Supporting Information for:

Unexpected Formation of Hexasubstituted Arenes through a Twofold Palladium-Mediated Ligand Arylation

Corin C. Wagen, Bryan T. Ingoglia, and Stephen L. Buchwald*

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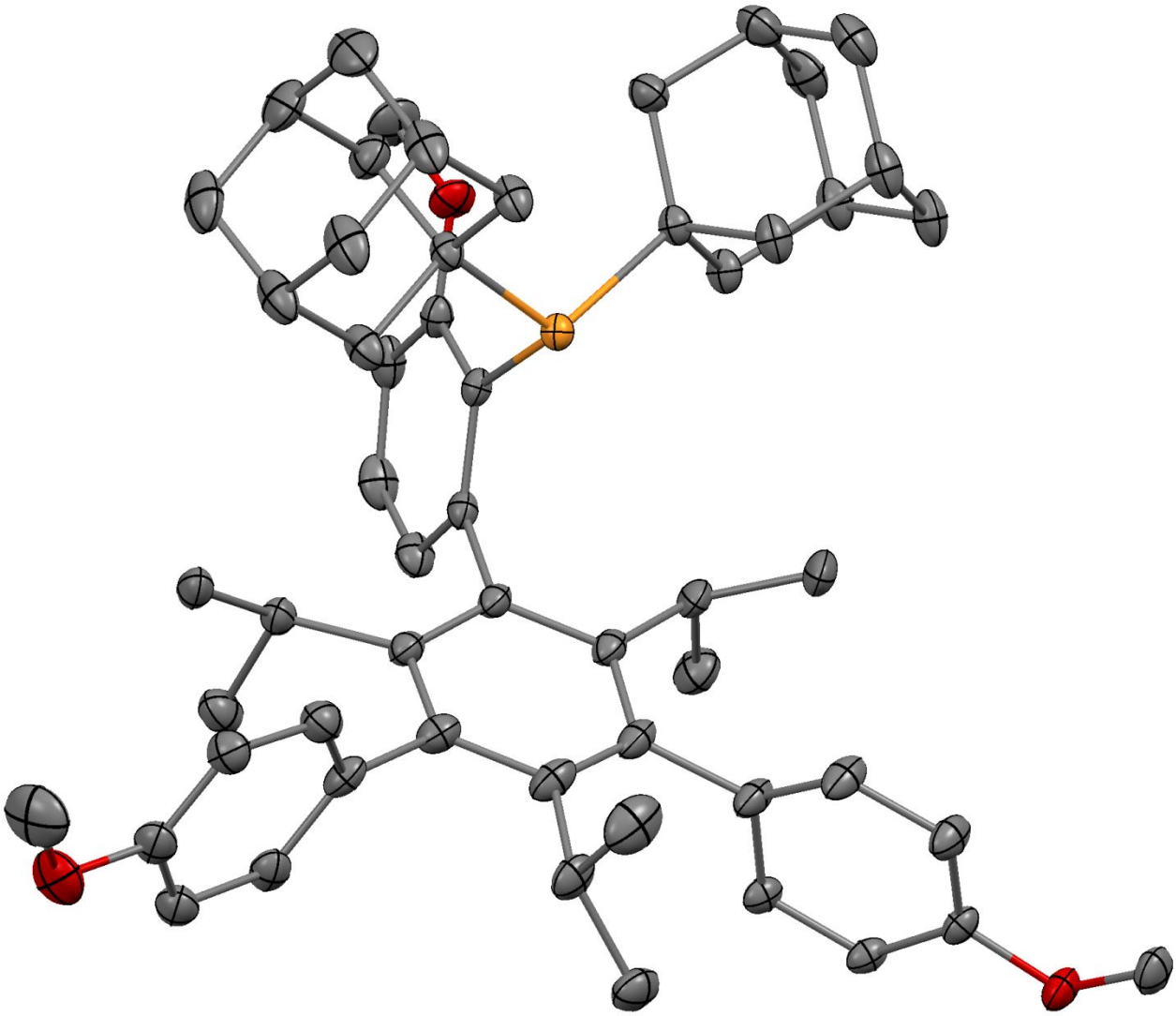
Thermal Ellipsoid Plot of 3:



Thermal ellipsoids depicted at 50% probability level. Hydrogen atoms have been omitted for clarity.

Crystallographic Details:

X-ray quality crystals of **3** were grown by dissolving **3** (5 mg) in CH_2Cl_2, layering MeOH on top, and aging at –20 °C for 2 weeks.

Low-temperature diffraction data (Φ-and ω-scans) were collected on a Bruker-AXS X8 Kappa Duo diffractometer coupled to a Smart APEX2 CCD detector with Mo Kα radiation (λ = 0.71073 Å) from an IμS micro-source for the structure of compound L2. Absorption and other corrections were applied using SADABS.[1] All structures were solved by direct methods using SHELXT[2] and refined against F2 on all data by full-matrix least squares with SHELXL-2017[3] using established refinement approaches.[4] All hydrogen atoms were included into the model at geometrically calculated positions and refined using a riding model. The isotropic displacement parameters of all hydrogen atoms were fixed to 1.2 times the Ueq value of the atoms they are linked to (1.5 times for methyl groups). Details about crystal properties, diffraction data, and crystal structures can be found in the table below.

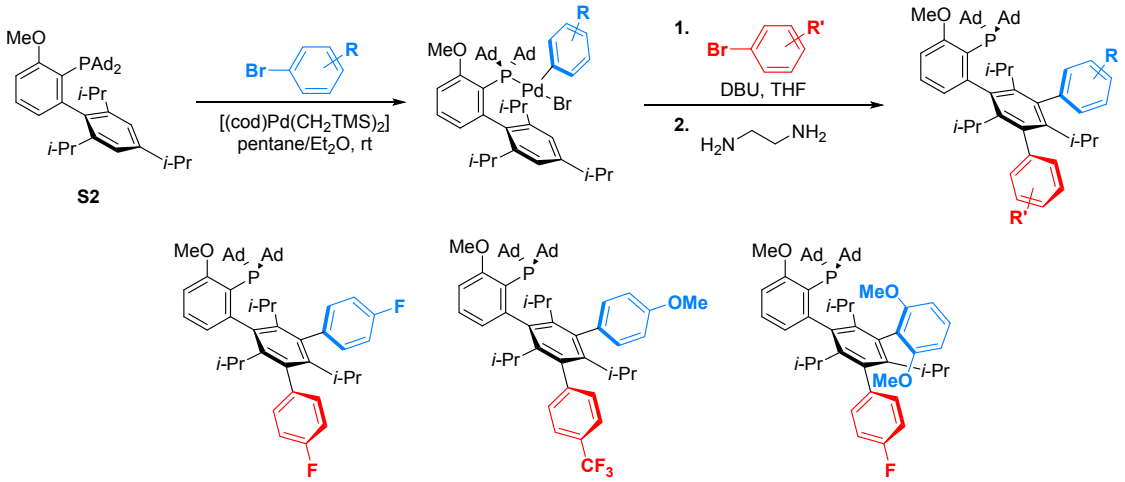
Compound **3** crystallizes in the monoclinic space group P21/n. SQUEEZE[5] as implemented in PLATON[6] was used to account for highly disordered solvent. The isopropyl group *para* to the phosphine-containing benzene ring crystallized as a mixture of rotamers, rendered inequivalent by the presence of the phosphine-containing ring.

Crystal data structure refinement for **3**:

Identification code	X8_18049	
Empirical formula	$C_{56}H_{71}O_3P$	
Formula weight	823.152	
Temperature	–173.0 °C	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P21/n	
Unit cell dimensions	a = 12.5922(9) Å b = 28.656(2) Å c = 13.3383(10) Å	α = 90.00° β = 100.726(2)° γ = 90.00°
Volume	4728.68 Å^3	
Z	4	
Density (calculated)	1.156 g/cm^3	
Absorption coefficient	0.101 mm^{-1}	
F(000)	1784	
Crystal size	0.210 x 0.160 x 0.120 mm^3	
Theta range for data collection	1.421 to 32.032°	
Reflections collected	365858	
Independent reflections	16449	
Absorption correction	T_{max} = 0.7464; T_{min} = 0.7268	
Refinement method	Full-matrix least squares on F^2	
Goodness-of-fit on F^2	1.067	

Additional Substrates:

The following hexasubstituted arenes were formed from S2 through the two-step sequence described in the text (as assessed by LCMS, ^{1}H NMR, and/or ^{31}P NMR), but could not successfully be separated from remaining aryl bromide or monoarylated product.



References:

(1) Krause, L.; Herbst-Irmer, R.; Sheldrick, G. M.; Stalke, D. Comparison of Silver and Molybdenum Microfocus X-Ray Sources for Single-Crystal Structure Determination. *J. Appl. Crystallogr.* **2015**, *48*, 3–10.

(2) Sheldrick, G. M.; IUCr. SHELXT – Integrated Space-Group and Crystal-Structure Determination. *Acta Crystallogr.* **2015**, *A71*, 3–8.

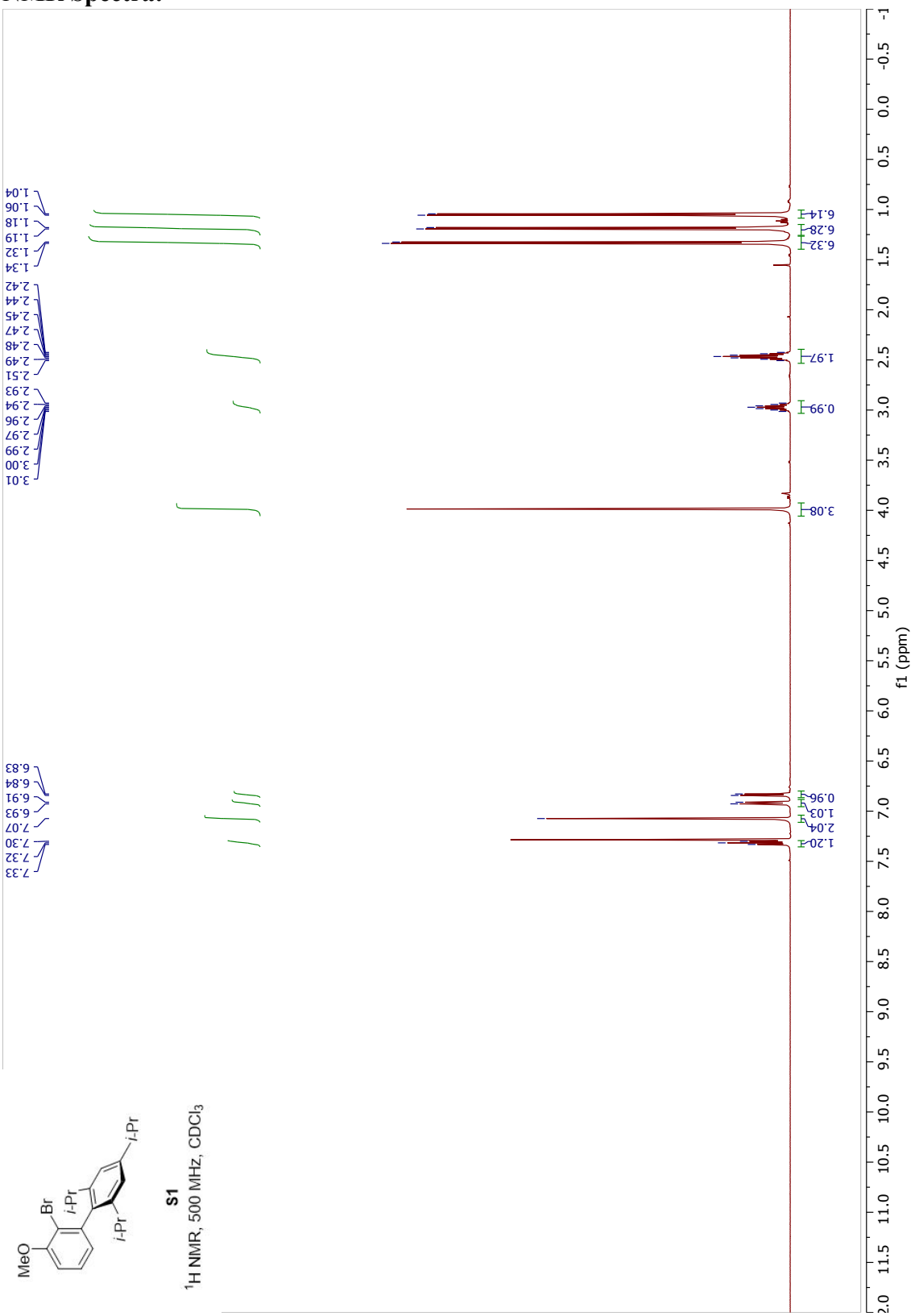
(3) Sheldrick, G. M. Crystal Structure Refinement with SHELXL. *Acta Crystallogr.* **2015**, *C71*, 3–8.

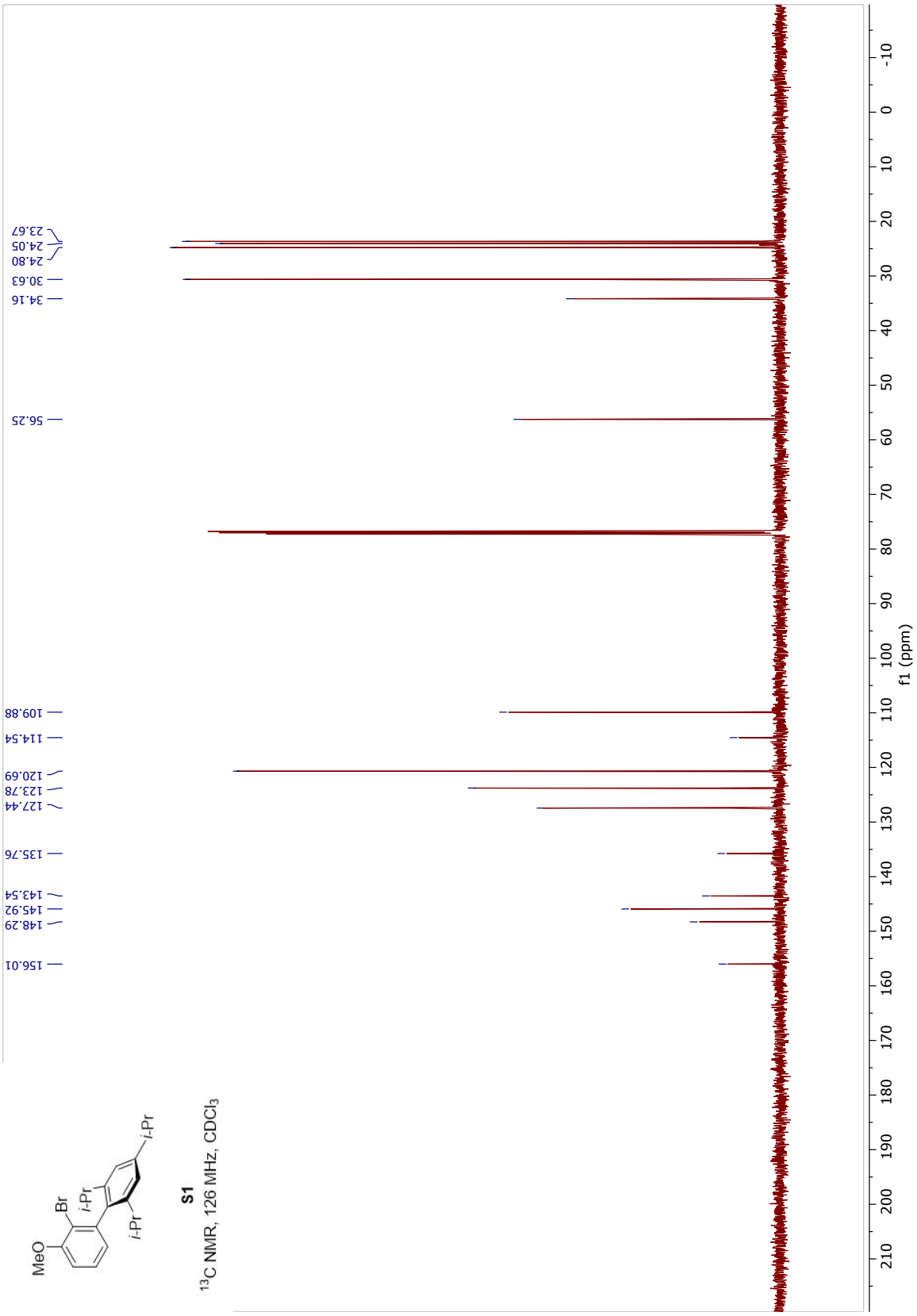
(4) Müller, P. Practical Suggestions for Better Crystal Structures. *Crystallogr. Rev.* **2009**, *15*, 57–83.

(5) van der Sluis, P.; Spek, A. L. BYPASS: An Effective Method for the Refinement of Crystal Structures Containing Disordered Solvent Regions. *Acta Crystallogr.* **1990**, *A46*, 194–201.

(6) Spek, A. L.; IUCr. Structure Validation in Chemical Crystallography. *Acta Crystallogr.* **2009**, *D65*, 148–155.

NMR Spectra:



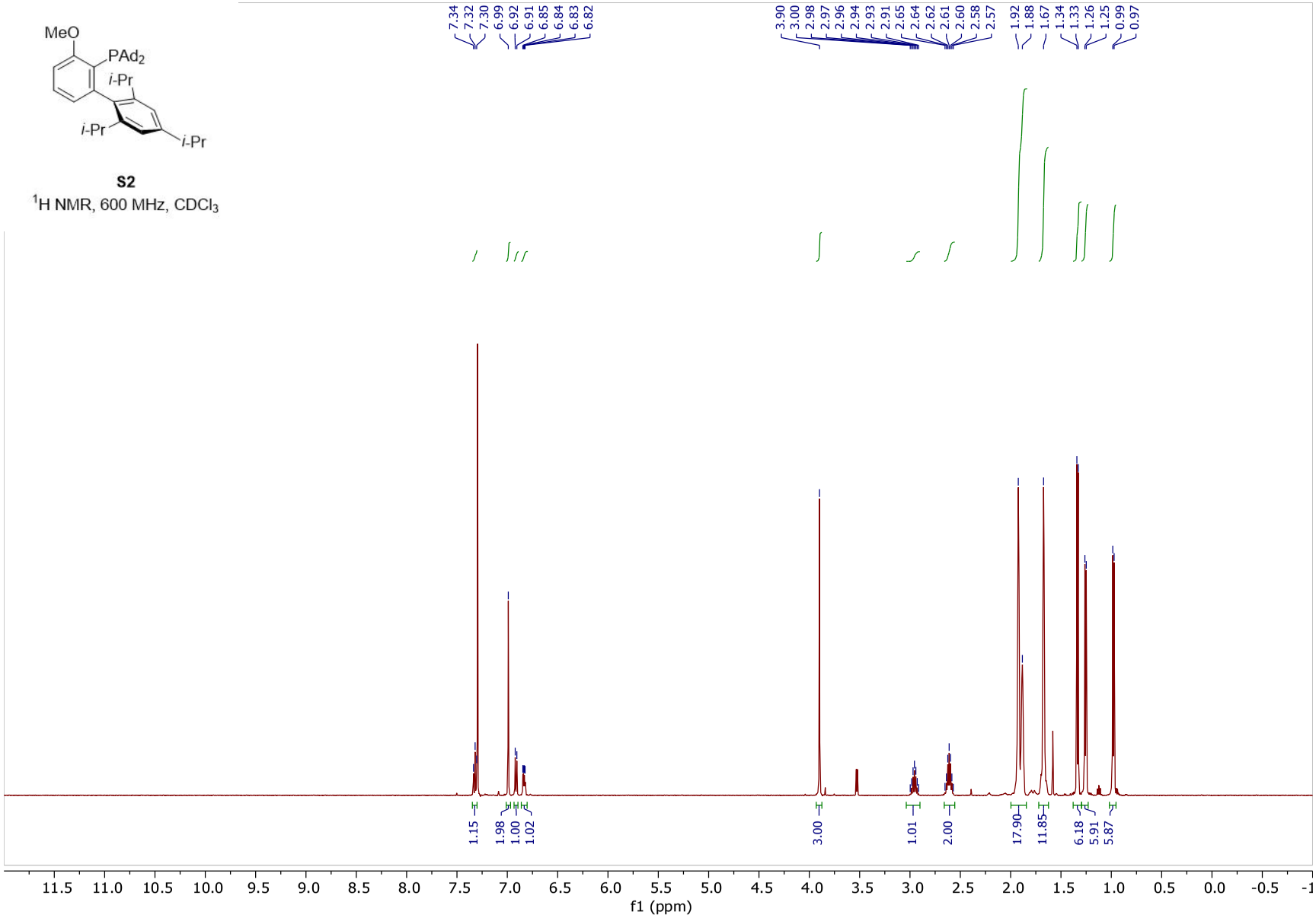


S1

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

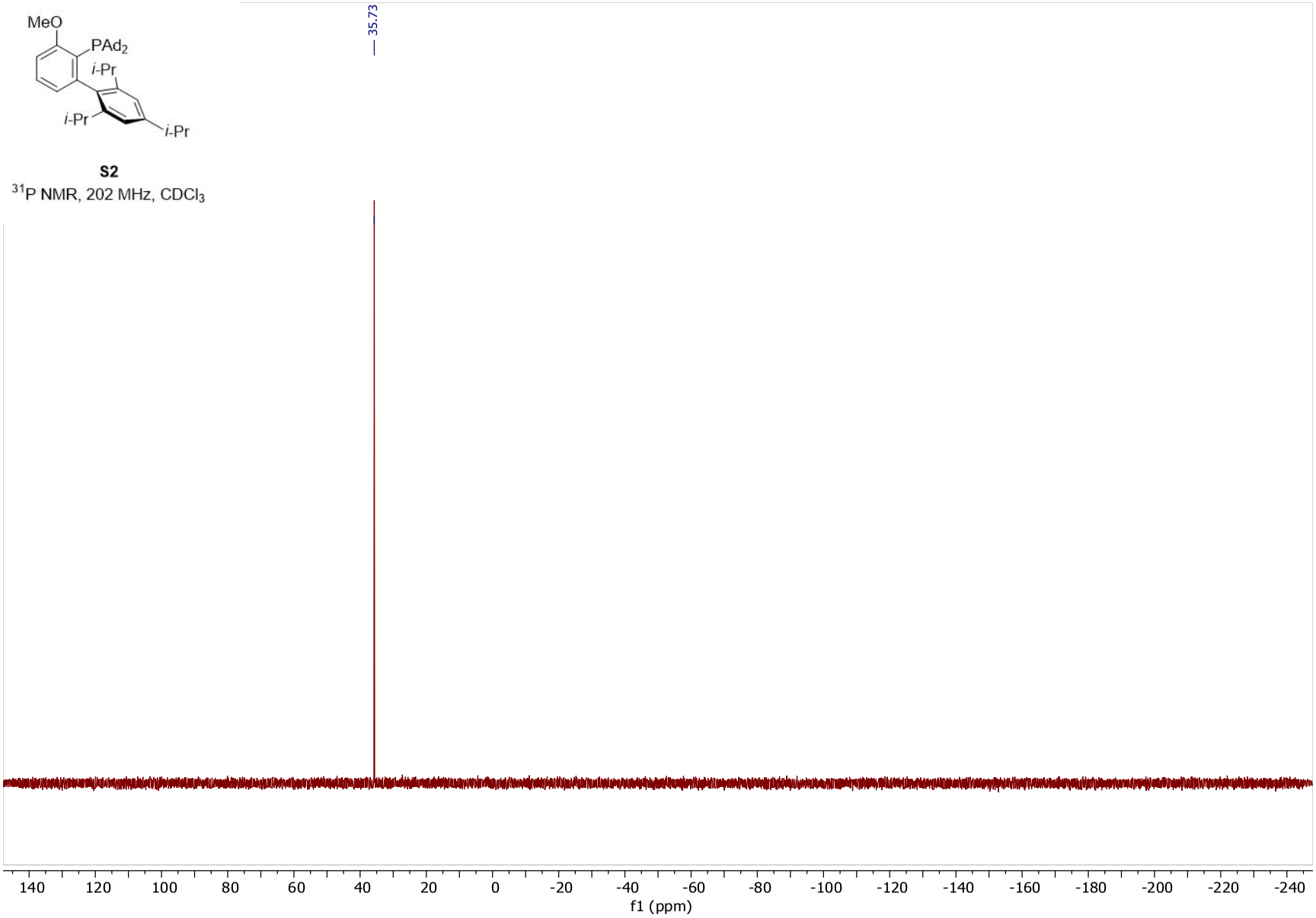
S2

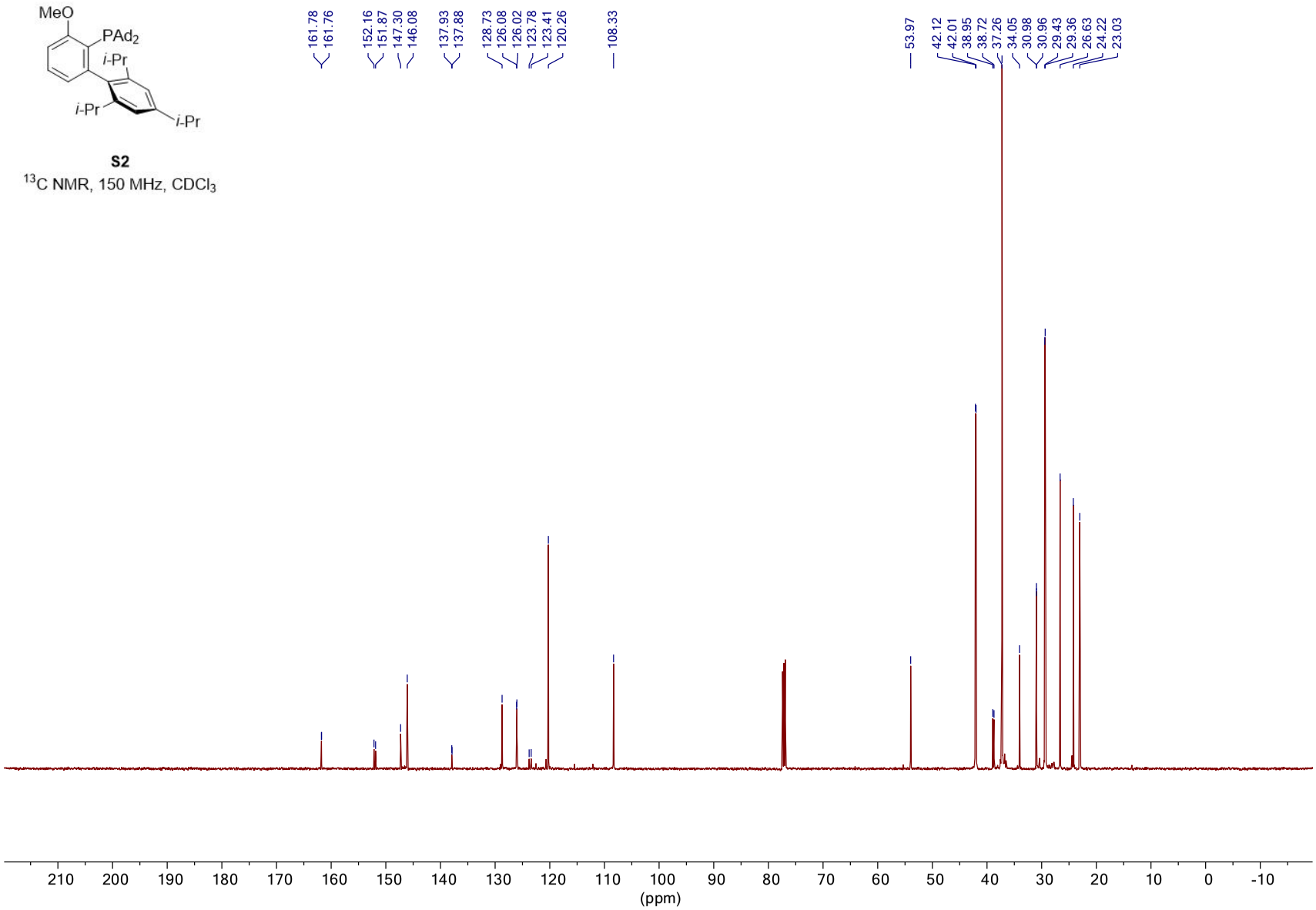
^{1}H NMR, 600 MHz, $CDCl_3$



S2

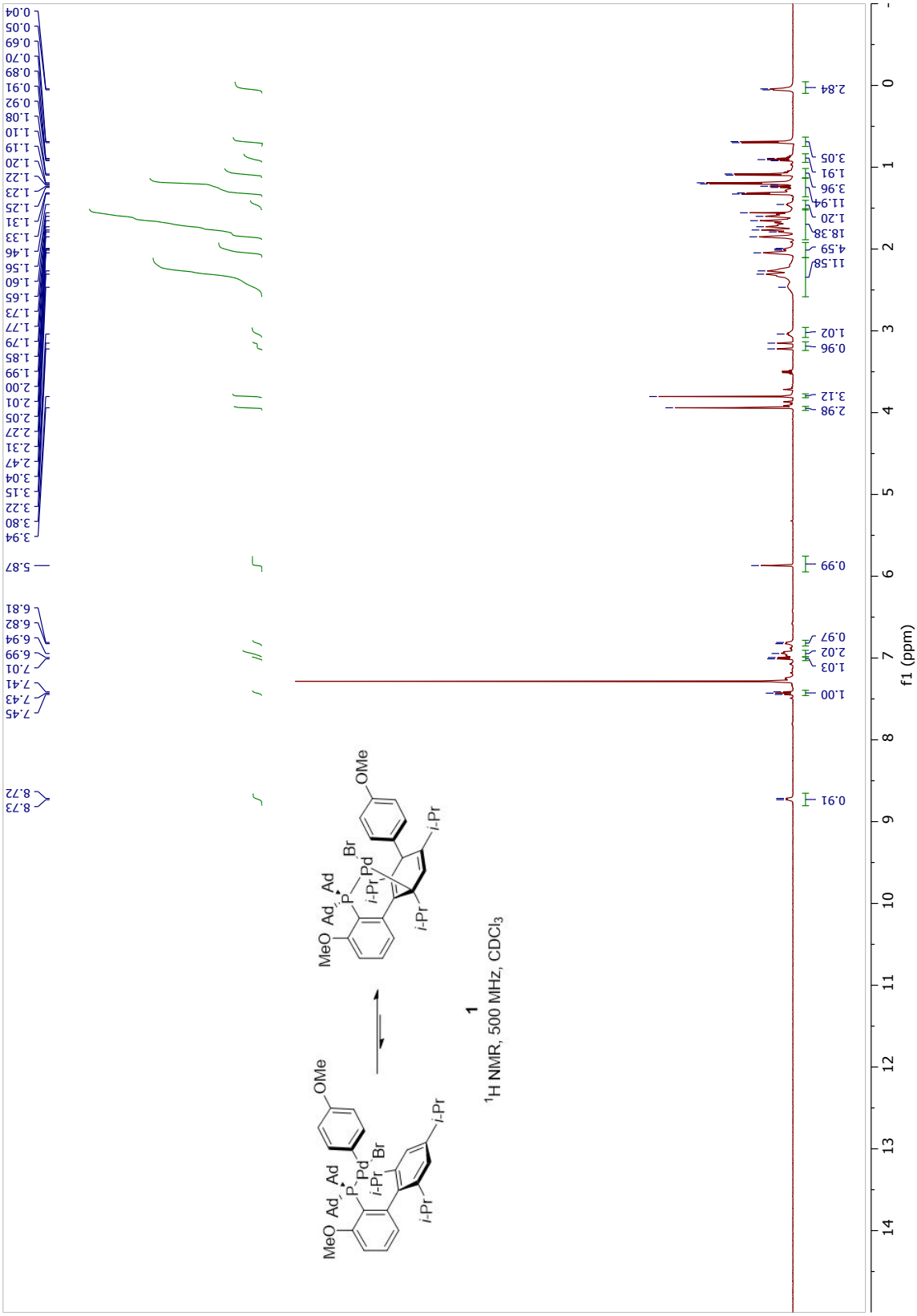
^{31}P NMR, 202 MHz, $CDCl_3$

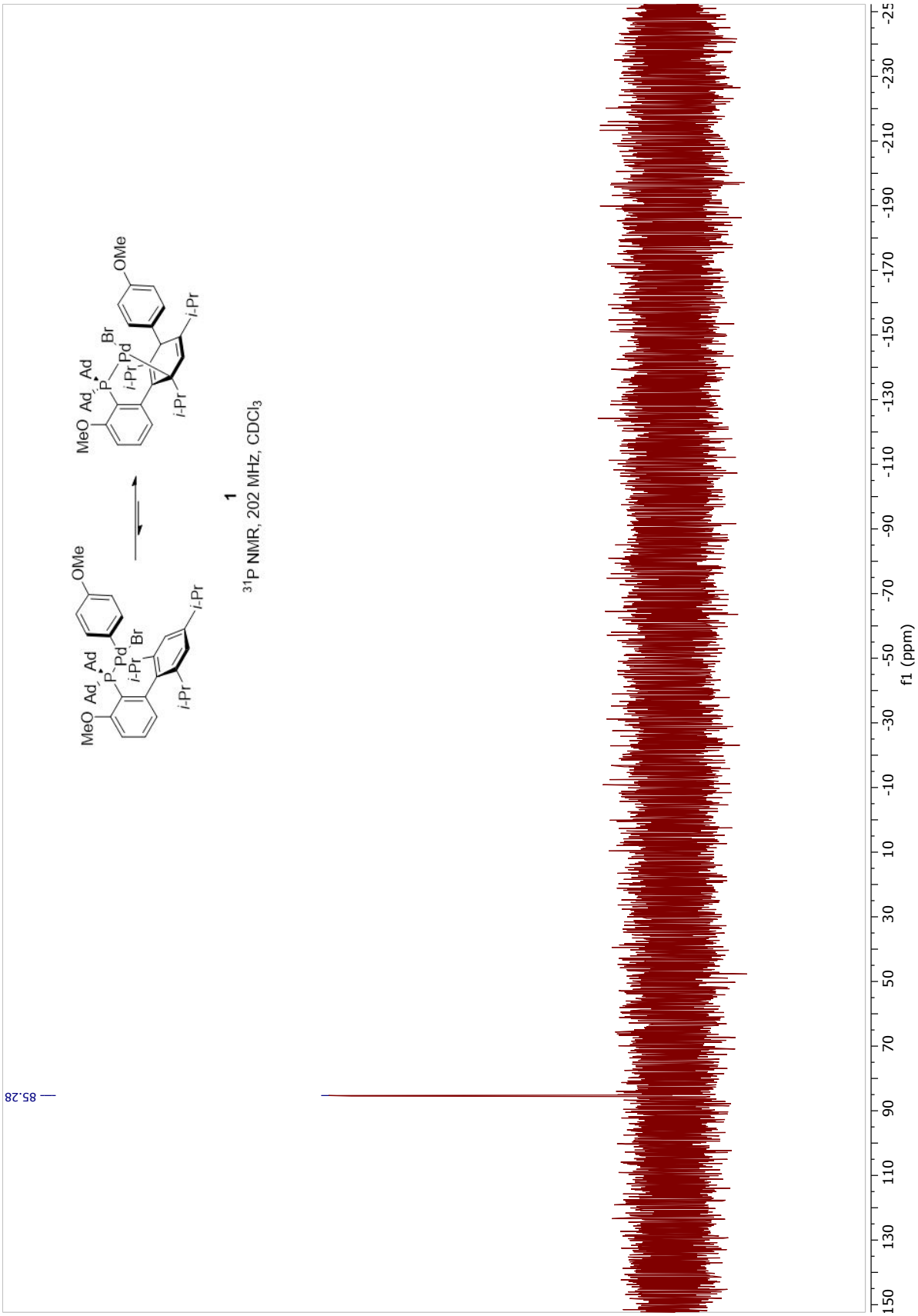


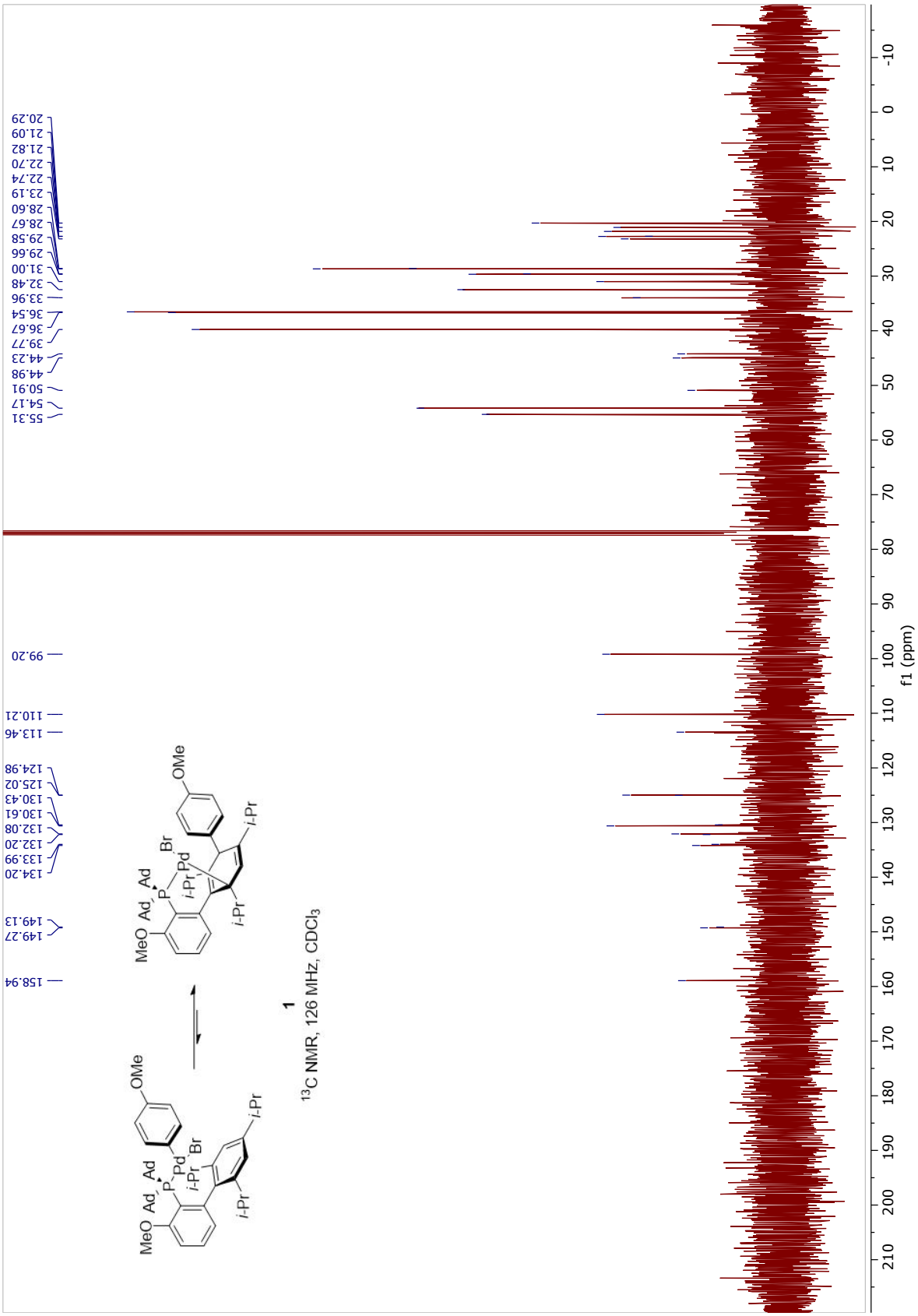


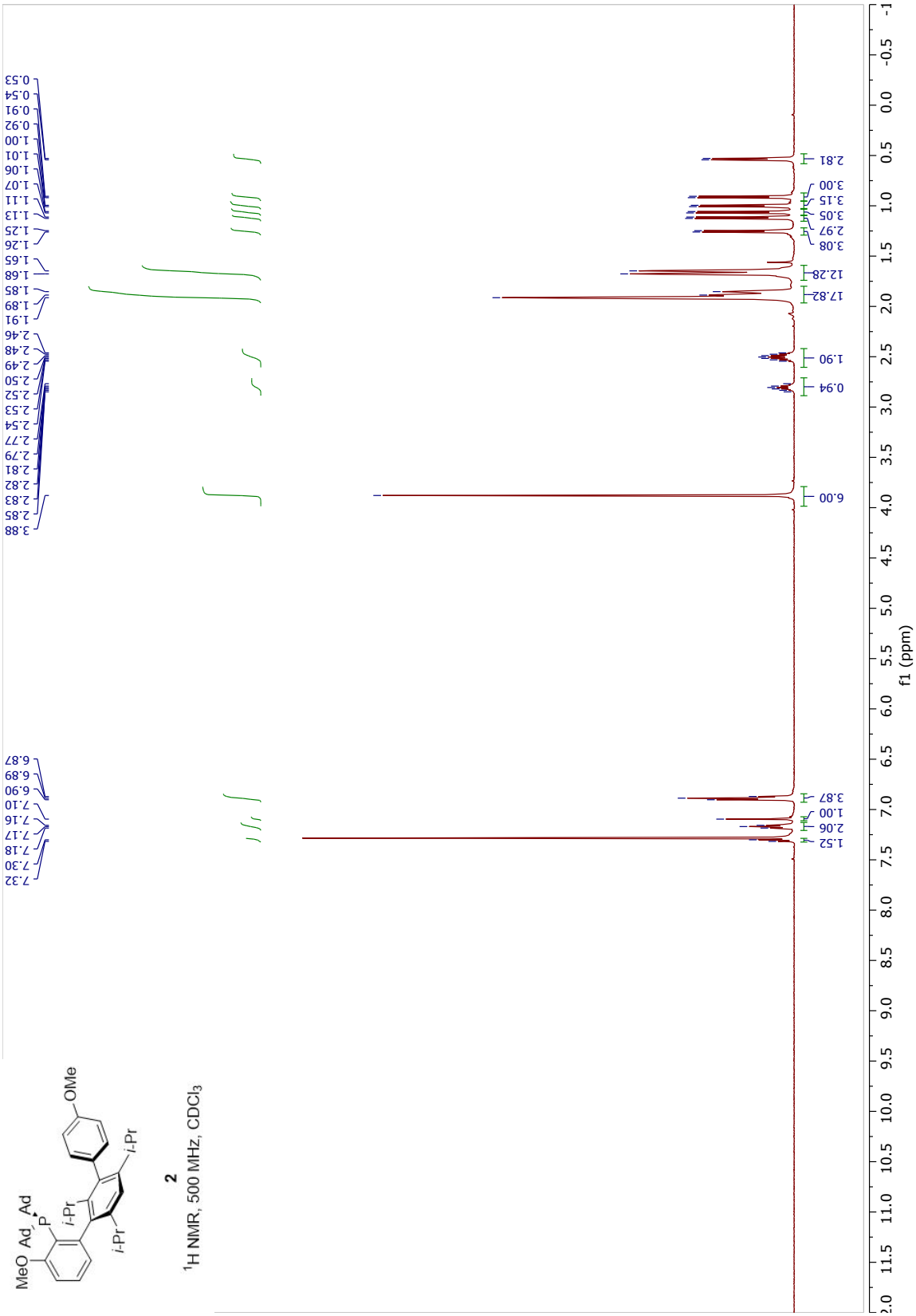
S2

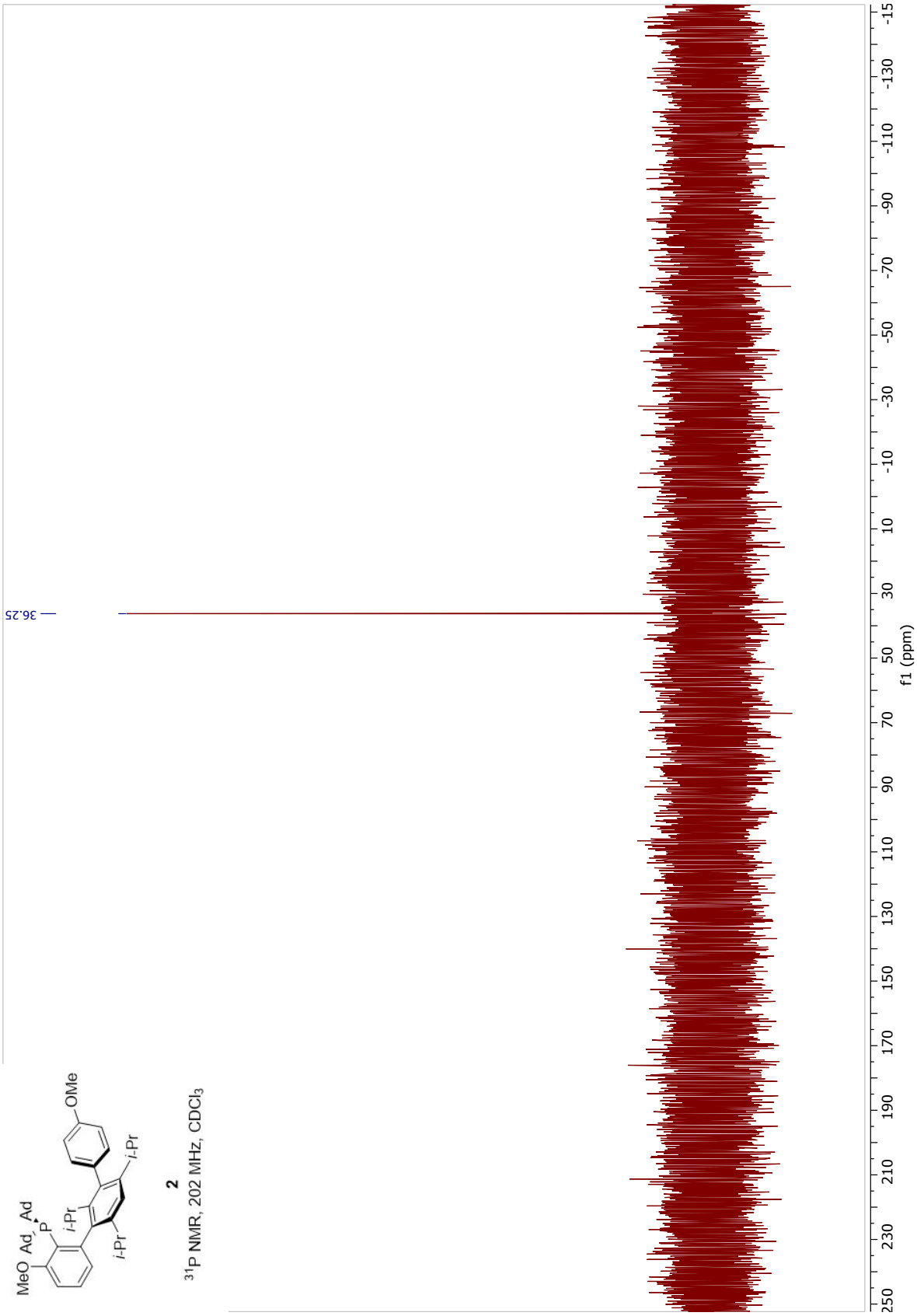
^{13}C NMR, 150 MHz, $CDCl_3$


MeO
Ad
Ad
P
Pd
Br
i-Pr
i-Pr
i-Pr
i-Pr
OMe
1
1H NMR, 500 MHz, CDCl3
f1 (ppm)


MeO
Ad
Ad
P
Pd
Br
i-Pr
i-Pr
i-Pr
OMe
i-Pr
1
31P NMR, 202 MHz, CDCl3
85.28
f1 (ppm)

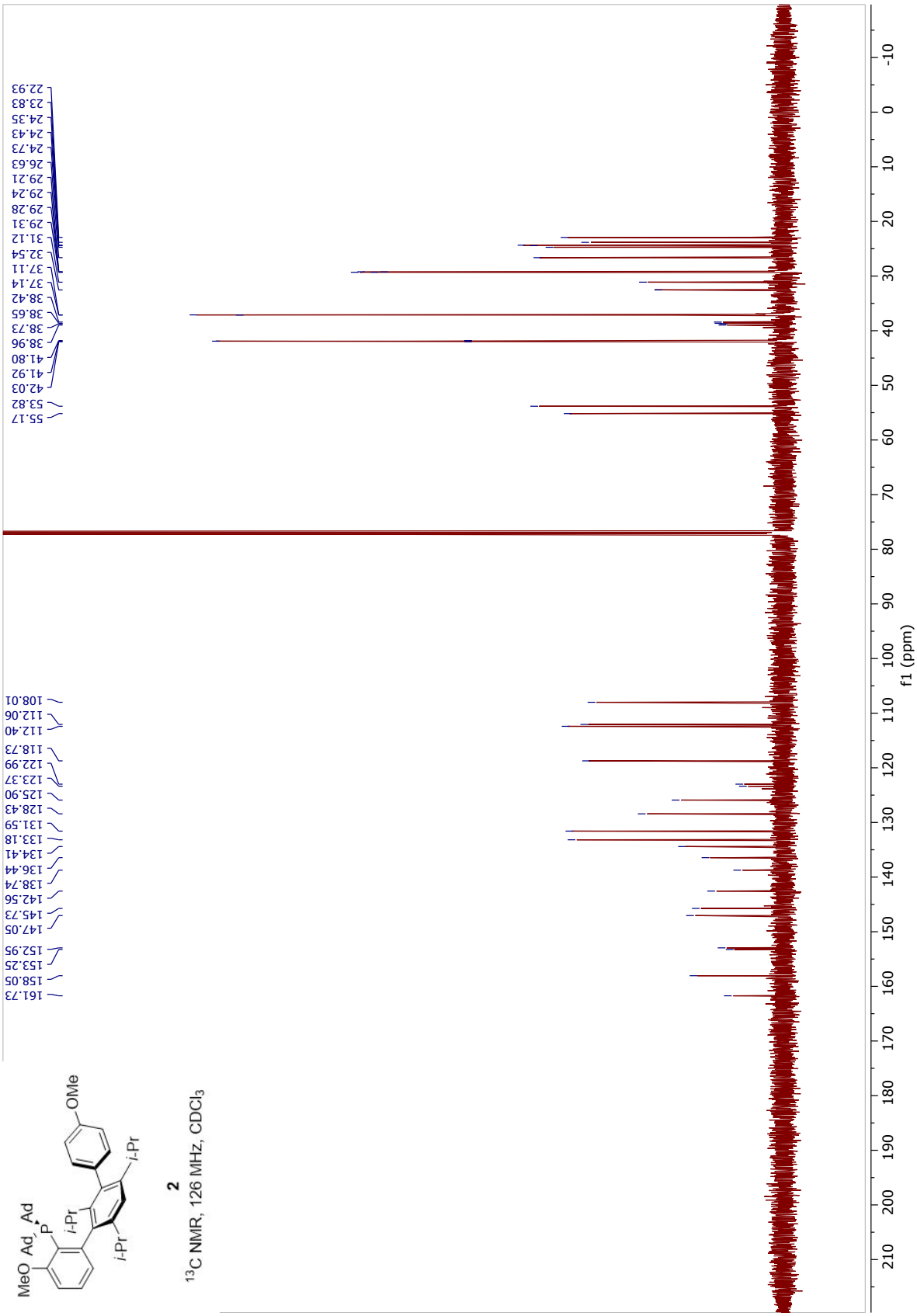

MeO
Ad
Ad
P
Pd
i-Pr
Br
OMe
i-Pr
i-Pr
1
^{13}C NMR, 126 MHz, $CDCl_3$
158.94
149.27
149.13
134.20
133.99
132.20
132.08
130.61
130.43
125.02
124.98
113.46
110.21
99.20
55.31
54.17
50.91
44.98
44.23
39.77
36.67
36.54
33.96
32.48
31.00
29.66
29.58
28.67
28.60
23.19
22.74
22.70
21.82
21.09
20.29
f1 (ppm)


MeO
Ad
Ad
P
i-Pr
i-Pr
i-Pr
OMe
2
1H NMR, 500 MHz, CDCl3
f1 (ppm)



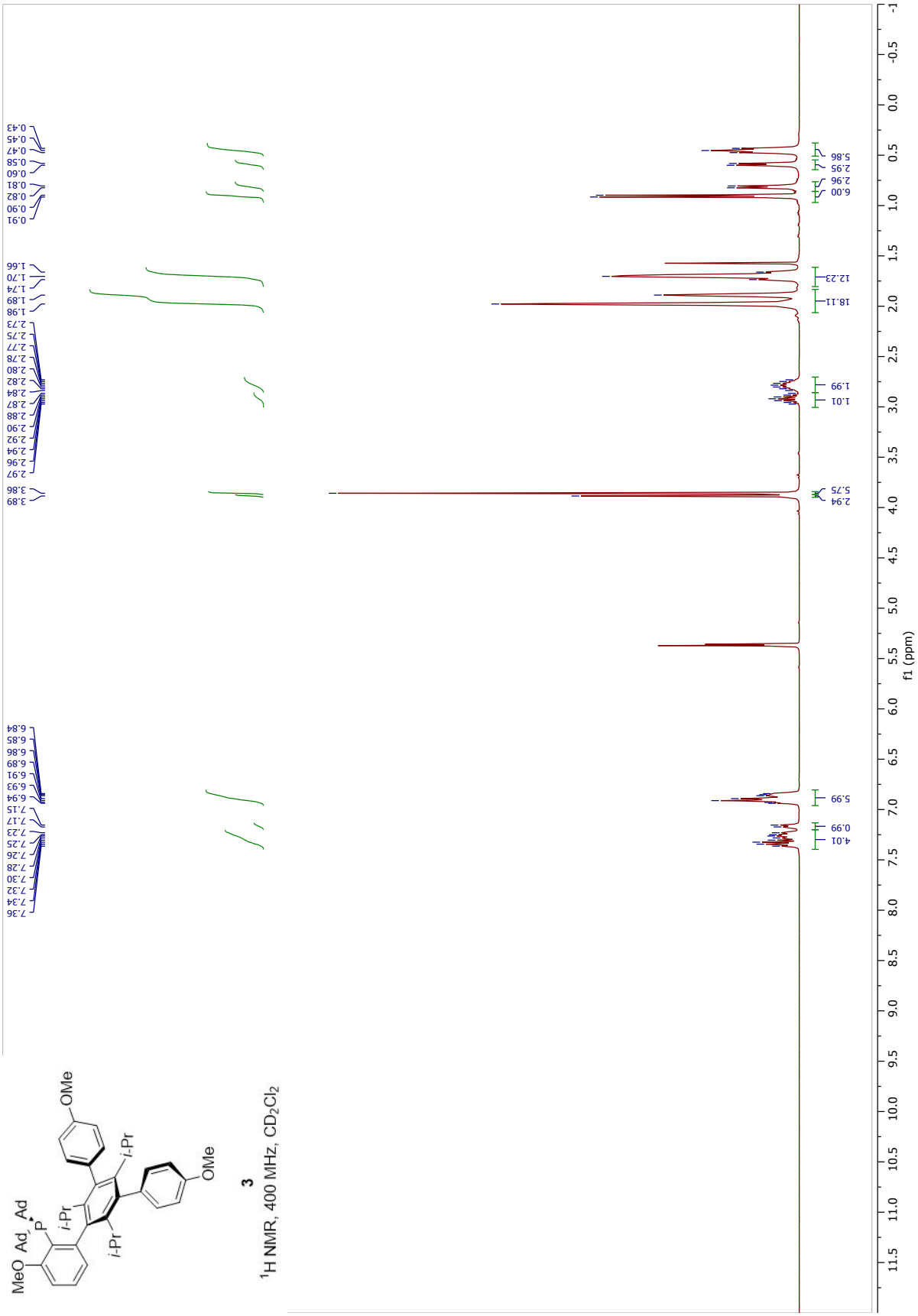
2

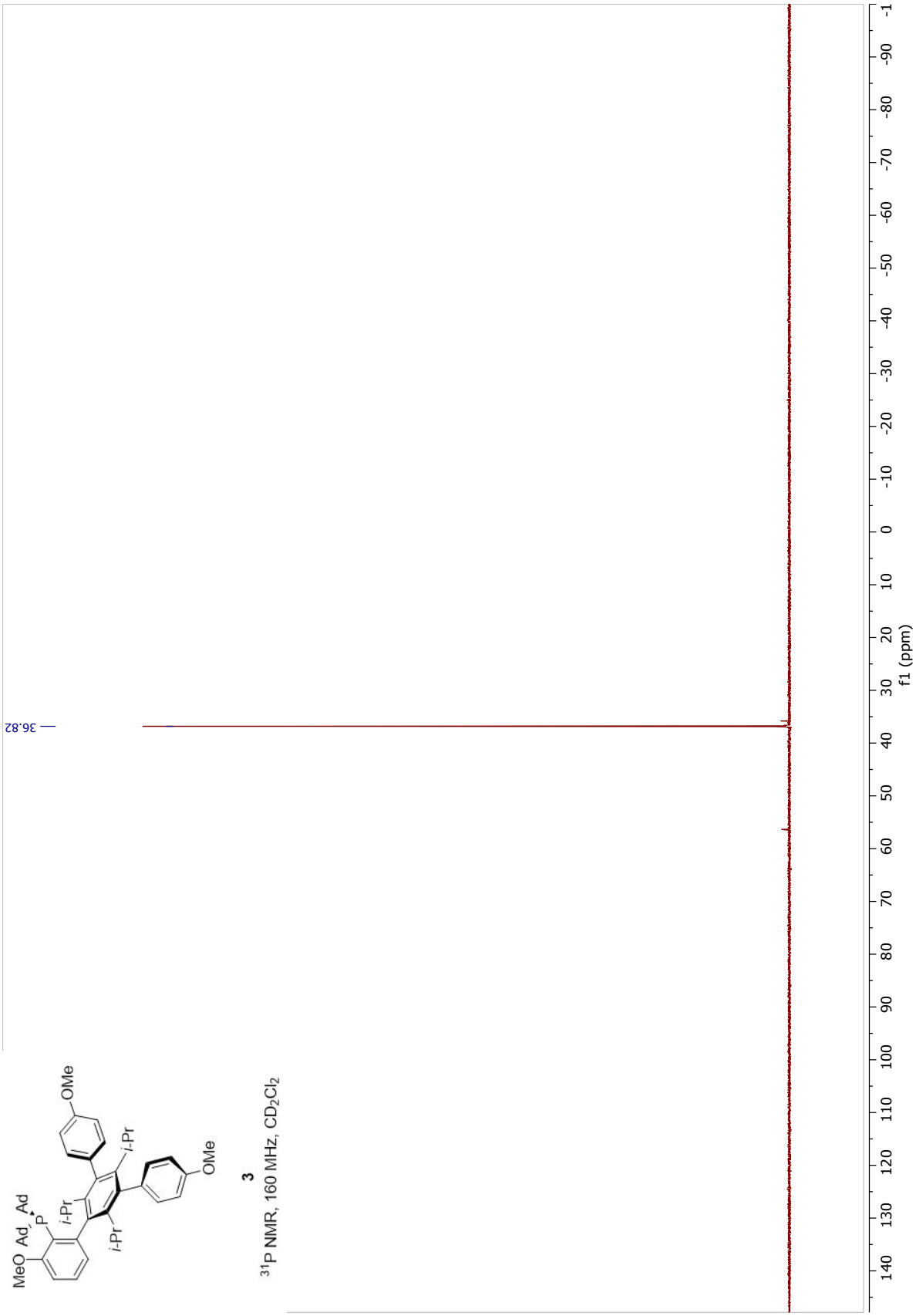
^{31}P NMR, 202 MHz, $CDCl_3$



2

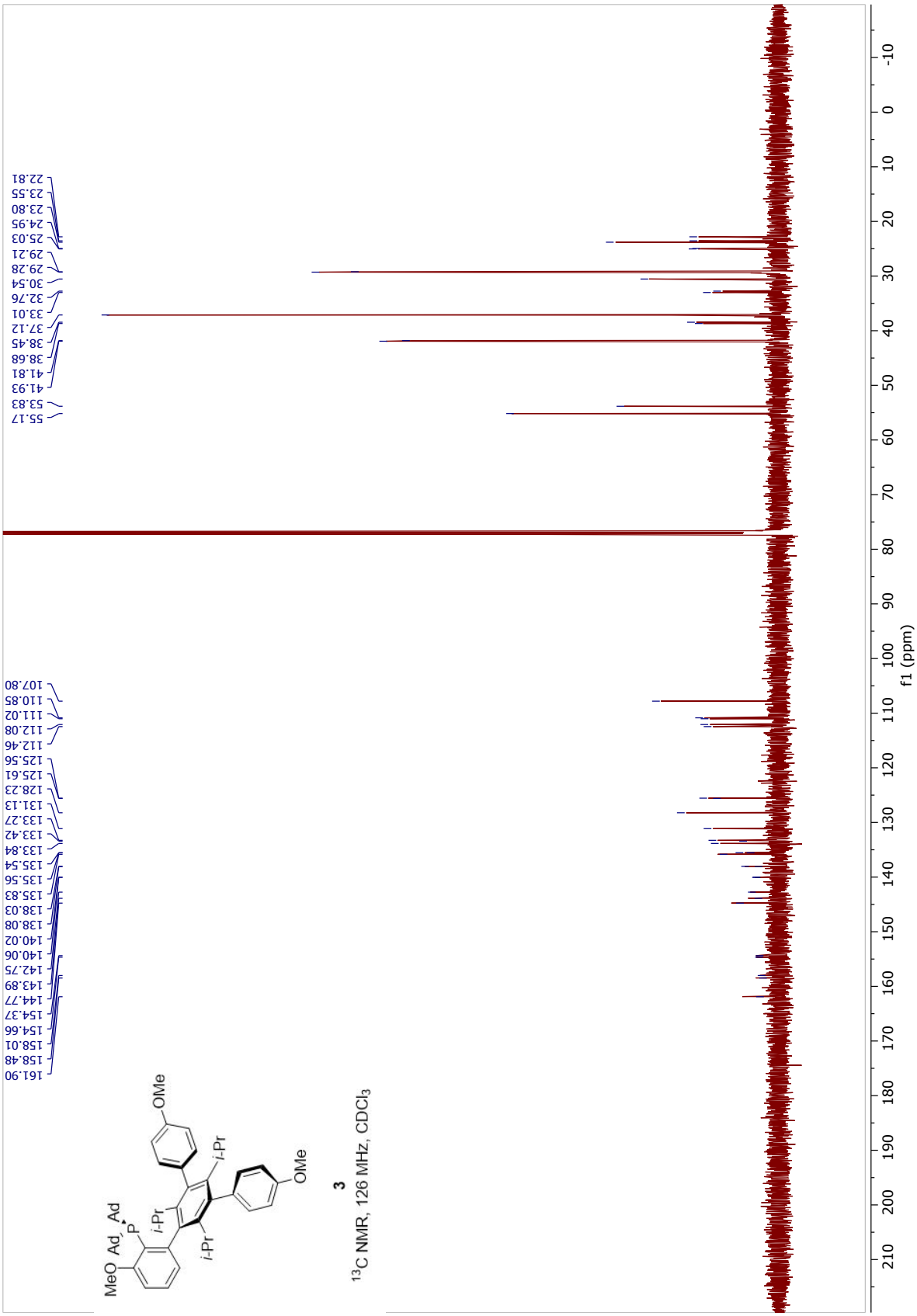
^{13}C NMR, 126 MHz, $CDCl_3$

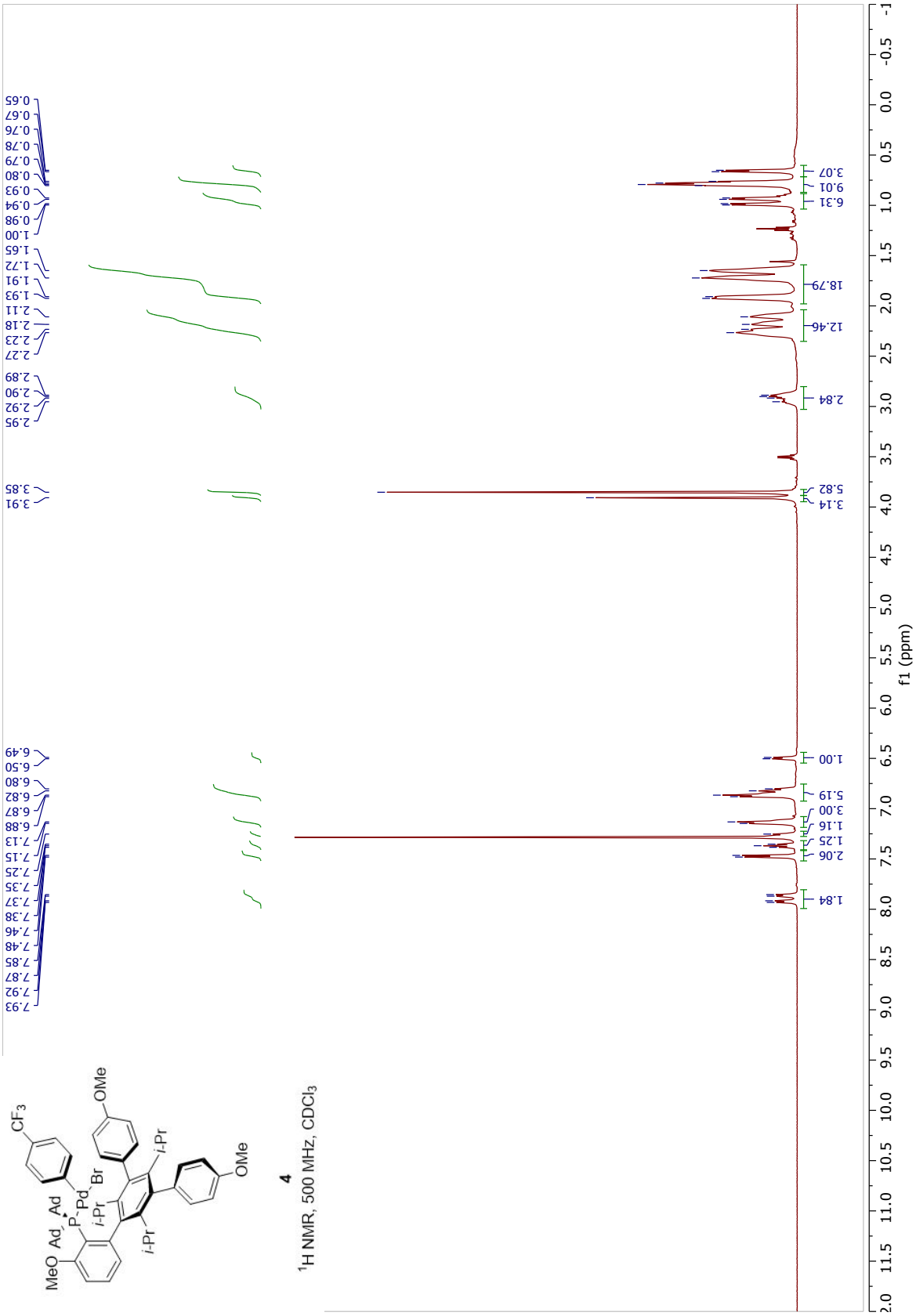

MeO
Ad
Ad
P
i-Pr
i-Pr
i-Pr
OMe
OMe
3
1H NMR, 400 MHz, CD2Cl2
f1 (ppm)



3

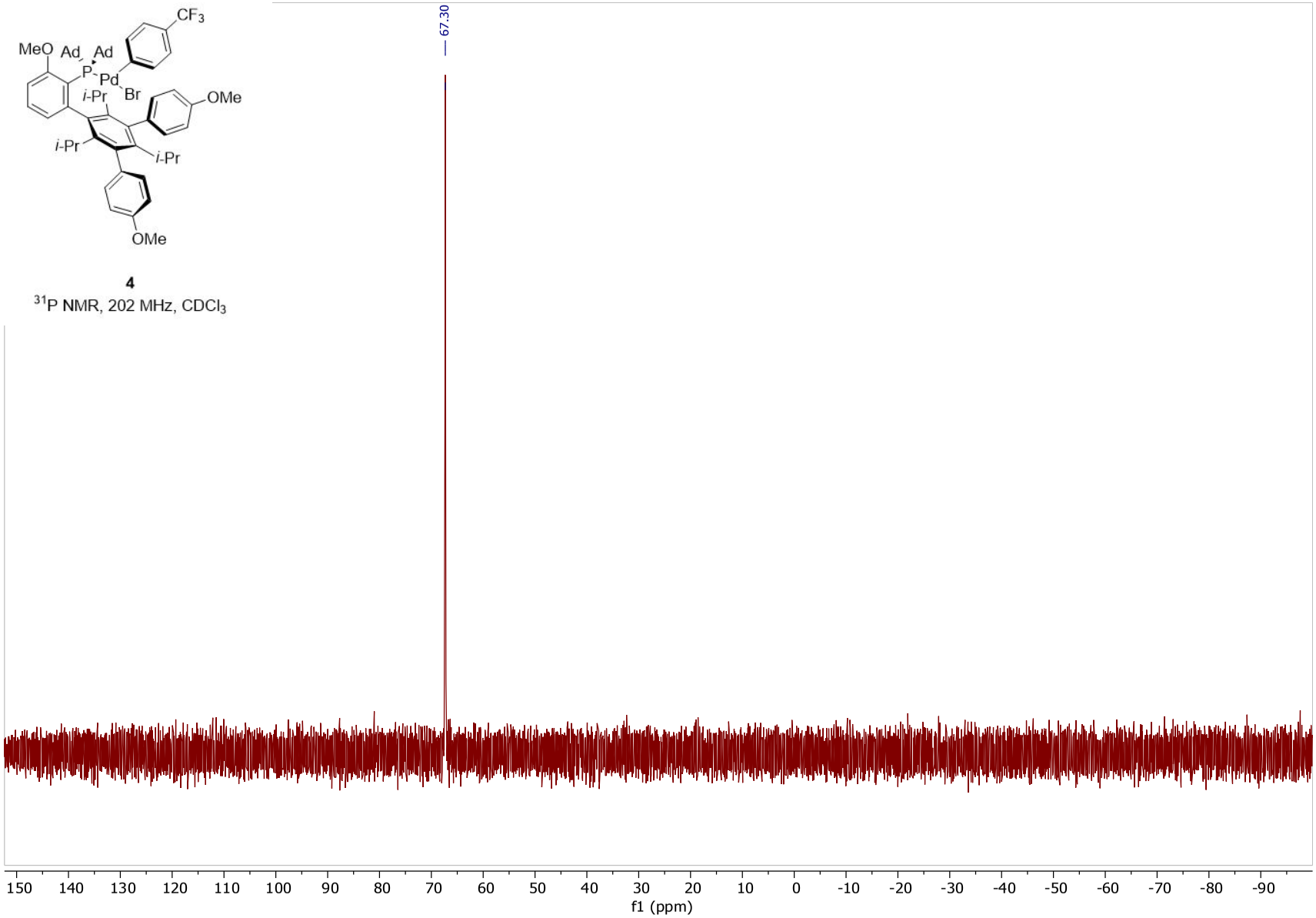
^{31}P NMR, 160 MHz, CD_2Cl_2

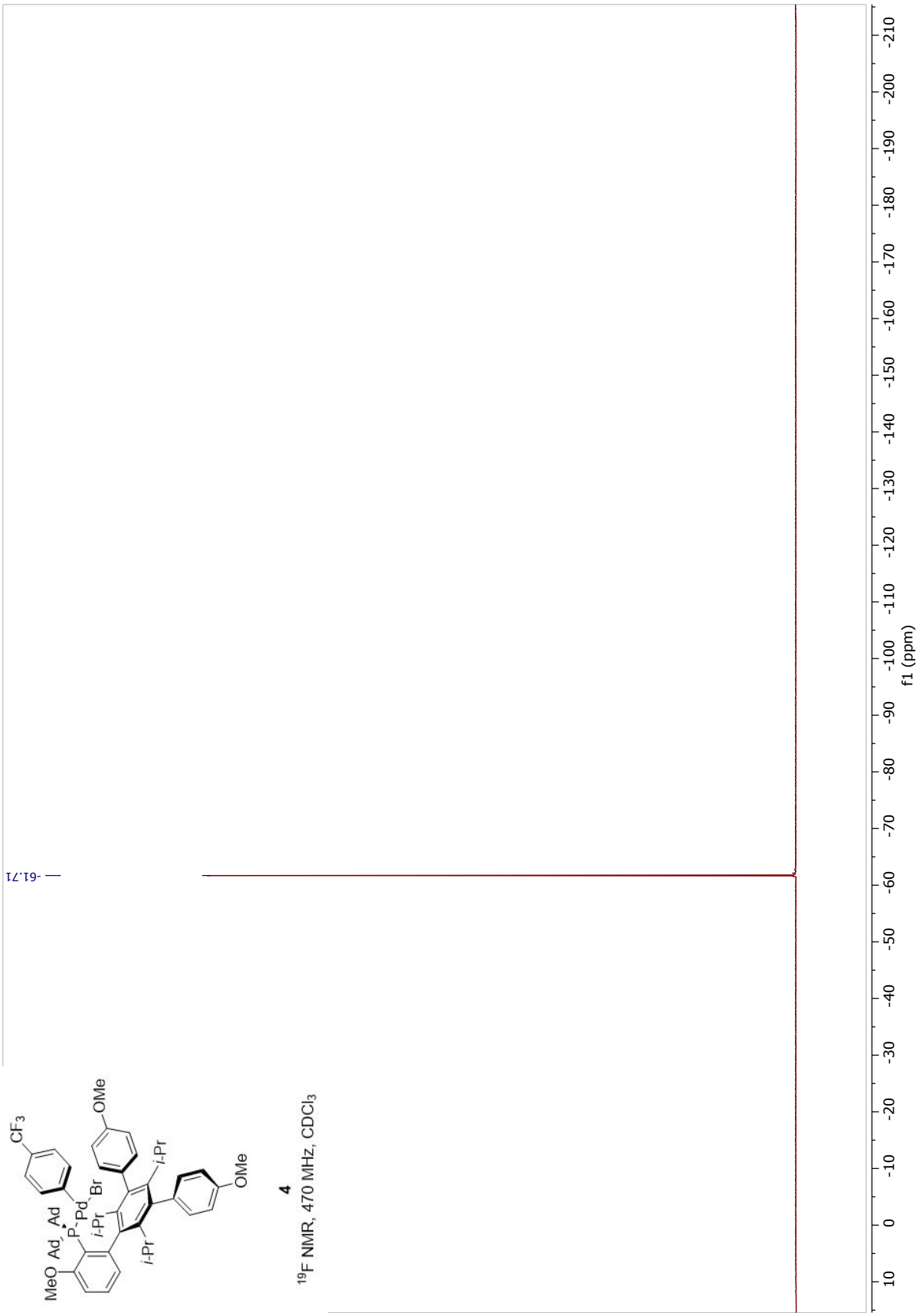

MeO
Ad
Ad
P
i-Pr
i-Pr
i-Pr
OMe
OMe
3
13C NMR, 126 MHz, CDCl3
161.90
158.48
158.01
154.66
154.37
144.77
143.89
142.75
140.06
140.02
138.08
138.03
135.83
135.56
135.54
133.84
133.42
133.27
131.13
128.23
125.61
125.56
112.46
112.08
111.02
110.85
107.80
55.17
53.83
41.93
41.81
38.68
38.45
37.12
33.01
32.76
30.54
29.28
29.21
25.03
24.95
23.80
23.55
22.81
f1 (ppm)


MeO
Ad
Ad
P
Pd
Br
i-Pr
i-Pr
i-Pr
OMe
OMe
CF3
4
1H NMR, 500 MHz, CDCl3
f1 (ppm)

4

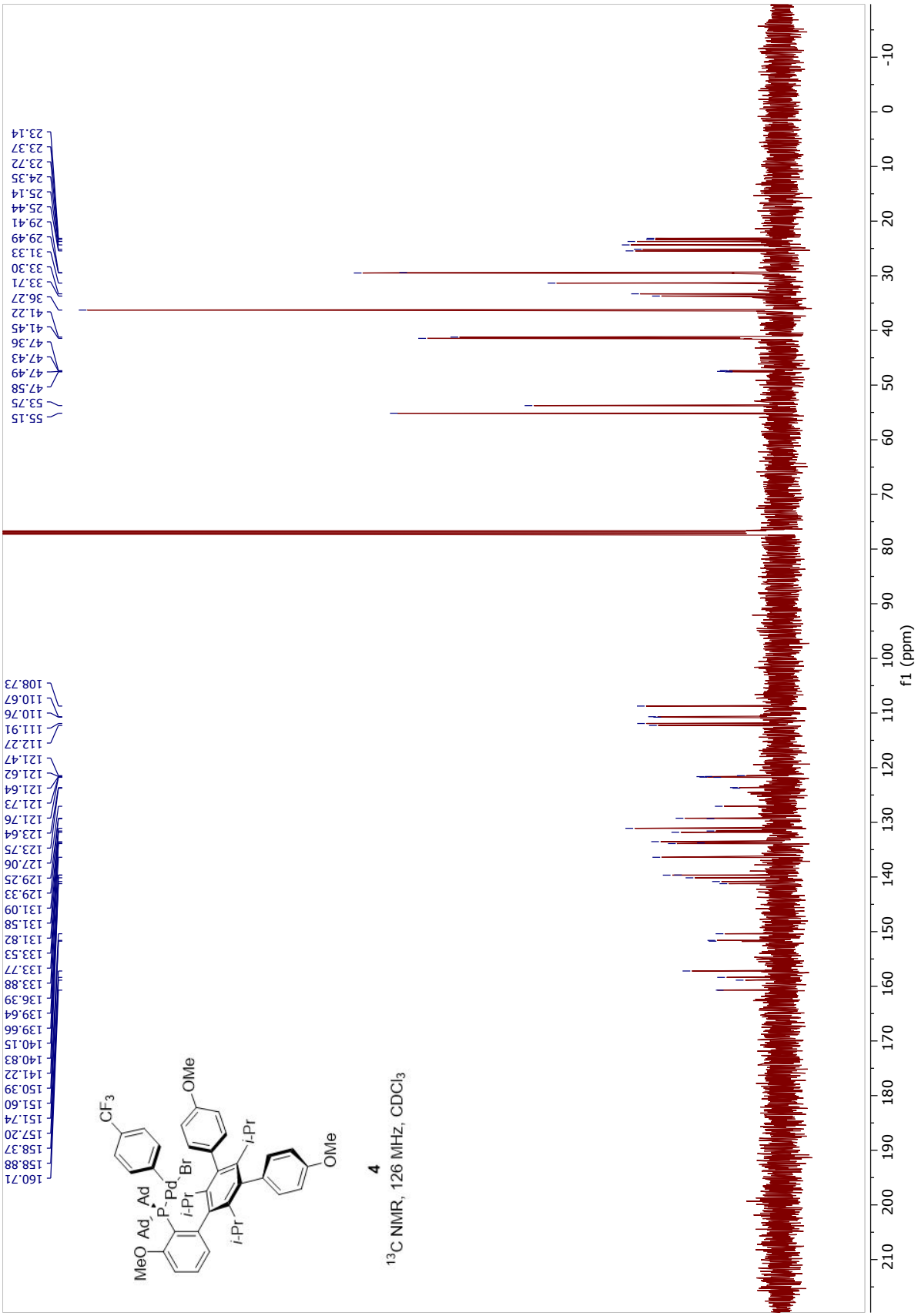
^{31}P NMR, 202 MHz, $CDCl_3$

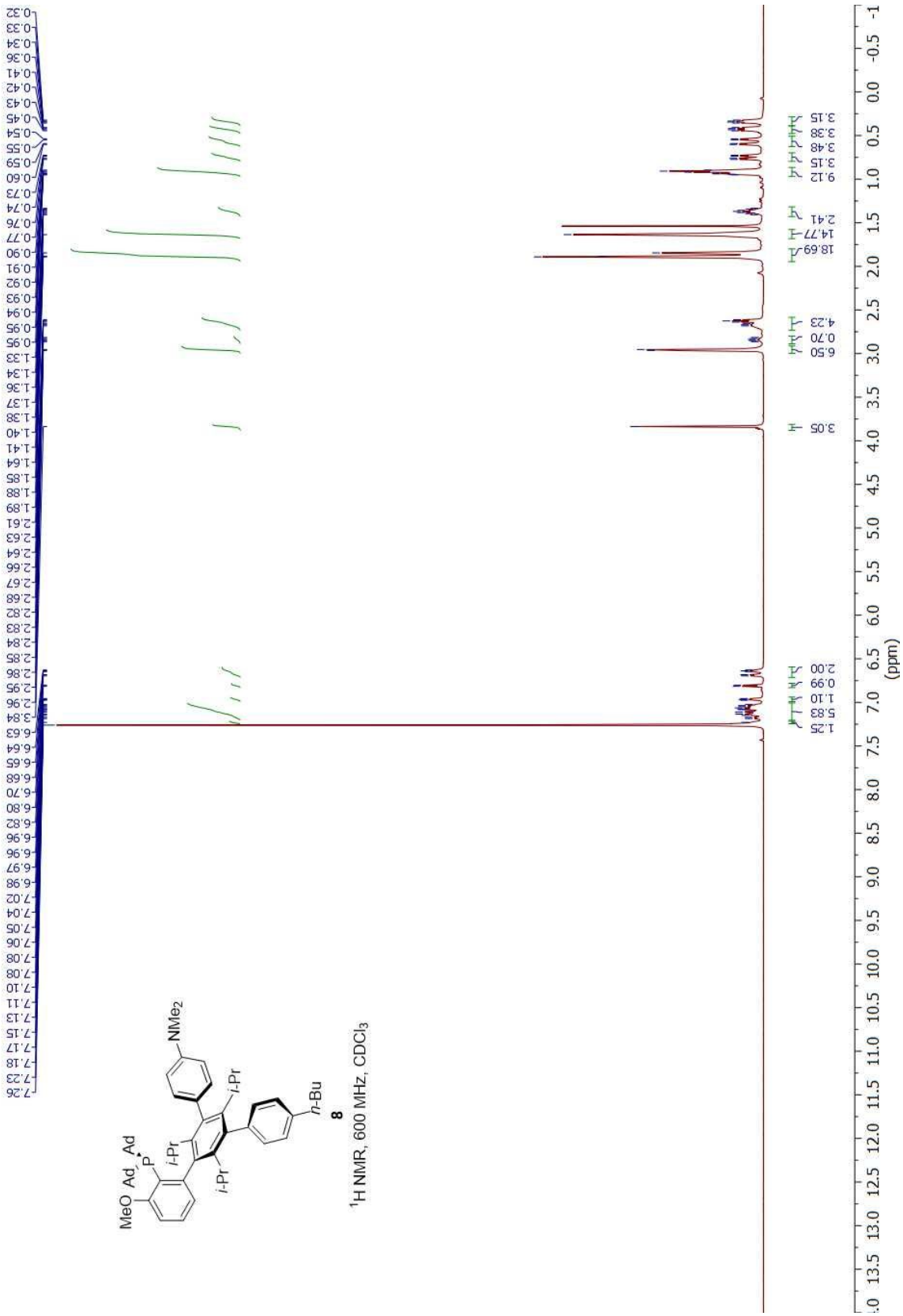




4

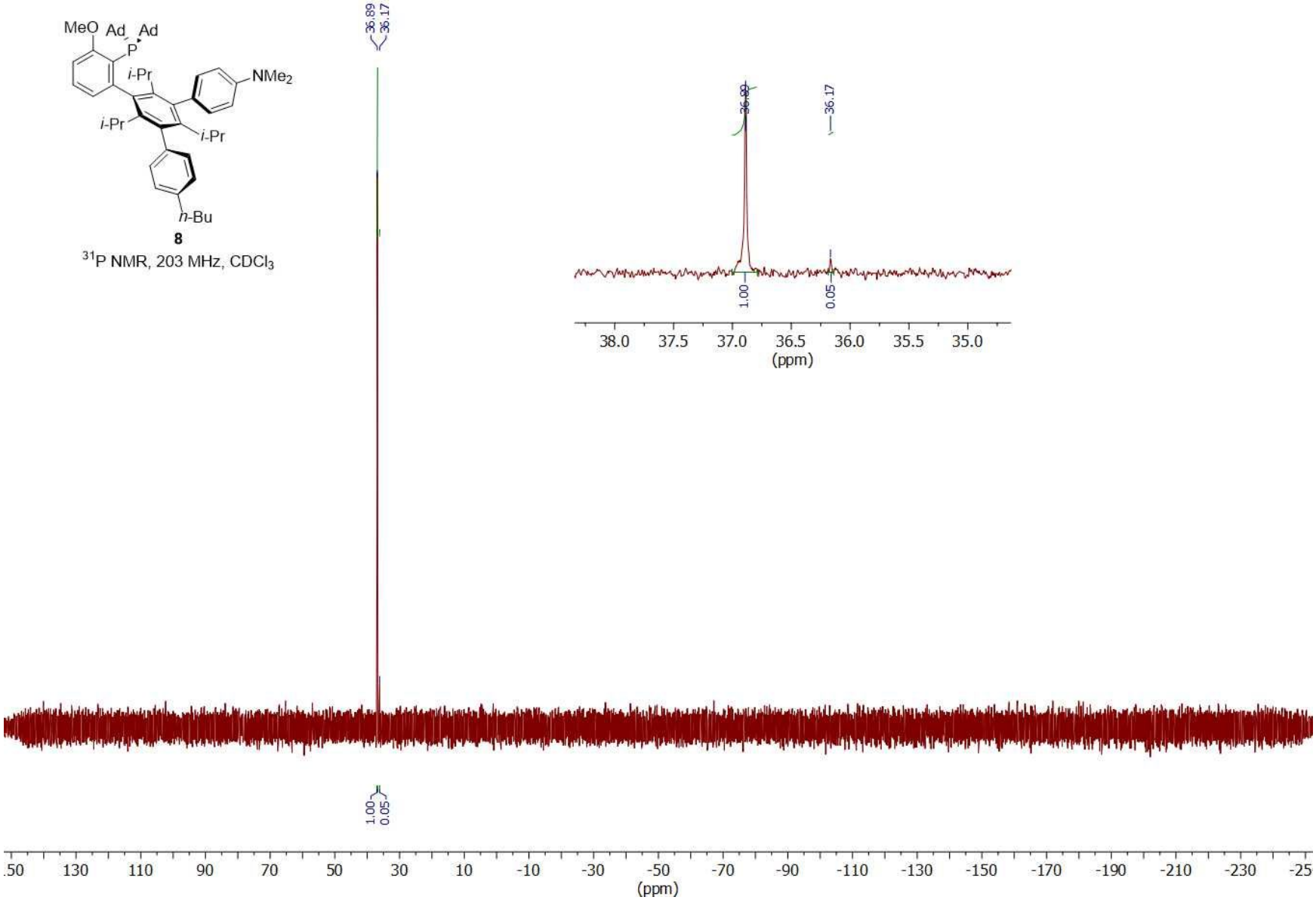
^{19}F NMR, 470 MHz, $CDCl_3$

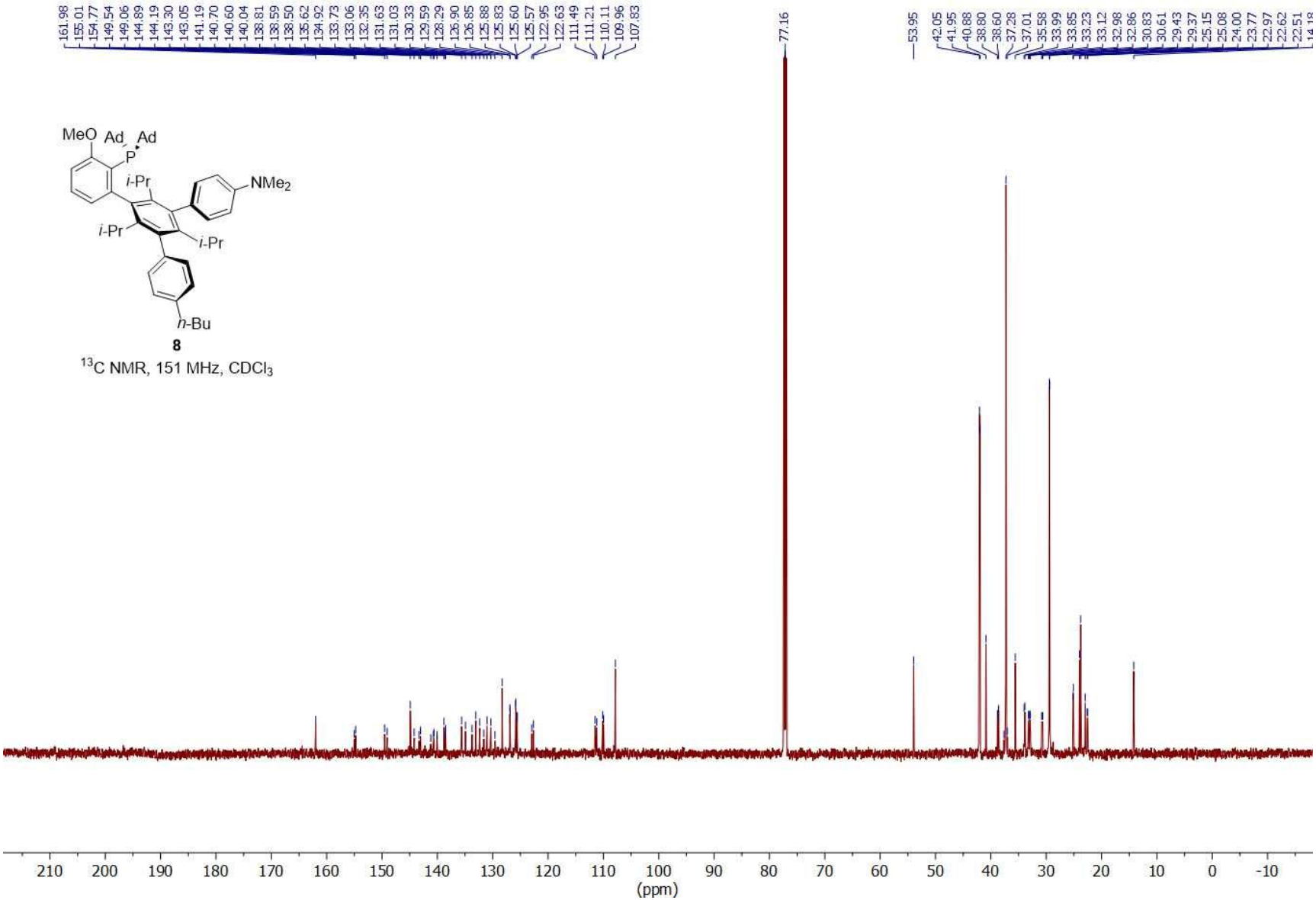

MeO
Ad
Ad
P
Pd
Br
i-Pr
i-Pr
i-Pr
OMe
OMe
CF3
4
13C NMR, 126 MHz, CDCl3
160.71
158.88
158.37
157.20
151.74
151.60
150.39
141.22
140.83
140.15
139.66
139.64
136.39
133.88
133.77
133.53
131.82
131.58
131.09
129.33
129.25
127.06
123.75
123.64
121.76
121.73
121.64
121.62
121.47
112.27
111.91
110.76
110.67
108.73
55.15
53.75
47.58
47.49
47.43
47.36
41.45
41.22
36.27
33.71
33.30
31.33
29.49
29.41
25.44
25.14
24.35
23.72
23.37
23.14
f1 (ppm)

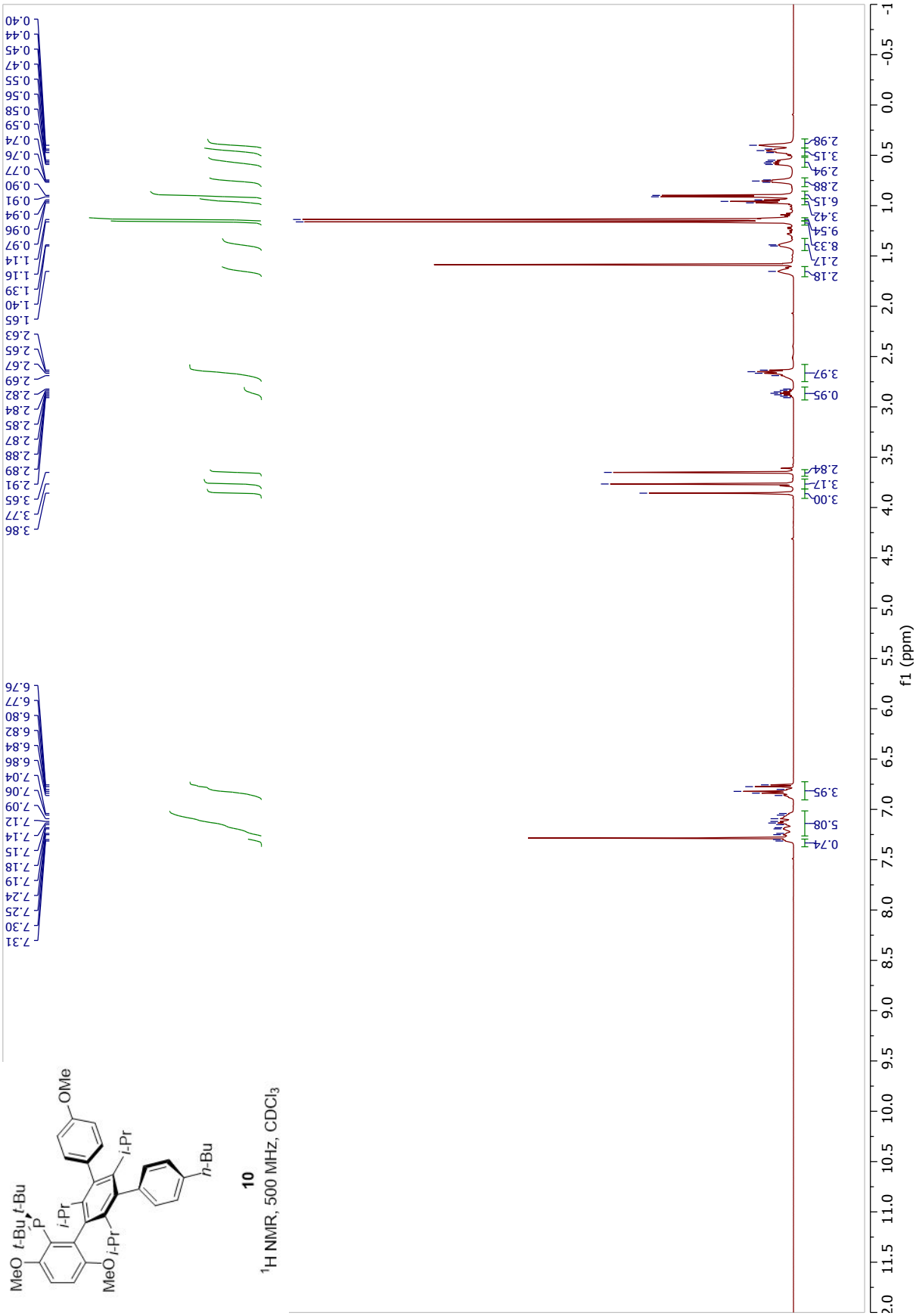

MeO
Ad
Ad
P
i-Pr
i-Pr
i-Pr
NMe2
n-Bu
8
1H NMR, 600 MHz, CDCl3
(ppm)

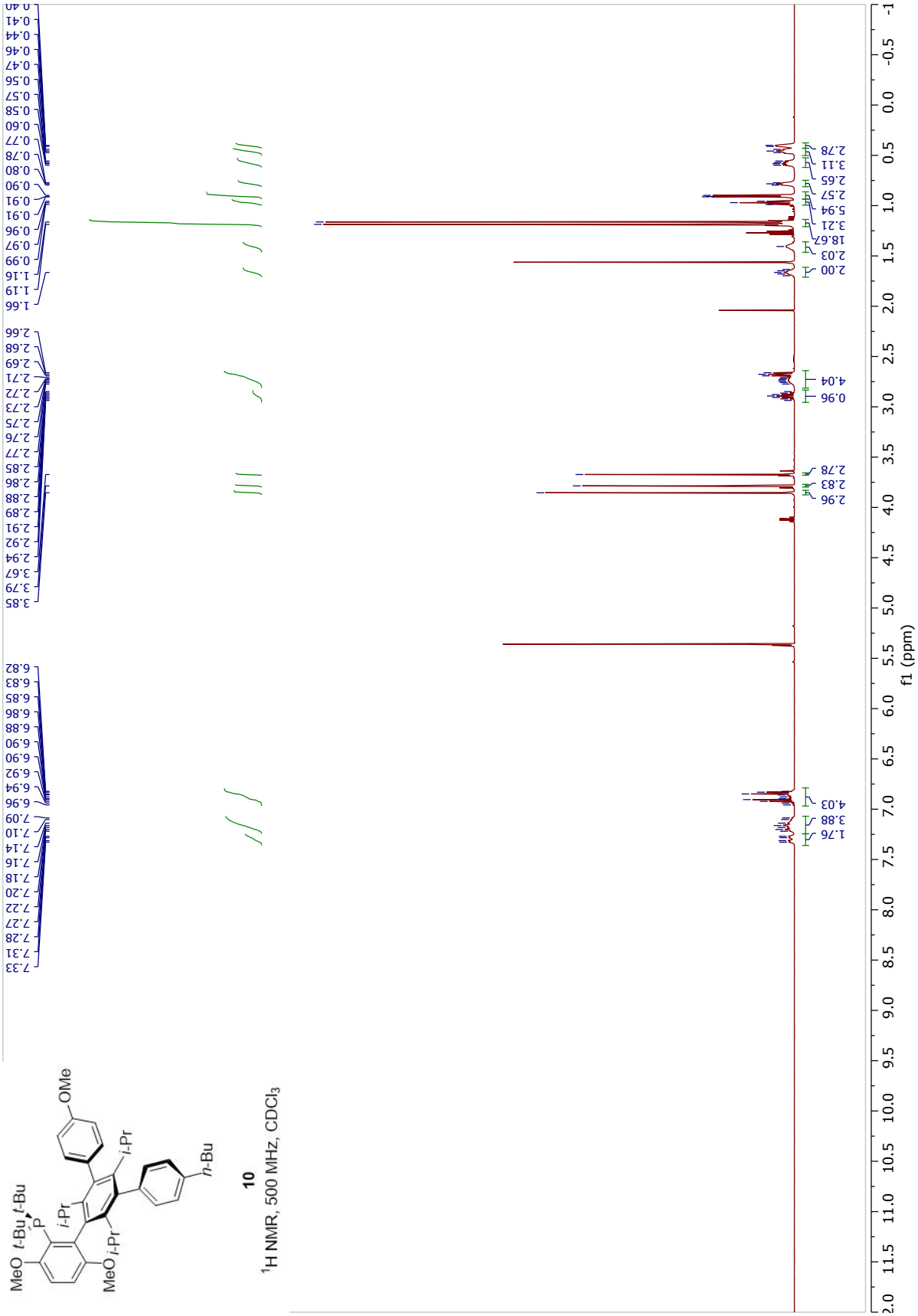
8

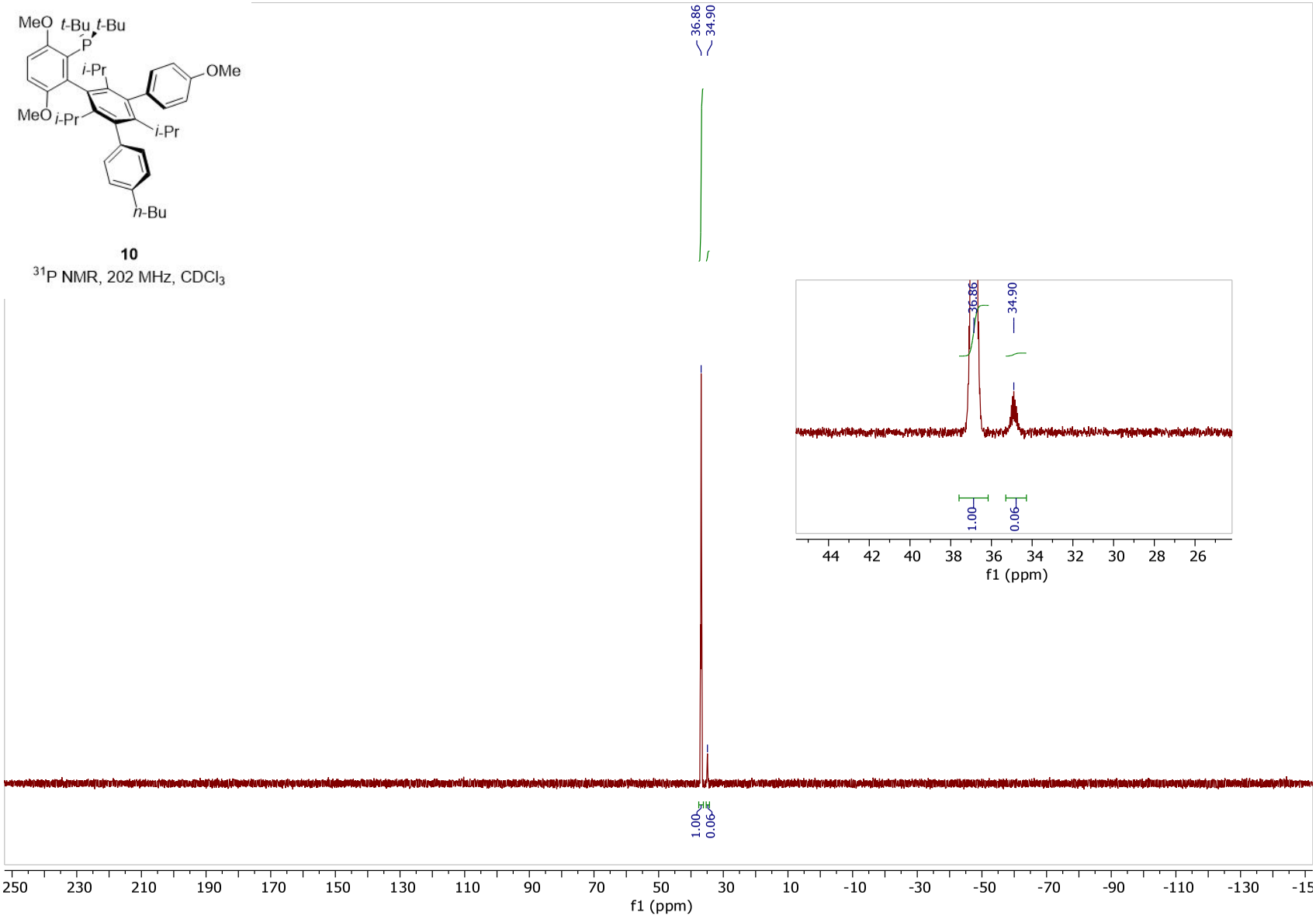
^{31}P NMR, 203 MHz, $CDCl_3$

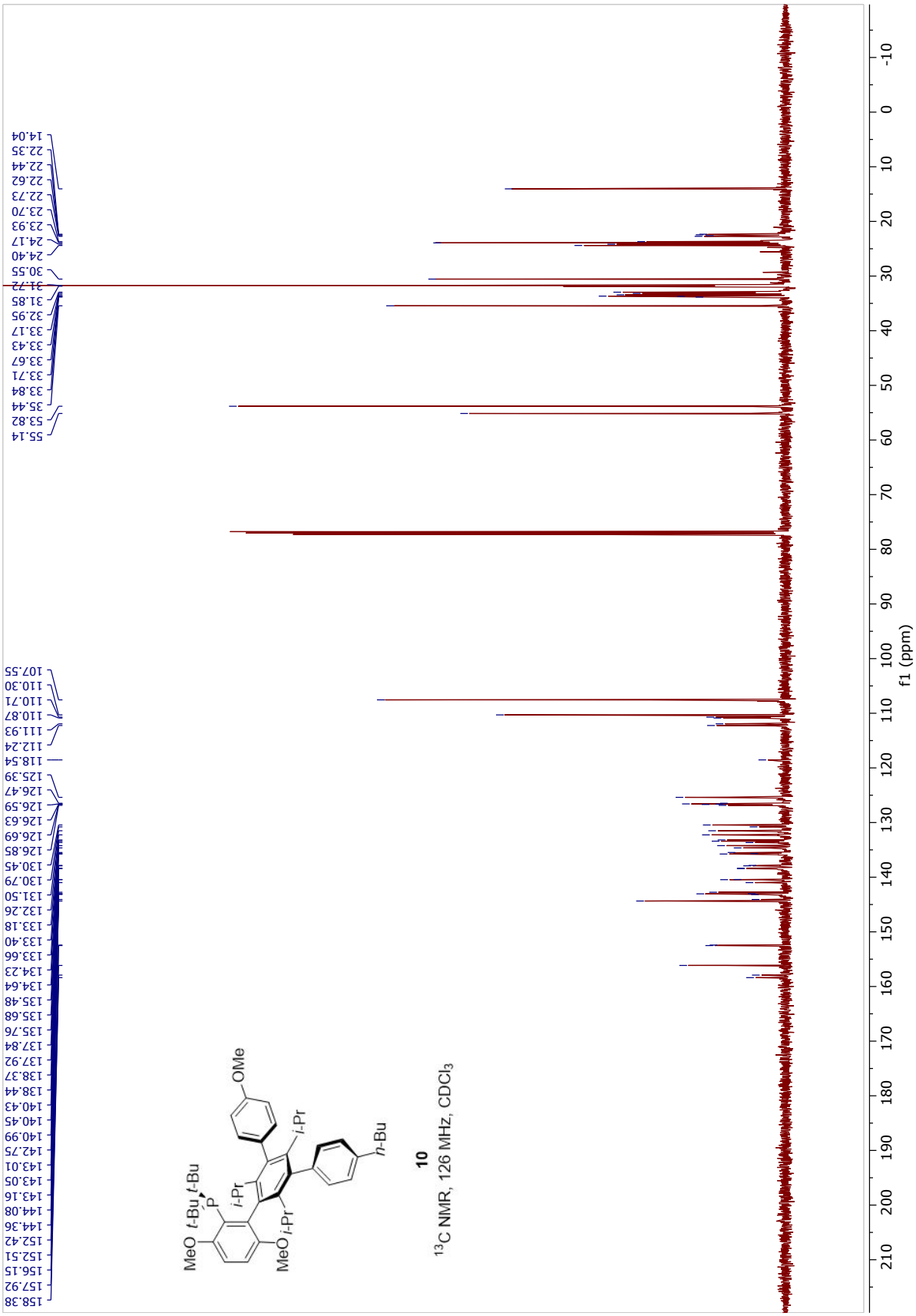



MeO
Ad
Ad
P
i-Pr
NMe2
i-Pr
i-Pr
n-Bu
8
13C NMR, 151 MHz, CDCl3
161.98
155.01
154.77
149.54
149.06
144.89
144.19
143.30
143.05
141.19
140.70
140.60
140.04
138.81
138.59
138.50
135.62
134.92
133.73
133.06
132.35
131.63
131.03
130.33
129.59
128.29
126.90
126.85
125.88
125.83
125.60
125.57
122.95
122.63
111.49
111.21
110.11
109.96
107.83
77.16
53.95
42.05
41.95
40.88
38.80
38.60
37.28
37.01
35.58
33.99
33.85
33.23
33.12
32.98
32.86
30.83
30.61
29.43
29.37
25.15
25.08
24.00
23.77
22.97
22.62
22.51
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
(ppm)


MeO
t-Bu
t-Bu
P
i-Pr
i-Pr
MeO
OMe
n-Bu
10
1H NMR, 500 MHz, CDCl3
f1 (ppm)


MeO
t-Bu
t-Bu
P
i-Pr
MeO
i-Pr
OMe
i-Pr
n-Bu
10
1H NMR, 500 MHz, CDCl3
f1 (ppm)


MeO
t-Bu
t-Bu
P
i-Pr
OMe
MeO
i-Pr
i-Pr
n-Bu
10
31P NMR, 202 MHz, CDCl3
36.86
34.90
1.00
0.06
f1 (ppm)


MeO
t-Bu
t-Bu
P
i-Pr
MeO
i-Pr
OMe
i-Pr
n-Bu
10
13C NMR, 126 MHz, CDCl3
158.38
157.92
156.15
152.51
152.42
144.36
144.08
143.16
143.05
143.01
142.75
140.99
140.45
140.43
138.44
138.37
137.92
137.84
135.76
135.68
135.48
134.64
134.23
133.66
133.40
133.18
132.26
131.50
130.79
130.45
126.85
126.69
126.63
126.59
126.47
125.39
118.54
112.24
111.93
110.87
110.71
110.30
107.55
55.14
53.82
35.44
33.84
33.71
33.67
33.43
33.17
32.95
31.85
31.72
30.55
24.40
24.17
23.93
23.70
22.73
22.62
22.44
22.35
14.04
f1 (ppm)