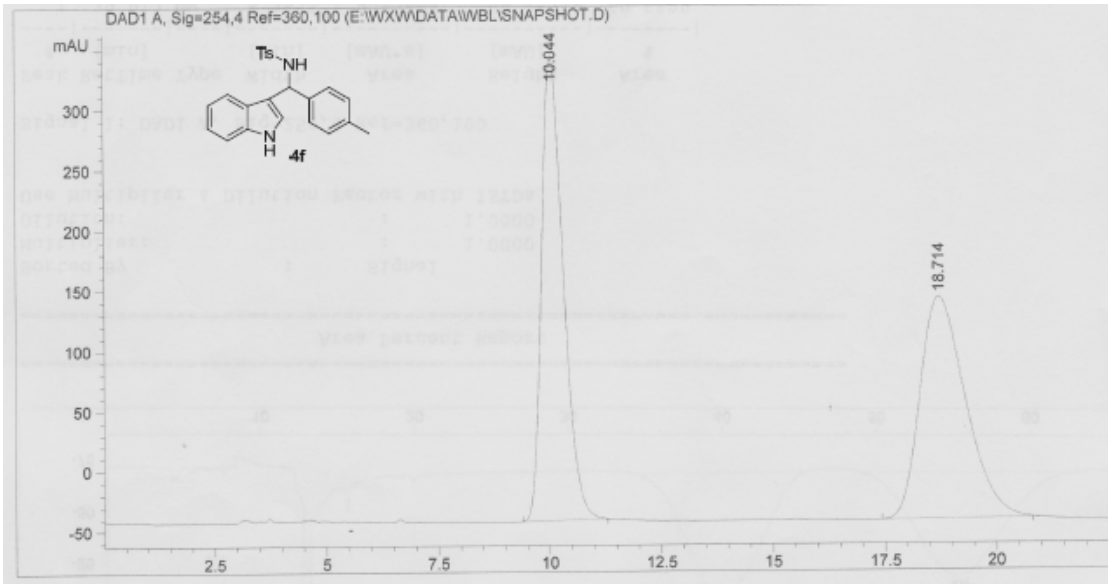
Signal 1: DAD1 C, Sig=210,8 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.418	MM	1.1457	1.62095e5	2357.93604	48.9904
2	29.238	MM	2.3469	1.68776e5	1198.58911	51.0096
Totals :				3.30871e5	3556.52515	



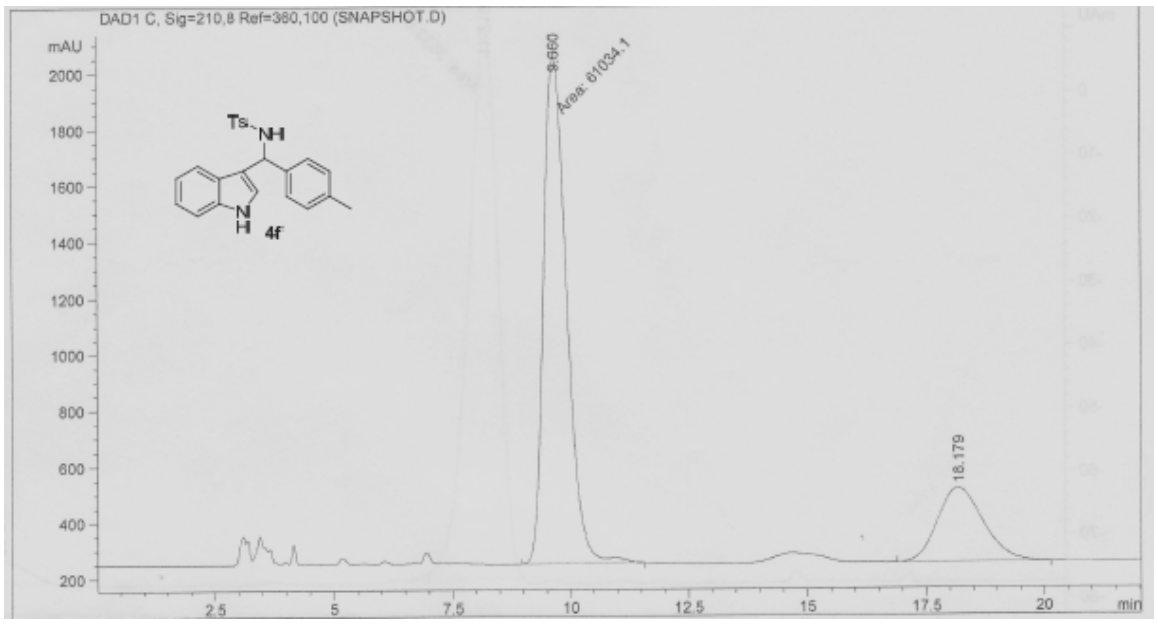
Peak Results

	Name	RT	Area	% Area	Height (µV)	Amount	Units
1		13.924	116306911	92.51	2222470		
2		27.338	9574203	7.49	107641		



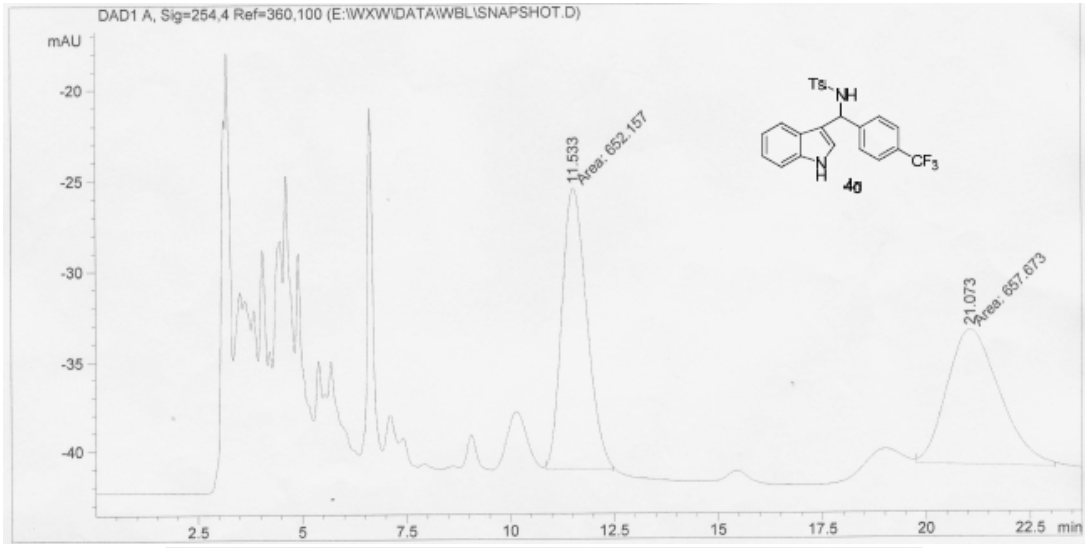
Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.044	BB	0.5228	1.30449e4	385.53177	50.0386
2	18.714	BB	1.0885	1.30248e4	183.40030	49.9614
Totals :				2.60697e4	568.93207	



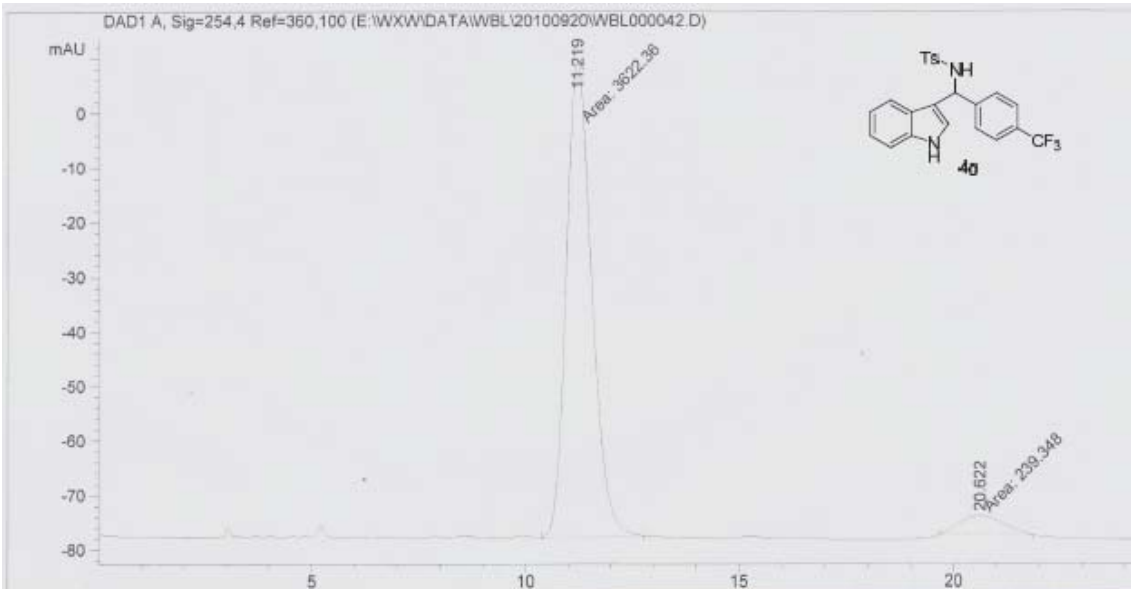
Signal 1: DAD1 C, Sig=210,8 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.660	MM	0.5658	6.10341e4	1797.76428	77.5492
2	18.179	BB	1.0515	1.76696e4	262.43613	22.4508
Totals :				7.87037e4	2060.20041	



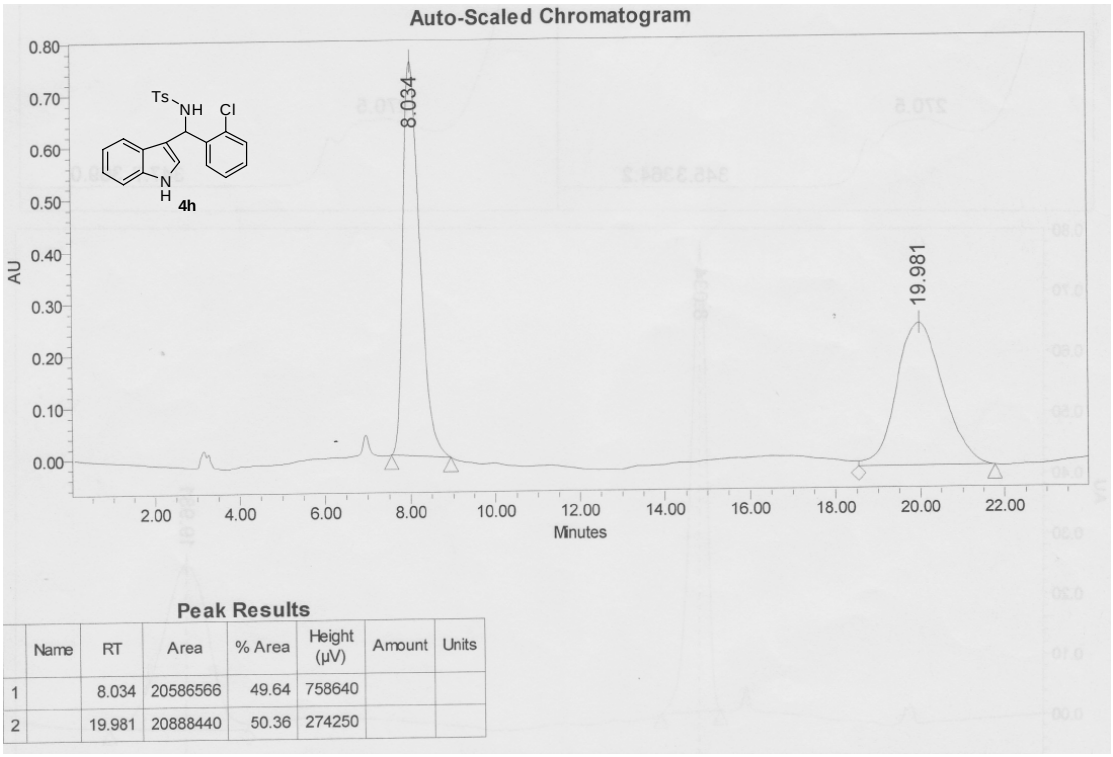
Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.533	MM	0.6975	652.15656	15.58248	49.7894
2	21.073	MM	1.4626	657.67255	7.49431	50.2106



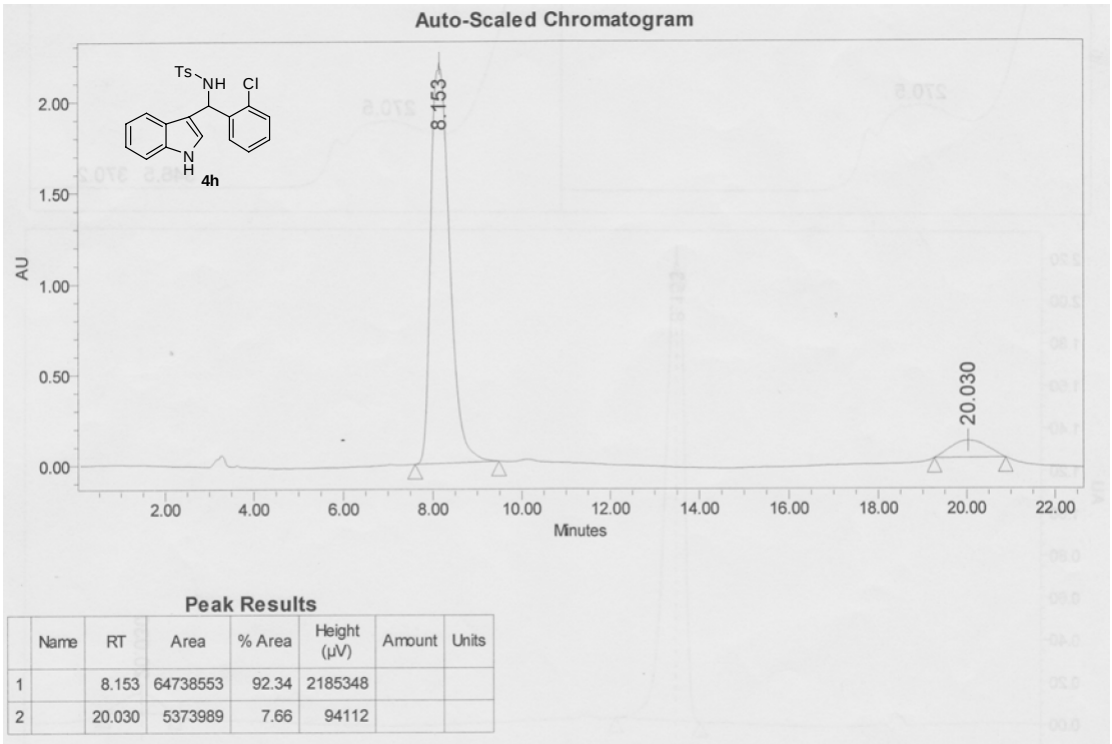
Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.219	MM	0.6953	3622.36304	86.82523	93.8020
2	20.622	MM	1.1824	239.34805	3.37363	6.1980
Totals :				3861.71109	90.19886	



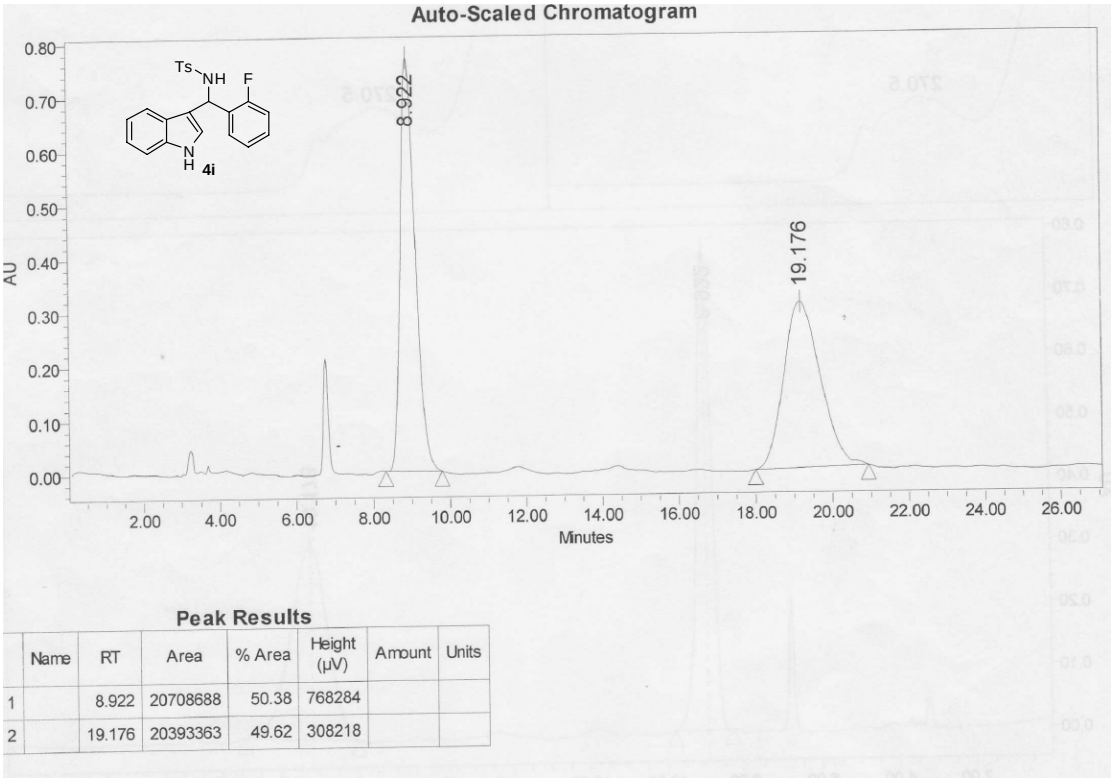
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		8.034	20586566	49.64	758640		
2		19.981	20888440	50.36	274250		



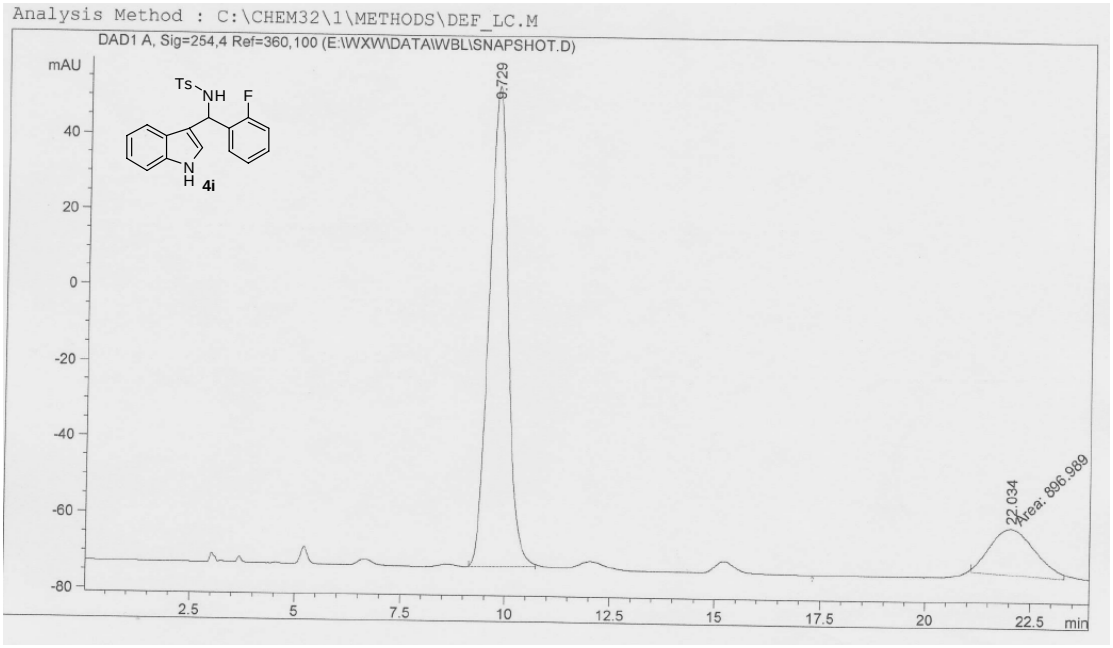
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		8.153	64738553	92.34	2185348		
2		20.030	5373989	7.66	94112		

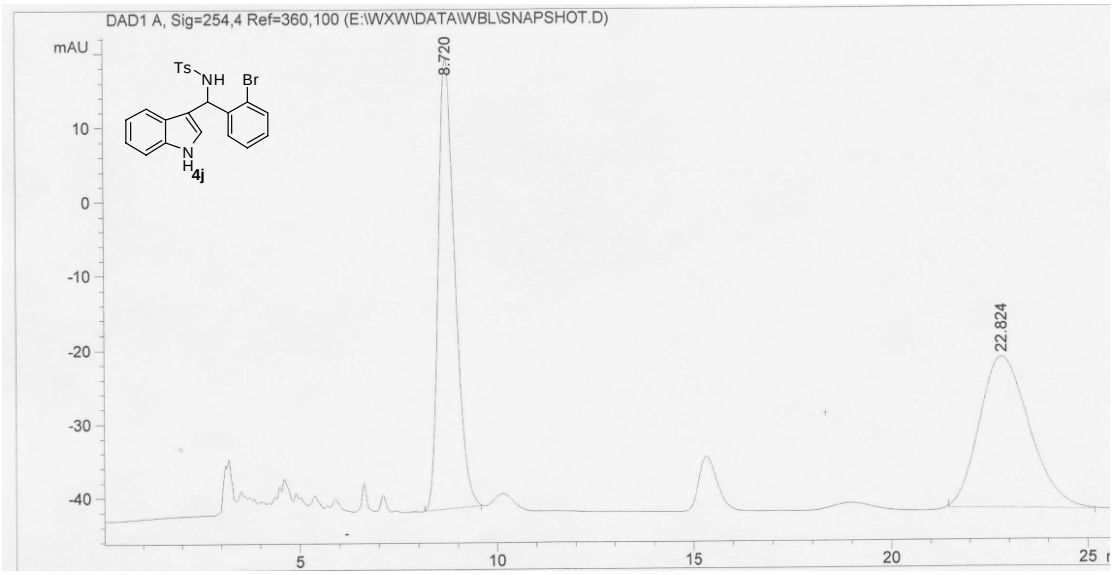


Peak Results

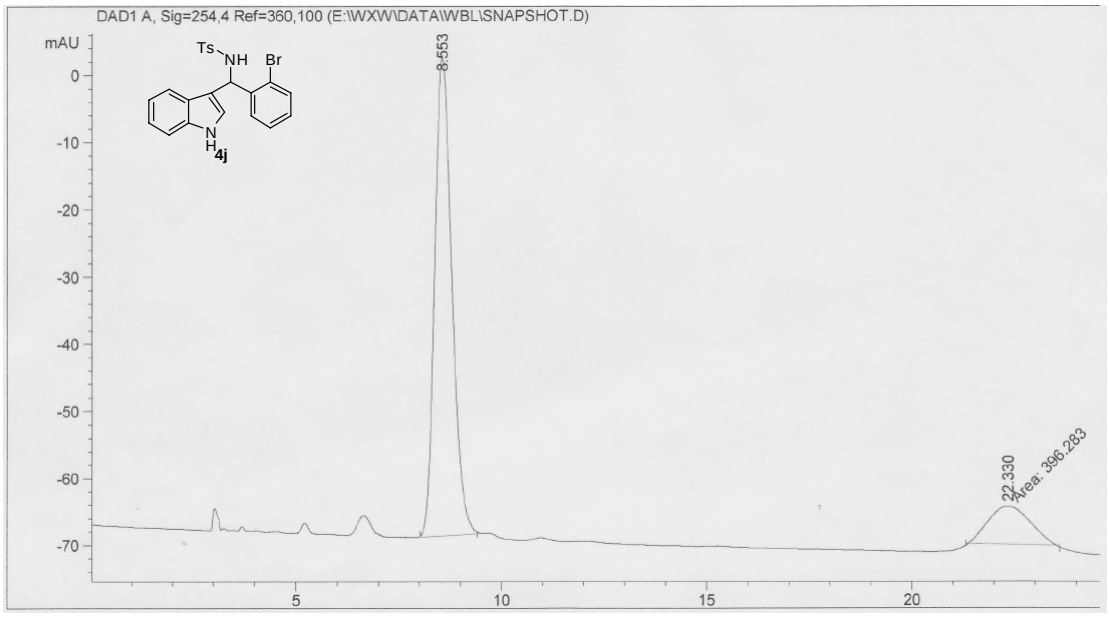
	Name	RT	Area	% Area	Height (µV)	Amount	Units
1		8.922	20708688	50.38	768284		
2		19.176	20393363	49.62	308218		



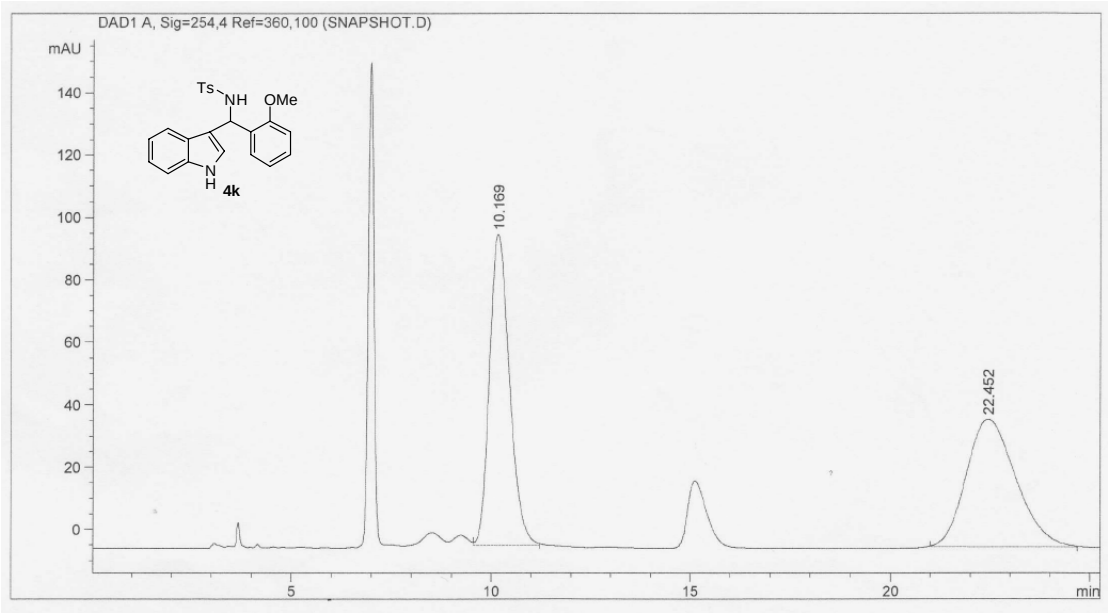
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.729	BB	0.4865	3970.61523	126.38480	81.5723
2	22.034	MM	1.2430	896.98938	12.02678	18.4277



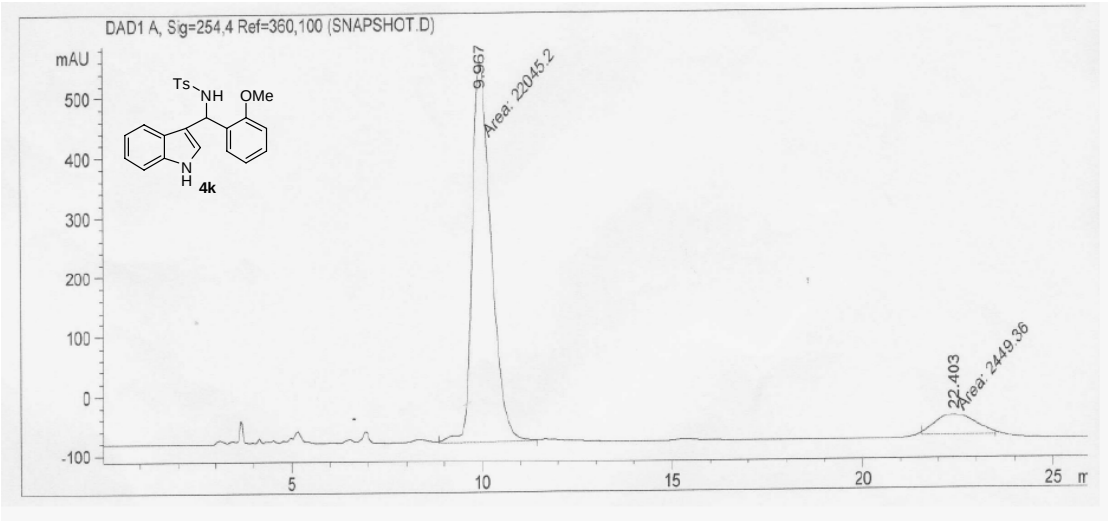
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.720	BB	0.4613	1808.43274	60.74955	50.1153
2	22.824	BB	1.3826	1800.11157	20.37676	49.8847



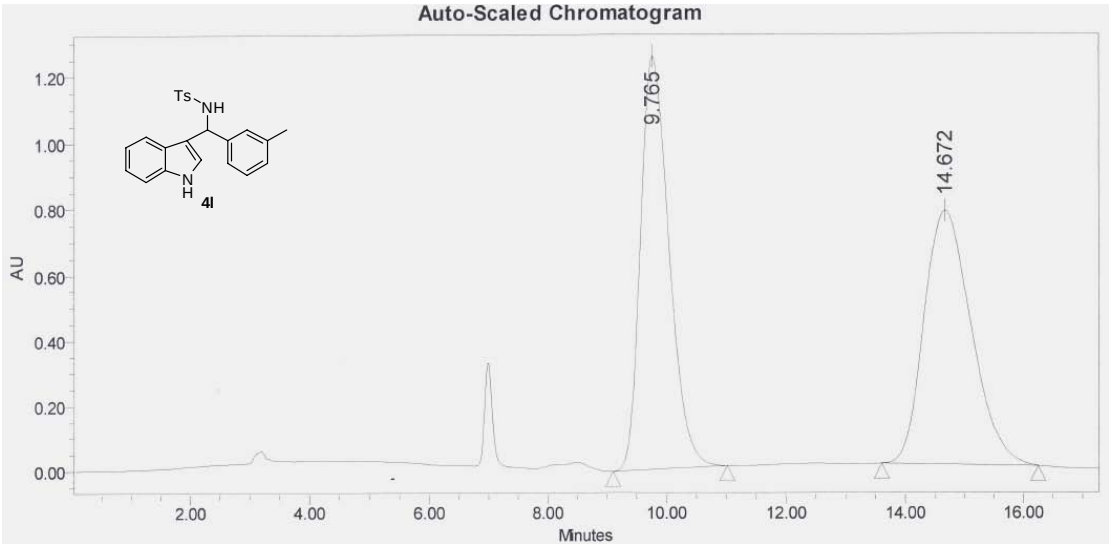
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.553	BB	0.4492	2069.39648	71.17509	83.9280
2	22.330	MM	1.1672	396.28342	5.65869	16.0720



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	10.169	VB	0.5379	3471.28052	99.78627	49.6501
2	22.452	BB	1.3159	3520.20972	40.82874	50.3499

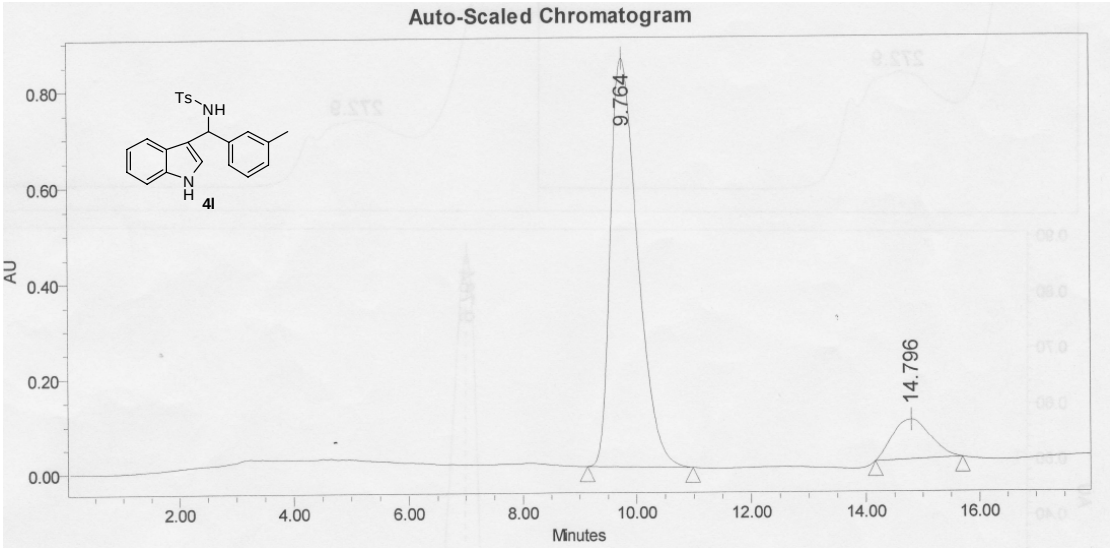


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.967	MM	0.5786	2.20452e4	635.04474	90.0004
2	22.403	MM	1.1948	2449.35645	34.16690	9.9996



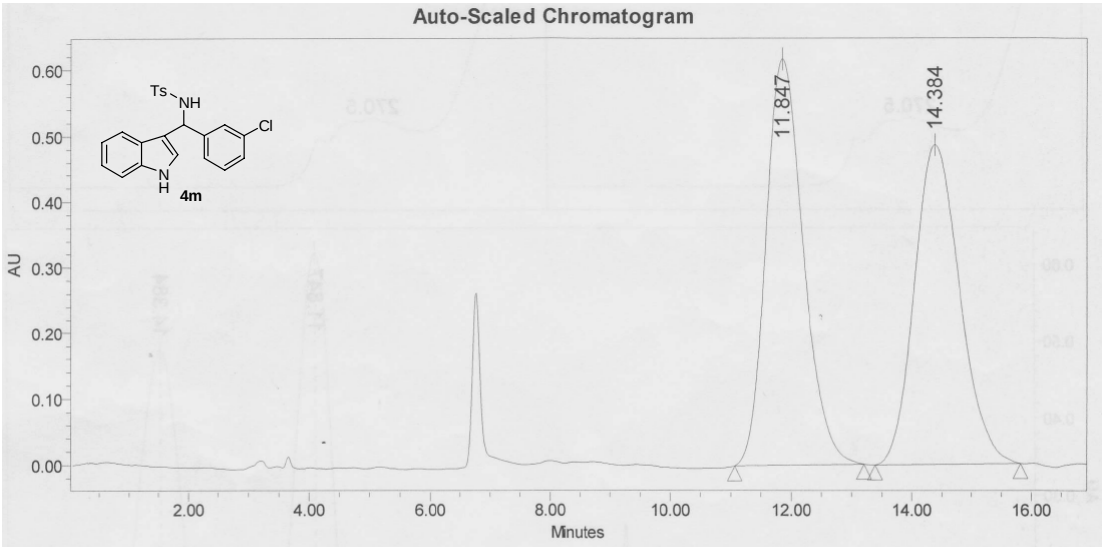
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		9.765	41976772	49.44	1255408		
2		14.672	42926468	50.56	773540		



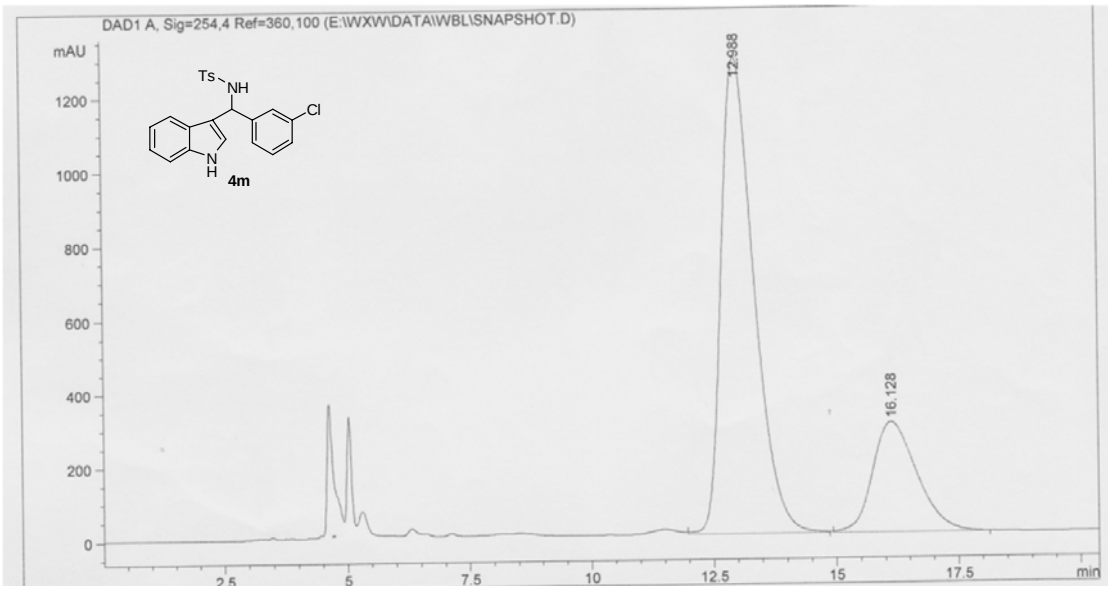
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		9.764	28352839	87.98	853033		
2		14.796	3874288	12.02	83995		

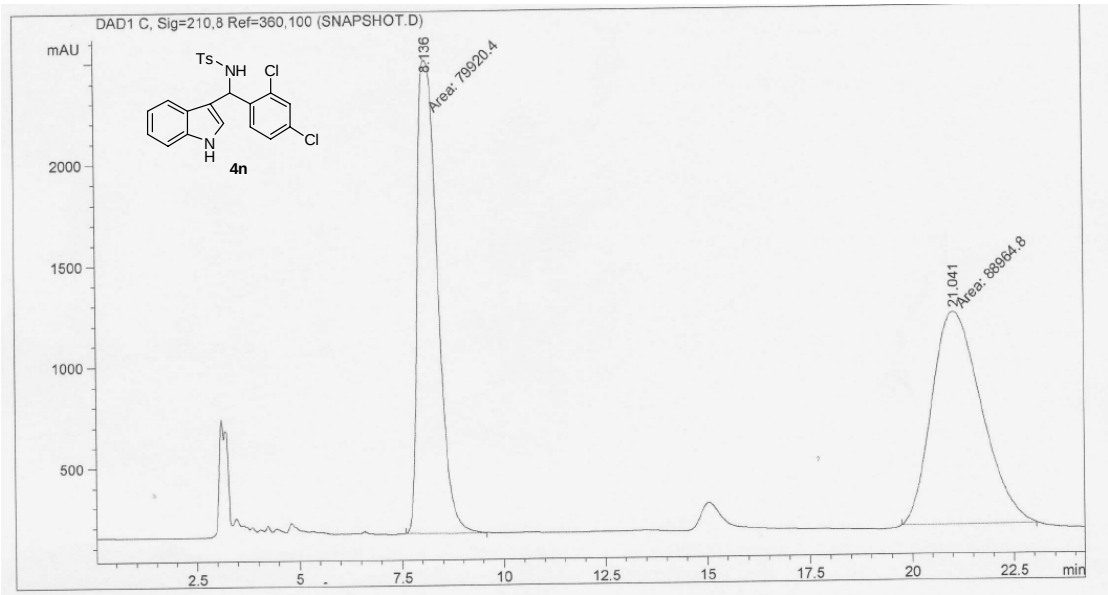


Peak Results

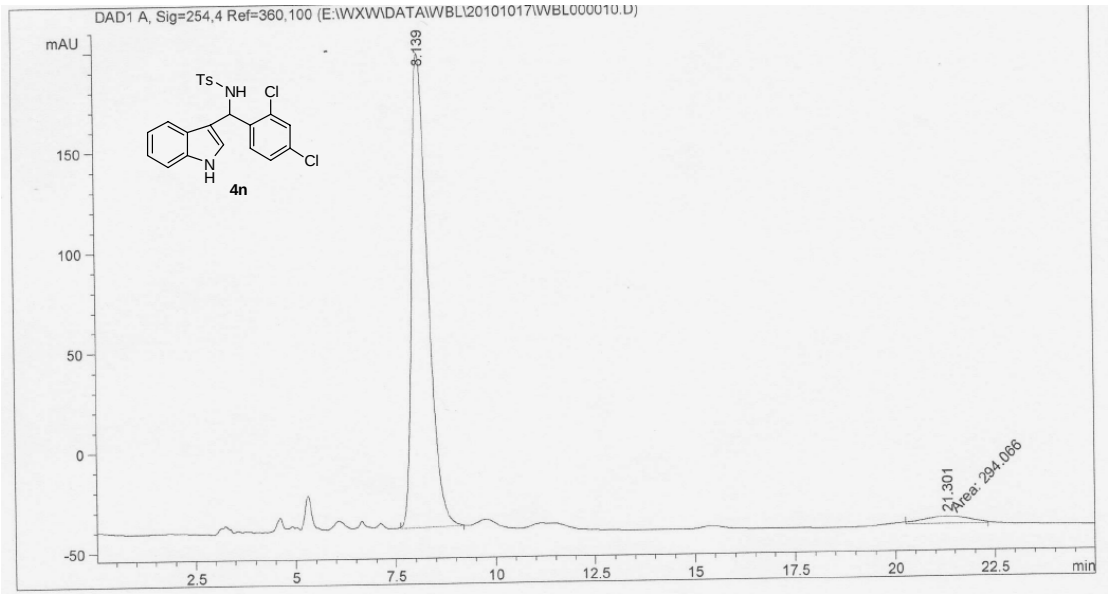
	Name	RT	Area	% Area	Height (µV)	Amount	Units
1		11.847	26428899	50.87	616907		
2		14.384	25526933	49.13	485338		



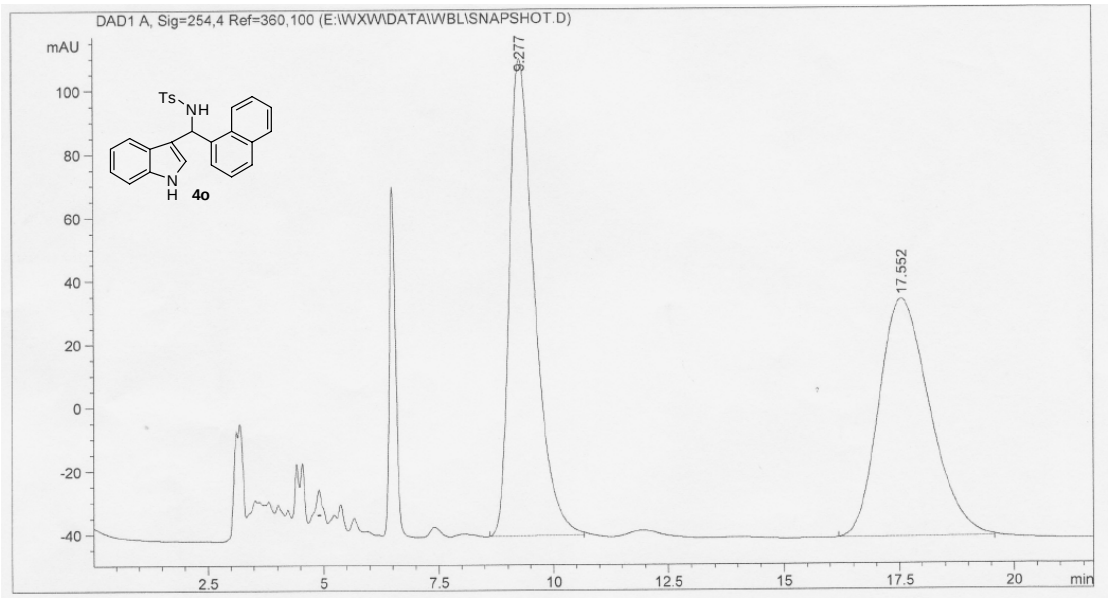
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	12.988	VB	0.7142	5.97189e4	1289.75598	76.2638
2	16.128	BB	0.9671	1.85868e4	296.62292	23.7362



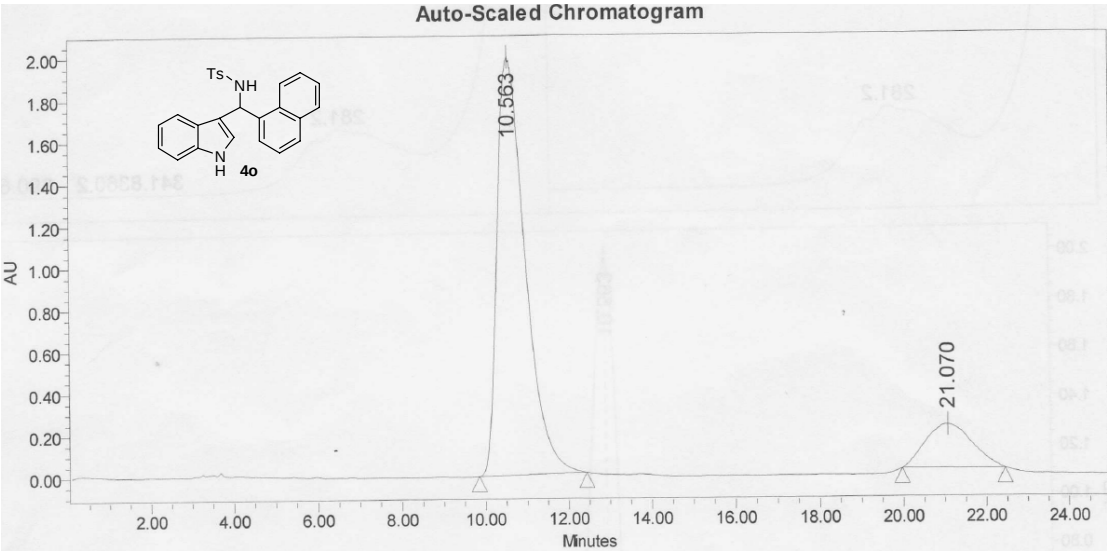
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.136	MM	0.5693	7.99204e4	2339.57178	47.3223
2	21.041	MM	1.4121	8.89648e4	1050.02124	52.6777



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.139	BB	0.4333	6647.92041	236.96684	95.7639
2	21.301	MM	1.3463	294.06607	3.64047	4.2361

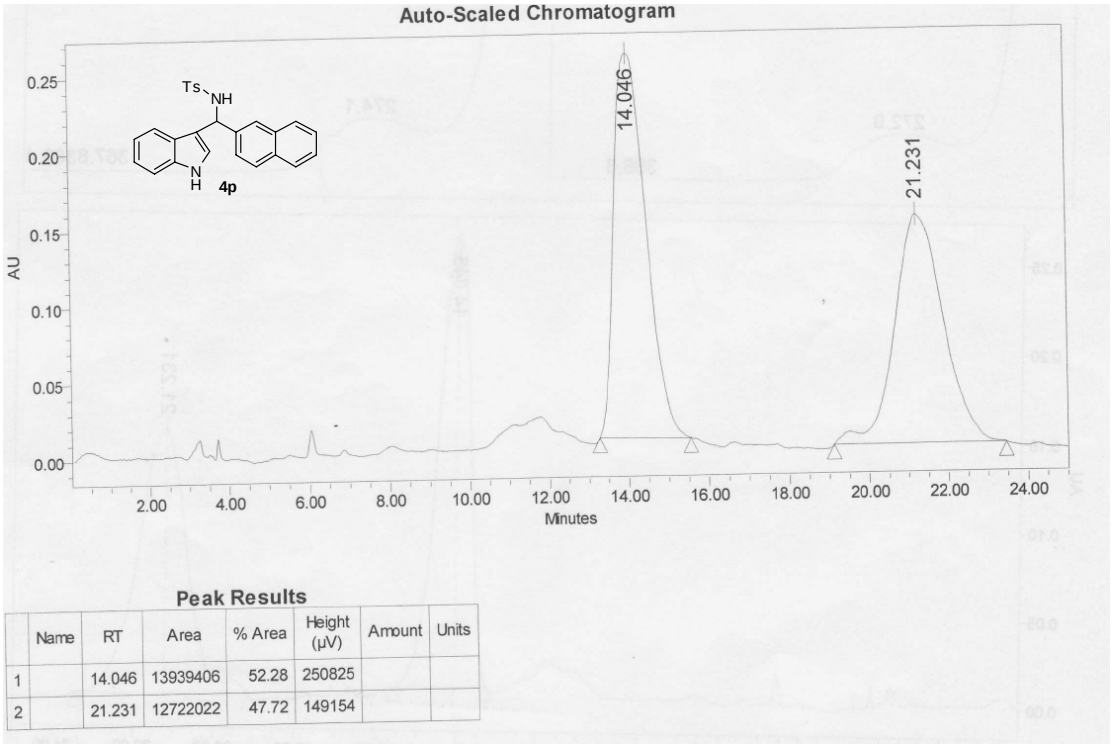


Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.277	BB	0.5781	5697.80859	150.34492	49.7973
2	17.552	BB	1.1855	5744.19922	74.67046	50.2027



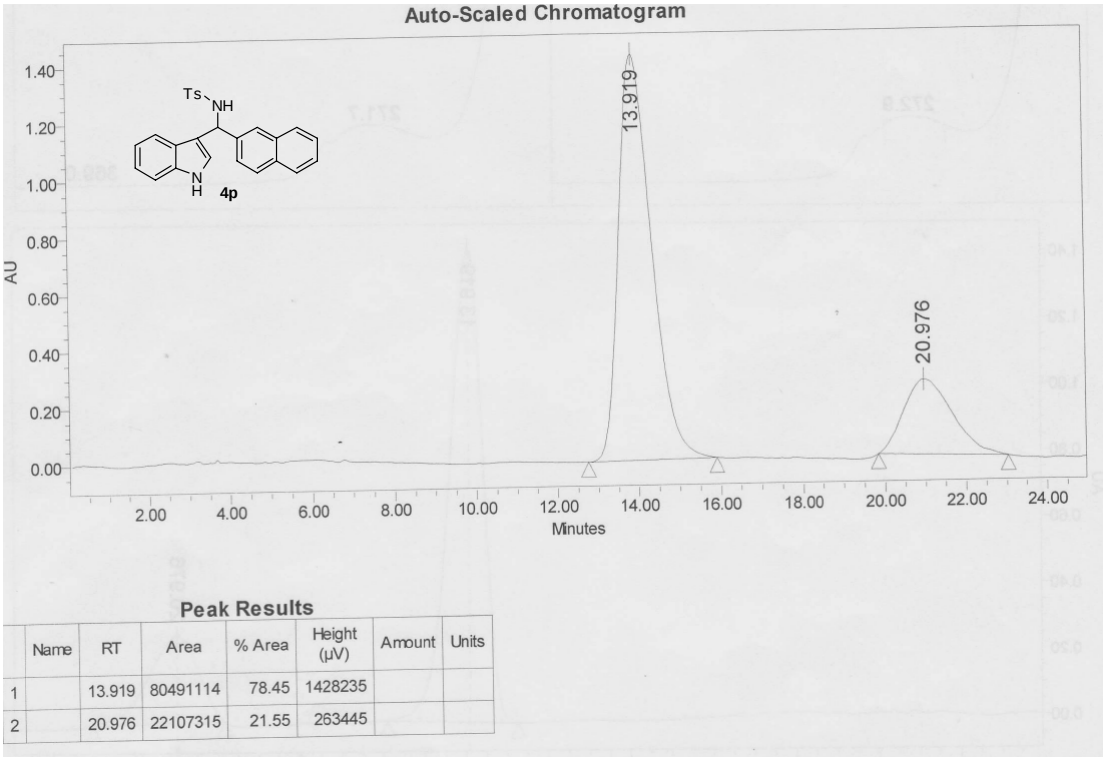
Peak Results

	Name	RT	Area	% Area	Height (µV)	Amount	Units
1		10.563	92772188	85.11	1988181		
2		21.070	16225778	14.89	208550		



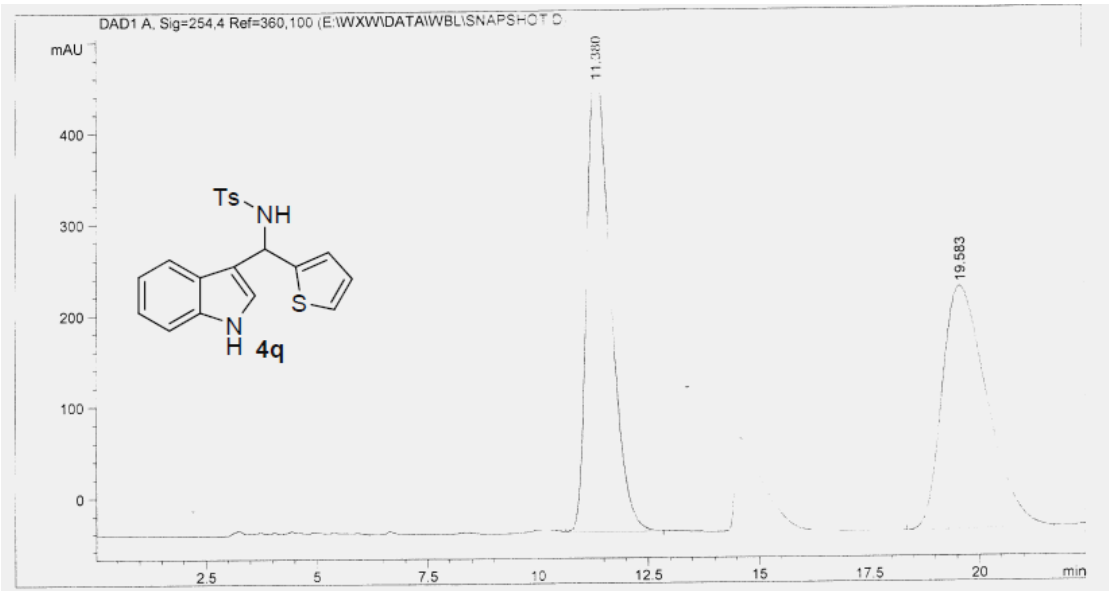
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		14.046	13939406	52.28	250825		
2		21.231	12722022	47.72	149154		



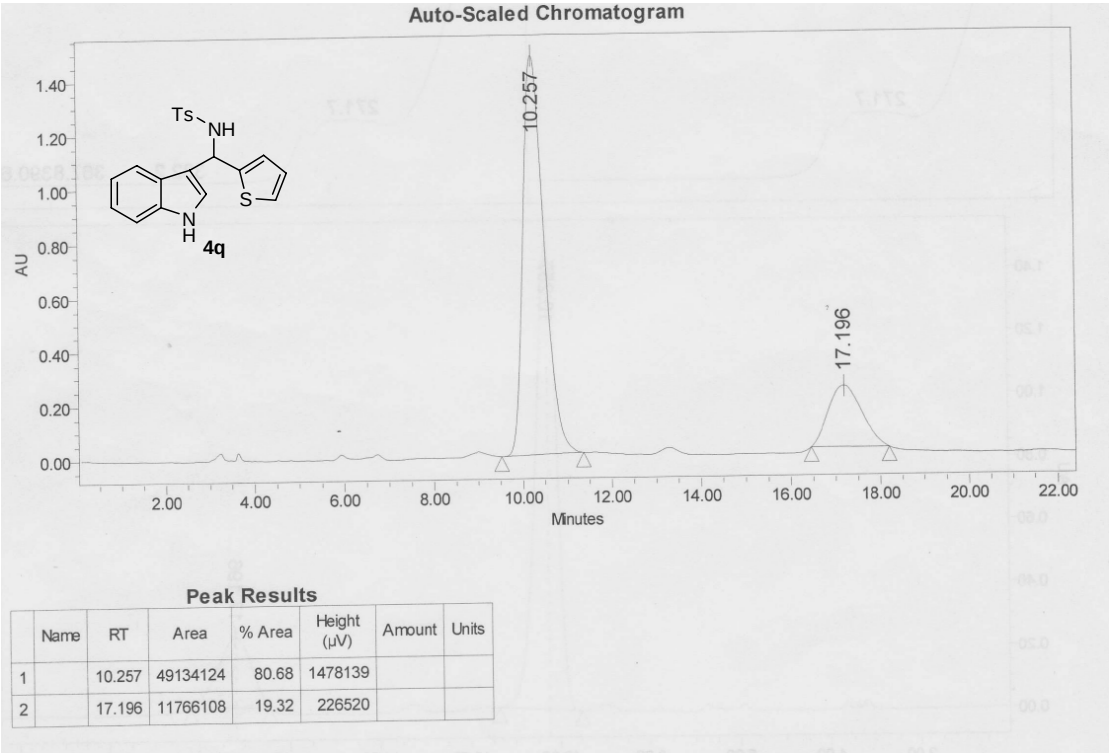
Peak Results

	Name	RT	Area	% Area	Height (μV)	Amount	Units
1		13.919	80491114	78.45	1428235		
2		20.976	22107315	21.55	263445		



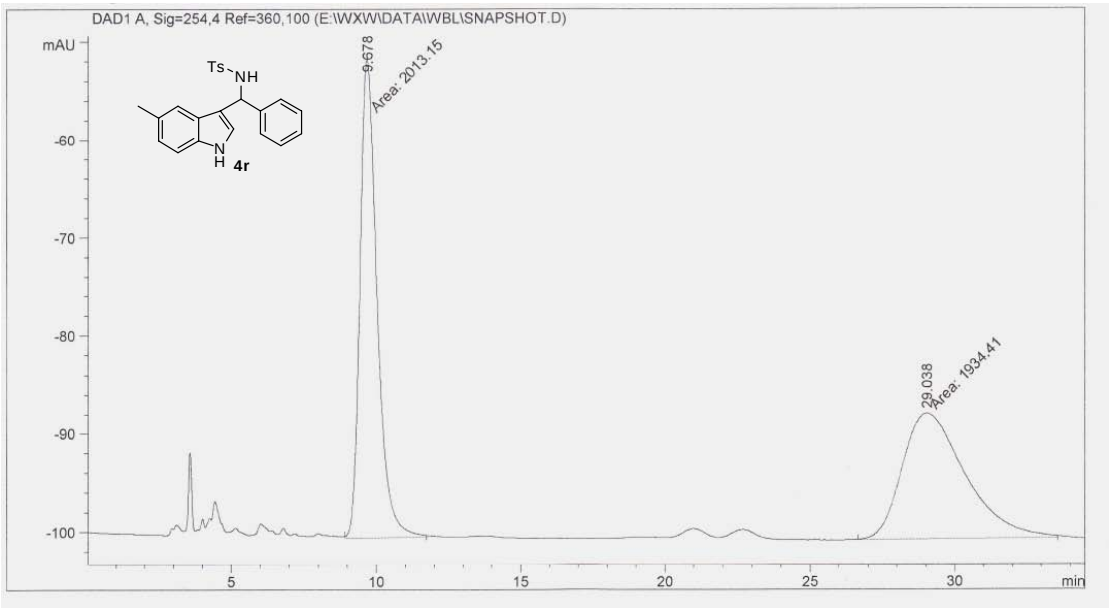
Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.380	VB	0.5722	1.91938e4	518.06628	50.6625
2	19.583	BB	1.0889	1.86918e4	265.64218	49.3375
Totals :				3.78856e4	783.70847	

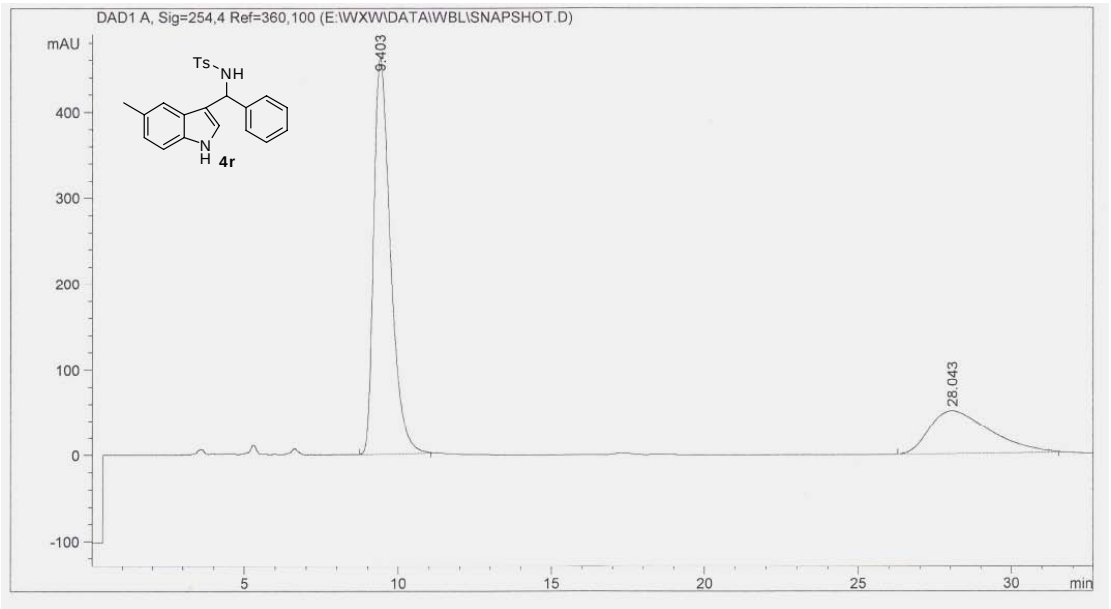


Peak Results

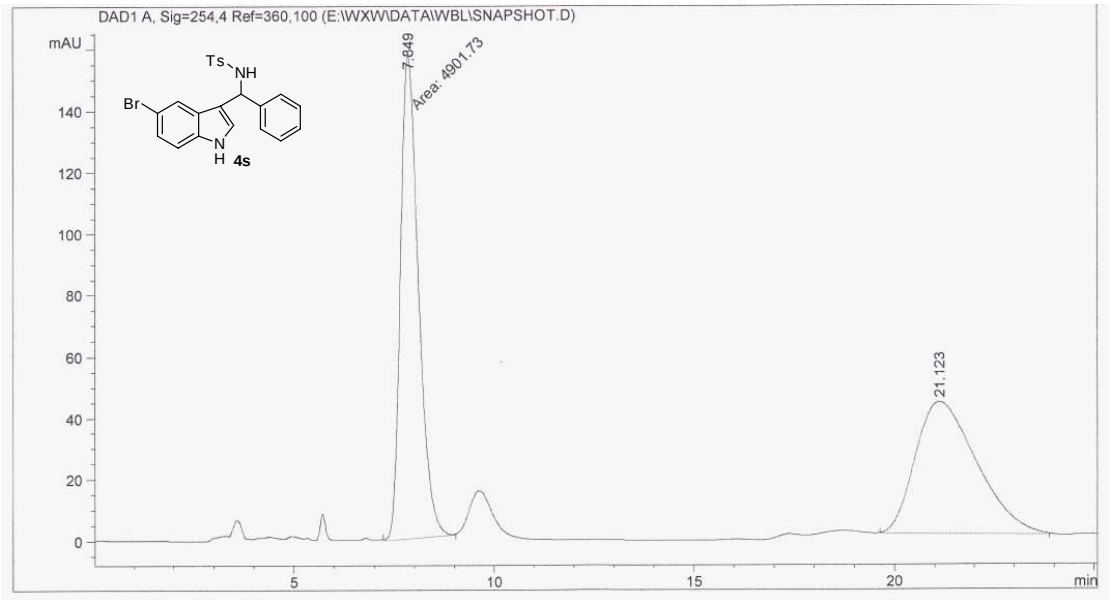
	Name	RT	Area	% Area	Height (µV)	Amount	Units
1		10.257	49134124	80.68	1478139		
2		17.196	11766108	19.32	226520		



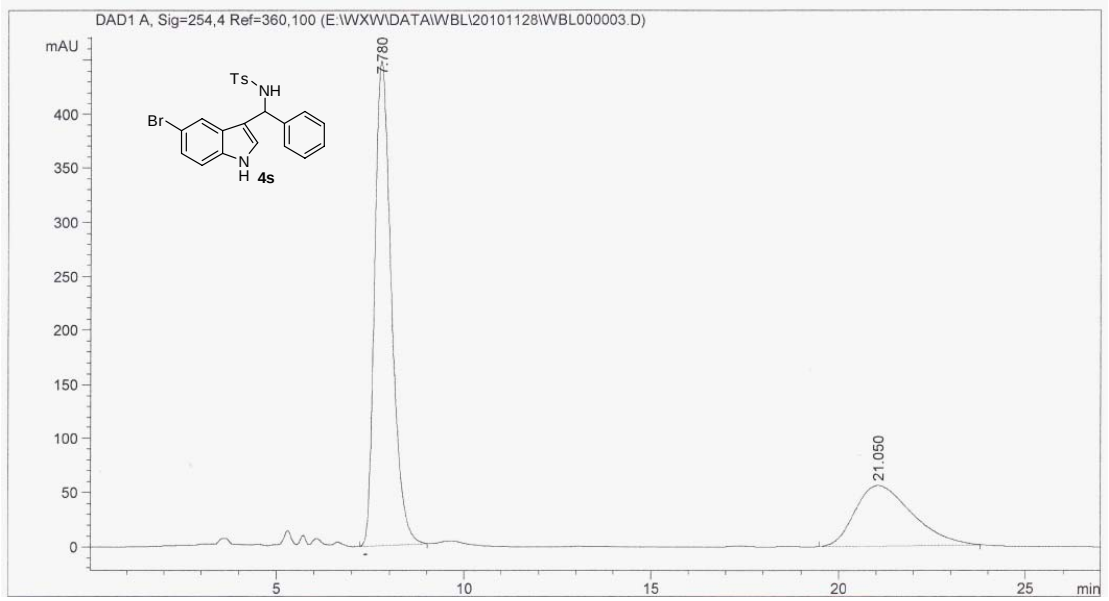
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.678	MM	0.6869	2013.15381	48.84984	50.9974
2	29.038	MM	2.5164	1934.41003	12.81183	49.0026



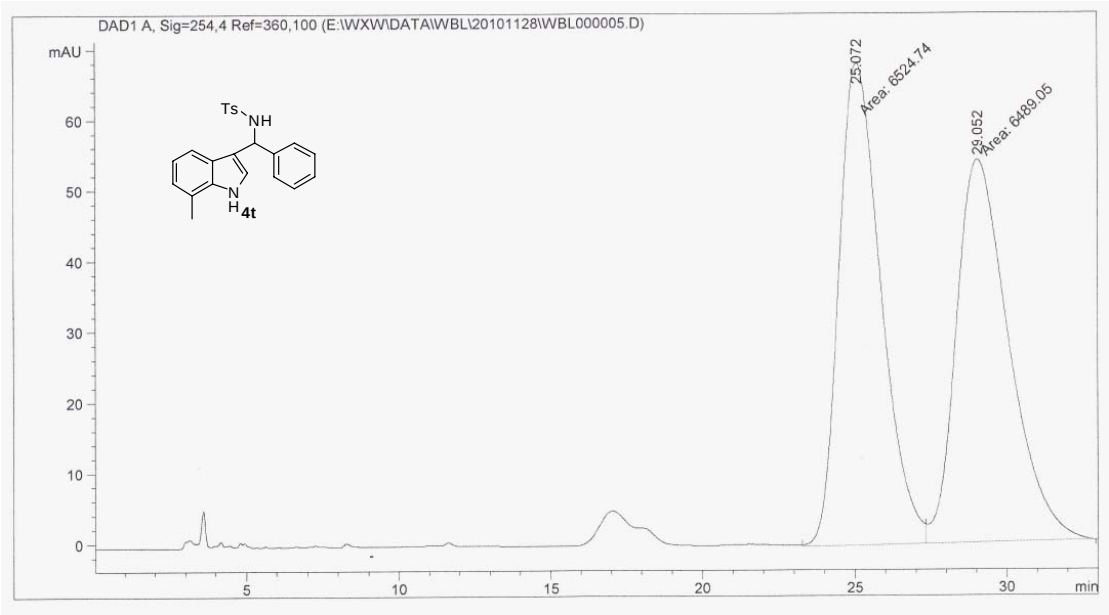
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.403	BB	0.5827	1.75613e4	460.68817	72.1197
2	28.043	BB	1.9176	6788.93701	49.95131	27.8803



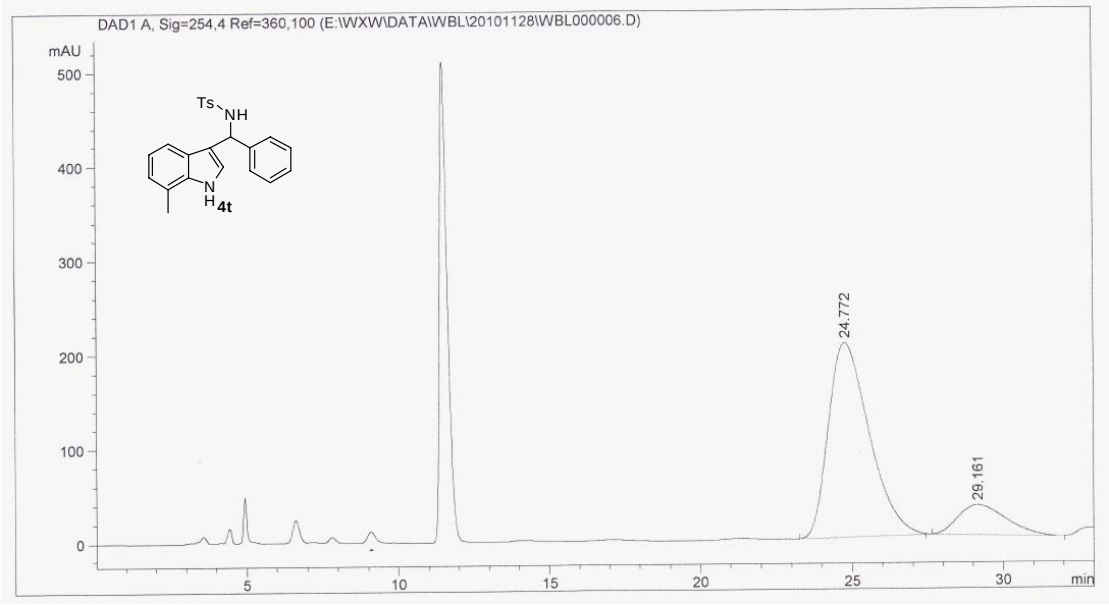
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.849	MM	0.5206	4901.72900	156.93617	51.8431
2	21.123	BB	1.5261	4553.19629	42.90331	48.1569



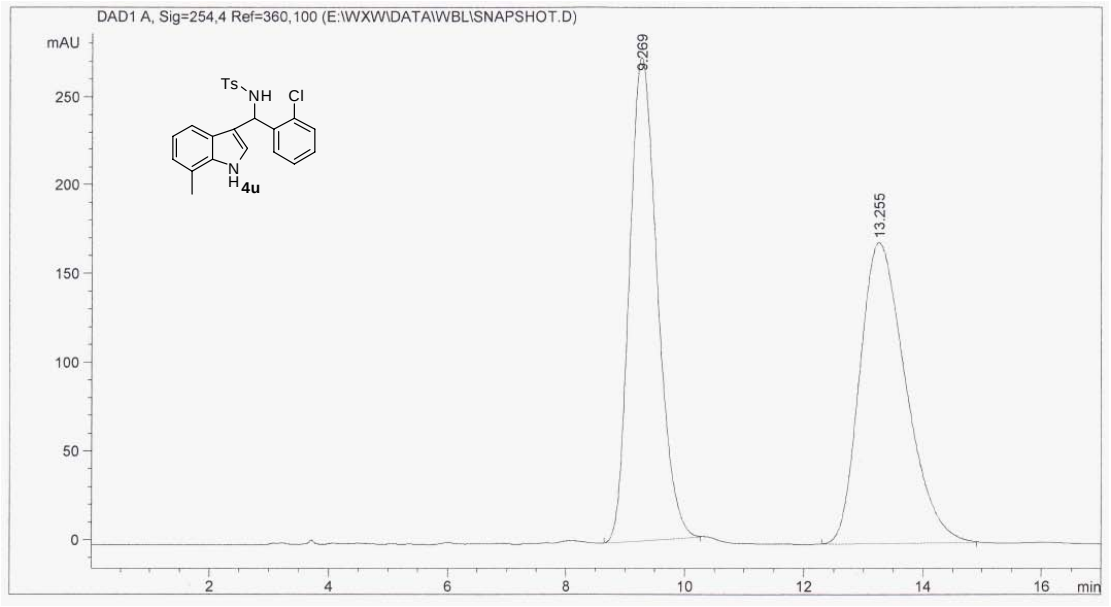
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	7.780	BB	0.4783	1.38951e4	447.40002	70.4390
2	21.050	BB	1.5339	5831.36230	55.22432	29.5610



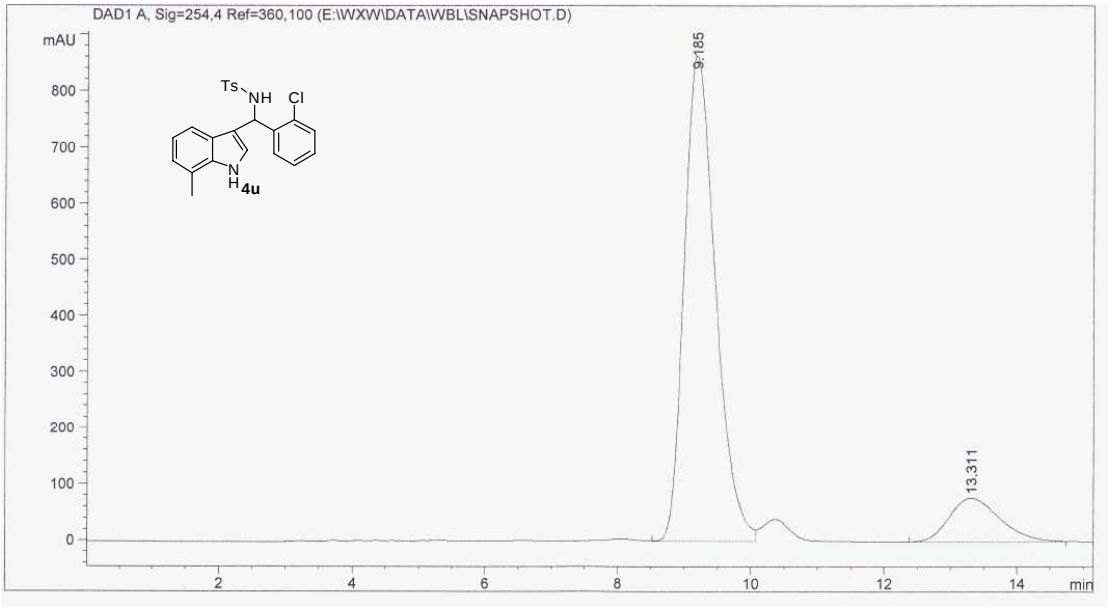
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	25.072	MF	1.5960	6524.73584	68.13607	50.1371
2	29.052	FM	2.0044	6489.05225	53.95677	49.8629



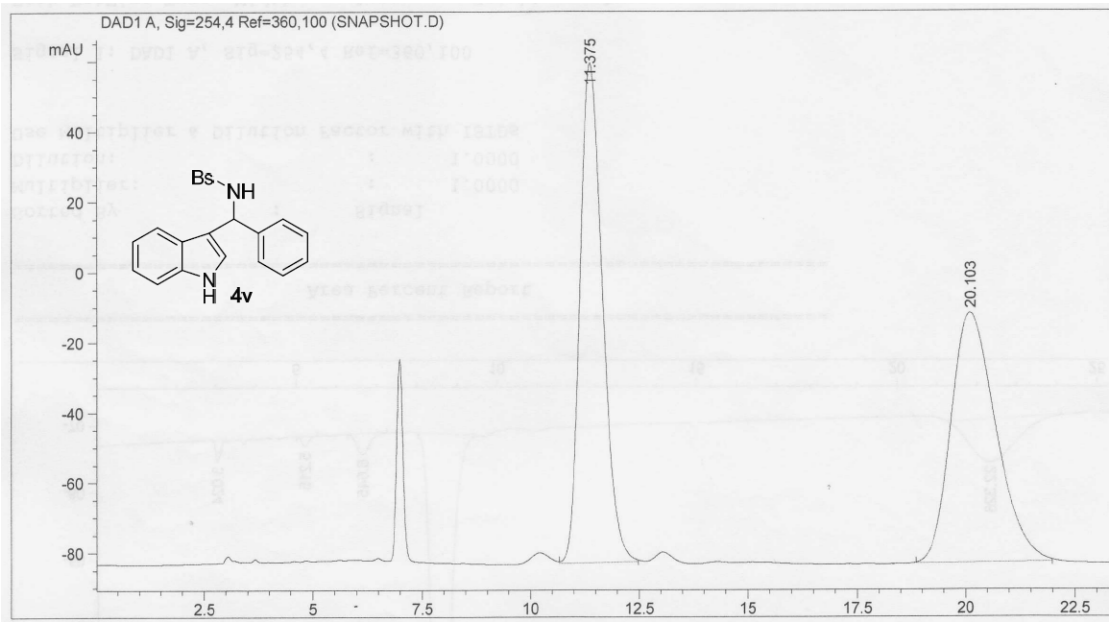
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.772	BB	1.4253	1.92860e4	206.18800	84.7856
2	29.161	BB	1.6099	3460.77954	31.35092	15.2144



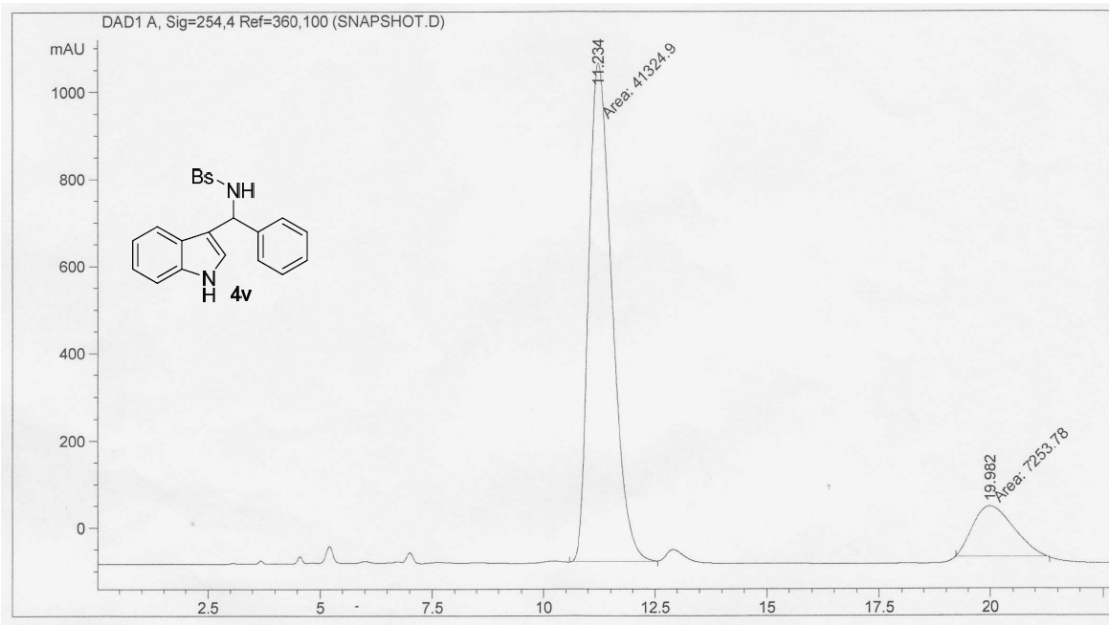
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.269	BB	0.5046	8886.19629	272.41666	49.4492
2	13.255	BB	0.8246	9084.15430	169.12946	50.5508



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	9.185	VV	0.5045	2.83035e4	863.39056	87.3961
2	13.311	BB	0.8236	4081.80273	76.85224	12.6039



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.375	VB	0.5606	5124.65332	142.14076	50.1822
2	20.103	BB	1.1108	5087.43115	70.93317	49.8178



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.234	MM	0.6028	4.13249e4	1142.60632	85.0680
2	19.982	MM	1.0500	7253.77637	115.13707	14.9320