

Asymmetric Dearomative Cascade Multiple Functionalizations of Activated N-Alkyl Pyridinium and Quinolinium Salts

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Supporting Information

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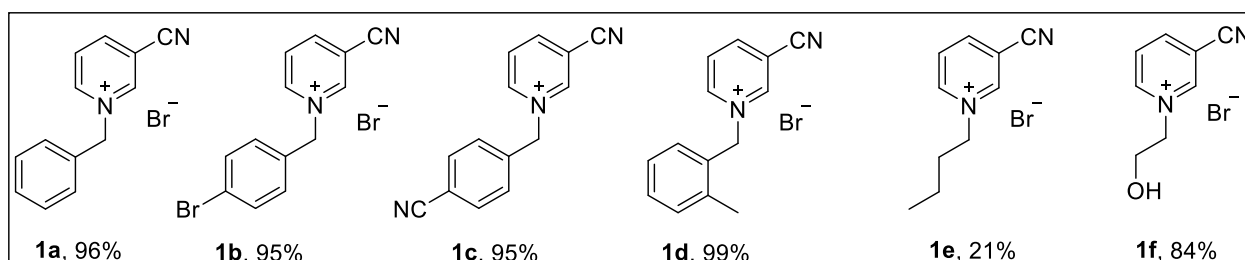
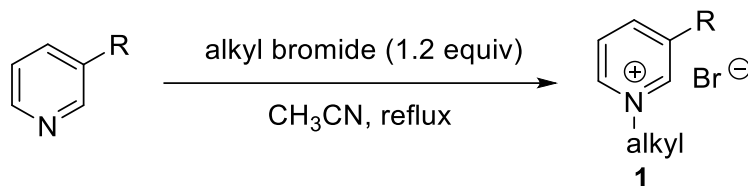
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1. General methods

Unless otherwise noted, all reactions were carried out under ambient atmosphere; when the reactions required heating, the heat source was oil bath. ^1H NMR (400 or 600 MHz), ^{13}C NMR (100 or 150 MHz) and ^{19}F NMR (376 MHz) spectra were recorded on Varian INOVA-400/54, Agilent DD2-600/54, Bruker AVANCE NEO 400 or Bruker AscendTM 400 instruments (Chemical shifts were reported in ppm from tetramethylsilane with the solvent resonance as the internal standard in CDCl_3 solution, unless otherwise noted). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, dd = double doublet, ddd = double double doublet, dt = double triplet; td = triple doublet; tt = triple triplet, m = multiplet, br = broad, and coupling constants J are reported in Hertz (Hz). High resolution mass spectra (HRMS) were recorded on a Waters SYNAPT G2, Agilent G1969-85000 or Shimadzu LCMS-IT-TOF using a time-of-flight mass spectrometer equipped with electrospray ionization (ESI) source. X-ray diffraction experiments were carried out on an Agilent Gemini or Xcalibur E and the data obtained were deposited at the Cambridge Crystallographic Data Centre. In each case, diastereomeric ratio was determined by ^1H NMR analysis and enantiomeric excess was determined by HPLC (Agilent Technologies: 1220 Infinity II, 1200 Series, 1260 Infinity) analysis on a chiral column in comparison with authentic racemate, using a Daicel Chiralpak AD-H Column (250 \times 4.6 mm), Chiralpak IG Column (250 \times 4.6 mm), Chiralpak ID Column (250 \times 4.6 mm), Chiralpak IB Column (250 \times 4.6 mm), Chiralpak IF Column (250 \times 4.6 mm) or Chiralpak IE Column (250 \times 4.6 mm). UV detection was monitored at 254 nm. The specific optical rotation was obtained from Rudolph Research Analytical Autopol I automatic polarimeter in CHCl_3 solution at 25 $^\circ\text{C}$. The melting point was obtained from WRX-4 Mel-Temp apparatus. Column chromatography was performed on silica gel (200–300 mesh) eluting with ethyl acetate (EtOAc) and petroleum ether or dichloromethane (DCM)/methanol (MeOH). TLC was performed on glass-backed silica plates. UV light, I_2 , and solution of potassium permanganate were used to visualize products or starting materials. All chemicals were used without purification as commercially available unless otherwise noted. Petroleum ether (60–90 $^\circ\text{C}$), dichloromethane (DCM) and 1,2-dichloroethane (DCE) was redistilled. The enones **2**,¹ cyclic 2,4-dienones **7a–7f**,^{2,3} primary amine catalysts **C1**, **C2**, **C5**, **C6**,⁴ and **C12**,⁵ were synthesized according to the literature procedures.

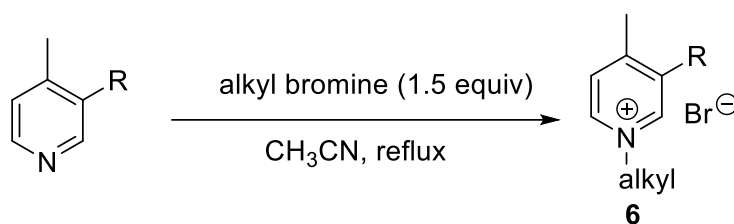
2. Preparation of substrates and catalysts

2.1 General procedure for the preparation of activated N-alkyl pyridinium salts^{6,7}



In a flask equipped with a magnetic stirring bar and a reflux condenser, pyridine derivative (2.0 mmol, 1.0 equiv) and alkyl bromide (3.0 mmol, 1.2 equiv) were dissolved in acetonitrile (5.0 mL) and the resulting mixture was heated at 80 °C. After completion (monitored by TLC, EtOAc/petroleum ether = 1:5), the mixture was cooled to 0 °C and EtOAc (4.0 mL) was added dropwise until a white precipitate was formed. The solid was then filtered and washed with cold Et₂O to afford the desired N-alkyl pyridinium salt **1**.

2.2 General procedure for the preparation of N-benzyl 4-methyl-3-nitropyridinium salt⁸

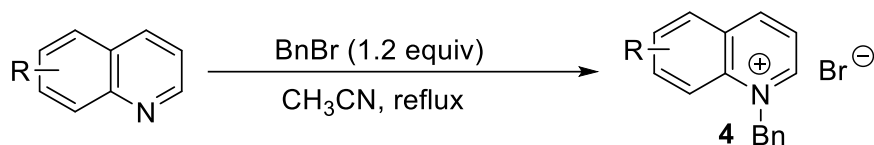


In a flask equipped with a magnetic stirring bar and a reflux condenser, 4-methyl-3-substituted (2.0 mmol, 1.0 equiv) and alkyl bromide (0.36 mL, 3.0 mmol, 1.5 equiv) were dissolved in acetonitrile (2.0 mL) and the resulting mixture was heated at 80 °C for 18 h. After completion (monitored by TLC, EtOAc/petroleum ether = 1:5), the mixture was cooled to 0 °C and EtOAc (4.0 mL) was added dropwise until a precipitate was formed. The solid was then filtered and washed repeatedly with cold Et₂O to afford the desired pyridinium salt **6**.

- (1) Barrios Antúnez, D.-J.; Greenhalgh, M. D.; Fallan, C.; Slawin, A. M. Z.; Smith, A. D. *Org. Biomol. Chem.* **2016**, *14*, 7268.
- (2) Kowalczyk, R.; Boratyński, P. J.; Wierzba, A. J.; Bąkiewicz, J. *RSC Adv.* **2015**, *5*, 66681.
- (3) Hénon, H.; Mauduit, M.; Alexakis, A. *Angew. Chem., Int. Ed.* **2008**, *47*, 9122.
- (4) Lee, A.; Michrowska, A.; Sulzer-Mosse, S.; List, B. *Angew. Chem., Int. Ed.* **2011**, *50*, 1707.
- (5) Kucherenko, A. S.; Kostenko, A. A.; Zhdankina, G. M.; Kuznetsova, O. Y.; Zlotin, S. G. *Green Chem.* **2018**, *20*, 754.
- (6) Zhang, M.; Lan, H.; Li, N.; Zhong, Q.; Zhu, H.; Liu, C.; Zhao, H. *J. Org. Chem.* **2020**, *85*, 8279.
- (7) Di Carmine, G.; Ragno, D.; Bortolini, O.; Giovannini, P. P.; Mazzanti, A.; Massi, A.; Fogagnolo, M. *J. Org. Chem.* **2018**, *83*, 2050.
- (8) Yan, R.-J.; Xiao, B.-X.; Ouyang, Q.; Liang, H.-P.; Du, W.; Chen, Y.-C. *Org. Lett.* **2018**, *20*, 8000.

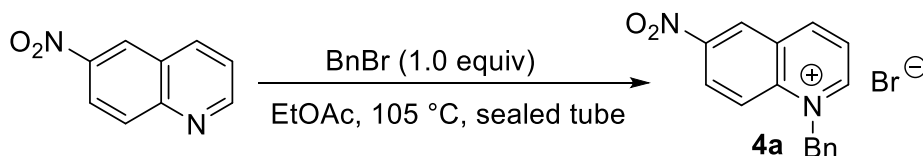
2.3 Procedure for the preparation of N-benzyl quinolinium salts

General procedure for the preparation of N-benzyl quinolinium salts 4



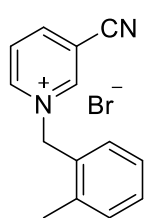
In a flask equipped with a magnetic stirring bar and a reflux condenser, quinoline derivative (2.0 mmol, 1.0 equiv) and alkyl bromide (3.0 mmol, 1.2 equiv) were dissolved in acetonitrile (5.0 mL) and the resulting mixture was heated at 80 °C for 48 h. After completion (monitored by TLC, EtOAc/petroleum ether = 1:5), the mixture was cooled to 0 °C and EtOAc (4.0 mL) was added dropwise until a precipitate was formed. The solid was then filtered and washed with EtOAc to afford the desired N-benzyl quinolinium salt **4** (except for **4a**).

Typical procedure for the preparation of N-benzyl quinolinium salts 4a



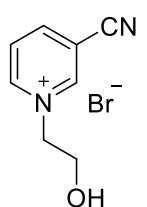
In a sealed tube equipped with a magnetic stirring bar, 6-nitroquinoline (0.87 g, 5.0 mmol, 1.0

equiv) and benzyl bromide (0.61 ml, 5.0 mmol, 1.0 equiv) were dissolved in EtOAc (10.0 mL) and the resulting mixture was heated at 105 °C for 3 days. A yellow precipitate was formed, which was cooled to rt, filtered and washed repeatedly with EtOAc to afford the 1-benzyl-6-nitroquinolin-1-ium bromide **4a**.



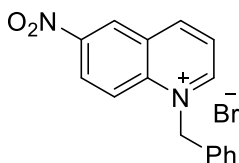
3-Cyano-1-(2-methylbenzyl)pyridin-1-ium bromide 1d: white solid, 99% yield, mp = 199–200 °C; ¹H NMR (400 MHz, D₂O) : δ (ppm) 1H NMR (400 MHz, D₂O) δ 9.32 (d, *J* = 1.6 Hz, 1H), 9.13 (d, *J* = 6.3 Hz, 1H), 8.97 (dt, *J* = 8.2, 1.4 Hz, 1H), 8.28 (dd, *J* = 8.1, 6.4 Hz, 1H), 7.56 – 7.44 (m, 1H), 7.45 – 7.33 (m, 3H), 5.97 (s, 2H), 2.27 (s, 3H);

¹³C NMR (100 MHz, D₂O): δ (ppm) 149.2, 147.8, 147.7, 138.6, 131.5, 131.4, 131.0, 129.0, 128.9, 127.1, 114.2, 113.2, 63.7, 18.1.



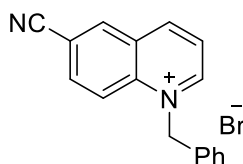
3-Cyano-1-(2-hydroxyethyl)pyridin-1-ium bromide 1f: white solid, 84% yield, mp = 126–127 °C; ¹H NMR (400 MHz, D₂O) : δ (ppm) 9.61 – 9.48 (m, 1H), 9.29 – 9.19 (m, 1H), 9.04 (dt, *J* = 8.1, 1.5 Hz, 1H), 8.37 (ddd, *J* = 9.3, 6.3, 2.6 Hz, 1H), 4.95 – 4.84 (m, 2H), 4.21 – 4.06 (m, 2H); ¹³C NMR (100 MHz, D₂O): δ (ppm) 149.2, 148.6, 148.5, 128.9,

113.9, 113.3, 64.6, 59.9.



1-Benzyl-6-nitroquinolin-1-ium bromide 4a: yellow solid, 20% yield, mp = 112–113 °C; ¹H NMR (400 MHz, DMSO-*d*₆) : δ (ppm) 10.02 (dd, *J* = 5.9, 1.5 Hz, 1H), 9.68 (d, *J* = 8.4 Hz, 1H), 9.55 (d, *J* = 2.6 Hz, 1H), 8.84 (dd, *J* = 9.7, 2.6 Hz, 1H), 8.76 (d, *J* = 9.7 Hz, 1H), 8.51 (dd, *J* = 8.4, 5.8 Hz, 1H), 7.53–7.32 (m,

5H), 6.50 (s, 2H); ¹³C NMR (100 MHz, DMSO-*d*₆): δ (ppm) 154.1, 150.5, 147.1, 140.1, 133.9, 130.2, 129.6, 129.4, 128.9, 128.0, 127.4, 125.0, 122.3, 61.0.

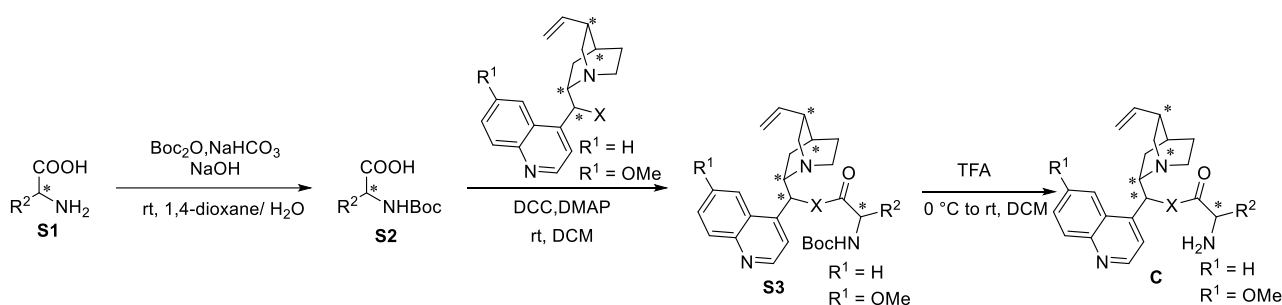


1-Benzyl-6-cyanoquinolin-1-ium bromide 4b: white solid, 49% yield, mp = 191–192 °C; ¹H NMR (400 MHz, DMSO-*d*₆) : δ (ppm) 9.92 (dd, *J* = 5.9, 1.5 Hz, 1H), 9.44 (dt, *J* = 8.5, 1.2 Hz, 1H), 9.20 (d, *J* = 1.9 Hz, 1H), 8.70 (d, *J* = 9.3 Hz, 1H), 8.54 (dd, *J* = 9.3, 1.9 Hz, 1H), 8.45 (dd, *J* = 8.4, 5.8 Hz, 1H), 7.54–

7.20 (m, 5H), 6.44 (s, 2H); ¹³C NMR (100 MHz, DMSO-*d*₆): δ (ppm) 153.6, 149.1, 139.4, 137.6, 136.4, 134.0, 129.9, 129.6, 129.4, 128.0, 124.8, 121.5, 117.5, 113.0, 60.7.

1-Benzyl-7-nitroquinolin-1-ium bromide 4c: yellow solid, 79% yield, mp = 235–236 °C; ¹H NMR (400 MHz, D₂O): δ (ppm) 9.58 (dd, *J* = 5.8, 1.5 Hz, 1H), 9.37–9.30 (m, 2H), 8.69 (dd, *J* = 9.1, 1.9 Hz, 1H), 8.63 (d, *J* = 9.0 Hz, 1H), 8.31 (dd, *J* = 8.6, 5.8 Hz, 1H), 7.62–7.31 (m, 5H), 6.43 (s, 2H); ¹³C NMR (100 MHz, D₂O): δ (ppm) 154.5, 153.1, 151.1, 140.2, 135.8, 135.4, 134.5, 132.2, 132.1, 130.5, 127.4, 126.1, 118.0, 64.1.

2.4 General procedure for the preparation of primary amine catalysts C3, C4, C7–C10

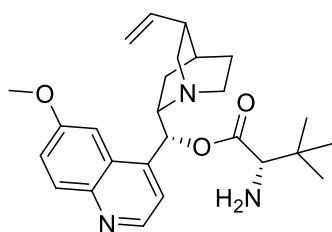


Preparation of S2: Amino acid **S1** (10 mmol) was dissolved in dioxane/water (2:1, 30 mL), and NaOH (1 M, 10 mL) was added. The mixture was cooled in an ice-bath, and (Boc)₂O (3.27 g, 15.0 mmol) and NaHCO₃ (840 mg, 10.0 mmol) were added. The reaction mixture was stirred at room temperature overnight, and then it was evaporated in vacuo. The residue was diluted with EtOAc (40 mL), and cooled in an ice-bath and acidified to pH = 2.5–3 with 1 M KHSO₄ aqueous solution. The organic layer was separated, and the aqueous fraction was extracted with EtOAc (20 mL × 2). The combined organic layers were washed with water, dried and evaporated, leaving products as a colorless oil in a quantitative yield. The crude product was used for the condensation step without further purification.

Preparation of S3: cinchona alkaloid was added to a solution of crude residue **S2** in dry DCM (50 mL). The mixture was cooled in an ice-bath, and DCC (2.06 g, 10.0 mmol), Et₃N (1.40 mL, 10.0 mmol) and DMAP (122 mg, 1.00 mmol) were added. After stirring at room temperature overnight, the precipitates were filtered and the cake was washed with DCM. The filtrate was dried and evaporated, and the residue was purified by chromatography on silica (DCM/MeOH = 50:1 to 25:1).

Preparation of C3, C4 and C7–C10: TFA (3 mL) was added to a solution of **S3** (3.0 mmol) in DCM (15 mL) in an ice-bath, and the mixture was stirred at room temperature for 5 h. The solution was

evaporated, and a solution of NaOH (1M) was added slowly at 0 °C until pH was adjusted to 9. The organic layer was separated, and the aqueous layer was extracted with DCM (25 mL × 2). The combined organic layers were dried and evaporated, and the residue was purified chromatographically on silica gel (DCM/MeOH = 50:1).



Quinyl (*S*)-2-amino-3,3-dimethylbutanoate C3: white solid, 13% yield

for 3 steps, mp = 101–102 °C; $[\alpha]_{\text{D}}^{25} = 8.6$ ($c = 1.0$ in CHCl_3); ^1H NMR

(400 MHz, CHCl_3): δ (ppm) 8.75 (d, $J = 4.6$ Hz, 1H), 8.01 (d, $J = 9.2$ Hz, 1H), 7.52 (d, $J = 2.7$ Hz, 1H), 7.40 (d, $J = 4.6$ Hz, 1H), 7.37 (dd, $J = 9.2$,

2.7 Hz, 1H), 6.57 (s, 1H), 5.99–5.70 (m, 1H), 5.05 (dt, $J = 5.4$, 1.6 Hz,

1H), 5.02 (d, $J = 1.5$ Hz, 1H), 3.97 (s, 3H), 3.44 (t, $J = 13.2$ Hz, 1H), 3.20 (s, 1H), 3.13–2.89 (m, 2H),

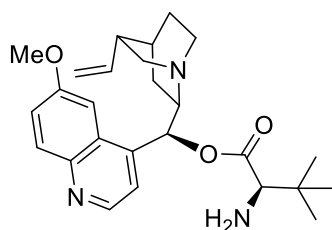
2.78–2.49 (m, 2H), 2.37–2.21 (m, 1H), 2.08–1.95 (m, 1H), 1.94–1.83 (m, 1H), 1.73 (m, 2H), 1.61–

1.53 (m, 2H), 1.51–1.42 (m, 1H), 0.82 (s, 9H); ^{13}C NMR (100 MHz, CHCl_3): δ (ppm) 174.6, 157.9,

147.4, 144.9, 143.2, 141.7, 131.8, 127.3, 121.9, 119.6, 114.6, 101.6, 63.7, 59.2, 56.4, 55.6, 42.3, 42.3,

39.6, 34.7, 27.7, 27.4, 26.2, 25.4; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{26}\text{H}_{36}\text{N}_3\text{O}_3$ 438.2751;

Found 438.2751.



Quinidinyll (*R*)-2-amino-3,3-dimethylbutanoate C4: white solid, 15%

yield for 3 steps, mp = 115–116 °C; $[\alpha]_{\text{D}}^{25} = +46.8$ ($c = 0.75$ in CHCl_3); ^1H NMR

(400 MHz, CHCl_3): δ (ppm) 8.74 (d, $J = 4.4$ Hz, 1H), 8.01 (d, $J = 9.2$ Hz, 1H), 7.48 (d, $J = 2.7$ Hz, 1H), 7.42–7.21 (m, 2H), 6.69–6.51

(m, 1H), 6.10–5.89 (m, 1H), 5.22–4.95 (m, 2H), 3.97 (s, 3H), 3.37 (q, $J = 8.7$ Hz, 1H), 3.21 (s, 1H),

2.94–2.82 (m, 2H), 2.81–2.59 (m, 2H), 2.42–2.16 (m, 1H), 1.88–1.82 (m, 1H), 1.82–1.75 (m, 1H),

1.71–1.50 (m, 5H), 0.84 (s, 9H); ^{13}C NMR (100 MHz, CHCl_3): δ (ppm) 174.6, 157.9, 147.4, 144.8,

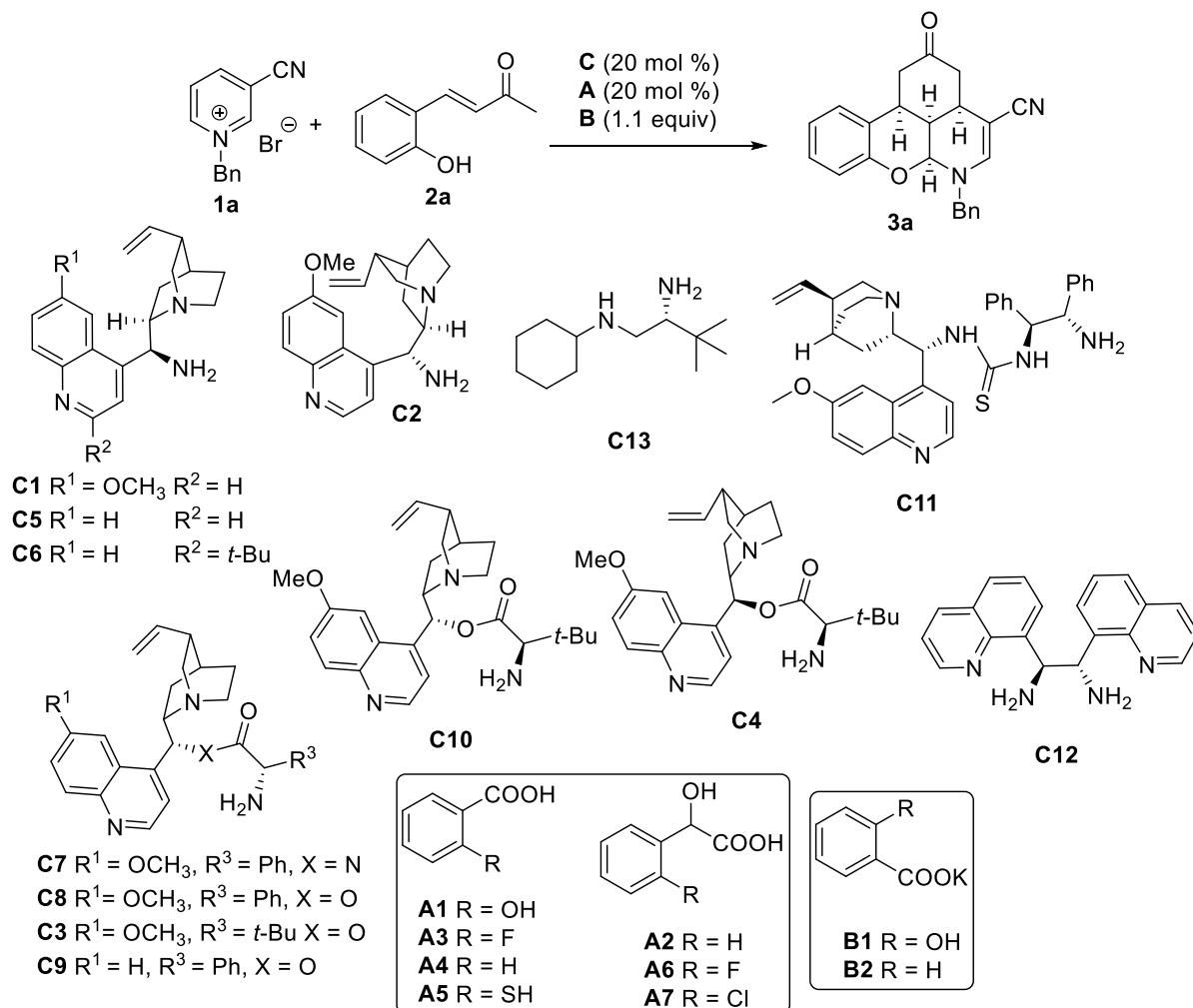
143.5, 140.3, 131.8, 127.3, 121.9, 119.3, 115.0, 101.5, 63.7, 59.3, 55.6, 49.7, 49.1, 39.7, 34.7, 29.7,

27.7, 26.4, 26.3, 24.6; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{26}\text{H}_{36}\text{N}_3\text{O}_3$ 438.2751; Found

438.2747.

3. Detailed screening conditions for dearomative cascade reactions

3.1 Complete screening conditions for dearomative cascade reaction of enone 2a and activated N-alkyl pyridinium salt 1a

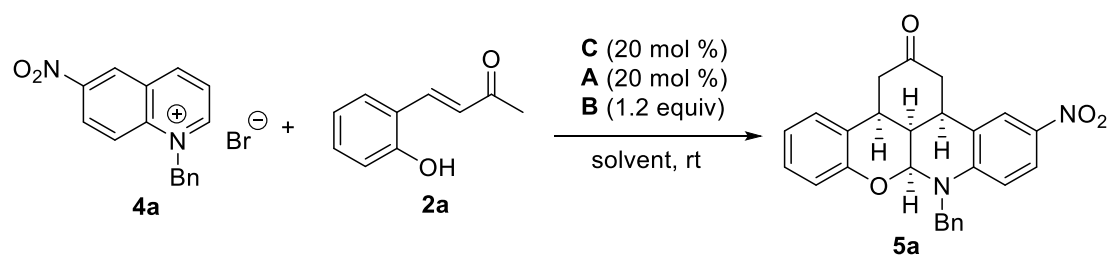


entry ^a	cat	B	A	solvent	T (°C)	t (h)	yield (%) ^b	ee (%) ^c
1	C1	B2	A1	CHCl ₃	rt	36	45	94
2	C5	B2	A1	CHCl ₃	rt	36	58	89
3	C6	B2	A1	CHCl ₃	rt	36	51	90
4	C13	B2	A1	CHCl ₃	rt	36	35	74
5	C11	B2	A1	CHCl ₃	rt	36	30	23
6	C1	B2	A3	CHCl ₃	rt	48	56	81
7	C1	B2	A4	CHCl ₃	rt	48	29	82
8	C1	B2	A5	CHCl ₃	rt	48	15	86
9	C1	B2	A2	CHCl ₃	rt	48	45	85
10	C1	B2	A6	CHCl ₃	rt	48	30	84
11	C1	B1	A1	CHCl ₃	rt	36	56	96
12	C1	AcONa	A1	CHCl ₃	rt	48	44	71

13	C1	B1	A1	CHCl ₃	40	36	63	94
14	C1	B1	A1	THF	40	36	37	87
15	C1	B1	A1	DCE	40	60	65	97
16	C1	B1	A1	CH ₃ CN	40	40	56	91
17	C1	B1	A1	DCM	40	18	62	95
18	C1	B1	A1	DCM	25	48	78	98

^aUnless noted otherwise, reactions were performed with pyridinium salt **1a** (0.11 mmol, 1.1 equiv), enone **2** (0.1 mmol, 1.0 equiv), **C** (20 mol %), **A** (20 mol %), **B** (1.1 equiv) in solvent (1.0 mL) at rt. ^bYield of the isolated product. ^cDetermined by HPLC analysis on a chiral stationary phase.

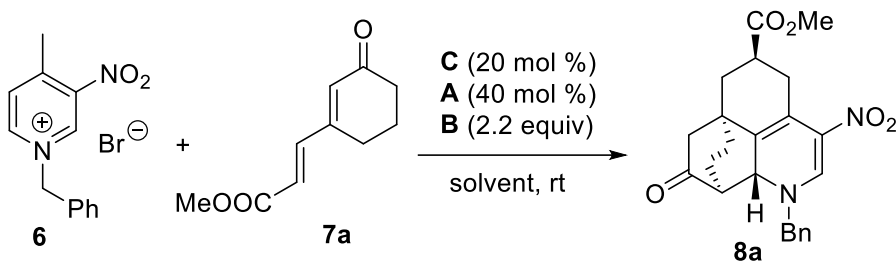
3.2 Complete screening conditions for dearomative cascade reaction with enone **2a** and N-alkyl quinolinium salt **4a**



entry ^a	cat	A	B	solvent	yield (%) ^b	ee (%) ^c
1	C1	A1	Na ₂ HPO ₄	DCM	71	3
2	C7	A1	Na ₂ HPO ₄	DCM	18	17
3	C8	A1	Na ₂ HPO ₄	DCM	48	37
4	C3	A1	Na ₂ HPO ₄	DCM	27	66
5	C9	A1	Na ₂ HPO ₄	DCM	31	37
6	C10	A1	Na ₂ HPO ₄	DCM	31	−40
7	C11	A1	Na ₂ HPO ₄	DCM	0	/
8	C12	A1	Na ₂ HPO ₄	DCM	33	−62
9	C3	A3	Na ₂ HPO ₄	DCM	37	70
10	C3	A5	Na ₂ HPO ₄	DCM	40	67
11	C3	A4	Na ₂ HPO ₄	DCM	23	70
12	C3	(<i>R</i>)-A2	Na ₂ HPO ₄	DCM	54	75
13	C3	(<i>R</i>)-A2	B1	DCM	52	48
14	C3	(<i>R</i>)-A2	B2	DCM	48	45
15	C3	(<i>R</i>)-A2	K ₂ CO ₃	DCM	0	/
16	C3	(<i>R</i>)-A2	Na ₂ HPO ₄	DCE	54	83
17	C3	(<i>R</i>)-A2	Na ₂ HPO ₄	CHCl ₃	43	71
18	C3	(<i>R</i>)-A2	Na ₂ HPO ₄	Tol	14	66
19 ^d	C3	(<i>R</i>)-A2	Na ₂ HPO ₄	DCE	70	87
20 ^d	C3	A2	Na ₂ HPO ₄	DCE	70	89

^aUnless noted otherwise, reactions were performed with alkylquinolinium salt **4a** (0.12 mmol, 1.2 equiv), enone **2a** (0.1 mmol, 1.0 equiv), **C** (20 mol %), **A** (20 mol %), **B** (1.1 equiv) in solvent (1.0 mL) at rt. ^bYield of the isolated product. ^cDetermined by HPLC analysis on a chiral stationary phase. ^dIn 2 ml DCE.

3.3 Complete screening conditions for dearomative cascade reaction with cyclic dienone **7a** and N,4-dialkyl pyridinium salt **6**

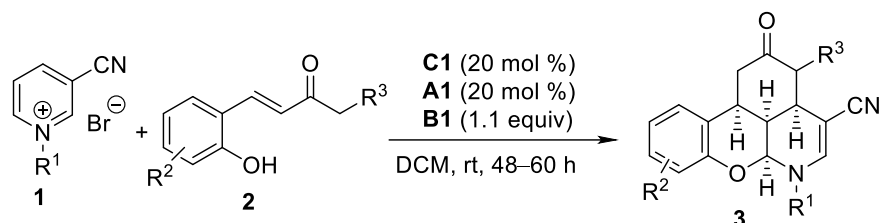


entry ^a	cat	A	B	solvent	yield (%) ^b	ee (%) ^c
1	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	CHCl ₃	38	75
2	C6	(<i>R</i>)- A2	Na ₂ HPO ₄	CHCl ₃	19	66
3	C8	(<i>R</i>)- A2	Na ₂ HPO ₄	CHCl ₃	16	-17
4	C10	(<i>R</i>)- A2	Na ₂ HPO ₄	CHCl ₃	14	-48
5	C12	(<i>R</i>)- A2	Na ₂ HPO ₄	CHCl ₃	0	-
6	C1	A1	B2	CHCl ₃	57	53
7	C1	A4	B2	CHCl ₃	30	52
8	C1	(<i>R</i>)- A2	B2	CHCl ₃	45	70
10	C1	(<i>R</i>)- A7	B2	CHCl ₃	60	63
11	C1	A7	B2	CHCl ₃	38	60
12	C1	AcOH	B2	CHCl ₃	27	67
13	C1	(<i>R</i>)- A2	B1	CHCl ₃	63	15
14	C1	(<i>R</i>)- A2	TEA	CHCl ₃	0	-
15	C1	(<i>R</i>)- A2	DBU	CHCl ₃	0	-
16	C1	(<i>R</i>)- A2	NaHCO ₃	CHCl ₃	33	45
17	C1	(<i>R</i>)- A2	KOAc	CHCl ₃	24	60
18 ^d	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	CHCl ₃	43	70
19 ^d	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	DCM	64	78
20 ^d	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	DCE	58	75
21 ^d	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	THF	60	70
23 ^d	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	Tol	20	76
23 ^d	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	CH ₃ CN	57	71
24 ^{d, e}	C1	(<i>R</i>)- A2	Na ₂ HPO ₄	DCM	75	81

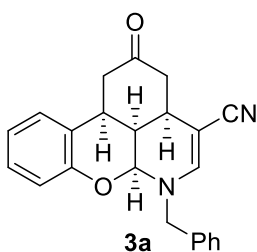
^aUnless noted otherwise, reactions were performed using **7a** (0.05 mmol, 1.0 equiv), **6** (0.06 mmol, 1.2 equiv), **C** (20 mol %), **A** (40 mol %), **B** (2.2 equiv) in solution (0.5 mL) at 25 °C for 48 h. ^bYield of the isolated product; ^cDetermined by HPLC analysis on a chiral stationary phase. ^d**7a** (0.1 mmol, 1.0 equiv), amine **C1** (20 mol %), and **A** (40 mol %) were stirred in solution (1.0 mL) at 25 °C. Followed by **B** (0.12 mmol, 1.2 equiv) and **6** (0.12 mmol, 1.2 equiv) were added uniformly in four portions in the period of 12 hours.

4. General procedure for dearomative cascade reaction with enones **2** and activated azaarene salts

4.1 General procedure for dearomative cascade reaction with enones **2** and activated N-alkyl pyridinium salts **1**



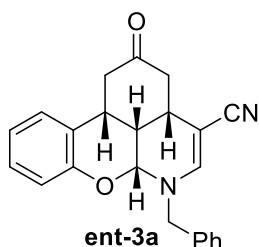
General procedure A: A mixture of activated N-alkyl pyridinium salt **1** (0.11 mmol, 1.1 equiv), enone **2** (0.1 mmol, 1.0 equiv), amine **C1** (20 mol %), acid **A1** (20 mol %) and **B1** (0.11 mmol, 1.1 equiv) was stirred in DCM (1.0 mL) at rt, and the reaction was monitored by TLC. After completion, the product **3** was obtained by flash chromatography on silica gel. The racemic **3** was generally obtained under the catalysis of benzylamine. The enantiomers were obtained with amine **C2**.



Synthesis of 3a: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 48 h. After

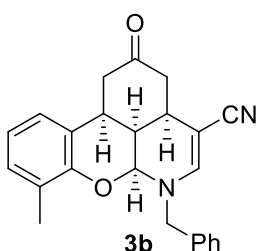
completion, it was purified by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) to give product **3a**: 27.8 mg (0.0781 mmol), as a white solid, 78% yield; mp = 96–97 °C; $[\alpha]_{\text{D}}^{25} = +73.6$ ($c = 0.60$ in CHCl_3); 98% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.45 min, t (major) = 16.70 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.42–7.32 (m, 3H), 7.28–7.25 (m, 2H), 7.12 (m, 2H), 7.98–6.94 (m, 1H), 6.92 (s, 1H), 6.85 (d, $J = 8.2$ Hz, 1H), 4.87 (d, $J = 2.5$ Hz, 1H), δ 4.57 (d, $J = 14.8$ Hz, 1H), 4.43 (d, $J = 14.8$ Hz, 1H), 3.85–3.76 (m, 1H), 2.98 (ddd, $J = 13.7, 8.7, 3.7$ Hz, 1H), 2.93–2.78 (m, 3H), 2.53 (dd, $J = 18.4, 3.7$ Hz, 1H), 2.29 (dd, $J = 18.4, 13.9$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 204.3, 149.8, 141.3, 131.6, 125.0, 124.43, 124.37, 124.3, 124.2, 120.1, 119.0, 116.3, 113.9, 78.2, 77.2, 53.0,

40.9, 37.3, 29.2, 27.7, 24.5; HRMS (ESI-TOF) m/z : $[M + Na]^+$ Calcd for $C_{23}H_{20}N_2O_2Na$ 379.1417; Found 379.1422.



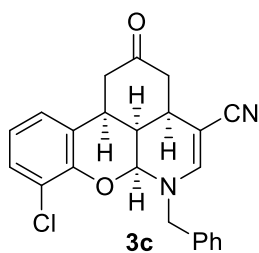
Synthesis of ent-3a: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), and amine **C2** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 48

h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **ent-3a**: 16.2 mg (0.0455 mmol), as a white solid, 46% yield; $[\alpha]_D^{25} = -70.3$ ($c = 0.60$ in $CHCl_3$); 95% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 17.08 min, t (major) = 13.61 min.



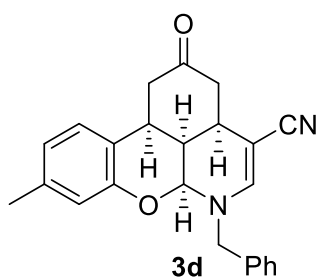
Synthesis of 3b: A mixture of (*E*)-4-(2-hydroxy-3-methylphenyl)but-3-en-2-one **2b** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 48 h. After

completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3b**: 10.0 mg (0.0270 mmol), as a white semi solid, 27% yield; $[\alpha]_D^{25} = +61.8$ ($c = 0.22$ in $CHCl_3$); 91% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 12.48 min, t (major) = 14.14 min; ¹H NMR (400 MHz, $CDCl_3$): δ (ppm) 7.42–7.31 (m, 3H), 7.30–7.26 (m, 2H), 7.02–6.91 (m, 3H), 6.90–6.80 (m, 1H), 4.85 (d, $J = 2.4$ Hz, 1H), 4.59 (d, $J = 14.8$ Hz, 1H), 4.44 (d, $J = 14.8$ Hz, 1H), 3.82 (dt, $J = 9.0, 4.1$ Hz, 1H), 3.04–2.94 (m, 1H), 2.90 (dd, $J = 16.3, 4.7$ Hz, 1H), 2.87–2.83 (m, 1H), 2.79 (dd, $J = 16.3, 3.5$ Hz, 1H), 2.54 (dd, $J = 18.4, 3.8$ Hz, 1H), 2.31 (dd, $J = 18.4, 13.9$ Hz, 1H), 2.16 (s, 3H); ¹³C NMR (150 MHz, $CDCl_3$): δ (ppm) 208.4, 151.9, 145.4, 135.6, 129.4, 129.1, 128.4, 128.1, 127.3, 125.9, 123.8, 122.4, 120.4, 82.5, 81.2, 57.2, 45.1, 41.4, 33.2, 32.0, 28.7, 15.6; HRMS (ESI-TOF) m/z : $[M + Na]^+$ Calcd for $C_{24}H_{22}N_2O_2Na$ 393.1573; Found 393.1574.



Synthesis of 3c: A mixture of (*E*)-4-(3-chloro-2-hydroxyphenyl)but-3-en-2-one **2c** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 60

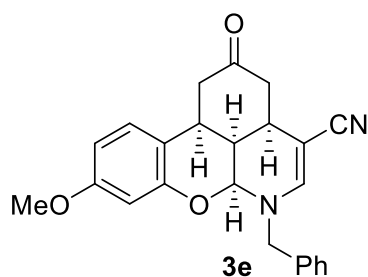
h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3c**: 10.5 mg (0.0228 mmol), as a white solid, 23% yield; mp = 78–80 °C; $[\alpha]_{\text{D}}^{25} = +29.1$ ($c = 0.36$ in CHCl_3); 95% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane: *i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 12.97 min, t (major) = 15.56 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.42–7.28 (m, 5H), 7.22 (dd, $J = 8.0, 1.5$ Hz, 1H), 7.02 (dt, $J = 7.9, 1.3$ Hz, 1H), 6.94 (d, 1H), 6.90 (d, $J = 7.9$ Hz, 1H), 4.85 (d, $J = 2.6$ Hz, 1H), 4.64 (d, $J = 14.6$ Hz, 1H), 4.46 (d, $J = 14.6$ Hz, 1H), 3.88–3.77 (m, 1H), 3.01 (ddd, $J = 13.8, 8.7, 3.8$ Hz, 1H), 2.97–2.83 (m, 2H), 2.79 (dd, $J = 16.2, 3.6$ Hz, 1H), 2.57 (dd, $J = 18.6, 3.7$ Hz, 1H), 2.31 (dd, $J = 18.6, 13.8$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 207.7, 149.6, 145.4, 135.2, 129.1, 128.9, 128.5, 128.4, 126.8, 126.2, 123.3, 123.2, 120.0, 82.8, 81.7, 57.0, 45.0, 41.3, 33.0, 32.2, 28.7; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{37}\text{ClNa}$ 415.0998; Found 415.1038; Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{35}\text{ClNa}$ 413.1027; Found 413.1024.



Synthesis of 3d: A mixture of (*E*)-4-(2-hydroxy-4-methylphenyl)but-3-en-2-one **2d** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL)

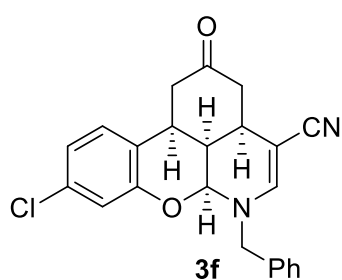
was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3d**: 20.0 mg (0.0541 mmol), as a white solid, yield 54%; mp = 129–130 °C; $[\alpha]_{\text{D}}^{25} = +57.7$ ($c = 0.60$ in CHCl_3); 94% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.67 min, t (major) = 15.23 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.41–7.31 (m, 3H), 7.29–7.26 (m, 2H), 6.98 (d, $J = 8.0$ Hz, 1H), 6.91 (s, 1H), 6.78 (dd, $J = 8.0, 1.8$ Hz, 1H), 6.67 (s, 1H), 4.85 (d, $J = 2.8$ Hz, 1H), 4.57

(d, $J = 14.8$ Hz, 1H), 4.43 (d, $J = 14.8$ Hz, 1H), 3.82–3.72 (m, 1H), 3.02–2.93 (m, 1H), 2.91–2.75 (m, 3H), 2.53 (dd, $J = 18.4, 3.7$ Hz, 1H), 2.28 (dd, $J = 18.4, 14.0$ Hz, 1H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 208.5, 153.6, 145.4, 138.6, 135.6, 129.1, 128.4, 128.20, 128.16, 124.1, 120.9, 120.3, 118.2, 82.2, 81.3, 57.1, 44.9, 41.3, 33.2, 31.5, 28.6, 21.0; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{24}\text{H}_{22}\text{N}_2\text{O}_2\text{Na}$ 393.1573; Found 393.1573.



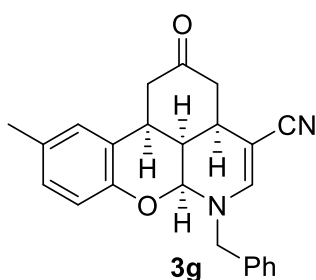
Synthesis of 3e: A mixture of (*E*)-4-(2-hydroxy-4-methoxyphenyl)but-3-en-2-one **2e** (19.2 mg, 0.1 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in

DCM (2.0 mL) was stirred at 4 °C for 8 days. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3e**: 16.6 mg (0.0430 mmol), as a white solid, 43% yield; mp = 133–135 °C; $[\alpha]_{\text{D}}^{25} = +31.1$ ($c = 1.1$ in CHCl_3); 96% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 19.69 min, t (major) = 22.43 min; ^1H NMR (400 MHz, CDCl_3): (ppm) δ 7.43–7.30 (m, 3H), 7.28–7.25 (m, 2H), 6.99 (d, $J = 8.6$ Hz, 1H), 6.91 (s, 1H), 6.55 (dd, $J = 8.6, 2.6$ Hz, 1H), 6.37 (d, $J = 2.6$ Hz, 1H), 4.87 (d, $J = 2.6$ Hz, 1H), 4.57 (d, $J = 14.8$ Hz, 1H), 4.43 (d, $J = 14.8$ Hz, 1H), 3.71–3.80 (m, 1H), 3.75 (s, 3H), 2.97 (ddd, $J = 13.4, 8.8, 3.8$ Hz, 1H), 2.82 (m, 2.71–2.92, 3H), 2.53 (dd, $J = 18.4, 3.8$ Hz, 1H), 2.26 (dd, $J = 18.4, 14.0$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 208.5, 159.5, 154.6, 145.3, 135.6, 129.1, 128.4, 128.2, 120.3, 115.9, 110.2, 102.4, 82.3, 81.4, 57.1, 55.4, 44.9, 41.3, 33.1, 31.3, 28.5; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{24}\text{H}_{22}\text{N}_2\text{O}_3\text{Na}$ 409.1523; Found 409.1526.



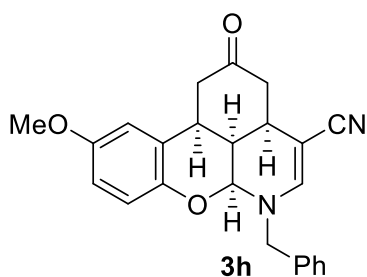
Synthesis of 3f: A mixture of (*E*)-4-(4-chloro-2-hydroxyphenyl)but-3-en-2-one **2f** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM

(1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:5) gave product **3f**: 27.0 mg (0.0692 mmol), as a white solid, yield 69%; mp = 156–157 °C; $[\alpha]_{\text{D}}^{25} = +49.5$ ($c = 1.60$ in CHCl_3); 96% ee, determined by HPLC analysis [Daicel Chiralpak AD-H, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 6.50 min, t (major) = 7.71 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.49–7.32 (m, 3H), 7.32–7.21 (m, 2H), 7.07–6.98 (m, 1H), 6.94 (dd, $J = 8.3, 2.2$ Hz, 1H), 6.91 (d, $J = 1.1$ Hz, 1H), 6.87 (d, $J = 2.2$ Hz, 1H), 4.86 (d, $J = 2.6$ Hz, 1H), 4.56 (d, $J = 14.8$ Hz, 1H), 4.43 (d, $J = 14.8$ Hz, 1H), 3.72–3.84 (m, 1H), 3.05–2.93 (m, 1H), 2.93–2.70 (m, 3H), 2.54 (dd, $J = 18.5, 3.8$ Hz, 1H), 2.22 (dd, $J = 18.5, 14.0$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 207.7, 154.5, 145.2, 135.4, 133.5, 129.5, 129.1, 128.5, 128.2, 123.4, 122.7, 120.1, 118.2, 82.5, 81.6, 57.1, 44.8, 41.2, 33.0, 31.6, 28.5; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{37}\text{ClNa}$ 415.0998; Found 415.1009; Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{35}\text{ClNa}$ 413.1027; Found 413.1027.



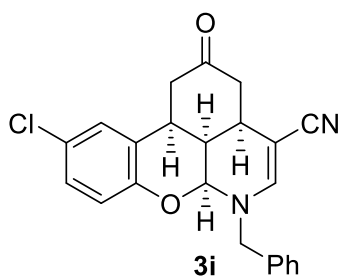
Synthesis of 3g: A mixture of (*E*)-4-(2-hydroxy-5-methylphenyl)but-3-en-2-one **2g** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL)

was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3g**: 31.4 mg (0.0849 mmol), as a white solid, 85% yield; mp = 155–156 °C; $[\alpha]_{\text{D}}^{25} = +95.6$ ($c = 0.55$ in CHCl_3); 95% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.40 min, t (major) = 16.05 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.40–7.31 (m, 3H), 7.29–7.26 (m, 2H), 6.96–6.87 (m, 3H), 6.74 (d, $J = 8.2$ Hz, 1H), 4.83 (d, $J = 2.6$ Hz, 1H), 4.56 (d, $J = 14.8$ Hz, 1H), 4.42 (d, $J = 14.8$ Hz, 1H), 3.72–3.80 (m, 1H), 2.97 (ddd, $J = 13.9, 8.7, 3.7$ Hz, 1H), 2.92–2.75 (m, 3H), 2.53 (dd, $J = 18.4, 3.7$ Hz, 1H), 2.31 (dd, $J = 18.4, 13.9$ Hz, 1H), 2.23 (s, 3H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.6, 151.6, 145.4, 135.6, 132.4, 129.14, 129.06, 128.6, 128.4, 128.2, 123.8, 120.4, 117.7, 82.2, 81.2, 57.1, 44.9, 41.4, 33.2, 31.8, 28.6, 20.8; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{24}\text{H}_{22}\text{N}_2\text{O}_2\text{Na}$ 393.1573; Found 393.1571.



Synthesis of 3h: A mixture of (*E*)-4-(2-hydroxy-5-methoxyphenyl)but-3-en-2-one **2h** (19.2 mg, 0.999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in

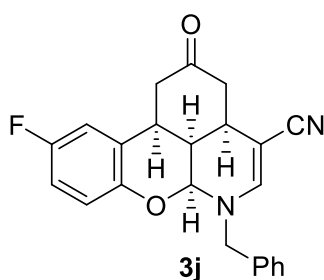
DCM (2.0 mL) was stirred at 4 °C for 7 days. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3h**: 25.0 mg (0.0648 mmol), as a white solid, 65% yield; mp = 142–143 °C; $[\alpha]_D^{25} = +71.2$ ($c = 1.7$ in CHCl_3); 96% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane: *i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: *t* (minor) = 18.76 min, *t* (major) = 21.40 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.32–7.41 (m, $J = 3$ H), 7.31–7.23 (m, 2H), 6.91 (s, 1H), 6.78 (d, $J = 8.9$ Hz, 1H), 6.69 (dd, $J = 8.9, 2.9$ Hz, 1H), 6.60 (d, $J = 2.9$ Hz, 1H), 4.81 (d, $J = 2.6$ Hz, 1H), 4.56 (d, $J = 14.8$ Hz, 1H), 4.42 (d, $J = 14.8$ Hz, 1H), 3.74–3.82 (m, 1H), 3.72 (s, 3H), 2.97 (ddd, $J = 12.5, 8.7, 3.8$ Hz, 1H), 2.92–2.70 (m, 3H), 2.55 (dd, $J = 18.4, 3.8$ Hz, 1H), 2.34 (dd, $J = 18.4, 13.9$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.3, 155.2, 147.6, 145.3, 135.6, 129.1, 128.4, 128.2, 125.0, 120.3, 118.8, 114.6, 112.8, 82.4, 81.2, 57.1, 55.7, 44.9, 41.4, 33.2, 32.2, 28.7; HRMS (ESI-TOF) *m/z*: $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{24}\text{H}_{23}\text{N}_2\text{O}_3$ 387.1703; Found 387.1702.



Synthesis of 3i: A mixture of (*E*)-4-(5-chloro-2-hydroxyphenyl)but-3-en-2-one **1i** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **2a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in

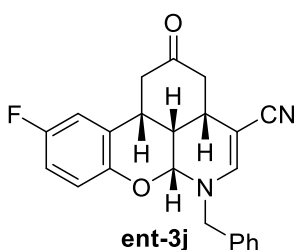
DCM (1.0 mL) was stirred at 4 °C for 60 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3i**: 25.1 mg (0.0643 mmol), as a white solid, 64% yield; mp = 105–106 °C; $[\alpha]_D^{25} = +102.6$ ($c = 1.20$ in CHCl_3); 97% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: *t* (minor) = 16.44 min, *t* (major) = 19.49 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.43–7.30 (m, 3H), 7.27 (d, $J = 1.9$ Hz, 1H), 7.25 (d, $J = 1.6$ Hz, 1H), 7.12–7.04 (m, 2H), 6.92 (d, $J = 1.2$ Hz, 1H), 6.79 (d, $J = 9.4$ Hz, 1H), 4.84 (d, $J = 2.6$ Hz, 1H), 4.56 (d, $J = 14.8$ Hz, 1H), 4.43 (d, $J = 14.8$ Hz, 1H), 3.74–3.84 (m, 1H),

3.04–2.94 (m, 1H), 2.94–2.72 (m, 3H), 2.56 (dd, $J = 18.4, 3.6$ Hz, 1H), 2.26 (dd, $J = 18.4, 14.0$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 207.8, 152.5, 145.3, 135.4, 129.1, 128.6, 128.5, 128.2, 127.9, 125.9, 120.1, 119.4, 82.5, 81.4, 57.1, 44.8, 41.3, 32.9, 31.9, 28.5; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{37}\text{ClNa}$ 415.0998; Found 415.1029; Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{35}\text{ClNa}$ 413.1027; Found 413.1029.



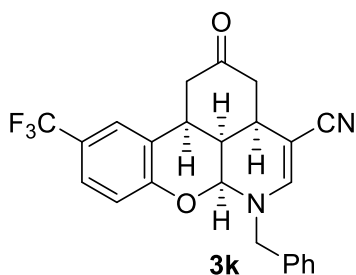
Synthesis of 3j: A mixture of (*E*)-4-(5-fluoro-2-hydroxyphenyl)but-3-en-2-one **1j** (18.0 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **2a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL)

was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3j**: 27.0 mg (0.0722 mmol), as a white solid, 72% yield; mp = 160–161 °C; $[\alpha]_{\text{D}}^{25} = +56.9$ ($c = 0.90$ in CHCl_3); 97% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.12 min, t (major) = 16.05 min; ^1H NMR (400 MHz, CDCl_3): δ (ppm) 7.30–7.43 (m, 3H), 7.31–7.22 (m, 2H), 6.92 (s, 1H), 6.86–6.73 (m, 3H), 4.84 (d, $J = 2.6$ Hz, 1H), 4.56 (d, $J = 14.8$ Hz, 1H), 4.43 (d, $J = 14.8$ Hz, 1H), 3.75–3.82 (m, 1H), 3.03–2.95 (m, 1H), 2.91 (dd, $J = 16.3, 4.7$ Hz, 1H), 2.83 (td, $J = 9.1, 2.6$ Hz, 1H), 2.75 (dd, $J = 16.3, 3.5$ Hz, 1H), 2.56 (dd, $J = 18.4, 3.7$ Hz, 1H), 2.29 (dd, $J = 18.4, 13.9$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 207.7, 158.2 (d, $J = 241.9$ Hz), 149.8 (d, $J = 2.2$ Hz), 145.2, 135.5, 129.1, 128.5, 128.2, 125.6 (d, $J = 7.1$ Hz), 120.1, 119.3 (d, $J = 8.3$ Hz), 115.6 (d, $J = 23.4$ Hz), 114.48 (d, $J = 23.4$ Hz), 82.5, 81.3, 57.1, 44.8, 41.3, 32.9, 32.2, 28.6; ^{19}F NMR (376 MHz, CDCl_3): δ (ppm) –119.45; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2\text{FNa}$ 397.1323; Found 397.1327.



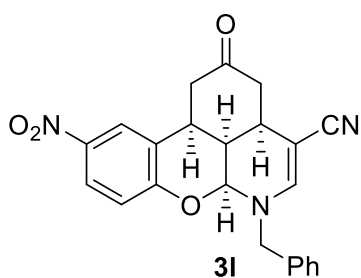
Synthesis of ent-3j: A mixture of (*E*)-4-(5-fluoro-2-hydroxyphenyl)but-3-en-2-one **1j** (18.0 mg, 0.1 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C2** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for

48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **ent-3j**: 21.5 mg (0.0574 mmol), as a white solid, 57% yield; $[\alpha]_D^{25} = -53.3$ ($c = 0.63$ in CHCl_3); 96% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 15.22 min, t (major) = 12.36 min.



Synthesis of 3k: A mixture of (*E*)-4-(2-hydroxy-5-(trifluoromethyl)phenyl)but-3-en-2-one **2k** (23.0 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv, amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in

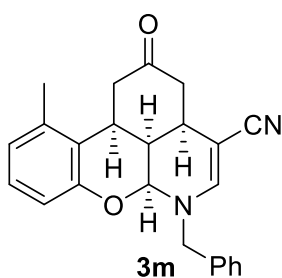
DCM (1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3k**: 34.4 mg (0.0811 mmol), as a white solid, 81% yield; mp = 220 °C; $[\alpha]_D^{25} = +96.2$ ($c = 1.1$ in CHCl_3); 97% ee, determined by HPLC analysis [Daicel Chiralpak IF, n -hexane/ i -PrOH = 80:20, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 18.92 min, t (major) = 20.51 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.23–7.36 (m, 5H), 7.22–7.14 (m, 2H), 6.89–6.81 (m, 2H), 4.82 (d, $J = 2.6$ Hz, 1H), 4.49 (d, $J = 14.8$ Hz, 1H), 4.36 (d, $J = 14.8$ Hz, 1H), 3.72–3.80 (m, $J = 8.8, 4.1$ Hz, 1H), 3.00–2.86 (m, 1H), 2.89–2.68 (m, 3H), 2.47 (dd, $J = 18.4, 3.7$ Hz, 1H), 2.13 (dd, $J = 18.4, 13.9$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 207.3, 156.6, 145.2, 135.3, 129.1, 128.6, 128.2, 125.9 (q, $J = 3.8$ Hz), 125.6 (q, $J = 3.5$ Hz), 125.3 (q, $J = 32.5$ Hz), 124.8, 123.8 (q, $J = 270$ Hz), 120.0, 118.6, 82.6, 81.6, 57.2, 44.7, 41.3, 32.9, 31.8, 28.5; ¹⁹F NMR (376 MHz, CDCl_3): δ (ppm) –61.76; HRMS (ESI-TOF) m/z : $[M + H]^+$ Calcd for $\text{C}_{24}\text{H}_{20}\text{N}_2\text{O}_2\text{F}_3$ 447.1291; Found 447.1287.



Synthesis of 3l: A mixture of (*E*)-4-(2-hydroxy-5-nitrophenyl)but-3-en-2-one **2l** (20.7 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in

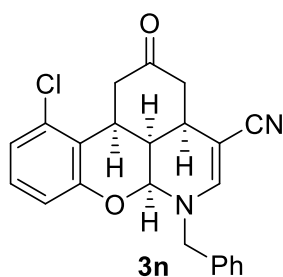
DCM (2.0 mL) was stirred at rt for 24 h. After completion, purification by flash chromatography on

silica gel (EtOAc/petroleum ether = 1:4) gave product **3l**: 24.3 mg (0.0606 mmol), as a white semisolid, 61% yield; $[\alpha]_{\text{D}}^{25} = +265.0$ ($c = 0.56$ in CHCl_3); 96% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 35.32 min, t (major) = 30.06 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.99 (d, $J = 2.6$ Hz, 1H), 7.94 (dd, $J = 9.0, 2.6$ Hz, 1H), 7.36–7.25 (m, 3H), 7.24–7.17 (m, 2H), 6.90–6.85 (m, 2H), 4.88 (d, $J = 2.6$ Hz, 1H), 4.51 (d, $J = 14.8$ Hz, 1H), 4.39 (d, $J = 14.8$ Hz, 1H), 3.90–3.76 (m, 1H), 3.01–2.92 (m, 1H), 2.94–2.75 (m, 3H), 2.51 (dd, $J = 18.6, 3.8$ Hz, 1H), 2.07 (dd, $J = 18.6, 13.9$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 206.8, 159.2, 145.0, 143.0, 135.1, 129.2, 128.7, 128.2, 125.1, 124.8, 124.3, 119.7, 118.8, 83.0, 82.0, 57.3, 44.7, 41.1, 32.6, 31.9, 28.3; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{20}\text{N}_3\text{O}_4$ 402.1448; Found 402.1448.

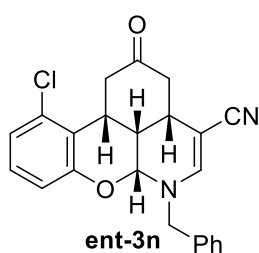


Synthesis of 3m: A mixture of (*E*)-4-(2-hydroxy-6-methylphenyl)but-3-en-2-one **2m** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for

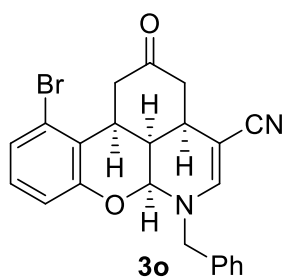
24 h. After completion, purification by flash chromatography on silica gel (EtOAc/ petroleum ether = 1:4) gave product **3m**: 28.9 mg (0.0781 mmol), as a white solid, 78% yield; mp = 189–190 °C; $[\alpha]_{\text{D}}^{25} = +101.3$ ($c = 0.60$ in CHCl_3); 96% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.46 min, t (major) = 20.21 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.29–7.39 (m, 3H), 7.20–7.25 (m, 2H), 7.02 (t, $J = 7.8$ Hz, 1H), 6.93 (s, 1H), 6.81 (d, $J = 7.5$ Hz, 1H), 6.70 (d, $J = 8.1$ Hz, 1H), 4.74 (d, $J = 2.9$ Hz, 1H), 4.54 (d, $J = 15.0$ Hz, 1H), 4.42 (d, $J = 15.0$ Hz, 1H), 3.93 (ddd, $J = 10.2, 5.7, 2.8$ Hz, 1H), 3.03 (dt, $J = 10.7, 7.6$ Hz, 1H), 2.91 (ddd, $J = 10.5, 7.8, 2.8$ Hz, 1H), 2.85 (dd, $J = 15.8, 5.7$ Hz, 1H), 2.70 (dd, $J = 15.8, 2.9$ Hz, 1H), 2.66–2.54 (m, 2H), 2.27 (s, 3H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.9, 154.9, 145.0, 137.0, 135.7, 129.1, 128.4, 128.1, 127.8, 125.6, 124.2, 120.6, 115.9, 83.7, 80.9, 57.1, 42.9, 41.4, 34.1, 31.2, 29.4, 19.3; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{24}\text{H}_{23}\text{N}_2\text{O}_2$ 371.1754; Found 371.1759.



Synthesis of 3n: A mixture of (*E*)-4-(6-chloro-2-hydroxyphenyl)but-3-en-2-one **2n** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3n**: 35.1 mg (0.090 mmol), as a white solid, 90% yield; mp = 148–149 °C; $[\alpha]_{\text{D}}^{25} = +109.9$ ($c = 1.7$ in CHCl_3); 95% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.24 min, t (major) = 16.17 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.41–7.29 (m, 3H), 7.26–7.20 (m, 2H), 7.10–6.99 (m, 2H), 6.93 (s, 1H), 6.78 (dd, $J = 7.9, 1.6$ Hz, 1H), 4.75 (dd, $J = 2.7, 1.4$ Hz, 1H), 4.54 (d, $J = 15.0$ Hz, 1H), 4.42 (d, $J = 15.0$ Hz, 1H), 4.03 (ddd, $J = 10.5, 5.8, 2.8$ Hz, 1H), 3.12 (dd, $J = 16.2, 2.8$ Hz, 1H), 3.09–2.98 (m, 1H), 2.92 (ddd, $J = 10.5, 7.8, 2.8$ Hz, 1H), 2.84 (dd, $J = 16.2, 5.8$ Hz, 1H), 2.66–2.45 (m, 2H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.6, 155.8, 144.8, 135.4, 133.9, 129.1, 128.7, 128.5, 128.1, 124.7, 124.0, 120.3, 117.0, 84.2, 81.2, 57.2, 42.2, 41.4, 33.7, 31.8, 29.3; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{37}\text{ClNa}$ 415.0998; Found 415.1035; Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{35}\text{ClNa}$ 413.1027; Found 413.1024.

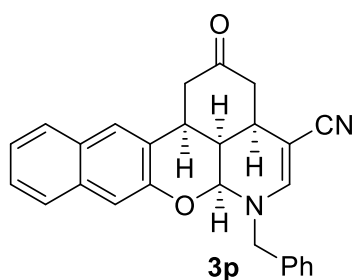


Synthesis of ent-3n: A mixture of (*E*)-4-(6-chloro-2-hydroxyphenyl)but-3-en-2-one **2n** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C2** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **ent-3n**: 32.5 mg (0.0833 mmol), as a white solid, 83% yield; $[\alpha]_{\text{D}}^{25} = -137.0$ ($c = 0.79$ in CHCl_3); 94% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane: *i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 16.43 min, t (major) = 13.25 min.



Synthesis of 3o: A mixture of (*E*)-4-(6-bromo-2-hydroxyphenyl)but-3-en-2-one **2o** (24.0 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for

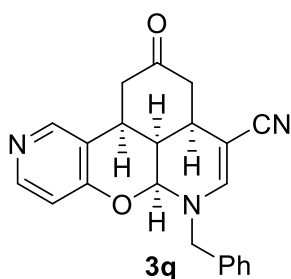
36 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3o**: 35.1 mg (0.0808 mmol), as a white solid, 81% yield; mp = 126–127 °C; $[\alpha]_{\text{D}}^{25} = +142.3$ ($c = 1.60$ in CHCl_3); 95% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 14.79 min, t (major) = 18.29 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.44–7.30 (m, 3H), 7.28–7.16 (m, 3H), 6.99 (t, $J = 8.1$ Hz, 1H), 6.93 (s, 1H), 6.81 (dd, $J = 8.2, 1.2$ Hz, 1H), 4.74 (s, 1H), 4.54 (d, $J = 15.0$ Hz, 1H), 4.42 (d, $J = 15.0$ Hz, 1H), 4.00 (ddd, $J = 10.5, 6.0, 2.8$ Hz, 1H), 3.15 (dd, $J = 16.0, 2.8$ Hz, 1H), 3.09–2.99 (m, 1H), 2.92 (ddd, $J = 10.7, 7.8, 2.9$ Hz, 1H), 2.83 (dd, $J = 16.0, 6.0$ Hz, 1H), 2.65–2.50 (m, 2H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.5, 155.8, 144.7, 135.4, 129.12, 129.10, 128.5, 128.1, 125.6, 123.9, 120.3, 117.7, 84.4, 81.2, 57.2, 42.6, 41.5, 33.9, 33.8, 29.4; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{79}\text{BrNa}$ 457.0522; Found 457.0528; Calcd for $\text{C}_{23}\text{H}_{19}\text{N}_2\text{O}_2^{81}\text{BrNa}$ 459.0502; Found 459.0504.



Synthesis of 3p: A mixture of (*E*)-4-(3-hydroxynaphthalen-2-yl)but-3-en-2-one **2p** (21.2 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), and amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in

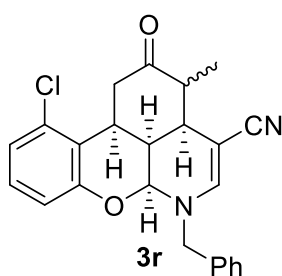
DCM (1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3p**: 21.4 mg (0.0527 mmol), as a white solid, 53% yield; mp = 213–214 °C; $[\alpha]_{\text{D}}^{25} = +273.0$ ($c = 0.37$ in CHCl_3); 96% ee, determined by HPLC analysis [Daicel Chiralpak AD-H, *n*-hexane/*i*-PrOH = 80:20, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 22.99 min, t (major) = 31.23 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.68 (dd, $J = 8.2, 3.9$ Hz, 2H), 7.61 (s, 1H), 7.44–7.31 (m, 5H), 7.30 (d, $J = 1.8$ Hz, 2H), 7.25 (s, 1H), 6.95 (s, 1H), 4.94 (d, J

= 2.6 Hz, 1H), 4.61 (d, J = 14.8 Hz, 1H), 4.46 (d, J = 14.8 Hz, 1H), 3.94–4.05 (m, 1H), 2.99–3.06 (m, 1H), 2.98 (d, J = 4.1 Hz, 2H), 2.90 (td, J = 9.1, 2.7 Hz, 1H), 2.56 (dd, J = 18.3, 3.8 Hz, 1H), 2.34 (dd, J = 18.3, 13.8 Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 208.1, 152.0, 145.4, 135.5, 133.3, 129.9, 129.1, 128.5, 128.3, 128.2, 127.6, 126.6, 126.5, 125.3, 124.7, 120.2, 113.4, 82.4, 81.6, 57.1, 45.6, 41.4, 33.0, 32.1, 28.7; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{27}\text{H}_{22}\text{N}_2\text{O}_2\text{Na}$ 429.1573; Found 429.1573.



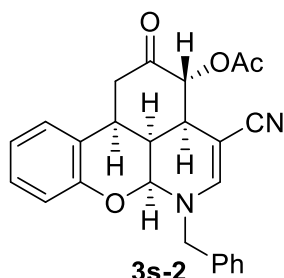
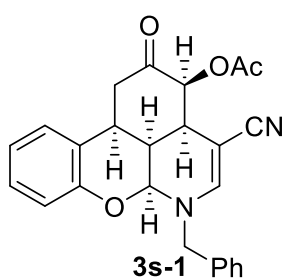
Synthesis of 3q: A mixture of (*E*)-4-(4-hydroxypyridin-3-yl)but-3-en-2-one **2q** (16.3 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at 4 °C for 60 h.

After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 2:1) gave product **3q**: 22.1 mg (0.0619 mmol), as a white solid, 62% yield; mp = 135–137 °C; $[\alpha]_{\text{D}}^{25} = +63.1$ (c = 0.70 in CHCl_3); 98% ee (the peaks of two enantiomers were assigned by using a mixture of **3q** and its enantiomer obtained with amine **C2**), determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 70:30, 1.0 mL min $^{-1}$, λ = 254 nm]: t (major) = 46.27 min, t (minor) = 52.73 min; ^1H NMR (400 MHz, CDCl_3): δ (ppm) 8.36 (s, 1H), 8.29 (d, J = 5.6 Hz, 1H), 7.43–7.34 (m, 3H), 7.27 (dd, J = 7.9, 1.8 Hz, 2H), 6.92 (t, J = 1.2 Hz, 1H), 6.77 (d, J = 5.6 Hz, 1H), 4.92 (d, J = 2.7 Hz, 1H), 4.56 (d, J = 14.8 Hz, 1H), 4.45 (d, J = 14.8 Hz, 1H), 3.82–3.1 (m, 1H), 3.06–2.97 (m, 1H), 2.97–2.81 (m, 3H), 2.58 (dd, J = 18.4, 3.7 Hz, 1H), 2.14 (dd, J = 18.4, 13.8 Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 206.9, 160.6, 150.7, 149.5, 145.1, 135.1, 129.2, 128.6, 128.2, 120.6, 119.7, 112.7, 82.5, 82.0, 57.2, 44.4, 41.1, 32.8, 29.6, 28.3; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{20}\text{N}_3\text{O}_2$ 358.1550; Found 358.1549.



Synthesis of 3r: A mixture of (*E*)-1-(2-chloro-6-hydroxyphenyl)pent-1-en-3-one **2r** (21.0 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for

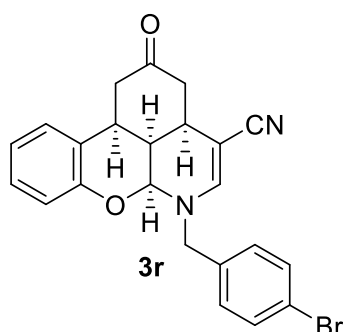
4 days. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3r** as inseparable diastereomers: 20.6 mg (0.0510mmol), as a white solid, 51% yield; mp = 141–142 °C; $[\alpha]_D^{25} = +131.2$ ($c = 0.59$ in CHCl_3); 3.6:1 dr; 97% ee, 96% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane: *i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t_1 (minor) = 8.76 min, t_1 (major) = 10.22 min, t_2 (minor) = 11.73 min, t_2 (major) = 12.17 min; for major diastereomer: ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.40–7.32 (m, 3H), 7.25–7.19 (m, 2H), 7.07–7.02 (m, 2H), 6.98 (s, 1H), 6.77 (dd, $J = 7.6, 1.9$ Hz, 1H), 4.72 (dd, $J = 3.3, 1.5$ Hz, 1H), 4.56 (d, $J = 15.1$ Hz, 1H), 4.45 (d, $J = 15.1$ Hz, 1H), 4.04 (ddd, $J = 10.9, 6.2, 2.5$ Hz, 1H), 2.99 (dd, $J = 15.8, 2.6$ Hz, 1H), 2.95–2.83 (m, 1H), 2.79–2.69 (m, 2H), 1.30 (d, $J = 6.6$ Hz, 3H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 210.5, 154.7, 144.4, 134.3, 132.8, 128.1, 127.51, 127.50, 127.0, 123.8, 123.7, 121.1, 115.8, 83.5, 77.9, 55.9, 45.2, 40.2, 34.2, 33.4, 29.8, 13.4; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{24}\text{H}_{22}\text{N}_2\text{O}_2^{37}\text{Cl}$ 407.1335; Found 407.1337; Calcd for $\text{C}_{24}\text{H}_{22}\text{N}_2\text{O}_2^{35}\text{Cl}$ 405.1364, Found 405.1369.



Synthesis of 3s: A mixture of (*E*)-4-(6-hydroxyphenyl)-2-oxobut-3-en-1-yl acetate **2s** (22.0 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (30.2 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20

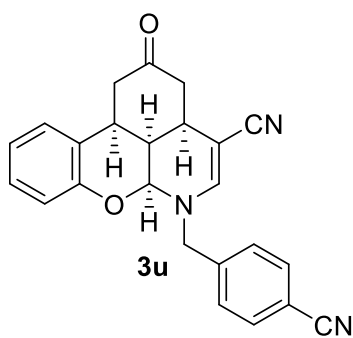
mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 60 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3s** (as a mixture of diastereomers, only **3s-1** can be partially isolated): 26.5 mg (0.0640 mmol), as a white solid, 64% yield; mp (**3s-1**) = 113–115 °C; $[\alpha]_D^{25}$ (**3s-1**) = -74.0 ($c = 0.47$ in CHCl_3); 1:1 dr; **3s-1**: 91% ee, determined by HPLC analysis

[Daicel Chiralpak IB-H, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: t (minor) = 35.83 min, t (major) = 38.50 min; **3s-2**: 94% ee, determined by HPLC analysis [Daicel Chiralpak IB-H, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: t (minor) = 30.94 min, t (major) = 43.39 min; ¹H NMR (400 MHz, CDCl₃, **3s-1**): δ (ppm) 7.33 (dd, *J* = 5.0, 1.9 Hz, 3H), 7.25–7.15 (m, 1H), 7.14–7.05 (m, 3H), 7.01 (d, *J* = 8.1 Hz, 1H), 6.97 (s, 1H), 5.74 (d, *J* = 3.7 Hz, 1H), 5.03 (d, *J* = 3.7 Hz, 1H), 4.21 (d, *J* = 14.5 Hz, 1H), 4.11 (d, *J* = 14.5 Hz, 1H), 3.62 (ddd, *J* = 13.7, 9.2, 4.7 Hz, 1H), 3.45 (dd, *J* = 8.2, 3.7 Hz, 1H), 3.24 (ddd, *J* = 8.7, 3.7, 9.2 Hz, 1H), 2.97 (dd, *J* = 18.9, 4.7 Hz, 1H), 2.61 (dd, *J* = 18.9, 13.7 Hz, 1H), 2.23 (s, 3H); ¹³C NMR (100 MHz, CDCl₃, **3s-1**): δ (ppm) 201.3, 170.2, 150.7, 149.3, 134.7, 129.1, 128.74, 128.71, 128.5, 128.4, 123.3, 122.3, 119.2, 117.6, 80.6, 78.6, 76.0, 53.9, 43.0, 35.2, 34.2, 27.2, 20.7; HRMS (ESI-TOF) *m/z*: [M + Na]⁺ Calcd for C₂₅H₂₂N₂O₄Na 437.1472; Found 437.1478.



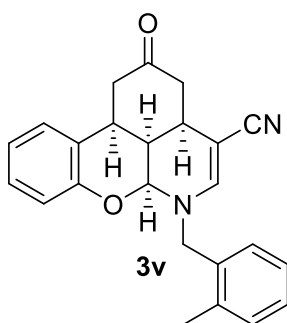
Synthesis of 3t: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-(4-bromobenzyl) 3-cyanopyridin-1-ium bromide **1b** (38.6 mg, 0.109 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 48 h. After completion, purification

by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3t**: 37.3 mg (0.0859 mmol), as a white solid, 86% yield; mp = 211–212 °C; $[\alpha]_D^{25}$ = +63.8 (*c* = 0.93 in CHCl₃); 96% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: t (minor) = 14.99 min, t (major) = 18.40 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 7.51 (d, *J* = 8.4 Hz, 2H), 7.14 (dd, *J* = 19.6, 8.3 Hz, 4H), 6.97 (dd, *J* = 8.0, 6.5 Hz, 1H), 6.89 (s, 1H), 6.83 (d, *J* = 8.0 Hz, 1H), 4.83 (d, *J* = 2.6 Hz, 1H), 4.53 (d, *J* = 15.0 Hz, 1H), 4.37 (d, *J* = 15.0 Hz, 1H), 3.76–3.85 (m, 1H), 3.04–2.93 (m, 1H), 2.75–2.95 (m, 3H), 2.54 (dd, *J* = 18.4, 3.8 Hz, 1H), 2.28 (dd, *J* = 18.4, 13.9 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 208.1, 153.7, 145.1, 134.6, 132.2, 129.9, 128.5, 128.4, 124.1, 123.2, 122.5, 120.0, 117.9, 82.1, 82.0, 56.5, 44.9, 41.3, 33.3, 31.8, 28.6; HRMS (ESI-TOF) *m/z*: [M + Na]⁺ Calcd for C₂₃H₁₉N₂O₂⁷⁹BrNa 457.0522; Found 457.0524, Calcd for C₂₃H₁₉N₂O₂⁸¹BrNa 459.0502; Found 459.0503.



Synthesis of 3u: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-(4-cyanobenzyl) 3-cyano-pyridin-1-ium bromide **1c** (33.0 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL)

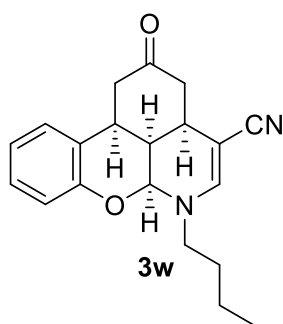
was stirred at rt for 60 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3u**: 28.1 mg (0.0738 mmol), as a white solid, 74% yield; mp = 117–118 °C; $[\alpha]_{\text{D}}^{25} = +68.0$ ($c = 0.96$ in CHCl_3); 97% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 28.86 min, t (major) = 33.63 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.68 (d, $J = 8.3$ Hz, 2H), 7.42 (d, $J = 8.0$ Hz, 2H), 7.12 (d, $J = 7.3$ Hz, 2H), 7.06–6.94 (m, 1H), 6.89 (s, 1H), 6.80 (dd, $J = 8.5, 1.4$ Hz, 1H), 4.84 (d, $J = 2.6$ Hz, 1H), 4.66 (d, $J = 15.7$ Hz, 1H), 4.48 (d, $J = 15.7$ Hz, 1H), 3.94–3.62 (m, 1H), 2.96–3.10 (m, 1H), 2.95–2.78 (m, 3H), 2.54 (dd, $J = 18.3, 3.7$ Hz, 1H), 2.28 (dd, $J = 18.3, 13.8$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.0, 153.5, 145.0, 141.3, 132.8, 128.7, 128.53, 128.50, 124.0, 123.3, 119.8, 118.3, 117.9, 112.4, 82.8, 82.4, 56.6, 44.8, 41.2, 33.3, 31.8, 28.5; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{24}\text{H}_{19}\text{N}_3\text{O}_2\text{Na}$ 404.1375; Found 404.1371.



Synthesis of 3v: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-(2-methylbenzyl) 3-cyano-pyridin-1-ium bromide **1d** (31.7 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 60 h. After completion, purification by flash chromatography on silica

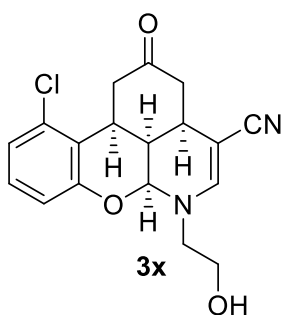
gel (EtOAc/petroleum ether = 1:4) gave product **3v**: 26.0 mg (0.0703 mmol), as a white solid, 70% yield; mp = 114–115 °C; $[\alpha]_{\text{D}}^{25} = +85.2$ ($c = 0.65$ in CHCl_3); 95% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.00 min, t (major) = 15.71 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.23–7.26 (m, 1H), 7.22–7.17 (m, 3H),

7.16–7.08 (m, 2H), 6.97 (td, $J = 7.5$, 1.3 Hz, 1H), 6.88–6.83 (m, 1H), 6.87 (s, 1H), 4.82 (d, $J = 2.6$ Hz, 1H), 4.58 (d, $J = 14.3$ Hz, 1H), 4.42 (d, $J = 14.3$ Hz, 1H), 3.76–3.86 (m, 1H), 2.90–3.00 (m, 1H), 2.92–2.78 (m, 3H), 2.54 (dd, $J = 18.4$, 3.8 Hz, 1H), 2.32 (s, 1H), 2.29 (dd, $J = 18.4$, 14 Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 208.4, 153.9, 145.1, 137.1, 133.0, 131.1, 129.6, 128.7, 128.5, 128.4, 126.5, 124.2, 123.1, 120.4, 117.9, 82.0, 81.3, 55.0, 44.9, 41.4, 33.2, 31.9, 28.7, 19.2; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{24}\text{H}_{22}\text{N}_2\text{O}_2\text{Na}$ 393.1579; Found 393.1574.



Synthesis of 3w: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-butyl 3-cyanopyridin-1-ium bromide **1e** (26.5 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel

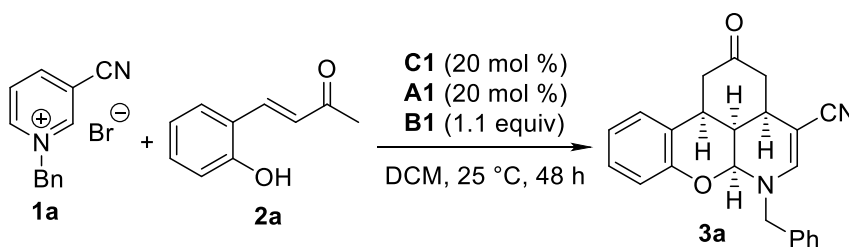
(EtOAc/petroleum ether = 1:4) gave product **3w**: 27.3 mg (0.0848 mmol), as a white solid, 85% yield; mp = 154 °C; $[\alpha]_{\text{D}}^{25} = +85.2$ ($c = 0.65$ in CHCl_3); 97% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 10.98 min, t (major) = 14.36 min; ^1H NMR (400 MHz, CDCl_3): δ (ppm) 7.13 (t, $J = 7.5$ Hz, 2H), 6.98 (td, $J = 7.5$, 1.3 Hz, 1H), 6.85 (s, 1H), 6.83 (d, $J = 7.8$ Hz, 1H), 4.94 (d, $J = 2.6$ Hz, 1H), 3.92–3.84 (m, 1H), 3.39 (dt, $J = 14.3$, 7.3 Hz, 1H), 3.24 (dt, $J = 14.3$, 7.3 Hz, 1H), 3.01–2.78 (m, 4H), 2.53 (dd, $J = 18.4$, 3.8 Hz, 1H), 2.29 (dd, $J = 18.4$, 14.0 Hz, 1H), 1.56–1.68 (m, 2H), 1.43–1.31 (m, 2H), 0.96 (t, $J = 7.3$ Hz, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 208.5, 154.0, 145.3, 128.5, 128.4, 124.2, 123.1, 120.6, 118.1, 83.2, 79.8, 53.9, 45.1, 41.3, 33.4, 32.0, 31.5, 28.5, 19.8, 13.8; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{24}\text{H}_{22}\text{N}_2\text{O}_2\text{Na}$ 345.1573; Found 345.1576.



Synthesis of 3x: A mixture of (*E*)-4-(6-chloro-2-hydroxyphenyl)but-3-en-2-one **2n** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-(2-hydroxyethyl) 3-cyanopyridin-1-ium bromide **1f** (25.1 mg, 0.110 mmol, 1.1 equiv), amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive **A1** (2.8 mg, 0.020 mol, 20 mol %) and **B1** (19.7 mg, 0.112 mmol, 1.1 equiv) in DCM (1.0 mL) was stirred at rt for 4 days. After completion, purification by flash chromatography on silica

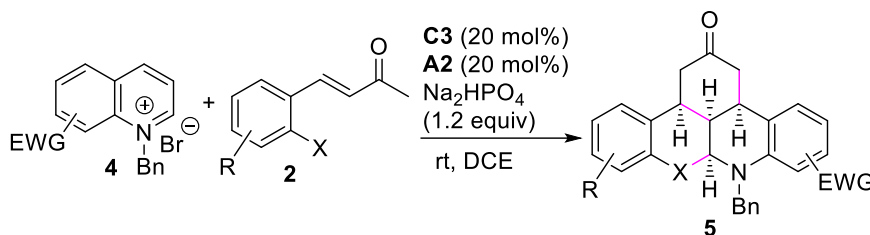
gel (EtOAc/petroleum ether = 1:1) gave product **3x**: 30.6 mg (0.0889 mmol), as a white semisolid, 89% yield; $[\alpha]_D^{25} = +152.0$ ($c = 0.01$ in CHCl_3); 93% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 10.44 min, t (major) = 20.96 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.16–7.00 (m, 2H), 6.93 (s, 1H), 6.78 (dd, $J = 7.2, 2.2$ Hz, 1H), 4.90 (s, 1H), 4.11 (ddd, $J = 10.1, 5.9, 2.7$ Hz, 1H), 3.90–3.74 (m, 2H), 3.56 (ddd, $J = 14.9, 6.7, 4.2$ Hz, 1H), 3.36 (ddd, $J = 14.9, 5.3, 3.9$ Hz, 1H), 3.16 (dd, $J = 16.1, 2.7$ Hz, 1H), 3.10–2.95 (m, 2H), 2.87 (dd, $J = 16.1, 5.8$ Hz, 1H), 2.62–2.45 (m, 2H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.5, 155.5, 144.8, 134.1, 128.8, 125.0, 124.1, 120.2, 116.9, 86.0, 80.9, 61.4, 57.0, 42.2, 41.2, 33.6, 31.9, 29.1; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{18}\text{H}_{17}\text{N}_2\text{O}_3^{37}\text{Cl}$ 347.0971; Found 347.0971; Calcd for $\text{C}_{18}\text{H}_{17}\text{N}_2\text{O}_3^{35}\text{Cl}$ 345.1000; Found 345.0997.

Asymmetric reaction on a 1.0 mmol scale

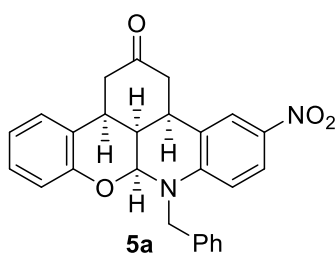


A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (162 mg, 1.00 mmol, 1.0 equiv) and N-benzyl 3-cyanopyridin-1-ium bromide **1a** (302 mg, 1.10 mmol, 1.1 equiv), amine **C1** (65.0 mg, 0.20 mmol, 20 mol %), acid additive **A1** (28.0 mg, 0.200 mmol, 20 mol %) and **B1** (197 mg, 1.10 mmol, 1.1 equiv) in DCM (10.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **3a**: 263.4 mg (0.739 mmol), as a white solid, 74% yield; 98% ee.

4.2 General procedure for dearomative cascade reaction with enones **2** and activated *N*-alkyl quinolinium salts **4**



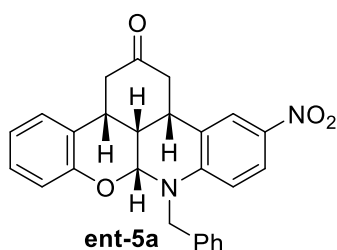
General procedure B: A mixture of activated *N*-alkyl quinolinium salt **4a** (0.12 mmol, 1.2 equiv), enone **2** (0.1 mmol, 1.0 equiv), amine **C2** (20 mol %), acid **A2** (20 mol %) and Na_2HPO_4 (0.12 mmol, 1.2 equiv) were stirred in DCE (2.0 mL) at rt, and the reaction was monitored by TLC. After completion, the product **5** were obtained by flash chromatography on silica gel. The racemic **5** was obtained under the catalysis of (\pm)-1,2-diphenylethane-1,2-diamine. The enantiomers were obtained with amine **C4**.



Synthesis of 5a: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and *N*-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.018 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv) in DCE (2.0 mL) was

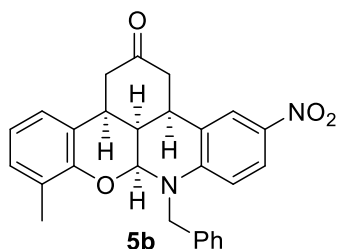
stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5a**: 29.9 mg (0.0702 mmol), as a yellow solid, 70% yield, mp = 196 °C; $[\alpha]_{\text{D}}^{25} = +10.4$ ($c = 0.87$ in CHCl_3); 89% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 16.64 min, t (major) = 17.90 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 8.03 (d, $J = 2.6$ Hz, 1H), 7.95 (dd, $J = 9.2, 2.7$ Hz, 1H), 7.43–7.27 (m, 5H), 7.19–7.12 (m, 1H), 7.14–7.08 (m, 1H), 6.98 (td, $J = 7.5, 1.3$ Hz, 1H), 6.84 (dd, $J = 8.1, 1.3$ Hz, 1H), 6.70 (d, $J = 9.2$ Hz, 1H), 5.21 (d, $J = 3.0$ Hz, 1H), 4.91 (d, $J = 17.0$ Hz, 1H), 4.83 (d, $J = 17.0$ Hz, 1H), 4.01–3.92 (m, 1H), 3.70–3.58 (m, 1H), 3.19 (td, $J = 9.1, 2.8$ Hz, 1H), 3.06 (dd, $J = 16.2, 4.8$ Hz, 1H), 2.87 (dd, $J = 16.2, 3.1$ Hz, 1H), 2.71 (dd, $J = 18.4, 13.9$ Hz, 1H), 2.61 (dd, $J = 18.4, 4.6$ Hz, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.7, 154.3, 147.1, 139.7, 136.3, 129.0,

128.5, 128.3, 127.8, 126.5, 125.4, 124.9, 124.5, 123.2, 123.1, 118.1, 112.5, 87.2, 55.0, 45.1, 44.9, 33.3, 32.4, 31.8; HRMS (ESI-TOF) m/z : $[M + Na]^+$ Calcd for $C_{26}H_{22}N_2O_4Na$ 449.1472; Found 449.1472.



Synthesis of ent-5a: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C4** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv) in DCE (2.0 mL) was

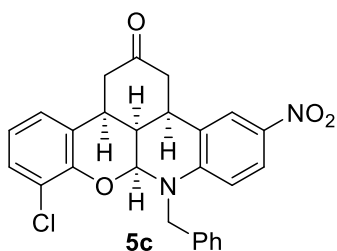
stirred at rt for 60 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **ent-5a**: 28.2 mg (0.0662 mmol), as a yellow solid, 66% yield, $[\alpha]_D^{25} = -12.5$ ($c = 0.59$ in $CHCl_3$); 89% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 18.07 min, t (major) = 16.48 min.



Synthesis of 5b: A mixture of (*E*)-4-(2-hydroxy-3-methylphenyl)but-3-en-2-one **2b** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **5a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv)

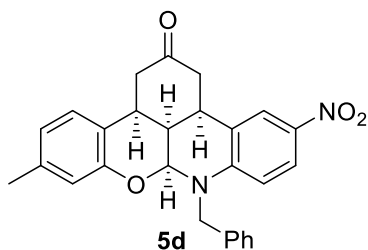
in DCE (1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5b**: 29.6 mg (0.0672 mmol), as a yellow solid, 67% yield; mp = 138–140 °C; $[\alpha]_D^{25} = -32.7$ ($c = 0.41$ in $CHCl_3$); 84% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 15.78 min, t (major) = 17.10 min; ¹H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.04 (d, $J = 2.7$ Hz, 1H), 7.96 (dd, $J = 9.2, 2.7$ Hz, 1H), 7.43–7.32 (m, 4H), 7.30 (dd, $J = 6.3, 2.4$ Hz, 1H), 7.03–6.93 (m, 2H), 6.92–6.82 (m, 1H), 6.69 (d, $J = 9.2$ Hz, 1H), 5.19 (d, $J = 2.8$ Hz, 1H), 4.89 (s, 2H), 4.04–3.87 (m, 1H), 3.74–3.50 (m, 1H), 3.23–3.14 (m, 1H), 3.07 (dd, $J = 16.1, 5.0$ Hz, 1H), 2.83 (dd, $J = 16.1, 3.0$ Hz, 1H), 2.76 (dd, $J = 18.5, 14.3$ Hz, 1H), 2.60 (dd, $J = 18.5, 4.3$ Hz, 1H), 2.10 (s, 3H); ¹³C NMR

(100 MHz, CDCl₃): δ 208.9, 152.4, 147.1, 139.6, 136.3, 129.4, 129.0, 127.7, 127.5, 126.4, 126.0, 125.4, 124.7, 124.5, 123.0, 122.5, 112.4, 87.7, 55.1, 45.3, 45.0, 33.2, 32.6, 32.1, 15.7; HRMS (ESI-TOF) m/z : $[M + Na]^+$ Calcd for C₂₇H₂₄N₂O₄Na 463.1628; Found 463.1632.



Synthesis of 5c: A mixture of (*E*)-4-(3-chloro-2-hydroxyphenyl)but-3-en-2-one **2c** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv)

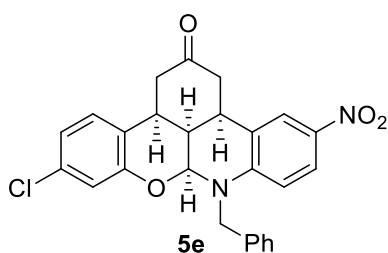
in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5c**: 26.6 mg (0.0578 mmol), as a yellow solid, 58% yield; mp = 124–126 °C; $[\alpha]_D^{25} = -56.7$ ($c = 0.65$ in CHCl₃); 81% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 15.83 min, t (major) = 19.60 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.03 (d, $J = 2.7$ Hz, 1H), 7.96 (dd, $J = 9.2, 2.6$ Hz, 1H), 7.46–7.31 (m, 4H), 7.34–7.25 (m, 1H), 7.19 (dd, $J = 7.8, 1.5$ Hz, 1H), 7.06 (dd, 1H), 6.96–6.86 (m, 1H), 6.74 (d, $J = 9.2$ Hz, 1H), 5.21 (d, $J = 2.8$ Hz, 1H), 4.94 (d, $J = 16.9$ Hz, 1H), 4.88 (d, $J = 16.9$ Hz, 1H), 4.03–3.94 (m, 1H), 3.73–3.59 (m, 1H), 3.27–3.14 (m, 1H), 3.09 (dd, $J = 16.1, 5.0$ Hz, 1H), 2.82 (dd, $J = 16.1, 3.0$ Hz, 1H), 2.73 (dd, $J = 18.6, 13.9$ Hz, 1H), 2.62 (dd, $J = 18.6, 4.6$ Hz, 1H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 208.4, 150.1, 146.9, 139.8, 136.0, 129.1, 128.9, 127.8, 127.1, 126.9, 126.6, 125.3, 124.6, 123.4, 123.3, 122.8, 112.6, 88.1, 54.8, 45.2, 44.8, 33.1, 32.8, 31.9; HRMS (ESI-TOF) m/z : $[M + Na]^+$ Calcd for C₂₆H₂₁N₂O₄³⁷Cl 485.1053; Found 485.1059; Calcd for C₂₆H₂₁N₂O₄³⁵Cl 483.1082; Found 483.1080.



Synthesis of 5d: A mixture of (*E*)-4-(2-hydroxy-4-methylphenyl)but-3-en-2-one **2d** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), and amine **C2** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2

equiv) in DCE (2.0 mL) was stirred at rt for 60 h. After completion, purification by flash

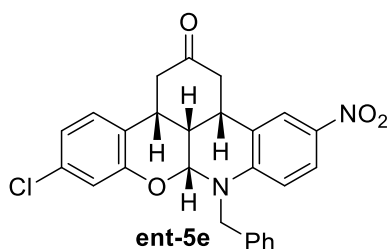
chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5d**: 29.1 mg (0.0661 mmol), as a yellow solid, 66% yield; mp = 106–108 °C; $[\alpha]_{\text{D}}^{25} = -27.1$ ($c = 0.73$ in CHCl_3); 86% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 17.02 min, t (major) = 15.70 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 8.03 (d, $J = 2.7$ Hz, 1H), 7.95 (dd, $J = 9.2, 2.7$ Hz, 1H), 7.43–7.27 (m, 5H), 7.03 (d, $J = 7.9$ Hz, 1H), 6.80 (dd, $J = 8.0, 1.8$ Hz, 1H), 6.69 (d, $J = 9.2$ Hz, 1H), 6.65 (d, $J = 1.8$ Hz, 1H), 5.19 (d, $J = 2.7$ Hz, 1H), 4.91 (d, $J = 17.0$ Hz, 1H), 4.82 (d, $J = 17.0$ Hz, 1H), 4.02–3.86 (m, 1H), 3.68–3.55 (m, 1H), 3.17 (td, $J = 9.0, 2.8$ Hz, 1H), 3.03 (dd, $J = 16.2, 4.7$ Hz, 1H), 2.85 (dd, $J = 16.1, 3.1$ Hz, 1H), 2.70 (dd, $J = 18.4, 14.0$ Hz, 1H), 2.60 (dd, $J = 18.4, 4.6$ Hz, 1H), 2.24 (s, 3H); ¹³C NMR (100 MHz, CDCl_3): δ 209.1, 154.0, 147.1, 139.6, 138.5, 136.4, 129.0, 128.2, 127.7, 126.4, 125.4, 124.5, 124.2, 123.1, 121.6, 118.4, 112.5, 87.2, 55.0, 45.1, 44.9, 33.2, 32.1, 31.7, 21.0; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{27}\text{H}_{24}\text{N}_2\text{O}_2\text{Na}$ 463.1628; Found 463.1624.



Synthesis of 5e: A mixture of (*E*)-4-(4-chloro-2-hydroxyphenyl)but-3-en-2-one **2f** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2

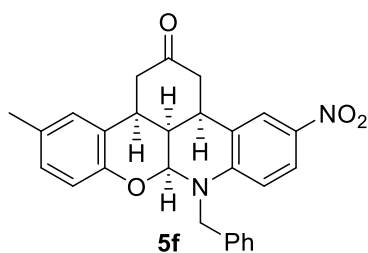
equiv) in DCE (1.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5e**: 25.2 mg (0.0548 mmol), as a yellow solid, 55% yield; mp = 127–128 °C; $[\alpha]_{\text{D}}^{25} = -40.0$ ($c = 0.45$ in CHCl_3); 83% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 18.50 min, t (major) = 16.15 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 8.03 (d, $J = 2.7$ Hz, 1H), 7.96 (dd, $J = 9.2, 2.6$ Hz, 1H), 7.45–7.28 (m, 5H), 7.08 (d, $J = 8.4$ Hz, 1H), 6.96 (dd, $J = 8.4, 2.1$ Hz, 1H), 6.86 (d, $J = 2.1$ Hz, 1H), 6.72 (d, $J = 9.2$ Hz, 1H), 5.19 (d, $J = 2.8$ Hz, 1H), 4.91 (d, $J = 16.9$ Hz, 1H), 4.81 (d, $J = 16.9$ Hz, 1H), 3.98–3.85 (m, 1H), 3.73–3.56 (m, 1H), 3.19 (td, $J = 9.1, 2.8$ Hz, 1H), 3.06 (dd, $J = 16.2, 4.8$ Hz, 1H), 2.83 (dd, $J = 16.2, 3.1$ Hz, 1H), 2.72–2.52 (m, 2H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 208.3, 154.9, 146.8, 139.8, 136.1, 133.5, 129.5, 129.1, 127.9, 126.5, 125.3, 124.5, 123.5, 123.4, 122.9, 118.3, 112.6, 87.5, 55.0, 44.9, 44.8, 33.0, 32.1, 31.6; HRMS

(ESI-TOF) m/z : $[M + Na]^+$ Calcd for $C_{26}H_{21}N_2O_4^{37}Cl$ 485.1053; Found 485.1060; Calcd for $C_{26}H_{21}N_2O_4^{35}Cl$ 483.1082; Found 483.1074.



Synthesis of ent-5e: A mixture of (*E*)-4-(4-chloro-2-hydroxyphenyl)but-3-en-2-one **2f** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C4** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2

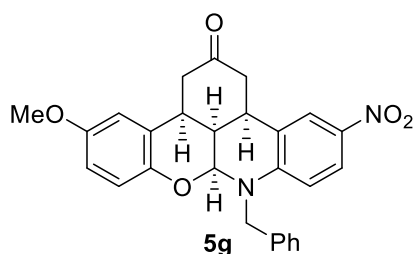
equiv) in DCE (2.0 mL) was stirred at rt for 60 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:5) gave product **ent-5e**: 30.9 mg (0.0672 mmol), as a yellow solid, 67% yield; $[\alpha]_D^{25} = +35.6$ ($c = 0.82$ in $CHCl_3$); 88% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min^{-1} , $\lambda = 254$ nm]: t (minor) = 15.60 min, t (major) = 17.80 min.



Synthesis of 5f: A mixture of (*E*)-4-(2-hydroxy-5-methylphenyl)but-3-en-2-one **2g** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv)

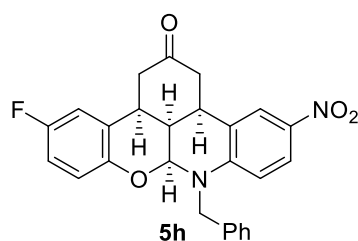
in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5f**: 34.4 mg (0.0782 mmol), as a yellow solid, 78% yield; mp = 110–112 °C; $[\alpha]_D^{25} = +32.0$ ($c = 0.79$ in $CHCl_3$); 86% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min^{-1} , $\lambda = 254$ nm]: t (minor) = 16.14 min, t (major) = 17.49 min; 1H NMR (400 MHz, $CDCl_3$): δ (ppm) 8.03 (d, $J = 2.7$ Hz, 1H), 7.95 (dd, $J = 9.2, 2.7$ Hz, 1H), 7.41–7.27 (m, 5H), 6.94 (d, $J = 2.1$ Hz, 1H), 6.91 (dd, $J = 8.3, 2.1$ Hz, 1H), 6.73 (d, $J = 8.2$ Hz, 1H), 6.69 (d, $J = 9.3$ Hz, 1H), 5.16 (d, $J = 2.6$ Hz, 1H), 4.90 (d, $J = 17.0$ Hz, 1H), 4.81 (d, $J = 17.0$ Hz, 1H), 3.99–3.86 (m, 1H), 3.70–3.51 (m, 1H), 3.16 (td, $J = 9.1, 2.8$ Hz, 1H), 3.04 (dd, $J = 16.3, 4.8$ Hz, 1H), 2.87 (dd, $J = 16.2, 3.1$ Hz, 1H), 2.73 (dd, $J = 18.4, 14.1$ Hz, 1H), 2.60 (dd, $J = 18.4, 4.3$ Hz, 1H), 2.25 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ (ppm) 209.0, 151.9, 147.1,

139.6, 136.3, 132.4, 129.1, 129.0, 128.7, 127.7, 126.4, 125.3, 124.5, 124.4, 123.0, 117.8, 112.4, 87.2, 54.9, 45.0, 45.0, 33.2, 32.3, 31.7, 20.8; HRMS (ESI-TOF) m/z : $[M + Na]^+$ Calcd for $C_{27}H_{24}N_2O_2Na$ 463.1628; Found 463.1622.



Synthesis of 5g: A mixture of (*E*)-4-(2-hydroxy-5-methoxyphenyl)but-3-en-2-one **2h** (19.2 mg, 0.1 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4mg, 0.120 mmol, 1.2 equiv), amine **C2** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol,

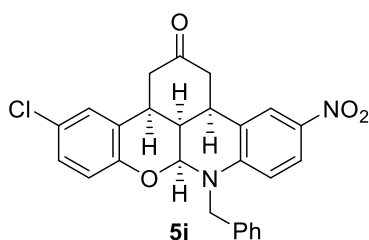
1.2 equiv) in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5g**: 33.5 mg (0.0734 mmol), as a yellow solid, 73% yield; mp = 115–117 °C; $[\alpha]_D^{25} = +38.3$ ($c = 0.82$ in CHCl₃); 88% ee, determined by HPLC analysis [Daicel Chiralpak AD-H, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 13.74 min, t (major) = 16.79 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.02 (d, $J = 2.6$ Hz, 1H), 7.94 (dd, $J = 9.2, 2.7$ Hz, 1H), 7.40–7.27 (m, 5H), 6.77 (d, $J = 8.7$ Hz, 1H), 6.72–6.62 (m, 3H), 5.14 (d, $J = 2.2$ Hz, 1H), 4.90 (d, $J = 17.0$ Hz, 1H), 4.82 (d, $J = 17.0$ Hz, 1H), 3.97–3.88 (m, 1H), 3.73 (s, 3H), 3.69–3.57 (m, 1H), 3.16 (td, $J = 9.1, 2.8$ Hz, 1H), 3.06 (dd, $J = 16.2, 4.9$ Hz, 1H), 2.84 (dd, $J = 16.2, 3.0$ Hz, 1H), 2.76 (dd, $J = 18.4, 14.2$ Hz, 1H), 2.60 (dd, $J = 18.4, 4.2$ Hz, 1H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 208.9, 155.2, 148.0, 147.1, 139.6, 136.4, 129.0, 127.8, 126.5, 125.7, 125.4, 124.5, 123.1, 118.9, 114.4, 112.9, 112.4, 87.4, 55.7, 55.0, 45.1, 45.0, 33.1, 32.8, 31.8; HRMS (ESI-TOF) m/z : $[M + Na]^+$ Calcd for $C_{27}H_{24}N_2O_5Na$ 479.1577; Found 479.1583.



Synthesis of 5h: A mixture of (*E*)-4-(5-fluoro-2-hydroxyphenyl)but-3-en-2-one **2j** (18.0 mg, 0.1 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv)

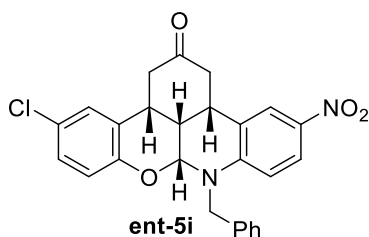
in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5h**: 32.2 mg (0.0725 mmol), as a yellow

solid, 73% yield; mp = 117–119 °C; $[\alpha]_{\text{D}}^{25} = +5.8$ ($c = 0.65$ in CHCl_3); 87% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 15.07 min, t (major) = 16.92 min; ^1H NMR (400 MHz, CDCl_3): δ 8.03 (d, $J = 2.7$ Hz, 1H), 7.95 (dd, $J = 9.2, 2.7$ Hz, 1H), 7.45–7.28 (m, 5H), 6.94–6.77 (m, 3H), 6.70 (d, $J = 9.2$ Hz, 1H), 5.17 (d, $J = 2.7$ Hz, 1H), 4.91 (d, $J = 17.0$ Hz, 1H), 4.82 (d, $J = 17.0$ Hz, 1H), 4.00–3.84 (m, 1H), 3.77–3.52 (m, 1H), 3.18 (td, $J = 9.1, 2.8$ Hz, 1H), 3.08 (dd, $J = 16.2, 4.9$ Hz, 1H), 2.81 (dd, $J = 16.2, 3.1$ Hz, 1H), 2.71 (dd, $J = 18.5, 13.6$ Hz, 1H), 2.62 (dd, $J = 18.6, 4.9$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 208.3, 158.2 (d, $J = 241.7$ Hz), 150.2, 146.9, 139.7, 136.1, 129.0, 127.8, 126.4, 126.3 (d, $J = 7.3$ Hz), 125.3, 124.5, 122.8, 119.4 (d, $J = 8.2$ Hz), 115.5 (d, $J = 23.5$ Hz), 114.5 (d, $J = 23.4$ Hz), 112.4, 87.4, 54.9, 44.9, 44.8, 32.8, 32.7, 31.7; ^{19}F NMR (376 MHz, CDCl_3): δ (ppm) –119.4; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{26}\text{H}_{21}\text{N}_2\text{O}_4\text{FNa}$ 467.1378; Found 467.1370.



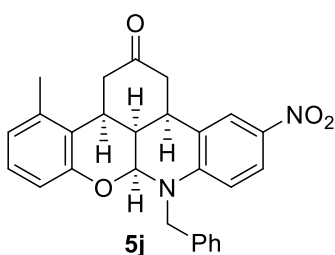
Synthesis of **5i:** A mixture of (*E*)-4-(5-chloro-2-hydroxyphenyl)but-3-en-2-one **2i** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv)

in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5i**: 38.2 mg (0.0830 mmol), as a yellow solid, 83% yield; mp = 116–117 °C; $[\alpha]_{\text{D}}^{25} = +69.3$ ($c = 0.15$ in CHCl_3); 89% ee, determined by HPLC analysis [Daicel Chiralpak ID, n -hexane/ i -PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 16.58 min, t (major) = 17.45 min; ^1H NMR (400 MHz, CDCl_3): δ (ppm) 8.03 (d, $J = 2.7$ Hz, 1H), 7.95 (dd, $J = 9.1, 2.7$ Hz, 1H), 7.41–7.28 (m, 5H), 7.13 (d, $J = 2.5$ Hz, 1H), 7.07 (dd, $J = 8.7, 2.5$ Hz, 1H), 6.78 (d, $J = 8.7$ Hz, 1H), 6.71 (d, $J = 9.2$ Hz, 1H), 5.17 (d, $J = 2.8$ Hz, 1H), 4.90 (d, $J = 16.9$ Hz, 1H), 4.81 (d, $J = 16.9$ Hz, 1H), 3.97–3.87 (m, 1H), 3.72–3.52 (m, 1H), 3.18 (td, $J = 9.1, 2.8$ Hz, 1H), 3.06 (dd, $J = 16.3, 4.9$ Hz, 1H), 2.83 (dd, $J = 16.3, 3.1$ Hz, 1H), 2.74–2.55 (m, 2H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 208.2, 152.9, 146.8, 139.8, 136.1, 129.1, 128.6, 128.3, 128.0, 127.9, 126.6, 126.5, 125.3, 124.5, 122.9, 119.6, 112.6, 87.4, 55.0, 44.91, 44.89, 32.9, 32.5, 31.6; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{26}\text{H}_{21}\text{N}_2\text{O}_4^{37}\text{Cl}$ 485.1053; Found 485.1060; Calcd for $\text{C}_{26}\text{H}_{21}\text{N}_2\text{O}_4^{35}\text{Cl}$



Synthesis of ent-5i: A mixture of (*E*)-4-(5-chloro-2-hydroxyphenyl)but-3-en-2-one **2i** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C4** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv)

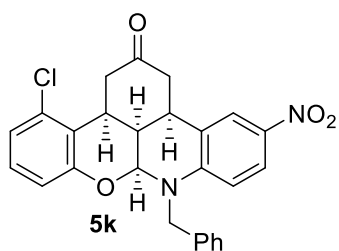
in DCE (2.0 mL) was stirred at rt for 60 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:5) gave product **5i**: 37.6 mg (0.0817 mmol), as a yellow solid, 82% yield, $[\alpha]_{\text{D}}^{25} = -70.8$ ($c = 0.65$ in CHCl₃); 86% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: *t* (minor) = 18.50 min, *t* (major) = 17.11 min.



Synthesis of 5j: A mixture of (*E*)-4-(2-hydroxy-6-methylphenyl)but-3-en-2-one **2m** (17.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv)

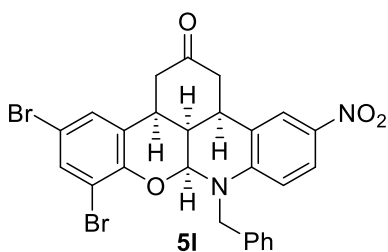
in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5j**: 25.2 mg (0.0573 mmol), as a yellow solid, 57% yield; mp = 219–220 °C; $[\alpha]_{\text{D}}^{25} = -3.5$ ($c = 0.69$ in CHCl₃); 81% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: *t* (minor) = 15.10 min, *t* (major) = 19.80 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.04 (d, $J = 2.4$ Hz, 1H), 7.95 (dd, $J = 9.2, 2.5$ Hz, 1H), 7.38–7.31 (m, 2H), 7.31–7.27 (m, 3H), 7.07–6.99 (m, 1H), 6.84 (d, $J = 7.5$ Hz, 1H), 6.72 (d, $J = 8.1$ Hz, 1H), 6.65 (d, $J = 9.1$ Hz, 1H), 5.05 (d, $J = 2.2$ Hz, 1H), 4.85 (m, 2H), 4.16–4.05 (m, 1H), 3.79–3.64 (m, 1H), 3.30–3.17 (m, 1H), 3.14–2.95 (m, 2H), 2.66 (dd, $J = 15.6, 2.3$ Hz, 1H), 2.59 (dd, $J = 19.2, 4.2$ Hz, 1H), 2.32 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 209.3, 155.2, 146.6, 139.3, 136.8, 136.2, 129.0, 127.8, 127.7, 126.3, 125.6, 125.4, 125.2, 124.8, 123.1, 116.1, 111.8, 88.7, 54.1, 44.6, 43.3, 34.0, 33.5, 31.2, 19.1; HRMS (ESI-TOF) *m/z*: [M + Na]⁺ Calcd

for C₂₇H₂₄N₂O₄Na 463.1628; Found 463.1624.



Synthesis of 5k: A mixture of (*E*)-4-(6-chloro-2-hydroxyphenyl)but-3-en-2-one **2n** (19.6 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv)

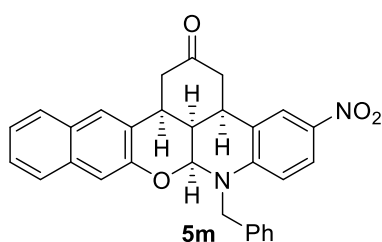
in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:6) gave product **5k**: 20.1 mg (0.0436 mmol), as a yellow solid, 44% yield; mp = 246 °C; [α]_D²⁵ = 65.2 (*c* = 0.84 in CHCl₃); 80% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: *t* (minor) = 15.67 min, *t* (major) = 17.48min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.06 (dd, *J* = 2.6, 0.7 Hz, 1H), 7.98 (dd, *J* = 9.2, 2.7 Hz, 1H), 7.40–7.32 (m, 2H), 7.32–7.26 (m, 3H), 7.12–7.03 (m, 2H), 6.81 (dd, *J* = 7.0, 2.3 Hz, 1H), 6.68 (d, *J* = 9.2 Hz, 1H), 5.09 (dd, *J* = 3.1, 1.4 Hz, 1H), 4.89 (d, *J* = 17.5 Hz, 1H), 4.83 (d, *J* = 17.5 Hz, 1H), 4.29–4.17 (m, 1H), 3.80–3.67 (m, 1H), 3.31–3.17 (m, 1H), 3.14–2.99 (m, 2H), 2.98 (dd, *J* = 19.0, 14.2 Hz, 1H), 2.62 (ddd, *J* = 19.0, 4.7, 1.2 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 209.1, 156.0, 146.3, 139.6, 136.0, 133.8, 129.1, 128.7, 127.8, 126.3, 125.3, 124.9, 124.8, 124.6, 122.9, 117.1, 112.0, 89.1, 54.3, 44.8, 42.5, 33.5, 33.2, 32.0; HRMS (ESI-TOF) *m/z*: [M + Na]⁺ Calcd for C₂₆H₂₁N₂O₄³⁷Cl 485.1053; Found 485.1068; Calcd for C₂₆H₂₁N₂O₄³⁵Cl 483.1082; Found 483.1082.



Synthesis of 5l: A mixture of (*E*)-4-(3,5-dibromo-2-hydroxyphenyl) but-3-en-2-one **2t** (31.8 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2

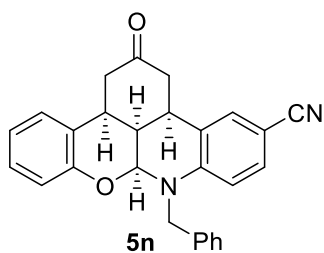
equiv) in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5l**: 37.0 mg (0.0636 mmol), as a yellow solid, 64% yield; mp = 146–148 °C; [α]_D²⁵ = +69.3 (*c* = 0.15 in CHCl₃); 80% ee,

determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: *t* (minor) = 17.23 min, *t* (major) = 19.90 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.05–7.99 (m, 1H), 7.99–7.89 (m, 1H), 7.49 (s, 1H), 7.42–7.33 (m, 4H), 7.33–7.27 (m, 1H), 7.23 (d, *J* = 2.3 Hz, 1H), 6.75 (dd, *J* = 9.4, 3.2 Hz, 1H), 5.16 (s, 1H), 4.94 (d, *J* = 16.9 Hz, 1H), 4.87 (d, *J* = 16.9 Hz, 1H), 4.01–3.90 (m, 1H), 3.73–3.58 (m, 1H), 3.26–3.14 (m, 1H), 3.10 (dd, *J* = 16.2, 5.2 Hz, 1H), 2.78 (dd, *J* = 16.3, 3.0 Hz, 1H), 2.72–2.57 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 207.9, 150.3, 146.7, 139.9, 135.8, 134.2, 130.5, 129.1, 128.8, 127.9, 126.7, 125.3, 124.6, 122.7, 115.3, 113.5, 112.7, 88.4, 54.7, 45.1, 44.8, 33.0, 32.8, 31.9; HRMS (ESI-TOF) *m/z*: [*M* + *H*]⁺ Calcd for C₂₆H₂₁N₂O₄⁸¹Br⁷⁹Br 584.9842; Found 584.9848; C₂₆H₂₁N₂O₄⁷⁹Br₂ 582.9863; Found 582.9801. C₂₆H₂₁N₂O₄⁸¹Br₂ 586.9822; Found 586.9838.



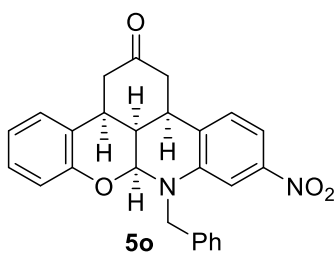
Synthesis of 5m: A mixture of (*E*)-4-(3-hydroxynaphthalen-2-yl) but-3-en-2-one **1p** (21.2 mg, 0.0999 mmol, 1.0 equiv) and *N*-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv)

in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5m**: 25.3 mg (0.0532 mmol), as a yellow solid, 53% yield; mp = 235–236 °C; [α]_D²⁵ = –47.1 (*c* = 0.79 in CHCl₃); 85% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: *t* (minor) = 24.03 min, *t* (major) = 21.64 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 7.96 (d, *J* = 2.6 Hz, 1H), 7.89 (dd, *J* = 9.2, 2.7 Hz, 1H), 7.62 (d, *J* = 8.1 Hz, 1H), 7.60–7.51 (m, 2H), 7.41–7.19 (m, 6H), 7.19 (d, *J* = 6.0 Hz, 2H), 6.65 (d, *J* = 9.2 Hz, 1H), 5.19 (d, *J* = 2.8 Hz, 1H), 4.87 (d, *J* = 16.9 Hz, 1H), 4.78 (d, *J* = 16.9 Hz, 1H), 4.18–3.99 (m, 1H), 3.65–3.49 (m, 1H), 3.16 (td, *J* = 9.0, 2.8 Hz, 1H), 3.06 (dd, *J* = 16.3, 4.9 Hz, 1H), 2.93 (dd, *J* = 16.2, 3.2 Hz, 1H), 2.68 (dd, *J* = 18.5, 14.0 Hz, 1H), 2.55 (dd, *J* = 18.5, 4.4 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 208.6, 152.5, 147.1, 139.7, 136.3, 133.4, 130.0, 129.1, 128.2, 127.8, 127.6, 126.58, 126.56, 126.5, 126.1, 125.3, 124.6, 124.5, 123.2, 113.5, 112.6, 87.5, 55.0, 45.8, 44.9, 33.1, 32.7, 31.8; HRMS (ESI-TOF) *m/z*: [*M* + Na]⁺ Calcd for C₃₀H₂₄N₂O₄Na 499.1628; Found 499.1630.



Synthesis of 5n: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-cyanoquinolin-1-ium bromide **4b** (39.0 mg, 0.12 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv) in DCE (2.0 mL) was

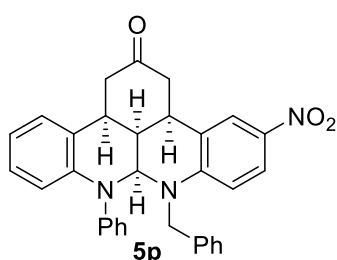
stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5n**: 31.1 mg (0.0766 mmol), as a yellow solid, 77% yield; mp = 119–121 °C; [α]_D²⁵ = +38.9 (*c* = 0.54 in CHCl₃); 82% ee, determined by HPLC analysis [Daicel Chiralpak IB, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: *t* (minor) = 15.29 min, *t* (major) = 17.89 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 7.45–7.27 (m, 6H), 7.19–7.06 (m, 2H), 7.02–6.93 (m, 1H), 6.83 (dd, *J* = 8.1, 1.2 Hz, 1H), 6.69 (d, *J* = 8.7 Hz, 1H), 5.18 (d, *J* = 2.7 Hz, 1H), 4.85 (d, *J* = 17.0 Hz, 1H), 4.78 (d, *J* = 17.0 Hz, 1H), 4.01–3.83 (m, 1H), 3.65–3.49 (m, 1H), 3.17 (td, *J* = 9.1, 2.8 Hz, 1H), 3.04 (dd, *J* = 16.2, 4.8 Hz, 1H), 2.87 (dd, *J* = 16.3, 3.2 Hz, 1H), 2.69 (dd, *J* = 18.4, 14.3 Hz, 1H), 2.53 (dd, *J* = 18.4, 4.2 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 208.9, 154.3, 145.2, 136.6, 133.1, 132.2, 129.0, 128.5, 128.3, 127.7, 126.5, 124.9, 123.7, 123.0, 119.5, 118.1, 113.2, 101.6, 87.2, 54.7, 45.0, 45.0, 33.3, 32.5, 31.5; HRMS (ESI-TOF) *m/z*: [M + Na]⁺ Calcd for C₂₇H₂₂N₂O₂Na 429.1573; Found 429.1574.



Synthesis of 5o: A mixture of (*E*)-4-(2-hydroxyphenyl)but-3-en-2-one **2a** (16.2 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 7-nitroquinolin-1-ium bromide **4c** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv) in DCE (2.0 mL) was

stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5o**: 26.2 mg (0.0615 mmol), as a yellow solid, 62% yield; mp = 187–189 °C; [α]_D²⁵ = +40.0 (*c* = 0.44 in CHCl₃); 89% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: *t* (minor) = 17.37 min, *t* (major) = 22.51 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 7.64 (dd, *J* = 8.3, 2.2 Hz, 1H), 7.59 (d, *J* = 2.2 Hz, 1H), 7.41–7.33 (m, 4H), 7.32–7.26 (m, 1H), 7.22 (d, *J* = 8.4 Hz, 1H), 7.17–7.08 (m, 2H), 6.97

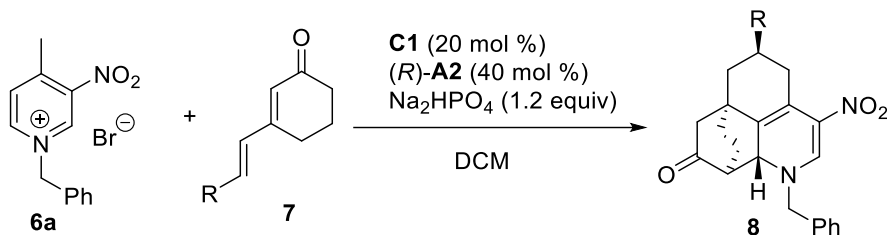
(td, $J = 7.5, 1.3$ Hz, 1H), 6.84 (dd, $J = 8.1, 1.3$ Hz, 1H), 5.19 (d, $J = 2.6$ Hz, 1H), 4.88 (d, $J = 16.4$ Hz, 1H), 4.75 (d, $J = 16.4$ Hz, 1H), 4.02–3.89 (m, 1H), 3.68–3.55 (m, 1H), 3.18 (td, $J = 9.1, 2.7$ Hz, 1H), 3.02 (dd, $J = 16.4, 4.6$ Hz, 1H), 2.90 (dd, $J = 16.4, 3.2$ Hz, 1H), 2.73–2.51 (m, 2H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 209.1, 154.4, 147.9, 142.6, 136.5, 130.3, 129.7, 129.0, 128.38, 128.35, 127.8, 127.0, 124.7, 122.9, 118.2, 113.9, 107.7, 86.7, 54.7, 44.9, 44.8, 33.4, 32.5, 31.8; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{26}\text{H}_{22}\text{N}_2\text{O}_4\text{Na}$ 449.1472; Found 449.1468.



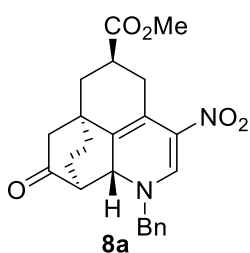
Synthesis of **5p:** A mixture of (*E*)-4-(2-(phenylamino)phenyl)but-3-en-2-one **2u** (23.7 mg, 0.0999 mmol, 1.0 equiv) and N-benzyl 6-nitroquinolin-1-ium bromide **4a** (41.4 mg, 0.120 mmol, 1.2 equiv), amine **C3** (8.7 mg, 0.020 mol, 20 mol %), acid additive **A2** (3.0 mg, 0.020 mol, 20 mol %) and Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv)

in DCE (2.0 mL) was stirred at rt for 48 h. After completion, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **5p**: 31.7 mg (0.0631 mmol), as a yellow solid, 63% yield; mp = 222–223 °C; $[\alpha]_{\text{D}}^{25} = -68.0$ ($c = 0.75$ in CHCl_3); 61% ee (the peaks of two enantiomers were assigned by using a mixture of **5p** and its enantiomer obtained with amine **C4**), determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min $^{-1}$, $\lambda = 254$ nm]: t (minor) = 25.71 min, t (major) = 28.23 min; ^1H NMR (400 MHz, CDCl_3): δ (ppm) 8.09 (s, 1H), 7.85 (d, $J = 9.2$ Hz, 1H), 7.50–7.07 (m, 7H), 7.07–6.68 (m, 6H), 6.38 (dd, $J = 29.0, 8.7$ Hz, 2H), 5.20 (s, 1H), 4.29 (d, $J = 16.5$ Hz, 1H), 4.07 (d, $J = 16.5$ Hz, 1H), 3.93–3.82 (m, 1H), 3.79–3.58 (m, 1H), 3.41–3.22 (m, 1H), 3.09–2.64 (m, 4H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 209.4, 149.5, 145.5, 144.3, 139.2, 136.9, 129.8, 128.8, 128.0, 127.5, 127.5, 126.8, 126.7, 126.04, 125.96, 125.1, 124.3, 123.9, 121.3, 119.1, 113.5, 74.1, 53.8, 44.4, 44.2, 37.0, 32.3, 32.0; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{32}\text{H}_{28}\text{N}_3\text{O}_3$ 502.2125; Found 502.2127.

4.3 General procedure for dearomative cascade reaction with cyclic dienones **7** and activated N,4-dialkyl pyridinium salt **6**

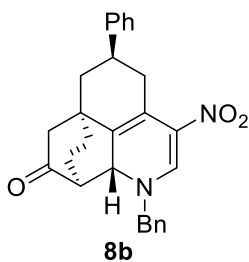


General procedure C: To the mixture of methyl (*E*)-3-(3-oxocyclohex-1-en-1-yl) acrylate **7** (0.1 mmol, 1.0 equiv), amine **C1** (20 mol %), and acid (*R*)-**A2** (40 mol %) in DCM (1.0 mL) were added Na_2HPO_4 (0.12 mmol, 1.2 equiv) and N-benzyl 4-methyl-3-nitropyridin-1-ium bromide **6** (0.12 mmol, 1.2 equiv) in four portions (12 h) at 25 °C. The reaction was monitored by TLC. After 48 h, the product **8** were obtained by flash chromatography on silica gel. The racemic **8** was generally obtained under the catalysis of (\pm)-1,2-diphenylethane-1,2-diamine.



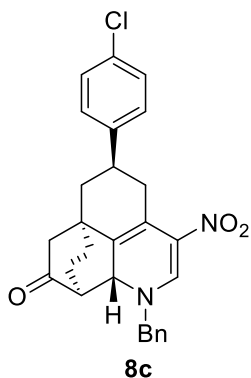
Synthesis of 8a: A mixture of methyl (*E*)-3-(3-oxocyclohex-1-en-1-yl)acrylate **7a** (18.0 mg, 0.0999 mmol, 1.0 equiv) and amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive (*R*)-**A2** (6.1 mg, 0.040 mol, 40 mol %) in DCM (1.0 mL) was stirred at 25 °C. Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv) and N-benzyl 4-methyl-3-nitropyridin-1-ium bromide **6** (37.0 mg, 0.120 mmol, 1.2 equiv)

were added uniformly in four portions in the period of 12 h. After 48 h, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4) gave product **8a**: 30.5 mg (0.0747 mmol), as a yellow solid, 75% yield; mp = 185°C; $[\alpha]_{\text{D}}^{25} = +344.7$ ($c = 0.89$ in CHCl_3); >19:1 dr; 81% ee, determined by HPLC analysis [Daicel Chiralpak AD-H, *n*-hexane/*i*-PrOH = 80:20, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 17.37 min, t (major) = 22.51 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 8.30 (s, 1H), 7.52–7.27 (m, 3H), 7.28–7.11 (m, 2H), 4.55 (d, $J = 15.4$ Hz, 1H), 4.33 (d, $J = 15.4$ Hz, 1H), 4.16 (s, 1H), 3.72 (s, 3H), 2.92–2.85 (m, 1H), 2.83–2.76 (m, 2H), 2.74–2.63 (m, 1H), 2.27–2.12 (m, 2H), 2.06–1.92 (m, 1H), 1.92–1.85 (m, 2H), 1.84–1.75 (m, 1H), 1.70 (t, $J = 13.1$ Hz, 1H), 1.47–1.36 (m, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 209.1, 174.0, 148.0, 131.8, 128.5, 128.0, 126.9, 126.8, 122.6, 119.9, 55.8, 54.9, 51.0, 48.1, 45.0, 35.8, 35.5, 33.3, 30.5, 27.5, 17.6; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{25}\text{N}_2\text{O}_5$ 409.1758; Found 409.1756.



Synthesis of 8b: A mixture of (*E*)-3-styrylcyclohex-2-en-1-one **7b** (19.8 mg, 0.0999 mmol, 1.0 equiv) and amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive (*R*)-**A2** (6.1 mg, 0.040 mol, 40 mol %) in DCM (1.0 mL) was stirred at 25 °C. Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv) and N-benzyl 4-methyl-3-nitropyridin-1-ium bromide **6** (37.0 mg, 0.120 mmol, 1.2 equiv) were added

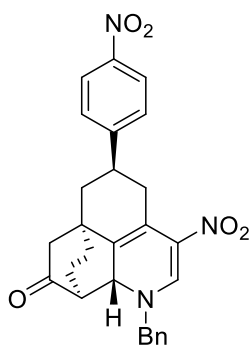
uniformly in four portions in the period of 12 h. After 48 h, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:5) gave product **8b**: 19.7 mg (0.0462 mmol), as a yellow solid, 46% yield; mp = 176 °C; [α]_D²⁵ = +363.9 (*c* = 0.31 in CHCl₃); >19:1 dr; 65% ee, determined by HPLC analysis [Daicel Chiralpak IE-H, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: *t* (minor) = 25.71 min, *t* (major) = 28.27 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.31 (s, 1H), 7.52–7.09 (m, 10H), 4.56 (d, *J* = 15.4 Hz, 1H), 4.35 (d, *J* = 15.4 Hz, 1H), 4.19 (s, 1H), 3.04–2.88 (m, 2H), 2.79–2.67 (m, 2H), 2.21 (s, 2H), 2.13–1.97 (m, 2H), 1.91–1.69 (m, 3H), 1.55–1.33 (m, 1H); ¹³C NMR (100 MHz, CDCl₃): δ (ppm) 210.9, 149.0, 145.0, 132.9, 129.5, 129.0, 128.7, 128.1, 127.9, 127.0, 126.7, 125.1, 121.1, 56.8, 56.0, 49.5, 46.1, 39.1, 37.9, 36.8, 34.1, 31.7, 18.8; HRMS (ESI-TOF) *m/z*: [M + Na]⁺ Calcd for C₂₇H₂₆N₂O₃Na 449.1836; Found 449.1840.



Synthesis of 8c: A mixture of (*E*)-3-(4-chlorostyryl)cyclohex-2-en-1-one **7c** (23.2 mg, 0.0999 mmol, 1.0 equiv) and amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive (*R*)-**A2** (6.1 mg, 0.040 mol, 40 mol %) in DCM (1.0 mL) was stirred at 25 °C. Na₂HPO₄ (17.0 mg, 0.120 mmol, 1.2 equiv) and N-benzyl 4-methyl-3-nitropyridin-1-ium bromide **6** (37.0 mg, 0.120 mmol, 1.2 equiv) were added uniformly in four portions in the period of 12 h. After 48 h, purification by flash chromatography on silica gel (EtOAc/petroleum ether =

1:5) gave product **8c**: 20.3 mg (0.0441 mmol), as a yellow solid, 44% yield; mp = 107–109 °C; [α]_D²⁵ = +299.4 (*c* = 0.35 in CHCl₃); >19:1 dr; 69% ee, determined by HPLC analysis [Daicel Chiralpak IE-H, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, λ = 254 nm]: *t* (minor) = 29.77 min, *t* (major) = 32.37 min; ¹H NMR (400 MHz, CDCl₃): δ (ppm) 8.31 (s, 1H), 7.47–7.34 (m, 3H), 7.34–7.24 (m, 4H), 7.18 (d, *J* = 8.1 Hz, 2H), 4.56 (d, *J* = 15.4 Hz, 1H), 4.35 (d, *J* = 15.4 Hz, 1H), 4.19 (s, 1H), 2.97–2.79 (m, 2H), 2.70 (dd, *J* = 8.7, 2.4 Hz, 2H), 2.21 (s, 2H), 2.05 (d, *J* = 8.4 Hz, 2H), 1.88–1.68 (m, 3H), 1.48–

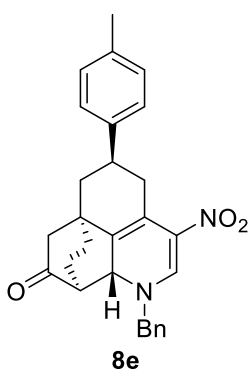
1.35 (m, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 210.6, 149.0, 143.5, 132.8, 132.3, 129.5, 129.0, 128.7, 128.4, 128.0, 127.8, 124.8, 121.0, 56.9, 55.9, 49.4, 46.1, 39.1, 37.9, 36.3, 34.0, 31.7, 18.7; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{27}\text{H}_{25}\text{N}_2\text{O}_3^{37}\text{Cl}$ 485.1416; Found 485.1412; Calcd for $\text{C}_{27}\text{H}_{25}\text{N}_2\text{O}_3^{35}\text{Cl}$ 483.1446; Found 483.1412.



8d

Synthesis of 8d: A mixture of (*E*)-3-(4-nitrostyryl)cyclohex-2-en-1-one **7d** (24.3 mg, 0.0999 mmol, 1.0 equiv) and amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive (*R*)-**A2** (6.1 mg, 0.040 mol, 40 mol %) in DCM (1.0 mL) was stirred at 25 °C. Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv) and N-benzyl 4-methyl-3-nitropyridin-1-ium bromide **6** (37.0 mg, 0.120 mmol, 1.2 equiv) were added uniformly in four portions in the period of 12 h. After 48 h, purification by flash chromatography on silica gel (EtOAc/petroleum ether =

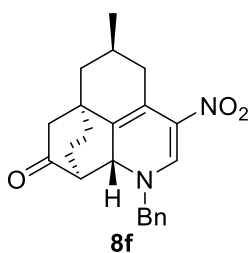
1:4) gave product **8d**: 28.5 mg (0.0605 mmol), as a yellow solid, 61% yield; mp = 137–142 °C; $[\alpha]_{\text{D}}^{25} = +403.8$ ($c = 0.63$ in CHCl_3); >19:1 dr; 82% ee, determined by HPLC analysis [Daicel Chiralpak IG, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 47.40 min, t (major) = 51.63 min; ^1H NMR (400 MHz, CDCl_3): δ (ppm) 8.33 (s, 1H), 8.19 (d, $J = 8.7$ Hz, 2H), 7.49–7.33 (m, 5H), 7.27 (d, $J = 6.1$ Hz, 2H), 4.58 (d, $J = 15.4$ Hz, 1H), 4.37 (d, $J = 15.4$ Hz, 1H), 4.21 (s, 1H), 3.21–3.00 (m, 1H), 2.97–2.91 (m, 1H), 2.75 (dd, $J = 8.4, 2.3$ Hz, 2H), 2.24 (s, 2H), 2.05 (t, $J = 10.1$ Hz, 2H), 1.93–1.70 (m, 3H), 1.47 (td, $J = 8.4, 8.0, 3.5$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ (ppm) 210.2, 152.6, 149.2, 146.8, 132.7, 129.5, 129.0, 128.0, 127.9, 127.8, 124.4, 124.0, 121.0, 56.9, 55.9, 49.3, 46.0, 38.7, 37.7, 37.0, 33.6, 31.7, 18.7; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{27}\text{H}_{25}\text{N}_3\text{O}_5\text{Na}$ 494.1686; Found 494.1682.



8e

Synthesis of 8e: A mixture of (*E*)-3-(4-methylstyryl)cyclohex-2-en-1-one **7e** (21.2 mg, 0.0999 mmol, 1.0 equiv) and amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive (*R*)-**A2** (6.1 mg, 0.040 mol, 40 mol %) in DCM (1.0 mL) was stirred at 25 °C. Na_2HPO_4 (17.0 mg, 0.120 mmol, 1.2 equiv) and N-benzyl 4-methyl-3-nitropyridin-1-ium bromide **6** (37.0 mg, 0.120 mmol, 1.2 equiv) were added uniformly in four portions in the period of 12 h. After 48 h,

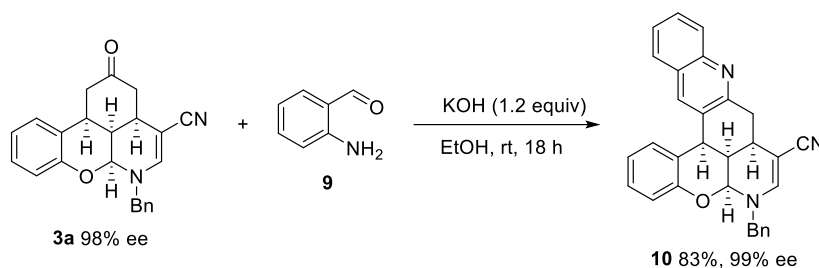
purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:5) gave product **8e**: 21.7 mg (0.0493 mmol), as a yellow solid, 49% yield; mp = 201–204 °C; $[\alpha]_{\text{D}}^{25} = +373.8$ ($c = 0.31$ in CHCl_3); >19:1 dr; 66% ee, determined by HPLC analysis [Daicel Chiralpak IE, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 27.91 min, t (major) = 35.36 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 8.31 (s, 1H), 7.47–7.32 (m, 3H), 7.27 (d, $J = 6.3$ Hz, 2H), 7.14 (s, 4H), 4.56 (d, $J = 15.4$ Hz, 1H), 4.35 (d, $J = 15.4$ Hz, 1H), 4.19 (s, 1H), 2.96–2.86 (m, 2H), 2.76–2.67 (m, 2H), 2.33 (s, 3H), 2.21 (s, 2H), 2.12–2.00 (m, 2H), 1.86–1.69 (m, 3H), 1.48–1.37 (m, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 210.9, 148.9, 142.1, 136.2, 132.9, 129.5, 129.3, 129.0, 128.2, 127.8, 126.9, 125.1, 121.0, 56.8, 55.9, 49.5, 46.1, 39.3, 37.9, 36.4, 34.2, 31.7, 21.0, 18.8; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{28}\text{H}_{28}\text{N}_2\text{O}_3\text{Na}$ 463.1992; Found 463.1994.



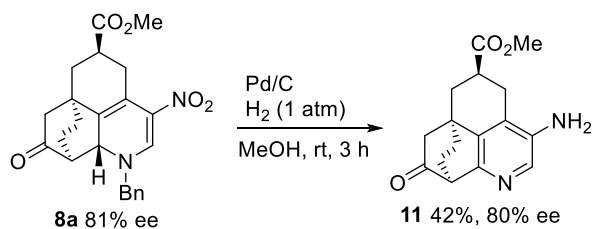
Synthesis of 8f: A mixture of (*E*)-3-(prop-1-en-1-yl)cyclohex-2-en-1-one **7f** (13.6 mg, 0.0999 mmol, 1.0 equiv) and amine **C1** (6.5 mg, 0.020 mol, 20 mol %), acid additive (*R*)-**A2** (6.1 mg, 0.040 mol, 40 mol %) in DCM (1.0 mL) was stirred at 25 °C. Na_2HPO_4 (17.0 mg, 0.145 mmol, 1.45 equiv) and N-benzyl 4-methyl-3-nitropyridin-1-ium bromide **6** (37.0 mg, 0.145 mmol, 1.45

equiv) were added uniformly in five portions in the period of 16 h. After 48 h, purification by flash chromatography on silica gel (EtOAc/petroleum ether = 1:8) gave product **8f**: 12.7 mg (0.0349 mmol), as a yellow solid, 35% yield; mp = 74–76 °C; $[\alpha]_{\text{D}}^{25} = +546.7$ ($c = 0.26$ in CHCl_3); >19:1 dr; 85% ee, determined by HPLC analysis [Daicel Chiralpak IE-H, *n*-hexane/*i*-PrOH = 60:40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 23.54 min, t (major) = 21.13 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 8.29 (s, 1H), 7.49–7.32 (m, 3H), 7.30–7.14 (m, 2H), 4.54 (d, $J = 15.5$ Hz, 1H), 4.32 (d, $J = 15.5$ Hz, 1H), 4.14 (s, 1H), 2.92–2.72 (m, 1H), 2.50 (dd, $J = 17.8, 5.0$ Hz, 1H), 2.30–2.18 (m, 1H), 2.13 (s, 2H), 2.05–1.94 (m, 1H), 1.89 (t, $J = 11.9$ Hz, 1H), 1.84–1.70 (m, 1H), 1.58–1.47 (m, 1H), 1.42–1.29 (m, 1H), 1.29–1.17 (m, 2H), 1.04 (d, $J = 6.5$ Hz, 3H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 211.3, 148.9, 132.9, 129.4, 128.9, 128.2, 127.8, 125.0, 121.3, 56.8, 55.9, 49.6, 46.2, 40.8, 37.5, 34.4, 31.8, 25.3, 21.9, 18.8; HRMS (ESI-TOF) m/z : $[\text{M} + \text{Na}]^+$ Calcd for $\text{C}_{22}\text{H}_{24}\text{N}_2\text{O}_3\text{Na}$ 387.1679; Found 387.1684.

5. Transformations of products



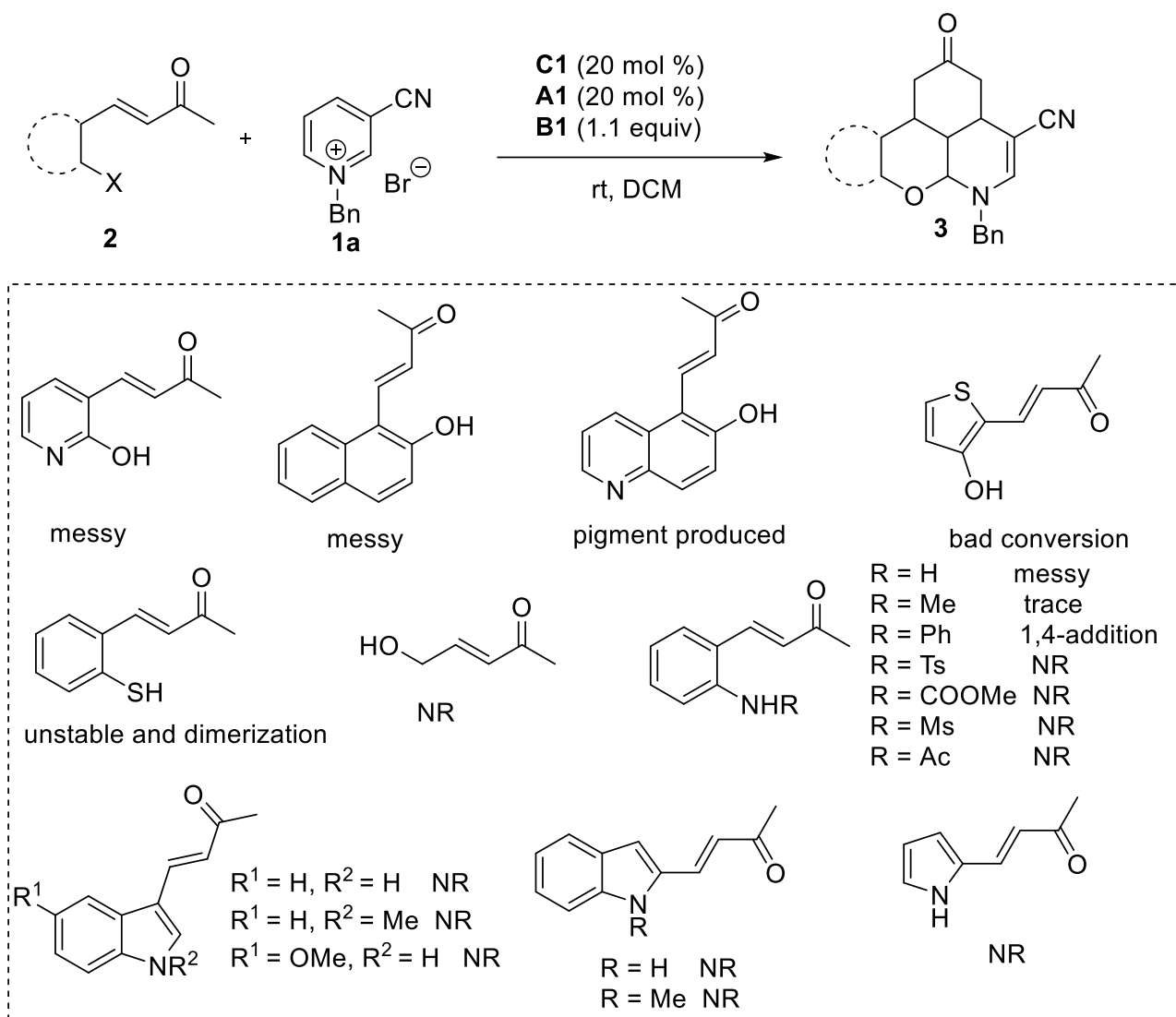
Synthesis of 10: To a solution of **3a** (35.6 mg, 0.0999 mmol) and 2-aminobenzaldehyde **9** (14.5 mg, 0.119 mol, 1.2 equiv) in EtOH (1.0 mL) was added KOH (6.7 mg, 0.12 mol, 1.2 equiv). The mixture was stirred at room temperature for 18 h. Then the mixture was concentrated under reduced pressure and purified by flash chromatography on silica gel (EtOAc/petroleum ether = 1:4 to 1:3) gave product **10**: 36.8 mg (0.0831 mmol), as a white solid, 83% yield; mp = 239–240 °C; $[\alpha]_{\text{D}}^{25} = +153.3$ ($c = 0.36$ in CHCl_3); 99% ee, determined by HPLC analysis [Daicel Chiralpak AD-H, *n*-hexane/*i*-PrOH = 60/40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 18.30 min, t (major) = 11.74 min; ¹H NMR (400 MHz, CDCl_3): δ 8.07 (s, 1H), 8.01 (d, $J = 8.4$ Hz, 1H), 7.85 (dd, $J = 8.1, 1.4$ Hz, 1H), 7.72–7.61 (m, 1H), 7.53 (td, $J = 7.4, 6.8, 1.2$ Hz, 1H), 7.43–7.28 (m, 5H), 7.09–7.01 (m, 1H), 6.94 (t, $J = 1.2$ Hz, 1H), 6.89–6.81 (m, 2H), 6.79–6.68 (m, 1H), 5.02 (d, $J = 2.7$ Hz, 1H), 4.68 (d, $J = 9.0$ Hz, 1H), 4.61 (d, $J = 14.7$ Hz, 1H), 4.46 (d, $J = 14.7$ Hz, 1H), 3.26 (dd, $J = 14.4, 3.0$ Hz, 1H), 3.00 (td, $J = 9.2, 2.7$ Hz, 1H), 2.90 (t, $J = 13.9$ Hz, 1H), 2.68–2.56 (m, 1H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 160.2, 154.1, 146.7, 145.6, 135.8, 134.1, 132.9, 129.9, 129.3, 129.0, 128.9, 128.4, 128.3, 128.1, 127.6, 127.3, 126.3, 123.2, 122.3, 120.4, 117.7, 83.8, 82.5, 57.2, 40.0, 36.7, 34.4, 33.0; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{30}\text{H}_{24}\text{N}_3\text{O}$ 442.1914; Found 442.1920.



A mixture of product **8a** (40.8 mg, 0.0999 mmol) and 10% palladium on charcoal (40.8 mg, 0.0100 mmol, 10 mol %,) in methanol (2 mL) was purged with hydrogen. The mixture was stirred at room temperature for 3 h, filtered through celite, washed with DCM and concentrated in vacuo. The residue was purified by column chromatography on silica gel (petroleum ether/EtOAc = 1:1 to 3:1) to give

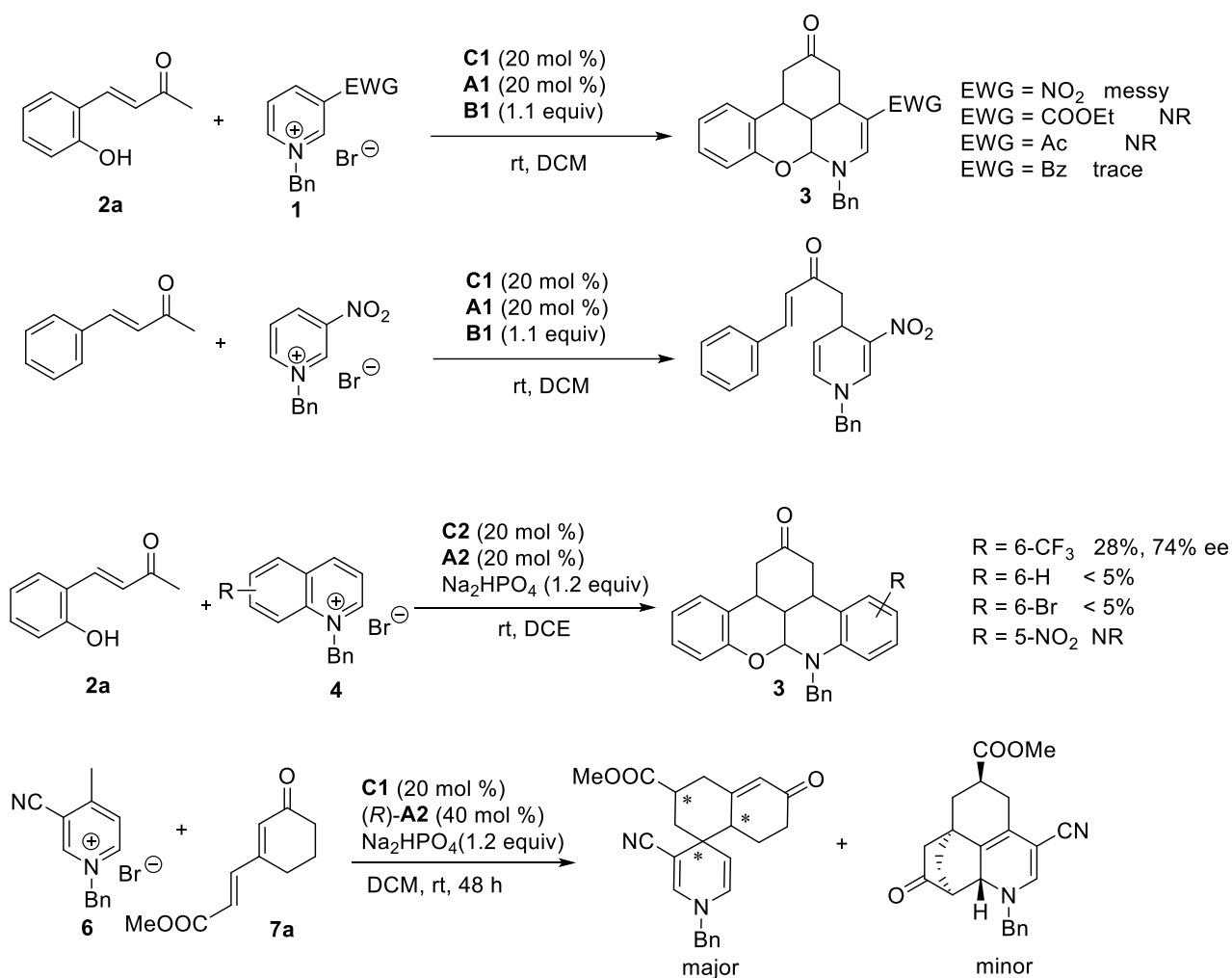
product **12**: 12.0 mg (0.0419 mmol), as a white solid, 42% yield; mp = 203–204 °C; $[\alpha]_{\text{D}}^{25} = +119.5$ ($c = 0.37$ in CHCl_3); 80% ee, determined by HPLC analysis [Daicel Chiralpak ID, *n*-hexane/*i*-PrOH = 60/40, 1.0 mL min⁻¹, $\lambda = 254$ nm]: t (minor) = 20.71 min, t (major) = 23.97 min; ¹H NMR (400 MHz, CDCl_3): δ (ppm) 7.87 (s, 1H), 3.77 (s, 3H), 3.73 (q, $J = 4.1, 3.3$ Hz, 1H), 2.93–2.71 (m, 2H), 2.58 (dd, $J = 16.0, 11.0$ Hz, 1H), 2.36 (d, $J = 18.4$ Hz, 1H), 2.28 (dt, $J = 13.6, 2.2$ Hz, 1H), 2.19–2.02 (m, 1H), 1.98–1.86 (m, 2H), 1.82–1.63 (m, 3H); ¹³C NMR (100 MHz, CDCl_3): δ (ppm) 209.5, 174.9, 145.8, 139.8, 134.3, 134.1, 126.5, 54.2, 52.2, 48.3, 37.5, 37.0, 35.3, 31.0, 25.7, 24.3; HRMS (ESI-TOF) m/z : $[\text{M} + \text{H}]^+$ Calcd for $\text{C}_{16}\text{H}_{18}\text{N}_2\text{O}_3$ 287.1390; Found 287.1381.

6. More substrate exploration



Scheme S1. More exploration on the reactions with diverse enones

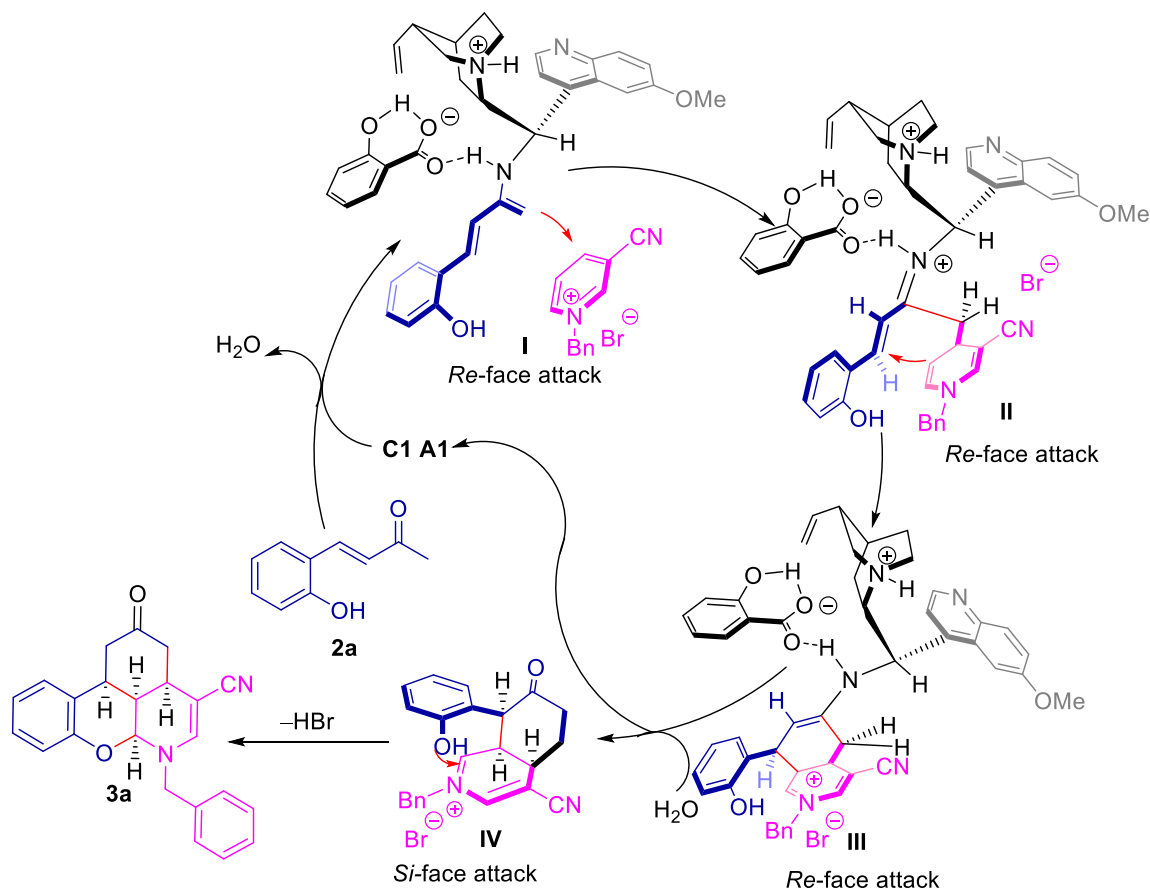
Then we explored the dearomative cascade reactions between other enones and pyridinium salt **1a** under the catalysis of **C1**. Unfortunately, there was no success and results were outlined in the above **Scheme S1**.



Scheme S2. More exploration on other pyridinium and quinolinium salts

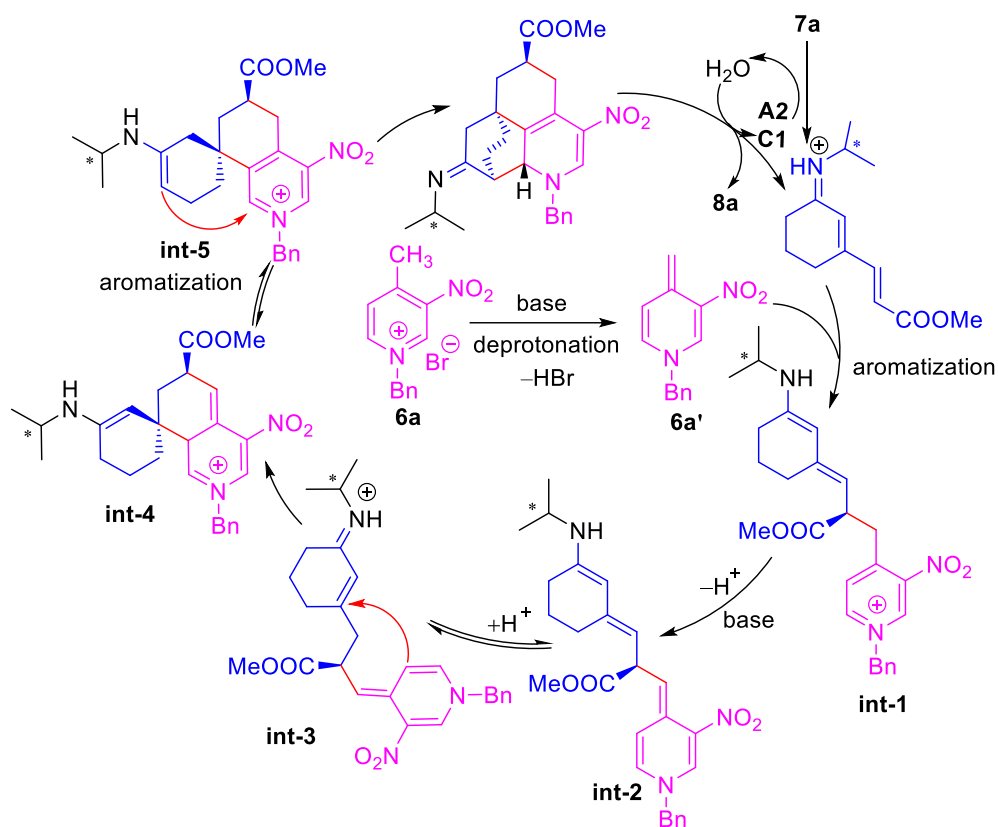
We found the 3-cyano group was essential for the dearomative cascade reaction. When other 3-EWG substituted pyridinium salts were tested, the reaction was messy for the 3-NO₂ substituted pyridinium salt. In addition, the reaction didn't occur for the salts with other weaker electron withdrawing groups. In addition, the unsuccessful attempts were summarized in **Scheme S2**.

7. Proposed catalytic mechanism



Scheme S3 Proposed mechanism and transition state for the formation of **3a**.

As outlined in Scheme S3, after condensation of chiral amine **C1** with compound **2a**, a cross dienamine intermediate **I** was formed and then attacked **1a** from *Re*-face to give **II**. Then a Michael reaction occurred for the dearomatized enamine-type intermediates, followed by hydrolysis of **III** to regenerate the catalyst. Finally, the hydroxyl group captured iminium ion from *Si*-face to give the desired product **3a**.



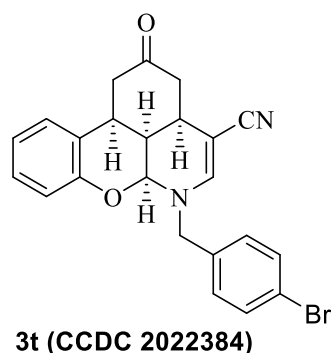
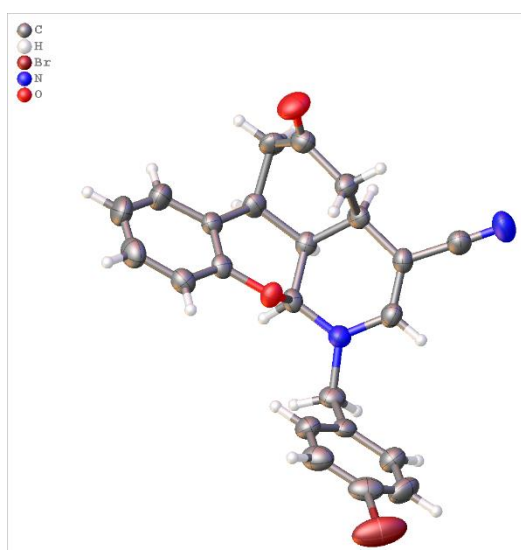
Scheme S4 Proposed reaction pathway for the formation of **8a**.

As outlined in Scheme S4, **7a** first was condensed with chiral amine **C1** to form an iminium ion intermediate. On the other hand, the activated nucleophile **6a'** formed by the deprotonation of **6a**, attacked the iminium ion intermediate to deliver **int-1**, followed by dearomatization and tautomerization to give **int-3**, and then an intramolecular Michael addition occurred to furnish spirocyclic **int-4**. After the second aromatization and tautomerization, **int-5** was generated and the enamine moiety attacked the pyridinium ring, finally furnishing fused and bridged architecture **8** after the release of the catalyst.

8. Crystal data and structural refinement

8.1 Procedure for the recrystallization of **3t**

To a 10 mL tube containing **3t** (20 mg) was added a 1:3 mixture of *n*-hexane and dichloromethane (about 3 mL). The mixture was heated until a clear solution was formed, which was kept aside overnight at room temperature to obtain crystals. The crystals were subjected for single crystal XRD to determine the absolute configuration of **3t**. The data were collected by an Xcalibur E equipped with a Mo radiation source ($K\alpha = 0.71073 \text{ \AA}$) at 293.15 K. CCDC 2022384 (**3t**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif.



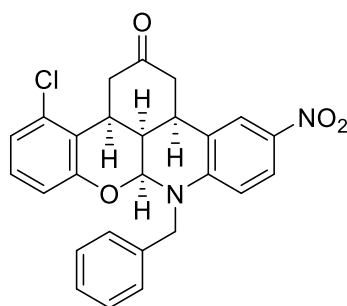
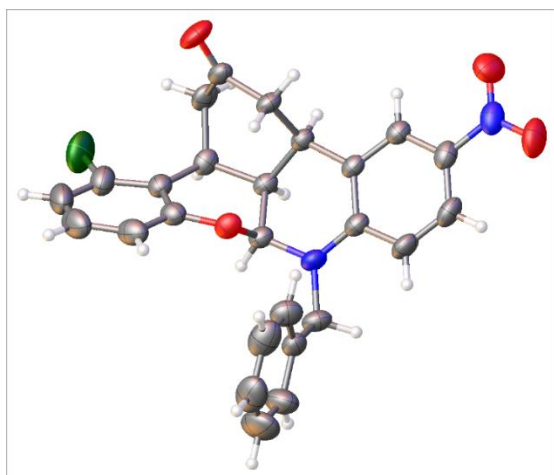
(ellipsoid contour probability 50%)

Identification code	3t
Empirical formula	$C_{23}H_{19}BrN_2O_2$
Formula weight	435.31
Temperature/K	293.15
Crystal system	orthorhombic
Space group	$P2_12_12_1$
$a/\text{\AA}$	5.7376(4)
$b/\text{\AA}$	8.6079(7)
$c/\text{\AA}$	39.542(3)
$\alpha/^\circ$	90

$\beta/^{\circ}$	90
$\gamma/^{\circ}$	90
Volume/ \AA^3	1952.9(3)
Z	4
$\rho_{\text{calc}}/\text{g}/\text{cm}^3$	1.481
μ/mm^{-1}	2.126
F(000)	888.0
Crystal size/ mm^3	$0.35 \times 0.3 \times 0.25$
Radiation	MoK α ($\lambda = 0.71073$)
2Θ range for data collection/ $^{\circ}$	6.182 to 52.72
Index ranges	$-6 \leq h \leq 7, -10 \leq k \leq 9, -49 \leq l \leq 48$
Reflections collected	11104
Independent reflections	3945 [$R_{\text{int}} = 0.0406, R_{\text{sigma}} = 0.0474$]
Data/restraints/parameters	3945/0/253
Goodness-of-fit on F^2	1.072
Final R indexes [$I \geq 2\sigma(I)$]	$R_1 = 0.0491, wR_2 = 0.1043$
Final R indexes [all data]	$R_1 = 0.0626, wR_2 = 0.1144$
Largest diff. peak/hole / $e \text{ \AA}^{-3}$	0.25/-0.65
Flack parameter	-0.004(6)

8.2 Procedure for the recrystallization of **5k**

To an NMR tube containing **5k** (25 mg) was added CDCl_3 (about 1.5 mL). Crystals were obtained by solvent evaporation at room temperature. The crystals were subjected for single crystal XRD to determine the absolute configuration of **5k**. The data were collected by an Agilent Gemini equipped with a Cu radiation source ($K\alpha = 1.54184 \text{ \AA}$) at 296.11 K. CCDC 2022385 (**5k**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif.



5k (CCDC 2022385)

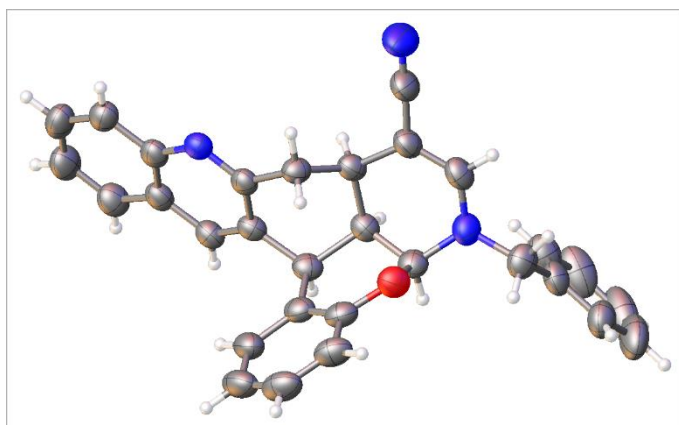
(ellipsoid contour probability 50%)

Identification code	5k
Empirical formula	$C_{26}H_{21}ClN_2O_4$
Formula weight	460.90
Temperature/K	296.11
Crystal system	orthorhombic
Space group	$P2_12_12_1$
$a/\text{\AA}$	8.9839(3)
$b/\text{\AA}$	10.1735(3)
$c/\text{\AA}$	23.7806(8)
$\alpha / ^\circ$	90
$\beta / ^\circ$	90
$\gamma / ^\circ$	90
Volume/ \AA^3	2173.48(12)
Z	4
$\rho_{\text{calc}}/\text{cm}^3$	1.408
μ/mm^{-1}	1.869
$F(000)$	960.0
Crystal size/ mm^3	$0.6 \times 0.4 \times 0.3$
Radiation	$\text{CuK}\alpha$ ($\lambda = 1.54184$)
2θ range for data collection/ $^\circ$	7.434 to 142.634

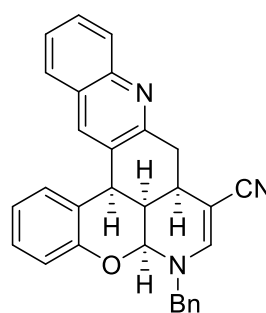
Index ranges	$-7 \leq h \leq 10, -12 \leq k \leq 12, -25 \leq l \leq 28$
Reflections collected	11768
Independent reflections	4160 [$R_{\text{int}} = 0.0475, R_{\text{sigma}} = 0.0394$]
Data/restraints/parameters	4248/0/298
Goodness-of-fit on F^2	1.059
Final R indexes [$I \geq 2\sigma(I)$]	$R_1 = 0.0559, wR_2 = 0.1394$
Final R indexes [all data]	$R_1 = 0.0559, wR^2 = 0.1464$
Largest diff. peak/hole / $e \text{ \AA}^{-3}$	0.26/-0.40
Flack parameter	0.005(13)

8.3 Procedure for the recrystallization of **10**

To a 10 mL tube containing **10** (25 mg) was added a 4:1 mixture of EtOAc and dichloromethane (about 2 mL). A clear solution was formed by ultrasound treatment, which was kept aside for 2 days at room temperature to obtain crystals. The crystals were subjected for single crystal XRD to determine the absolute configuration of **10**. The data were collected by an Agilent Gemini equipped with a Cu radiation source ($K\alpha = 1.54184 \text{ \AA}$) at 295.9(4) K. CCDC 2023072 (**10**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif.



(ellipsoid contour probability 50%)



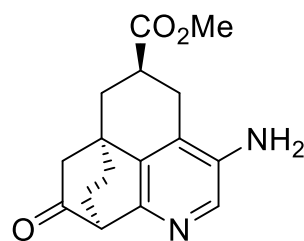
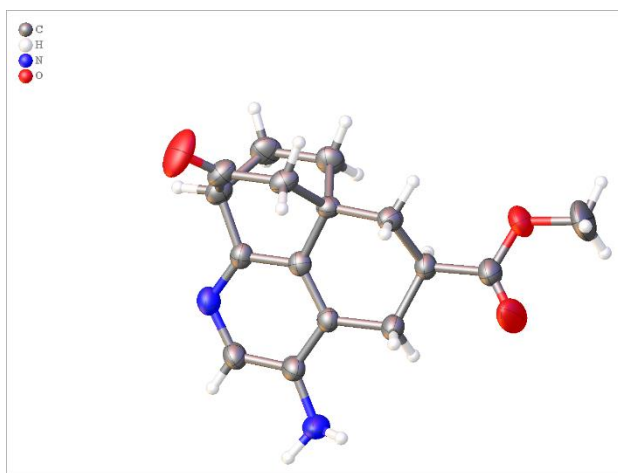
10 (CCDC 2023072)

Identification code	10
Empirical formula	$C_{30}H_{23}N_3O$
Formula weight	441.51

Temperature/K	295.9(4)
Crystal system	orthorhombic
Space group	P2 ₁ 2 ₁ 2 ₁
a/Å	9.3601(3)
b/Å	12.7584(4)
c/Å	18.9146(6)
α / °	90
β / °	90
γ / °	90
Volume/Å ³	2258.78(12)
Z	4
$\rho_{\text{calc}}/\text{cm}^3$	1.298
μ/mm^{-1}	0.626
F (000)	928.0
Crystal size/mm ³	0.55 × 0.3 × 0.2
Radiation	CuK α (λ = 1.54184)
2 Θ range for data collection/°	8.36 to 128.742
Index ranges	-10 ≤ h ≤ 6, -14 ≤ k ≤ 14, -21 ≤ l ≤ 22
Reflections collected	10552
Independent reflections	3761 [R_{int} = 0.0615, R_{sigma} = 0.0488]
Data/restraints/parameters	3761/14/307
Goodness-of-fit on F ²	1.037
Final R indexes [$I \geq 2\sigma(I)$]	R_1 = 0.0673, wR_2 = 0.1655
Final R indexes [all data]	R_1 = 0.0711, wR_2 = 0.1733
Largest diff. peak/hole / e Å ⁻³	0.23/-0.38
Flack parameter	-0.1(4)

8.4 Procedure for the recrystallization of **11**

To a 10 mL tube containing **11** (15 mg) was added a 5:1 mixture of EtOAc and dichloromethane (about 2 mL). A clear solution was formed by ultrasound treatment, which was kept aside for 2 days at room temperature to obtain crystals. The crystals were subjected for single crystal XRD to determine the absolute configuration of **11**. The data were collected by an Agilent Gemini equipped with a Cu radiation source ($K\alpha = 1.54184 \text{ \AA}$) at 296.3(4) K. CCDC 2022386 (**11**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif.



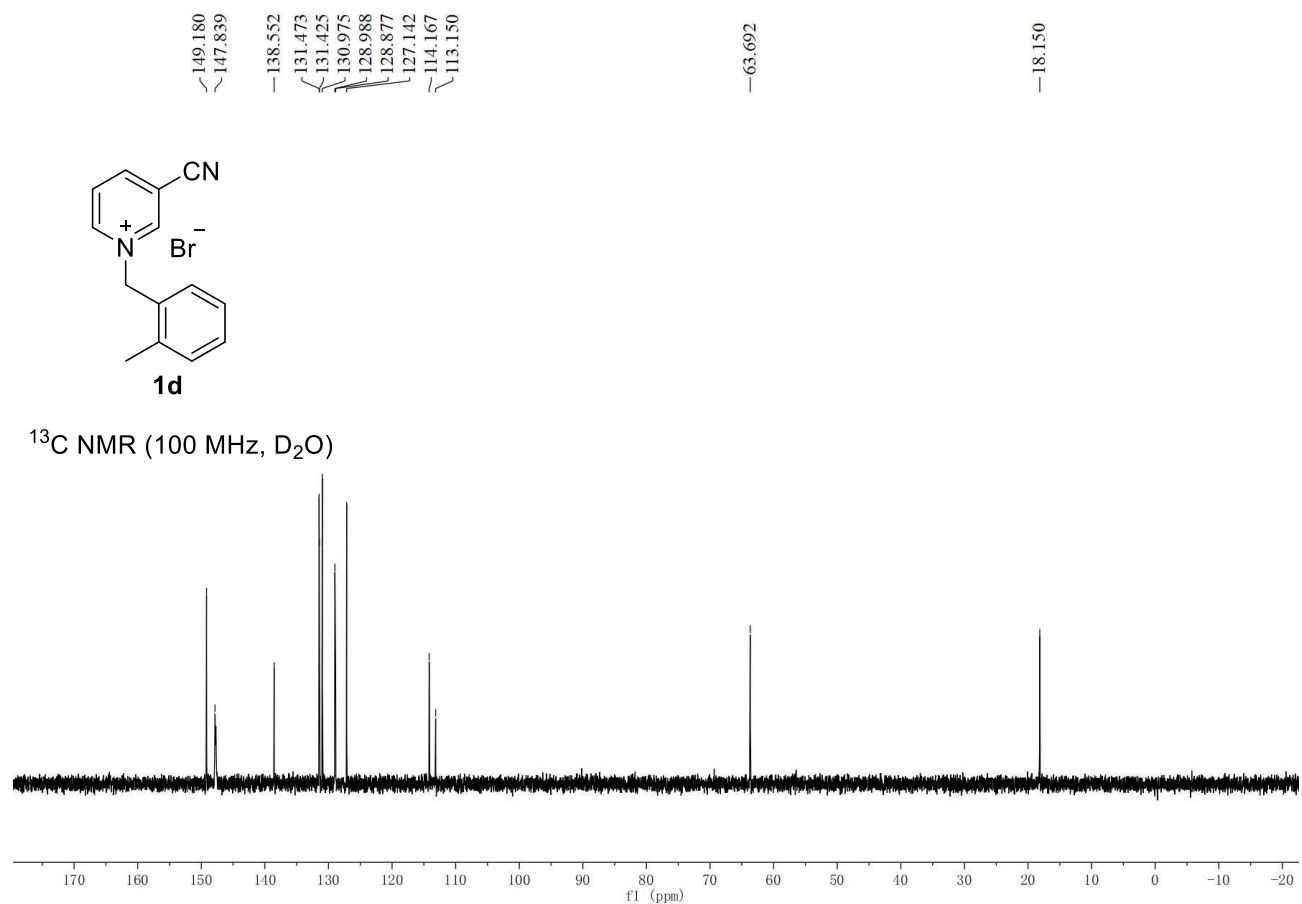
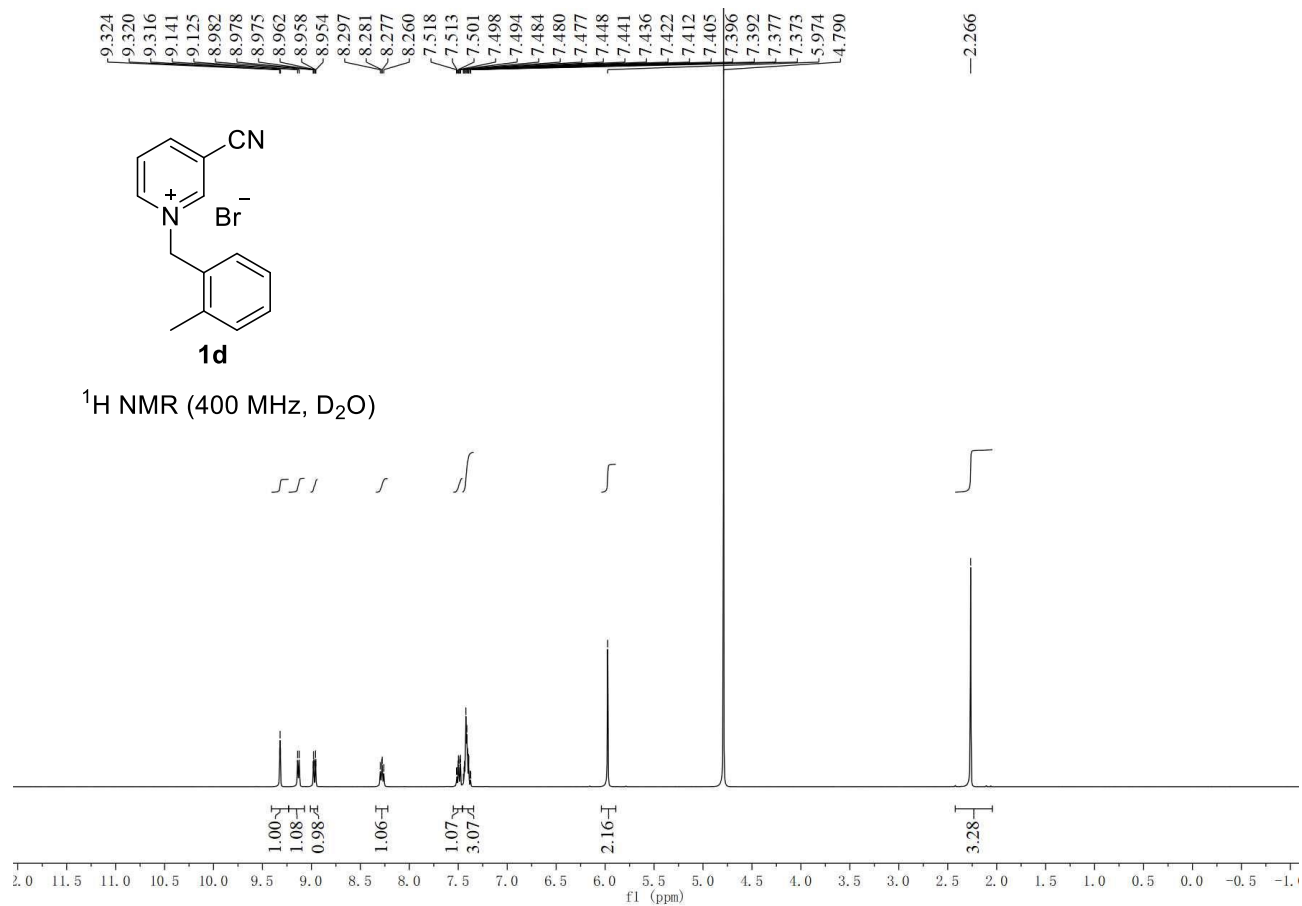
11 (CCDC 2022386)

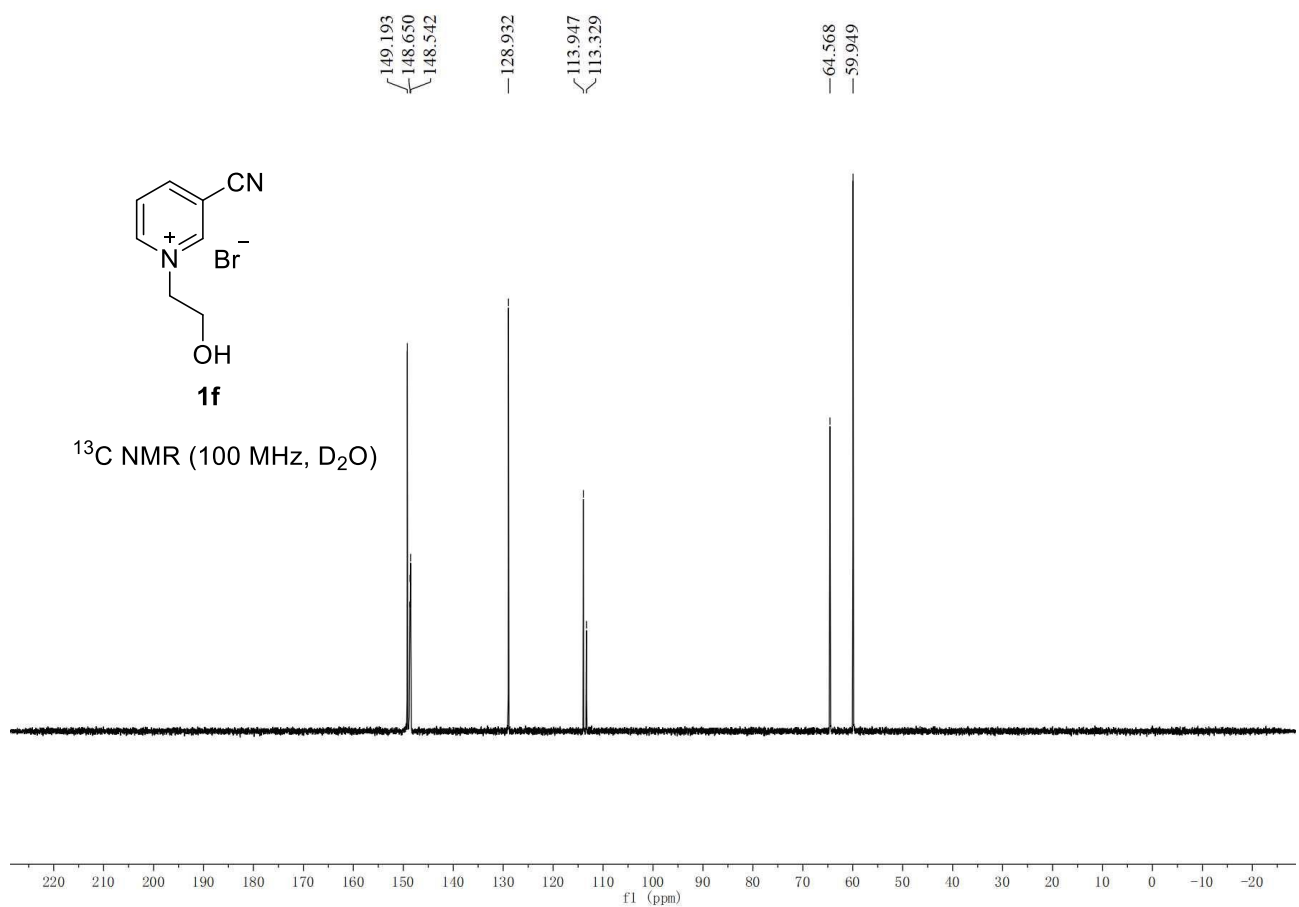
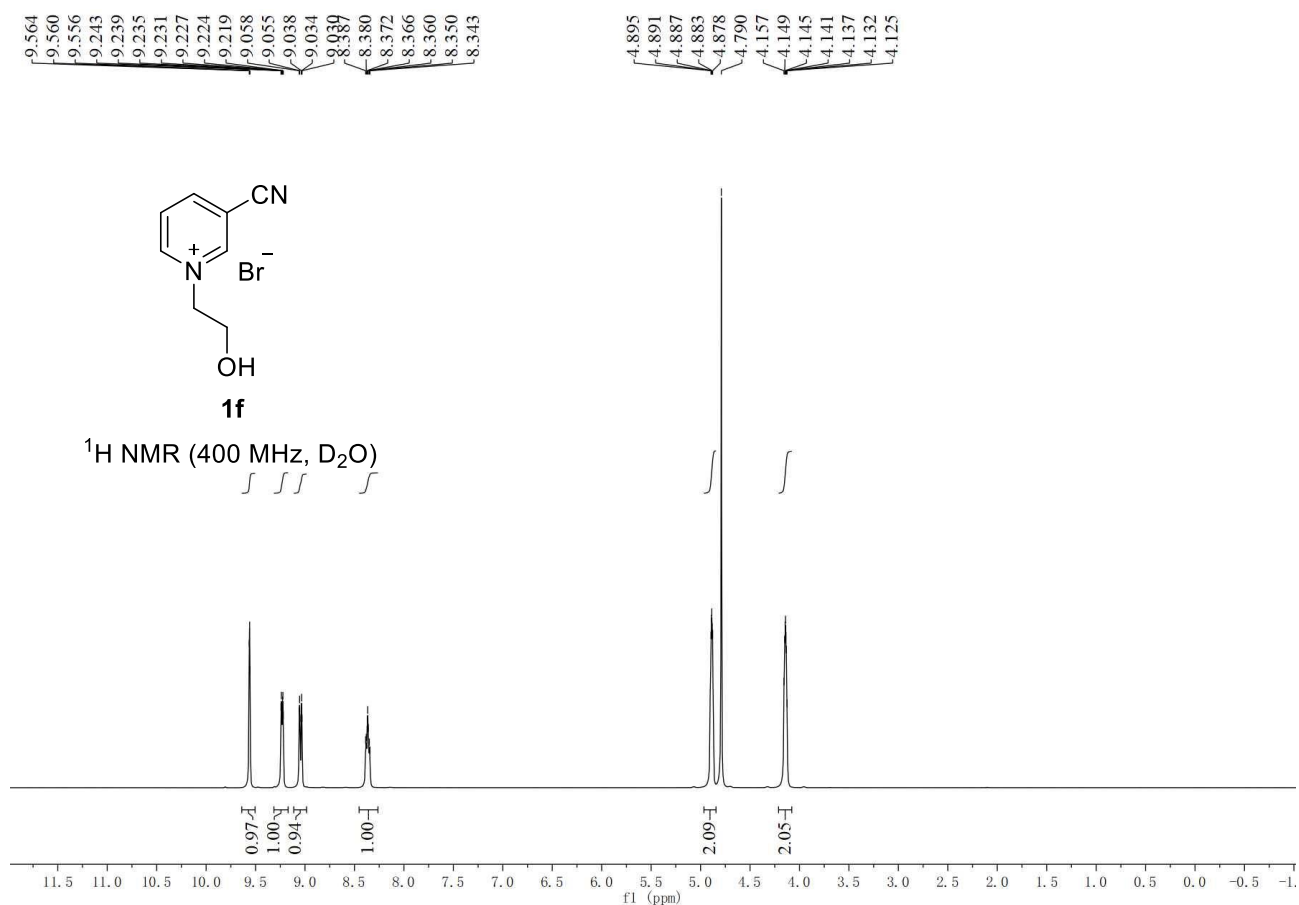
(ellipsoid contour probability 50%)

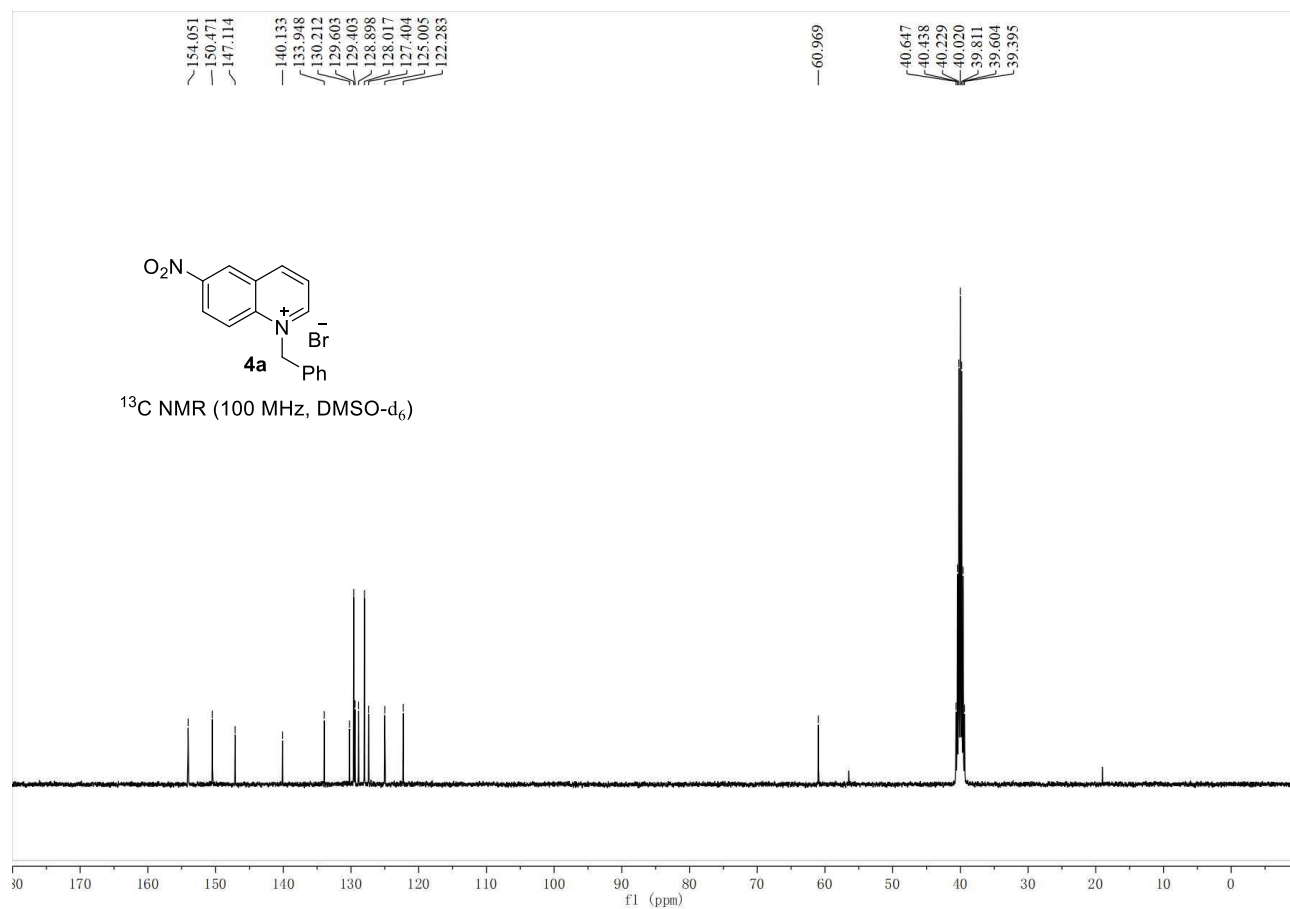
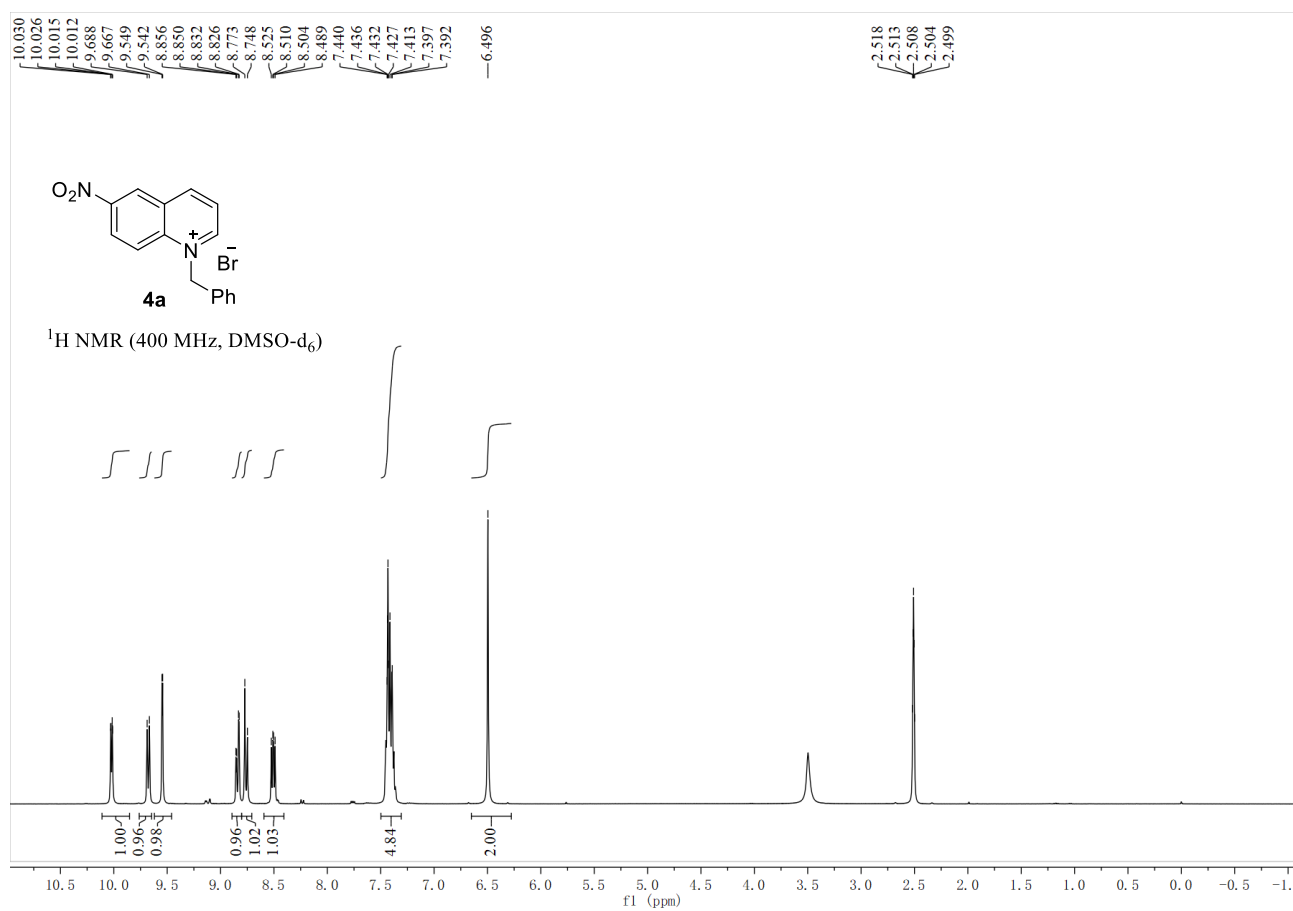
Identification code	11
Empirical formula	$C_{16}H_{18}N_2O_3$
Formula weight	286.32
Temperature/K	296.3(4)
Crystal system	orthorhombic
Space group	$P2_12_12_1$
$a/\text{\AA}$	5.70829(12)
$b/\text{\AA}$	11.8370(3)
$c/\text{\AA}$	21.2874(5)
$\alpha / ^\circ$	90
$\beta / ^\circ$	90
$\gamma / ^\circ$	90

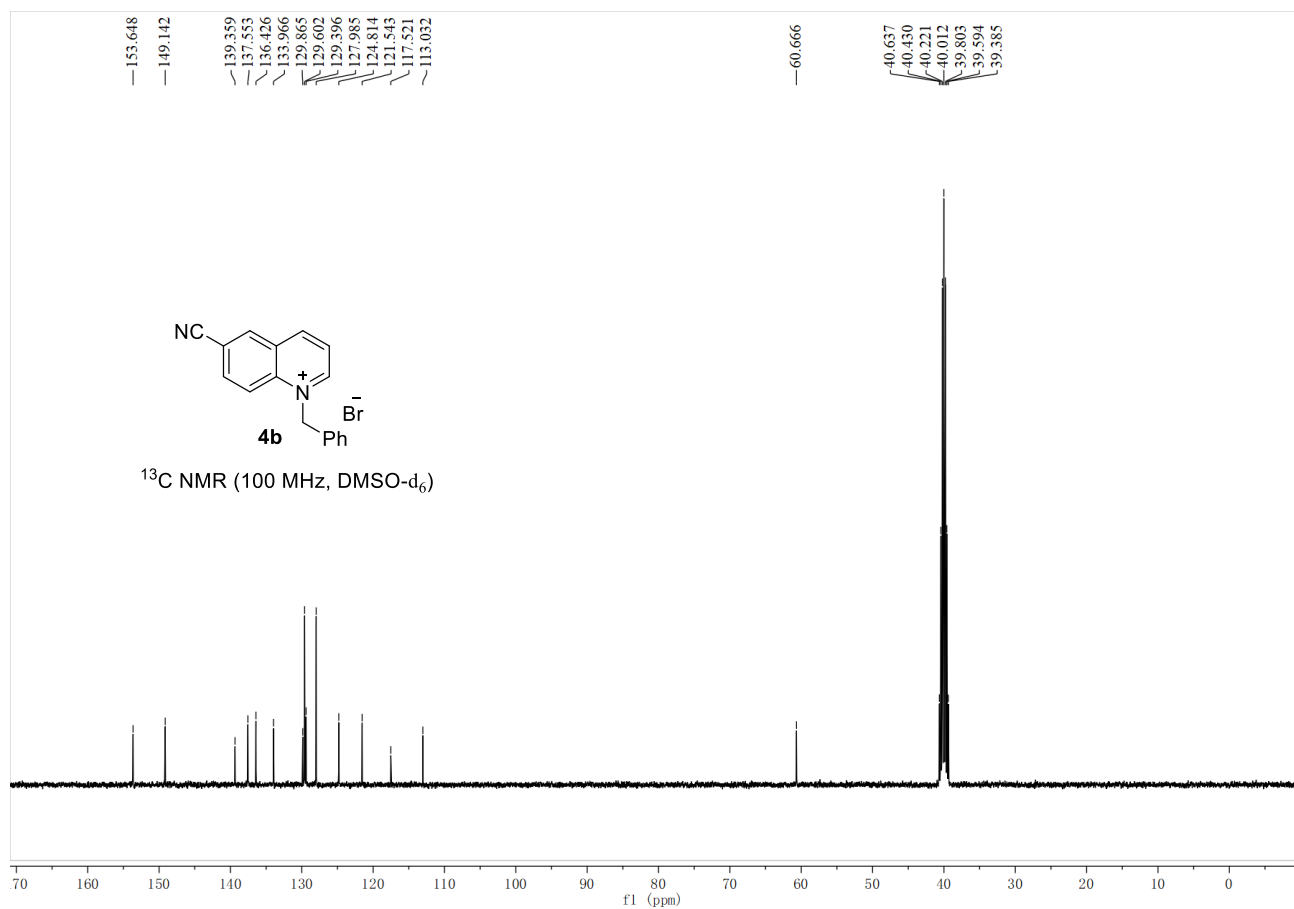
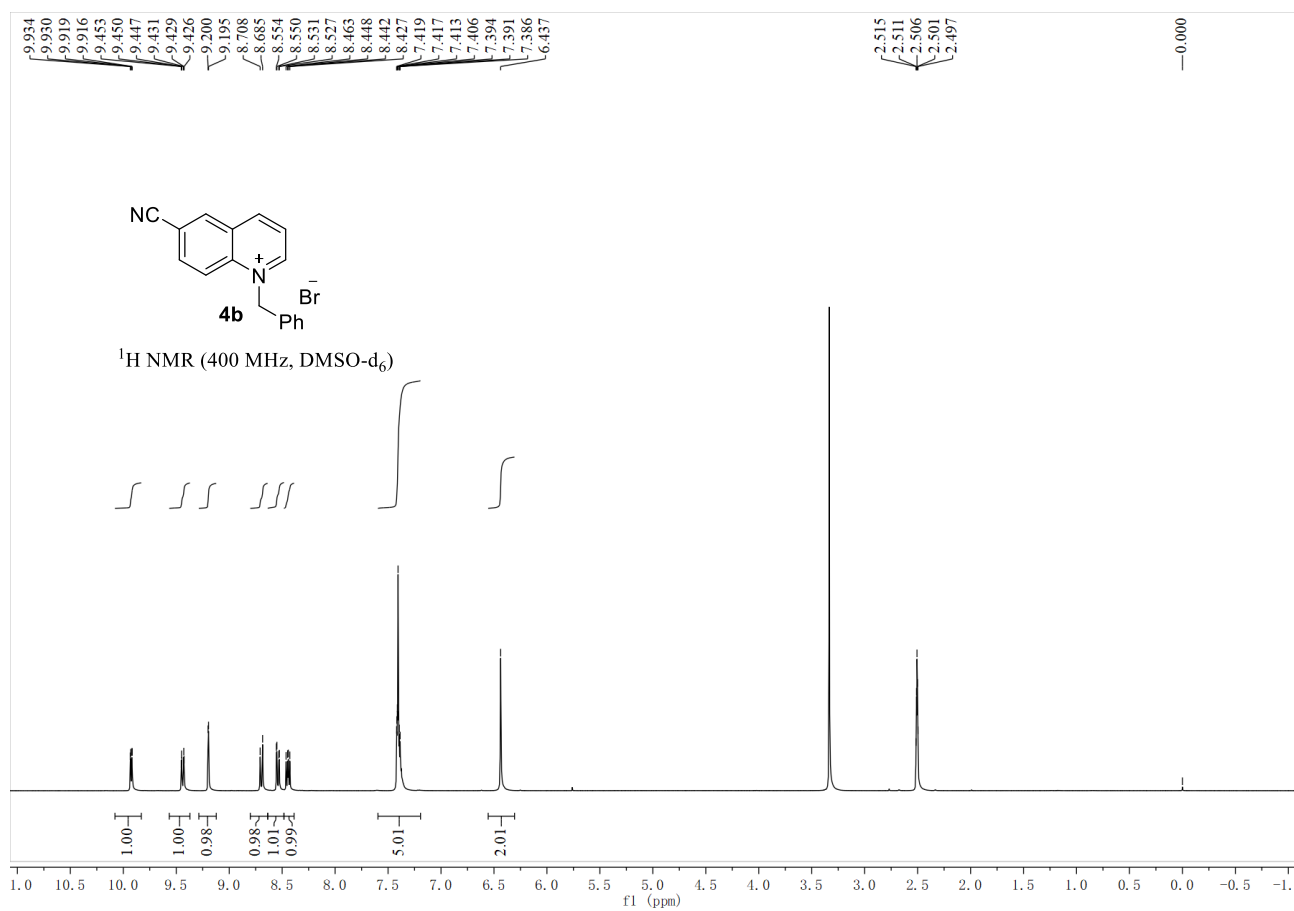
Volume/Å ³	1438.37(6)
Z	4
ρ _{calc} /cm ³	1.322
μ/mm ⁻¹	0.753
F (000)	608.0
Crystal size/mm ³	0.6 × 0.4 × 0.2
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	8.548 to 134.106
Index ranges	-6 ≤ h ≤ 4, -14 ≤ k ≤ 14, -25 ≤ l ≤ 25
Reflections collected	7455
Independent reflections	2564 [R _{int} = 0.0407, R _{sigma} = 0.0374]
Data/restraints/parameters	2564/0/198
Goodness-of-fit on F ²	1.057
Final R indexes [I ≥ 2σ (I)]	R ₁ = 0.0464, wR ₂ = 0.1257
Final R indexes [all data]	R ₁ = 0.0495, wR ₂ = 0.1304
Largest diff. peak/hole / e Å ⁻³	0.19/-0.22
Flack parameter	-0.1(2)

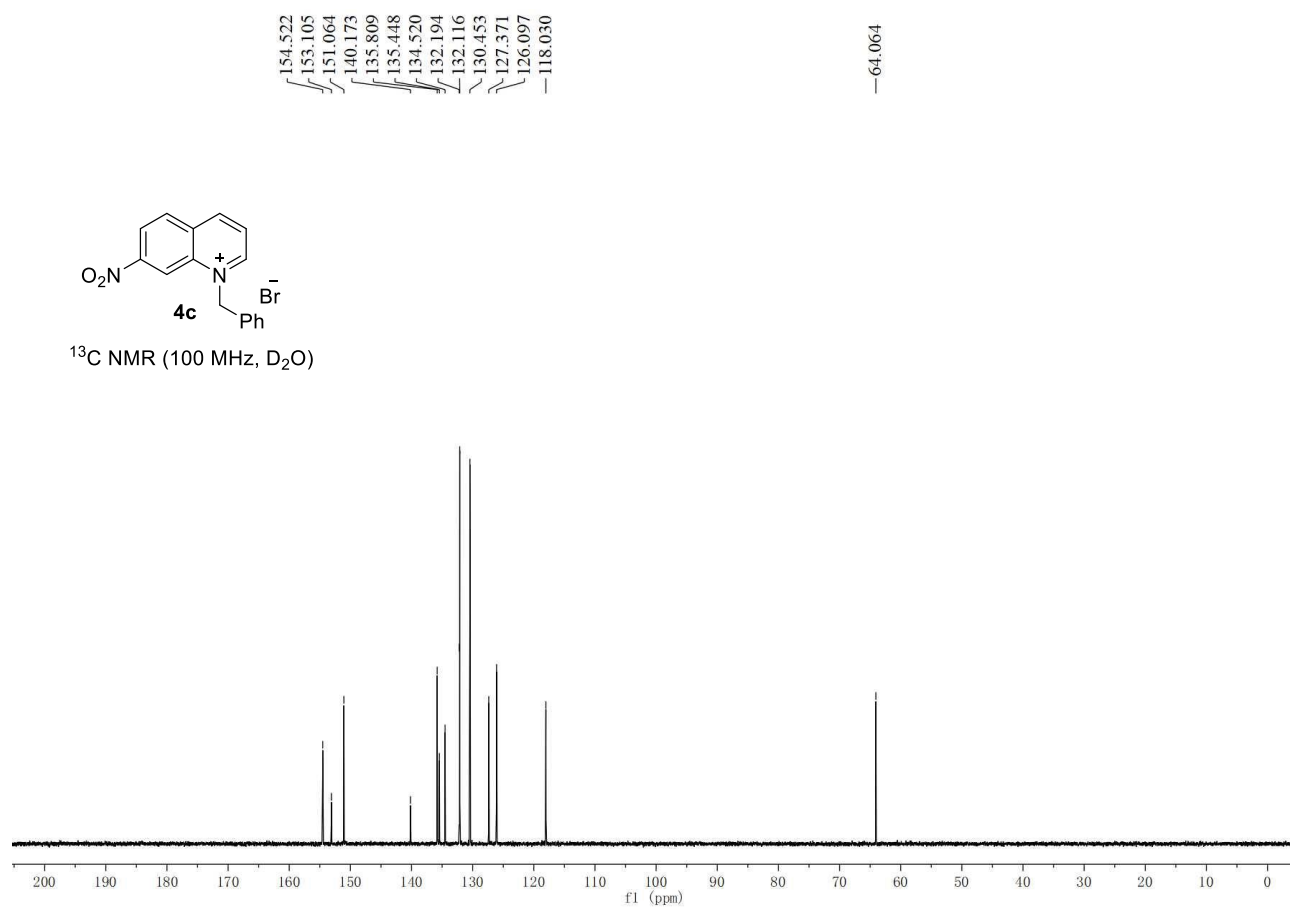
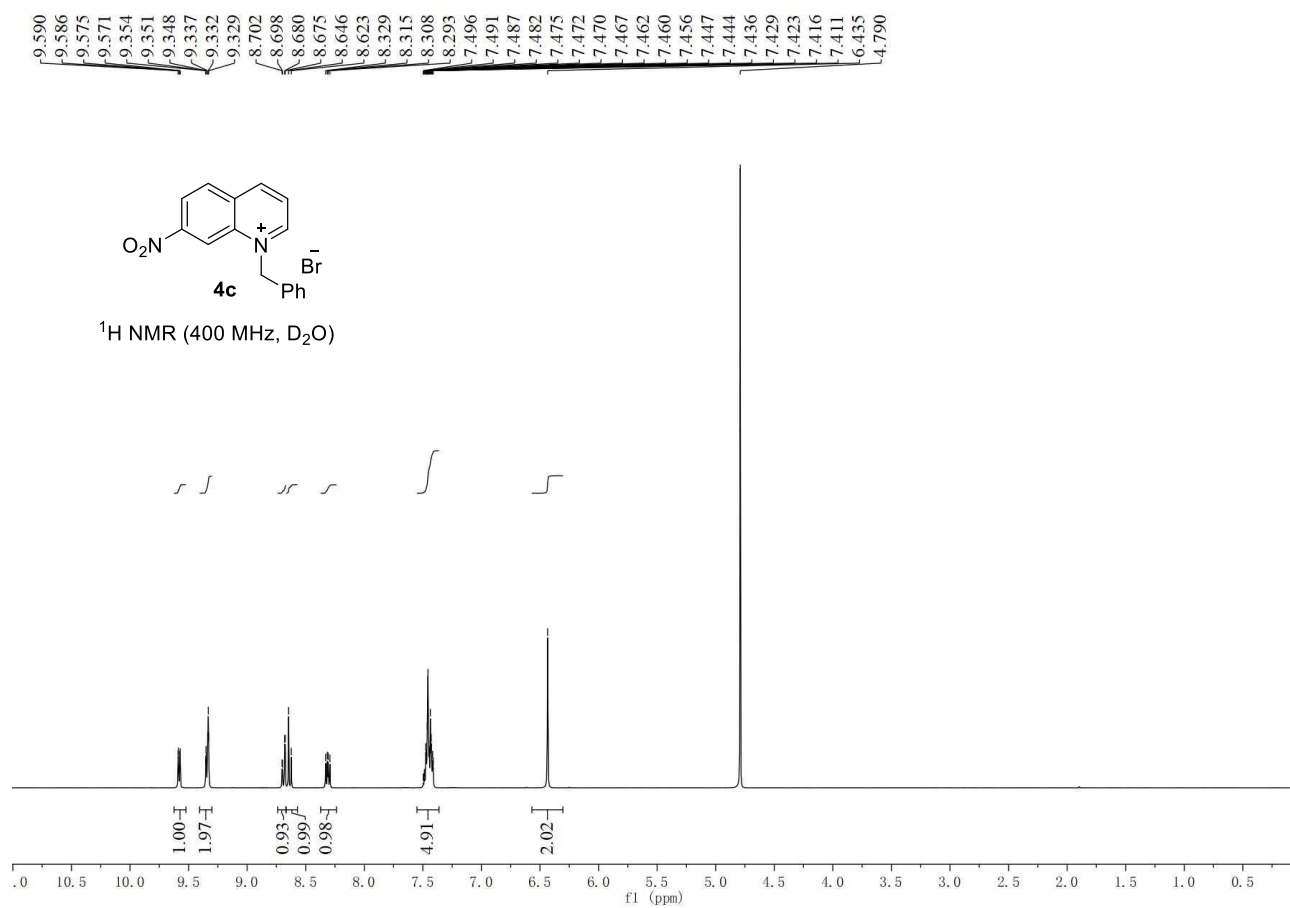
9. NMR, HRMS spectra and HPLC chromatograms

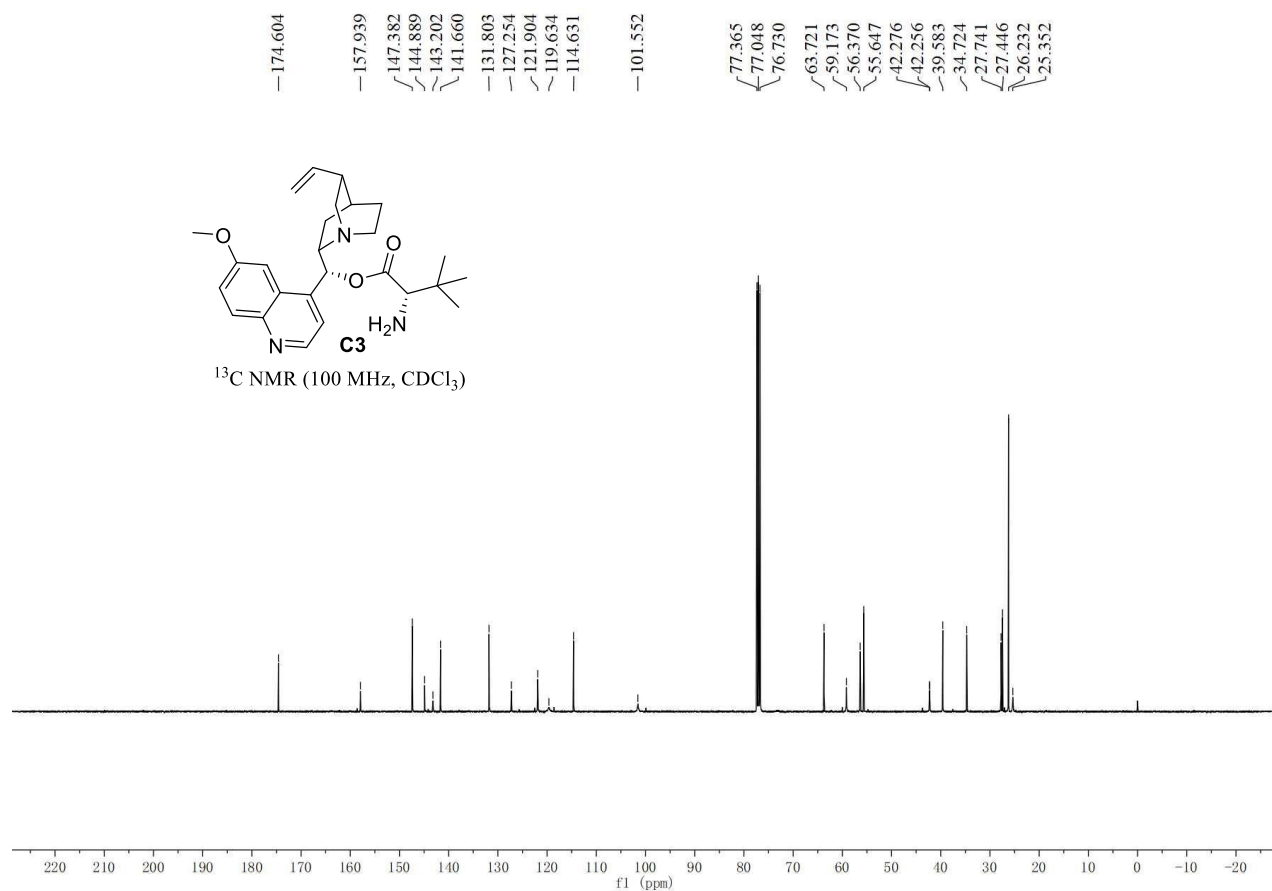
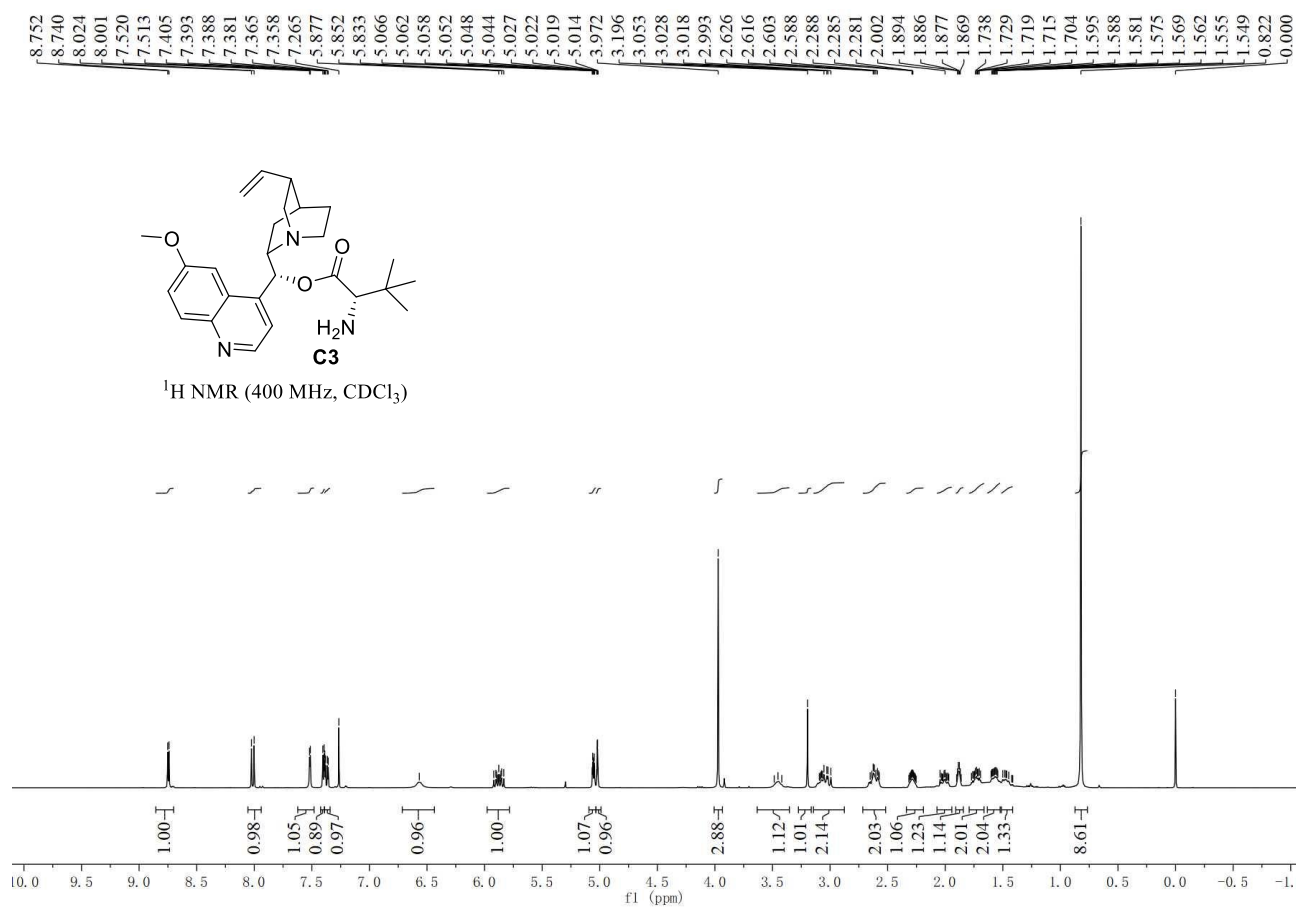


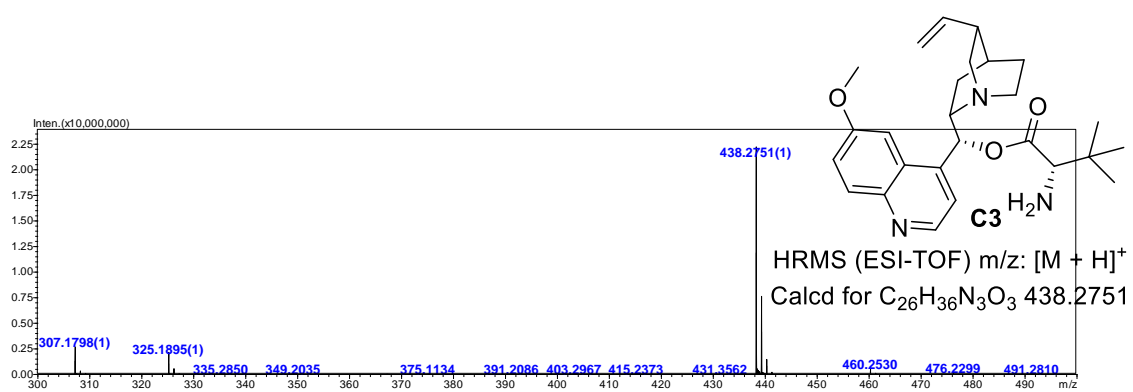


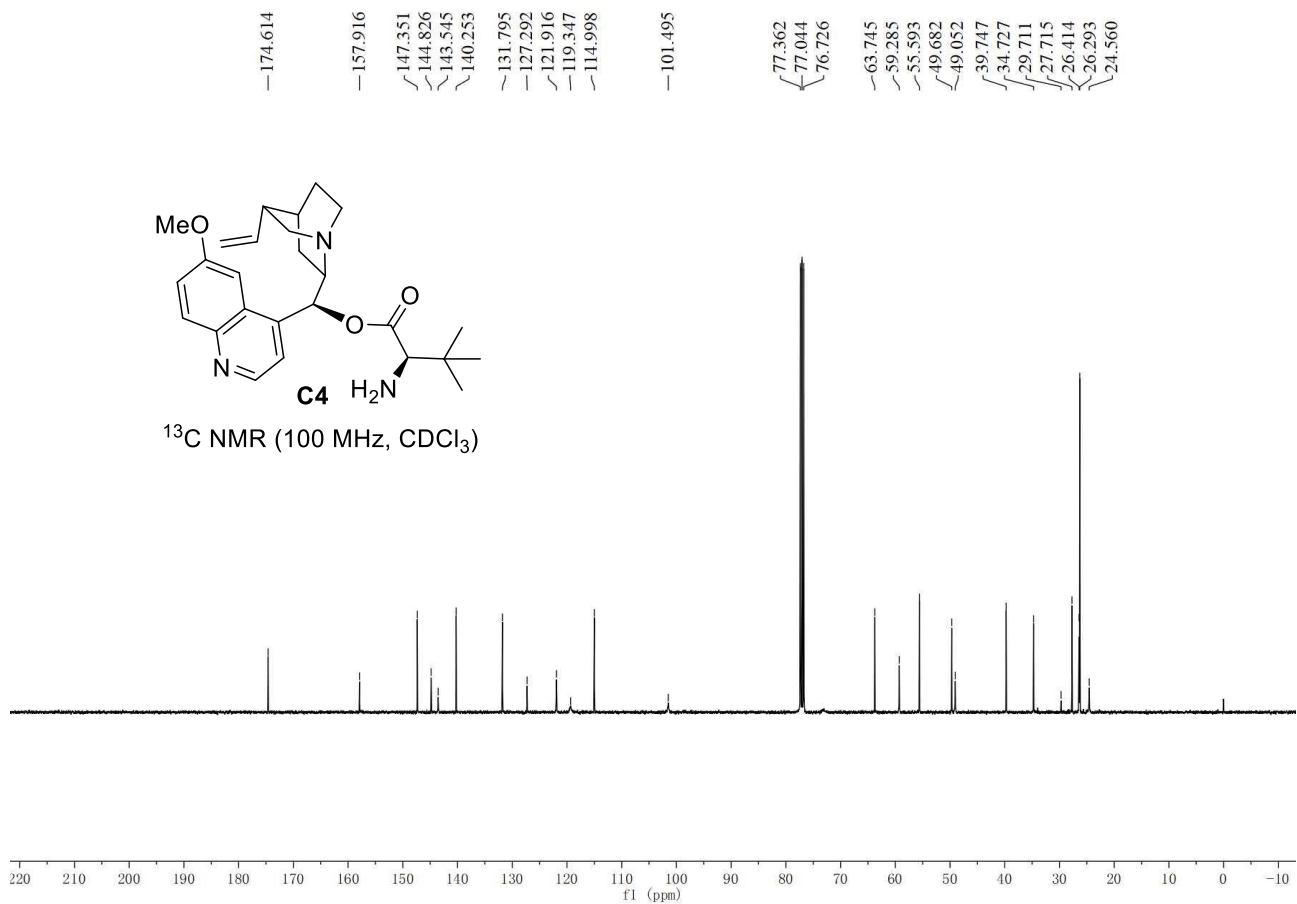
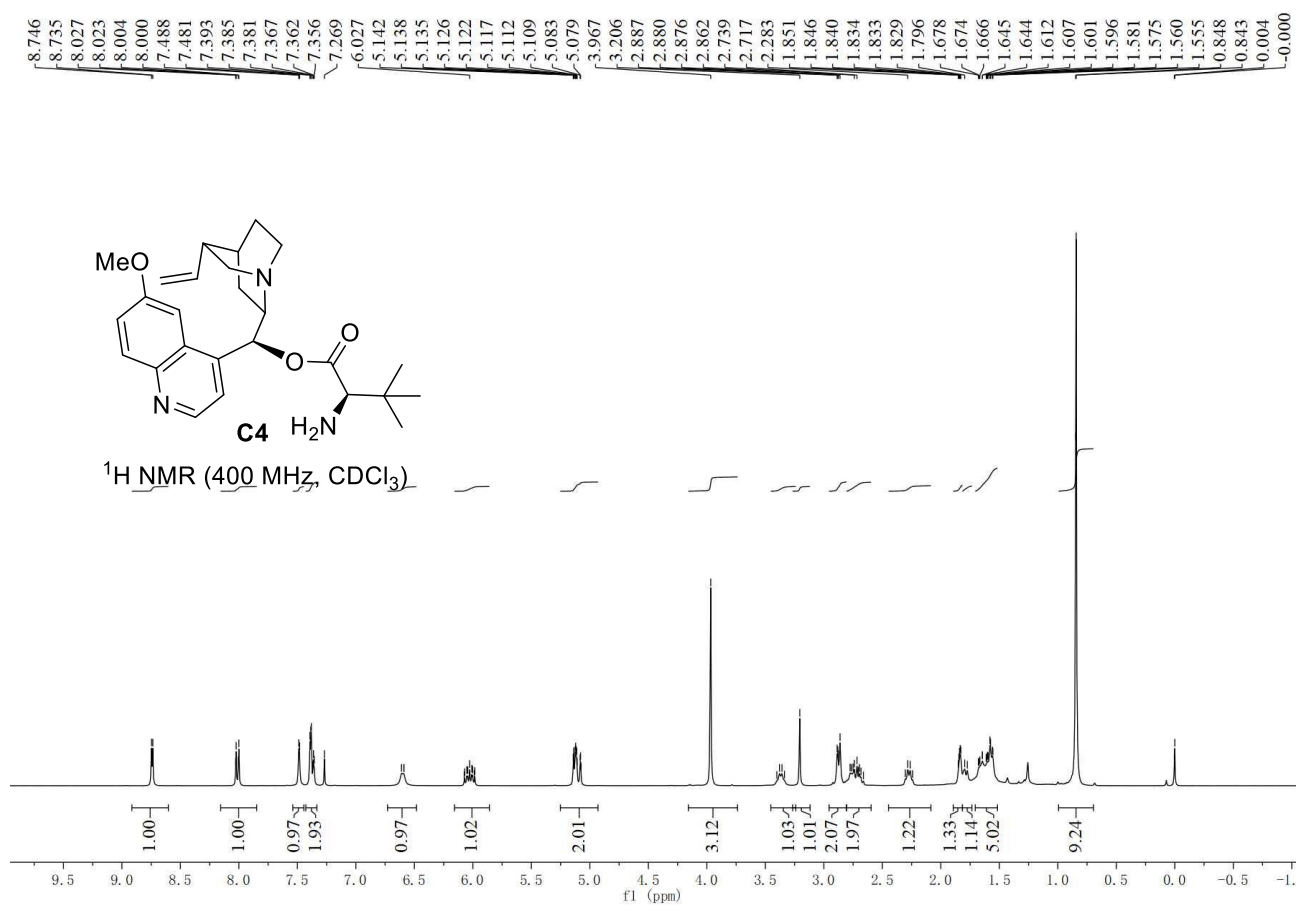


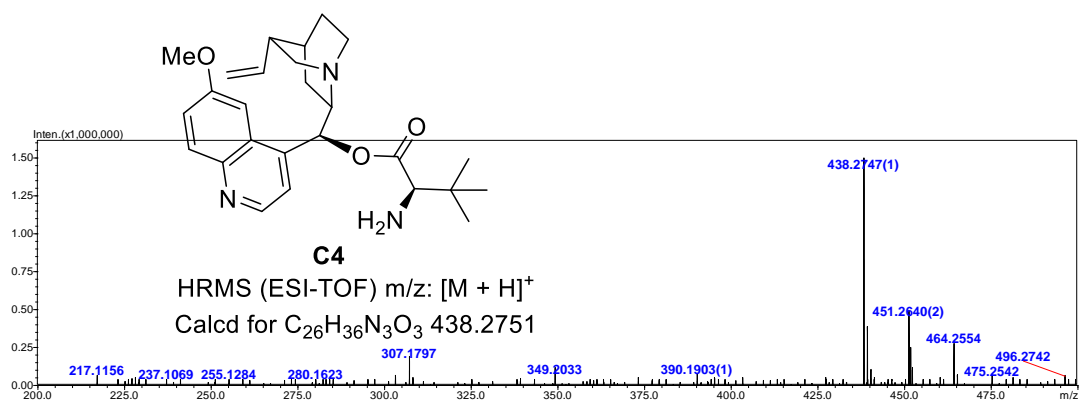


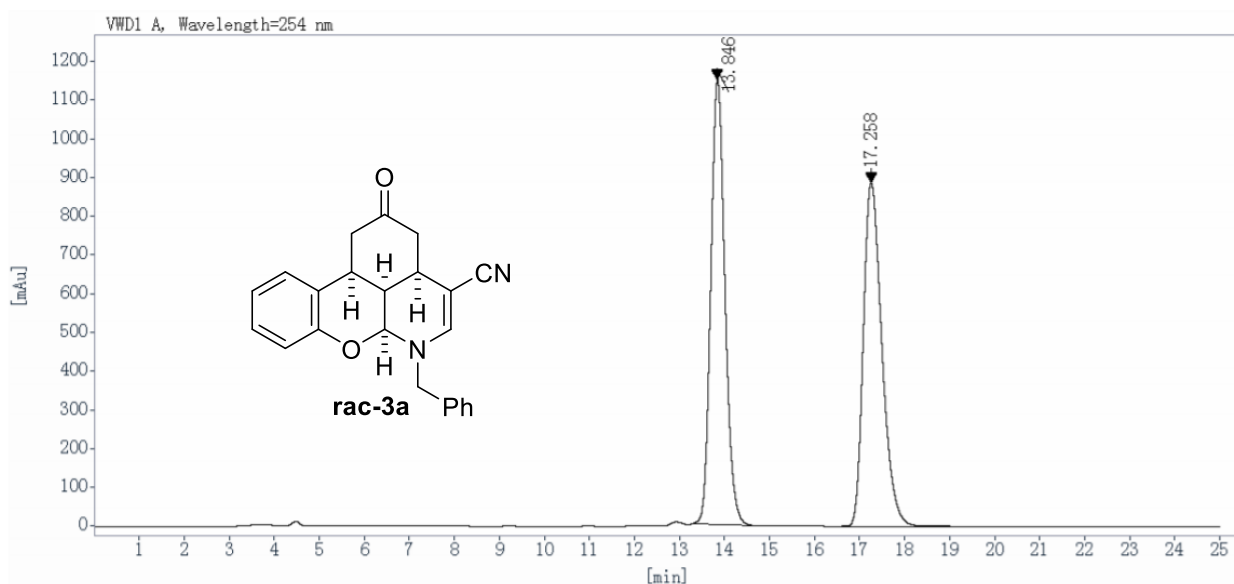




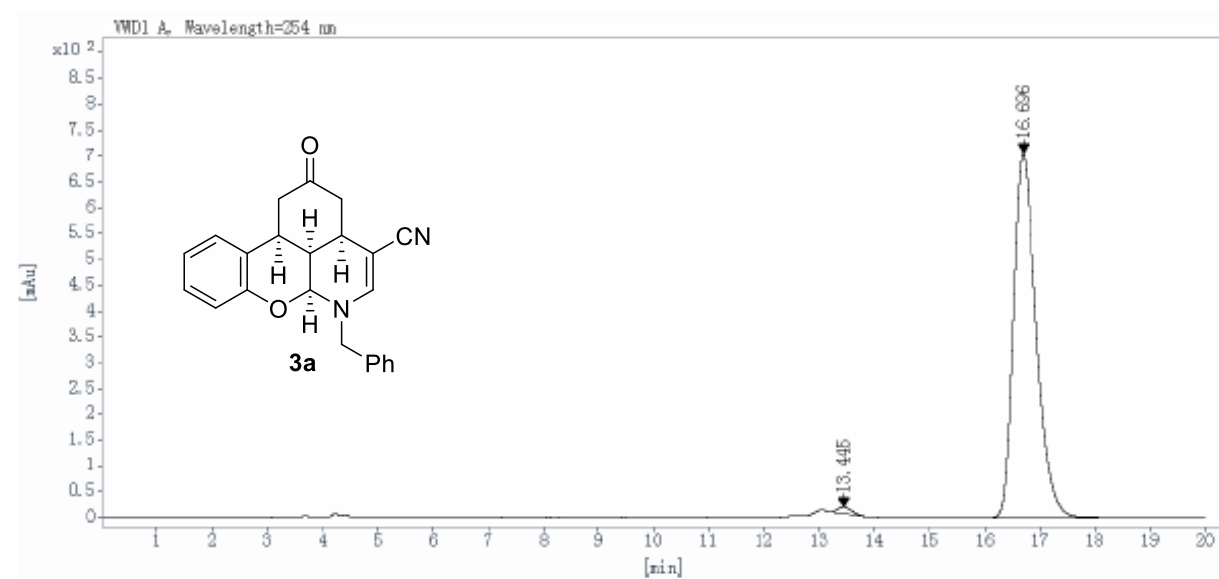




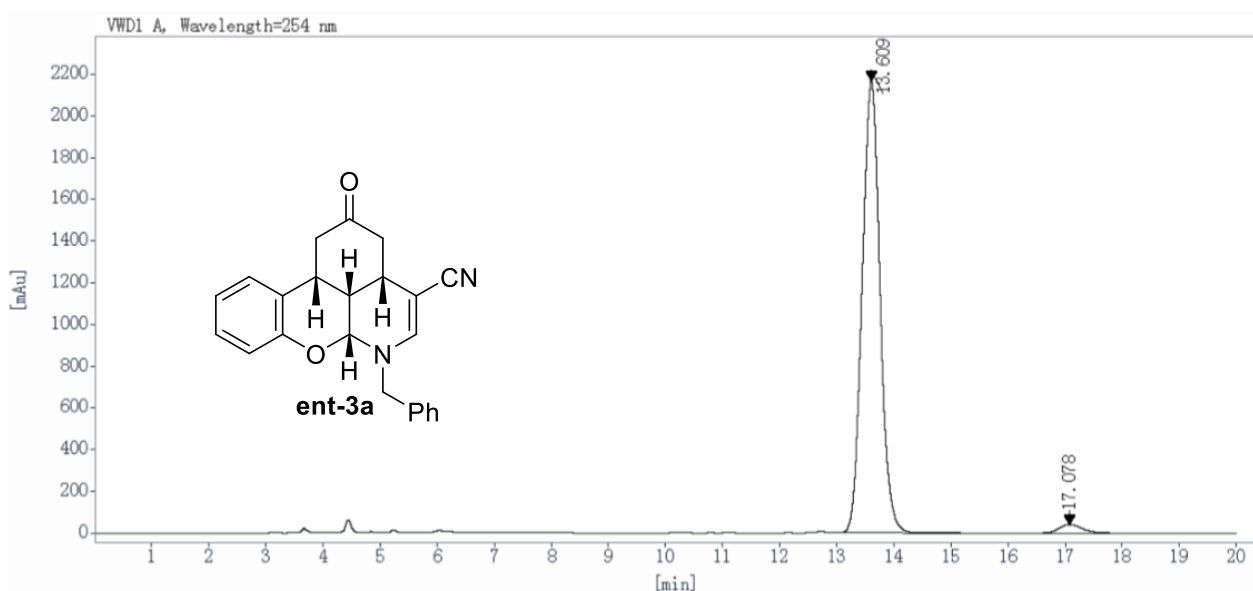




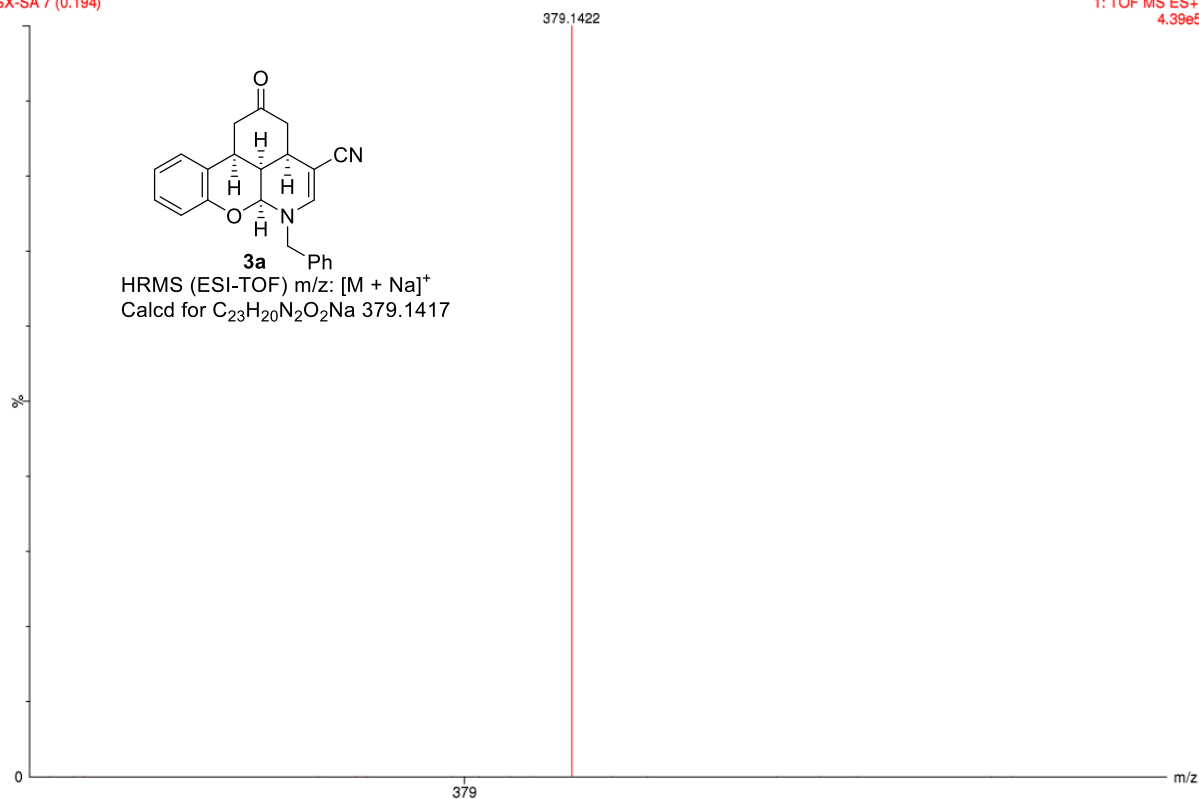
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13.846	BB	0.34	1150.6011	25126.6035	49.8225
17.258	BBA	0.44	887.8301	25305.6152	50.1775
Totals:				50432.2188	100.0000

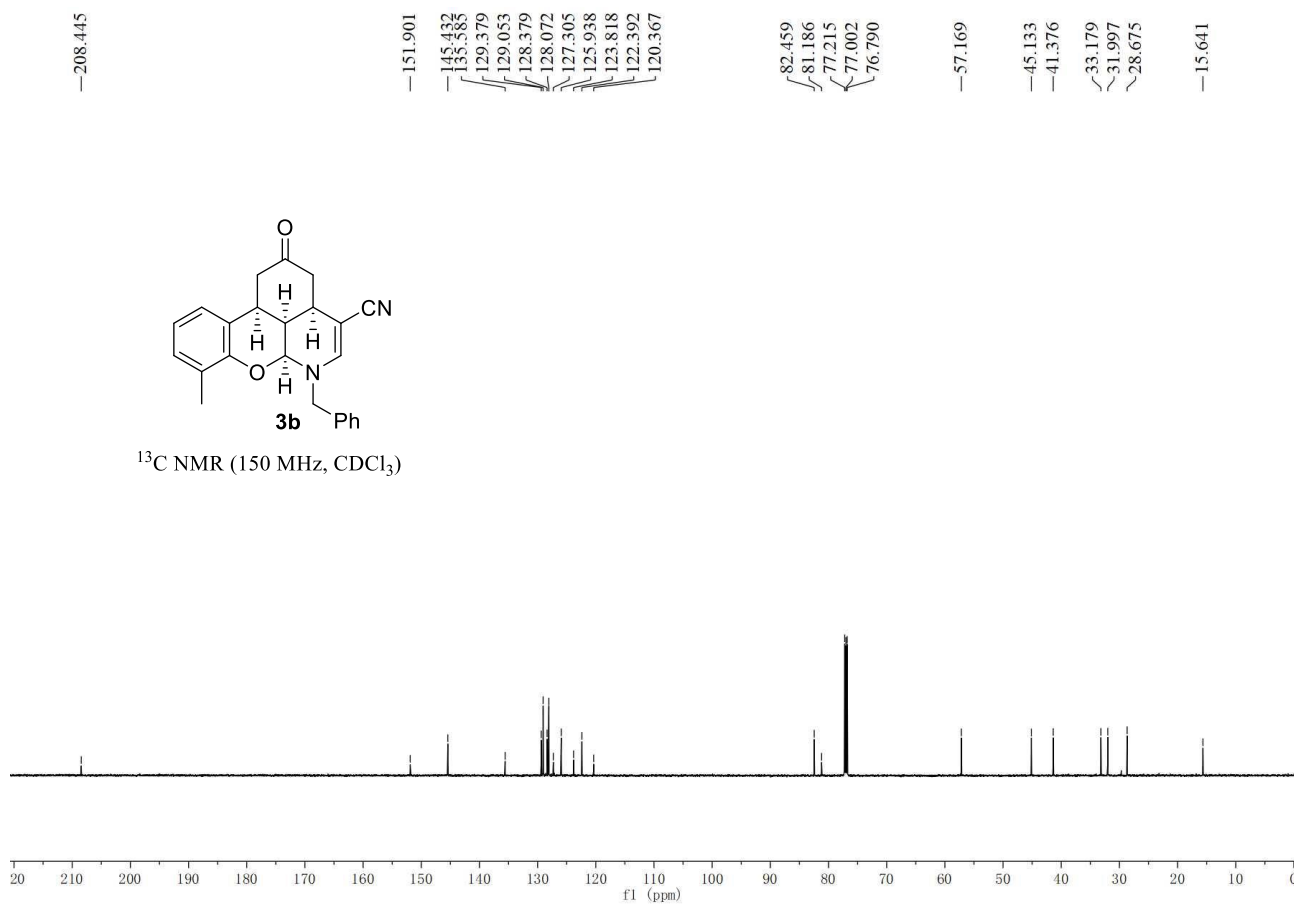
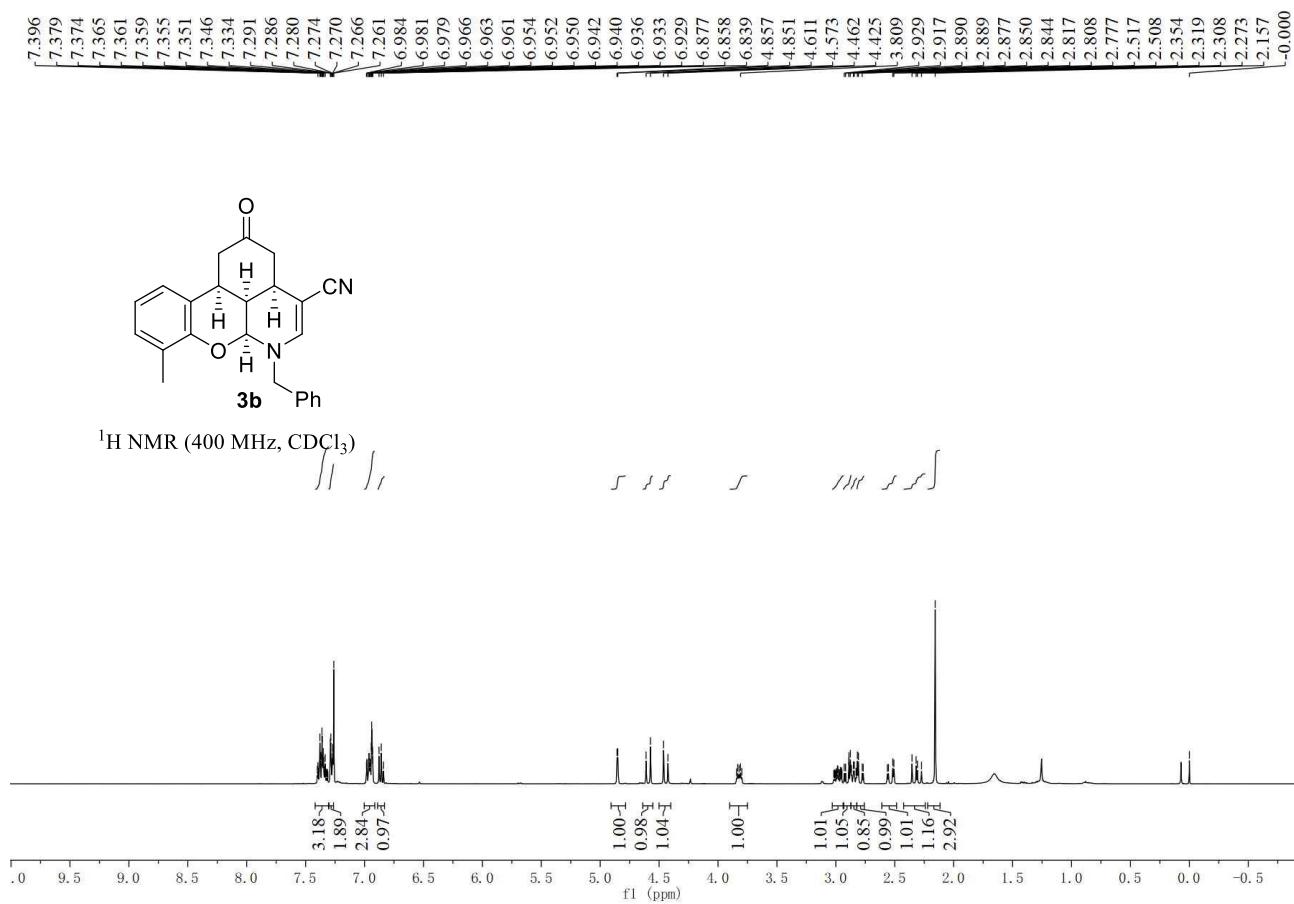


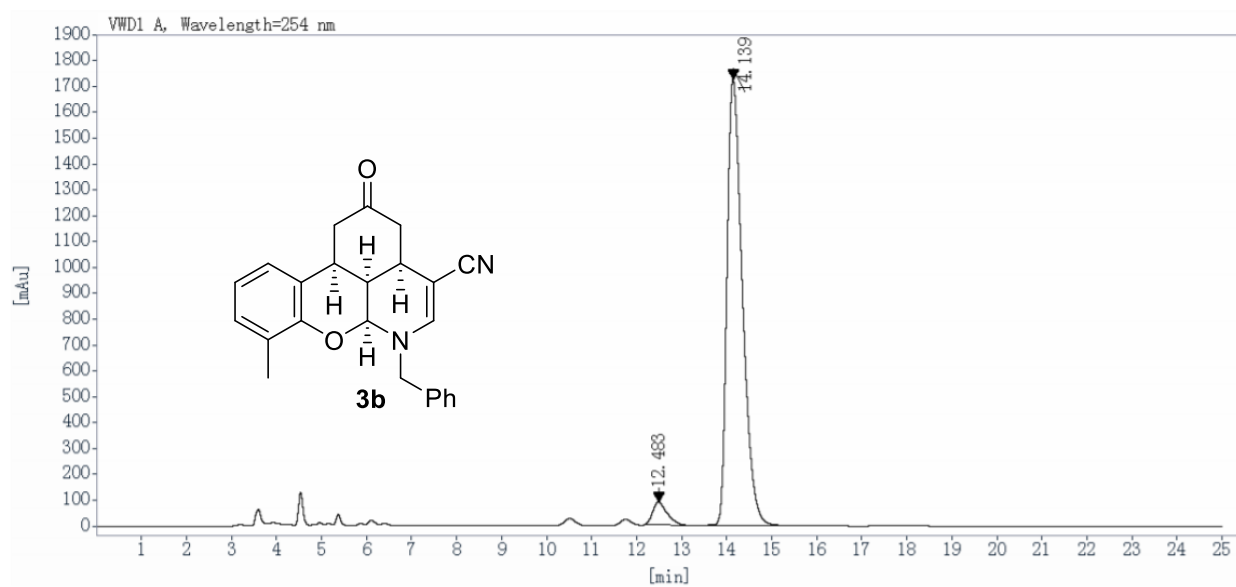
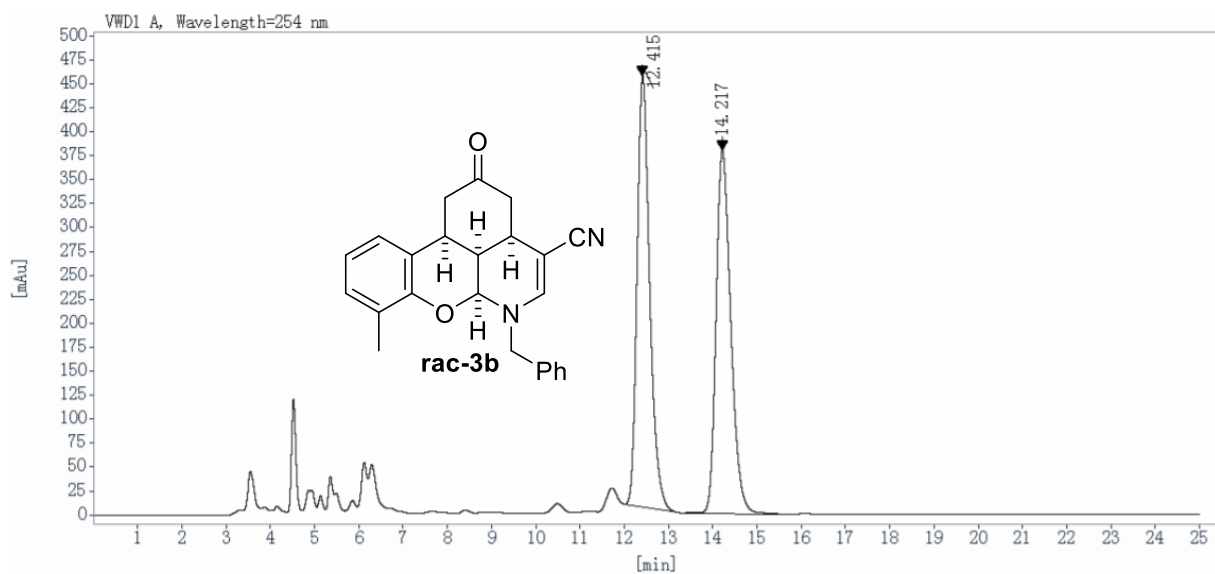
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
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16.696	BB	0.44	704.6625	20036.7871	98.9235
Totals:				20254.8235	100.0000



SX-SA 7 (0.194)



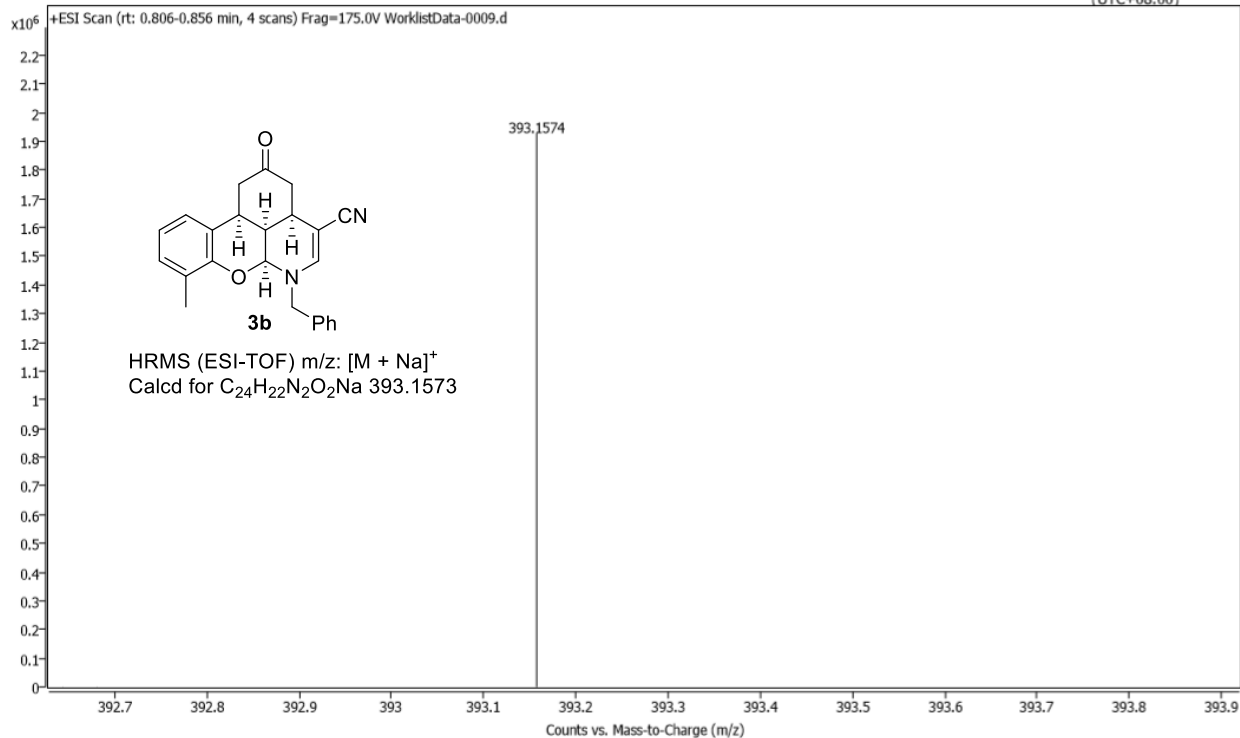


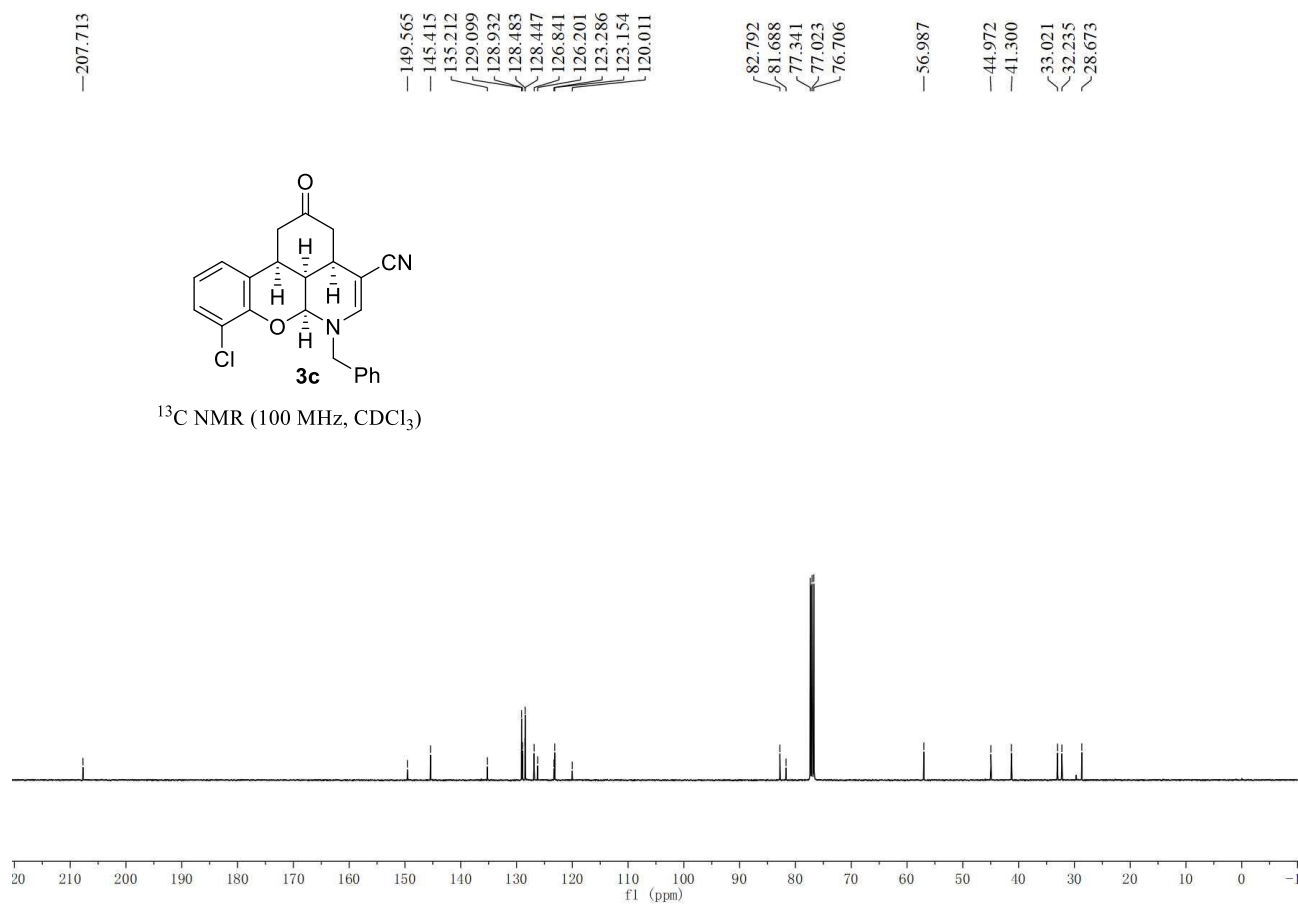
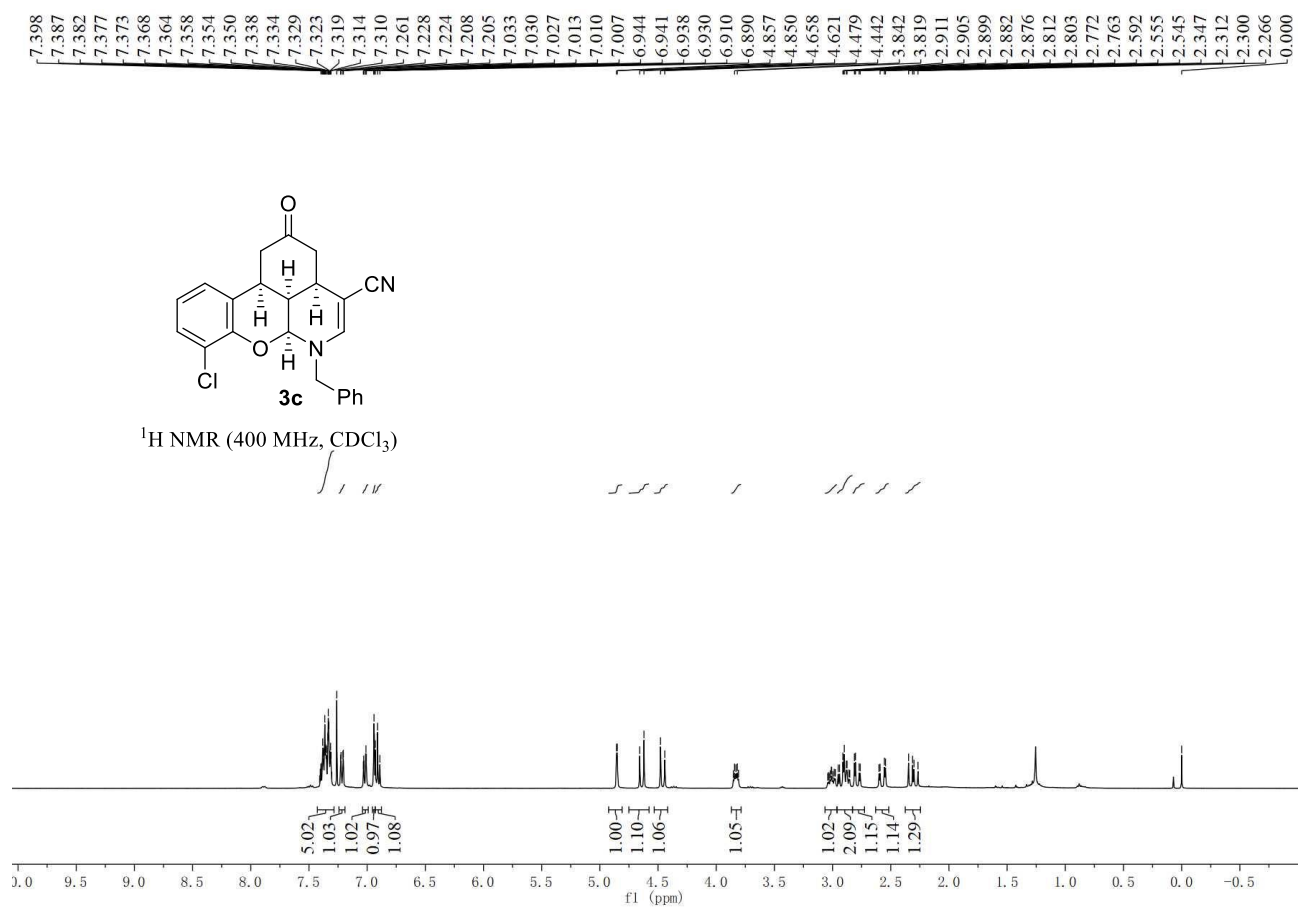


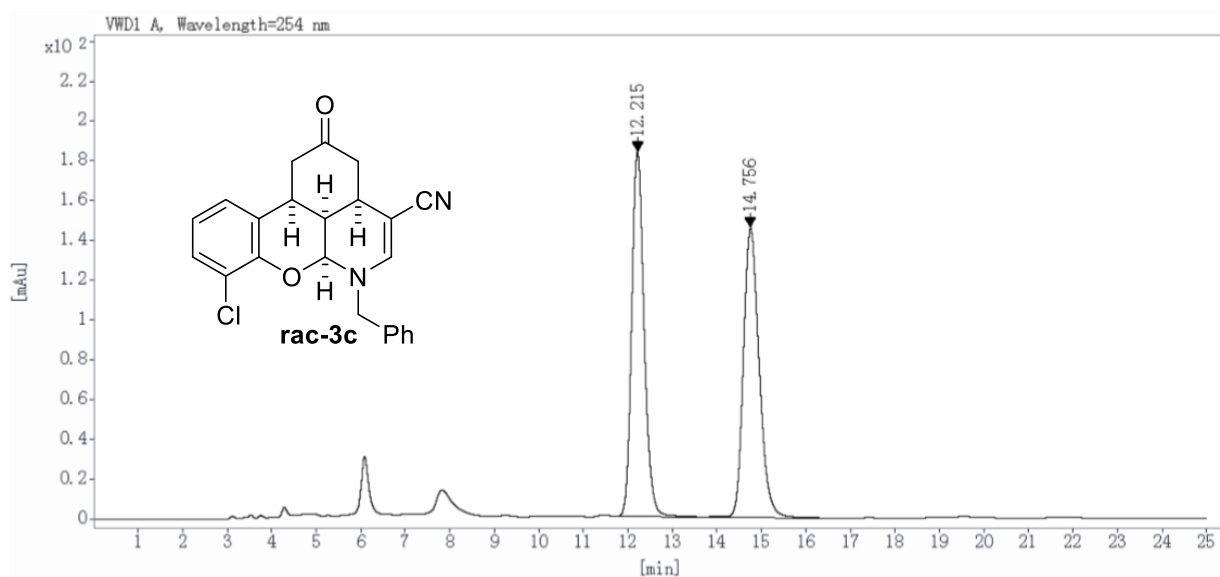
Spectrum Plot Report



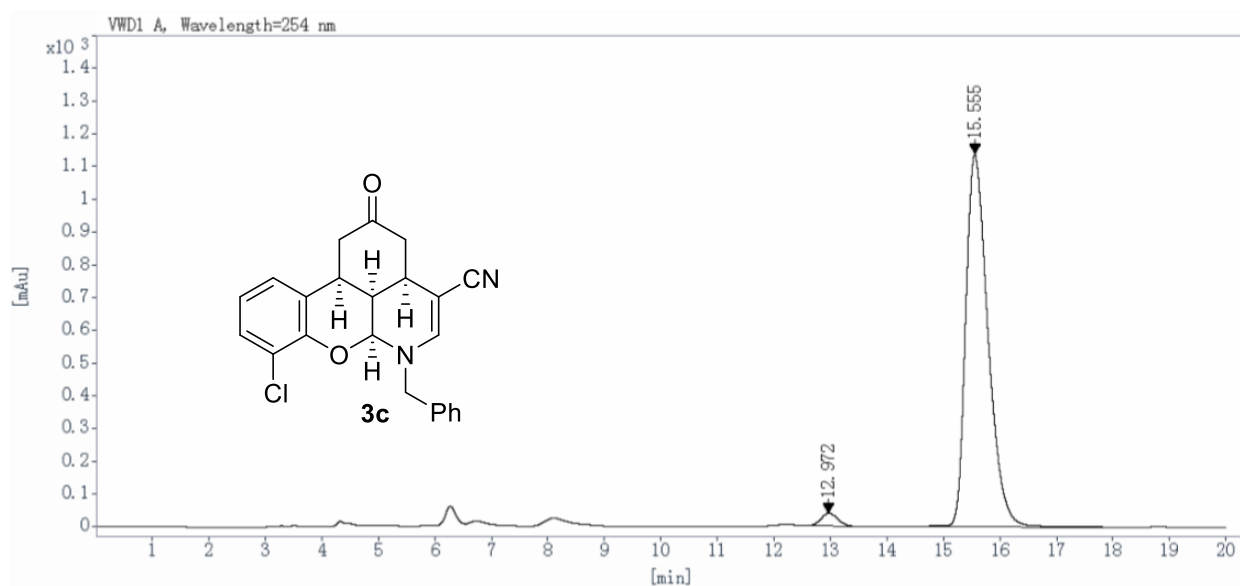
Name	cyc-190621-9	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	WorklistData-0009.d	Method (Acq)	TOF.m		Acq. Time (Local)
					7/4/2019 4:19:49 PM (UTC+08:00)







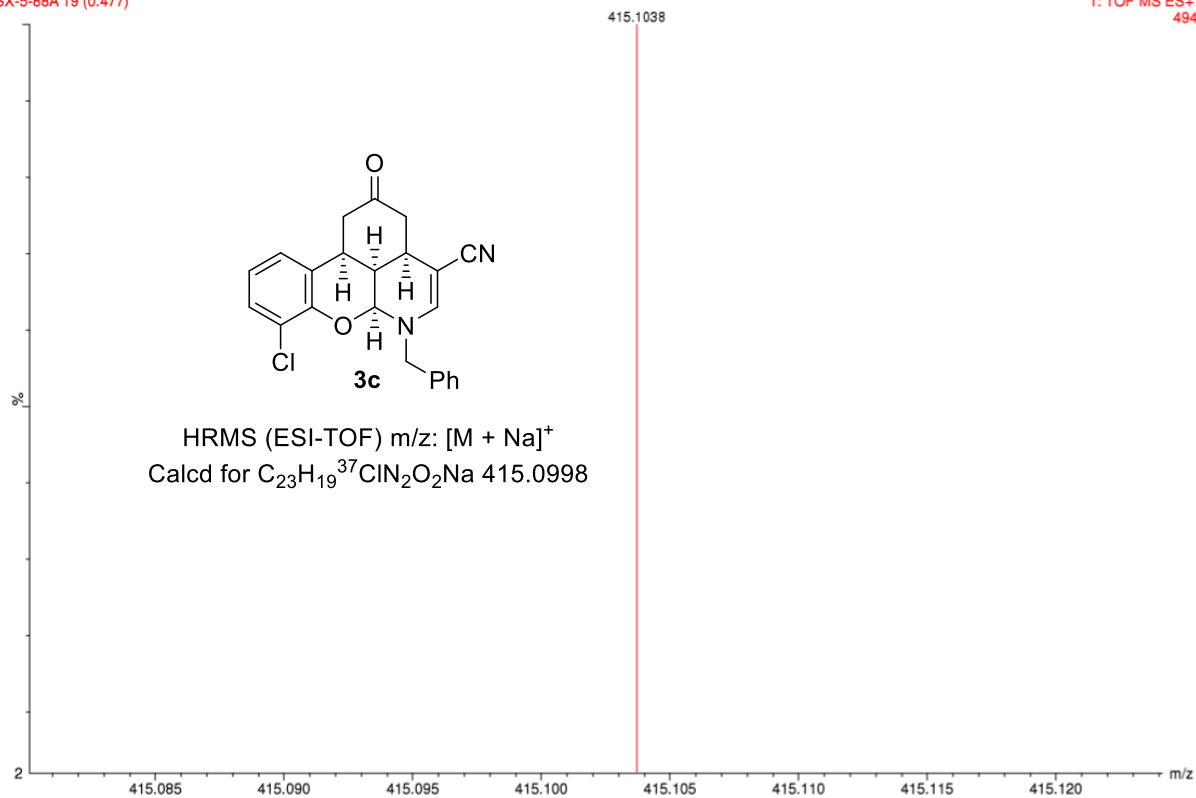
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
12.215	BB	0.30	183.3132	3544.1355	49.8137
14.756	VB R	0.38	145.7604	3570.6499	50.1863
Totals:				7114.7854	100.0000



Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
12.972	BB	0.31	38.7840	776.2845	2.4353
15.555	VB R	0.42	1137.2030	31099.5488	97.5647
Totals:				31875.8334	100.0000

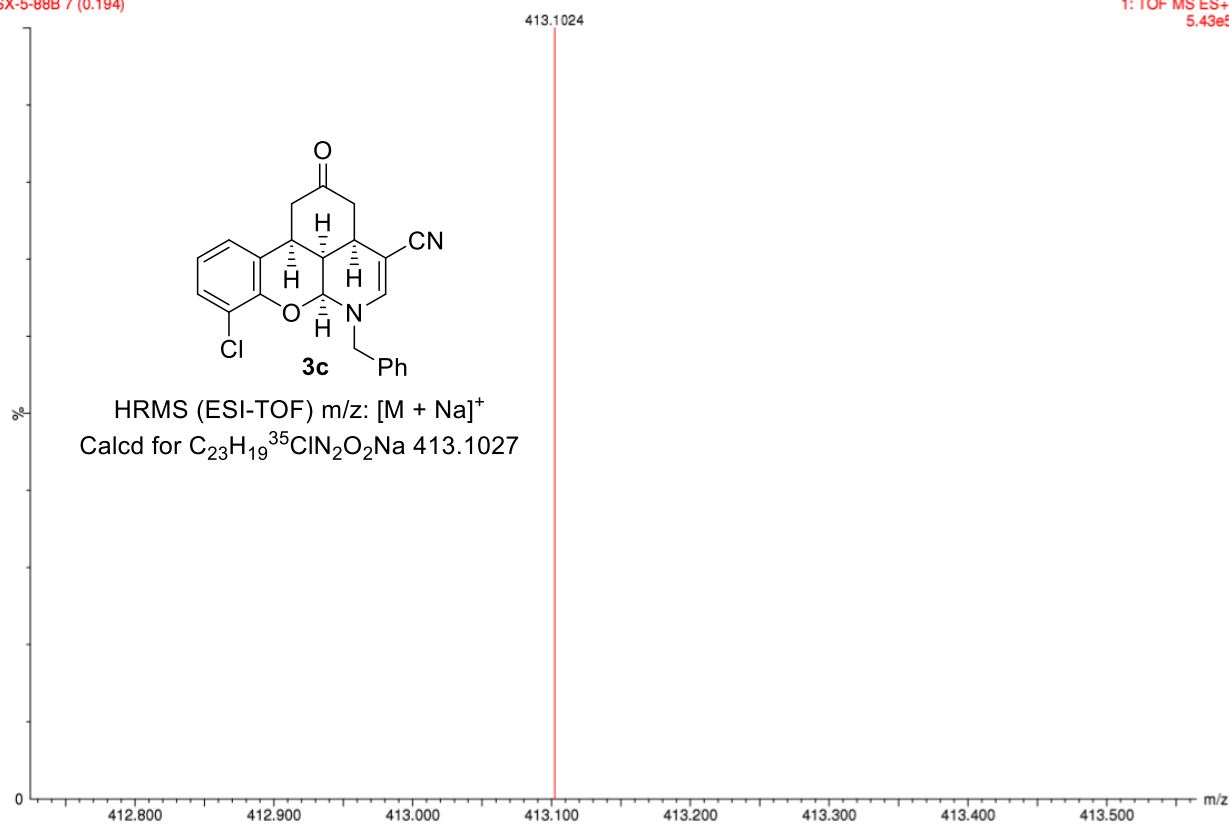
SX-5-88A 19 (0.477)

1: TOF MS ES+
494

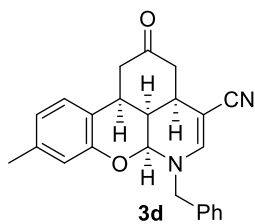


SX-5-88B 7 (0.194)

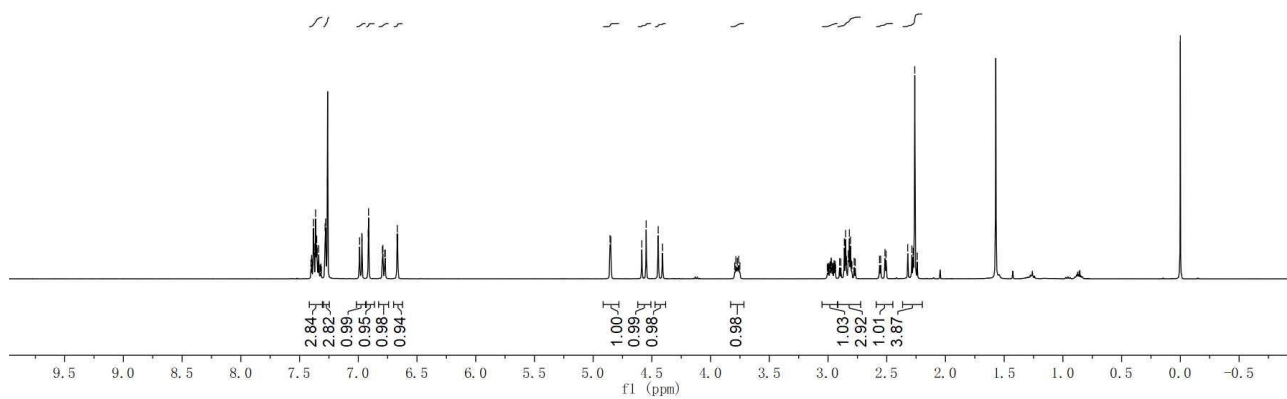
1: TOF MS ES+
5.43e5



7.403
7.398
7.393
7.387
7.381
7.376
7.367
7.363
7.358
7.354
7.349
7.344
7.337
7.283
7.278
7.263
6.989
6.970
6.968
6.915
6.912
6.910
6.795
6.790
6.775
6.770
6.670
6.667
6.664
4.857
4.849
4.586
4.549
4.446
4.409
3.795
3.785
3.773
3.761
3.751
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2.971
2.961
2.949
2.946
2.942
2.939
2.902
2.891
2.861
2.850
2.844
2.842
2.827
2.819
2.809
2.799
2.797
2.777
2.768
2.561
2.552
2.515
2.506
2.321
2.286
2.275
2.262
2.240
0.000



^1H NMR (400 MHz, CDCl_3)



—208.473

—153.592

—145.378

—138.561

—135.633

—129.062

—128.404

—128.200

—128.158

—124.103

—120.940

—120.339

—118.202

—82.155

—81.317

—77.359

—77.042

—76.724

—57.085

—44.935

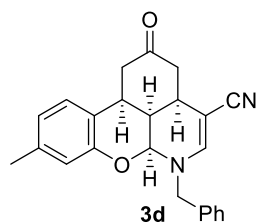
—41.325

—33.232

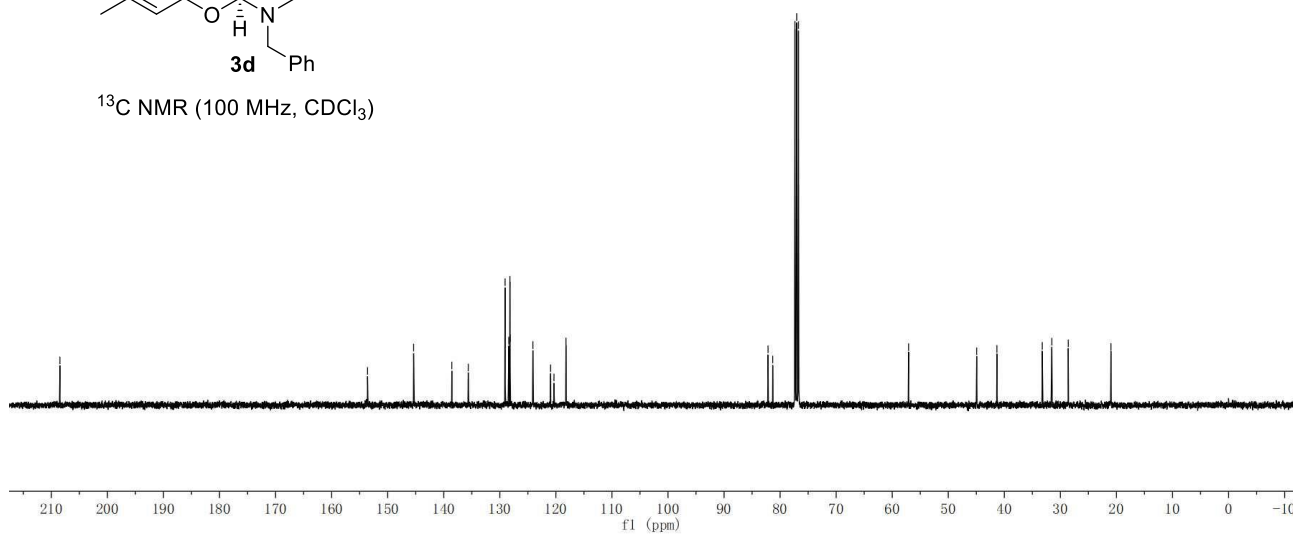
—31.526

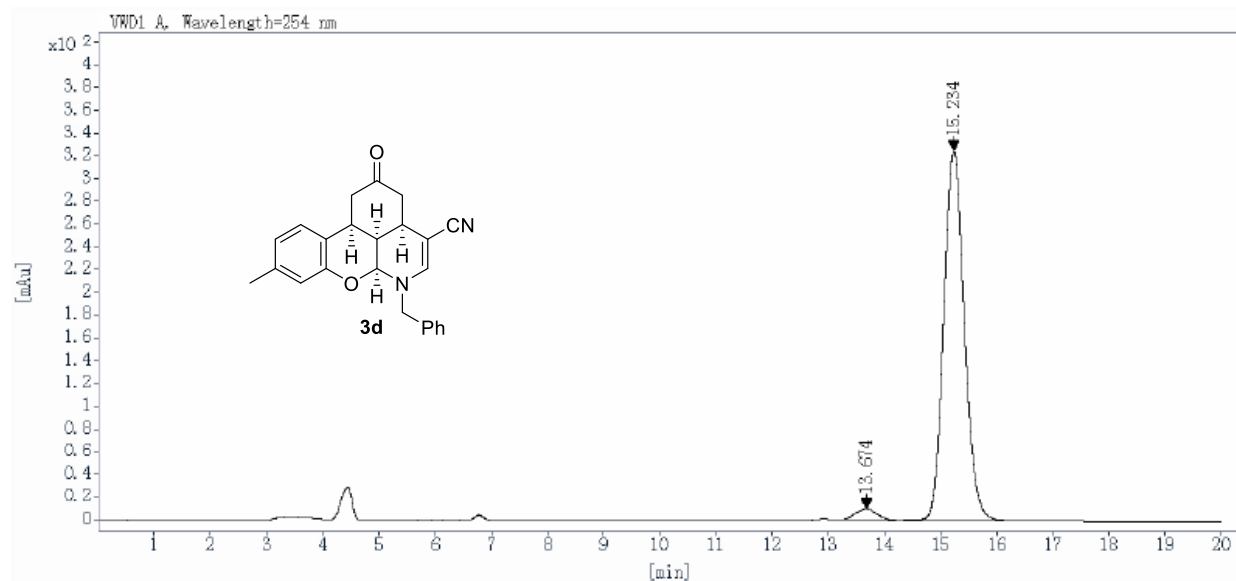
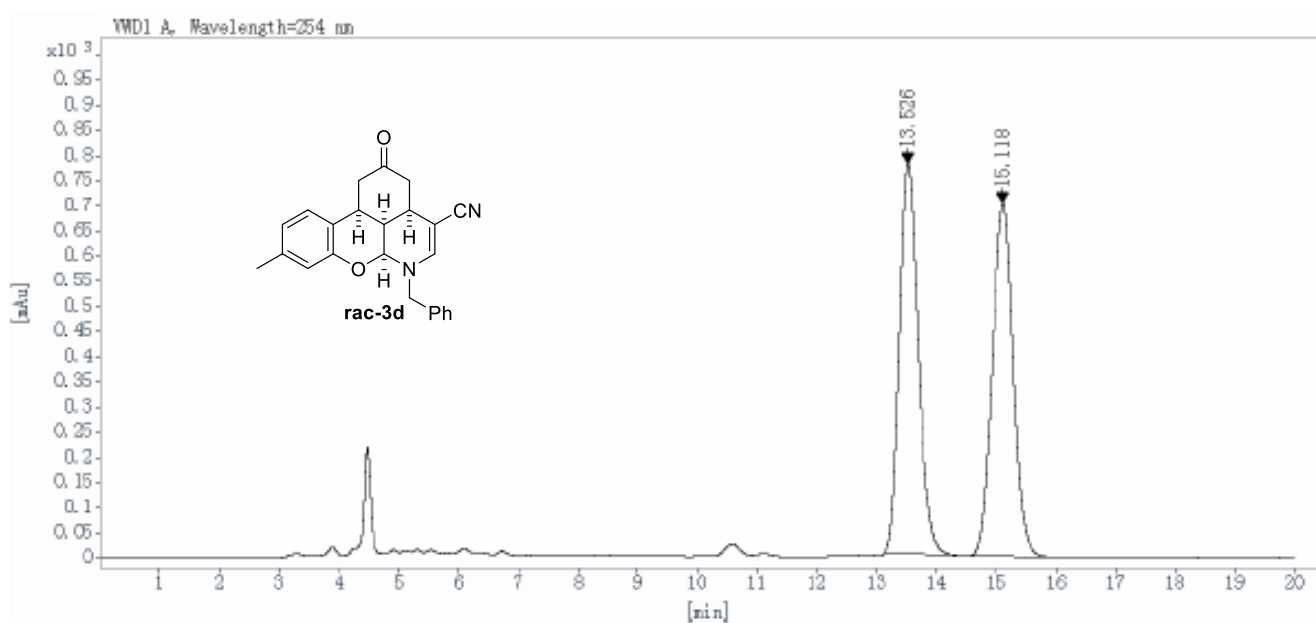
—28.597

—20.985



^{13}C NMR (100 MHz, CDCl_3)

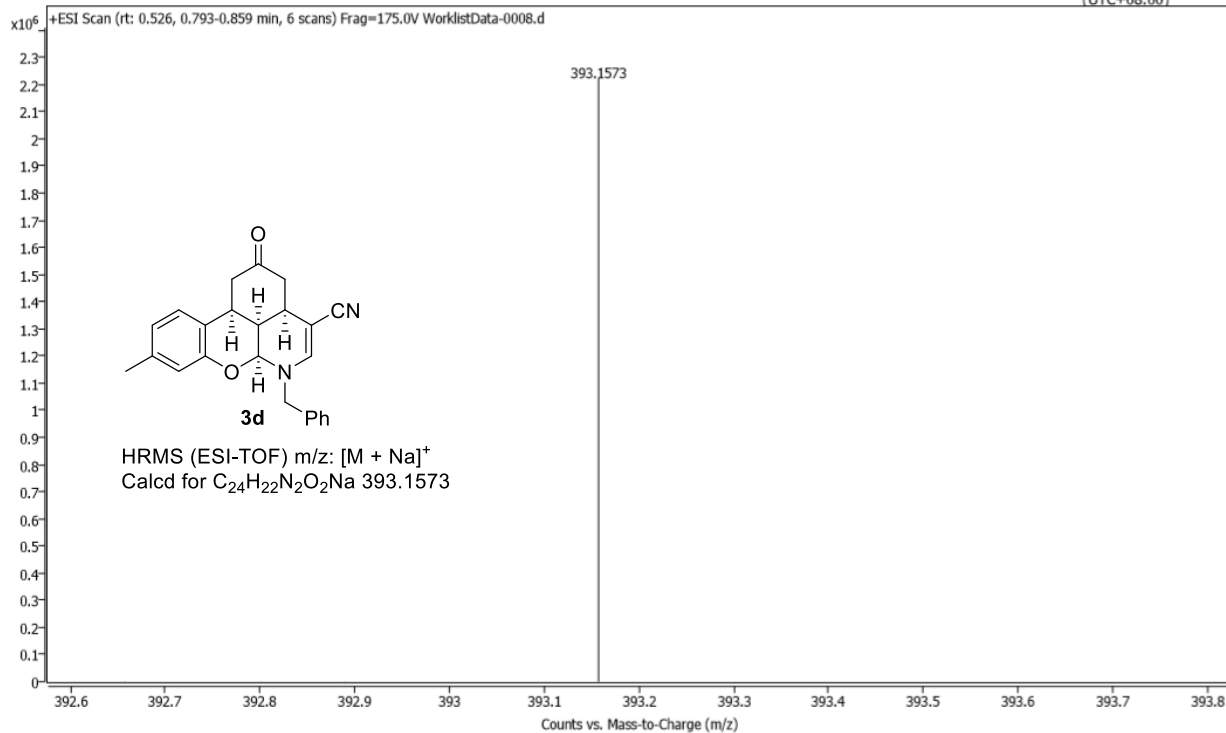


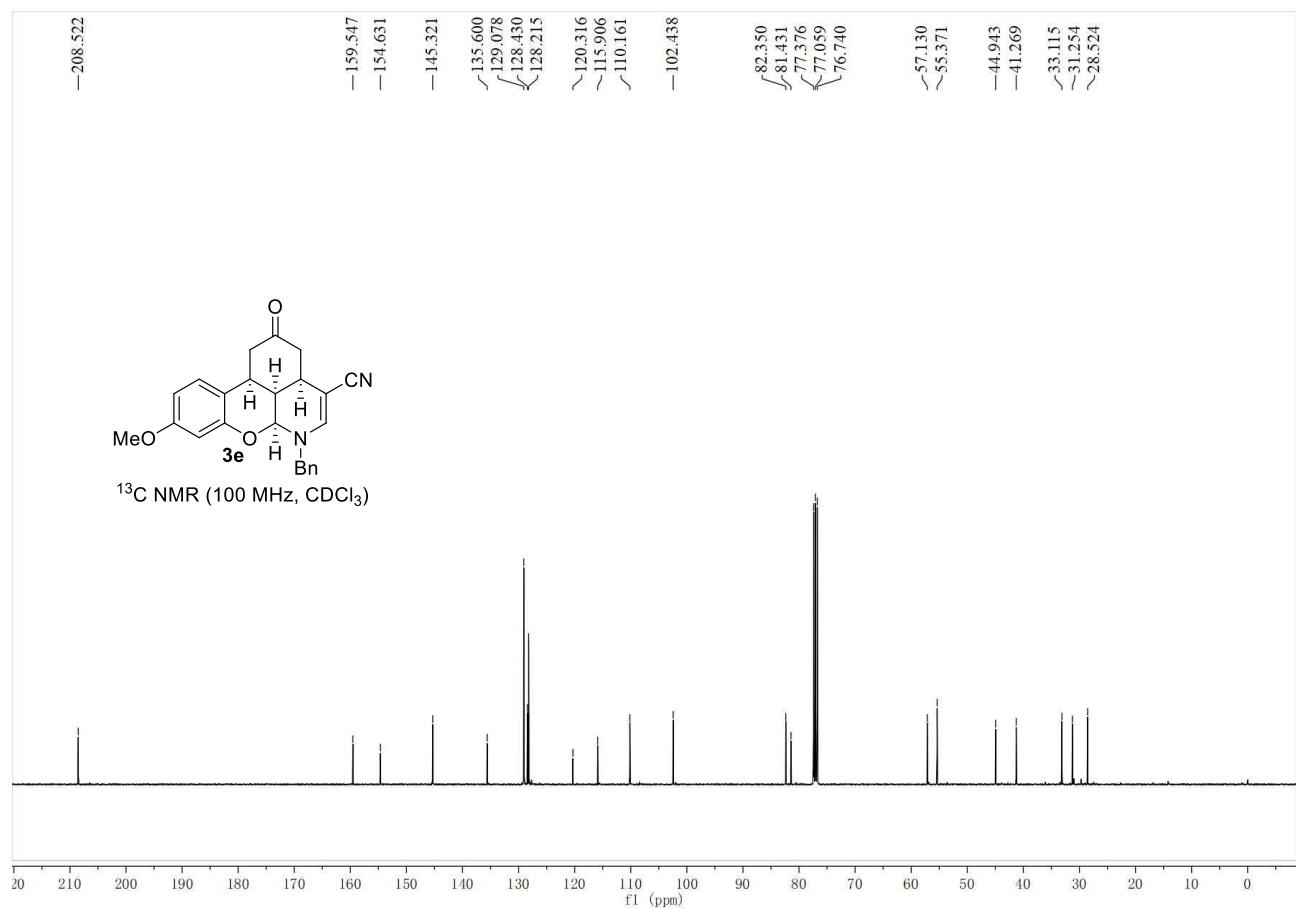
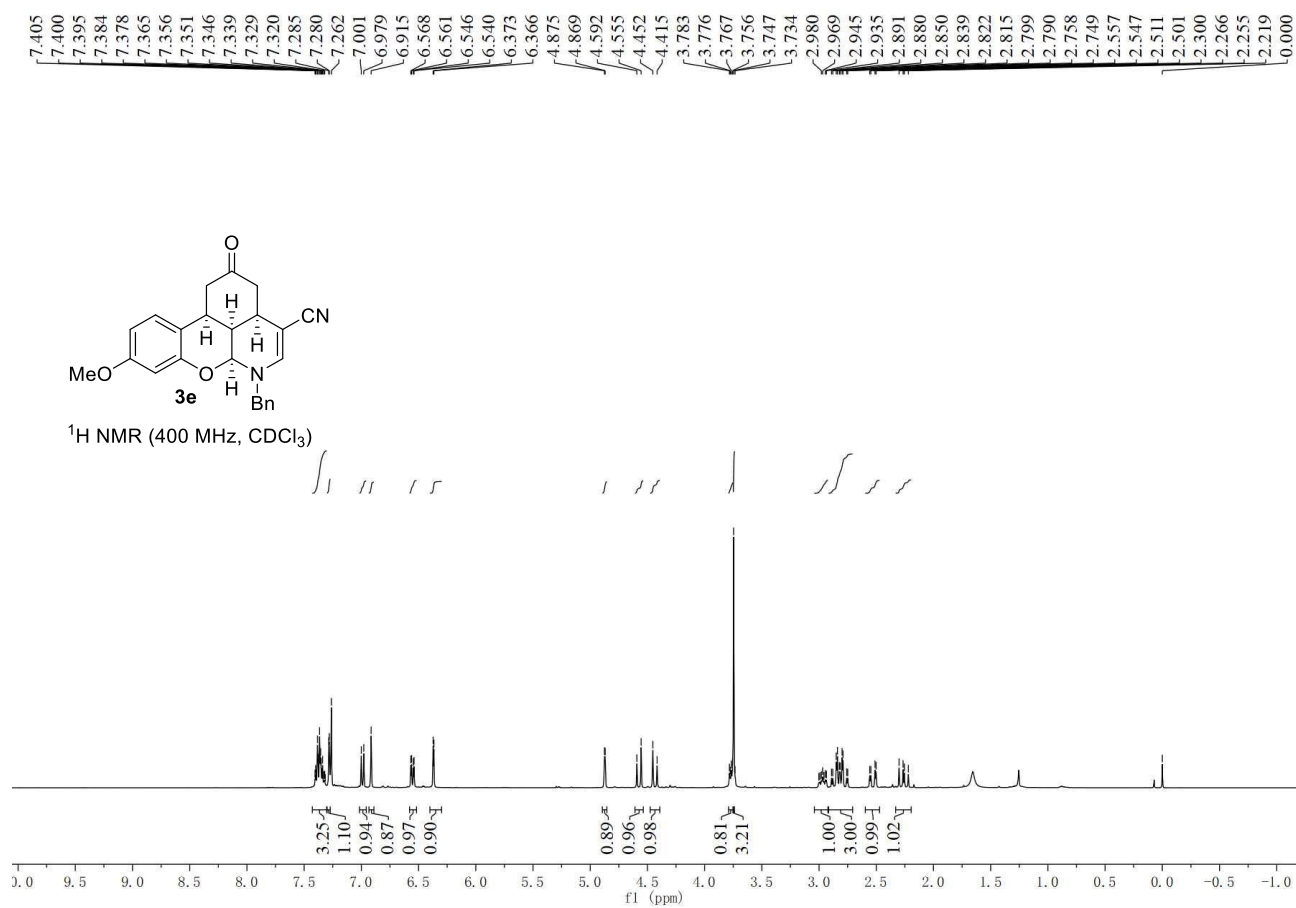


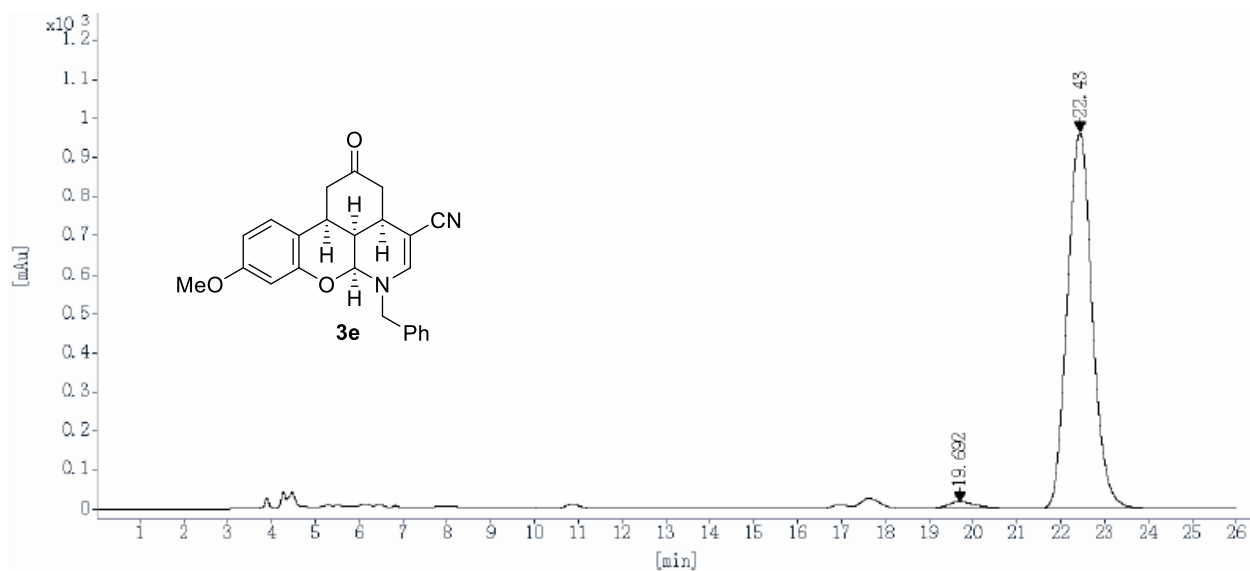
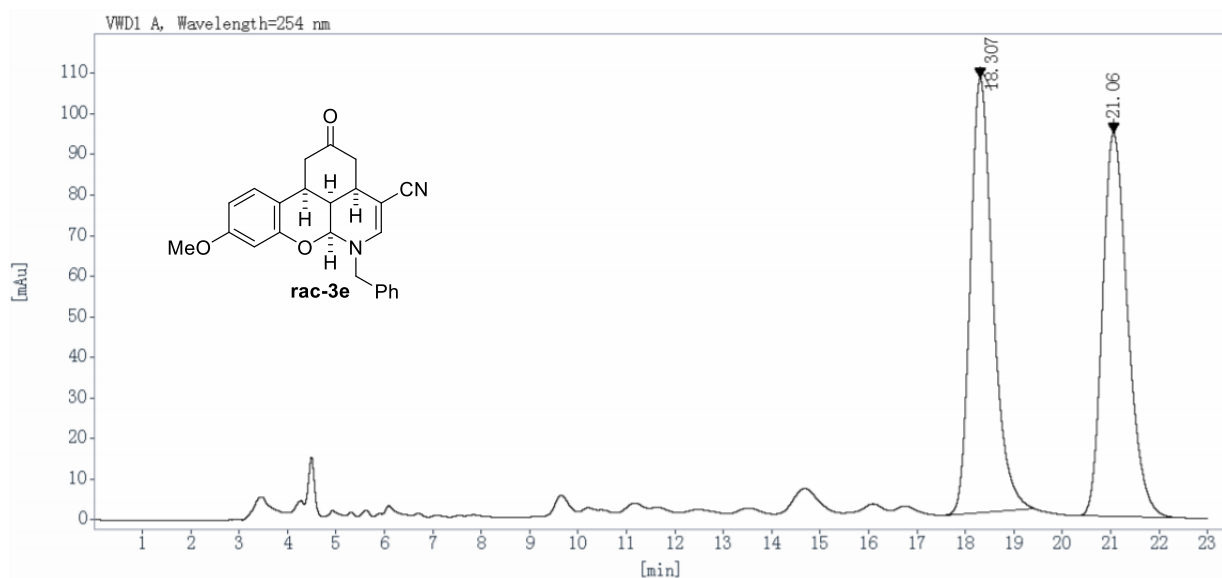
Spectrum Plot Report



Name	Rack Pos.	Instrument	Operator
Inj. Vol. (ul)	Plate Pos.	IRM Status	
Data File	Method (Acq)	Comment	
WorklistData-0008.d			Success
			Acq. Time (Local)
			7/4/2019 4:15:59 PM (UTC+08:00)

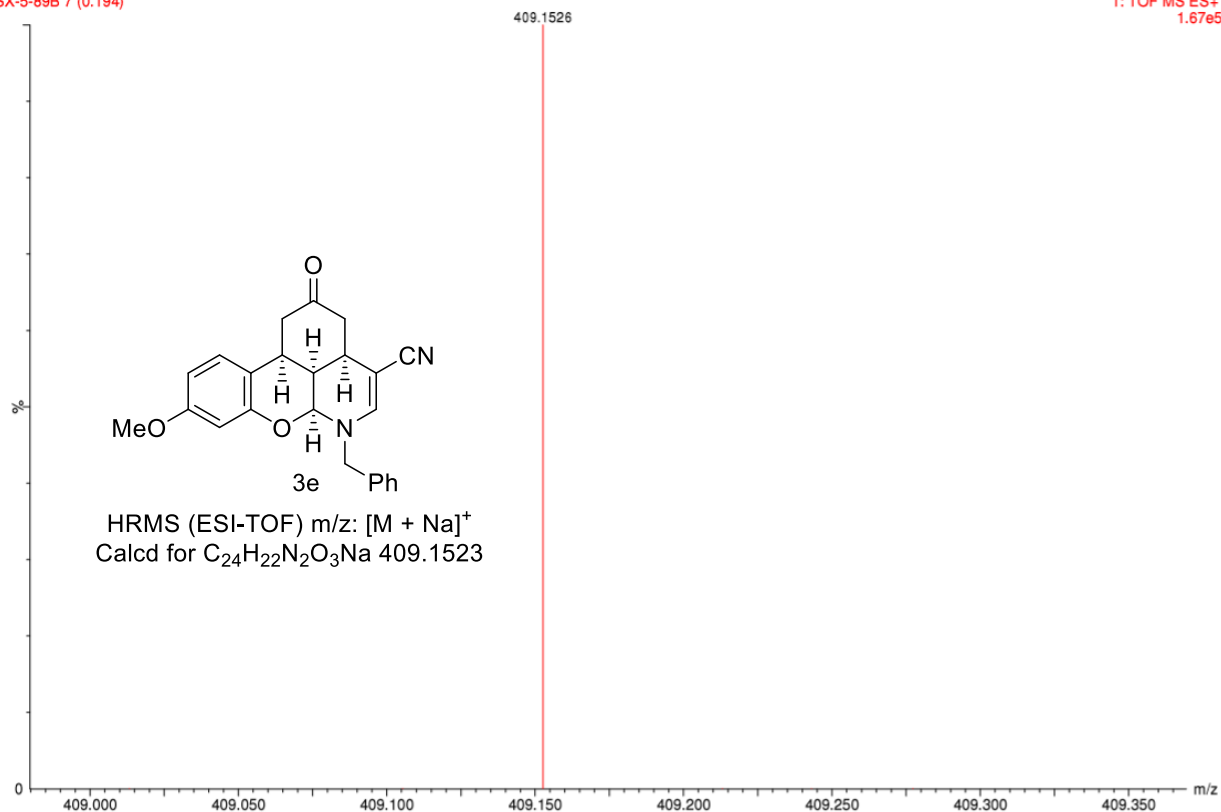


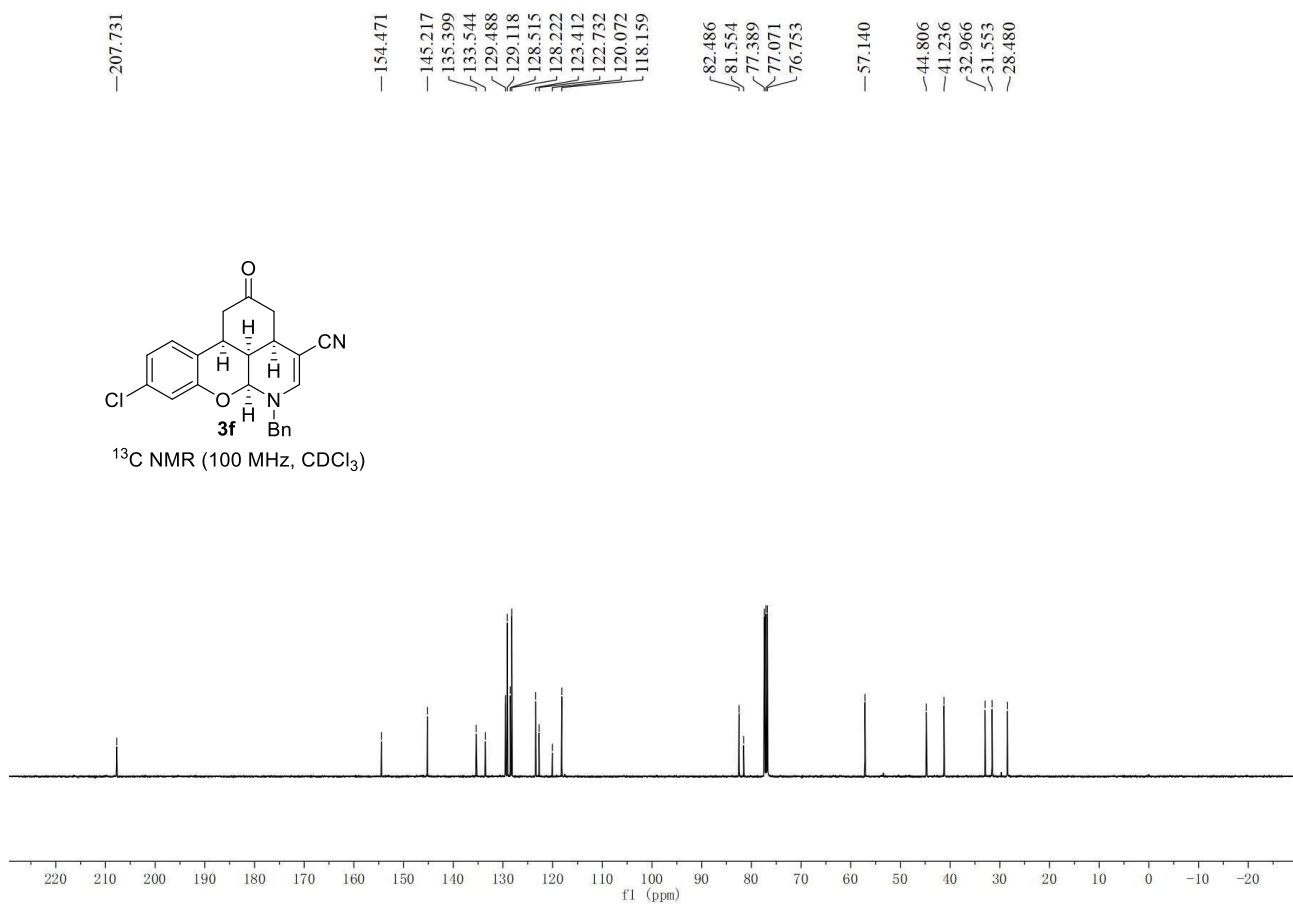
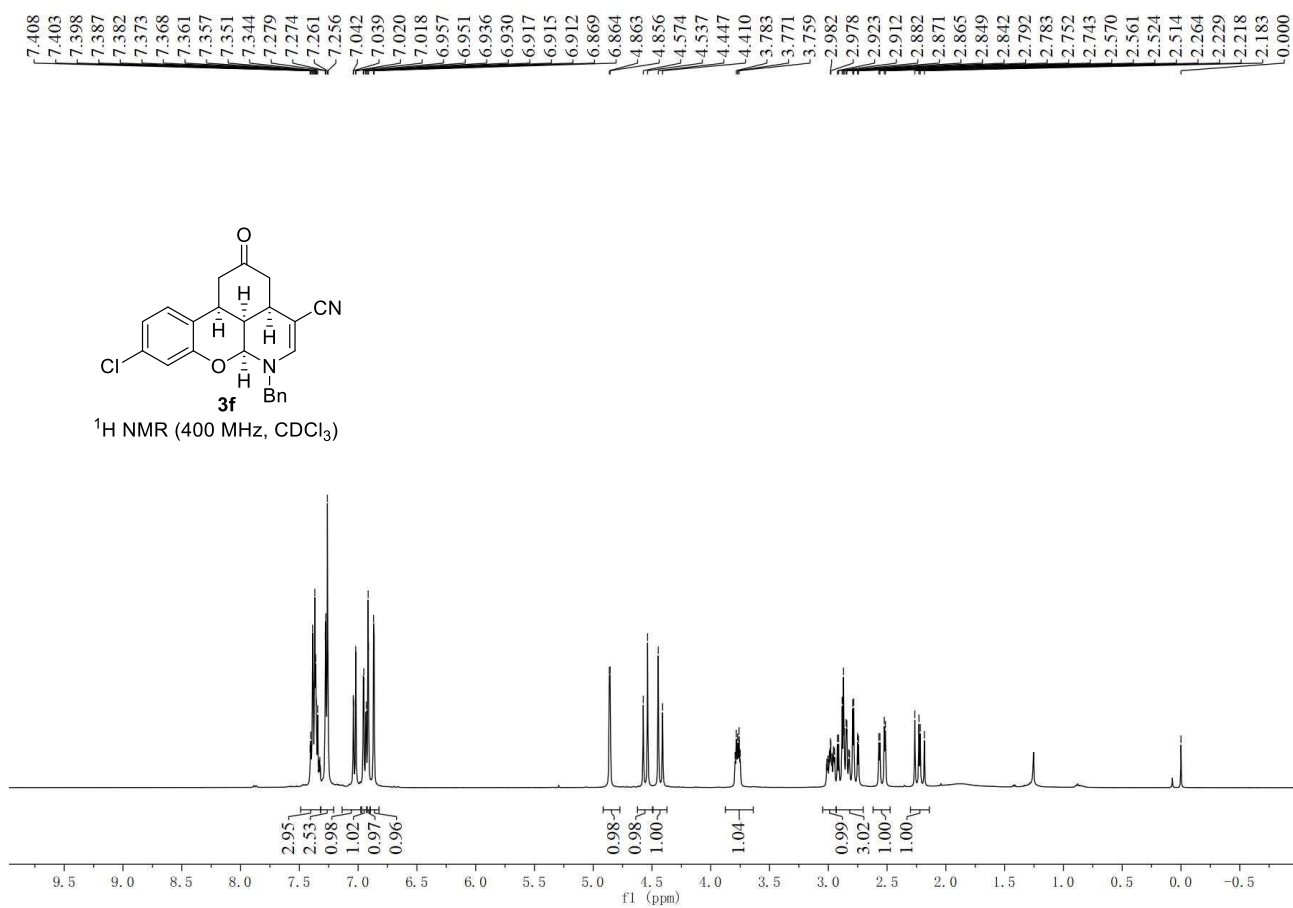


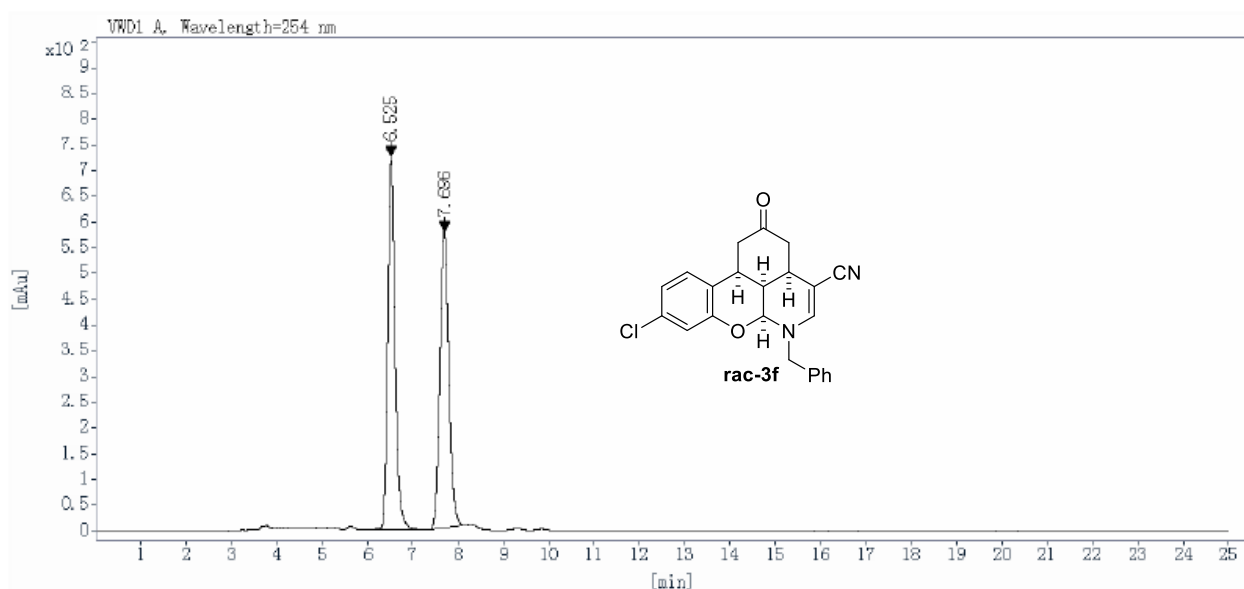


SX-5-89B 7 (0.194)

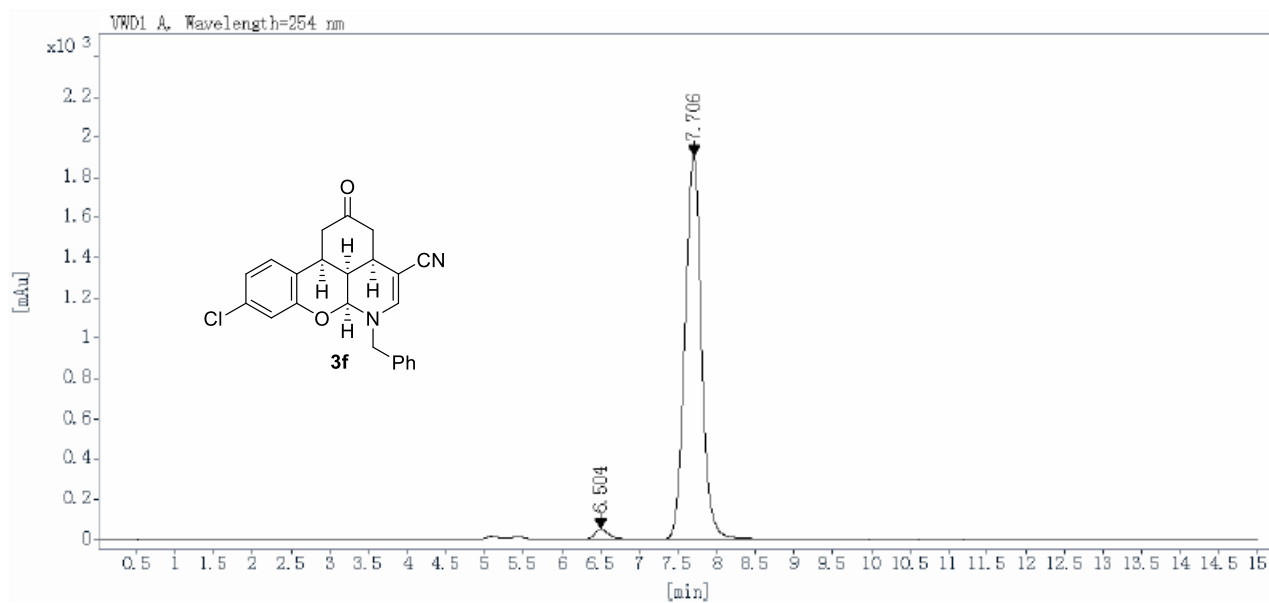
1: TOF MS ES+
1.67e5







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
6.525	VB R	0.17	723.0023	8226.5508	50.9252
7.696	BBA	0.21	574.9030	7927.6411	49.0748
Totals:				16154.1919	100.0000

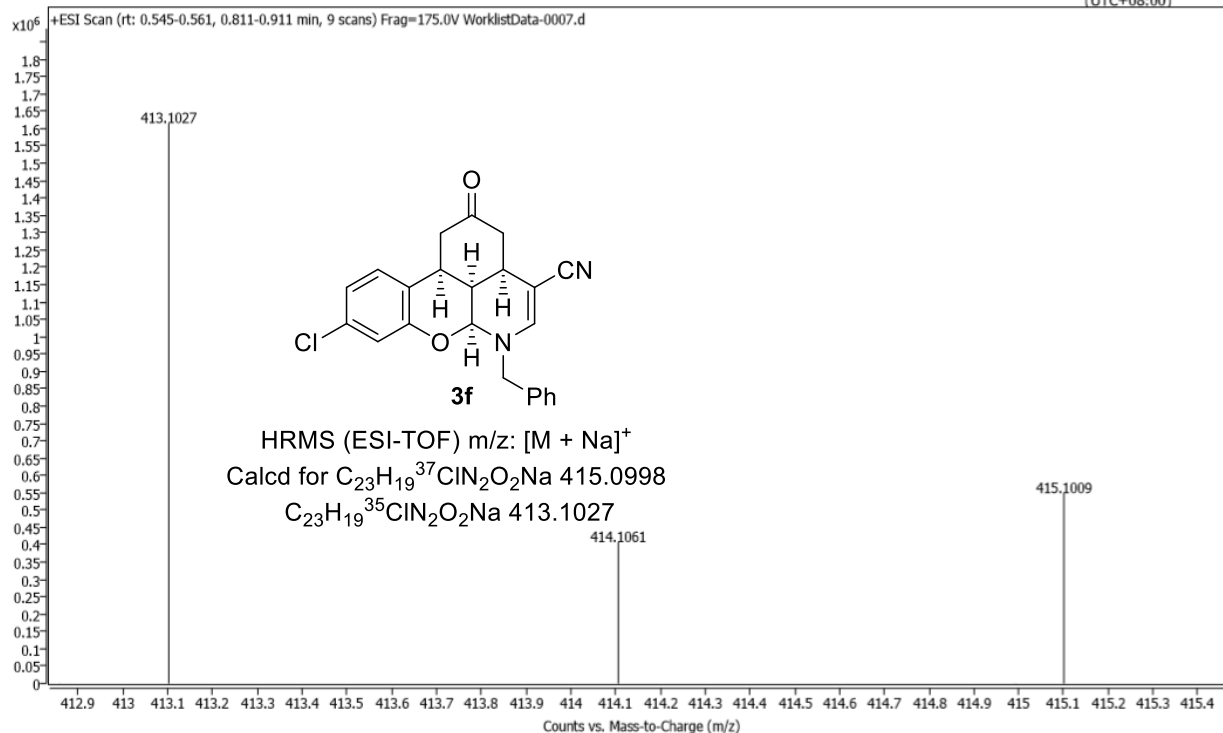


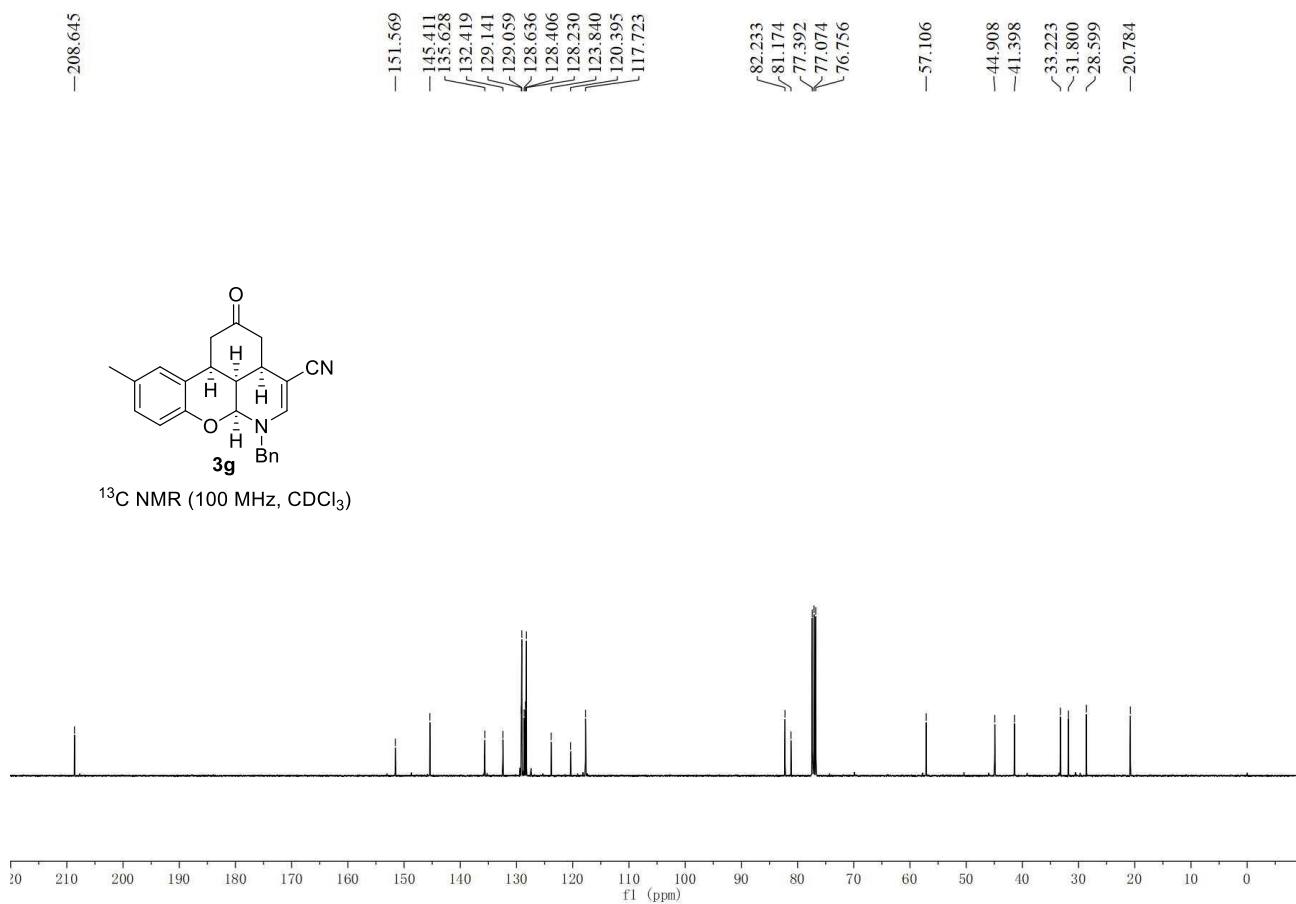
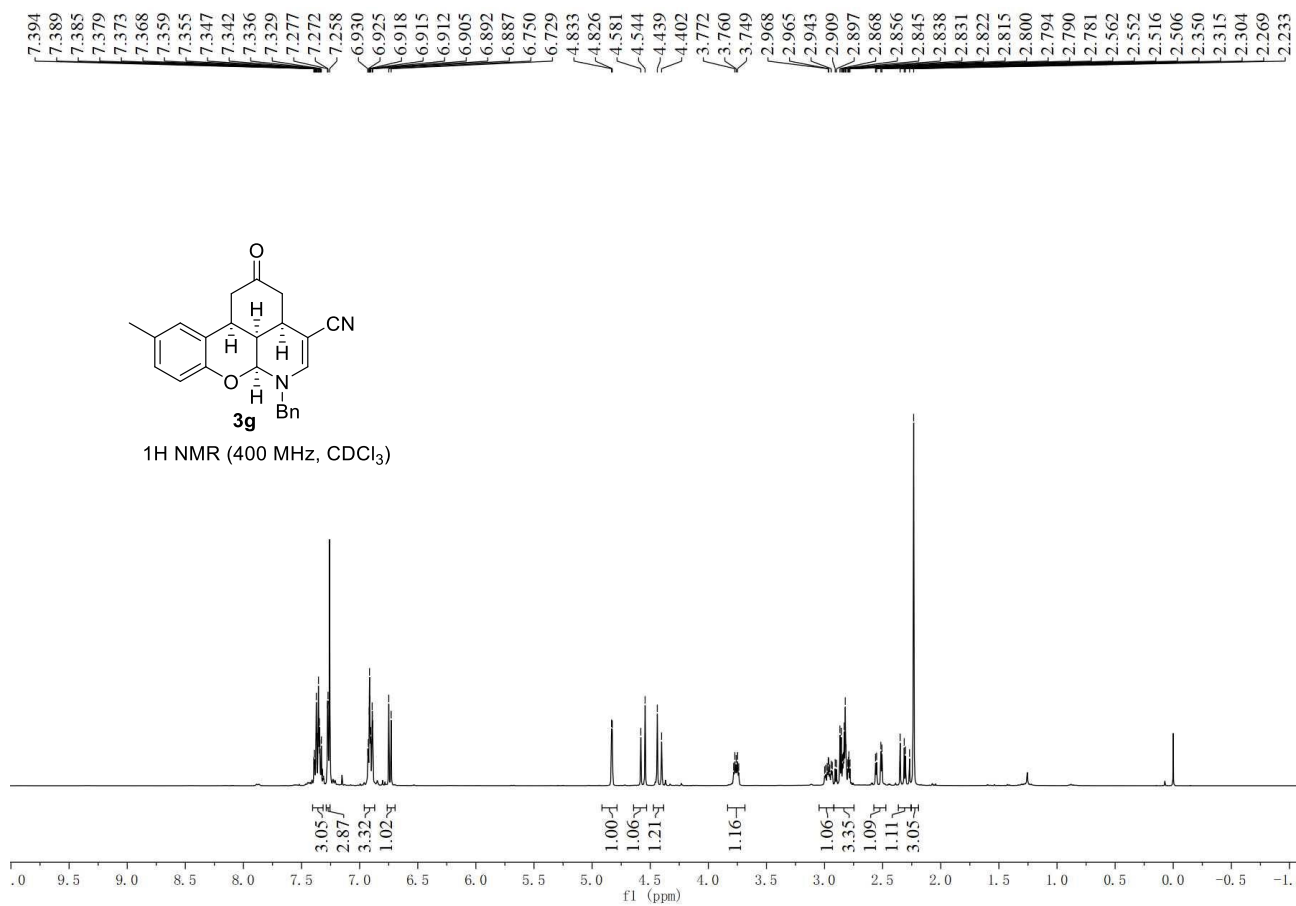
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
6.504	BB	0.19	50.4729	636.6685	2.1874
7.706	BBA	0.23	1903.3988	28469.9219	97.8126
Totals:				29106.5904	100.0000

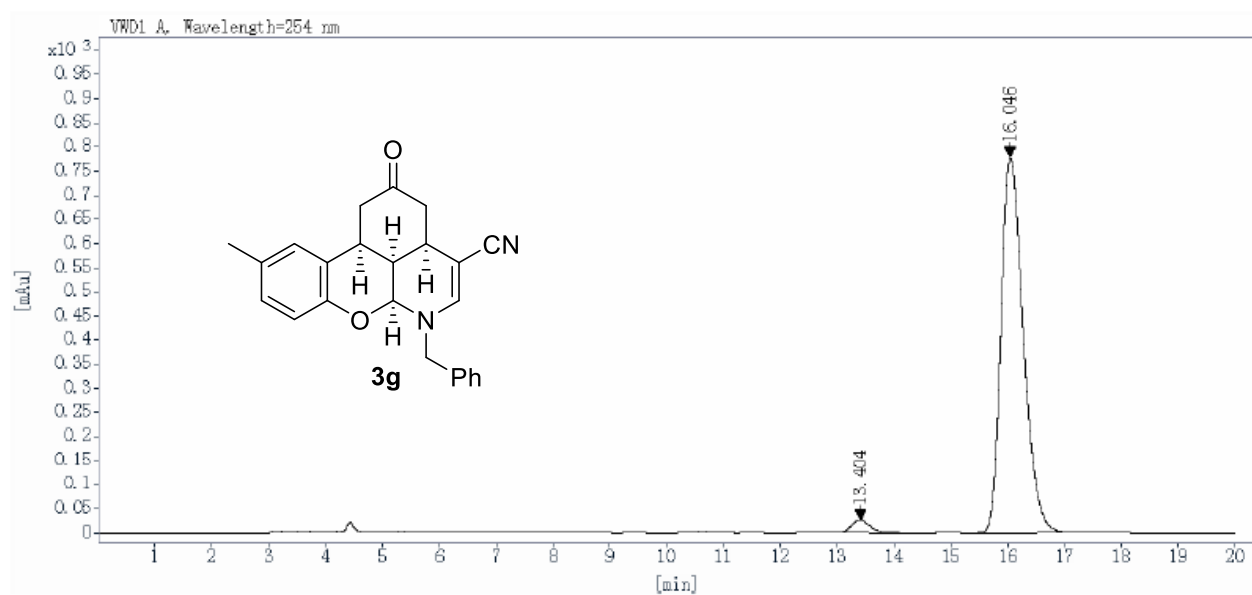
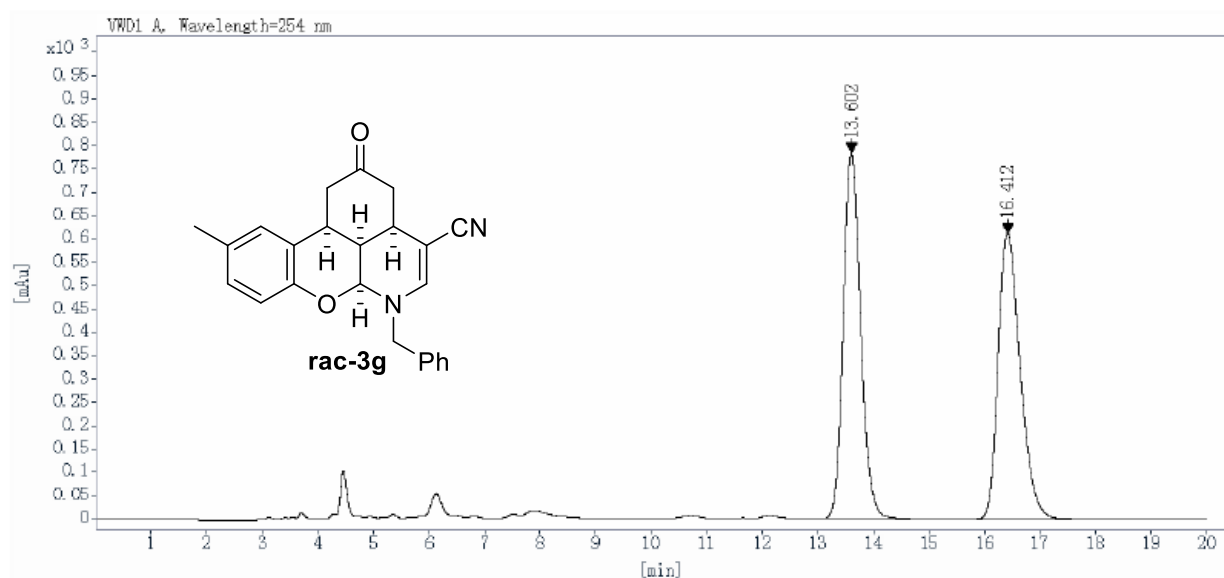
Spectrum Plot Report



Name	cyc-190621-7	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	WorklistData-0007.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 7/4/2019 4:12:09 PM (UTC+08:00)

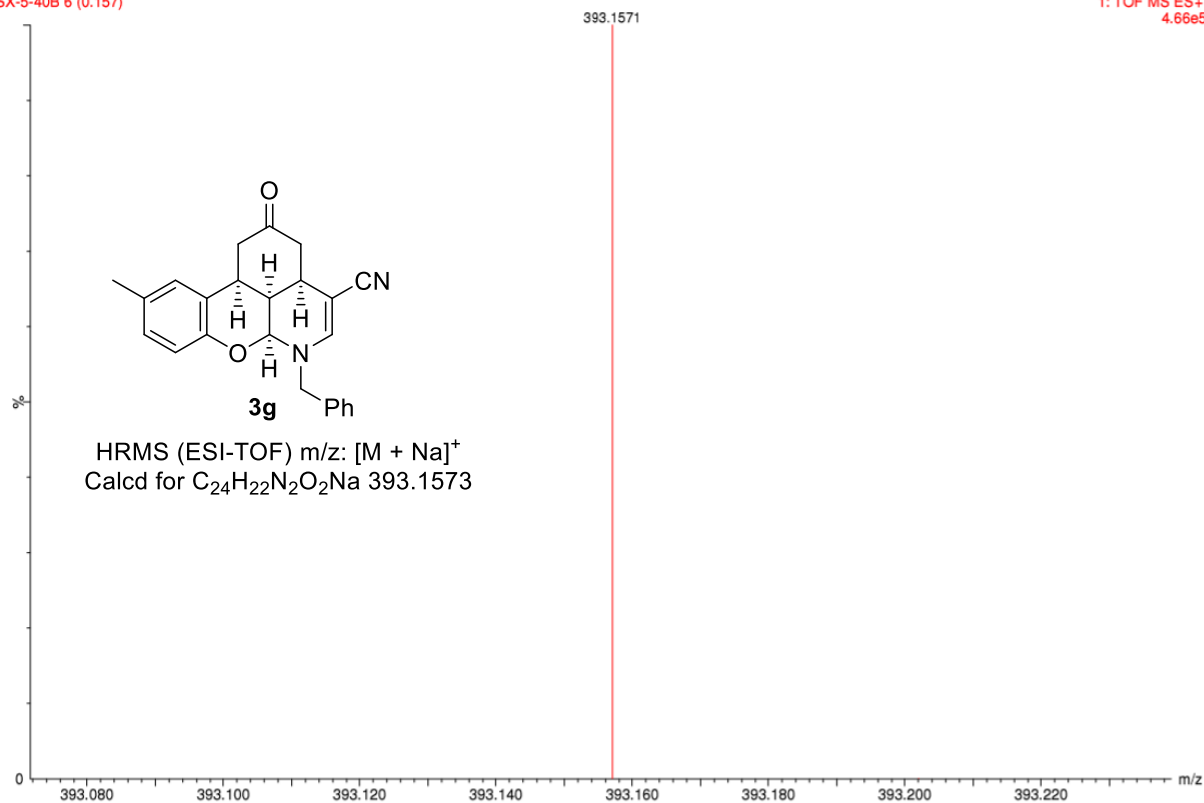


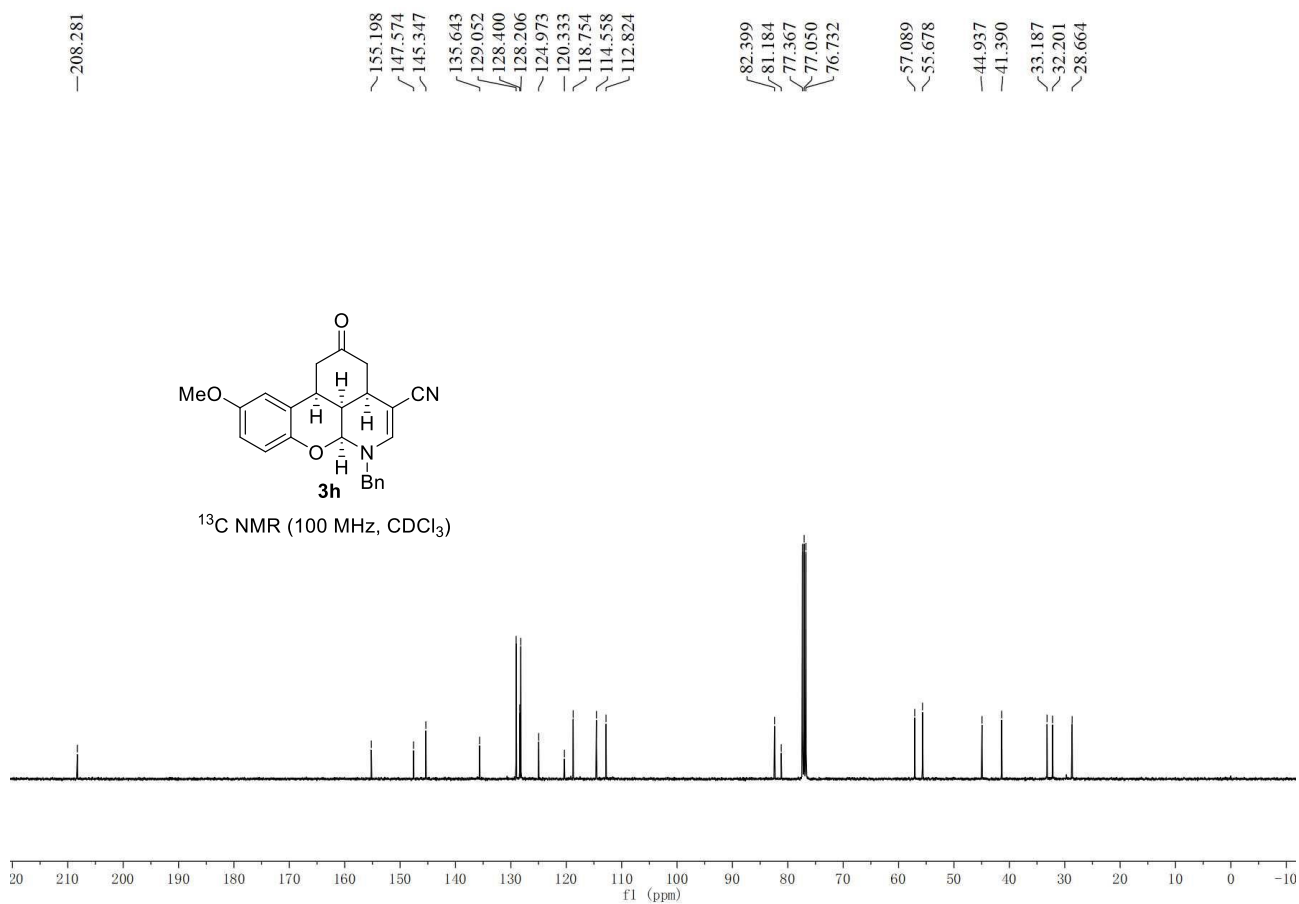
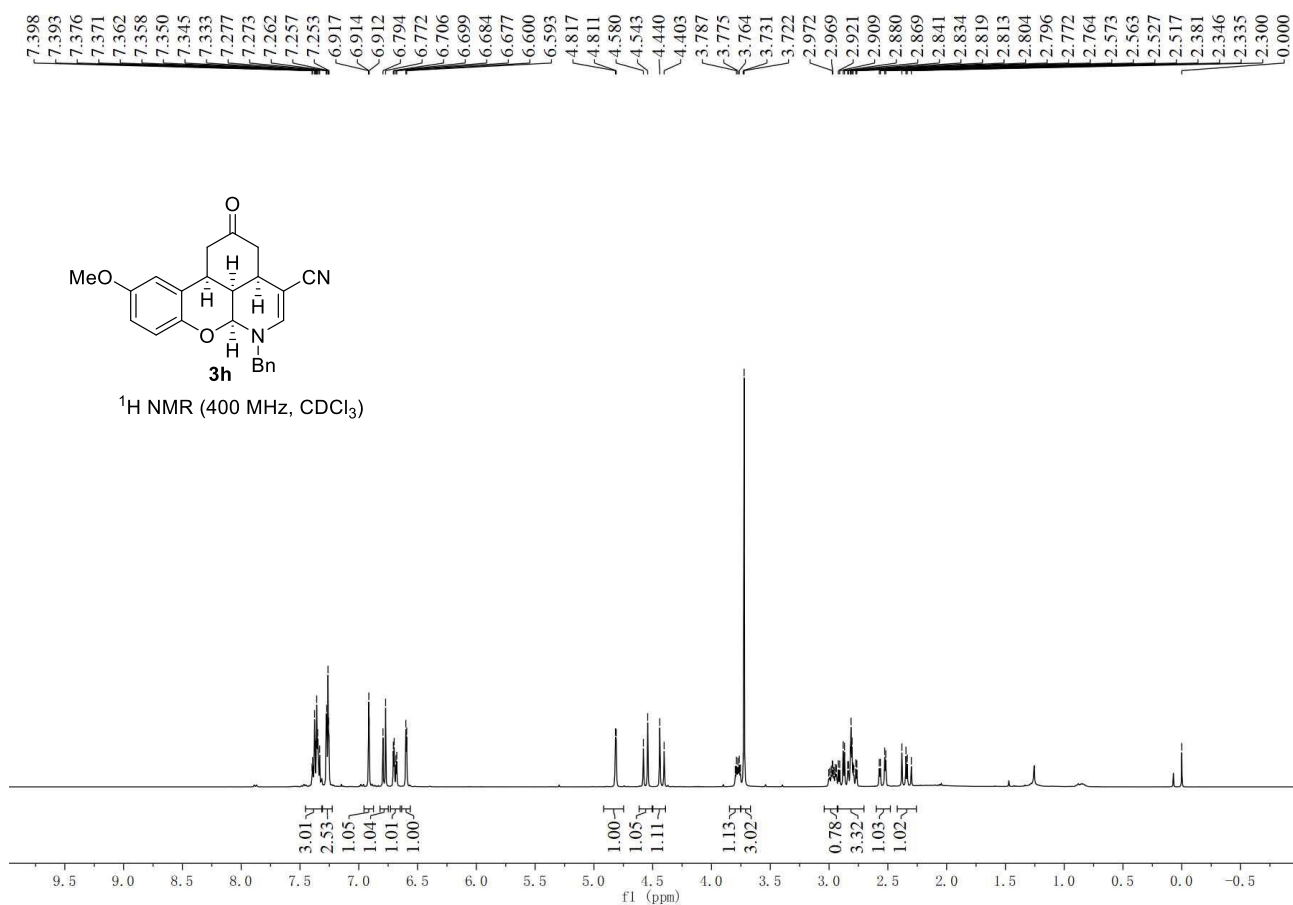


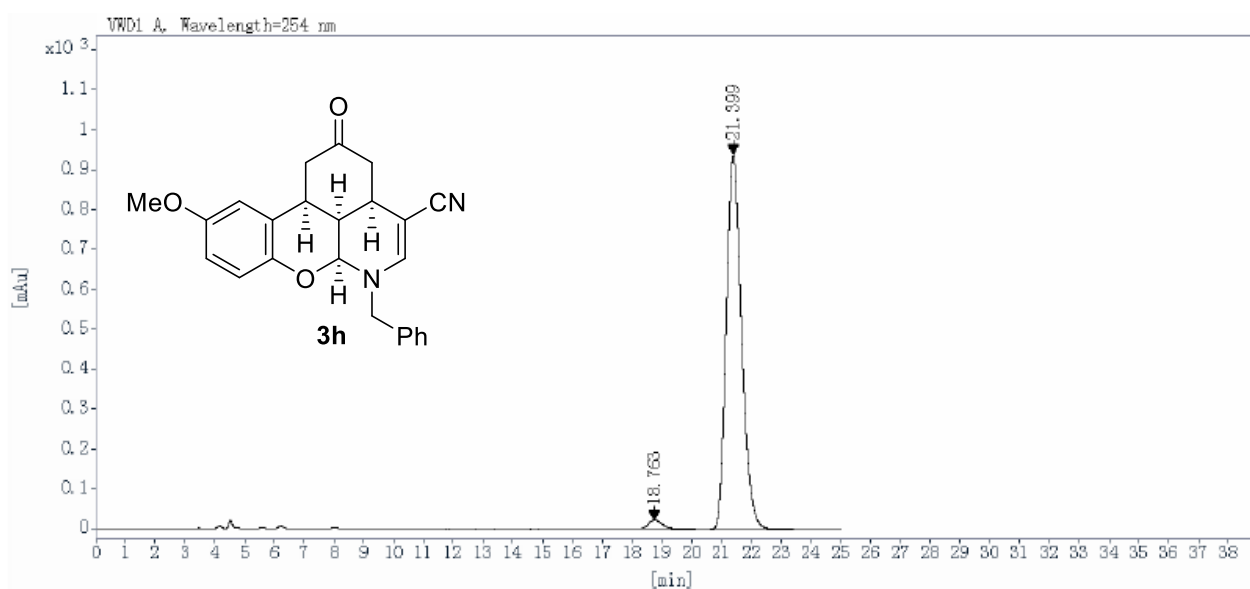
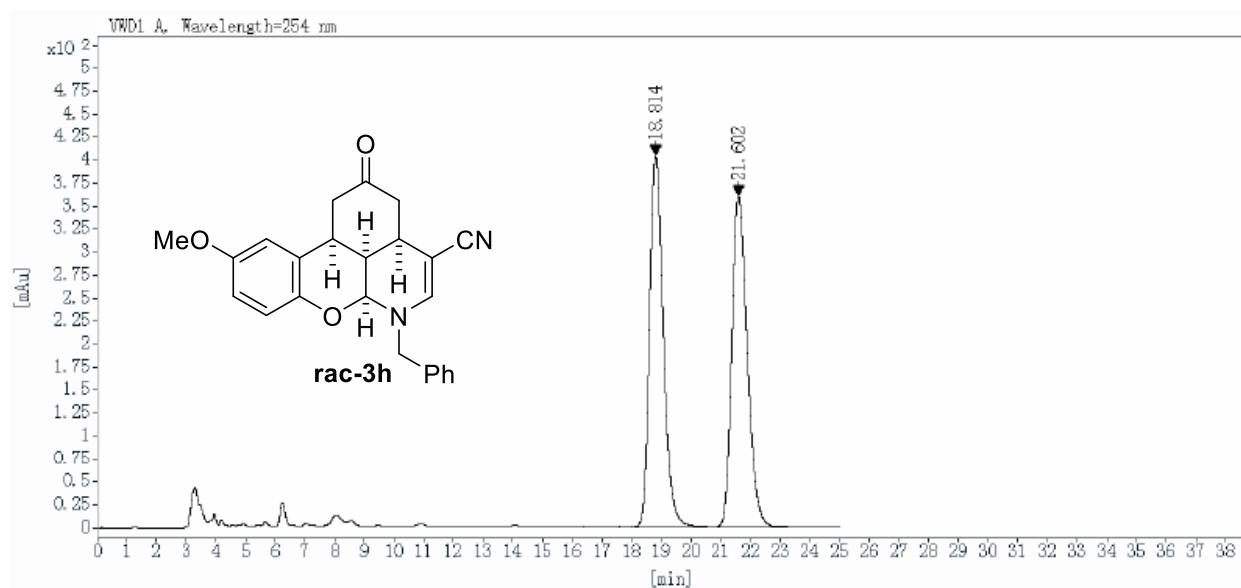


SX-5-40B 6 (0.157)

1: TOF MS ES+
4.66e5

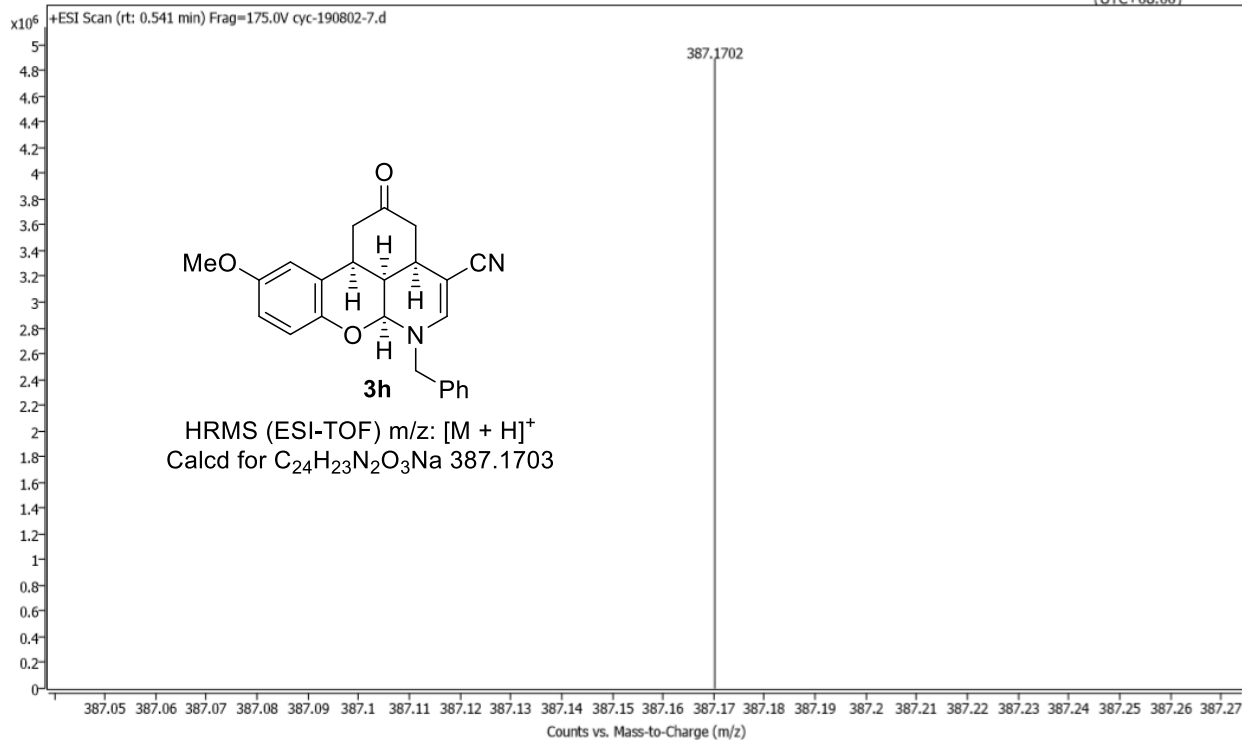


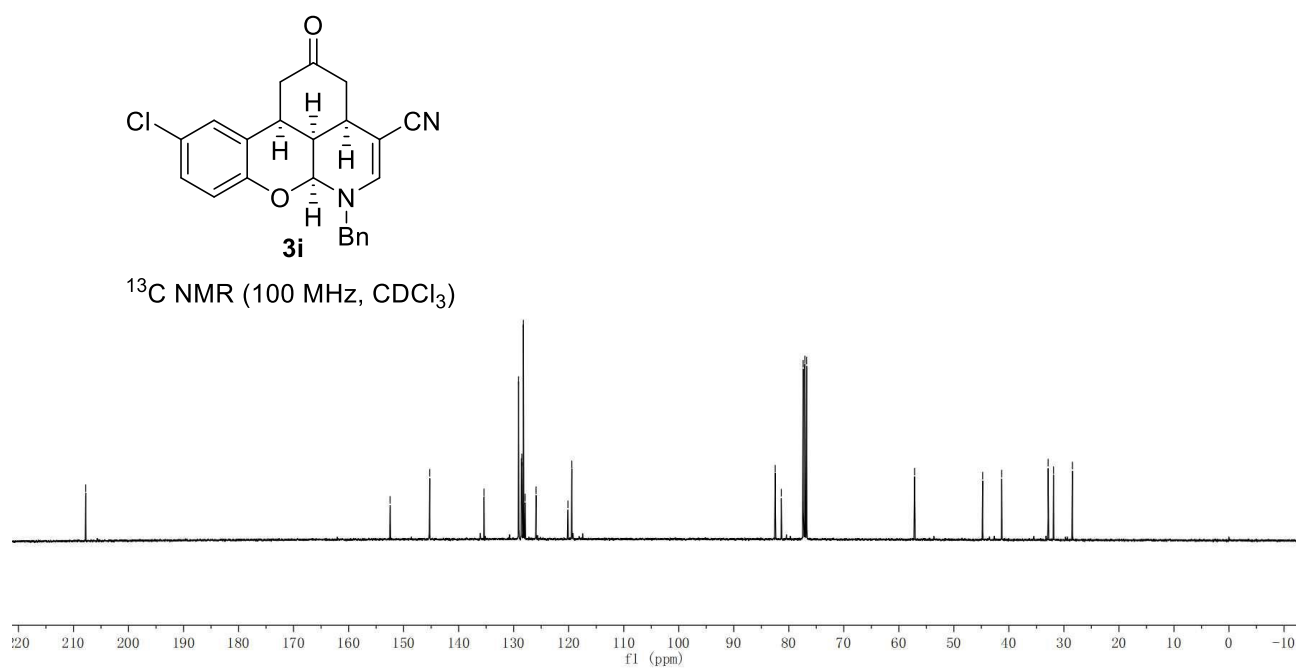
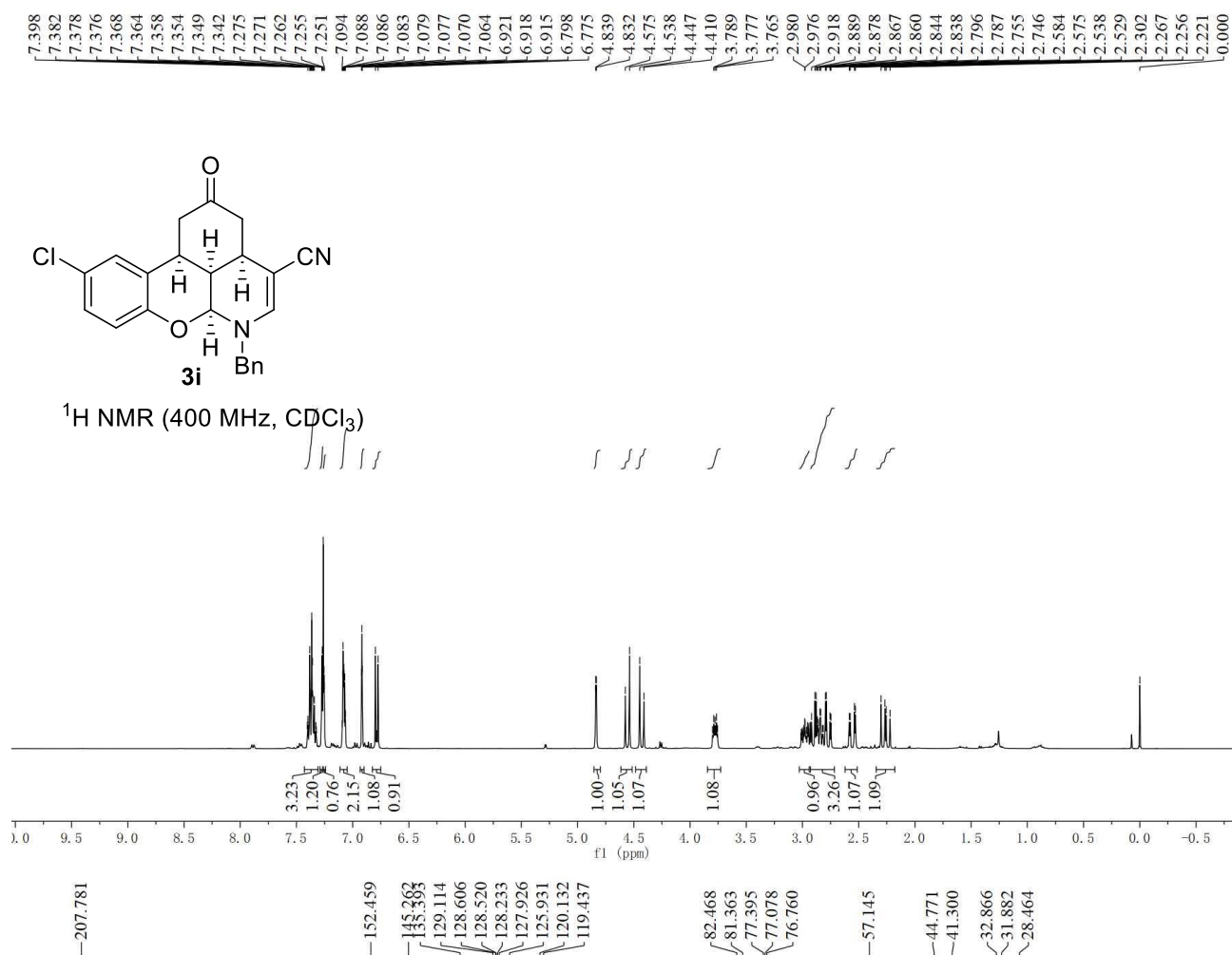


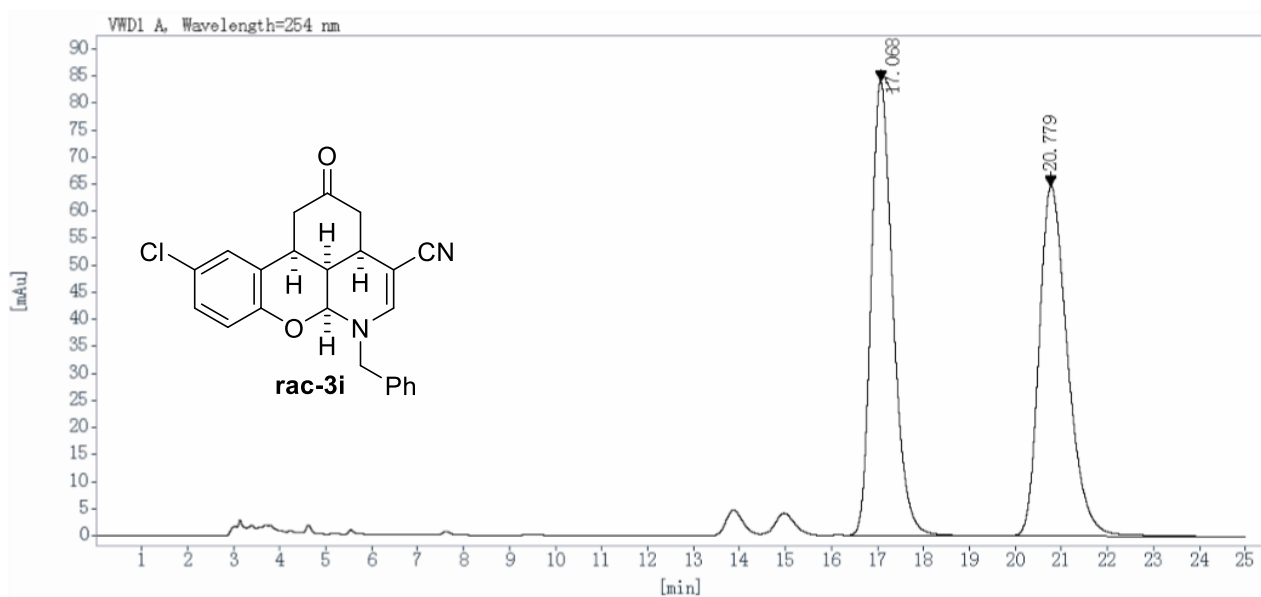


Spectrum Plot Report

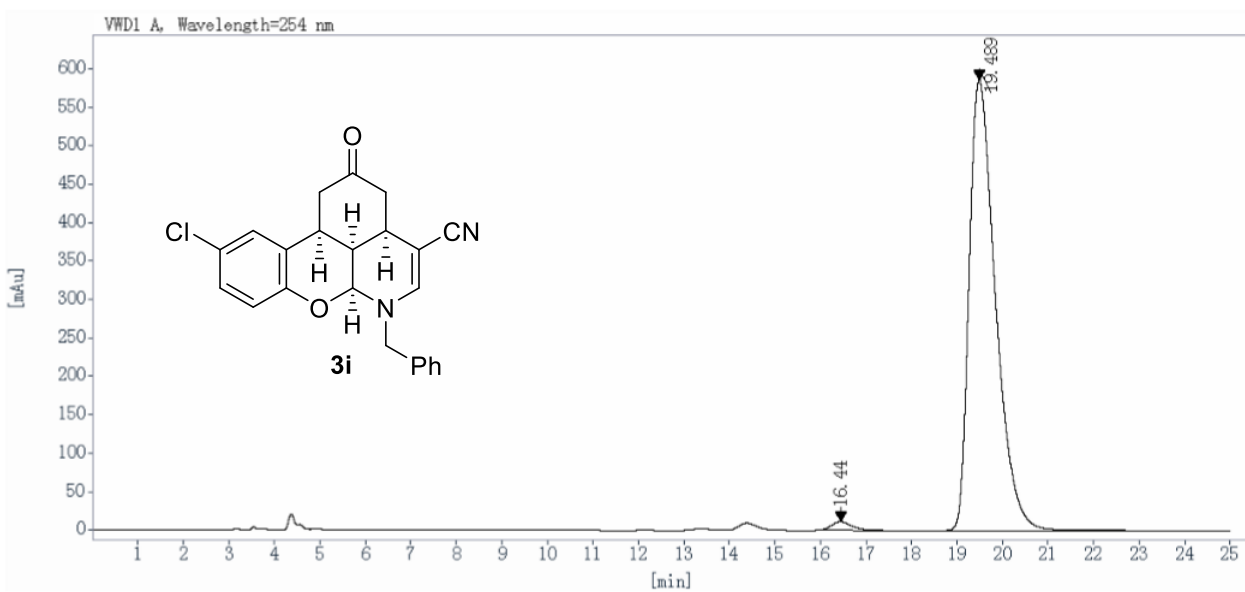
Name	cyc-190802-7	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Some ions missed	
Data File	cyc-190802-7.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 8/8/2019 9:14:18 PM (UTC+08:00)







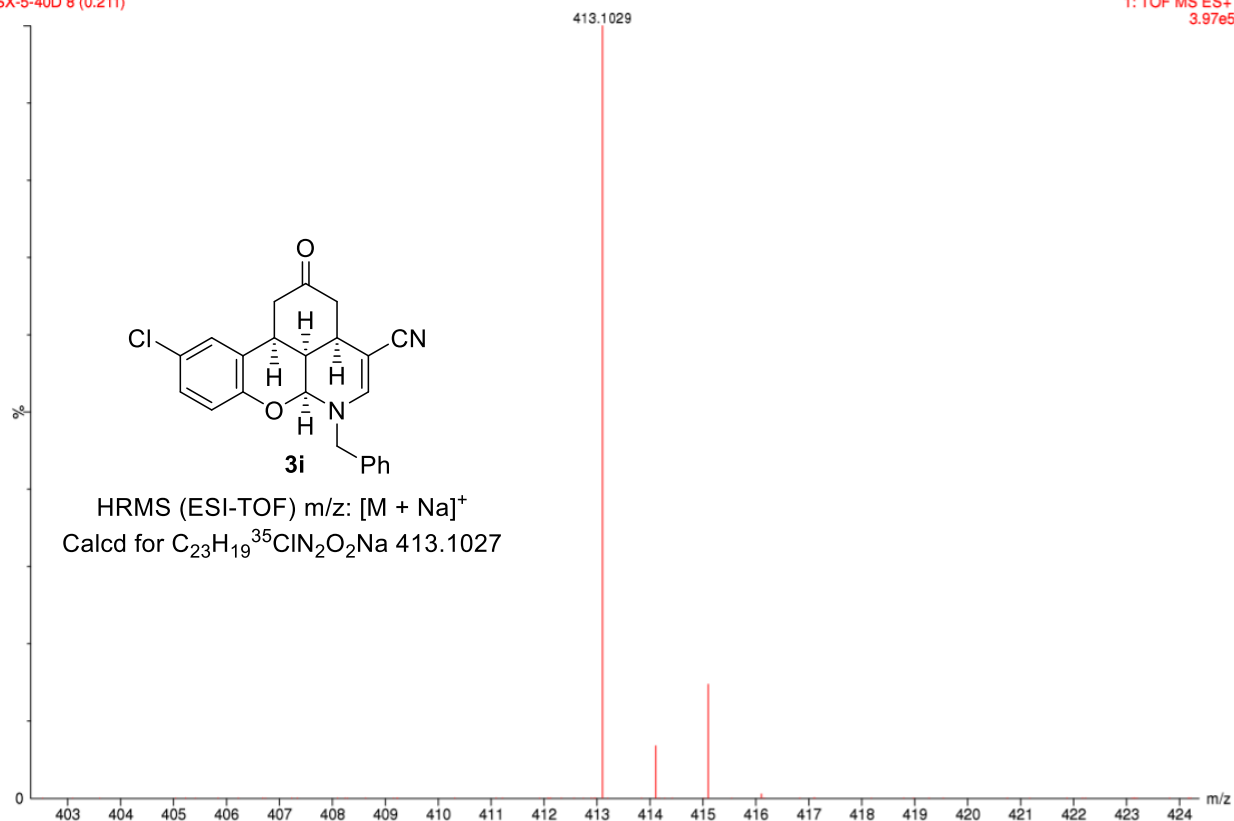
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
17.068	BB	0.50	84.0735	2760.4548	49.8701
20.779	BB	0.66	64.7009	2774.8335	50.1299
Totals:				5535.2883	100.0000



Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.440	BB	0.48	10.9458	338.9474	1.4231
19.489	BB	0.61	586.0291	23478.2793	98.5769
Totals:				23817.2267	100.0000

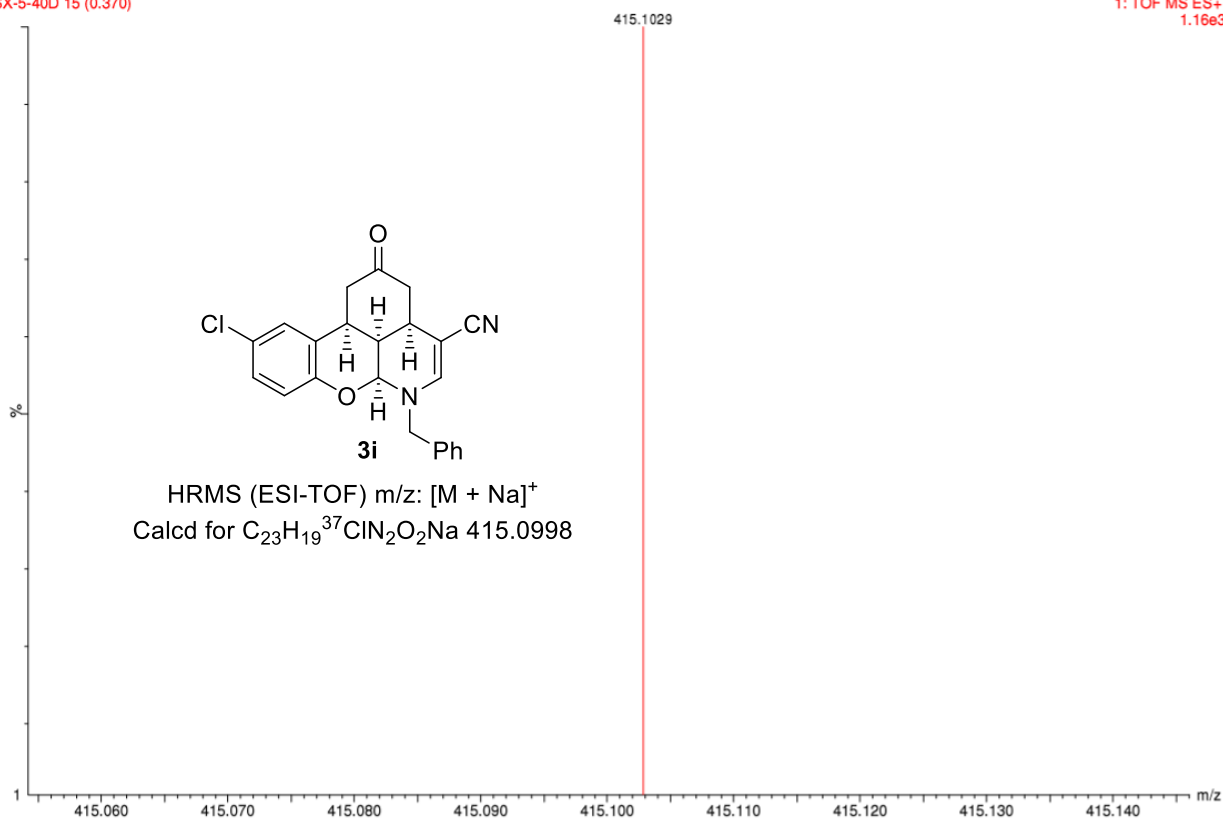
SX-5-40D 8 (0.211)

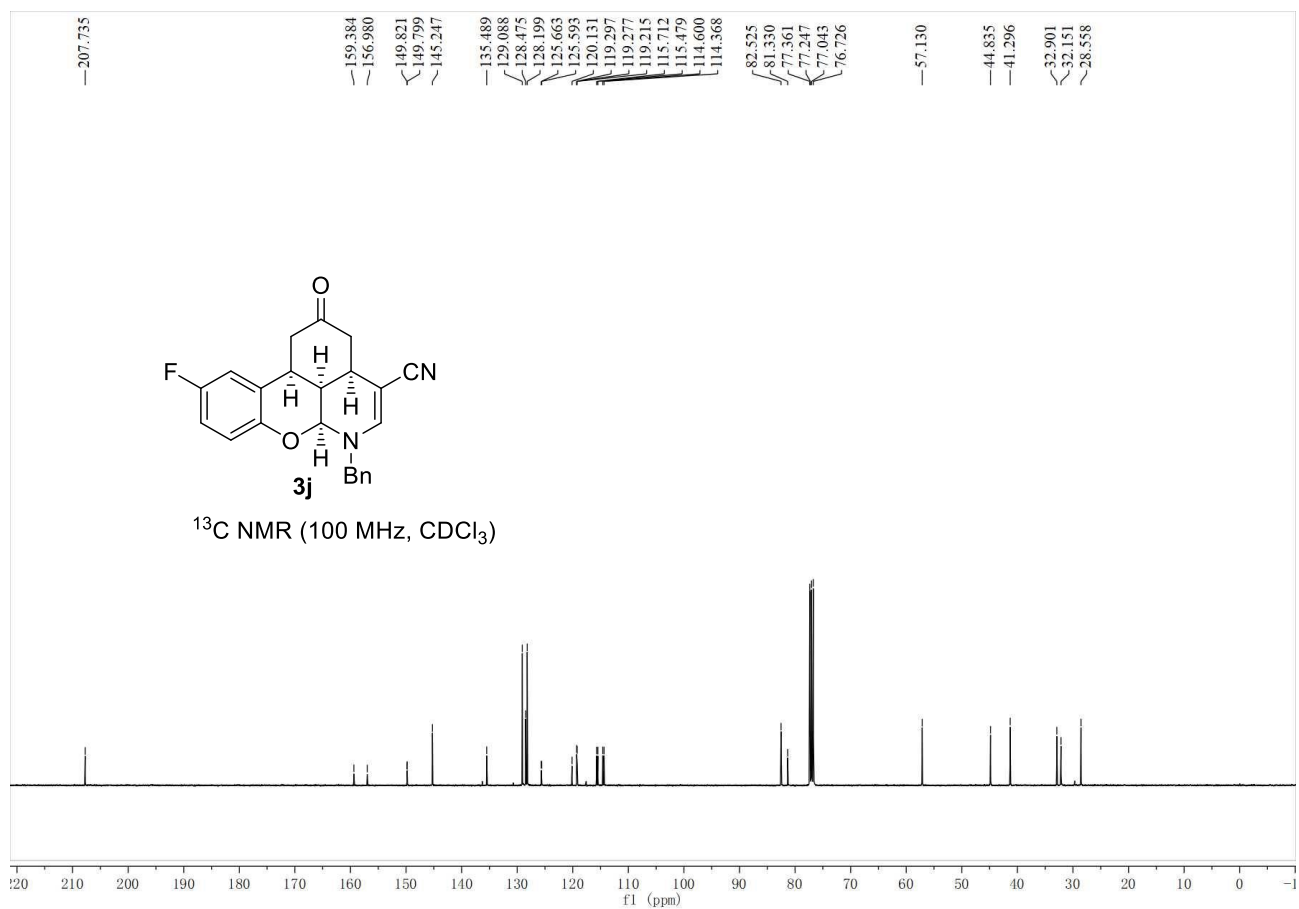
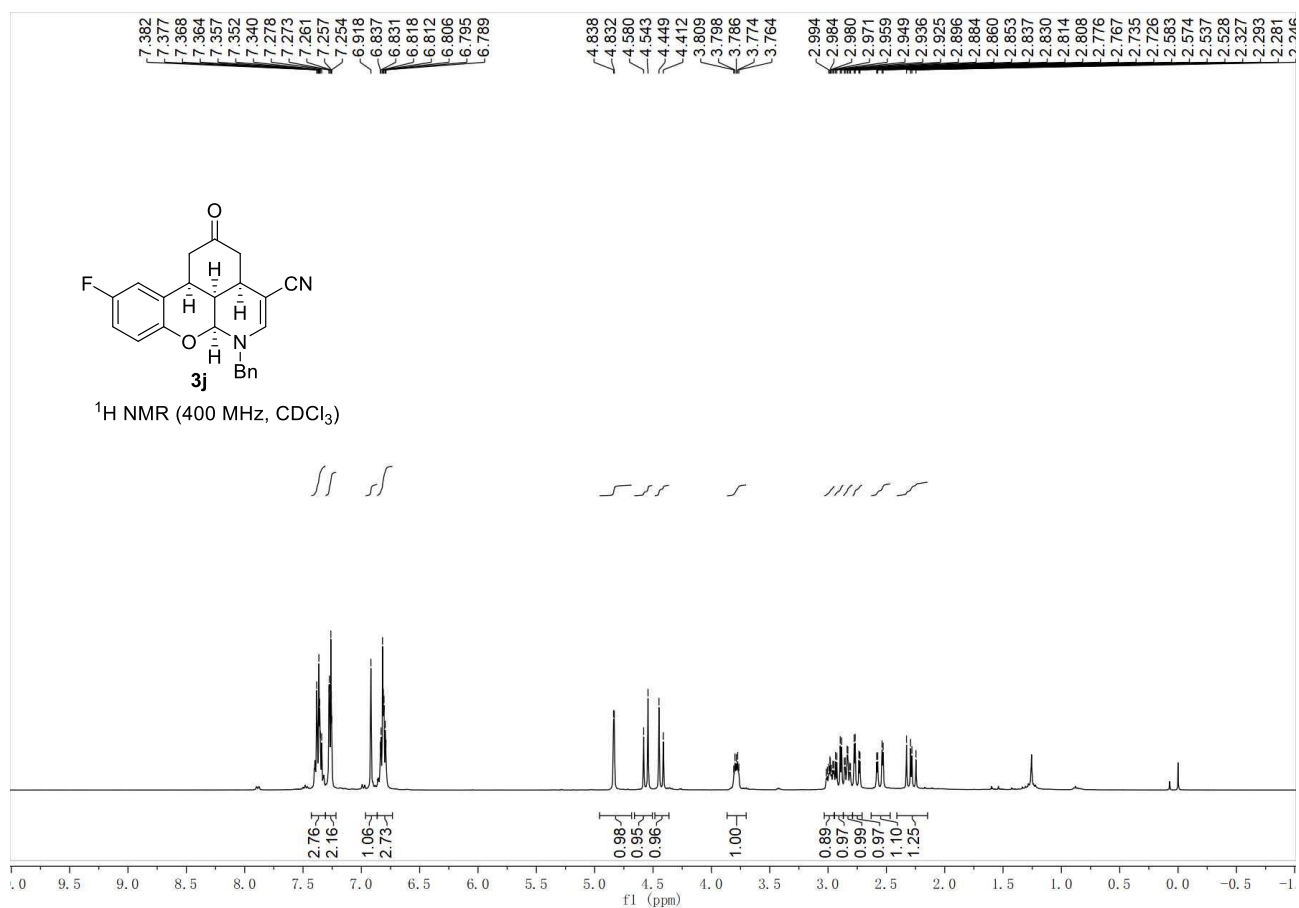
1: TOF MS ES+
3.97e5



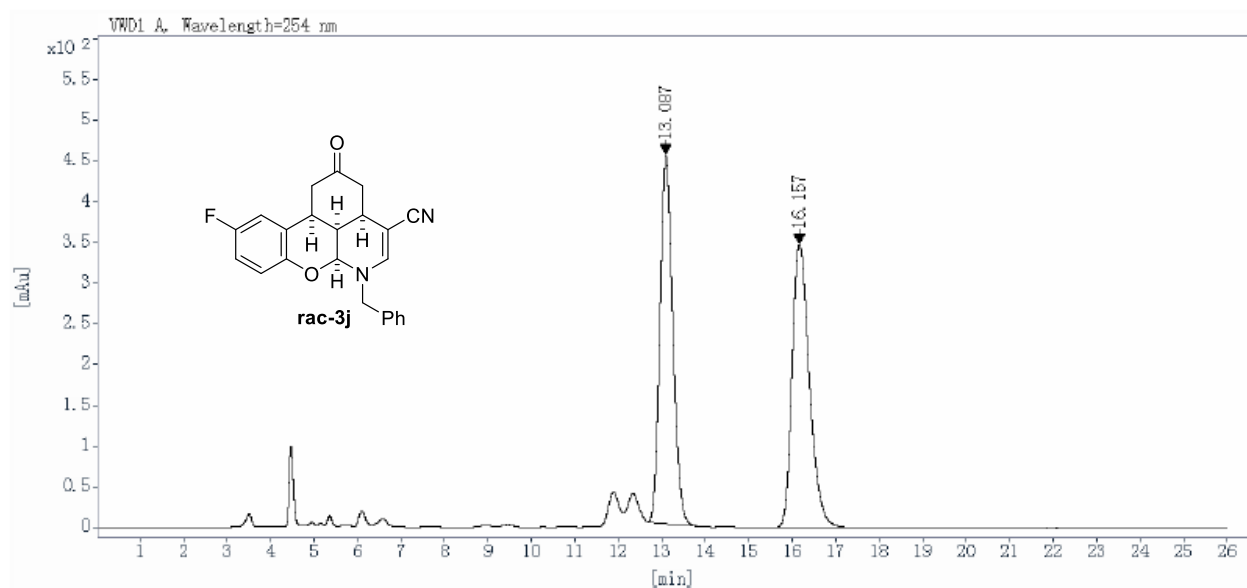
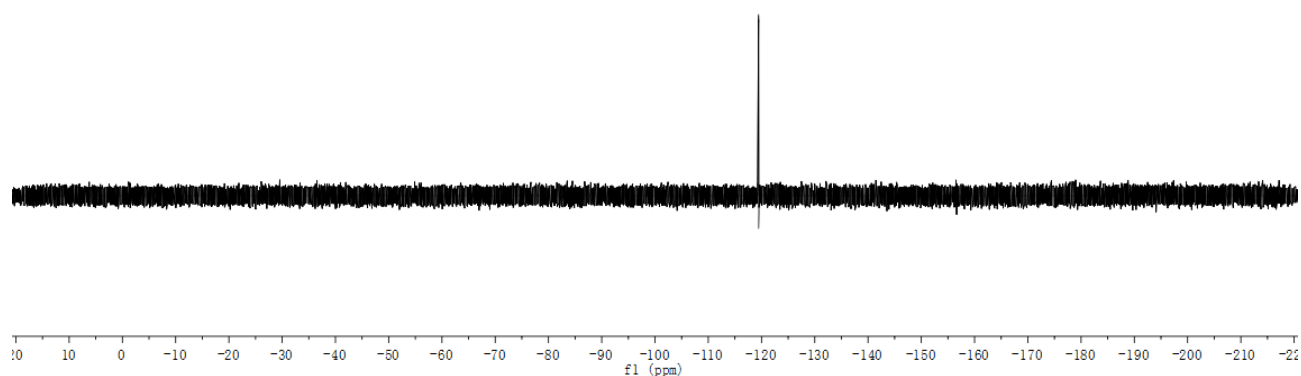
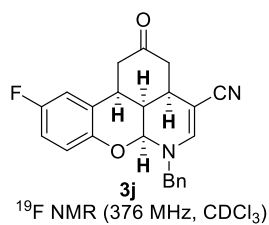
SX-5-40D 15 (0.370)

1: TOF MS ES+
1.16e3

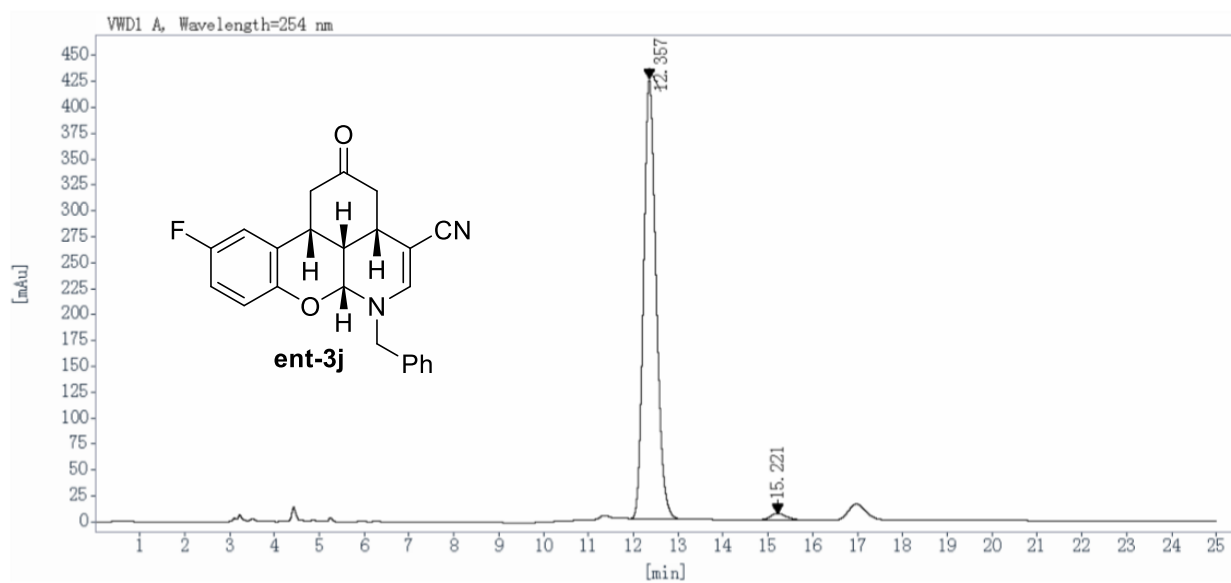
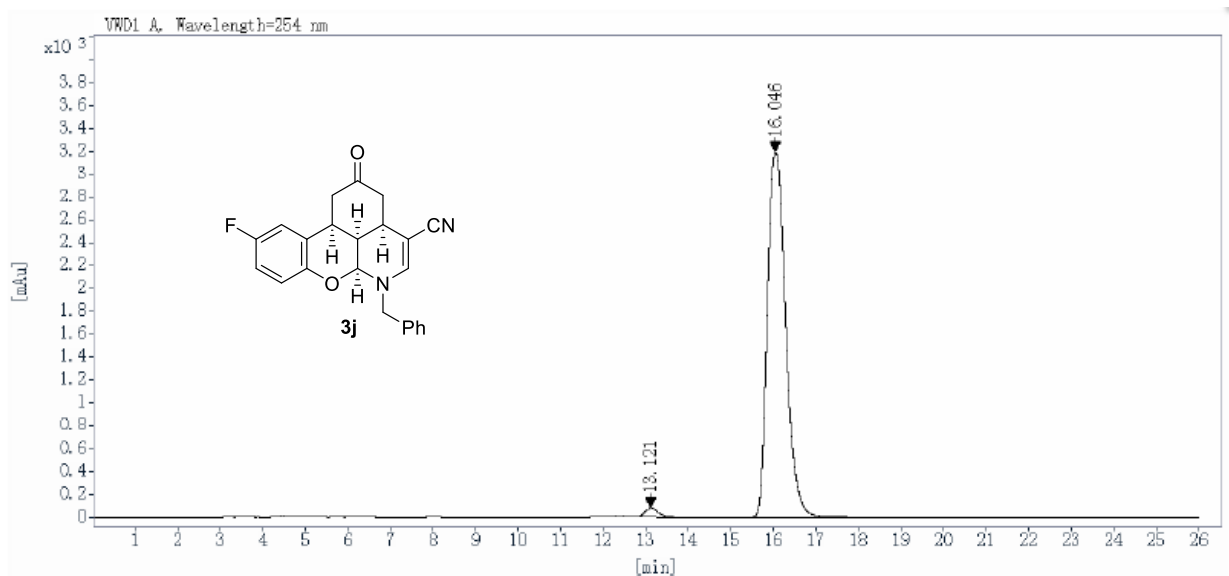




—119,448

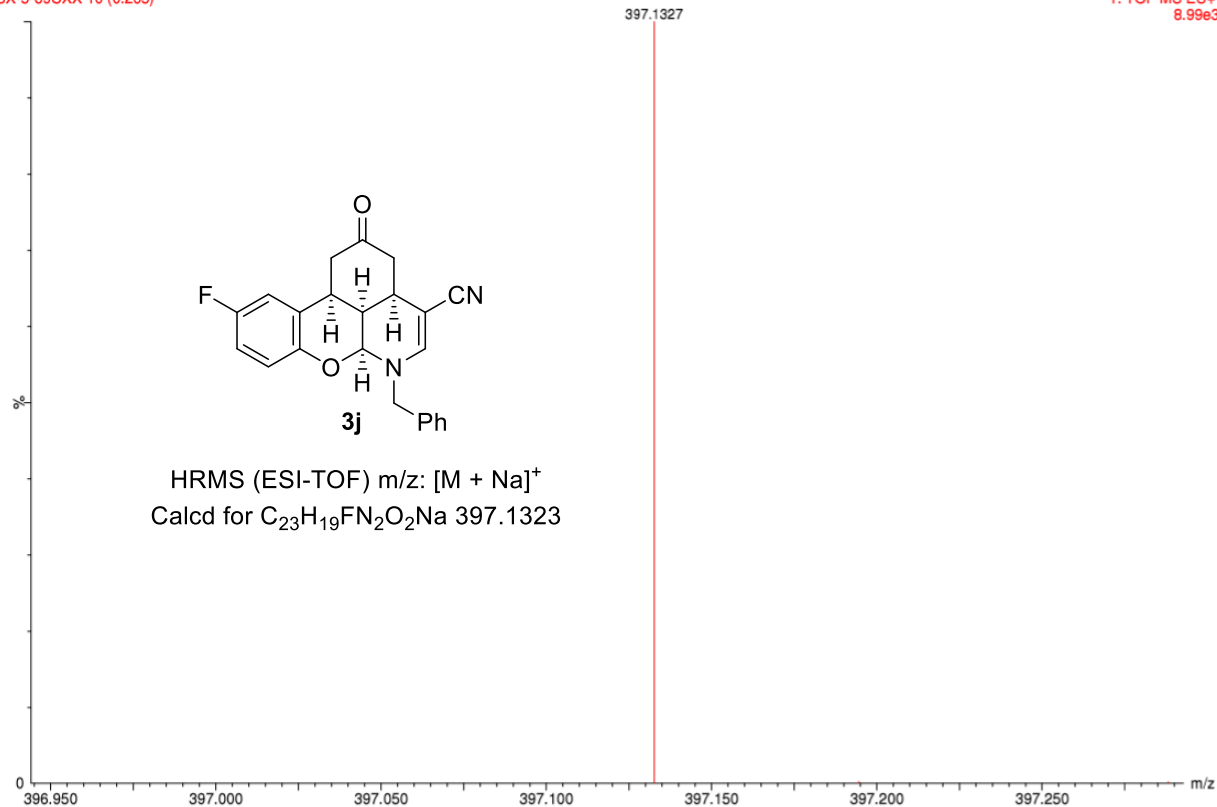


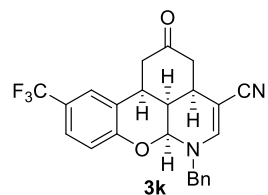
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
13.087	BB	0.32	452.6000	9321.4033	49.2768
16.157	BB	0.43	348.3522	9594.9990	50.7232
Totals:				18916.4023	100.0000



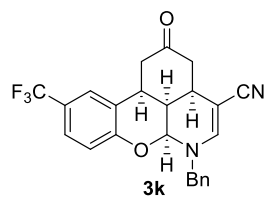
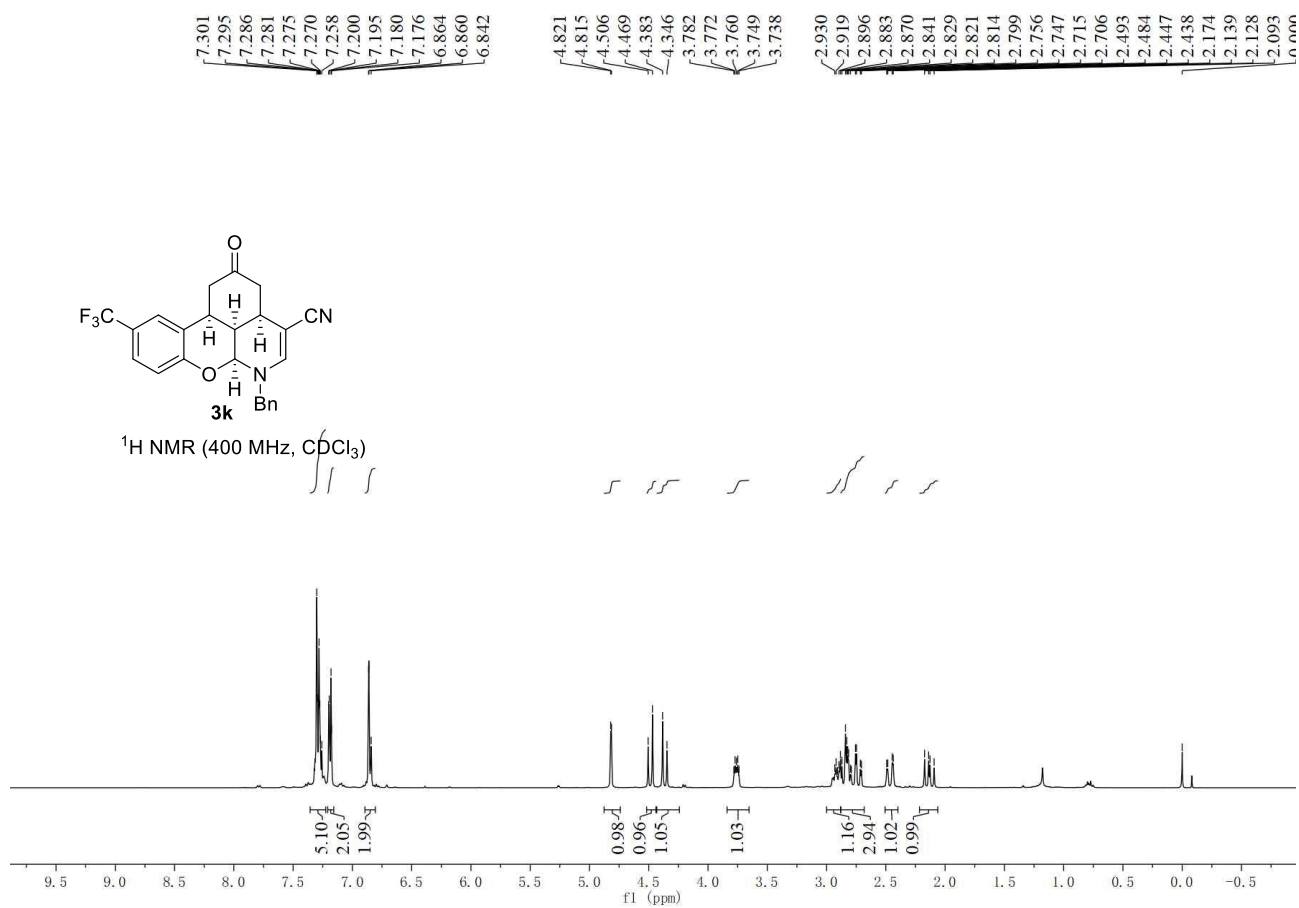
SX-5-89CXX 10 (0.265)

1: TOF MS ES+
8.99e3

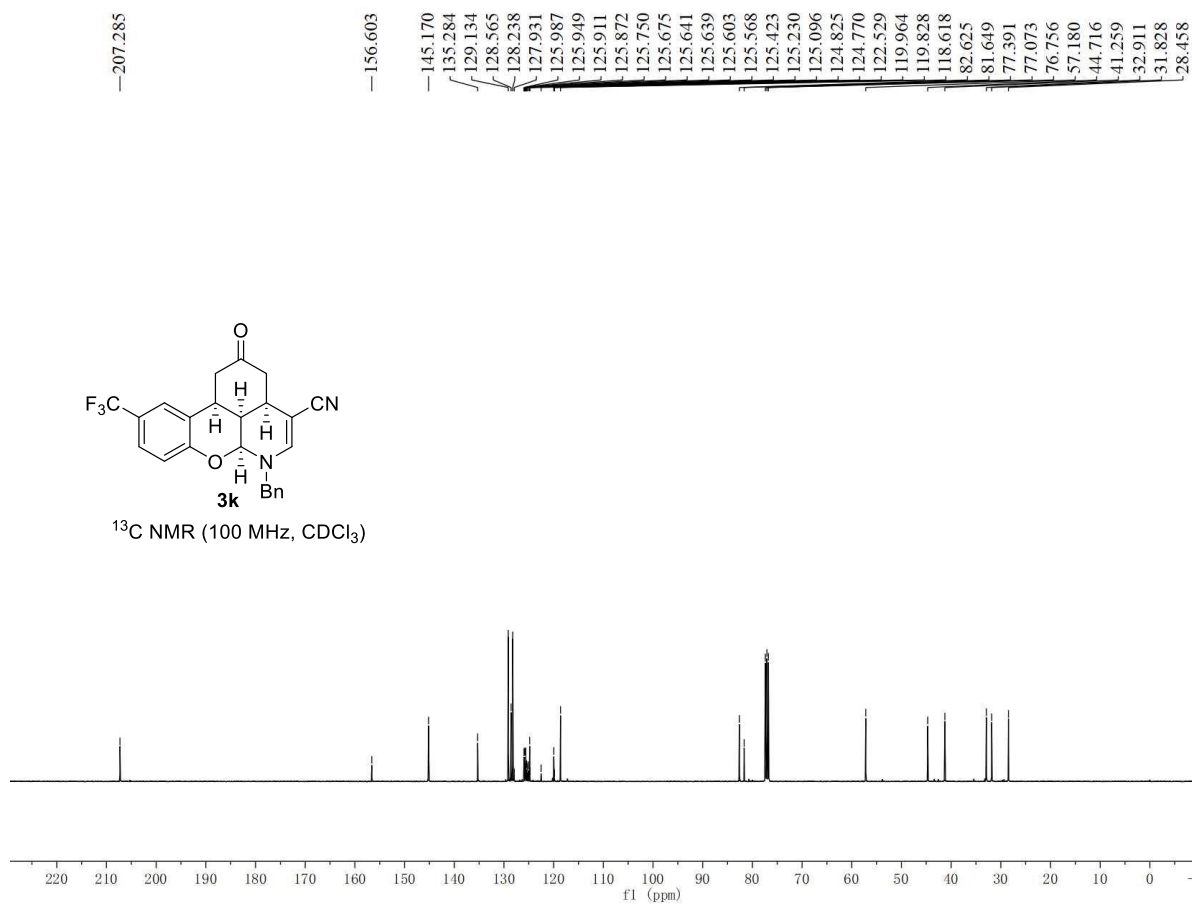




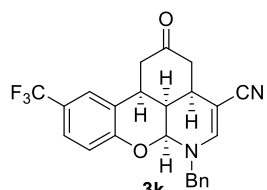
^1H NMR (400 MHz, CDCl_3)



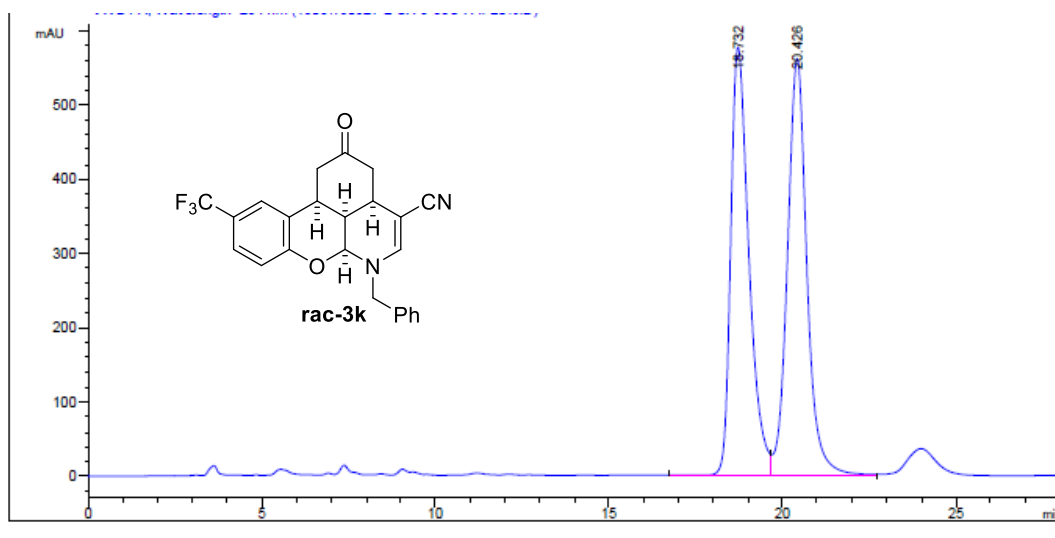
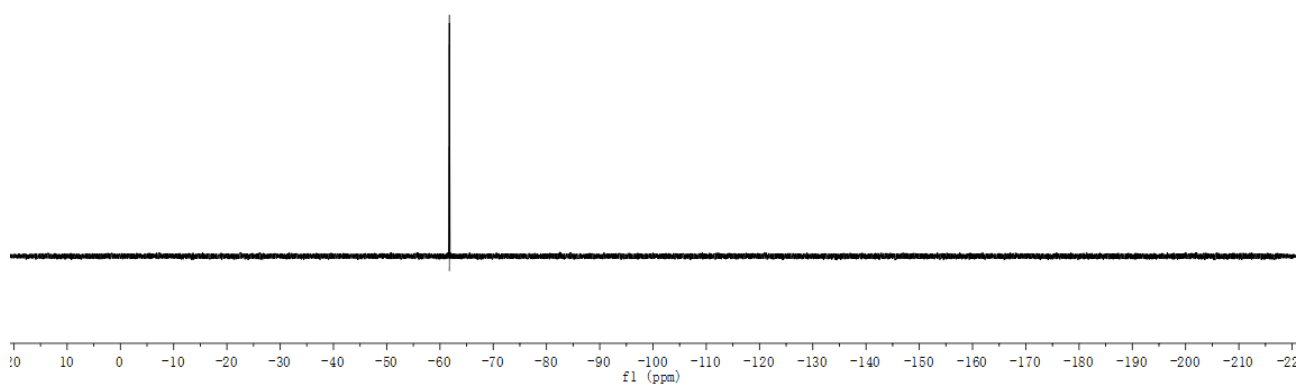
^{13}C NMR (100 MHz, CDCl_3)



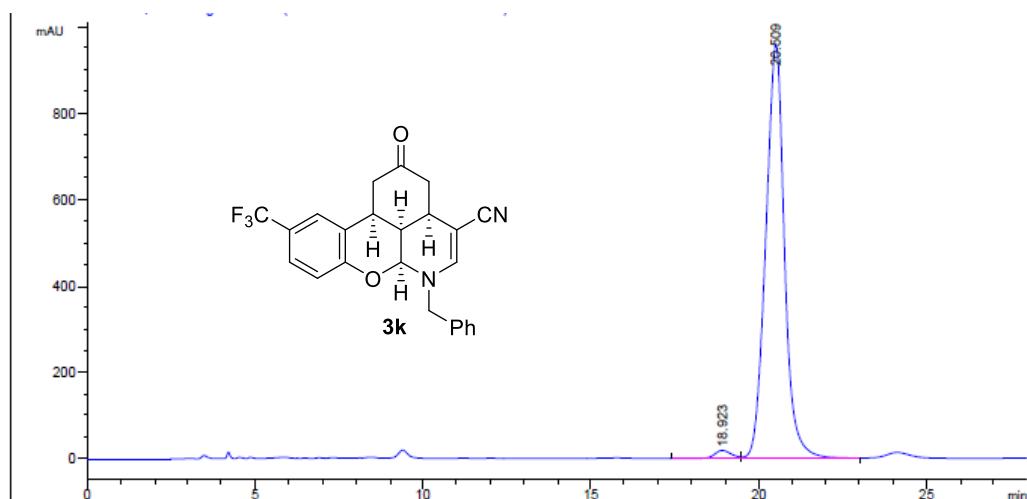
—61.762



¹⁹F NMR (376 MHz, CDCl₃)

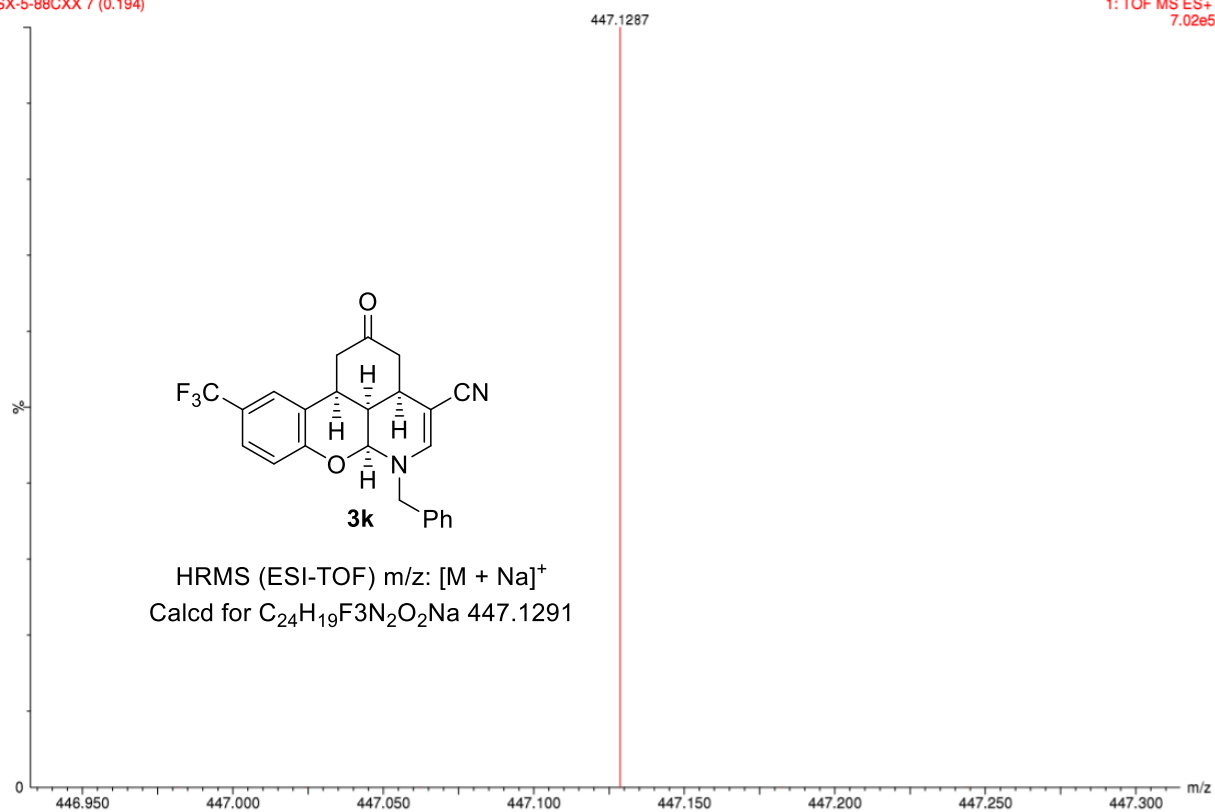


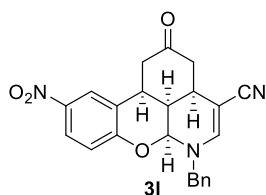
Peak #	RetTime [min]	Type	Width [min]	Area mAU	Height [mAU]	Area %
1	18.732	BV	0.5532	2.09681e4	575.47424	48.9622
2	20.426	VV	0.5946	2.16570e4	560.65485	51.0378
Totals :				4.26251e4	1136.12909	



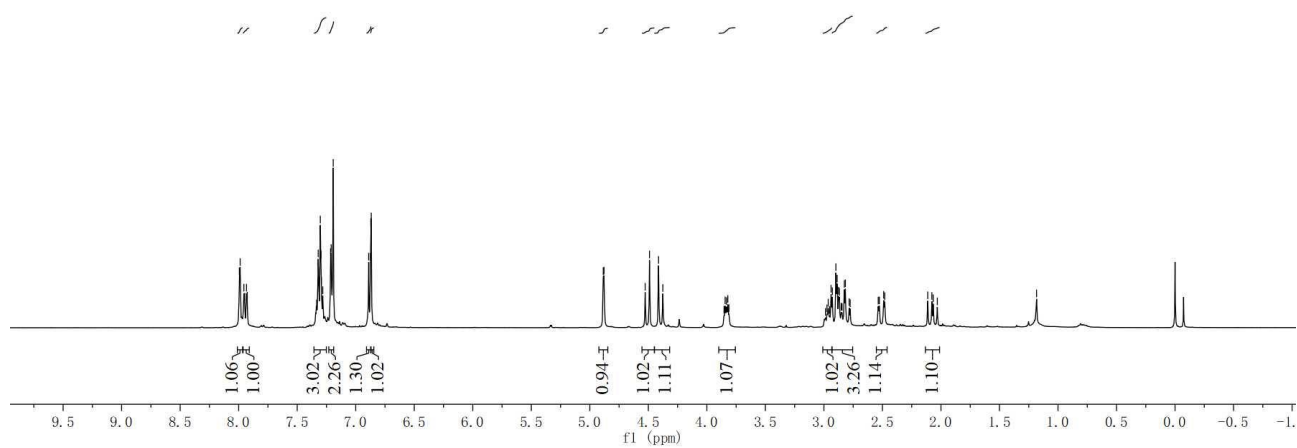
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.923	BV	0.5338	648.00433	18.63547	1.7089
2	20.509	VBA	0.5938	3.72713e4	957.73682	98.2911
Totals :				3.79193e4	976.37229	

SX-5-88CXX 7 (0.194)





^1H NMR (400 MHz, CDCl_3)



—206.753

—159.245

—144.983

—143.006

—135.057

—129.201

—128.688

—128.241

—125.056

—124.835

—124.321

—119.676

—118.831

—83.034

—81.969

—77.369

—77.052

—76.734

—57.266

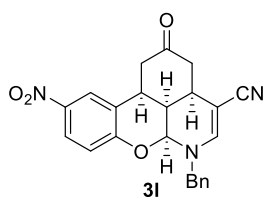
—44.729

—41.134

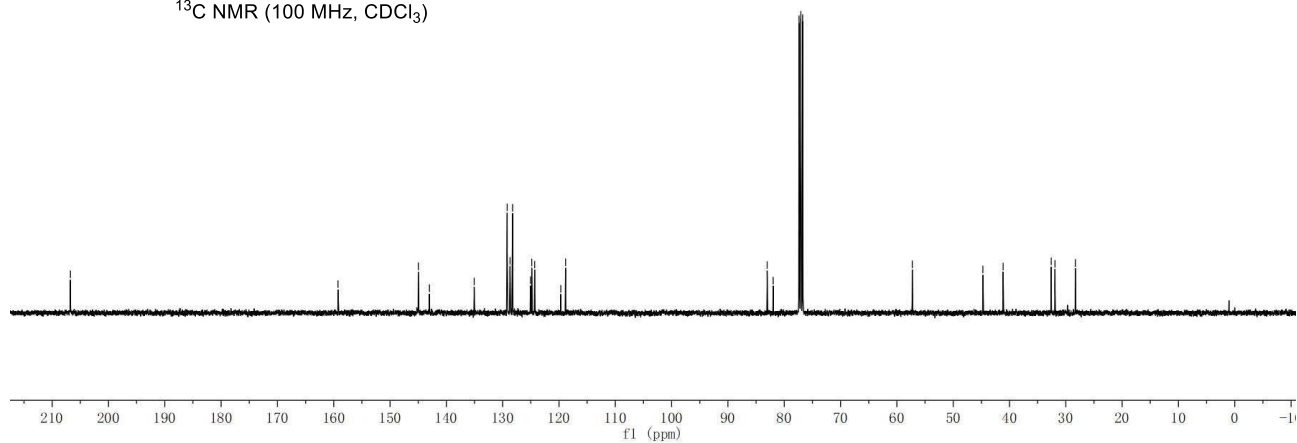
—32.591

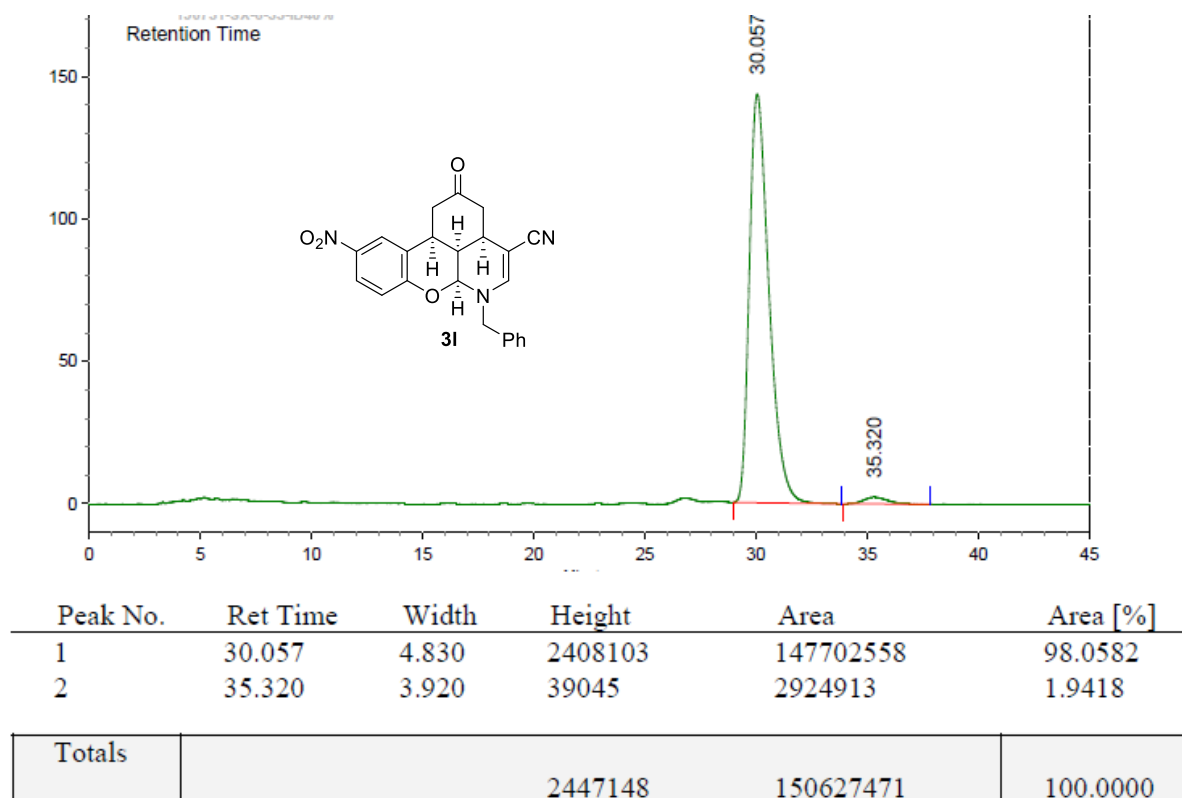
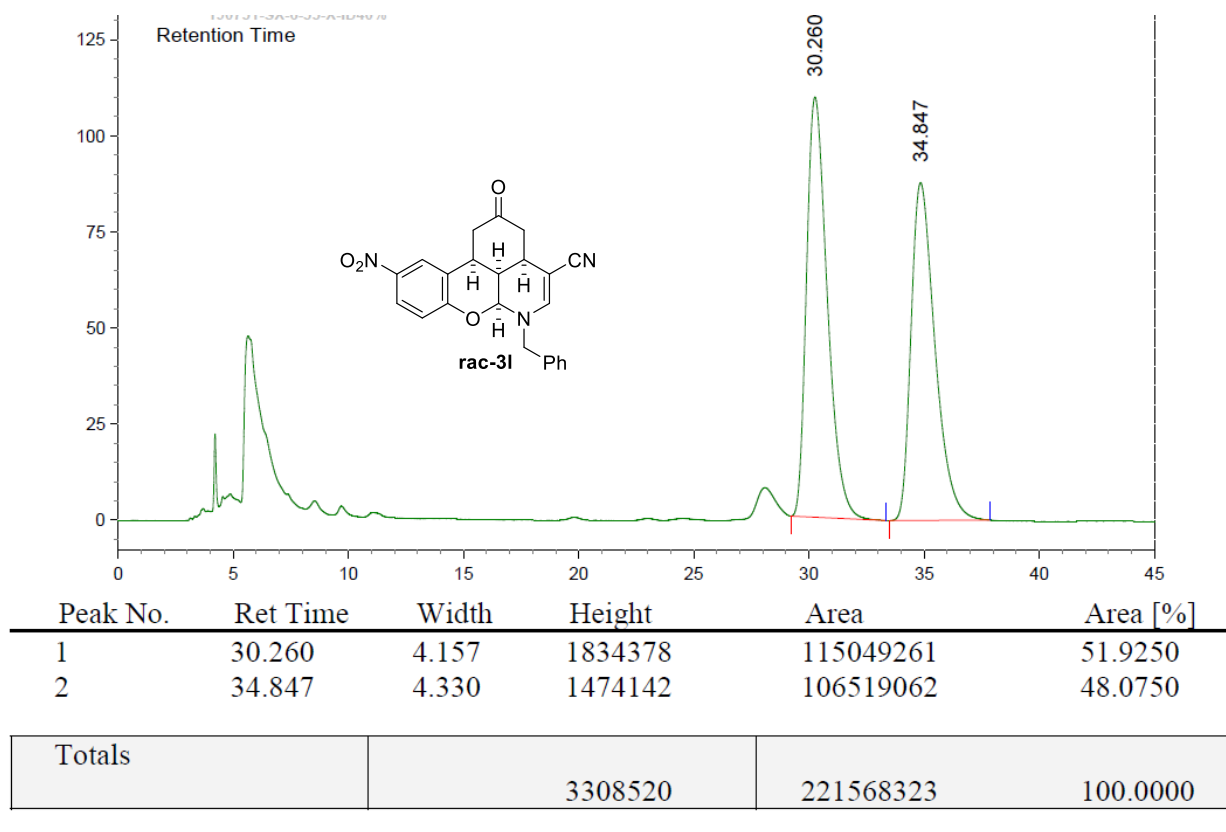
—31.919

—28.308



^{13}C NMR (100 MHz, CDCl_3)

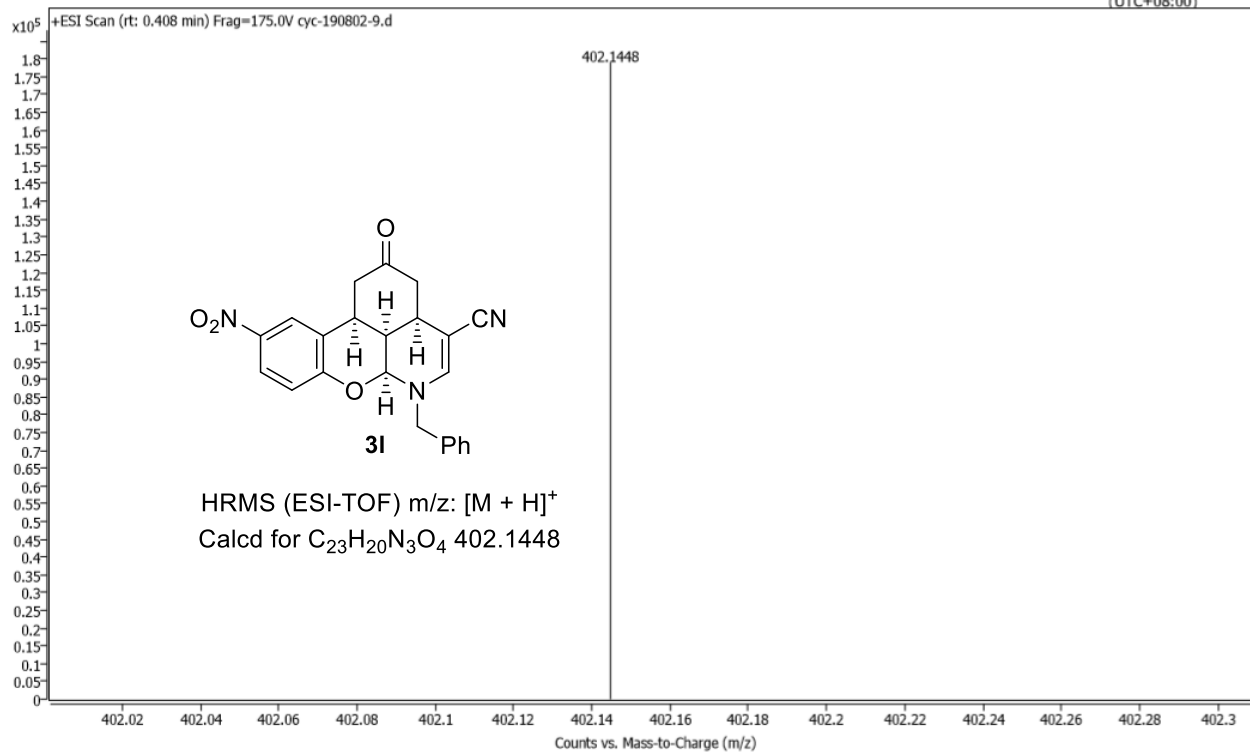


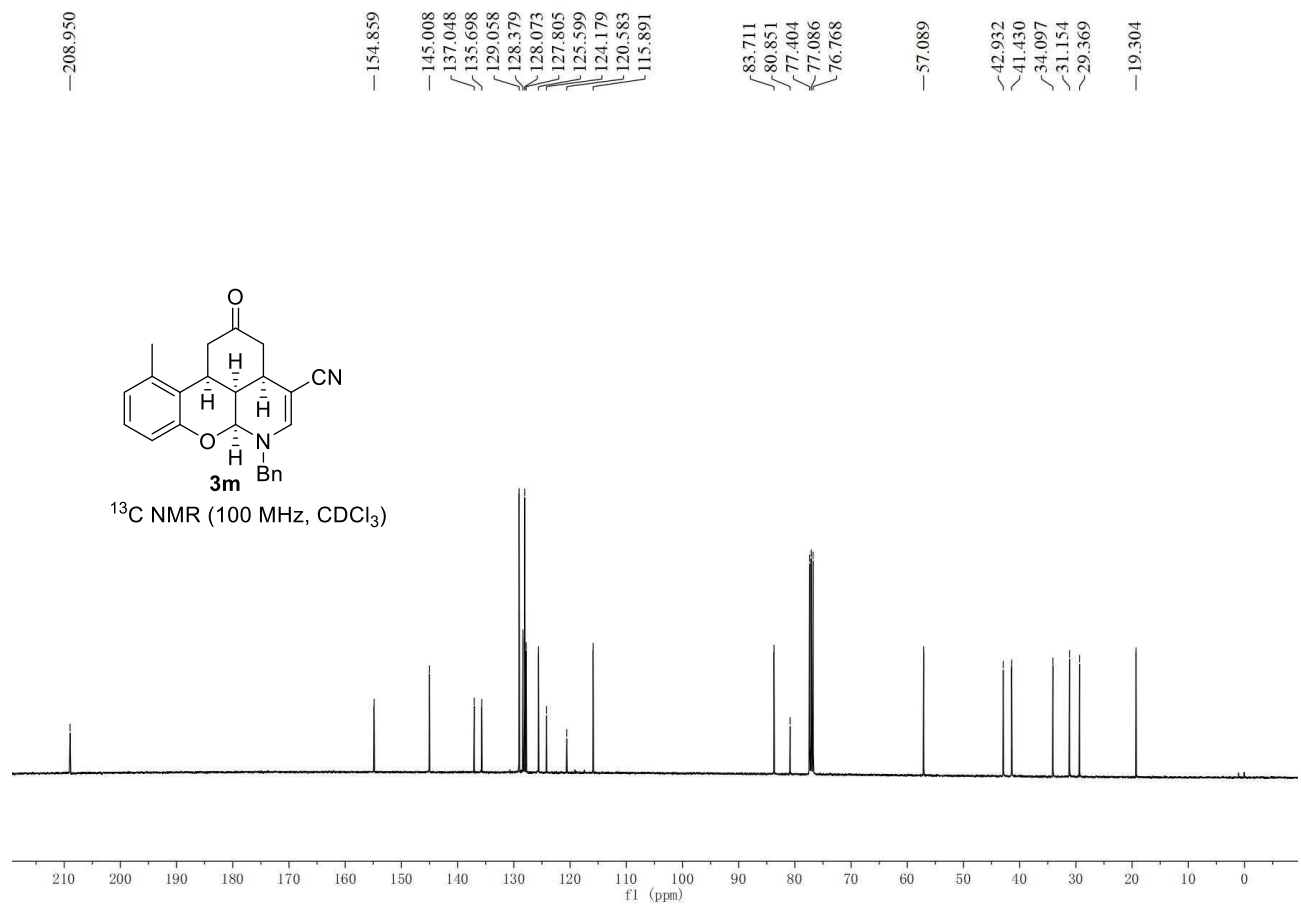
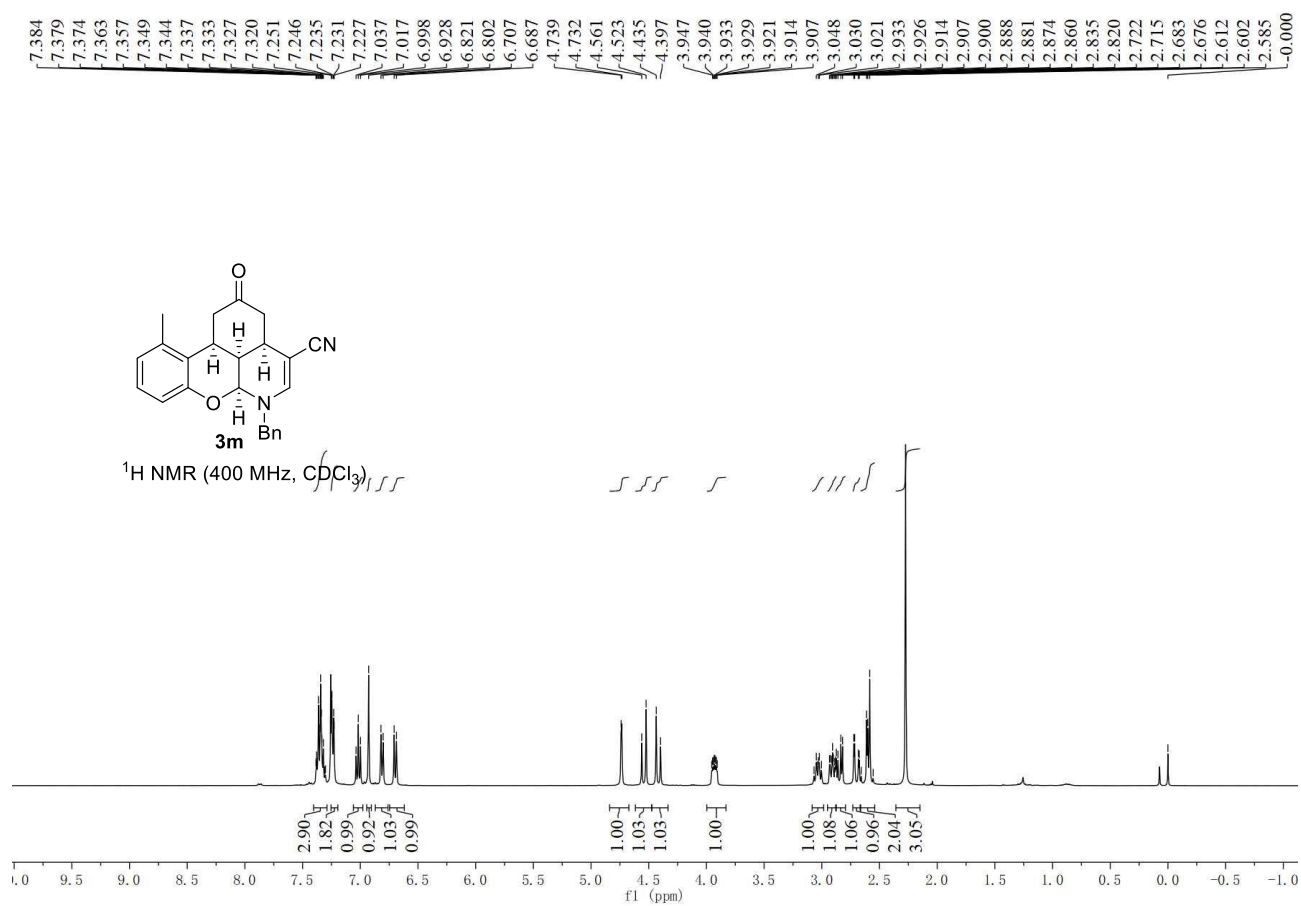


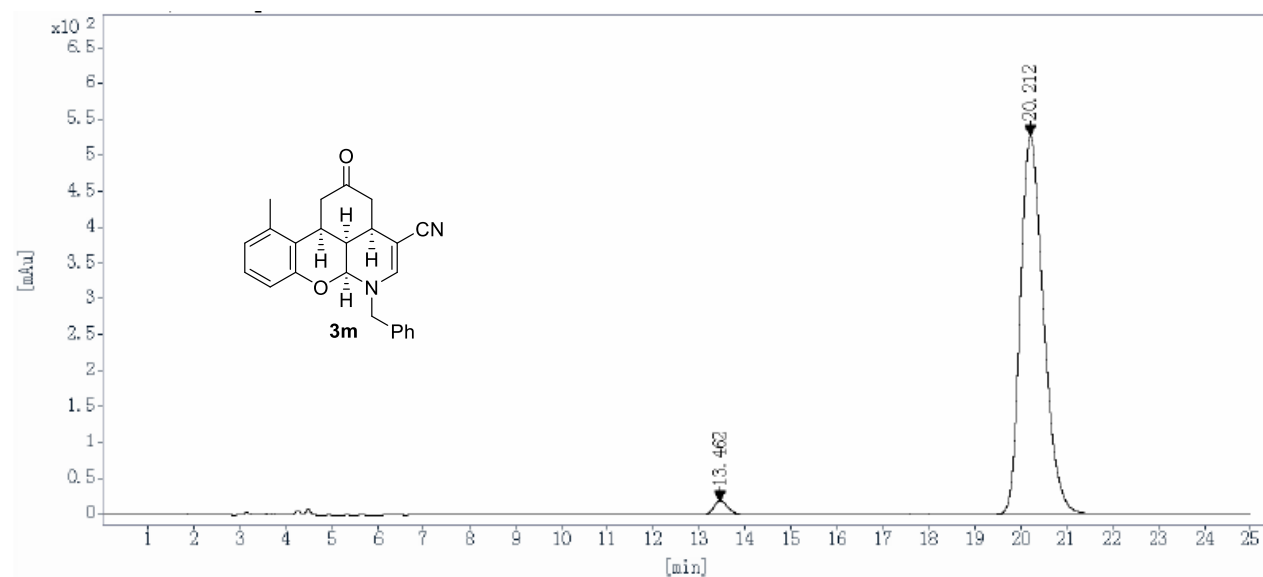
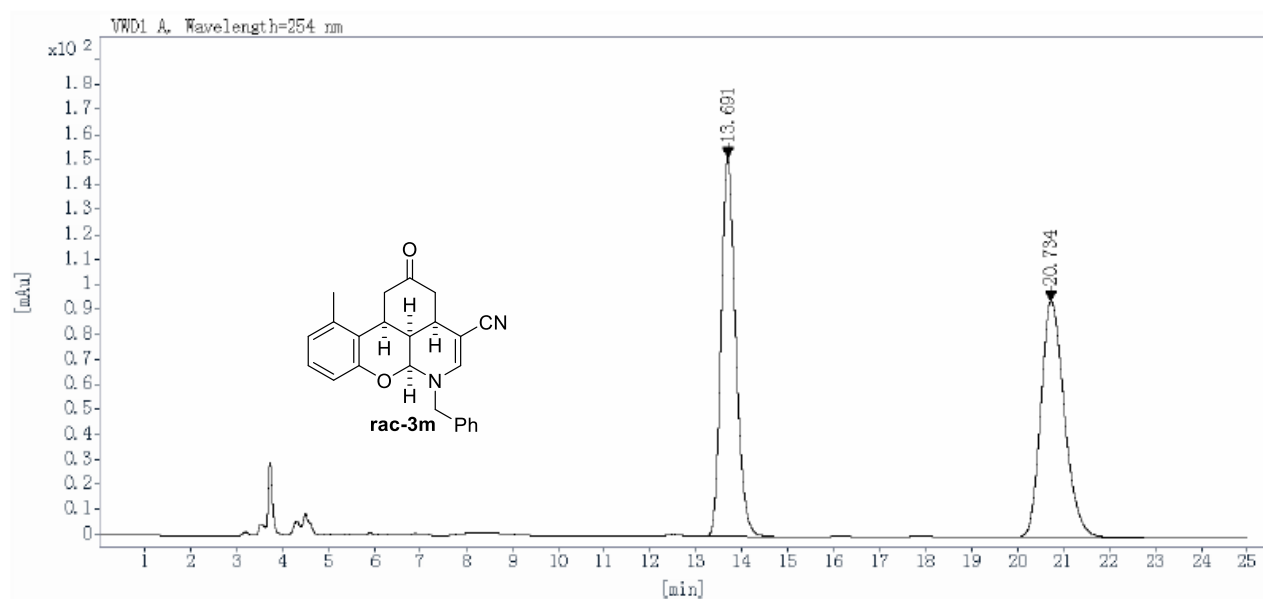
Spectrum Plot Report



Name	cyc-190802-9	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-190802-9.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 8/8/2019 9:20:20 PM (UTC+08:00)



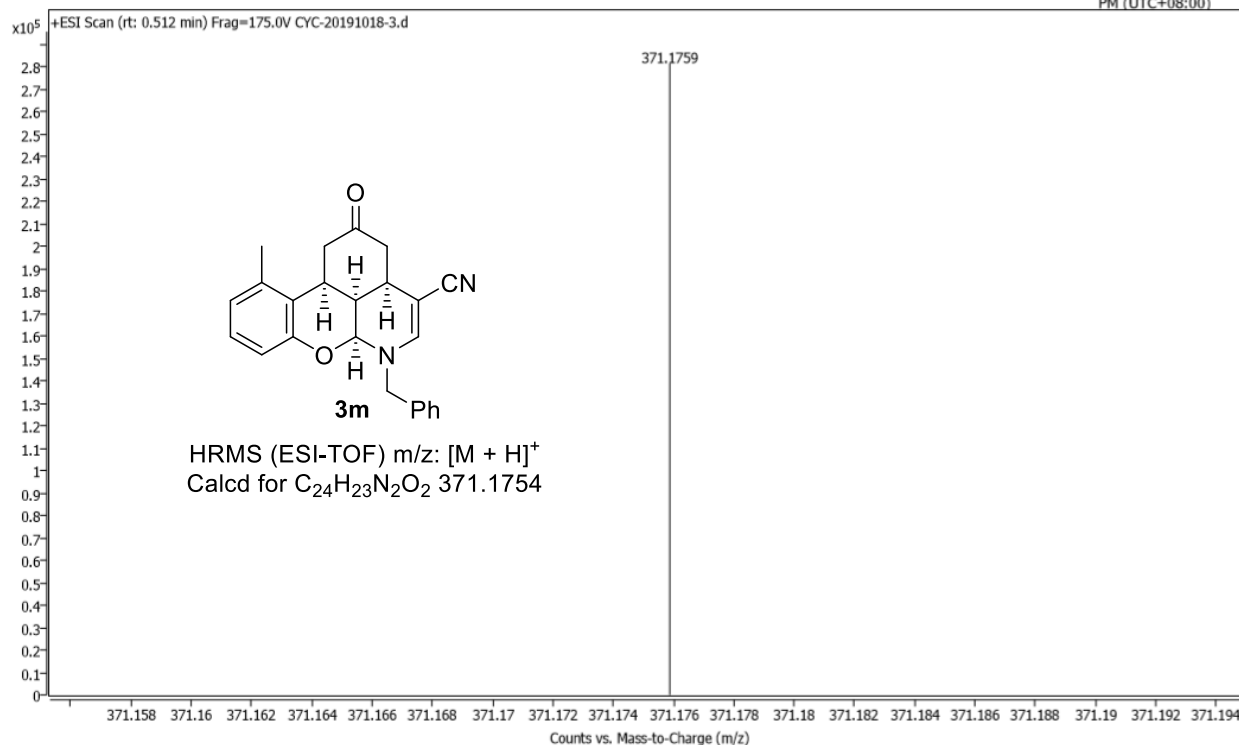


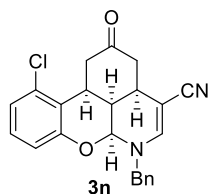
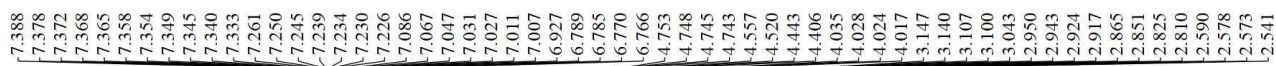


User Spectrum Plot Report

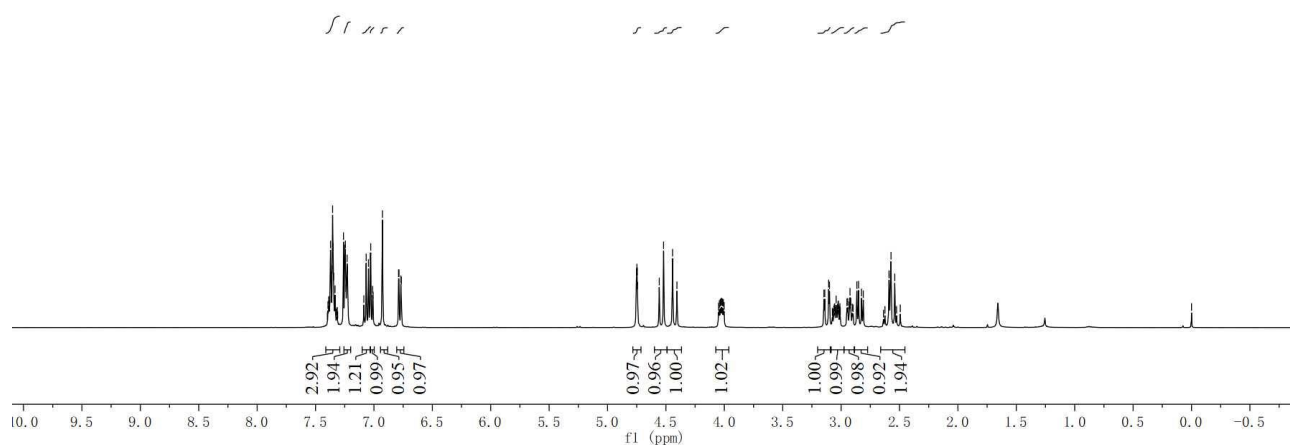


Name	CYC-20191018-3	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191018-3.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 10/29/2019 4:28:32 PM (UTC+08:00)





^1H NMR (400 MHz, CDCl_3)



—208.581

—155.804

—144.783

135.436

133.896

129.117

128.710

128.506

128.097

124.658

123.994

120.317

116.957

84.176

81.210

77.414

77.096

76.778

—57.174

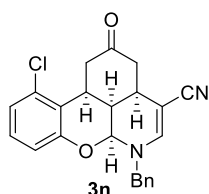
—42.174

41.371

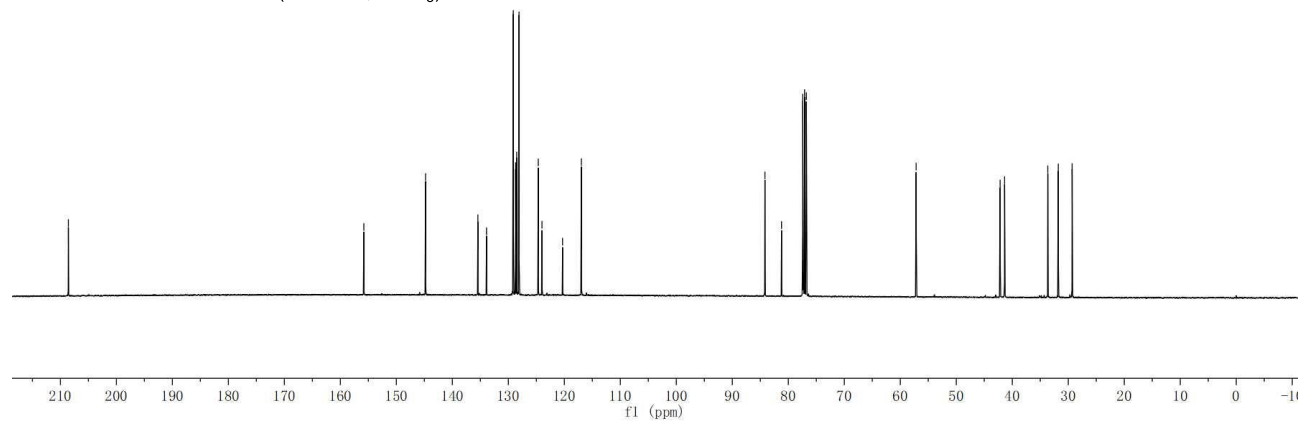
33.656

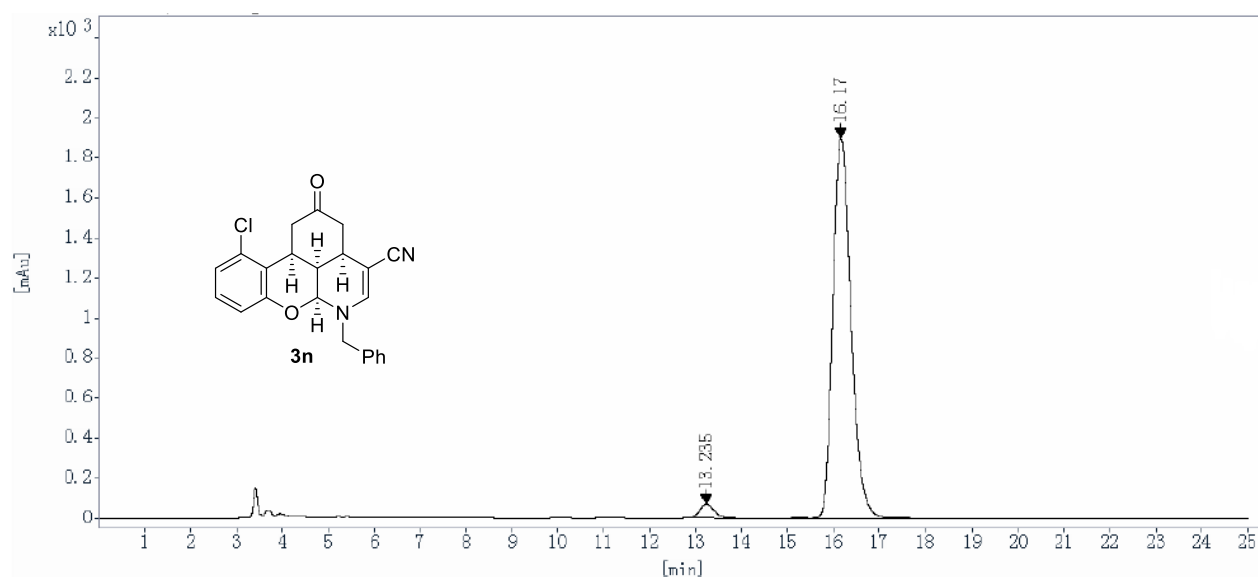
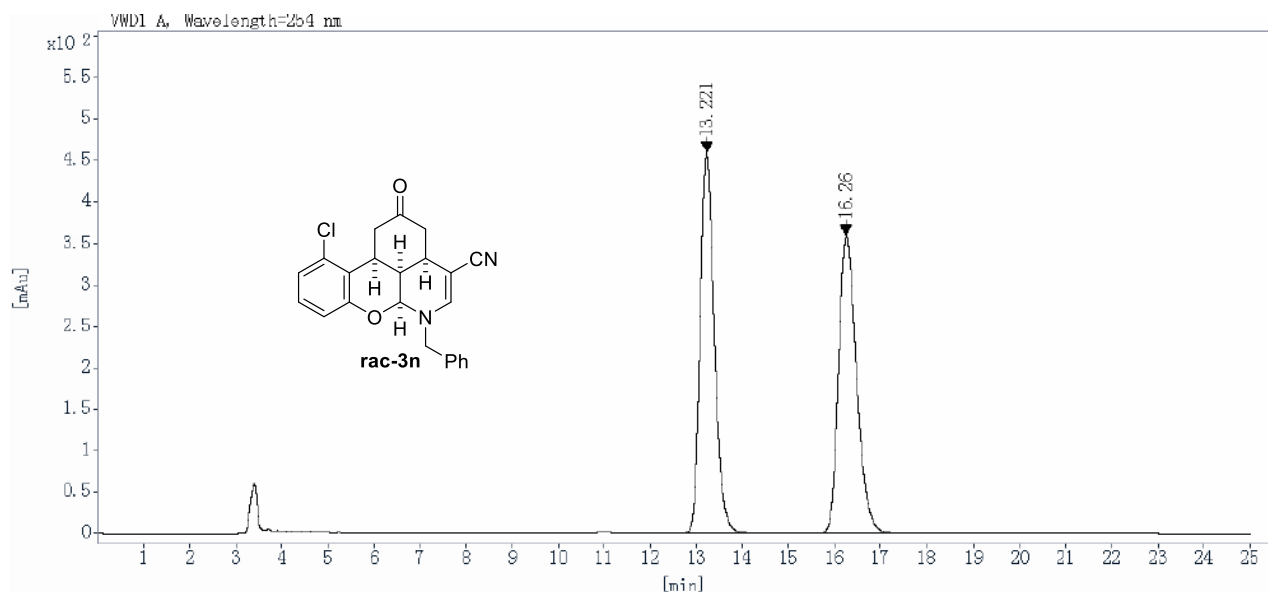
31.786

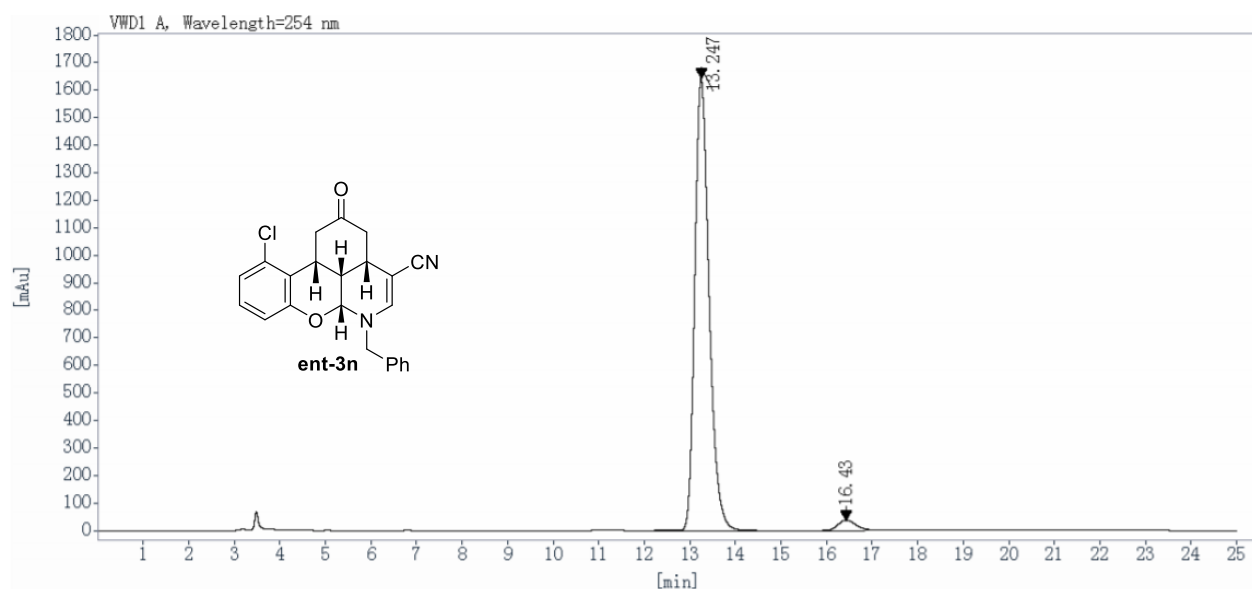
29.313



^{13}C NMR (100 MHz, CDCl_3)



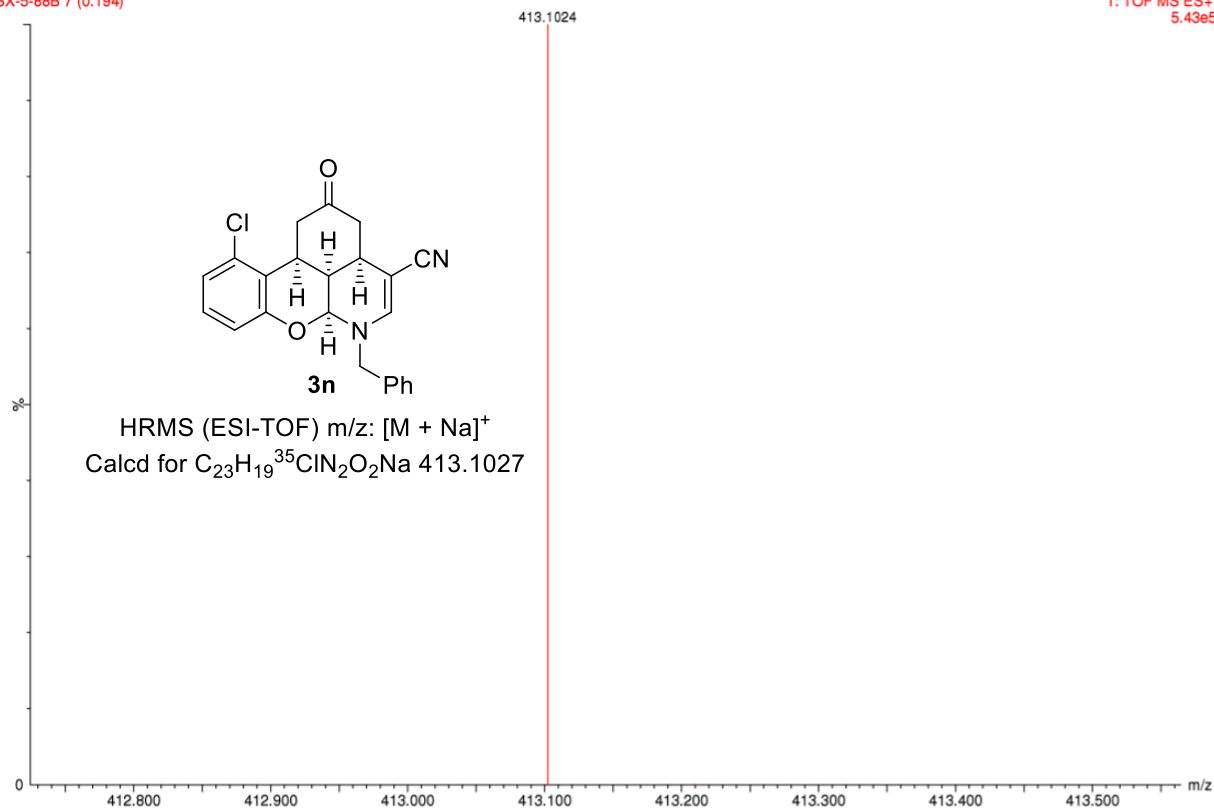




Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
13.247	VB R	0.34	1643.4685	35836.3047	97.1208
16.430	BB	0.44	37.2393	1062.4050	2.8792
Totals:				36898.7097	100.0000

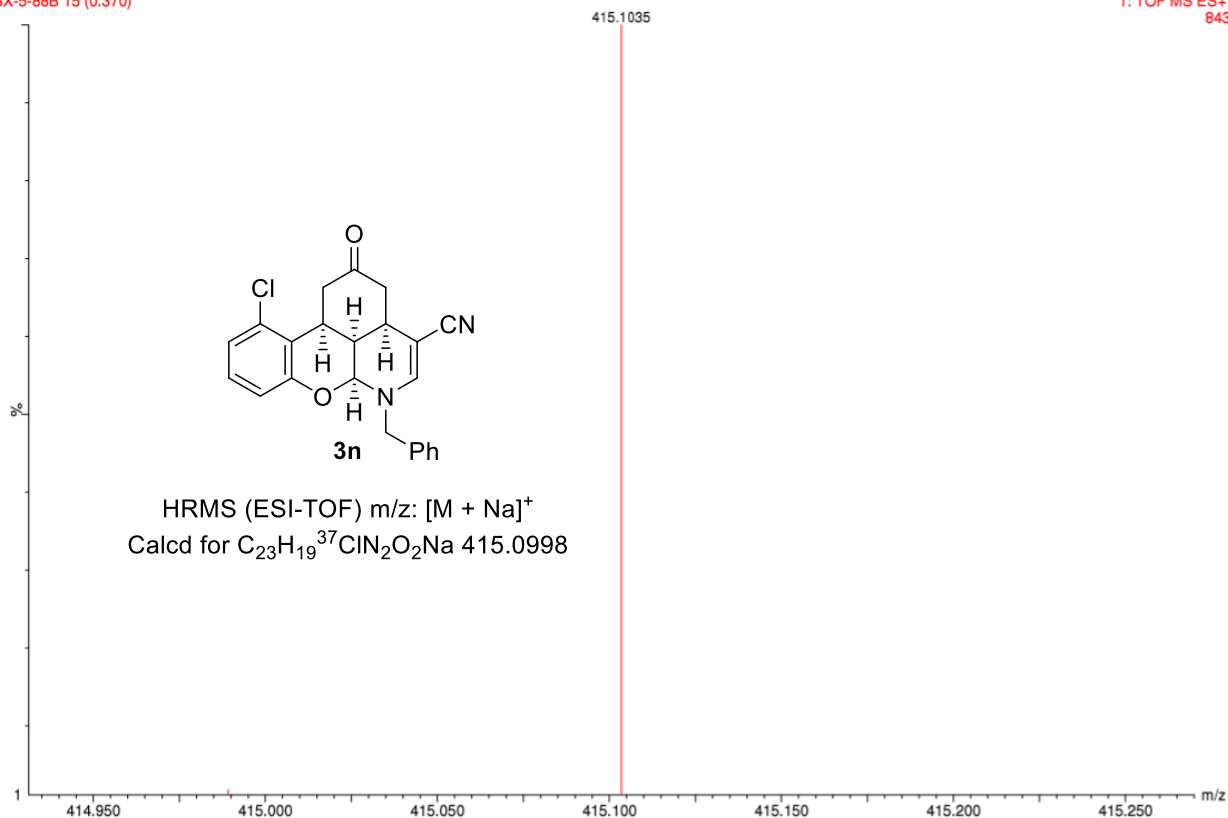
SX-5-88B 7 (0.194)

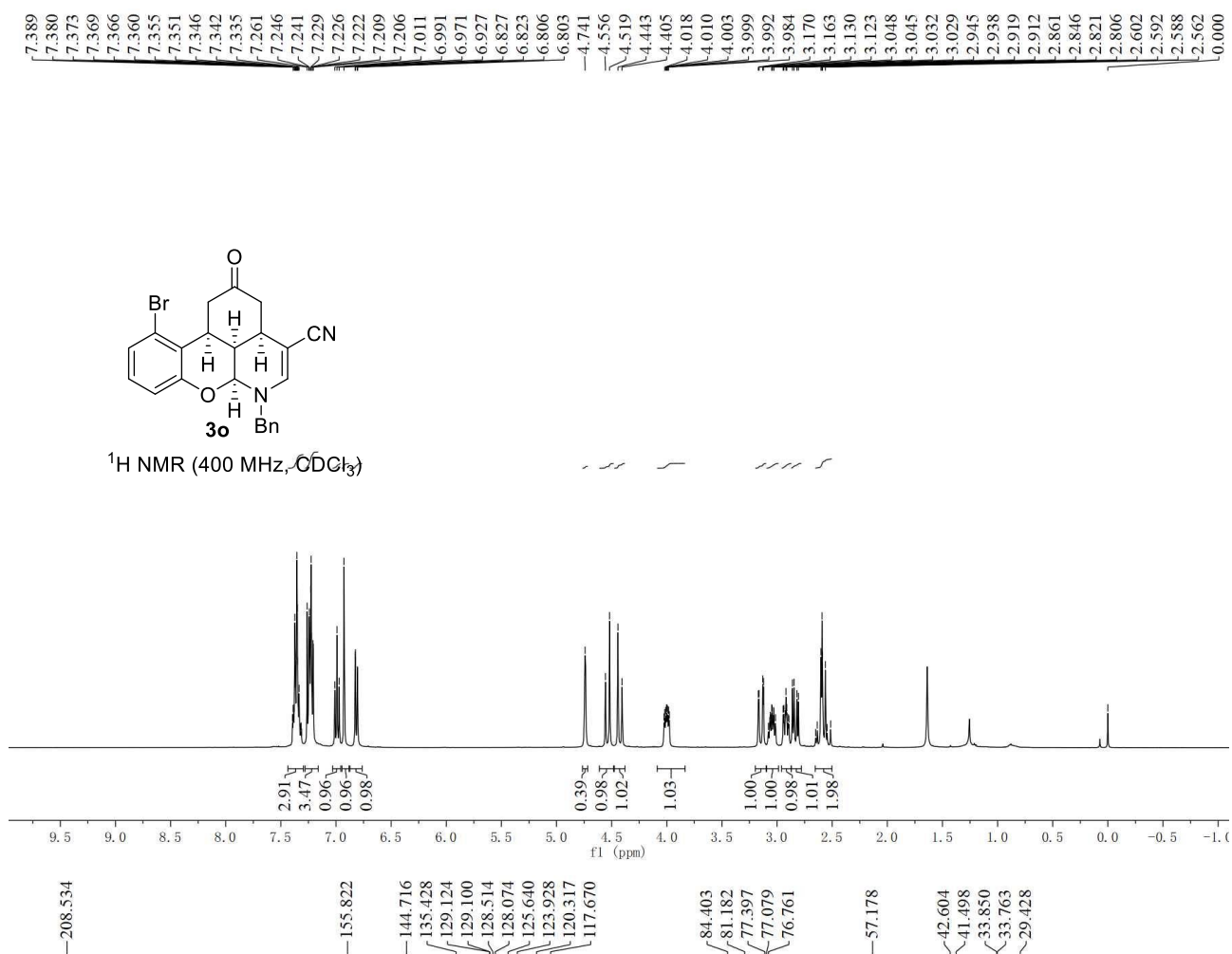
1: TOF MS ES+
5.43e5

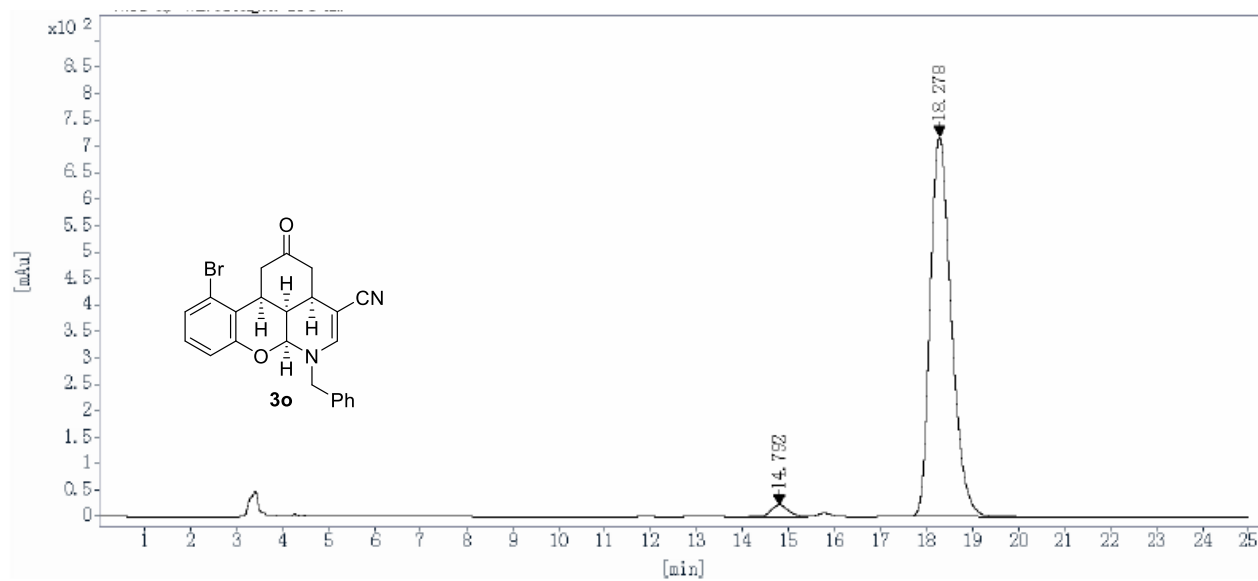
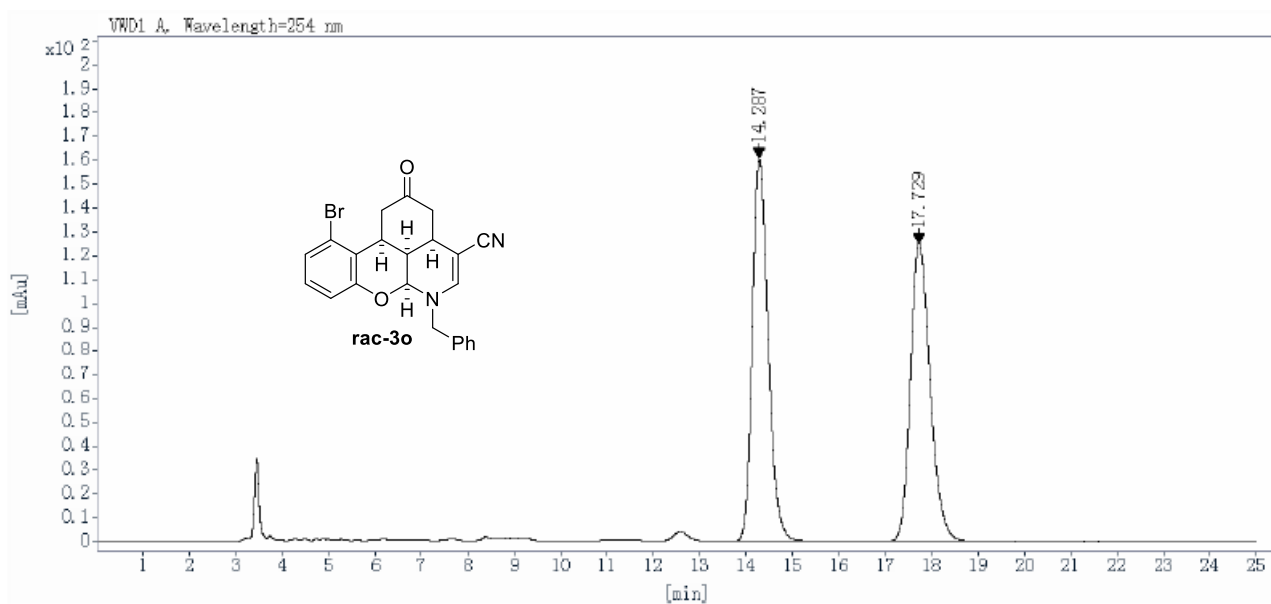


SX-5-88B 15 (0.370)

1: TOF MS ES+
843



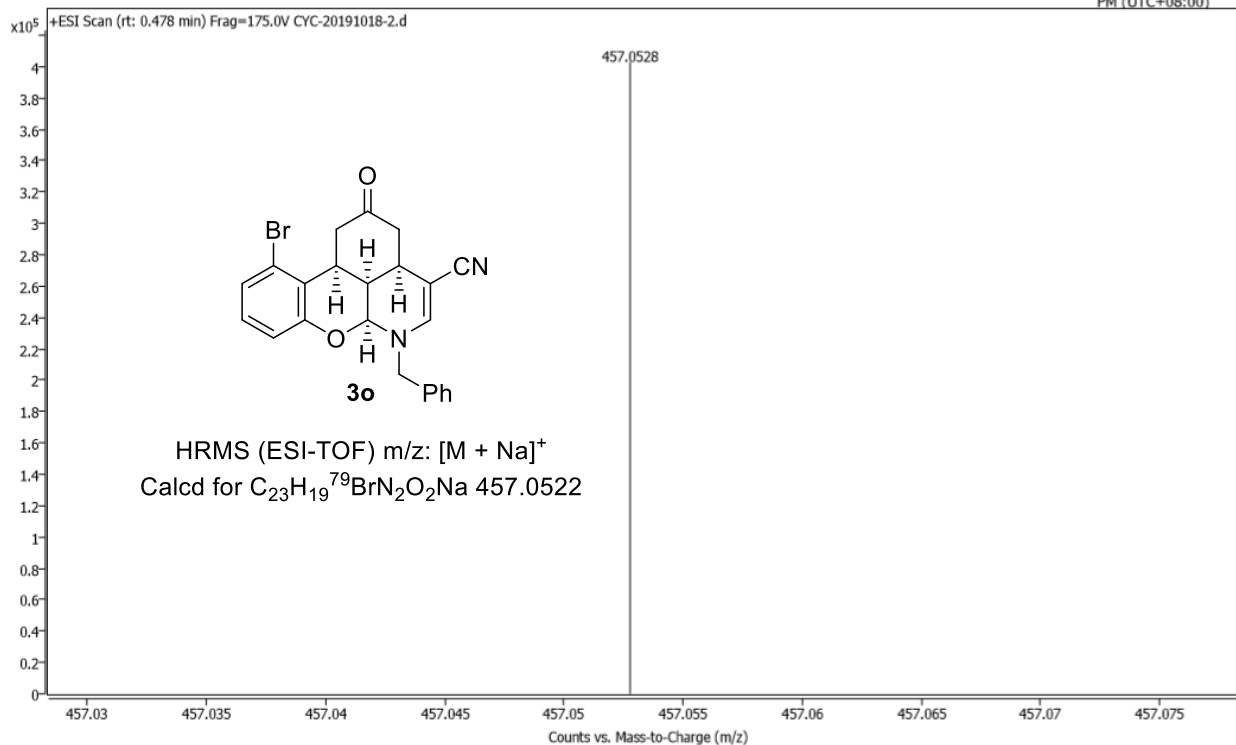




User Spectrum Plot Report



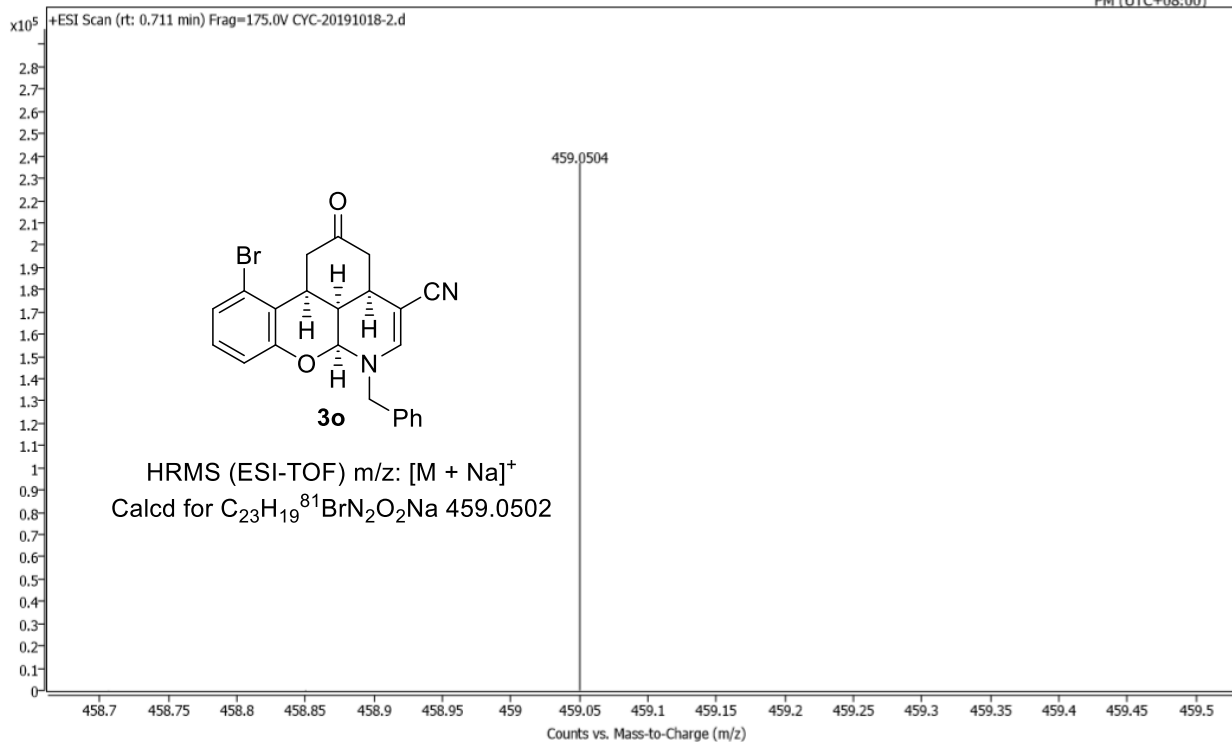
Name	CYC-20191018-2	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191018-2.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 10/29/2019 4:25:31 PM (UTC+08:00)



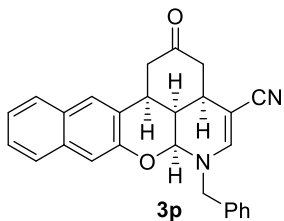
User Spectrum Plot Report



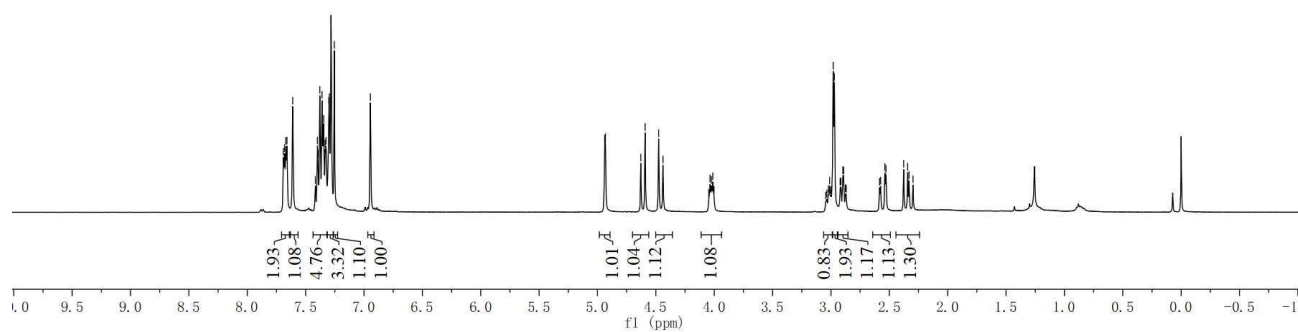
Name	CYC-20191018-2	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191018-2.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 10/29/2019 4:25:31 PM (UTC+08:00)



7.690
7.681
7.670
7.660
7.611
7.417
7.400
7.394
7.378
7.373
7.360
7.350
7.346
7.333
7.325
7.301
7.297
7.254
6.945
4.938
4.932
4.629
4.592
4.476
4.439
4.047
4.036
4.024
4.012
4.002
3.044
3.035
3.022
3.012
2.999
2.981
2.970
2.921
2.914
2.898
2.892
2.876
2.869
2.584
2.574
2.538
2.529
2.377
2.343
2.331
2.297



^1H NMR (400 MHz, CDCl_3)



—208.125

—151.989

—145.434

—135.316

—133.339

—129.891

—129.100

—128.472

—128.314

—128.210

—127.587

—126.639

—126.454

—125.261

—124.664

—120.243

—113.357

—82.397

—81.566

—77.378

—77.060

—76.743

—57.127

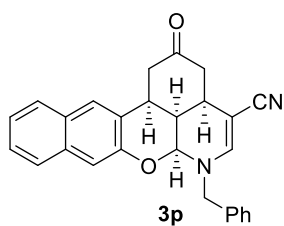
—45.635

—41.423

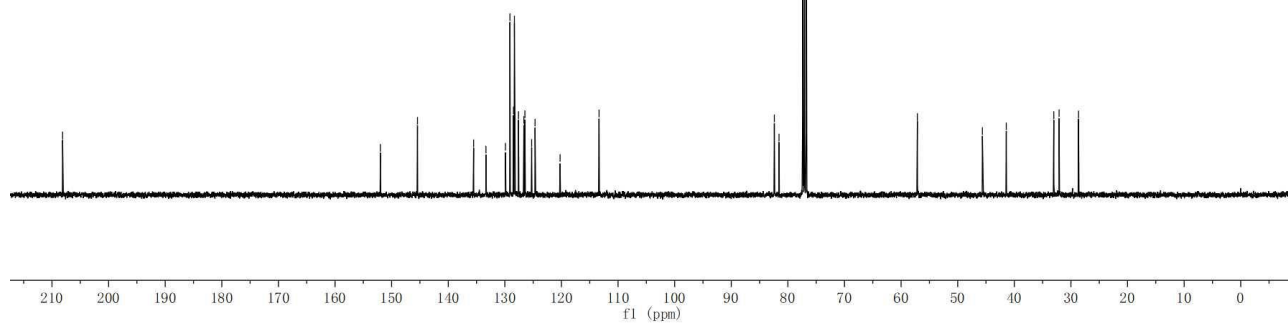
—33.022

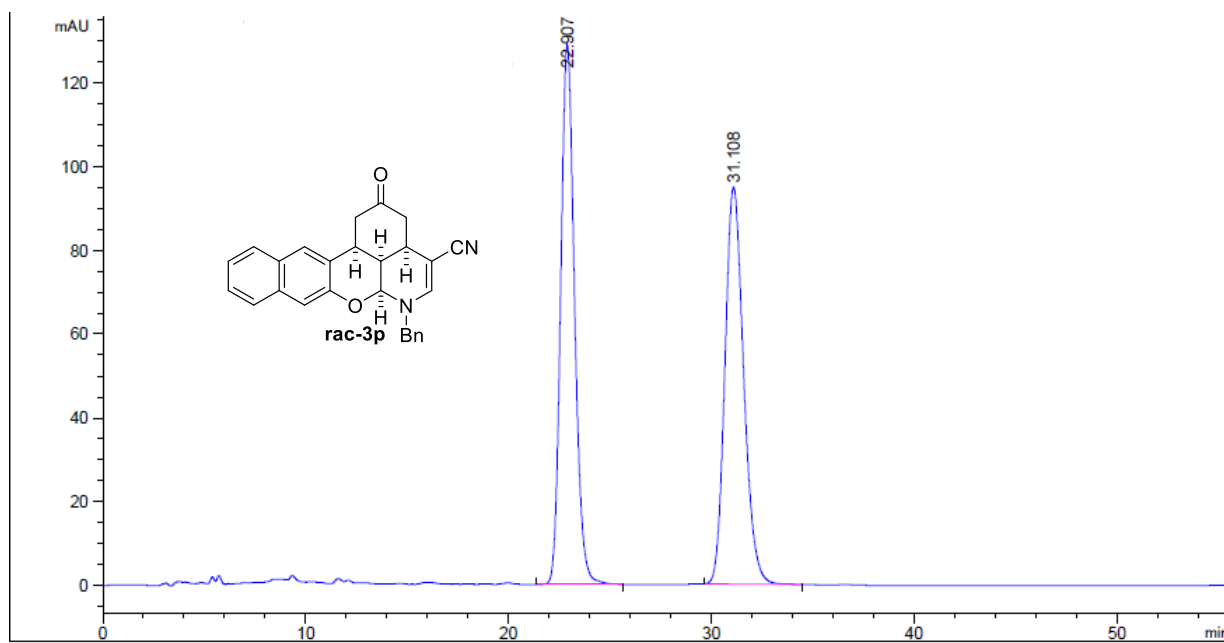
—32.086

—28.654

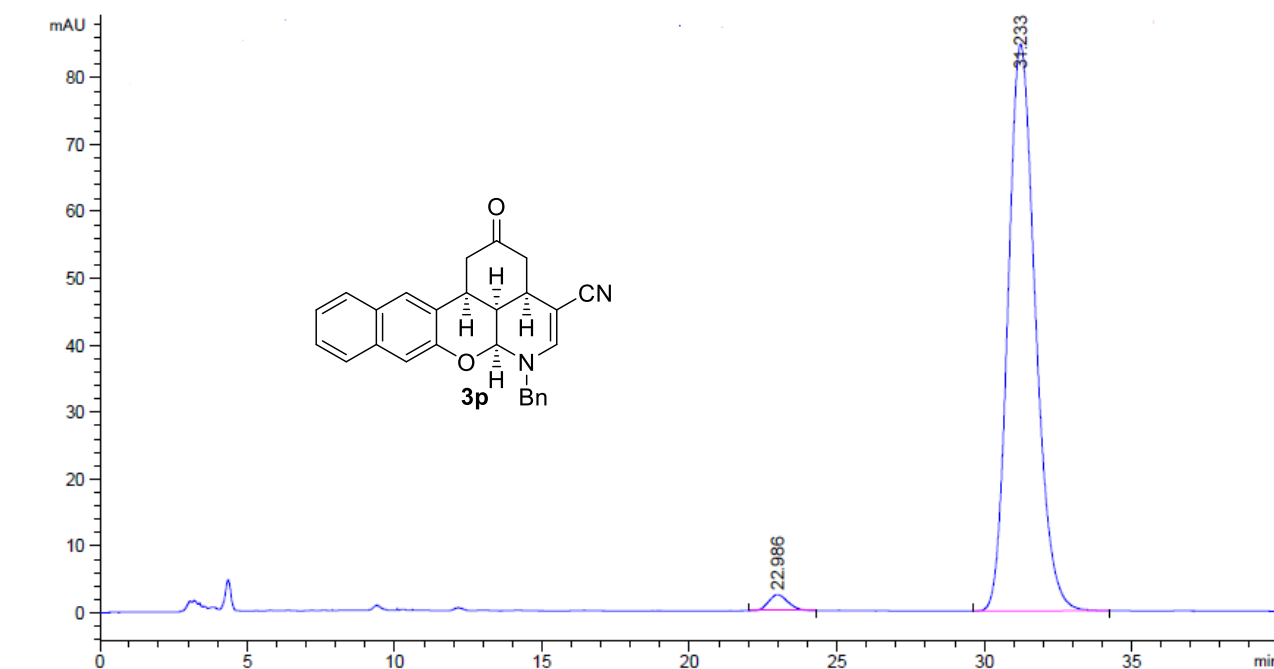


^{13}C NMR (100 MHz, CDCl_3)





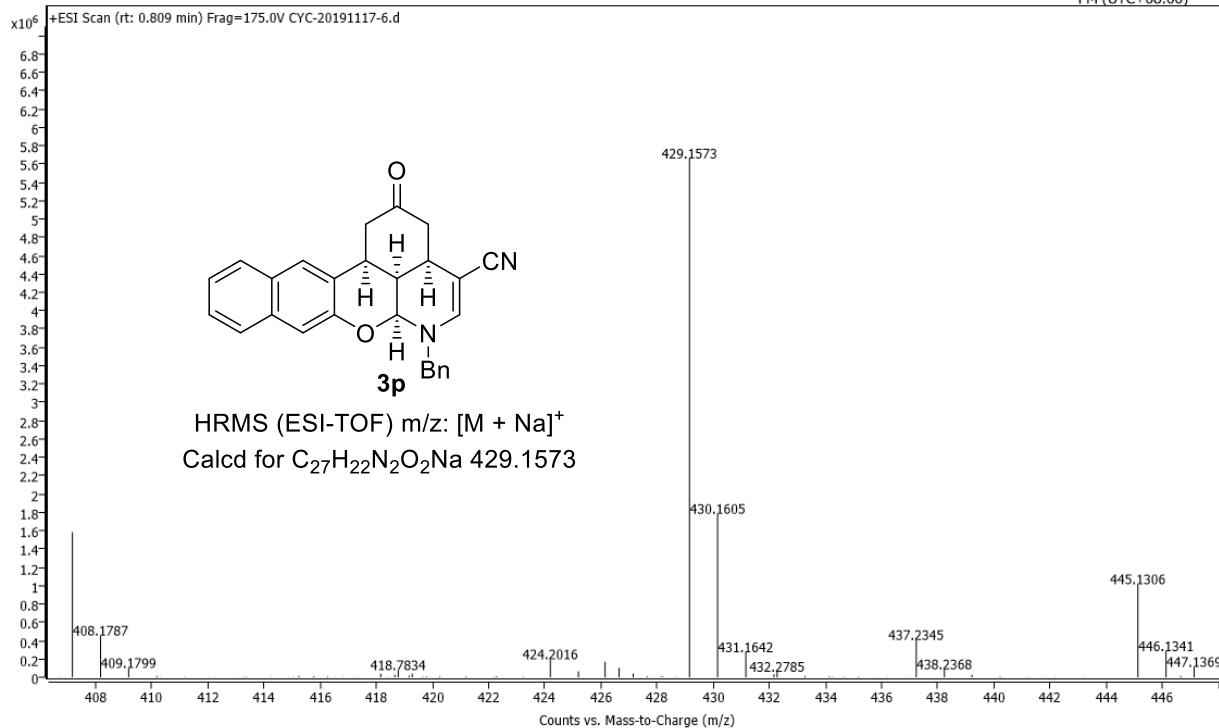
	Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1	22.907	BB	0.7300	6114.67139	129.15787	50.2203
2	31.108	BB	0.9853	6061.03125	94.72869	49.7797

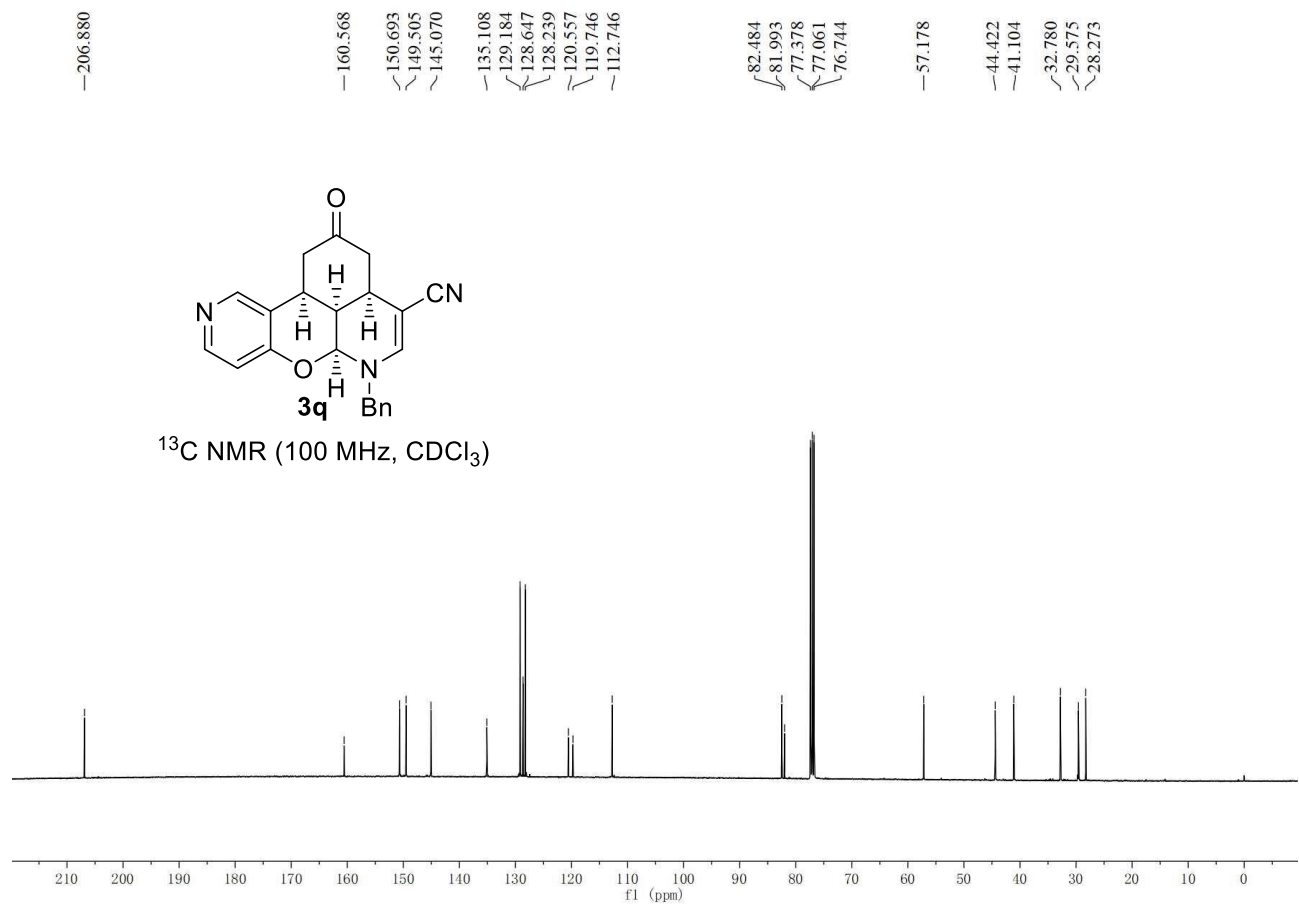
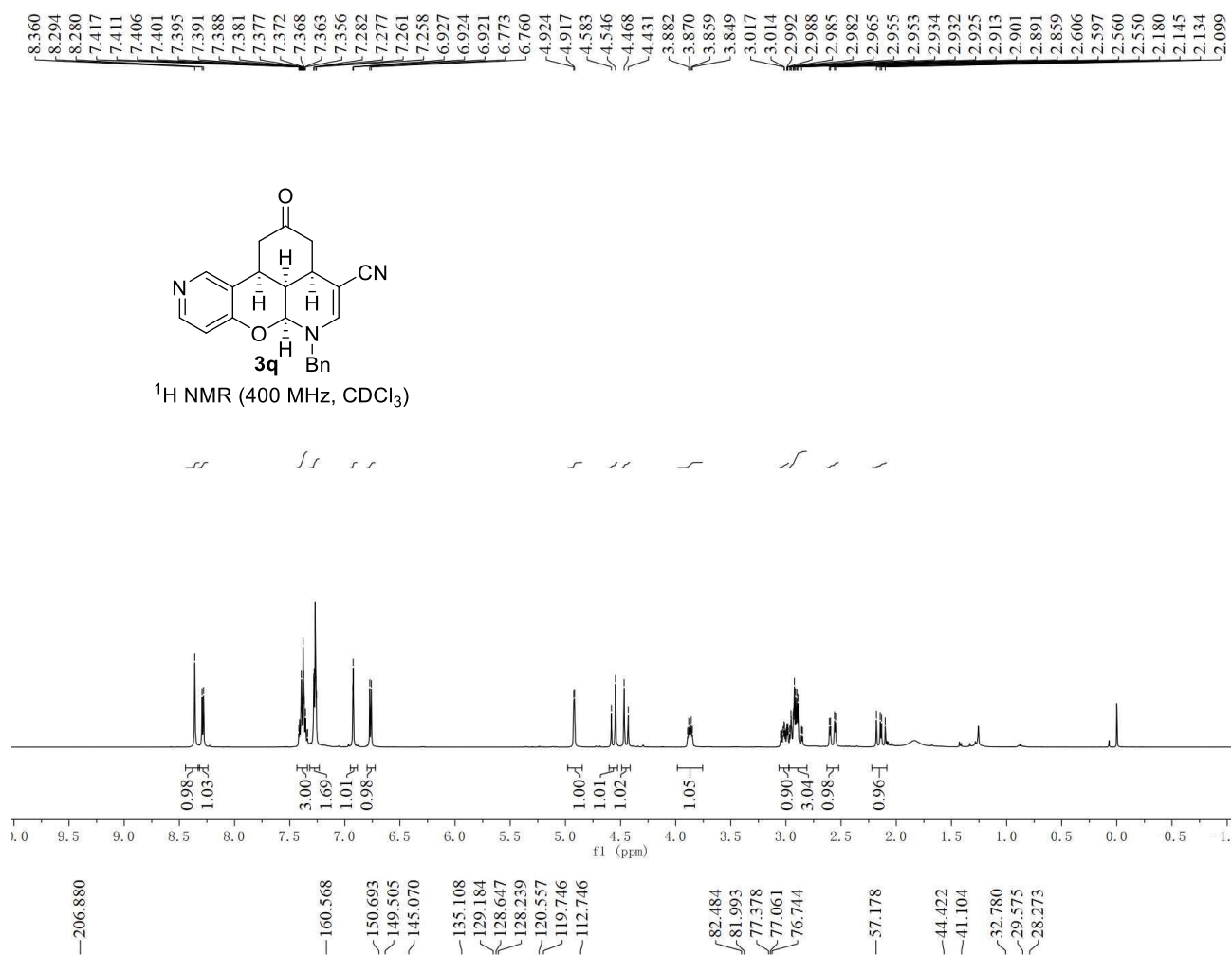


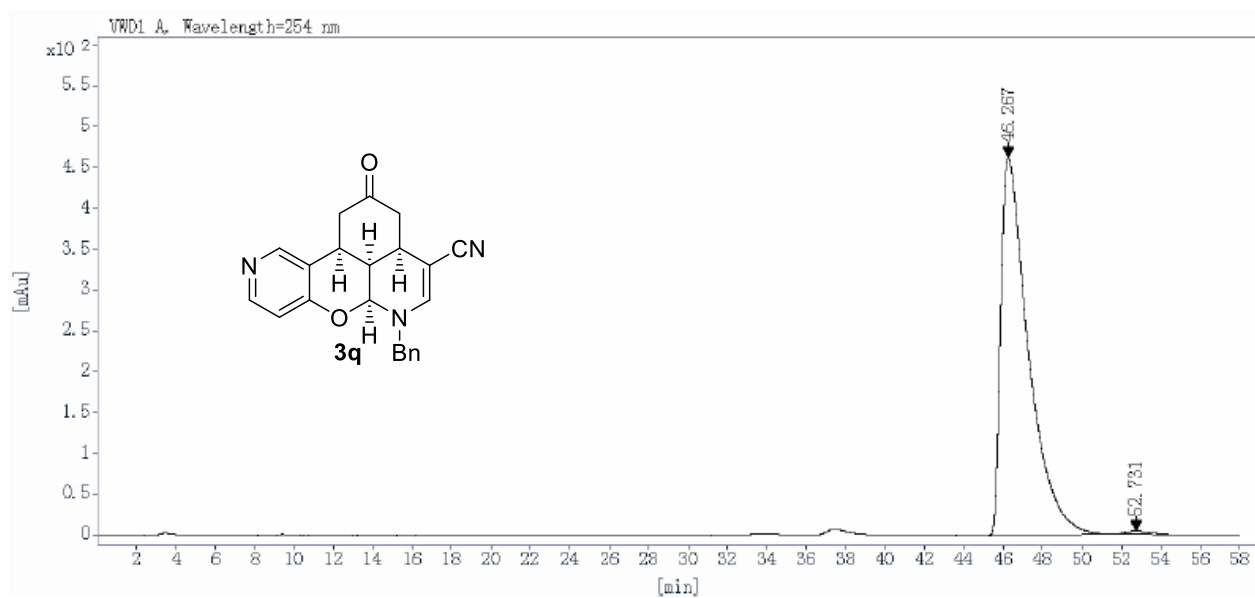
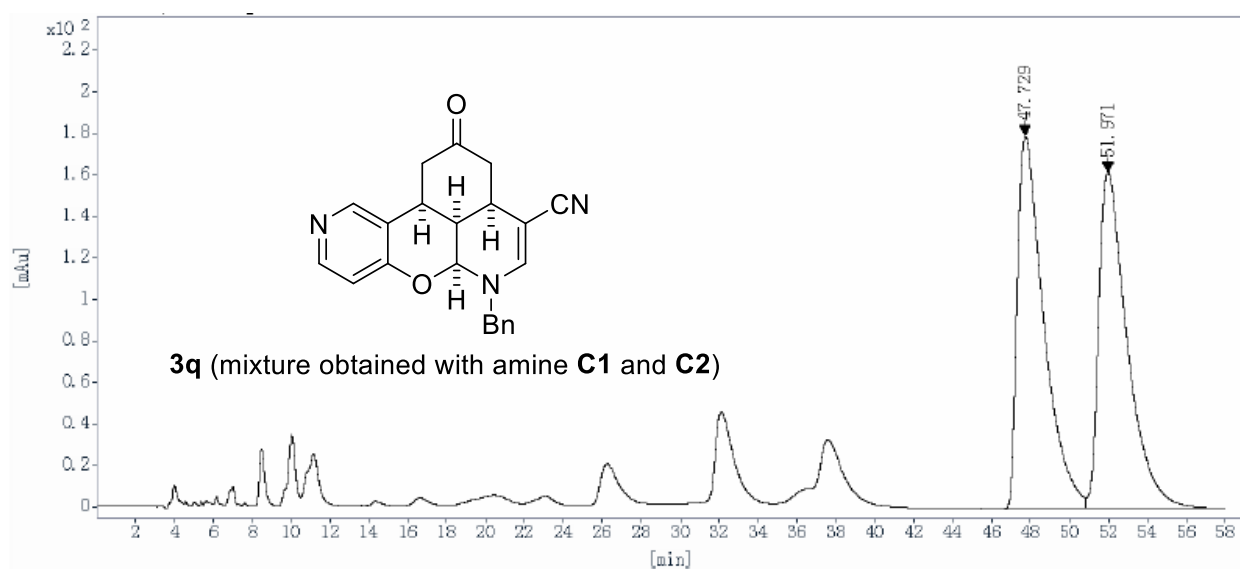
	Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1	22.986	BB	0.6740	111.72887	2.38177	2.0079
2	31.233	BB	0.9953	5452.76123	84.74212	97.9921

User Spectrum Plot Report

Name	CYC-20191117-6	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191117-6.d	Method (Acq)	TOF.m		Acq. Time (Local)
					11/21/2019 9:05:31 PM (UTC+08:00)



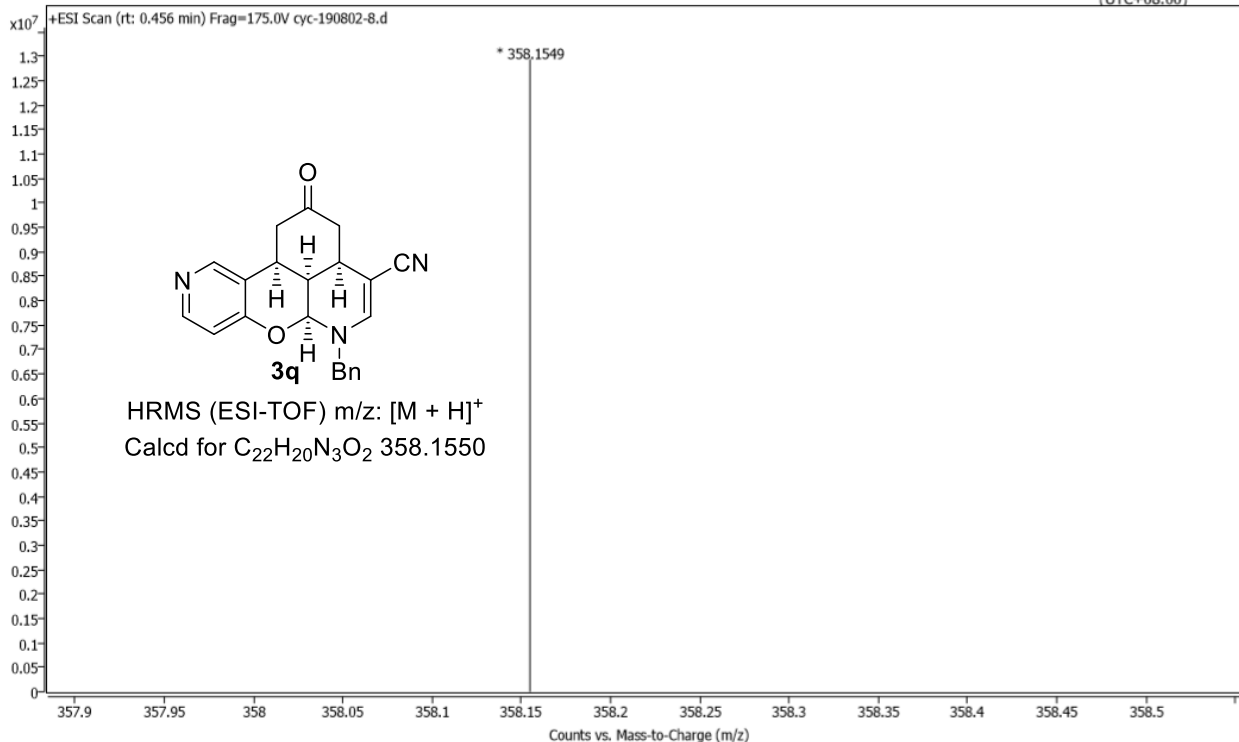


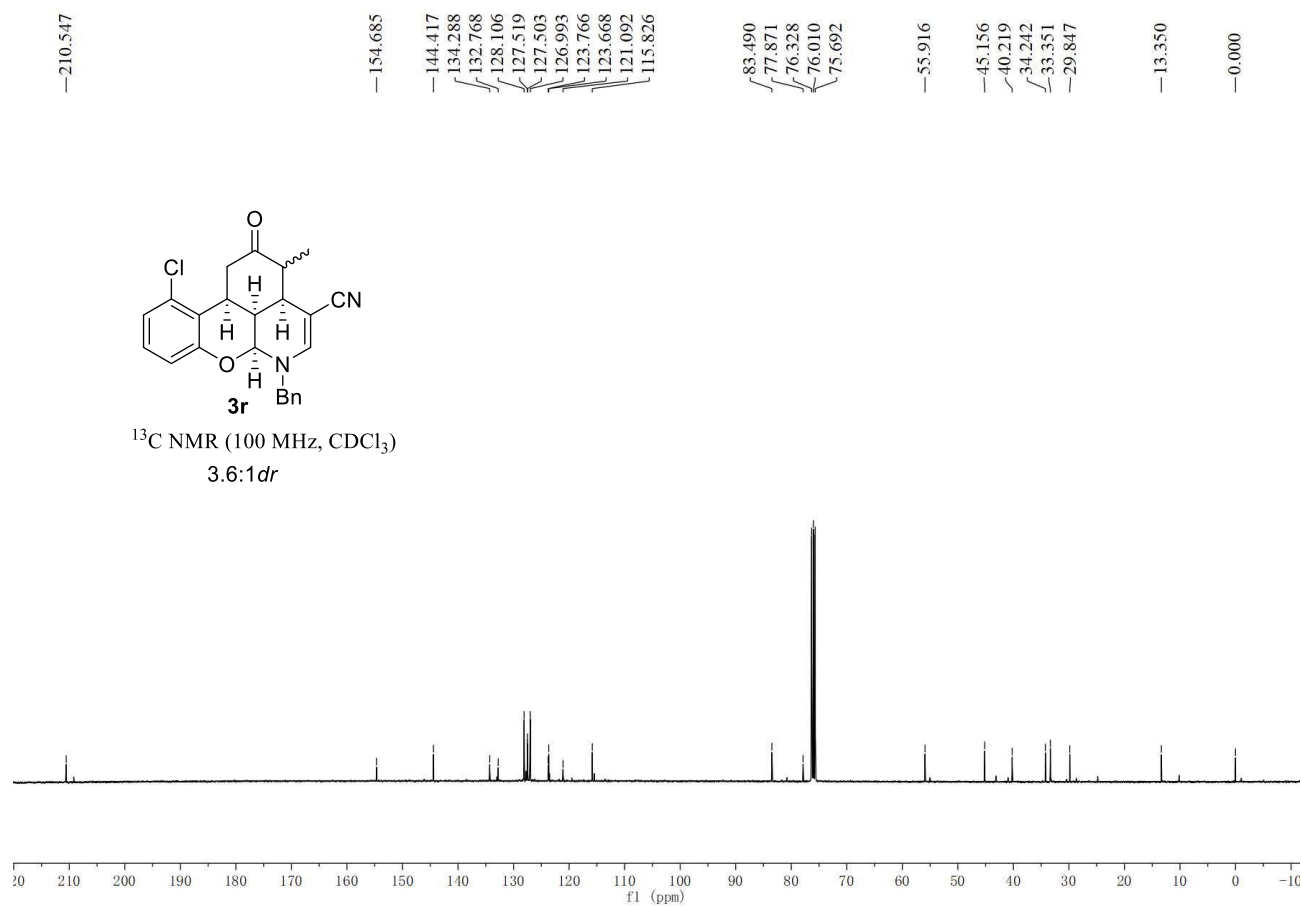
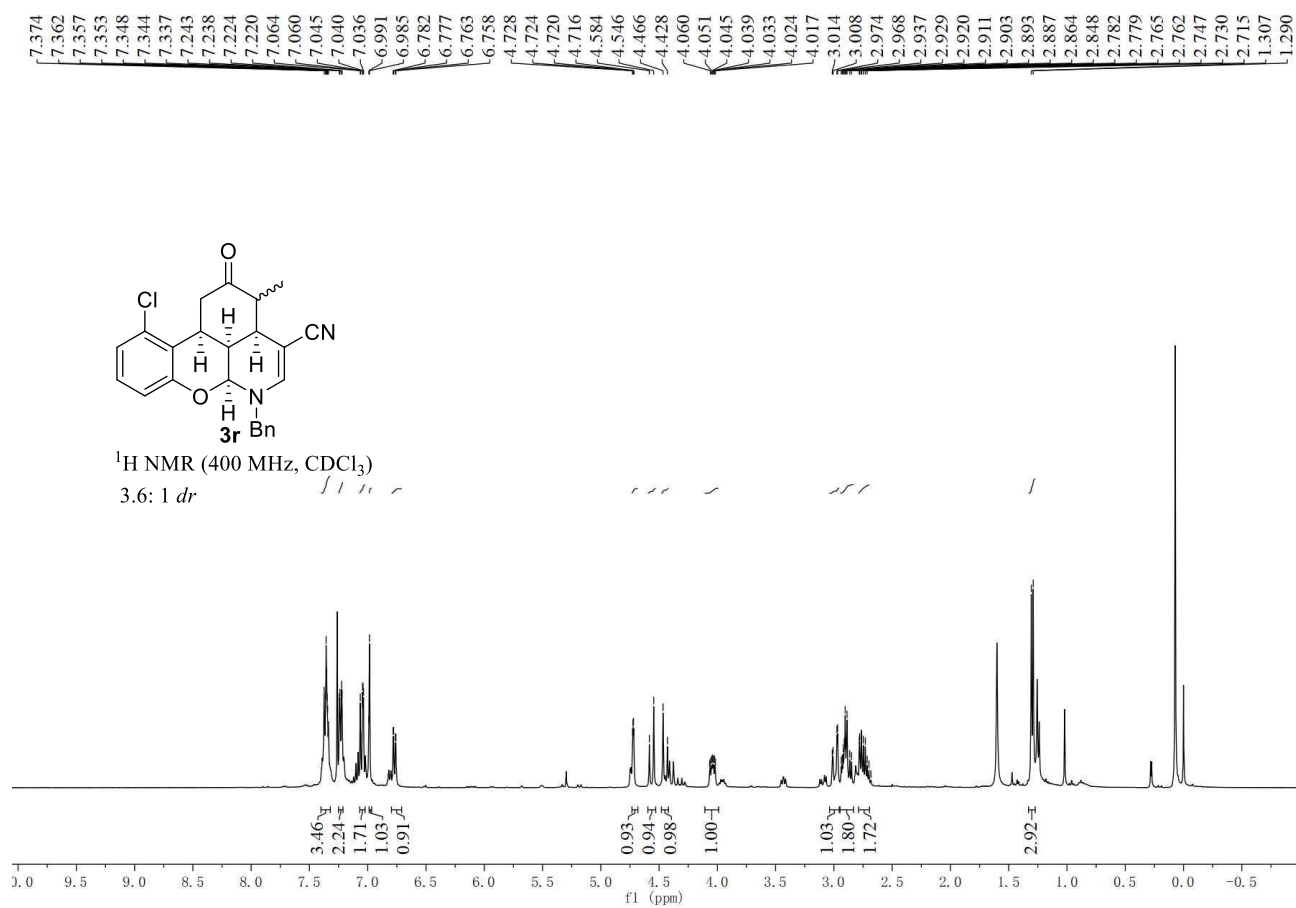


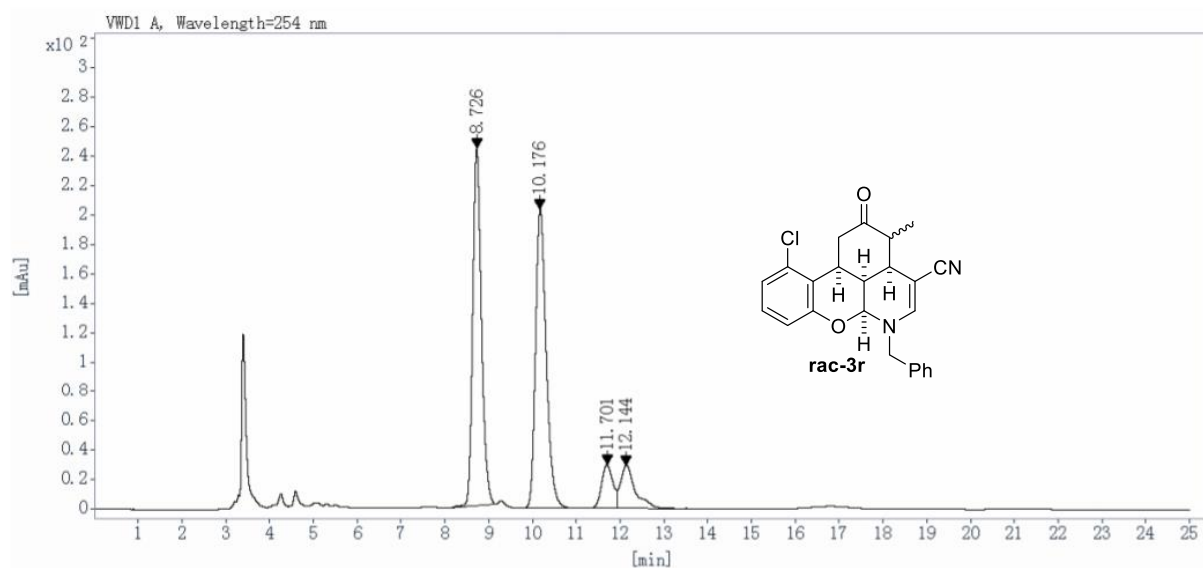
Spectrum Plot Report



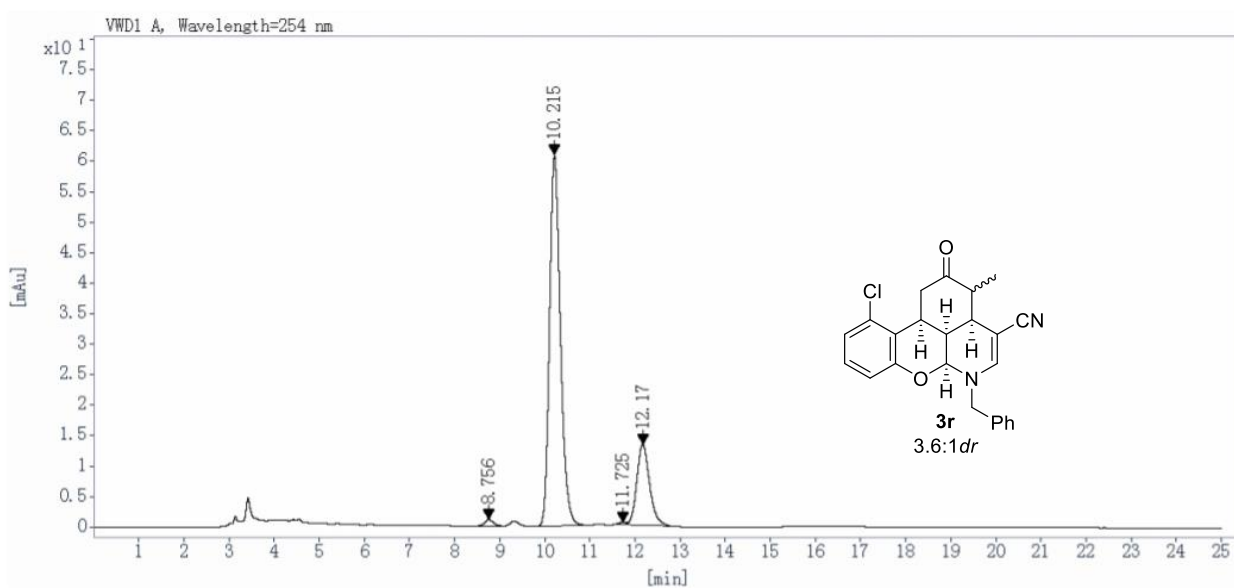
Name	cyc-190802-8	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-190802-8.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local)
					8/8/2019 9:17:19 PM (UTC+08:00)







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
8.726	BB	0.21	242.6295	3353.0234	42.0242
10.176	BB	0.26	203.2005	3415.0430	42.8015
11.701	VV R	0.28	29.2551	525.4814	6.5860
12.144	VB	0.34	29.0846	685.2460	8.5883
Totals:				7978.7938	100.0000

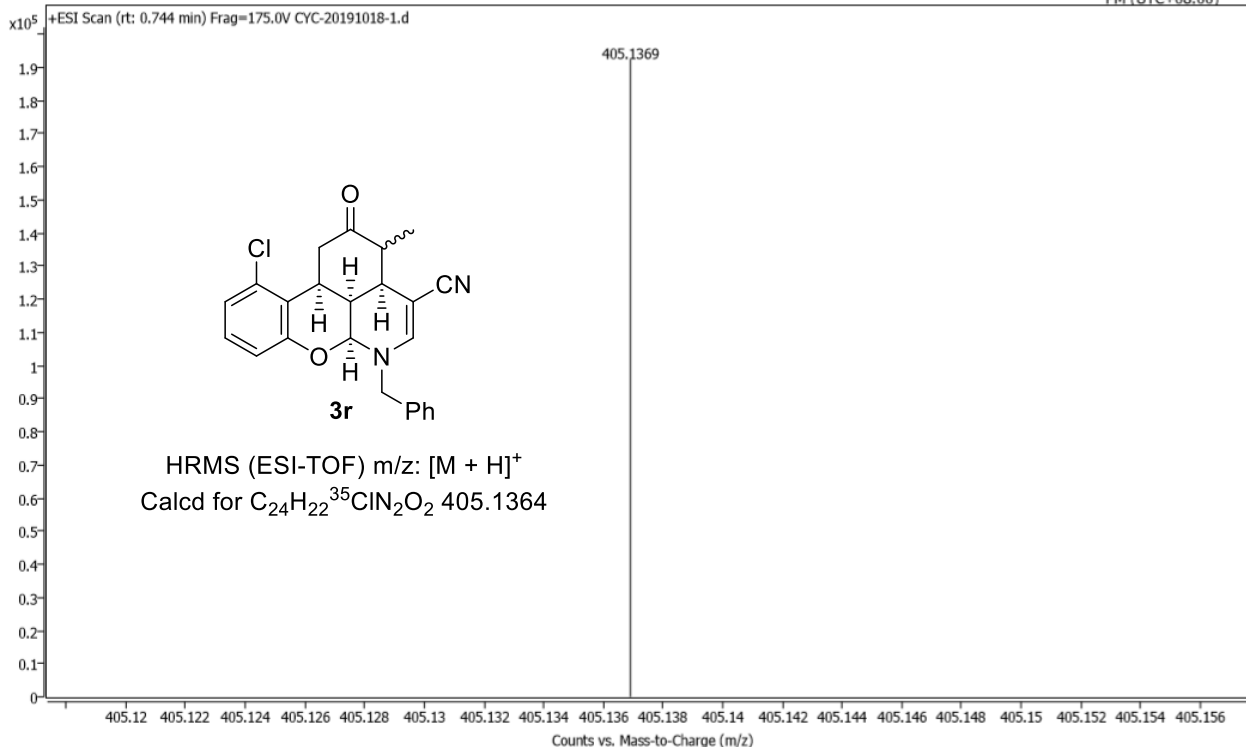


Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
8.756	BBA	0.21	1.0490	14.3321	1.1065
10.215	BB	0.26	60.7742	1013.0850	78.2131
11.725	BV E	0.18	0.3161	3.6149	0.2791
12.170	VBAR	0.30	13.3115	264.2566	20.4014
Totals:				1295.2886	100.0000

User Spectrum Plot Report



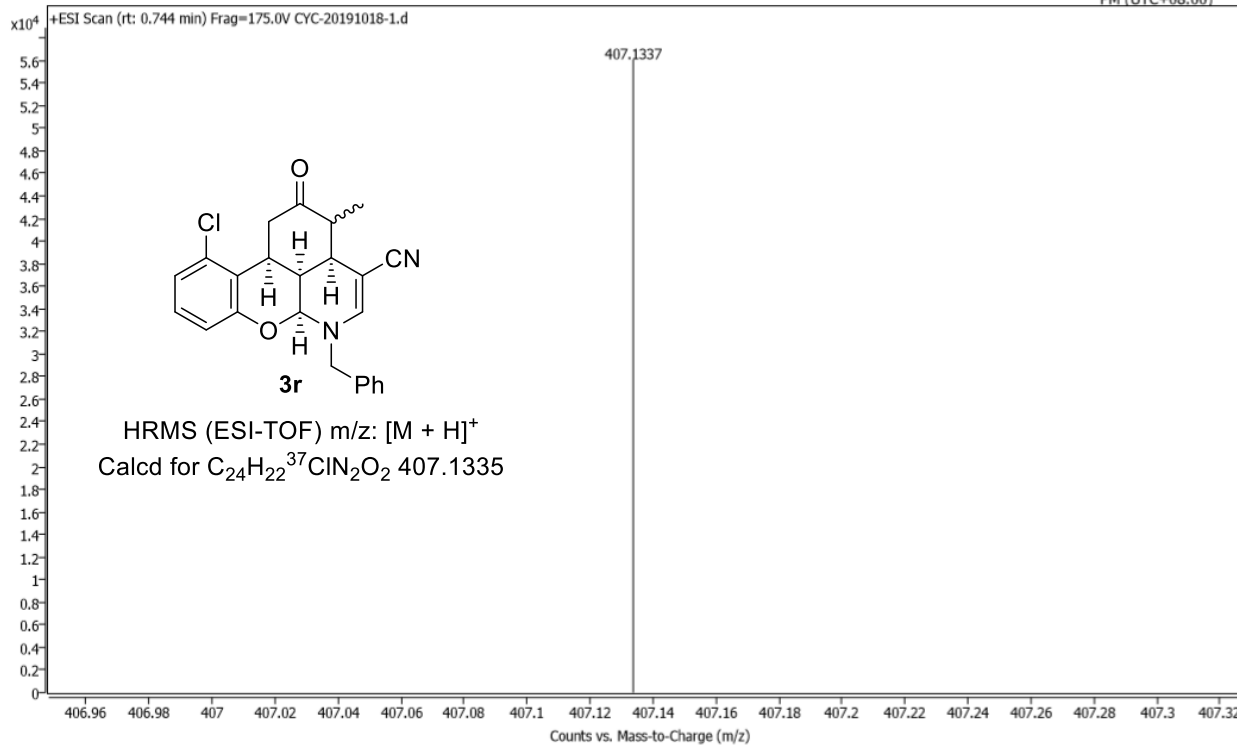
Name	CYC-20191018-1	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191018-1.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 10/29/2019 4:22:30 PM (UTC+08:00)



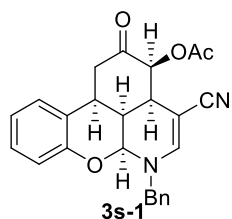
User Spectrum Plot Report



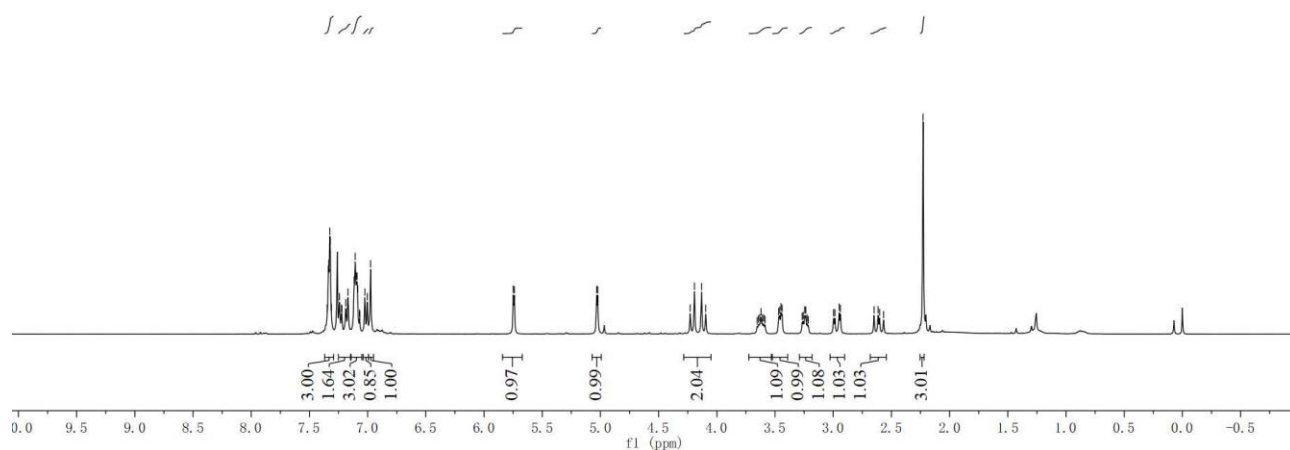
Name	CYC-20191018-1	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191018-1.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 10/29/2019 4:22:30 PM (UTC+08:00)



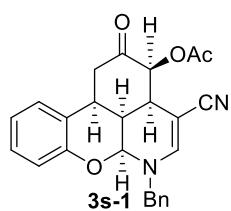
7.348
7.338
7.334
7.326
7.321
7.311
7.243
7.225
7.221
7.188
7.169
7.116
7.107
7.097
7.091
7.086
7.070
7.067
7.024
7.004
6.975
5.749
5.740
5.032
5.023
4.228
4.192
4.132
4.095
3.654
3.642
3.631
3.620
3.608
3.597
3.585
3.585
3.469
3.460
3.448
3.439
3.267
3.257
3.245
3.236
3.223
3.214
2.997
2.985
2.950
2.938
2.649
2.615
2.601
2.568
2.228



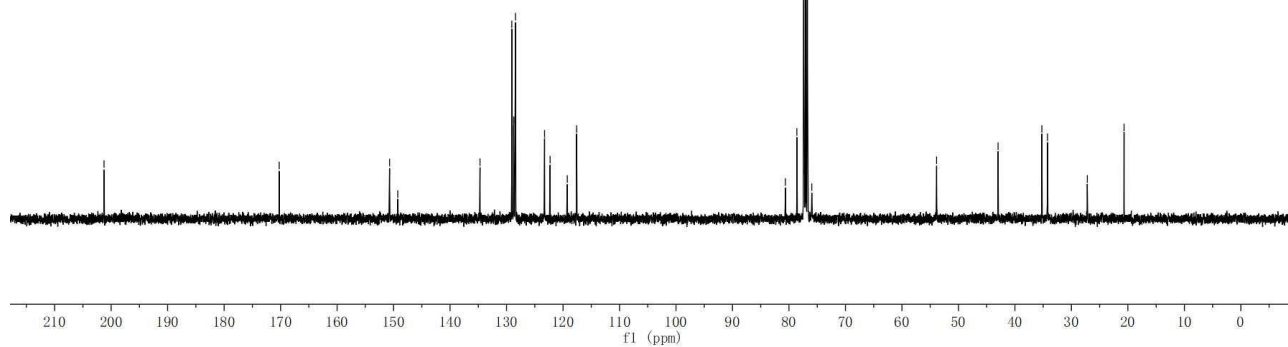
^1H NMR (400 MHz, CDCl_3)

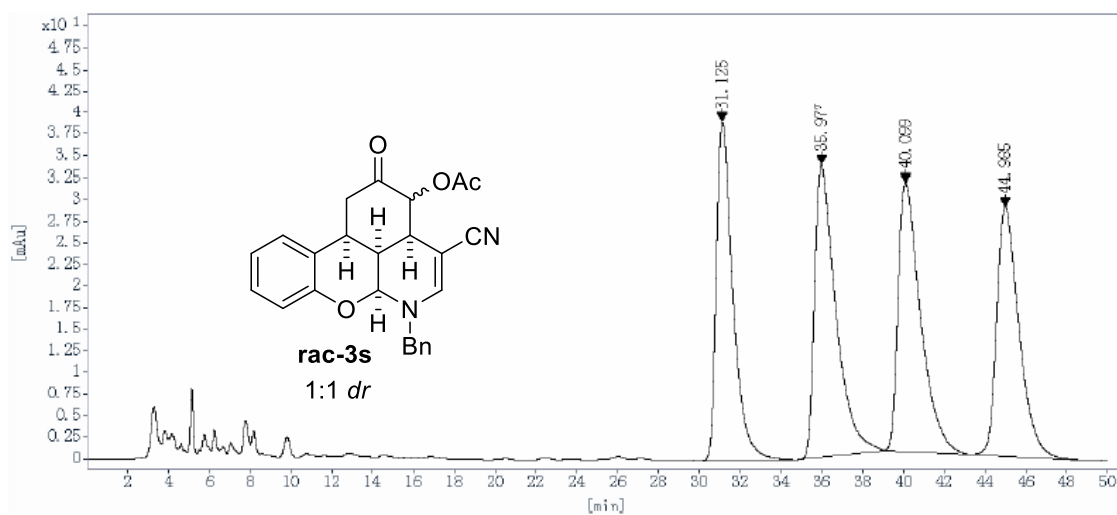
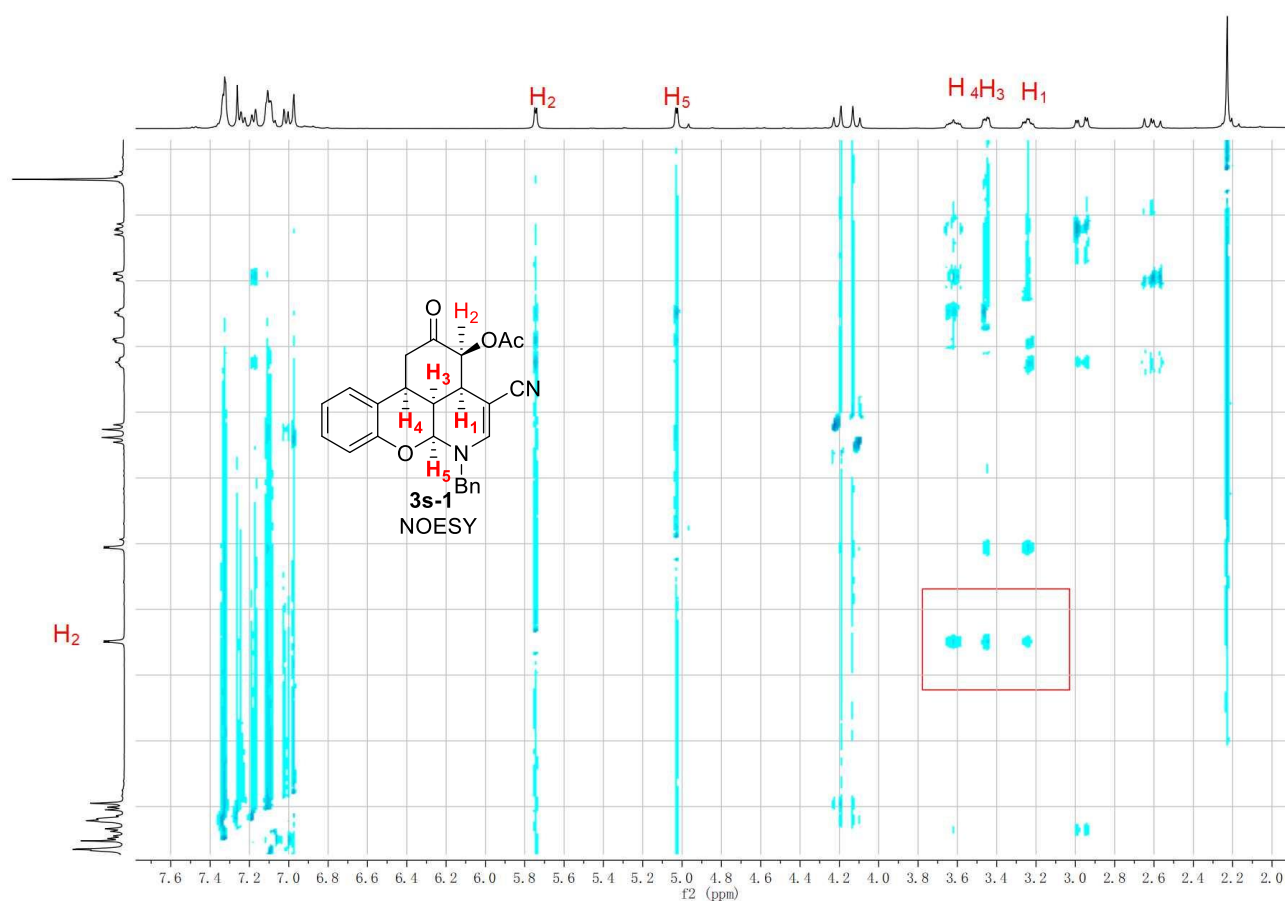


201.254
170.249
150.708
149.252
134.698
129.071
128.740
128.712
128.494
128.418
123.268
122.291
119.249
117.594
80.635
78.602
77.372
77.258
77.055
76.737
75.955
53.863
42.983
35.228
34.235
27.185
20.678

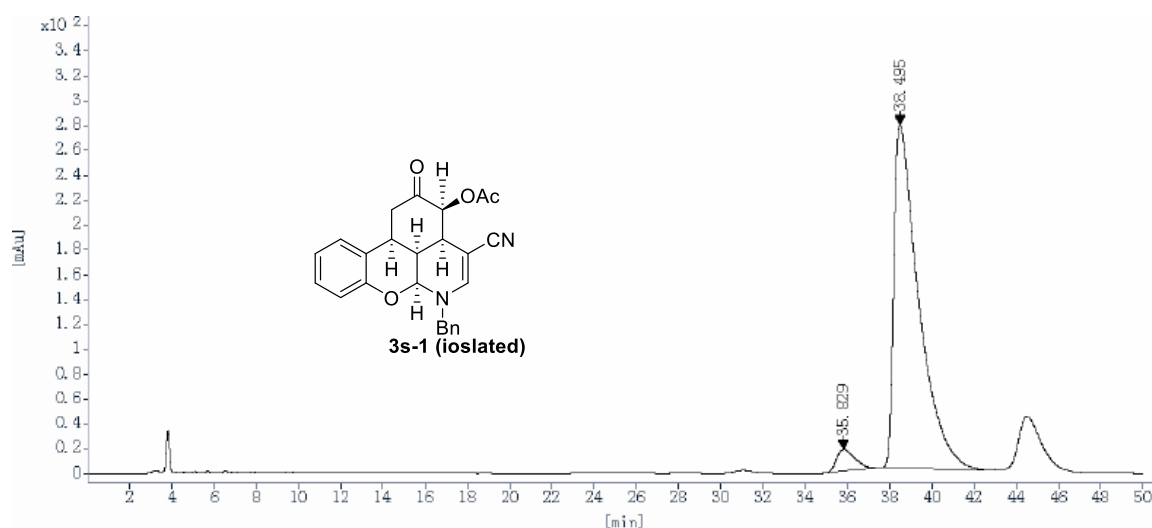


^{13}C NMR (100 MHz, CDCl_3)

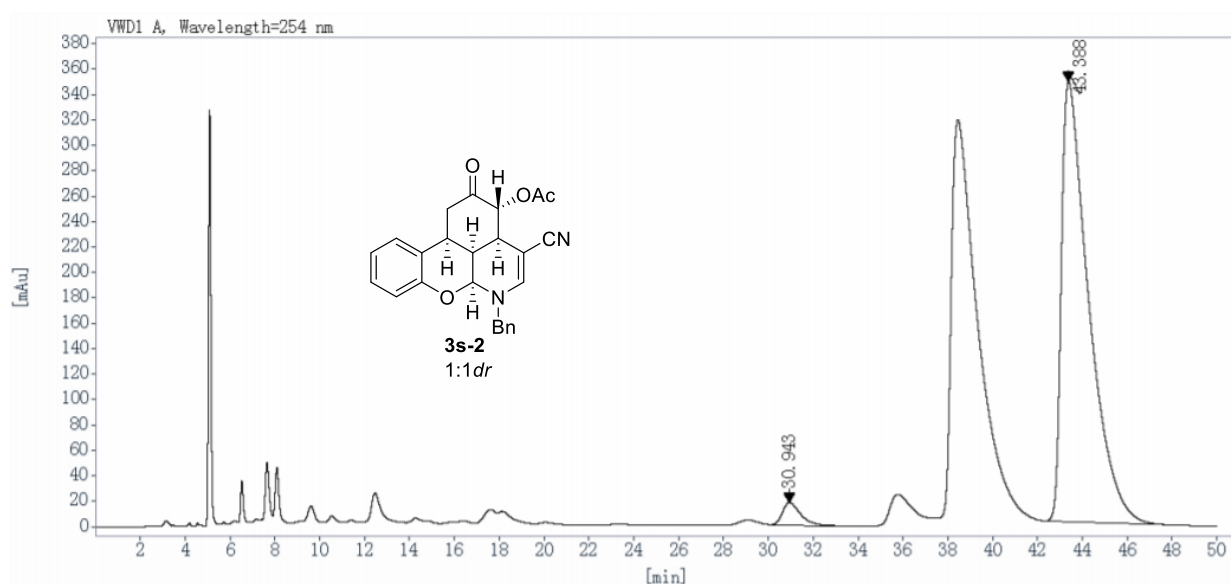




Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
31.125	BB	0.85	39.0780	2208.8010	23.9454
35.977	BB	1.06	33.7108	2452.5779	26.5881
40.099	BB	1.13	31.0673	2377.3142	25.7722
44.985	BB	1.14	28.8901	2185.6467	23.6943
Totals:				9224.3398	100.0000



Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
35.829	BB	0.94	17.5585	1078.0302	4.5592
38.495	BB	1.18	276.1418	22567.2324	95.4408
Totals:				23645.2626	100.0000

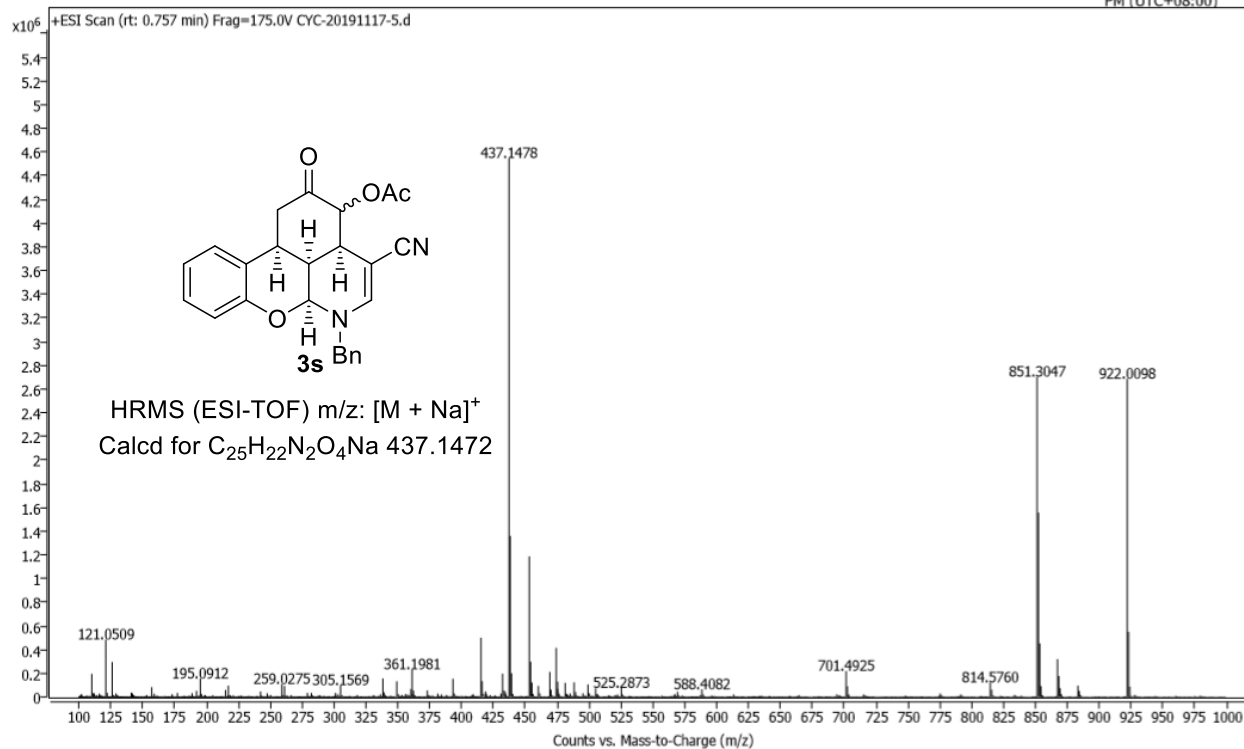


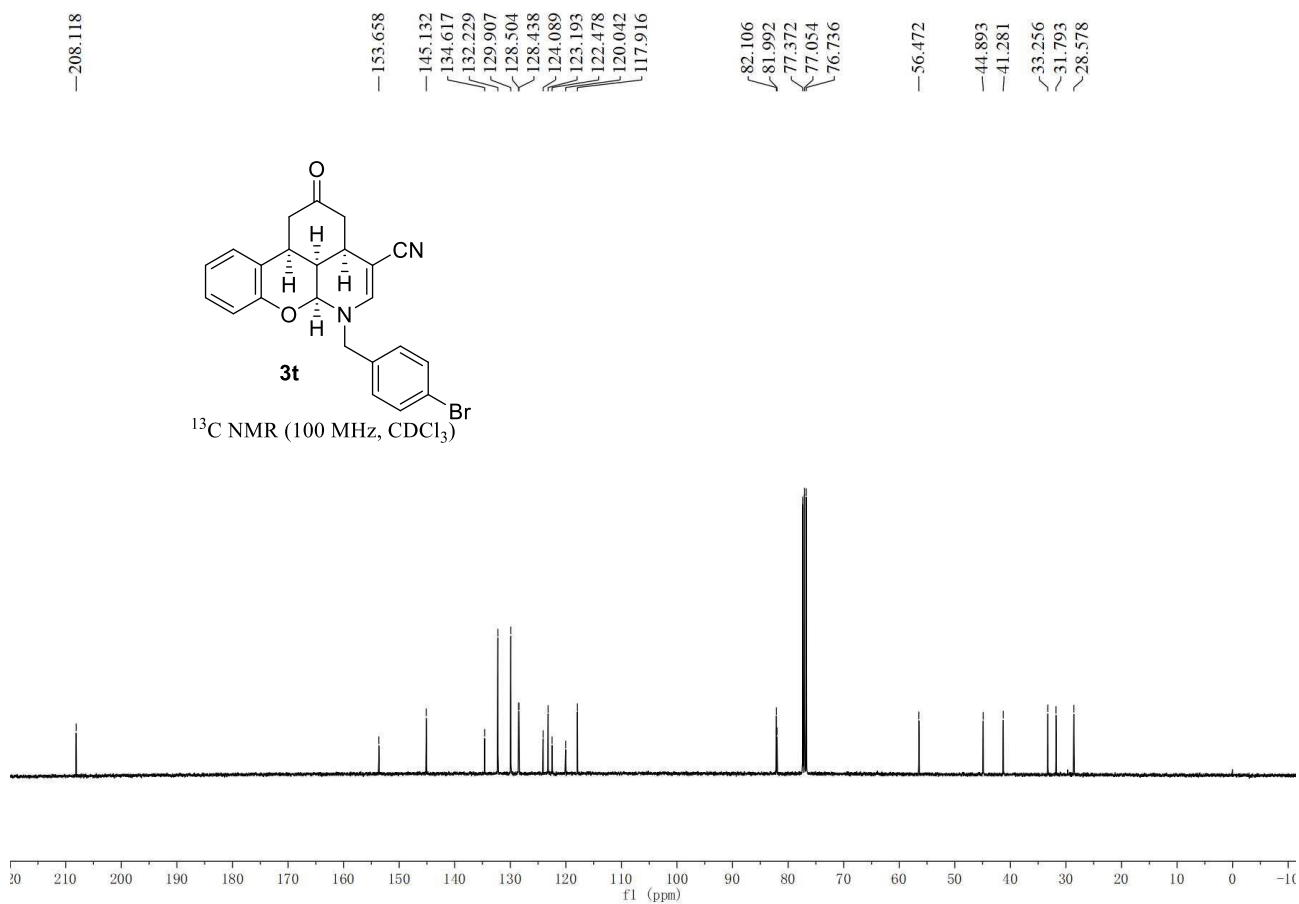
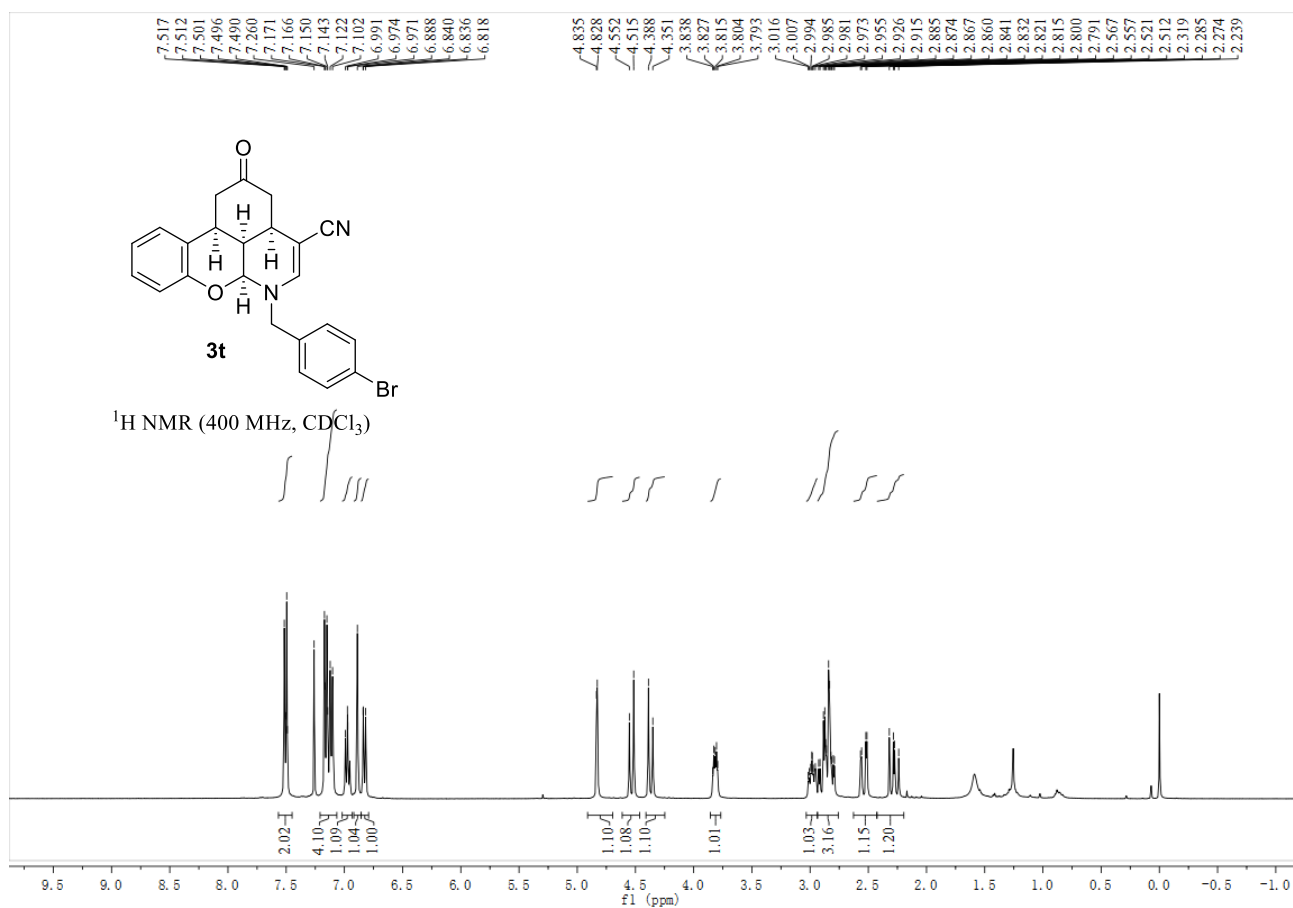
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
30.943	BBA	0.81	17.6849	960.4539	3.1760
43.388	BBA	1.23	346.3489	29280.4277	96.8240
Totals:				30240.8817	100.0000

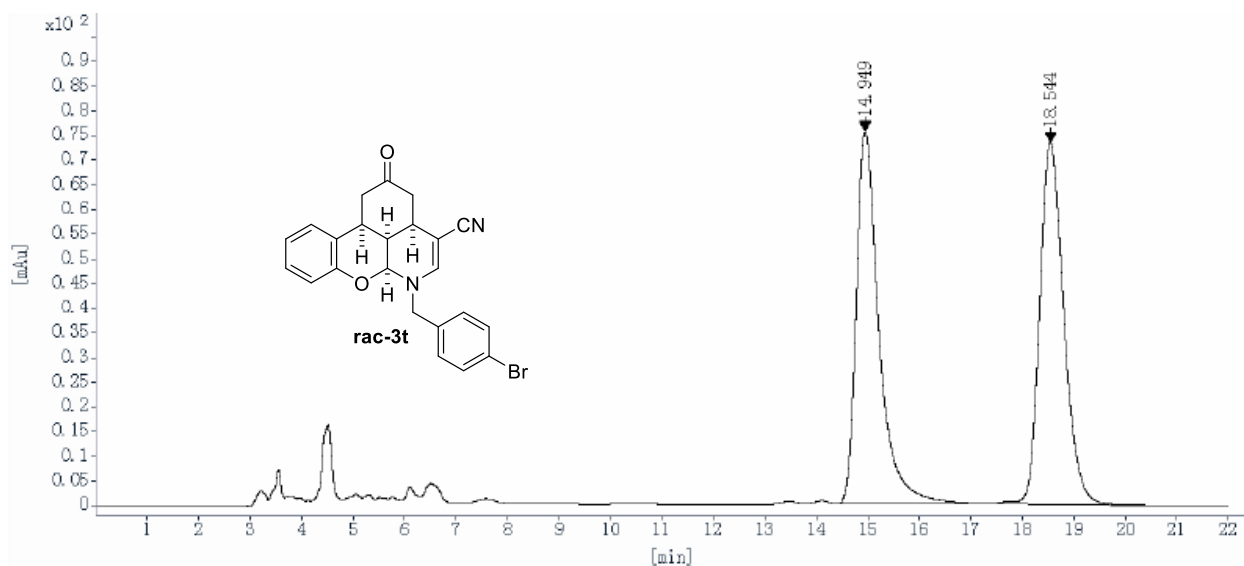
Spectrum Plot Report



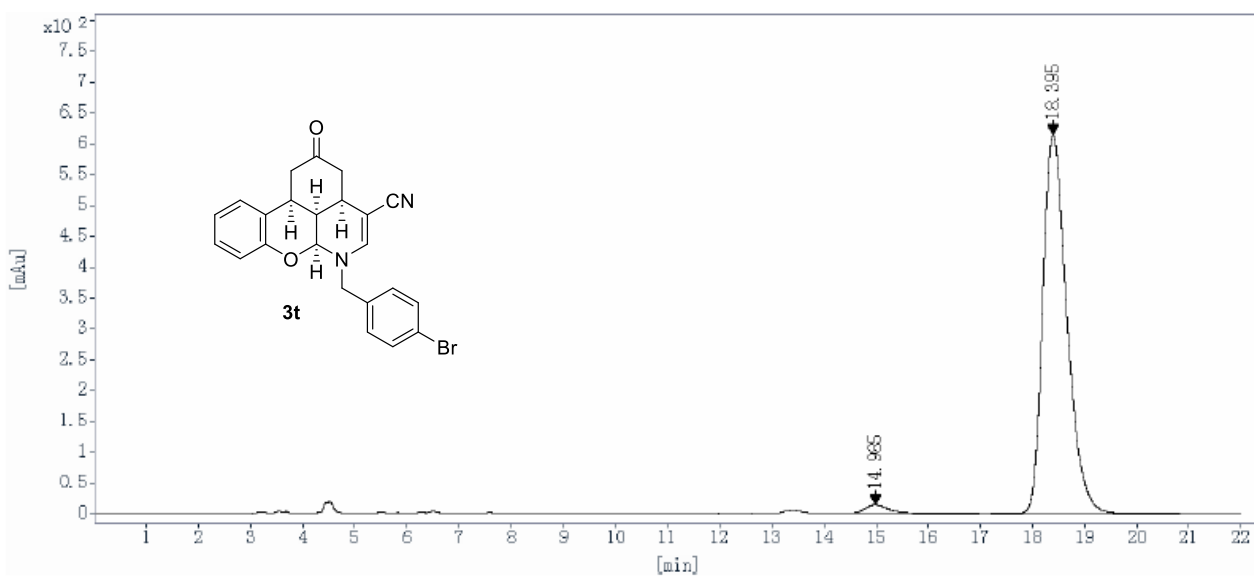
Name	CYC-20191117-5	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191117-5.d	Method (Acq)	TOF.m		Acq. Time (Local)
					11/21/2019 9:02:30 PM (UTC+08:00)







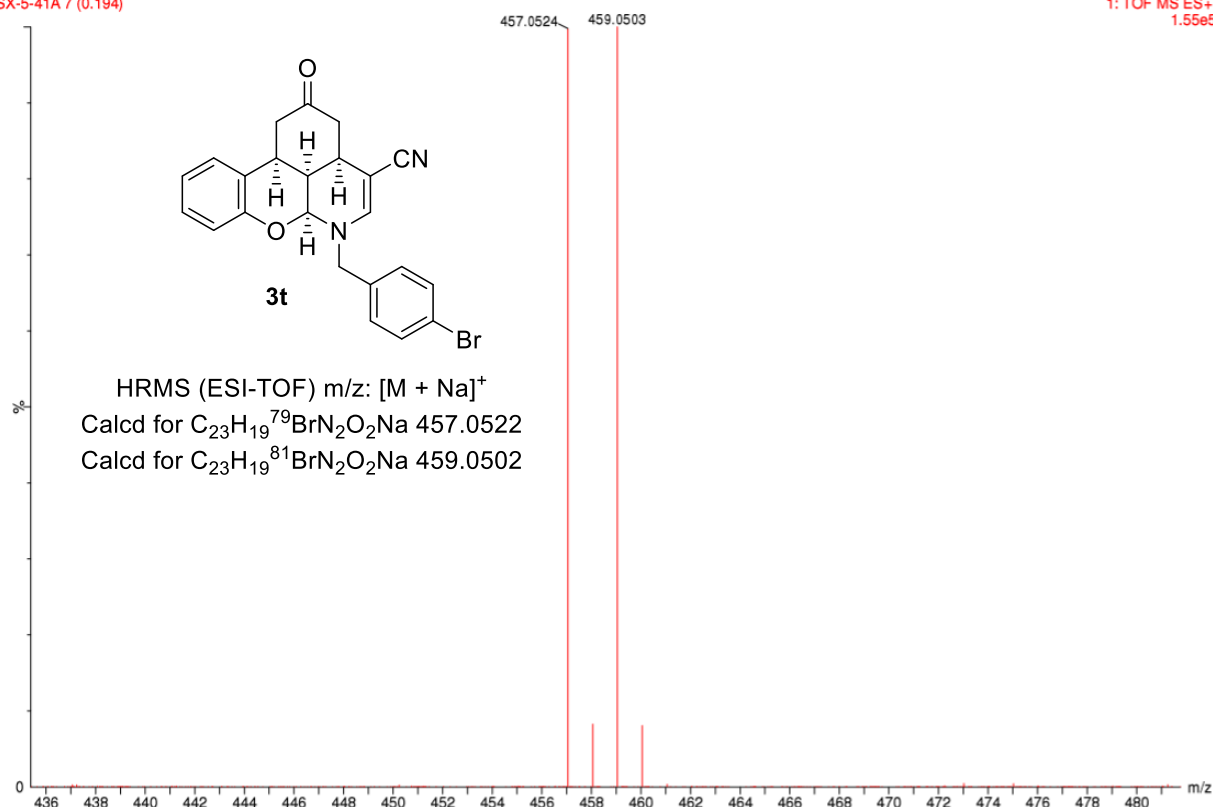
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
14.949	BB	0.46	75.4141	2311.8191	49.2566
18.544	BB	0.50	73.3446	2381.6030	50.7434
Totals:				4693.4221	100.0000

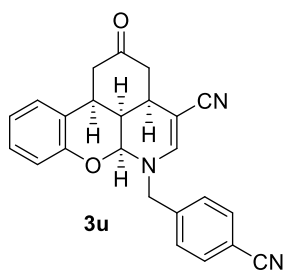


Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
14.985	BB	0.51	13.5490	460.4789	2.2778
18.395	BB	0.49	614.1894	19755.2012	97.7222
Totals:				20215.6801	100.0000

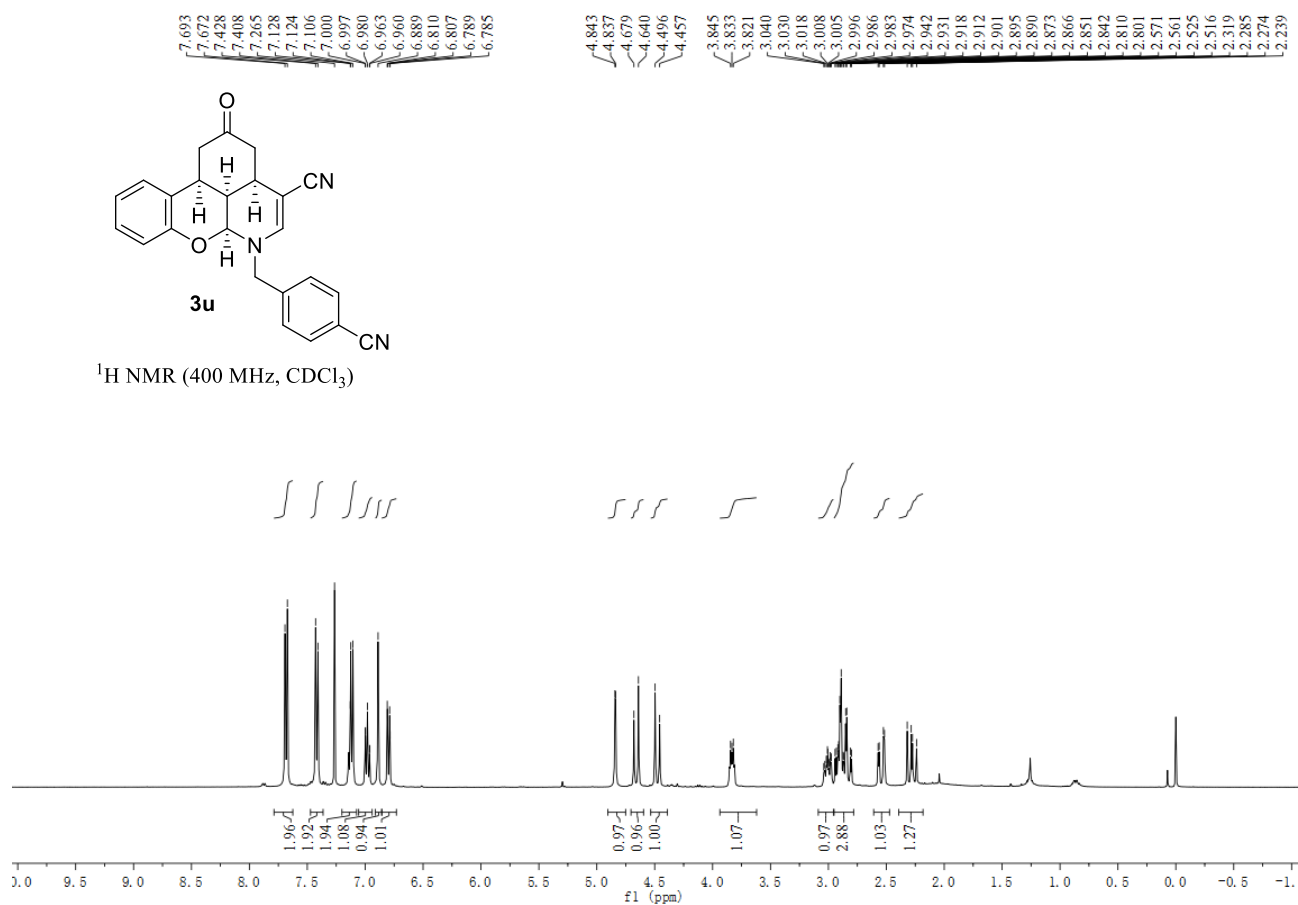
SX-5-41A 7 (0.194)

1: TOF MS ES+
1.55e5





^1H NMR (400 MHz, CDCl_3)



—207.978

—153.500

—145.000

—141.282

—132.843

—128.670

—128.528

—128.497

—124.006

—123.319

—119.763

—118.317

—117.876

—112.392

—82.795

—82.445

—77.389

—77.071

—76.754

—56.646

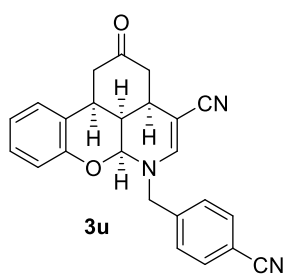
—44.849

—41.211

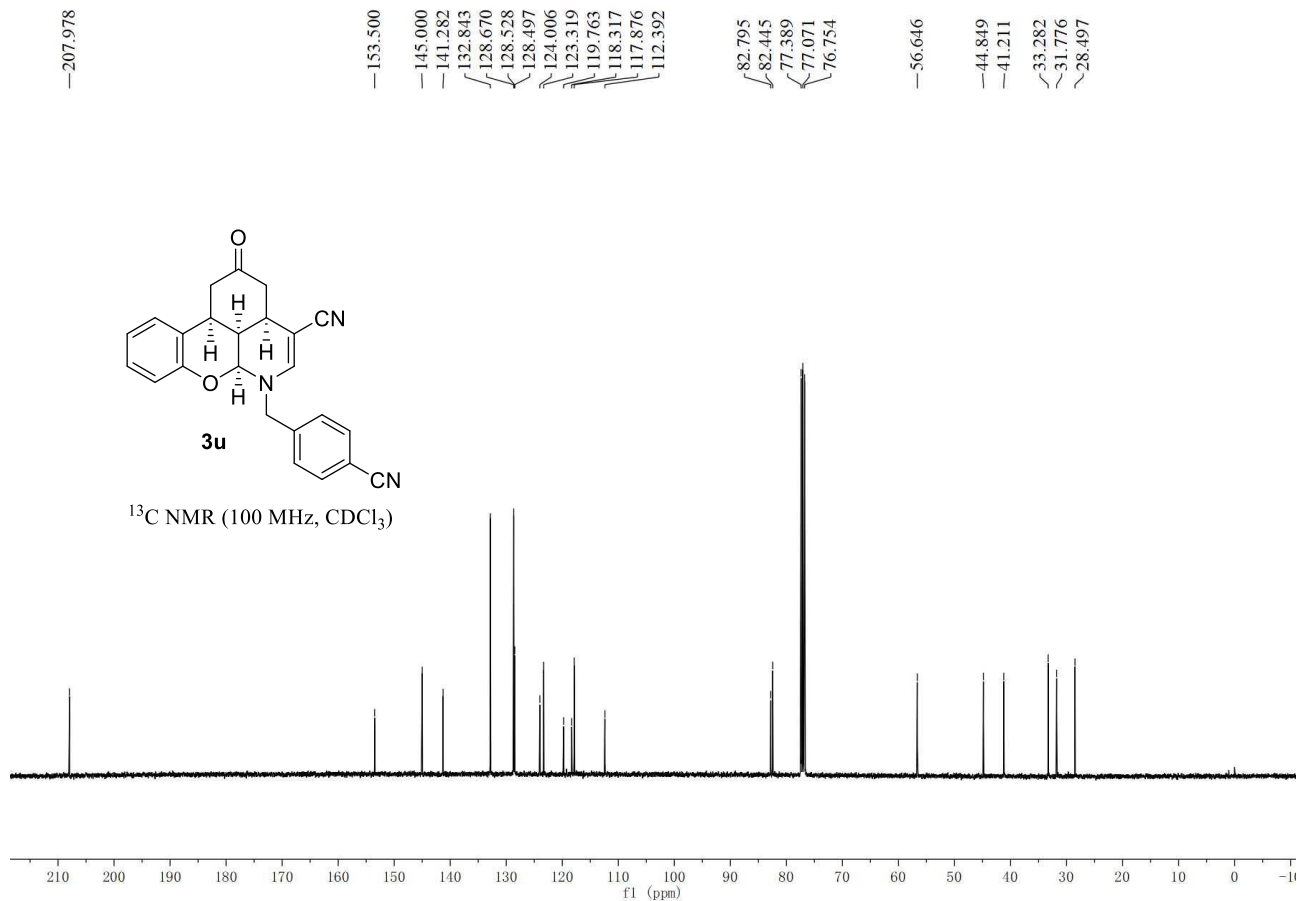
—33.282

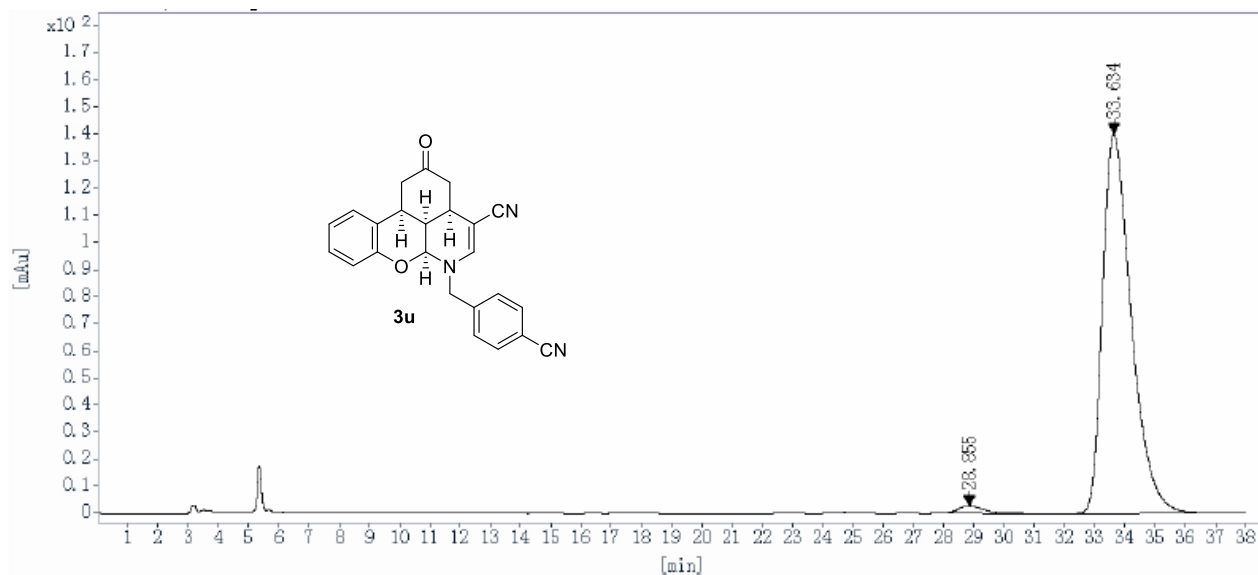
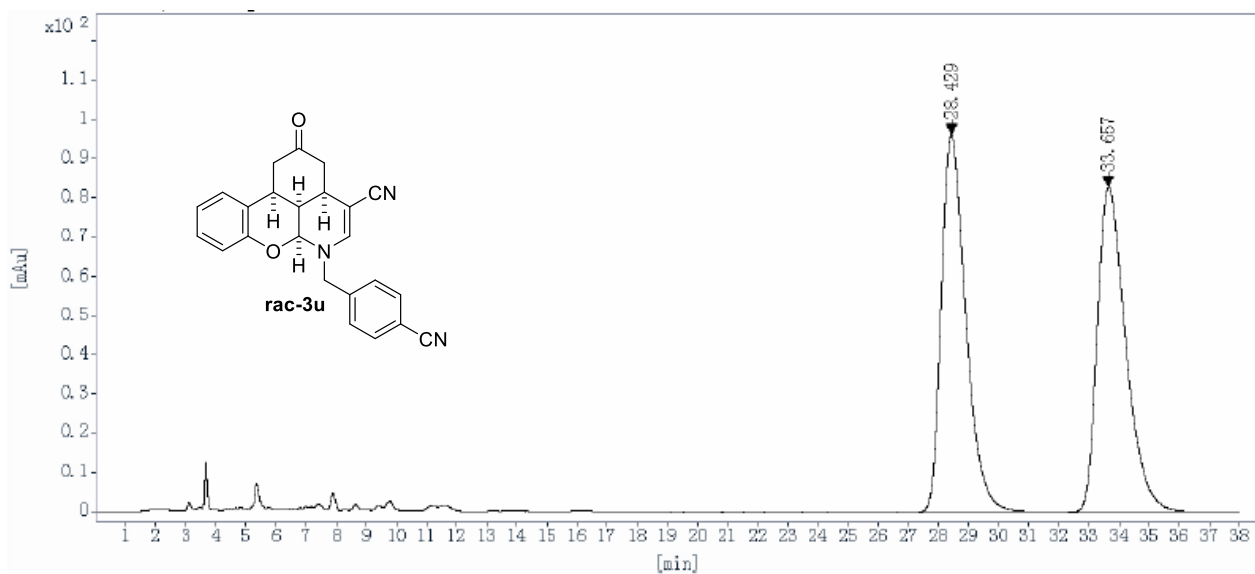
—31.776

—28.497



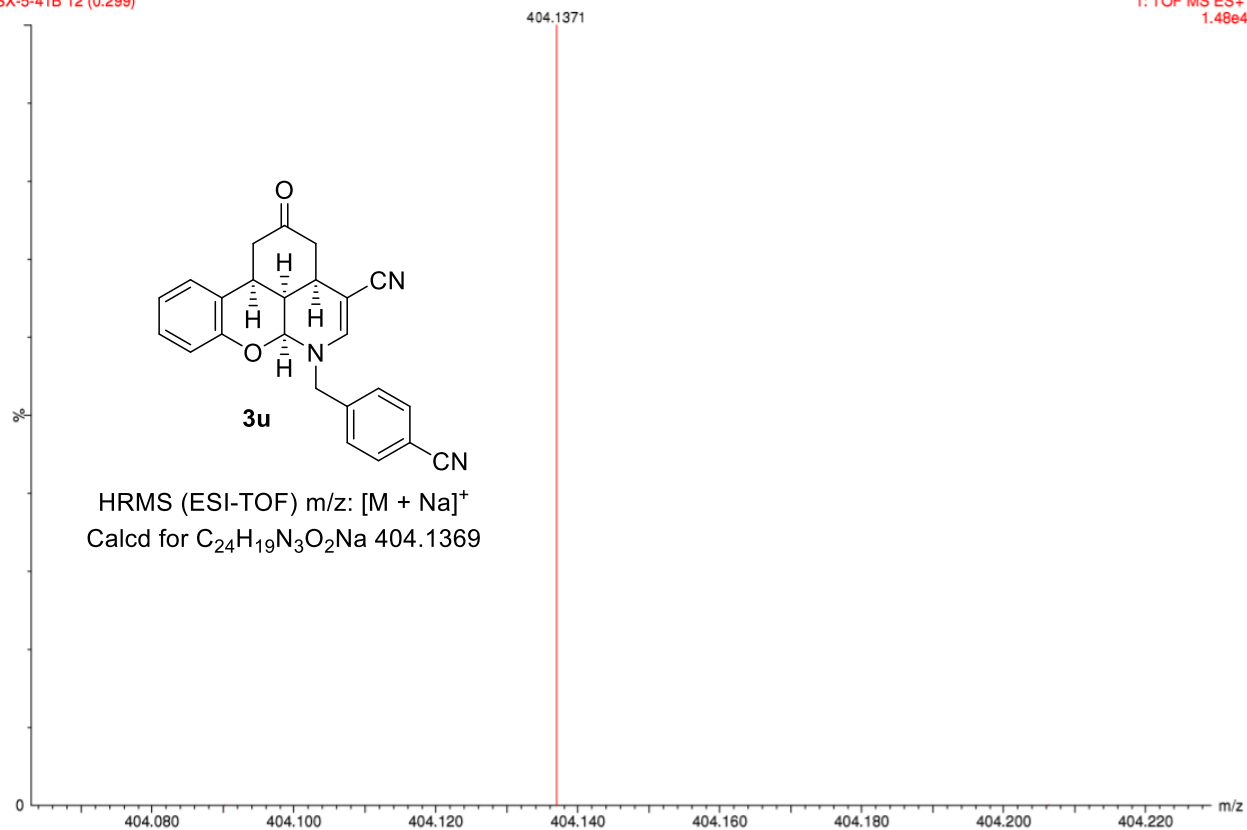
^{13}C NMR (100 MHz, CDCl_3)

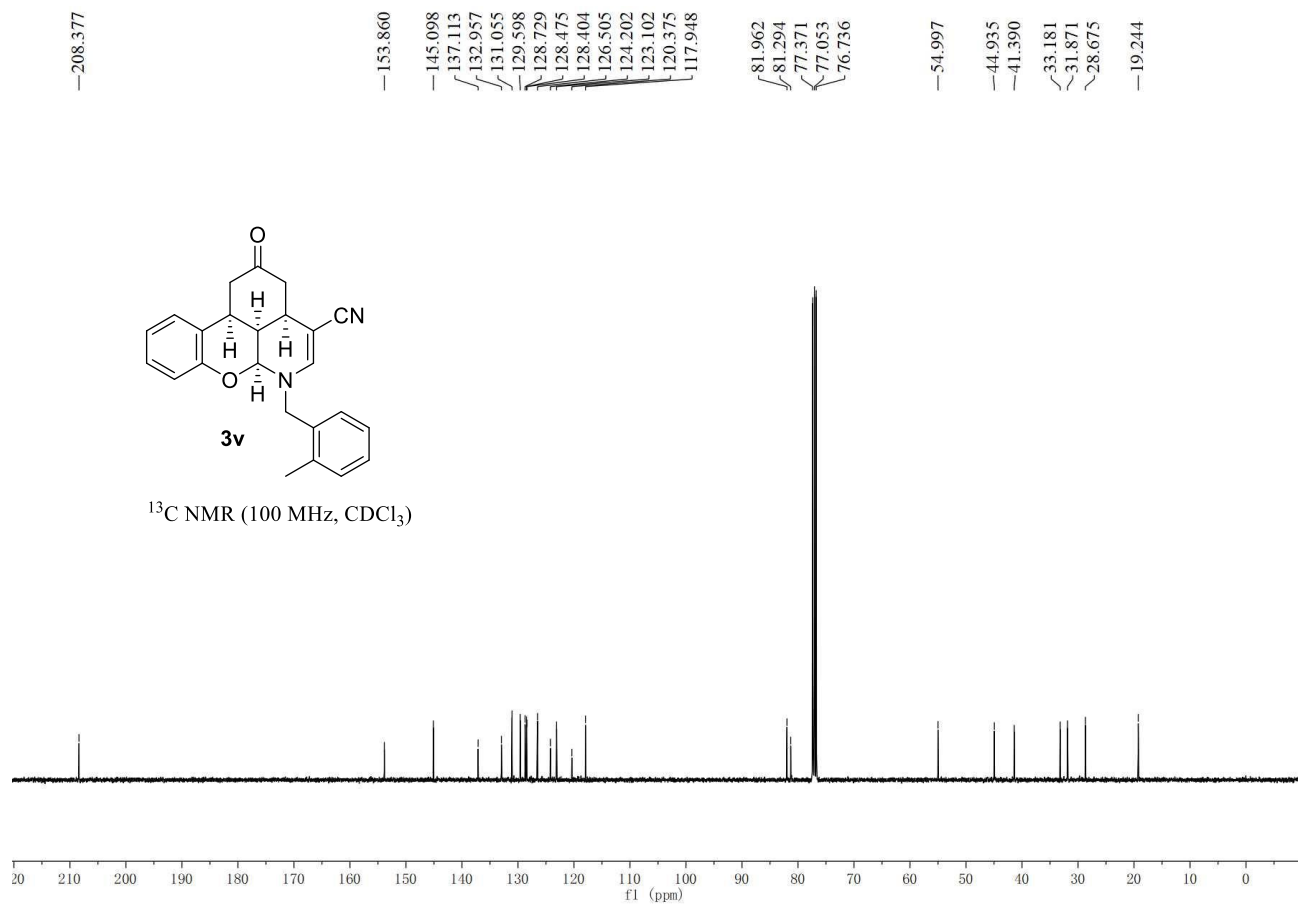
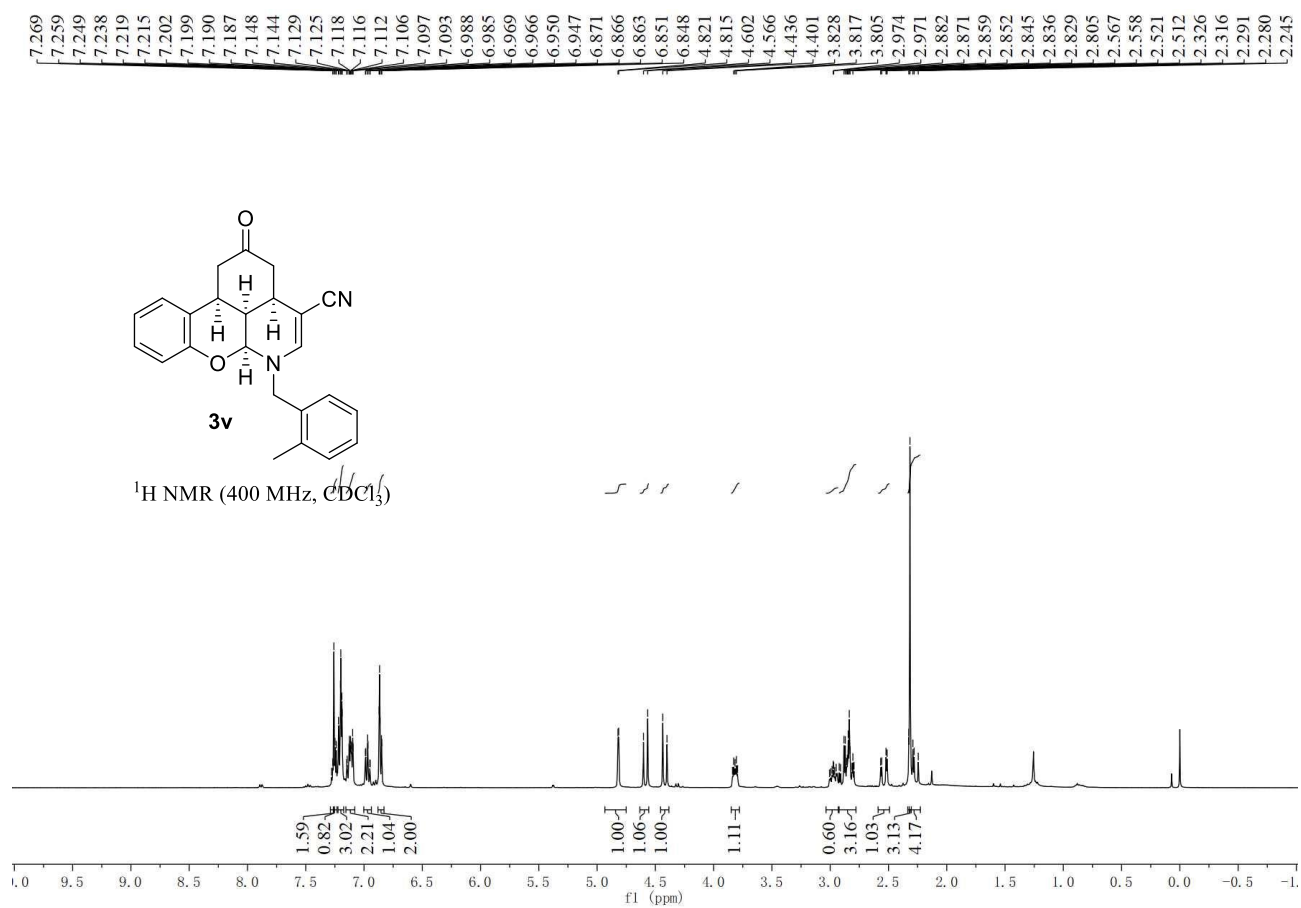


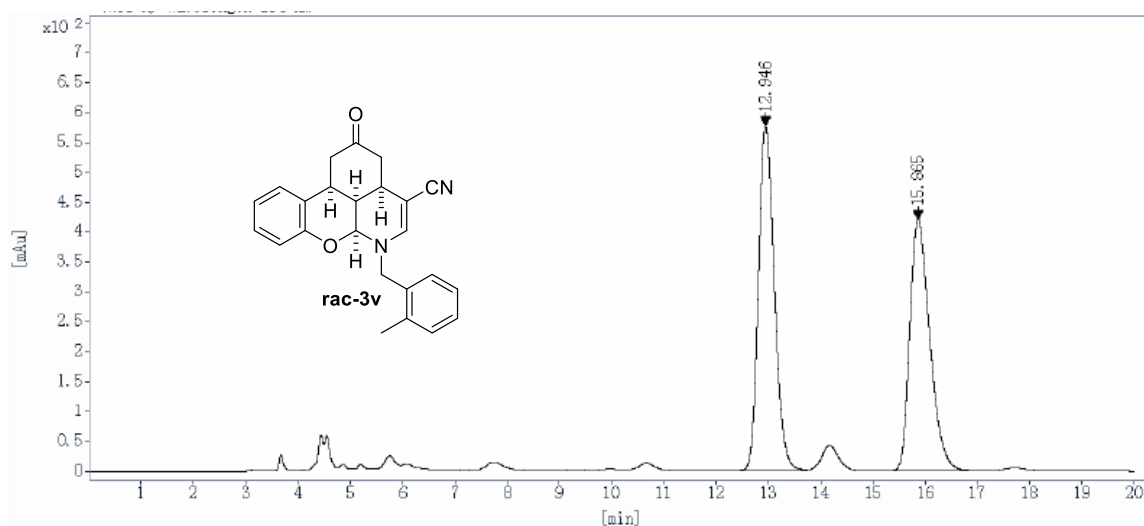


SX-5-41B 12 (0.299)

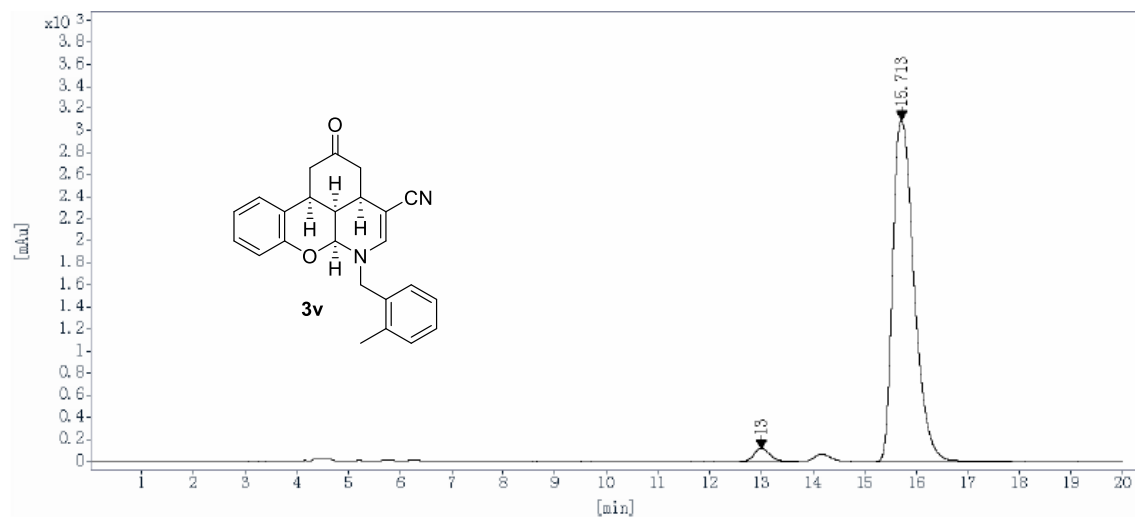
1: TOF MS ES+
1.48e4







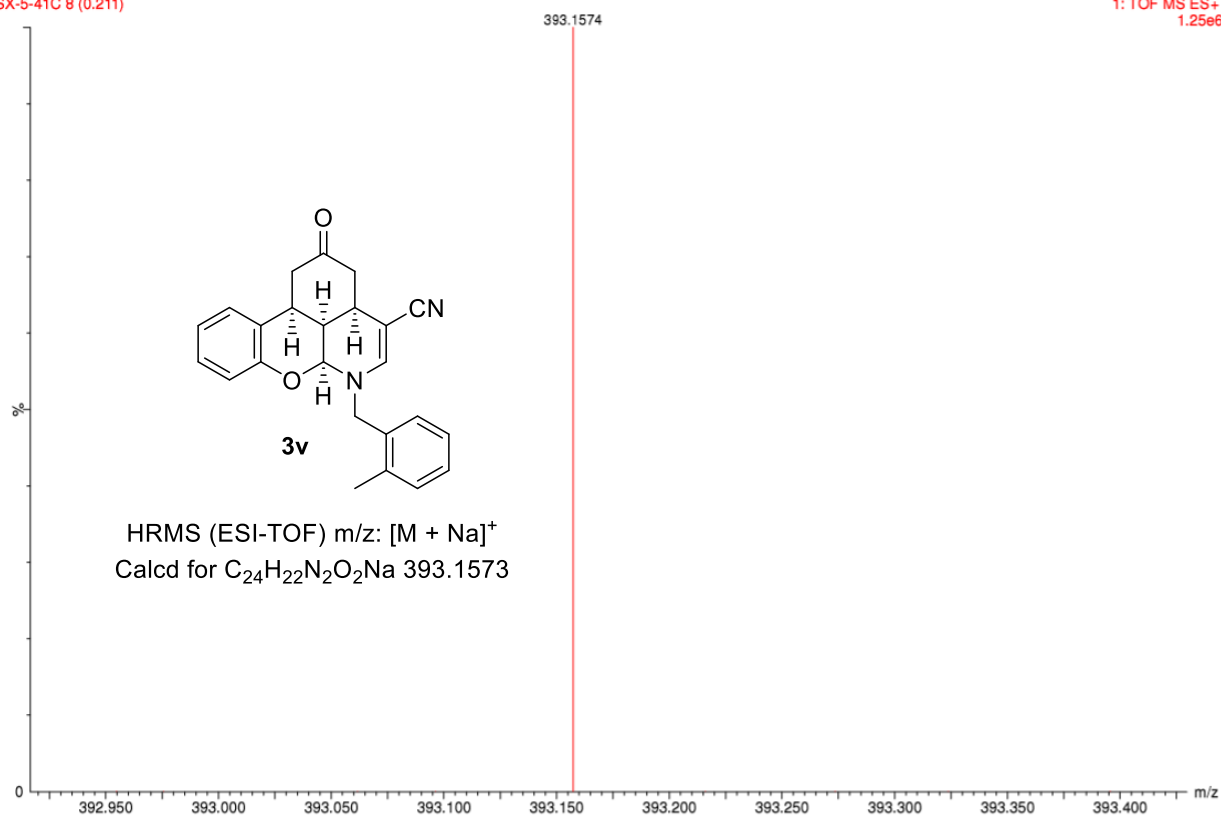
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
12.946	BV	0.33	575.9871	12219.7900	52.3236
15.865	BB	0.41	420.8748	11134.4795	47.6764
Totals:				23354.2695	100.0000

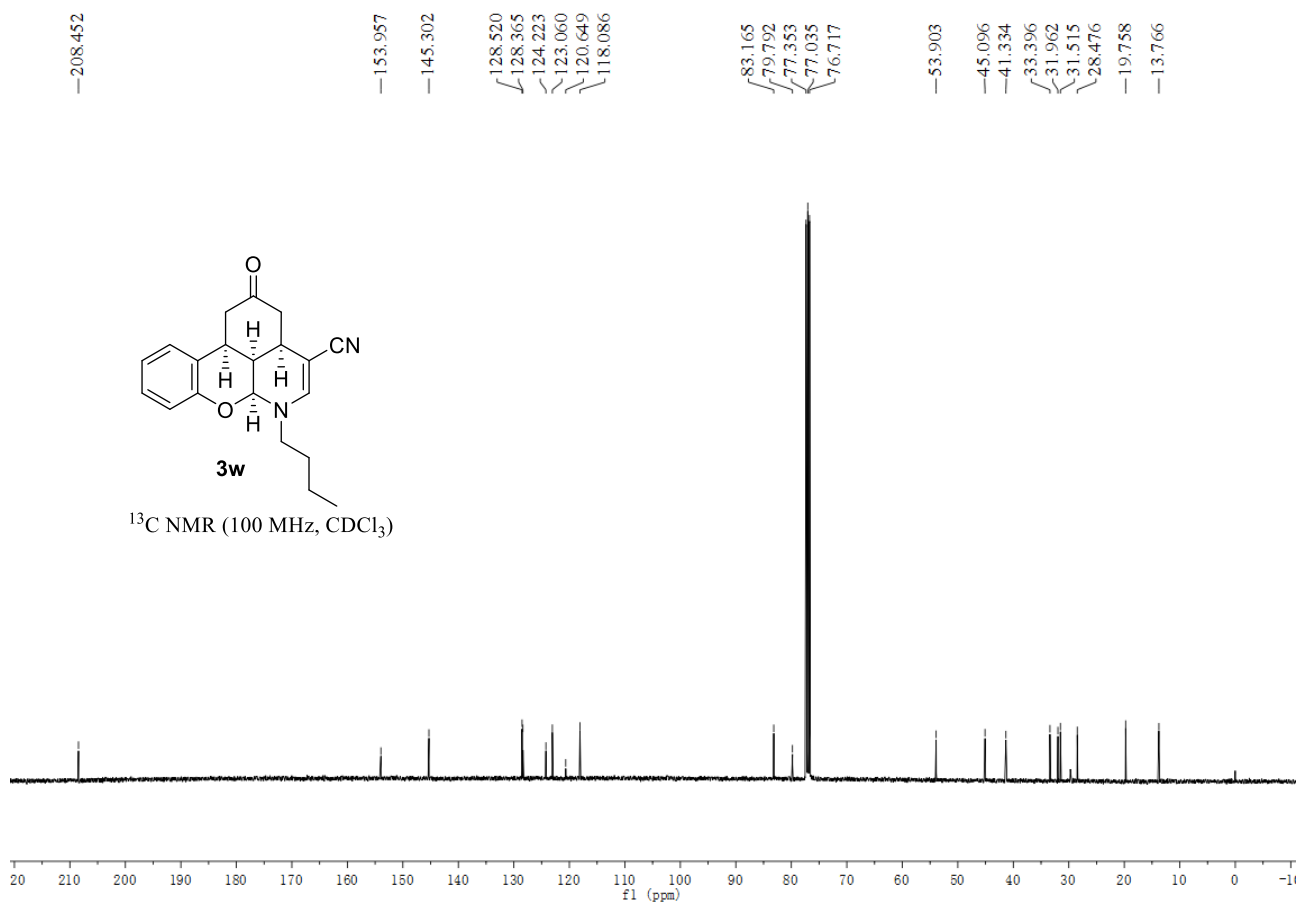
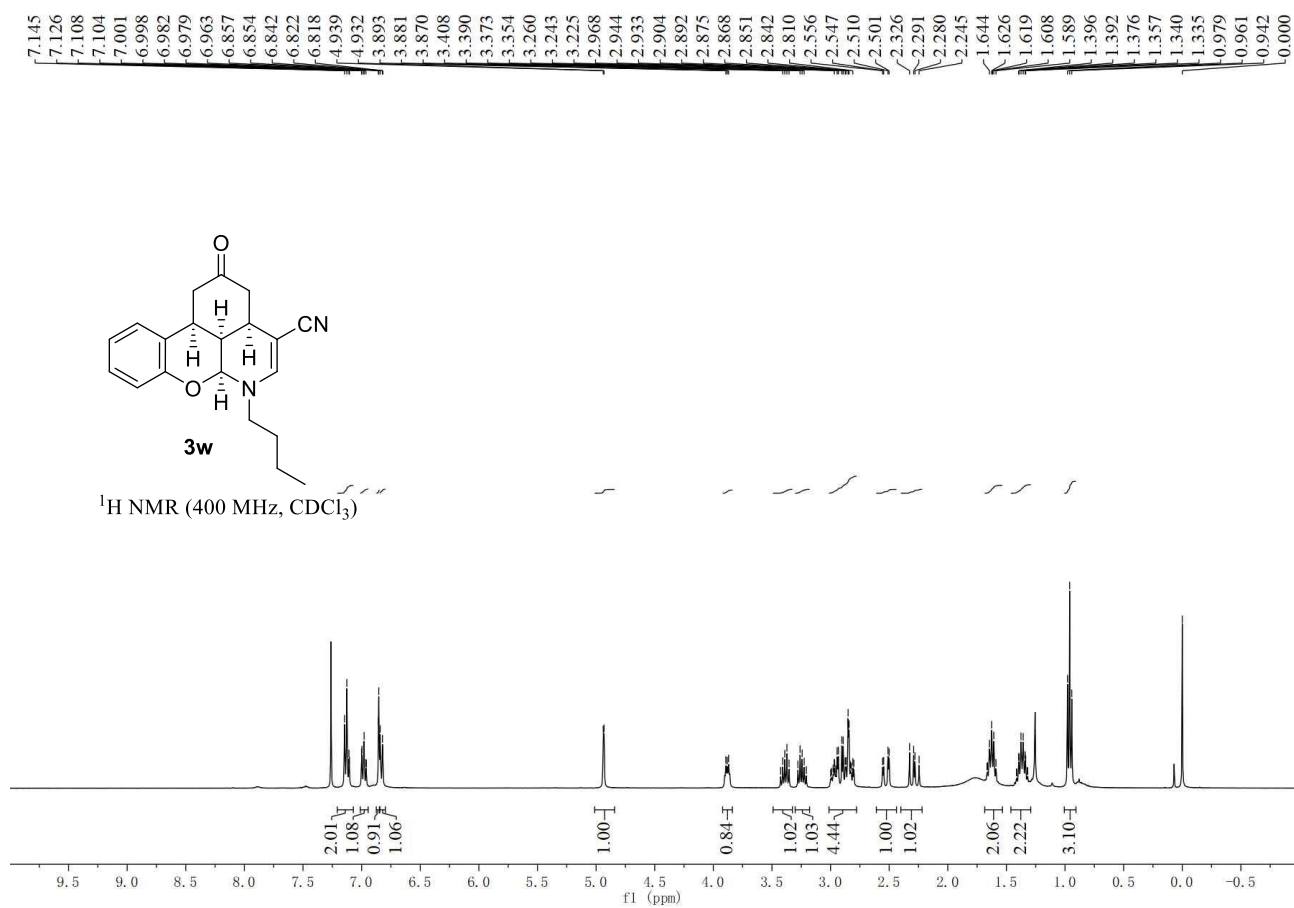


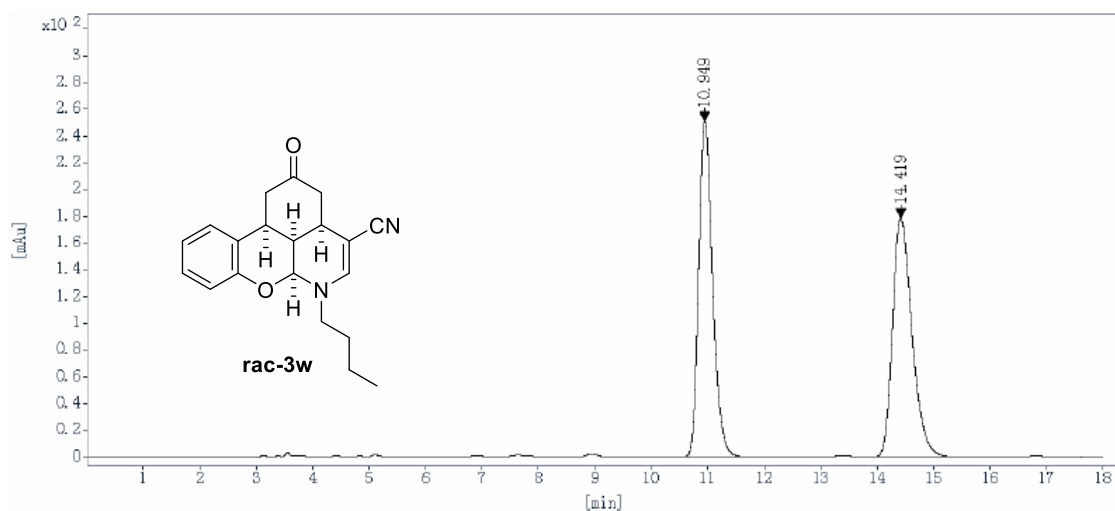
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
13.000	BV	0.34	115.5932	2506.0115	2.7485
15.713	BB	0.45	3091.0000	88670.5156	97.2515
Totals:				91176.5271	100.0000

SX-5-41C 8 (0.211)

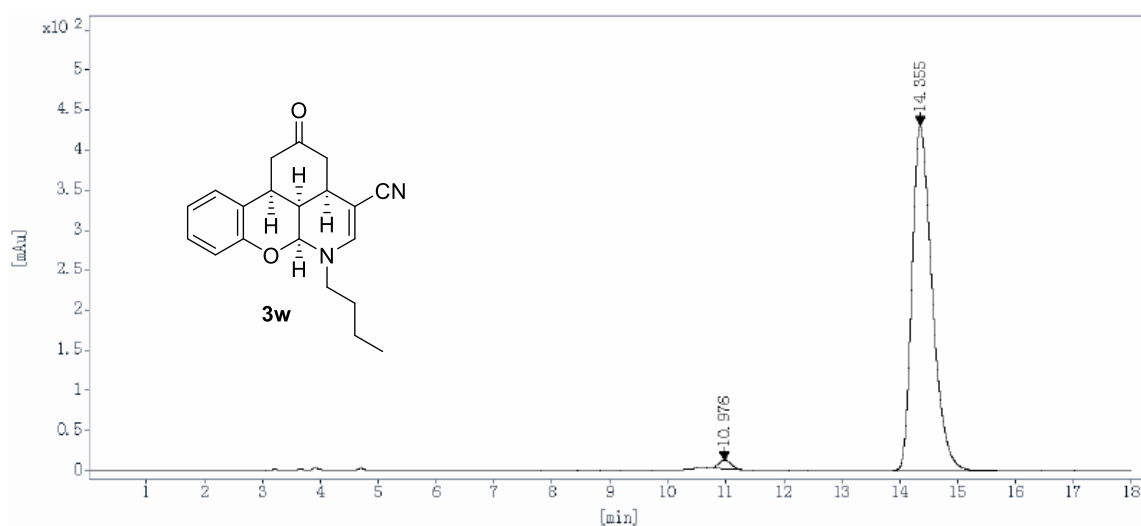
1: TOF MS ES+
1.25e6





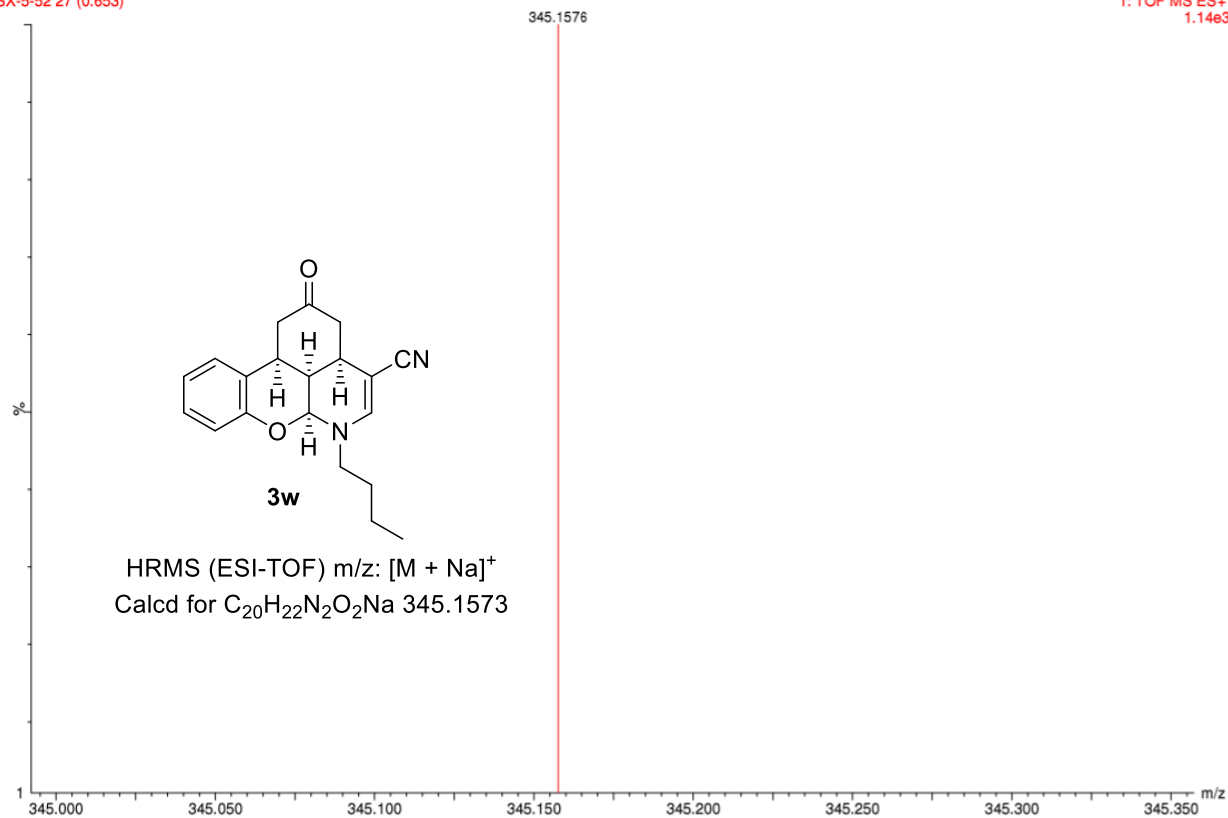


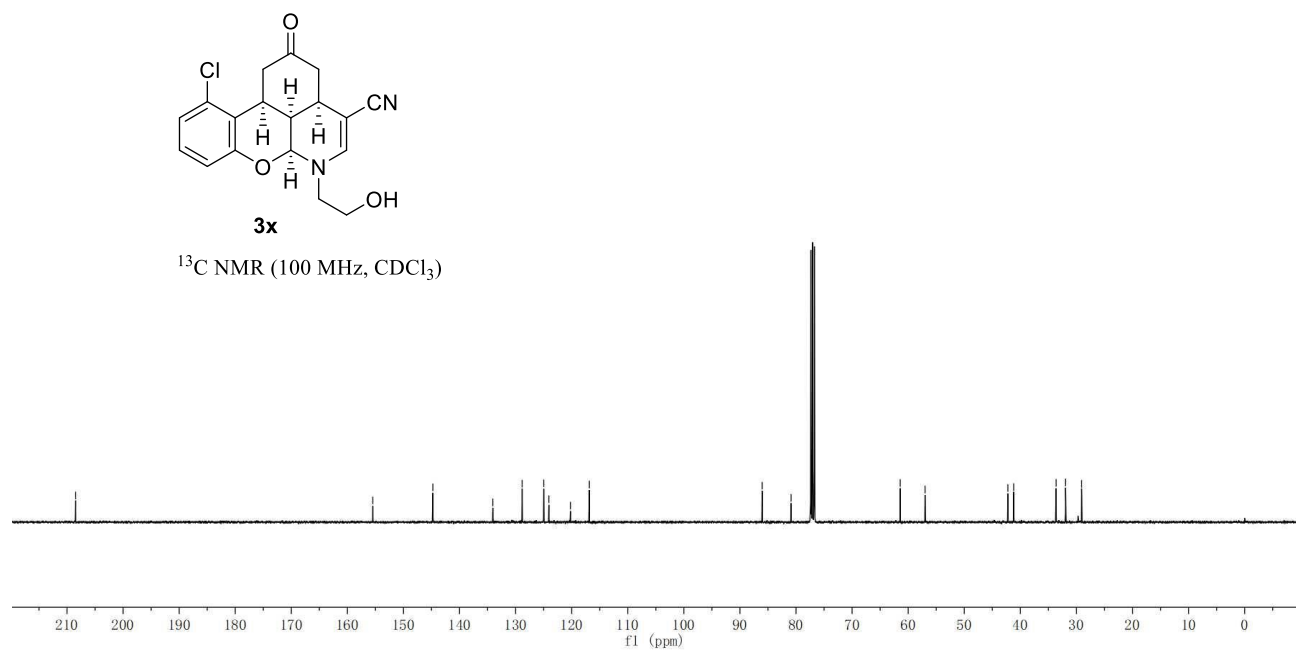
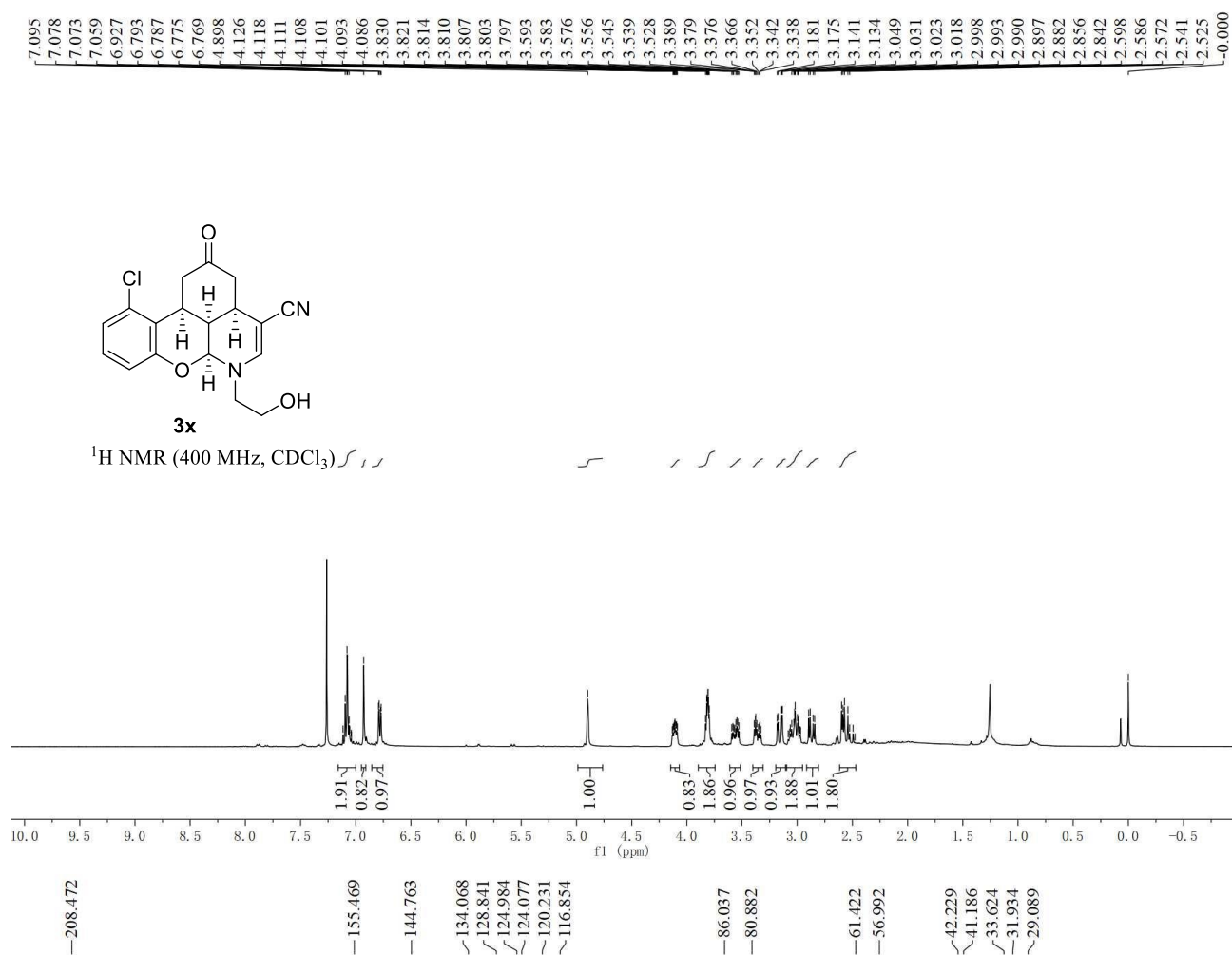
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
10.949	BB	0.26	250.8640	4297.1152	50.1527
14.419	BB	0.37	178.6262	4270.9492	49.8473
Totals:				8568.0645	100.0000

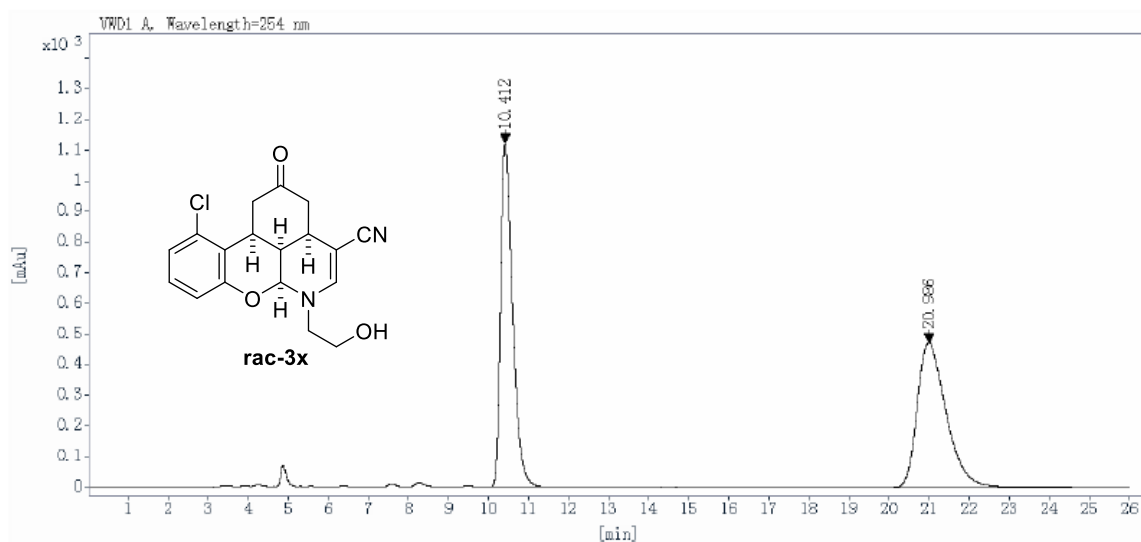


Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
10.976	BB	0.24	10.9160	166.9727	1.5892
14.355	BB	0.37	429.9457	10339.5820	98.4108
Totals:				10506.5547	100.0000

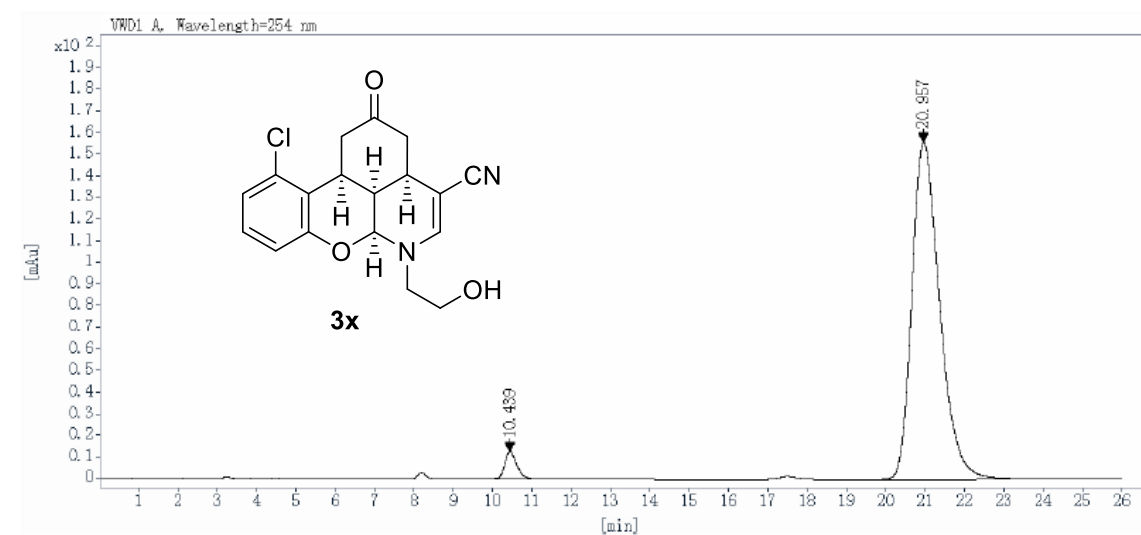
1: TOF MS ES+
1.14e3







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
10.412	BB	0.32	1122.2574	23385.5273	49.7544
20.986	BB	0.77	472.1183	23616.3770	50.2456
Totals:				47001.9043	100.0000

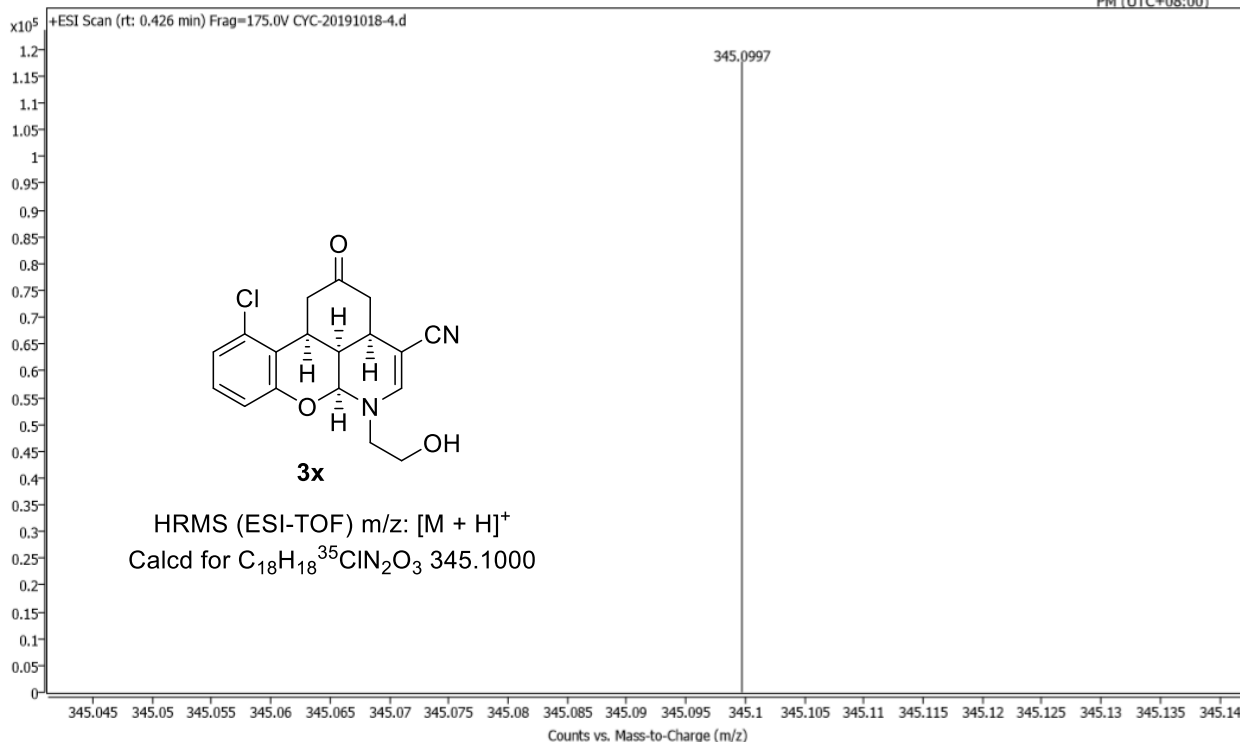


Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
10.439	BB	0.33	12.6559	273.7483	3.4554
20.957	BB	0.75	155.8393	7648.5938	96.5446
Totals:				7922.3420	100.0000

User Spectrum Plot Report



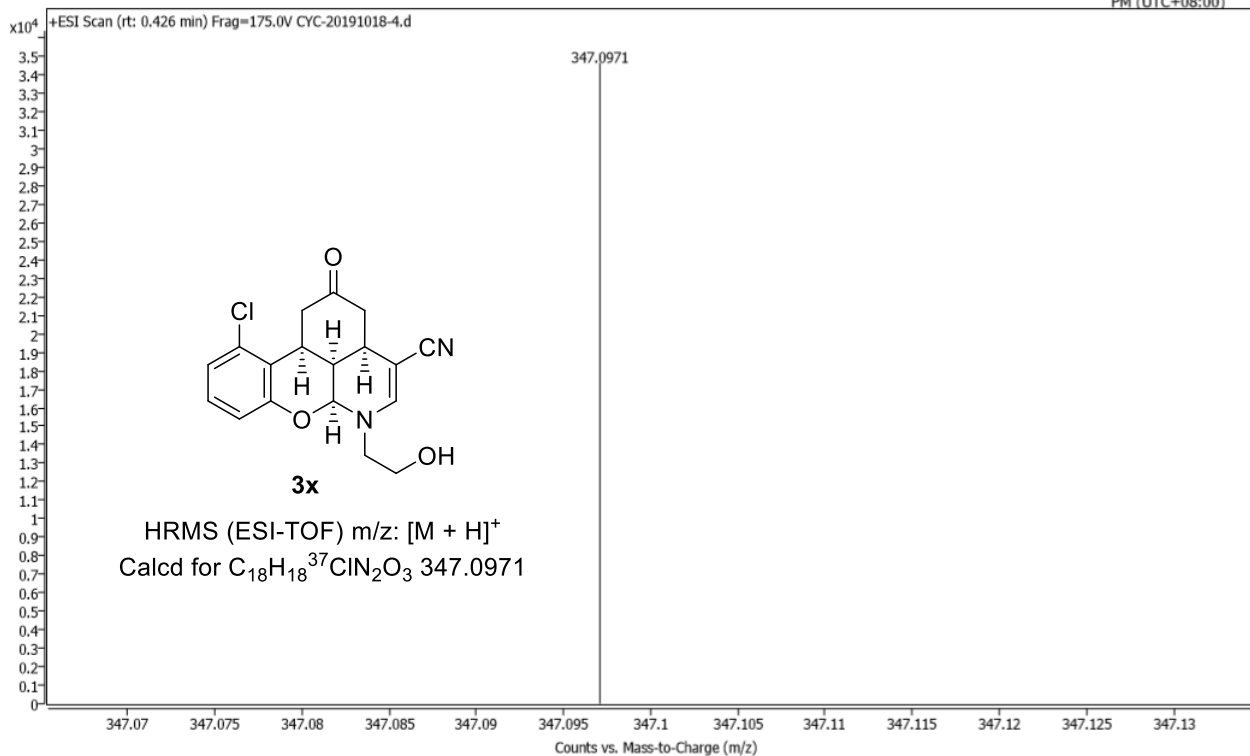
Name	CYC-20191018-4	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191018-4.d	Method (Acq)	TOF.m		Acq. Time (Local)
					10/29/2019 4:43:33 PM (UTC+08:00)

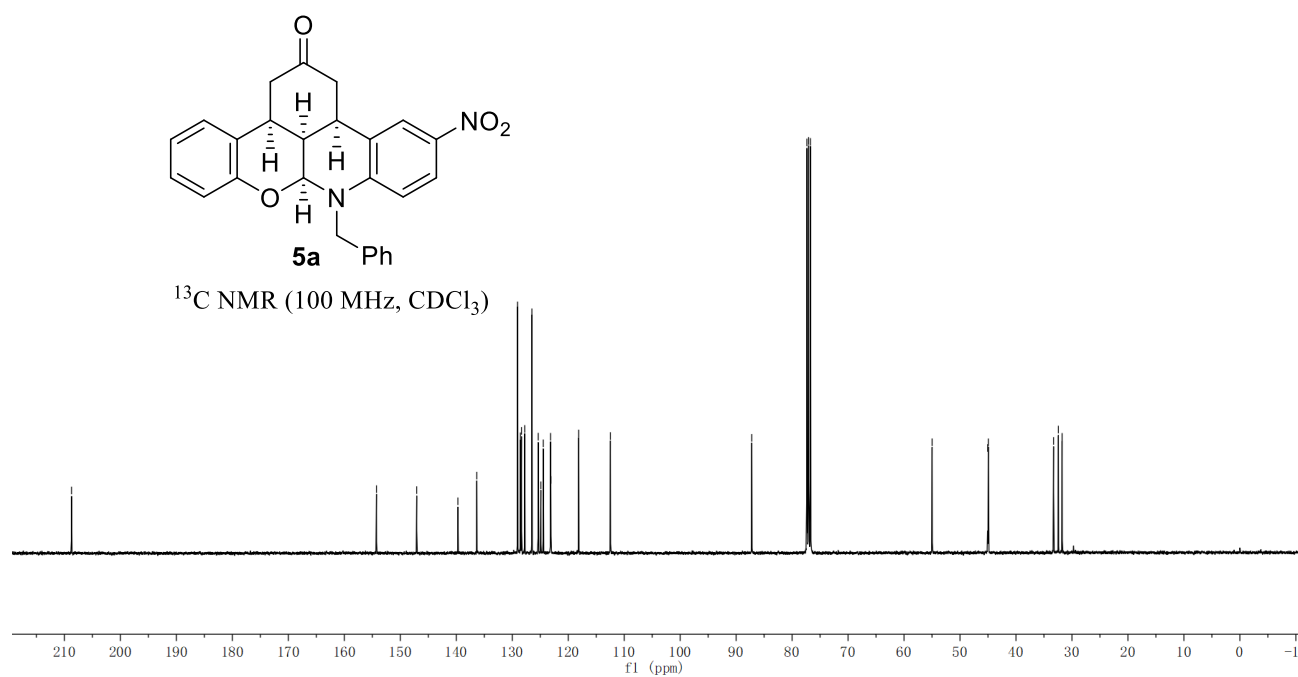
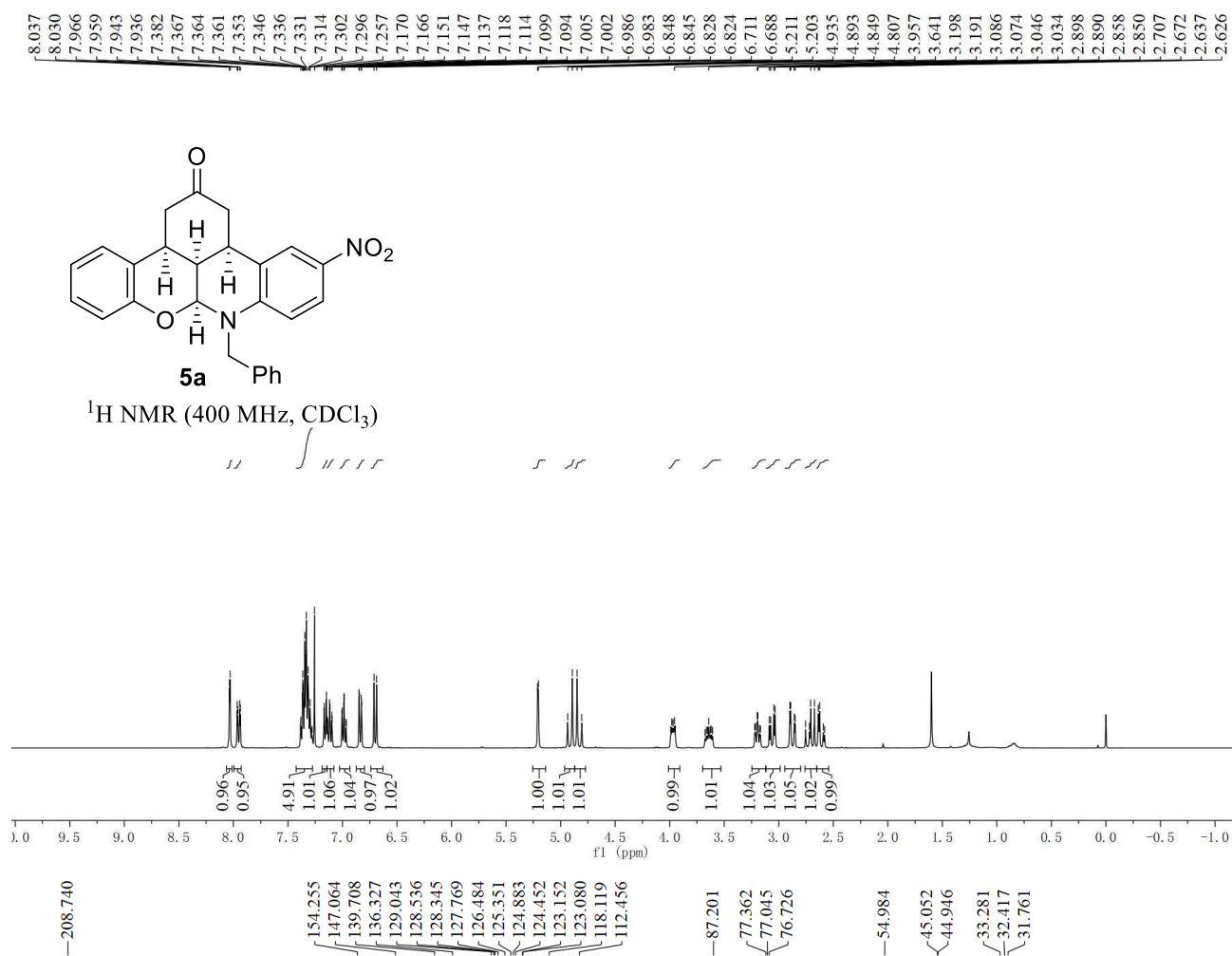


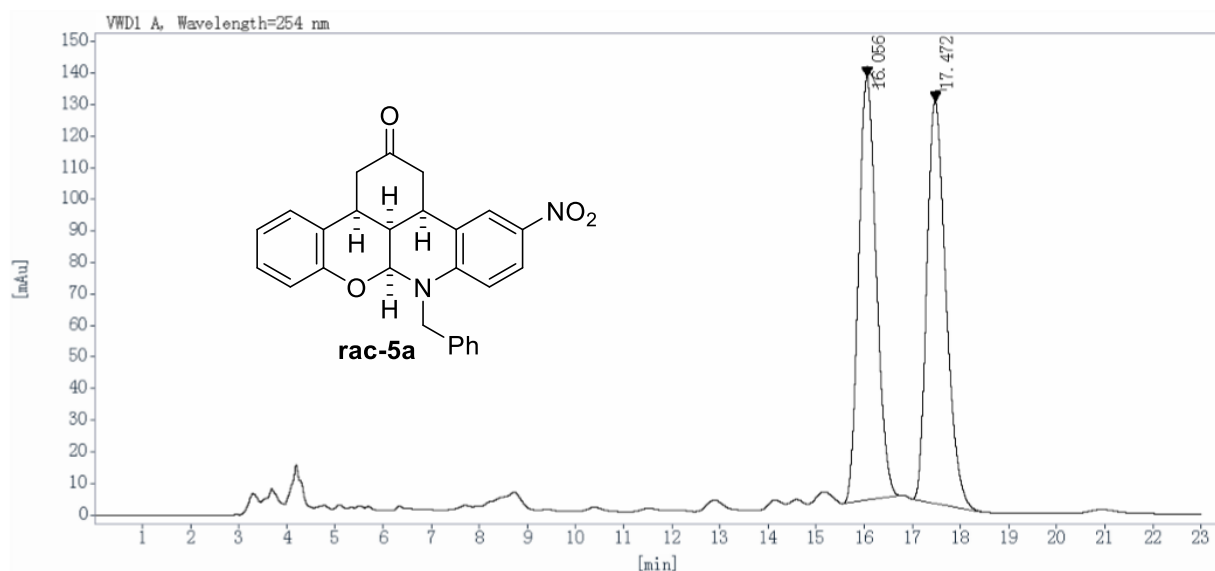
User Spectrum Plot Report



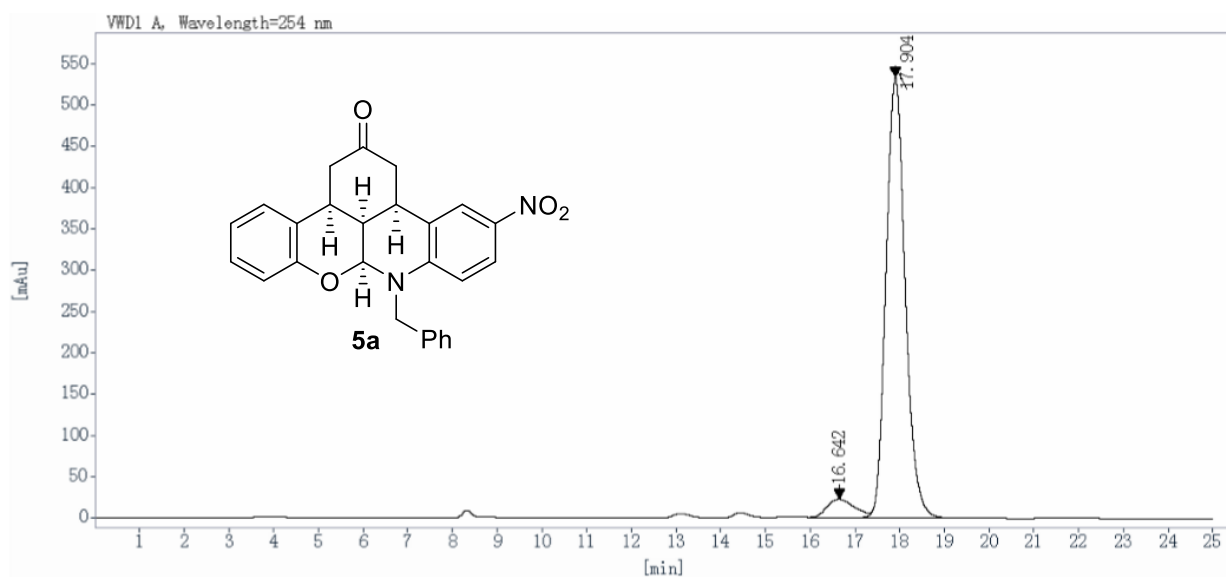
Name	CYC-20191018-4	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191018-4.d	Method (Acq)	TOF.m		Acq. Time (Local)
					10/29/2019 4:43:33 PM (UTC+08:00)



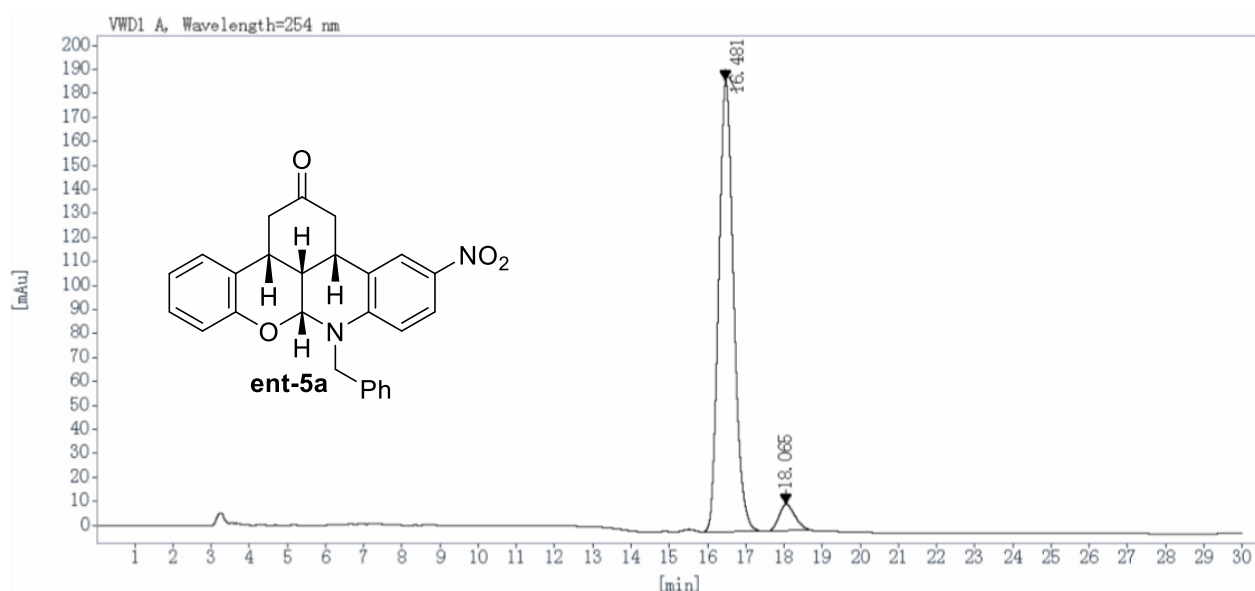




Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.056	BB	0.40	134.2299	3425.7644	49.3655
17.472	BB	0.43	127.4256	3513.8259	50.6345
Totals:				6939.5903	100.0000



Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.642	BV E	0.66	22.1565	948.1024	5.6313
17.904	VB R	0.46	533.9049	15888.1875	94.3687
Totals:				16836.2899	100.0000

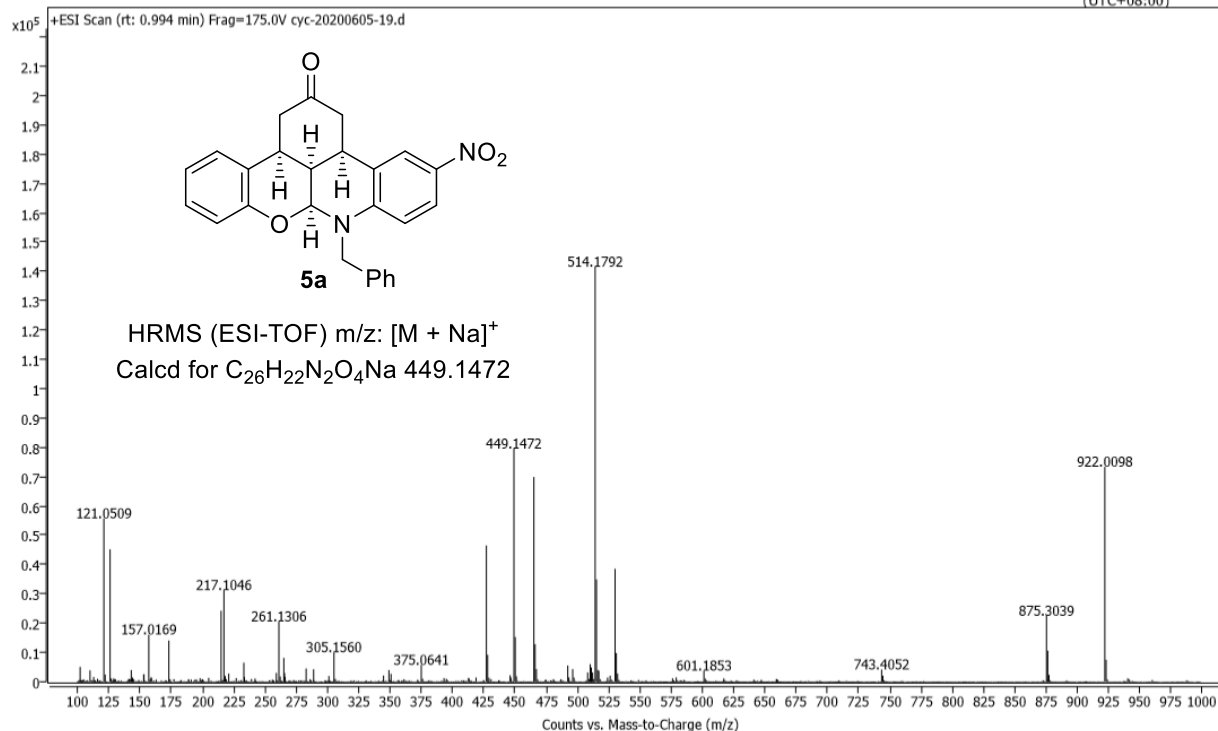


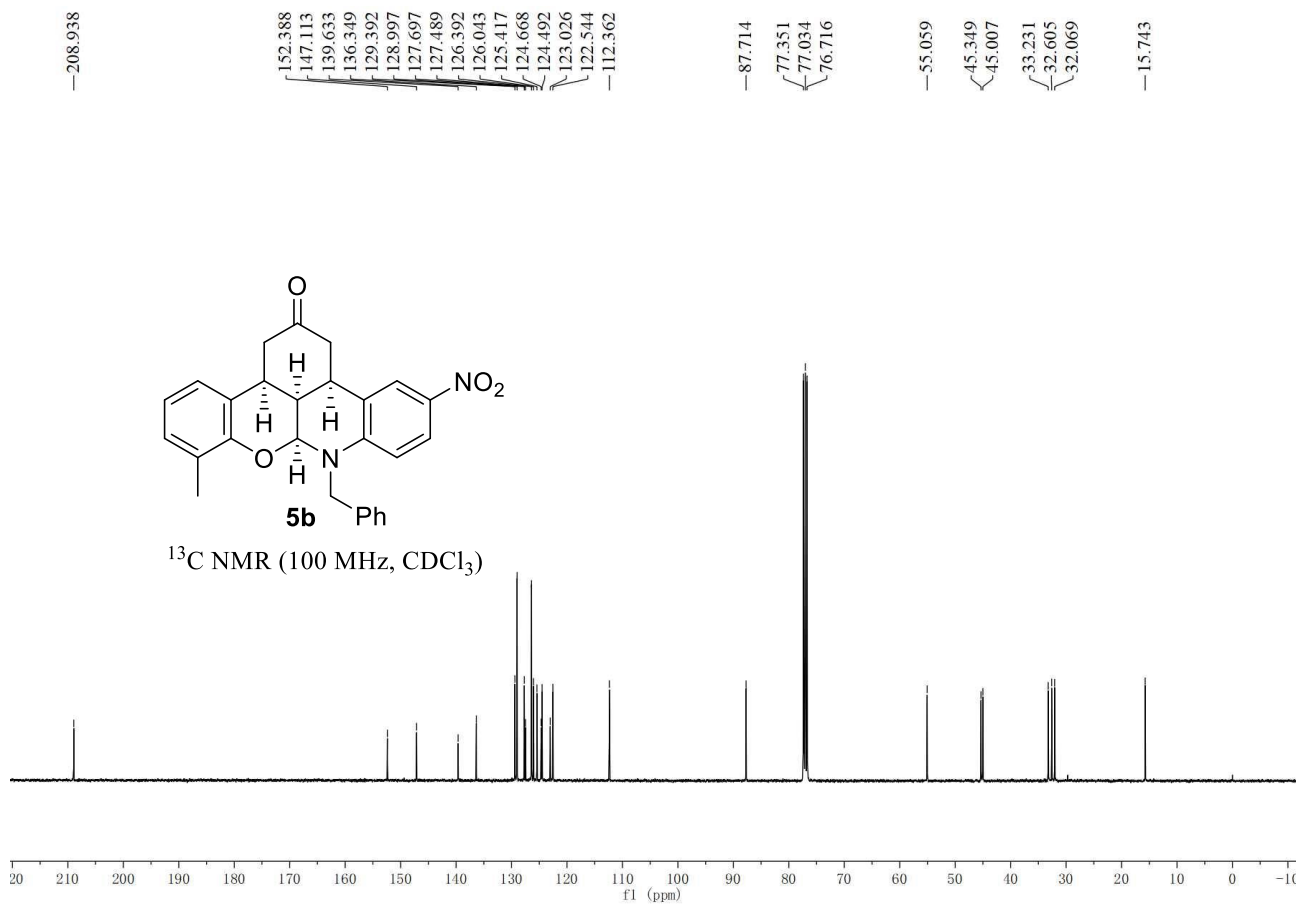
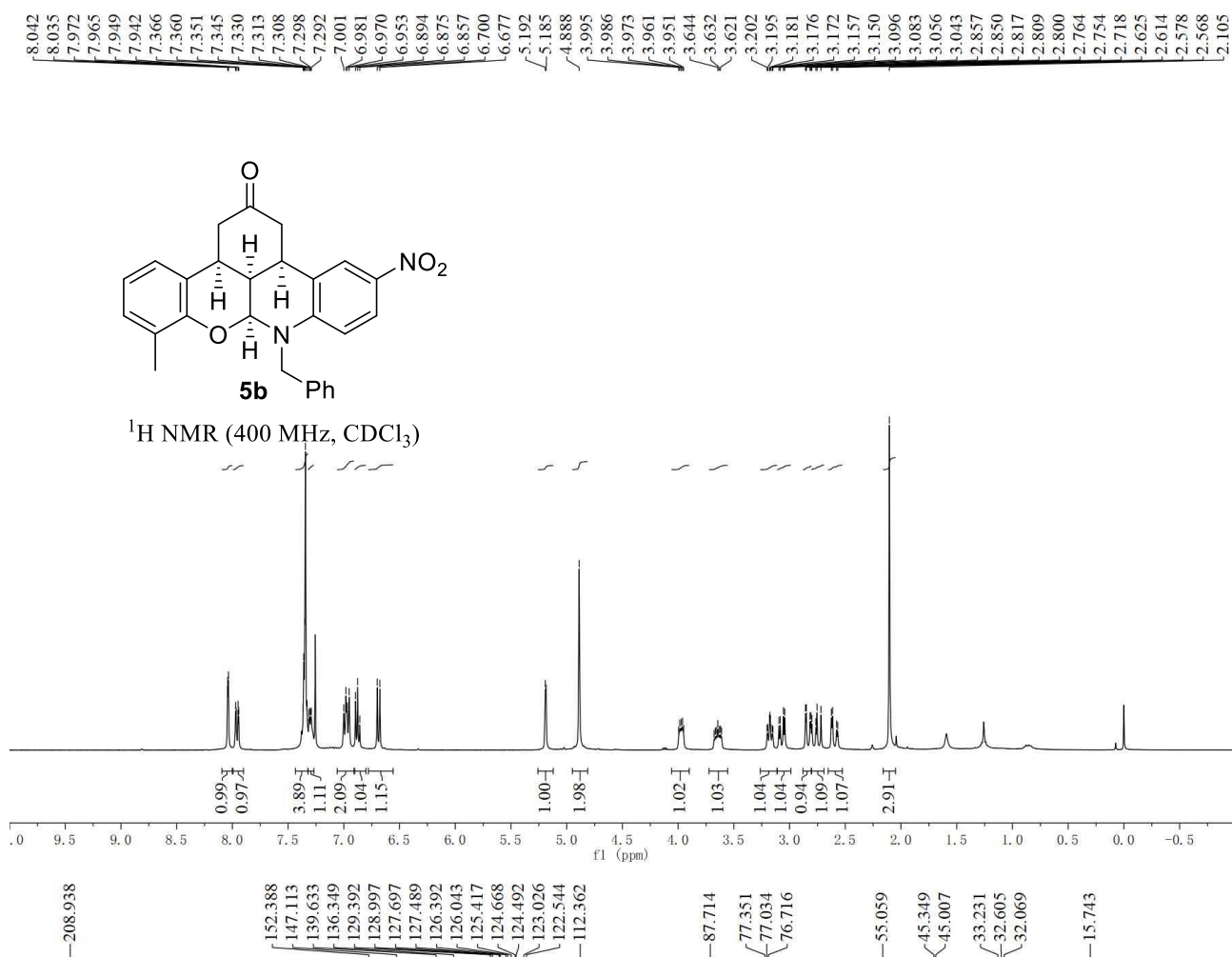
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.481	BB	0.42	188.0964	5119.7842	94.2221
18.065	BBA	0.45	10.9120	313.9573	5.7779
Totals:				5433.7415	100.0000

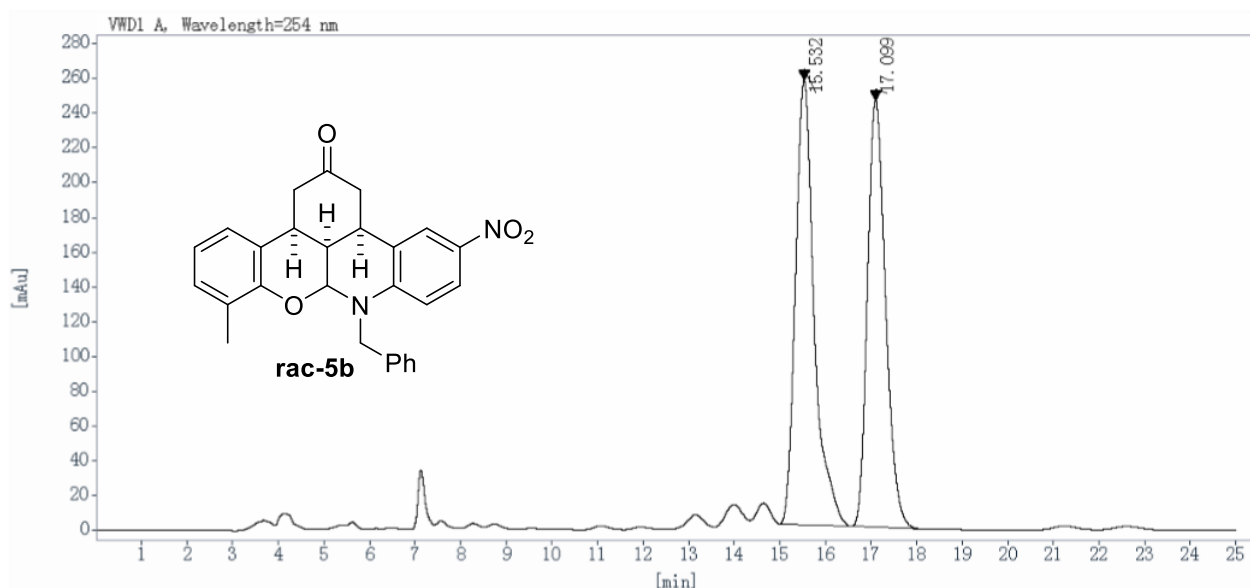
Spectrum Plot Report



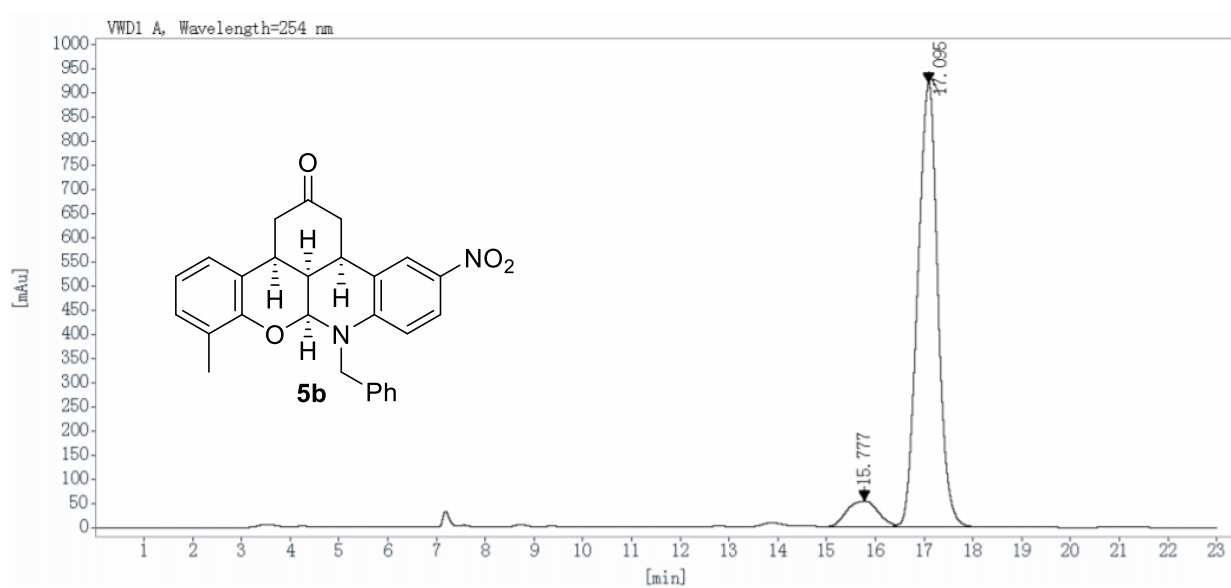
Name	cyc-20200605-19	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200605-19.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local)
					6/14/2020 6:10:49 PM (UTC+08:00)







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.532	BB	0.43	255.8836	7279.7813	51.8132
17.099	BB	0.43	245.2826	6770.2598	48.1868
Totals:				14050.0410	100.0000

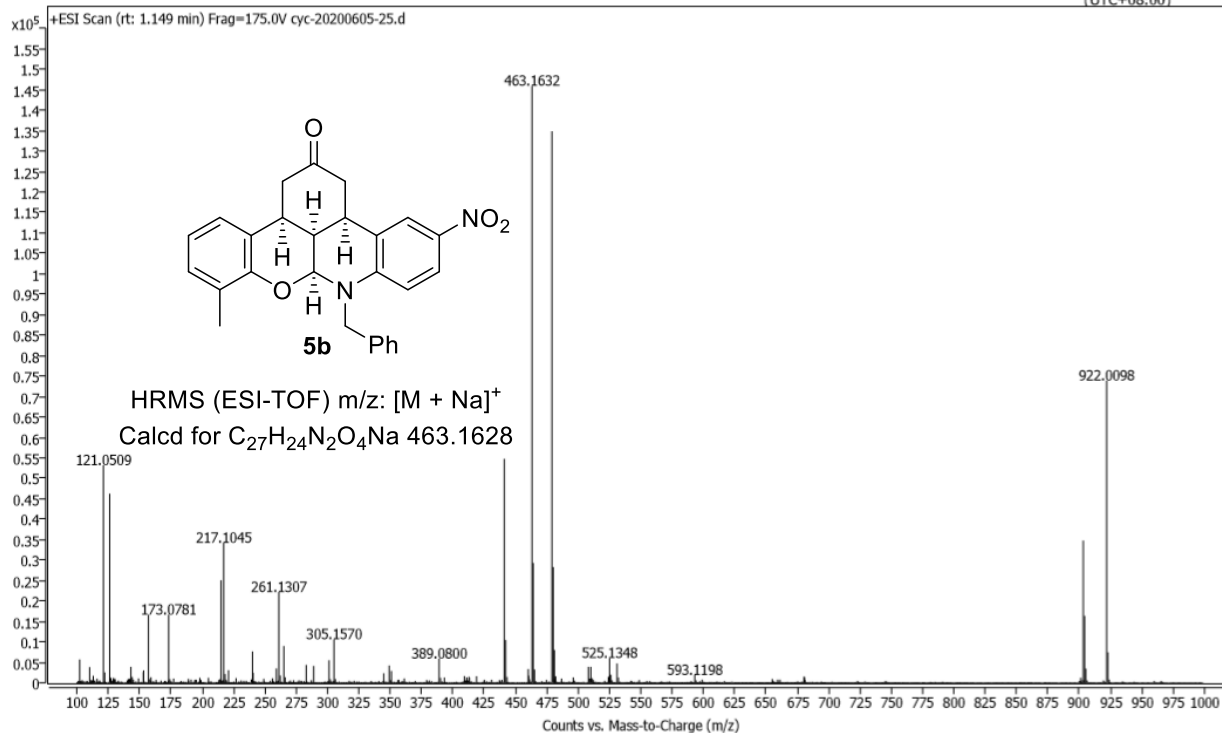


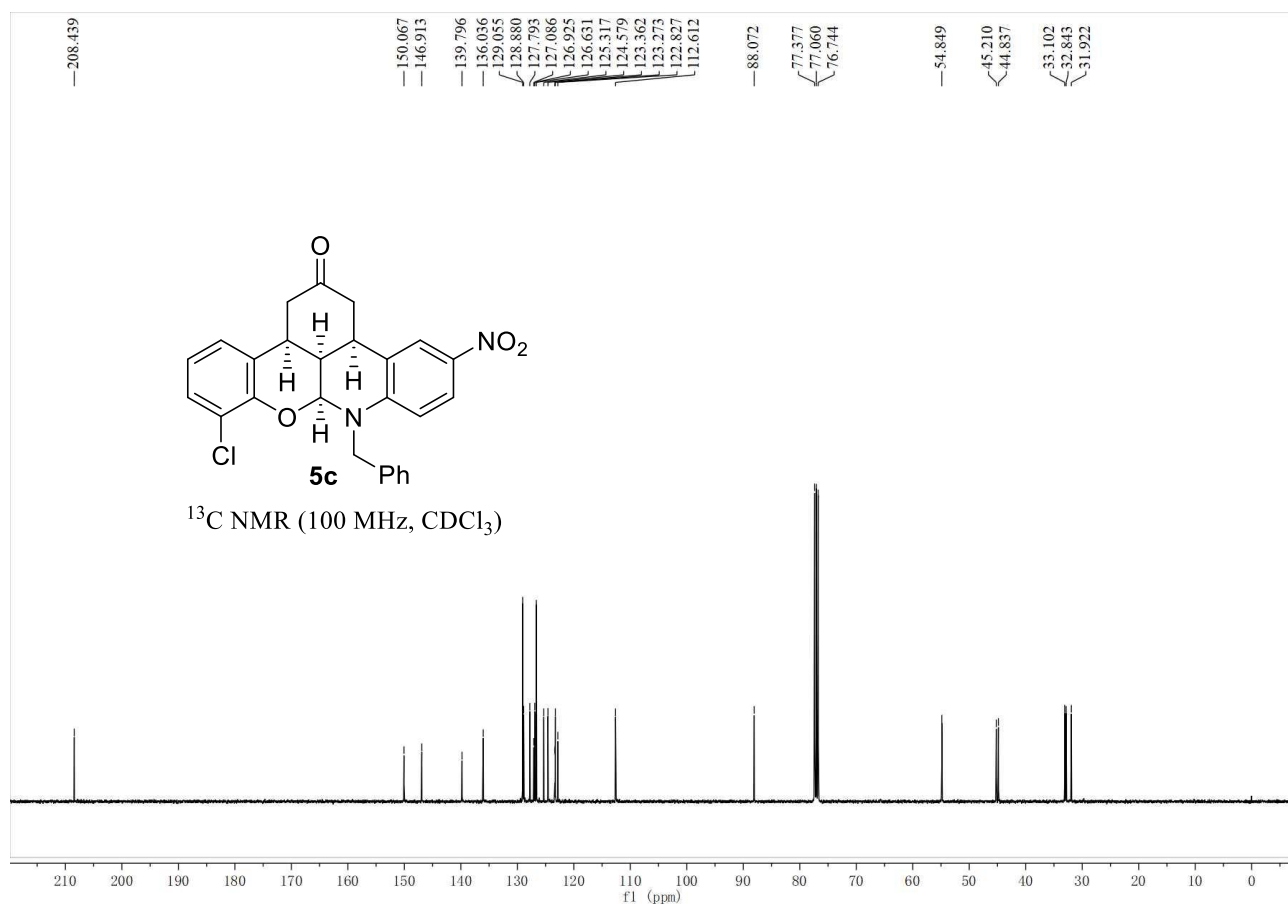
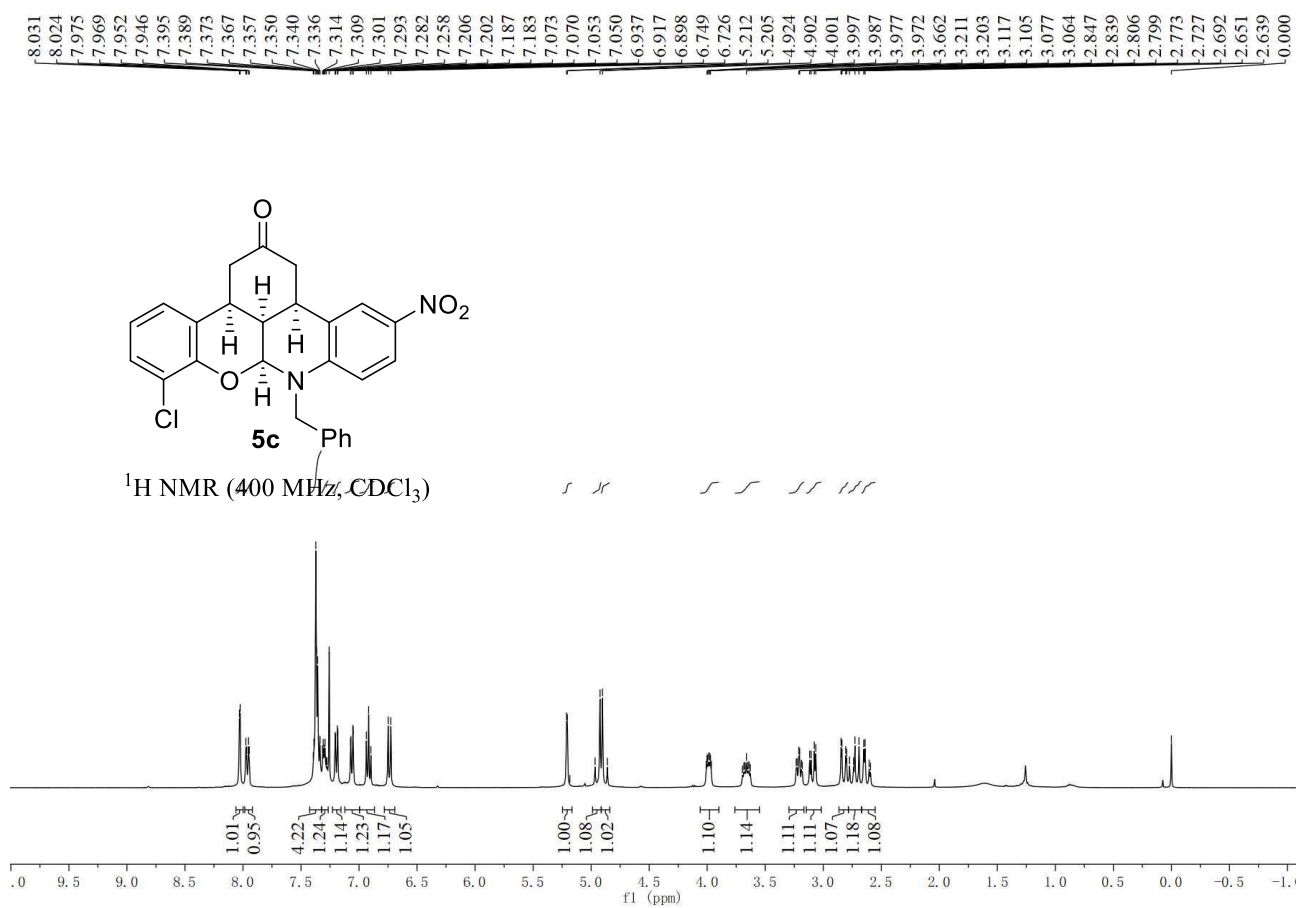
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.777	BV E	0.72	53.1608	2354.1287	8.1992
17.095	VB R	0.45	920.8774	26357.5098	91.8008
Totals:				28711.6384	100.0000

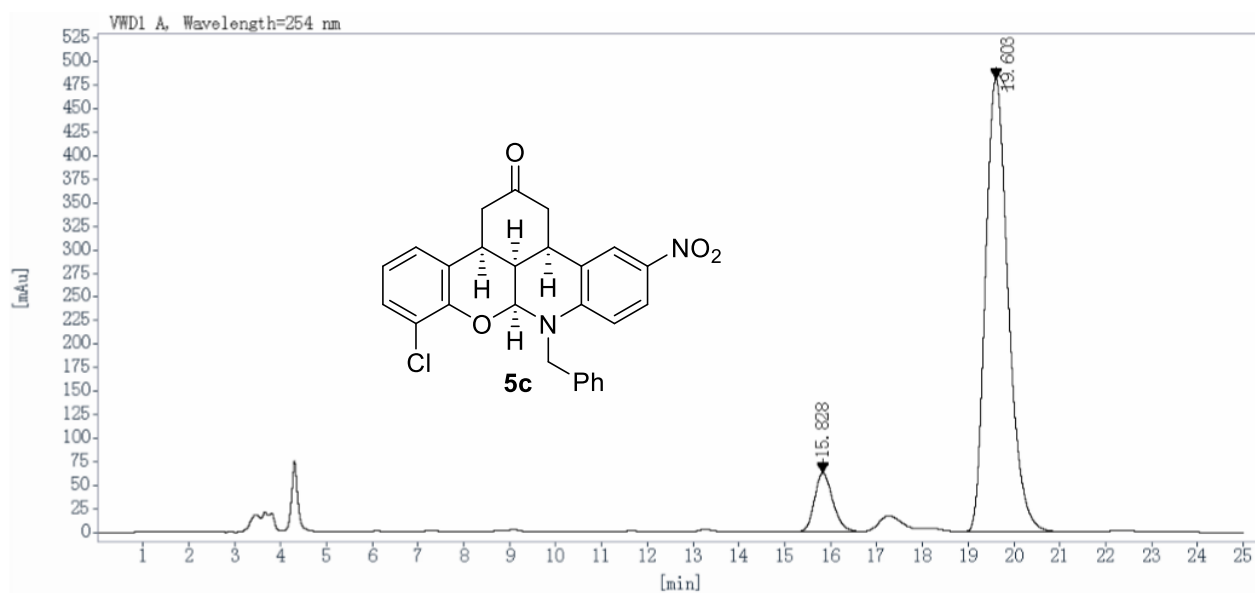
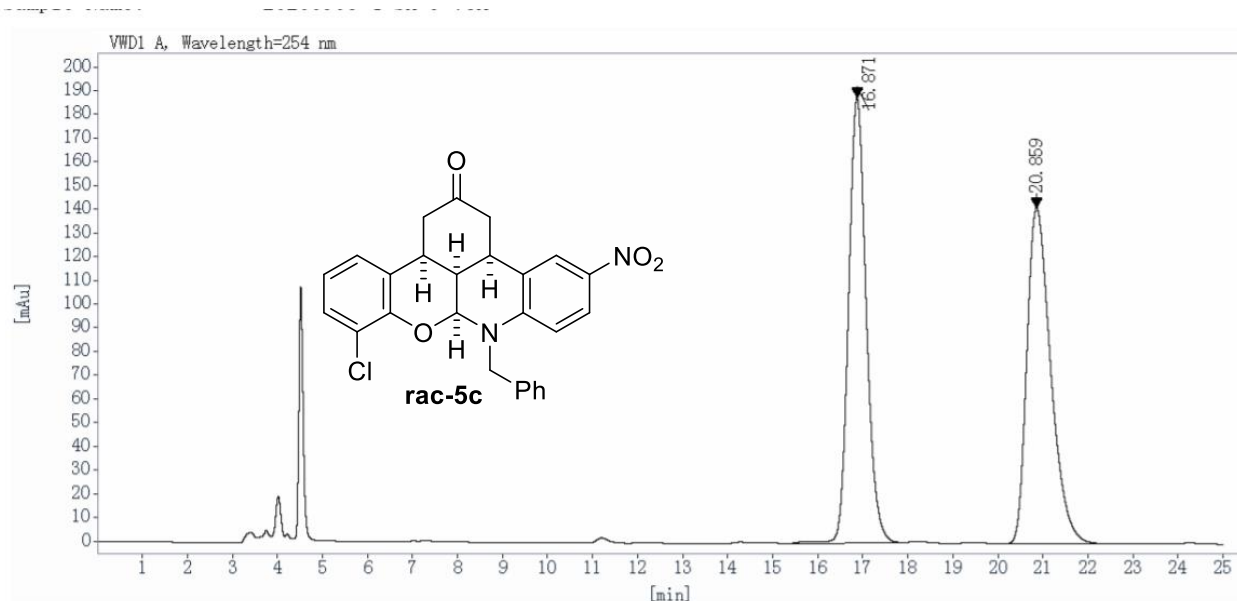
Spectrum Plot Report



Name	cyc-20200605-25	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200605-25.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/14/2020 6:28:54 PM (UTC+08:00)



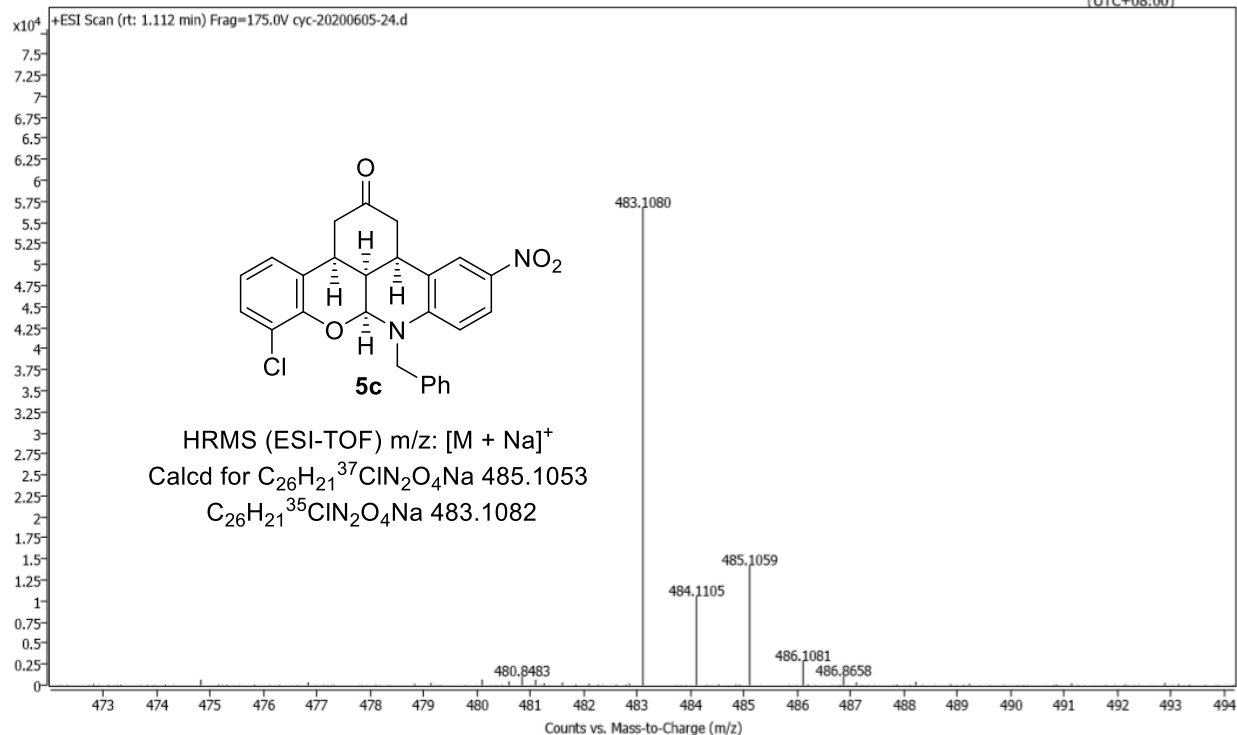


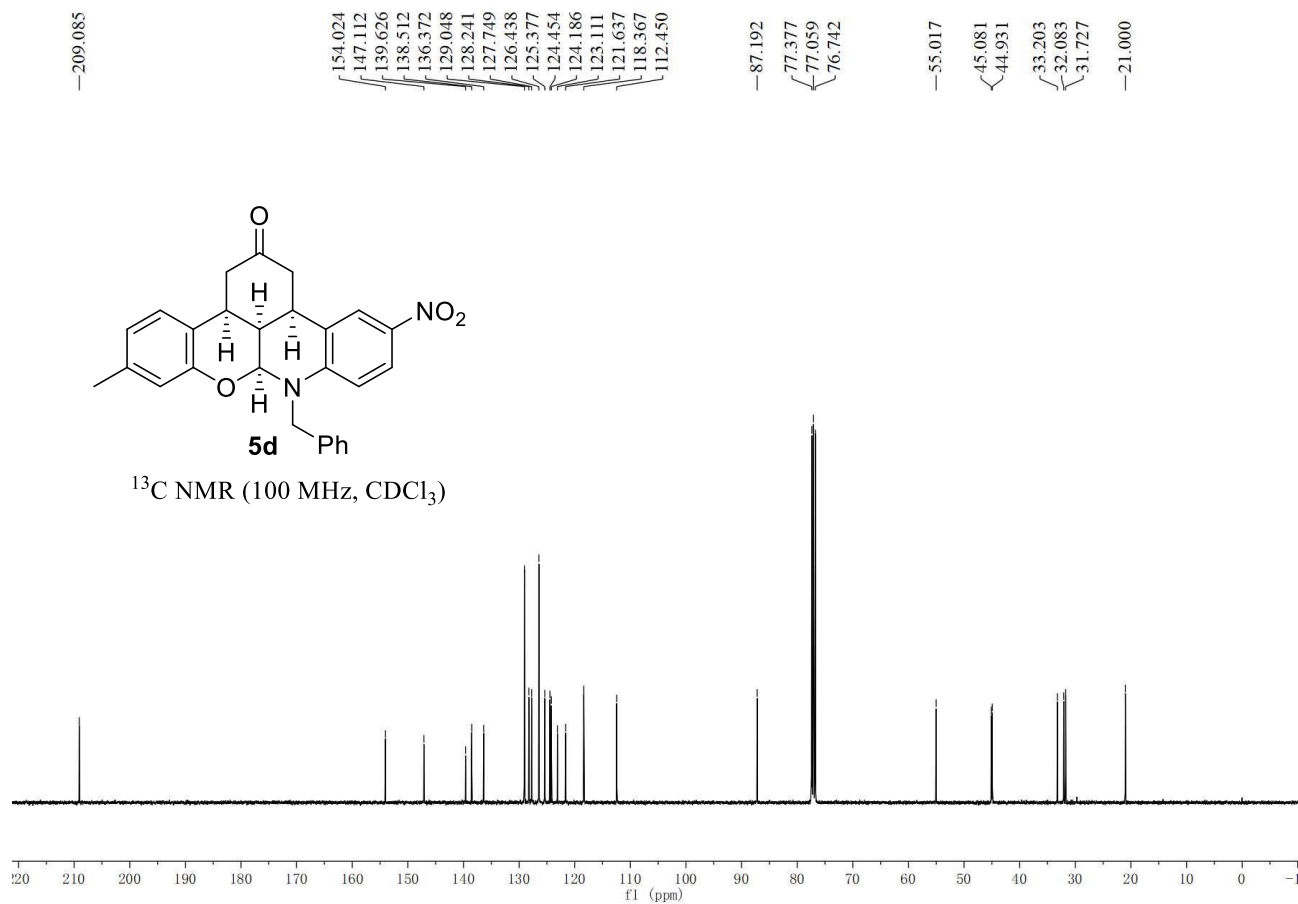
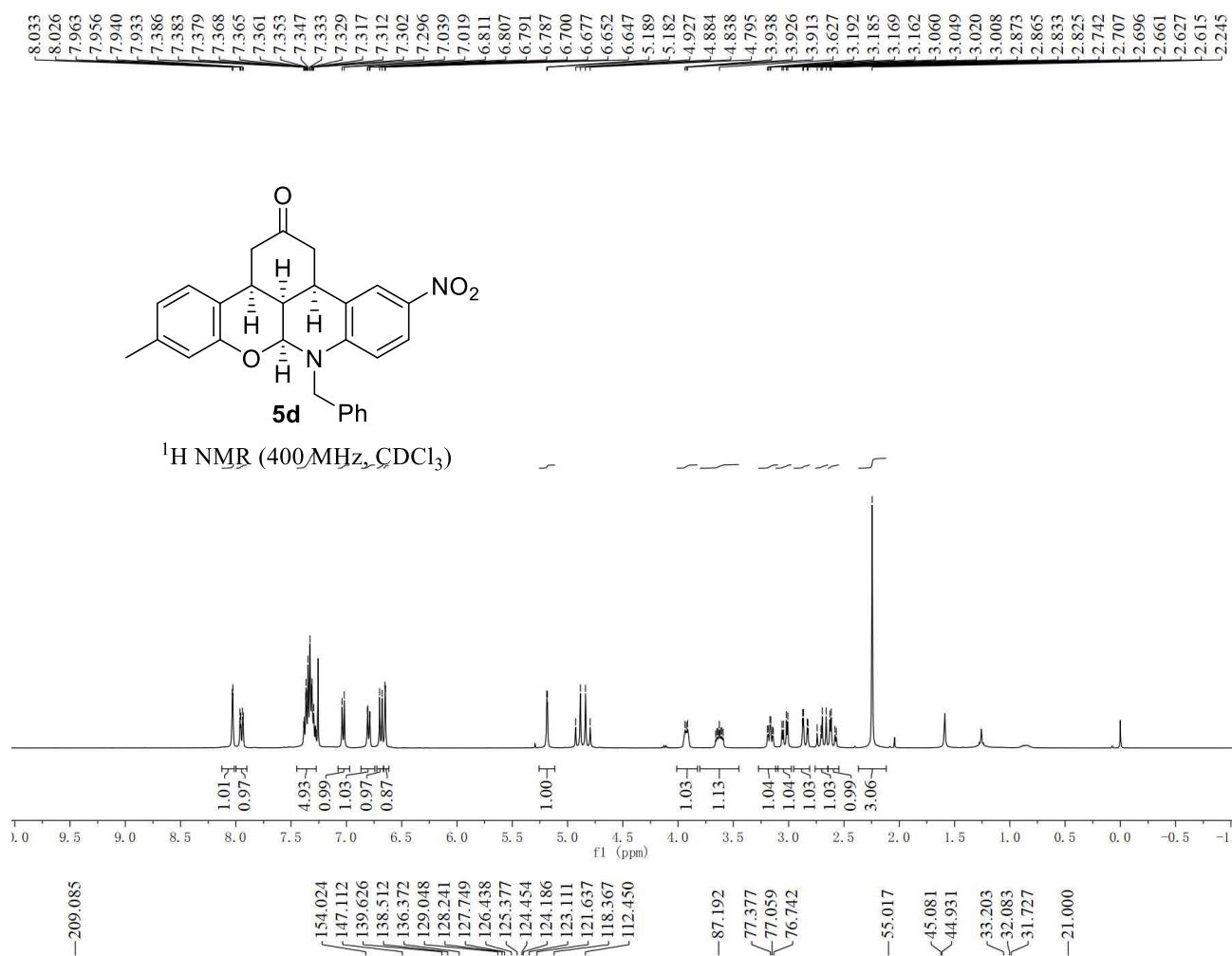


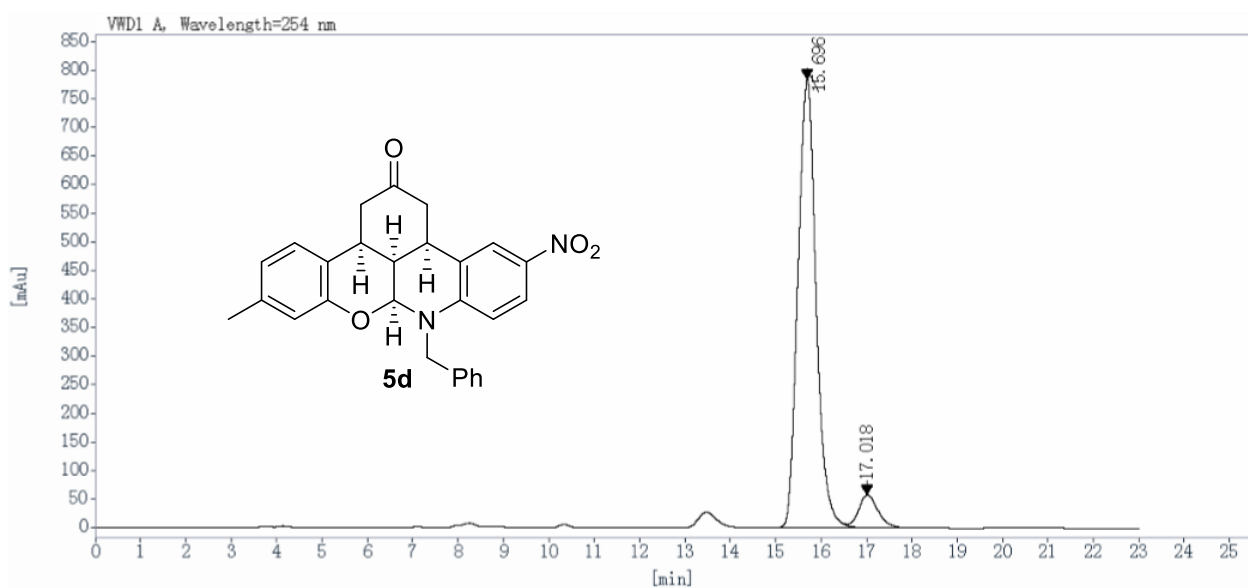
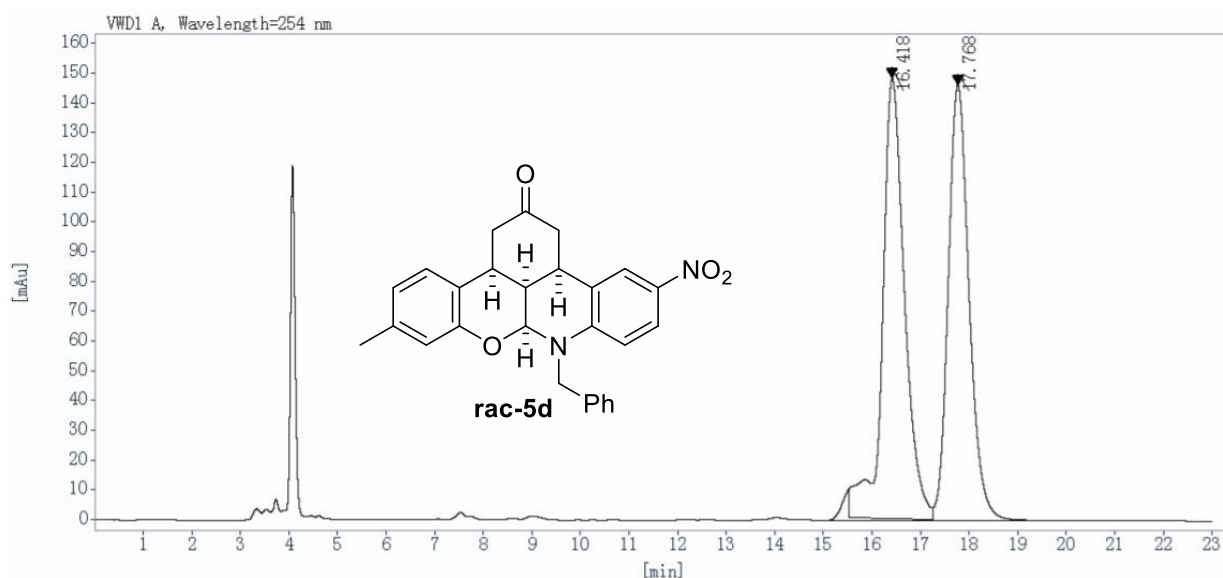
Spectrum Plot Report



Name	cyc-20200605-24	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200605-24.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/14/2020 6:25:53 PM (UTC+08:00)

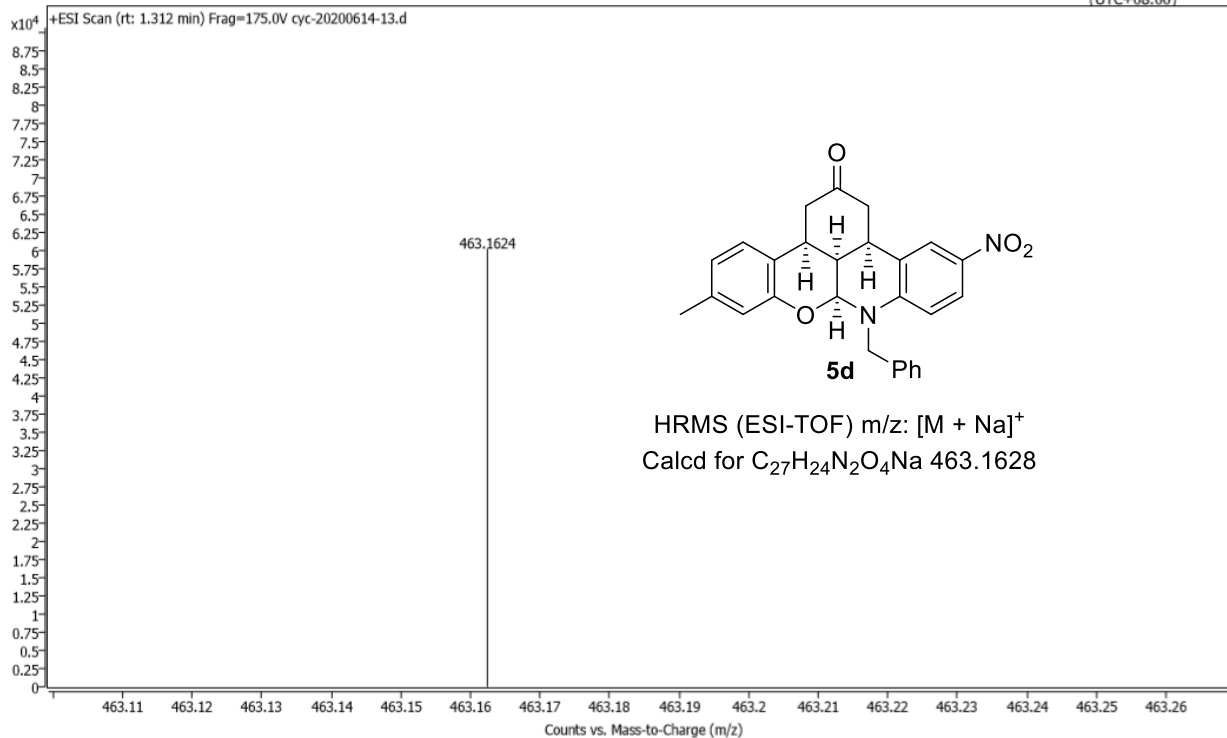


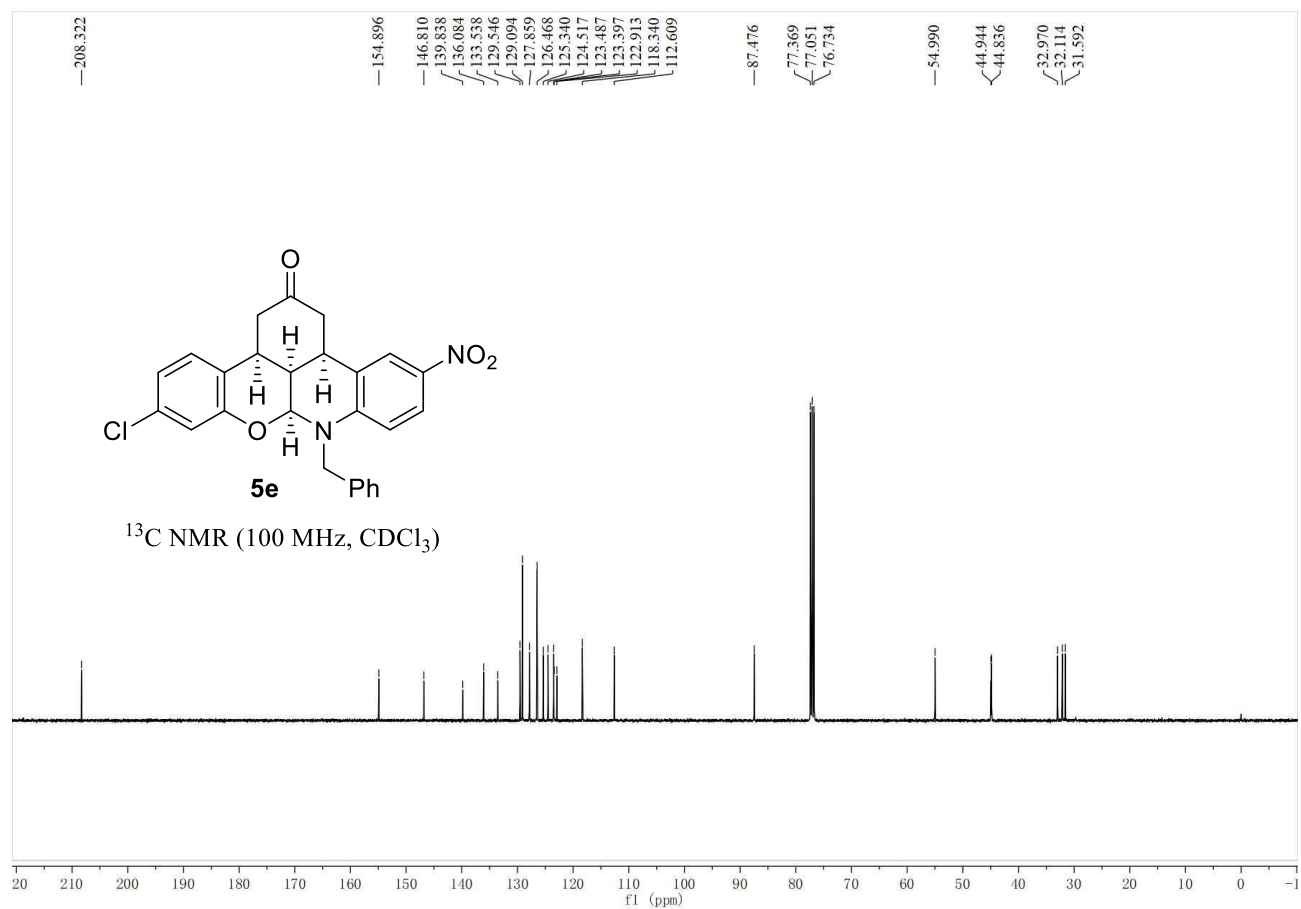
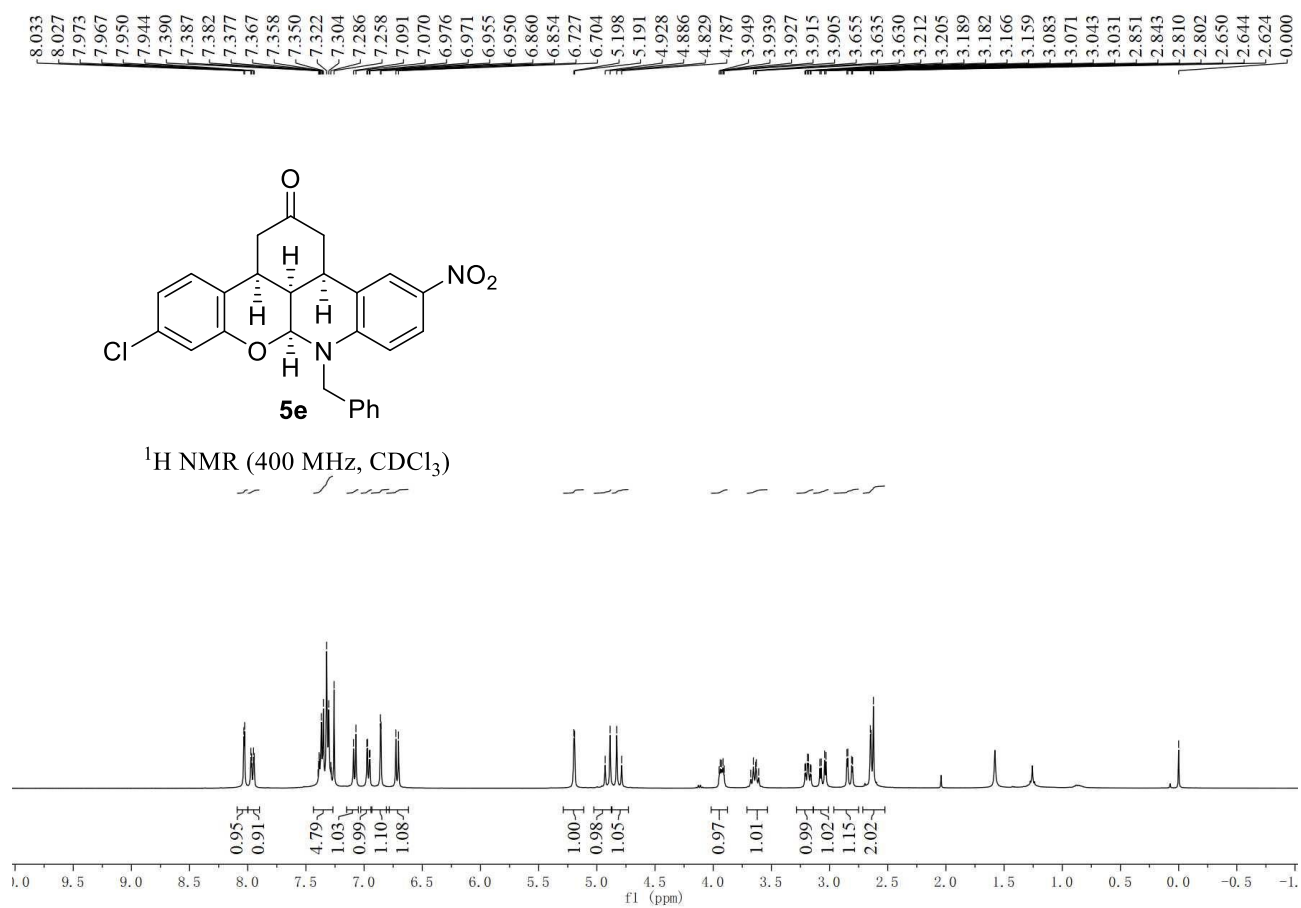


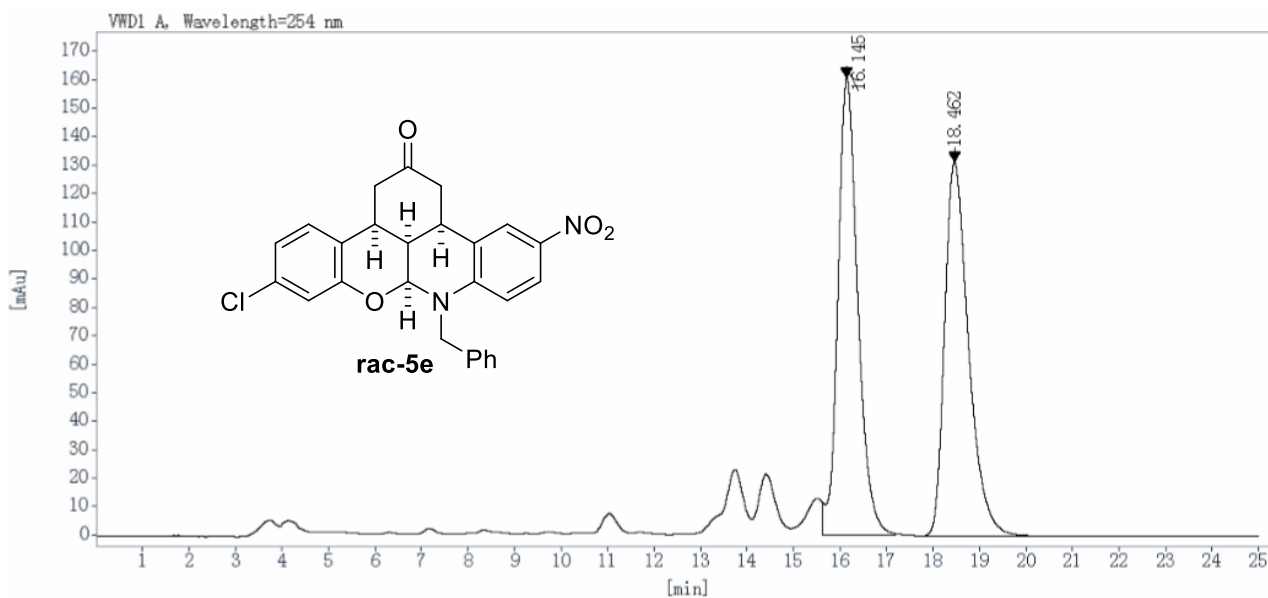


Spectrum Plot Report

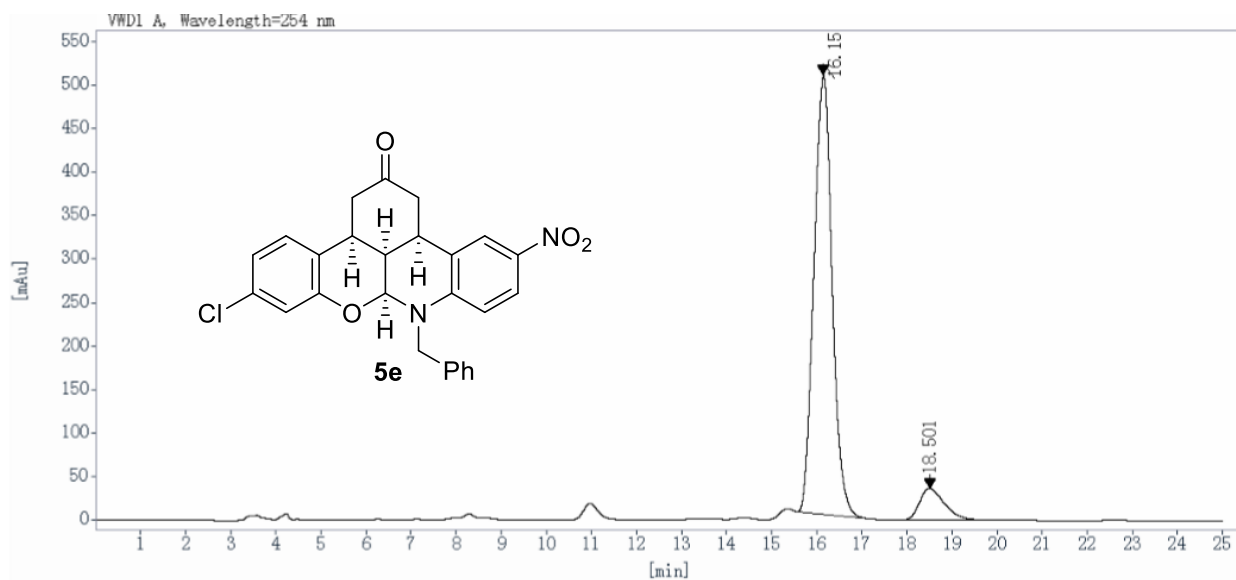
Name	cyc-20200614-13	Rack Pos.	Instrument	Instrument 1	Operator	
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	Acq. Time (Local)	6/18/2020 5:06:30 PM
Data File	cyc-20200614-13.d	Method (Acq)	TOF.m	Comment		(UTC+08:00)



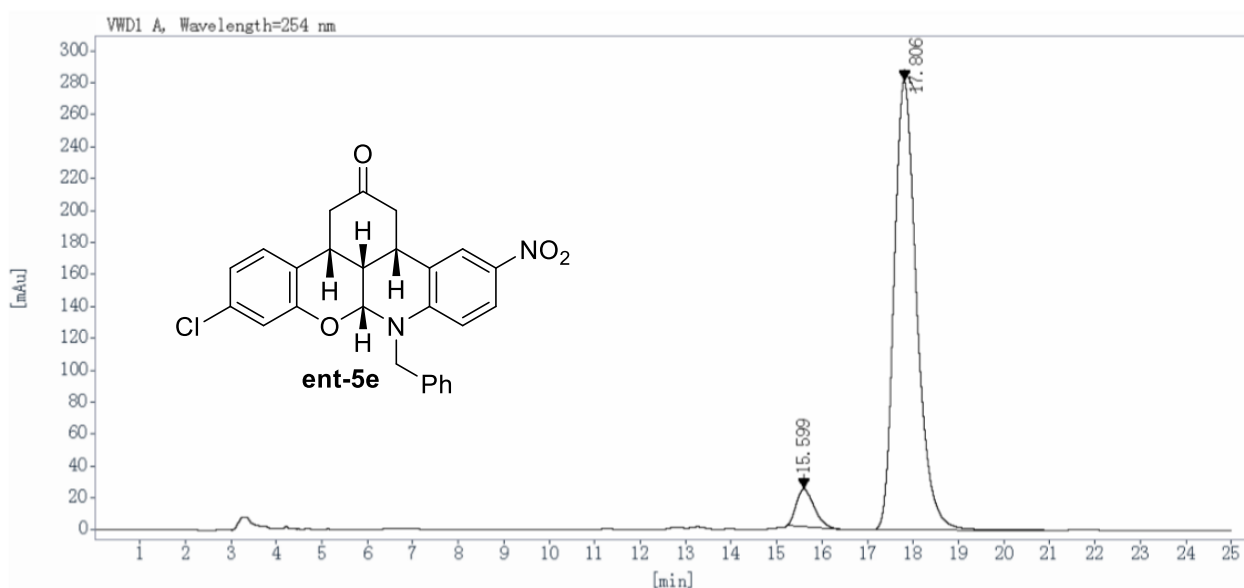




Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.145	MM	0.49	160.8528	4775.3569	50.4112
18.462	BB	0.55	131.4129	4697.4517	49.5888
Totals:				9472.8086	100.0000



Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.150	BB	0.44	505.5937	14174.6738	91.3640
18.501	BBA	0.57	35.9966	1339.8384	8.6360
Totals:				15514.5122	100.0000

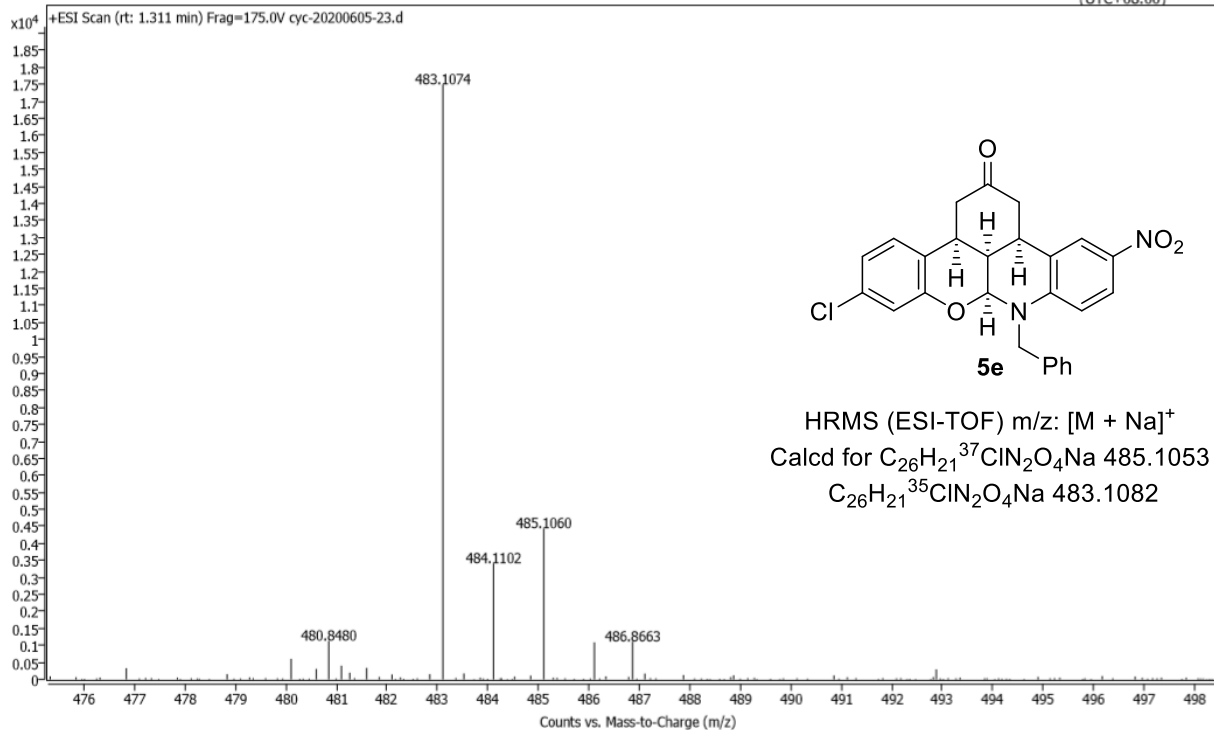


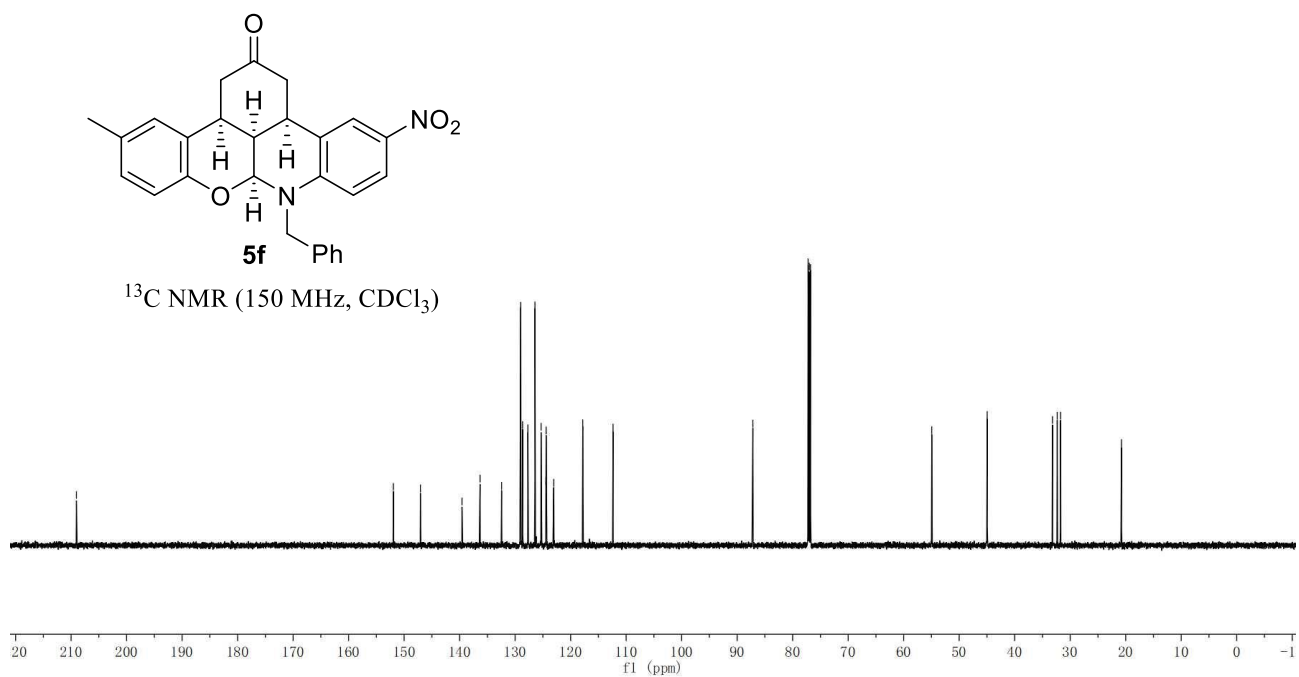
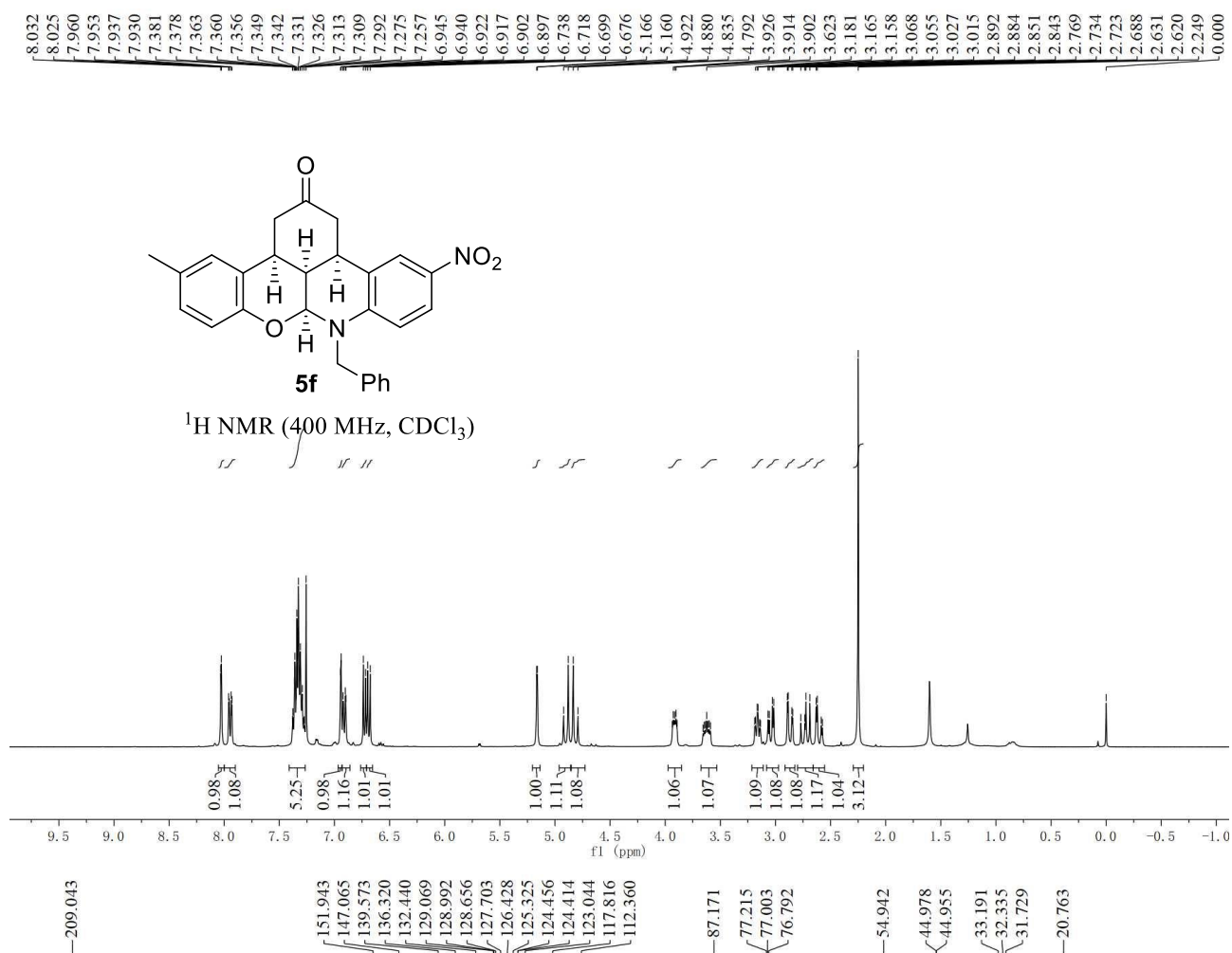
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.599	BB	0.43	23.6384	646.1224	6.2718
17.806	BB	0.53	281.4138	9655.9111	93.7282
Totals:				10302.0335	100.0000

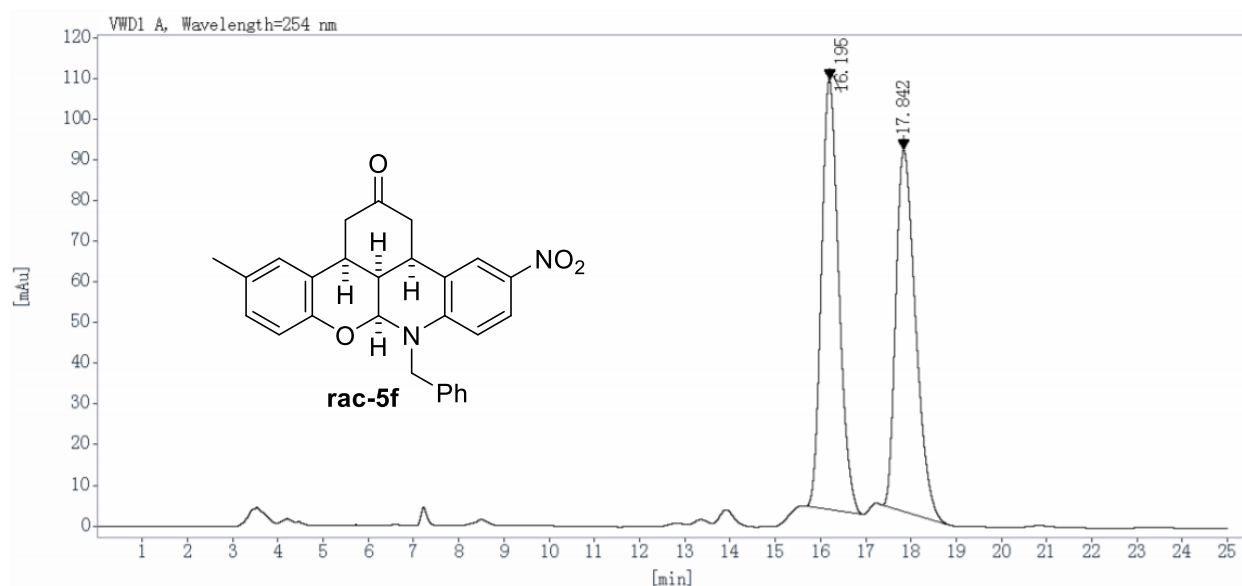
Spectrum Plot Report



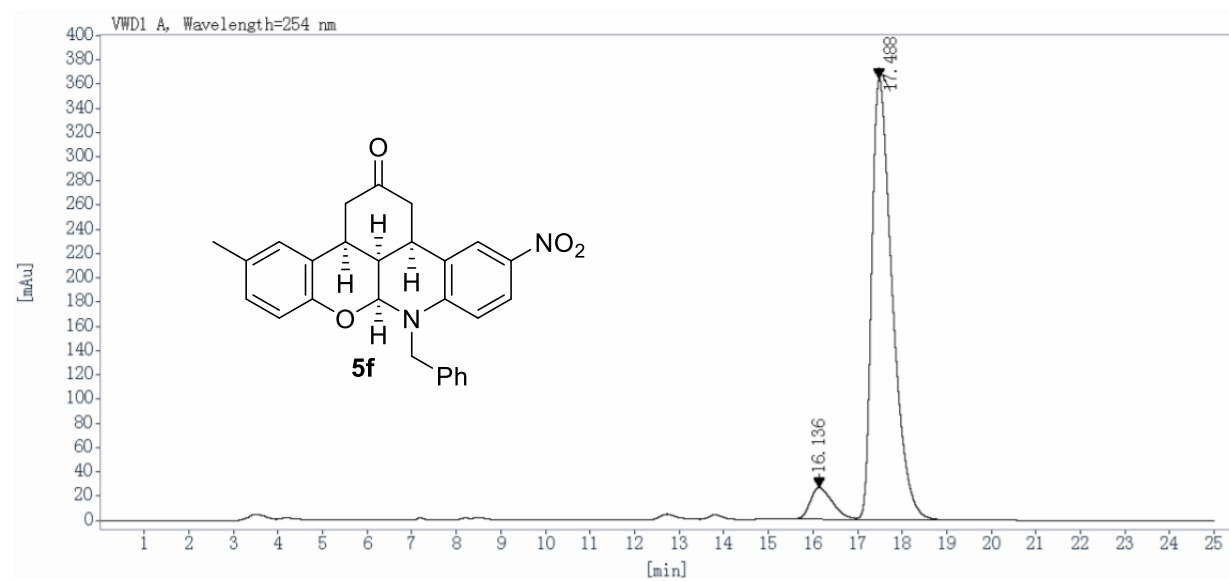
Name	cyc-20200605-23	Rack Pos.		Instrument	Instrument 1	Operator	
Inj. Vol. (ul)	10	Plate Pos.		IRM Status	Success	Acq. Time (Local)	6/14/2020 6:22:52 PM
Data File	cyc-20200605-23.d	Method (Acq)	TOF.m	Comment		(UTC+08:00)	







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.195	BB	0.41	105.8552	2810.1204	50.9903
17.842	BB	0.47	88.9930	2700.9700	49.0097
Totals:				5511.0903	100.0000

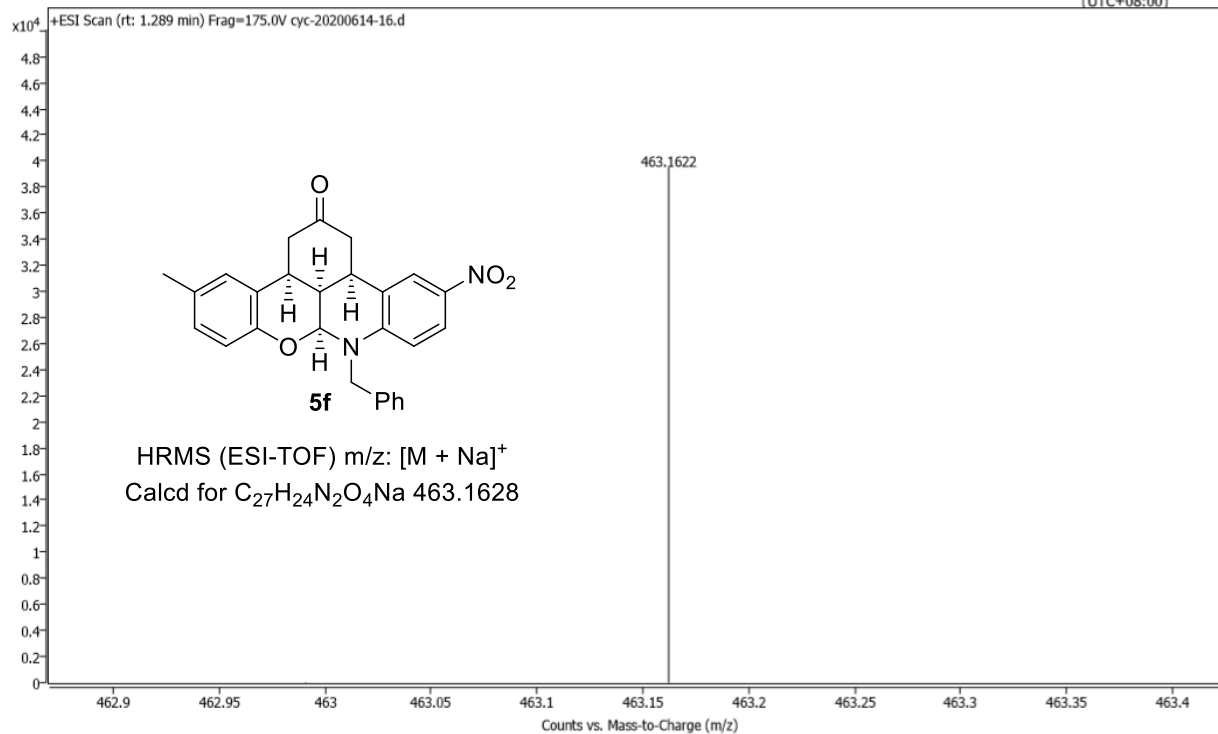


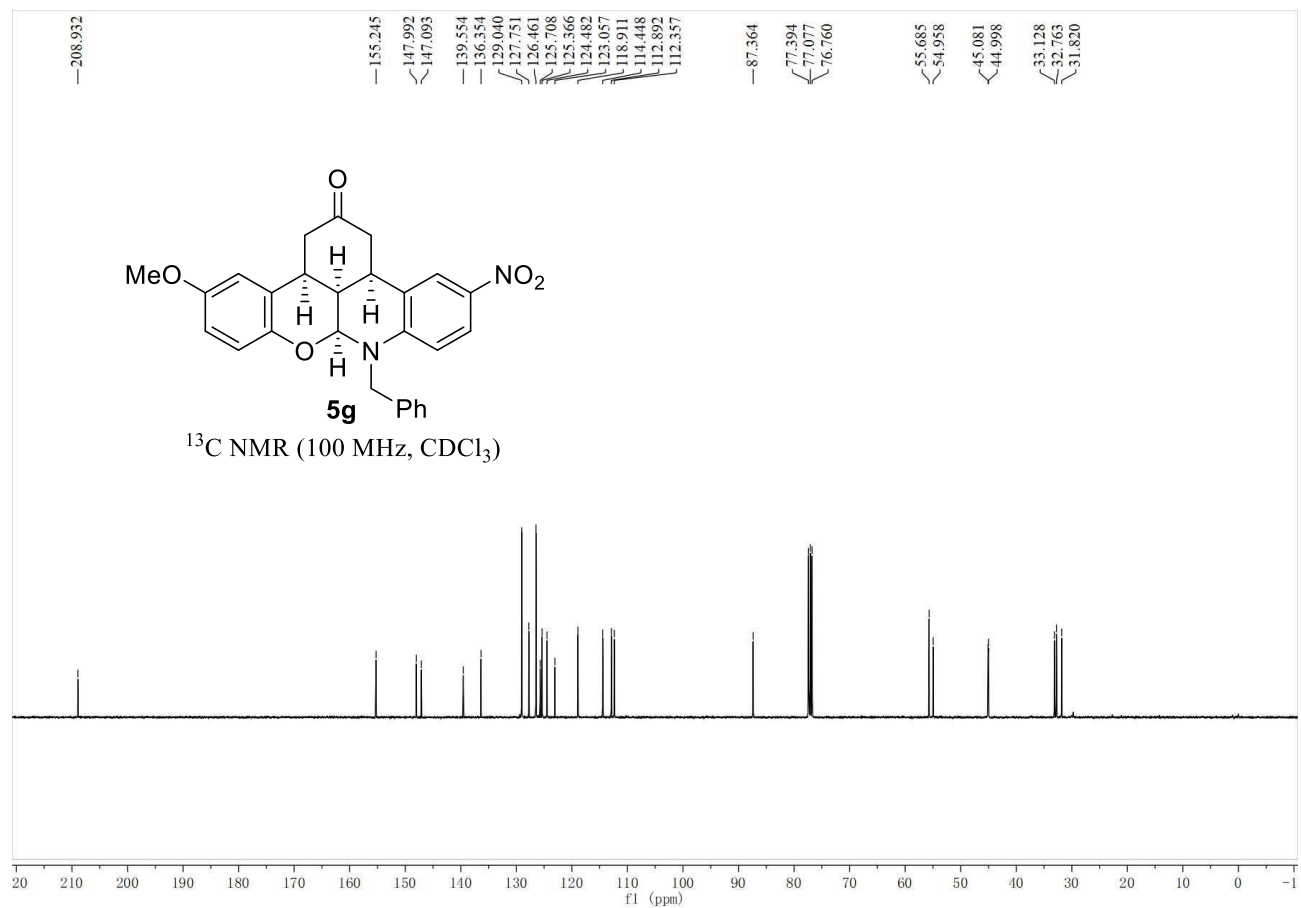
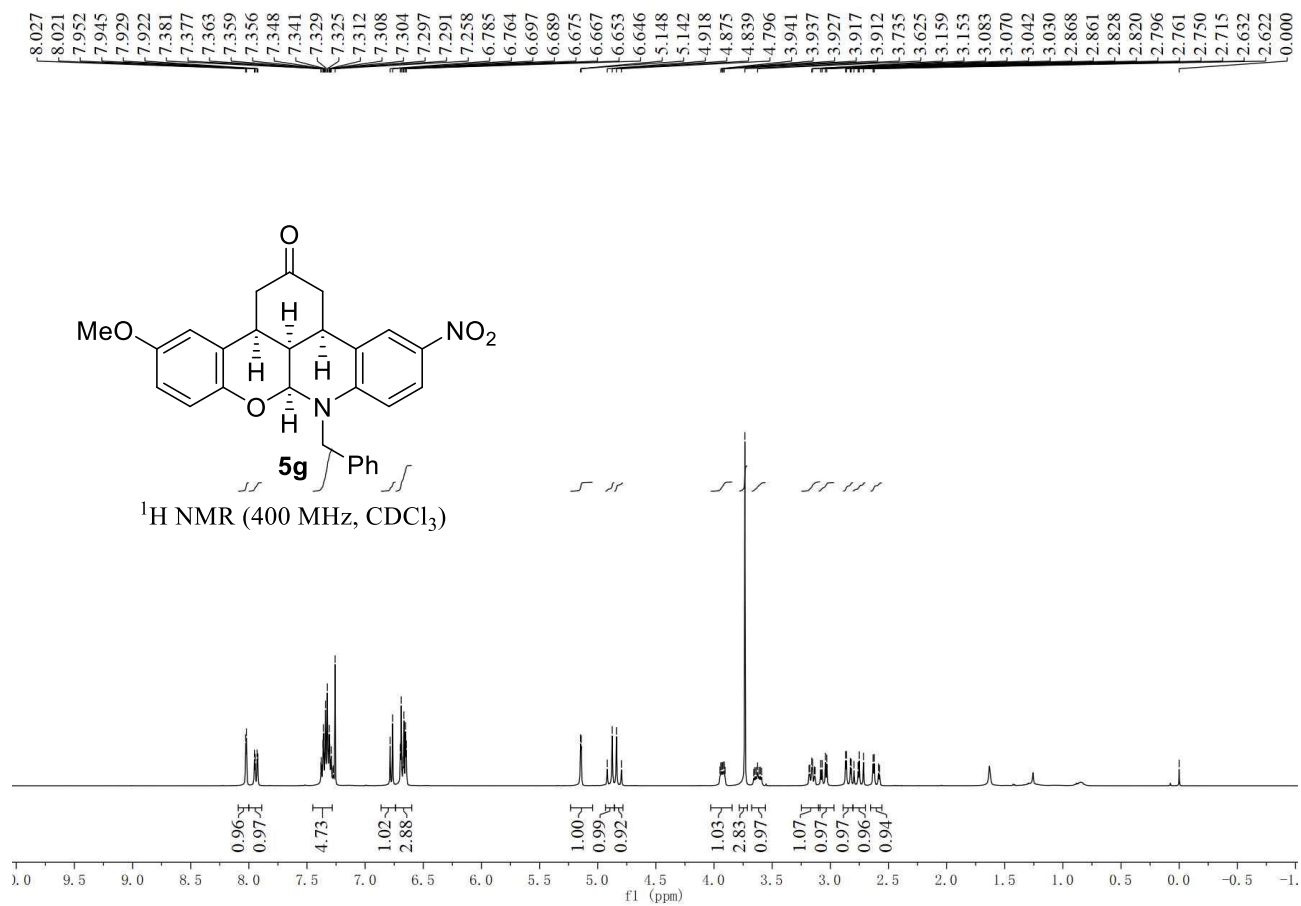
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
16.136	BV	0.54	25.8398	887.9476	7.1103
17.488	VB	0.49	363.9063	11600.2256	92.8897
Totals:				12488.1732	100.0000

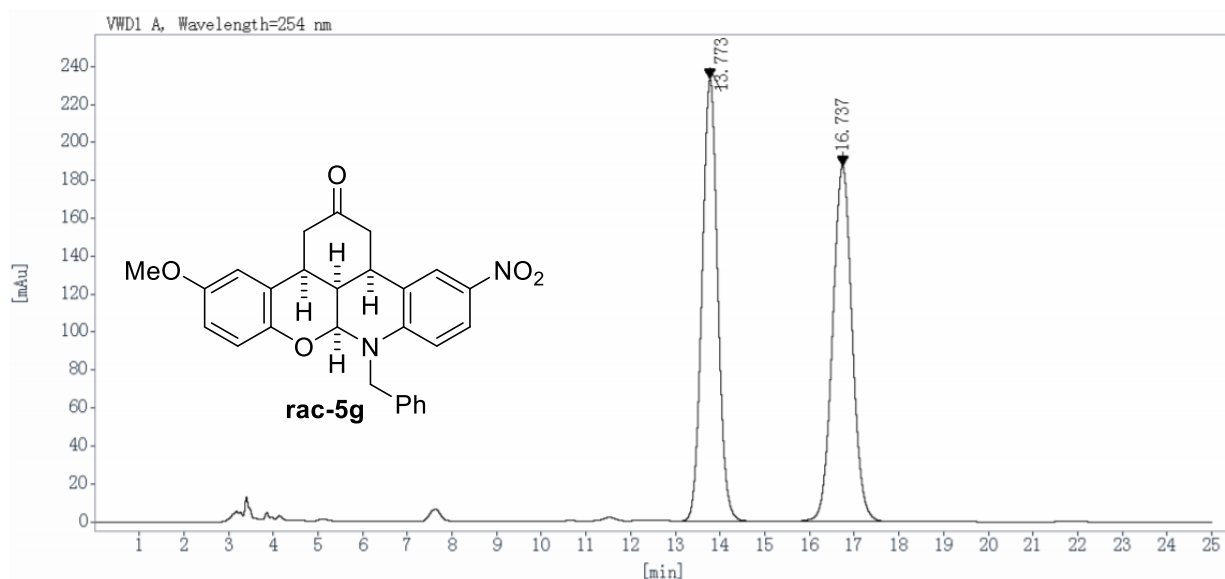
Spectrum Plot Report



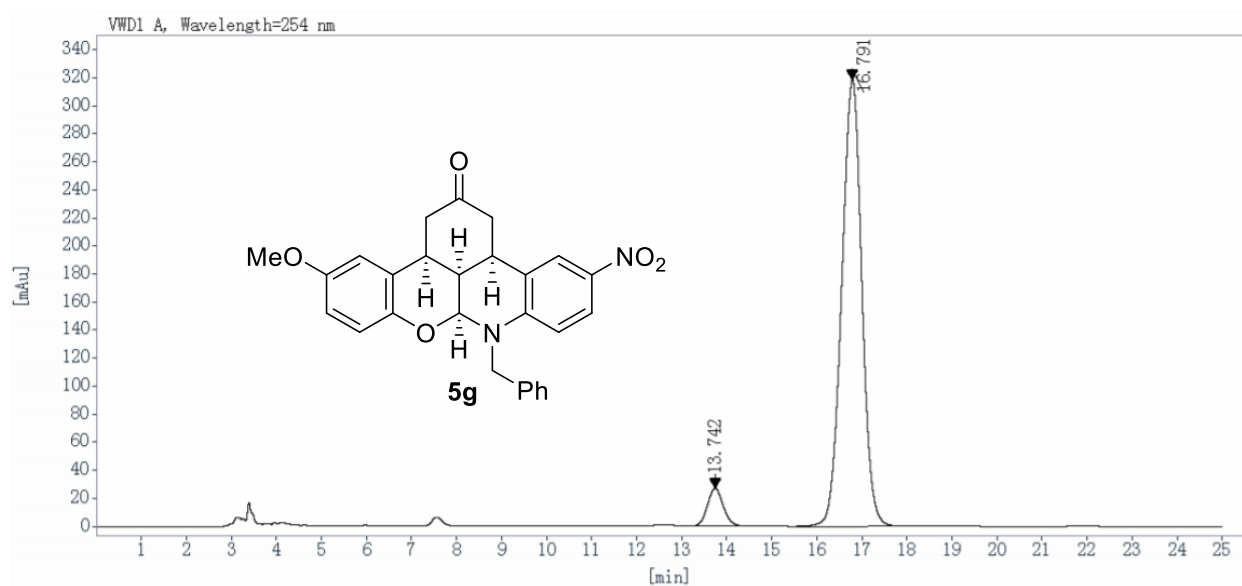
Name	cyc-20200614-16	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200614-16.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/18/2020 5:15:31 PM (UTC+08:00)







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
13.773	BB	0.38	233.3705	5665.1899	49.8232
16.737	BB	0.47	187.4850	5705.3984	50.1768
Totals:				11370.5884	100.0000

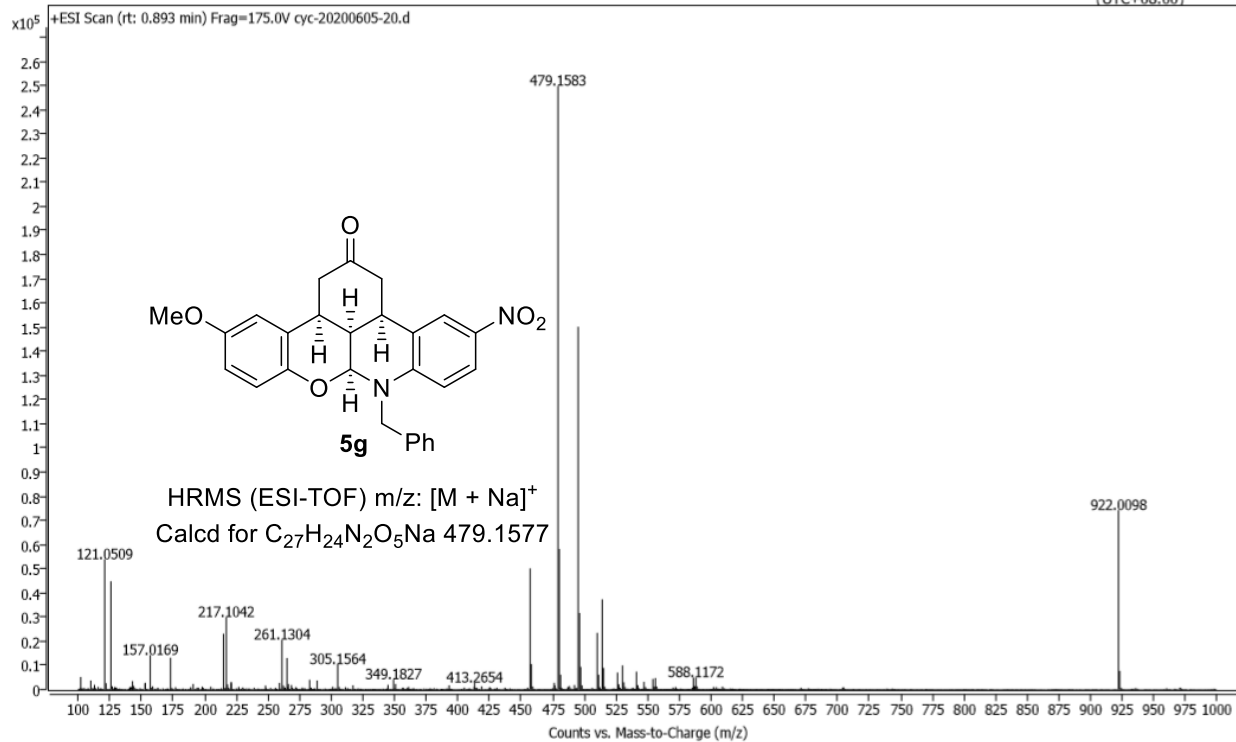


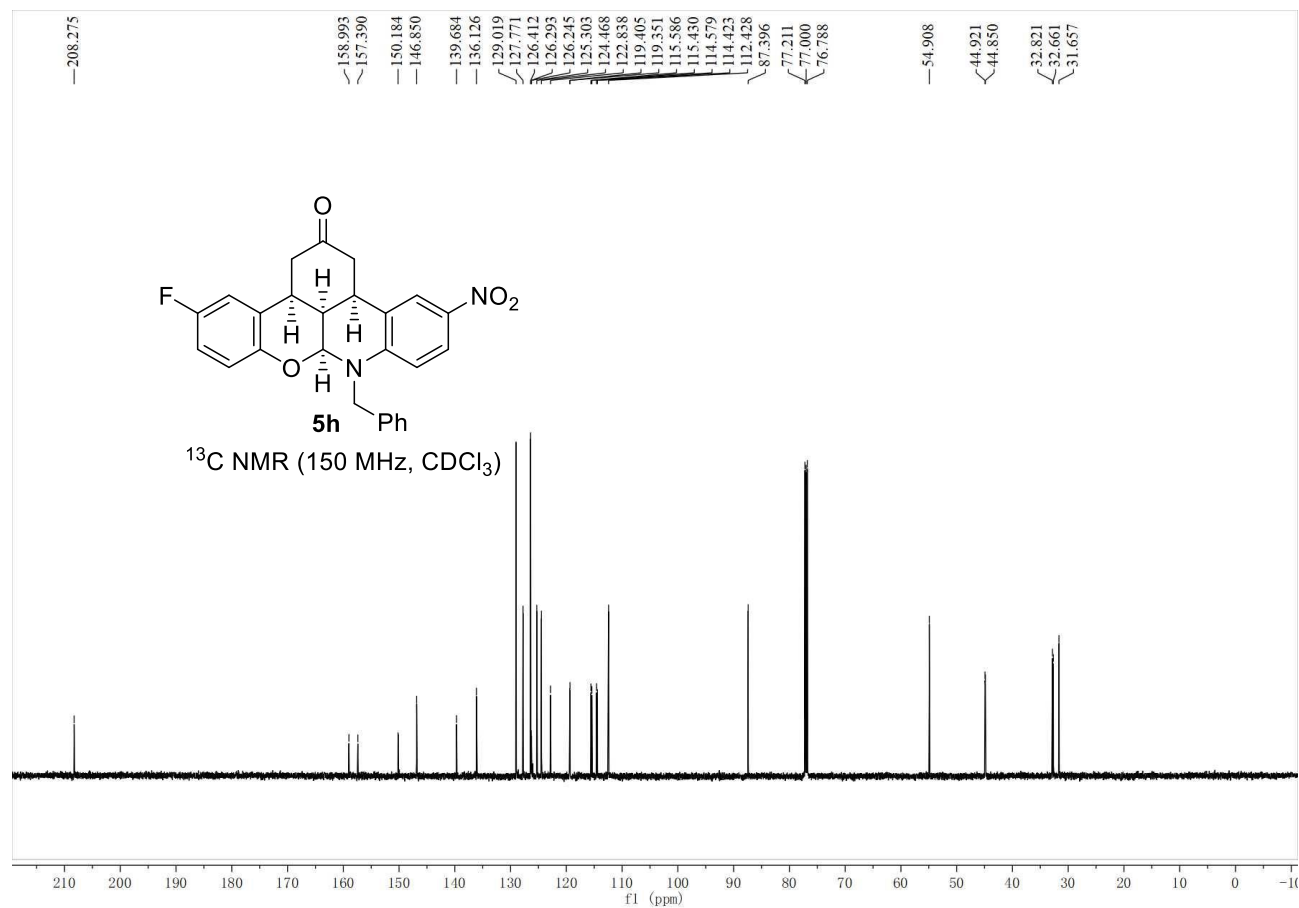
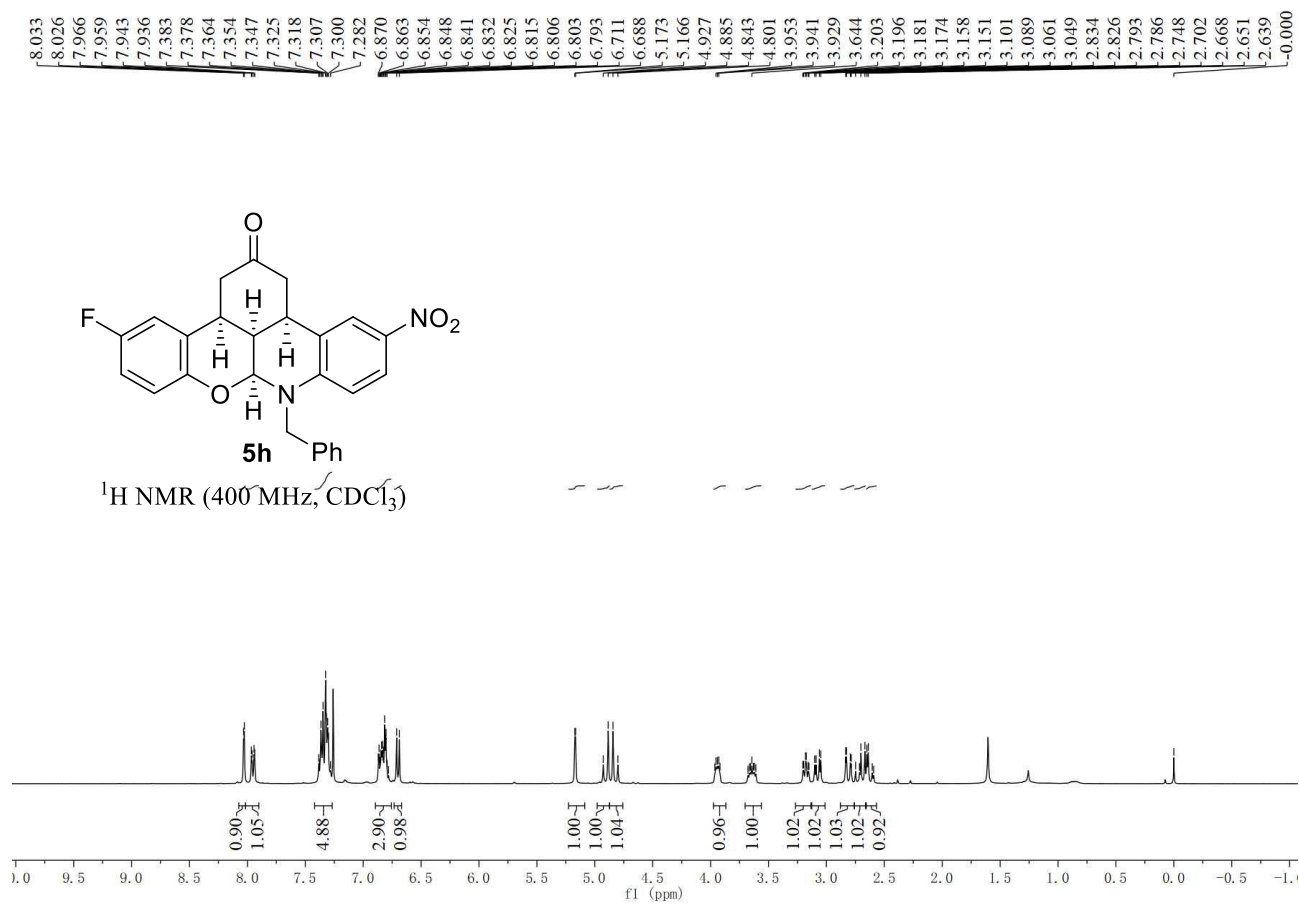
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
13.742	BB	0.38	26.8399	651.3505	6.1917
16.791	BB	0.48	318.5732	9868.4443	93.8083
Totals:				10519.7949	100.0000

Spectrum Plot Report

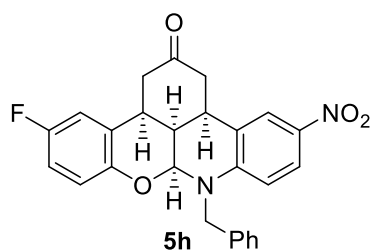


Name	cyc-20200605-20	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200605-20.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/14/2020 6:13:50 PM (UTC+08:00)

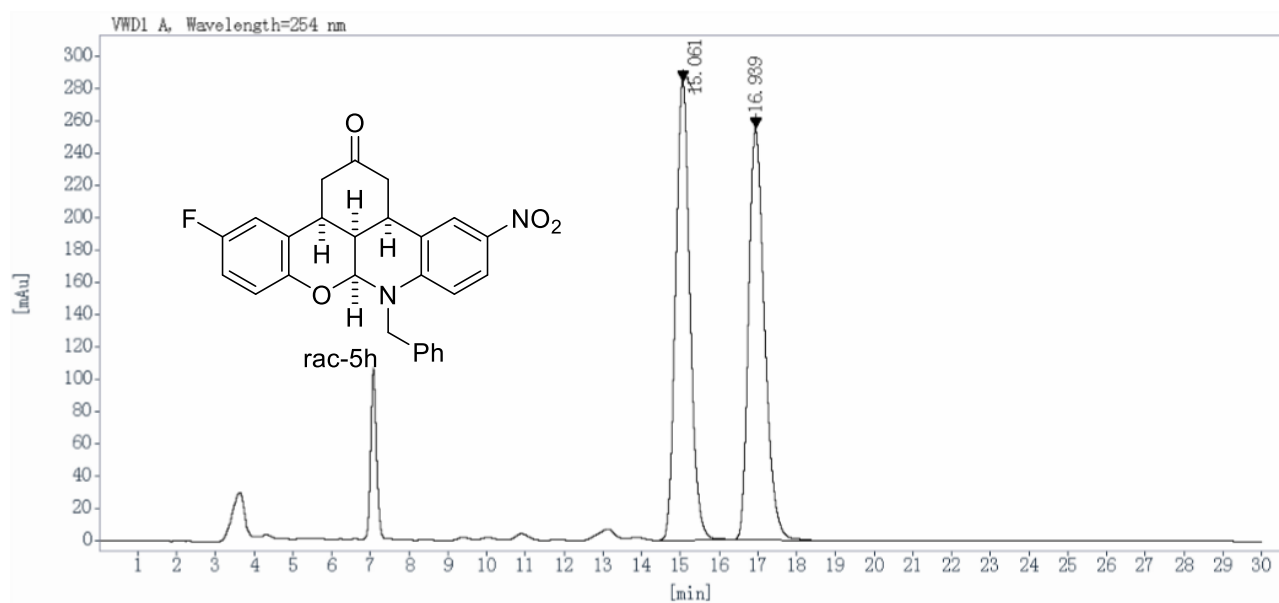
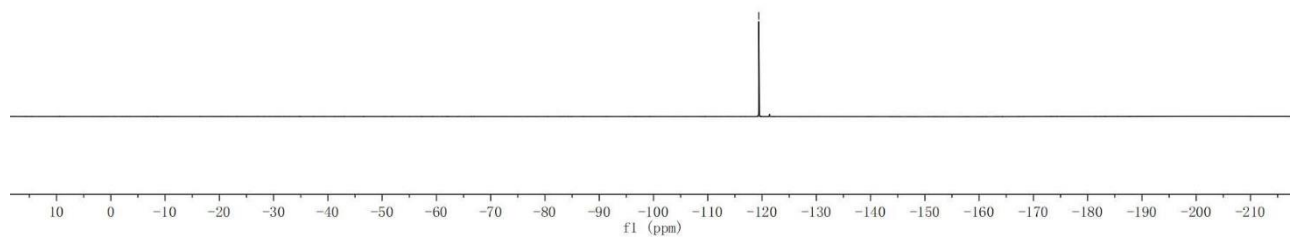




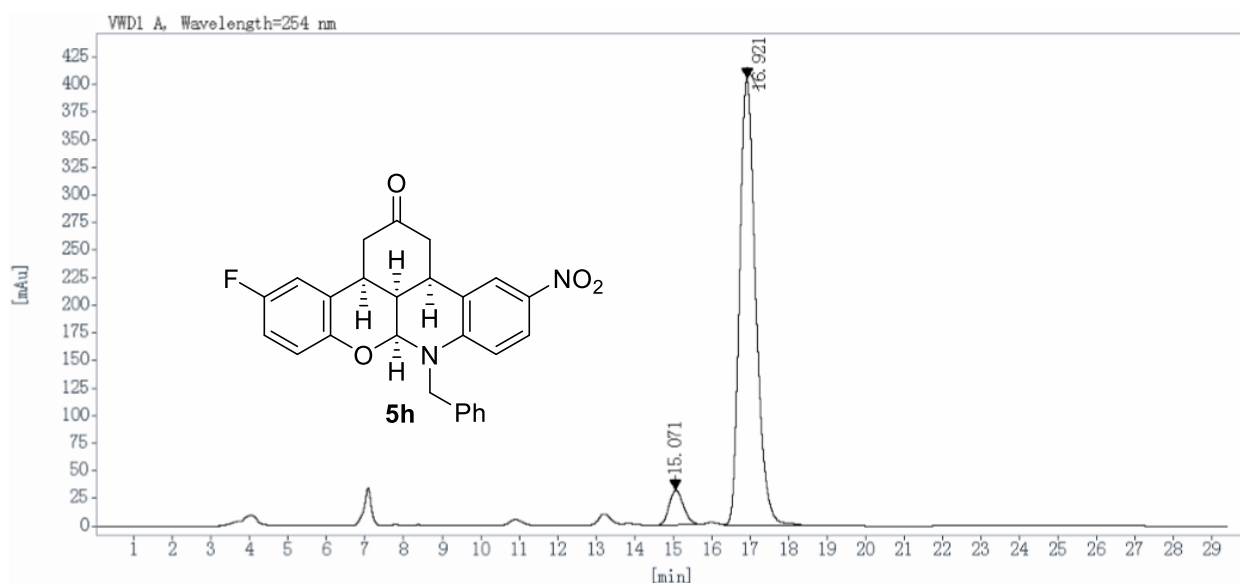
---119.414



¹⁹F NMR (376 MHz, CDCl₃)



Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.061	BB	0.40	284.2456	7307.6021	49.9185
16.939	BB	0.44	254.7342	7331.4688	50.0815
Totals:				14639.0708	100.0000

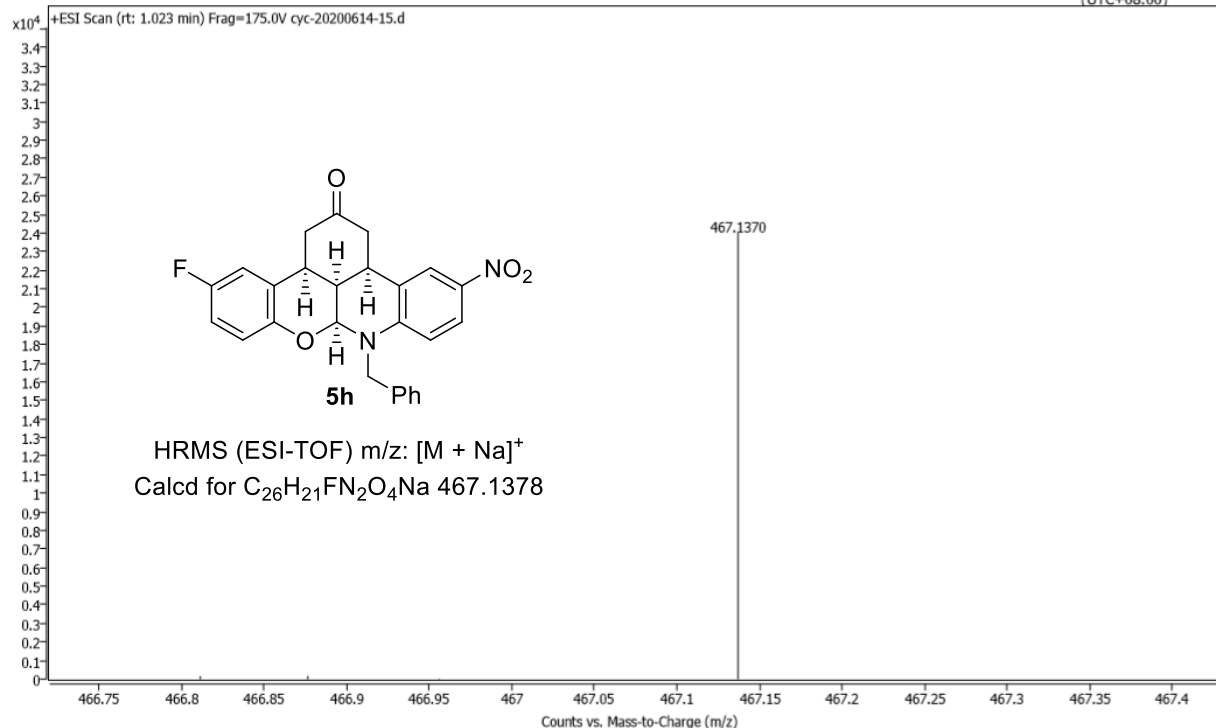


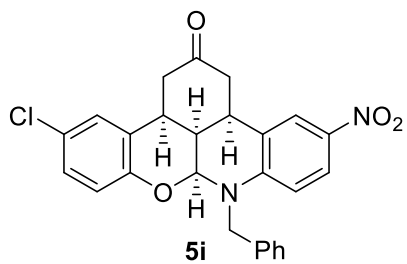
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.071	BB	0.40	31.4864	812.9145	6.4473
16.921	BB	0.45	405.0982	11795.6201	93.5527
Totals:				12608.5346	100.0000

Spectrum Plot Report

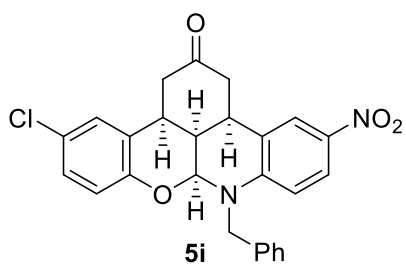
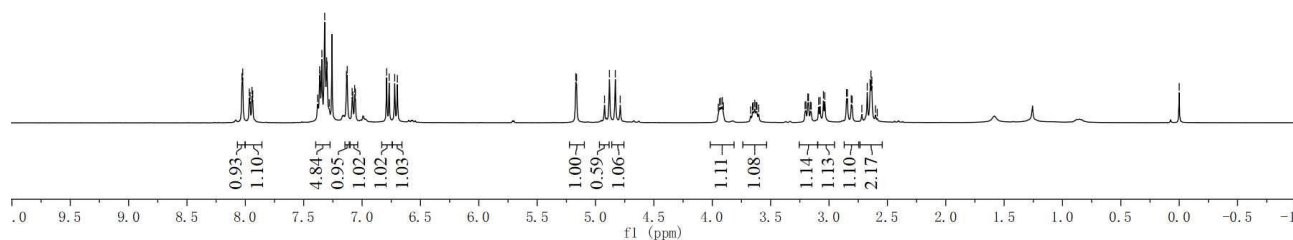


Name	cyc-20200614-15	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200614-15.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/18/2020 5:12:30 PM (UTC+08:00)

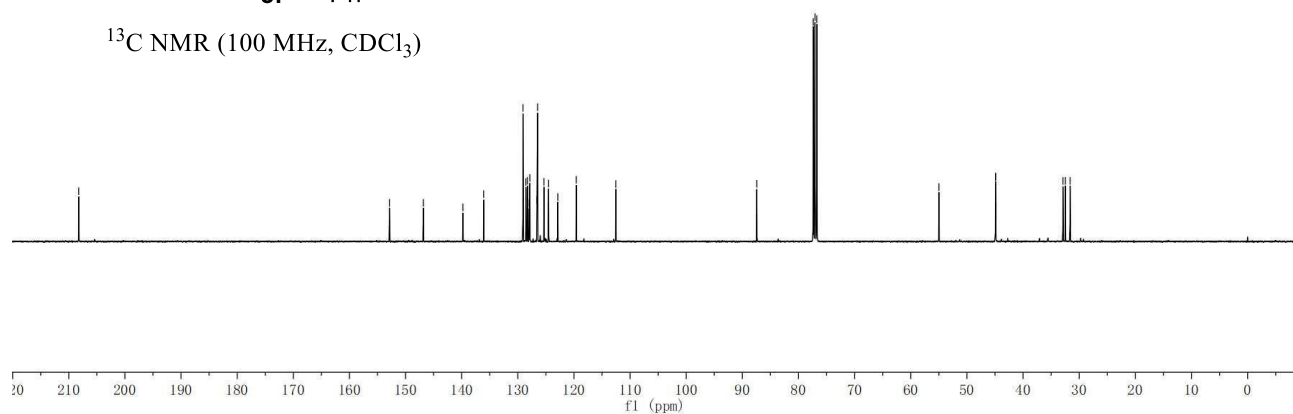


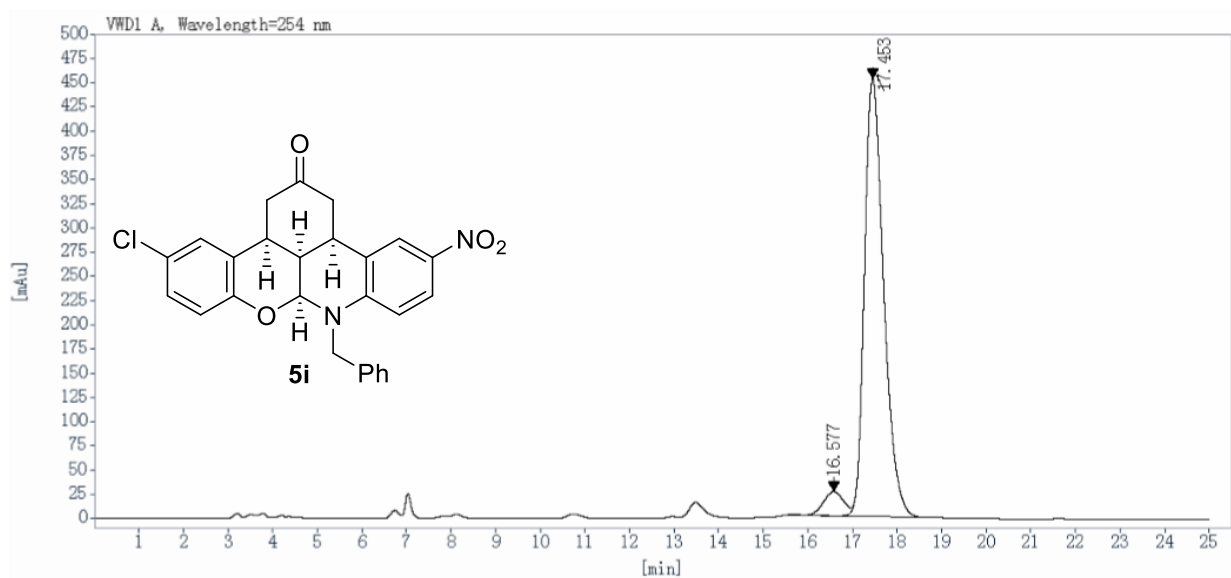
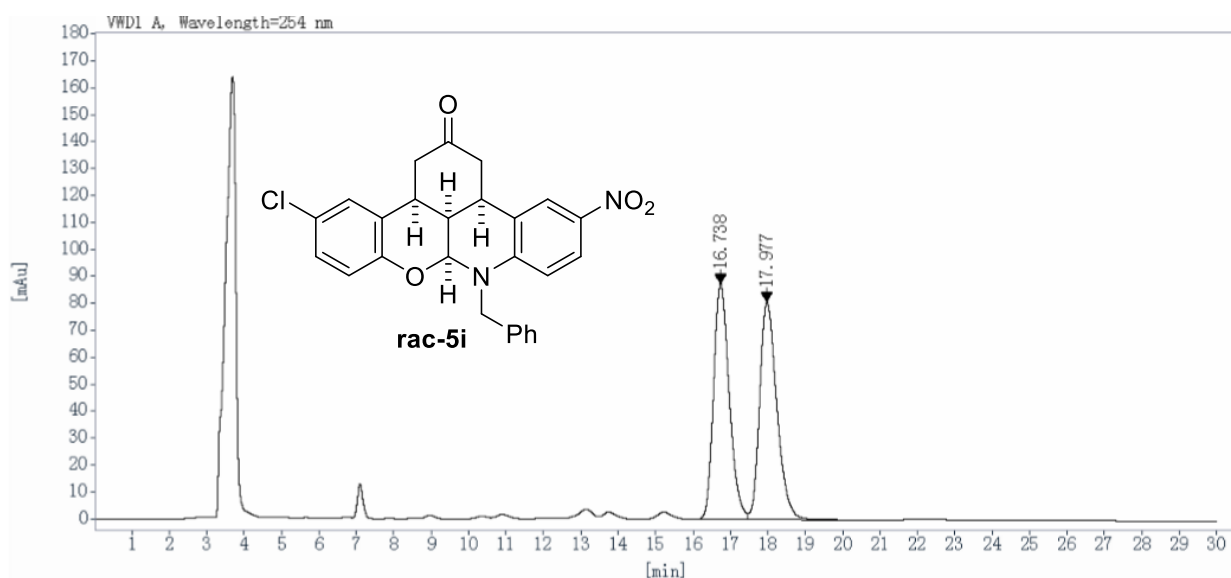


^1H NMR (400 MHz, CDCl_3)



^{13}C NMR (100 MHz, CDCl_3)

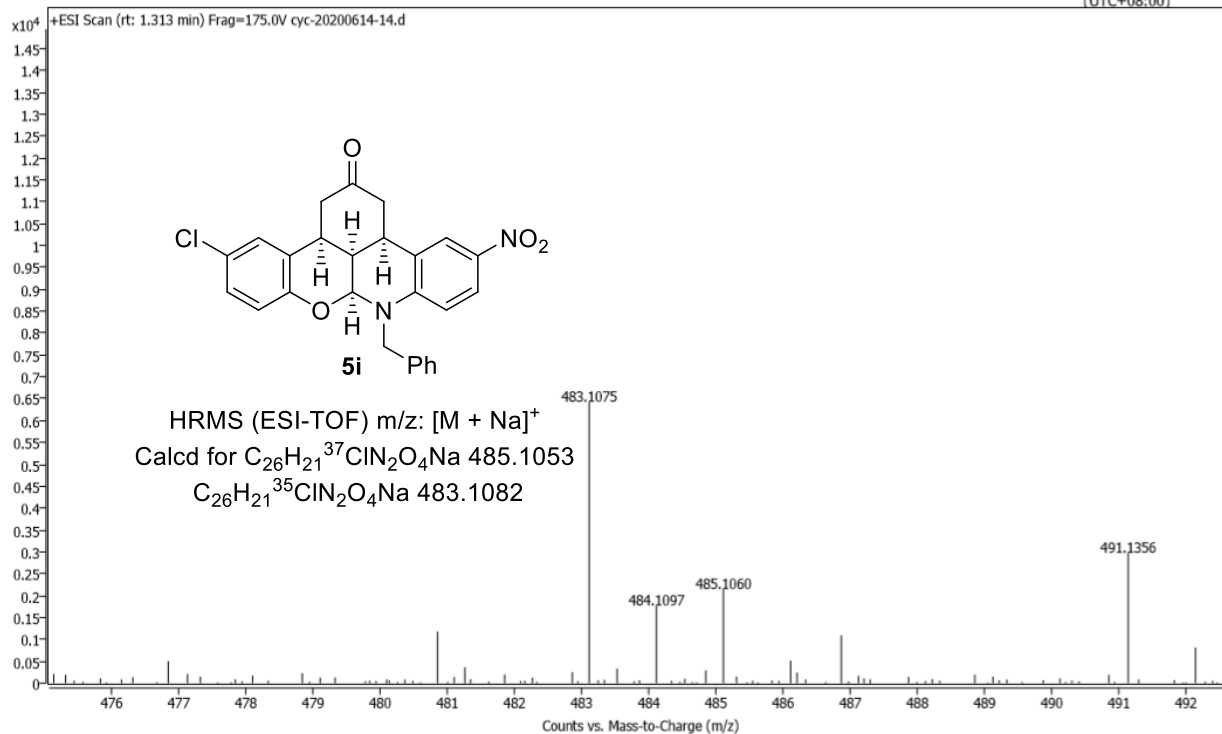


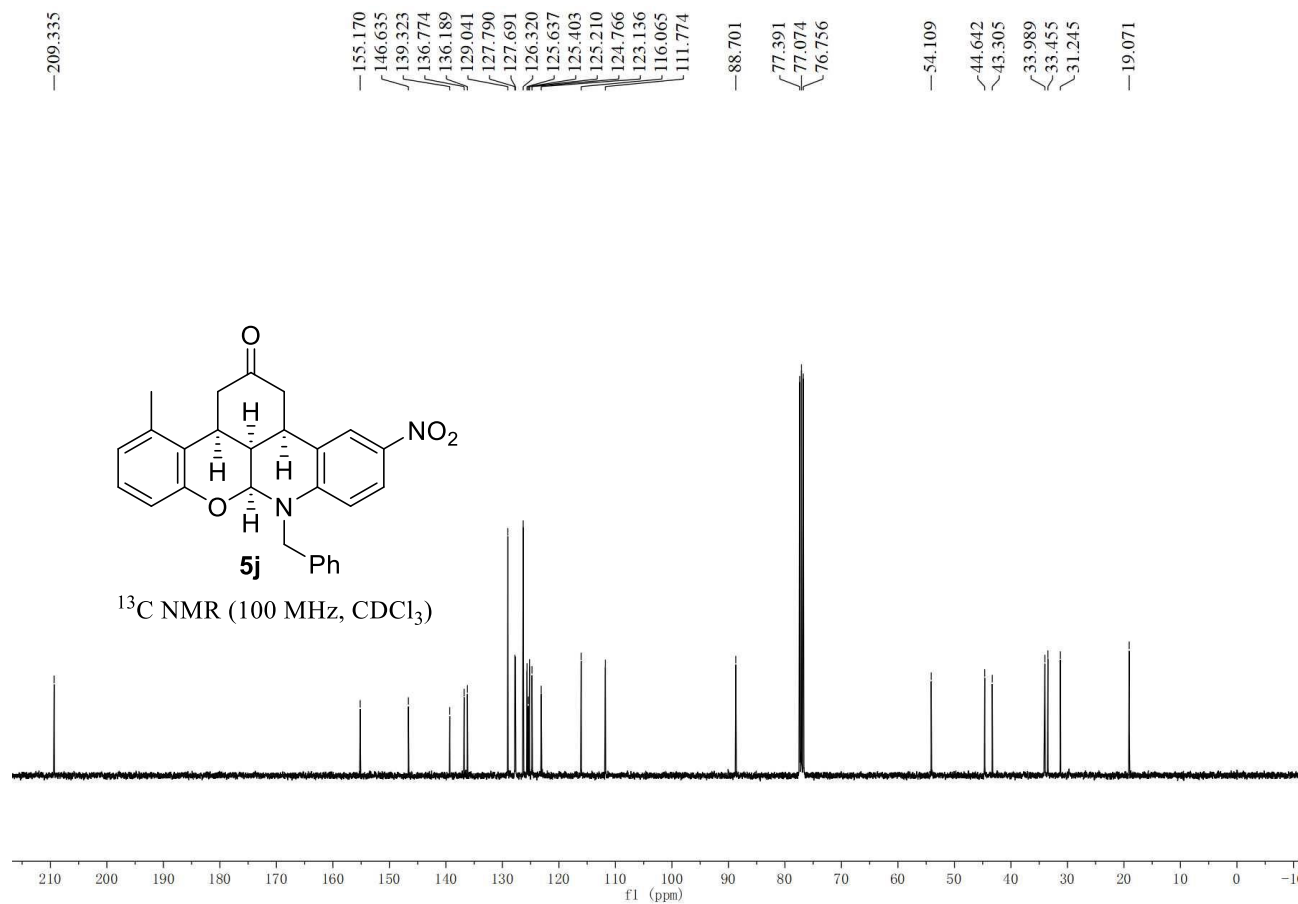
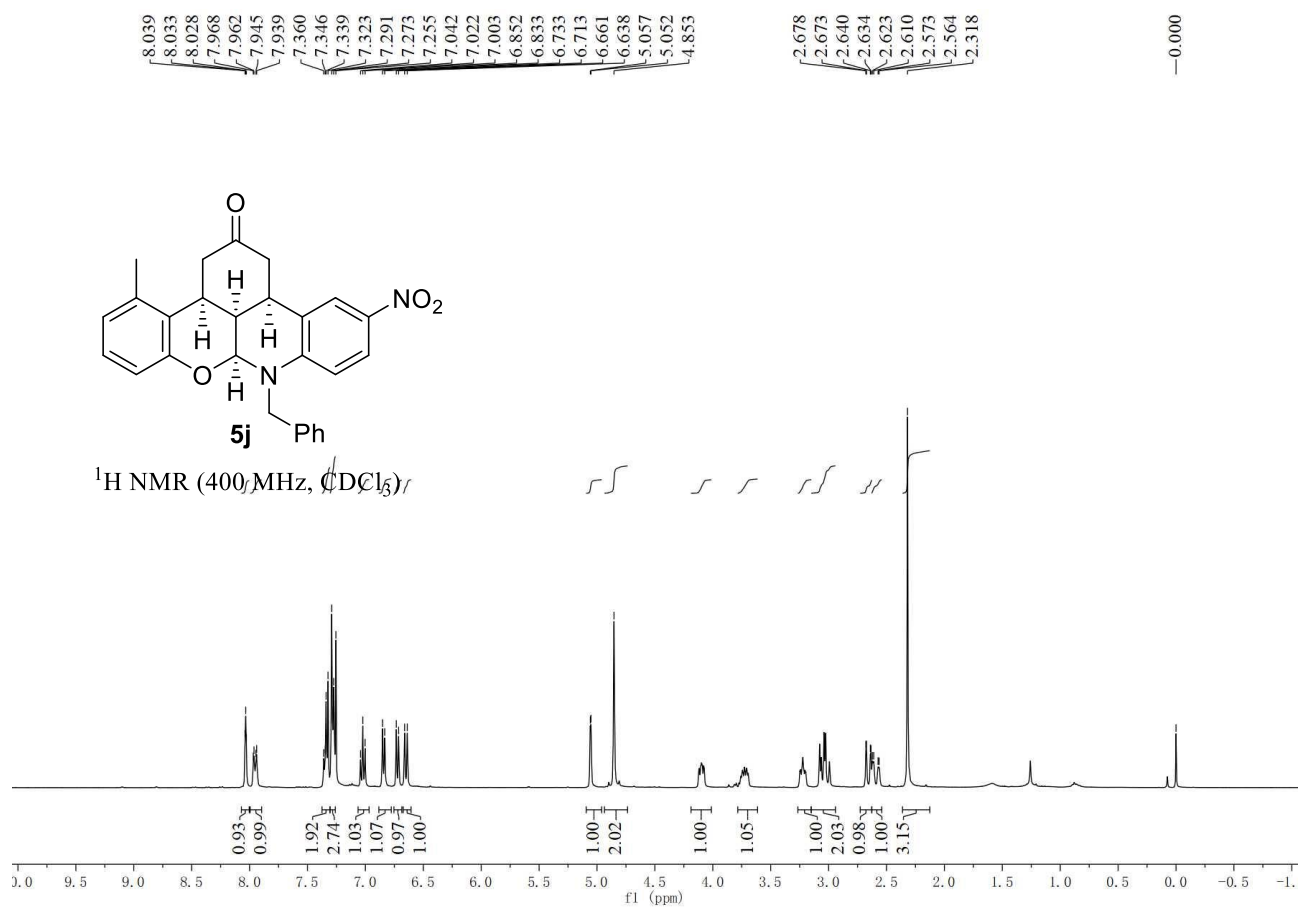


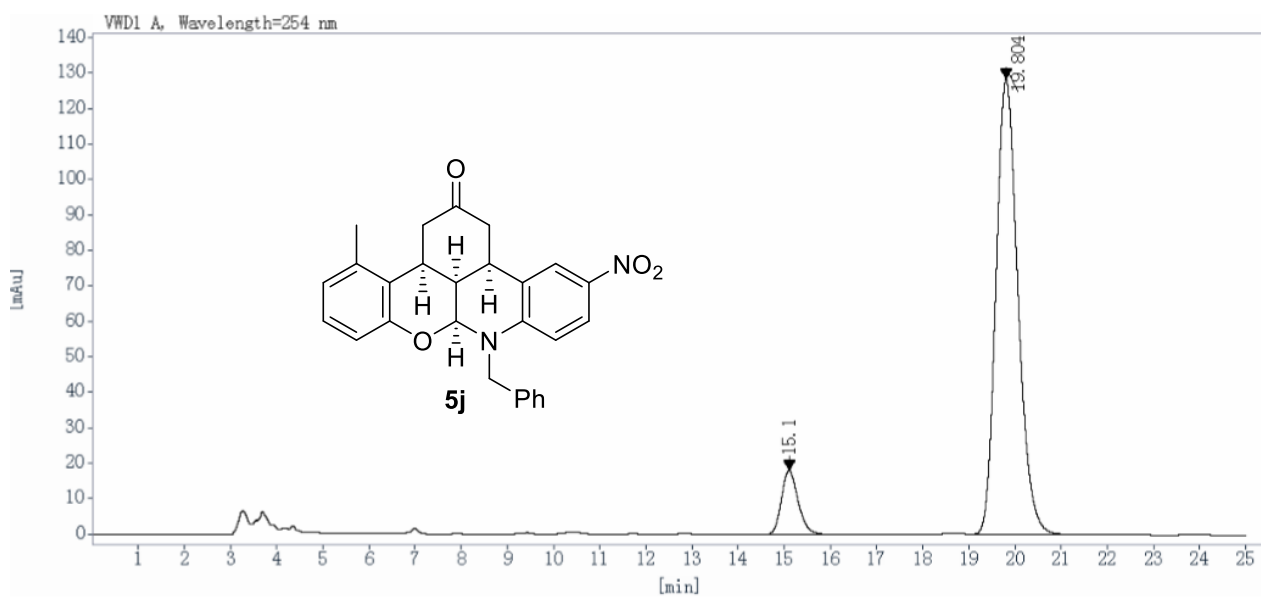
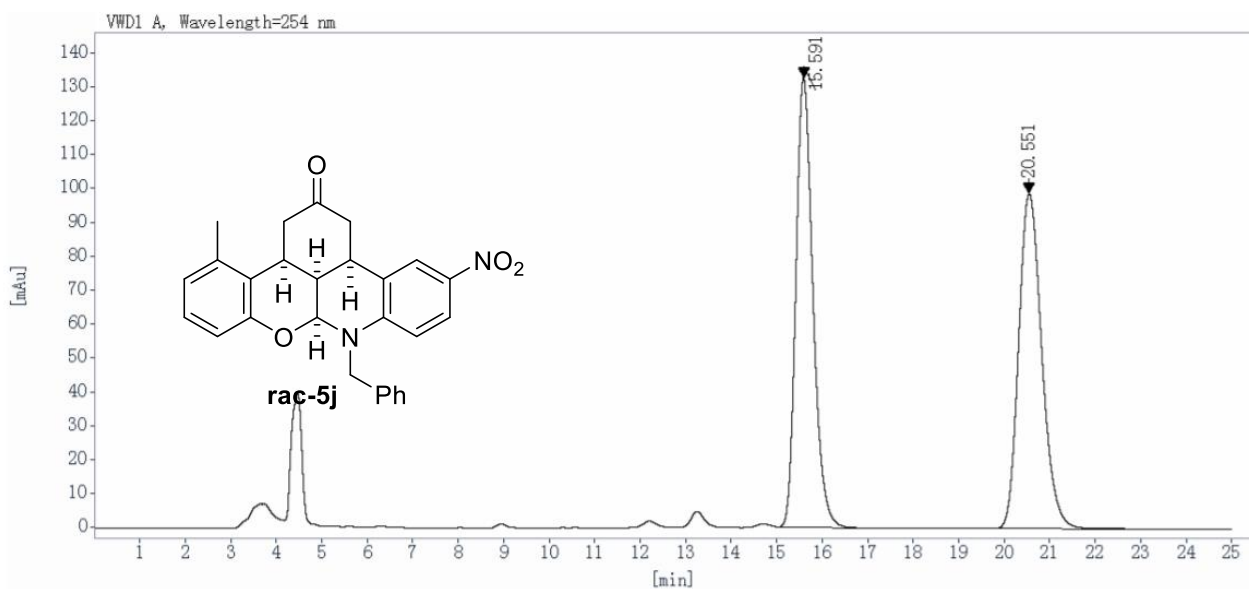
Spectrum Plot Report



Name	cyc-20200614-14	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200614-14.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/18/2020 5:09:31 PM (UTC+08:00)



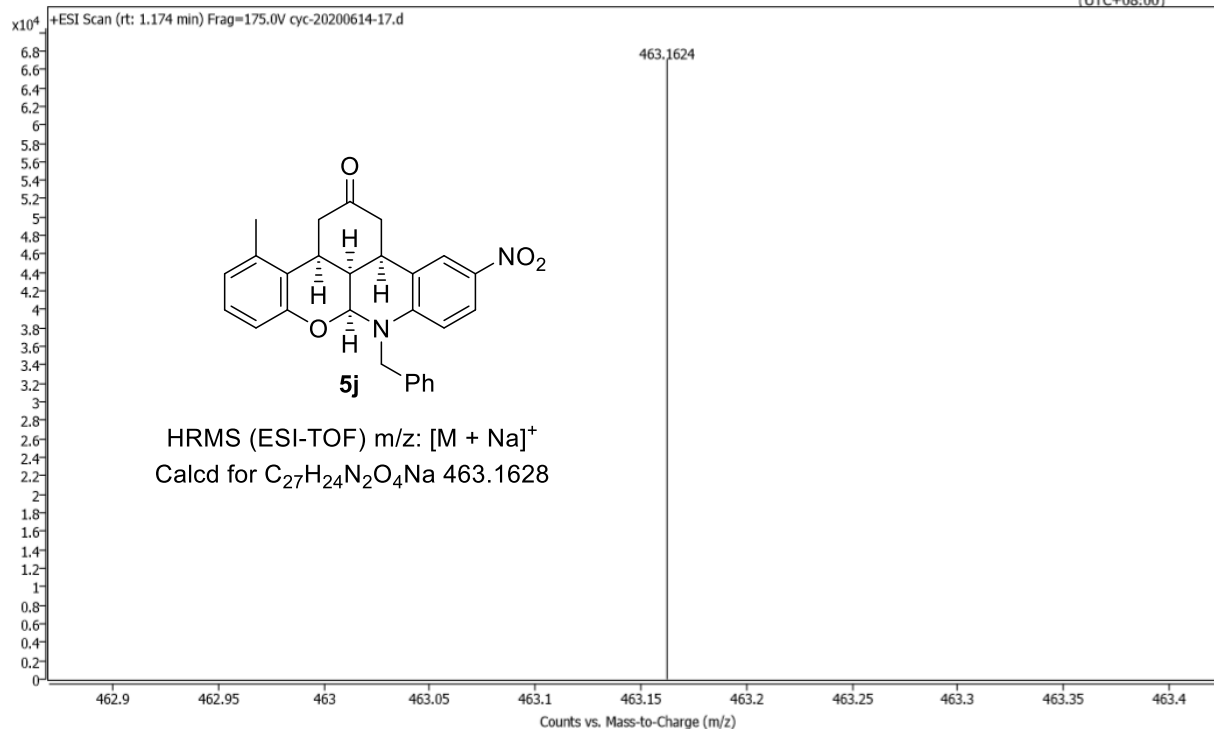


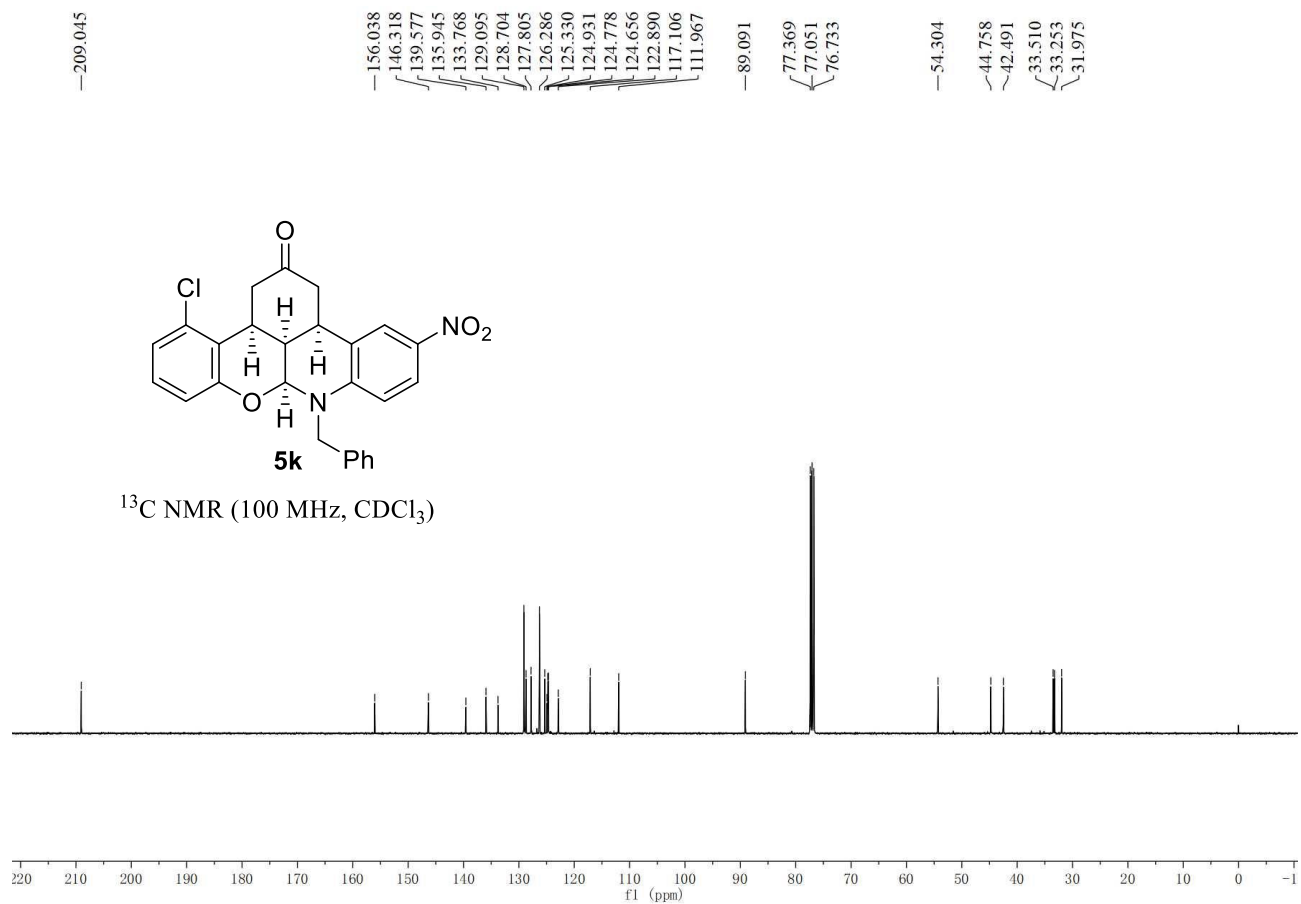
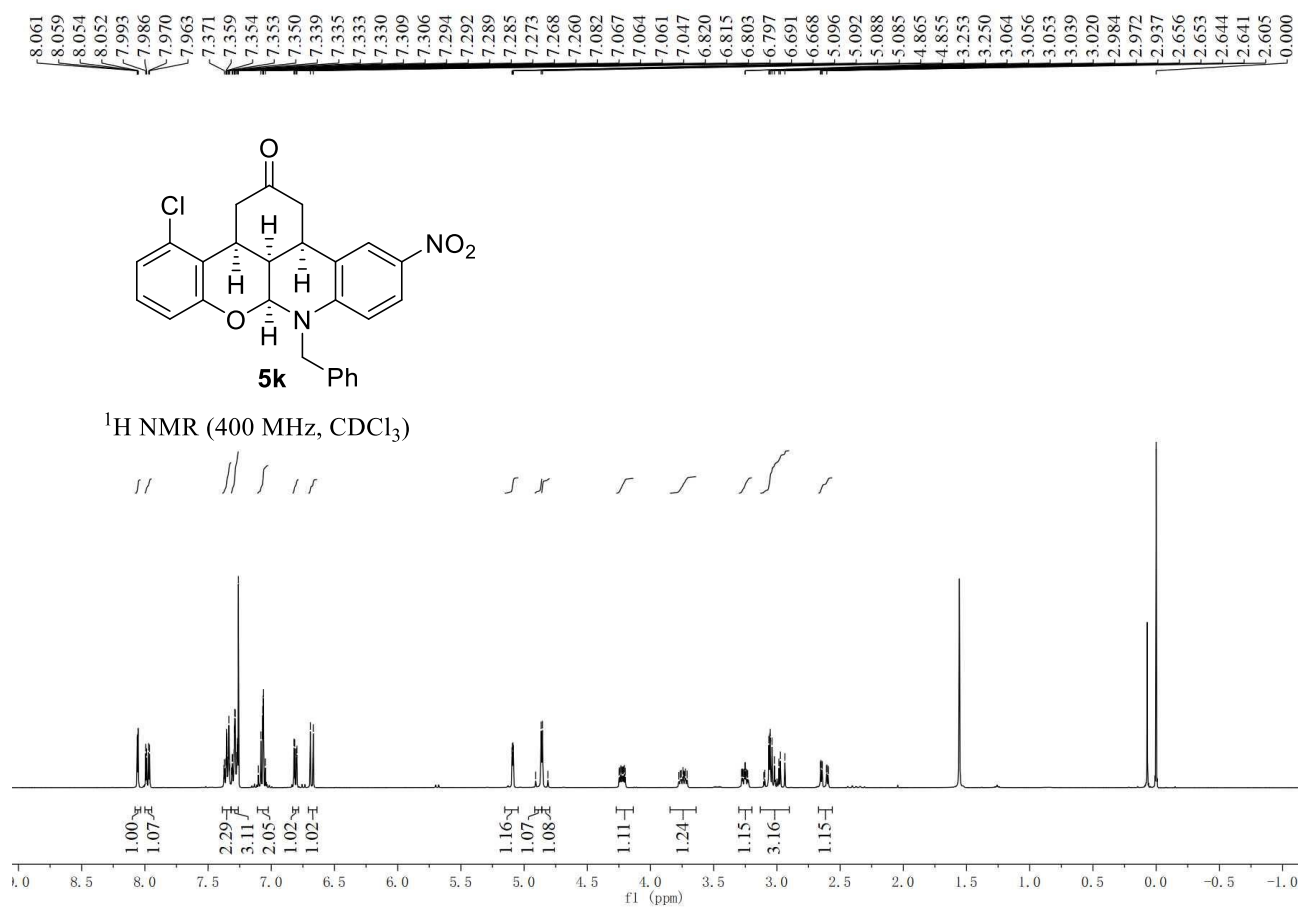


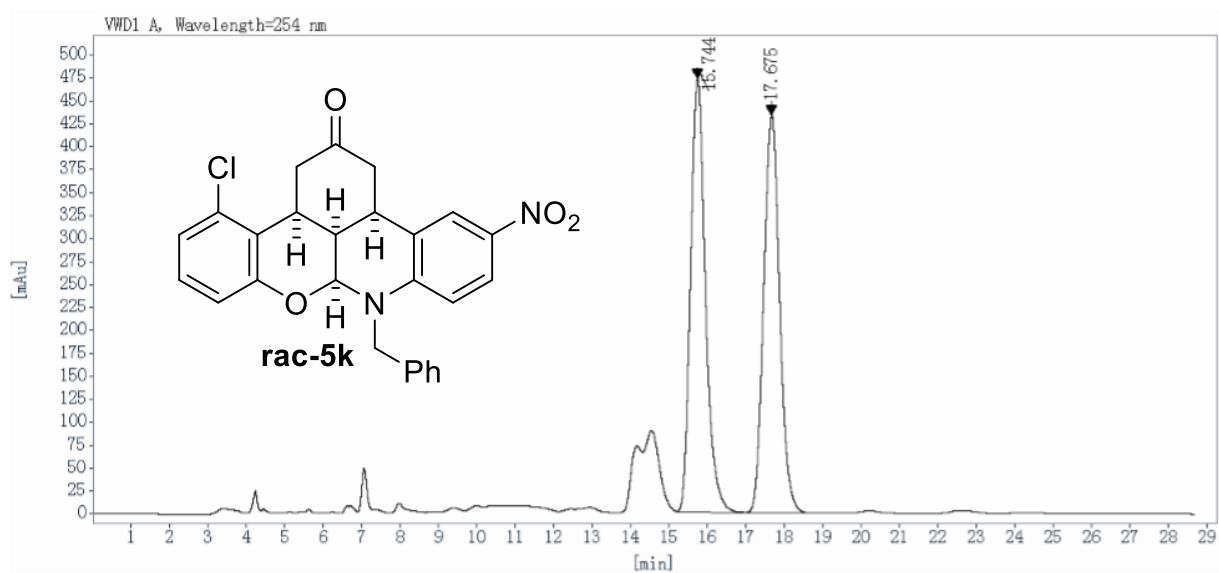
Spectrum Plot Report



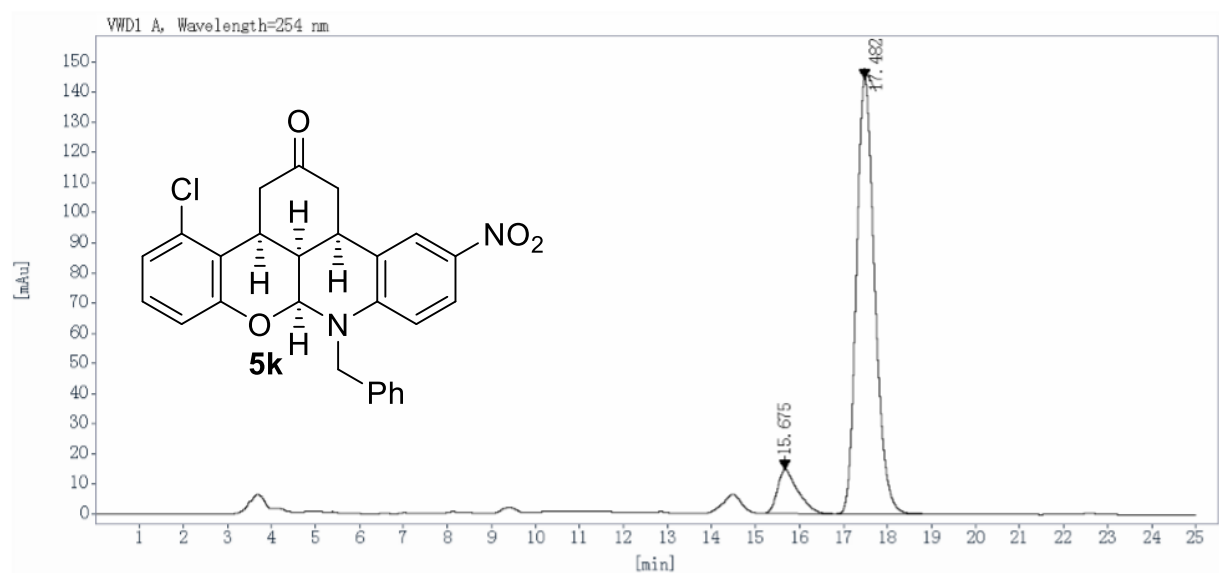
Name	cyc-20200614-17	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200614-17.d	Method (Acq)	TOF.m		Acq. Time (Local)
					6/18/2020 5:18:32 PM (UTC+08:00)



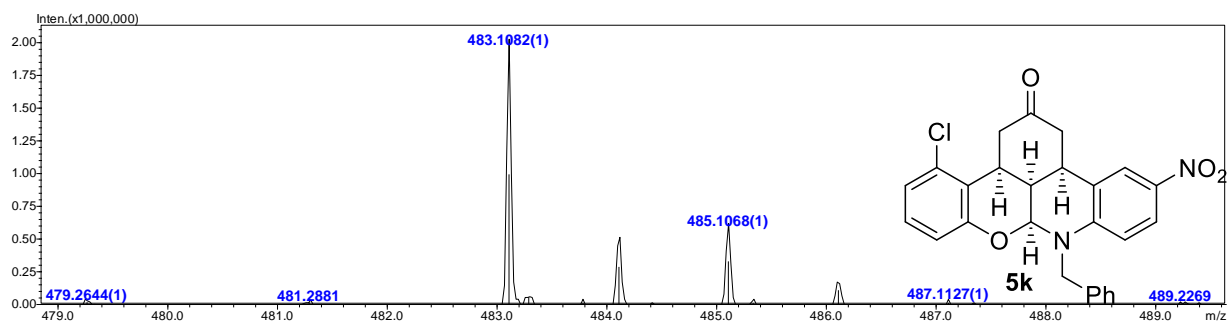




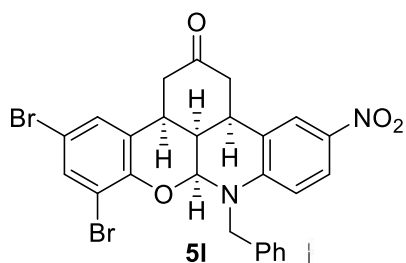
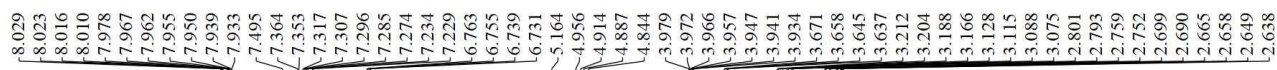
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.744	BB	0.41	472.2356	12676.2998	50.4532
17.675	BB	0.45	433.5867	12448.5723	49.5468
Totals:				25124.8721	100.0000



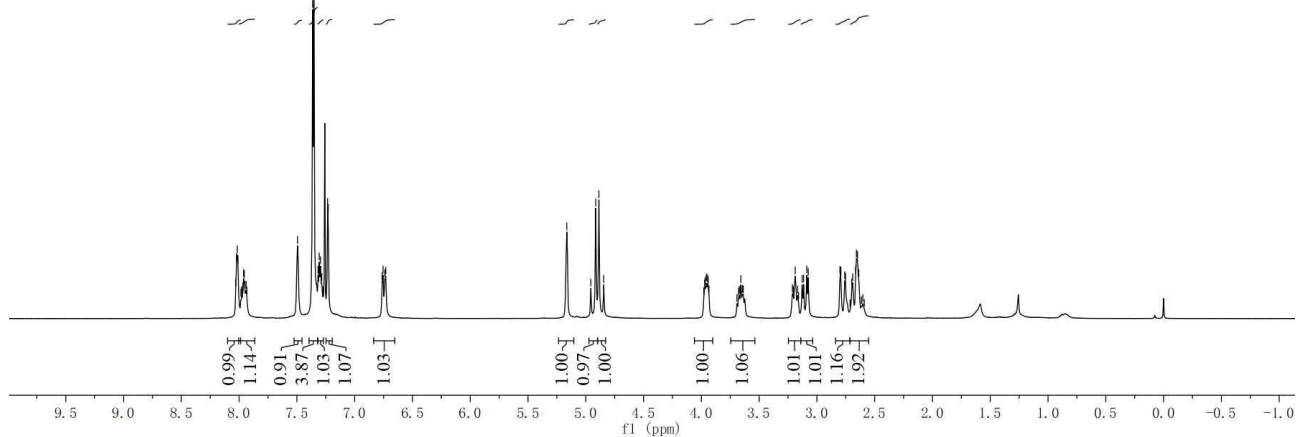
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.675	BB	0.47	14.4694	467.3577	10.0410
17.482	BB	0.45	144.3224	4187.1289	89.9590
Totals:				4654.4866	100.0000



HRMS (ESI-TOF) m/z : $[M + Na]^+$
 Calcd for $C_{26}H_{21}^{37}ClN_2O_4Na$ 485.1053
 $C_{26}H_{21}^{35}ClN_2O_4Na$ 483.1082

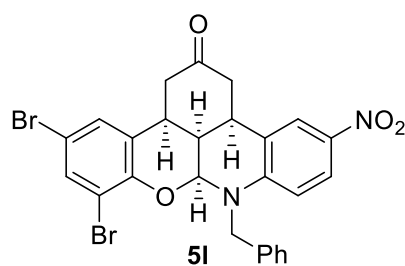


1H NMR (400 MHz, $CDCl_3$)

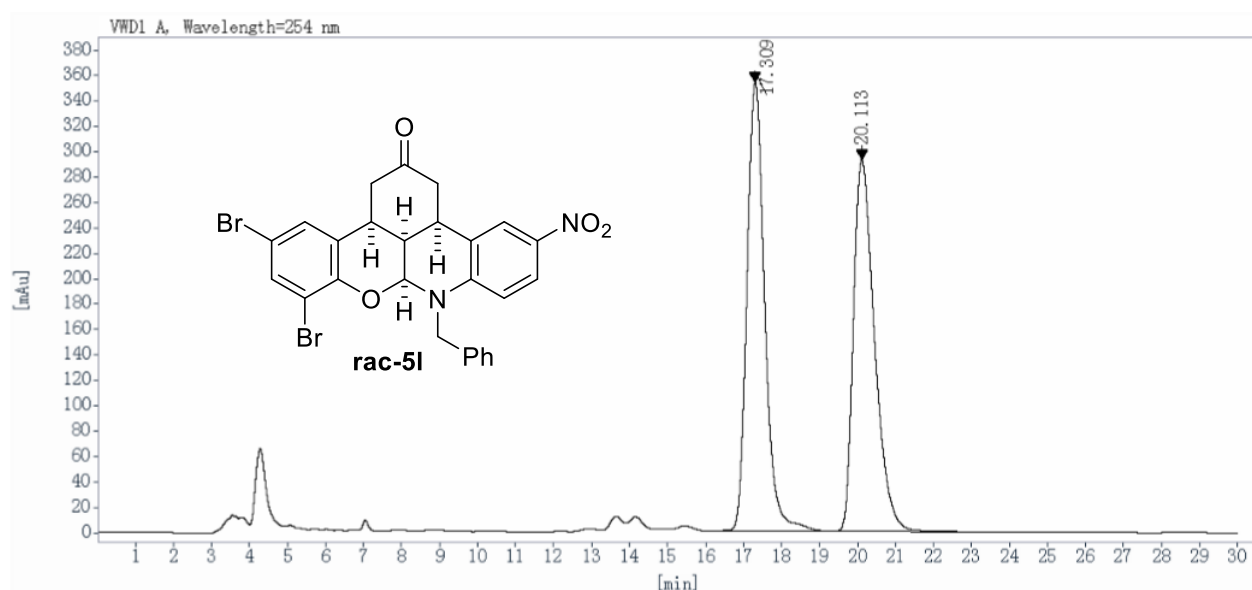
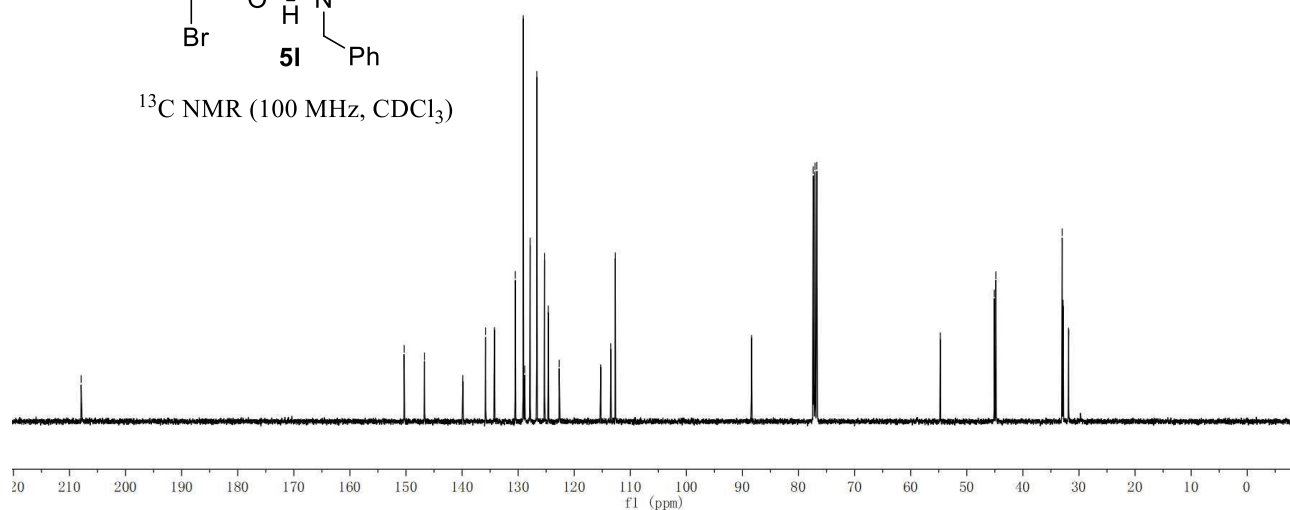


—207.937

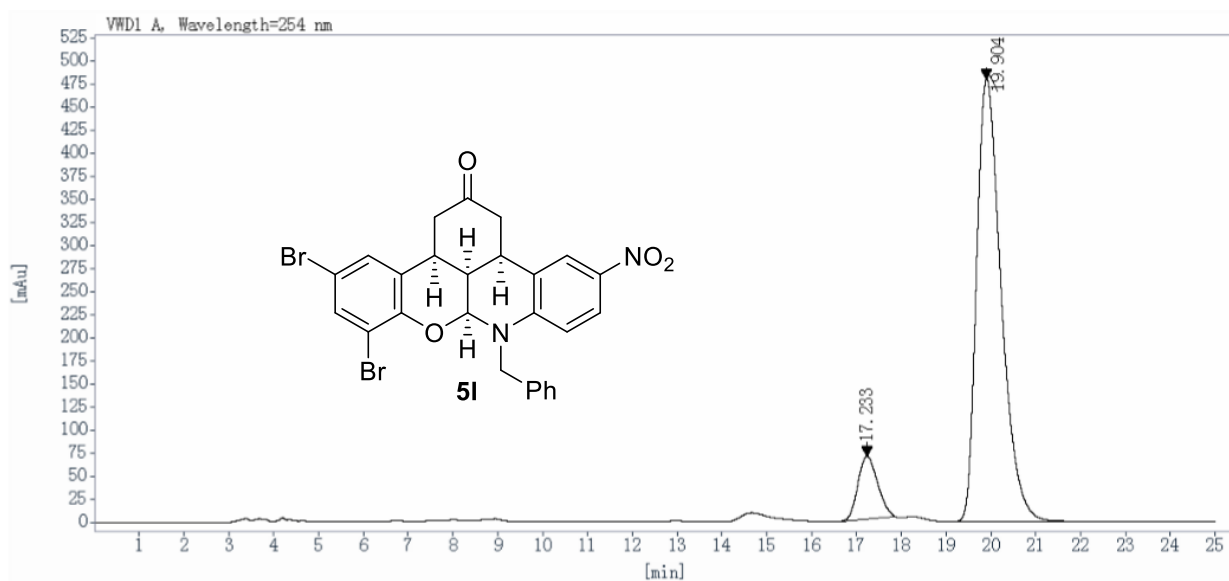
150.334
146.707
139.879
135.817
134.247
130.517
129.099
128.840
127.873
126.679
125.310
124.632
122.683
115.297
113.500
112.678
—88.383
77.386
77.068
76.750
—54.730
45.097
44.820
32.999
32.839
31.855



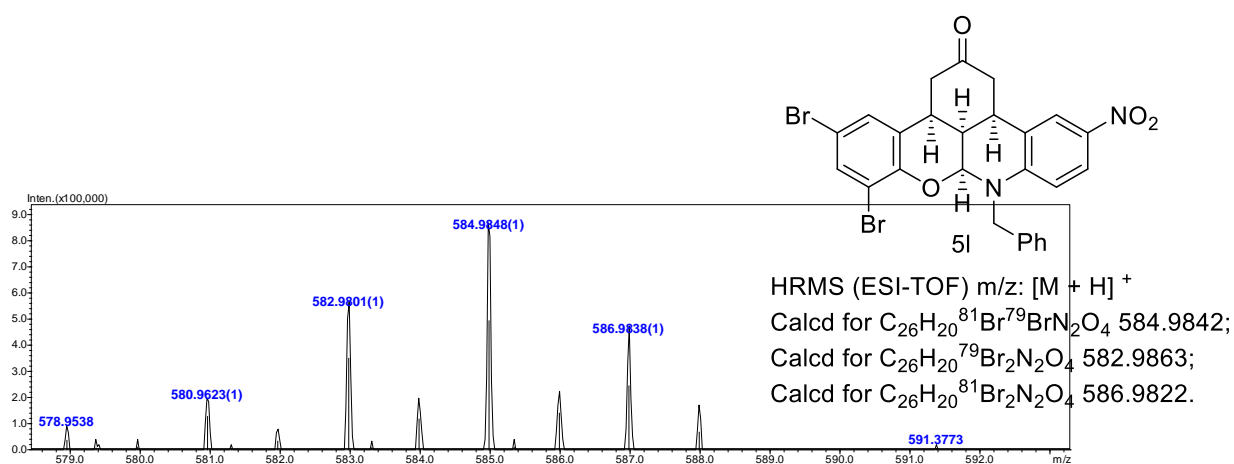
¹³C NMR (100 MHz, CDCl₃)

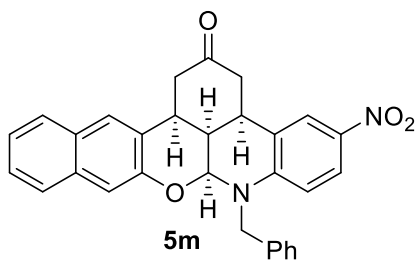


Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
17.309	BB	0.50	354.0330	11529.5527	50.4005
20.113	BB	0.59	293.0110	11346.3350	49.5995
Totals:				22875.8877	100.0000



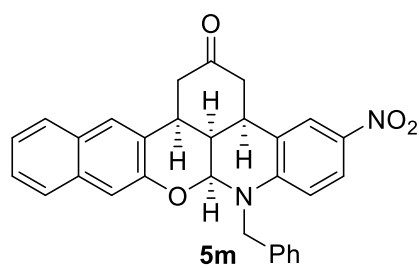
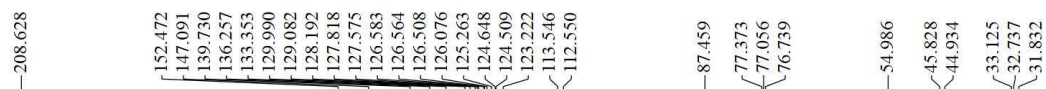
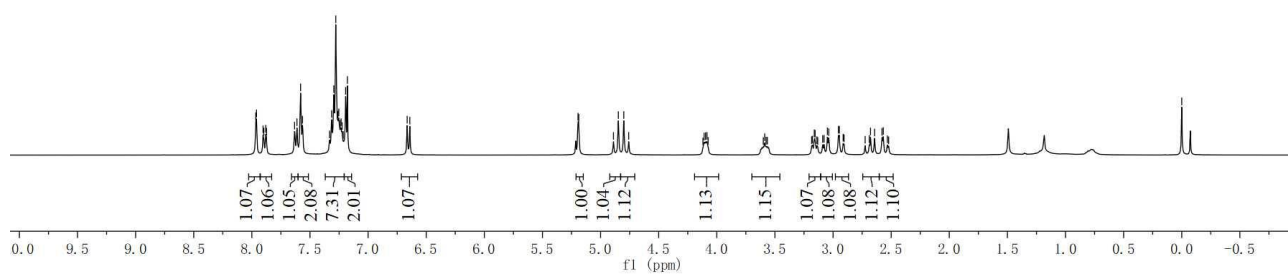
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
17.233	BBA	0.48	67.7496	2067.2837	10.1454
19.904	BB	0.59	479.7300	18309.2090	89.8546
Totals:				20376.4927	100.0000



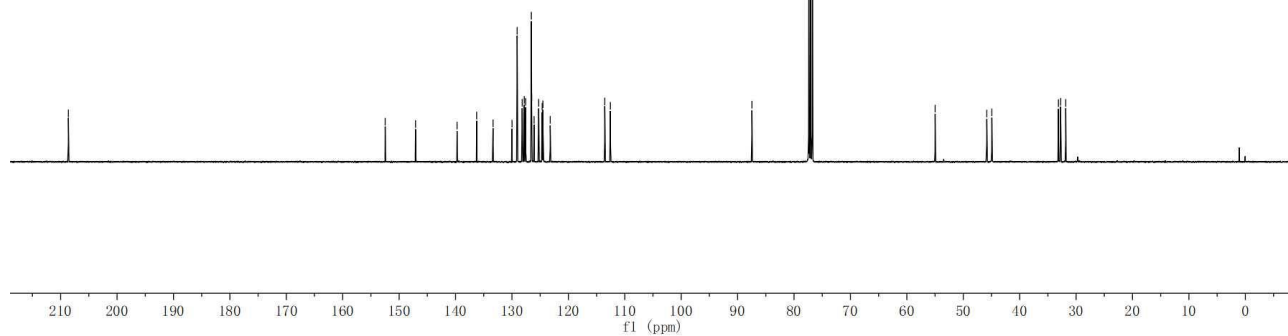


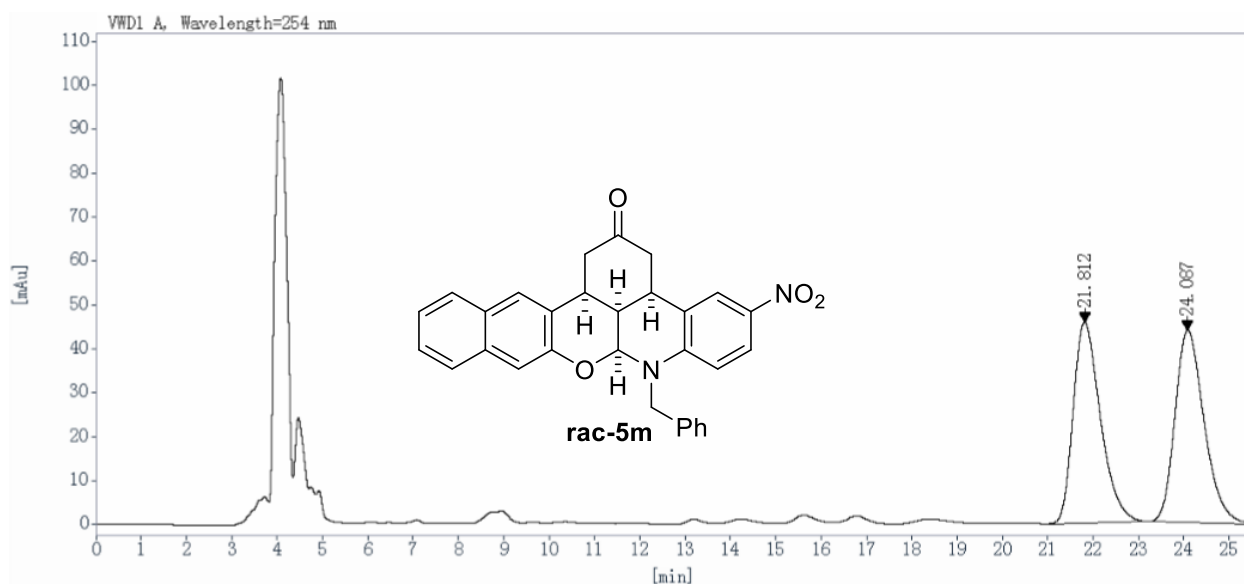
^1H NMR (400 MHz, CDCl_3)

1.07 1.06 1.05 7.31 2.01 1.07 1.00 1.04 1.12 1.13 1.15 1.07 1.08 1.08 1.12 1.10

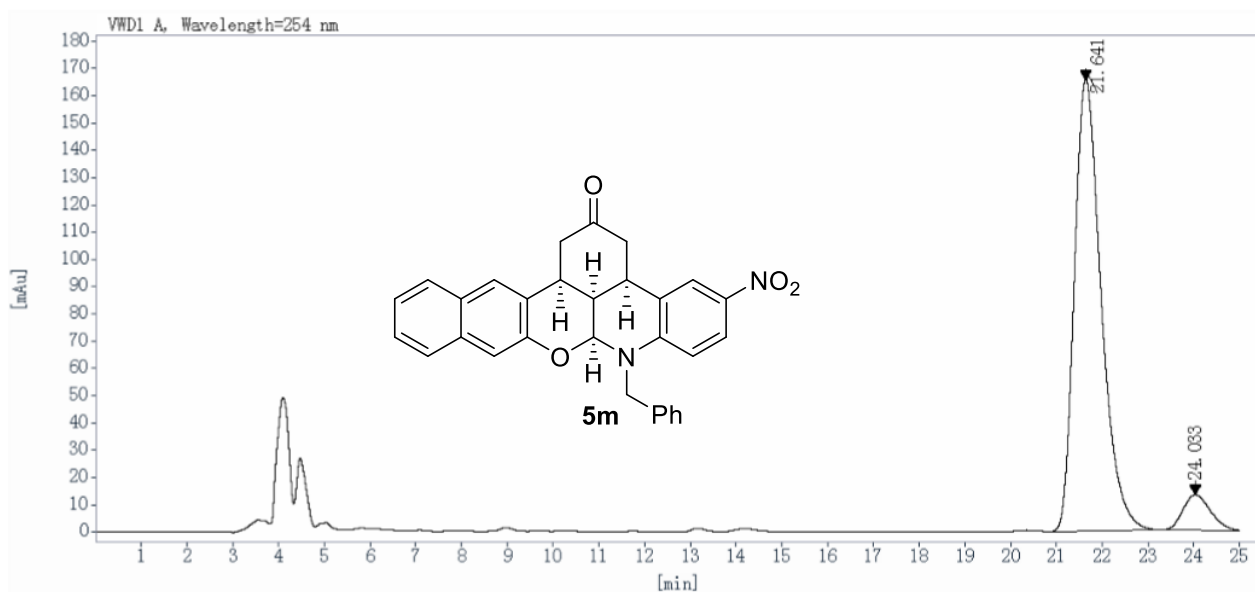


^{13}C NMR (100 MHz, CDCl_3)





Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
21.812	BB	0.64	45.6682	1912.1482	49.5249
24.087	BB	0.69	43.7092	1948.8364	50.4751
Totals:				3860.9846	100.0000

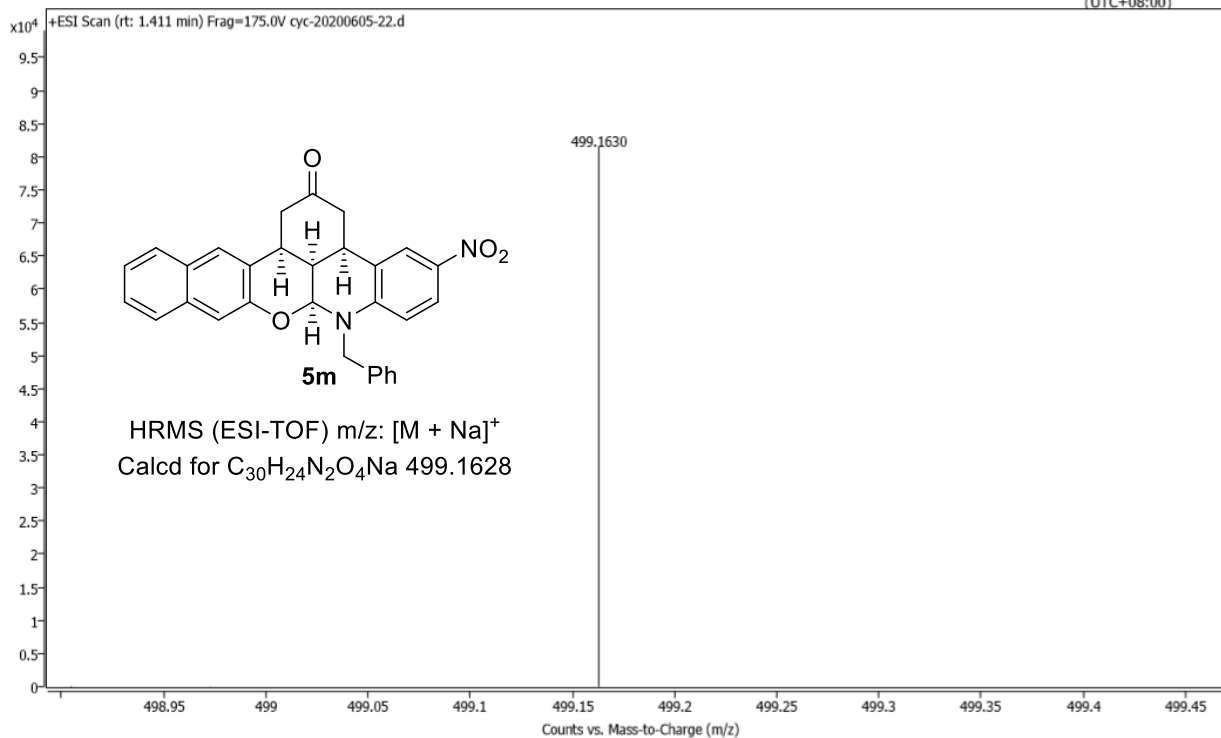


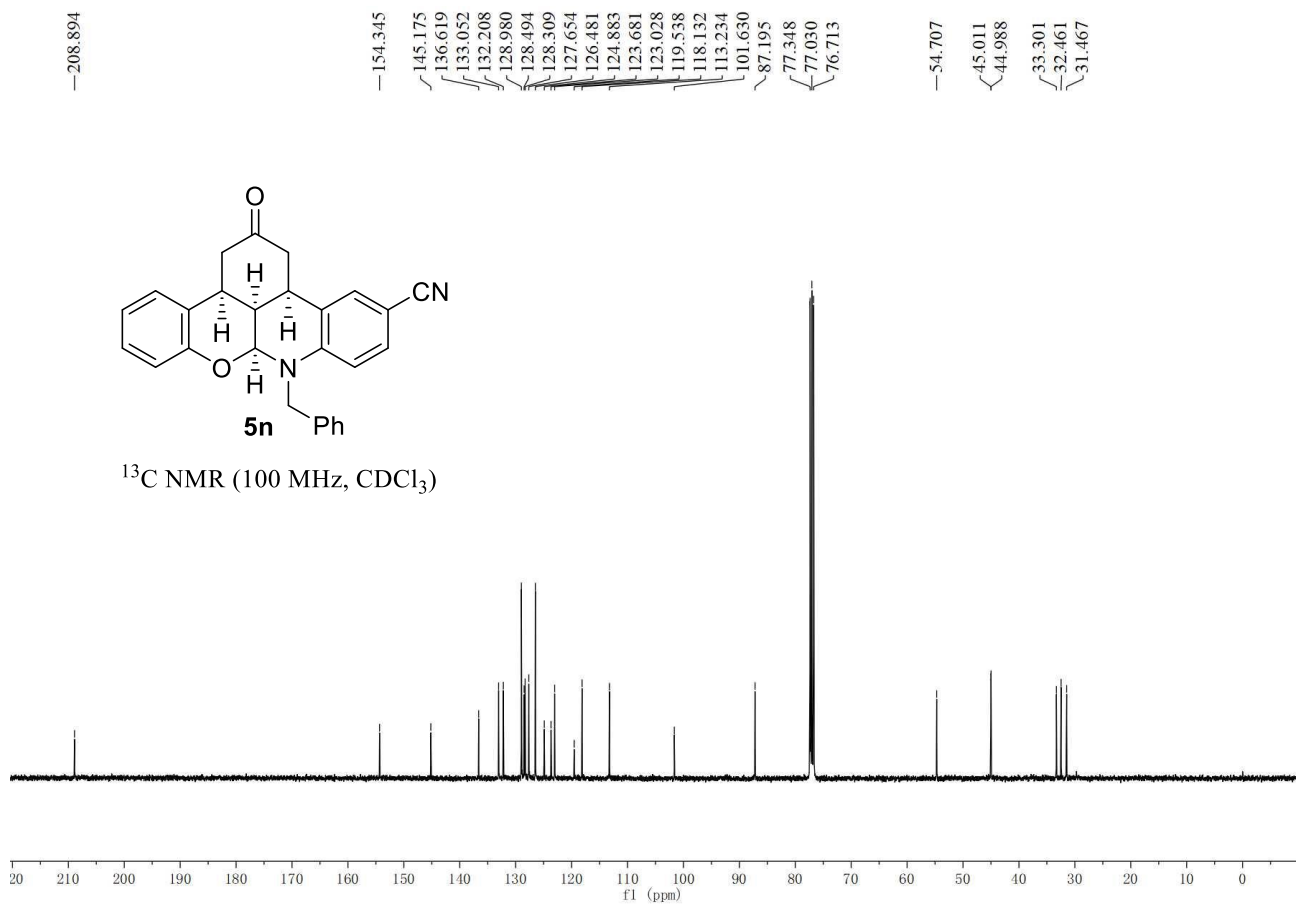
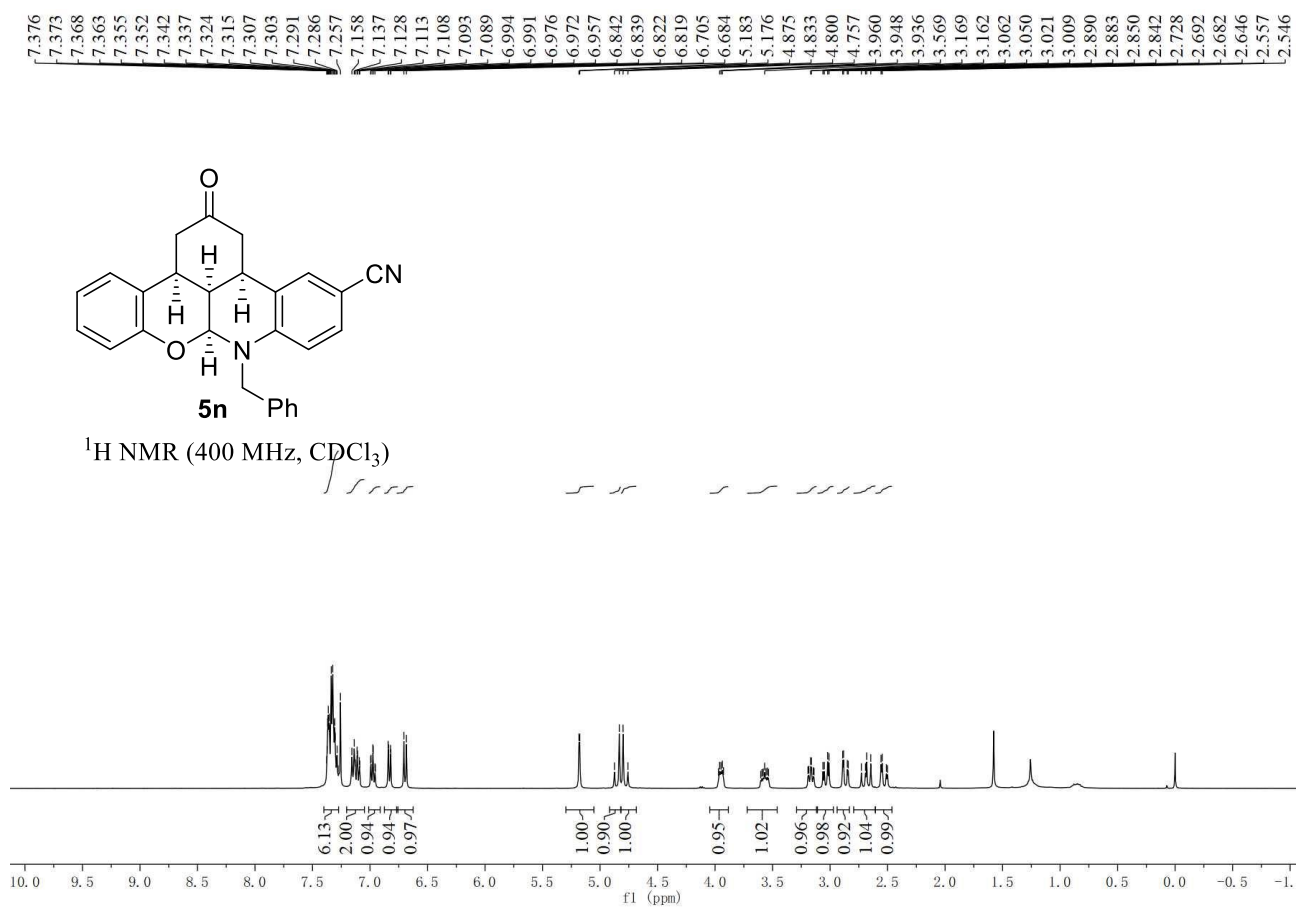
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
21.641	BB	0.63	165.4010	6751.2100	92.5548
24.033	BBA	0.65	12.9086	543.0745	7.4452
Totals:				7294.2844	100.0000

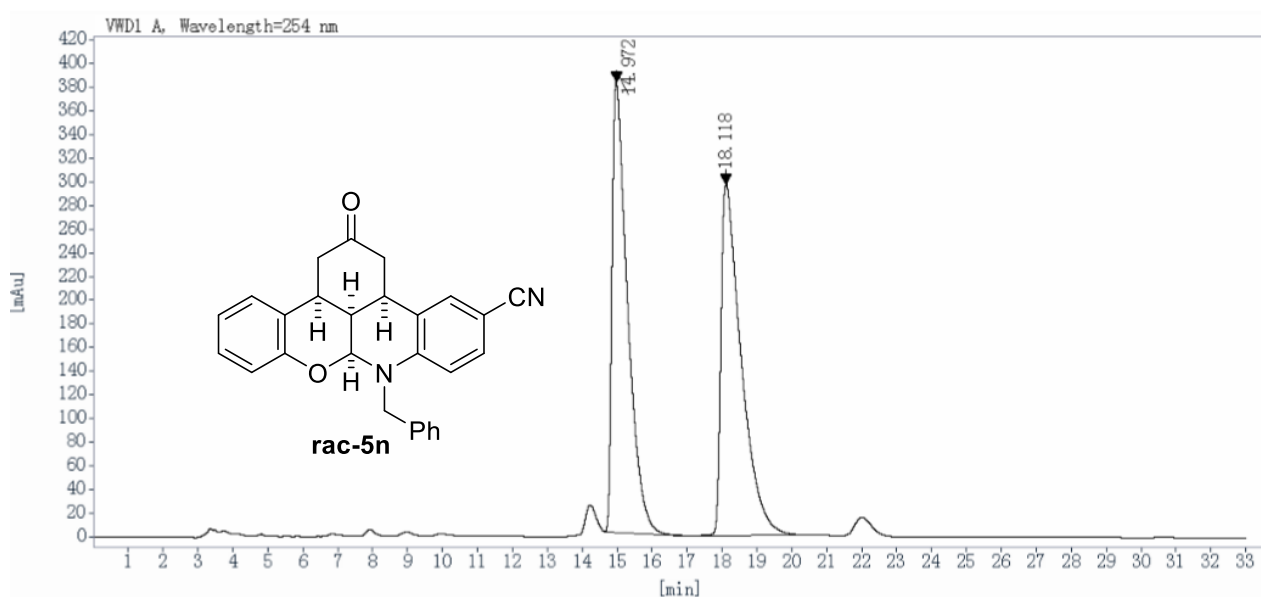
Spectrum Plot Report



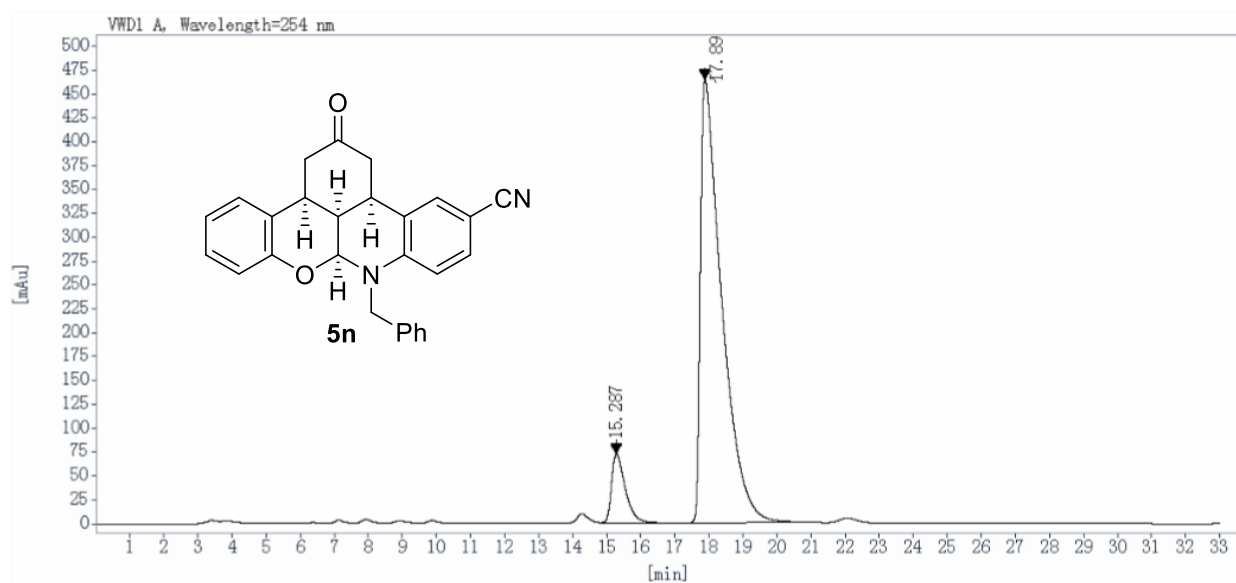
Name	cyc-20200605-22	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200605-22.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/14/2020 6:19:52 PM (UTC+08:00)







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
14.972	BB	0.45	379.9055	11699.4131	49.4676
18.118	BB	0.59	296.5181	11951.2559	50.5324
Totals:				23650.6689	100.0000

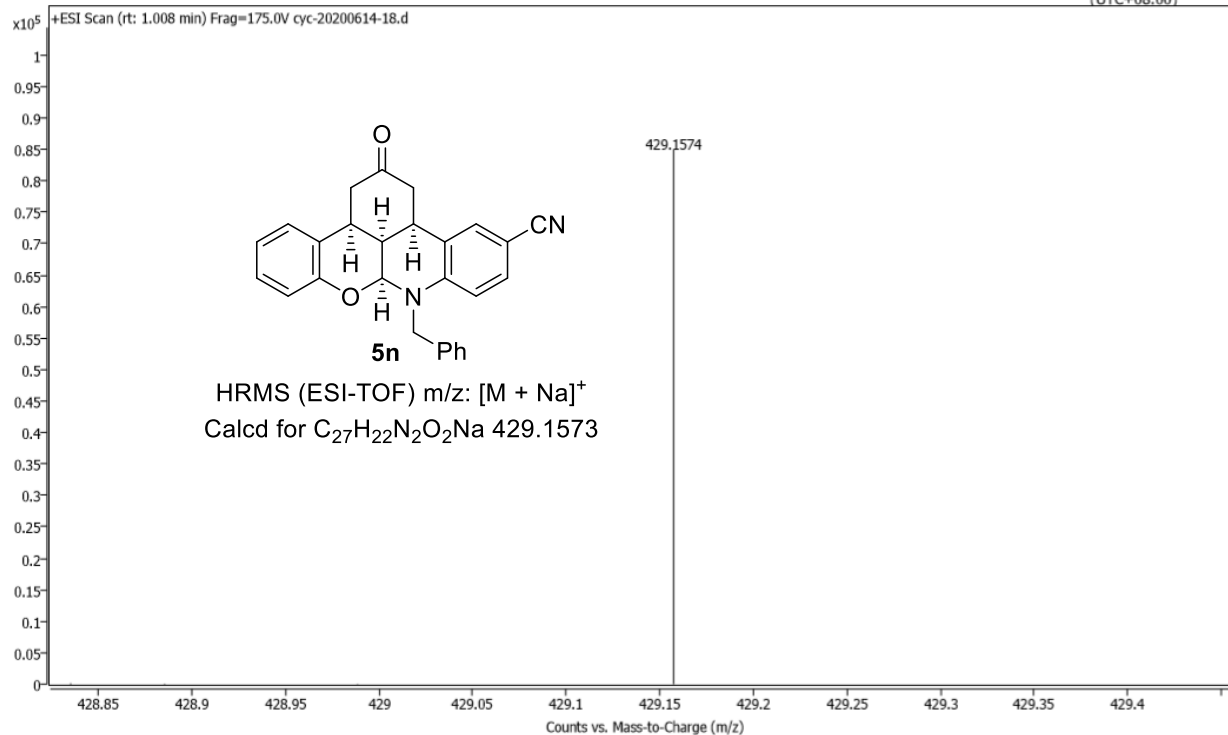


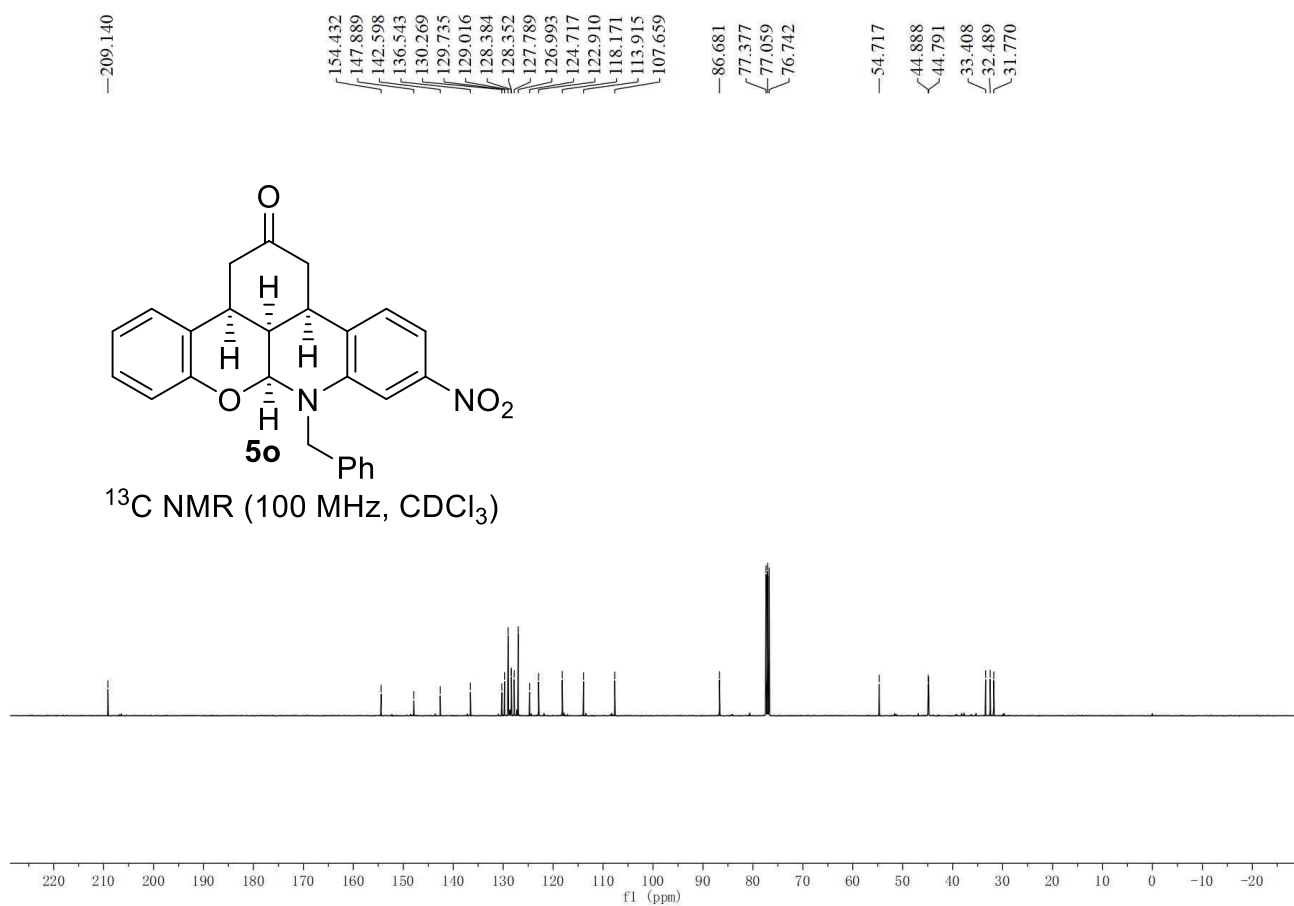
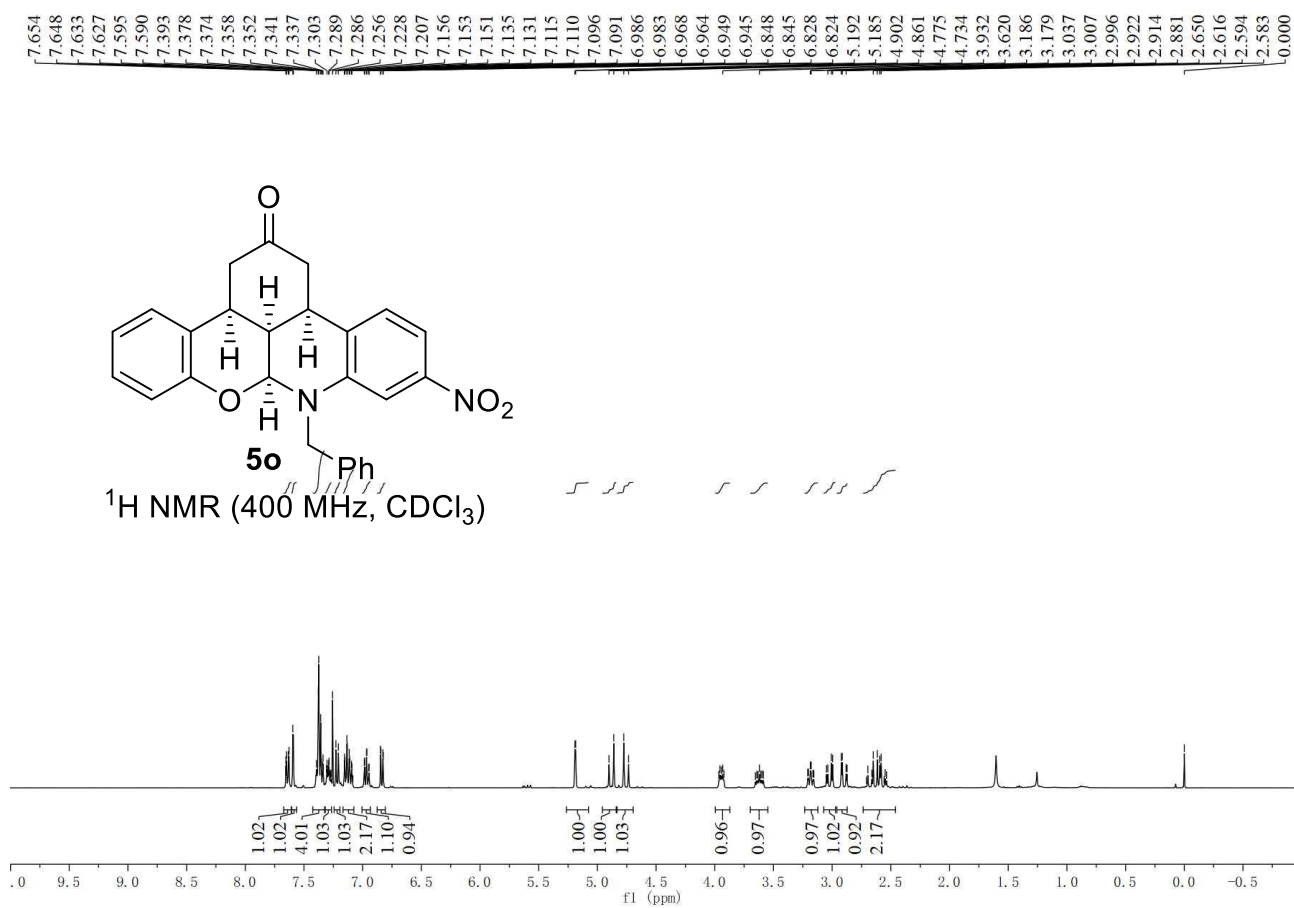
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
15.287	BB	0.42	72.2633	2017.2246	9.0914
17.890	BBA	0.62	464.9817	20171.1328	90.9086
Totals:				22188.3574	100.0000

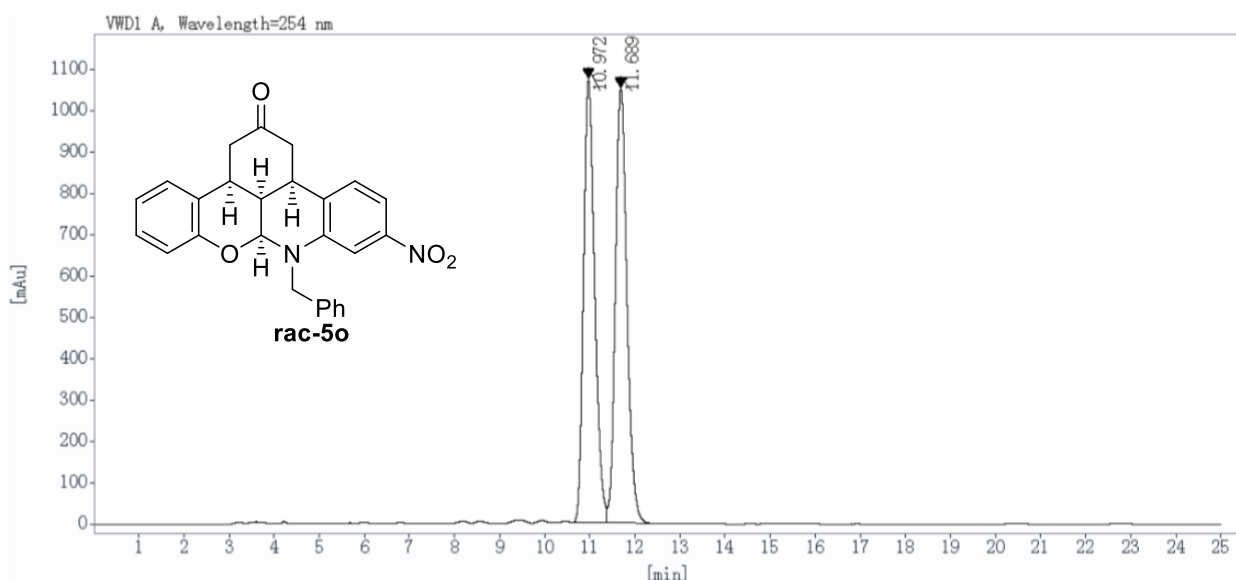
Spectrum Plot Report



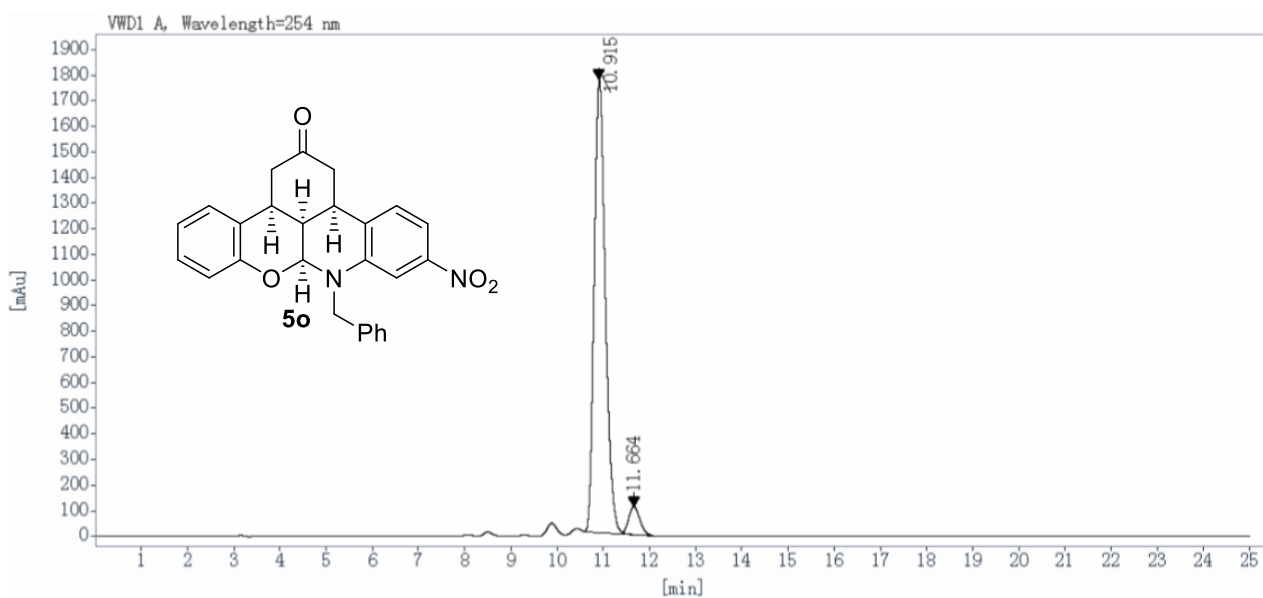
Name	cyc-20200614-18	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200614-18.d	Method (Acq)	TOF.m		Acq. Time (Local)
					6/18/2020 5:21:33 PM (UTC+08:00)







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
10.972	BV	0.26	1074.5470	18399.5684	49.6717
11.689	VB	0.27	1051.9778	18642.8242	50.3283

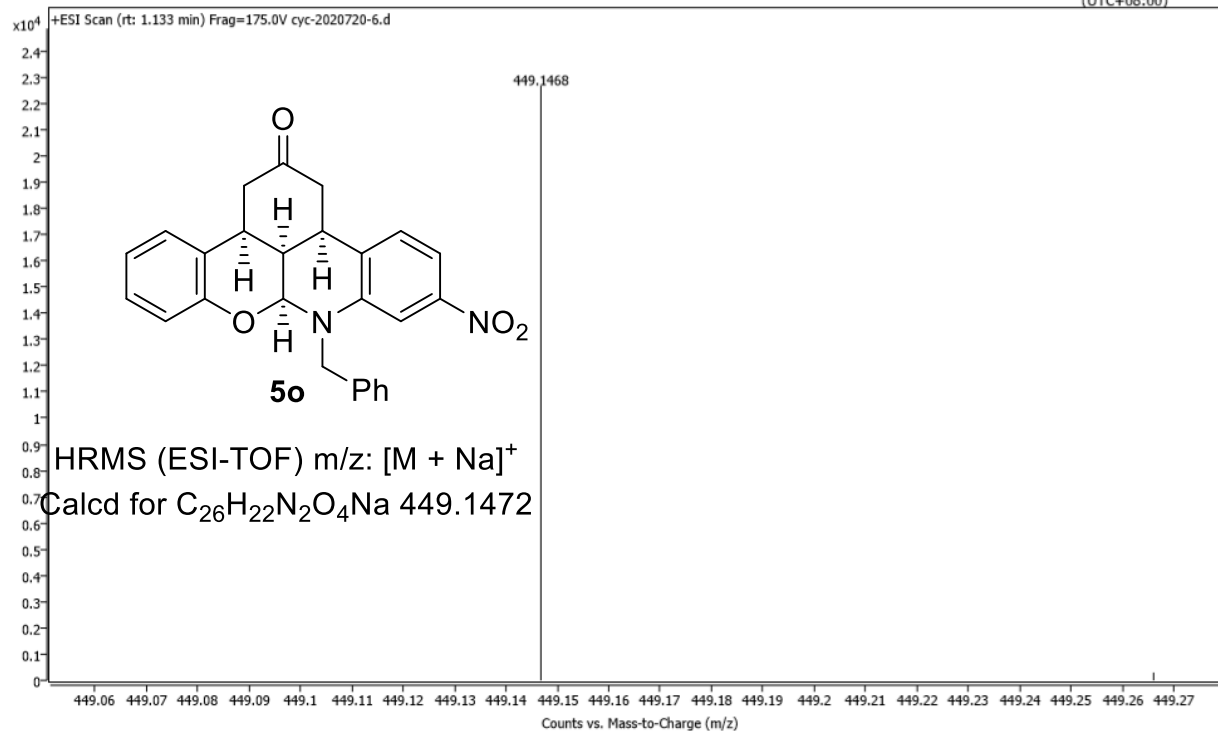


Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
10.915	BV R	0.26	1768.8953	29567.3555	94.2101
11.664	VB E	0.26	108.5706	1817.1340	5.7899
Totals:				31384.4895	100.0000

Spectrum Plot Report

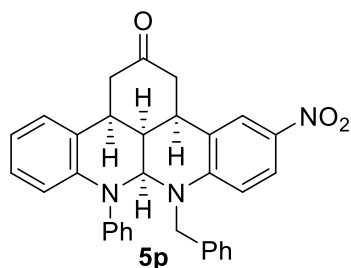


Name	cyc-2020720-6	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-2020720-6.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local)
					7/24/2020 3:27:19 PM (UTC+08:00)

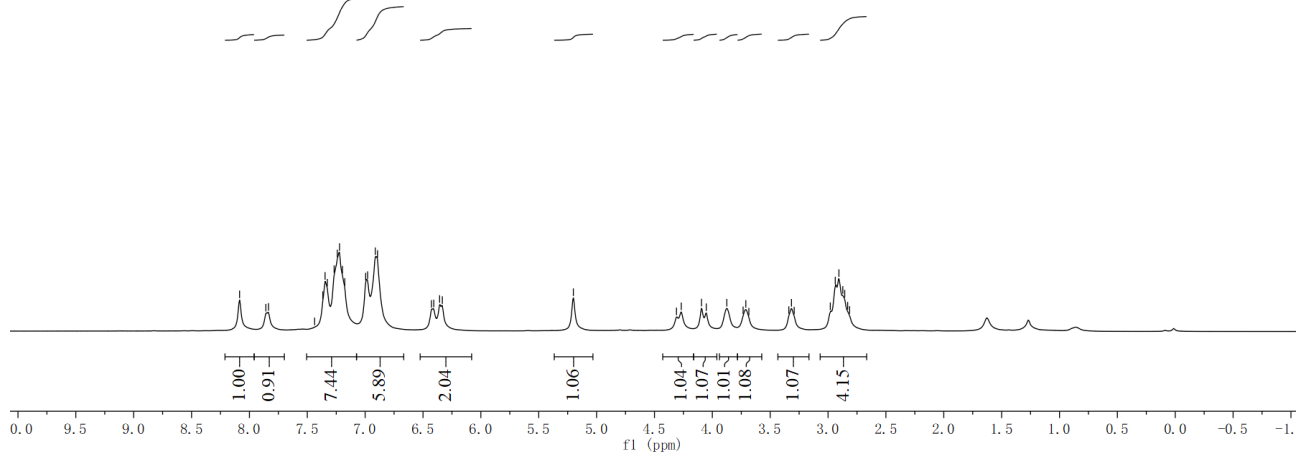


8.085
7.858
7.835
7.436
7.366
7.346
7.327
7.268
7.241
7.222
7.196
7.176
6.996
6.979
6.913
6.893
6.427
6.407
6.356
6.333

5.201
4.310
4.269
4.093
4.053
3.875
3.734
3.710
3.684
3.339
3.316
3.292
2.981
2.938
2.906
2.873
2.856
2.830
2.814



^1H NMR (400 MHz, CDCl_3)

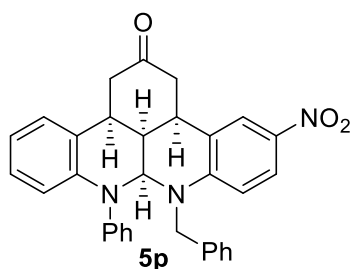


209.414

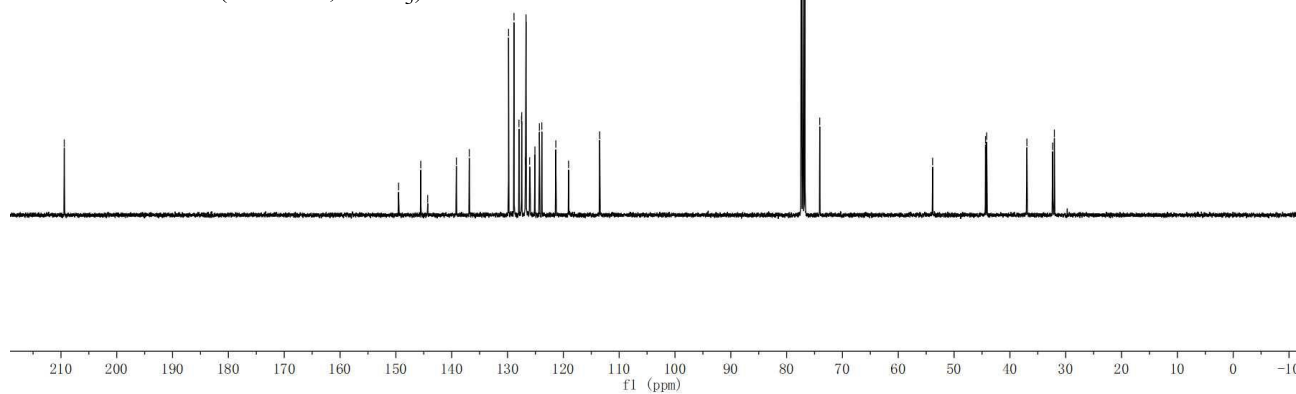
149.513
145.543
144.301
139.167
136.854
129.809
128.843
127.951
127.488
127.455
126.785
126.685
126.041
125.959
125.090
124.289
123.854
121.342
119.065
113.489

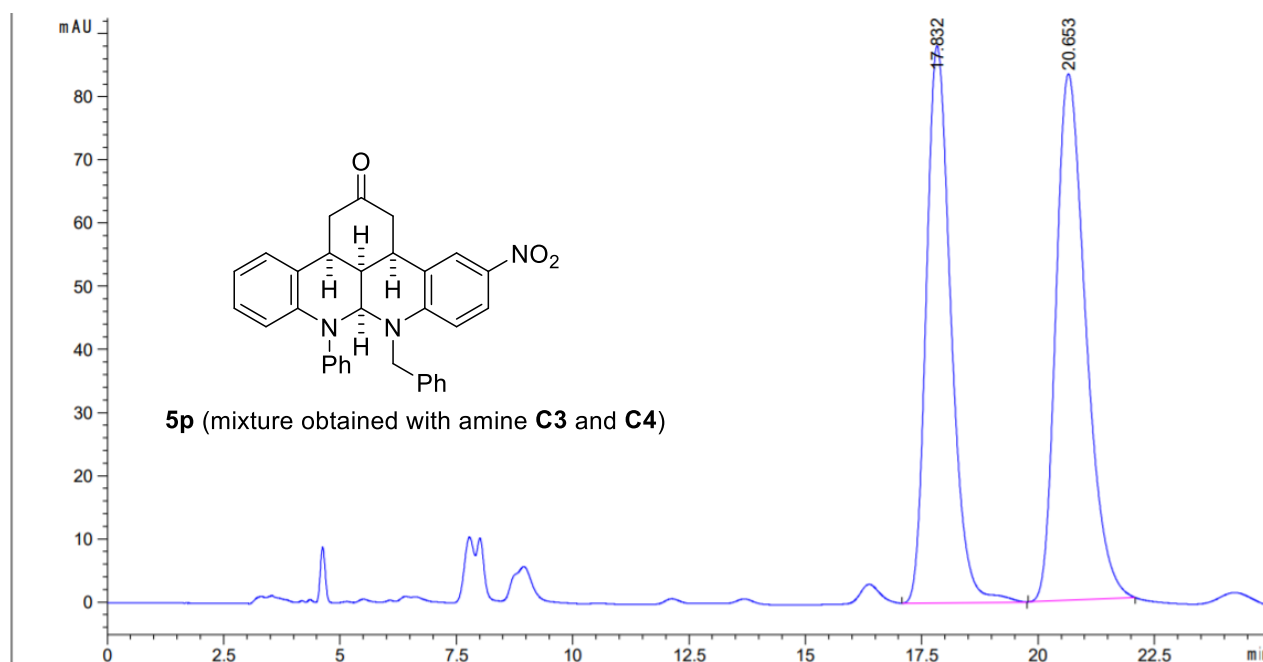
77.380
77.063
76.745
74.069

53.848
44.378
44.157
36.952
32.340
32.038

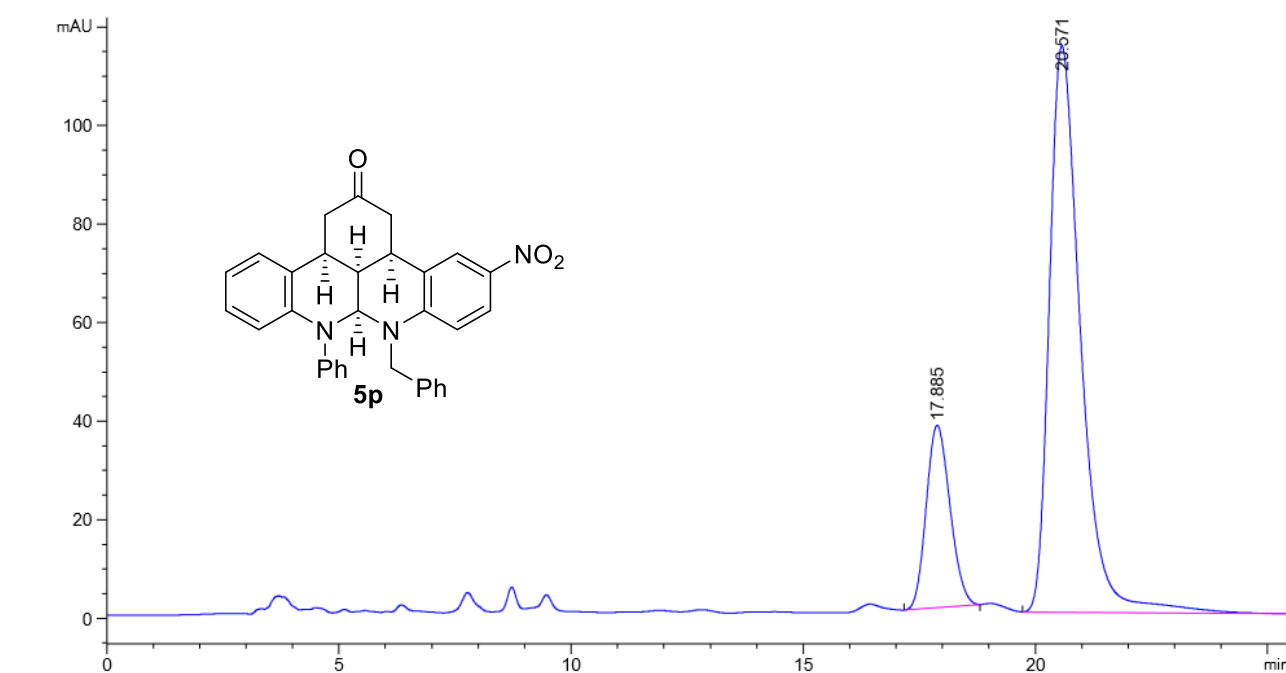


^{13}C NMR (100 MHz, CDCl_3)

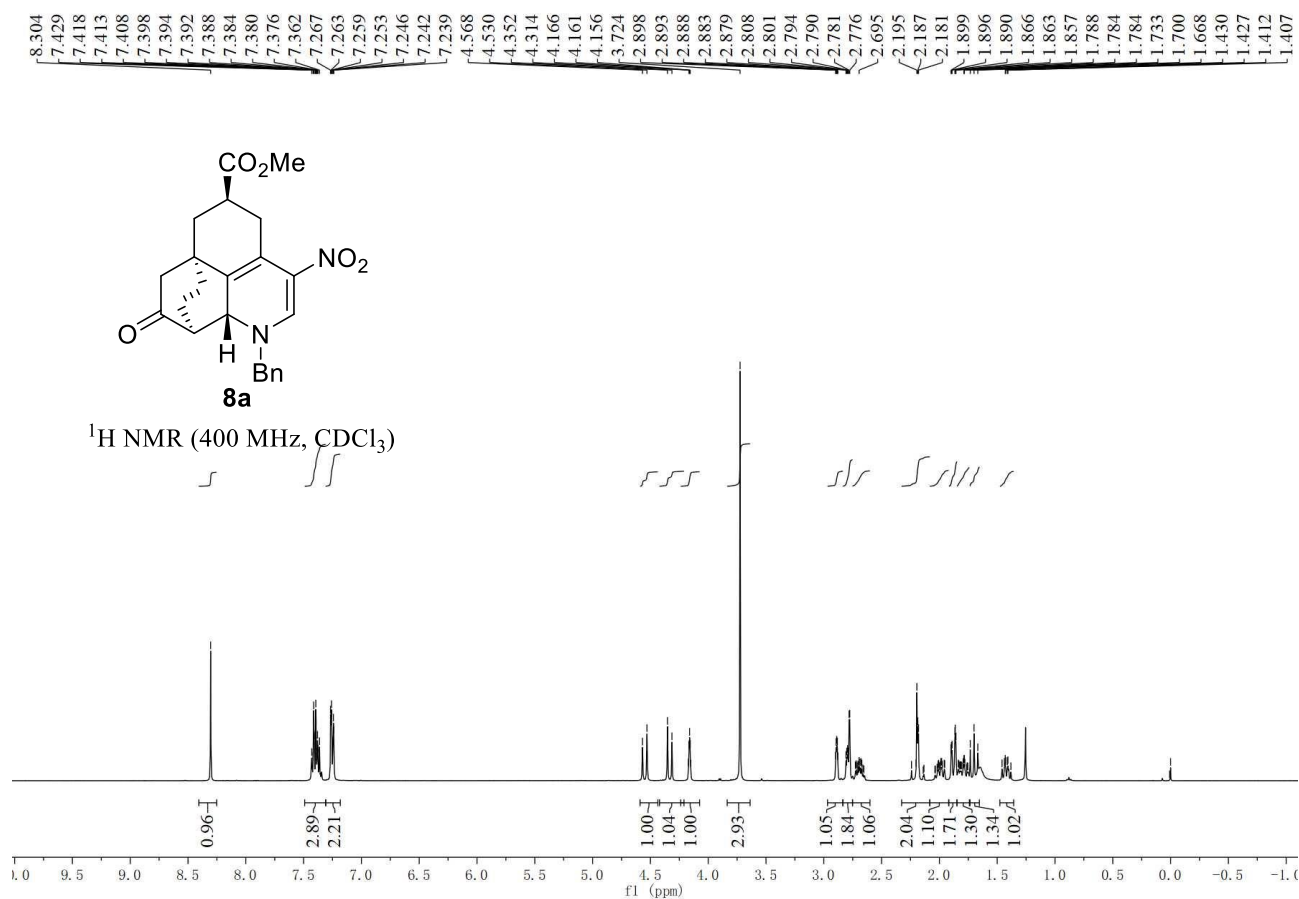
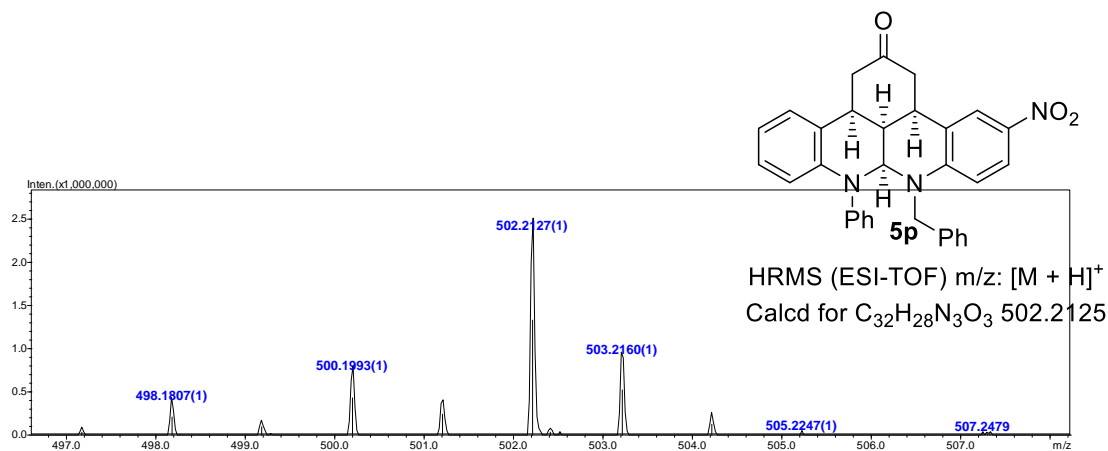


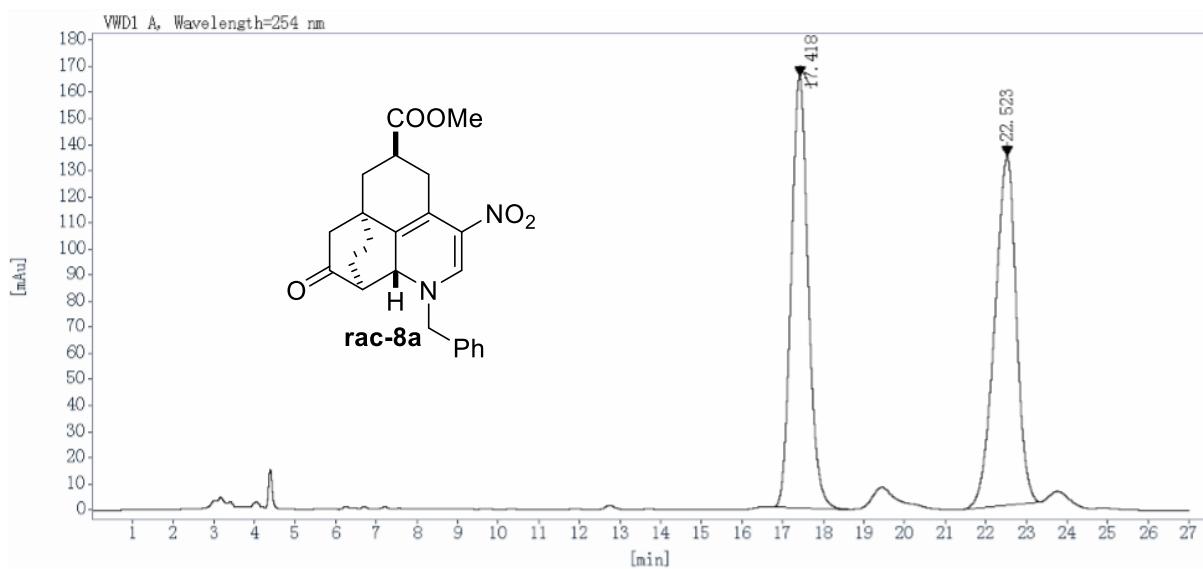
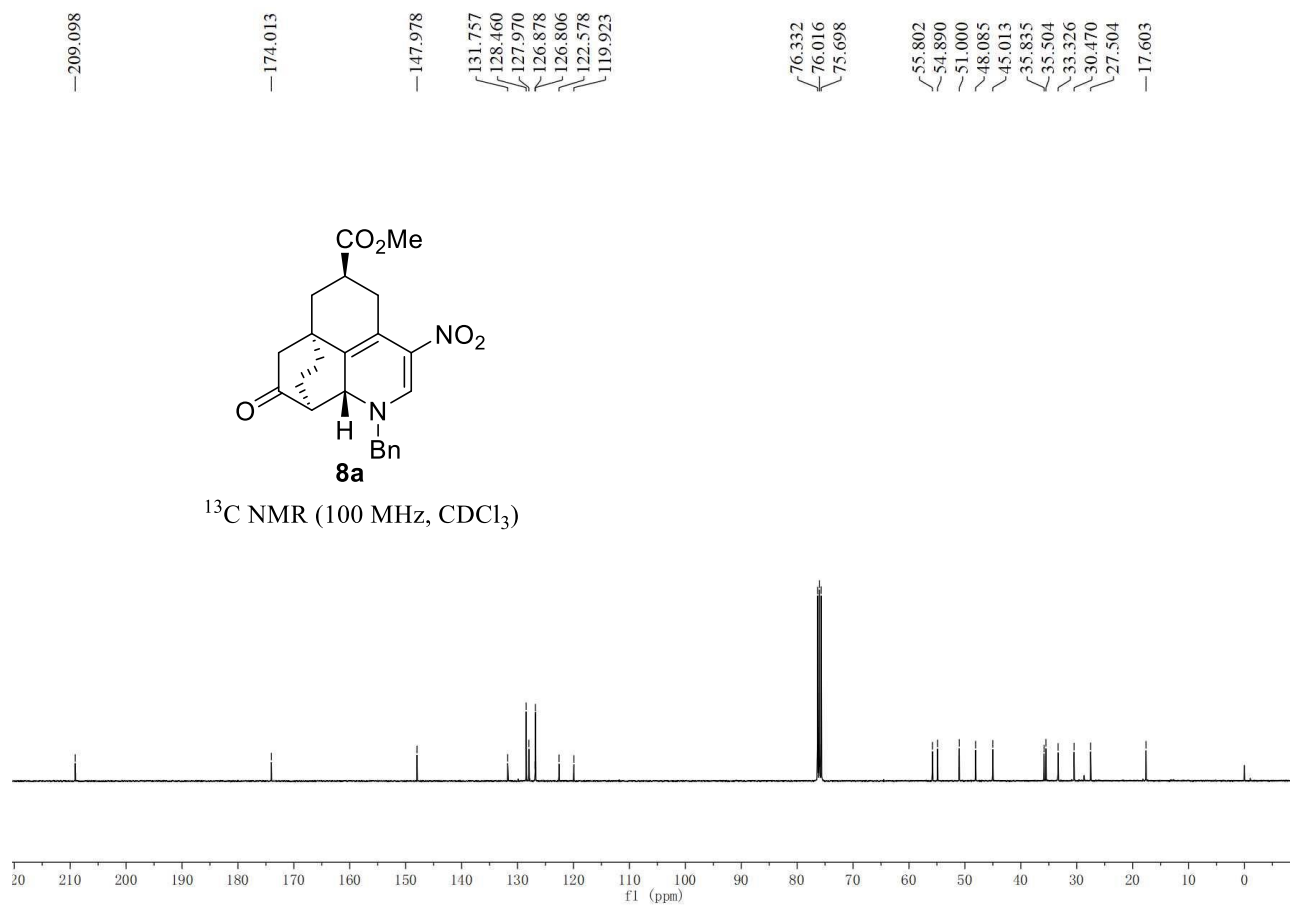


Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1 17.832	BB	0.5682	3249.40503	88.19733	46.6104
2 20.653	BBA	0.6840	3722.01636	83.36429	53.3896

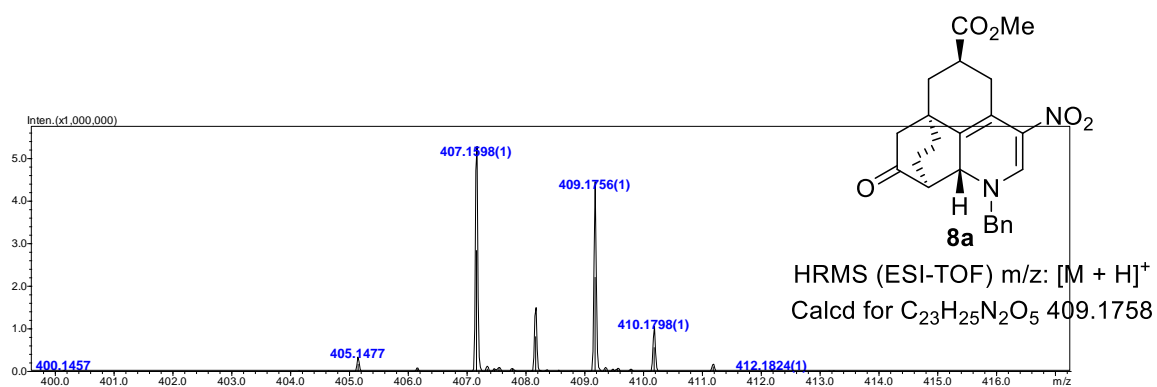
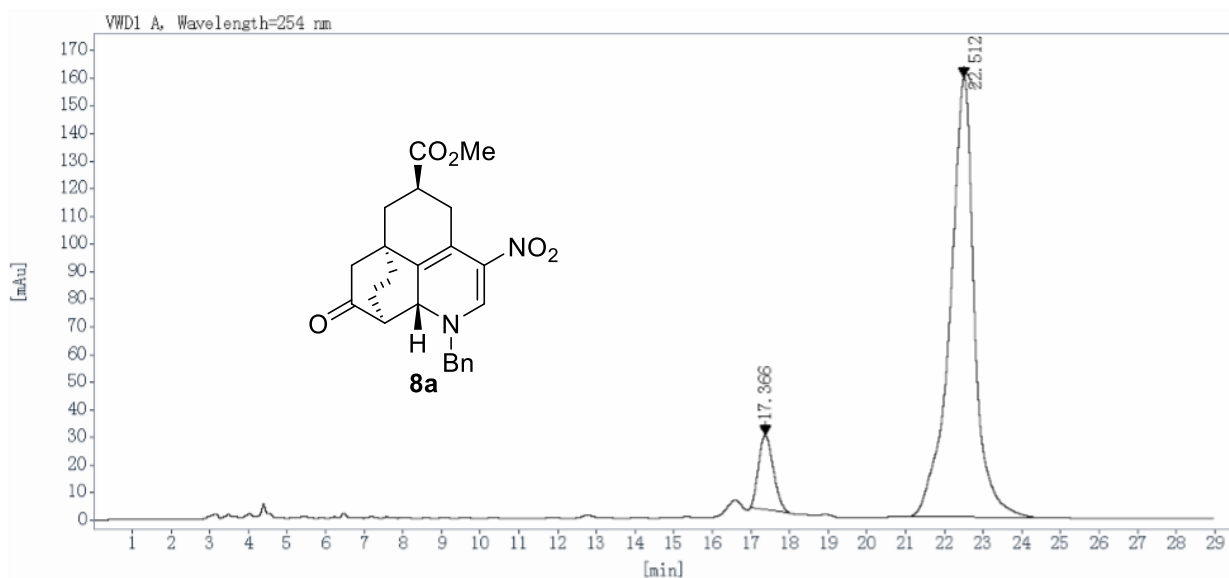


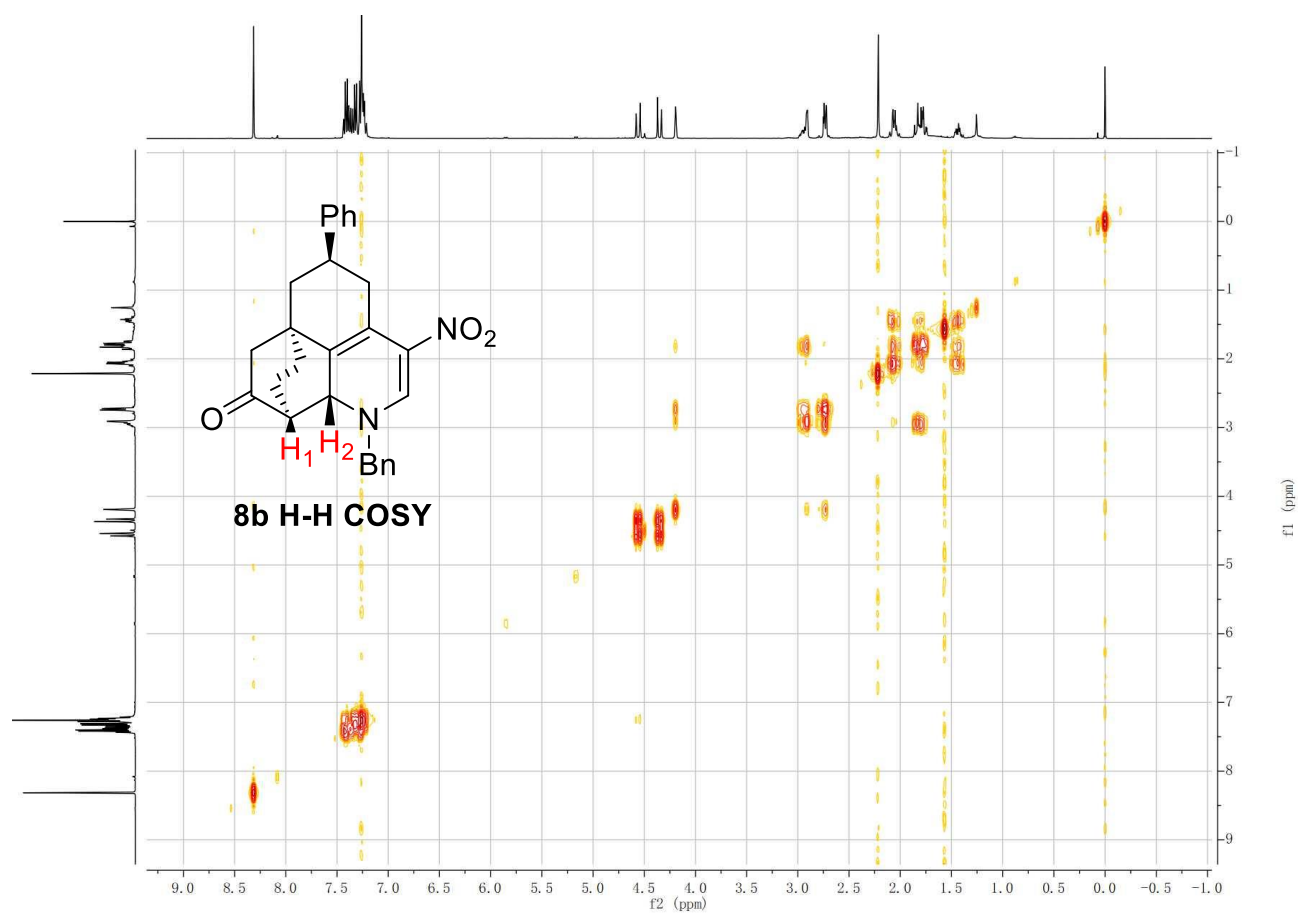
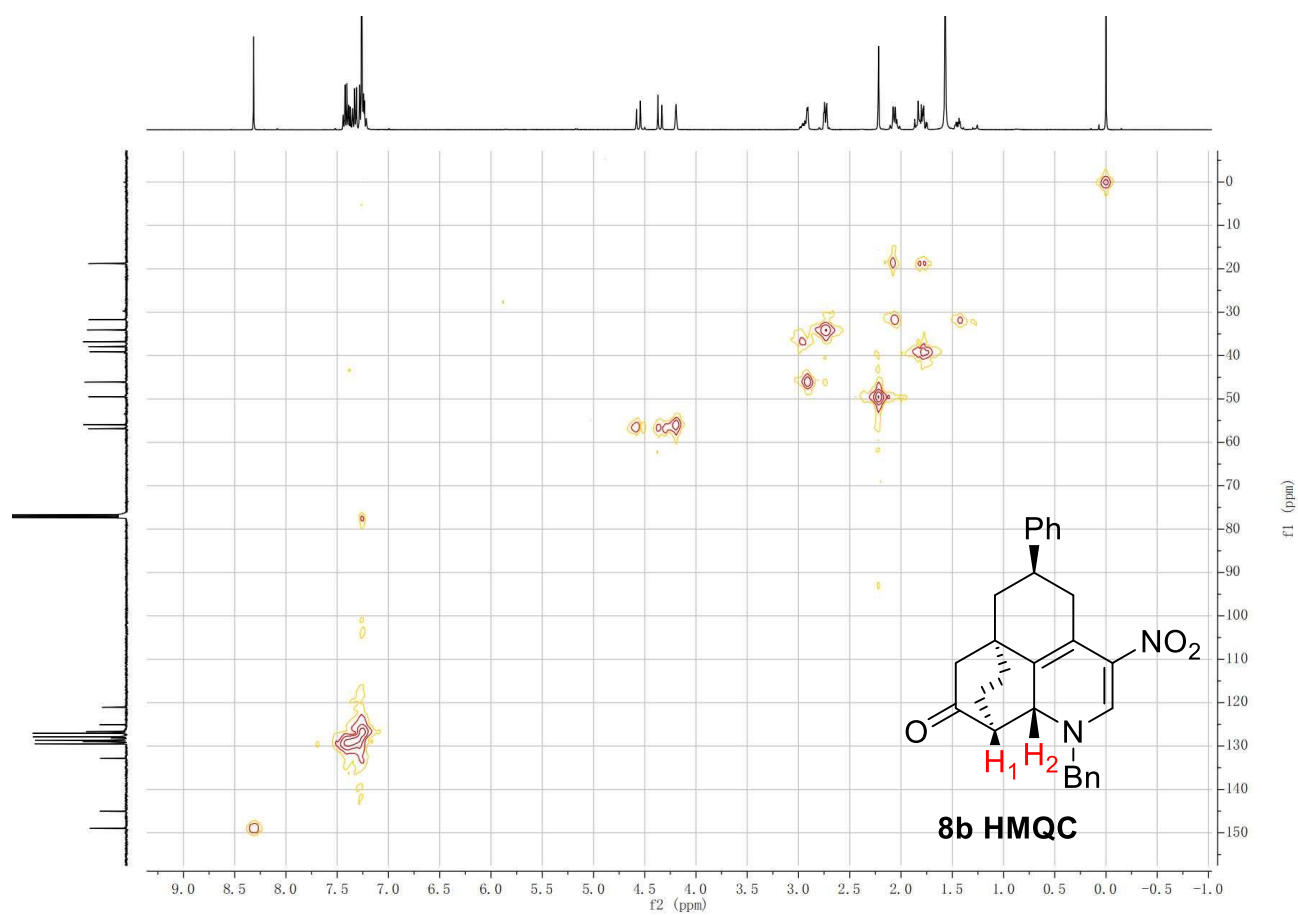
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1 17.885	BB	0.5524	1317.33337	36.98318	19.6144
2 20.571	BBA	0.7140	5398.82031	114.93725	80.3856

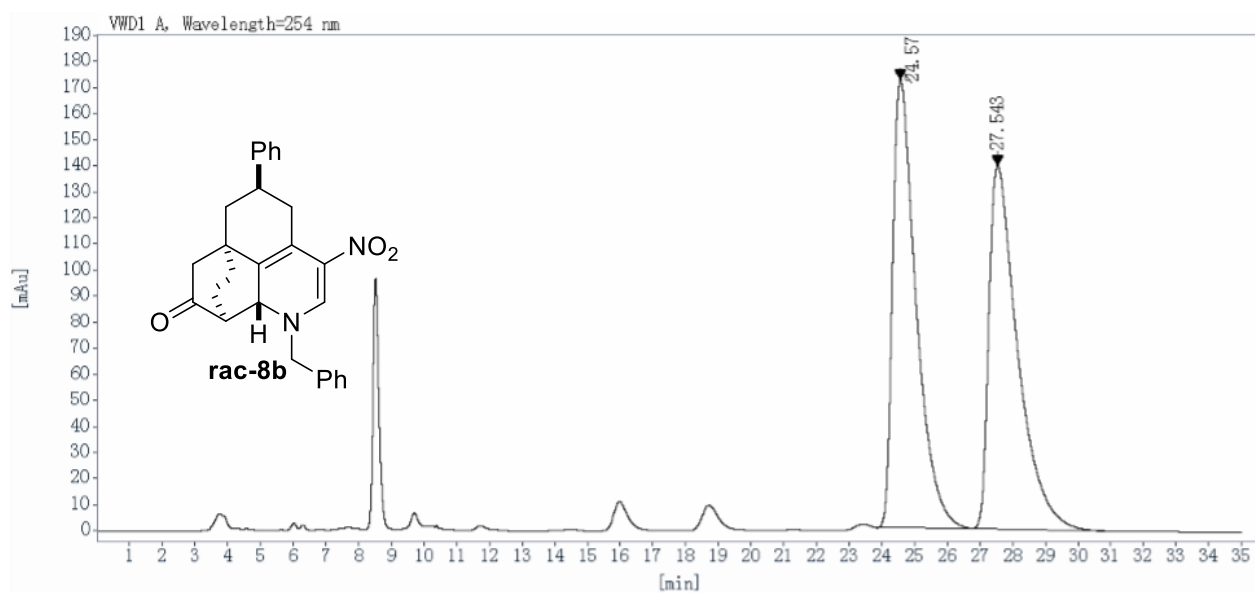
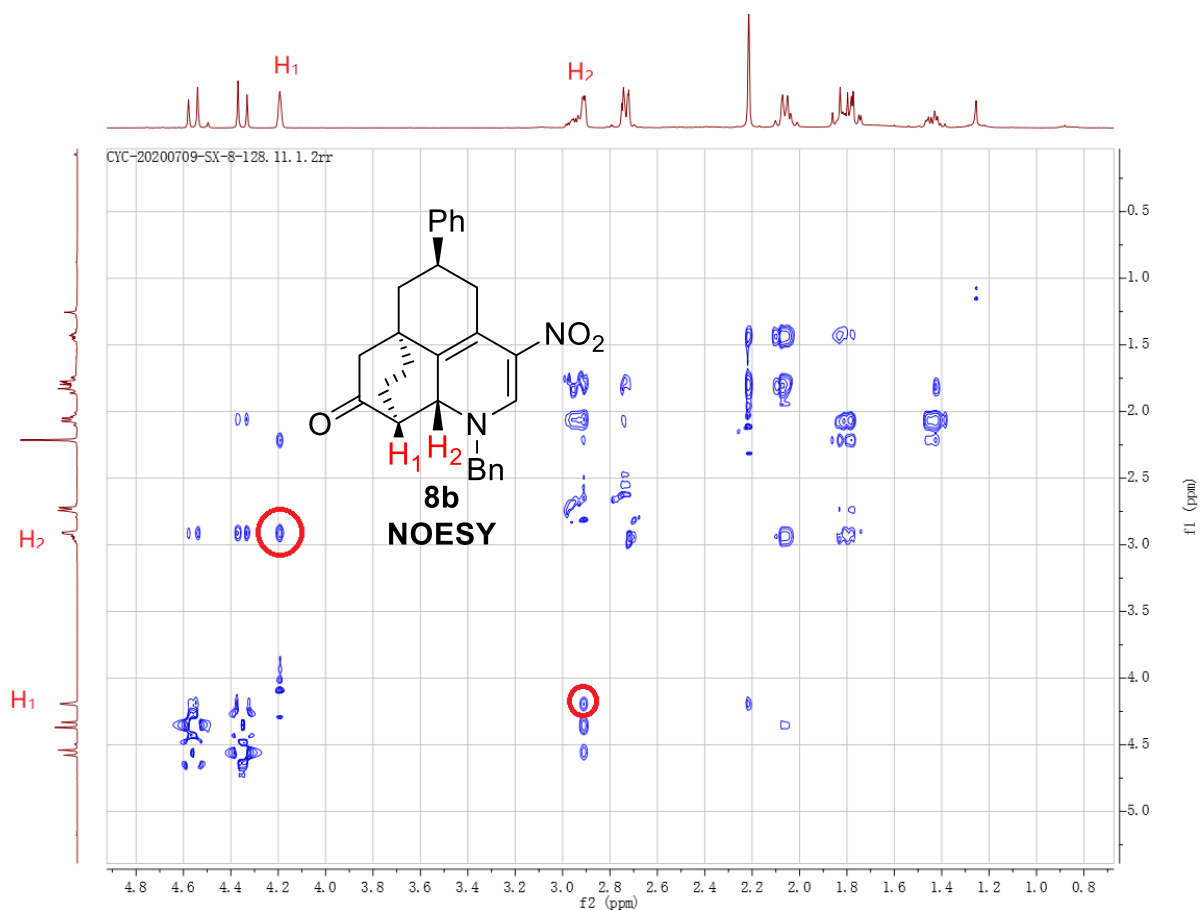




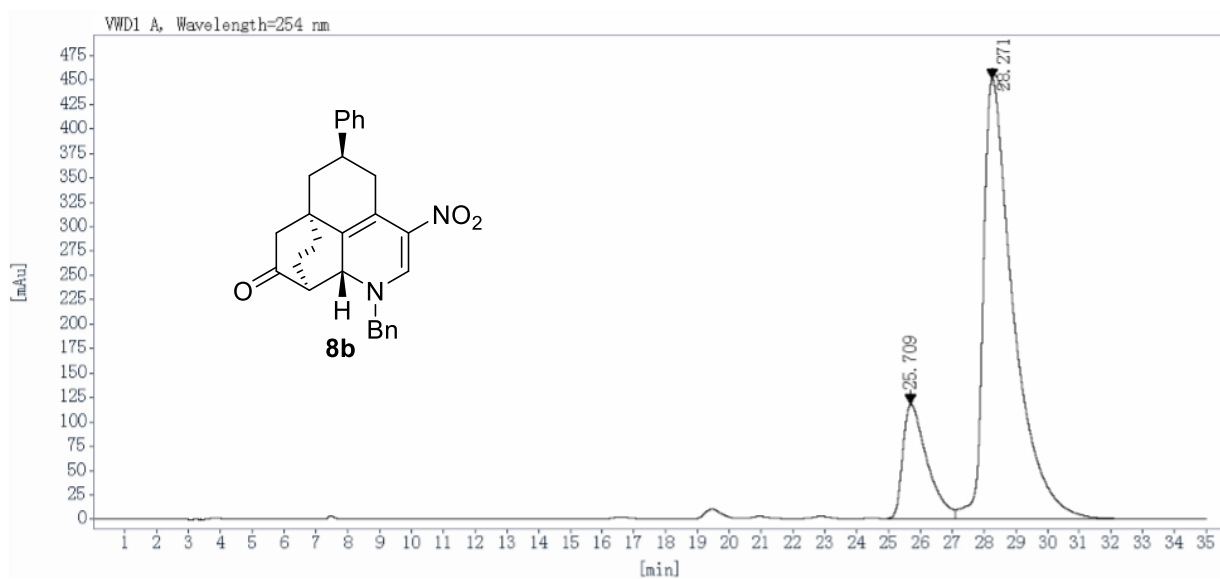
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
17.418	BB	0.45	165.4417	4792.8354	49.1920
22.523	BB	0.56	133.8709	4950.2793	50.8080
Totals:				9743.1147	100.0000







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
24.570	BB	0.75	172.0205	8563.0547	50.1850
27.543	BB	0.90	139.4481	8499.9150	49.8150
Totals:				17062.9697	100.0000

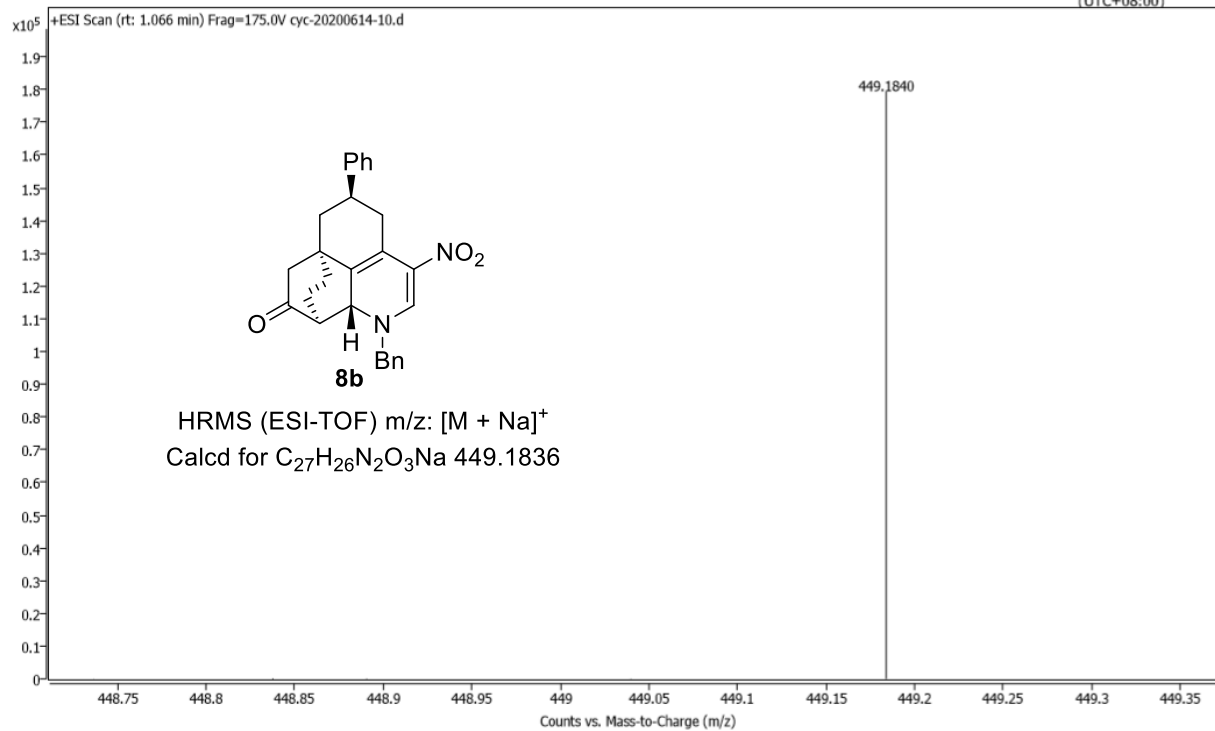


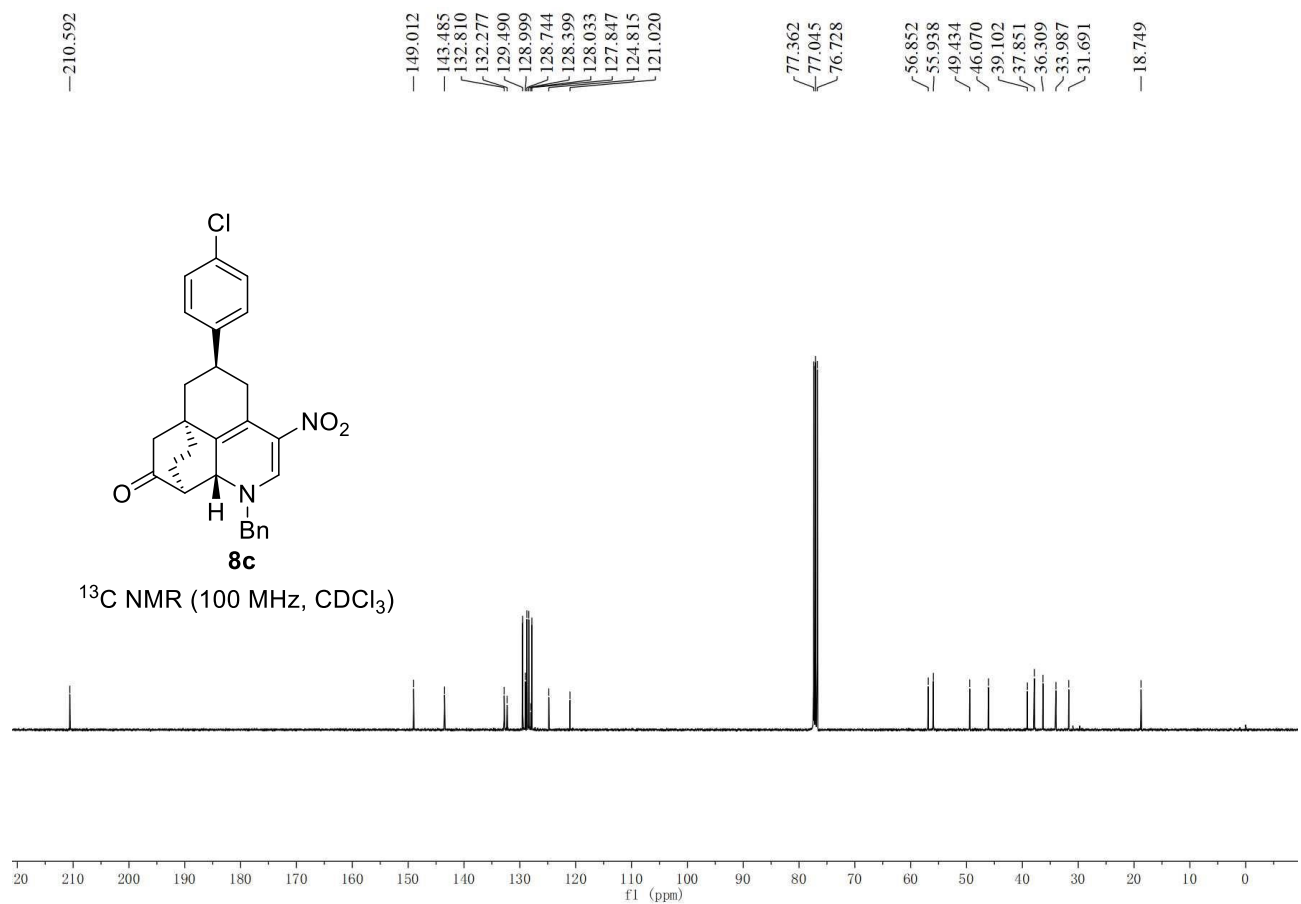
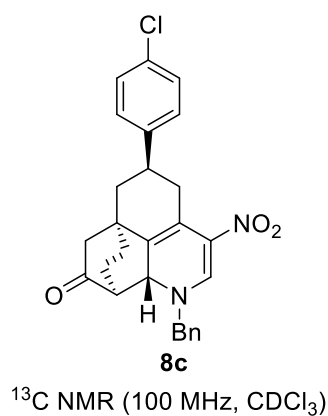
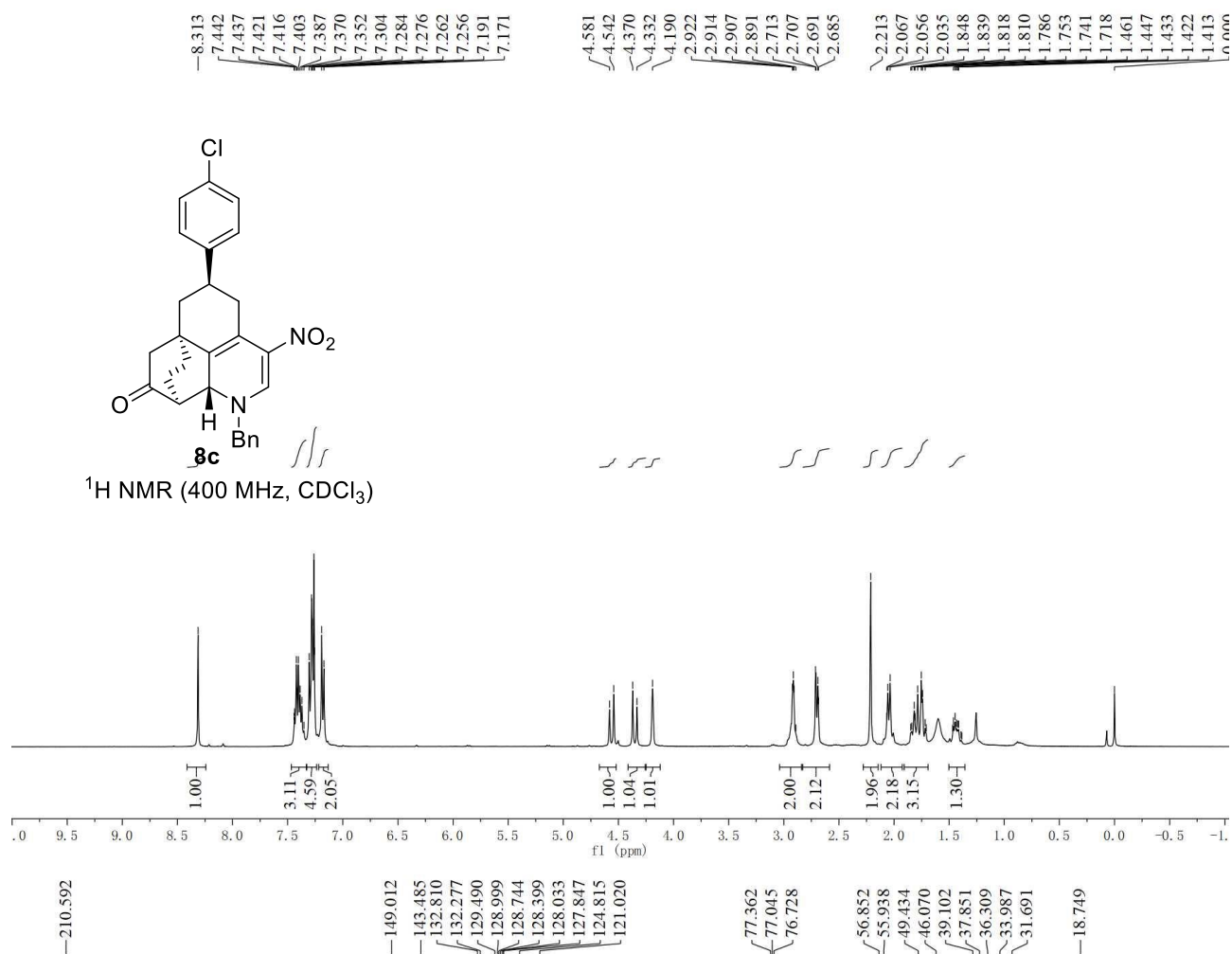
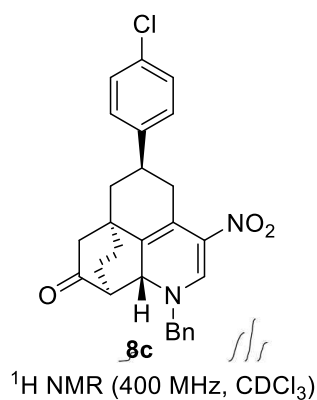
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
25.709	BV	0.80	117.1124	6223.1846	17.3359
28.271	VB	0.96	450.8990	29674.5664	82.6641
Totals:				35897.7510	100.0000

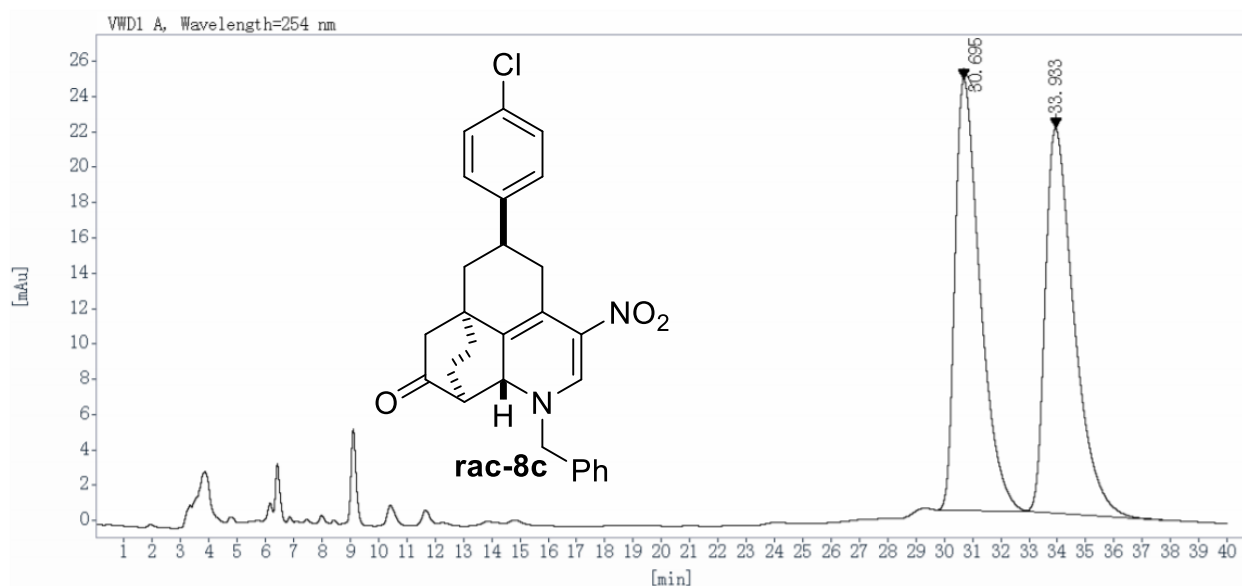
Spectrum Plot Report



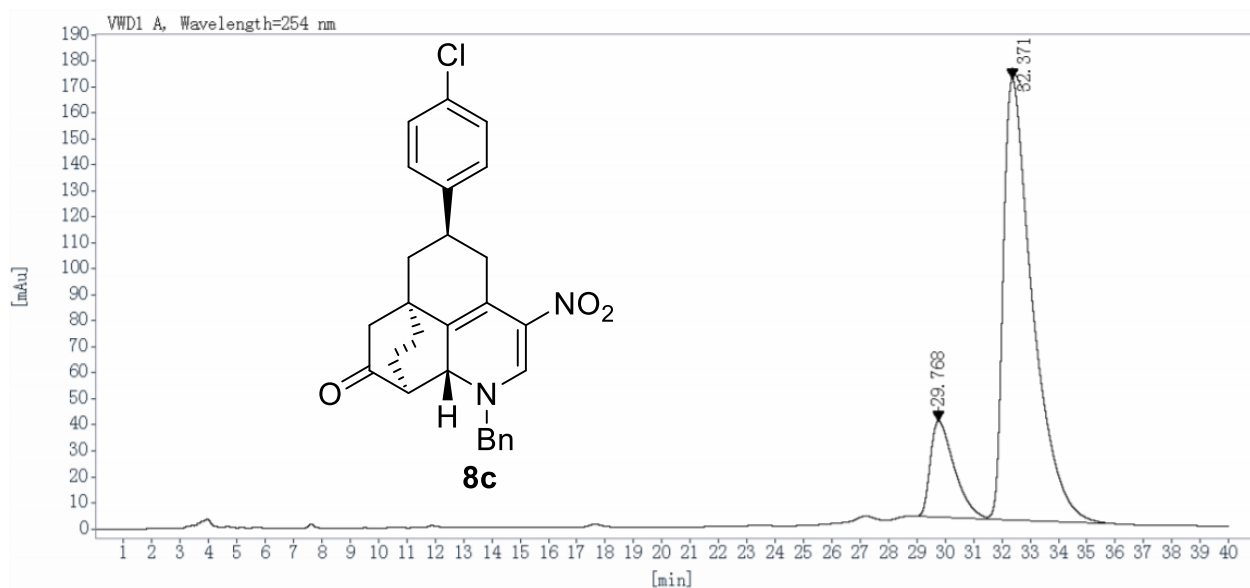
Name	cyc-20200614-10	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-20200614-10.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 6/18/2020 4:57:30 PM (UTC+08:00)







Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
30.695	BB	0.93	24.4035	1501.4353	49.3630
33.933	BB	1.06	21.7460	1540.1831	50.6370
Totals:				3041.6184	100.0000

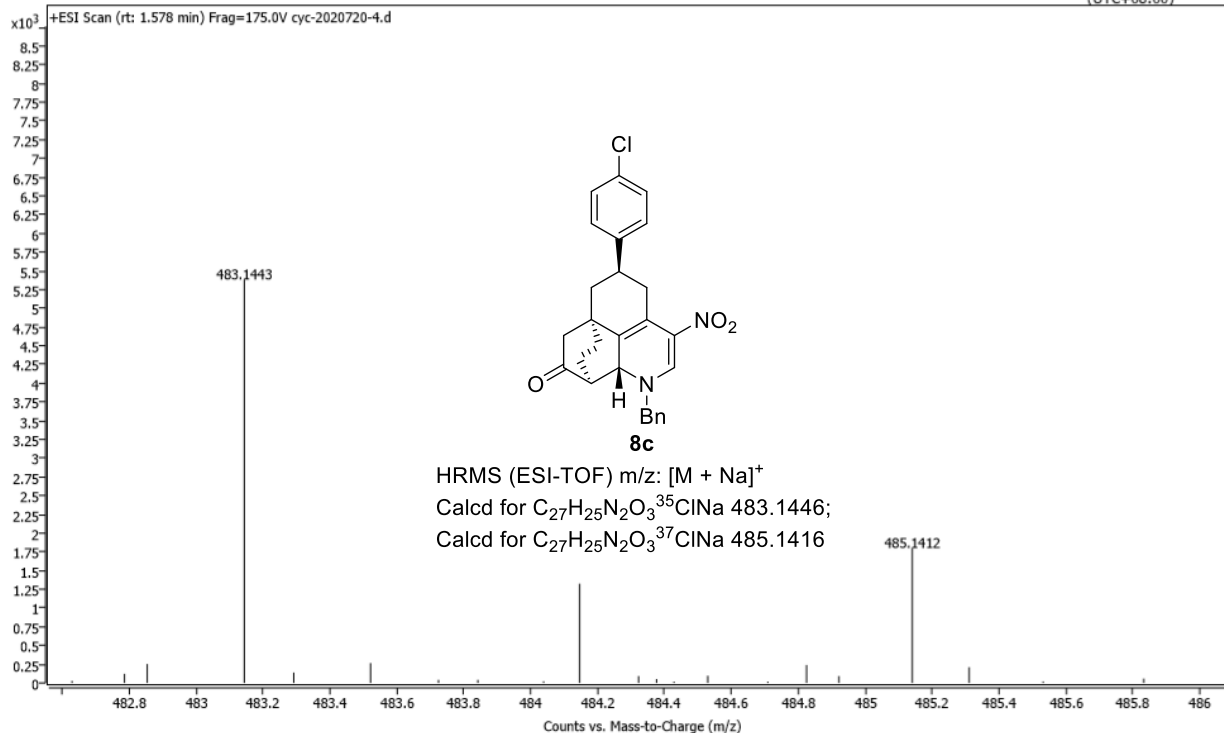


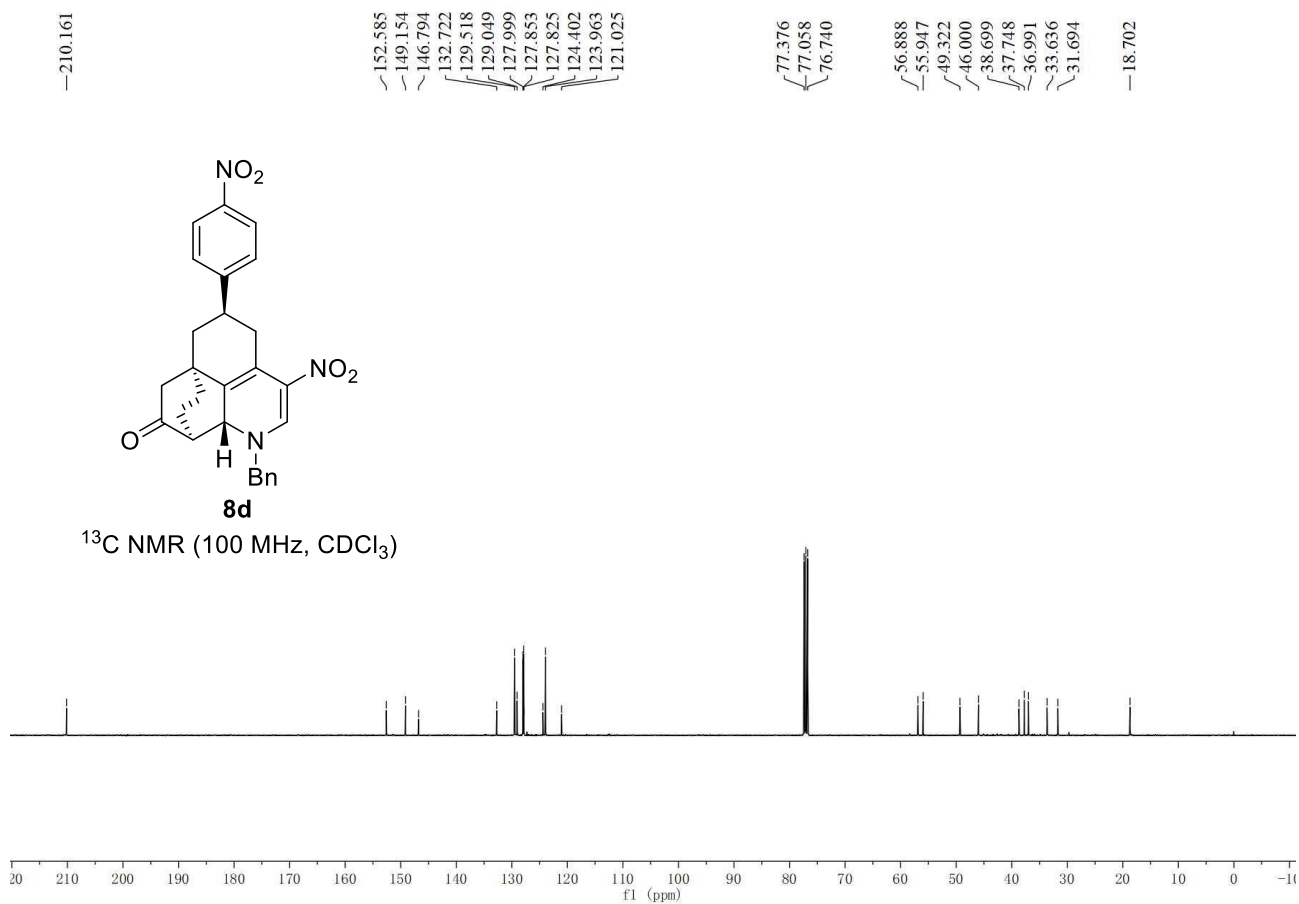
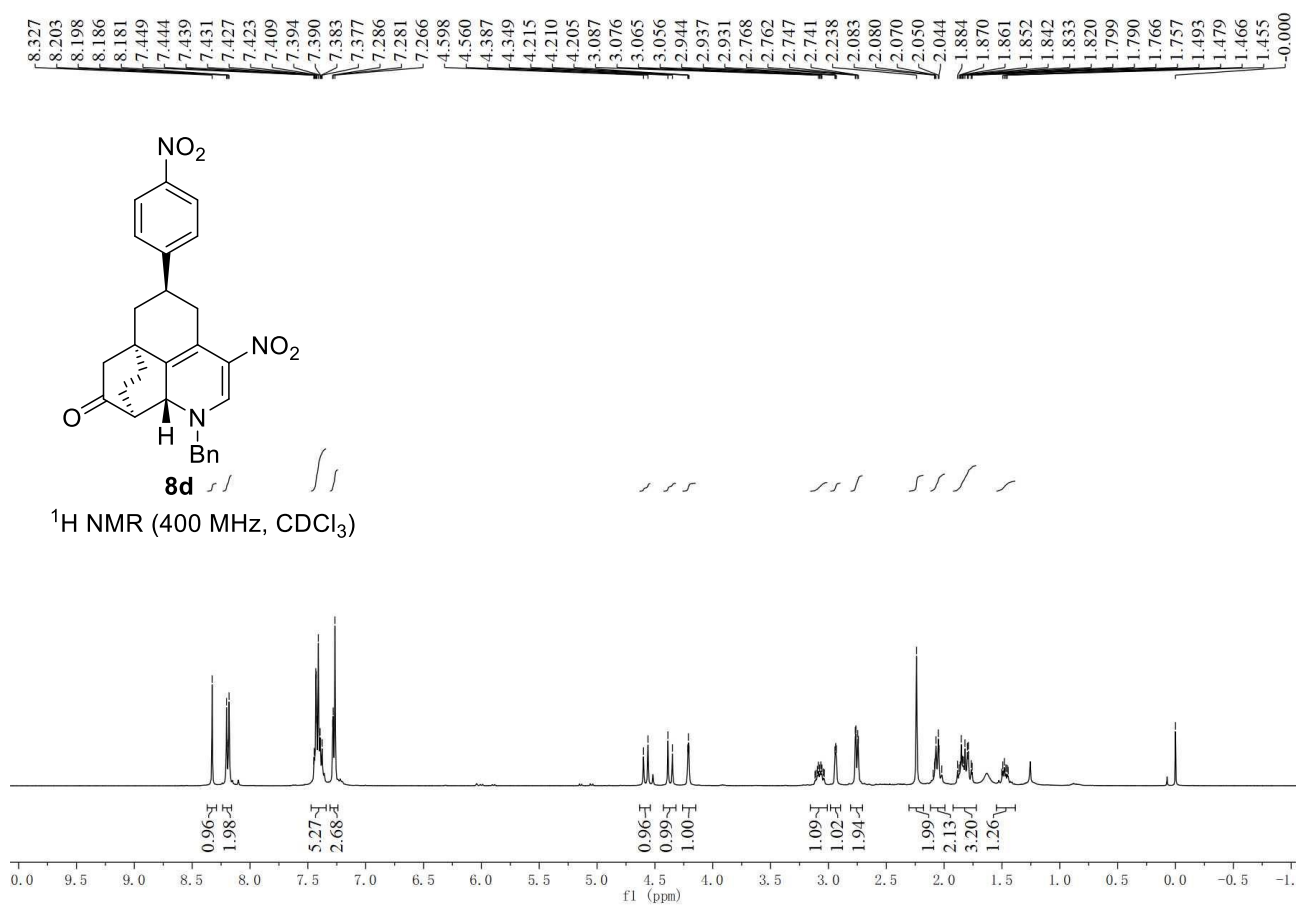
Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
29.768	BV	0.89	36.9707	2181.1409	15.1756
32.371	VB	1.06	169.8061	12191.5059	84.8244
Totals:				14372.6467	100.0000

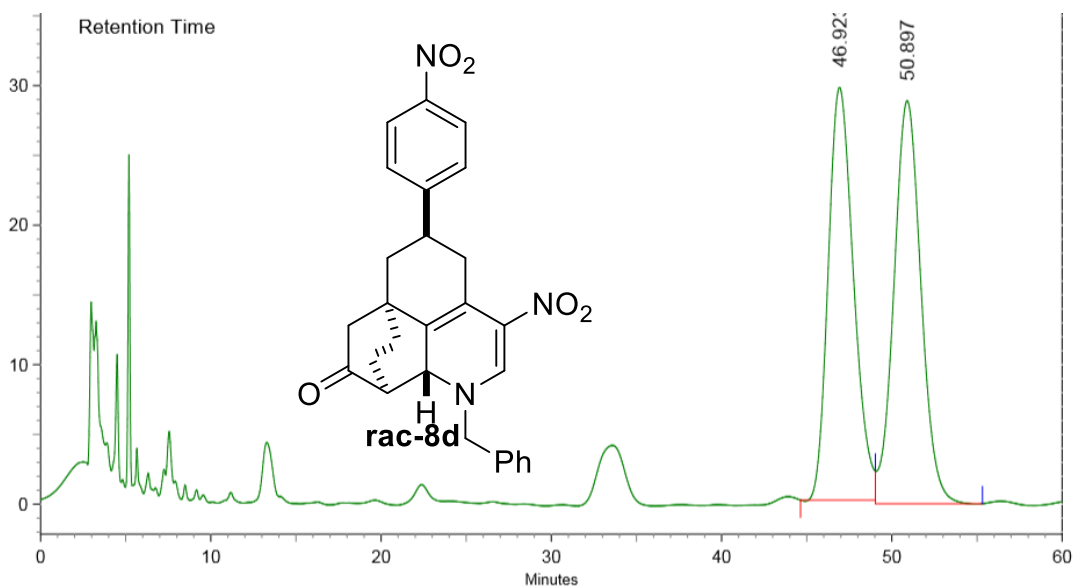
Spectrum Plot Report



Name	cyc-2020720-4	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-2020720-4.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 7/24/2020 3:21:17 PM (UTC+08:00)

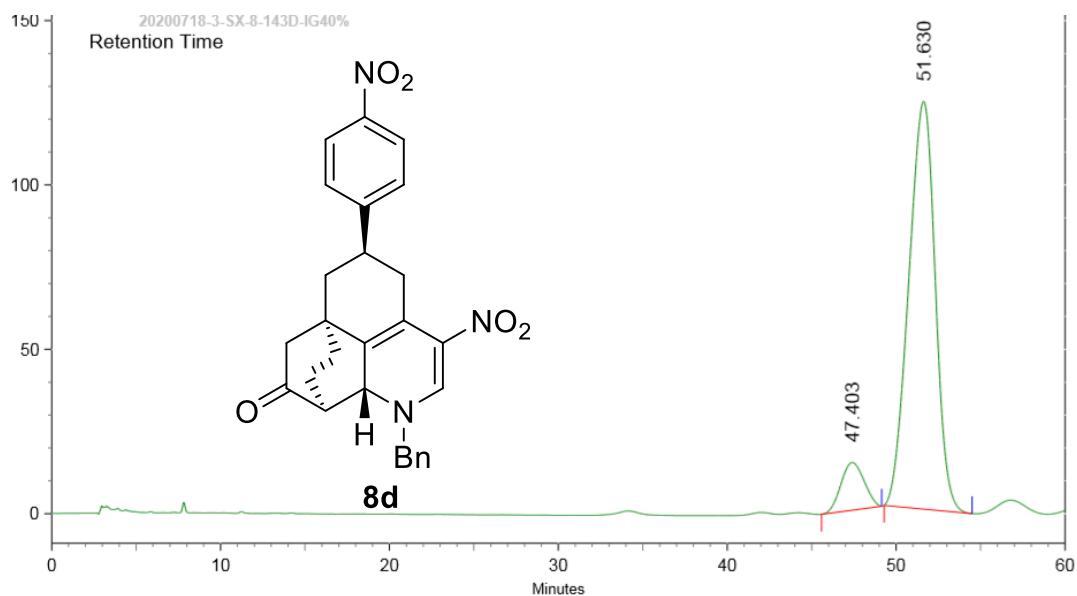






AREA PERCENT REPORT

Peak No.	Ret Time	Width	Height	Area	Area [%]
1	46.923	4.393	496230	51172685	48.8419
2	50.897	6.292	484622	53599499	51.1581
Totals					
			980852	104772184	100.0000



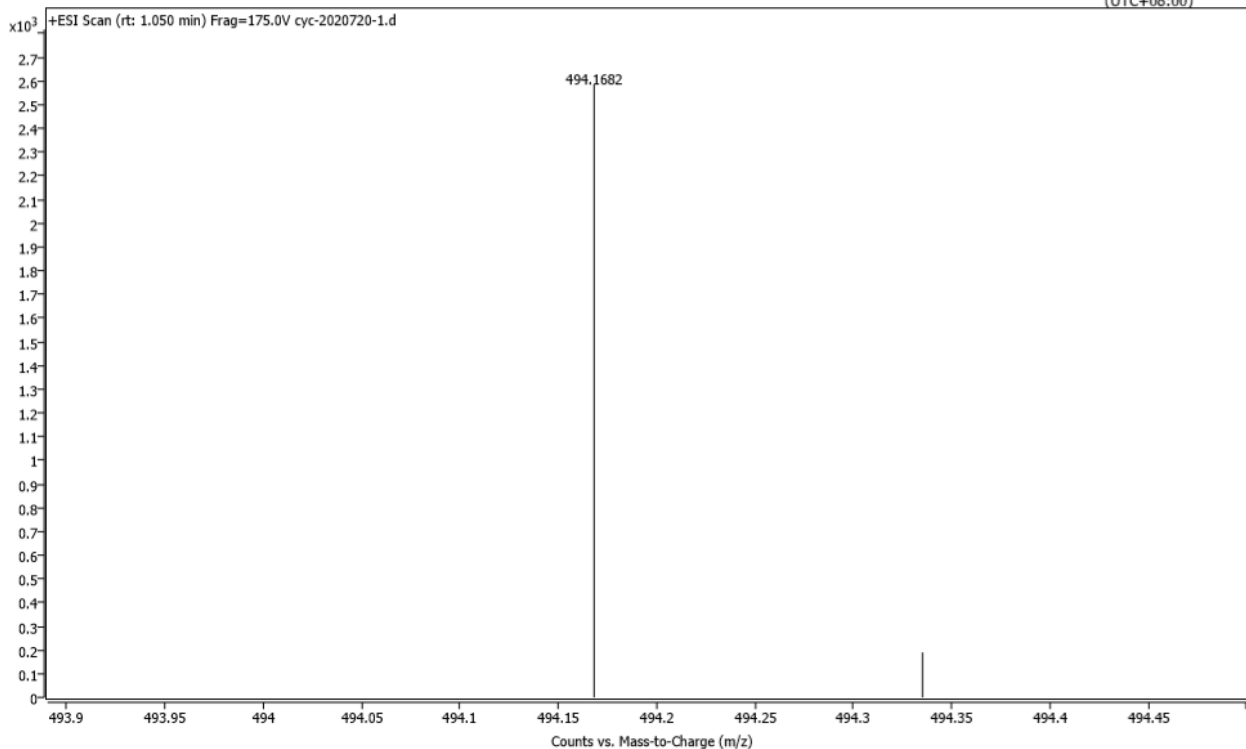
AREA PERCENT REPORT

Peak No.	Ret Time	Width	Height	Area	Area [%]
1	47.403	3.563	243369	23139177	9.2657
2	51.630	5.207	2081047	226590958	90.7343
Totals					
			2324416	249730135	100.0000

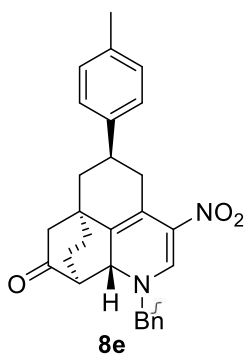
Spectrum Plot Report



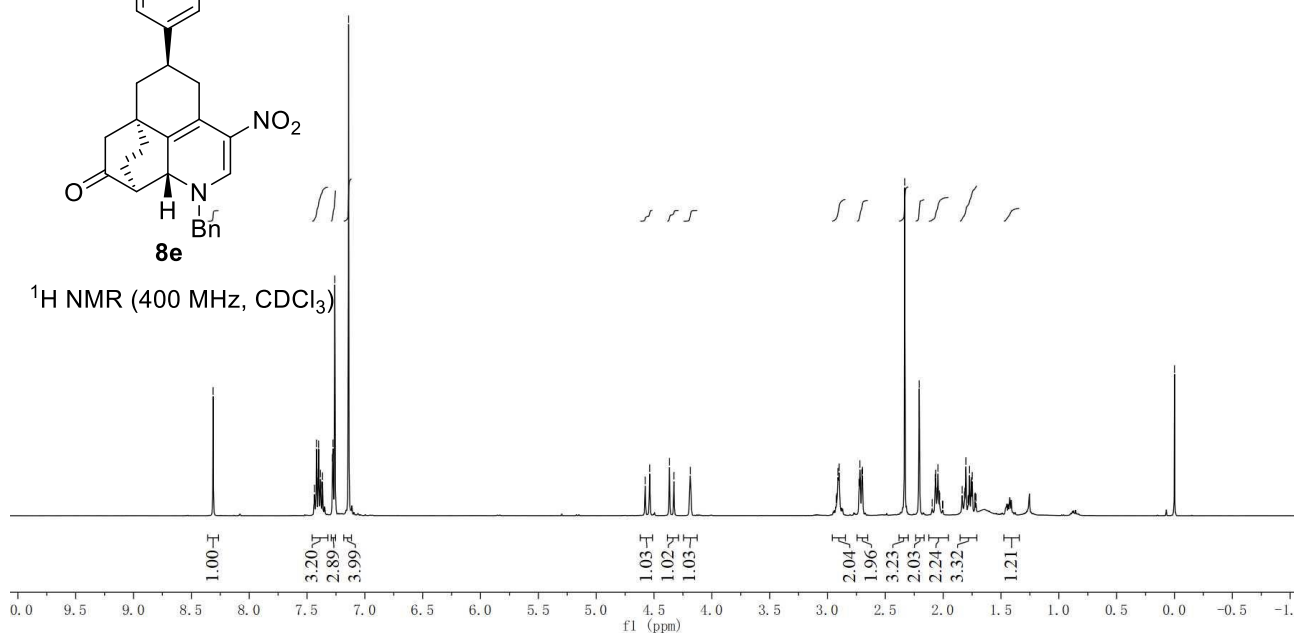
Name	cyc-2020720-1	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-2020720-1.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local) 7/24/2020 3:12:06 PM (UTC+08:00)



8.312, 7.435, 7.418, 7.414, 7.404, 7.400, 7.384, 7.380, 7.366, 7.280, 7.276, 7.270, 7.260, 7.141, 4.576, 4.538, 4.536, 4.366, 4.328, 4.186, 2.924, 2.920, 2.910, 2.899, 2.727, 2.720, 2.715, 2.703, 2.697, 2.333, 2.207, 2.095, 2.069, 2.064, 2.052, 2.045, 2.033, 2.030, 2.006, 2.003, 1.836, 1.816, 1.812, 1.803, 1.785, 1.781, 1.772, 1.759, 1.756, 1.749, 1.726, 1.723, 1.716, 0.000



¹H NMR (400 MHz, CDCl₃)

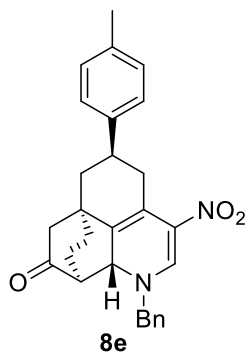


—210.895

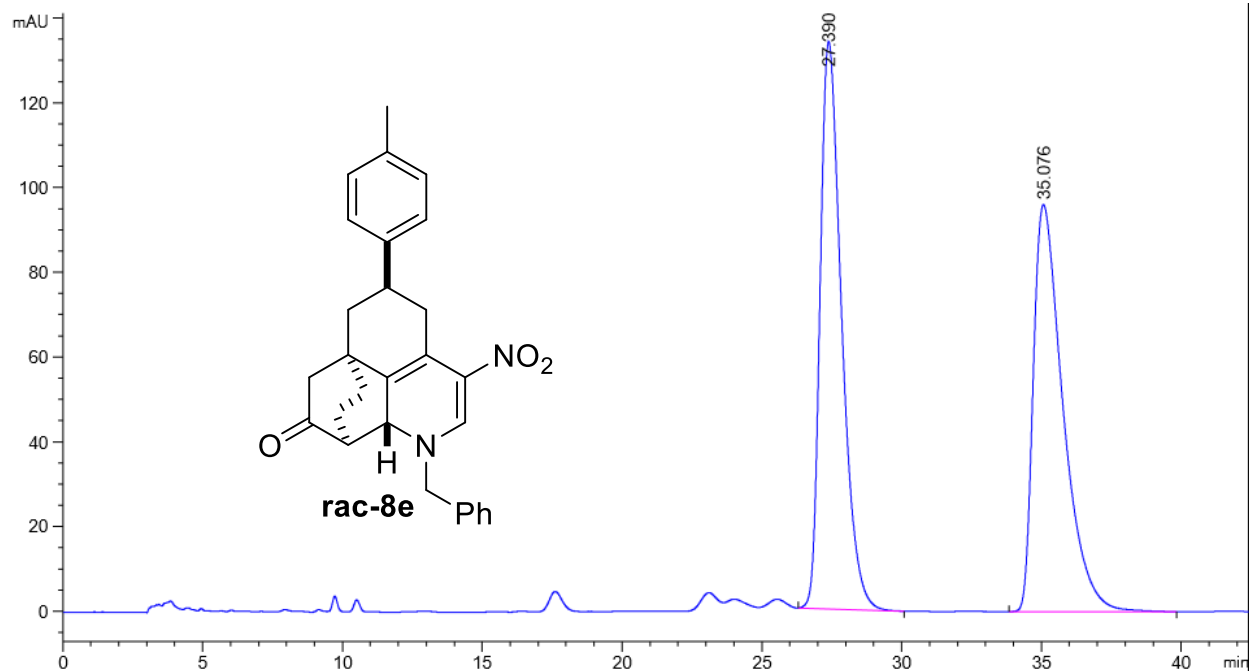
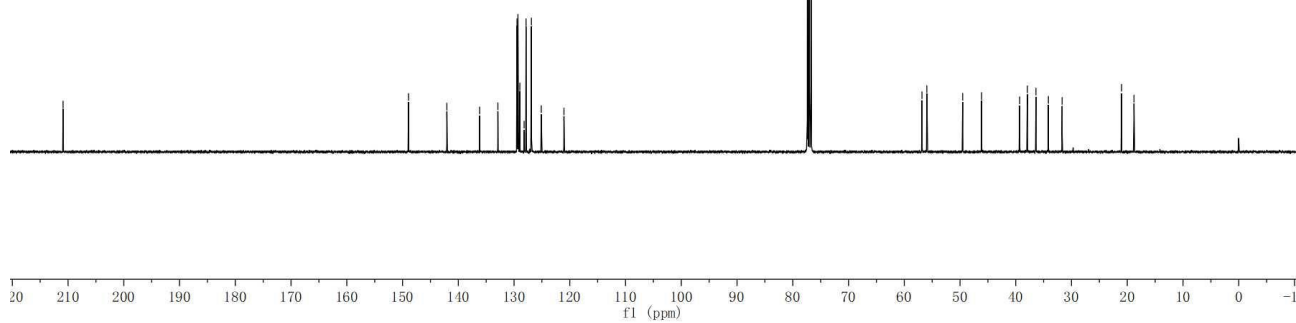
148.925
142.051
136.173
132.898
129.468
129.302
128.956
128.194
127.850
126.882
125.121
121.048

77.362
77.045
76.727

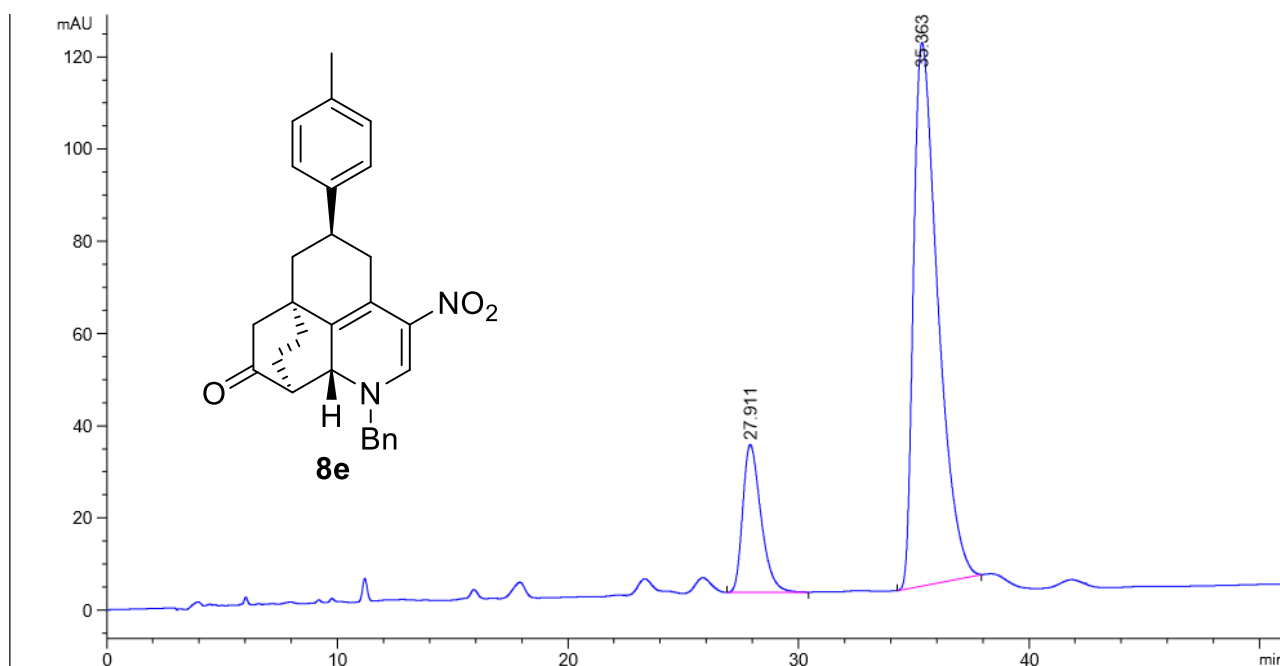
56.825
55.950
49.524
46.131
39.305
37.922
36.377
34.151
31.688
21.024
18.793



^{13}C NMR (100 MHz, CDCl_3)



	Ret Time	Peak	Width	Height	Area	Area
	[min]	Type	[min]	[mAU]	[mAU*s]	[%]
1	27.390	BB	0.8160	7126.36182	133.90598	50.1389
2	35.076	BB	1.0938	7086.87744	96.05139	49.8611

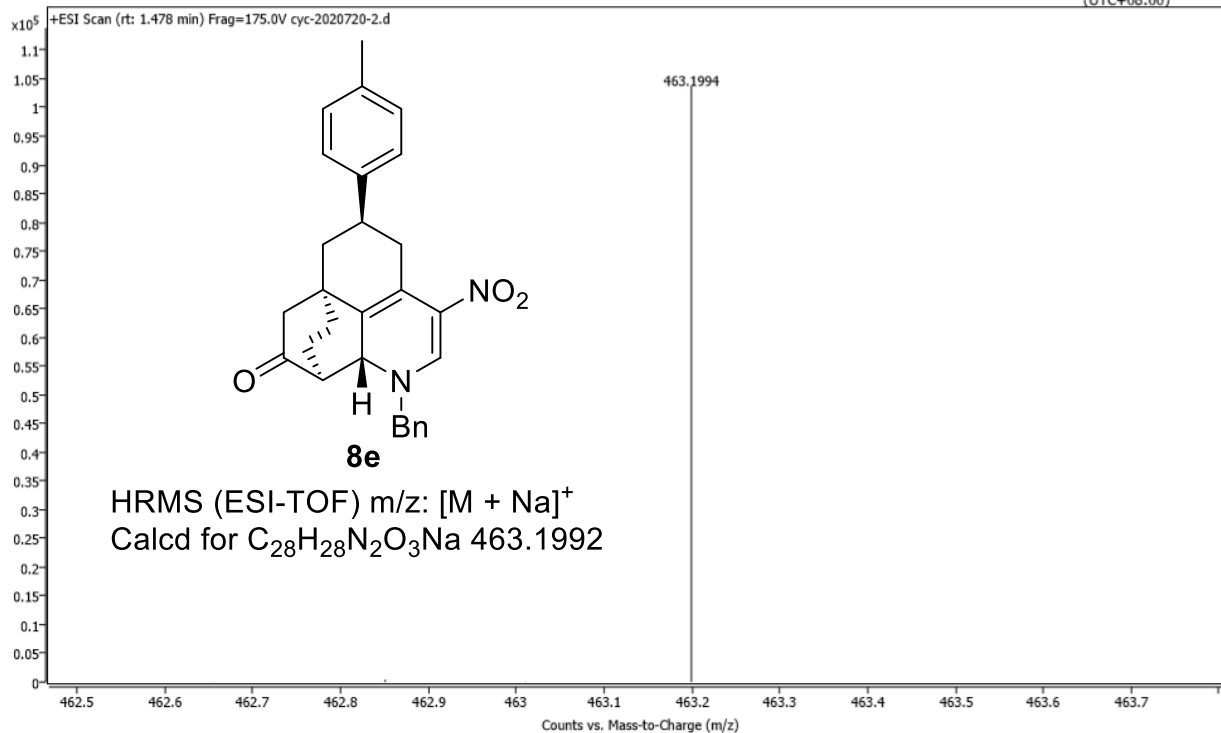


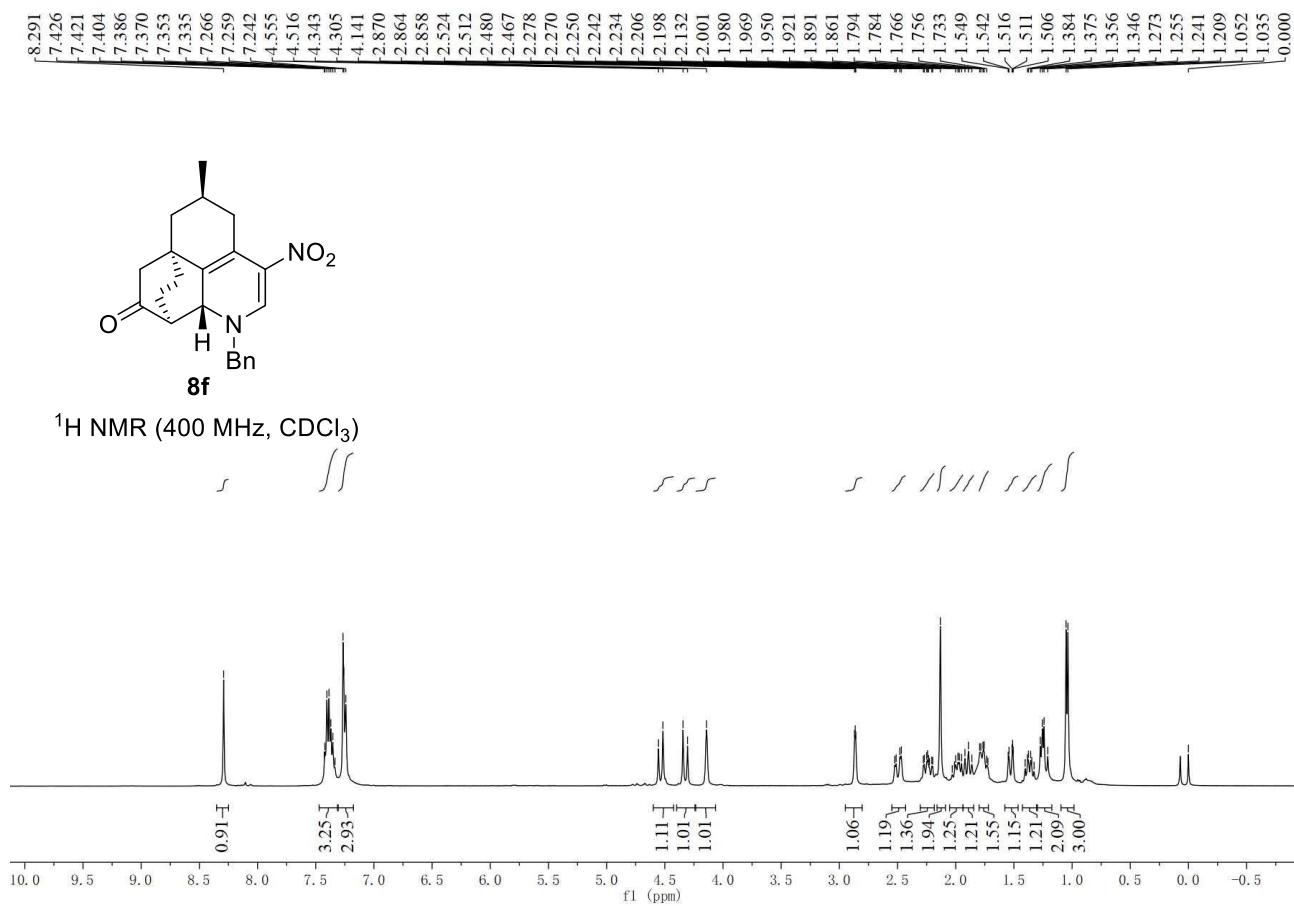
	Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1	27.911	BB	0.8303	1765.22314	32.05513	16.9547
2	35.363	BB	1.1112	8646.15820	117.78127	83.0453

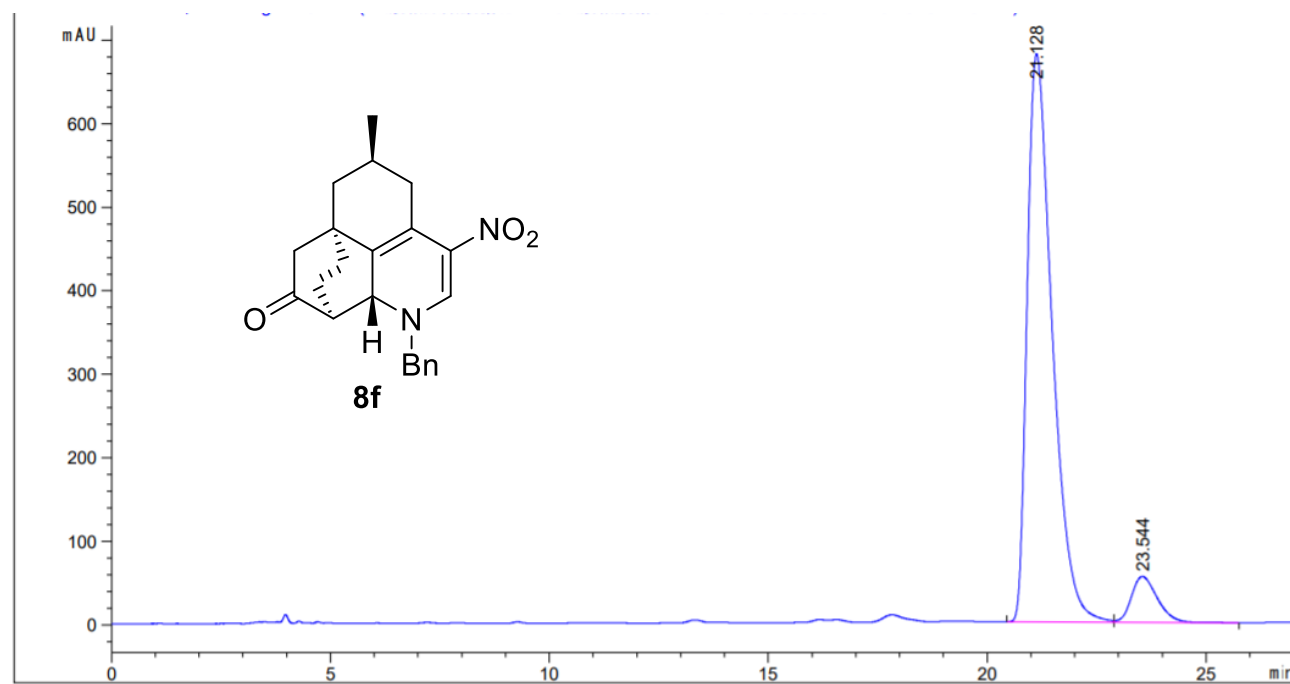
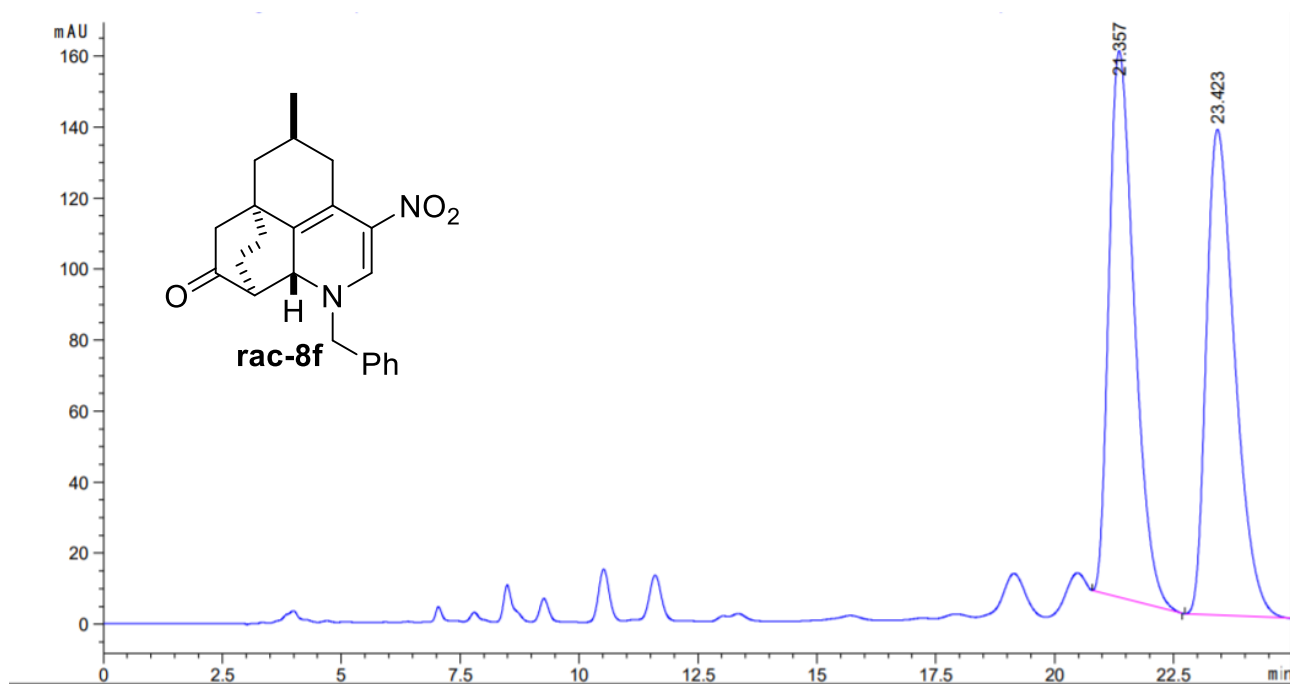
Spectrum Plot Report



Name: cyc-2020720-2
 Inj. Vol. (ul): 10
 Data File: cyc-2020720-2.d
 Rack Pos.:
 Plate Pos.:
 Method (Acq): TOF.m
 Instrument: IRM Status
 Comment:
 Instrument 1: Success
 Operator:
 Acq. Time (Local): 7/24/2020 3:15:15 PM
 (UTC+08:00)



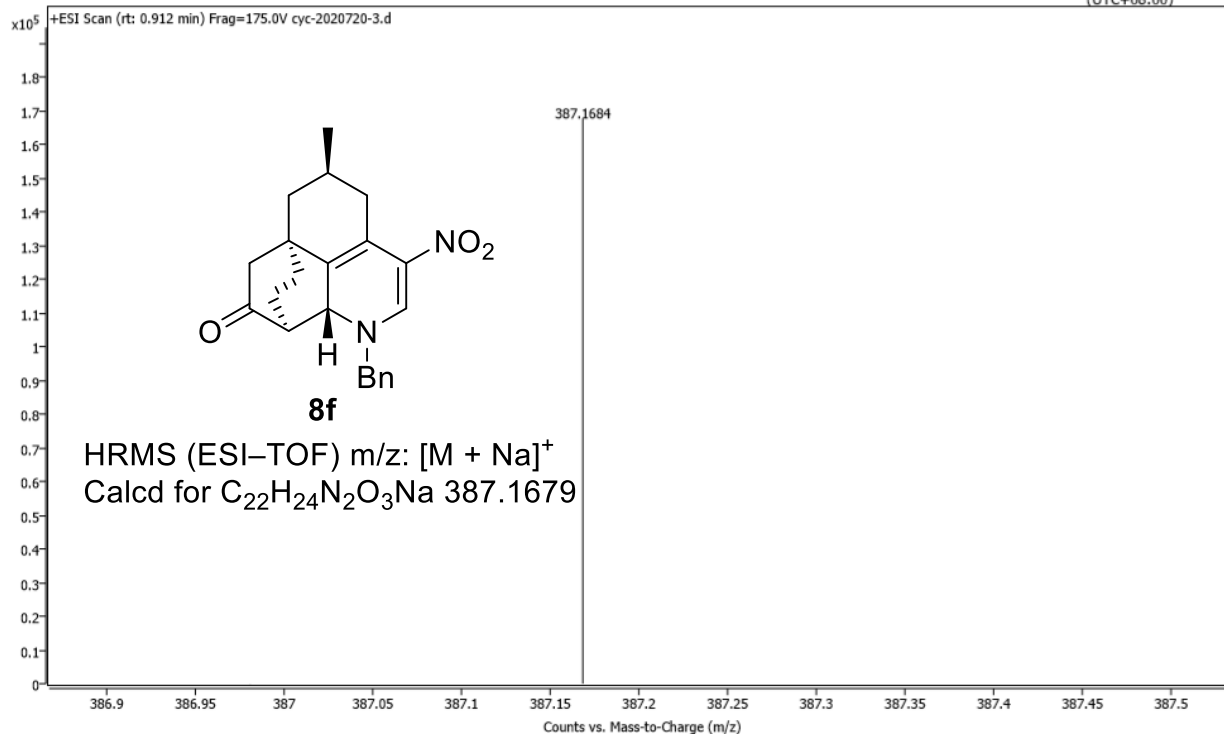


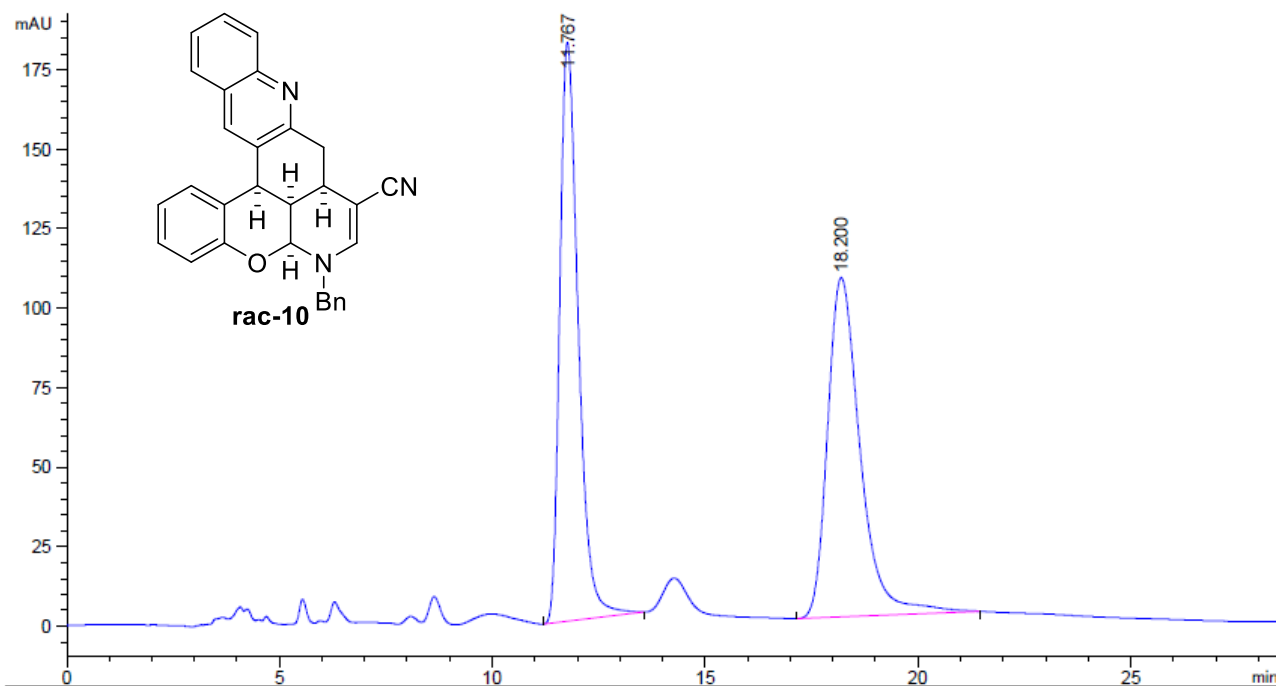


Spectrum Plot Report

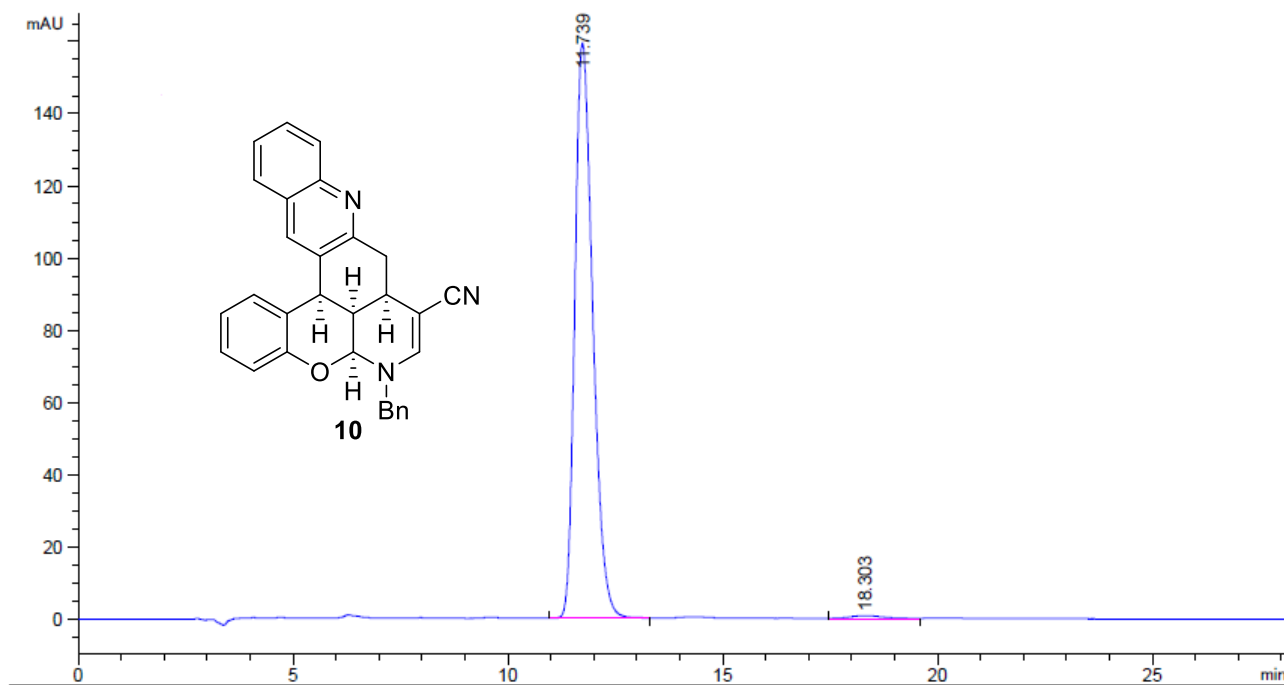


Name	cyc-2020720-3	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	cyc-2020720-3.d	Method (Acq)	TOF.m		Acq. Time (Local)
					7/24/2020 3:18:16 PM (UTC+08:00)





	Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1	11.767	BB	0.4628	5490.62695	181.93011	49.0860
2	18.200	BBA	0.8152	5695.10986	106.65697	50.9140

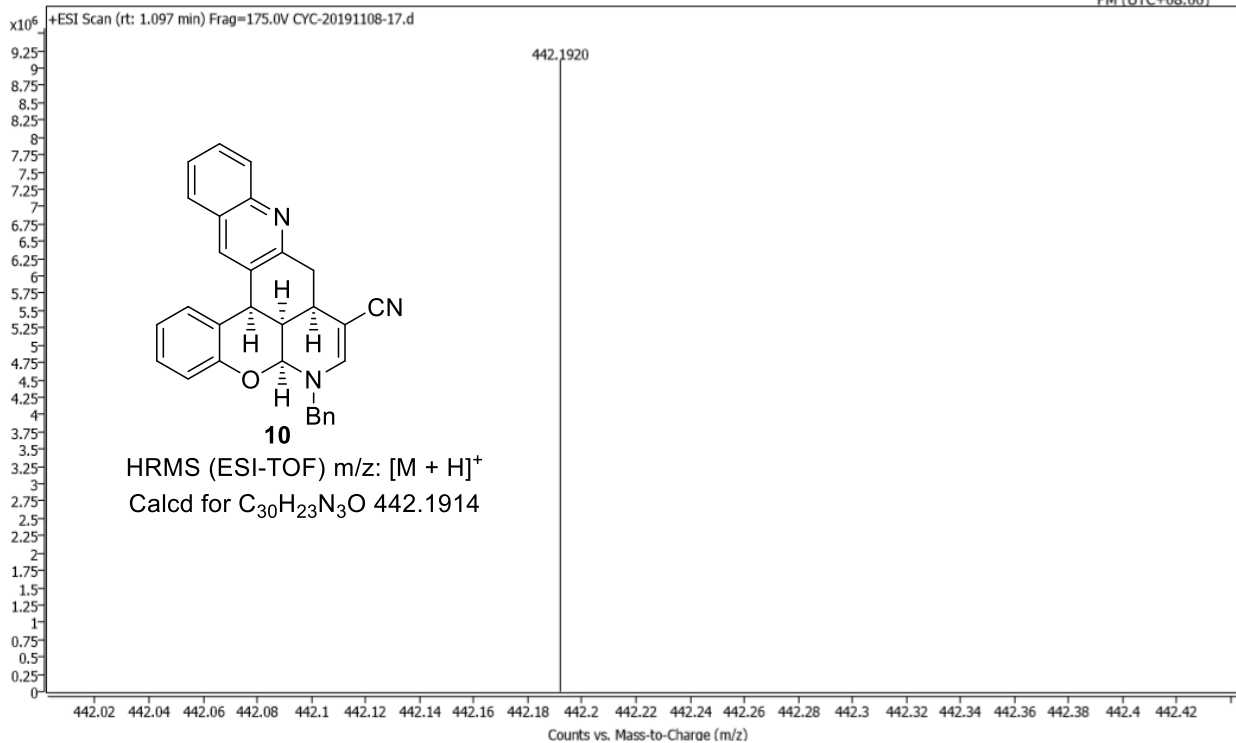


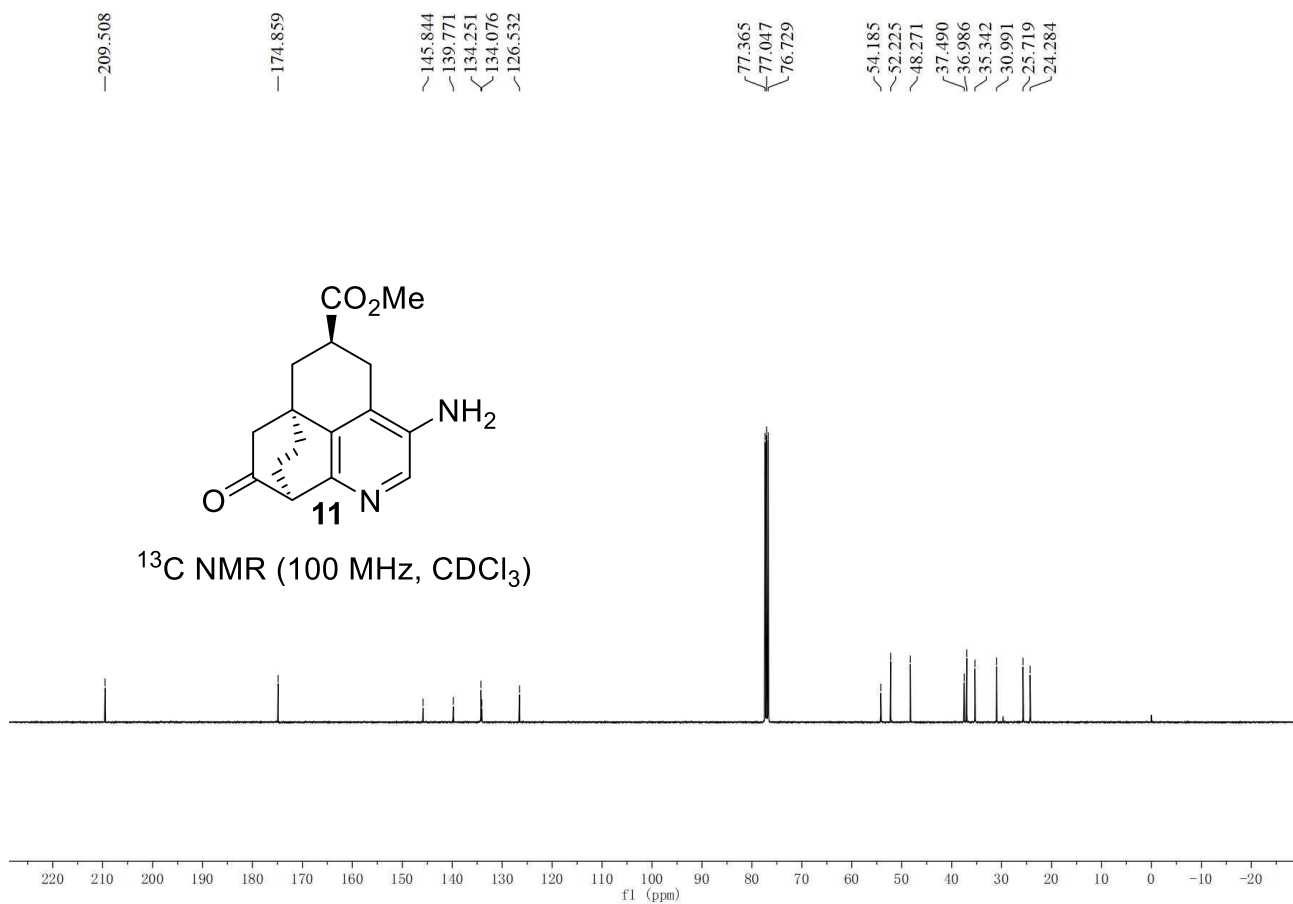
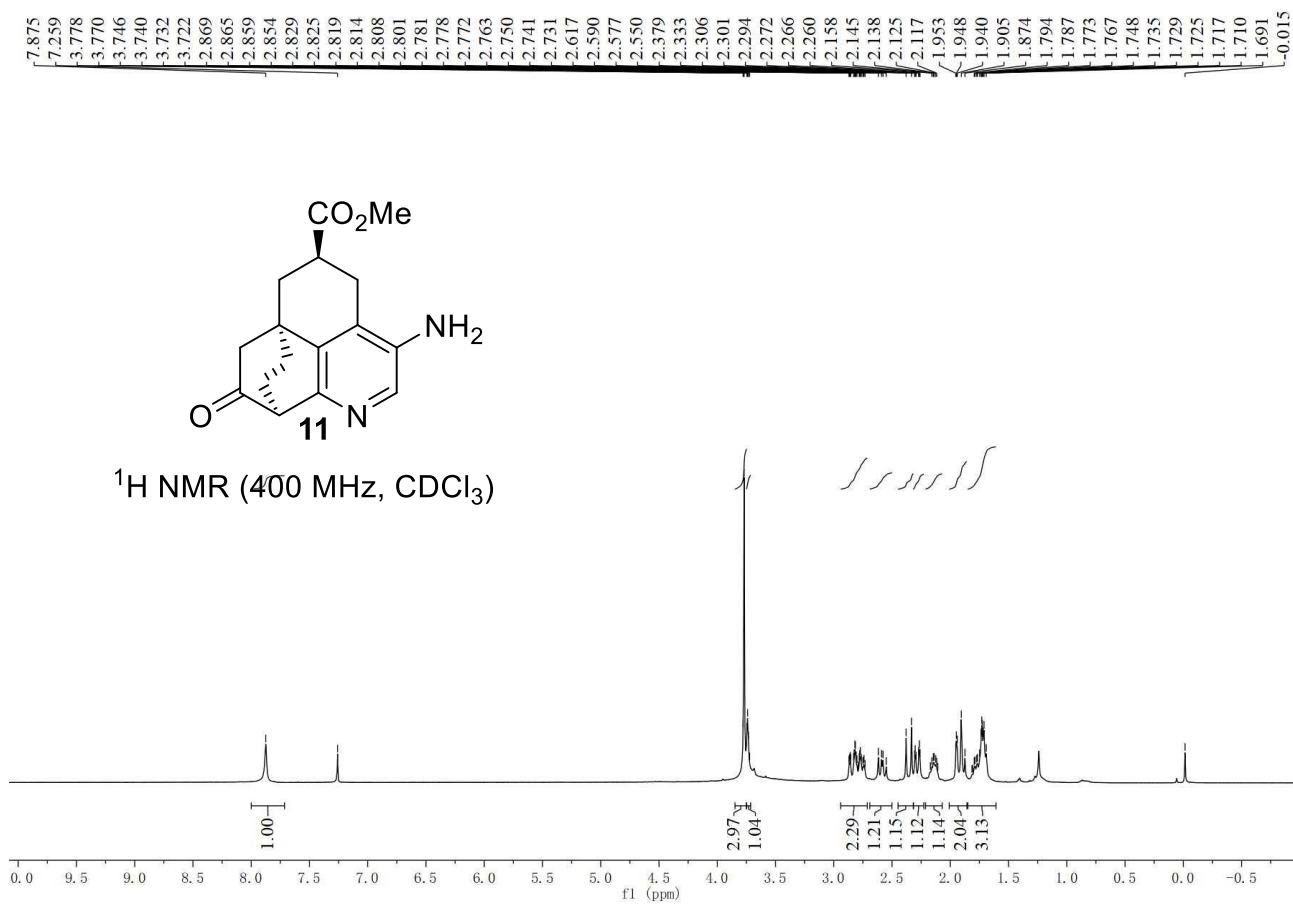
	Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1	11.739	BBA	0.4487	4611.46777	159.14609	99.2176
2	18.303	BB	0.6124	36.36558	7.45955e-1	0.7824

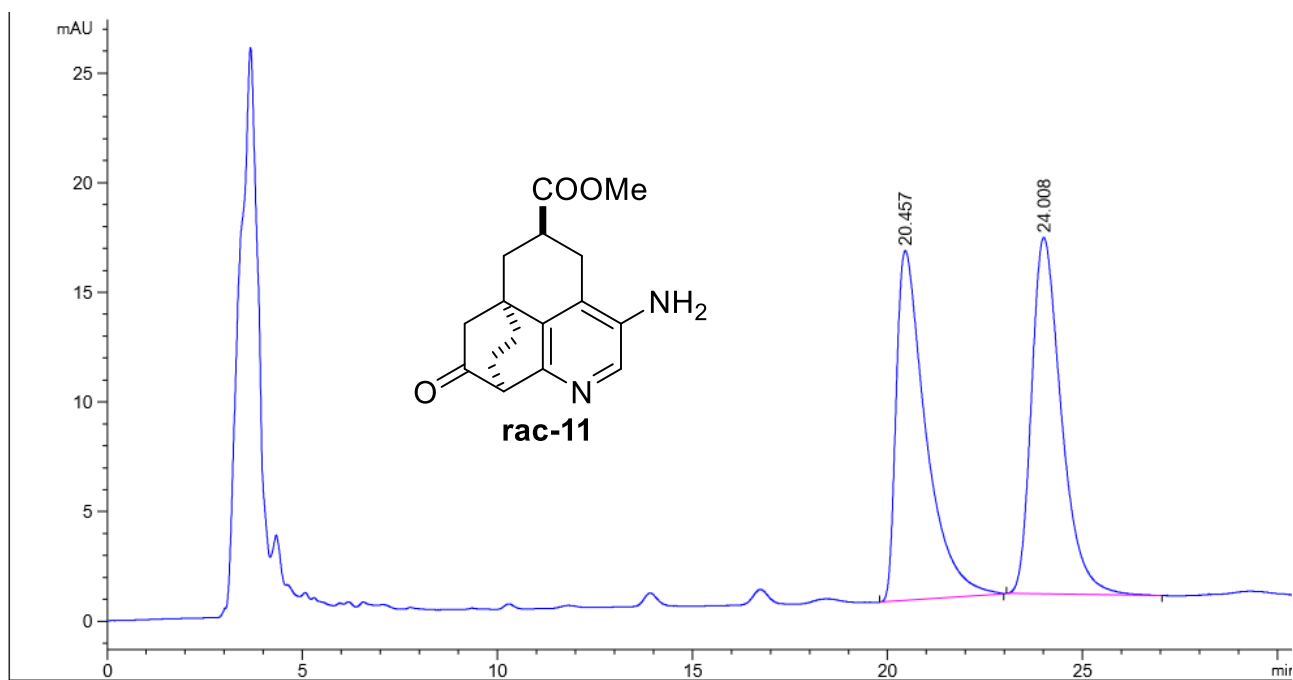
Spectrum Plot Report



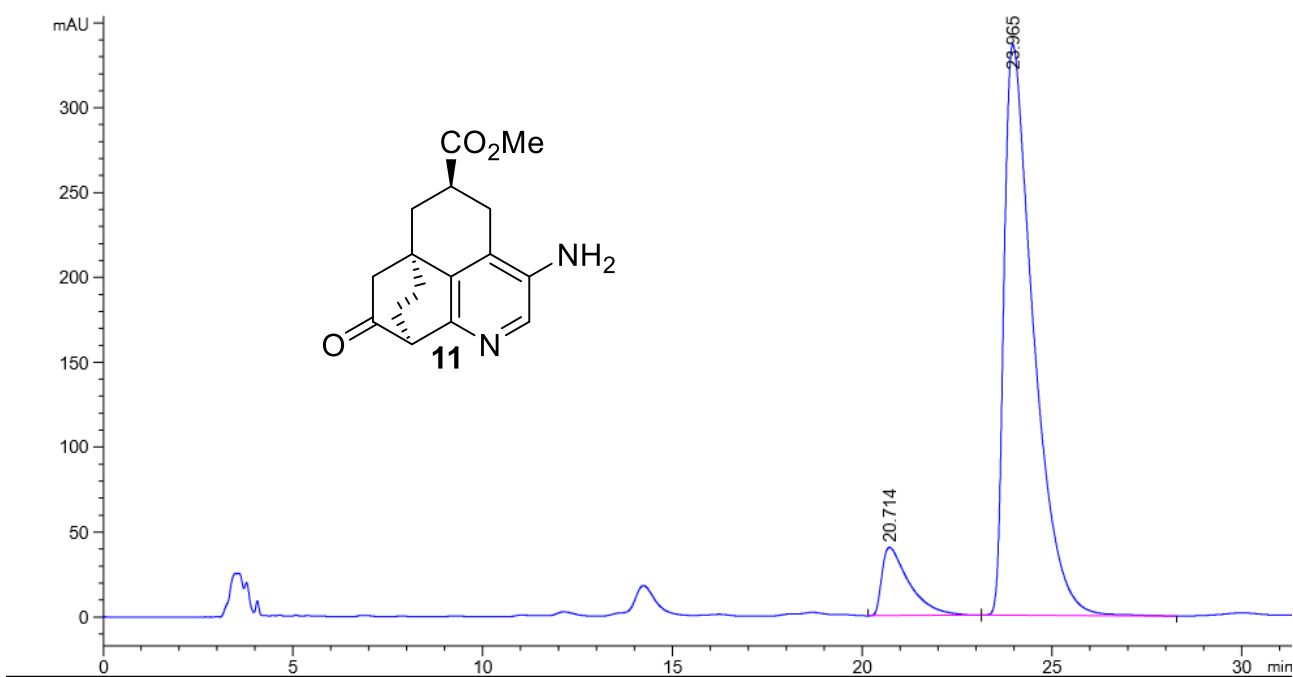
Name	CYC-20191108-17	Rack Pos.	Instrument	Instrument 1	Operator
Inj. Vol. (ul)	10	Plate Pos.	IRM Status	Success	
Data File	CYC-20191108-17.d	Method (Acq)	TOF.m	Comment	Acq. Time (Local)
					11/13/2019 6:27:41 PM (UTC+08:00)







	Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1	20.457	BB	0.7618	840.82062	15.95749	49.2976
2	24.008	BB	0.7926	864.78210	16.25152	50.7024



	Ret Time [min]	Peak Type	Width [min]	Height [mAU]	Area [mAU*s]	Area [%]
1	20.714	BB	0.7245	2008.40002	40.27477	9.9861
2	23.965	BB	0.7969	1.81035e4	336.33798	90.0139

