Supplementary Material (part 1)

All starting materials were obtained from commercial suppliers and used without purification. NMR spectra were recorded on a 300 MHz and 200 MHz Brucker spectrometers. Chemical shifts were reported in ppm relative to the residual solvent peak (7.27 ppm for $CHCl_3$) for ^{1}H spectra, (77.00 ppm for $CDCl_3$) for ^{13}C spectra and referenced to H_3PO_4 for ^{31}P spectra. High Resolution Mass spectroscopy data were recorded on an Autospec Ultima (Waters/Micromass) device with a resolution of 5000 RP at 5%. Allylphosphonate was prepared according to reference[1]. Thin-layer chromatography (TLC) was carried out on aluminium sheets precoated with silica gel 60 F254. Column chromatography separations were performed using silica gel (0.040-0.060 mm).

Procedure for the synthesis of allylphosphonochloridate 1

To a solution of allylphosphonate (5 mmol) in 5mL of dry dichloromethane, oxalyl chloride (15 mmol) was added dropwise under argon atmosphere. The reaction mixture was stirred for 20 h at room temperature. The solvent and the excess's oxalyl chloride were removed under vacuum, the residue purified by silica gel column chromatography using ethyl acetate/methanol mixture (8/2) as eluent.

General procedure for the synthesis of compounds 3, 4, 5 and 6

To a cold solution of phosphonochloridate (0.4 mmol) in toluene (1 mL) was slowly added dropwise amine (0.8 mmol). The solution was heated until full conversion of the starting material was confirmed by TLC. Solvent was evaporated and the crude material was purified by silica gel column chromatography using a mixture of ethyl acetate/methanol (9/1) as eluent.

Allylphosphonochloridate 1

Yield = 91%; Viscous oil; ^{1}H NMR (200 Mhz, $CDCl_3$): 1.22 (m, 6H); 3.25 (d, $^{2}J_{HP}$ = 21.0 Hz, 2H); 4.10 (m, 4H); 5.83 (d, $^{4}J_{HP}$ = 3.0 Hz, 1H); 6.34 (d, $^{4}J_{HP}$ = 6.0 Hz, 1H); ^{13}C NMR (75.43 MHz, $CDCl_3$): 14.02 (CH_3), 15.70 (CH_3), 36.03 (CH_2−P(O), $^{1}J_{PC}$ = 124.4 Hz), 61.34 (CH_2−O), 63.70 (CH_2−O), 129.84 (CH_2=C, $^{3}J_{PC}$ = 11.3 Hz), 130.26 (C=C(O), $^{2}J_{PC}$ = 12.0 Hz) 165.19 (C(O), $^{3}J_{PC}$ = 5.2 Hz); ^{31}P NMR (121.44 MHz, $CDCl_3$): 38.40; HRMS Calcd for $C_7H_{13}O_4PCl$ 241.0397, found 241.0390.

[1] Mrabet, H. Zantour, H. *Phosphorus Sulfur Silicon Relat Elem*. **2004**,*179*, 25–33.

Ethyl 2-((ethoxy(phenylamino)phosphoryl)methyl)acrylate 3a

Yield = 60%; Viscous oil; ^{1}H NMR (300 Mhz, $CDCl_3$): 1.13 (t, $^3J_{HH}$ = 6.0 Hz, 3H); 1.23 (t, $^3J_{HH}$ = 6.0 Hz, 3H); 3.05 (m, 2H); 4.05 (m, 4H); 5.71 (d, $^4J_{HP}$ = 6.0 Hz, 1H); 6.24 (d, $^4J_{HP}$ = 3.0 Hz, 1H); 6.71 (d, $^2J_{HP}$ = 6.0 Hz, 1H); 7.08 (m, 5H). ^{13}C NMR (75.43 MHz, $CDCl_3$): 14.04 (CH_3), 16.08 (CH_3), 29.07 (CH_2−P(O), $^1J_{PC}$ = 126.7 Hz), 60.59 (CH_2−OP), 61.17 (CH_2−OC(O)), 117.27-140.44 (C_{Ar}), 128.96 (C=C(O), $^2J_{PC}$ = 10.5 Hz); 131.41 (CH_2=C, $^3J_{PC}$ = 9.8 Hz), 166.21 (C(O), $^3J_{PC}$ = 4.5 Hz), ^{31}P NMR (80.96 MHz, $CDCl_3$): 25.50, HRMS Calcd for $C_{14}H_{20}NO_4NaP$ 320.1028, found 320.1034.

Ethyl 2-((((2,3-dihydro-1H-inden-4-yl)amino)(ethoxy)phosphoryl)methyl)acrylate 3b

Yield = 58%; Viscous oil; ^{1}H NMR (300 Mhz, $CDCl_3$): 1.27 (t, $^3J_{HH}$ = 6.0 Hz, 3H); 1.34 (t, $^3J_{HH}$ = 6.0 Hz, 3H); 2.11 (qun, $^3J_{HH}$ = 6.0 Hz, 2H); 2.75 (t, $^3J_{HH}$ = 6.0 Hz, 2H); 2.94 (t, $^3J_{HH}$ = 6.0 Hz, 2H); 4.16 (m, 4H); 5.02 (d, $^2J_{HP}$ = 6.0 Hz, 1H); 5.80 (d, $^4J_{HP}$ = 3.0 Hz, 1H); 6.36 (d, $^4J_{HP}$ = 6.0 Hz, 1H); 7.05 (m, 3H). ^{13}C NMR (75.43 MHz, $CDCl_3$): 14.08 (CH_3), 16.14 (CH_3), 24.57 (CH_2), 29.53 (CH_2−P(O), $^1J_{PC}$ = 126.7 Hz), 29.67 (CH_2), 33.38 (CH_2), 61.02 (CH_2−OP), 61.24 ((CH_2−OC(O)), 113.48-145.71 (C_{Ar}), 129.00 (C=C(O), $^2J_{PC}$ = 10.5 Hz); 131.53 (CH_2=C, $^3J_{PC}$ = 9.8 Hz), 166.33 (C(O), $^3J_{PC}$ = 4.5 Hz), ^{31}P NMR (80.96 MHz, $CDCl_3$): 25.12, HRMS Calcd for $C_{17}H_{25}NO_4P$ 338.1521, found 338.1516.

Ethyl 2-((((3s,5s,7s)-adamantan-1-ylamino)(ethoxy)phosphoryl)methyl)acrylate 3c

Yield = 48%; Viscous oil; ^{1}H NMR (200 Mhz, $CDCl_3$): 1.28 (m, 6H); 1.81(m, 15H); 2.78(s, 1H); 2.88 (m, 2H); 4.02 (m, 2H); 4.22 (m, 2H); 5.84 (d, $^4J_{HP}$ = 6.0 Hz, 1H); 6.30 (d, $^4J_{HP}$ = 6.0 Hz, 1H), ^{13}C NMR (75.43 MHz, $CDCl_3$): 14.19 (CH_3), 16.33 (CH_3), 29.74 (CH), 32.95 (CH_2−P(O), $^1J_{PC}$ = 123.7 Hz), 36.04 (CH_2), 44.86 (C-NP), 51.45 (CH_2), 60.17 (CH_2−OP), 61.19 ((CH_2−OC(O)), 128.30 (C=C(O), $^2J_{PC}$ = 9.8 Hz); 132.62 (CH_2=C, $^3J_{PC}$ = 9.8 Hz), 166.95 (C(O), $^3J_{PC}$ = 4.5 Hz), ^{31}P NMR (80.96 MHz, $CDCl_3$): 27.53, HRMS Calcd for $C_{18}H_{31}NO_4P$ 356.1991, found 356.1034.

Ethyl 1-benzyl-2-ethoxy-1,2-azaphospholidine-4-carboxylate 2-oxide 4a

Yield = 70%; Viscous oil; ^{1}H NMR (300 Mhz, $CDCl_3$): 1.14 (t, $^3J_{HH}$ = 6.0 Hz, 3H); 1.25 (t, $^3J_{HH}$ = 6.0 Hz, 3H); 1.99 (m, 2H); 3.01 (m, 3H); 4.09 (m, 6H); 7.23 (m, 5H), ^{13}C NMR (75.43 MHz, $CDCl_3$): 14.06 (CH_3), 16.67 (CH_3), 24.48 (CH_2−P(O), $^1J_{PC}$ = 120.6 Hz), 37.31 (CH_2-N) 47.40 (CH-C(O)); 47.85 (Ar-CH_2-N), 61.29 (CH_2−OC(O)), 61.93 (CH_2−OP, $^2J_{PC}$ = 6.0 Hz), 127.38-137.49 (C_{Ar}), 171.74 (C(O), $^3J_{PC}$ = 18.1 Hz), ^{31}P NMR (121.44 MHz, $CDCl_3$): δ_1 = 43.57 / δ_2 = 43.32, HRMS Calcd for $C_{15}H_{22}NO_4NaP$ 334.1184, found 334.1190.

Ethyl 1-((1s,3s)-adamantan-1-ylmethyl)-2-ethoxy-1,2-azaphospholidine-4-carboxylate 2-oxide 4b

Yield = 39%; Viscous oil; ^{1}H NMR (200 Mhz, CDCl$_3$): 1.30 (m, 6H); 1.97 (m, 17H); 2.65 (m, 2H); 3.31 (m, 3H); 4.10 (m, 4H), ^{13}C NMR (75.43 MHz, CDCl$_3$): 14.15 (CH$_3$), 16.56 (CH$_3$), 24.18 (CH$_2$–P(O), $^{1}J_{PC}$ = 119.9 Hz), 28.35 (CH), 34.91 (CH) 36.90 (CH-C(O)), 37.90 (C), 40.79 (CH$_2$), 52.67 (CH$_2$-N), 58.31 (CH$_2$-N), 61.32 (CH$_2$–OC(O)), 61.90 (CH$_2$–OP, $^{2}J_{PC}$ = 6.0 Hz), 172.03 (C(O), $^{3}J_{PC}$ = 18.1 Hz), ^{31}P NMR (80.96 MHz, CDCl$_3$): 45.96. HRMS Calcd for $C_{19}H_{33}NO_4P$ 370.2142, found 370.2140.

Ethyl 2-ethoxy-1-((R)-1-phenylethyl)-1,2-azaphospholidine-4-carboxylate 2-oxide 4c

Yield = 58%; Viscous oil; ^{1}H NMR (200 Mhz, CDCl$_3$): 1.32 (m, 6H); 1.62 (m, 3H); 2.06 (m, 2H); 3.08 (m, 3H); 4.07 (m, 4H); 4.50 (m, 1H); 7.34 (m, 5H), ^{13}C NMR (75.43 MHz, CDCl$_3$): δ_1 = 14.11 / δ_2 = 14.06 (CH$_3$), 16.50 (CH$_3$), 19.07 (CH$_3$), δ_1 = 25.29 / δ_2 = 24.33 (CH$_2$–P(O)), δ_1 = 37.62 / δ_2 = 37.58 (CH-C(O), δ_1 = 44.49 / δ_2 = 44.40 (CH$_2$-N), 53.03 (Ar-CH-N), δ_1 = 61.31 / δ_2 = 61.26 (CH$_2$–OC(O)), δ_1 = 62.20/ δ_2 = 62.12 (CH$_2$–OP), δ_1 = 127.19-142.25/ δ_2 = 126.96-142.21 (C$_{Ar}$), δ_1 = 171.96/ δ_2 = 171.77 (C(O)), ^{31}P NMR (80.96 MHz, CDCl$_3$): δ_1 = 43.61 / δ_2 = 43.28, HRMS Calcd for $C_{16}H_{25}NO_4P$ 326.1515, found 326.1519.

Ethyl 2-ethoxy-1-(pyridin-2-ylmethyl)-1,2-azaphospholidine-4-carboxylate 2-oxide 4d

Yield = 79%; Viscous oil; ^{1}H NMR (300 Mhz, CDCl$_3$): 1.19 (m, 6H); 2.05 (m, 2H); 3.20 (m, 3H); 4.11 (m, 6H); 7.42 (m, 3H); 8.45 (d, $^{2}J_{HH}$ = 3Hz, 1H^{13}C NMR (75.43 MHz, CDCl$_3$): δ_1 = 14.02 / δ_2 = 14.11 (CH$_3$), δ_1 = 16.50 / δ_2 = 16.58 (CH$_3$), δ_1 = 24.30 / δ_2 = 24.02 (CH$_2$–P(O), $^{1}J_{PC}$ = 120.6 Hz), δ_1 = 37.55 / δ_2 = 37.31 (CH$_2$-N), δ_1 = 47.90 / δ_2 = 47.83 (CH-C(O)), δ_1 = 49.71 / δ_2 = 49.52 (Ar-CH$_2$-N), δ_1 = 61.33 / δ_2 = 61.30 (CH$_2$–OC(O)), δ_1 = 62.39 / δ_2 = 62.31 (CH$_2$–OP), δ_1 = 121.83-157.83 / δ_2 = 121.74-157.78 (C$_{Ar}$), δ_1 = 171.79 / δ_2 = 171.75 (C(O)),^{31}P NMR (80.96 MHz, CDCl$_3$): δ_1 = 44.15 / δ_2 = 44.20, HRMS Calcd for $C_{14}H_{22}N_2O_4P$ 313.3085, found 313.3083.

Ethyl 2-ethoxy-1-(thiophen-2-ylmethyl)-1,2-azaphospholidine-4-carboxylate 2-oxide 4e

Yield = 91%; Viscous oil; ^{1}H NMR (200 Mhz, CDCl$_3$): δ_1 = 1.22 / δ_2 = 1.24 (t, $^{3}J_{HH}$ = 6.0 Hz, 3H); δ_1 = 1.31 / δ_2 = 1.33 (t, $^{3}J_{HH}$ = 6.0 Hz, 3H); δ_1 = 2.06 / δ_2 = 2.18 (m, 2H); δ_1 = 3.17 / δ_2 = 3.23 (m, 3H); δ_1 = 4.23 / δ_2 = 4.20 (m, 6H); δ_1 = 7.12 / δ_2 = 7.10 (m, 3H), ^{13}C NMR (75.43 MHz, CDCl$_3$): δ_1 = 14.10 / δ_2 = 14.11 (CH$_3$), δ_1 = 16.56 / δ_2 = 16.54 (CH$_3$), δ_1 = 24.60 / δ_2 = 24.56 (CH$_2$–P(O), $^{1}J_{PC}$ = 121.4 Hz), δ_1 = 37.25 / δ_2 = 37.56 (CH$_2$-N), δ_1 = 42.75 / δ_2 = 42.50 (Ar-CH$_2$-N), δ_1 = 47.31 / δ_2 = 47.44(CH-C(O), $^{2}J_{PC}$ = 19.6 Hz), δ_1 = 61.38 / δ_2 = 61.41 (CH$_2$–OC(O)), δ_1 = 61.86 / δ_2 = 62.38 (CH$_2$–OP, $^{2}J_{PC}$ = 6.7 Hz), δ_1 = 125.34-141.14 / δ_2 = 125.43-140.65 (C$_{Ar}$), δ_1

= 171.73 / δ_2 = 172.01 (C(O), $^3J_{PC}$ = 18.1 Hz), ^{31}P NMR (80.96 MHz, $CDCl_3$): δ_1 = 43.54 / δ_2 = 43.47, HRMS Calcd for $C_{13}H_{21}NO_4PS$ 318.3481, found 318.3479.

Ethyl 2-ethoxy-1-(furan-2-ylmethyl)-1,2-azaphospholidine-4-carboxylate 2-oxide 4f

Yield = 86%; Viscous oil; ^{1}H NMR (200 Mhz, $CDCl_3$): δ_1 = 1.22 / δ_2 = 1.28 (m, 6H); δ_1 = 2.07 / δ_2 = 2.12 (m, 2H); δ_1 = 3.23 / δ_2 = 3.23 (m, 3H); δ_1 = 4.05 / δ_2 = 4.08 (m, 6H); δ_1 = 6.28 / δ_2 = 6.31 (m, 2H), δ_1 = 7.34 / δ_2 = 7.35 (m, 1H), ^{13}C NMR (75.43 MHz, $CDCl_3$): δ_1 = 14.09 / δ_2 = 14.11(CH_3), δ_1 = 16.47/ δ_2 = 16.47 (CH_3), δ_1 = 24.50 / δ_2 = 24.12 (CH_2−P(O), $^1J_{PC}$ = 122.1 Hz), δ_1 = 37.16/ δ_2 = 37.56 (CH-C(O), $^2J_{PC}$ = 5.2 Hz), δ_1 = 40.83 / δ_2 = 40.54 (Ar-CH_2-N), δ_1 = 48.02 / δ_2 = 48.05 (CH_2-N), δ_1 = 61.36/ δ_2 = 61.40 (CH_2−OC(O)), δ_1 = 61.58 / δ_2 = 62.23 (CH_2−OP, $^2J_{PC}$ = 6.0 Hz), δ_1 = 108.00-151.55/ δ_2 = 108.09-151.25 (C_{Ar}), δ_1 = 171.76 / δ_2 = 171.59 (C(O), $^3J_{PC}$ = 18.1 Hz), ^{31}P NMR (80.96 MHz, $CDCl_3$): δ_1 = 43.57 / δ_2 = 43.56, HRMS Calcd for $C_{13}H_{21}NO_5P$ 302.1151, found 302.1150.

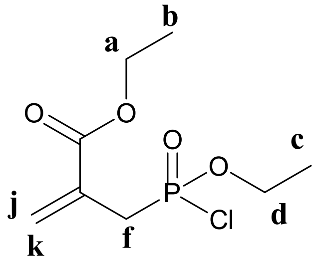
Ethyl 2-ethoxy-1,6-dimethyl-1,6,2-diazaphosphocane-4-carboxylate 2-oxide 5

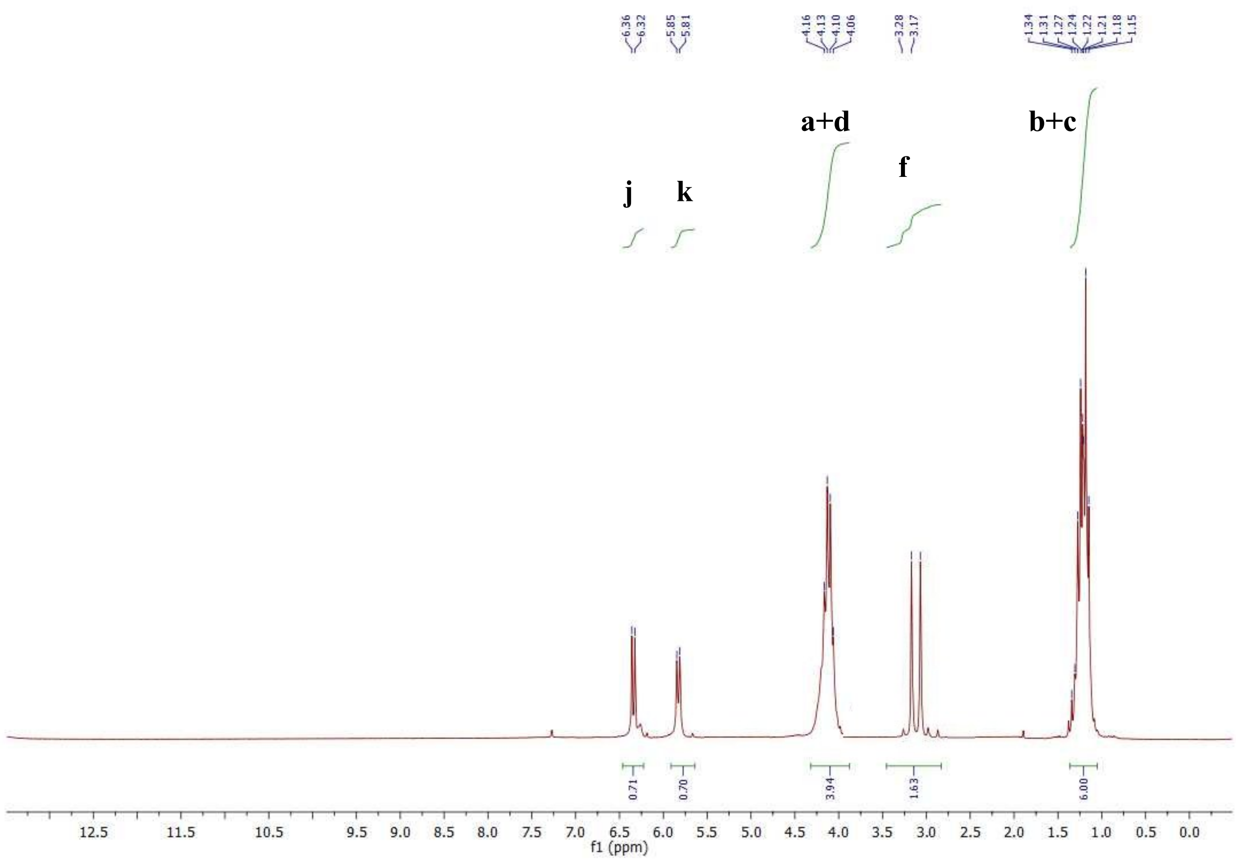
Yield = 72%; Viscous oil; ^{1}H NMR (200 Mhz, $CDCl_3$): δ_1 = 1.24 / δ_2 = 1.26 (t, 3H); δ_1 = 1.28 / δ_2 = 1.29 (t, 3H); δ_1 = 2.15 / δ_2 = 2.14 (m, 2H); δ_1 = 2.37 / δ_2 = 2.46 (s, 3H); δ_1 = 2.57 / δ_2 = 2.42 (m, 2H); δ_1 = 2.62 / δ_2 = 2.68 (d, 3H); δ_1 = 2.90 / δ_2 = 2.77 (m,1H); δ_1 = 2.91 / δ_2 = 2.65 (m, 2H); δ_1 = 3.14 / δ_2 = 3.10 (m, 2H); δ_1 = 3.93 / δ_2 = 3.95 (m, 2H); δ_1 = 4.12 / δ_2 = 4.14 (q, 2H); ^{13}C NMR (75.43 MHz, $CDCl_3$): 14.17 (CH_3), δ_1 = 14.31 / δ_2 = 13.87 (CH_3), δ_1 = 16.50 / δ_2 = 16.05 (CH_3), δ_1 = 25.03 / δ_2 = 27.46 (CH_2−P(O)), δ_1 = 32.83 / δ_2 = 32.9 (CH_3-N), δ_1 = 41.21 / δ_2 = 39.9 (C-C(O)), δ_1 = 44.02 / δ_2 = 45.19 (CH_3-N), δ_1 = 49.19 / δ_2 = 47.27 (CH_2-N), δ_1 = 53.91 / δ_2 = 52.98 (CH_2-N), δ_1 = 57.25 / δ_2 = 56.18 (CH_2-N), δ_1 = 59.14 / δ_2 = 59.04 (CH_2−OP), δ_1 = 60.88 / δ_2 = 60.70 (CH_2−OC(O)), δ_1 = 174.31 / δ_2 = 173.51 (C(O)); ^{31}P NMR (80.96 MHz, $CDCl_3$): δ_1 = 34.24 / δ_2 = 35.09, HRMS Calcd for $C_{12}H_{26}N_2O_4P$ 293.1630, found 293.1631.

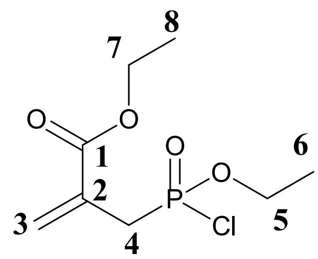
Ethyl 2-ethoxy-1,6-dimethyl-1,6,2-diazaphosphonane-4-carboxylate 2-oxide 6

Yield = 34%; Viscous oil; ^{1}H NMR (300 Mhz, $CDCl_3$): 1.20 (m, 6H); 1.76 (m, 2H); 1.85 (m, 2H); 2.10 (s, 3H); 2.37 (m, 2H); 2.55 (m, 3H); 2.75 (m, 2H); 2.91 (m, 2H); 2.94 (m, 1H); 3.96 (m, 4H); ^{13}C NMR (75.43 MHz, $CDCl_3$): 14.18 (CH_3), 16.83 (CH_3), 23.10 (CH_2), 26.09 (CH_2−P(O), $^1J_{PC}$ = 135.0 Hz), 33.09(C-C(O)), 40.02 (CH_2-N), 41.71 (CH_3-N), 46.26 (CH_2-N), 53.42 (CH_2-N), 59.82 (CH_3-N), 59.89 (CH_2-OP), 60.50 (CH_2-O), 175.33 (C(O)), ^{31}P NMR (80.96 MHz, $CDCl_3$): δ_1 = 34.54 / δ_2 = 34.72, HRMS Calcd for $C_{13}H_{28}N_2O_4P$ 307.1787, found 307.1785.

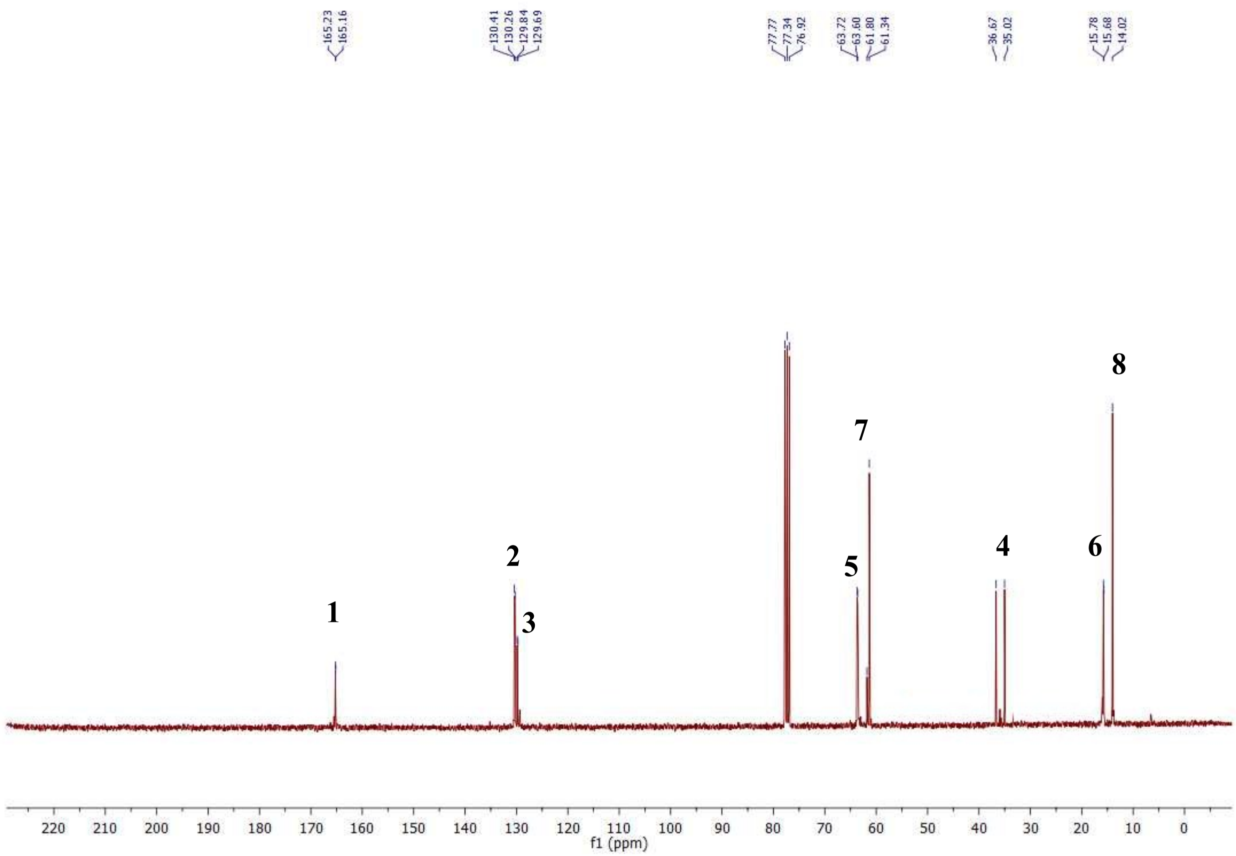
Phosphonochloridate 1



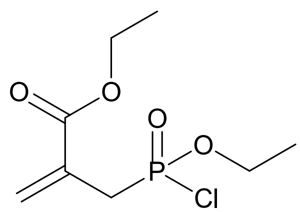


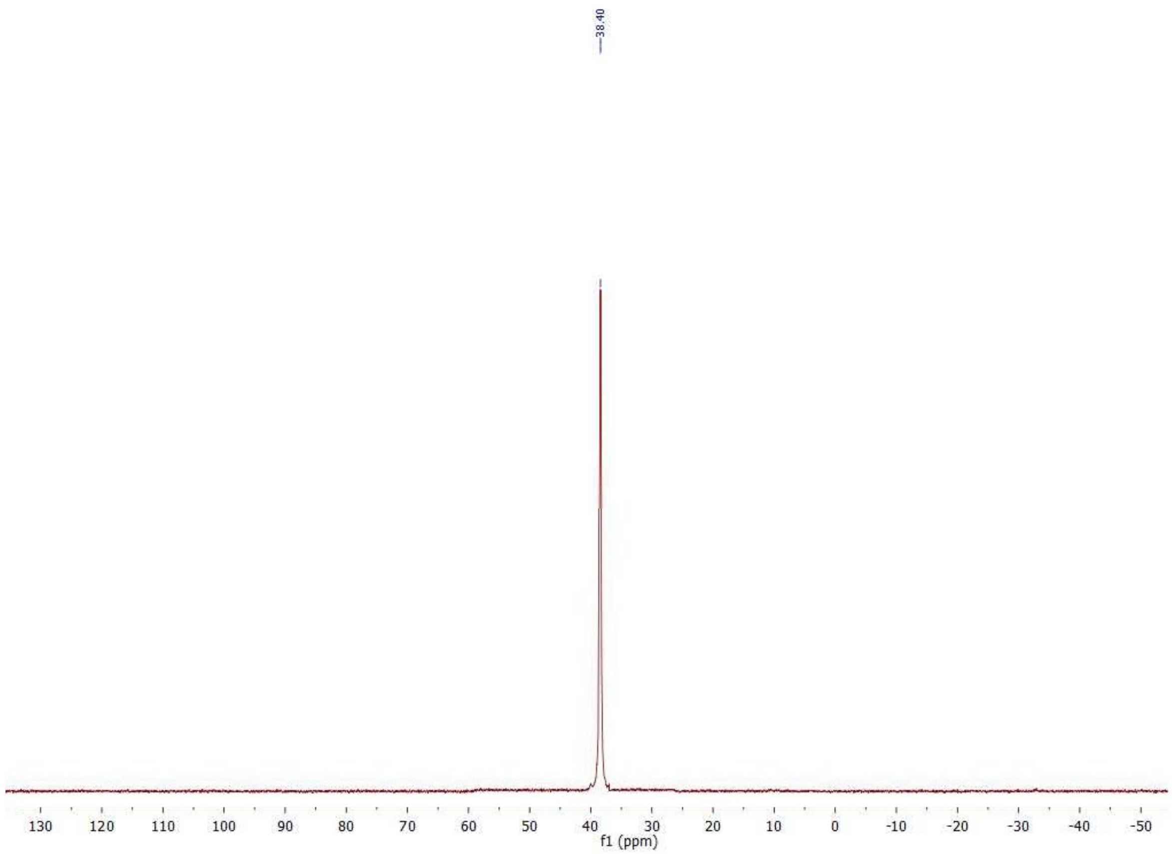


O
O
O
P
O
Cl
1
2
3
4
5
6
7
8

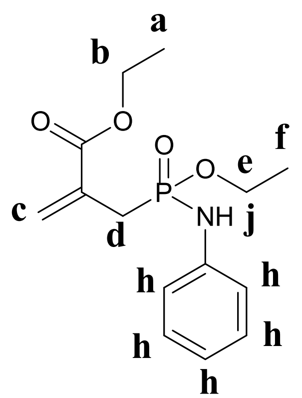


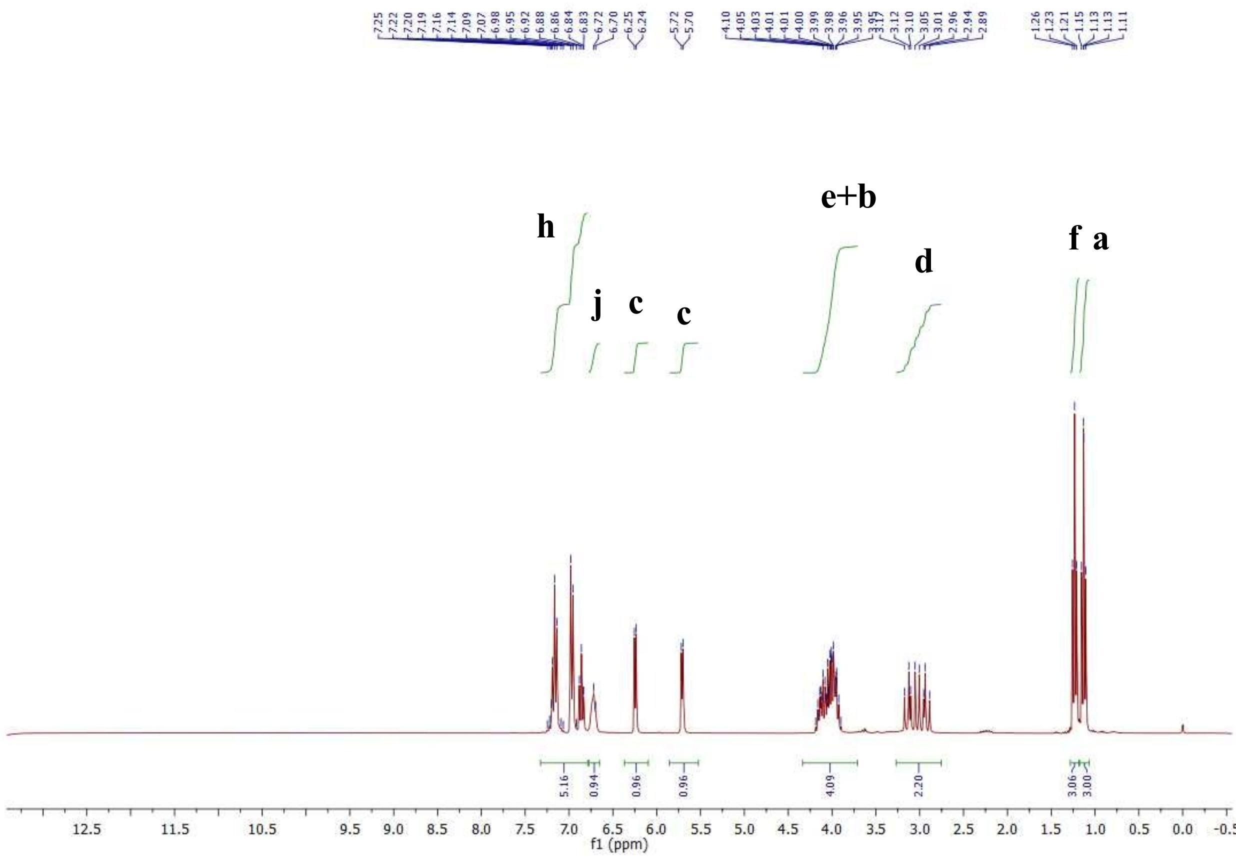
165.23
165.16
130.41
130.26
129.84
129.69
77.77
77.34
76.92
63.72
63.60
61.80
61.34
36.67
35.02
15.78
15.68
14.02
1
2
3
5
7
4
6
8
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

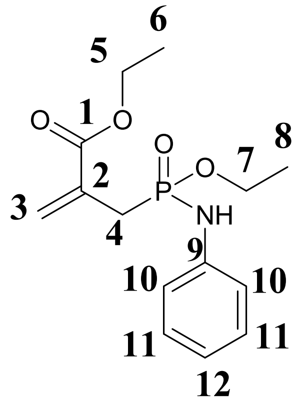

O
O
O
O
P
Cl

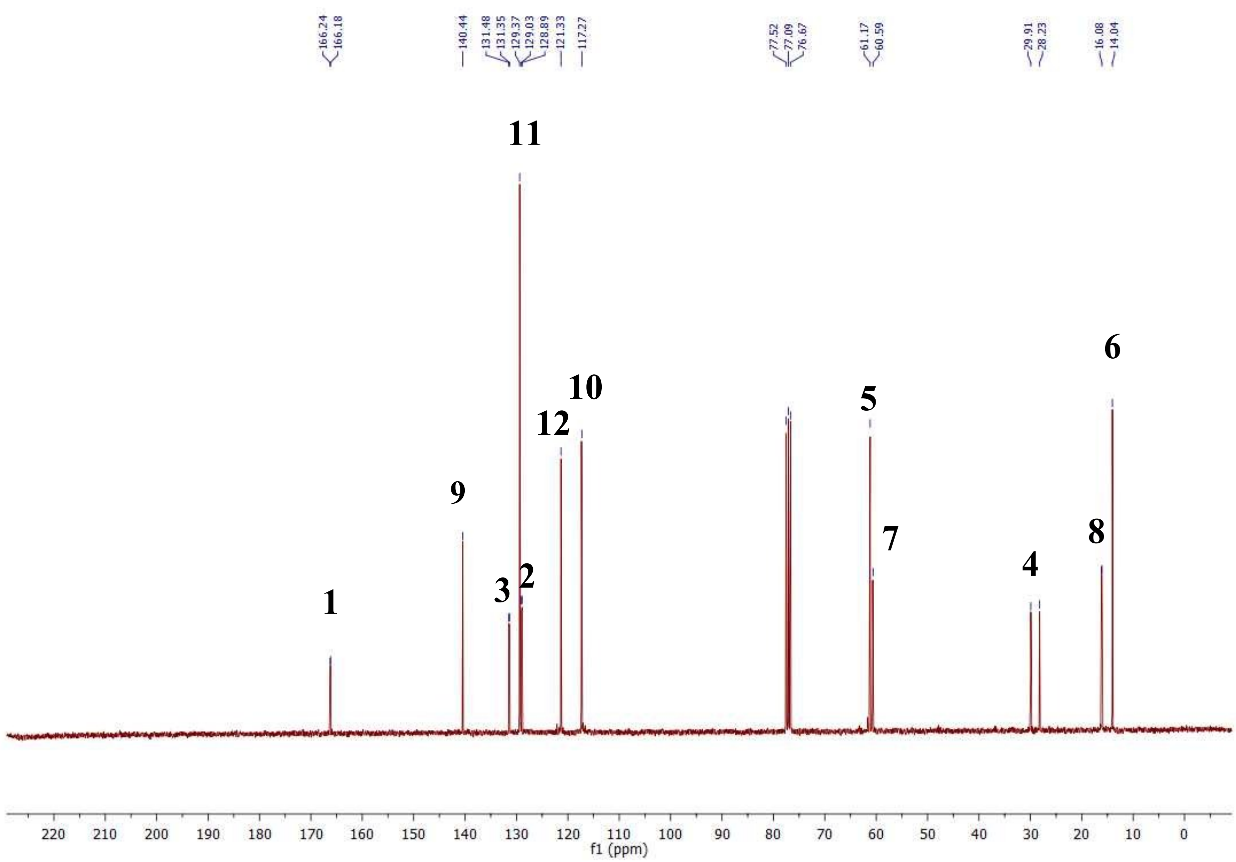

38.40
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
f1 (ppm)

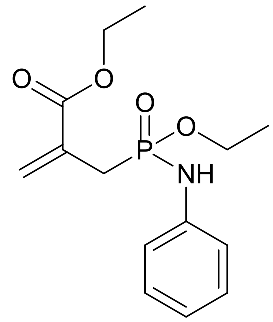
Compound 3a

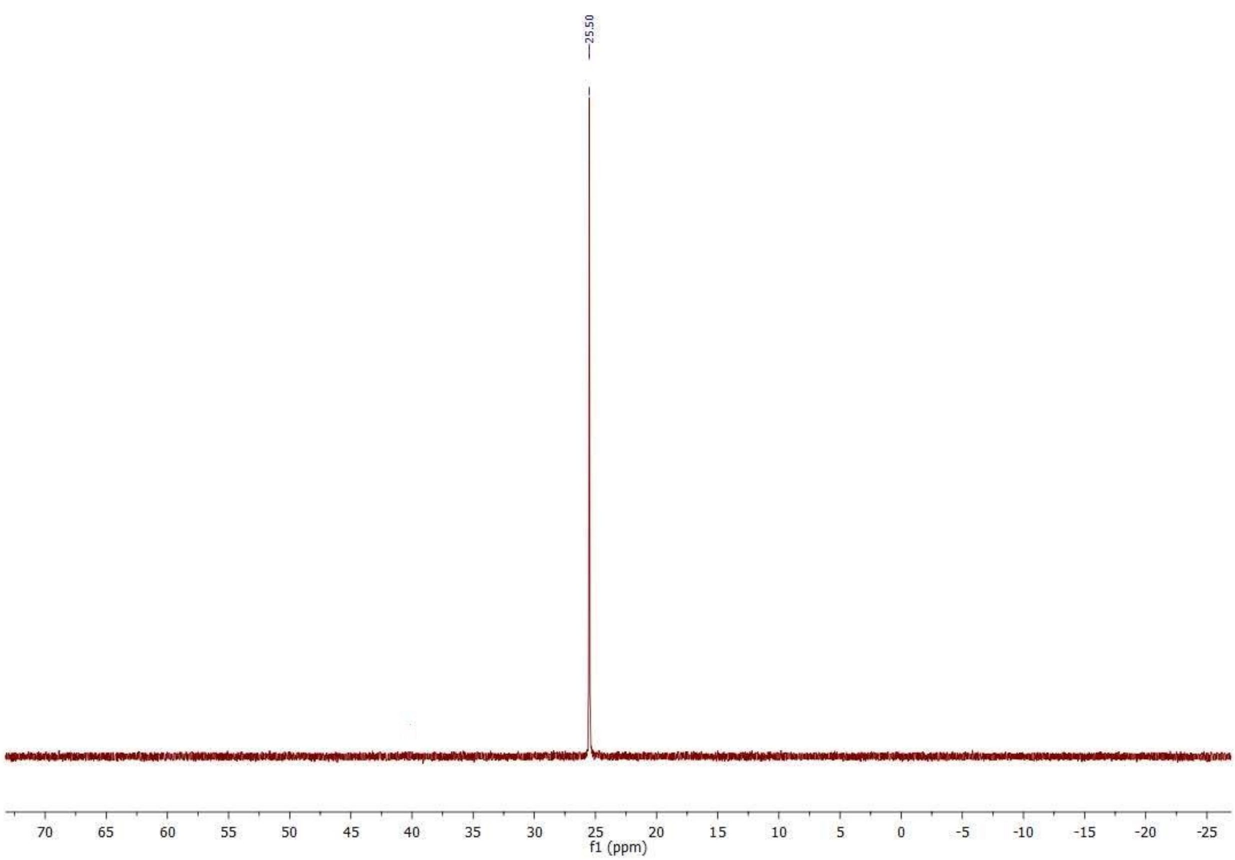

a
b
f
e
c
d
j
h
h
h
h
h
O
O
O
O
P
NH


h
j
c
c
e+b
d
f a
5.16
0.94
0.96
0.96
4.09
2.20
3.06
3.00
12.5
11.5
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

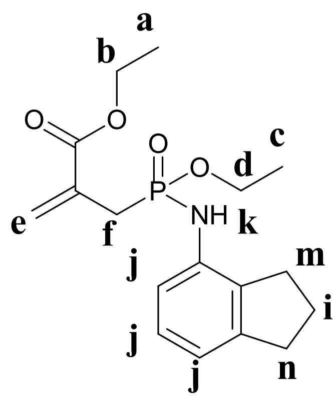

6
5
1
O
O
O
P
O
7
8
2
3
NH
4
9
10
10
11
11
12

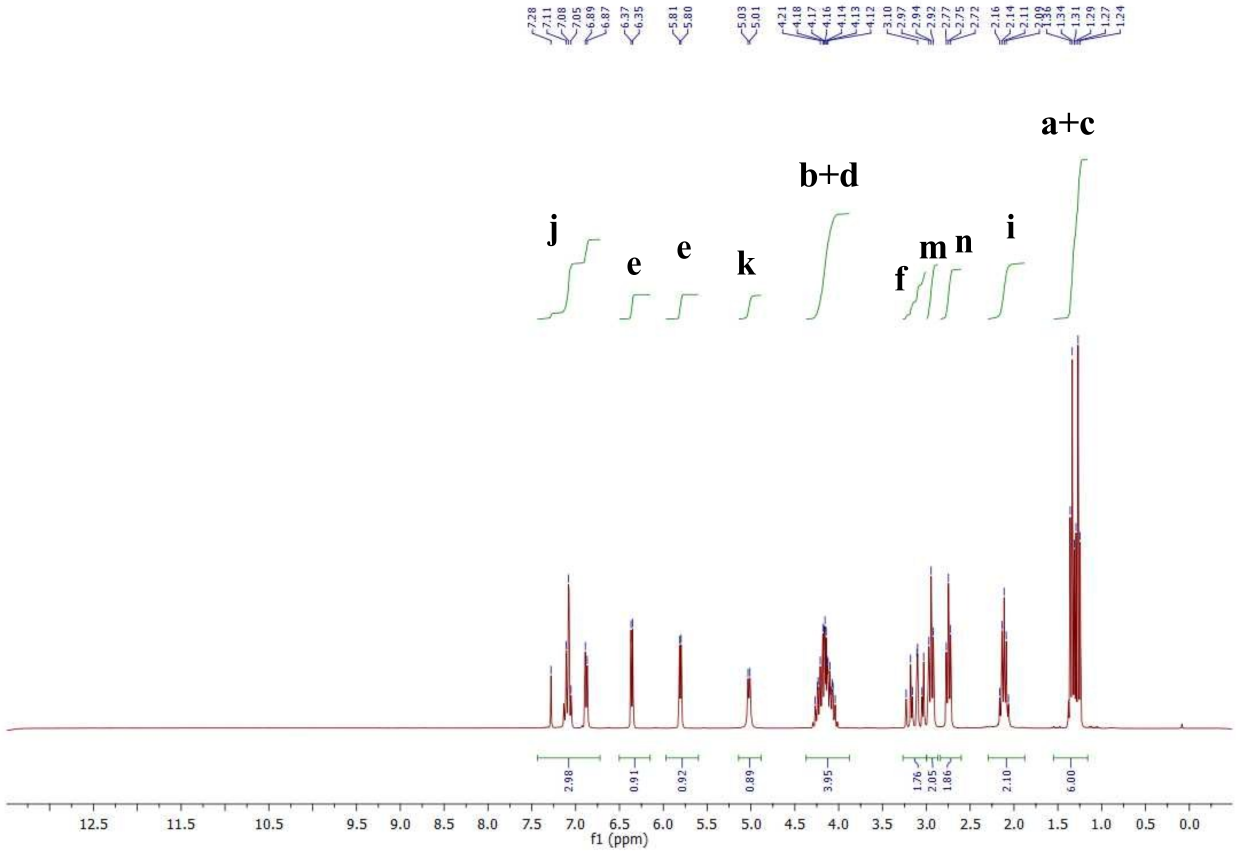

166.24
166.18
140.44
131.48
131.35
129.37
129.03
128.89
121.33
117.27
77.52
77.09
76.67
61.17
60.59
29.91
28.23
16.08
14.04
11
6
10
5
12
9
7
8
4
3
2
1
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

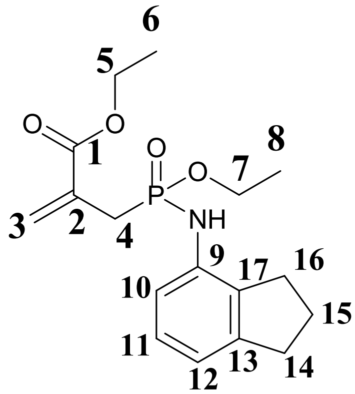



25.50
70 65 60 55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25
f1 (ppm)

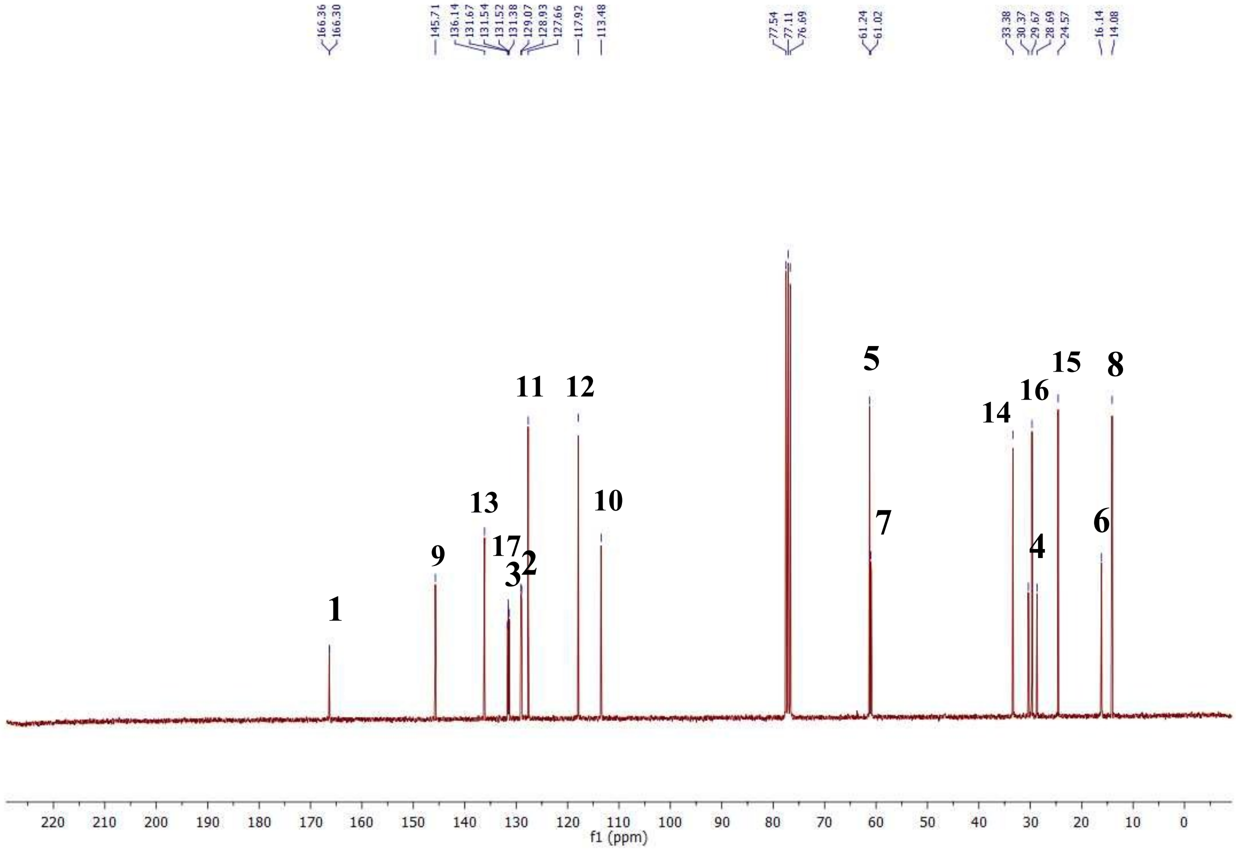
Compound 3b


a
b
c
d
O
O
O
O
P
NH
k
e
f
j
j
j
m
i
n

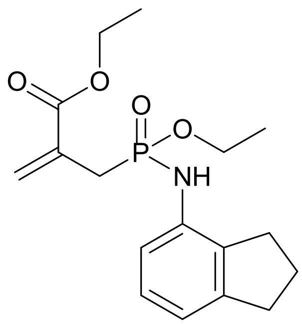

a+c
b+d
j
e
e
k
f
m
n
i
2.98
0.91
0.92
0.89
3.95
1.76
2.05
1.86
2.10
6.00
f1 (ppm)



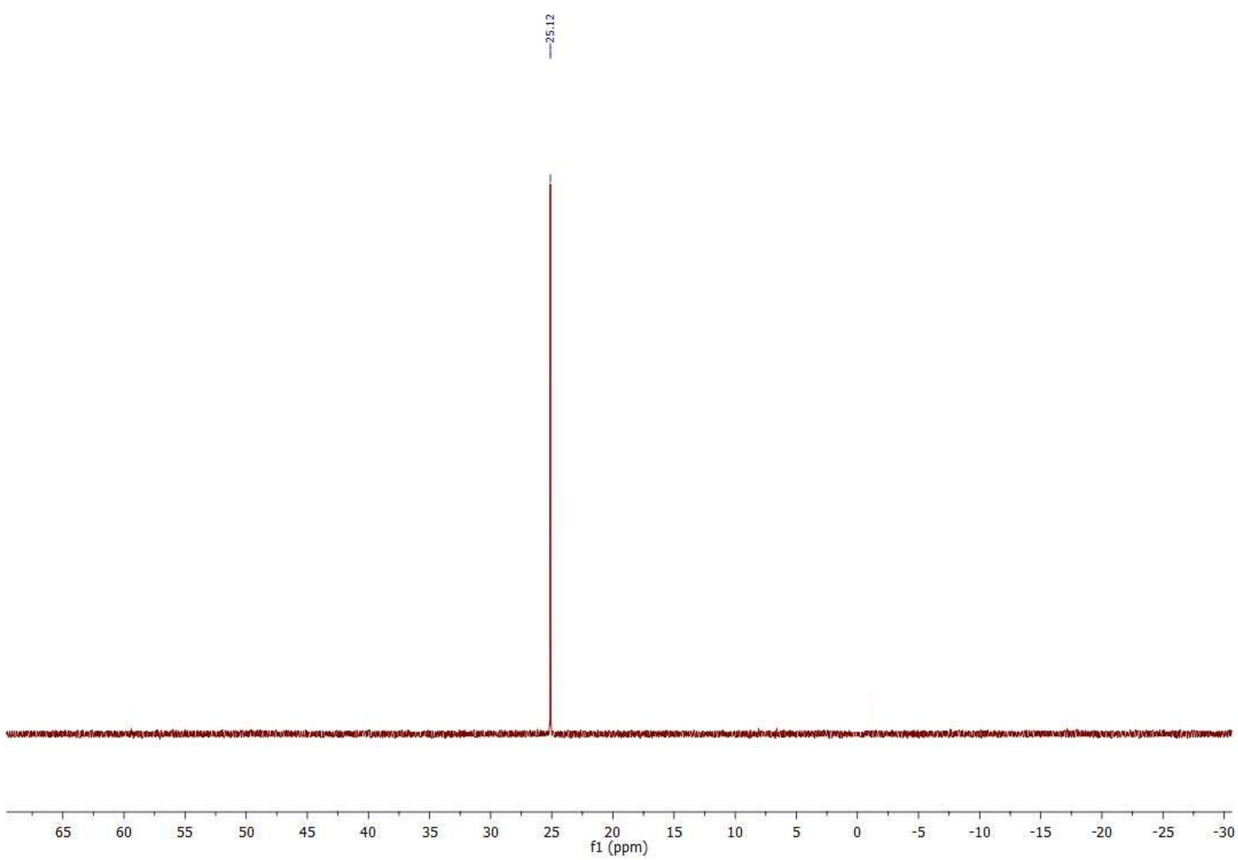
O
O
O
P
O
NH
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17



166.36
166.30
145.71
136.14
131.67
131.54
131.52
131.38
129.07
128.93
127.66
117.92
113.48
77.54
77.11
76.69
61.24
61.02
33.38
30.37
29.67
28.69
24.57
16.14
14.08
1
9
13
17
3
2
11
12
10
5
7
14
16
15
8
4
6
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)

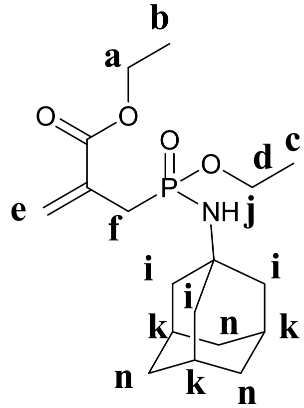


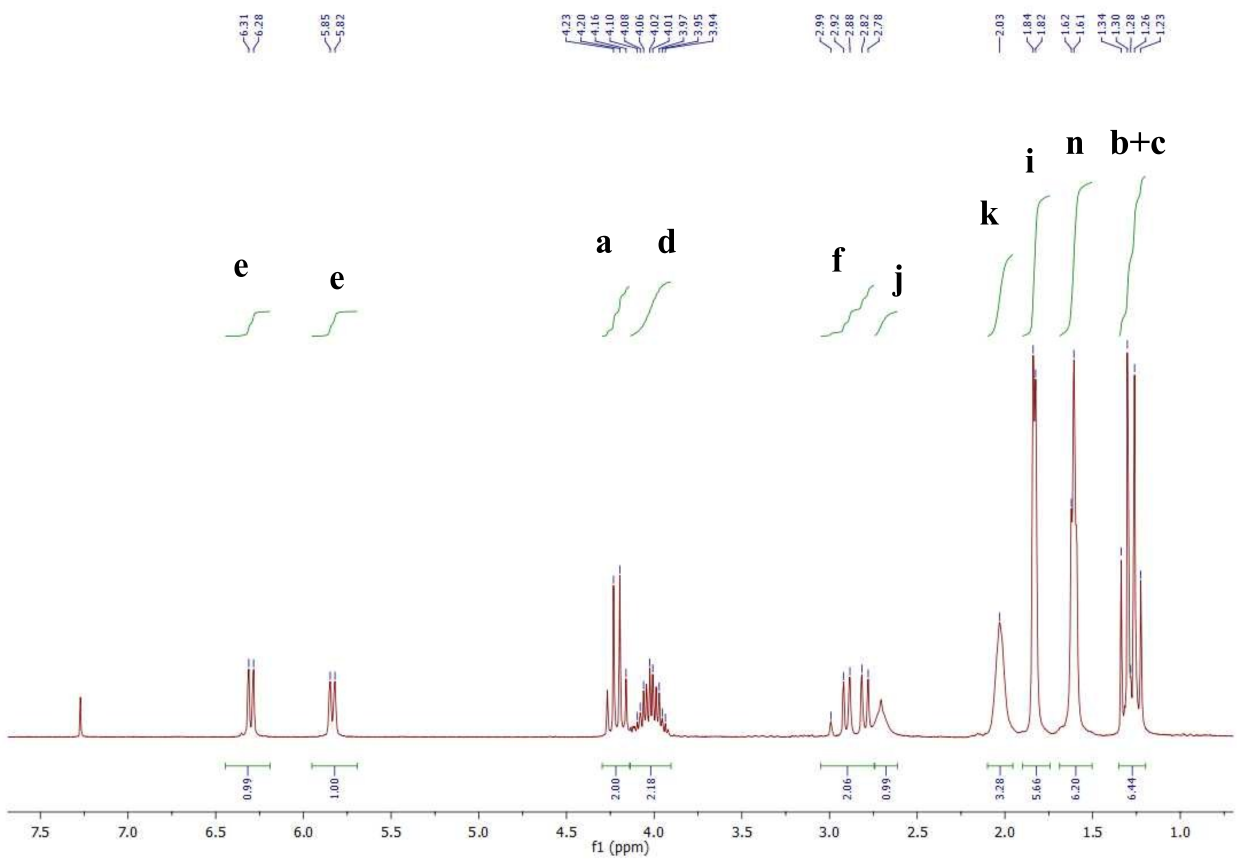
O
O
O
P
O
NH

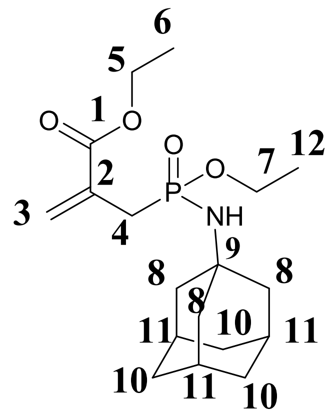


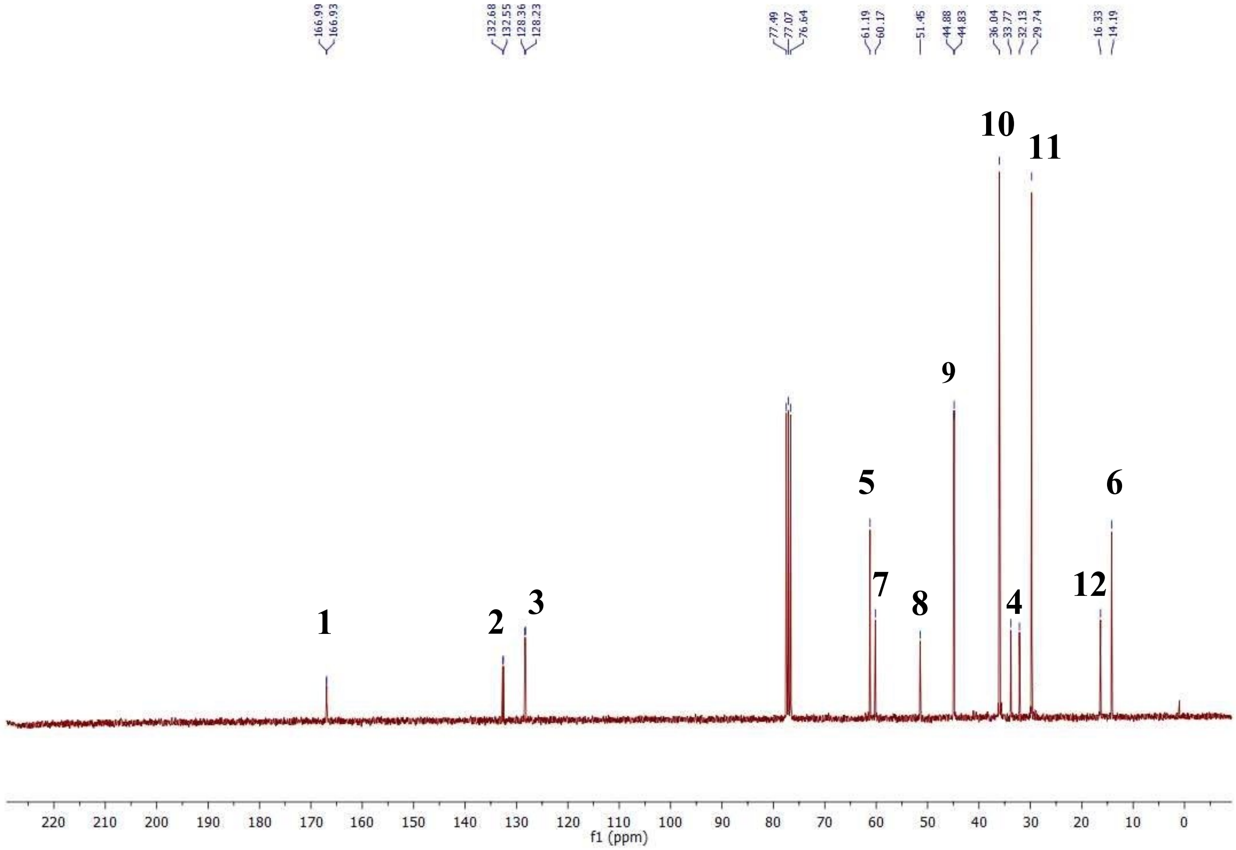
25.12
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
f1 (ppm)

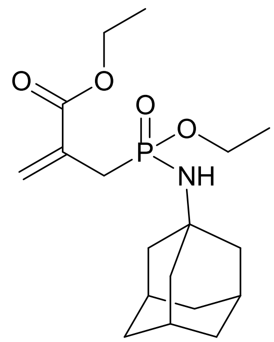
Compound 3c

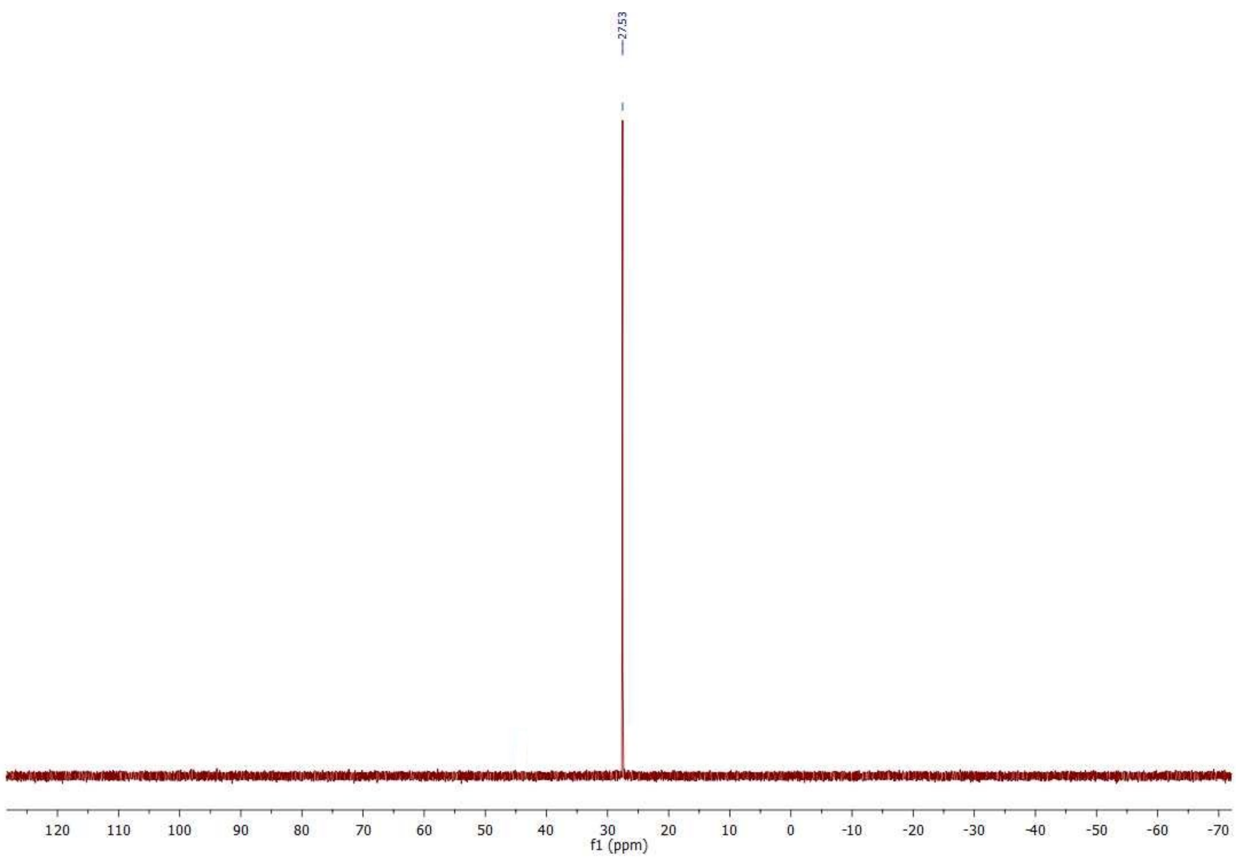




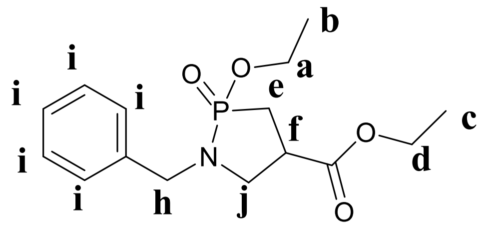

6
5
1
O
O
O
P
O
7
12
2
3
4
NH
9
8
8
8
10
11
11
10
11
10


166.99
166.93
132.68
132.55
128.36
128.23
77.49
77.07
76.64
61.19
60.17
51.45
44.88
44.83
36.04
33.77
32.13
29.74
16.33
14.19
10
11
9
5
6
1
2
3
7
8
4
12
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)

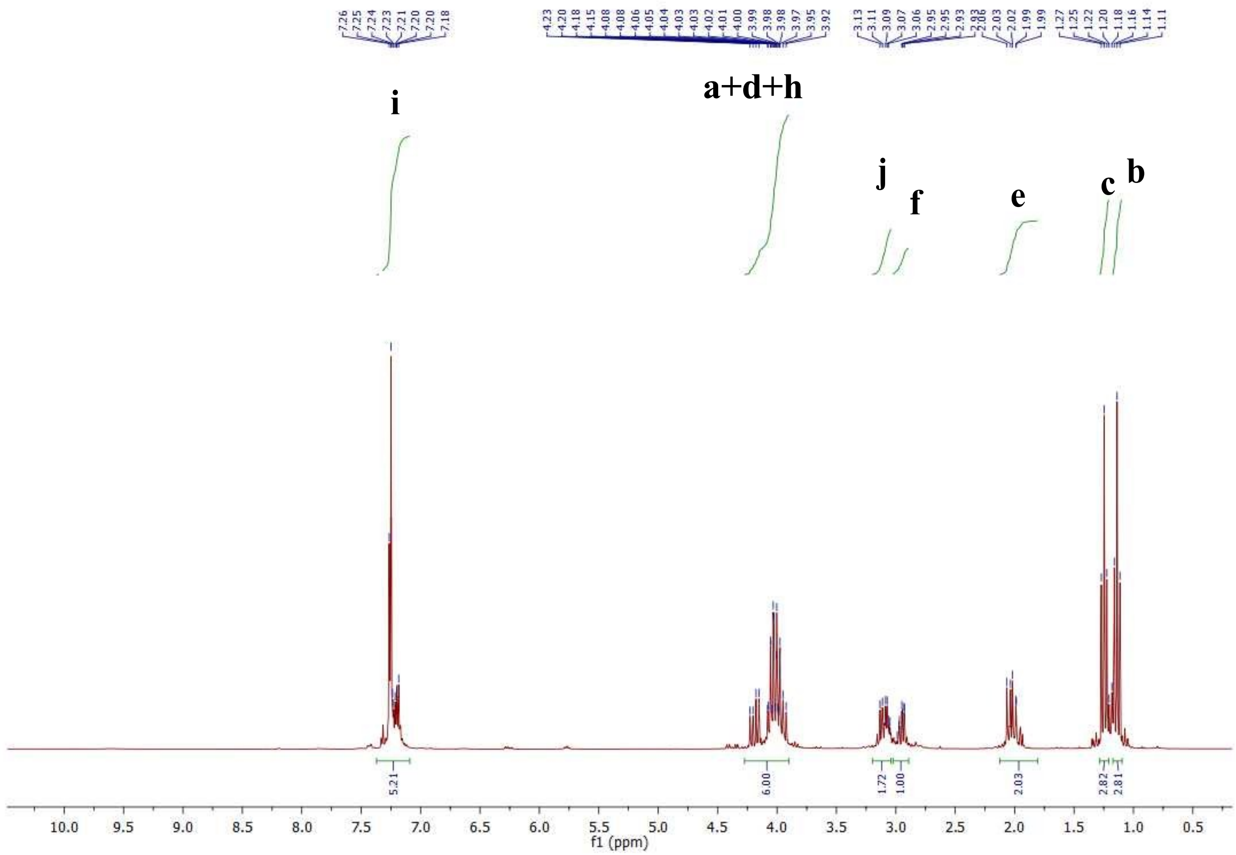

O
O
O
P
O
NH


27.53
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
f1 (ppm)

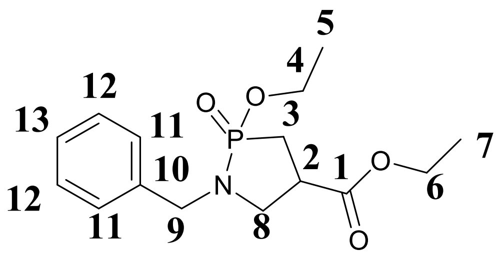
Compound 4a



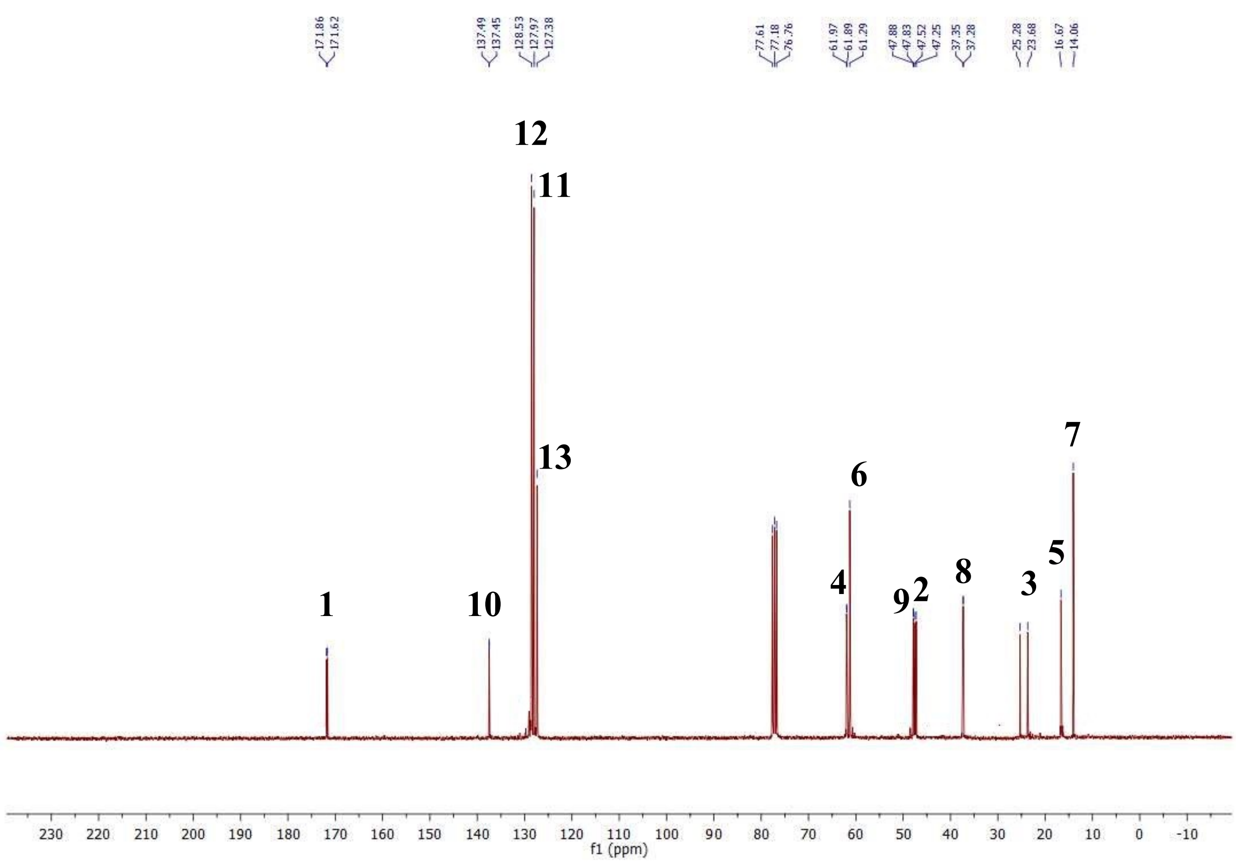
i
i
i
i
i
h
j
N
P
O
O
e
a
b
f
O
O
d
c



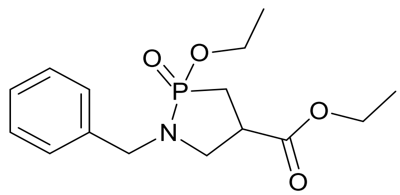
i
a+d+h
j
f
e
c
b
5.21
6.00
1.72
1.00
2.03
2.82
2.81
f1 (ppm)

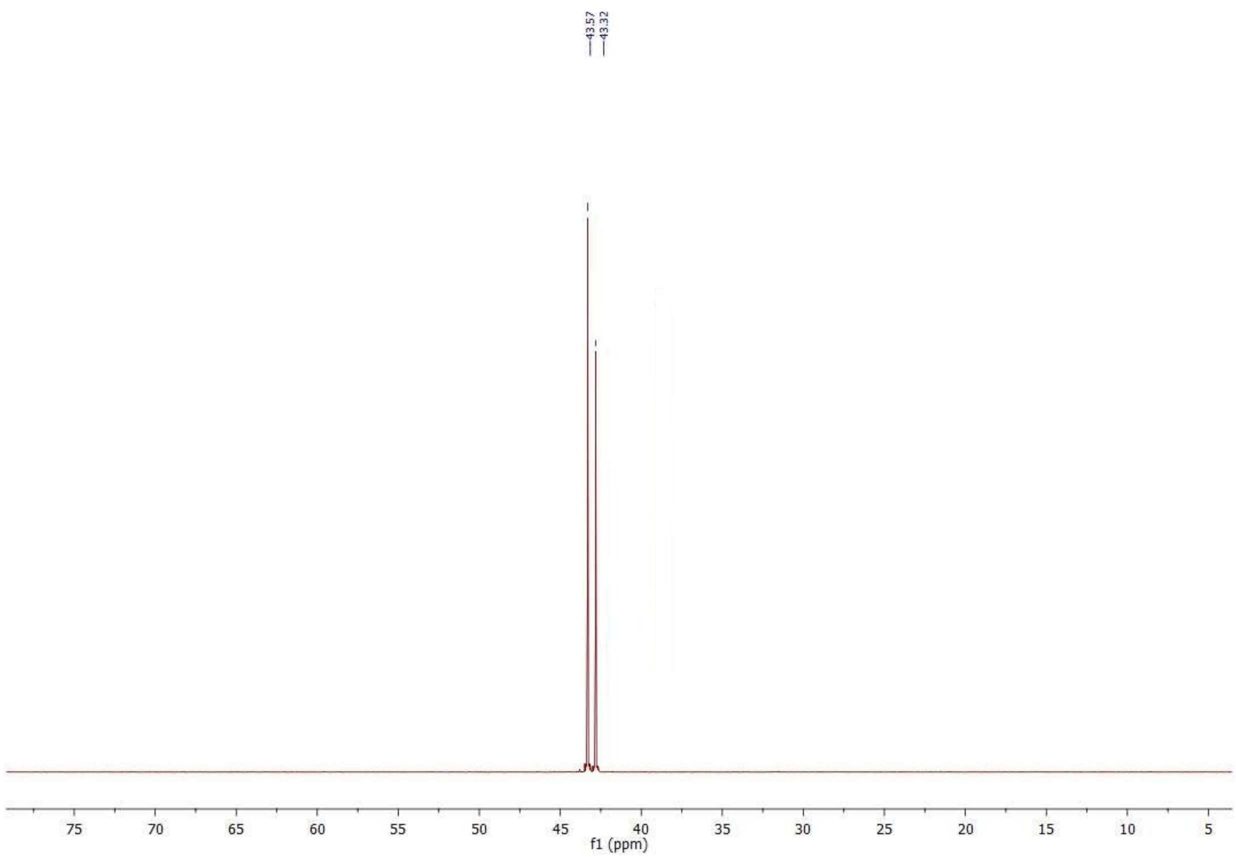


5
4
O
O
P
3
2
1
O
7
6
12
13
11
10
N
12
11
9
8
O

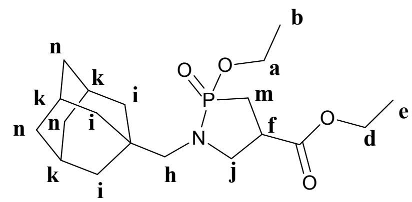


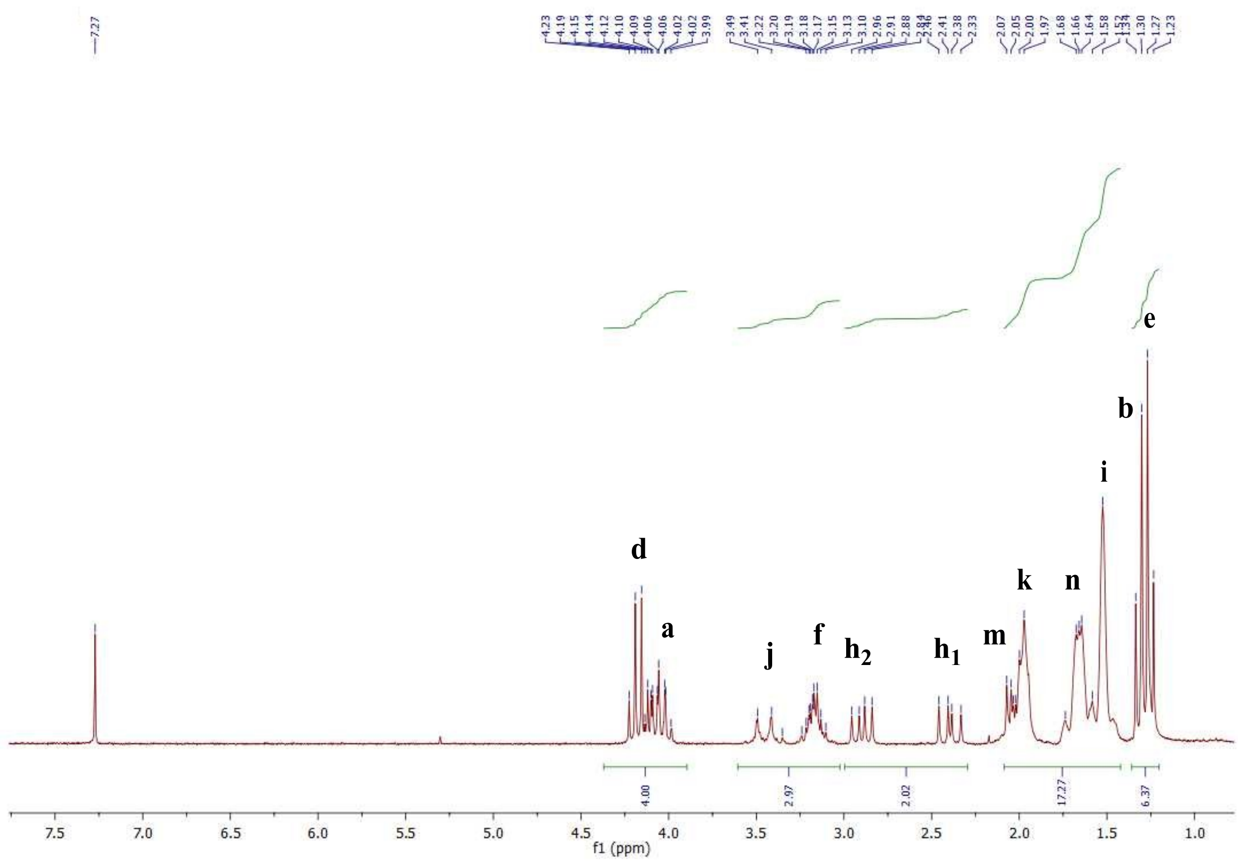
171.86
171.62
137.49
137.45
128.53
127.97
127.38
77.61
77.18
76.76
61.97
61.89
61.29
47.88
47.83
47.52
47.25
37.35
37.28
25.28
23.68
16.67
14.06
12
11
13
1
10
4
6
9
2
8
3
5
7
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

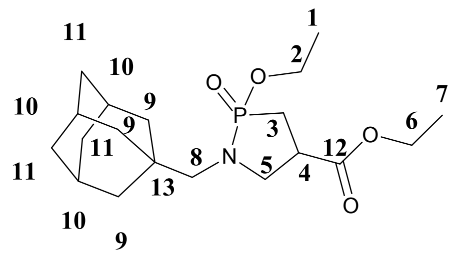


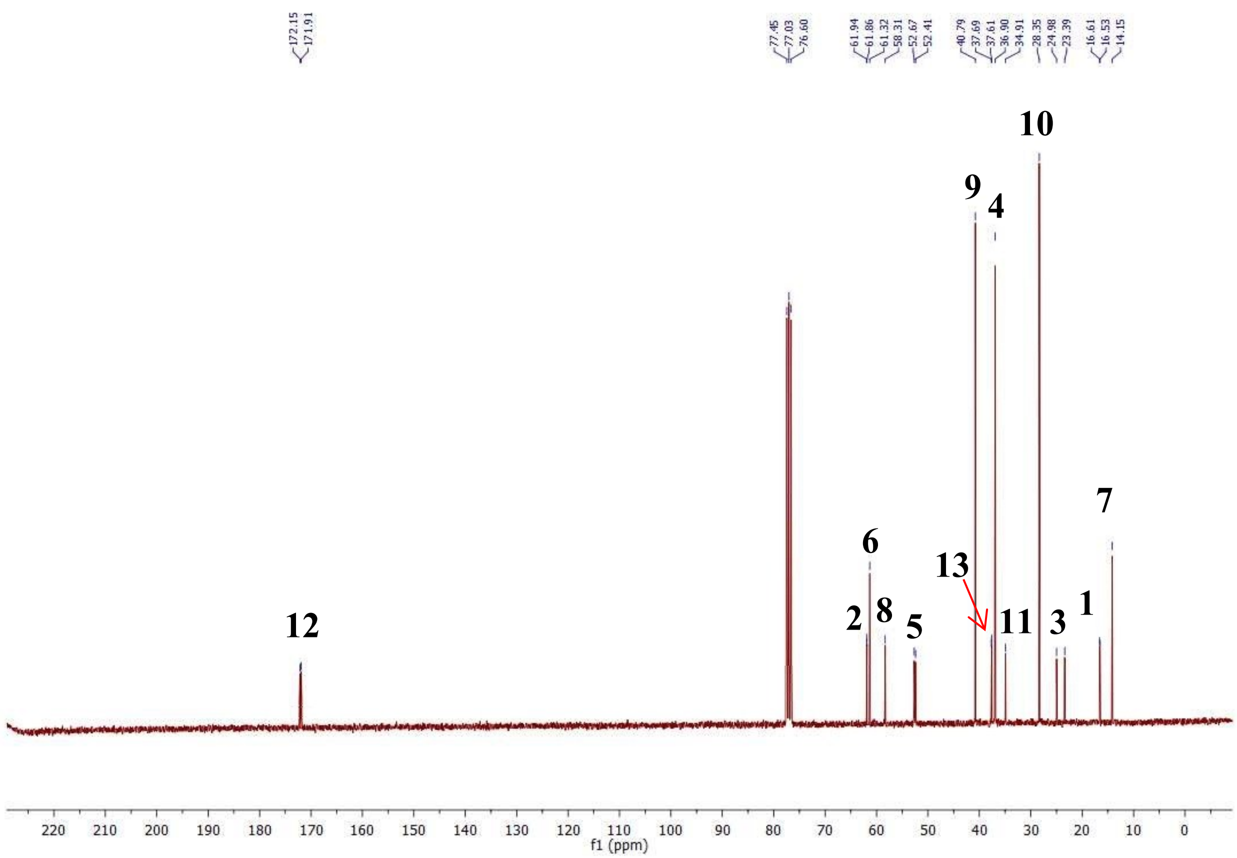

43.57
43.32
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
f1 (ppm)

Compound 4b

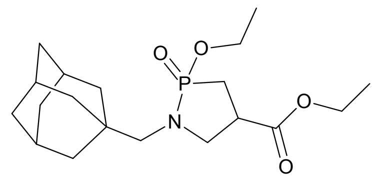


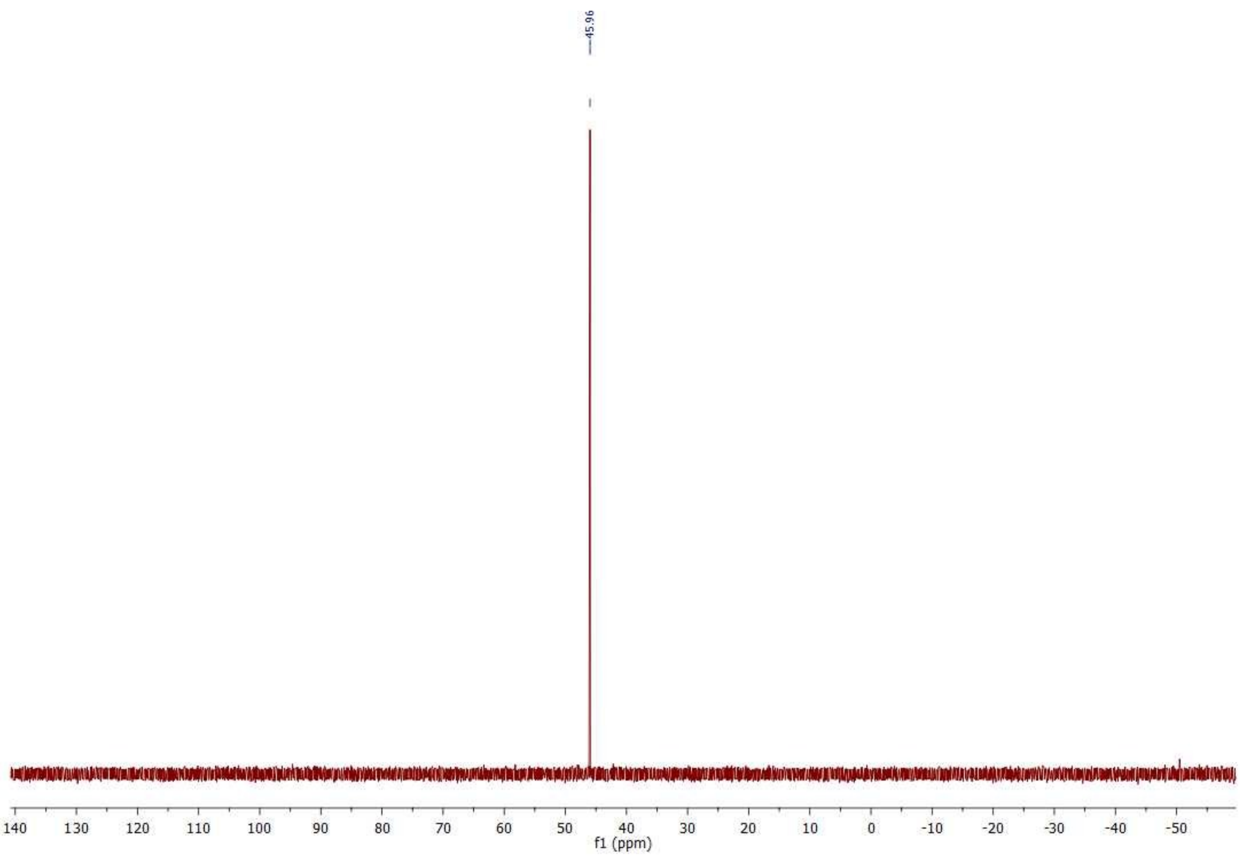


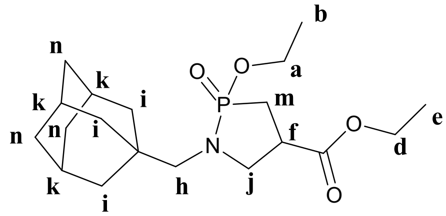




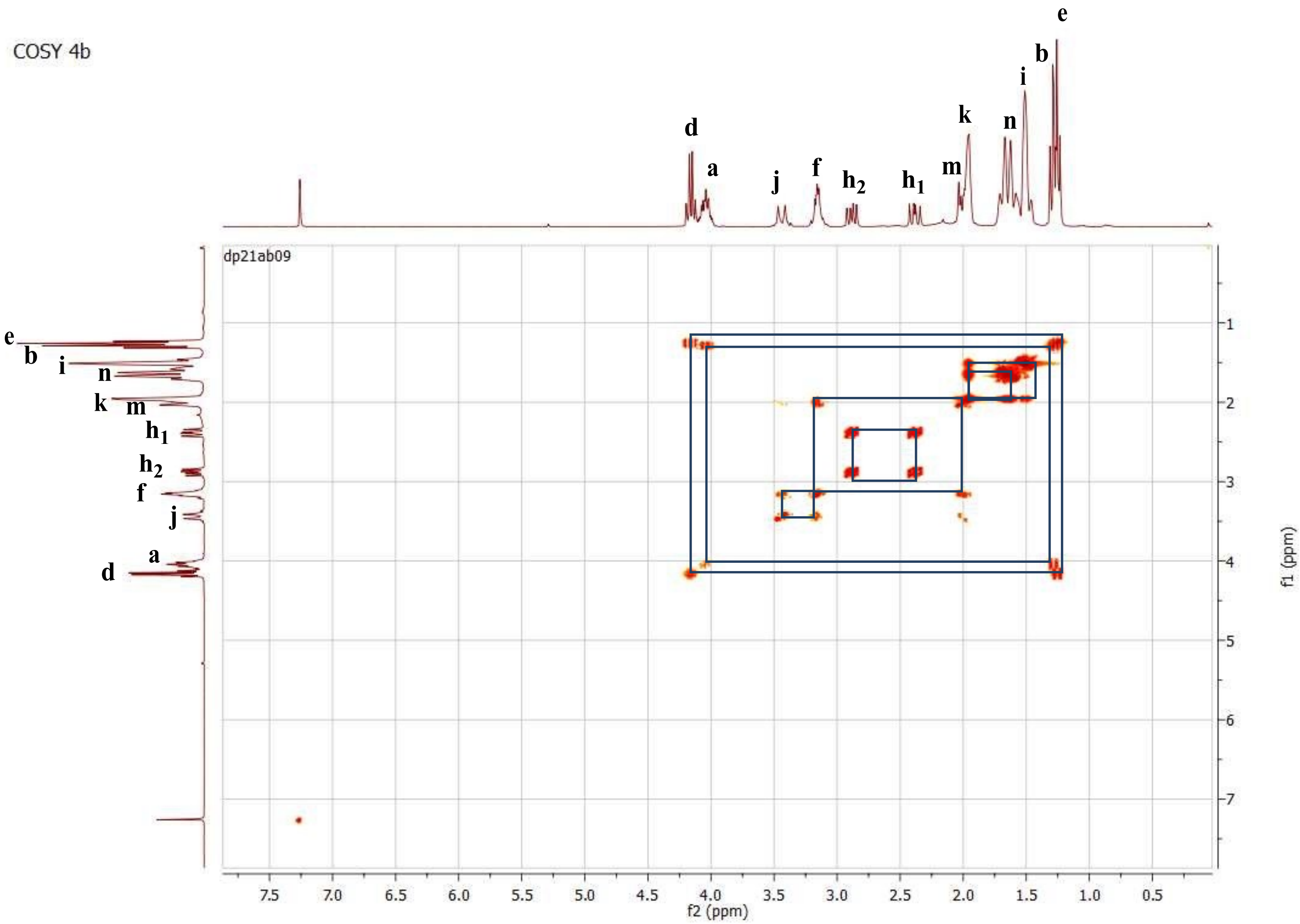
172.15
171.91
77.45
77.03
76.60
61.94
61.86
61.32
58.31
52.67
52.41
40.79
37.69
37.61
36.90
34.91
28.35
24.98
23.39
16.61
16.53
14.15
12
2
6
8
5
9
4
10
13
11
3
1
7
f1 (ppm)


O
P
O
N
O
O

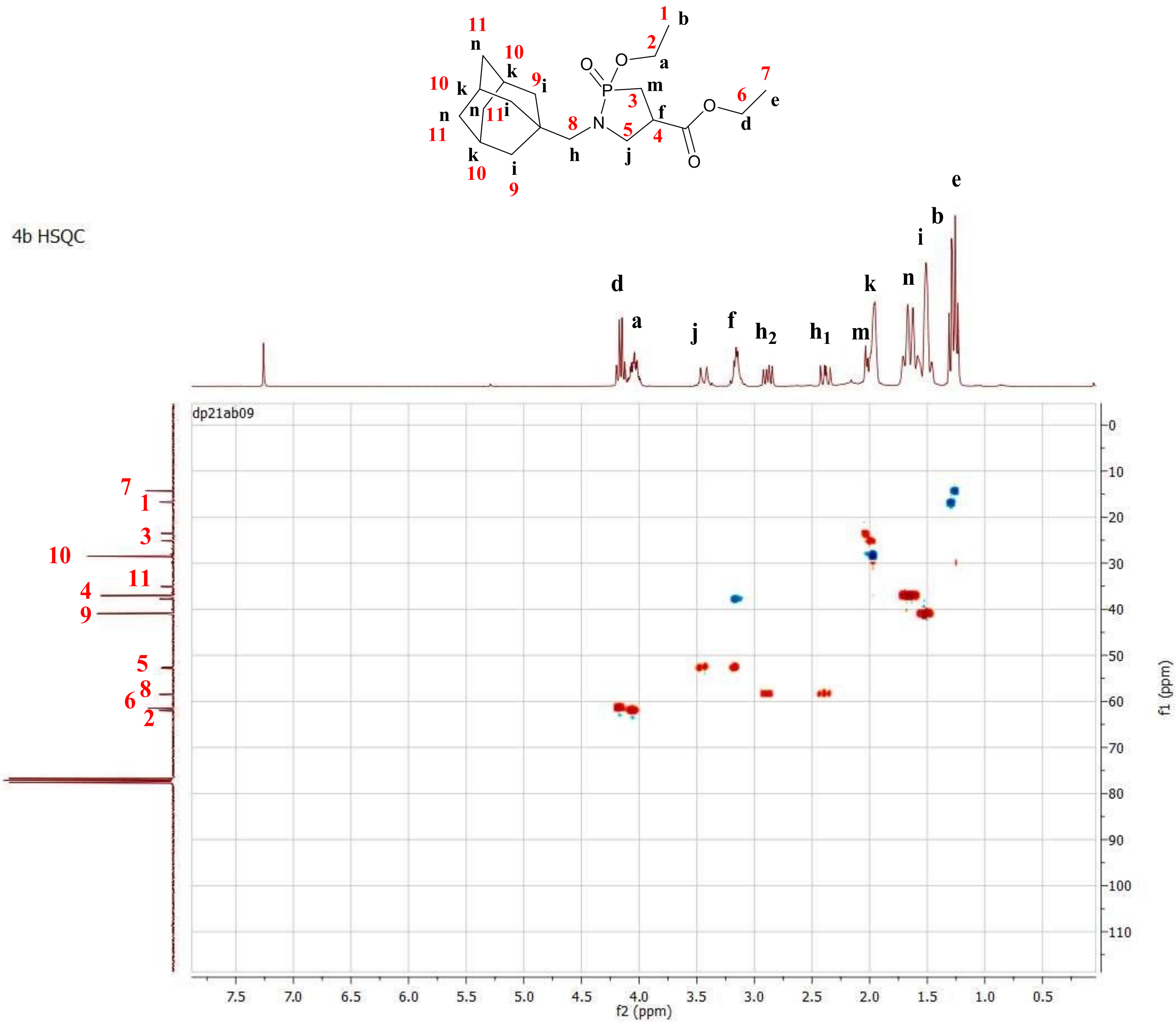

45.96
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
f1 (ppm)



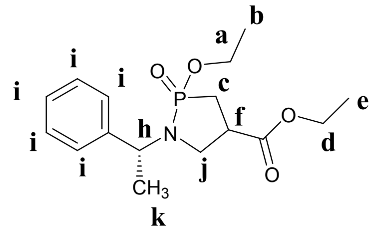
COSY 4b

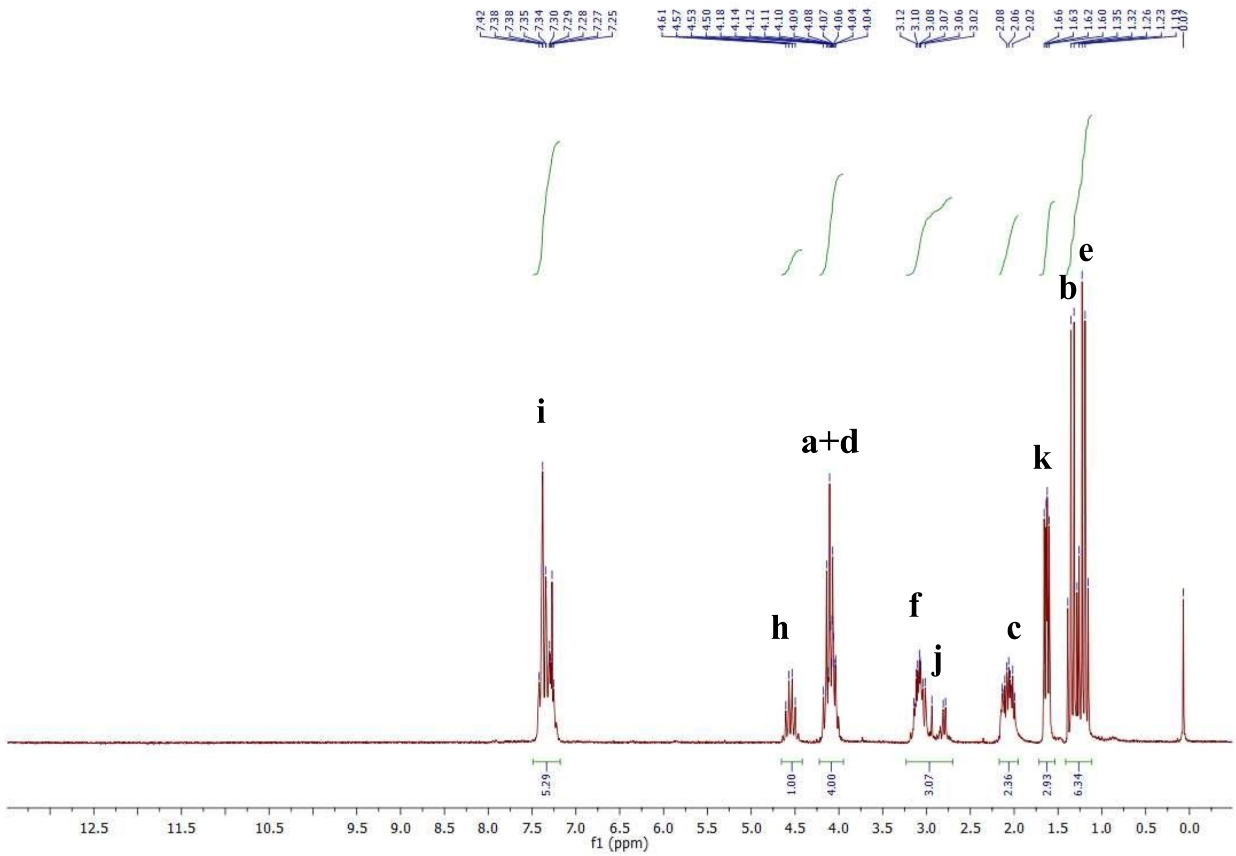


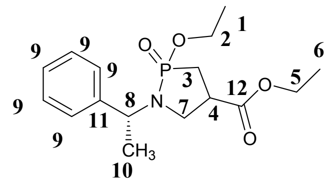
4b HSQC



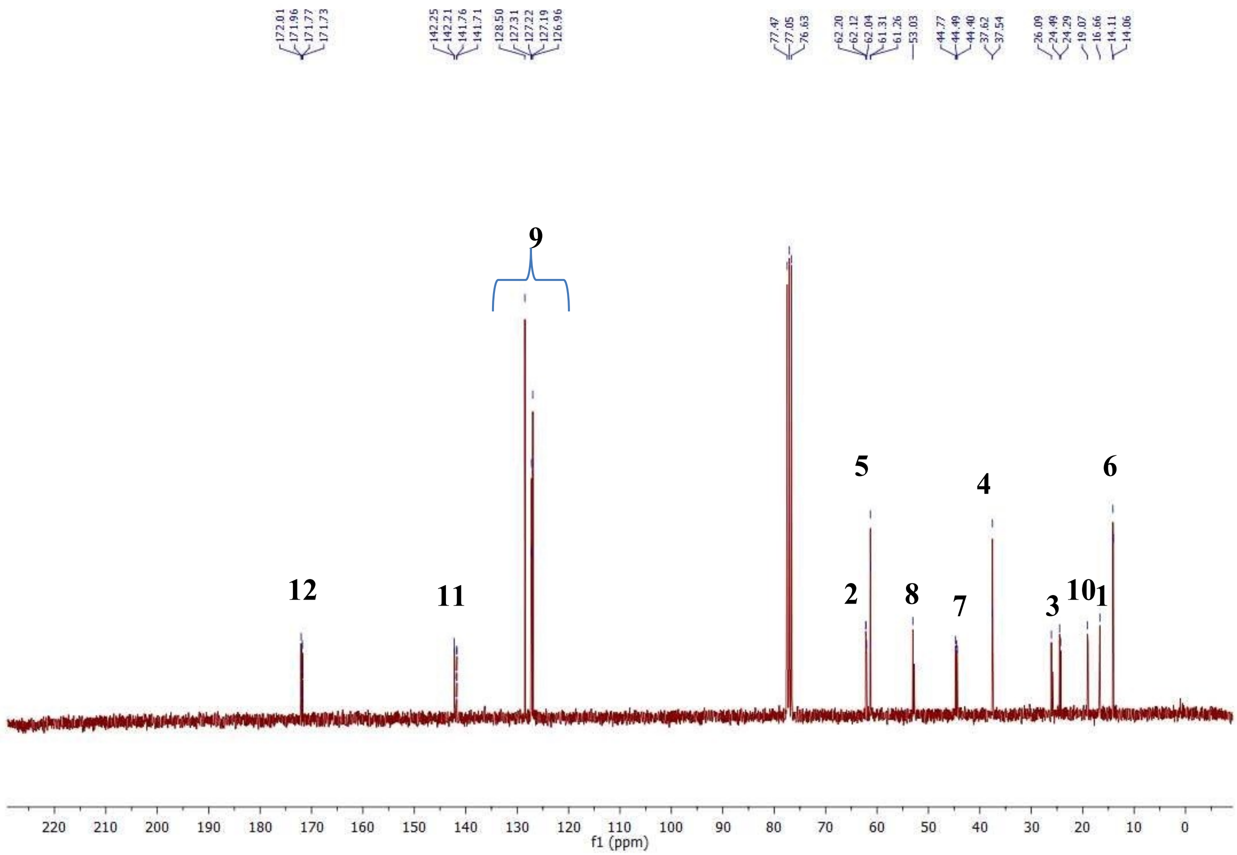
Compound 4c


a
b
c
d
e
f
h
i
j
k
CH3
O
P
N

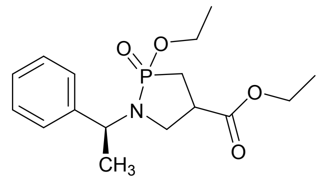

i
a+d
h
f
j
c
k
b
e
5.29
1.00
4.00
3.07
2.36
2.93
6.34
12.5
11.5
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



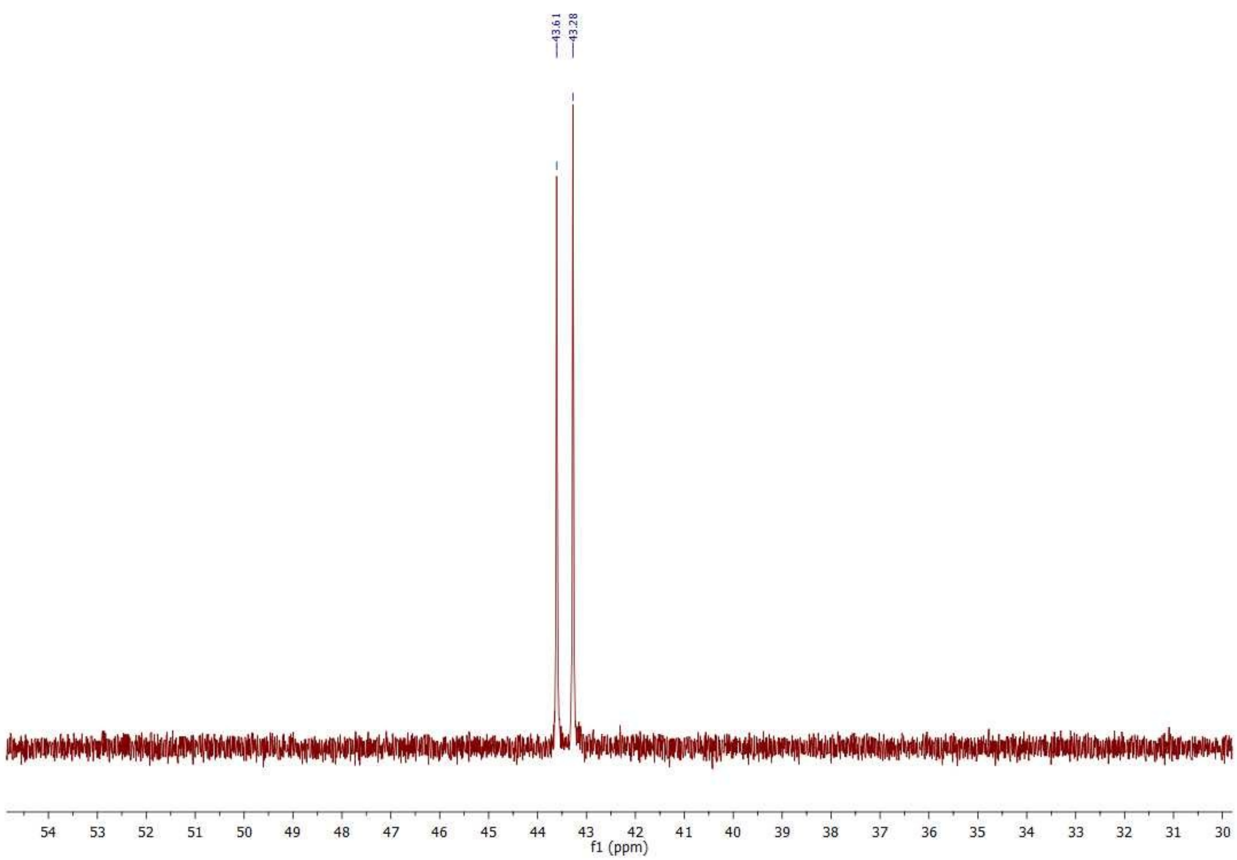
O
P
N
O
O
O
CH3
1
2
3
4
5
6
7
8
9
10
11
12



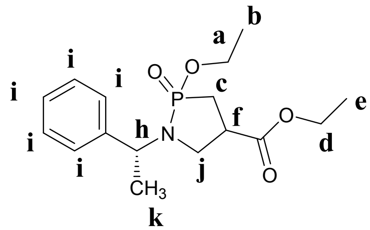
172.01
171.96
171.77
171.73
142.25
142.21
141.76
141.71
128.50
127.31
127.22
127.19
126.96
77.47
77.05
76.63
62.20
62.12
62.04
61.31
61.26
53.03
44.77
44.49
44.40
37.62
37.54
26.09
24.49
24.29
19.07
16.66
14.11
14.06
9
12
11
5
2
8
7
4
3
10
1
6
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

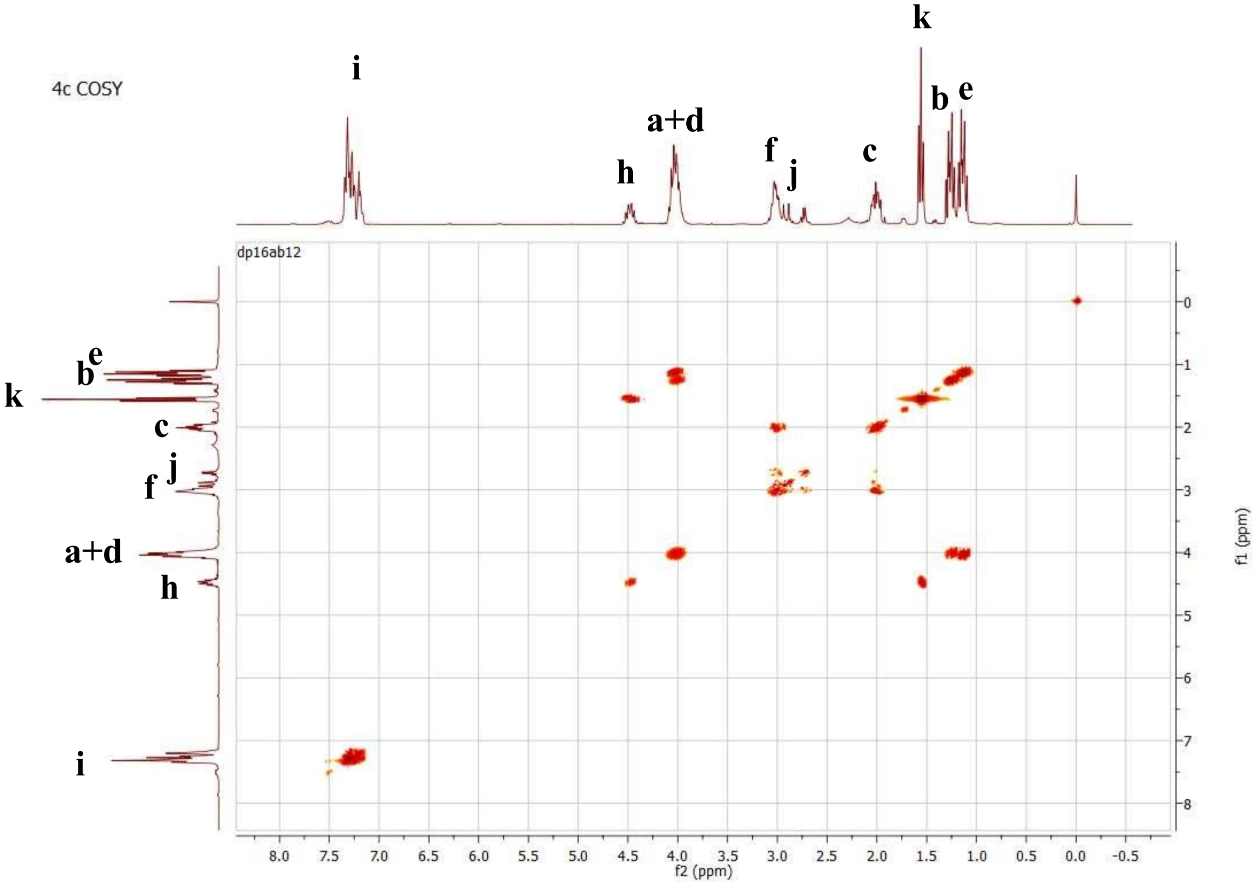


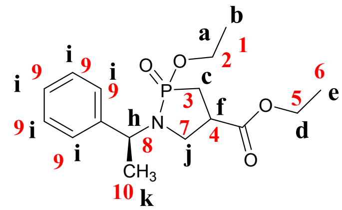
O
O
P
N
O
O
O
CH3



43.61
43.28
54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30
f1 (ppm)

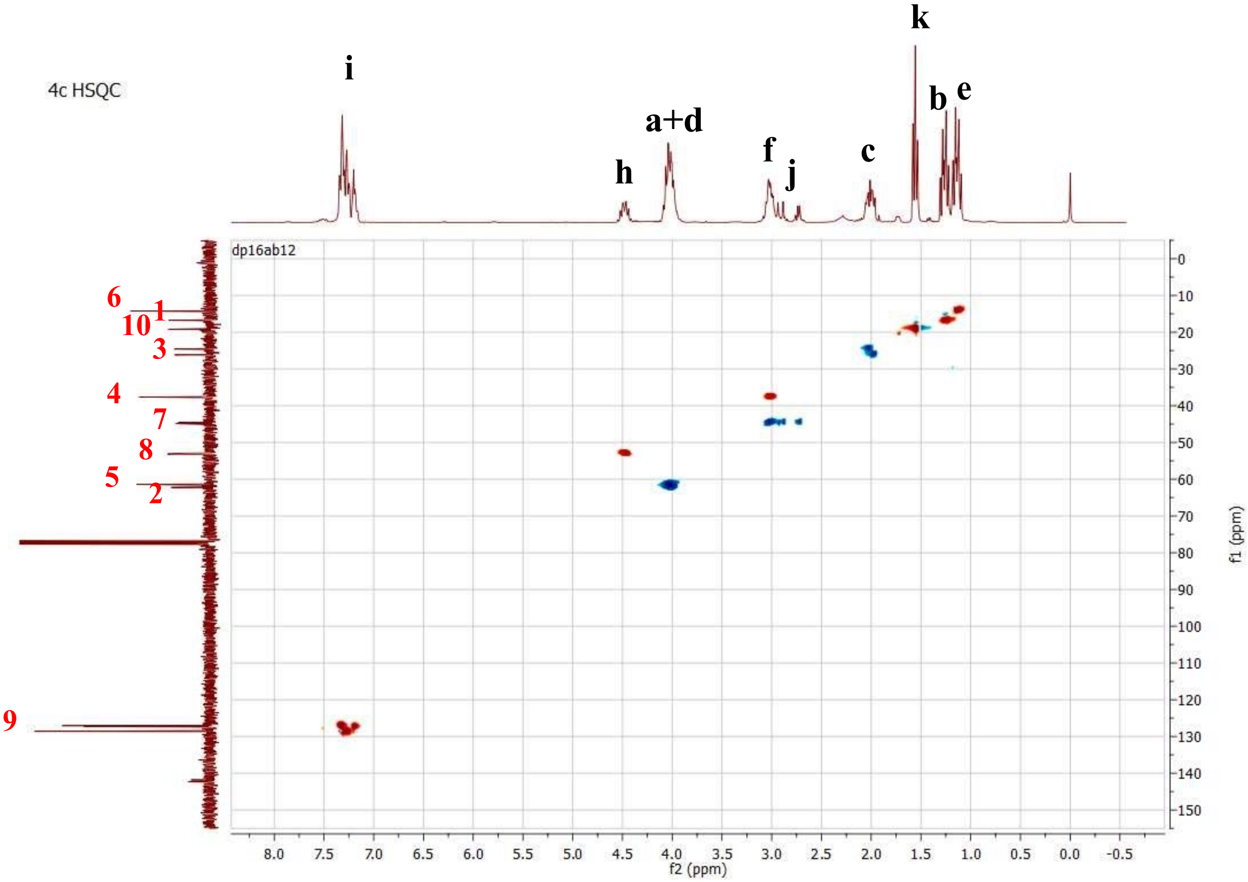

a
b
O
P
O
c
f
O
e
i
i
i
h
N
i
i
j
O
d
CH3
k


4c COSY
dp16ab12
i
h
a+d
f
j
c
k
b
e
f2 (ppm)
f1 (ppm)



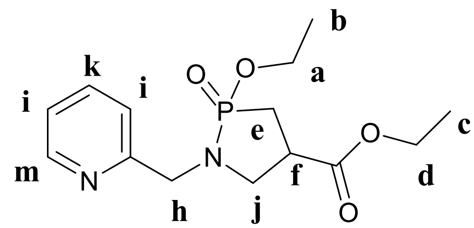
a
b
1
2
i
9
9
i
i
9
9
O
O
P
c
3
f
O
5
6
e
9 i
h
N
7
4
d
9
i
j
8
O
CH3
10 k

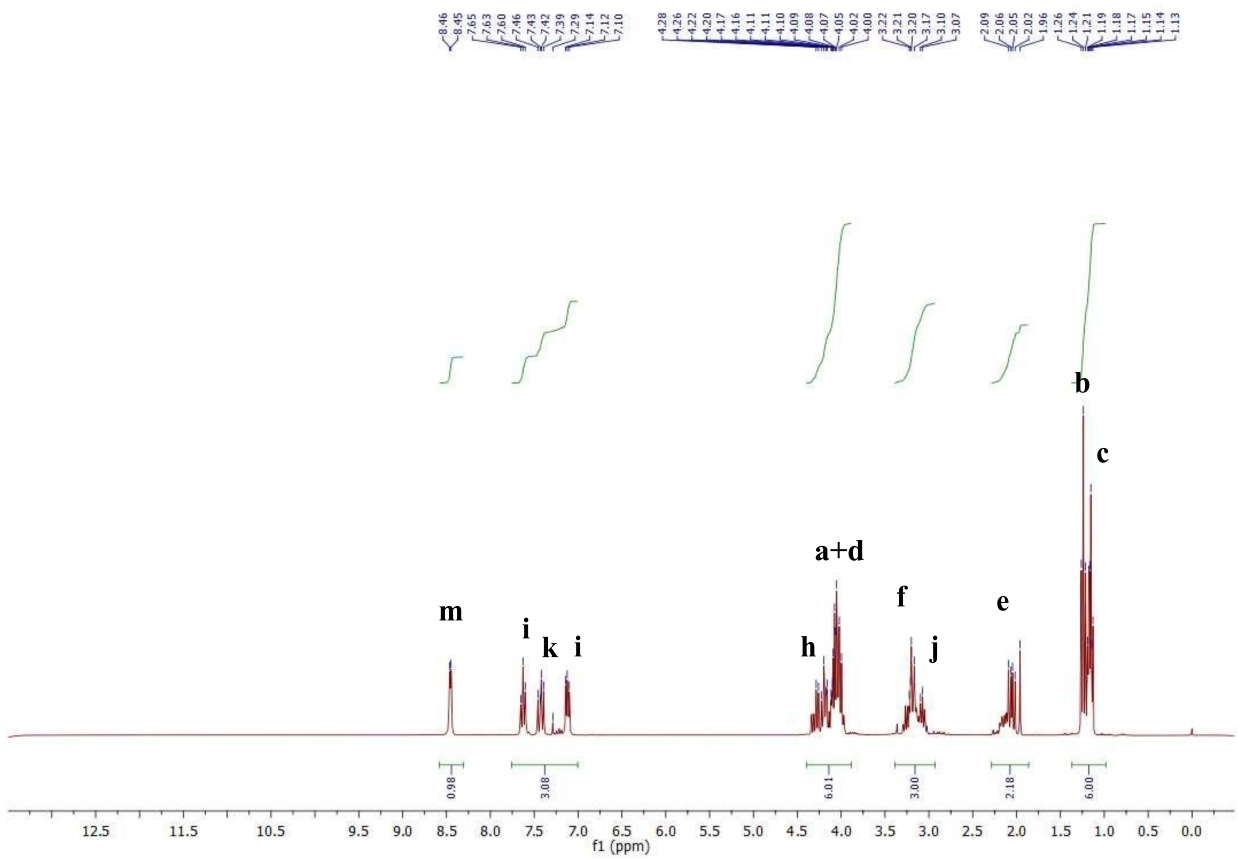
4c HSQC

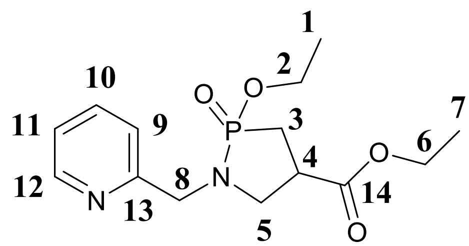


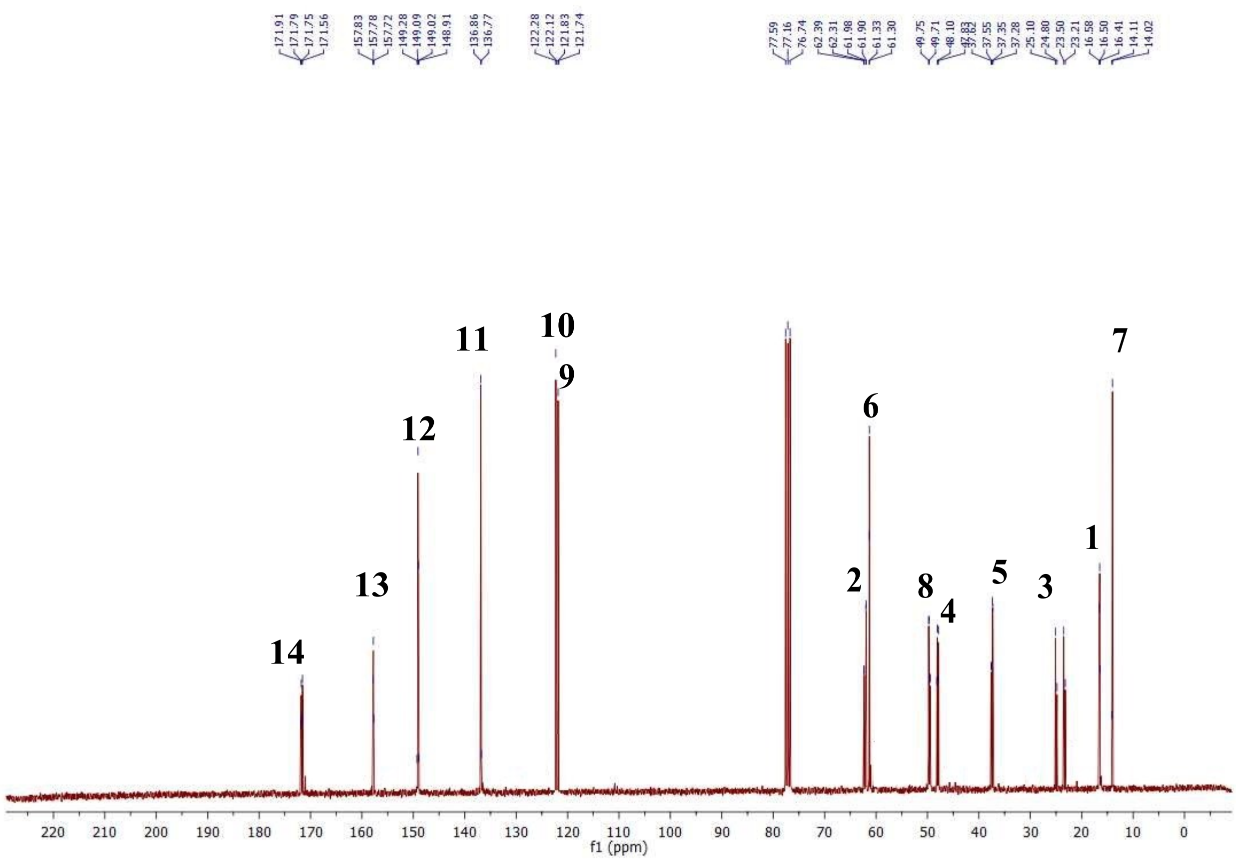
i
h
a+d
f
j
c
k
b
e
dp16ab12
6
1
10
3
4
7
8
5
2
9
f2 (ppm)
f1 (ppm)

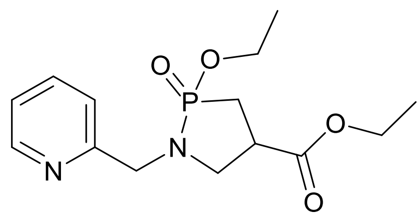
Compound 4d mixture of diastereomers

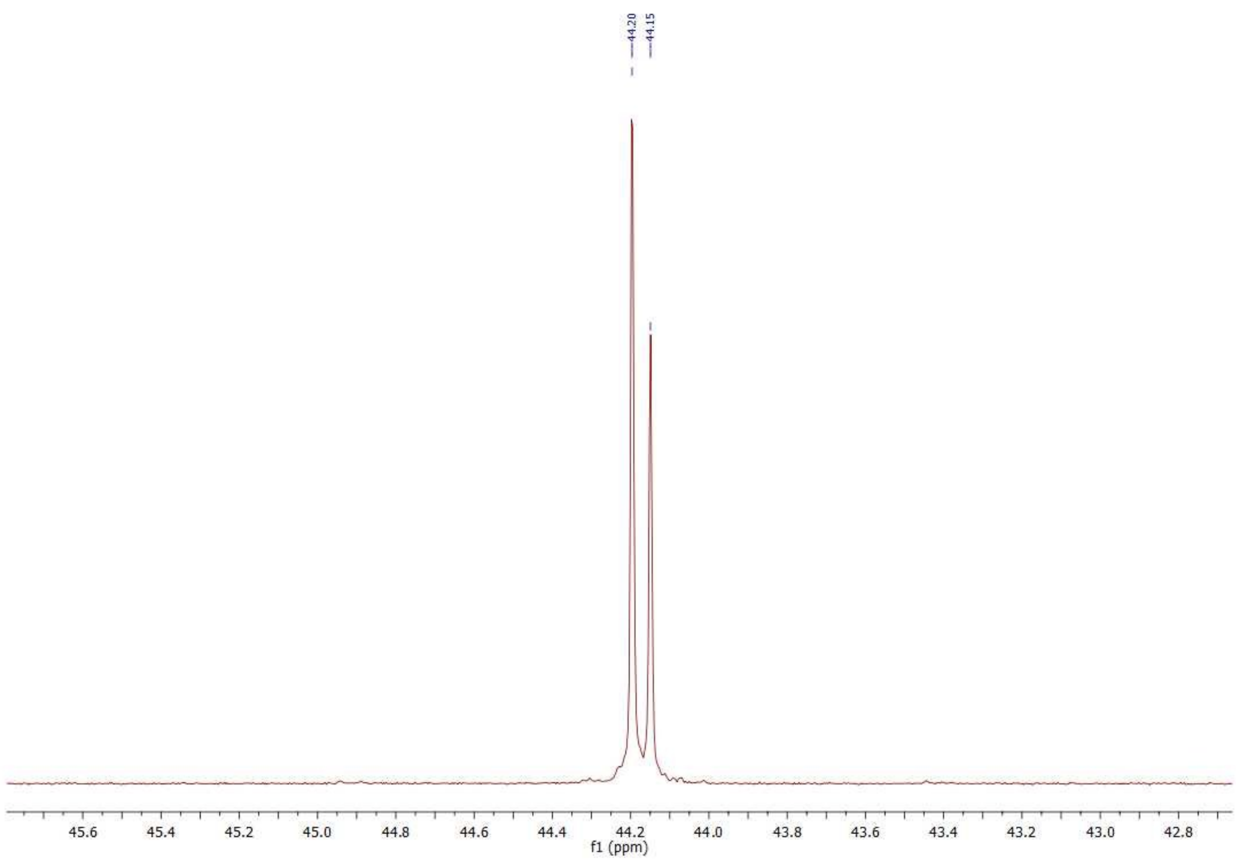


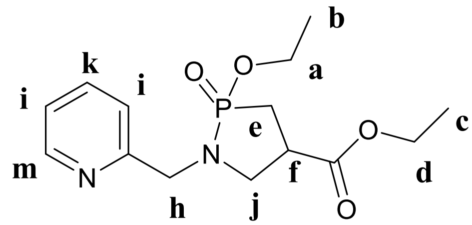


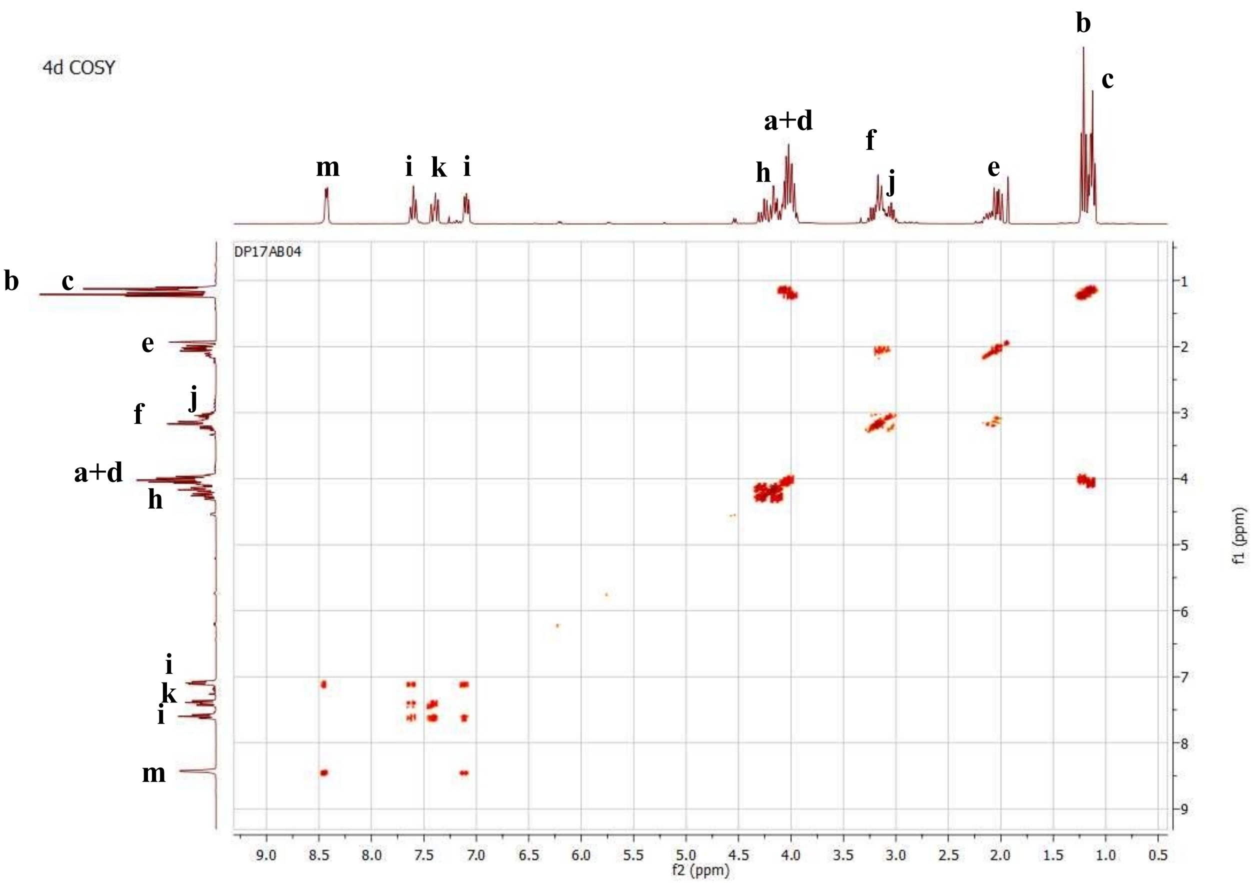

1
2
O
10
O
P
3
11
9
7
4
O
6
N
8
12
N
13
14
5
O

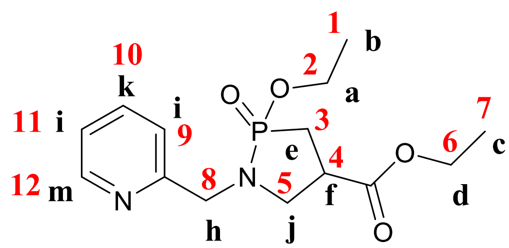

171.91
171.79
171.75
171.56
157.83
157.78
157.72
149.28
149.09
149.02
148.91
136.86
136.77
122.28
122.12
121.83
121.74
77.59
77.16
76.74
62.39
62.31
61.98
61.90
61.33
61.30
49.75
49.71
48.10
37.55
37.35
37.28
25.10
24.80
23.50
23.21
16.58
16.50
16.41
14.11
14.02
14
13
12
11
10
9
6
7
2
8
4
5
3
1
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
P
O
O
N
N
O

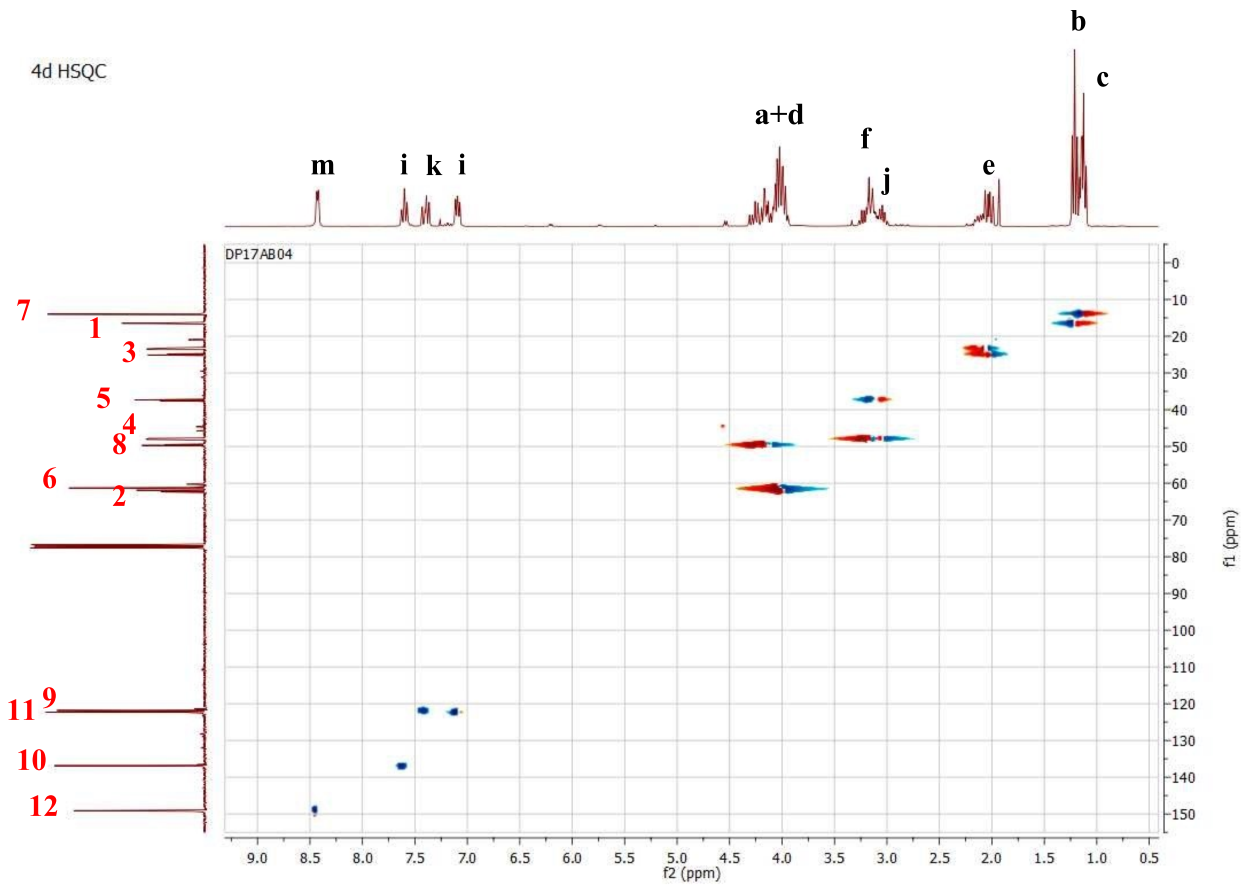

44.20
44.15
45.6
45.4
45.2
45.0
44.8
44.6
44.4
44.2
44.0
43.8
43.6
43.4
43.2
43.0
42.8
f1 (ppm)


b
a
k
i
i
e
m
N
f
d
c
h
j
O
P


4d COSY
DP17AB04
m
i
k
i
h
a+d
f
j
e
b
c
f2 (ppm)
f1 (ppm)



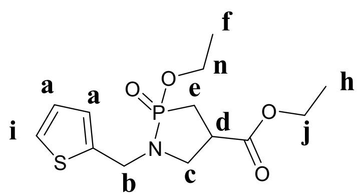
1
b
2
a
10
k
i
3
11 i
9
e
4
6
c
7
8
5
12 m
f
d
h
j

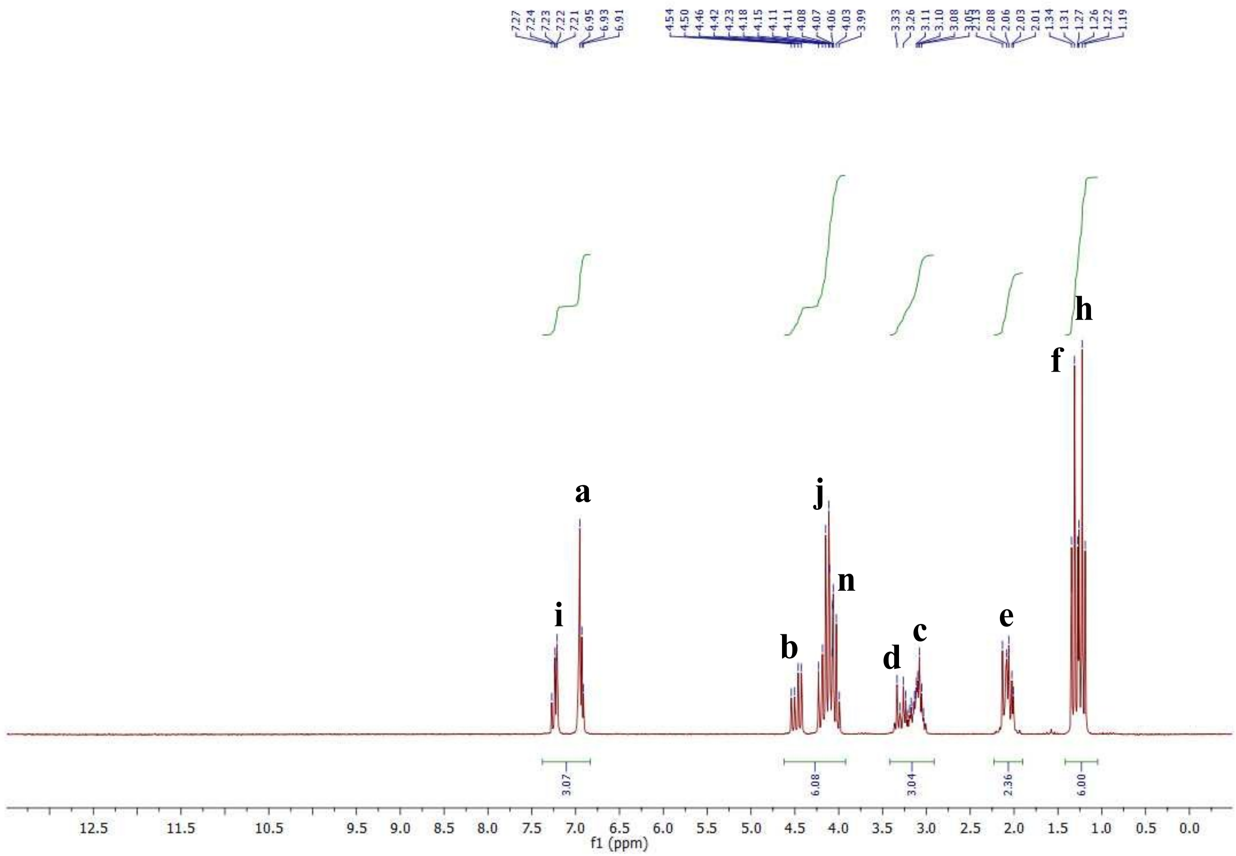


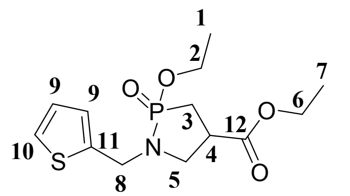
4d HSQC
DP17AB04
m
i
k
i
a+d
f
j
e
b
c
7
1
3
5
4
8
6
2
11
9
10
12
f2 (ppm)
f1 (ppm)

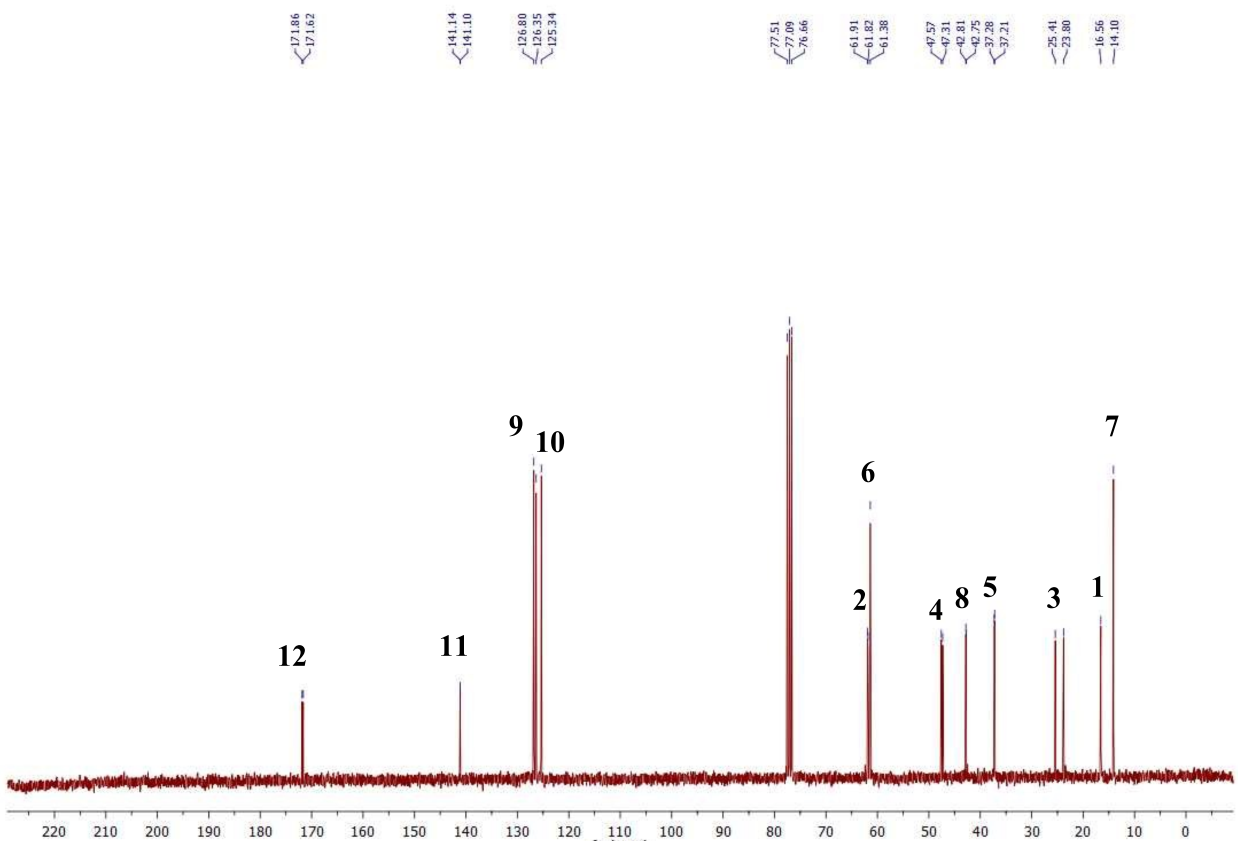
Supplementary Material (part 2)

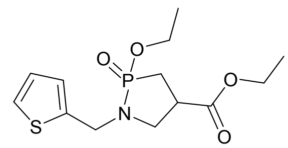
Compound 4e (1st dia)

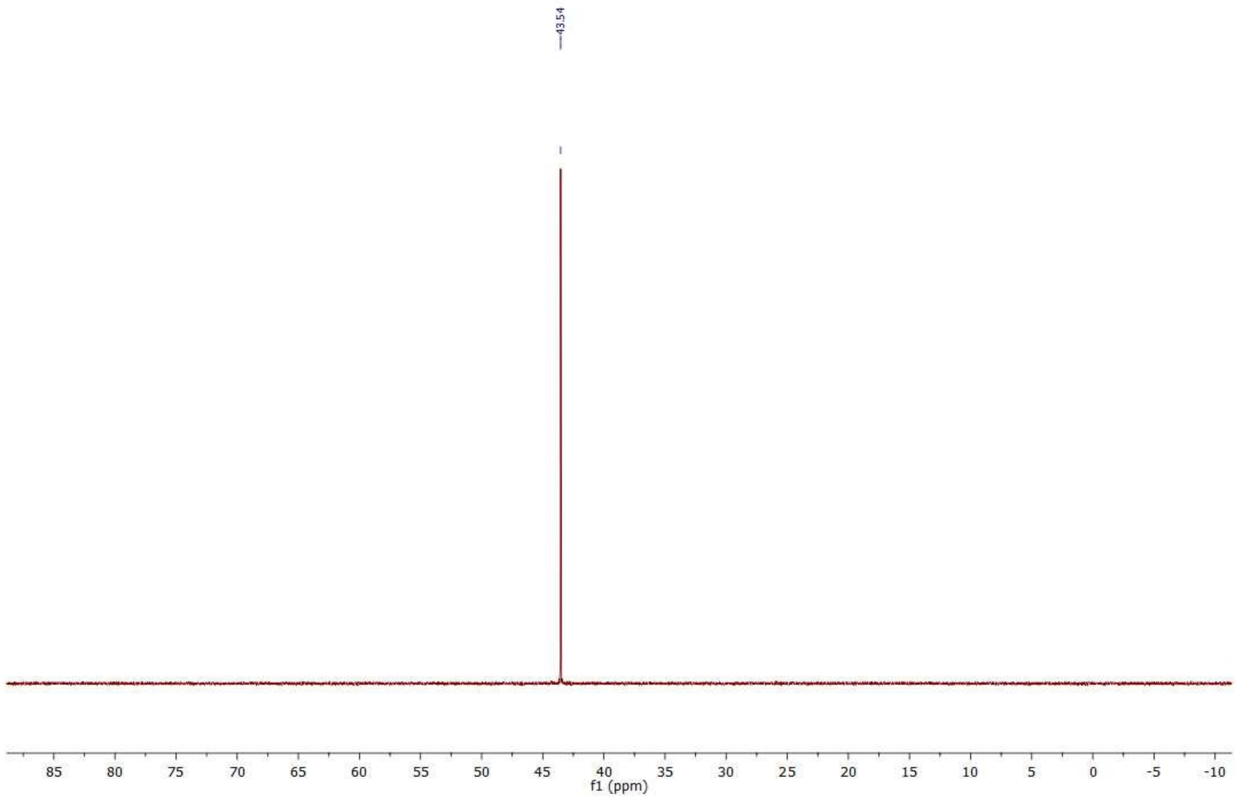


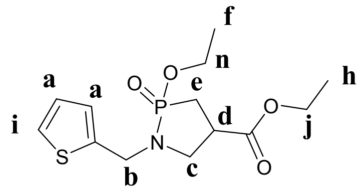



1
2
7
6
9
9
3
12
10
11
4
8
5

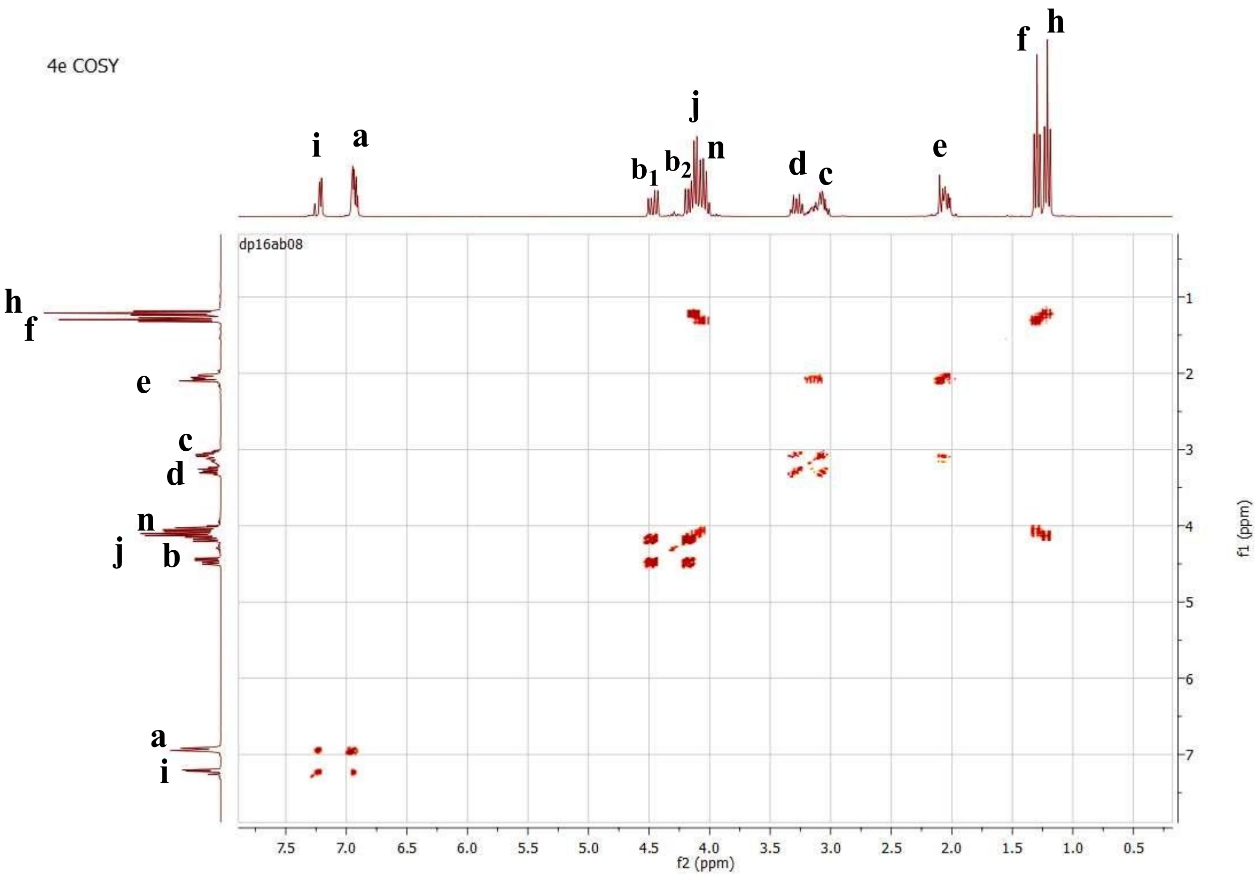

171.86
171.62
141.14
141.10
126.80
126.35
125.34
77.51
77.09
76.66
61.91
61.82
61.38
47.57
47.31
42.81
42.75
37.28
37.21
25.41
23.80
16.56
14.10
12
11
9
10
6
2
4
8
5
3
1
7
f1 (ppm)

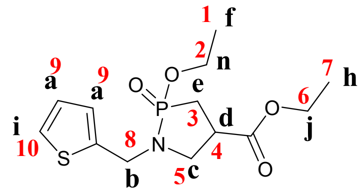

O
O
P
N
S
O
O


43.54
85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0 -5 -10
f1 (ppm)

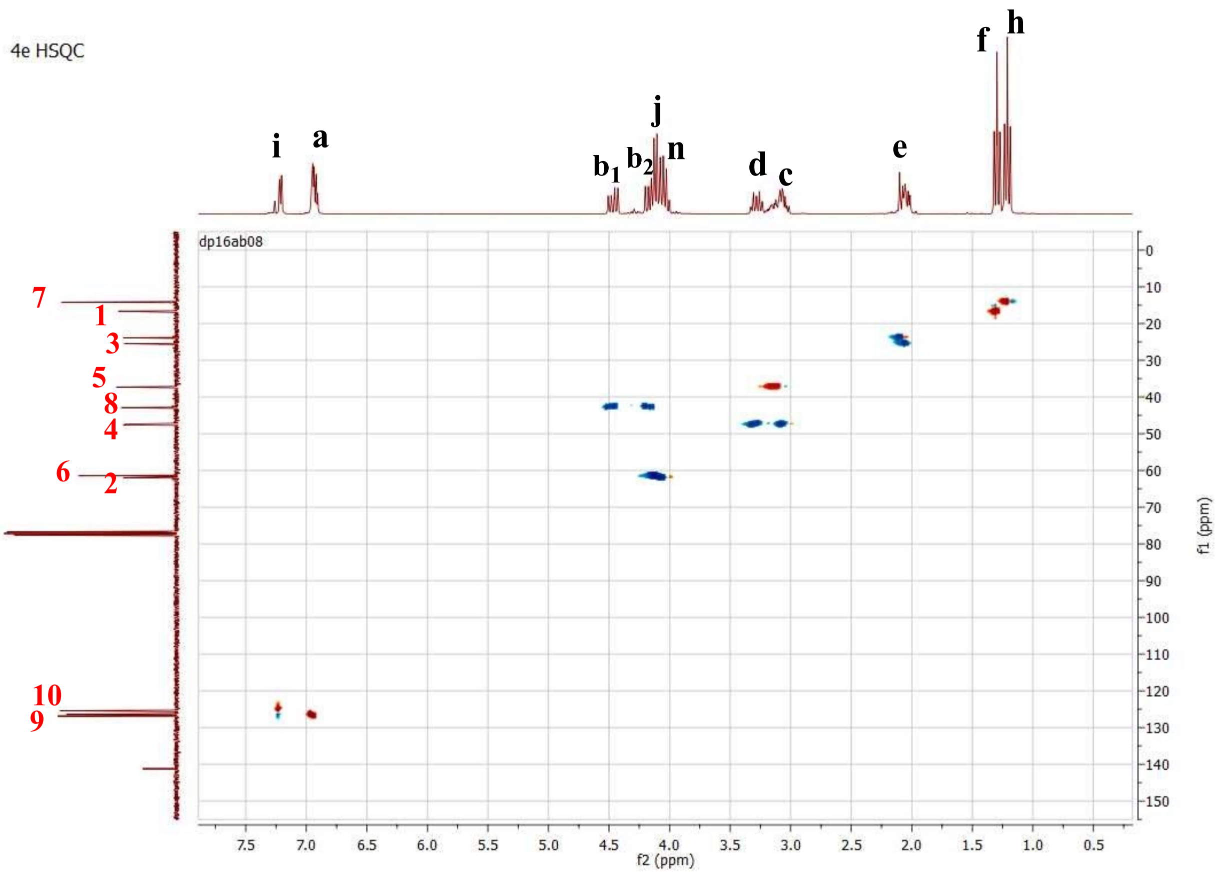


4e COSY

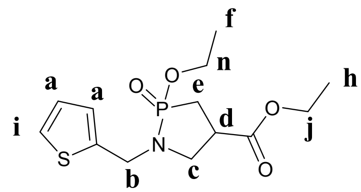


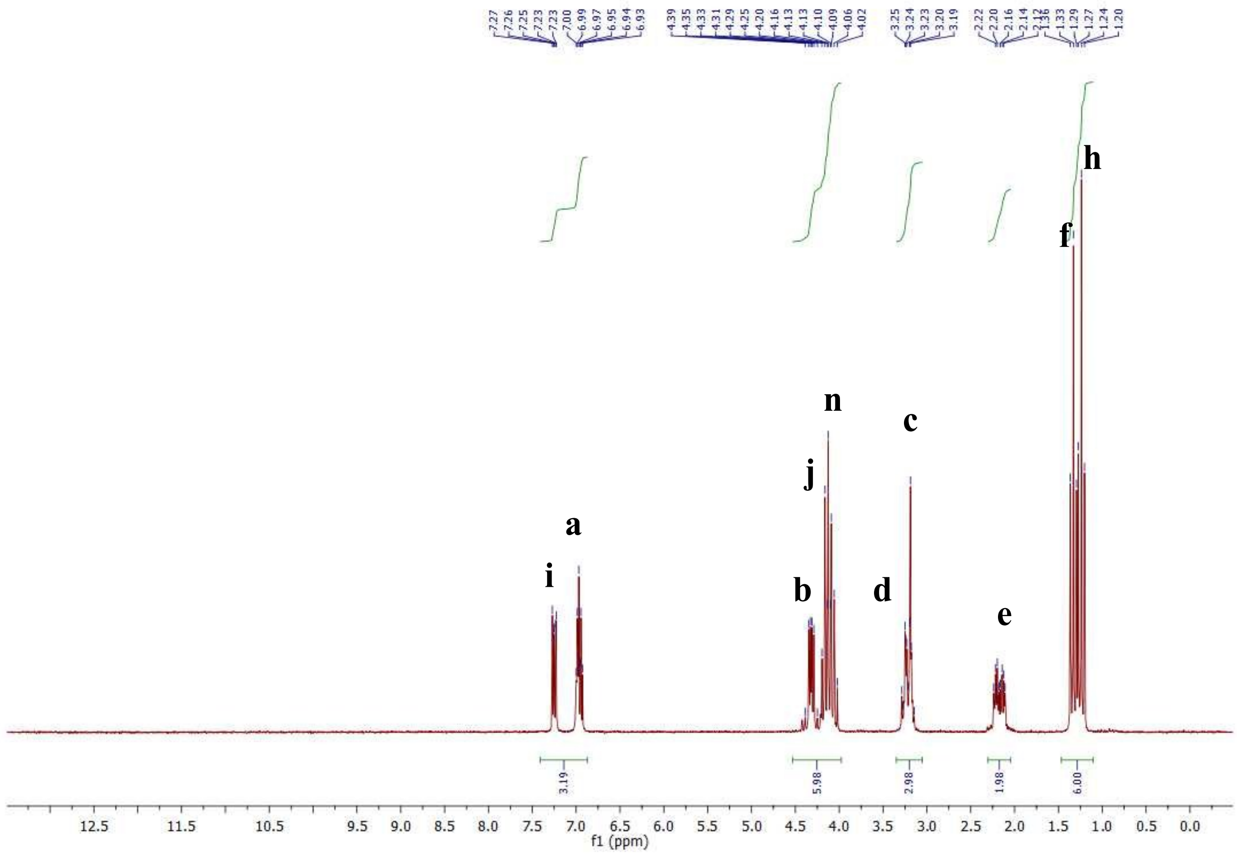

1
f
2
n
O
e
9
a
9
a
O
P
3
d
O
7
h
6
j
i
10
S
8
b
N
5c
4
O

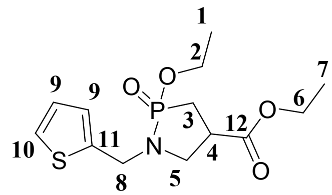
4e HSQC


i
a
b1
b2
j
n
d
c
e
f
h
dp16ab08
7
1
3
5
8
4
6
2
10
9
f1 (ppm)
f2 (ppm)

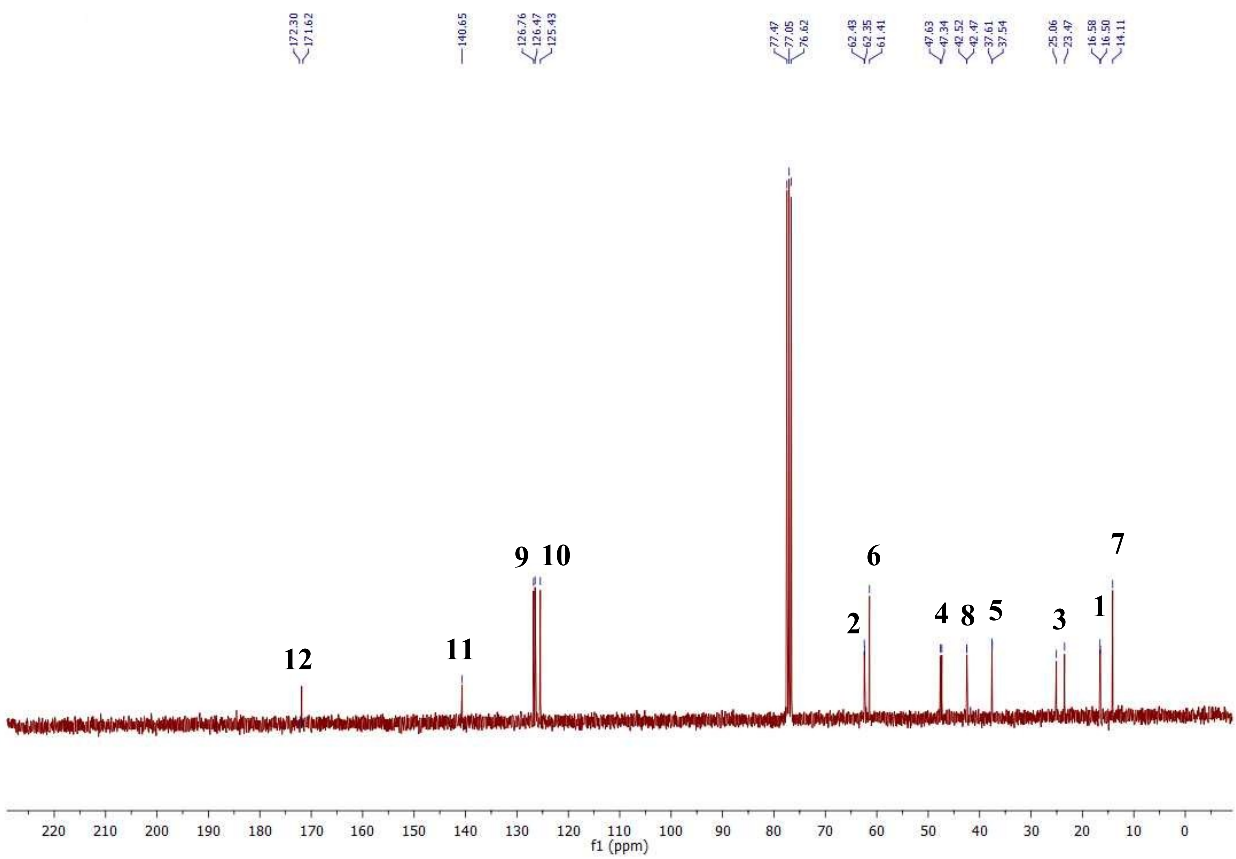
Compound 4e (2nd dia)



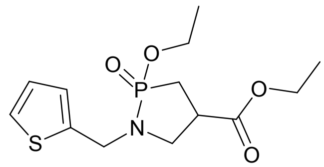


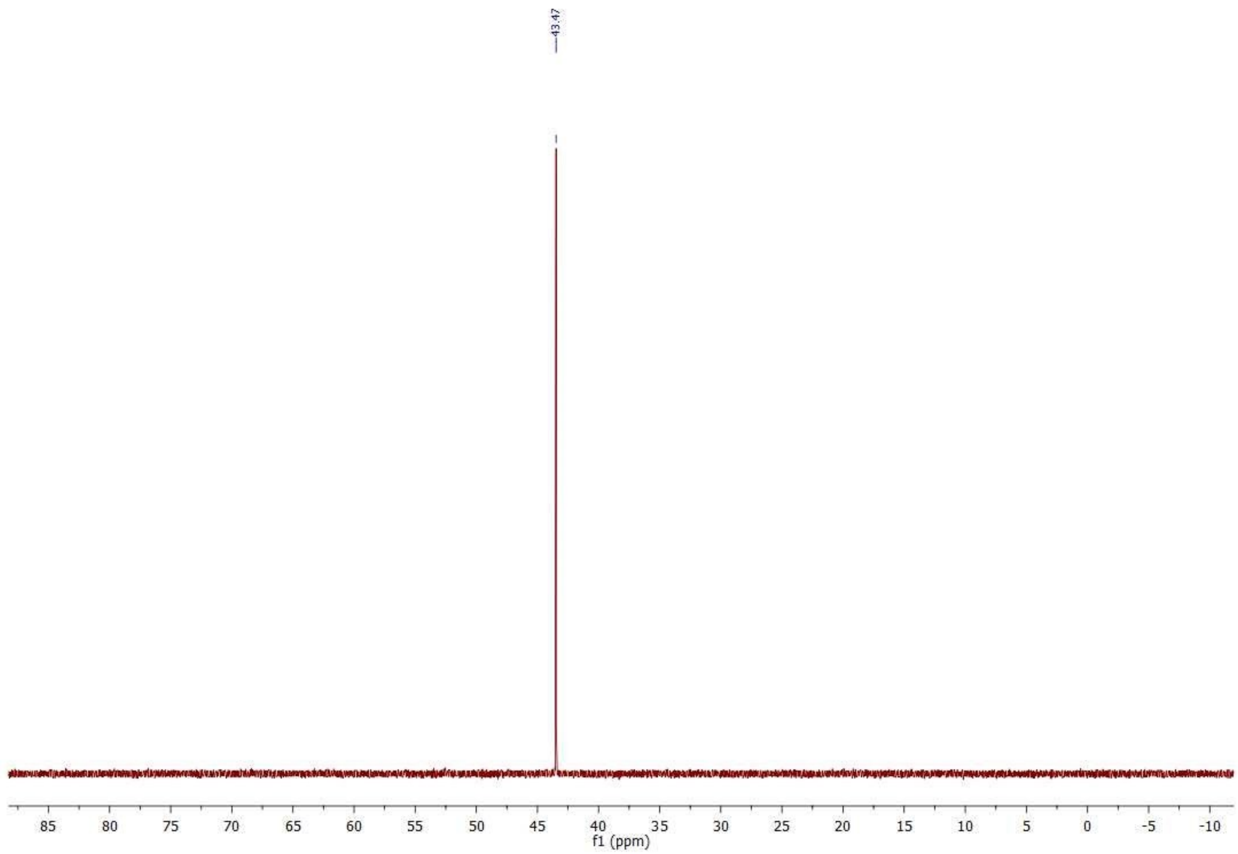


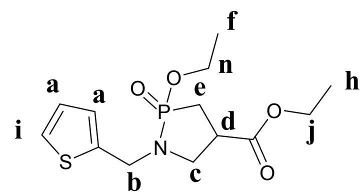
1
2
7
6
9
9
3
12
10
11
4
8
5

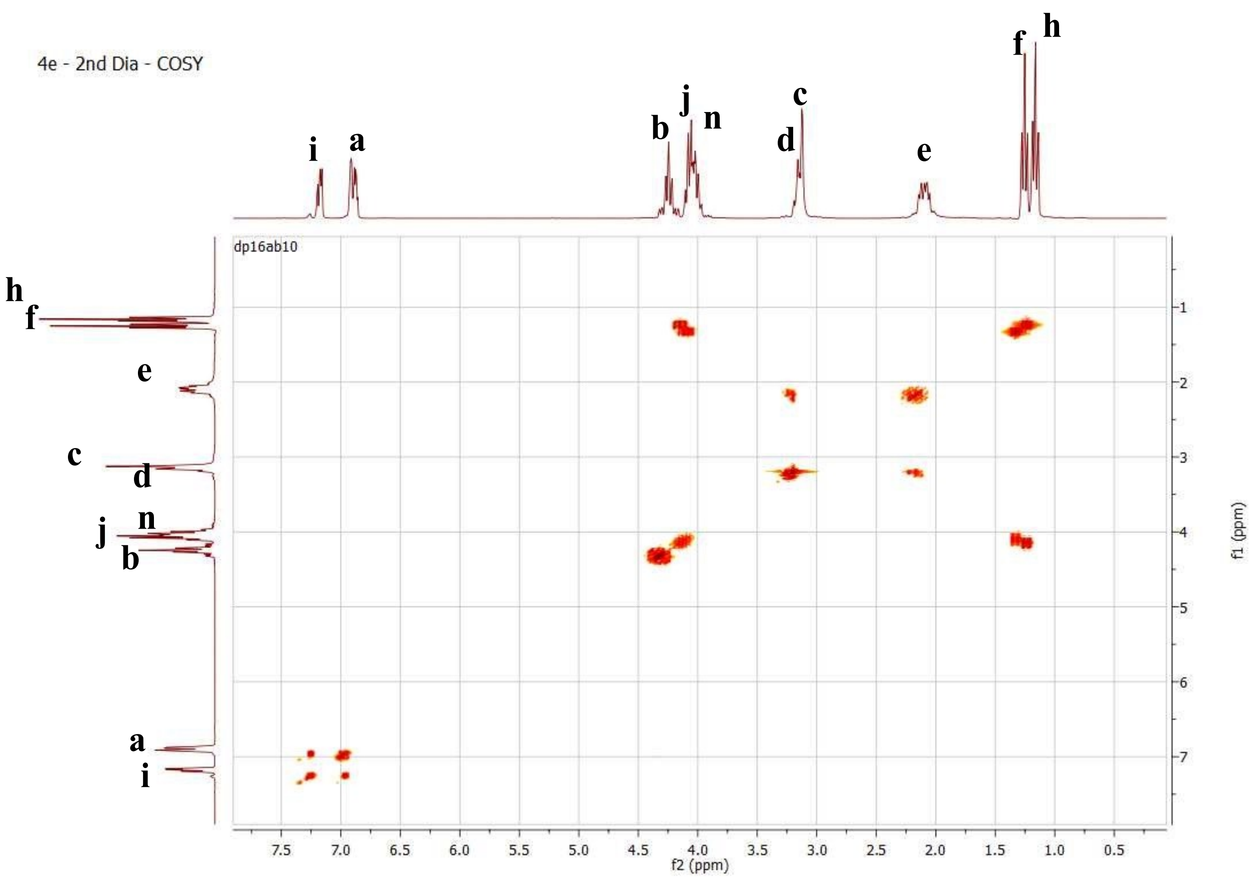


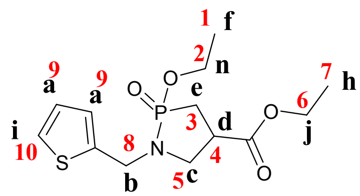
172.30
171.62
140.65
126.76
126.47
125.43
77.47
77.05
76.62
62.43
62.35
61.41
47.63
47.34
42.52
42.47
37.61
37.54
25.06
23.47
16.58
16.50
14.11
12
11
9
10
2
6
4
8
5
3
1
7
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
P
O
N
S
O
O

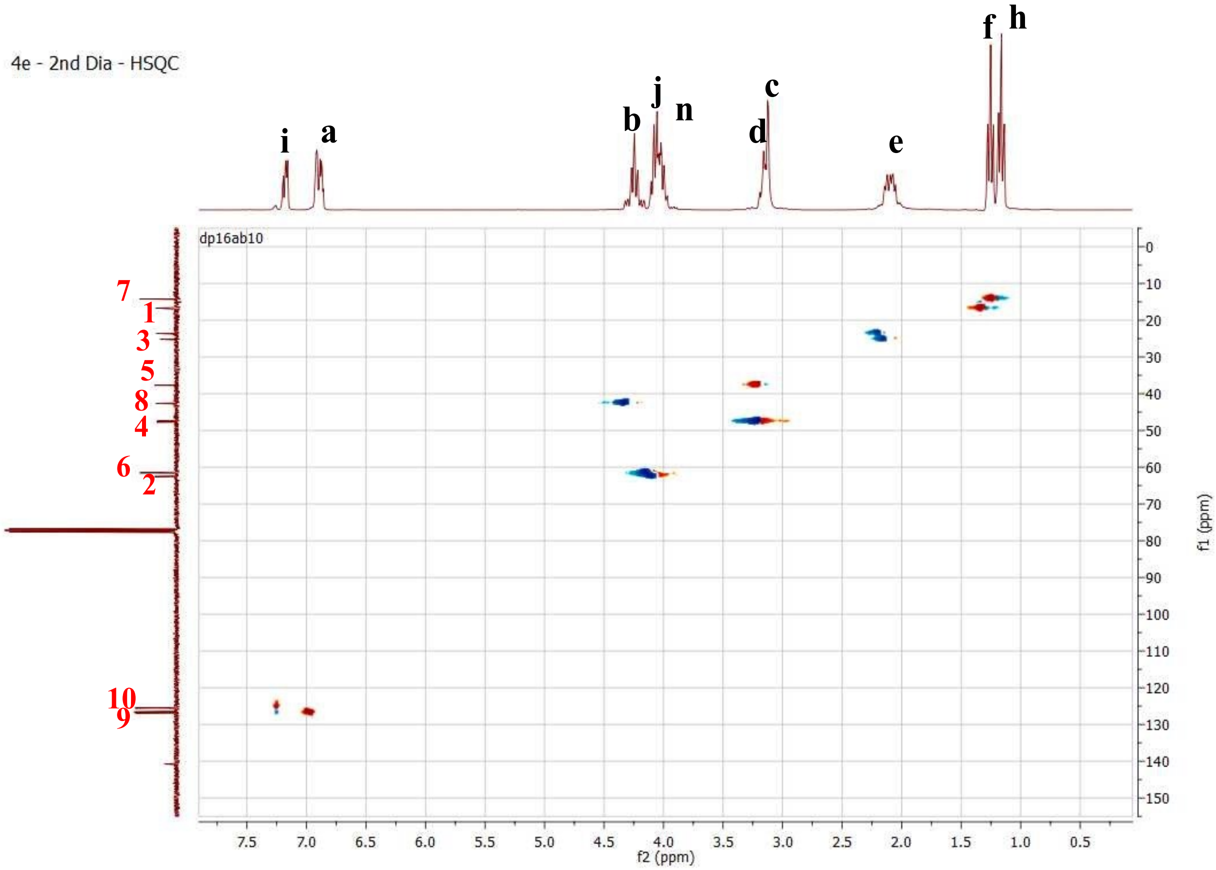

43.47
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
f1 (ppm)


a
a
i
S
b
N
c
P
O
e
O
n
f
d
O
j
h
O

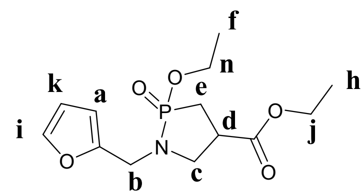

4e - 2nd Dia - COSY
dp16ab10
i
a
b
j
n
d
c
e
f
h
f2 (ppm)
f1 (ppm)

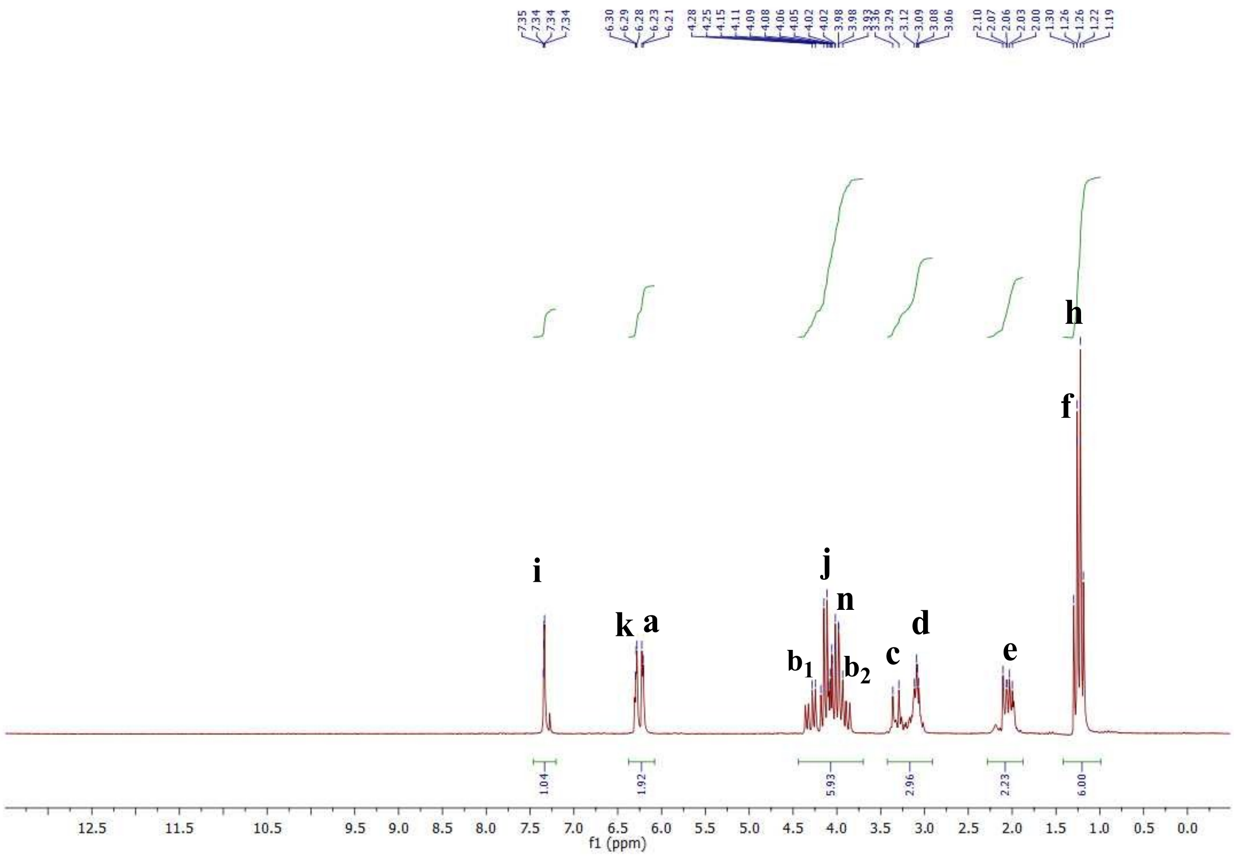


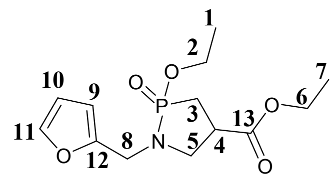
4e - 2nd Dia - HSQC

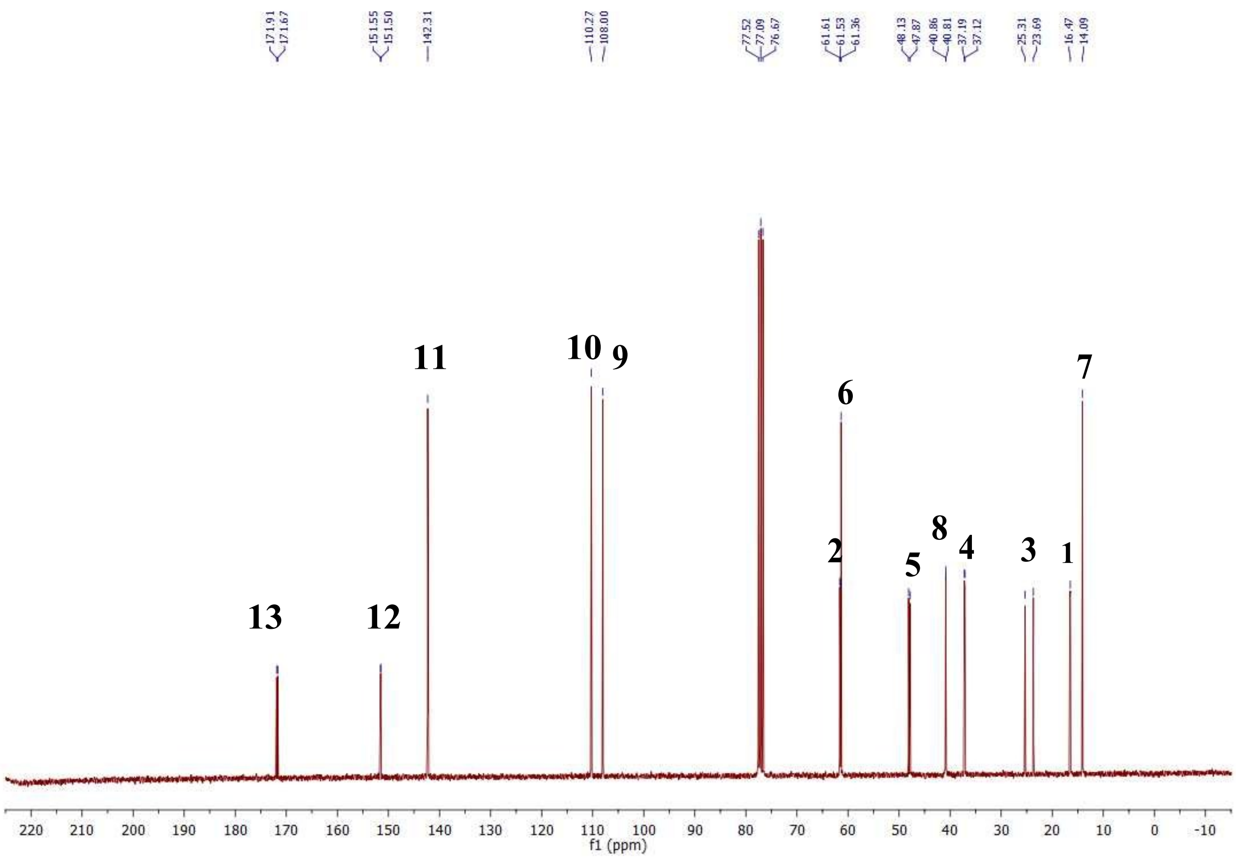


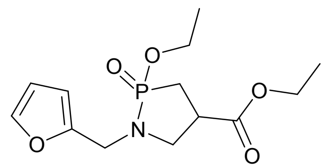
Compound 4f (1st dia)

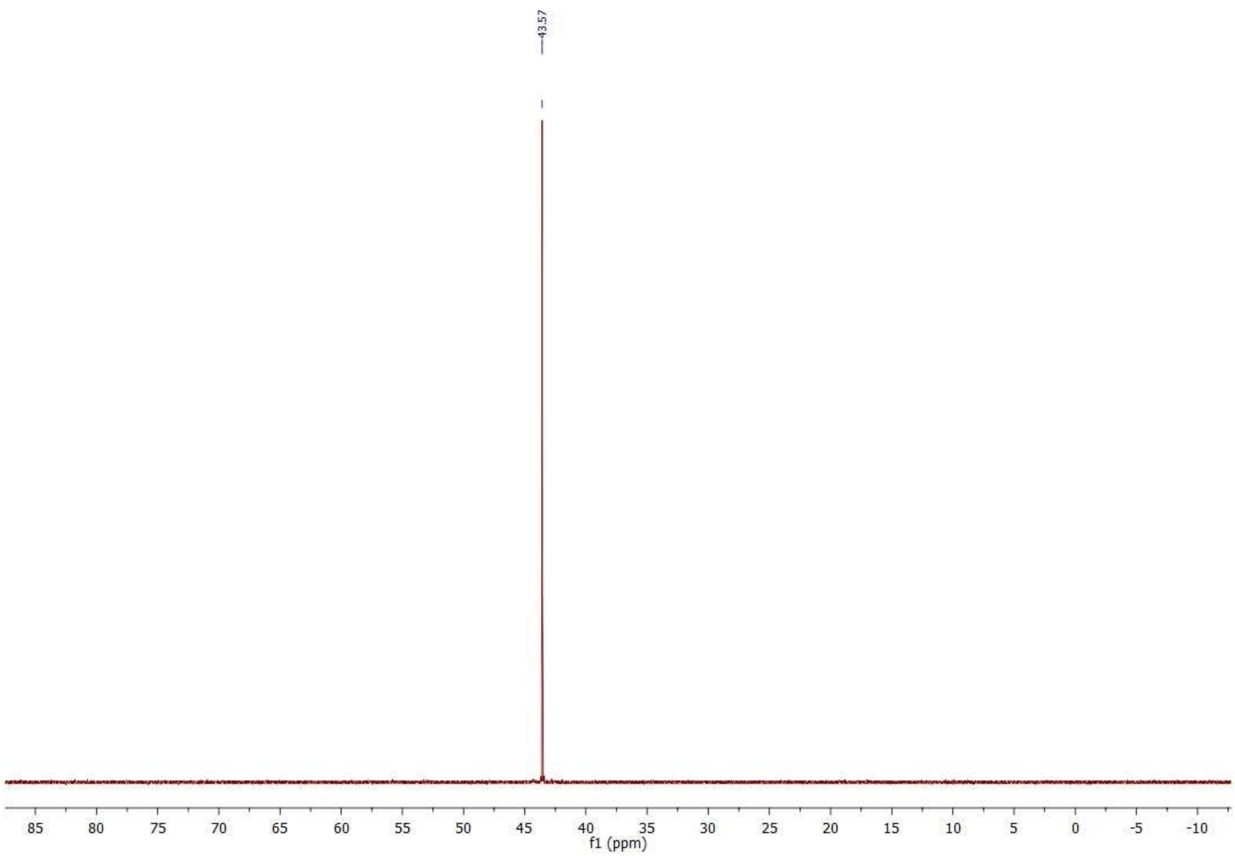


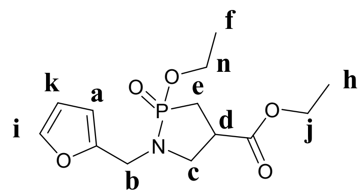


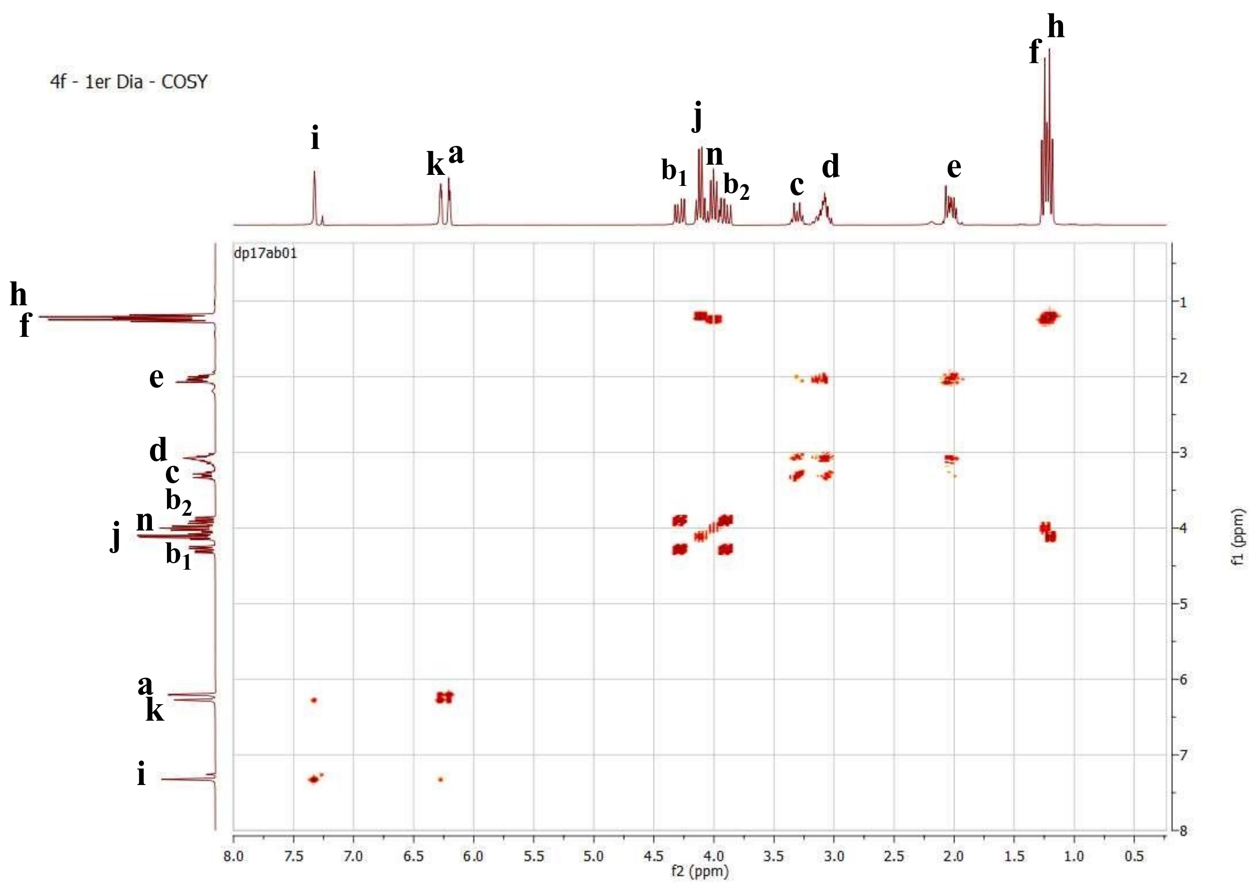

1
2
7
10
9
6
3
13
11
8
5
4
12

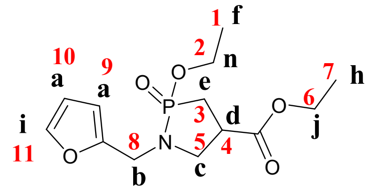

171.91
171.67
151.55
151.50
142.31
110.27
108.00
77.52
77.09
76.67
61.61
61.53
61.36
48.13
47.87
40.86
40.81
37.19
37.12
25.31
23.69
16.47
14.09
13
12
11
10
9
6
2
5
8
4
3
1
7
f1 (ppm)

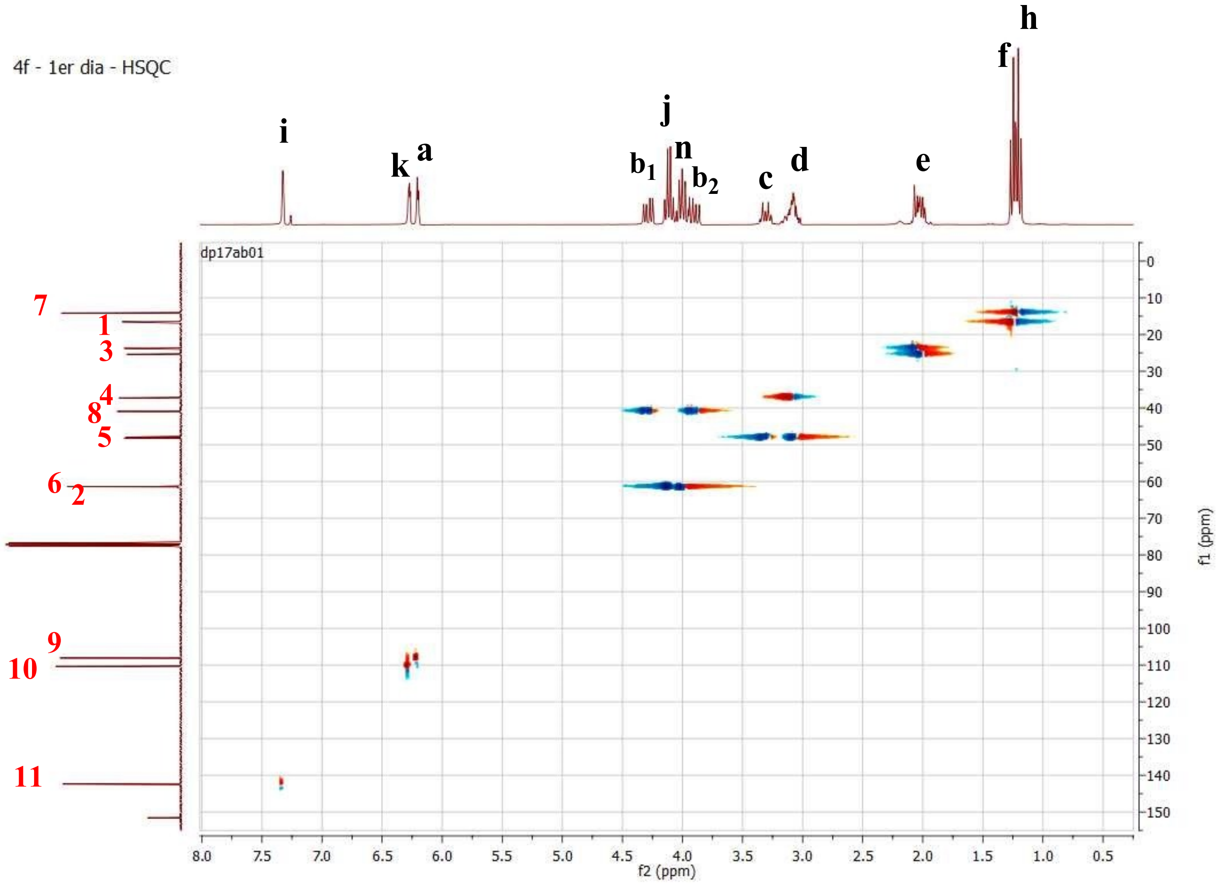



43.57
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
f1 (ppm)


k
a
i
f
n
e
h
d
j
b
c

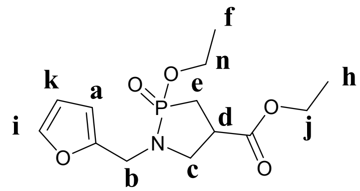

4f - 1er Dia - COSY
dp17ab01
i
k a
b1
j
n
b2
c d
e
f h
f2 (ppm)
f1 (ppm)

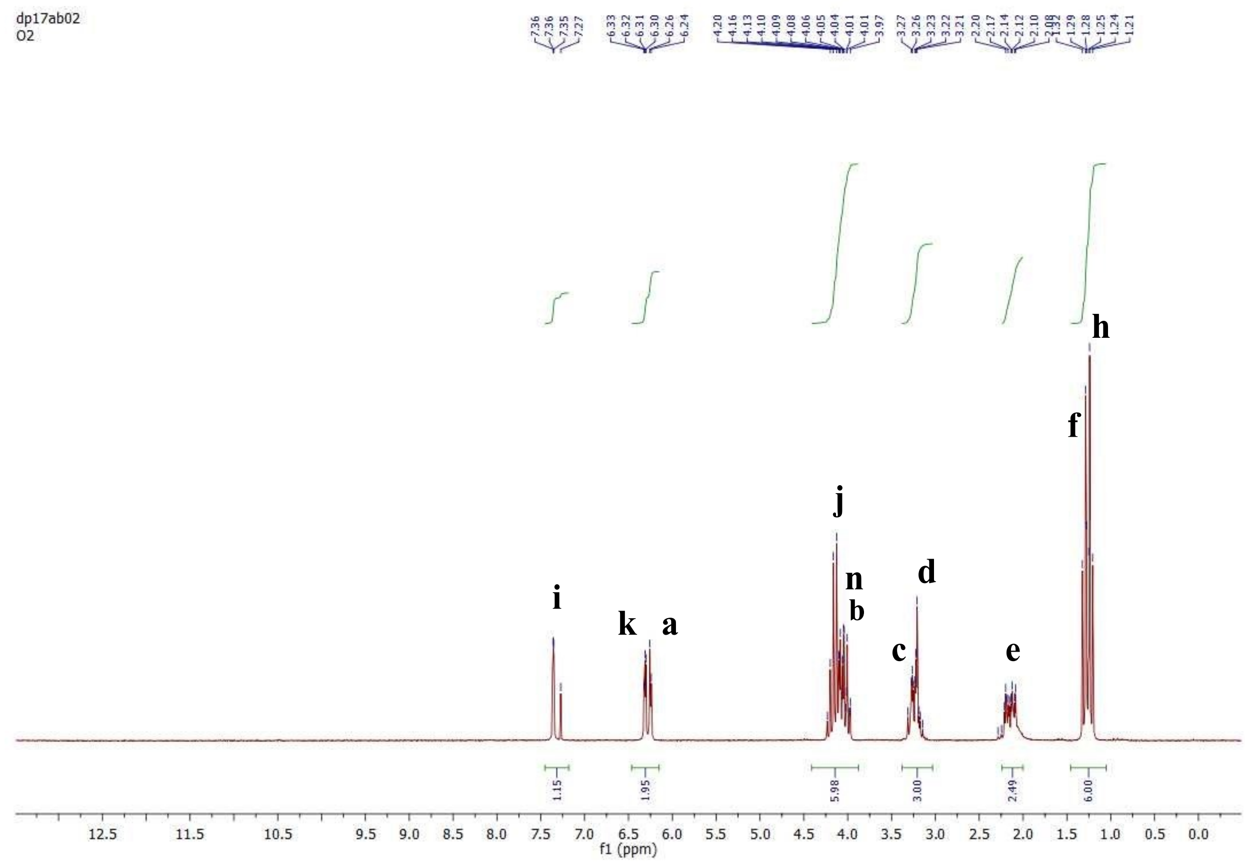


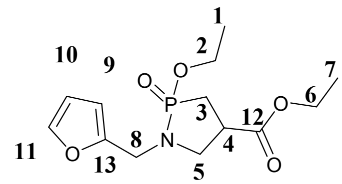


4f - 1er dia - HSQC
dp17ab01
f2 (ppm)
f1 (ppm)

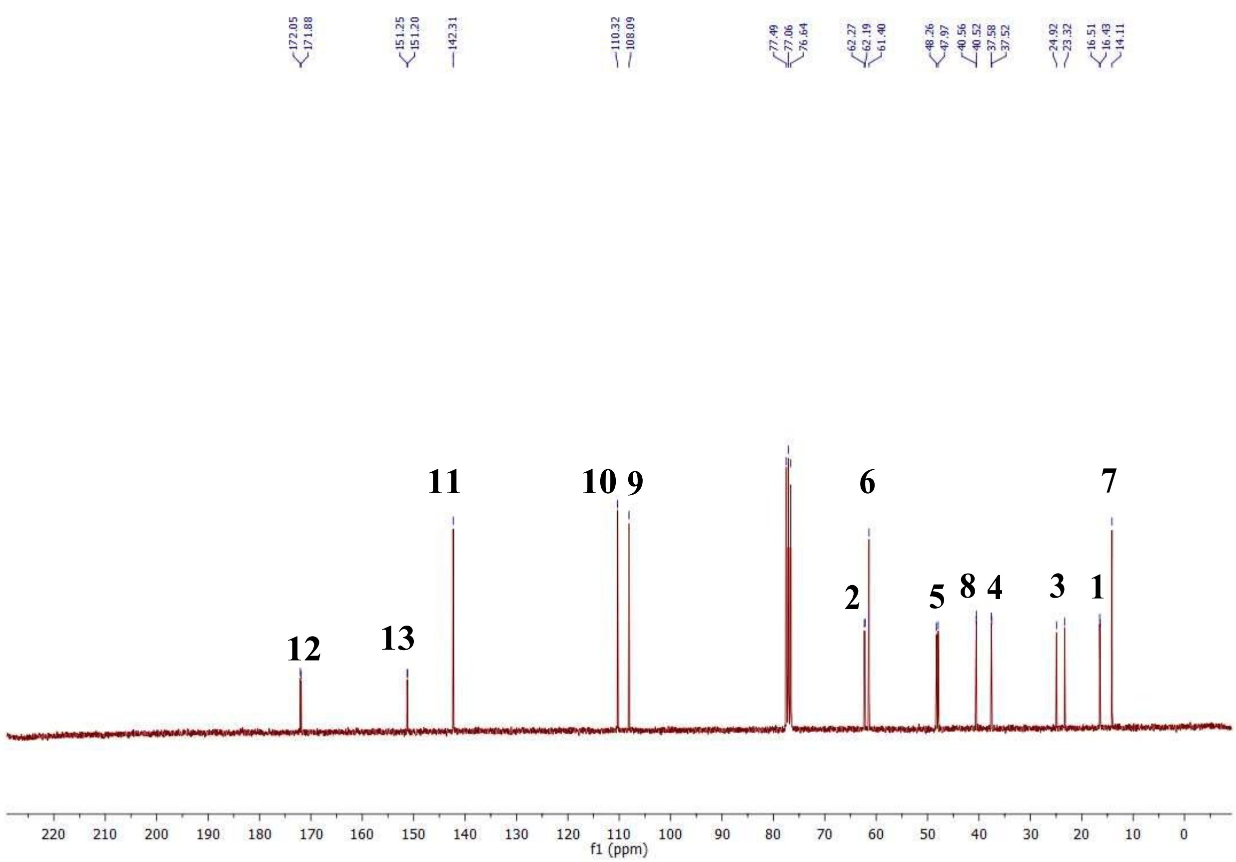
Compound 4f (2nd dia)



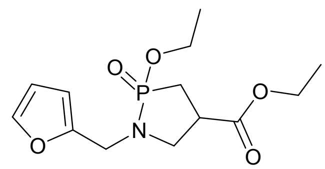


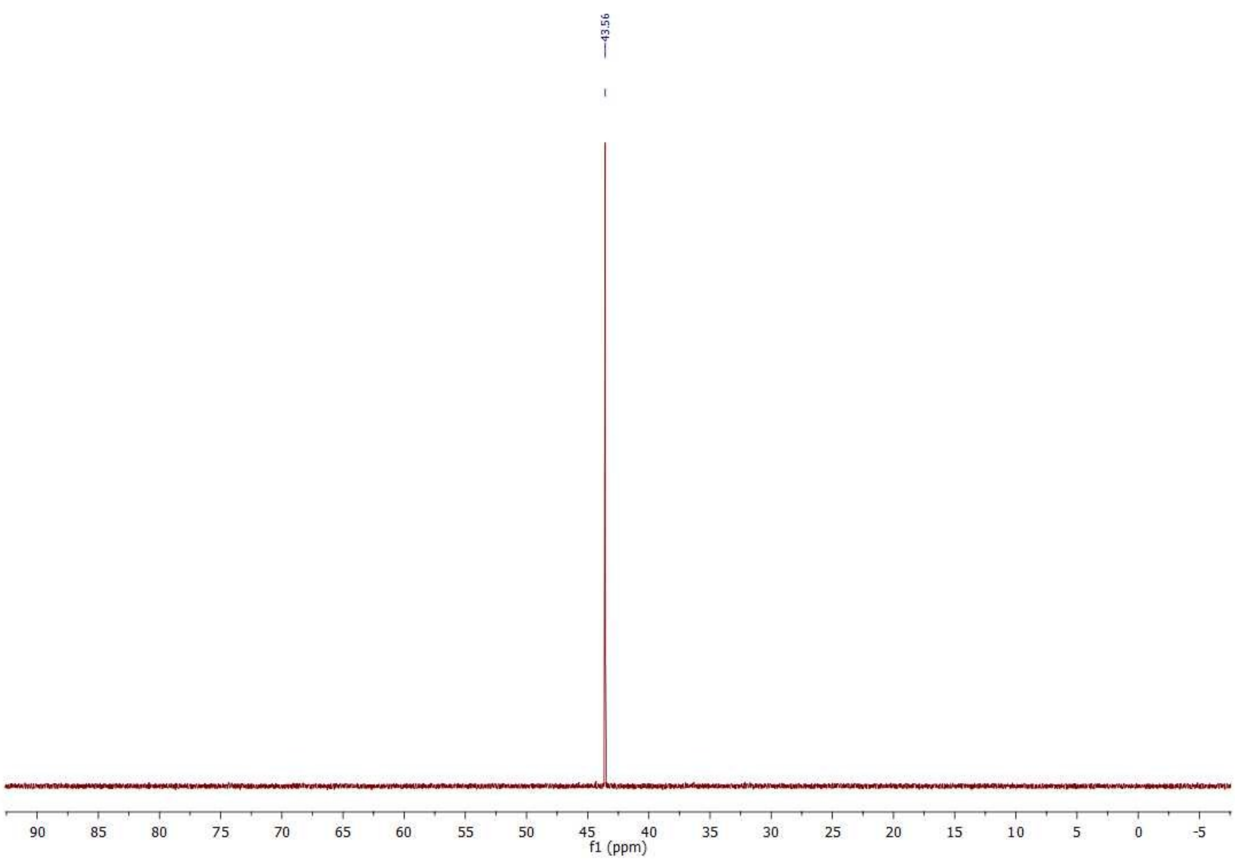


1
2
10
9
O
P
3
12
O
6
7
11
8
N
4
O
13
5

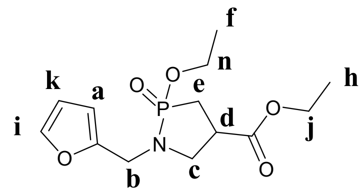


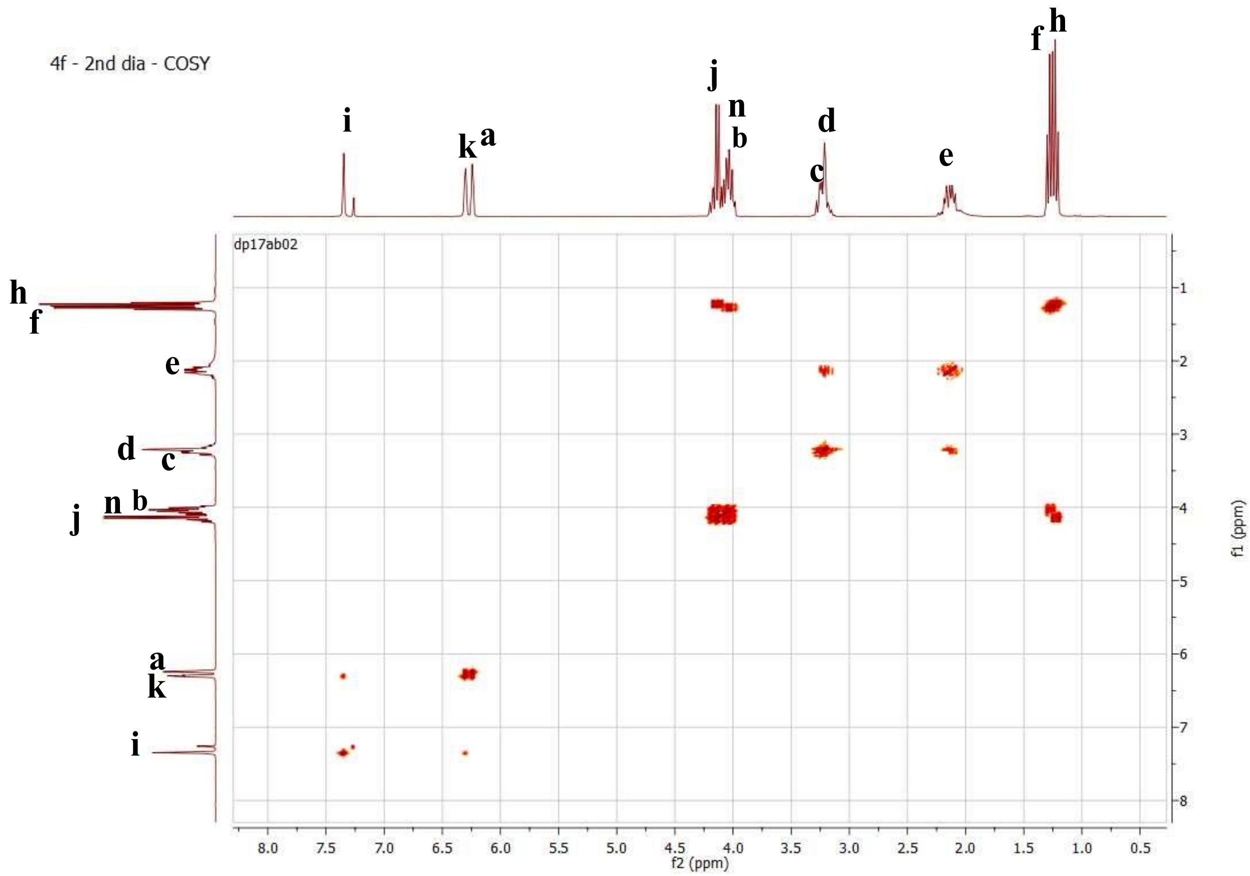
172.05
171.88
151.25
151.20
142.31
110.32
108.09
77.49
77.06
76.64
62.27
62.19
61.40
48.26
47.97
40.56
40.52
37.58
37.52
24.92
23.32
16.51
16.43
14.11
12
13
11
10
9
6
2
5
8
4
3
1
7
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

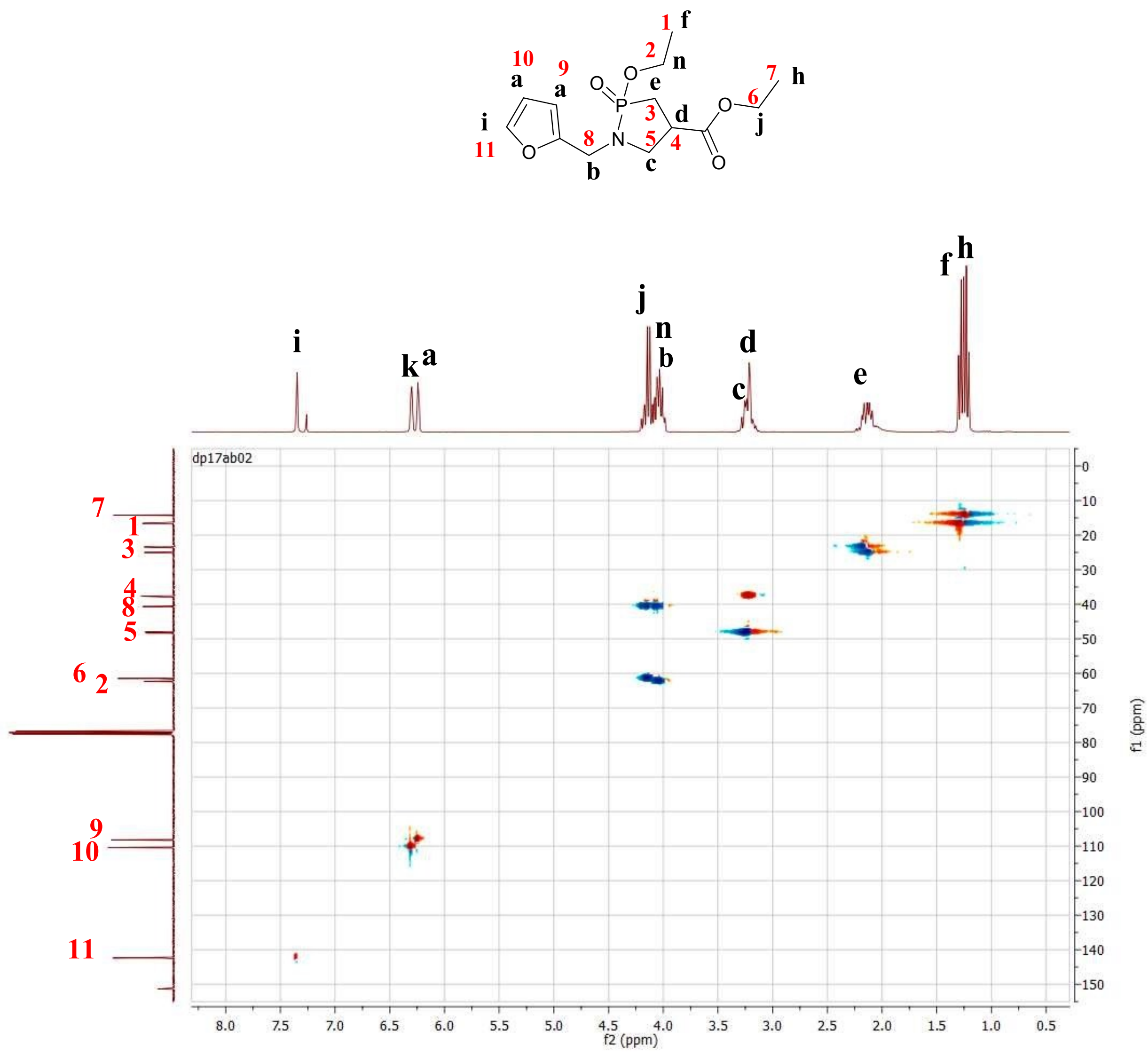




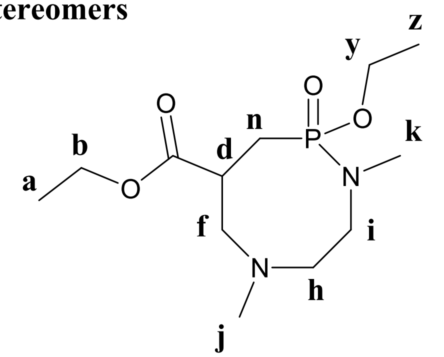
43.56
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
f1 (ppm)

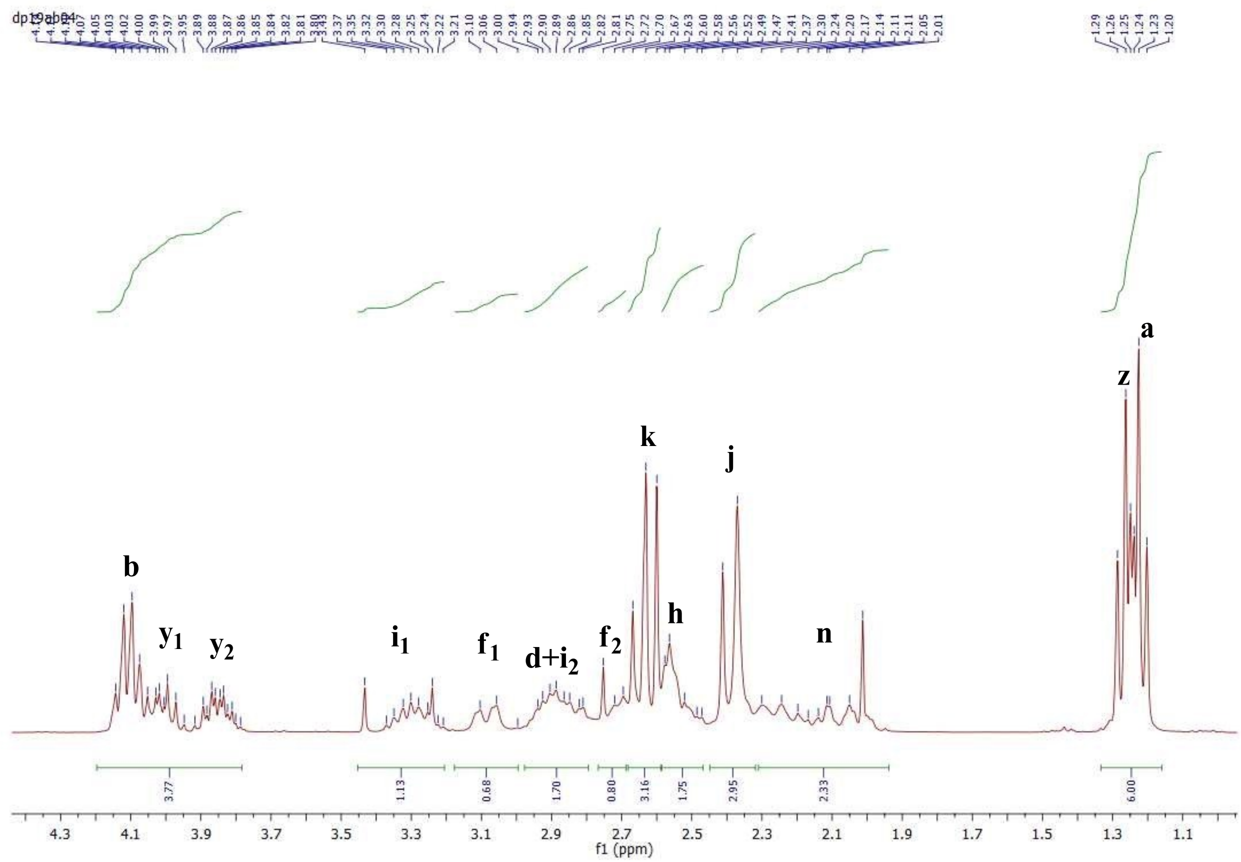

f
n
h
k
a
O
O
e
P
d
O
i
N
j
O
c
O
b
O

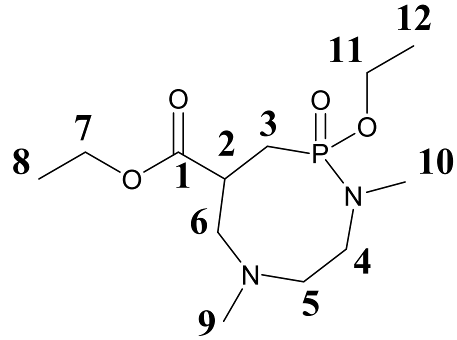

4f - 2nd dia - COSY
i
k
a
j
n
b
c
d
e
f
h
dp17ab02
f2 (ppm)
f1 (ppm)


dp17ab02
f2 (ppm)
f1 (ppm)
i
k a
j
n
b
c
d
e
f
h
7
1
3
4
8
5
6 2
9
10
11

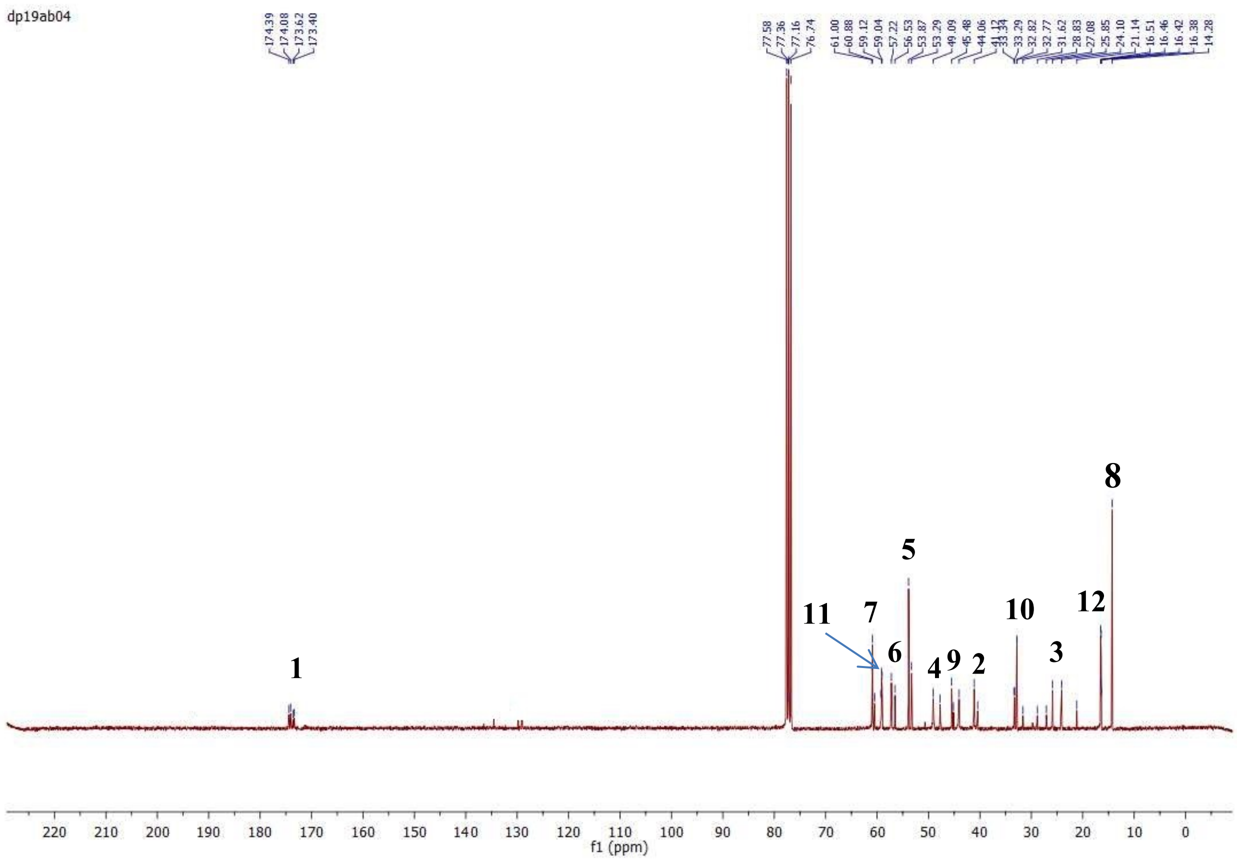
Compound 5 mixture of diastereomers



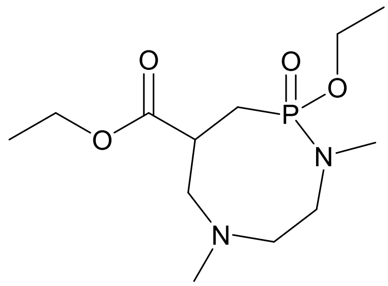


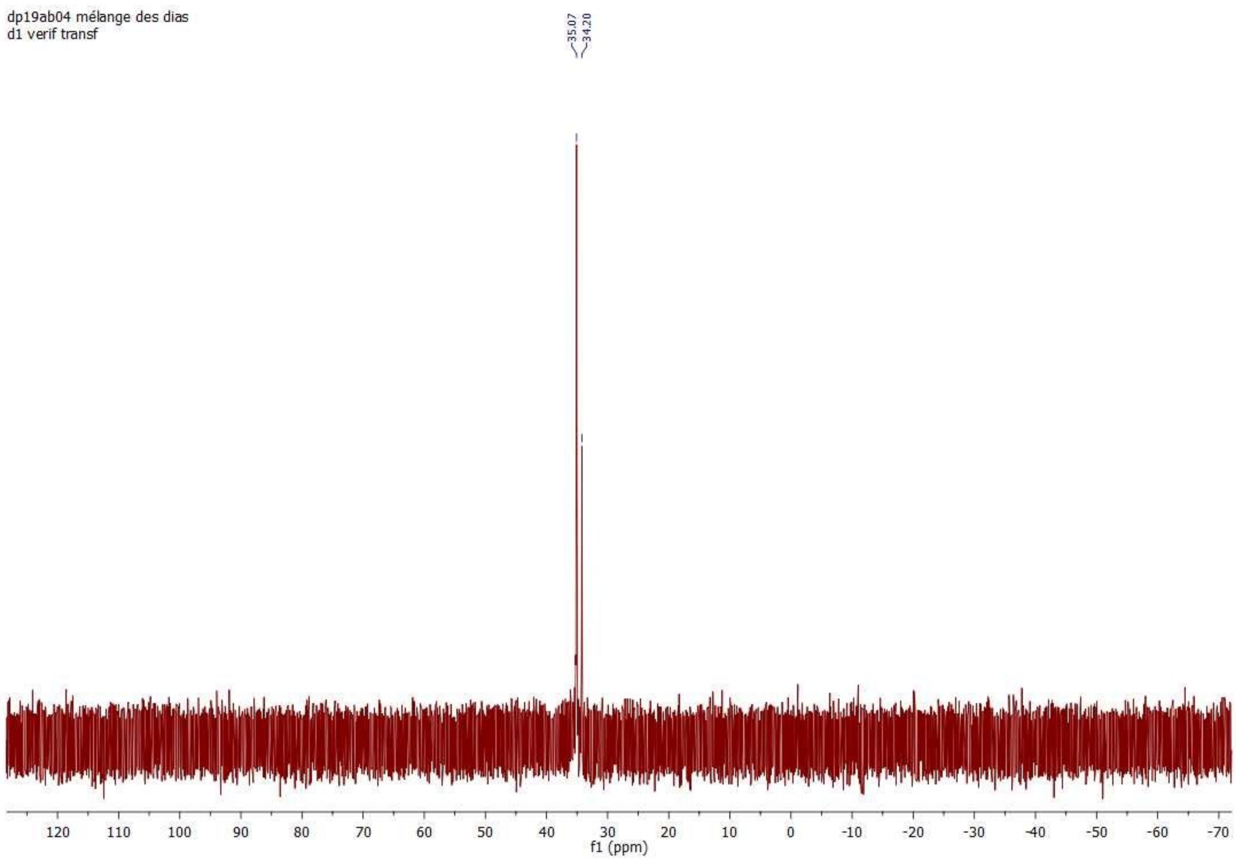


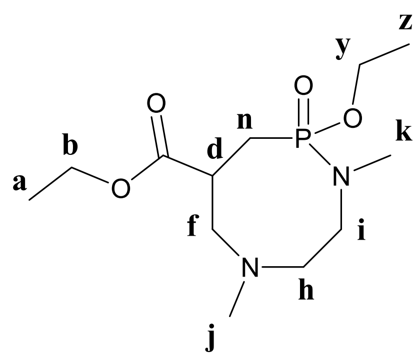
1
2
3
4
5
6
7
8
9
10
11
12
O
O
O
O
P
N
N

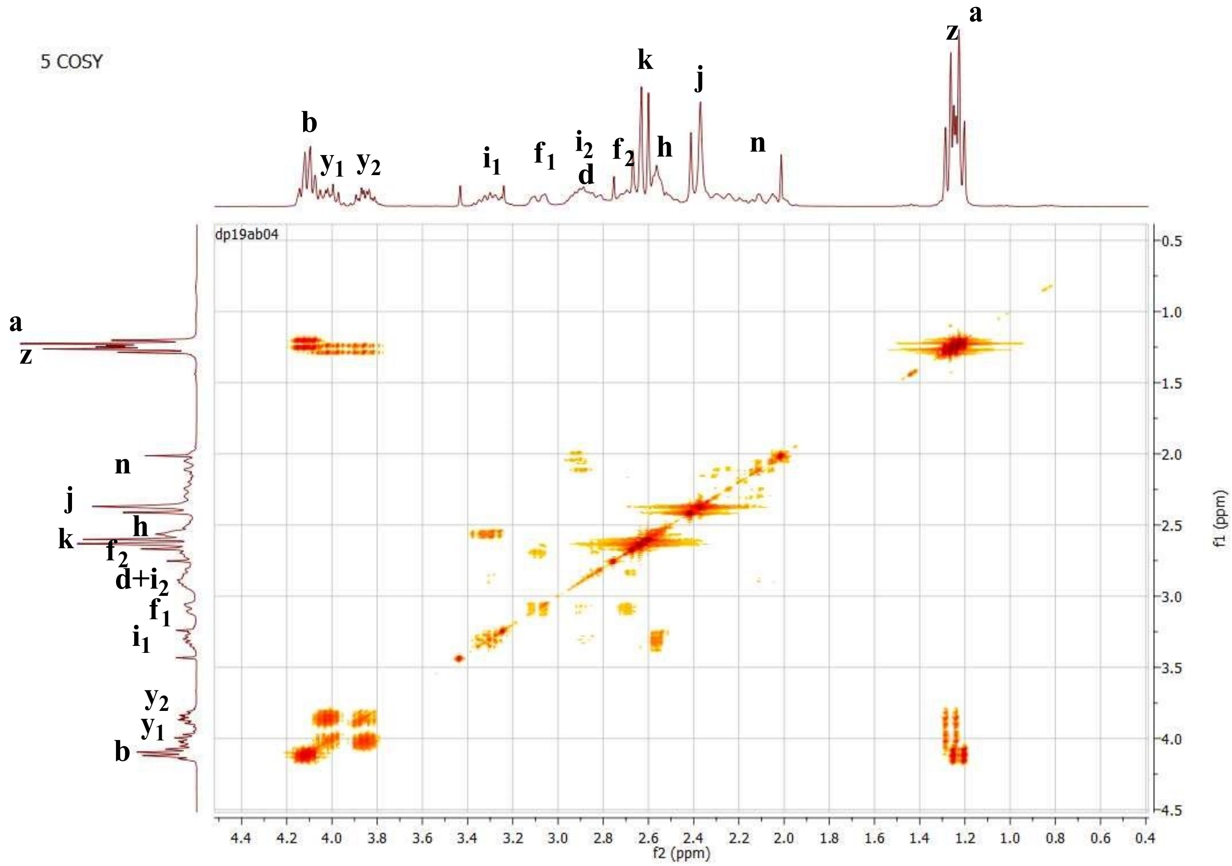


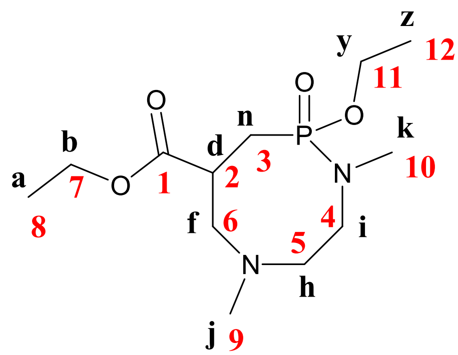
dp19ab04
174.39
174.08
173.62
173.40
77.58
77.36
77.16
76.74
61.00
60.88
59.12
59.04
57.22
56.53
53.87
53.29
49.09
45.48
44.06
41.12
33.34
33.29
32.82
32.77
31.62
28.83
27.08
25.85
24.10
21.14
16.51
16.46
16.42
16.38
14.28
1
11
7
6
5
4
9
2
10
3
12
8
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
O
O
P
O
O
N
N

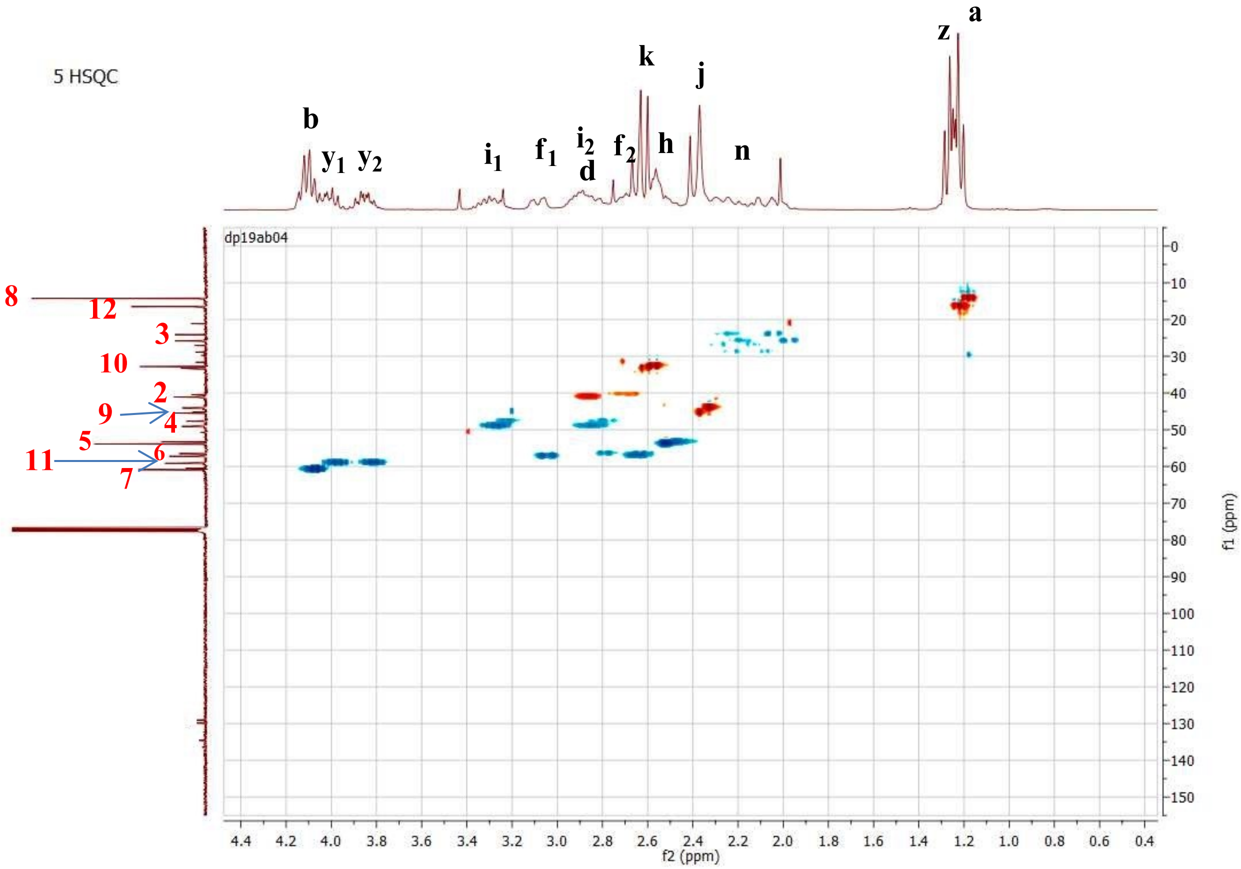

dp19ab04 mélange des dias
d1 verif transf
35.07
34.20
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
f1 (ppm)



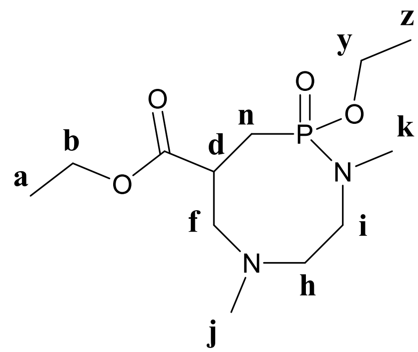

5 COSY
dp19ab04
f2 (ppm)
f1 (ppm)

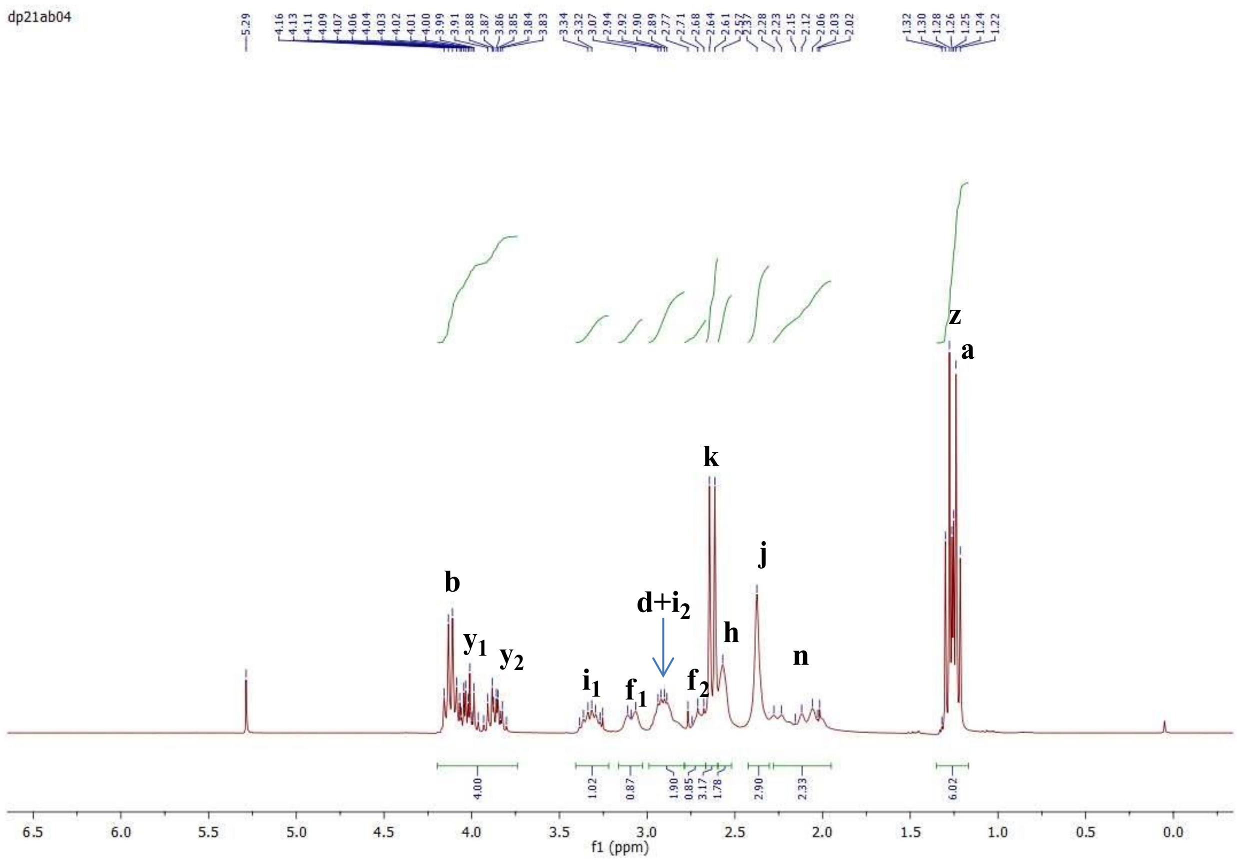

a
b
7
8
O
O
1
d
2
n
3
P
O
O
y
z
11
12
k
N
10
4
i
5
h
N
j
9
f
6

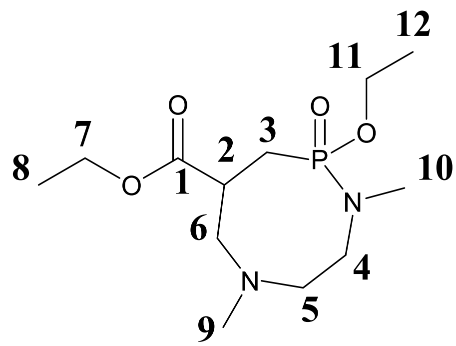
5 HSQC


dp19ab04
b
y1
y2
i1
f1
i2
d
f2
k
h
j
n
z
a
8
12
3
10
2
9
4
5
11
6
7
f2 (ppm)
f1 (ppm)

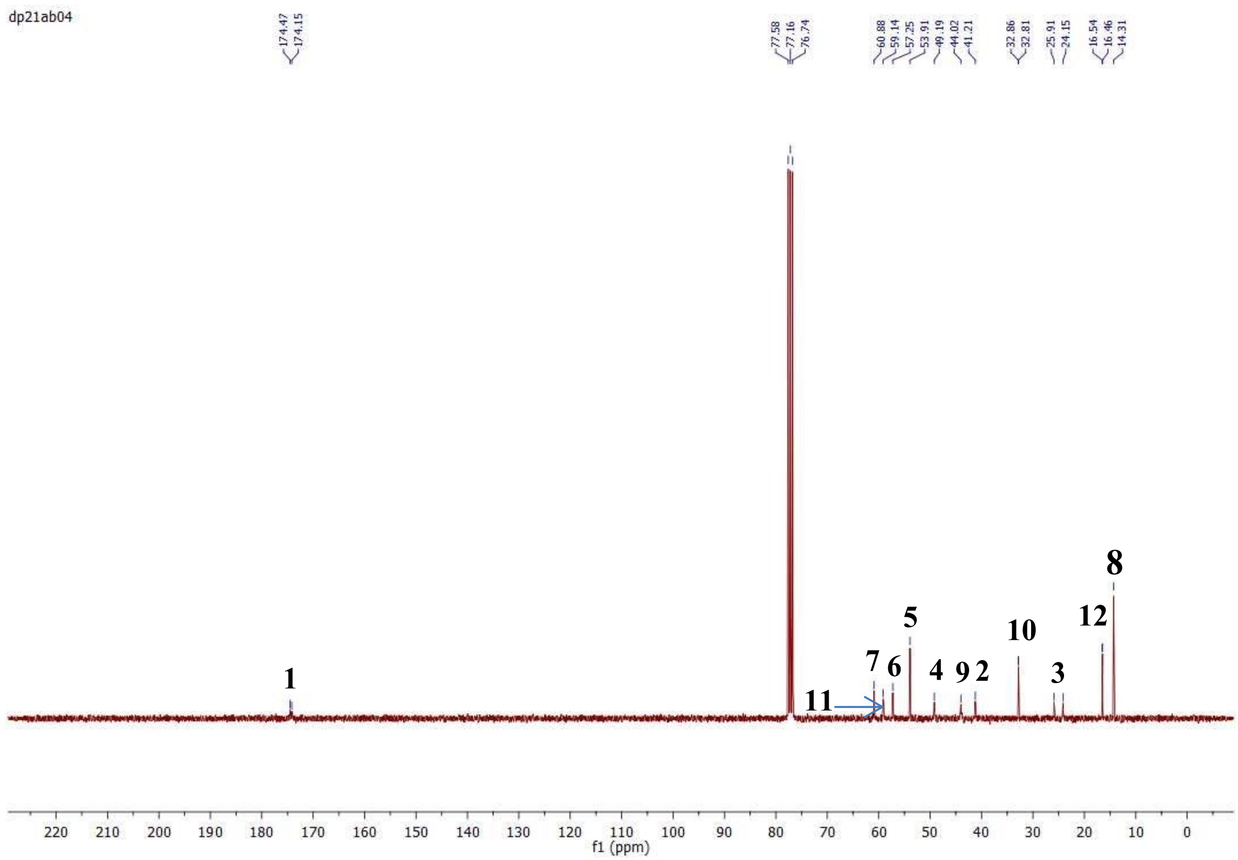
Compound 5 (1st dia)



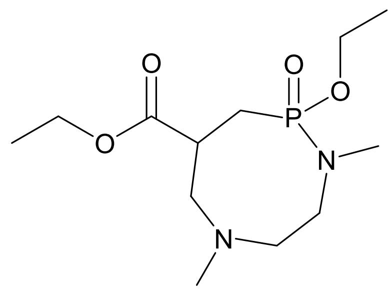


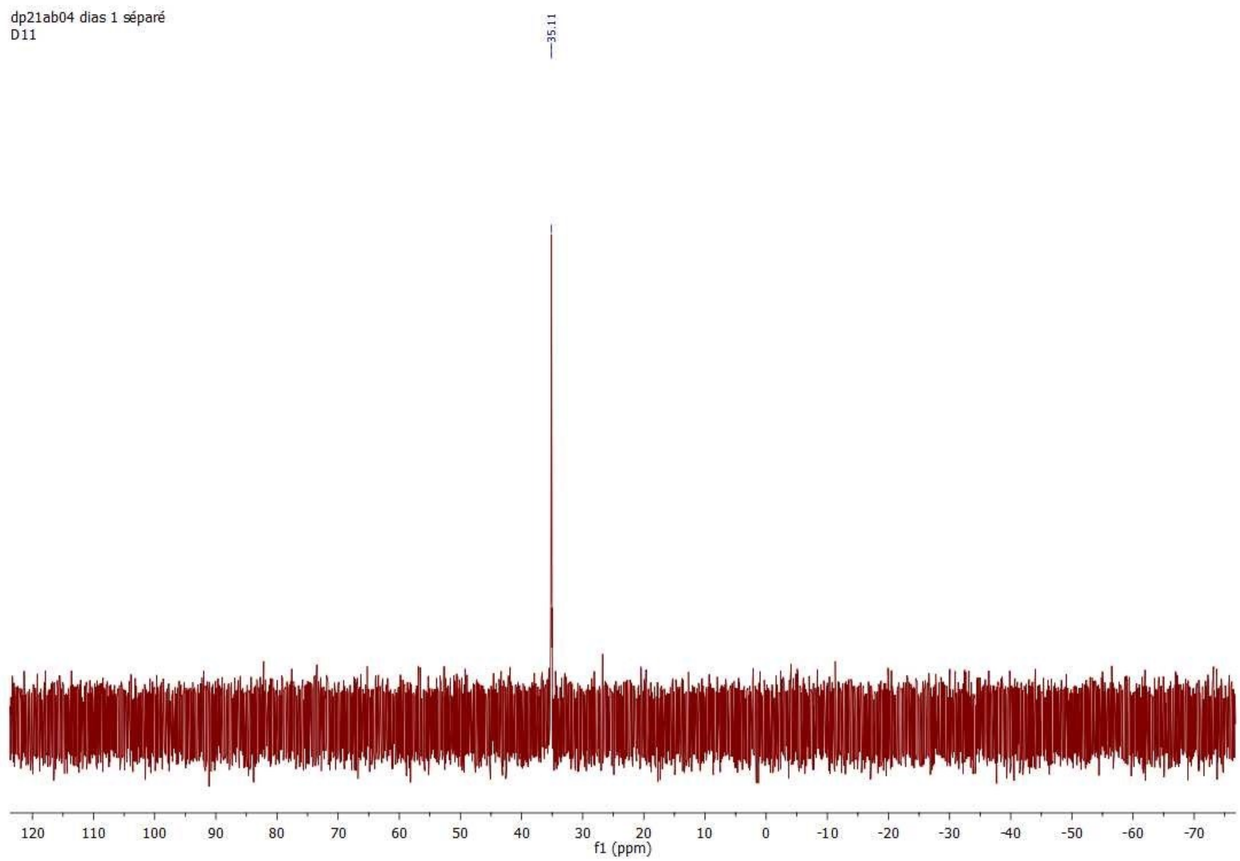


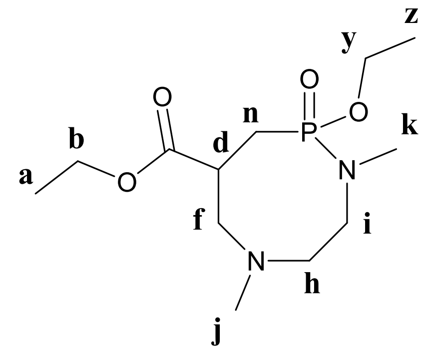
12
11
O
O
7
8
O
1
2
3
P
O
10
N
6
4
N
9
5



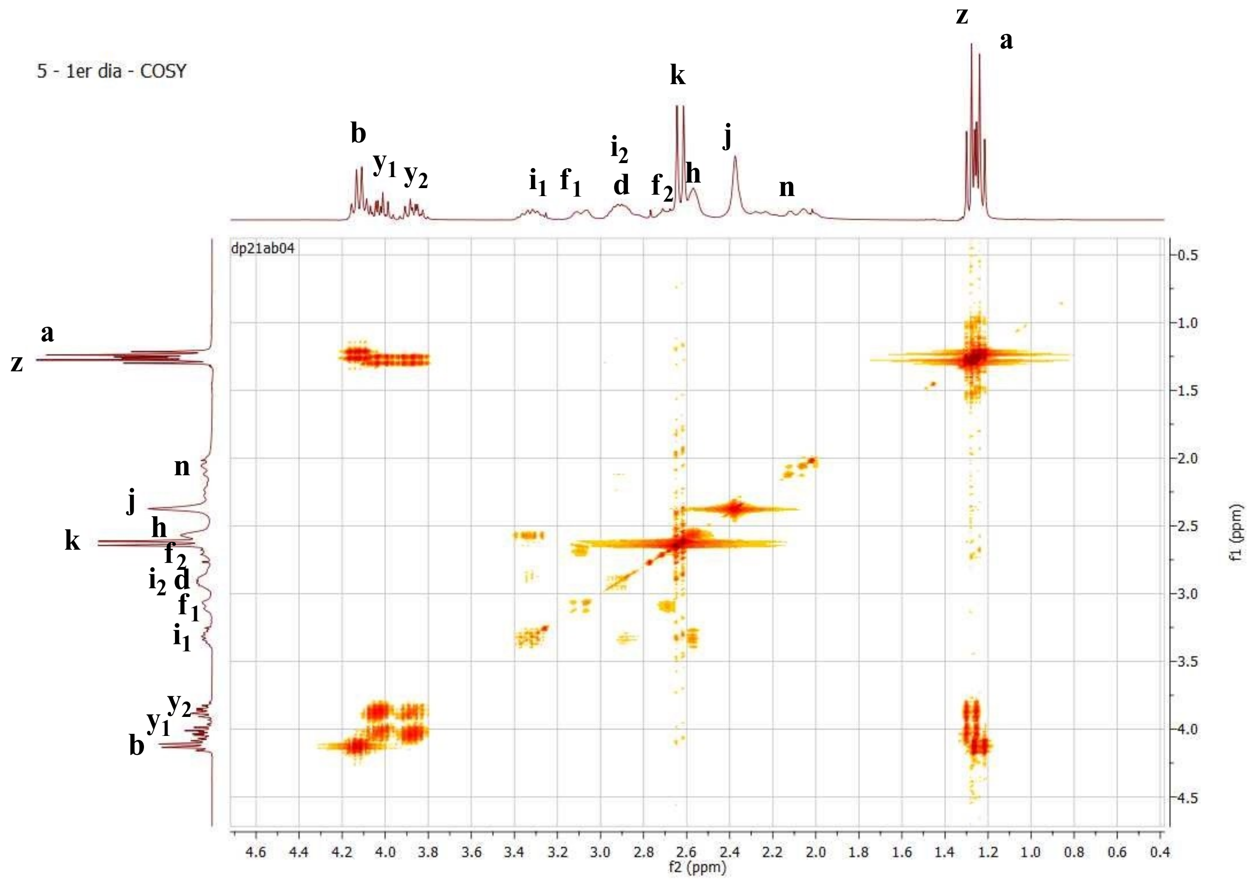
dp21ab04
174.47
174.15
77.58
77.16
76.74
60.88
59.14
57.25
53.91
49.19
44.02
41.21
32.86
32.81
25.91
24.15
16.54
16.46
14.31
1
11
7
6
5
4
9
2
10
3
12
8
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



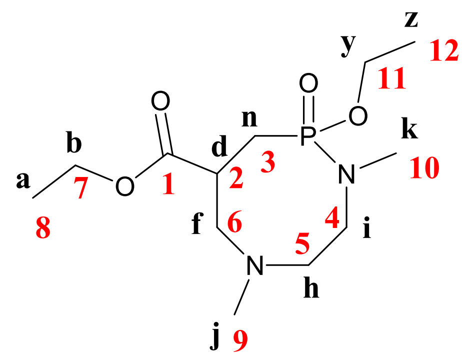

dp21ab04 dias 1 séparé
D11
35.11
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
f1 (ppm)



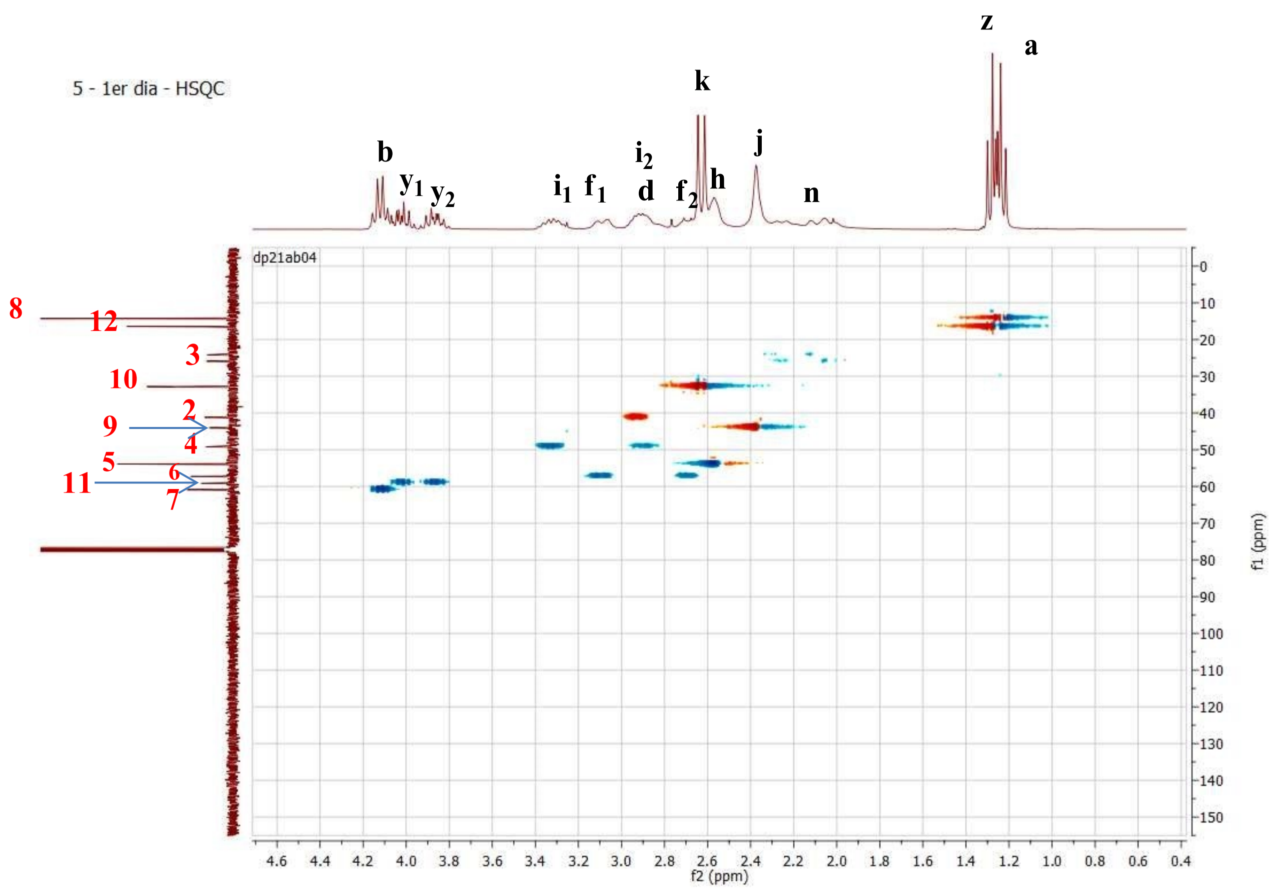
a
b
d
n
f
i
h
j
k
y
z
O
P
N



5 - 1er dia - COSY
dp21ab04
z
a
k
b
y1
y2
i1
f1
i2
d
f2
h
j
n
f2 (ppm)
f1 (ppm)

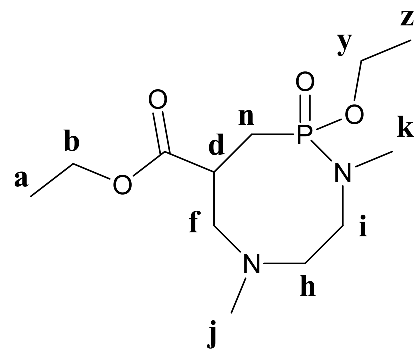


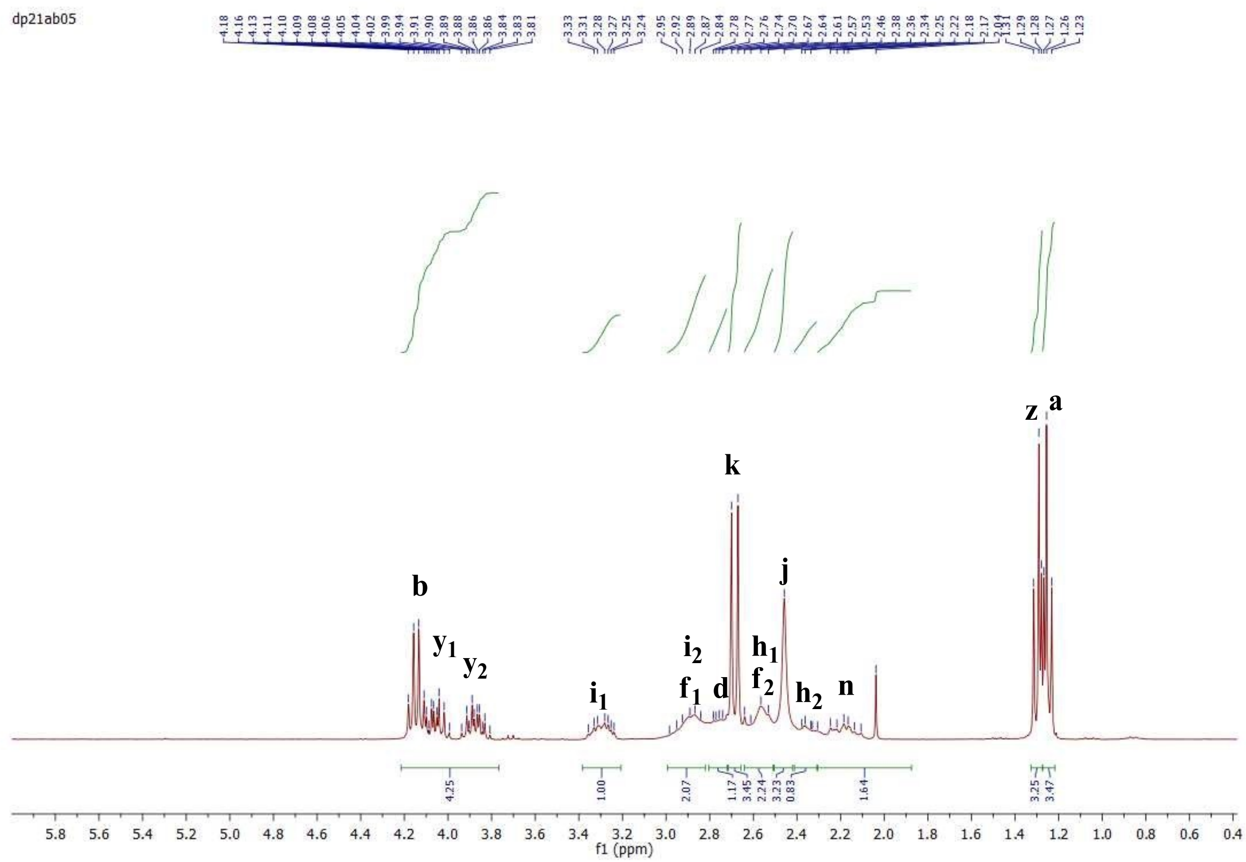
a
b
d
n
f
h
i
j
k
y
z
1
2
3
4
5
6
7
8
9
10
11
12

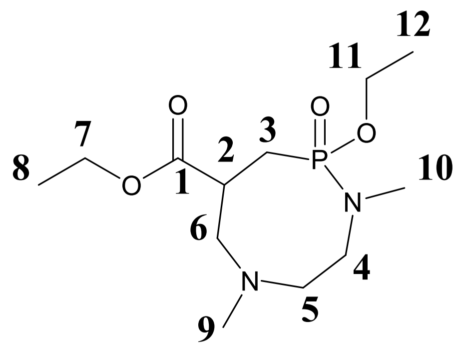


5 - 1er dia - HSQC
dp21ab04
z
a
k
b
y1
y2
i1
f1
i2
d
f2
h
j
n
8
12
3
10
2
9
4
5
6
11
7
f2 (ppm)
f1 (ppm)

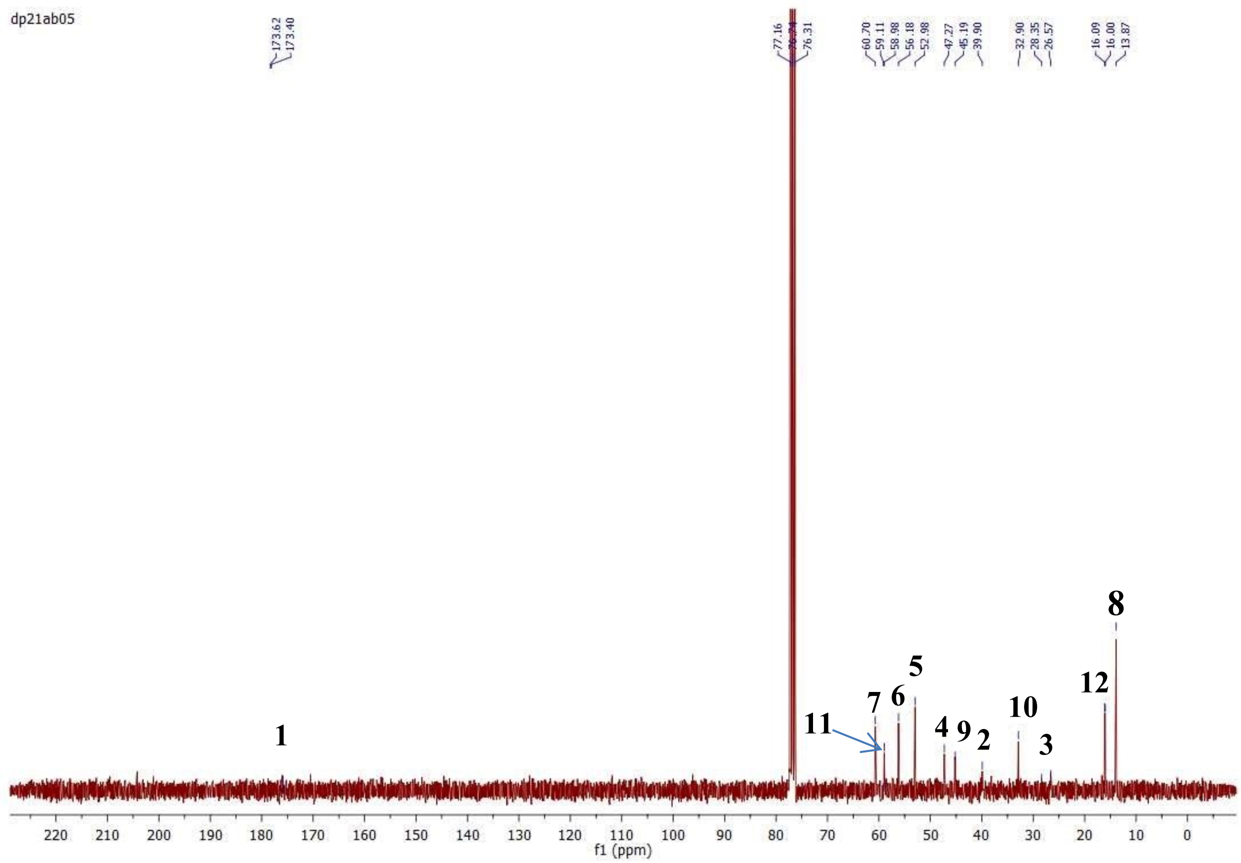
Compound 5 (2nd dias)



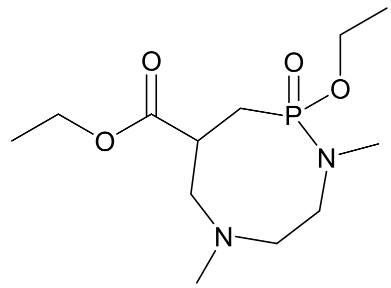


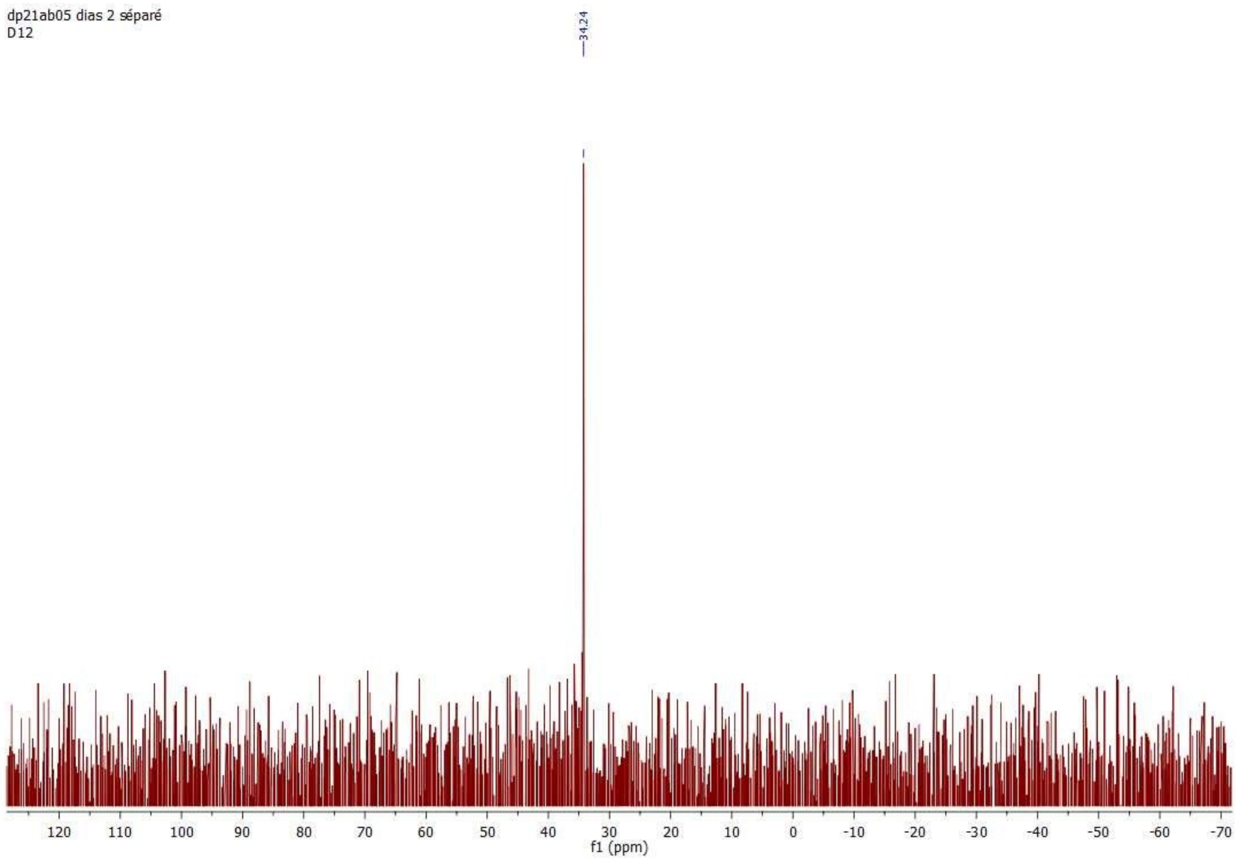


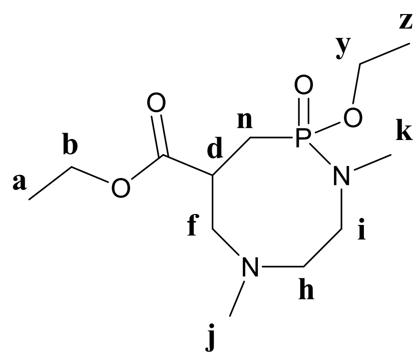
12
11
O
O
P
O
O
O
N
N
1
2
3
4
5
6
7
8
9
10



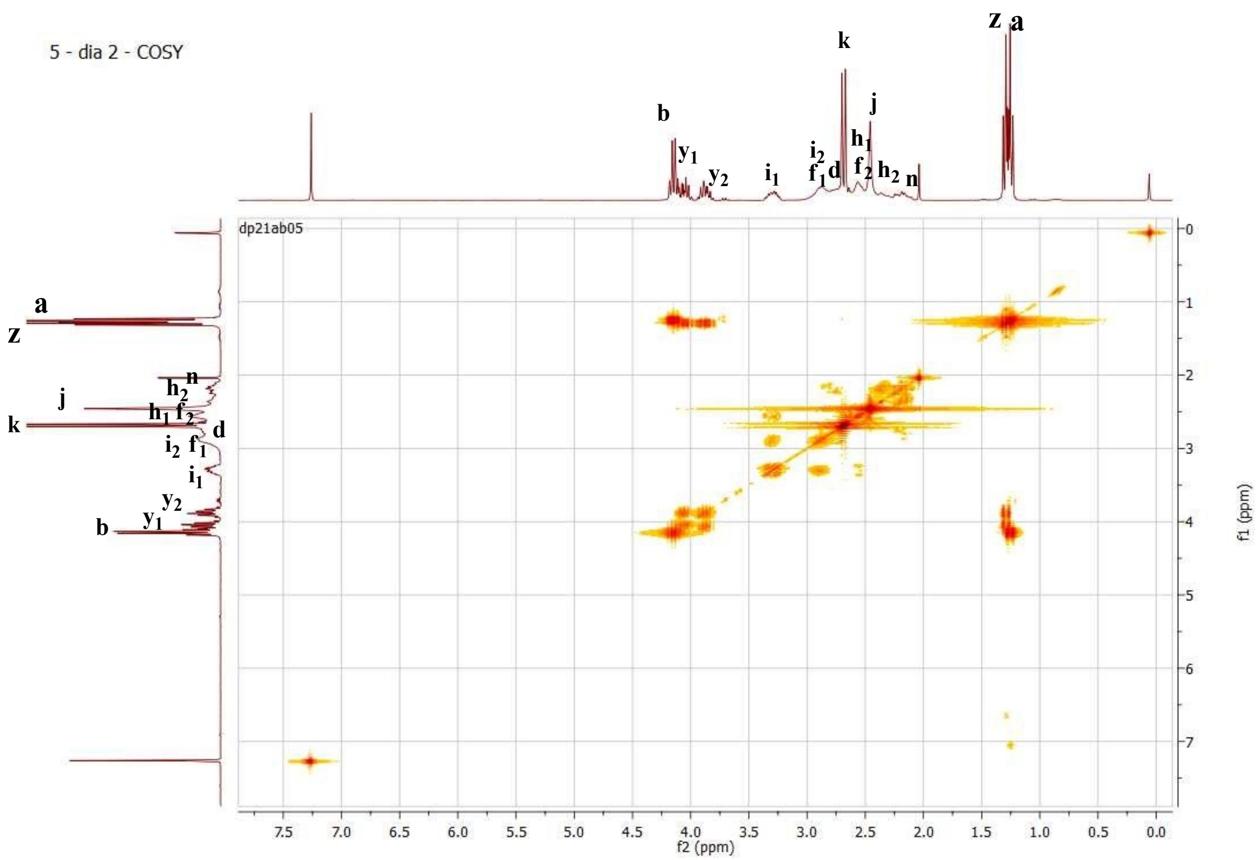
dp21ab05
173.62
173.40
77.16
76.31
60.70
59.11
58.98
56.18
52.98
47.27
45.19
39.90
32.90
28.35
26.57
16.09
16.00
13.87
1
11
7
6
5
4
9
2
10
3
12
8
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
O
O
P
O
O
N
N

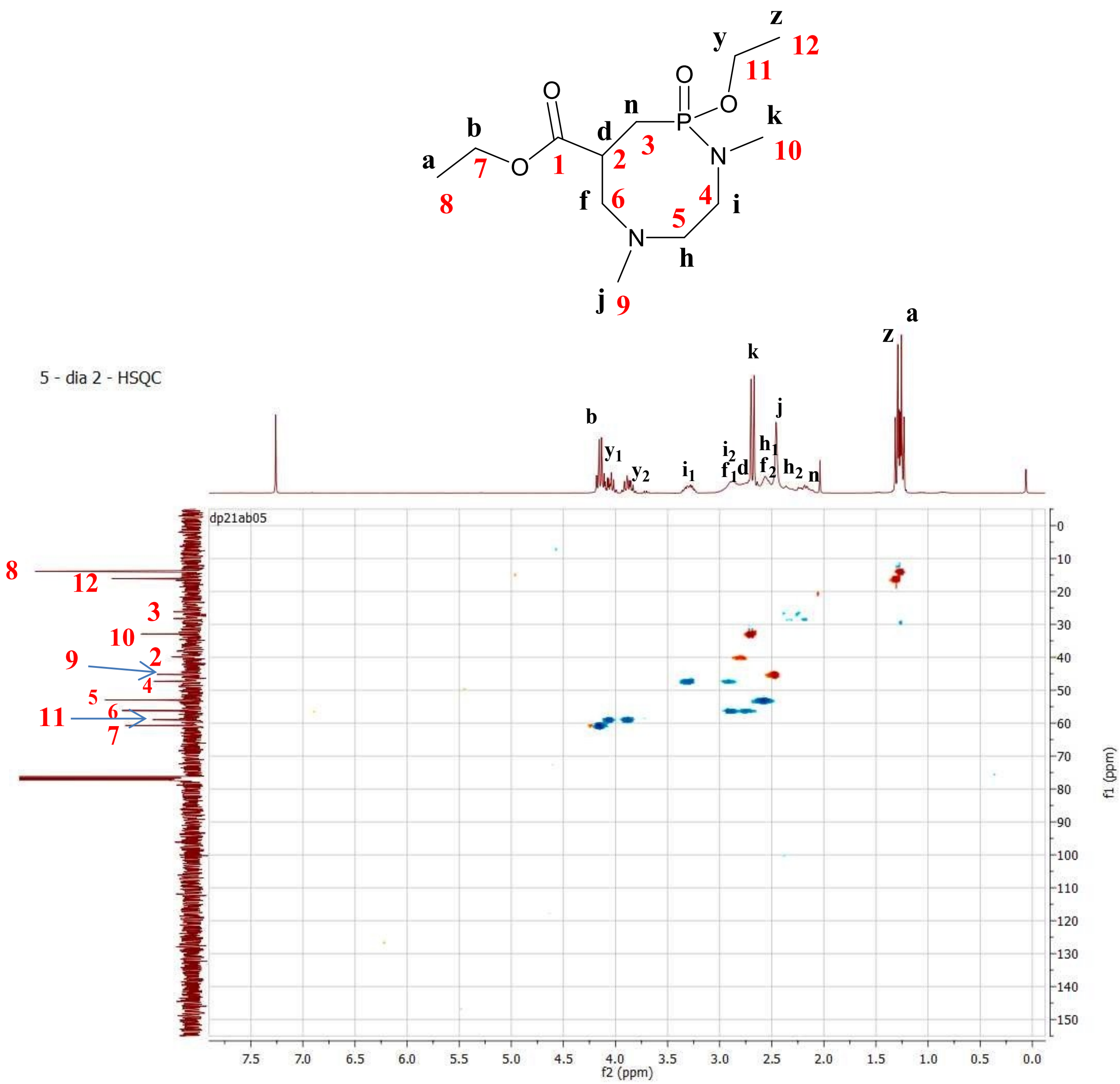

dp21ab05 dias 2 séparé
D12
34.24
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
f1 (ppm)



O
O
P
O
O
N
N
a
b
d
n
y
z
k
i
h
f
j

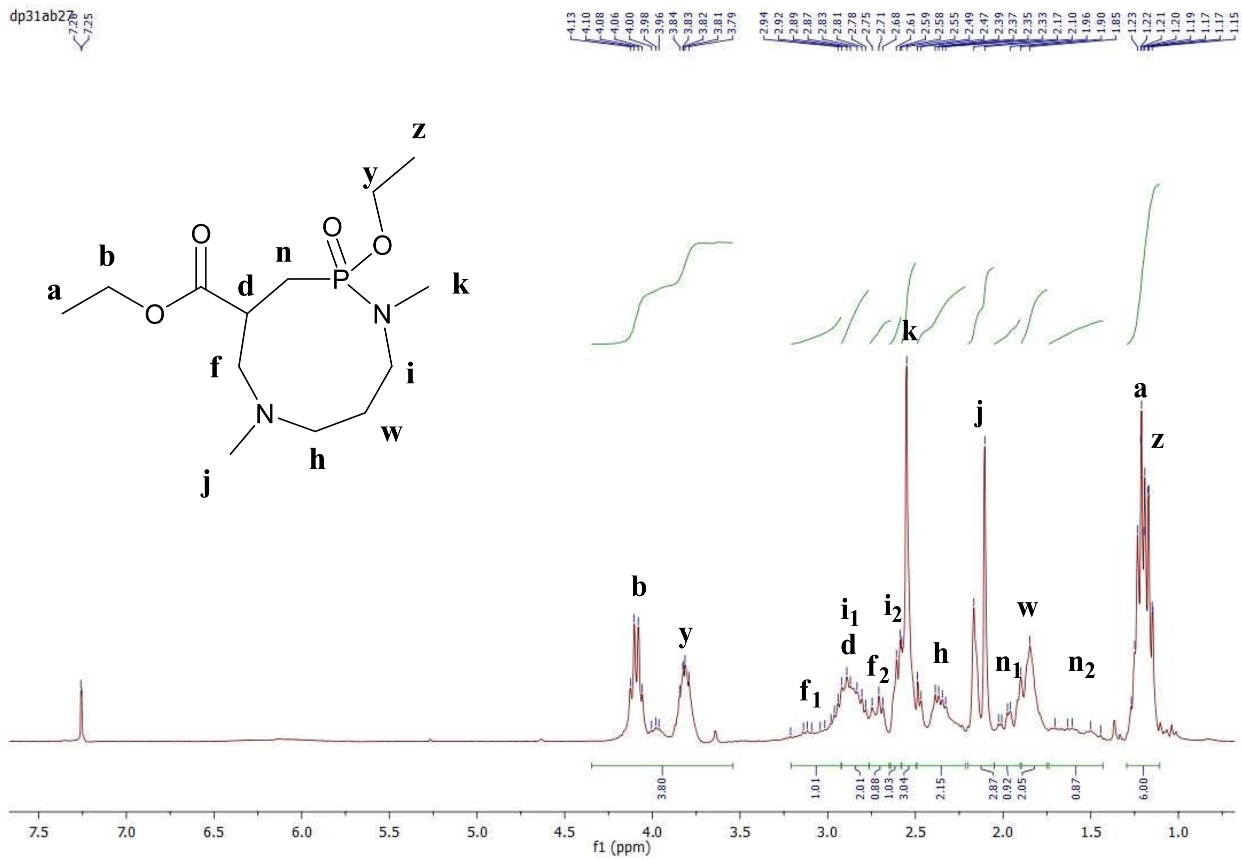


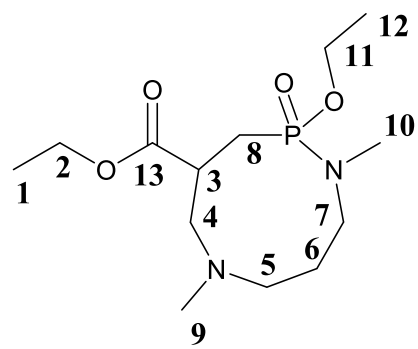
5 - dia 2 - COSY
dp21ab05
f2 (ppm)
f1 (ppm)


5 - dia 2 - HSQC
dp21ab05
f2 (ppm)
f1 (ppm)

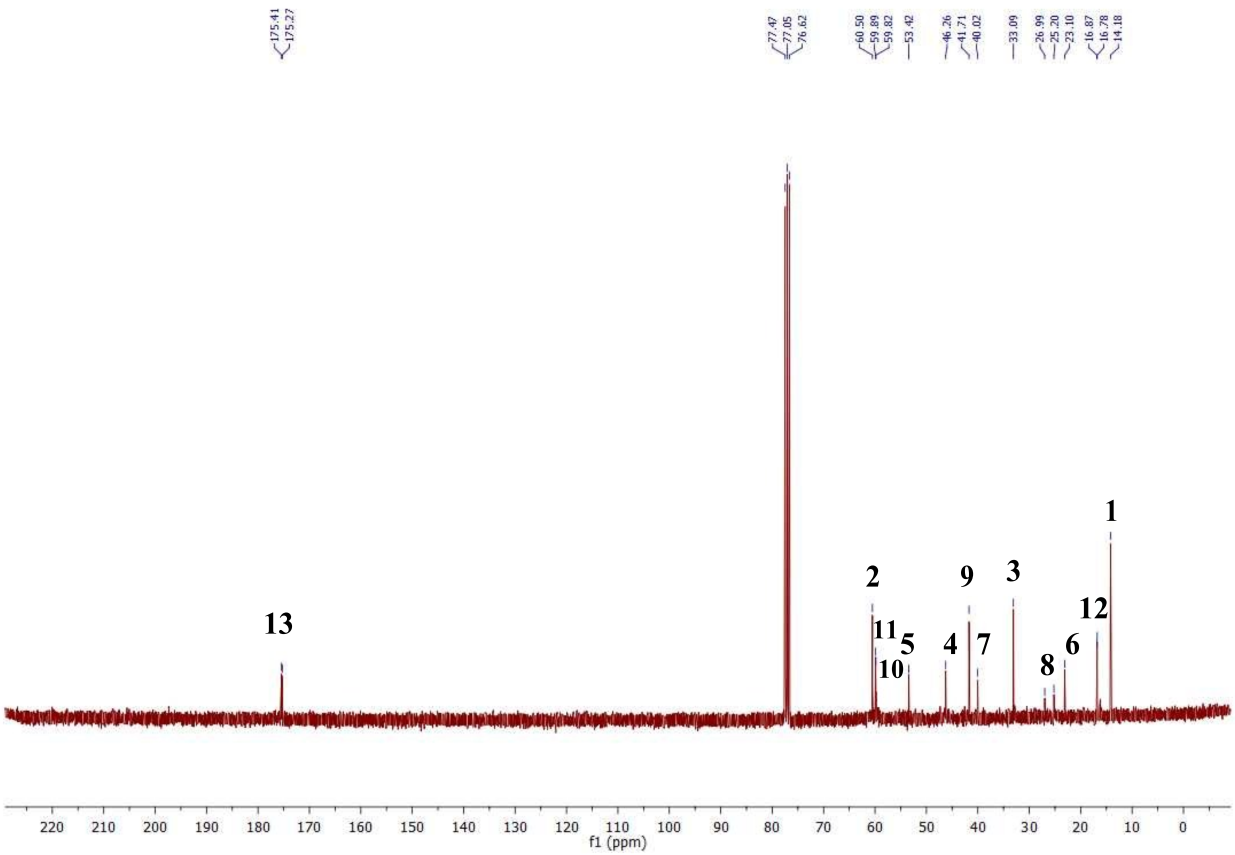
&

Compound 6 mixture of diastereomers

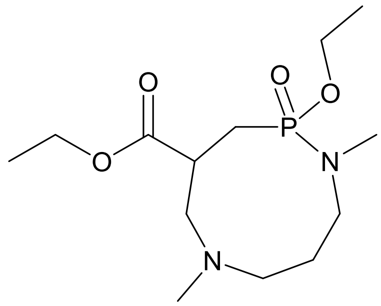


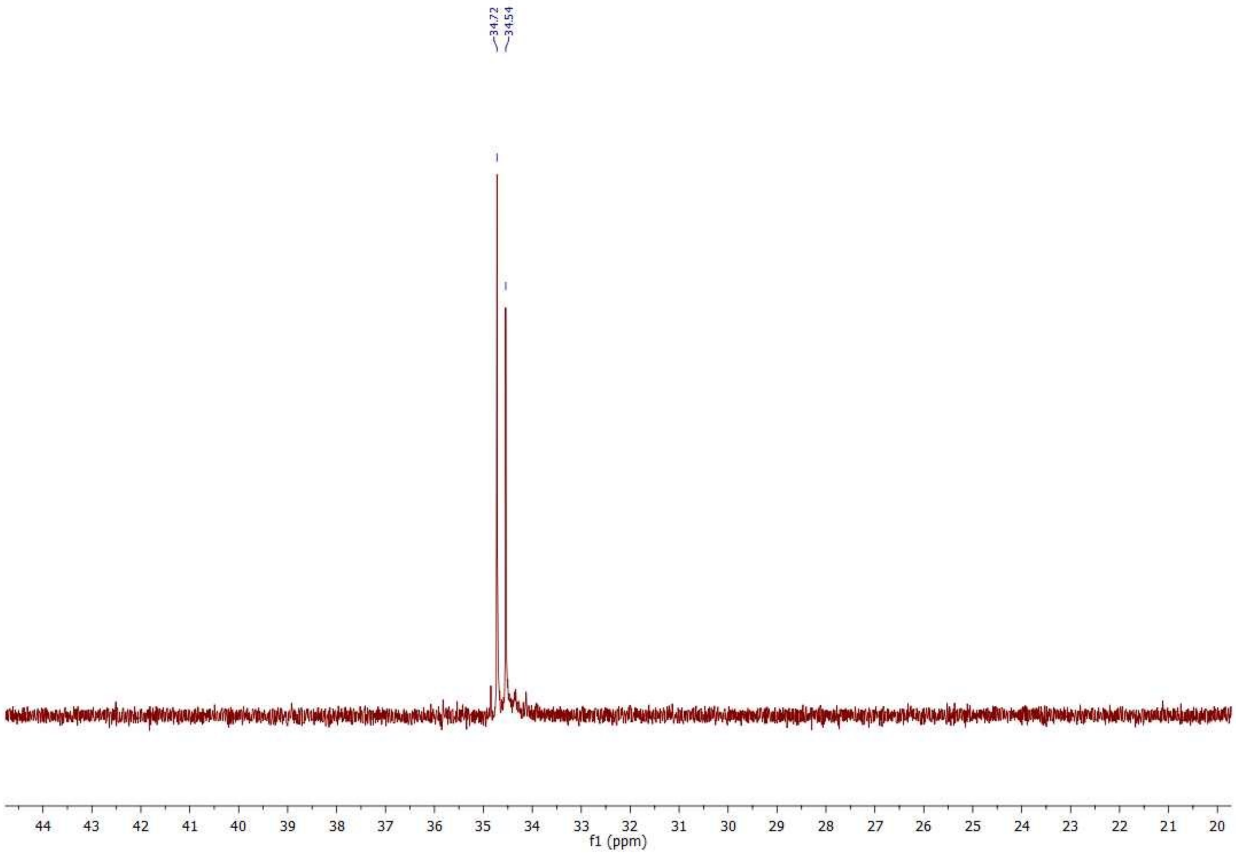


12
11
O
O
10
P
N
8
O
2
O
13
3
1
4
7
6
5
N
9

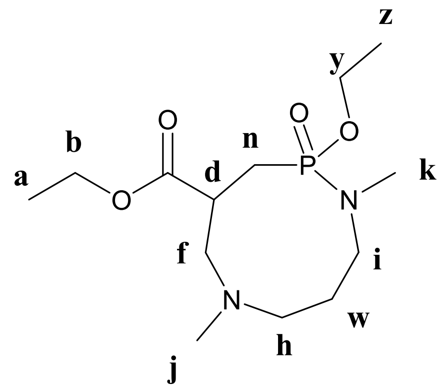


175.41
175.27
77.47
77.05
76.62
60.50
59.89
59.82
53.42
46.26
41.71
40.02
33.09
26.99
25.20
23.10
16.87
16.78
14.18
13
2
11
10
5
4
9
7
3
8
6
12
1
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

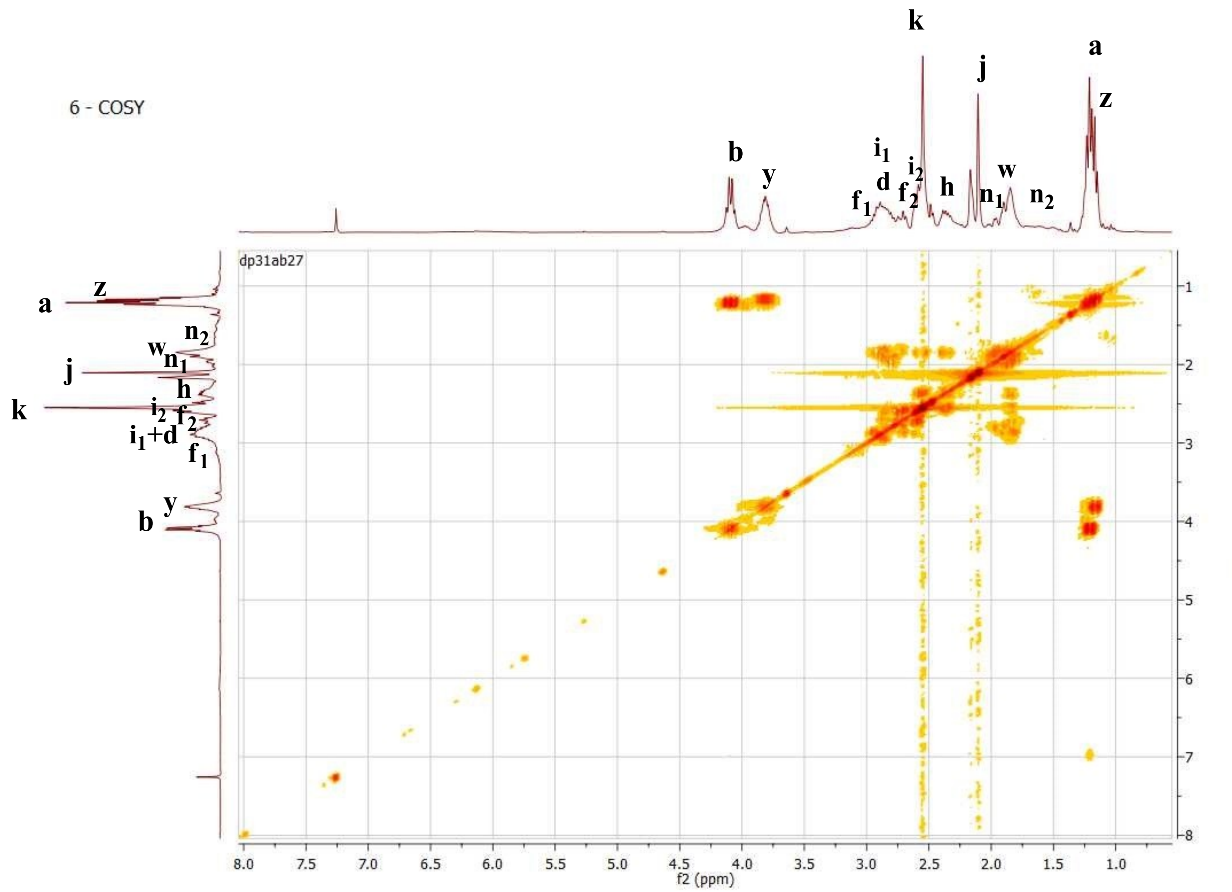




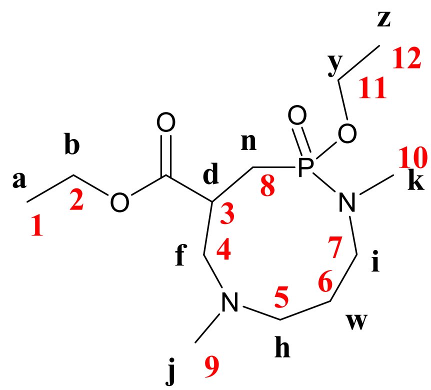
34.72
34.54
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
f1 (ppm)

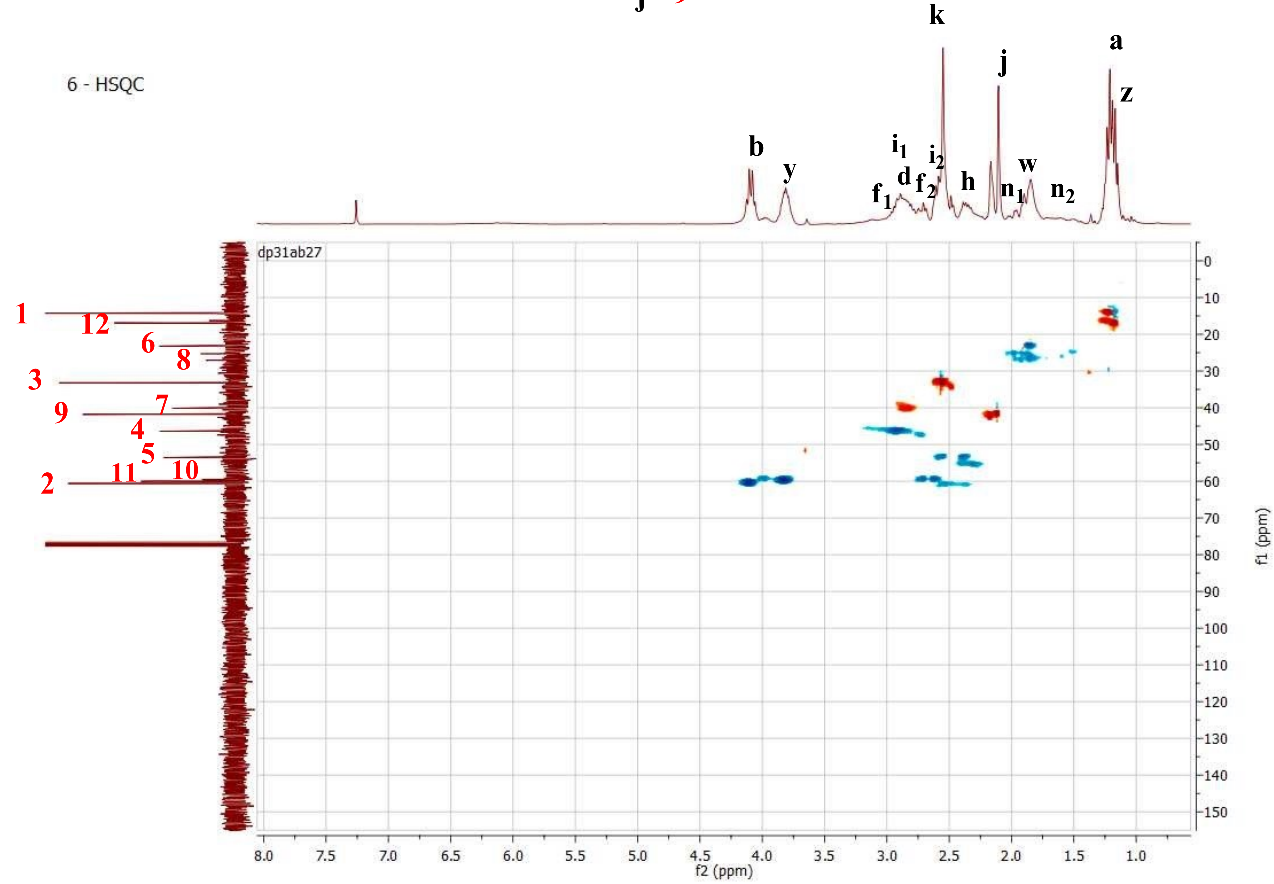


z
y
O
O
P
N
k
n
b
O
a
d
O
f
i
N
w
j
h



6 - COSY
dp31ab27
f2 (ppm)
f1 (ppm)




6 - HSQC
dp31ab27
f2 (ppm)
f1 (ppm)

Computational details.

A conformational search based on molecular dynamics (MM+) employing *HyperChem8.0.7* was used on both diastereomers in order to find the lowest energy conformations for each diastereomers. The latest conformations were firstly pre-optimized at the AM1 level and further optimized using DFT geometry optimizations using the hybrid B3LYP functional and the 6-311++G(d,p) basis set. To be sure that all optimized structures lay at a local point on the potential energy surface, harmonic vibrational frequencies of all structures were performed. None of the predicted spectra has any imaginary frequencies. GIAO (Gauge Invariant Atomic Orbital) method was used on these optimized structures in *Gaussian09* to compute isotropic magnetic shielding constants at PBE0/6-311+G(2d,p) level of theory for ^{1}H and ^{13}C nuclei or B3LYP/6-311++G(d,p) level of theory for ^{31}P nuclei.

HyperChem: HyperChem(TM) Professional 8.0.7, Hypercube, Inc., 1115 NW 4th Street, Gainesville, Florida 32601, USA

Gaussian 09, Revision A.02, Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Scalmani, G.; Barone, V.; Mennucci, B.; Petersson, G. A.; Nakatsuji, H.; Caricato, M.; Li, X.; Hratchian, H. P.; Izmaylov, A. F.; Bloino, J.; Zheng, G.; Sonnenberg, J. L.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Vreven, T.; Montgomery, Jr., J. A.; Peralta, J. E.; Ogliaro, F.; Bearpark, M.; Heyd, J. J.; Brothers, E.; Kudin, K. N.; Staroverov, V. N.; Kobayashi, R.; Normand, J.; Raghavachari, K.; Rendell, A.; Burant, J. C.; Iyengar, S. S.; Tomasi, J.; Cossi, M.; Rega, N.; Millam, J. M.; Klene, M.; Knox, J. E.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann R. E.,; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Martin, R. L.; Morokuma, K.; Zakrzewski, V. G.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Dapprich, S.; Daniels, A. D.; Farkas, O.; Foresman, J. B.; Ortiz, J. V.; Cioslowski, J.; and D. J. Fox, Gaussian, Inc., Wallingford CT, 2009.

B3LYP: (a) Becke, A. D. *J. Chem. Phys.*, **1993**, *98*, 1372 – 1377. (b) Becke, A. D. *J. Chem. Phys.*, **1993**, *98*, 5648 – 5652. (c) Lee, C.; Yang, W.; Parr, R. G. *Phys. Rev. B*, **1988**, *37*, 785 – 789. (d) Stephens, P. J.; Devlin, F. J.; Chabalowski, C. F.; Frish, M. J. *J Phys. Chem.*, **1994**, *98*, 11623 – 11627.

PBEO : J. P. Perdew, K. Burke, and M. Ernzerhof, *Phys. Rev. Lett.*, **1996**, *77*, 3865 – 3868. (b) J. P. Perdew, K. Burke, and M. Ernzerhof, *Phys. Rev. Lett.*, **1997**, *78,* 1396. (c) C. Adamo and V. Barone, *J. Chem. Phys.*, **1999**, *110*, 6158 – 6169.

GIAO: (a) Ditchfield, R. *Mol Phys.* **1974**, *27*, 789 – 807. (b) Wolinski, K; Hilton, J. F.; Pulay, P. *J. Am. Chem. Soc.* **1990**, *112*, 8251 – 8260. Gauss, J.; Stanton, J. F. *J. Chem. Phys* **1995**, *103*, 3561 – 3577 (c) Cheeseman, J. R.; Trucks, G. W.; Keith, T. A.; Frisch, M. J. *J. Chem. Phys.* **1996**, *104*, 5497 – 5509.

Chemical Shifts: Computed chemical shifts and empirical scaling at the PBE0/6-311+G(2d,p) level of theory

	^{1}H	^{13}C	^{31}P
Slope (m)	-1.0742	-1.0423	1.09
Intercept (b)	31.8259	181.1937	-9.2

The equations shown below were applied on the computed NMR isotropic magnetic shielding constants in order to scale the chemical shifts.

- for ^{1}H and ^{13}C nuclei :

$$\delta_{scaled} = \frac{b - \sigma}{m}$$

δ = computed chemical shift relative to TMS
σ = computed isotropic magnetic shielding constant
m = slope
b = intercept

- For ^{31}P nucleus :

$$\delta_{scaled} = \frac{(\sigma_{ref} - \sigma_{Nuclei}) - b}{m}$$

δ_{scaled} = computed chemical shift relative to Phosphoroic acid
σ_{ref} = ^{31}P computed isotropic magnetic shielding constant of the reference compound (Here reference compound is H_3PO_4)
σ_{Nuclei} = Nuclei computed isotropic magnetic shielding constant
m = slope
b = intercept

References for empirical scaling:

^{1}H and ^{13}C empirical scaling: G. K. Pierens *J. Comput. Chem.*, **2014**, *35*, 1388.
^{31}P empirical scaling: Latypov, S. K.; Polyancev, F. M.; Yakhvarov, D. G.; Sinyashin, O. G. *Phys. Chem. Chem. Phys.* **2015**, *17*, 6976 – 6987.

Basis set: 6-311++G(d,p) : (a) (b) Muñoz, M. A.; Joseph-Nathan, P. *Magn. Reson. Chem.* **2009**, *47*, 578 – 584. (c) Musielak, B.; Holak, T. A.; Rys, B. *J. Org. Chem.* **2015**, *80*, 9231 – 9239.77

Table 1. Comparison of scaled experimental and calculated chemical shifts for ^{1}H and ^{13}C.

Nucleus[a]	^{13}C NMR chemical shifts (ppm)				^{1}H NMR chemical shifts (ppm)			
	Experimental[b]		Computed		Experimental[b]		Computed	
	δ_{dia1}	δ_{dia2}	δ_{5a1}	δ_{5a2}	δ_{dia1}	δ_{dia2}	δ_{5a1}	δ_{5a2}
1	174,3	173,5	172,0	172,6				
2	41,2	39,9	40,6	40,2	2,90	2,77	2,67	2,84
3	25,0	27,5	28,6	31,1	2,15	2,14	2,47[c]	2,40[c]
4	49,2	47,3	49,5	46,4	2,91	2,91	2,67	2,63
					3,32	3,30	3,25	3,39
5	53,9	53,0	51,4	51,0	2,57	2,42	2,44[c]	2,49
6	57,3	56,2	54,2	48,0	2,72	2,77	2,47	2,20
					3,09	2,91	2,75	2,95
7	60,9	60,7	59,4	60,3	4,12	4,14	4,19	4,08
8	14,3	13,9	14,4	14,4	1,24	1,26	1,24	1,22
9	44,0	45,2	44,0	40,9	2,37	2,46	2,30	2,28
10	32,8	32,9	29,7	31,7	2,62	2,68	2,61	2,61
11	59,1	59,0	56,9	58,2	3,93	3,95	3,89	3,76
12	16,5	16,1	15,3	15,0	1,28	1,29	1,19	1,17

[a] See Scheme 2 for the numbering system. [b] NMR spectra were recorded in $CDCl_3$. [c] Because discrimination of protons located at C3 and C5 in experimental data was not possible, computed data result from an average between chemical shifts of the corresponding protons in each computed diastereomer.

Table 2. Pairwise computed and experimental NMR data comparison for ^{1}H nuclei

Nucleus	^{1}H			
	$\lvert\delta_{dia1} - \delta_{5a1}\rvert$	$\lvert\delta_{dia1} - \delta_{5a2}\rvert$	$\lvert\delta_{dia2} - \delta_{5a1}\rvert$	$\lvert\delta_{dia2} - \delta_{5a2}\rvert$
2	0,23	0,06	0,10	0,07
3	0,32	0,25	0,33	0,26
4	0,24	0,28	0,24	0,28
	0,07	0,07	0,05	0,09
5	0,13	0,08	0,02	0,07
6	0,25	0,52	0,30	0,57
	0,34	0,14	0,16	0,04
7	0,07	0,04	0,05	0,06
8	0,00	0,02	0,02	0,04
9	0,07	0,09	0,16	0,18
10	0,01	0,01	0,07	0,07
11	0,04	0,17	0,06	0,19
12	0,09	0,11	0,10	0,12
CMAD[a]	0,14	0,14	0,13	0,16
Largest Δδ	0,57			

[a] CMAD is the corrected mean absolute deviation, obtained following the equation

$$\frac{1}{n}\sum_{i=1}^{n}\lvert\delta_{compt,i} - \delta_{expt,i}\rvert$$

, where δ_{compt} refers to the scaled computed chemical shift.

Table 3. Pairwise computed and experimental NMR data comparison for ^{13}C nuclei

Nucleus	^{13}C			
	$\|\delta_{dia1} - \delta_{5a1}\|$	$\|\delta_{dia1} - \delta_{5a2}\|$	$\|\delta_{dia2} - \delta_{5a1}\|$	$\|\delta_{dia2} - \delta_{5a2}\|$
1	2,32	1,69	1,52	0,89
2	0,66	1,00	0,65	0,31
3	3,55	6,05	1,12	3,62
4	0,31	2,77	2,23	0,85
5	2,53	2,90	1,60	1,97
6	3,05	9,22	1,98	8,15
7	1,53	0,55	1,35	0,37
8	0,11	0,10	0,55	0,54
9	0,03	3,08	1,14	4,25
10	3,14	1,10	3,21	1,17
11	2,27	0,91	2,17	0,81
12	1,21	1,46	0,76	1,01
CMAD[a]	1,73	2,57	1,52	2,00
Largest Δδ	9,22			

[a]CMAD is the corrected mean absolute deviation, obtained following the equation

$$\frac{1}{n}\sum_{i=1}^{n}|\delta_{compt,i} - \delta_{expt,i}|$$

, where δ_{compt} refers to the scaled computed chemical shift.

Chemical Shifts: Computed chemical shifts and empirical scaling at the B3LYP/6-311++G(d,p) level of theory

	^{1}H	^{13}C	^{31}P
Slope	1.0405	1.0335	1.09
Intercept	31.984	180.6184	-9.2

The equations shown below were applied on the computed NMR isotropic magnetic shielding constants in order to scale the CS.

- for ^{1}H and ^{13}C nuclei :

$$\delta_{scaled} = \frac{b - \sigma}{m}$$

δ = computed chemical shift relative to TMS
σ = computed isotropic magnetic shielding constant
m = slope
b = intercept

- For ^{31}P nucleus :

$$\delta_{scaled} = \frac{(\sigma_{ref} - \sigma_{Nuclei}) - b}{m}$$

δ_{scaled} = computed chemical shift relative to TMS
σ_{ref} = ^{31}P computed isotropic magnetic shielding constant of the reference compound (Here reference compound is H_3PO_4)
σ_{Nuclei} = Nuclei computed isotropic magnetic shielding constant
m = slope
b = intercept

References for empirical scaling:

^{1}H empirical scaling: Jain, R.; Bally, T.; Rablen, P. R. *J. Org. Chem.* **2009**, *74*, 4017 – 4013.
^{13}C empirical scaling: Konstantinov, I. A.; Broadbelt, L. J. *J. Phys. Chem. A* **2011**, *115*, 12364 – 12372.
^{31}P empirical scaling: Latypov, S. K.; Polyancev, F. M.; Yakhvarov, D. G.; Sinyashin, O. G. *Phys. Chem. Chem. Phys.* **2015**, *17*, 6976 – 6987.

Basis set: 6-311++G(d,p) : (a) Rablen, P. R.; Pearlman, S. A.; Finkbiner J. *J. Phys. Chem. A* **1999**, *103*, 7357 – 7363. (b) Muñoz, M. A.; Joseph-Nathan, P. *Magn. Reson. Chem.* **2009**, *47*, 578 – 584. (c) Musielak, B.; Holak, T. A.; Rys, B. *J. Org. Chem.* **2015**, *80*, 9231 – 9239.

Table 4. Comparison of scaled experimental and calculated chemical shifts for ^{1}H and ^{13}C.

Nucleus[a]	^{13}C NMR chemical shifts (ppm)				^{1}H NMR chemical shifts (ppm)			
	Experimental[b]		Computed		Experimental[b]		Computed	
	δ_{dia1}	δ_{dia2}	δ_{5a1}	δ_{5a2}	δ_{dia1}	δ_{dia2}	δ_{5a1}	δ_{5a2}
1	174,3	173,5	170,4	171,5				
2	41,2	39,9	40,1	39,7	2,90	2,77	2,51	2,58
3	25,0	27,5	27,8	30,1	2,15	2,14	2,42[c]	2,33[c]
4	49,2	47,3	49,4	46,3	2,91	2,91	2,59	2,58
					3,32	3,30	3,29	3,39
5	53,9	53,0	51,6	48,0	2,57	2,42	2,39[c]	2,47[c]
6	57,3	56,2	54,1	51,3	2,72	2,77	2,40	2,16
					3,09	2,91	2,73	3,00
7	60,9	60,7	59,0	59,6	4,12	4,14	4,24	4,13
8	14,3	13,9	13,2	13,0	1,24	1,26	1,34	1,27
9	44,0	45,2	43,5	40,2	2,37	2,46	2,27	2,25
10	32,8	32,9	28,6	31,1	2,62	2,68	2,68	2,66
11	59,1	59,0	55,9	57,4	3,93	3,95	3,66	3,74
12	16,5	16,1	14,2	13,9	1,28	1,29	1,22	1,21

[a] See Scheme 2 for the numbering system. [b] NMR spectra were recorded in $CDCl_3$. [c] Because discrimination of protons located at C3 and C5 in experimental data was not possible, computed data result from an average between chemical shifts of the corresponding protons in each computed diastereomer.

Table 5. Pairwise computed and experimental NMR data comparison

Nucleus	^{13}C				^{1}H			
	$\|\delta_{dia1} - \delta_{5a1}\|$	$\|\delta_{dia1} - \delta_{5a2}\|$	$\|\delta_{dia2} - \delta_{5a1}\|$	$\|\delta_{dia2} - \delta_{5a2}\|$	$\|\delta_{dia1} - \delta_{5a1}\|$	$\|\delta_{dia1} - \delta_{5a2}\|$	$\|\delta_{dia2} - \delta_{5a1}\|$	$\|\delta_{dia2} - \delta_{5a2}\|$
1	3,9	2,8	3,1	2,0				
2	1,1	1,5	0,2	0,2	0,39	0,32	0,26	0,19
3	2,8	5,0	0,4	2,6	0,27	0,18	0,28	0,19
4	0,2	2,8	2,1	0,9	0,32	0,33	0,32	0,33
					0,03	0,07	0,01	0,09
5	2,3	5,9	1,4	5,0	0,18	0,10	0,03	0,05
6	3,1	5,9	2,0	4,8	0,32	0,56	0,37	0,61
					0,36	0,09	0,18	0,09
7	1,9	1,3	1,7	1,1	0,12	0,01	0,10	0,01
8	1,2	1,3	0,7	0,8	0,10	0,03	0,08	0,01
9	0,6	3,8	1,7	5,0	0,10	0,12	0,19	0,21
10	4,2	1,7	4,3	1,8	0,06	0,04	0,00	0,02
11	3,2	1,8	3,1	1,7	0,27	0,19	0,29	0,21
12	2,3	2,6	1,9	2,1	0,06	0,07	0,07	0,08
CMAD[a]	**2,2**	**3,0**	**1,9**	**2,3**	**0,20**	**0,16**	**0,17**	**0,16**
Largest Δδ	**5,9**				**Largest Δδ**	**0,61**		

[a]CMAD is the corrected mean absolute deviation, obtained following the equation $\frac{1}{n}\sum_{i=1}^{n}|\delta_{compt,i} - \delta_{expt,i}|$, where δ_{compt} refers to the scaled computed chemical shift.

Graphics 1. Comparison of Δδ between experimental data for 5dia1 and 5dia2 in blue and between computed data for 5a1 and 5a2 in red.