Supporting Information

Synthesis and Evaluation of C2-Symmetric SPIROL-based *bis*-Oxazoline Ligands

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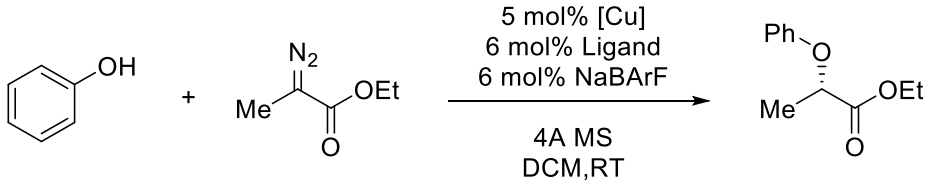
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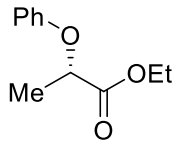
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General Information. Unless otherwise stated, all reagents were purchased from commercial suppliers (Sigma Aldrich, Fischer Scientific and Strem), and used without further purification. All reactions were carried out under an atmosphere of nitrogen in flame-dried glassware with magnetic stirring, unless otherwise noted. Air-sensitive reagents and solutions were transferred via syringe or cannula and were introduced to the apparatus through rubber septa. Reactions were cooled via external cooling baths: ice water (0°C), dry ice-acetone (–78°C), or Neslab CB 80 immersion cooler (0 to –60°C). Heating was achieved using a silicone oil bath with regulated by an electronic contact thermometer. Deionized water was used in the preparation of all aqueous solutions and for all aqueous extractions. Solvents used for extraction and column chromatography were ACS or HPLC grade (purchased from Fischer Scientific). Dry tetrahydrofuran (THF), dichloromethane (DCM), toluene (PhMe), and diethyl ether (Et_2O) were prepared by filtration through a column (Innovative Technologies) of activated alumina under nitrogen atmosphere. Reactions were monitored by nuclear magnetic resonance (NMR, see below) or thin layer chromatography (TLC) on silica gel precoated glass plates (0.25 mm, SiliCycle, SiliaPlate). TLC plate visualization was accomplished by irradiation with UV light at 254 nm or by staining with a potassium permanganate ($KMnO_4$) or cerium ammonium molybdate (CAM) solution. Flash chromatography was performed using SiliCycle SiliaFlash P60 (230-400 mesh) silica gel. Powdered 4 Å molecular sieves were pre-activated by flame-drying under vacuum before use.

Proton (^1H), carbon (^{13}C), and fluorine (^{19}F) NMR spectra were recorded on Varian VNMRS 700 (700 MHz), Varian VNMRS 600 (600 MHz), Bruker Avance Neo 500 (500 MHz), Varian VNMRS 500 (500 MHz), Varian INOVA 500 (500 MHz), or Varian MR400 (400 MHz). ^1H, ^{13}C, and ^{19}F NMR spectra are referenced on a unified scale, where the single reference is the frequency of the residual solvent peak in the ^1H NMR spectrum. Chemical shifts (δ) are reported in parts per million (ppm) relative to tetramethylsilane for ^1H and ^{13}C NMR and trichlorofluoromethane for ^{19}F. Data is reported as (br = broad, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet; coupling constant(s) in Hz; integration). Slight shape deformation of the peaks in some cases due to weak coupling (e.g. aromatic protons) is not explicitly mentioned. High resolution mass spectra (HRMS) were recorded on the Agilent 6230 TOF HPLC-MS. The enantiomeric excesses were determined by HPLC analysis employing a chiral stationary phase column and conditions specified in the individual experiment. Optical rotations were measured at room temperature in a solvent of choice on a JASCO P-2000 digital polarimeter at 589 nm (D-line). Fourier-transform infrared spectroscopy (FT-IR) were performed at room temperature on a Thermo-Nicolet IS-50 equipped with an ATR accessory with a diamond crystal and converted into inverse domain (wavenumbers in cm^{-1}).



The CuCl (1.0 mg, 0.01 mmol), **4** (6.8 mg, 0.012 mmol), NaBArF (11.3 mg, 0.012 mmol) and 300 mg 4Å molecular sieves were introduced into an oven-dried 1-dram vial. DCM (2.0 mL) was added, and the solution was stirred at room temperature under nitrogen for 2 hours. Phenol (94.1 mg, 1.0 mmol) and ethyl α-diazopropionate (26.0 mg, 0.2 mmol) were added to the reaction mixture, and the resulting mixture was stirred at room temperature for 3 hours. After filtrating and removing solvent in vacuum the product was purified by the column chromatography (SiO_2, 6% Et_2OAc in hexanes) to afford the product as a clear oil (34 mg, 88%, 97% ee)



ethyl (*S*)-2-phenoxypropanoate

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.30 – 7.26 (m, 2H), 6.97 (td, *J* = 7.4, 1.1 Hz, 1H), 6.90 – 6.86 (m, 2H), 4.75 (q, *J* = 6.8 Hz, 1H), 4.22 (q, *J* = 7.1 Hz, 2H), 1.62 (d, *J* = 6.8 Hz, 3H), 1.25 (t, *J* = 7.1 Hz, 3H).

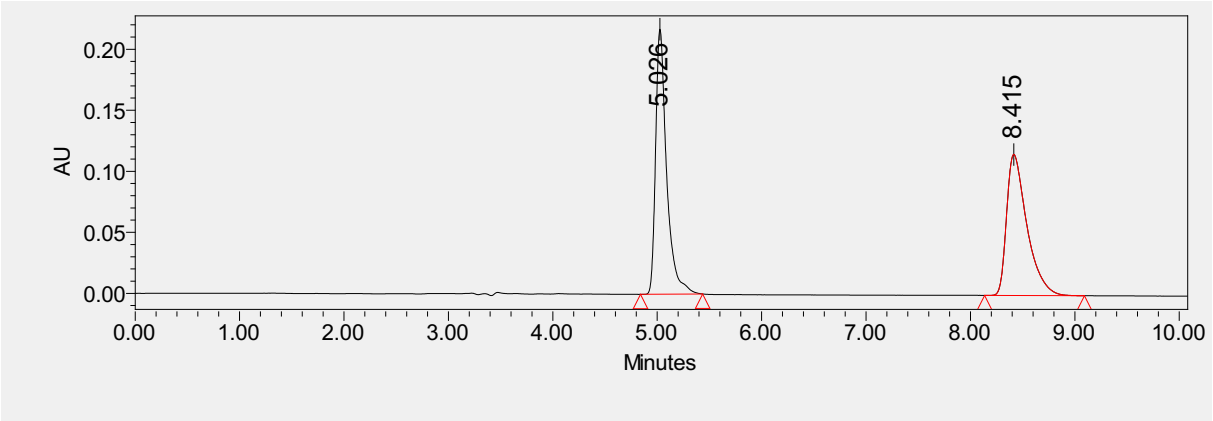
^{13}C NMR (176 MHz, cdcl$_3$) δ 172.26, 157.58, 129.50, 121.53, 115.09, 72.60, 61.24, 18.55, 14.10.

ESI-HRMS Calcd. for $C_{11}H_{15}O_3^+$ 195.1016 $[M+H]^+$, found 195.1011

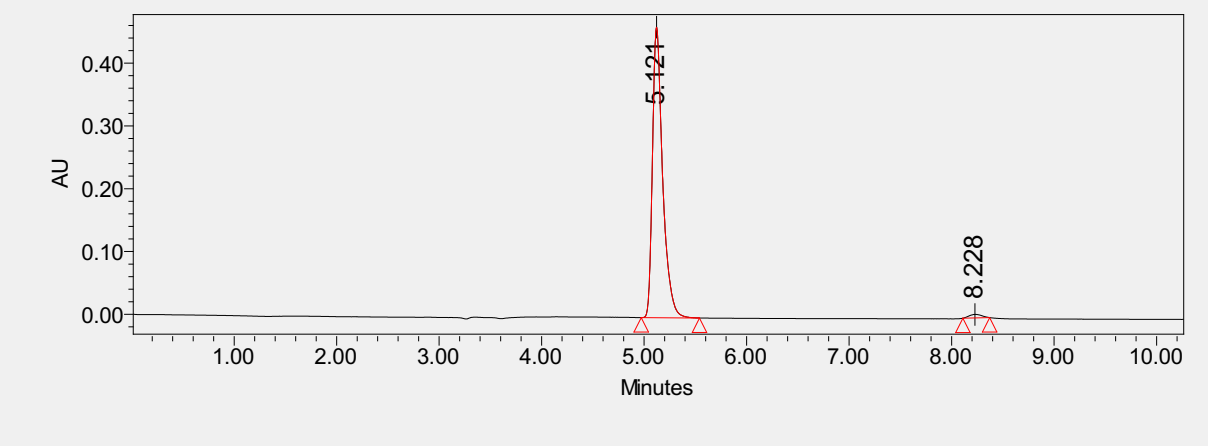
IR (film): ν_{max} = 2986, 2938, 2125, 1751, 1732, 1600, 1588, 1494, 1445, 1375, 1273, 1238, 1191, 1174, 1132, 1096, 1078, 1049, 1017, 945, 884, 750, 624 cm^{-1}

$[\alpha]_D$: -23.20 (c = 2.00 in $CHCl_3$) [Literature[2]: **$[\alpha]_D$**: -41.3 (c = 0.8 in $CHCl_3$) for 90% ee]

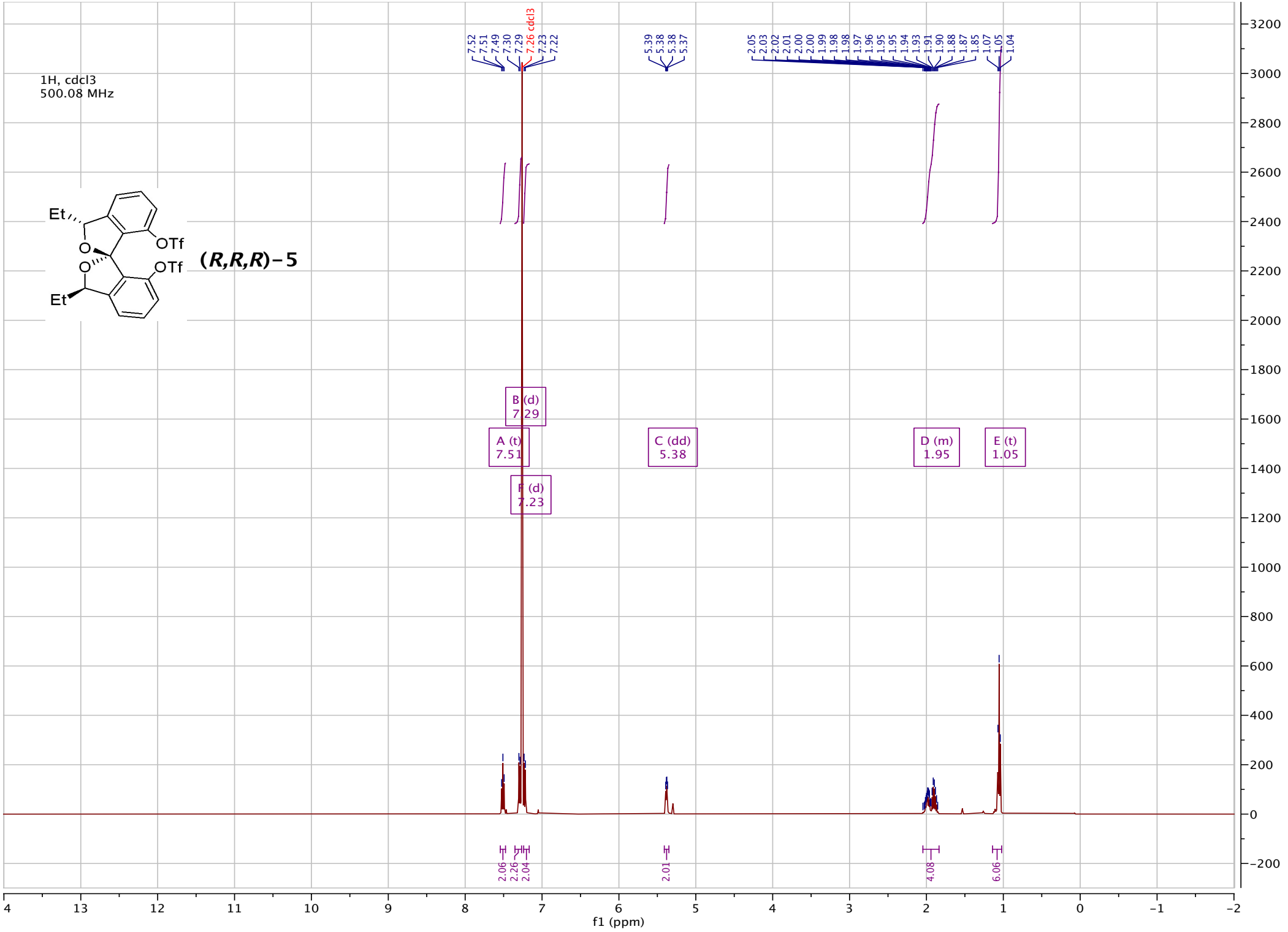
ee: 97% ee [HPLC condition: Chiralcel OD-H column, n-Hexane/i-PrOH = 90:10, flow rate = 1.0 mL/min, , t_R = 5.02 min for (*S*)-enantiomer, t_R = 8.41 min for (*R*)-enantiomer]

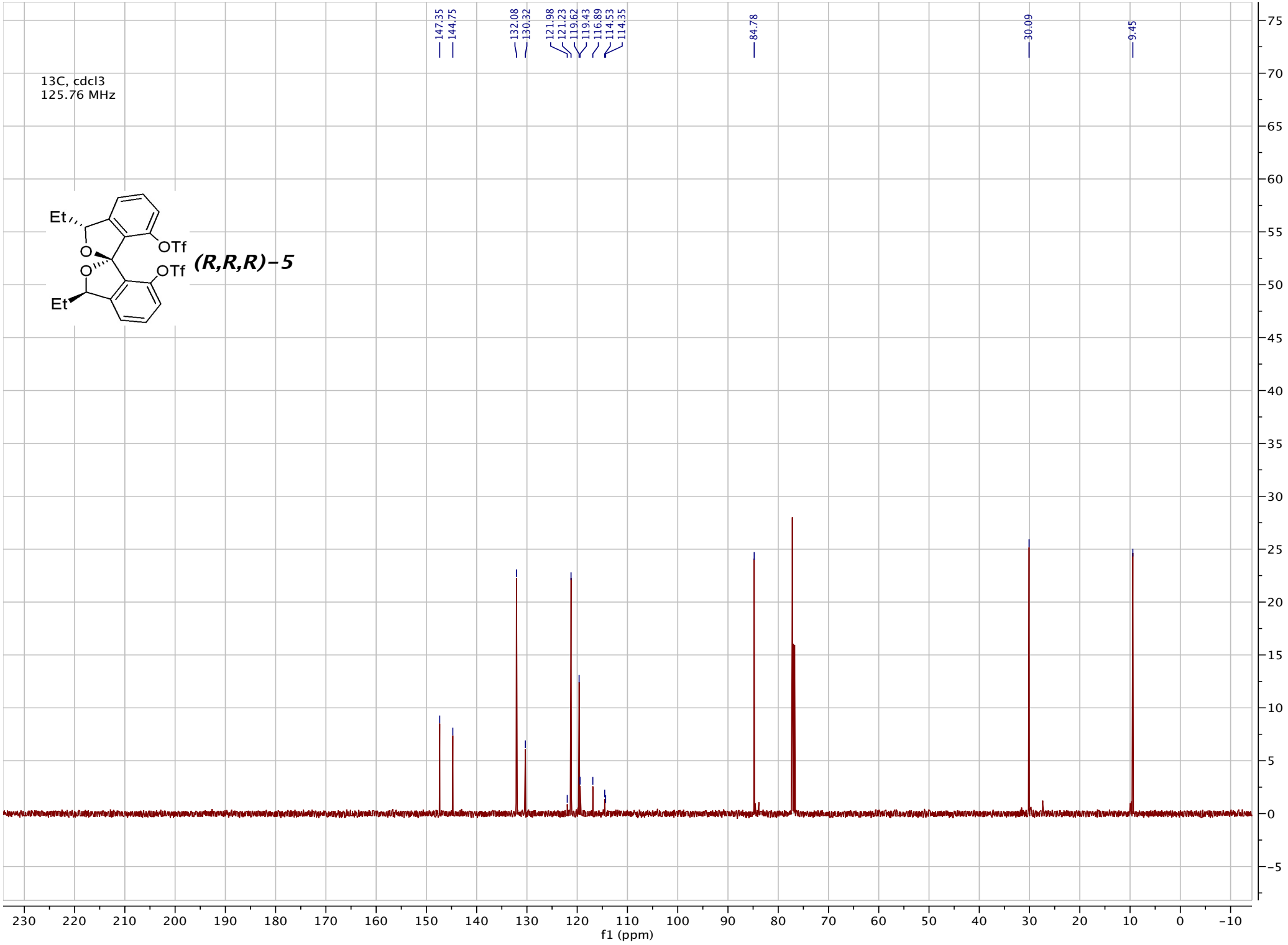


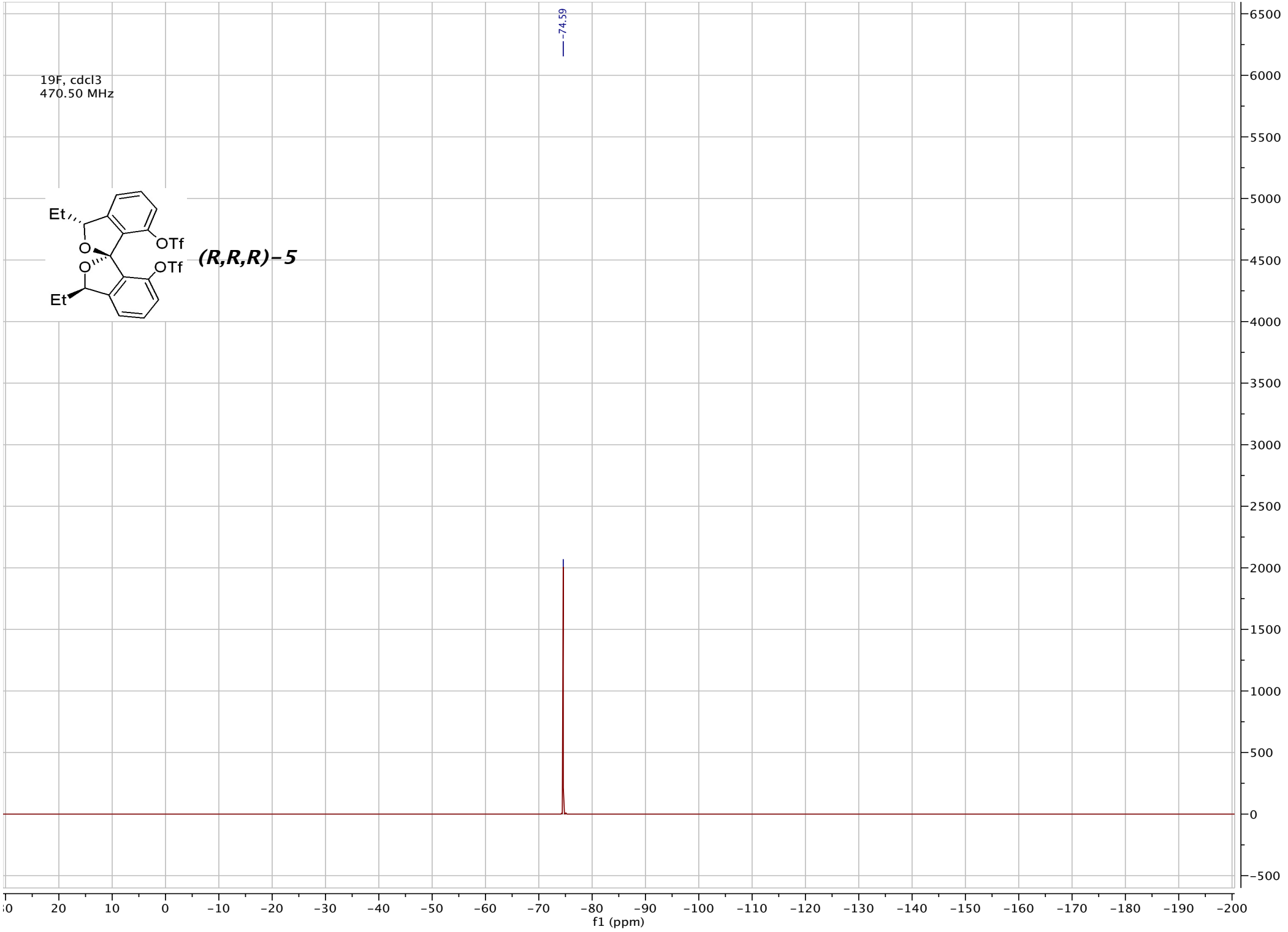
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2	8.415	1407630	49.52	104333	bb		Unknown

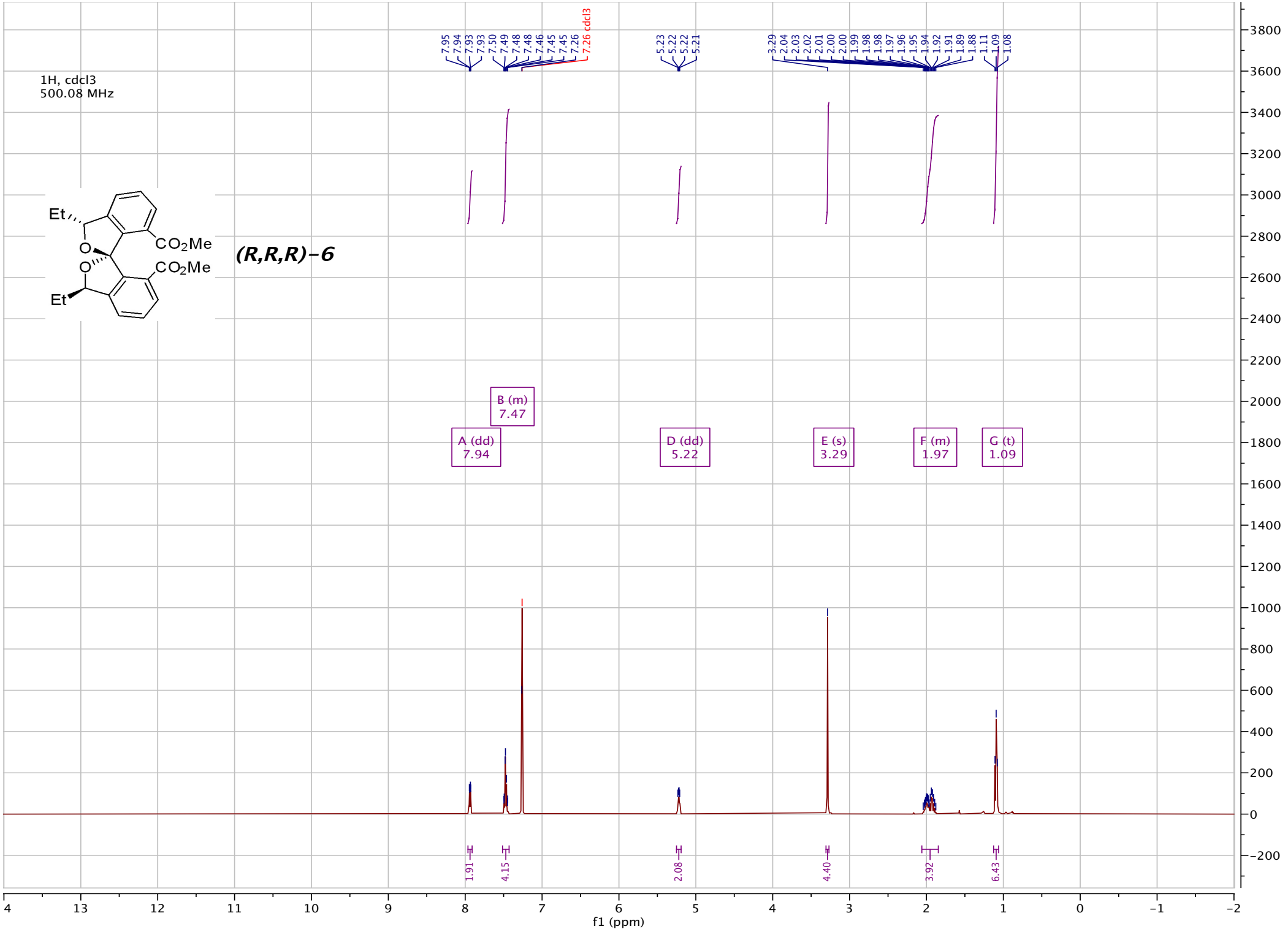


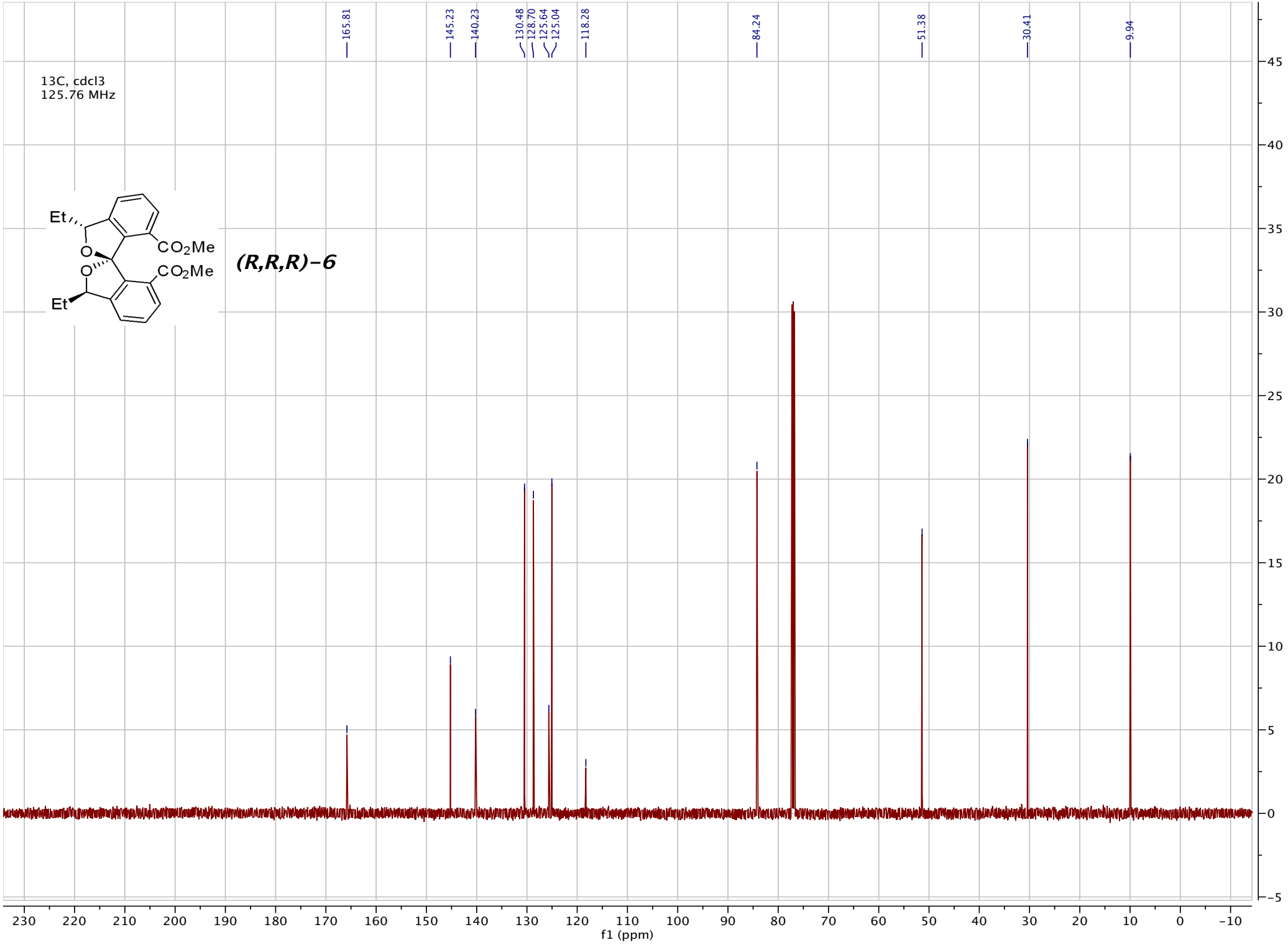
	Retention Time	Area	% Area	Height	Int Type	Amount	Peak Type
1	5.121	3199041	98.52	462566	bb		Unknown
2	8.228	47974	1.48	5682	bb		Unknown


1H, cdcl3
500.08 MHz
Et
O
OTf
O
OTf
Et
(R,R,R)−5
7.52
7.51
7.49
7.30
7.29
7.26 cdcl3
7.23
7.22
5.39
5.38
5.38
5.37
2.05
2.03
2.02
2.01
2.00
2.00
1.99
1.98
1.98
1.97
1.96
1.95
1.95
1.94
1.93
1.91
1.90
1.88
1.87
1.85
1.07
1.05
1.04
B (d)
7.29
A (t)
7.51
F (d)
7.23
C (dd)
5.38
D (m)
1.95
E (t)
1.05
2.06
2.26
2.04
2.01
4.08
6.06
f1 (ppm)

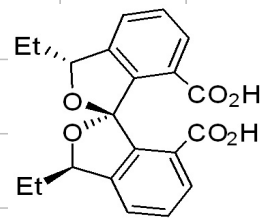

147.35
144.75
132.08
130.32
121.98
121.23
119.62
119.43
116.89
114.53
114.35
84.78
30.09
9.45
13C, cdcl3
125.76 MHz
Et
O
OTf
O
OTf
Et
(R,R,R)-5
f1 (ppm)


19F, cdcl3
470.50 MHz
-74.59
Et
O
OTf
O
OTf
Et
(R,R,R)–5
f1 (ppm)

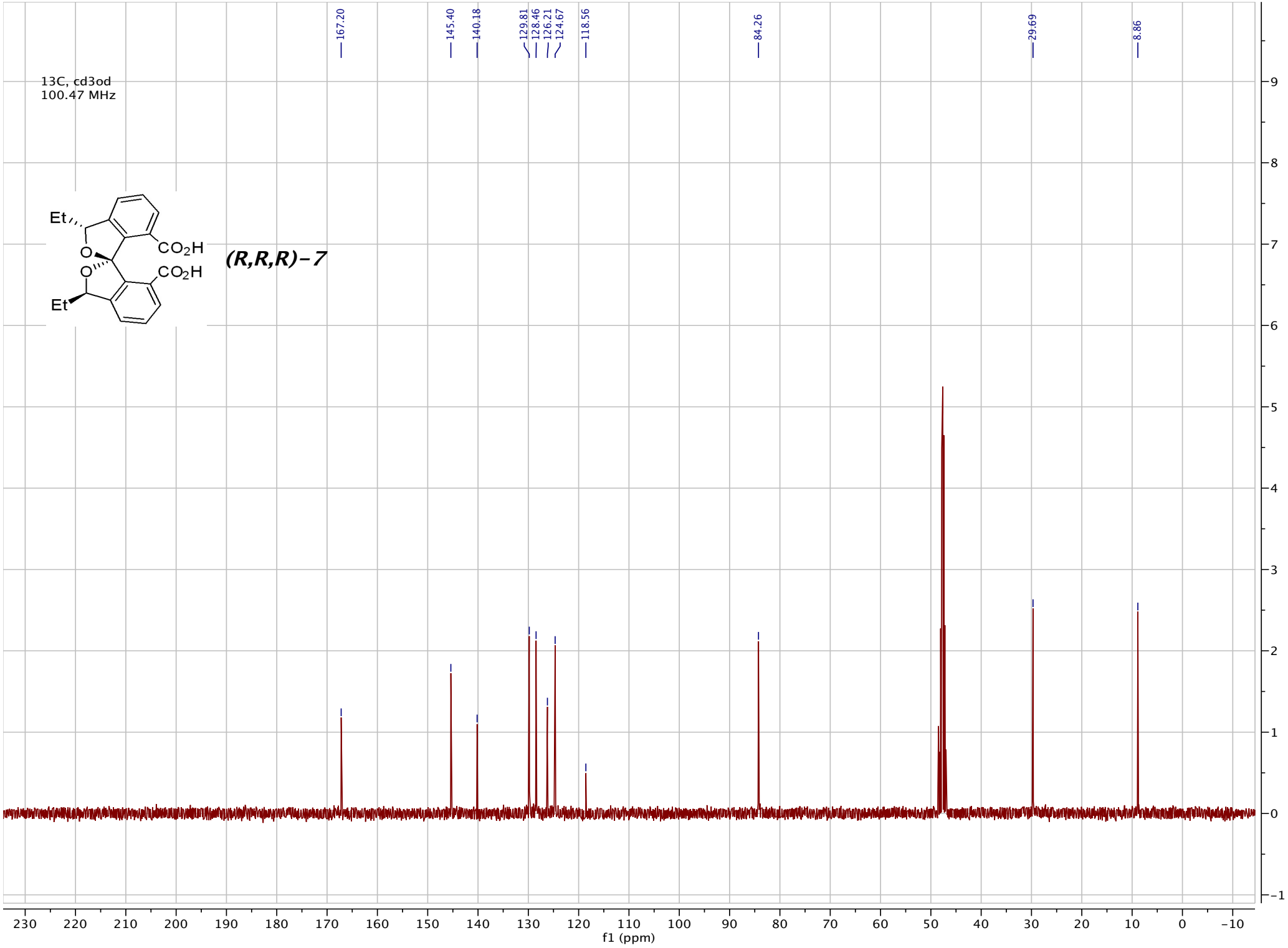

1H, cdcl3
500.08 MHz
(R,R,R)-6
Et
CO2Me
CO2Me
Et
7.95 7.94 7.93 7.93 7.50 7.49 7.48 7.48 7.46 7.45 7.45 7.26 7.26 cdcl3
5.23 5.22 5.22 5.21
3.29 2.04 2.03 2.02 2.01 2.00 2.00 1.99 1.98 1.98 1.97 1.96 1.95 1.94 1.92 1.91 1.89 1.88 1.11 1.09 1.08
A (dd) 7.94
B (m) 7.47
D (dd) 5.22
E (s) 3.29
F (m) 1.97
G (t) 1.09
1.91
4.15
2.08
4.40
3.92
6.43
f1 (ppm)

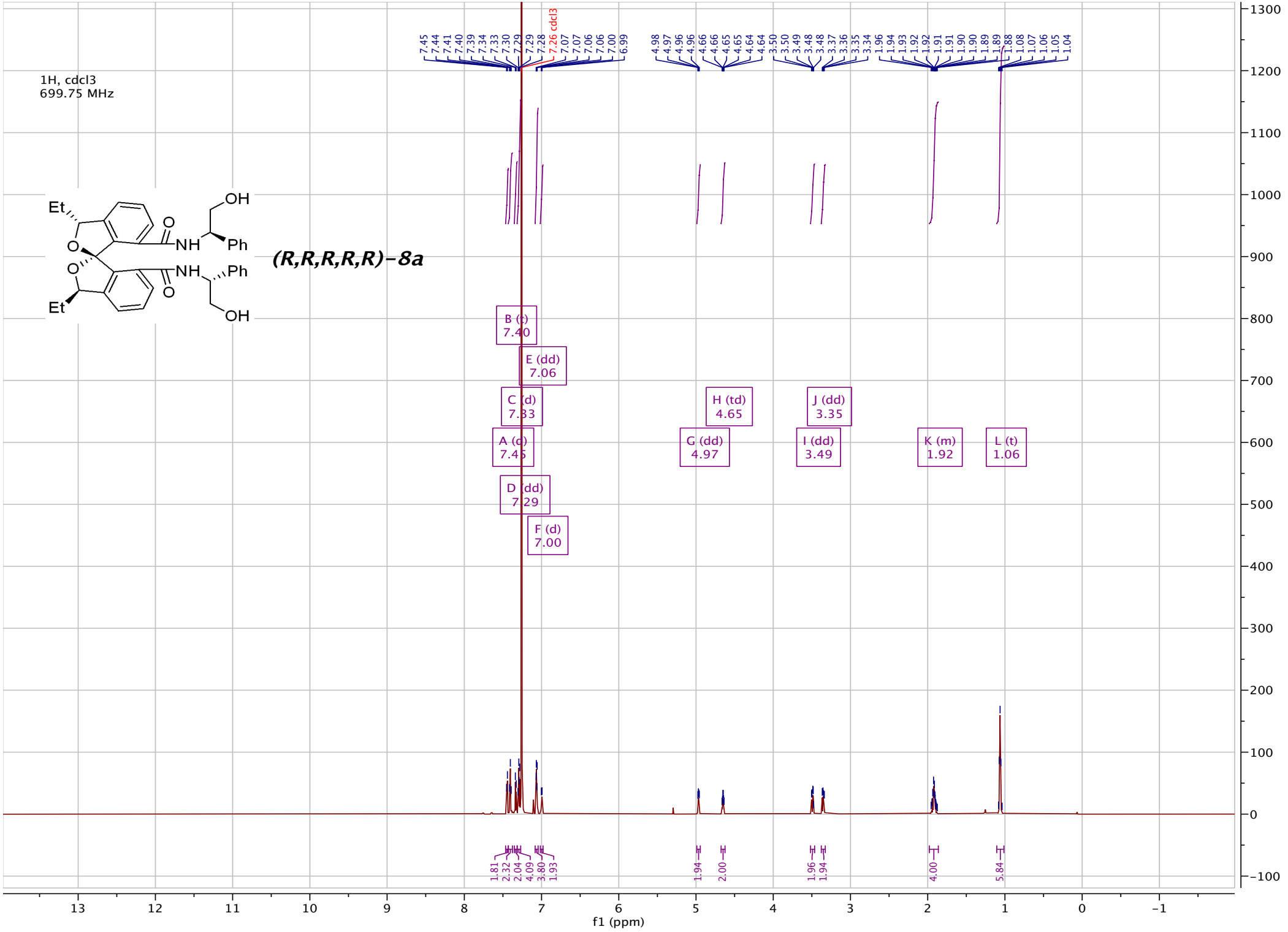

13C, cdcl3
125.76 MHz
Et
O
O
Et
CO2Me
CO2Me
(R,R,R)-6
165.81
145.23
140.23
130.48
128.70
125.64
125.04
118.28
84.24
51.38
30.41
9.94
f1 (ppm)

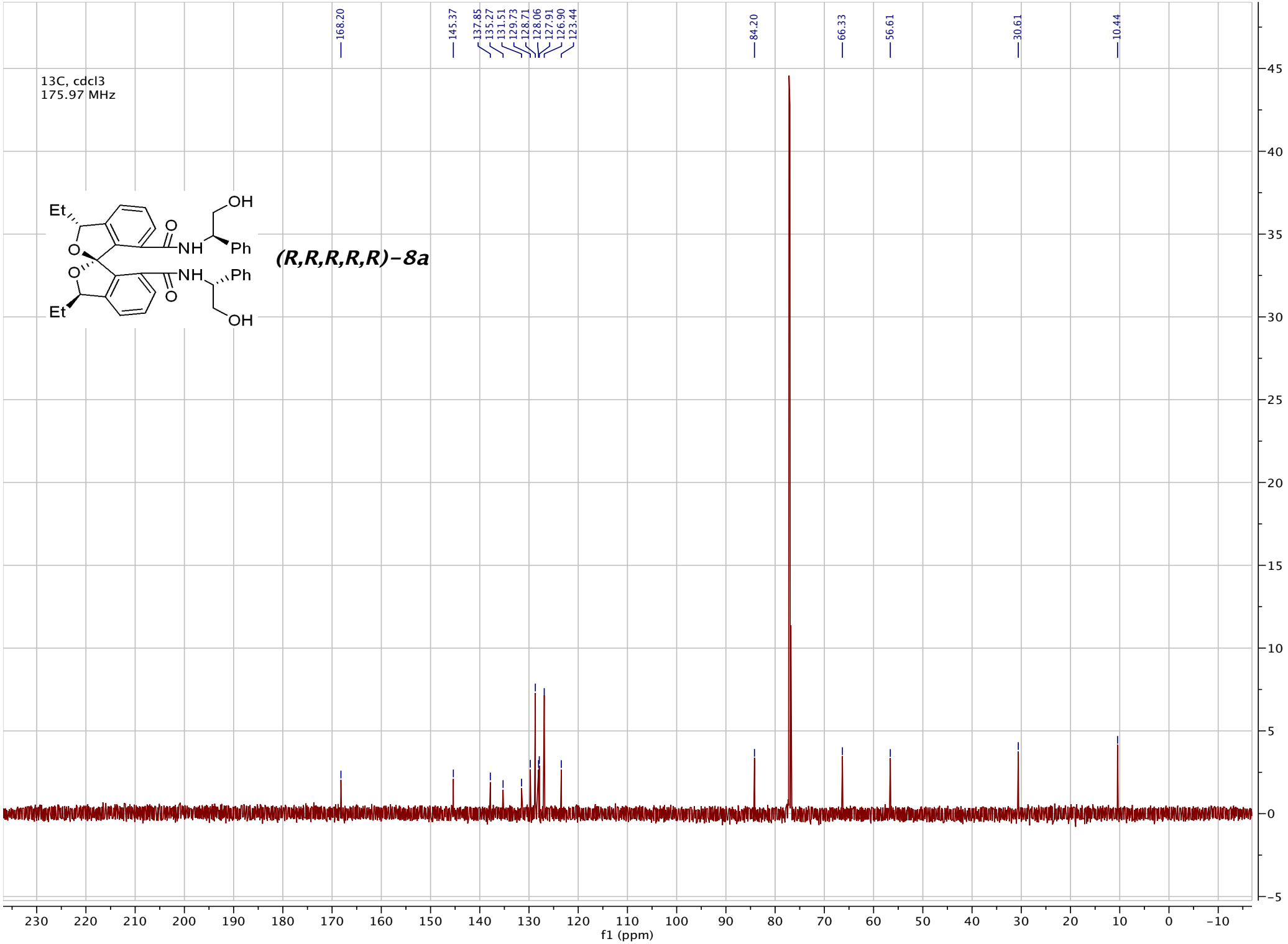
1H, cd3od
399.54 MHz

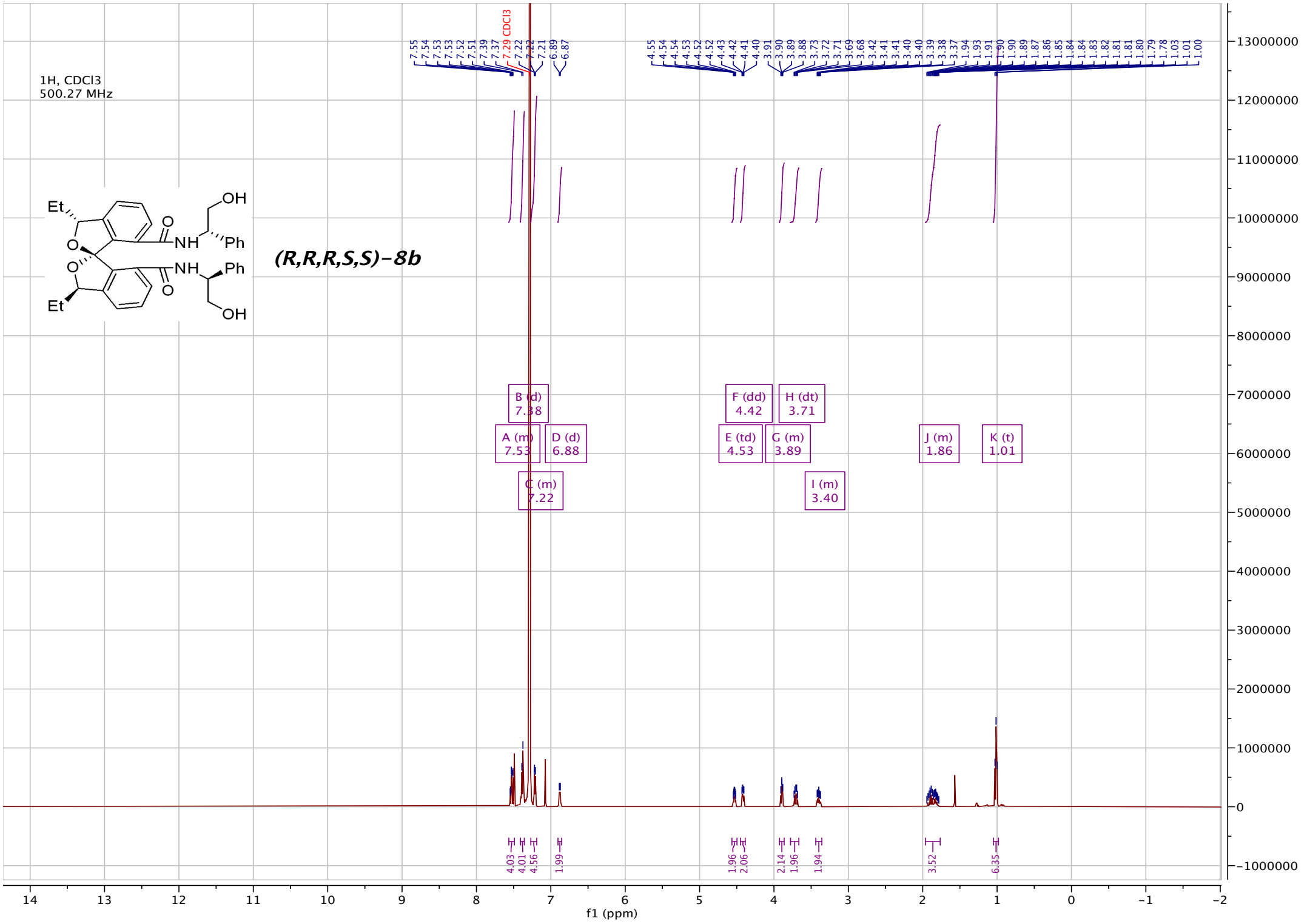


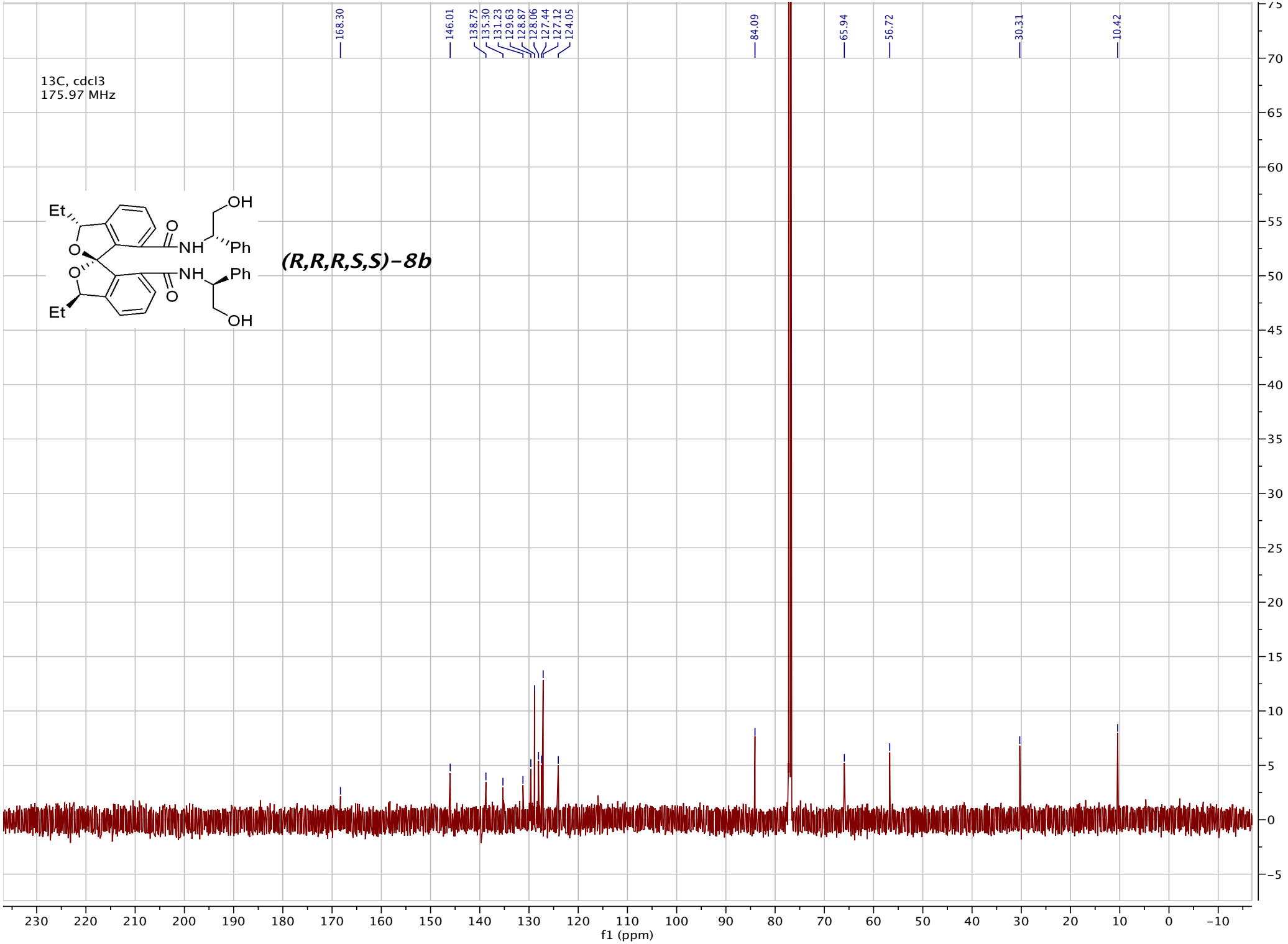
(R,R,R)–7

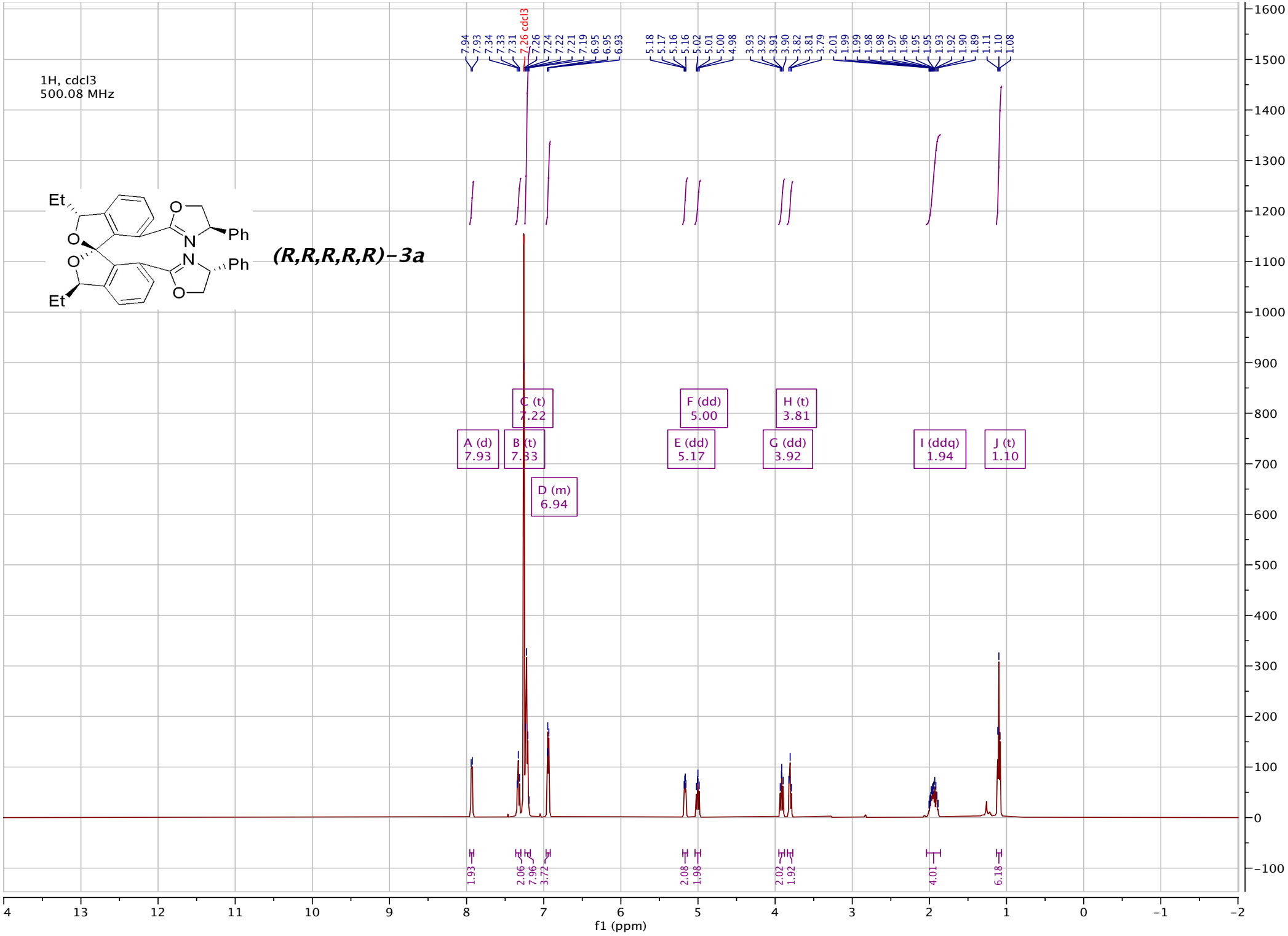

13C, cd3od
100.47 MHz
Et
O
O
Et
CO2H
CO2H
(R,R,R)-7
167.20
145.40
140.18
129.81
128.46
126.21
124.67
118.56
84.26
29.69
8.86
f1 (ppm)

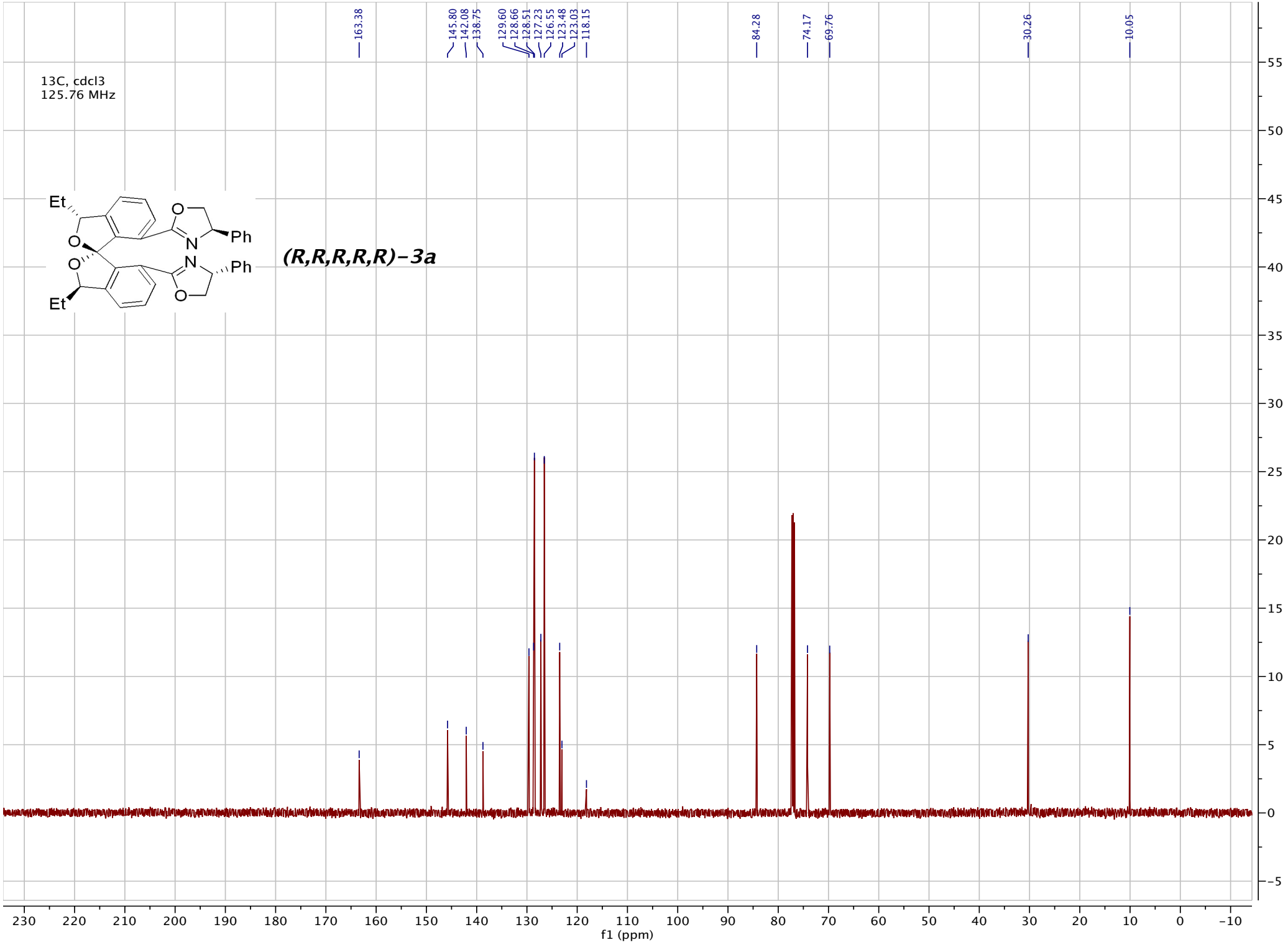

1H, cdcl3
699.75 MHz
(R,R,R,R,R)–8a
B (t)
7.40
E (dd)
7.06
C (d)
7.33
A (o)
7.45
D (dd)
7.29
F (d)
7.00
H (td)
4.65
G (dd)
4.97
J (dd)
3.35
I (dd)
3.49
K (m)
1.92
L (t)
1.06
f1 (ppm)

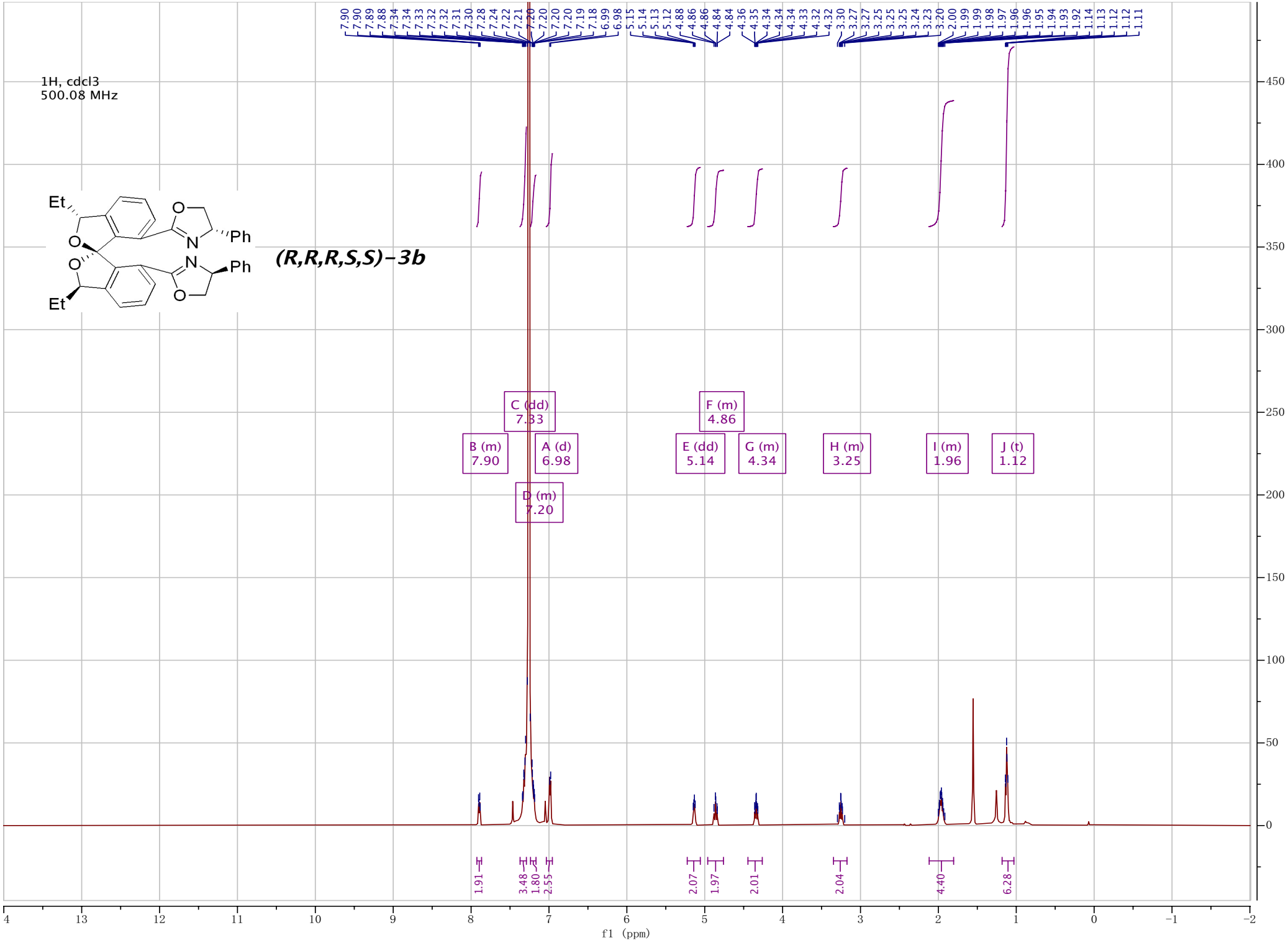

13C, cdcl3
175.97 MHz
168.20
145.37
137.85
135.27
131.51
129.73
128.71
128.06
127.91
126.90
123.44
84.20
66.33
56.61
30.61
10.44
Et
OH
O
NH
Ph
O
O
NH
Ph
O
Et
OH
(R,R,R,R,R)–8a
f1 (ppm)

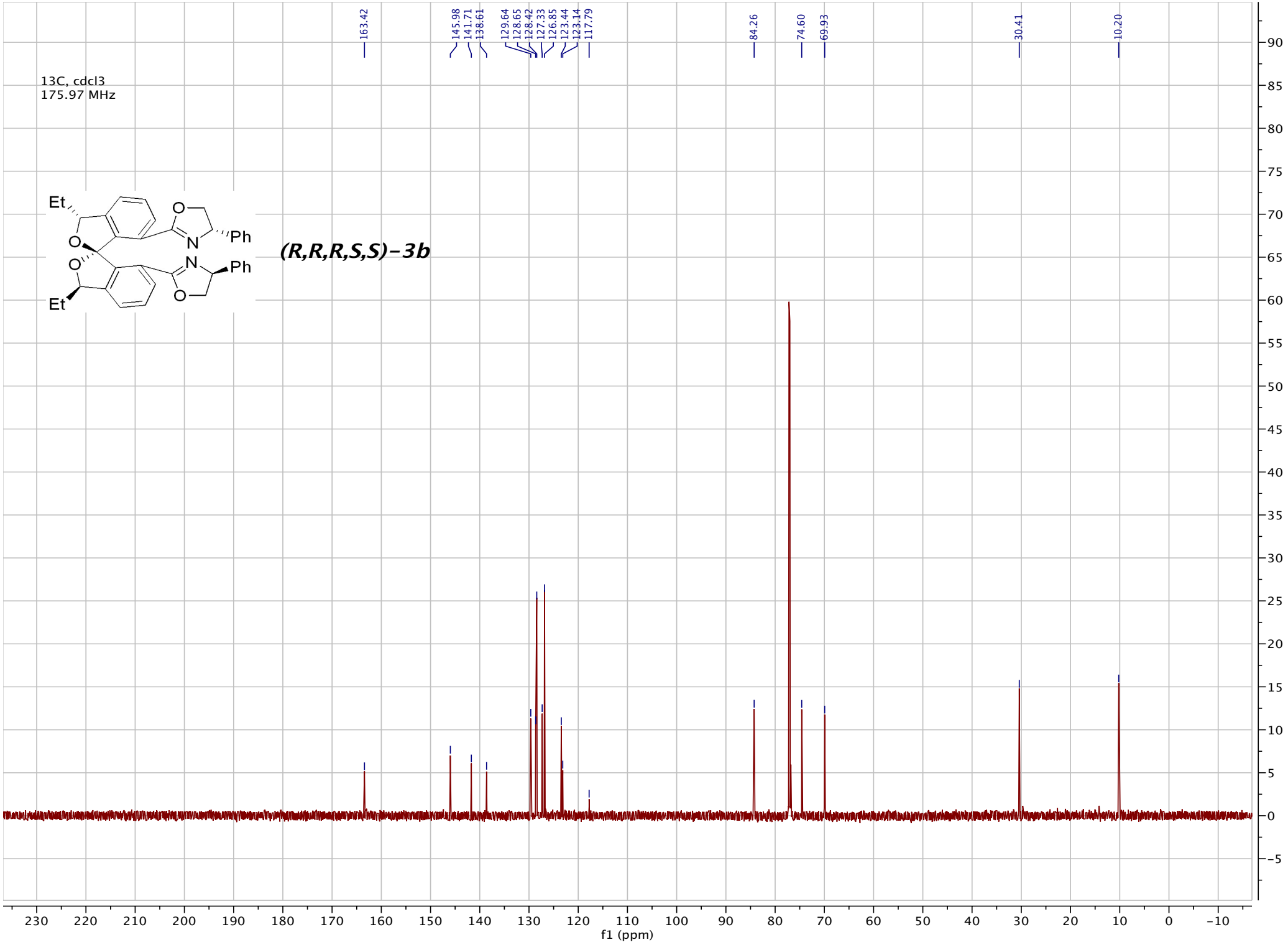

1H, CDCl3
500.27 MHz
(R,R,R,S,S)-8b
B (d) 7.38
A (m) 7.53
D (d) 6.88
C (m) 7.22
F (dd) 4.42
H (dt) 3.71
E (td) 4.53
G (m) 3.89
I (m) 3.40
J (m) 1.86
K (t) 1.01
f1 (ppm)

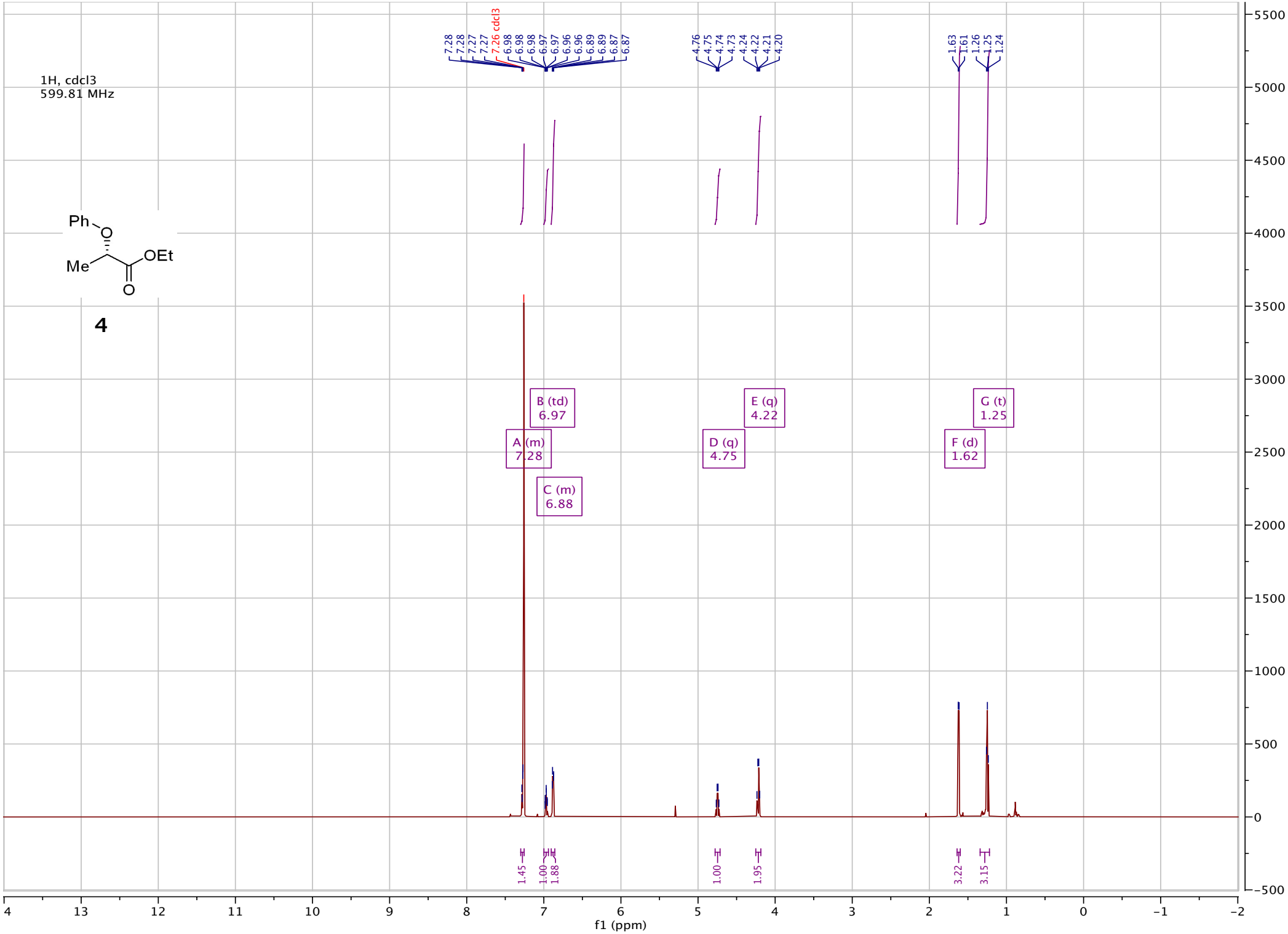

168.30
146.01
138.75
135.30
131.23
129.63
128.87
128.06
127.44
127.12
124.05
84.09
65.94
56.72
30.31
10.42
13C, cdcl3
175.97 MHz
Et
OH
O
NH
Ph
O
NH
Ph
O
Et
OH
(R,R,R,S,S)-8b
f1 (ppm)

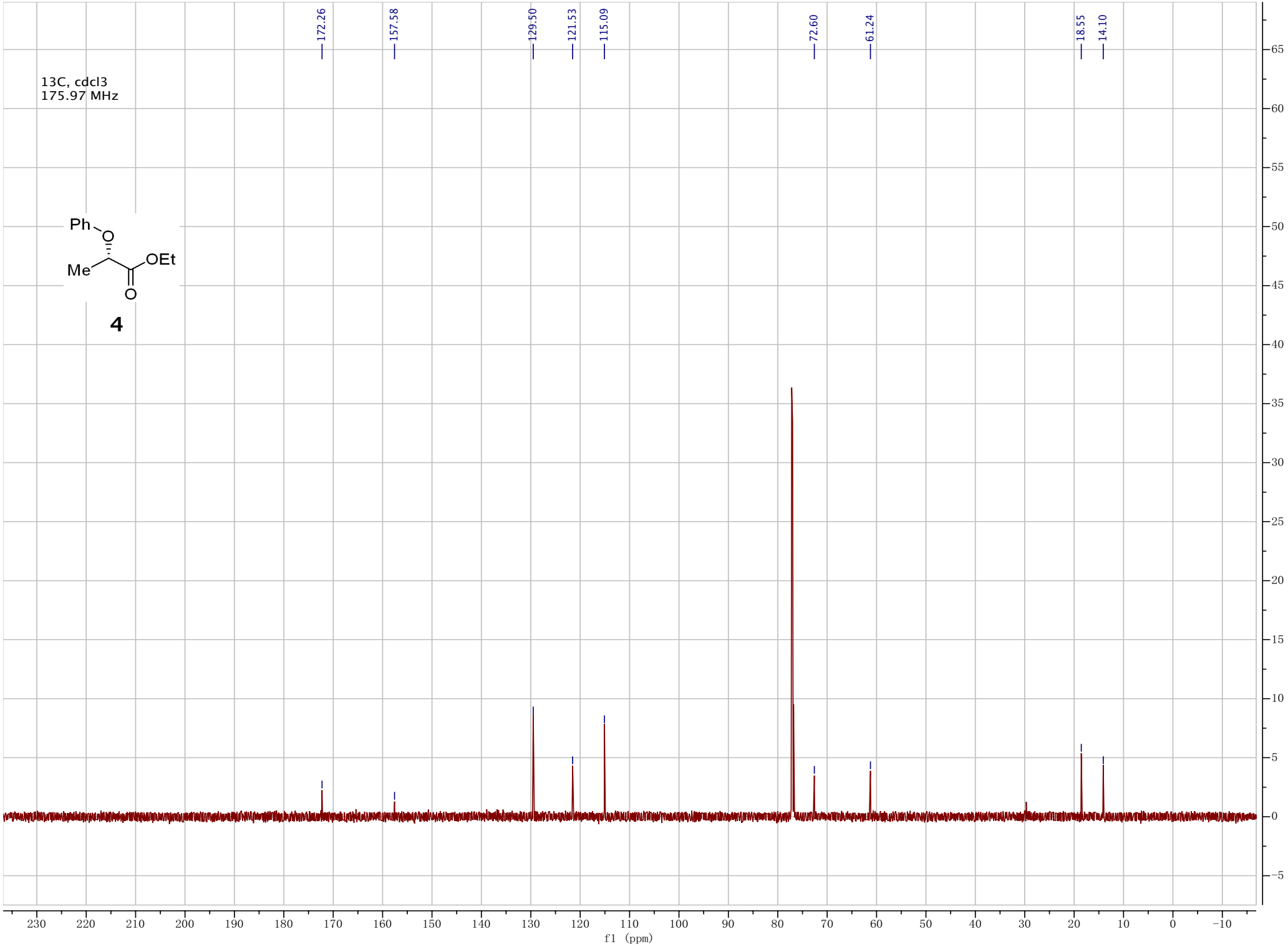

1H, cdcl3
500.08 MHz
(R,R,R,R,R)–3a
7.94 7.93 7.34 7.33 7.31 7.26 cdcl3 7.24 7.22 7.21 7.19 6.95 6.95 6.93
5.18 5.17 5.16 5.16 5.02 5.01 5.00 4.98
3.93 3.92 3.91 3.90 3.82 3.81 3.79
2.01 1.99 1.99 1.98 1.98 1.97 1.96 1.95 1.95 1.93 1.92 1.90 1.89 1.11 1.10 1.08
A (d) 7.93
B (t) 7.33
C (t) 7.22
D (m) 6.94
E (dd) 5.17
F (dd) 5.00
G (dd) 3.92
H (t) 3.81
I (ddq) 1.94
J (t) 1.10
1.93 2.06 7.96 3.72 2.08 1.98 2.02 1.92 4.01 6.18
f1 (ppm)


163.38
145.80
142.08
138.75
129.60
128.66
128.51
127.23
126.55
123.48
123.03
118.15
84.28
74.17
69.76
30.26
10.05
13C, cdcl3
125.76 MHz
Et
O
N
Ph
O
O
N
Ph
Et
O
(R,R,R,R,R)-3a
f1 (ppm)


1H, cdcl3
500.08 MHz
Et
Ph
Ph
Et
(R,R,R,S,S)-3b
C (dd)
7.33
F (m)
4.86
B (m)
7.90
A (d)
6.98
E (dd)
5.14
G (m)
4.34
H (m)
3.25
I (m)
1.96
J (t)
1.12
D (m)
7.20
1.91
3.48
1.80
2.55
2.07
1.97
2.01
2.04
4.40
6.28
f1 (ppm)


163.42
145.98
141.71
138.61
129.64
128.65
128.42
127.33
126.85
123.44
123.14
117.79
84.26
74.60
69.93
30.41
10.20
13C, cdcl3
175.97 MHz
Et
O
Ph
N
O
O
N
Ph
Et
O
(R,R,R,S,S)–3b
f1 (ppm)


1H, cdcl3
599.81 MHz
7.28
7.28
7.27
7.27
7.26 cdcl3
6.98
6.98
6.98
6.97
6.97
6.96
6.96
6.89
6.89
6.87
6.87
4.76
4.75
4.74
4.73
4.24
4.22
4.21
4.20
1.63
1.61
1.26
1.25
1.24
Ph
O
Me
OEt
O
4
B (td)
6.97
A (m)
7.28
C (m)
6.88
E (q)
4.22
D (q)
4.75
G (t)
1.25
F (d)
1.62
1.45
1.00
1.88
1.00
1.95
3.22
3.15
f1 (ppm)


172.26
157.58
129.50
121.53
115.09
72.60
61.24
18.55
14.10
13C, cdcl3
175.97 MHz
Ph
O
Me
OEt
O
4
f1 (ppm)