Supporting Information

A Chemical Equivalent of Arene Monooxygenases: Dearomative Synthesis of Arene Oxides and Oxepines

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TABLE OF CONTENTS

1. General Experimental

Unless otherwise noted, all reactions were carried out under inert atmosphere. *N*-Methyl-1,2,4-triazoline-3,5-dione (MTAD) was prepared according to the literature procedure, sublimed, and stored in a −40 °C freezer.[1] $Mn(ClO_4)_2 \cdot 6H_2O$ and picolinic acid were purchased from Acros Organics. Peracetic Acid (32wt% in dilute acetic acid) was purchased from Sigma Aldrich. Acetonitrile and propionitrile were stored over 4 Å molecular sieves. Nickel oxide,[2] peracetic acid (8-10% in acetic acid),[3] hydroxycarbonimidic dibromide,[4] and 2-methylquinolin-4-yl pivalate,[5] were synthesized according to literature procedures. All other chemicals were purchased from commercial vendors and used without further purification.

Analytical thin-layer chromatography was performed on Merck silica gel 60 F_{254} glass plates. Visualization was accomplished with UV light and/or potassium permanganate ($KMnO_4$). Retention factor (R_f) values reported were measured using a 5 × 2 cm TLC plate in a developing chamber containing the solvent system described. Flash column chromatography was performed using Silicycle SiliaFlash® P60 (SiO_2, 40-63 μm particle size, 230-400 mesh).

^1H and ^{13}C NMR spectra were recorded on Varian Unity 500 (500 MHz, ^1H; 126 MHz, ^{13}C) MHz or Bruker 500 (500 MHz, ^1H; 126 MHz, ^{13}C) spectrometers. Spectra are referenced to residual chloroform (δ = 7.26 ppm, 1H; 77.16 ppm, ^{13}C) or residual methanol (δ = 3.31 ppm, ^1H; 49.0 ppm, ^{13}C). Chemical shifts are reported in parts per million (ppm). Multiplicities are indicated by s (singlet), d (doublet), t (triplet), q (quartet), and m (multiplet). Coupling constants *J* are reported in Hertz (Hz).

Mass spectrometry (MS) was performed by the University of Illinois Mass Spectrometry Laboratory. Electron Impact (EI^+) spectra were performed at 70 eV using methane as the carrier gas, with time-of-flight (TOF) mass analyzer. Chemical Ionization (CI^+) spectra were performed with methane reagent gas, with either a double focusing sector field (DFSF) or time-of-flight (TOF) mass analyzer. Electrospray Ionization (ESI^+) spectra were performed using a time-of-flight (TOF) mass analyzer. Data are reported in the form of m/z (intensity relative to the base peak = 100).

Infrared spectra were measured neat on a Perkin-Elmer spectrum BX FT-IR spectrometer. Peaks are reported in cm^{-1} with indicated relative intensities: s (strong, 0–33% T); m (medium, 34–66% T), w (weak, 67–100% T), and br (broad).

Visible-light spectrum of LED was recorder using Avantes Sensline Avaspec-ULS TEC Spectrometer.

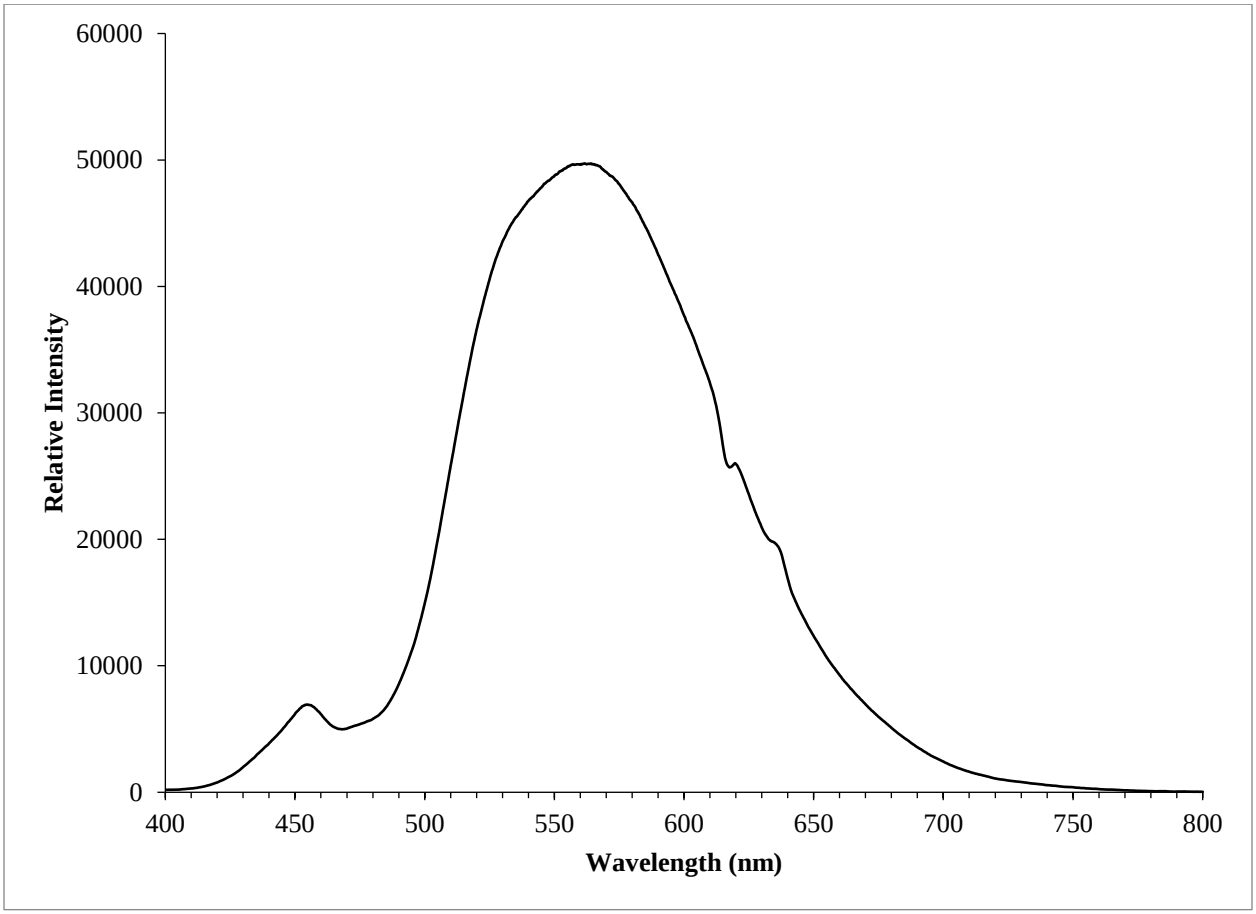
Melting points were measured on a Buchi B-540 meting point apparatus and are uncorrected.

2. Experimental Set-up

2-1. LED light source

Generic cool white light LED corn bulbs were used for the photochemical experiments. These can be obtained from several manufactures over amazon.com and proved to give consistent results as well as identical visible spectra. Detailed info:

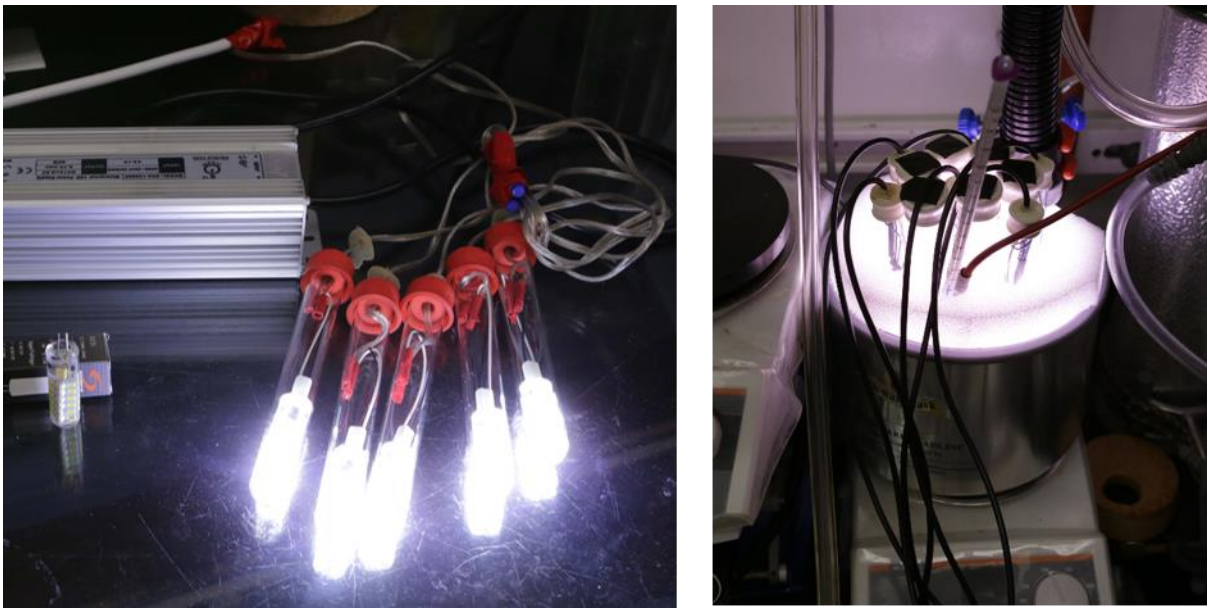
Socket: G4
LED Chip: 48 LEDs SMD 2835
Consume wattage: 4W
Input voltage: AC / DC 12V
Beam degree: 360 degrees
Color temperature: 6500K (Cool White)
Initial Lumens (lm): 290



Spectra S1. Spectrum of a LED bulb used.

2-2. Set-up for small scale reactions (<2.0 mmol scale)

Six 4 W LED corn bulbs (12V, cool white light 6500K) were wired to a suitable 12V power supply, then sealed into test tubes and capped with septa (Picture S1). Lights and reaction tubes were arranged in a merry-go-round fashion for maximal exposure of each reaction vessel to light source and submerged in a −78 °C bath. Generally, up to four 1.0 mmol scale reactions can be run in the same bath using five 4 W lamps positioned around them.



Picture S1. Assembly of LED bulbs for small-scale photochemical reactions.

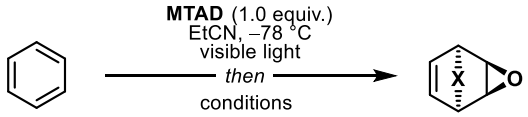
2-3. Set-up for large scale reactions (2 - 25 mmol scale)

Eight 4 W LED corn bulbs (12V, cool white light 6500K) were wired to a suitable 12V power supply, then sealed into test tubes and capped with septa (see Picture S1). Lights were arranged in a merry-go-round fashion around a 250 mL clear borosilicate glass bottle (Picture S2). A normal reagent or media bottle can be used. The whole set-up was kept submerged in a cold bath during the photochemical reaction.

Picture S2. Photochemical set-up for large scale reactions.

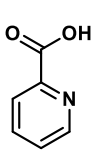
3. Experimental Procedures

3-1. Table S1: Optimization of arenophile-mediated epoxidation of benzene.

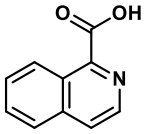


9a (10.0 equiv.) → **8a**

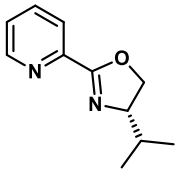
Entry	[Mn] (mol%)	Ligand (mol%)	Oxidant	Temp. (°C)	Time (h)	Yield
1	NA	NA	DMDO	–50 to rt	3	N.R.
2	NA	NA	mCPBA	–78 to rt	3	N.R.
3	$Mn(ClO_4)_2$ (20 mol%)	**2** (100)	CH_3CO_3H (6.0 equiv.)	–78	2	6%
4	$Mn(ClO_4)_2$ (20 mol%)	**2** (100)	CH_3CO_3H (1.0 equiv.)	–78	2	N.R.
5	$Mn(ClO_4)_2$ (20 mol%)	**2** (100)	CH_3CO_3H (1.0 equiv.)	–78 to rt	2	18% (3:1 d.r.)
6	$Mn(ClO_4)_2$ (20 mol%)	**5** (40)	CH_3CO_3H (2.0 equiv.)	–78	2	20% (4:1 d.r.)
7	$Mn(ClO_4)_2$ (20 mol%)	**4** (40)	CH_3CO_3H (2.0 equiv.)	–78	2	23% (3:1 d.r.)
8	$Mn(ClO_4)_2$ (20 mol%)	**5** (40)	CH_3CO_3H (6.0 equiv.)	–78	2	25% (3:1 d.r.)
9	$Mn(ClO_4)_2$ (5 mol%)	**5** (10)	CH_3CO_3H (6.0 equiv.)	–78	2	25% (3:1 d.r.)
10	$Mn(ClO_4)_2$ (5 mol%)	**5** (10)	CH_3CO_3H (12.0 equiv.)	–78	2	N.R.
11	$Mn(ClO_4)_2$ (25 mol%)	**5** (50)	CH_3CO_3H[a] (3.0 equiv.)	–78	2	45% (3:1 d.r.)
12	$Mn(ClO_4)_2$ (20 mol%)	**5** (40)	CH_3CO_3H[a] (3.0 equiv.) slow addition	–78	2	30% (4:1 d.r.)
13	$Mn(ClO_4)_2$ (20 mol%)	**5** (40)	CH_3CO_3H[a] (4.0 equiv.)	–78	2	40% (3:1 d.r.)
14	$Mn(ClO_4)_2$ (100 mol%)	**5** (200)	CH_3CO_3H[a] (4.0 equiv.)	–78	2	N.R.
15	$Mn(ClO_4)_2$ (10 mol%)	**5** (20)	CH_3CO_3H[a] (4.0 equiv.)	–78	2	23% (3:1 d.r.)
16	$Mn(ClO_4)_2$ (5 mol%)	**5** (10)	CH_3CO_3H[a] (4.0 equiv.)	–78	2	11% (3:1 d.r.)



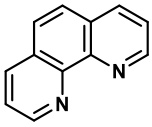
ligand 2



ligand 3



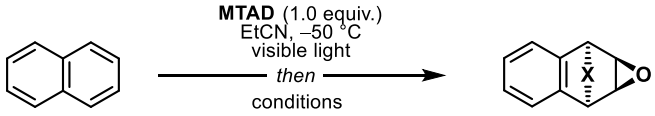
ligand 4



ligand 5

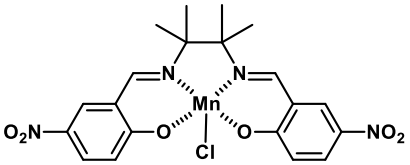
[a]freshly-prepared, H_2SO_4-free CH_3CO_3H

3-2. Table S2: Optimization of arenophile-mediated epoxidation of naphthalene.

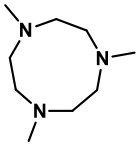


15a **16a**

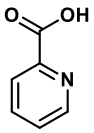
Entry	[Mn] (mol%)	Ligand (mol%)	Oxidant	Temp. (°C)	Time (h)	Yield
1	NA	NA	DMDO	–50 to rt	3	N.R.
2	NA	NA	mCPBA	–78 to rt	3	N.R.
3	$MnSO_4$ (10 mol%)	**1** (20)	H_2O_2 (2.0 equiv.)	0	2	N.R.
4	$Cu(MeCN)_4PF_6$ (20 mol%)	NA	mCPBA (4.0 equiv.)	–78	2	N.R.
5	**Catalyst 1 (20 mol %)**	NA	NMO (10 equiv.) mCPBA, (4.0 equiv.)	–78	1.5	30%
6	**Catalyst 1 (20 mol %)**	NA	NMO (10 equiv.) mCPBA, (4.0 equiv.)	–20	1.5	11%
7	$Mn(ClO_4)_2$ (10 mol%)	**2** (50)	CH_3CO_3H (1.0 equiv.)	–78	2	21%
8	$Mn(ClO_4)_2$ (10 mol%)	**2** (50)	CH_3CO_3H (2.0 equiv.)	–78	2	43% (2.1:1 d.r.)
9	$Mn(ClO_4)_2$ (10 mol%)	**2** (50)	CH_3CO_3H (4.0 equiv.)	–78	2	76% (1.7:1 d.r.)
10	$Mn(ClO_4)_2$ (20 mol%)	**2** (100)	CH_3CO_3H (4.0 equiv.)	–78	2	83% (1.6:1 d.r.)
11	$Mn(ClO_4)_2$ (5 mol%)	**2** (25)	CH_3CO_3H (4.0 equiv.)	–20	2	84% (1.6:1 d.r.)
12	$Mn(ClO_4)_2$ (5 mol%)	**2** (12.5)	CH_3CO_3H (4.0 equiv.)	–20	2	40% (1.6:1 d.r.)
13	$Mn(ClO_4)_2$ (3 mol%)	**2** (15)	CH_3CO_3H (4.0 equiv.)	–20	2	82% (1.6:1 d.r.)
14	$Mn(ClO_4)_2$ (5 mol%)	**3** (25)	CH_3CO_3H (4.0 equiv.)	–20	2	65% (2.4:1 d.r.)



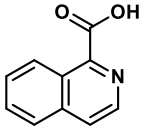
catalyst 1



ligand 1

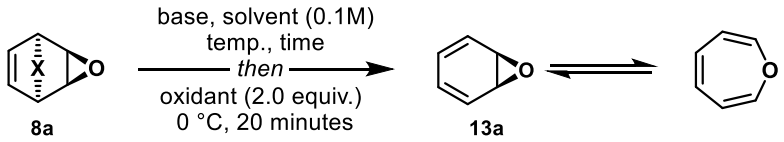


ligand 2



ligand 3

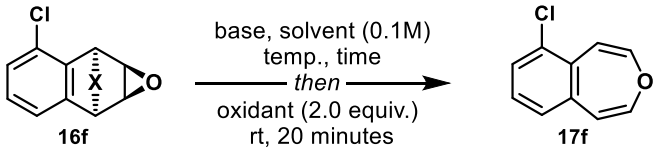
3-3.Table S3: Optimization of cycloreversion to arene oxides.



8a 13a

Entry	Base	Solvent	Oxidant	Temp. (°C)	Time	Yield
1	KOH	iPrOH	$CuCl_2$	100	16	N.R.
2	NA	N_2H_4	$CuCl_2$	100	16	N.R.
3	KOH	iPrOH	$CuCl_2 \cdot 6H_2O$ (0.05 equiv.), O_2, 16h	40	2	phenol exclusively
4	KOH	iPrOH	$CuCl_2 \cdot 6H_2O$	40	2	phenol
5	KOH	iPrOH	PIDA	40	2	decomp.
6	KOH	iPrOH	Ni_2O_3 (3.0 equiv.), 1min.	40	2	58%

3-4.Table S4: Optimization of cycloreversion to benzoxepine.

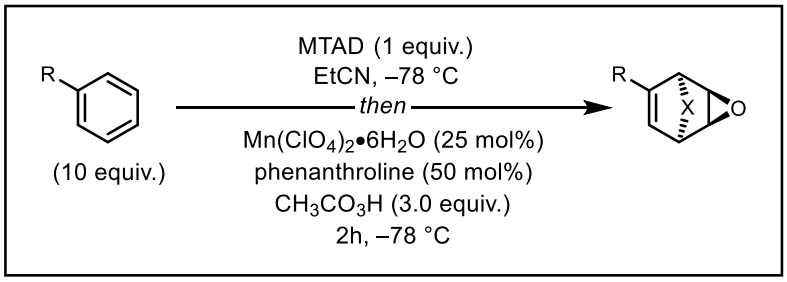


16f 17f

Entry	Base	Solvent	Oxidant	Temp. (°C)	Time (h)	Yield
1	KOH	iPrOH	$CuCl_2$	100	16	N.R.
2	KOH	iPrOH (1mM)	$CuCl_2$	100	16	N.R.
3	KOH	iPrOH	$CuCl_2$	100	16	N.R.
4	NA	N_2H_4	$CuCl_2$	100	16	N.R.
5	NA	N_2H_4	$CuCl_2$	100	8	N.R.
6	KOH	iPrOH	Ni_2O_3	40	2	76%
7	KOH	iPrOH	PIDA	40	2	60%
8	KOH	iPrOH	$K_3Fe(CN)_6$	40	2	70%
9	KOH	iPrOH	$CuCl_2$	40	2	83%
10	KOH	iPrOH	$CuCl_2 \cdot 6H_2O$	40	2	82%
11	KOH	iPrOH	$CuCl_2 \cdot 6H_2O$ (0.05 equiv.), O_2, 16h	40	2	76%

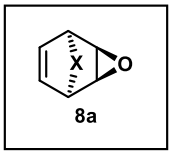
3-5.Dearomative epoxidation of monocyclic arenes

3-5.1 General procedure for dearomative epoxidation with arenes



This procedure was modified from the literature protocol.[3]

N-Methyl-1,2,4-triazoline-3,5-dione (**7**, MTAD, 113.4 mg, 1.0 mmol, 1.0 equiv.) was placed in a test tube and propionitrile (10 mL, 0.1 M) was added at room temperature and placed in a −78 °C chiller. Arene (10.0 mmol, 10 equiv.) was added slowly and the solution was stirred under irradiation with LED lights at −78 °C until the solution had become colorless, which took about 12 hours with the described set up (see Section 2-2.). Upon decolorization, a solution of $Mn(ClO_4)_2 \cdot 6H_2O$ (90.3 mg, 0.25 mmol, 25mol%) and 1,10-phenanthroline (90.1 mg, 0.5 mmol, 50 mol%) in acetonitrile (3 mL, sonicated for 1 minute), was added over the course of 10 seconds, being careful to ensure proper mixing. To this solution, was quickly added freshly-prepared peracetic acid[3] (8-10 wt% in acetic acid, 3.0 equiv.) and left to stir for two hours at −78 °C. Afterwards, a 10% sodium thiosulfate solution (20 mL) was added and the organic phase was separated. The aqueous phase was extracted with ethyl acetate (3 × 15 mL). The organic extracts were combined and passed through a silica plug which was washed with CH_2Cl_2 (15 mL). The organic phase was then dried over $MgSO_4$ and concentrated under reduced pressure. The compound was isolated by flash chromatography (SiO_2, hexanes: ethyl acetate mixtures).



5-methyl-1a,2,8,8a-tetrahydro-4H-2,8-ethenooxireno[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-4,6(5H)-dione (8a):

Following the general procedure (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a white solid (93 mg, 3:1 d.r., 45%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

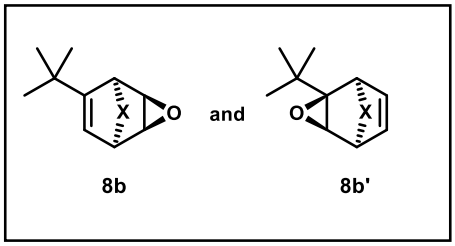
^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.16 – 6.00 (m, 2H), 5.20 (dd, *J* = 4.8, 3.2, 1.6 Hz, 2H), 3.67 (dd, *J* = 3.2, 1.6 Hz, 2H), 3.01 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 158.2, 125.0, 54.6, 42.1, 25.7

HRMS: (ESI-TOF, m/z) calcd. For $C_9H_{10}N_3O_3$ $[M+H]^+$, 208.0717; found: 208.0722

IR: (ATR, neat, cm^{-1}) 2923 (w), 1761 (m), 1708 (s), 1605 (m), 1511 (m), 1456 (m), 1401 (m), 1389 (m), 1373 (w), 1196 (m), 1080 (w), 1029 (w), 1011 (w), 955 (w), 930 (w), 529 (w)

m.p.= 188 – 191 °C



9-(*tert*-butyl)-5-methyl-1a,2,8,8a-tetrahydro-4H-2,8-ethenooxireno[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-4,6(5H)-dione (8b):

Following the general procedure (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a yellow oil (155 mg, 5:1 d.r., 3:1 r.r., 59%). where the major diastereomer was inseparable from the constitutional isomer (3:1).

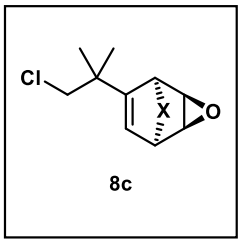
R_f = 0.4 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 5.63 (ddd, *J* = 6.2, 2.3, 1.0 Hz, 1H), 5.22 (dd, *J* = 4.5, 2.3 Hz, 1H), 5.12 (dd, *J* = 6.2, 4.2 Hz, 1H), 3.62 (t, *J* = 4.5 Hz, 1H), 3.58 (td, *J* = 4.2, 1.0 Hz, 1H), 2.98 (d, *J* = 1.3 Hz, 3H), 1.03 (s, 9H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 158.3, 157.8, 157.4, 156.9, 148.6, 127.1, 123.9, 113.3, 57.0, 55.2, 55.1, 54.2, 46.5, 42.7, 41.9, 33.1, 31.8, 27.9, 25.9, 25.6, 25.6

HRMS: (ESI-TOF, m/z) calcd. For $C_{13}H_{18}N_3O_3$ $[M+H]^+$, 264.1343; found: 264.1353

IR: (ATR, neat, cm^{-1}) 2964 (w), 2872 (w), 1773 (m), 1703 (s), 1632 (m), 1453 (m), 1394 (m), 1366 (w), 1201 (m), 1092 (w), 1009 (w), 957 (m), 768 (w)



9-(1-chloro-2-methylpropan-2-yl)-5-methyl-1a,2,8,8a-tetrahydro-4H-2,8-ethenooxireno[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-4,6(5H)-dione (8c):

Following the general procedure (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as an off-white oil (123 mg, 7:1 d.r., 41%)

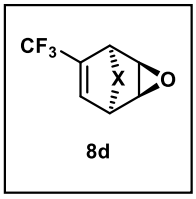
R_f = 0.4 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 5.76 (dd, *J* = 6.2, 2.3 Hz, 1H), 5.18 (m, 2H), 3.66 (t, *J* = 4.3 Hz, 1H), 3.62 (t, *J* = 4.3 Hz, 1H), 3.49 (d, *J* = 11.1 Hz, 1H), 3.36 (d, *J* = 11.1 Hz, 1H), 2.97 (s, 3H), 1.15 (s, 3H), 1.13 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 158.1, 157.5, 142.6, 118.0, 54.8, 54.3, 52.4, 42.5, 42.0, 38.4, 25.7, 24.5, 23.4

HRMS: (ESI-TOF, m/z) calcd. For $C_{13}H_{17}N_3O_3$ $[M+H]^+$, 298.0953; found: 298.0959

IR: (ATR, neat, cm^{-1}) 2970 (w), 1706 (s), 1455 (m), 1394 (w), 1229 (m), 1205 (m), 954 (w), 769 (w), 527 (w)



5-methyl-9-(trifluoromethyl)-1a,2,8,8a-tetrahydro-4H-2,8-ethenooxireno[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-4,6(5H)-dione (8d):

Following the general procedure (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a yellow oil (105 mg, >20:1 d.r., 38%).

R_f = 0.4 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

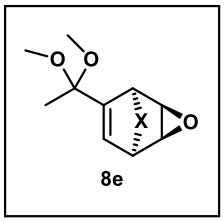
^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.60 – 6.44 (m, 1H), 5.39 (dd, *J* = 4.4, 2.3 Hz, 1H), 5.34 (dd, *J* = 6.1, 4.4 Hz, 1H), 3.79 (t, *J* = 4.3 Hz, 1H), 3.75 (td, *J* = 4.3, 0.9 Hz, 1H), 3.02 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.7, 157.1, 127.9 (q, *J* = 36.57) , 125.9 (q, *J* = 5.78) ,120.0 (q, *J* = 120.24), 53.5, 53.3, 42.0, 41.4, 25.9

^{19}F NMR: (471 MHz, $CDCl_3$) δ -67.37

HRMS: (ESI-TOF, m/z) calcd. For $C_{10}H_9N_3O_3F_3$ $[M+H]^+$, 276.0591; found: 276.0594

IR: (ATR, neat, cm^{-1}) 2970 (w), 1718 (s), 1455 (m), 1375 (m), 1266 (w), 1216 (m), 768 (w), 527 (w)



9-(1,1-dimethoxyethyl)-5-methyl-1a,2,8,8a-tetrahydro-4H-2,8-ethenooxireno[2,3- d][1,2,4]triazolo[1,2-a]pyridazine-4,6(5H)-dione (8e):

The work-up is modified from the general procedure as follows:

The reaction was quenched with a 10% sodium thiosulfate solution (20 mL) and saturated $NaHCO_3$ (40 mL) and the organic phase was separated. The aqueous phase was extracted with ethyl acetate (3 × 15 mL). The organic extracts were combined and passed through a silica plug and flushed with CH_2Cl_2 (15 mL). The organic phase was then dried over $MgSO_4$ and concentrated under reduced pressure. The title compound was isolated by column chromatography (SiO_2, hexanes:ethyl acetate (SiO_2, 5:1 to 1:1 with 1% Et_3N) as a light yellow oil (77 mg, >20:1 d.r., 26%).

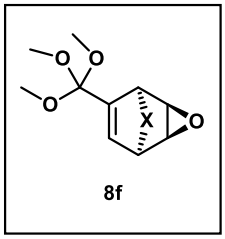
R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.06 (ddd, *J* = 6.2, 2.2, 1.0 Hz, 1H), 5.30 (dd, *J* = 4.2, 2.2 Hz, 1H), 5.23 (dd, *J* = 6.2, 4.2 Hz, 1H), 3.66 (m, 2H), 3.17 (s, 3H), 3.13 (s, 3H), 2.99 (s, 3H), 1.31 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.6, 157.1, 140.4, 120.0, 99.1, 54.8, 54.2, 49.5, 49.2, 42.9, 42.1, 25.6, 22.8

HRMS: (ESI-TOF, m/z) calcd. For $C_{13}H_{17}N_3O_5Na$ $[M+Na]^+$, 318.1066; found:318.1073

IR: (ATR, neat, cm^{-1}) 2956 (w), 1777 (m), 1708 (s), 1455 (m), 1397 (m), 1190 (m), 1144 (m), 1040 (s), 917(w), 732 (w), 732 (m)



5-methyl-9-(trimethoxymethyl)-1a,2,8,8a-tetrahydro-4H-2,8-ethenooxireno[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-4,6(5H)-dione (8f):

The work-up is modified from the general procedure as follows:

The reaction was quenched with a 10% sodium thiosulfate solution (20mL) and saturated $NaHCO_3$ (40 mL) and the organic phase was separated. The aqueous phase was extracted with ethyl acetate (3 × 15 mL). The organic extracts were combined and passed through a silica plug and flushed with CH_2Cl_2 (15 mL). The organic phase was then dried over $MgSO_4$ and concentrated under reduced pressure. The title compound was isolated by column chromatography (SiO_2, hexanes:ethyl acetate (SiO_2, 5:1 to 1:1 with 1% Et_3N) as an off-white solid (141 mg, >20:1 d.r., 45%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.18 (dd, *J* = 6.1, 2.1 Hz, 1H), 5.37 – 5.21 (m, 2H), 3.74 – 3.62 (m, 2H), 3.12 (d, *J* = 0.9 Hz, 9H), 2.97 (s, 3H)

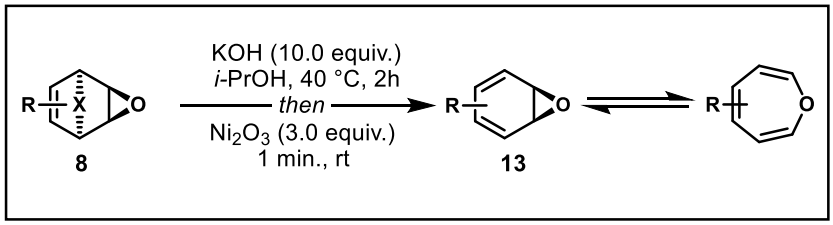
^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.2, 156.3, 134.3, 123.6, 112.3, 54.4, 53.7, 49.9, 42.7, 42.1, 25.6

HRMS: (ESI-TOF, m/z) calcd. For $C_{13}H_{17}N_3O_6Na$ $[M+Na]^+$, 334.1001; found:334.1030

IR: (ATR, neat, cm^{-1}) 2949 (w), 1778 (m), 1704 (s), 1451 (m), 1394 (m), 1242 (m), 1181 (m), 1094 (s), 1065 (s), 768 (w), 529 (w)

m.p. = 162 – 164 °C

3-5.2 General procedure for the synthesis of arene oxides/oxepines



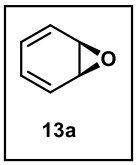
To a vial containing finely ground KOH (120 mg, 10 equiv., 90 wt%), and substrate (0.20 mmol, 1.0 equiv.) under nitrogen was added *i*PrOH (2 mL, 0.1 M) and degassed with sonication and nitrogen for 15 min. The reaction was heated to 40 °C with vigorous stirring (1000 rpm) for 2 hours or until complete conversion by TLC. Upon completion, the reaction was cooled in an ice bath and H_2O (2 mL) was added. AcOH was then carefully added dropwise until pH 5. The semicarbazide intermediate was then extracted out with ethyl acetate (3 × 5 mL). The organic layers were combined, dried with $NaHCO_3$ and concentrated under reduced pressure.

This mixture containing the semicarbazide was added to vial, followed by $CDCl_3$ (2.0 mL, 0.1 M), and sparged with nitrogen for 15 minutes. Next, nickel oxide (Ni_2O_3, 30% active basis, 330 mg, 3.0 equiv.) was added as a solid under a stream of nitrogen (note: vigorous gas evolution was observed). The solution was agitated manually for 1 minute, filtered through a celite plug, and the celite was washed thoroughly with $CDCl_3$ to yield the resulting arene-oxide as a solution. Due to the pronounced instability and volatility of

these arene-oxides, further purification was impractical and yields were determined by ^{1}H-NMR internal standard ($MeNO_2$). MeNCO was observed as a byproduct after filtering through celite in all cases. IR spectra were not acquired due to the instability of these compounds upon sample preparation.

Note: *Arene oxides are suspected carcinogens. Caution in the handling of these compounds should be used.*

Note: *In many instances, due to the valence tautomerization of arene-oxide/oxepins, ^{13}C signals corresponding to the carbon next to oxygen can be severely broadened. In these cases, it was necessary to assign these peaks via HSQC/HMBC.*



13a

Benzene-Oxide (7-oxabicyclo[4.1.0]hepta-2,4-diene, 13a):

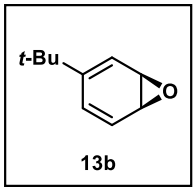
Following the general procedure (0.20 mmol scale), the title compound was obtained as a yellow solution in $CDCl_3$ using $MeNO_2$ as internal standard (58% yield). See ^{1}H NMR spectra of **13a** for graphical visualization of internal standard.

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.26 (dd, *J* = 5.1, 2.9 Hz, 2H), 5.94 (td, *J* = 4.8, 2.9 Hz, 2H), 5.09 (d, *J* = 4.8 Hz, 2H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 129.5, 121.5, 105.3

HRMS: (EI, m/z) calcd. For C_6H_6O $[M]^{\cdot+}$, 94.04132; found: 94.04195

The analytical data were in accordance with previously reported values.[7]



13b

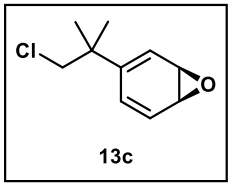
3-(*tert*-butyl)-7-oxabicyclo[4.1.0]hepta-2,4-diene (13b):

Since the undesirable constitutional isomer (**8b'**) was inseperable from **8b**, the resultant semicarbazides were separated after KOH hydrolysis utilizing a silica plug (ethyl acetate, 100%). The title compound was obtained as a yellow solution in $CDCl_3$ using $MeNO_2$ as internal standard (82% yield).

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.32 (dt, *J* = 8.5, 1.5 Hz, 1H), 6.12 (dd, *J* = 8.5, 4.3 Hz, 1H), 6.01 (ddd, *J* = 4.7, 1.5, 0.8 Hz, 1H), 4.71 (dd, *J* = 4.7, 2.5 Hz, 1H), 4.65 (ddd, *J* = 4.0, 2.5, 1.2 Hz, 1H), 1.13 (s, 9H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 150.4, 126.6, 123.7, 118.0, 84.6*, 85.6*, 35.0, 29.5 *(*detected by HSQC)*

HRMS: (ESI-TOF, m/z) calcd. For $C_{10}H_{15}O$ $[M+H]^{+}$, 151.1117; found: 151.1124



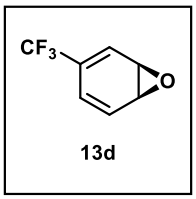
3-(1-chloro-2-methylpropan-2-yl)-7-oxabicyclo[4.1.0]hepta-2,4-diene (13c):

Following the general procedure (0.20 mmol scale), the title compound was obtained as a yellow solution in $CDCl_3$ using $MeNO_2$ as internal standard (79% yield).

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.28 (d, *J* = 8.3 Hz, 1H), 6.12 (dd, *J* = 8.3, 4.4 Hz, 1H), 6.01 (d, *J* = 4.8 Hz, 1H), 4.82 (dd, *J* = 4.8, 2.2 Hz, 1H), 4.79 – 4.75 (m, 1H), 3.49 (s, 2H), 1.23 (s, 6H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 145.57, 126.7, 123.6, 119.7, 89.8*, 89.3*, 54.3, 40.2, 25.2 *(*detected by HMBC)*

HRMS: (ESI-TOF, m/z) calcd. For $C_{10}H_{14}OCl$ $[M+H]^+$, 185.0728; found: 185.0740



3-(trifluoromethyl)-7-oxabicyclo[4.1.0]hepta-2,4-diene (13d):

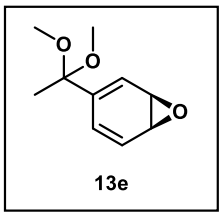
Following the general procedure (0.20 mmol scale), the title compound was obtained as a yellow solution in $CDCl_3$ using $MeNO_2$ as internal standard (74% yield).

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.59 (d, *J* = 7.1 Hz, 1H), 6.04 (d, *J* = 5.0 Hz, 1H), 5.94 (dd, *J* = 6.9, 5.0 Hz, 1H), 5.40 (m, 2H)

^{13}C NMR: (500 MHz, $CDCl_3$) δ 131.5 (q, *J* = 31.3 Hz), 128.4 (q, *J* = 4.9 Hz), 123.1 (q, *J* = 272.5 Hz), 119.5, 118.5, 117.2*, 117.1 (q, *J* = 3.6 Hz) *(*signal detected by HSQC)*

^{19}F NMR: (471 MHz, $CDCl_3$) δ -67.38

HRMS: (ESI-TOF, m/z) calcd. For $C_7H_6OF_3$ $[M+H]^+$, 163.0365; found: 163.0373



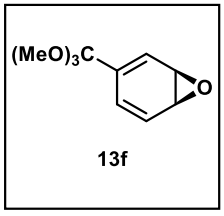
3-(1,1-dimethoxyethyl)-7-oxabicyclo[4.1.0]hepta-2,4-diene (13e):

Following the general procedure (0.20 mmol scale), the title compound was obtained as a yellow solution in $CDCl_3$ using $MeNO_2$ as internal standard (74% yield).

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.41 (dt, *J* = 8.0, 1.2 Hz, 1H), 6.17 – 6.12 (m, 1H), 6.04 (dd, *J* = 8.0, 4.5 Hz, 1H), 4.93 (dd, *J* = 4.8, 1.7 Hz, 1H), 4.90 (dt, *J* = 4.5, 1.7 Hz, 1H), 3.15 (s, 6H), 1.39 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 142.5, 127.4, 122.3, 120.4, 100.8, 96.3, 96.2, 49.0, 23.8

HRMS: (EI, m/z) calcd. For $C_{10}H_{14}O_3$ $[M]^{\cdot+}$, 182.0937; found:182.0949



3-(trimethoxymethyl)-7-oxabicyclo[4.1.0]hepta-2,4-diene (13f):

Following the general procedure (0.20 mmol scale), the title compound was obtained as a yellow solution in $CDCl_3$ using $MeNO_2$ as internal standard (73% yield).

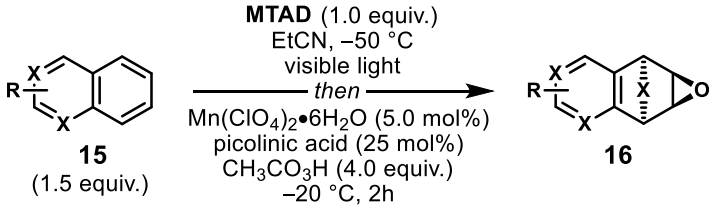
^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.48 (d, *J* = 7.7 Hz, 1H), 6.11 (d, *J* = 4.5 Hz, 1H), 5.98 (dd, *J* = 7.7, 4.5 Hz, 1H), 5.09 (m, 2H), 3.15 (s, 9H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 136.8, 129.1, 121.1, 120.9, 113.9, 104.9, 104.2, 49.7

HRMS: (ESI-TOF, m/z) calcd. For $C_{10}H_{14}O_4Na$ $[M+Na]^+$, 221.0790; found: 221.0799

3-6 Dearomative epoxidation of polycyclic arenes

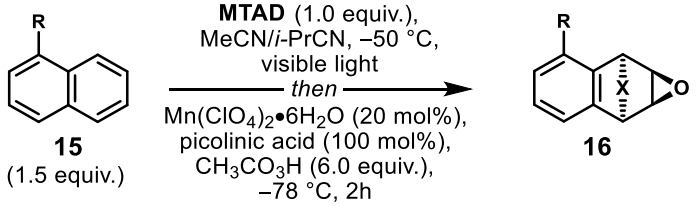
3-6.1 General procedure for dearomative epoxidation with polycyclic arenes at −20 °C (General Procedure A)



This procedure was modified from the literature protocol.[6]

A solution of *N*-methyl-1,2,4-triazoline-3,5-dione (**7**, MTAD, 113.4 mg, 1.0 mmol, 1.0 equiv.) and arene (1.5 mmol, 1.5 equiv.) in propionitrile (10.0 mL) was irradiated with LED lights at −78 °C under a nitrogen atmosphere (see Section 2-2.). Upon decolorization, which generally proceeds within 3 – 12 hours with the described setup, the reaction vessel was transferred to a −20 °C bath under high stirring (600 rpm). A suspension of $Mn(ClO_4)_2 \cdot 6H_2O$ (18.1 mg, 0.05 mmol, 0.05 equiv., 5 mol%) and picolinic acid (31 mg, 0.25 mmol, 0.25 equiv., 25 mol%) in acetonitrile (4 mL, sonicated for 1 minute), was added to the reaction mixture over the course of 10 seconds, being careful to ensure proper mixing. To this solution was added peracetic acid (32 wt% in dilute acetic acid, 0.84 mL, 4.0 equiv.) over the course of 10 seconds. The reaction was then left to stir for 2 hours at −20 °C. Afterwards, a 10% sodium thiosulfate solution (20 mL) was added and the aqueous phase was separated. The organic phase was extracted with ethyl acetate (3 × 15 mL), then the organic extracts were combined, dried over $MgSO_4$, and concentrated under reduced pressure. The product was immediately isolated by flash chromatography (SiO_2, hexanes: ethyl acetate mixtures).

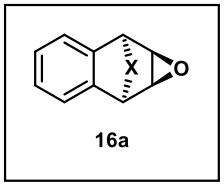
3-6.2 General procedure for dearomative epoxidation with polycyclic arenes at −78 °C (General Procedure B)



This procedure was modified from the literature protocol.[6]

A solution of *N*-methyl-1,2,4-triazoline-3,5-dione (**7**, MTAD, 113.4 mg, 1.0 mmol, 1.0 equiv.) and arene (1.5 mmol, 1.5 equiv.) in propionitrile (10.0 mL) was irradiated with LED lights at −78 °C under a nitrogen atmosphere (see Section 2-2.). Upon decolorization, which generally proceeds within 8 – 12 hours with the described setup, the reaction was then transferred to a bath at −78 °C under high stirring (600 rpm). A

suspension of $Mn(ClO_4)_2 \cdot 6H_2O$ (72.4 mg, 0.20 mmol, 0.20 equiv.) and picolinic acid (123.1 mg, 1.0 mmol, 1.0 equiv.) in acetonitrile (8 mL, sonicated for 1 minute), was added over the course of 10 seconds, being careful to ensure proper mixing. To this solution was added peracetic acid (32 wt% in dilute acetic acid, 1.3 mL, 6.0 equiv.) over the course of 1 hour in 6 evenly spaced portions and left to stir for another hour at −78 °C. The reaction was warmed to room temperature, upon which a 10% sodium thiosulfate solution (20 mL) was added and the organic phase was separated. The aqueous phase was extracted with ethyl acetate (3 × 15 mL). The organic extracts were combined and filtered through a plug of silica gel, which was washed with CH_2Cl_2 (15 mL). The organic phase was then dried over $MgSO_4$ and concentrated under reduced pressure. The product was immediately isolated by flash chromatography (SiO_2, hexanes: ethyl acetate mixtures).



2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-1,3(2H)-dione (16a):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a white solid (217 mg, 1.6:1 d.r., 84%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

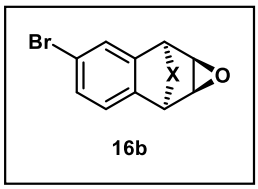
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.41 (dd, *J* = 5.4, 3.2 Hz, 2H), 7.30 – 7.23 (m, 2H), 5.66 (dd, *J* = 3.2, 1.7 Hz, 2H), 3.89 (dd, *J* = 3.2, 1.7 Hz, 2H), 2.82 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.1, 129.87, 129.83, 124.4, 57.8, 44.4, 25.5

HRMS: (ESI-TOF, m/z) calcd. for $C_{13}H_{12}N_3O_3$ $[M+H]^+$, 258.0873; found: 258.0887

IR: (ATR, neat, cm^{-1}) = 3014 (w), 1761 (m), 1701 (s), 1467(m), 1447(m), 1395 (m), 1227 (w), 1214 (w), 1170 (w), 1037 (w), 964 (m), 923 (w), 864 (m), 755 (m), 701 (w), 662 (w), 552 (m), 502 (w)

m.p. = 244 – 245 °C



7-bromo-2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-1,3(2H)-dione (16b):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a white solid (183 mg, 5:1 d.r., 54%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

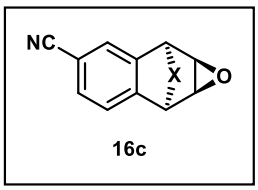
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.59 – 7.52 (m, 1H), 7.44 – 7.38 (m, 1H), 7.14 (d, *J* = 7.9 Hz, 1H), 5.62 (dd, *J* = 9.7, 3.4 Hz, 2H), 3.89 (d, *J* = 3.4 Hz, 2H), 2.85 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.0, 156.9, 132.9, 131.6, 128.7, 127.7, 126.1, 123.7, 57.3, 57.2, 44.3, 44.2, 25.7

HRMS: (ESI-TOF, m/z) calculated for $C_{13}H_{11}N_3O_3$ $[M+H]^+$, 335.9978; found: 335.9989

IR: (ATR, neat, cm^{-1}) 1771 (m), 1705 (s), 1453 (m), 1394 (w), 1199 (w), 963 (w), 851 (w), 767 (w), 730 (w), 571 (w), 523 (m)

m.p. = 194 – 196 °C



2-methyl-1,3-dioxo-2,3,5,10-tetrahydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-7-carbonitrile (16c):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 1:1) as a colorless oil (160.2 mg, 7:1 d.r., 57%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

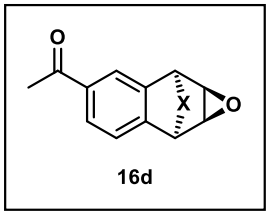
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.73 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.55 (d, *J* = 1.6 Hz, 1H), 7.39 (d, *J* = 7.7 Hz, 1H), 5.71 (m, 2H), 4.02 – 3.89 (m, 2H), 2.84 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.78*, 134.4, 134.0, 131.1, 127.9, 125.4, 117.8, 113.9, 57.2, 57.0, 44.2, 44.1, 25.7 *(*2 peaks overlapping)*

HRMS: (ESI-TOF, m/z) calculated for $C_{14}H_{11}N_4O_3$ $[M+H]^+$, 283.0826; found: 283.0835

IR: (ATR, neat, cm^{-1}) 3055 (w), 2231 (w), 1772 (m), 1701 (s), 1451 (m), 1394 (w), 1197 (w), 1033 (m), 964 (m), 911 (m), 852 (m), 728 (m), 590 (w), 539 (m)

m.p. = 97 – 100 °C



7-acetyl-2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-1,3(2H)-dione (16d):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a white solid (183 mg, 5:1 d.r., 61%).

R_f = 0.2 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

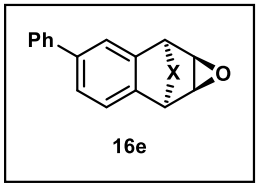
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.02 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.84 (d, *J* = 1.7 Hz, 1H), 7.37 (d, *J* = 7.8 Hz, 1H), 5.76 – 5.69 (m, 2H), 3.97 – 3.90 (m, 2H), 2.82 (s, 3H), 2.60 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 196.9, 156.88*, 138.4, 134.4, 130.4, 130.0, 124.8, 124.3, 57.7, 57.3, 44.4, 44.3, 26.8, 25.6 *(*2 peaks overlapping)*

HRMS: (ESI-TOF, m/z) calculated for $C_{15}H_{14}N_3O_4$ $[M+H]^+$, 300.0979; found: 300.0995.

IR: (ATR, neat, cm^{-1}) 3006 (w), 2954 (w), 2252 (w), 1771 (m), 1704 (s), 1454 (m), 1394 (m), 1359 (m), 1270 (w), 1194 (w), 1031 (w), 913 (w), 852 (w), 766 (w), 729 (m), 655 (w), 603 (w), 562 (m), 523 (w).

m.p. = 176.5 °C (decomp.)



2-methyl-7-phenyl-5,10-dihydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-1,3(2H)-dione (16e):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 1:1) as a colorless gel (136 mg, 3:1 d.r., inseperable, 41%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

Discernable major diastereomer ^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.32 (d, *J* = 7.7 Hz, 1H), 5.74 – 5.67 (m, 2H), 3.97 – 3.87 (m, 2H), 2.85 (s, 3H)

Major diastereomer ^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.1, 157.0, 142.9, 140.0, 130.4, 129.2, 129.0, 128.4, 128.0, 127.3, 124.8, 123.2, 57.9, 57.6, 44.6, 44.6, 25.6.5

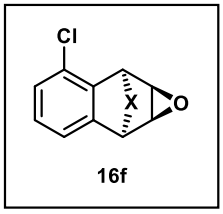
Discernable minor diastereomer ^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 1.7 Hz, 1H), 5.56 (ddd, *J* = 9.1, 3.1, 1.1 Hz, 1H), 3.73 (dt, *J* = 2.9, 1.4 Hz, 1H), 3.10 (s, 1H)

Minor diastereomer ^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.98, 156.97, 142.8, 140.0, 136.6, 134.7, 128.7, 128.2, 128.0, 127.4, 126.2, 124.8, 57.8, 57.7, 54.3, 53.9, 25.7

^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 1.7 Hz, 0.4H), 7.62 (m, 1.3H), 7.59 – 7.51 (m, 3.4H), 7.50 – 7.34 (m, 5.3H), 7.32 (d, *J* = 7.7 Hz, 1H), 5.71 (ddt, *J* = 7.3, 5.0, 2.7 Hz, 2H), 5.56 (ddd, *J* = 9.1, 3.1, 1.1 Hz, 0.8H), 3.96 – 3.88 (m, 2H), 3.73 (dt, *J* = 2.9, 1.4 Hz, 0.8H), 3.10 (s, 1H), 2.85 (s, 3H)

HRMS: (ESI-TOF, m/z) calculated for $C_{19}H_{16}N_3O_3$ $[M+H]^+$, 334.1186; found: 334.1191.

IR: (ATR, neat, cm^{-1}) 3497 (w), 1760 (m), 1682 (s,br), 1451 (m), 1387 (m), 1217 (m), 1026 (w), 917 (w), 837 (w), 758 (m), 711 (m)



6-chloro-2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-1,3(2H)-dione (16f):

Following **General Procedure B** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a white solid (219 mg, >20:1 d.r., 75%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

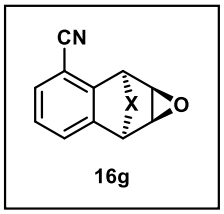
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.42 (dd, *J* = 8.3, 1.0 Hz, 1H), 7.33 (t, *J* = 7.8 Hz, 1H), 7.19 – 7.10 (m, 1H), 6.14 (d, *J* = 4.6 Hz, 1H), 5.64 (d, *J* = 4.5 Hz, 1H), 3.93 (t, *J* = 4.5 Hz, 1H), 3.88 (t, *J* = 4.4 Hz, 1H), 2.84 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.0, 156.9, 131.7, 130.7, 130.32, 130.30, 128.20, 122.94, 57.5, 54.6, 44.13, 44.11, 25.7

HRMS: (ESI-TOF, m/z) calcd. for $C_{13}H_{11}N_3O_3Cl$ $[M+H]^+$, 292.0484; found: 292.0489

IR: (ATR, neat, cm^{-1}) = 1771 (m), 1708 (s), 1451 (m), 1394 (w), 1269 (w), 1234 (w), 1200 (w), 1171 (w), 1033 (w), 963 (m), 852 (m), 769 (w), 734 (w), 720 (w), 705 (w), 580 (m), 456 (w)

m.p. = 195 – 196 °C



2-methyl-1,3-dioxo-2,3,5,10-tetrahydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-6-carbonitrile (16g):

Following **General Procedure B** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a white solid (212 mg, 6:1 d.r., 75%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

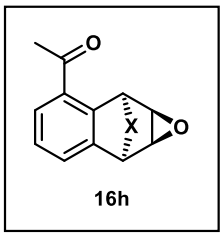
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.71 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.58 – 7.44 (m, 2H), 6.05 (d, *J* = 4.5 Hz, 1H), 5.72 (d, *J* = 4.5 Hz, 1H), 3.97 (dt, *J* = 23.8, 4.4 Hz, 2H), 2.84 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.0, 156.7, 133.2, 133.0, 131.2, 130.3, 128.8, 115.6, 109.2, 57.2, 55.6, 44.0, 43.9, 25.7

HRMS: (ESI-TOF, m/z) calculated for $C_{14}H_{11}N_4O_3$ $[M+H]^+$, 283.0826; found: 283.0833

IR: (ATR, neat, cm^{-1}) = 3021 (w), 2231 (w), 1713 (s), 1448 (s), 1392 (s), 1272 (w), 1243 (w), 1196 (m), 1178 (m), 1113 (w), 1032 (w), 965 (m), 849 (m), 764 (s), 702 (m), 598 (m), 533 (m)

m.p. = 212 °C (decomp.)



6-acetyl-2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxireno[1,2,4]triazolo[1,2-b]phthalazine-1,3(2H)-dione (16h):

Following **General Procedure B** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) as a white solid (189 mg, 5.5:1 d.r., 63%).

R_f = 0.2 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

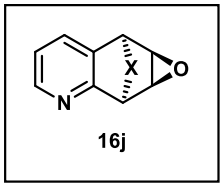
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.86 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 1H), 7.40 (dd, *J* = 7.6, 1.1 Hz, 1H), 6.91 (d, *J* = 4.4 Hz, 1H), 5.67 (d, *J* = 4.4 Hz, 1H), 3.96 (t, *J* = 4.4 Hz, 1H), 3.90 (t, *J* = 4.4 Hz, 1H), 2.82 (d, *J* = 0.8 Hz, 3H), 2.63 (d, *J* = 0.8 Hz, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 199.4, 157.1, 156.5, 133.4, 131.5, 130.39, 130.35, 129.3, 128.5, 57.5, 53.6, 44.0, 43.9, 28.7, 25.6

HRMS: (ESI-TOF, m/z) calculated for $C_{15}H_{14}N_3O_4$ $[M+H]^+$, 300.0979; found: 300.0974

IR: (ATR, neat, cm^{-1}) 3051 (w), 2954 (w), 2253 (w), 1771 (m), 1702 (s), 1587 (w), 1447 (m), 1394 (m), 1358 (w), 1261 (m) 1201 (m), 1131 (w), 1034 (w), 1018 (w), 962 (m), 912 (m), 853 (m), 709 (m), 727 (s), 647 (w), 600 (w), 509 (w).

m.p. = 159 – 161 °C



16j

8-methyl-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16j):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (172 mg, 5:1 d.r., 67%).

R_f = 0.2 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

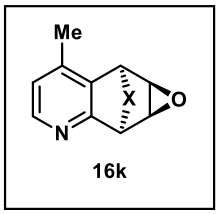
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.58 (d, *J* = 5.1 Hz, 1H), 7.59 (d, *J* = 7.6 Hz, 1H), 7.35 (dd, *J* = 7.6, 5.1 Hz, 1H), 5.84 (dd, *J* = 4.6, 1.1 Hz, 1H), 5.73 (dd, *J* = 4.6, 1.1 Hz, 1H), 4.07 – 3.86 (m, 2H), 2.85 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.9, 156.4, 150.6, 150.2, 132.2, 125.1, 124.8, 59.2, 56.7, 44.4, 44.0, 25.7.

HRMS: (ESI-TOF, m/z) calculated for $C_{12}H_{11}N_4O_3$ $[M+H]^+$, 259.0826 found: 259.0826.

IR: (ATR, neat, cm^{-1}): 1764 (m), 1694 (s), 1577 (w), 1448 (m), 1395 (m), 1209 (w), 1118 (w), 1035 (w), 964 (w), 809 (w), 757 (m), 556 (m).

m.p. = 189 – 191 °C



16k

4,8-dimethyl-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16k):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (197 mg, >20:1 d.r., 72%).

R_f =0.3 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

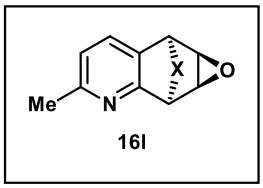
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.40 (d, *J* = 5.3 Hz, 1H), 7.16 (d, *J* = 5.3 Hz, 1H), 5.94 (d, *J* = 4.3 Hz, 1H), 5.79 (d, *J* = 4.3 Hz, 1H), 3.98 – 3.91 (m, 2H), 2.85 (s, 3H), 2.43 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.4, 156.6, 150.0, 149.7, 142.6, 126.3, 124.4, 59.6, 53.4, 44.4, 43.9, 25.7, 17.6.

HRMS: (ESI-TOF, m/z) calculated for $C_{13}H_{13}N_4O_3$ $[M+H]^+$, 273.0982 found: 273.0986.

IR: (ATR, neat, cm^{-1}) 1764 (m), 1698 (s), 1593 (m), 1447 (m), 1400 (m), 1204 (w), 1032 (w), 963 (m), 921 (w), 870 (w), 851 (m), 766 m), 754 (m), 710 (w), 634 (w), 591 (w), 517 (w), 490 (w).

m.p. = 220 – 223 °C



16l

2,8-dimethyl-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16l):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (171 mg, 8:1 d.r., 63%).

R_f = 0.4 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

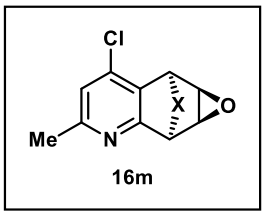
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.44 (d, *J* = 7.7 Hz, 1H), 7.16 (d, *J* = 7.7 Hz, 1H), 5.75 (d, *J* = 4.5 Hz, 1H), 5.68 (d, *J* = 4.5 Hz, 1H), 3.92 (t, *J* = 4.4 Hz, 1H), 3.88 (t, *J* = 4.4 Hz, 1H), 2.83 (s, 3H), 2.53 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 159.9, 156.8, 156.3, 149.5, 132.3, 124.1, 122.0, 59.2, 56.4, 44.4, 43.9, 25.6, 24.5.

HRMS: (ESI-TOF, m/z) calculated for $C_{13}H_{13}N_4O_3$ $[M+H]^+$, 273.0982 found: 273.0986.

IR: (ATR, neat, cm^{-1}) 1772 (m), 1702 (s), 1599 (m), 1448 (w), 1394 (w), 1273 (w), 1196 (w), 1032 (w), 986 (w), 960 (m), 911 (m), 870 (w), 766 (w), 725 (m), 546 (m), 526 (w).

m.p. = 214 – 216 °C



16m

4-chloro-2,8-dimethyl-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16m):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (180 mg, >20:1 d.r., 59%).

R_f = 0.5 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

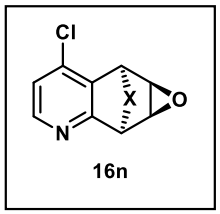
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.22 (s, 1H), 6.11 – 6.07 (m, 1H), 5.78 – 5.74 (m, 1H), 3.97 – 3.92 (m, 2H), 2.89 (s, 3H), 2.54 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 161.1, 156.6, 156.2, 150.7, 140.2, 124.5, 120.9, 59.0, 53.5, 44.3, 43.8, 25.8, 24.4.

HRMS: (ESI-TOF, m/z) calculated for $C_{13}H_{12}N_4O_3Cl$ $[M+H]^+$, 307.0592 found: 307.0601.

IR: (ATR, neat, cm^{-1}) 1774 (m), 1710 (s), 1591 (m), 1566 (m), 1452 (m), 1395 (w), 1269 (w), 1231 (w), 1193 (m), 1034 (w), 962 (w), 898 (w), 854 (w), 768 (w), 753 (w), 706 (w), 646 (w), 602 (w).

m.p. = 269 – 270 °C (decomp.)



16n

4-chloro-8-methyl-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16n):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (246 mg, >20:1 d.r., 84%)

R_f =0.5 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

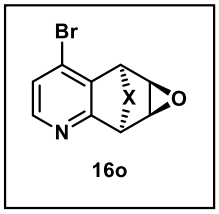
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.46 (d, *J* = 5.5 Hz, 1H), 7.38 (d, *J* = 5.5 Hz, 1H), 6.15 (dq, *J* = 3.0, 1.1 Hz, 1H), 5.93 – 5.75 (m, 1H), 4.04 – 3.90 (m, 2H), 2.89 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.6, 156.3, 151.5, 151.0, 140.3, 125.4, 124.0, 59.0, 53.6, 44.2, 43.8, 25.8.

HRMS: (ESI-TOF, m/z) calculated for $C_{12}H_{10}N_4O_3Cl$ $[M+H]^+$, 293.0436 found: 293.0448.

IR: (ATR, neat, cm^{-1}) 1768 (m), 1705 (s), 1578 (w), 1446 (m), 1403 (m), 1227 (w), 1201 (m), 1039 (w), 978 (w), 964 (m), 921 (w), 852 (m), 766 (m), 722 (m), 591 (w), 591 (m).

m.p. = 218 – 221 °C (decomp.)



16o

4-bromo-8-methyl-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16o):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (285 mg, >20:1 d.r., 85%).

R_f =0.5 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

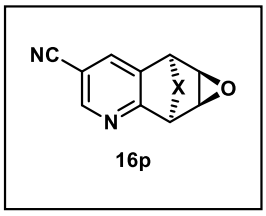
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.36 (d, *J* = 5.5 Hz, 1H), 7.54 (d, *J* = 5.5 Hz, 1H), 6.14 – 6.09 (m, 1H), 5.84 – 5.79 (m, 1H), 4.01 – 3.95 (m, 2H), 2.89 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.6, 156.3, 151.1, 150.9, 130.2, 128.5, 126.3, 59.1, 55.8, 44.2, 43.8, 25.8.

HRMS: (ESI-TOF, m/z) calculated for $C_{12}H_{10}N_4O_3Br$ $[M+H]^+$, 336.9931 found: 336.9948.

IR: (ATR, neat, cm^{-1}) 1771(m), 1711(s), 1556 (m), 1456 (m), 1396 (m), 1229 (m), 1200 (m), 1035 (w), 963(m), 851(w), 765(m), 706 (w), 586 (w), 522(w).

m.p. = 253 – 254 °C with decomposition



16p

8-methyl-7,9-dioxo-5,8,9,11-tetrahydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-3-carbonitrile (16p):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (253 mg, 12:1 d.r., 89%).

R_f =0.5 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

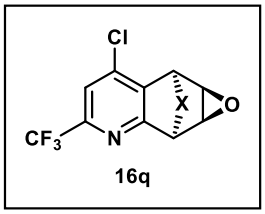
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.86 (d, *J* = 1.9 Hz, 1H), 7.86 (d, *J* = 1.9 Hz, 1H), 5.89 (d, *J* = 4.6 Hz, 1H), 5.79 (d, *J* = 4.6 Hz, 1H), 4.03 (m, 2H), 2.88 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.5, 156.0, 153.7, 153.6, 135.0, 125.4, 115.8, 111.2, 58.8, 55.9, 44.3, 43.8, 25.9.

HRMS: (ESI-TOF, m/z) calculated for $C_{13}H_{10}N_5O_3$ $[M+H]^+$, 284.0778 found: 284.0784.

IR: (ATR, neat, cm^{-1}) 2236 (w), 1776(m), 1710 (s), 1456 (m), 1394 (m), 1210(w), 1035 (w), 967 (w), 914 (w), 848 (w), 766 (w), 728 (m), 646 (w), 593 (w), 544 (w), 525 (w).

m.p. = 239 – 241 °C (decomp.)



16q

4-chloro-8-methyl-2-(trifluoromethyl)-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16q):

1.05 equivalents (243 mg, 1.05 mmol) of arene was used. With a slight modification to **General Procedure A** (1.0 mmol), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (277 mg, >20:1 d.r., 72%).

R_f =0.7 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.77 (s, 1H), 6.19 (dd, *J* = 3.4, 1.7 Hz, 1H), 5.91 (dd, *J* = 3.4, 1.7 Hz, 1H), 4.03 (m, 2H), 2.91 (s, 3H)

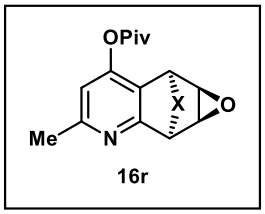
^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.2, 155.7, 152.0, 149.6 (q, *J*=36.0) , 141.7, 127.0, 122.7 (q, *J* = 2.9 Hz), 120.6 (q, *J* = 275.0 Hz), 58.4, 53.1, 44.1, 43.7, 25.9.

^{19}F NMR: (471 MHz, $CDCl_3$) δ -67.65.

HRMS: (ESI-TOF, m/z) calculated for $C_{13}H_9N_4O_3F_3Cl$ $[M+H]^+$, 361.0310 found: 361.0310.

IR: (ATR, neat, cm^{-1}) 1779 (m), 1707 (s), 1578 (w), 1452 (m), 1394 (w), 1347 (m), 1192 (m), 1108 (w), 964 (w), 866 (w), 845 (w), 767 (w), 754 (w), 735 (m), 723 (m).

m.p. = 223 – 225 °C



16r

2,8-dimethyl-7,9-dioxo-5,8,9,11-tetrahydro-7H-5,11-[2,3]epoxirenopyrido[2,3-d][1,2,4]triazolo[1,2-a]pyridazin-4-yl pivalate (16r):

Following **general procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (185 mg, 0.568 mmol, >20:1 d.r., 50%).

R_f =0.5 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

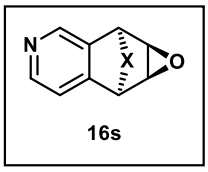
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.06 (s, 1H), 5.80 – 5.73 (m, 2H), 3.97 – 3.90 (m, 2H), 2.87 (s, 3H), 2.56 (s, 3H), 1.42 (s, 9H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 175.6, 161.6, 156.8, 156.4, 153.0, 151.5, 117.4, 114.5, 59.0, 51.9, 44.4, 43.9, 39.8, 27.2, 25.8, 24.7.

IR: (ATR, neat, cm^{-1}) 2977 (w), 1764 (m), 1714 (s), 1587 (m), 1454 (m), 1396 (w), 1344 (w), 1095 (m), 961 (w), 731 (w), 533 (w), 498 (w).

HRMS: (ESI-TOF, m/z) calculated for $C_{18}H_{21}N_4O_5$ $[M+H]^+$, 373.1507 found: 373.1506.

m.p. = 237 – 238 °C



16s

2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxirenopyrido[3,4-d][1,2,4]triazolo[1,2-a]pyridazine-1,3(2H)-dione (16s):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (187mg, 5:1 d.r., 72%).

R_f = 0.2 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

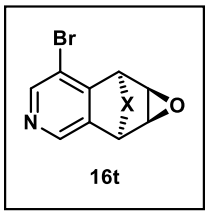
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.71 (s, 1H), 8.52 (s, 1H), 7.21 (d, *J* = 4.7 Hz, 1H), 5.74 (d, *J* = 4.4 Hz, 1H), 5.67 (d, *J* = 4.4 Hz, 1H), 3.93 (m, 2H), 2.82 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.8, 156.7, 151.8, 144.7, 137.9, 125.4, 119.0 56.5, 55.4, 44.3, 43.8, 25.7.

HRMS: (ESI-TOF, m/z) calculated for $C_{12}H_{11}N_4O_3$ $[M+H]^+$, 259.0826 found: 259.0828.

IR: (ATR, neat, cm^{-1}): 3059 (w), 1709 (s), 1609 (w), 1456 (m), 1395 (m), 1269 (w), 1207 (w), 1097 (w), 692 (w), 766 (w), 733 (w), 560 (w)

m.p. = 226 °C (decomp.)



16t

9-bromo-2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxirenopyrido[3,4-d][1,2,4]triazolo[1,2-a]pyridazine-1,3(2H)-dione (16t):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (223 mg, >20:1 d.r., 66%).

R_f = 0.4 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

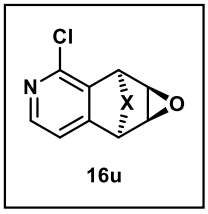
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.81 (s, 1H), 8.42 (s, 1H), 6.06 (d, *J* = 4.5 Hz, 1H), 5.73 (d, *J* = 4.5 Hz, 1H), 3.97 (m, 2H), 2.87 (s, 3H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.7, 156.5, 153.2, 143.2, 138.2, 126.8, 117.3, 55.8, 55.2, 44.1, 43.6, 25.8.

HRMS: (ESI-TOF, m/z) calculated for $C_{12}H_{10}N_4O_3Br$ $[M+H]^+$, 336.9931 found: 336.9940.

IR: (ATR, neat, cm^{-1}) 1775 (m), 1706 (s), 1595 (w), 1553 (w), 1449 (m), 1393 (w), 1192 (m), 1159 (w), 1101 (w), 1034 (w), 963 (w), 909 (w), 847 (w), 766 (w), 727 (m), 576 (m), 512(w).

m.p. = 243 °C (decomp.)



6-chloro-2-methyl-5,10-dihydro-1H-5,10-[2,3]epoxirenopyrido[3,4-d][1,2,4]triazolo[1,2-a]pyridazine-1,3(2H)-dione (16u):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (166 mg, >20:1 d.r., 57%).

R_f =0.4 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

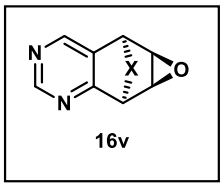
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.45 (d, *J* = 5.6 Hz, 1H), 7.38 (d, *J* = 5.6 Hz, 1H), 6.24 – 5.99 (m, 1H), 5.85 – 5.77 (m, 1H), 4.07 – 3.89 (m, 2H), 2.89 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.7, 156.6, 151.3, 146.9, 140.8, 124.5, 118.3, 56.4, 54.7, 44.0, 43.5, 25.9.

HRMS: (ESI-TOF, m/z) calculated for $C_{12}H_{10}N_4O_3Cl$ $[M+H]^+$, 293.0436 found: 293.0437.

IR: (ATR, neat, cm^{-1}): 1773 (w), 1710 (s) , 1601 (w), 1560 (w), 1452 (m), 1412 (w), 1395 (w), 1189 (w), 964 (w), 855 (w), 767 (w), 733 (w), 585 (w), 519 (w).

m.p. = 238 – 239 °C



8-methyl-5,11-dihydro-7H-5,11-[2,3]epoxirenopyrimido[4,5-d][1,2,4]triazolo[1,2-a]pyridazine-7,9(8H)-dione (16v):

Following **General Procedure A** (1.0 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as an off-white solid (186 mg, >20:1 d.r., 72%).

R_f =0.3 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 9.25 (s, 1H), 8.64 (s, 1H), 5.80 (m, 2H), 4.06 – 3.97 (m, 2H), 2.88 (s, 3H).

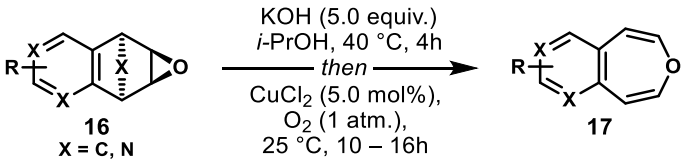
^{13}C NMR: (126 MHz, $CDCl_3$) δ 160.2, 158.1, 156.6, 156.0, 151.5, 122.9, 58.2, 54.4, 44.4, 43.5, 25.9.

HRMS: (ESI-TOF, m/z) calculated for $C_{11}H_{10}N_5O_3$ $[M+H]^+$, 260.0778 found: 260.0784.

IR: (ATR, neat, cm^{-1}) 1774 (m), 1709 (s), 1594 (w), 1568 (m), 1458 (w), 1395 (w), 1218 (w), 965 (w), 848 (w), 766 (w), 677 (w), 565 (w).

m.p. = 217 – 218 °C

3-6.3 General procedure for the cycloreversion to benzoxepines:



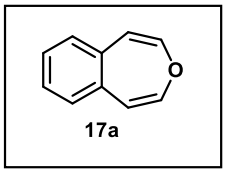
To a vial containing finely ground KOH (156 mg, 5.0 equiv., 90 wt%), and substrate (0.500 mmol, 1.0 equiv.) under nitrogen was added *i*-PrOH (5.0 mL, 0.1 M) and degassed with nitrogen/sonication for 15 min. The reaction was heated to 40 °C with vigorous stirring (700 rpm) and progress was monitored by TLC in 30 min intervals. Upon completion, the reaction was cooled in an ice bath and H_2O (5.0 mL) were added. AcOH is then carefully added dropwise until pH = 5, upon which gas evolution is observed. $CuCl_2$ dihydrate (4.3 mg, 25 μmol, 0.05 mol%). was then added as a solid, followed by sparging with oxygen, and the reaction was stirred for 10-16 h under an atmosphere of oxygen (balloon).

Work-up for hydrocarbon arene-derived benzoxepines:

Upon completion, the reaction was partitioned between diethyl ether (10 mL) and saturated brine (10 mL) and the organic layer was extracted with ether (3 × 10 mL). The combined organics were washed with brine, dried over $MgSO_4$, filtered, and concentrated under vacuum and isolated by flash chromatography (SiO_2, hexanes:ethyl acetate mixtures). Compounds are volatile; thus, execute caution when putting the compound under vacuum.

Work-up for heteroarene-derived benzoxepines:

Upon completion, the reaction was poured into saturated aqueous $NaHCO_3$ (10 mL). The aqueous phase was extracted with ethyl acetate (3 × 10 mL). The combined organics were then washed with brine, dried over $MgSO_4$, filtered, and concentrated under vacuum and isolated by flash chromatography (SiO_2, hexanes:ethyl acetate mixtures). Compounds are volatile; thus, caution is needed upon drying the compound under reduced pressure.



3-Benzoxepin (benzo[*d*]oxepine, 17a):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a bright yellow solid (59 mg, 82%).

R_f = 0.4 (SiO_2, hexanes, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.90 (dd, *J* = 5.6, 3.3 Hz, 2H), 6.63 (dd, *J* = 5.5, 3.4 Hz, 2H), 5.67 (d, *J* = 7.4 Hz, 2H), 5.06 (d, *J* = 7.4 Hz, 2H).

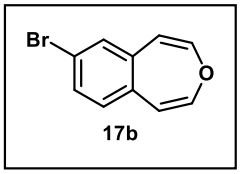
^{13}C NMR: (126 MHz, $CDCl_3$) δ 146.1, 136.0, 129.1, 127.8, 113.3.

HRMS: (EI-TOF, m/z) calcd. For $C_{10}H_8O$ $[M]^+$, 144.05697; found: 144.05719.

IR: (ATR, neat, cm^{-1}) = 3050 (w), 2926 (w), 1658 (m), 1635 (m), 1496 (m), 1438 (m), 1316 (s), 1254 (m), 1211 (m), 1118 (m), 1049 (s), 921 (m), 847 (m), 770 (s).

m.p. = 81 – 82 °C

The analytical data were in accordance with previously reported values.[8]



7-bromobenzo[*d*]oxepine (17b):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1:0 to 10:1) as a yellow solid (86 mg, 77%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

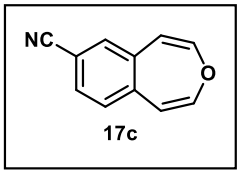
^{1}H NMR: (500 MHz, CD_3CN) δ 7.08 (dd, *J* = 8.1, 2.1 Hz, 1H), 6.86 (d, *J* = 2.1 Hz, 1H), 6.59 (d, *J* = 8.1 Hz, 1H), 5.73 (m, 2H), 5.10 (m, 2H)

^{13}C NMR: (126 MHz, CD_3CN) δ 148.2, 147.4, 139.0, 135.9, 132.4, 131.7, 131.4, 121.8, 113.0, 112.5

HRMS: (EI, m/z) calcd. For $C_{10}H_7OBr$ $[M]^+$, 221.9675; found: 221.9674

IR: (ATR, neat, cm^{-1}) 1670 (m), 1634 (m), 1576 (w), 1491 (m), 1397 (m), 1367 (m), 1318 (m), 1254 (w), 1211 (m), 1130 (w), 1089 (w), 1049 (s), 888(w), 872 (w), 873 (m), 828 (m), 762 (m), 733 (w), 583 (w)

m.p. = 69 – 71 °C



Benzo[*d*]oxepine-7-carbonitrile (17c):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a yellow solid (69 mg, 82%).

R_f = 0.5 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

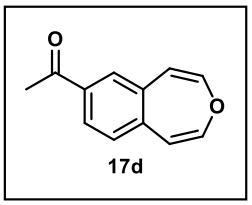
^{1}H NMR: (500 MHz, CD_3CN) δ 7.24 (dd, *J* = 7.9, 1.7 Hz, 1H), 6.94 (d, *J* = 1.7 Hz, 1H), 6.75 (d, *J* = 7.9 Hz, 1H), 5.73 (m, 2H), 5.10 (m, 2H)

^{13}C NMR: (126 MHz, CD_3CN) δ 149.6, 148.5, 141.8, 138.0, 132.8, 132.6, 130.4, 119.2, 112.5, 112.1, 111.8

HRMS: (ESI-TOF, m/z) calcd. For $C_{11}H_8NO$ $[M+H]^+$, 170.600; found: 170.0606

IR: (ATR, neat, cm^{-1}): 3073 (w), 2227 (m), 1671 (m), 1591 (m), 1498 (w), 1326 (m), 1257 (w), 1205 (w), 1053 (s), 901 (w), 844 (w), 651 (m)

m.p. = 83 – 84 °C



1-(benzo[*d*]oxepin-7-yl)ethan-1-one (17d):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a yellow solid (68 mg, 73%).

R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

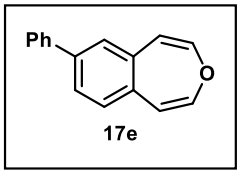
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.48 – 7.40 (m, 1H), 7.14 (d, *J* = 1.8 Hz, 1H), 6.64 (d, *J* = 7.8 Hz, 1H), 5.66 (m, 2H), 5.01 (m, 2H), 2.48 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 197.0, 148.0, 146.4, 141.1, 136.4, 136.3, 129.1, 128.51, 128.48, 112.4, 112.0, 25.6

HRMS: (ESI-TOF, m/z) calcd. For $C_{12}H_{11}O_2$ $[M+H]^+$, 187.0754 found: 187.0756

IR: (ATR, neat, cm^{-1}) 3346 (w), 1730 (w), 1675 (s), 1593 (m), 1566 (w), 1406 (w), 1356 (m), 1311 (m), 1273 (m), 1192 (w), 1147 (w), 1082 (w), 1049 (m), 972 (w), 933 (w), 838 (m), 763 (m), 636 (w), 570 (m).

m.p. = 71 – 74 °C (decomp.)



7-phenylbenzo[*d*]oxepine (17e):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a yellow solid (90 mg, 82%).

R_f = 0.5 (SiO_2, hexanes, UV)

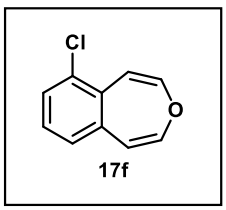
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.53 – 7.48 (m, 2H), 7.40 (m, 2H), 7.35 – 7.30 (m, 1H), 7.13 (dd, *J* = 7.8, 2.0 Hz, 1H), 6.87 (d, *J* = 2.0 Hz, 1H), 6.70 (d, *J* = 7.8 Hz, 1H), 5.70 (m, 2H), 5.10 (m, 2H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 146.20, 146.17, 140.6, 140.2, 136.4, 135.0, 129.6, 128.9, 128.0, 127.6, 126.7, 126.3, 113.1, 112.8

HRMS (ESI-TOF, m/z) calcd. For $C_{16}H_{13}O$ $[M+H]^+$, 221.0961; found: 221.0956

IR (ATR, neat, cm^{-1}): 3057 (w), 3037 (w), 1667 (m), 1562 (w), 1485(w), 1325 (m), 1264 (w), 1201 (w), 1051 (s), 892 (w), 849 (w), 691 (s)

m.p. = 91 – 92 °C



6-chlorobenzo[*d*]oxepine (17f):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a yellow oil (68 mg, 76%).

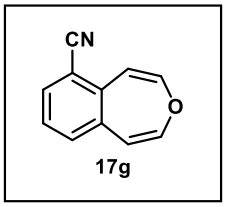
R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.04 (dd, *J* = 7.8, 1.3 Hz, 1H), 6.90 (t, *J* = 7.8 Hz, 1H), 6.63 (dd, *J* = 7.8, 1.3 Hz, 1H), 5.91 (d, *J* = 7.3 Hz, 1H), 5.85 (d, *J* = 7.0 Hz, 1H), 5.74 (d, *J* = 7.3 Hz, 1H), 5.25 (d, *J* = 7.0 Hz, 1H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 148.0, 147.9, 137.9, 133.3, 133.0, 128.6, 128.6, 127.8, 113.9, 110.5.

HRMS: (EI-TOF, m/z) calcd. For $C_{10}H_7OCl$ $[M]^{\cdot+}$, 178.01799; found: 178.01804.

IR: (ATR, neat, cm^{-1}) = 3060 (w), 1667 (m), 1636 (m), 1466 (w), 1433 (s), 1299 (w), 1223 (w), 1080 (m), 1053 (s), 938 (m), 893 (w), 851 (w), 826 (w), 803 (w), 762 (s).



Benzo[*d*]oxepine-6-carbonitrile (17g):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a yellow solid (62 mg, 73%).

R_f = 0.5 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.19 (dd, *J* = 7.7, 1.4 Hz, 1H), 6.97 (t, *J* = 7.7 Hz, 1H), 6.80 (dd, *J* = 7.7, 1.4 Hz, 1H), 5.84 (d, *J* = 7.5 Hz, 1H), 5.73 (d, *J* = 7.3 Hz, 1H), 5.53 (d, *J* = 7.5 Hz, 1H), 5.09 (d, *J* = 7.3 Hz, 1H).

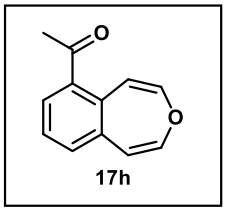
^{13}C NMR: (126 MHz, $CDCl_3$) δ 149.9, 148.0, 139.5, 137.4, 132.8, 131.4, 128.1, 117.5, 112.7, 111.5, 109.8.

HRMS: (ESI-TOF, m/z) calcd. For $C_{11}H_8NO$ $[M+H]^+$, 170.0600; found: 170.0603.

IR: (ATR, neat, cm^{-1}) = 3077 (w), 3010 (w), 2226 (m), 1672(s), 1634 (m), 1466 (m), 1449(m),

1312 (s), 1241 (m), 1093 (m), 1066 (m), 957 (m), 922 (m), 851 (m), 803(m), 767 (m).

m.p. = 81 – 84 °C



1-(benzo[*d*]oxepin-6-yl)ethan-1-one (17h):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a yellow oil (65 mg, 70%).

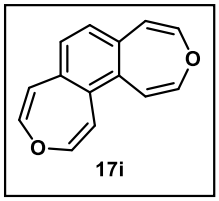
R_f = 0.5 in (SiO_2, hexanes:ethyl acetate = 9:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.25 (d, *J* = 5.7 Hz, 1H), 7.08 (t, *J* = 7.7 Hz, 1H), 6.89 (dd, *J* = 7.7, 1.3 Hz, 1H), 5.95 (m, 2H), 5.82 (d, *J* = 7.0 Hz, 1H), 5.40 (d, *J* = 7.0 Hz, 1H), 2.52 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 202.9, 148.6, 147.9, 139.0, 137.7, 133.9, 131.9, 127.3, 127.1, 114.5, 112.3, 30.6

HRMS: (ESI-TOF, m/z) calcd. For $C_{12}H_{10}O$ $[M]^+$, 186.06753; found: 186.06801

IR: (ATR, neat, cm^{-1}) 3066 (w), 1678 (s), 1633 (m), 1444 (w), 1352 (m), 1260 (s), 1056(s), 1014 (m), 980 (m), 938 (m), 896 (w), 852 (w), 815 (m), 766 (s), 592 (w)



Benzo[1,2-d:3,4-*d'*]bis(oxepine) (17i):

Epoxidation was telescoped using **General Procedure B** without purification. After extraction with ethyl acetate (3 × 15 mL), the organic extracts were combined and run through a plug of silica gel, and flushed with CH_2Cl_2 (15 mL). The organic phase was then dried over $MgSO_4$ and concentrated under reduced pressure. No flash chromatography was performed, and the crude mixture was immediately subjected to cycloreversion conditions. The title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1 to 10:1) as a yellow solid (35 mg, 33%).

R_f = 0.4 (SiO_2, hexanes, UV)

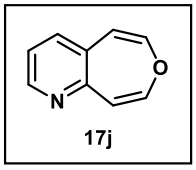
^{1}H NMR: (500MHz, $CDCl_3$) δ 6.55 (s, 2H), 6.00 (d, *J* = 7.0 Hz, 2H), 5.95 (d, *J* = 6.8 Hz, 2H), 5.47 (d, *J* = 7.0 Hz, 2H), 5.34 (d, *J* = 6.8 Hz, 2H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 147.5, 147.3, 135.2, 133.3, 128.5, 114.7, 112.0

HRMS: (EI, m/z) calculated for $C_{14}H_{10}O_2$ $[M]^+$ calculated: 210.06753 found: 210.06800

IR: (ATR, neat, cm^{-1}) 3052 (w), 1660 (m), 1632 (m), 1480 (w), 1401 (w), 1275 (m), 1121 (s), 978 (w), 950 (w), 854 (w), 759 (s), 738 (w)

m.p. = 83 – 86 °C



Oxepino[4,5-*b*]pyridine (17j):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow solid (90 mg, 82%).

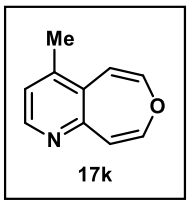
R_f = 0.5 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.05 (s, 1H), 6.84 (dd, *J* = 7.7, 1.5 Hz, 1H), 6.77 (dd, *J* = 7.7, 4.8 Hz, 1H), 5.81 (d, *J* = 7.7 Hz, 1H), 5.68 (d, *J* = 7.5 Hz, 1H), 5.28 (d, *J* = 7.7 Hz, 1H), 4.93 (d, *J* = 7.5 Hz, 1H).

^{13}C NMR: (126 MHz, $CDCl_3$) δ 155.9, 149.0, 147.4, 147.1, 135.2, 132.9, 122.0, 114.9, 110.6.

HRMS: (ESI-TOF, m/z) calcd. For C_9H_8O $[M+H]^+$, 146.0600; found: 146.0600

IR: (ATR, neat, cm^{-1}) 3046 (w), 1671 (m), 1634 (m), 1571 (m), 1451 (s), 1303 (w), 1271 (w), 1228 (w), 1121 (m), 1044 (w), 873 (w), 789 (w), 575 (w).



4-methyloxepino[4,5-*b*]pyridine (17k):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow oil (59 mg, 74%).

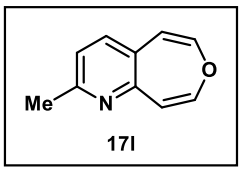
R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 5.0 Hz, 1H), 6.72 (d, *J* = 5.0 Hz, 1H), 6.02 (d, *J* = 7.2 Hz, 1H), 5.95 (d, *J* = 7.2 Hz, 1H), 5.55 (d, *J* = 7.2 Hz, 1H), 5.36 (d, *J* = 7.2 Hz, 1H), 2.14 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 155.4, 150.1, 147.9, 147.5, 144.0, 131.3, 123.8, 116.5, 109.0, 19.3

HRMS: (ESI-TOF, m/z) calcd. For $C_{10}H_{10}NO$ $[M+H]^+$, 160.0757; found: 160.0776

IR: (ATR, neat, cm^{-1}) 3052 (w), 2979 (w), 1668 (m), 1633 (m), 1581 (m), 1496 (s), 1264 (w), 1218 (w), 1109 (m), 1019 (w), 833 (w), 765 (w), 681 (w)



17l

2-methyloxepino[4,5-*b*]pyridine (17l):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow oil (62 mg, 78%).

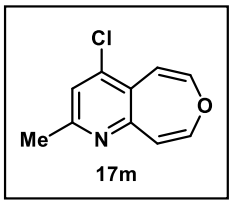
R_f = 0.3 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.78 (d, *J* = 7.7 Hz, 1H), 6.65 (d, *J* = 7.7 Hz, 1H), 5.84 (dd, *J* = 7.6, 1.8 Hz, 1H), 5.69 (dd, *J* = 7.4, 1.8 Hz, 1H), 5.31 (dd, *J* = 7.6, 2.0 Hz, 1H), 4.98 (dd, *J* = 7.4, 1.8 Hz, 1H), 2.35 (d, *J* = 1.8 Hz, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.3, 155.1, 148.9, 146.4, 135.8, 129.8, 121.3, 115.4, 110.9, 24.0

HRMS: (ESI-TOF, m/z) calcd. For $C_{10}H_{10}NO$ $[M+H]^+$, 160.0757; found: 160.0763

IR: (ATR, neat, cm^{-1}) 3052 (w), 1670 (m), 1634 (m), 1587 (m), 1469 (s), 1284 (w), 1213 (w), 1129 (m), 1044 (w), 835 (w), 759 (w), 614(w), 557 (w)



17m

4-chloro-2-methyloxepino[4,5-*b*]pyridine (17m):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow oil (70.2 mg, 0.36 mmol, 73%).

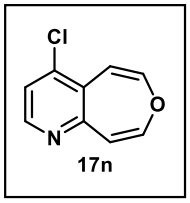
R_f = 0.5 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.79 (s, 1H), 5.98 (d, *J* = 7.4 Hz, 1H), 5.89 (d, *J* = 7.3 Hz, 1H), 5.57 (d, *J* = 7.3 Hz, 1H), 5.44 (d, *J* = 7.4 Hz, 1H), 2.35 (s, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.2, 156.4, 150.6, 148.1, 141.4, 127.6, 122.0, 115.6, 107.6, 23.9

HRMS: (ESI-TOF, m/z) calculated for $C_{10}H_9NOCl$ $[M+H]^+$, 194.0367 found: 194.0373

IR: (ATR, neat, cm^{-1}): 3006 (w), 2921 (w), 1669(m), 1634 (m), 1572 (m), 1538 (m),1443 (w), 1262 (w), 1048 (s), 955 (w), 808 (w)



4-chlorooxepino[4,5-*b*]pyridine (17n):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow solid (65 mg, 72%).

R_f= 0.7 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

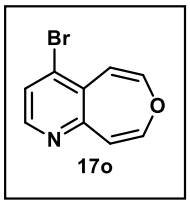
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.98 (d, *J* = 5.4 Hz, 1H), 6.89 (d, *J* = 5.4 Hz, 1H), 5.96 (d, *J* = 7.5 Hz, 1H), 5.89 (d, *J* = 7.5 Hz, 1H), 5.56 (d, *J* = 7.5 Hz, 1H), 5.43 (d, *J* = 7.5 Hz, 1H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 157.3, 150.7, 148.9, 147.9, 141.1, 130.8, 122.9, 115.4, 107.2

HRMS: (ESI-TOF, m/z) calcd. For C_9H_7ClO $[M+H]^+$, 180.0211; found: 180.0198

IR: (ATR, neat, cm^{-1}) 3083 (w), 1670 (m), 1634 (m), 1552 (w), 1438 (s), 1389 (w), 1302 (m), 1262 (w), 1199 (w), 1098 (m), 900 (w), 853 (w), 786 (w), 760 (w), 567 (w)

m.p. = 67 – 71 °C (decomp.)



4-bromooxepino[4,5-*b*]pyridine (17o):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow solid (81 mg, 72%).

R_f = 0.7 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

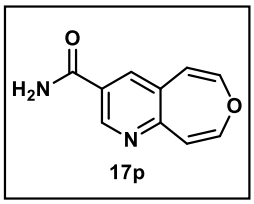
^{1}H NMR: (500 MHz, CD_3CN) δ 7.90 (d, *J* = 5.3 Hz, 1H), 7.20 (d, *J* = 5.3 Hz, 1H), 6.07 (d, *J* = 7.4 Hz, 1H), 6.01 (d, *J* = 7.3 Hz, 1H), 5.63 (dd, *J* = 7.3, 0.8 Hz, 1H), 5.48 (d, *J* = 7.4 Hz, 1H)

^{13}C NMR: (126 MHz, CD_3CN) δ 157.5, 152.0, 150.2, 149.0, 132.92, 132.88, 127.1, 116.3, 111.0

HRMS: (ESI-TOF, m/z) calculated for C_9H_7NOBr $[M+H]^+$, 223.9706 found: 223.9711

IR: (ATR, neat, cm^{-1}) 3057 (w), 1751 (m), 1668 (m), 1633 (m), 1545 (w), 1494 (s), 1387 (w), 1259 (w), 1223 (w), 1197 (m), 1095 (w), 888 (w), 765 (w), 651 (w)

m.p. = 61 – 64 °C (decomp.)



Oxepino[4,5-*b*]pyridine-3-carboxamide (17p):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow solid (60 mg, 63%).

R_f = 0.2 (SiO_2, hexanes:ethyl acetate = 1:3, UV)

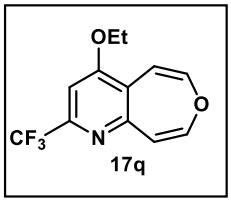
^{1}H NMR: (500 MHz, MeOD) δ 8.40 (d, *J* = 2.1 Hz, 1H), 7.40 (d, *J* = 2.1 Hz, 1H), 5.94 (d, *J* = 7.9 Hz, 1H), 5.76 (d, *J* = 7.7 Hz, 1H), 5.23 (d, *J* = 7.9 Hz, 1H), 5.09 (d, *J* = 7.7 Hz, 1H)

^{13}C NMR: (126 MHz, MeOD) δ 169.2, 159.8, 152.2, 148.8, 147.2, 135.8, 134.4, 129.3, 113.9, 110.6

HRMS: (ESI-TOF, m/z) calculated for $C_{10}H_9N_2O_2$ $[M+H]^+$, 189.0659 found: 189.0657

IR: (ATR, neat, cm^{-1}) 3288 (m, br), 2980 (w), 1673 (m), 1629 (s), 1630 (s), 1458 (m), 1399 (w), 1234 (s), 927 (w).

m.p. = 122 °C (decomp.)



4-ethoxy-2-(trifluoromethyl)oxepino[4,5-*b*]pyridine (17q):

Ethanol was used instead of *i*-PrOH. Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow solid (99 mg, 77%).

R_f = 0.6 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

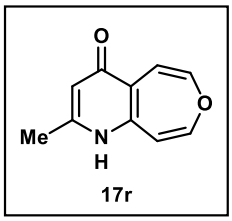
^{1}H NMR: (500 MHz, $CDCl_3$) δ 6.76 (s, 1H), 5.95 (d, *J* = 7.4 Hz, 1H), 5.86 (d, *J* = 7.4 Hz, 1H), 5.55 (d, *J* = 7.4 Hz, 1H), 5.46 (dd, *J* = 7.4, 0.9 Hz, 1H), 4.07 (q, *J* = 7.0 Hz, 2H), 1.43 (td, *J* = 7.0, 0.9 Hz, 3H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 161.1, 157.1, 150.9, 148.4, 147.6 (q, *J* = 34.3 Hz), 123.7, 121.3 (q, *J* = 274.1 Hz), 115.3, 104.7, 102.7 (q, *J* = 3.0 Hz), 64.8, 14.5

HRMS: (ESI-TOF, m/z) calcd. For $C_{12}H_{11}NO_2F_3$ $[M+H]^+$, 258.0736; found: 258.0746

IR: (ATR, neat, cm^{-1}): 2988 (w), 2944 (w), 1740 (m), 1591 (m), 1419 (s), 1386 (w), 1244 (w), 1181 (w), 1093 (s), 911 (w), 768 (w)

m.p. = 128 – 131 °C (decomp.)



2-methyl-4a,9a-dihydrooxepino[4,5-*b*]pyridin-4(1*H*)-one (17r):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, MeOH in ethyl acetate, 0 to 30%) as a yellow oil (63 mg, 72%).

R_f = 0.8 (SiO_2, methanol, UV)

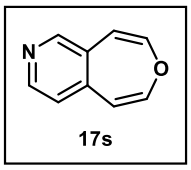
^{1}H NMR: (500 MHz, MeOD) δ 6.23 (d, *J* = 6.7 Hz, 1H), 6.12 (s, 1H), 5.89 (d, *J* = 6.5 Hz, 1H), 5.83 (d, *J* = 6.5 Hz, 1H), 5.46 (d, *J* = 6.7 Hz, 1H), 2.26 (s, 3H)

^{13}C NMR: (126 MHz, MeOD) δ 178.2, 154.3, 149.3, 147.1, 145.8, 122.7, 115.1, 110.5, 109.5, 18.8

HRMS: (ESI-TOF, m/z) calculated for $C_{10}H_{10}NO_2$ $[M+H]^+$, 176.0706 found: 176.0713

IR: (ATR, neat, cm^{-1}) 3281 (m, b), 1642 (m), 1602 (m), 1494 (s), 1250 (w), 1214 (w), 1167 (w), 968 (w), 760 (w)

m.p. = color change from yellow to grey (onset at 131 °C, assumed decomposition) took place slowly and no melting was observed up to 250 °C



Oxepino[4,5-*c*]pyridine (17s):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow oil (58 mg, 79%).

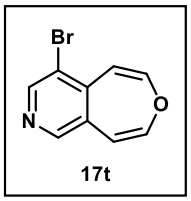
R_f = 0.4 (SiO_2, hexanes:ethyl acetate = 2:1, UV)

^{1}H NMR: (500 MHz, CD_3CN) δ 8.07 (s, 1H), 7.76 (s, 1H), 6.54 (d, *J* = 4.8 Hz, 1H), 5.78 (d, *J* = 7.5 Hz, 1H), 5.72 (d, *J* = 7.5 Hz, 1H), 5.10 (d, *J* = 7.5 Hz, 1H), 5.03 (d, *J* = 7.6 Hz, 1H)

^{13}C NMR: (126 MHz, CD_3CN) δ 151.2, 151.1, 149.6, 148.6, 144.3, 131.8, 123.4, 111.5, 110.6

HRMS: (ESI-TOF, m/z) calculated for C_9H_8NO $[M+H]^+$, 146.0600 found: 146.0601

IR: (ATR, neat, cm^{-1}) 3028 (w), 1667 (m), 1634 (w), 1582 (m), 1495 (w), 1404 (s), 1327 (w), 1220 (w), 1045 (s), 842 (m), 760 (m)



4-bromooxepino[4,5-*c*]pyridine (17t):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow oil (72 mg, 64%).

R_f = 0.2 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

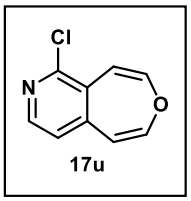
^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.27 (s, 1H), 7.69 (s, 1H), 5.89 (d, *J* = 7.6 Hz, 1H), 5.78 (d, *J* = 7.3 Hz, 1H), 5.49 (d, *J* = 7.6 Hz, 1H), 5.11 (d, *J* = 7.3 Hz, 1H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 151.9, 151.8, 149.4, 147.5, 142.5, 132.7, 120.6, 110.5, 110.1

HRMS: (ESI-TOF, m/z) calculated for C_9H_7BrNO $[M+H]^+$, 223.9706 found: 223.9696

IR: (ATR, neat, cm^{-1}): 3038 (w), 3001 (w), 1669 (m), 1629 (m), 1564 (s), 1531 (w), 1247 (s), 1211 (w), 1196 (w), 1055 (s), 936 (w), 760 (w)

m.p. = 81 °C (decomp.)



1-chlorooxepino[4,5-*c*]pyridine (17u):

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 10:1 to 2:1) as a yellow oil (60 mg, 67%).

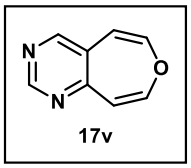
R_f = 0.5 (SiO_2, hexanes:ethyl acetate = 2:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.94 (d, *J* = 4.9 Hz, 1H), 6.50 (d, *J* = 4.9 Hz, 1H), 5.89 (m, 2H), 5.62 (d, *J* = 7.3 Hz, 1H), 5.14 (d, *J* = 7.3 Hz, 1H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 152.1, 149.7, 149.4, 149.0, 146.8, 129.4, 122.3, 111.6, 109.9

HRMS: (ESI-TOF, m/z) calculated for C_9H_7NOCl $[M+H]^+$, 180.0211 found: 180.0219

IR: (ATR, neat, cm^{-1}) 3053 (w), 1668 (m), 1631 (m), 1466 (s), 1392 (w), 1288 (w), 1185 (w), 1057 (m), 901 (w), 763 (w)



17v

Oxepino[4,5-*d*]pyrimidine (17v):

Extraction from 4:1 chloroform:isopropanol (3 x 15mL)

Following the general procedure (0.5 mmol scale), the title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 3:1 to 1:2) as a yellow oil (32 mg, 44%).

R_f = 0.24 (SiO_2, hexanes:ethyl acetate = 1:2, UV)

^{1}H NMR: (500 MHz, CD_3OD) δ 8.46 (s, 1H), 7.80 (s, 1H), 5.99 (d, *J* = 7.9 Hz, 1H), 5.74 (d, *J* = 7.7 Hz, 1H), 5.05 (d, *J* = 7.9 Hz, 1H), 5.01 (d, *J* = 7.7 Hz, 1H)

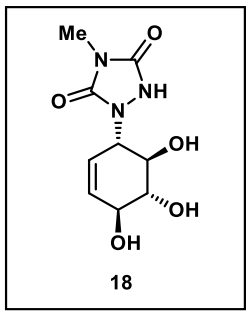
^{13}C NMR: (126 MHz, CD_3OD) δ 165.2, 158.2, 155.6, 154.5, 149.9, 132.0, 112.7, 107.6

HRMS: (ESI-TOF, m/z) calculated for $C_8H_7N_2O$ $[M+H]^+$, 147.0553 found: 147.0560

IR: (ATR, neat, cm^{-1}) 1672 (m), 1563 (m), 1456 (s), 1391 (w), 1309 (w), 1049 (m), 767 (w)

3-7. Derivatization

4-methyl-1-(4,5,6-trihydroxycyclohex-2-en-1-yl)-1,2,4-triazolidine-3,5-dione (18):



18

Compound **8a** (20 mg, 0.14 mmol) and water (1.0 mL, 0.1 M) were added to a 4 mL vial, followed by perchloric acid (90mg, 70 wt%, 6.5 equiv.). The reaction mixture was capped and stirred at 100 °C until complete consumption of starting material was observed by TLC. The reaction was concentrated under reduced pressure at room temperature, loaded onto celite and isolated by flash chromatography (MeCN, SiO_2, hexanes 100% to ethyl acetate 100% to 7:3 ethyl acetate: methanol). The fractions containing product were evaporated under reduced pressure, dissolved in acetonitrile, and filtered (ptfe) to remove any residual silica and evaporated once more. The desired product was obtained as a white solid (17 mg, 71%).

R_f= 0.2 (SiO_2, ethyl acetate:methanol = 7:3 , $KMnO_4$)

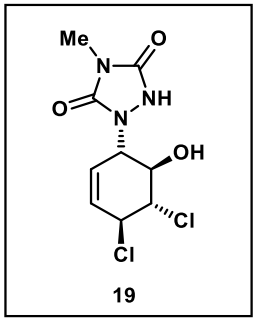
^{1}H NMR: (500 MHz, D_2O, MeOD ref.) δ 6.09 (dddd, *J* = 10.1, 4.3, 2.1, 1.0 Hz, 1H), 5.75 (ddt, *J* = 10.1, 3.7, 1.0 Hz, 1H), 4.99 (ddt, *J* = 5.6, 3.7, 1.6 Hz, 1H), 4.45 – 4.33 (m, 1H), 4.17 (dd, *J* = 9.0, 5.6 Hz, 1H), 4.05 (dd, *J* = 9.0, 4.3 Hz, 1H), 3.05 (s, 3H)

^{13}C NMR: (126 MHz, D_2O, MeOD ref.) δ 156.4, 156.3, 133.7, 125.4, 70.8, 69.1, 66.5, 55.7, 25.8

HRMS: (ESI-TOF, m/z) calculated for $C_9H_{14}N_3O_5$ $[M+H]^+$, 244.09280 found: 244.0926

IR: (ATR, neat, cm^{-1}) 3332 (s, br.), 2924 (w), 1680 (s), 1483 (m), 1399 (m), 1092 (w), 1036 (w), 763 (w), 618 (w)

m.p. = 223 °C (decomp.)



19

1-(4,5-dichloro-6-hydroxycyclohex-2-en-1-yl)-4-methyl-1,2,4-triazolidine-3,5-dione (19):

Compound **8a** (30 mg, 0.14 mmol) and concentrated HCl (14mL, 0.01 M) were added to a 20 mL vial, and stirred at room temperature for 3 hours. Afterwards, the reaction was portioned between water (14 mL) and ethyl acetate (14 mL). The organic layer was extracted with ethyl acetate (3 × 15 mL). The combined organic layers, were dried with $MgSO_4$, filtered, and concentrated under reduced pressure. The crude reaction mixture was loaded on celite and isolated by flash chromatography (CH_2Cl_2, SiO_2, hexanes:ethyl acetate 3:1 to 100% ethyl acetate) to yield the desired product as a white solid (23 mg, 57%).

R_f= 0.82 (SiO_2, ethyl acetate, UV)

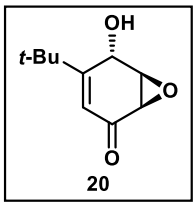
^{1}H NMR: (500 MHz, MeOD) δ 5.82 (d, *J* = 10.2 Hz, 1H), 5.63 (d, *J* = 10.2 Hz, 1H), 4.81 – 4.66 (m, 2H), 4.10 (dd, *J* = 10.9, 8.7 Hz, 1H), 4.00 (dd, *J* = 10.9, 8.1 Hz, 1H), 3.01 (s, 3H)

^{13}C NMR: (126 MHz, MeOD) δ 154.2*, 130.7, 129.7, 72.9, 69.4, 63.2, 58.5, 25.5 *(* 2 signals assigned by HMBC)*

HRMS: (ESI-TOF, m/z) calculated for $C_9H_{12}N_3O_3Cl_2$ $[M+H]^+$, 280.0250 found: 280.0257

IR (ATR, neat, cm^{-1}): 3331 (s, br.), 2970 (w), 1740 (m), 1677 (s), 1488 (m), 1366(m), 1224 (w), 1121 (w), 857(w), 764 (m), 537 (w).

m.p. = 197 – 199 °C



20

(1R,5S,6R)-4-(*tert*-butyl)-5-hydroxy-7-oxabicyclo[4.1.0]hept-3-en-2-one (20):

To a vial containing finely ground KOH (51 mg, 10.0 equiv., 90 wt%), and **8b** (30 mg, 5:1 r.r., 0.09 mmol) under nitrogen was added *i*-PrOH (1.1 mL, 0.1 M) and degassed with sonication and nitrogen for 15 min. The reaction was heated to 40 °C with vigorous stirring (1000 rpm) for 2 hours. Upon completion, the reaction was cooled in an ice bath and H_2O (1.1 mL) was added. AcOH is then carefully added dropwise until pH 5. The semicarbazide intermediate was then extracted out with ethyl acetate (3 × 5 mL). The organic layers were combined, dried with $NaHCO_3$ and concentrated under reduced pressure.

The crude residue was then re-dissolved in CH_2Cl_2 (1.1 mL, 0.1 M), and the resulting solution was sparged with nitrogen for 15 minutes. To this vial, nickel oxide (Ni_2O_3, 30% active basis, 150 mg, 3.0 equiv.) was added as a solid under a stream of nitrogen. The solution was agitated manually for 1 minute and filtered through a celite plug (pipette). To this solution, 5,10,15,20-Tetraphenyl-21*H*,23*H*-porphine(1.0 mg, 0.02 equiv.) was added and the solution was sparged with oxygen for 20 minutes and cooled to – 40 °C . Upon cooling, an overhead lamp was used to irradiate the reaction mixture for 4 hours at – 40 °C . Afterwards, the overhead lamp was turned off and *N*,*N*-diisopropylethylamine (52.0 mg, 2.0 equiv.) was added – 40 °C

and the solution was stirred for 4 hours at – 40 °C . The reaction was worked up by adding H_2O (3 mL) and extracting the organic layer CH_2Cl_2 (3 × 3 mL). The organic layer was dried with $MgSO_4$ and concentrated under reduced pressure. The resultant crude mixture was loaded onto celite and isolated by flash chromatography (CH_2Cl_2, SiO_2, hexanes: ethyl acetate = 10:1 to 3:1) to give the desired compound as a colorless oil (5.7 mg, 35%).

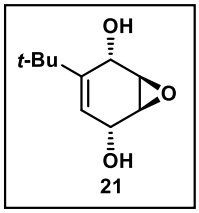
R_f= 0.4 (SiO_2, hexanes:ethyl acetate = 1:1, UV, $KMnO_4$)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 5.95 (d, *J* = 1.8 Hz, 1H), 4.86 (ddd, *J* = 9.3, 2.0, 0.9 Hz, 1H), 3.84 (dd, *J* = 3.8, 2.0 Hz, 1H), 3.45 (ddd, *J* = 3.8, 1.8, 0.9 Hz, 1H), 1.89 – 1.72 (m, 1H), 1.22 (s, 9H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 195.3, 166.0, 121.7, 63.7, 55.9, 52.1, 36.0, 29.5

IR: (ATR, neat, cm^{-1}) 3401 (w, br.), 2965(m), 1665 (s), 1370 (2), 1248 (w), 1037 (m), 854 (w), 732 (w)

HRMS: (ESI-TOF, m/z) calculated for $C_{10}H_{15}O_3$ $[M+Na]^+$, 183.1016 found: 183.1015



21

(1R,2S,5R,6S)-3-(*tert*-butyl)-7-oxabicyclo[4.1.0]hept-3-ene-2,5-diol (21):

To a vial containing finely ground KOH (51 mg, 10 equiv., 90 wt%), and **8b** (5:1 r.r., 0.09 mmol) under nitrogen was added *i*-PrOH (1.1 mL, 0.1 M) and the solution degassed with sonication and nitrogen for 15 min. The reaction was heated to 40 °C with vigorous stirring (1000 rpm) for 2 hours. Upon completion, the reaction was cooled in an ice bath and H_2O (1.1 mL) was added. AcOH was then carefully added dropwise until pH 5. The aqueous phase was then extracted with ethyl acetate (3 × 5 mL). The combined organic layers were dried with $MgSO_4$ and concentrated under reduced pressure.

The crude residue was then re-dissolved in CH_2Cl_2 (1.1 mL, 0.1 M), and the resulting solution was sparged with nitrogen for 15 minutes. To this vial, nickel oxide (Ni_2O_3, 30% active basis, 150 mg, 3.0 equiv.) was added as a solid under a stream of nitrogen. The solution was agitated manually for 1 minute, filtered through a celite plug. To this solution, 5,10,15,20-tetraphenyl-21*H*,23*H*-porphine (1.0 mg, 0.02 equiv.) was added and the solution was sparged with oxygen for 20 minutes and cooled to – 40 °C . Upon cooling, an overhead lamp was used to irradiate the reaction mixture for 4 hours at – 40 °C. Afterwards, a solution of thiourea (42 mg, 6.0 equiv.) in methanol (1.0 mL) was added and the reaction was warmed to room temperature. The reaction was diluted with H_2O (3 mL) and the aqueous phase was extracted with CH_2Cl_2 (3 × 3 mL). The combined organic layers were dried with $MgSO_4$ and concentrated under reduced pressure. The resultant crude mixture was loaded onto celite and isolated by flash chromatography (CH_2Cl_2, SiO_2, hexanes: ethyl acetate = 3:1 to 1:3) to give the desired compound as a colorless oil (6.3 mg, 38%).

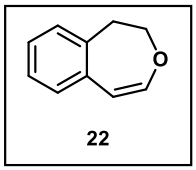
R_f= 0.2 (SiO_2, hexanes:ethyl acetate = 1:2, UV, $KMnO_4$)

^{1}H NMR: (500 MHz, CD_3CN) δ 5.61 (dd, *J* = 5.8, 1.6 Hz, 1H), 4.52 (d, *J* = 5.8 Hz, 1H), 4.36 – 4.28 (m, 1H), 3.27 (ddd, *J* = 3.8, 2.6, 1.4 Hz, 1H), 3.21 – 3.13 (m, 1H), 3.09 (s, 1H), 2.89 (d, *J* = 8.6 Hz, 1H), 1.08 (s, 9H)

^{13}C NMR: (126 MHz, CD_3CN) δ 147.8, 120.8, 64.0, 63.5, 54.0, 51.9, 35.7, 29.8

IR: (ATR, neat, cm^{-1}) 3324 (m, br.), 2961 (m), 2877 (w), 1665 (w), 1462 (2), 1366 (w), 1251 (w), 1022 (s), 1003 (s), 834 (w), 804 (w)

HRMS: (ESI-TOF, m/z) calculated for $C_{10}H_{16}O_3Na$ $[M+Na]^+$, 207.0997 found: 207.1006



1,2-dihydrobenzo[*d*]oxepine (22):

Benzoxepine **17a** (67 mg, 0.46 mmol) and methanol (2.0 mL, 0.2 M) were added to a 4 mL vial. The solution was sparged with nitrogen under sonication for 15 minutes, followed by the addition of Rh/Al_2O_3 (29 mg, 3 mol%). and sparged for an additional 10 minutes. The reaction mixture was sparged with hydrogen for 3 minutes and left to stir (1000 rpm) under a hydrogen atmosphere (1 atm) until full completion of the starting material was observed (ca. 1 hour). The reaction was filtered through celite and concentrating under reduced pressure. The resultant crude mixture was loaded onto celite and isolated by flash chromatography (CH_2Cl_2, SiO_2, hexanes 100%) to yield the desired compound as a colorless oil (60 mg, 88%).

R_f= 0.6 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

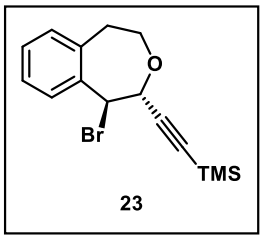
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.18 – 7.10 (m, 2H), 7.08 – 7.04 (m, 2H), 6.43 (dd, *J* = 8.1, 0.7 Hz, 1H), 5.40 (d, *J* = 8.1 Hz, 1H), 4.40 – 4.20 (m, 2H), 3.20 – 3.04 (m, 2H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 145.3, 139.2, 135.3, 129.2, 128.6, 126.5, 125.4, 105.2, 70.2, 38.8

HRMS: (EI-TOF, m/z) calcd. for $C_{10}H_{10}O$ $[M]^+$, 146.07262; found: 146.07319

IR: (ATR, neat, cm^{-1}) = 3045 (w), 2971 (w), 1632 (s), 1492 (m), 1463 (w), 1414 (w), 1318 (m), 1307 (m), 1208 (w), 1124 (s), 1081 (s), 957 (m), 832 (m)

The analytical data were in accordance with previously reported values.[10]



((1-bromo-1,2,4,5-tetrahydrobenzo[*d*]oxepin-2-yl)ethynyl)trimethylsilane (23):

This procedure was modified from the literature protocol of Watson:[12]

Compound **22** (38 mg, 0.26 mmol) and *N*-bromosuccinimide (60 mg, 1.3 equiv.) were added to a 4 mL vial and of CH_2Cl_2 (3.0 mL, 0.1 M) and cooled to –20 °C. Acetic anhydride (1.6 mg, 1.6 uL, 6 mol%). and acetic acid (160 mg, 10 equiv.) were added sequentially, and the reaction was stirred at –20 °C overnight. The reaction was quenched with H_2O (3 mL) and the aqueous phase was extracted with CH_2Cl_2 (3 × 3 mL). The combined organics were dried with $MgSO_4$ and concentrated under reduced pressure.

In a nitrogen filled glovebox, $ZnBr_2$ (5.5 mg, 10 mol%) was added to the crude reaction mixture and the reaction was sealed and removed from the glovebox. CH_2Cl_2 (1.4 mL) was added and the reaction mixture was cooled to 0 °C. Hunig's base (48 mg, 1.5 equiv.) and ethynyltrimethylsilane (32 mg, 1.3 equiv.) were added sequentially. $BF_3{\cdot}OEt_2$ (70 mg, 2.0 equiv.) was added dropwise and the reaction was stirred overnight at 0 °C. Upon completion by TLC, H_2O (5 mL) was added and aqueous phase was extracted with CH_2Cl_2

(3 × 5mL). The combined organic extracts were dried with $MgSO_4$, filtered, concentrated under reduced pressure, loaded onto celite and purified by flash chromatography (CH_2Cl_2, SiO_2, hexanes:ethyl acetate 1:0 to 5:1) to yield the product as a colorless gel (49 mg, 62% over two steps).

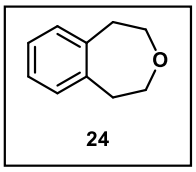
R_f= 0.2 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.24 – 7.13 (m, 3H), 7.10 (d, *J* = 7.4 Hz, 1H), 5.15 (d, *J* = 3.9 Hz, 1H), 4.90 (d, *J* = 4.0 Hz, 1H), 4.12 (t, *J* = 12.1 Hz, 1H), 4.03 (ddd, *J* = 12.1, 4.2, 2.8 Hz, 1H), 3.72 (ddd, *J* = 15.3, 11.5, 2.8 Hz, 1H), 2.68 (dd, *J* = 15.3, 4.1 Hz, 1H), -0.04 (s, 9H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 141.2, 137.6, 130.61, 130.59, 129.0, 126.3, 99.5, 97.2, 71.3, 64.7, 59.0, 38.2, -0.4

HRMS: (ESI-TOF, m/z) calculated for $C_{15}H_{20}OBrSi$ $[M+H]^+$, 323.0461 found: 323.0472

IR: (ATR, neat, cm^{-1}): 2958 (w), 2170 (w), 1491 (m), 1308 (w), 1249 (s), 1166 (s), 1116 (w), 1022 (w), 753 (m), 721 (m), 692 (m)



1,2,4,5-tetrahydrobenzo[*d*]oxepine (24):

Benzoxepin **17a (**20 mg, 0.14 mmol) was charged into a 4 mL vial and methanol (1.4 mL, 0.1 M) was added. The solution was sparged with nitrogen under sonication for 15 minutes, followed by the addition of Rh/Al_2O_3 (8 mg, 3 mol%). and sparged for an additional 10 minutes. The reaction mixture was sparged with hydrogen (1 atm) for 3 minutes and left to stir (1000 rpm) overnight. The reaction was filtered through celite and concentrating under reduced pressure to yield the desired compound as a colorless oil (19.3 mg, 94%).

R_f= 0.3 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

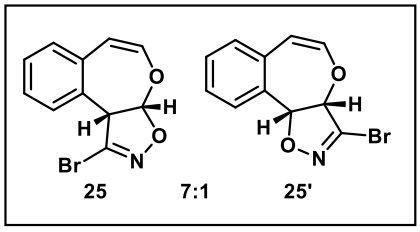
^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.17 – 7.03 (m, 4H), 3.84 – 3.76 (m, 4H), 3.00 (dd, *J* = 5.8, 3.7 Hz, 4H)

^{13}C NMR: (126 MHz, $CDCl_3$) δ 141.7, 129.5, 126.5, 70.4, 40.1

HRMS: (EI, m/z) calcd. For $C_{10}H_{12}O$ $[M]^+$, 148.08882 found:148.08840

IR: (ATR, neat, cm^{-1}) = 3019 (m), 2926 (m), 1493(w), 1454 (w), 1430 (w), 1302 (m), 1251 (m), 752(s)

The analytical data were in accordance with previously reported values.[11]



(3a*R,10b*R**)-1-bromo-3a,10b-dihydrobenzo[4,5]oxepino[3,2-*d*]isoxazole) (25):**

This procedure was modified from the literature protocol of Baran.[9]

A 4 mL vial was charged with benzoxepine **17a** (40 mg, 0.28 mmol, 1.0 equiv.), hydroxycarbonimidic dibromide (84.4 mg, 1.5 equiv., 0.42 mmol), potassium carbonate (115 mg, 3.0 equiv., 0.8mmol), and acetonitrile (2.8 mL). The reaction mixture was left to stir at room temperature overnight. Upon completion, the reaction was partitioned with H_2O (3 mL) and ethyl acetate (3 mL). The aqueous phase was extracted with ethyl acetate (3 × 3 mL), dried

with $MgSO_4$, and concentrated under reduced pressure. The resultant crude mixture was loaded onto celite and isolated by flash chromatography (CH_2Cl_2, SiO_2, hexanes: ethyl acetate = 1:0 to 5:1) to give the desired compound as a colorless oil (61 mg, 7:1 r.r., inseparable mixture, 83%).

R_f= 0.2 (SiO_2, hexanes:ethyl acetate = 9:1, UV)

Major Constitutional Isomer ^{1}H NMR: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.45 – 7.42 (m, 1H), 7.39 – 7.31 (m, 2H), 7.26 – 7.22 (m, 1H), 6.70 (d, *J* = 6.1 Hz, 1H), 6.46 (d, *J* = 7.4 Hz, 1H), 6.12 (d, *J* = 6.1 Hz, 1H), 4.59 (d, *J* = 7.4 Hz, 1H)

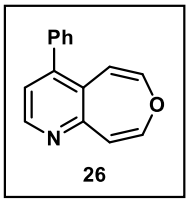
Major Constitutional Isomer ^{13}C NMR: (126 MHz, $CDCl_3$) δ 145.6, 141.0, 135.3, 132.0, 130.8, 129.5, 129.3, 128.0, 117.7, 115.2, 61.9

Visible Minor Constitutional Isomer ^{1}H NMR: (500 MHz, $CDCl_3$) δ 7.21 – 7.19 (m, 1H), 6.54 (d, *J* = 6.1 Hz, 1H), 6.14 (d, *J* = 6.1 Hz, 1H), 5.65 (d, *J* = 8.1 Hz, 1H), 5.29 (d, *J* = 8.1 Hz, 1H) *(*two protons are obscured by major constitutional isomer)*

Minor Constitutional Isomer ^{13}C NMR: (126 MHz, $CDCl_3$) δ 144.9, 138.5, 135.3, 135.3, 131.8, 130.1, 130.0, 127.6, 120.7, 96.5, 87.3

HRMS: (ESI-TOF, m/z) calculated for $C_{11}H_9NO_2Br$ $[M+H]^+$, 265.9811 found: 265.9826

IR: (ATR, neat, cm^{-1}): 2970 (w), 1738 (m), 1639 (w), 1451 (w), 1366 (w), 1126 (s), 1093 (s), 754 (s), 553 (w)



26

4-phenyloxepino[4,5-b]pyridine (26):

Compound **17o** (40 mg, 0.18 mmol), $Pd(PPh_3)_4$ (21 mg, 10 mol%), phenylboronic acid (65 mg, 3.0 equiv.), and cesium carbonate (116 mg, 2.0 equiv.) were added to a 4mL vial inside a glovebox. The vial was capped and removed from the glovebox, and MeCN (1.8 mL, 0.1 M) was added and the reaction was heated to 80 °C and stirred (1000 rpm) overnight. After 24h, the reaction was portioned between water (5 mL) and ethyl acetate (5 mL). The organic layer was extracted with ethyl acetate (3 × 10 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The material was loaded onto celite and isolated by flash chromatography (CH_2Cl_2, SiO_2, hexanes:ethyl acetate 1:0 to 1:1) to yield the product as a yellow oil (25.3 mg, 64%).

R_f= 0.6 (SiO_2, hexanes:ethyl acetate = 1:1, UV)

^{1}H NMR: (500 MHz, $CDCl_3$) δ 8.20 (dd, *J* = 5.0, 1.0 Hz, 1H), 7.46 – 7.35 (m, 3H), 7.31 – 7.27 (m, 2H), 6.83 (dd, *J* = 5.0, 1.0 Hz, 1H), 6.07 (dd, *J* = 7.3, 1.0 Hz, 1H), 5.82 (dd, *J* = 7.3, 1.0 Hz, 1H), 5.62 (dd, *J* = 7.3, 1.0 Hz, 1H), 5.17 (dd, *J* = 7.3, 1.0 Hz, 1H)

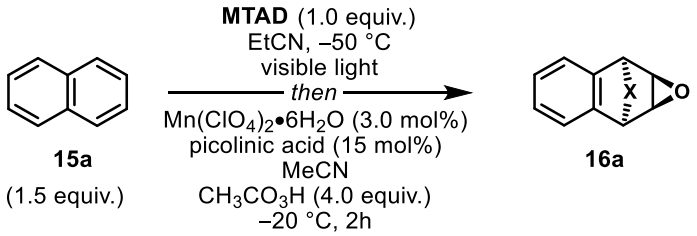
^{13}C NMR: (126 MHz, $CDCl_3$) δ 156.1, 150.3, 147.8, 147.4, 147.2, 138.1, 129.8, 129.1, 128.5, 128.3, 122.7, 116.2, 110.5

HRMS: (ESI-TOF, m/z) calculated for $C_{15}H_{12}NO$ $[M+H]^+$, 222.0913 found: 222.0914

IR: (ATR, neat, cm^{-1}) 3055 (w), 1737 (s), 1669 (m), 1577 (w), 1537 (w), 1494 (m), 1195 (w), 1048 (w), 1026 (w), 701 (w), 586 (w)

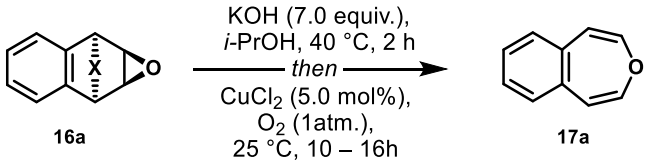
3-8. Large-scale procedures

Gram-scale synthesis of 16a:



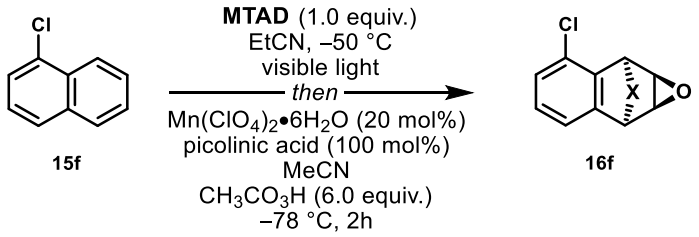
A solution of *N*-methyl-1,2,4-triazoline-3,5-dione (**7**, MTAD, 800 mg, 7.1 mmol, 1.0 equiv.) and naphthalene (**15a**, 1.5 g, 10.6 mmol, 1.5 equiv.) in propionitrile (71 mL, 0.1M) was irradiated with LED lights at −78 °C under a nitrogen atmosphere (see Section 2-3.). Upon decolorization, the reaction vessel was transferred to a −20 °C bath under moderate stirring (300 rpm). A suspension of $Mn(ClO_4)_2 \cdot (H_2O)_6$ (77 mg, 0.21 mmol, 0.03 equiv.) and picolinic acid (131 mg, 1.1 mmol, 0.15 equiv.) in acetonitrile (60 mL, sonicated for 5 minutes), was added over the course of 10 seconds, being careful to ensure proper mixing to prevent cycloreversion. To this solution, peracetic acid (32 wt% in dilute acetic acid, 6.0 mL, 4.0 equiv.) was added in 0.25 mL portions. Overall, the addition of peracetic acid took 5 minutes. The reaction was then left to stir for 2 hours at −20 °C. Afterwards, a 10% sodium thiosulfate solution (80 mL) was added and the phases were separated. The aqueous phase was extracted with ethyl acetate (3 × 100mL), then the organic extracts were combined, dried over $MgSO_4$, and concentrated under reduced pressure. The title compound was immediately isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) to yield a brown solid that was analytically pure by ^{1}H-NMR. The solid was triturated with methanol (30 mL) to yield the title compound **16a** as an off-white solid (1.51g, 1.7:1 d.r., 83%).

Gram-scale synthesis of 17a:



To a vial containing finely ground KOH (1.8 g, 7.0 equiv., 90 wt%), and **16a** (1.08g, 4.20 mmol, 1.0 equiv.) under nitrogen was added *i*-PrOH (42 mL, 0.1 M) and degassed with sonication and nitrogen for 20 min. The reaction was heated to 40 °C with vigorous stirring (700 rpm) and progress was monitored by TLC in 30 min intervals. After 2 hours, the reaction was cooled in an ice bath and H_2O (42 mL) were added. AcOH was then carefully added dropwise until pH = 5. Then $CuCl_2 \cdot (H_2O)_2$ (39 mg, 0.2 mmol, 0.05 mol%) was added as a solid, followed by sparging with oxygen, and the reaction was stirred overnight under an atmosphere of oxygen. Upon completion, diethyl ether (40 mL) and saturated brine (40 mL) were added to the reaction mixture and the organic layer was extracted with ether (3 × 30 mL), until the organic phase was no longer yellow. The combined organics were washed with brine (30 mL), dried over $MgSO_4$, filtered, and concentrated under vacuum. The title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 1:0 to 10:1) to afford **17a** as a bright yellow solid (520 mg, 86%).

Gram-scale synthesis of 16f:



A solution of *N*-methyl-1,2,4-triazoline-3,5-dione (**7**, MTAD, 600 mg, 5.31 mmol, 1.0 equiv.) in propionitrile (71 mL, 0.1 M) was placed in a bath pre-cooled to −78 °C using a chiller. After cooling for 10 minutes, 1-chloronaphthalene (**15f**, 1.29g, 8.0 mmol, 1.5 equiv.) was added slowly, after which the solution was irradiated with LED lights at −78 °C until the solution had become colorless (see Section 2-3.). Upon decolorization, the reaction was then transferred to a bath at −78 °C under moderate stirring (400 rpm). A suspension of $Mn(ClO_4)_2 \cdot (H_2O)_6$ (375 mg, 1.06 mmol, 0.20 equiv.) and picolinic acid (653 mg, 5.31 mmol, 1.0 equiv.) in acetonitrile (31 mL, sonicated for 30 seconds – 1 minute), was added over the course of 10 seconds, being careful to ensure proper mixing such that the dearomatized product does not cyclorevert. To this solution, peracetic acid (32 wt% in dilute acetic acid, 6.9 mL, 6.0 equiv.), was added over the course of 1 hour in 6 evenly spaced portions and left to stir for another hour at −78 °C. Afterward, the reaction was warmed to room temperature and a 10% sodium thiosulfate solution (60 mL) and the organic phase was separated. The aqueous phase was extracted with ethyl acetate (3 × 40 mL). The organic extracts were combined, passed through a silica plug, and flushed with CH_2Cl_2 (40 mL). The organic phase was then dried over $MgSO_4$ and concentrated under reduced pressure. The title compound was isolated by flash chromatography (SiO_2, hexanes:ethyl acetate = 5:1 to 1:1) to afford **16f** as an off-white solid (1.15 g, >20:1 d.r., 75%).

4. Crystallographic studies

X-ray diffraction experiments were carried out on single crystals mounted on Cryo-loops using Paratone-N or Krytox oils. The data was collected on Bruker D8 Venture / Photon II or on a Bruker APEX II diffractometers in George L. Clark X-ray Facility at UIUC. Multi-scan absorption correction was applied. The space group was determined in XPREP (Bruker AXS). The solutions were obtained using Intrinsic Phasing method, as implemented in SHELXT,[13] and refined using full-matrix least squares against F^2, as implemented in SHELXL,[14] using OLEX2[15] as the graphical user interface.

Crystallographic Data for compound 8a

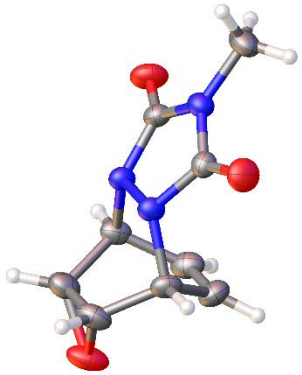


Table S5. Crystal data and structure refinement.

CCDC	1988277
Empirical formula	$C_9H_9N_3O_3$
Formula weight	207.19
Temperature/K	296.15
Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	7.5594(7)
b/Å	15.3365(14)
c/Å	7.7117(7)
α/°	90
β/°	98.206(2)
γ/°	90
Volume/Å^3	884.90(14)
Z	4
ρ_{calc}g/cm^3	1.555
μ/mm^{-1}	0.120
F(000)	432.0
Crystal size/mm^3	0.532 × 0.453 × 0.302
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	7.546 to 61.076
Index ranges	$-10 \leq h \leq 9$, $-21 \leq k \leq 21$, $-11 \leq l \leq 10$
Reflections collected	12250
Independent reflections	2701 [R_{int} = 0.0190, R_{sigma} = 0.0151]
Data/restraints/parameters	2701/0/137
Goodness-of-fit on F^2	1.036
Final R indexes [I>=2σ (I)]	R_1 = 0.0418, wR_2 = 0.1241
Final R indexes [all data]	R_1 = 0.0469, wR_2 = 0.1304
Largest diff. peak/hole / e Å^{-3}	0.32/-0.30

Crystallographic Data for compound 16f

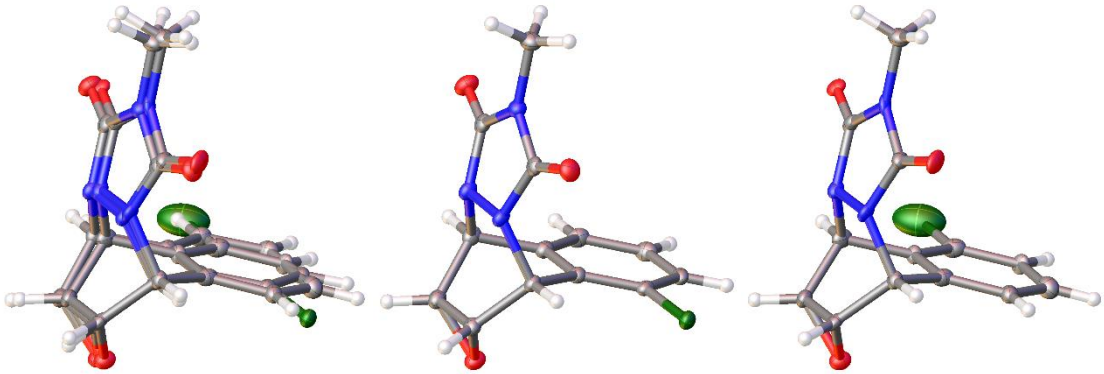


Table S6. Crystal data and structure refinement

CCDC	1988278
Empirical formula	$C_{13}H_{10}ClN_3O_3$
Formula weight	291.69
Temperature/K	100.01
Crystal system	orthorhombic
Space group	Pbca
a/Å	6.8955(2)
b/Å	15.5594(4)
c/Å	21.9079(6)
α/°	90
β/°	90
γ/°	90
Volume/Å^3	2350.50(11)
Z	8
ρ_{calc}g/cm^3	1.649
μ/mm^{-1}	0.337
F(000)	1200.0
Crystal size/mm^3	0.281 × 0.126 × 0.089
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	5.236 to 56.64
Index ranges	$-9 \leq h \leq 9$, $-20 \leq k \leq 20$, $-29 \leq l \leq 29$
Reflections collected	27140
Independent reflections	2925 [R_{int} = 0.0470, R_{sigma} = 0.0233]
Data/restraints/parameters	2925/756/305
Goodness-of-fit on F^2	1.099
Final R indexes [I>=2σ (I)]	R_1 = 0.0335, wR_2 = 0.0788
Final R indexes [all data]	R_1 = 0.0418, wR_2 = 0.0826
Largest diff. peak/hole / e Å^{-3}	0.32/-0.25

Crystallographic Data for compound 17a

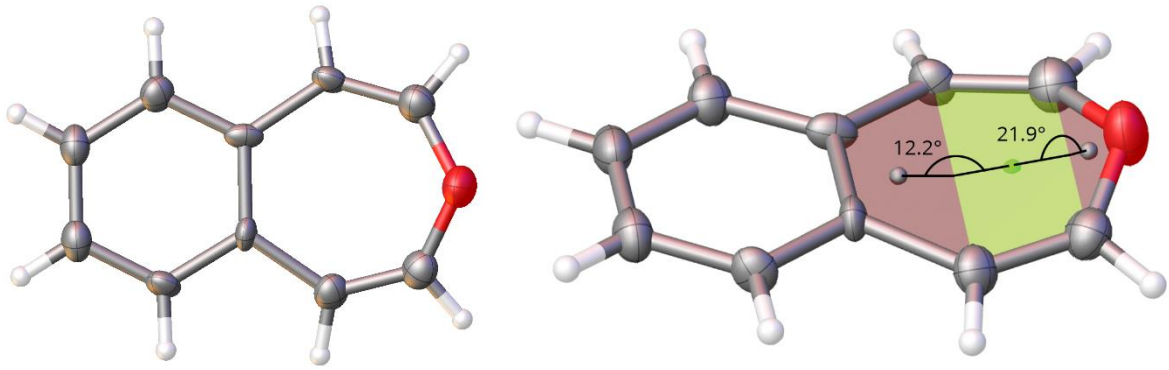


Table S7. Crystal data and structure refinement.

CCDC	1988276
Empirical formula	$C_{10}H_8O$
Formula weight	144.16
Temperature/K	100.0
Crystal system	monoclinic
Space group	$P2_1/c$
a/Å	7.8858(2)
b/Å	6.0451(2)
c/Å	8.4347(3)
α/°	90
β/°	114.3054(10)
γ/°	90
Volume/Å^3	366.45(2)
Z	2
ρ_{calc}g/cm^3	1.307
μ/mm^{-1}	0.083
F(000)	152.0
Crystal size/mm^3	0.541 × 0.227 × 0.142
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	8.578 to 56.54
Index ranges	$-10 \leq h \leq 10$, $-8 \leq k \leq 8$, $-11 \leq l \leq 11$
Reflections collected	8457
Independent reflections	901 [R_{int} = 0.0175, R_{sigma} = 0.0113]
Data/restraints/parameters	901/86/88
Goodness-of-fit on F^2	1.166
Final R indexes [I>=2σ (I)]	R_1 = 0.0421, wR_2 = 0.1120
Final R indexes [all data]	R_1 = 0.0430, wR_2 = 0.1126
Largest diff. peak/hole / e Å^{-3}	0.19/-0.16

Crystallographic data for compound 16q

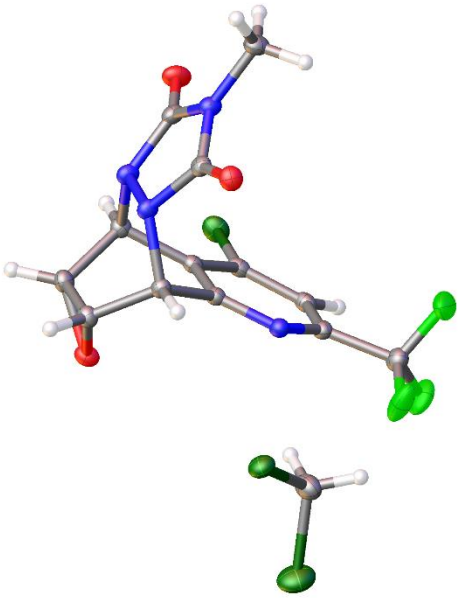


Table S8. Crystal data and structure refinement.

CCDC	1988279
Empirical formula	$C_{13.5}H_9Cl_2F_3N_4O_3$
Formula weight	403.15
Temperature/K	99.99
Crystal system	monoclinic
Space group	C2/c
a/Å	24.6871(11)
b/Å	6.8296(3)
c/Å	21.0493(9)
α/°	90
β/°	119.6990(10)
γ/°	90
Volume/Å^3	3082.8(2)
Z	8
ρ_{calc}g/cm^3	1.737
μ/mm^{-1}	0.479
F(000)	1624.0
Crystal size/mm^3	0.709 × 0.614 × 0.567
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	6.26 to 56.674
Index ranges	$-32 \leq h \leq 32$, $-9 \leq k \leq 9$, $-28 \leq l \leq 28$
Reflections collected	100114
Independent reflections	3825 [R_{int} = 0.0364, R_{sigma} = 0.0129]
Data/restraints/parameters	3825/13/246

Goodness-of-fit on F^2	1.038
Final R indexes [I>=2σ (I)]	R_1 = 0.0283, wR_2 = 0.0730
Final R indexes [all data]	R_1 = 0.0294, wR_2 = 0.0740
Largest diff. peak/hole / e $Å^{-3}$	0.41/-0.35

5. References:

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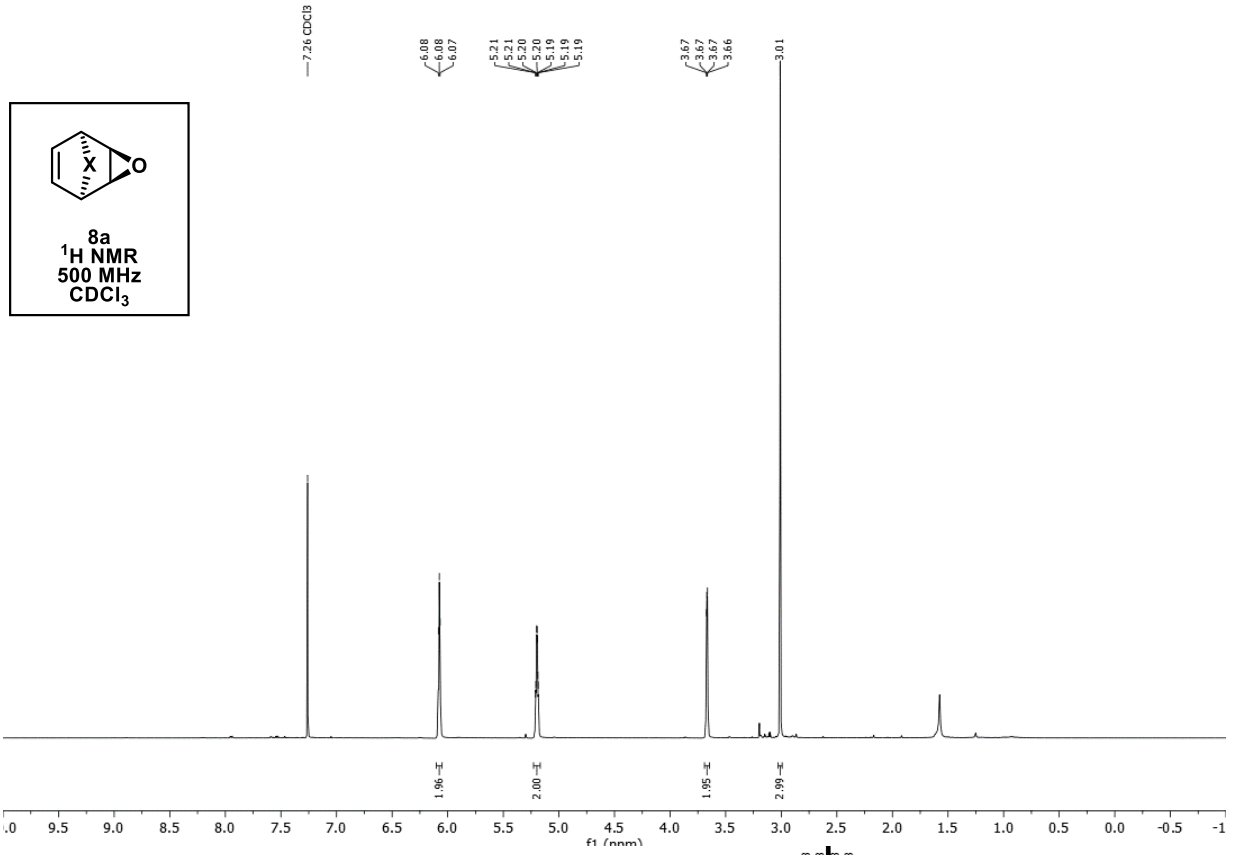
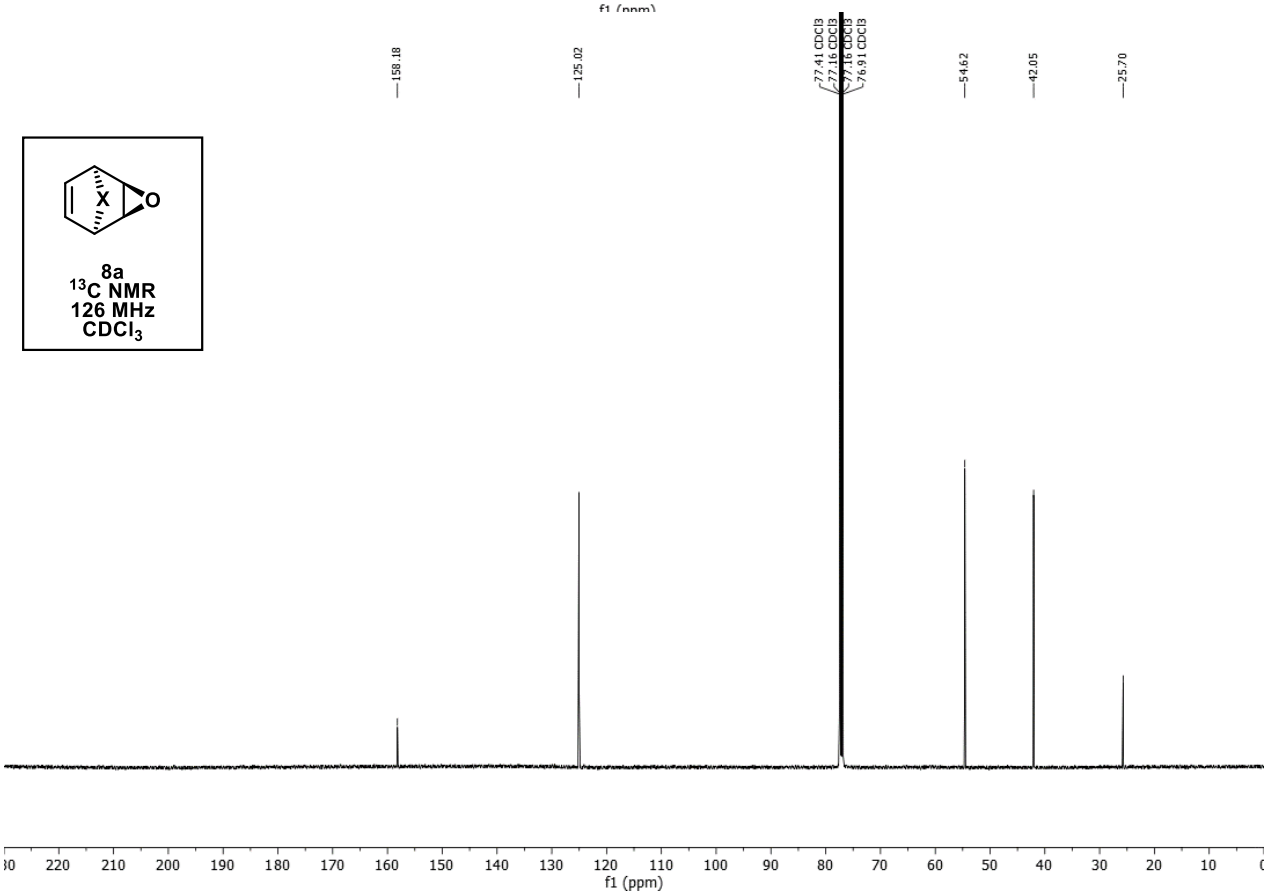
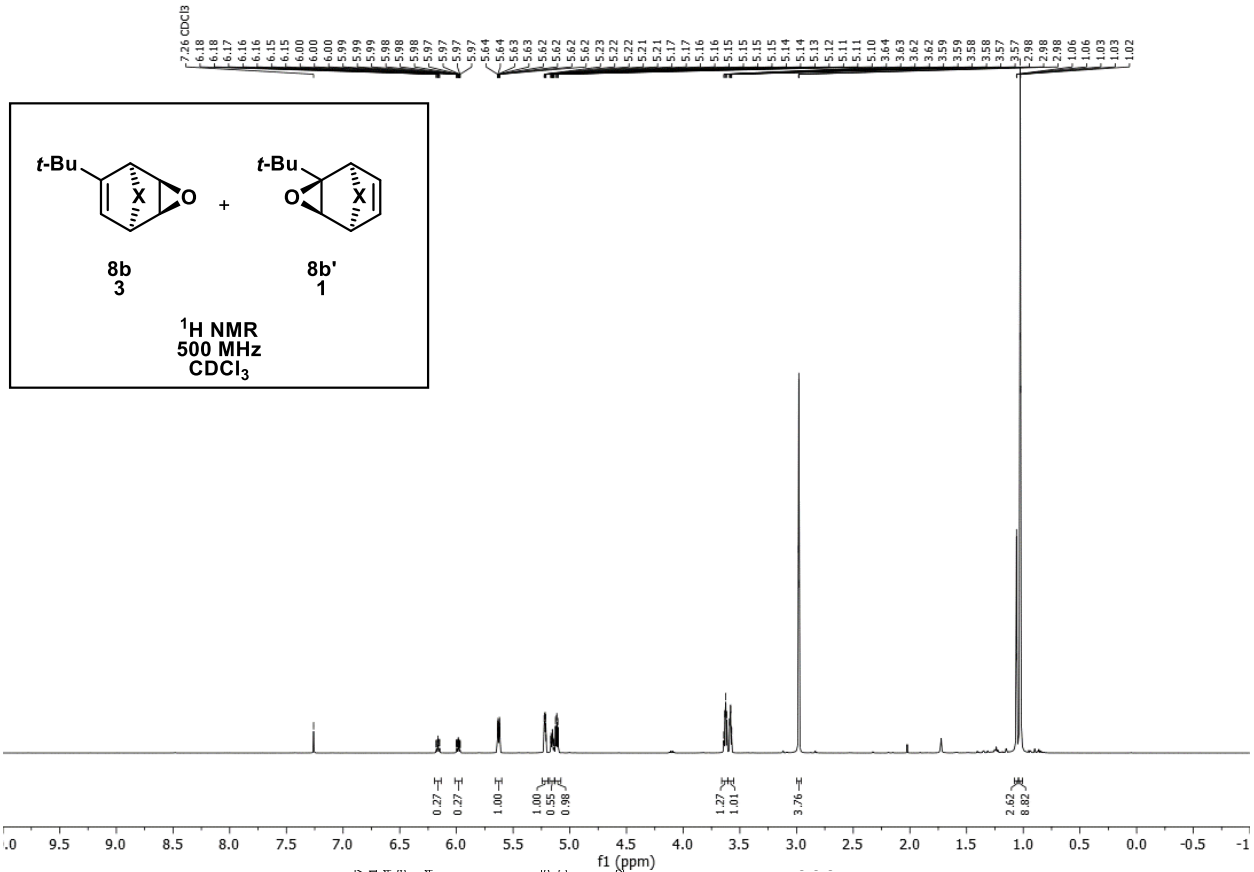


8a
^{1}H NMR
500 MHz
$CDCl_3$



8a
^{13}C NMR
126 MHz
$CDCl_3$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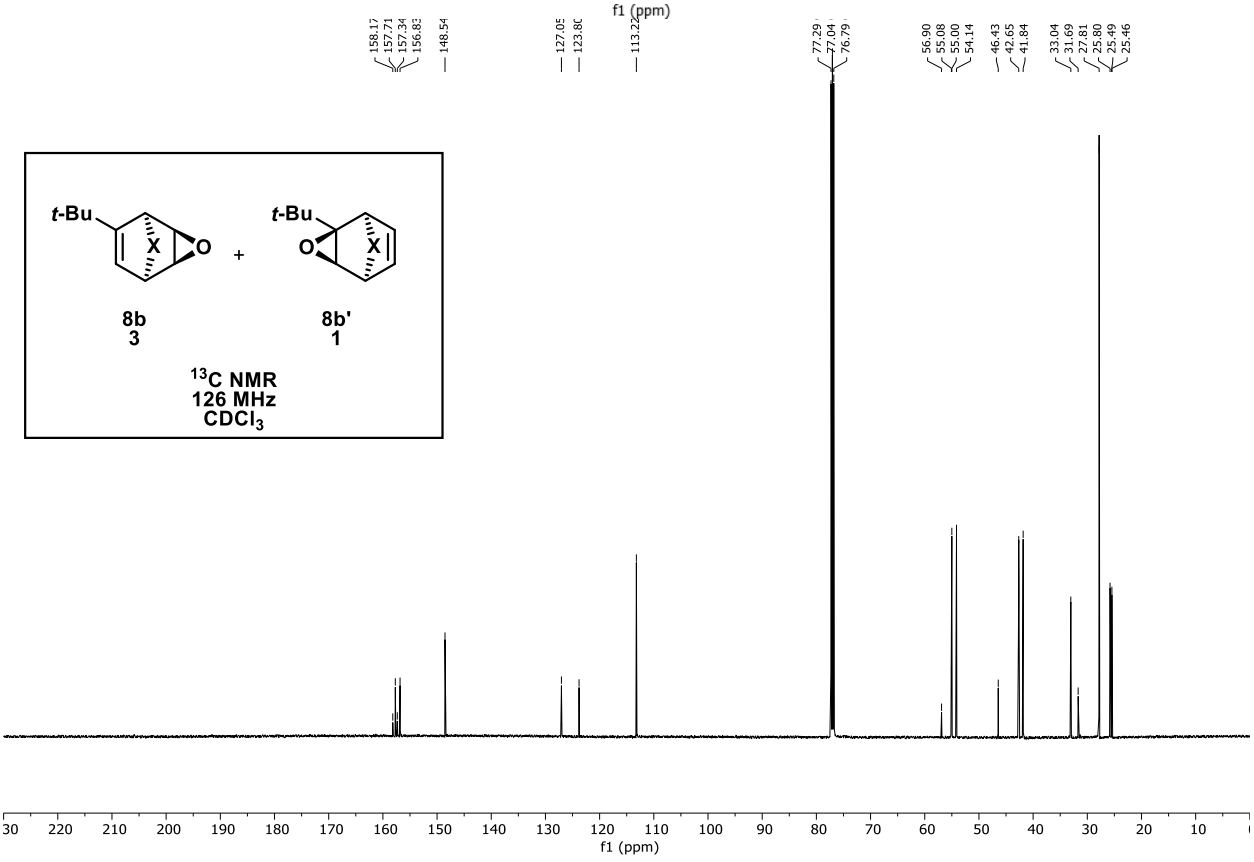
O
+
t-Bu
O
X
8b
3
8b'
1
1H NMR
500 MHz
CDCl3
f1 (ppm)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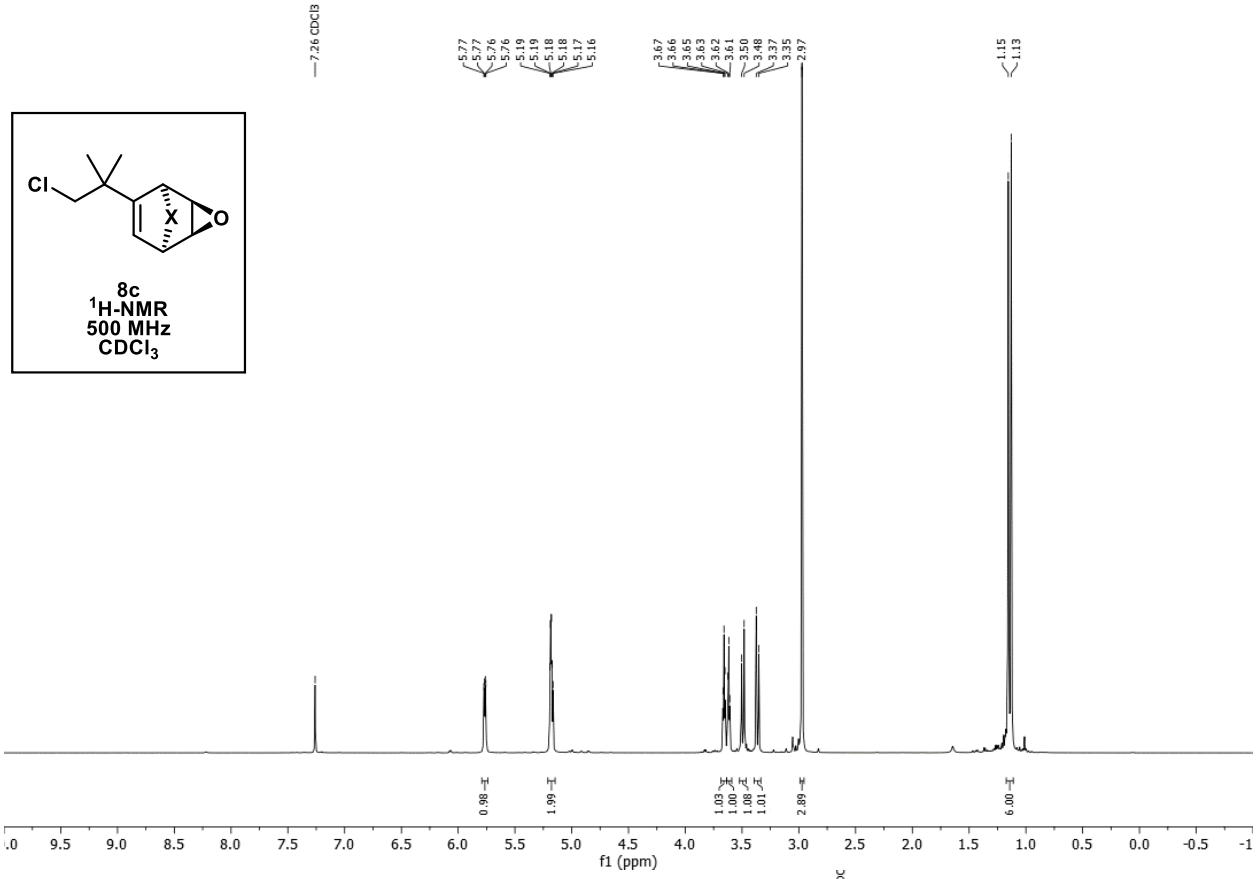
X
O
+
t-Bu
O
X
8b
3
8b'
1
13C NMR
126 MHz
CDCl3
f1 (ppm)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O
8c
1H-NMR
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CDCl3
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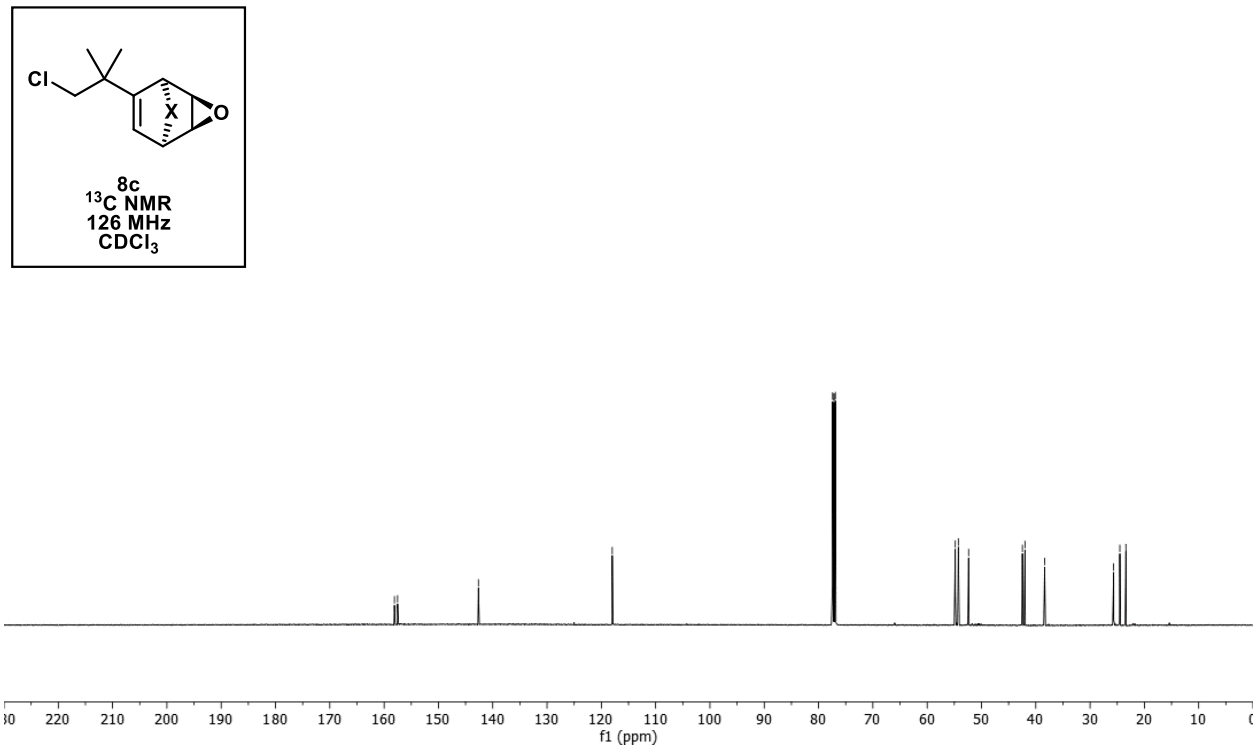
5.77
5.77
5.76
5.76
5.19
5.19
5.18
5.18
5.17
5.16
3.67
3.66
3.65
3.63
3.62
3.61
3.50
3.48
3.37
3.35
2.97
1.15
1.13
0.98
1.99
1.03
1.00
1.08
1.01
2.89
6.00
f1 (ppm)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X
O
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117.99
77.41
77.16
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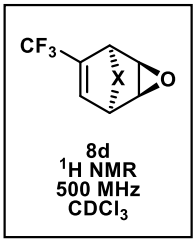
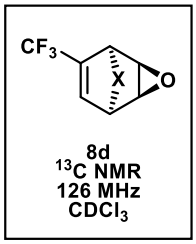
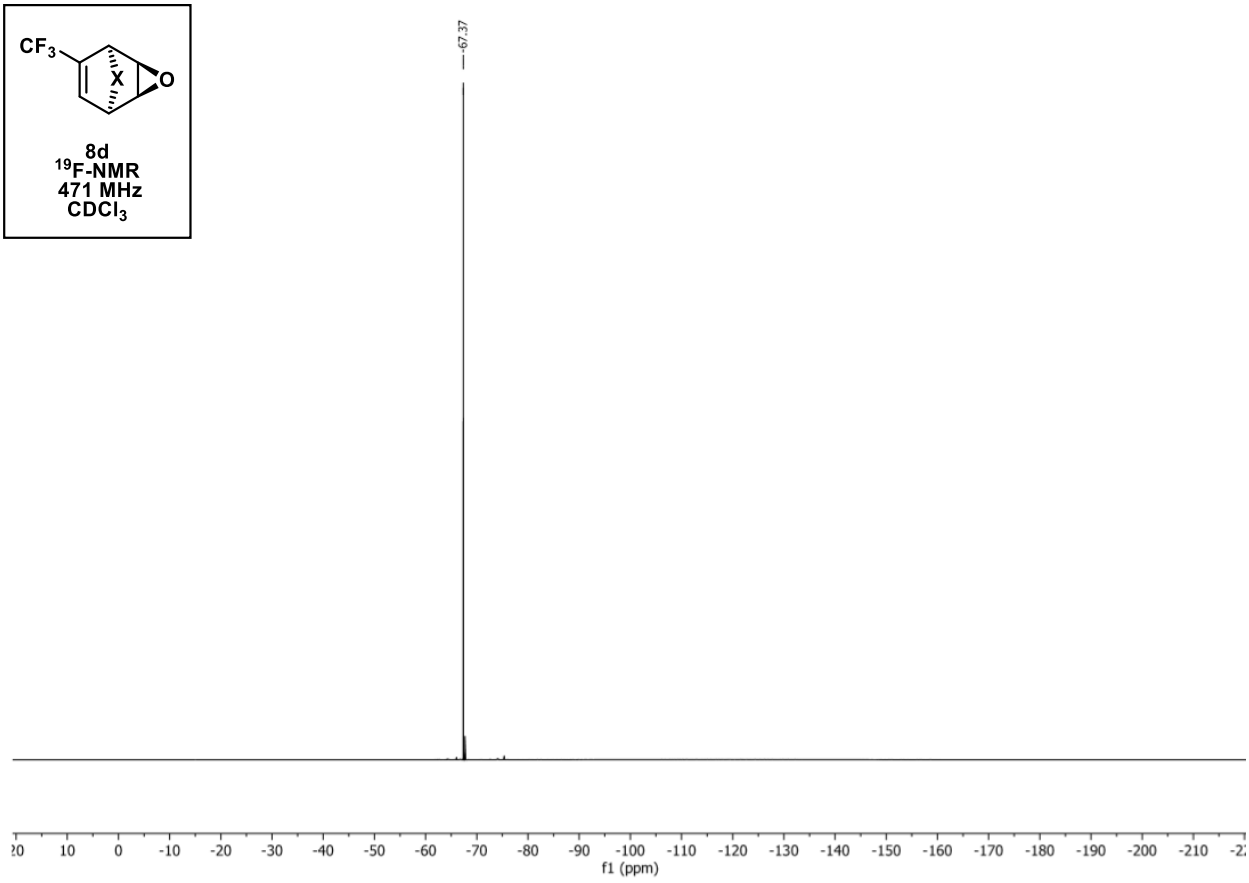
76.91
54.82
54.26
52.37
42.47
41.99
38.37
25.66
24.52
23.40
f1 (ppm)



8d
^{1}H NMR
500 MHz
$CDCl_3$



8d
^{13}C NMR
126 MHz
$CDCl_3$


CF3
X
O
8d
19F-NMR
471 MHz
CDCl3
-67.37
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
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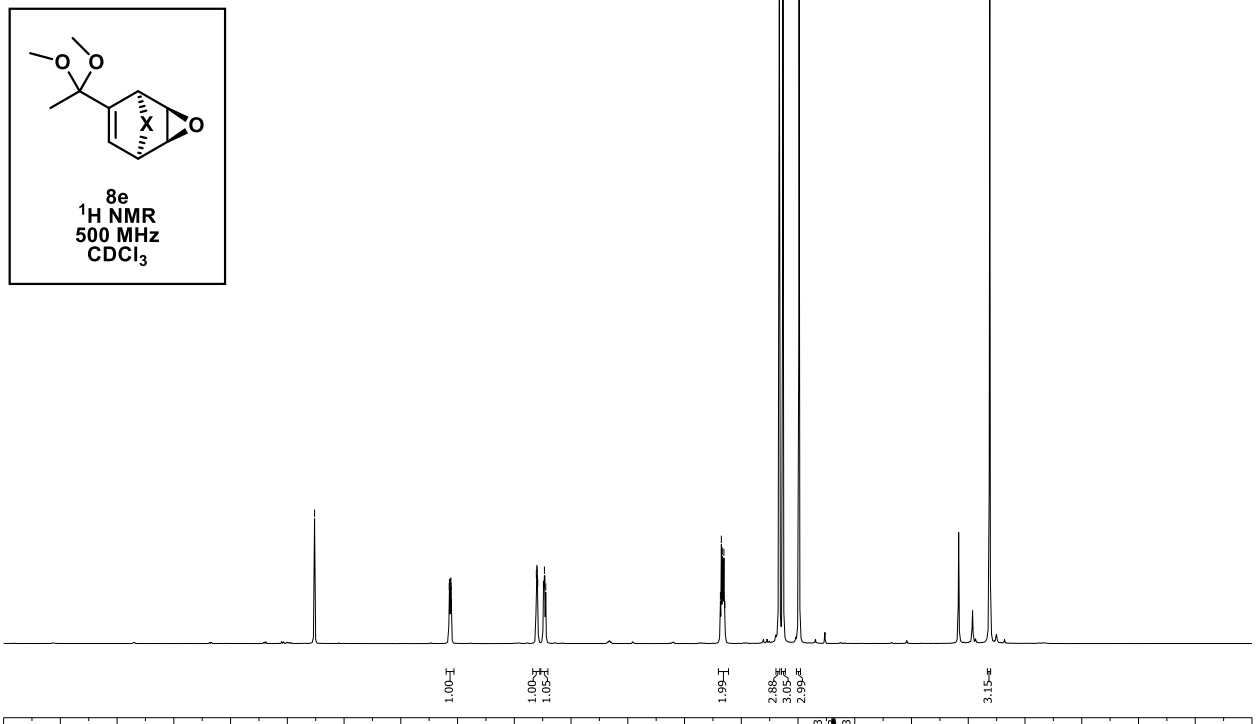
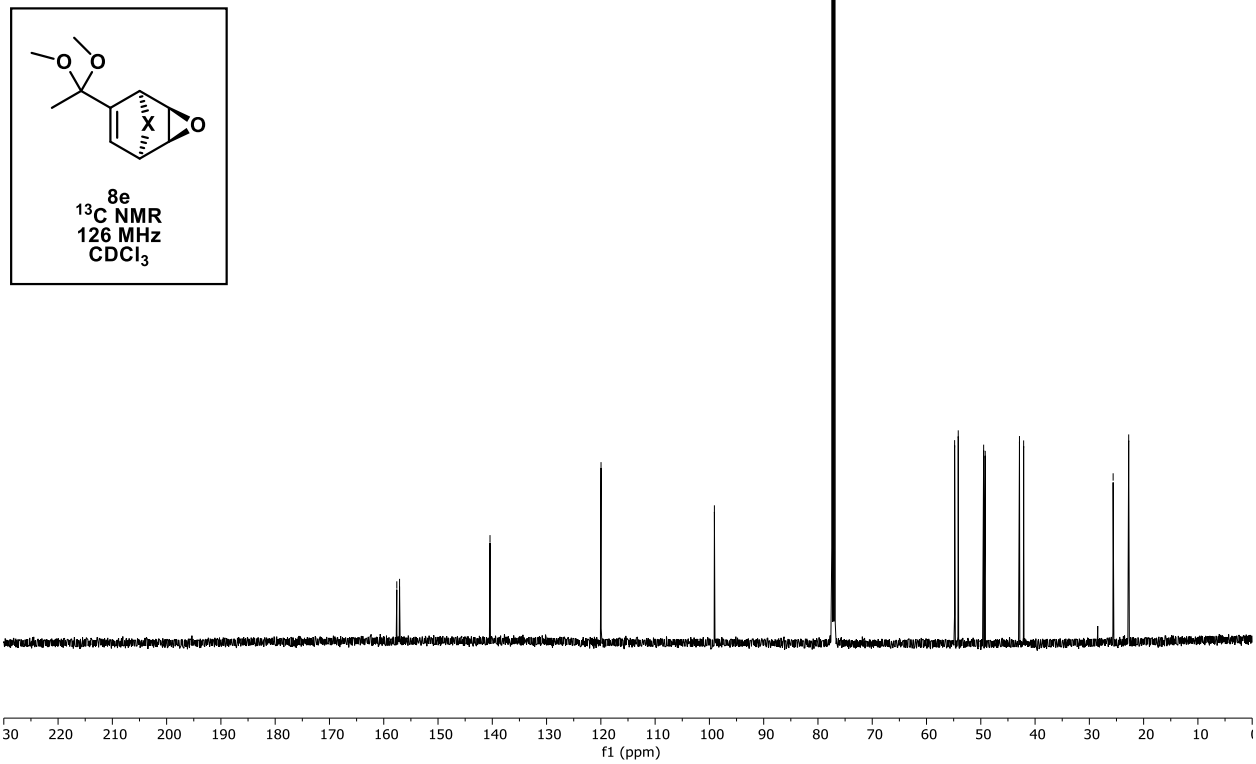
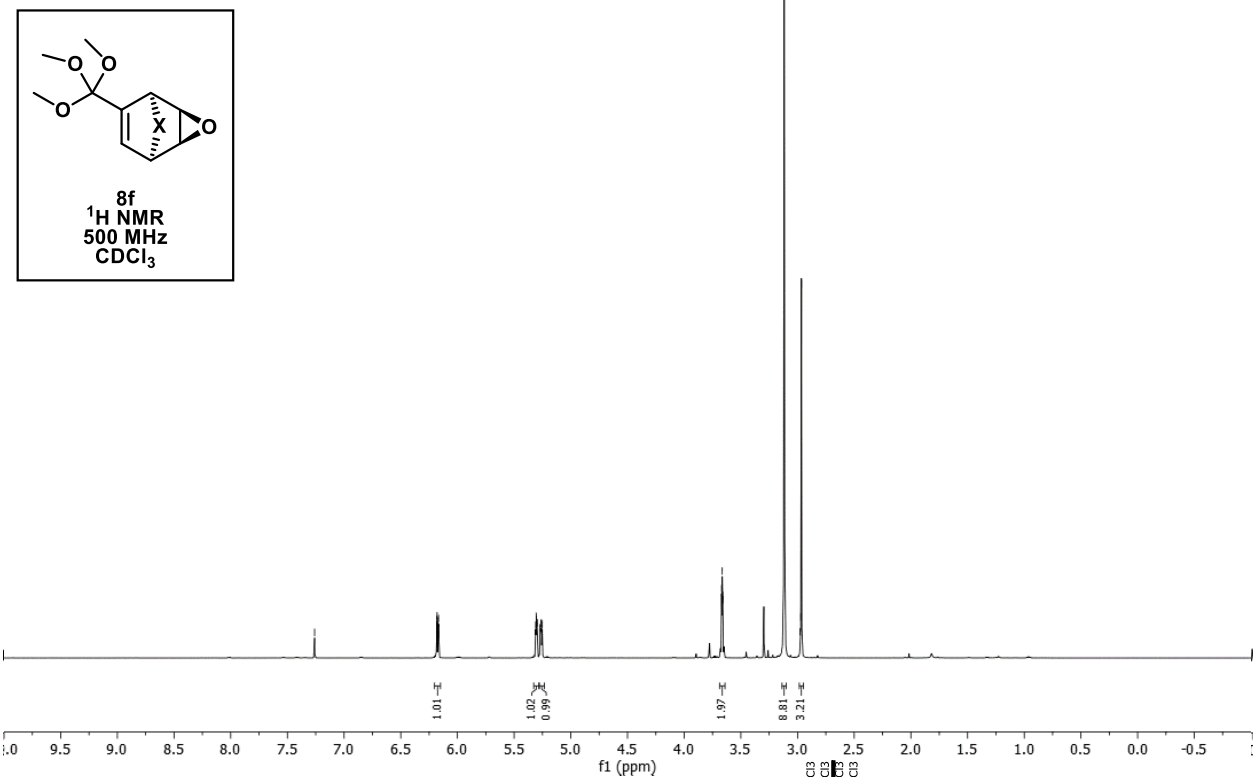
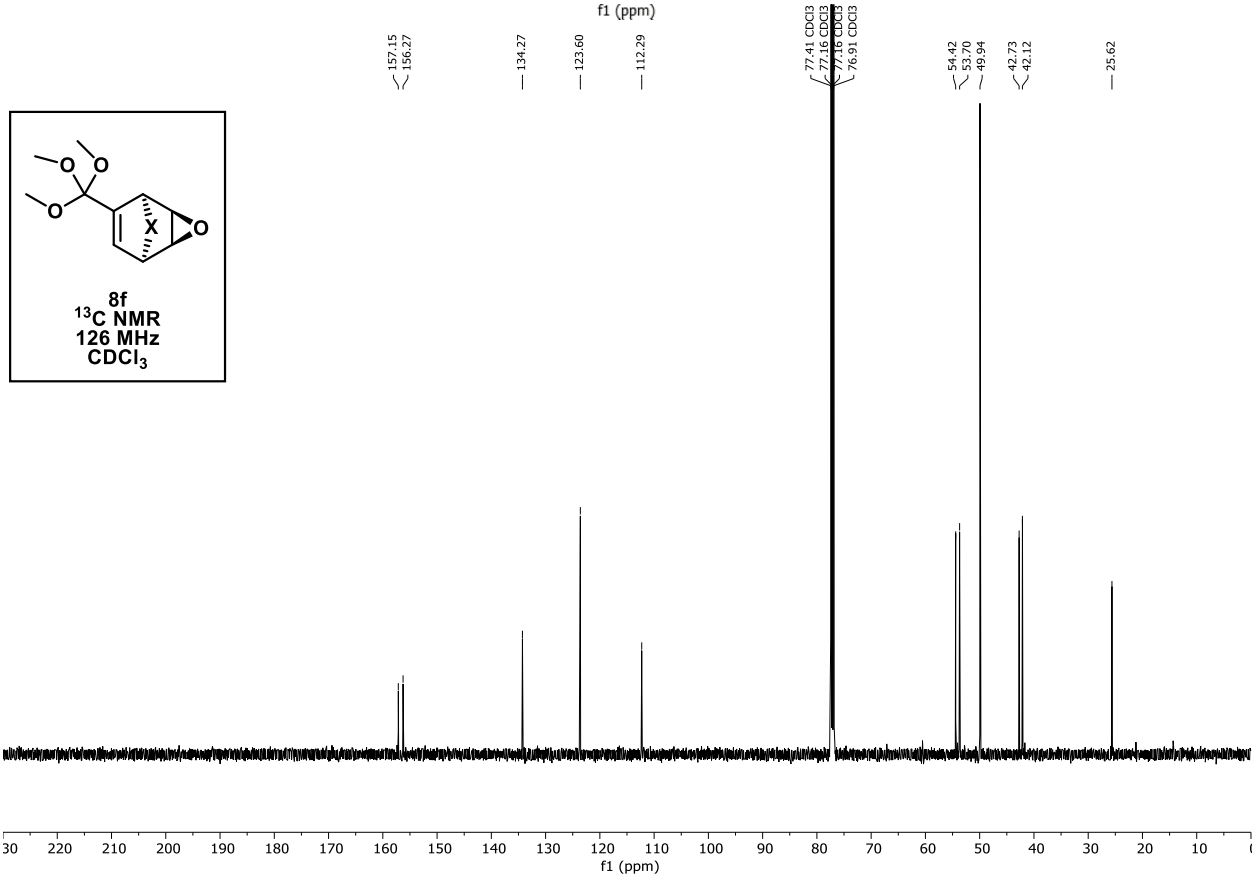
-200
-210
f1 (ppm)


8e
1H NMR
500 MHz
CDCl3

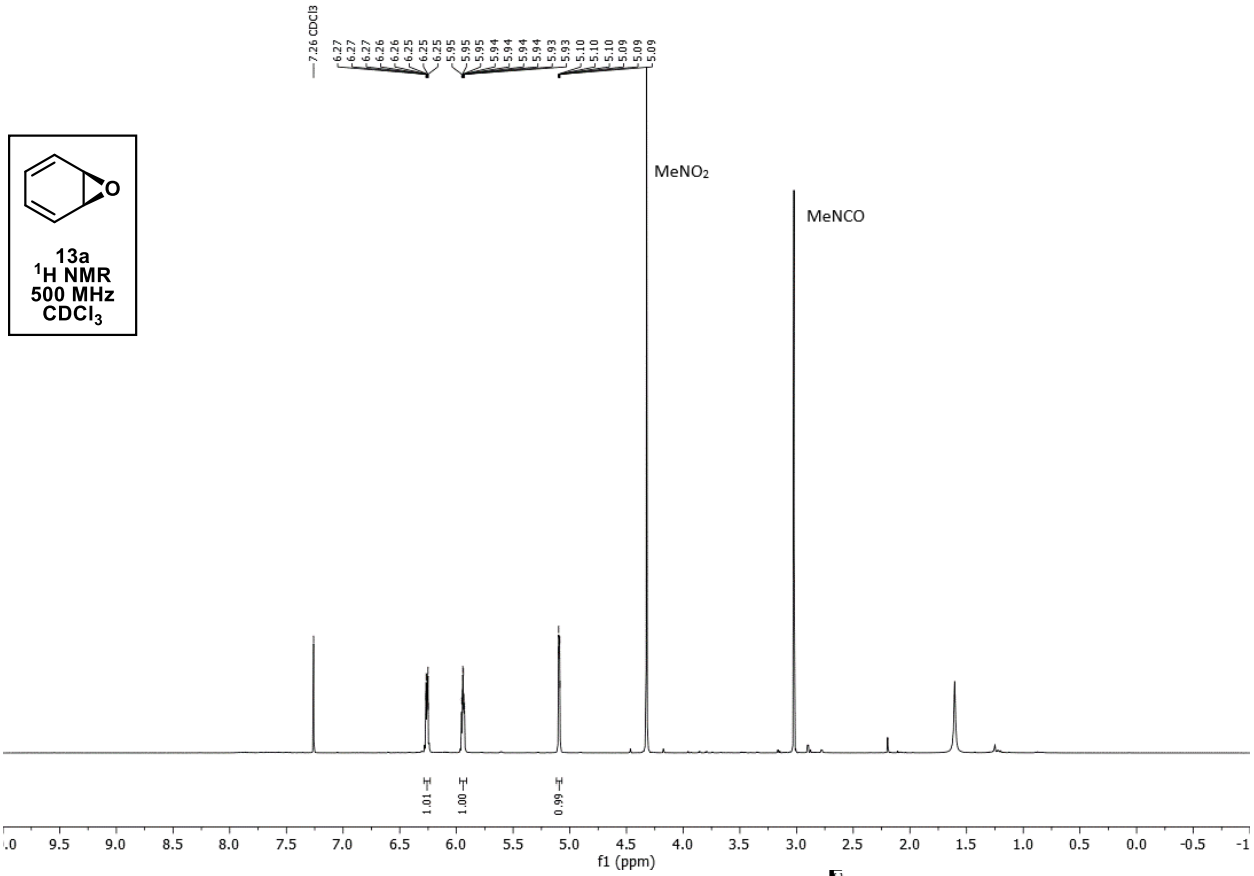

8e
13C NMR
126 MHz
CDCl3



8f
^{1}H NMR
500 MHz
$CDCl_3$



8f
^{13}C NMR
126 MHz
$CDCl_3$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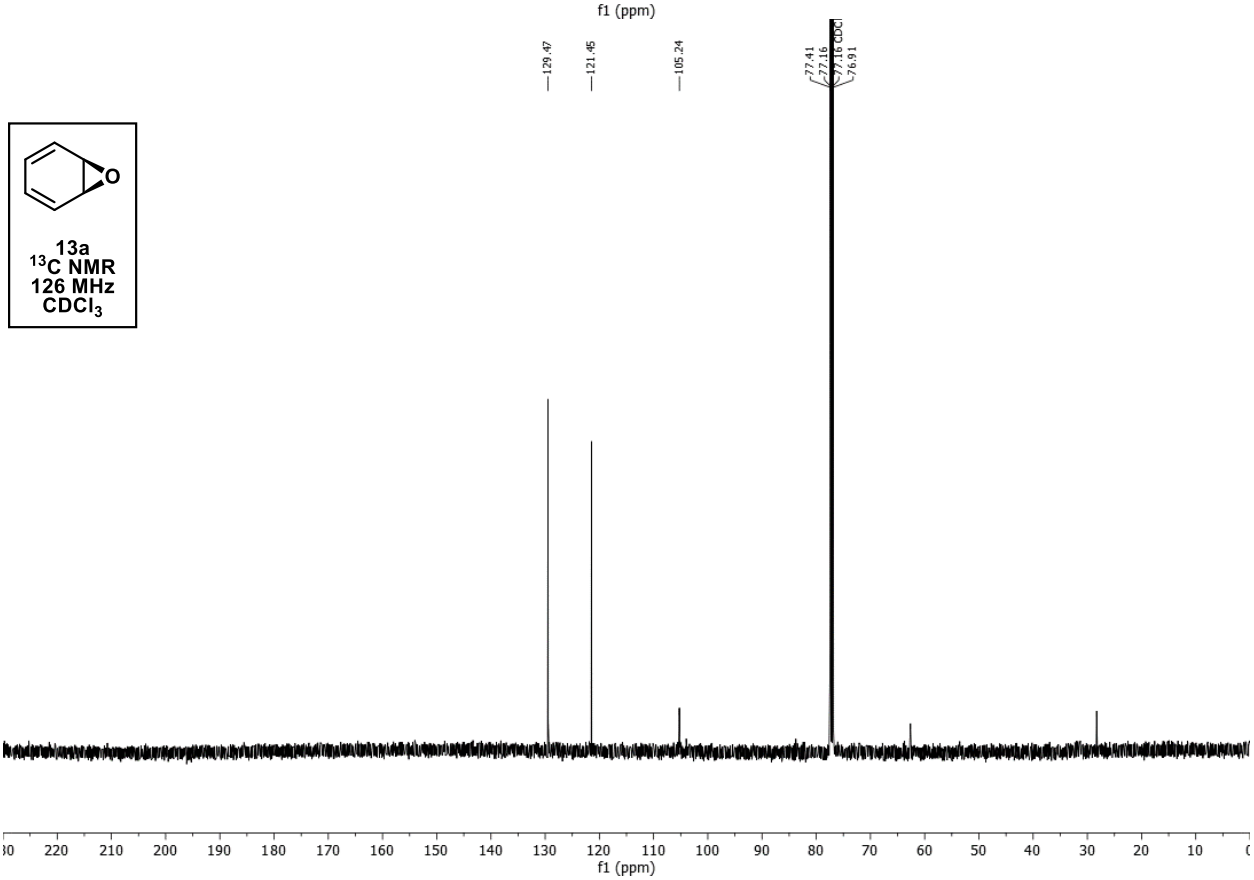
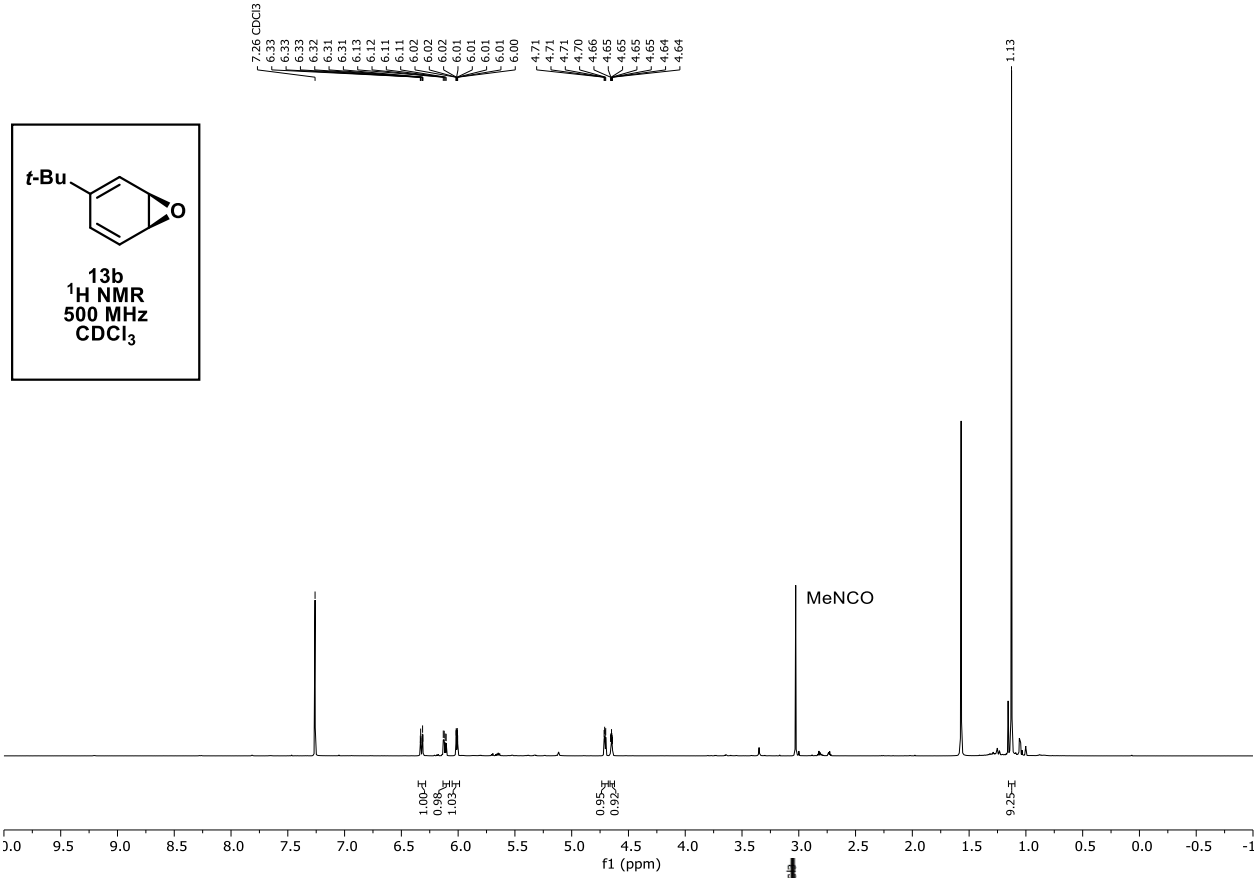
500 MHz
CDCl3
MeNO2
MeNCO
f1 (ppm)


13a
13C NMR
126 MHz
CDCl3
f1 (ppm)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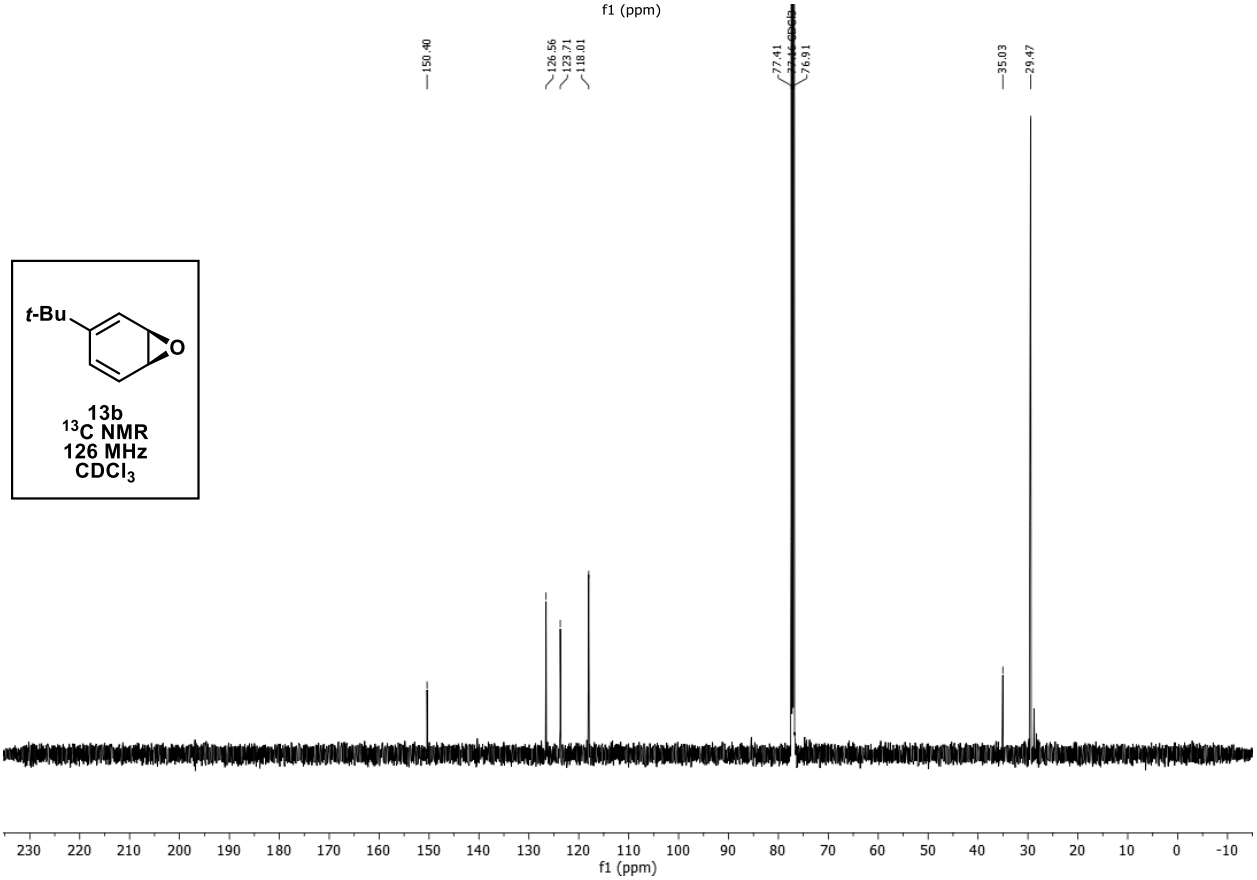
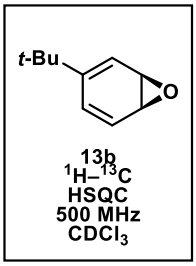
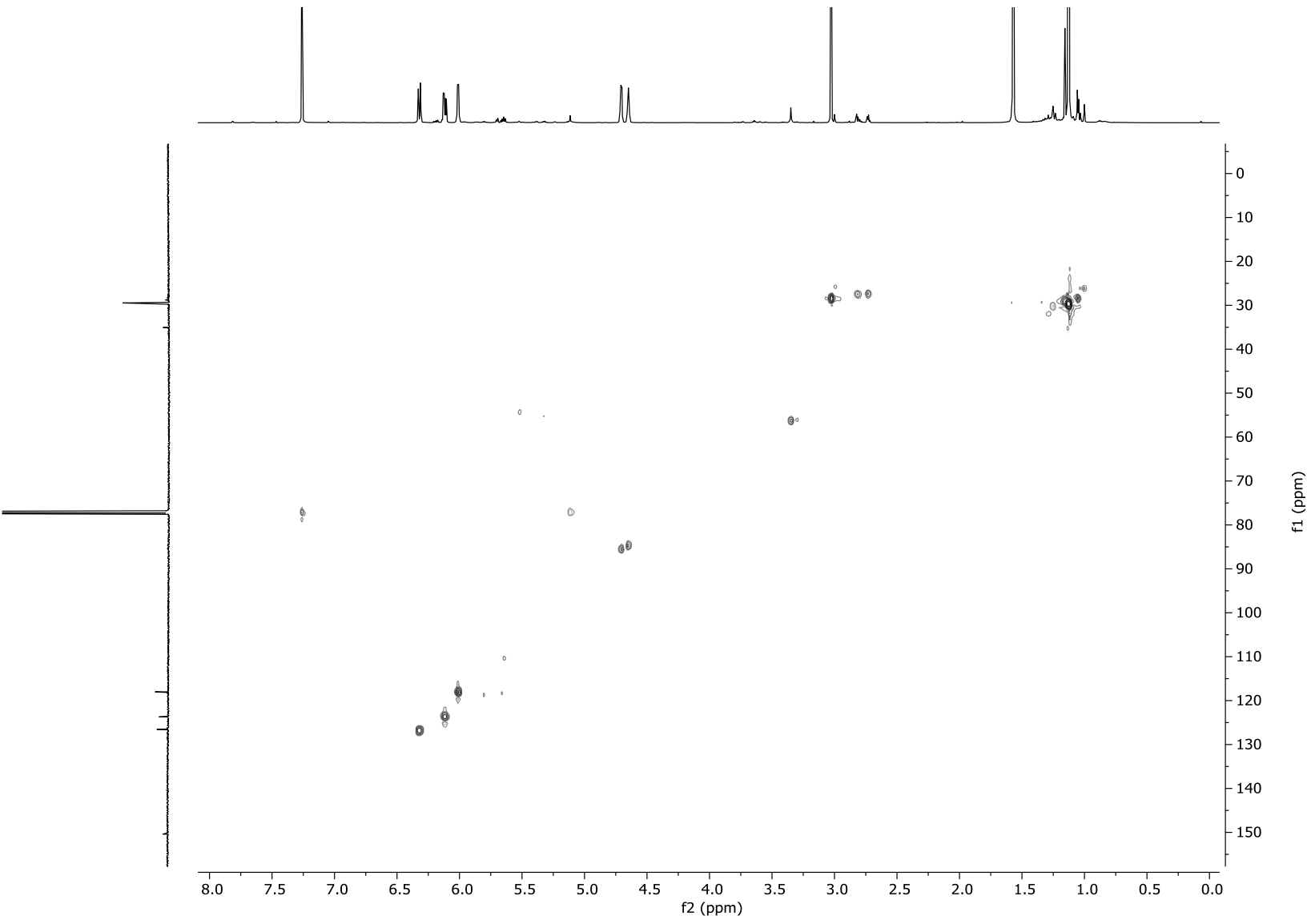
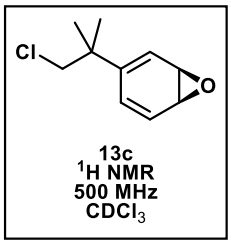
1H NMR
500 MHz
CDCl3
MeNCO
f1 (ppm)


t-Bu
O
13b
13C NMR
126 MHz
CDCl3
f1 (ppm)

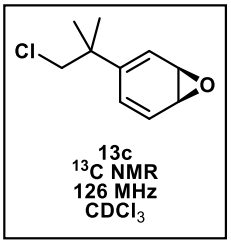


13b
^{1}H–^{13}C
HSQC
500 MHz
$CDCl_3$

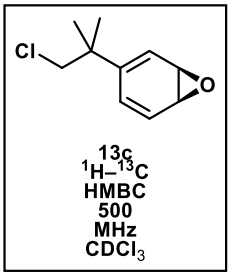




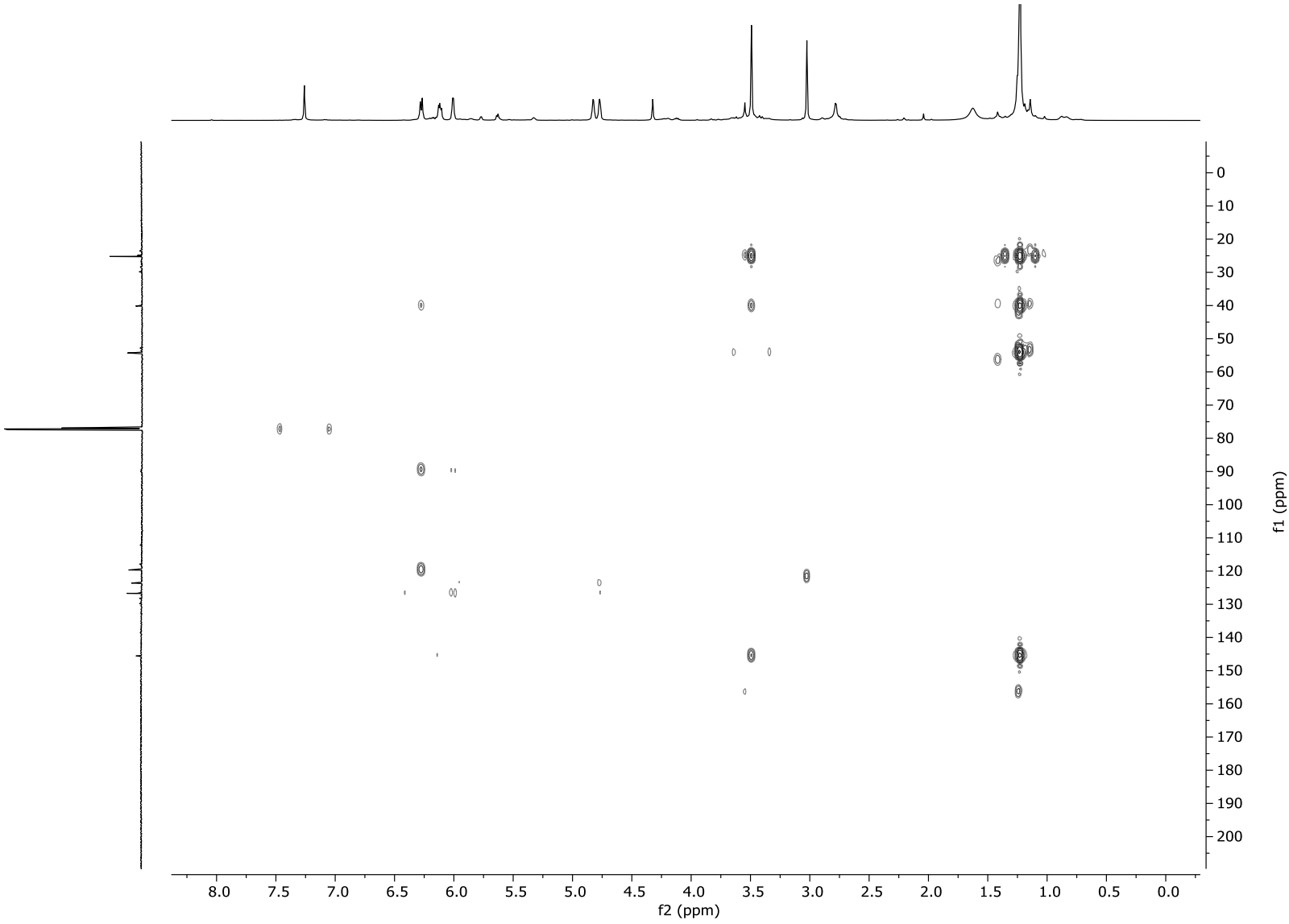
13c
^{1}H NMR
500 MHz
$CDCl_3$

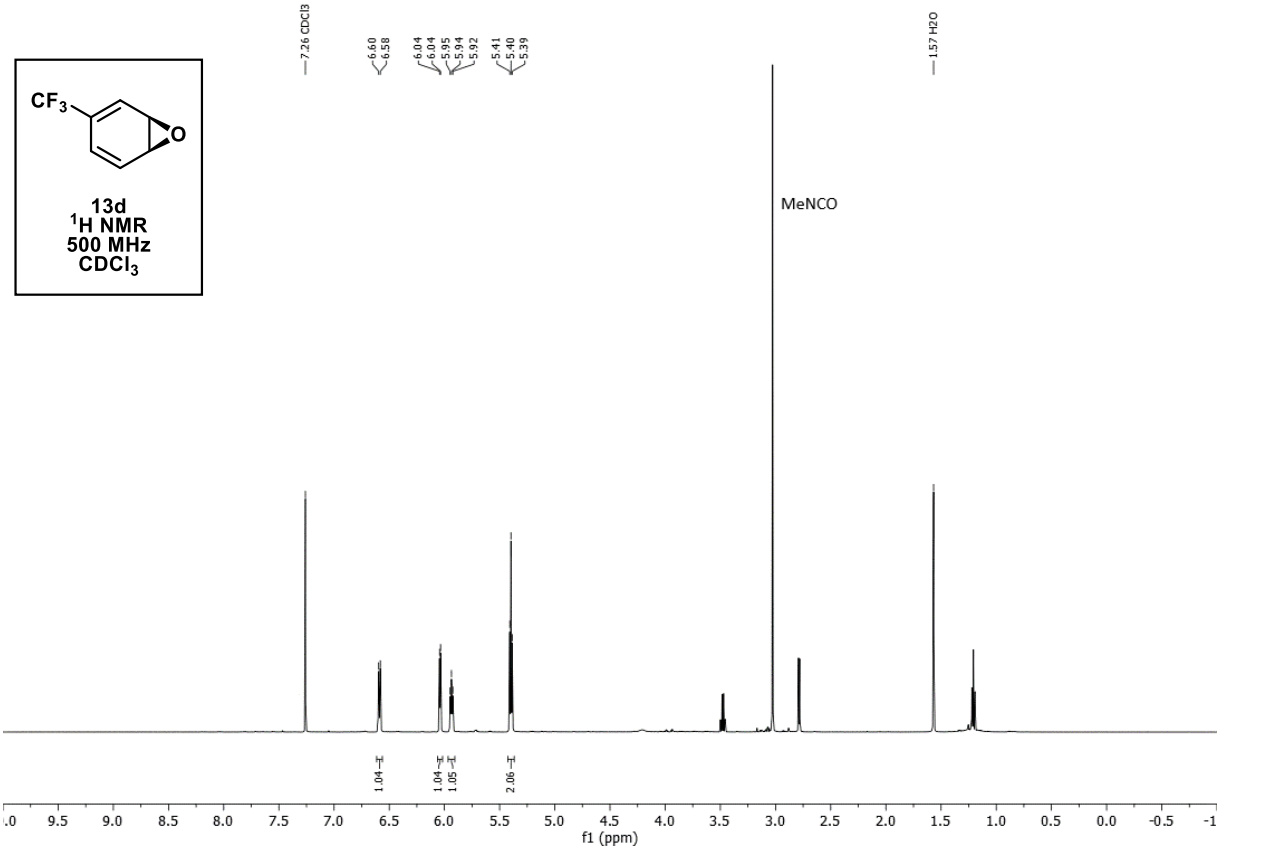


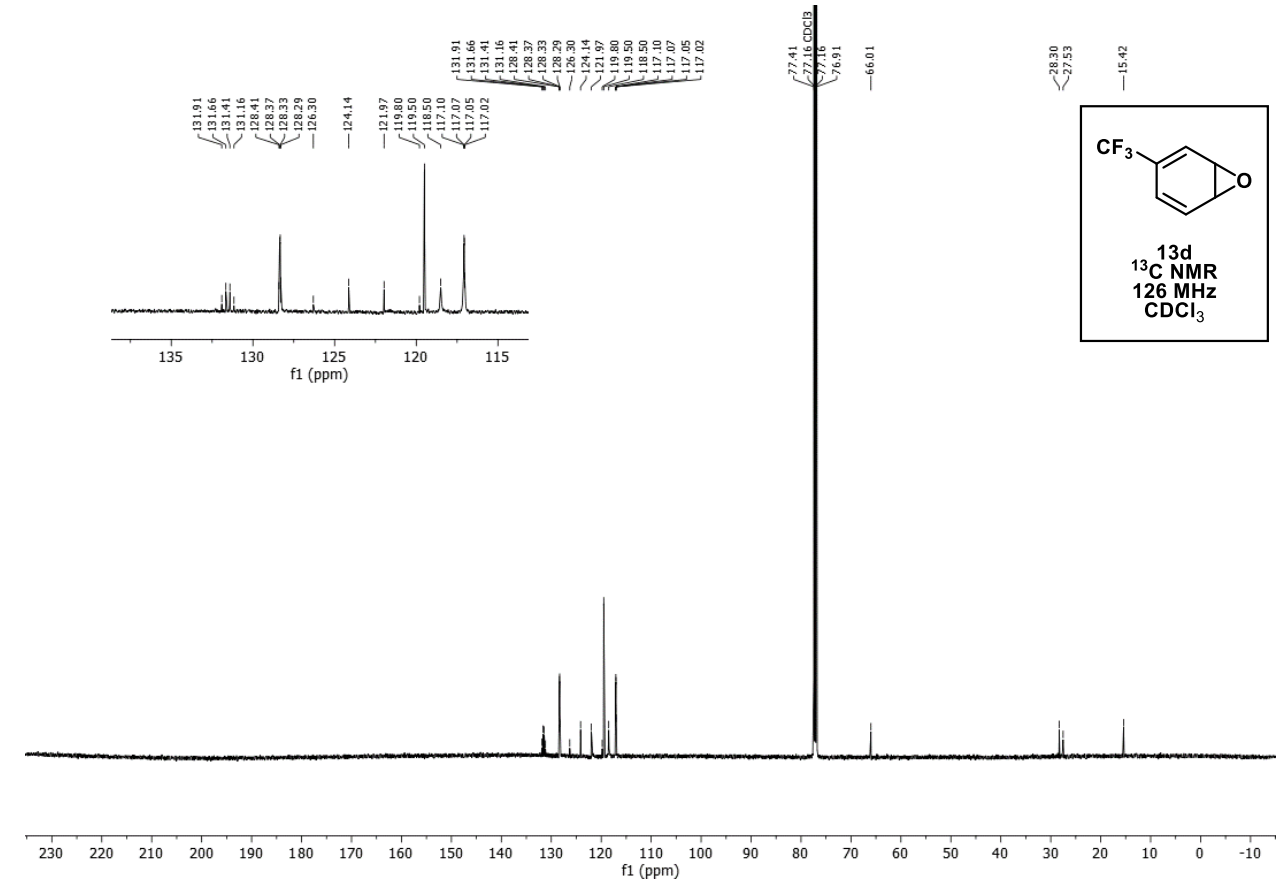
13c
^{13}C NMR
126 MHz
$CDCl_3$

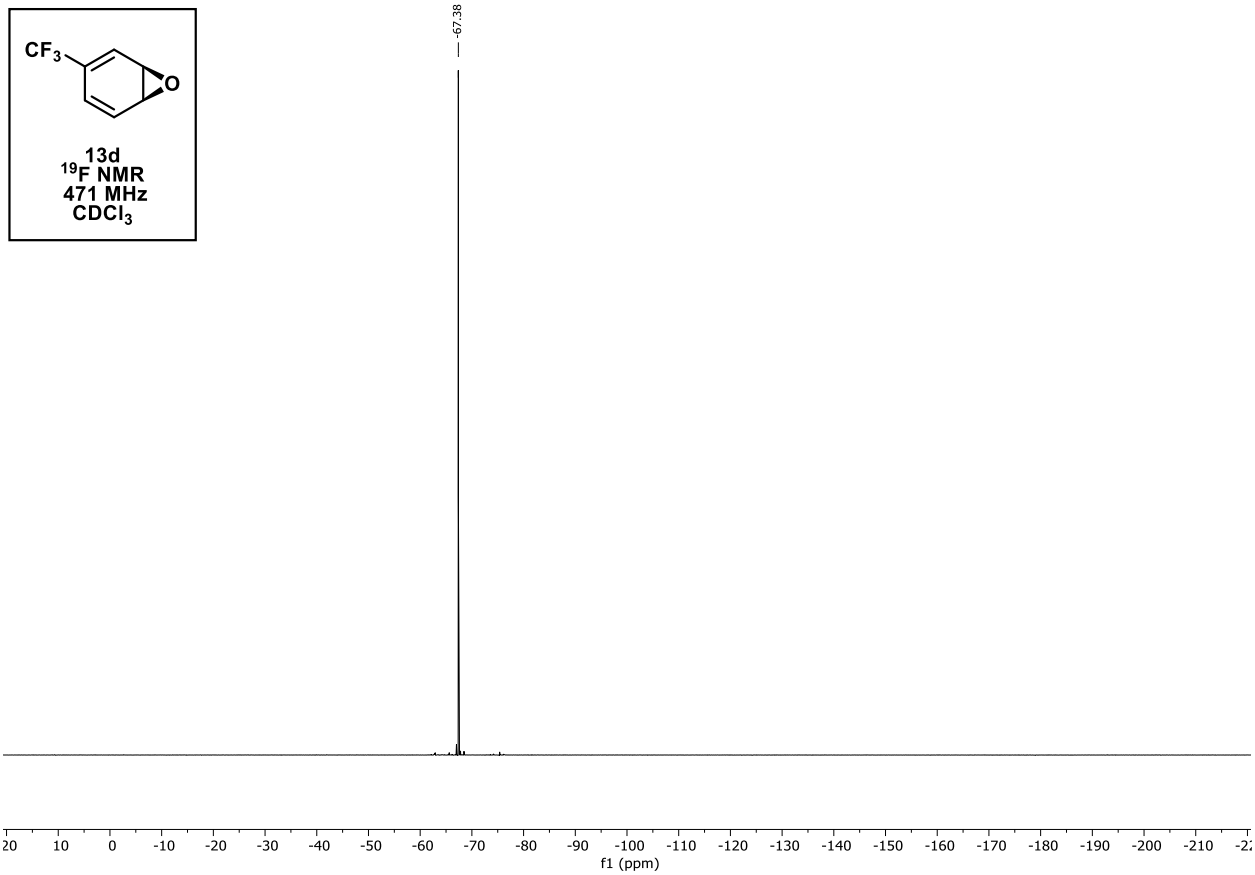


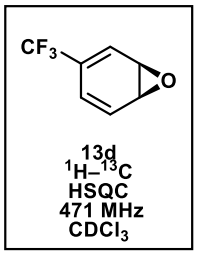
13c
^{1}H–^{13}C
HMBC
500
MHz
$CDCl_3$



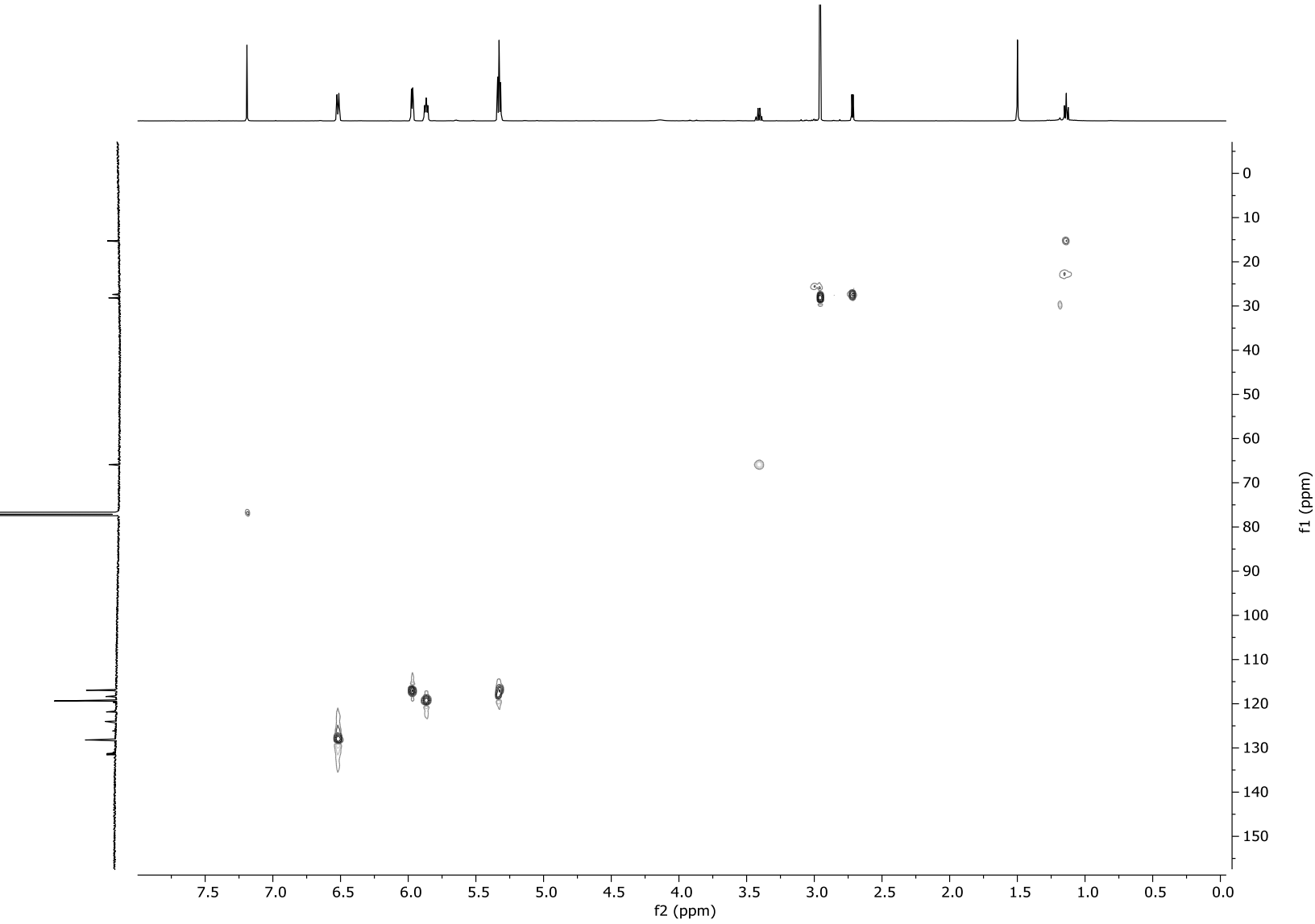

CF3
O
13d
1H NMR
500 MHz
CDCl3
7.26 CDCl3
6.60
6.58
6.04
6.04
5.95
5.94
5.92
5.41
5.40
5.39
1.57 H2O
MeNCO
1.04
1.04
1.05
2.06
f1 (ppm)

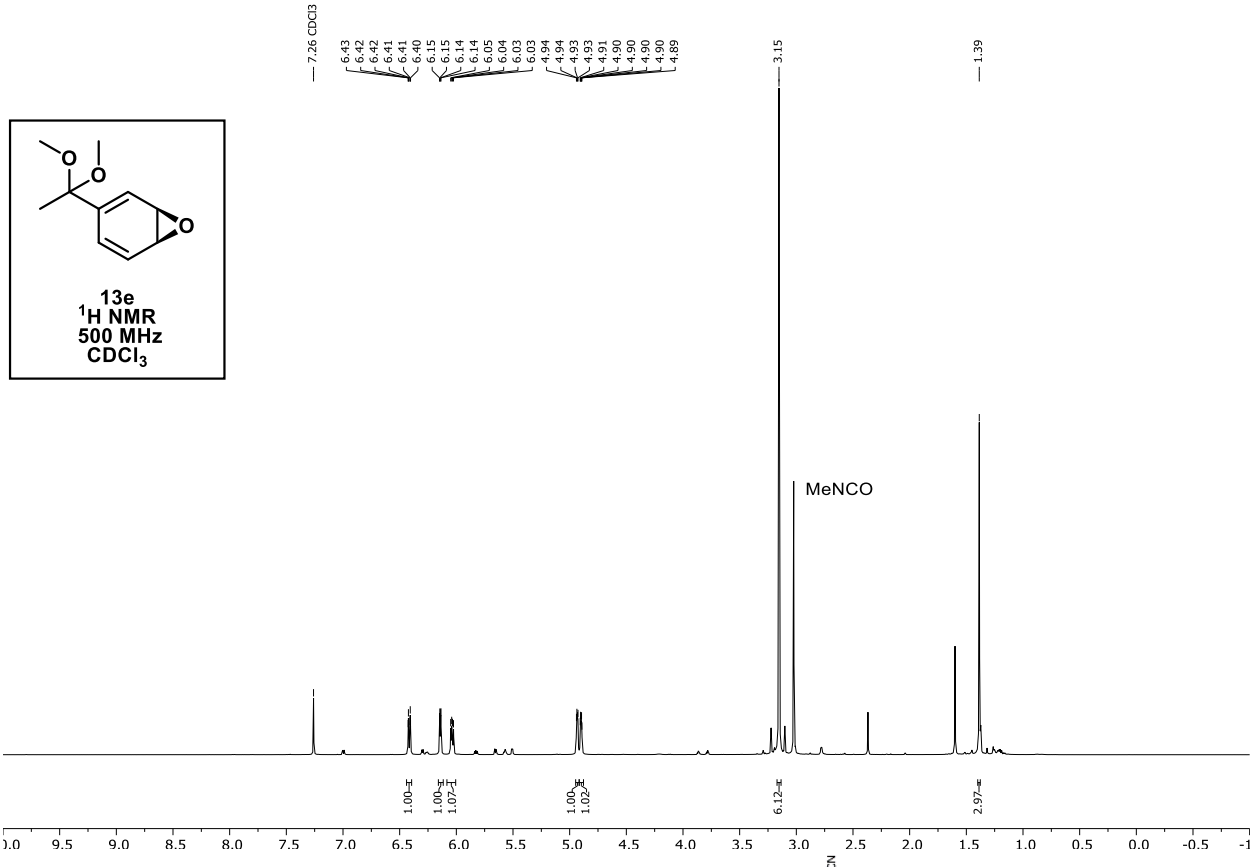

131.91
131.66
131.41
131.16
128.41
128.37
128.33
128.29
126.30
124.14
121.97
119.80
119.50
118.50
117.10
117.07
117.05
117.02
77.41
77.16 CDCl3
76.91
66.01
28.30
27.53
15.42
CF3
O
13d
13C NMR
126 MHz
CDCl3
f1 (ppm)


CF3
O
13d
19F NMR
471 MHz
CDCl3
-67.38
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

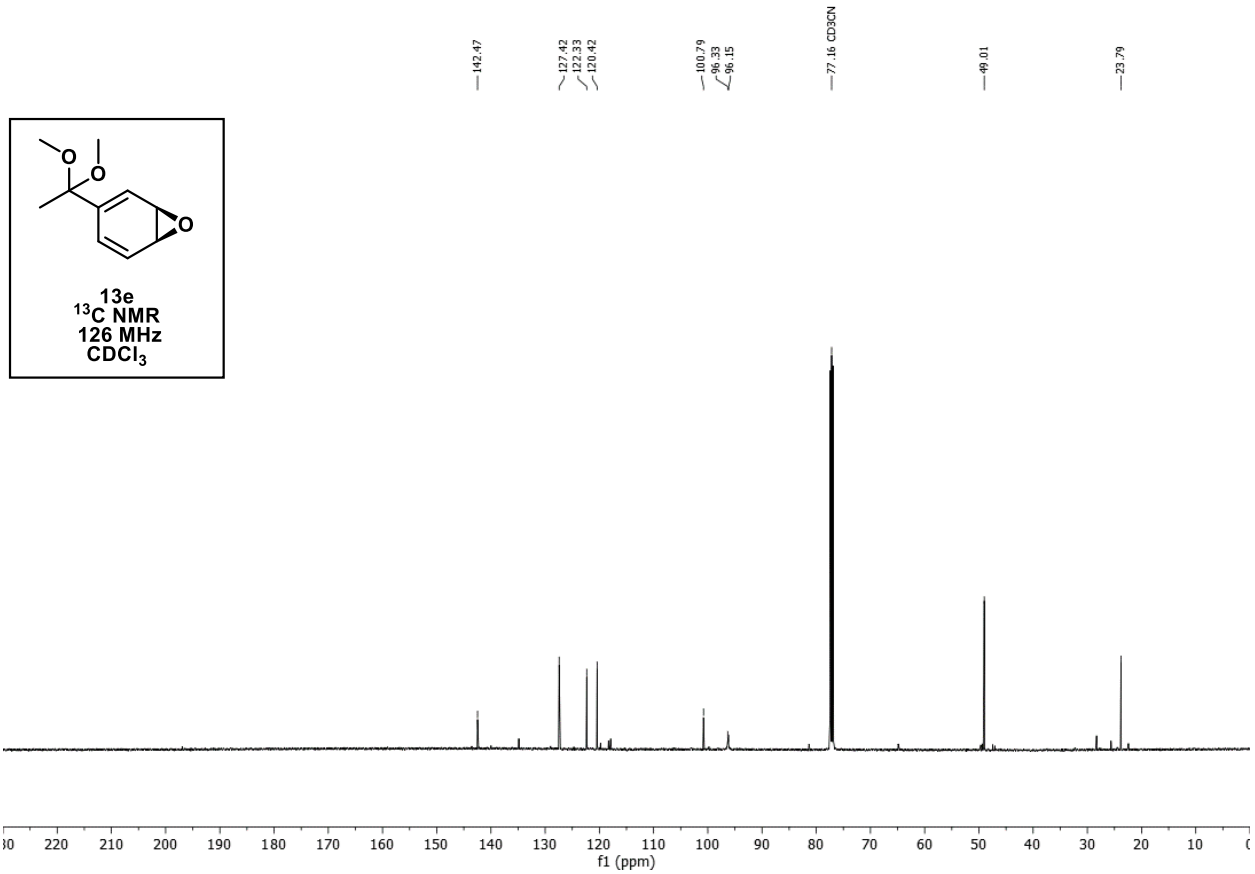


13d
$^{1}H-^{13}C$ HSQC
471 MHz
$CDCl_3$

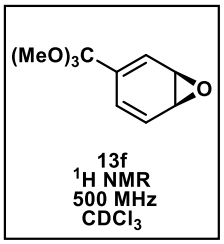




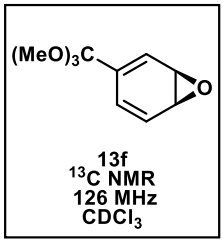
13e
^{1}H NMR
500 MHz
$CDCl_3$



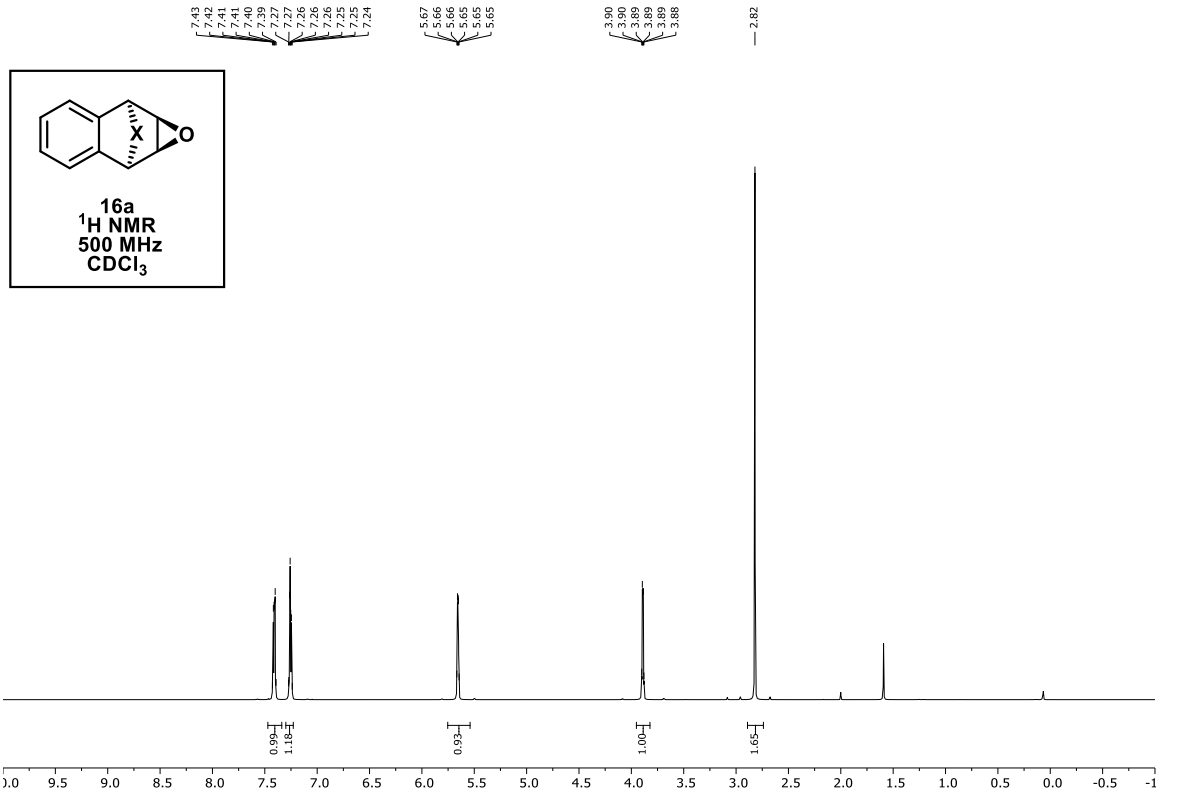
13e
^{13}C NMR
126 MHz
$CDCl_3$

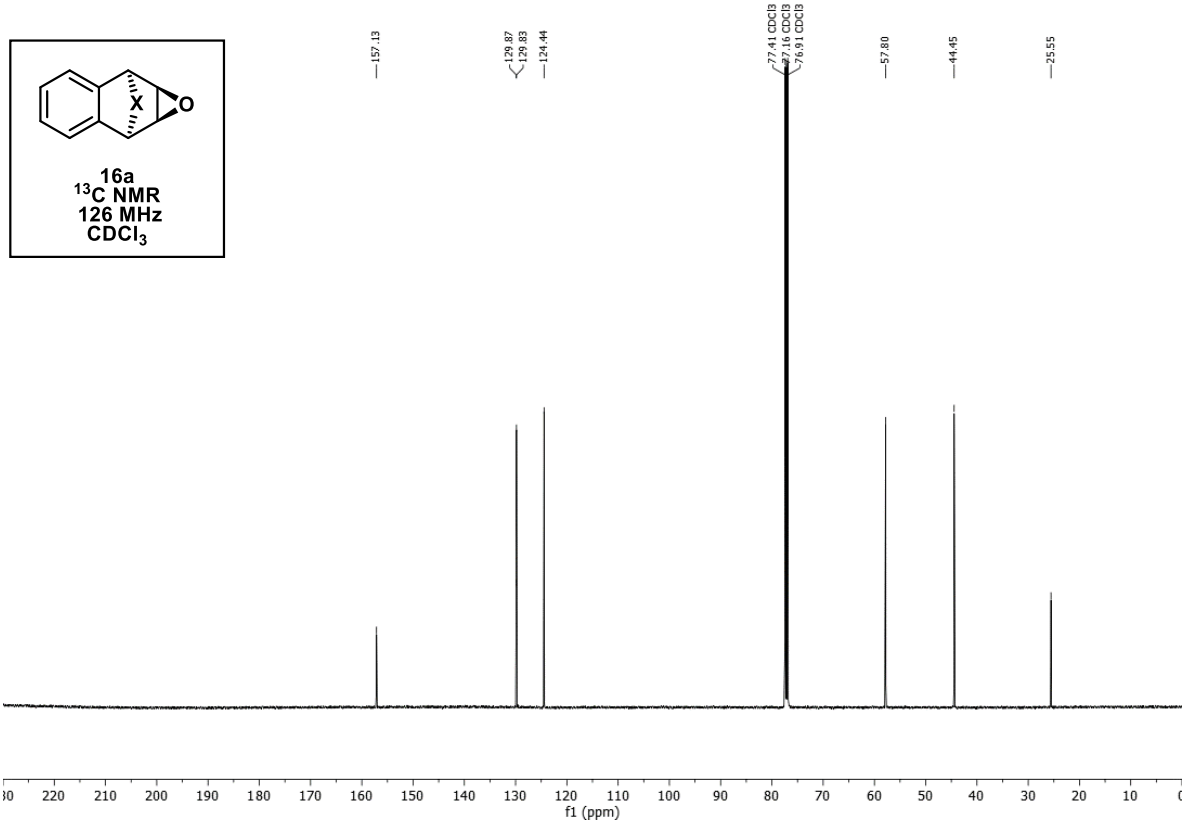


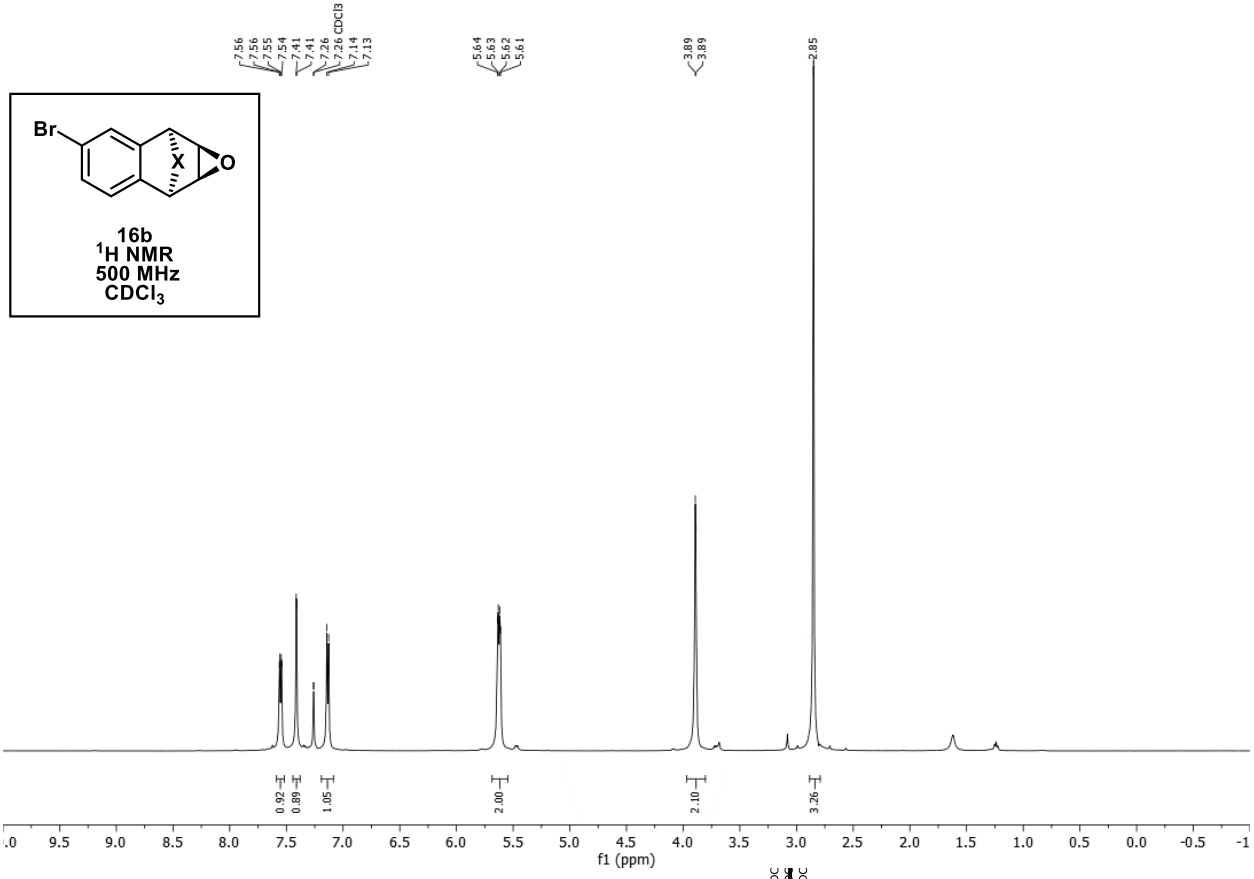
13f
^{1}H NMR
500 MHz
$CDCl_3$

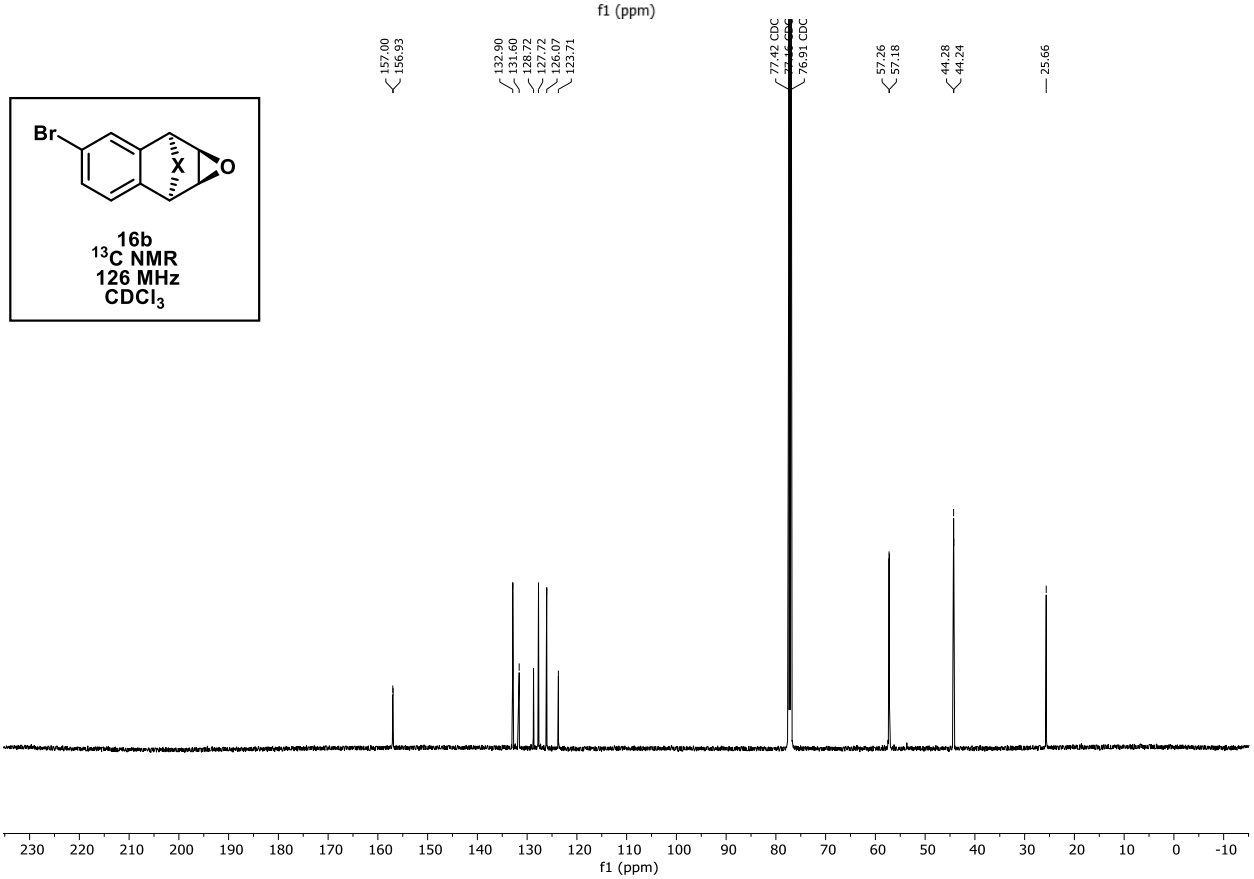


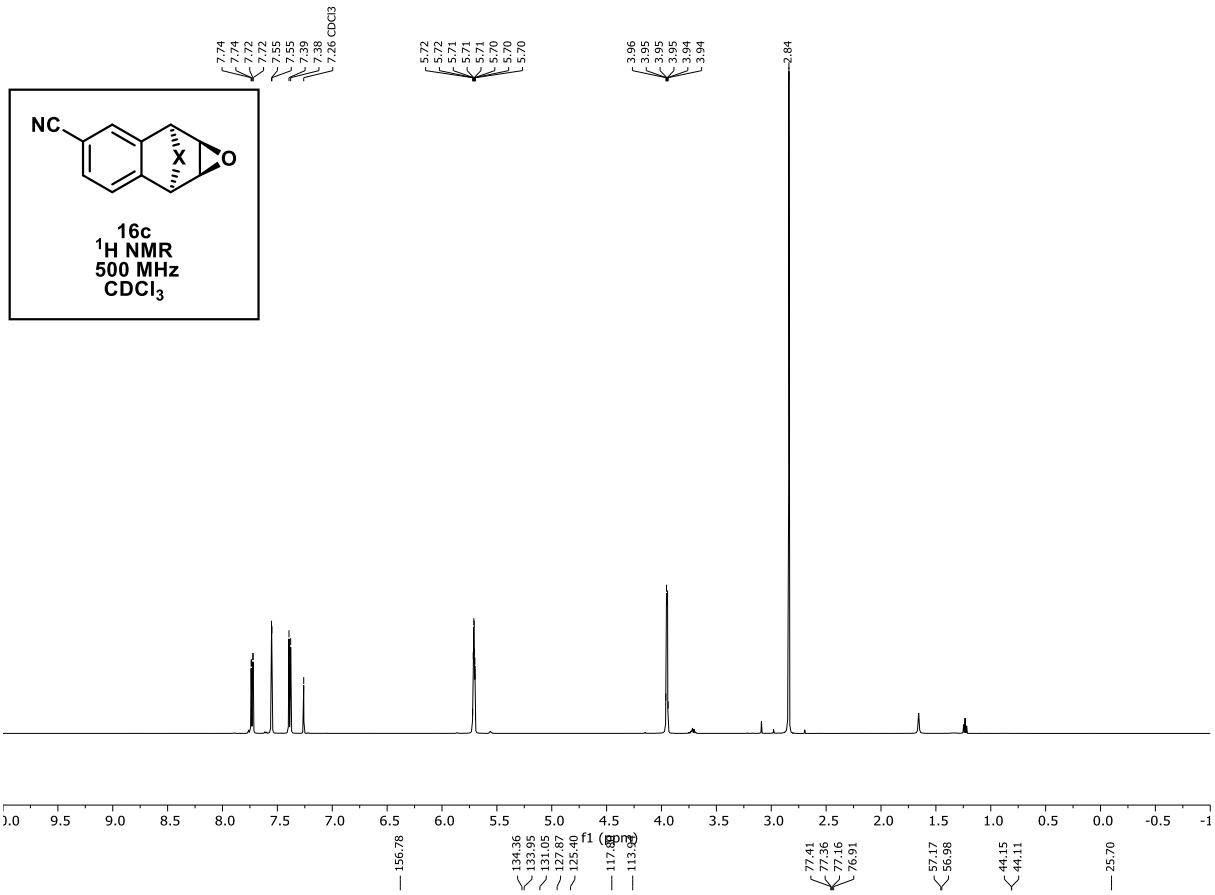
13f
^{13}C NMR
126 MHz
$CDCl_3$

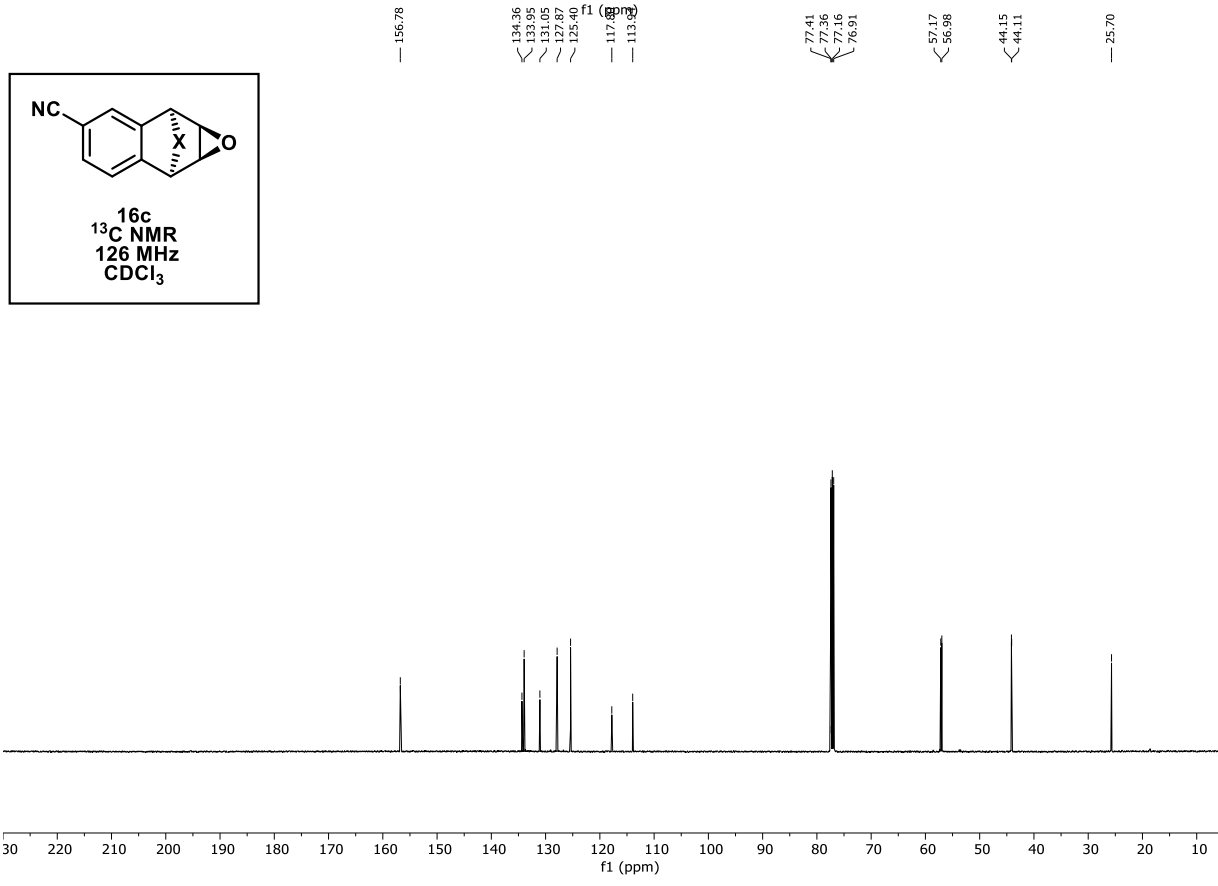

16a
1H NMR
500 MHz
CDCl3

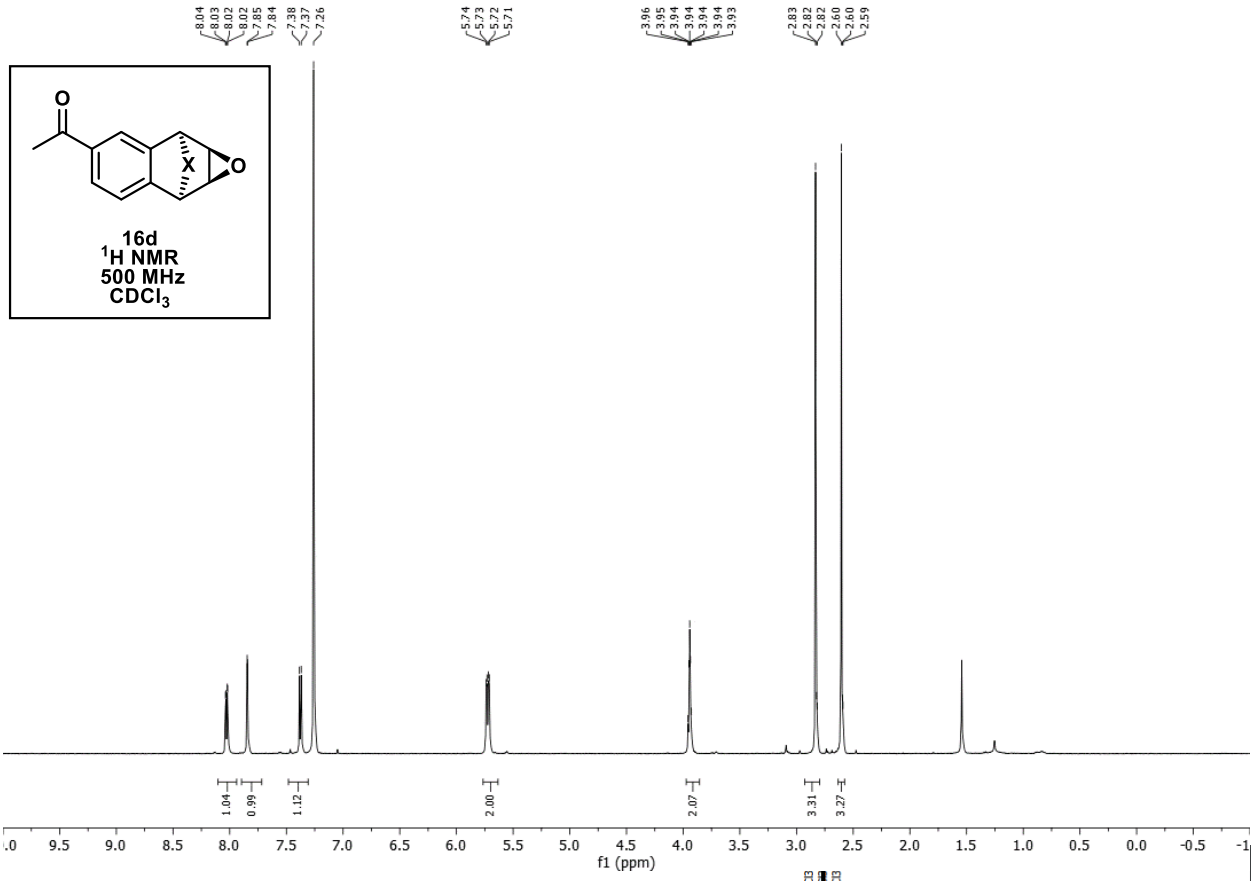

16a
13C NMR
126 MHz
CDCl3
f1 (ppm)

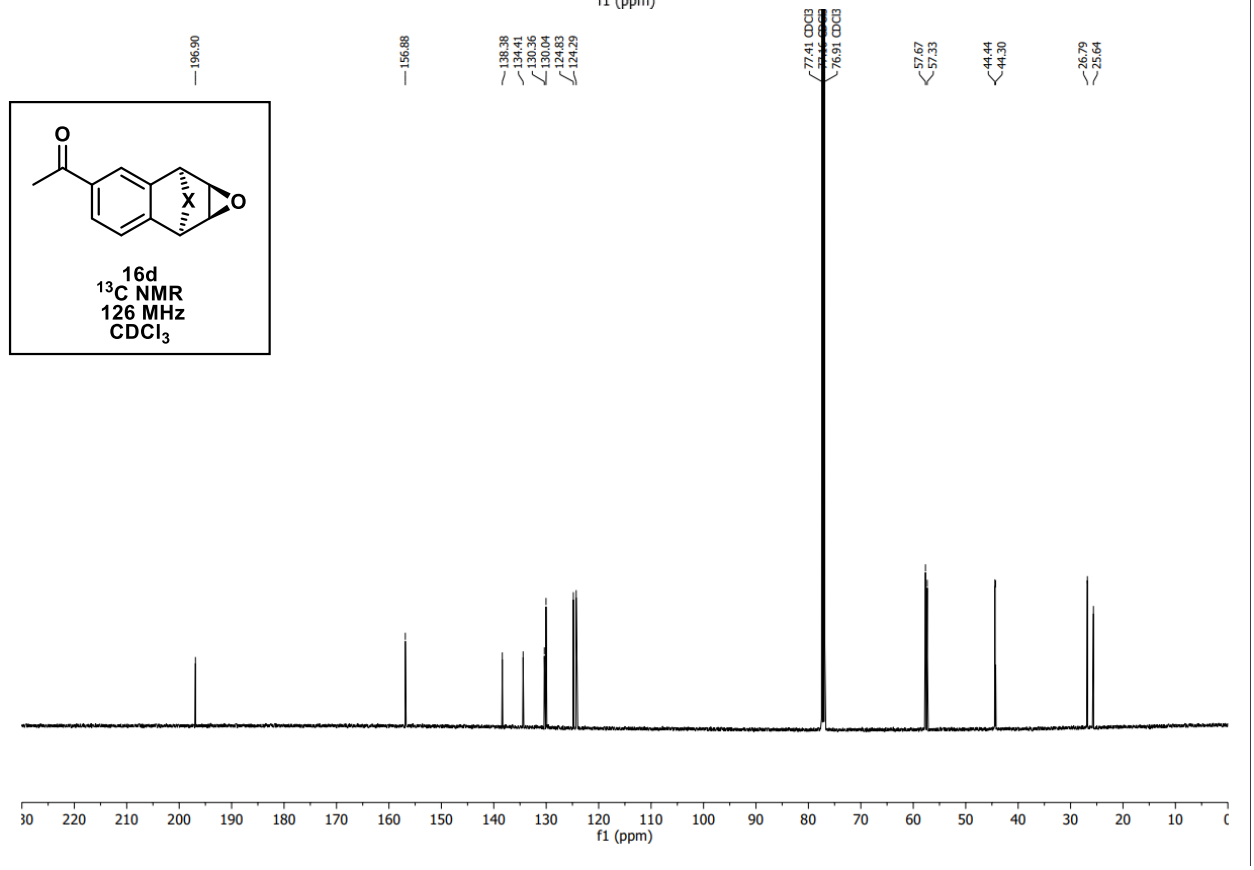

Br
X
O
16b
1H NMR
500 MHz
CDCl3
7.56
7.56
7.55
7.54
7.41
7.41
7.26
7.26 CDCl3
7.14
7.13
5.64
5.63
5.62
5.61
3.89
3.89
2.85
0.92
0.89
1.05
2.00
2.10
3.26
f1 (ppm)

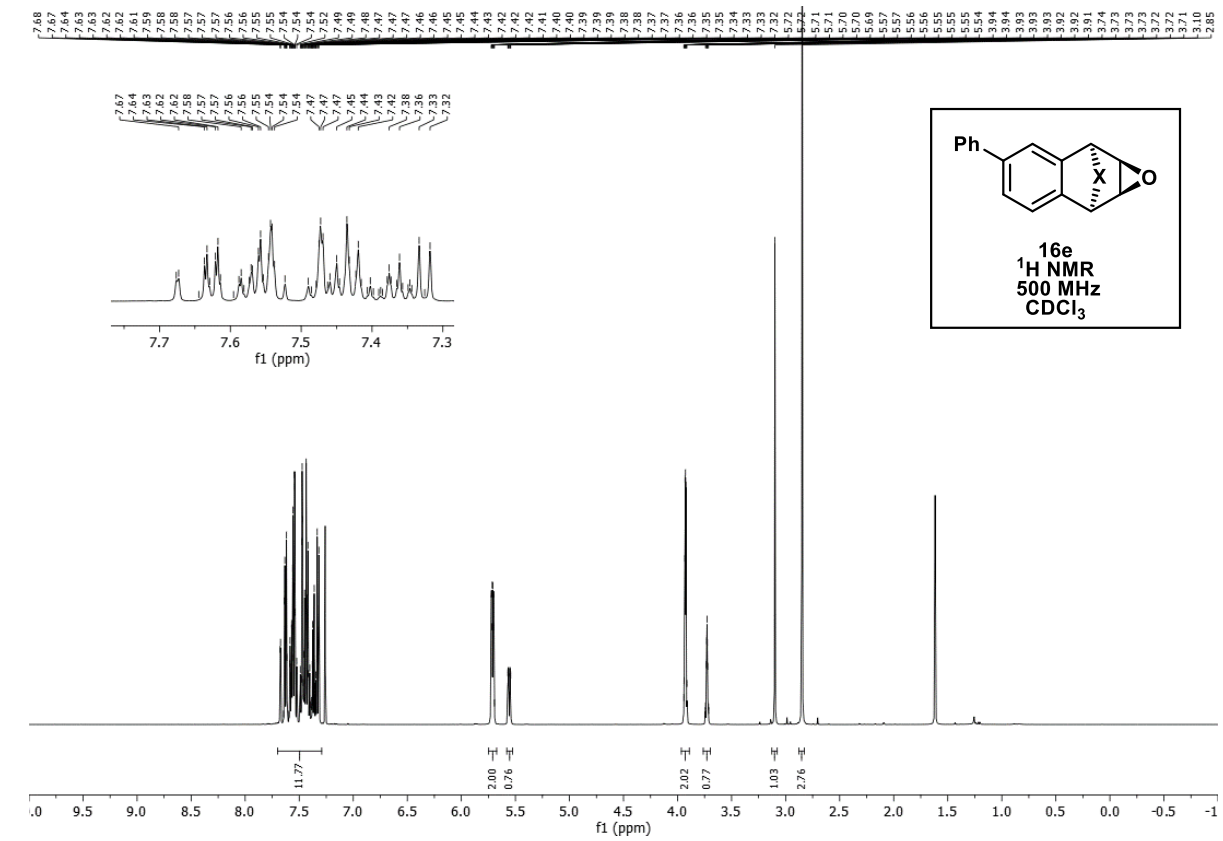

Br
X
O
16b
13C NMR
126 MHz
CDCl3
157.00
156.93
132.90
131.60
128.72
127.72
126.07
123.71
77.42 CDC
76.91 CDC
57.26
57.18
44.28
44.24
25.66
f1 (ppm)

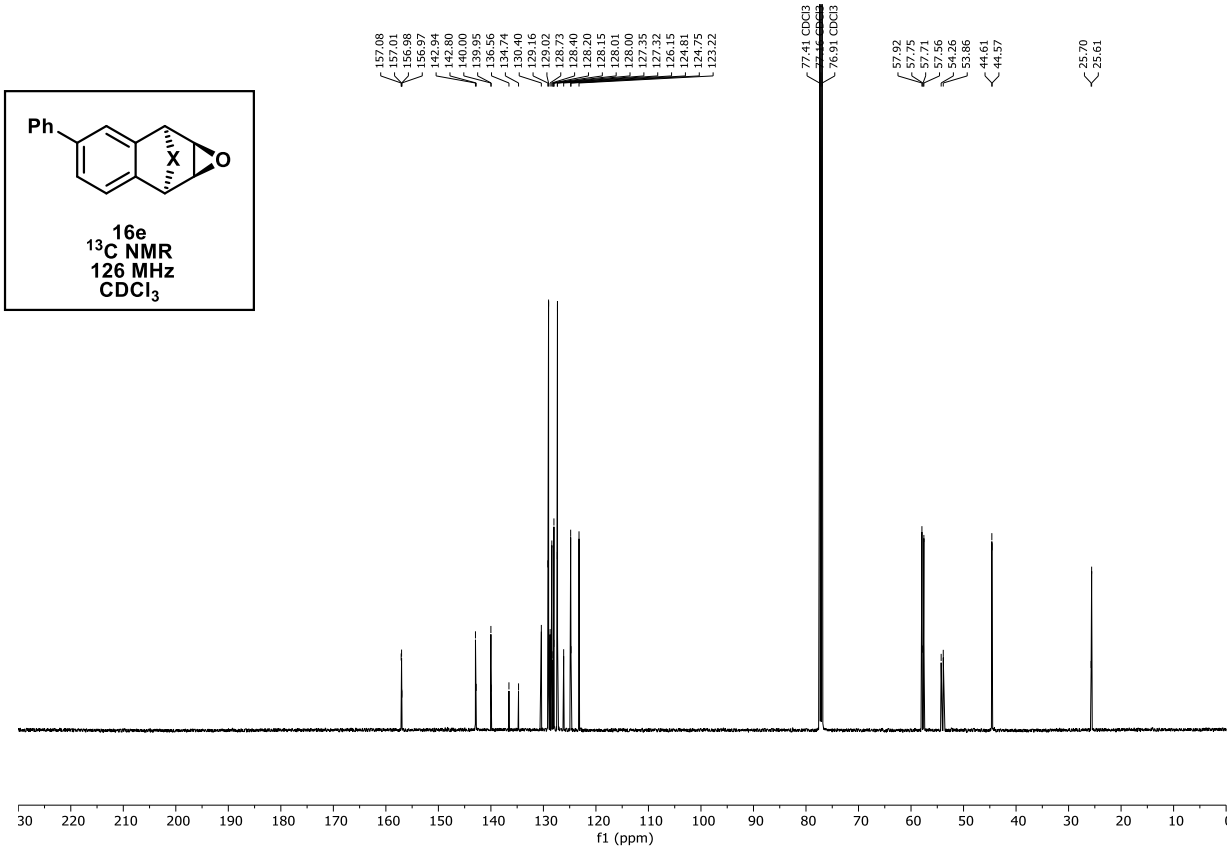

7.74
7.74
7.72
7.72
7.72
7.55
7.55
7.39
7.38
7.26 CDCl3
5.72
5.72
5.71
5.71
5.71
5.70
5.70
5.70
3.96
3.95
3.95
3.95
3.94
3.94
2.84
NC
X
O
16c
1H NMR
500 MHz
CDCl3
f1 (ppm)

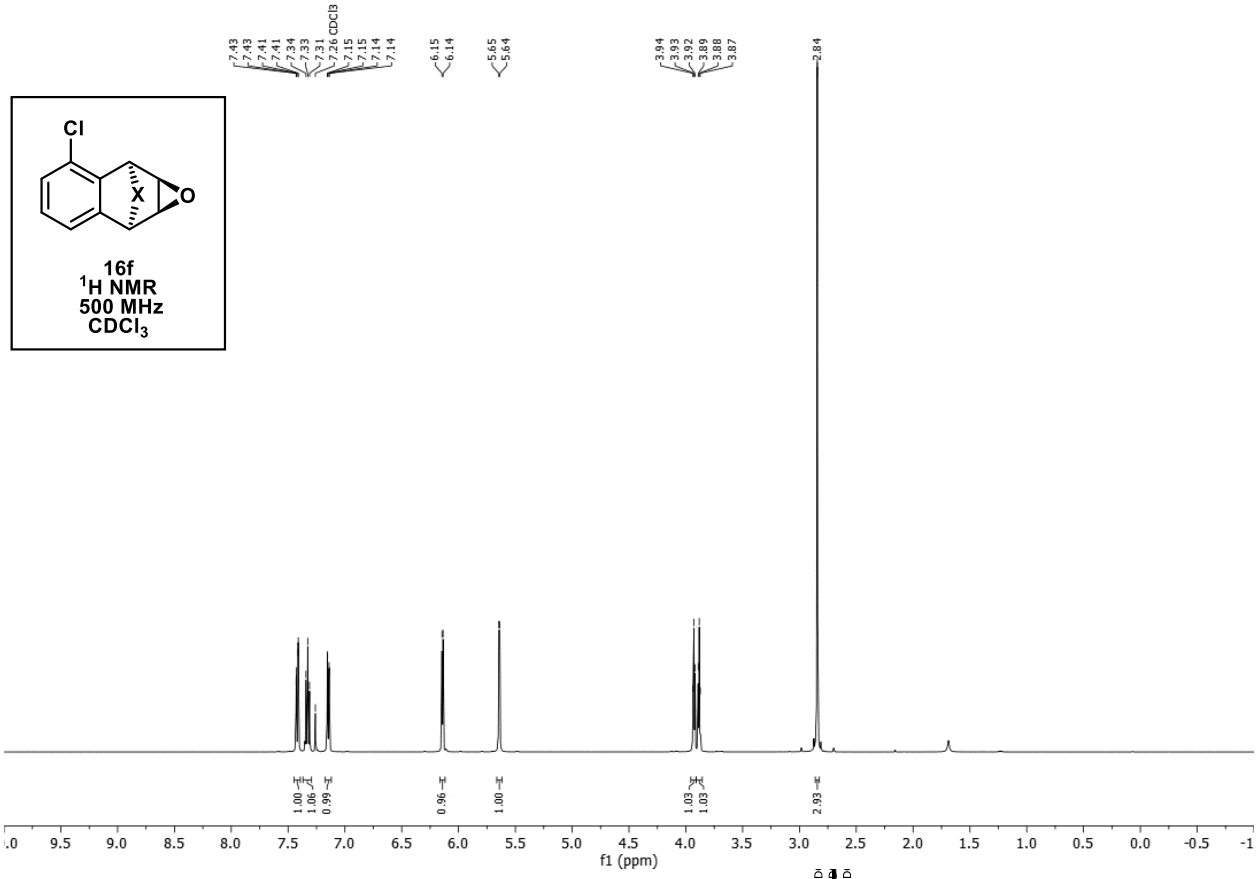

156.78
134.36
133.95
131.05
127.87
125.40
117.87
113.84
77.41
77.36
77.16
76.91
57.17
56.98
44.15
44.11
25.70
NC
X
O
16c
13C NMR
126 MHz
CDCl3
f1 (ppm)

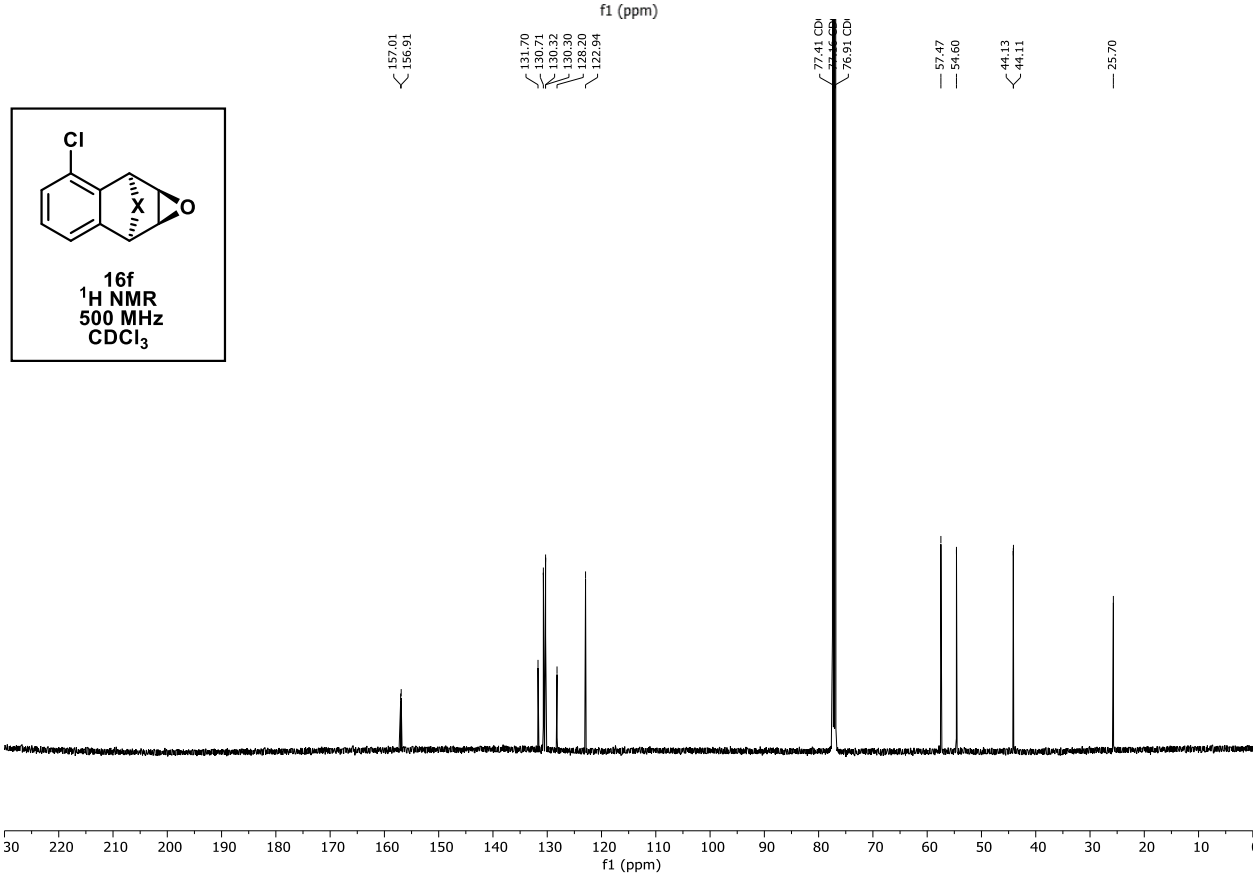

16d
1H NMR
500 MHz
CDCl3
f1 (ppm)

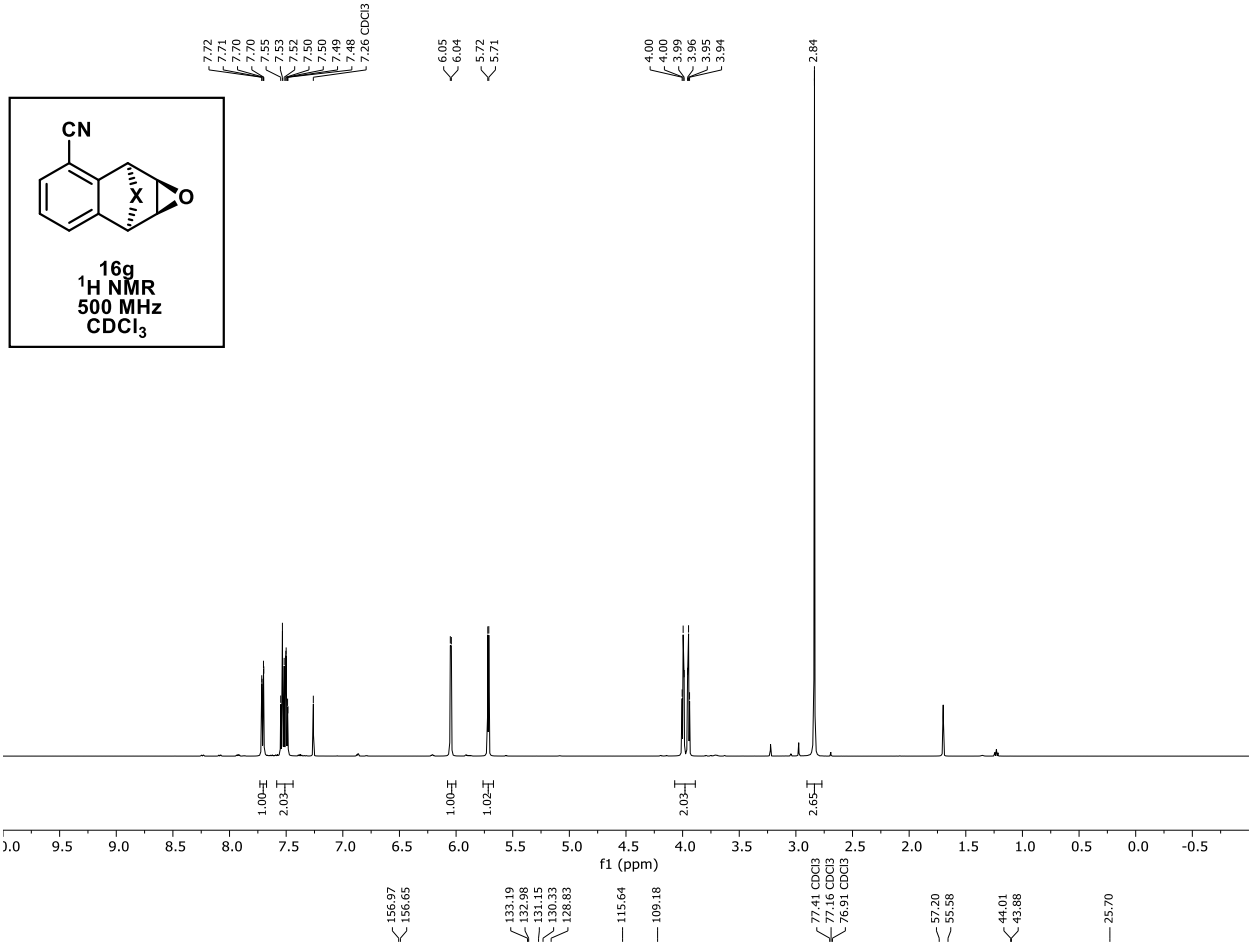

16d
13C NMR
126 MHz
CDCl3
f1 (ppm)


Ph
X
O
16e
^{1}H NMR
500 MHz
$CDCl_3$
f1 (ppm)


Ph
X
O
16e
^{13}C NMR
126 MHz
$CDCl_3$
f1 (ppm)

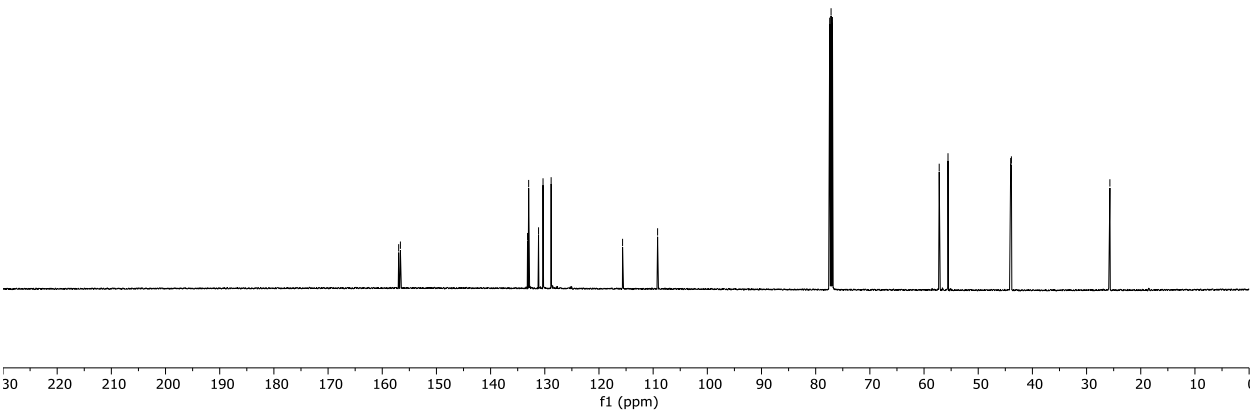

Cl
X
O
16f
1H NMR
500 MHz
CDCl3
7.43
7.43
7.41
7.41
7.34
7.33
7.31
7.26 CDCl3
7.15
7.15
7.14
7.14
6.15
6.14
5.65
5.64
3.94
3.93
3.92
3.89
3.88
3.87
2.84
1.00
1.06
0.99
0.96
1.00
1.03
1.03
2.93
f1 (ppm)

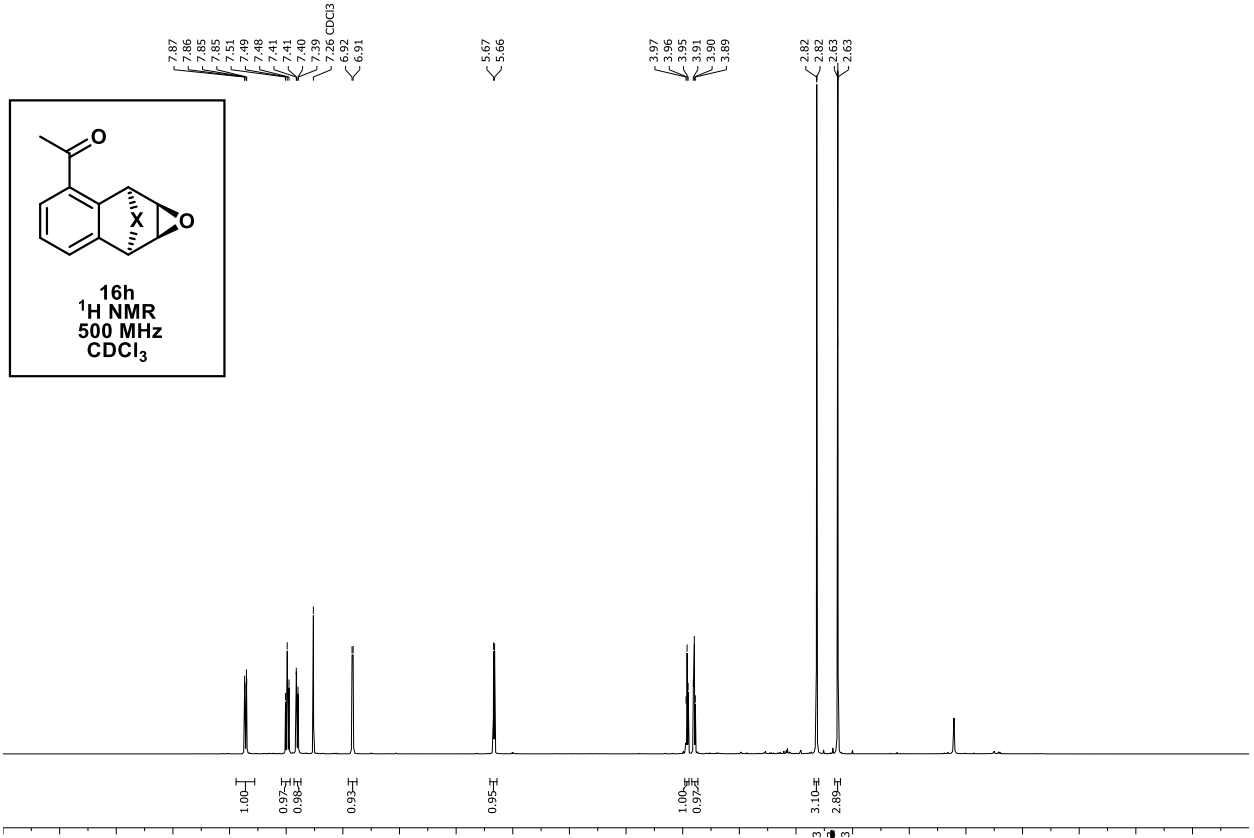

Cl
X
O
16f
1H NMR
500 MHz
CDCl3
157.01
156.91
131.70
130.71
130.32
130.30
128.20
122.94
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
57.47
54.60
44.13
44.11
25.70
f1 (ppm)

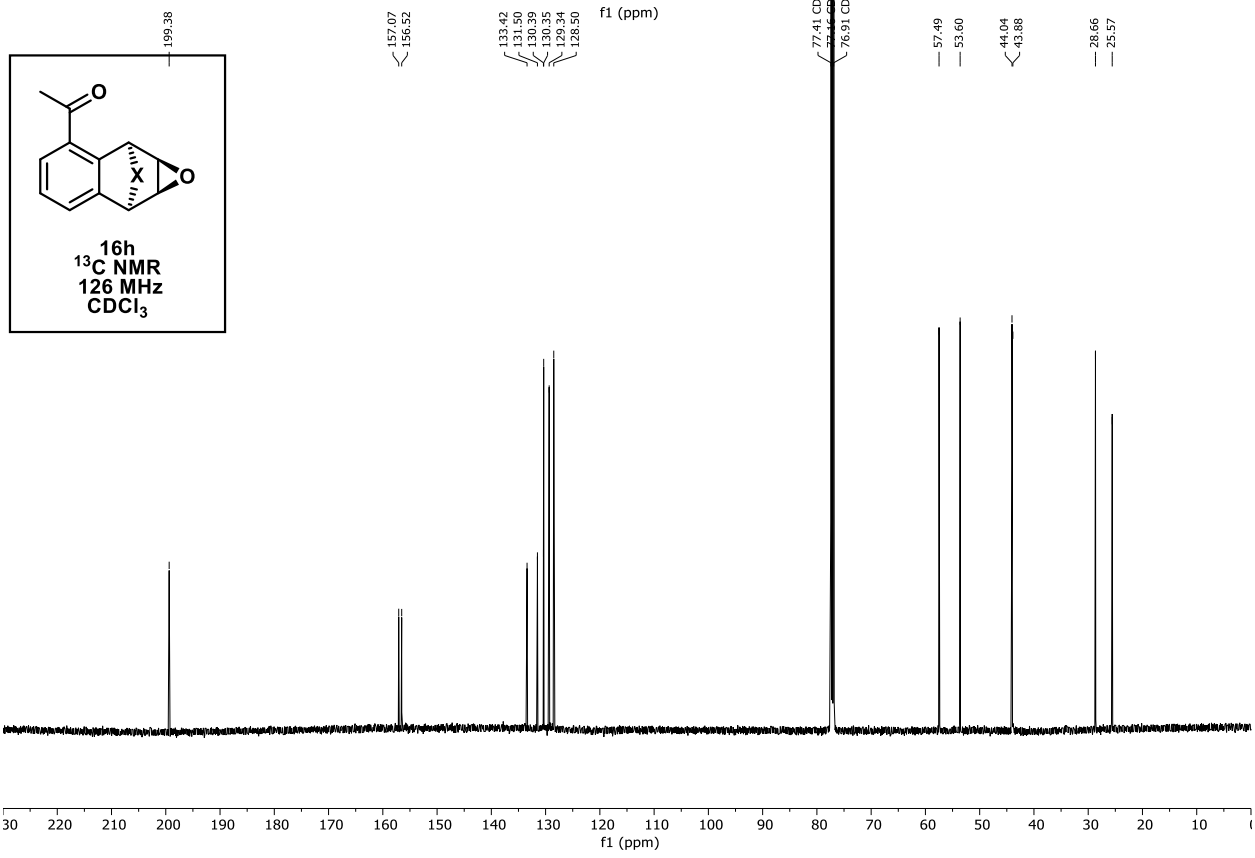

CN
X
O
16g
1H NMR
500 MHz
CDCl3
7.72
7.71
7.70
7.70
7.55
7.53
7.52
7.50
7.50
7.49
7.48
7.26 CDCl3
6.05
6.04
5.72
5.71
4.00
4.00
3.99
3.96
3.95
3.94
2.84
1.00
2.03
1.00
1.02
2.03
2.65
f1 (ppm)

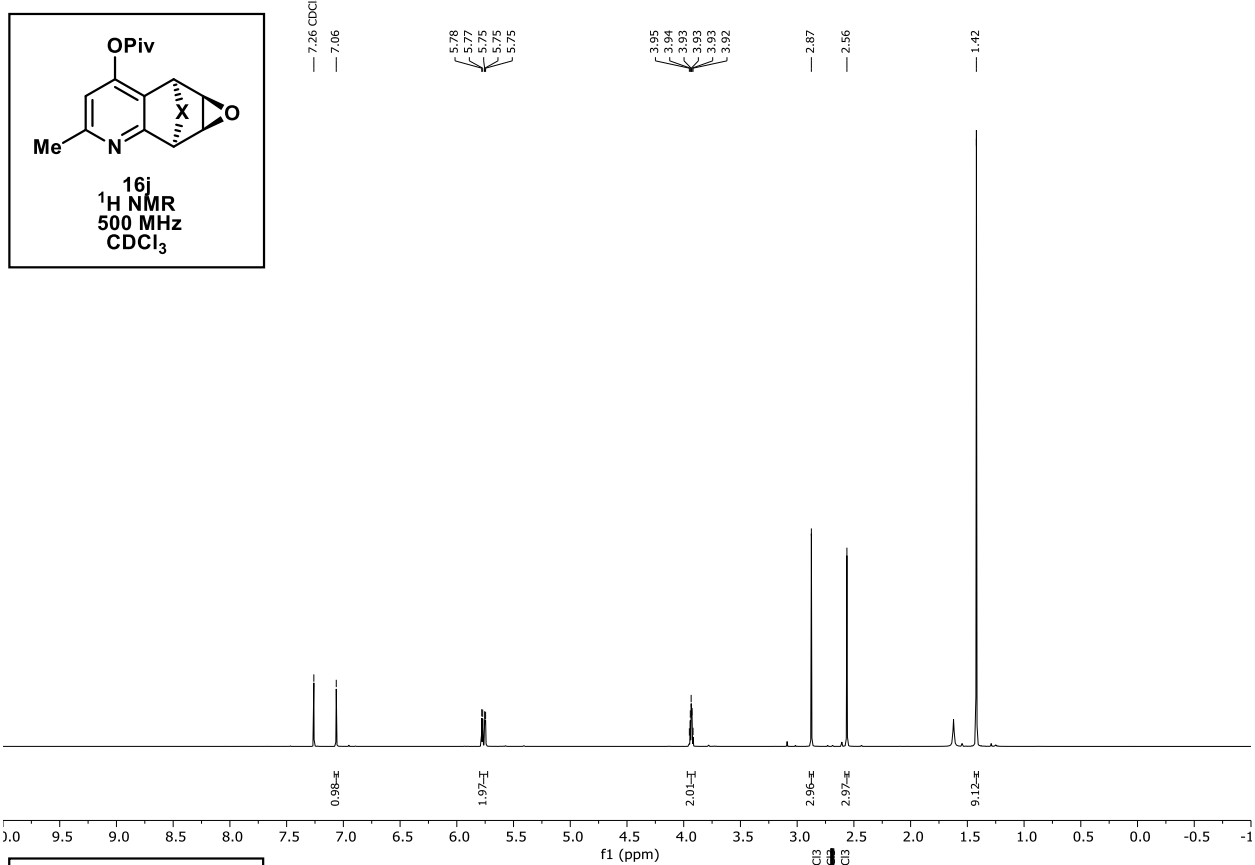
156.97
156.65
133.19
132.98
131.15
130.33
128.83
115.64
109.18
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
57.20
55.58
44.01
43.88
25.70

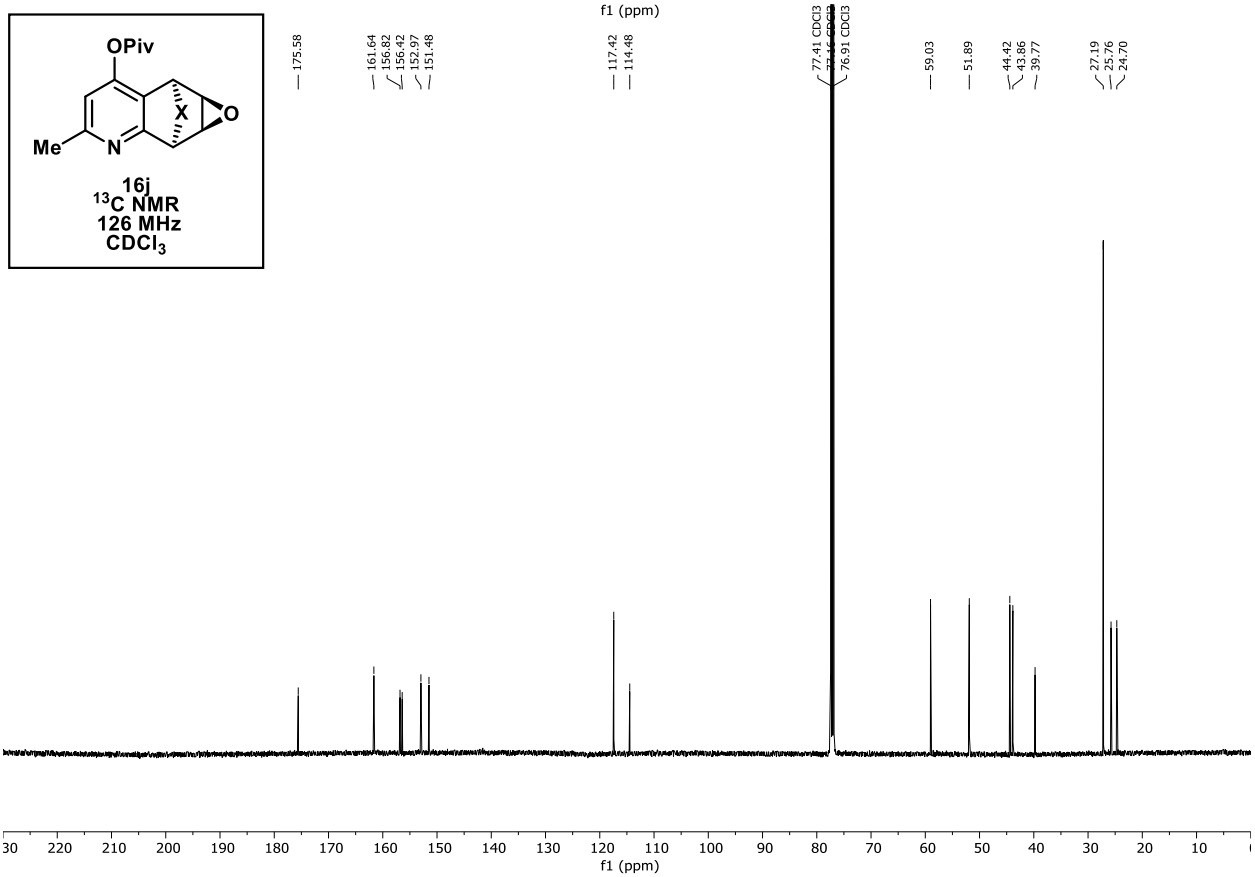

CN
X
O
16g
13C NMR
126 MHz
CDCl3

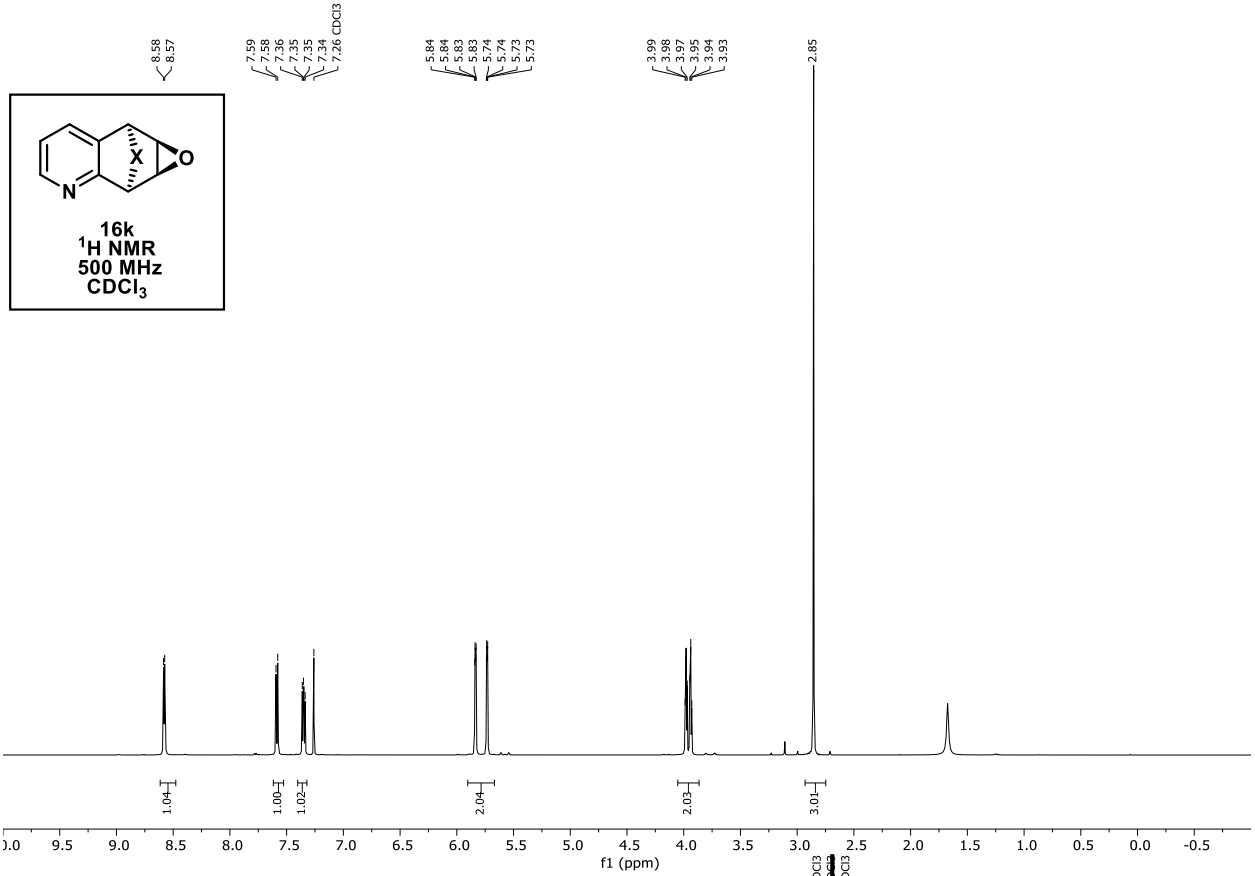

f1 (ppm)

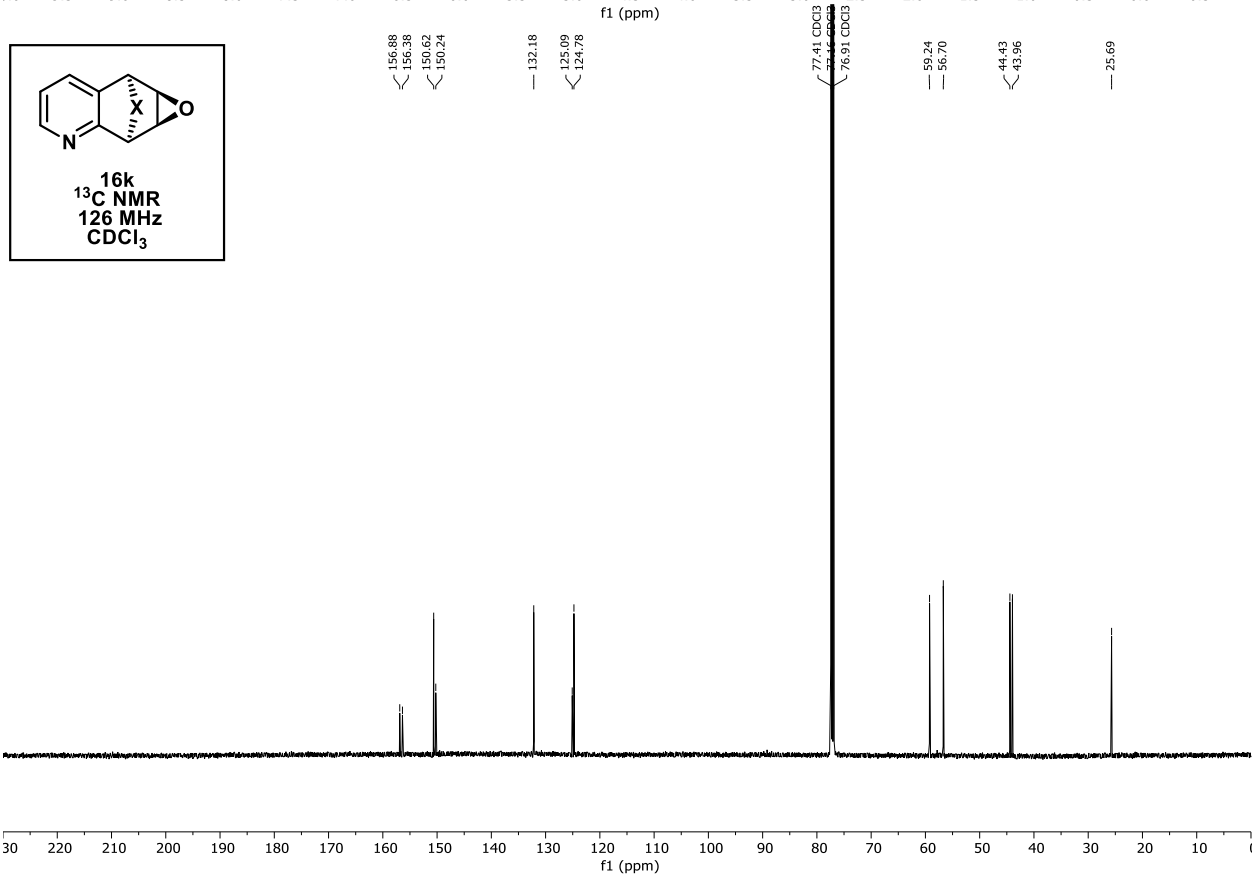

7.87
7.86
7.85
7.85
7.51
7.49
7.48
7.41
7.41
7.40
7.39
7.26 CDCl3
6.92
6.91
5.67
5.66
3.97
3.96
3.95
3.91
3.90
3.89
2.82
2.82
2.63
2.63
O
X
O
16h
1H NMR
500 MHz
CDCl3
1.00
0.97
0.98
0.93
0.95
1.00
0.97
3.10
2.89
f1 (ppm)

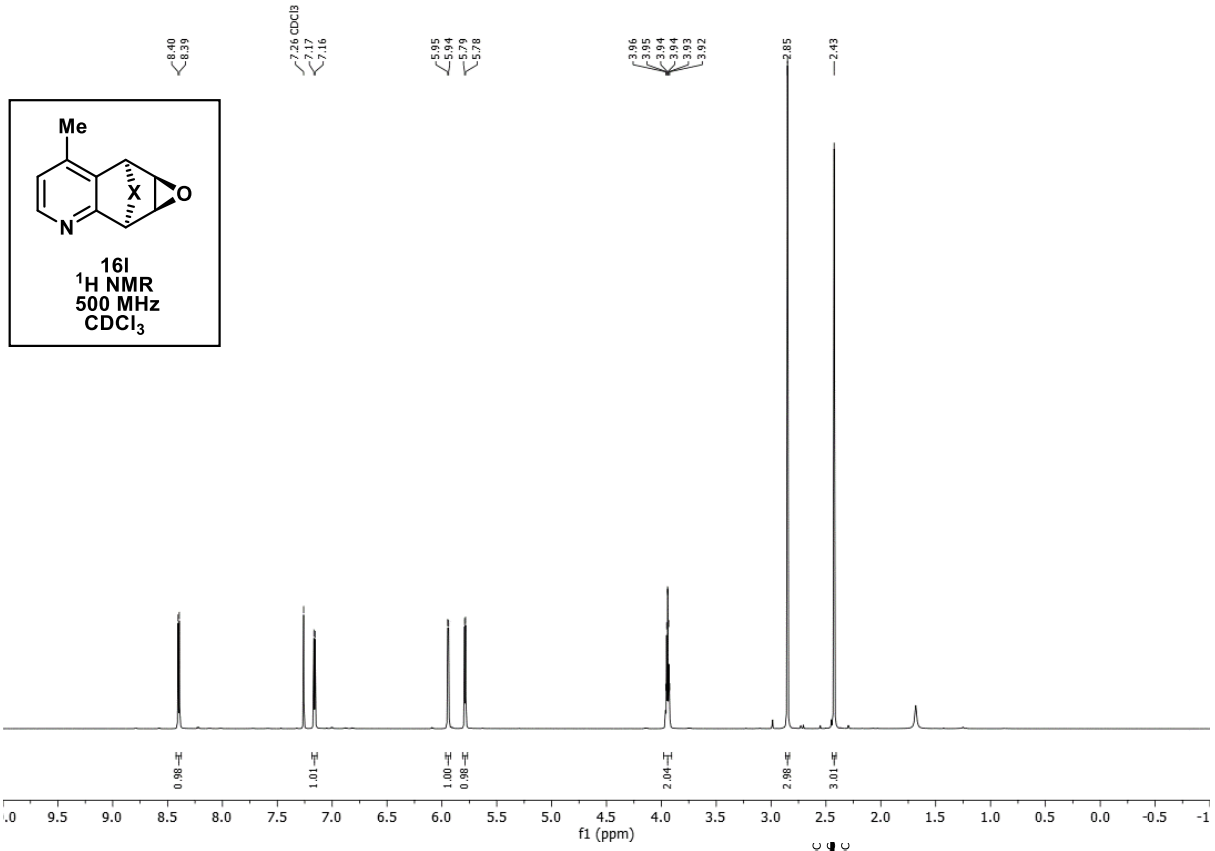

199.38
157.07
156.52
133.42
131.50
130.39
130.35
129.34
128.50
77.41 CDCl3
76.91 CDCl3
57.49
53.60
44.04
43.88
28.66
25.57
O
X
O
16h
13C NMR
126 MHz
CDCl3
f1 (ppm)

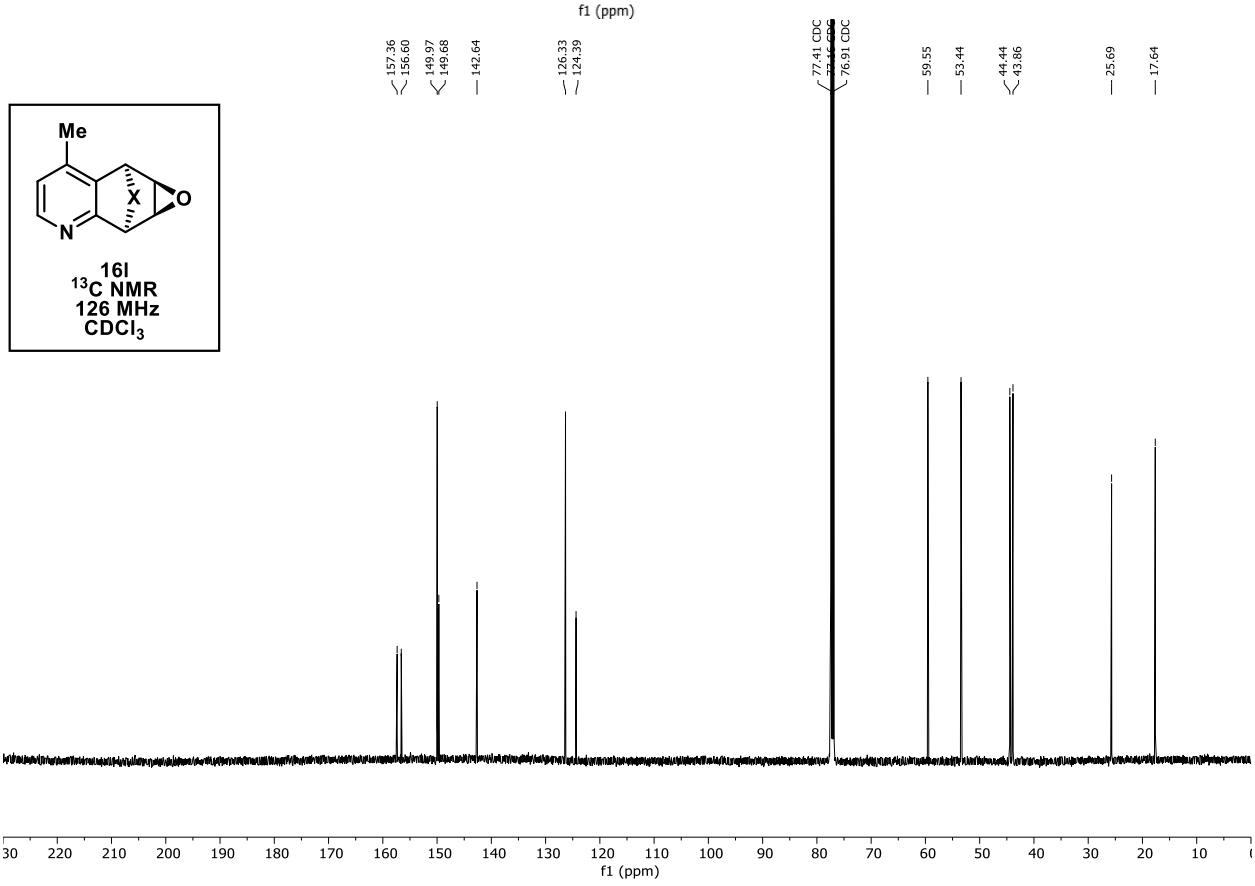

OPiv
Me
N
X
O
16j
1H NMR
500 MHz
CDCl3
7.26 CDCl3
7.06
5.78
5.77
5.75
5.75
5.75
5.75
3.95
3.94
3.93
3.93
3.93
3.92
2.87
2.56
1.42
0.98
1.97
2.01
2.96
2.97
9.12
f1 (ppm)

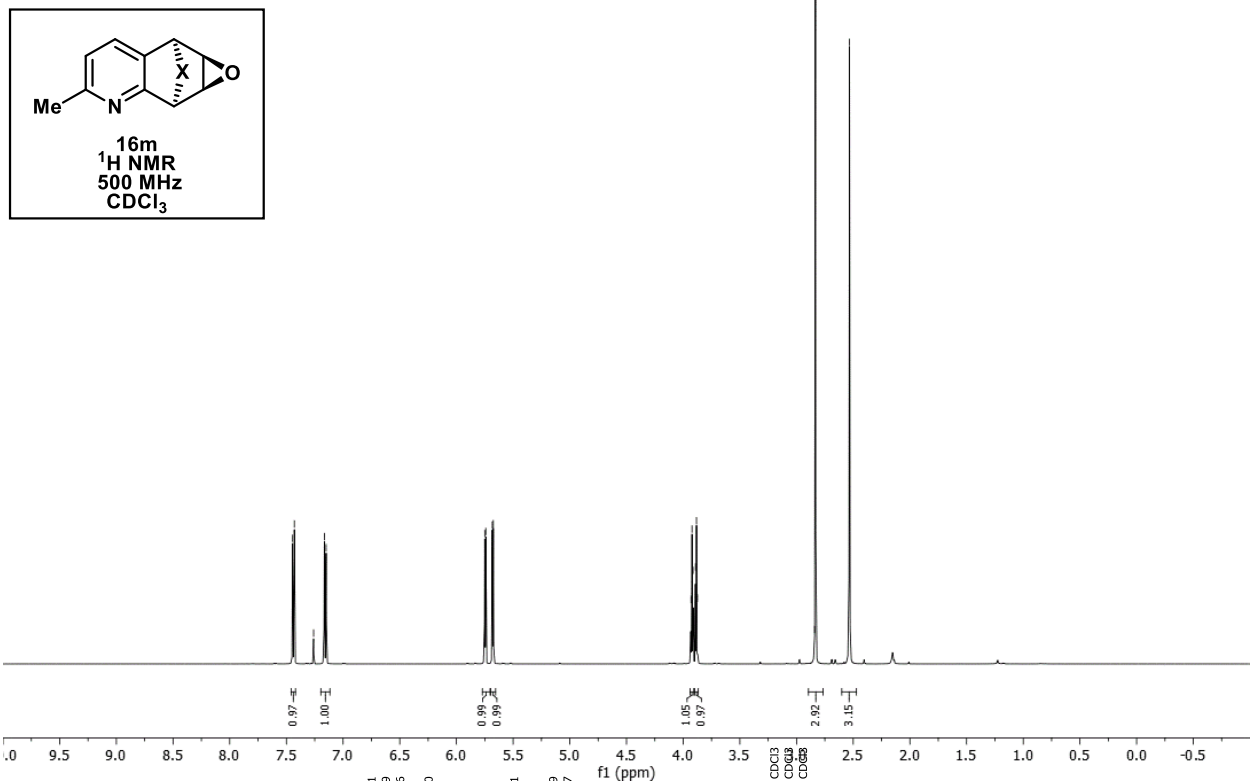

OPiv
Me
N
X
O
16j
13C NMR
126 MHz
CDCl3
175.58
161.64
156.82
156.42
152.97
151.48
117.42
114.48
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
59.03
51.89
44.42
43.86
39.77
27.19
25.76
24.70
f1 (ppm)

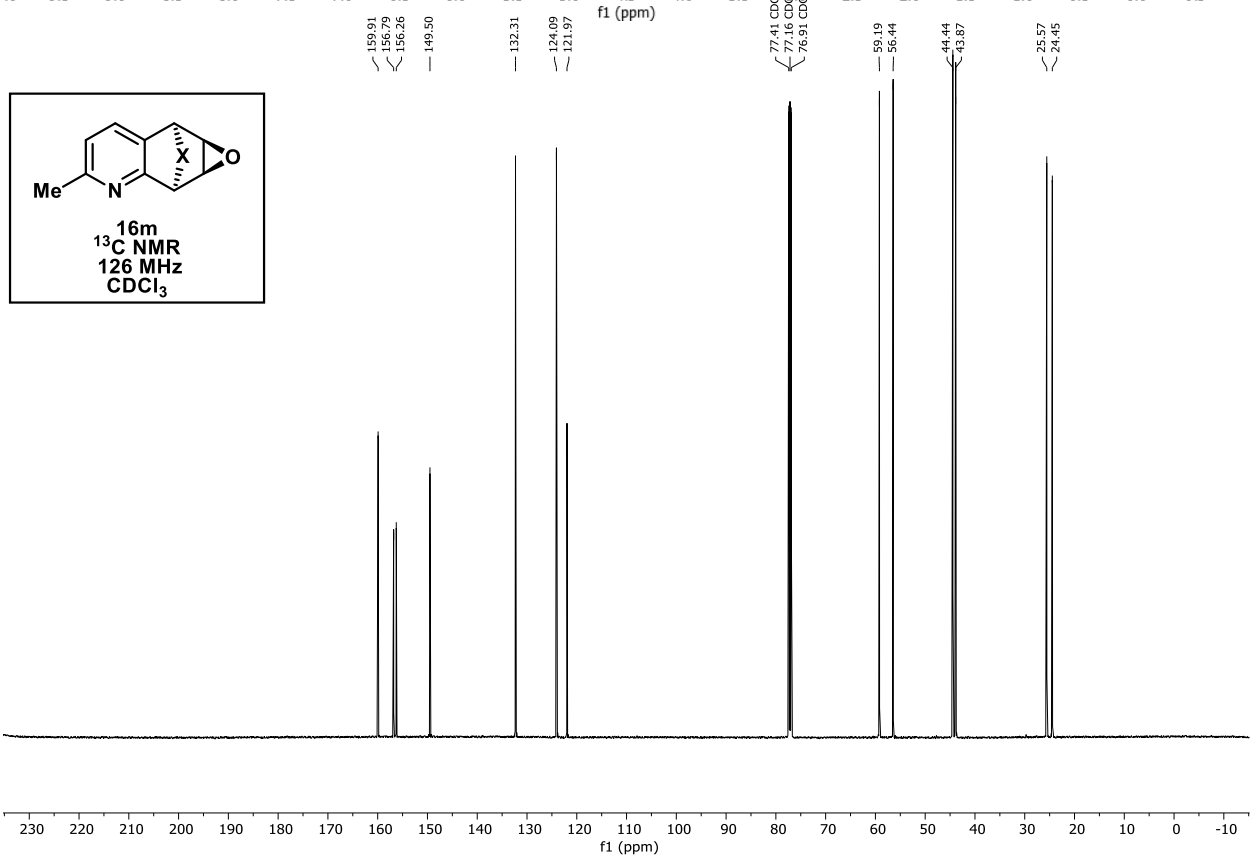

16k
1H NMR
500 MHz
CDCl3
8.58
8.57
7.59
7.58
7.36
7.35
7.35
7.34
7.26 CDCl3
5.84
5.84
5.83
5.83
5.74
5.74
5.73
5.73
3.99
3.98
3.97
3.95
3.94
3.93
2.85
1.04
1.00
1.02
2.04
2.03
3.01
f1 (ppm)

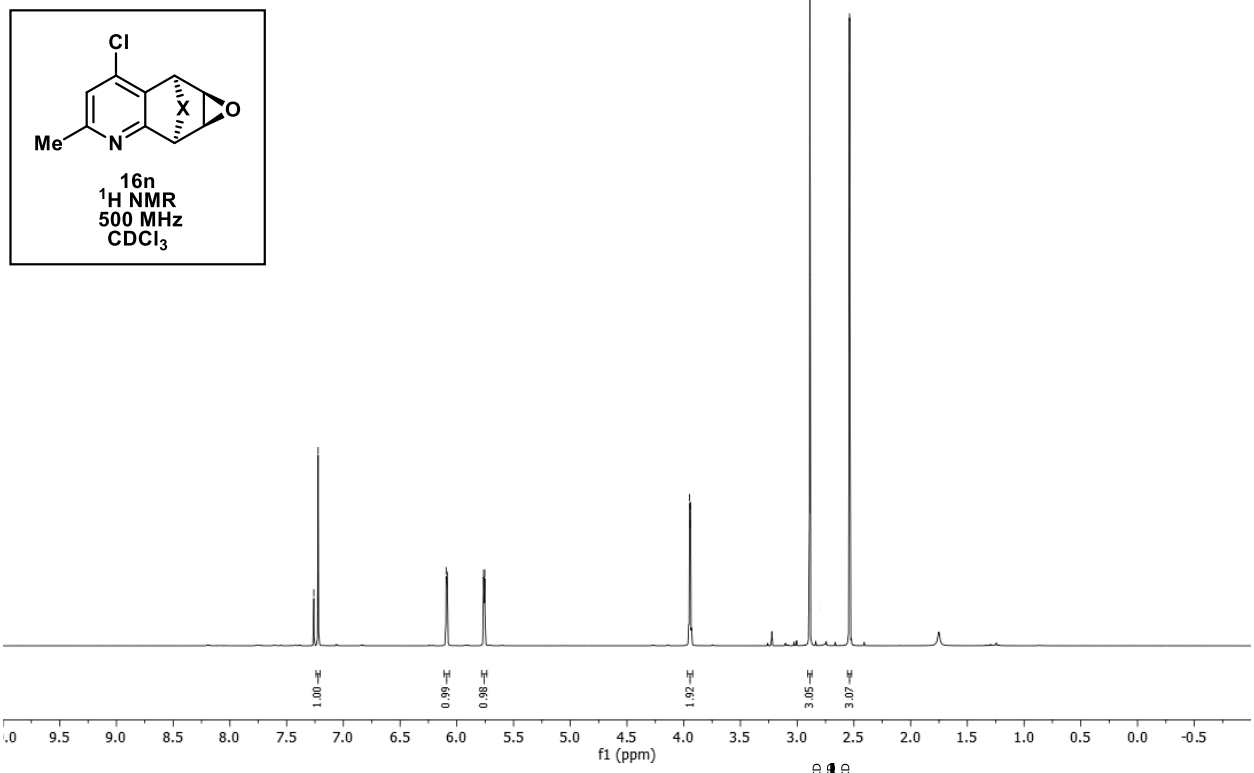

16k
13C NMR
126 MHz
CDCl3
156.88
156.38
150.62
150.24
132.18
125.09
124.78
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
59.24
56.70
44.43
43.96
25.69
f1 (ppm)

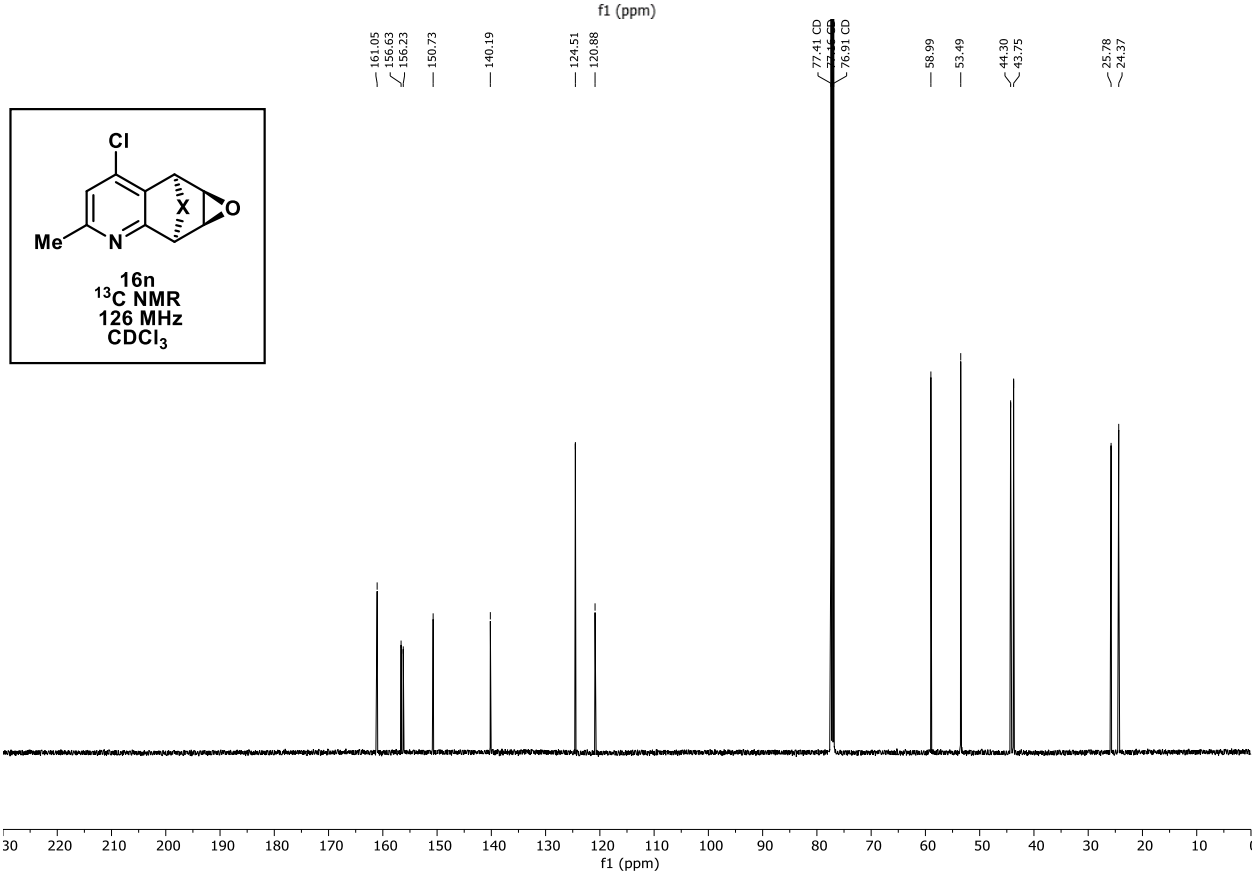

Me
X
O
N
16l
1H NMR
500 MHz
CDCl3
8.40
8.39
7.26 CDCl3
7.17
7.16
5.95
5.94
5.79
5.78
3.96
3.95
3.94
3.94
3.93
3.92
2.85
2.43
0.98
1.01
1.00
0.98
2.04
2.98
3.01
f1 (ppm)

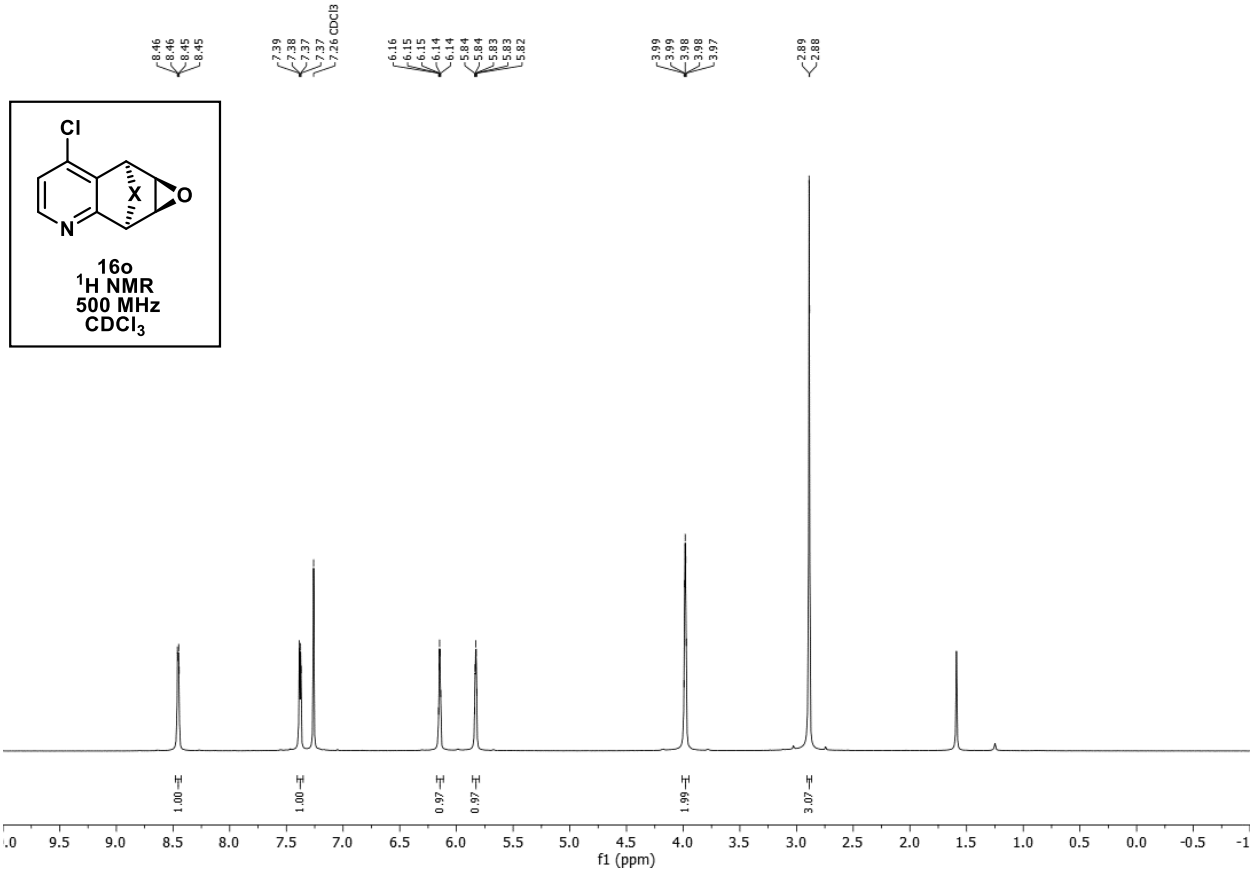

Me
X
O
N
16l
13C NMR
126 MHz
CDCl3
157.36
156.60
149.97
149.68
142.64
126.33
124.39
77.41 CDC
76.91 CDC
59.55
53.44
44.44
43.86
25.69
17.64
f1 (ppm)

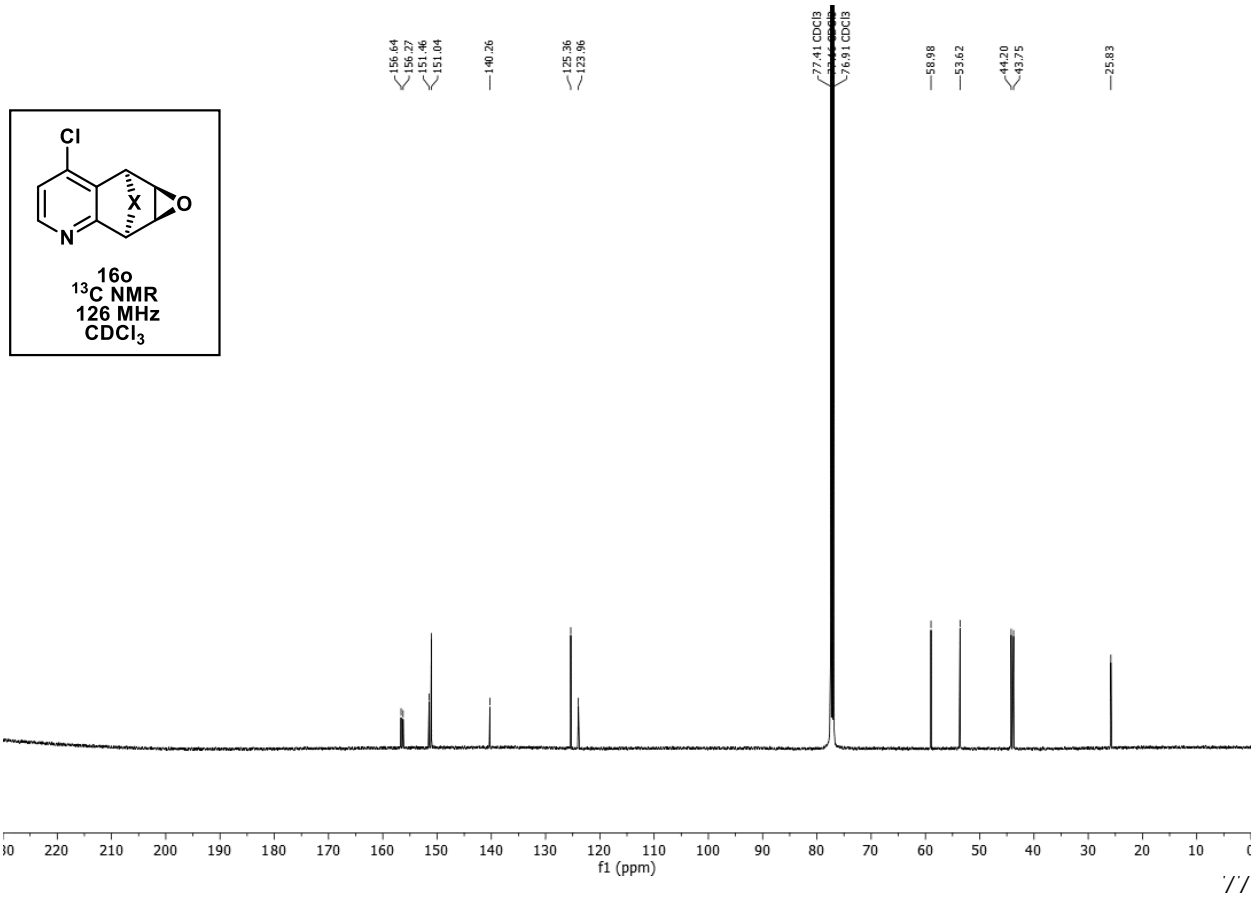

Me
N
X
O
16m
1H NMR
500 MHz
CDCl3
7.45
7.43
7.26 CDCl3
7.17
7.15
5.75
5.74
5.68
5.67
3.93
3.92
3.91
3.89
3.88
3.87
2.84
2.83
2.53
0.97
1.00
0.99
0.99
1.05
0.97
2.92
3.15
f1 (ppm)

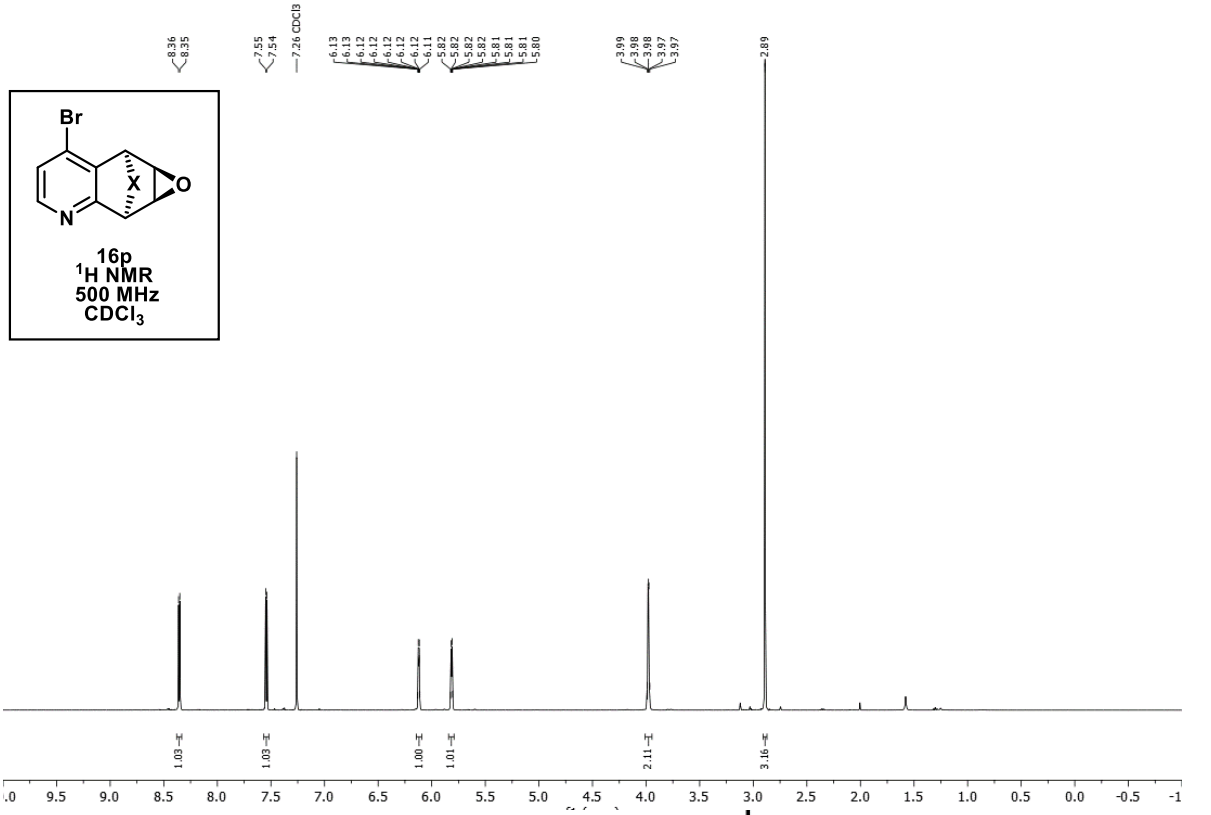

Me
N
X
O
16m
13C NMR
126 MHz
CDCl3
159.91
156.79
156.26
149.50
132.31
124.09
121.97
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
59.19
56.44
44.44
43.87
25.57
24.45
f1 (ppm)


Cl
X
O
Me
N
16n
1H NMR
500 MHz
CDCl3
7.26 CDCl3
7.22
6.09
6.09
6.08
5.76
5.76
5.75
3.95
3.94
3.94
2.89
2.54
1.00
0.99
0.98
1.92
3.05
3.07
f1 (ppm)


Cl
X
O
Me
N
16n
13C NMR
126 MHz
CDCl3
161.05
156.63
156.23
150.73
140.19
124.51
120.88
77.41 CD
76.91 CD
58.99
53.49
44.30
43.75
25.78
24.37
f1 (ppm)


8.46
8.46
8.45
8.45
7.39
7.38
7.37
7.37
7.26 CDCl3
6.16
6.15
6.15
6.14
6.14
5.84
5.84
5.83
5.83
5.82
3.99
3.99
3.98
3.98
3.97
2.89
2.88
Cl
X
O
N
16o
1H NMR
500 MHz
CDCl3
1.00
1.00
0.97
0.97
1.99
3.07
f1 (ppm)


156.64
156.27
151.46
151.04
140.26
125.36
123.96
77.41 CDCl3
76.91 CDCl3
58.98
53.62
44.20
43.75
25.83
Cl
X
O
N
16o
13C NMR
126 MHz
CDCl3
f1 (ppm)


Br
X
O
N
16p
^{1}H NMR
500 MHz
$CDCl_3$
8.36
8.35
7.55
7.54
7.26 CDCl3
6.13
6.13
6.12
6.12
6.12
6.12
6.12
6.12
6.11
5.82
5.82
5.82
5.82
5.81
5.81
5.81
5.80
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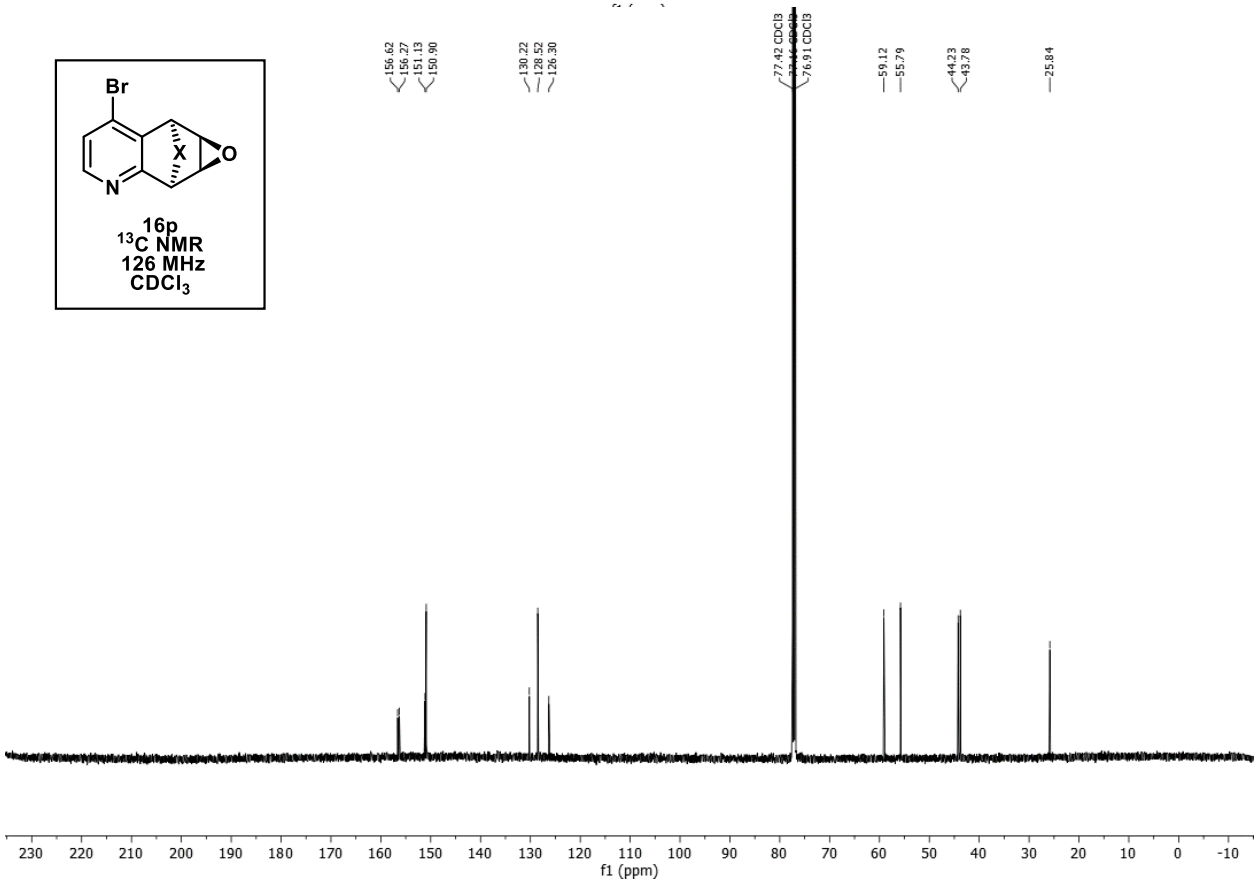
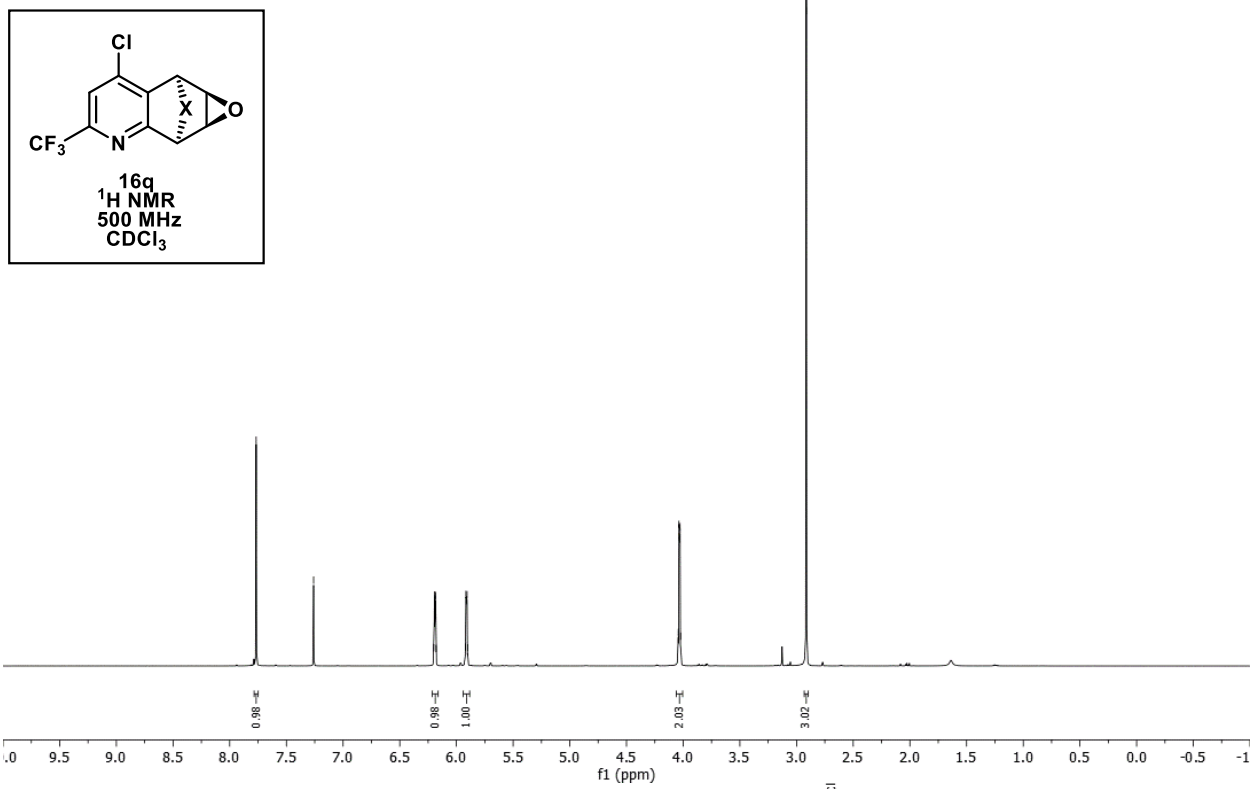
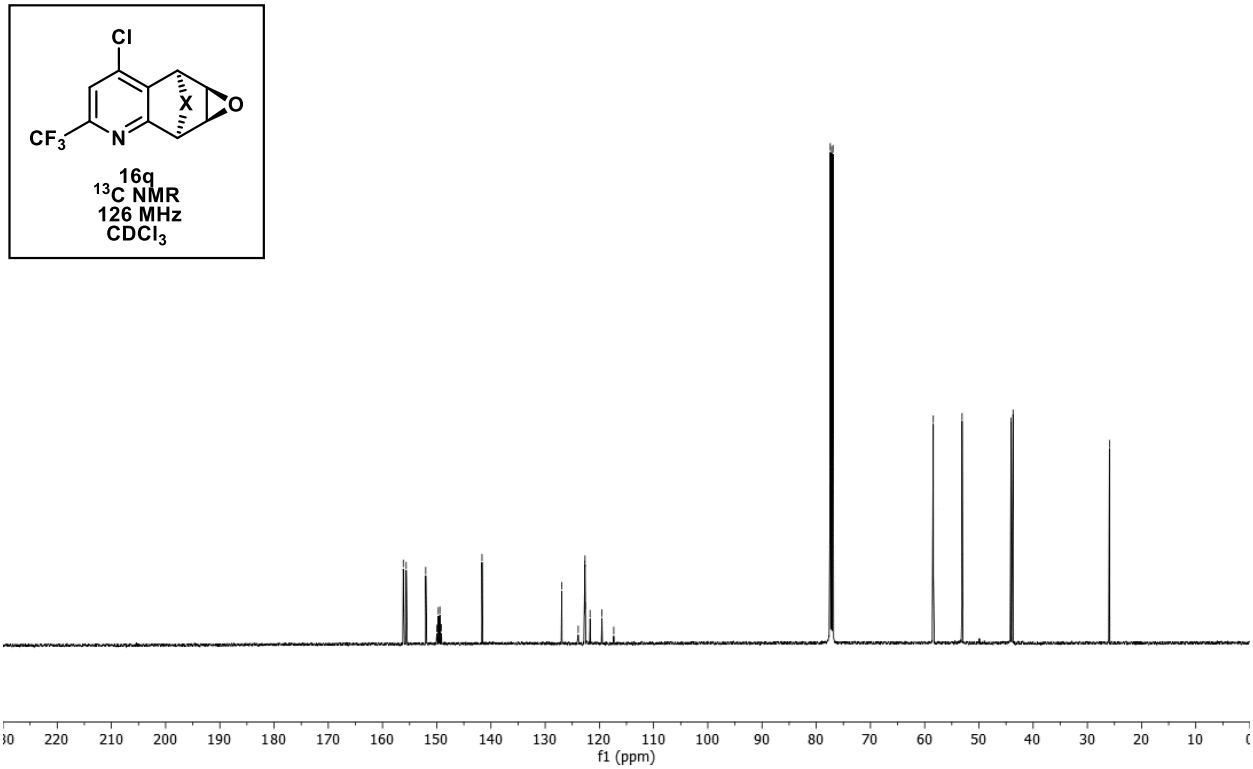
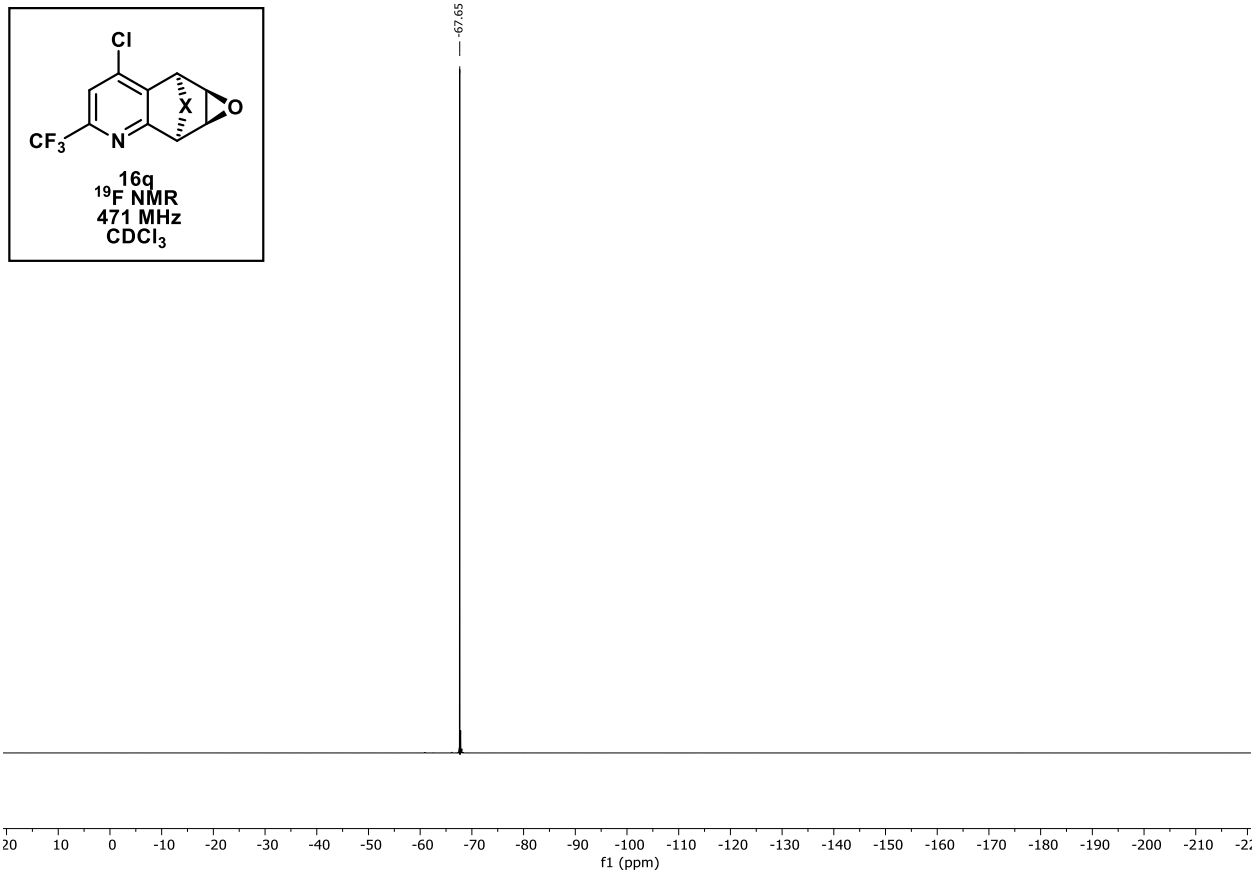
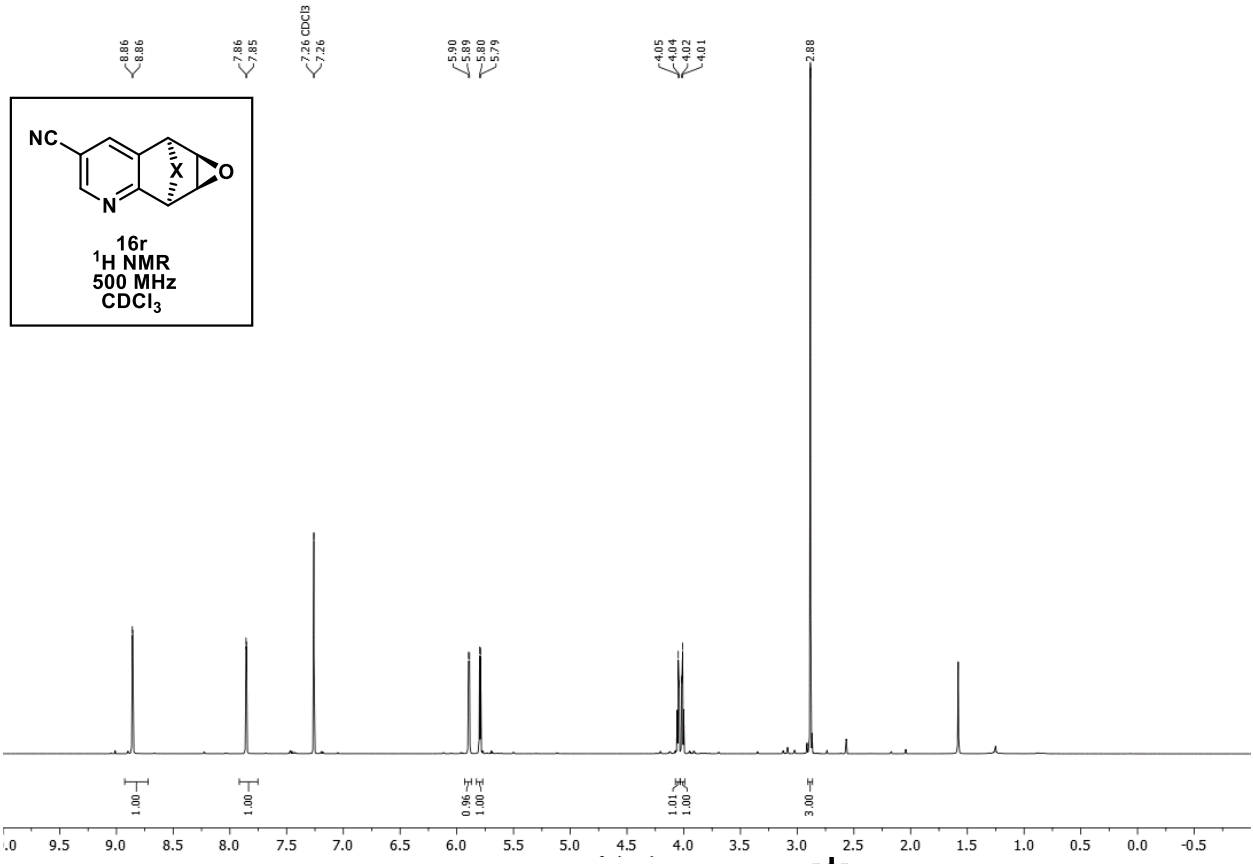
1.03
1.03
1.00
1.01
2.11
3.16

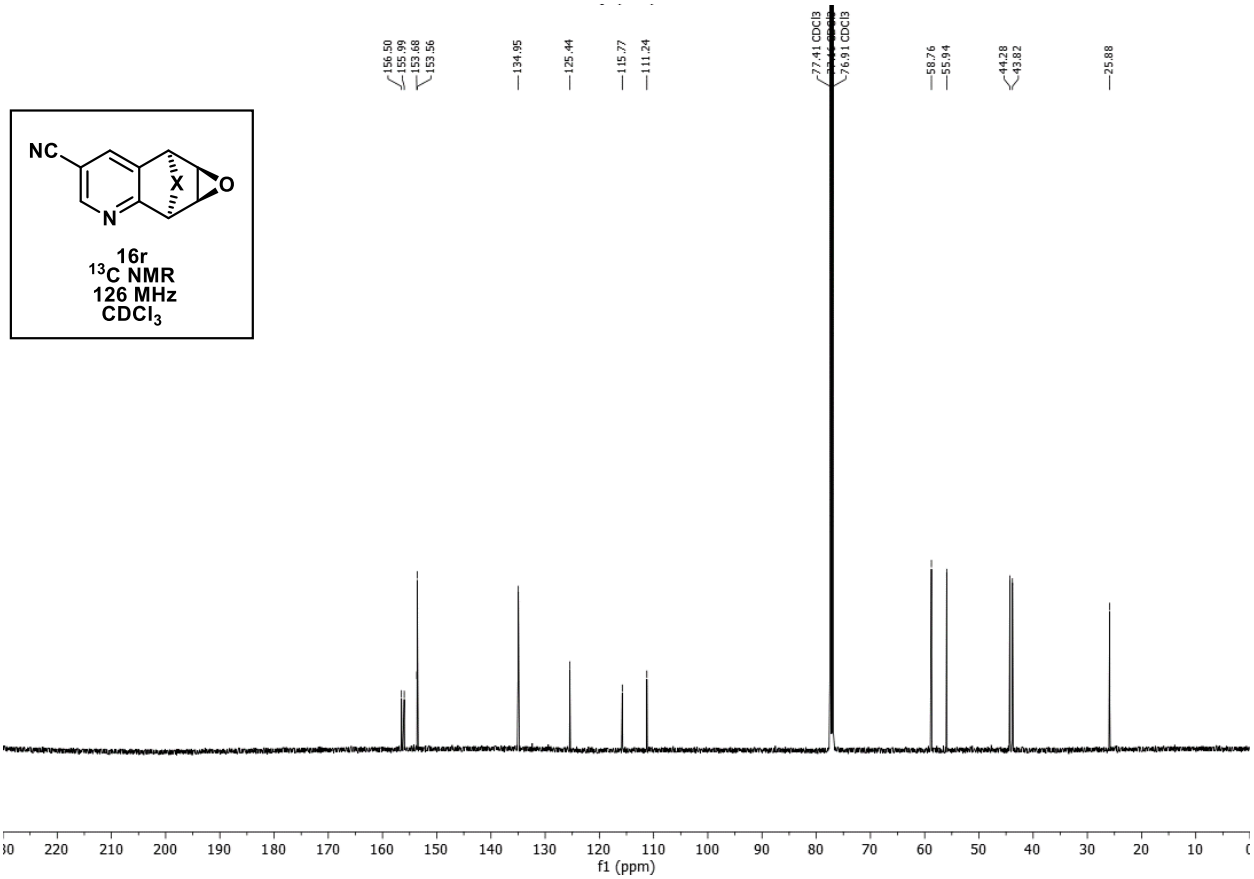

Br
X
O
N
16p
^{13}C NMR
126 MHz
$CDCl_3$
156.62
156.27
151.13
150.90
130.22
128.52
126.30
77.42 CDCl3
76.91 CDCl3
59.12
55.79
44.23
43.78
25.84
f1 (ppm)

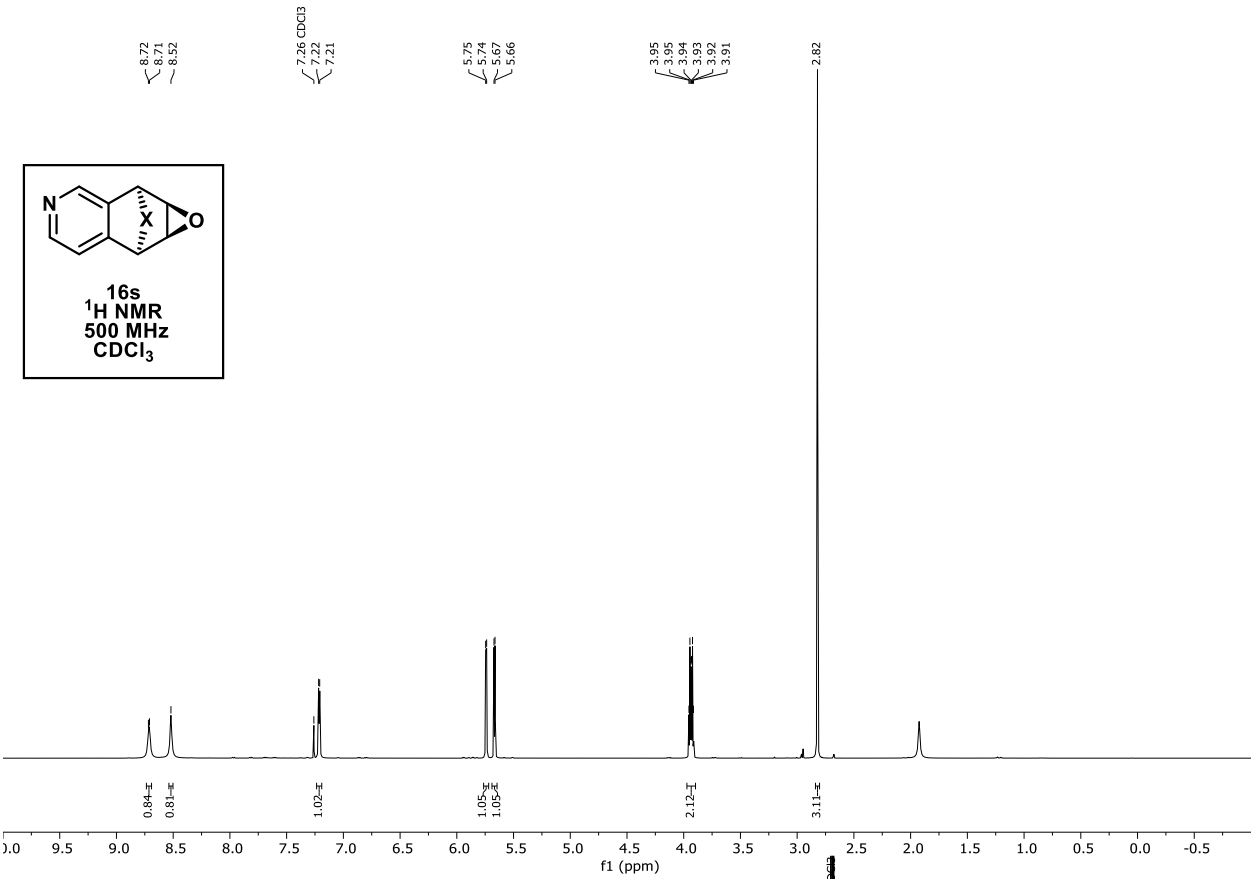

Cl
X
O
CF3
N
16q
1H NMR
500 MHz
CDCl3
7.77
7.26 CDCl3
6.20
6.19
6.19
6.19
6.18
6.18
5.92
5.92
5.91
5.91
5.91
5.90
4.04
4.04
4.03
4.03
4.03
4.02
2.91
0.98
0.98
1.00
2.03
3.02
f1 (ppm)

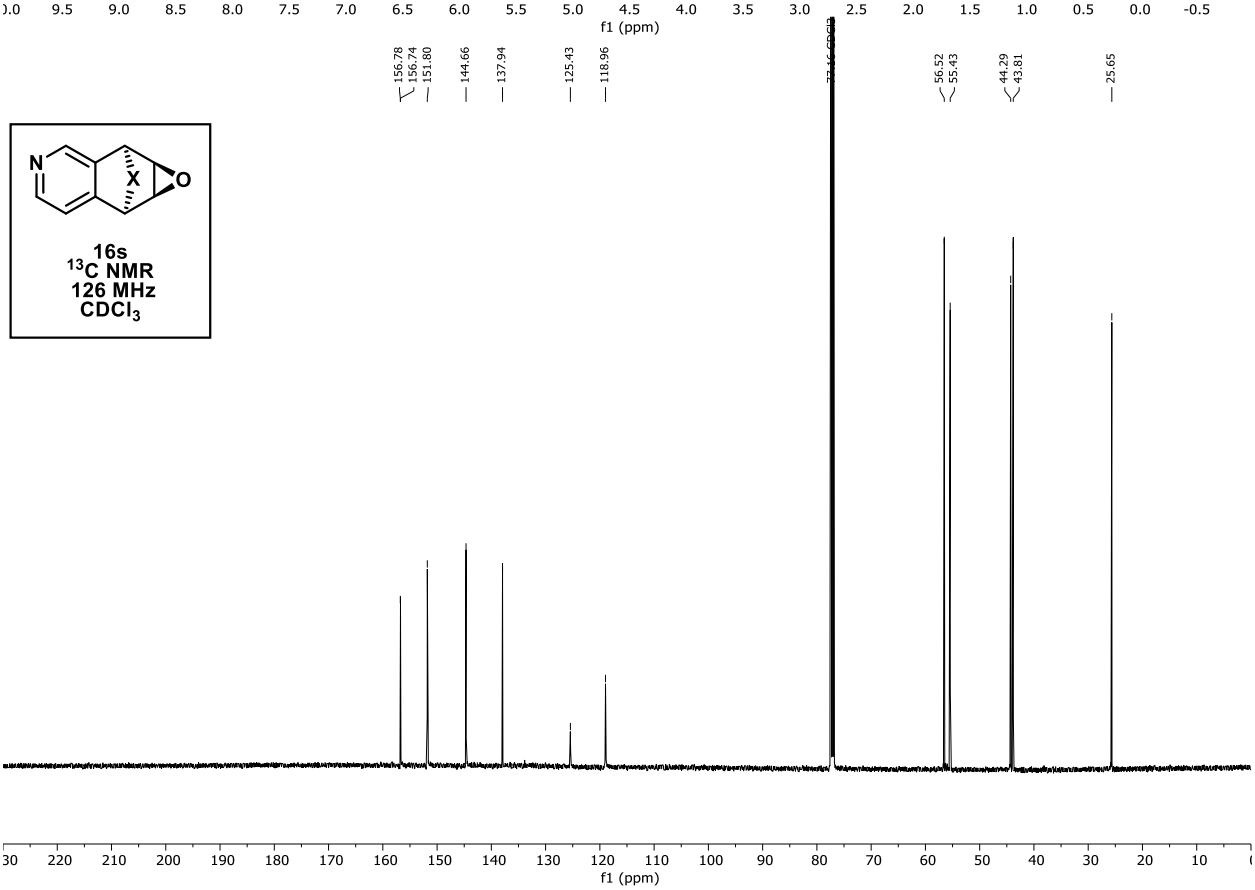

Cl
X
O
CF3
N
16q
13C NMR
126 MHz
CDCl3
156.16
155.64
152.03
149.99
149.70
149.42
149.13
141.65
126.94
123.90
122.70
122.68
122.65
122.63
121.72
119.53
117.35
77.41
77.16 CDCl
76.91
58.41
53.10
44.05
43.69
25.92
f1 (ppm)

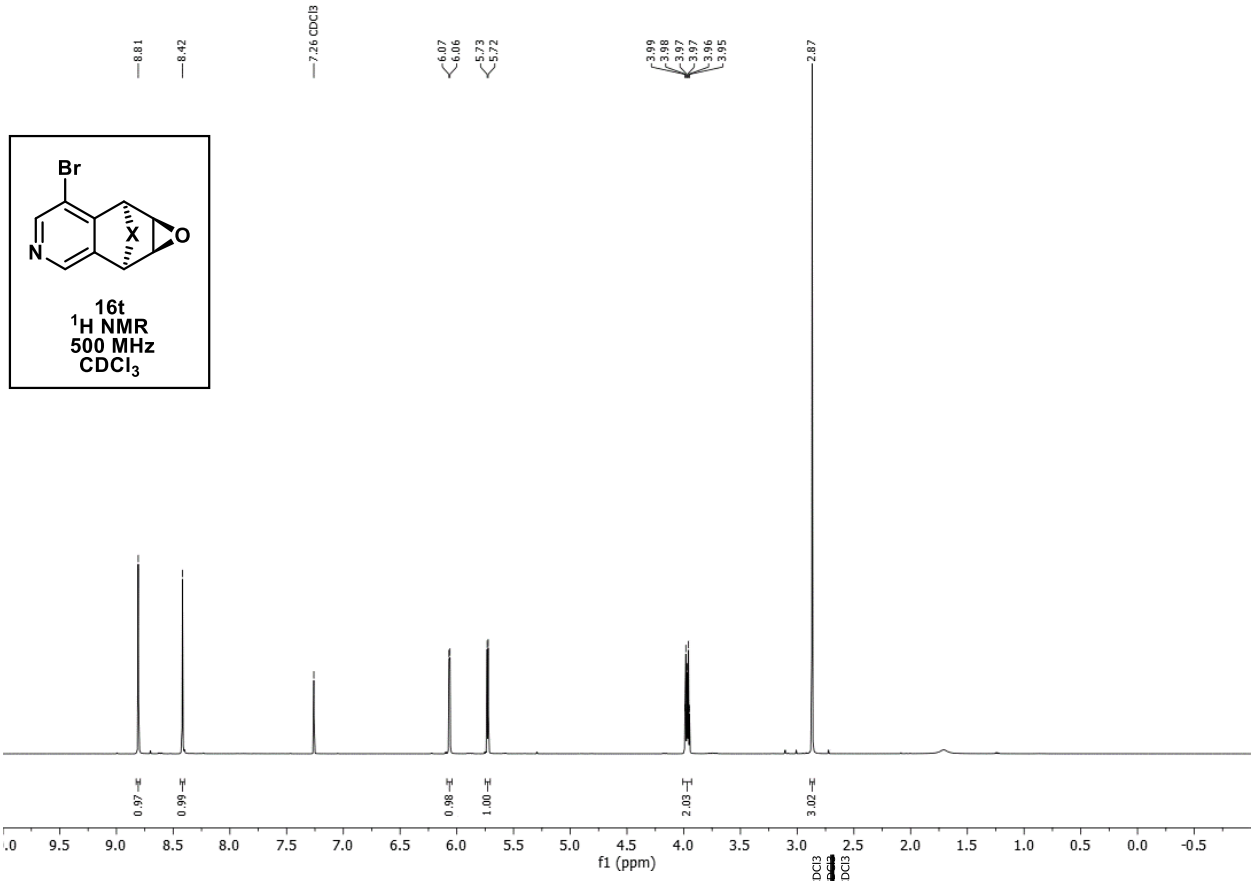

Cl
X
O
CF3
N
16q
19F NMR
471 MHz
CDCl3
-67.63
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

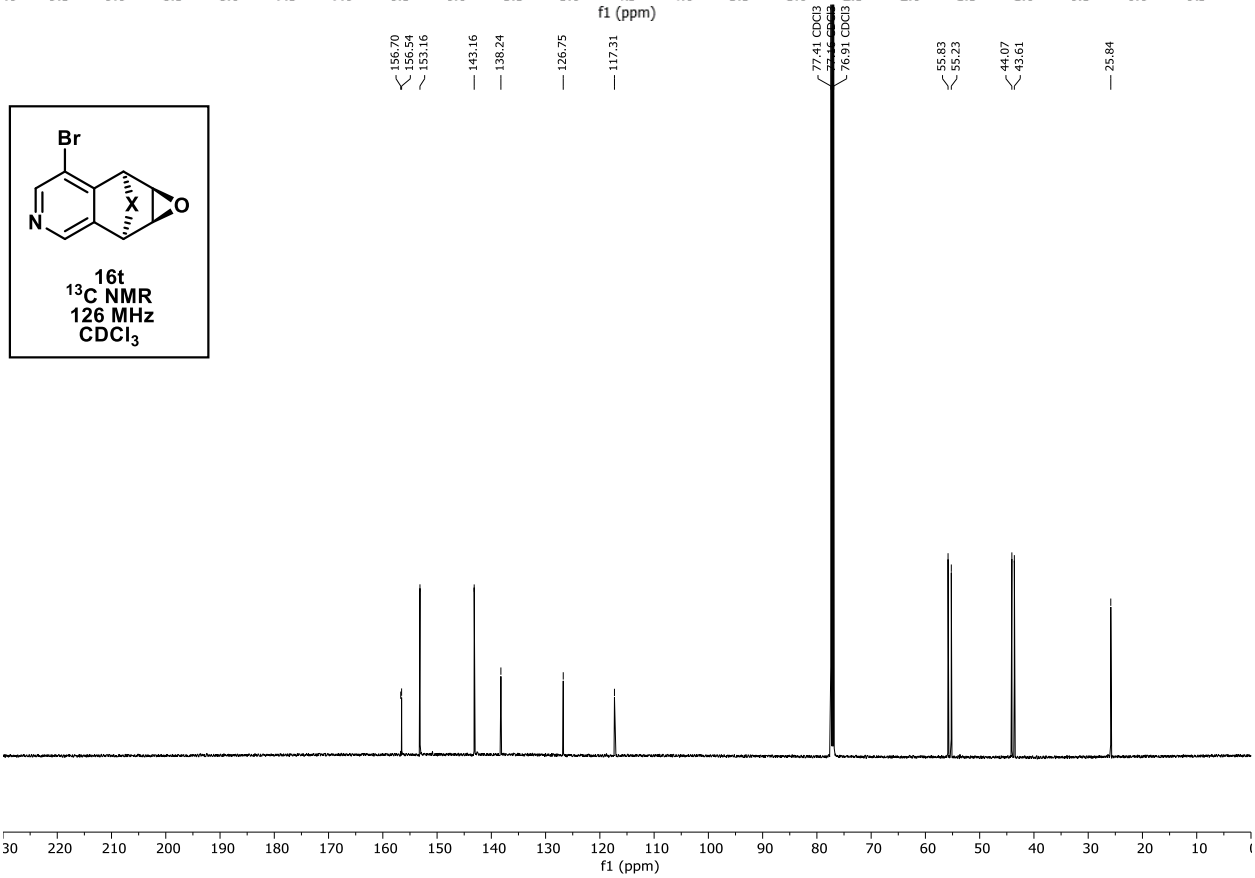

8.86
8.86
7.86
7.85
7.26 CDCl3
7.26
5.90
5.89
5.80
5.79
4.05
4.04
4.02
4.01
2.88
NC
X
O
N
16r
1H NMR
500 MHz
CDCl3
1.00
1.00
0.96
1.00
1.01
1.00
3.00
f1 (ppm)

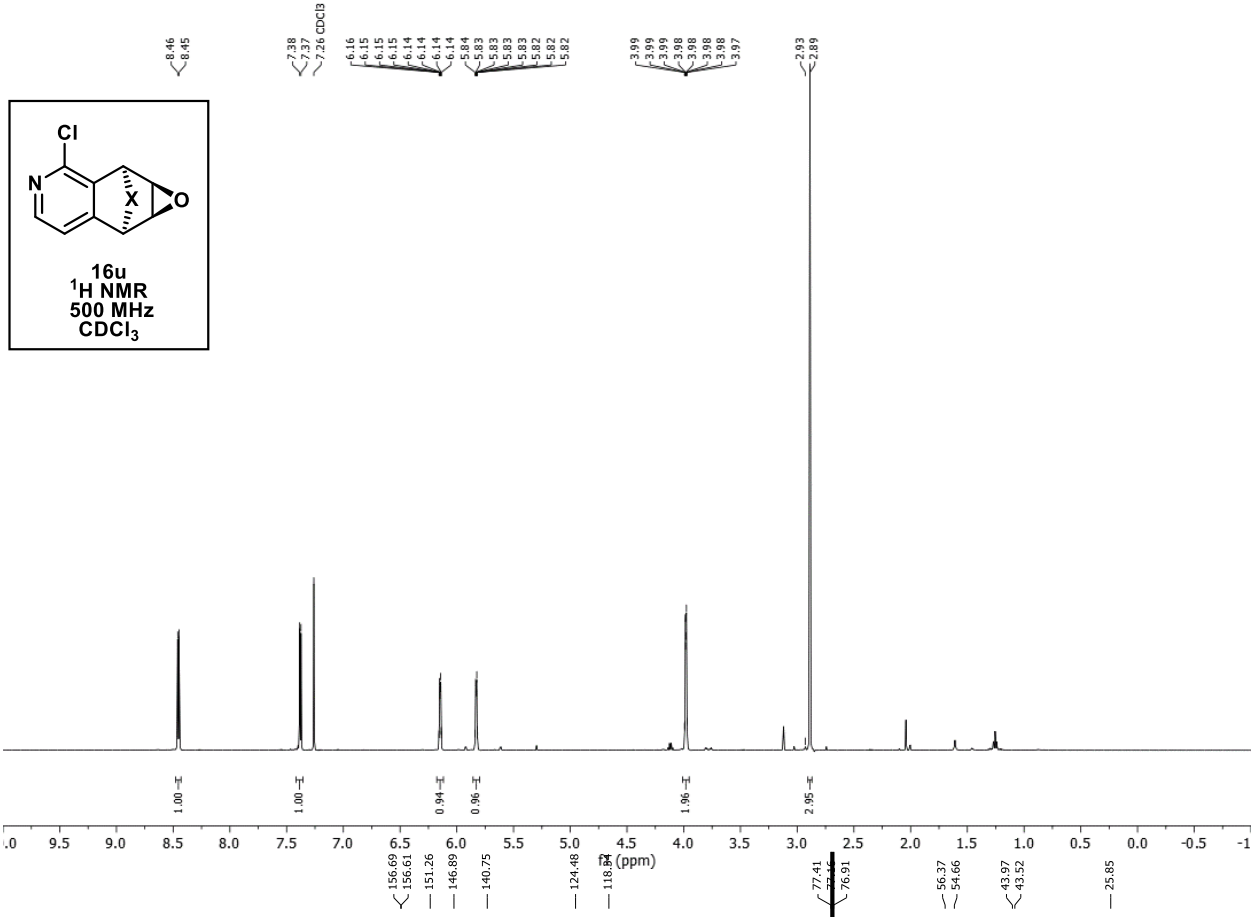

156.50
155.99
153.68
153.56
134.95
125.44
115.77
111.24
77.41 CDCl3
76.91 CDCl3
58.76
55.94
44.28
43.82
25.88
NC
X
O
N
16r
13C NMR
126 MHz
CDCl3
f1 (ppm)

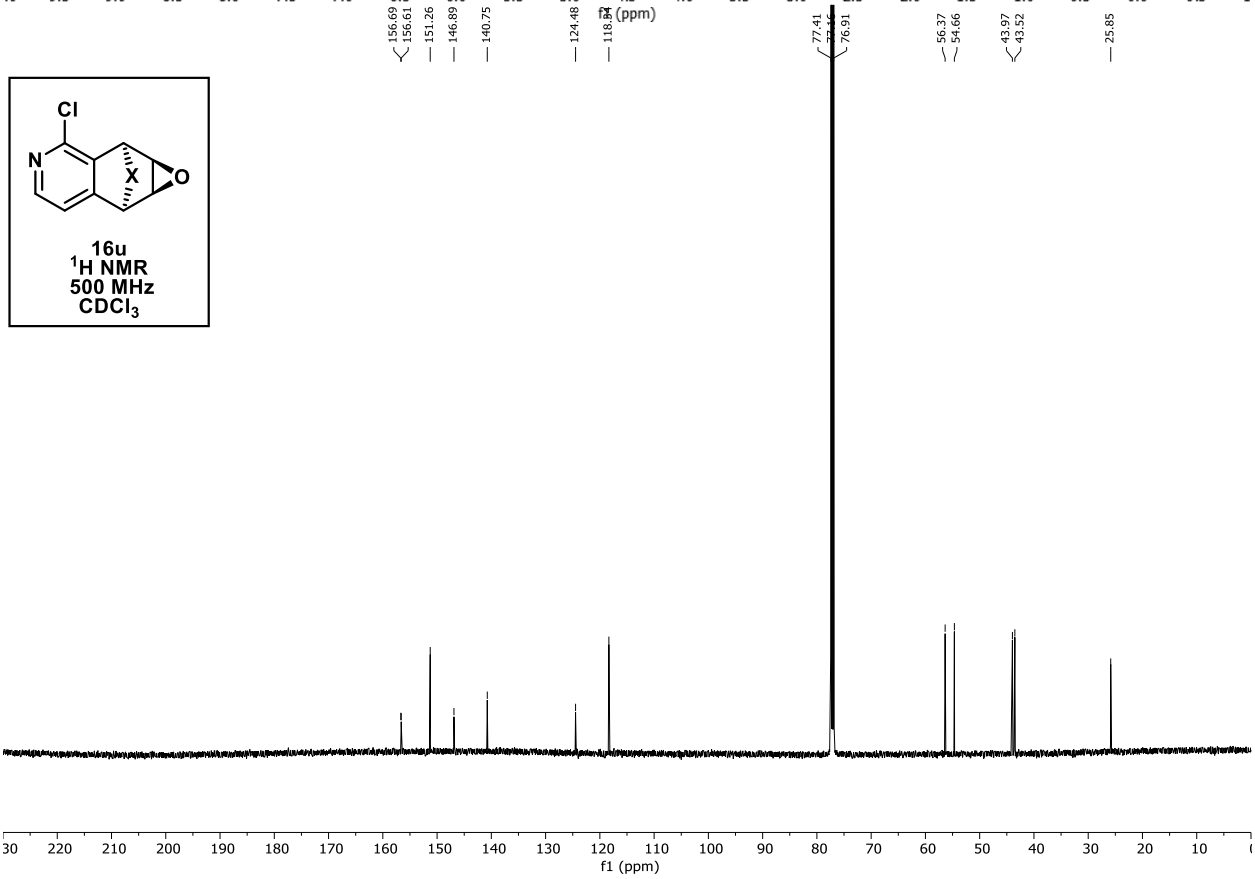

8.72
8.71
8.52
7.26 CDCl3
7.22
7.21
5.75
5.74
5.67
5.66
3.95
3.95
3.94
3.93
3.92
3.91
2.82
N
X
O
16s
1H NMR
500 MHz
CDCl3
0.84
0.81
1.02
1.05
1.05
2.12
3.11
f1 (ppm)

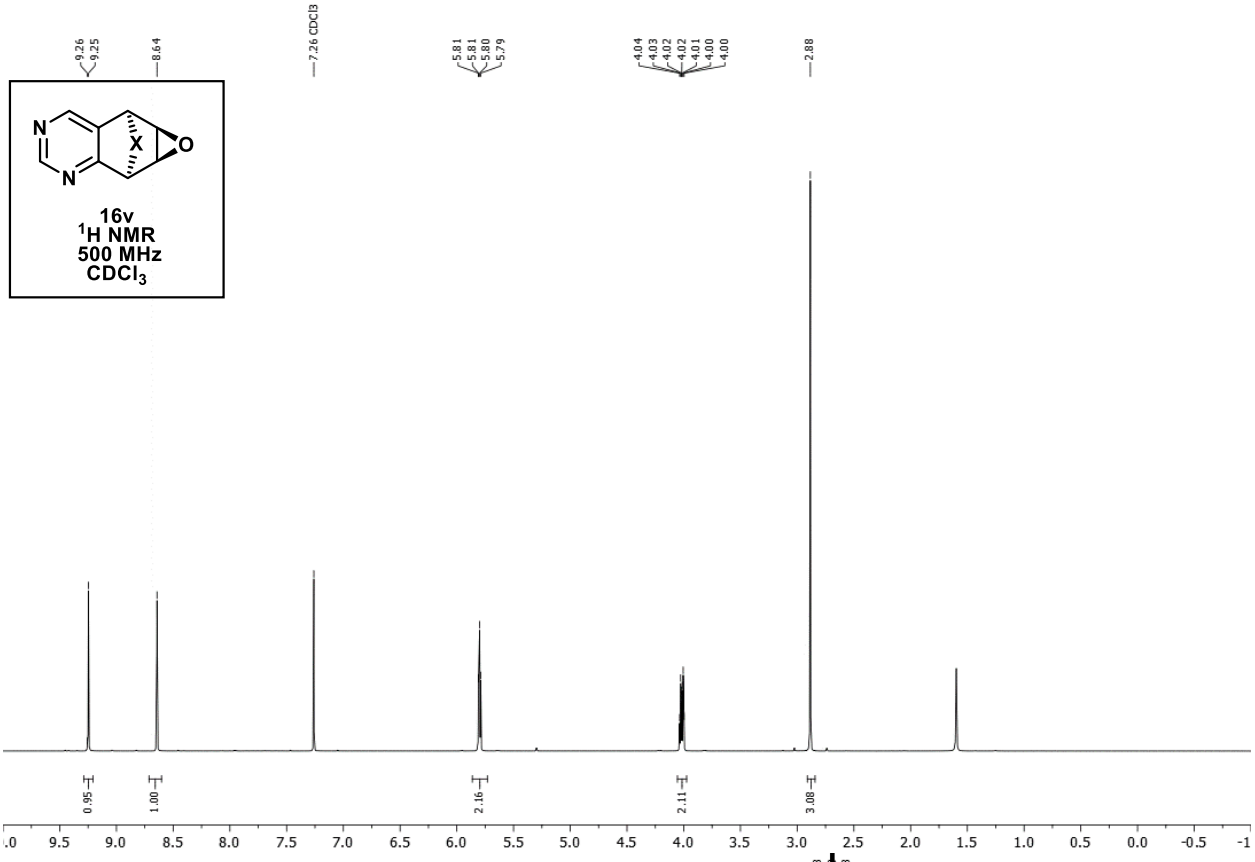

156.78
156.74
151.80
144.66
137.94
125.43
118.96
77.16 CDCl3
56.52
55.43
44.29
43.81
25.65
N
X
O
16s
13C NMR
126 MHz
CDCl3
f1 (ppm)

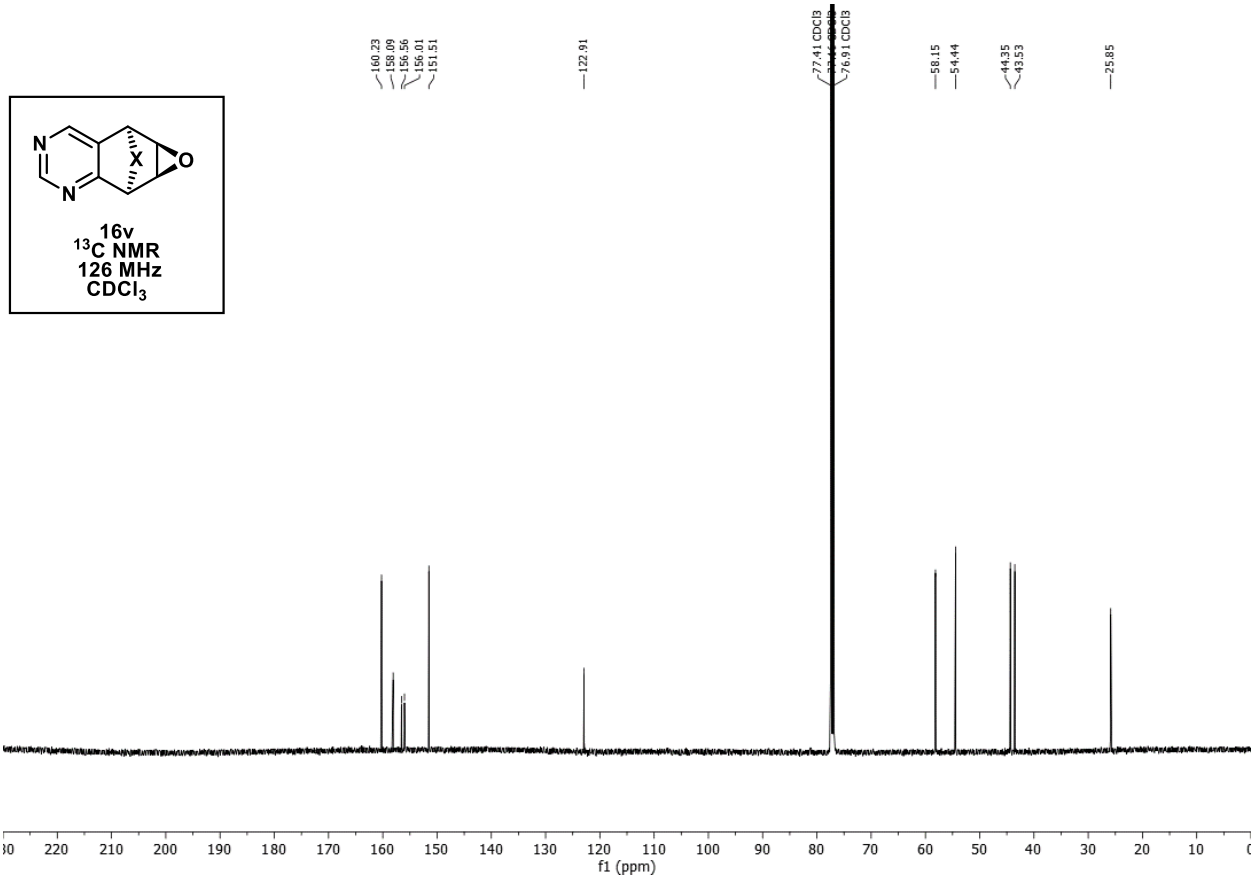

8.81
8.42
7.26 CDCl3
6.07
6.06
5.73
5.72
3.99
3.98
3.97
3.97
3.97
3.96
3.95
2.87
Br
X
O
N
16t
1H NMR
500 MHz
CDCl3
0.97
0.99
0.98
1.00
2.03
3.02
f1 (ppm)

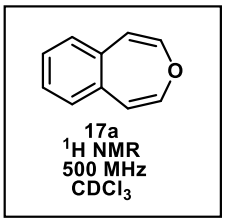

156.70
156.54
153.16
143.16
138.24
126.75
117.31
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
55.83
55.23
44.07
43.61
25.84
Br
X
O
N
16t
13C NMR
126 MHz
CDCl3
f1 (ppm)


Cl
N
X
O
16u
1H NMR
500 MHz
CDCl3
8.46
8.45
7.38
7.37
7.26 CDCl3
6.16
6.15
6.15
6.15
6.14
6.14
6.14
6.14
5.84
5.83
5.83
5.83
5.83
5.82
5.82
5.82
3.99
3.99
3.99
3.98
3.98
3.98
3.98
3.97
2.93
2.89
1.00
1.00
0.94
0.96
1.96
2.95
f2 (ppm)

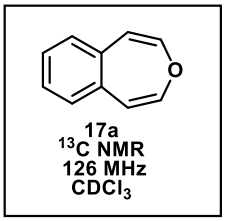

Cl
N
X
O
16u
1H NMR
500 MHz
CDCl3
156.69
156.61
151.26
146.89
140.75
124.48
118.84
77.41
77.16
76.91
56.37
54.66
43.97
43.52
25.85
f1 (ppm)


9.26
9.25
8.64
7.26 CDCl3
5.81
5.81
5.80
5.79
4.04
4.03
4.02
4.02
4.01
4.00
4.00
2.88
16v
1H NMR
500 MHz
CDCl3
0.95
1.00
2.16
2.11
3.08

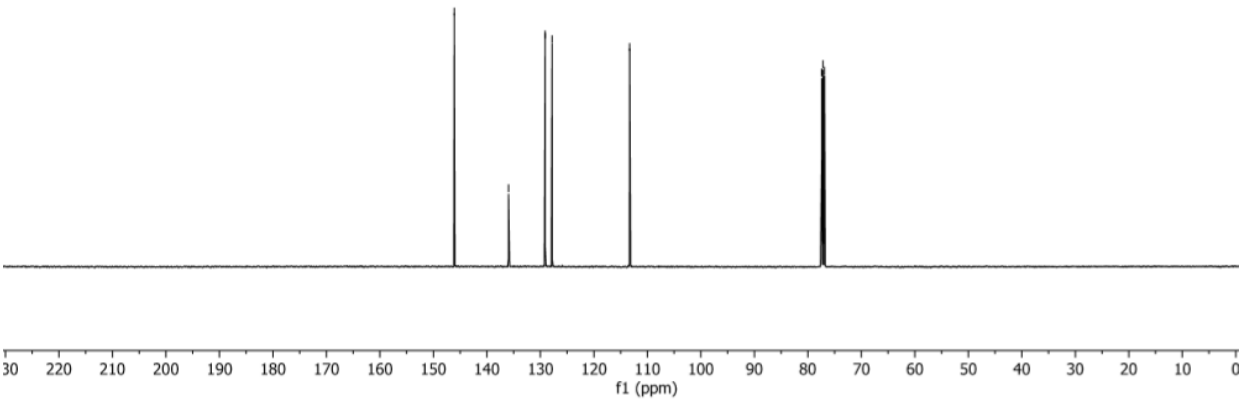

160.23
158.09
156.56
156.01
151.51
122.91
77.41 CDCl3
76.91 CDCl3
58.15
54.44
44.35
43.53
25.85
16v
13C NMR
126 MHz
CDCl3
f1 (ppm)

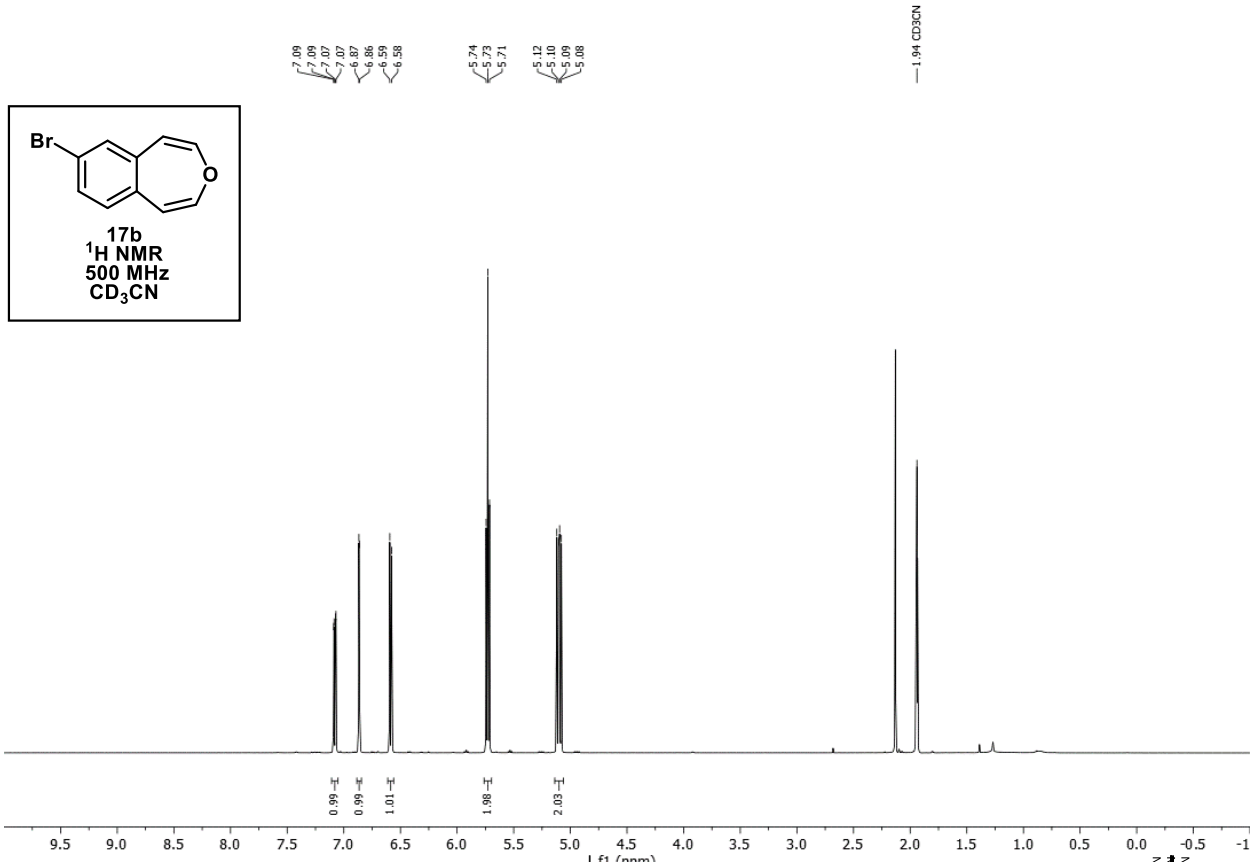


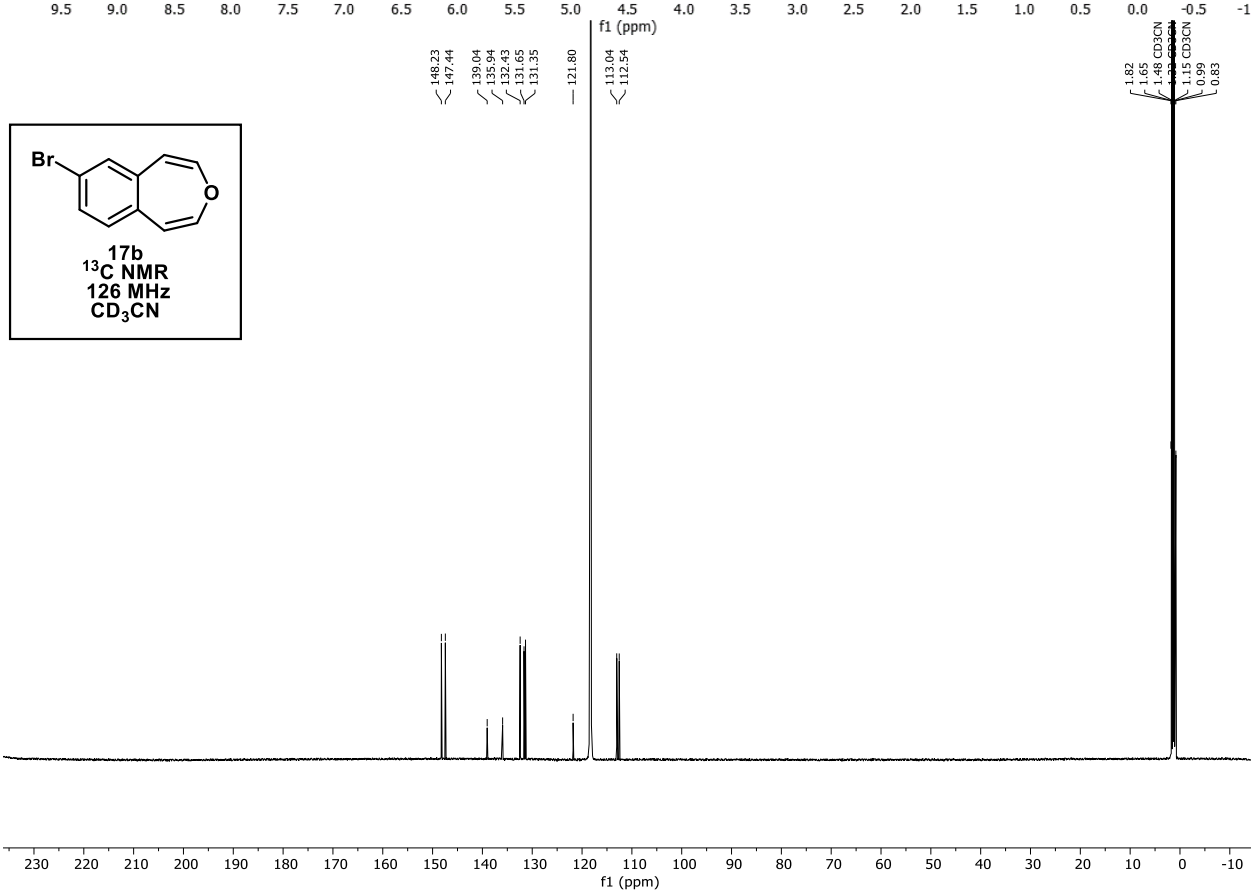
17a
^{1}H NMR
500 MHz
$CDCl_3$

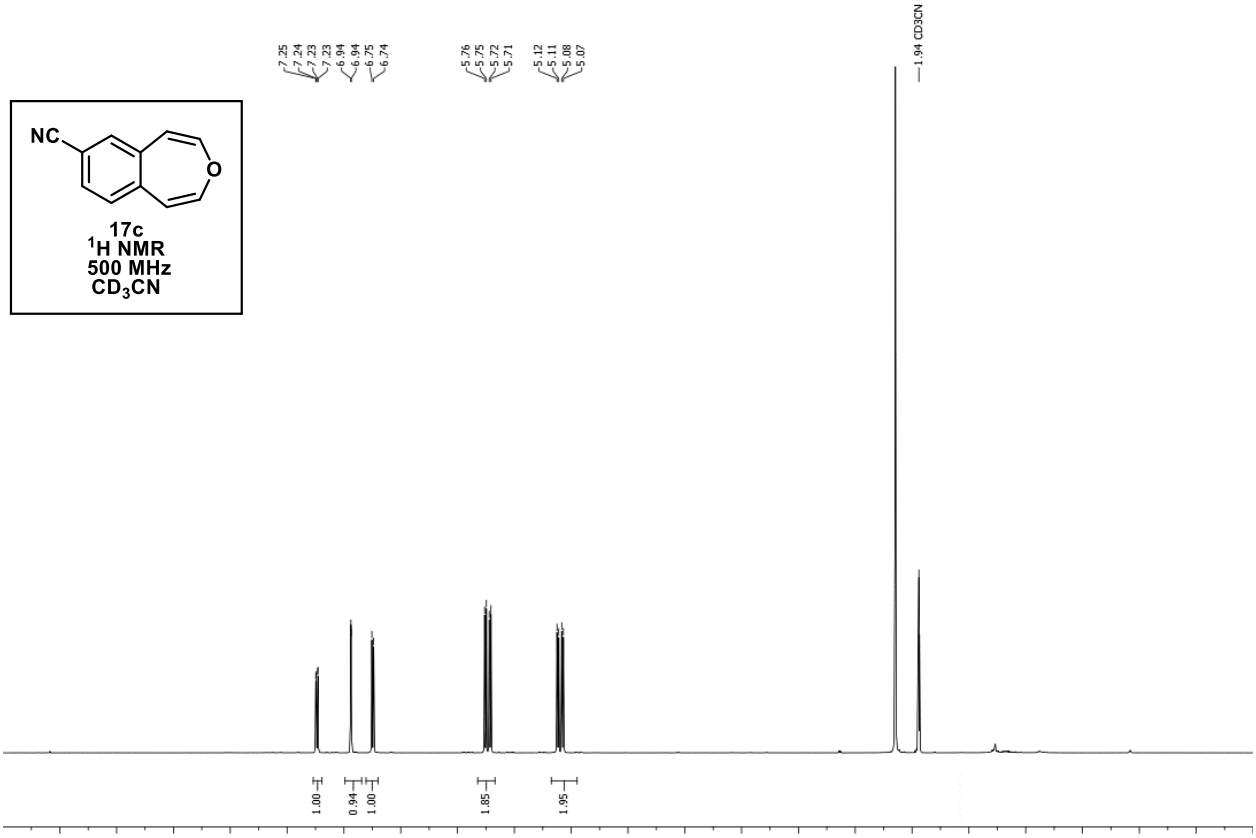


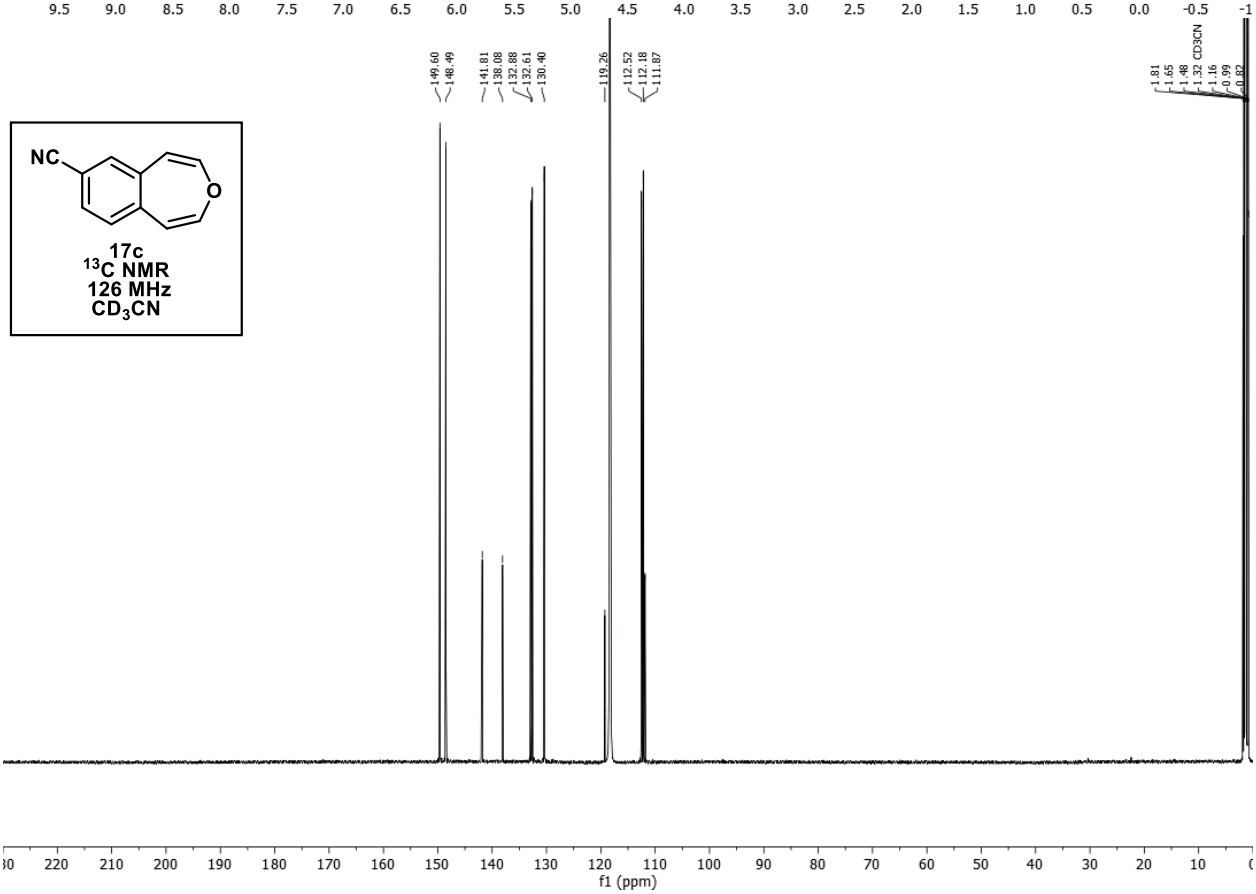
17a
^{13}C NMR
126 MHz
$CDCl_3$

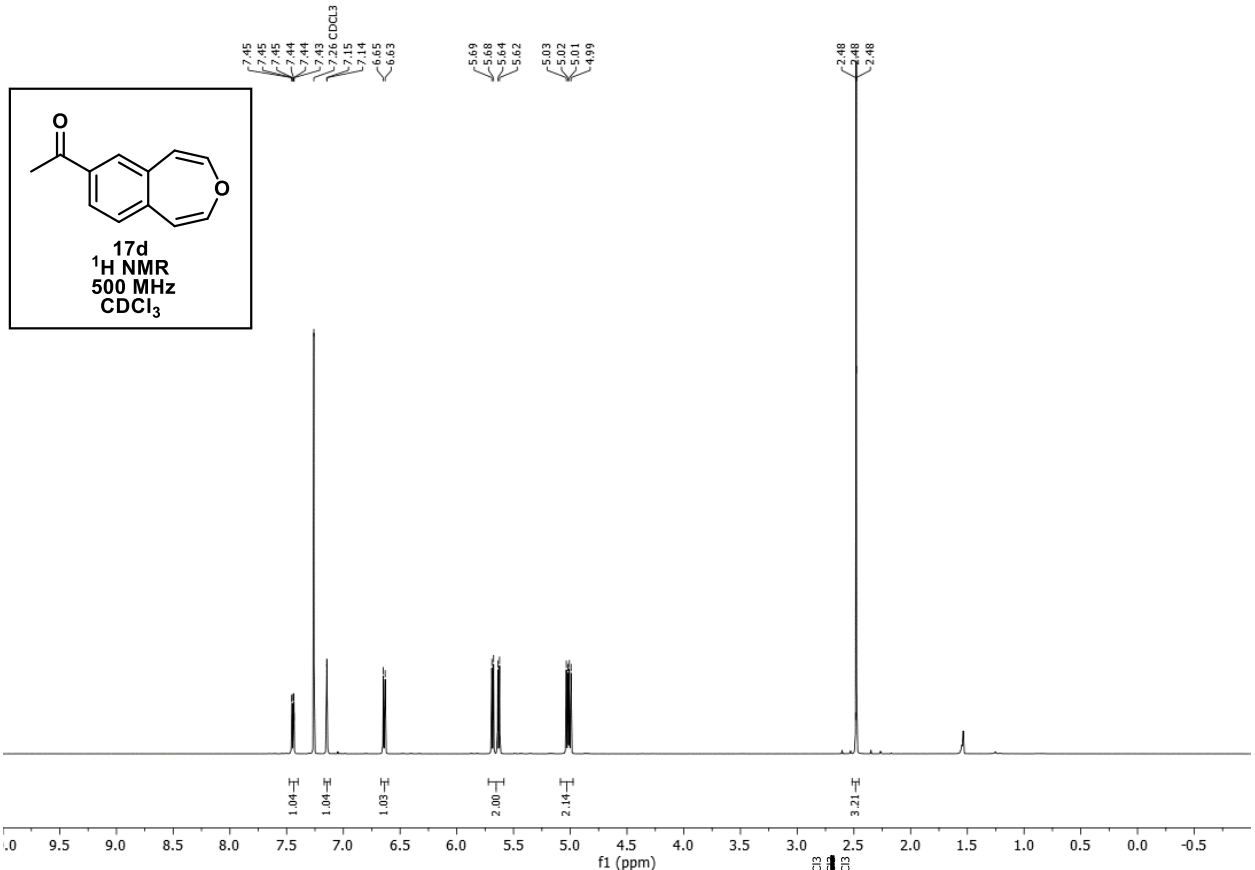


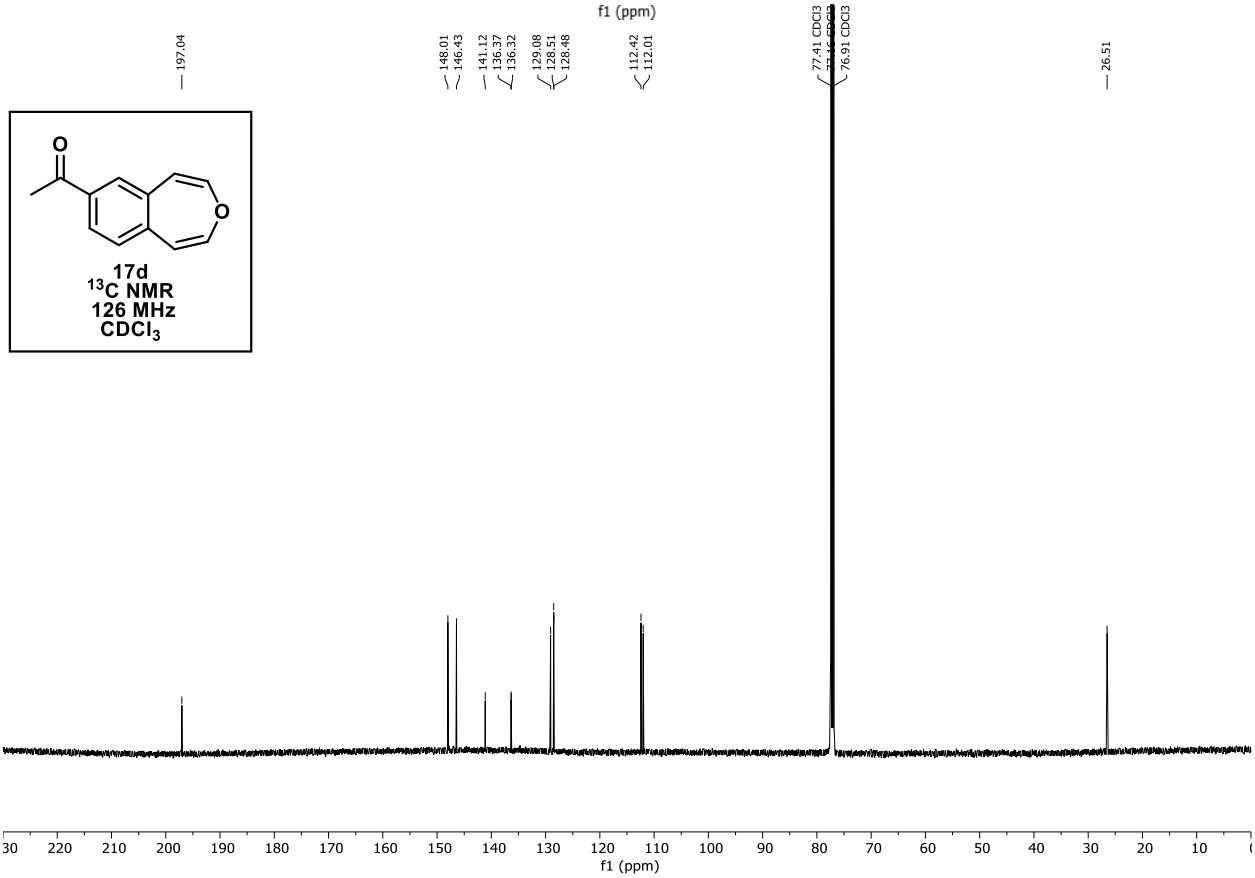

Br
O
17b
1H NMR
500 MHz
CD3CN
7.09
7.09
7.07
7.07
6.87
6.86
6.59
6.58
5.74
5.73
5.71
5.12
5.10
5.09
5.08
1.94 CD3CN
0.99
0.99
1.01
1.98
2.03
f1 (ppm)

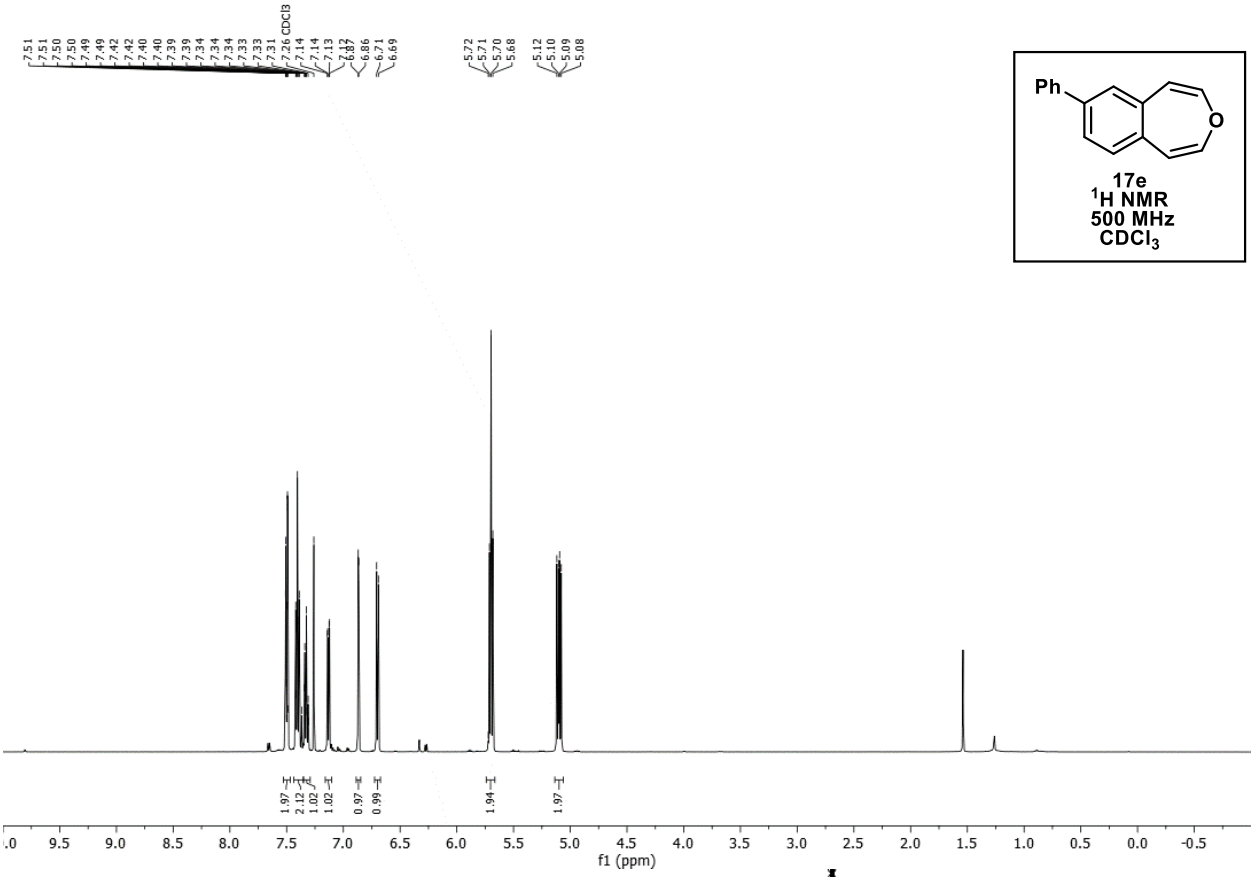

Br
O
17b
13C NMR
126 MHz
CD3CN
148.23
147.44
139.04
135.94
132.43
131.65
131.35
121.80
113.04
112.54
1.82
1.65
1.48 CD3CN
1.15 CD3CN
0.99
0.83
f1 (ppm)

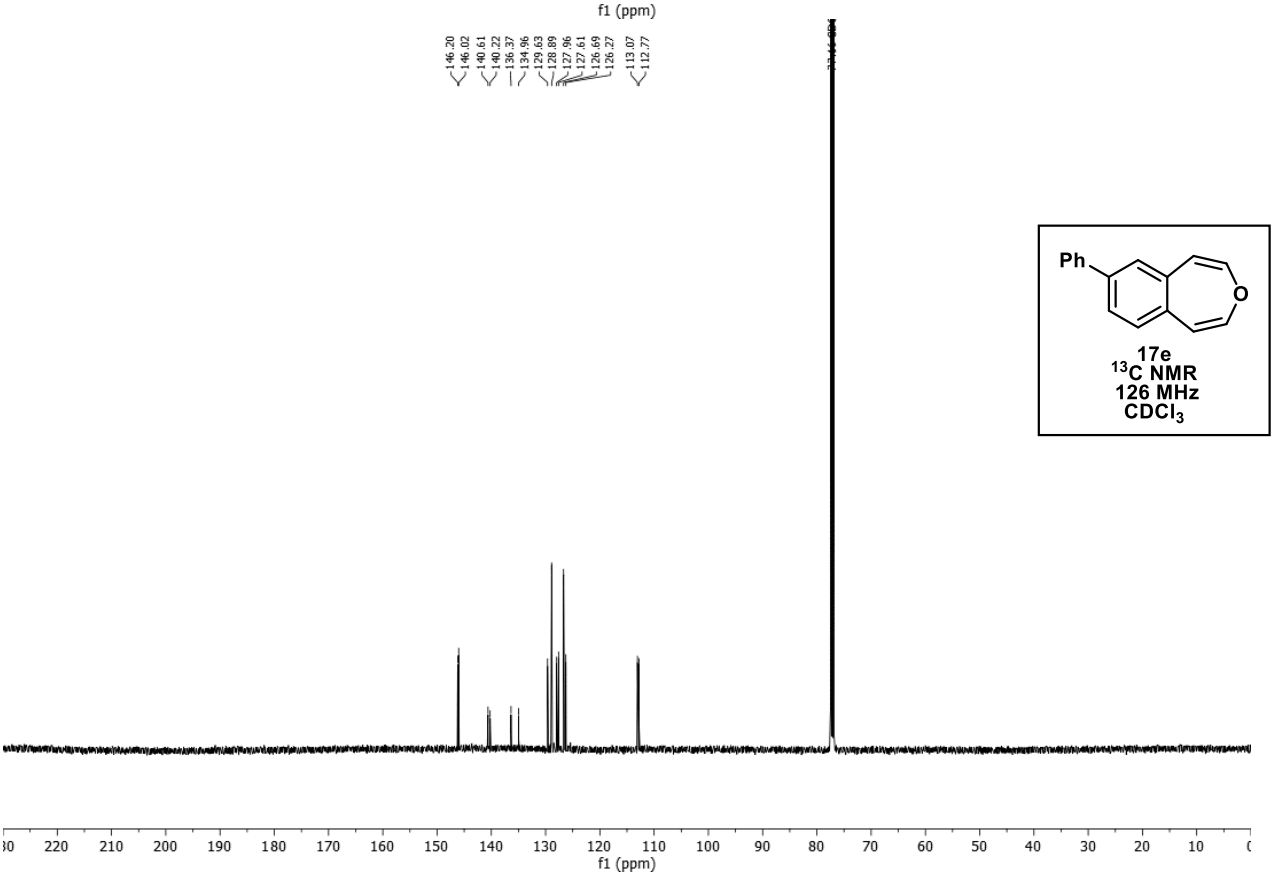

NC
O
17c
^{1}H NMR
500 MHz
CD_3CN
7.25
7.24
7.23
7.23
6.94
6.94
6.75
6.74
5.76
5.75
5.72
5.71
5.12
5.11
5.08
5.07
1.94 CD3CN
1.00
0.94
1.00
1.85
1.95
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5

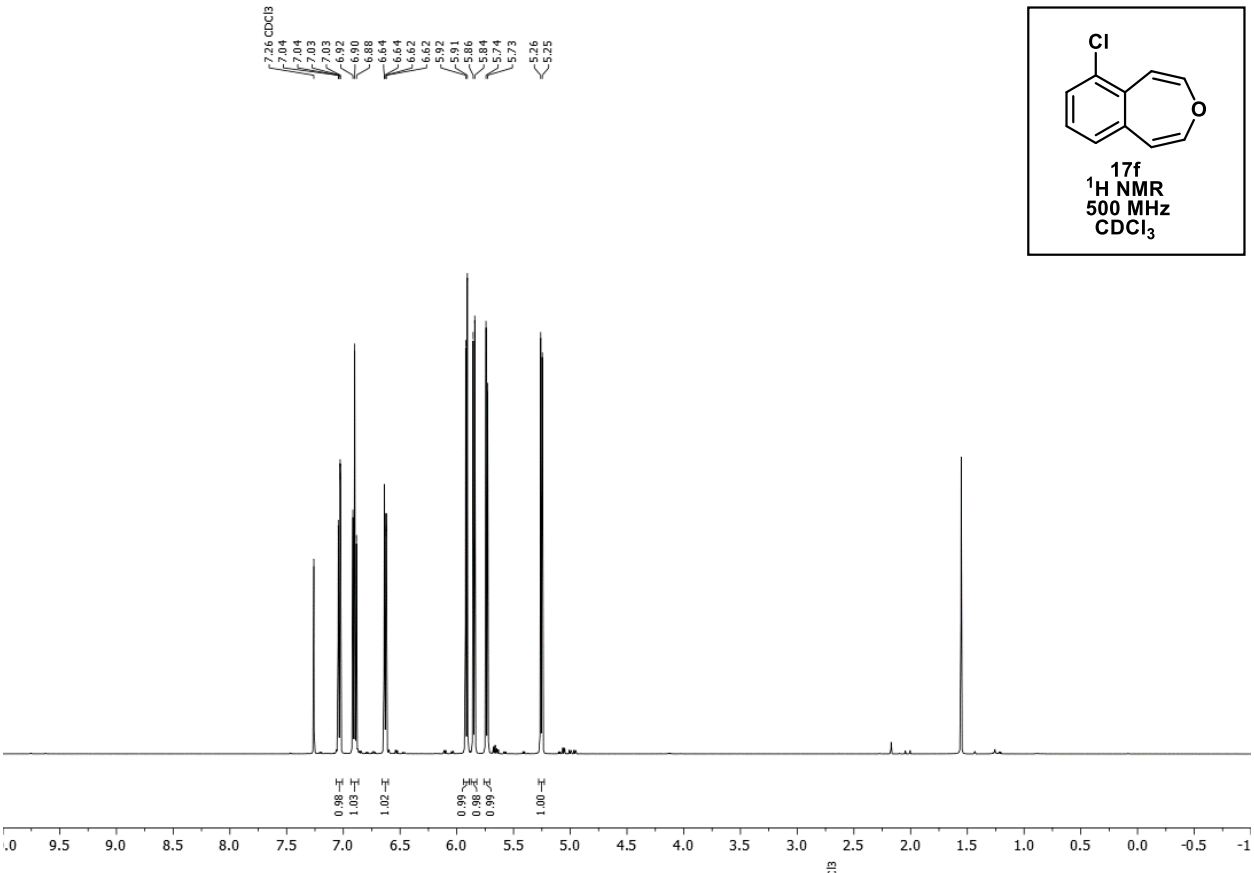

NC
O
17c
^{13}C NMR
126 MHz
CD_3CN
149.60
148.49
141.81
138.08
132.88
132.61
130.40
119.26
112.52
112.18
111.87
1.81
1.65
1.40
1.32 CD3CN
1.16
0.99
0.82
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

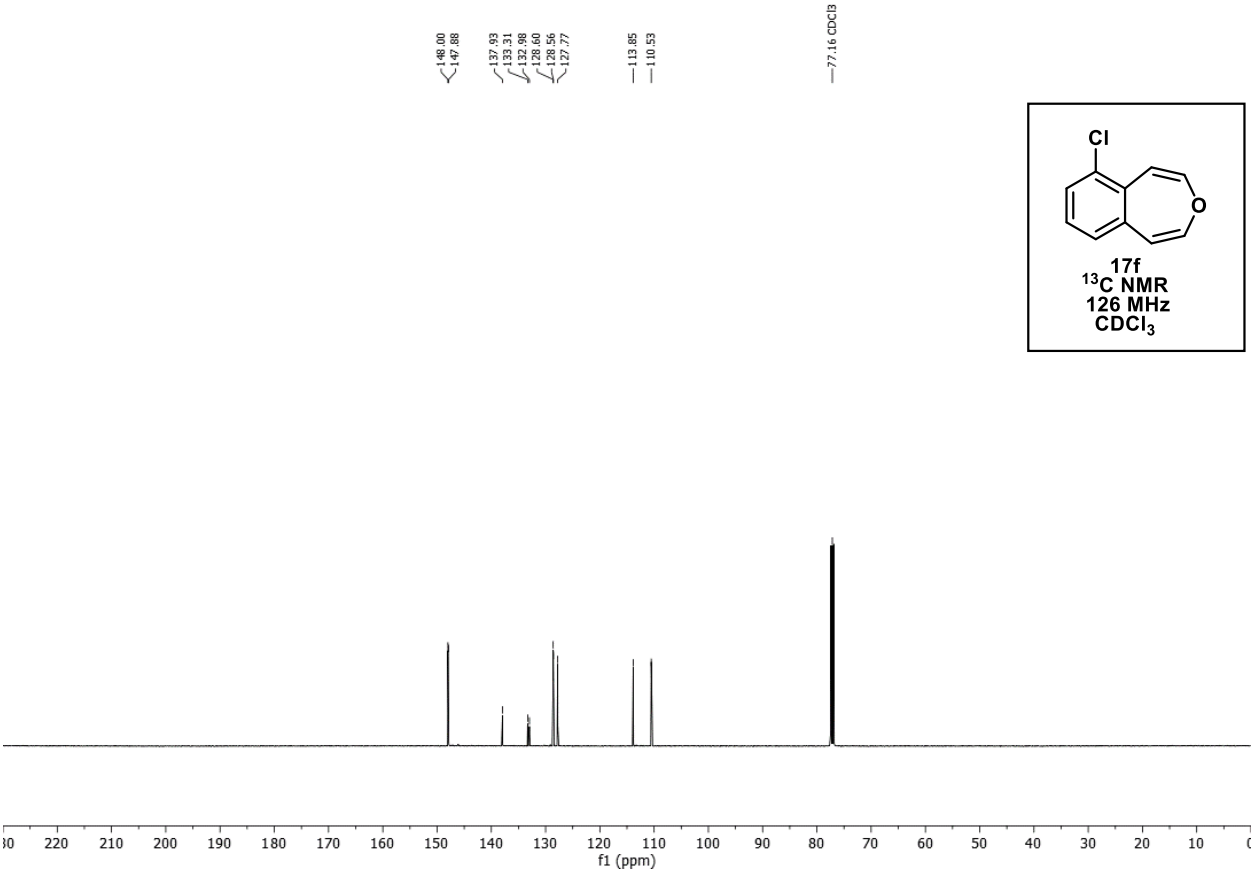

17d
1H NMR
500 MHz
CDCl3
f1 (ppm)

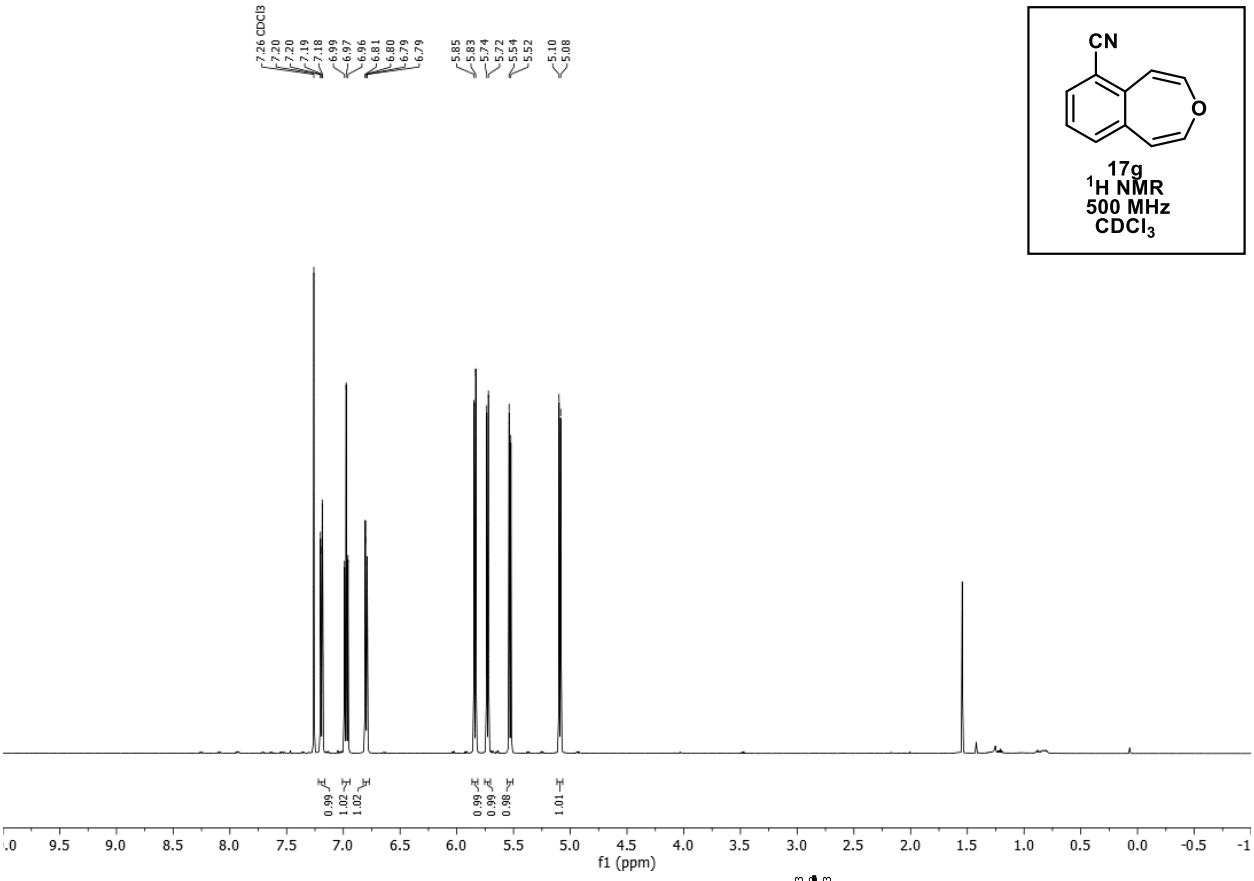

17d
13C NMR
126 MHz
CDCl3
f1 (ppm)

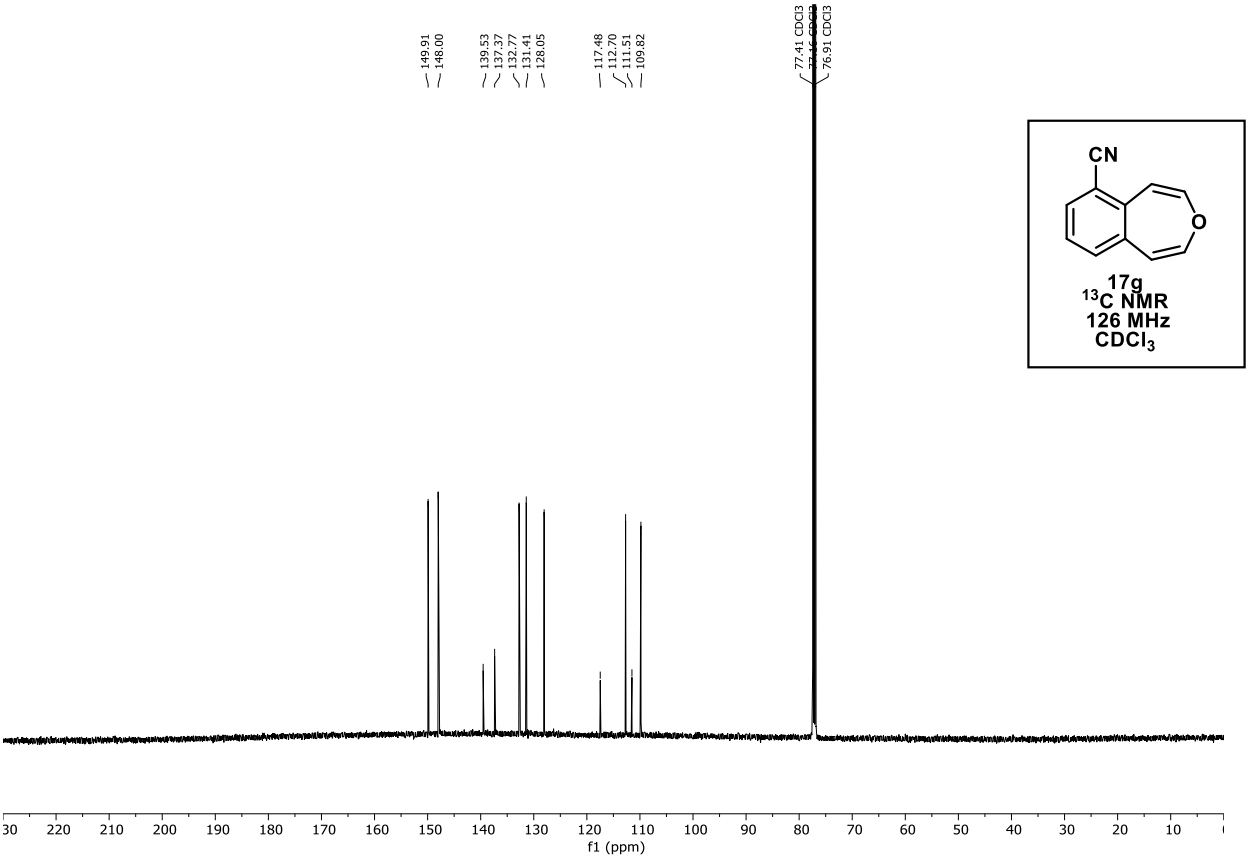

Ph
O
17e
^{1}H NMR
500 MHz
$CDCl_3$
f1 (ppm)

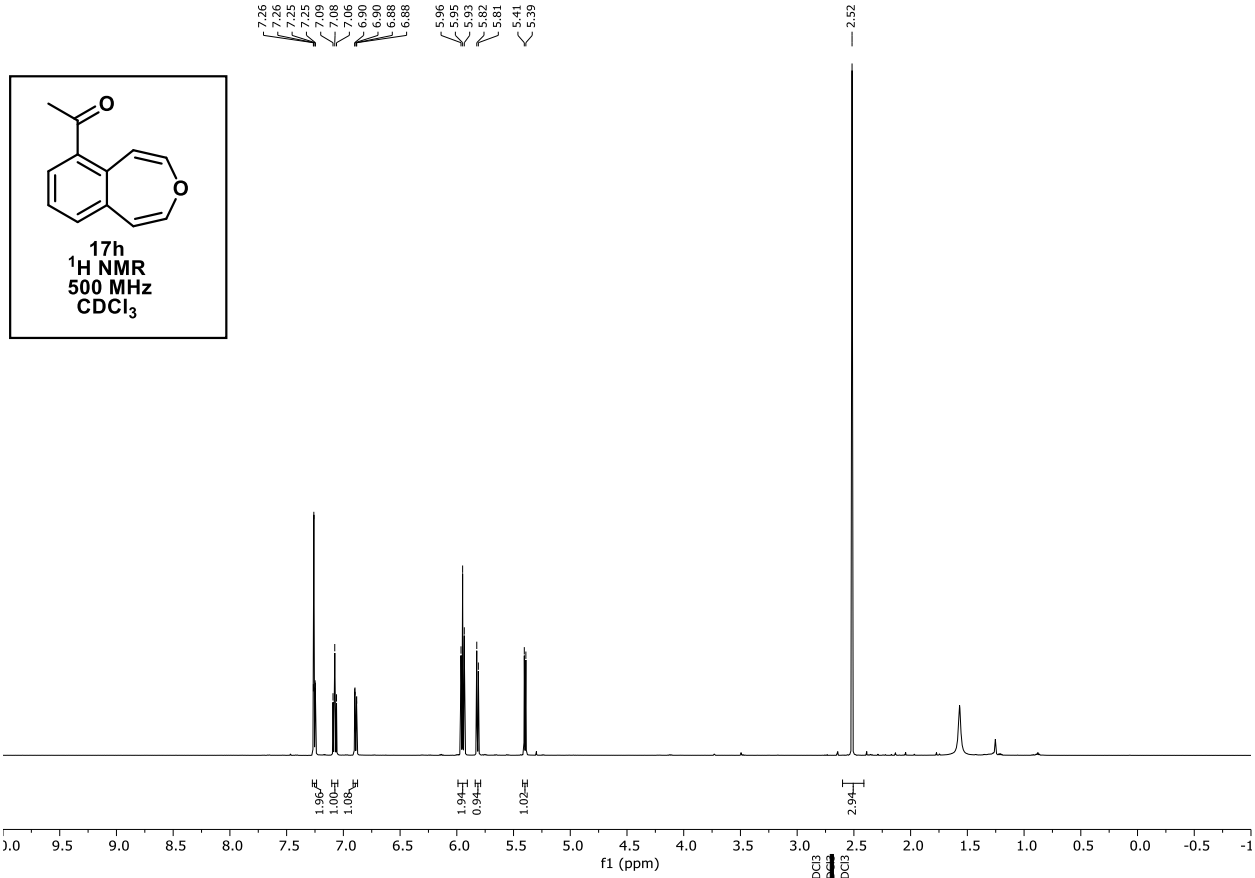

Ph
O
17e
^{13}C NMR
126 MHz
$CDCl_3$
f1 (ppm)

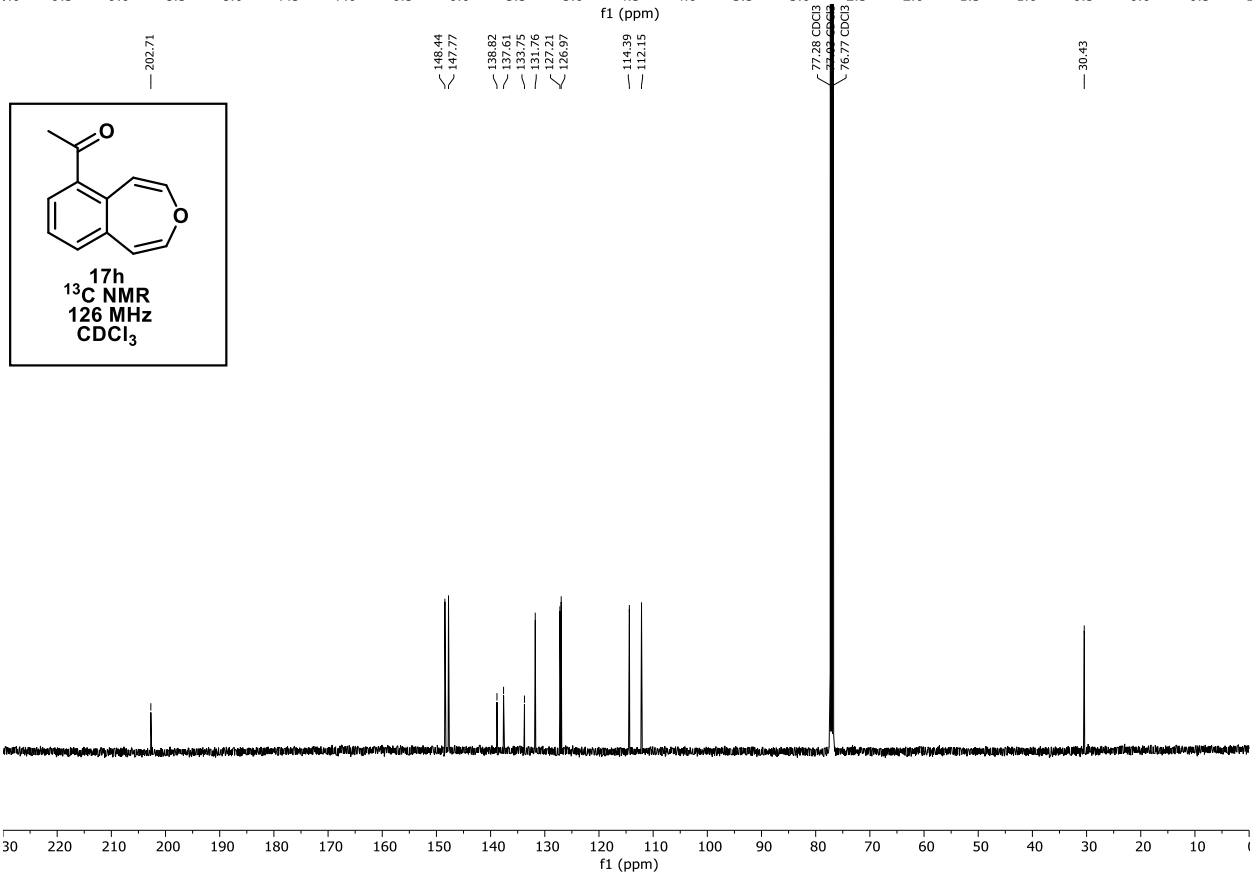

7.26 CDCl3
7.04
7.04
7.03
7.03
7.03
6.92
6.90
6.88
6.64
6.64
6.62
6.62
5.92
5.91
5.86
5.84
5.74
5.73
5.26
5.25
0.98
1.03
1.02
0.99
0.98
0.99
1.00
Cl
O
17f
1H NMR
500 MHz
CDCl3

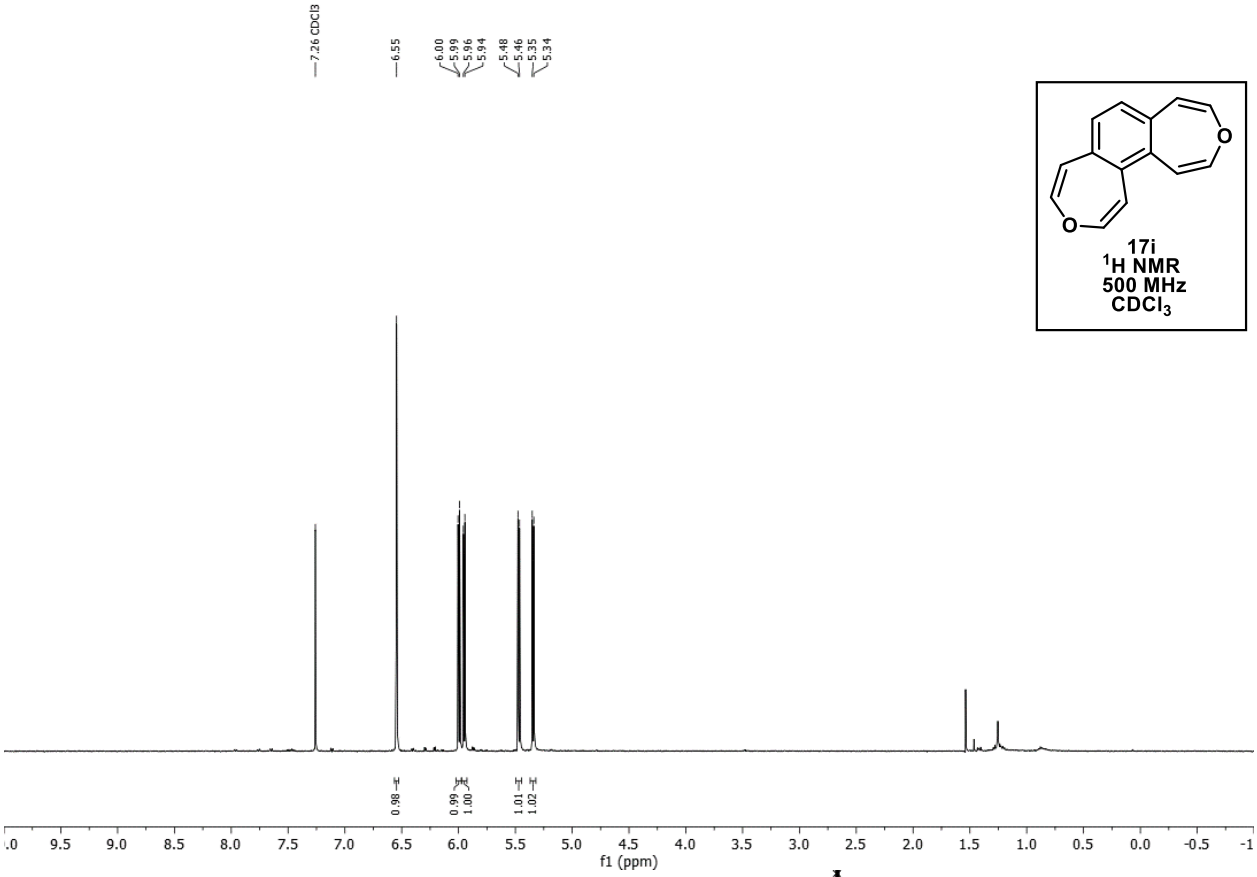

148.00
147.88
137.93
133.31
132.98
128.60
128.56
127.77
113.85
110.53
77.16 CDCl3
Cl
O
17f
13C NMR
126 MHz
CDCl3
f1 (ppm)


7.26 CDCl3
7.20
7.20
7.19
7.18
6.99
6.97
6.96
6.81
6.80
6.79
6.79
5.85
5.83
5.74
5.72
5.54
5.52
5.10
5.08
CN
O
17g
1H NMR
500 MHz
CDCl3
0.99
1.02
1.02
0.99
0.99
0.98
1.01
f1 (ppm)

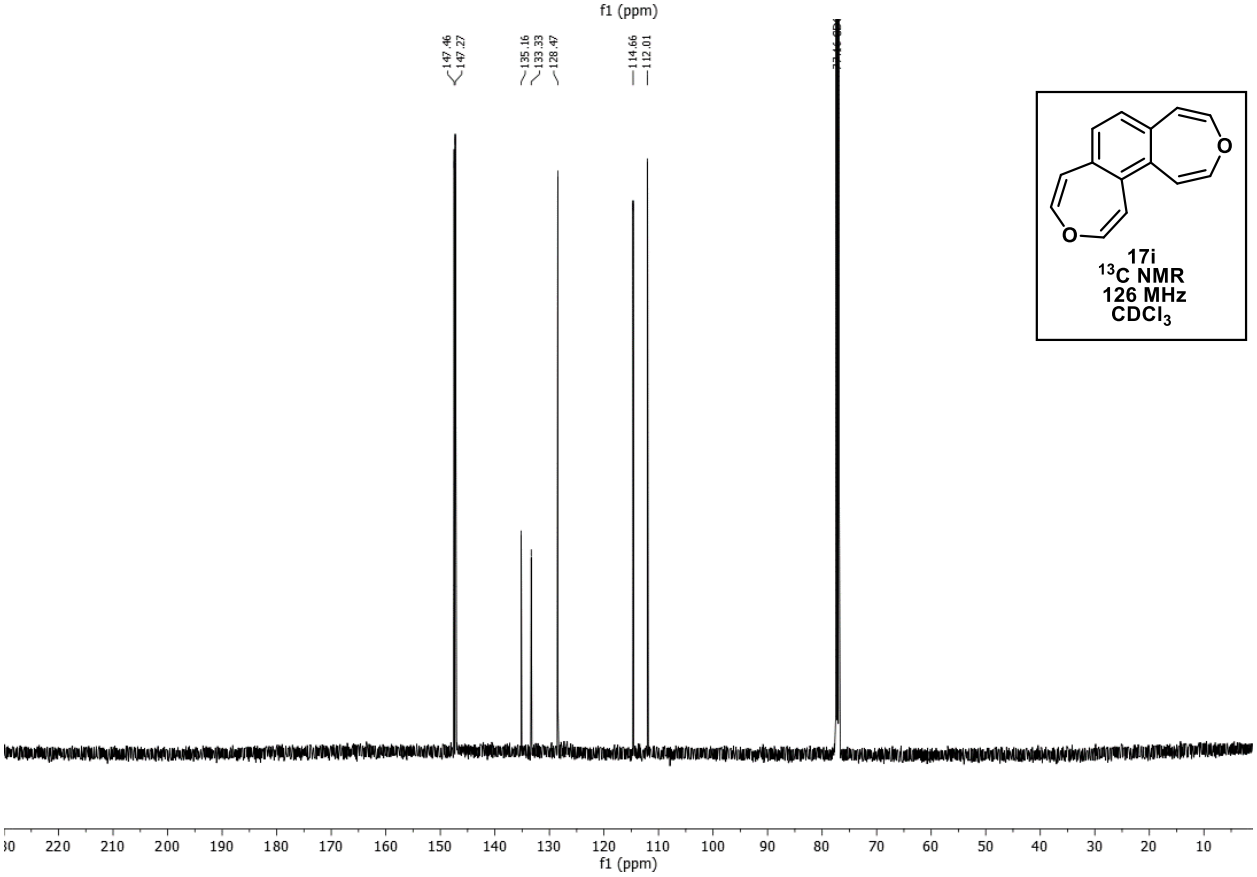

149.91
148.00
139.53
137.37
132.77
131.41
128.05
117.48
112.70
111.51
109.82
77.41 CDCl3
76.91 CDCl3
CN
O
17g
13C NMR
126 MHz
CDCl3
f1 (ppm)


17h
1H NMR
500 MHz
CDCl3
7.26
7.26
7.25
7.25
7.09
7.08
7.06
6.90
6.90
6.88
6.88
5.96
5.95
5.93
5.82
5.81
5.41
5.39
2.52
1.96
1.00
1.08
1.94
0.94
1.02
2.94
f1 (ppm)

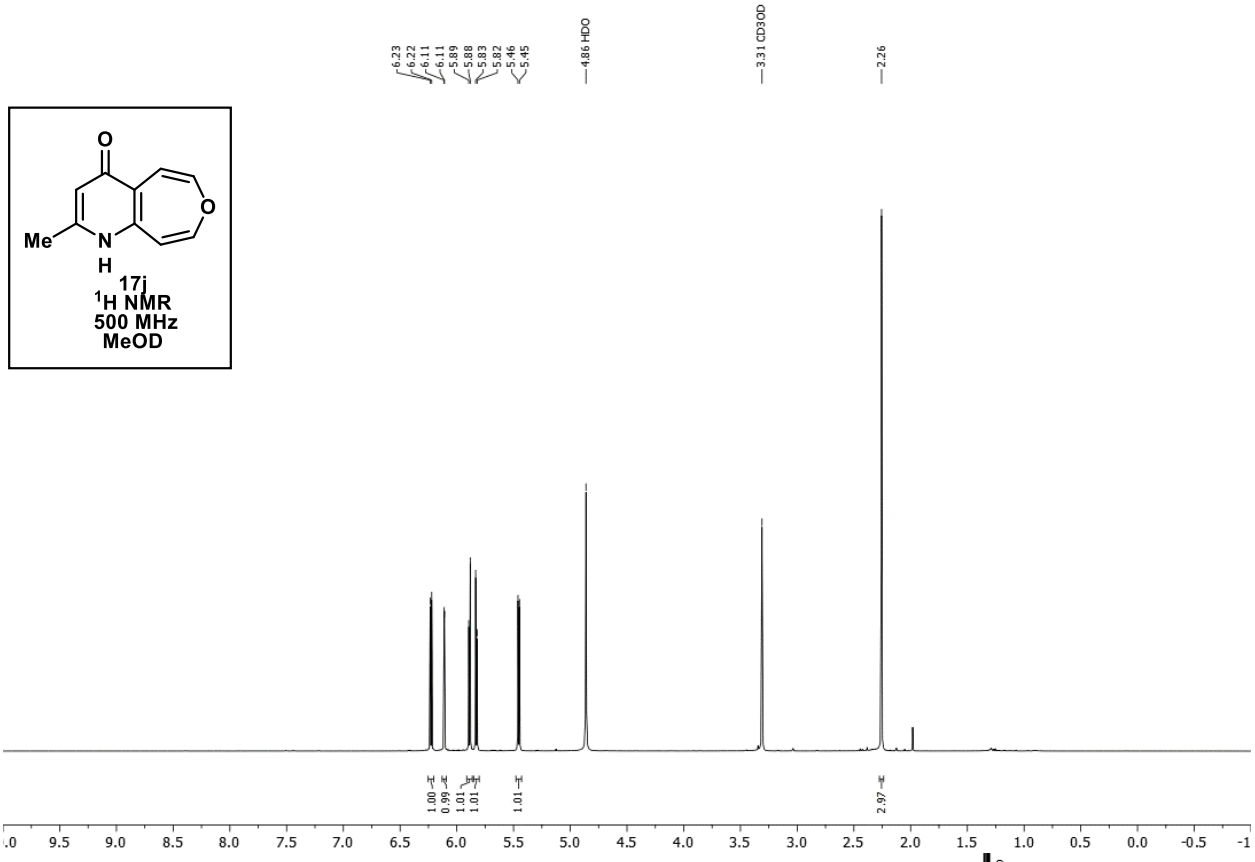

17h
13C NMR
126 MHz
CDCl3
202.71
148.44
147.77
138.82
137.61
133.75
131.76
127.21
126.97
114.39
112.15
77.28 CDCl3
77.02 CDCl3
76.77 CDCl3
30.43
f1 (ppm)

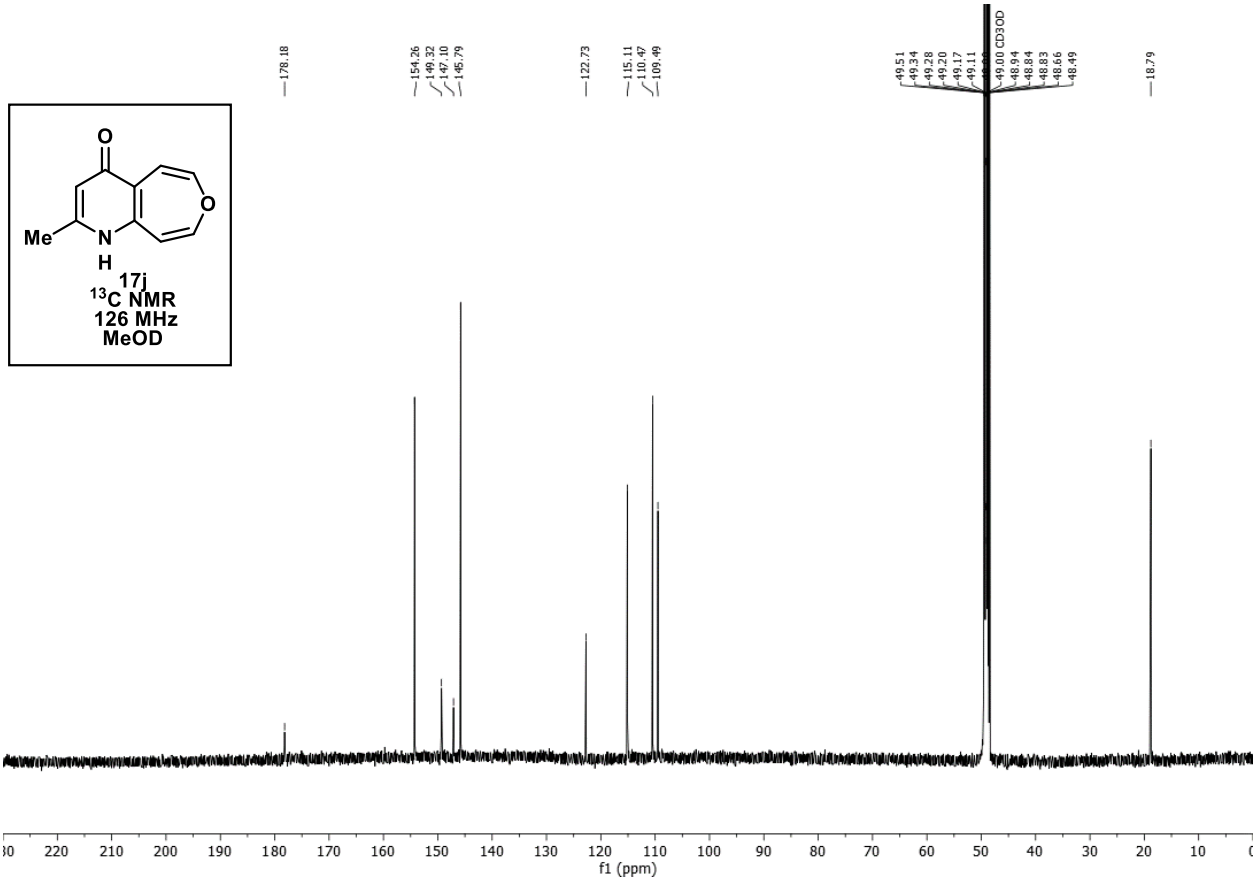


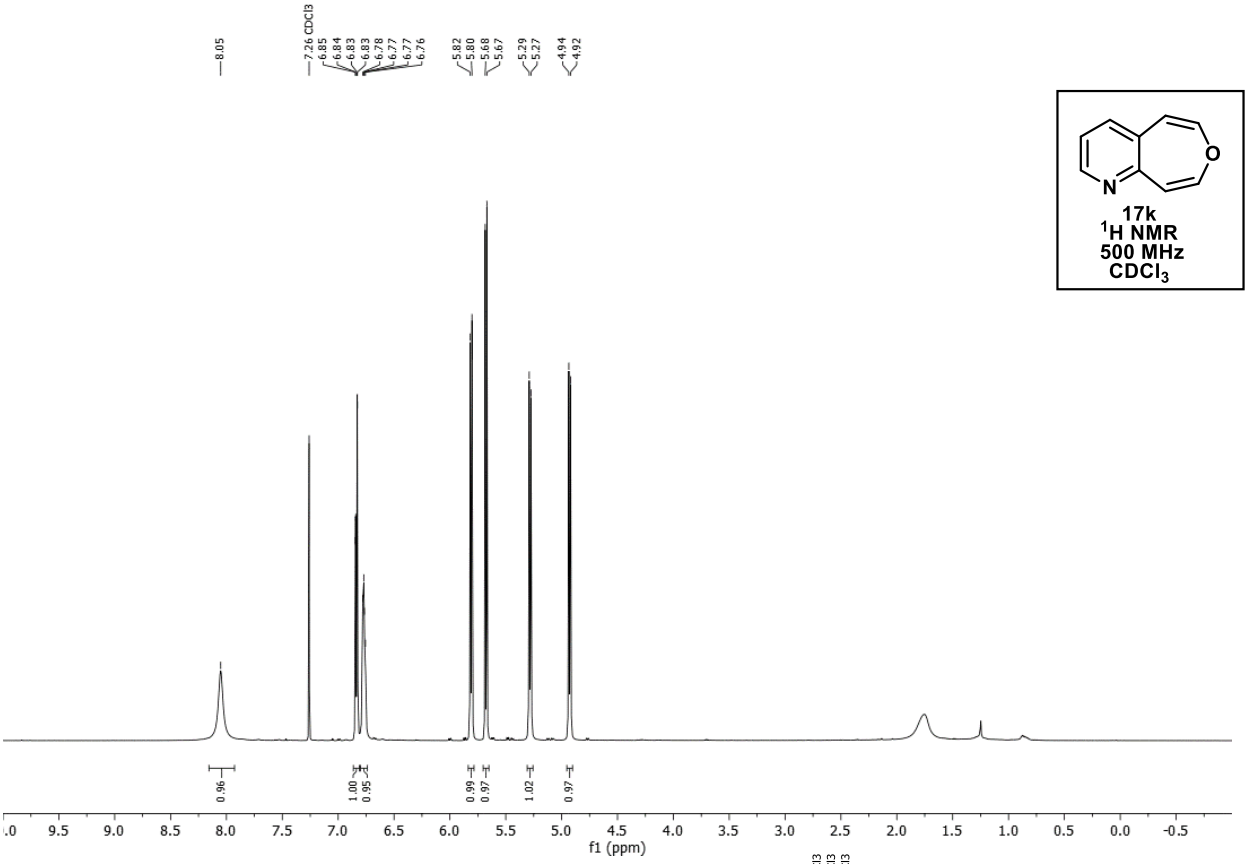
17i
^{1}H NMR
500 MHz
$CDCl_3$

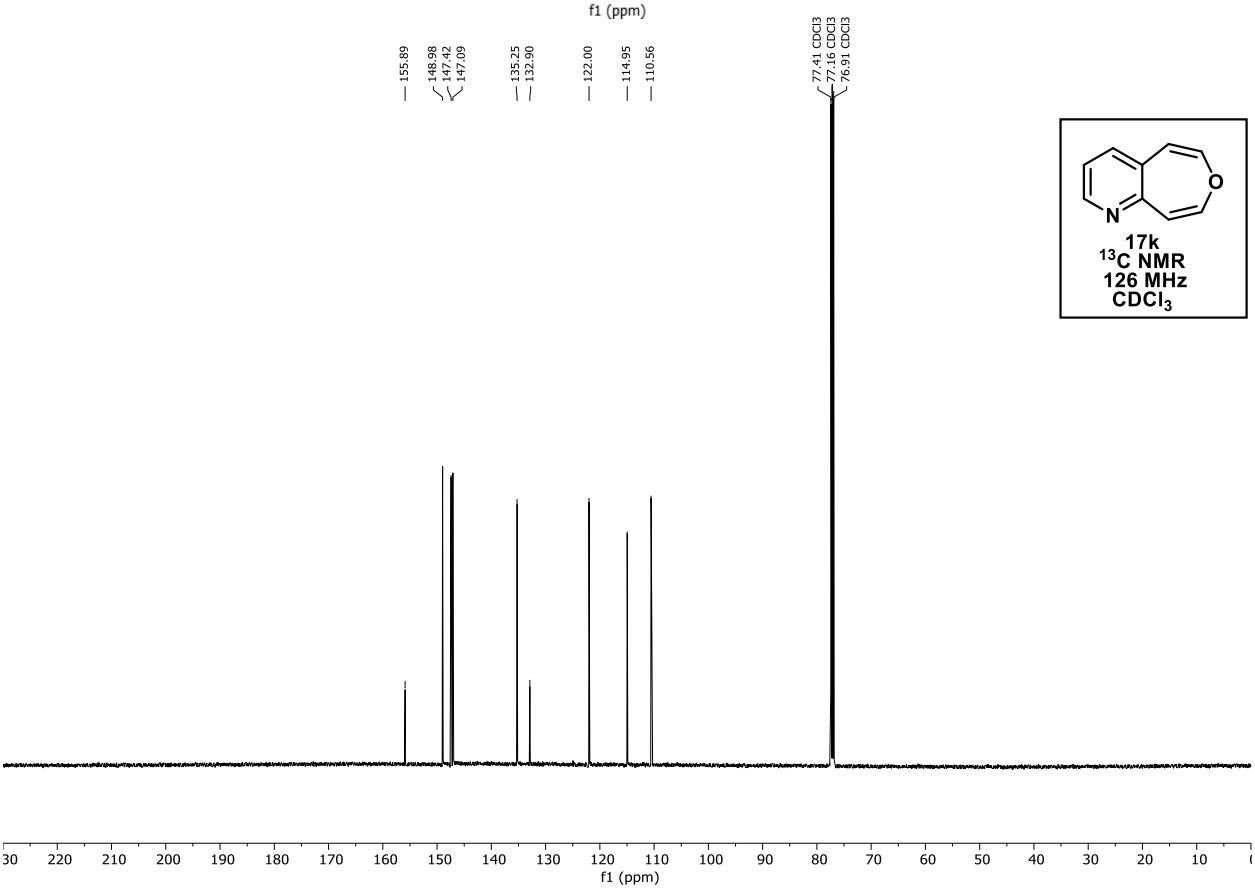


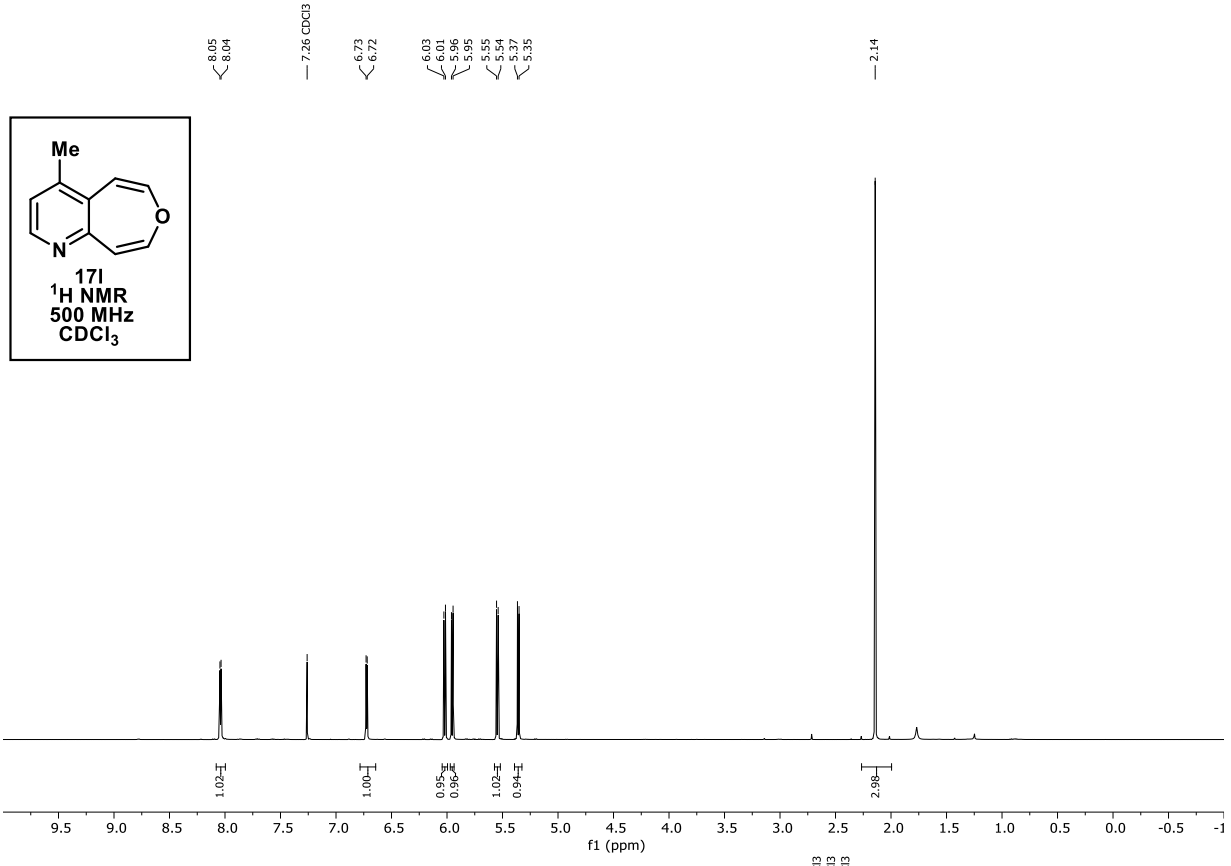
17i
^{13}C NMR
126 MHz
$CDCl_3$

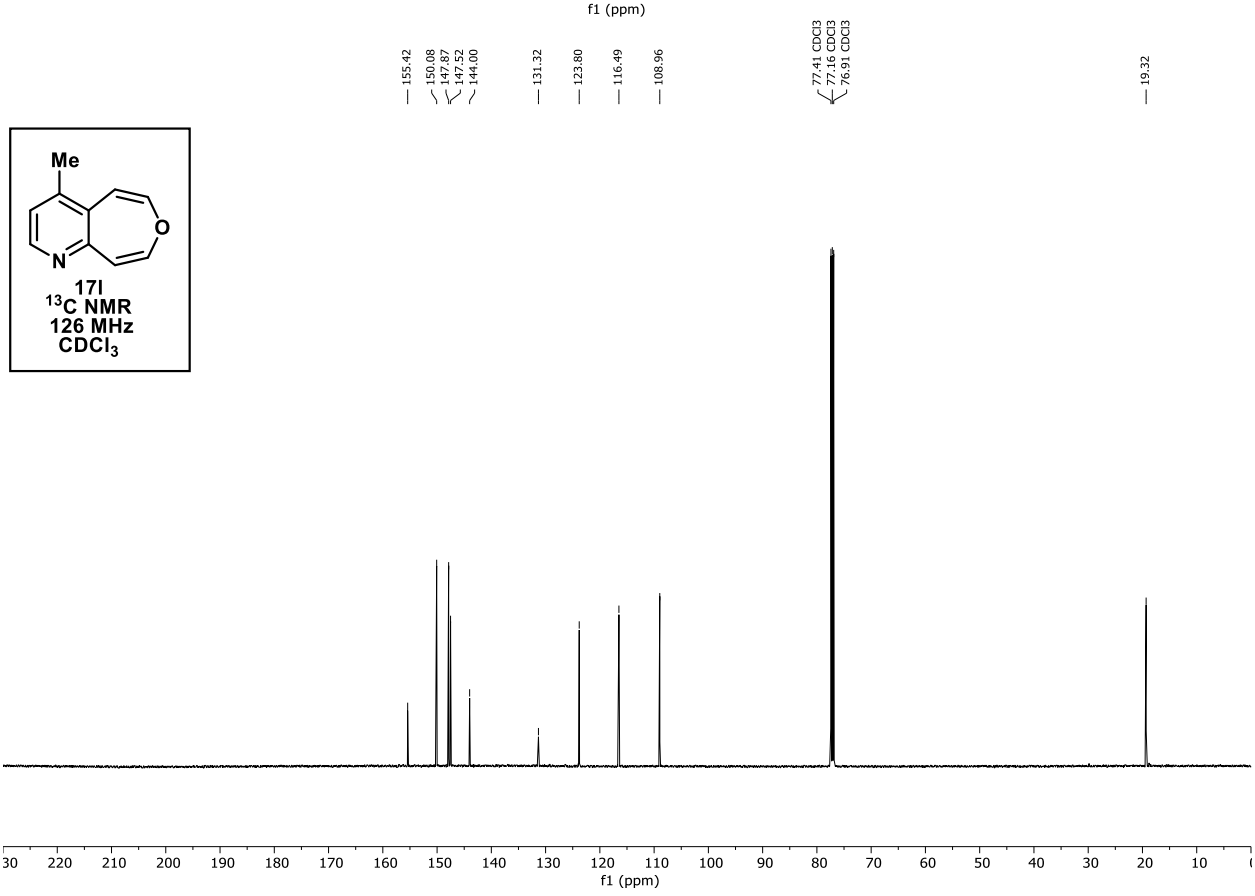

6.23
6.22
6.11
6.11
5.89
5.88
5.83
5.82
5.46
5.45
4.86 HDO
3.31 CD3OD
2.26
O
Me
N
H
O
17j
1H NMR
500 MHz
MeOD
1.00
0.99
1.01
1.01
1.01
2.97
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5

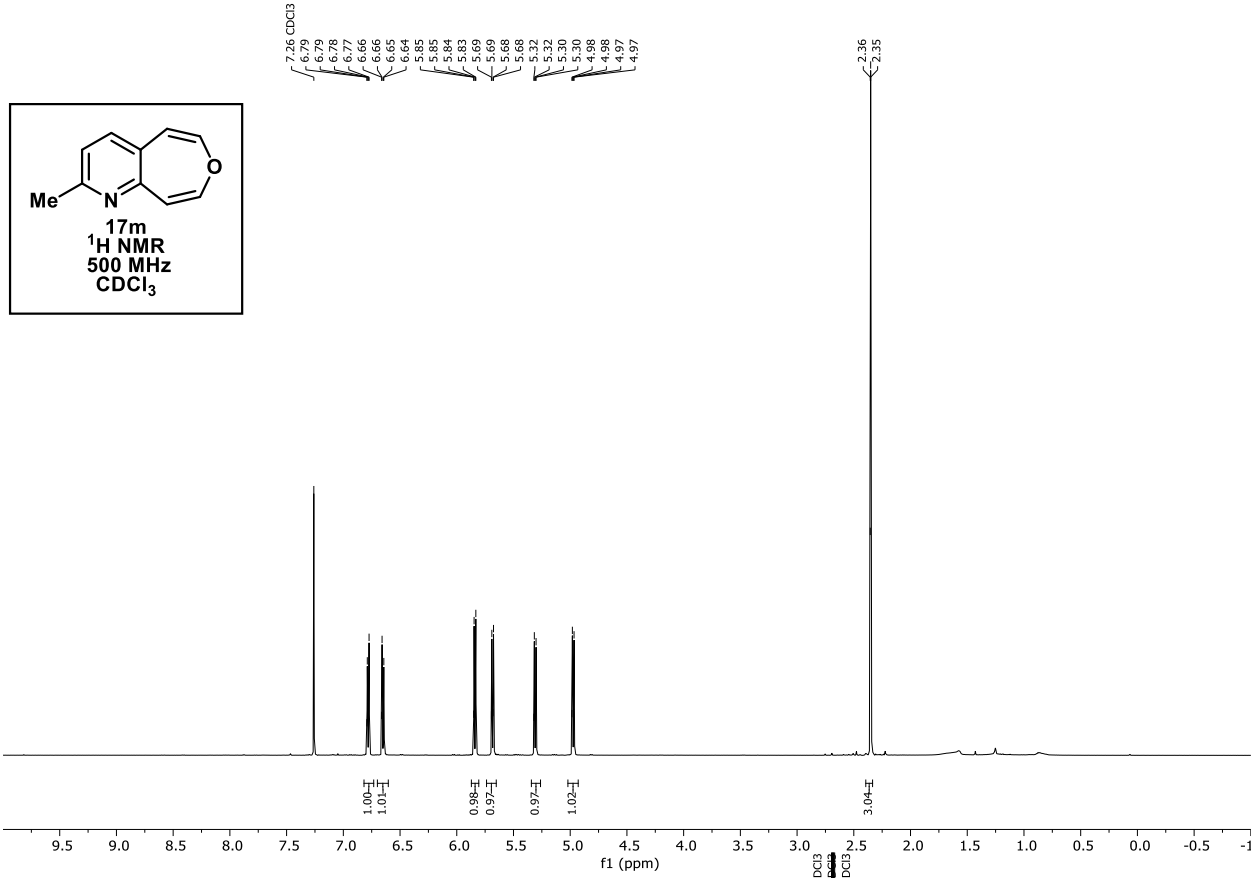

178.18
154.26
149.32
147.10
145.79
122.73
115.11
110.47
109.49
49.51
49.34
49.28
49.20
49.17
49.11
49.00 CD3OD
48.94
48.84
48.83
48.66
48.49
18.79
O
Me
N
H
O
17j
13C NMR
126 MHz
MeOD
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

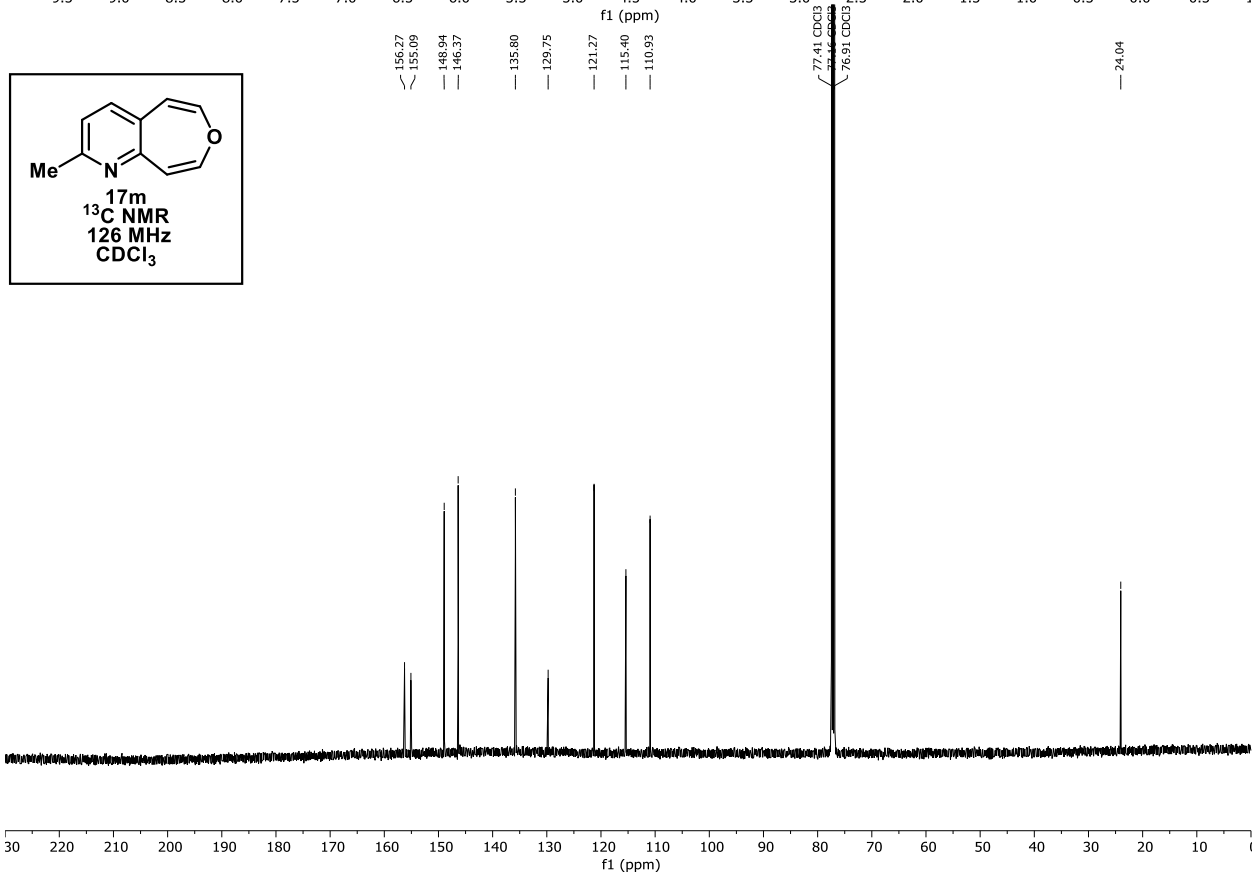

8.05
7.26 CDCl3
6.85
6.84
6.83
6.83
6.78
6.77
6.77
6.76
5.82
5.80
5.68
5.67
5.29
5.27
4.94
4.92
0.96
1.00
0.95
0.99
0.97
1.02
0.97
f1 (ppm)
17k
1H NMR
500 MHz
CDCl3

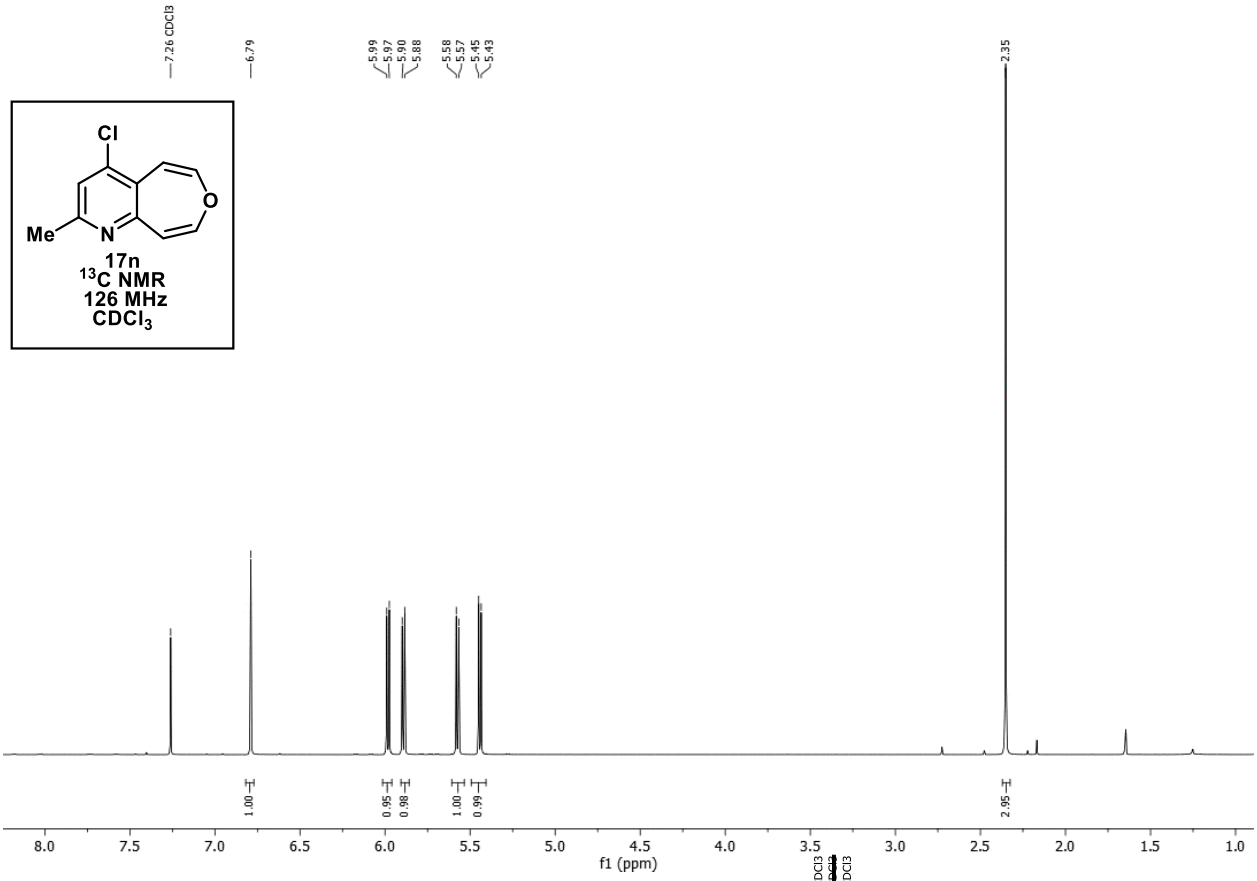

155.89
148.98
147.42
147.09
135.25
132.90
122.00
114.95
110.56
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
f1 (ppm)
17k
13C NMR
126 MHz
CDCl3

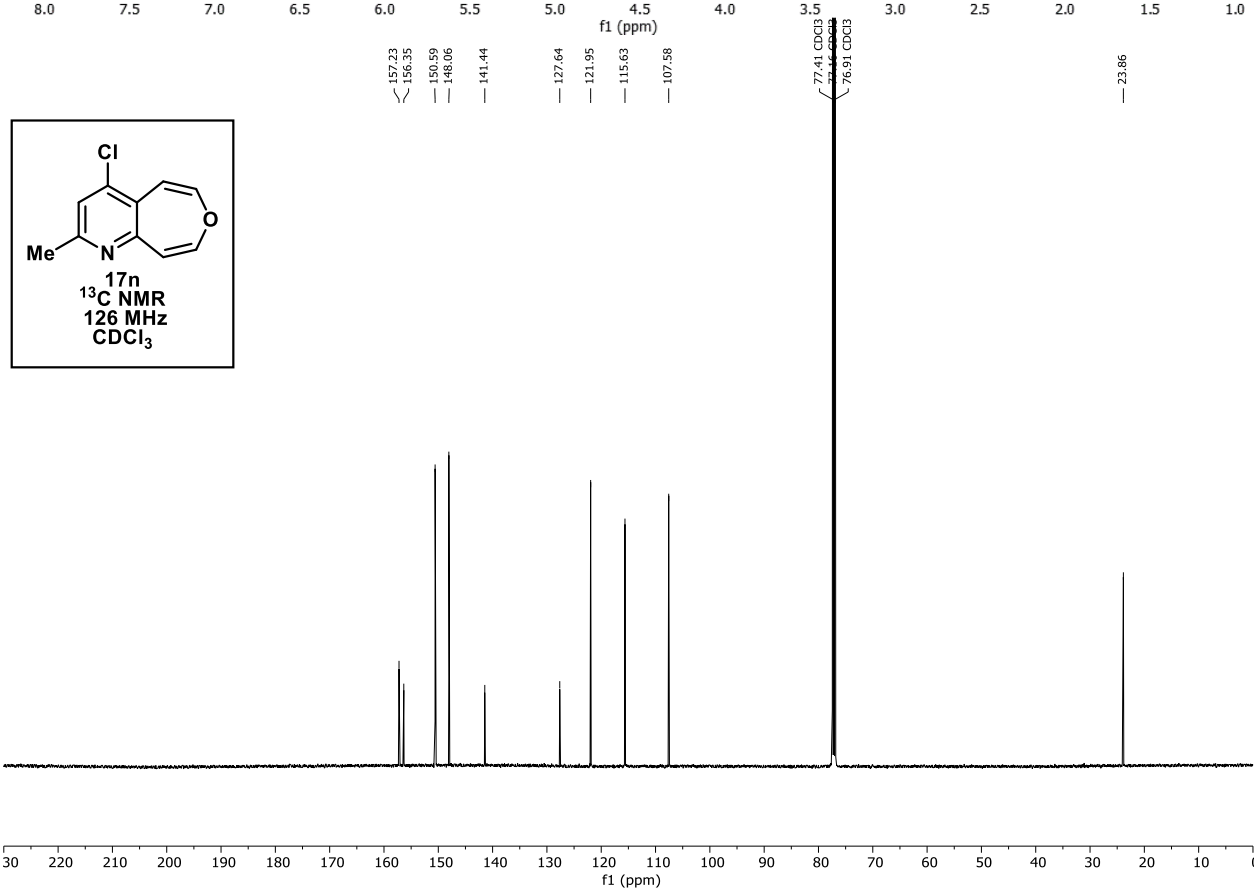

8.05
8.04
7.26 CDCl3
6.73
6.72
6.03
6.01
5.96
5.95
5.55
5.54
5.37
5.35
2.14
Me
O
N
17l
1H NMR
500 MHz
CDCl3
1.02
1.00
0.95
0.96
1.02
0.94
2.98
f1 (ppm)

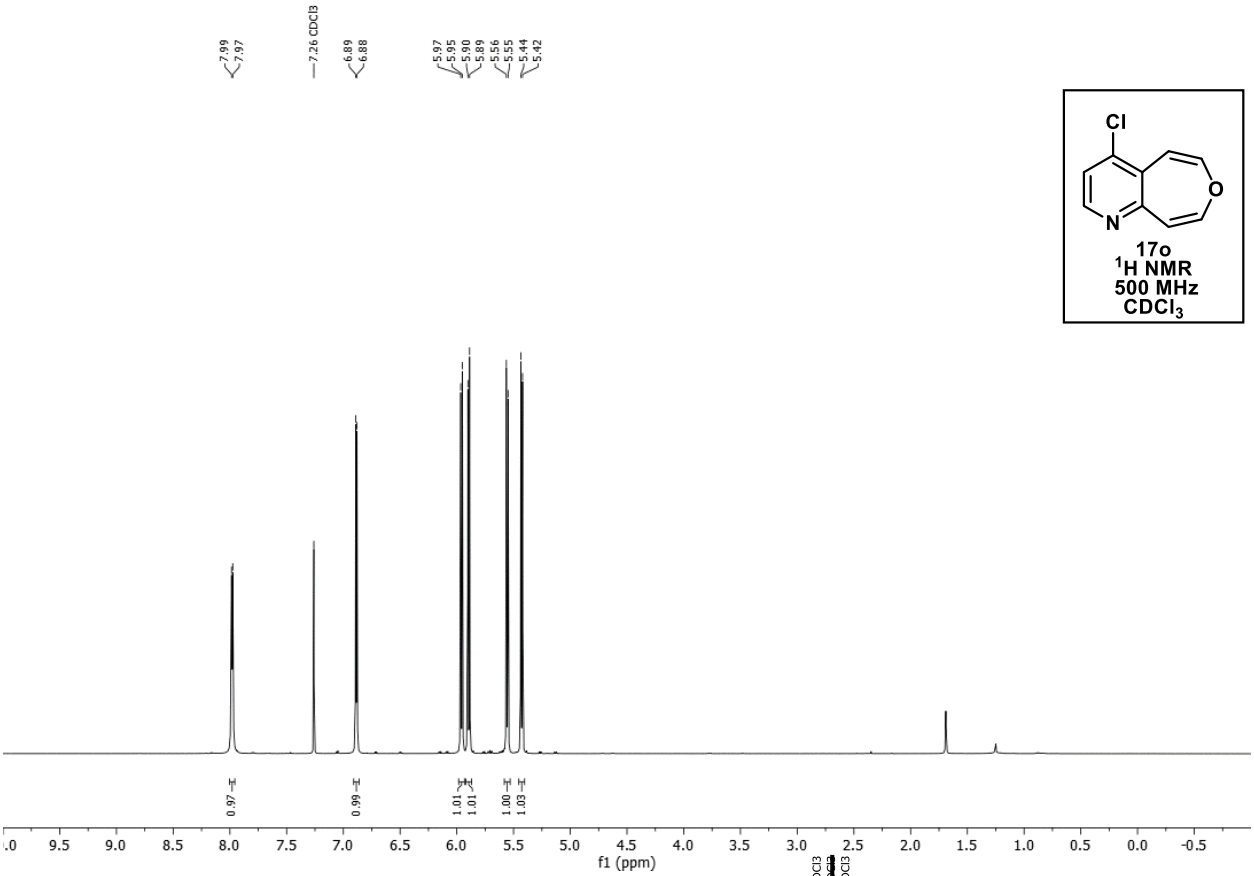

155.42
150.08
147.87
147.52
144.00
131.32
123.80
116.49
108.96
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
19.32
Me
O
N
17l
13C NMR
126 MHz
CDCl3
f1 (ppm)

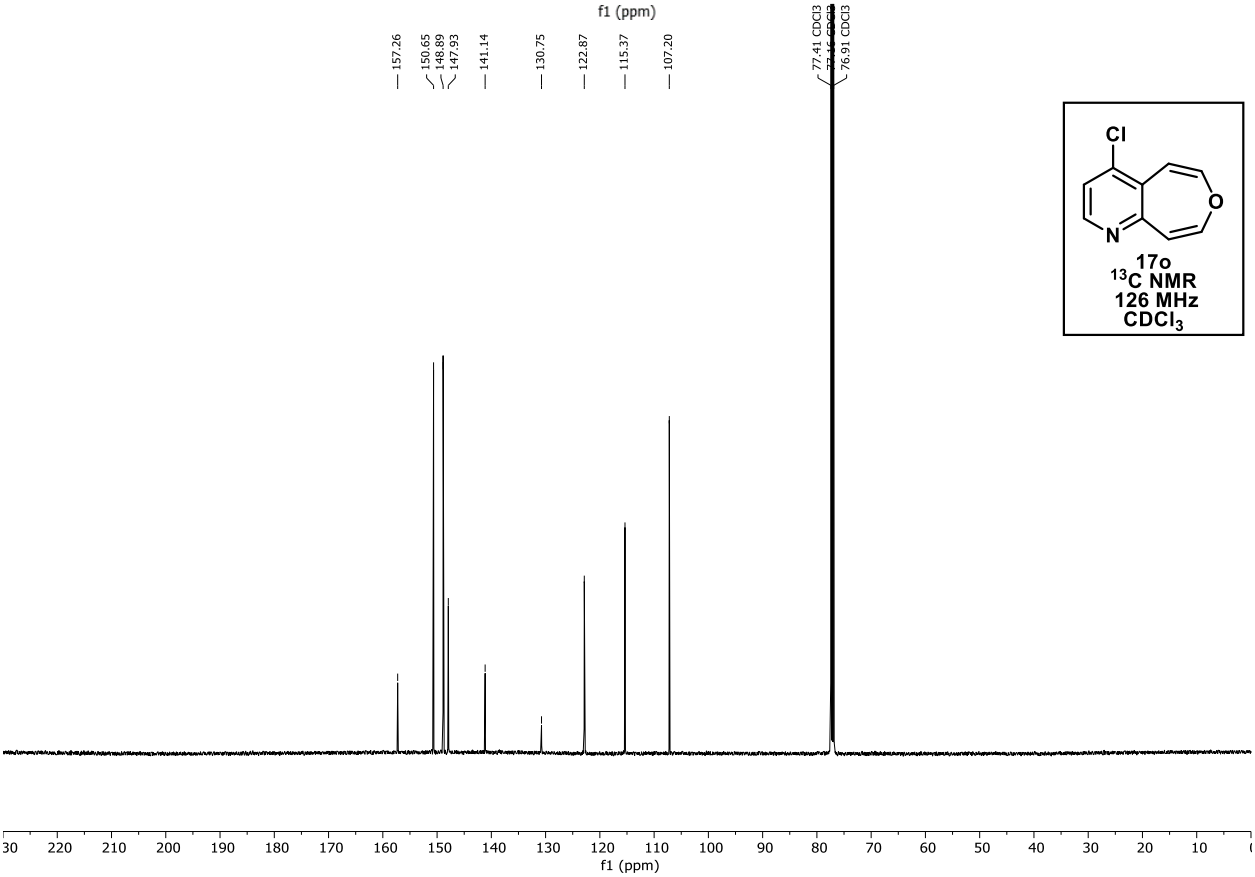

Me
N
O
17m
1H NMR
500 MHz
CDCl3
7.26 CDCl3
6.79
6.79
6.78
6.77
6.66
6.66
6.65
6.64
5.85
5.85
5.84
5.83
5.69
5.69
5.68
5.68
5.32
5.32
5.30
5.30
4.98
4.98
4.97
4.97
2.36
2.35
1.00
1.01
0.98
0.97
0.97
1.02
3.04
f1 (ppm)

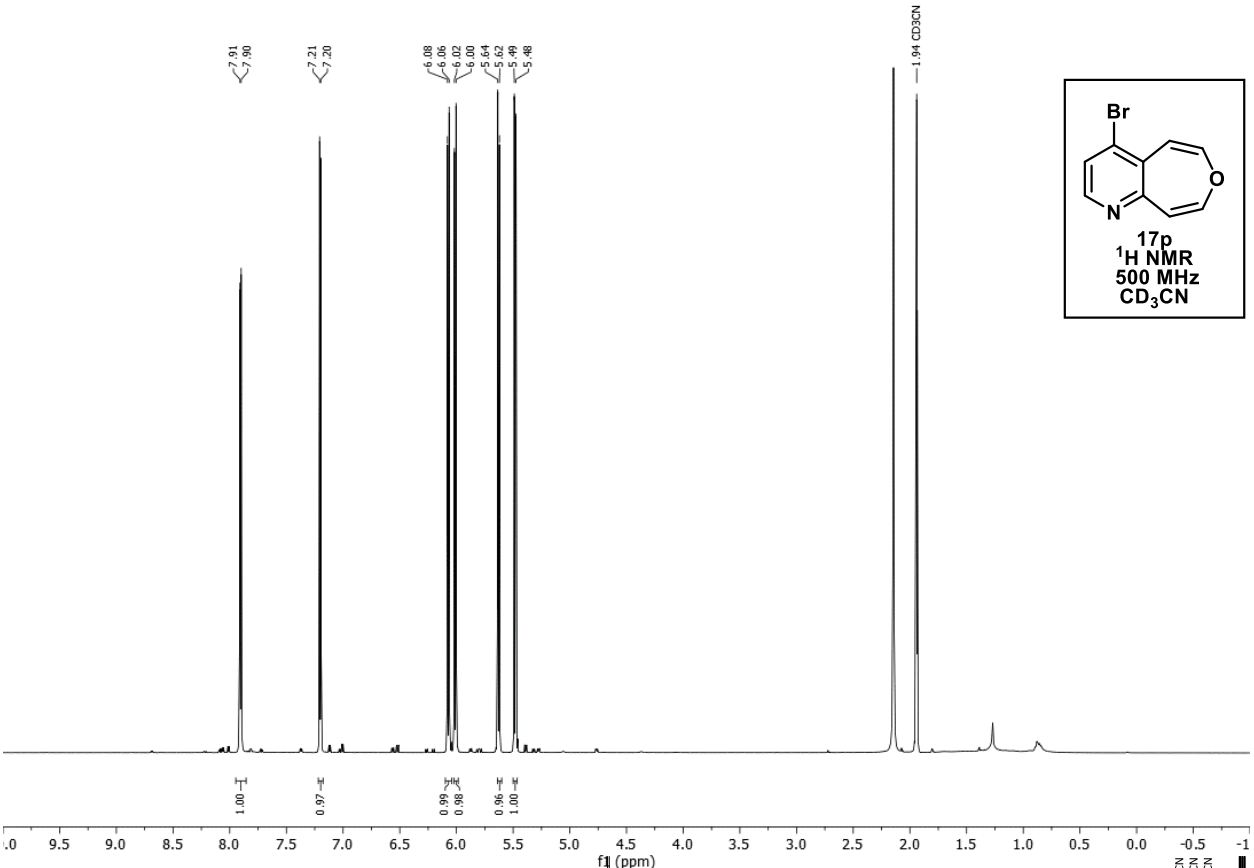

Me
N
O
17m
13C NMR
126 MHz
CDCl3
156.27
155.09
148.94
146.37
135.80
129.75
121.27
115.40
110.93
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
24.04
f1 (ppm)

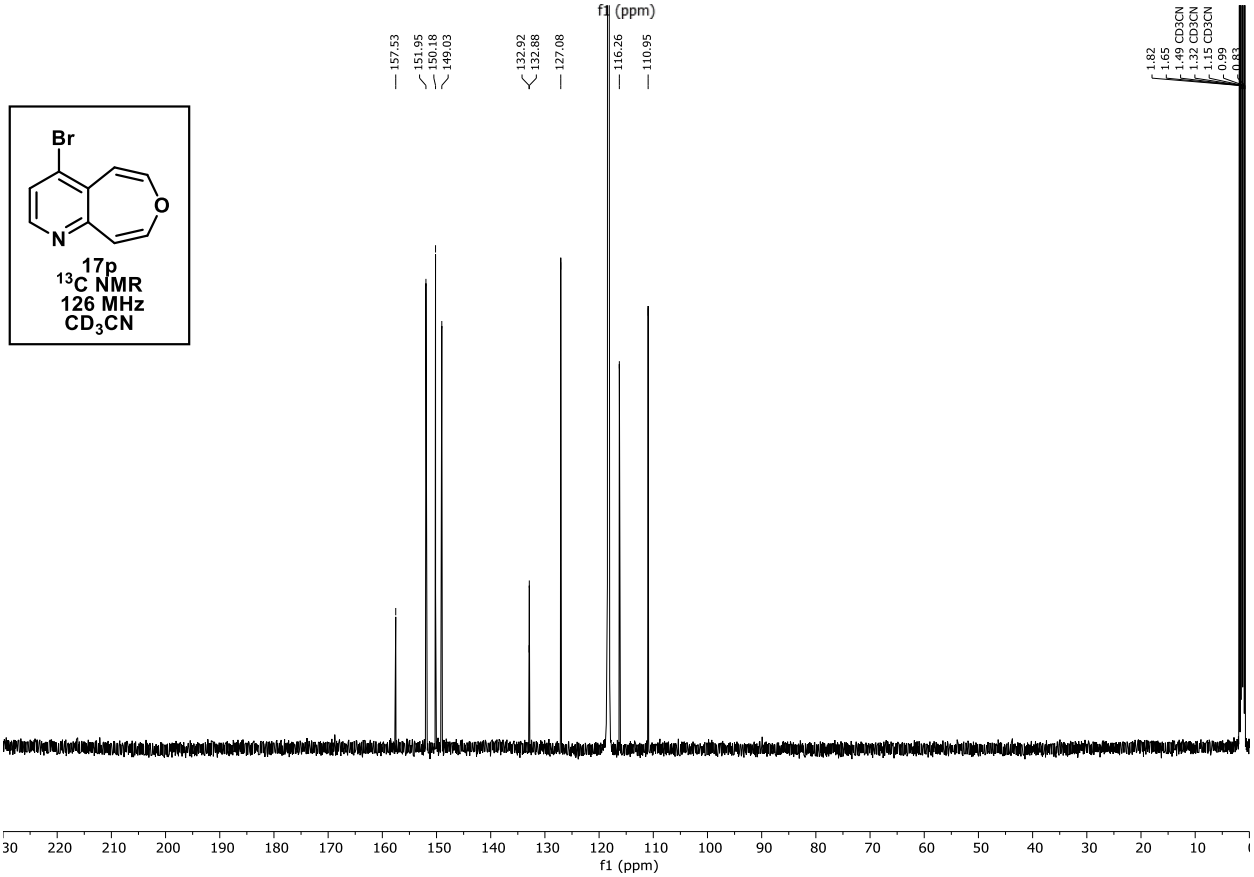

7.26 CDCl3
6.79
5.99
5.97
5.90
5.88
5.58
5.57
5.45
5.43
2.35
Cl
O
Me
N
17n
13C NMR
126 MHz
CDCl3
1.00
0.95
0.98
1.00
0.99
2.95
f1 (ppm)

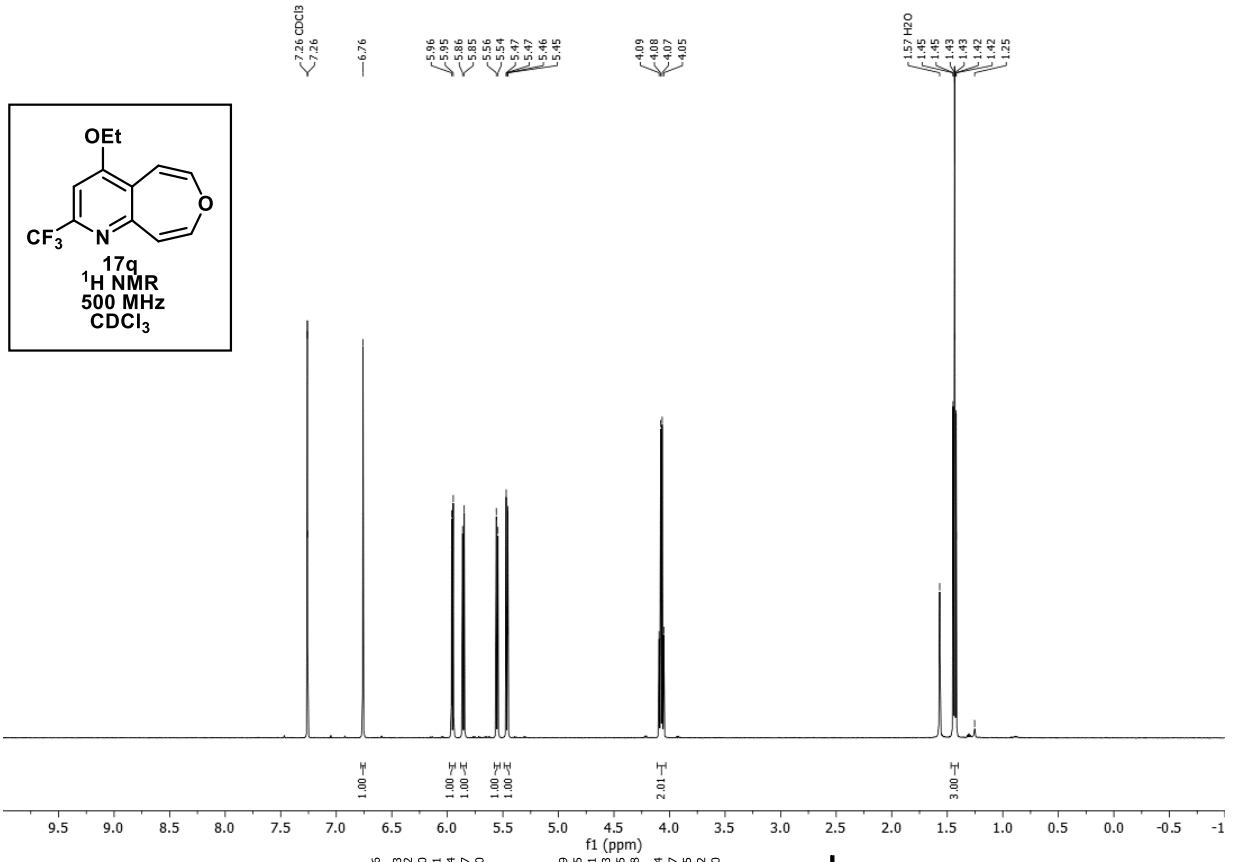

157.23
156.35
150.59
148.06
141.44
127.64
121.95
115.63
107.58
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
23.86
Cl
O
Me
N
17n
13C NMR
126 MHz
CDCl3
f1 (ppm)

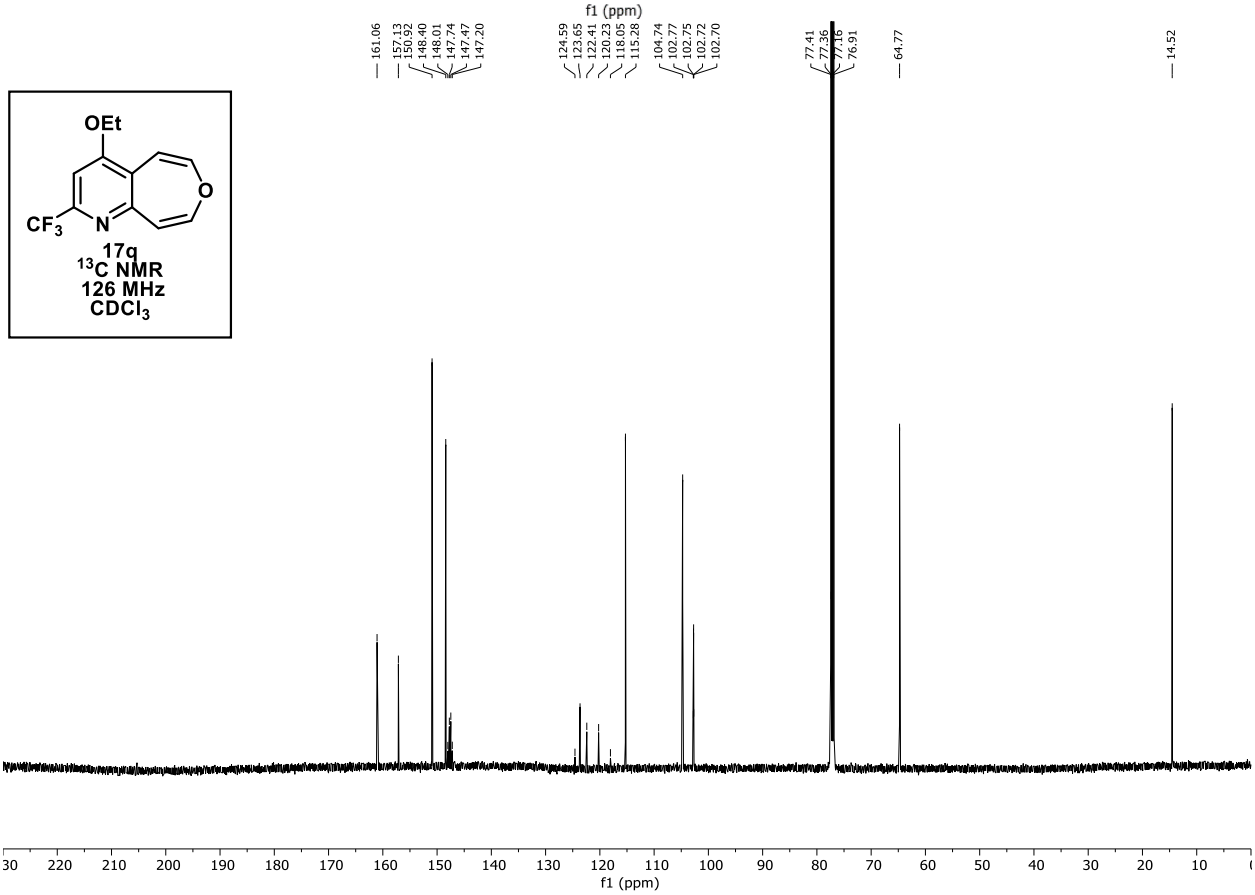

7.99
7.97
7.26 CDCl3
6.89
6.88
5.97
5.95
5.90
5.89
5.56
5.55
5.44
5.42
Cl
O
N
17o
1H NMR
500 MHz
CDCl3
0.97
0.99
1.01
1.01
1.00
1.03
f1 (ppm)

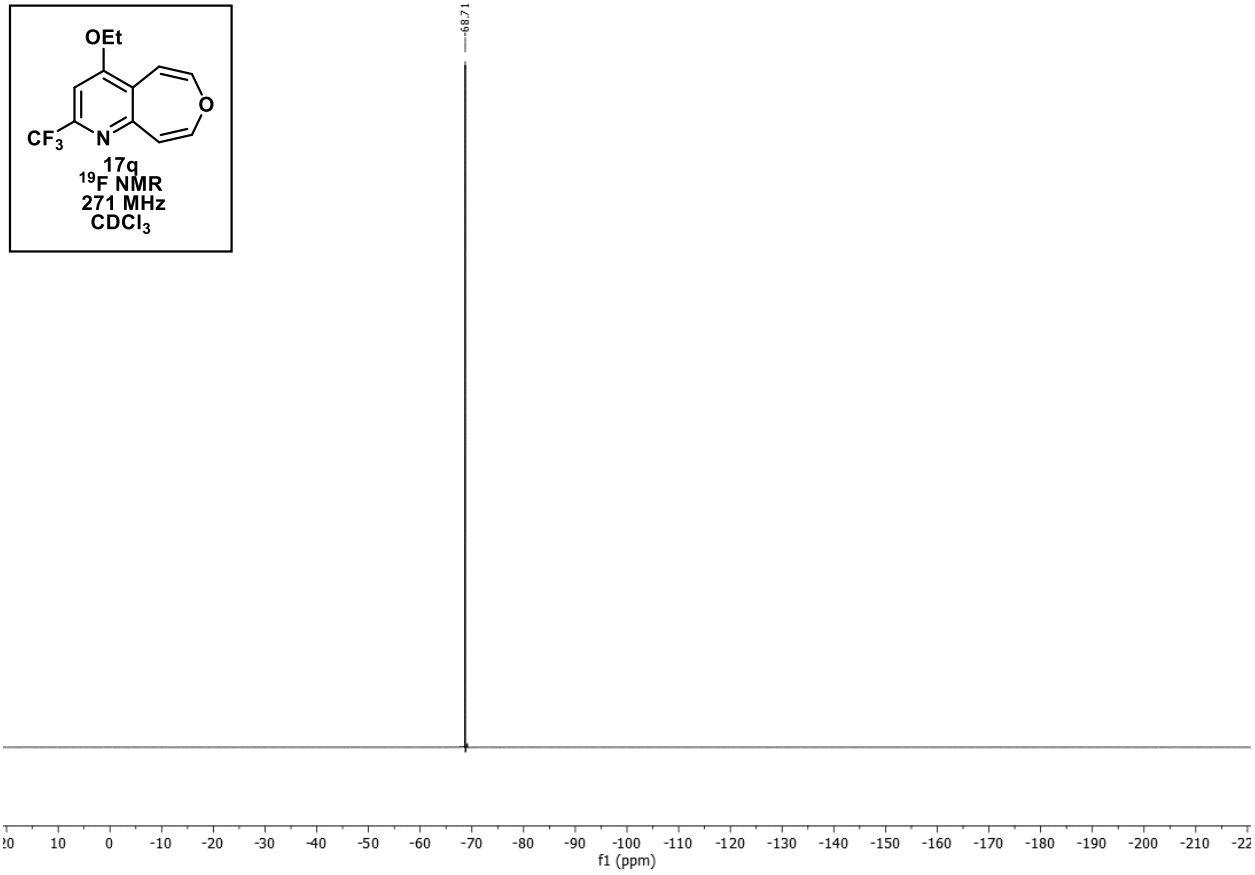

157.26
150.65
148.89
147.93
141.14
130.75
122.87
115.37
107.20
77.41 CDCl3
76.91 CDCl3
Cl
O
N
17o
13C NMR
126 MHz
CDCl3
f1 (ppm)

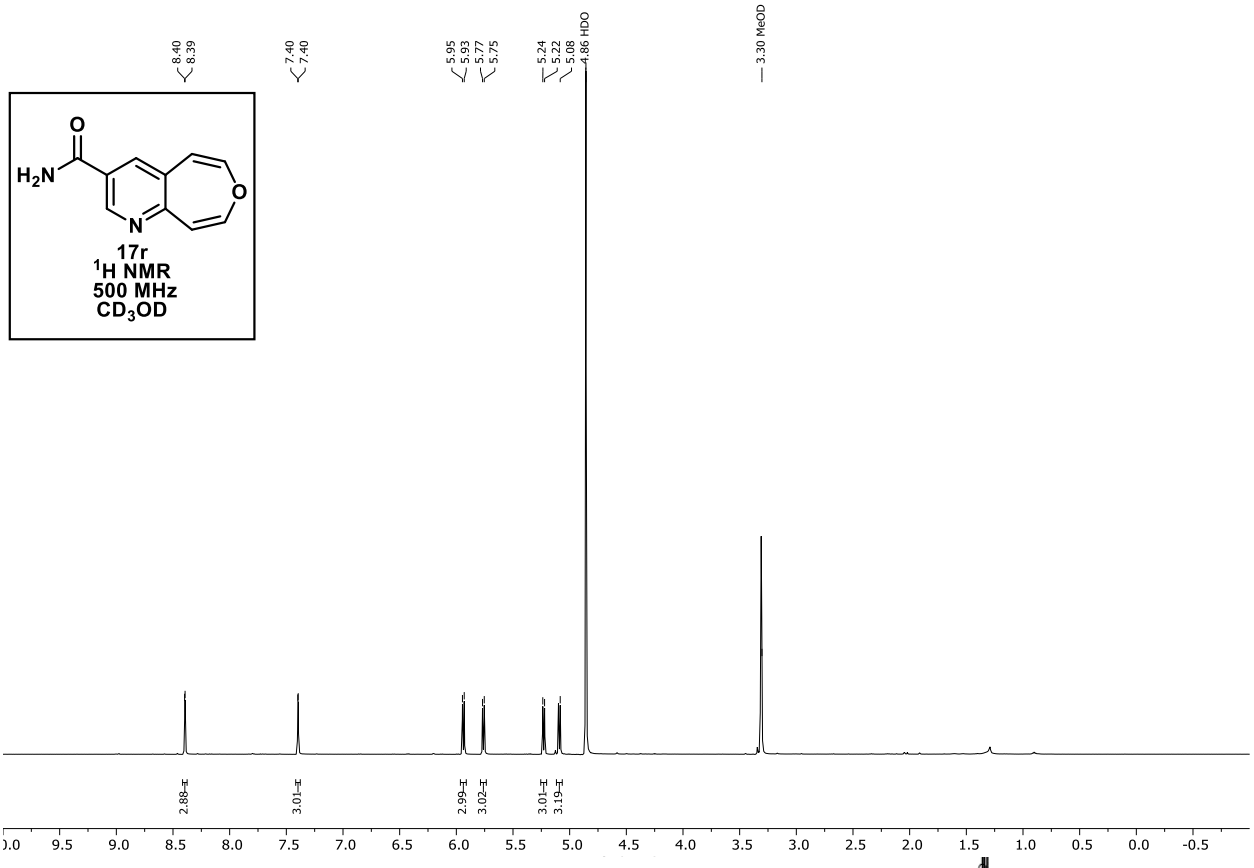

7.91
7.90
7.21
7.20
6.08
6.06
6.02
6.00
5.64
5.62
5.49
5.48
1.94 CD3CN
1.00
0.97
0.99
0.98
0.96
1.00
f1 (ppm)
Br
O
N
17p
1H NMR
500 MHz
CD3CN

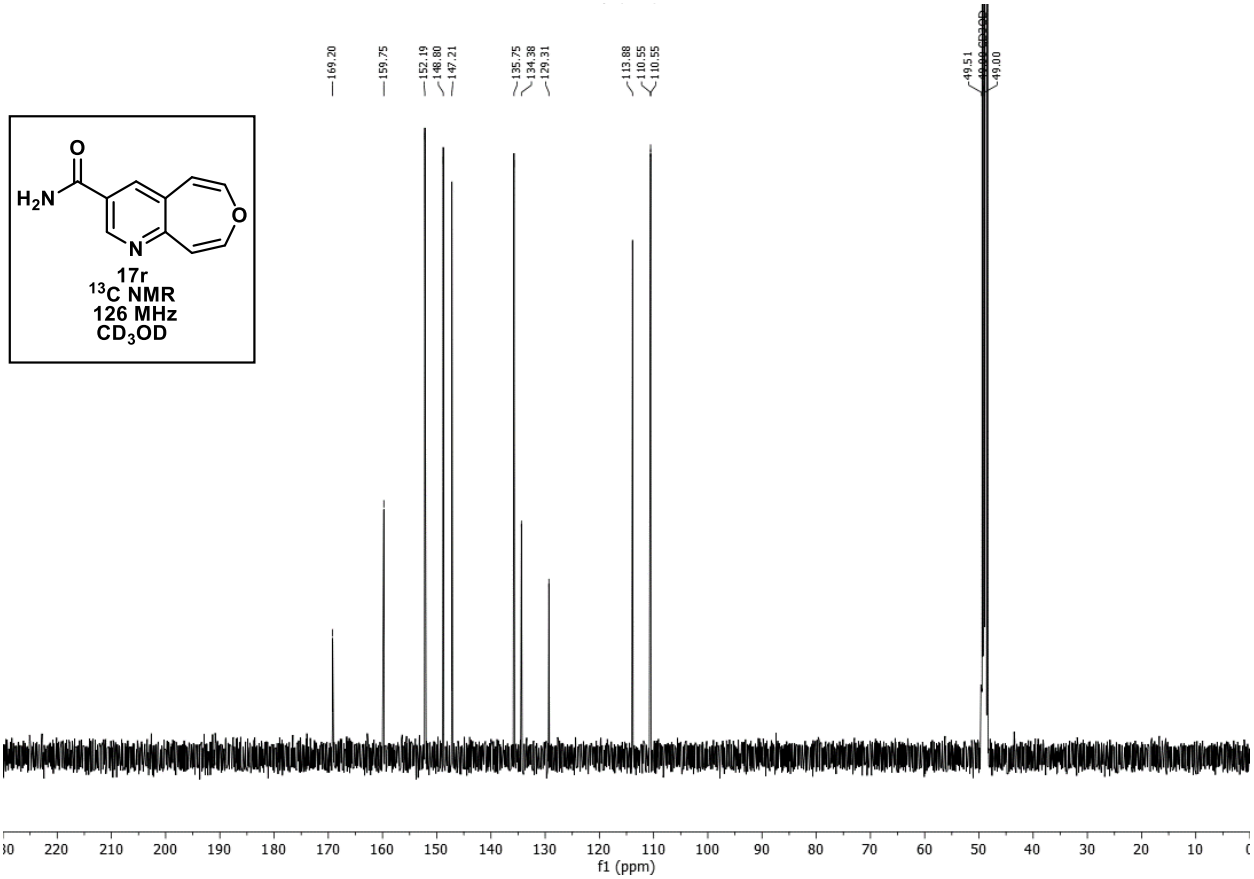

157.53
151.95
150.18
149.03
132.92
132.88
127.08
116.26
110.95
1.82
1.65
1.49 CD3CN
1.32 CD3CN
1.15 CD3CN
0.99
0.83
f1 (ppm)
Br
O
N
17p
13C NMR
126 MHz
CD3CN

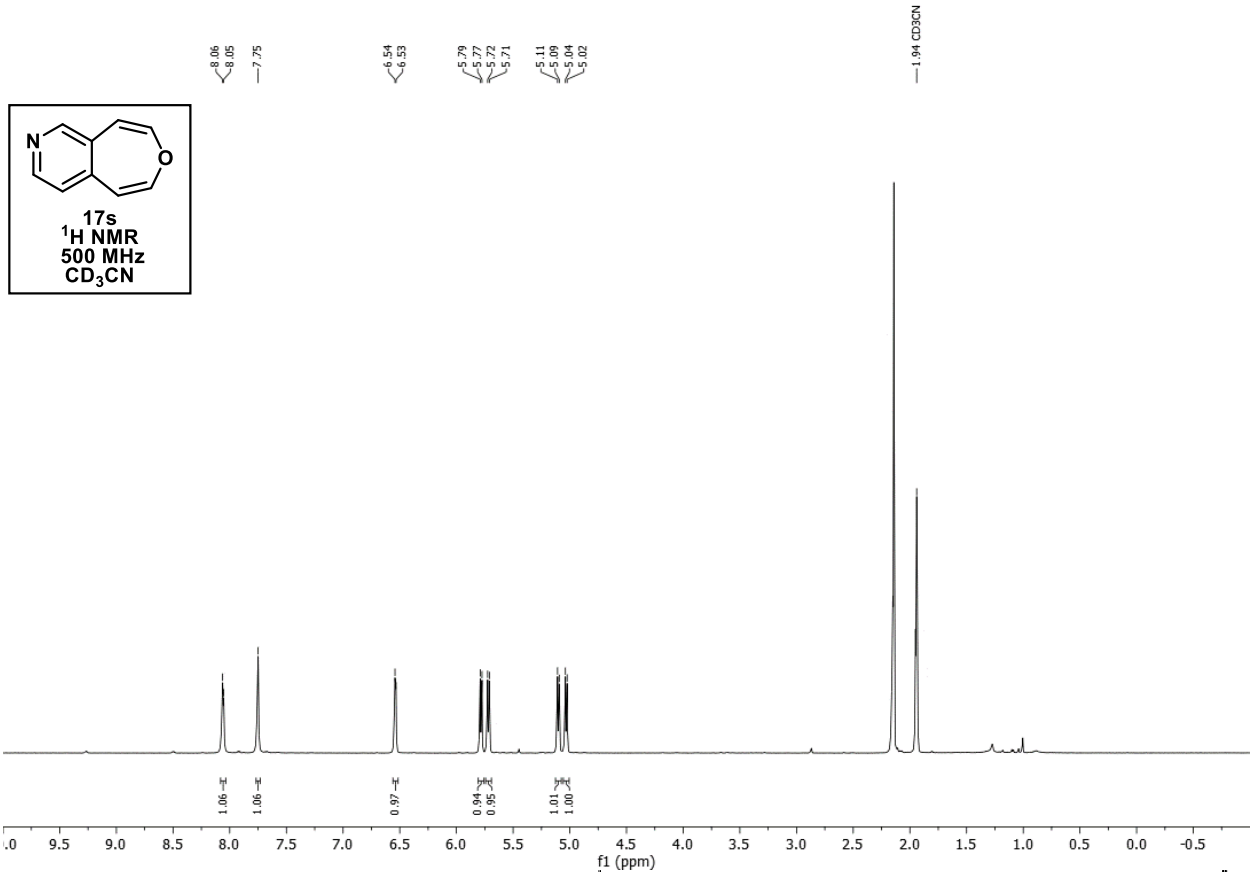

OEt
O
CF3
N
17q
1H NMR
500 MHz
CDCl3
f1 (ppm)

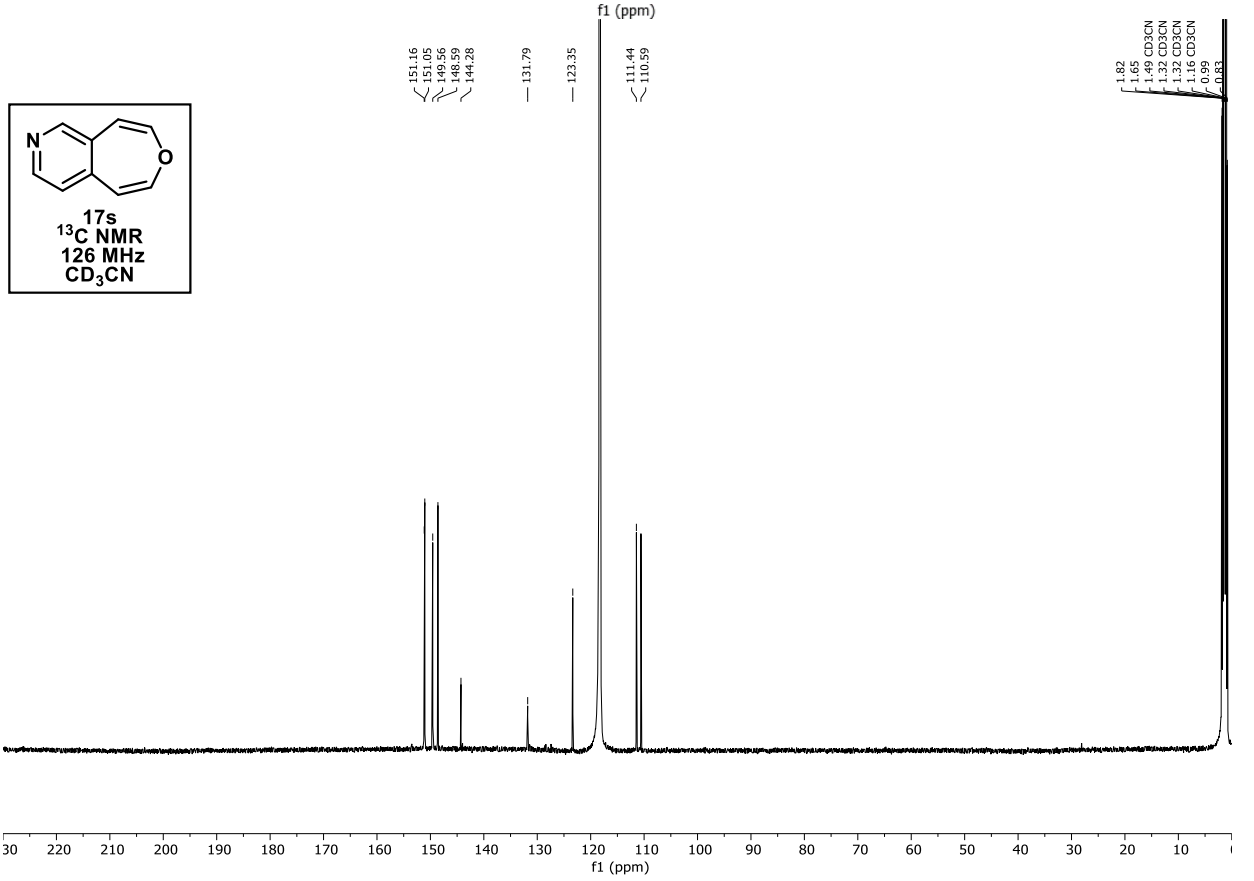

OEt
O
CF3
N
17q
13C NMR
126 MHz
CDCl3
f1 (ppm)

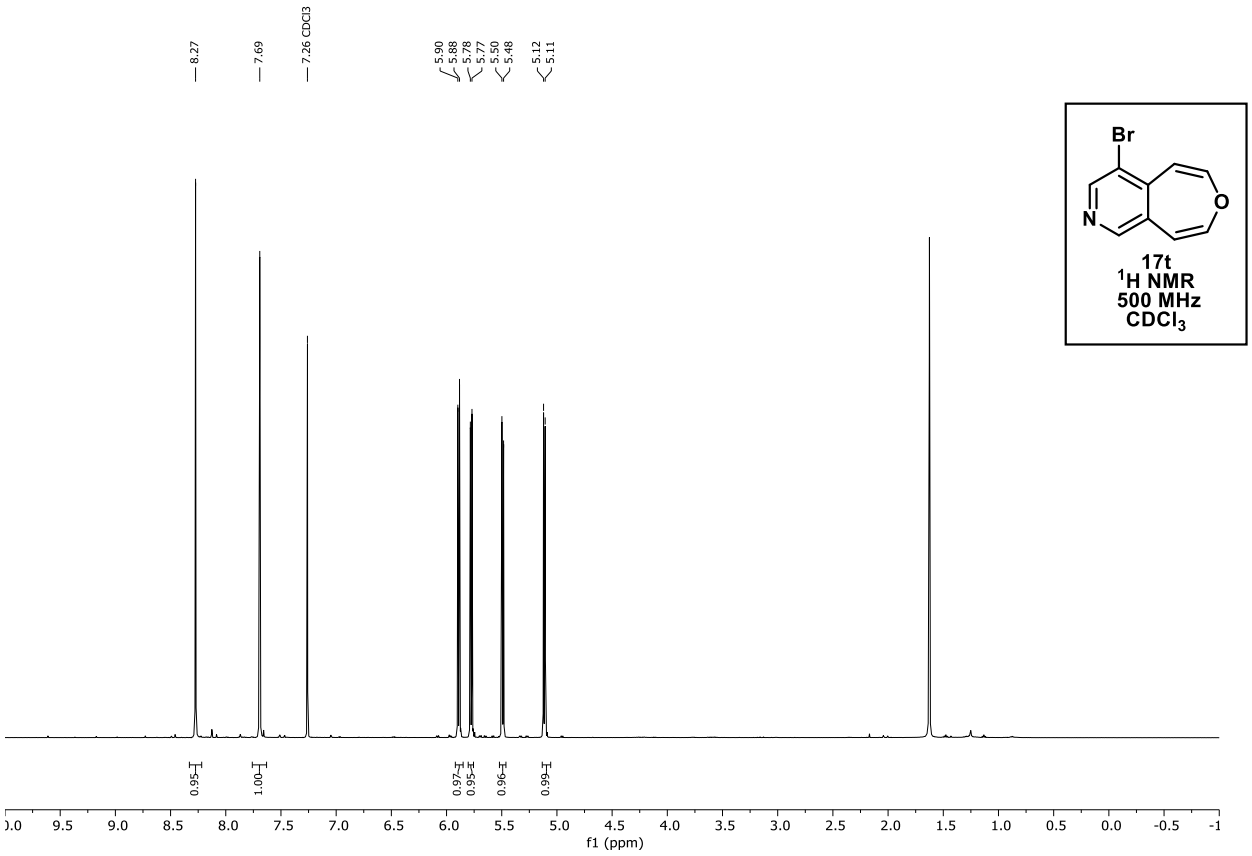

OEt
CF3
N
O
17q
19F NMR
271 MHz
CDCl3
-68.71
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

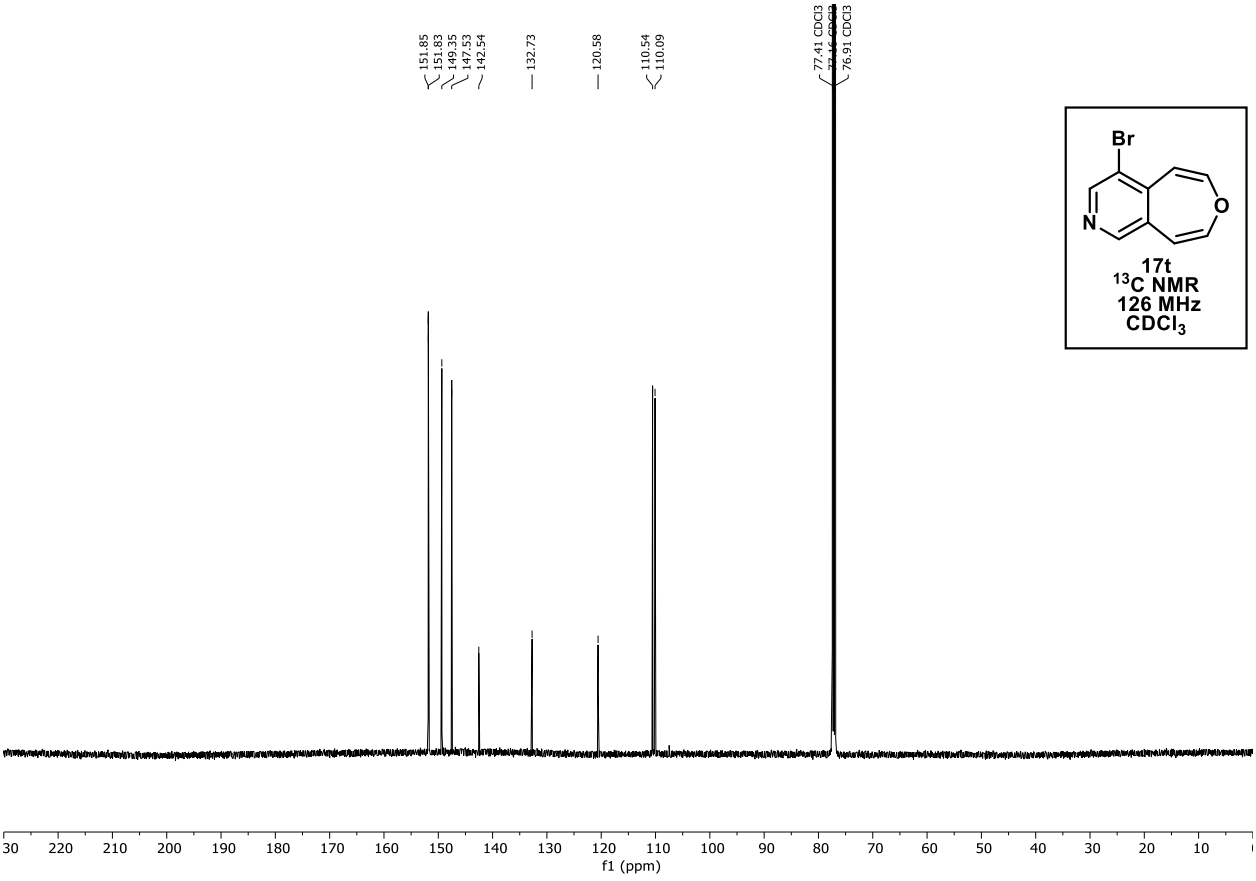

17r
1H NMR
500 MHz
CD3OD
8.40
8.39
7.40
7.40
5.95
5.93
5.77
5.75
5.24
5.22
5.08
4.86 HDO
3.30 MeOD
2.88
3.01
2.99
3.02
3.01
3.19

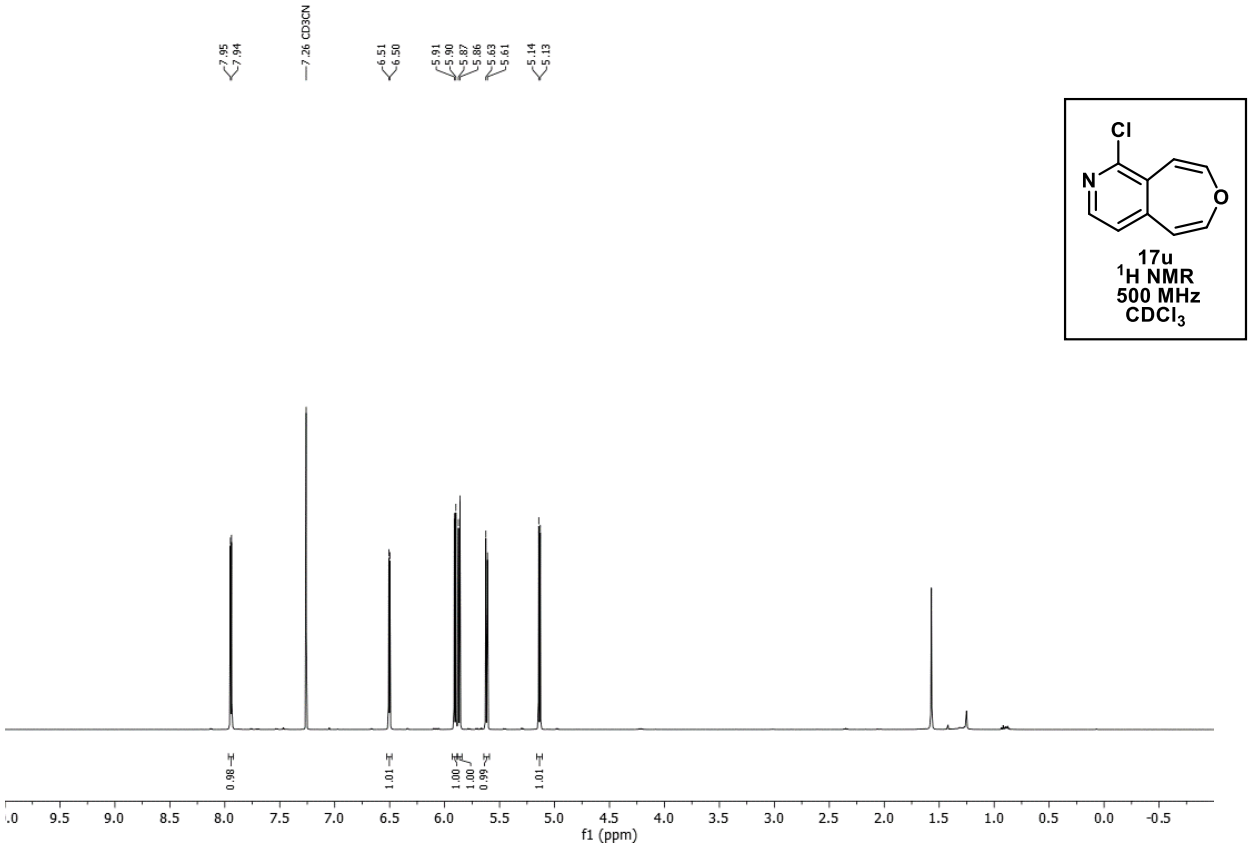

17r
13C NMR
126 MHz
CD3OD
169.20
159.75
152.19
148.80
147.21
135.75
134.38
129.31
113.88
110.55
110.55
49.51
49.00
f1 (ppm)

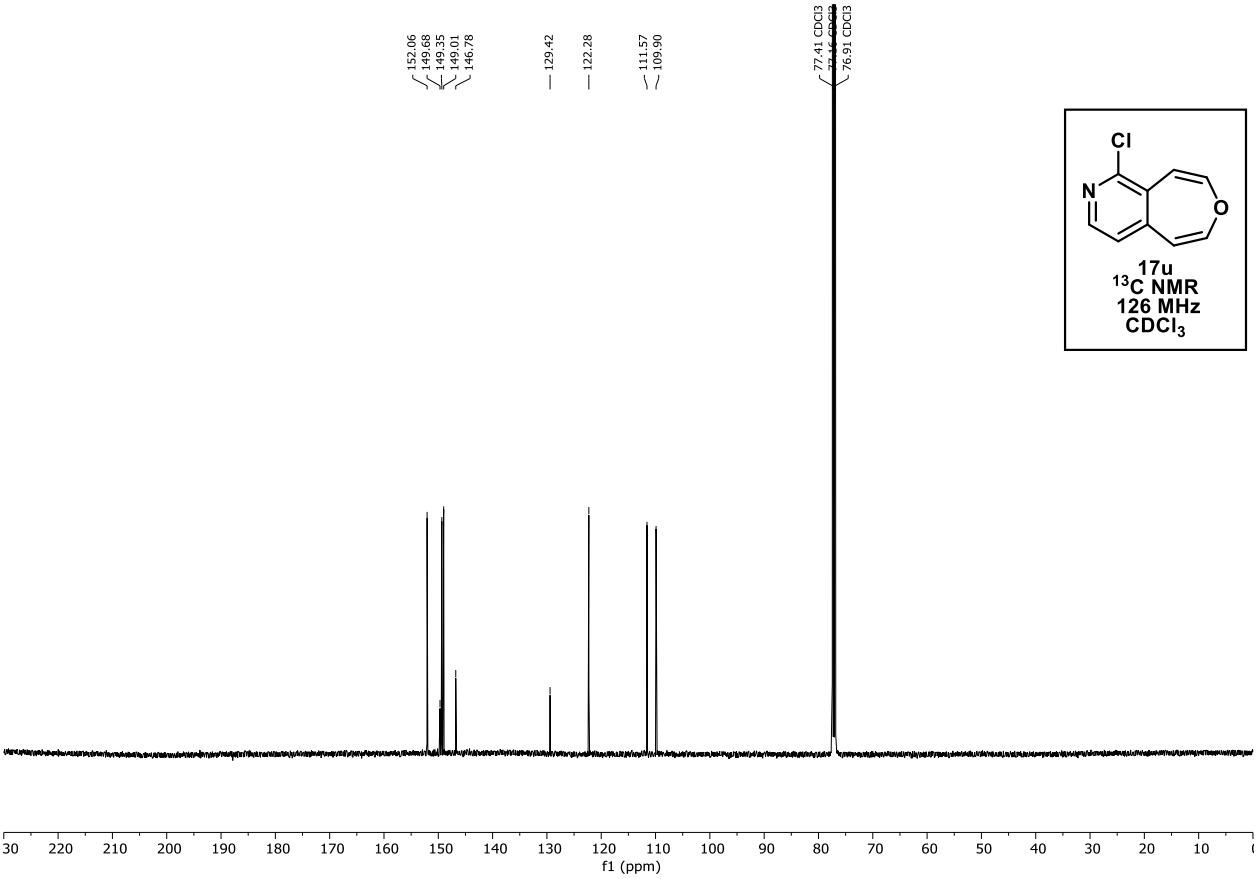

8.06
8.05
7.75
6.54
6.53
5.79
5.77
5.72
5.71
5.11
5.09
5.04
5.02
1.94 CD3CN
17s
1H NMR
500 MHz
CD3CN
1.06
1.06
0.97
0.94
0.95
1.01
1.00
f1 (ppm)

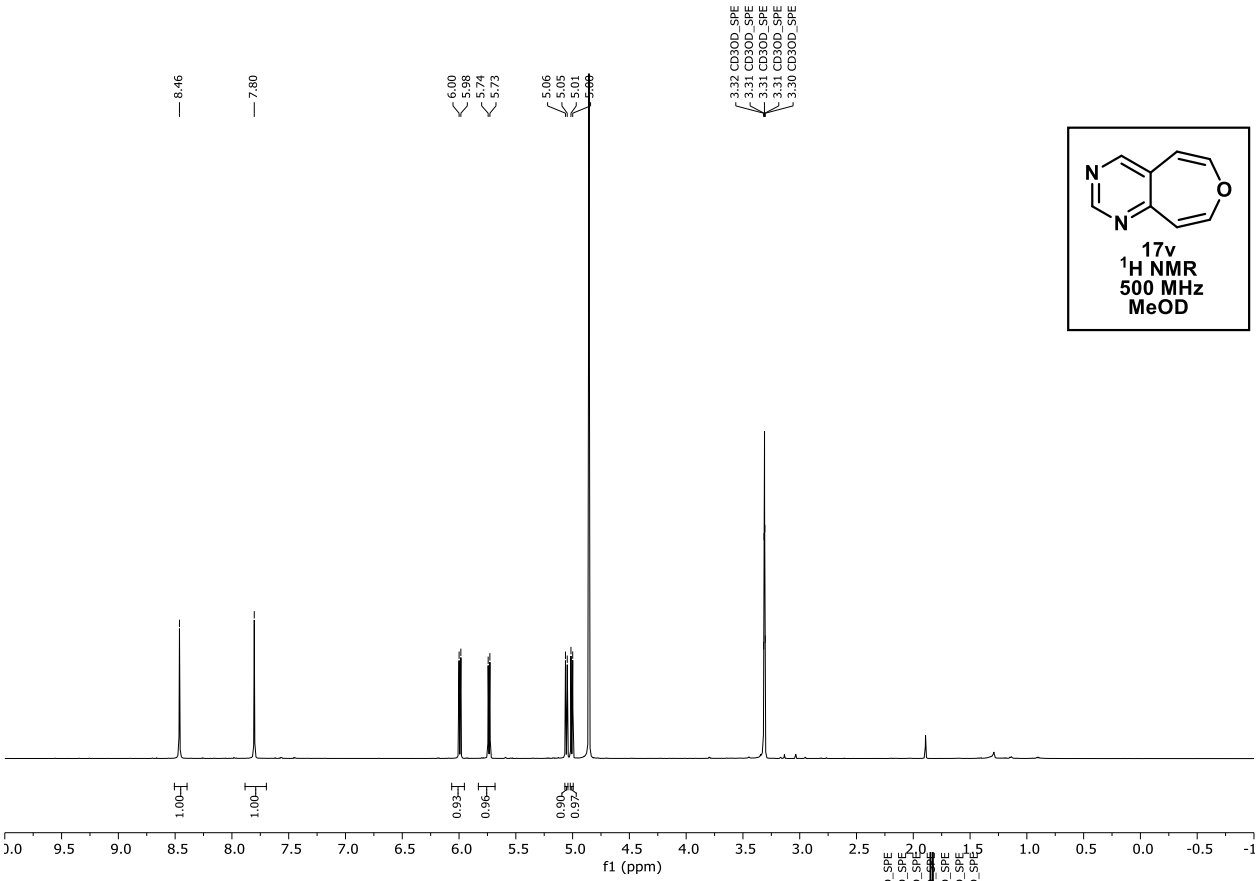

151.16
151.05
149.56
148.59
144.28
131.79
123.35
111.44
110.59
1.82
1.65
1.49 CD3CN
1.32 CD3CN
1.32 CD3CN
1.16 CD3CN
0.99
0.83
17s
13C NMR
126 MHz
CD3CN
f1 (ppm)

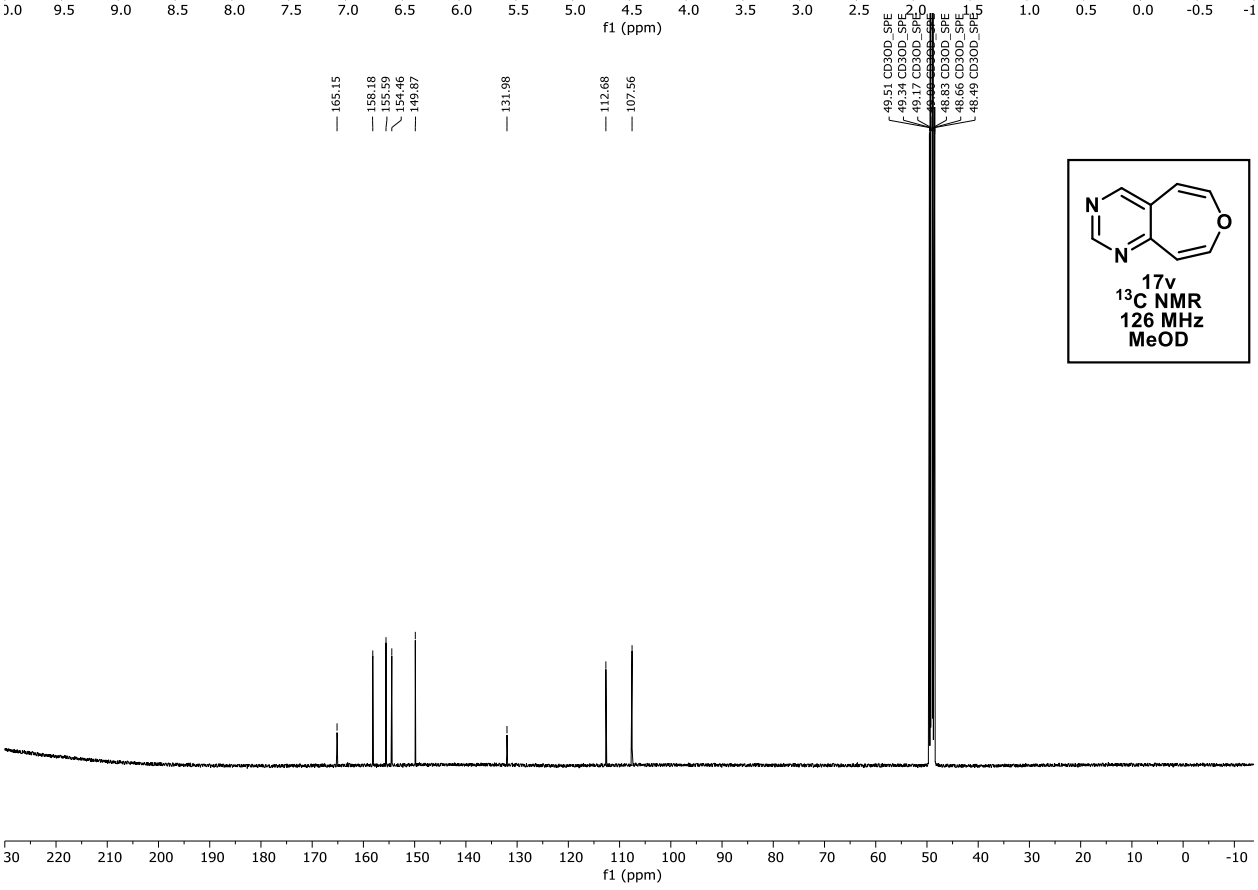

8.27
7.69
7.26 CDCl3
5.90
5.88
5.78
5.77
5.50
5.48
5.12
5.11
0.95
1.00
0.97
0.95
0.96
0.99
f1 (ppm)
Br
N
O
17t
1H NMR
500 MHz
CDCl3

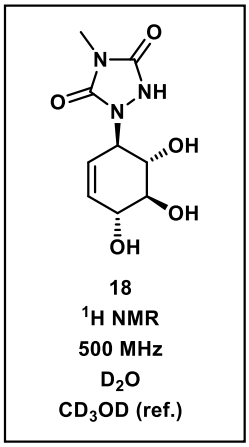

151.85
151.83
149.35
147.53
142.54
132.73
120.58
110.54
110.09
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
f1 (ppm)
Br
N
O
17t
13C NMR
126 MHz
CDCl3


7.95
7.94
7.26 CD3CN
6.51
6.50
5.91
5.90
5.87
5.86
5.63
5.61
5.14
5.13
Cl
N
O
17u
1H NMR
500 MHz
CDCl3
0.98
1.01
1.00
1.00
0.99
1.01
f1 (ppm)

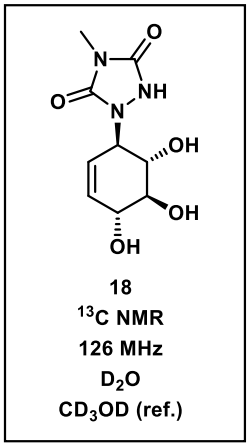

152.06
149.68
149.35
149.01
146.78
129.42
122.28
111.57
109.90
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
Cl
N
O
17u
13C NMR
126 MHz
CDCl3
f1 (ppm)


8.46
7.80
6.00
5.98
5.74
5.73
5.06
5.05
5.01
5.00
3.32 CD3OD_SPE
3.31 CD3OD_SPE
3.31 CD3OD_SPE
3.31 CD3OD_SPE
3.30 CD3OD_SPE
1.00
1.00
0.93
0.96
0.90
0.97
f1 (ppm)
17v
1H NMR
500 MHz
MeOD

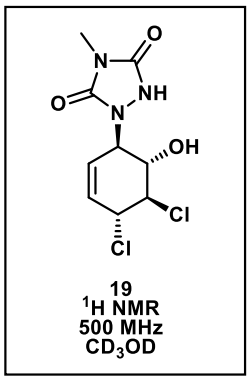

165.15
158.18
155.59
154.46
149.87
131.98
112.68
107.56
49.51 CD3OD_SPE
49.34 CD3OD_SPE
49.17 CD3OD_SPE
48.83 CD3OD_SPE
48.66 CD3OD_SPE
48.49 CD3OD_SPE
f1 (ppm)
17v
13C NMR
126 MHz
MeOD



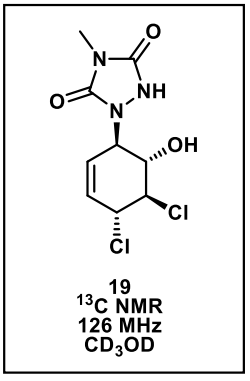
18
^{1}H NMR
500 MHz
D_2O
CD_3OD (ref.)



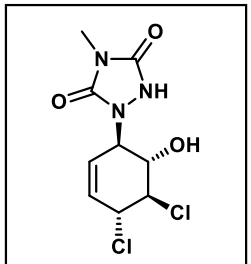
18
^{13}C NMR
126 MHz
D_2O
CD_3OD (ref.)



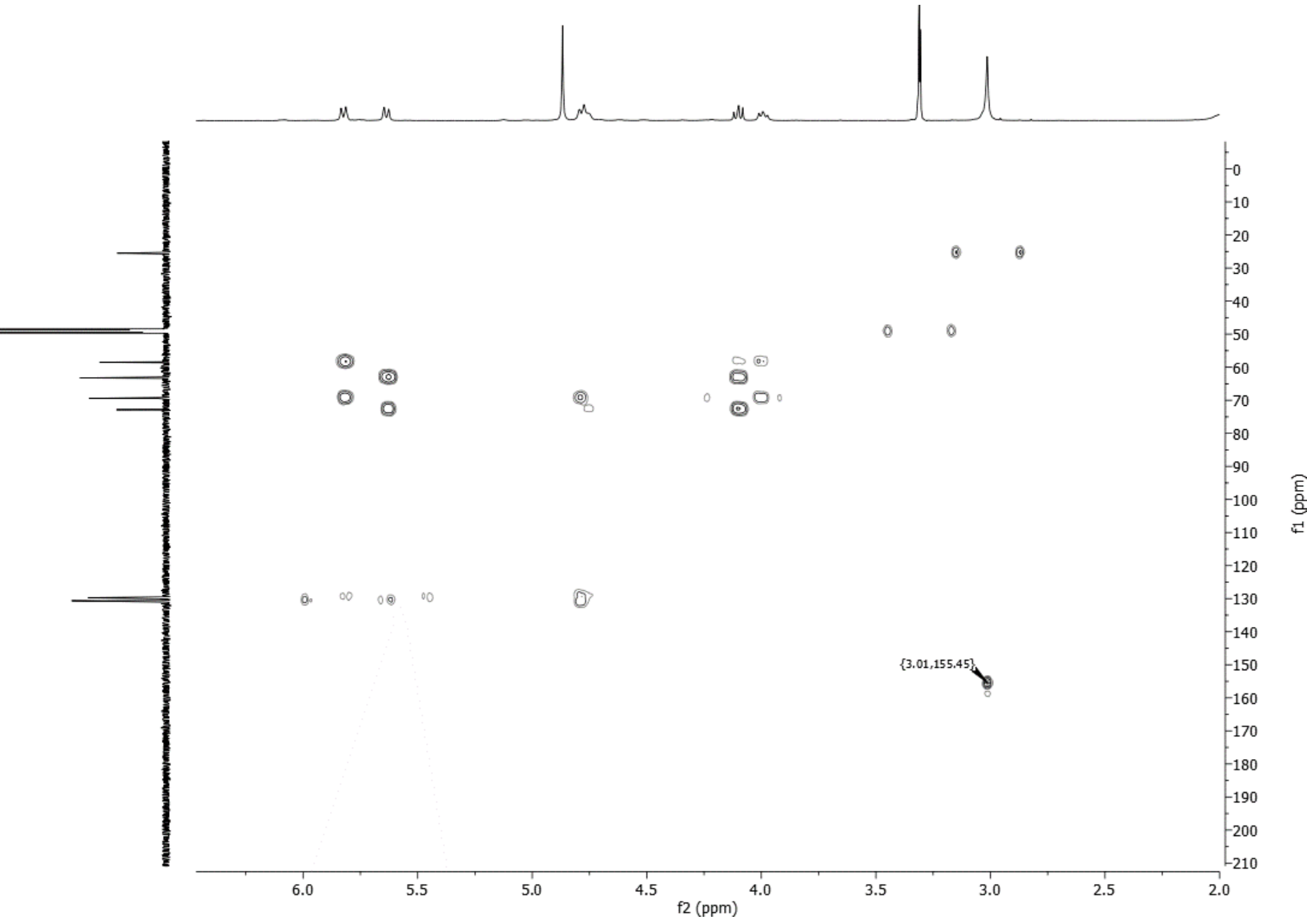
19
^{1}H NMR
500 MHz
CD_3OD

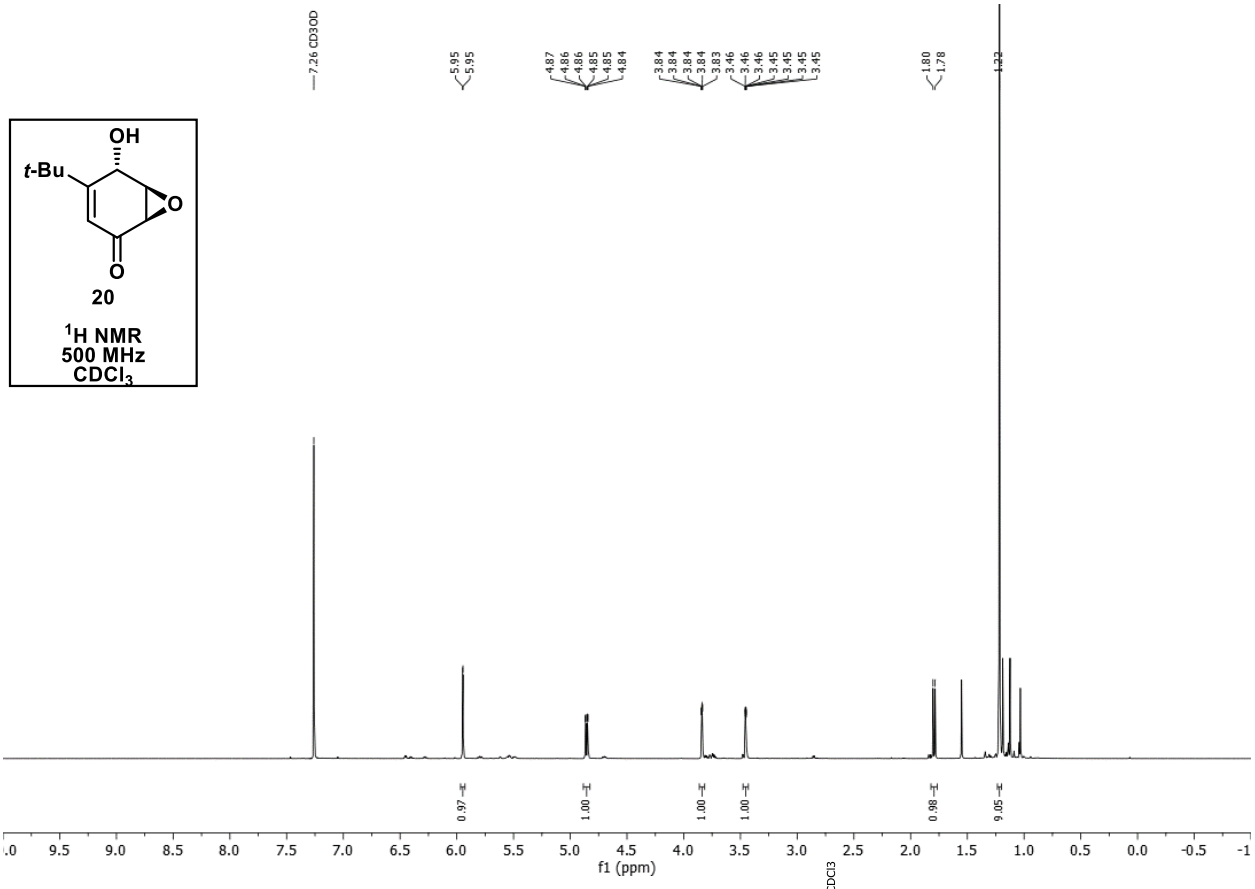


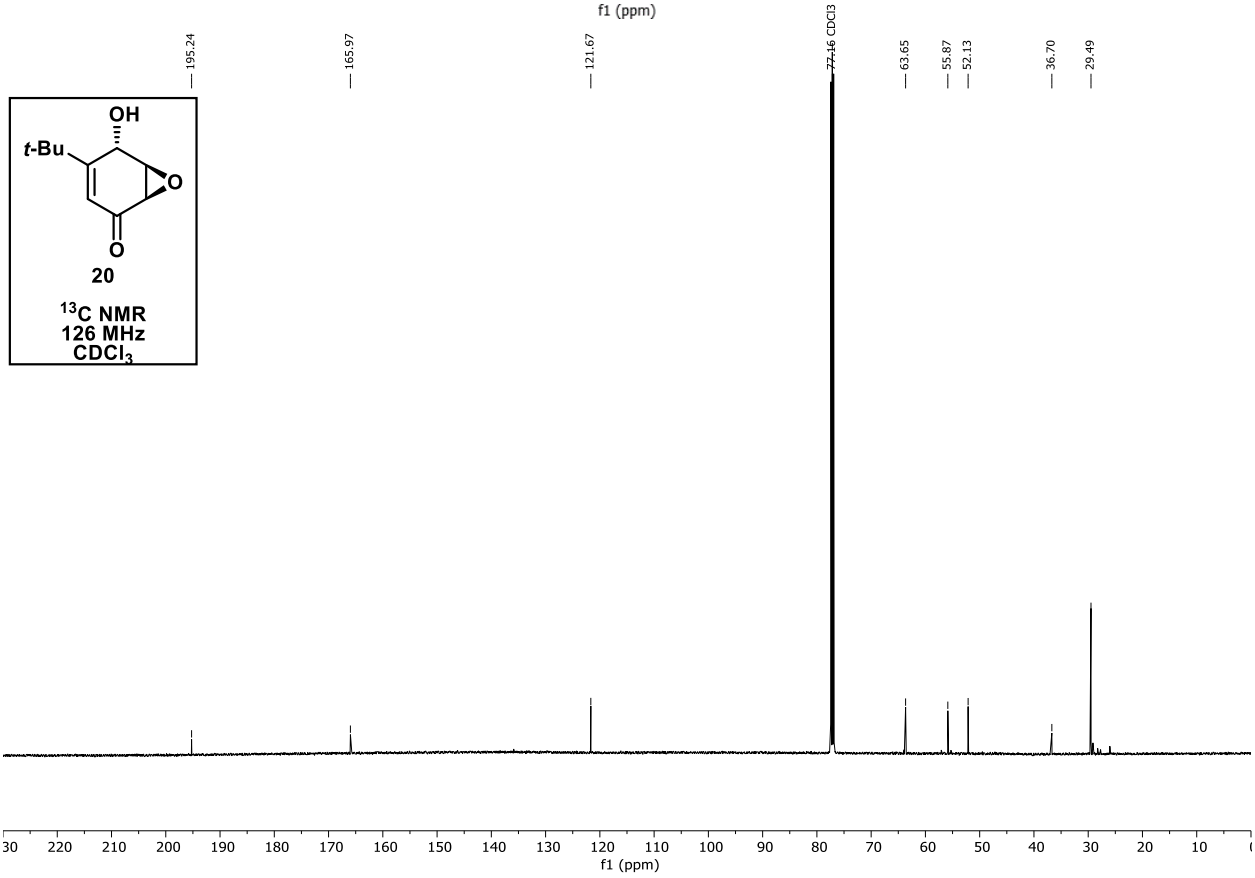
19
^{13}C NMR
126 MHz
CD_3OD

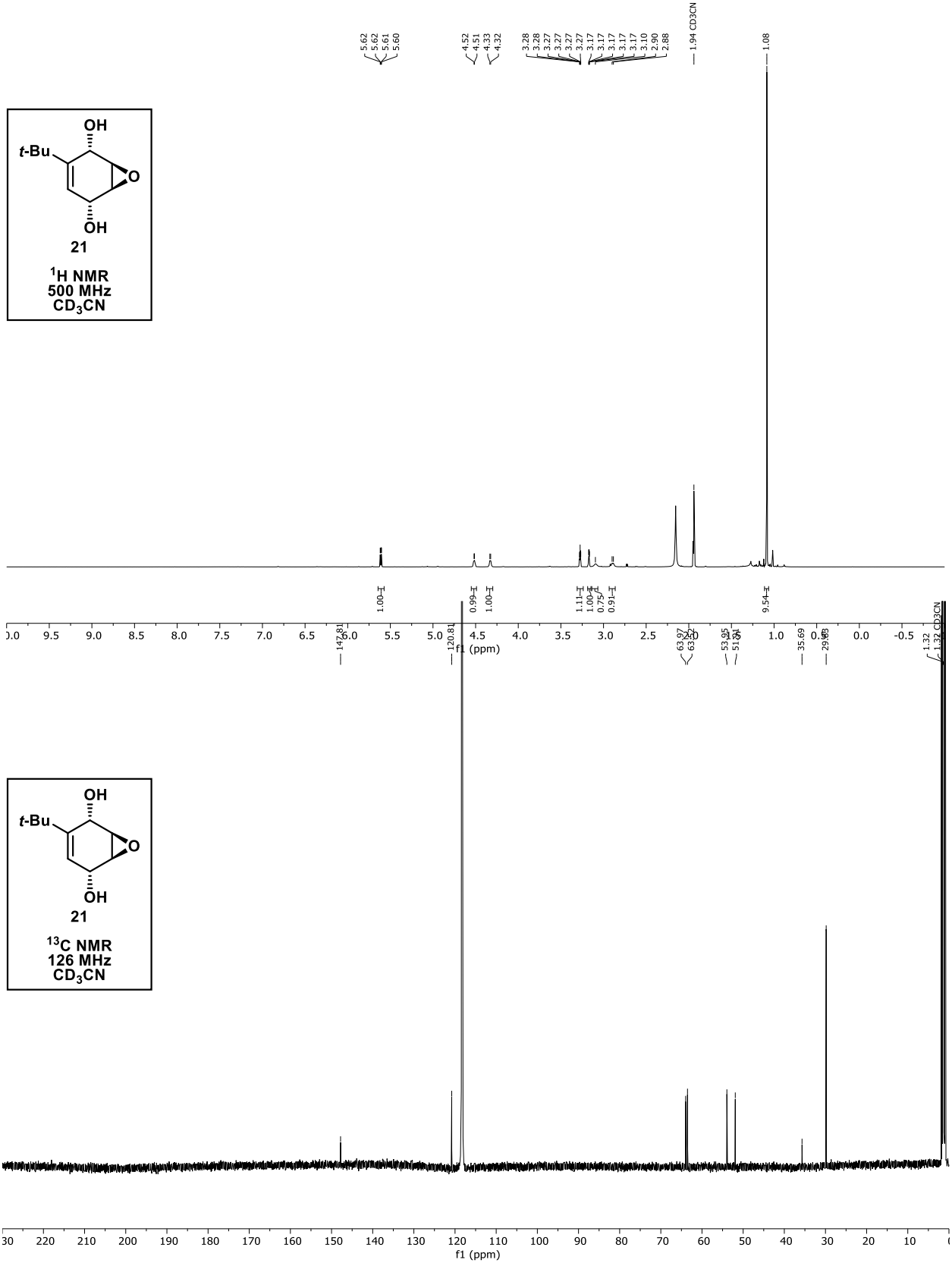


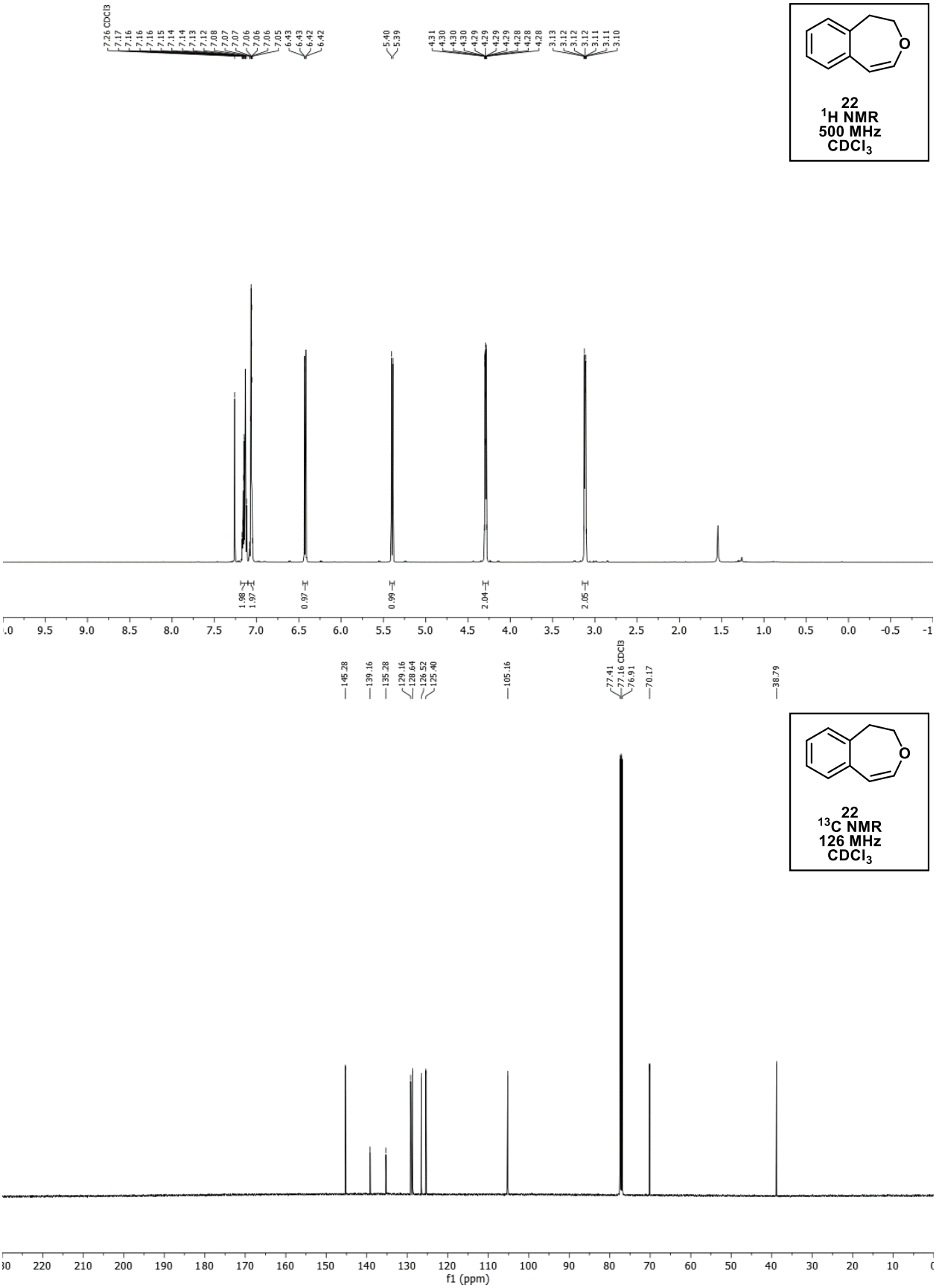
19
HMBC
^{1}H–^{13}C
500 MHz
CD_3OD

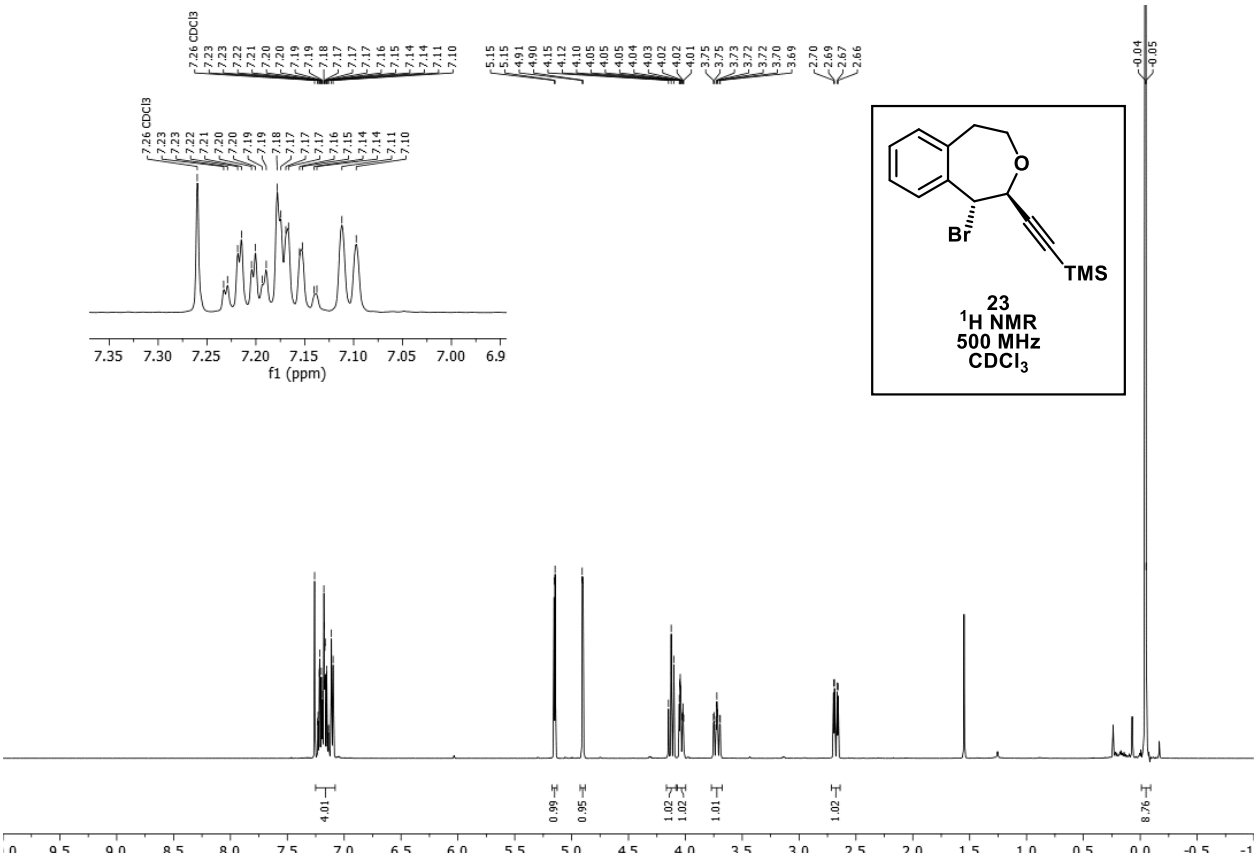


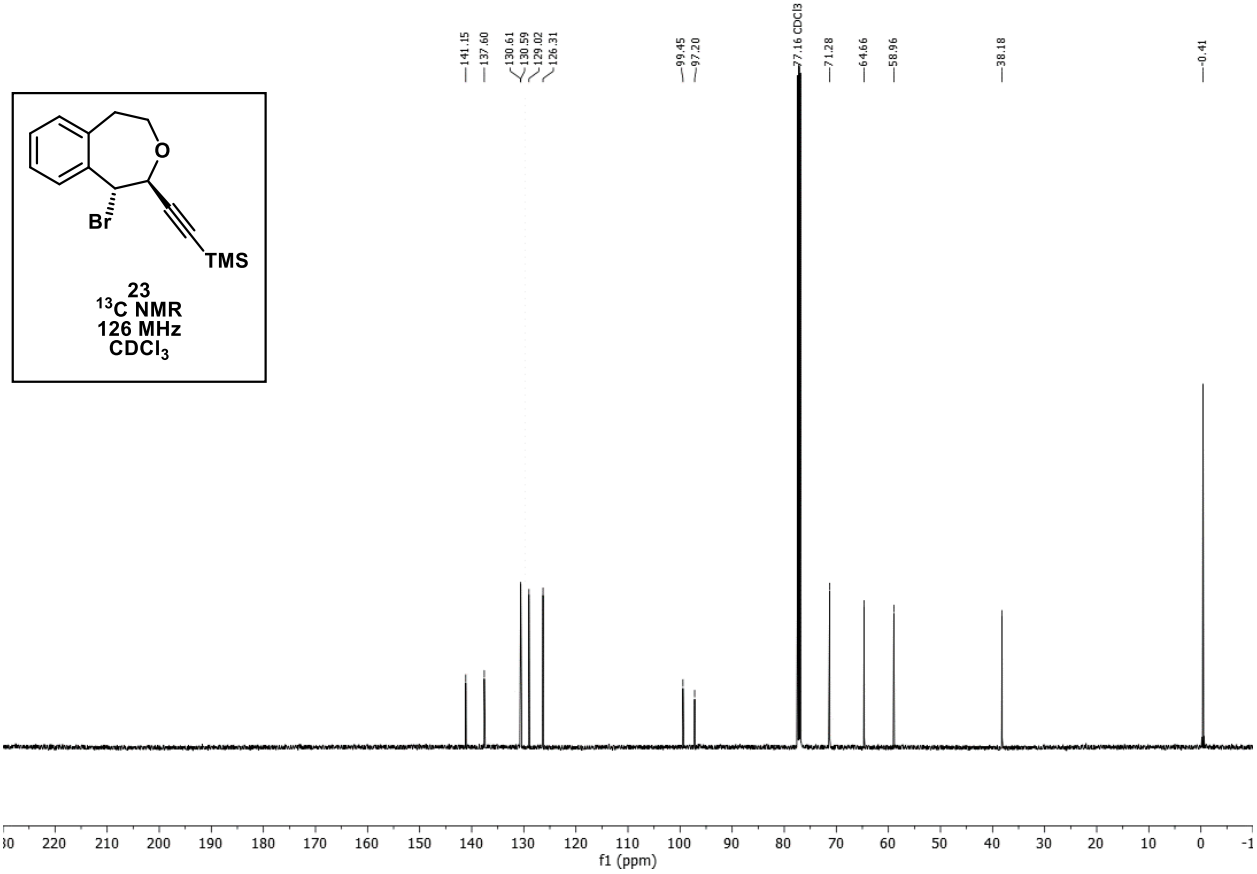

OH
t-Bu
O
O
20
1H NMR
500 MHz
CDCl3
7.26 CD3OD
5.95
5.95
4.87
4.86
4.86
4.85
4.85
4.84
3.84
3.84
3.84
3.84
3.83
3.46
3.46
3.46
3.45
3.45
3.45
3.45
1.80
1.78
1.32
0.97
1.00
1.00
1.00
0.98
9.05
f1 (ppm)

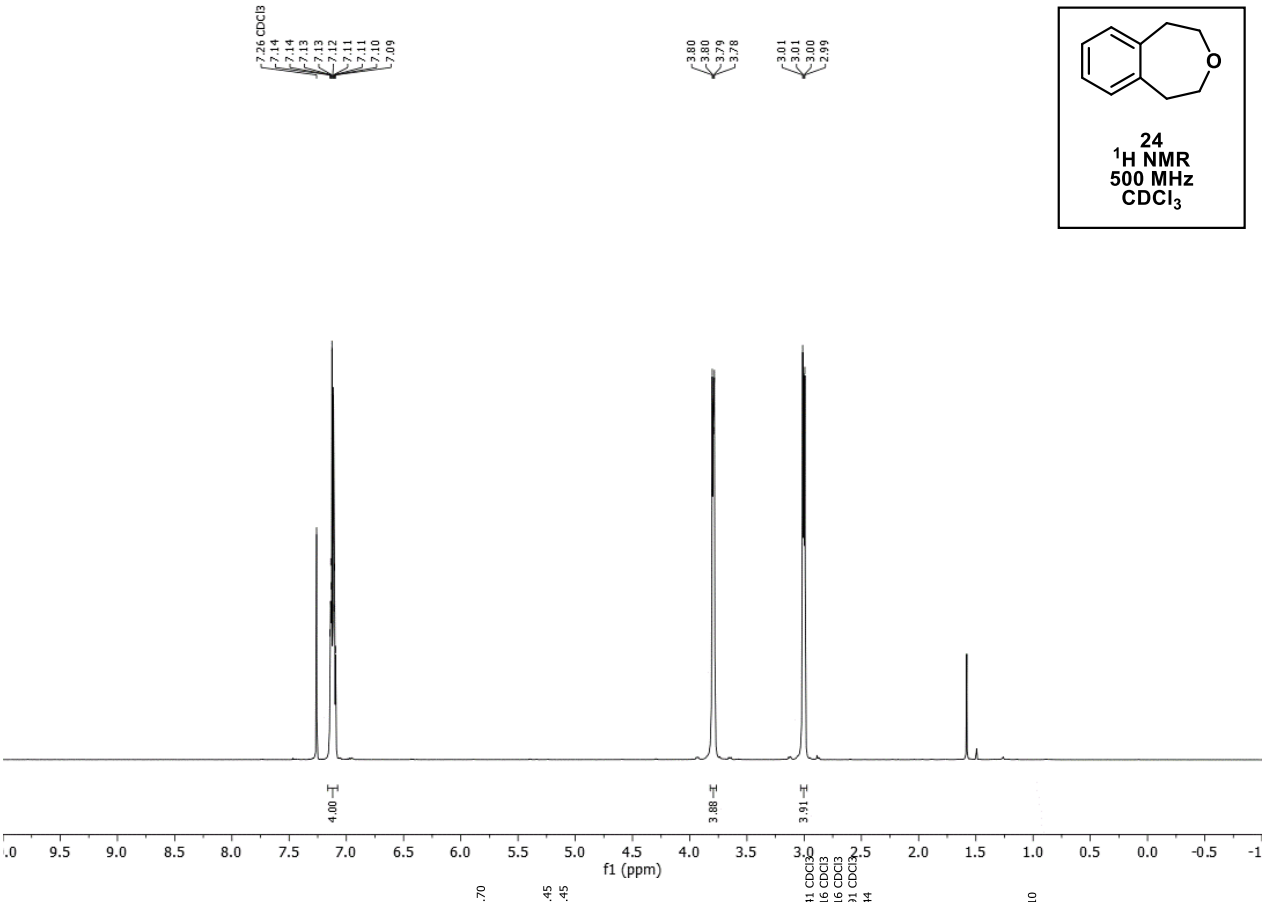

OH
t-Bu
O
O
20
13C NMR
126 MHz
CDCl3
195.24
165.97
121.67
77.16 CDCl3
63.65
55.87
52.13
36.70
29.49
f1 (ppm)

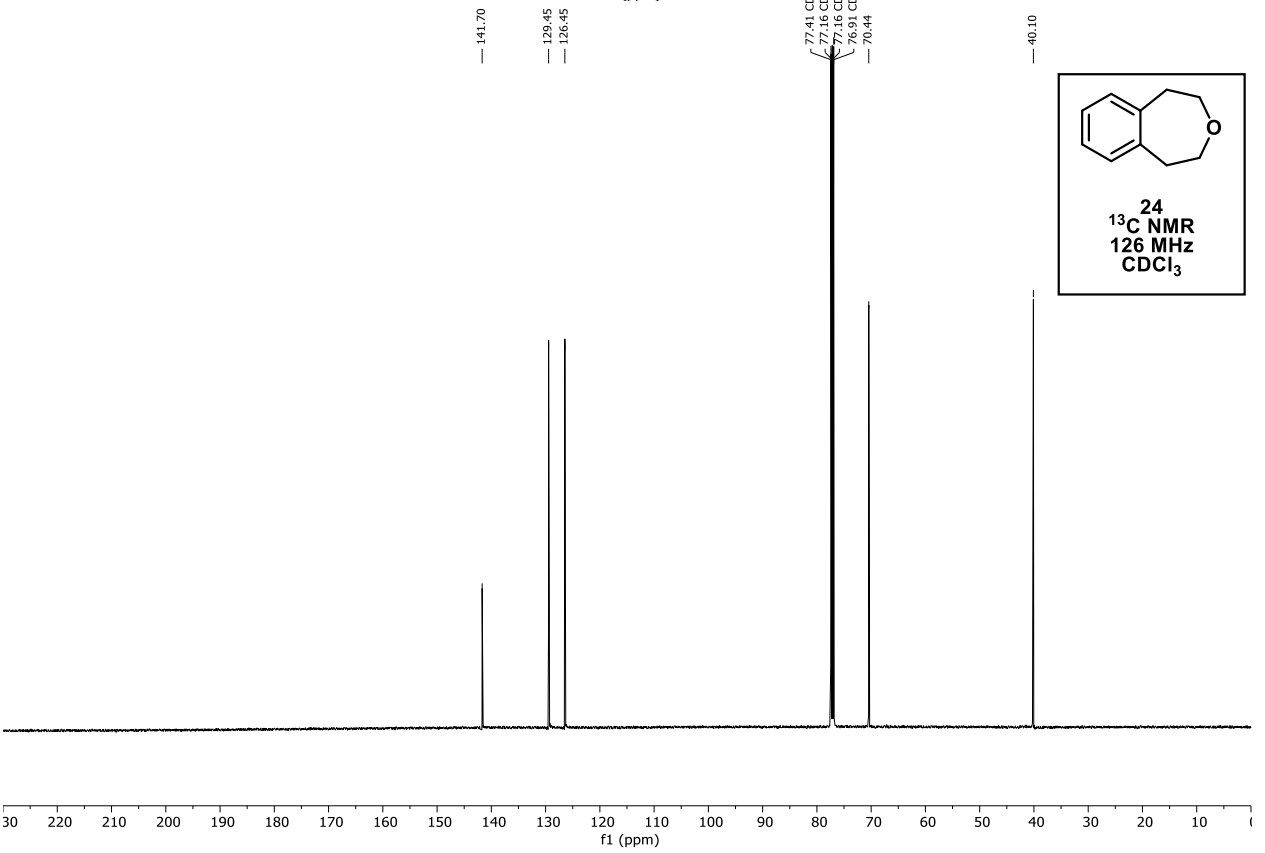

OH
t-Bu
O
OH
21
1H NMR
500 MHz
CD3CN
5.62
5.62
5.61
5.60
4.52
4.51
4.33
4.32
3.28
3.28
3.27
3.27
3.27
3.27
3.17
3.17
3.17
3.17
3.17
3.10
2.90
2.88
1.94 CD3CN
1.08
1.00
0.99
1.00
1.11
1.00
0.75
0.91
9.54
f1 (ppm)
147.81
120.81
63.97
63.52
53.95
51.94
35.69
29.88
1.32
1.32 CD3CN
OH
t-Bu
O
OH
21
13C NMR
126 MHz
CD3CN
f1 (ppm)

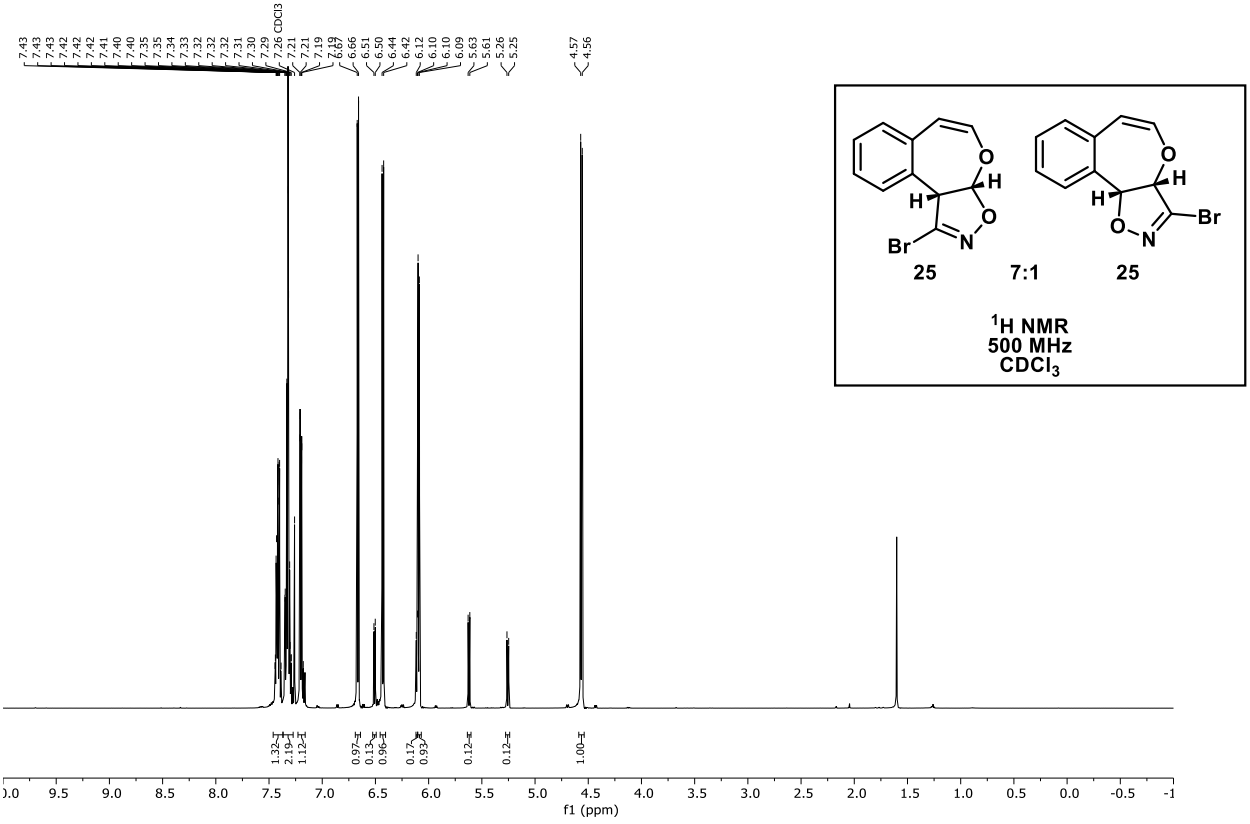

22
1H NMR
500 MHz
CDCl3
22
13C NMR
126 MHz
CDCl3
f1 (ppm)

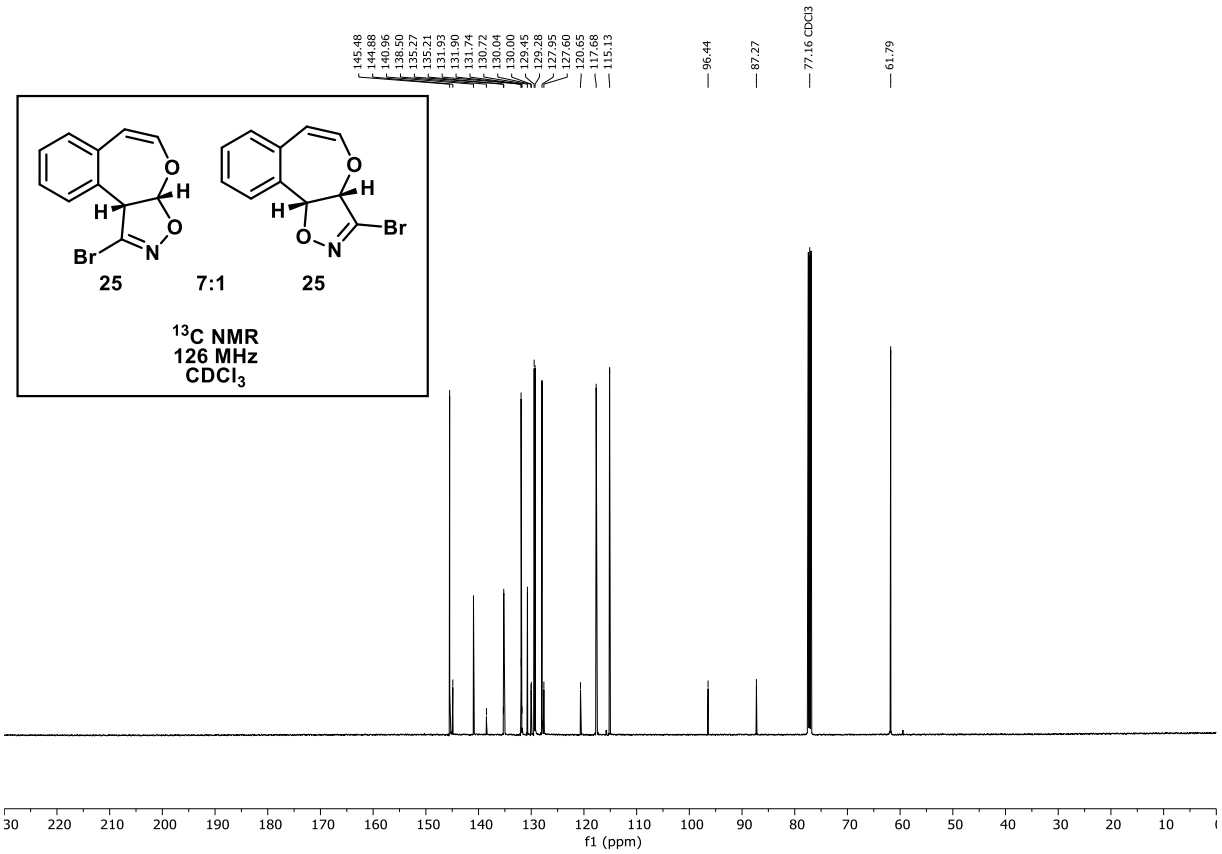

23
1H NMR
500 MHz
CDCl3
Br
O
TMS
f1 (ppm)

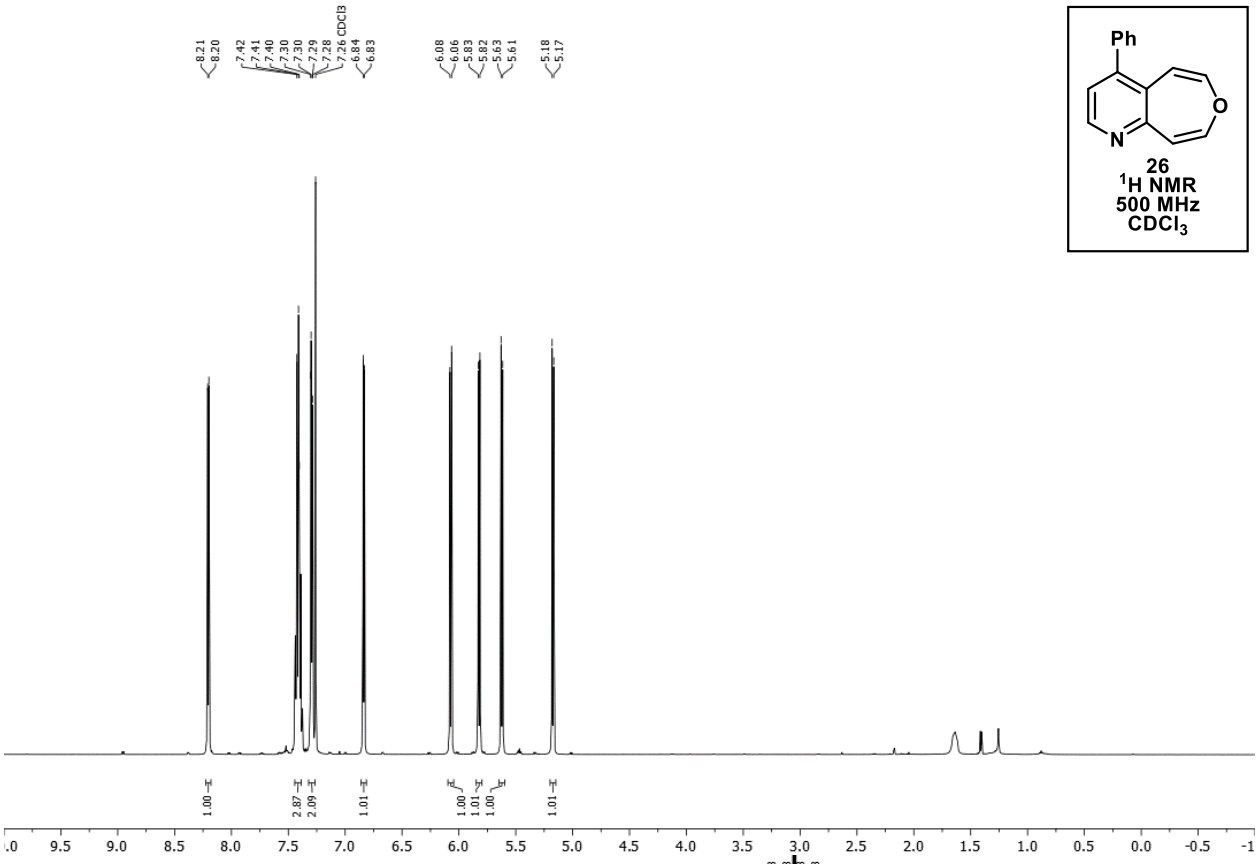

23
13C NMR
126 MHz
CDCl3
Br
O
TMS
f1 (ppm)

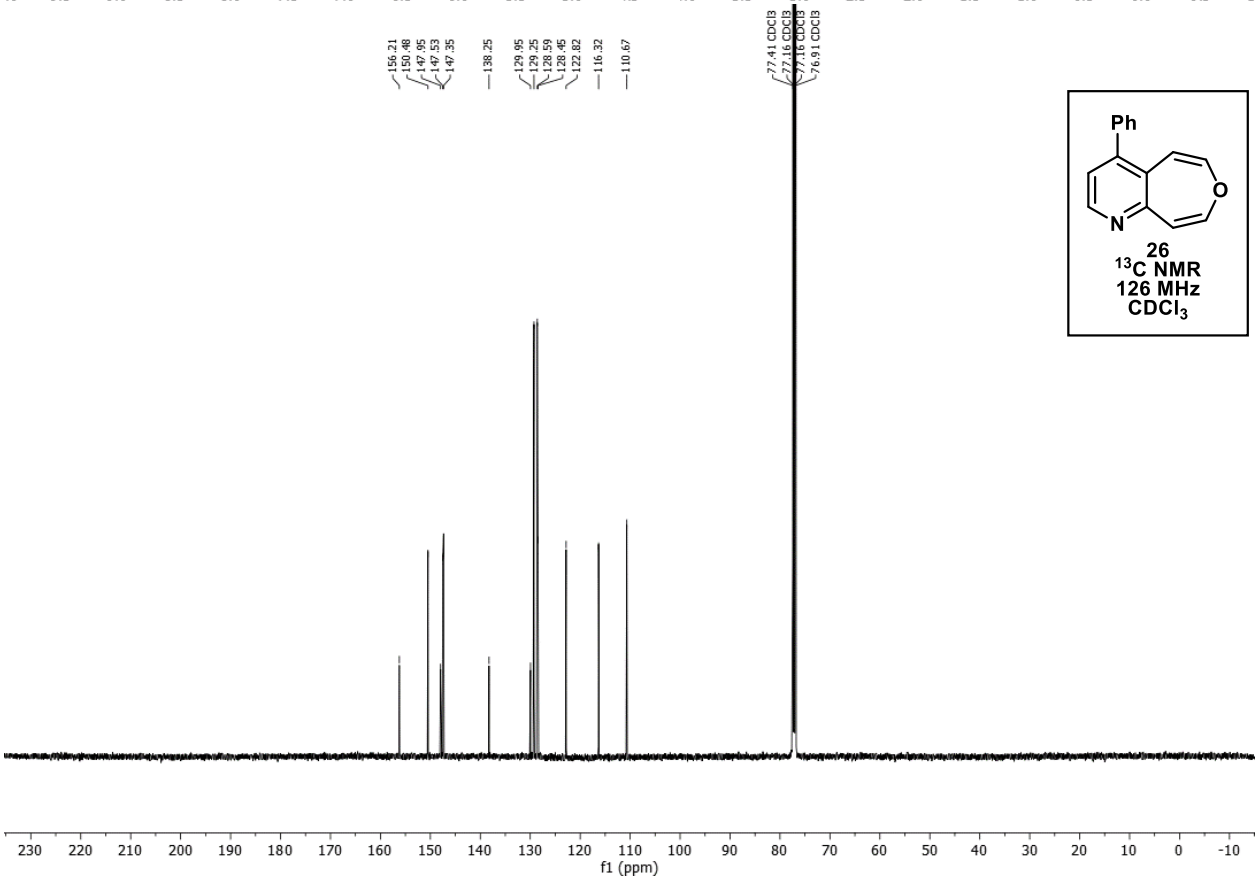

7.26 CDCl3
7.14
7.14
7.13
7.13
7.12
7.11
7.11
7.10
7.09
3.80
3.80
3.79
3.78
3.01
3.01
3.00
2.99
4.00
3.88
3.91
f1 (ppm)
24
1H NMR
500 MHz
CDCl3


141.70
129.45
126.45
77.41 CDCl3
77.16 CDCl3
77.16 CDCl3
76.91 CDCl3
70.44
40.10
f1 (ppm)
24
13C NMR
126 MHz
CDCl3


7.43
7.43
7.43
7.42
7.42
7.42
7.41
7.40
7.40
7.35
7.35
7.34
7.33
7.32
7.32
7.32
7.31
7.30
7.29
7.26 CDCl3
7.21
7.21
7.19
6.67
6.66
6.51
6.50
6.44
6.42
6.12
6.10
6.10
6.09
5.63
5.61
5.26
5.25
4.57
4.56
1.32
2.19
1.12
0.97
0.13
0.96
0.17
0.93
0.12
0.12
1.00
f1 (ppm)
25
7:1
25
1H NMR
500 MHz
CDCl3


145.48
144.88
140.96
138.50
135.27
135.21
131.93
131.90
131.74
130.72
130.04
130.00
129.45
129.28
127.95
127.60
120.65
117.68
115.13
96.44
87.27
77.16 CDCl3
61.79
f1 (ppm)
25
7:1
25
13C NMR
126 MHz
CDCl3


8.21
8.20
7.42
7.41
7.40
7.30
7.30
7.29
7.28
7.26 CDCl3
6.84
6.83
6.08
6.06
5.83
5.82
5.63
5.61
5.18
5.17
1.00
2.87
2.09
1.01
1.00
1.01
1.00
1.01
Ph
O
N
26
1H NMR
500 MHz
CDCl3


156.21
150.48
147.95
147.53
147.35
138.25
129.95
129.25
128.59
128.45
122.82
116.32
110.67
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
Ph
O
N
26
13C NMR
126 MHz
CDCl3
f1 (ppm)