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1. General information

A. Chemicals and Reagents

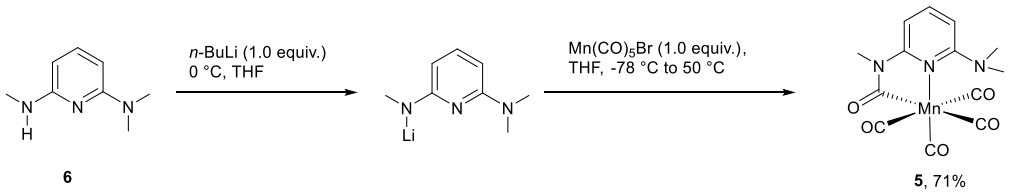
All manipulations were carried out under an inert N_2(g) atmosphere using glovebox techniques. Solvents were purified using a two-column solid-state purification system (Innovative Technology, NJ, USA) and transferred to the glovebox without exposure to air. Deuterated solvents were purchased from Cambrige Isotope Laboratories, Inc. and Gute Chemie, and were degassed and stored over activated 3Å molecular sieves. Compounds **9**[1, 2], **11**[3], **12**[4], **13**[5] was synthesized according to literature. All other reagents were purchased from commercial sources. Liquid compounds were degassed by standard freeze-pump-thaw procedures prior to use.

B. Physical Methods

The ^{1}H, ^{19}F and ^{13}C spectra were recorded on a Bruker Avance 400 spectrometer. The chemical shifts (δ) are given in parts per million relative to solvent peaks ($CDCl_3$ δ 7.26ppm ^{1}H NMR and 77.16 ppm in ^{13}C NMR, CD_3CN, 1.94 ppm in ^{1}H NMR and 1.32 in ^{13}C NMR, CD_2Cl_2, 5.32 ppm in ^{1}H NMR and 53.84 in ^{13}C NMR, THF-d_8, 1.72 ppm in ^{1}H NMR and 25.31 in ^{13}C NMR). IR spectra of the complexes were recorded as solution samples on a Varian 800 FT-IR spectrometer. Elemental analyses were performed on a Carlo Erba EA 1110 CHN instrument at EPFL. X-ray diffraction studies were carried out in the EPFL Crystallographic Facility. Data collections were performed at low temperature using four-circle kappa diffractometers equipped with CCD detectors. Data were reduced and then corrected for absorption. Solution, refinement and geometrical calculations for all crystal structures were performed by SHELXTL.[6, 7]

2. Experimental details

2.1 Synthesis of complex 5



Scheme 1 Synthesis of complex **5**.

Compound **6** (600 mg, 1.0 equiv.) was dissolved in 25 mL dry THF in a Schlenk flask. To this solution, *n*-BuLi (1.0 equiv.) was added dropwise at 0 °C and the solution was further stirred for 30 min at 0 °C. In another Schlenk flask a THF solution of $Mn(CO)_5Br$ (1.10 g, 1.0 equiv.) was cooled to -78 °C. The solution of deprotonated **6** was then added dropwise to the $Mn(CO)_5Br$ solution at -78 °C. The resulting mixture was allowed to slowly warm to room temperature and was further heated to 50 °C. After stirring at 50 °C overnight, the mixture was cooled to room temperature. The THF solvent was removed. The residue was further purified by silica gel chromatography in glovebox using ethyl acetate/hexane as eluent. Yield 71%. Single crystal suitable for X-ray test was obtained via layer diffusion of pentane to a THF solution of complex at -22 °C.

2.2 General procedure for hydrogenation of aldehydes, ketones and imines.

Substrate (1.0 equiv., 1 mmol for aldehydes and ketones, 0.2 mmol for imines), *N*-methyl pyrrolidine (0.5 equiv.), complex **5** (0.02 equiv.) and dry THF (1 mL for aldehydes and ketone, 0.5 mL for imines) were added to a 2 mL tube. The tube was then put into a 50 mL autoclave. After addition of 50 bar H_2 gas, the autoclave was heated to 100 °C for 24 h. Products were isolated and purified through a short silica gel chromatography using ethyl acetate/hexane as eluent.

2.3 General procedure for hydrogenation of methenyl-H_4MPT^+ mimic substrates

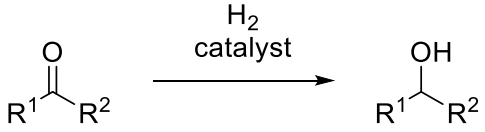
Substrate (1.0 equiv., 0.1 mmol), *N*-methyl pyrrolidine (5 equiv.), complex **5** (0.025 equiv.) and 3 mL dry dioxane were added to a 10 mL vial. The vial was then put into a 250 mL autoclave. After addition of 50 bar H_2 gas, the autoclave was heated to 80 °C for 24 h. Yield of **10a** and **10b** was determined by ^1H NMR using 1,3,5-trimethoxybenzene as internal standard. **10c-e** were isolated and purified through a silica gel chromatography using ethyl acetate/hexane as eluent.

2.4 General procedure for asymmetric relay hydrogenation

Substrate (1.0 equiv., 0.1 mmol), **13** (0.02 mmol, 0.2 equiv.), $La(OTf)_3$ (0.02 mmol, 0.2 equiv.), complex **5** (0.1 equiv.) and 1 mL dry $CHCl_3$ were added to a 2 mL tube. The tube was then put into a 50 mL autoclave. After addition of 50 bar H_2 gas, the autoclave was heated to 80 °C for 48 h. Products were isolated and purified through preparative TLC. Ee was determined by chiral HPLC using OD-H column.

2.5 Reaction condition optimization

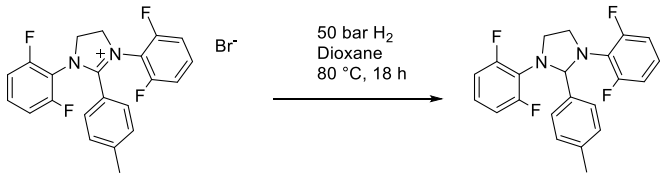
Table S1 Optimization of reaction conditions for hydrogenation of benzaldehyde and acetophenone.



	substrate	Catalyst (mol%)	Base (mol%)	solvent	T (°C)	Time	P (bar)	Yield (%)
1	benzaldehyde	**4**(5)	MP(25)	THF	50	16 h	50	7
2	benzaldehyde	**4**(5)	MP(25)	THF	80	16 h	50	100
3	benzaldehyde	**4**(5)	MP(25)	CH_3CN	80	16 h	50	72
4	benzaldehyde	**4**(5)	MP(25)	MeOH	80	16 h	50	84
5	benzaldehyde	**4**(1)	MP(20)	THF	80	16 h	50	100
6	benzaldehyde	**4**(1)	MP(20)	THF	80	16 h	30	98
7	benzaldehyde	**4**(1)	MP(20)	THF	80	16 h	10	88
8	benzaldehyde	**4**(1)	MP(20)	THF	80	16 h	1	1
9	acetophenone	**4**(2)	MP(50)	THF	100	24 h	50	45
10	acetophenone	**5**(2)	MP(50)	THF	100	24 h	50	91

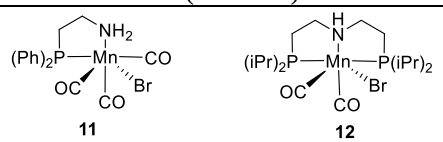
MP = *N*-methyl pyrrolidine

Table S2 Optimization of reaction conditions for hydrogenation of **9a**



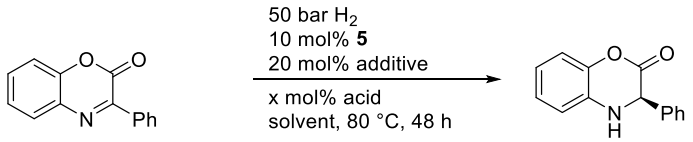
9a **10a**

	catalyst	Base	Concentration	Yield
1	**5**(20 mol%)	MP(1.0 equiv.)	0.50	25%
2	**5** (20 mol%)	MP(2.0 equiv.)	0.50	53%
3	**5** (20 mol%)	MP(5.0 equiv.)	0.50	67%
4	**5** (10 mol%)	MP(5.0 equiv.)	0.50	62%
5	**5** (10 mol%)	MP(5.0 equiv.)	0.25	87%
6	**5** (10 mol%)	MP(5.0 equiv.)	0.17	90%
7	**5** (5.0 mol%)	MP(5.0 equiv.)	0.17	94%
8	**5** (2.5 mol%)	MP(5.0 equiv.)	0.17	92%
9	**4** (2.5 mol%)	MP(5.0 equiv.)	0.17	43%
10	**11**(2.5 mol%)	MP(5.0 equiv.) KOtBu(10 mol%)	0.17	0%
11	**12**(2.5 mol%)	MP(5.0 equiv.) KOtBu(10 mol%)	0.17	0%



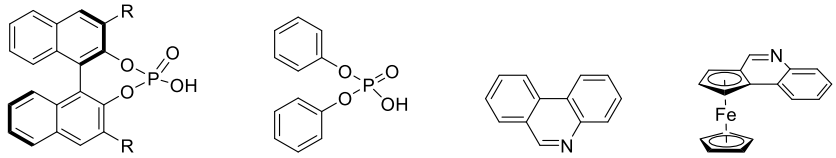
11 **12**

Table S3 Optimization of reaction conditions for asymmetric hydrogenation of **13a** catalyzed by **5**.



15a **16a**

	Additive (%)	Acid (%)	solvent	Yield	ee
1	--	**17a** (10)	dioxane	<2%[a]	--
2	**19** (20)	**17a** (10)	dioxane	70%[a]	--
3	**19** (20)	**17b** (5)	dioxane	<2%[a,c]	--
4	**19** (20)	**17b** (5)	toluene	36%[a,c]	70%
5	**19** (20)	**17b** (5)	mesitylene	81%[b,c]	80%
6	**13** (20)	**18** (20)	mesitylene	<5%	--
7	**13** (20)	**18** (20)	$CHCl_3$	46%	94%
8	**13** (20)	$Sm(OTf)_3$ (20)	$CHCl_3$	<5%	--
9	**13** (20)	$La(OTf)_3$ (20)	$CHCl_3$	63%	96%



17a, R = H
17b, R = 2,4,6-triisopropyl phenyl

18 **19** **13**

[a]18 h of reaction time; [b]72 h of reaction time; [c]60 °C

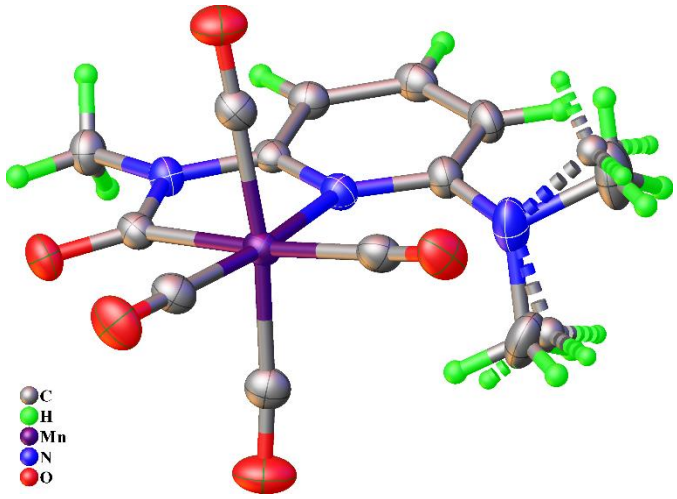
3. Characterization of complex 5

^{1}H NMR (400 MHz, THF-d_8) δ 7.77 (t, J = 8.0 Hz, 1H), 6.82 (d, J = 7.7 Hz, 1H), 6.75 (d, J = 8.2 Hz, 1H), 3.15 (s, 3H), 2.74 (s, 6H).
^{13}C NMR (101 MHz, THF) δ 218.26, 216.55, 214.90, 213.62, 168.47, 161.40, 141.41, 109.20, 105.54, 44.29, 27.46.
HRMS (APCI/QTOF) m/z: $[M + Na]^+$ Calcd for $C_{13}H_{12}MnN_3NaO_5^+$ 368.0050; Found 368.0049

IR: ν(cm^{-1}) 1952 (s, terminal CO), 1975 (s, terminal CO), and 2072 (s, terminal CO)

Anal. Calcd for $C_{11}H_7MnN_2O_5$: C, 45.2; H, 3.5; N, 12.2. Found: C, 45.1; H, 3.5; N, 12.0.

Crystal structure



Experimental. Single clear pale yellow plate-shaped crystals of complex **5** were obtained by recrystallisation from THF/pentane at -22 °C. A suitable crystal of 0.54×0.24×0.16 mm^3 was selected and mounted on a suitable support on a SuperNova, Dual, Cu at zero, Atlas diffractometer. The crystal was kept at a steady T = 140.00(10) K during data collection. The structure was solved with the **ShelXT** [6] structure solution program using the dual solution method and by using **Olex2** [8] as the graphical interface. The model was refined with version 2018/3 of **ShelXL** [6] using full matrix least squares on $|\boldsymbol{F}|^2$ minimisation.

Crystal Data. $C_{13}H_{12}MnN_3O_5$, M_r = 345.20, monoclinic, $P2_1/c$ (No. 14), a = 13.2766(3) Å, b = 6.48128(12) Å, c = 17.8426(4) Å, β = 103.307(2)°, α = γ = 90°, V = 1494.12(5) $Å^3$, T = 140.00(10) K, Z = 4, Z' = 1, μ(CuKα) = 7.447, 9742 reflections measured, 3033 unique (R_{int} = 0.0260) which were used in all calculations. The final wR_2 was 0.0781 (all data) and R_1 was 0.0285 (I > 2(I)).

Compound	**Complex 5**
Formula	$C_{13}H_{12}MnN_3O_5$
$D_{calc.}$/ g cm^{-3}	1.535
μ/mm^{-1}	7.447
Formula Weight	345.20
Colour	clear pale yellow
Shape	plate
Size/mm^3	0.54×0.24×0.16
T/K	140.00(10)
Crystal System	monoclinic
Space Group	$P2_1/c$
a/Å	13.2766(3)
b/Å	6.48128(12)
c/Å	17.8426(4)
α/°	90
β/°	103.307(2)
γ/°	90
V/$Å^3$	1494.12(5)
Z	4
Z'	1
Wavelength/Å	1.54184
Radiation type	CuKα
Θ_{min}/°	5.094
Θ_{max}/°	75.239
Measured Refl.	9742
Independent Refl.	3033
Reflections with I > 2(I)	2936
R_{int}	0.0260
Parameters	224
Restraints	19
Largest Peak/e $Å^{-3}$	0.421
Deepest Hole/e $Å^{-3}$	-0.383
GooF	1.057
wR_2 (all data)	0.0781
wR_2	0.0772
R_1 (all data)	0.0294
R_1	0.0285

Detailed experimental procedure:

A clear pale yellow plate-shaped crystal with dimensions of 0.54×0.24×0.16 mm^3 was mounted on a suitable support. Data were collected using a SuperNova, Dual, Cu at zero, Atlas diffractometer operating at T = 140.00(10) K.

Data were measured using ω scans using CuKα radiation. The total number of runs and images was based on the strategy calculation from the program **CrysAlisPro** (Rigaku, V1.171.38.46, 2015). The maximum resolution achieved was Θ = 75.239˚ (0.83 Å).

The diffraction pattern was indexed. The total number of runs and images was based on the strategy calculation from the program **CrysAlisPro** (Rigaku, V1.171.38.46, 2015) and the unit cell was refined using **CrysAlisPro** (Rigaku, V1.171.38.46, 2015) on 5255 reflections, 54% of the observed reflections.

Data reduction, scaling and absorption corrections were performed using **CrysAlisPro** (Rigaku, V1.171.38.46, 2015). The final completeness is 100.00 % out to 75.239˚ in Θ. A Gaussian absorption correction was performed using **CrysAlisPro** 1.171.38.46 (Rigaku Oxford Diffraction, 2018) Numerical absorption correction based on Gaussian integration over a multifaceted crystal model/Empirical absorption correction using spherical harmonics as implemented in SCALE3 ABSPACK scaling algorithm.. The absorption coefficient μ of this material is 7.447 mm^{-1} at this wavelength (λ = 1.542Å) and the minimum and maximum transmissions are 0.197 and 0.766.

The structure was solved and the space group $P2_1/c$ (# 14) determined by the **ShelXT** [6] structure solution program using dual and refined by full matrix least squares on $|\boldsymbol{F}|^2$ using version 2018/3 of **ShelXL** [7]. All non-hydrogen atoms were refined anisotropically. Hydrogen atom positions were calculated geometrically and refined using the riding model.

There is a single molecule in the asymmetric unit, which is represented by the reported sum formula. In other words: Z is 4 and Z' is 1.

CCDC- 1958229 contains the supplementary crystallographic data for **5**. These data can be obtained free of charge from *The Cambridge Crystallographic Data Centre via* www.ccdc.cam.ac.uk/data_request/cif.

IR spectrum

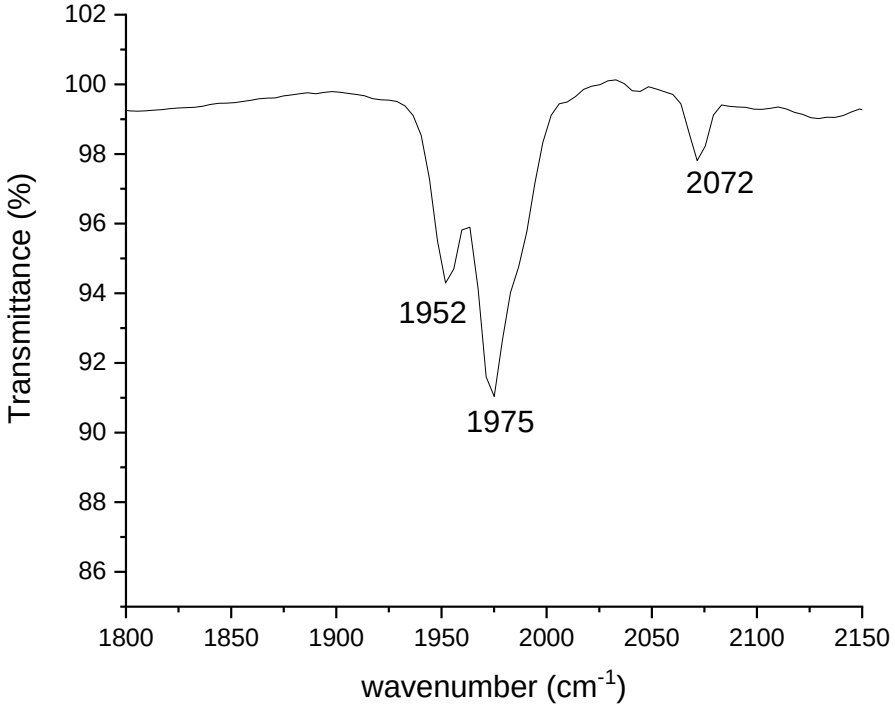
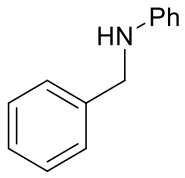


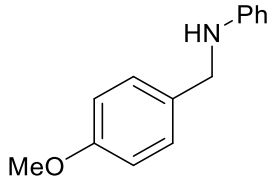
Figure S1 IR spectrum of complex **5** in THF solution

4. Characterization of compounds



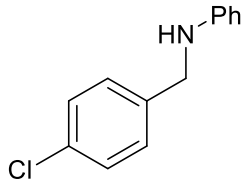
8j

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.45 – 7.28 (m, 5H), 7.25 – 7.17 (m, 2H), 6.81 – 6.73 (m, 1H), 6.71 – 6.63 (m, 2H), 4.36 (s, 2H), 4.08 (s, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 148.34, 139.64, 129.49, 128.85, 127.74, 127.45, 117.81, 113.09, 48.55.



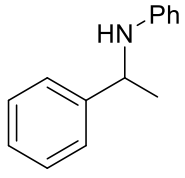
8k

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.32 (d, *J* = 8.7 Hz, 2H), 7.21 (dd, *J* = 8.5, 7.2 Hz, 2H), 6.92 (d, *J* = 8.6 Hz, 2H), 6.75 (ddd, *J* = 8.4, 6.8, 1.1 Hz, 1H), 6.67 (d, *J* = 7.3 Hz, 2H), 4.28 (s, 2H), 4.01 (s, 1H), 3.83 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 158.98, 148.29, 131.50, 129.36, 128.93, 117.63, 114.14, 112.98, 55.40, 47.92.



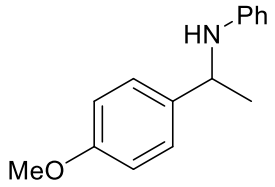
8l

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.36-7.29 (m, 4H), 7.24 – 7.17 (m, 2H), 6.76 (tt, *J* = 7.3, 1.1 Hz, 1H), 6.68 – 6.60 (m, 2H), 4.33 (s, 2H), 4.10 (s, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 147.91, 138.10, 132.98, 129.42, 128.86, 128.81, 117.94, 113.03, 47.73.



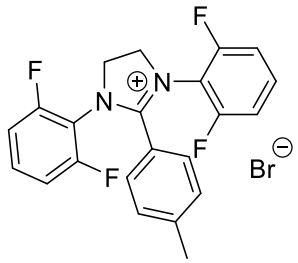
8m

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.43 – 7.31 (m, 4H), 7.29 – 7.22 (m, 1H), 7.15-7.08 (m, 2H), 6.71 – 6.64 (m, 1H), 6.58-6.50 (m, 2H), 4.52 (q, *J* = 6.7 Hz, 1H), 4.11 (s, 1H), 1.55 (d, *J* = 6.7 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 147.36, 145.32, 129.23, 128.76, 127.00, 125.98, 117.40, 113.46, 53.62, 25.13.



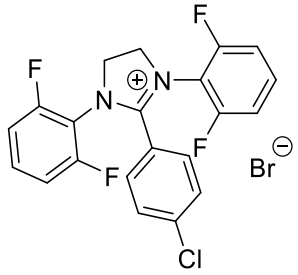
8n

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.35 – 7.27 (m, 2H), 7.17 – 7.07 (m, 2H), 6.92 – 6.85 (m, 2H), 6.67 (tt, *J* = 7.3, 1.1 Hz, 1H), 6.59 – 6.50 (m, 2H), 4.47 (q, *J* = 6.7 Hz, 1H), 4.06 (s, 1H), 3.80 (s, 3H), 1.52 (d, *J* = 6.7 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 158.61, 147.42, 137.34, 129.21, 127.02, 117.33, 114.12, 113.47, 55.36, 52.98, 25.09.



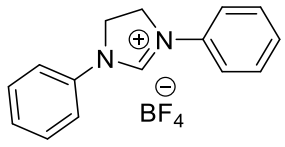
9a

^{1}H NMR (400 MHz, Acetonitrile-d_3) δ 7.64 – 7.48 (m, 2H), 7.24 – 7.05 (m, 8H), 4.68 (s, 4H), 2.27 (s, 3H).
^{13}C NMR (101 MHz, Acetonitrile-d_3) δ 170.14, 158.64 (dd, *J* = 253.9, 3.3 Hz), 147.27, 134.06 (t, *J* = 10.1 Hz), 131.02, 129.16, 114.30 (t, *J* = 16.1 Hz), 113.91 (dd, *J* = 19.3, 3.6 Hz), 53.22, 21.67.
^{19}F NMR (376 MHz, CD_3CN) δ -118.50.



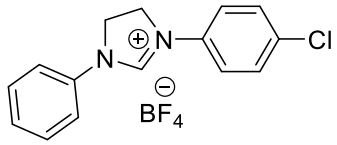
9b

^{1}H NMR (400 MHz, Acetonitrile-d_3) δ 7.56 (tt, *J* = 8.6, 6.3 Hz, 2H), 7.44 – 7.35 (m, 2H), 7.35 – 7.27 (m, 2H), 7.22 – 7.07 (m, 4H), 4.72 (s, 4H).
^{13}C NMR (101 MHz, Acetonitrile-d_3) δ 169.04, 158.44 (dd, *J* = 254.3, 3.2 Hz), 141.52, 134.22 (t, *J* = 10.1 Hz), 130.91, 130.85, 119.97, 113.99 (dd, *J* = 19.1, 3.6 Hz), 113.80 (t, *J* = 16.0 Hz), 53.41.
^{19}F NMR (376 MHz, CD_3CN) δ -118.12.



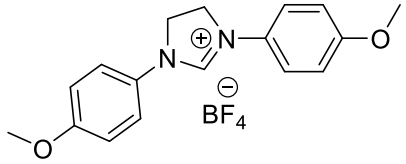
9c

^{1}H NMR (400 MHz, Acetonitrile-d_3) δ 9.08 (s, 1H), 7.62 – 7.52 (m, 4H), 7.51 – 7.37 (m, 6H), 4.58 (s, 4H).
^{13}C NMR (101 MHz, CD_3CN) δ 152.42, 136.87, 131.02, 128.85, 119.69, 50.03.
^{19}F NMR (376 MHz, CD_3CN) δ -151.78.



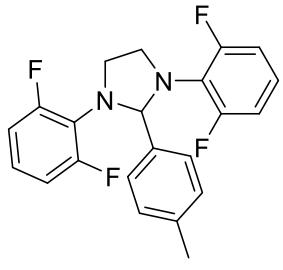
9d

^{1}H NMR (400 MHz, Acetonitrile-d_3) δ 9.07 (s, 1H), 7.60-7.53 (m, 4H), 7.52 – 7.33 (m, 5H), 4.56 (s, 4H).
^{13}C NMR (101 MHz, CD_3CN) δ 152.64, 136.75, 135.75, 133.75, 131.06, 130.96, 129.03, 121.35, 119.79, 50.18, 50.12.
^{19}F NMR (376 MHz, CD_3CN) δ -151.71.



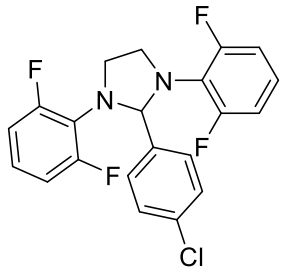
9e

^{1}H NMR (400 MHz, Acetonitrile-d_3) δ 8.81 (s, 1H), 7.38 (d, J = 9.1 Hz, 4H), 7.07 (d, J = 9.1 Hz, 4H), 4.50 (s, 4H), 3.84 (s, 6H).
^{13}C NMR (101 MHz, CD_3CN) δ 160.08, 151.71, 130.03, 121.46, 116.02, 56.43, 50.45.
^{19}F NMR (376 MHz, CD_3CN) δ -151.79.



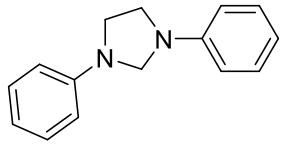
10a

^{1}H NMR (400 MHz, Acetonitrile-d_3) δ 7.23 (d, J = 7.6 Hz, 2H), 7.01 – 6.89 (m, 4H), 6.84 (q, J = 8.4, 7.5 Hz, 4H), 6.07 (s, 1H), 4.10 – 3.95 (m, 2H), 3.67 – 3.51 (m, 2H), 2.18 (s, 3H).
^{13}C NMR (101 MHz, Acetonitrile-d_3) δ 159.92 (dd, J = 247.2, 7.8 Hz), 139.30, 138.70, 129.52, 128.96, 125.13 (t, J = 10.3 Hz), 123.87 (t, J = 13.8 Hz), 113.00 (dd), 80.05 (p, J = 4.5 Hz), 51.36 (t, J = 3.6 Hz), 21.10.
^{19}F NMR (376 MHz, CD_3CN) δ -119.24.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{22}H_{19}F_4N_2^+$ 387.1479; Found 387.1478



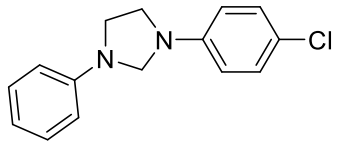
10b

^{1}H NMR (400 MHz, Acetonitrile-d_3) δ 7.33 (dd, J = 8.5, 2.1 Hz, 2H), 7.16 (dd, J = 8.5, 2.1 Hz, 2H), 6.98 (qd, J = 7.8, 7.3, 3.5 Hz, 2H), 6.86 (q, J = 8.4, 7.3 Hz, 4H), 6.03 (s, 1H), 4.07 – 3.94 (m, 2H), 3.71 – 3.54 (m, 2H).
^{13}C NMR (101 MHz, Acetonitrile-d_3) δ 160.00 (dd, J = 247.4, 7.5 Hz), 140.71, 134.60, 130.67, 128.92, 125.58 (t, J = 10.3 Hz), 123.54 (t, J = 13.9 Hz), 113.09 (dd), 79.94 (p, J = 4.0 Hz), 51.47.
^{19}F NMR (376 MHz, CD_3CN) δ -119.26.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{21}H_{16}ClF_4N_2^+$ 407.0933; Found 407.0931.



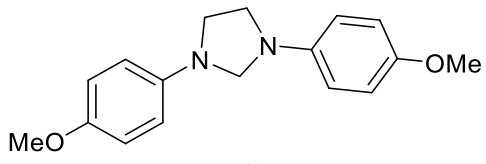
10c

^{1}H NMR (400 MHz, Chloroform-d) δ 7.33 (t, J = 7.7 Hz, 4H), 6.84 (t, J = 7.4 Hz, 2H), 6.70 (d, J = 8.2 Hz, 4H), 4.69 (s, 2H), 3.67 (s, 4H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 146.52, 129.48, 117.77, 112.57, 65.98, 46.60.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{15}H_{15}N_2^+$ 223.1230; Found 223.1225.



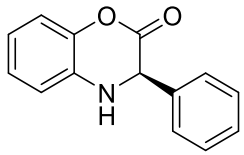
10d

^{1}H NMR (400 MHz, Chloroform-d) δ 7.30 (t, J = 7.4 Hz, 2H), 7.23 (d, J = 7.9 Hz, 2H), 6.82 (t, J = 7.4 Hz, 1H), 6.66 (d, J = 8.0 Hz, 2H), 6.57 (d, J = 7.5 Hz, 2H), 4.62 (s, 2H), 3.63 (h, J = 6.8, 6.4 Hz, 4H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 146.39, 145.05, 129.52, 129.30, 122.66, 118.00, 113.57, 112.65, 66.03, 46.72, 46.62.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{15}H_{14}ClN_2^+$ 257.0840; Found 257.0846.



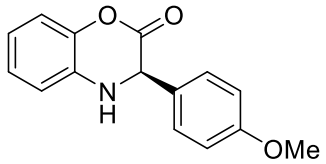
10e

^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 6.87 (d, J = 8.7 Hz, 4H), 6.63 (d, J = 8.8 Hz, 4H), 4.54 (s, 2H), 3.75 (s, 6H), 3.57 (s, 4H).
^{13}C NMR (101 MHz, CD_2Cl_2) δ 152.57, 141.88, 115.22, 113.81, 67.74, 56.04, 47.78.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{17}H_{21}N_2O_2^+$ 285.1598; Found 285.1591.



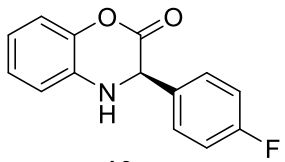
16a

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44-7.33 (m, 5H), 7.07-6.99 (m, 2H), 6.87 (t, *J* = 7.8 Hz, 1H), 6.81 (d, *J* = 7.8 Hz, 1H), 5.06 (s, 1H), 4.22 (br, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 165.32, 141.03, 136.48, 132.49, 129.11, 127.60, 125.31, 120.51, 117.09, 115.01, 59.39.
HRMS (APPI/LTQ-Orbitrap) m/z: $[M + H_{-1}]^+$ Calcd for $C_{14}H_{10}NO_2^+$ 224.0706; Found 224.0697.



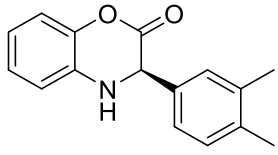
16b

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.33 (d, *J* = 8.3 Hz, 2H), 7.09 – 6.98 (m, 2H), 6.89-6.77 (m, 4H), 5.00 (s, 1H), 4.18 (br, 1H), 3.80 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 165.64, 160.22, 141.14, 132.69, 128.93, 128.53, 125.26, 120.53, 117.13, 114.98, 114.53, 58.97, 55.48.
HRMS (APCI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{15}H_{14}NO_3^+$ 256.0968; Found 256.0969.



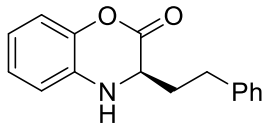
16c

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.45-7.36 (m, 2H), 7.12 – 6.98 (m, 4H), 6.89 (td, *J* = 7.8, 1.5 Hz, 1H), 6.83 (dd, *J* = 7.8, 1.6 Hz, 1H), 5.05 (s, 1H), 4.21 (s, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 165.23, 164.37, 161.91, 141.06, 132.39, 132.24, 132.21, 129.59, 129.50, 125.39, 120.77, 117.17, 116.22, 116.00, 115.08, 58.82.
^{19}F NMR (376 MHz, $CDCl_3$) δ -112.44.
HRMS (APPI/LTQ-Orbitrap) m/z: $[M + H_{-1}]^+$ Calcd for $C_{14}H_9FNO_2^+$ 242.0612; Found 242.0601.



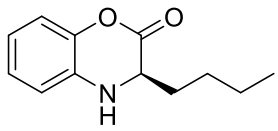
16d

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.18 (s, 1H), 7.15-7.09 (m, 2H), 7.07 – 6.97 (m, 2H), 6.90 – 6.83 (m, 1H), 6.83 – 6.76 (m, 1H), 4.99 (s, 1H), 2.25 (s, 6H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 165.64, 141.14, 137.75, 137.50, 133.85, 132.68, 130.31, 128.88, 125.23, 124.95, 120.46, 117.10, 114.97, 59.26, 19.98, 19.65.
HRMS (APCI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{16}H_{16}NO_2^+$ 254.1176; Found 254.1176.



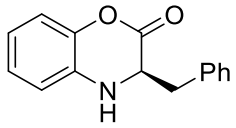
16e

^{1}H NMR (400 MHz, Chloroform-*d*) δ7.35 – 7.26 (m, 2H), 7.28 – 7.17 (m, 3H), 7.03-6.95 (m, 2H), 6.84 (t, *J* = 7.8 Hz, 1H), 6.66 (d, *J* = 7.8 Hz, 1H), 3.93 (dd, *J* = 7.4, 5.2 Hz, 1H), 3.75 (br, 1H), 2.83 (hept, *J* = 7.2 Hz, 2H), 2.30 (dq, *J* = 14.2, 6.0 Hz, 1H), 2.09 (dq, *J* = 15.0, 7.7 Hz, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 166.55, 141.24, 140.49, 132.32, 128.88, 128.54, 126.60, 125.09, 120.52, 116.91, 115.34, 54.57, 32.79, 31.87.
HRMS (APCI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{16}H_{16}NO_2^+$ 254.1176; Found 254.1174.



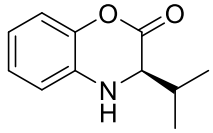
16f

^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.98 (t, *J* = 8.2 Hz, 2H), 6.83 (t, *J* = 7.8 Hz, 1H), 6.77 (d, *J* = 7.7 Hz, 1H), 3.91 (dd, *J* = 7.8, 5.2 Hz, 1H), 3.60-4.25 (br, 1H), 2.00 – 1.84 (m, 1H), 1.77 (h, *J* = 8.4, 8.0 Hz, 1H), 1.51 – 1.27 (m, 4H), 0.92 (t, *J* = 7.1 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 166.81, 141.17, 132.50, 125.05, 120.28, 116.83, 115.20, 54.93, 31.04, 27.45, 22.46, 13.97.
HRMS (APCI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{12}H_{16}NO_2^+$ 206.1176; Found 206.1173.



16g

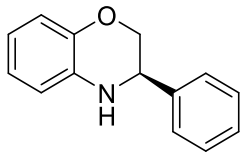
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.42-7.36 (m, 2H), 7.35 – 7.28 (m, 1H), 7.20 (d, *J* = 7.4 Hz, 2H), 7.04 (dd, *J* = 8.0, 1.6 Hz, 1H), 6.99 (t, *J* = 7.6 Hz, 1H), 6.86 (t, *J* = 7.8 Hz, 1H), 6.65 (d, *J* = 7.8 Hz, 1H), 4.10 (dd, *J* = 11.1, 3.3 Hz, 1H), 3.79 (br, 1H), 3.34 (dd, *J* = 13.7, 3.3 Hz, 1H), 2.92 (dd, *J* = 13.7, 11.0 Hz, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 166.40, 141.27, 136.00, 131.94, 129.42, 129.29, 127.61, 125.26, 120.55, 116.99, 115.48, 56.04, 37.08.
HRMS (APCI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{15}H_{14}NO_2^+$ 240.1019; Found 240.1019.



16h

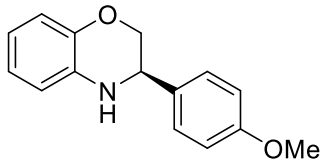
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.03 – 6.91 (m, 2H), 6.86 – 6.70 (m, 2H), 3.99 (s, 1H), 3.76 (d, *J* = 6.1 Hz, 1H), 2.34 – 2.09 (m, *J* = 6.9 Hz, 1H), 1.06 (d, *J* = 7.0 Hz, 3H), 1.01 (d, *J* = 6.7 Hz, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 165.82, 140.87, 132.23, 125.08, 119.92, 116.72, 114.85, 60.55, 30.06, 18.98, 17.74.

HRMS (APPI/LTQ-Orbitrap) m/z: $[M + H]^+$ Calcd for $C_{11}H_{14}NO_2^+$ 192.1019; Found 192.1011.



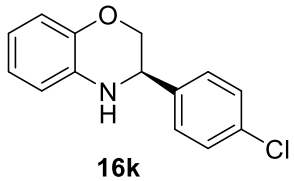
16i

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.49 – 7.31 (m, 5H), 6.94 – 6.79 (m, 2H), 6.77 – 6.61 (m, 2H), 4.52 (dd, *J* = 8.6, 3.0 Hz, 1H), 4.31 (dd, *J* = 10.7, 3.0 Hz, 1H), 4.02 (dd, *J* = 10.7, 8.6 Hz, 1H), 3.60-4.20 (br, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 143.67, 139.22, 133.93, 128.94, 128.46, 127.32, 121.60, 119.10, 116.72, 115.54, 71.06, 54.34.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{14}H_{14}NO^+$ 212.1070; Found 212.1070.



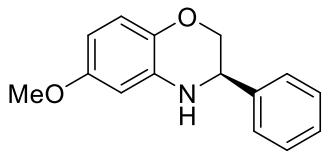
16j

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.39 – 7.28 (m, 2H), 6.92 (d, *J* = 8.0 Hz, 2H), 6.89 – 6.76 (m, 2H), 6.76 – 6.63 (m, 2H), 4.53 – 4.40 (m, 1H), 4.40 – 4.04 (m, 2H), 3.98 (t, *J* = 9.7 Hz, 1H), 3.82 (s, 3H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 159.79, 143.73, 133.85, 131.13, 128.50, 121.55, 119.20, 116.71, 115.63, 114.35, 71.15, 55.48, 53.76.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{15}H_{16}NO_2^+$ 242.1176; Found 242.1175.



16k

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.36 (m, 4H), 6.90 – 6.78 (m, 2H), 6.76-6.64 (m, 2H), 4.50 (dd, *J* = 8.4, 3.0 Hz, 1H), 4.00-4.40 (br, 1H), 4.26 (dd, *J* = 10.7, 3.0 Hz, 1H), 3.97 (dd, *J* = 10.7, 8.4 Hz, 1H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 143.68, 137.75, 134.26, 133.48, 129.15, 128.68, 121.74, 119.44, 116.82, 115.70, 70.80, 53.77.
HRMS (ESI/QTOF) m/z: $[M + H]^+$ Calcd for $C_{14}H_{13}ClNO^+$ 246.0680; Found 246.0680.

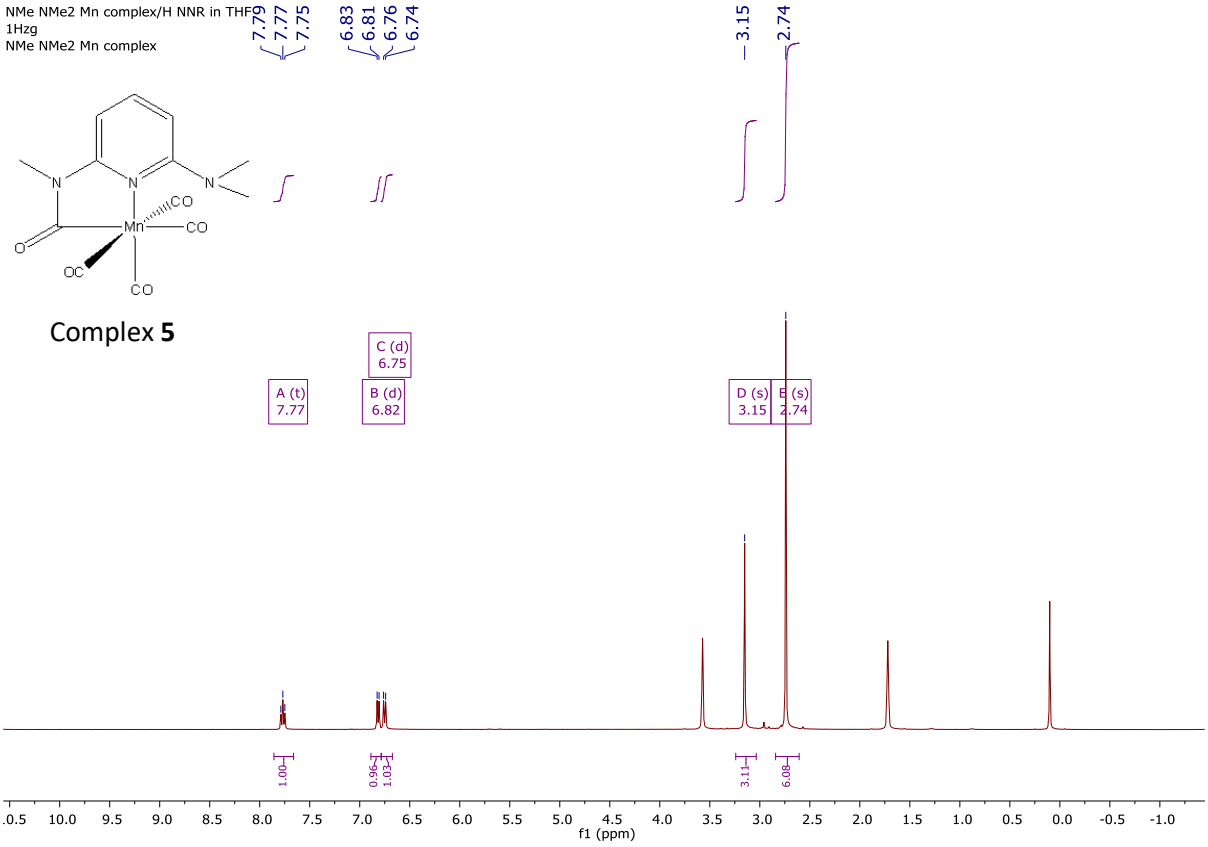


16l

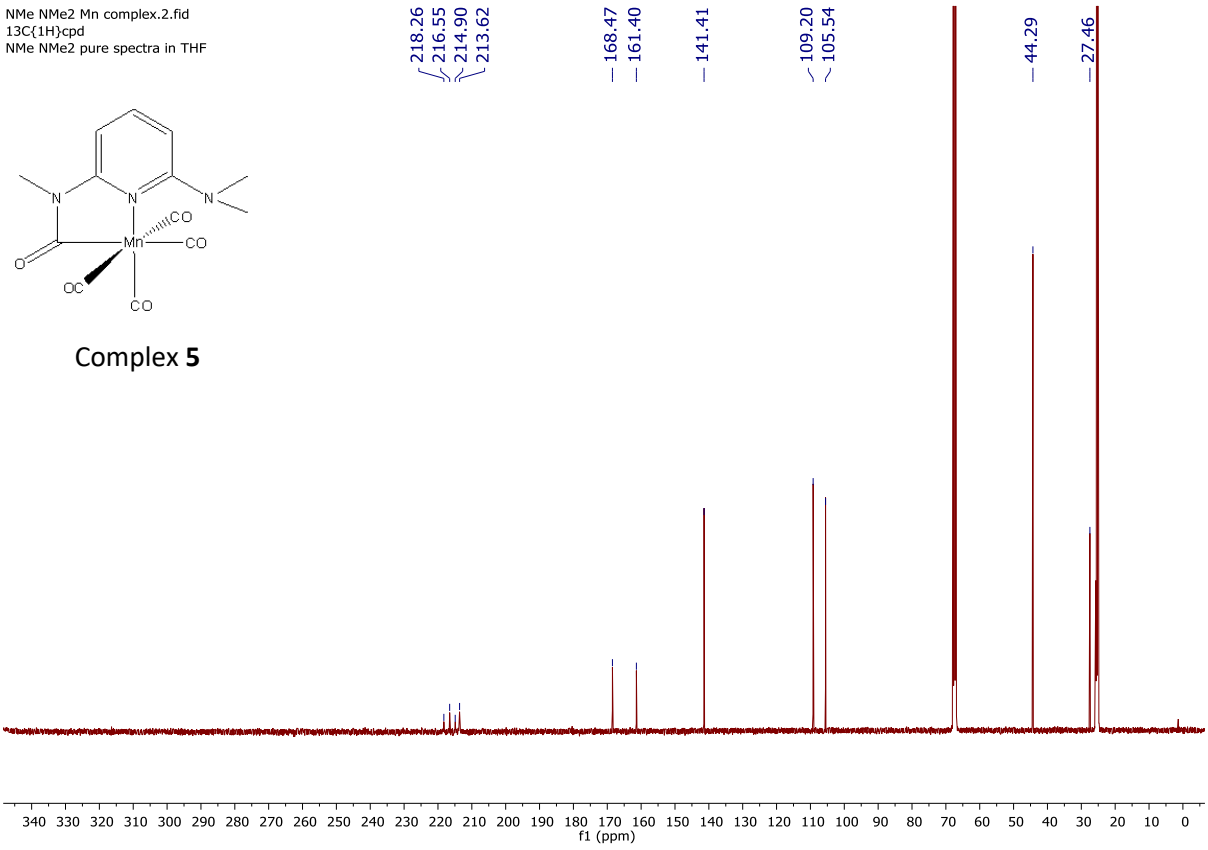
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44 – 7.32 (m, 5H), 6.86 (s, 1H), 6.78 (d, *J* = 8.4 Hz, 1H), 6.58 (d, *J* = 8.3 Hz, 1H), 4.48 (d, *J* = 8.6 Hz, 1H), 4.29 (d, *J* = 10.7 Hz, 1H), 3.99 (t, *J* = 9.6 Hz, 1H), 4.55-3.80 (br, 1H)

^{13}C NMR (101 MHz, $CDCl_3$) δ 144.18, 138.71, 132.55, 129.03, 128.65, 127.31, 123.39, 121.42, 116.92, 116.09, 70.98, 54.18.

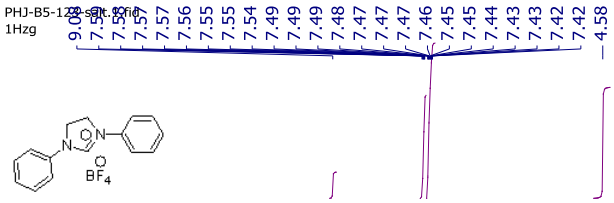
5. Spectra



Complex **5**



Complex **5**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9.08
7.58
7.57
7.57
7.56
7.55
7.55
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7.48
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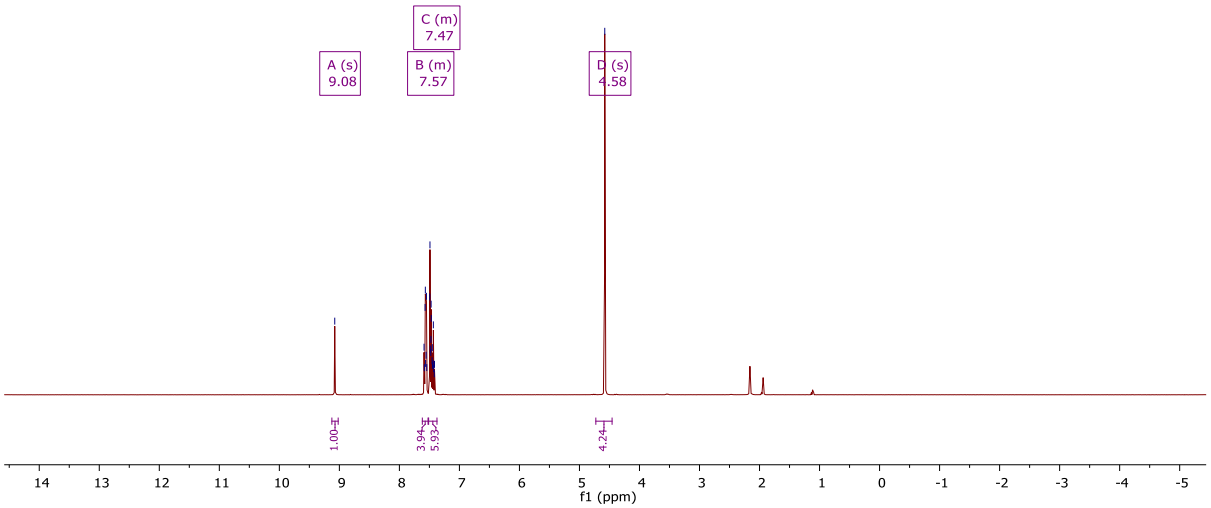
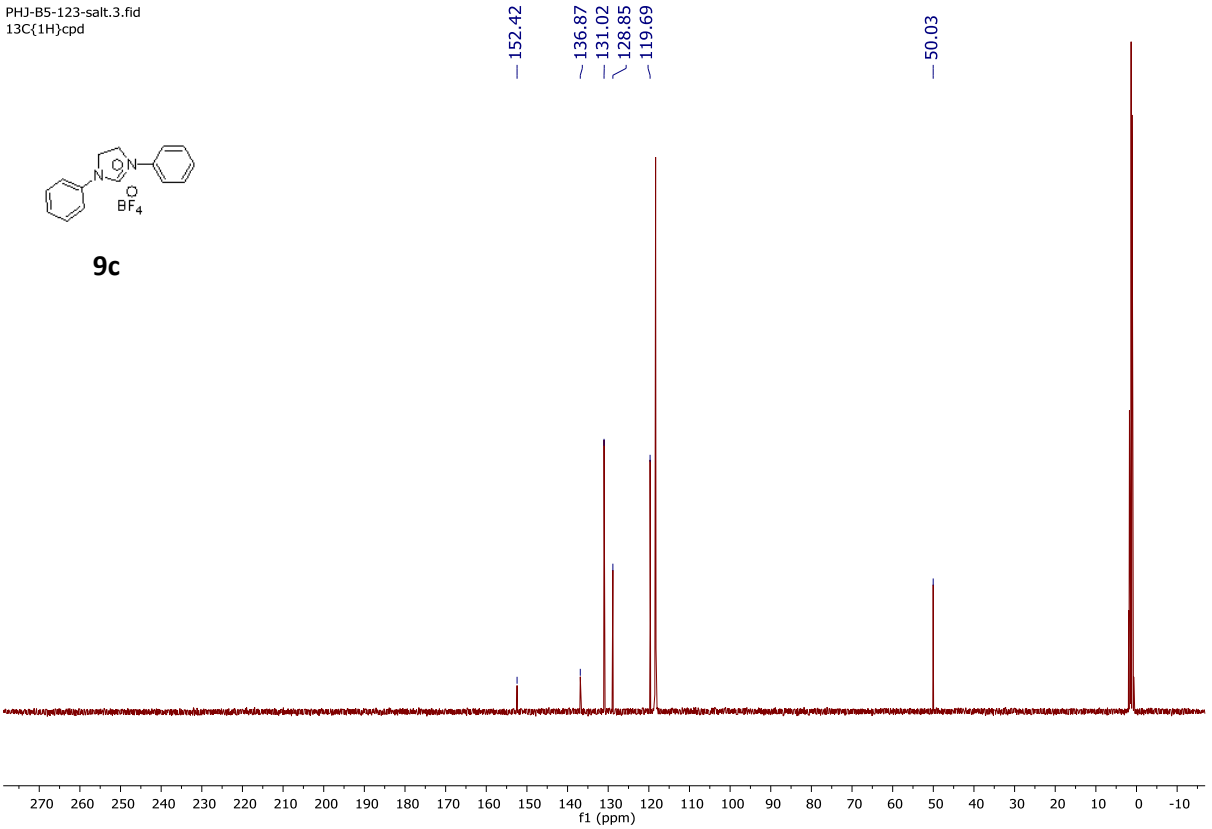
7.43
7.42
7.42
4.58
BF4

9c

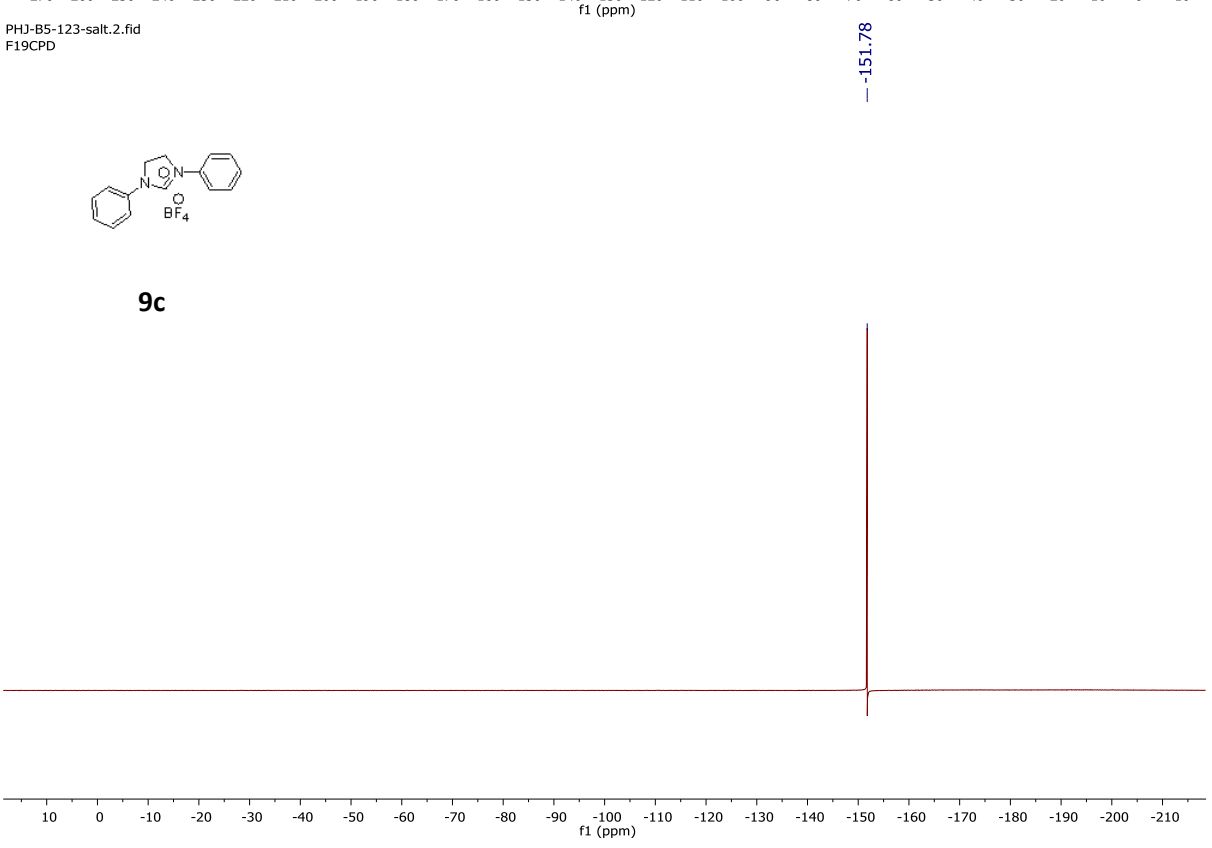

A (s)
9.08
C (m)
7.47
B (m)
7.57
D (s)
4.58
1.00
3.94
5.93
4.24
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
f1 (ppm)

PHJ-B5-123-salt.3.fid
13C{1H}cpd

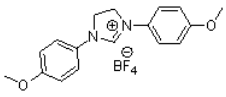


9c

PHJ-B5-123-salt.2.fid
F19CPD

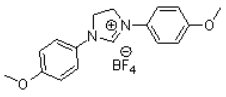


9c



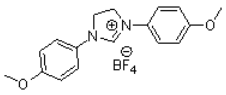
9e

8.81
7.39
7.37
7.09
7.06
4.50
3.84
1.00
3.96
3.94
4.10
6.03
f1 (ppm)



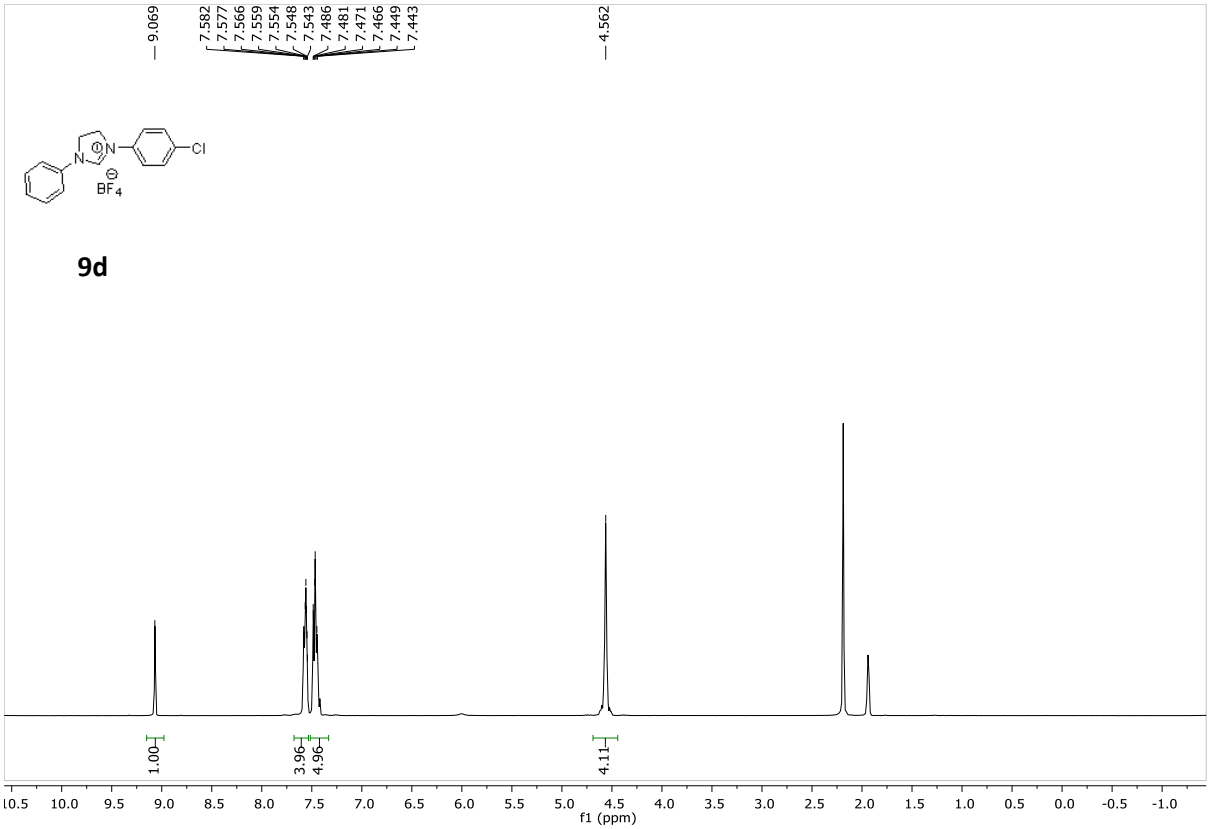
9e

160.08
151.71
130.03
121.46
116.02
56.43
50.45
f1 (ppm)

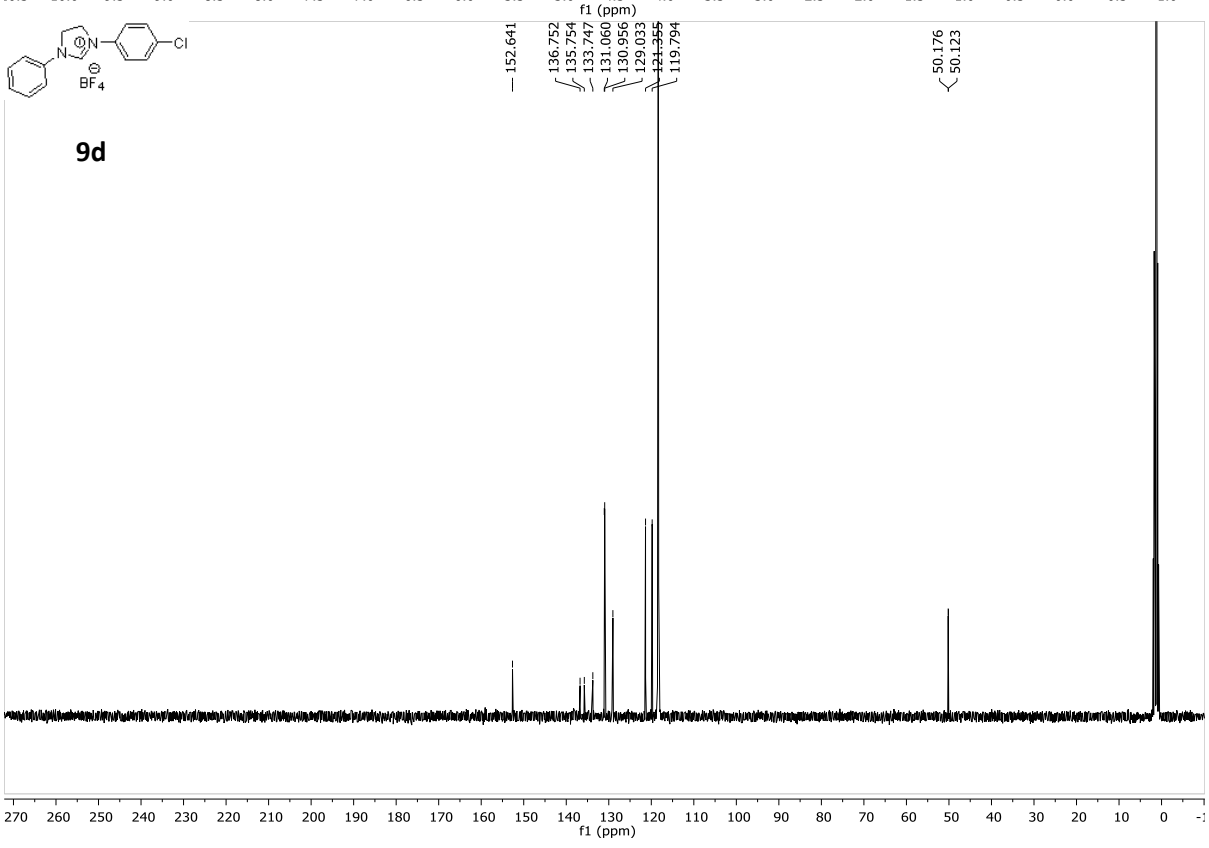


9e

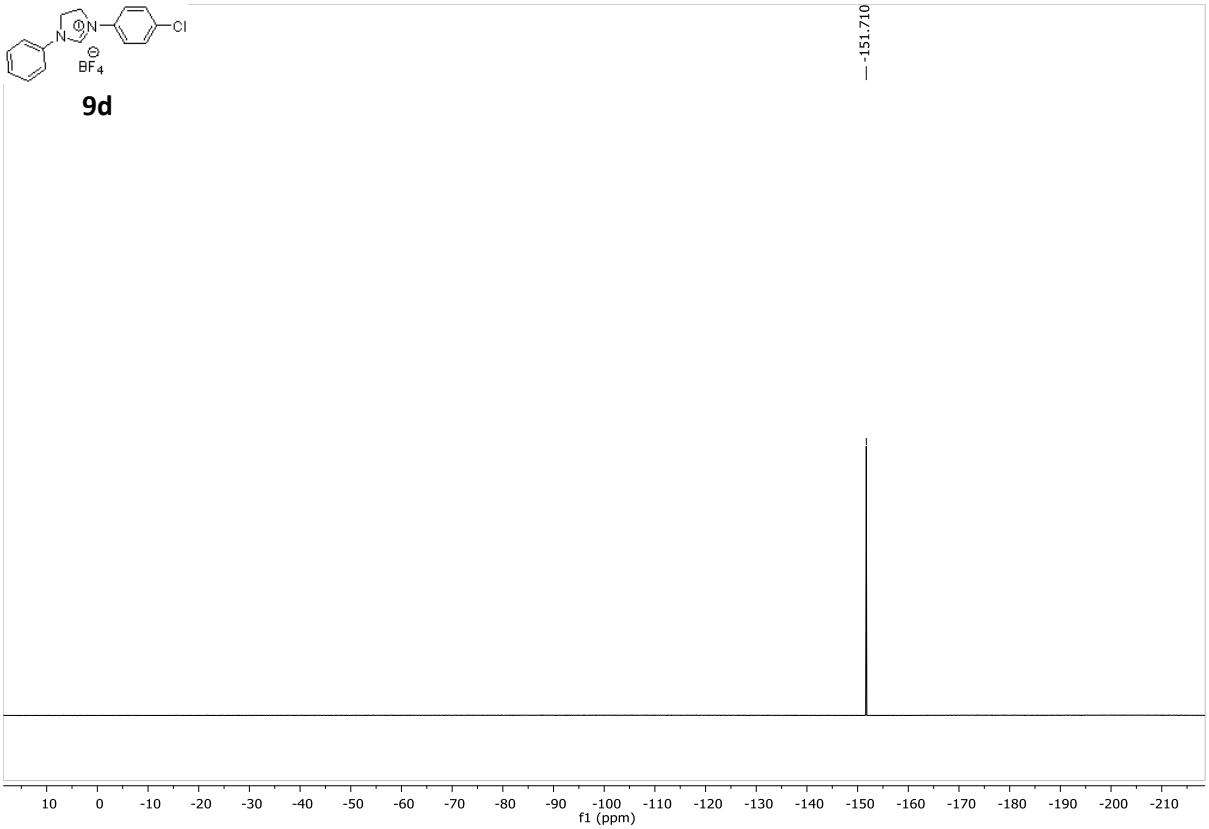
-151.79
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


9.069
7.582
7.577
7.566
7.559
7.554
7.548
7.543
7.486
7.481
7.471
7.466
7.449
7.443
4.562
Cl
BF4
1.00
3.96
4.96
4.11
f1 (ppm)

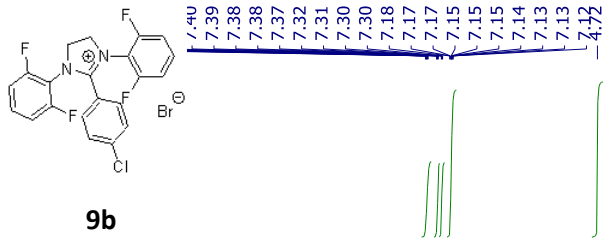
9d


152.641
136.752
135.754
133.747
131.060
130.956
129.033
121.355
119.794
50.176
50.123
Cl
BF4
f1 (ppm)

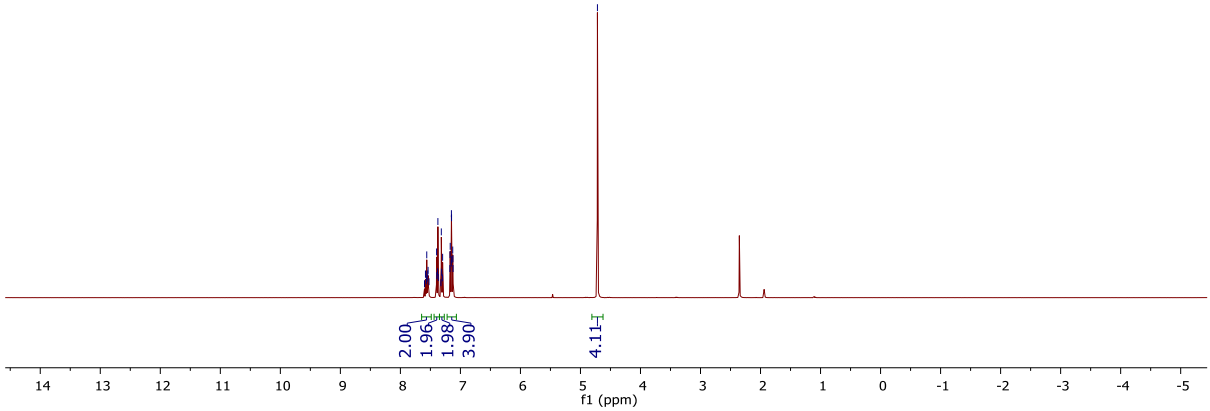
9d

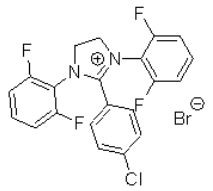

Cl
BF4
-151.710
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

9d


7.40
7.39
7.38
7.38
7.37
7.32
7.31
7.30
7.30
7.18
7.17
7.17
7.15
7.15
7.15
7.14
7.13
7.13
7.12
4.72
F
F
N
N
F
F
Br
Cl

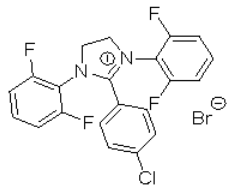
9b


2.00
1.96
1.98
3.90
4.11
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
f1 (ppm)


F
F
N
N
F
F
Br
Cl

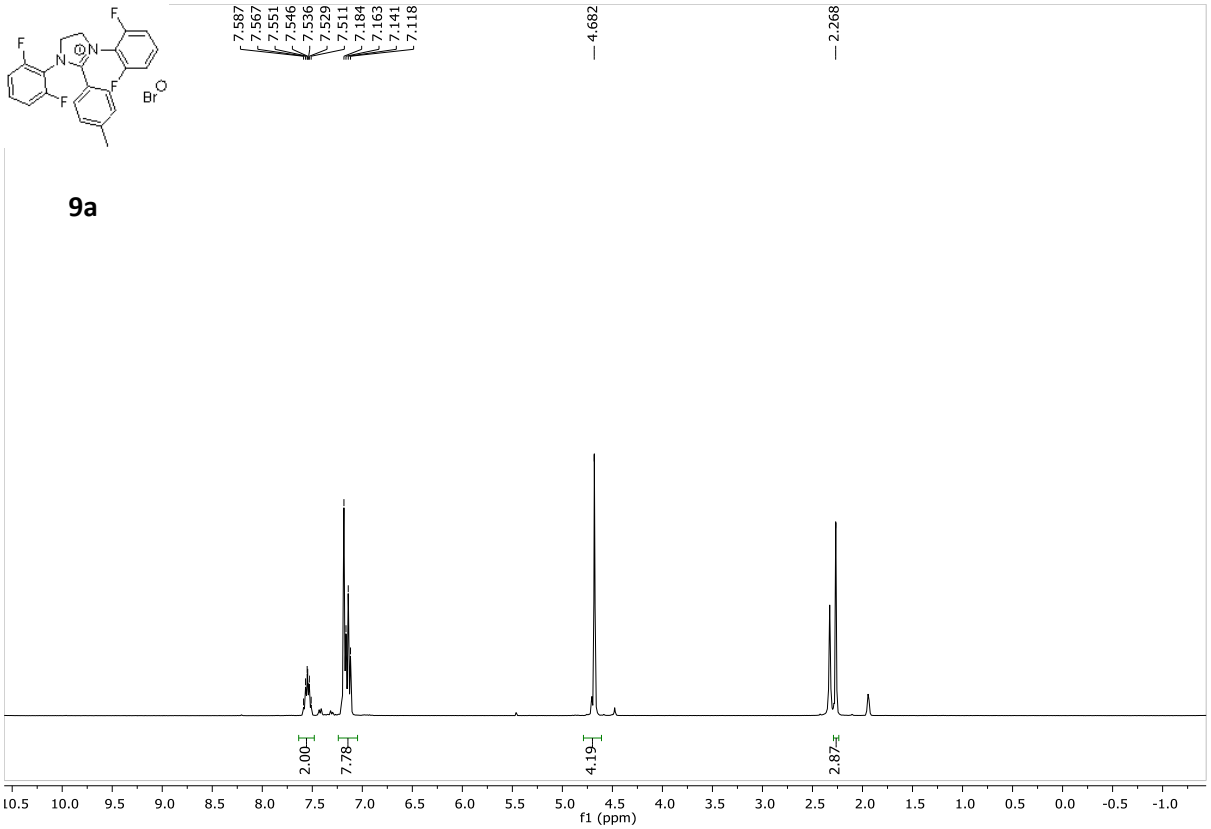
9b

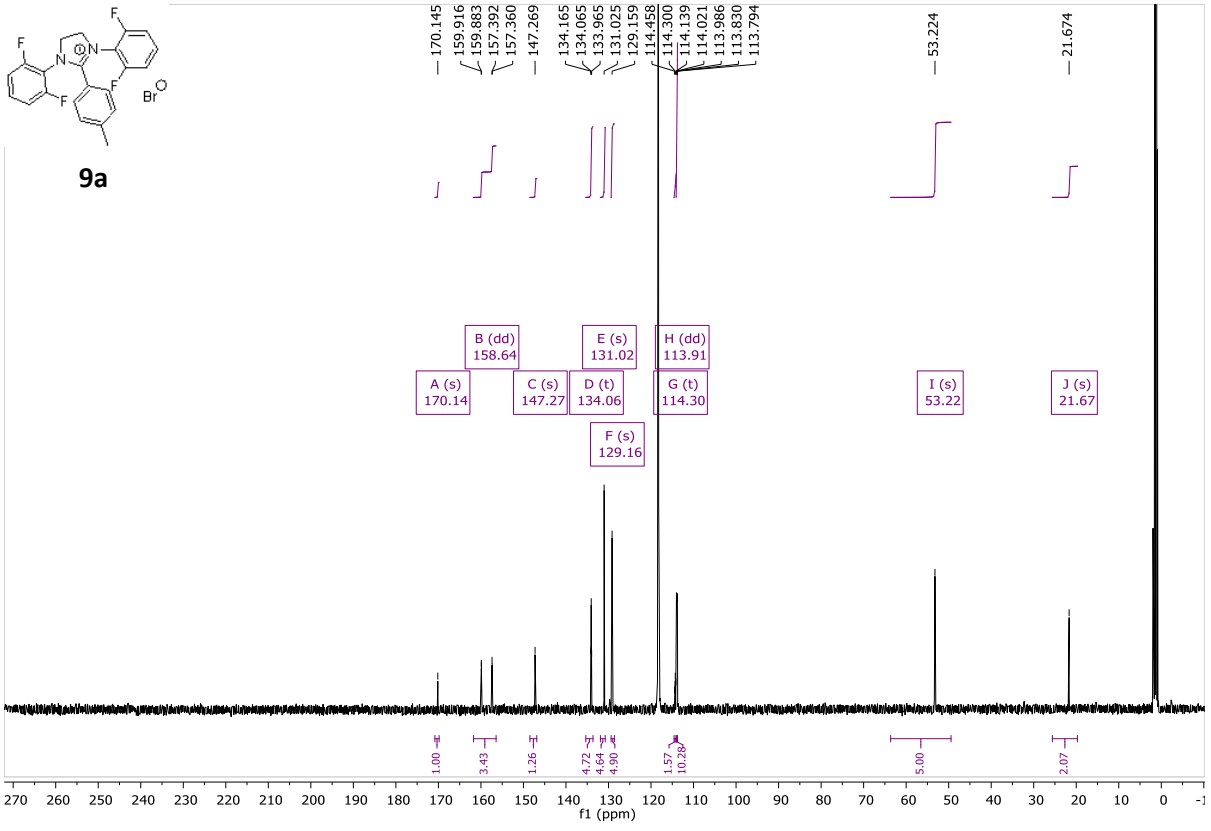
169.04
159.72
159.68
157.19
157.16
141.52
134.32
134.22
134.12
130.91
130.85
119.97
114.10
114.07
113.96
113.91
113.88
113.80
113.64
53.41
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

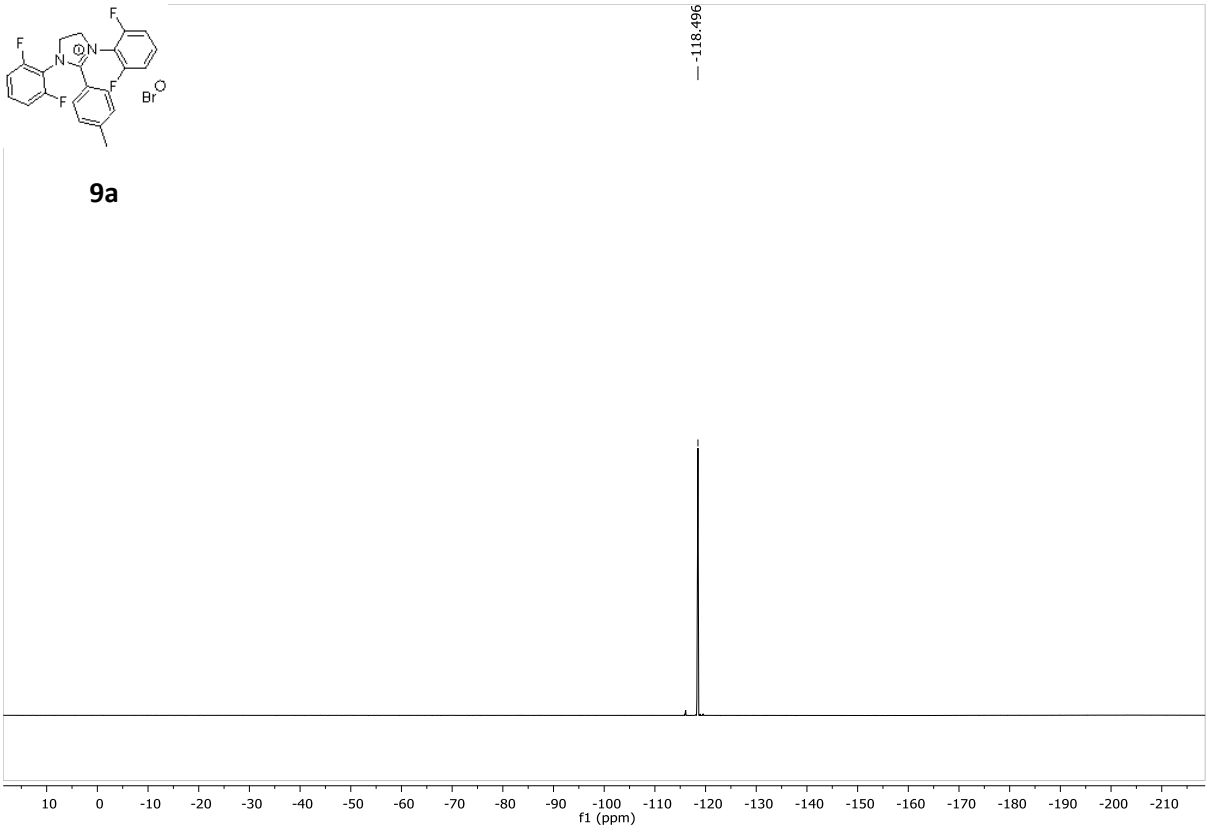

F
F
N
N
F
F
Br
Cl

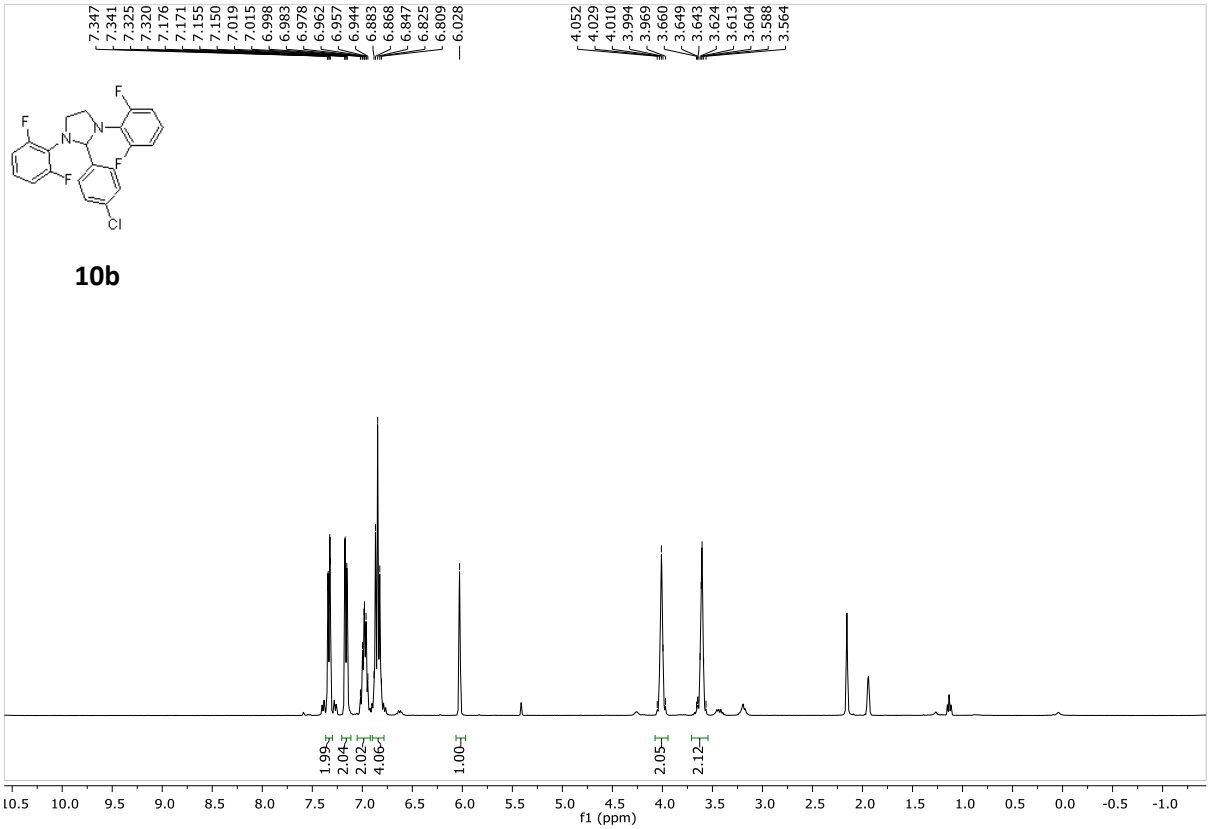
9b

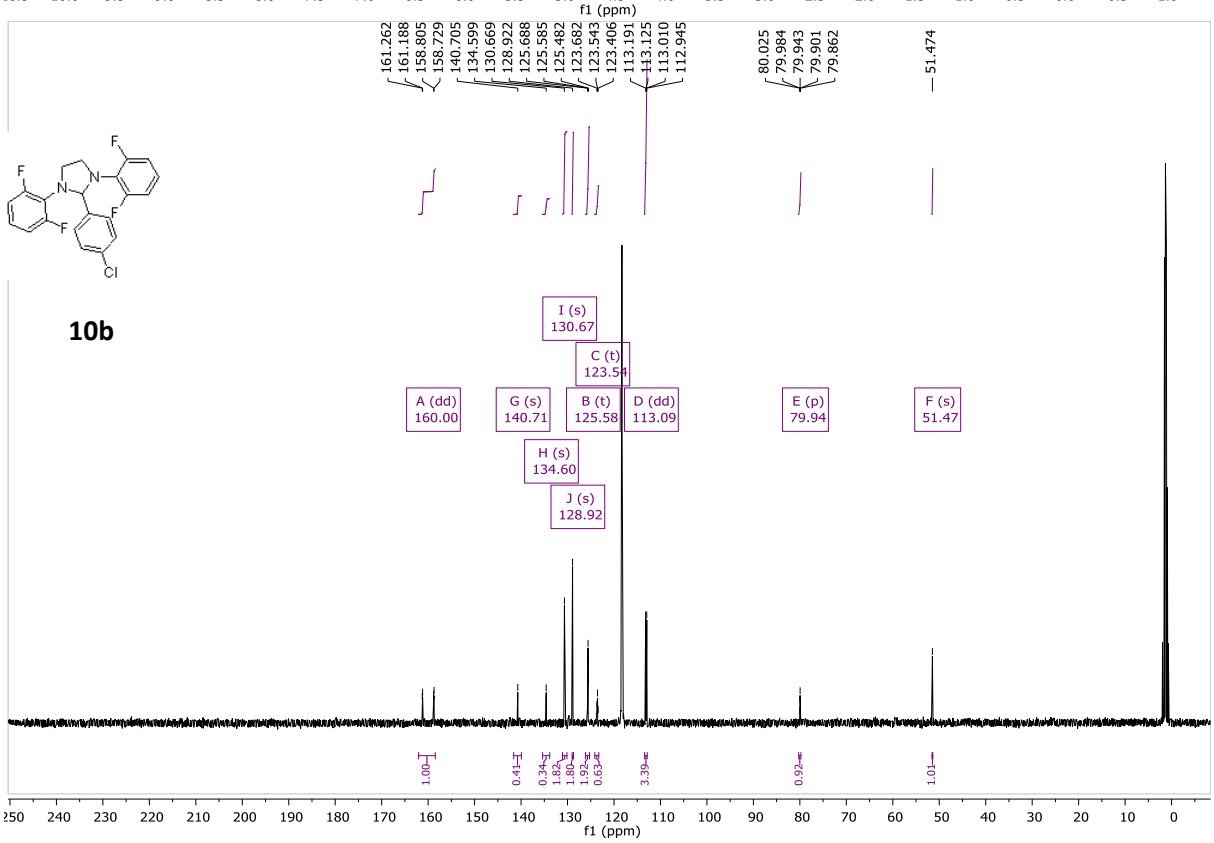
-118.12
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

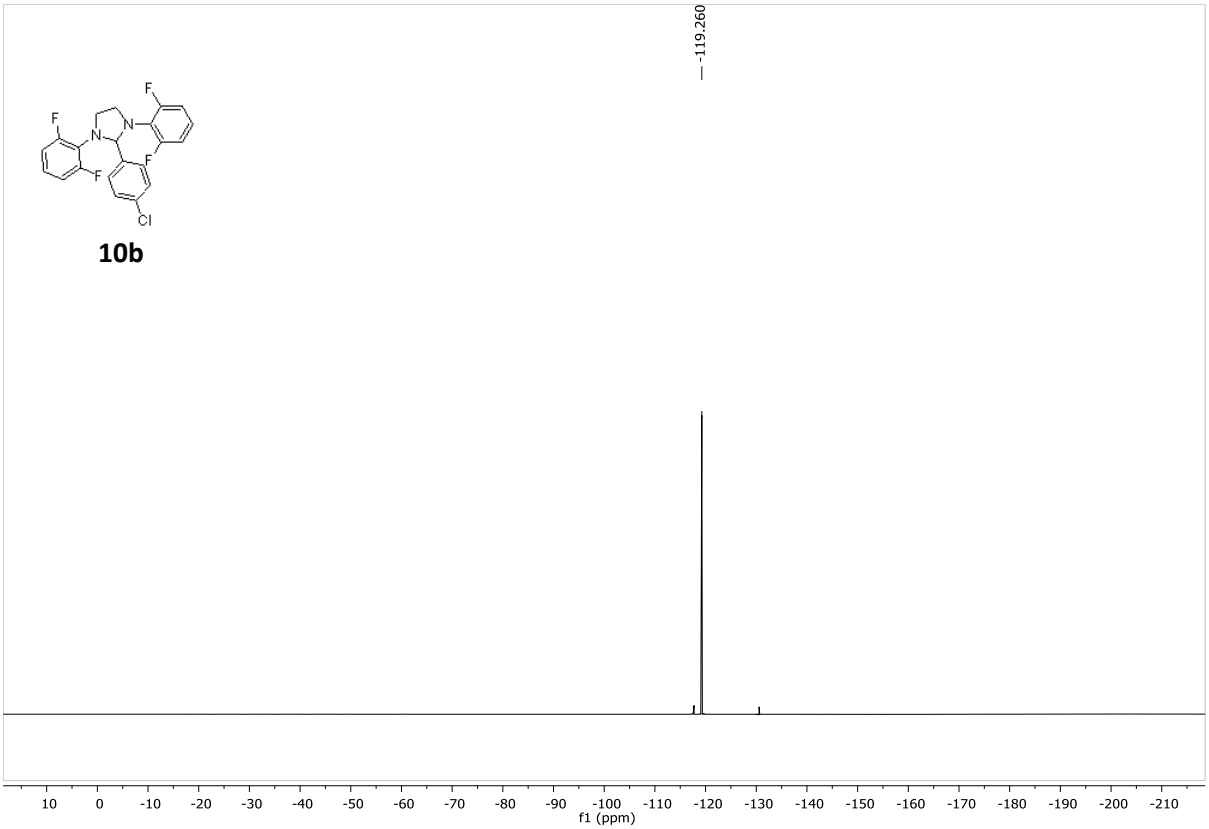

9a
7.587
7.567
7.551
7.546
7.536
7.529
7.511
7.184
7.163
7.141
7.118
4.682
2.268
2.00
7.78
4.19
2.87
f1 (ppm)


9a
170.145
159.916
159.883
157.392
157.360
147.269
134.165
134.065
133.965
131.025
129.159
114.458
114.300
114.139
114.021
113.986
113.830
113.794
53.224
21.674
B (dd)
158.64
E (s)
131.02
H (dd)
113.91
A (s)
170.14
C (s)
147.27
D (t)
134.06
G (t)
114.30
I (s)
53.22
J (s)
21.67
F (s)
129.16
1.00
3.43
1.26
4.72
4.64
4.90
1.57
10.28
5.00
2.07
f1 (ppm)

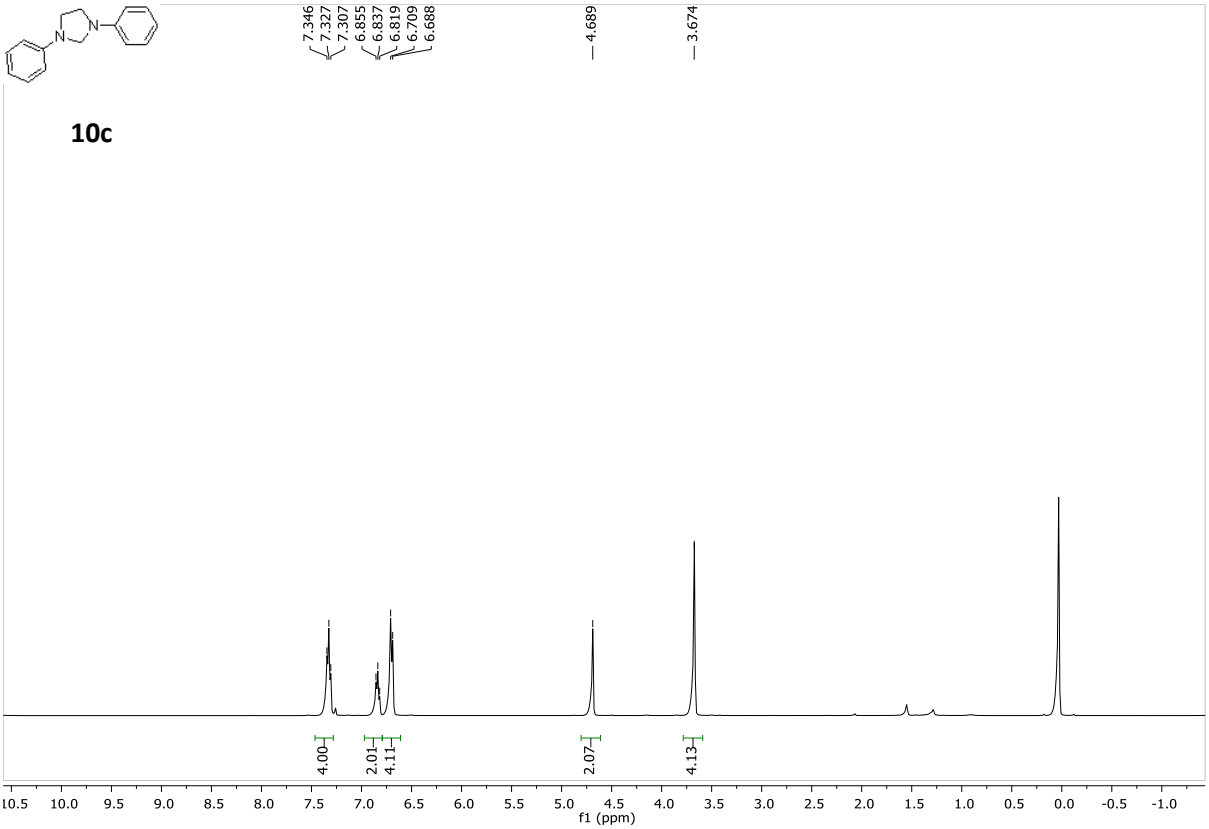

F
F
N
N
F
F
Br
O
-118.496
9a
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

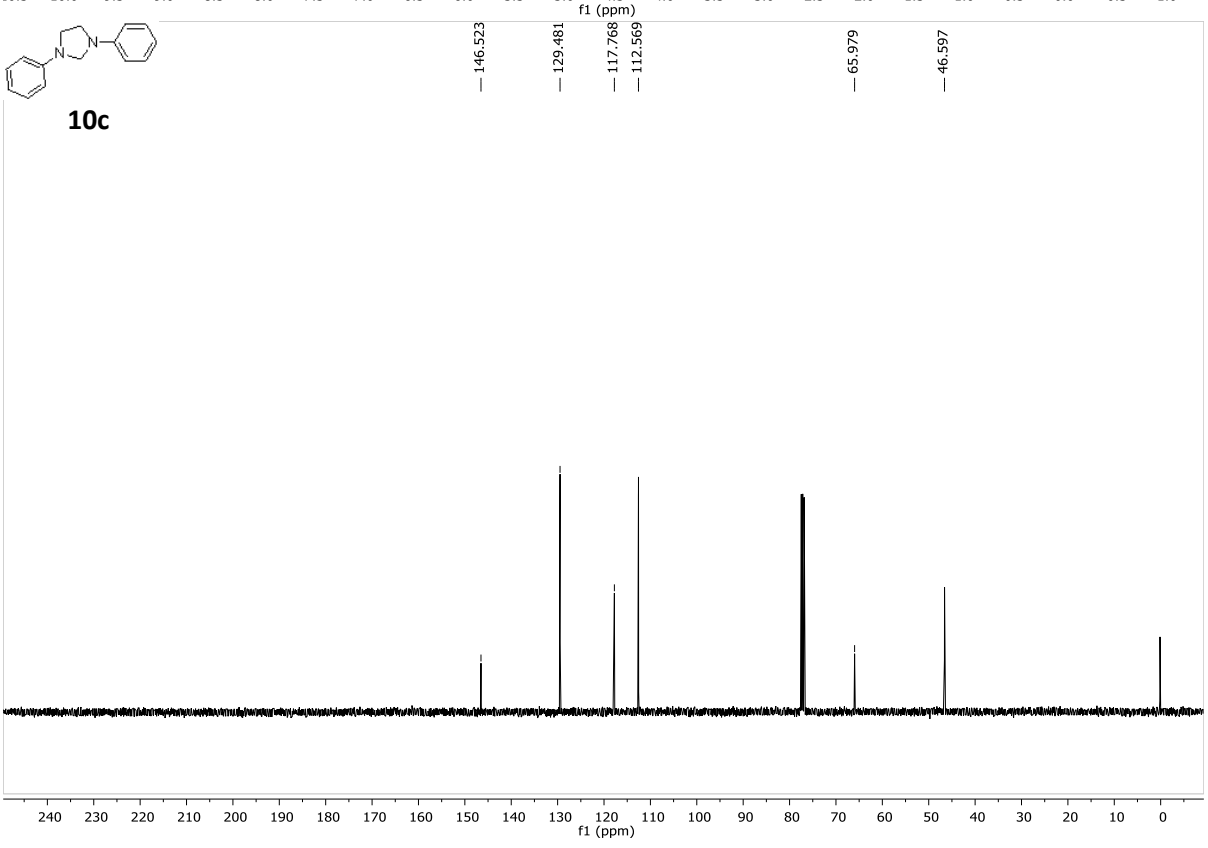

7.347
7.341
7.325
7.320
7.176
7.171
7.155
7.150
7.019
7.015
6.998
6.983
6.978
6.962
6.957
6.944
6.883
6.868
6.847
6.825
6.809
6.028
4.052
4.029
4.010
3.994
3.969
3.660
3.649
3.643
3.624
3.613
3.604
3.588
3.564
10b
1.99
2.04
2.02
4.06
1.00
2.05
2.12
f1 (ppm)

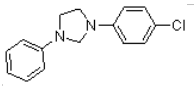

161.262
161.188
158.805
158.729
140.705
134.599
130.669
128.922
125.688
125.585
125.482
123.682
123.543
123.406
113.191
113.125
113.010
112.945
80.025
79.984
79.943
79.901
79.862
51.474
10b
I (s)
130.67
C (t)
123.54
A (dd)
160.00
G (s)
140.71
B (t)
125.58
D (dd)
113.09
E (p)
79.94
F (s)
51.47
H (s)
134.60
J (s)
128.92
1.00
0.41
0.34
1.82
1.80
1.92
0.63
3.39
0.92
1.01
f1 (ppm)


-119.260
F
F
N
N
F
F
Cl
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)

10b

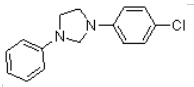

7.346
7.327
7.307
6.855
6.837
6.819
6.709
6.688
4.689
3.674
10c
4.00
2.01
4.11
2.07
4.13
f1 (ppm)


146.523
129.481
117.768
112.569
65.979
46.597
10c
f1 (ppm)



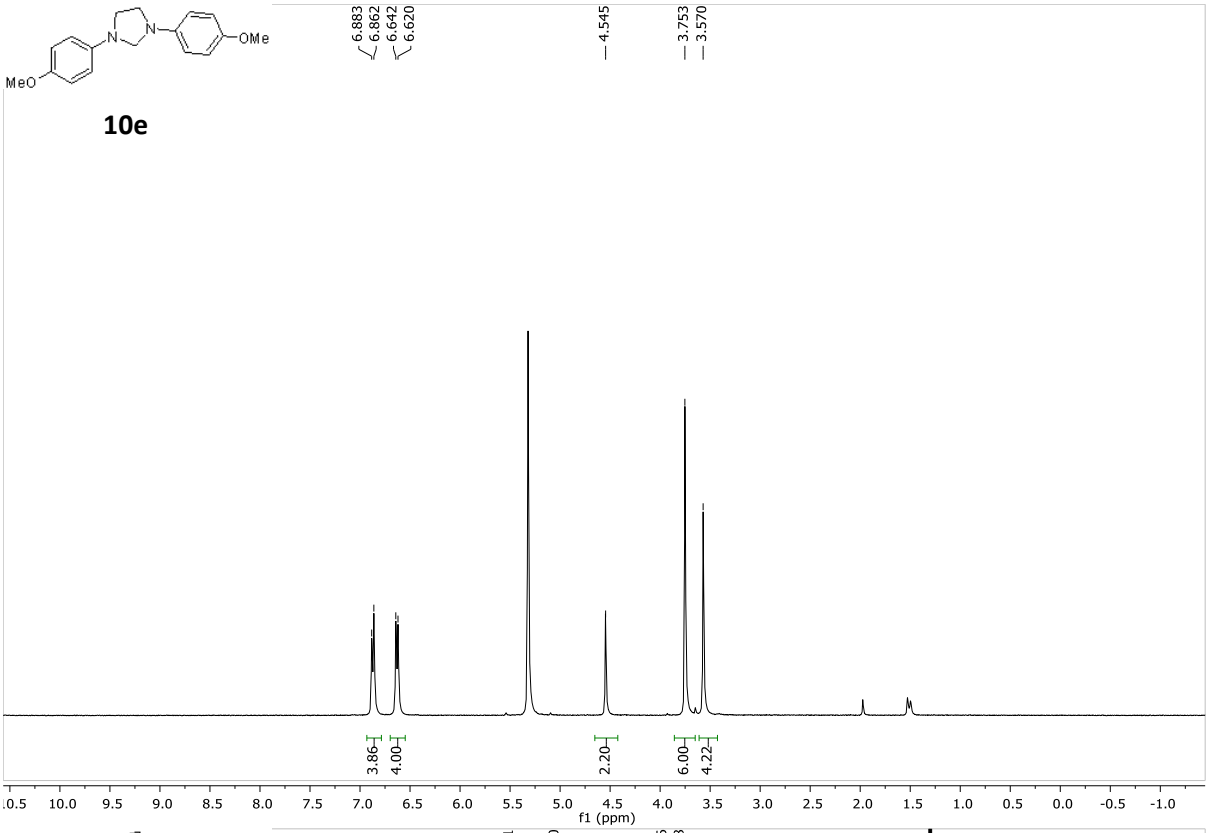
10d

7.320
7.315
7.297
7.278
7.241
7.221
6.836
6.818
6.799
6.671
6.652
6.577
6.559
1.99
2.17
1.00
2.03
2.02
2.04
4.12
f1 (ppm)

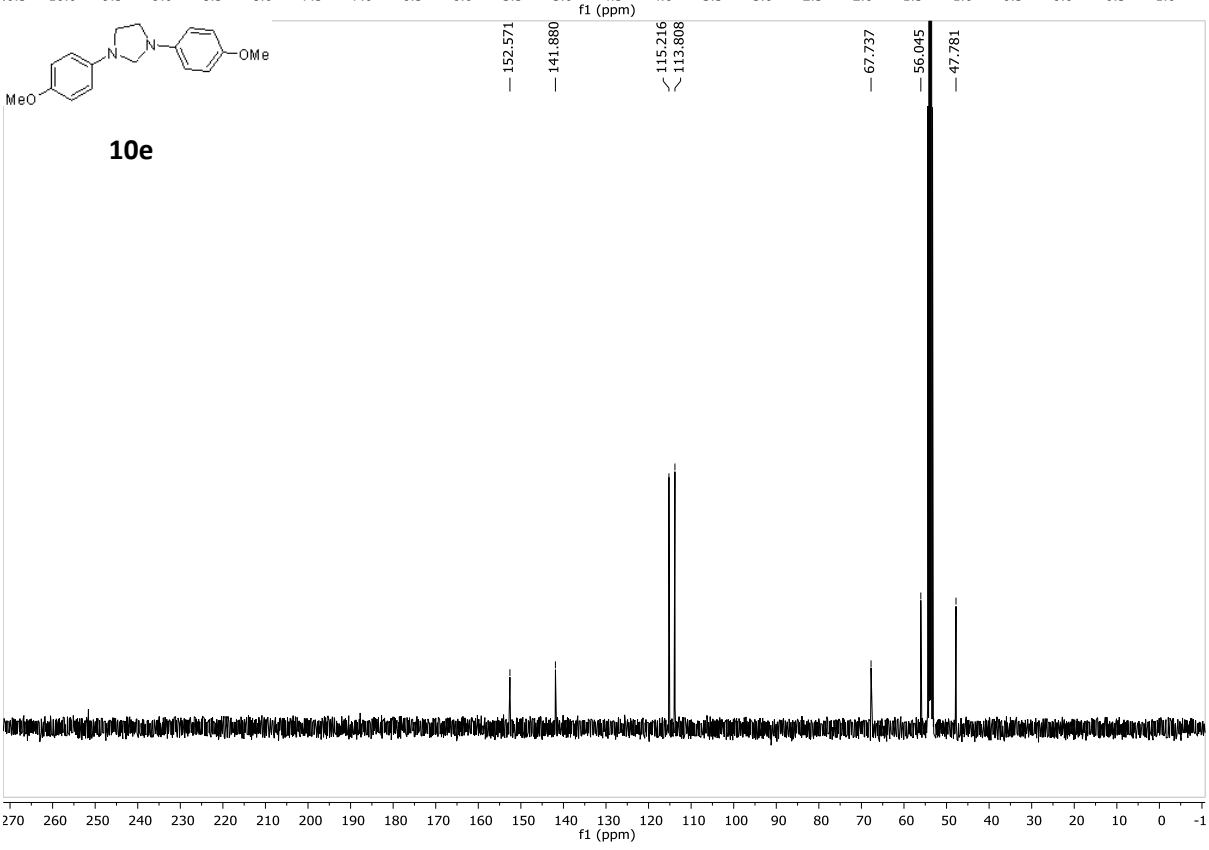


10d

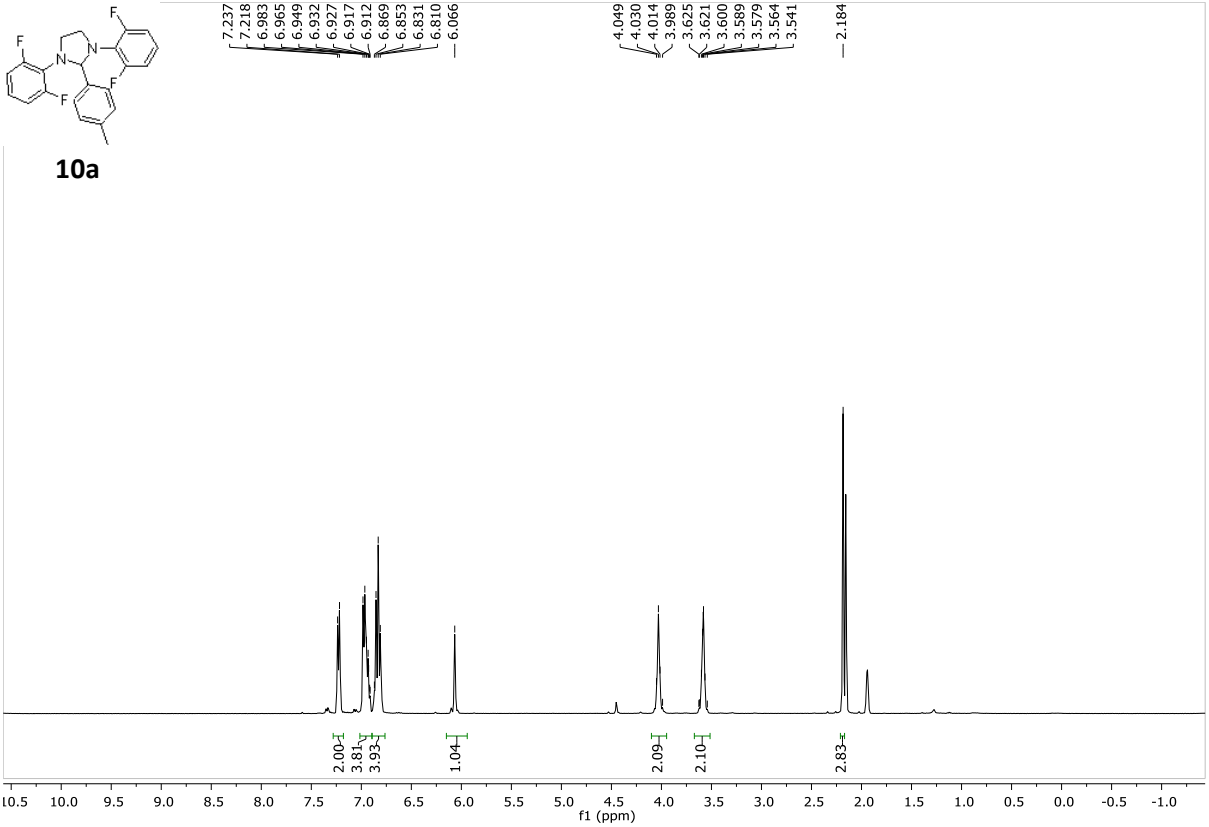
146.391
145.047
129.516
129.303
122.658
117.999
113.571
112.647
66.027
46.723
46.619
f1 (ppm)

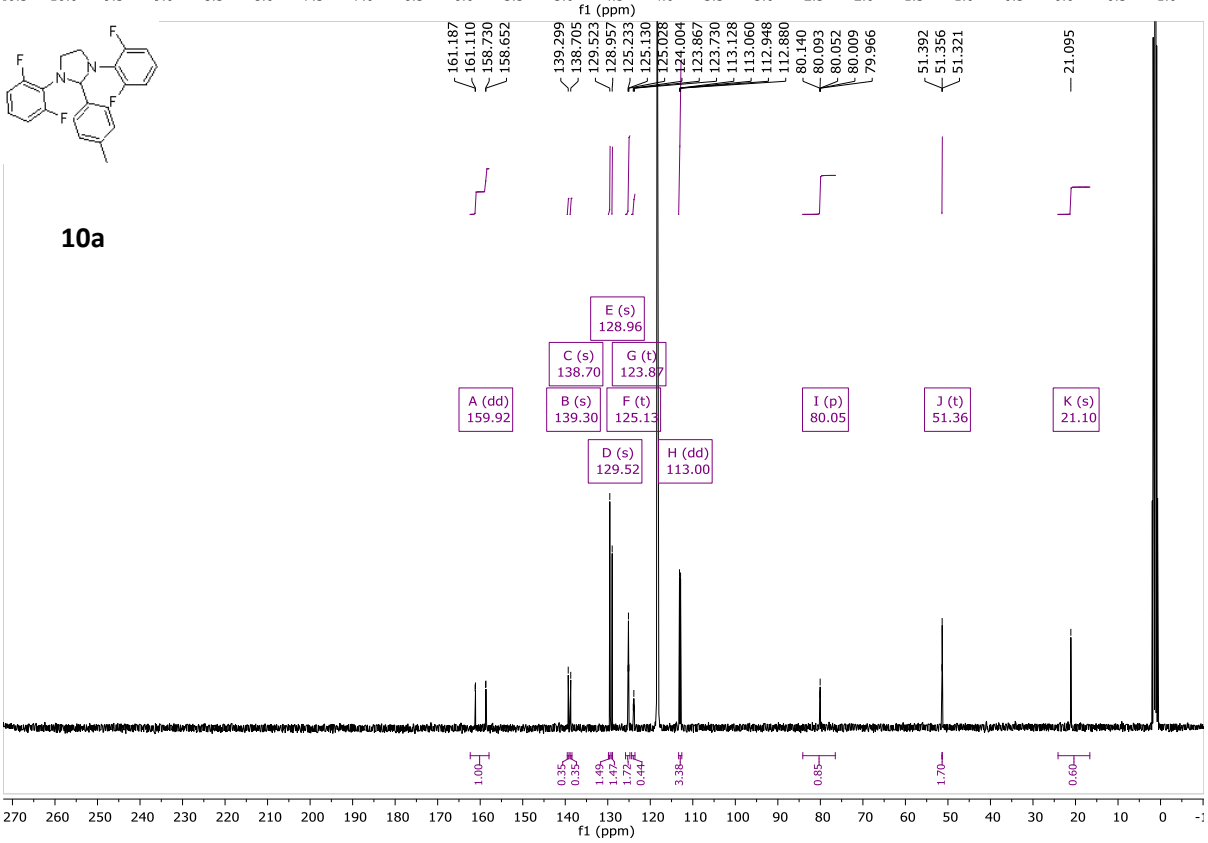

MeO
OMe
6.883
6.862
6.642
6.620
4.545
3.753
3.570
3.86
4.00
2.20
6.00
4.22
f1 (ppm)

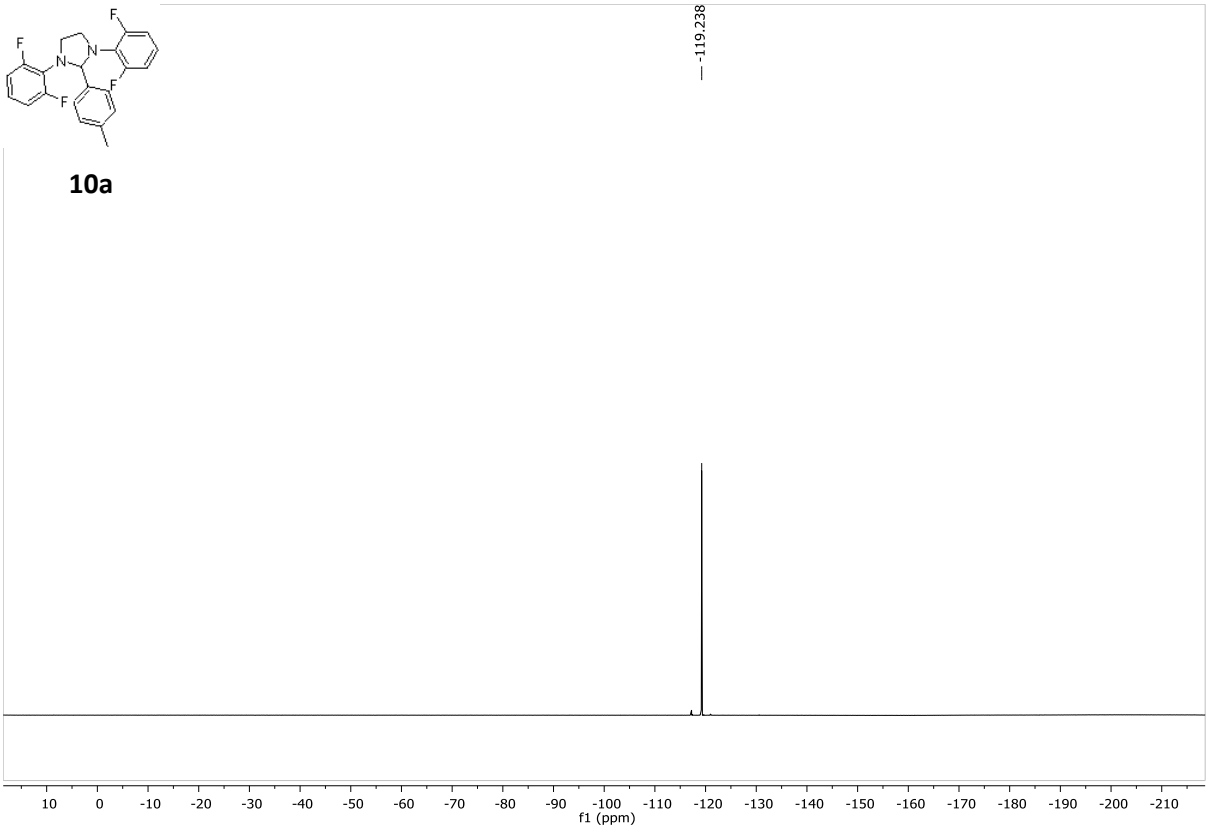
10e


MeO
OMe
152.571
141.880
115.216
113.808
67.737
56.045
47.781
f1 (ppm)

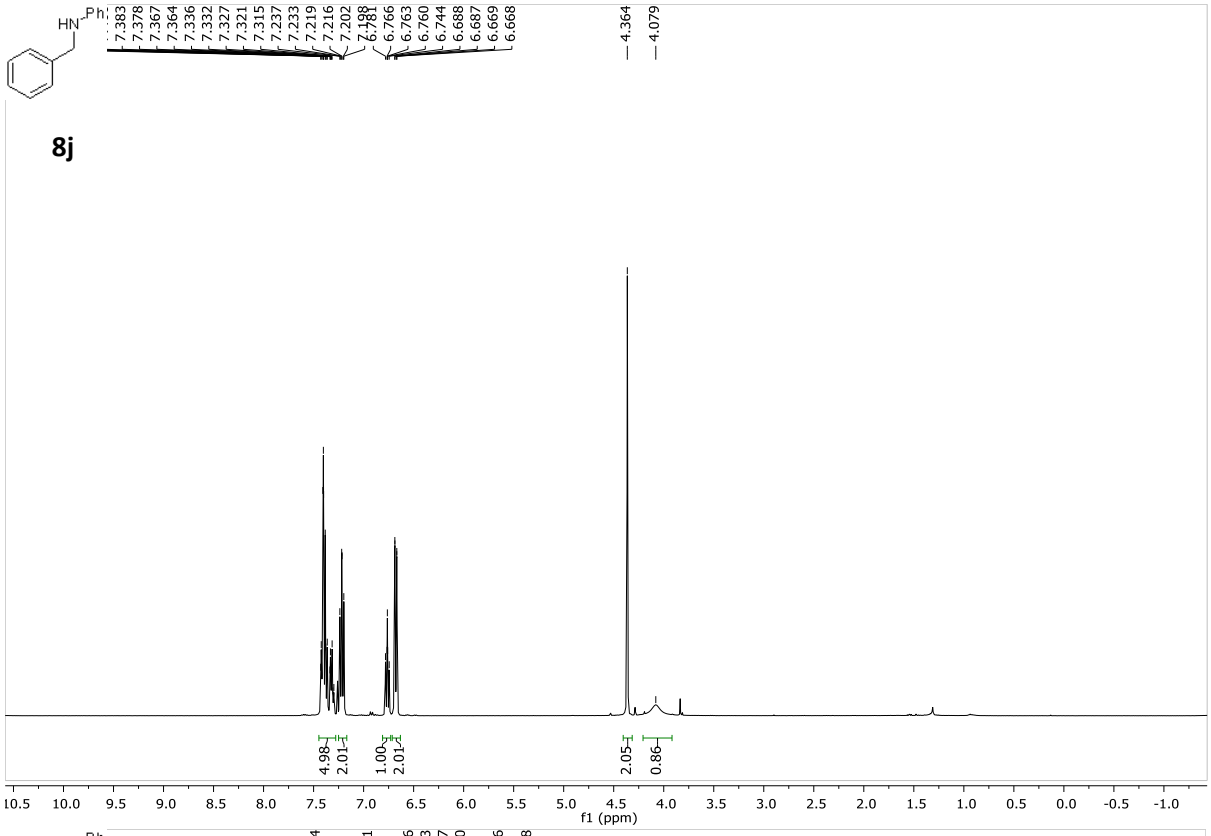
10e

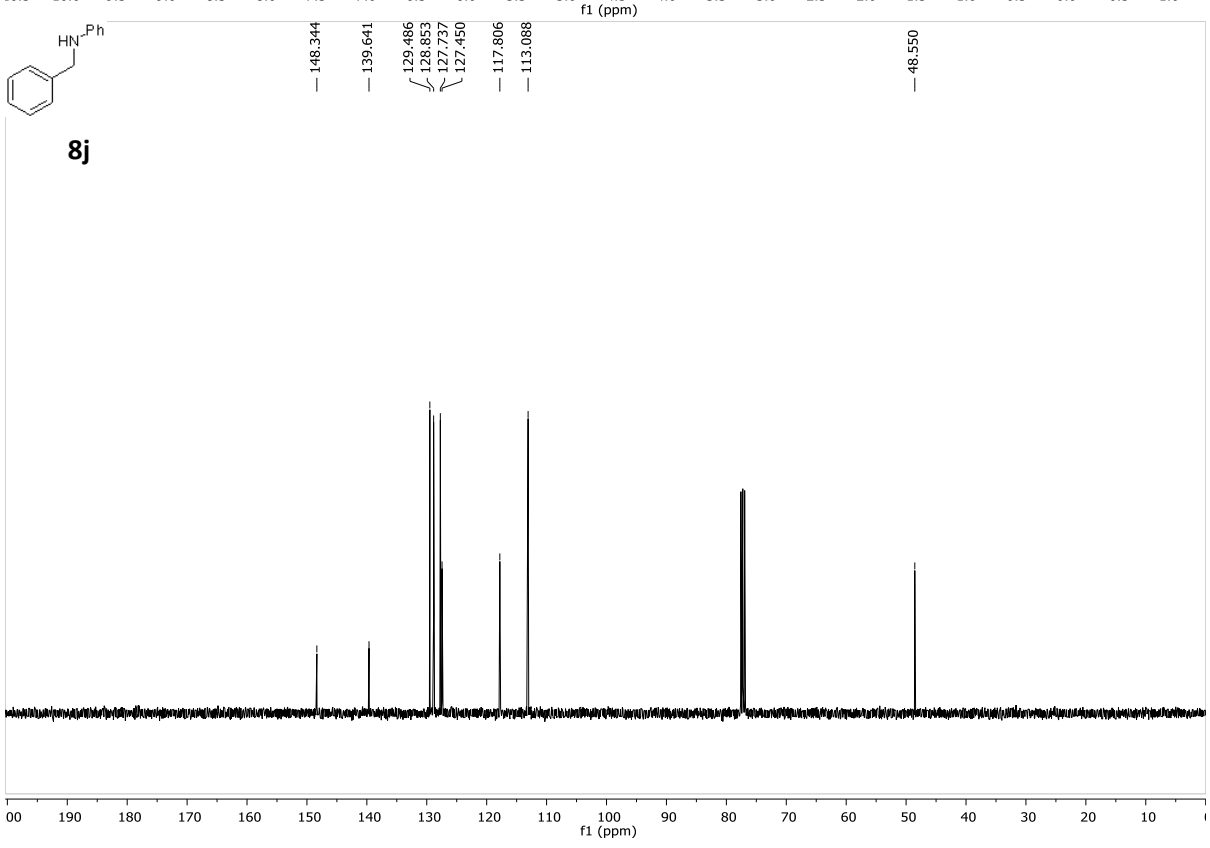

10a
7.237
7.218
6.983
6.965
6.949
6.932
6.927
6.917
6.912
6.869
6.853
6.831
6.810
6.066
4.049
4.030
4.014
3.989
3.625
3.621
3.600
3.589
3.579
3.564
3.541
2.184
2.00
3.81
3.93
1.04
2.09
2.10
2.83
f1 (ppm)

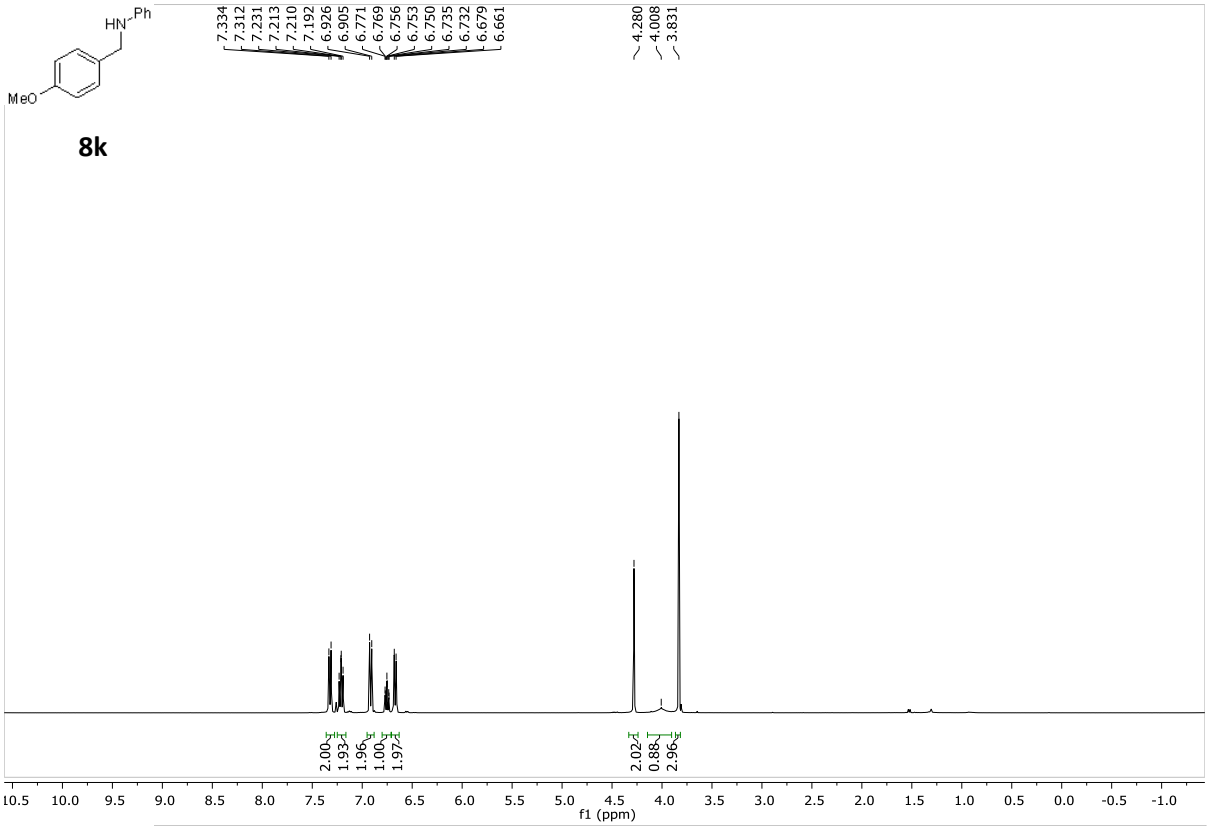

10a
161.187
161.110
158.730
158.652
139.299
138.705
129.523
128.957
125.233
125.130
125.028
124.004
123.867
123.730
113.128
113.060
112.948
112.880
80.140
80.093
80.052
80.009
79.966
51.392
51.356
51.321
21.095
E (s)
128.96
C (s)
138.70
G (t)
123.87
A (dd)
159.92
B (s)
139.30
F (t)
125.13
I (p)
80.05
J (t)
51.36
K (s)
21.10
D (s)
129.52
H (dd)
113.00
1.00
0.35
0.35
1.49
1.47
1.72
0.44
3.38
0.85
1.70
0.60
f1 (ppm)

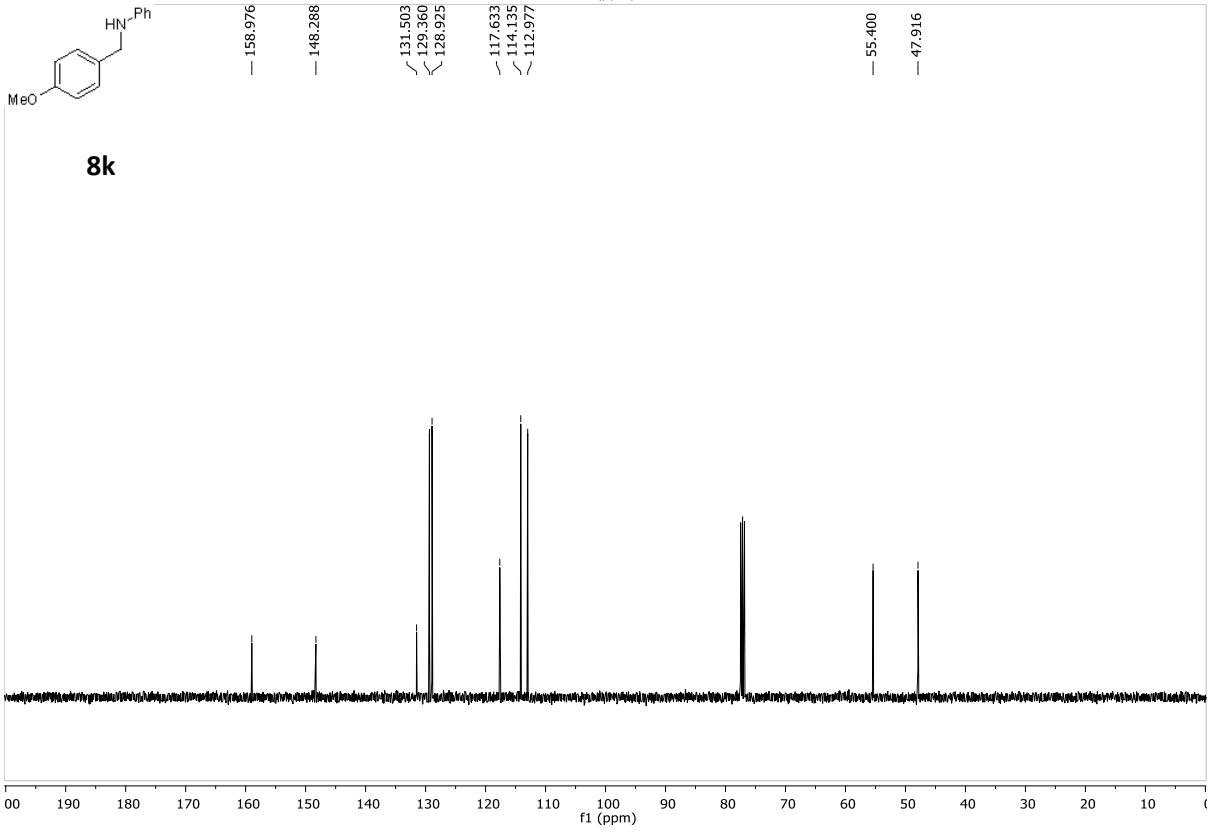

F
F
N
N
F
F
-119.238
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

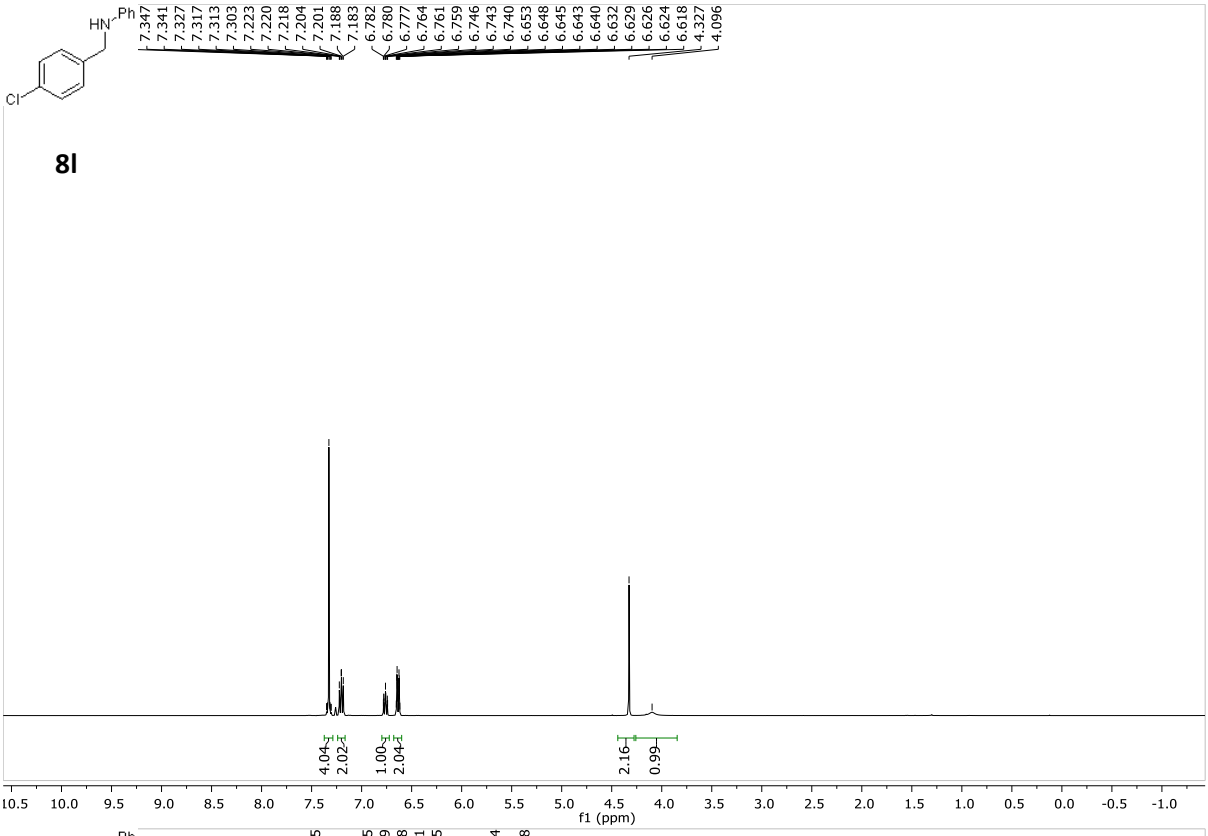
10a


HN
Ph
7.383
7.378
7.367
7.364
7.336
7.332
7.327
7.321
7.315
7.237
7.233
7.219
7.216
7.202
6.766
6.763
6.760
6.744
6.688
6.687
6.669
6.668
4.364
4.079
8j
4.98
2.01
1.00
2.01
2.05
0.86
f1 (ppm)

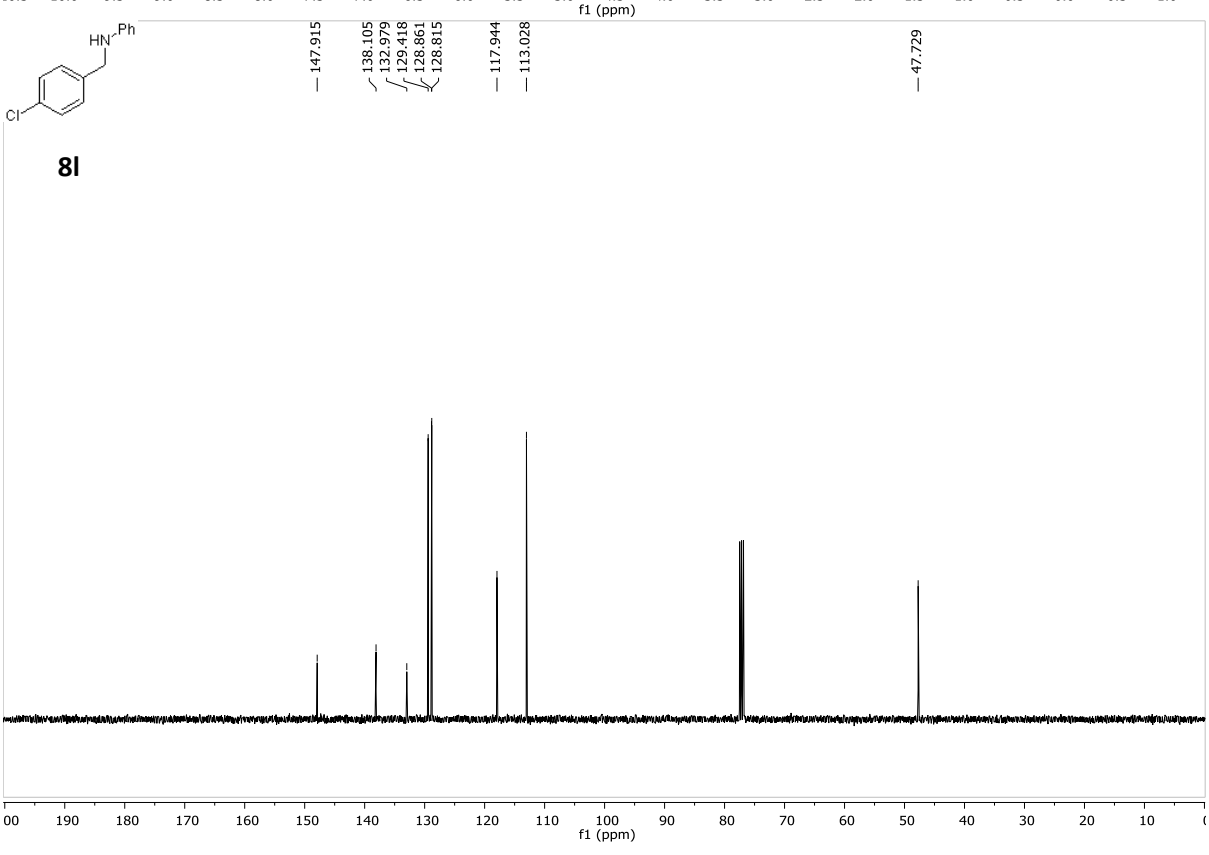

HN
Ph
148.344
139.641
129.486
128.853
127.737
127.450
117.806
113.088
48.550
8j
f1 (ppm)


HN
Ph
MeO
8k
7.334
7.312
7.231
7.213
7.210
7.192
6.926
6.905
6.771
6.769
6.756
6.753
6.750
6.735
6.732
6.679
6.661
4.280
4.008
3.831
2.00
1.93
1.96
1.00
1.97
2.02
0.88
2.96
f1 (ppm)

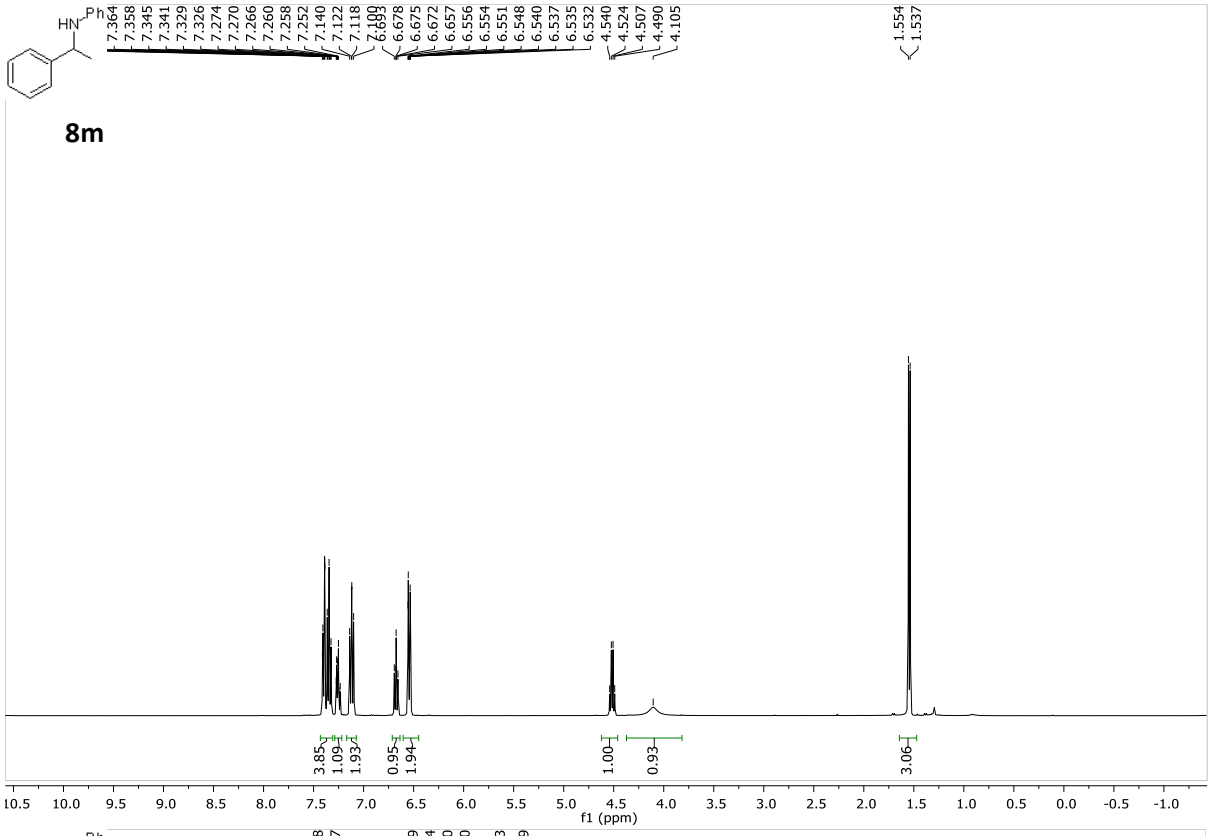

HN
Ph
MeO
8k
158.976
148.288
131.503
129.360
128.925
117.633
114.135
112.977
55.400
47.916
f1 (ppm)

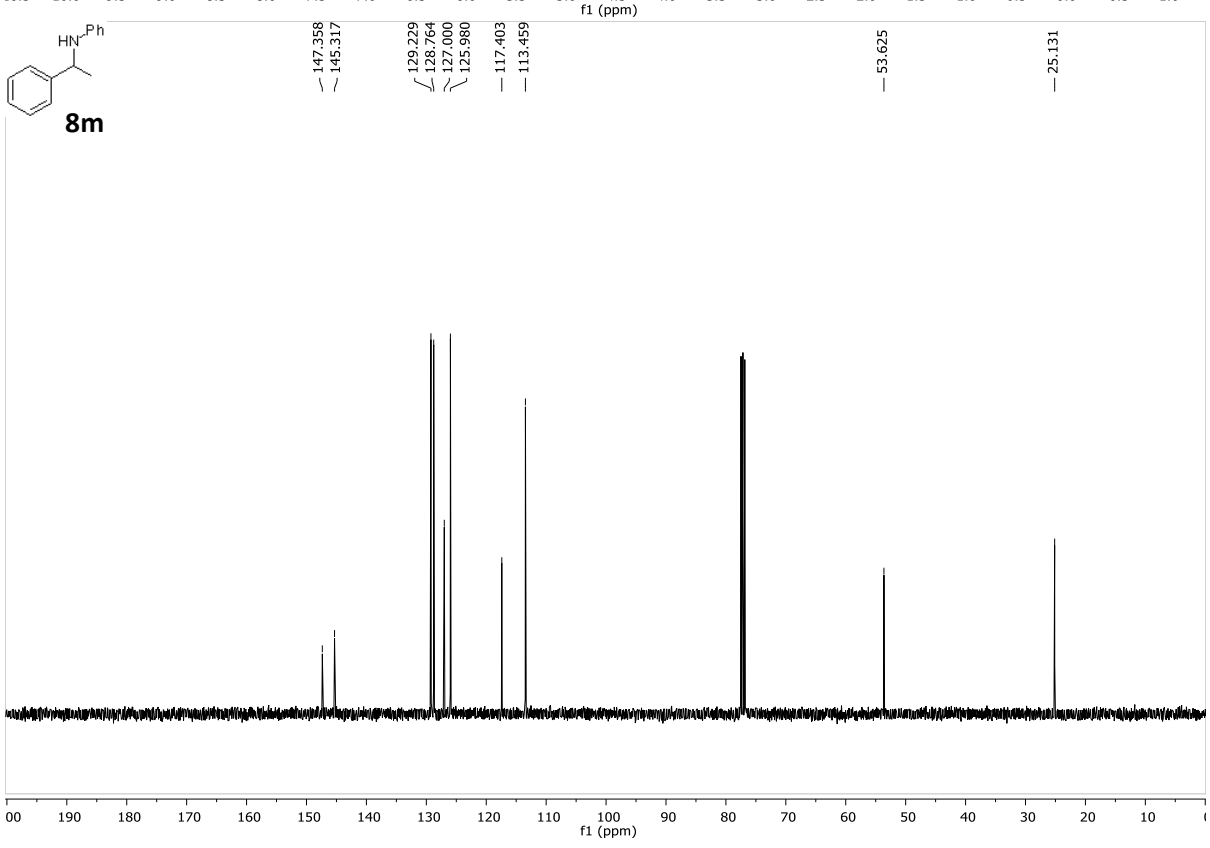

HN
Ph
Cl
7.347
7.341
7.327
7.317
7.313
7.303
7.223
7.220
7.218
7.204
7.201
7.188
7.183
6.782
6.780
6.777
6.764
6.761
6.759
6.746
6.743
6.740
6.653
6.648
6.645
6.643
6.640
6.632
6.629
6.626
6.624
6.618
4.327
4.096
4.04
2.02
1.00
2.04
2.16
0.99
f1 (ppm)

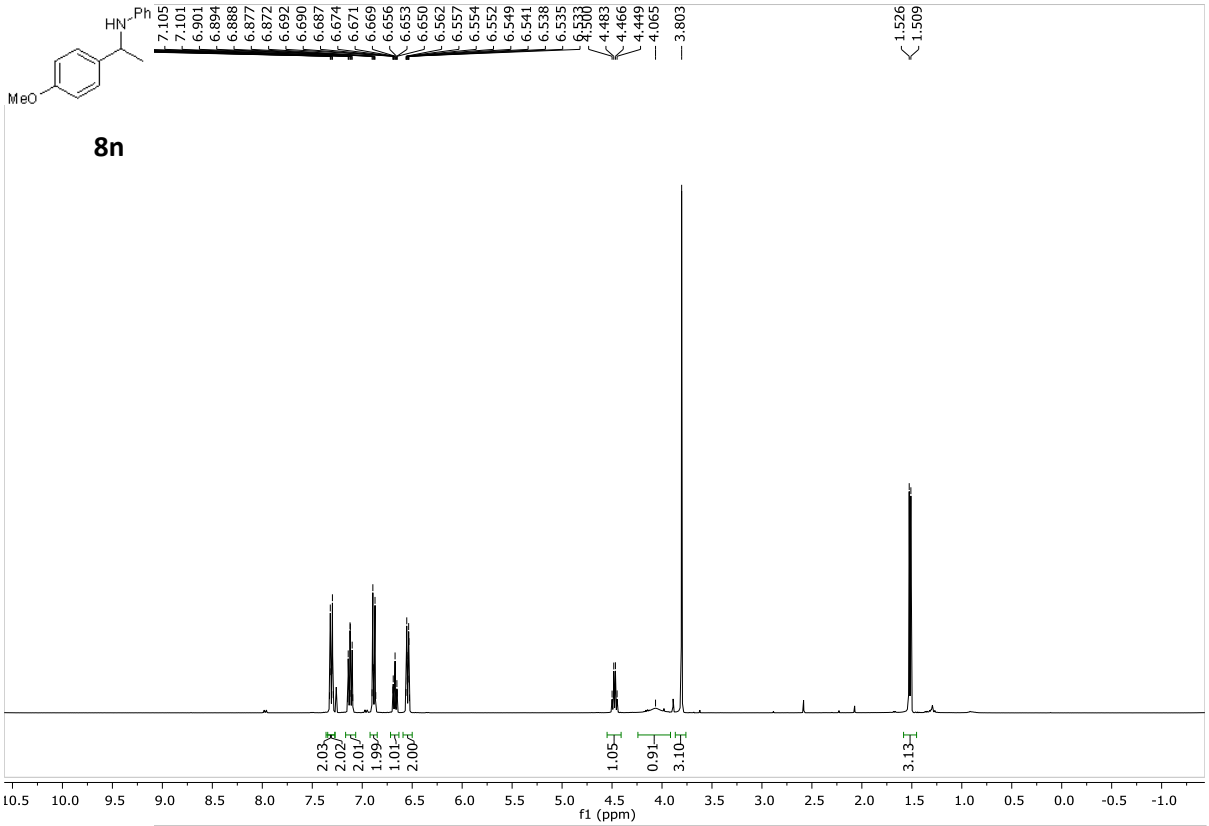
8l

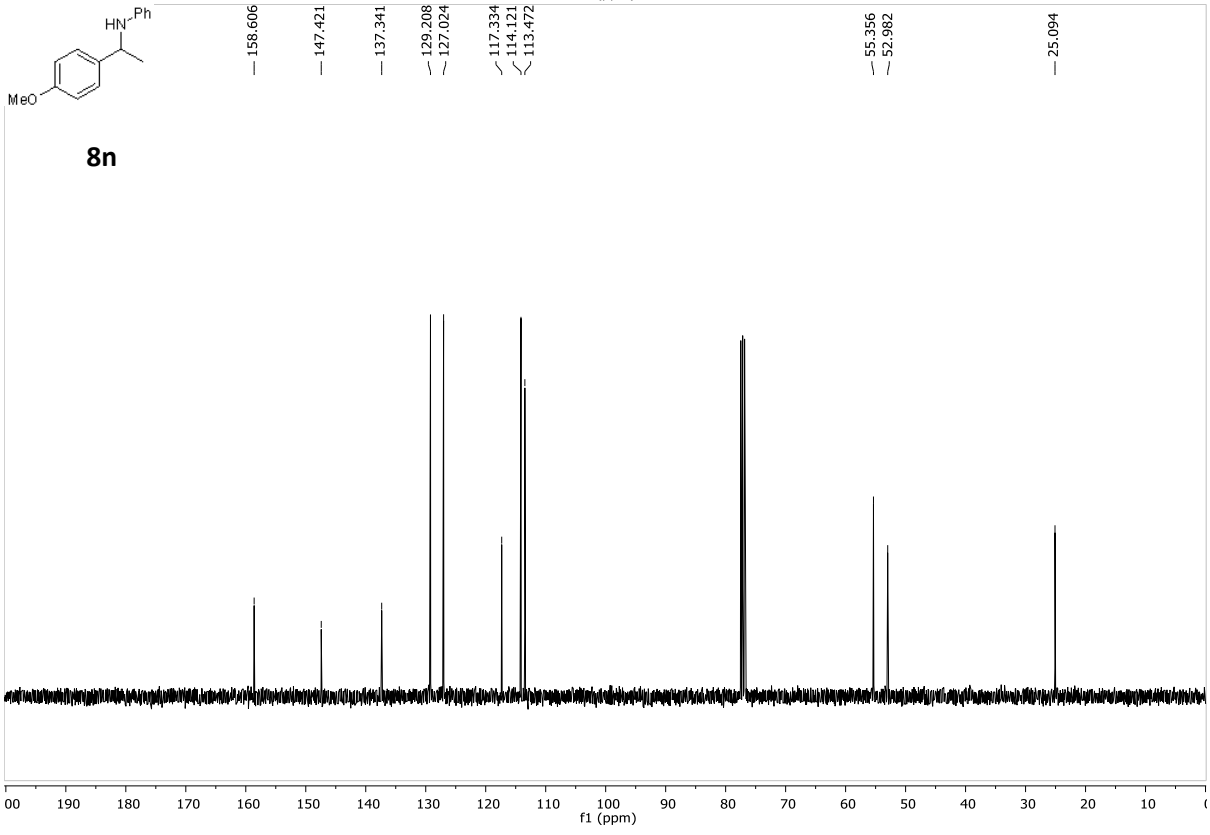

HN
Ph
Cl
147.915
138.105
132.979
129.418
128.861
128.815
117.944
113.028
47.729
f1 (ppm)

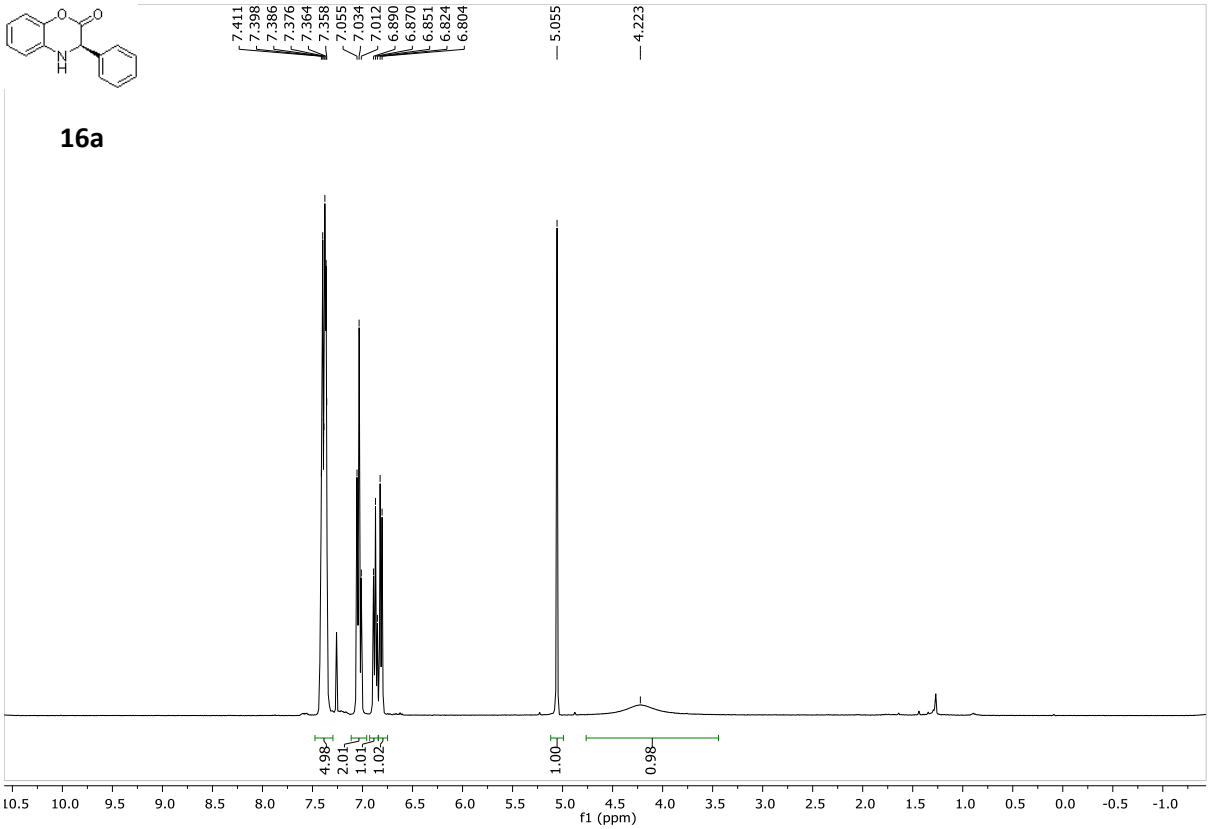
8l

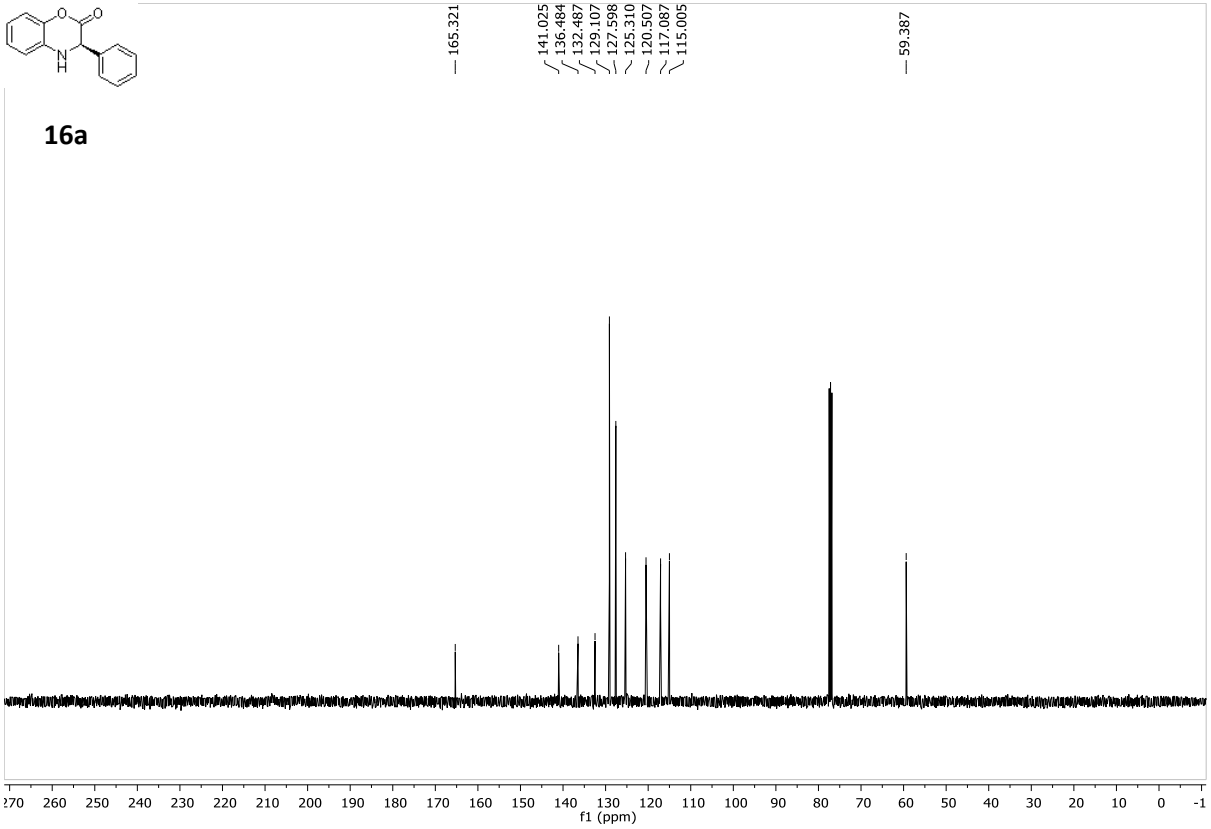

HN
Ph
7.364
7.358
7.345
7.341
7.329
7.326
7.274
7.270
7.266
7.260
7.258
7.252
7.140
7.122
7.118
7.100
6.693
6.678
6.675
6.672
6.657
6.556
6.554
6.551
6.548
6.540
6.537
6.535
6.532
4.540
4.524
4.507
4.490
4.105
1.554
1.537
8m
3.85
1.09
1.93
0.95
1.94
1.00
0.93
3.06
f1 (ppm)

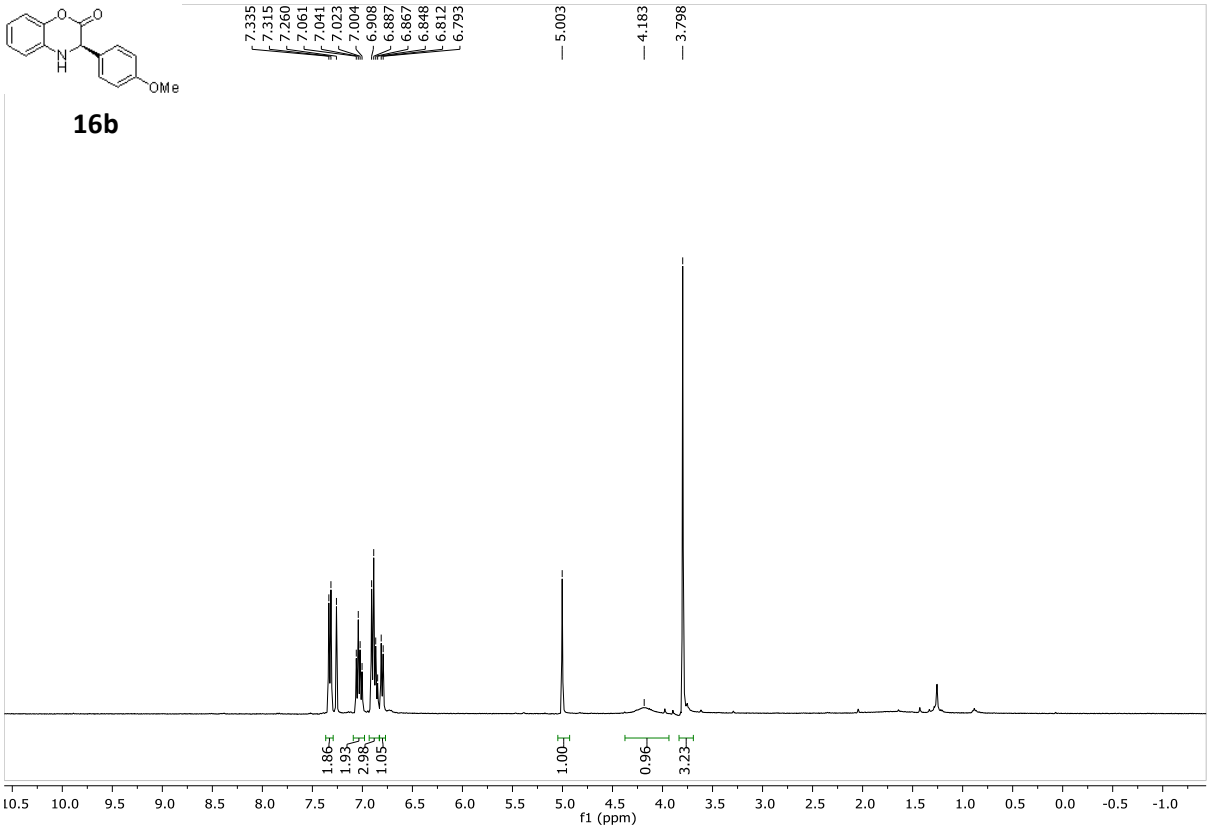

HN
Ph
147.358
145.317
129.229
128.764
127.000
125.980
117.403
113.459
53.625
25.131
8m
f1 (ppm)

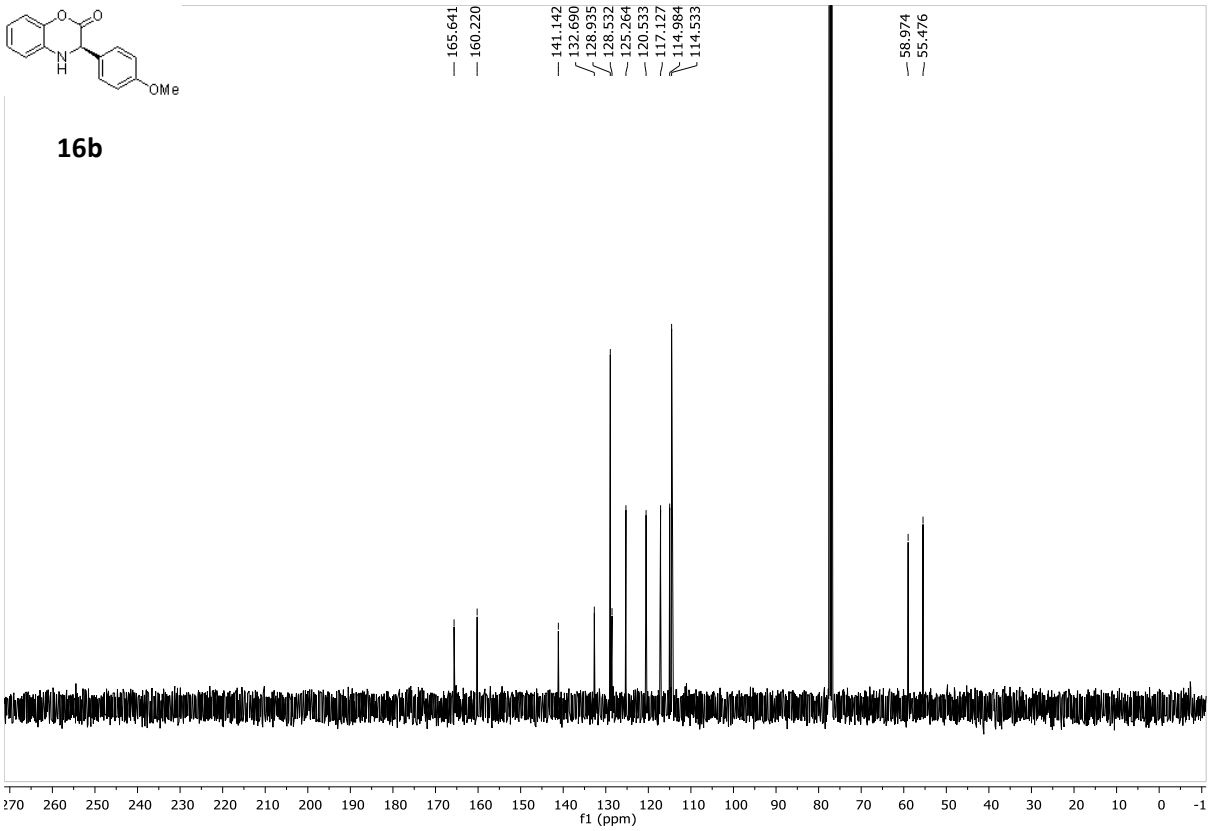

HN
Ph
MeO
7.105
7.101
6.901
6.894
6.888
6.877
6.872
6.692
6.690
6.687
6.674
6.671
6.669
6.656
6.653
6.650
6.562
6.557
6.554
6.552
6.549
6.541
6.538
6.535
6.533
4.500
4.483
4.466
4.449
4.065
3.803
1.526
1.509
8n
2.03
2.02
2.01
1.99
1.01
2.00
1.05
0.91
3.10
3.13
f1 (ppm)

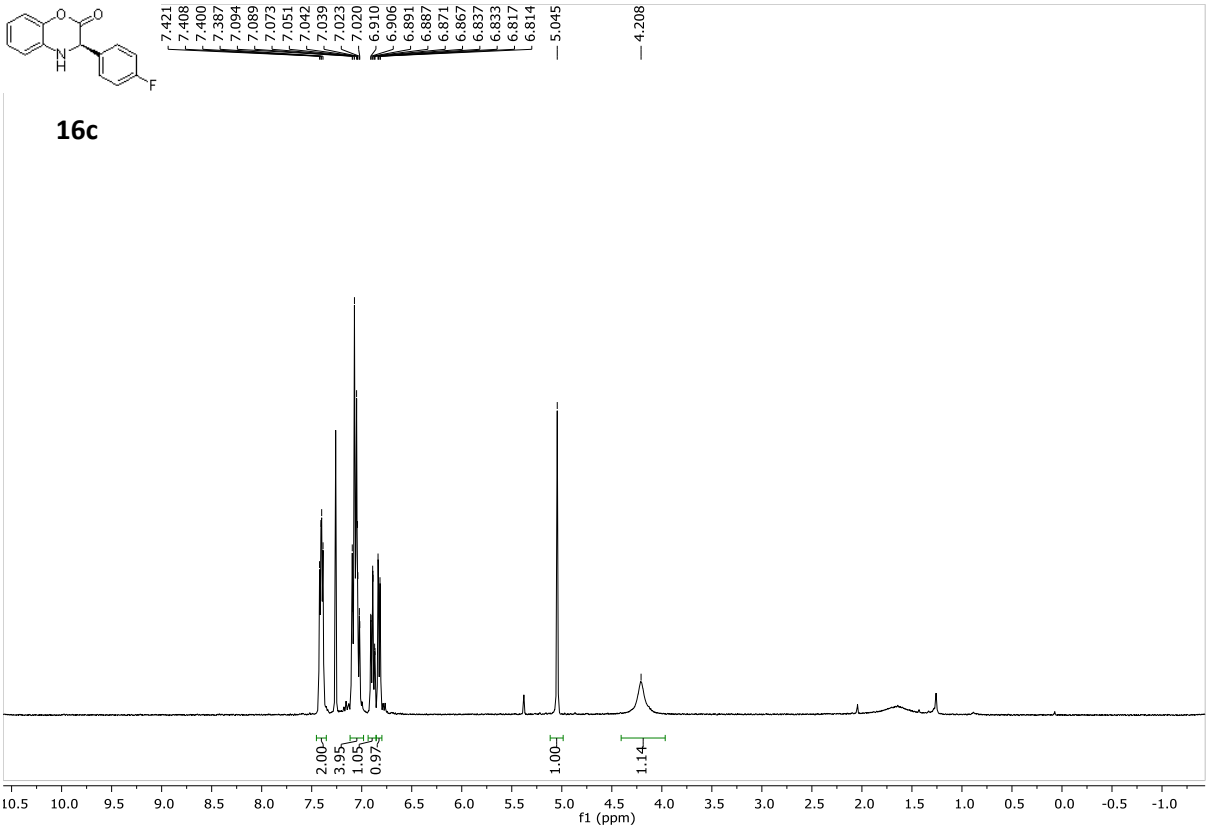

HN
Ph
MeO
158.606
147.421
137.341
129.208
127.024
117.334
114.121
113.472
55.356
52.982
25.094
8n
f1 (ppm)

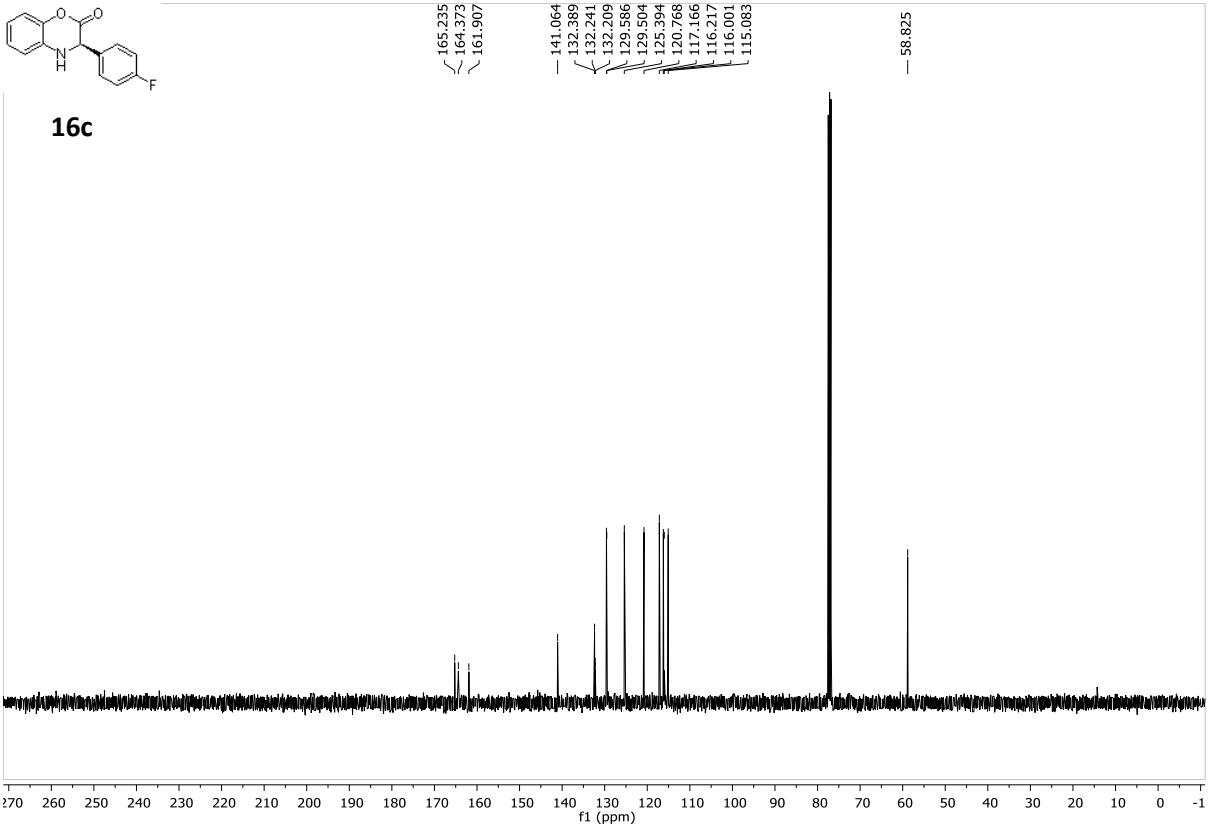

7.411
7.398
7.386
7.376
7.364
7.358
7.055
7.034
7.012
6.890
6.870
6.851
6.824
6.804
5.055
4.223
16a
4.98
2.01
1.01
1.02
1.00
0.98
f1 (ppm)

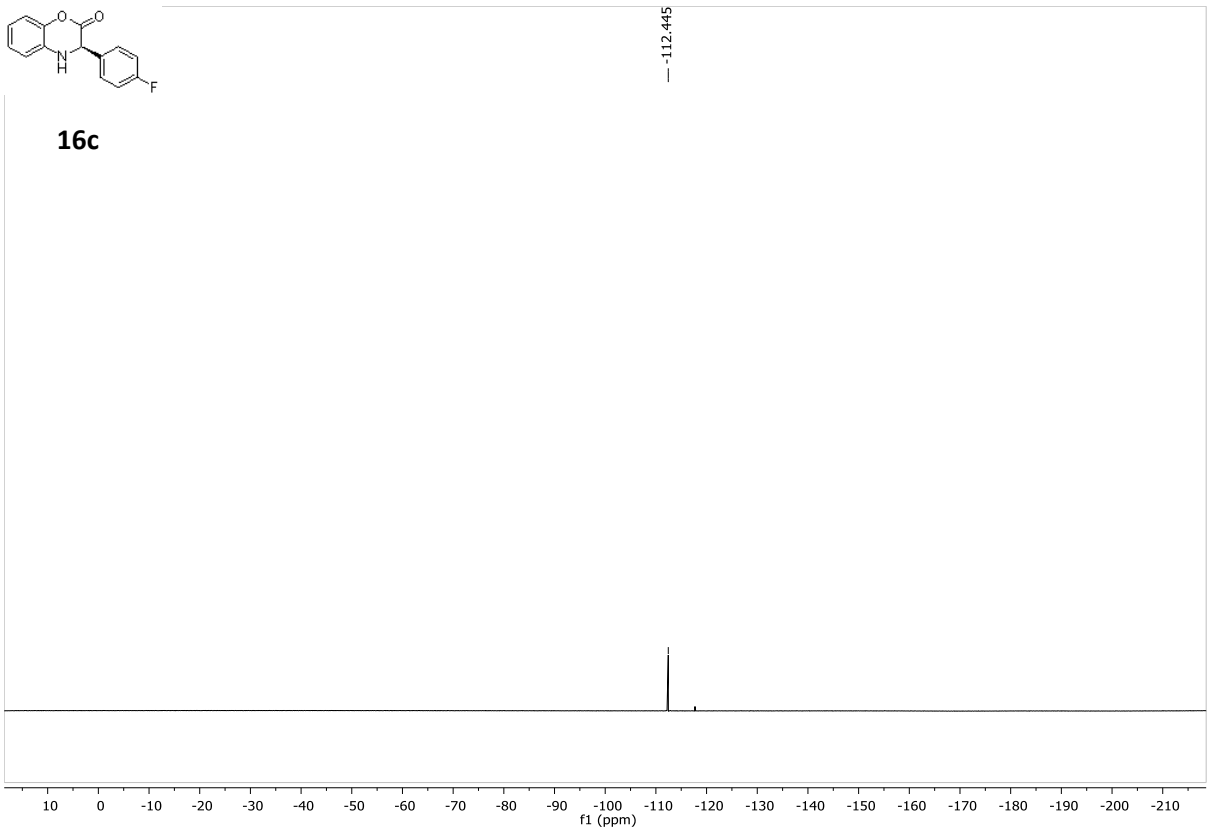

165.321
141.025
136.484
132.487
129.107
127.598
125.310
120.507
117.087
115.005
59.387
16a
f1 (ppm)

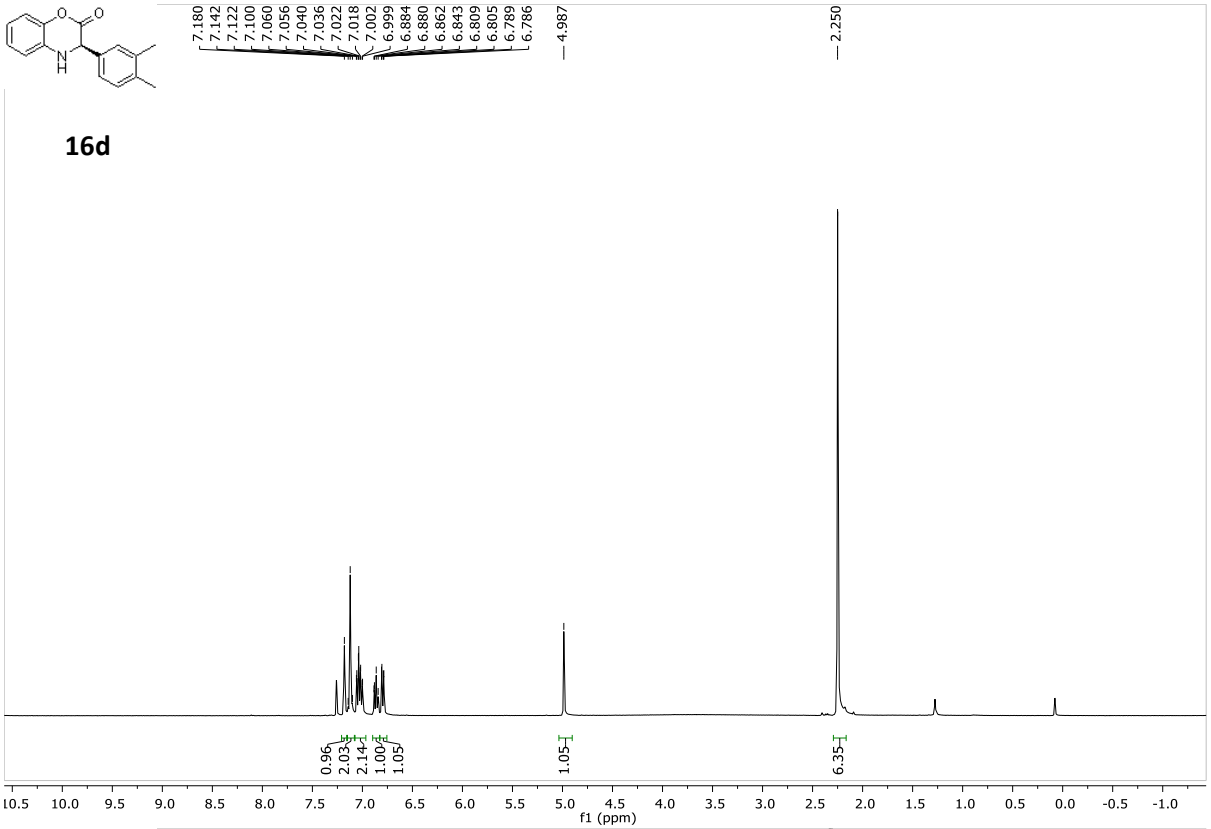

7.335
7.315
7.260
7.061
7.041
7.023
7.004
6.908
6.887
6.867
6.848
6.812
6.793
5.003
4.183
3.798
OMe
16b
1.86
1.93
2.98
1.05
1.00
0.96
3.23
f1 (ppm)

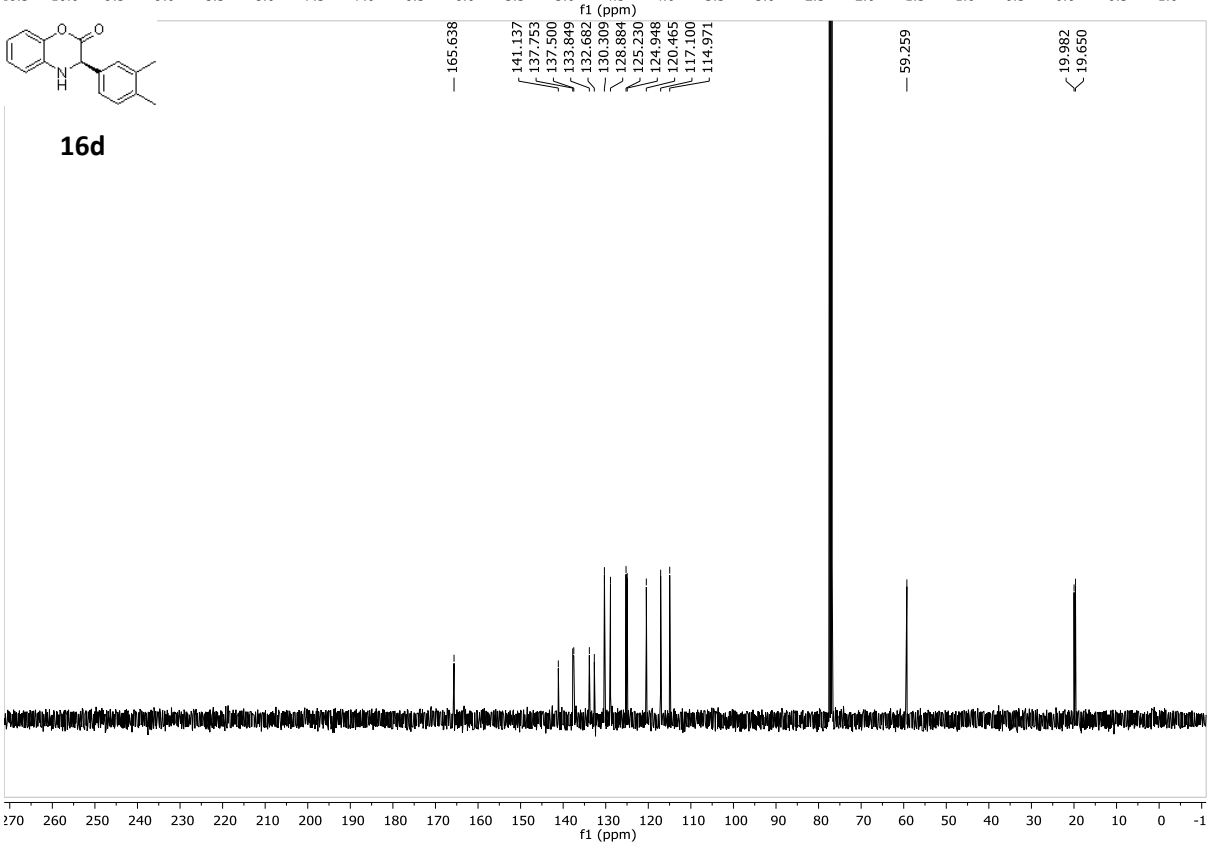

165.641
160.220
141.142
132.690
128.935
128.532
125.264
120.533
117.127
114.984
114.533
58.974
55.476
OMe
16b
f1 (ppm)

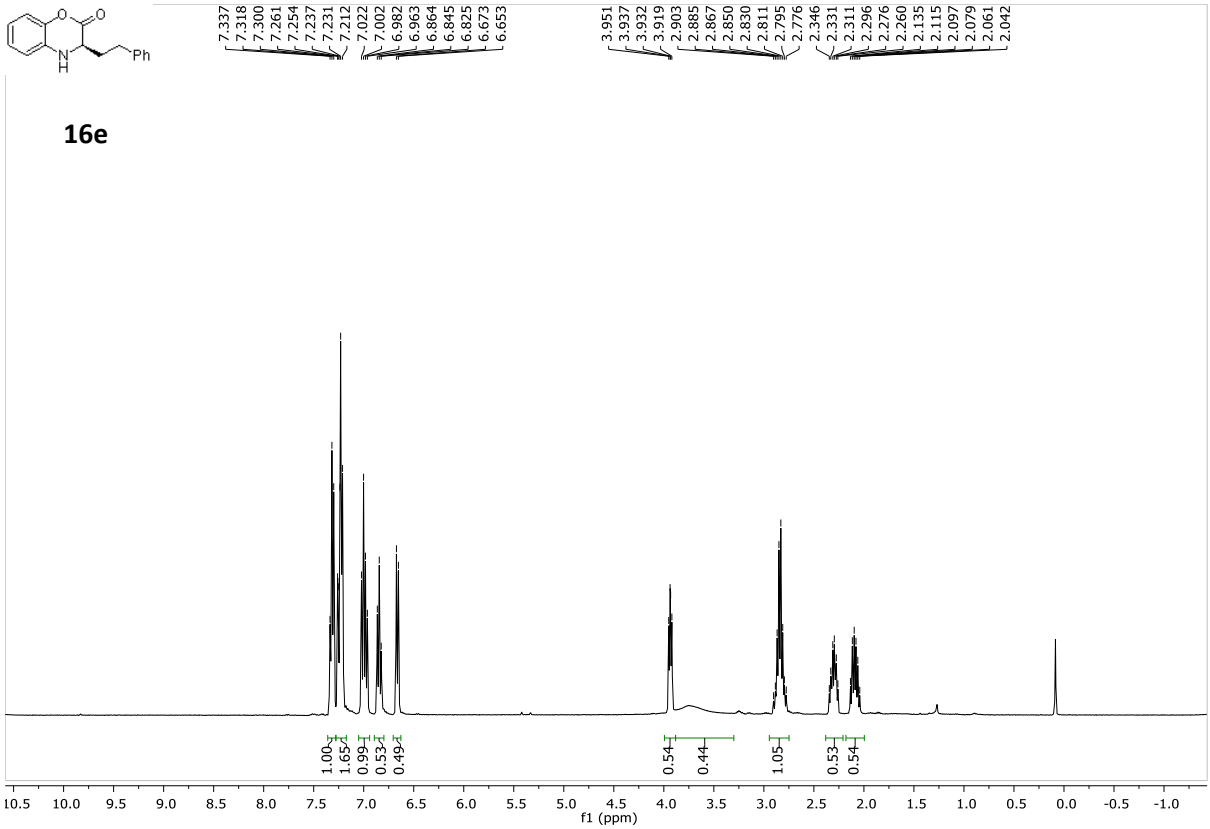

7.421
7.408
7.400
7.387
7.094
7.089
7.073
7.051
7.042
7.039
7.023
7.020
6.910
6.906
6.891
6.887
6.871
6.867
6.837
6.833
6.817
6.814
5.045
4.208
16c
2.00
3.95
1.05
0.97
1.00
1.14
f1 (ppm)

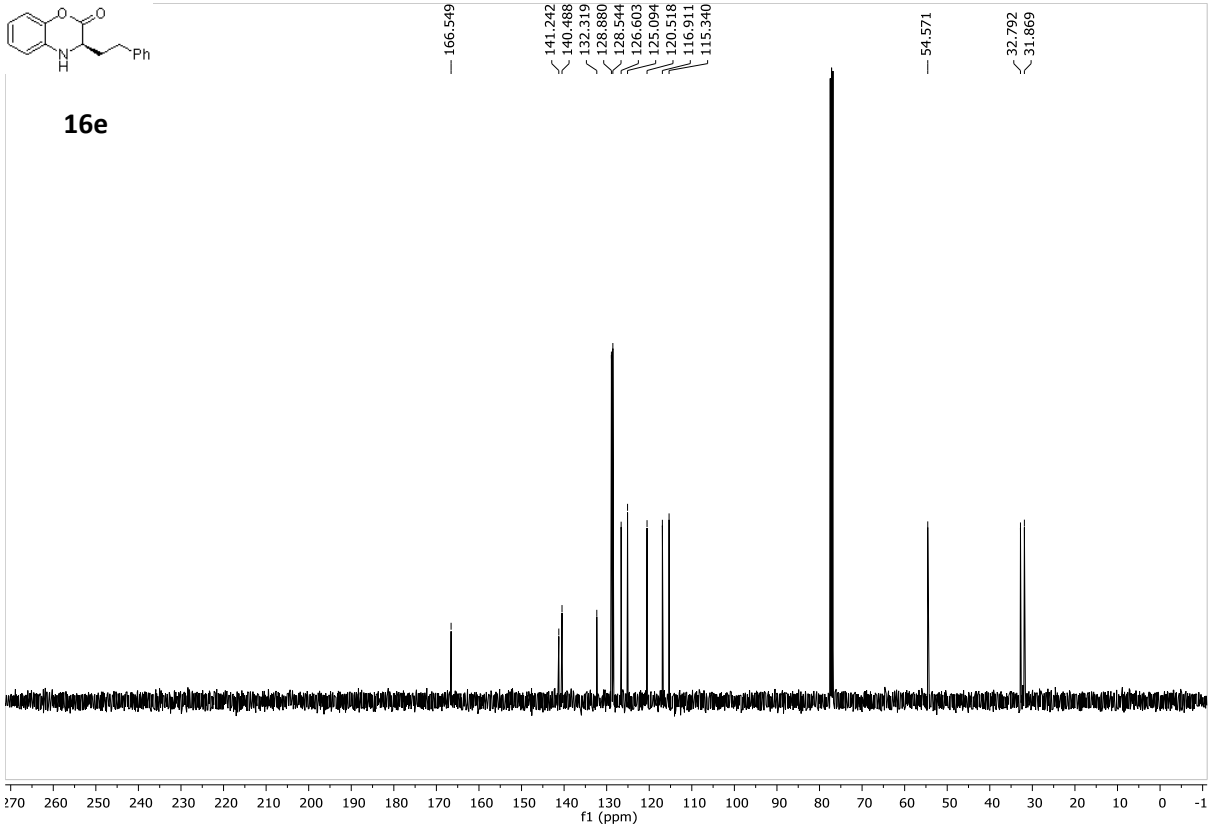

165.235
164.373
161.907
141.064
132.389
132.241
132.209
129.586
129.504
125.394
120.768
117.166
116.217
116.001
115.083
58.825
16c
f1 (ppm)

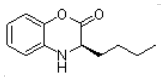

-112.445
16c
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


7.180
7.142
7.122
7.100
7.060
7.056
7.040
7.036
7.022
7.018
7.002
6.999
6.884
6.880
6.862
6.843
6.809
6.805
6.789
6.786
4.987
2.250
16d
0.96
2.03
2.14
1.00
1.05
1.05
6.35
f1 (ppm)


165.638
141.137
137.753
137.500
133.849
132.682
130.309
128.884
125.230
124.948
120.465
117.100
114.971
59.259
19.982
19.650
16d
f1 (ppm)

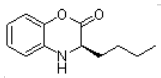

7.337
7.318
7.300
7.261
7.254
7.237
7.231
7.212
7.022
7.002
6.982
6.963
6.864
6.845
6.825
6.673
6.653
3.951
3.937
3.932
3.919
3.903
2.885
2.867
2.850
2.830
2.811
2.795
2.776
2.346
2.331
2.311
2.296
2.276
2.260
2.135
2.115
2.097
2.079
2.061
2.042
16e
1.00
1.65
0.99
0.53
0.49
0.54
0.44
1.05
0.53
0.54
f1 (ppm)


166.549
141.242
140.488
132.319
128.880
128.544
126.603
125.094
120.518
116.911
115.340
54.571
32.792
31.869
16e
f1 (ppm)



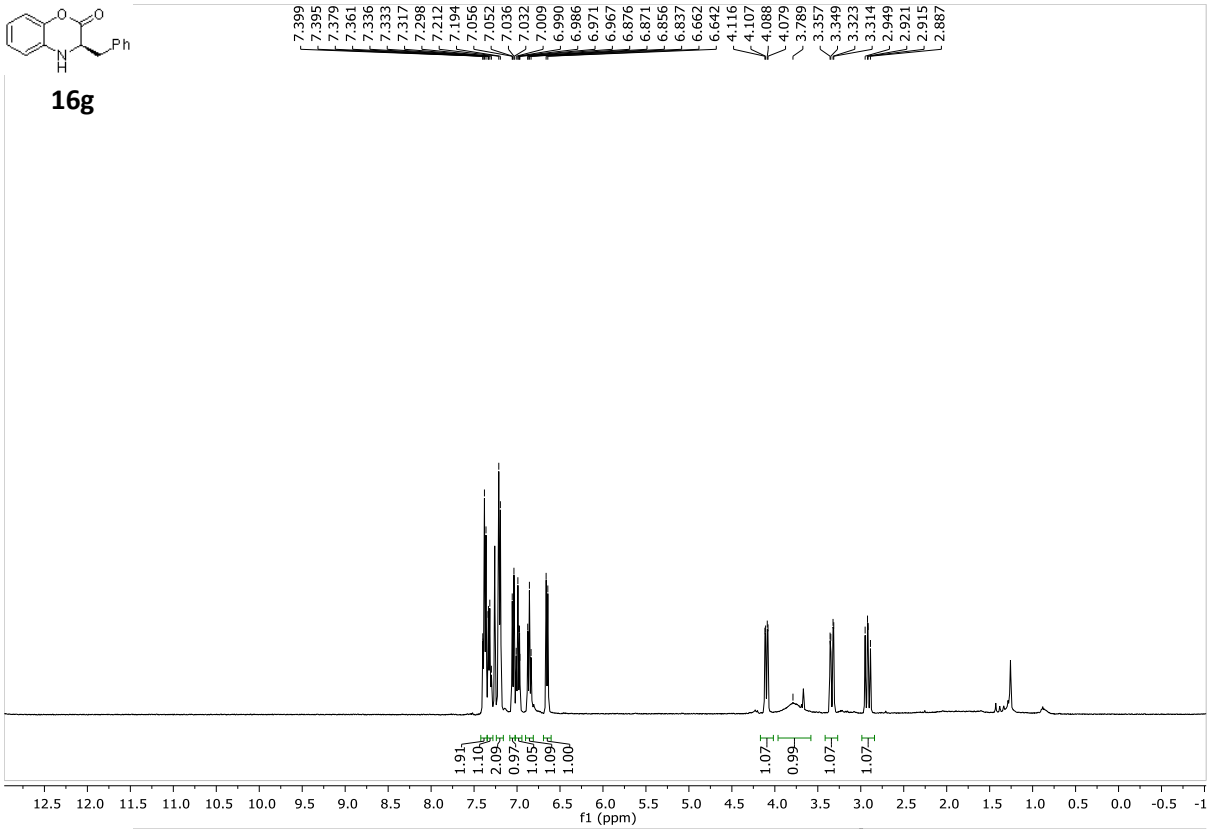
16f

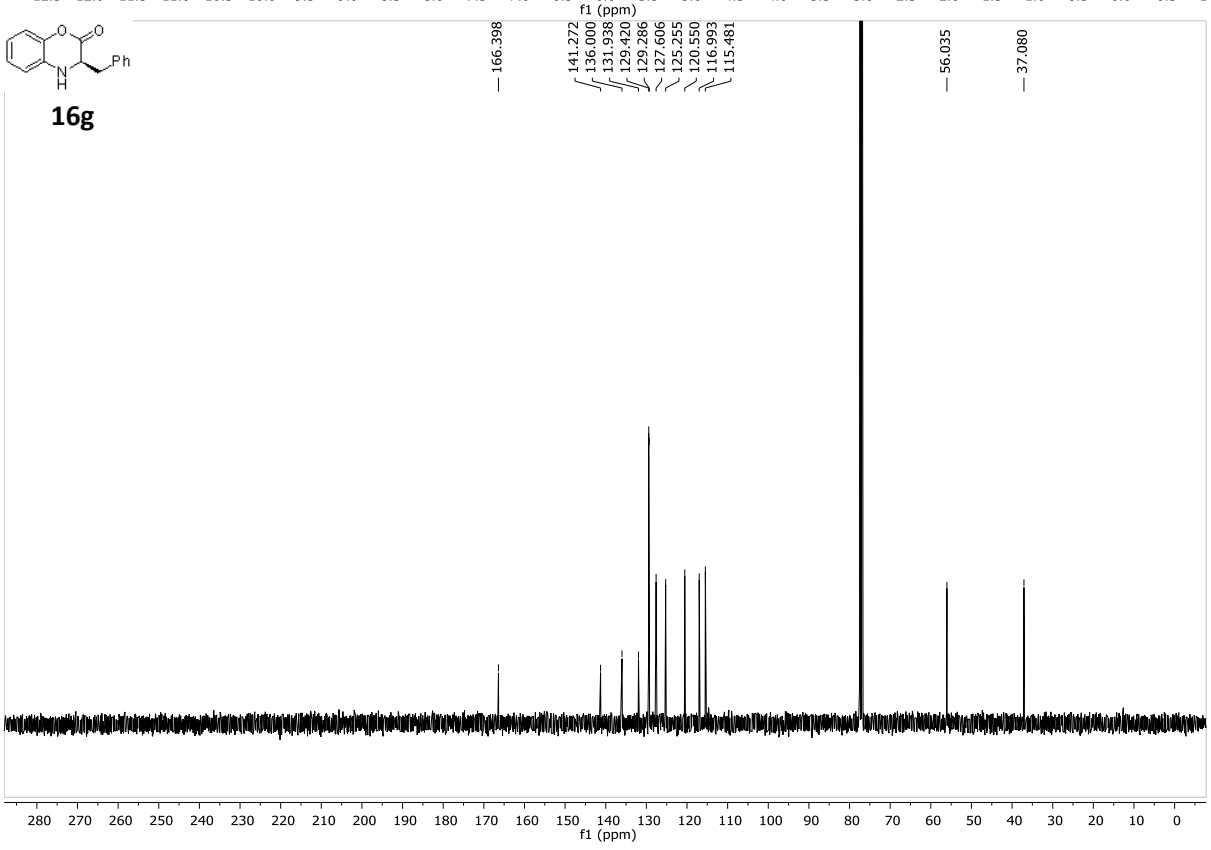
7.005
6.985
6.964
6.847
6.828
6.808
6.779
6.760
3.926
3.913
3.907
3.893
1.962
1.948
1.940
1.935
1.927
1.909
1.895
1.888
1.875
1.814
1.795
1.777
1.758
1.743
1.739
1.736
1.722
1.463
1.459
1.451
1.441
1.432
1.421
1.421
1.404
1.390
1.373
1.357
1.353
1.339
1.334
0.936
0.918
0.901
2.00
1.02
1.03
1.98
1.03
1.08
4.27
3.23
f1 (ppm)

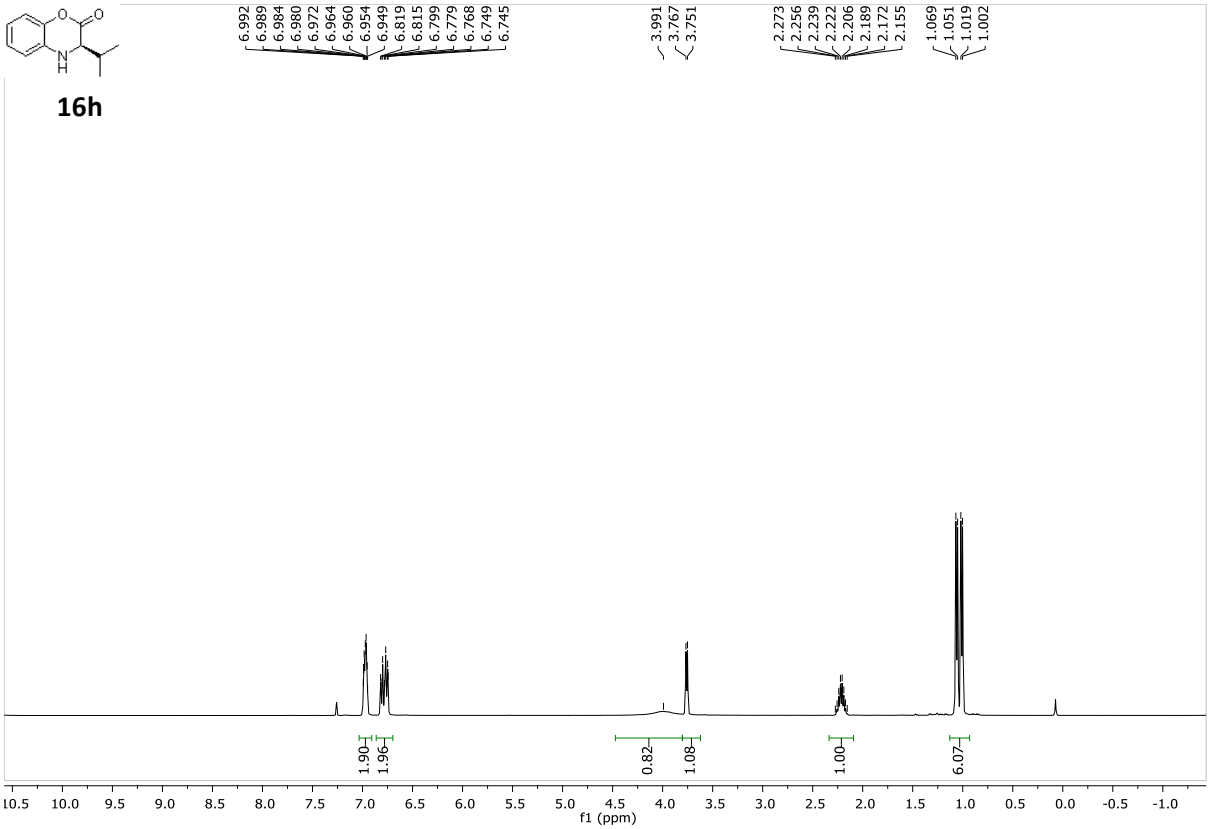


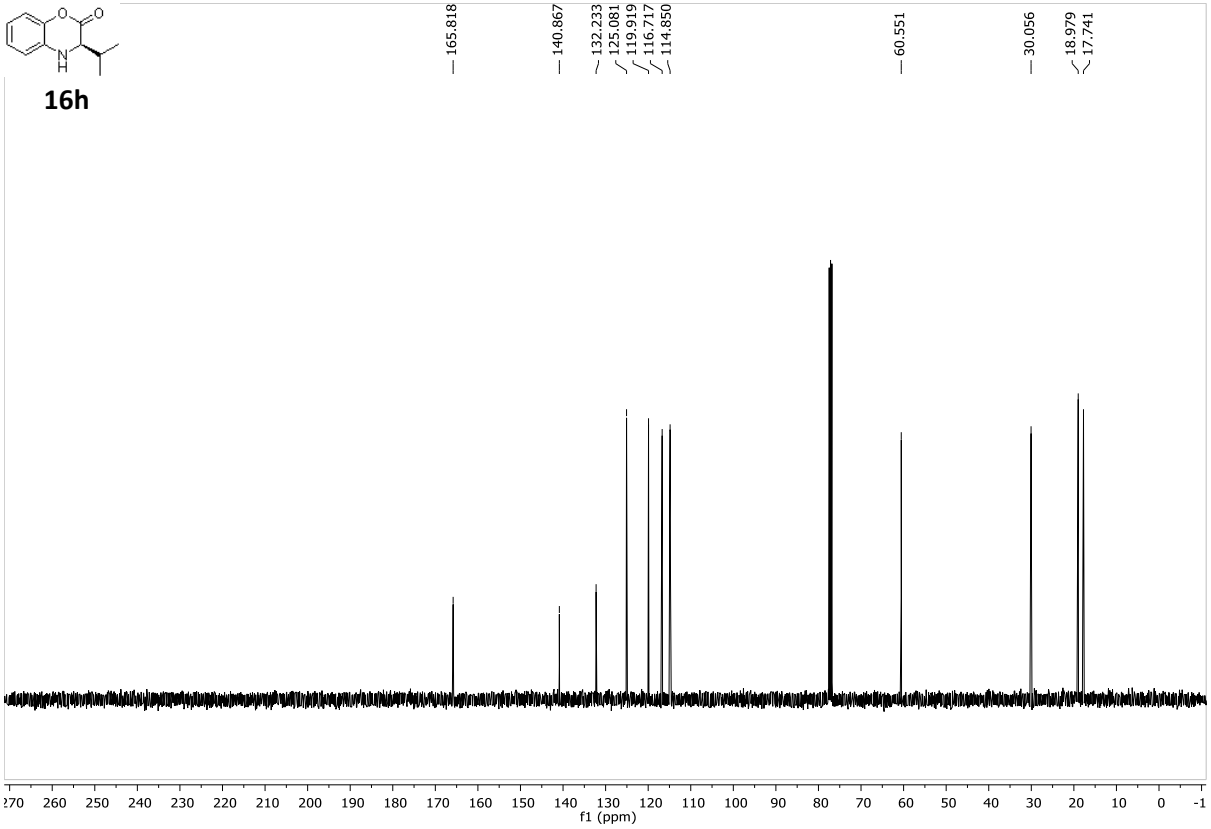
16f

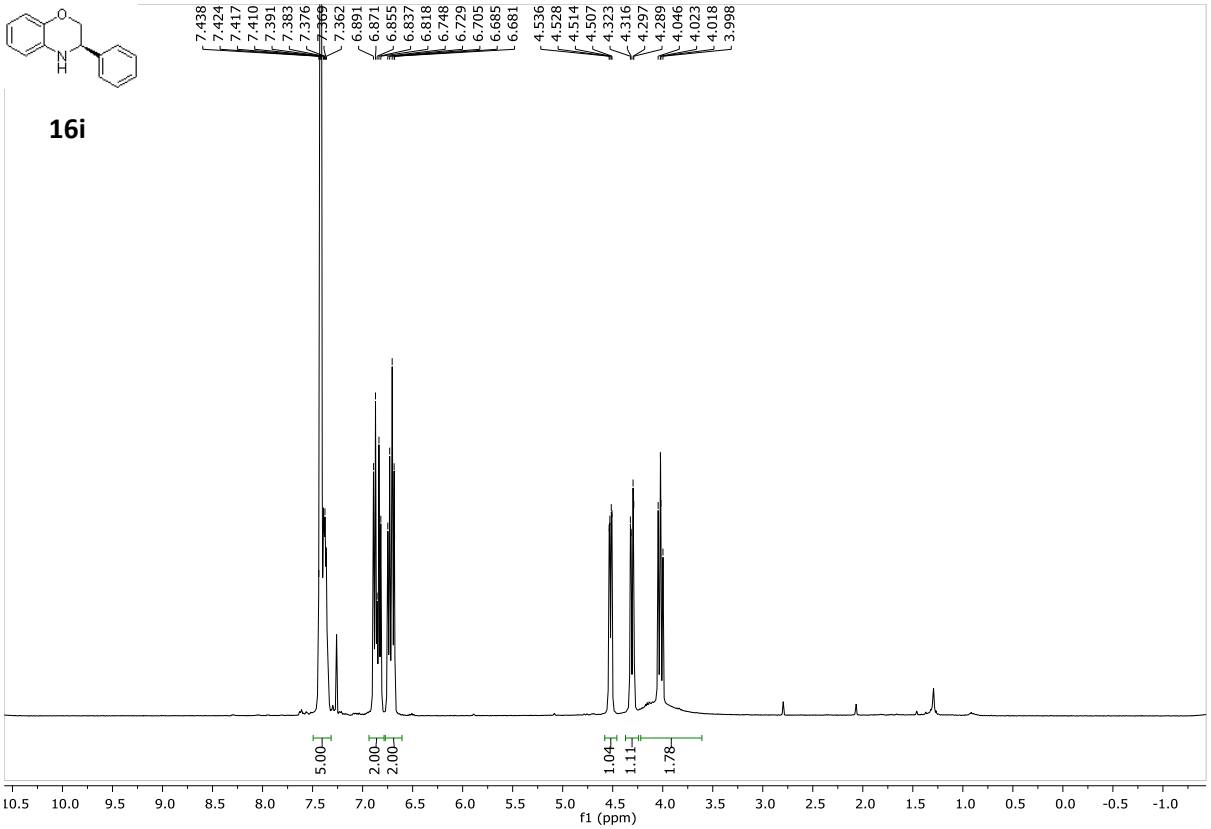
166.813
141.168
132.495
125.046
120.284
116.830
115.198
54.934
31.036
27.450
22.462
13.969
f1 (ppm)


16g
7.399
7.395
7.379
7.361
7.336
7.333
7.317
7.298
7.212
7.194
7.056
7.052
7.036
7.032
7.009
6.990
6.986
6.971
6.967
6.876
6.871
6.856
6.837
6.662
6.642
4.116
4.107
4.088
4.079
3.789
3.357
3.349
3.323
3.314
2.949
2.921
2.915
2.887
1.91
1.10
2.09
0.97
1.05
1.09
1.00
1.07
0.99
1.07
1.07
f1 (ppm)


16g
166.398
141.272
136.000
131.938
129.420
129.286
127.606
125.255
120.550
116.993
115.481
56.035
37.080
f1 (ppm)


16h
6.992
6.989
6.984
6.980
6.972
6.964
6.960
6.954
6.949
6.819
6.815
6.799
6.779
6.768
6.749
6.745
3.991
3.767
3.751
2.273
2.256
2.239
2.222
2.206
2.189
2.172
2.155
1.069
1.051
1.019
1.002
1.90
1.96
0.82
1.08
1.00
6.07
f1 (ppm)


16h
165.818
140.867
132.233
125.081
119.919
116.717
114.850
60.551
30.056
18.979
17.741
f1 (ppm)


16i
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7.424
7.417
7.410
7.391
7.383
7.376
7.369
7.362
6.891
6.871
6.855
6.837
6.818
6.748
6.729
6.705
6.685
6.681
4.536
4.528
4.514
4.507
4.323
4.316
4.297
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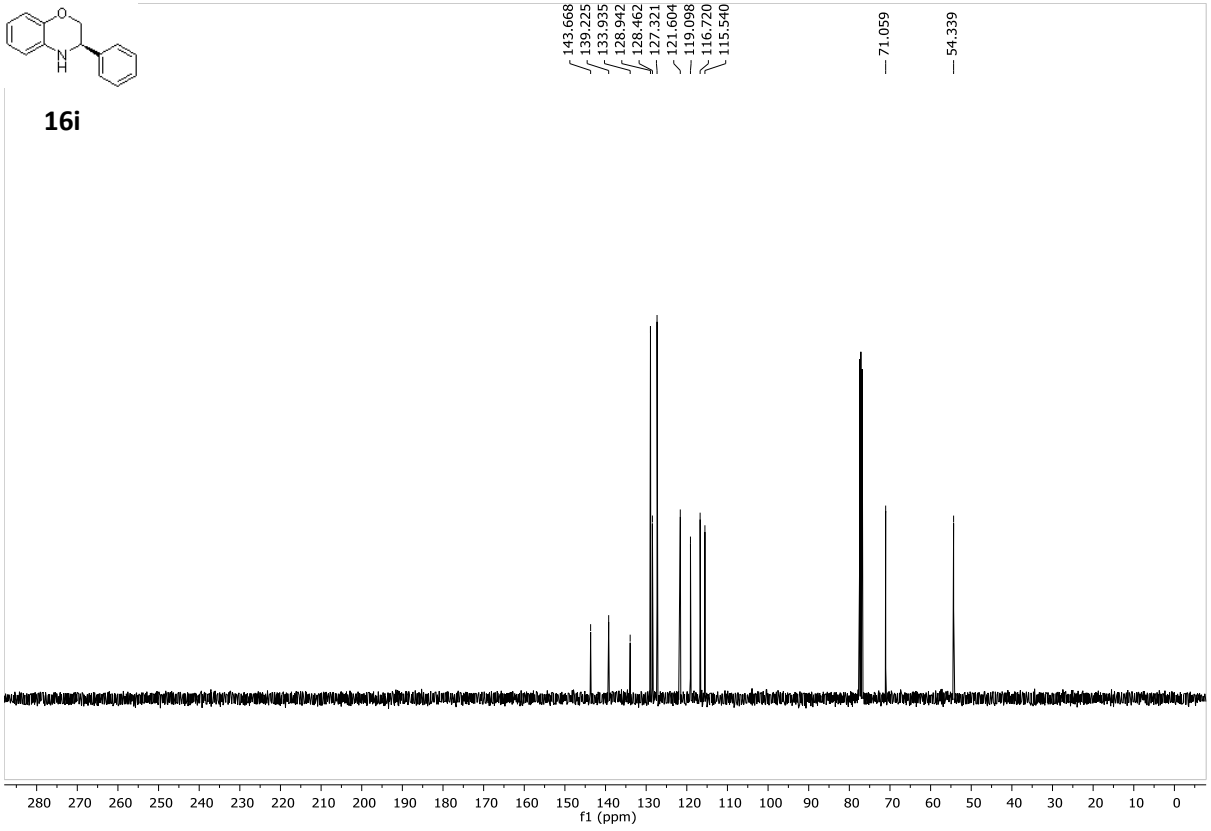
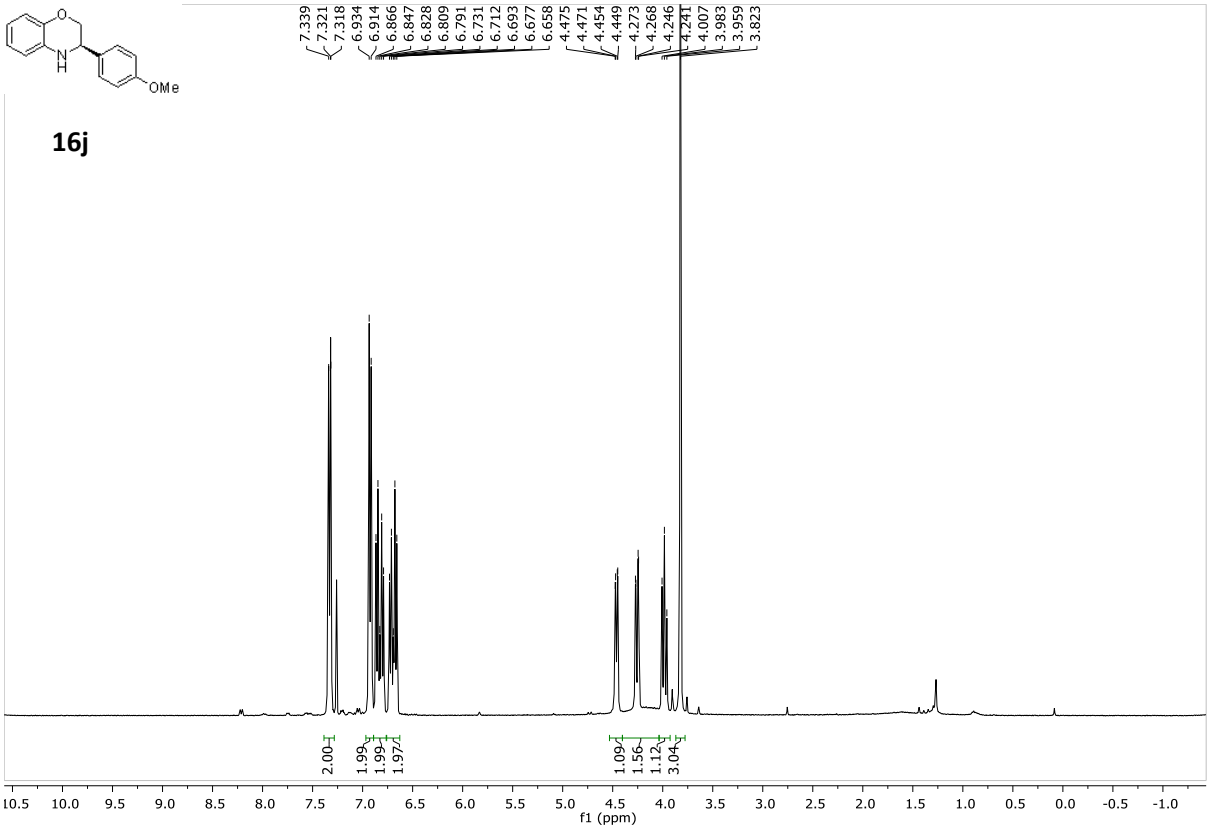
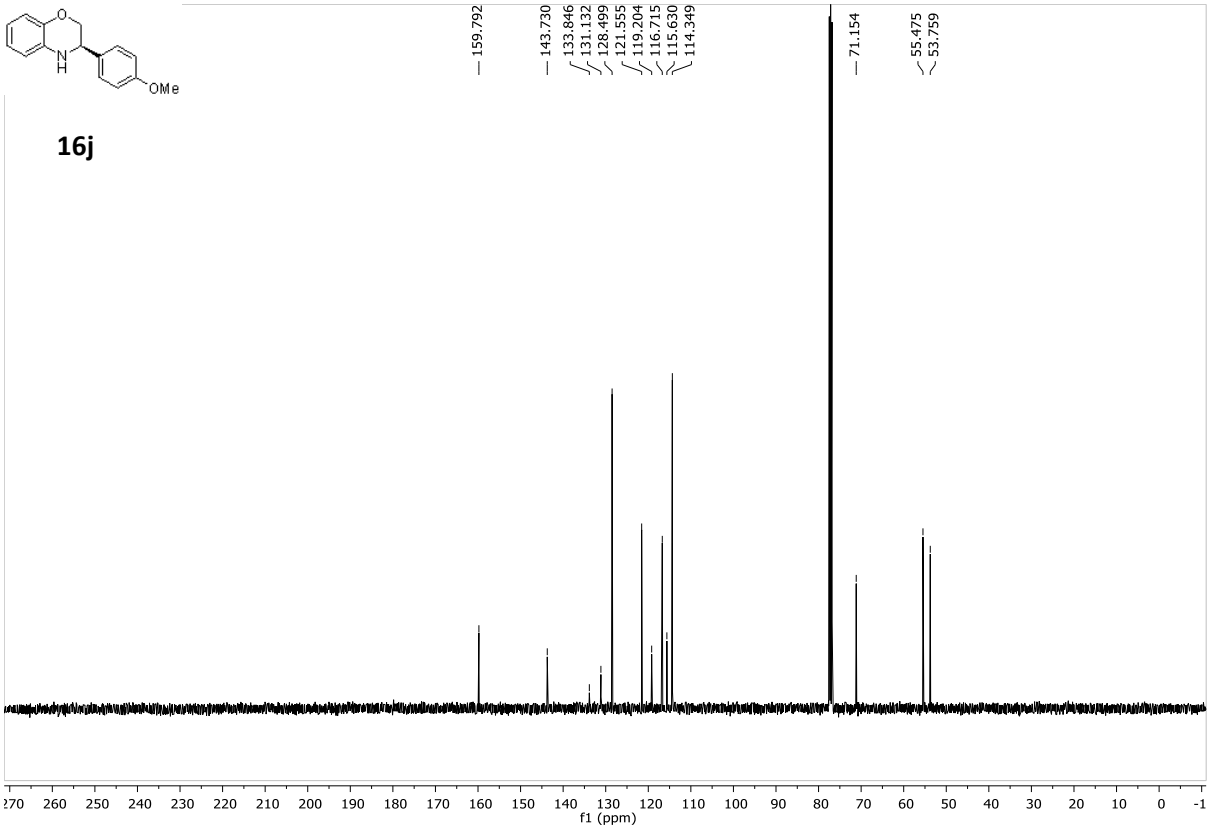
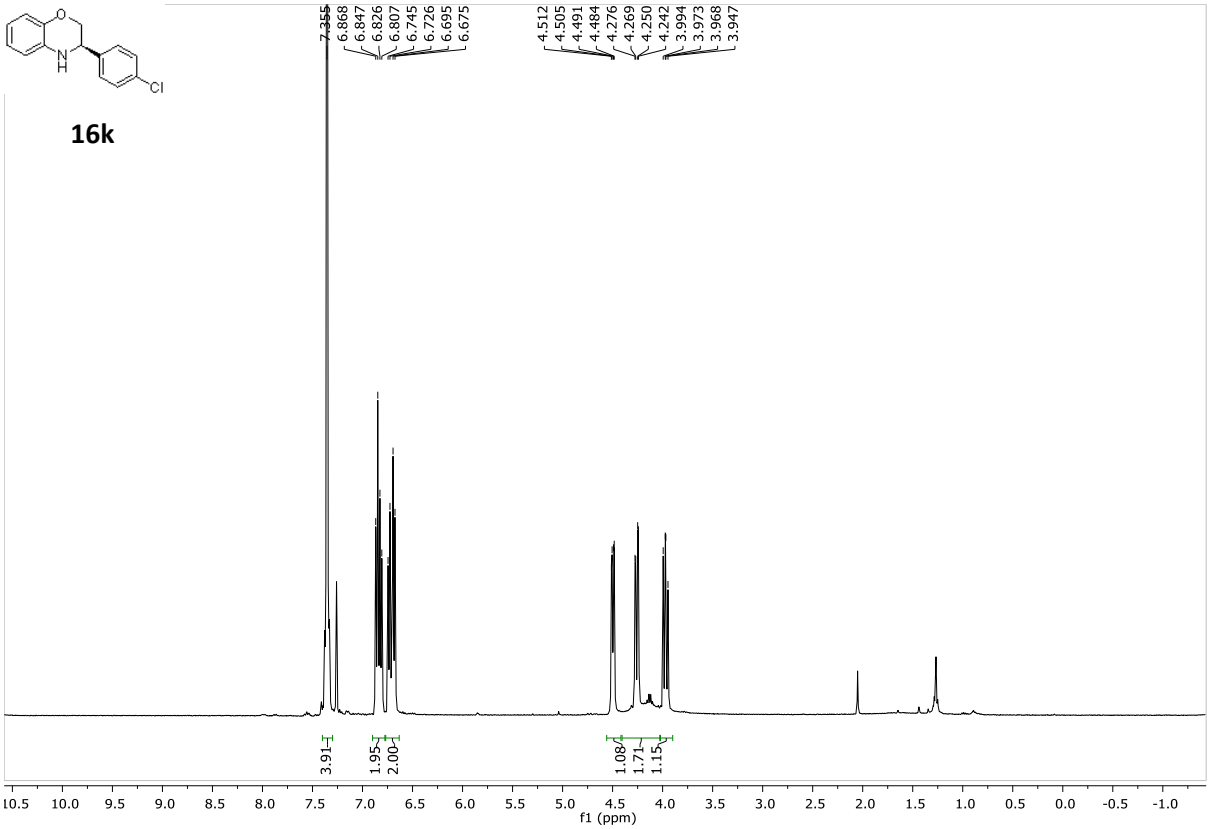
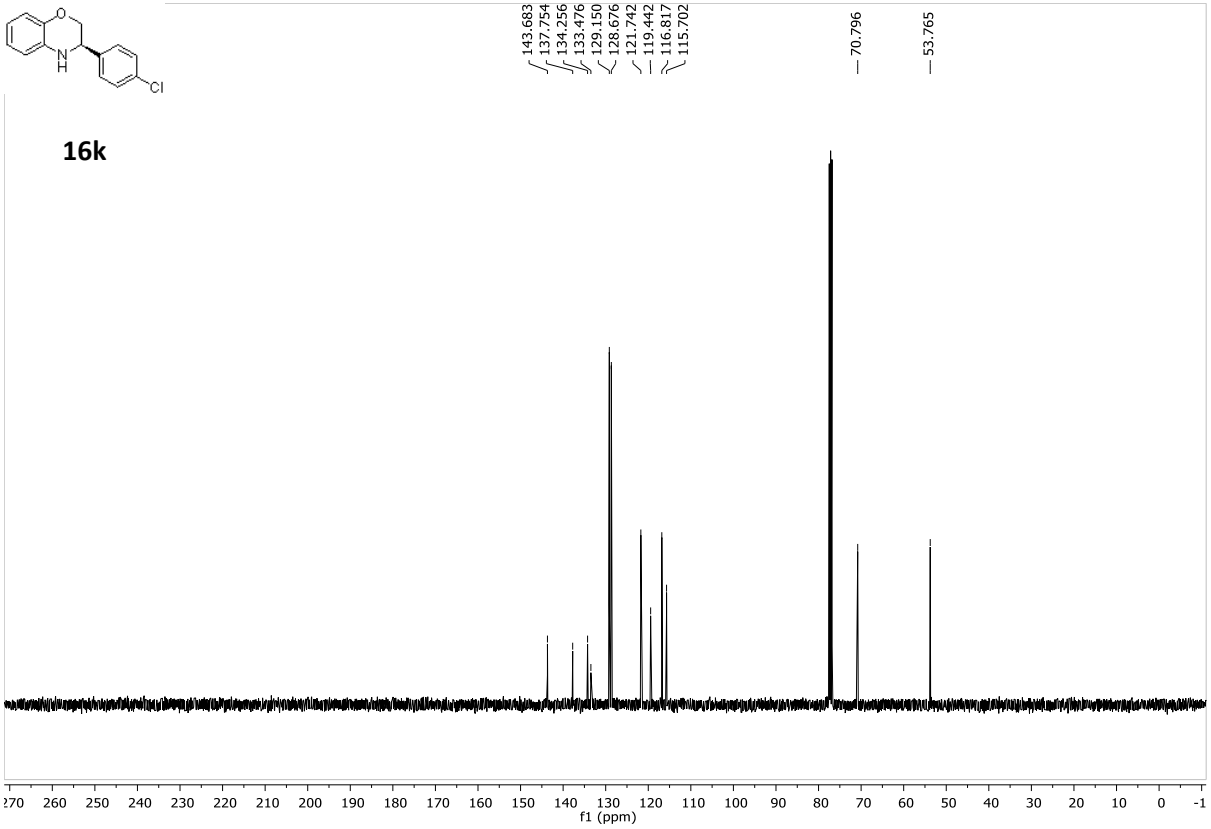
4.046
4.023
4.018
3.998
5.00
2.00
2.00
1.04
1.11
1.78
f1 (ppm)

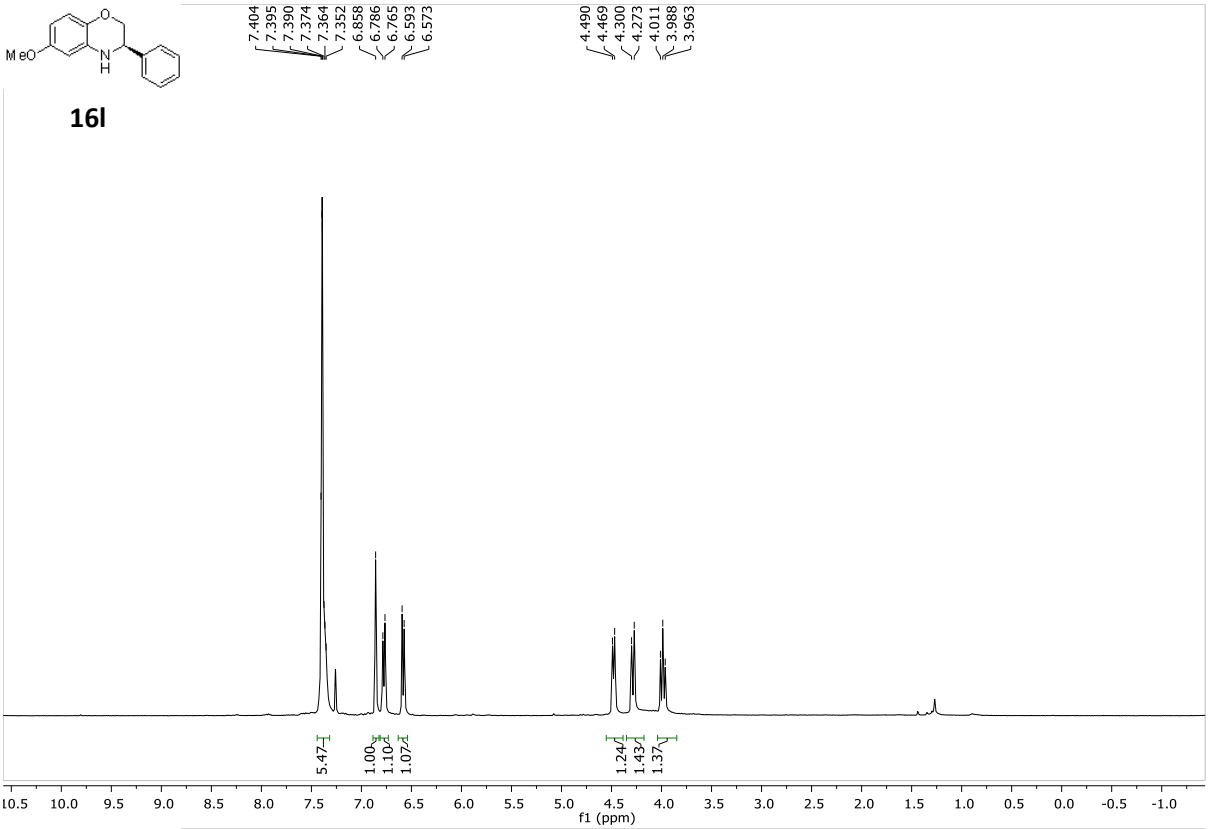

16i
143.668
139.225
133.935
128.942
128.462
127.321
121.604
119.098
116.720
115.540
71.059
54.339
f1 (ppm)


OMe
16j
7.339
7.321
7.318
6.934
6.914
6.866
6.847
6.828
6.809
6.791
6.731
6.712
6.693
6.677
6.658
4.475
4.471
4.454
4.449
4.273
4.268
4.246
4.241
4.007
3.983
3.959
3.823
2.00
1.99
1.99
1.97
1.09
1.56
1.12
3.04
f1 (ppm)

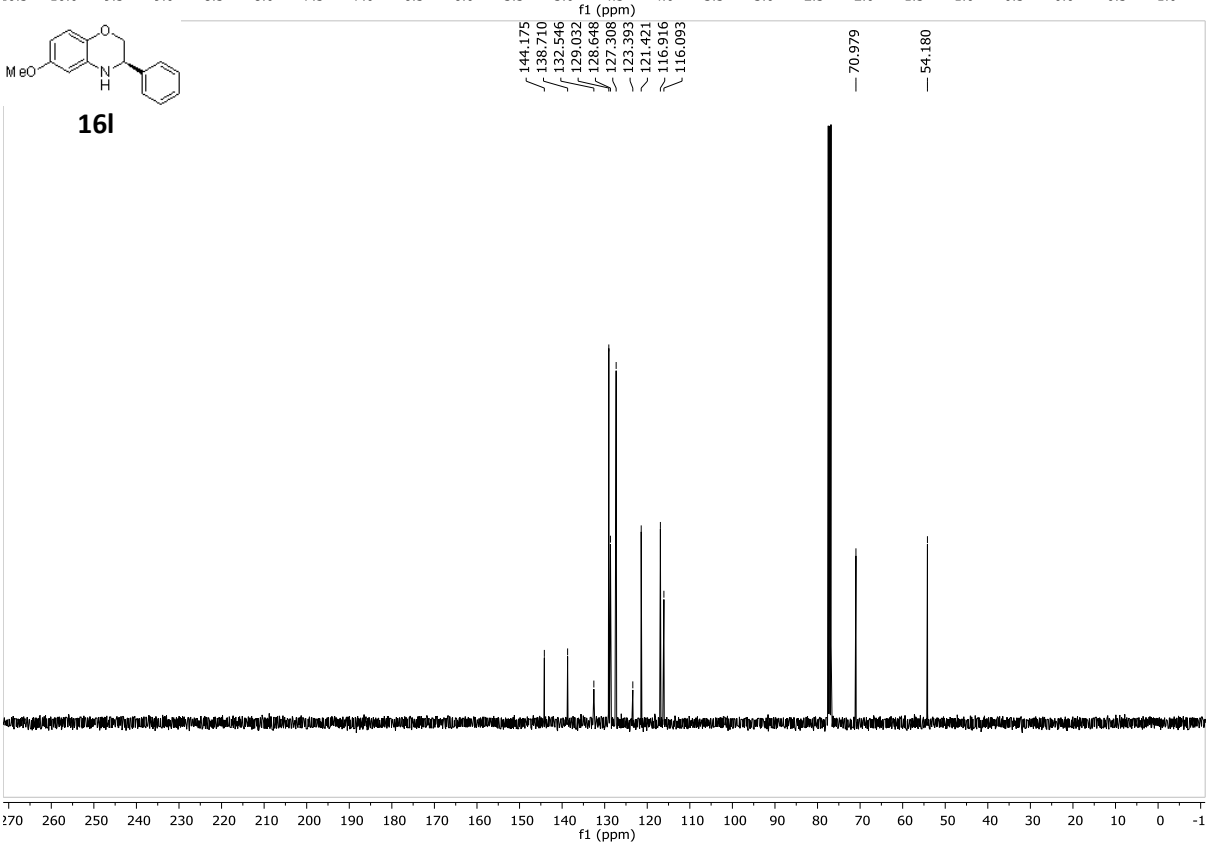

OMe
16j
159.792
143.730
133.846
131.132
128.499
121.555
119.204
116.715
115.630
114.349
71.154
55.475
53.759
f1 (ppm)


16k
7.355
6.868
6.847
6.826
6.807
6.745
6.726
6.695
6.675
4.512
4.505
4.491
4.484
4.276
4.269
4.250
4.242
3.994
3.973
3.968
3.947
3.91
1.95
2.00
1.08
1.71
1.15
f1 (ppm)


16k
143.683
137.754
134.256
133.476
129.150
128.676
121.742
119.442
116.817
115.702
70.796
53.765
f1 (ppm)


MeO
O
N
H
7.404
7.395
7.390
7.374
7.364
7.352
6.858
6.786
6.765
6.593
6.573
4.490
4.469
4.300
4.273
4.011
3.988
3.963
5.47
1.00
1.10
1.07
1.24
1.43
1.37
f1 (ppm)

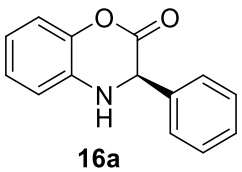
16l


MeO
O
N
H
144.175
138.710
132.546
129.032
128.648
127.308
123.393
121.421
116.916
116.093
70.979
54.180
f1 (ppm)

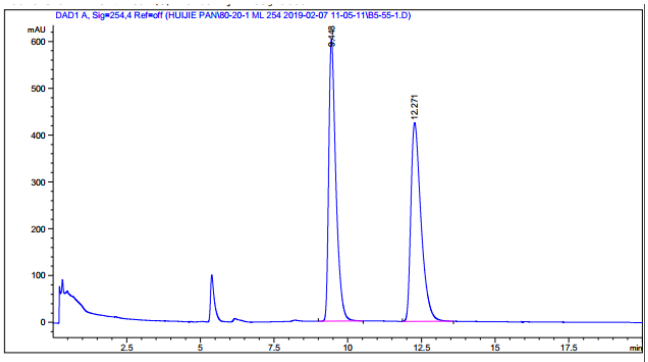
16l

6. HPLC traces

Ee of product **16** was determined by HPLC using chiral column OD-H. Eluents of iPrOH/hexane (30/70 or 10/90) was used. Racemic samples were prepared via hydrogenation using Pd/C catalyst.

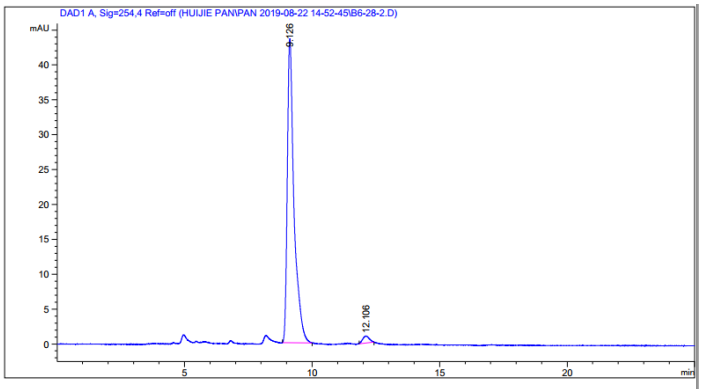


16a



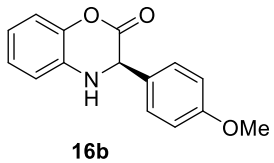

```
================================================================================
                              Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   9.448 BB    0.2494 1.01614e4   602.13177  49.9609
   2  12.271 BB    0.3460 1.01773e4   424.06400  50.0391

Totals :                  2.03388e4  1026.19577
```

Figure S2 HPLC report of racemic **16a**

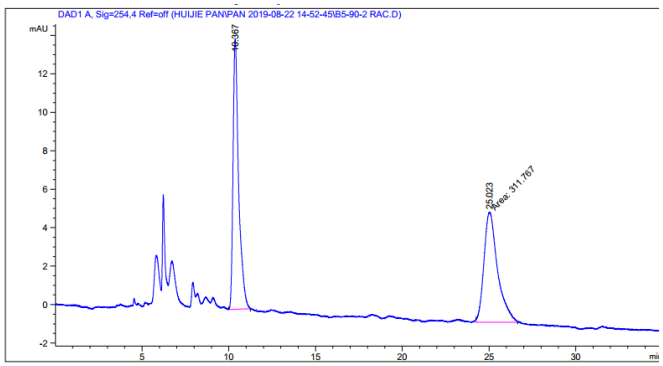



```
================================================================================
                              Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   9.126 BB    0.2462  798.46417   43.58370  97.8073
   2  12.106 BB    0.2084   17.90042    1.01181   2.1927
```

Figure S3 HPLC report of enantioenriched **16a**

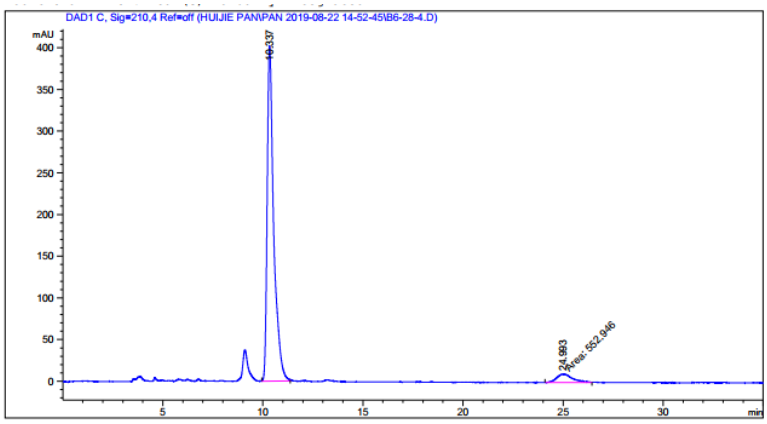


16b



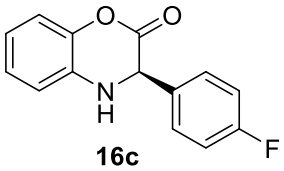

```
================================================================================
                              Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  10.367 BB    0.2652  315.06192   14.07457  50.2628
   2  25.023 MM    0.9060  311.76721    5.73494  49.7372
```

Figure S4 HPLC report of racemic **16b**



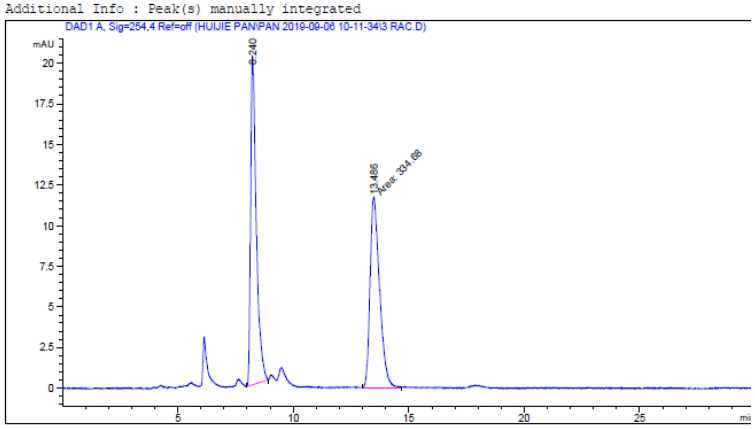

```
================================================================================
                              Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 C, Sig=210,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  10.337 VV    0.2790 9112.08203  401.99298  94.2789
   2  24.993 MM    0.9087  552.94592   10.14203   5.7211
```

Figure S5 HPLC report of enantioenriched **16b**



16c

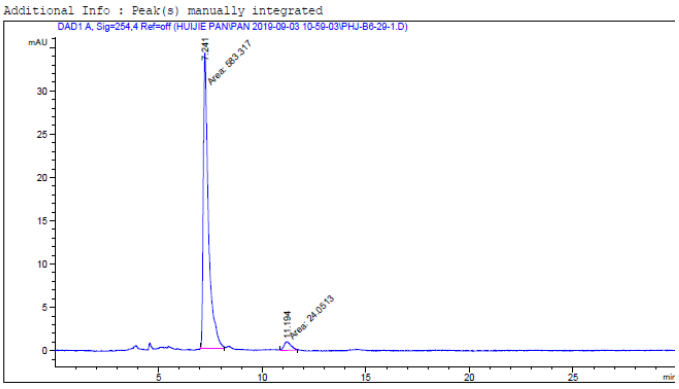
Additional Info : Peak(s) manually integrated




```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   8.240 BB    0.2220  345.72812   20.26914  50.8118
   2  13.486 MM    0.4764  334.68045   11.70756  49.1882
```

Figure S6 HPLC report of racemic **16c**

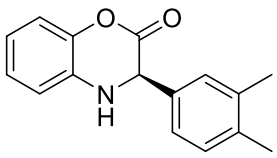
Additional Info : Peak(s) manually integrated



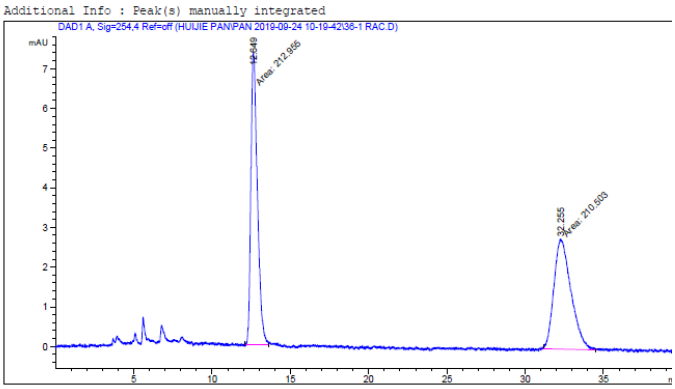

```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   7.241 MM    0.2843  583.31665   34.19418  96.0401
   2  11.194 MM    0.3913   24.05129    1.02443   3.9599
```

Figure S7 HPLC report of chiral **16c**

*HPLC report of enantioenriched **16c***

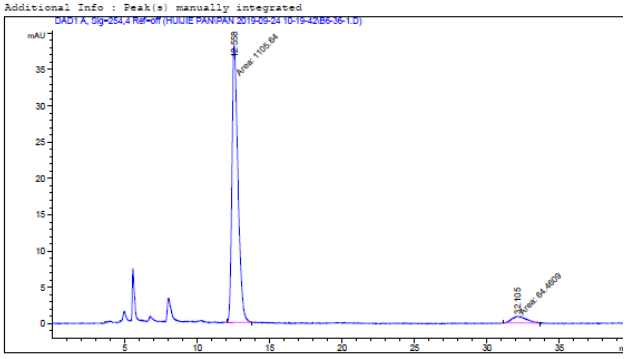


16d



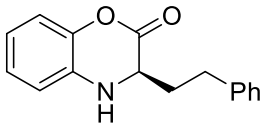

```
================================================================================
                              Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.649 MM    0.4809  212.95543    7.38025  50.2896
   2  32.255 MM    1.2575  210.50282    2.78990  49.7104
```

Figure S8 HPLC report of racemic **16d**

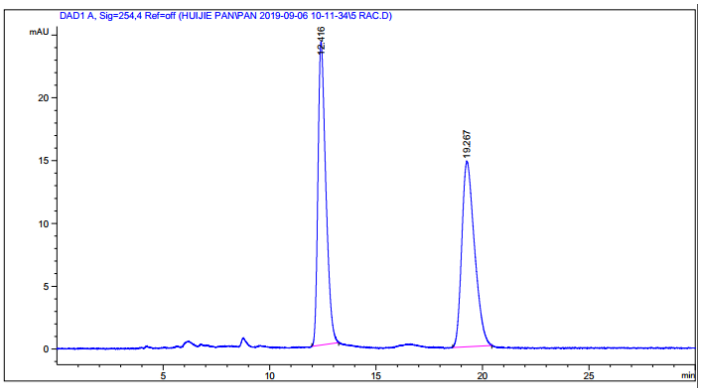



```
================================================================================
                              Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.558 MM    0.4821 1105.64209   38.22450  94.4910
   2  32.105 MM    1.1639   64.46085 9.23052e-1   5.5090
```

Figure S9 HPLC report of enantioenriched **16d**

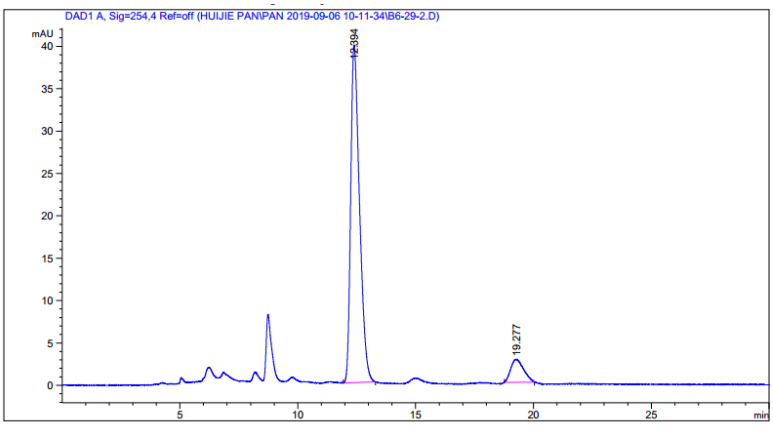


16e



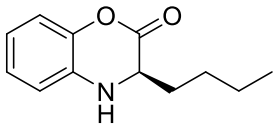

```
================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]    [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.416 BB    0.3010  619.15851   24.16058  50.1989
   2  19.267 BB    0.4870  614.25244   14.76048  49.8011
```

Figure S10 HPLC report of racemic **16e**

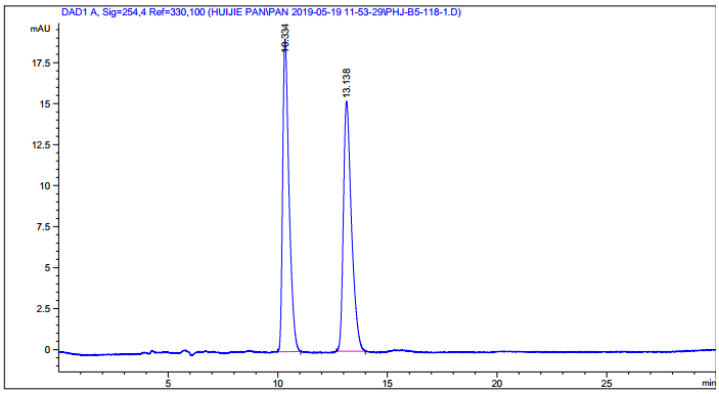



```
================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]    [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.394 BB    0.3058 1034.21118   39.84653  91.0446
   2  19.277 BB    0.4415  101.72789    2.71291   8.9554
```

Figure S11 HPLC report of enantioenriched **16e**

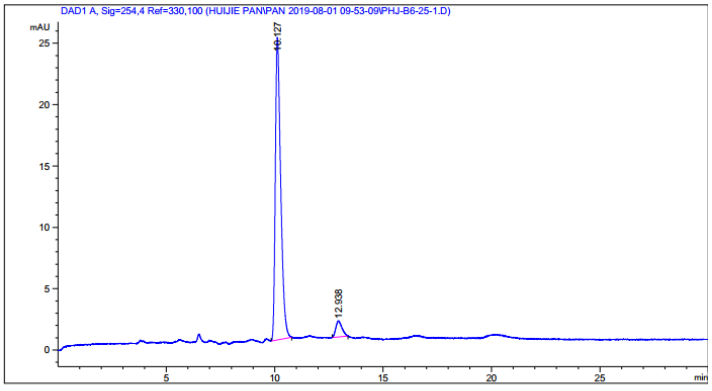


16f



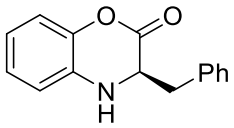

```
================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=330,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  10.334 BB    0.2363  383.97266   19.08164  49.5781
   2  13.138 BB    0.3009  390.50702   15.24051  50.4219
```

Figure S12 HPLC report of racemic **16f**

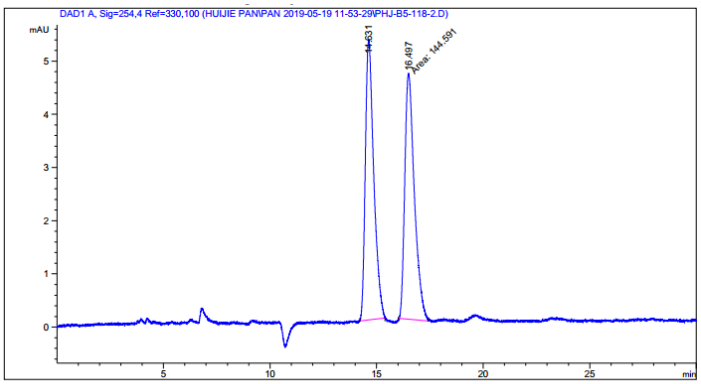



```
================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=330,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  10.127 BB    0.2184  423.49857   24.65500  94.1730
   2  12.938 BB    0.2333   26.20432    1.31865   5.8270
```

Figure S13 HPLC report of racemic **16f**

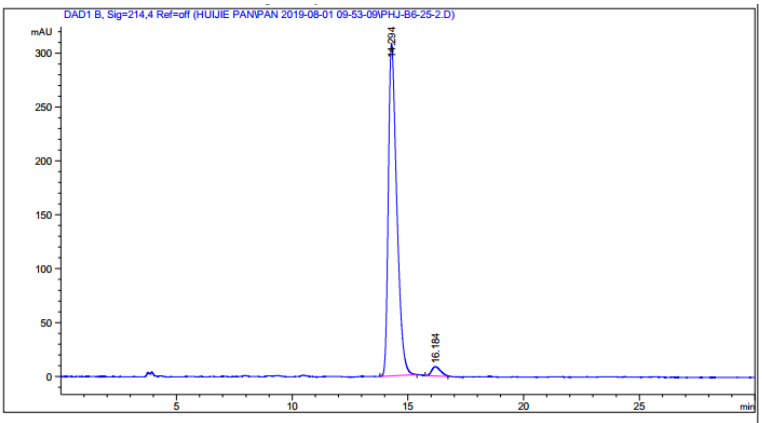


16g



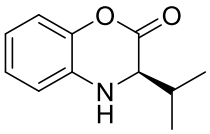

```
================================================================
                    Area Percent Report
================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=330,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  14.631 BB    0.3228  144.36594    5.25920  49.9611
   2  16.497 MM    0.5209  144.59065    4.62665  50.0389
```

Figure S14 HPLC report of racemic **16g**

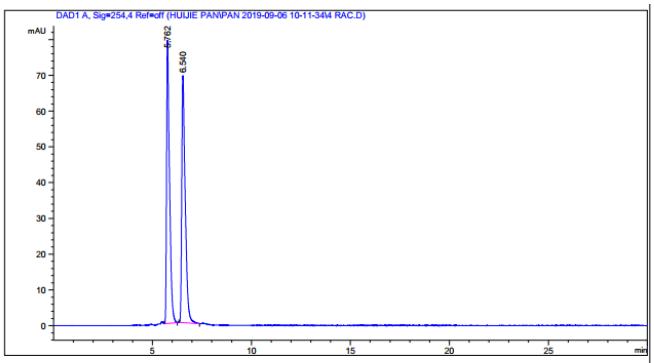



```
================================================================
                    Area Percent Report
================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 B, Sig=214,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  14.294 BB    0.3547 7799.38379  308.73080  97.0632
   2  16.184 BV    0.3156  235.98488    8.79266   2.9368
```

Figure S15 HPLC report of enantioenriched **16f**

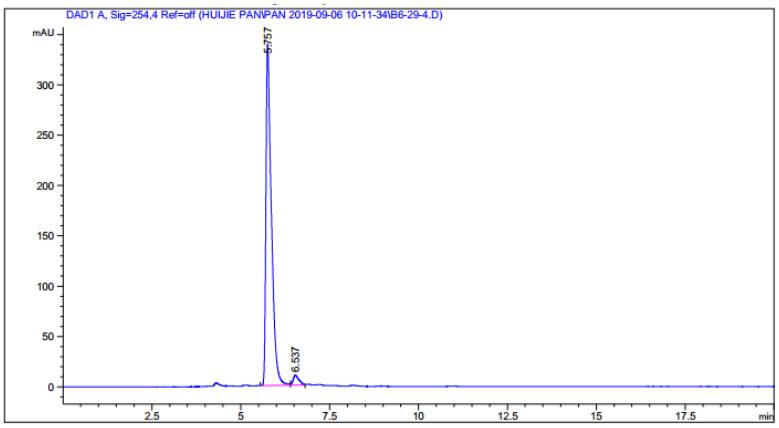


16h



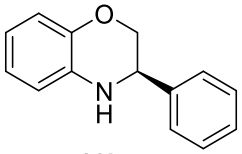

```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   5.762 BB    0.1468  820.36578   79.23567  49.4927
   2   6.540 BB    0.1719  837.18274   69.05141  50.5073
```

Figure S16 HPLC report of racemic **16h**

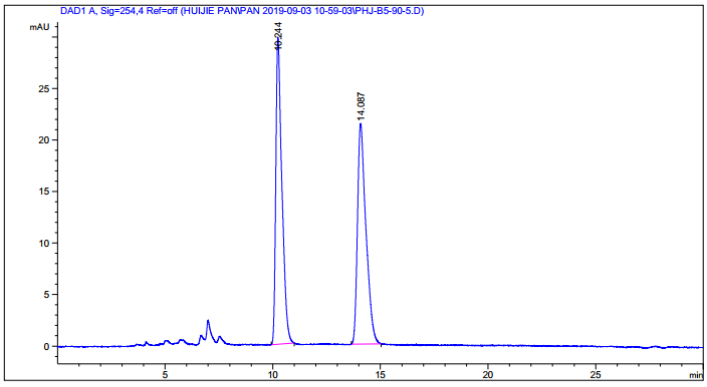



```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   5.757 BV    0.1502 3613.69141  339.43896  96.9033
   2   6.537 VV    0.1527  115.48173    9.96519   3.0967
```

Figure S17 HPLC report of enantioenriched **16h**

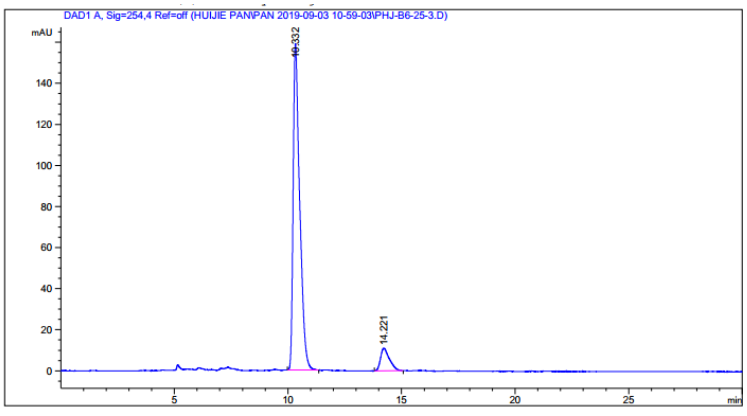


16i



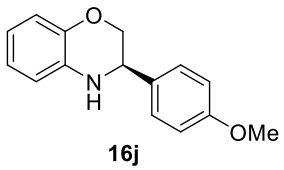

```
=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  10.244 BB    0.2608  585.28052   29.77947  50.0409
   2  14.087 BB    0.3214  584.32446   21.41022  49.9591
```

Figure S18 HPLC report of racemic **16i**

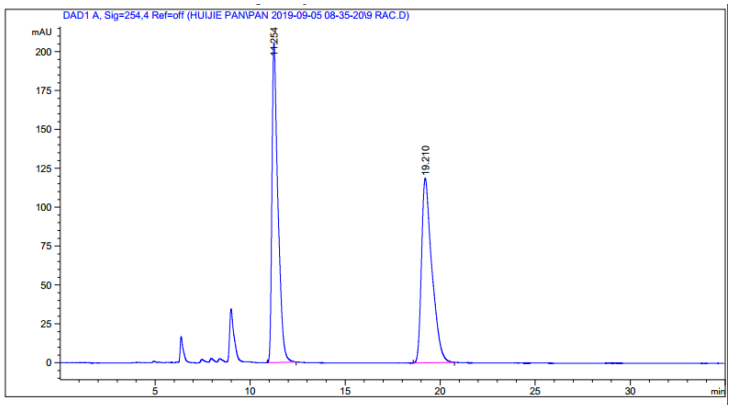



```
=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  10.332 BB    0.2839 3180.06323  158.99118  91.3875
   2  14.221 BB    0.3192  299.69513   11.07387   8.6125
```

Figure S19 HPLC report of enantioenriched **16i**

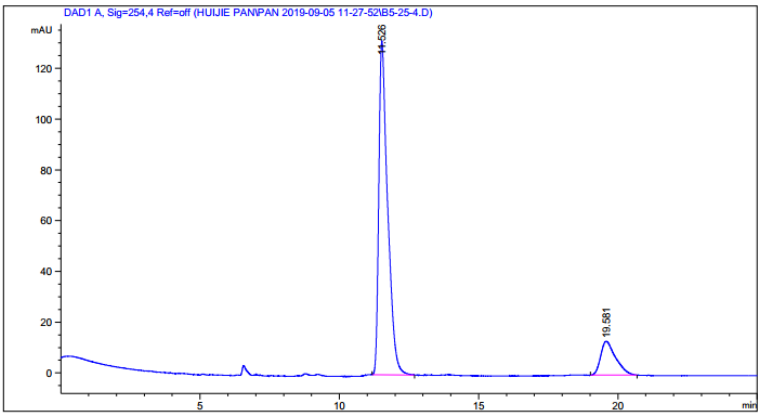


16j



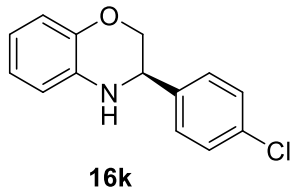

```
=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  11.254 BB    0.3055 4488.06543  205.75160  49.8689
   2  19.210 BB    0.4463 4511.66943  118.60239  50.1311
```

Figure S20 HPLC report of racemic **16j**



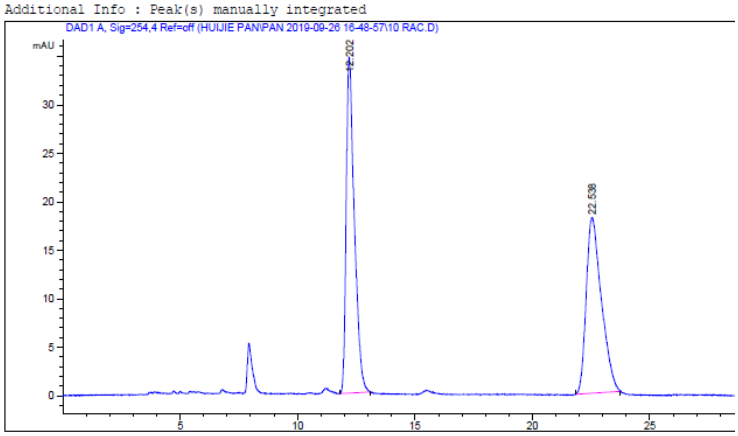

```
=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  11.526 BB    0.3066 2895.20874  131.62619  85.3243
   2  19.581 BB    0.4366  497.97427   13.36787  14.6757
```

Figure S21 HPLC report of enantioenriched **16j**



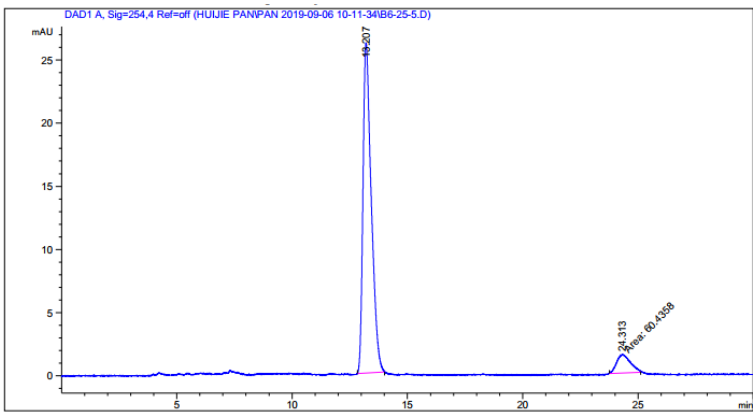
16k

Additional Info : Peak(s) manually integrated



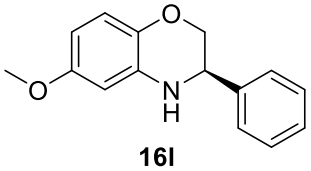

```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  12.202 BB    0.2845  835.94067   34.64918  50.6863
   2  22.538 BB    0.5261  813.30438   18.12062  49.3137
```

Figure S22 HPLC report of racemic **16k**



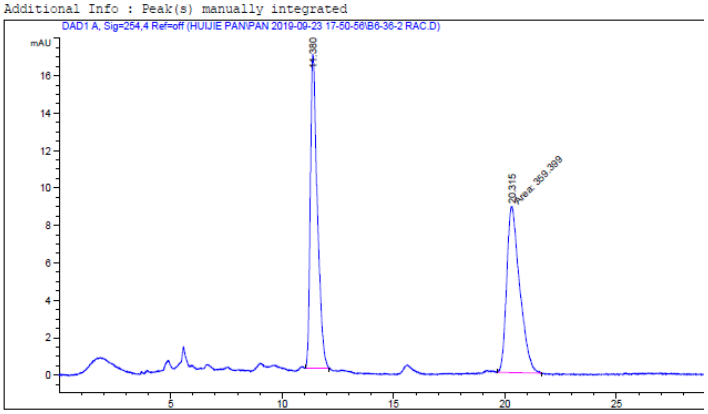

```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  13.207 BB    0.2960  652.81299   26.12785  91.5267
   2  24.313 MM    0.6863   60.43580    1.46765   8.4733
```

Figure S23 HPLC report of enantioenriched **16k**



16l

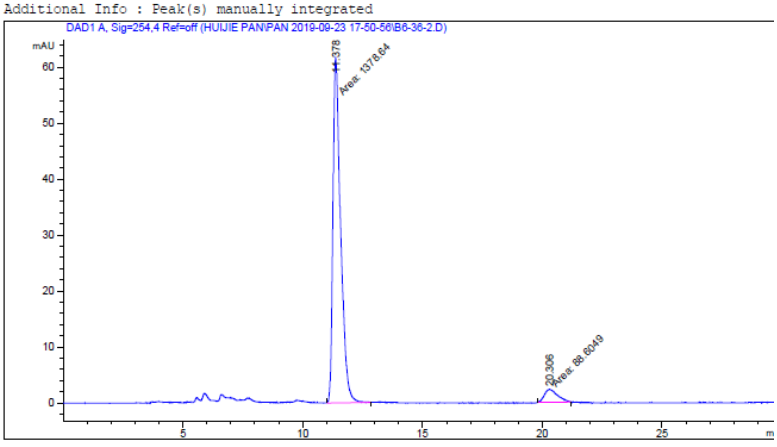
Additional Info : Peak(s) manually integrated




```
==================================================================
                        Area Percent Report
==================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  11.380 BB    0.2564  367.09018   16.80236  50.5294
   2  20.315 MM    0.6751  359.39859    8.87302  49.4706
```

Figure S24 HPLC report of racemic **16l**

Additional Info : Peak(s) manually integrated




```
==================================================================
                        Area Percent Report
==================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=off

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  11.378 MM    0.3721 1378.64172   61.74678  93.9611
   2  20.306 MM    0.6425   88.60489    2.29847   6.0389
```

Figure S25 HPLC report of enantioenriched **16l**

Reference

[1] K. F. Kalz, A. Brinkmeier, S. Dechert, R. A. Mata, F. Meyer, *J. Am. Chem. Soc.* **2014**, *136*, 16626-16634.

[2] M. Hatazawa, N. Yoshie, H. Seino, *Inorg. Chem.* **2017**, *56*, 8087-8099.

[3] R. van Putten, E. A. Uslamin, M. Garbe, C. Liu, A. Gonzalez-de-Castro, M. Lutz, K. Junge, E. J. M. Hensen, M. Beller, L. Lefort, E. A. Pidko, *Angew. Chem. Int. Ed.* **2017**, *56*, 7531-7534.

[4] S. Elangovan, C. Topf, S. Fischer, H. Jiao, A. Spannenberg, W. Baumann, R. Ludwig, K. Junge, M. Beller, *J. Am. Chem. Soc.* **2016**, *138*, 8809-8814.

[5] J. Wang, Z.-H. Zhu, M.-W. Chen, Q.-A. Chen, Y.-G. Zhou, *Angew. Chem. Int. Ed.* **2019**, *58*, 1813-1817.

[6] G. M. Sheldrick, *Acta Cryst.* **2015**, *A71*, 3-8.

[7] G. M. Sheldrick, *Acta Cryst.* **2015**, *C71*, 3-8.

[8] O. V. Dolomanov, Bourhis, L. J., Gildea, R. J., Howard, J. A. K., Puschmann, H. , *J. Appl. Cryst.* **2009**, *42*, 339-341.