Total Syntheses of (–)-Deoxoapodine, (–)-Kopsifoline D and (–)-Beninine

Yi-Guo Zhou,[a] Henry N. C. Wong[a,b,c] and Xiao-Shui Peng*,[a,b,c]

[a]*Department of Chemistry, and State Key Laboratory of Synthetic Chemistry, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong SAR, China*

[b]*School of Science and Engineering, The Chinese University of Hong Kong (Shenzhen), China*

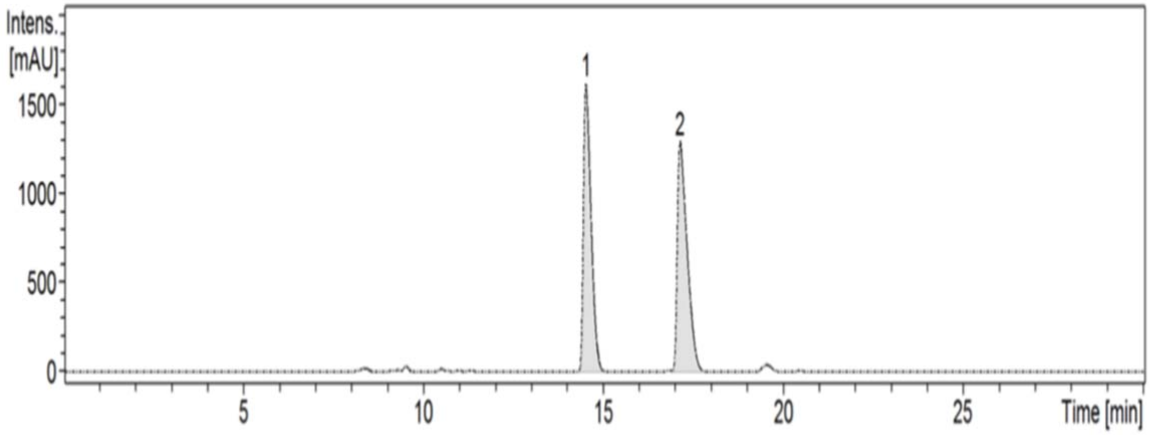
[c]*Shenzhen Municipal Key Laboratory of Chemical Synthesis of Medicinal Organic Molecules, Shenzhen Research Institute, The Chinese University of Hong Kong, No. 10, Second Yuexing Road, Shenzhen 518507, China*

E-mail: *xspeng@cuhk.edu.hk; xspeng@cuhk.edu.cn*

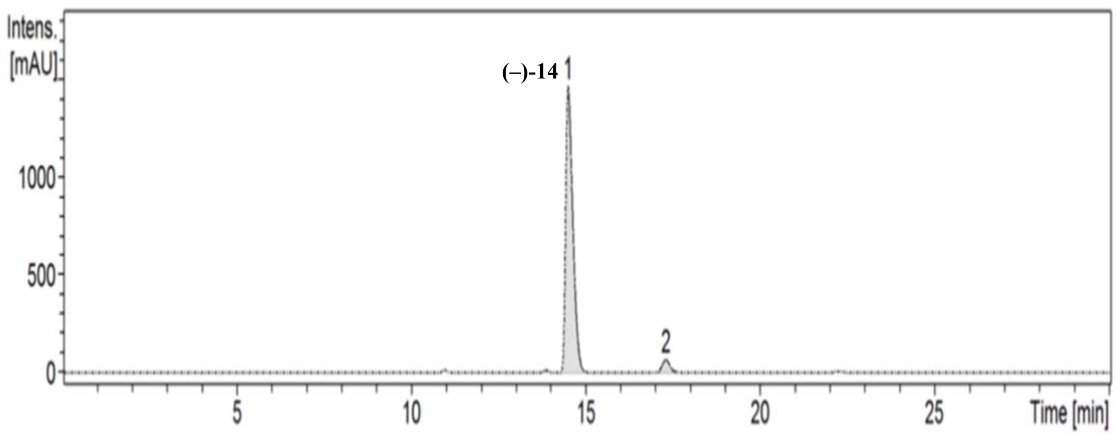
Table of contents

1. HPLC chromatogram of compound 14

Figure S1



#	RT [min]	Chromatogram	Area	Area %	S/N	Area Frac. %
1	14.5	UV Chromatogram, 254 nm	23695	97.40	1616173.1	49.34
2	17.1	UV Chromatogram, 254 nm	24326	100.00	1288719.1	50.66

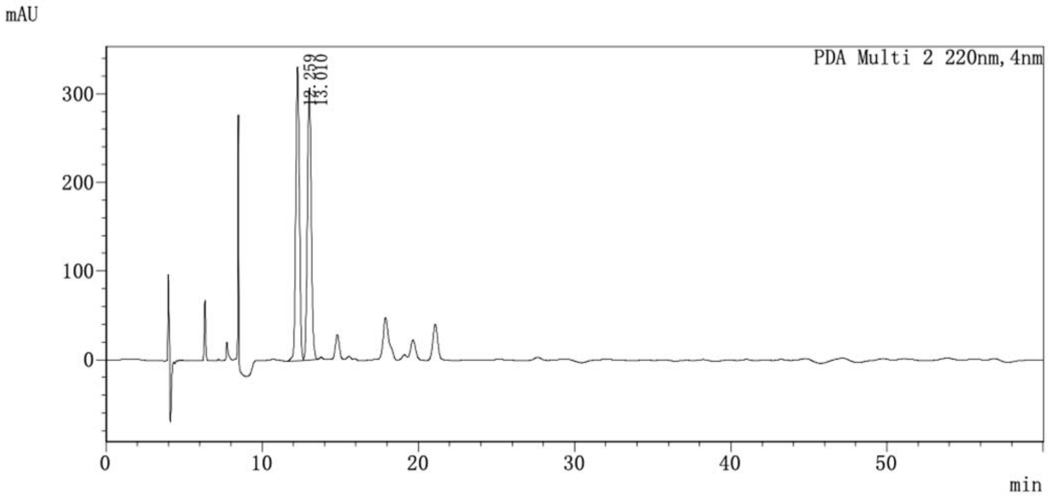


#	RT [min]	Chromatogram	Area	Area %	S/N	Area Frac. %
1	14.5	UV Chromatogram, 254 nm	20775.3	100.00	1462178.8	95.12
2	17.3	UV Chromatogram, 254 nm	1066.8	5.13	68450.6	4.88

2. HPLC chromatogram of compound 15

Figure S2

< Chromatogram >

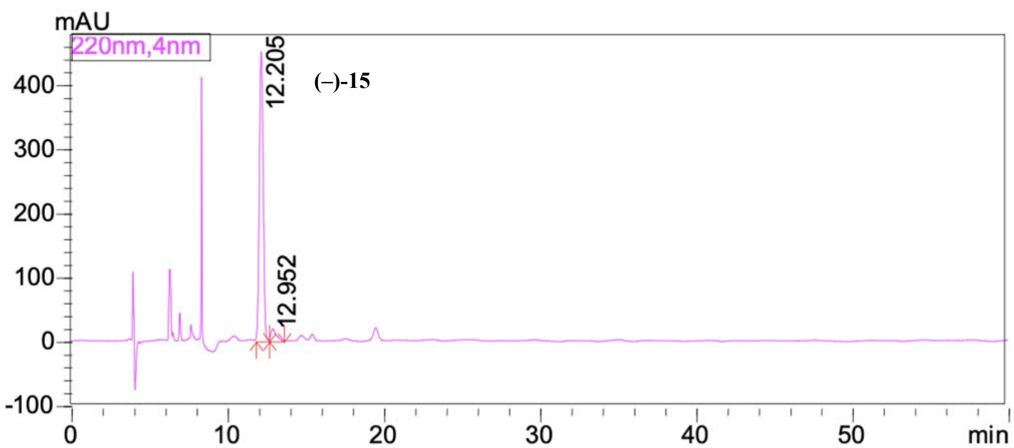


<Column Performance Report>

Peak No.	Time	Area	Area %	Plate number	Tailing	Resolution
1	12.259	5315007	49.995	13033	1.038	--
2	13.010	5315989	50.005	12683	1.096	1.685

Figure S3

< Chromatogram >



<Column Performance Report>

Peak No.	Time	Area	Area %	Plate number	Tailing	Resolution
1	12.205	7807612	95.035	10842	1.050	--
2	12.952	407889	4.965	8798	--	1.465

3. Comparison of NMR data for (–)-deoxoapodine (1)

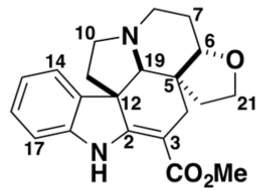


Table S1 Comparison of ^{1}H NMR data of (–)-deoxoapodine (1) with literature data[4]

Assignment	**Movassaghi's synthetic** (–)-deoxoapodine (**1**) (400 MHz, $CDCl_3$, 25 ºC)	**Our synthetic** (–)-deoxoapodine (**1**) (400 MHz, $CDCl_3$, 23 ºC)
N1-H	8.90 (br s, 1H)	8.90 (br s, 1H)
C2	–	–
C3	–	–
C4	2.76 (d, *J* = 14.7 Hz, 1H) 2.31 (dd, *J* = 14.6, 1.8 Hz, 1H)	2.75 (d, *J* = 14.8 Hz, 1H) 2.30 (dd, *J* = 14.6, 1.8 Hz, 1H)
C5	–	–
C6	3.70 –3.65 (m, 1H)	3.72 –3.64 (m, 1H)
C7	2.00 – 1.92 (m, 2H)	2.00 – 1.93 (m, 2H)
C8	2.99 – 2.91 (m, 1H) 2.77 – 2.70 (m, 1H)	2.98 – 2.92 (m, 1H) 2.76 – 2.69 (m, 1H)
C10	2.99 – 2.91 (m, 1H) 2.67 (ddd, *J* = 11.1, 8.5, 4.6 Hz, 1H)	2.98 – 2.92 (m, 1H) 2.67 (ddd, *J* = 11.3, 8.5, 4.5 Hz, 1H)
C11	2.04 (ddd, *J* = 11.2, 11.2, 6.2 Hz, 1H) 1.77 (dd, *J* = 11.5, 4.4 Hz, 1H)	2.03 (ddd, *J* = 11.3, 11.3, 6.3 Hz, 1H) 1.77 (dd, *J* = 11.5, 4.0 Hz, 1H)
C12	–	–
C13	–	–
C14	7.24 (d, *J* = 7.4 Hz, 1H)	7.24 (d, *J* = 7.4 Hz, 1H)
C15	6.88 (td, *J* = 7.5, 1.0 Hz, 1H)	6.88 (td, *J* = 7.5, 1.0 Hz, 1H)
C16	7.14 (td, *J* = 7.7, 1.2 Hz, 1H)	7.14 (td, *J* = 7.7, 1.2 Hz, 1H)
C17	6.81 (d, *J* = 7.7 Hz, 1H)	6.81 (d, *J* = 7.7 Hz, 1H)
C18	–	–
C19	2.83 (s, 1H)	2.82 (s, 1H)
C20	1.45 (ddd, *J* = 12.8, 9.9, 7.4 Hz, 1H) 1.29 (ddd, *J* = 13.0, 8.4, 4.7 Hz, 1H)	1.45 (ddd, *J* = 12.8, 10.0, 7.5 Hz, 1H) 1.29 (ddd, *J* = 12.9, 8.3, 4.6 Hz, 1H)
C21	3.81 – 3.73 (m, 1H) 3.72 – 3.65 (m, 1H)	3.81 – 3.74 (m, 1H) 3.72 – 3.64 (m, 1H)
CO_2CH_3	3.78 (s, 3H)	3.78 (s, 3H)

Table S2 Comparison of ^{13}C NMR data of (–)-deoxoapodine (1) with literature data[4]

Assignment	Movassaghi's synthetic (–)-deoxoapodine (1) (100 MHz, $CDCl_3$, 25 ºC)	Our synthetic (–)-deoxoapodine (1) (125 MHz, $CDCl_3$, 25 ºC)	Chemical Shift Difference $\Delta = \delta$ (our synthetic, solvent ref. δ 77.16) – δ (Movassaghi's synthetic)
C2	167.5	167.4	-0.1
C3	94.1	94.0	0.1
C4	27.8	27.8	0.0
C5	46.8	46.8	0.0
C6	80.1	80.1	0.0
C7	27.0	27.0	0.0
C8	46.1	46.1	0.0
C10	51.7	51.7	0.0
C11	45.3	45.3	0.0
C12	55.3	55.3	0.0
C13	138.0	138.0	0.0
C14	121.5	121.5	0.0
C15	120.9	120.9	0.0
C16	127.9	127.9	0.0
C17	109.5	109.5	0.0
C18	143.2	143.2	0.0
C19	68.9	68.9	0.0
C20	35.1	35.1	0.0
C21	65.1	65.1	0.0
CO_2CH_3	168.9	168.9	0.0
CO_2**C**H_3	51.2	51.2	0.0

4. Comparison of NMR data for (–)-kopsifoline D (6)

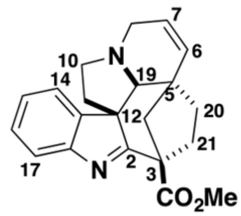


Table S3 Comparison of ^{1}H NMR data of (–)-kopsifoline D (6) with literature data[5]

Assignment	**Naturally occurring** (–)-kopsifoline D (**6**) (400 MHz, $CDCl_3$)	**Our synthetic** (–)-kopsifoline D (**6**) (400 MHz, $CDCl_3$, 23 ºC)
N1-H	–	–
C2	–	–
C3	–	–
C4	1.78 (dd, *J* = 13, 2 Hz, 1H) 2.63 (br d, *J* = 13 Hz, 1H)	1.77 (dd, *J* = 12.4, 1.8 Hz, 1H) 2.63 (d, *J* = 10.5 Hz, 1H)
C5	–	–
C6	5.64 (dt, *J* = 10, 2 Hz, 1H)	5.63 (dt, *J* = 10.1, 2.0 Hz, 1H)
C7	5.77 (ddd, *J* = 10, 4, 2 Hz, 1H)	5.76 (ddd, *J* = 10.1, 4.3, 1.7 Hz, 1H)
C8	3.42 (dd, *J* = 17, 4 Hz, 1H) 3.59 (br d, *J* = 17 Hz, 1H)	3.41 (ddd, *J* = 18.0, 4.5, 1.7 Hz, 1H) 3.58 (dt, *J* = 17.7, 2.1 Hz, 1H)
C10	3.31 (m, 1H) 3.36 (td, *J* = 8, 6 Hz, 1H)	3.32 – 3.25 (m, 1H) 3.35 (td, *J* = 8.4, 6.0 Hz, 1H)
C11	2.14 (m, 1H) 2.61 (m, 1H)	2.18 – 2.03 (m, 1H) 2.66 – 2.56 (m, 1H)
C12	–	–
C13	–	–
C14	7.48 (br d, *J* = 8 Hz, 1H)	7.47 (d, *J* = 7.3 Hz, 1H)
C15	7.30 (td, *J* = 8, 2 Hz, 1H)	7.30 (td, *J* = 7.6, 1.3 Hz, 1H)
C16	7.20 (td, *J* = 8, 2 Hz, 1H)	7.19 (td, *J* = 7.4, 1.1 Hz, 1H)
C17	7.57 (dd, *J* = 8, 2 Hz, 1H)	7.57 (d, *J* = 7.7 Hz, 1H)
C18	–	–
C19	2.78 (br s, 1H)	2.77 (d, *J* = 1.7 Hz, 1H)
C20	1.20 (m, 1H) 1.69 (m, 1H)	1.23 – 1.14 (m, 1H) 1.69 (ddd, *J* = 14.3, 11.8, 2.5 Hz, 1H)
C21	2.13 (dddd, *J* = 12, 9, 3, 2 Hz, 1H) 2.43 (td, *J* = 12, 8 Hz, 1H)	2.18 – 2.03 (m, 1H) 2.43 (td, *J* = 12.1, 8.5 Hz, 1H)
CO_2CH_3	3.79 (s, 3H)	3.79 (s, 3H)

Table S4 Comparison of ^{13}C NMR data of (–)-kopsifoline D (6) with literature data[5]

Assignment	**Naturally occurring** (–)-kopsifoline D (**6**) (100 MHz, $CDCl_3$)	**Our synthetic** (–)-kopsifoline D (**6**) (125 MHz, $CDCl_3$, 25 ºC)	**Chemical Shift Difference** Δ = δ (our synthetic, solvent ref. δ 77.16) – δ (naturally occurring)
C2	187.7	188.3	0.6
C3	56.5	56.6	0.1
C4	43.4	43.4	0.0
C5	42.3	42.4	0.1
C6	132.5	132.5	0.0
C7	125.2	125.4	0.2
C8	46.9	46.9	0.0
C10	50.9	50.9	0.0
C11	34.7	34.8	0.1
C12	63.0	62.7	-0.3
C13	147.0	147.2	0.2
C14	121.6	121.5	-0.1
C15	125.8	125.9	0.1
C16	127.5	127.5	0.0
C17	120.3	120.4	0.1
C18	154.3	154.4	0.1
C19	69.1	69.1	0.0
C20	35.0	35.0	0.0
C21	39.0	39.0	0.0
$CO_2\mathbf{C}H_3$	52.6	52.6	0.0
$\mathbf{C}O_2CH_3$	172.2	172.4	0.2

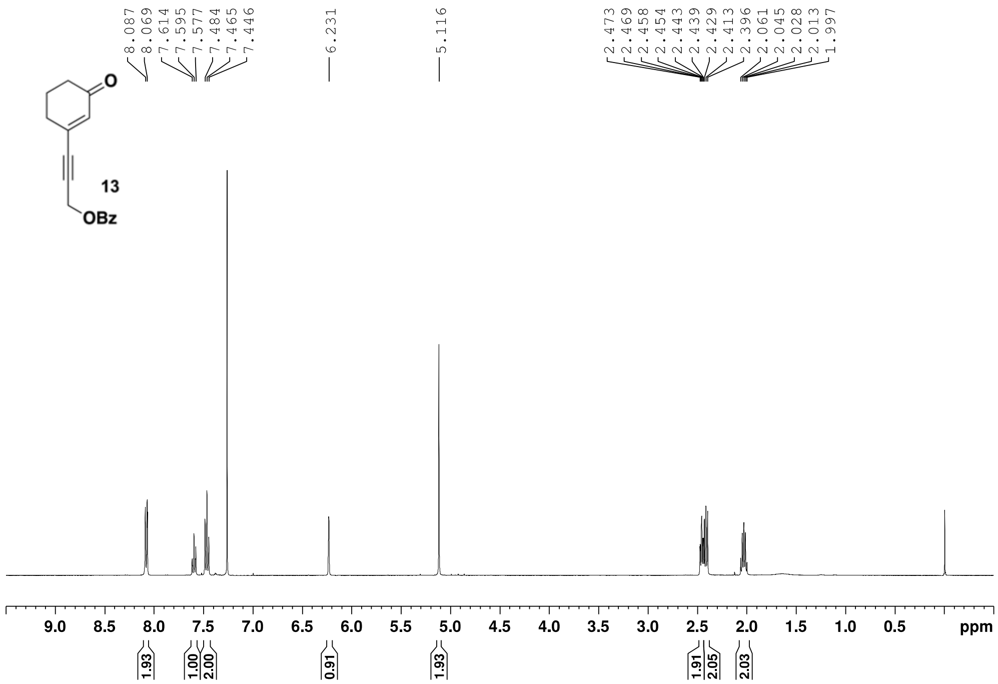
Table S5 Comparison of ^{1}H NMR data of (–)-kopsifoline D (6) with literature data[7]

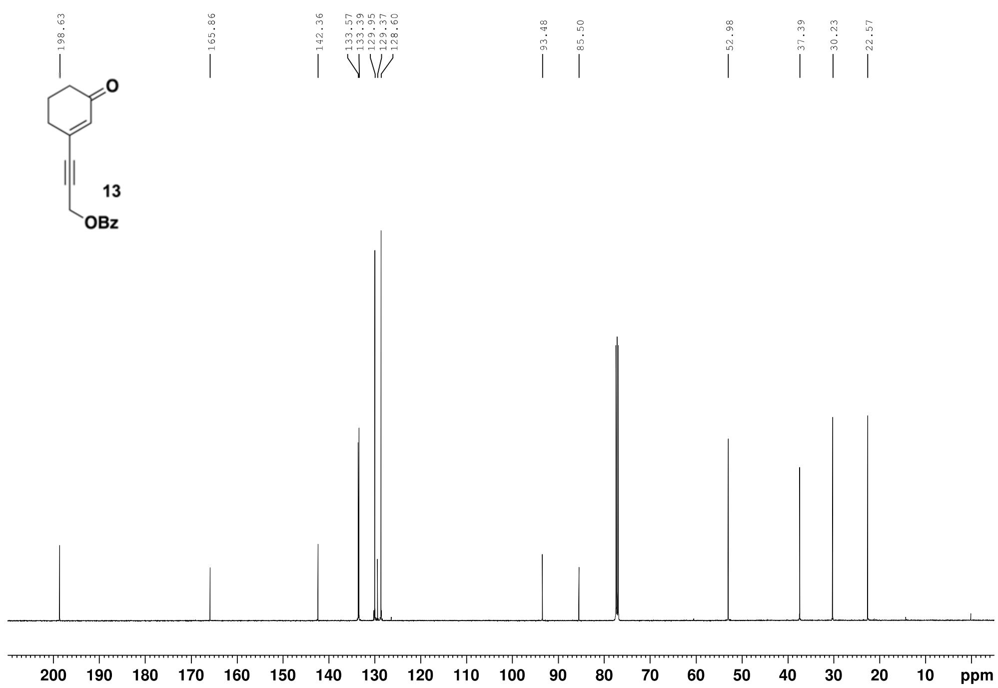
Assignment	**Boger's synthetic** (–)-kopsifoline D (**6**) (500 MHz, $CDCl_3$)	**Our synthetic** (–)-kopsifoline D (**6**) (400 MHz, $CDCl_3$, 23 ºC)
N1-H	–	–
C2	–	–
C3	–	–
C4	1.77 (d, *J* = 12.3 Hz, 1H) 2.63 (br d, *J* = 11.7 Hz, 1H)	1.77 (dd, *J* = 12.4, 1.8 Hz, 1H) 2.63 (d, *J* = 10.5 Hz, 1H)
C5	–	–
C6	5.63 (d, *J* = 10.2 Hz, 1H)	5.63 (dt, *J* = 10.1, 2.0 Hz, 1H)
C7	5.76 (dd, *J* = 10.2, 4.2 Hz, 1H)	5.76 (ddd, *J* = 10.1, 4.3, 1.7 Hz, 1H)
C8	3.41 (dd, *J* = 17.7, 4.4 Hz, 1H) 3.58 (d, *J* = 17.6 Hz, 1H)	3.41 (ddd, *J* = 18.0, 4.5, 1.7 Hz, 1H) 3.58 (dt, *J* = 17.7, 2.1 Hz, 1H)
C10	3.32 – 3.25 (m, 1H) 3.35 (q, *J* = 7.8 Hz, 1H)	3.32 – 3.25 (m, 1H) 3.35 (td, *J* = 8.4, 6.0 Hz, 1H)
C11	2.18 – 2.03 (m, 1H) 2.65 – 2.56 (m, 1H)	2.18 – 2.03 (m, 1H) 2.66 – 2.56 (m, 1H)
C12	–	–
C13	–	–
C14	7.47 (d, *J* = 7.3 Hz, 1H)	7.47 (d, *J* = 7.3 Hz, 1H)
C15	7.29 (t, *J* = 7.6 Hz, 1H)	7.30 (td, *J* = 7.6, 1.3 Hz, 1H)
C16	7.19 (t, *J* = 7.4 Hz, 1H)	7.19 (td, *J* = 7.4, 1.1 Hz, 1H)
C17	7.57 (d, *J* = 7.7 Hz, 1H)	7.57 (d, *J* = 7.7 Hz, 1H)
C18	–	–
C19	2.77 (s, 1H)	2.77 (d, *J* = 1.7 Hz, 1H)
C20	1.23 – 1.14 (m, 1H) 1.69 (t, *J* = 13.1 Hz, 1H)	1.23 – 1.14 (m, 1H) 1.69 (ddd, *J* = 14.3, 11.8, 2.5 Hz, 1H)
C21	2.18 – 2.03 (m, 1H) 2.43 (td, *J* = 11.9, 8.2 Hz, 1H)	2.18 – 2.03 (m, 1H) 2.43 (td, *J* = 12.1, 8.5 Hz, 1H)
CO_2CH_3	3.79 (s, 3H)	3.79 (s, 3H)

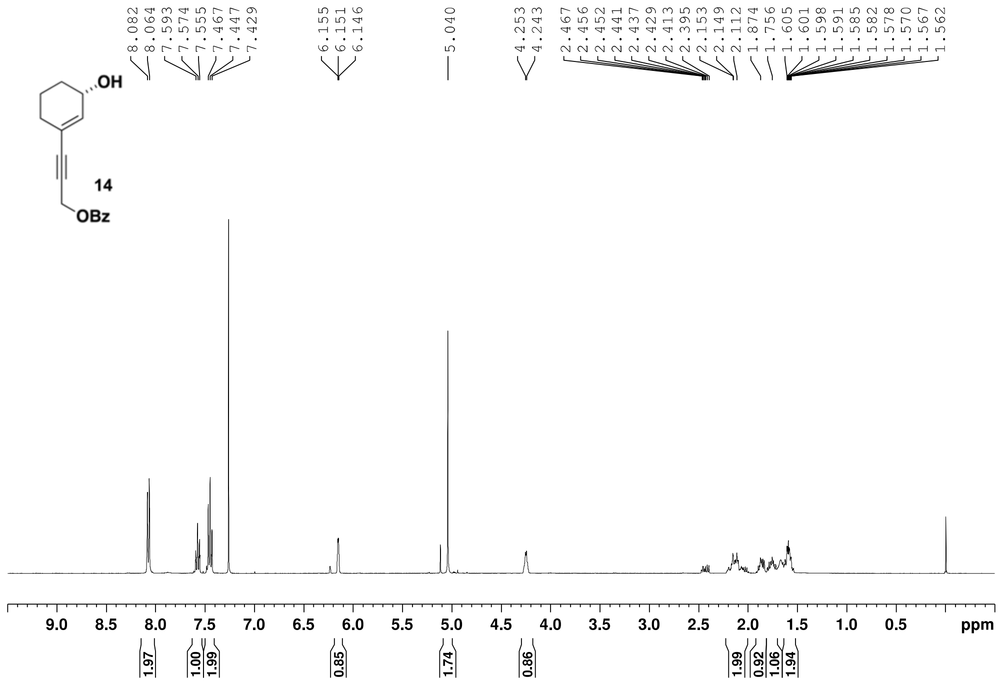
Table S6 Comparison of ^{13}C NMR data of (–)-kopsifoline D (6) with literature data[7]

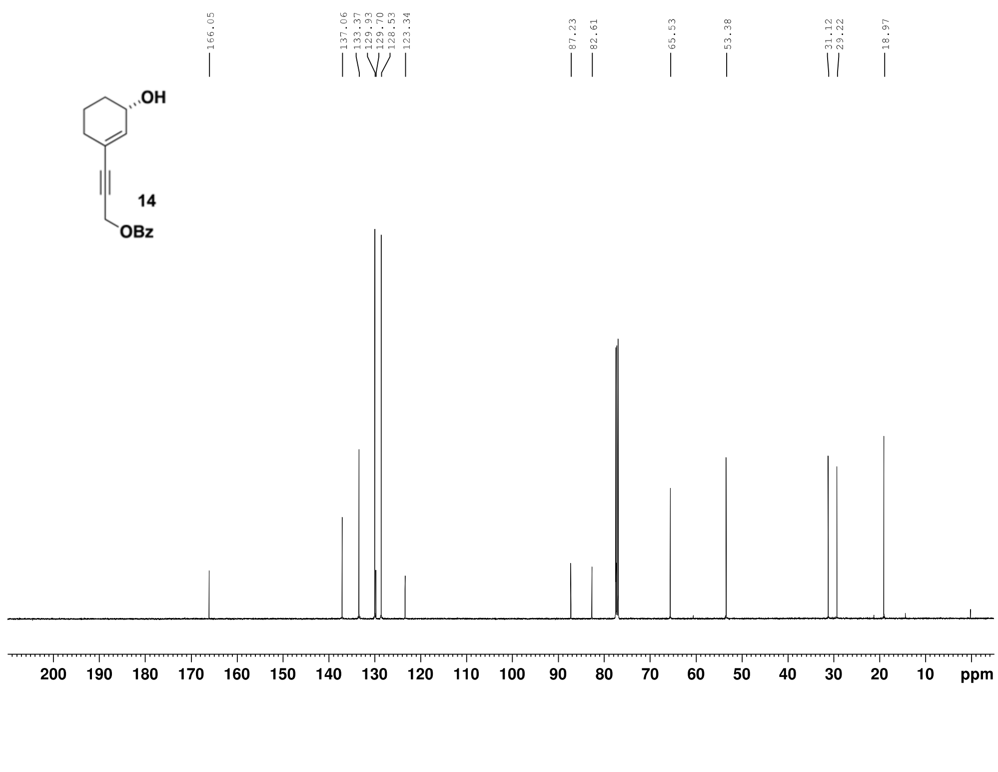
Assignment	**Boger's synthetic** (–)-kopsifoline D (**6**) (150 MHz, $CDCl_3$)	**Our synthetic** (–)-kopsifoline D (**6**) (125 MHz, $CDCl_3$, 25 ºC)	**Chemical Shift Difference** $\Delta = \delta$ (our synthetic, solvent ref. δ 77.16) – δ (Boger's synthetic)
C2	188.3	188.3	0.0
C3	56.5	56.6	0.1
C4	43.4	43.4	0.0
C5	42.3	42.4	0.1
C6	132.5	132.5	0.0
C7	125.3	125.4	0.1
C8	46.9	46.9	0.0
C10	50.9	50.9	0.0
C11	34.8	34.8	0.0
C12	62.7	62.7	0.0
C13	147.2	147.2	0.0
C14	121.5	121.5	0.0
C15	125.9	125.9	0.0
C16	127.5	127.5	0.0
C17	120.3	120.4	0.1
C18	154.4	154.4	0.0
C19	69.1	69.1	0.0
C20	35.0	35.0	0.0
C21	39.0	39.0	0.0
$CO_2\mathbf{C}H_3$	52.6	52.6	0.0
$\mathbf{C}O_2CH_3$	172.4	172.4	0.0

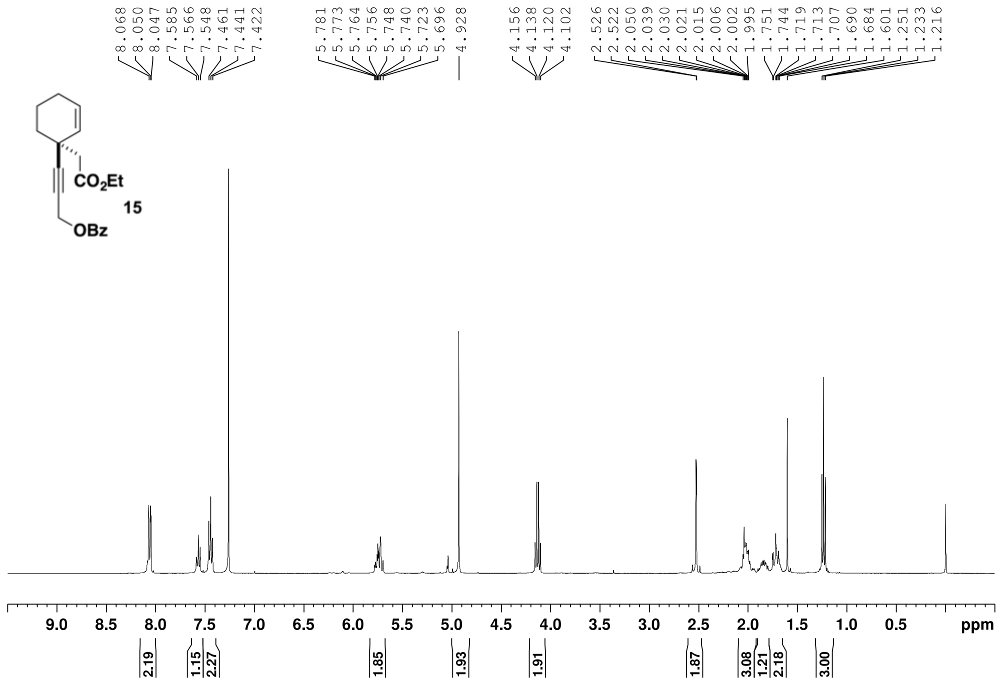
5. NMR spectra

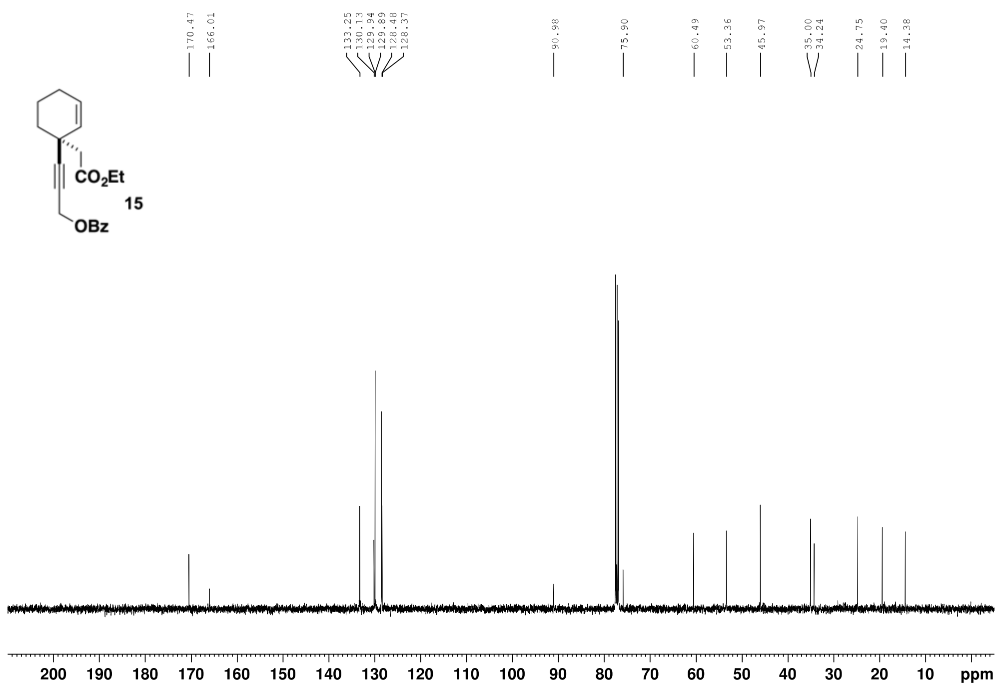


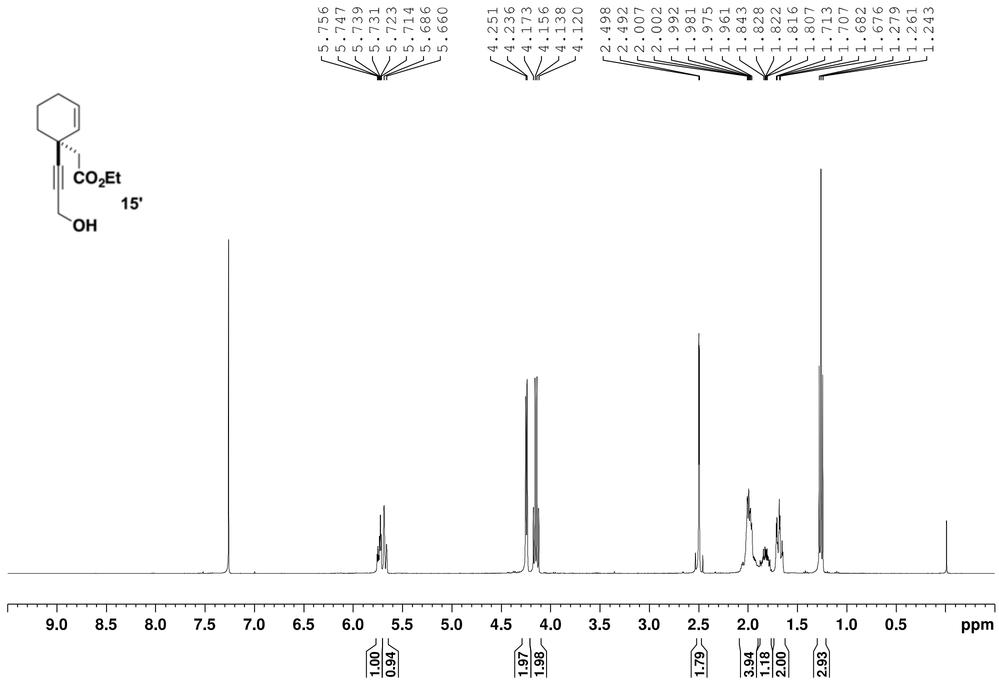



OH
14
OBz
8.082
8.064
7.593
7.574
7.555
7.467
7.447
7.429
6.155
6.151
6.146
5.040
4.253
4.243
2.467
2.456
2.452
2.441
2.437
2.429
2.413
2.395
2.153
2.149
2.112
1.874
1.756
1.605
1.601
1.598
1.591
1.585
1.582
1.578
1.570
1.567
1.562
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.97
1.00
1.99
0.85
1.74
0.86
1.99
0.92
1.06
1.94

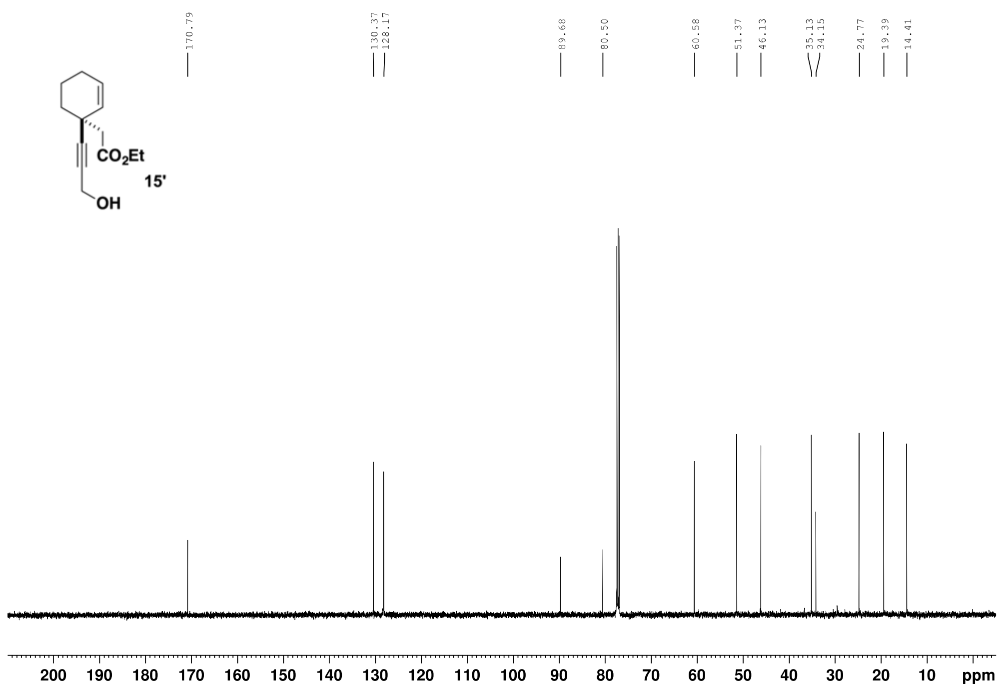

OH
14
OBz
166.05
137.06
133.37
129.93
129.70
128.53
123.34
87.23
82.61
65.53
53.38
31.12
29.22
18.97
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


8.068 8.050 8.047 7.585 7.566 7.548 7.461 7.441 7.422
5.781 5.773 5.764 5.756 5.748 5.740 5.723 5.696
4.928
4.156 4.138 4.120 4.102
2.526 2.522 2.050 2.039 2.030 2.021 2.015 2.006 2.002 1.995 1.751 1.744 1.719 1.713 1.707 1.690 1.684 1.601 1.251 1.233 1.216
CO2Et
15
OBz
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.19 1.15 2.27 1.85 1.93 1.91 1.87 3.08 1.21 2.18 3.00

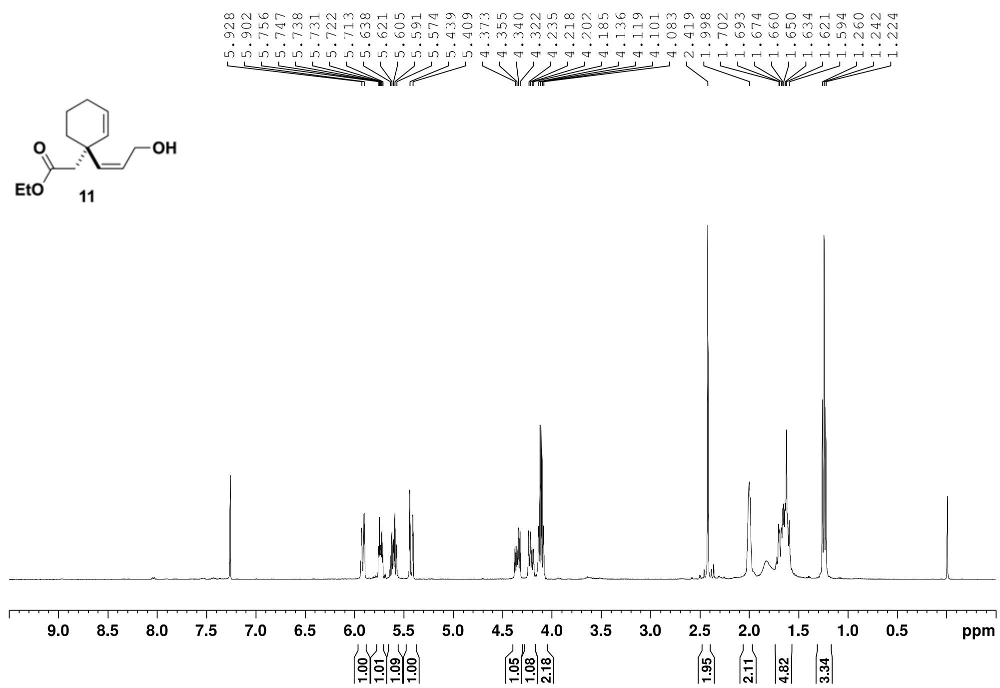

170.47 166.01
133.25 130.13 129.94 129.89 128.48 128.37
90.98
75.90
60.49
53.36
45.97
35.00 34.24
24.75
19.40
14.38
CO2Et
15
OBz
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

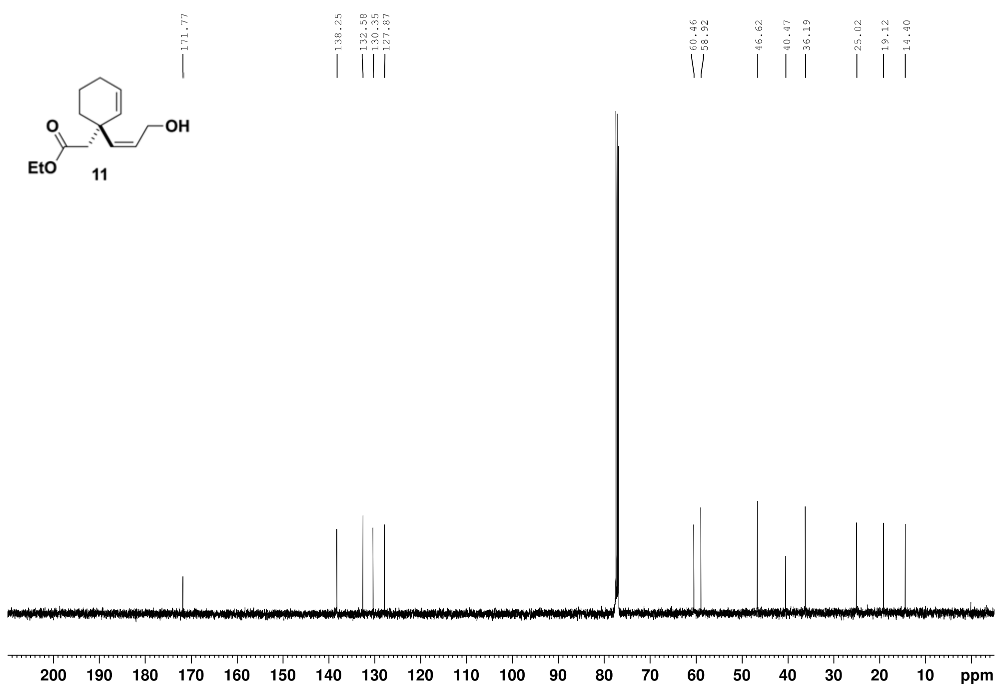


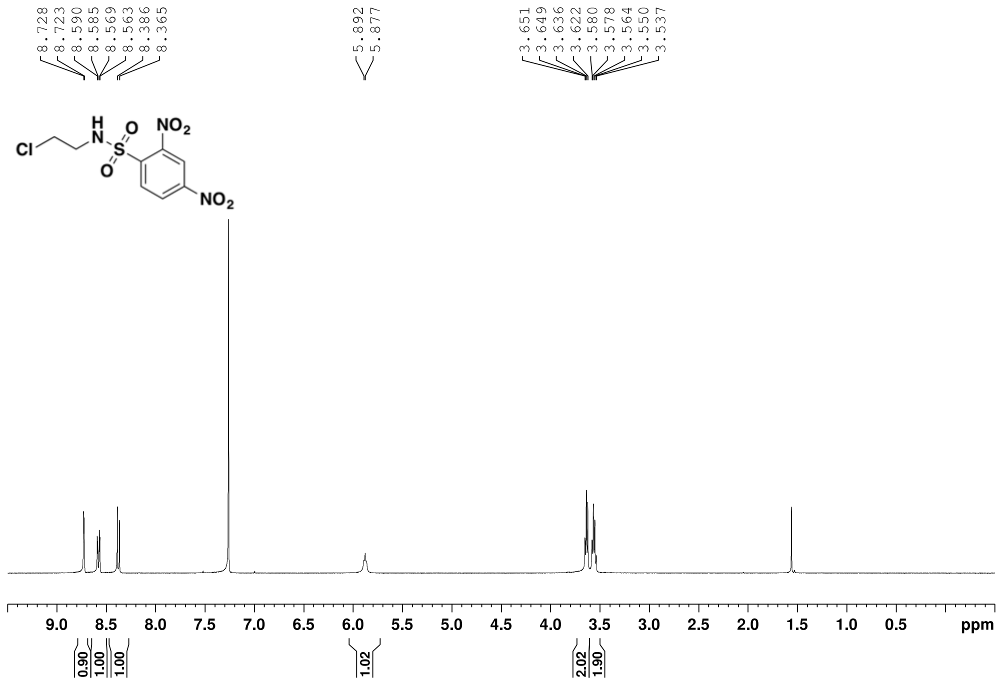
5.756
5.747
5.739
5.731
5.723
5.714
5.686
5.660
4.251
4.236
4.173
4.156
4.138
4.120
2.498
2.492
2.007
2.002
1.992
1.981
1.975
1.961
1.843
1.828
1.822
1.816
1.807
1.713
1.707
1.682
1.676
1.279
1.261
1.243
CO2Et
15'
OH
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.00
0.94
1.97
1.98
1.79
3.94
1.18
2.00
2.93

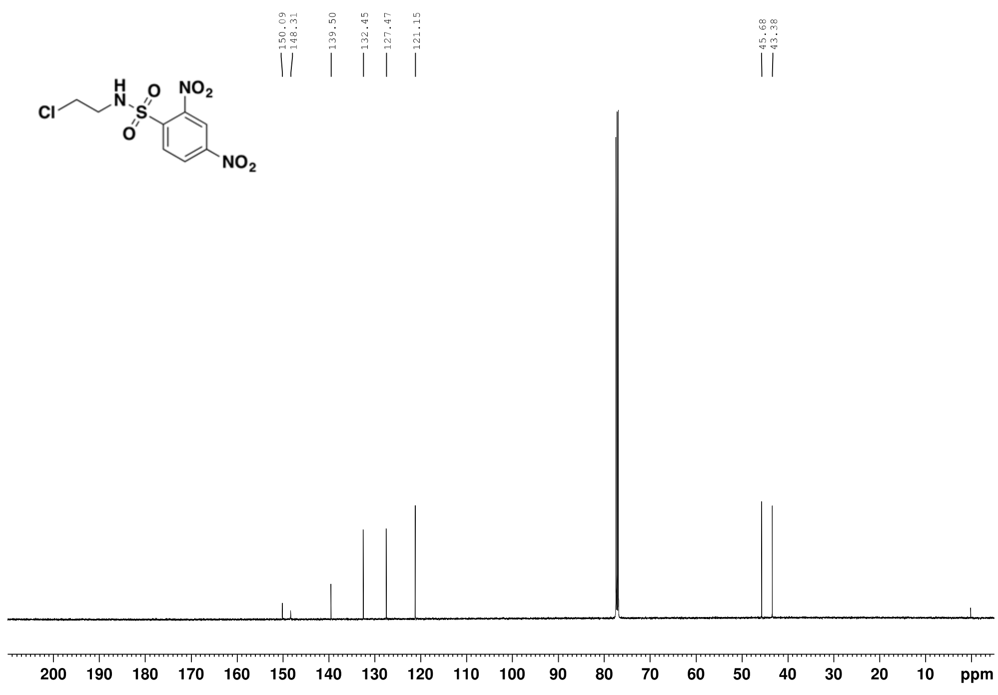


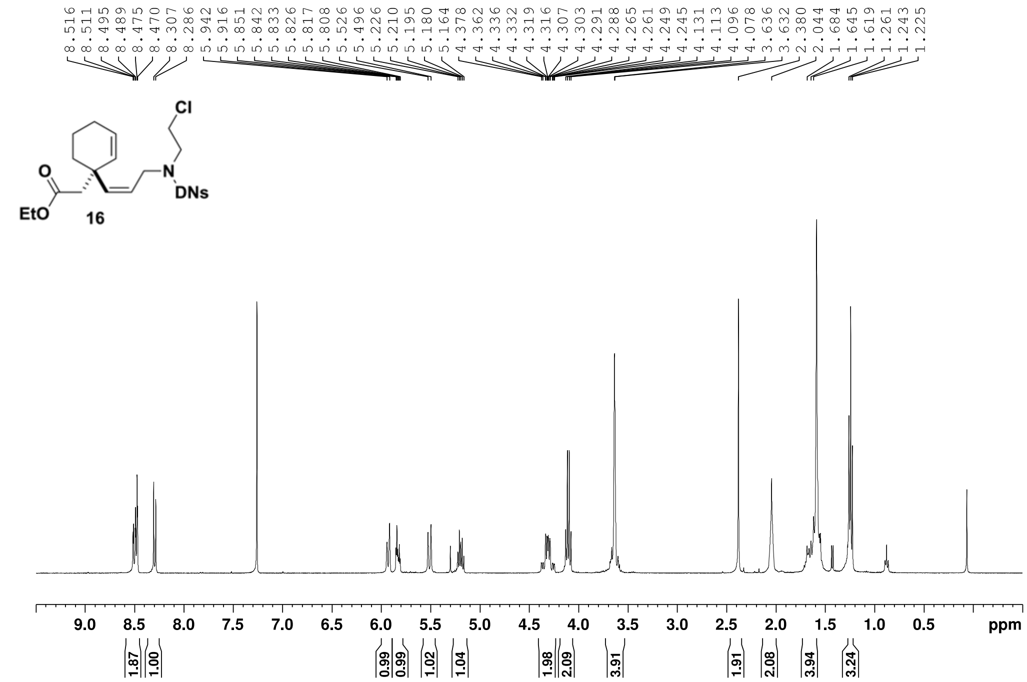
170.79
130.37
128.17
89.68
80.50
60.58
51.37
46.13
35.13
34.15
24.77
19.39
14.41
CO2Et
15'
OH
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm



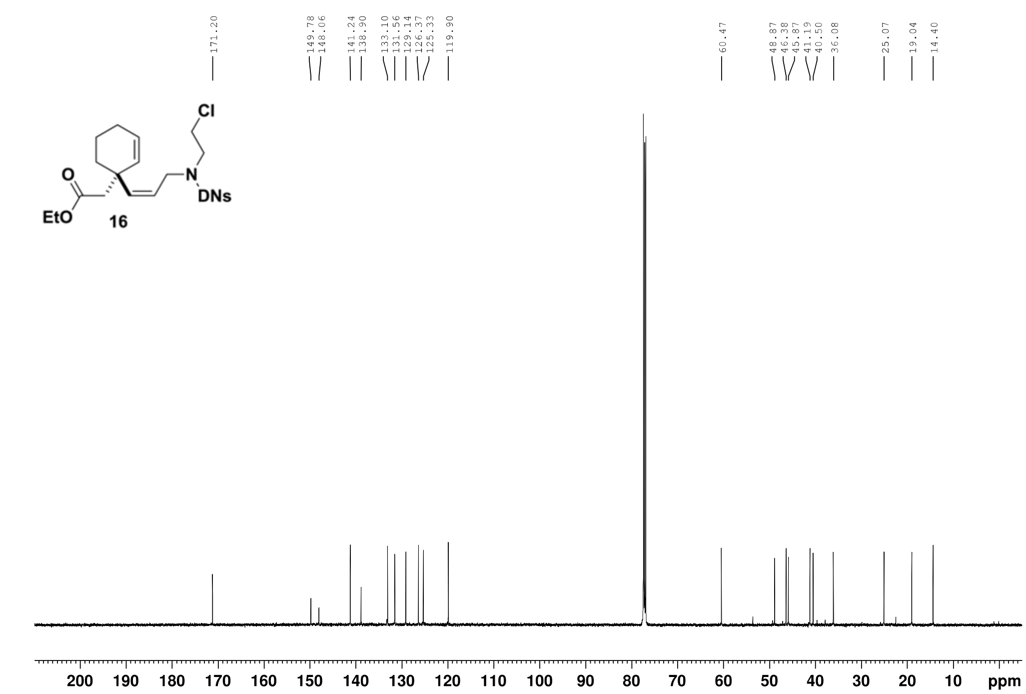




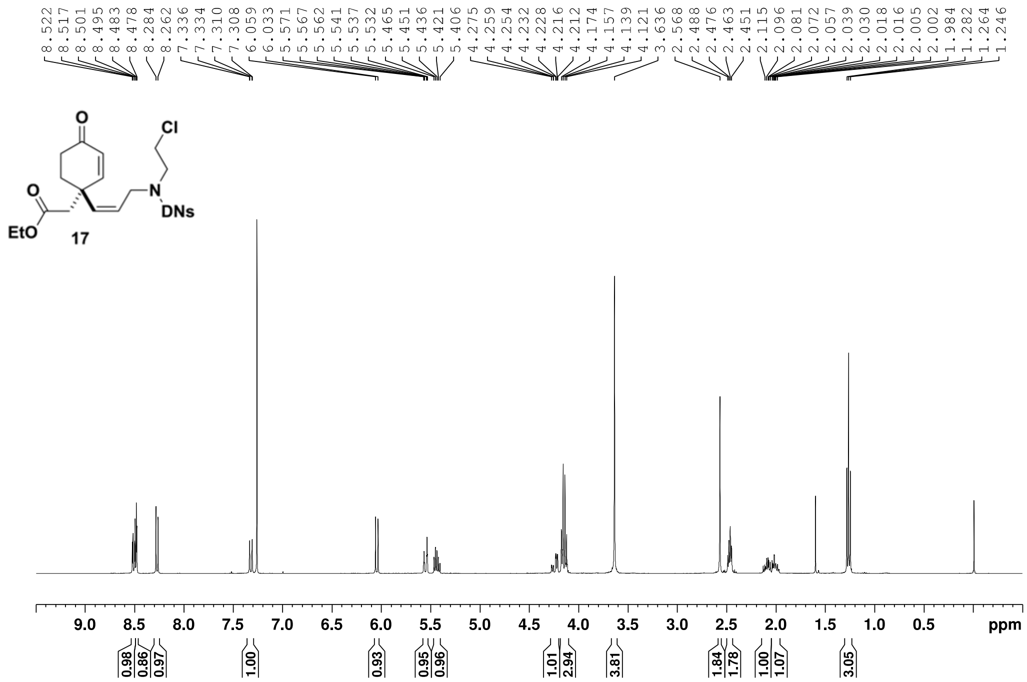


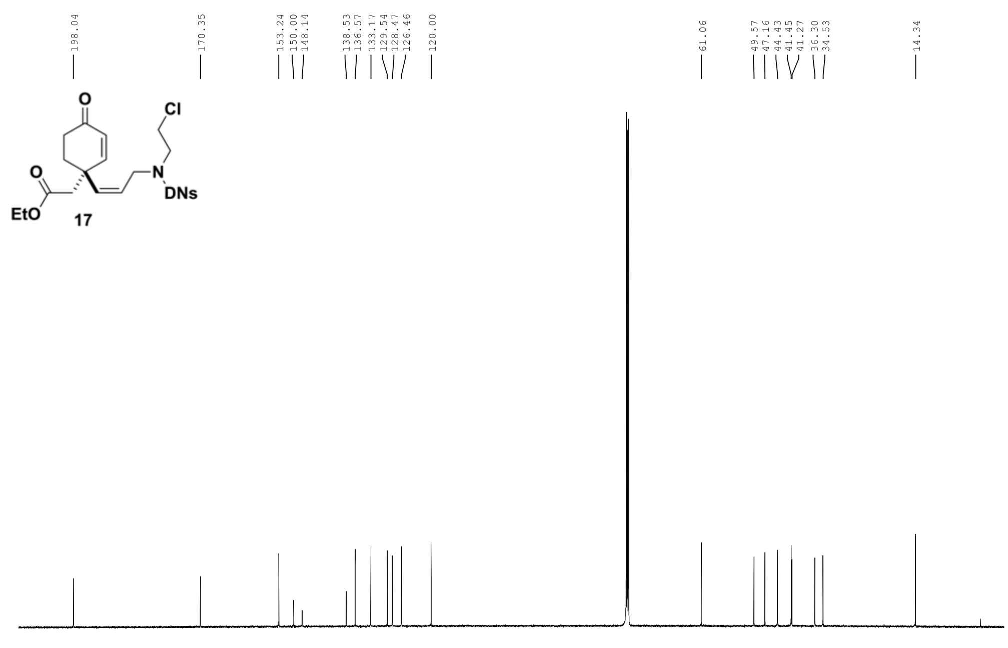


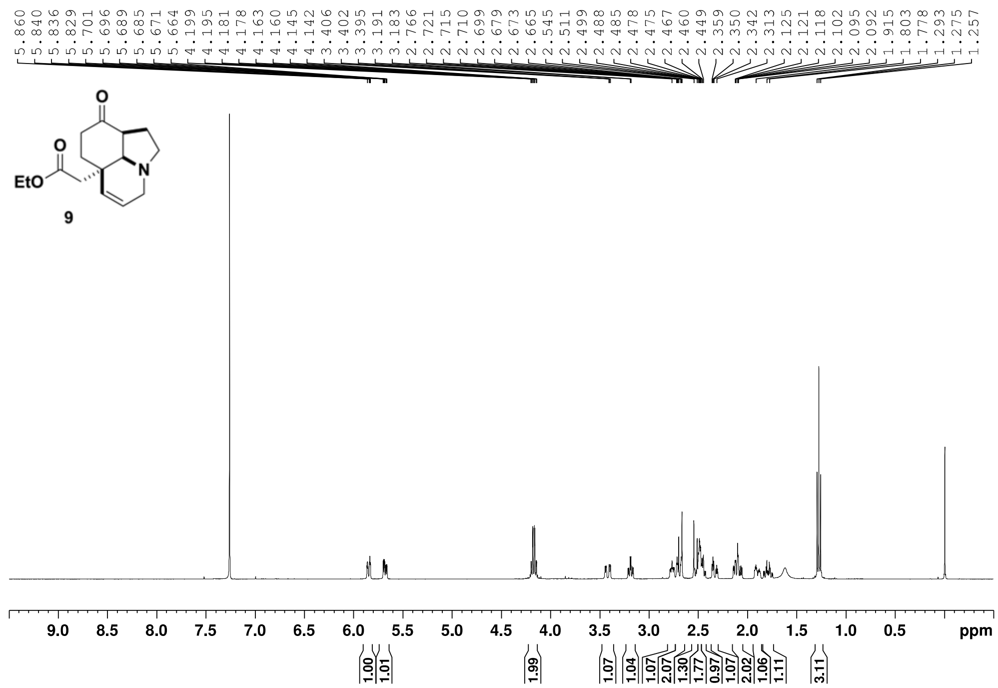
8.516 8.511 8.495 8.489 8.475 8.470 8.307 8.286 5.942 5.916 5.851 5.842 5.833 5.826 5.817 5.808 5.526 5.496 5.226 5.210 5.195 5.180 5.164 4.378 4.362 4.336 4.332 4.319 4.316 4.307 4.303 4.291 4.288 4.265 4.261 4.249 4.245 4.131 4.113 4.096 4.078 3.636 3.632 2.380 2.044 1.684 1.645 1.619 1.261 1.243 1.225
Cl
O
N
DNs
EtO
16
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.87 1.00 0.99 0.99 1.02 1.04 1.98 2.09 3.91 1.91 2.08 3.94 3.24

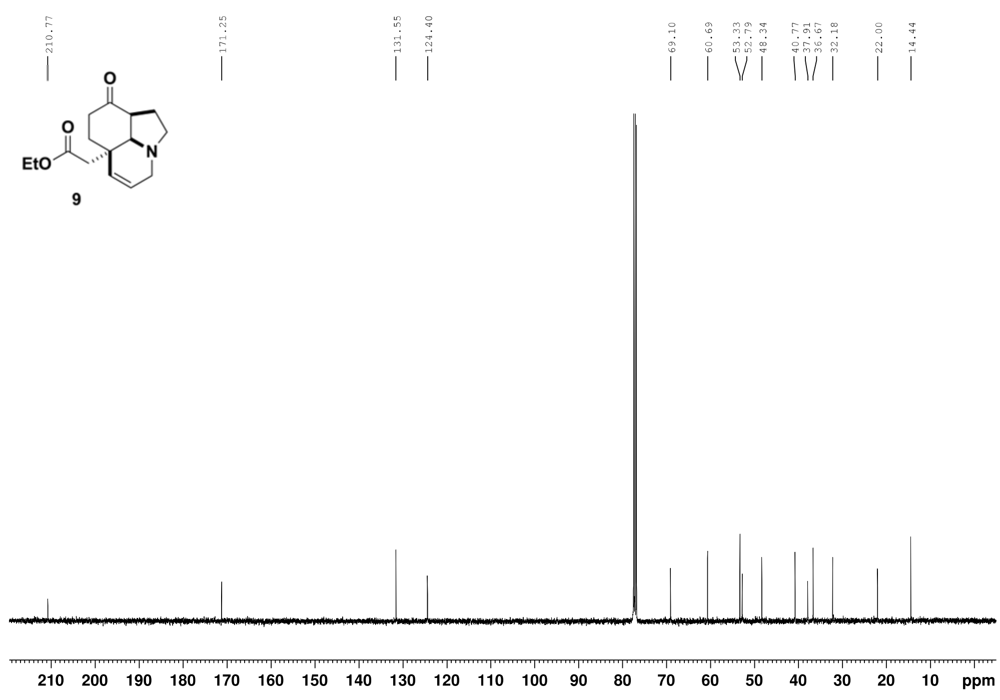


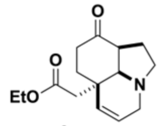
171.20
149.78 148.06 141.24 138.90 133.10 131.56 129.14 126.37 125.33 119.90
60.47
48.87 46.38 45.87 41.19 40.50 36.08
25.07 19.04 14.40
Cl
O
N
DNs
EtO
16
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm



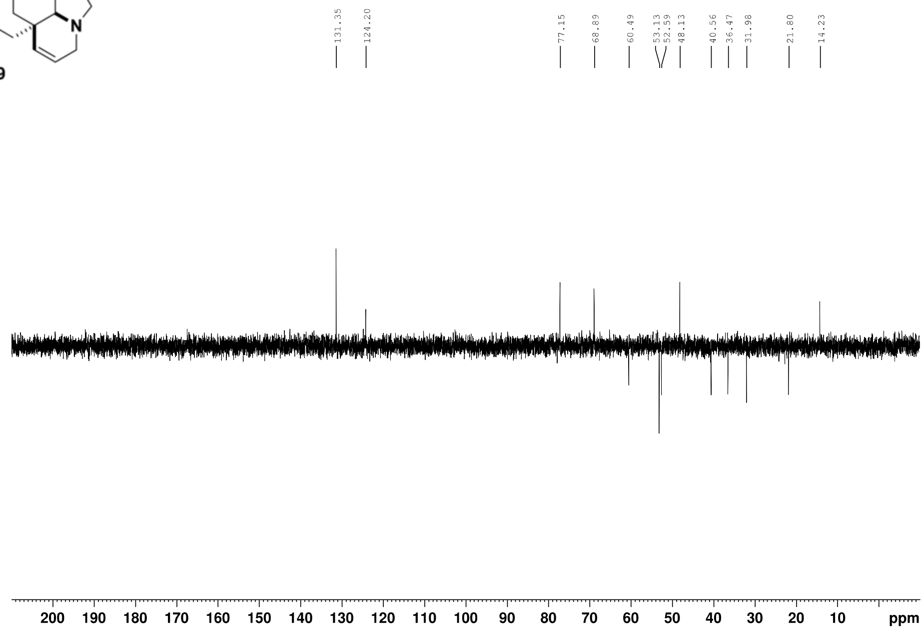



5.860 5.840 5.836 5.829 5.701 5.696 5.689 5.685 5.671 5.664 4.199 4.195 4.181 4.178 4.163 4.160 4.145 4.142 3.406 3.402 3.395 3.191 3.183 2.766 2.721 2.715 2.710 2.699 2.679 2.673 2.665 2.545 2.511 2.499 2.488 2.485 2.478 2.475 2.467 2.460 2.449 2.359 2.350 2.342 2.313 2.125 2.121 2.118 2.102 2.095 2.092 1.915 1.803 1.778 1.293 1.275 1.257
O
EtO
N
9
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.00 1.01 1.99 1.07 1.04 1.07 2.07 1.30 1.77 0.97 1.07 2.02 1.06 1.11 3.11

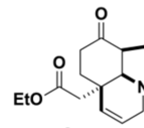

210.77 171.25 131.55 124.40 69.10 60.69 53.33 52.79 48.34 40.77 37.91 36.67 32.18 22.00 14.44
O
EtO
N
9
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm



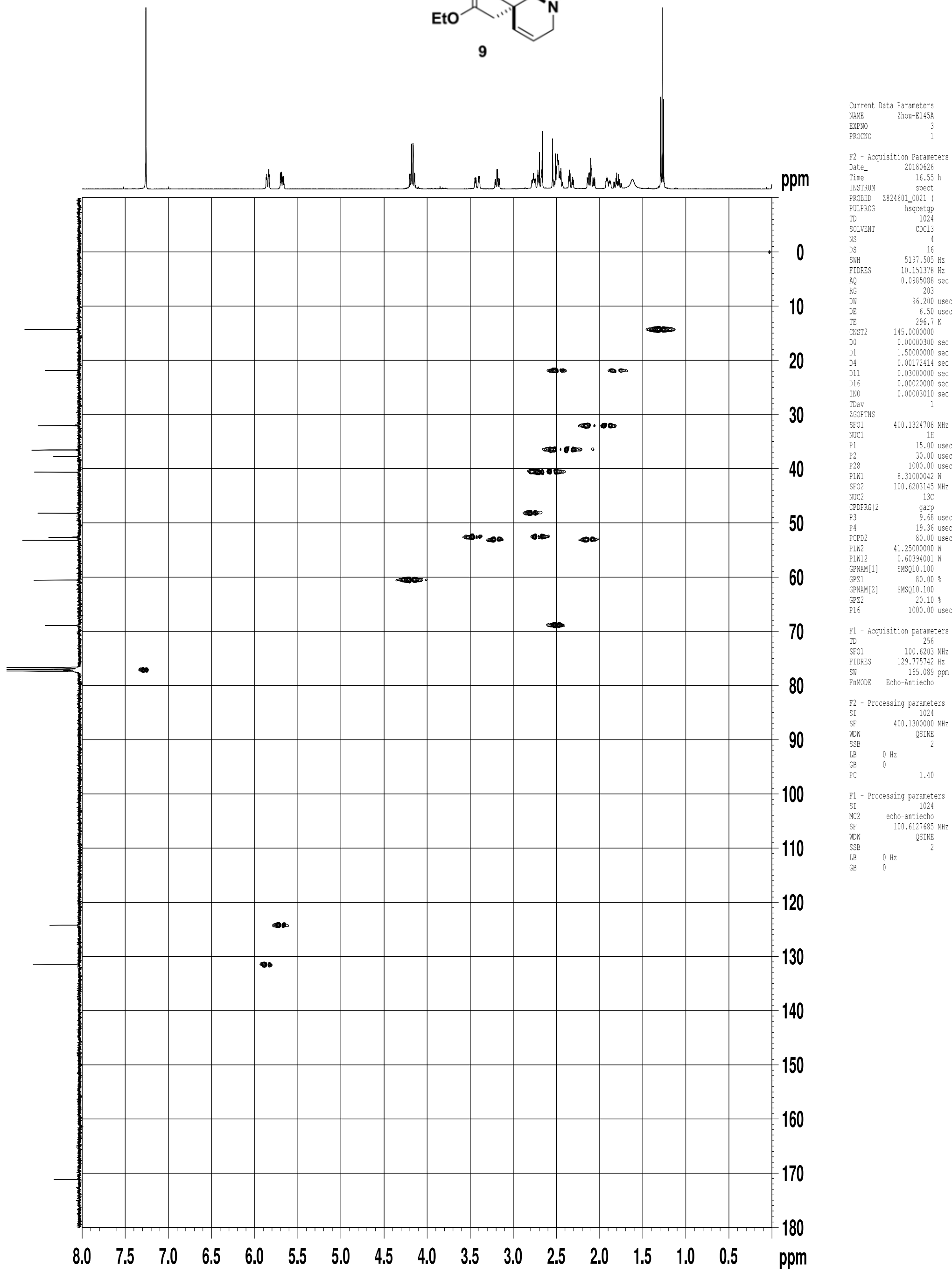
9

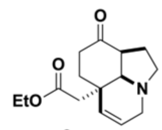


131.35
124.20
77.15
68.89
60.49
53.13
52.59
48.13
40.56
36.47
31.98
21.80
14.23
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

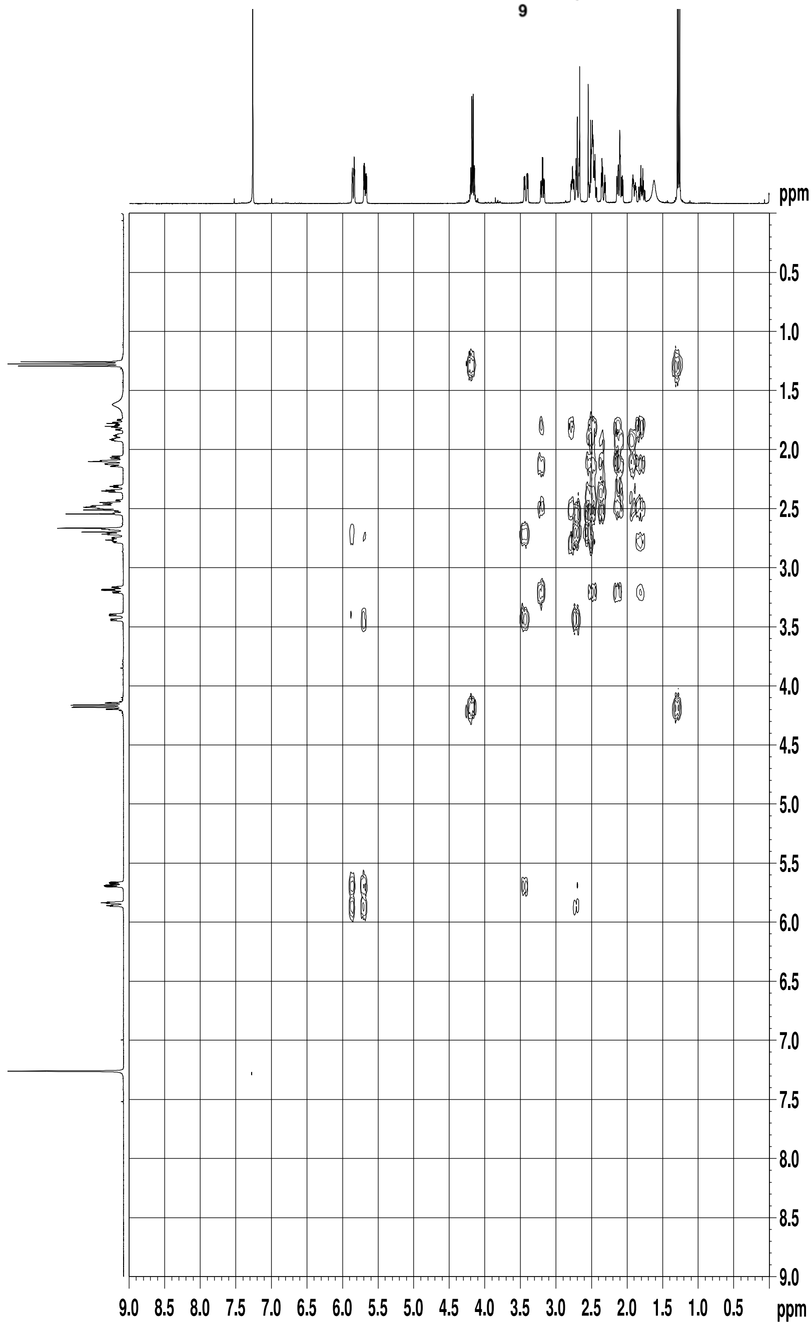

O
O
EtO
N

9


ppm
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
ppm
Current Data Parameters
NAME Zhou-E145A
EXPNO 3
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180626
Time 16.55 h
INSTRUM spect
PROBHD Z824601_0021 (
PULPROG hsqcetgp
TD 1024
SOLVENT CDCl3
NS 4
DS 16
SWH 5197.505 Hz
FIDRES 10.151378 Hz
AQ 0.0985088 sec
RG 203
DW 96.200 usec
DE 6.50 usec
TE 296.7 K
CNST2 145.0000000
D0 0.00000300 sec
D1 1.50000000 sec
D4 0.00172414 sec
D11 0.03000000 sec
D16 0.00020000 sec
IN0 0.00003010 sec
TDav 1
ZGOPTNS
SFO1 400.1324708 MHz
NUC1 1H
P1 15.00 usec
P2 30.00 usec
P28 1000.00 usec
PLW1 8.31000042 W
SFO2 100.6203145 MHz
NUC2 13C
CPDPRG[2 garp
P3 9.68 usec
P4 19.36 usec
PCPD2 80.00 usec
PLW2 41.25000000 W
PLW12 0.60394001 W
GPNAM[1] SMSQ10.100
GPZ1 80.00 %
GPNAM[2] SMSQ10.100
GPZ2 20.10 %
P16 1000.00 usec
F1 - Acquisition parameters
TD 256
SFO1 100.6203 MHz
FIDRES 129.775742 Hz
SW 165.089 ppm
FnMODE Echo-Antiecho
F2 - Processing parameters
SI 1024
SF 400.1300000 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0
PC 1.40
F1 - Processing parameters
SI 1024
MC2 echo-antiecho
SF 100.6127685 MHz
WDW QSINE
SSB 2
LB 0 Hz
GB 0



9



Bruker Advance III 400

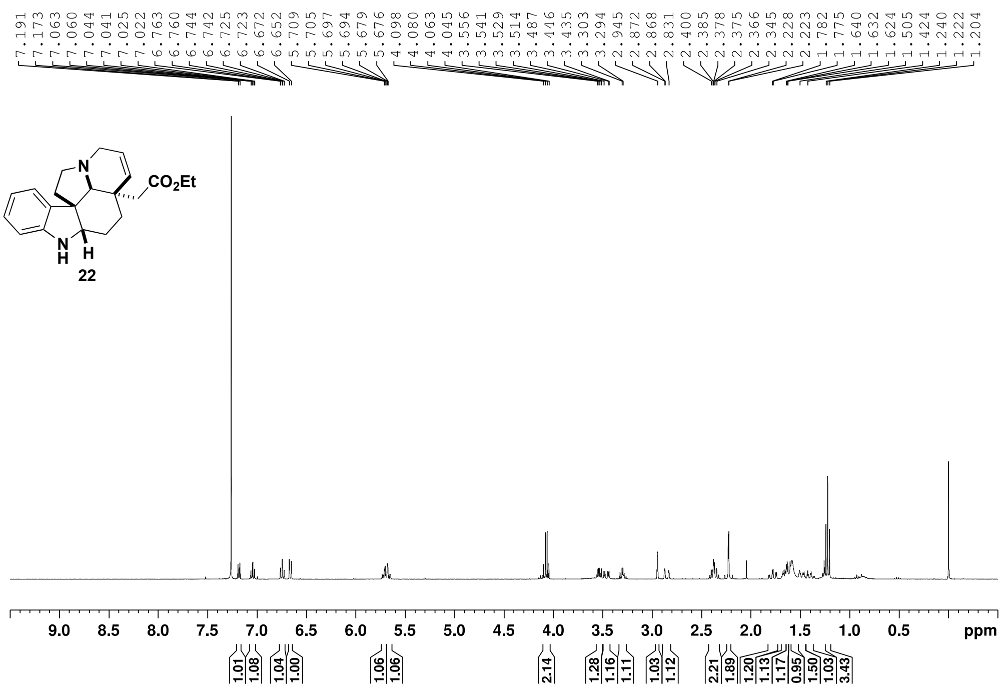
Current Data Parameters
NAME Zhou-E145A
EXPNO 4
PROCNO 1

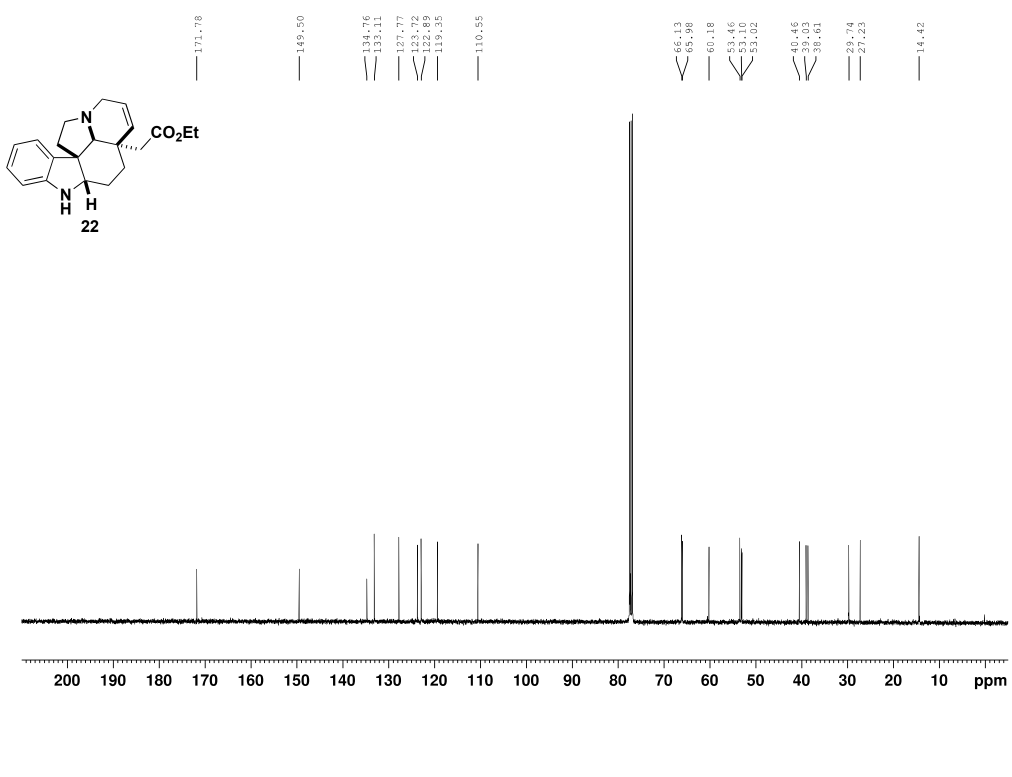
F2 - Acquisition Parameters
Date_ 20180626
Time 17.24 h
INSTRUM spect
PROBHD Z824601_0021 (
PULPROG cosygpmfqf
TD 2048
SOLVENT CDCl3
NS 8
DS 16
SWH 5197.505 Hz
FIDRES 5.075689 Hz
AQ 0.1970176 sec
RG 203
DW 96.200 usec
DE 6.50 usec
TE 296.7 K
D0 0.00000300 sec
D1 2.00000000 sec
D13 0.00000400 sec
D16 0.00020000 sec
IN0 0.00019240 sec
TDav 1
SFO1 400.1324008 MHz
NUC1 1H
P1 15.00 usec
PLW1 8.31000042 W
GPNAM[1] SMSQ10.100
GPZ1 16.00 %
GPNAM[2] SMSQ10.100
GPZ2 12.00 %
GPNAM[3] SMSQ10.100
GPZ3 40.00 %
P16 1000.00 usec

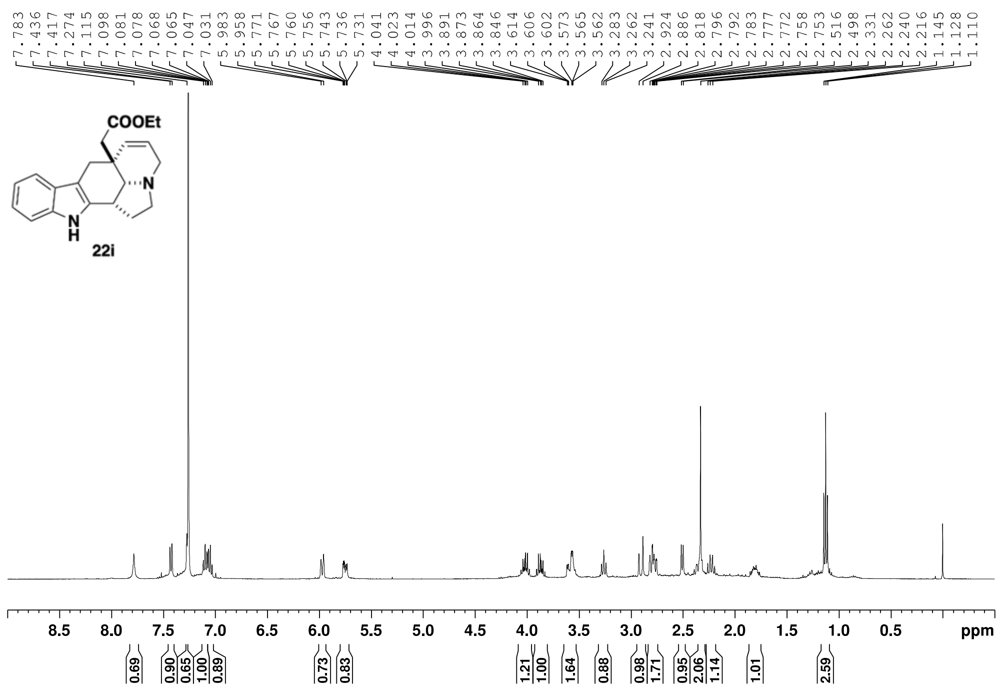
F1 - Acquisition parameters
TD 128
SFO1 400.1324 MHz
FIDRES 81.211021 Hz
SW 12.989 ppm
FnMODE QF

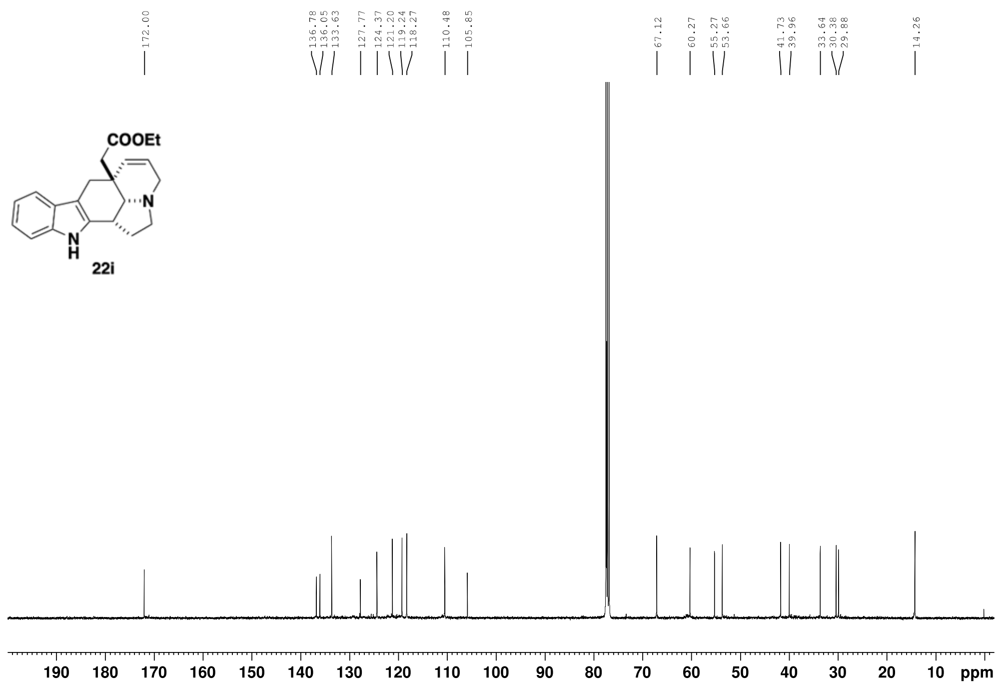
F2 - Processing parameters
SI 1024
SF 400.1300000 MHz
WDW SINE
SSB 0
LB 0 Hz
GB 0
PC 1.40

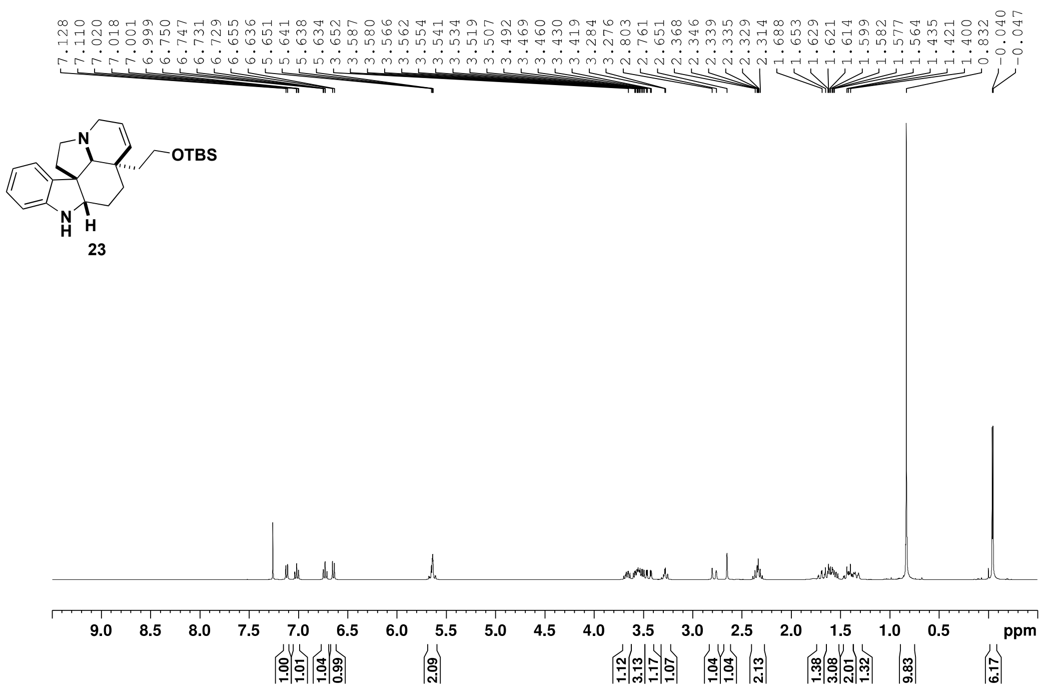
F1 - Processing parameters
SI 1024
MC2 QF
SF 400.1300000 MHz
WDW SINE
SSB 0
LB 0 Hz
GB 0

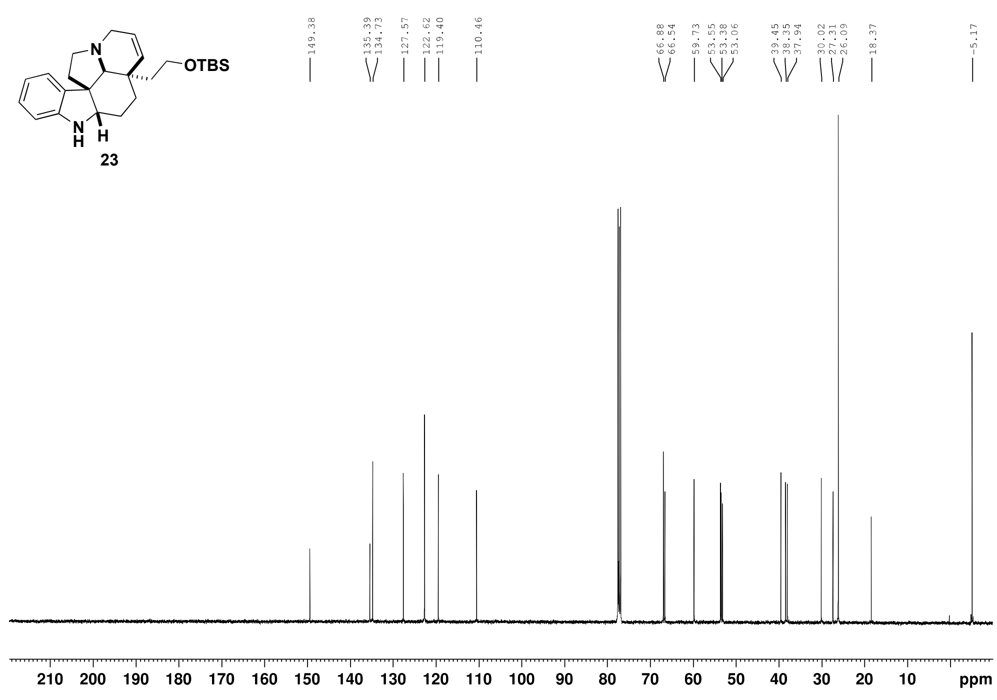

7.191 7.173 7.063 7.060 7.044 7.041 7.025 7.022 6.763 6.760 6.744 6.742 6.725 6.723 6.672 6.652 5.709 5.705 5.697 5.694 5.679 5.676 4.098 4.080 4.063 4.045 3.556 3.541 3.529 3.514 3.487 3.446 3.435 3.303 3.294 2.945 2.872 2.868 2.831 2.400 2.385 2.378 2.375 2.366 2.345 2.228 2.223 1.782 1.775 1.640 1.632 1.624 1.505 1.424 1.240 1.222 1.204
N
CO2Et
NH
H
22
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.01 1.08 1.04 1.00 1.06 1.06 2.14 1.28 1.16 1.11 1.03 1.12 2.21 1.89 1.20 1.13 1.17 0.95 1.50 1.03 3.43

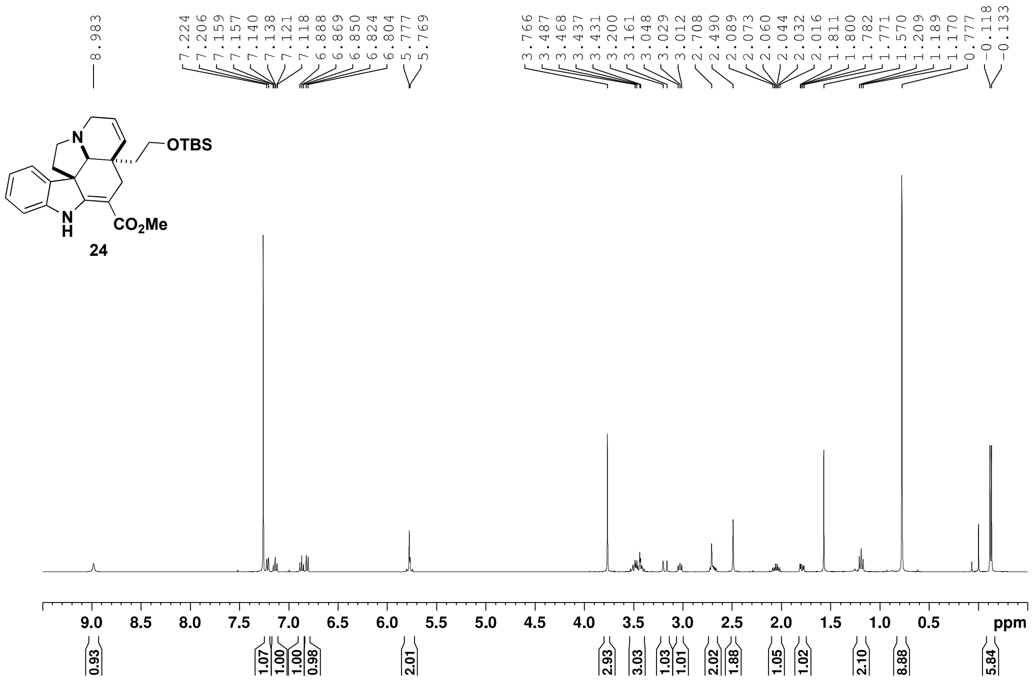

171.78 149.50 134.76 133.11 127.77 123.72 122.89 119.35 110.55 66.13 65.98 60.18 53.46 53.10 53.02 40.46 39.03 38.61 29.74 27.23 14.42
N
CO2Et
NH
H
22
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

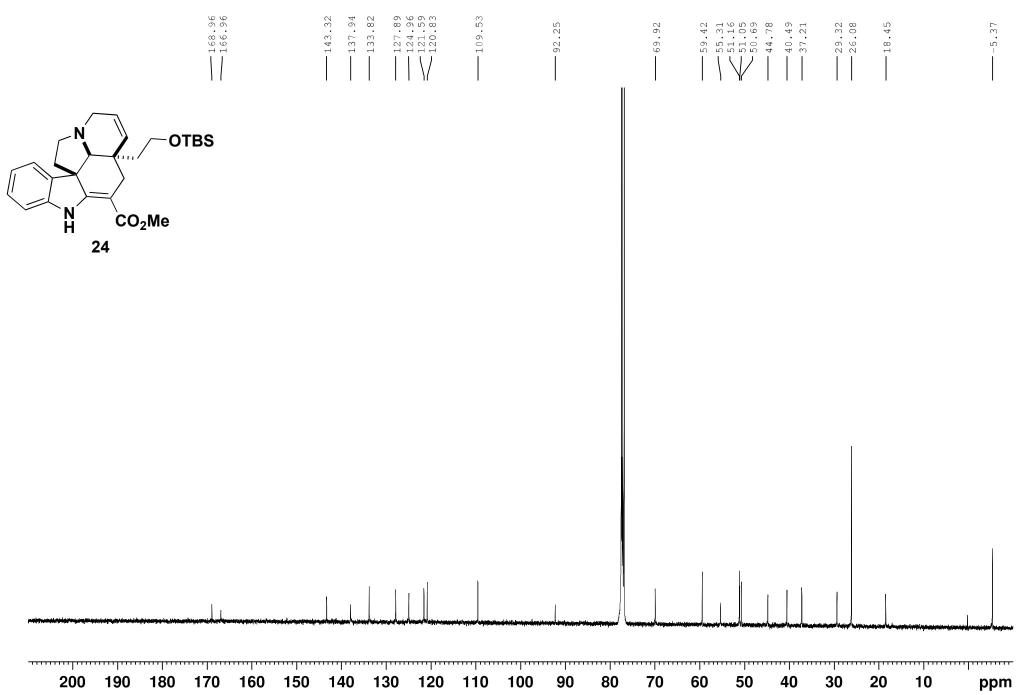

7.783
7.436
7.417
7.274
7.115
7.098
7.081
7.078
7.068
7.065
7.047
7.031
5.983
5.958
5.771
5.767
5.760
5.756
5.743
5.736
5.731
4.041
4.023
4.014
3.996
3.891
3.873
3.864
3.846
3.614
3.606
3.602
3.573
3.565
3.562
3.283
3.262
3.241
2.924
2.886
2.818
2.796
2.792
2.783
2.777
2.772
2.758
2.753
2.516
2.498
2.331
2.262
2.240
2.216
1.145
1.128
1.110
COOEt
N
N
H
22i
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
0.69
0.90
0.65
1.00
0.89
0.73
0.83
1.21
1.00
1.64
0.88
0.98
1.71
0.95
2.06
1.14
1.01
2.59

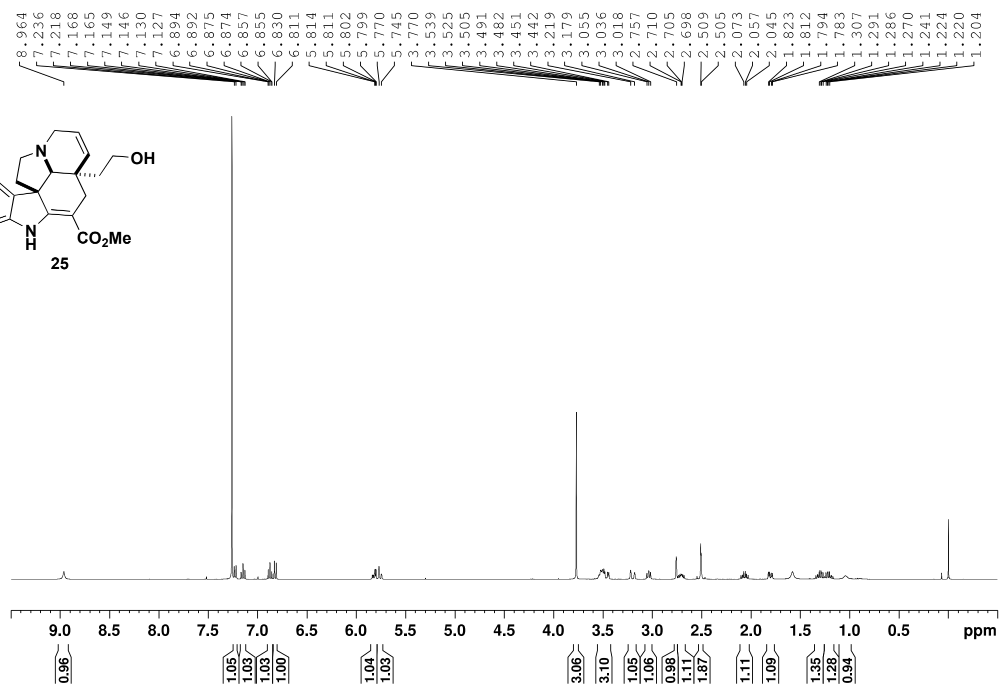

172.00
136.78
136.05
133.63
127.77
124.37
121.20
119.24
118.27
110.48
105.85
67.12
60.27
55.27
53.66
41.73
39.96
33.64
30.38
29.88
14.26
COOEt
N
N
H
22i
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

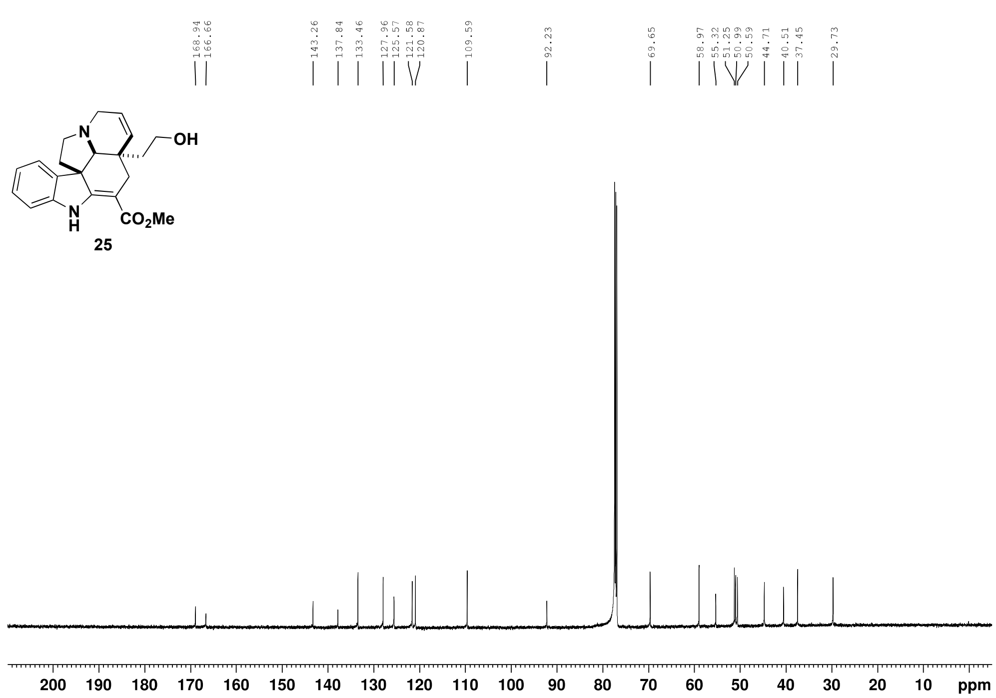

7.128
7.110
7.020
7.018
7.001
6.999
6.750
6.747
6.731
6.729
6.655
6.636
5.651
5.641
5.638
5.634
3.652
3.587
3.580
3.566
3.562
3.554
3.541
3.534
3.519
3.507
3.492
3.469
3.460
3.430
3.419
3.284
3.276
2.803
2.761
2.651
2.368
2.346
2.339
2.335
2.329
2.314
1.688
1.653
1.629
1.621
1.614
1.599
1.582
1.577
1.564
1.435
1.421
1.400
0.832
-0.040
-0.047
N
OTBS
N
H
H
23
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.00
1.01
1.04
0.99
2.09
1.12
3.13
1.17
1.07
1.04
1.04
2.13
1.38
3.08
2.01
1.32
9.83
6.17

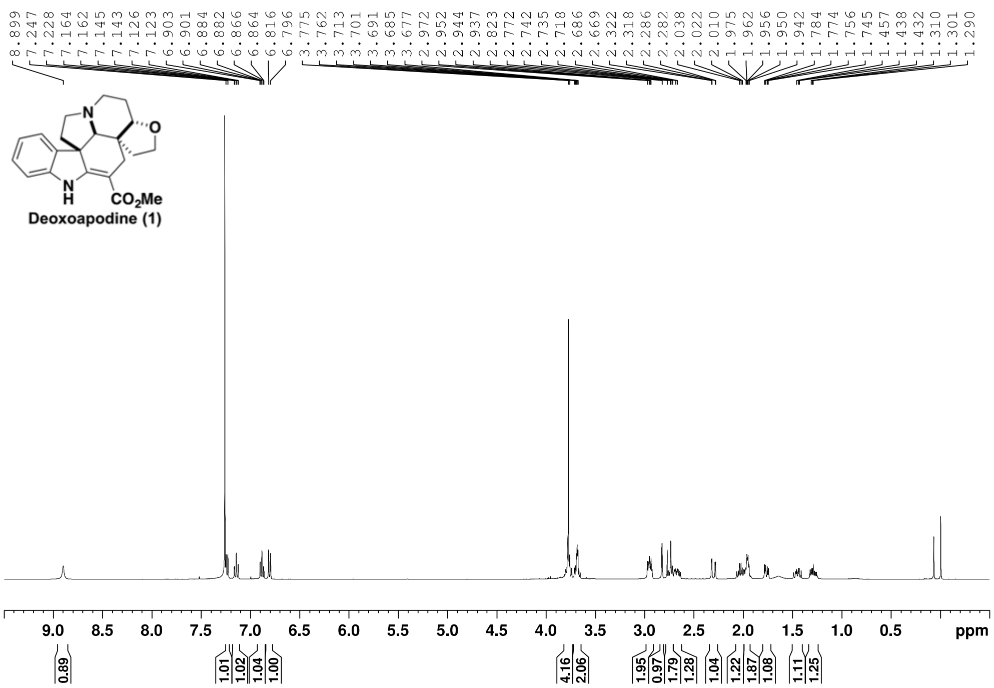

149.38
135.39
134.73
127.57
122.62
119.40
110.46
66.88
66.54
59.73
53.55
53.38
53.06
39.45
38.35
37.94
30.02
27.31
26.09
18.37
-5.17
N
OTBS
N
H
H
23
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

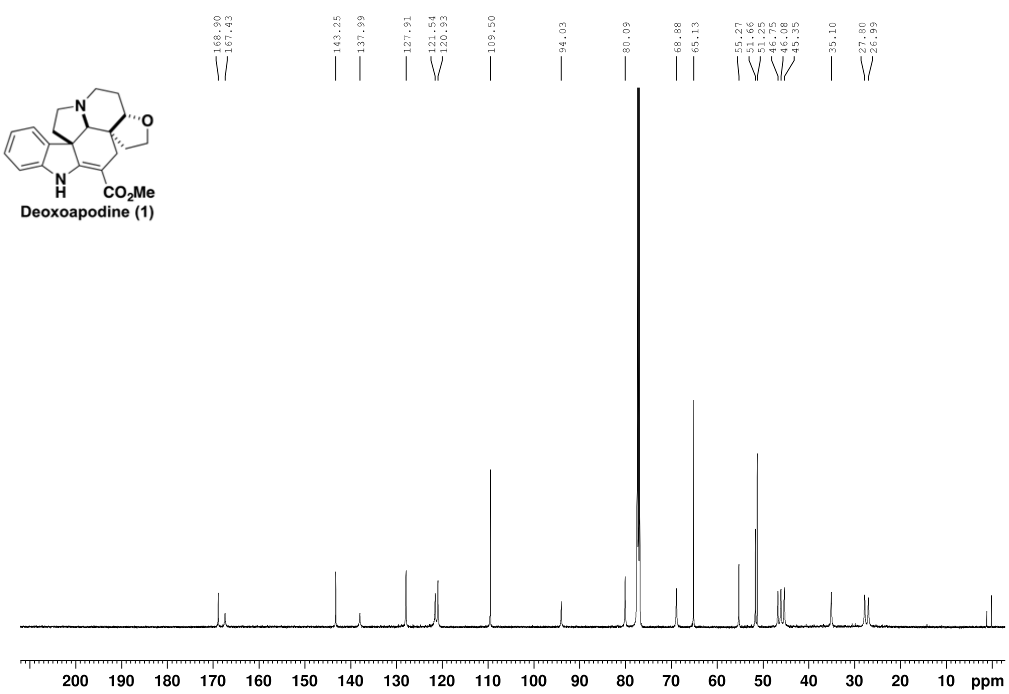

8.983
7.224
7.206
7.159
7.157
7.140
7.138
7.121
7.118
6.888
6.869
6.850
6.824
6.804
5.777
5.769
3.766
3.487
3.468
3.437
3.431
3.200
3.161
3.048
3.029
3.012
2.708
2.490
2.089
2.073
2.060
2.044
2.032
2.016
1.811
1.800
1.782
1.771
1.570
1.209
1.189
1.170
0.777
-0.118
-0.133
OTBS
N
NH
CO2Me
24
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
0.93
1.07
1.00
1.00
0.98
2.01
2.93
3.03
1.03
1.01
2.02
1.88
1.05
1.02
2.10
8.88
5.84

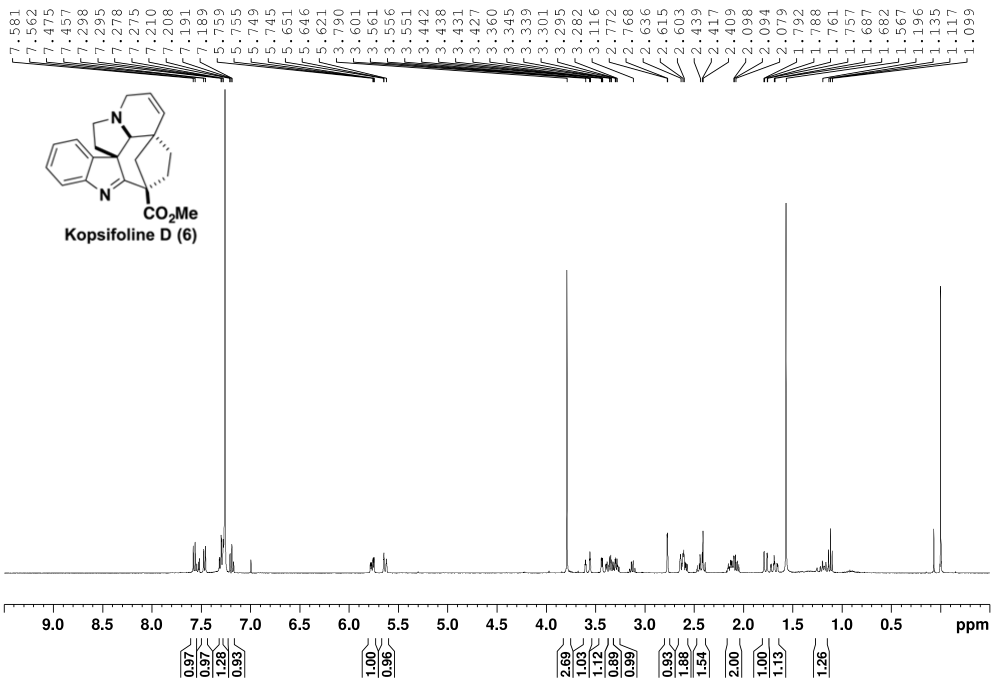

168.96
166.96
143.32
137.94
133.82
127.89
124.96
121.59
120.83
109.53
92.25
69.92
59.42
55.31
51.16
51.05
50.69
44.78
40.49
37.21
29.32
26.08
18.45
-5.37
OTBS
N
NH
CO2Me
24
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

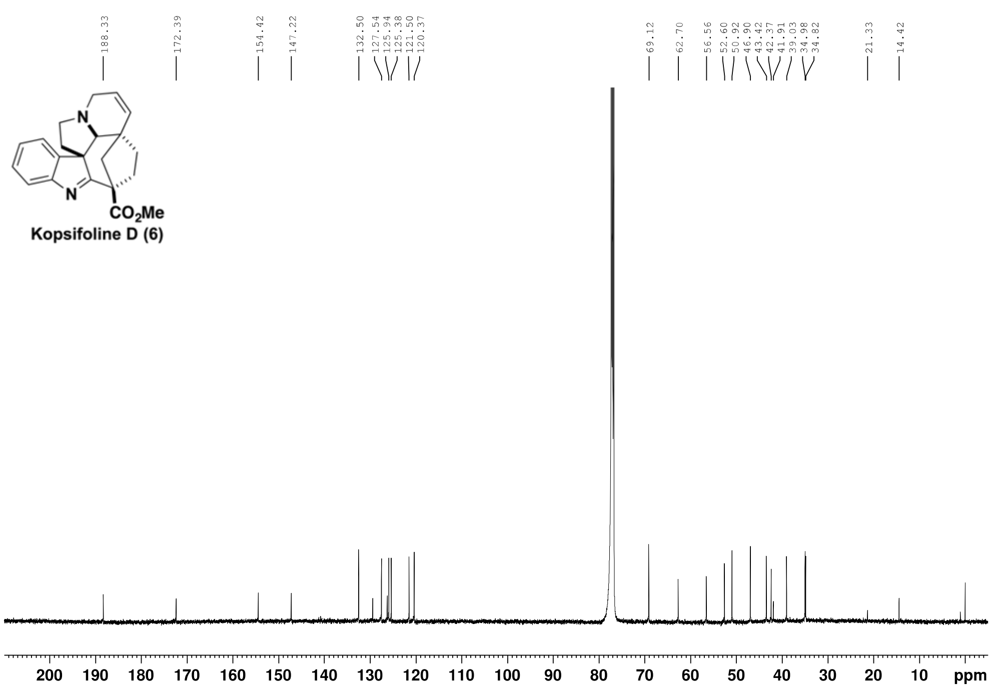

8.964 7.236 7.218 7.168 7.165 7.149 7.146 7.130 7.127 6.894 6.892 6.875 6.874 6.857 6.855 6.830 6.811 5.814 5.811 5.802 5.799 5.770 5.745 3.770 3.539 3.525 3.505 3.491 3.482 3.451 3.442 3.219 3.179 3.055 3.036 3.018 2.757 2.710 2.705 2.698 2.509 2.505 2.073 2.057 2.045 1.823 1.812 1.794 1.783 1.307 1.291 1.286 1.270 1.241 1.224 1.220 1.204
N
OH
H
CO_2Me
25
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
0.96 1.05 1.03 1.03 1.00 1.04 1.03 3.06 3.10 1.05 1.06 0.98 1.11 1.87 1.11 1.09 1.35 1.28 0.94

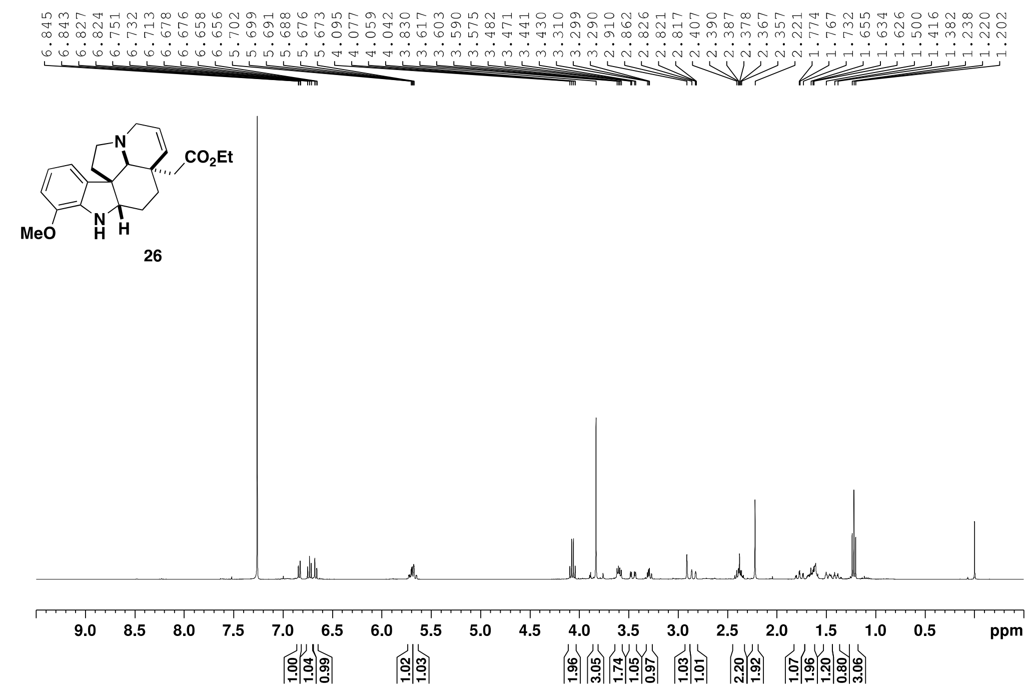

168.94 166.66 143.26 137.84 133.46 127.96 125.57 121.58 120.87 109.59 92.23 69.65 58.97 55.32 51.25 50.99 50.59 44.71 40.51 37.45 29.73
N
OH
H
CO_2Me
25
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

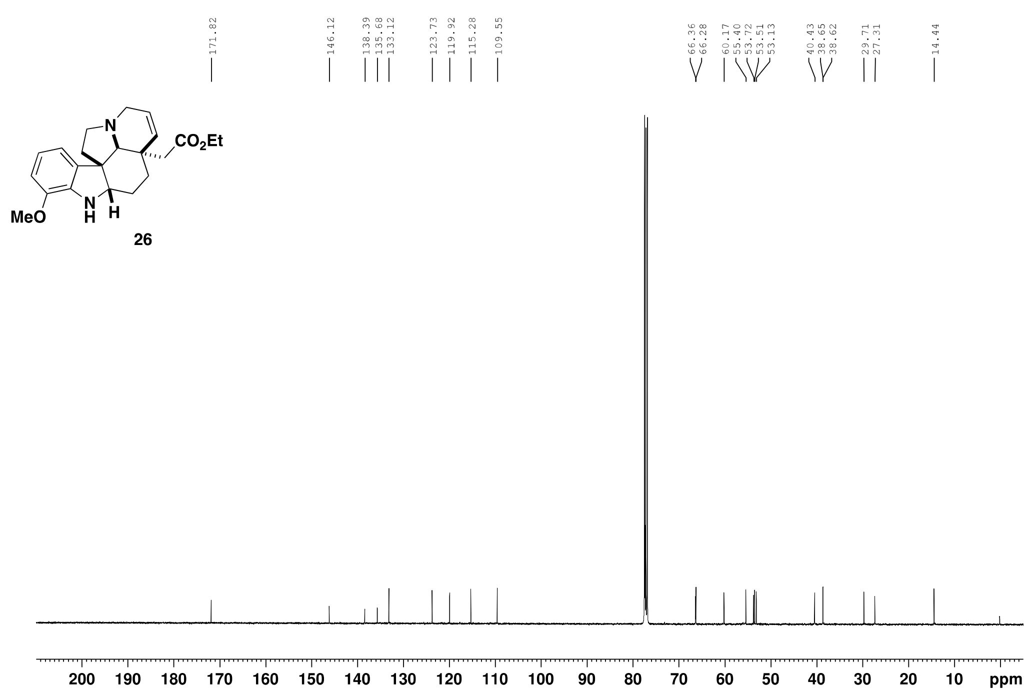

8.899 7.247 7.228 7.164 7.162 7.145 7.143 7.126 7.123 6.903 6.901 6.884 6.882 6.866 6.864 6.816 6.796 3.775 3.762 3.713 3.701 3.691 3.685 3.677 2.972 2.952 2.944 2.937 2.823 2.772 2.742 2.735 2.718 2.686 2.669 2.322 2.318 2.286 2.282 2.038 2.022 2.010 1.975 1.962 1.956 1.950 1.942 1.784 1.774 1.756 1.745 1.457 1.438 1.432 1.310 1.301 1.290
N
O
N
H
CO2Me
Deoxoapodine (1)
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
0.89 1.01 1.02 1.04 1.00 4.16 2.06 1.95 0.97 1.79 1.28 1.04 1.22 1.87 1.08 1.11 1.25

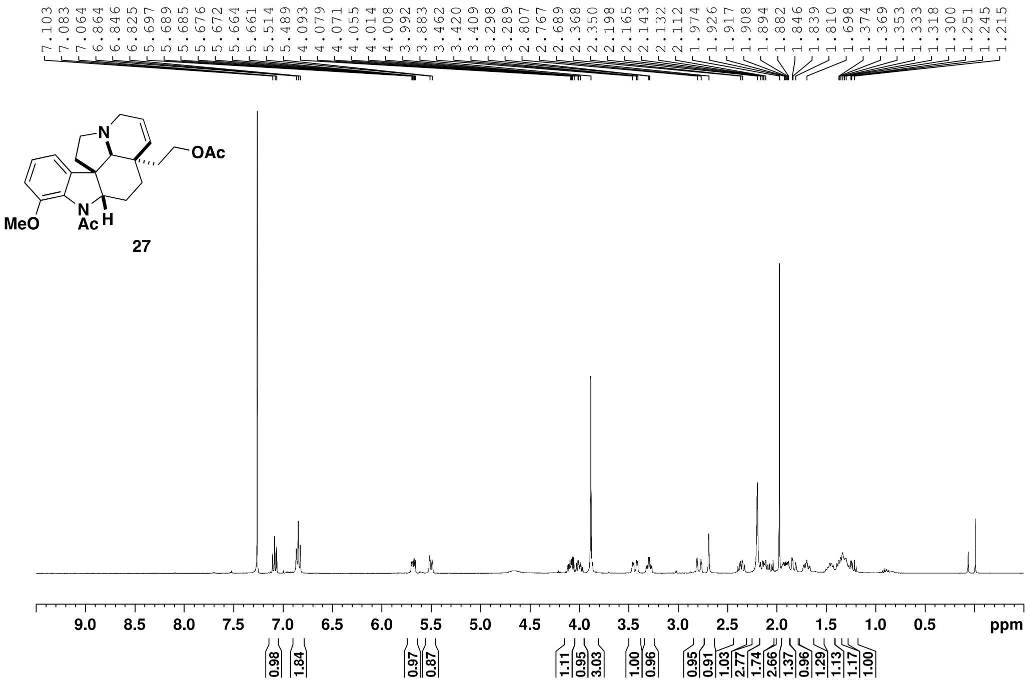

168.90 167.43 143.25 137.99 127.91 121.54 120.93 109.50 94.03 80.09 68.88 65.13 55.27 51.66 51.25 46.75 46.08 45.35 35.10 27.80 26.99
N
O
N
H
CO2Me
Deoxoapodine (1)
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


7.581 7.562 7.475 7.457 7.298 7.295 7.278 7.275 7.210 7.208 7.191 7.189 5.759 5.755 5.749 5.745 5.651 5.646 5.621 3.790 3.601 3.561 3.556 3.551 3.442 3.438 3.431 3.427 3.360 3.345 3.339 3.301 3.295 3.282 3.116 2.772 2.768 2.636 2.615 2.603 2.439 2.417 2.409 2.098 2.094 2.079 1.792 1.788 1.761 1.757 1.687 1.682 1.567 1.196 1.135 1.117 1.099
N
N
CO_2Me
Kopsifoline D (6)
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
0.97 0.97 1.28 0.93 1.00 0.96 2.69 1.03 1.12 0.89 0.99 0.93 1.88 1.54 2.00 1.00 1.13 1.26

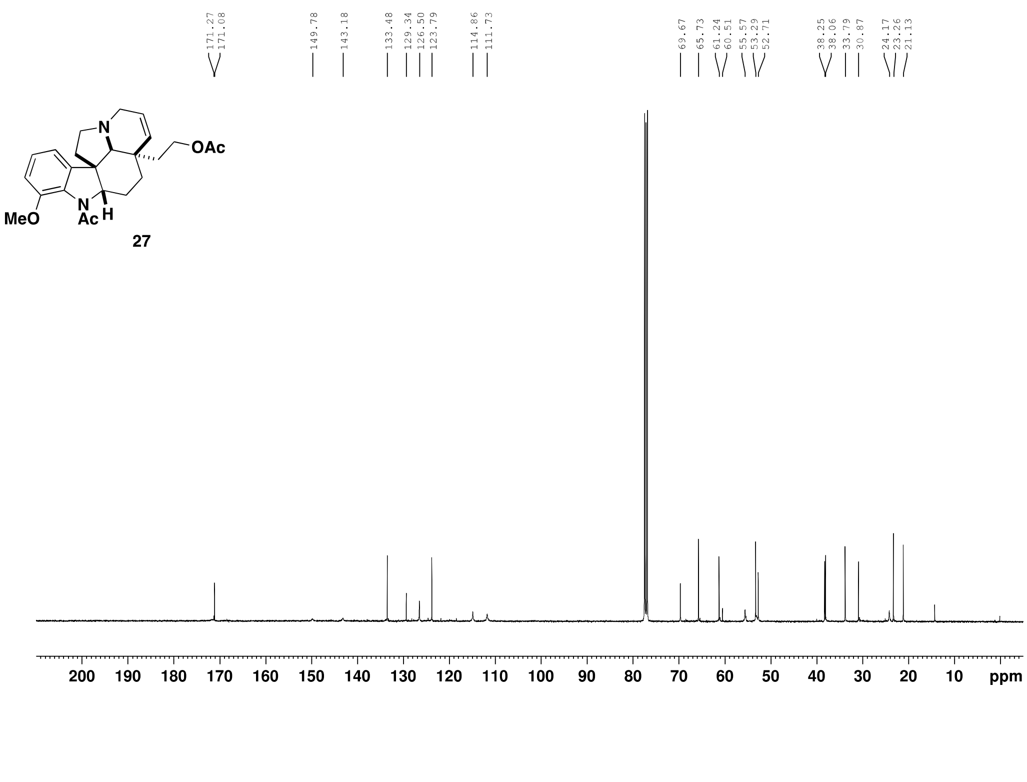

188.33 172.39 154.42 147.22 132.50 127.54 125.94 125.38 121.50 120.37 69.12 62.70 56.56 52.60 50.92 46.90 43.42 42.37 41.91 39.03 34.98 34.82 21.33 14.42
N
N
CO_2Me
Kopsifoline D (6)
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


6.845 6.843 6.827 6.824 6.751 6.732 6.713 6.678 6.676 6.658 6.656 5.702 5.699 5.691 5.688 5.676 5.673 4.095 4.077 4.059 4.042 3.830 3.617 3.603 3.590 3.575 3.482 3.471 3.441 3.430 3.310 3.299 3.290 2.910 2.862 2.826 2.821 2.817 2.407 2.390 2.387 2.378 2.367 2.357 2.221 1.774 1.767 1.732 1.655 1.634 1.626 1.500 1.416 1.382 1.238 1.220 1.202
N
CO_2Et
MeO
H
H
26
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.00 1.04 0.99 1.02 1.03 1.96 3.05 1.74 1.05 0.97 1.03 1.01 2.20 1.92 1.07 1.96 1.20 0.80 3.06

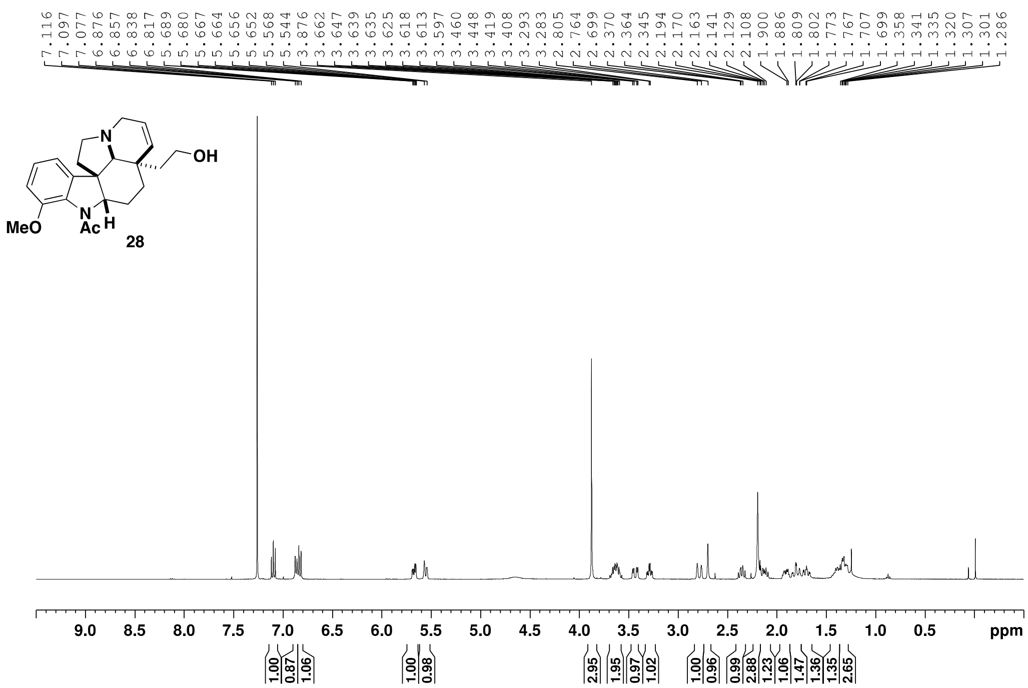

171.82 146.12 138.39 135.68 133.12 123.73 119.92 115.28 109.55 66.36 66.28 60.17 55.40 53.72 53.51 53.13 40.43 38.65 38.62 29.71 27.31 14.44
N
CO_2Et
MeO
H
H
26
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

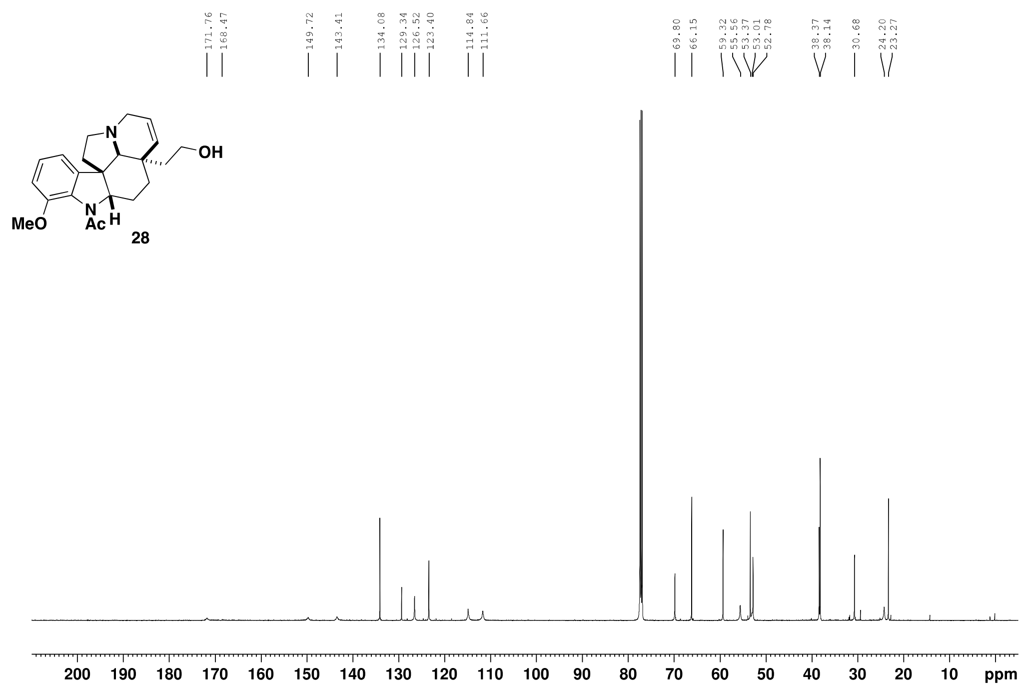

7.103 7.083 7.064 6.864 6.846 6.825 5.697 5.689 5.685 5.676 5.672 5.664 5.661 5.514 5.489 4.093 4.079 4.071 4.055 4.014 4.008 3.992 3.883 3.462 3.420 3.409 3.298 3.289 2.807 2.767 2.689 2.368 2.350 2.198 2.165 2.143 2.132 2.112 1.974 1.926 1.917 1.908 1.894 1.882 1.846 1.839 1.810 1.698 1.374 1.369 1.353 1.333 1.318 1.300 1.251 1.245 1.215
OAc
N
MeO
N
Ac
H
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
0.98 1.84 0.97 0.87 1.11 0.95 3.03 1.00 0.96 0.95 0.91 1.03 2.77 1.74 2.66 1.37 0.96 1.29 1.13 1.17 1.00

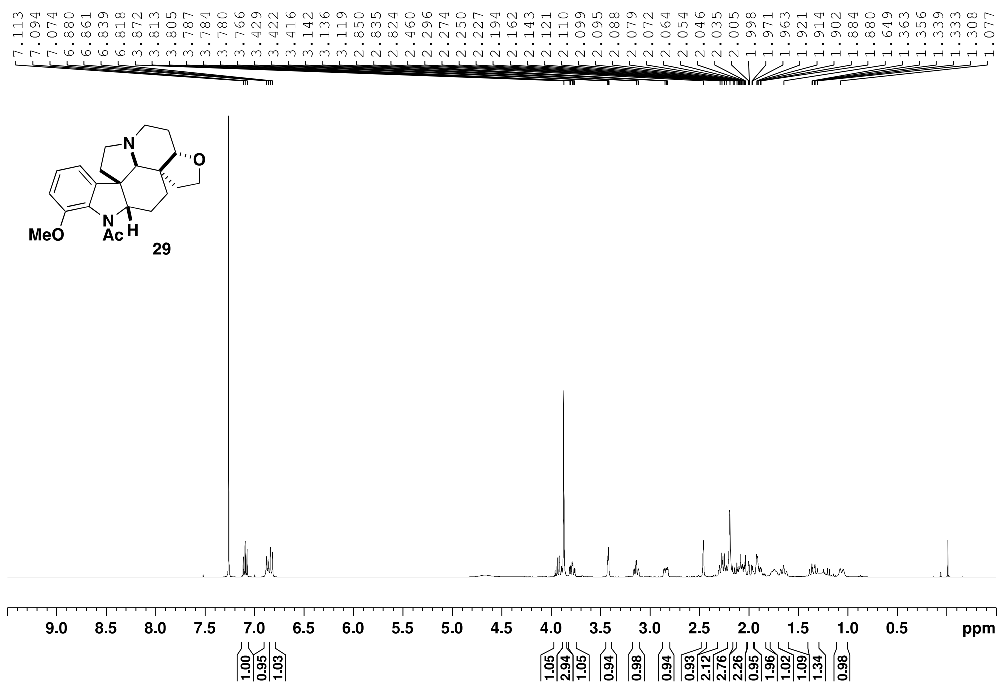
27

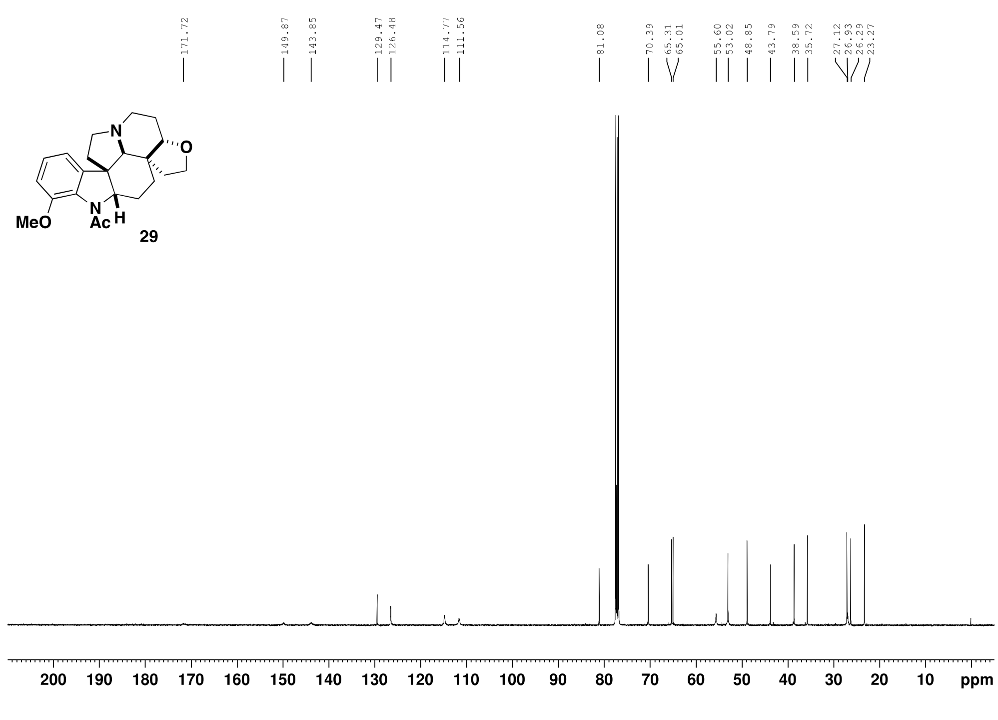

171.27 171.08 149.78 143.18 133.48 129.34 126.50 123.79 114.86 111.73 69.67 65.73 61.24 60.51 55.57 53.29 52.71 38.25 38.06 33.79 30.87 24.17 23.26 21.13
OAc
N
MeO
N
Ac
H
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

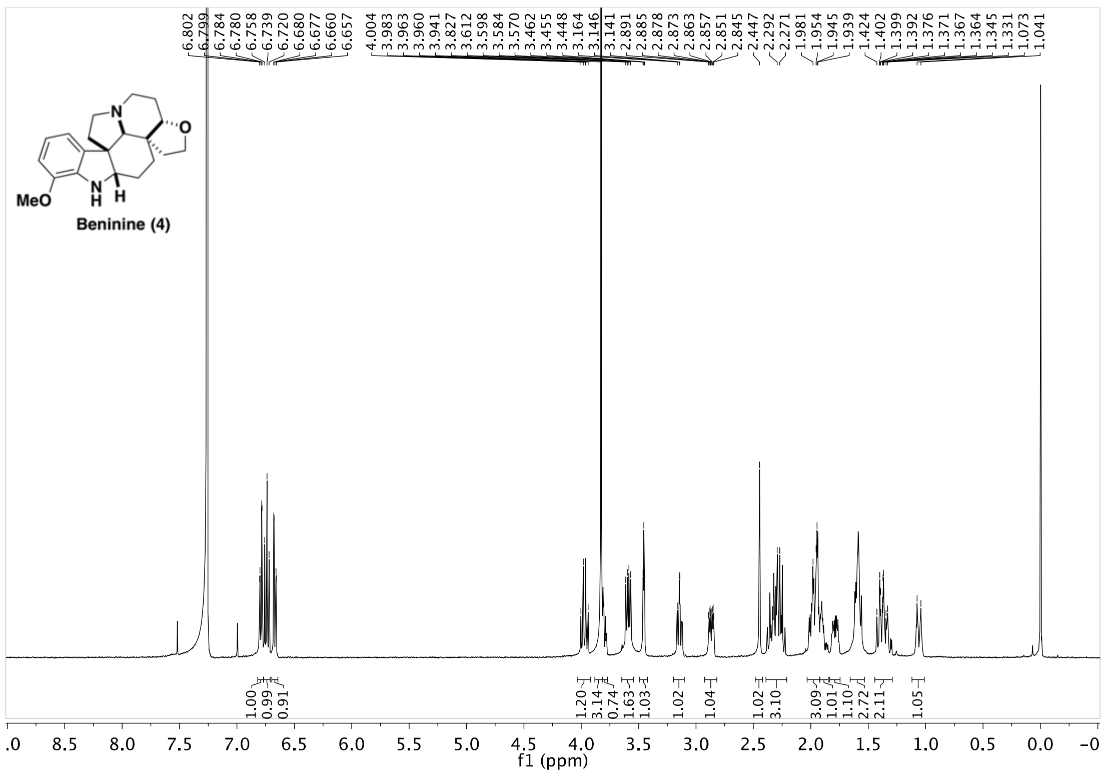
27

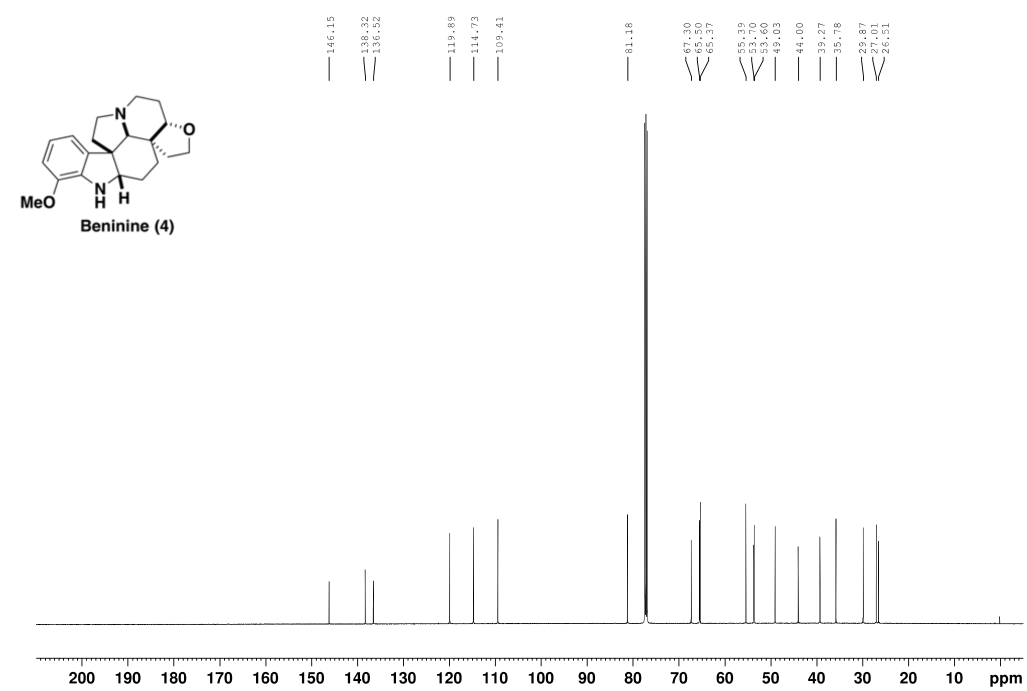

7.116 7.097 7.077 6.876 6.857 6.838 6.817 5.689 5.680 5.667 5.664 5.656 5.652 5.568 5.544 3.876 3.662 3.647 3.639 3.635 3.625 3.618 3.613 3.597 3.460 3.448 3.419 3.408 3.293 3.283 2.805 2.764 2.699 2.370 2.364 2.345 2.194 2.170 2.163 2.141 2.129 2.108 1.900 1.886 1.809 1.802 1.773 1.767 1.707 1.699 1.358 1.341 1.335 1.320 1.307 1.301 1.286
N
OH
MeO
N
Ac
H
28
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.00 0.87 1.06 1.00 0.98 2.95 1.95 0.97 1.02 1.00 0.96 0.99 2.88 1.23 1.06 1.47 1.36 1.35 2.65


171.76 168.47 149.72 143.41 134.08 129.34 126.52 123.40 114.84 111.66 69.80 66.15 59.32 55.56 53.37 53.01 52.78 38.37 38.14 30.68 24.20 23.27
N
OH
MeO
N
Ac
H
28
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm





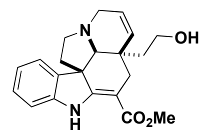

6.802 6.799 6.784 6.780 6.758 6.739 6.720 6.680 6.677 6.660 6.657 4.004 3.983 3.963 3.960 3.941 3.827 3.612 3.598 3.584 3.570 3.462 3.455 3.448 3.164 3.146 3.141 2.891 2.885 2.878 2.873 2.863 2.857 2.851 2.845 2.447 2.292 2.271 1.981 1.954 1.945 1.939 1.424 1.402 1.399 1.392 1.376 1.371 1.367 1.364 1.345 1.331 1.073 1.041
MeO
N
H
H
O
Beninine (4)
1.00 0.99 0.91 1.20 3.14 0.74 1.63 1.03 1.02 1.04 1.02 3.10 3.09 1.01 1.10 2.72 2.11 1.05
f1 (ppm)


146.15 138.32 136.52 119.89 114.73 109.41 81.18 67.30 65.50 65.37 55.39 53.70 53.60 49.03 44.00 39.27 35.78 29.87 27.01 26.51
MeO
N
H
H
O
Beninine (4)
ppm

6. X-ray Structure Determination of 25 and Beninine (4)

X-ray data of **25** (CCDC 1897697) was collected at 293 K on a Bruker SMART 1000 CCD diffractometer using Mo-K radiation. CCDC 1897697 contains the supplementary crystallographic data for this paper. These data are provided free of charge by The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Table S7 Crystal data and structure refinement.



25

Identification code	zhoue181	
Empirical formula	C21 H24 N2 O3	
Formula weight	352.42	
Temperature	297(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group	P-1	
Unit cell dimensions	a = 8.2482(4) Å	〈= 96.3456(14)°.
	b = 10.0471(5) Å	®= 99.4230(13)°.
	c = 12.1109(5) Å	© = 112.2777(12)°.
Volume	899.67(7) $Å^3$	
Z	2	
Density (calculated)	1.301 Mg/m^3	
Absorption coefficient	0.087 mm^{-1}	
F(000)	376	
Crystal size	0.500 x 0.400 x 0.300 mm^3	
Theta range for data collection	2.231 to 25.242°.	
Index ranges	-9<=h<=9, -12<=k<=12, -14<=l<=14	
Reflections collected	32898	
Independent reflections	3246 [R(int) = 0.0307]	
Completeness to theta = 25.242°	99.7 %	
Absorption correction	multi-scan	
Max. and min. transmission	0.7456 and 0.6434	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3246 / 0 / 236	
Goodness-of-fit on F^2	1.034	
Final R indices [I>2sigma(I)]	R1 = 0.0391, wR2 = 0.0992	
R indices (all data)	R1 = 0.0477, wR2 = 0.1062	
Extinction coefficient	0.104(8)	
Largest diff. peak and hole	0.246 and -0.246 e.$Å^{-3}$	

Table S8 Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for p. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
N(1)	3299(2)	6986(1)	6931(1)	37(1)
N(2)	431(2)	7402(1)	9837(1)	37(1)
O(1)	2175(2)	4043(1)	6139(1)	52(1)
O(2)	-393(2)	2545(1)	6519(1)	50(1)
O(3)	-3839(2)	6968(2)	5508(1)	67(1)
C(1)	3718(2)	8483(2)	6997(1)	32(1)
C(2)	4774(2)	9448(2)	6413(1)	40(1)
C(3)	4895(2)	10872(2)	6586(1)	43(1)
C(4)	4003(2)	11315(2)	7315(1)	44(1)
C(5)	2985(2)	10342(2)	7921(1)	39(1)
C(6)	2851(2)	8924(2)	7762(1)	32(1)
C(7)	1992(2)	7653(1)	8335(1)	30(1)
C(8)	3227(2)	7894(2)	9538(1)	39(1)
C(9)	2268(2)	8407(2)	10339(1)	42(1)
C(10)	-978(2)	7580(2)	10307(1)	47(1)
C(11)	-2737(2)	6447(2)	9633(2)	51(1)
C(12)	-2901(2)	5688(2)	8628(2)	47(1)
C(13)	-1399(2)	5942(2)	7993(1)	35(1)
C(14)	-2139(2)	5964(2)	6744(1)	42(1)
C(15)	-2601(2)	7253(2)	6558(1)	47(1)
C(16)	146(2)	7394(2)	8612(1)	30(1)
C(17)	-702(2)	4712(2)	8032(1)	37(1)
C(18)	847(2)	4989(2)	7442(1)	33(1)
C(19)	2020(2)	6396(2)	7538(1)	32(1)
C(20)	974(2)	3859(2)	6650(1)	36(1)
C(21)	-401(3)	1379(2)	5710(2)	59(1)

Table S9 Bond lengths [Å] and angles [°] for p.

N(1)-C(19)	1.3715(17)
N(1)-C(1)	1.3999(18)
N(2)-C(10)	1.4352(19)
N(2)-C(9)	1.445(2)
N(2)-C(16)	1.4625(17)
O(1)-C(20)	1.2196(18)
O(2)-C(20)	1.3437(19)
O(2)-C(21)	1.439(2)
O(3)-C(15)	1.419(2)
C(1)-C(2)	1.382(2)
C(1)-C(6)	1.3908(19)
C(2)-C(3)	1.386(2)
C(3)-C(4)	1.375(2)
C(4)-C(5)	1.393(2)
C(5)-C(6)	1.375(2)
C(6)-C(7)	1.5121(19)
C(7)-C(19)	1.5115(18)
C(7)-C(16)	1.5445(18)
C(7)-C(8)	1.5712(19)
C(8)-C(9)	1.511(2)
C(10)-C(11)	1.490(3)
C(11)-C(12)	1.321(2)
C(12)-C(13)	1.518(2)
C(13)-C(16)	1.533(2)
C(13)-C(14)	1.541(2)
C(13)-C(17)	1.550(2)
C(14)-C(15)	1.512(2)
C(17)-C(18)	1.5149(19)
C(18)-C(19)	1.356(2)
C(18)-C(20)	1.449(2)
C(19)-N(1)-C(1)	110.19(11)
C(10)-N(2)-C(9)	118.64(13)
C(10)-N(2)-C(16)	112.14(12)
C(9)-N(2)-C(16)	106.89(11)
C(20)-O(2)-C(21)	116.44(13)

C(2)-C(1)-C(6)	121.77(13)
C(2)-C(1)-N(1)	128.97(13)
C(6)-C(1)-N(1)	109.25(12)
C(1)-C(2)-C(3)	117.60(14)
C(4)-C(3)-C(2)	121.36(14)
C(3)-C(4)-C(5)	120.38(15)
C(6)-C(5)-C(4)	119.10(14)
C(5)-C(6)-C(1)	119.75(13)
C(5)-C(6)-C(7)	132.35(13)
C(1)-C(6)-C(7)	107.77(12)
C(19)-C(7)-C(6)	101.22(11)
C(19)-C(7)-C(16)	114.83(11)
C(6)-C(7)-C(16)	118.51(11)
C(19)-C(7)-C(8)	110.15(11)
C(6)-C(7)-C(8)	109.12(11)
C(16)-C(7)-C(8)	103.00(11)
C(9)-C(8)-C(7)	102.71(11)
N(2)-C(9)-C(8)	100.22(12)
N(2)-C(10)-C(11)	108.57(13)
C(12)-C(11)-C(10)	122.30(14)
C(11)-C(12)-C(13)	124.78(15)
C(12)-C(13)-C(16)	106.93(12)
C(12)-C(13)-C(14)	108.34(13)
C(16)-C(13)-C(14)	112.89(12)
C(12)-C(13)-C(17)	110.94(12)
C(16)-C(13)-C(17)	108.21(12)
C(14)-C(13)-C(17)	109.52(12)
C(15)-C(14)-C(13)	115.55(13)
O(3)-C(15)-C(14)	112.55(14)
N(2)-C(16)-C(13)	108.47(11)
N(2)-C(16)-C(7)	104.47(11)
C(13)-C(16)-C(7)	115.40(11)
C(18)-C(17)-C(13)	111.31(11)
C(19)-C(18)-C(20)	118.62(13)
C(19)-C(18)-C(17)	117.75(12)
C(20)-C(18)-C(17)	122.94(13)
C(18)-C(19)-N(1)	129.91(13)
C(18)-C(19)-C(7)	122.63(12)

N(1)-C(19)-C(7)	107.29(12)
O(1)-C(20)-O(2)	121.81(13)
O(1)-C(20)-C(18)	125.04(14)
O(2)-C(20)-C(18)	113.15(13)

Symmetry transformations used to generate equivalent atoms:

Table S10 Anisotropic displacement parameters (Å^{2}x 10^3) for p. The anisotropic displacement factor exponent takes the form: -2□^{2}[h^2 a*^{2}U^{11} + ... + 2 h k a* b* U^{12}]

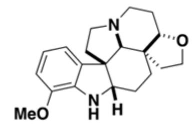
	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
N(1)	37(1)	34(1)	44(1)	5(1)	20(1)	16(1)
N(2)	45(1)	41(1)	31(1)	7(1)	16(1)	20(1)
O(1)	58(1)	42(1)	61(1)	0(1)	30(1)	21(1)
O(2)	54(1)	30(1)	62(1)	-4(1)	21(1)	13(1)
O(3)	75(1)	105(1)	40(1)	0(1)	1(1)	66(1)
C(1)	30(1)	34(1)	32(1)	4(1)	7(1)	12(1)
C(2)	37(1)	44(1)	36(1)	7(1)	14(1)	13(1)
C(3)	43(1)	40(1)	40(1)	14(1)	11(1)	7(1)
C(4)	48(1)	30(1)	51(1)	9(1)	10(1)	12(1)
C(5)	42(1)	34(1)	42(1)	4(1)	14(1)	15(1)
C(6)	30(1)	31(1)	32(1)	4(1)	8(1)	11(1)
C(7)	31(1)	28(1)	31(1)	4(1)	10(1)	12(1)
C(8)	37(1)	40(1)	37(1)	6(1)	5(1)	16(1)
C(9)	51(1)	43(1)	30(1)	3(1)	6(1)	18(1)
C(10)	63(1)	49(1)	43(1)	13(1)	30(1)	30(1)
C(11)	52(1)	51(1)	66(1)	19(1)	38(1)	24(1)
C(12)	38(1)	39(1)	65(1)	11(1)	24(1)	11(1)
C(13)	34(1)	32(1)	40(1)	6(1)	14(1)	12(1)
C(14)	35(1)	43(1)	43(1)	0(1)	4(1)	15(1)
C(15)	47(1)	57(1)	41(1)	6(1)	6(1)	30(1)
C(16)	35(1)	29(1)	31(1)	7(1)	13(1)	16(1)
C(17)	44(1)	28(1)	41(1)	6(1)	17(1)	13(1)
C(18)	38(1)	30(1)	35(1)	6(1)	11(1)	16(1)
C(19)	33(1)	33(1)	33(1)	6(1)	10(1)	17(1)
C(20)	42(1)	32(1)	38(1)	6(1)	10(1)	18(1)
C(21)	62(1)	38(1)	70(1)	-14(1)	13(1)	18(1)

Table S11 Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2$x 10 ^{3}) for p.

	x	y	z	U(eq)
H(1A)	3775	6505	6563	44
H(3A)	-3465	6672	4988	100
H(2A)	5381	9151	5922	48
H(3B)	5593	11542	6202	52
H(4A)	4081	12270	7403	53
H(5A)	2404	10647	8427	47
H(8A)	3307	6989	9687	47
H(8B)	4427	8630	9600	47
H(9A)	2649	8302	11113	51
H(9B)	2442	9416	10330	51
H(10A)	-944	8551	10274	57
H(10B)	-821	7470	11098	57
H(11A)	-3754	6267	9931	62
H(12A)	-4017	4943	8284	56
H(14A)	-1254	5953	6309	50
H(14B)	-3211	5071	6440	50
H(15A)	-3110	7497	7178	56
H(15B)	-1508	8094	6572	56
H(16A)	-176	8209	8452	36
H(17A)	-311	4658	8819	45
H(17B)	-1673	3778	7663	45
H(21A)	-1428	496	5685	89
H(21B)	-457	1636	4969	89
H(21C)	677	1227	5937	89

X-ray data of Beninine **(4)** (CCDC 1897696) was collected at 293 K on a Bruker SMART 1000 CCD diffractometer using Mo-K radiation. CCDC 1897696 contains the supplementary crystallographic data for this paper. These data are provided free of charge by The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Table S12 Crystal data and structure refinement



Beninine (4)

Identification code	zhouF007	
Empirical formula	C20 H26 N2 O2	
Formula weight	326.43	
Temperature	296(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	$P2_1/c$	
Unit cell dimensions	a = 8.5202(4) Å	α= 90°.
	b = 11.2279(6) Å	β= 102.0455(13)°.
	c = 17.8067(8) Å	γ = 90°.
Volume	1665.95(14) $Å^3$	
Z	4	
Density (calculated)	1.301 Mg/m^3	
Absorption coefficient	0.084 mm^{-1}	
F(000)	704	
Crystal size	0.500 x 0.400 x 0.300 mm^3	
Theta range for data collection	2.158 to 25.248°.	
Index ranges	-10<=h<=10, -13<=k<=13, -21<=l<=21	
Reflections collected	27450	
Independent reflections	3003 [R(int) = 0.0431]	
Completeness to theta = 25.242°	99.6 %	
Absorption correction	multi-scan	
Max. and min. transmission	0.7456 and 0.6197	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3003 / 0 / 217	
Goodness-of-fit on F^2	1.083	
Final R indices [I>2sigma(I)]	R1 = 0.0479, wR2 = 0.1315	
R indices (all data)	R1 = 0.0577, wR2 = 0.1404	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.502 and -0.453 e.$Å^{-3}$	

Table S13 Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for p. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(1)	6298(2)	8072(1)	7710(1)	49(1)
O(2)	1171(2)	9333(1)	11028(1)	48(1)
N(1)	4672(2)	6700(1)	8644(1)	42(1)
N(2)	673(2)	6647(1)	9923(1)	38(1)
C(1)	7258(2)	8857(2)	7365(1)	57(1)
C(2)	4916(2)	8535(2)	7878(1)	37(1)
C(3)	4239(2)	9624(2)	7640(1)	43(1)
C(4)	2851(2)	9994(2)	7865(1)	44(1)
C(5)	2123(2)	9300(2)	8338(1)	37(1)
C(6)	2819(2)	8215(2)	8587(1)	32(1)
C(7)	4187(2)	7829(2)	8348(1)	34(1)
C(8)	2341(2)	7252(1)	9094(1)	32(1)
C(9)	3941(2)	6544(2)	9320(1)	39(1)
C(10)	5055(2)	7009(2)	10044(1)	42(1)
C(11)	4208(2)	7134(2)	10710(1)	43(1)
C(12)	2849(2)	8032(2)	10516(1)	32(1)
C(13)	3433(2)	9310(2)	10442(1)	37(1)
C(14)	2078(2)	10069(2)	10615(1)	44(1)
C(15)	1963(2)	8201(2)	11174(1)	42(1)
C(16)	750(2)	7249(2)	11245(1)	52(1)
C(17)	-309(2)	6933(2)	10477(1)	46(1)
C(18)	1652(2)	7667(1)	9783(1)	30(1)
C(19)	-256(2)	6358(2)	9158(1)	46(1)
C(20)	955(2)	6450(2)	8646(1)	48(1)

Table S14 Bond lengths [Å] and angles [°] for p.

O(1)-C(2)	1.376(2)
O(1)-C(1)	1.426(2)
O(2)-C(14)	1.435(2)
O(2)-C(15)	1.436(2)
N(1)-C(7)	1.402(2)
N(1)-C(9)	1.476(2)
N(2)-C(17)	1.456(2)
N(2)-C(19)	1.462(2)
N(2)-C(18)	1.469(2)
C(2)-C(3)	1.380(3)
C(2)-C(7)	1.389(2)
C(3)-C(4)	1.389(3)
C(4)-C(5)	1.385(2)
C(5)-C(6)	1.387(2)
C(6)-C(7)	1.391(2)
C(6)-C(8)	1.518(2)
C(8)-C(18)	1.539(2)
C(8)-C(9)	1.557(2)
C(8)-C(20)	1.565(2)
C(9)-C(10)	1.525(3)
C(10)-C(11)	1.518(2)
C(11)-C(12)	1.519(2)
C(12)-C(15)	1.532(2)
C(12)-C(13)	1.534(2)
C(12)-C(18)	1.535(2)
C(13)-C(14)	1.517(3)
C(15)-C(16)	1.511(3)
C(16)-C(17)	1.515(3)
C(19)-C(20)	1.517(3)
C(2)-O(1)-C(1)	117.01(16)
C(14)-O(2)-C(15)	108.65(13)
C(7)-N(1)-C(9)	105.83(13)
C(17)-N(2)-C(19)	113.84(14)
C(17)-N(2)-C(18)	111.70(14)
C(19)-N(2)-C(18)	103.33(13)
O(1)-C(2)-C(3)	126.15(16)

O(1)-C(2)-C(7)	115.19(16)
C(3)-C(2)-C(7)	118.63(16)
C(2)-C(3)-C(4)	120.23(16)
C(5)-C(4)-C(3)	121.51(17)
C(4)-C(5)-C(6)	118.23(16)
C(5)-C(6)-C(7)	120.36(15)
C(5)-C(6)-C(8)	131.79(15)
C(7)-C(6)-C(8)	107.82(14)
C(2)-C(7)-C(6)	121.00(16)
C(2)-C(7)-N(1)	127.49(16)
C(6)-C(7)-N(1)	111.51(15)
C(6)-C(8)-C(18)	116.91(13)
C(6)-C(8)-C(9)	100.86(13)
C(18)-C(8)-C(9)	114.09(13)
C(6)-C(8)-C(20)	111.99(14)
C(18)-C(8)-C(20)	102.01(13)
C(9)-C(8)-C(20)	111.38(14)
N(1)-C(9)-C(10)	110.76(14)
N(1)-C(9)-C(8)	102.96(13)
C(10)-C(9)-C(8)	113.59(14)
C(11)-C(10)-C(9)	112.23(14)
C(10)-C(11)-C(12)	110.40(14)
C(11)-C(12)-C(15)	112.51(13)
C(11)-C(12)-C(13)	113.21(14)
C(15)-C(12)-C(13)	99.79(14)
C(11)-C(12)-C(18)	110.84(14)
C(15)-C(12)-C(18)	109.76(13)
C(13)-C(12)-C(18)	110.25(13)
C(14)-C(13)-C(12)	103.50(13)
O(2)-C(14)-C(13)	107.11(15)
O(2)-C(15)-C(16)	109.73(15)
O(2)-C(15)-C(12)	105.01(13)
C(16)-C(15)-C(12)	115.49(16)
C(15)-C(16)-C(17)	112.30(15)
N(2)-C(17)-C(16)	110.17(14)
N(2)-C(18)-C(12)	111.29(13)
N(2)-C(18)-C(8)	102.93(13)
C(12)-C(18)-C(8)	117.57(12)

N(2)-C(19)-C(20)	103.97(14)
C(19)-C(20)-C(8)	105.54(14)

Symmetry transformations used to generate equivalent atoms:

Table S15 Anisotropic displacement parameters (Å^{2}x 10^3) for p. The anisotropic displacement factor exponent takes the form: -2π^2[h^2 a*^{2}U^{11} + ... + 2 h k a* b* U^{12}]

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	51(1)	57(1)	47(1)	-4(1)	26(1)	-4(1)
O(2)	48(1)	49(1)	50(1)	-1(1)	20(1)	5(1)
N(1)	51(1)	32(1)	51(1)	-3(1)	25(1)	8(1)
N(2)	31(1)	34(1)	50(1)	9(1)	12(1)	-5(1)
C(1)	52(1)	76(2)	50(1)	-11(1)	26(1)	-21(1)
C(2)	41(1)	45(1)	28(1)	-7(1)	11(1)	-6(1)
C(3)	52(1)	47(1)	30(1)	5(1)	10(1)	-10(1)
C(4)	53(1)	40(1)	36(1)	8(1)	4(1)	2(1)
C(5)	37(1)	42(1)	32(1)	3(1)	5(1)	4(1)
C(6)	34(1)	34(1)	27(1)	-2(1)	6(1)	-2(1)
C(7)	39(1)	33(1)	30(1)	-5(1)	10(1)	-2(1)
C(8)	33(1)	28(1)	35(1)	1(1)	7(1)	-2(1)
C(9)	41(1)	29(1)	50(1)	6(1)	19(1)	4(1)
C(10)	31(1)	47(1)	49(1)	12(1)	10(1)	11(1)
C(11)	34(1)	53(1)	41(1)	15(1)	5(1)	9(1)
C(12)	30(1)	39(1)	30(1)	7(1)	7(1)	0(1)
C(13)	34(1)	44(1)	32(1)	0(1)	2(1)	-8(1)
C(14)	48(1)	40(1)	42(1)	-4(1)	6(1)	-5(1)
C(15)	40(1)	53(1)	34(1)	7(1)	10(1)	4(1)
C(16)	53(1)	61(1)	50(1)	19(1)	27(1)	4(1)
C(17)	38(1)	44(1)	63(1)	17(1)	23(1)	-2(1)
C(18)	26(1)	28(1)	35(1)	6(1)	8(1)	-1(1)
C(19)	37(1)	36(1)	62(1)	-1(1)	6(1)	-10(1)
C(20)	47(1)	44(1)	50(1)	-9(1)	7(1)	-12(1)

Table S16 Hydrogen coordinates (x 10^4) and isotropic displacement parameters (Å^{2}x 10 ^{3}) for p.

	x	y	z	U(eq)
H(1A)	5271	6201	8468	51
H(1B)	8184	8438	7276	85
H(1C)	6641	9143	6886	85
H(1D)	7596	9518	7702	85
H(3A)	4715	10112	7329	51
H(4A)	2400	10725	7694	52
H(5A)	1192	9555	8483	45
H(9A)	3711	5699	9384	46
H(10A)	5955	6468	10189	51
H(10B)	5476	7779	9936	51
H(11A)	4969	7394	11164	52
H(11B)	3782	6368	10820	52
H(13A)	4427	9462	10809	45
H(13B)	3600	9462	9928	45
H(14A)	2506	10754	10922	52
H(14B)	1400	10350	10141	52
H(15A)	2755	8249	11659	50
H(16A)	82	7525	11589	63
H(16B)	1311	6540	11468	63
H(17A)	-977	6255	10538	56
H(17B)	-1007	7599	10290	56
H(18A)	933	8342	9617	36
H(19A)	-1127	6921	9001	55
H(19B)	-697	5561	9146	55
H(20A)	471	6810	8157	57
H(20B)	1358	5668	8552	57

7. Thermo ellipsoid plots for 25 and Beninine (4)

Single crystals of **25** and **4** were grown from ethyl acetate by the slow evaporation method. X-ray data of **25** and **4** (CCDC 1897697) were collected at 293 K on a Bruker SMART 1000 CCD diffractometer using Mo-K radiation.

Figure S4 ORTEP drawing of 25 showing thermal ellipsoids at the 50% probability level

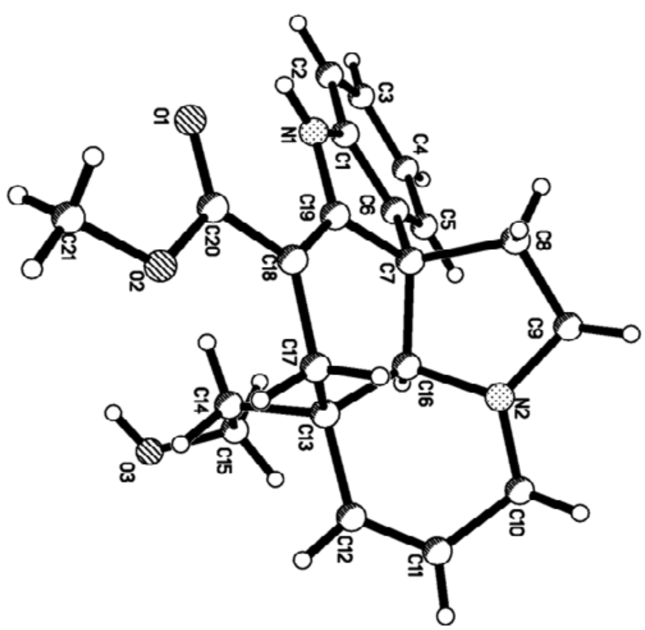
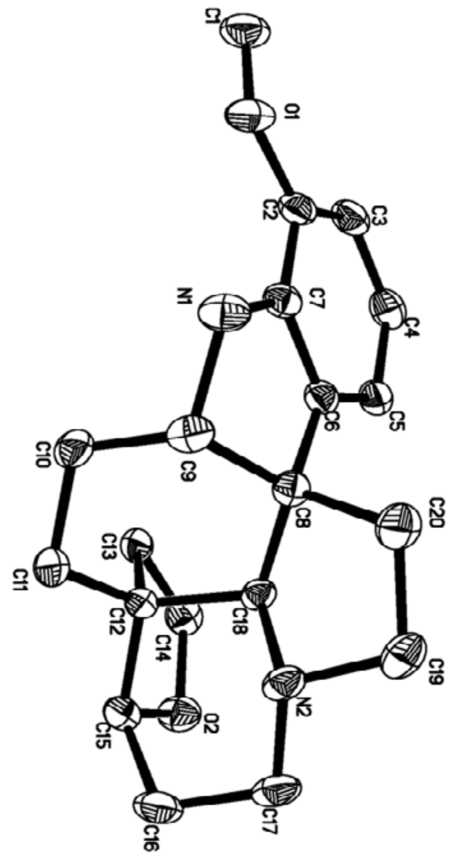


Figure S5 ORTEP drawing of 4 showing thermal ellipsoids at the 50% probability level



References:

1. Kim, J.-Y.; Suhl, C.-H.; Lee, J.-H.; Cho, C.-G. *Org. Lett.* **2017**, *19*, 6168-6171.
2. Moreno, J.; Picazo, E.; Morrill, L. A.; Smith, J. M.; Garg, N. K. *J. Am. Chem. Soc.* **2016**, *138*, 1162-1165.
3. Overman, L. E.; Robertson, G. M.; Robichaud, A. J. *J. Am. Chem. Soc.* **1991**, *113*, 2598-2610.
4. Kang, T.; White, K. L.; Mann, T. J.; Hoveyda, A. H.; Movassaghi, M. *Angew. Chem. Int. Ed.* **2017**, *56*, 13857-13860; *Angew. Chem.* **2017**, *129*, 14045-14048.
5. Kam, T.-S.; Choo, Y.-M. *Helv. Chim. Acta* **2004**, *87*, 991-998.
6. Batesky, D. C.; Goldfogel, M. J.; Weix, D. J. *J. Org. Chem.* **2017**, *82*, 9931-9936.
7. Lee, K.; Boger, D. L. *J. Am. Chem. Soc.* **2014**, *136*, 3312-3317.