Electronic Supplementary Material (ESI) for Chemical Science.

Supporting Information

Oxidative Organocatalysed Enantioselective Coupling of Indoles with Aldehydes that Forms Quaternary Carbon Stereocentres

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1. General Methods

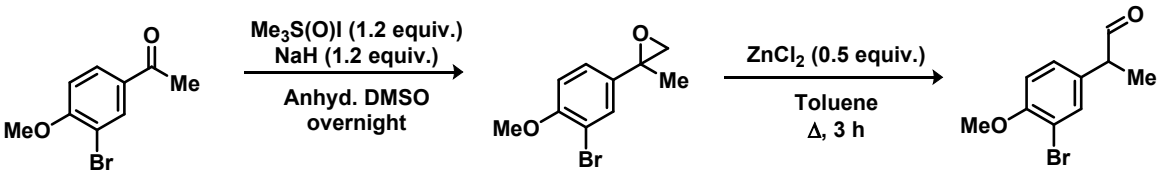
NMR spectra were acquired on a Bruker AVANCE III HD spectrometer running at 400 MHz for ^{1}H, 100 MHz for ^{13}C and 376 MHz for ^{19}F. Chemical shifts (δ) are reported in ppm relative to residual solvent signals ($CHCl_3$, 7.26 ppm for ^{1}H NMR; $CDCl_3$, 77.16 ppm for ^{13}C NMR). Chemical shifts (δ) for ^{19}F NMR are reported in ppm relative to $CFCl_3$ as external reference. The following abbreviations are used to indicate the multiplicity in NMR spectra: s, singlet; d, doublet; t, triplet; q, quartet; p, pentet; dd, double doublet; ddd, double double doublet; dt, double triplet; td, triple doublet; tt, triple triplet; m, multiplet; bs, broad signal. ^{13}C NMR spectra were acquired in a broad band decoupled mode. Mass spectra were recorded on a Bruker MicroTOF-Q High-Performance LC-MS system using electrospray (ES^+) ionisation. Dichloromethane was dried over molecular sieves (4 Å). Analytical thin layer chromatography (TLC) was performed using pre-coated aluminium-backed plates (Merck Kieselgel 60 F_{254}) and visualised by UV radiation, *p*-anisaldehyde stain or 2,4-DNPH stain. For flash chromatography (FC) Iatrobeads were used. Optical rotations were measured on a Bellingham + Stanley ADP440+ polarimeter, [α] values are given in $deg \cdot cm^3 \cdot g^{-1} \cdot dm^{-1}$; concentration c in $g \cdot (100\ mL)^{-1}$. The enantiomeric excess (ee) of the products was determined by chiral stationary phase Waters ACQUITY UPC^2 (Daicel Chiralpak). H_2-DDQ was synthesised according to literature procedure.[1] Racemic samples for UPC^2 analysis were prepared using achiral 1-(2-aminoethyl)piperidine **3h** as catalyst.

1. C. Qiu, L. Jin, Z. Huang, Z. Tang, A. Lei, Z. Shen, N. Sun, W. Mo, B. Hu, X. Hu, *ChemCatChem* 2012, **4**, 76-80.

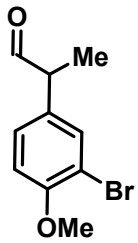
2. Synthesis of Starting Materials

2.1 Synthesis of Aldehydes

Aldehydes **1a**,**m**-**o**,**s**,**u** were prepared according to a known literature procedure.[2] Aldehyde **1r** is commercially available and was purified by FC before use. Aldehydes **1q**,**r**,**t** were prepared according to known literature procedures.[3] All aldehydes were stored at -20 °C under an Ar atmosphere.



To a stirring solution of NaH (60% in mineral oil, 1.05 g, 26.2 mmol) in dry DMSO (30 mL), $Me_3S(O)I$ (5.76 g, 26.2 mmol) was added at RT. The reaction mixture was left stirring for 1 h at RT. 3-Bromo-4-methoxyacetophenone (5.00 g, 21.8 mmol) was added portion-wise and the reaction mixture was left stirring overnight. The reaction mixture was diluted with H_2O (40 mL), followed by extractions with EtOAc (3 x 40 mL). The combined organic phases were dried over Na_2SO_4 and the solvent was evaporated under vacuum to yield the crude epoxide. The epoxide was used without further purification.



4q

Toluene (28 mL) was added to a round bottom flask equipped with the epoxide, $ZnCl_2$ (1.49 g, 10.9 mmol), and stir bar. The resulting solution was heated and held at reflux for 3 h. Subsequent solvent removal and purification *via* FC on silica gel (CH_2Cl_2:pentane 75%) yielded the desired product (1.2 g, 23%).

^{1}H NMR (400 MHz, $CDCl_3$): δ 9.64 (d, *J* = 1.5 Hz, 1H), 7.40 (d, *J* = 2.3 Hz, 1H), 7.11 (dd, *J* = 8.4, 2.3 Hz, 1H), 6.90 (d, *J* = 8.4 Hz, 1H), 3.90 (s, 3H), 3.56 (q, *J* = 7.0 Hz, 1H), 1.42 (d, *J* = 7.0 Hz, 3H).
^{13}C NMR (100 MHz, $CDCl_3$): δ 200.7, 155.5, 133.2, 131.2, 128.5, 112.5, 112.4, 56.5, 51.9, 14.8.
HRMS (ESI+) *m/z* calcd. for $C_{10}H_{12}BrO_2$ $[M+H]^+$: 243.0015; found: 243.0014.

2. X. Mo, D. G. Hall, *J. Am. Chem. Soc.* 2016, **138**, 10762-10765.
3. D. Destro, S. Sanchez, M. Cortigiani, M. F. A. Adamo, *Org. Biomol. Chem*. 2017, **15**, 5227-5235.

2.2 Synthesis of Catalysts

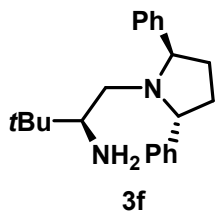
Synthesis of aminocatalysts **3d**,**e** were performed using literature procedures[4,5] and analytical data were found to be in accordance with the previously reported values.[6]

Synthesis of aminocatalyst **3f** is not reported in the literature references and characterisation data have been provided.

Boc-L-*tert*-leucine (1.00 g, 4.32 mmol, 1.00 equiv.) was dissolved in dry CH_2Cl_2 (7.0 mL) and cooled to 0 °C. A solution of DCC (936 mg, 4.54 mmol, 1.05 equiv.) in dry CH_2Cl_2 (5.0 mL) was slowly added. The mixture was stirred for 30 min. before (2*R*,5*R*)-2,5-diphenylpyrrolidine (965 mg, 4.32 mmol, 1.00 equiv.) in CH_2Cl_2 (2.0 mL) was added dropwise. The resulting mixture was stirred overnight (27 h) before the precipitate was filtered off and washed with CH_2Cl_2. The filtrate was washed with 2% HCl (aq.), 4% $NaHCO_3$ (aq.) and brine, dried with Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by FC on silica gel (pentane/EtOAc) to give the desired product with impurities in ca. 65% yield. No further purification was done and the unclean product was used directly for the next step.

The product (1.24 g, 2.84 mmol, 1.00 equiv.) was dissolved in MeOH (8.0 mL) and cooled to 0 °C. Acetyl chloride (1.80 mL, 25.2 mmol, 8.90 equiv.) was slowly added. The mixture was stirred at RT overnight (18 h). After 18 h full conversion of the starting material was observed by TLC analysis and the solvent was removed under reduced pressure. CH_2Cl_2 (4 mL) and H_2O (4 mL) were added to dissolve the compound and the pH value was adjusted to ca. 12 by addition of solid K_2CO_3. The aqueous phase was extracted with CH_2Cl_2 (4 x) and the combined organic phase dried with Na_2SO_4, filtered and concentrated. The residue was used directly in the next step without any purification.

The amide (1.1 g, 3.3 mmol, 1.0 equiv.) was dissolved in THF (anhyd., 10 mL) and cooled to 0 °C. $LiAlH_4$ (0.5 g, 13 mmol, 4.0 equiv.) was added in small portions under stirring. The reaction was stirred 30 min. at 0 °C before the ice bath was removed and stirring continued at RT overnight. After 22 h the reaction was carefully quenched by addition of NaOH (aq., 4 M) while cooled in an ice bath. The solids were filtered off and washed by THF. The filtrate was dried with Na_2SO_4, filtered and concentrated under reduced pressure to leave a pale yellow oil. The product was purified by FC on silica gel (column packed with CH_2Cl_2, sample loaded, 15 mL CH_2Cl_2 with 1% Et_3N, then CH_2Cl_2 to CH_2Cl_2 with 8% MeOH).
The desired product was collected as a yellow oil in 47% yield (36% yield over the three steps).



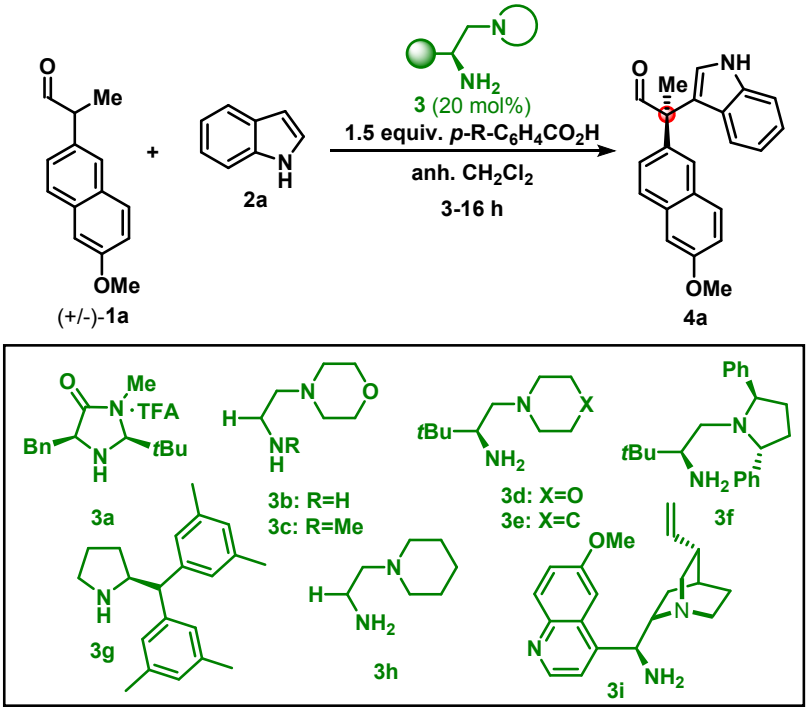
3f

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38 – 7.30 (m, 8H), 7.25 (tt, *J* = 5.8, 1.9 Hz, 2H), 4.38 – 4.29 (m, 2H), 2.65 (dd, *J* = 12.0, 2.5 Hz, 1H), 2.62 – 2.49 (m, 2H), 2.35 (dd, *J* = 12.0, 2.5 Hz, 1H), 2.03 – 1.91 (m, 3H), 0.58 (s, 9H).
^{13}C NMR (100 MHz, $CDCl_3$): δ 143.6 (2C), 128.6 (4C), 128.1 (4C), 127.3 (2C), 66.0 (2C), 56.7, 47.8, 33.7 (2C), 32.8, 26.1 (3C).
HRMS (ESI+) *m*/*z* calcd. for $C_{22}H_{31}N_2$ $[M+H]^+$: 323.2497; found: 323.2482.

4. L. M. Schneider, V. M. Schmiedel, T. Pecchioli, D. Lentz, C. Merten, M. Christmann, *Org. Lett. 2017*, **19**, 2310−2313.
5. S. Duan, S. Li, X. Ye, N.-N. Du, C.-H. Tan, Z. Jiang, *J. Org. Chem.* 2015, **80**, 7770-7778.
6. Y. Gao, Q. Ren, L. Wang, J. Wang, *Chem. Eur. J.* 2010, **16**, 13068-13071.

3. Optimisation Studies

Table S1. Screening of catalysts and oxidants for the enantioselective coupling of aldehyde **1a** to indole **2a**.[a]

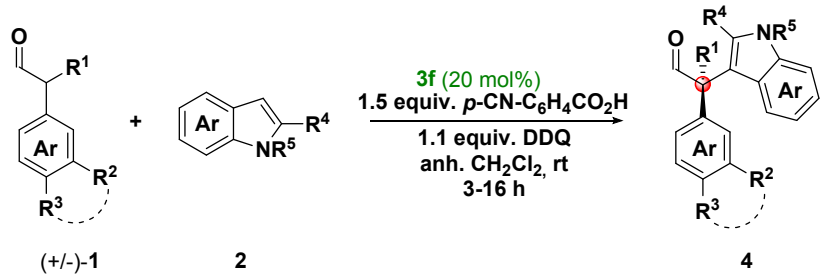


Entry	Cat.	Acid [R]	Oxidant	Temp. [°C]	Time [h]	Yield [%]	ee [%]
1[b]	**3a**	-	CAN	RT	3	0	-
2[b]	**3a**	-	CAN	-20	16	0	-
3[c]	**3b**	-	CAN	-20	16	0	-
4[c]	**3b**	-CN	CAN	-20	16	0	-
5[b]	**3a**	-	$Cu(OTf)_2$	-20	16	0	-
6[c]	**3b**	-	$Cu(OTf)_2$	-20	16	0	-
7	**3b**	-	DDQ	RT	16	38	-
8	**3c**	-	DDQ	RT	16	0	-
9	**3d**	-	DDQ	RT	16	41	66
10	**3d**	-OMe	DDQ	RT	3	50[d]	62
11	**3d**	-H	DDQ	RT	3	70[d]	66
12	**3d**	-CN	DDQ	RT	3	70	70
13	**3d**	-CN	Fluoranil	RT	3	31	63
14	**3d**	-CN	Chloranil	RT	3	10	43
15	**3e**	-CN	DDQ	RT	3	63	58
16	**3f**	-CN	DDQ	RT	3	64	82
17[e]	**3f**	-CN	DDQ	RT	3	73	94
18	**3g**	-CN	DDQ	RT	3	0	-
19	**3h**	-CN	DDQ	RT	3	45	-
20	**3i**	-CN	DDQ	RT	3	30	37

[a] Performed on a 0.10 mmol scale under Ar: 1.0 equiv. **1**, 5.0 equiv. **2**, 0.20 equiv. **3**, 1.5 equiv. acid, 1.1 equiv. oxidant and 0.4 mL CH_2Cl_2. [b] 2.0 equiv. oxidant and 0.4 mL DME. [c] 2.0 equiv. oxidant and 0.4 mL CH_2Cl_2. [d] Determined by NMR (1,3,5-trimethoxybenzene was used as standard). [e] DDQ added in portions.

4. General Procedures for the Enantioselective Coupling of Indoles to Aldehydes

4.1 Asymmetric Synthesis of Oxidative Cross-coupling Products 4a-v Using DDQ as Oxidant

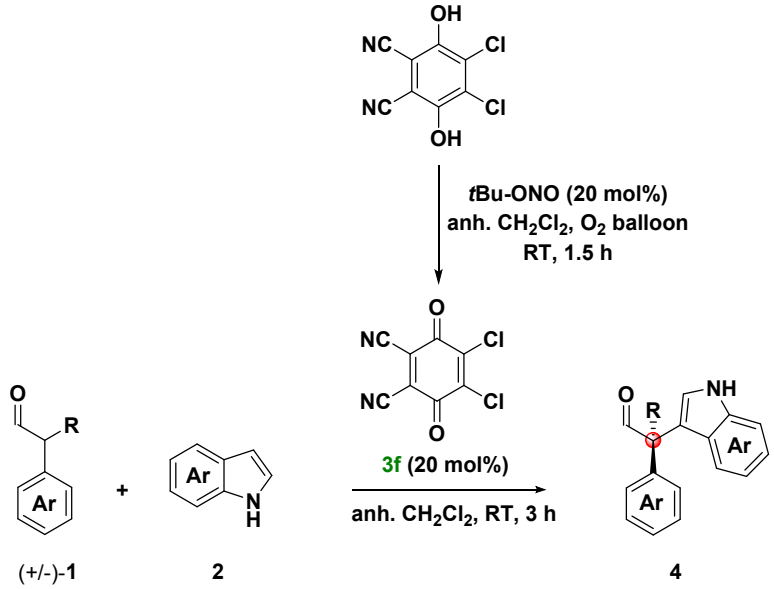


(+/-)-**1** **2** **4**

General Procedure A:

To a flame-dried 4 mL glass vial equipped with a magnetic stirring bar, reagents and solvent were added in the following order; catalyst **3f** (0.020 mmol, 20 mol%), *p*-CN-benzoic acid (0.15 mmol, 1.5 equiv.), indole **2** (0.5 mmol, 5 equiv.), aldehyde **1** (0.1 mmol, 1 equiv.) and anhyd. CH_2Cl_2 (0.4 mL). The vial was quickly flushed with Ar and the first portion of DDQ (0.05 mmol, 0.5 equiv.) was added. After 15 min. of stirring, the last portion of DDQ (0.06 mmol, 0.6 equiv.) was added and the reaction was stirred for the noted amount of time at RT to afford the chiral oxidative cross-coupling products **4**.

4.2 Asymmetric Synthesis of Oxidative Cross-coupling Products 4a,g,r,u Using O_2 as Terminal Oxidant

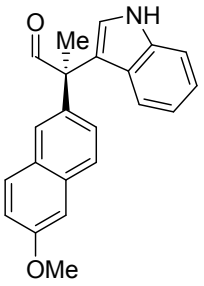


General Procedure B:

To a flame-dried 4 mL glass vial equipped with a magnetic stirring bar and a cap containing a PTFE/silicone septum, H_2-DDQ was added. In another flame-dried vial *t*BuONO was predissolved in 0.4 mL anhyd. CH_2Cl_2 and transferred to the vial containing the H_2-DDQ. An oxygen balloon was added and the suspension stirred at RT for 1.5 h. Following this, the solvent was removed *via* evaporation using a N_2 stream and added portions-wise to a third flame-dried 4 mL vial containing the catalyst **3f** (0.02 mmol, 20 mol%), *p*-CN-benzoic acid (0.15 mmol, 1.5 equiv.), indole **2** (0.5 mmol, 5 equiv.), aldehyde **1** (0.1 mmol, 1 equiv.) and 0.4 mL CH_2Cl_2. The vial was flushed with Ar and the reaction was stirred at RT for 3 h to afford the chiral oxidative cross-coupling products **4**.

4.3 Characterisation of Chiral Oxidative Cross-coupling Products 4a-v

(*R*)-2-(1H-Indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4a



4a

Following the general procedure A, the product was isolated in 82% yield as a light yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent. Following the general procedure B, the product was isolated in 73% yield. Following the general procedure C, the product was isolated in 53% yield.

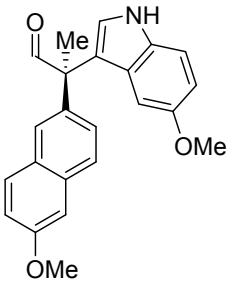
^{1}H NMR (400 MHz, $CDCl_3$): δ 10.03 (s, 1H), 8.31 (bs, 1H), 7.73 – 7.60 (m, 3H), 7.43 – 7.37 (m, 1H), 7.30 (dd, *J* = 8.6, 2.0 Hz, 1H), 7.22 – 7.08 (m, 4H), 7.05 – 6.99 (m, 1H), 6.95 – 6.84 (m, 1H), 3.92 (s, 3H), 1.92 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.2, 158.0, 137.1, 136.5, 133.7, 129.7, 129.0, 127.5, 126.6, 126.3, 125.9, 123.5, 122.4, 121.2, 119.8, 119.1, 115.8, 111.6, 105.6, 55.7, 55.5, 23.1.

HRMS (ESI+) *m*/*z* calcd. for $C_{22}H_{19}NO_2$ $[M+H]^+$: 330.1489; found: 330.1492.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.25 min; t_{minor} = 4.53 min; **General Procedure A:** 94% ee. $[\alpha]_D^{25}$ = +21.3 (*c* 1.0, CH_2Cl_2). **General Procedure B:** 90% ee.

(*R*)-2-(5-Methoxy-1H-indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4b



4b

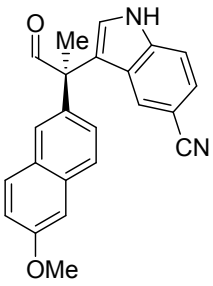
Following the general procedure A, the product was isolated in 67% yield as a light yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent. Following the general procedure B, the product was isolated in 73% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 9.98 (s, 1H), 8.18 (bs, 1H), 7.74 – 7.58 (m, 3H), 7.36 – 7.20 (m, 2H), 7.20 – 7.06 (m, 3H), 6.83 (dd, *J* = 8.8, 2.5 Hz, 1H), 6.44 (d, *J* = 2.5 Hz, 1H), 3.92 (s, 3H), 3.49 (s, 3H), 1.91 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.1, 158.0, 153.9, 136.3, 133.7, 132.2, 129.7, 129.0, 127.4, 126.7, 126.4, 126.4, 124.3, 119.1, 115.5, 112.6, 112.2, 105.6, 103.1, 55.8, 55.7, 55.5, 23.0.

HRMS (ESI+) *m*/*z* calcd. for $C_{23}H_{21}NO_3$ $[M+Na]^+$: 382.1414; found: 382.1421. **UPC²**: Chiralpak IB-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.47 min; t_{minor} = 4.71 min; **General Procedure A:** 93% ee. $[\alpha]_D^{27}$ = +6.5 (*c* 0.5, CH_2Cl_2).

(*R*)-3-(2-(6-Methoxynaphthalen-2-yl)-1-oxopropan-2-yl)-1H-indole-5-carbonitrile, 4c



4c

Following the general procedure A, the product was isolated in 33% yield as a light yellow oil by FC on Iatrobeads using CH_2Cl_2:EtOAc 100:0 to 98:2 as eluent. Following the general procedure B, the product was isolated in 65% yield.

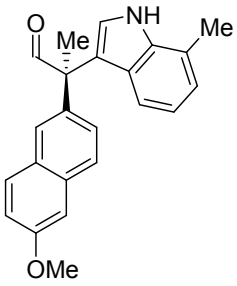
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.95 (s, 1H), 8.61 (bs, 1H), 7.71 (d, *J* = 8.6, 1H), 7.67 (d, *J* = 8.9 Hz, 1H), 7.63 – 7.60 (m, 1H), 7.48 – 7.43 (m, 1H), 7.41 – 7.35 (m, 2H), 7.34 – 7.31 (m, 1H), 7.23 (dd, *J* = 8.6, 2.0 Hz, 1H), 7.19 – 7.13 (m, 2H), 3.93 (s, 3H), 1.93 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.5, 158.3, 138.7, 135.3, 134.0, 129.7, 129.0, 127.9, 126.7, 126.3, 126.1, 125.8, 125.5, 125.5, 120.5, 119.5, 117.6, 112.6, 105.8, 103.2, 55.5, 55.4 23.0.

HRMS (ESI+) *m*/*z* calcd. for $C_{23}H_{18}N_2O_2$ $[M+H]^+$: 355.1441; found: 355.1443.

UPC²: Chiralpak ID-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.94 min; t_{minor} = 4.04 min; **General Procedure A:** 88% ee. $[\alpha]_D^{25}$ = -1.24 (*c* 1.0, CH_2Cl_2).

(*R*)-2-(6-Methoxynaphthalen-2-yl)-2-(7-methyl-1H-indol-3-yl)propanal, 4d



4d

Following the general procedure A, the product was isolated in 55% yield as a brown oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

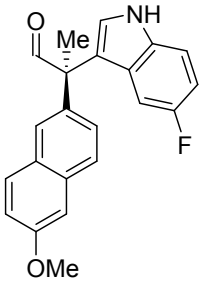
^{1}H NMR (400 MHz, $CDCl_3$): δ 10.04 (s, 1H), 8.21 (bs, 1H), 7.76 – 7.60 (m, 3H), 7.30 (dd, *J* = 8.6, 2.0 Hz, 1H), 7.21 (d, *J* = 2.6 Hz, 1H), 7.19 – 7.10 (m, 2H), 6.98 (d, *J* = 6.9 Hz, 1H), 6.91 – 6.79 (m, 2H), 3.92 (s, 3H), 2.52 (s, 3H), 1.92 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.2, 158.0, 136.7, 136.6, 133.7, 129.7, 129.0, 127.5, 126.6, 126.3, 125.5, 123.1, 123.0, 120.7, 120.1, 119.1, 119.0, 116.5, 105.6, 55.8, 55.5, 23.1, 16.8.

HRMS (ESI+) *m*/*z* calcd. for $C_{23}H_{21}NO_2$ $[M+H]^+$: 344.1645; found: 344.1644.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.33 min; t_{minor} = 4.81 min; **General Procedure A:** 85% ee. $[\alpha]_D^{24}$ = +27.4 (*c* 1.0, CH_2Cl_2).

(*R*)-2-(5-Fluoro-1H-indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4e



4e

Following the general procedure A, the product was isolated in 66% yield as a yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

^{1}H NMR (400 MHz, $CDCl_3$): δ 9.95 (s, 1H), 8.26 (bs, 1H), 7.84 – 7.54 (m, 3H), 7.33 – 7.24 (m, 2H), 7.21 (d, *J* = 2.6 Hz, 1H), 7.16 – 7.09 (m, 2H), 6.89 (td, *J* = 9.0, 2.6 Hz, 1H), 6.64 (dd, *J* = 9.9, 2.6 Hz, 1H), 3.90 (s, 3H), 1.88 (s, 3H).

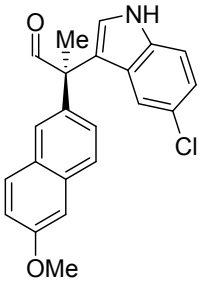
^{13}C NMR (100 MHz, $CDCl_3$): δ 198.8, 158.1, 157.6 (d, *J* = 234 Hz), 135.9, 133.8, 133.5, 129.7, 129.0, 127.6, 126.4, 126.3, 126.3, 125.1, 119.2, 116.2 (d, *J* = 5 Hz), 112.2 (d, *J* = 9 Hz), 111.1 (d, *J* = 24 Hz), 106.1 (d, *J* = 24 Hz), 105.7, 55.5, 55.5, 22.9.

^{19}F NMR (376 MHz, $CDCl_3$): δ -123.4 (s, 1F).

HRMS (ESI+) *m*/*z* calcd. for $C_{22}H_{18}FNO_2$ $[M+H]^+$: 348.1394; found: 348.1398.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 8.83 min; t_{minor} = 8.65 min; **General Procedure A:** 86% ee. $[\alpha]_D^{27}$ = +16.6 (*c* 1.0, CH_2Cl_2).

(*R*)-2-(5-Chloro-1H-indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4f



4f

Following the general procedure A, the product was isolated in 64% yield as a brown oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

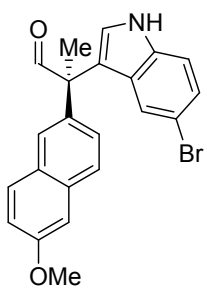
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.98 (s, 1H), 8.34 (bs, 1H), 7.76 – 7.60 (m, 3H), 7.36 – 7.26 (m, 2H), 7.23 – 7.09 (m, 4H), 7.03 (d, *J* = 2.0 Hz, 1H), 3.92 (s, 3H), 1.91 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.9, 158.1, 135.9, 135.4, 133.8, 129.7, 129.0, 127.6, 127.0, 126.4 (s, 2C), 125.6, 124.8, 123.0, 120.4, 119.3, 116.0, 112.6, 105.7, 55.6, 55.5, 23.0.

HRMS (ESI+) *m*/*z* calcd. for $C_{22}H_{18}ClNO_2$ $[M+H]^+$: 364.1099; found: 364.1100.

UPC²: Chiralpak IB-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (1.24%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 19.05 min; t_{minor} = 19.39 min; **General Procedure A:** 85% ee. $[\alpha]_D^{25}$ = +8.2 (*c* 1.0, CH_2Cl_2).

(*R*)-2-(5-Bromo-1H-indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4g



4g

Following the general procedure A, the product was isolated in 88% yield as a yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent. Following the general procedure C, the product was isolated in 82% yield.

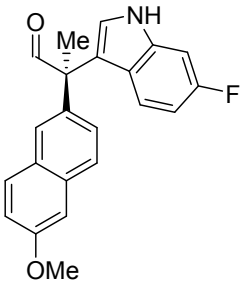
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.98 (s, 1H), 8.32 (bs, 1H), 7.75 – 7.61 (m, 3H), 7.32 – 7.26 (m, 3H), 7.22 – 7.11 (m, 4H), 3.93 (s, 3H), 1.91 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.9, 158.1, 135.8, 135.7, 133.9, 129.7, 129.0, 127.6 (2C), 126.4, 126.4, 125.6, 124.7, 123.5, 119.3, 116.0, 113.2, 113.1, 105.7, 55.6, 55.5, 23.0.

HRMS (ESI+) *m/z* calcd. for $C_{22}H_{18}BrNO_2$ $[M+H]^+$: 408.0594; found: 408.0591.

UPC²: Chiralpak IB-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.90 min; t_{minor} = 4.99 min; **General Procedure A:** 90% ee. $[\alpha]_D^{25}$ = -9.6 (*c* 0.5, CH_2Cl_2). **General Procedure B:** 80% ee.

(*R*)-2-(6-Fluoro-1H-indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4h



4h

Following the general procedure A, the product was isolated in 55% yield as a yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

^{1}H NMR (400 MHz, $CDCl_3$): δ 9.98 (s, 1H), 8.23 (bs, 1H), 7.80 – 7.55 (m, 3H), 7.29 (d, *J* = 2.0 Hz, 1H), 7.19 (d, *J* = 2.4 Hz, 1H), 7.17 – 7.10 (m, 2H), 7.08 (dd, *J* = 9.2, 2.4 Hz, 1H), 6.90 (dd, *J* = 8.9, 5.3 Hz, 1H), 6.65 (td, *J* = 9.2, 2.4 Hz, 1H), 3.92 (s 3H), 1.90 (s, 3H).

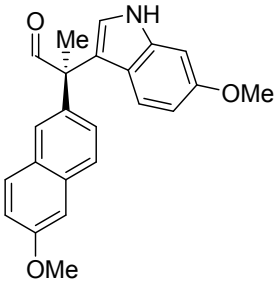
^{13}C NMR (100 MHz, $CDCl_3$): δ 199.1, 160.2 (d, *J* = 240 Hz), 158.2, 137.2 (d, *J* = 10 Hz), 136.4, 133.9, 129.8, 129.1, 127.6, 126.6, 126.4, 123.9 (d, *J* = 4 Hz), 122.6, 122.2 (d, *J* = 10 Hz), 119.3, 116.4, 108.9 (d, *J* = 24 Hz), 105.8, 97.9 (d, *J* = 24 Hz), 55.7, 55.6, 23.1.

^{19}F NMR (376 MHz, $CDCl_3$): δ -120.5 (s, 1F).

HRMS (ESI+) *m/z* calcd. for $C_{22}H_{18}FNO_2$ $[M+H]^+$: 348.1394; found: 348.1394.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 25% (1.66%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 9.63 min; t_{minor} = 9.86 min; **General Procedure A:** 85% ee. $[\alpha]_D^{25}$ = +11.3 (*c* 1.0, CH_2Cl_2).

(*R*)-2-(6-Methoxy-1H-indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4i



4i

Following the general procedure A, the product was isolated in 20% yield as a light yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

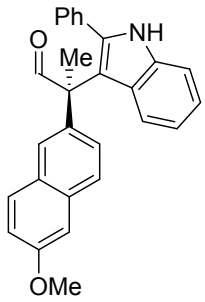
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.99 (s, 1H), 8.13 (bs, 1H), 7.74 – 7.60 (m, 3H), 7.29 (dd, *J* = 8.6, 2.1 Hz, 1H), 7.17 – 7.08 (m, 3H), 6.91 – 6.84 (m, 2H), 6.56 (dd, *J* = 8.6, 2.1 Hz, 1H), 3.92 (s, 3H), 3.81 (s, 3H), 1.89 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.1, 158.0, 156.7, 137.9, 136.7, 133.7, 129.7, 129.0, 127.4, 126.6, 126.3, 122.2, 121.8, 120.2, 119.1, 116.0, 109.9, 105.7, 94.8, 55.7, 55.7, 55.5, 23.1.

HRMS (ESI+) *m/z* calcd. for $C_{23}H_{21}NO_3$ $[M+H]^+$: 360.1594; found: 360.1596.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.71 min; t_{minor} = 4.99 min; **General Procedure A:** 85% ee. $[\alpha]_D^{27}$ = +39.6 (*c* 0.3, CH_2Cl_2).

(*R*)-2-(6-Methoxynaphthalen-2-yl)-2-(2-phenyl-1H-indol-3-yl)propanal, 4j



4j

Following the general procedure A, the product was isolated in 53% yield as a light yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

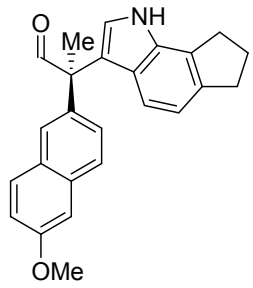
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.57 (s, 1H), 8.13 (bs, 1H), 7.73 (d, *J* = 1.9 Hz, 1H), 7.66 (d, *J* = 8.7 Hz, 1H), 7.60 (d, *J* = 8.7 Hz, 1H), 7.43 (ddd, *J* = 5.7, 4.2, 2.7 Hz, 2H), 7.40 – 7.29 (m, 5H), 7.21 – 7.10 (m, 2H), 7.07 (d, *J* = 2.5 Hz, 1H), 6.90 – 6.78 (m, 2H), 3.90 (s, 3H), 2.03 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.1, 158.0, 136.1, 136.1, 135.2, 133.6, 133.2, 130.3 (2C), 129.8, 129.1 (2C), 128.4 (2C), 127.3 (2C), 127.1, 127.0, 122.5, 121.4, 119.9, 119.0, 114.4, 110.9, 105.5, 56.0, 55.4, 22.2.

HRMS (ESI+) *m/z* calcd. for $C_{28}H_{23}NO_2$ $[M+H]^+$: 406.1802; found: 406.1805.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.90 min; t_{minor} = 4.39 min; **General Procedure A:** 89% ee. $[\alpha]_D^{25}$ = -94.8 (*c* 0.5, CH_2Cl_2).

(*R*)-2-(6-Methoxynaphthalen-2-yl)-2-(1,6,7,8-tetrahydrocyclopenta[g]indol-3-yl)propanal, 4k



4k

Following the general procedure A, the product was isolated in 40% yield as a dark red oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

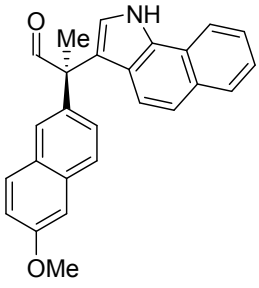
^{1}H NMR (400 MHz, $CDCl_3$): δ 10.03 (s, 1H), 8.09 (bs, 1H), 7.79 – 7.53 (m, 3H), 7.31 (dd, *J* = 8.6, 2.0 Hz, 1H), 7.14 (dt, *J* = 11.3, 2.3 Hz, 3H), 6.83 (s, 2H), 3.92 (s, 3H), 3.03 (dt, *J* = 25.0, 7.4 Hz, 4H), 2.21 (p, *J* = 7.4 Hz, 2H), 1.91 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.2, 158.0, 139.1, 136.8, 134.3, 133.7, 129.7, 129.0, 127.5, 126.7, 126.3, 125.9, 124.5, 122.7, 119.3, 119.1, 116.9, 116.6, 105.7, 55.8, 55.5, 33.2, 30.0, 25.5, 23.1.

HRMS (ESI+) *m/z* calcd. for $C_{25}H_{23}NO_2$ $[M+H]^+$: 370.1802; found: 370.1806.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.73 min; t_{minor} = 5.27 min; **General Procedure A:** 91% ee. $[\alpha]_D^{25}$ = +45.6 (*c* 0.5, CH_2Cl_2).

(*R*)-2-(1H-Benzo[g]indol-3-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4l



4l

Following the general procedure A, the product was isolated in 29% yield as a grey solid by FC on Iatrobeads using CH_2Cl_2 as eluent.

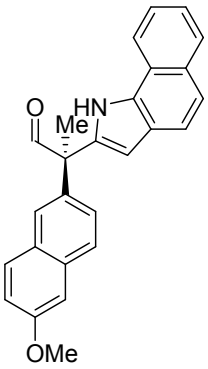
^{1}H NMR (400 MHz, $CDCl_3$): δ 10.07 (s, 1H), 9.00 (bs, 1H), 8.04 (dd, *J* = 8.2, 1.1 Hz, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.72 – 7.64 (m, 3H), 7.55 (ddd, *J* = 8.2, 6.9, 1.3 Hz, 1H), 7.43 (ddd, *J* = 8.2, 7.0, 1.3 Hz, 1H), 7.32 (dd, *J* = 8.7, 2.0 Hz, 1H), 7.28 (d, *J* = 2.4 Hz, 1H), 7.16 – 6.99 (m, 4H), 3.92 (s, 3H), 1.96 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.1, 158.0, 136.8, 133.8, 131.9, 130.4, 129.7, 129.0, 129.0, 127.5, 126.6, 126.4, 125.8, 124.5, 122.0, 121.8, 121.4, 120.7, 120.7, 119.4, 119.2, 117.9, 105.7, 55.9, 55.5, 23.3.

HRMS (ESI+) *m/z* calcd. for $C_{26}H_{21}NO_2$ $[M+H]^+$: 380.1645; found: 380.1647.

UPC²: Chiralpak ID-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 5.01 min; t_{minor} = 4.79 min; **General Procedure A:** 89% ee. $[\alpha]_D^{26}$ = +48.6 (*c* 0.33, CH_2Cl_2).

(*R*)-2-(1H-Benzo[g]indol-2-yl)-2-(6-methoxynaphthalen-2-yl)propanal, 4l'



4l'

Following the general procedure A, the product was isolated in 53% yield as a grey solid by FC on Iatrobeads using CH_2Cl_2 as eluent.

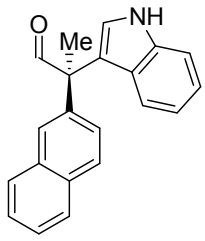
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.97 (s, 1H), 8.94 (s, 1H), 8.03 – 7.84 (m, 2H), 7.76 (d, *J* = 8.6 Hz, 1H), 7.73 – 7.63 (m, 3H), 7.54 (d, *J* = 8.6 Hz, 1H), 7.48 (ddd, *J* = 8.3, 6.9, 1.4 Hz, 1H), 7.45 – 7.39 (m, 1H), 7.31 (dd, *J* = 8.6, 2.0 Hz, 1H), 7.20 – 7.09 (m, 2H), 6.62 (d, *J* = 2.3 Hz, 1H), 3.93 (s, 3H), 2.04 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.8, 158.4, 136.0, 135.5, 134.1, 131.4, 130.6, 129.7, 129.0, 128.9, 128.0, 126.6, 126.2, 125.7, 124.2, 124.1, 121.6, 121.2, 120.6, 119.6, 119.6, 105.7, 104.5, 56.2, 55.5, 22.8.

HRMS (ESI+) *m/z* calcd. for $C_{26}H_{21}NO_2$ $[M+H]^+$: 380.1645; found: 380.1647.

UPC^2: Chiralpak IDB-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.73 min; t_{minor} = 4.61 min; **General Procedure A:** 47% ee. $[\alpha]_D^{25}$ = -12.8 (*c* 1.0, CH_2Cl_2).

***(R)*-2-(1H-Indol-3-yl)-2-(naphthalen-2-yl)propanal, 4m**



4m

Following the general procedure A, the product was isolated in 65% yield as a light yellow oil by FC on Iatrobeads using pentane:CH_2Cl_2 2:1 to 1:2 as eluent.

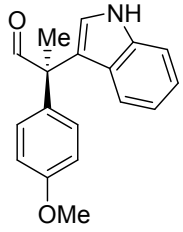
^{1}H NMR (400 MHz, $CDCl_3$): δ 10.06 (s, 1H), 8.28 (bs, 1H), 7.86 – 7.70 (m, 4H), 7.52 – 7.45 (m, 2H), 7.42 (dt, *J* = 8.2, 0.9 Hz, 1H), 7.35 (dd, *J* = 8.6, 1.9 Hz, 1H), 7.22 (d, *J* = 2.6 Hz, 1H), 7.18 (ddd, *J* = 8.2, 7.0, 1.2 Hz, 1H), 7.03 (dd, *J* = 8.2, 1.1 Hz, 1H), 6.90 (ddd, *J* = 8.1, 7.0, 1.0 Hz, 1H), 1.94 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.0, 139.1, 137.1, 133.5, 132.6, 128.6, 128.2, 127.7, 126.4, 126.3, 126.2, 126.1, 125.9, 123.6, 122.5, 121.2, 120.0, 115.8, 111.6, 56.0, 23.1.

HRMS (ESI+) *m/z* calcd. for $C_{21}H_{17}NO$ $[M+H]^+$: 300.1383; found: 300.1385.

UPC^2: Chiralpak IC-3 column [CO_2/MeOH gradient, 1% MeOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.96 min; t_{minor} = 4.32; **General Procedure A:** 92% ee. $[\alpha]_D^{24}$ = +28.0 (*c* 1.0, CH_2Cl_2).

(*R*)-2-(1H-Indol-3-yl)-2-(4-methoxyphenyl)propanal, 4n



4n

Following the general procedure A, the product was isolated in 60% yield as a light yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

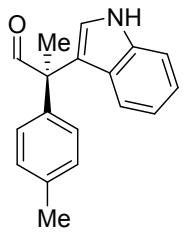
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.91 (s, 1H), 8.24 (bs, 1H), 7.40 (dt, *J* = 8.3, 1.0 Hz, 1H), 7.22 – 7.11 (m, 4H), 7.06 (dd, *J* = 8.3, 1.0 Hz, 1H), 6.96 (ddd, *J* = 8.0, 6.9, 1.0 Hz, 1H), 6.91 – 6.83 (m, 2H), 3.81 (s, 3H), 1.83 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.2, 158.8, 137.1, 133.2, 129.1 (2C), 125.9, 123.3, 122.5, 121.3, 119.8, 116.3, 114.2 (2C), 111.6, 55.4, 55.1, 23.1.

HRMS (ESI+) *m/z* calcd. for $C_{18}H_{17}NO_2$ $[M+H]^+$: 280.1332; found: 280.1339.

UPC^2: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.69 min; t_{minor} = 3.91 min; **General Procedure A:** 86% ee. $[\alpha]_D^{25}$ = +19.8 (*c* 1.0, CH_2Cl_2).

(*R*)-2-(1H-Indol-3-yl)-2-(*p*-tolyl)propanal, 4o



4o

Following the general procedure A, the product was isolated in 47% yield as a light yellow oil by FC on Iatrobeads using pentane:CH_2Cl_2 2:1 to 1:2 as eluent.

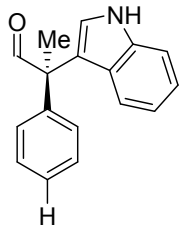
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.93 (s, 1H), 8.22 (bs, 1H), 7.45 – 7.35 (m, 1H), 7.22 – 7.10 (m, 6H), 7.05 (dd, *J* = 8.1, 1.1 Hz, 1H), 6.99 – 6.90 (m, 1H), 2.35 (s, 3H), 1.83 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.2, 138.3, 137.1, 137.0, 129.6 (2C), 127.8 (2C), 125.9, 123.3, 122.5, 121.3, 119.8, 116.2, 111.5, 55.5, 23.1, 21.2.

HRMS (ESI+) *m*/*z* calcd. for $C_{18}H_{17}NO$ $[M+H]^+$: 264.1383; found: 264.1386.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.57 min; t_{minor} = 3.82 min; **General Procedure A:** 94% ee. $[\alpha]_D^{24}$ = +34.7 (*c* 0.38, CH_2Cl_2).

(*R*)-2-(1H-Indol-3-yl)-2-phenylpropanal, 4p



4p

Following the general procedure A, the product was isolated in 20% yield as a dark red oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

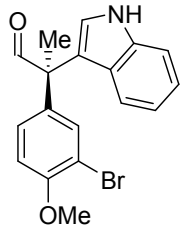
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.96 (s, 1H), 8.24 (bs, 1H), 7.41 (dt, *J* = 8.2, 1.0 Hz, 1H), 7.36 – 7.27 (m, 3H), 7.25 – 7.21 (m, 2H), 7.20 – 7.14 (m, 2H), 7.05 – 6.99 (m, 1H), 6.95 (ddd, *J* = 8.2, 6.9, 1.0 Hz, 1H), 1.85 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 199.1, 141.4, 137.1, 128.9 (2C), 127.9 (2C), 127.3, 125.9, 123.4, 122.5, 121.2, 119.9, 116.0, 111.6, 55.8, 23.1.

HRMS (ESI+) *m*/*z* calcd. for $C_{17}H_{15}NO_2$ $[M+H]^+$: 250.1226; found: 250.1226.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.34 min; t_{minor} = 3.60 min; **General Procedure A:** 66% ee. $[\alpha]_D^{25}$ = +352.0 (*c* 0.07, CH_2Cl_2).

(*R*)-2-(3-Bromo-4-methoxyphenyl)-2-(1H-indol-3-yl)propanal, 4q



4q

Following the general procedure A, the product was isolated in 42% yield as a dark yellow oil by FC on Iatrobeads using CH_2Cl_2 as eluent.

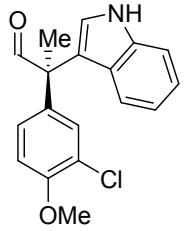
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.86 (s, 1H), 8.25 (bs, 1H), 7.43 (d, *J* = 2.3 Hz, 1H), 7.43 – 7.39 (m, 1H), 7.24 – 7.15 (m, 1H), 7.16 (d, *J* = 2.6 Hz, 1H), 7.12 (dd, *J* = 8.6, 2.3 Hz, 1H), 7.08 – 7.03 (m, 1H), 7.02 – 6.93 (m, 1H), 6.85 (d, *J* = 8.6 Hz, 1H), 3.88 (s, 3H), 1.82 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.5, 155.1, 137.1, 134.8, 132.7, 128.2, 125.6, 123.3, 122.6, 121.1, 120.0, 115.5, 112.0 (2C), 111.6, 56.4, 54.9, 23.1.

HRMS (ESI+) *m*/*z* calcd. for $C_{18}H_{16}BrNO_2$ $[M+H]^+$: 358.0437; found: 358.0443.

UPC²: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.87 min; t_{minor} = 4.01 min; **General Procedure A:** 89% ee. $[\alpha]_D^{25}$ = +5.0 (*c* 0.36, CH_2Cl_2).

(*R*)-2-(3-Chloro-4-methoxyphenyl)-2-(1H-indol-3-yl)propanal, 4r



4r

Following the general procedure A, the product was isolated in 88% yield as a light red oil by FC on Iatrobeads using pentane:CH_2Cl_2 1:1 to 1:3 as eluent. Following the general procedure C, the product was isolated in 49% yield.

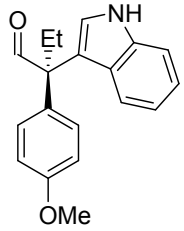
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.87 (s, 1H), 8.29 (bs, 1H), 7.40 (d, *J* = 8.2 Hz, 1H), 7.28 – 7.22 (m, 1H), 7.21 – 7.17 (m, 1H), 7.15 (d, *J* = 2.6 Hz, 1H), 7.11 – 7.04 (m, 2H), 7.00 – 6.96 (m, 1H), 6.87 (d, *J* = 8.6 Hz, 1H), 3.89 (s, 3H), 1.82 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.6, 154.2, 137.1, 134.4, 129.7, 127.4, 125.6, 123.4, 122.7, 122.6, 121.0, 120.0, 115.5, 112.2, 111.7, 56.3, 54.9, 23.1.

HRMS (ESI+) *m*/*z* calcd. for $C_{18}H_{16}ClNO_2$ $[M+H]^+$: 314.0942; found: 314.0948.

UPC^2: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.83 min; t_{minor} = 3.96 min; **General Procedure A:** 91% ee. $[\alpha]_D^{25}$ = +13.8 (*c* 1.0, CH_2Cl_2). **General Procedure B:** 87% ee.

(*R*)-2-(1H-Indol-3-yl)-2-(4-methoxyphenyl)butanal, 4s



4s

Following the general procedure A, the product was isolated in 56% yield as a light red oil by FC on Iatrobeads using pentane:CH_2Cl_2 1:1 to 1:6 as eluent.

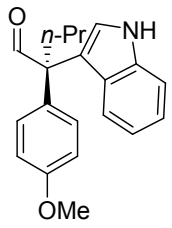
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.76 (s, 1H), 8.26 (bs, 1H), 7.38 (d, *J* = 8.2, 1H), 7.30 (d, *J* = 2.6 Hz, 1H), 7.21 – 7.11 (m, 3H), 6.99 – 6.91 (m, 2H), 6.90 – 6.85 (m, 2H), 3.81 (s, 3H), 2.45 – 2.38 (m, 2H), 0.78 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.5, 158.7, 136.8, 131.1, 130.0 (2C), 126.2, 124.1, 122.4, 121.4, 119.7, 114.3, 114.0 (2C), 111.4, 59.3, 55.4, 27.4, 9.5.

HRMS (ESI+) *m*/*z* calcd. for $C_{19}H_{19}NO_2$ $[M+Na]^+$: 316.1308; found: 316.1311.

UPC^2: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.78 min; t_{minor} = 4.11 min; **General Procedure A:** 56% ee. $[\alpha]_D^{25}$ = +25.2 (*c* 0.5, CH_2Cl_2).

(*R*)-2-(1H-indol-3-yl)-2-(4-methoxyphenyl)pentanal, 4t



4t

Following the general procedure A, the product was isolated in 42% yield as a light yellow oil by FC on Iatrobeads using pentane:CH_2Cl_2 1:1 to 1:3 as eluent.

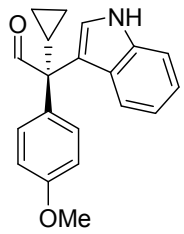
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.74 (s, 1H), 8.23 (bs, 1H), 7.38 (d, *J* = 8.2 Hz, 1H), 7.30 (d, *J* = 2.6 Hz, 1H), 7.19 – 7.15 (m, 3H), 6.96 – 6.91 (m, 2H), 6.90 – 6.85 (m, 2H), 3.80 (s, 3H), 2.37 – 2.19 (m, 2H), 1.21 – 1.04 (m, 2H), 0.89 (t, *J* = 7.3 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.4, 158.7, 136.8, 131.3, 129.9 (2C), 126.2, 124.0, 122.4, 121.4, 119.7, 114.6, 114.0 (2C), 111.4, 58.9, 55.4, 37.0, 18.4, 14.7.

HRMS (ESI+) *m*/*z* calcd. for $C_{20}H_{21}NO_2$ $[M+H]^+$: 308.1645; found: 308.1649.

UPC^2: Chiralpak IC-3 column [CO_2/MeOH gradient, 1% MeOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.41 min; t_{minor} = 3.51 min; **General Procedure A:** 49% ee. $[\alpha]_D^{26}$ = +19.2 (*c* 0.5, CH_2Cl_2).

(*R*)-2-Cyclopropyl-2-(1H-indol-3-yl)-2-(4-methoxyphenyl)acetaldehyde, 4u



4u

Following the general procedure A, the product was isolated in 85% yield as a light redbrown oil by FC on Iatrobeads using pentane:CH_2Cl_2 1:1 to 1:3 to 1:6 as eluent. Following the general procedure C, the product was isolated in 46% yield.

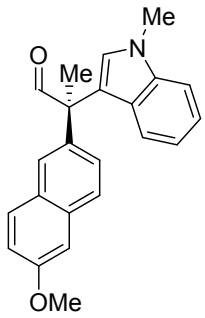
^{1}H NMR (400 MHz, $CDCl_3$): δ 9.90 (s, 1H), 8.27 (bs, 1H), 7.39 – 7.36 (m, 2H), 7.17 – 7.11 (m, 3H), 6.92 – 6.83 (m, 4H), 3.80 (s, 3H), 1.80 (tt, *J* = 8.4, 5.5 Hz, 1H), 0.65 – 0.49 (m, 2H), 0.07 – 0.02 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.7, 158.9, 136.8, 131.0 (2C), 129.1, 126.3, 125.0, 122.3, 121.3, 119.8, 114.2, 113.6 (2C), 111.4, 59.4, 55.3, 14.9, 1.4, 0.8.

HRMS (ESI+) *m*/*z* calcd. for $C_{20}H_{19}NO_2$ $[M+H]^+$: 306.1489; found: 306.1491.

UPC^2: Chiralpak IC-3 column [CO_2/MeOH gradient, 1% MeOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 3.76 min; t_{minor} = 3.93 min; **General Procedure A:** 47% ee. $[\alpha]_D^{25}$ = +11.6 (*c* 1.0, CH_2Cl_2). **General Procedure B:** 53% ee.

(*R*)-2-(6-Methoxynaphthalen-2-yl)-2-(1-methyl-1H-indol-3-yl)propanal, 4v



4v

Following the general procedure A, the product was isolated in 23% yield as a yellow oil by FC on Iatrobeads using pentane:CH_2Cl_2 1:1 to 1:3 as eluent.

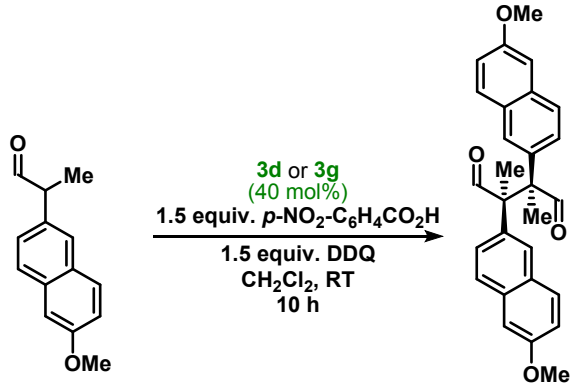
^{1}H NMR (400 MHz, $CDCl_3$): δ 10.02 (s, 1H), 7.71 – 7.66 (m, 3H), 7.36 – 7.31 (m, 2H), 7.23 – 7.13 (m, 3H), 7.05 – 7.01 (m, 2H), 6.92 – 6.82 (m, 1H), 3.92 (s, 3H), 3.83 (s, 3H), 1.91 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$): δ 198.9, 158.0, 137.9, 136.8, 133.7, 129.7, 129.0, 128.2, 127.4, 126.6, 126.4, 126.2, 122.0, 121.3, 119.4, 119.1, 114.1, 109.7, 105.6, 55.7, 55.5, 33.1, 23.2.

HRMS (ESI+) *m*/*z* calcd. for $C_{23}H_{21}NO_2$ $[M+H]^+$: 344.1645; found: 344.1653.

UPC^2: Chiralpak IC-3 column [CO_2/*i*PrOH gradient, 1% *i*PrOH (0.5 min), then gradient from 1% to 40% (10%/min), 120 bar, 40 °C], 3.0 mL·min^{-1}; t_{major} = 4.65 min; t_{minor} = 5.02 min; **General Procedure A:** 80% ee. $[\alpha]_D^{24}$ = +33.2 (*c* 1.0, CH_2Cl_2).

5. Homo-coupling of 1a using 3d or 3g



A flame dried 4 mL glass vial equipped with a magnetic stirring bar was charged with **3d** or **3g** (0.04 mmol, 0.40 equiv.), **1a** (0.20 mmol, 2.0 equiv.), *p*-NO_2-$C_6H_4CO_2H$ (0.150 mmol, 1.50 equiv.), and dry CH_2Cl_2 (0.4 mL). To the resulting mixture DDQ (0.150 mmol, 1.50 equiv.) was added. The vial was flushed with Ar, and the reaction mixture was stirred for 10 h.

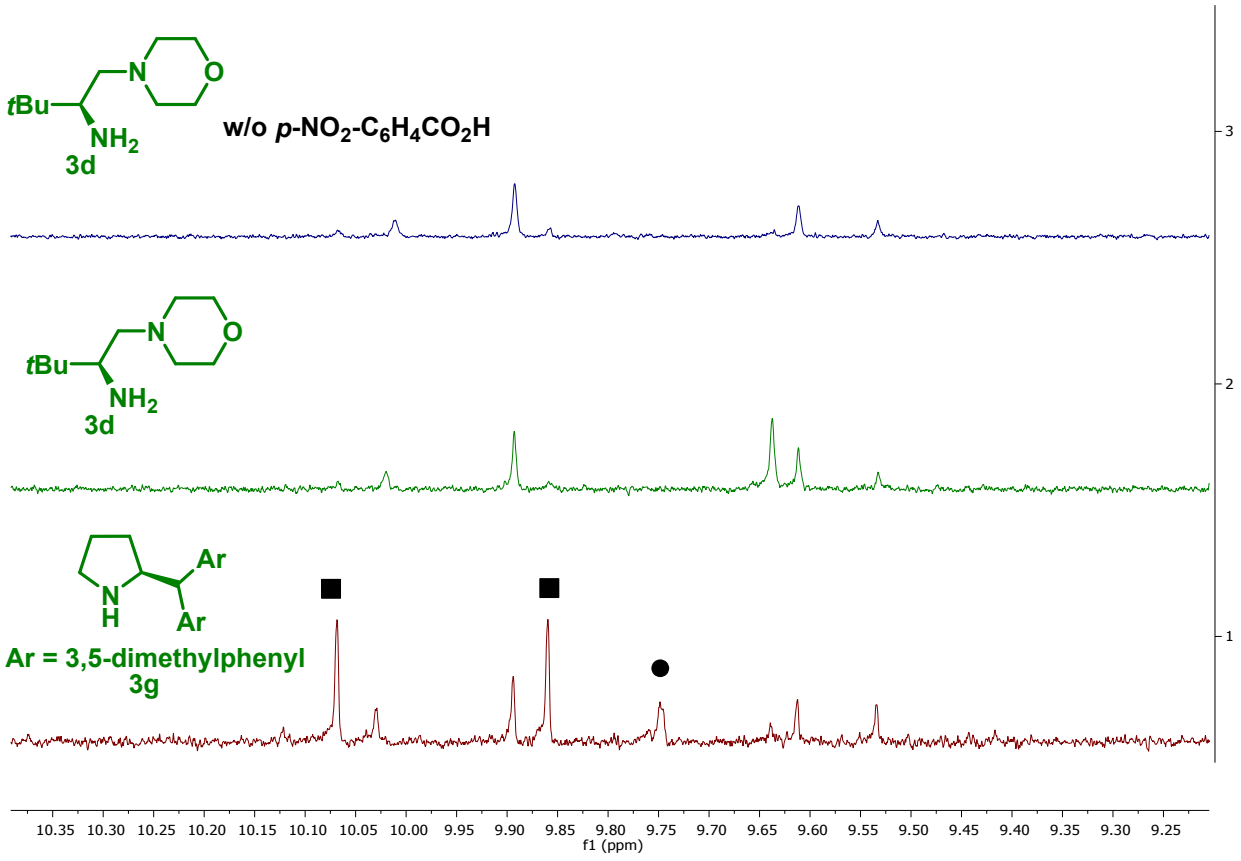
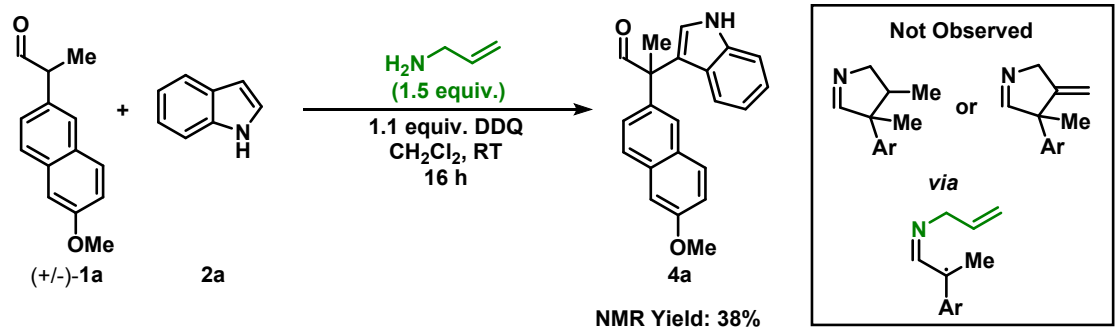


Figure S1. NMR of aldehyde region from the homo-coupling of **1a**. ■ **= 5a** (homo-coupling), ● = **1a**.

6. Radical Clock and Trapping Experiments

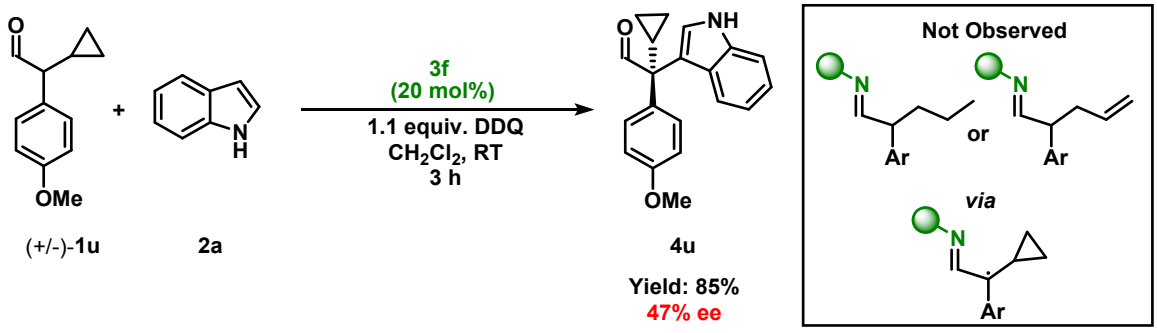
6.1 Allylamine Trapping Experiment

To a flame-dried 4 mL glass vial equipped with a magnetic stirring bar, reagents and solvent were added in the following order; allylamine (0.15 mmol, 1.5 equiv.), indole **2a** (0.5 mmol, 5 equiv.), aldehyde **1a** (0.1 mmol, 1 equiv.), trimethoxy benzene (0.033 mmol), and anhyd. CH_2Cl_2 (0.4 mL). The vial was quickly flushed with Ar and the first portion of DDQ (0.05 mmol, 0.5 equiv.) was added. After 15 min. of stirring, the last portion of DDQ (0.06 mmol, 0.6 equiv.) was added and the reaction was stirred for 16 h at RT to afford the oxidative cross-coupling products **4a**.



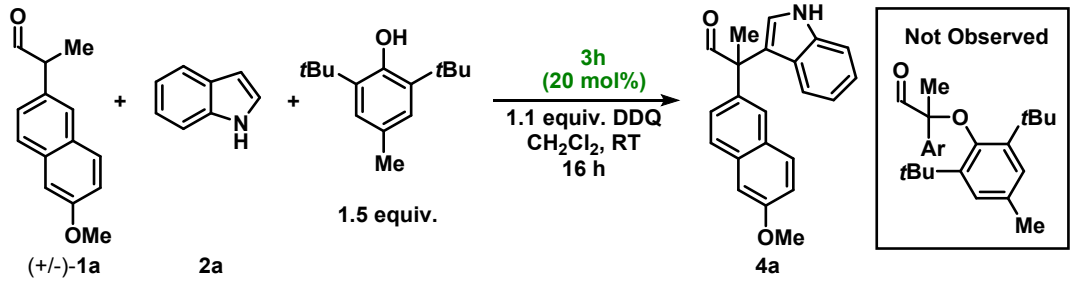
6.2 Cyclopropyl Radical Clock Experiment

To a flame-dried 4 mL glass vial equipped with a magnetic stirring bar, reagents and solvent were added in the following order; catalyst **3f** (0.020 mmol, 20 mol%), *p*-CN-benzoic acid (0.15 mmol, 1.5 equiv.), indole **2a** (0.5 mmol, 5 equiv.), aldehyde **1u** (0.1 mmol, 1 equiv.) and anhyd. CH_2Cl_2 (0.4 mL). The vial was quickly flushed with Ar and the first portion of DDQ (0.05 mmol, 0.5 equiv.) was added. After 15 min. of stirring, the last portion of DDQ (0.06 mmol, 0.6 equiv.) was added and the reaction was stirred for 3 h at RT to afford the chiral oxidative cross-coupling products **4u**.



6.3 BHT Trapping Experiment

To a flame-dried 4 mL glass vial equipped with a magnetic stirring bar, reagents and solvent were added in the following order; **3h** (0.010 mmol, 20 mol%), indole **2a** (0.25 mmol, 5 equiv.), aldehyde **1a** (0.050 mmol, 1 equiv.), BHT (0.075 mmol, 1.5 equiv.), trimethoxy benzene (0.033 mmol), and anhyd. CH_2Cl_2 (0.2 mL). The vial was quickly flushed with Ar and the first portion of DDQ (0.025 mmol, 0.5 equiv.) was added. After 15 min. of stirring, the last portion of DDQ (0.03 mmol, 0.6 equiv.) was added and the reaction was stirred for 16 h at RT to afford the oxidative cross-coupling products **4a**.

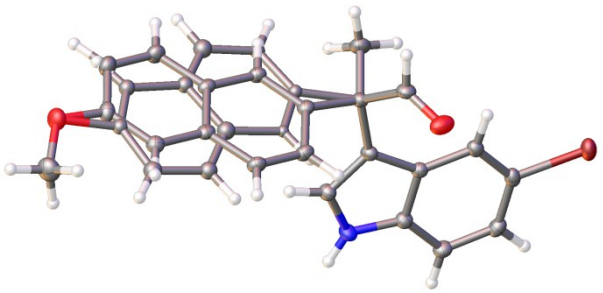


NMR Yield: 28%

7. Crystallographic Data

Crystallographic data for the crystal structure of **4g**

Item	Value
Molecular formula	$C_{22}H_{18}BrNO_2$
Formula weight	408.28
Crystal system	Orthorhombic
Space Group	$P2_12_12_1$
a (Å)	9.3465
b (Å)	10.4901
c (Å)	18.9441
α (°)	90
β (°)	90
γ (°)	90
Volume (Å^3)	1857.4
Z	4
T (K)	100
ρ (g cm^{-1})	1.46
λ (Å)	0.56086
μ (mm^{-1})	1.2
# measured refl	84357
# unique refl	6463
R_{int}	0.0404
# parameters	278
R(F^2), all refl	0.0237
R_w(F^2), all refl	0.05
Goodness of fit	1.053



Crystal data for **4g**: $C_{22}H_{18}BrNO_2$, *M* = 408.28, orthorhombic, space group P $2_12_12_1$ (no. 19), *a* = 9.3465(7) Å, *b* = 10.4901(8) Å, *c* = 18.9441(15) Å, Flack parameter = 0.009, *V* = 1857.4(2) Å^3, *T* = 100 K, *Z* = 4, d_c = 1.46 g cm^{-3}, *μ*(Mo Kα, λ = 0.56086 Å) = 1.2 mm^{-1}, 84357 reflections collected, 6463 unique [R_{int} = 0.0404], which were used in all calculations. Refinement on F^2, final R(F) = 0.0237, R_w(F2) = 0.05. CCDC 1863137.

8. Computational Studies

Full *Gaussian09* Reference

Gaussian 09, Revision D.01, M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, B. Mennucci, G. A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H. P. Hratchian, A. F. Izmaylov, J. Bloino, G. Zheng, J. L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. Bearpark, J. J. Heyd, E. Brothers, K. N. Kudin, V. N. Staroverov, T. Keith, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J. M. Millam, M. Klene, J. E. Knox, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, R. L. Martin, K. Morokuma, V. G. Zakrzewski, G. A. Voth, P. Salvador, J. J. Dannenberg, S. Dapprich, A. D. Daniels, O. Farkas, J. B. Foresman, J. V. Ortiz, J. Cioslowski, and D. J. Fox, Gaussian, Inc., Wallingford CT, **2013**.

Computational methods

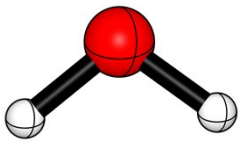
All calculations were performed using *Gaussian09*, and were analyzed using *GaussView5*. All minima were found using DFT at the B3LYP/6-31+G(d,p) level of theory[7] with implicit SMD model of solvation in dichloromethane (smd,solvent = dichloromethane)[8] for all structures (T = 298 K). Minima were determined to be stationary points by the inclusion of a frequency calculation indicating no imaginary frequencies.

7. a) Becke, A. D. *J. Chem. Phys.* 1993, 98, 1372; b) Becke, A. D. *J. Chem. Phys.* 1993, **98**, 5648; c) Lee, C.; Yang, W.; Parr, R. G. *Phys. Rev. B* 1988, **37**, 785-789.
8. Manerich, A. V.; Cramer, C. J., Truhlar, D. G. *J. Phys. Chem. B.* 2009, 113, 6378.

8.1 Ground state computations (geometric coordinates and DFT energies)

Table S2. Geometric coordinates and DFT energies for water (H_2O).

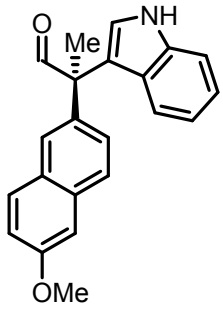
H_2O



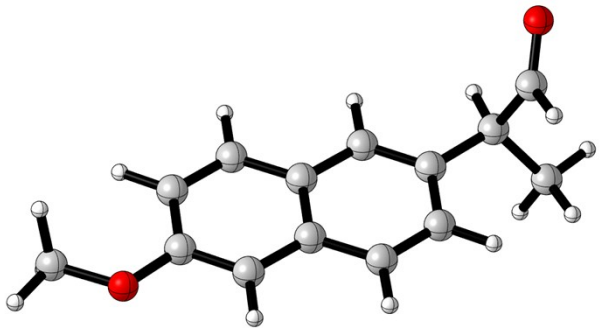
No imaginary frequencies found
G = –47966.2708 kcal/mol

```
Zero-point correction=                           0.020986(Hartree/Particle)
Thermal correction to Energy=                    0.023822
Thermal correction to Enthalpy=                  0.024766
Thermal correction to Gibbs Free Energy=         0.003325
Sum of electronic and zero-point Energies=           -76.421454
Sum of electronic and thermal Energies=              -76.418618
Sum of electronic and thermal Enthalpies=            -76.417673
Sum of electronic and thermal Free Energies=         -76.439115
---------------------------------------------------------------------
 Center     Atomic                   Forces (Hartrees/Bohr)
 Number     Number              X              Y              Z
---------------------------------------------------------------------
      1        8          -0.000001835   -0.000055831   -0.000003344
      2        1           0.000024858    0.000027091    0.000002298
      3        1          -0.000023022    0.000028740    0.000001045
---------------------------------------------------------------------
```

Table S3. Geometric coordinates and DFT energies for aldehyde **xx**



4a



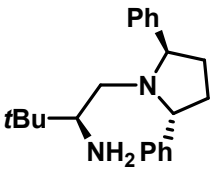
No imaginary frequencies found

G = –434377.1851 kcal/mol

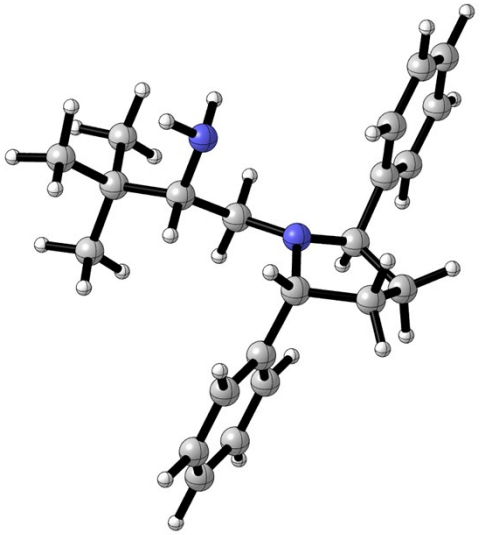
```
Zero-point correction=                           0.244860(Hartree/Particle)
Thermal correction to Energy=                    0.259341
Thermal correction to Enthalpy=                  0.260285
Thermal correction to Gibbs Free Energy=         0.202949
Sum of electronic and zero-point Energies=           -692.182167
Sum of electronic and thermal Energies=              -692.167686
Sum of electronic and thermal Enthalpies=            -692.166742
Sum of electronic and thermal Free Energies=         -692.224078
```

Center Number	Atomic Number	Forces (Hartrees/Bohr) X	Y	Z
1	6	-0.000005446	0.000007758	0.000007269
2	6	0.000006660	-0.000000827	0.000002799
3	6	-0.000008061	0.000001933	-0.000001590
4	6	-0.000007553	-0.000001743	0.000003292
5	6	0.000006171	0.000000563	0.000007762
6	6	-0.000002796	-0.000005146	0.000009075
7	1	-0.000001415	-0.000000076	-0.000008115
8	1	-0.000001119	0.000000404	-0.000001750
9	6	0.000008943	-0.000000105	-0.000005721
10	6	0.000012020	0.000001260	-0.000001575
11	1	-0.000000261	0.000000215	0.000010690
12	1	-0.000000644	0.000000300	0.000012046
13	6	-0.000004434	0.000006741	-0.000002836
14	6	-0.000005865	-0.000008804	-0.000008627
15	1	-0.000000822	-0.000000462	0.000004748
16	1	0.000002323	0.000001852	-0.000010340
17	8	-0.000001907	0.000000854	0.000004202
18	6	0.000002013	-0.000001141	0.000010686
19	1	-0.000001176	0.000001769	0.000014347
20	1	0.000001044	0.000000191	0.000014177
21	1	-0.000003654	0.000003854	0.000013691
22	6	-0.000001363	-0.000000882	-0.000007878
23	1	0.000001360	-0.000000479	-0.000001218
24	6	-0.000004181	-0.000000416	-0.000014497
25	1	-0.000005088	0.000004100	-0.000007128
26	1	-0.000001168	0.000001970	-0.000008278
27	1	-0.000001580	0.000001563	-0.000012247
28	6	0.000002592	-0.000016266	-0.000015669
29	1	0.000006867	-0.000001101	-0.000007058
30	8	0.000008540	0.000002123	-0.000000256

Table S4. Geometric coordinates and DFT energies for aminocatalyst **3f.**



3f



No imaginary frequencies found

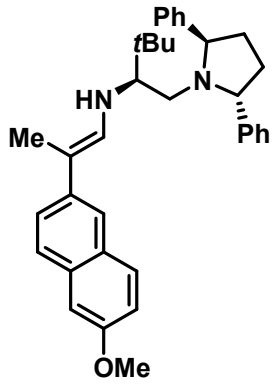
G = –605913.9896 kcal/mol

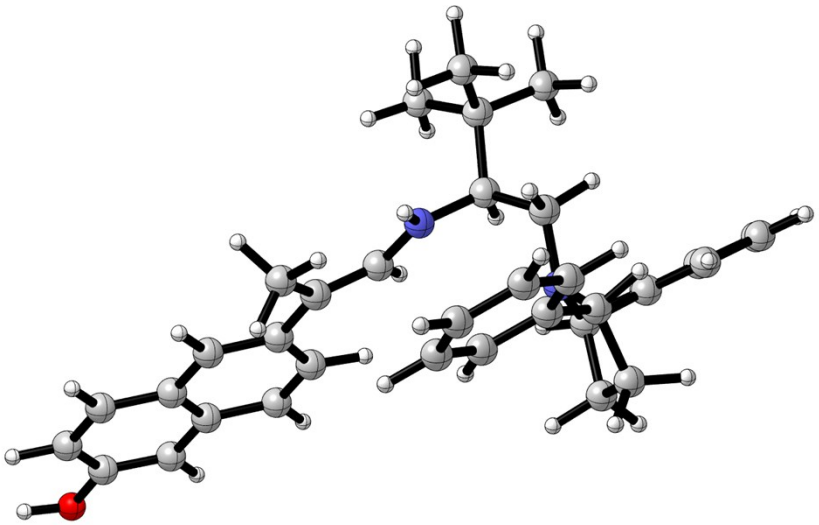
Zero-point correction=
0.476073(Hartree/Particle)
Thermal correction to Energy=
0.499369
Thermal correction to Enthalpy=
0.500314
Thermal correction to Gibbs Free Energy=
0.422277
Sum of electronic and zero-point Energies= -965.531569
Sum of electronic and thermal Energies= -965.508273
Sum of electronic and thermal Enthalpies= -965.507329
Sum of electronic and thermal Free Energies= -965.585365

Center Number	Atomic Number	Forces (Hartrees/Bohr) X	Y	Z
1	6	-0.000000542	0.000005240	0.000006852
2	1	-0.000000009	-0.000000828	0.000000728
3	1	-0.000001302	-0.000001718	0.000000806
4	6	-0.000002125	-0.000000622	0.000000818
5	1	-0.000002447	0.000000503	0.000000335
6	6	-0.000004213	-0.000003057	0.000004266
7	6	-0.000000664	0.000002111	0.000003081
8	1	-0.000001767	0.000001192	0.000002550
9	1	-0.000001818	0.000000483	0.000003532
10	1	-0.000002463	-0.000001648	0.000004037
11	6	0.000000073	-0.000001529	0.000003993
12	1	-0.000001955	-0.000000710	0.000003035
13	1	-0.000001713	-0.000002811	0.000002362
14	1	-0.000002388	-0.000001034	0.000004480
15	6	0.000000618	-0.000003226	-0.000001312
16	1	-0.000001364	-0.000002999	0.000003286
17	1	-0.000001260	-0.000002742	0.000003469
18	1	0.000000044	-0.000003642	0.000002371
19	6	-0.000000021	0.000002192	0.000002601
20	6	0.000003874	-0.000003253	0.000002495
21	6	0.000001809	0.000005244	-0.000002192
22	1	-0.000000388	0.000002520	-0.000002450
23	6	-0.000001210	0.000001110	-0.000001669
24	1	0.000002411	0.000000303	0.000000319
25	1	0.000000404	0.000000180	-0.000002008
26	1	0.000001984	0.000001368	-0.000004979
27	1	0.000001787	-0.000000587	-0.000004036
28	1	0.000002036	0.000002526	-0.000002248
29	7	-0.000006104	-0.000006528	-0.000010101
30	6	0.000005367	-0.000001984	-0.000000690
31	6	-0.000000022	-0.000000855	-0.000004767

32	6	0.000001772	-0.000001334	-0.000001285
33	6	0.000000914	-0.000005343	-0.000003452
34	1	0.000002479	-0.000002135	-0.000001468
35	6	0.000003063	-0.000001483	-0.000005431
36	1	0.000000508	-0.000000666	-0.000003293
37	6	0.000004556	-0.000002055	-0.000002815
38	1	0.000003287	-0.000004038	-0.000002556
39	1	0.000001962	-0.000003228	-0.000003902
40	1	0.000002422	-0.000004822	-0.000003320
41	6	0.000005635	0.000000044	0.000002193
42	6	-0.000000705	0.000006754	-0.000001937
43	6	-0.000003752	0.000000259	-0.000001300
44	6	-0.000002815	0.000002756	0.000002929
45	1	-0.000001500	0.000004137	0.000000332
46	6	0.000000947	0.000004948	-0.000002379
47	1	-0.000000405	0.000003045	-0.000001077
48	6	-0.000003290	0.000003616	0.000003765
49	1	-0.000002303	0.000005962	0.000000628
50	1	-0.000000589	0.000002905	0.000001369
51	1	-0.000000854	0.000004919	0.000001670
52	7	0.000001506	0.000001503	0.000003299
53	1	0.000000236	-0.000000677	-0.000000417
54	1	0.000000296	-0.000000264	-0.000000519

Table S5. Geometric coordinates and DFT energies for enamine.





No imaginary frequencies found

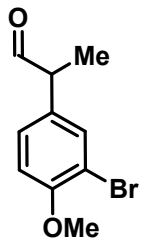
G = –967680.9284 kcal/mol

```
Zero-point correction=                           0.669092(Hartree/Particle)
Thermal correction to Energy=                    0.704663
Thermal correction to Enthalpy=                  0.705608
Thermal correction to Gibbs Free Energy=         0.598752
Sum of electronic and zero-point Energies=          -1542.027315
Sum of electronic and thermal Energies=             -1541.991744
Sum of electronic and thermal Enthalpies=           -1541.990799
Sum of electronic and thermal Free Energies=        -1542.097655
```

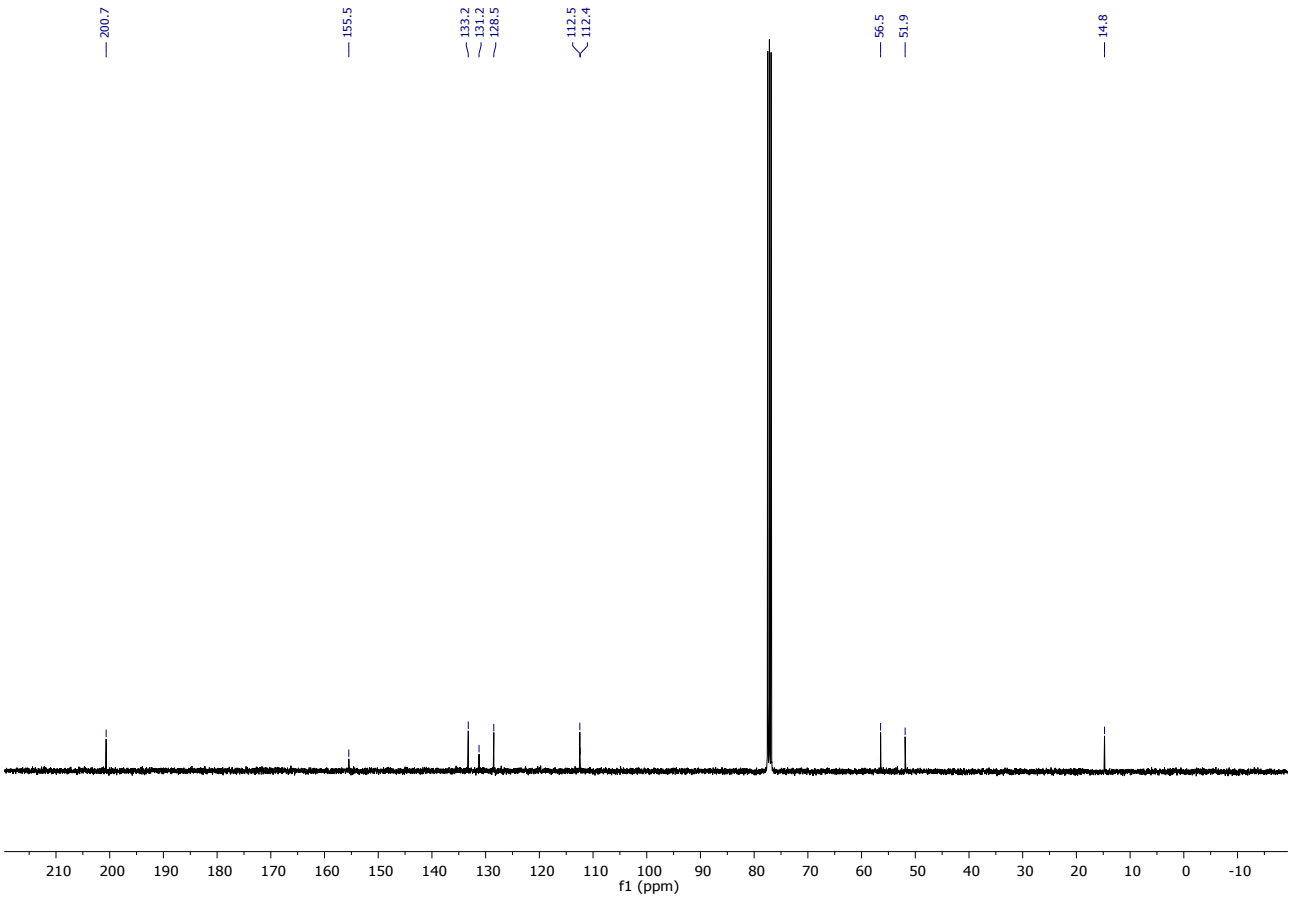
Center Number	Atomic Number	Forces (Hartrees/Bohr) X	Y	Z
1	6	-0.000006728	-0.000004333	-0.000001899
2	1	0.000001385	-0.000002122	0.000000394
3	1	-0.000002260	-0.000000656	-0.000002742
4	6	0.000007898	-0.000001502	-0.000001194
5	1	-0.000003643	-0.000000922	-0.000000129
6	6	-0.000001061	0.000003946	-0.000000204
7	1	-0.000000673	-0.000000002	0.000001862
8	1	-0.000001425	-0.000000933	0.000002832
9	1	-0.000001599	0.000002879	0.000002029
10	7	-0.000006654	0.000006094	0.000007538
11	6	0.000000558	0.000001303	0.000007203
12	6	-0.000002285	-0.000004900	-0.000005386
13	1	-0.000000034	0.000002000	0.000002320
14	6	0.000002790	-0.000001308	0.000005190
15	1	-0.000002127	0.000002918	0.000004280
16	6	-0.000005755	0.000008946	0.000002370
17	6	-0.000002290	-0.000004356	0.000006562
18	1	0.000001769	0.000000843	-0.000000501
19	6	0.000002430	0.000004949	0.000004093
20	1	-0.000001704	0.000001804	0.000003886
21	1	-0.000000825	-0.000003219	-0.000002573
22	6	-0.000003491	-0.000001958	-0.000004668
23	6	-0.000004136	-0.000002364	-0.000001844
24	1	-0.000000912	-0.000000903	-0.000003296
25	1	-0.000001984	-0.000000981	-0.000002901
26	1	-0.000003998	-0.000002291	-0.000003256
27	6	-0.000004408	-0.000001876	-0.000002637

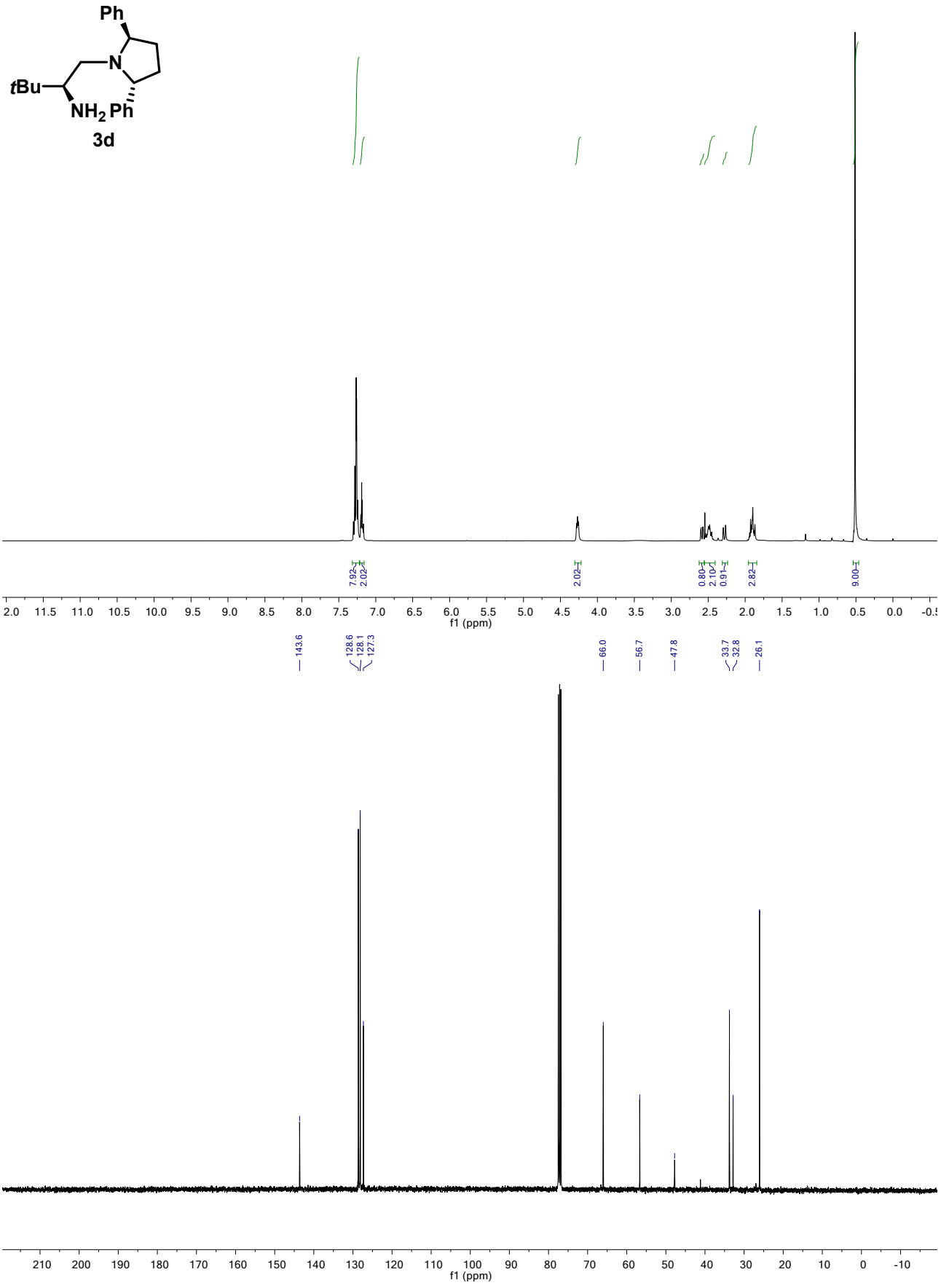
28	1	-0.000002200	-0.000000725	-0.000000713
29	1	-0.000001592	0.000001116	0.000000386
30	1	-0.000003943	-0.000000206	-0.000001328
31	6	-0.000003334	0.000001083	-0.000003068
32	1	-0.000003485	-0.000001163	-0.000002013
33	1	-0.000001936	-0.000000738	-0.000001115
34	1	-0.000002805	-0.000001929	-0.000003072
35	6	0.000008152	0.000002332	-0.000000085
36	6	0.000002550	-0.000005638	0.000003298
37	6	0.000000584	0.000000314	-0.000003514
38	1	0.000000088	-0.000002835	-0.000002288
39	6	0.000005088	-0.000004869	-0.000004788
40	1	0.000002480	-0.000000142	-0.000001622
41	1	0.000002398	-0.000001089	0.000000417
42	1	0.000003906	-0.000001592	-0.000001615
43	1	0.000003206	-0.000001738	-0.000001341
44	1	0.000004074	-0.000000371	-0.000002827
45	7	0.000007213	0.000005067	-0.000005035
46	6	0.000003716	0.000002586	-0.000005312
47	6	0.000003440	-0.000004676	-0.000000448
48	6	-0.000000703	0.000003547	-0.000005180
49	6	0.000000076	0.000001617	-0.000002704
50	1	0.000002323	-0.000002728	-0.000002284
51	6	-0.000000234	-0.000004934	0.000003114
52	1	0.000002626	-0.000000502	0.000004003
53	6	0.000006152	0.000000386	-0.000000630
54	1	0.000002552	-0.000001189	-0.000001394
55	1	0.000003576	0.000000575	0.000000553
56	1	0.000003634	-0.000000201	-0.000000503
57	6	-0.000003499	-0.000001946	-0.000002642
58	6	0.000004345	-0.000001657	-0.000003269
59	6	0.000001294	-0.000000520	-0.000006079
60	6	-0.000002037	-0.000001980	-0.000004278
61	1	-0.000000733	-0.000000682	-0.000001102
62	6	-0.000001146	-0.000002722	-0.000002985
63	1	0.000001213	0.000000041	-0.000004351
64	6	0.000003698	-0.000002733	-0.000004640
65	1	0.000000062	-0.000001924	-0.000003259
66	1	0.000001580	-0.000002816	-0.000006003
67	1	-0.000000128	-0.000003944	-0.000005984
68	6	-0.000001544	-0.000001630	0.000004780
69	6	-0.000000510	0.000005644	0.000002845
70	6	-0.000006069	0.000003555	0.000009519
71	1	0.000001425	0.000004573	0.000006266
72	6	-0.000004869	0.000005027	0.000005252
73	6	0.000003398	0.000009448	0.000002486
74	1	-0.000003364	0.000001384	0.000006829
75	6	0.000004912	-0.000000709	0.000008317
76	1	-0.000002765	0.000003499	0.000004018
77	8	-0.000001094	0.000003897	0.000009236
78	1	-0.000000609	0.000003780	0.000008824

9. NMR Spectra



1s

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N
tBu
NH2 Ph
3d
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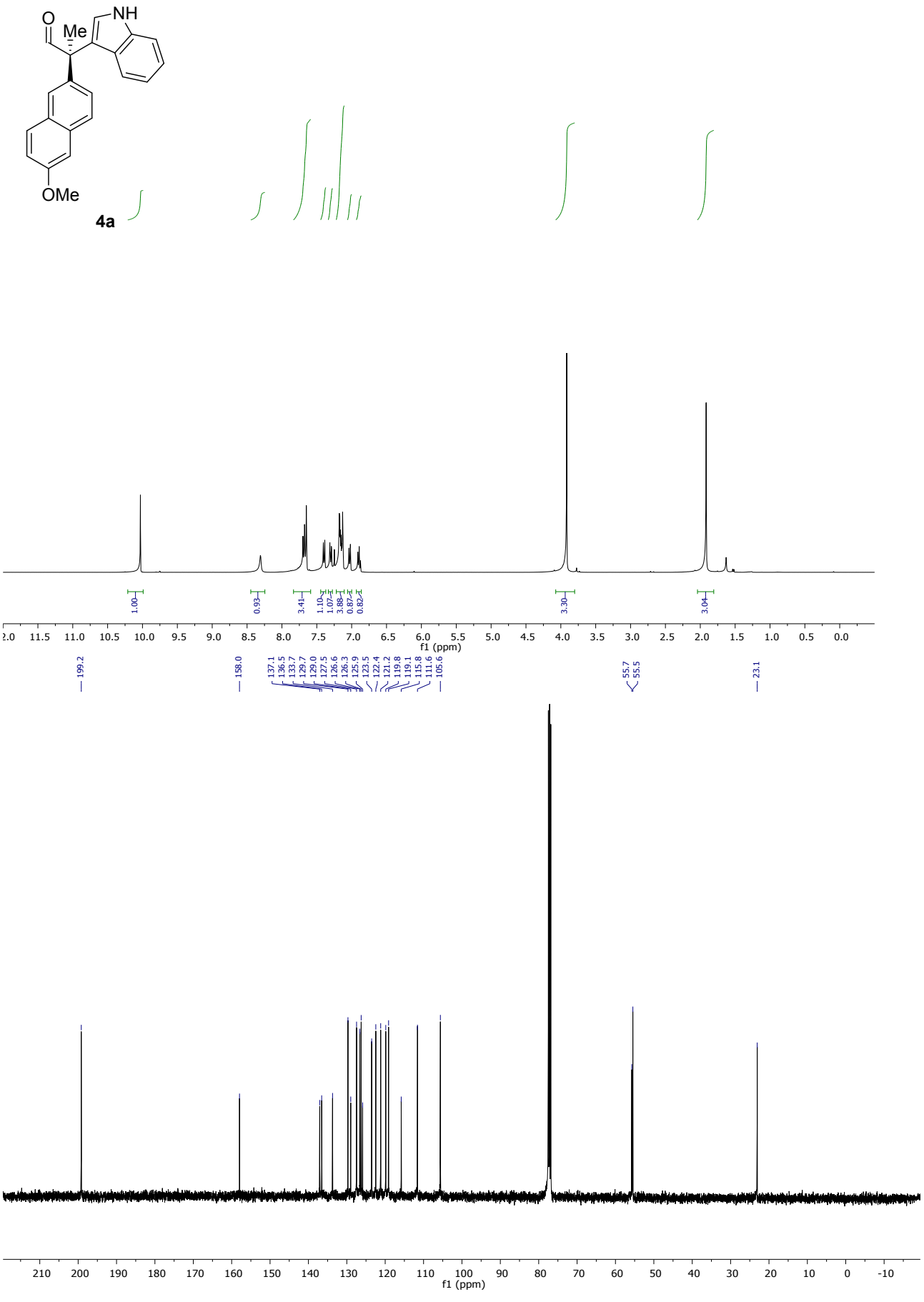
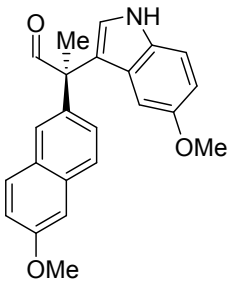
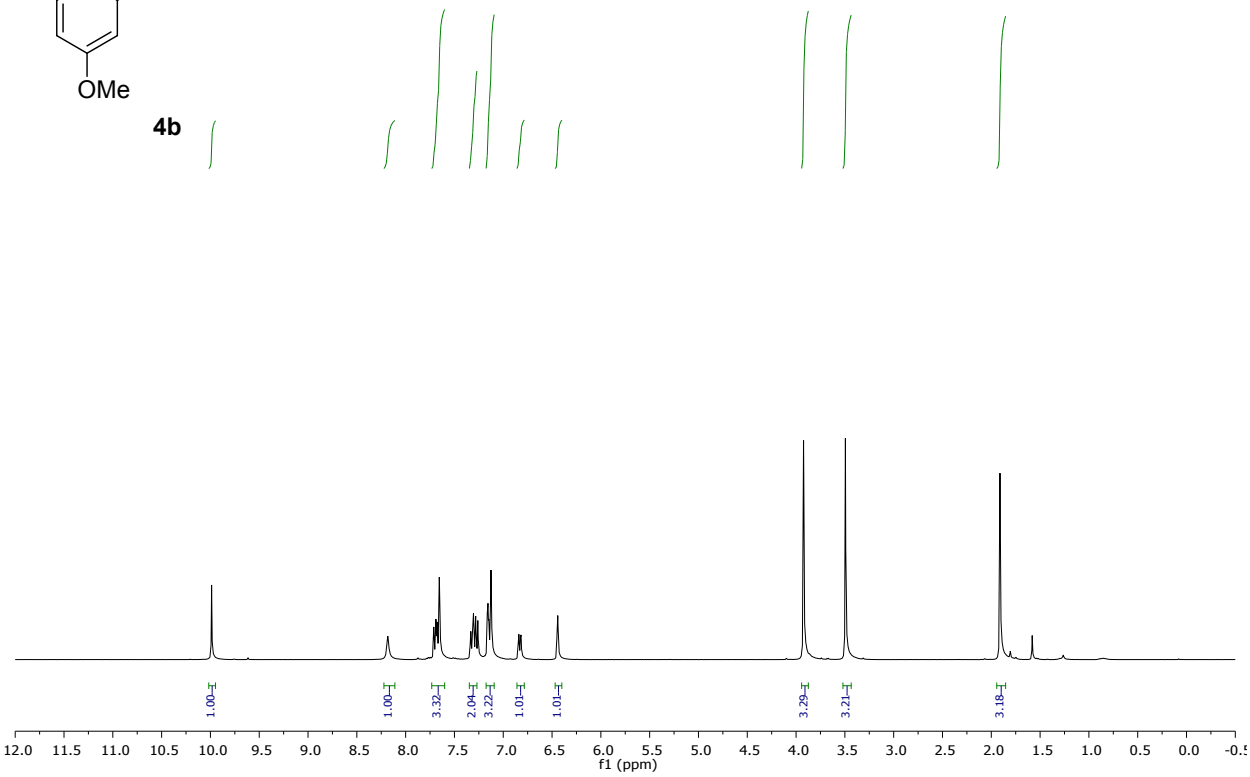
2.02
2.02
0.80
2.10
0.91
2.82
9.00
f1 (ppm)
143.6
128.6
128.1
127.3
66.0
56.7
47.8
33.7
32.8
26.1
f1 (ppm)


O
Me
NH
OMe
4a
1.00
0.93
3.41
1.10
1.07
3.88
0.87
0.82
3.30
3.04
f1 (ppm)
199.2
158.0
137.1
136.5
133.7
129.7
129.0
127.5
126.6
126.3
125.9
123.5
122.4
121.2
119.8
119.1
115.8
111.6
105.6
55.7
55.5
23.1
f1 (ppm)


O
Me
NH
OMe
OMe

4b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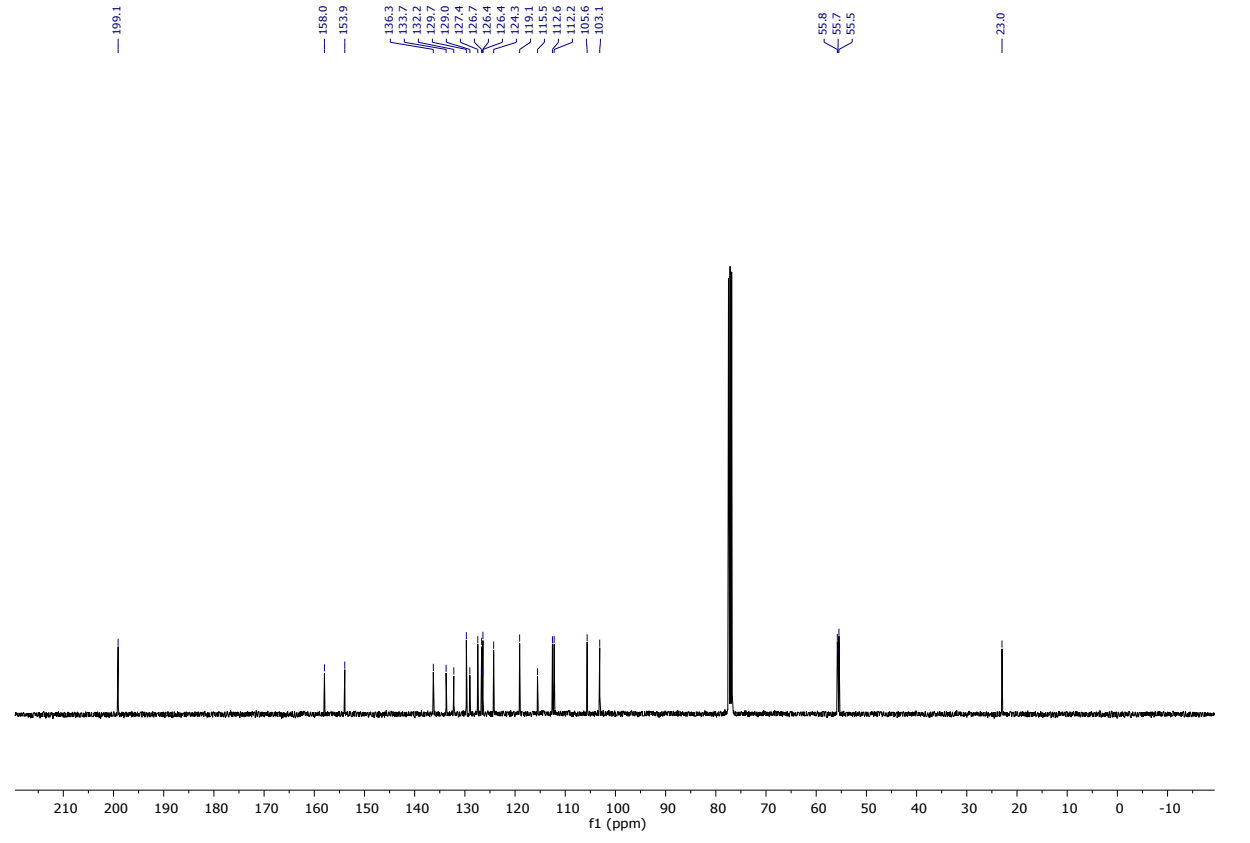
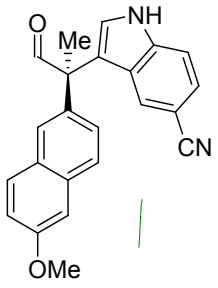
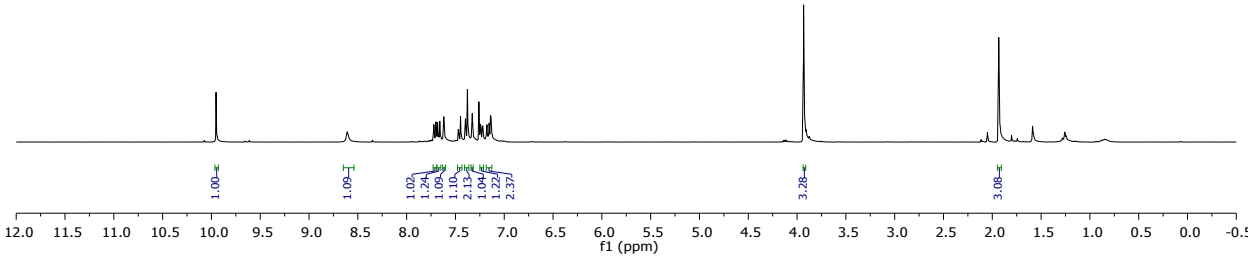
1.00
3.32
2.04
3.22
1.01
1.01
3.29
3.21
3.18
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

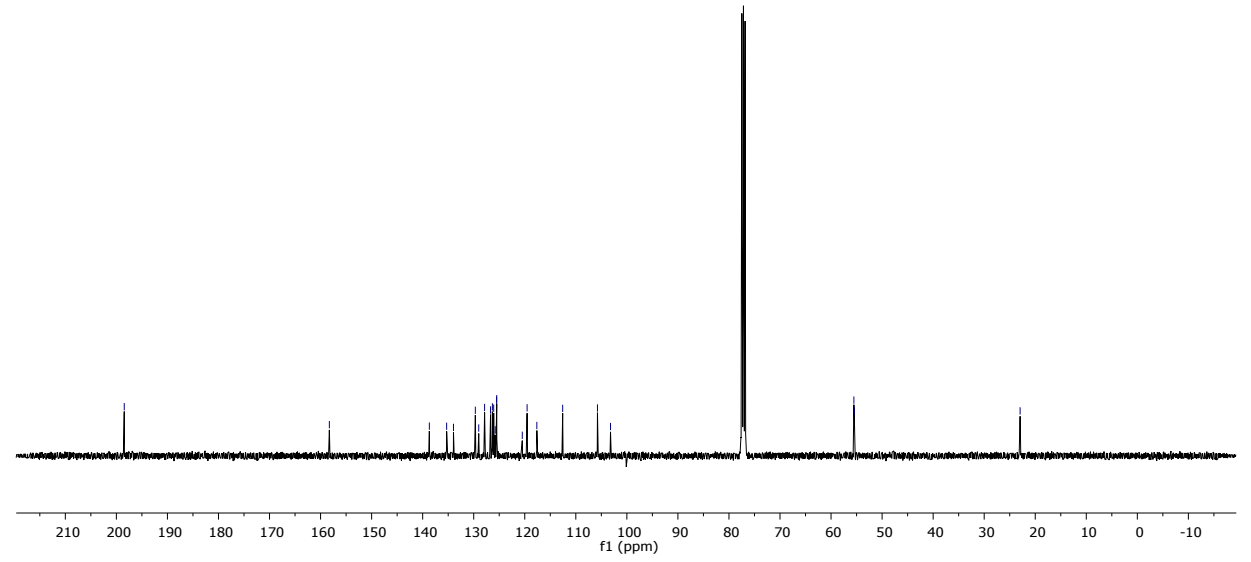

199.1
158.0
153.9
136.3
133.7
132.2
129.7
129.0
127.4
126.7
126.4
126.4
124.3
119.1
115.5
112.6
112.2
105.6
103.1
55.8
55.7
55.5
23.0
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

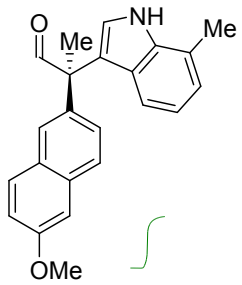

O
Me
NH
CN
OMe

4c


1.00
1.09
1.02
1.24
1.06
1.10
2.13
1.04
1.22
2.37
3.28
3.08
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

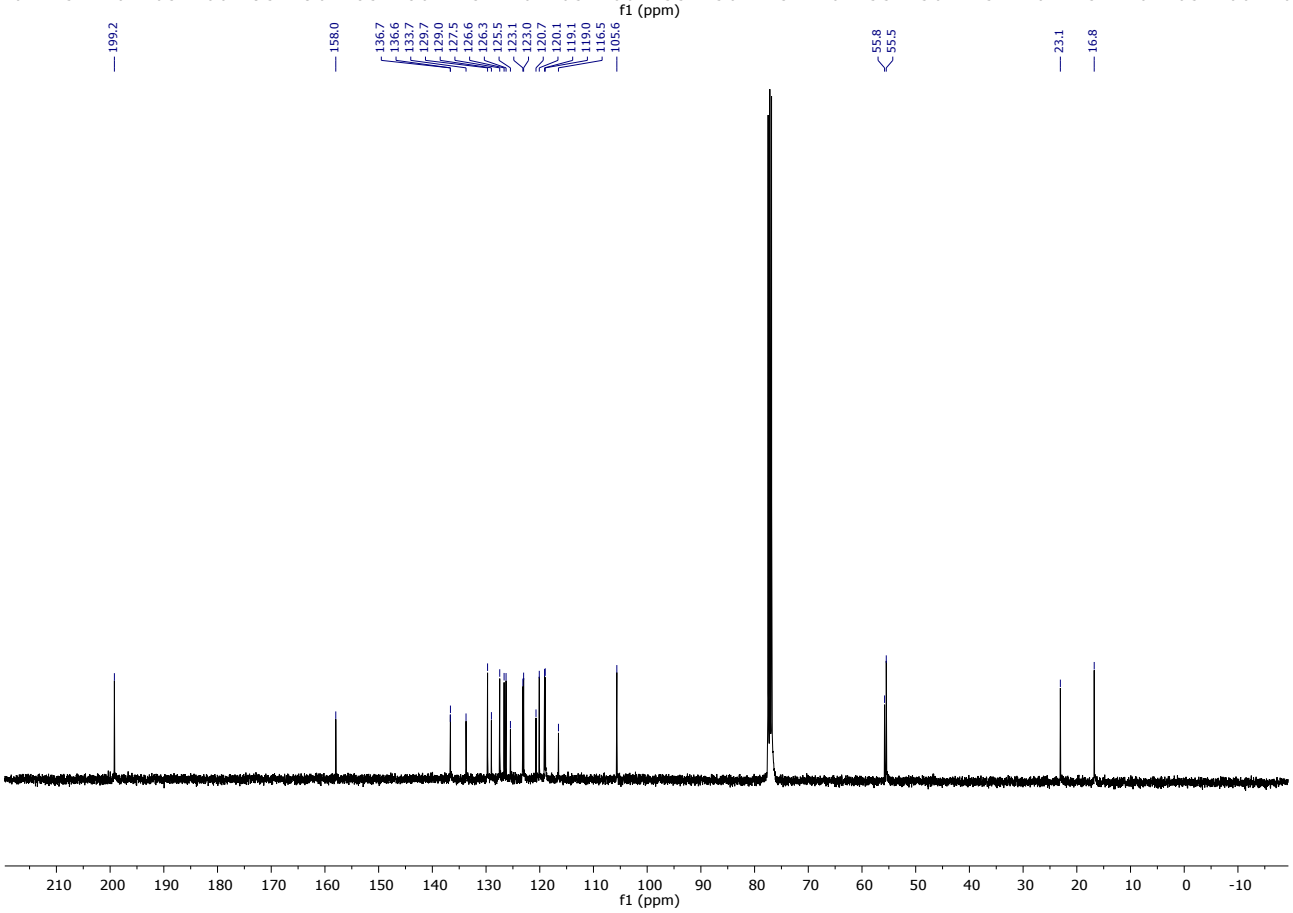

198.5
158.3
138.7
135.3
134.0
129.7
129.0
127.9
126.7
126.3
126.1
125.8
125.5
125.5
120.5
119.5
117.6
112.6
105.8
103.2
55.5
55.4
23.0


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
Me
NH
Me
OMe

4d

1.00
0.95
3.10
0.93
1.01
2.26
1.12
2.23
3.27
3.14
3.00
f1 (ppm)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158.0
136.7
136.6
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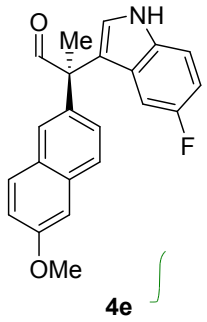
129.7
129.0
127.5
126.6
126.3
125.5
123.1
123.0
120.7
120.1
119.1
119.0
116.5
105.6
55.8
55.5
23.1
16.8
f1 (ppm)


O
Me
NH
F
OMe

4e

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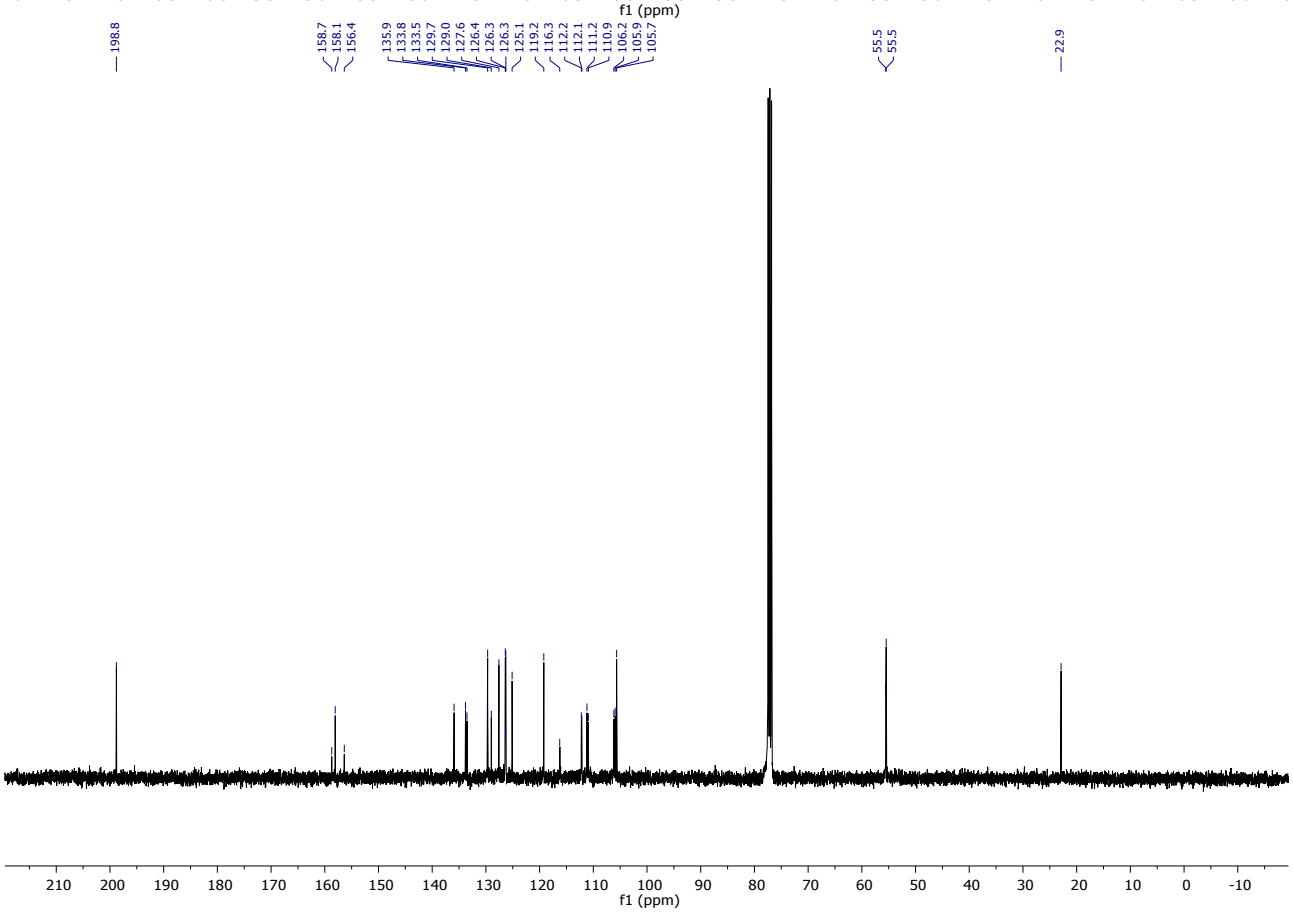
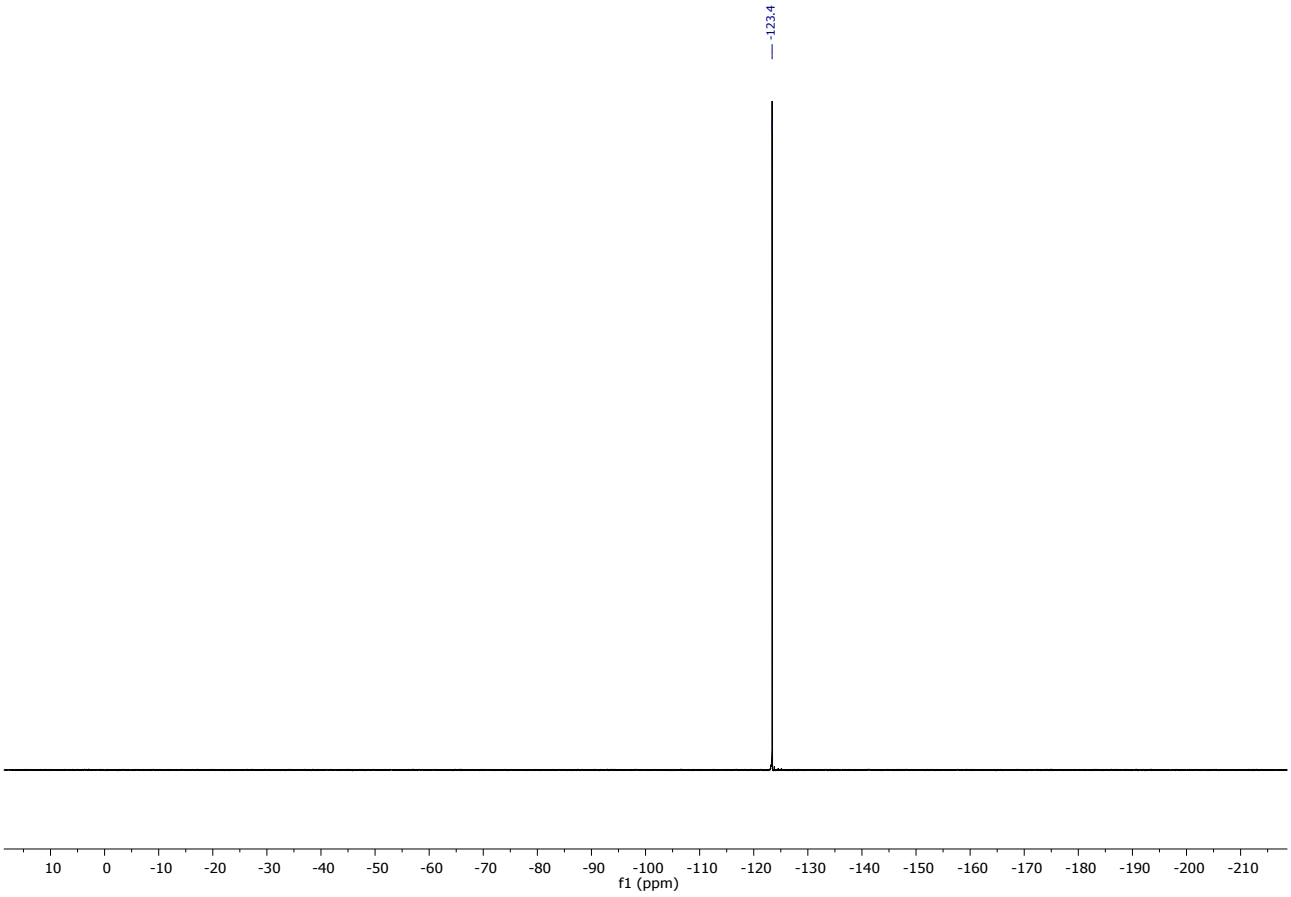
1.11
3.18
2.03
1.30
2.36
1.16
1.06
3.31
3.17
f1 (ppm)


198.8
158.7
158.1
156.4
135.9
133.8
133.5
129.7
129.0
127.6
126.4
126.3
126.3
125.1
119.2
116.3
112.2
112.1
111.2
110.9
106.2
105.9
105.7
55.5
55.5
22.9
f1 (ppm)


-123.4
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
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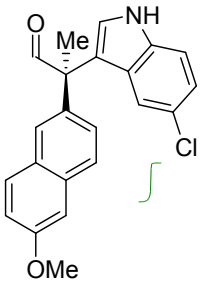
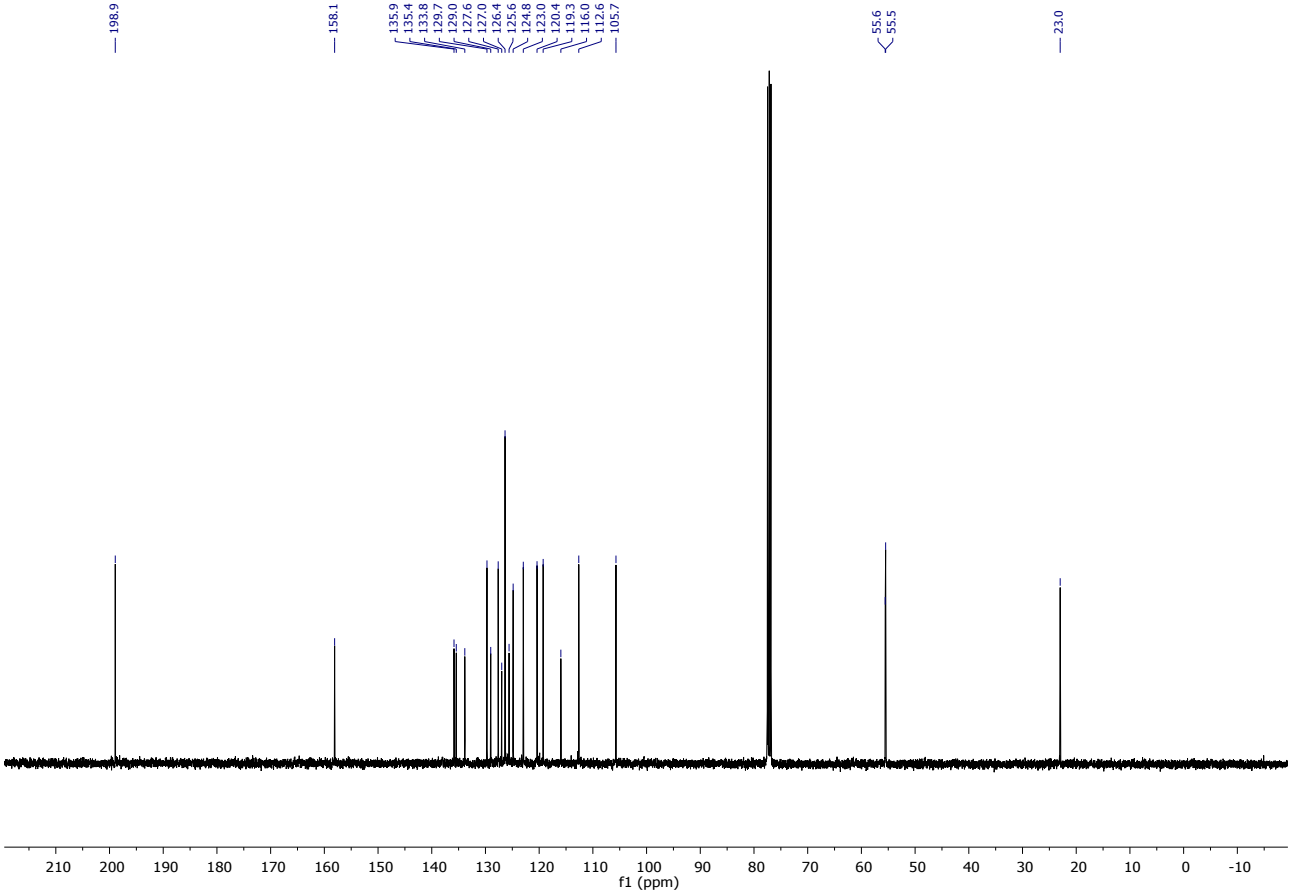
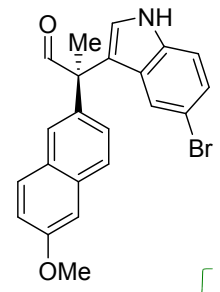
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


O
Me
NH
Cl
OMe

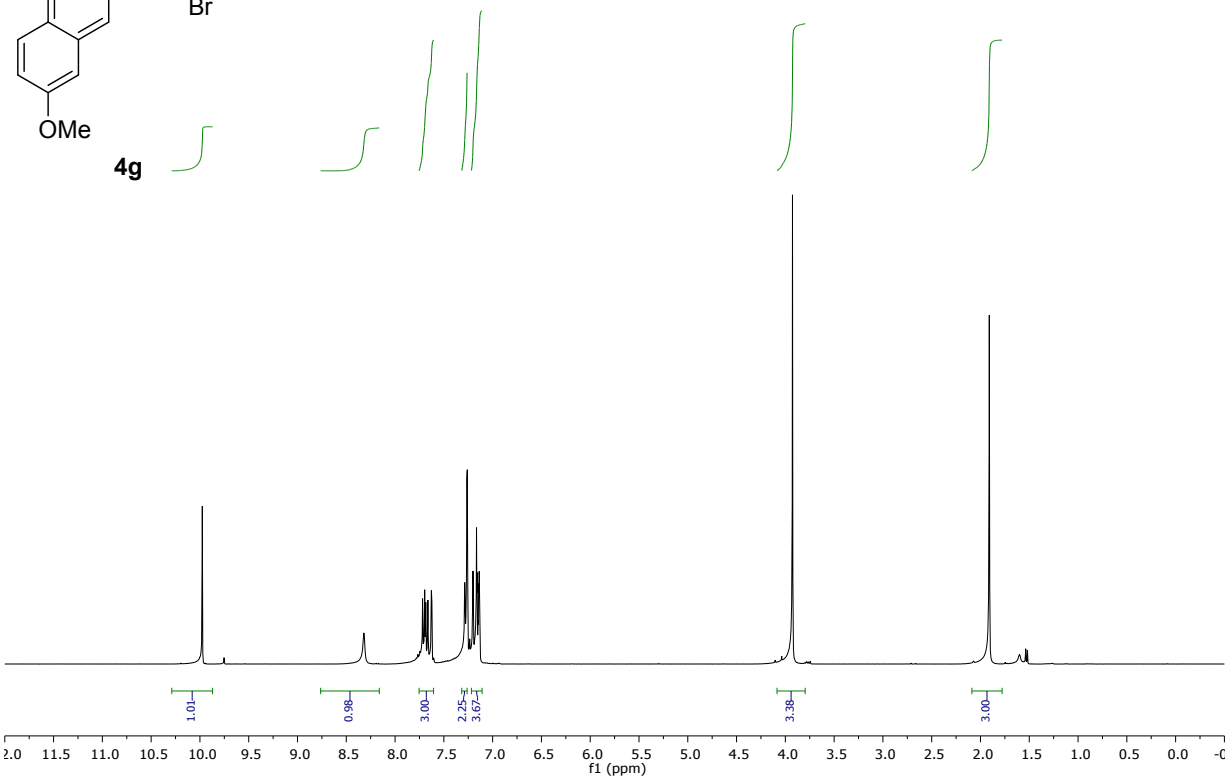
4f

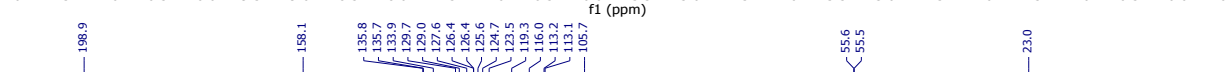
1.00
1.03
3.12
1.97
4.19
0.94
3.19
3.04
f1 (ppm)

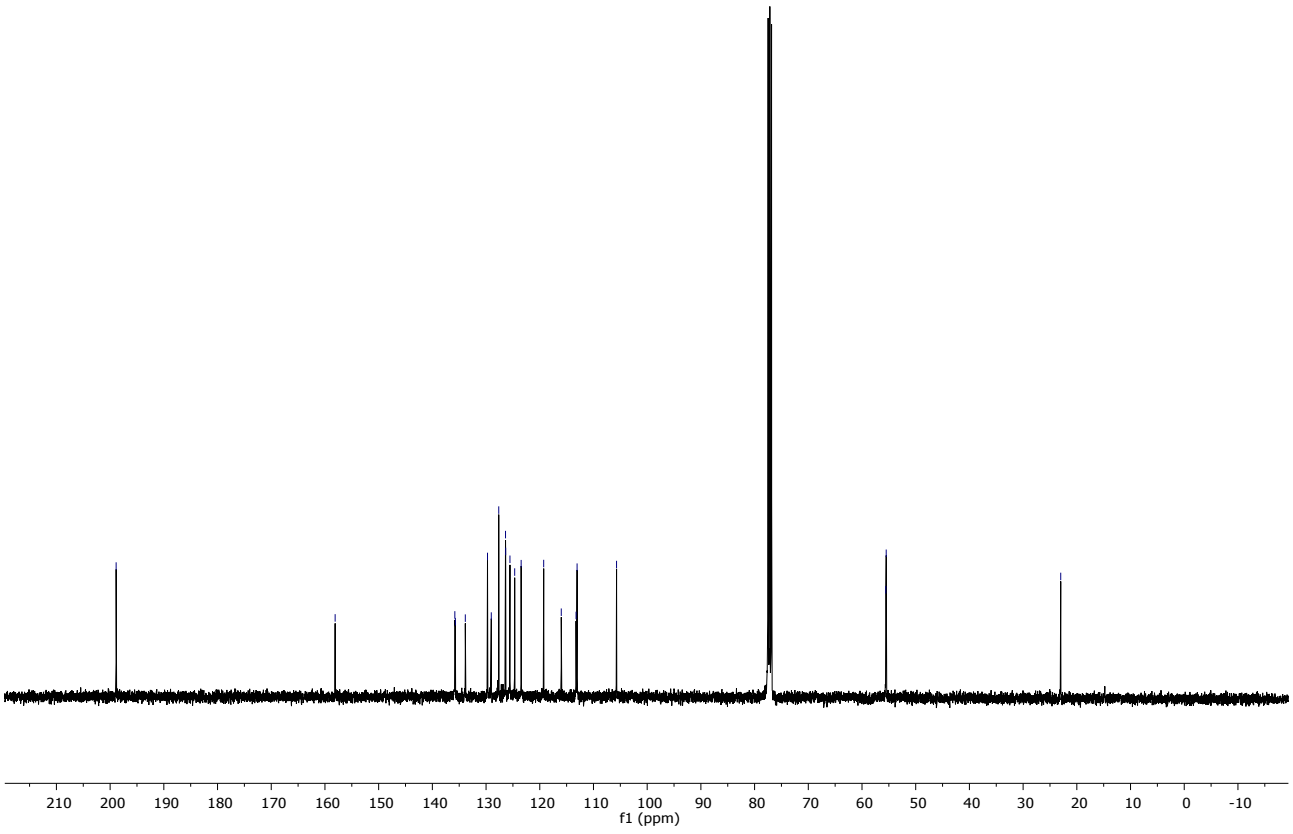

198.9
158.1
135.9
135.4
133.8
129.7
129.0
127.6
127.0
126.4
125.6
124.8
123.0
120.4
119.3
116.0
112.6
105.7
55.6
55.5
23.0
f1 (ppm)

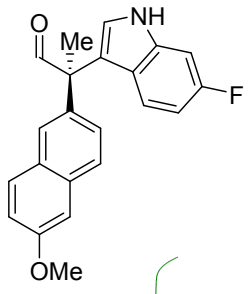

O
Me
NH
Br
OMe

4g


1.01
0.98
3.00
2.25
3.67
3.38
3.00
f1 (ppm)


198.9
158.1
135.8
135.7
133.9
129.7
129.0
127.6
126.4
126.4
125.6
124.7
123.5
119.3
116.0
113.2
113.1
105.7
55.6
55.5
23.0

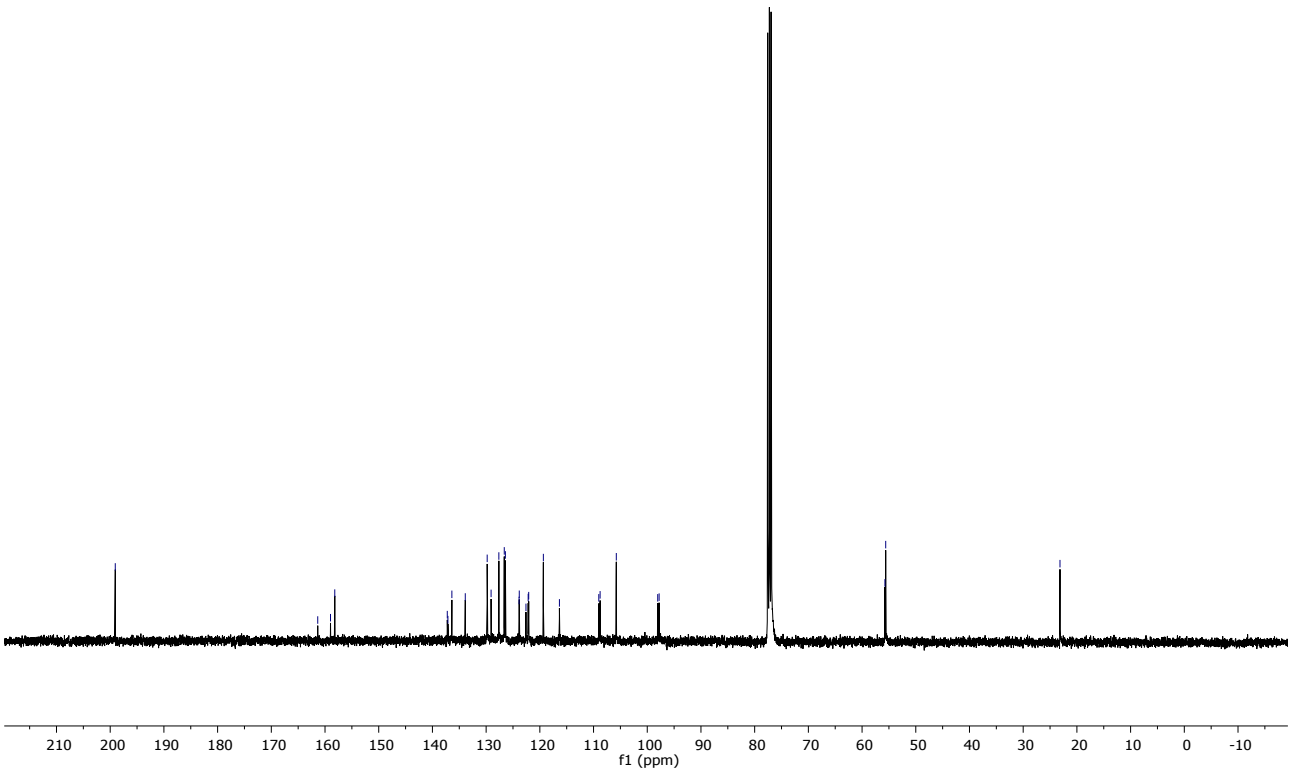

f1 (ppm)

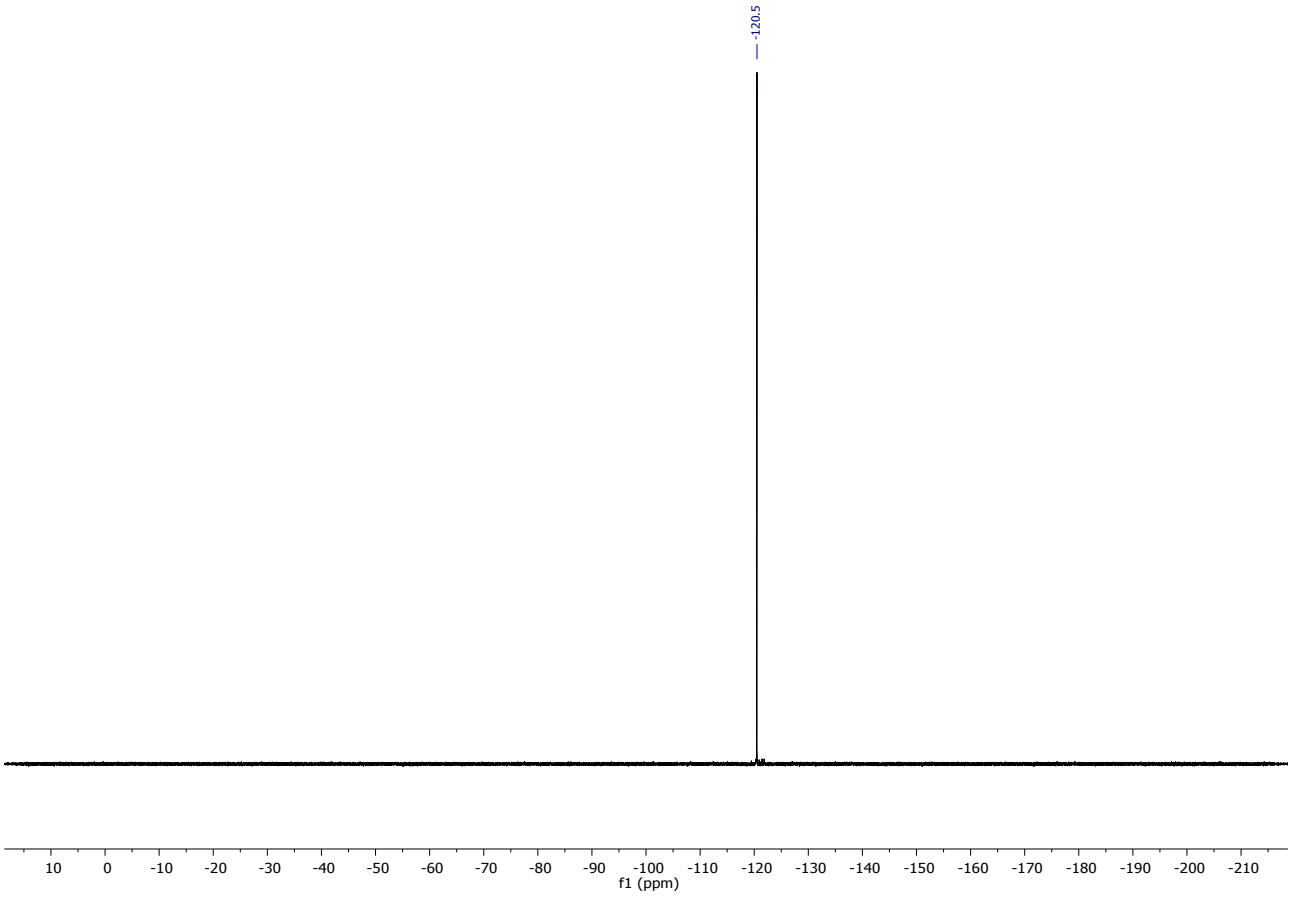

O
Me
NH
F
OMe

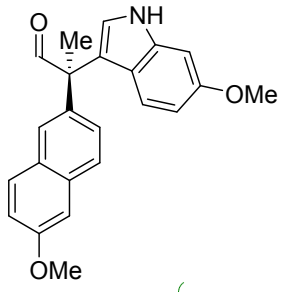
4h

1.00
0.96
2.92
0.74
2.35
1.05
0.93
0.83
3.00
2.66
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

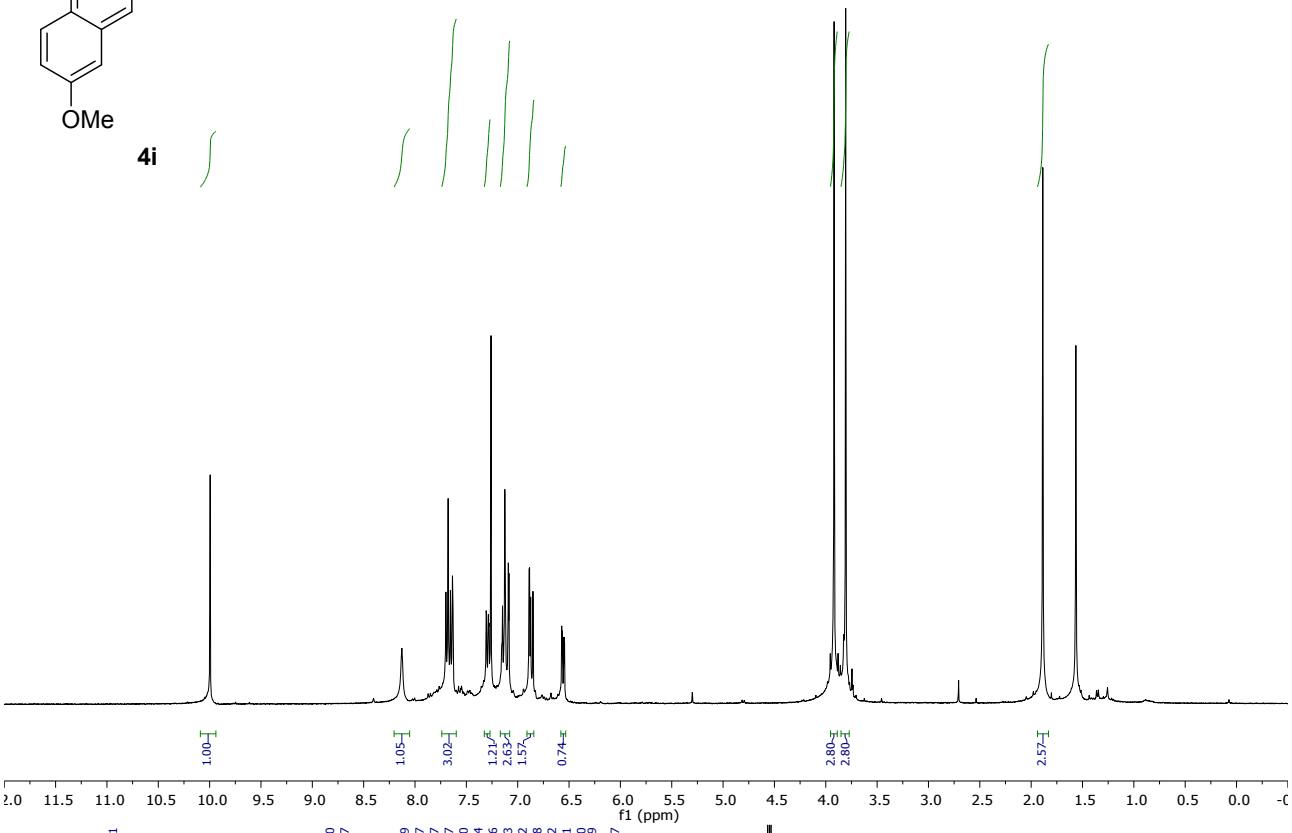
199.1
161.4
159.0
158.2
137.2
137.1
136.4
133.9
129.8
129.1
127.6
126.6
126.4
123.9
123.8
122.6
122.2
122.1
119.3
116.4
109.0
108.8
105.8
98.0
97.8
55.7
55.6
23.1

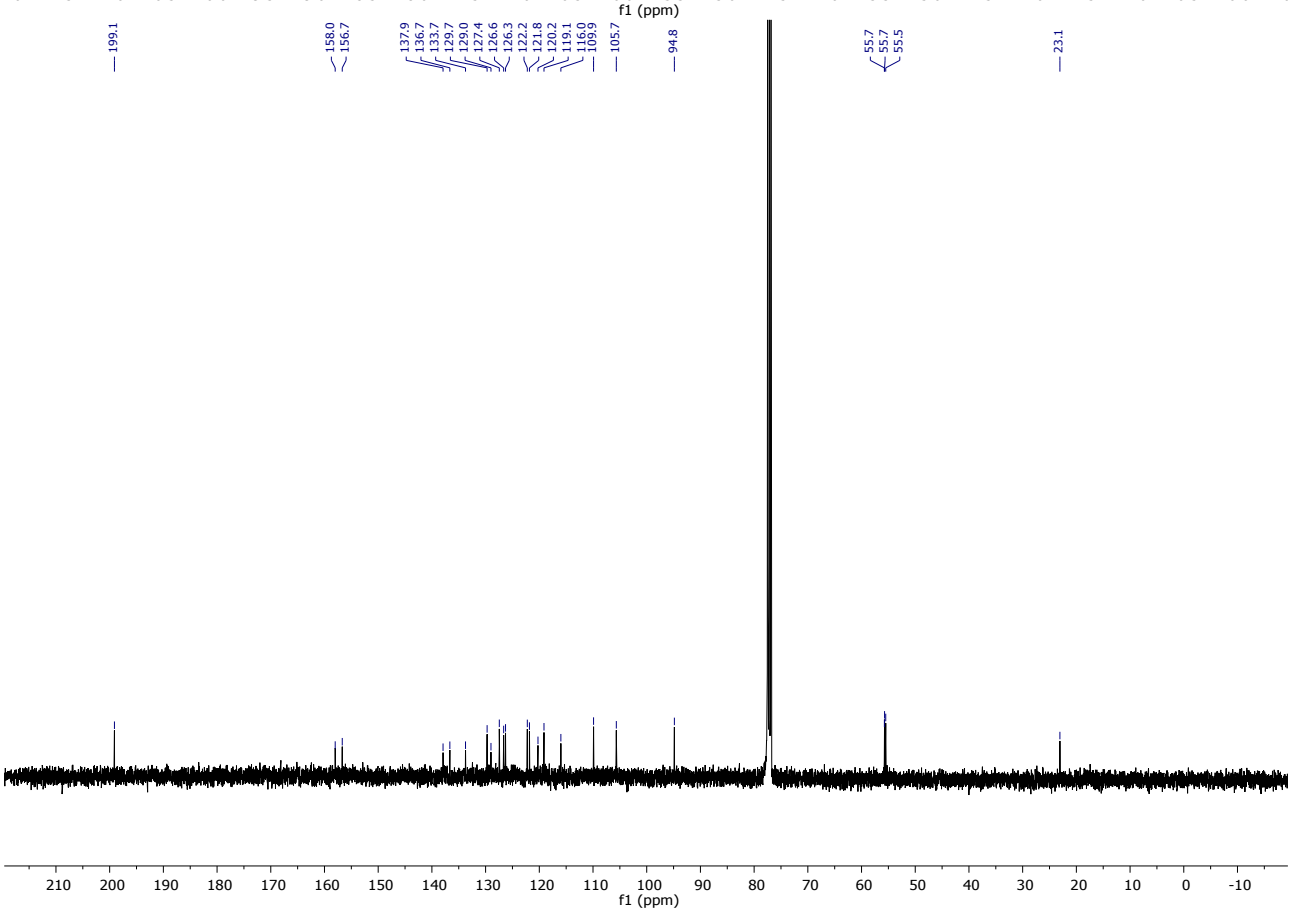

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

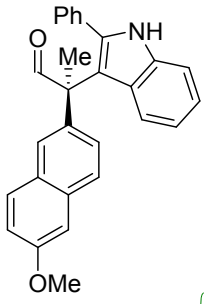

-120.5
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


O
Me
NH
OMe
OMe

4i

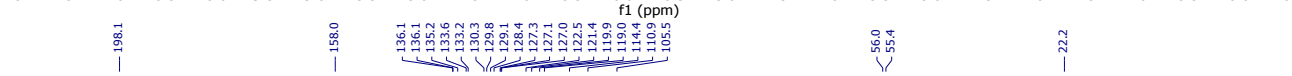

1.00
1.05
3.02
1.21
2.63
1.57
0.74
2.80
2.80
2.57
f1 (ppm)

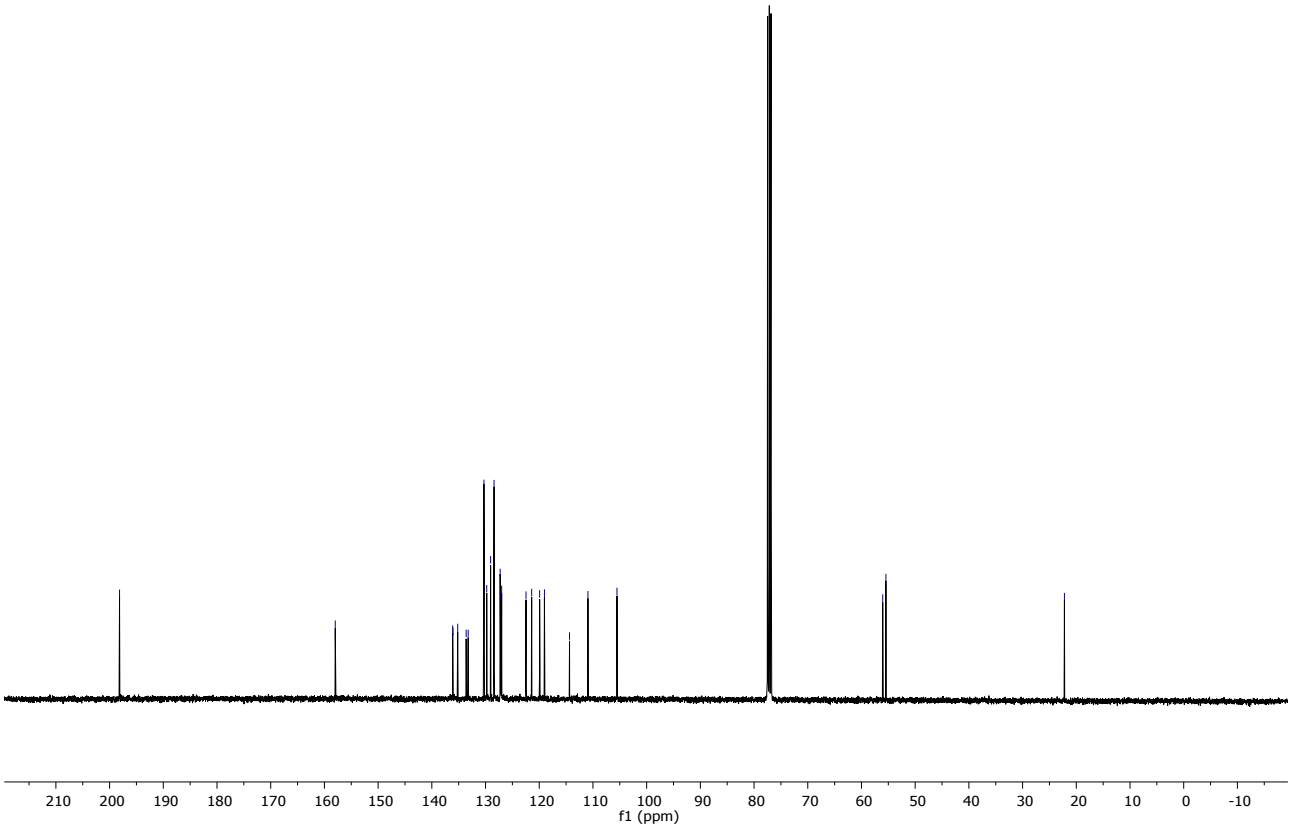

199.1
158.0
156.7
137.9
136.7
133.7
129.7
129.0
127.4
126.6
126.3
122.2
121.8
120.2
119.1
115.0
105.9
105.7
94.8
55.7
55.7
55.5
23.1
f1 (ppm)

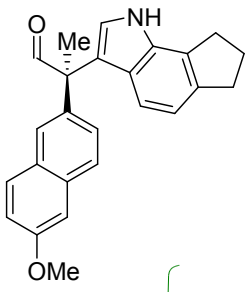

Ph
NH
O
Me
OMe

4l

1.00
1.03
1.09
1.01
1.07
2.07
5.21
2.14
1.08
2.09
3.22
3.16
f1 (ppm)

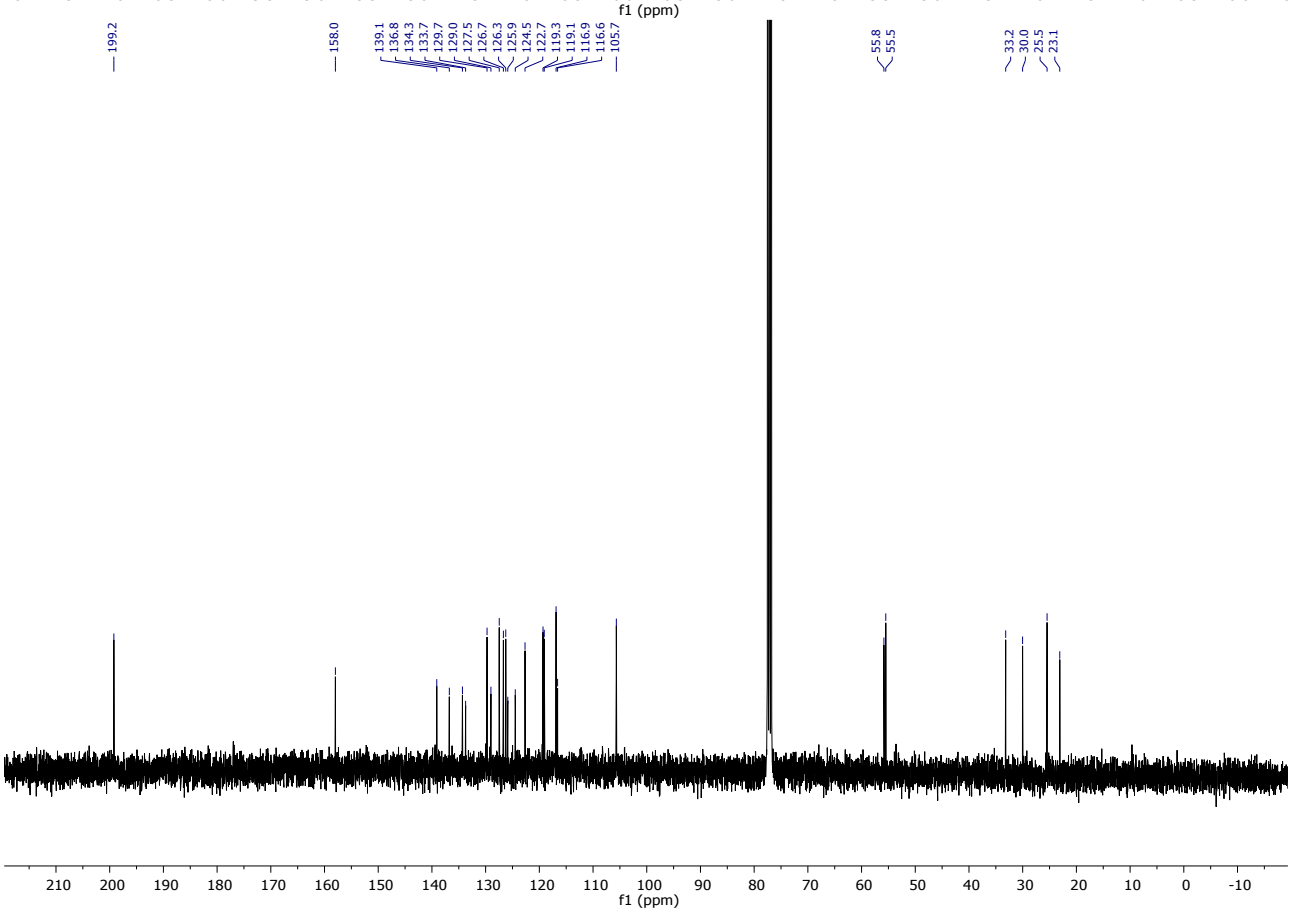

198.1
158.0
136.1
136.1
135.2
133.6
133.2
130.3
129.8
129.1
128.4
127.3
127.1
127.0
122.5
121.4
119.9
119.0
114.4
110.9
105.5
56.0
55.4
22.2

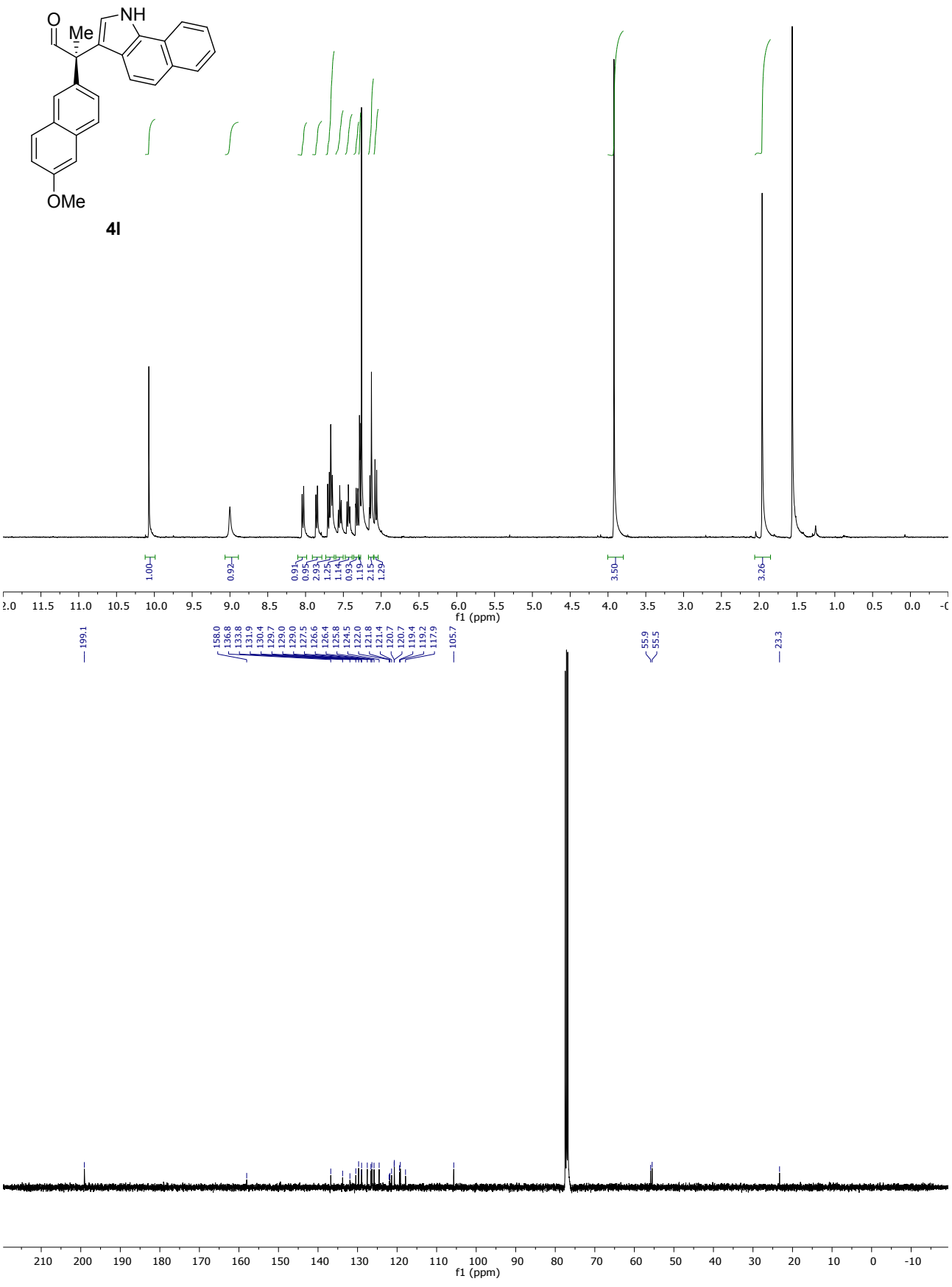

f1 (ppm)

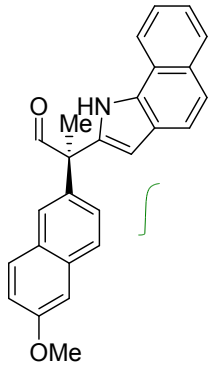

O
Me
NH
OMe

4k

1.00
0.99
3.17
0.93
2.95
1.87
3.31
4.03
2.15
2.95
f1 (ppm)

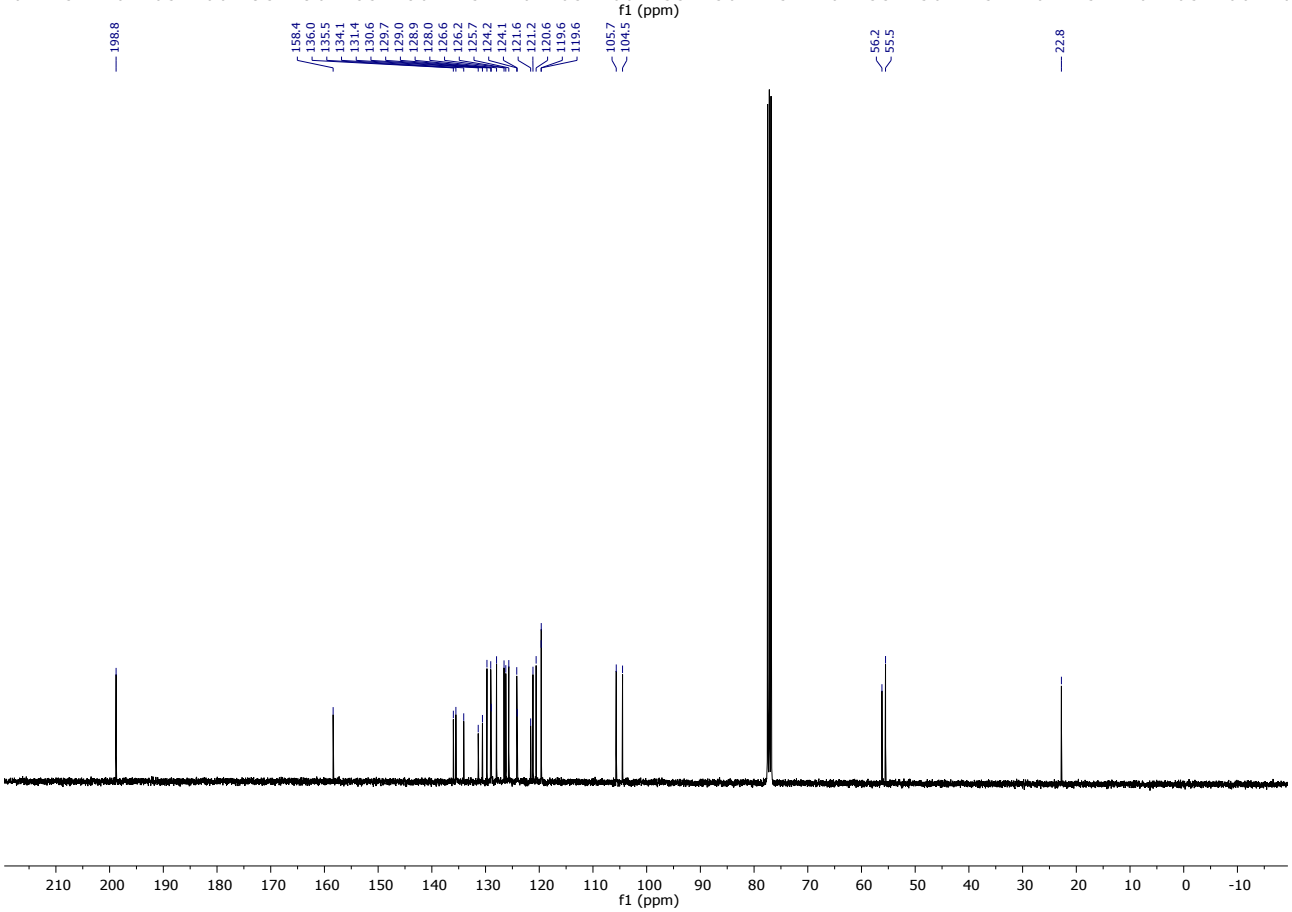

199.2
158.0
139.1
136.8
134.3
133.7
129.7
129.0
127.5
126.7
126.3
125.9
124.5
122.7
119.3
119.1
116.9
116.6
105.7
55.8
55.5
33.2
30.0
25.5
23.1
f1 (ppm)

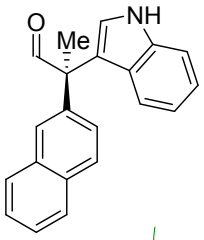

O
Me
NH
OMe
4l
1.00
0.92
0.91
0.95
2.93
1.25
1.14
0.93
1.19
2.15
1.29
3.50
3.26
f1 (ppm)
199.1
158.0
136.8
133.8
131.9
130.4
129.7
129.0
129.0
127.5
126.6
126.4
125.8
124.5
122.0
121.8
121.4
120.7
120.7
119.4
119.2
117.9
105.7
55.9
55.5
23.3
f1 (ppm)


O
HN
Me
OMe

4l'

1.00
0.97
2.05
0.90
3.17
1.05
2.21
0.82
2.08
0.98
3.26
3.19
f1 (ppm)

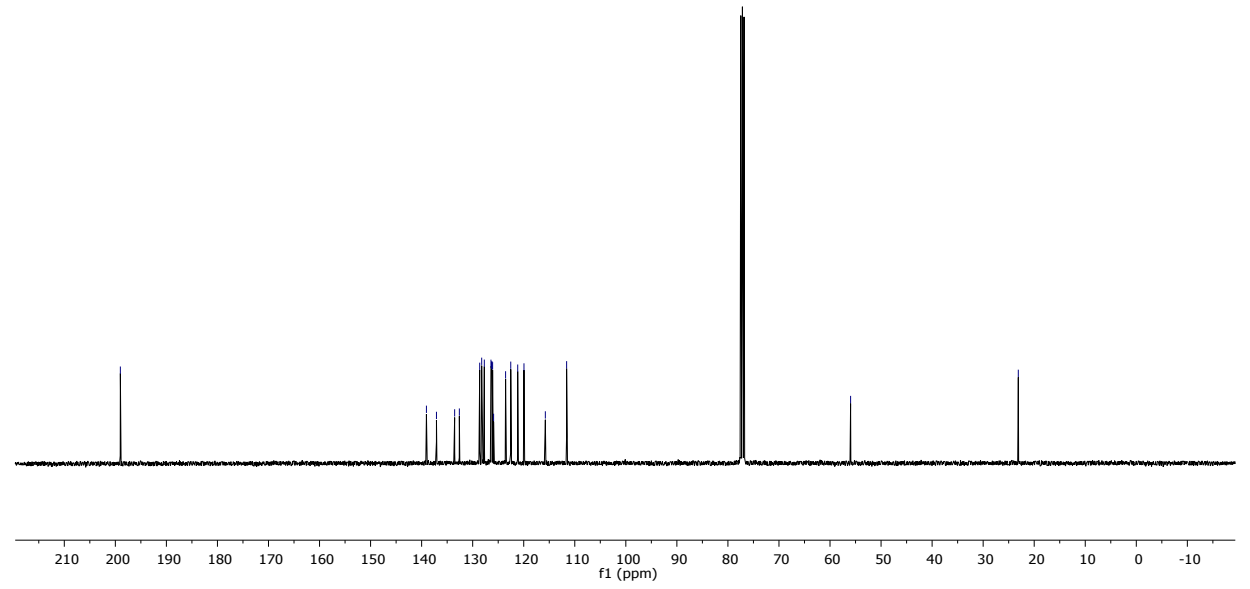

198.8
158.4
136.0
135.5
134.1
131.4
130.6
129.7
129.0
128.9
128.0
126.6
126.2
125.7
124.2
124.1
121.6
121.2
120.6
119.6
119.6
105.7
104.5
56.2
55.5
22.8
f1 (ppm)

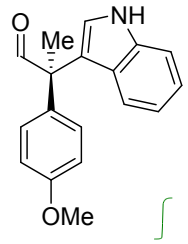

O
Me
NH

4m

1.00
1.00
4.32
2.07
1.06
1.03
1.01
1.14
1.04
1.06
3.19
f1 (ppm)

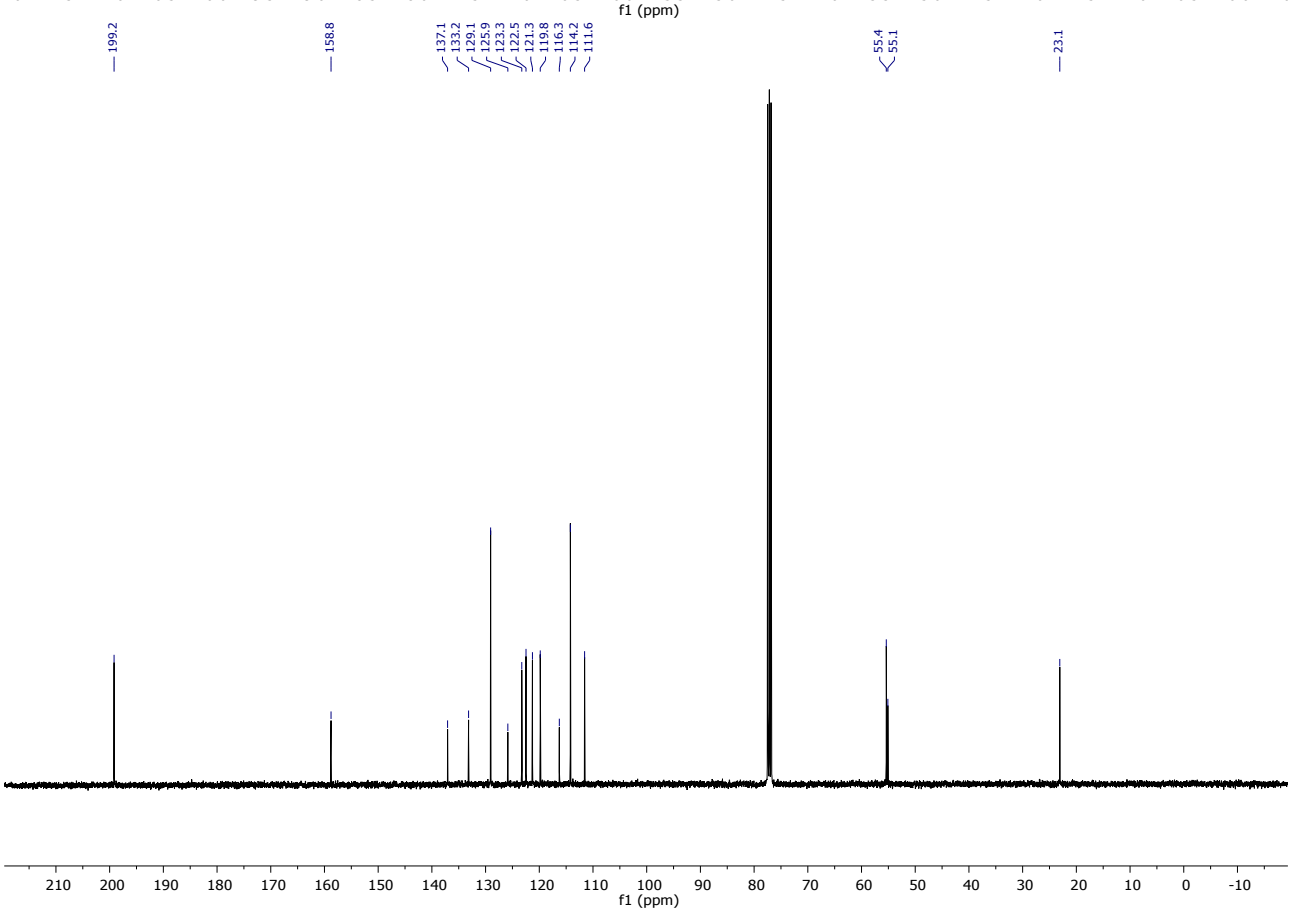

199.0
139.1
137.1
133.5
132.6
128.6
128.2
127.7
126.4
126.3
126.2
126.1
125.9
123.6
122.5
121.2
120.0
115.8
111.6
56.0
23.1

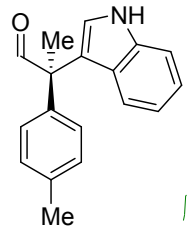

f1 (ppm)


O
Me
NH
OMe

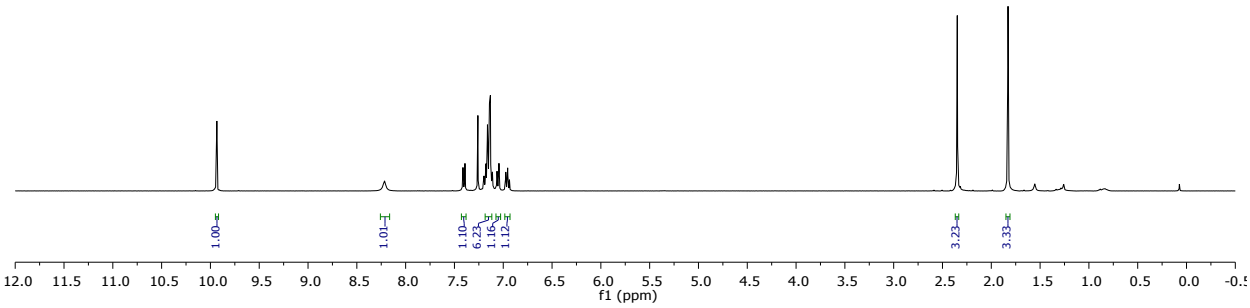
4n

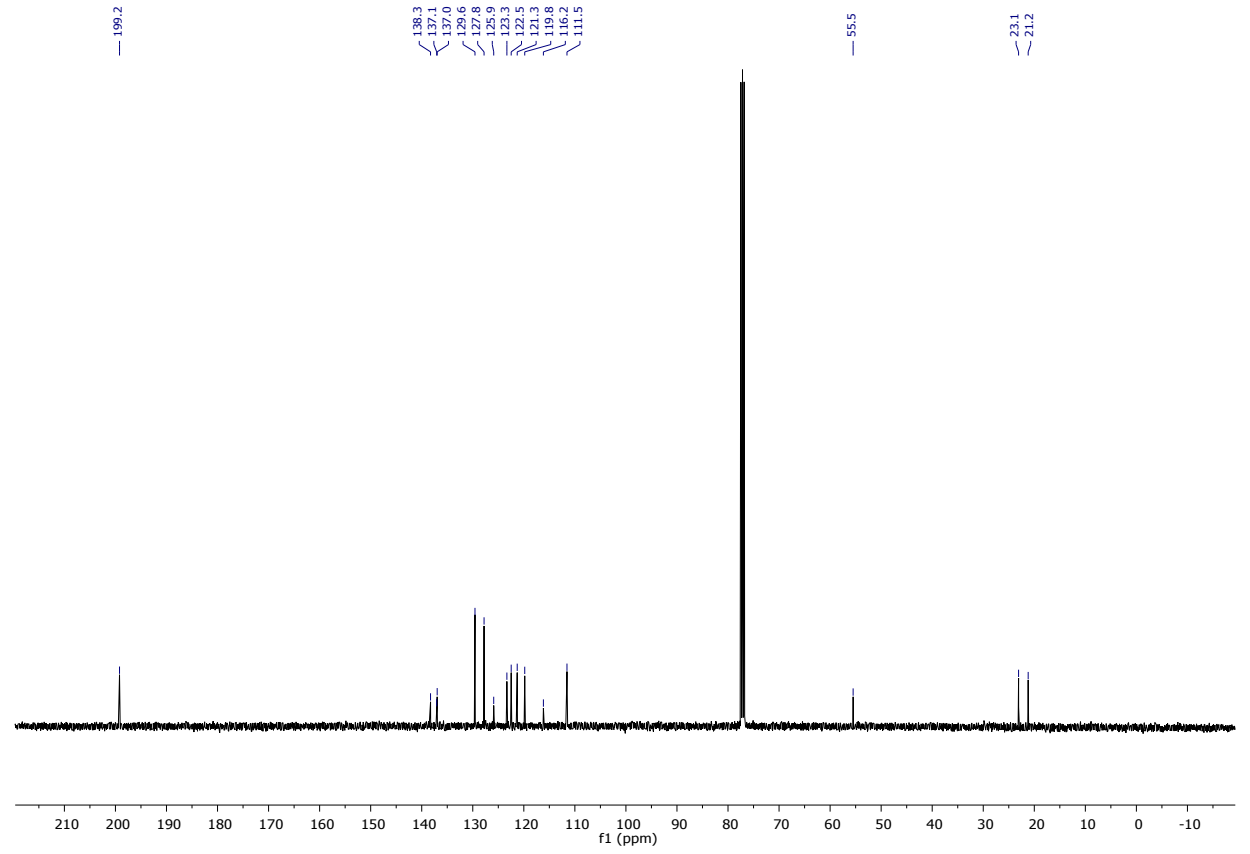
1.00
0.94
0.97
4.10
1.02
1.02
2.05
3.18
3.10
f1 (ppm)

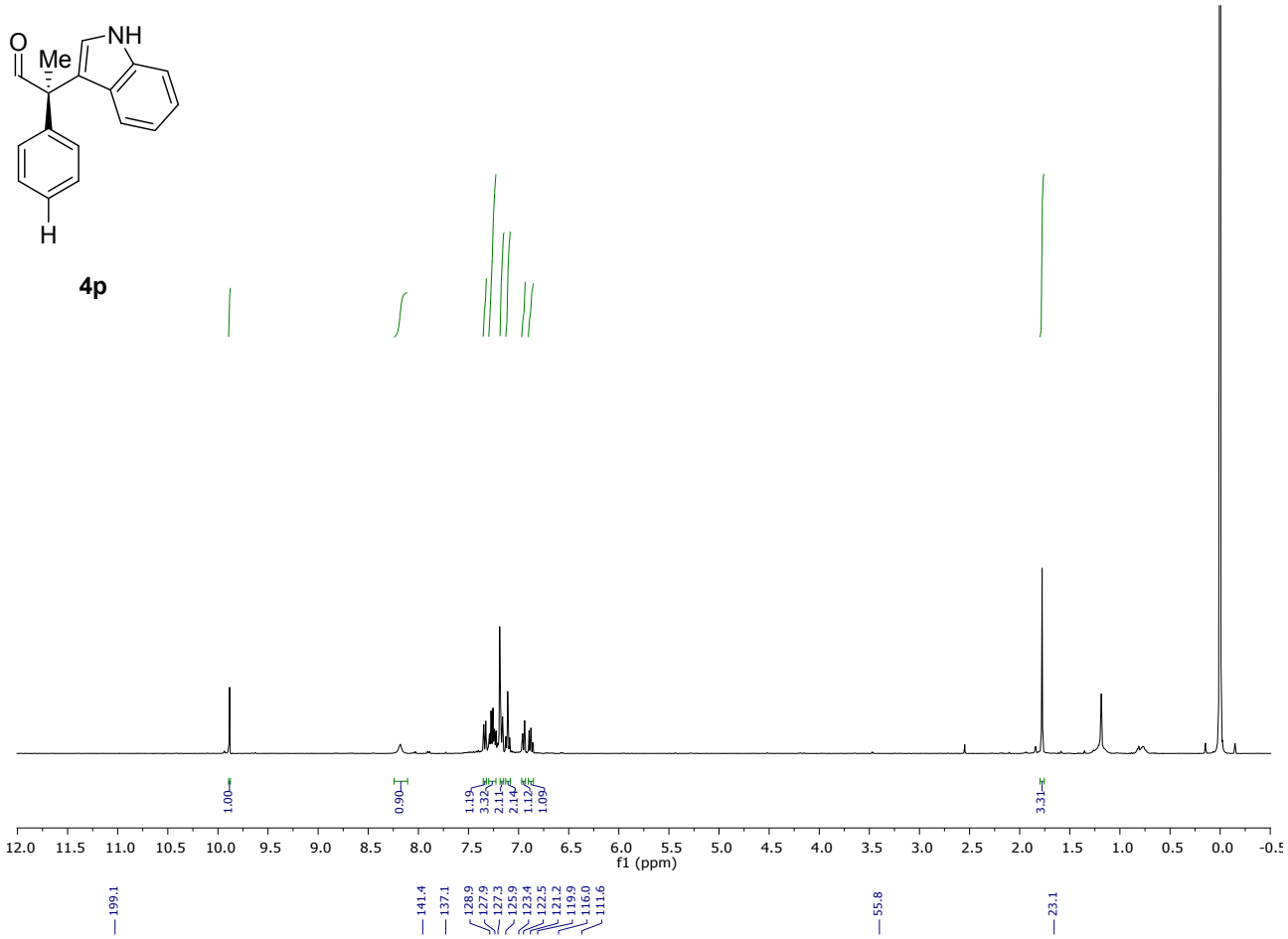

199.2
158.8
137.1
133.2
129.1
125.9
123.3
122.5
121.3
119.8
116.3
114.2
111.6
55.4
55.1
23.1
f1 (ppm)

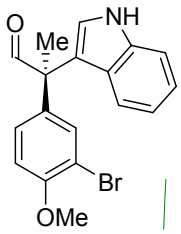

O
NH
Me
Me

4o


1.00
1.01
1.10
6.23
1.16
1.12
3.23
3.33
f1 (ppm)

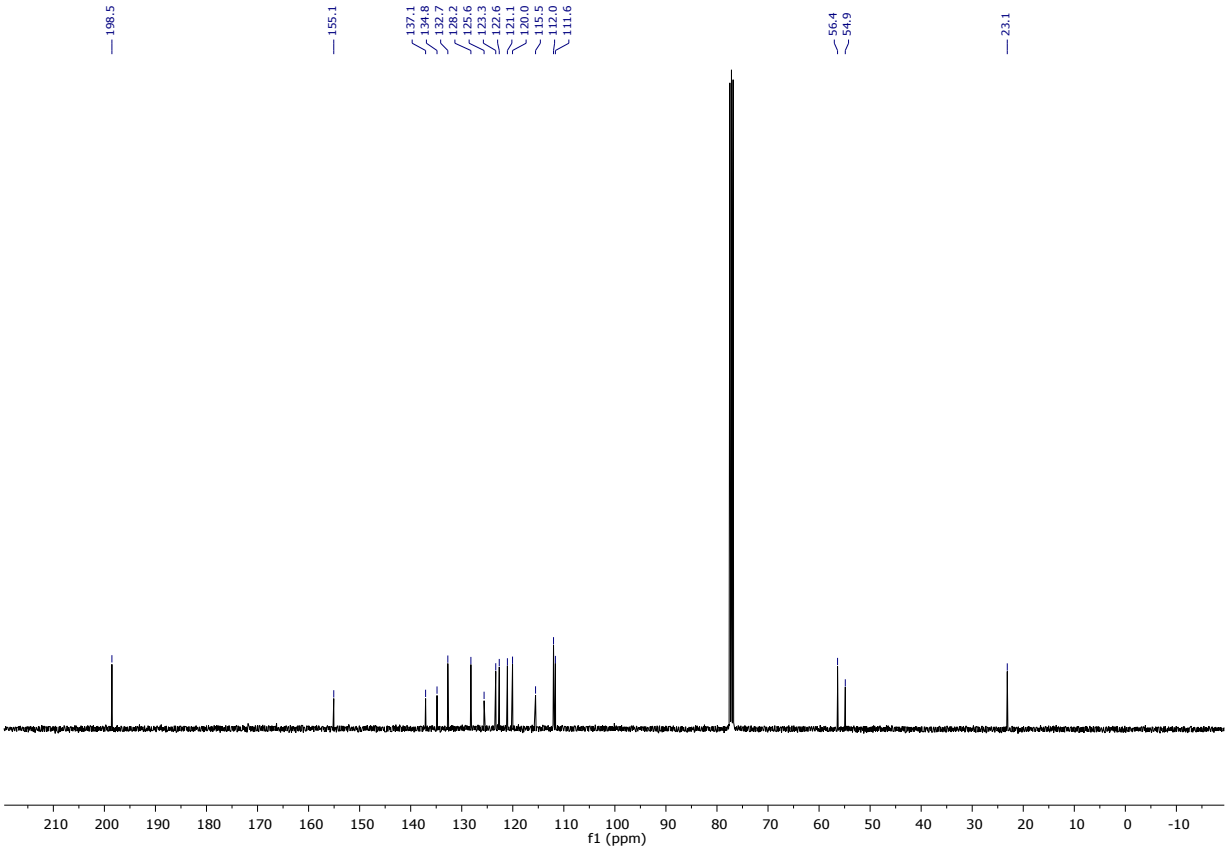

199.2
138.3
137.1
137.0
129.6
127.8
125.9
123.3
122.5
121.3
119.8
116.2
111.5
55.5
23.1
21.2
f1 (ppm)

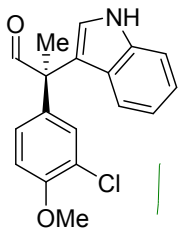

O
Me
NH
H
4p
1.00
0.90
1.19
3.32
2.11
2.14
1.12
1.09
3.31
f1 (ppm)
199.1
141.4
137.1
128.9
127.9
127.3
125.9
123.4
122.5
121.2
119.9
116.0
111.6
55.8
23.1
f1 (ppm)


O
Me
NH
Br
OMe

4q

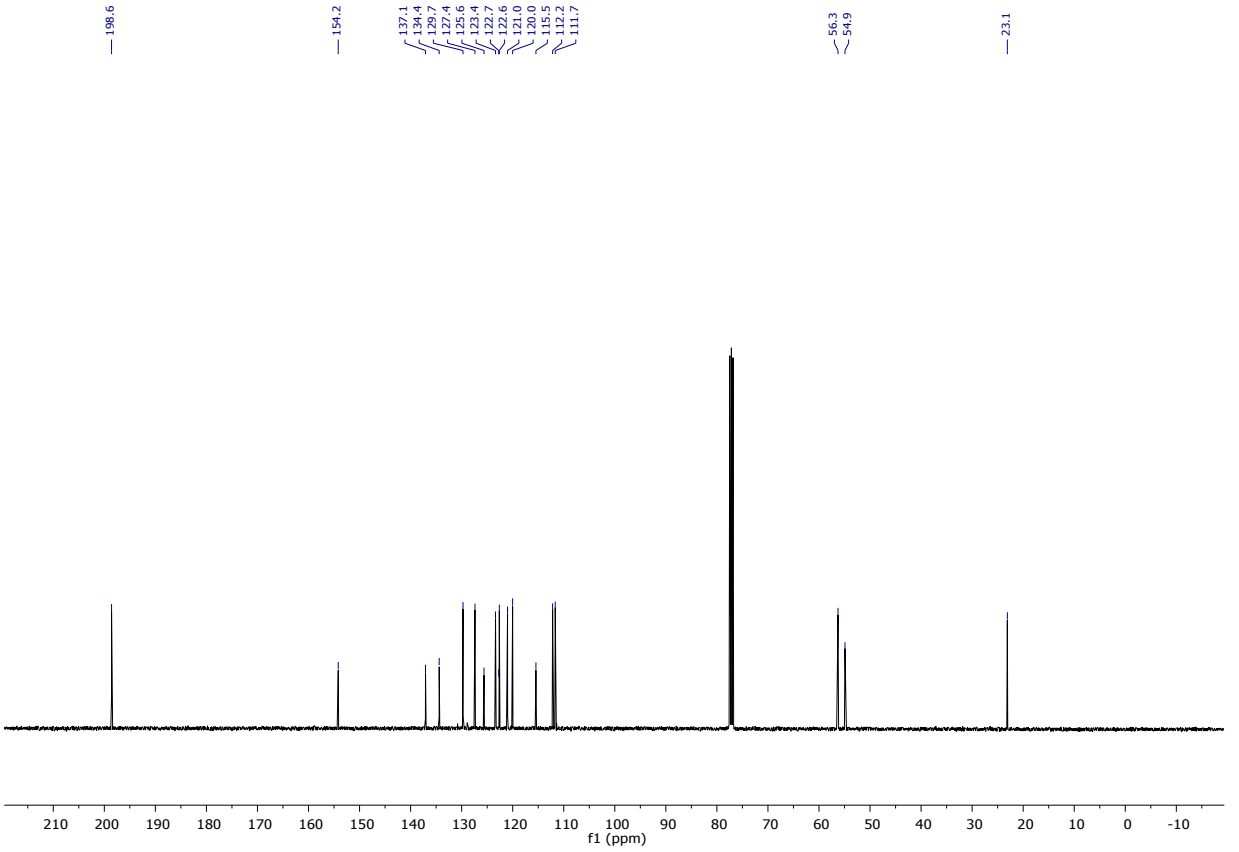
1.00
0.93
0.97
1.08
1.09
1.04
1.06
1.03
1.06
1.03
3.08
3.16
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

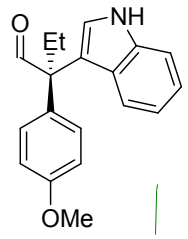

198.5
155.1
137.1
134.8
132.7
128.2
125.6
123.3
122.6
121.1
120.0
115.5
112.0
111.6
56.4
54.9
23.1
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
Me
NH
Cl
OMe

4r

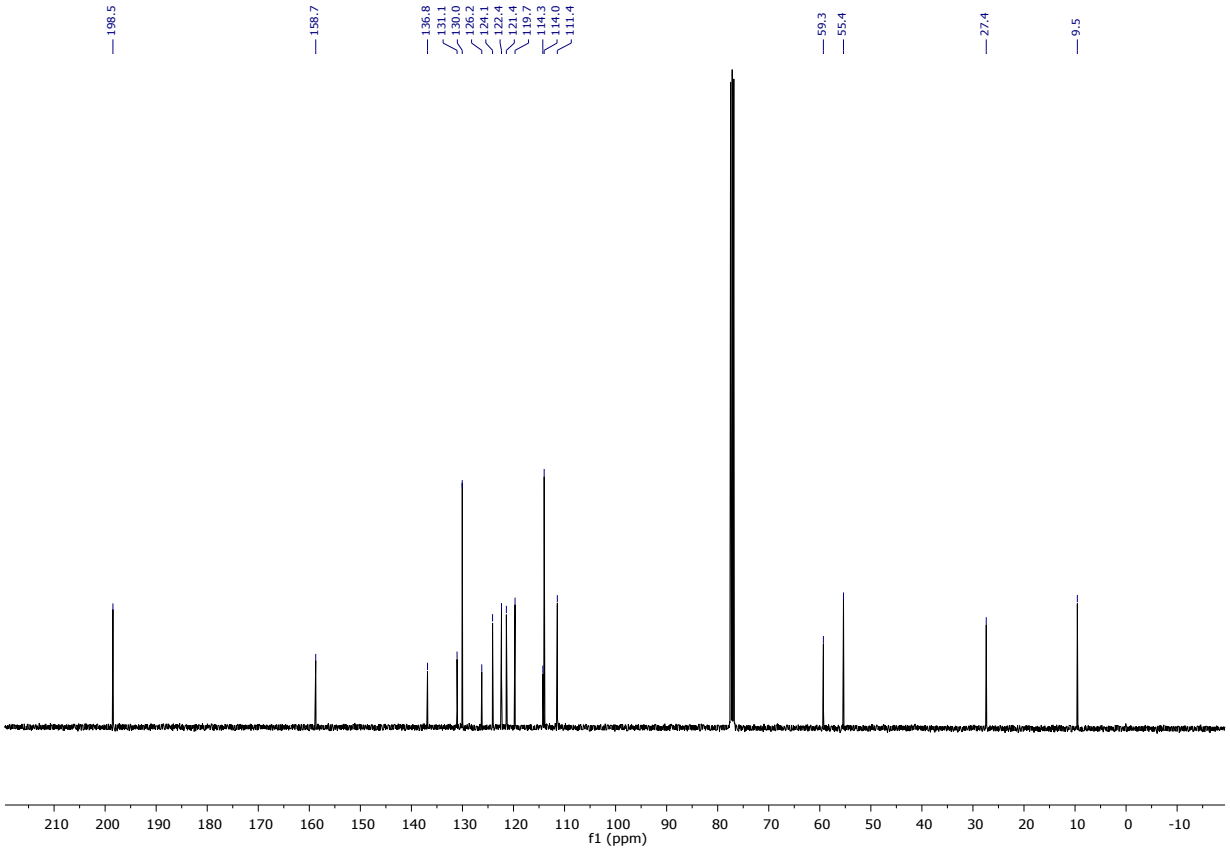
1.00
1.01
1.08
1.28
1.08
1.09
2.11
1.10
1.05
3.11
3.09
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

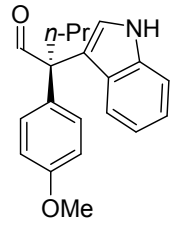

198.6
194.2
137.1
134.4
129.7
127.4
125.6
123.4
122.7
122.6
121.0
120.0
115.5
112.2
111.7
56.3
54.9
23.1
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
Et
NH
OMe

4s

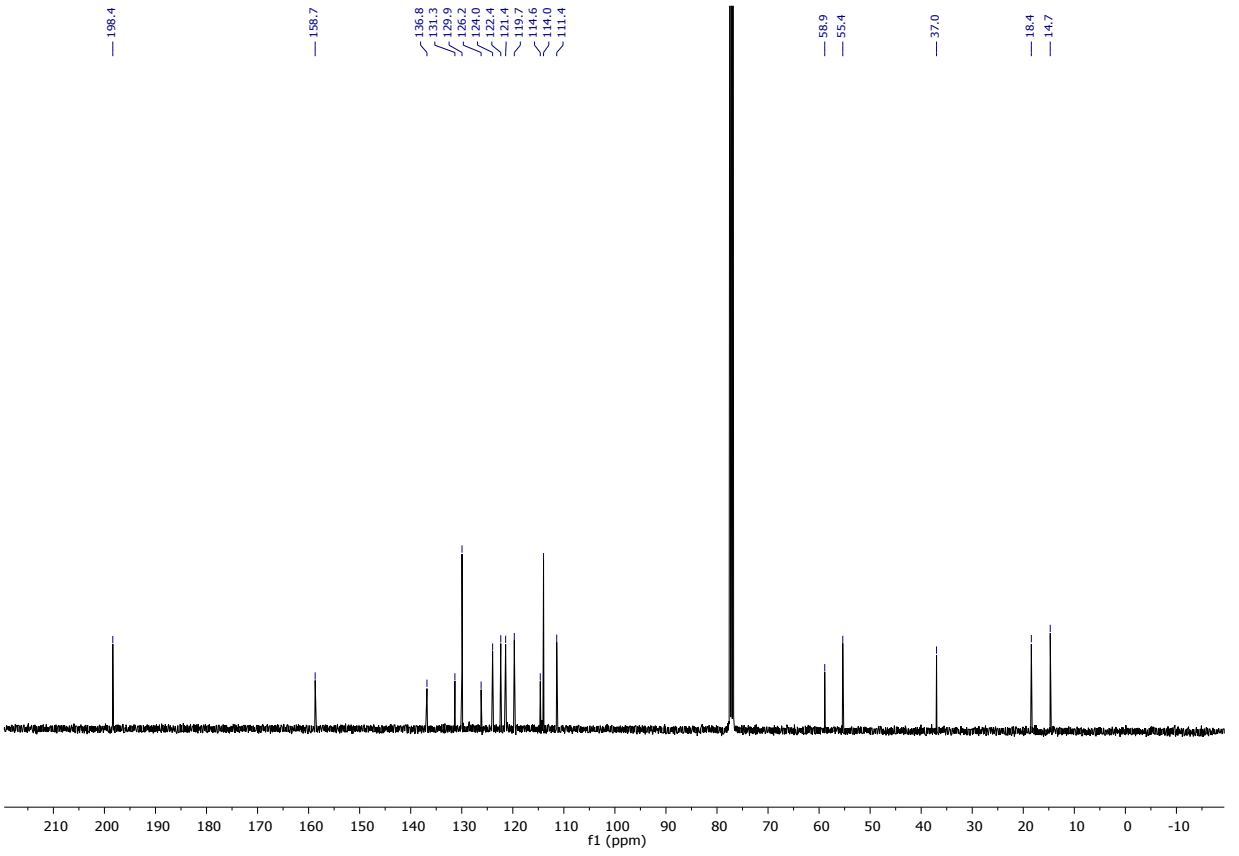
1.00
0.96
1.04
1.04
3.09
2.02
2.17
3.18
2.13
3.16
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

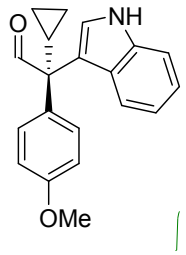

198.5
158.7
136.8
131.1
130.0
126.2
124.1
122.4
121.4
119.7
114.3
114.0
111.4
59.3
55.4
27.4
9.5
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
n-Pr
NH
OMe

4t

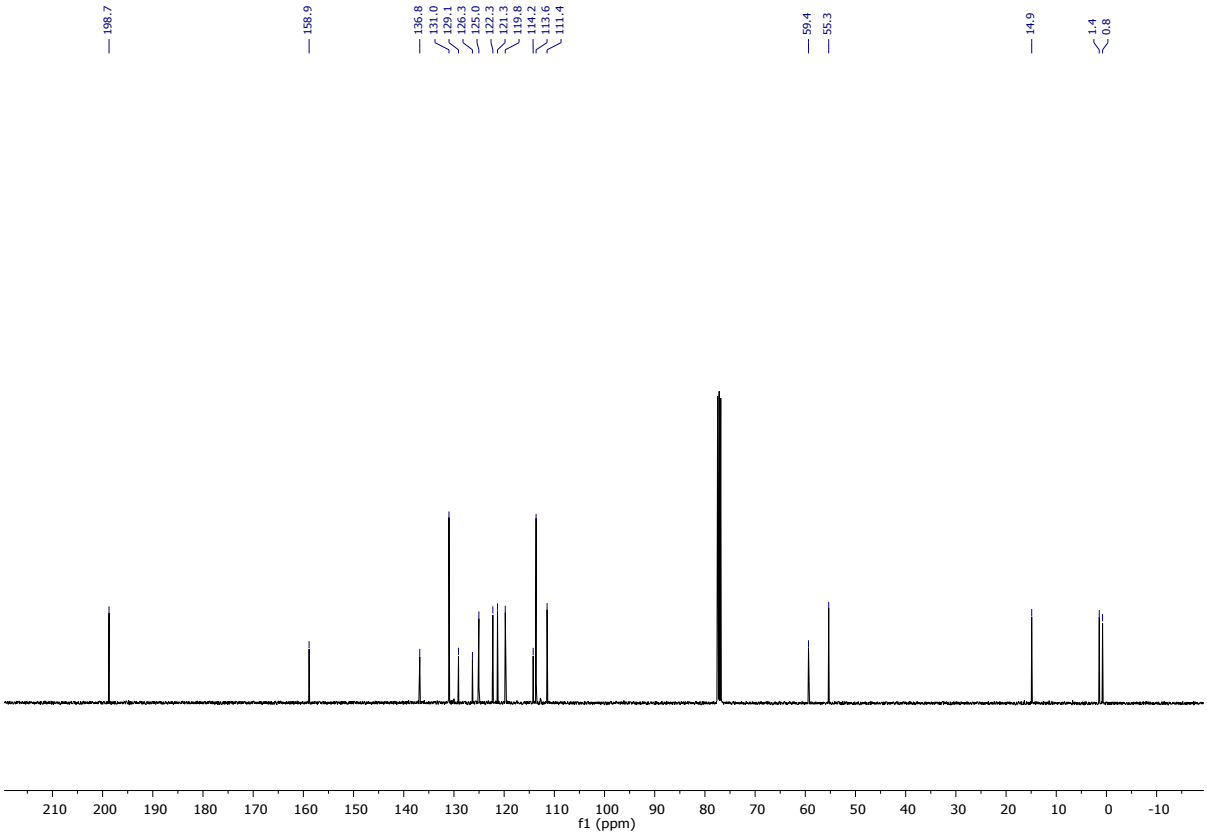
1.00
0.98
1.03
0.99
3.05
2.01
2.11
3.01
2.08
2.16
3.11
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

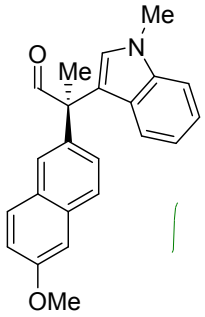

198.4
158.7
136.8
131.3
129.9
126.2
124.0
122.4
121.4
119.7
114.6
114.0
111.4
58.9
55.4
37.0
18.4
14.7
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
NH
OMe

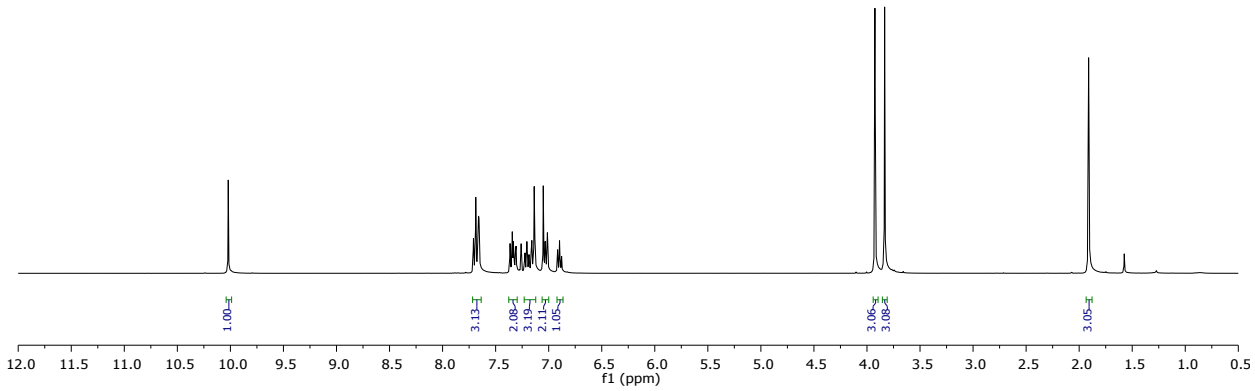
4u

1.00
0.97
2.05
3.10
4.07
3.17
1.07
2.06
2.09
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

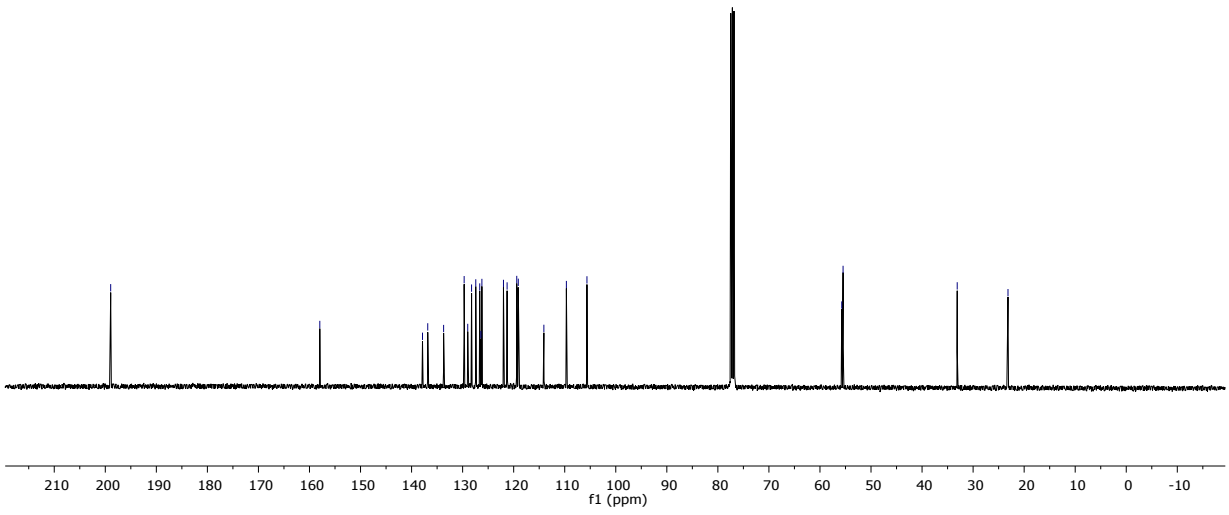

198.7
158.9
136.8
131.0
129.1
126.3
125.0
122.3
121.3
119.8
114.2
113.6
111.4
59.4
55.3
14.9
1.4
0.8
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


Me
N
O
Me
OMe

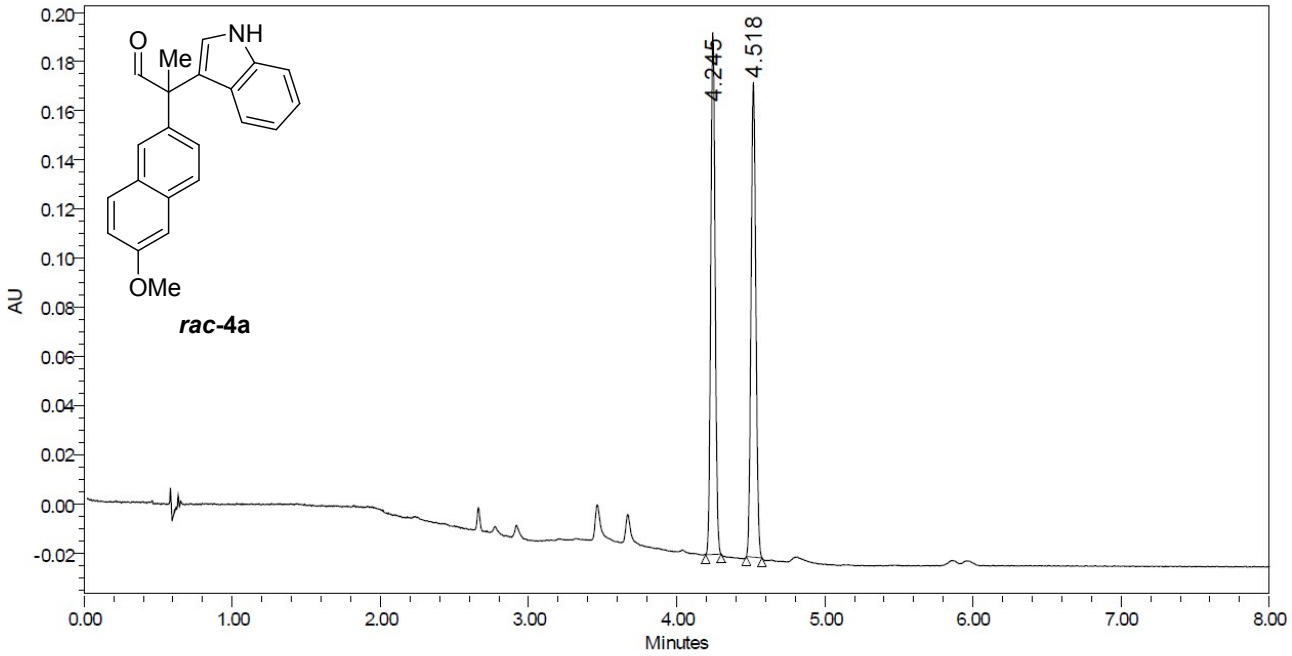
4v


1.00
3.13
2.08
3.19
2.11
1.05
3.06
3.08
3.05
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

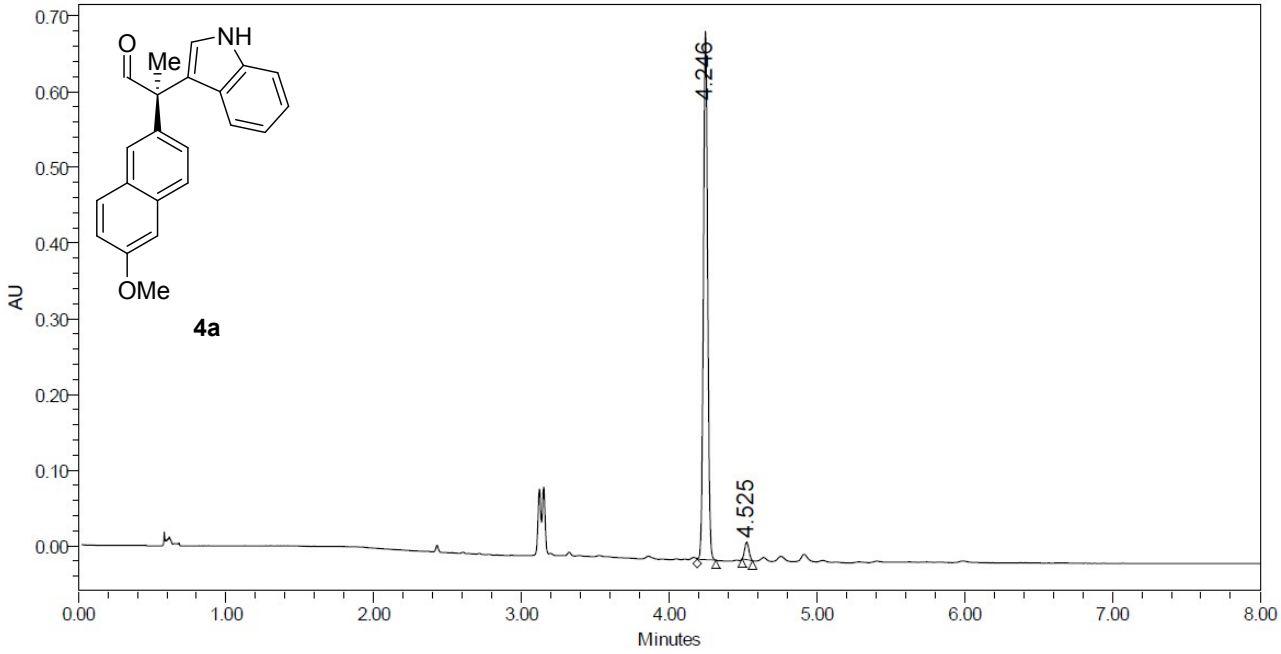

198.9
158.0
137.9
136.8
133.7
129.7
129.0
128.2
127.4
126.6
126.4
126.2
122.0
121.3
119.4
119.1
114.1
109.7
105.6
55.7
55.5
33.1
23.2


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

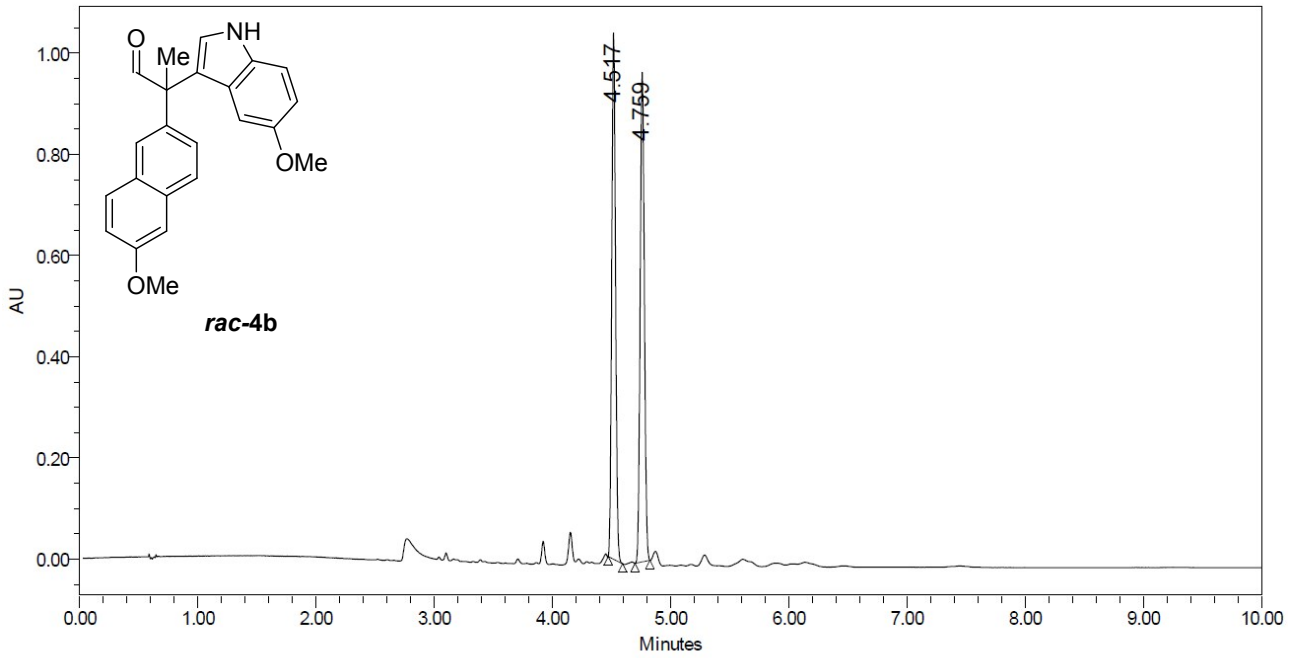
9. UPC-traces



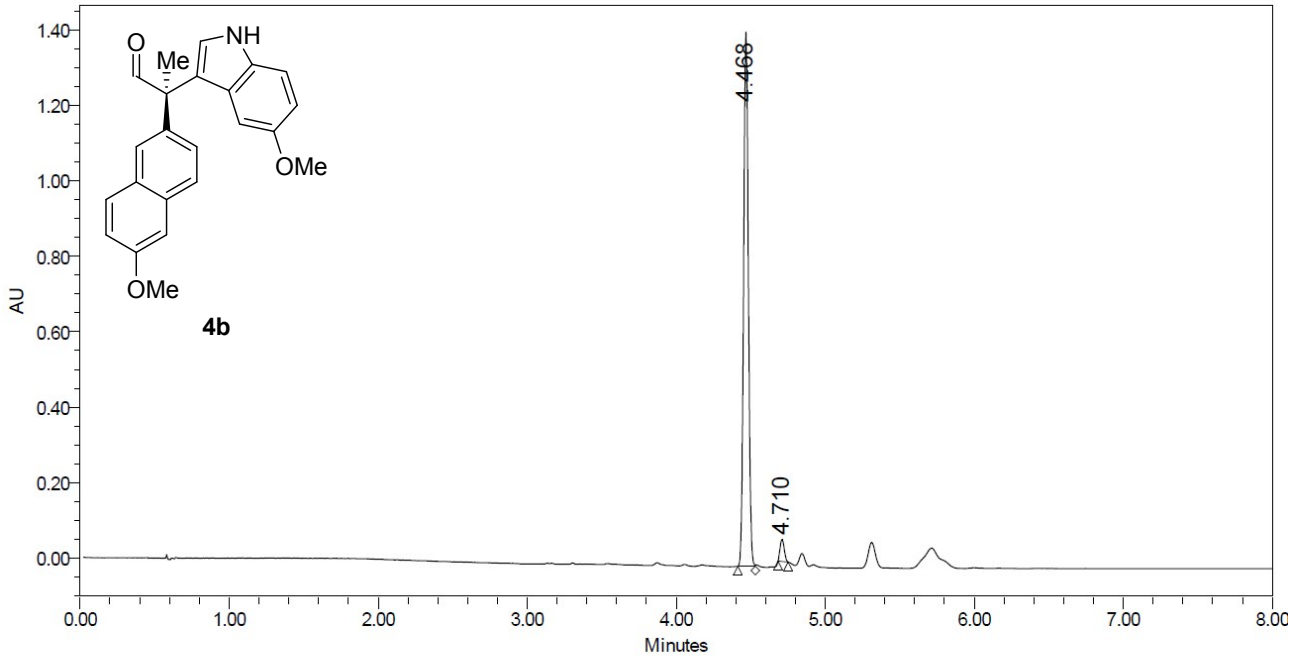
	Retention Time (min)	% Area
1	4.245	49.97
2	4.518	50.03



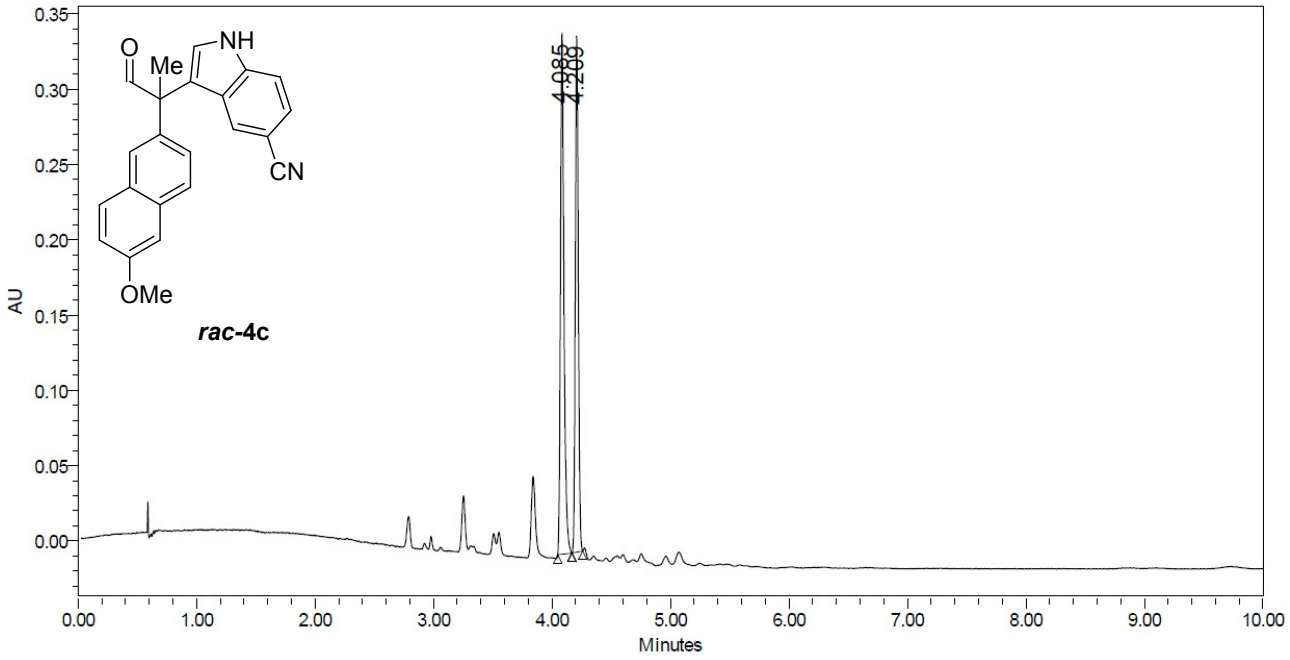
	Retention Time (min)	% Area
1	4.246	96.75
2	4.525	3.25



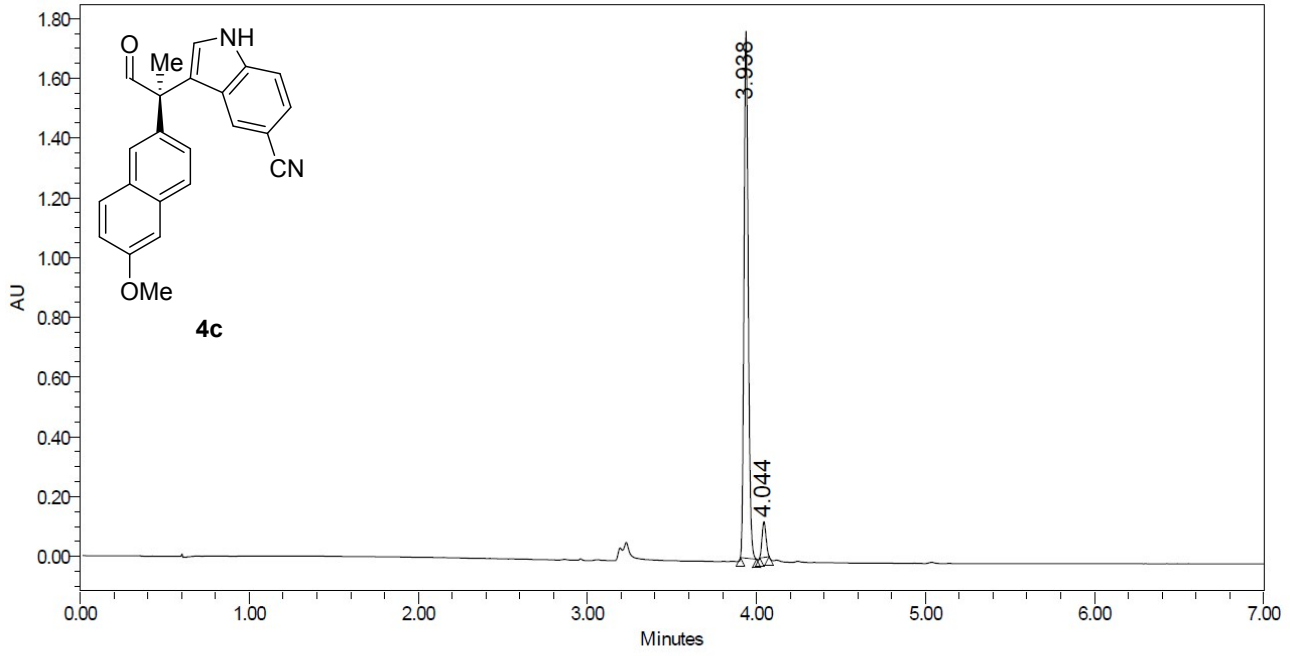
	Retention Time (min)	% Area
1	4.517	49.53
2	4.759	50.47



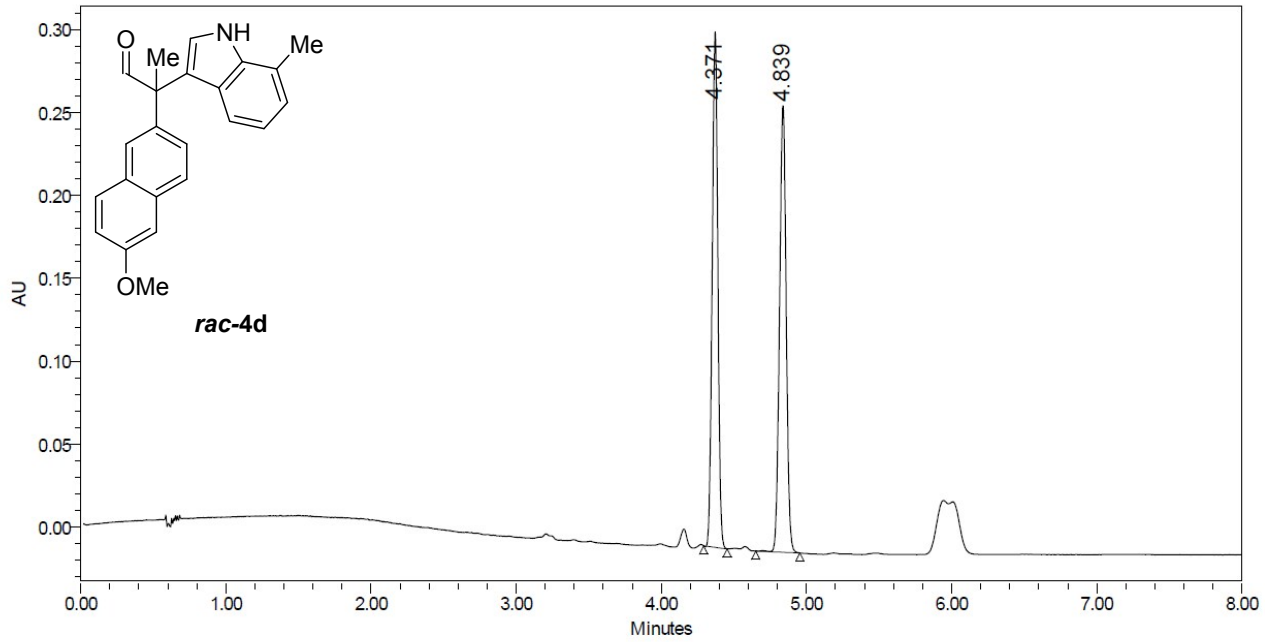
	Retention Time (min)	% Area
1	4.468	96.45
2	4.710	3.55



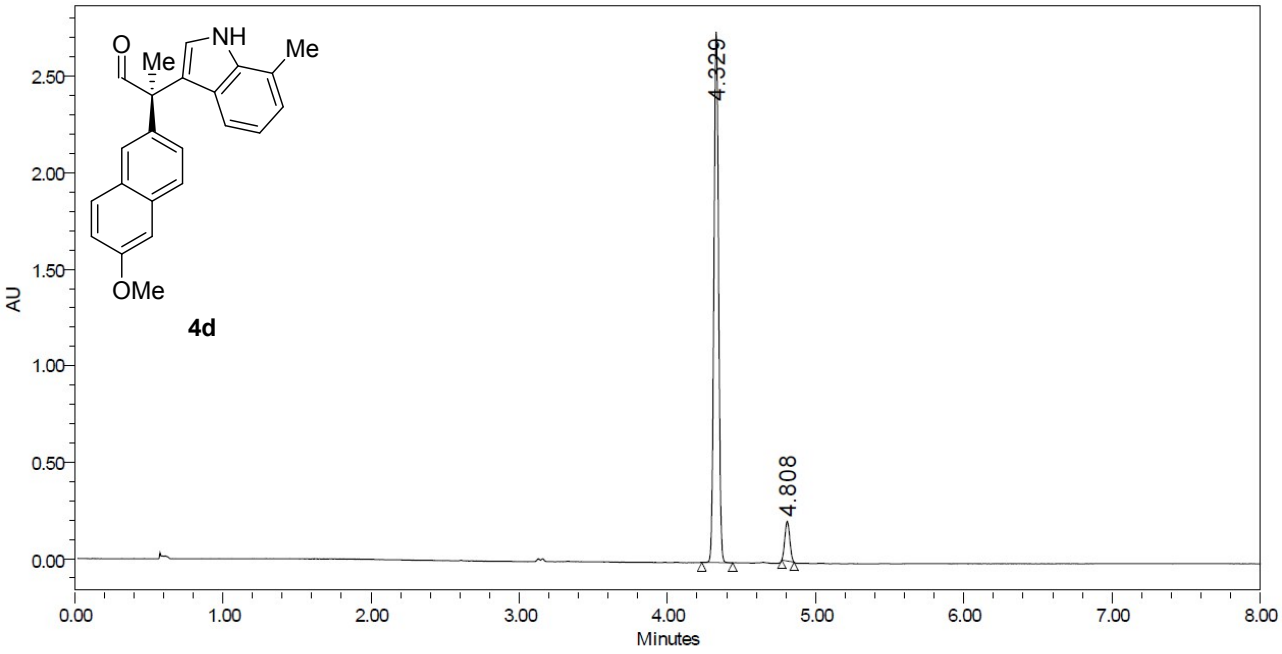
	Retention Time (min)	% Area
1	4.085	54.33
2	4.209	45.67



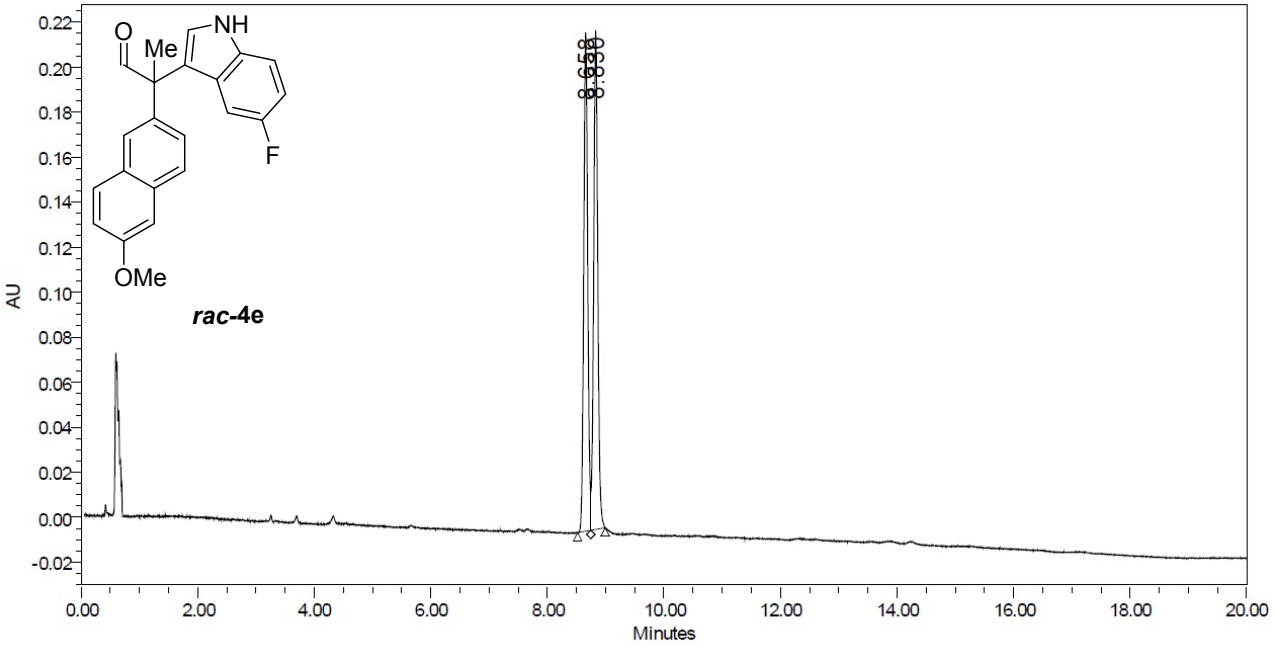
	Retention Time (min)	% Area
1	3.938	94.05
2	4.044	5.95



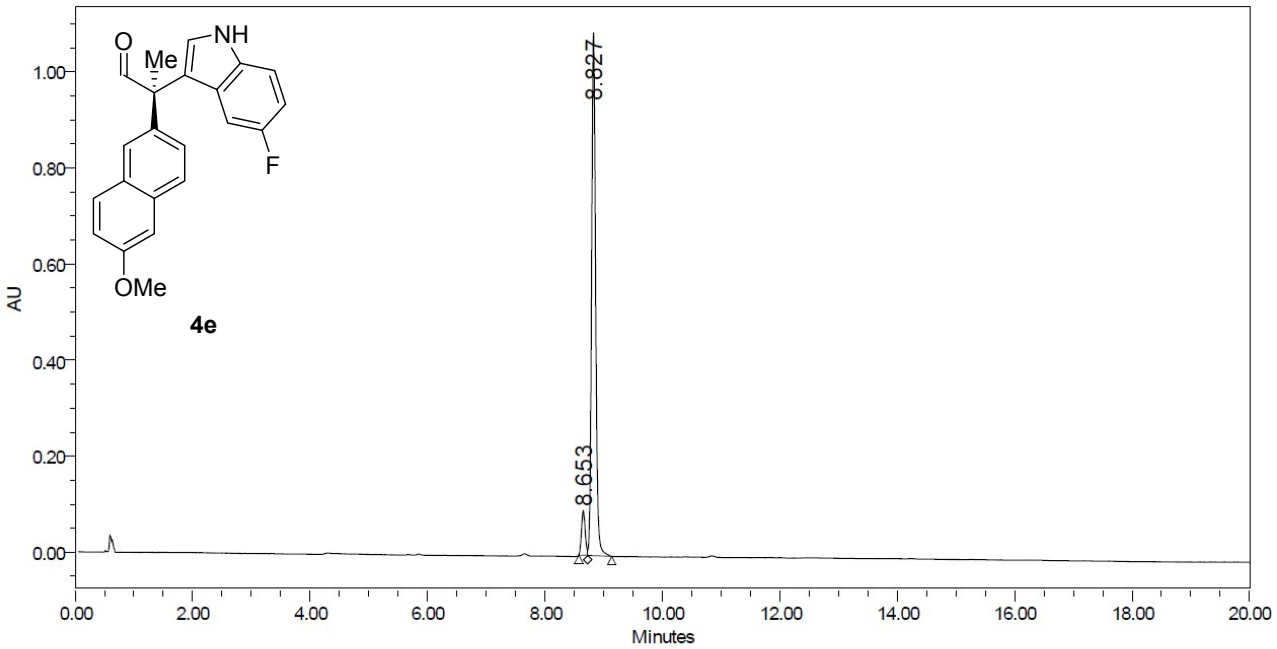
	Retention Time (min)	% Area
1	4.371	49.45
2	4.839	50.55



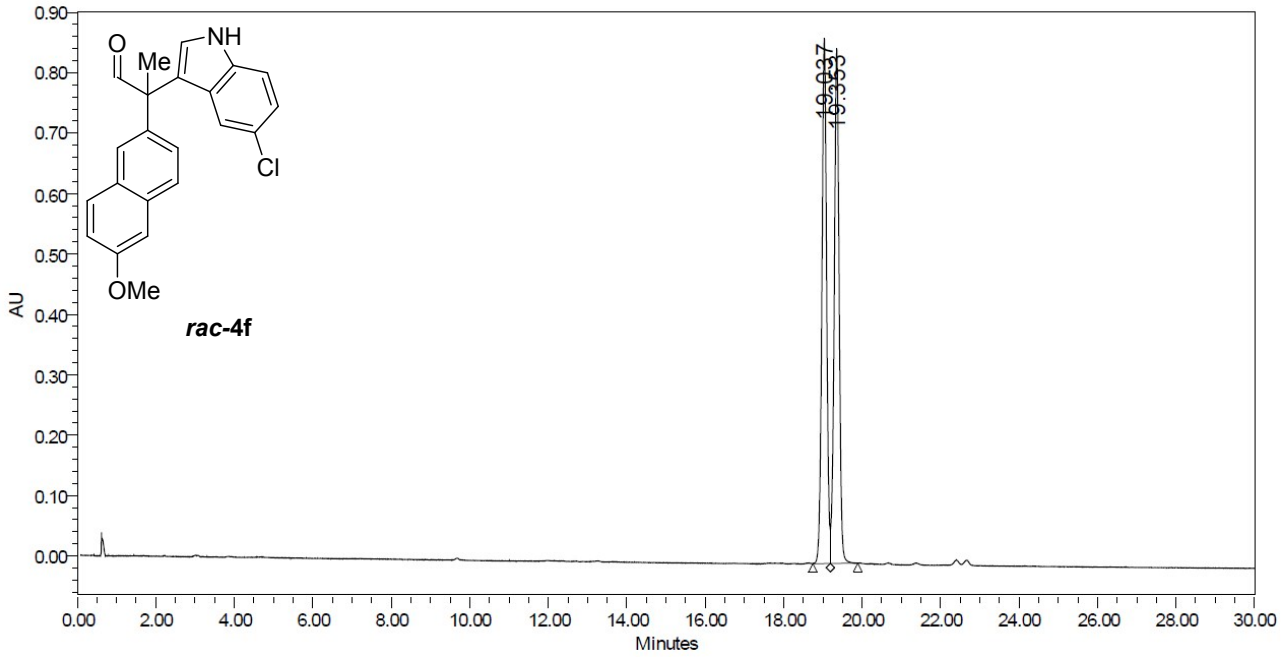
	Retention Time (min)	% Area
1	4.329	92.71
2	4.808	7.29



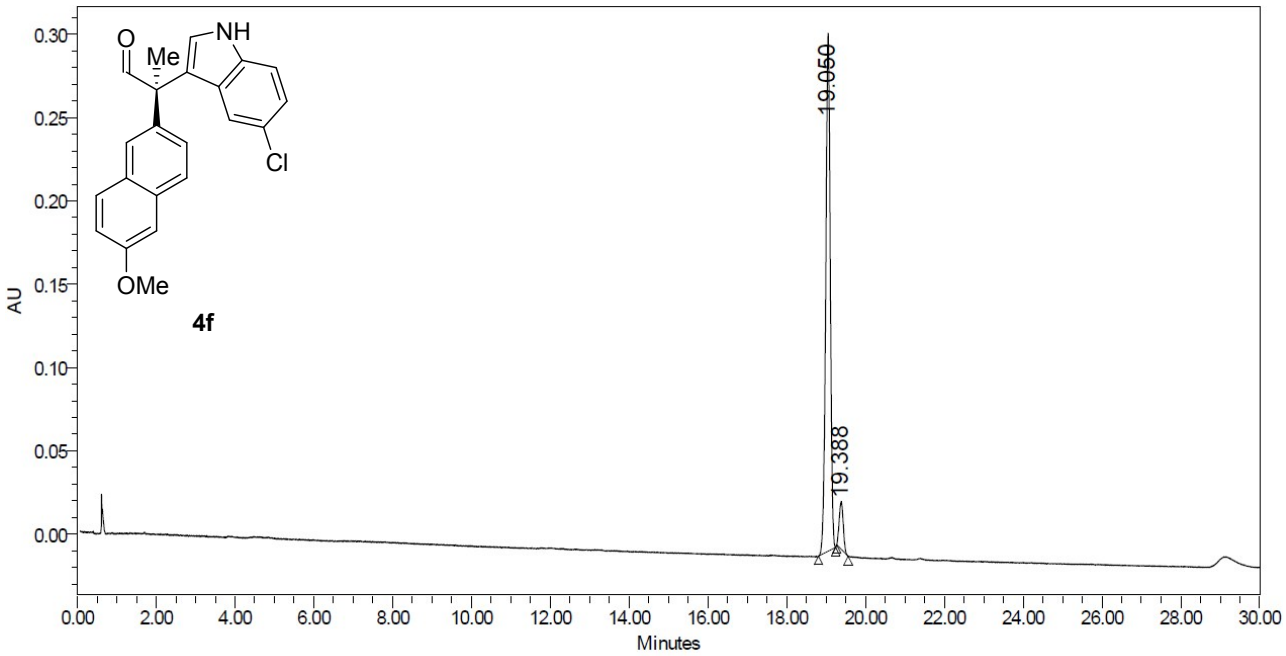
	Retention Time (min)	% Area
1	8.658	49.08
2	8.830	50.92



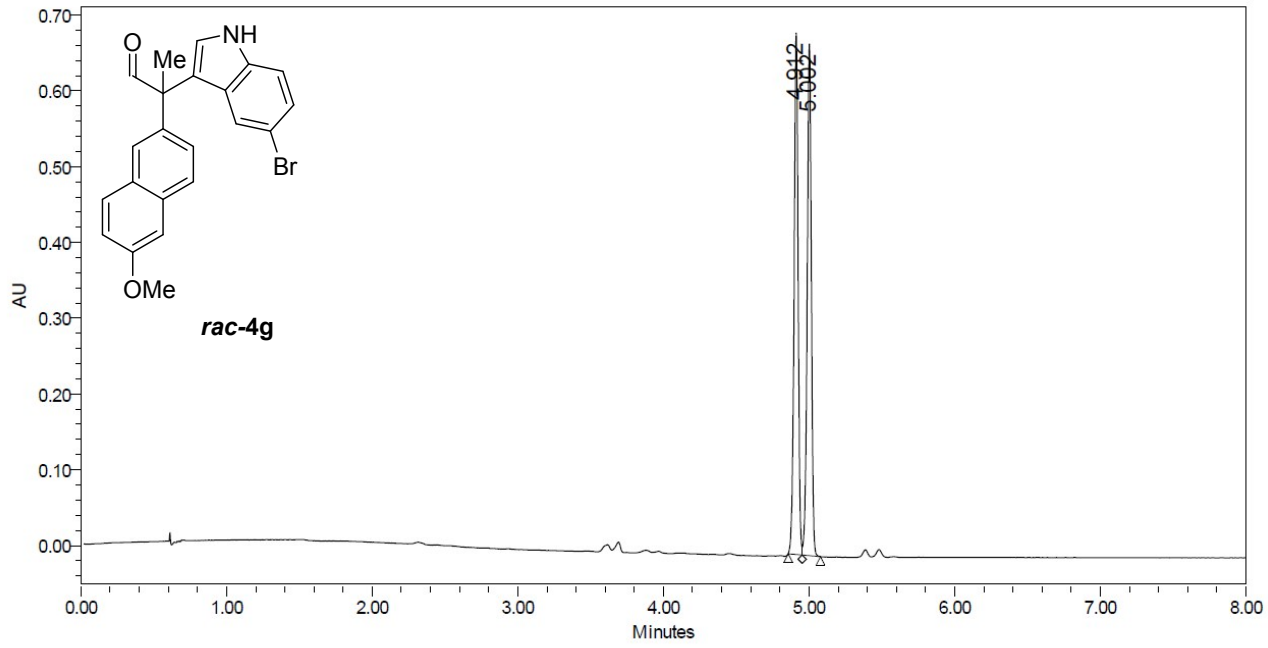
	Retention Time (min)	% Area
1	8.653	7.11
2	8.827	92.89



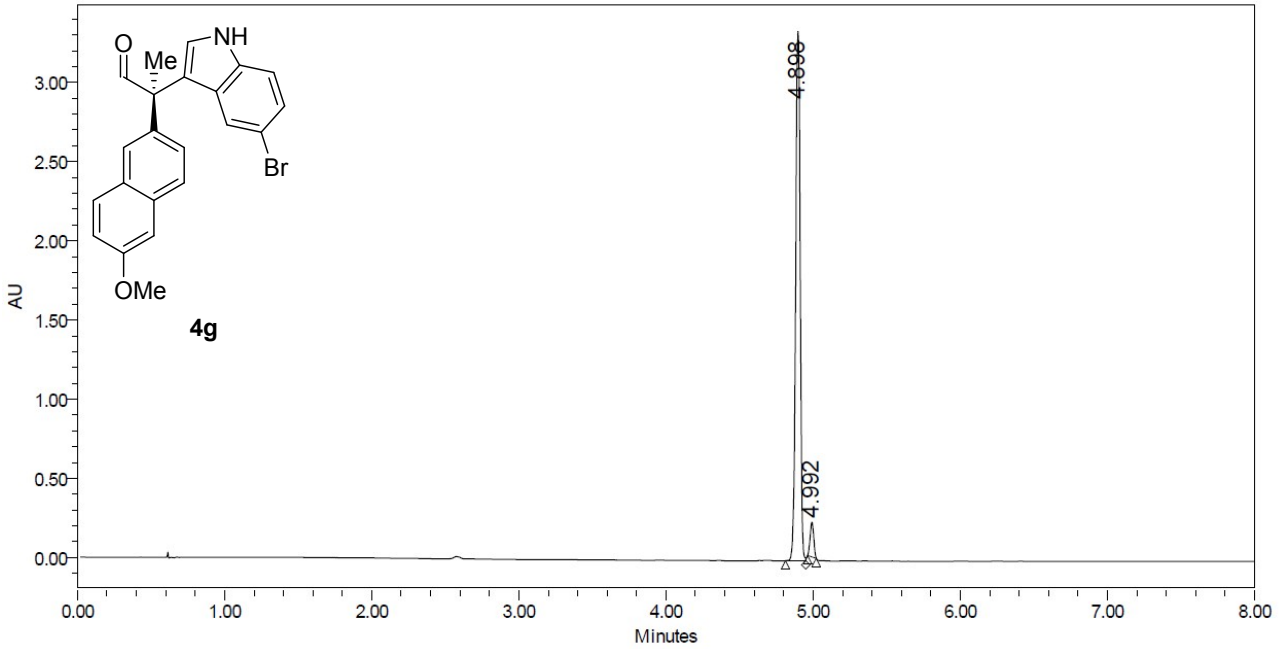
	Retention Time (min)	% Area
1	19.037	49.60
2	19.353	50.40



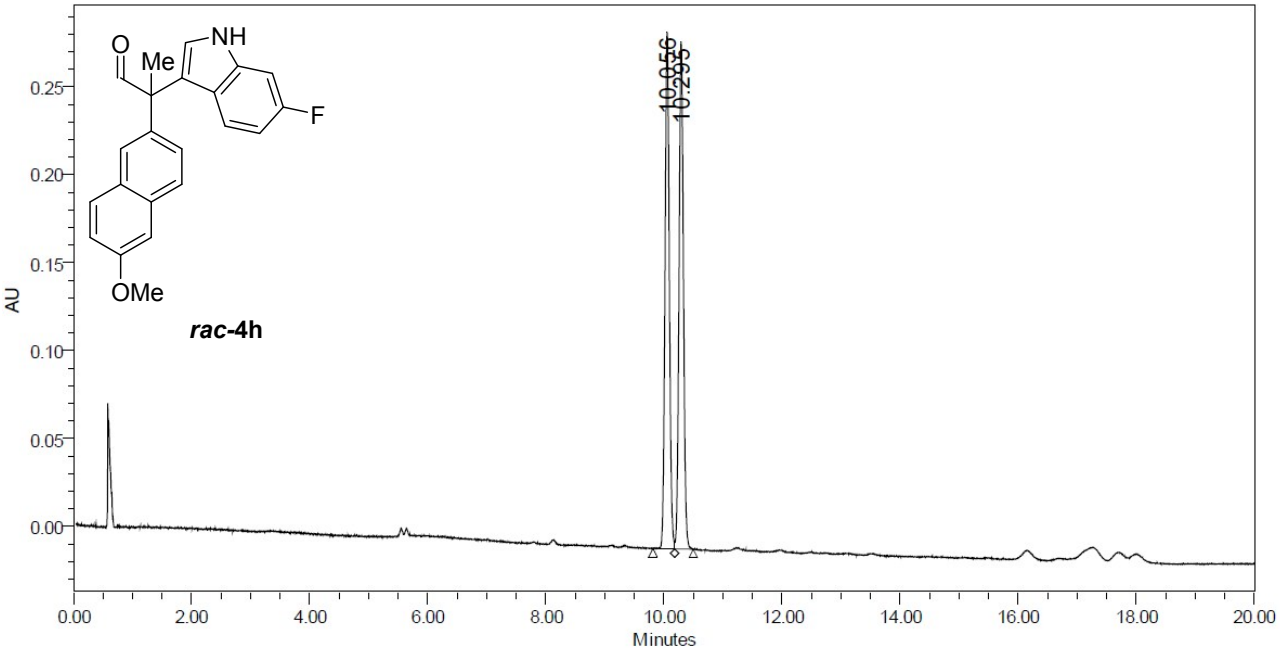
	Retention Time (min)	% Area
1	19.050	92.43
2	19.388	7.57



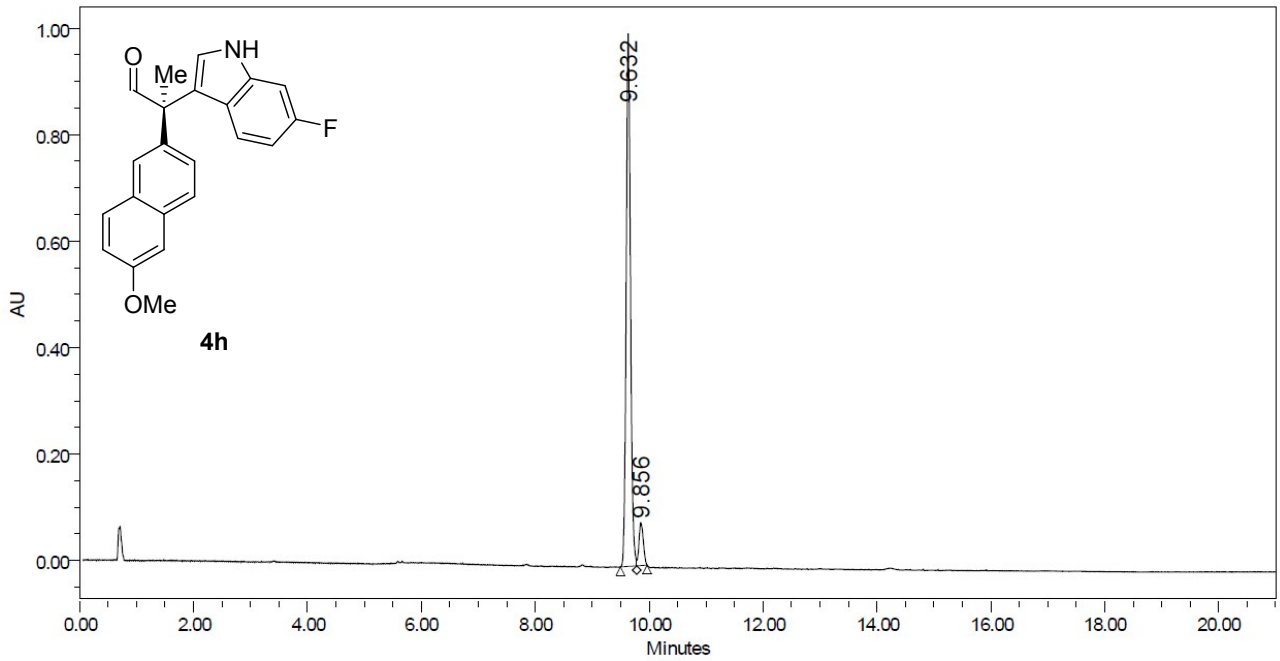
	Retention Time (min)	% Area
1	4.912	49.75
2	5.002	50.25



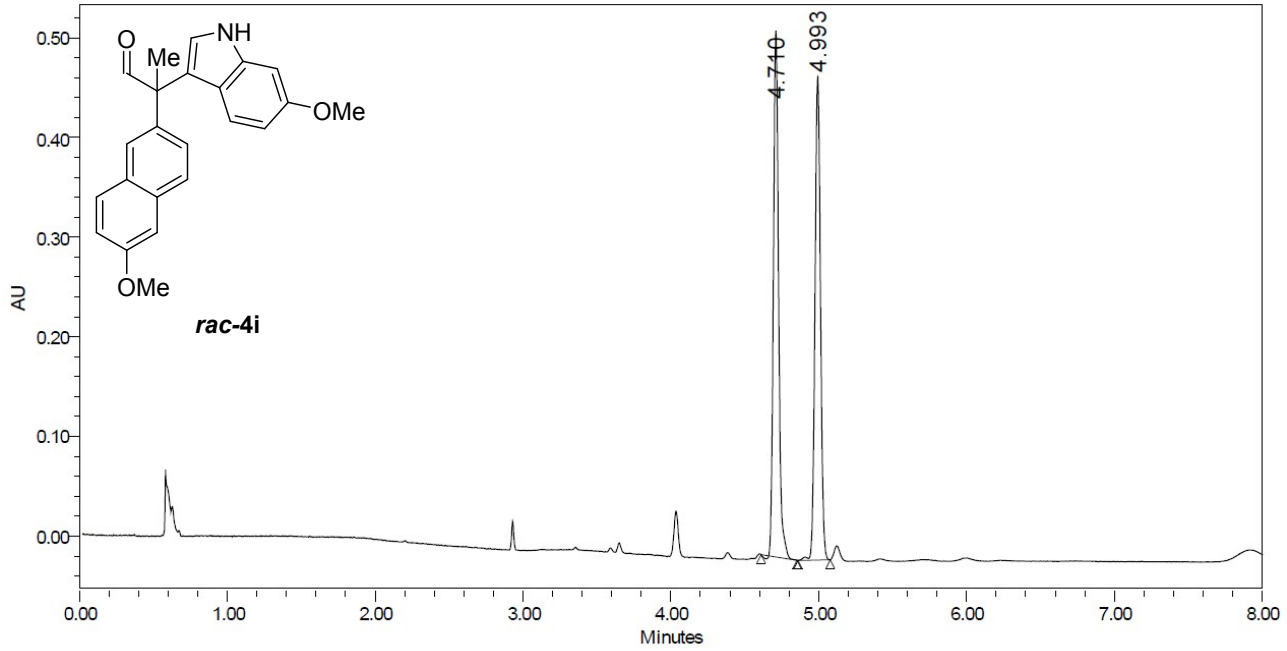
	Retention Time (min)	% Area
1	4.898	95.10
2	4.992	4.90



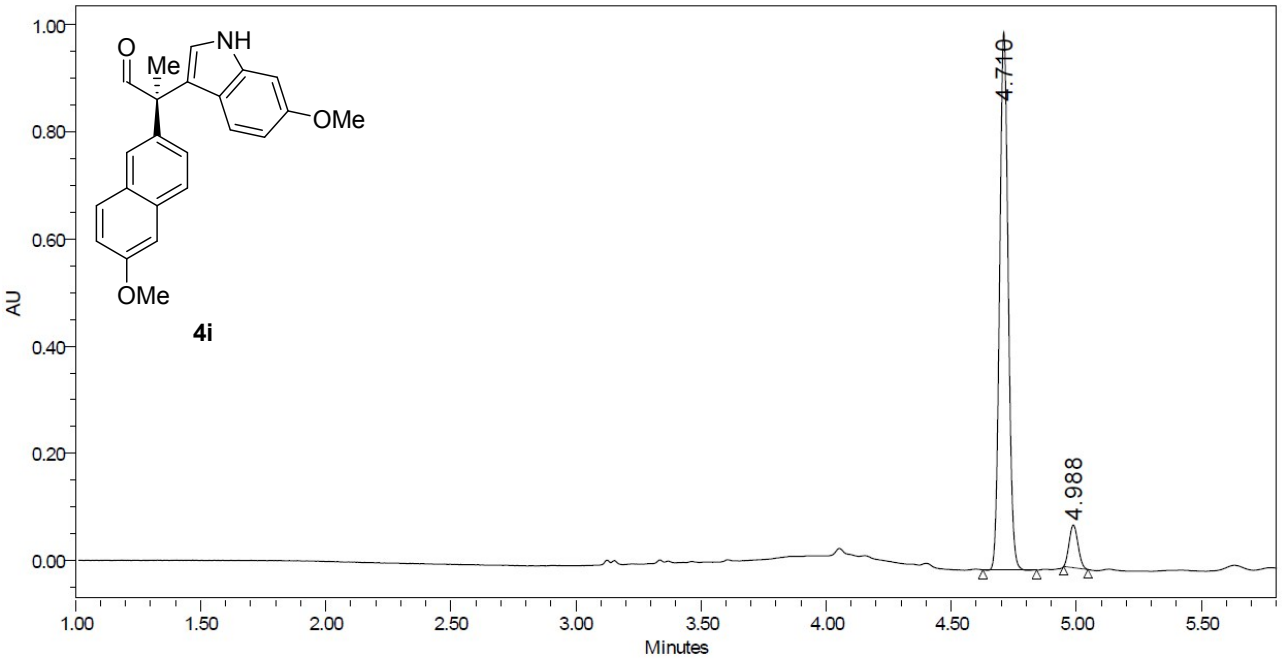
	Retention Time (min)	% Area
1	10.056	49.98
2	10.295	50.02



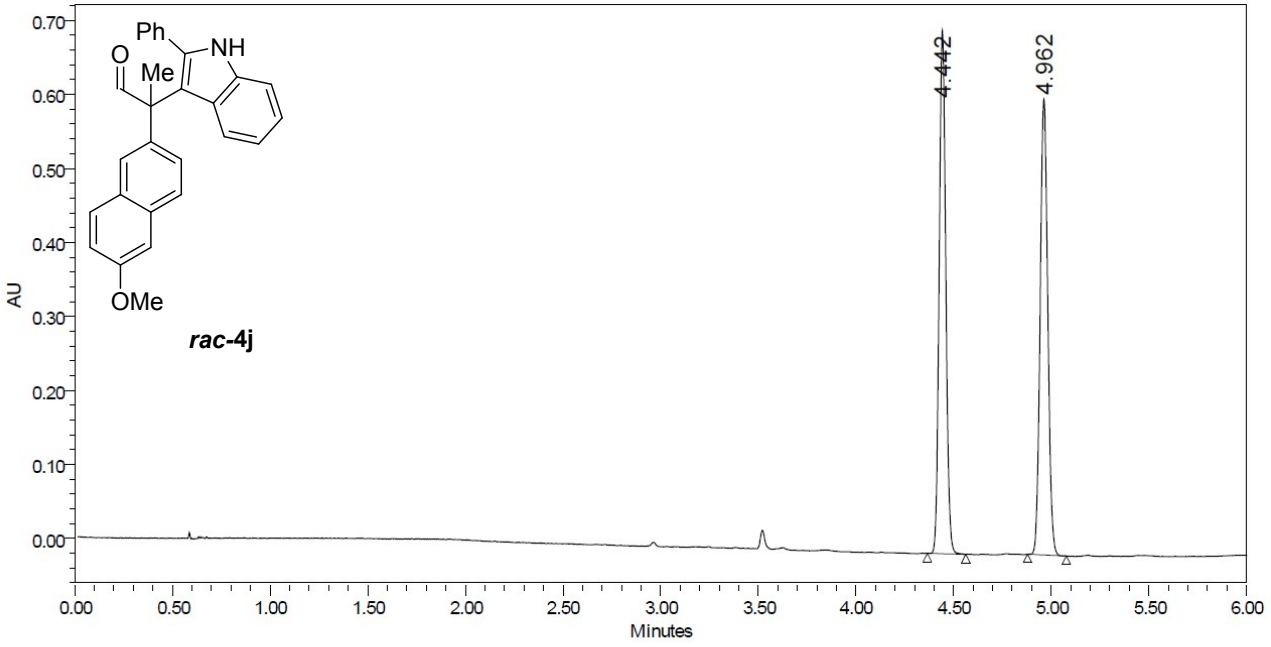
	Retention Time (min)	% Area
1	9.632	92.52
2	9.856	7.48



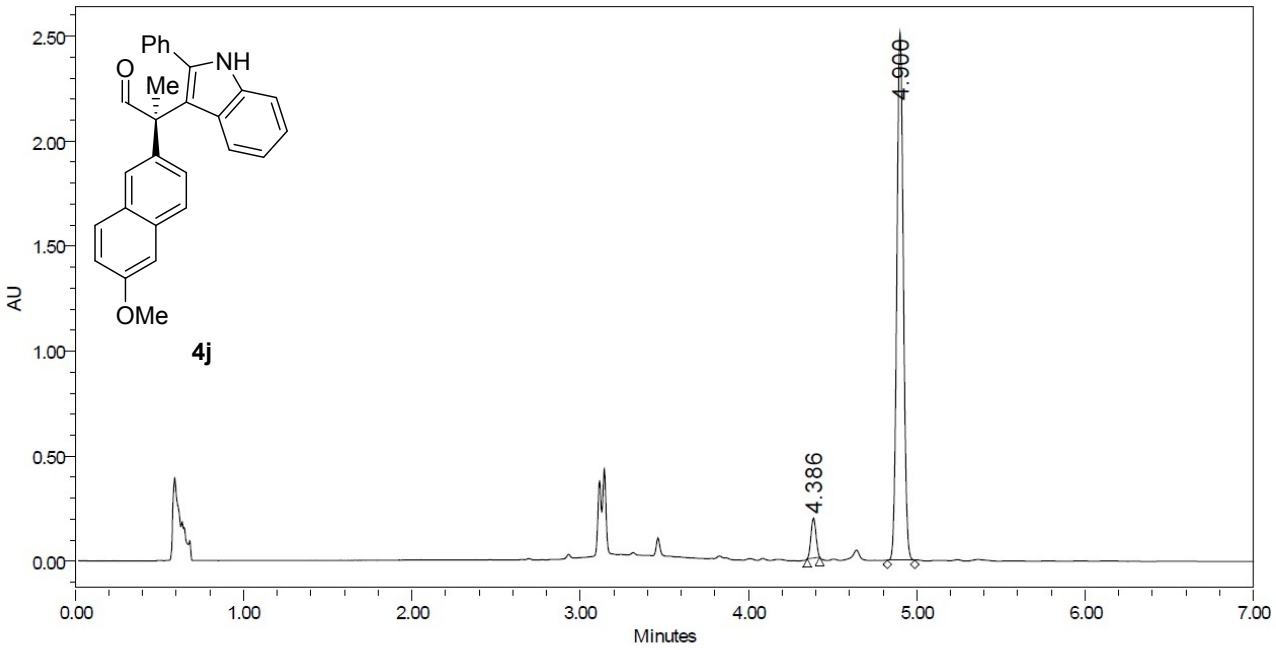
	Retention Time (min)	% Area
1	4.710	50.70
2	4.993	49.30



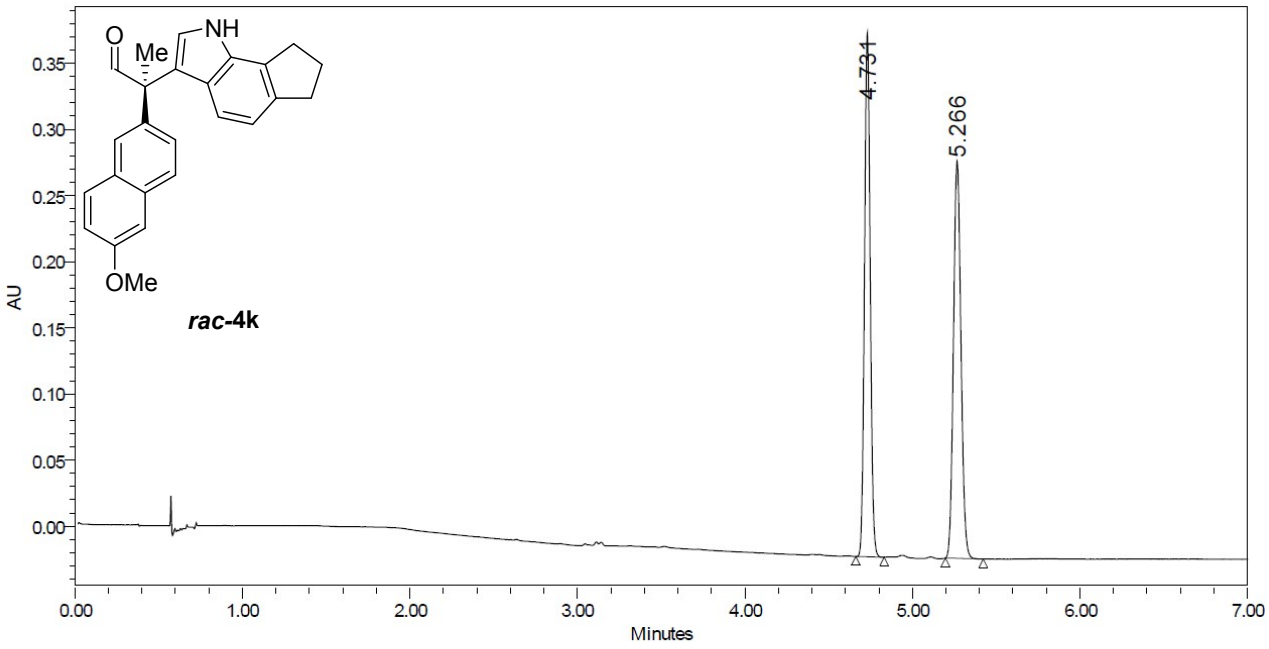
	Retention Time (min)	% Area
1	4.710	92.46
2	4.988	7.54



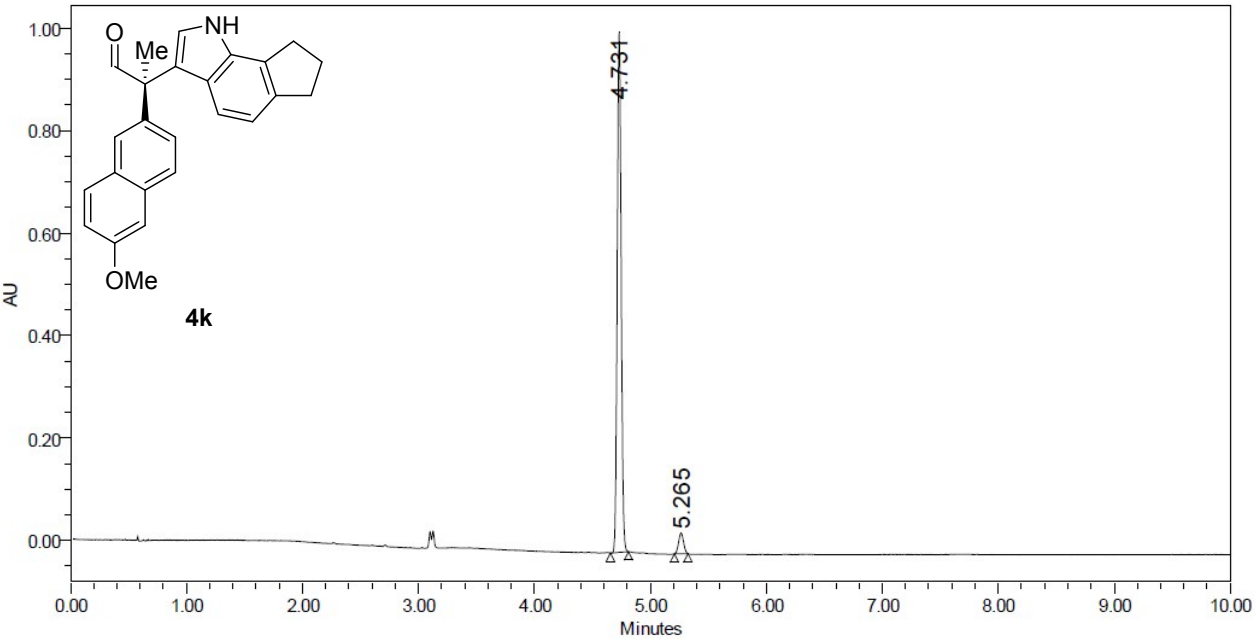
	Retention Time (min)	% Area
1	4.442	49.90
2	4.962	50.10



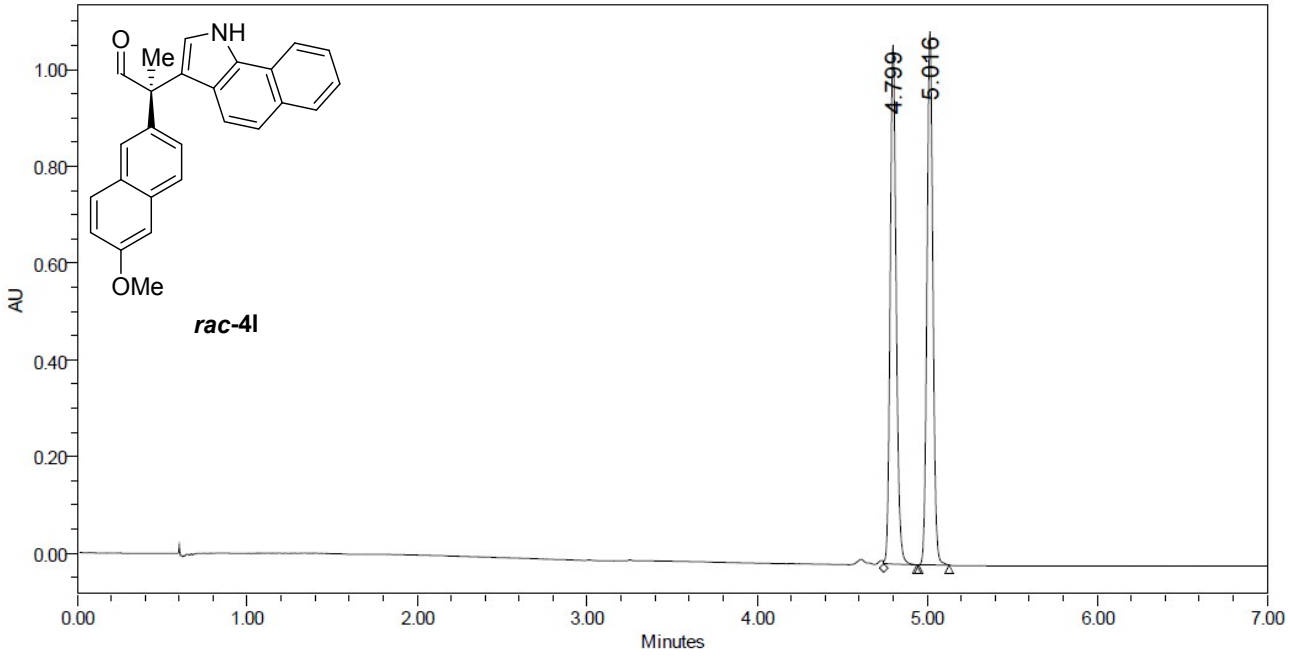
	Retention Time (min)	% Area
1	4.386	5.50
2	4.900	94.50



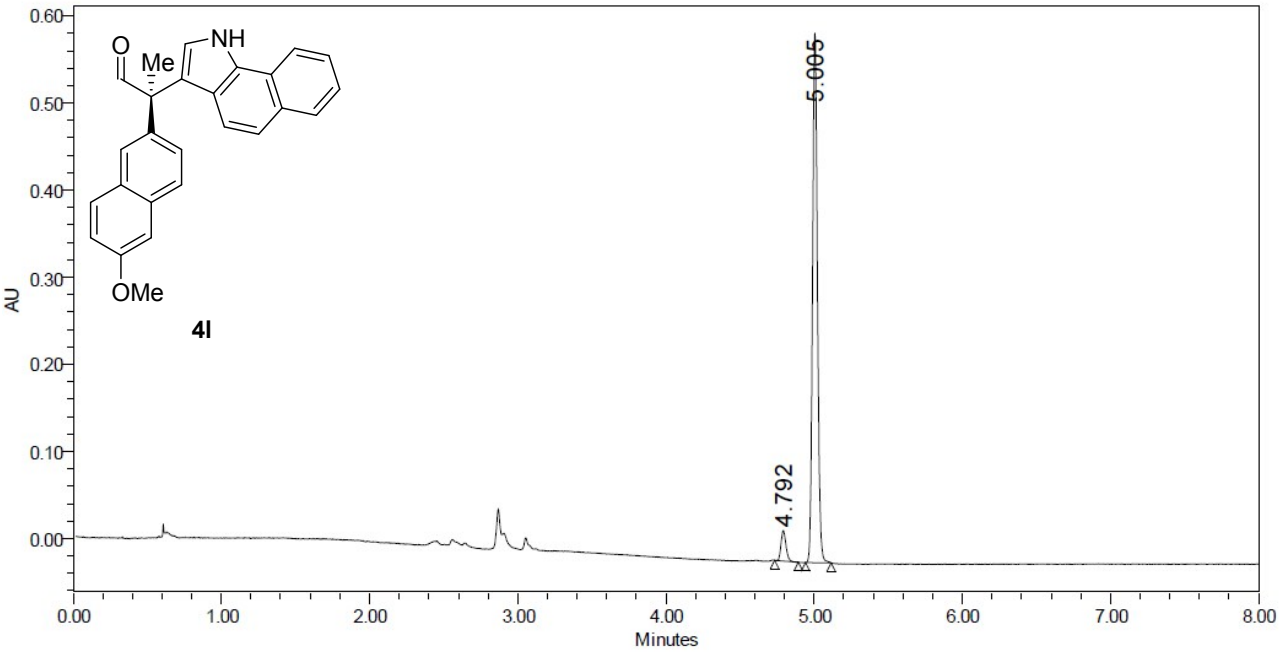
	Retention Time (min)	% Area
1	4.731	50.17
2	5.266	49.83



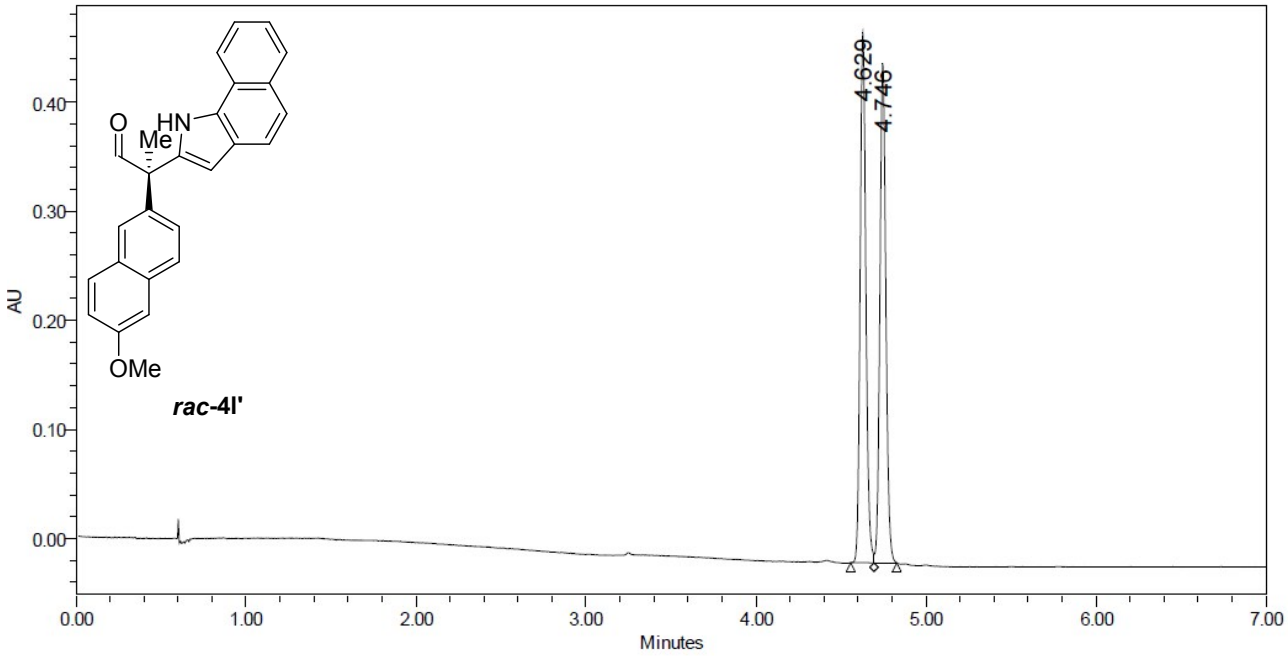
	Retention Time (min)	% Area
1	4.731	95.27
2	5.265	4.73



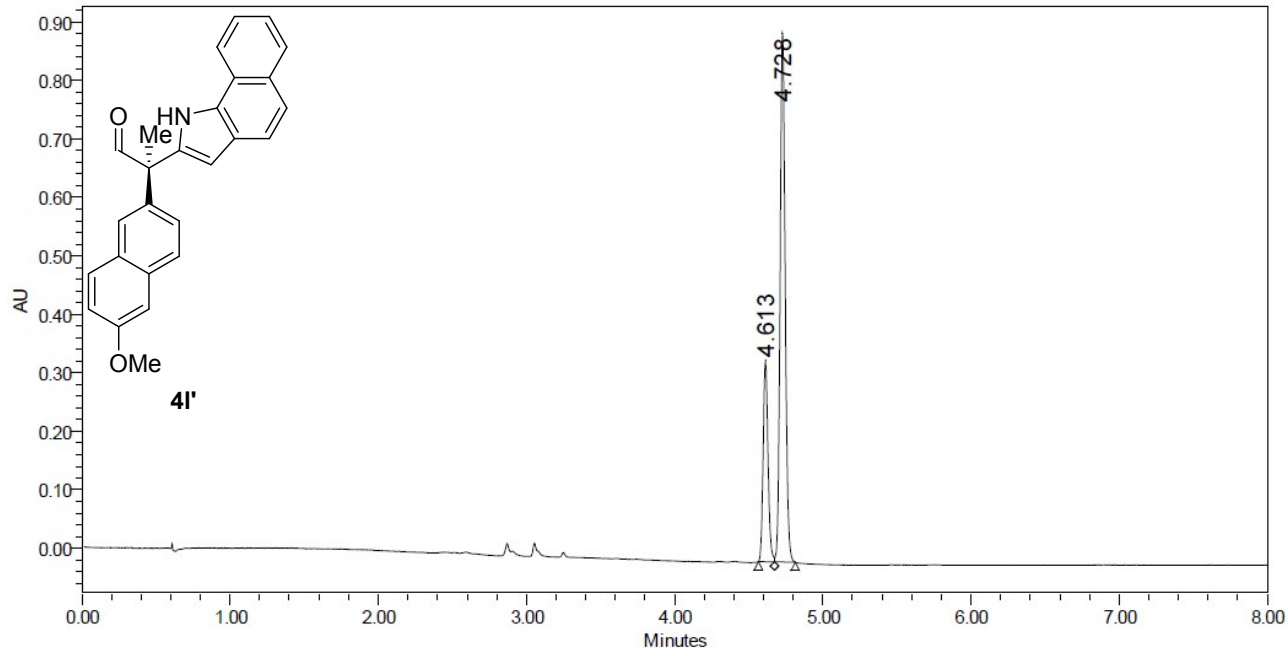
	Retention Time (min)	% Area
1	4.799	49.76
2	5.016	50.24



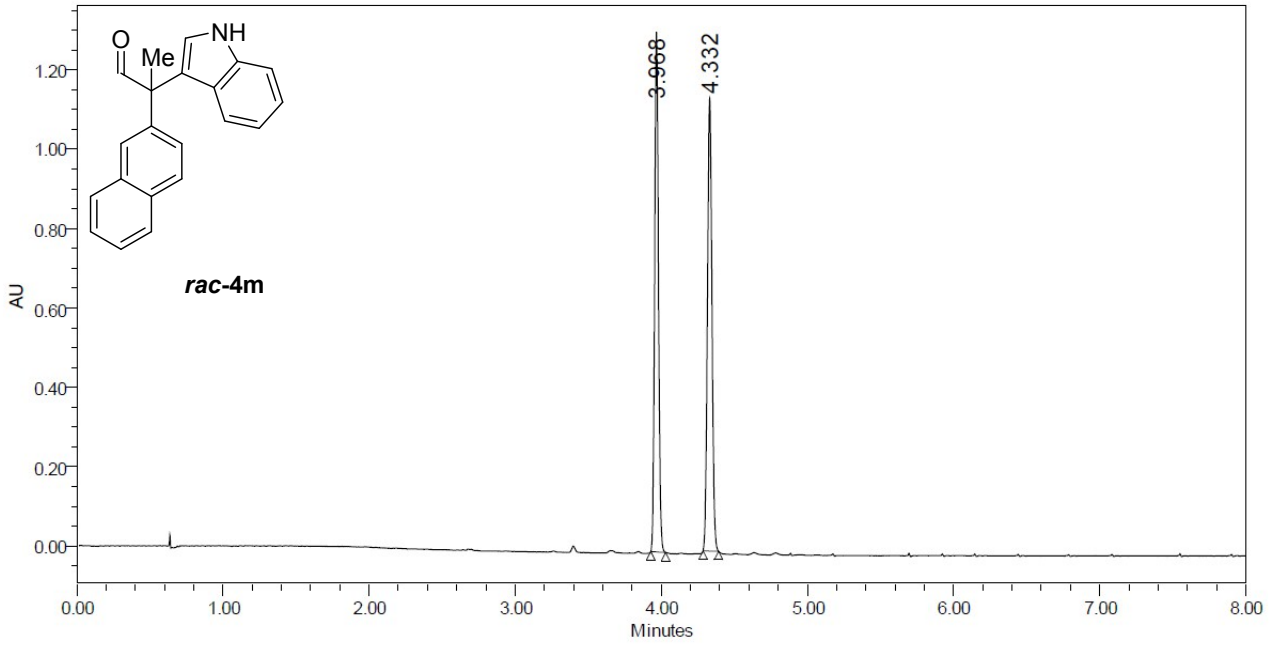
	Retention Time (min)	% Area
1	4.792	5.50
2	5.005	94.50



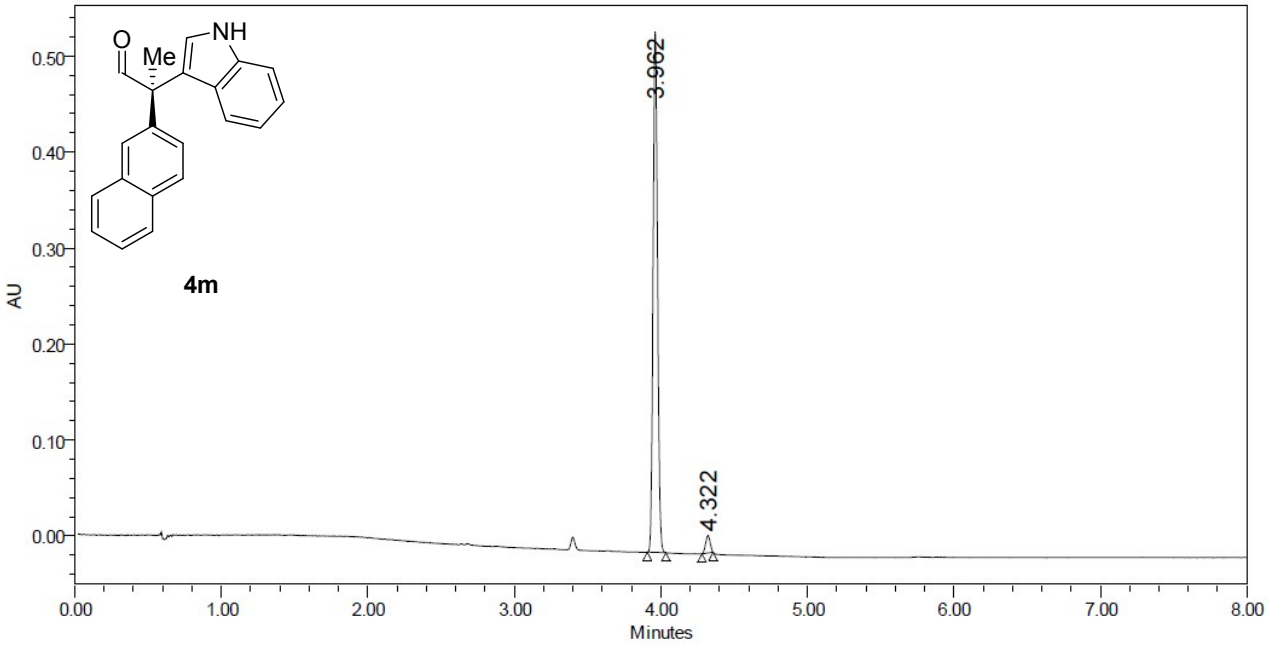
	Retention Time (min)	% Area
1	4.629	50.53
2	4.746	49.47



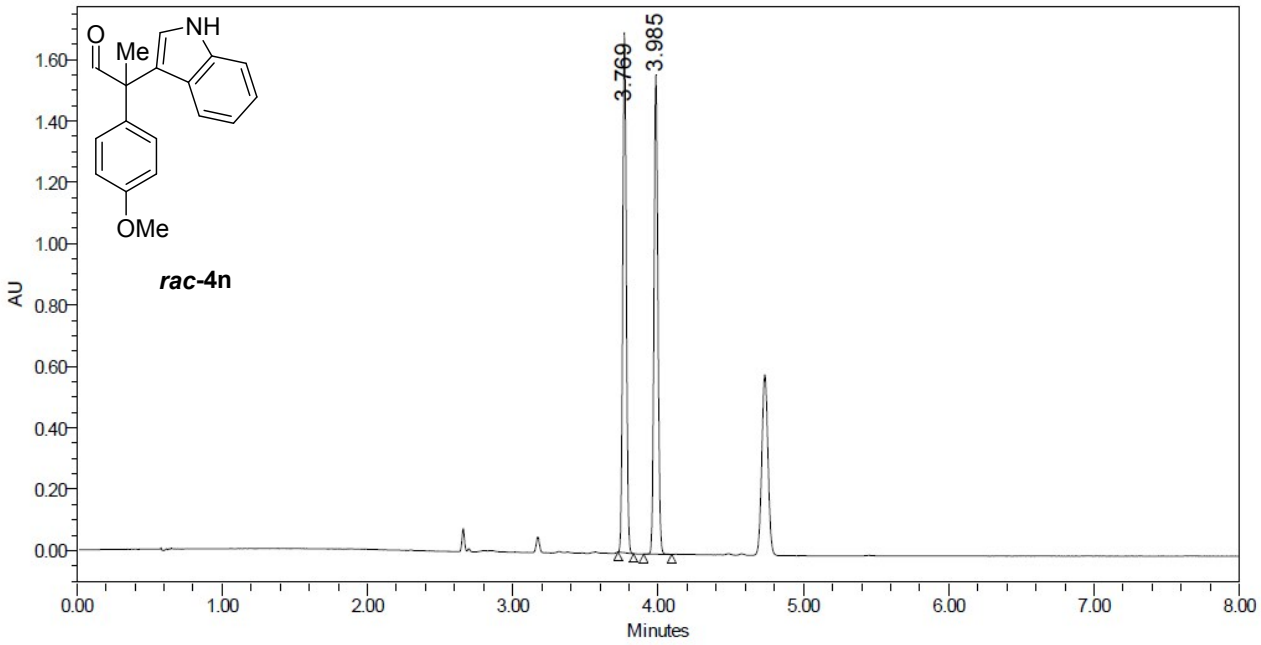
	Retention Time (min)	% Area
1	4.613	26.50
2	4.728	73.50



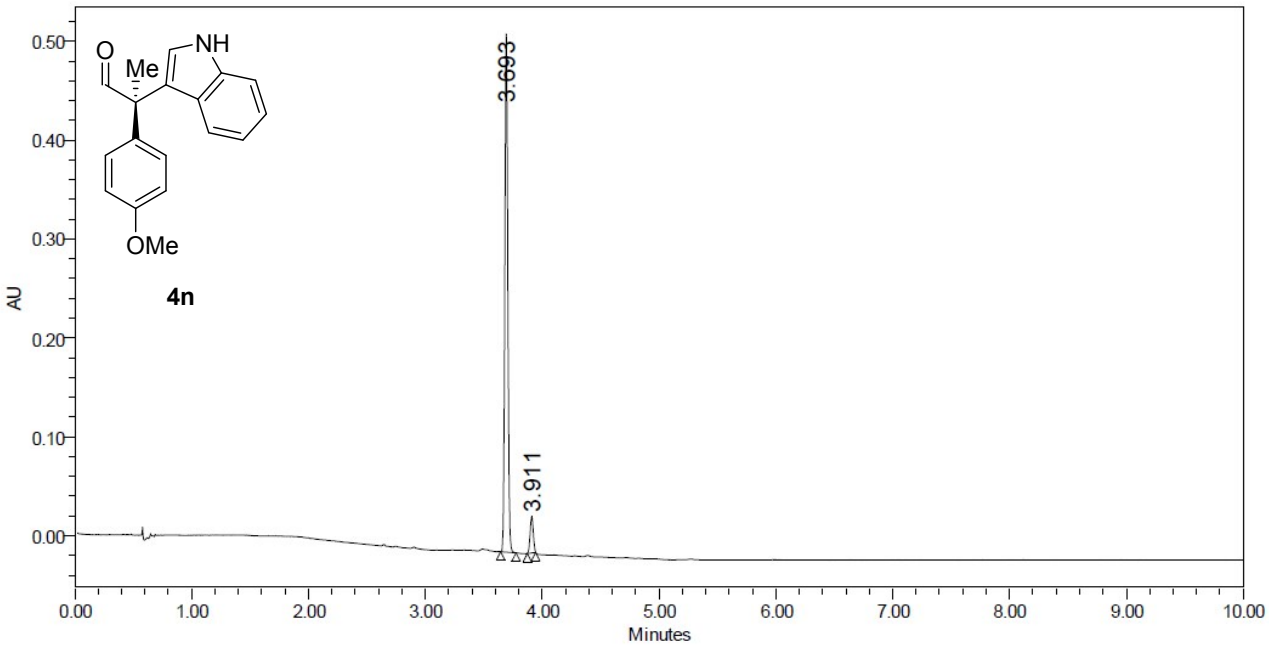
	Retention Time (min)	% Area
1	3.968	49.13
2	4.332	50.87



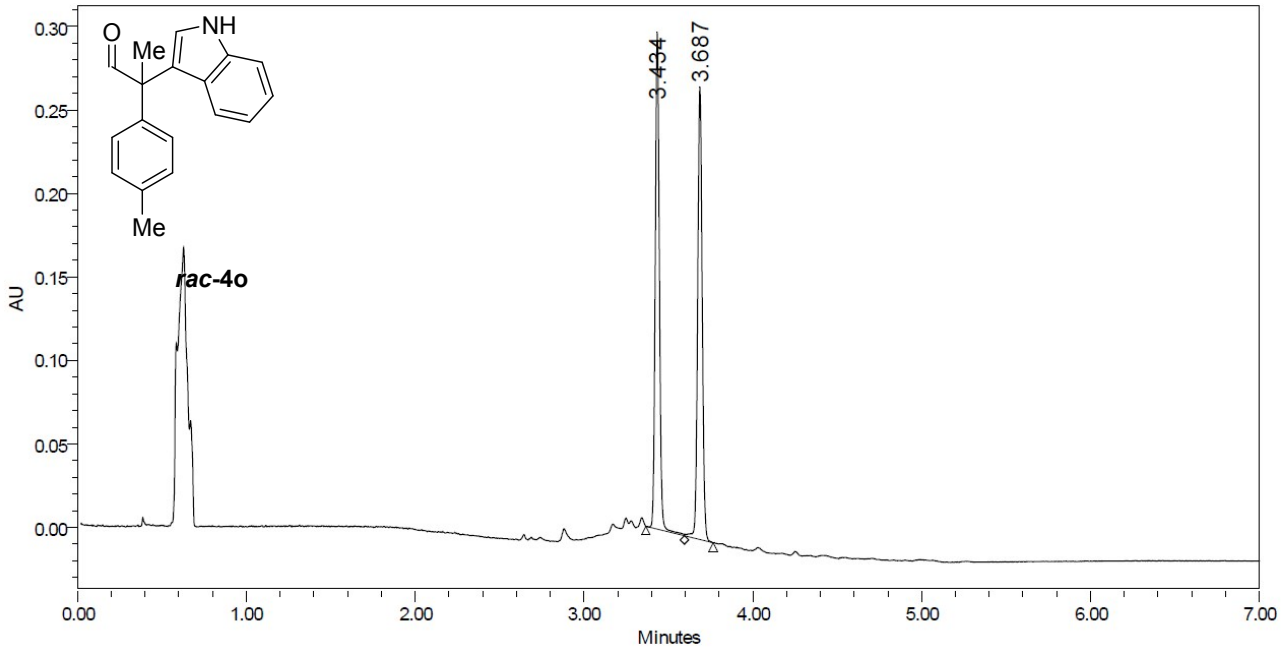
	Retention Time (min)	% Area
1	3.962	96.73
2	4.322	3.27



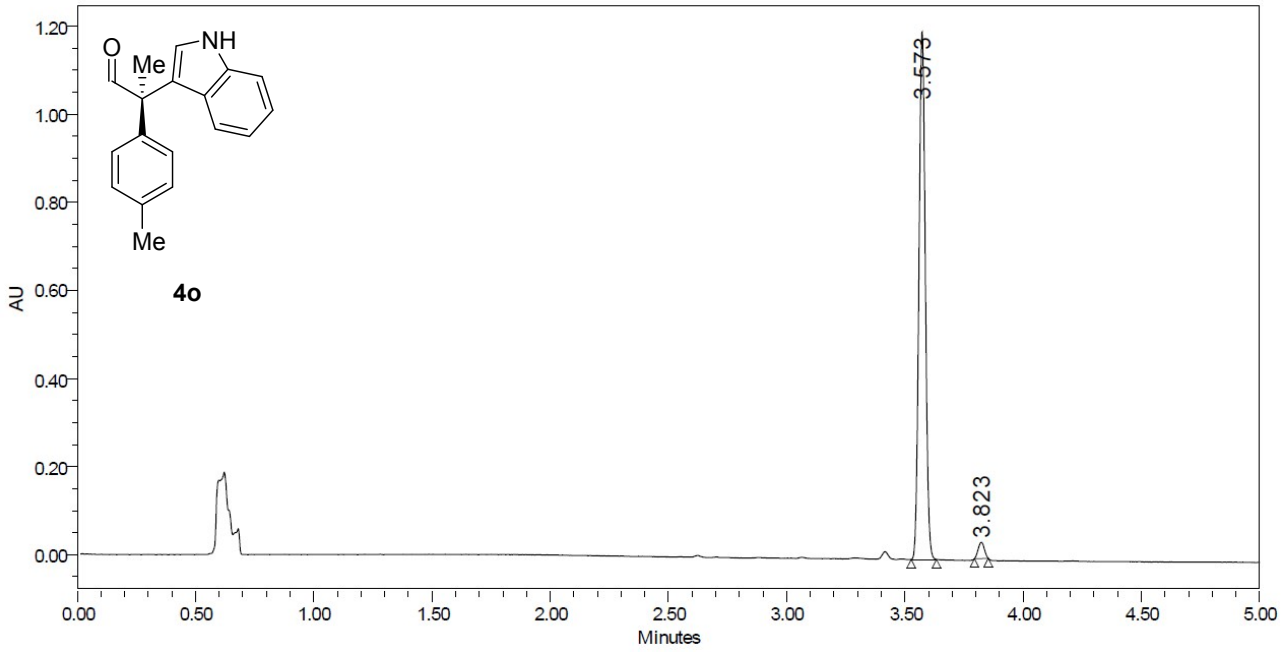
	Retention Time (min)	% Area
1	3.769	49.70
2	3.985	50.30



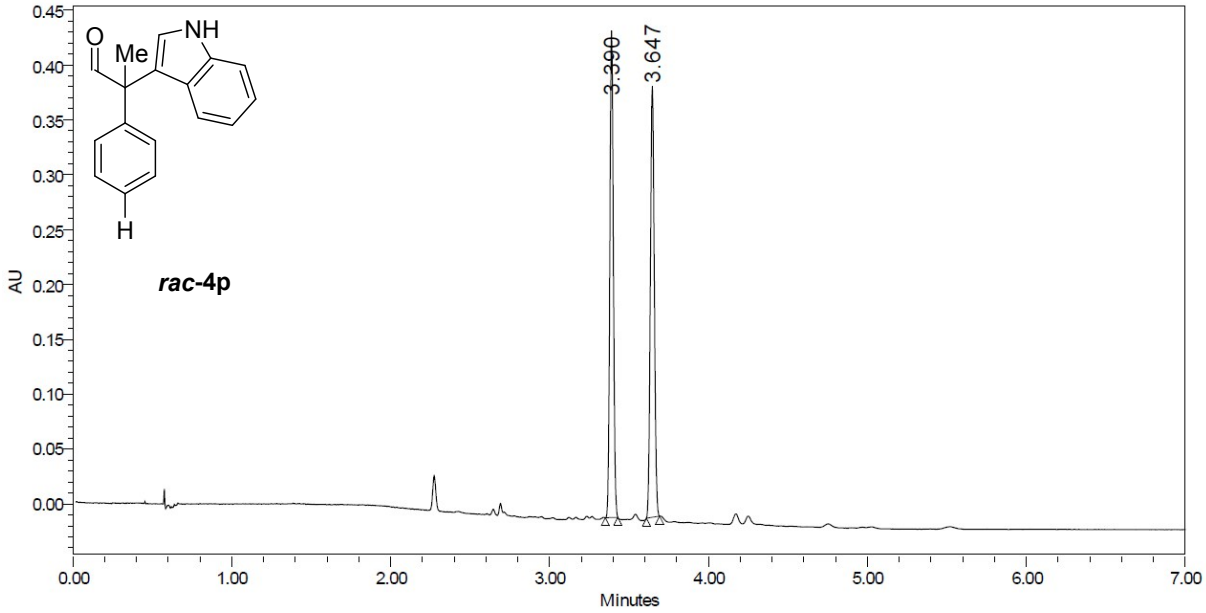
	Retention Time (min)	% Area
1	3.693	93.22
2	3.911	6.78



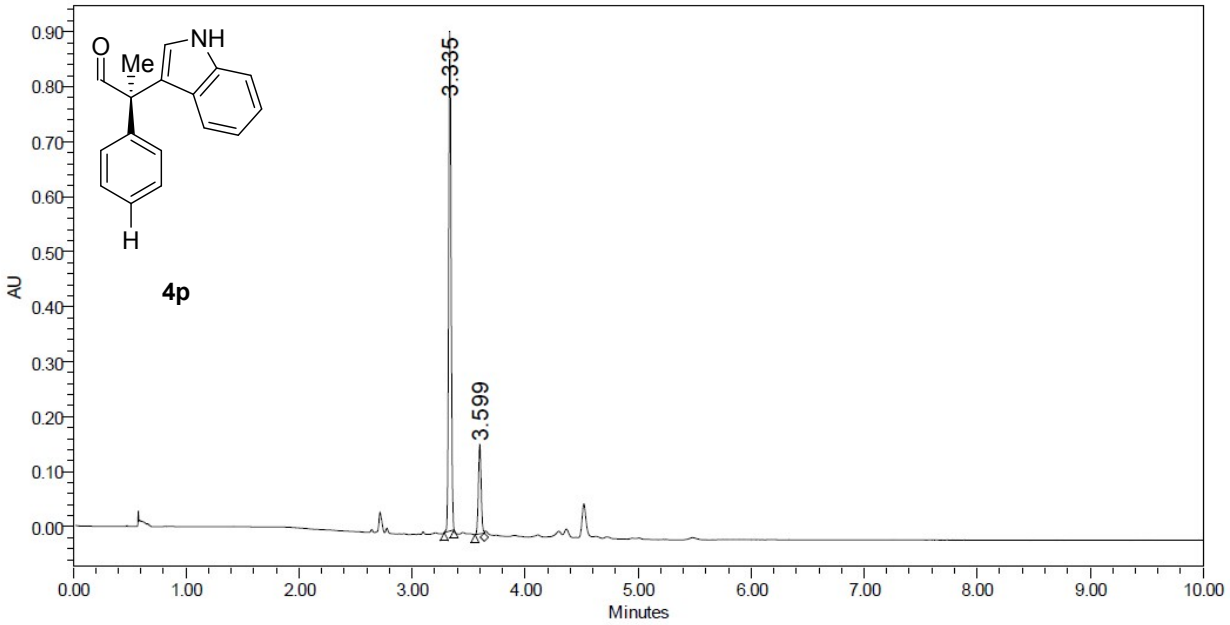
	Retention Time (min)	% Area
1	3.434	50.02
2	3.687	49.98



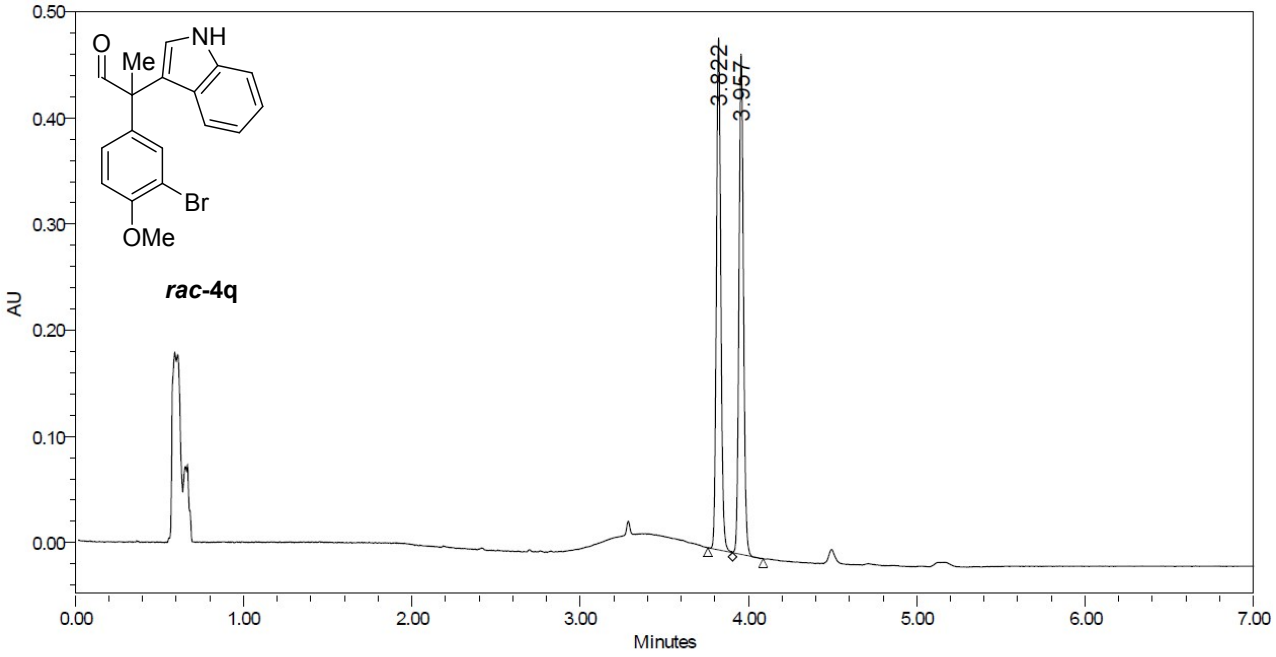
	Retention Time (min)	% Area
1	3.573	97.13
2	3.823	2.87



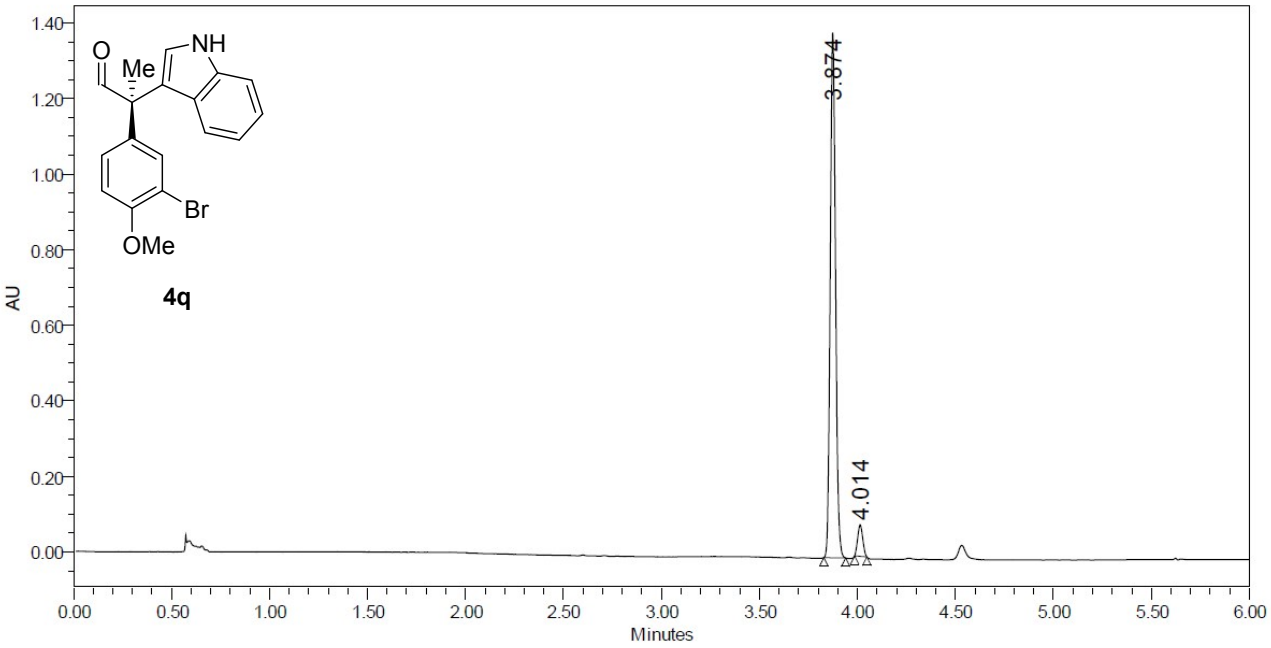
	Retention Time (min)	% Area
1	3.390	50.08
2	3.647	49.92



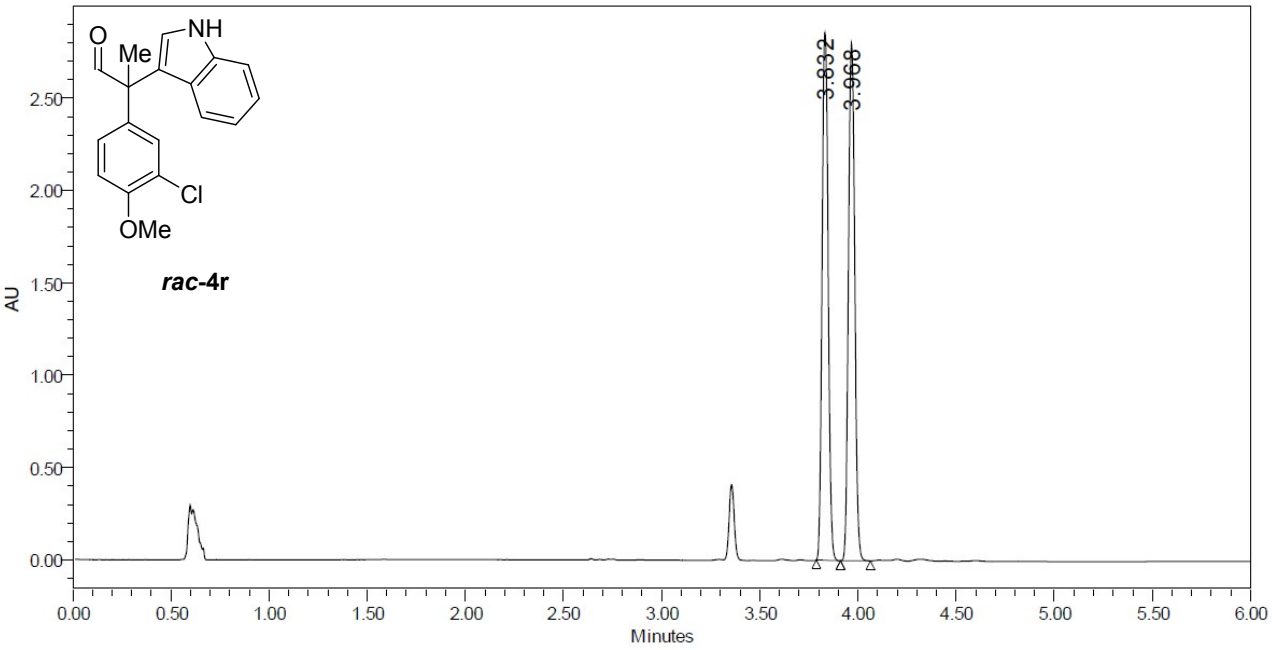
	Retention Time (min)	% Area
1	3.335	83.06
2	3.599	16.94



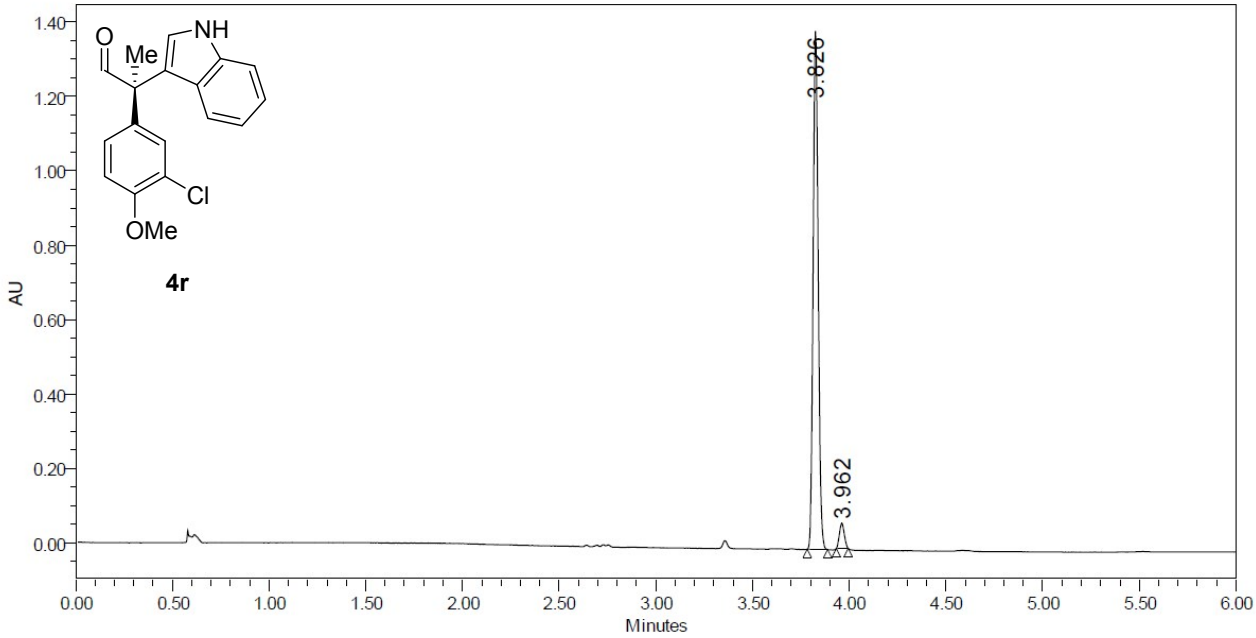
	Retention Time (min)	% Area
1	3.822	49.93
2	3.957	50.07



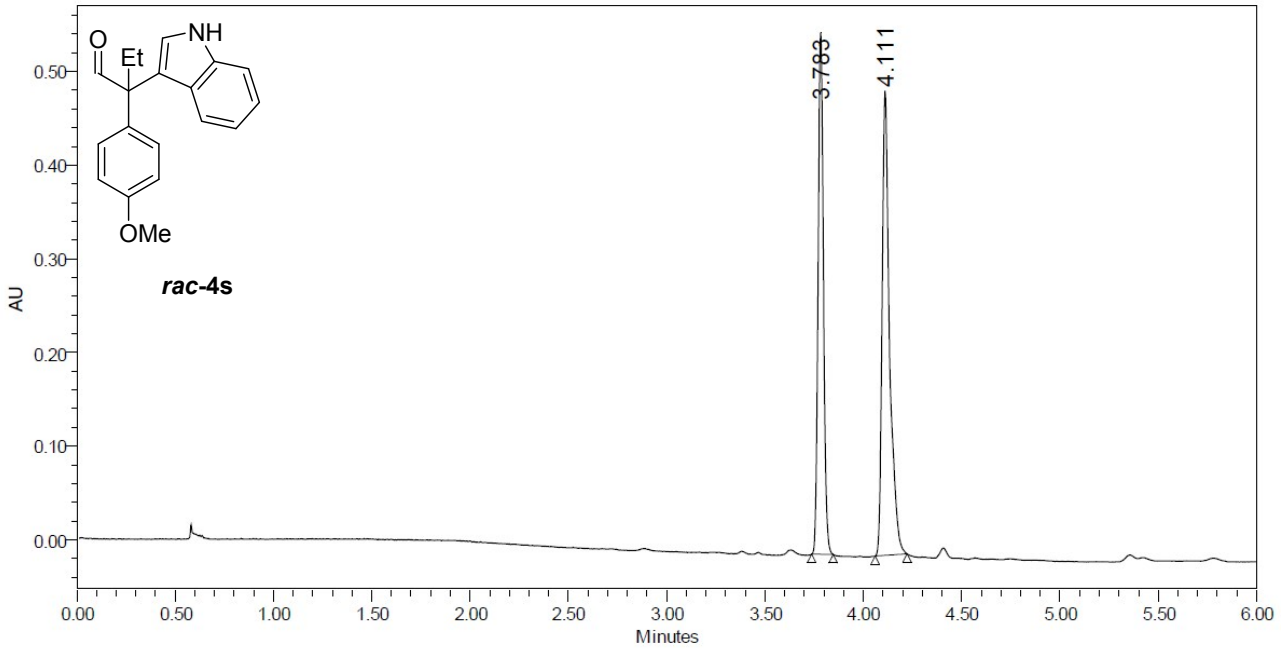
	Retention Time (min)	% Area
1	3.874	94.62
2	4.014	5.38



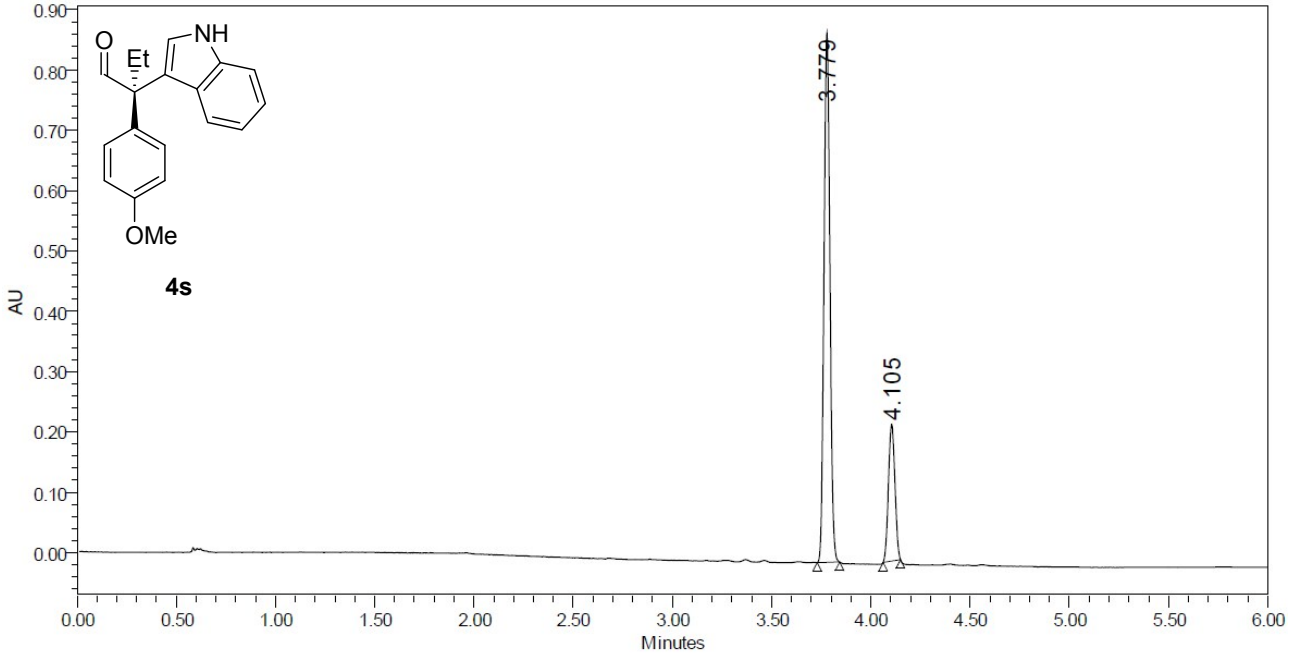
	Retention Time (min)	% Area
1	3.832	49.53
2	3.968	50.47



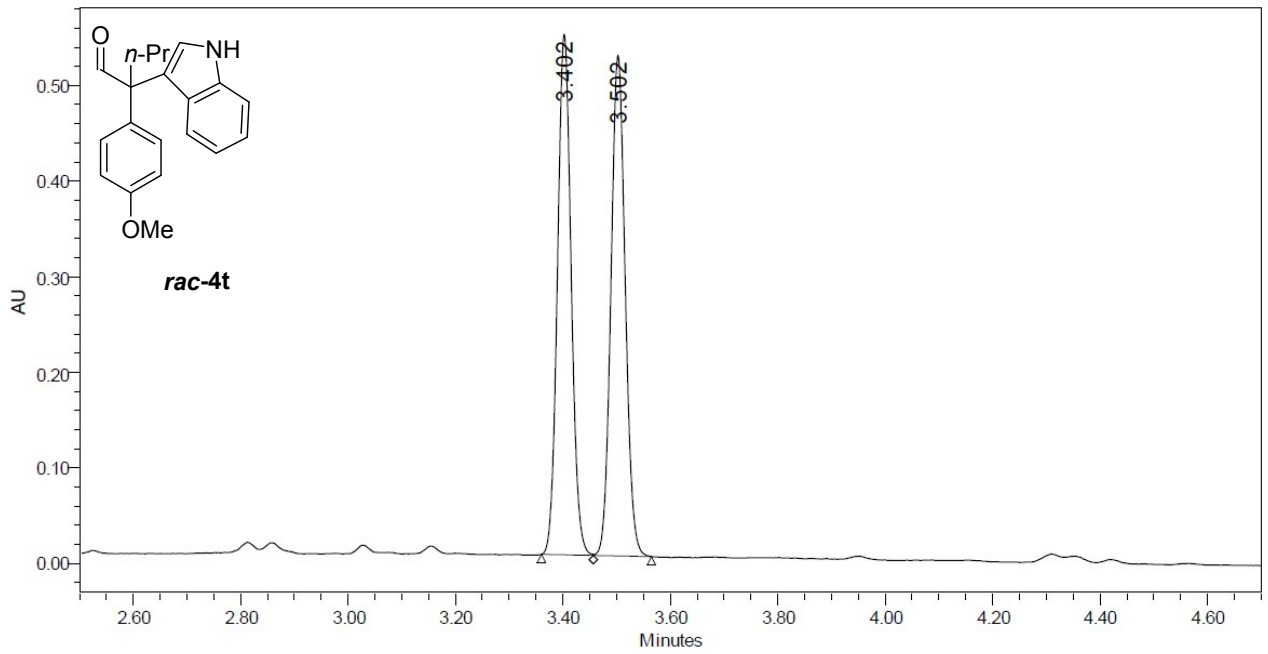
	Retention Time (min)	% Area
1	3.826	95.55
2	3.962	4.45



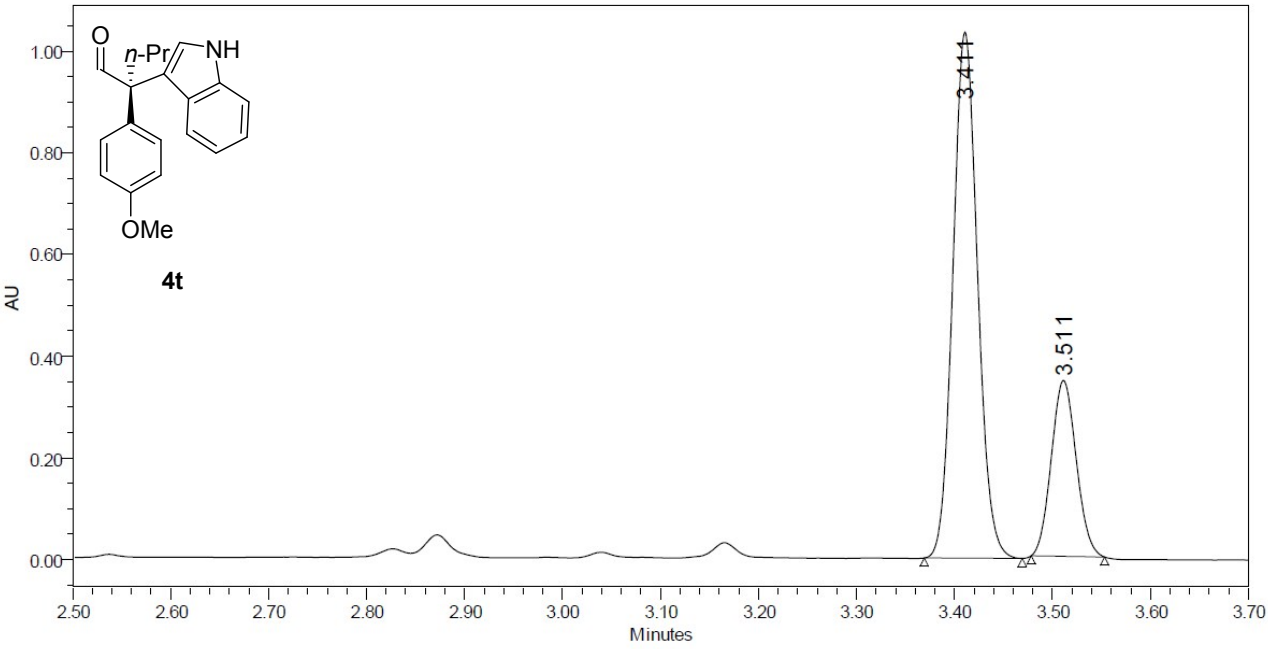
	Retention Time (min)	% Area
1	3.783	44.61
2	4.111	55.39



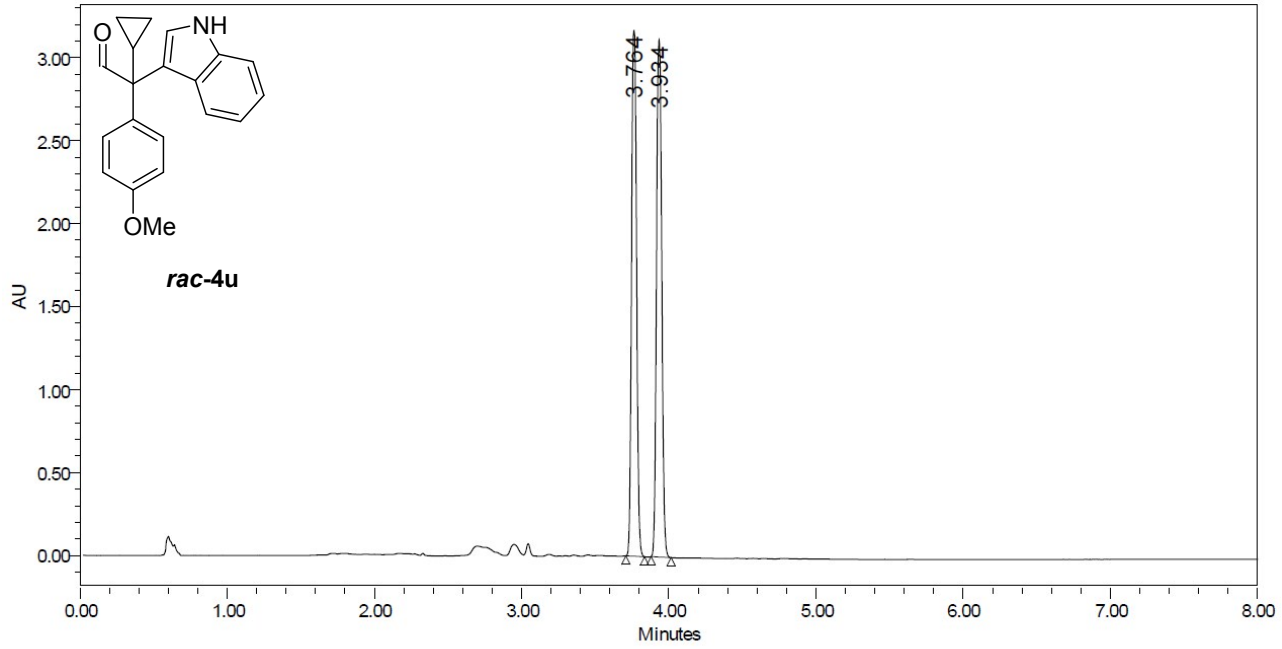
	Retention Time (min)	% Area
1	3.779	77.99
2	4.105	22.01



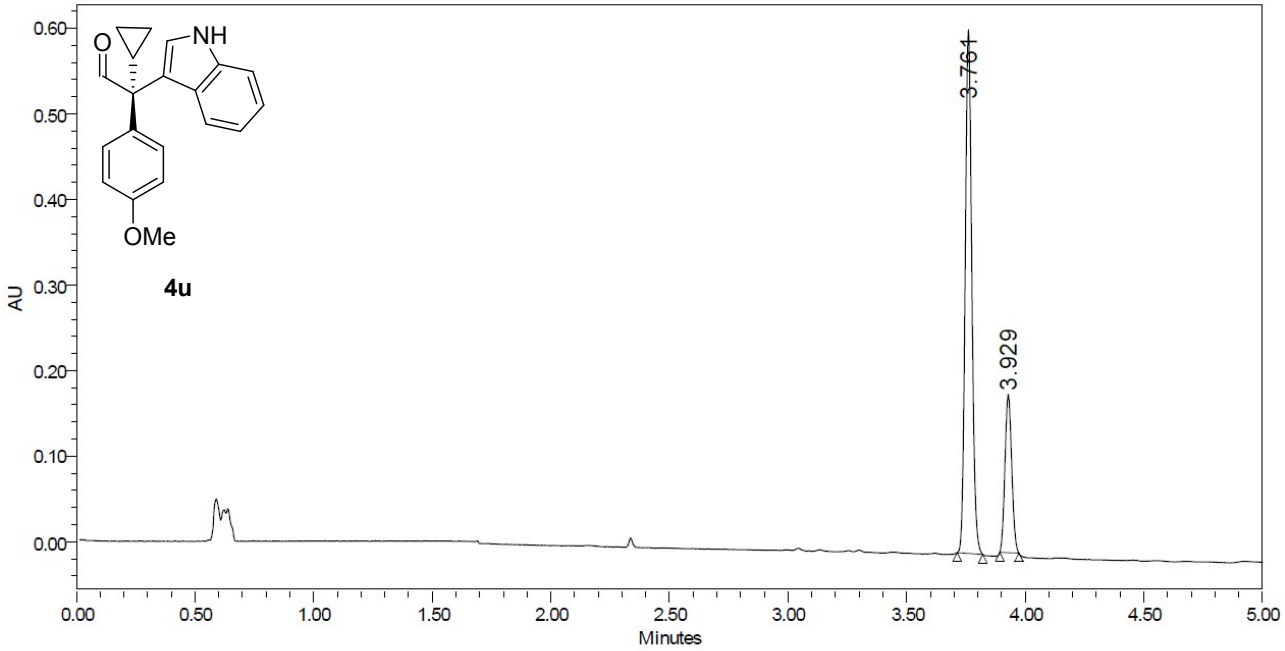
	Retention Time (min)	% Area
1	3.402	49.98
2	3.502	50.02



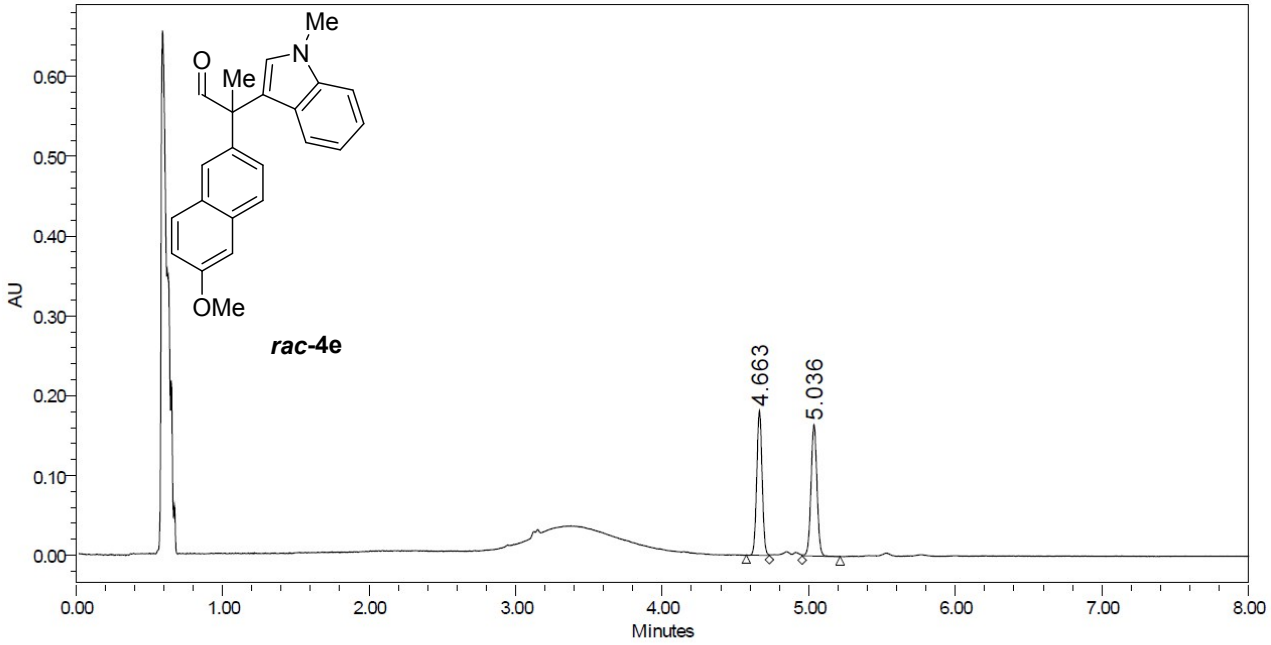
	Retention Time (min)	% Area
1	3.411	74.64
2	3.511	25.36



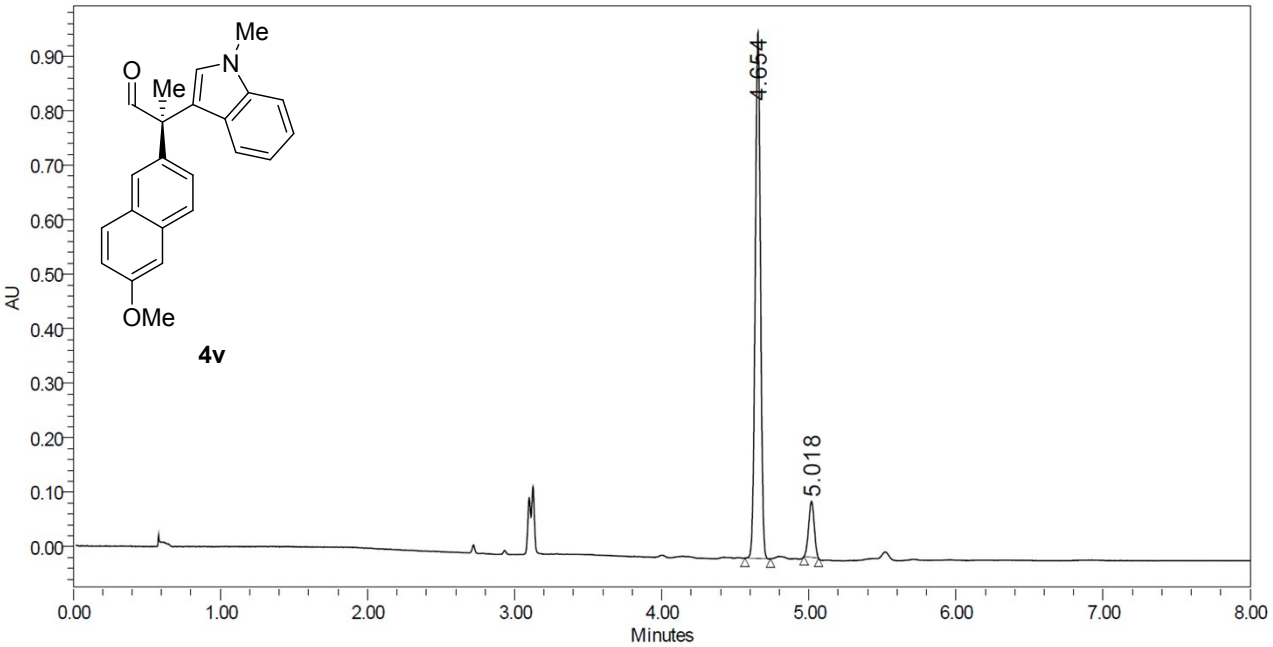
	Retention Time (min)	% Area
1	3.764	49.35
2	3.934	50.65



	Retention Time (min)	% Area
1	3.761	76.45
2	3.929	23.55



	Retention Time (min)	% Area
1	4.663	49.66
2	5.036	50.34



	Retention Time (min)	% Area
1	4.654	89.82
2	5.018	10.18