

Supporting Information

Room-Temperature *meta*-Functionalization: Pd(II)-Catalyzed Synthesis of 1,3,5-trialkenyl Arene and *meta*-Hydroxylated Olefin

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General Consideration:

Reagent Information. Unless otherwise stated, all reactions were carried out under air atmosphere in screw cap reaction tubes. All solvents were bought from Merck and TCI [1,1,1,3,3,3-Hexafluoro-2-propanol (HFIP); CAS: 920-66-1] in a sure-seal bottle and were used as received. Silver carbonate, all MPAA ligands were purchased from Alfa Aesar. Diethyl benzyl phosphonates for the synthesis of final starting materials were obtained from Aldrich and Alfa Aesar. Olefins were obtained from Alfa Aesar, Sigma Aldrich and Spectrochem. For column chromatography, silica gel (100–200 mesh) obtained from SRL Co. was used. A gradient elution using pet ether and ethyl acetate was performed, based on Merck aluminum TLC sheets (silica gel 60F₂₅₄).

Analytical Information. All isolated compounds were characterized by ¹H, ¹³C, and in few cases 1D-NOE, NOESY, HSQC NMR spectroscopy, IR spectroscopy, Gas chromatography mass spectra (GC–MS)/HR-MS for some compounds. Copies of NMR files can be found in the supporting information. Unless otherwise stated, all Nuclear Magnetic Resonance spectra were recorded on a Bruker 400 and 500 MHz instrument. ³¹P-NMR spectra reported in the supporting information was recorded in Bruker 500 MHz instrument. The references used for the NMR are tetramethylsilane (TMS) for ¹H and ¹³C-NMR. All ¹H-NMR experiments are reported in units, parts per million (ppm), and were measured relative to the signals for residual chloroform (7.26 ppm) in the deuterated solvent, unless otherwise stated. All ¹³C-NMR spectra were reported in ppm relative to deuteriochloroform (77.23 ppm), unless otherwise stated, and all were obtained with ¹H decoupling. Neat infrared spectra were recorded on a Perkin-Elmer spectrum one FT-IR spectrometer. The data was recorded in transmittance mode (%T, cm⁻¹).-The melting points were measured in Büchi Melting Point Model B-545 apparatus. All NMR analysis were performed 1,3,5-trimethoxybenzene as the internal standard. High-resolution mass spectra (HRMS) were recorded on a micro-mass ESI TOF (time of flight) mass spectrometer.

Description of Reaction Tube:



Figure S1.Pictorial description of reaction tube for meta-functionalizations: Fisherbrand Disposable Borosilicate Glass Tubes (16*125mm) with Threaded End (Fisher Scientific Order No. 1495935A) [left]; Kimble Black Phenolic Screw Thread Closures with Open Tops (Fisher Scientific Order No. 033407E) [right]; Thermo Scientific National PTFE/Silicone Septa for Sample Screw Thread Caps (Fisher Scientific Order No. 03394A) [right].

Optimization details for Activation of Remote *Meta*-C-H Bonds:

Optimization for mono-olefination

Temperature Screening:

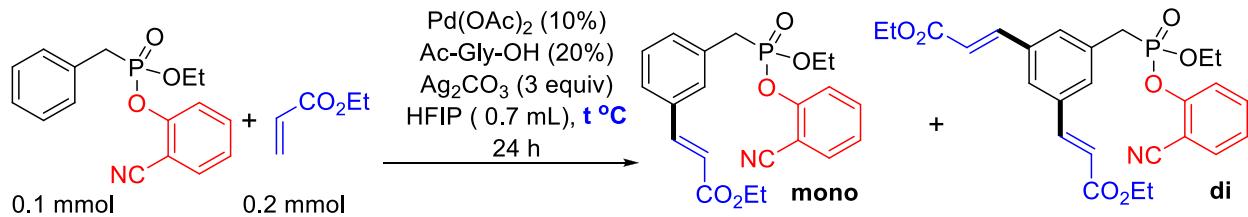
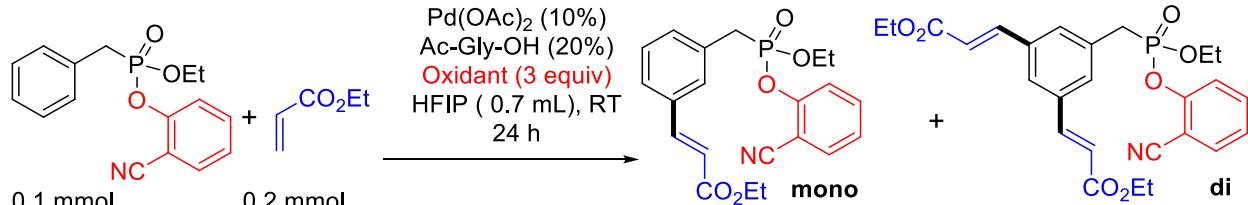


Table S1:

entry	Temperature (°C)	Mono-product (%)	Di-product (%)	Selectivity (<i>meta</i> : others)
1	30 (RT)	74	11	>20:1
2	50	55	32	>20:1
3	80	10	83	>20:1
4	90	10	81	>20:1
5	100	8	79	>20:1

Yield and selectivity were determined based on ¹H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Oxidant Screening:



Scheme S2: Oxidant screening

Table S2:

entry	Oxidant	Mono-product (%)	Di-product (%)	Selectivity (<i>meta</i> : others)
1	-	0	0	-
2	AgOAc	71	8	>20:1
3	Ag ₂ CO ₃	74	11	>20:1
4	AgNO ₃	52	7	>20:1
5	Ag ₂ SO ₄	53	6	>20:1
6	Cu(OAc) ₂	-	-	-
6	CuCl ₂	-	-	-

7	PhI(OAc) ₂	-	trace	-
8	K ₂ S ₂ O ₈	-	trace	-

Yield and selectivity were determined based on ¹H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Optimization of oxidant loading:

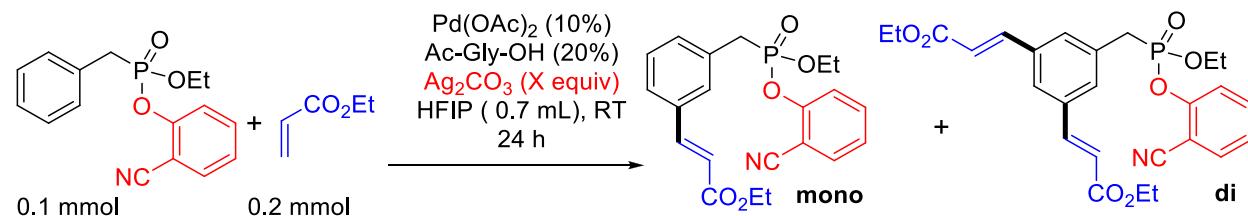
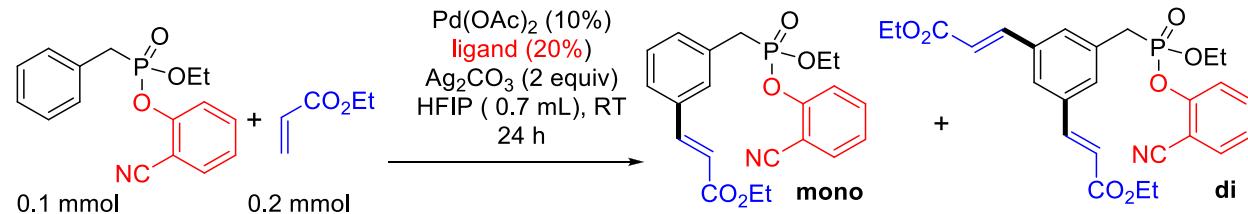


Table S3:

entry	Ag ₂ CO ₃ (X equiv)	Mono-product (%)	Di-product (%)	Selectivity (<i>meta</i> : others)
1	1	60	8	>20:1
2	1.5	67	7	>20:1
3	2	79	6	>20:1
4	2.5	78	11	>20:1
5	3	74	11	>20:1
7	4	74	13	>15:1

Yield and selectivity were determined based on ¹H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Ligand Screening:



Scheme S4: Ligand screening

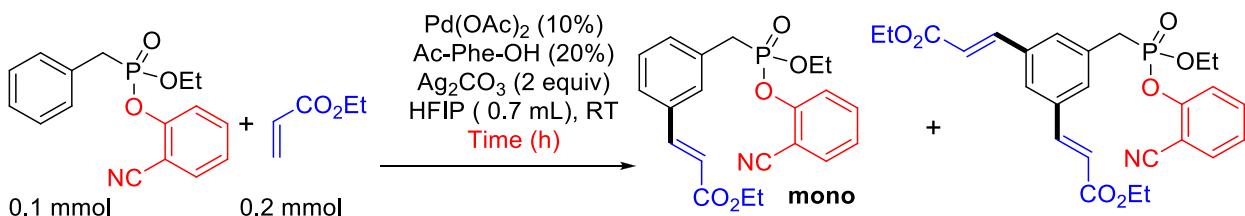
Table S4:

entry	Ligand	Mono-product (%)	Di-product (%)	Selectivity (<i>meta</i> : others)
1	-	37	0	>20:1
2	N-Acetyl-L-phenylalanine (Ac-Phe-OH)	81	0	>20:1
3	<i>N</i> -Acetyl-DL-valine	56	0	>20:1
4	<i>N</i> -Acetylglycine	79	6	>20:1
5	<i>N</i> -Acetylalanine	77	0	>20:1

6	<i>N</i> -Acetyl-L-leucine	63	0	>20:1
7	N-Boc-D-valine	62	8	>20:1
8	<i>D,L</i> -Proline	5	0	-
9	<i>N</i> -Boc proline	4	0	-
10	1,10-Phenanthroline.H ₂ O	-	-	-
11	3,4,7,8-Tetramethyl-1,10-phenanthroline	-	-	-
12	Racemic-BINAM	-	-	-
13	R-BINAM	-	-	-

Yield and selectivity were determined based on ¹H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Time Screening:



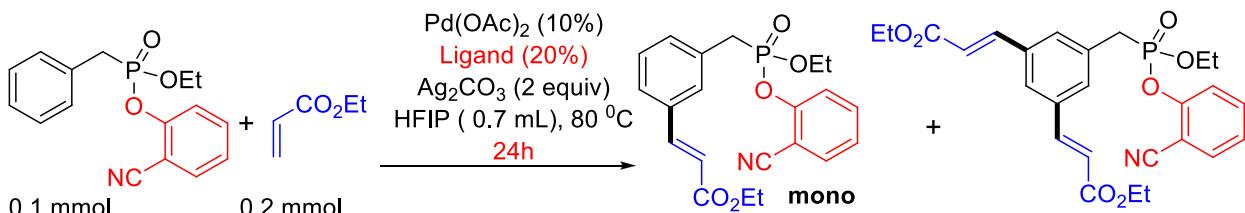
Scheme S5: Time screening

Table S5:

entry	Time (h)	Mono-product (%)	Di-product (%)	Selectivity (<i>meta</i> : others)
1	18	74	0	>20:1
2	24	81	0	>20:1
3	30	83	0	>20:1
4	36	87	0	>20:1
5	42	86	4	>20:1
6	48	86	8	>20:1

Yield and selectivity were determined based on ¹H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Optimization of di-olefination: (ligand screening)



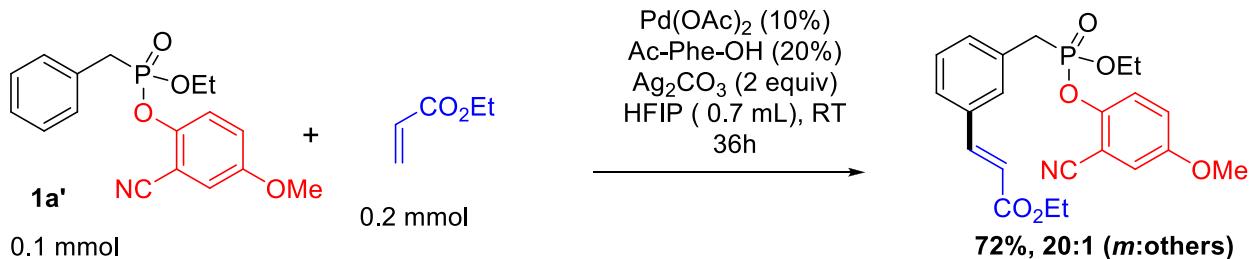
Scheme S6: Ligand screening

Table S6:

entry	Ligand	Mono-product (%)	Di-product (%)	Selectivity (<i>meta</i> : others)

1	<i>N</i> -Acetyl-L-phenylalanine	12	78	>20:1
2	<i>N</i> -Acetyl-DL-valine	11	47	>20:1
3	<i>N</i>-Acetylglycine (Ac-Gly-OH)	5	88	>20:1
4	<i>N</i> -Acetylalanine	17	72	>20:1
5	<i>N</i> -Acetyl-L-leucine	19	49	>20:1
6	N-Boc-D-valine	24	56	>20:1
7	<i>D,L</i> -Proline	12	0	-
8	<i>N</i> -Boc proline	-	-	-
9	1,10-Phenanthroline.H ₂ O	-	-	-
10	3,4,7,8-Tetramethyl-1,10-phenanthroline	-	-	-
11	Racemic-BINAM	-	-	-
12	R-BINAM	-	-	-

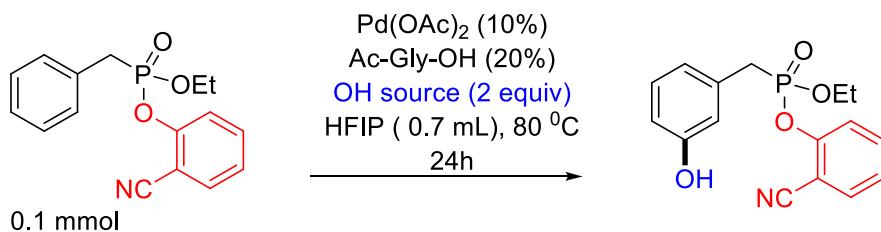
Olefination with MBM scaffolds:



Scheme S7: Results with MBM scaffolds

Optimization of Hydroxylation:

Screening of -OH source:



Scheme S8: Hydroxyl source screening

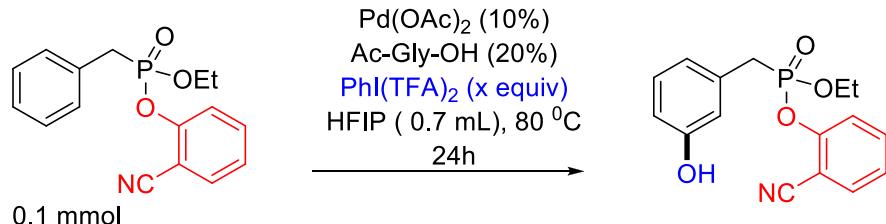
Table S7:

entry	Pd-salt	-OH source	Yield	Selectivity <i>meta</i> :others
1	$\text{Pd}(\text{OAc})_2$	TBHP	0	
2	$\text{Pd}(\text{OAc})_2$	H_2O_2	0	
3	$\text{Pd}(\text{OAc})_2$	TEMPO	0	

4	Pd(OAc) ₂	K ₂ S ₂ O ₈ , CF ₃ COOH	0	
5	Pd(OAc) ₂	Na ₂ S ₂ O ₈ , dioxane	0	
6	Pd(OAc) ₂	PhI(TFA) ₂ , CF ₃ CH ₂ OH	35	>20:1
7	Pd(OAc) ₂	PhI(TFA) ₂ , HFIP	62	>20:1

Yield and selectivity were determined based on ¹H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Optimization of PhI(TFA)₂ loading:



Scheme S9: Screening of PhI(TFA)₂ loading

Table S8:

entry	PhI(TFA) ₂ (equiv)	Yield (%)
1	2	62
2	2.5	62
3	3	65
4	3.5	66
5	4	67

Yield and selectivity were determined based on ¹H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Ligand Screening:



Scheme S10: Ligand screening

Table S9:

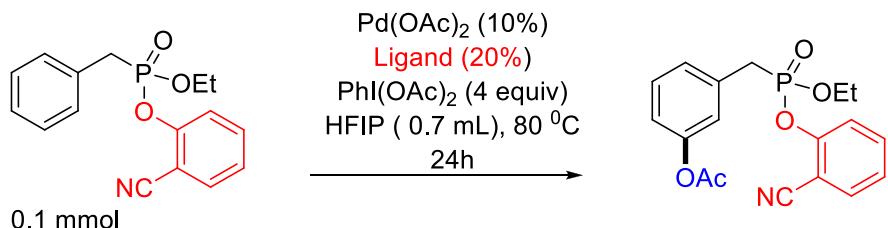
entry	Ligand	Yield (%)
1	Ac-Gly-OH	67
2	Ac-Phe-OH	64
3	For-Gly-OH	69
4	Boc-Gly-OH	68
5	Boc-Val-OH	69

6	Boc-Ala-OH	74
7	Boc-Phe-OH	70

Yield and selectivity were determined based on ^1H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Optimization of Acetoxylation:

Ligand Screening:



Scheme S11: Ligand screening

Table S10:

entry	Ligand	Yield (%)	Selectivity (<i>meta</i> :other)
1	Ac-Gly-OH	71	>20:1
2	Ac-Phe-OH	67	„
3	For-Gly-OH	61	„
4	Boc-Gly-OH	58	„
5	Boc-Val-OH	63	„
6	Boc-Ala-OH	68	„
7	Boc-Phe-OH	61	„

Yield and selectivity were determined based on ^1H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Optimization with combination of PhI(OAc)_2 and Ac_2O :



Scheme S12: Ligand Screening with Ac_2O

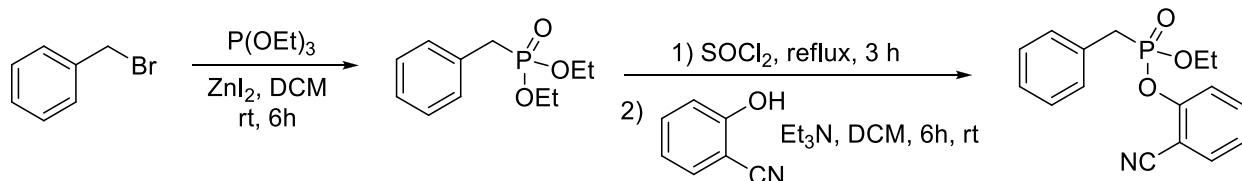
Table S11:

entry	Ligand	Yield (%)	Selectivity (<i>meta</i> :other)
1	Ac-Gly-OH	78	>20:1
2	Ac-Phe-OH	72	„
3	For-Gly-OH	62	„

4	Boc-Gly-OH	57	„
5	Boc-Val-OH	66	„
6	Boc-Ala-OH	67	„
7	Boc-Phe-OH	64	„

Yield and selectivity were determined based on ^1H NMR of crude reaction mixture using 1,3,5-trimethoxybenzene as an internal standard.

Synthesis of starting materials:



Scheme S13: Starting material synthesis

Oven dried clean round bottom flask was charged with magnetic stir-bar, benzyl bromide derivative (1 mmol) and $\text{P}(\text{OEt})_3$ (1.2 mmol). 5 ml of dry DCM was added to the RB and stirred at room temperature in the presence of catalytic amount of ZnI_2 (0.2 mmol). After 6 h the reaction was taken out and evaporated under reduced pressure to obtained crude materials which was then purified by column chromatography as petroleum ether/ ethyl acetate as the eluent.

An oven dried clean round bottom flask was charged with magnetic stir-bar and diethyl benzylic phosphonates, and then SOCl_2 was added as a solvent amount to the reaction mixture and stirred at reflux condition. After 3 h the excess amount of SOCl_2 was removed by rotavapor and the crude phosphoryl chloride derivatives was charged for next step esterification.

Under nitrogen atmosphere Et_3N was added to the 2-hydroxybenzonitrile solution in DCM. The reaction was stirred at 0 °C for 10 mins. Under nitrogen atmosphere Phosphonyl chloride was added to the reaction in portion until effervescence stopped and then transferred to room temperature and stirred overnight. The progress of the reaction was monitored by TLC. Upon completion the reaction was quenched by adding water and the desired compound was extracted with ethyl acetate. Combined organic portion was dried over anhydrous Na_2SO_4 . The crude mixture was concentrated under reduced pressure and purified by column chromatography using silica gel (100-200 mesh size) and petroleum ether/ ethyl acetate as the eluent.

General procedure of *meta*-mono-olefination of Phosphonate ester (Procedure A):

An oven-dried screw cap reaction tube was charged with a magnetic stir-bar, $\text{Pd}(\text{OAc})_2$ (10 mol%, 5 mg), Ac-Phe-OH (20 mol%, 8 mg), Ag_2CO_3 (2 equiv.; 110 mg), corresponding benzylic phosphonate ester (0.2 mmol) and olefin (0.4 mmol). Solid reagents were weighed first followed by liquid reagents. 1.5 mL of 1,1,1,3,3-Hexafluoro-2-propanol (HFIP) were added. The reaction mixture was stirred vigorously at room temperature for 36 h. The reaction was

taken out after 36 h and the reaction mixture was diluted with EtOAc and filtered through a celite pad. After filtration and evaporation of the solvent, the crude mixture was purified by column chromatography using silica gel (100-200 mesh size) and petroleum ether/ ethyl acetate as the eluent.

General Procedure of *meta*-di-olefination of Phosphonate ester (Procedure B):

An oven-dried screw cap reaction tube was charged with a magnetic stir-bar, , Pd(OAc)₂ (10 mol%, 5 mg), Ac-Gly-OH (20 mol%, 5 mg), Ag₂CO₃ (2 equiv.; 110 mg), phosphonate ester (0.2 mmol) and olefin (0.4 mmol). Solid reagents were weighed first followed by liquid reagents. 1.5 mL of 1,1,1,3,3-Hexafluoro-2-propanol (HFIP) was added. The reaction mixture was stirred vigorously on a preheated oil bath at 80 °C along. The reaction was taken out after 24 h and the reaction mixture was diluted with EtOAc and filtered through a celite pad. After filtration and evaporation of the solvent, the crude mixture was purified by column chromatography using silica gel (100-200 mesh size) and petroleum ether/ ethyl acetate as the eluent.

General Procedure of *meta*-heterodi-olefination of Phosphonate ester (Procedure C):

Hetero di-olefination is a two step process. In first step mono-olefination can be done by following *meta*-mono olefination condition at room temperature (**procedure A**). After isolation of mono olefinated product, this product was subjected for another olefination reaction using other olefin following *meta*-di-olefination reaction condition at 80 °C (**procedure B**).

General procedure of *meta*-hydroxylation of Phosphonate ester:

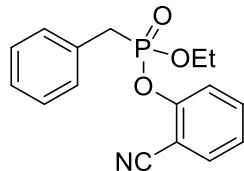
An oven-dried screw cap reaction tube was charged with a magnetic stir-bar, , Pd(OAc)₂ (10 mol%, 5 mg), Boc-Ala-OH (20 mol%, 7.5 mg), PhI(TFA)₂ (4 equiv.; 340 mg) and corresponding phosphonate ester (0.2 mmol). Solid reagents were weighed first followed by liquid reagents. 1.5 mL of 1,1,1,3,3-Hexafluoro-2-propanol (HFIP) was added. The reaction mixture was stirred vigorously on a preheated oil bath at 80 °C along. The reaction was taken out after 24 h and the reaction mixture was diluted with EtOAc and filtered through a celite pad. After filtration and evaporation of the solvent, the crude mixture was purified by column chromatography using silica gel (100-200 mesh size) and petroleum ether/ ethyl acetate as the eluent.

General procedure of *meta*-acetoxylation of Phosphonate ester:

An oven-dried screw cap reaction tube was charged with a magnetic stir-bar, , Pd(OAc)₂ (10 mol%, 5 mg), Ac-Gly-OH (20 mol%, 5 mg), PhI(OAc)₂ (2 equiv.; 130 mg), Ac₂O (2 equiv, 30 μ l) and corresponding phosphonate ester (0.2 mmol). Solid reagents were weighed first followed by liquid reagents. 1.5 mL of 1,1,1,3,3-Hexafluoro-2-propanol (HFIP) was added. The reaction mixture was stirred vigorously on a preheated oil bath at 80 °C along. The reaction

was taken out after 24 h and the reaction mixture was diluted with EtOAc and filtered through a celite pad. After filtration and evaporation of the solvent, the crude mixture was purified by column chromatography using silica gel (100-200 mesh size) and petroleum ether/ ethyl acetate as the eluent.

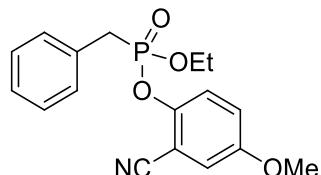
Characterization of the *Benzylidene Phosphonate ester* substrates:



2-cyanophenyl ethyl benzylphosphonate (1a):

¹H NMR (500 MHz, Chloroform-d) δ: 7.59 (dt, J = 7.7, 1.2 Hz, 1H), 7.47 (ddd, J = 8.9, 7.5, 1.7 Hz, 1H), 7.39 – 7.34 (m, 2H), 7.34 – 7.31 (m, 1H), 7.31 – 7.24 (m, 3H), 7.22 – 7.17 (m, 1H), 4.23 – 4.14 (m, 2H), 3.44 (d, J = 21.9 Hz, 2H), 1.25 (t, J = 7.0 Hz, 3H).

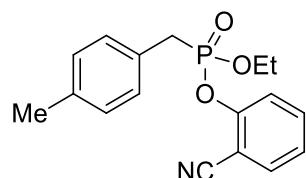
¹³C NMR (126 MHz, CDCl₃) δ: 152.31, 134.52, 134.15, 133.62, 133.13, 130.16, 130.11, 128.93, 128.90, 127.60, 127.57, 125.24, 125.19, 121.20, 121.18, 116.41, 115.54, 105.67, 64.22, 64.16, 34.57, 33.48, 16.30, 16.25.



2-cyano-4-methoxyphenyl ethyl benzylphosphonate (1a'):

¹H NMR (400 MHz, Chloroform-d) δ: 7.34 – 7.27 (m, 3H), 7.26 (s, 1H), 7.20 (td, J = 6.8, 1.7 Hz, 1H), 7.10 (dd, J = 9.1, 1.2 Hz, 1H), 6.99 (d, J = 3.2 Hz, 1H), 6.94 (dd, J = 9.1, 3.1 Hz, 1H), 4.16 – 4.05 (m, 2H), 3.75 – 3.68 (m, 3H), 3.37 (d, J = 21.8 Hz, 2H), 1.18 (t, J = 7.1 Hz, 3H).

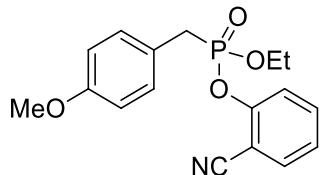
¹³C NMR (101 MHz, CDCl₃) δ: 155.98, 145.83, 145.75, 130.00, 129.95, 129.91, 129.88, 128.64, 128.61, 127.24, 127.20, 122.30, 122.27, 120.41, 117.05, 115.30, 105.93, 63.68, 63.60, 55.81, 34.49, 33.11, 16.14, 16.08.



2-cyanophenyl ethyl 4-methylbenzylphosphonate (1b):

¹H NMR (500 MHz, Chloroform-d) δ: 7.58 (dd, J = 7.8, 1.6 Hz, 1H), 7.46 (td, J = 8.0, 1.7 Hz, 1H), 7.29 (d, J = 8.5 Hz, 1H), 7.24 (dd, J = 8.1, 2.7 Hz, 2H), 7.18 (t, J = 7.6 Hz, 1H), 7.11 (d, J = 7.7 Hz, 2H), 4.19 – 4.12 (m, 2H), 3.39 (d, J = 21.6 Hz, 2H), 2.30 (d, J = 2.5 Hz, 3H), 1.24 (t, J = 7.0 Hz, 3H).

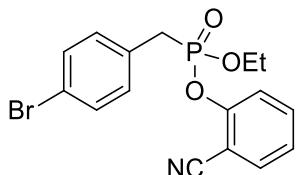
¹³C NMR (126 MHz, CDCl₃) δ: 152.61, 152.54, 137.16, 137.12, 134.38, 133.55, 130.00, 129.95, 129.57, 129.54, 126.80, 126.72, 124.91, 121.23, 121.21, 115.63, 105.64, 63.85, 63.79, 34.26, 33.15, 21.18, 16.35, 16.30.



2-cyanophenyl ethyl 4-methoxybenzylphosphonate (1c):

¹H NMR (400 MHz, Chloroform-d) δ: 7.62 – 7.55 (m, 1H), 7.46 (ddt, J = 9.9, 7.8, 2.0 Hz, 1H), 7.29 – 7.21 (m, 3H), 7.21 – 7.14 (m, 1H), 6.84 (dd, J = 8.4, 6.1 Hz, 2H), 4.20 – 4.09 (m, 2H), 3.76 (s, 3H), 3.36 (d, J = 21.3 Hz, 2H), 1.24 (t, J = 7.1 Hz, 3H).

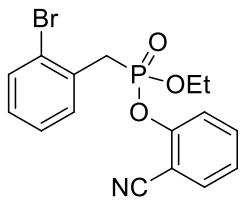
¹³C NMR (101 MHz, CDCl₃) δ: 159.03, 152.58, 134.39, 133.83, 133.54, 131.17, 131.10, 125.67, 124.93, 121.73, 121.63, 121.19, 121.17, 115.60, 114.33, 114.30, 105.59, 77.52, 77.20, 76.88, 63.86, 63.78, 55.34, 33.85, 32.47, 16.35, 16.29.



2-cyanophenyl ethyl 4-bromobenzylphosphonate (1d):

¹H NMR (500 MHz, Chloroform-d) δ: 7.62 – 7.55 (m, 1H), 7.53 – 7.47 (m, 1H), 7.42 (dd, J = 8.3, 3.4 Hz, 2H), 7.36 – 7.30 (m, 1H), 7.22 (dp, J = 8.4, 3.0 Hz, 3H), 4.16 (ddt, J = 8.1, 6.6, 3.2 Hz, 2H), 3.39 (d, J = 22.0 Hz, 2H), 1.25 (t, J = 7.1 Hz, 3H).

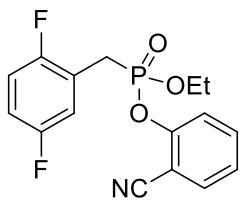
¹³C NMR (126 MHz, CDCl₃) δ: 152.26, 152.20, 134.54, 133.93, 133.65, 132.00, 131.98, 131.81, 131.75, 129.05, 128.98, 125.24, 121.67, 121.63, 121.17, 115.53, 105.68, 64.20, 64.14, 34.13, 33.02, 16.33, 16.29.



2-cyanophenyl ethyl 2-bromobenzylphosphonate (1e):

¹H NMR (500 MHz, Chloroform-d) δ: 7.62 – 7.51 (m, 3H), 7.50 – 7.45 (m, 1H), 7.35 (d, J = 8.5 Hz, 1H), 7.29 (dd, J = 8.7, 6.6 Hz, 1H), 7.20 (t, J = 7.6 Hz, 1H), 7.12 (td, J = 7.8, 2.2 Hz, 1H), 4.27 – 4.12 (m, 2H), 3.69 (d, J = 22.3 Hz, 2H), 1.29 – 1.22 (m, 3H).

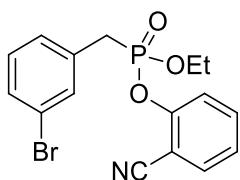
¹³C NMR (126 MHz, CDCl₃) δ: 152.30, 152.23, 134.32, 133.60, 133.18, 133.16, 131.98, 131.94, 130.39, 130.32, 129.10, 129.07, 127.78, 124.97, 120.92, 115.43, 105.61, 64.05, 63.99, 34.48, 33.37, 16.27, 16.22.



2-cyanophenyl ethyl 2,5-difluorobenzylphosphonate (1f):

¹H NMR (500 MHz, Chloroform-d) δ: 7.65 – 7.61 (m, 1H), 7.57 – 7.54 (m, 1H), 7.44 (dt, J = 8.5, 1.2 Hz, 1H), 7.27 – 7.23 (m, 1H), 7.18 (ddq, J = 8.6, 5.8, 2.7 Hz, 1H), 7.03 (tdd, J = 8.9, 4.6, 1.1 Hz, 1H), 6.99 – 6.94 (m, 1H), 4.27 – 4.21 (m, 2H), 3.49 (d, J = 22.0 Hz, 2H), 1.28 (t, J = 7.0 Hz, 3H).

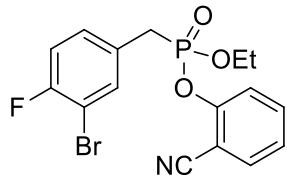
¹³C NMR (126 MHz, CDCl₃) δ 152.19, 152.13, 134.59, 134.51, 133.75, 133.68, 125.30, 121.04, 118.50, 118.42, 118.27, 118.23, 116.88, 116.81, 116.68, 116.61, 116.10, 116.03, 115.88, 115.84, 115.37, 105.81, 64.28, 64.22, 27.61, 26.48, 16.30, 16.26.



2-cyanophenyl ethyl 3-bromobenzylphosphonate (1g):

¹H NMR (500 MHz, Chloroform-d) δ: 7.59 (dt, J = 7.7, 1.9 Hz, 1H), 7.49 (dq, J = 7.3, 1.5 Hz, 2H), 7.41 – 7.33 (m, 2H), 7.33 – 7.28 (m, 1H), 7.24 – 7.18 (m, 2H), 4.18 (ttd, J = 8.7, 7.1, 5.4 Hz, 2H), 3.39 (dd, J = 22.0, 1.3 Hz, 2H), 1.26 (td, J = 7.1, 2.1 Hz, 3H).

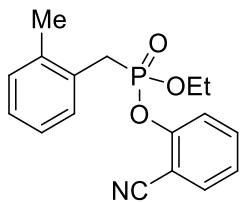
¹³C NMR (126 MHz, CDCl₃) δ: 152.37, 134.49, 133.94, 133.66, 133.03, 132.97, 132.40, 132.33, 130.70, 130.67, 130.39, 130.37, 128.84, 128.79, 126.08, 125.22, 122.74, 121.18, 115.52, 105.71, 64.13, 64.07, 34.35, 33.25, 16.35, 16.31.



2-cyanophenyl ethyl 3-bromo-4-fluorobenzylphosphonate (1h):

¹H NMR (500 MHz, Chloroform-d) δ: 7.63 (dt, *J* = 7.8, 1.2 Hz, 1H), 7.56 – 7.48 (m, 2H), 7.38 (dt, *J* = 8.6, 1.2 Hz, 1H), 7.29 (dp, *J* = 8.2, 2.6, 1.8 Hz, 1H), 7.23 (t, *J* = 7.6 Hz, 1H), 7.06 (tt, *J* = 8.5, 1.2 Hz, 1H), 4.24 – 4.18 (m, 2H), 3.37 (d, *J* = 21.7 Hz, 2H), 1.27 (td, *J* = 7.0, 1.4 Hz, 3H).

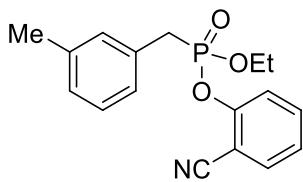
¹³C NMR (101 MHz, CDCl₃) δ: 152.13, 134.83, 134.76, 134.41, 133.56, 130.65, 130.58, 130.51, 127.56, 127.52, 127.42, 125.18, 121.08, 121.05, 116.81, 116.78, 116.59, 116.56, 115.38, 109.29, 105.59, 64.04, 63.96, 33.64, 32.25, 16.25, 16.19.



2-cyanophenyl ethyl 2-methylbenzylphosphonate (1i):

¹H NMR (500 MHz, CDCl₃) δ 7.61 – 7.57 (m, 1H), 7.48 – 7.43 (m, 1H), 7.35 – 7.30 (m, 1H), 7.17 (tdd, *J* = 13.4, 9.4, 4.3 Hz, 5H), 4.14 (dq, *J* = 14.2, 7.1 Hz, 2H), 3.47 (d, *J* = 22.2 Hz, 2H), 2.42 (s, 3H), 1.23 (t, *J* = 7.1 Hz, 3H).

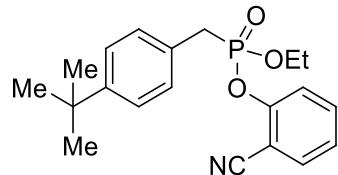
¹³C NMR (126 MHz, CDCl₃) δ 152.56, 152.51, 137.45, 137.39, 134.42, 133.58, 131.04, 130.99, 130.82, 130.79, 128.52, 128.44, 127.74, 127.71, 126.41, 126.38, 124.98, 121.19, 121.17, 115.63, 105.65, 63.88, 63.82, 32.02, 30.91, 20.10, 16.32, 16.27.



2-cyanophenyl ethyl 3-methylbenzylphosphonate (1j):

¹H NMR (400 MHz, CDCl₃) δ 7.61 – 7.56 (m, 1H), 7.49 – 7.44 (m, 1H), 7.29 (d, *J* = 8.5 Hz, 1H), 7.25 – 7.18 (m, 2H), 7.18 – 7.12 (m, 2H), 7.06 (d, *J* = 7.8 Hz, 1H), 4.23 – 4.13 (m, 2H), 3.39 (d, *J* = 21.8 Hz, 2H), 2.31 (s, 3H), 1.25 (t, *J* = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ 152.60, 152.52, 138.57, 138.54, 134.39, 133.84, 133.54, 130.90, 130.84, 129.78, 129.69, 128.76, 128.72, 128.26, 128.22, 127.18, 127.11, 125.69, 124.94, 121.17, 121.14, 115.61, 105.60, 63.89, 63.82, 34.74, 33.36, 21.39, 16.34, 16.28.



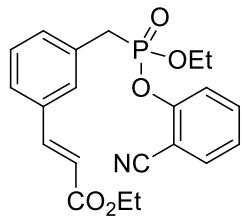
2-cyanophenyl ethyl 4-tert-butylbenzylphosphonate (1k):

¹H NMR (400 MHz, CDCl₃) δ 7.55 (d, *J* = 7.9 Hz, 1H), 7.45 – 7.37 (m, 1H), 7.34 – 7.24 (m, 4H), 7.21 – 7.12 (m, 2H), 4.26 – 4.11 (m, 2H), 3.40 (d, *J* = 21.6 Hz, 2H), 1.28 (s, 9H), 1.25 (d, *J* = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ 152.60, 152.54, 150.43, 150.40, 134.27, 133.45, 129.81, 129.76, 126.68, 126.61, 125.79, 125.76, 124.85, 121.10, 121.08, 115.57, 105.57, 63.79, 63.73, 34.12, 33.01, 31.35, 16.29, 16.24.

Characterization of the *meta*-olefinated compounds:

1. Meta-selective mono-olefination



(E)-ethyl 3-((3-((2-cyanophenoxy)ethoxy)phosphoryl)methyl)phenylacrylate (2a):

Yield : 84% (67 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

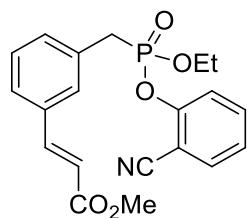
Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (500 MHz, Chloroform-d) δ: 7.66 (d, *J* = 16.0 Hz, 1H), 7.61 – 7.58 (m, 1H), 7.52 – 7.48 (m, 2H), 7.43 (dd, *J* = 7.6, 1.9 Hz, 1H), 7.40 (dt, *J* = 8.4, 1.9 Hz, 1H), 7.34 (dt, *J* = 7.7, 3.4

Hz, 2H), 7.21 (t, J = 7.6 Hz, 1H), 6.45 (d, J = 16.0 Hz, 1H), 4.28 (q, J = 7.1 Hz, 2H), 4.16 (ddq, J = 12.3, 7.0, 3.9, 3.3 Hz, 2H), 3.47 (d, J = 21.9 Hz, 2H), 1.33 (t, J = 7.1 Hz, 3H), 1.24 (t, J = 7 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 167.04, 152.35, 144.11, 135.23, 135.20, 134.52, 133.69, 132.00, 131.94, 129.79, 129.72, 129.51, 127.24, 127.20, 125.20, 121.27, 119.12, 115.62, 105.87, 64.13, 64.06, 60.74, 34.87, 33.48, 16.45, 14.49.

HRMS: [(M + Na)⁺] Calcd.: 422.1128; observed: 422.1130



(E)-methyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate(2b):

Yield : 82% (63 mg)

Appearance: Liquid

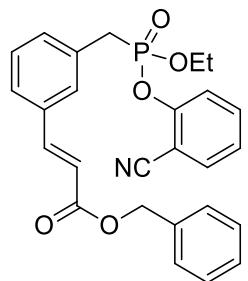
R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (400 MHz, Chloroform-d) δ 7.64 (d, J = 16.1 Hz, 2H), 7.60 (dt, J = 7.8, 1.2 Hz, 1H), 7.53 (d, J = 2.6 Hz, 3H), 7.51 – 7.47 (m, 1H), 7.41 – 7.37 (m, 1H), 7.24 – 7.20 (m, 1H), 6.45 (d, J = 16 Hz, 1H), 4.26 – 4.14 (m, 2H), 3.80 (s, 1H), 3.46 (d, J = 22.0 Hz, 2H), 1.26 (t, J = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 167.20, 152.31, 143.51, 135.82, 135.79, 134.55, 133.69, 132.04, 131.94, 131.07, 131.00, 126.88, 126.85, 125.32, 121.22, 121.20, 119.59, 115.57, 105.77, 64.19, 64.11, 52.02, 34.74, 33.36, 16.46.

HRMS: [(M + Na)⁺] Calcd.: 408.0971; observed: 408.0976.



(E)-benzyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2c):

Yield : 68% (62 mg)

Appearance: Liquid

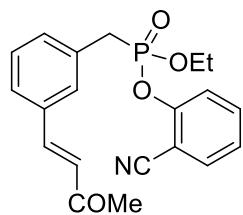
R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (400 MHz, Chloroform-d) δ: 7.68 (d, J = 16.0 Hz, 1H), 7.58 (dd, J = 7.8, 1.6 Hz, 2H), 7.52 – 7.46 (m, 2H), 7.41 – 7.37 (m, 3H), 7.36 – 7.33 (m, 3H), 7.32 – 7.27 (m, 1H), 7.19 (td, J = 7.7, 2.5 Hz, 2H), 6.48 (d, J = 16.0 Hz, 1H), 5.24 (s, 2H), 4.21 – 4.15 (m, 2H), 3.44 (d, J = 22.0 Hz, 2H), 1.24 (t, J = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 166.74, 152.36, 144.65, 136.16, 134.46, 134.40, 133.63, 133.59, 132.09, 132.02, 131.09, 130.21, 130.14, 129.75, 129.47, 128.91, 128.71, 128.36, 127.18, 125.14, 124.98, 121.24, 118.66, 115.55, 105.73, 66.50, 64.05, 63.97, 34.78, 33.40, 16.40.

HRMS: [(M +Na)⁺] Calcd.: 484.1284; observed: 484.1278.



(E)-2-cyanophenyl ethyl 3-(3-oxobut-1-en-1-yl)benzylphosphonate (2d):

Yield : 80% (59 mg)

Appearance: Liquid

R_f: 0.4 (50% ethyl acetate/pet-ether mixture)

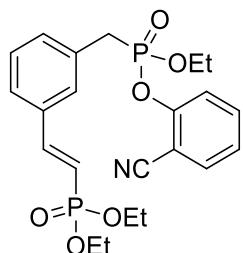
Isolation: Petroleum ether :ethyl acetate (v/v) (3:2)

¹H NMR (500 MHz, Chloroform-d) δ: 7.59 (dt, J = 7.7, 1.2 Hz, 1H), 7.55 (dd, J = 3.0, 1.6 Hz, 1H), 7.52 – 7.43 (m, 3H), 7.42 – 7.33 (m, 3H), 7.21 (tt, J = 7.6, 0.9 Hz, 1H), 6.71 (d, J = 16.3 Hz, 1H), 4.18 (dqd, J = 8.3, 7.0, 5.5 Hz, 2H), 3.45 (d, J = 21.9 Hz, 2H), 2.36 (s, 3H), 1.25 (t, J = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 198.50, 152.45, 142.96, 135.21, 135.18, 134.51, 133.69, 132.22, 132.17, 131.17, 131.09, 130.07, 130.02, 129.58, 129.56, 127.76, 127.33, 127.30, 125.18, 121.20, 121.18, 115.62, 105.71, 64.11, 64.05, 34.68, 33.58, 27.76, 16.41, 16.37.

HRMS: [(M +Na)⁺] Calcd.: 392.1022; observed: 392.1027.

IR (thin film): 2983, 2232, 1669, 1601, 1488, 1261, 1037, 921, 694 cm⁻¹



(E)-2-cyanophenyl ethyl 3-(2-(diethoxyphosphoryl)vinyl)benzylphosphonate (2e):

Yield : 65% (60 mg)

Appearance: Liquid

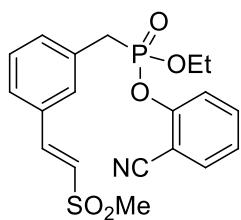
R_f: 0.2 (80% ethyl acetate/pet-ether mixture)

Isolation: Ethyl acetate :Methanol (v/v) (20:1)

¹H NMR (500 MHz, Chloroform-d) δ: 7.59 (dd, J = 7.8, 1.6 Hz, 1H), 7.52 – 7.43 (m, 3H), 7.42 – 7.37 (m, 2H), 7.34 (d, J = 8.0 Hz, 2H), 7.23 – 7.18 (m, 1H), 6.26 (t, J = 17.5 Hz, 1H), 4.15 (dd, J = 28.6, 10.2, 7.3, 3.8 Hz, 6H), 3.44 (d, J = 21.9 Hz, 2H), 1.34 (t, J = 7.1 Hz, 6H), 1.25 (t, J = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 152.52, 152.45, 148.20, 148.15, 135.67, 135.49, 134.50, 133.66, 131.98, 131.93, 131.03, 130.95, 129.48, 129.46, 129.27, 129.22, 127.05, 127.03, 125.17, 121.22, 121.20, 115.63, 115.60, 114.11, 105.72, 64.05, 63.99, 62.09, 62.05, 34.68, 33.58, 16.59, 16.54, 16.41, 16.37.

HRMS: [(M +Na)⁺] Calcd.: 486.1180; observed: 486.1180.



(E)-2-cyanophenyl ethyl 3-(2-(methylsulfonyl)vinyl)benzylphosphonate (2f):

Yield : 78% (63 mg)

Appearance: Liquid

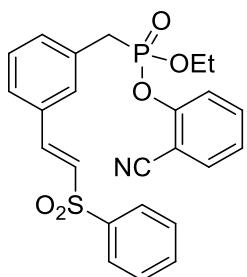
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate (v/v) (1:1)

¹H NMR (400 MHz, Chloroform-d) δ: 7.62 – 7.58 (m, 2H), 7.57 (s, 1H), 7.51 (ddd, J = 9.1, 7.5, 1.7 Hz, 1H), 7.45 (dq, J = 4.6, 2.3 Hz, 1H), 7.40 (t, J = 4.6 Hz, 3H), 7.22 (t, J = 7.6 Hz, 1H), 6.96 (d, J = 15.5 Hz, 1H), 4.27 – 4.12 (m, 2H), 3.46 (d, J = 22.0 Hz, 2H), 3.03 (s, 3H), 1.27 (t, J = 7.0 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 152.40, 143.40, 134.59, 133.75, 133.10, 133.04, 132.88, 131.57, 129.88, 129.80, 129.76, 128.16, 128.12, 127.17, 125.26, 121.15, 121.13, 115.65, 105.70, 64.20, 64.12, 43.42, 34.86, 33.47, 16.47, 16.41.

HRMS: [(M +Na)⁺] Calcd.: 428.0692; observed: 428.0698



(E)-2-cyanophenyl ethyl 3-(2-(phenylsulfonyl)vinyl)benzylphosphonate (2g):

Yield : 75% (69.5 mg)

Appearance: Liquid

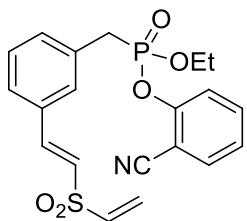
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate (v/v) (1:1)

¹H NMR (400 MHz, Chloroform-d) δ : 7.99 – 7.91 (m, 2H), 7.68 – 7.60 (m, 2H), 7.58 – 7.53 (m, 3H), 7.51 – 7.46 (m, 2H), 7.42 (dq, J = 6.4, 2.2 Hz, 1H), 7.39 – 7.34 (m, 3H), 7.19 (tt, J = 7.7, 0.9 Hz, 1H), 6.89 (d, J = 15.4 Hz, 1H), 4.17 (ddtd, J = 10.8, 9.0, 7.1, 3.9 Hz, 2H), 3.43 (d, J = 22.0 Hz, 2H), 1.24 (t, J = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl_3) δ : 152.41, 141.93, 140.77, 134.53, 133.68, 133.59, 133.15, 133.11, 132.95, 132.88, 131.45, 131.35, 129.98, 129.91, 129.72, 129.69, 129.51, 128.19, 128.02, 127.99, 127.91, 125.23, 121.17, 121.14, 115.58, 105.67, 64.15, 64.07, 34.78, 33.39, 16.42, 16.36.

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 490.0849; observed: 490.0844.



(E)-2-cyanophenyl ethyl 3-(2-(vinylsulfonyl)vinyl)benzylphosphonate (2h):

Yield : 82% (68 mg)

Appearance: Liquid

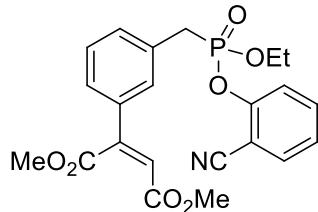
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate (v/v) (1:1)

¹H NMR (400 MHz, Chloroform-d) δ : 7.60 (d, J = 7.3 Hz, 1H), 7.56 – 7.48 (m, 3H), 7.45 (dq, J = 6.2, 2.1 Hz, 1H), 7.38 (d, J = 9.3 Hz, 3H), 7.22 (t, J = 7.6 Hz, 1H), 6.81 (d, J = 15.5 Hz, 1H), 6.65 (dd, J = 16.6, 9.8 Hz, 1H), 6.45 (d, J = 16.6 Hz, 1H), 6.09 (d, J = 9.8 Hz, 1H), 4.19 (dq, J = 8.4, 7.1, 4.9 Hz, 2H), 3.45 (d, J = 22.0 Hz, 2H), 1.25 (t, J = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 152.31, 143.92, 137.81, 134.55, 133.71, 133.12, 133.06, 131.56, 131.46, 130.01, 129.94, 129.76, 129.73, 128.99, 128.03, 127.99, 126.34, 125.26, 121.15, 115.59, 105.75, 64.15, 64.07, 34.80, 33.42, 16.43, 16.38.

HRMS: [(M + Na)⁺] Calcd.: 440.0692; observed: 440.0692.



Dimethyl 2-(3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)maleate (2i):

Yield : 71% (62 mg)

Appearance: Liquid

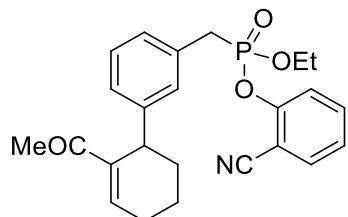
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate (v/v) (1:1)

¹H NMR (400 MHz, Chloroform-d) δ: 7.59 (dt, J = 7.7, 1.2 Hz, 1H), 7.49 (ddd, J = 8.5, 7.6, 1.8 Hz, 1H), 7.45 (q, J = 2.2 Hz, 2H), 7.39 – 7.35 (m, 2H), 7.33 (dt, J = 8.4, 1.2 Hz, 1H), 7.21 (tt, J = 7.7, 0.9 Hz, 1H), 6.31 (s, 1H), 4.19 (dddd, J = 10.1, 7.0, 3.2, 1.6 Hz, 2H), 3.92 (s, 3H), 3.78 (s, 3H), 3.45 (d, J = 22.0 Hz, 2H), 1.27 (t, J = 7.2 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 168.28, 165.50, 152.33, 148.47, 134.53, 133.68, 132.44, 132.38, 131.32, 129.69, 129.66, 128.38, 128.30, 126.11, 126.07, 125.23, 121.24, 117.90, 115.58, 105.83, 64.14, 64.07, 52.94, 52.25, 34.87, 33.48, 29.85, 16.40, 16.34.

HRMS: Calcd.: 466.1035; observed: 466.1038.



2-Cyanophenyl ethyl ((6'-acetyl-1',2',3',4'-tetrahydro-[1,1'-biphenyl]-3-yl)methyl)phosphonate (2j):

Yield : 79% (66 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

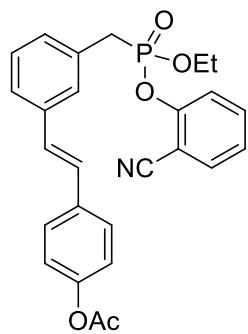
Isolation: Petroleum ether :ethyl acetate (v/v) (3:2)

¹H NMR (400 MHz, Chloroform-d) δ: 7.56 (dt, J = 7.8, 2.5 Hz, 1H), 7.45 (qd, J = 8.5, 1.8 Hz, 1H), 7.22 – 7.12 (m, 4H), 7.09 (ddd, J = 5.5, 3.7, 1.5 Hz, 1H), 7.07 – 6.82 (m, 2H), 4.16 (ttd, J = 7.0, 3.4, 1.8 Hz, 2H), 3.99 (d, J = 4.7 Hz, 1H), 3.39 (dd, J = 21.9, 4.4 Hz, 2H), 2.44 – 2.37 (m, 1H), 2.37 – 2.12 (m, 4H), 1.90 – 1.63 (m, 2H), 1.55 – 1.35 (m, 2H), 1.26 (t, J = 7.1 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 198.69, 152.54, 145.97, 142.69, 140.90, 134.63, 133.46, 129.40, 129.35, 128.92, 128.89, 127.97, 127.91, 127.40, 127.19, 124.96, 121.31, 120.13, 115.75, 105.58, 63.89, 63.83, 38.43, 34.80, 33.70, 31.30, 26.29, 26.02, 16.95, 16.40, 16.35.

HRMS: [(M + Na)⁺] Calcd.: 446.1492; observed: 446.1494.

IR (thin film): 2946, 2234, 1662, 1450, 1238, 1029, 925, 767 cm⁻¹



(E)-4-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)styryl)phenyl acetate (2k):

Yield : 56% (51 mg)

Appearance: Liquid

R_f: 0.4 (30% ethyl acetate/pet-ether mixture)

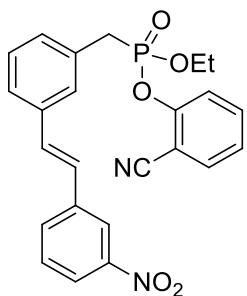
Isolation: Petroleum ether :ethyl acetate (v/v) (3:1)

¹H NMR (400 MHz, Chloroform-d) δ: 7.59 (dt, J = 7.7, 1.2 Hz, 1H), 7.54 – 7.44 (m, 4H), 7.40 (dq, J = 7.6, 1.8 Hz, 1H), 7.36 – 7.28 (m, 2H), 7.26 (s, 1H), 7.19 (ddt, J = 8.5, 7.6, 0.8 Hz, 1H), 7.13 – 7.05 (m, 3H), 7.01 (d, J = 16.4 Hz, 1H), 4.20 (dqd, J = 10.7, 7.1, 2.2 Hz, 2H), 3.46 (d, J = 21.9 Hz, 2H), 2.31 (s, 3H), 1.26 (t, J = 6.9 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 169.62, 152.68, 150.31, 137.89, 137.87, 135.15, 134.48, 133.63, 130.54, 130.47, 129.49, 129.44, 129.30, 129.27, 128.47, 128.35, 128.28, 128.23, 127.64, 125.77, 125.74, 125.04, 121.98, 121.19, 115.71, 105.68, 64.05, 63.99, 34.81, 33.71, 21.32, 16.44, 16.39.

HRMS: [(M + Na)⁺] Calcd.: 484.1284; observed: 484.1287.

IR (thin film): 2932, 2233, 1759, 1600, 1230, 1220, 1168, 1034, 919, 827 cm⁻¹



(E)-2-cyanophenyl ethyl 3-(3-nitrostyryl)benzylphosphonate (2l):

Yield : 61% (55 mg)

Appearance: Liquid

R_f: 0.4 (30% ethyl acetate/pet-ether mixture)

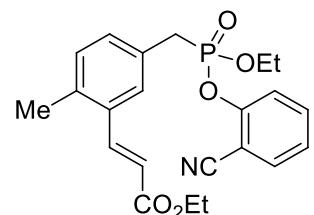
Isolation: Petroleum ether :ethyl acetate (v/v) (3:1)

¹H NMR (500 MHz, Chloroform-d) δ : 8.41 (t, $J = 2.0$ Hz, 1H), 8.11 (dd, $J = 8.2, 2.2$ Hz, 1H), 7.79 (d, $J = 7.8$ Hz, 1H), 7.64 – 7.56 (m, 2H), 7.56 – 7.46 (m, 2H), 7.46 – 7.40 (m, 1H), 7.40 – 7.28 (m, 3H), 7.24 – 7.19 (m, 3H), 4.21 (dtq, $J = 14.4, 7.3, 4.7, 3.8$ Hz, 2H), 3.48 (d, $J = 21.8$ Hz, 2H), 1.27 (t, $J = 7.1$ Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ : 152.54, 148.87, 139.17, 137.02, 134.52, 133.67, 132.48, 131.29, 130.82, 130.75, 130.27, 130.21, 129.76, 129.42, 128.54, 128.48, 126.85, 126.16, 125.11, 122.28, 121.20, 121.09, 115.70, 105.67, 64.10, 64.04, 34.78, 33.68, 16.45, 16.40.

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 471.1080; observed: 471.1076.

IR (thin film): 2983, 2233, 1600, 1529, 1488, 1351, 1262, 1237, 1034, 919, 807, 697 cm⁻¹



(E)-ethyl 3-((5-((2-cyanophenoxy)(ethoxy)phosphorylmethyl)-2-methylphenyl)acrylate (2m):

Yield : 74% (61 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

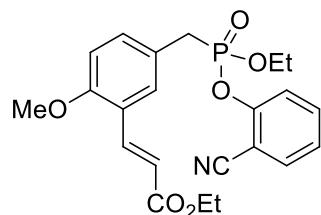
¹H NMR (400 MHz, Chloroform-d) δ : 7.91 (d, $J = 15.9$ Hz, 1H), 7.59 (dt, $J = 7.7, 1.2$ Hz, 1H), 7.52 – 7.45 (m, 3H), 7.35 (d, $J = 8.5$ Hz, 1H), 7.20 (t, $J = 7.6$ Hz, 1H), 7.14 (d, $J = 7.8$ Hz, 1H),

6.36 (d, $J = 15.8$ Hz, 1H), 4.26 – 4.22 (m, 2H), 4.13 (dt, $J = 9.0, 7.1, 2.2$ Hz, 2H), 3.43 (d, $J = 21.7$ Hz, 2H), 2.39 (d, $J = 2.3$ Hz, 3H), 1.31 (t, $J = 7.1$ Hz, 3H), 1.26 (t, $J = 7.0$ Hz, 3H).

^{13}C NMR (101 MHz, CDCl₃) δ : 167.10, 152.48, 141.80, 136.92, 136.88, 134.46, 133.98, 133.63, 131.61, 131.55, 131.41, 131.38, 128.07, 127.99, 125.08, 121.26, 121.24, 120.00, 115.59, 105.80, 63.99, 63.91, 60.66, 34.43, 33.05, 19.57, 16.42, 16.36, 14.46.

HRMS: [(M + Na)⁺] Calcd.: 436.1284; observed: 436.1286.

IR (thin film): 2983, 2231, 1711, 1601, 1488, 1236, 1183, 1036, 847 cm⁻¹



(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methoxyphenyl)acrylate (2n):

Yield : 75% (64 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

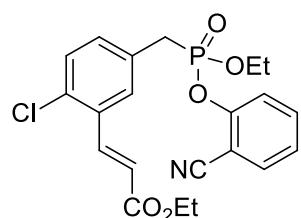
Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

^1H NMR (500 MHz, Chloroform-d) δ : 7.90 (d, $J = 16.1$ Hz, 1H), 7.59 (dd, $J = 7.8, 1.7$ Hz, 1H), 7.51 – 7.47 (m, 1H), 7.46 – 7.44 (m, 1H), 7.34 (d, $J = 8.4$ Hz, 2H), 7.23 – 7.18 (m, 1H), 6.86 (d, $J = 8.5$ Hz, 1H), 6.50 (d, $J = 16.3$ Hz, 1H), 4.24 (qd, $J = 7.1, 0.8$ Hz, 2H), 4.20 – 4.13 (m, 2H), 3.85 (s, 3H), 3.37 (d, $J = 21.3$ Hz, 2H), 1.31 (t, $J = 7.1$ Hz, 3H), 1.23 (t, $J = 7.1$ Hz, 3H).

^{13}C NMR (126 MHz, CDCl₃) δ : 167.53, 157.78, 152.52, 139.53, 134.49, 133.64, 133.01, 132.96, 130.47, 130.41, 125.12, 123.83, 122.05, 121.97, 121.24, 121.22, 119.48, 115.61, 111.72, 105.77, 64.03, 63.97, 60.53, 55.75, 33.72, 32.61, 16.42, 16.38, 14.48.

^{31}P NMR (202 MHz, CDCl₃) δ : 24.40

HRMS: [(M + Na)⁺] Calcd.: 452.1214; observed: 452.1214.



(E)-ethyl 3-((2-chlorophenoxy)(ethoxy)phosphoryl)methyl)-2-methoxyphenyl)acrylate (2p):

Yield : 76% (65 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

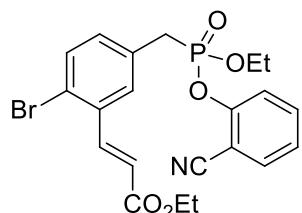
Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (500 MHz, Chloroform-d) δ: 8.01 (d, J = 16.0 Hz, 1H), 7.60 (dt, J = 8.2, 2.7 Hz, 2H), 7.54 – 7.48 (m, 1H), 7.39 – 7.34 (m, 2H), 7.33 – 7.28 (m, 1H), 7.23 (t, J = 7.6 Hz, 1H), 6.43 (d, J = 16.0 Hz, 1H), 4.26 (q, J = 7.1 Hz, 2H), 4.22 – 4.14 (m, 2H), 3.41 (d, J = 22.0 Hz, 2H), 1.33 (t, J = 7.1 Hz, 3H), 1.26 (t, J = 7.1 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 166.55, 152.30, 139.90, 134.57, 134.17, 133.69, 133.16, 132.62, 132.57, 130.65, 130.62, 129.44, 129.23, 129.17, 125.31, 121.63, 121.25, 121.23, 115.57, 105.78, 64.15, 64.09, 60.88, 34.19, 33.08, 16.43, 16.39, 14.43.

HRMS: [(M +Na)⁺] Calcd.: 456.0738; observed: 456.0735.

IR (thin film): 2986, 2233, 1713, 1488, 1237, 1037, 923, 765 cm⁻¹



(E)-ethyl 3-(2-bromo-5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2q):

Yield: 74% (70 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

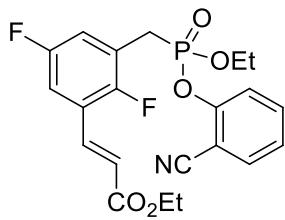
Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (400 MHz, Chloroform-d) δ: 7.97 (d, J = 15.9 Hz, 1H), 7.65 – 7.45 (m, 4H), 7.38 (d, J = 8.4 Hz, 1H), 7.26 (s, 1H), 7.22 (d, J = 7.9 Hz, 1H), 6.39 (d, J = 16.0 Hz, 1H), 4.33 – 4.10 (m, 4H), 3.40 (d, J = 22.0 Hz, 2H), 1.33 (t, J = 7.1 Hz, 3H), 1.26 (t, J = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 166.47, 152.39, 152.33, 142.46, 135.08, 135.06, 134.59, 133.93, 133.91, 133.71, 132.82, 132.76, 130.23, 130.16, 129.41, 129.35, 125.33, 124.45, 124.41, 121.85, 121.29, 121.27, 115.58, 105.82, 64.19, 64.13, 60.91, 34.29, 33.18, 16.46, 16.41, 14.45.

HRMS: [(M +Na)⁺] Calcd.: 500.0224; observed: 500.0219.

IR (thin film): 2983, 2233, 1712, 1263, 1239, 1036, 920, 763 cm⁻¹



(E)-ethyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2,5-difluorophenyl)acrylate (2r):

Yield : 84% (72 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

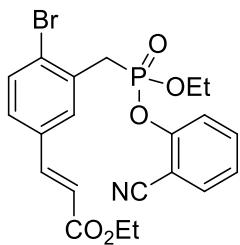
Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (500 MHz, Chloroform-d) δ : 7.74 (dd, $J = 16.2, 1.0$ Hz, 1H), 7.63 (dt, $J = 7.9, 1.1$ Hz, 1H), 7.58 – 7.54 (m, 1H), 7.46 (dt, $J = 8.4, 1.2$ Hz, 1H), 7.26 (s, 1H), 7.23 (ddd, $J = 10.8, 5.9, 1.8$ Hz, 1H), 7.18 (ddq, $J = 8.3, 5.5, 3.1$ Hz, 1H), 6.49 (d, $J = 16.2$ Hz, 1H), 4.32 – 4.22 (m, 4H), 3.50 (d, $J = 21.8$ Hz, 2H), 1.34 (t, $J = 7.1$ Hz, 3H), 1.29 (t, $J = 7.1$ Hz, 3H).

¹³C NMR (126 MHz, CDCl_3) δ : 166.37, 152.10, 152.04, 135.74, 134.53, 133.76, 125.40, 122.48, 122.44, 121.07, 121.05, 120.16, 120.08, 119.96, 119.88, 115.32, 114.15, 113.93, 105.86, 64.36, 64.30, 60.96, 27.68, 26.55, 16.33, 16.28, 14.36.

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 458.0939; observed: 458.0937.

IR (thin film): 2985, 2234, 1714, 1488, 1449, 1280, 1184, 1036, 923, 766 cm^{-1}



(E)-ethyl 3-((4-bromo-3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2s):

Yield : 81% (77 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

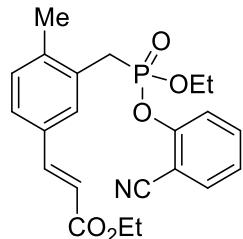
Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (500 MHz, Chloroform-d) δ : 7.64 (q, $J = 3.8, 3.2$ Hz, 1H), 7.63 – 7.55 (m, 3H), 7.51 – 7.47 (m, 1H), 7.40 (d, $J = 8.5$ Hz, 1H), 7.28 (d, $J = 8.4$ Hz, 1H), 7.22 (t, $J = 7.8$ Hz, 1H), 6.43 (d,

$J = 16.0$ Hz, 1H), 4.27 – 4.16 (m, 4H), 3.69 (d, $J = 22.3$ Hz, 2H), 1.35 – 1.29 (m, 3H), 1.27 (d, $J = 7.0$ Hz, 3H).

^{13}C NMR (126 MHz, CDCl_3) δ : 166.76, 152.23, 142.84, 134.49, 133.87, 133.84, 133.74, 133.69, 131.44, 131.40, 128.15, 128.12, 127.00, 126.93, 125.32, 125.23, 121.08, 119.76, 115.47, 105.79, 64.29, 64.24, 60.79, 34.55, 33.44, 16.39, 16.35, 14.42.

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 500.0224; observed: 500.0227.



(E)-ethyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-4-methylphenyl)acrylates (2t):

Yield : 77% (63 mg)

Appearance: Liquid

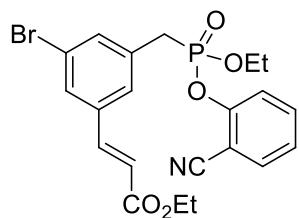
R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

^1H NMR (400 MHz, CDCl_3) δ 7.63 (d, $J = 5.4$ Hz, 1H), 7.60 (d, $J = 2.9$ Hz, 1H), 7.52 – 7.45 (m, 2H), 7.37 – 7.32 (m, 1H), 7.29 (d, $J = 8.6$ Hz, 1H), 7.21 (t, $J = 7.7$ Hz, 2H), 6.38 (d, $J = 16.0$ Hz, 1H), 4.28 – 4.21 (m, 2H), 4.19 – 4.10 (m, 2H), 3.47 (d, $J = 22.2$ Hz, 2H), 2.44 (s, 3H), 1.33 (t, $J = 7.1$ Hz, 3H), 1.23 (t, $J = 7.1$ Hz, 3H).

^{13}C NMR (101 MHz, CDCl_3) δ 167.24, 152.57, 152.48, 144.12, 140.14, 140.07, 134.53, 133.69, 132.82, 132.78, 131.49, 131.46, 130.78, 130.72, 129.52, 129.42, 127.21, 127.18, 125.16, 121.19, 118.04, 115.68, 105.96, 64.06, 63.98, 60.64, 32.25, 30.88, 20.23, 16.41, 16.35, 14.49.

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 436.1286; observed: 436.1289.



(E)-ethyl 3-(3-bromo-5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2u):

Yield : 82% (78 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

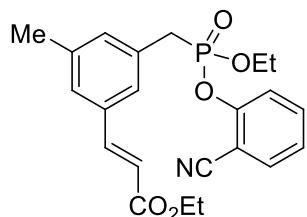
¹H NMR (500 MHz, Chloroform-*d*) δ: 7.63 (d, *J* = 7.8 Hz, 1H), 7.60 – 7.50 (m, 4H), 7.46 (s, 1H), 7.41 (d, *J* = 8.5 Hz, 1H), 7.26 (q, *J* = 8.0 Hz, 1H), 6.44 (d, *J* = 16.0 Hz, 1H), 4.24 (dt, *J* = 23.3, 7.6 Hz, 4H), 3.43 (d, *J* = 22.0 Hz, 2H), 1.34 (t, *J* = 7.2 Hz, 3H), 1.28 (t, *J* = 7.5 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 166.54, 152.30, 152.23, 142.42, 137.00, 136.97, 134.56, 134.37, 134.32, 133.70, 133.09, 133.01, 129.87, 129.84, 128.46, 128.41, 125.38, 123.32, 123.29, 121.24, 120.50, 115.50, 105.85, 64.26, 64.20, 60.87, 34.30, 33.19, 16.41, 16.36, 14.41.

³¹P NMR (202 MHz, CDCl₃) δ: 22.84

HRMS: [(M +Na)⁺] Calcd.: 500.0224; observed: 500.0220.

IR (thin film): 2986, 2230, 1712, 1640, 1264, 1032, 922, 766 cm⁻¹



(E)-ethyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-methylphenyl)acrylates (2v):

Yield : 80% (66 mg)

Appearance: Liquid

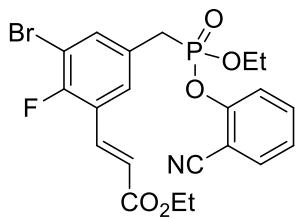
R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (400 MHz, CDCl₃) δ 7.60 (dd, *J* = 11.9, 4.1 Hz, 2H), 7.54 – 7.43 (m, 1H), 7.34 (d, *J* = 8.5 Hz, 1H), 7.30 (s, 1H), 7.25 – 7.18 (m, 3H), 6.40 (d, *J* = 16.0 Hz, 1H), 4.40 – 4.13 (m, 4H), 3.42 (d, *J* = 21.9 Hz, 2H), 2.33 (s, 3H), 1.33 (t, *J* = 7.1 Hz, 3H), 1.26 (t, *J* = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ 167.10, 152.40, 152.32, 144.26, 139.34, 135.04, 134.51, 134.27, 133.67, 133.16, 132.86, 132.75, 130.59, 130.50, 127.99, 126.88, 126.82, 125.15, 121.18, 121.13, 120.10, 118.78, 116.38, 115.58, 105.69, 64.18, 64.10, 60.67, 34.59, 33.22, 21.30, 16.37, 16.31, 14.42.

HRMS: [(M +Na)⁺] Calcd.: 436.1286; observed: 436.1287.



(E)-ethyl 3-(3-bromo-5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-fluorophenyl)27crylates (2w):

Yield : 75% (75 mg)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

¹H NMR (400 MHz, Chloroform-*d*) δ: 7.72 (d, *J* = 16.2 Hz, 1H), 7.61 (dt, *J* = 7.8, 1.2 Hz, 1H), 7.58 – 7.50 (m, 2H), 7.47 (dt, *J* = 5.5, 2.5 Hz, 1H), 7.41 (dt, *J* = 8.6, 1.2 Hz, 1H), 7.28 – 7.24 (m, 1H), 6.54 (d, *J* = 16.2 Hz, 1H), 4.28 – 4.18 (m, 4H), 3.41 (d, *J* = 21.7 Hz, 2H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.28 (t, *J* = 7.1 Hz, 3H).

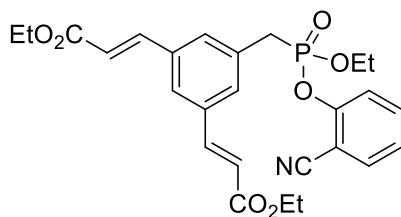
¹³C NMR (101 MHz, CDCl₃) δ: 166.44, 152.17, 136.07, 136.00, 135.90, 134.60, 133.71, 129.59, 129.56, 129.49, 127.84, 127.79, 125.45, 122.84, 122.78, 121.26, 121.23, 115.49, 110.38, 105.87, 64.30, 64.22, 60.98, 33.82, 32.42, 16.44, 16.38, 14.41.

³¹P NMR (202 MHz, CDCl₃) δ: 22.75

HRMS: [(M +Na)⁺] Calcd.: 518.0134; observed: 518.0136.

IR (thin film): 2986, 2233, 1714, 1488, 1273, 1184, 1037, 923, 765 cm⁻¹

Homo-diolefination and Hetero di-olefination:



(2E,2'E)-diethyl 3,3'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylene)diacrylate (3a):

Yield : 85% (85 mg)

Appearance: Liquid

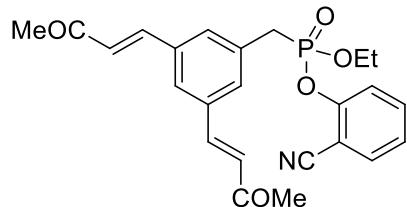
R_f: 0.3 (40% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (3:2)

¹H NMR (500 MHz, Chloroform-d) δ: 7.63 (d, J = 16.1 Hz, 2H), 7.60 (dt, J = 7.7, 1.2 Hz, 1H), 7.54 (d, J = 1.8 Hz, 1H), 7.53 (d, J = 2.4 Hz, 2H), 7.51 – 7.48 (m, 1H), 7.41 – 7.37 (m, 1H), 7.22 (t, J = 7.5 Hz, 1H), 6.46 (d, J = 16.0 Hz, 2H), 4.26 (q, J = 7.1 Hz, 4H), 4.22 – 4.11 (m, 2H), 3.46 (d, J = 22.0 Hz, 2H), 1.33 (t, J = 7.1 Hz, 6H), 1.26 (t, J = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 166.75, 152.31, 143.22, 135.89, 134.56, 133.70, 131.98, 131.91, 131.03, 130.97, 126.73, 126.70, 125.33, 121.29, 121.27, 120.09, 115.55, 105.90, 64.21, 64.15, 60.85, 34.62, 33.51, 16.46, 16.41, 14.46.

HRMS: [(M +Na)⁺] Calcd.: 520.1496; observed: 520.1492.



2-cyanophenyl ethyl 3,5-bis((E)-3-oxobut-1-en-1-yl)benzylphosphonate (3b):

Yield : 78% (67 mg)

Appearance: Liquid

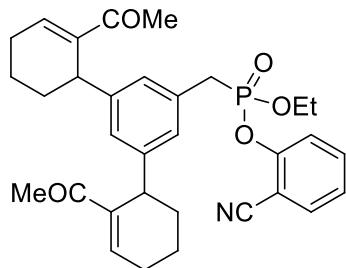
R_f: 0.2 (40% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-d) δ: 7.63 – 7.59 (m, 2H), 7.58 (dd, J = 2.8, 1.5 Hz, 2H), 7.54 – 7.51 (m, 1H), 7.49 (d, J = 16.5 Hz, 2H), 7.42 (dt, J = 8.5, 1.2 Hz, 1H), 7.23 (tt, J = 7.6, 0.8 Hz, 1H), 6.75 (d, J = 16.3 Hz, 2H), 4.25 – 4.15 (m, 2H), 3.48 (d, J = 22.0 Hz, 2H), 2.38 (s, 6H), 1.27 (t, J = 7.1 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 198.28, 152.42, 141.90, 136.02, 136.00, 134.63, 134.50, 133.77, 132.13, 132.05, 131.51, 131.45, 128.48, 127.04, 127.01, 125.38, 121.16, 121.14, 116.54, 115.64, 105.75, 64.32, 64.26, 34.62, 33.51, 28.01, 16.48, 16.43.

HRMS: [(M +Na)⁺] Calcd.: 460.1284; observed: 460.1288.



2-cyanophenyl ethyl ((6,6''-diacetyl-1,1'',2,2'',3,3'',4,4''-octahydro-[1,1':3',1''-terphenyl]-5'-yl)methyl)phosphonate (3c):

Yield : 69% (75 mg)

Appearance: Liquid

R_f: 0.3 (40% ethyl acetate/pet-ether mixture)

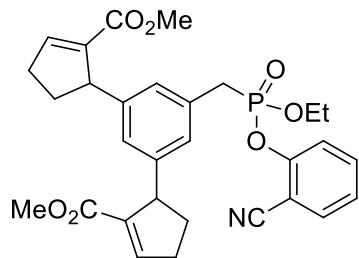
Isolation: Petroleum ether :ethyl acetate(v/v) (3:2)

¹H NMR (400 MHz, Chloroform-d) δ: 7.52 (dt, J = 8.1, 2.3 Hz, 1H), 7.42 (dtd, J = 8.9, 7.3, 1.8 Hz, 1H), 7.12 (dt, J = 11.3, 3.5 Hz, 3H), 6.94 – 6.66 (m, 3H), 6.56 (dd, J = 39.8, 8.5 Hz, 1H), 4.14 (dddd, J = 12.3, 10.1, 8.2, 6.0 Hz, 2H), 3.93 (q, J = 5.6, 4.9 Hz, 2H), 3.39 – 3.25 (m, 2H), 2.45 – 2.34 (m, 2H), 2.25 (ttt, J = 8.0, 5.7, 3.0 Hz, 1H), 2.20 – 2.09 (m, 5H), 1.77 (tdt, J = 15.4, 13.2, 6.3 Hz, 2H), 1.68 – 1.47 (m, 2H), 1.47 – 1.34 (m, 3H), 1.24 (q, J = 7.2 Hz, 4H).

¹³C NMR (126 MHz, CDCl₃) δ: 198.89, 198.65, 152.52, 145.96, 145.75, 142.19, 142.09, 141.01, 140.86, 134.82, 134.71, 133.23, 133.17, 129.25, 127.75, 127.56, 127.51, 127.19, 127.01, 124.75, 121.31, 121.29, 115.81, 105.26, 63.69, 63.63, 38.55, 38.37, 34.80, 33.73, 26.21, 26.19, 26.04, 25.93, 17.06, 16.83, 16.37, 16.31.

HRMS: [(M +Na)⁺] Calcd.: 568.2223; observed: 568.2220.

IR (thin film): 2831, 2233, 1667, 1239, 1029, 924, 768 cm⁻¹



dimethyl 5,5'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylenebis(cyclopent-1-enecarboxylate) (3d):

Yield : 72% (78 mg)

Appearance: Liquid

R_f: 0.3 (40% ethyl acetate/pet-ether mixture)

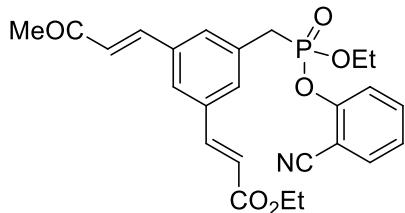
Isolation: Petroleum ether :ethyl acetate(v/v) (3:2)

¹H NMR (400 MHz, Chloroform-d) δ: 7.59 – 7.53 (m, 1H), 7.48 – 7.36 (m, 1H), 7.20 – 7.12 (m, 1H), 7.04 – 6.89 (m, 5H), 6.86 (q, J = 2.1 Hz, 1H), 4.21 – 4.10 (m, 2H), 4.10 – 4.02 (m, 2H), 3.55 (d, J = 5.6 Hz, 6H), 3.36 (dd, J = 21.8, 4.6 Hz, 2H), 2.61 (ddt, J = 17.3, 8.9, 2.8 Hz, 1H), 2.46 (ttd, J = 13.1, 6.5, 5.8, 3.7 Hz, 3H), 2.00 – 1.69 (m, 4H), 1.28 – 1.16 (m, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 165.27, 165.24, 152.71, 146.02, 145.99, 145.29, 145.24, 139.16, 139.13, 134.55, 134.48, 134.42, 133.45, 133.44, 129.97, 126.79, 126.62, 126.50, 125.28, 124.83, 121.36, 115.70, 105.72, 63.82, 63.76, 51.40, 51.37, 50.04, 50.01, 34.81, 34.20, 33.71, 32.34, 16.38, 16.34.

HRMS: $[(M + Na)^+]$ Calcd.: 572.1809; observed: 572.1804.

IR (thin film): 2951, 2233, 1718, 1449, 1280, 1236, 1032, 922, 767 cm^{-1}



(E)-ethyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-oxobut-1-en-1-yl)phenyl)30carylates (3e):

Yield : 81% (78 mg)

Appearance: Liquid

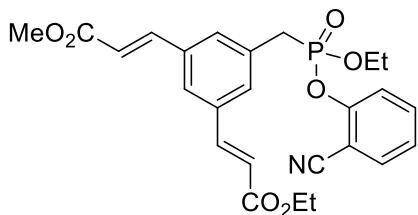
R_f: 0.3 (40% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (3:2)

¹H NMR (500 MHz, Chloroform-d) δ : 7.67 – 7.59 (m, 2H), 7.57 (d, $J = 2.2$ Hz, 2H), 7.55 – 7.44 (m, 3H), 7.40 (dd, $J = 8.7, 2.5$ Hz, 1H), 7.23 (td, $J = 7.7, 2.5$ Hz, 1H), 6.74 (dd, $J = 16.3, 2.5$ Hz, 1H), 6.47 (dd, $J = 16.0, 2.5$ Hz, 1H), 4.33 – 4.17 (m, 4H), 3.47 (dd, $J = 22.0, 2.5$ Hz, 2H), 2.38 (d, $J = 2.6$ Hz, 3H), 1.36 – 1.31 (m, 3H), 1.30 – 1.25 (m, 3H).

¹³C NMR (126 MHz, CDCl₃) δ : 198.25, 166.73, 152.40, 143.14, 141.97, 135.93, 135.91, 134.58, 133.72, 132.05, 131.97, 131.28, 131.23, 131.18, 128.41, 126.87, 126.85, 125.35, 121.21, 121.19, 120.16, 115.59, 105.76, 64.25, 64.19, 60.87, 34.60, 33.50, 27.98, 16.46, 16.41, 14.45.

HRMS: $[(M + Na)^+]$ Calcd.: 490.1390; observed: 490.1382.



(E)-ethyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-methoxy-3-oxoprop-1-en-1-yl)phenyl)30carylates (3f):

Yield : 82% (79 mg)

Appearance: Liquid

R_f: 0.3 (40% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (3:2)

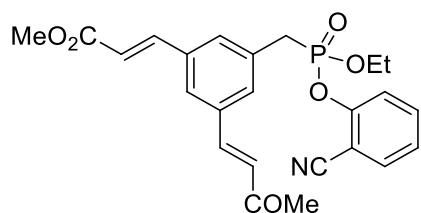
¹H NMR (500 MHz, Chloroform-d) δ : 7.66 (d, $J = 4.9$ Hz, 1H), 7.61 (dd, $J = 11.6, 6.4$ Hz, 2H), 7.56 – 7.49 (m, 4H), 7.39 (d, $J = 8.5$ Hz, 1H), 7.22 (t, $J = 7.6$ Hz, 1H), 6.46 (dd, $J = 16.1, 3.1$ Hz,

2H), 4.26 (q, $J = 7.1$ Hz, 2H), 4.23 – 4.15 (m, 2H), 3.81 (s, 3H), 3.47 (d, $J = 22.0$ Hz, 2H), 1.33 (t, $J = 7.1$ Hz, 3H), 1.27 (t, $J = 7.3$ Hz, 3H).

^{13}C NMR (126 MHz, CDCl_3) δ : 167.21, 166.75, 152.37, 143.54, 143.20, 135.93, 135.90, 135.82, 135.80, 134.56, 133.70, 132.00, 131.93, 131.09, 131.03, 131.01, 130.95, 126.81, 126.78, 125.33, 121.26, 121.24, 120.11, 119.58, 115.57, 105.82, 64.20, 64.14, 60.86, 52.02, 34.61, 33.51, 16.46, 16.41, 14.47.

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 506.1339; observed: 506.1338.

IR (thin film): 2925, 2233, 1713, 1640, 1447, 1173, 1036, 919, 785 cm^{-1}



(E)-methyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl-5-((E)-3-oxobut-1-en-1-yl)phenyl)31crylates (3g):

Yield : 84% (75 mg)

Appearance: Liquid

R_f: 0.3 (40% ethyl acetate/pet-ether mixture)

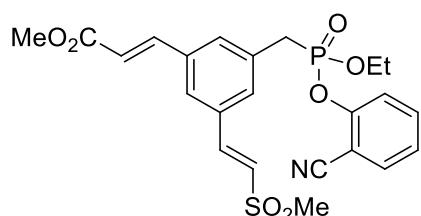
Isolation: Petroleum ether :ethyl acetate(v/v) (3:2)

^1H NMR (500 MHz, Chloroform-*d*) δ : 7.65 (d, $J = 16.1$ Hz, 1H), 7.62 – 7.57 (m, 3H), 7.54 – 7.51 (m, 2H), 7.47 – 7.38 (m, 2H), 7.22 (d, $J = 7.7$ Hz, 1H), 6.74 (d, $J = 16.3$ Hz, 1H), 6.47 (d, $J = 16.0$ Hz, 1H), 4.21 (dtd, $J = 8.3, 7.0, 1.5$ Hz, 2H), 3.81 (s, 3H), 3.48 (d, $J = 22.0$ Hz, 2H), 2.38 (s, 3H), 1.27 (t, $J = 7.2$ Hz, 3H).

^{13}C NMR (126 MHz, CDCl_3) δ : 198.33, 167.20, 152.29, 143.45, 141.97, 135.93, 135.91, 135.88, 135.85, 134.60, 133.74, 132.04, 131.96, 131.35, 131.29, 131.22, 131.17, 128.42, 126.96, 126.94, 125.37, 121.18, 121.16, 119.64, 115.60, 105.77, 64.28, 64.22, 52.05, 34.59, 33.48, 27.99, 16.46, 16.41.

^{31}P NMR (202 MHz, CDCl_3) δ : 23.23

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 476.1233; observed: 476.1231.



(E)-methyl 3-((3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-2-(methylsulfonyl)vinyl)phenyl)32crylates (3h):

Yield : 78% (75 mg)

Appearance: Liquid

R_f: 0.3 (40% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (3:2)

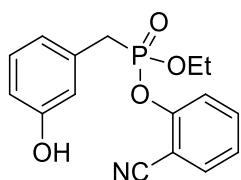
¹H NMR (500 MHz, Chloroform-d) δ: 7.60 (ddd, *J* = 15.2, 7.4, 3.6 Hz, 5H), 7.55 – 7.50 (m, 2H), 7.43 (d, *J* = 8.7 Hz, 1H), 7.23 (d, *J* = 7.7 Hz, 1H), 7.02 (d, *J* = 15.4 Hz, 1H), 6.48 (d, *J* = 16.1 Hz, 1H), 4.22 (dddd, *J* = 18.7, 12.0, 5.0, 3.2 Hz, 2H), 3.82 (s, 3H), 3.49 (d, *J* = 22.0 Hz, 2H), 3.04 (s, 3H), 1.29 (t, *J* = 7.3 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 167.08, 152.36, 143.04, 142.54, 139.47, 136.16, 136.13, 134.66, 133.79, 132.47, 132.39, 132.03, 131.97, 131.09, 131.03, 128.20, 127.64, 127.61, 125.42, 121.12, 121.10, 120.08, 115.64, 105.65, 64.34, 64.28, 52.12, 43.35, 34.66, 33.55, 16.50, 16.46.

³¹P NMR (202 MHz, CDCl₃) δ: 22.91

HRMS: [(M +Na)⁺] Calcd.: 512.0903; observed: 512.0908.

Meta-Hydroxylation:



2-cyanophenyl ethyl 3-hydroxybenzylphosphonate (4a):

Yield : 70% (44 mg)

Appearance: Liquid

R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

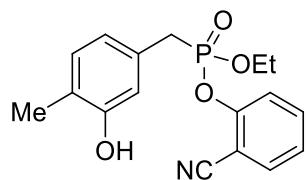
¹H NMR (500 MHz, Chloroform-d) δ: 7.59 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.48 (td, *J* = 8.1, 7.7, 1.8 Hz, 1H), 7.30 (d, *J* = 8.5 Hz, 1H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.13 (t, *J* = 7.8 Hz, 1H), 6.97 (q, *J* =

2.2 Hz, 1H), 6.84 – 6.77 (m, 1H), 6.74 (dt, J = 8.3, 2.5 Hz, 1H), 4.21 – 4.11 (m, 2H), 3.39 (d, J = 21.7 Hz, 2H), 1.24 (t, J = 7.0 Hz, 3H).

^{13}C NMR (126 MHz, CDCl_3) δ : 157.01, 152.44, 152.37, 134.66, 133.68, 130.82, 130.74, 130.10, 130.07, 125.22, 121.85, 121.79, 121.23, 121.20, 117.21, 117.16, 115.78, 115.13, 115.10, 105.59, 64.46, 64.40, 34.56, 33.46, 16.36, 16.31.

^{31}P NMR (202 MHz, CDCl_3) δ : 24.70

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 340.0708; observed: 340.0707.



2-cyanophenyl ethyl 3-hydroxy-4-methylbenzylphosphonate (4b):

Yield : 71% (47 mg)

Appearance: Liquid

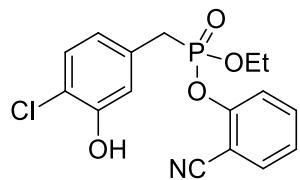
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

^1H NMR (500 MHz, Chloroform-d) δ : 7.58 (dd, J = 7.8, 1.6 Hz, 1H), 7.47 (ddd, J = 9.0, 7.6, 1.8 Hz, 1H), 7.33 (d, J = 8.5 Hz, 1H), 7.19 (t, J = 7.6 Hz, 1H), 7.00 (d, J = 7.6 Hz, 1H), 6.97 (t, J = 2.2 Hz, 1H), 6.71 (dt, J = 7.7, 2.1 Hz, 1H), 4.16 (dq, J = 8.5, 7.1 Hz, 2H), 3.36 (dd, J = 21.6, 1.9 Hz, 2H), 2.17 (d, J = 2.5 Hz, 3H), 1.24 (t, J = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, CDCl_3) δ : 155.12, 152.49, 152.42, 134.61, 133.62, 131.25, 131.22, 127.83, 127.75, 125.10, 124.10, 124.06, 121.61, 121.55, 121.24, 121.22, 116.59, 116.54, 115.86, 105.50, 64.42, 64.36, 34.21, 33.10, 16.36, 16.31, 15.82.

HRMS: $[(\text{M} + \text{Na})^+]$ Calcd.: 354.0866; observed: 354.0863.



2-cyanophenyl ethyl 4-chloro-3-hydroxybenzylphosphonate (4c):

Yield : 62% (43 mg)

Appearance: Liquid

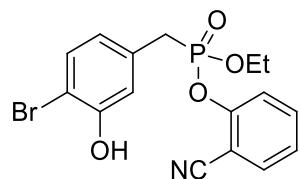
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-d) δ: 7.60 (dt, J = 7.7, 1.2 Hz, 1H), 7.52 (ddd, J = 9.0, 7.6, 1.7 Hz, 1H), 7.38 (dd, J = 8.4, 1.2 Hz, 1H), 7.25 – 7.20 (m, 2H), 7.07 (t, J = 2.5 Hz, 1H), 6.83 (dt, J = 8.1, 2.5 Hz, 1H), 4.18 (dqd, J = 11.1, 7.1, 2.8 Hz, 2H), 3.38 (d, J = 21.9 Hz, 2H), 1.26 (t, J = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 152.40, 152.12, 134.64, 133.73, 130.27, 130.19, 129.76, 129.73, 125.29, 122.86, 122.80, 121.28, 121.26, 119.71, 119.68, 118.13, 118.08, 115.69, 105.68, 64.39, 64.33, 34.29, 33.18, 16.40, 16.36.

HRMS: [(M +K)⁺] Calcd.: 390.0059; observed: 390.0058.



2-cyanophenyl ethyl 4-bromo-3-hydroxybenzylphosphonate (4d):

Yield : 67% (53 mg)

Appearance: Liquid

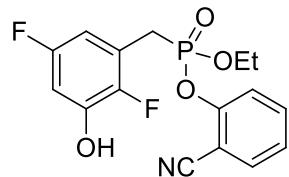
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (400 MHz, Chloroform-d) δ: 7.60 (dt, J = 7.8, 1.2 Hz, 1H), 7.52 (ddd, J = 9.1, 7.6, 1.7 Hz, 1H), 7.37 (ddd, J = 9.3, 7.9, 1.1 Hz, 2H), 7.23 (t, J = 7.6 Hz, 1H), 7.07 (t, J = 2.5 Hz, 1H), 6.76 (dt, J = 8.2, 2.4 Hz, 1H), 4.18 (dqd, J = 8.2, 7.1, 1.3 Hz, 2H), 3.37 (d, J = 22.1 Hz, 2H), 1.25 (t, J = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 153.22, 153.19, 152.27, 134.66, 133.72, 132.85, 132.82, 130.96, 130.86, 125.32, 123.26, 123.18, 121.27, 121.25, 117.96, 117.89, 115.70, 109.52, 109.47, 105.64, 64.45, 64.37, 34.42, 33.03, 16.41, 16.35.

HRMS: [(M +Na)⁺] Calcd.: 417.9814; observed: 417.9811.



2-cyanophenyl ethyl 2,5-difluoro-3-hydroxybenzylphosphonate (4e):

Yield : 62% (44 mg)

Appearance: Liquid

R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

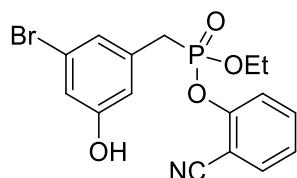
Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (400 MHz, Chloroform-d) δ: 7.63 (dq, J = 7.7, 1.6, 1.0 Hz, 1H), 7.55 (ddd, J = 9.0, 7.5, 1.7 Hz, 1H), 7.46 – 7.42 (m, 1H), 7.28 – 7.22 (m, 1H), 6.60 (td, J = 9.3, 4.8, 4.1, 2.9 Hz, 2H), 4.27 – 4.15 (m, 2H), 3.43 (dd, J = 22.0, 1.3 Hz, 2H), 1.29 (t, J = 7.1 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 152.16, 152.09, 145.48, 134.69, 133.85, 125.46, 121.18, 121.12, 121.10, 115.38, 108.47, 108.31, 108.28, 105.75, 104.90, 104.69, 64.63, 64.57, 27.75, 26.61, 16.38, 16.33.

HRMS: [(M +Na)⁺] Calcd.: 376.0521; observed: 376.0529.

IR (thin film): 2925, 2237, 1601, 1489, 1235, 1037, 926, 764 cm⁻¹



2-cyanophenyl ethyl 3-bromo-5-hydroxybenzylphosphonate (4f):

Yield : 61% (48 mg)

Appearance: Liquid

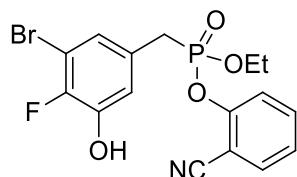
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-*d*) δ: 7.64 (d, J = 7.9 Hz, 1H), 7.55 (q, J = 8.8, 8.3 Hz, 1H), 7.51 – 7.36 (m, 2H), 7.31 – 7.17 (m, 2H), 6.92 (d, J = 8.3 Hz, 1H), 4.23 (dh, J = 16.2, 8.8, 8.0 Hz, 2H), 3.37 (d, J = 21.3 Hz, 2H), 1.30 (t, J = 7.3 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 152.41, 152.34, 152.21, 134.75, 134.59, 133.80, 133.73, 133.55, 133.49, 130.89, 130.84, 125.41, 125.31, 121.31, 121.29, 116.57, 115.58, 110.46, 105.85, 64.30, 64.24, 33.44, 32.33, 16.43, 16.38.

HRMS: [(M +Na)⁺] Calcd.: 417.9814; observed: 417.9819.



2-cyanophenyl ethyl 3-bromo-4-fluoro-5-hydroxybenzylphosphonate (4g):

Yield : 65% (53 mg)

Appearance: Liquid

R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

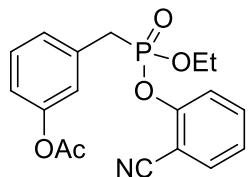
Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-*d*) δ: 7.65 (d, *J* = 7.7 Hz, 1H), 7.57 (t, *J* = 8.0 Hz, 1H), 7.41 (d, *J* = 8.4 Hz, 1H), 7.32 – 7.23 (m, 1H), 7.06 (d, *J* = 7.1 Hz, 1H), 7.00 (dd, *J* = 5.6, 2.7 Hz, 1H), 4.28 – 4.17 (m, 2H), 3.37 (d, *J* = 21.6 Hz, 2H), 1.30 (t, *J* = 7.7 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 152.17, 152.10, 134.74, 133.78, 126.83, 126.75, 125.56, 125.22, 125.16, 121.26, 121.24, 118.57, 118.53, 115.61, 114.23, 109.64, 109.47, 105.75, 64.75, 64.69, 33.74, 32.62, 16.38, 16.33.

HRMS: [(M +Na)⁺] Calcd.: 435.9720; observed: 435.9722.

Meta-Acetoxylation:



3-((2-cyanophenoxy)(ethoxy)phosphorylmethyl)phenyl acetate (5a):

Yield : 76% (55 mg)

Appearance: Liquid

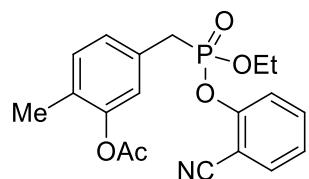
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-d) δ: 7.58 (dd, J = 7.8, 1.7 Hz, 1H), 7.51 – 7.45 (m, 1H), 7.31 (q, J = 8.0 Hz, 2H), 7.25 – 7.16 (m, 2H), 7.13 (q, J = 2.3 Hz, 1H), 7.00 (dt, J = 8.2, 2.5 Hz, 1H), 4.24 – 4.11 (m, 2H), 3.43 (d, J = 22.0 Hz, 2H), 2.27 (s, 3H), 1.25 (t, J = 7.1 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 169.48, 152.34, 151.00, 150.97, 134.53, 133.62, 131.72, 131.64, 129.87, 129.84, 127.71, 127.65, 125.12, 123.46, 123.40, 121.30, 121.28, 120.91, 120.88, 115.63, 105.73, 64.14, 64.08, 34.55, 33.45, 21.24, 16.37, 16.32.

HRMS: [(M +Na)⁺] Calcd.: 382.0817; observed: 382.0822.



5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl-2-methylphenyl acetate (5b):

Yield : 73% (54 mg)

Appearance: Liquid

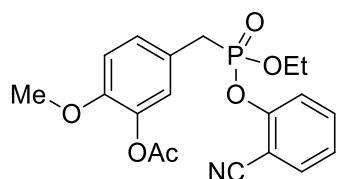
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (400 MHz, Chloroform-d) δ: 7.58 (dt, J = 7.7, 1.2 Hz, 1H), 7.49 (ddd, J = 8.5, 7.5, 1.8 Hz, 1H), 7.30 (dt, J = 8.5, 1.2 Hz, 1H), 7.20 (dt, J = 7.6, 0.9 Hz, 1H), 7.18 – 7.15 (m, 1H), 7.13 (dt, J = 7.8, 2.1 Hz, 1H), 7.05 (t, J = 2.2 Hz, 1H), 4.17 (dq, J = 8.3, 7.1, 1.4 Hz, 2H), 3.39 (d, J = 21.7 Hz, 2H), 2.29 (s, 3H), 2.14 (d, J = 2.5 Hz, 3H), 1.24 (t, J = 7.1 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 169.23, 152.47, 152.39, 149.53, 134.53, 133.59, 131.55, 131.52, 129.56, 129.52, 128.91, 128.81, 127.86, 127.79, 125.03, 123.68, 123.61, 121.34, 121.31, 115.67, 105.65, 64.09, 64.02, 34.28, 32.89, 20.91, 16.38, 16.32, 15.99.

HRMS: [(M +Na)⁺] Calcd.: 396.0971; observed: 396.0977.



5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl-2-methoxyphenyl acetate (5c):

Yield : 74% (58 mg)

Appearance: Liquid

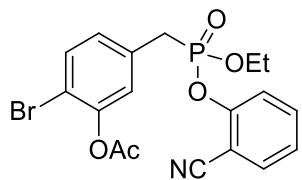
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-d) δ: 7.62 – 7.57 (m, 1H), 7.50 (ddd, J = 9.0, 7.7, 1.8 Hz, 1H), 7.29 (d, J = 8.5 Hz, 1H), 7.23 – 7.18 (m, 2H), 7.08 (t, J = 2.4 Hz, 1H), 6.91 (d, J = 8.4 Hz, 1H), 4.18 (qdt, J = 7.2, 4.7, 2.6 Hz, 2H), 3.81 (s, 3H), 3.37 (d, J = 21.4 Hz, 2H), 2.29 (s, 3H), 1.26 (t, J = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 169.10, 152.54, 152.47, 150.73, 139.94, 139.91, 134.61, 133.64, 128.67, 128.61, 125.10, 124.69, 124.64, 122.33, 122.25, 121.38, 121.36, 115.72, 112.83, 112.80, 105.75, 64.14, 64.08, 56.12, 33.76, 32.64, 20.82, 16.44, 16.39.

HRMS: [(M + Na)⁺] Calcd.: 412.0919; observed: 412.0922.



2-bromo-5-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenyl acetate (5d):

Yield : 64% (55 mg)

Appearance: Liquid

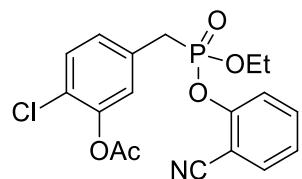
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-d) δ: 7.64 (dt, J = 7.7, 1.2 Hz, 1H), 7.53 (ddd, J = 16.7, 8.0, 1.4 Hz, 2H), 7.34 (dd, J = 8.7, 1.3 Hz, 1H), 7.22 (t, J = 7.7 Hz, 1H), 7.19 (t, J = 2.5 Hz, 1H), 7.14 (dt, J = 8.3, 2.5 Hz, 1H), 4.25 – 4.18 (m, 2H), 3.40 (d, J = 22.0 Hz, 2H), 2.36 (s, 3H), 1.27 (t, J = 7.1 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 168.56, 152.35, 152.28, 148.59, 134.65, 133.71, 133.67, 131.20, 131.13, 129.19, 129.14, 125.58, 125.53, 125.29, 121.36, 121.34, 115.66, 105.79, 64.34, 64.28, 34.24, 33.12, 20.94, 16.42, 16.38.

HRMS: [(M + Na)⁺] Calcd.: 459.9921; observed: 459.9917.



2-chloro-5-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenyl acetate (5e):

Yield : 67% (53 mg)

Appearance: Liquid

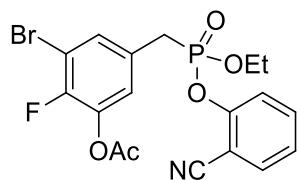
R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-d) δ: 7.61 (dt, *J* = 7.7, 1.2 Hz, 1H), 7.52 (ddd, *J* = 8.5, 7.5, 1.7 Hz, 1H), 7.40 – 7.37 (m, 1H), 7.33 (dt, *J* = 8.4, 1.2 Hz, 1H), 7.23 (dt, *J* = 7.7, 0.9 Hz, 1H), 7.20 (dt, *J* = 4.7, 2.2 Hz, 2H), 4.19 (dq, *J* = 8.3, 7.1, 4.3 Hz, 2H), 3.41 (dd, *J* = 22.1, 1.0 Hz, 2H), 2.34 (s, 3H), 1.26 (t, *J* = 7.0 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 168.52, 152.28, 147.27, 134.66, 134.52, 133.72, 130.67, 130.64, 130.40, 130.32, 128.86, 128.81, 125.54, 125.49, 125.31, 121.37, 121.34, 120.64, 116.57, 105.81, 64.35, 64.29, 34.20, 33.09, 20.77, 16.43, 16.38.

HRMS: [(M + Na)⁺] Calcd.: 416.0425; observed: 416.0429.



3-bromo-5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl-2-fluorophenyl acetate (5f):

Yield : 59% (53 mg)

Appearance: Liquid

R_f: 0.3 (50% ethyl acetate/pet-ether mixture)

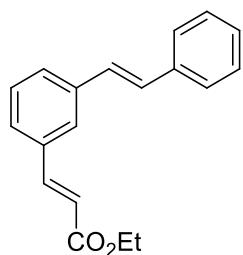
Isolation: Petroleum ether :ethyl acetate(v/v) (1:1)

¹H NMR (500 MHz, Chloroform-*d*) δ: 7.61 (dt, *J* = 7.7, 1.3 Hz, 1H), 7.53 (dddd, *J* = 9.4, 5.2, 3.5, 1.7 Hz, 1H), 7.41 (qd, *J* = 4.8, 4.3, 2.0 Hz, 1H), 7.37 (dt, *J* = 8.5, 1.2 Hz, 1H), 7.23 (tt, *J* = 7.6, 0.9 Hz, 1H), 7.16 (dt, *J* = 6.4, 2.5 Hz, 1H), 4.24 – 4.16 (m, 2H), 3.36 (d, *J* = 21.9 Hz, 2H), 2.32 (s, 3H), 1.27 (t, *J* = 7.3 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 168.00, 152.27, 152.21, 150.02, 149.98, 138.97, 138.83, 134.64, 133.72, 132.04, 131.99, 127.66, 127.62, 127.58, 127.54, 125.38, 124.85, 124.80, 121.25, 115.58, 110.35, 110.16, 105.73, 64.35, 64.29, 33.74, 32.62, 20.59, 16.42, 16.37.

³¹P NMR (202 MHz, CDCl₃) δ: 22.52

HRMS: [(M + Na)⁺] Calcd.: 477.9829; observed: 477.9834.



(E)-ethyl 3-(3-styrylphenyl)39cylates (6a):

Yield: 75% (41 mg, 0.2 mmol scale).

Appearance: Solid

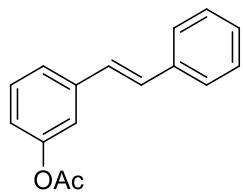
R_f: 0.5 (5% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether: ethyl acetate (v/v) (99:1)

¹H NMR (500 MHz, Chloroform-*d*) δ: 7.74 (dd, *J* = 16.0, 1.8 Hz, 1H), 7.68 (t, *J* = 1.8 Hz, 1H), 7.58 – 7.53 (m, 3H), 7.45 (dt, *J* = 7.7, 1.6 Hz, 1H), 7.40 (dd, *J* = 8.6, 6.8 Hz, 3H), 7.34 – 7.27 (m, 1H), 7.15 (dd, *J* = 8.9, 1.8 Hz, 2H), 6.52 (dd, *J* = 16.0, 1.7 Hz, 1H), 4.31 (qd, *J* = 7.1, 1.8 Hz, 2H), 1.38 (td, *J* = 7.1, 1.8 Hz, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 14.4, 60.6, 118.6, 126.1, 126.6, 127.1, 127.8, 127.9, 128.2, 128.8, 129.2, 129.7, 134.9, 137.0, 138.0, 144.5, 167.0.

HRMS: [(M+Na)⁺] calcd: 301.1199; observed: 301.1199.



(E)-3-styrylphenyl acetate (6b):

Yield: 69% (32 mg, 0.2 mmol scale).

Appearance: Solid

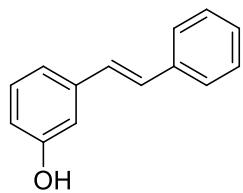
R_f: 0.5 (10% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether: ethyl acetate (v/v) (95:5)

¹H NMR (400 MHz, Chloroform-d) δ: 7.56 – 7.51 (m, 2H), 7.42 – 7.37 (m, 4H), 7.33 – 7.27 (m, 2H), 7.12 (d, *J* = 3.0 Hz, 2H), 7.05 – 7.00 (m, 1H), 2.34 (s, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 169.58, 151.17, 139.15, 137.06, 129.86, 129.70, 128.82, 127.99, 127.77, 126.72, 124.30, 120.75, 119.35, 21.27.

HRMS: [(M + Na)⁺] Calcd.: 261.0888; observed: 261.0893.



(E)-3-styrylphenol (6c):

Yield: 64% (26 mg, 0.2 mmol scale).

Appearance: Solid

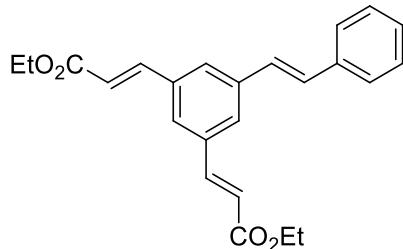
R_f: 0.5 (10% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether: ethyl acetate (v/v) (95:5)

¹H NMR (400 MHz, Chloroform-d) δ: 7.54 – 7.48 (m, 2H), 7.41 – 7.33 (m, 2H), 7.31 – 7.21 (m, 2H), 7.13 – 7.05 (m, 3H), 7.00 (t, *J* = 1.9 Hz, 1H), 6.75 (ddd, *J* = 8.0, 2.5, 1.0 Hz, 1H).

¹³C NMR (101 MHz, CDCl₃) δ: 155.94, 139.29, 137.32, 130.06, 129.39, 128.87, 128.40, 127.93, 126.74, 119.67, 114.85, 113.13.

HRMS: Calcd.: 219.0783; observed: 219.0783.



(2E,2'E)-diethyl 3,3'-(5-styryl-1,3-phenylene)diacrylate (6d):

Yield: 68% (50 mg, 0.2 mmol scale).

Appearance: Solid

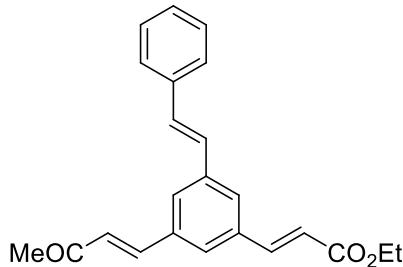
R_f: 0.5 (10% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether: ethyl acetate (v/v) (96:4)

¹H NMR (400 MHz, Chloroform-*d*) δ: 7.70 (d, *J* = 16.0 Hz, 2H), 7.64 (d, *J* = 1.5 Hz, 2H), 7.56 – 7.50 (m, 3H), 7.39 (dd, *J* = 8.4, 6.8 Hz, 2H), 7.33 – 7.27 (m, 1H), 7.17 (d, *J* = 16.4 Hz, 1H), 7.08 (d, *J* = 16.3 Hz, 1H), 6.51 (d, *J* = 16.0 Hz, 2H), 4.29 (q, *J* = 7.1 Hz, 4H), 1.36 (t, *J* = 7.1 Hz, 6H).

¹³C NMR (101 MHz, CDCl₃) δ: 14.4, 60.8, 119.6, 126.5, 126.8, 127.1, 127.5, 128.3, 129.0, 130.6, 135.6, 136.7, 138.8, 143.7, 166.8.

HRMS: [(M+Na)⁺] calcd: 399.1570; observed: 399.1568.



(E)-ethyl 3-(3-((E)-3-oxobut-1-enyl)-5-styrylphenyl)41crylates (6e):

Yield: 71% (49 mg, 0.2 mmol scale).

Appearance: Solid

R_f: 0.5 (5% ethyl acetate/pet-ether mixture)

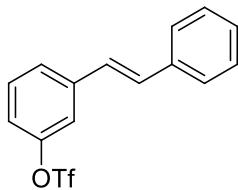
Isolation: Petroleum ether: ethyl acetate (v/v) (9:1)

¹H NMR (500 MHz, Chloroform-*d*) δ: 7.70 (d, *J* = 16.1 Hz, 1H), 7.67 (d, *J* = 1.7 Hz, 2H), 7.57 – 7.50 (m, 4H), 7.39 (t, *J* = 7.5 Hz, 2H), 7.34 – 7.28 (m, 1H), 7.18 (d, *J* = 16.3 Hz, 1H), 7.09 (d,

$J = 16.3$ Hz, 1H), 6.79 (d, $J = 16.2$ Hz, 1H), 6.52 (d, $J = 16.0$ Hz, 1H), 4.29 (q, $J = 7.1$ Hz, 2H), 2.41 (s, 3H), 1.36 (t, $J = 7.1$ Hz, 3H).

^{13}C NMR (126 MHz, CDCl_3) δ : 14.3, 27.8, 60.7, 119.6, 126.6, 126.7, 126.9, 127.5, 127.6, 128.0, 128.3, 128.8, 130.7, 135.5, 135.6, 136.6, 138.8, 142.3, 143.5, 166.7, 198.1.

HRMS: $[(\text{M}+\text{Na})^+]$ calcd: 369.1466; observed: 369.1468



(E)-3-styrylphenyl trifluoromethanesulfonate (7):

Yield: 85% (279 mg, 1 mmol scale).

Appearance: liquid

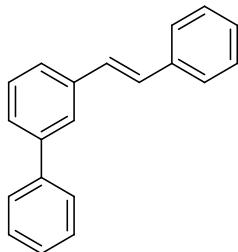
R_f: 0.5 (5% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether: ethyl acetate (v/v) (97:3)

^1H NMR (400 MHz, Chloroform-d) δ : 7.52 (ddt, $J = 7.1, 6.0, 1.4$ Hz, 3H), 7.46 – 7.35 (m, 4H), 7.35 – 7.28 (m, 1H), 7.18 – 7.10 (m, 2H), 7.07 (d, $J = 16.4$ Hz, 1H).

^{13}C NMR (101 MHz, CDCl_3) δ : 151.09, 140.38, 136.57, 131.44, 130.55, 128.99, 128.56, 126.96, 126.64, 126.51, 120.05, 119.07.

HRMS: Calcd.: 351.0277; observed: 351.0275.



(E)-3-styryl-1,1'-biphenyl (7a):

Yield: 75% (38 mg, 0.2 mmol scale).

Appearance: Solid

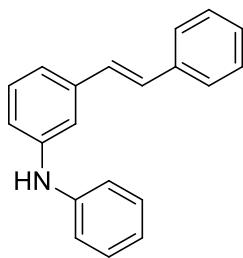
R_f: 0.5 (pet-ether)

Isolation: Petroleum ether

^1H NMR (500 MHz, Chloroform-d) δ 7.74 (t, $J = 1.8$ Hz, 1H), 7.68 – 7.62 (m, 2H), 7.59 – 7.54 (m, 2H), 7.54 – 7.43 (m, 5H), 7.39 (t, $J = 7.6$ Hz, 3H), 7.32 – 7.26 (m, 1H), 7.20 (s, 2H).

^{13}C NMR (126 MHz, CDCl_3) δ : 141.89, 141.28, 137.96, 137.43, 129.27, 129.22, 128.96, 128.89, 128.76, 127.88, 127.58, 127.39, 126.73, 126.70, 125.60, 125.55.

HRMS: Calcd.: 279.1148; observed: 279.1151.



(E)-N-phenyl-3-styrylaniline (7b):

Yield: 83% (45mg, 0.2 mmol scale).

Appearance: Solid

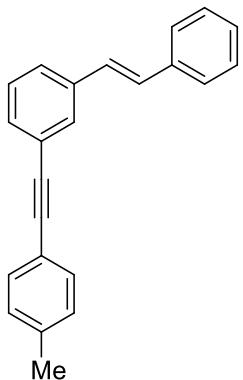
R_f: 0.5 (10% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether: ethyl acetate (v/v) (95:5)

¹H NMR (400 MHz, Chloroform-d) δ 7.55 – 7.47 (m, 3H), 7.37 (t, J = 7.6 Hz, 3H), 7.31 – 7.26 (m, 1H), 7.26 – 7.20 (m, 2H), 7.18 (d, J = 7.9 Hz, 1H), 7.13 – 7.03 (m, 4H), 6.99 (t, J = 2.0 Hz, 1H), 6.74 (dt, J = 8.1, 2.6 Hz, 3H).

¹³C NMR (101 MHz, CDCl₃) δ: 156.02, 139.23, 137.32, 130.03, 129.51, 129.32, 128.86, 128.43, 127.90, 126.73, 119.57, 119.24, 115.67, 114.88, 113.14.

HRMS: Calcd.: 294.1256; observed: 294.1258.



(E)-1-styryl-3-(p-tolylethynyl)benzene (7c):

Yield: 94% (55mg, 0.2 mmol scale).

Appearance: Solid

R_f: 0.5 (pet-ether)

Isolation: Petroleum ether

¹H NMR (500 MHz, Chloroform-d) δ 7.71 (d, J = 1.8 Hz, 1H), 7.57 – 7.51 (m, 2H), 7.47 (dd, J = 8.3, 2.0 Hz, 3H), 7.43 (dt, J = 7.7, 1.4 Hz, 1H), 7.37 (dt, J = 19.5, 7.6 Hz, 3H), 7.32 – 7.25 (m, 1H), 7.22 – 7.06 (m, 4H), 2.39 (s, 3H).

¹³C NMR (126 MHz, CDCl₃) δ: 138.65, 137.66, 137.25, 131.70, 130.75, 129.63, 129.62, 129.32, 128.89, 128.85, 126.76, 126.50, 124.02, 89.85, 88.79, 21.71.

HRMS: Calcd.: 317.1304; observed: 317.1308.

¹H NMR Study:

Pd(Oac)₂ (0.05 mmol, 11 mg), Ac-Phe-OH (0.1 mmol, 21 mg), substrate **1a** (0.5 mmol, 15 mg), HFIP (25 μl) were taken in a NMR tube and then recorded the ¹H NMR spectrum.

Out of two different modes (linear and side-on) of nitrile bindings, linear coordination was confirmed from downfield shift of *ortho* and *para* proton of 2-cyano phenol core in ¹H spectra of substrate **1a**.

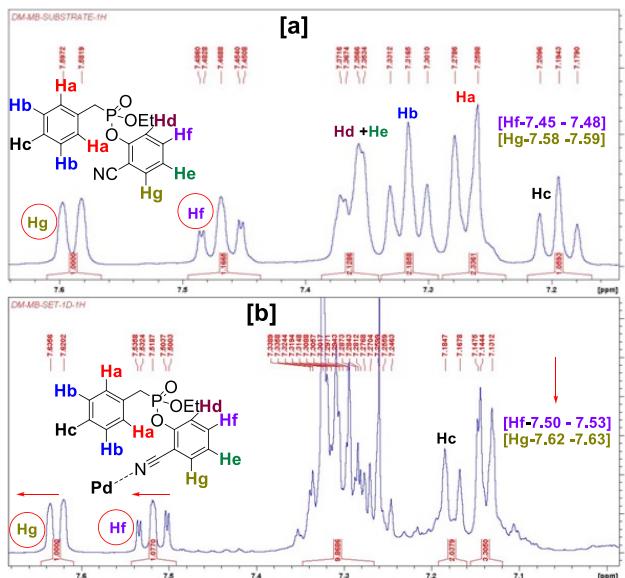


Figure S2: ¹H NMR Study

ESI-MS study:

Pd(Oac)₂ (0.05 mmol, 11 mg), Ac-Phe-OH (0.1 mmol, 21 mg), substrate **1a** (0.5 mmol, 15 mg), HFIP (25 μl) were mixed within a sample vial then stirred for 1 h. After that ESI-MS spectrum was recorded.

In mass spectrum, a metal-ligand-substrate adduct such as [(Ac-Phe-OH)Pd^{II}(**1a**-H⁺)] was appeared as a possible intermediate species with desired isotopic pattern.

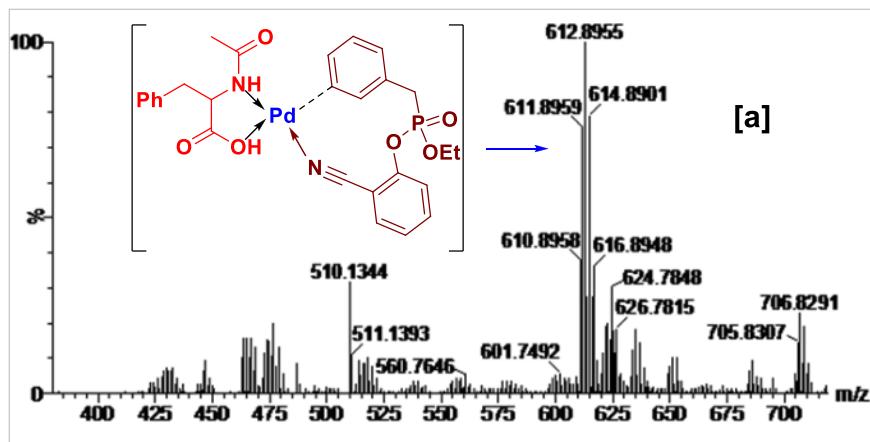


Figure S3: ESI-MS study

In order to further confirm the formation of macrocyclic intermediate, **1a** was replaced with 4-methyl substituted phosphonic ester (**1b**), that also exhibits ligand free intermediate formation such as $[\text{Pd}^{\text{II}}(\mathbf{1b}-\text{H}^+)]$.

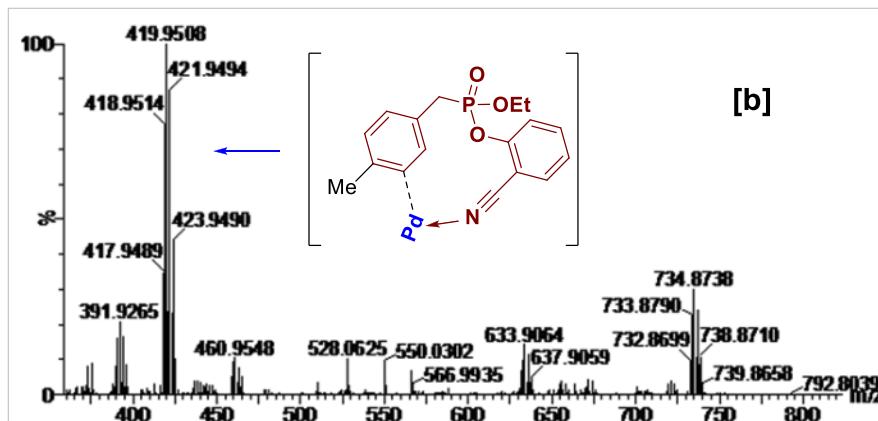
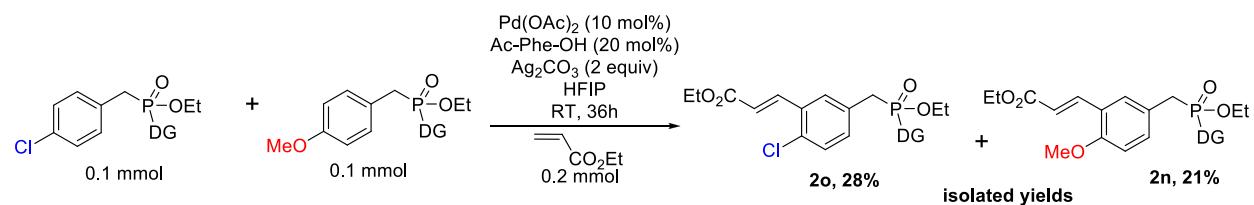


Figure S4: ESI-MS study

Intermolecular competition experiment:

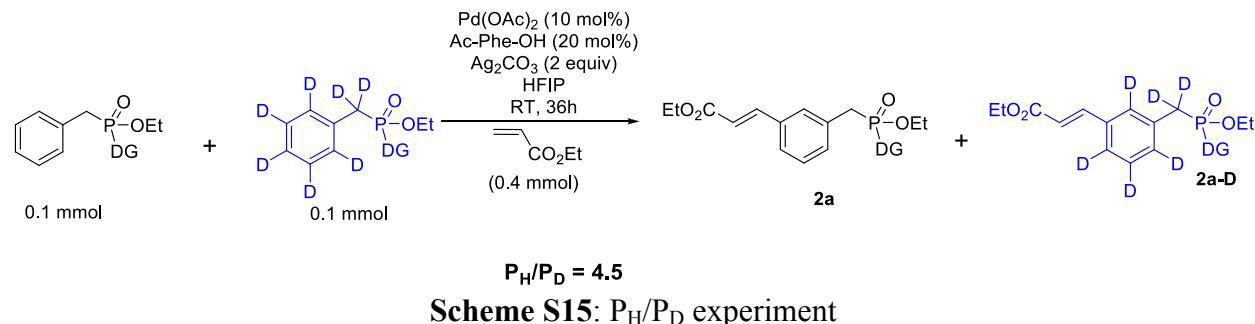


Scheme S14: Intermolecular competition experiment

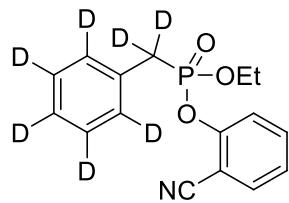
An oven-dried screw cap reaction tube was charged with a magnetic stir-bar, $\text{Pd}(\text{OAc})_2$ (10 mol%, 5 mg), Ac-Phe-OH (20 mol%, 8 mg), Ag_2CO_3 (2 equiv.; 110 mg), 4-chloro benzylphosphonate ester (0.1 mmol, 34 mg) and 4-methoxy benzylphosphonate (0.1 mmol, 33

mg) and ethyl acrylate (0.2 mmol). Solid reagents were weighed first followed by liquid reagents. 1.5 mL of 1,1,1,3,3-Hexafluoro-2-propanol (HFIP) were added. The reaction mixture was stirred vigorously at room temperature for 36 h. The reaction was taken out after 36 h and the reaction mixture was diluted with EtOAc and filtered through a celite pad. After filtration and evaporation of the solvent, the crude mixture was purified by column chromatography using silica gel (100-200 mesh size) and petroleum ether/ ethyl acetate as the eluent (13:7). Compound 2o was isolated in 12 mg, and compound 2n was isolated in 9 mg.

Intermolecular KIE experiment:



An oven-dried screw cap reaction tube was charged with a magnetic stir-bar, $Pd(OAc)_2$ (10 mol%, 5 mg), Ac-Phe-OH (20 mol%, 8 mg), Ag_2CO_3 (2 equiv.; 110 mg), benzylphosphonate ester 1a (0.1 mmol, 30 mg) and [D_7] benzylphosphonate (0.1 mmol, 31 mg) and ethyl acrylate (0.4 mmol). Solid reagents were weighed first followed by liquid reagents. 1.5 mL of 1,1,1,3,3-Hexafluoro-2-propanol (HFIP) were added. The reaction mixture was stirred vigorously at room temperature for 36 h. The reaction was taken out after 36 h and the reaction mixture was diluted with EtOAc and filtered through a celite pad. After filtration and evaporation of the solvent, the crude mixture was purified by column chromatography using silica gel (100-200 mesh size) and petroleum ether/ ethyl acetate as the eluent (13:7). After isolation, P_H/P_D was calculated from 1H NMR spectrum of the isolated product. From NMR spectrum product distribution P_H/P_D was found 4.5.

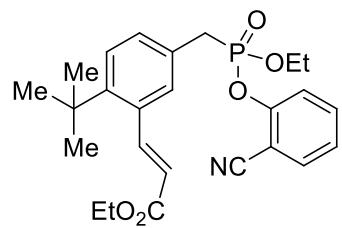


[D₇] Benzylphosphonate ester (1a-D):

¹H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, $J = 7.8$ Hz, 1H), 7.50 – 7.43 (m, 1H), 7.24 (d, $J = 7.8$ Hz, 1H), 7.19 (t, $J = 7.6$ Hz, 1H), 4.21 – 4.11 (m, 2H), 1.24 (t, $J = 7.1$ Hz, 3H).

¹³C NMR (126 MHz, $CDCl_3$) δ 152.27, 134.56, 134.40, 133.65, 133.55, 129.68 (m), 128.33 (m), 126.97 (t), 125.31, 125.01, 121.18, 121.16, 120.73, 120.71, 115.27, 105.67, 65.63, 65.58, 34.00 (m), 32.95 (m), 16.13, 16.08.

HRMS: [M+ Na⁺] Calcd.: 331.1199; observed: 331.1193.



Isolated yield: 15% (10 mg, 0.15 mmol scale)

Appearance: Liquid

R_f: 0.3 (30% ethyl acetate/pet-ether mixture)

Isolation: Petroleum ether :ethyl acetate(v/v) (13:7)

(E)-ethyl 3-(2-tert-butyl-5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylates (2o):

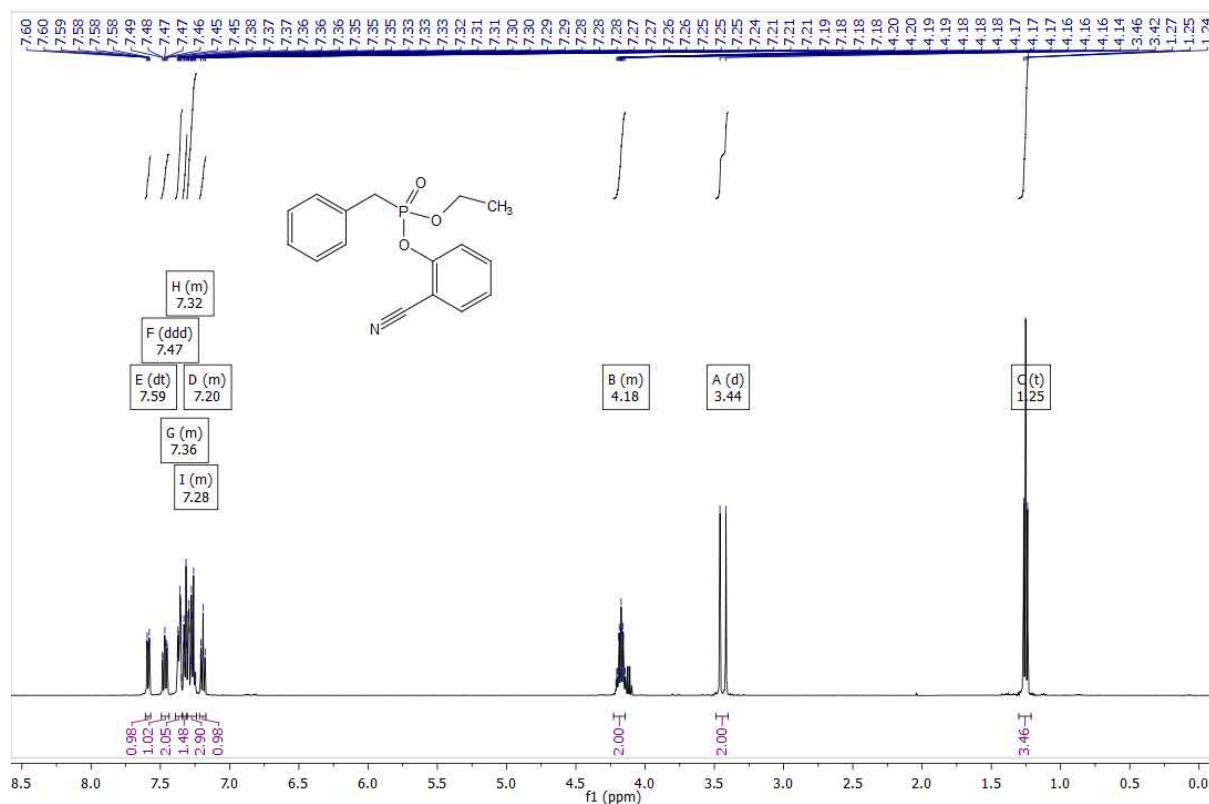
¹H NMR (400 MHz, CDCl₃) δ 8.04 (d, *J* = 15.7 Hz, 1H), 7.61 – 7.55 (m, 3H), 7.45 (ddd, *J* = 8.5, 7.6, 1.7 Hz, 1H), 7.37 (dd, *J* = 4.1, 2.1 Hz, 2H), 7.19 (dd, *J* = 11.1, 4.1 Hz, 1H), 6.34 (d, *J* = 15.7 Hz, 1H), 4.35 – 4.16 (m, 4H), 3.56 (d, *J* = 22.1 Hz, 2H), 1.39 (td, *J* = 7.1, 1.1 Hz, 3H), 1.34 (t, *J* = 7.1 Hz, 3H), 1.31 (s, 9H).

¹³C NMR (101 MHz, CDCl₃) δ 166.86, 152.59, 152.47, 142.34, 142.31, 134.63, 134.41, 133.99, 133.92, 133.74, 133.67, 131.84, 131.78, 129.32, 127.84, 127.80, 126.75, 126.65, 125.34, 124.99, 124.14, 124.10, 120.99, 120.96, 120.65, 115.57, 105.75, 64.04, 63.96, 60.78, 31.75, 31.35, 30.37, 16.37, 16.30, 14.51.

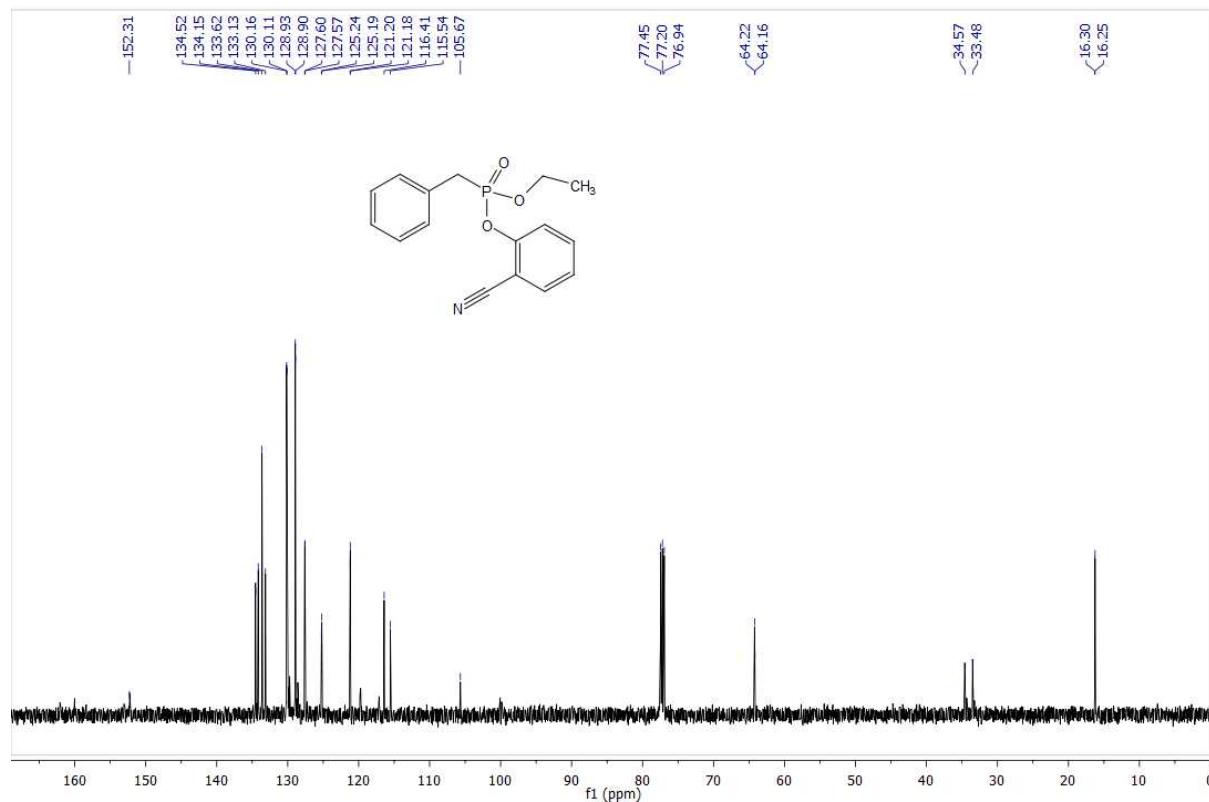
Substrate NMR:

2-cyanophenyl ethyl benzylphosphonate (1a):

2-cyanophenyl ethyl benzylphosphonate



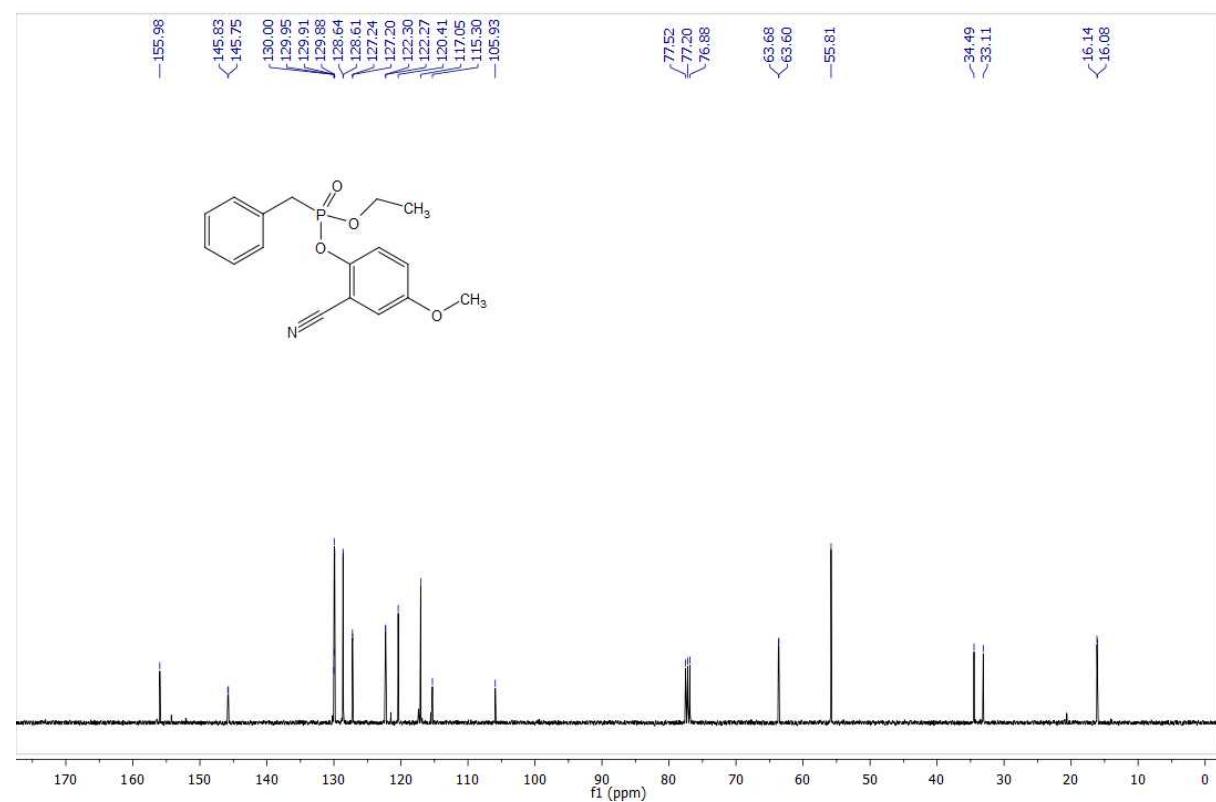
2-cyanophenyl ethyl benzylphosphonate



2-cyano-4-methoxyphenyl ethyl benzylphosphonate (1a'):

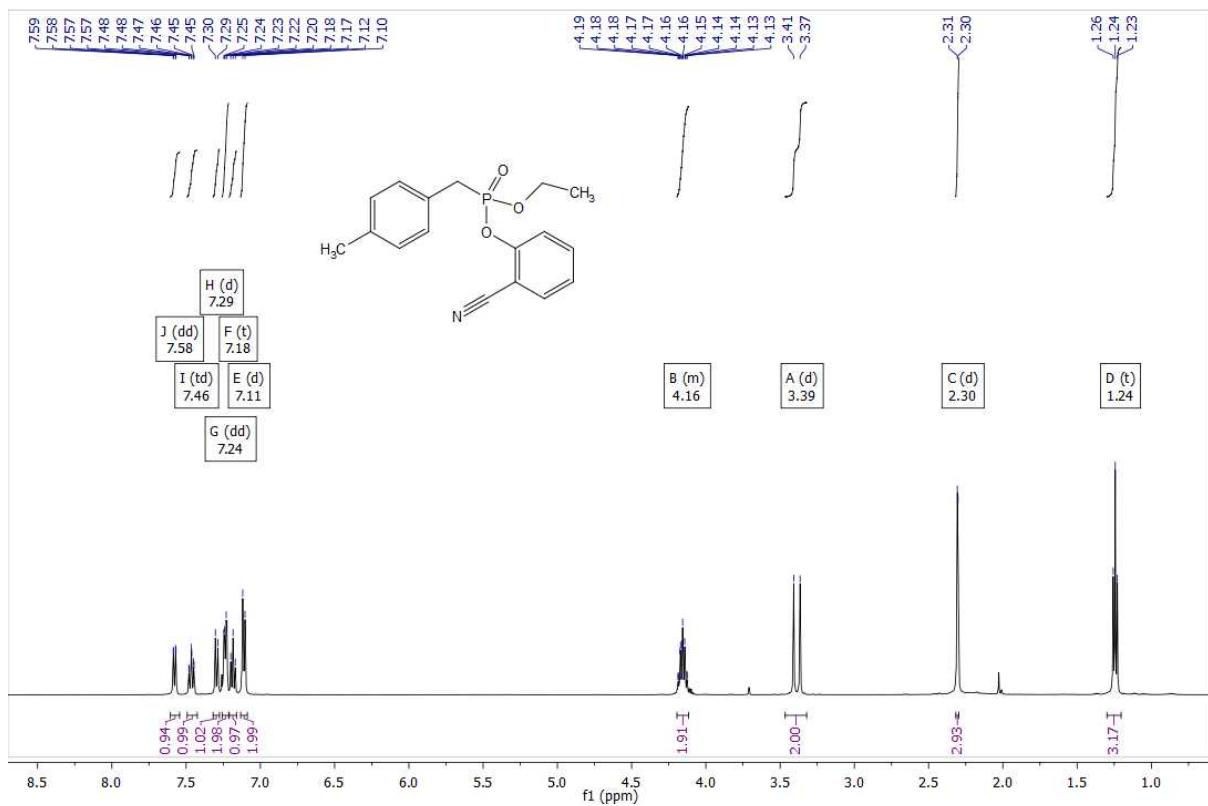


2-cyano-4-methoxyphenyl ethyl benzylphosphonate

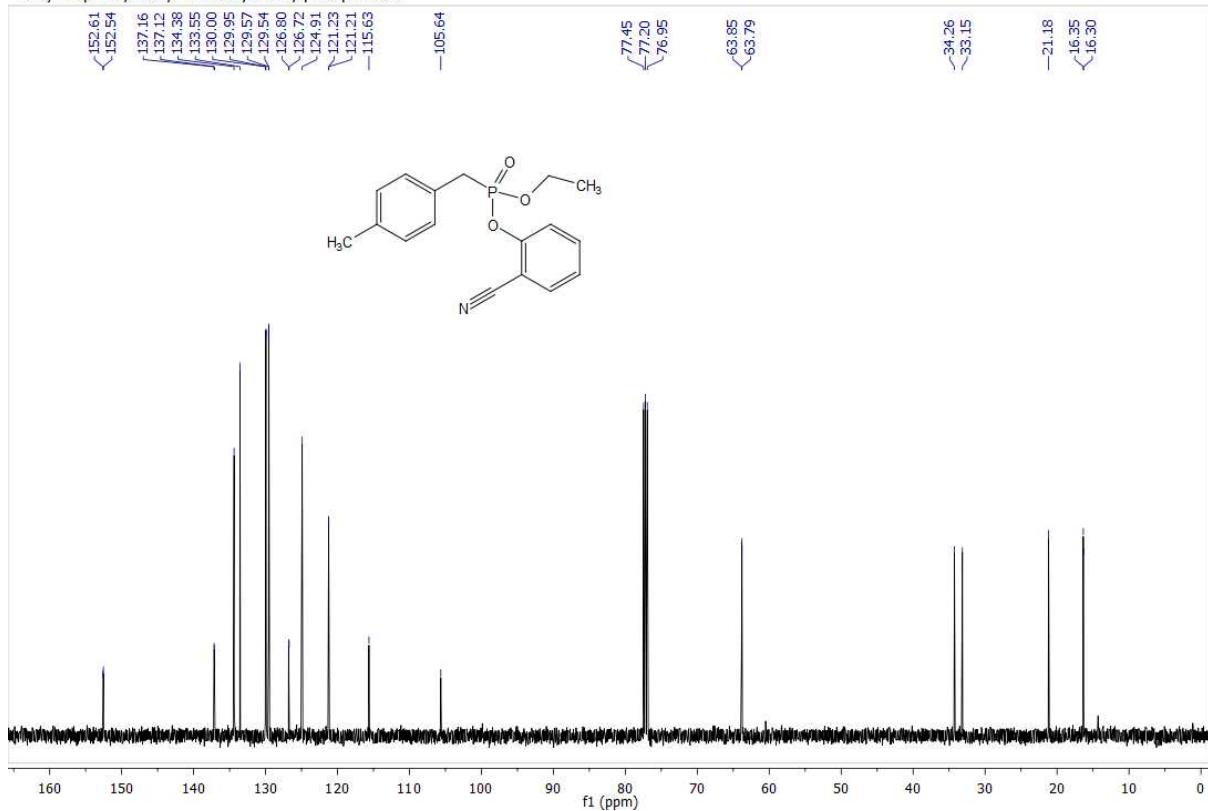


2-cyanophenyl ethyl 4-methylbenzylphosphonate (1b):

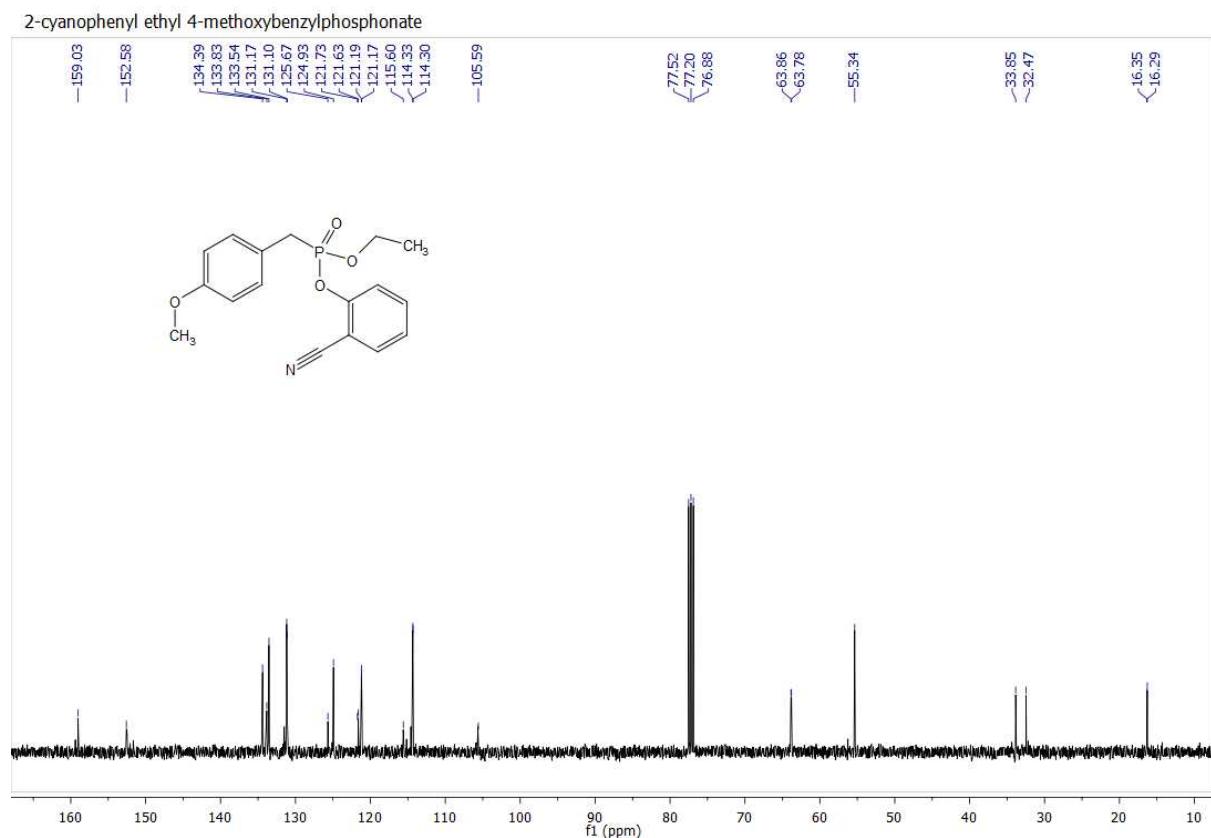
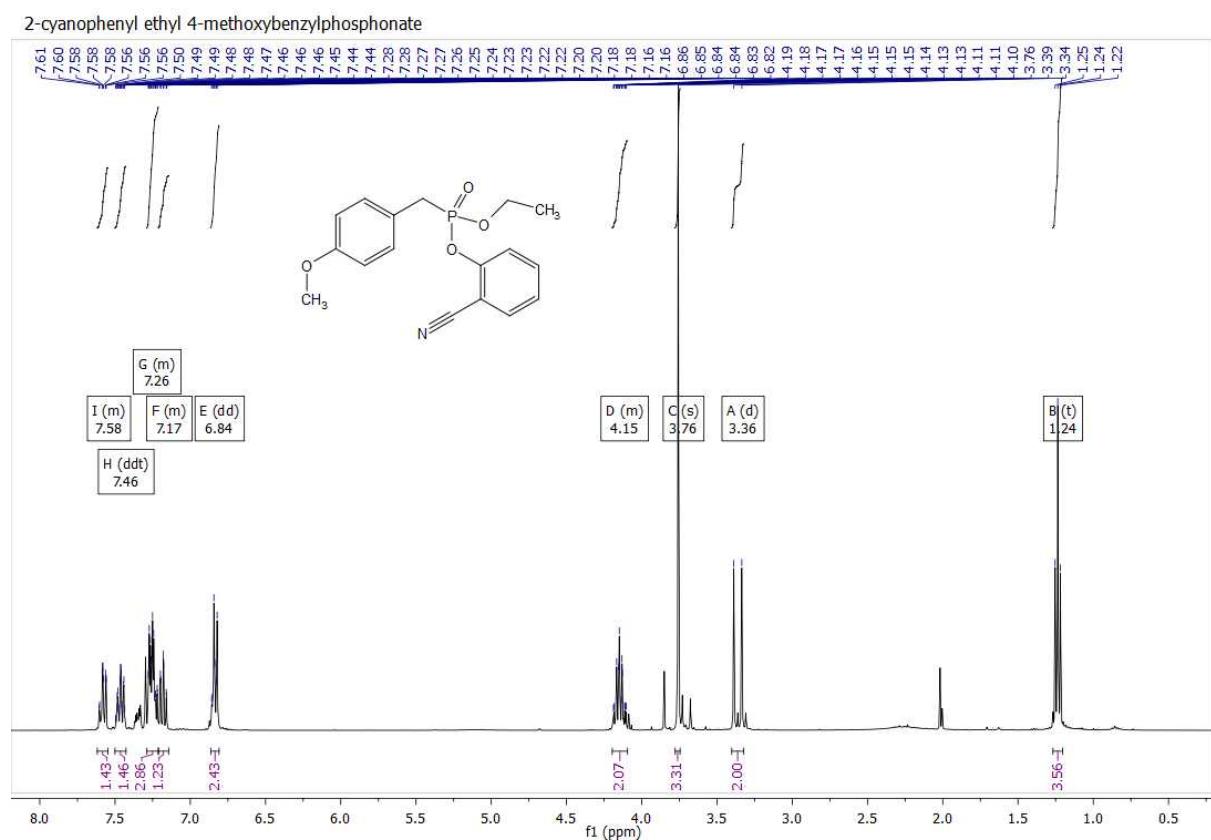
2-cyanophenyl ethyl 4-methylbenzylphosphonate



2-cyanophenyl ethyl 4-methylbenzylphosphonate

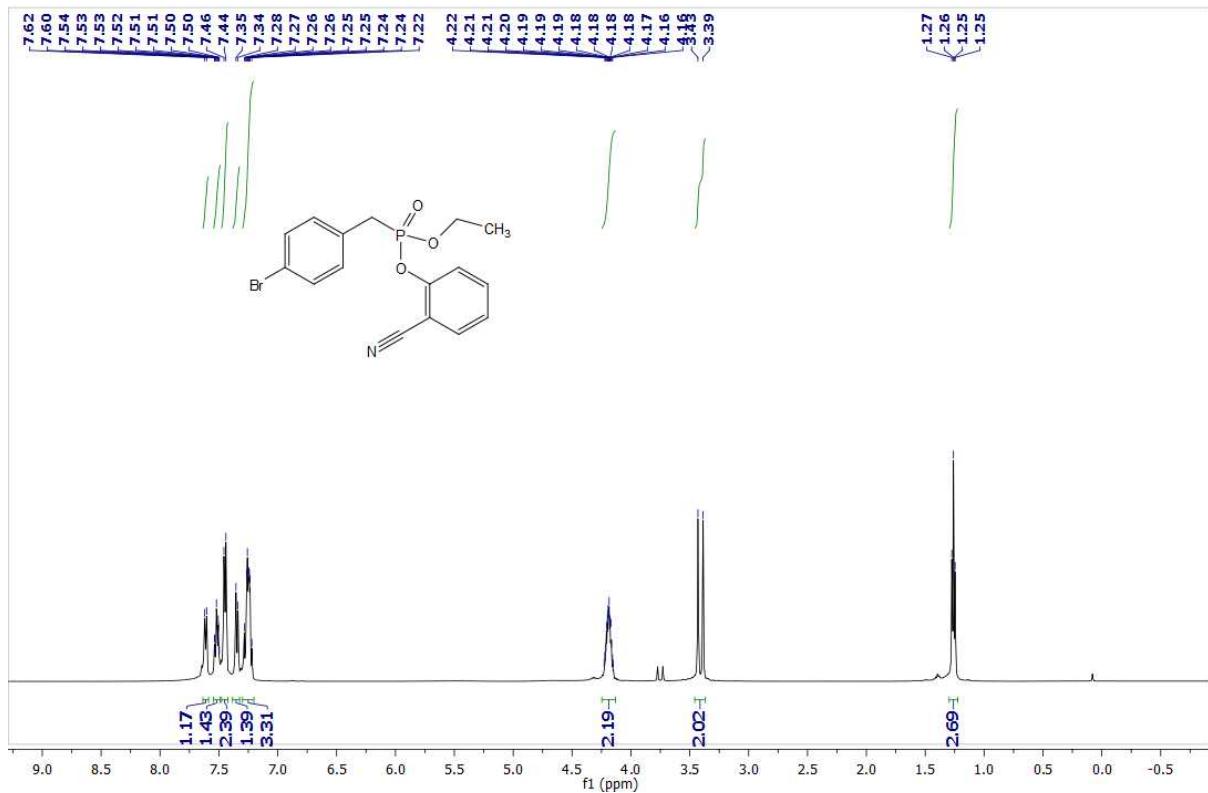


2-cyanophenyl ethyl 4-methoxybenzylphosphonate (1c):

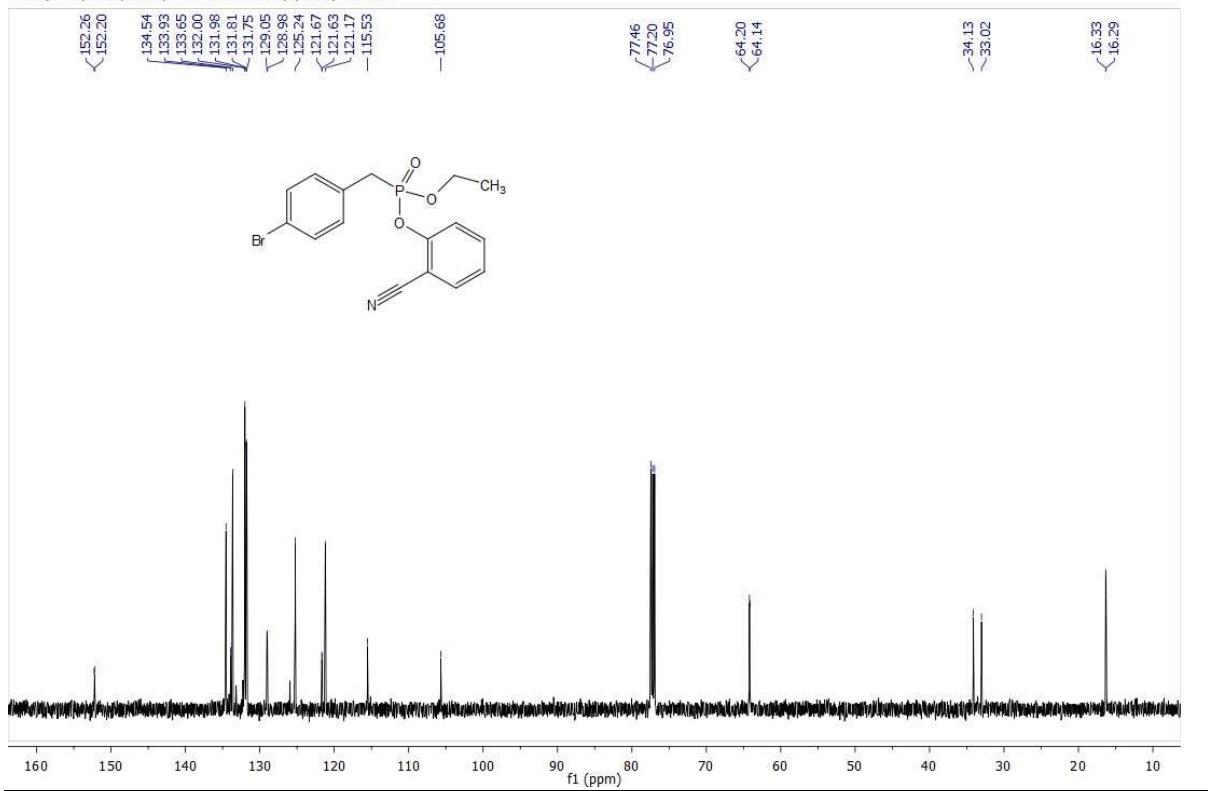


2-cyanophenyl ethyl 4-bromobenzylphosphonate (1d):

2-cyanophenyl ethyl 4-bromobenzylphosphonate

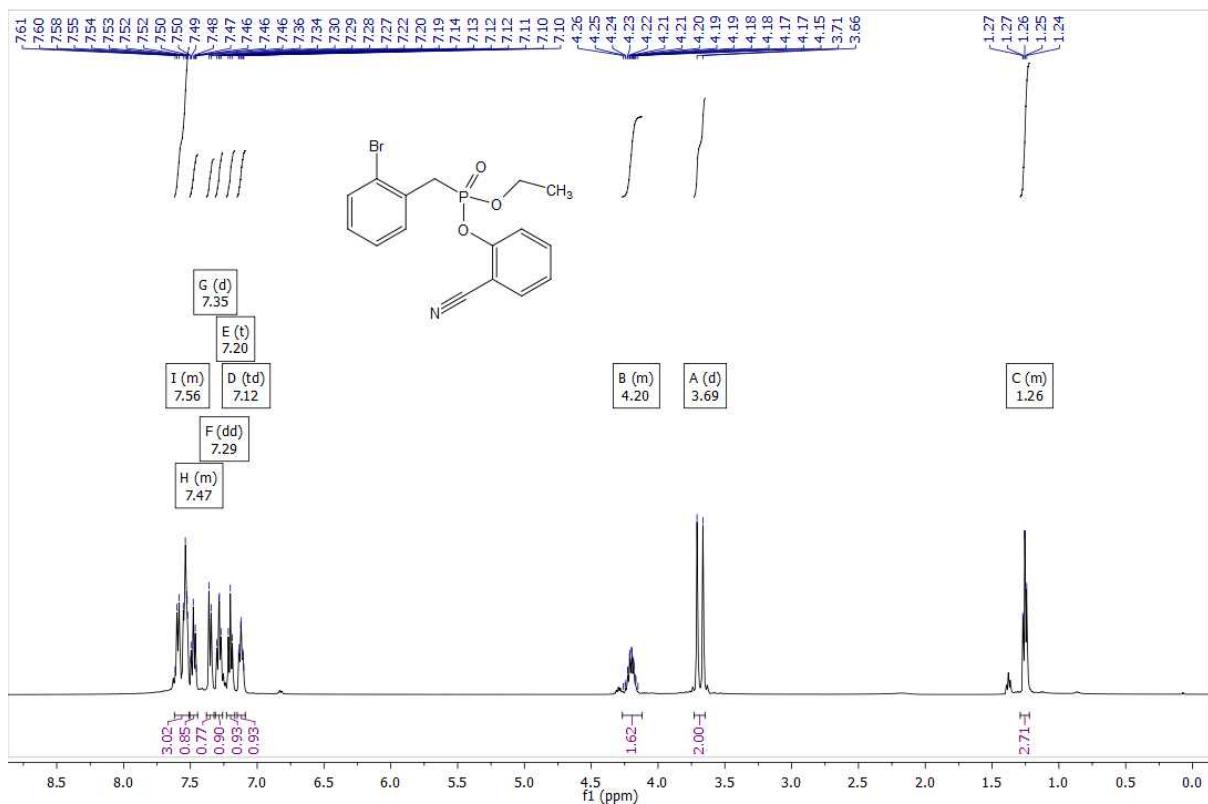


2-cyanophenyl ethyl 4-bromobenzylphosphonate

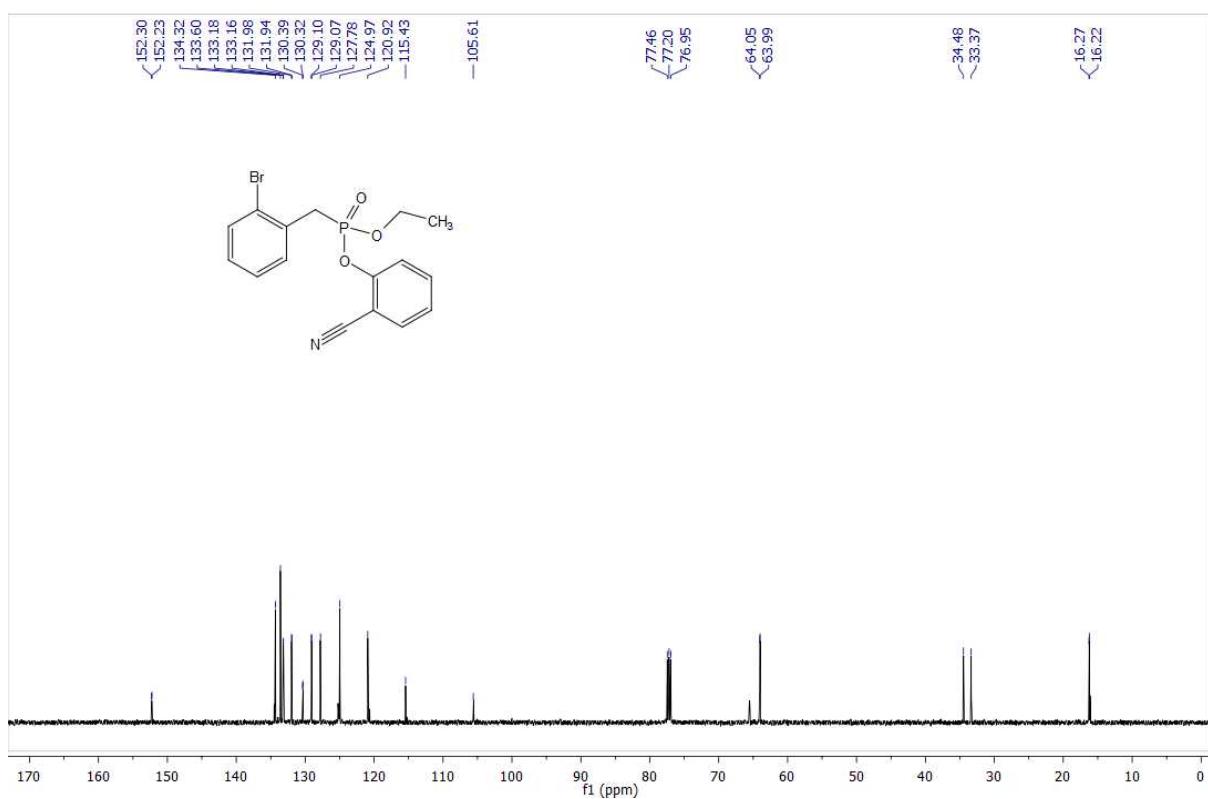


2-cyanophenyl ethyl 2-bromobenzylphosphonate (1e):

2-cyanophenyl ethyl 2-bromobenzylphosphonate

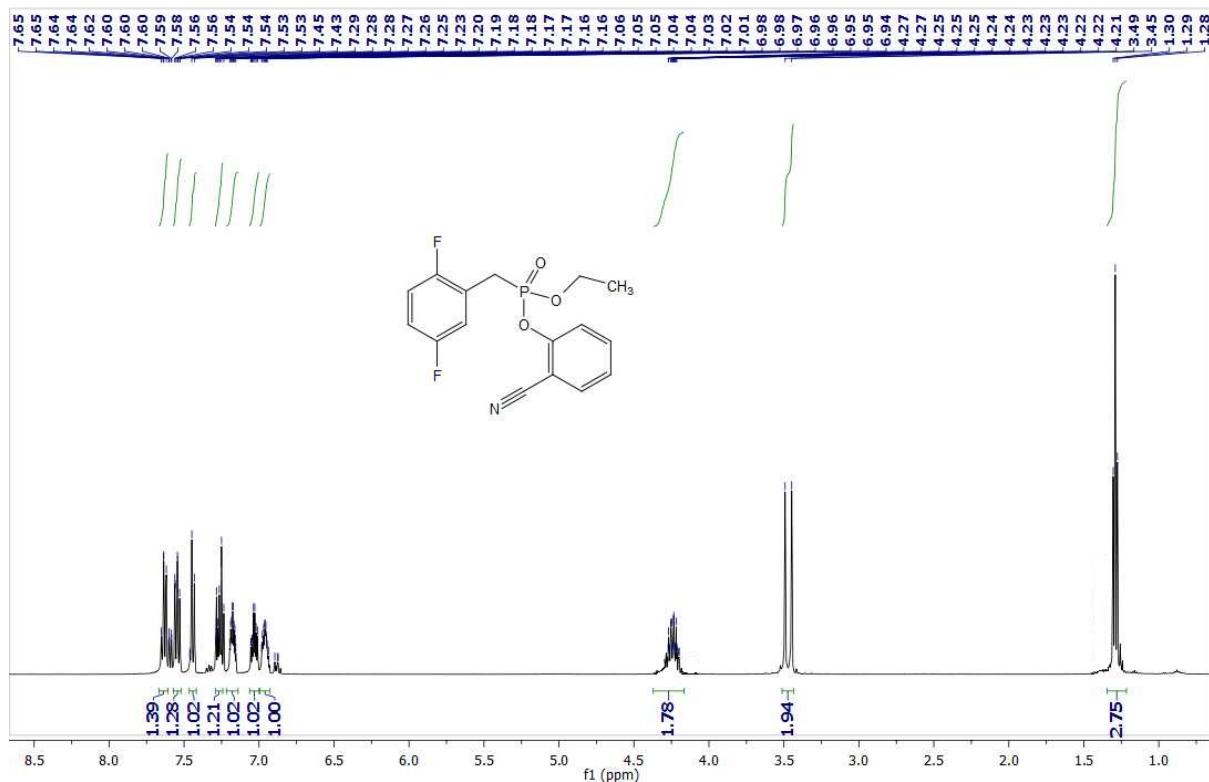


2-cyanophenyl ethyl 2-bromobenzylphosphonate

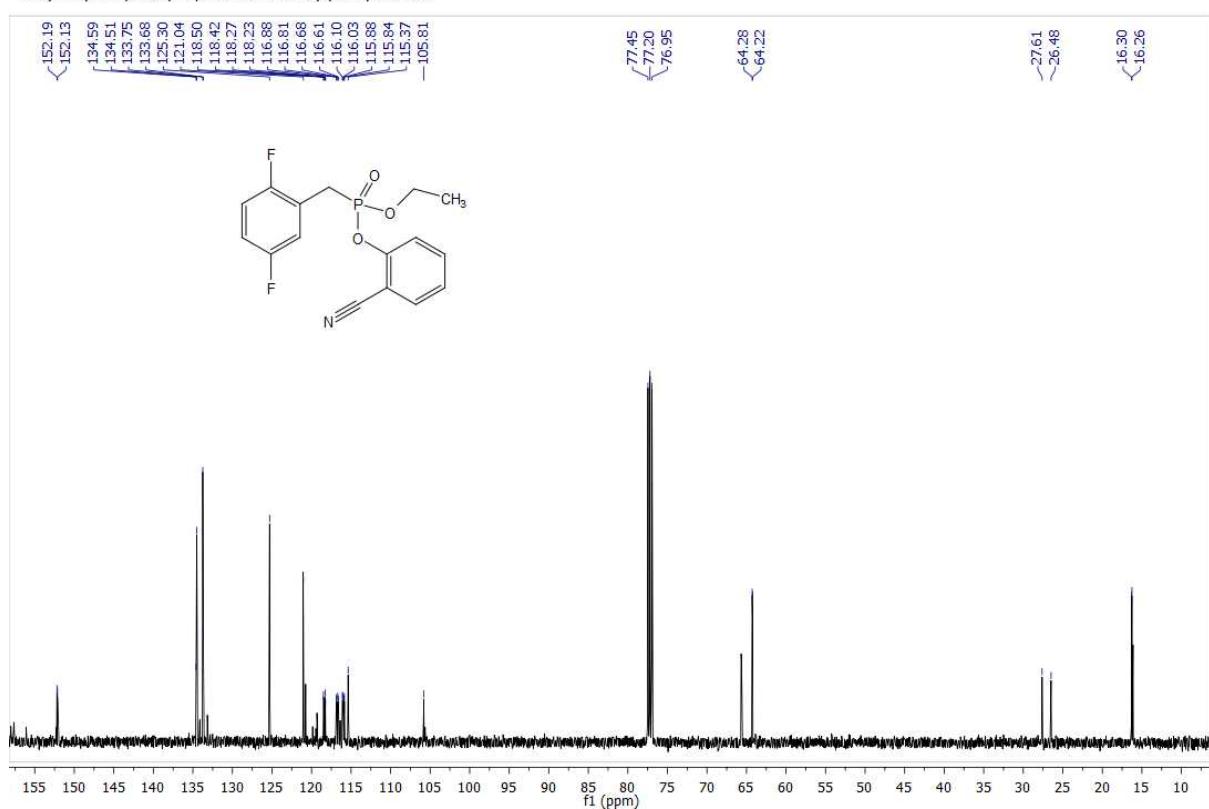


2-cyanophenyl ethyl 2,5-difluorobenzylphosphonate (1f):

2-cyanophenyl ethyl 2,5-difluorobenzylphosphonate

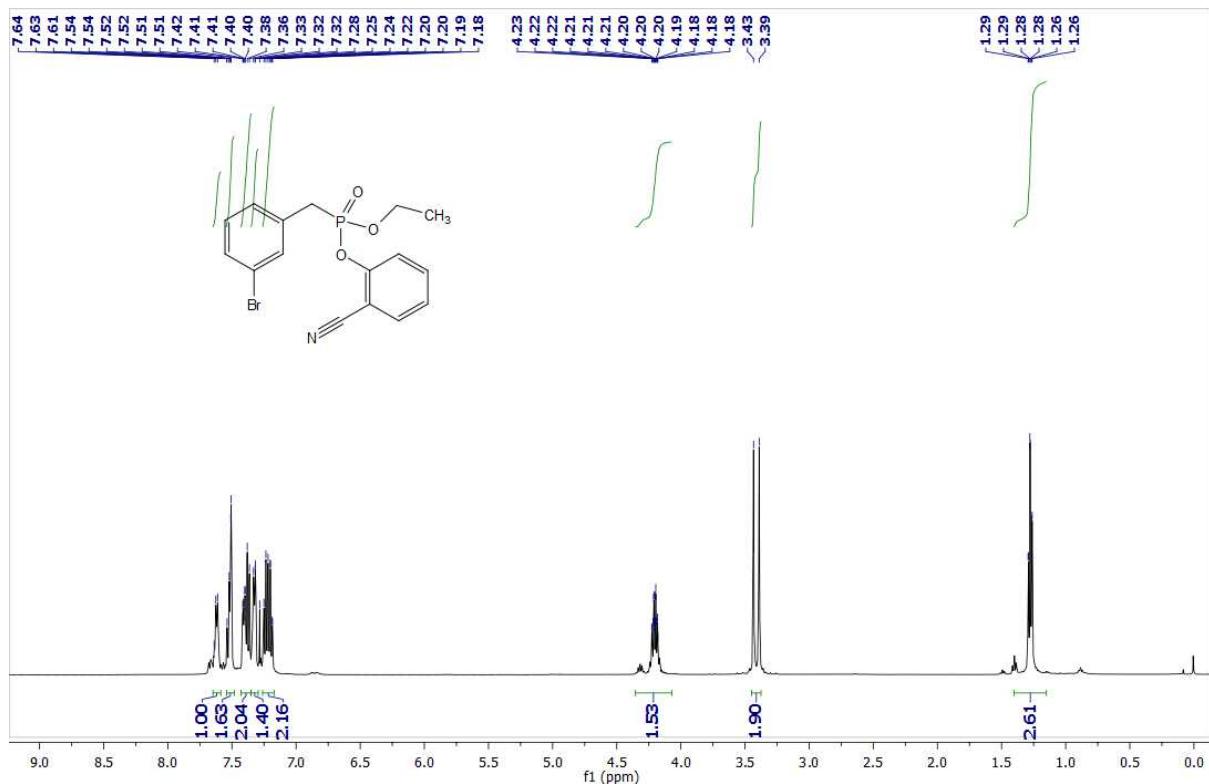


2-cyanophenyl ethyl 2,5-difluorobenzylphosphonate

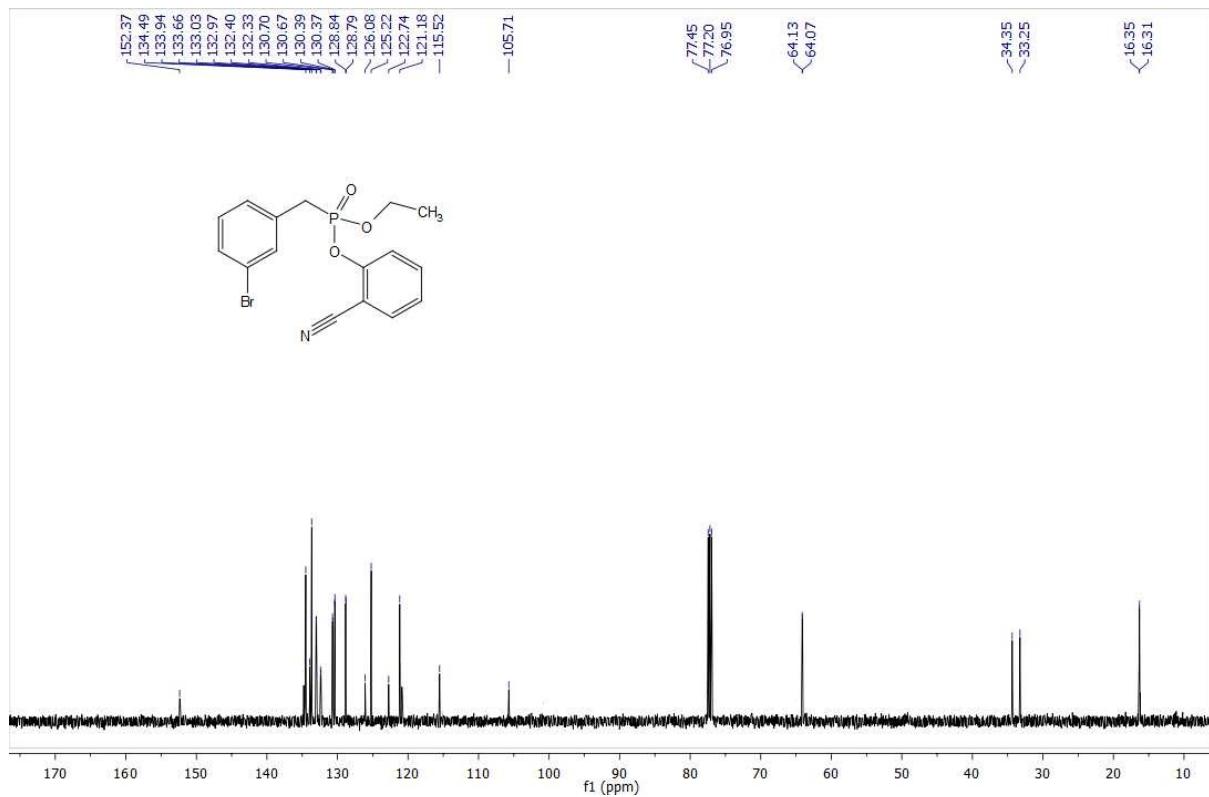


2-cyanophenyl ethyl 3-bromobenzylphosphonate (1g):

2-cyanophenyl ethyl 3-bromobenzylphosphonate

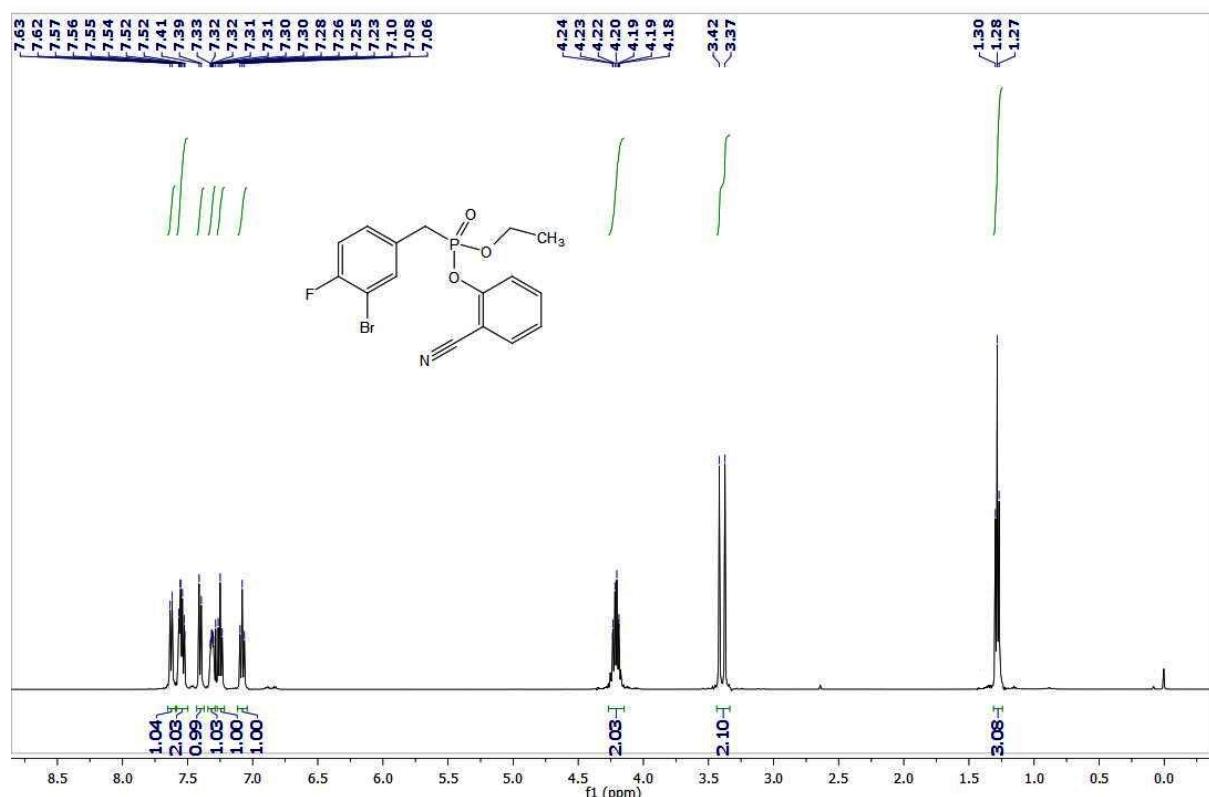


2-cyanophenyl ethyl 3-bromobenzylphosphonate

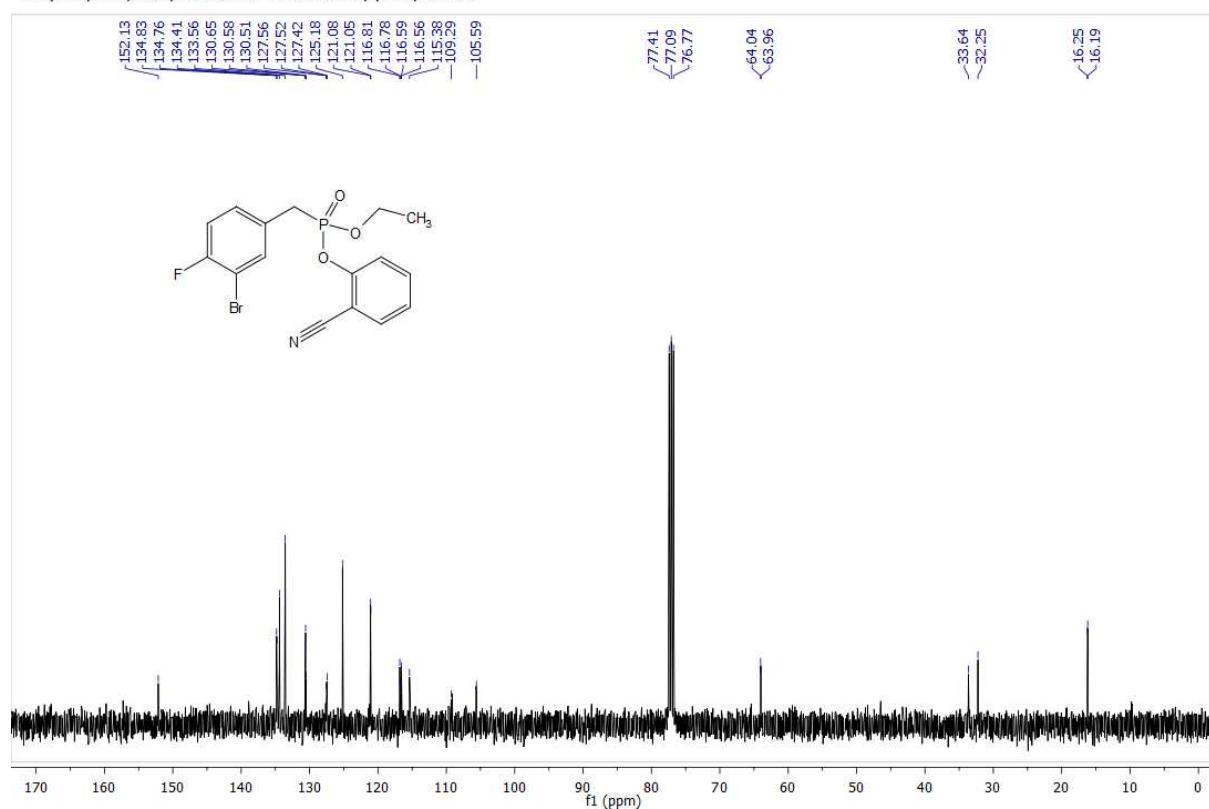


2-cyanophenyl ethyl 3-bromo-4-fluorobenzylphosphonate (1h):

2-cyanophenyl ethyl 3-bromo-4-fluorobenzylphosphonate

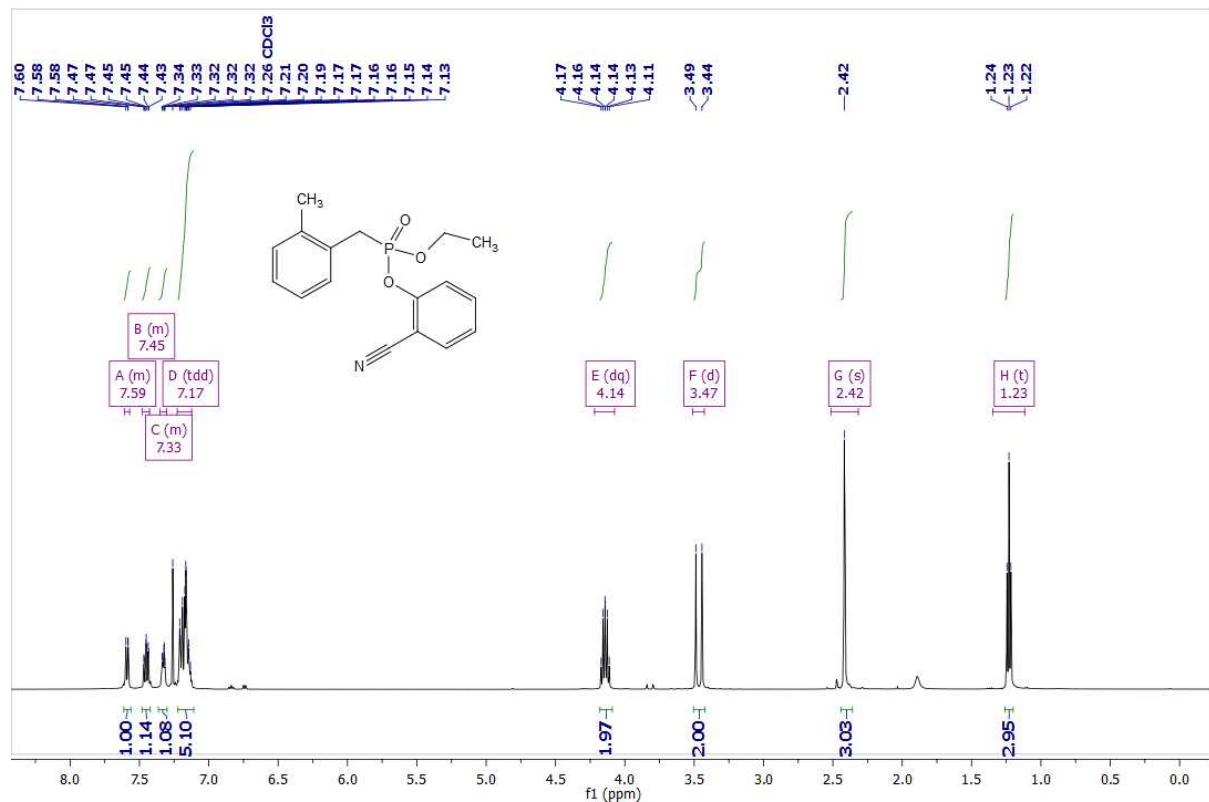


2-cyanophenyl ethyl 3-bromo-4-fluorobenzylphosphonate

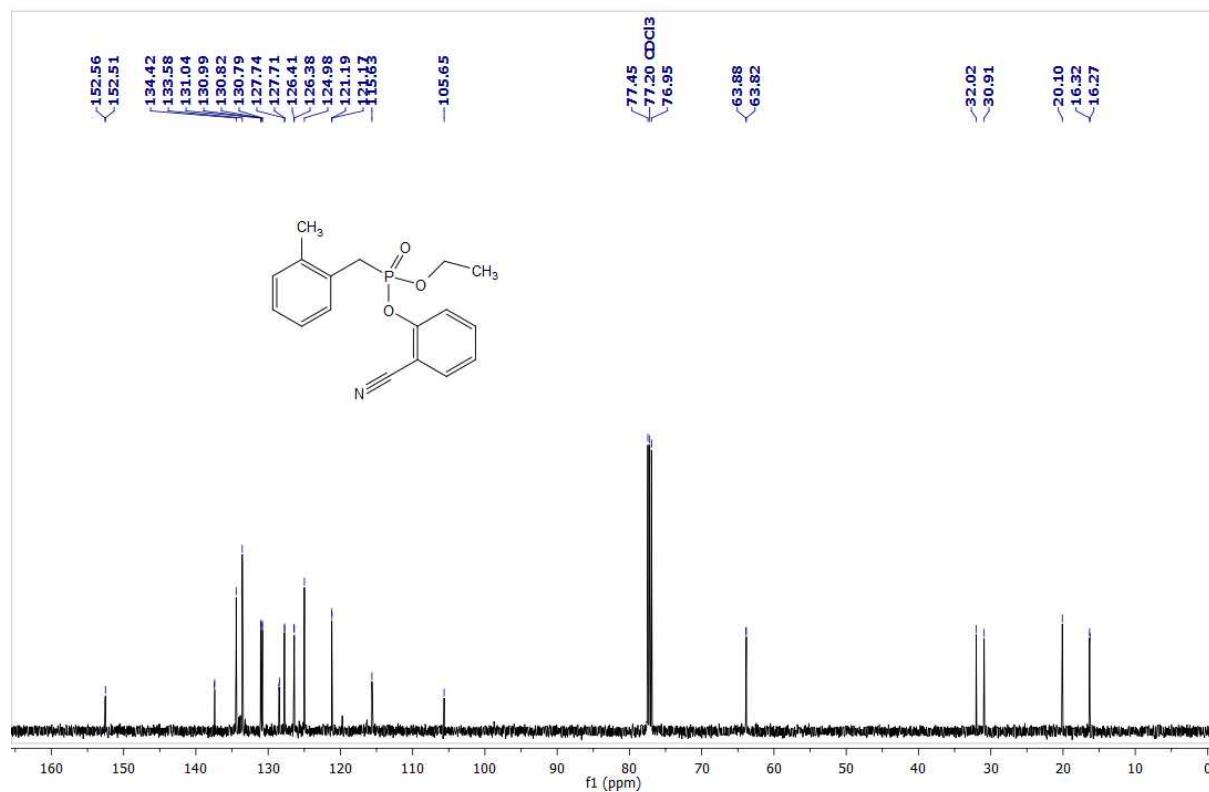


2-cyanophenyl ethyl 2-methylbenzylphosphonate (1i):

2-cyanophenyl ethyl 2-methylbenzylphosphonate

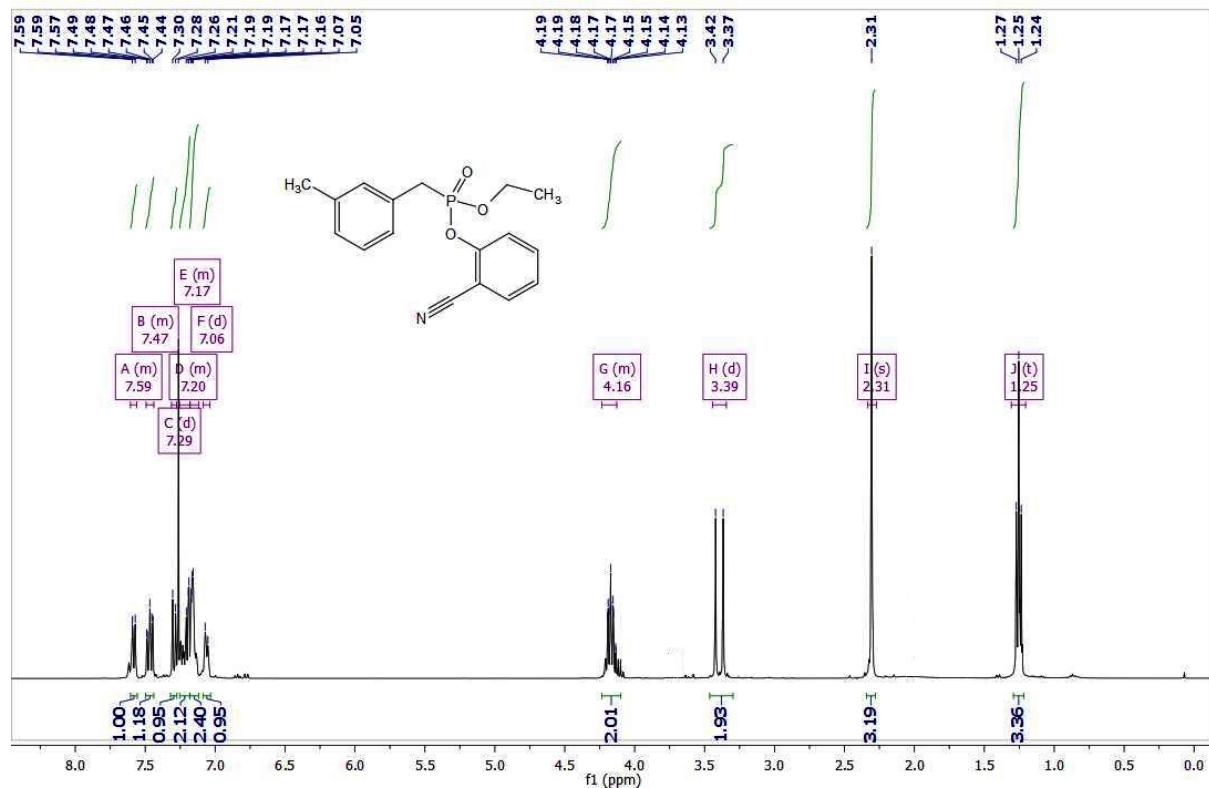


2-cyanophenyl ethyl 2-methylbenzylphosphonate

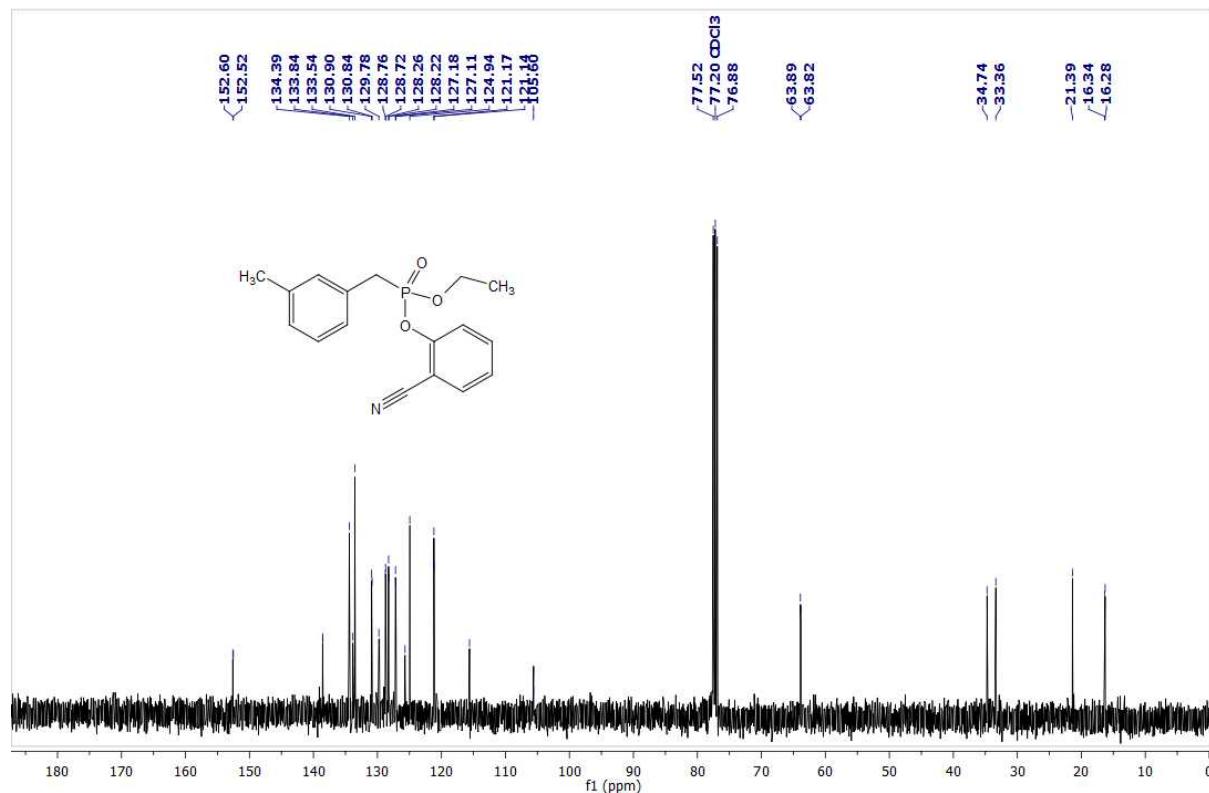


2-cyanophenyl ethyl 3-methylbenzylphosphonate (1j):

2-cyanophenyl ethyl 3-methylbenzylphosphonate

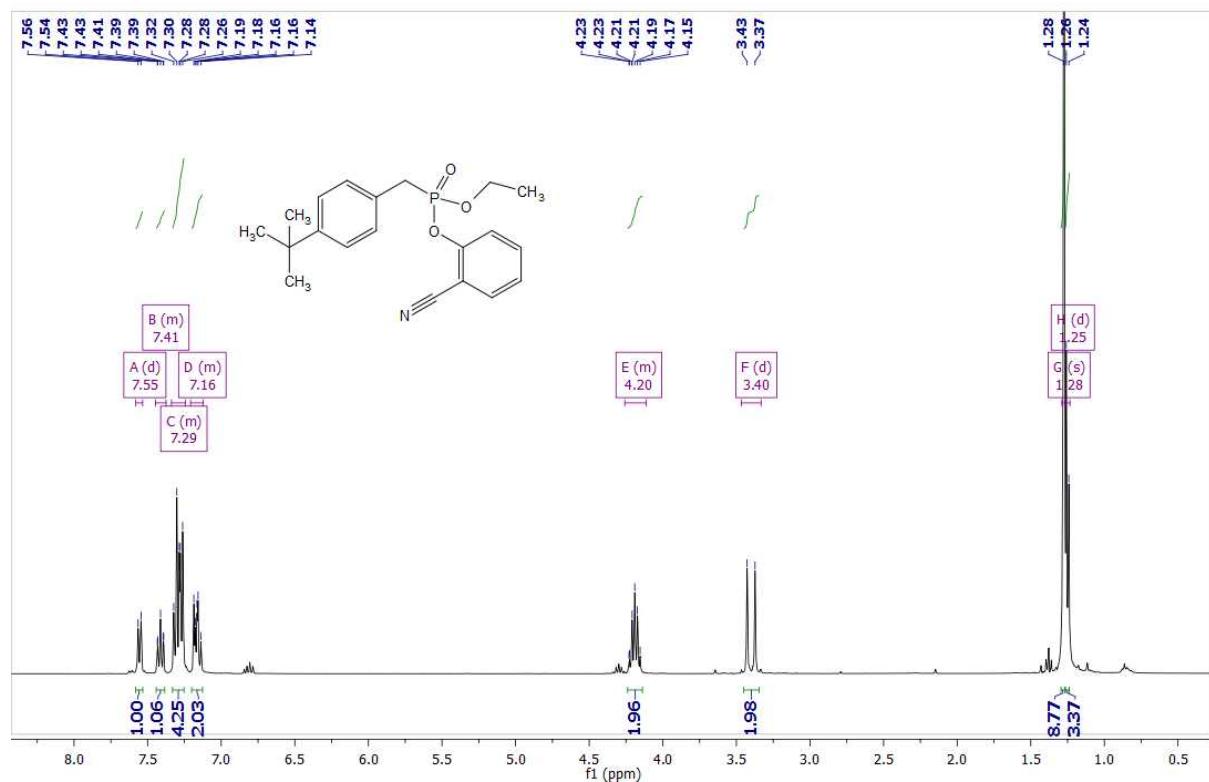


2-cyanophenyl ethyl 3-methylbenzylphosphonate

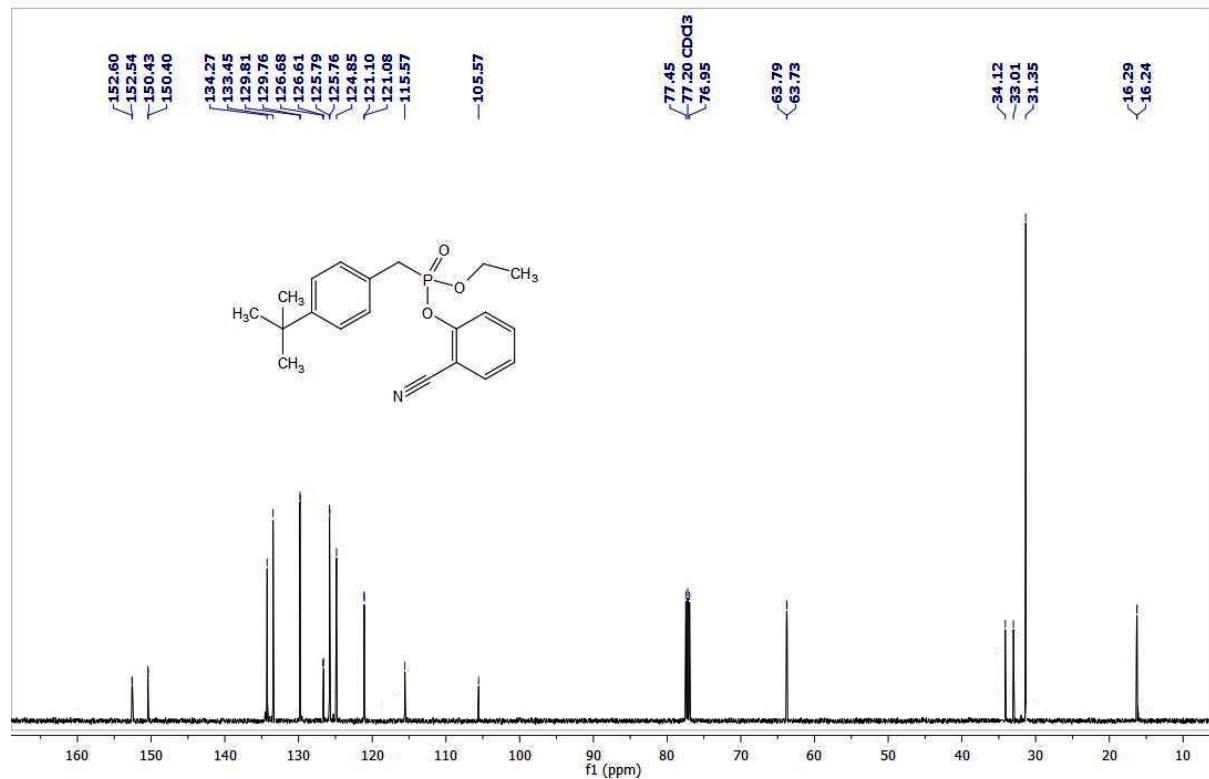


2-cyanophenyl ethyl 4-tert-butylbenzylphosphonate (1k):

2-cyanophenyl ethyl 4-tert-butylbenzylphosphonate



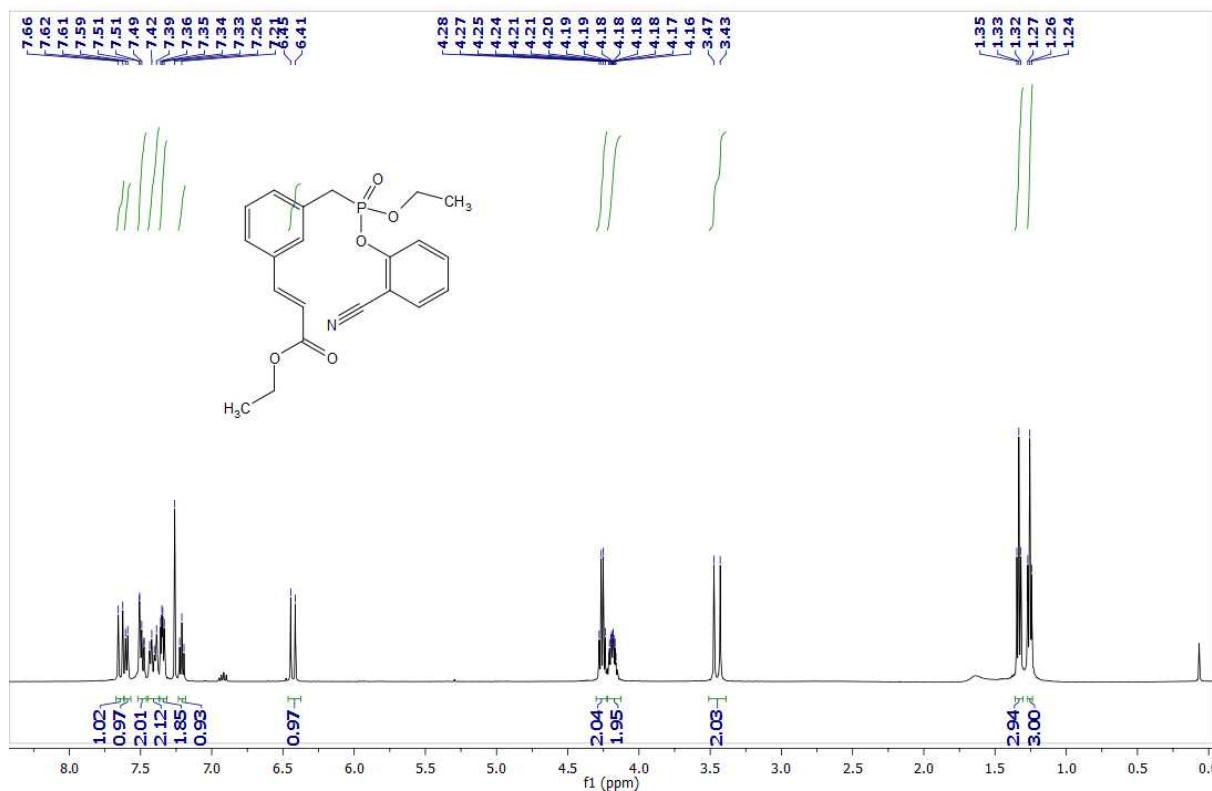
2-cyanophenyl ethyl 4-tert-butylbenzylphosphonate



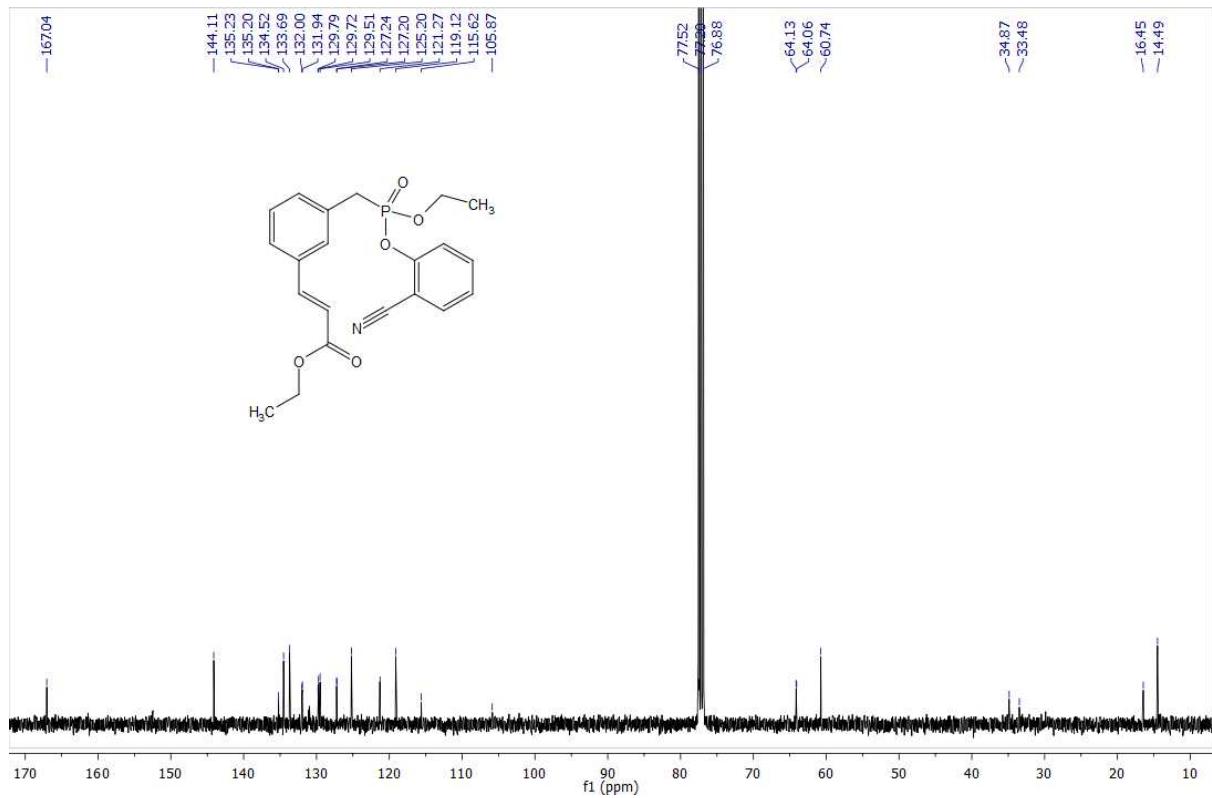
Mono-Olefinated Products:

(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenylacrylate (2a):

(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenylacrylate

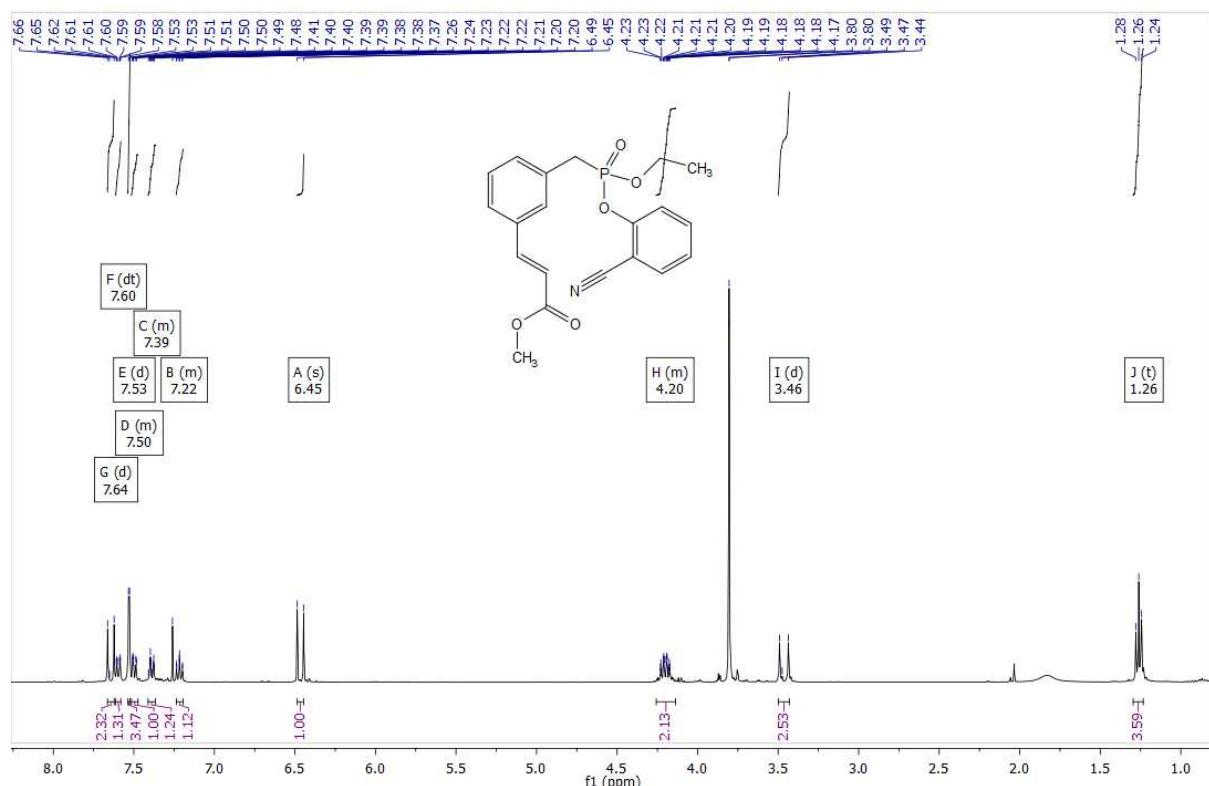


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenylacrylate

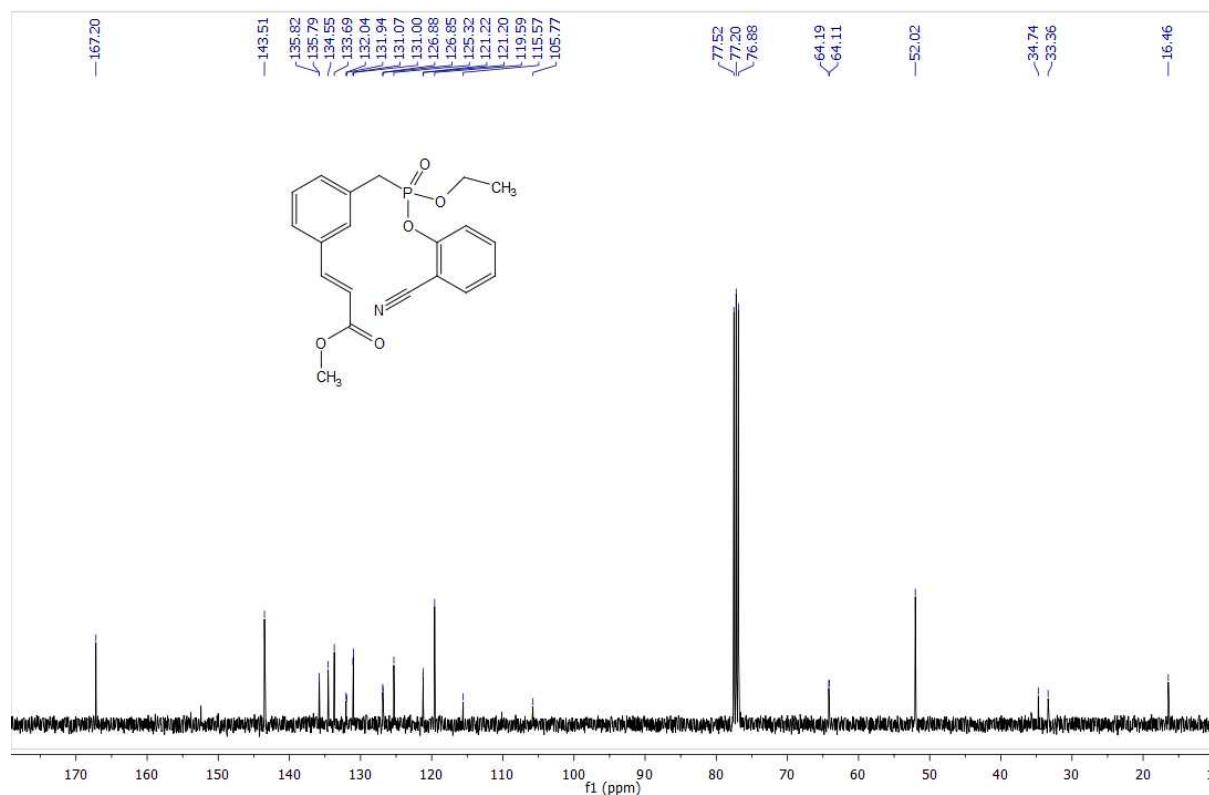


(E)-methyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenyl)acrylate(2b):

(E)-methyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenyl)acrylate

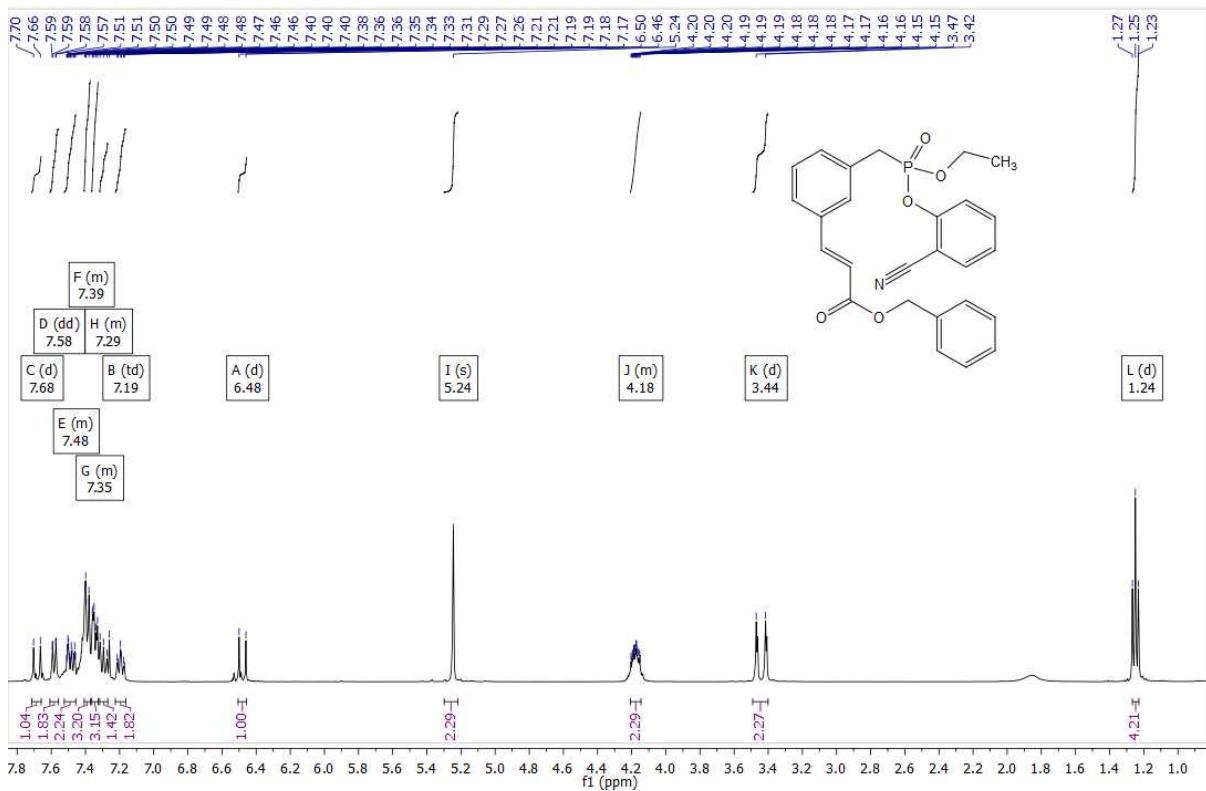


(E)-methyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methylphenyl)acrylate

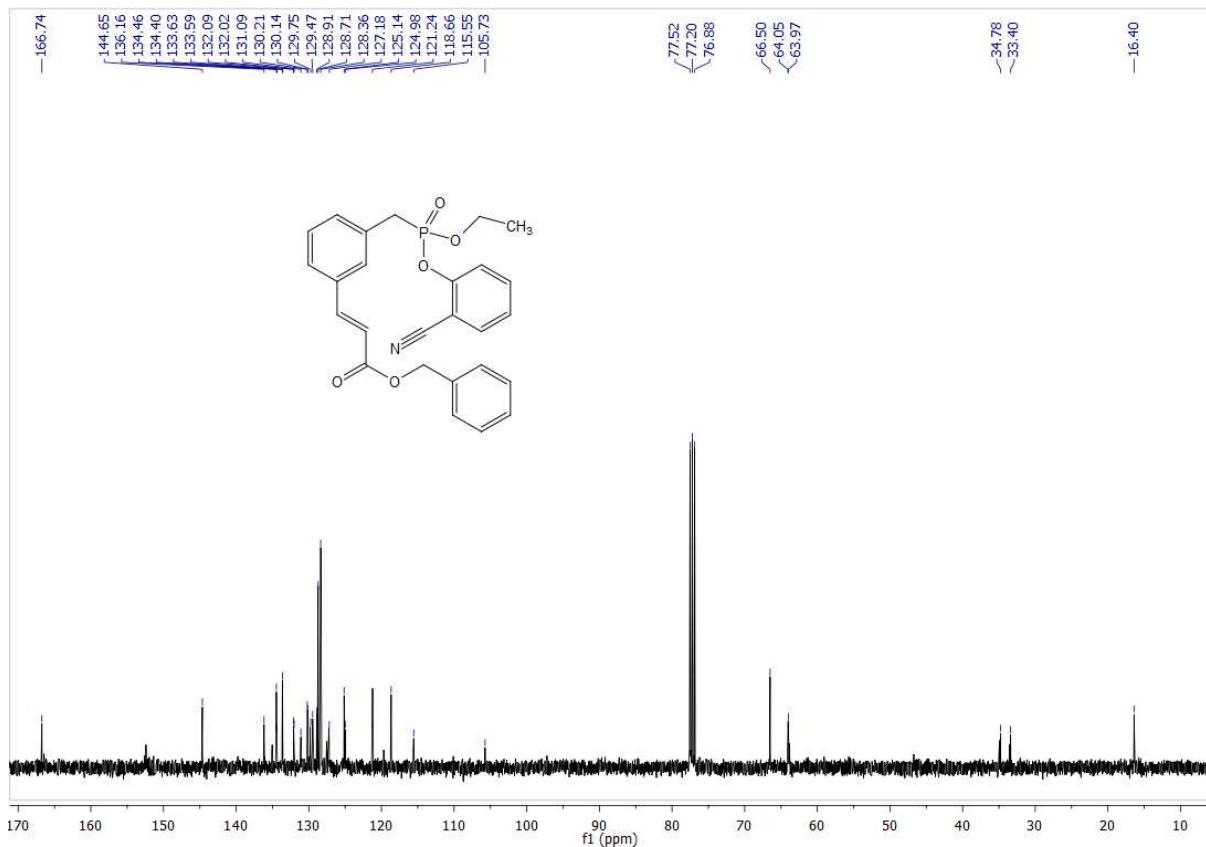


(E)-benzyl 3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2c):

(E)-benzyl 3-((2-cyanophenoxy)(ethoxy)phosphorylmethyl)phenyl)acrylate

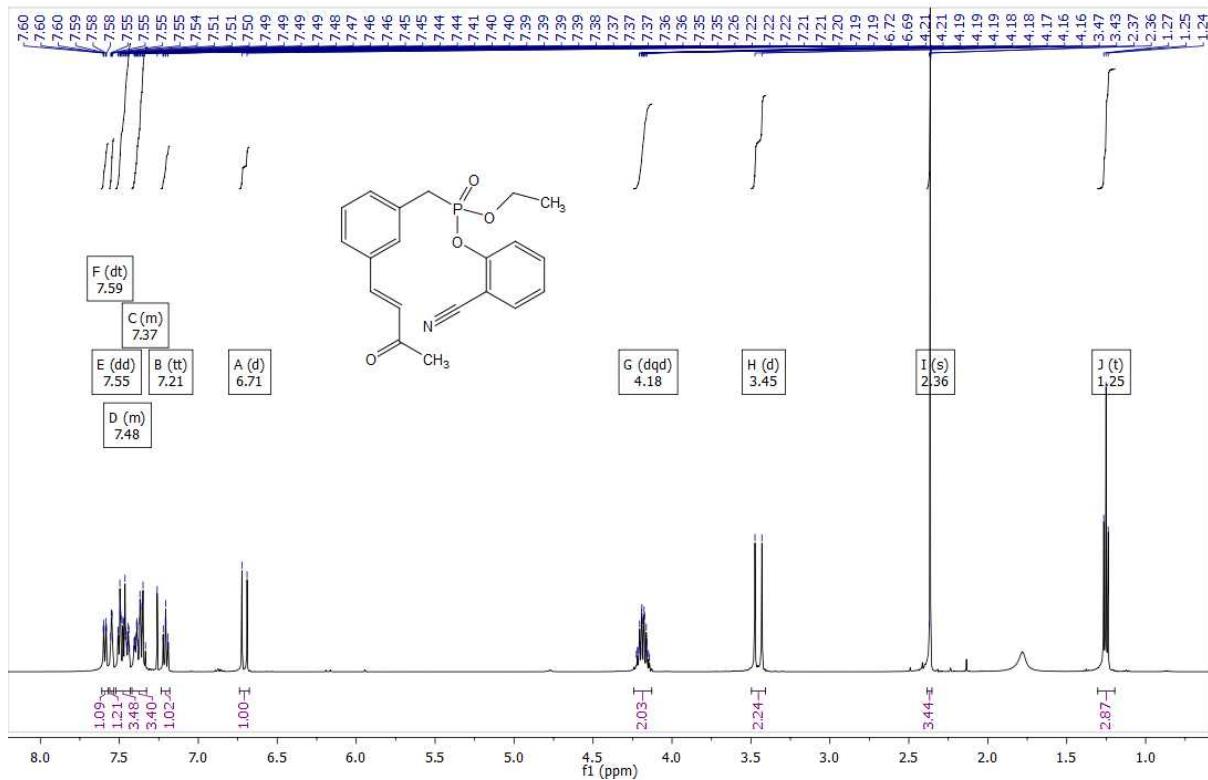


(E)-benzyl 3-((2-cyanophenoxy)(ethoxy)phosphorylmethyl)phenyl)acrylate

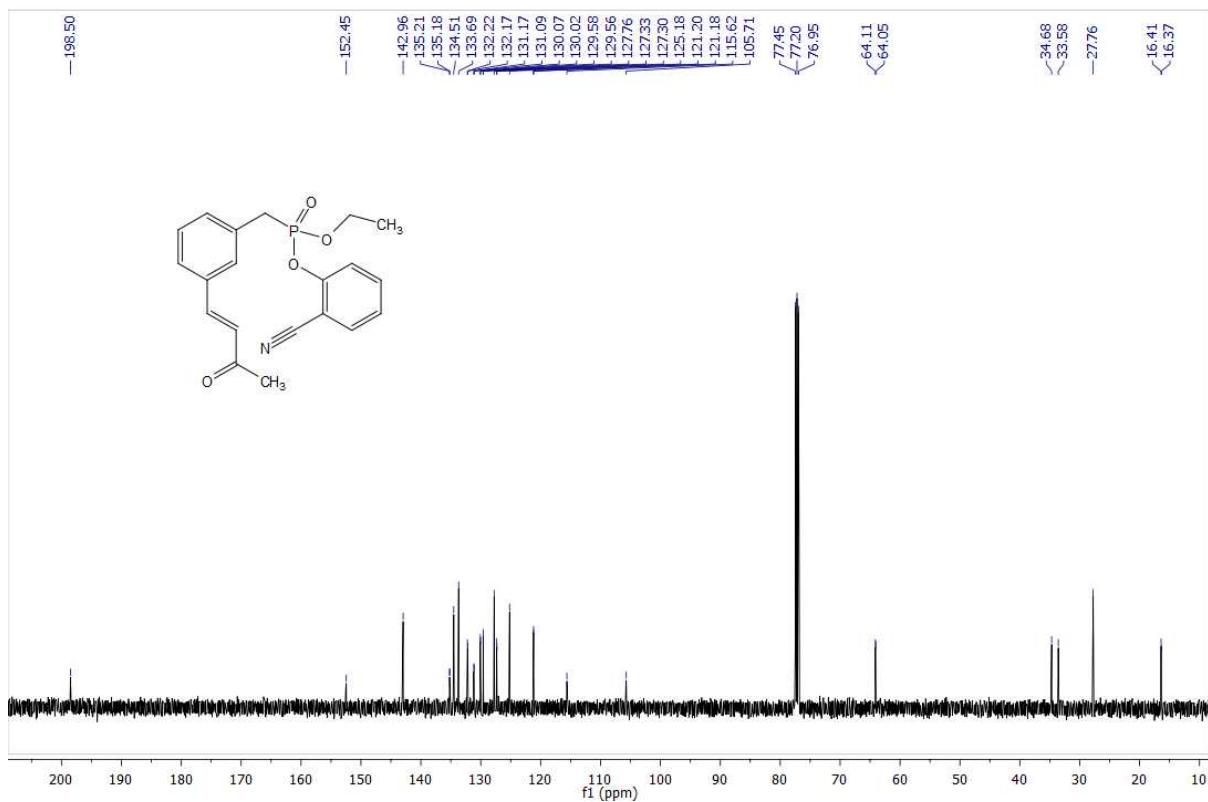


(E)-2-cyanophenyl ethyl 3-(3-oxobut-1-en-1-yl)benzylphosphonate (2d):

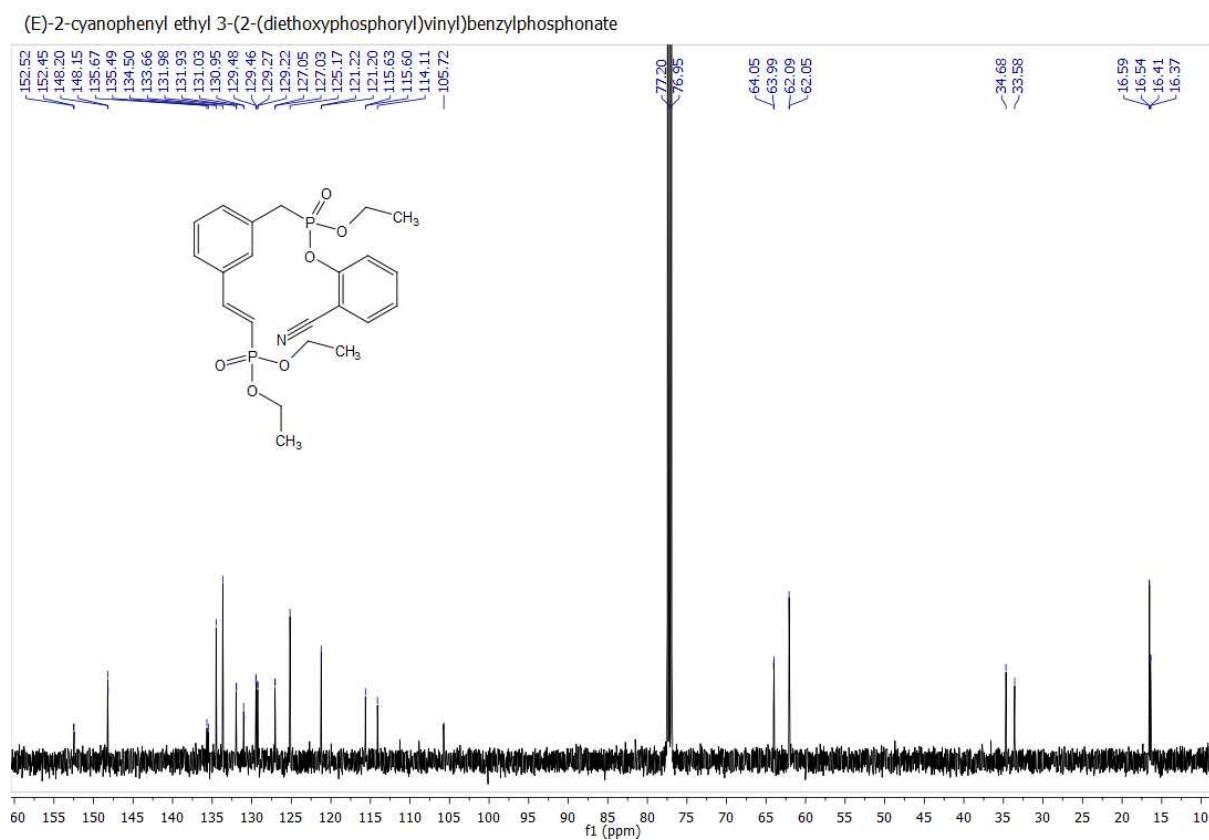
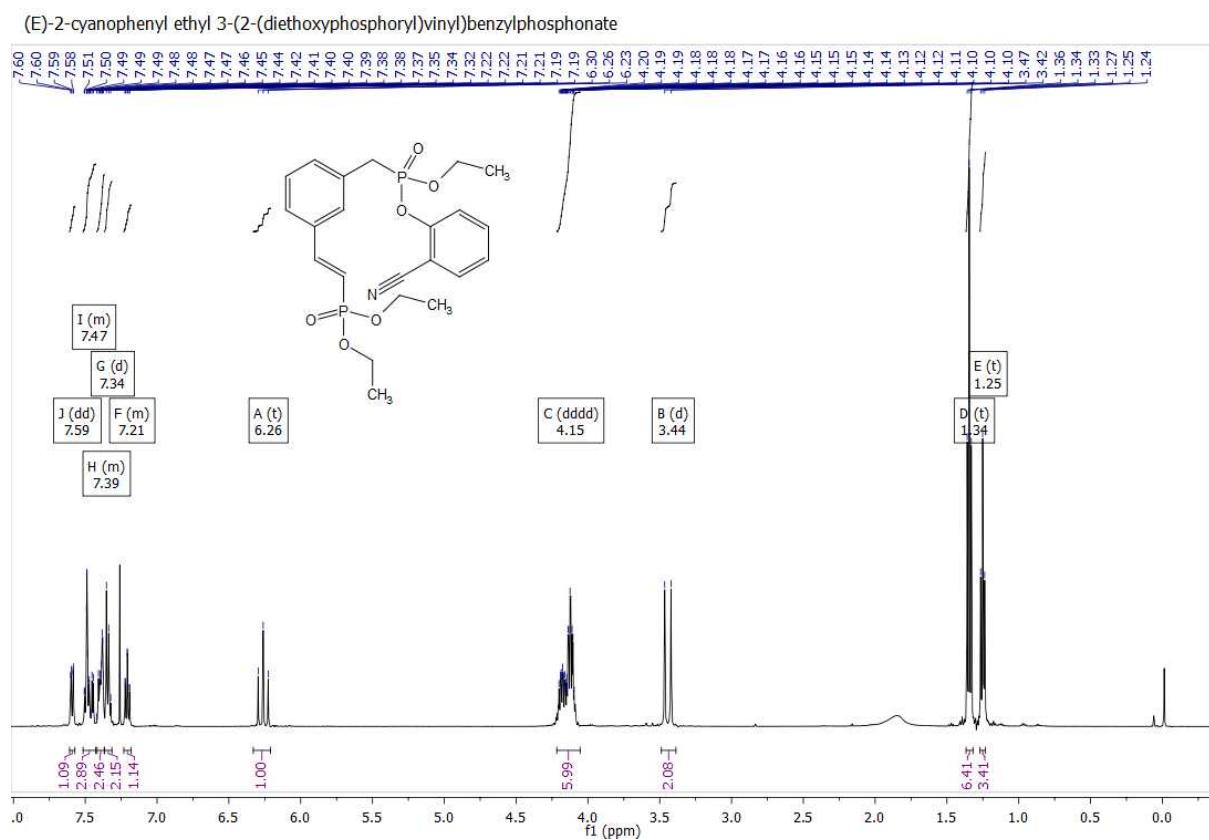
(E)-2-cyanophenyl ethyl 3-(3-oxobut-1-en-1-yl)benzylphosphonate



(E)-2-cyanophenyl ethyl 3-(3-oxobut-1-en-1-yl)benzylphosphonate

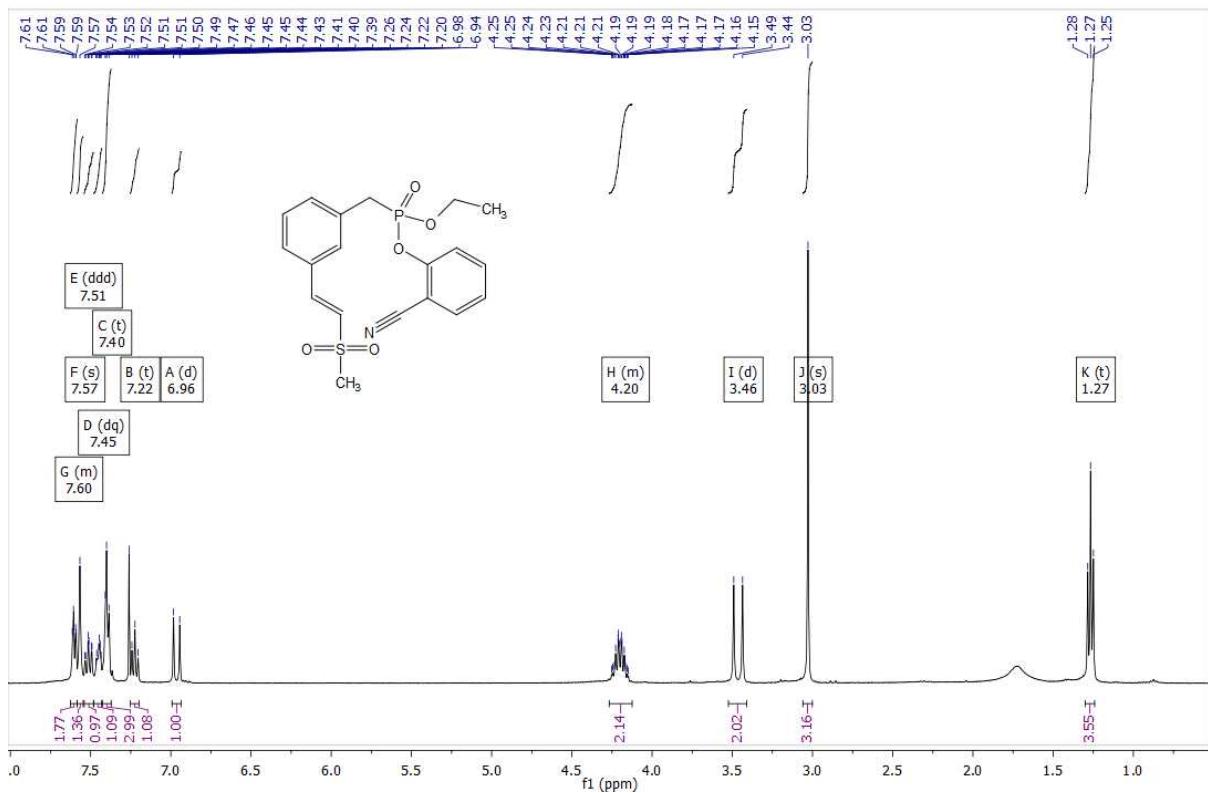


(E)-2-cyanophenyl ethyl 3-(diethoxyphosphoryl)vinylbenzylphosphonate (2e):

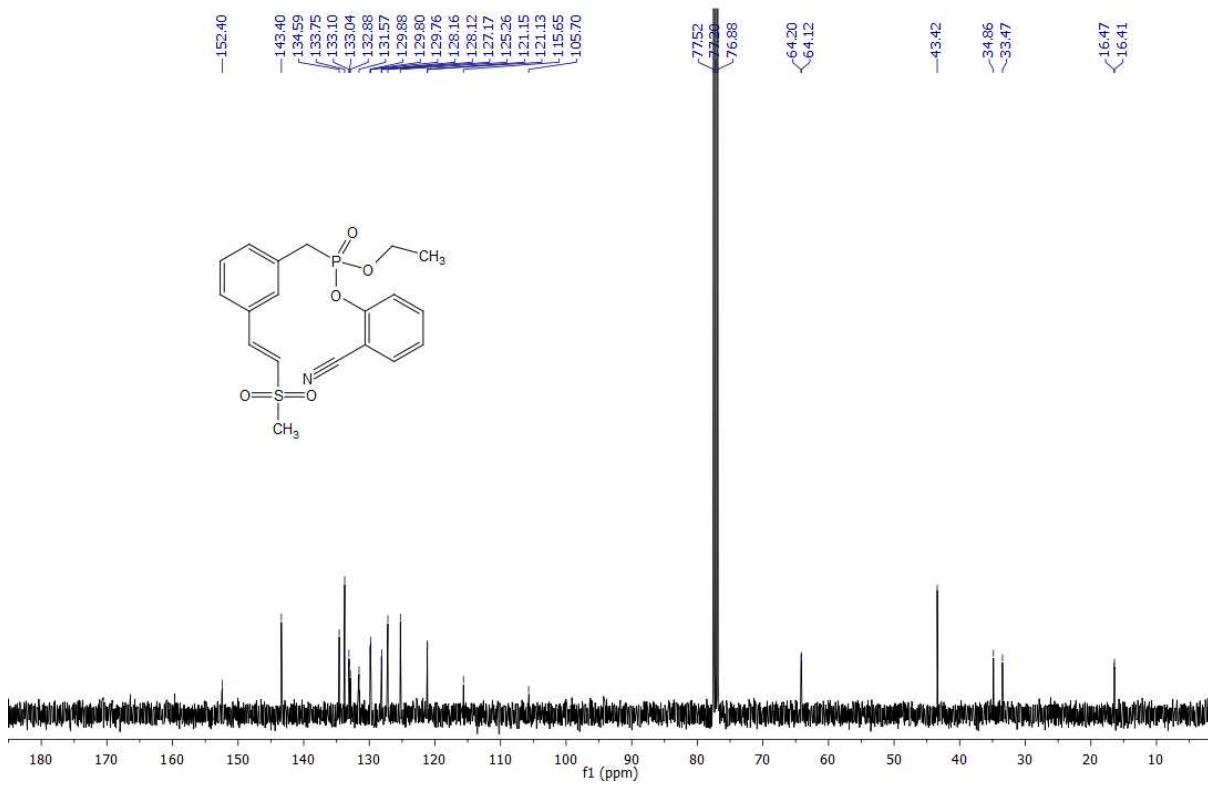


(E)-2-cyanophenyl ethyl 3-(2-(methylsulfonyl)vinyl)benzylphosphonate (2f):

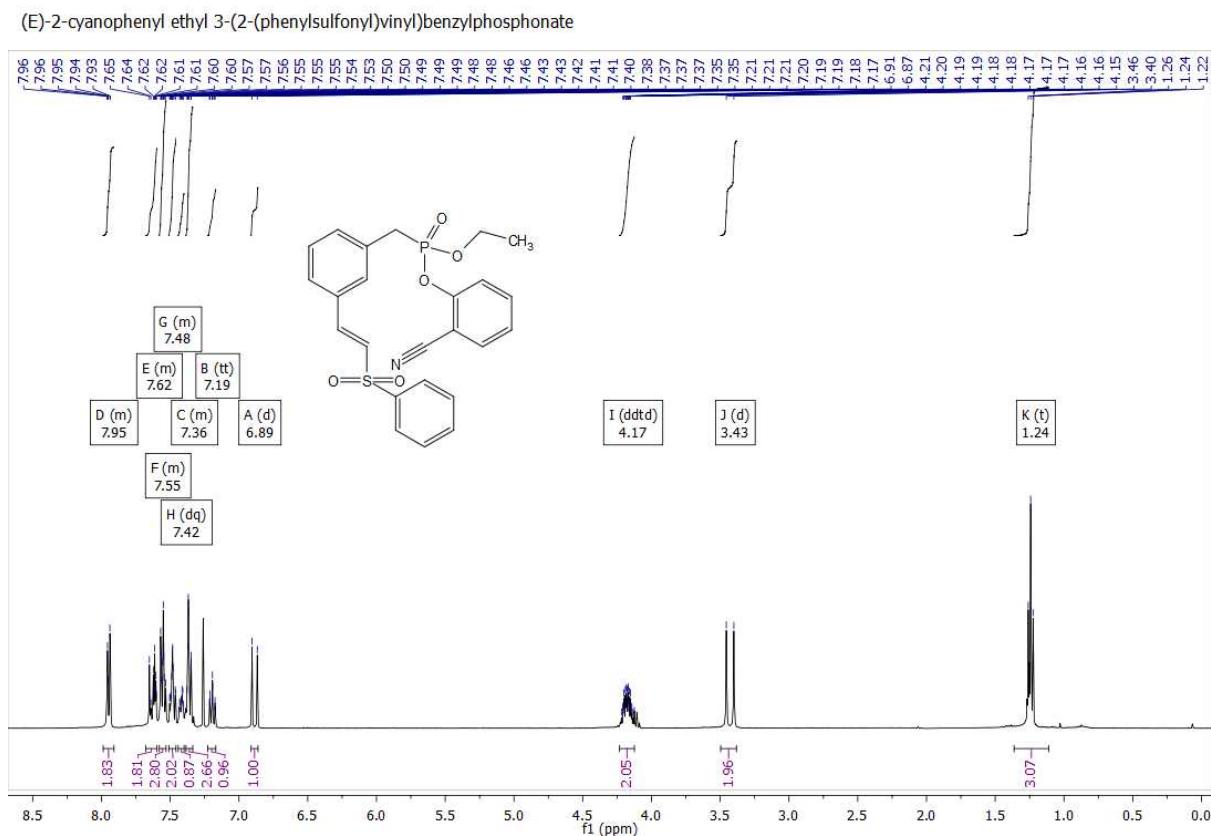
(E)-2-cyanophenyl ethyl 3-(2-(methylsulfonyl)vinyl)benzylphosphonate



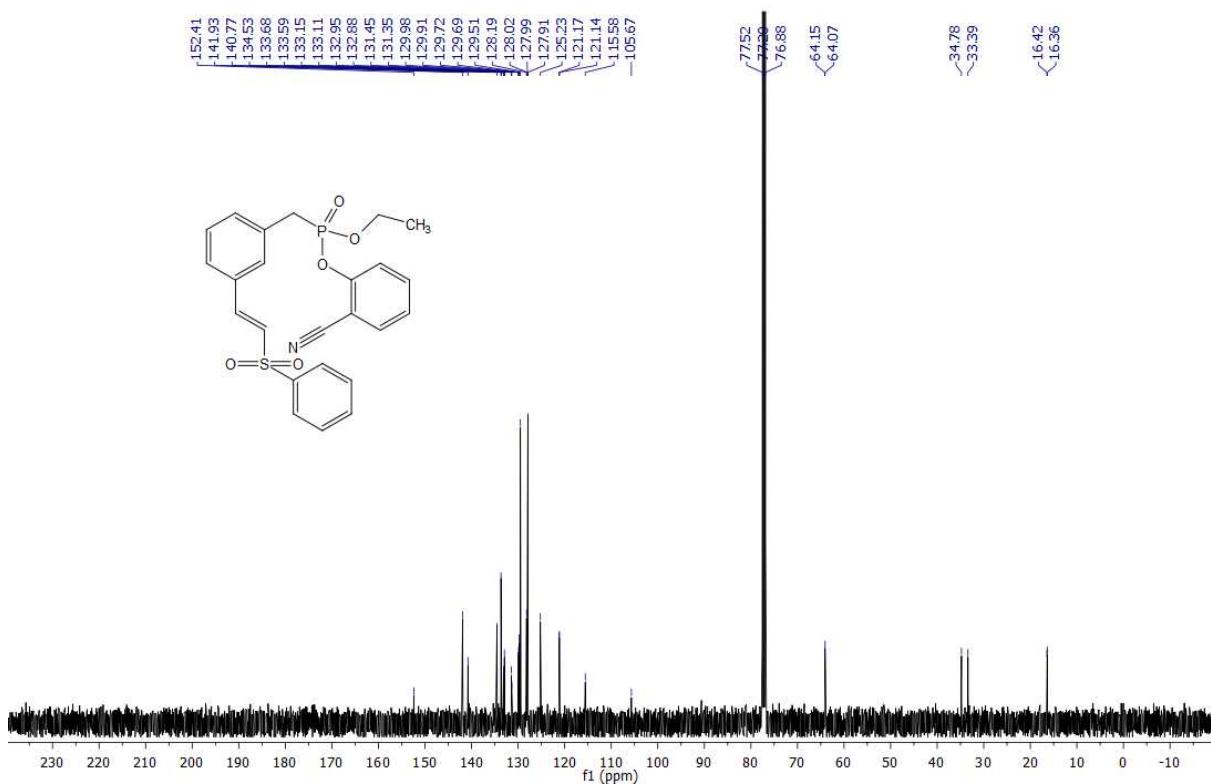
(E)-2-cyanophenyl ethyl 3-(2-(methylsulfonyl)vinyl)benzylphosphonate



(E)-2-cyanophenyl ethyl 3-(2-(phenylsulfonyl)vinyl)benzylphosphonate (2g):

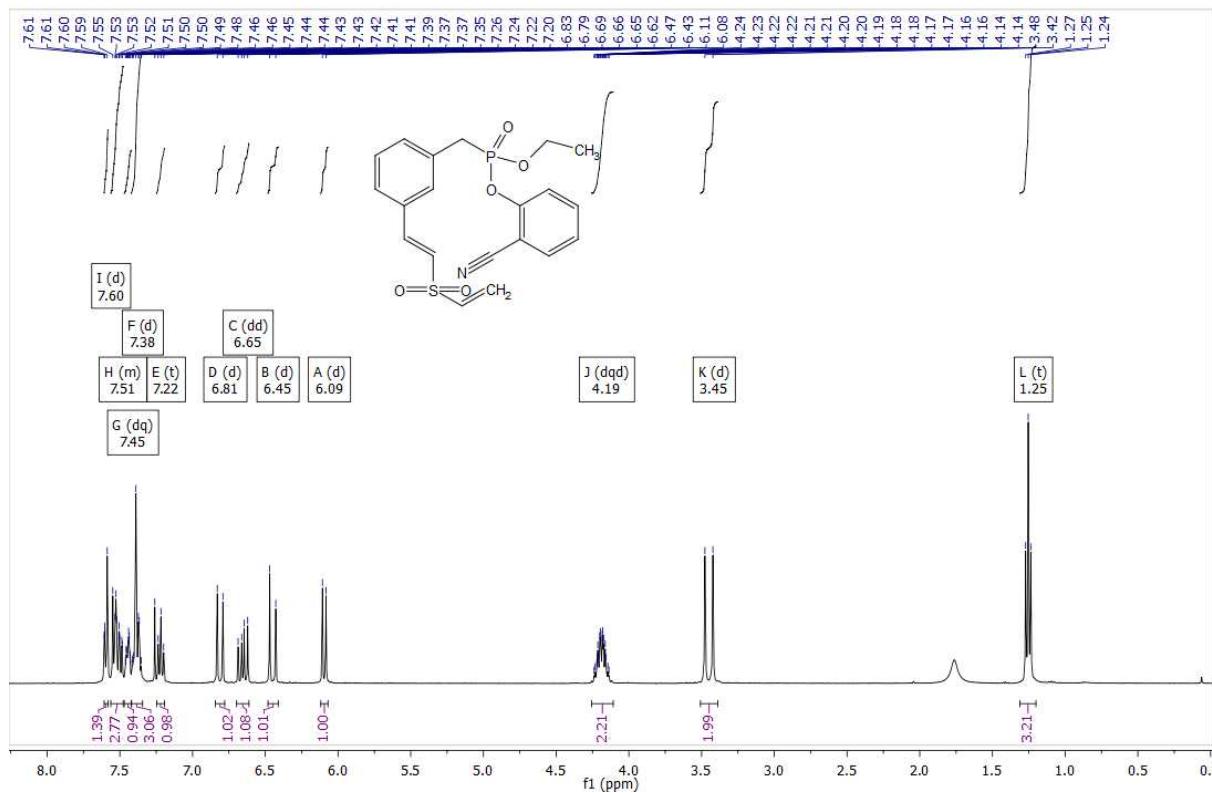


(E)-2-cyanophenyl ethyl 3-(2-(phenylsulfonyl)vinyl)benzylphosphonate

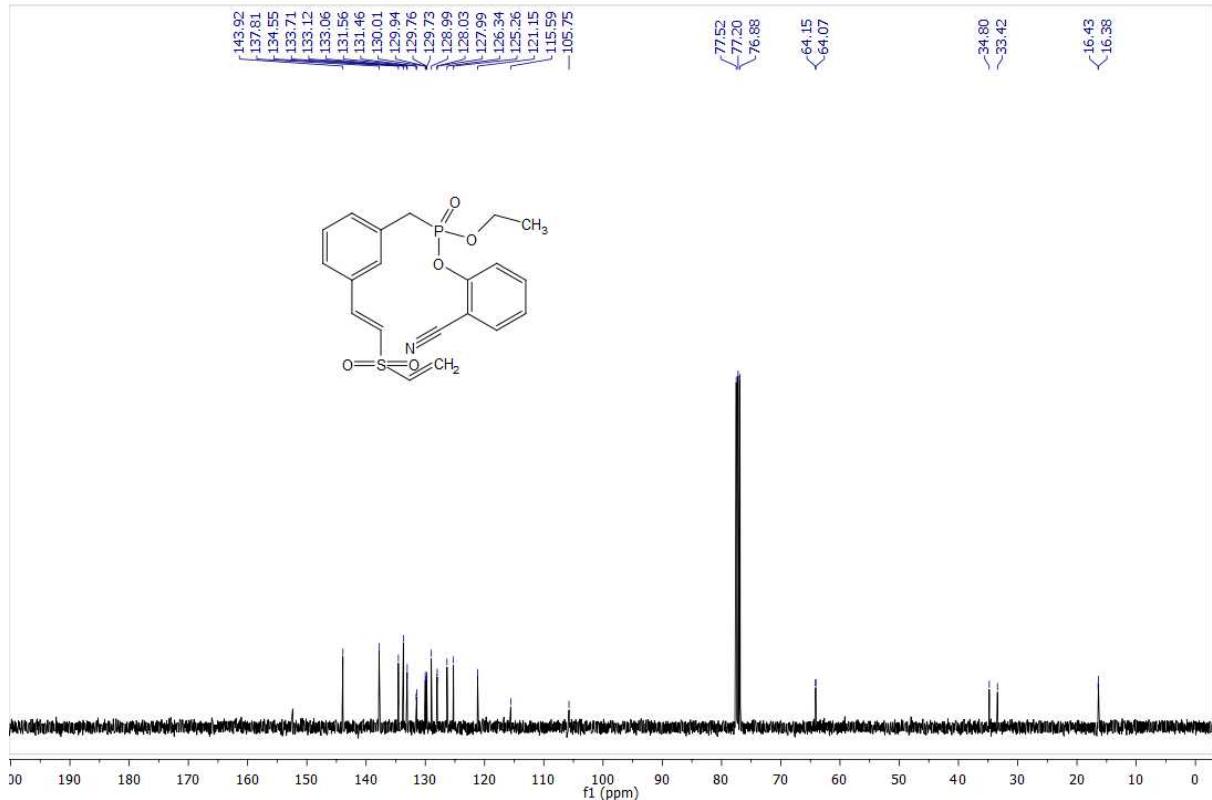


(E)-2-cyanophenyl ethyl 3-(2-(vinylsulfonyl)vinyl)benzylphosphonate (2h):

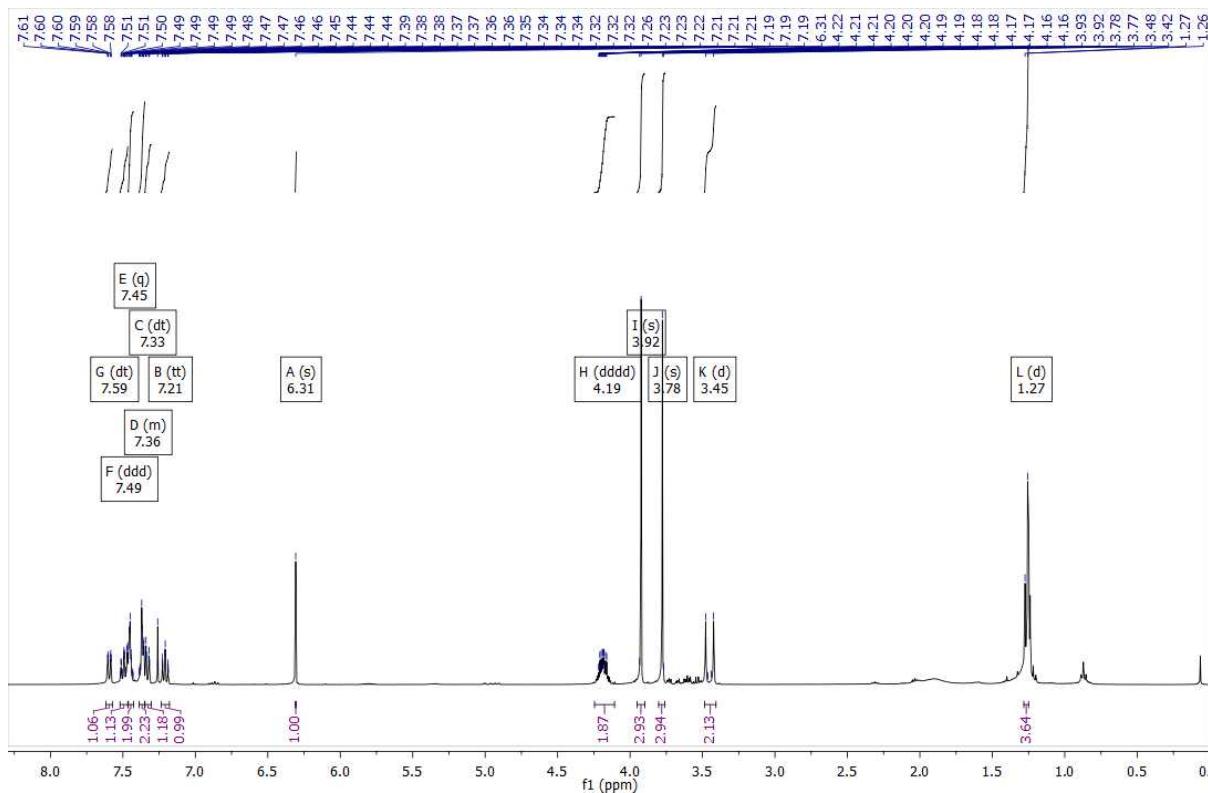
(E)-2-cyanophenyl ethyl 3-(2-(vinylsulfonyl)vinyl)benzylphosphonate



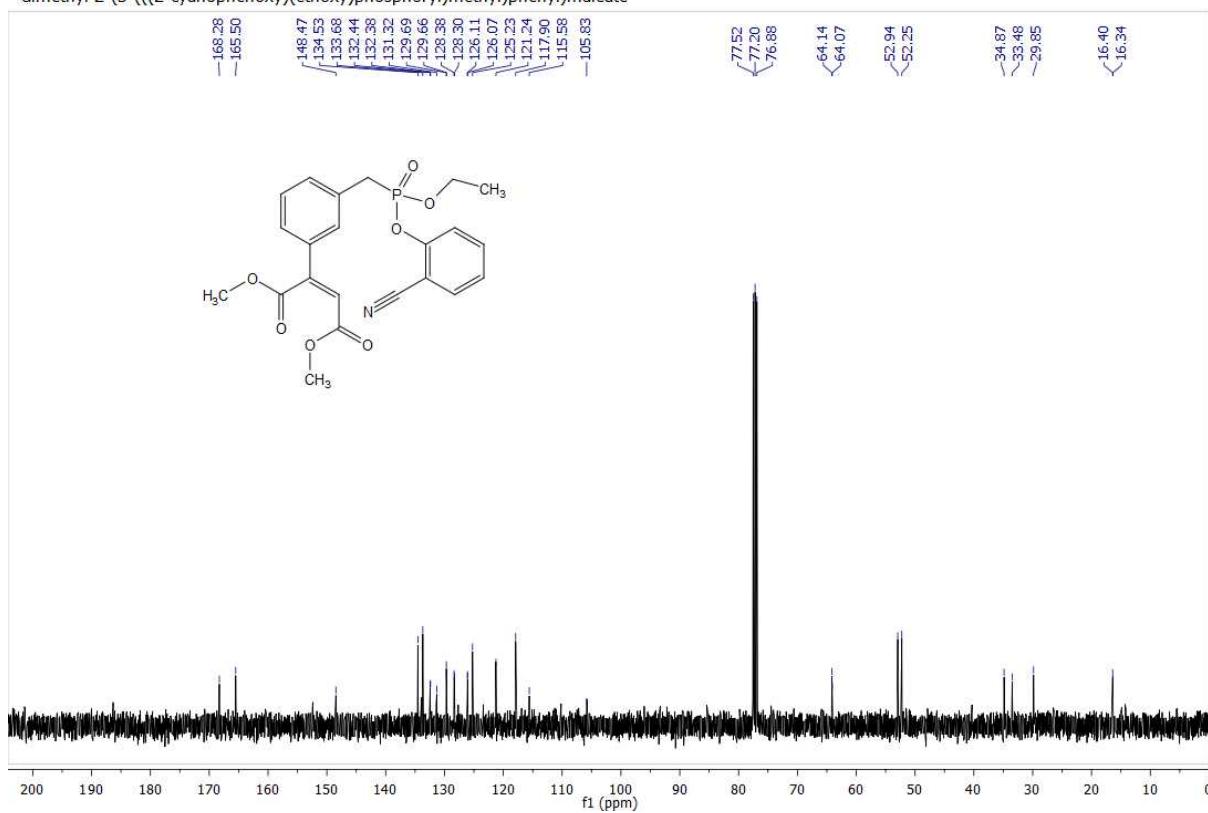
(E)-2-cyanophenyl ethyl 3-(2-(vinylsulfonyl)vinyl)benzylphosphonate



Dimethyl 2-(3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)maleate (2i):

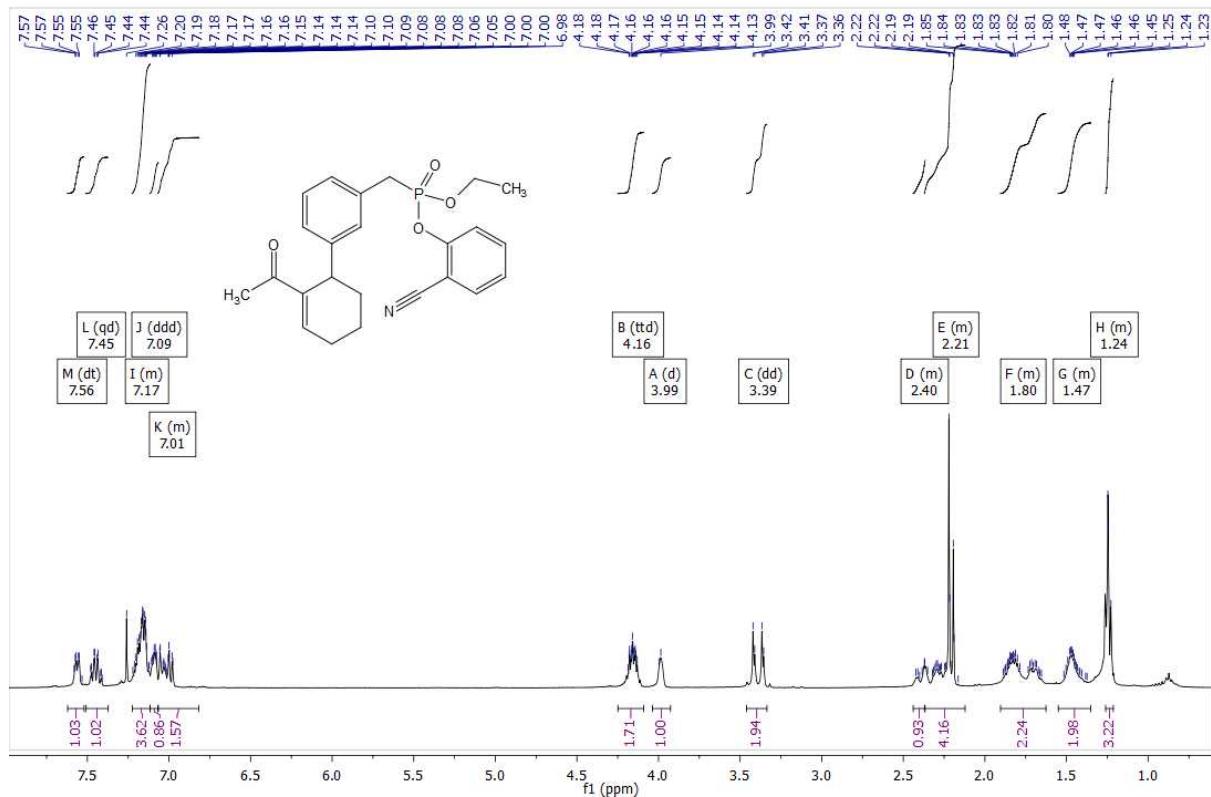


dimethyl 2-(3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)maleate

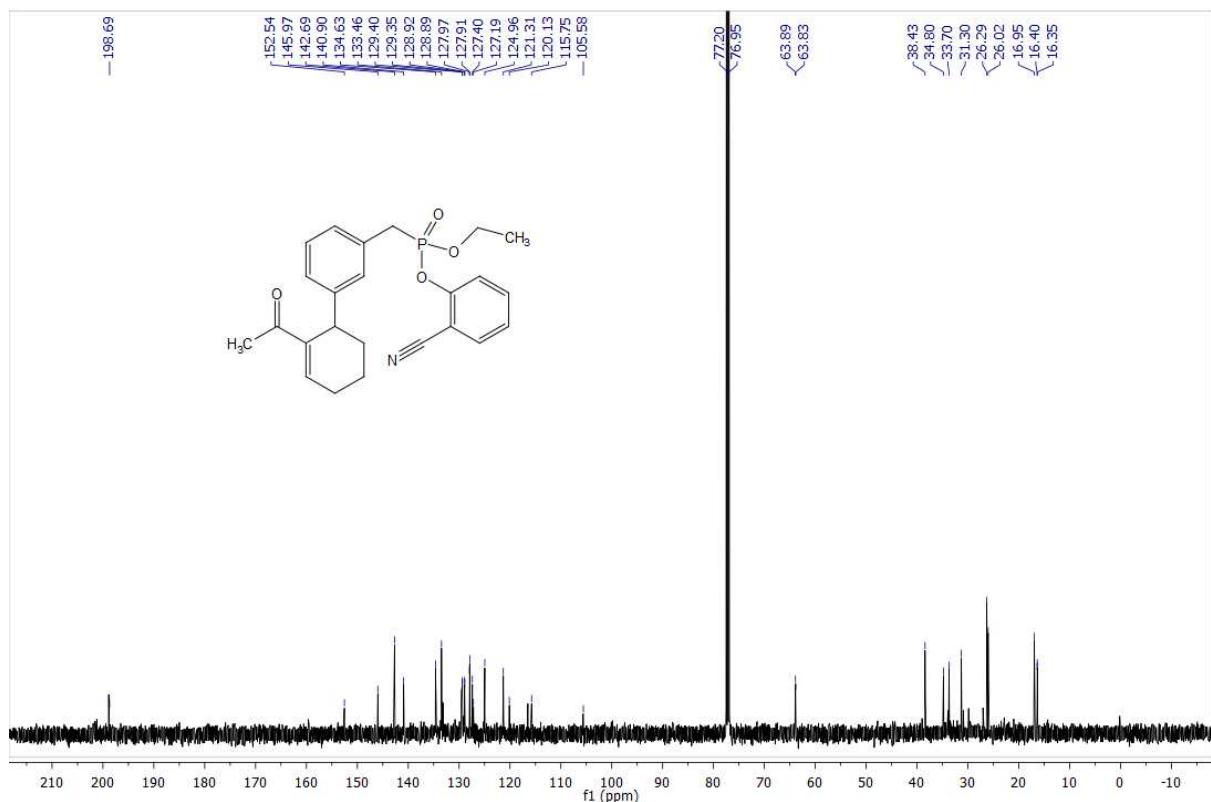


2-Cyanophenyl ethyl ((6'-acetyl-1',2',3',4'-tetrahydro-[1,1'-biphenyl]-3-yl)methyl)phosphonate (2j):

2-cyanophenyl ethyl ((6'-acetyl-1',2',3',4'-tetrahydro-[1,1'-biphenyl]-3-yl)methyl)phosphonate

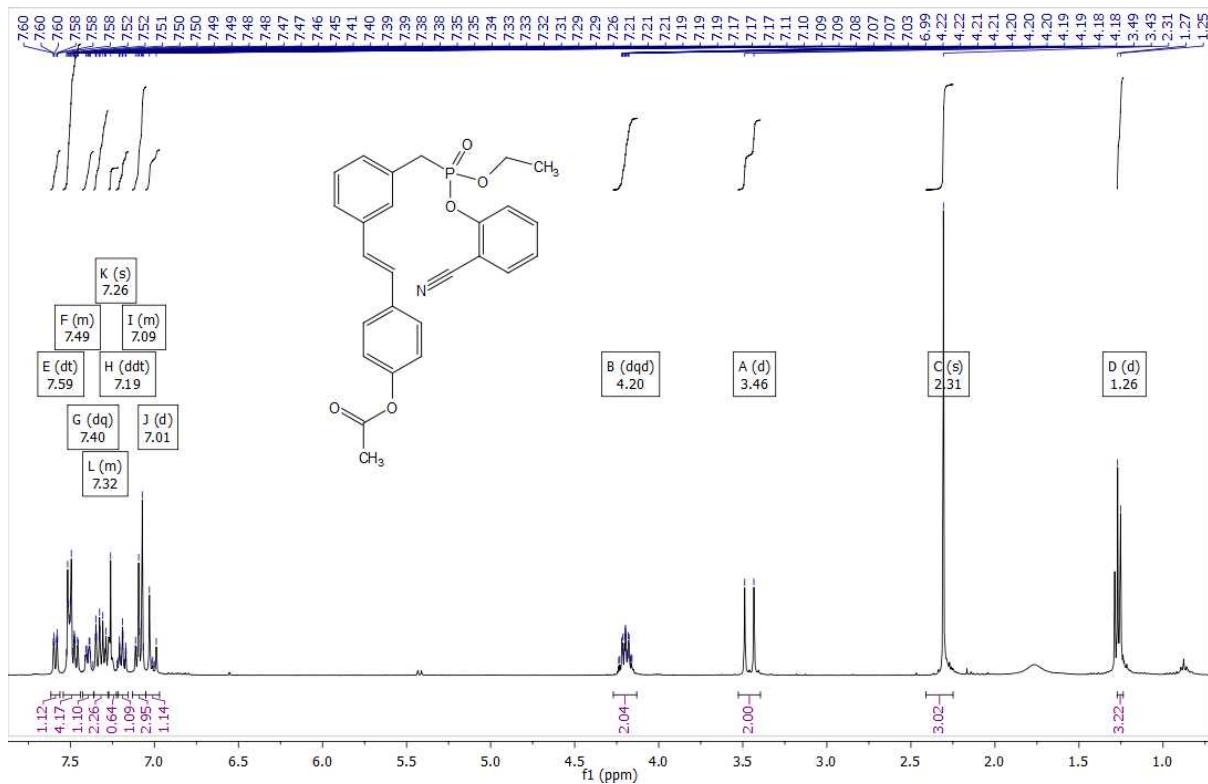


2-cyanophenyl ethyl ((6'-acetyl-1',2',3',4'-tetrahydro-[1,1'-biphenyl]-3-yl)methyl)phosphonate

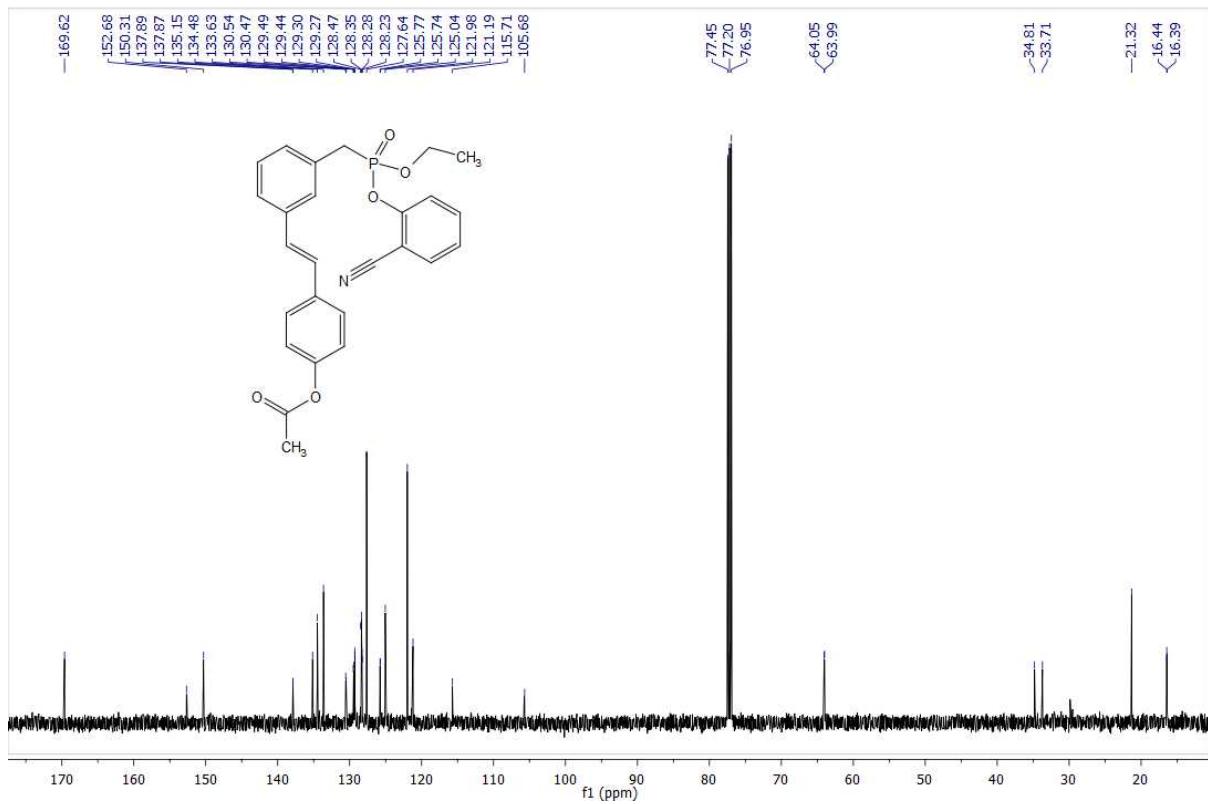


(E)-4-(3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)styryl)phenyl acetate (2k):

(E)-4-(3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)styryl)phenyl acetate

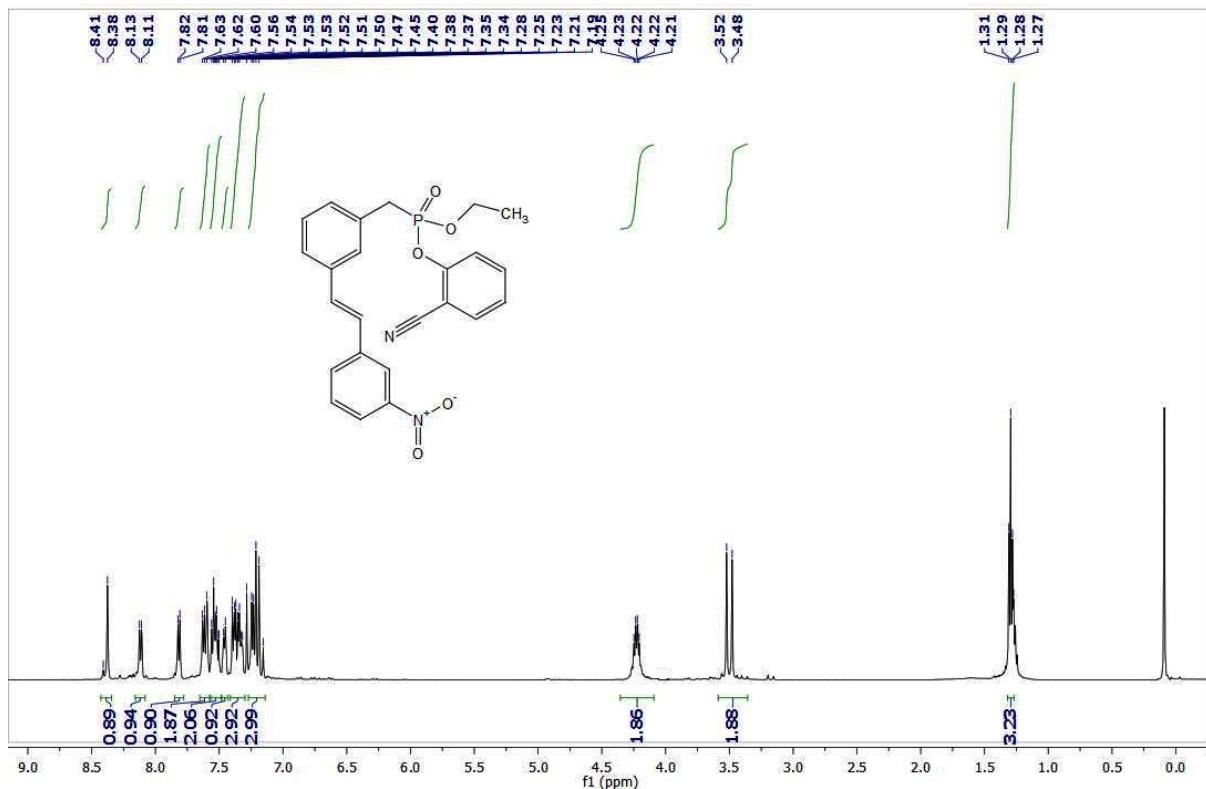


(E)-4-(3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)styryl)phenyl acetate

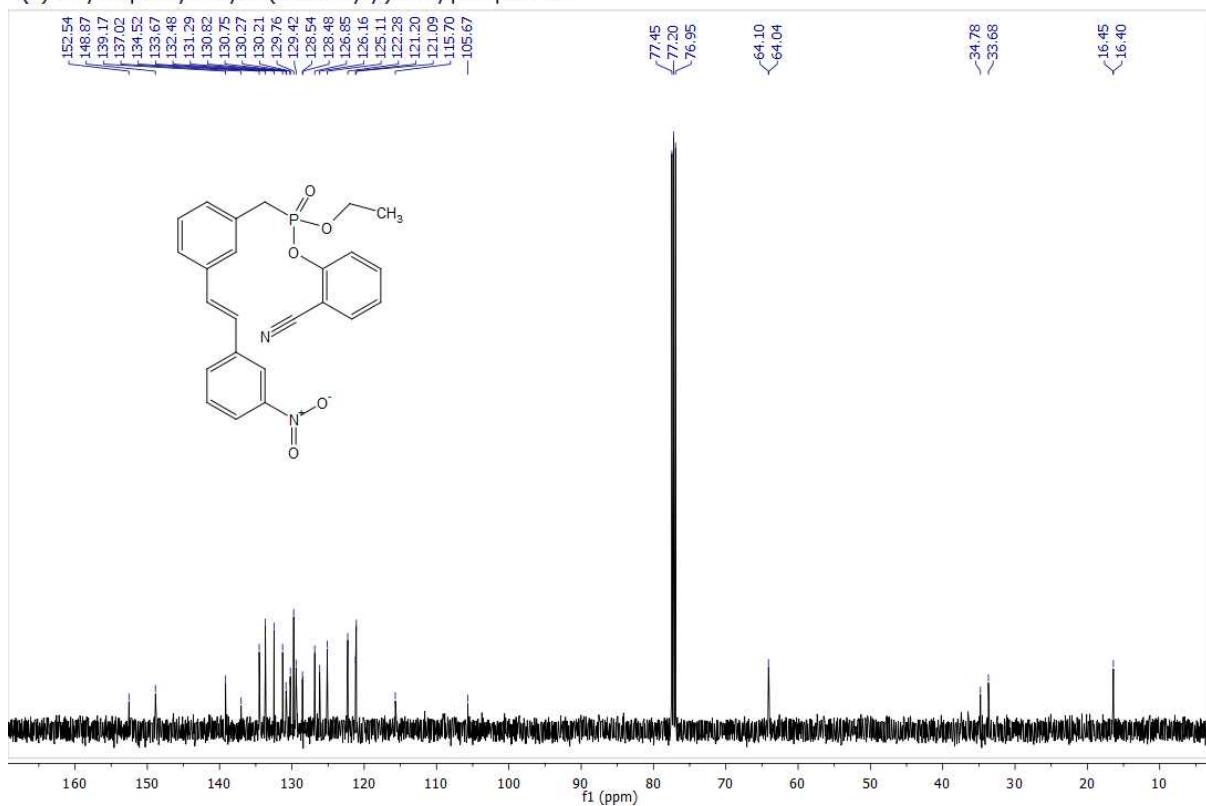


(E)-2-cyanophenyl ethyl 3-(3-nitrostyryl)benzylphosphonate (2l):

(E)-2-cyanophenyl ethyl 3-(3-nitrostyryl)benzylphosphonate

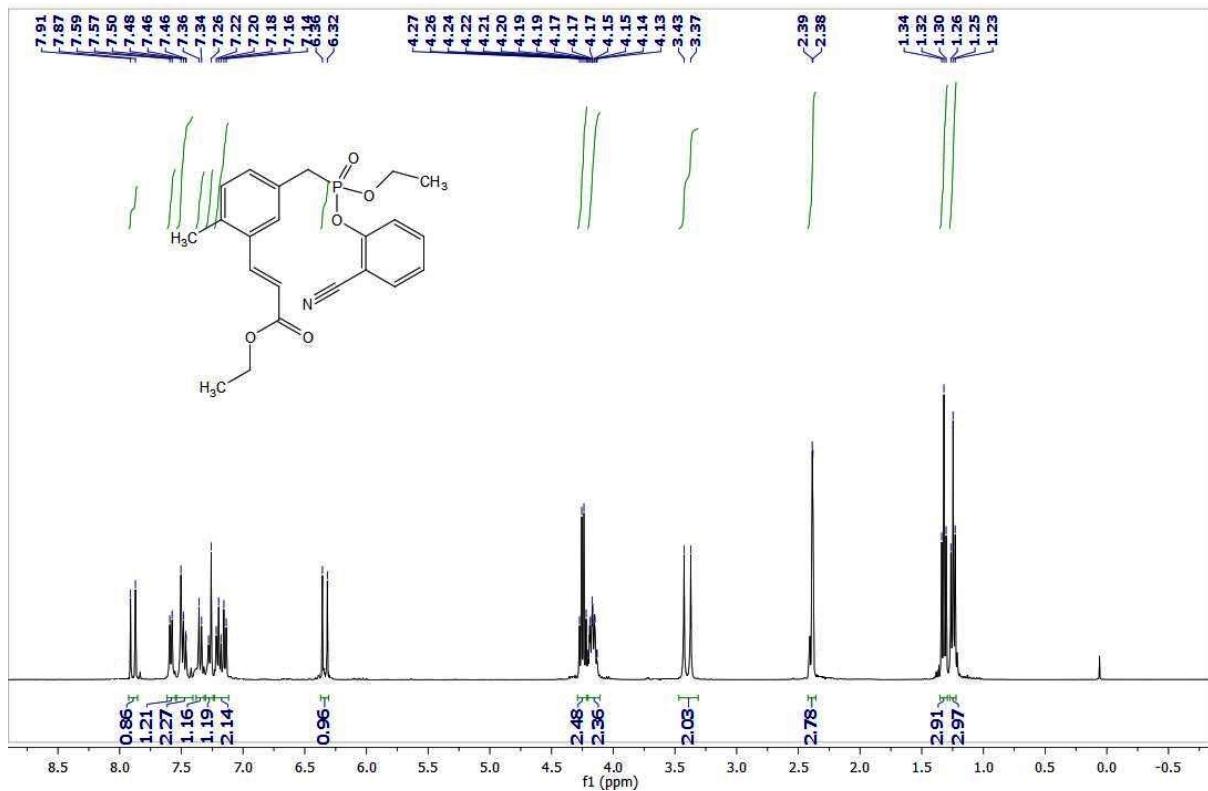


(E)-2-cyanophenyl ethyl 3-(3-nitrostyryl)benzylphosphonate

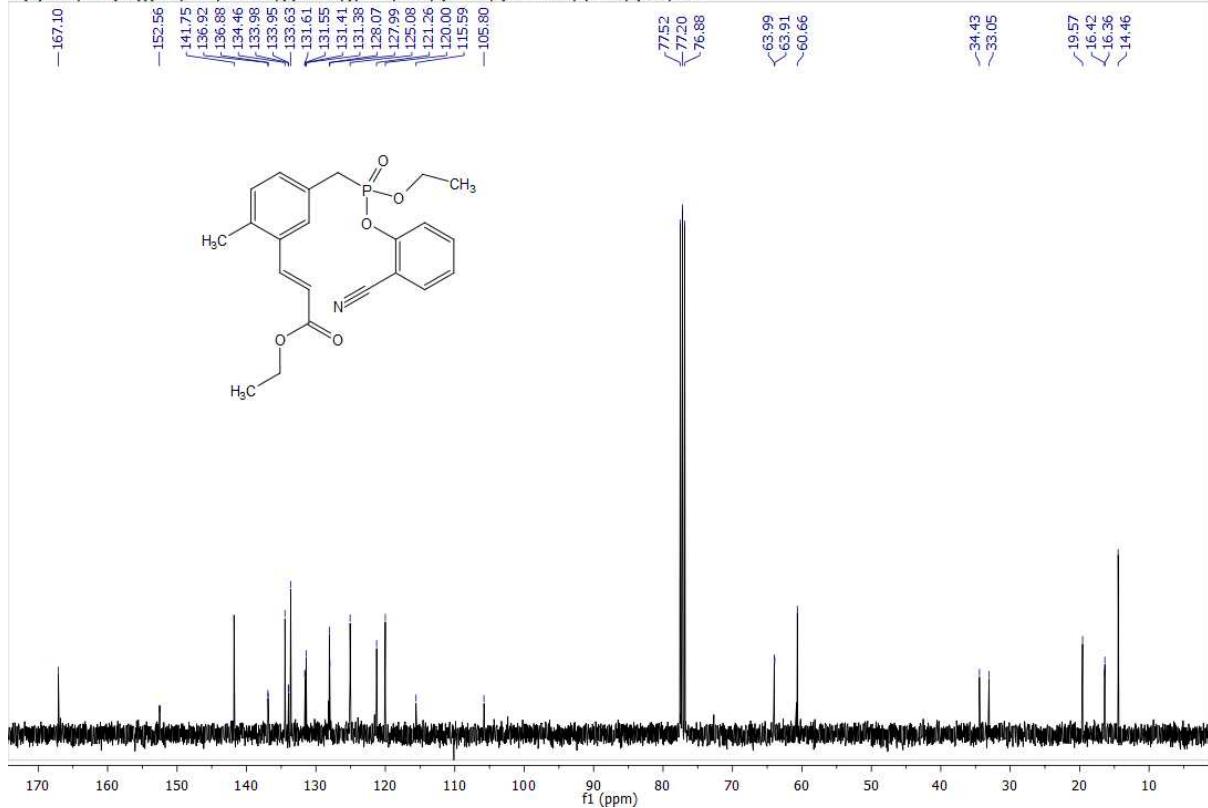


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methylphenyl)acrylate (2m):

(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methylphenyl)acrylate

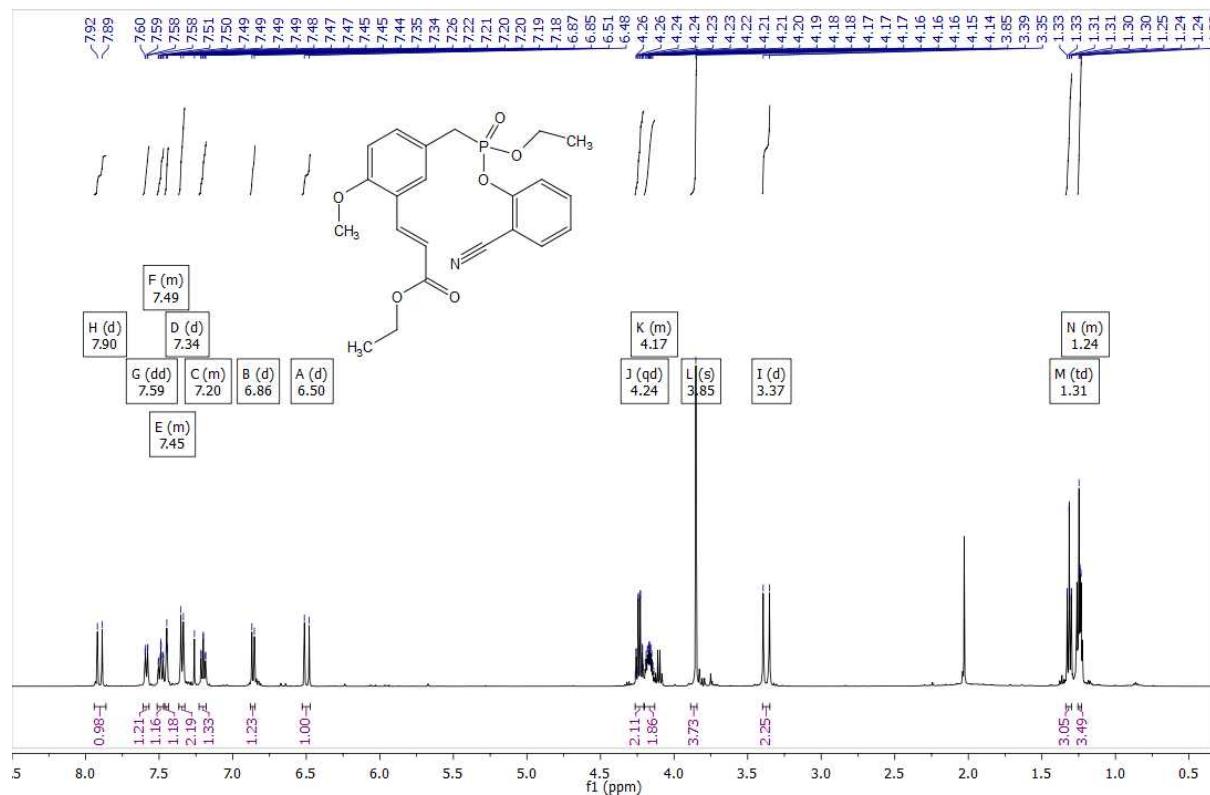


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methylphenyl)acrylate

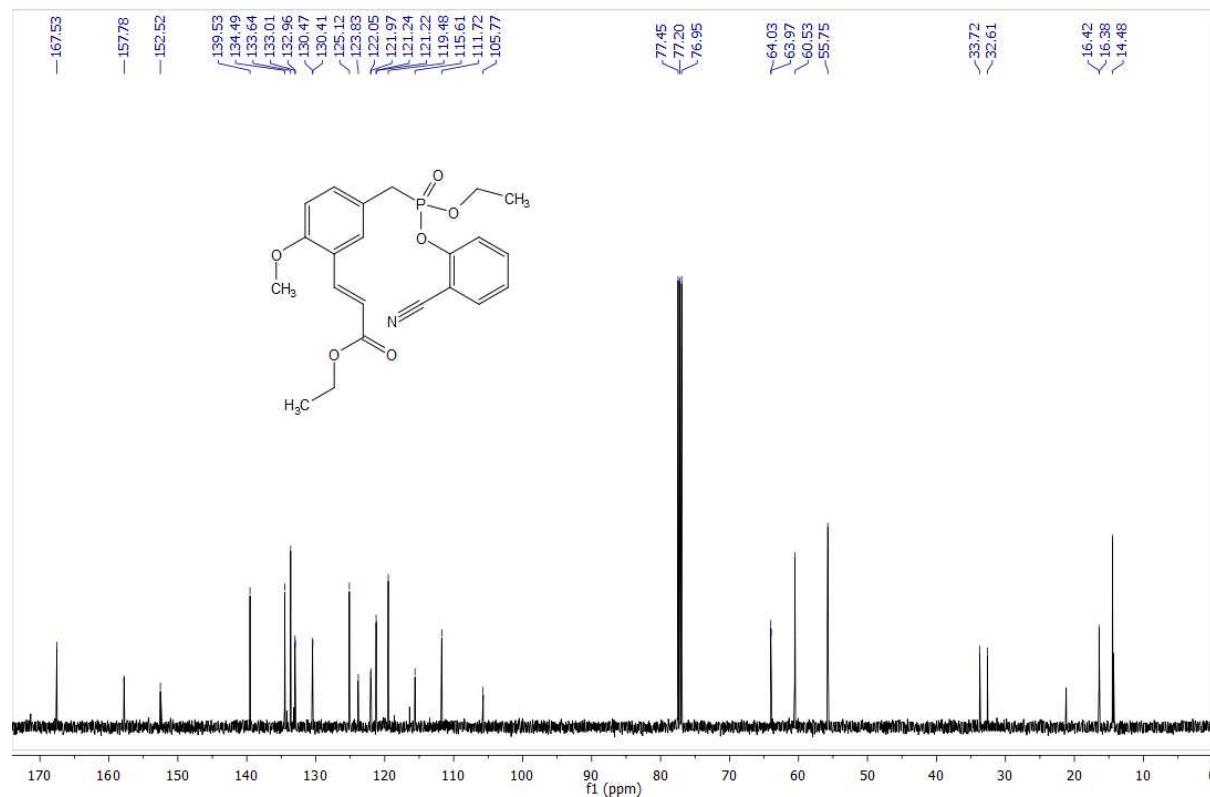


(E)-ethyl 3-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methoxyphenyl)acrylate (2n):

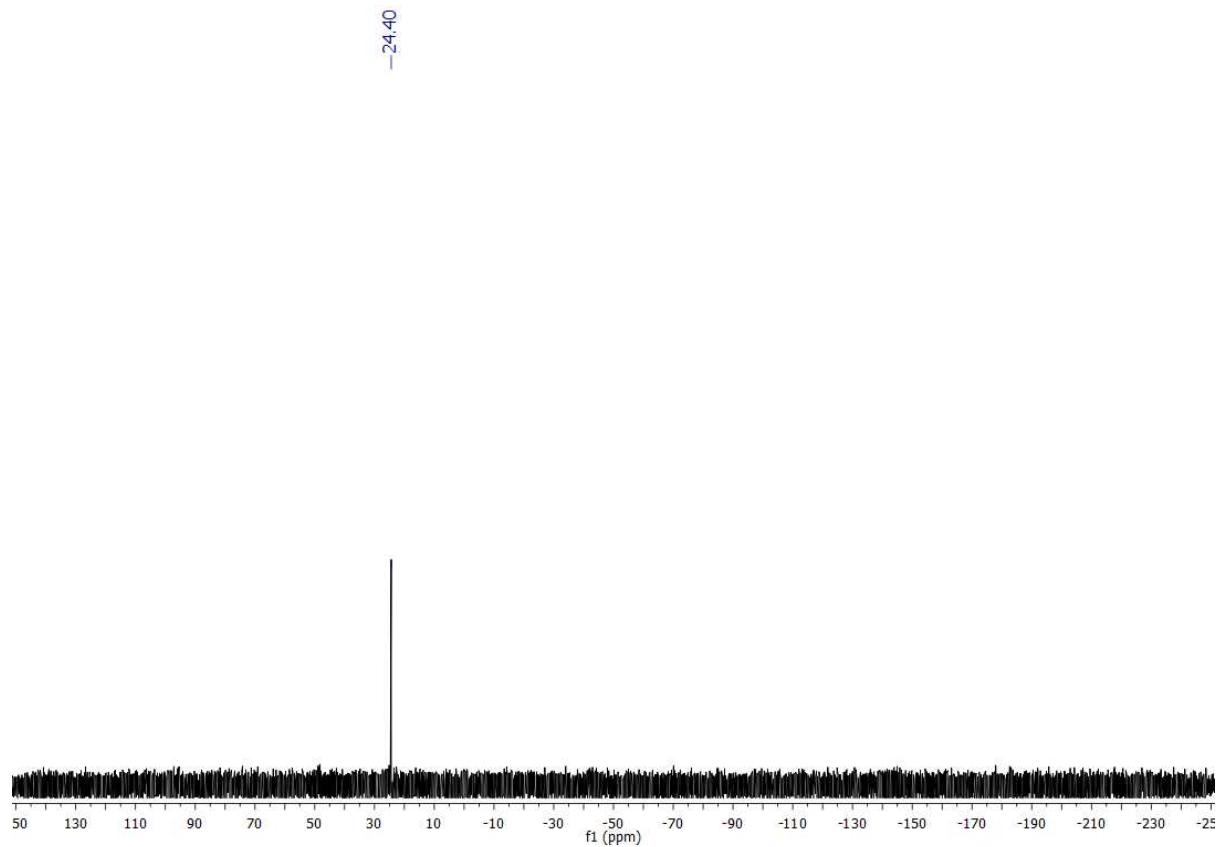
(E)-ethyl 3-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methoxyphenyl)acrylate



(E)-ethyl 3-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methoxyphenyl)acrylate

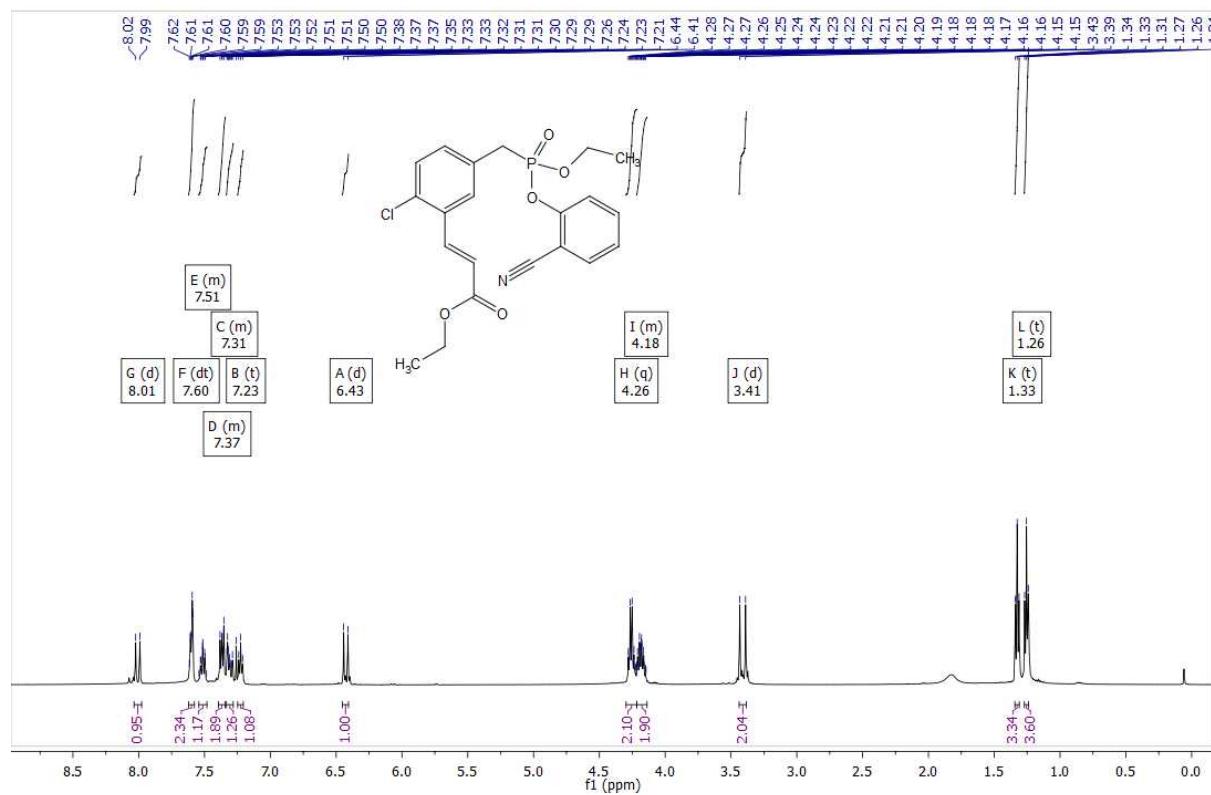


31P NMR:

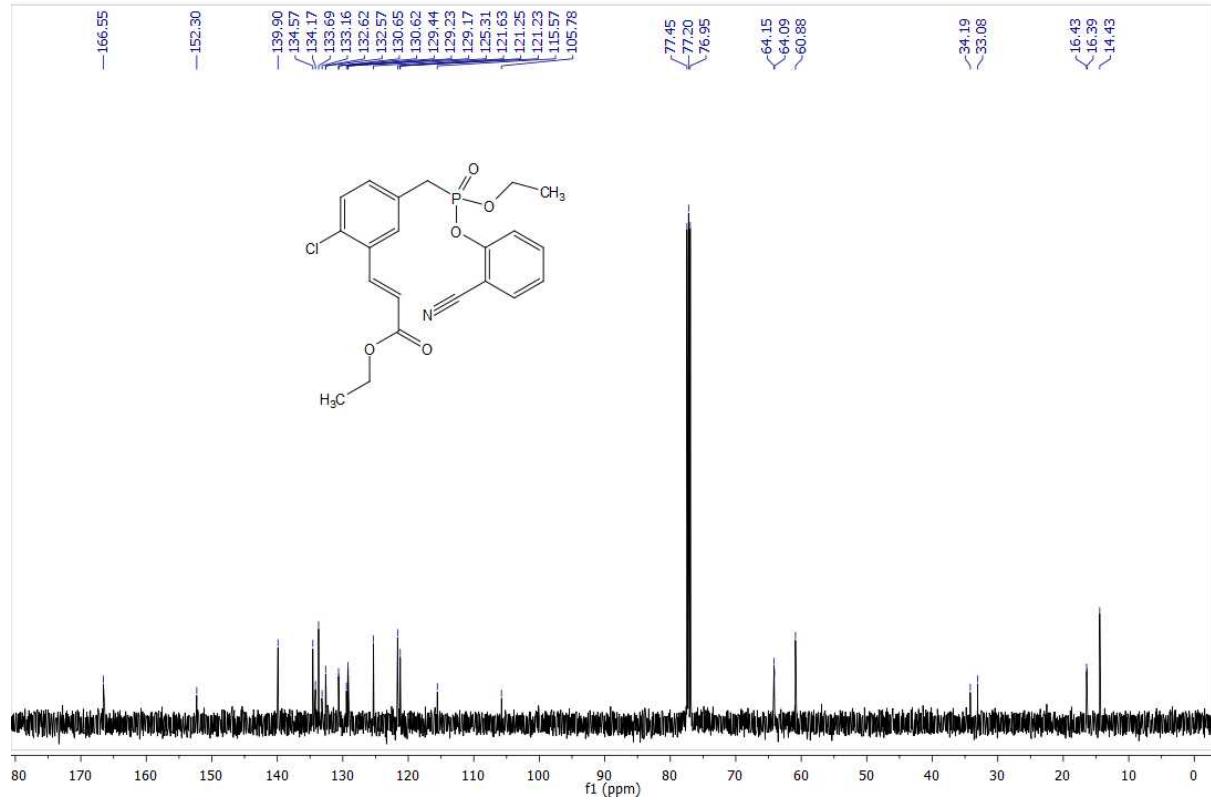


(E)-ethyl 3-(2-chloro-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2p):

(E)-ethyl 3-(2-chloro-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate

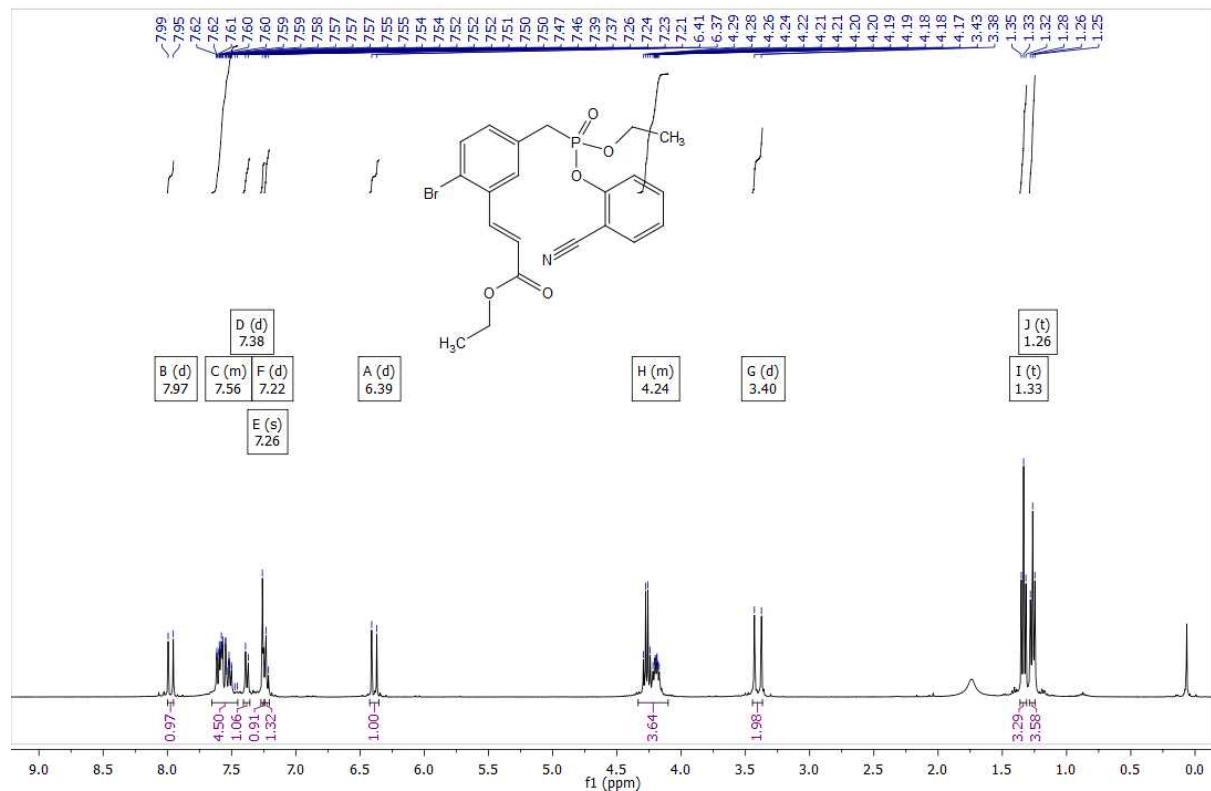


(E)-ethyl 3-(2-chloro-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate

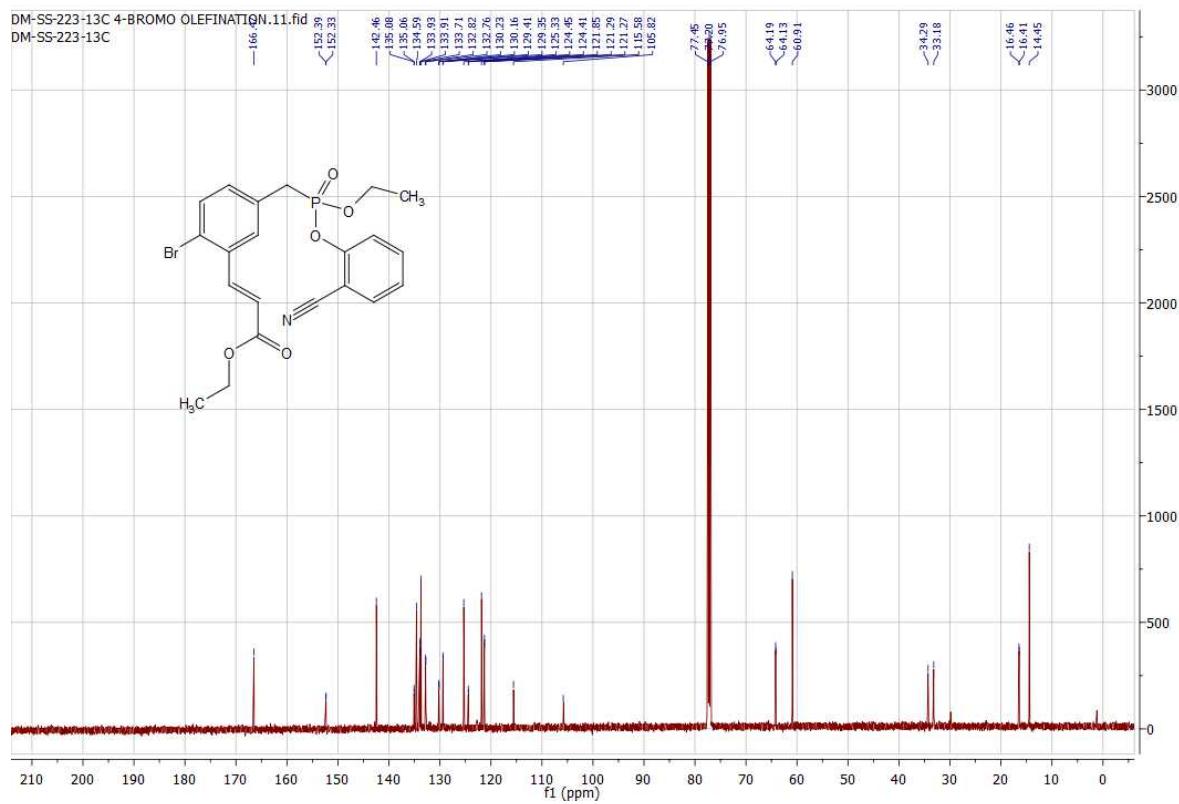


(E)-ethyl 3-(2-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2q):

(E)-ethyl 3-(2-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate

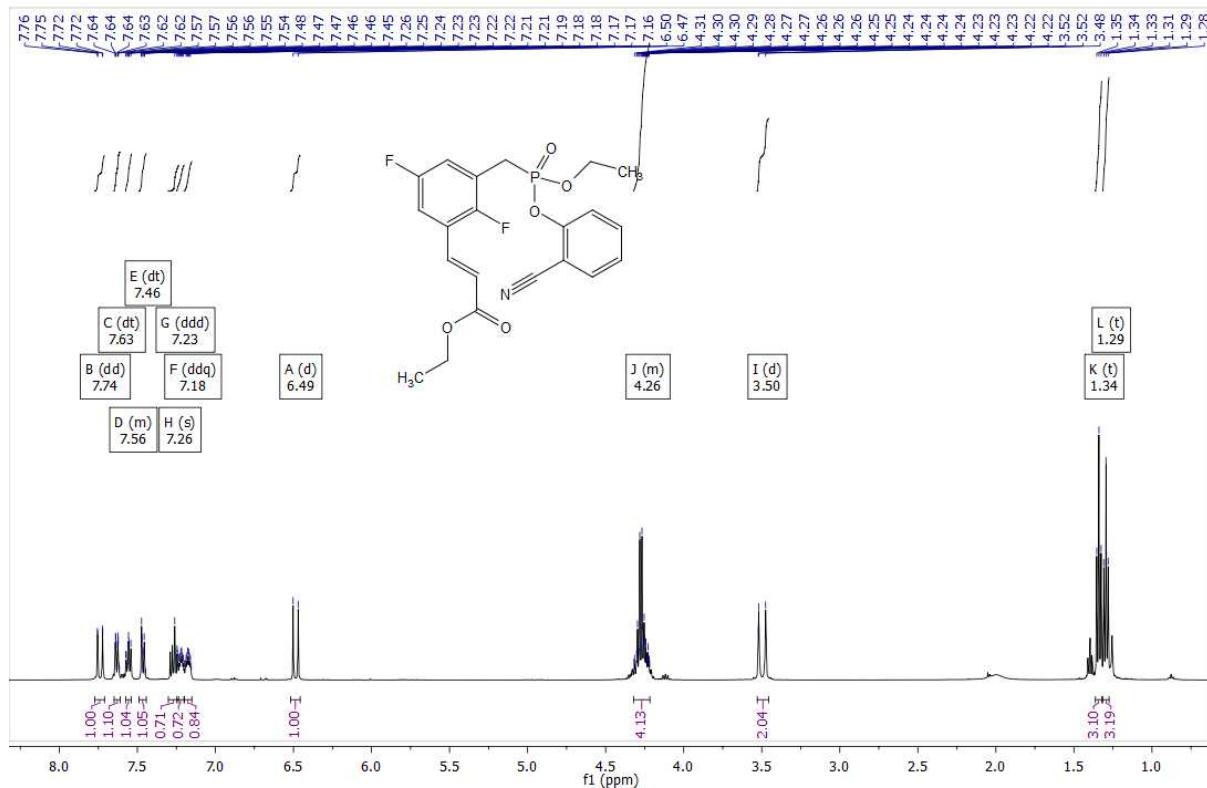


(E)-ethyl 3-(2-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate

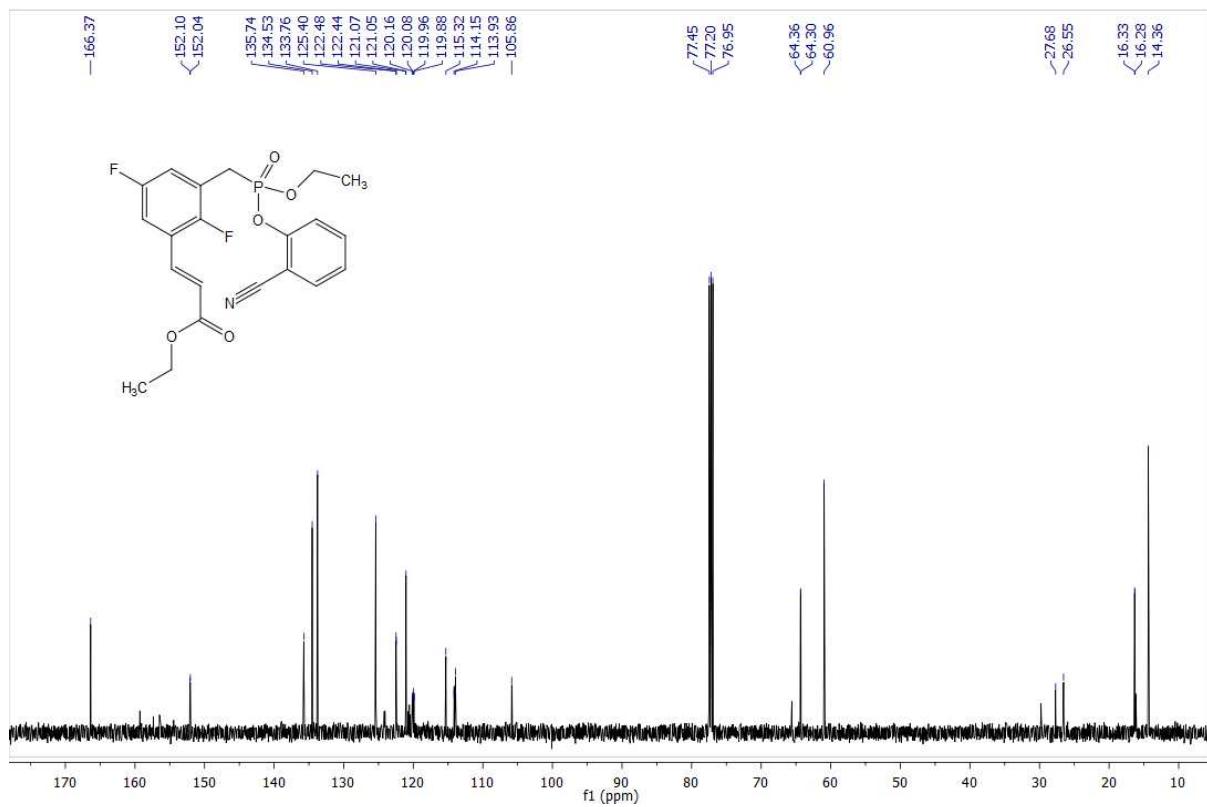


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2,5-difluorophenylacrylate (2r):

(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2,5-difluorophenylacrylate

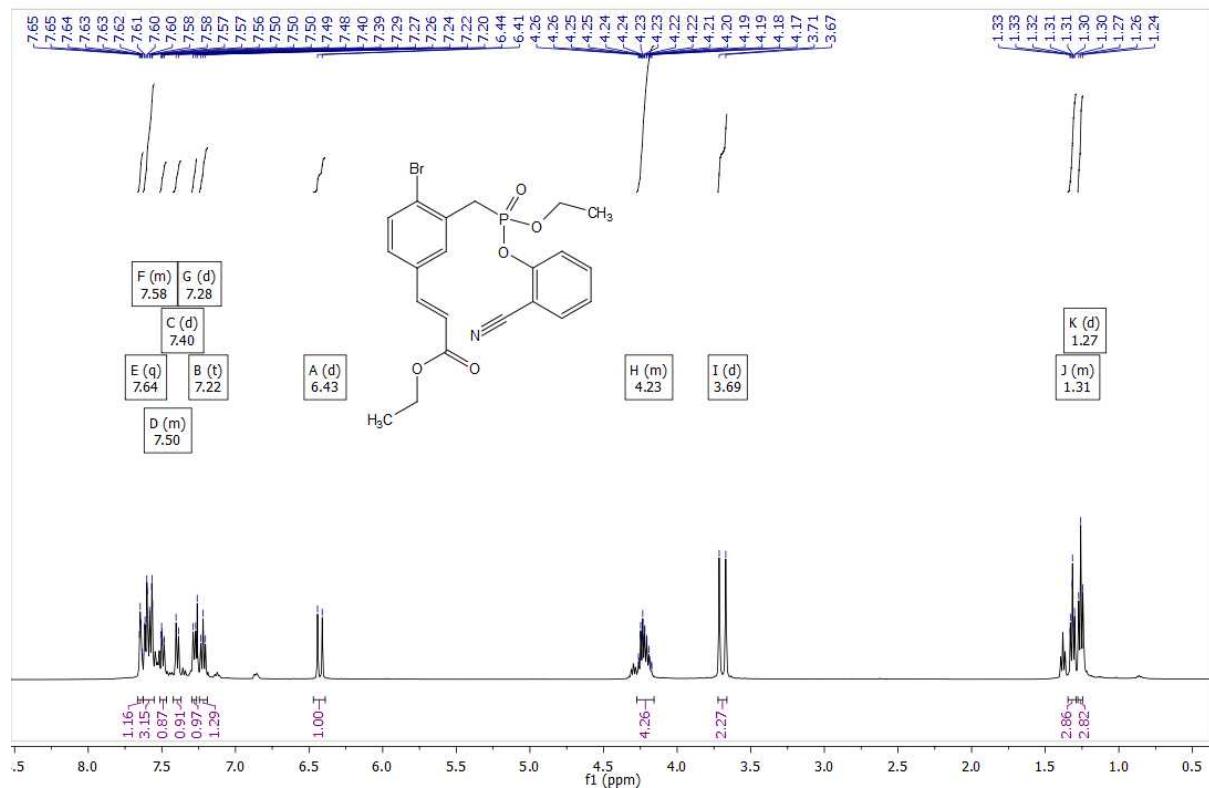


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2,5-difluorophenylacrylate

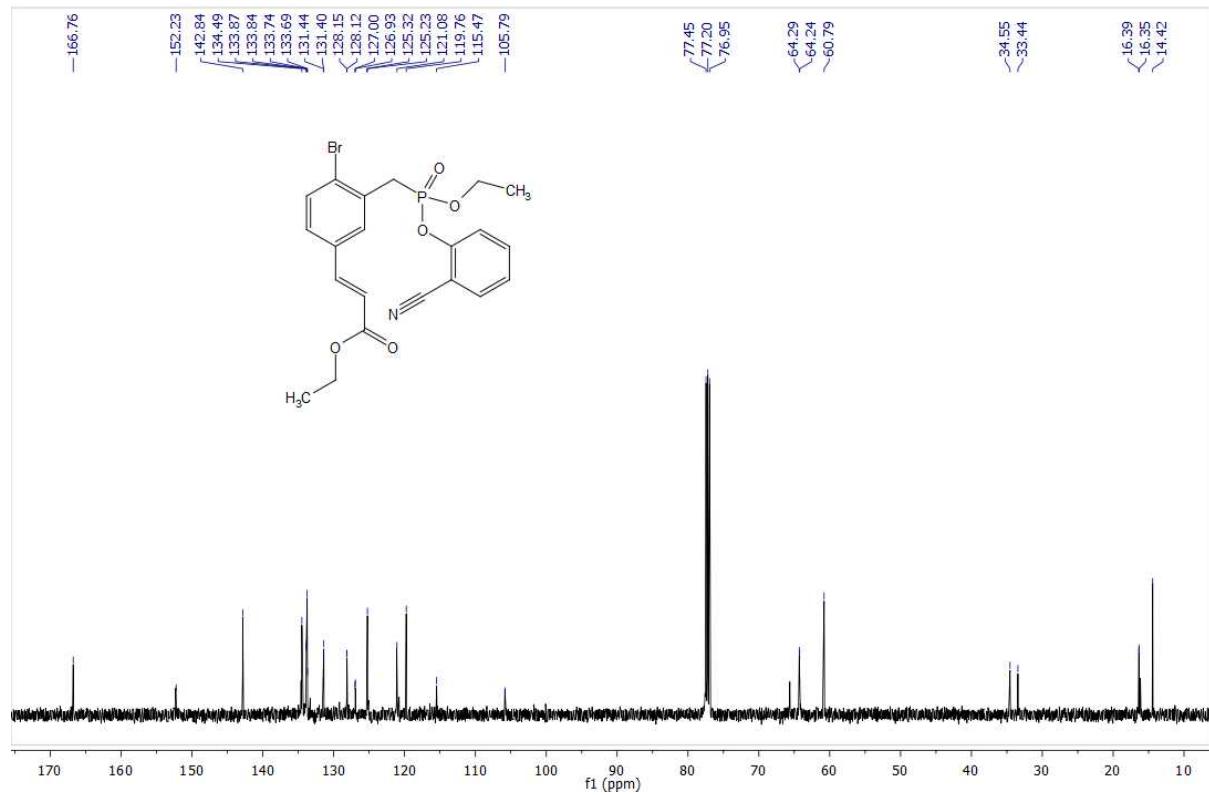


(E)-ethyl 3-(4-bromo-3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2s):

(E)-ethyl 3-(4-bromo-3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate

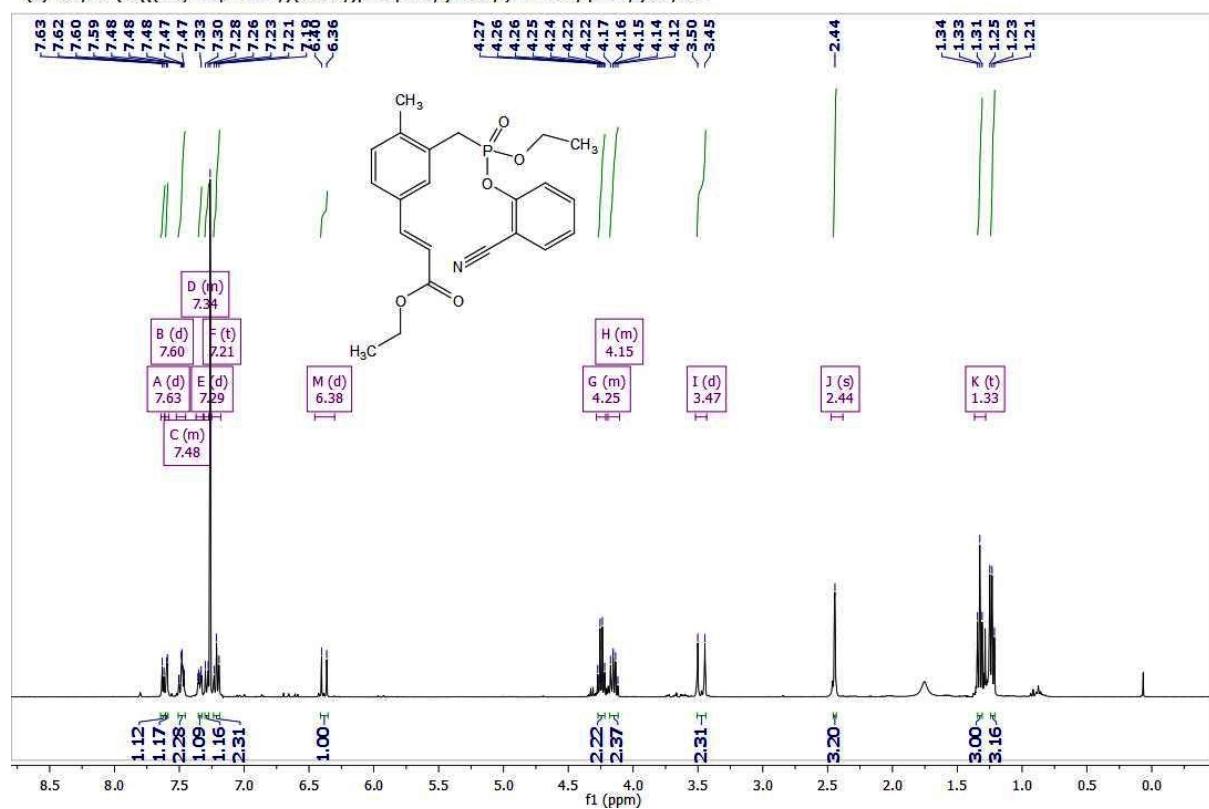


(E)-ethyl 3-(4-bromo-3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate

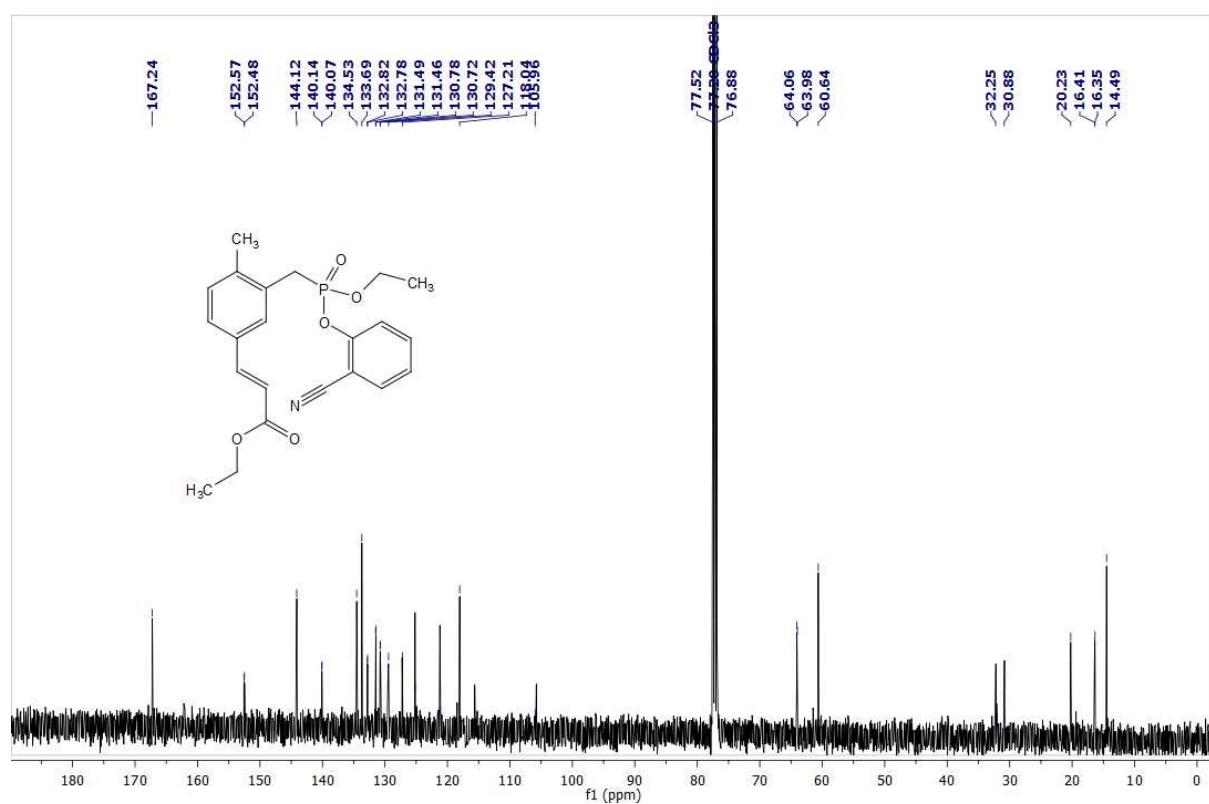


(E)-ethyl 3-((3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-4-methylphenyl)acrylates (2t):

(E)-ethyl 3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-4-methylphenyl)acrylate

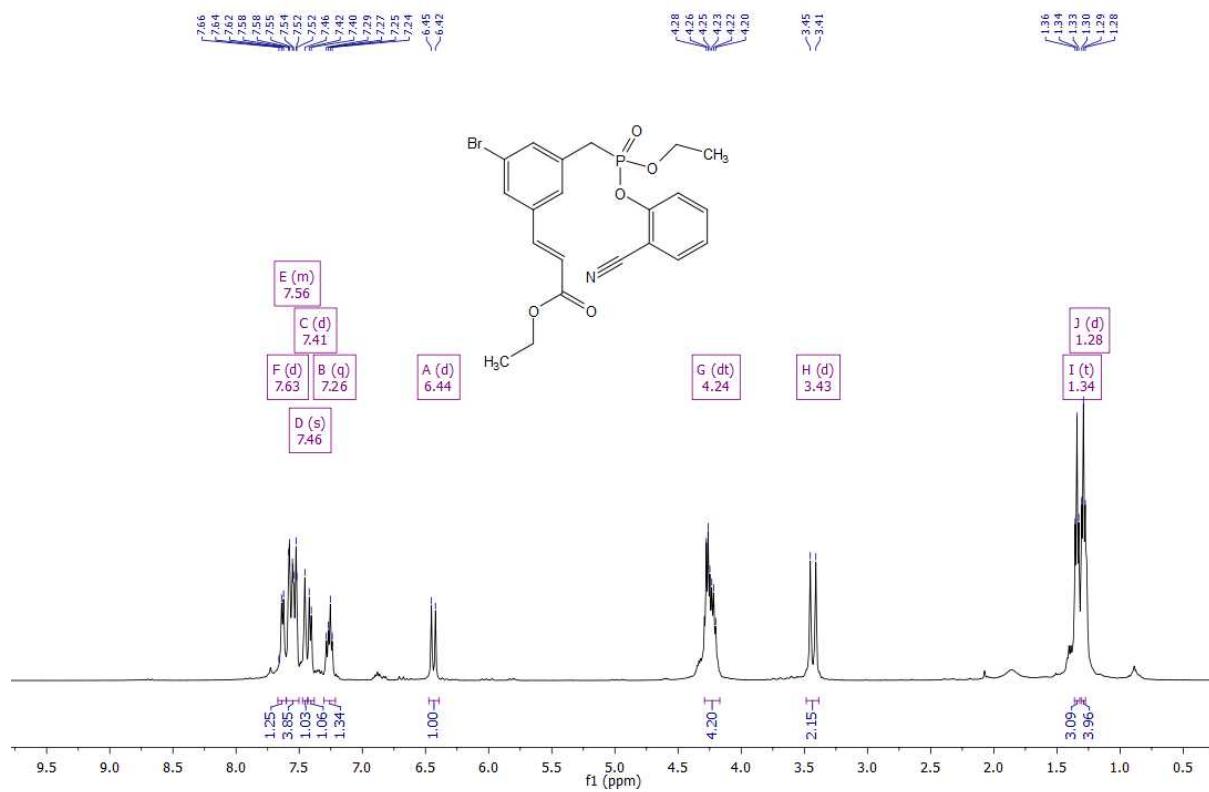


(E)-ethyl 3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-4-methylphenyl)acrylate

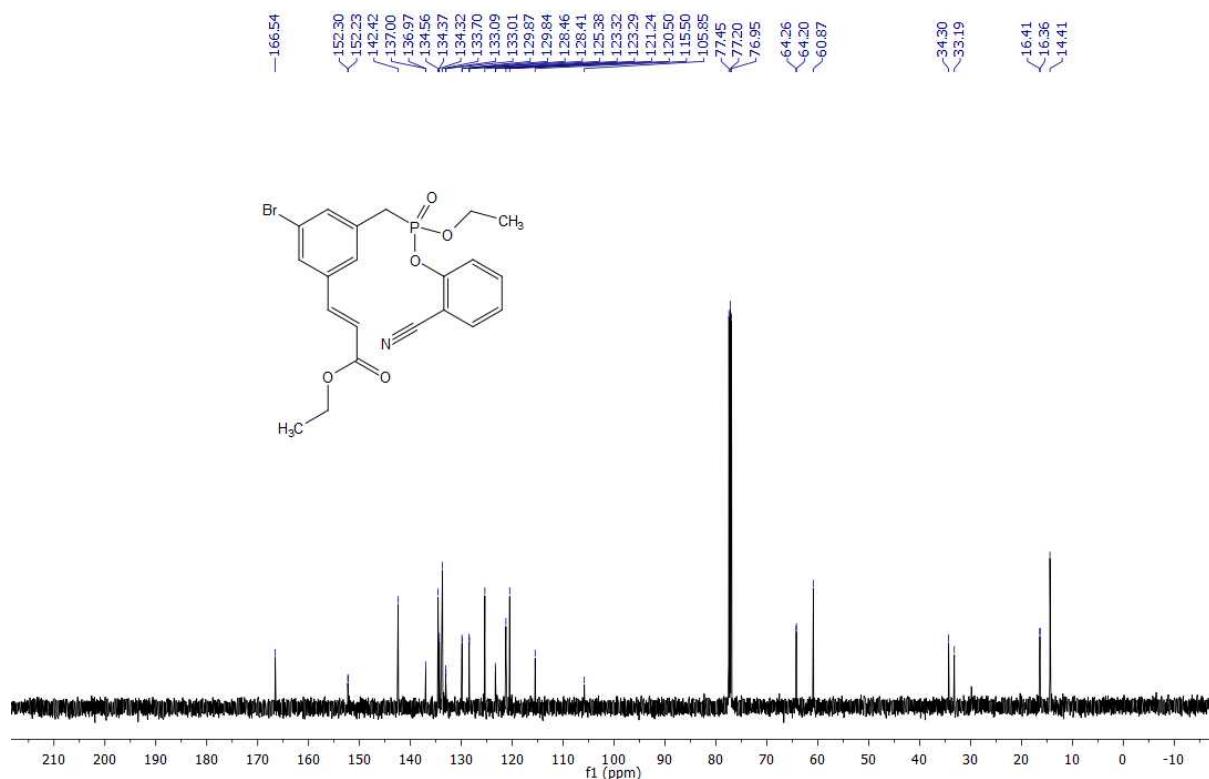


(E)-ethyl 3-(3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate (2u):

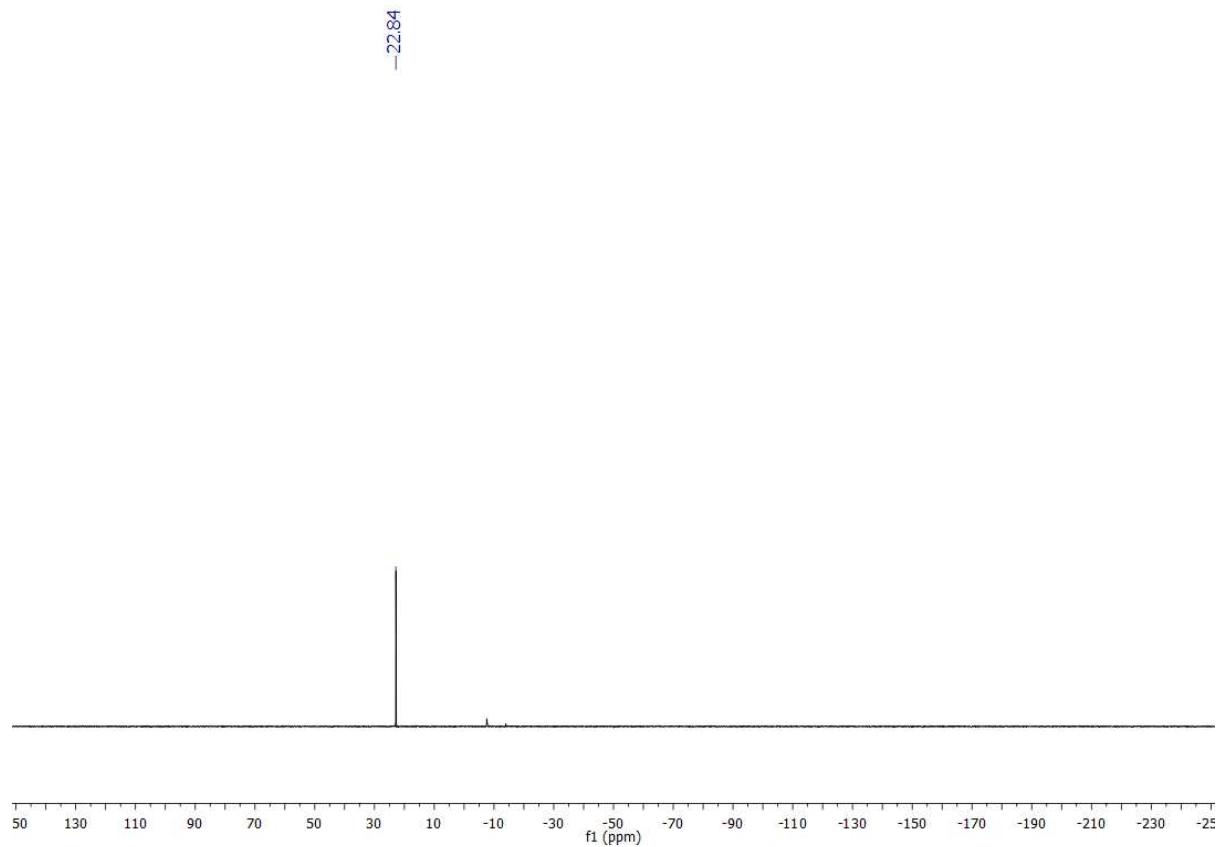
(E)-ethyl 3-(3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate



(E)-ethyl 3-(3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate

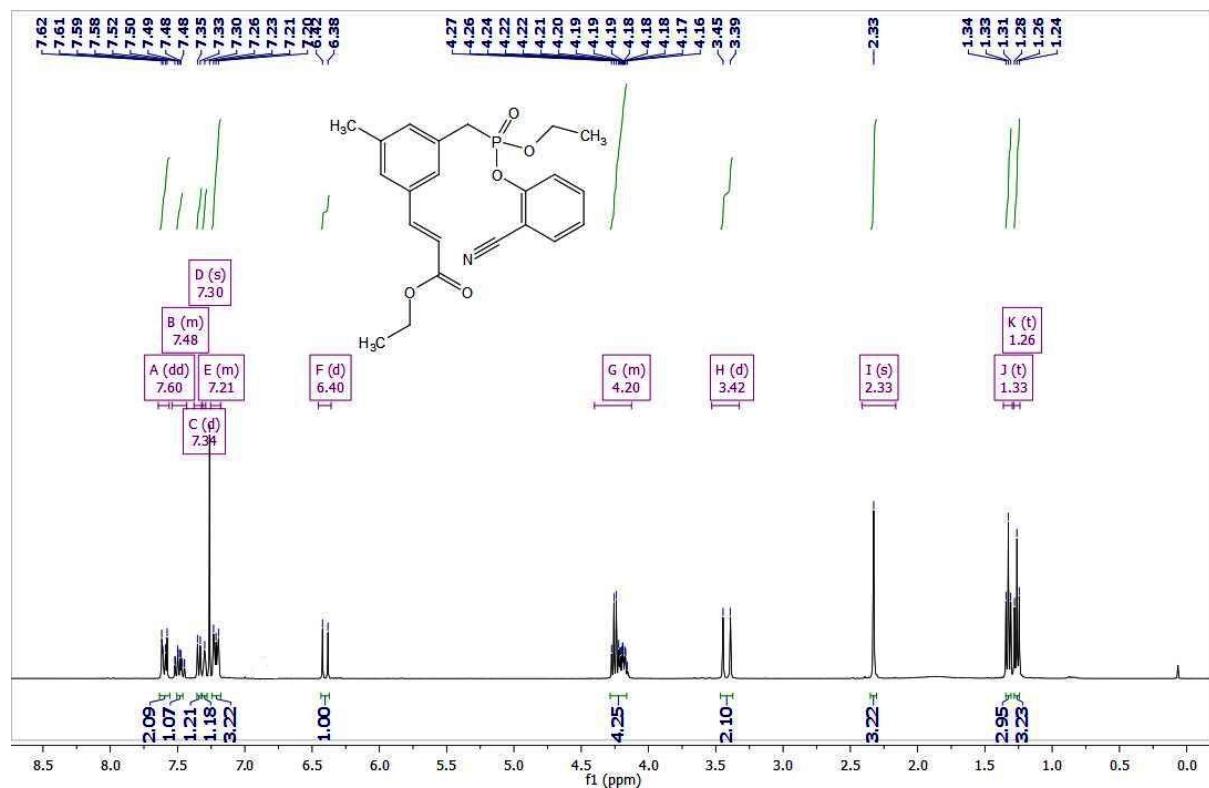


31P NMR:

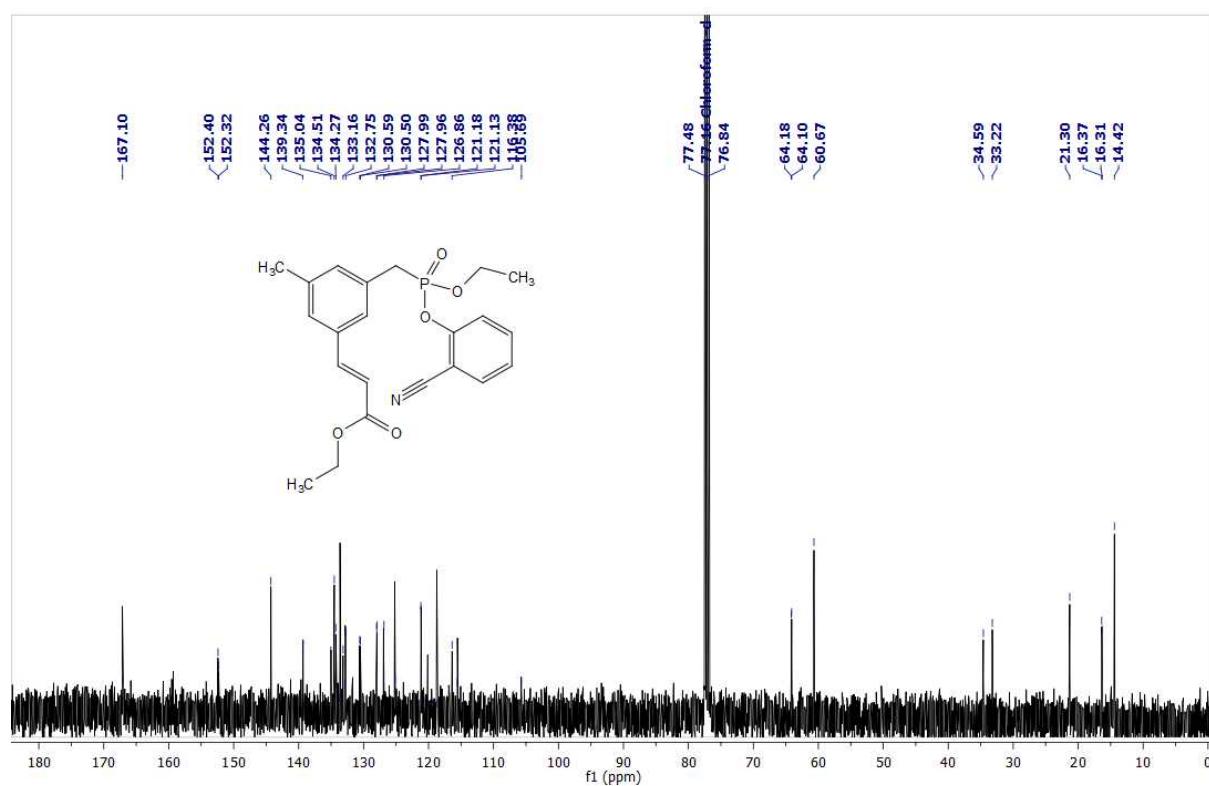


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-methylphenyl)acrylates (2v):

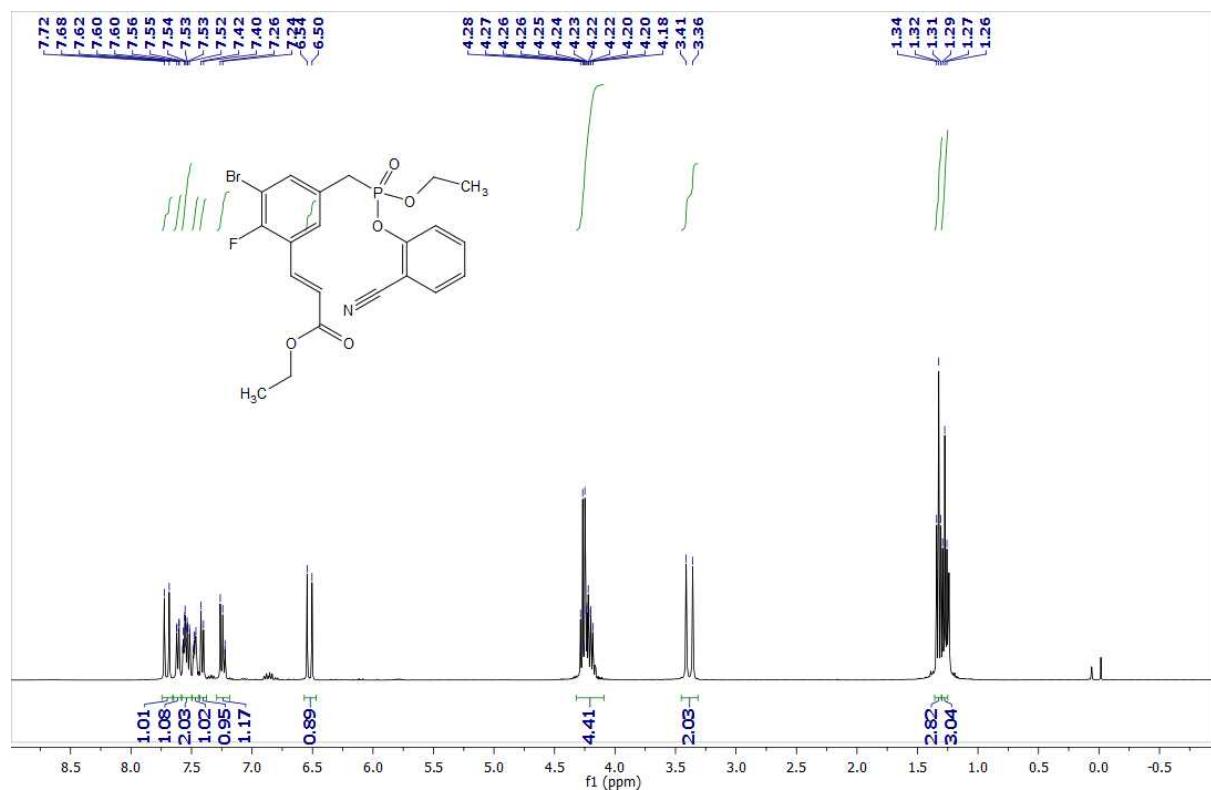
(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-methylphenyl)acrylate



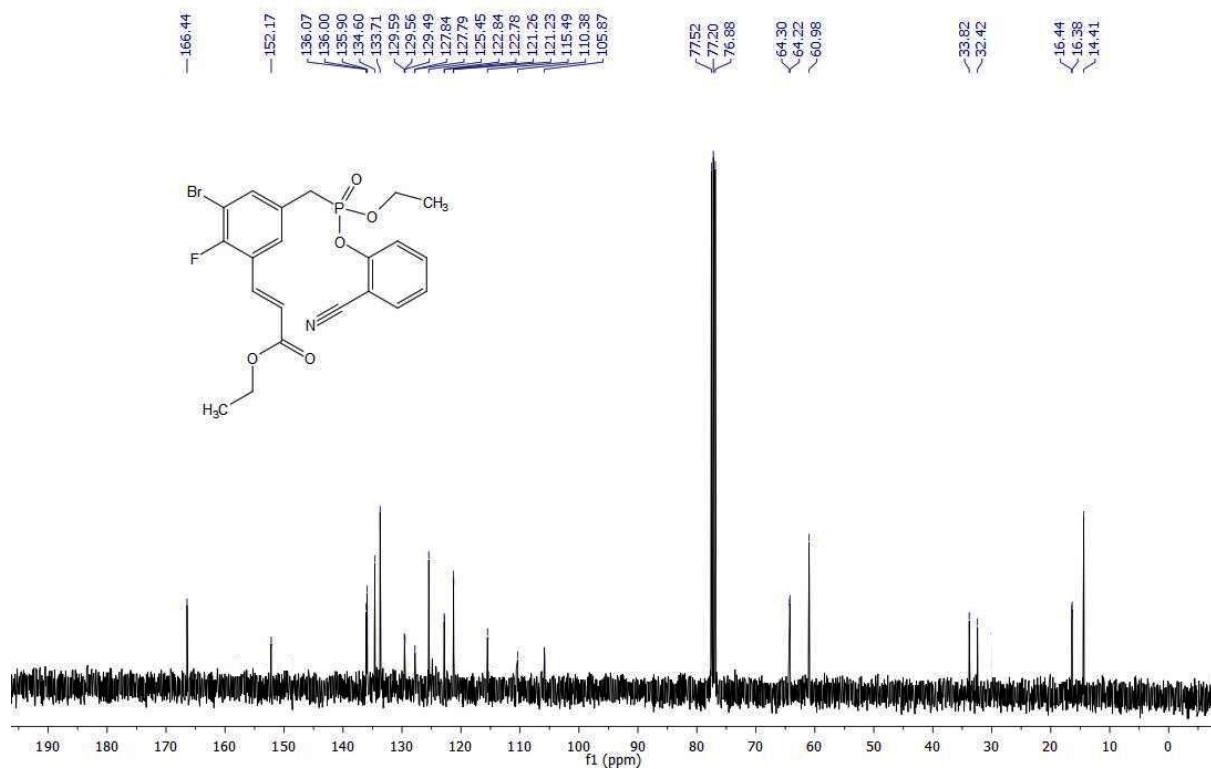
(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-methylphenyl)acrylate



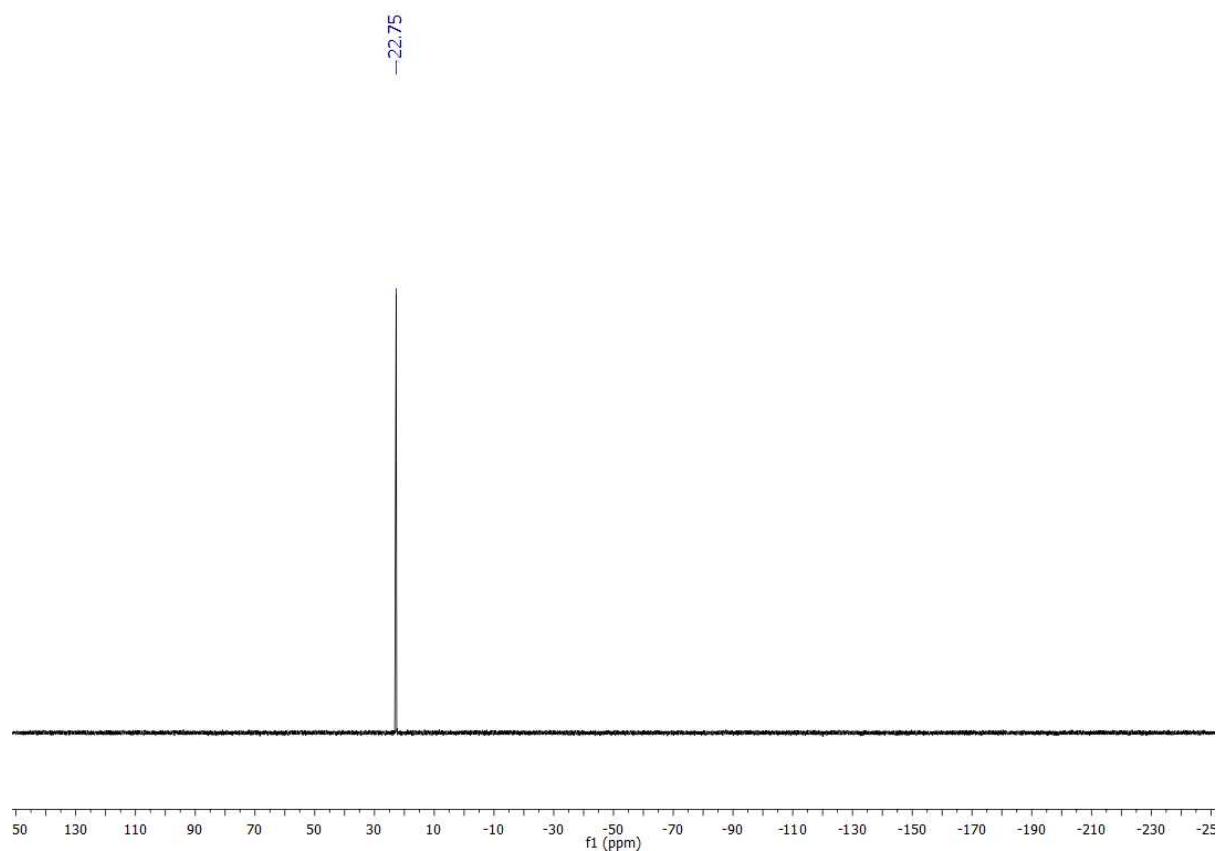
(E)-ethyl 3-(3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-fluorophenyl)acrylate (2w):



(E)-ethyl 3-(3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-fluorophenyl)acrylate



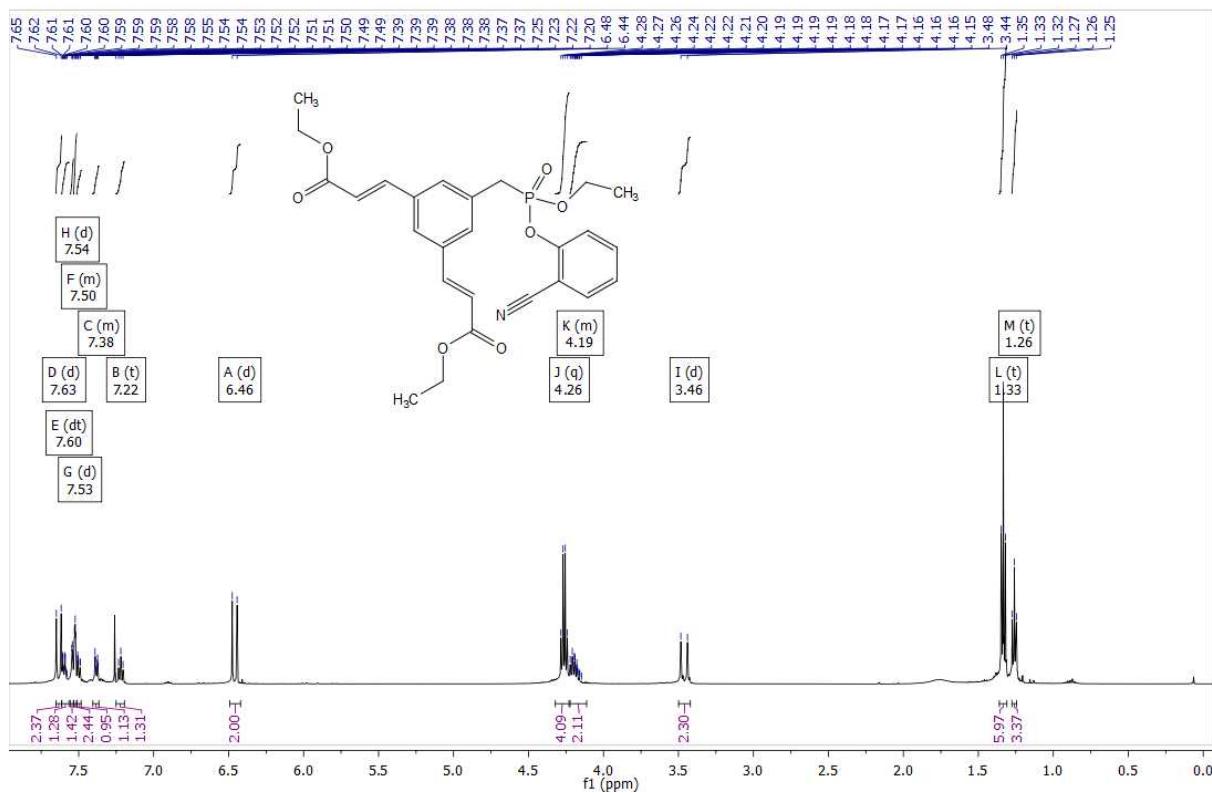
31P NMR:



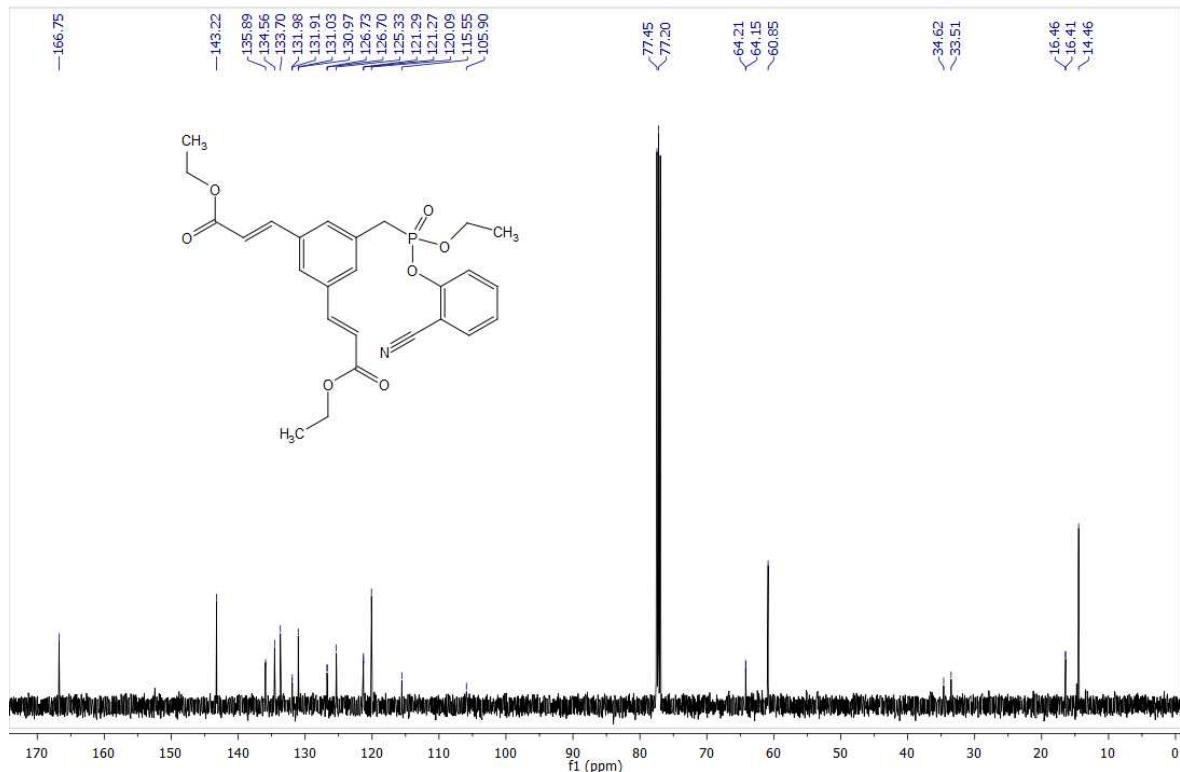
Homo-diolefination and Hetero di-olefination:

(2E,2'E)-diethyl 3,3'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylene)diacrylate (3a):

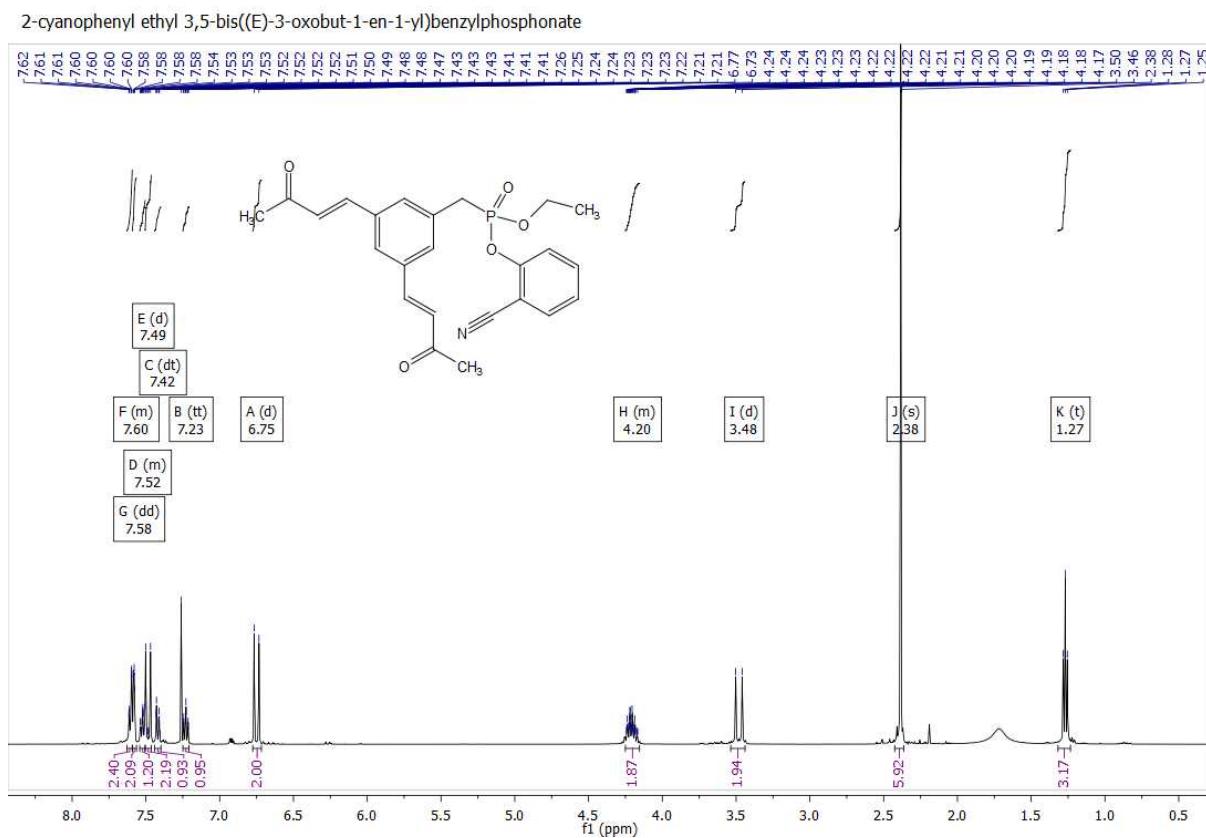
(2E,2'E)-diethyl 3,3'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylene)diacrylate



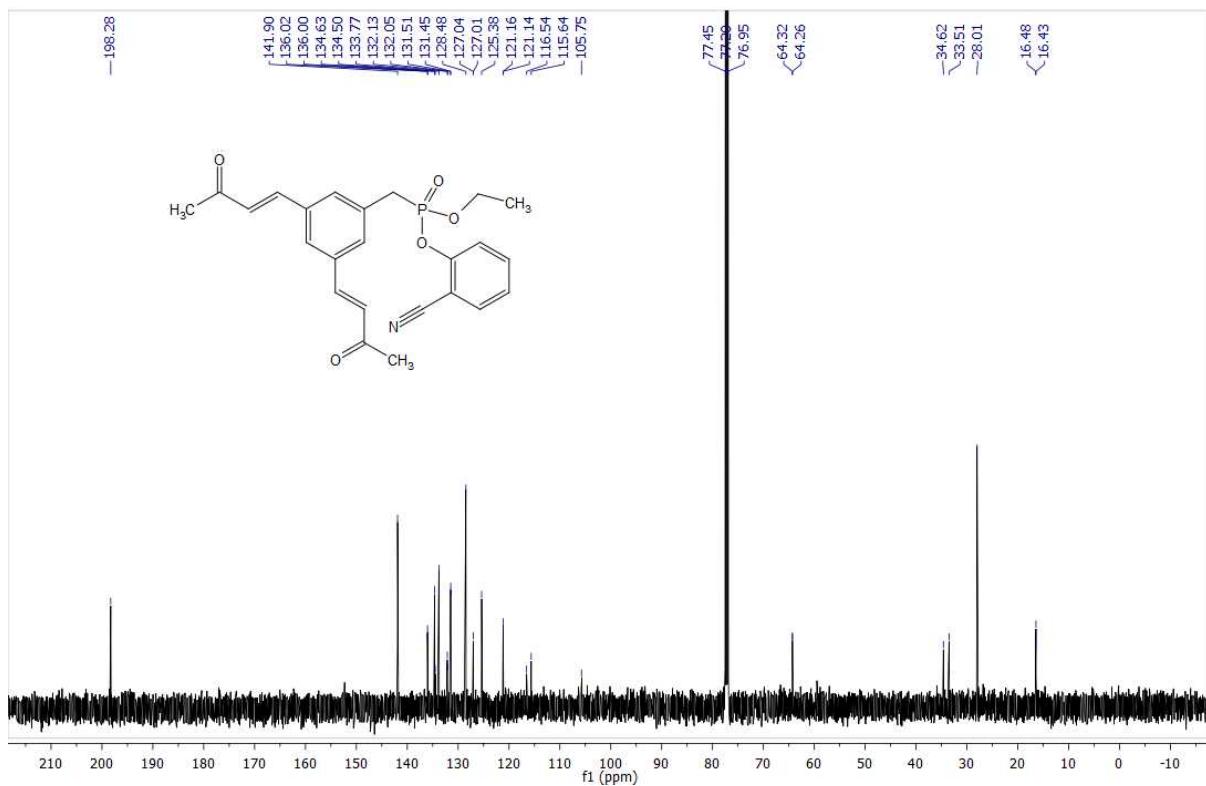
(2E,2'E)-diethyl 3,3'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylene)diacrylate



2-cyanophenyl ethyl 3,5-bis((E)-3-oxobut-1-en-1-yl)benzylphosphonate (3b):

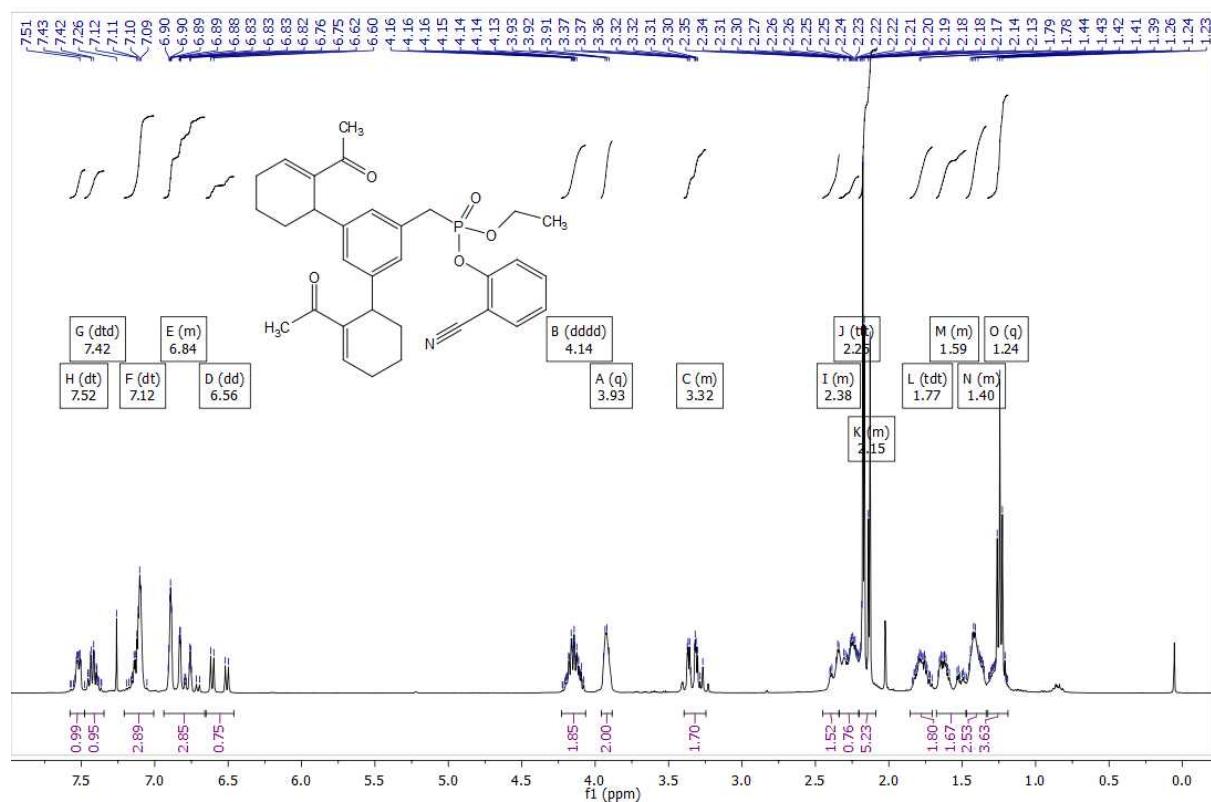


2-cyanophenyl ethyl 3,5-bis((E)-3-oxobut-1-en-1-yl)benzylphosphonate

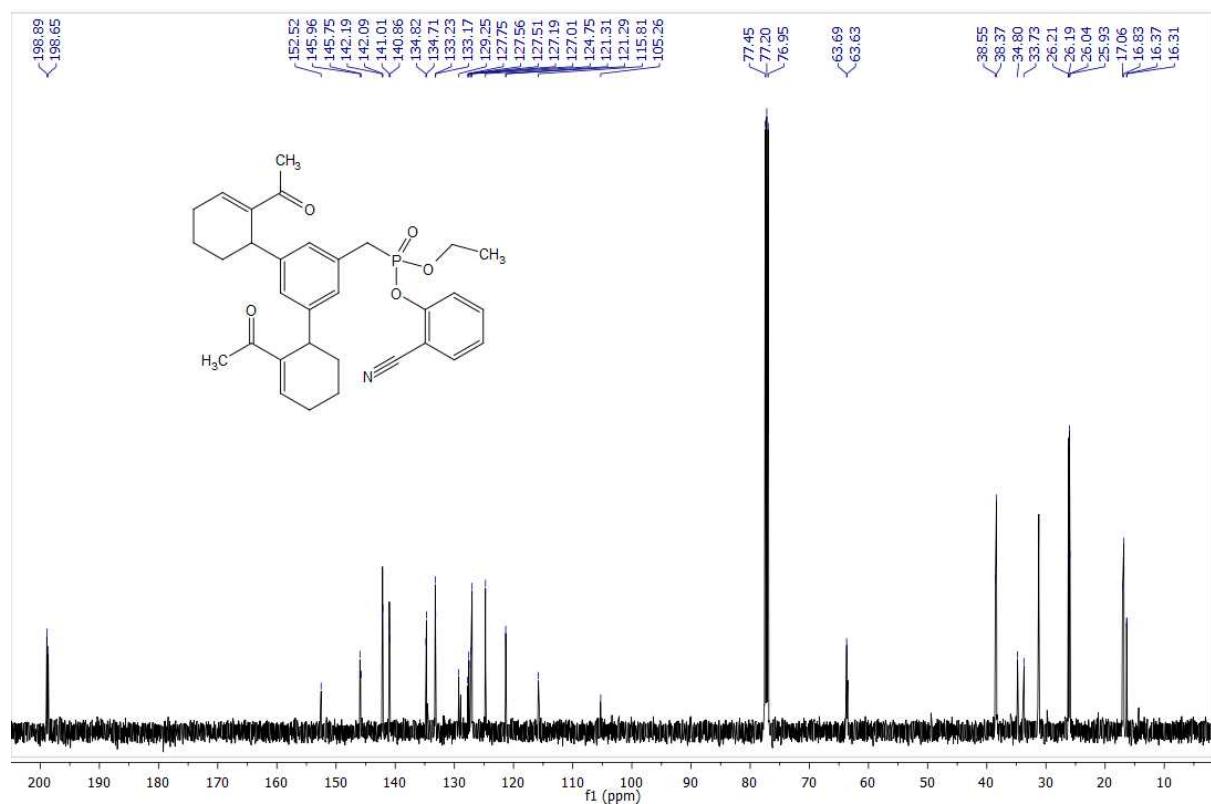


2-cyanophenyl ethyl ((6,6''-diacetyl-1,1'',2,2'',3,3'',4,4''-octahydro-[1,1':3',1''-terphenyl]-5'-yl)methyl)phosphonate (3c):

2-cyanophenyl ethyl ((6,6"-diacetyl-1,1",2,2",3,3",4,4"-octahydro-[1,1':3',1"-terphenyl]-5'-yl)methyl)phosphonate

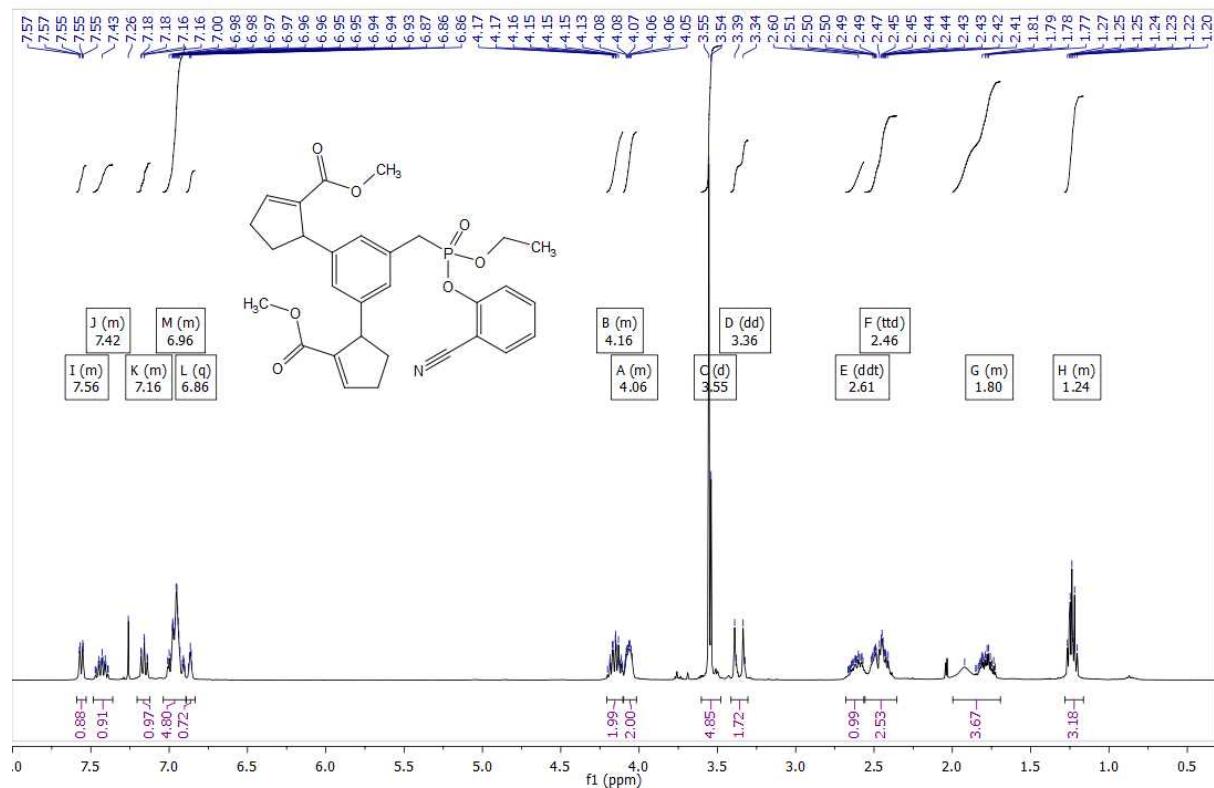


2-cyanophenyl ethyl ((6,6"-diacetyl-1,1",2,2",3,3",4,4"-octahydro-[1,1':3",1"-terphenyl]-5"-yl)methyl)phosphonate

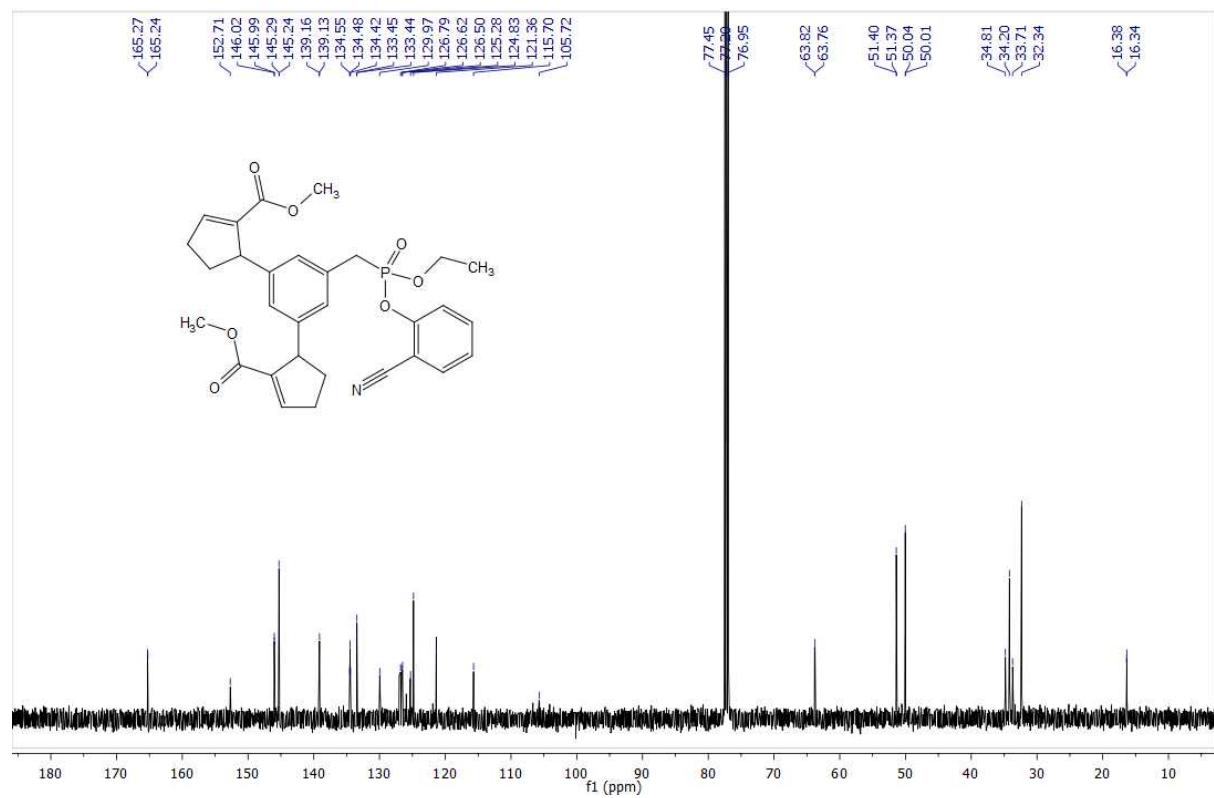


dimethyl 5,5'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylene)bis(cyclopent-1-enecarboxylate) (3d):

dimethyl 5,5'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylene)bis(cyclopent-1-enecarboxylate)

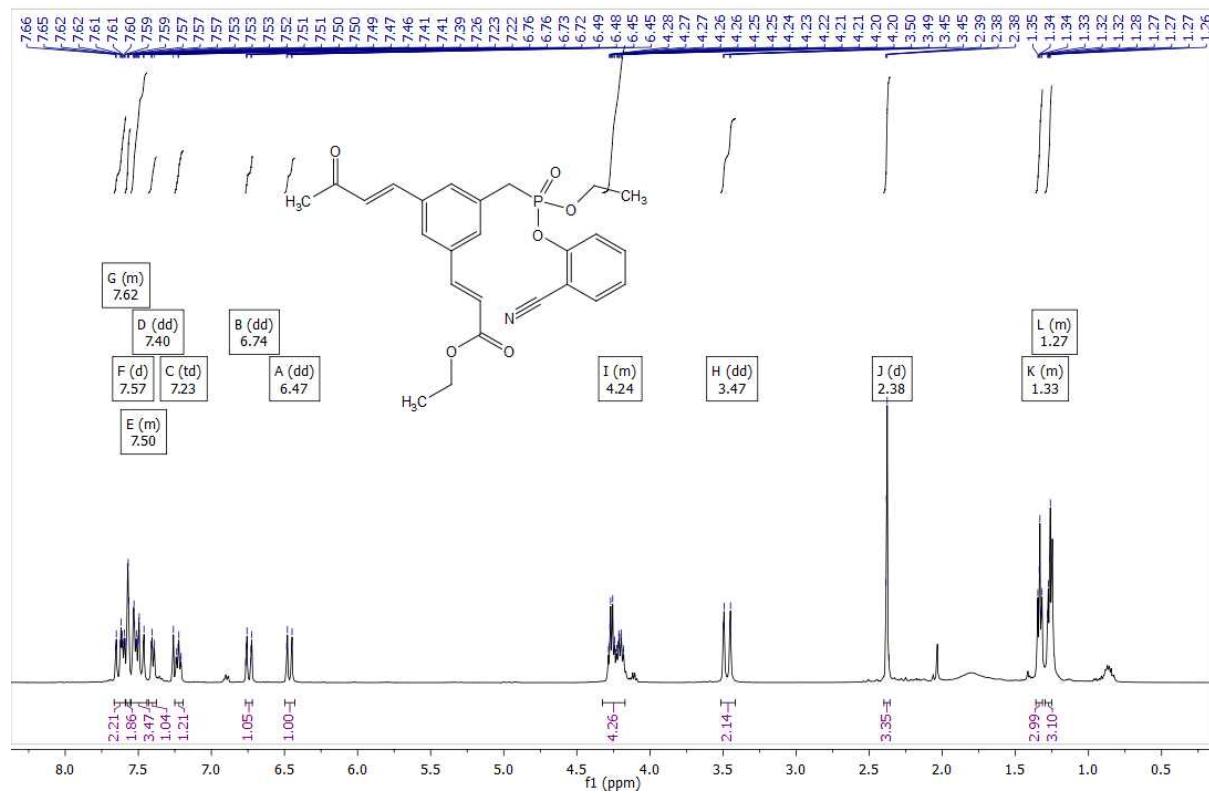


dimethyl 5,5'-(5-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-1,3-phenylene)bis(cyclopent-1-enecarboxylate)

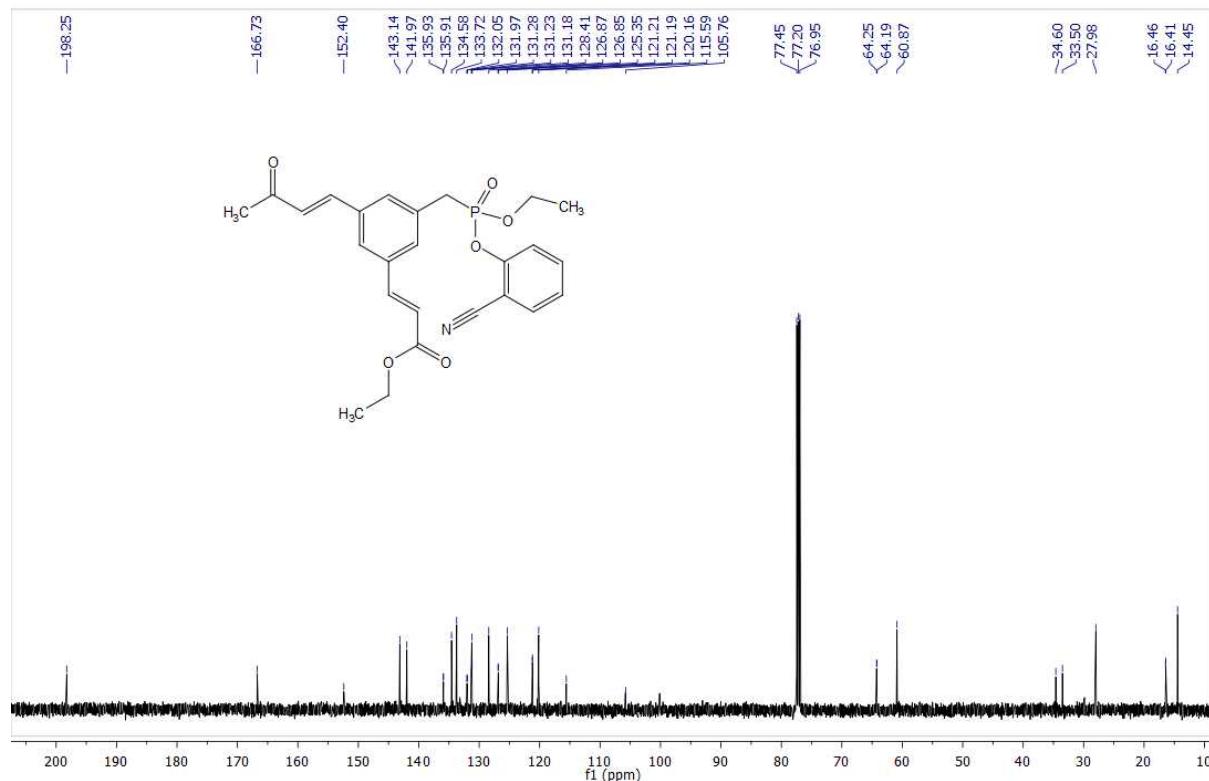


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl-5-((E)-3-oxobut-1-en-1-yl)phenylacrylate (3e):

(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl-5-((E)-3-oxobut-1-en-1-yl)phenylacrylate

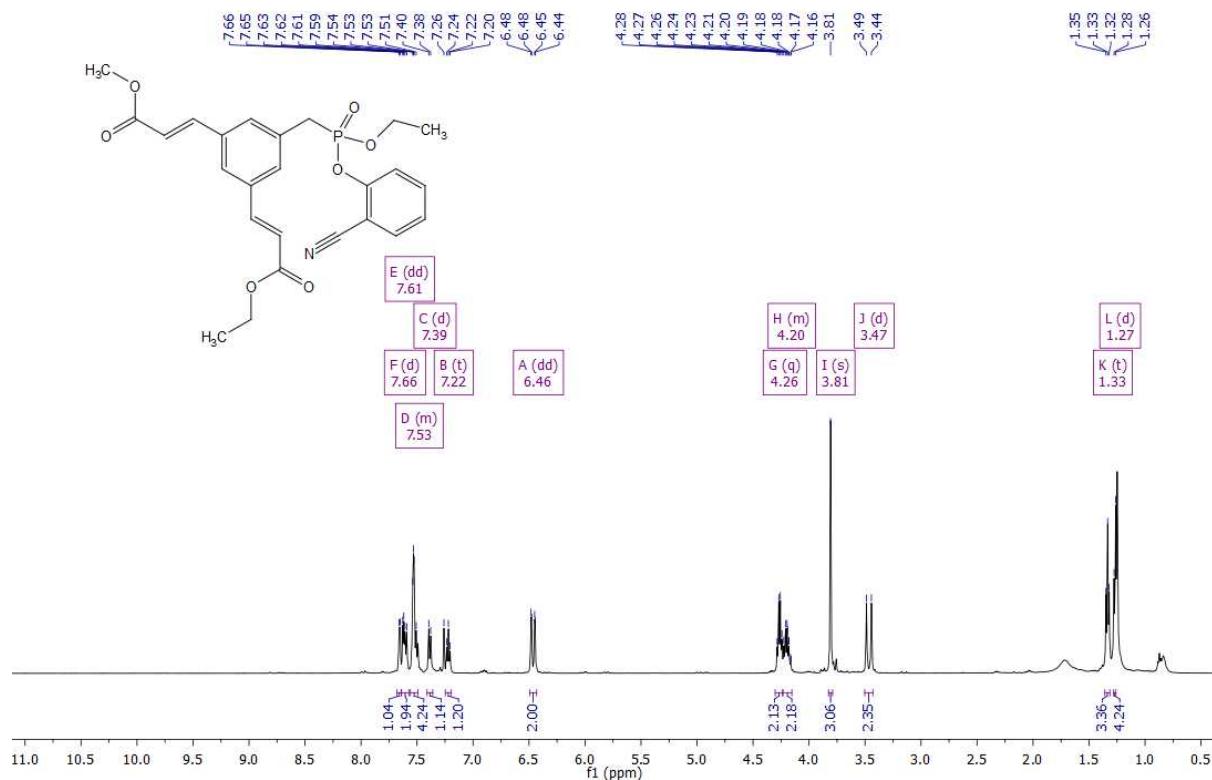


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl-5-((E)-3-oxobut-1-en-1-yl)phenylacrylate

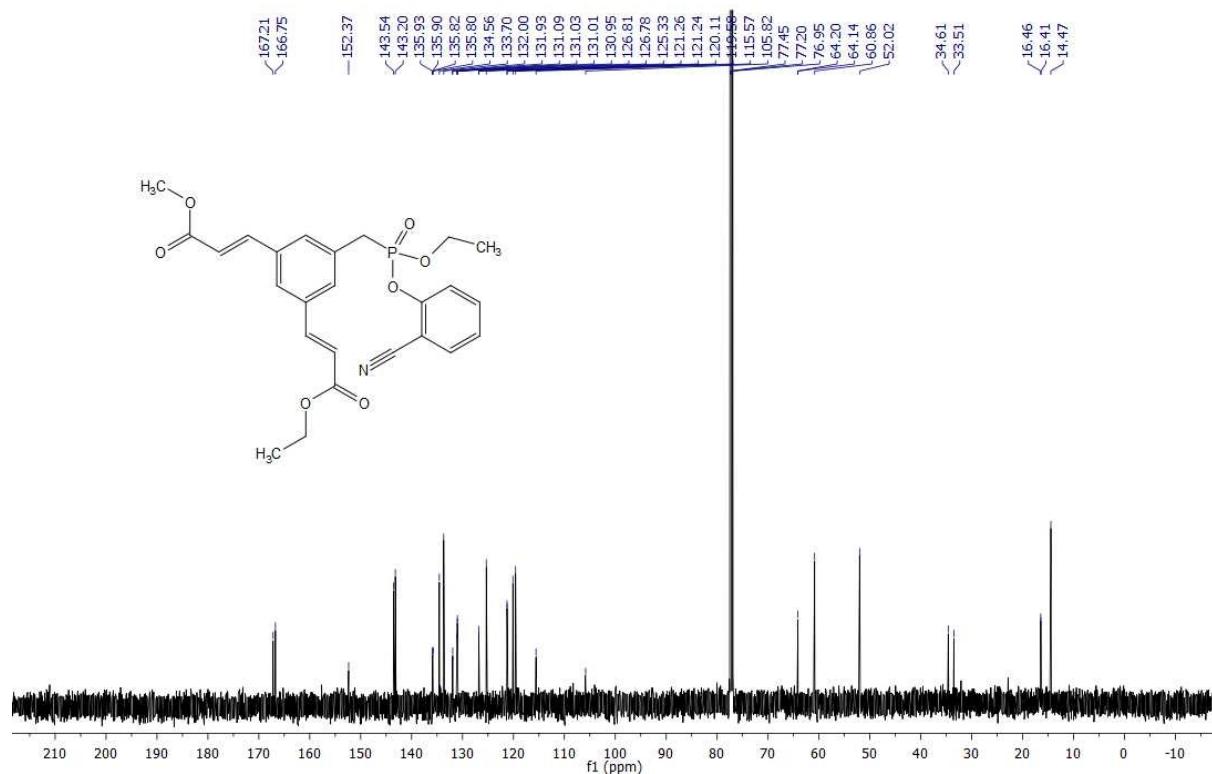


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-methoxy-3-oxoprop-1-en-1-yl)phenyl)acrylate (3f):

(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-methoxy-3-oxoprop-1-en-1-yl)phenyl)acrylate

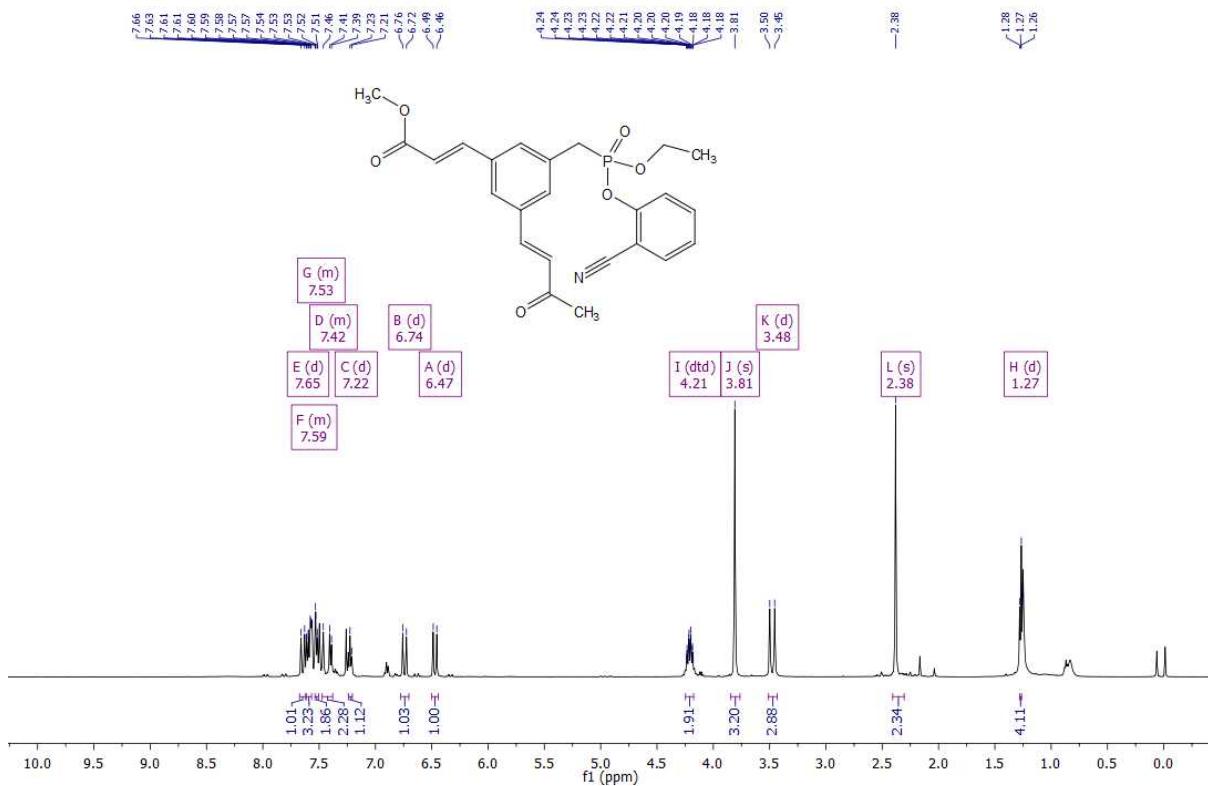


(E)-ethyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-methoxy-3-oxoprop-1-en-1-yl)phenyl)acrylate

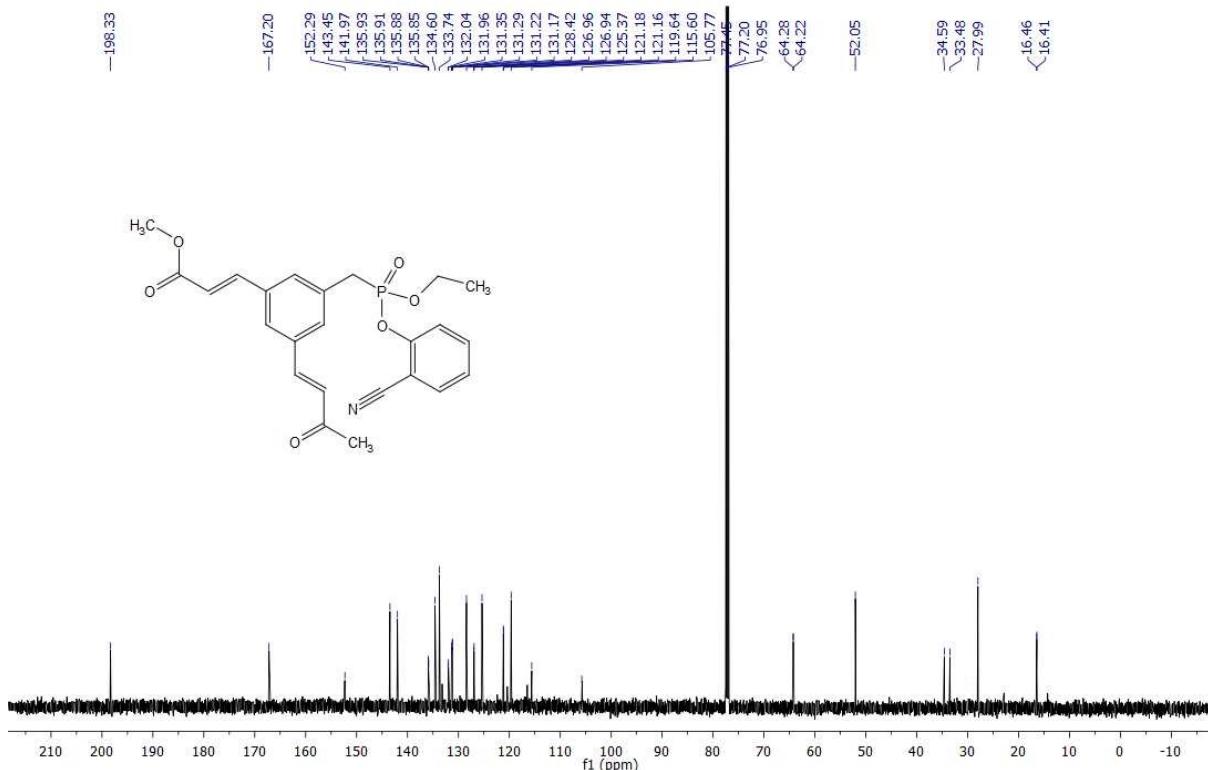


(E)-methyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-oxobut-1-en-1-yl)phenyl)acrylate (3g):

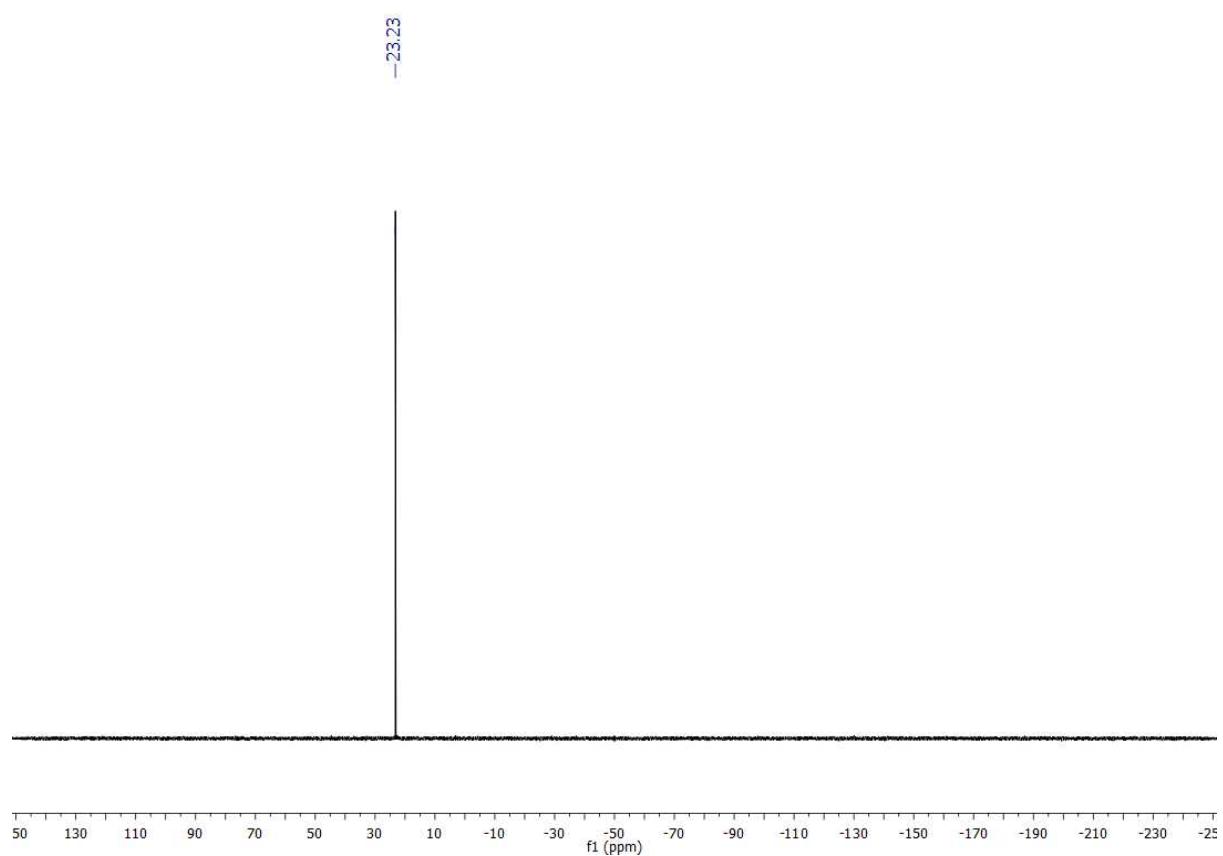
(E)-methyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-oxobut-1-en-1-yl)phenyl)acrylate



(E)-methyl 3-((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-3-oxobut-1-en-1-yl)phenyl)acrylate

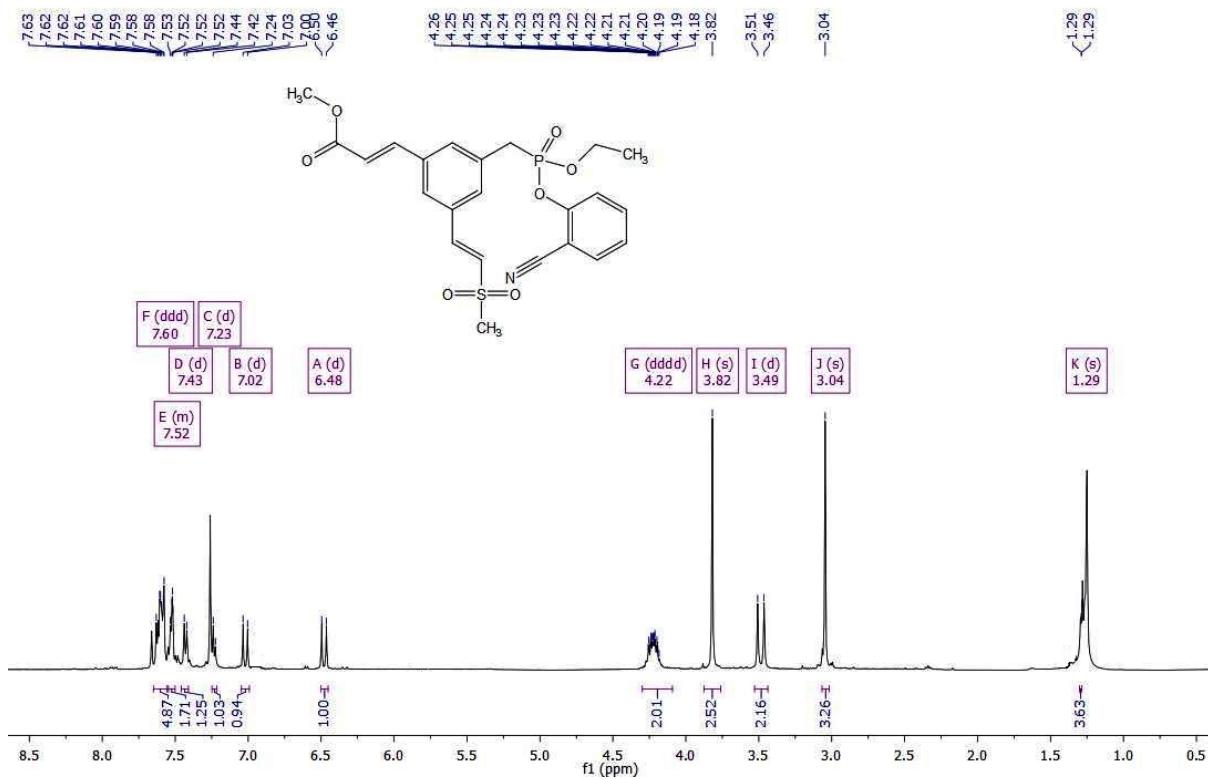


31P NMR:

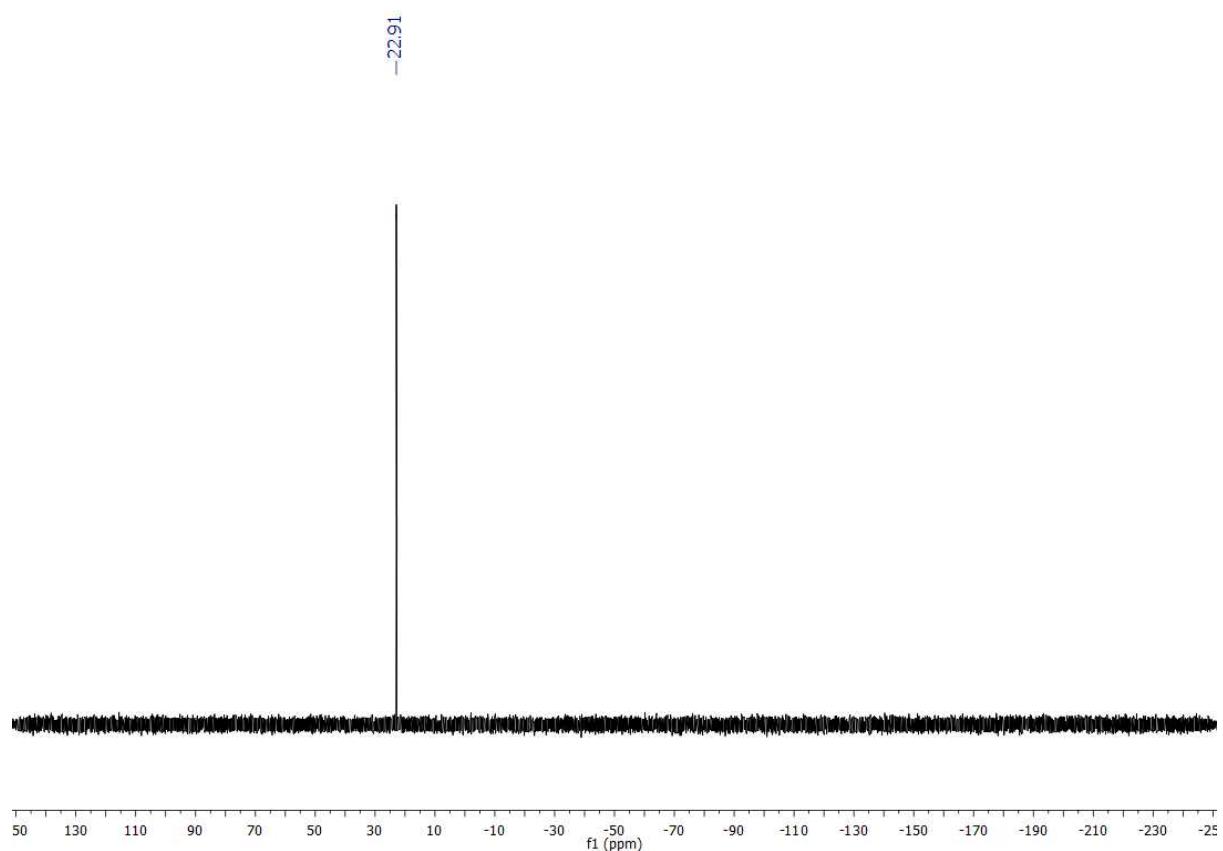


(E)-methyl 3-(3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-2-(methylsulfonyl)vinyl)phenyl)acrylate (3h):

(E)-methyl 3-(3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-5-((E)-2-(methylsulfonyl)vinyl)phenyl)acrylate

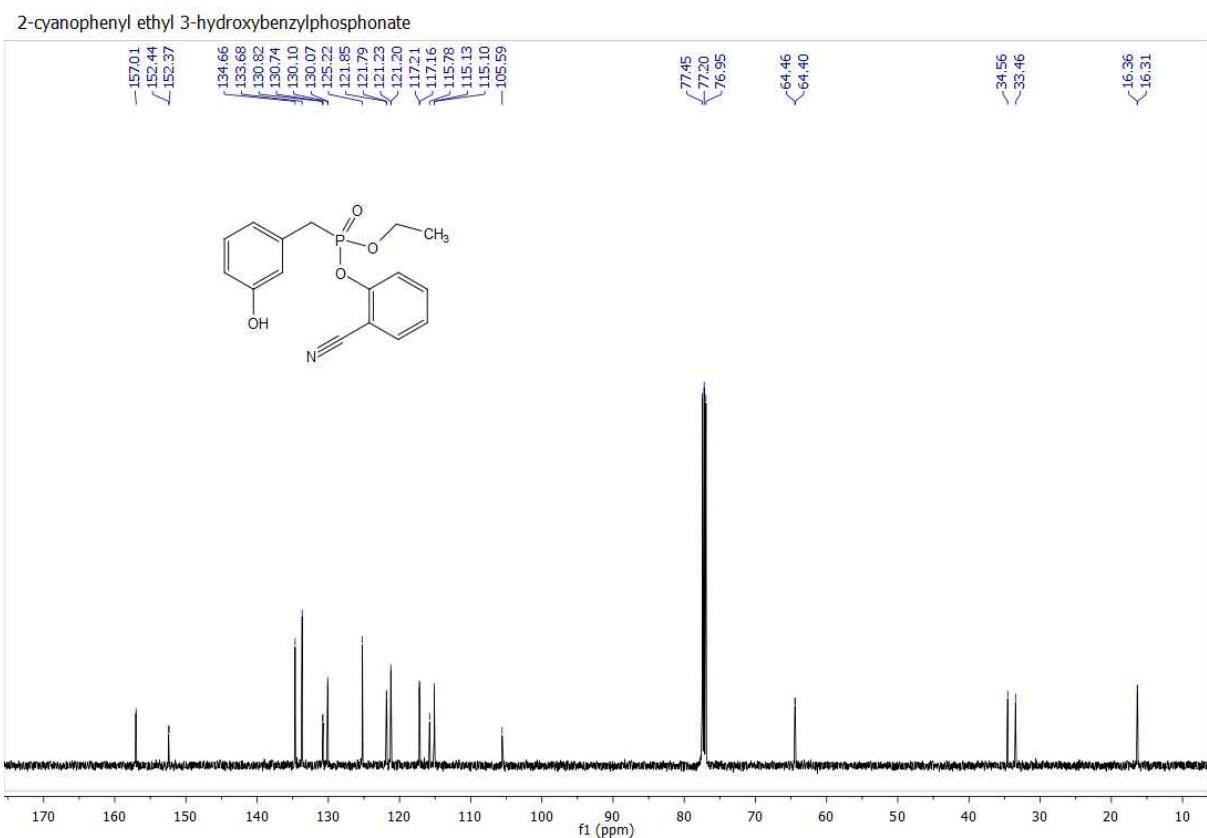


31P NMR:

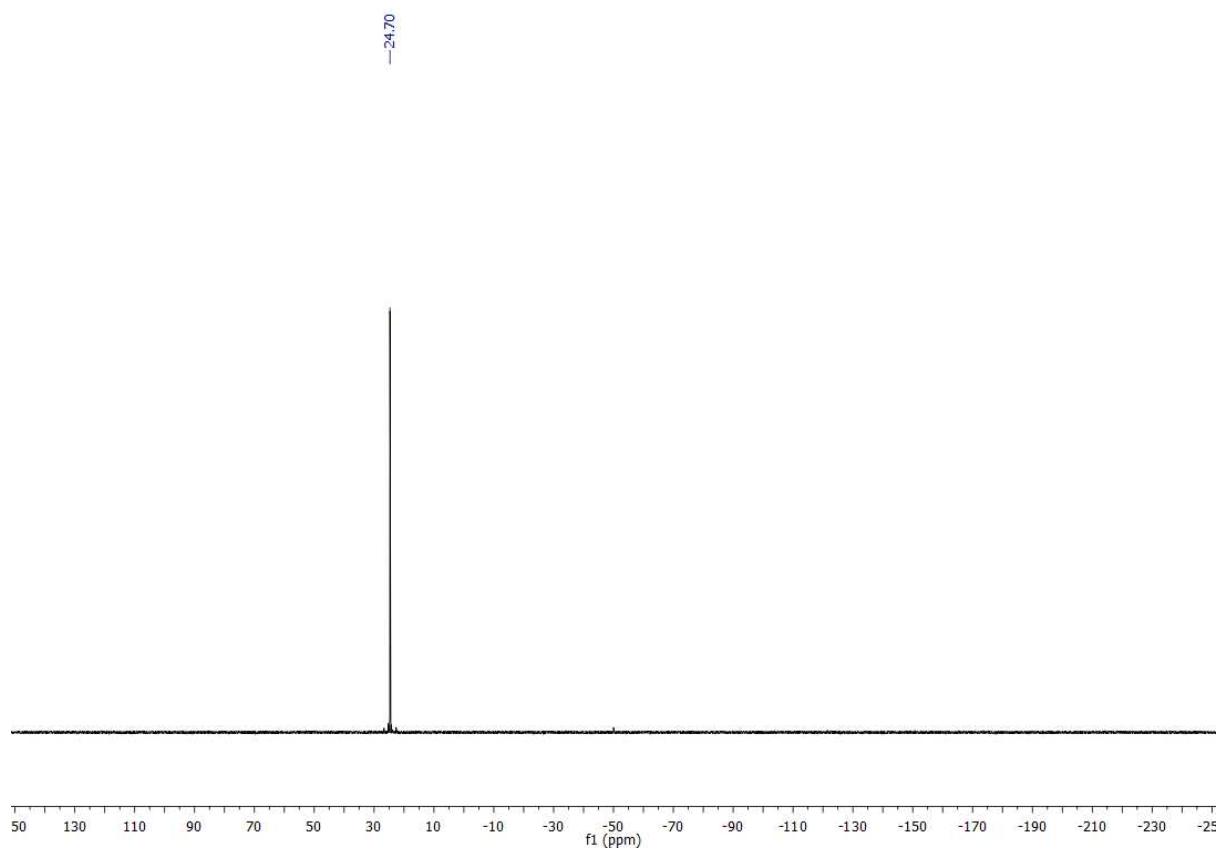


Meta-Hydroxylation:

2-cyanophenyl ethyl 3-hydroxybenzylphosphonate (4a):

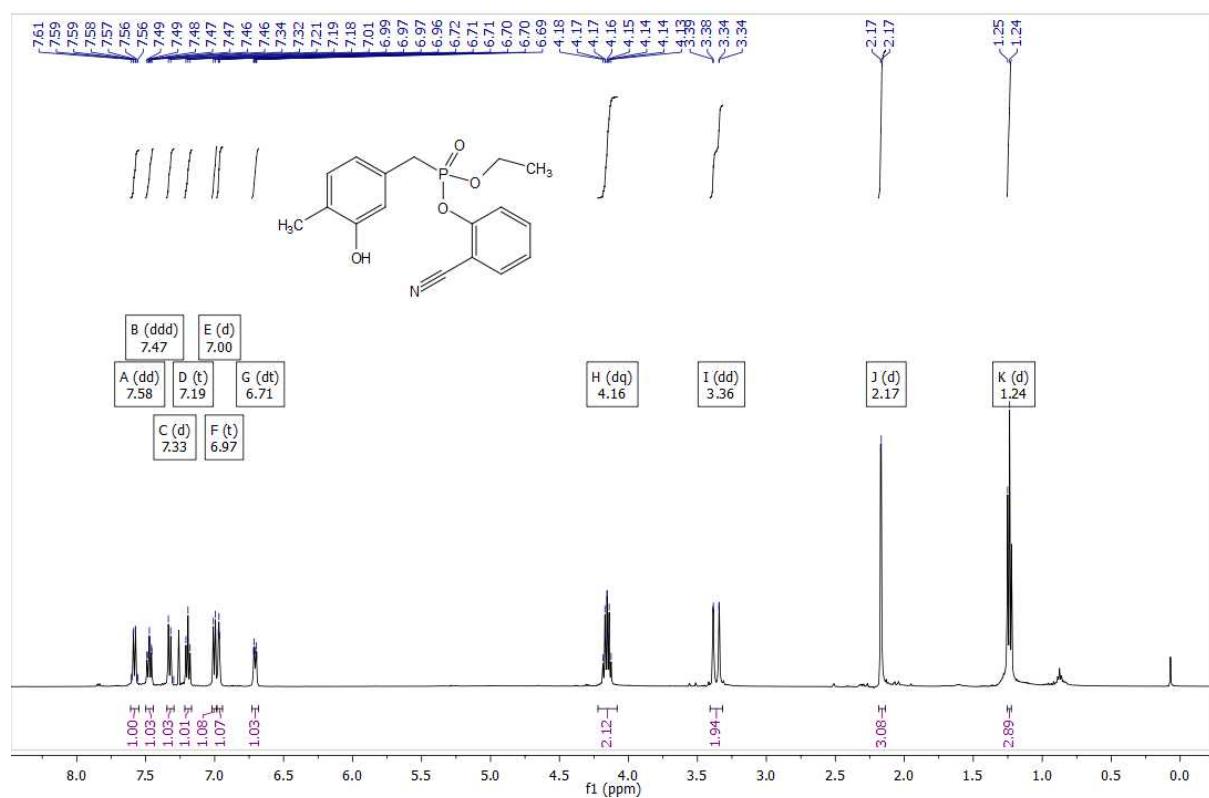


31P NMR:

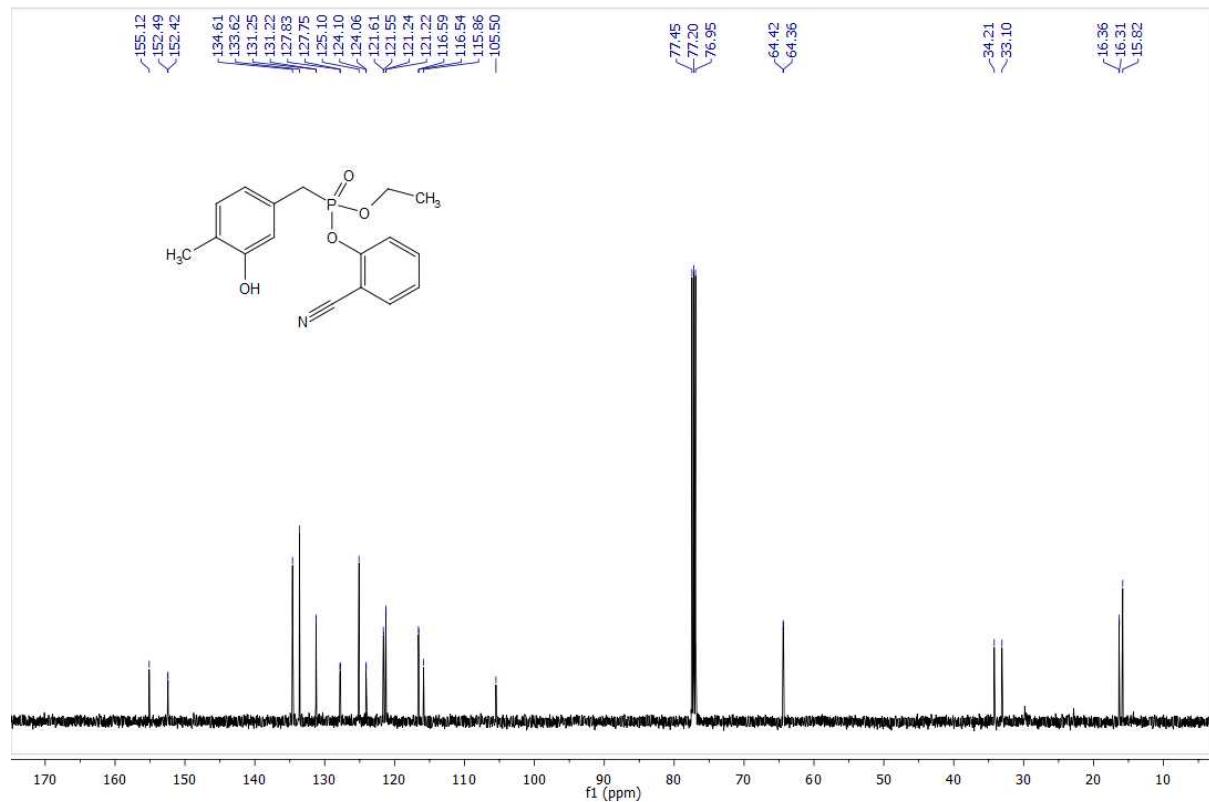


2-cyanophenyl ethyl 3-hydroxy-4-methylbenzylphosphonate (4b):

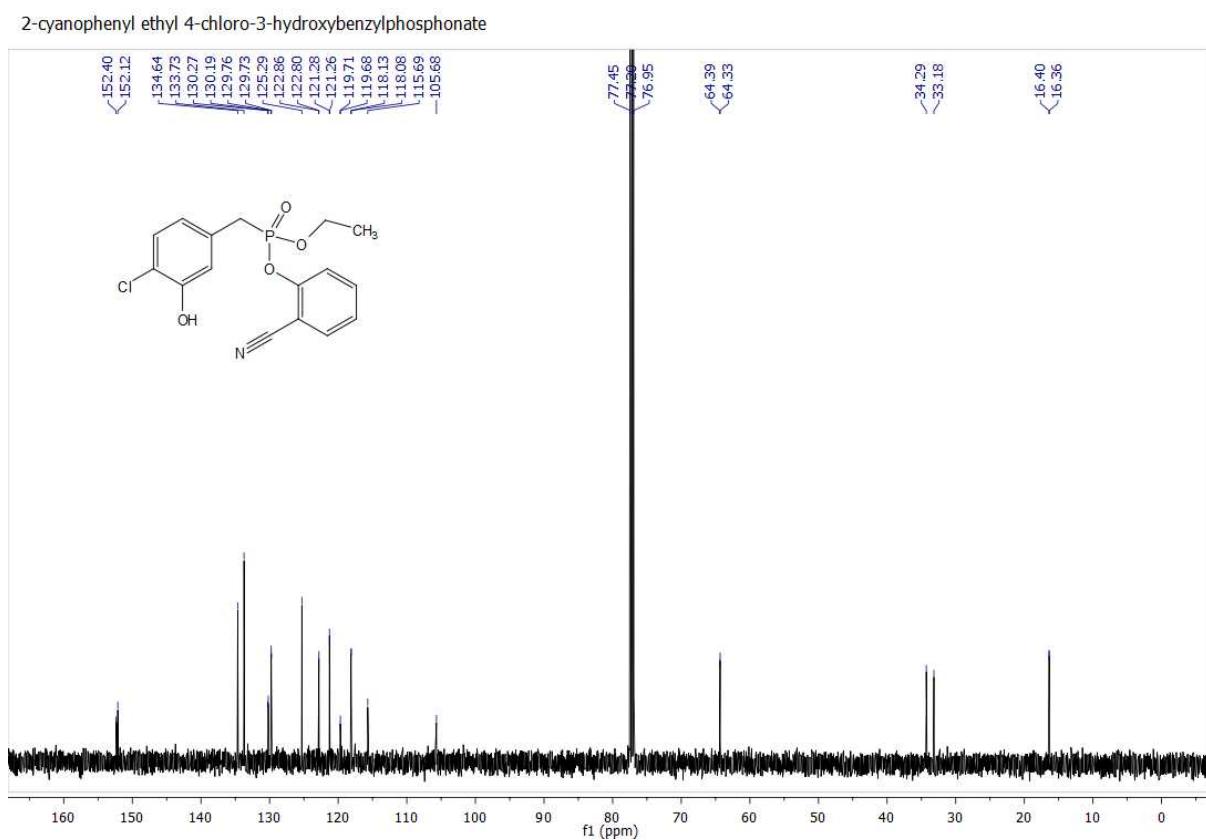
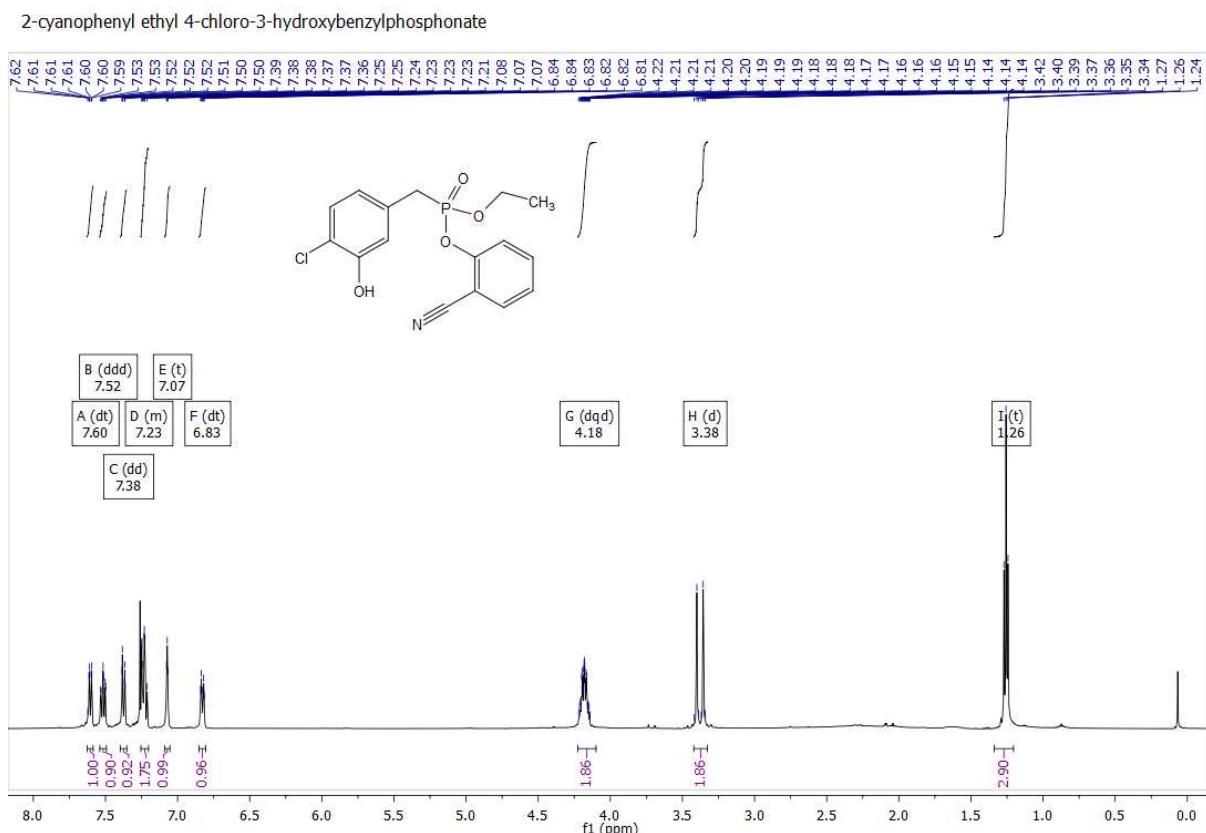
2-cyanophenyl ethyl 3-hydroxy-4-methylbenzylphosphonate



2-cyanophenyl ethyl 3-hydroxy-4-methylbenzylphosphonate

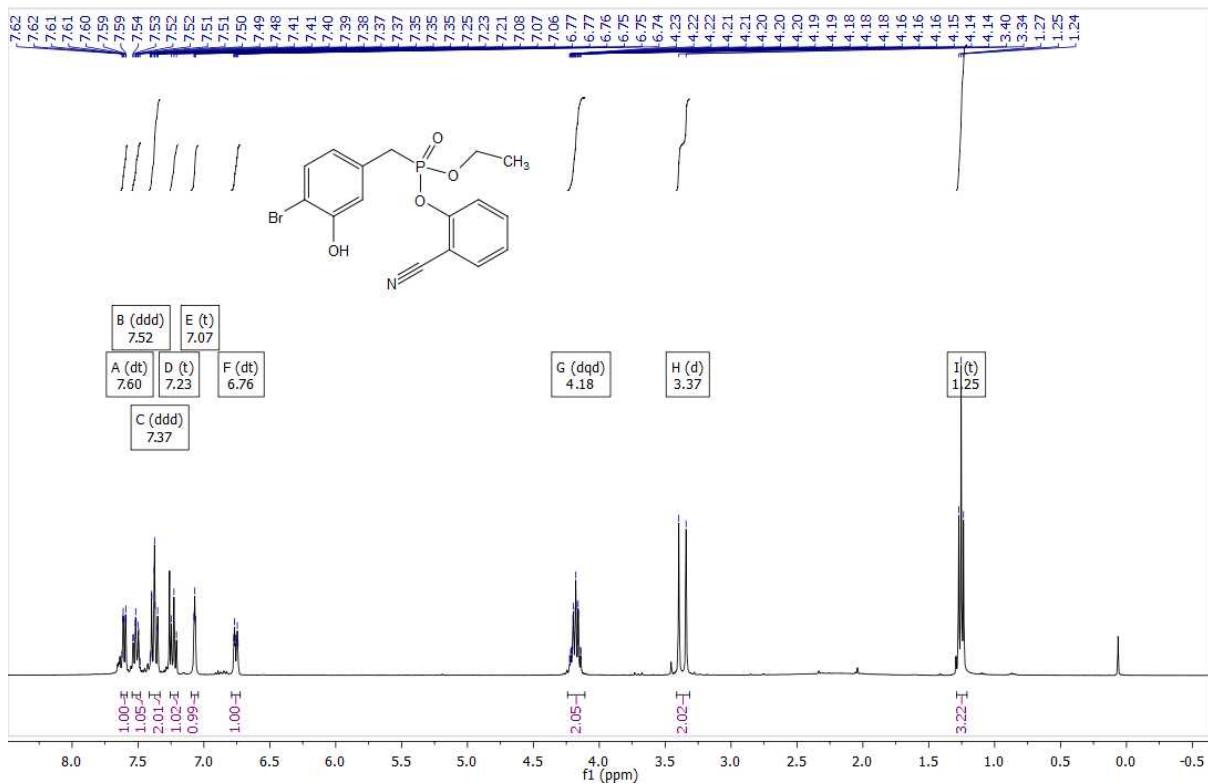


2-cyanophenyl ethyl 4-chloro-3-hydroxybenzylphosphonate (4c):

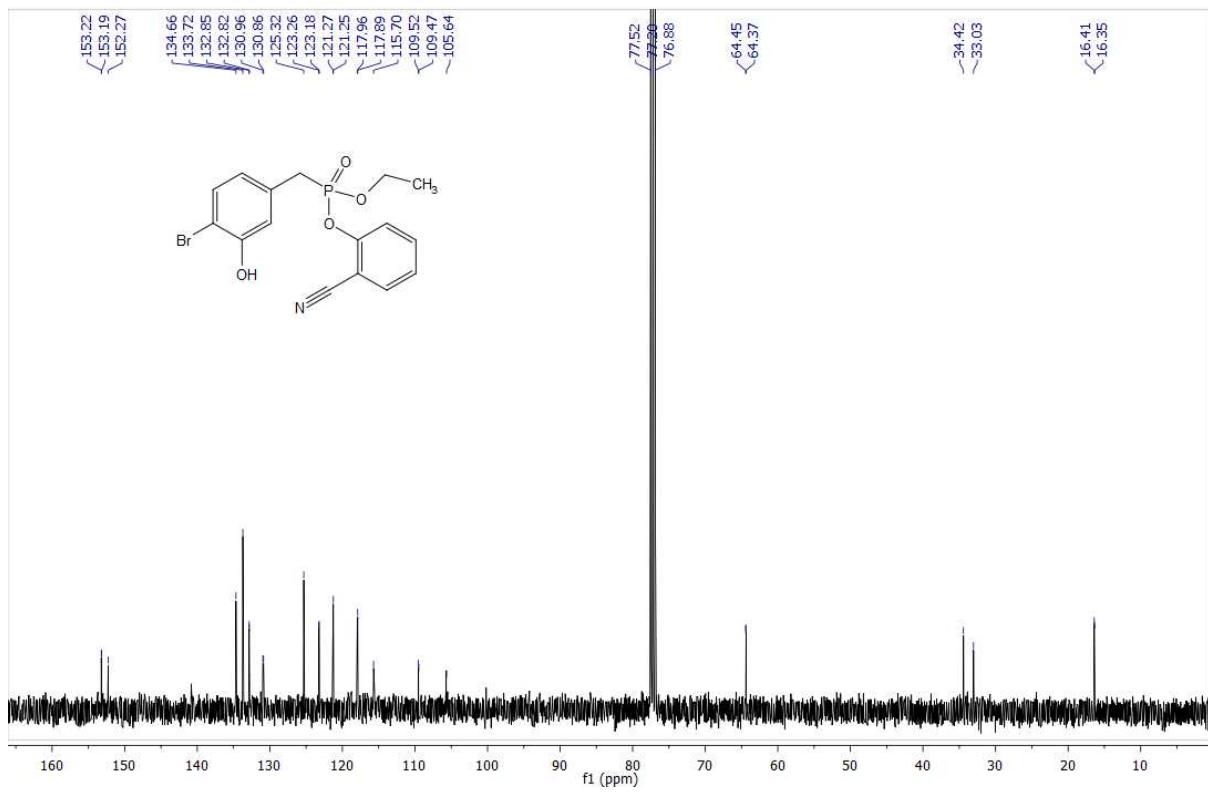


2-cyanophenyl ethyl 4-bromo-3-hydroxybenzylphosphonate (4d):

2-cyanophenyl ethyl 4-bromo-3-hydroxybenzylphosphonate

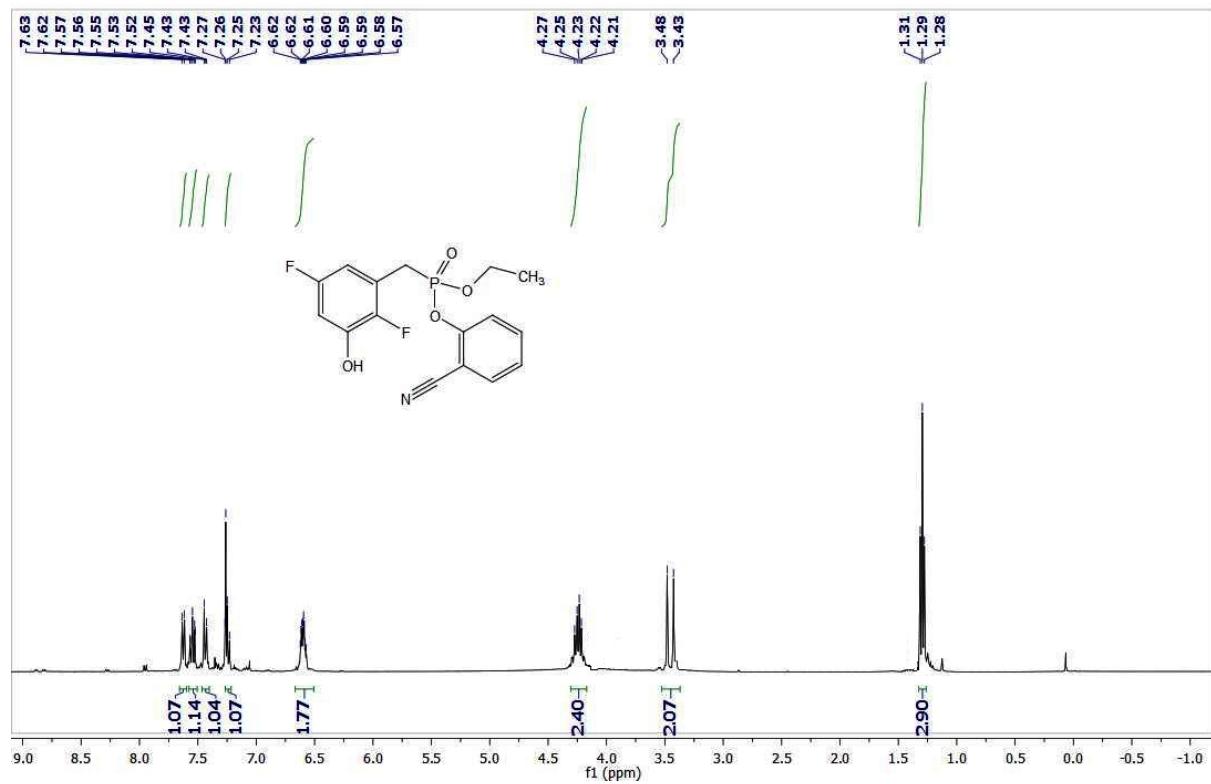


2-cyanophenyl ethyl 4-bromo-3-hydroxybenzylphosphonate

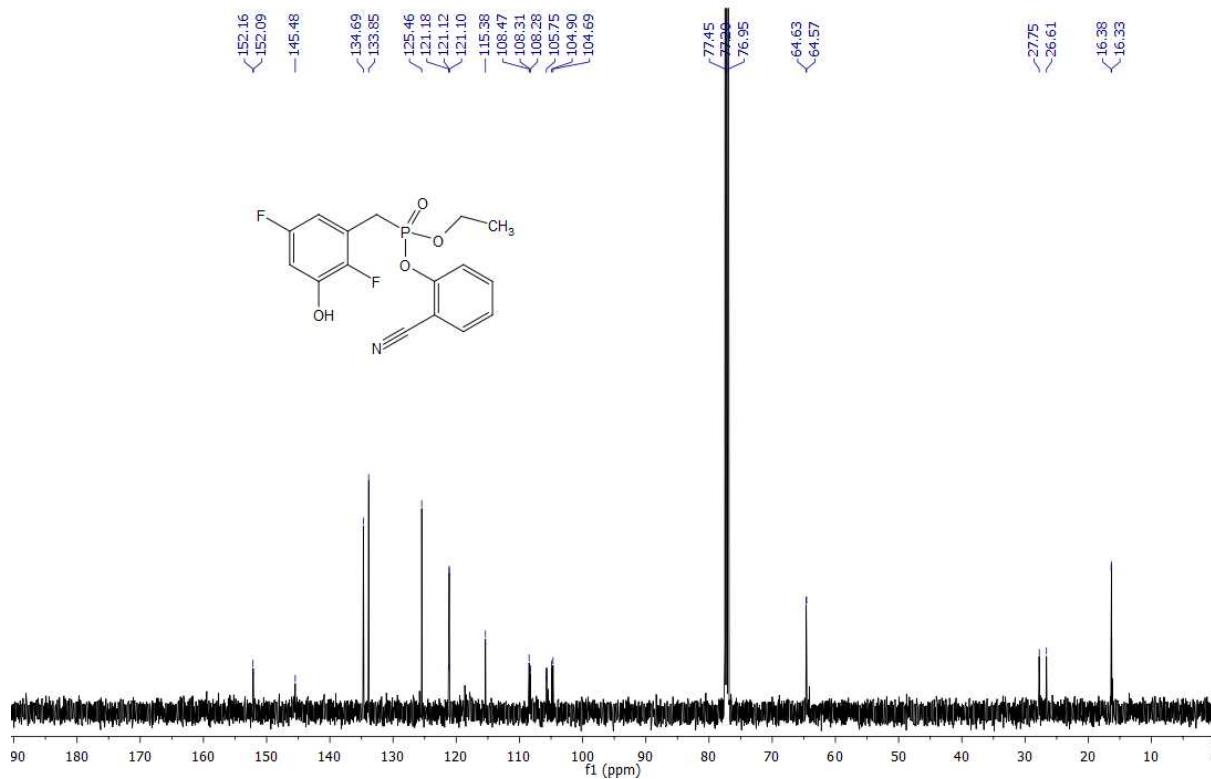


2-cyanophenyl ethyl 2,5-difluoro-3-hydroxybenzylphosphonate (4e):

2-cyanophenyl ethyl 2,5-difluoro-3-hydroxybenzylphosphonate

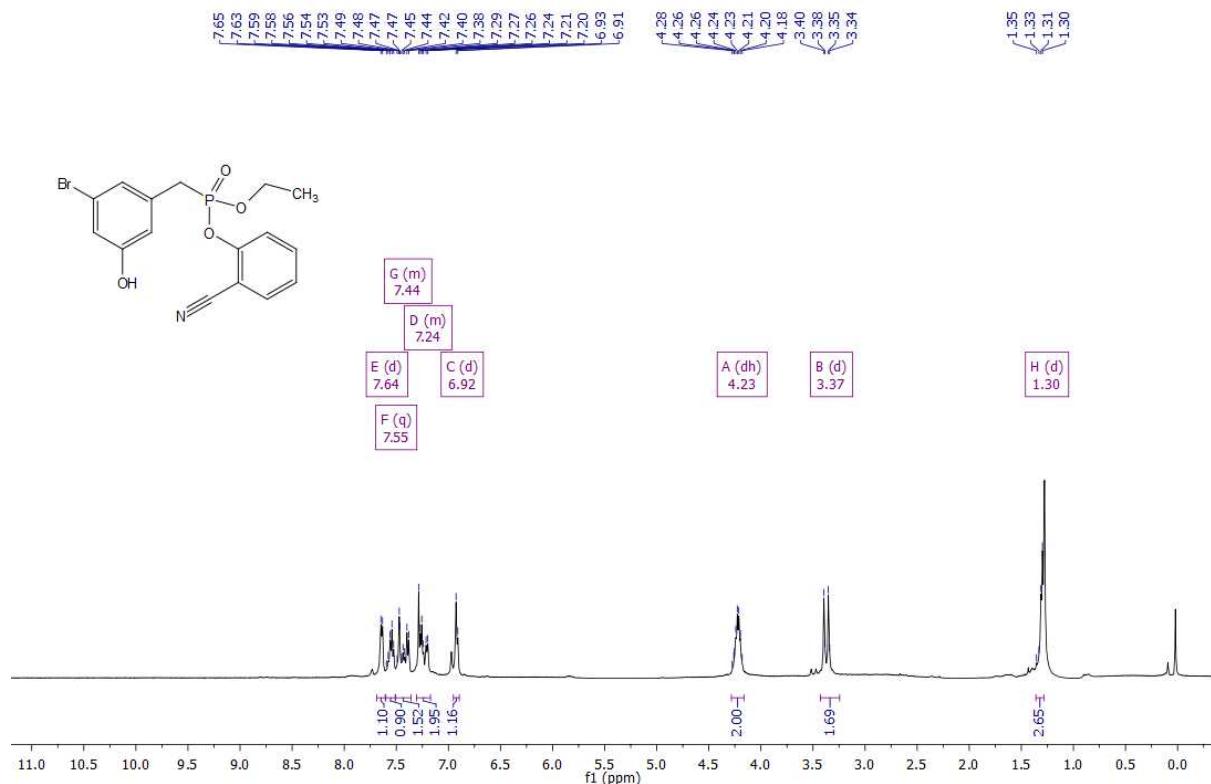


2-cyanophenyl ethyl 2,5-difluoro-3-hydroxybenzylphosphonate

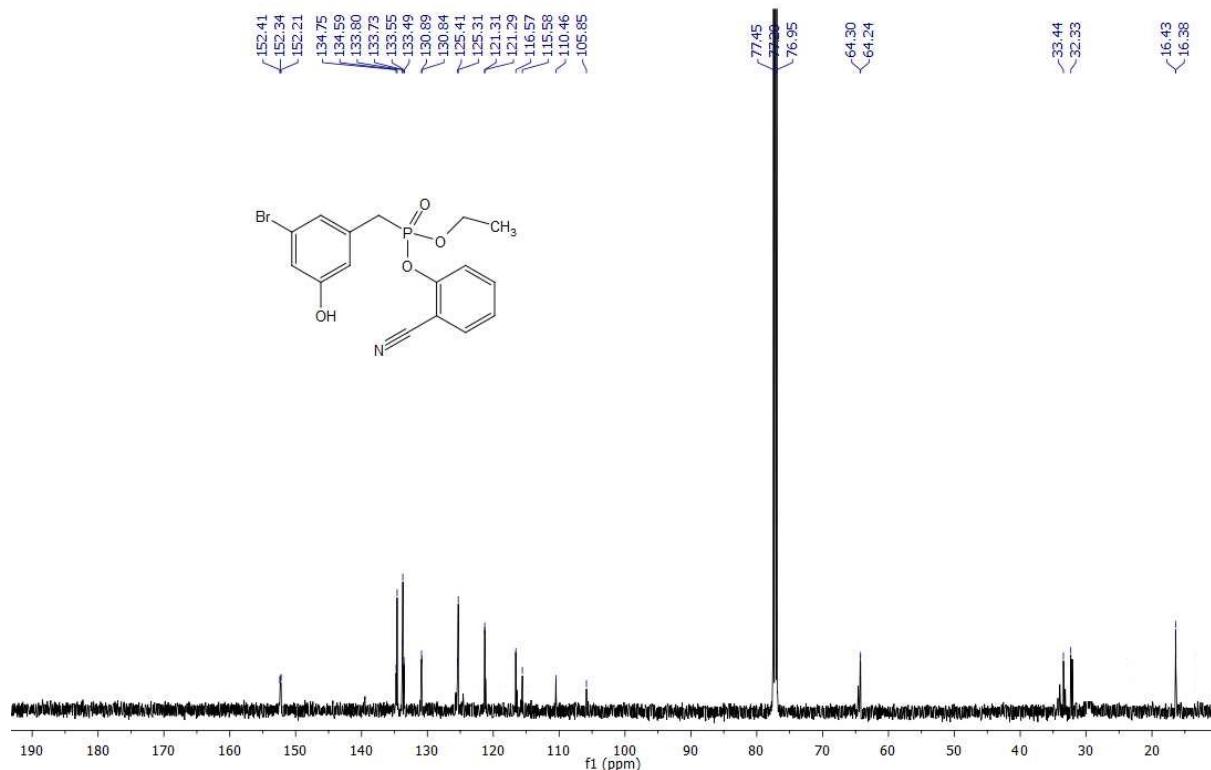


2-cyanophenyl ethyl 3-bromo-5-hydroxybenzylphosphonate (4f):

2-cyanophenyl ethyl 3-bromo-5-hydroxybenzylphosphonate

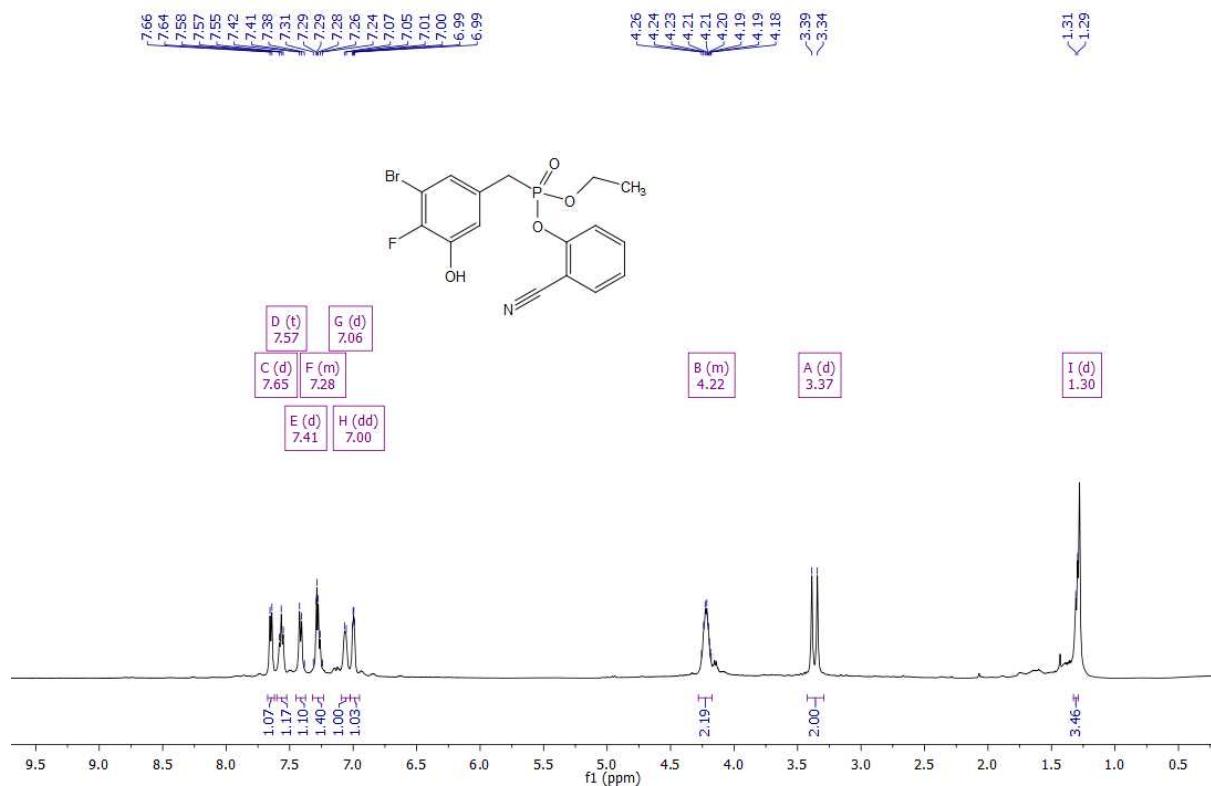


2-cyanophenyl ethyl 3-bromo-5-hydroxybenzylphosphonate

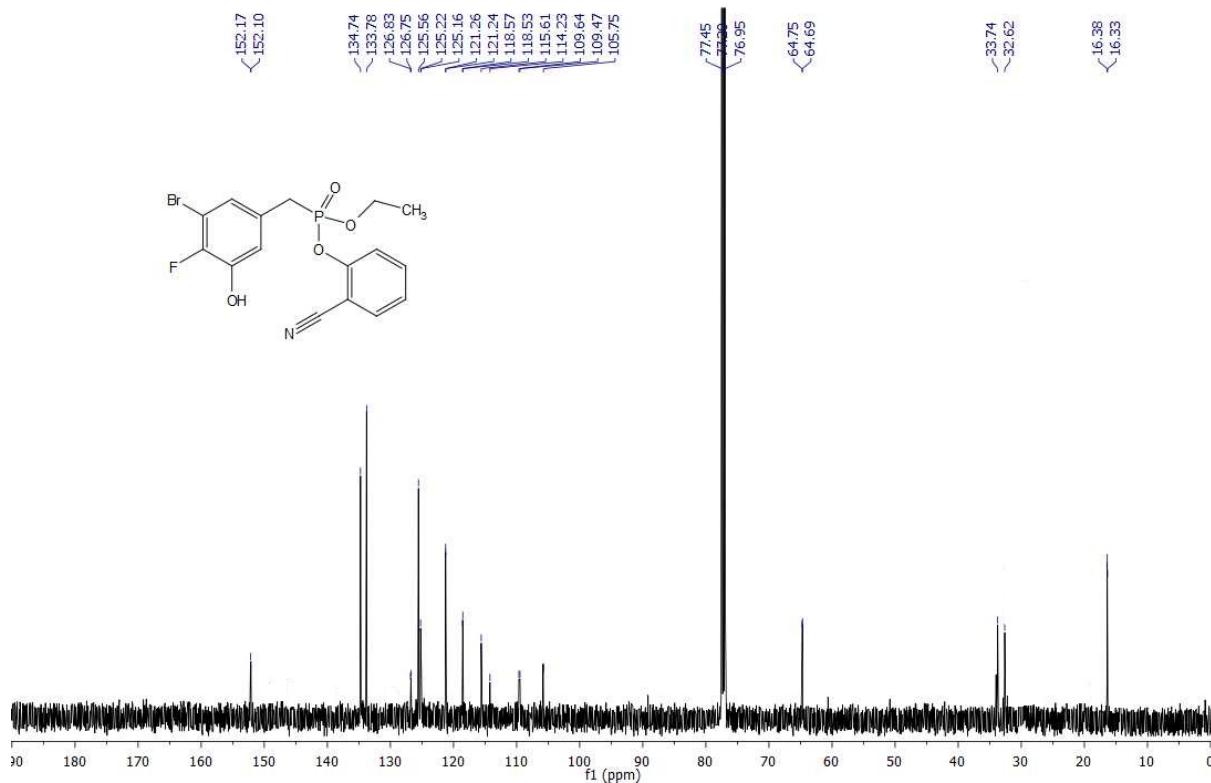


2-cyanophenyl ethyl 3-bromo-4-fluoro-5-hydroxybenzylphosphonate (4g):

2-cyanophenyl ethyl 3-bromo-4-fluoro-5-hydroxybenzylphosphonate



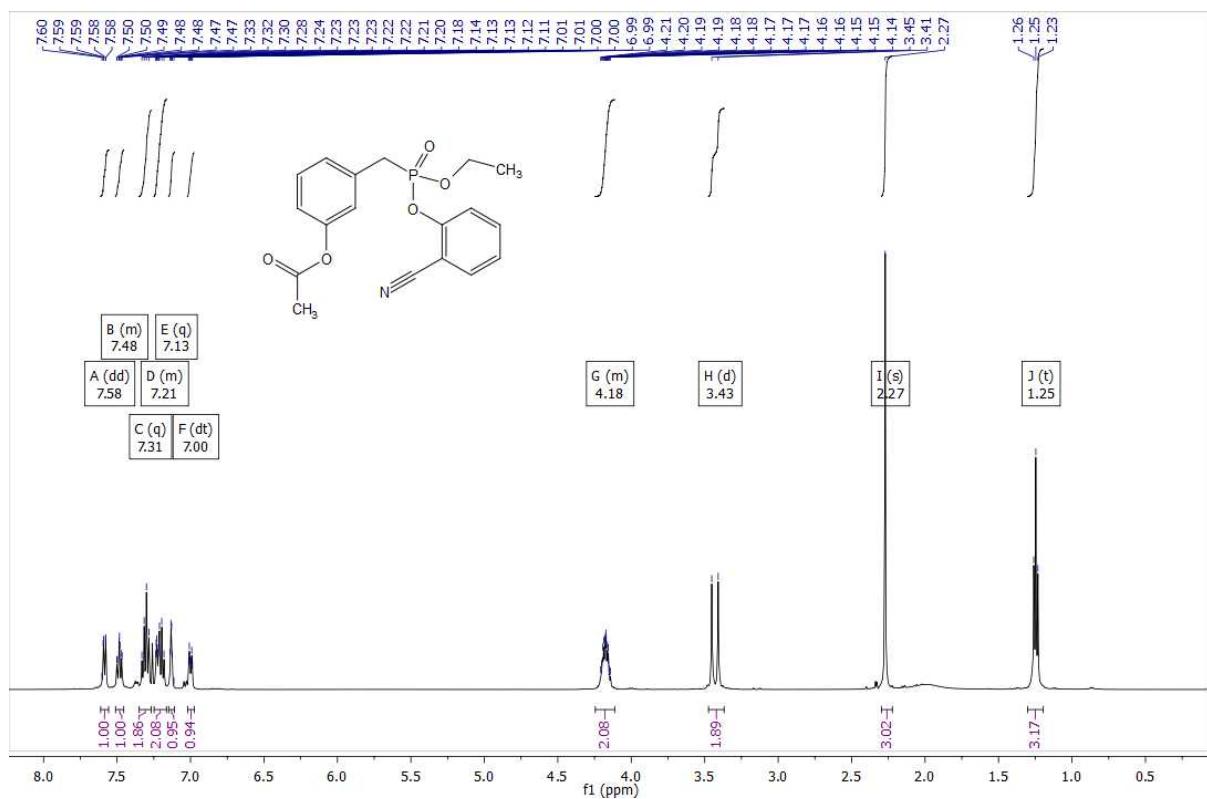
2-cyanophenyl ethyl 3-bromo-4-fluoro-5-hydroxybenzylphosphonate



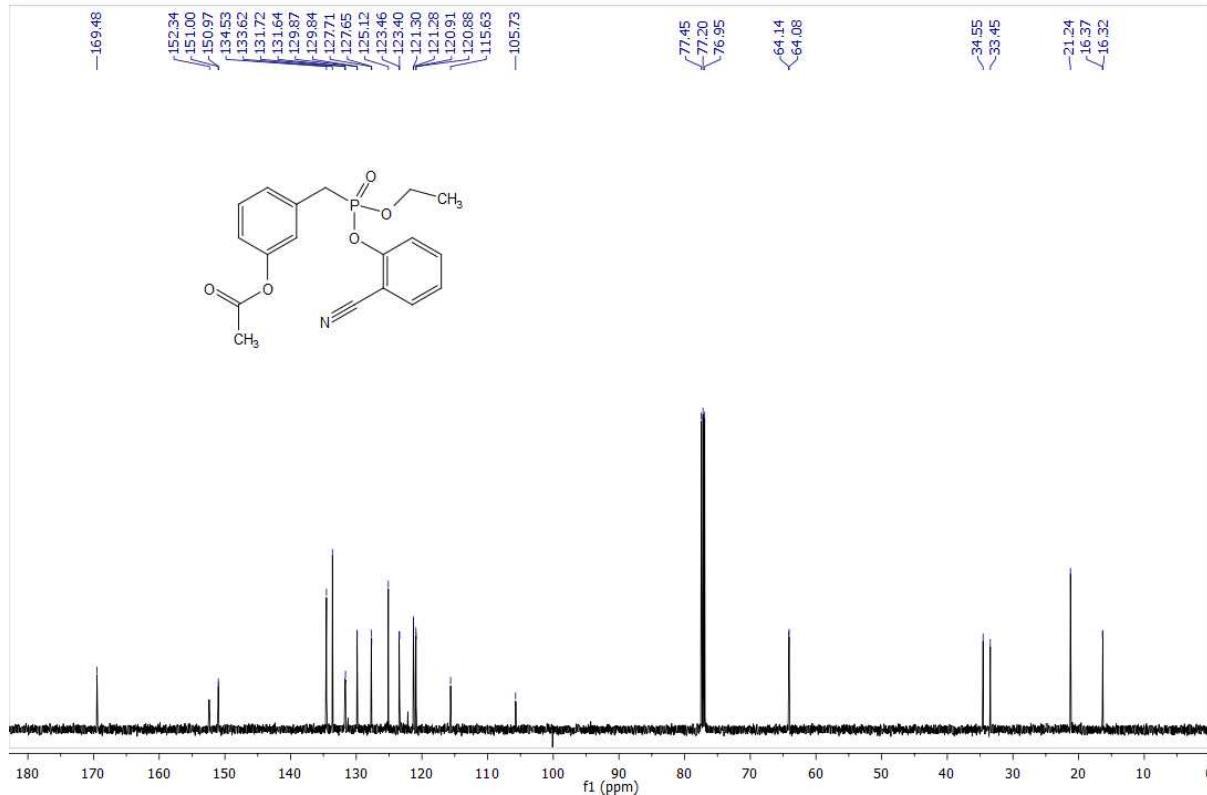
Meta-Acetoxylation:

3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate (5a**):**

3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate

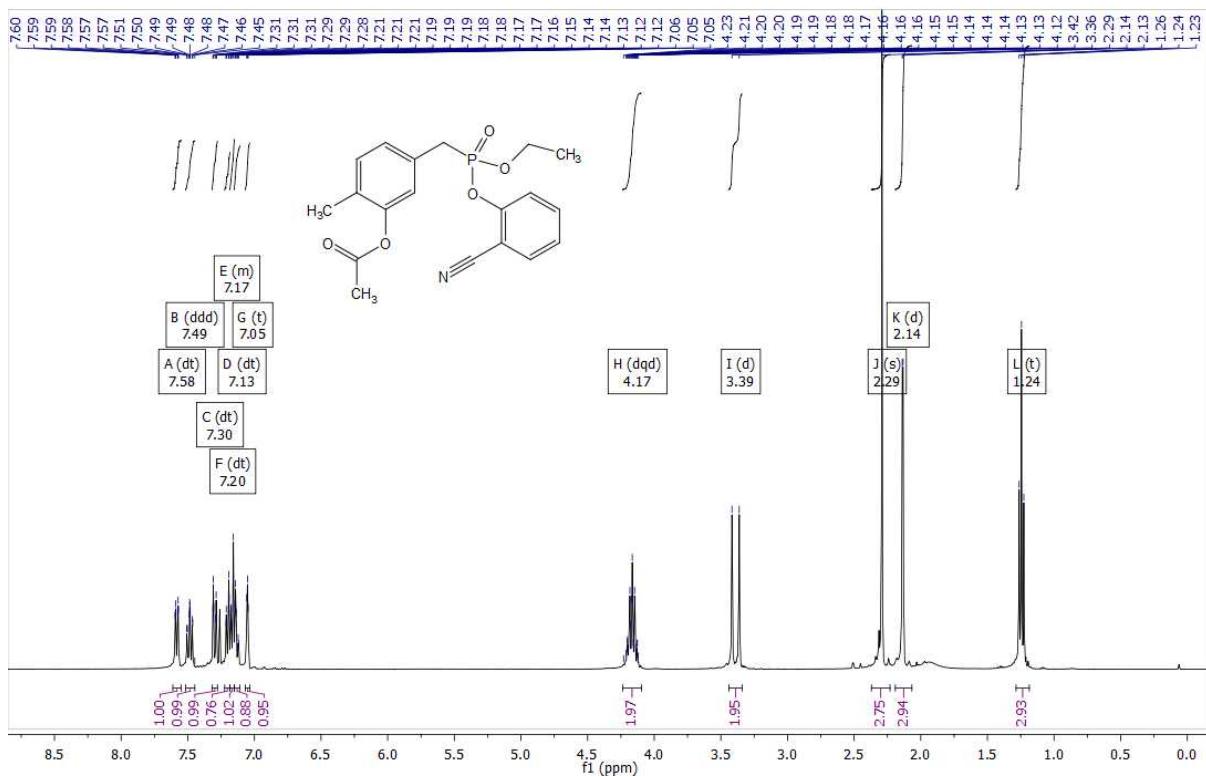


3-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate

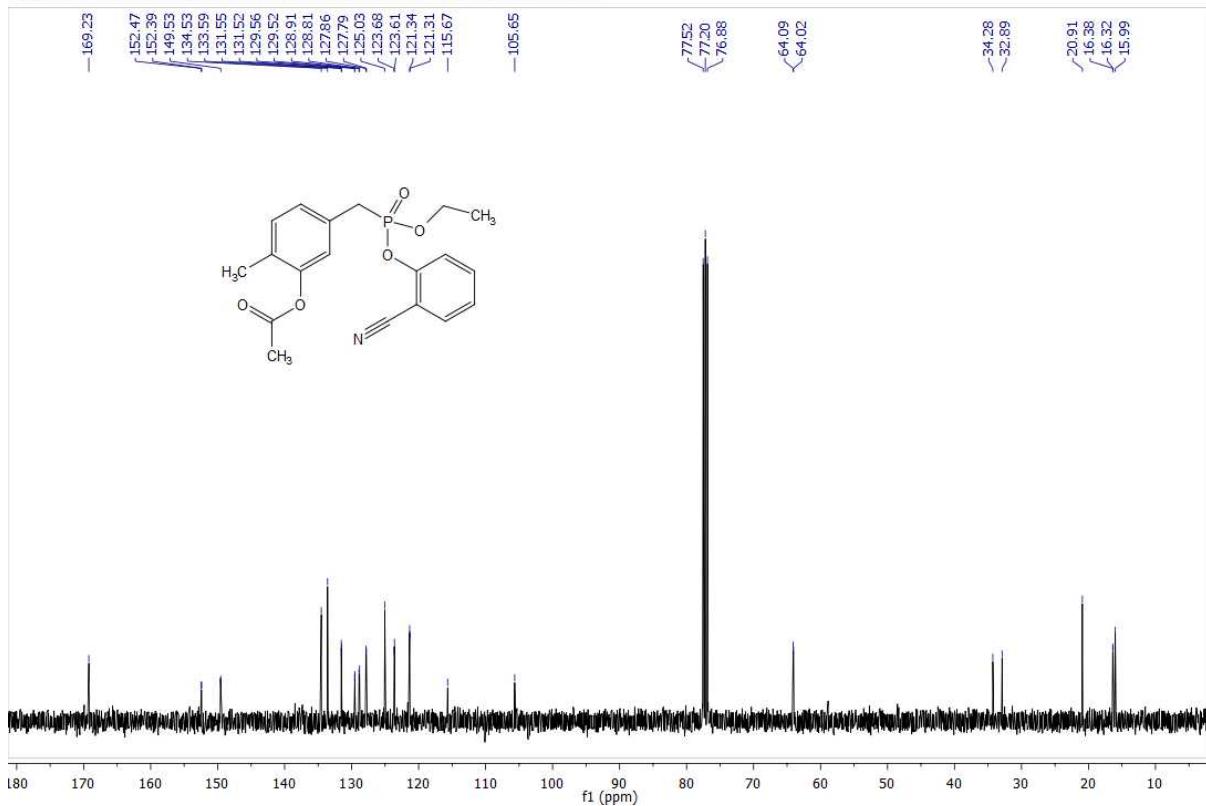


5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methylphenyl acetate (5b):

5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methylphenyl acetate



5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methylphenyl acetate

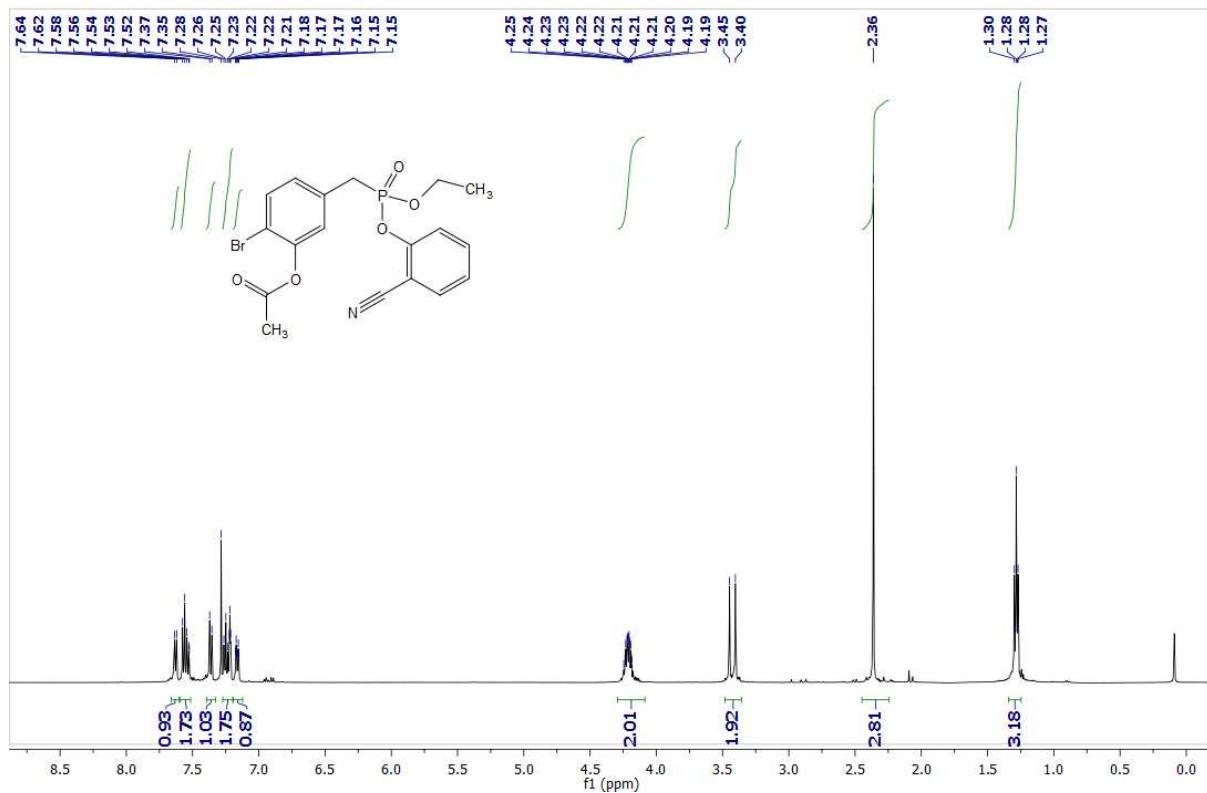


5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-methoxyphenyl acetate (5c):

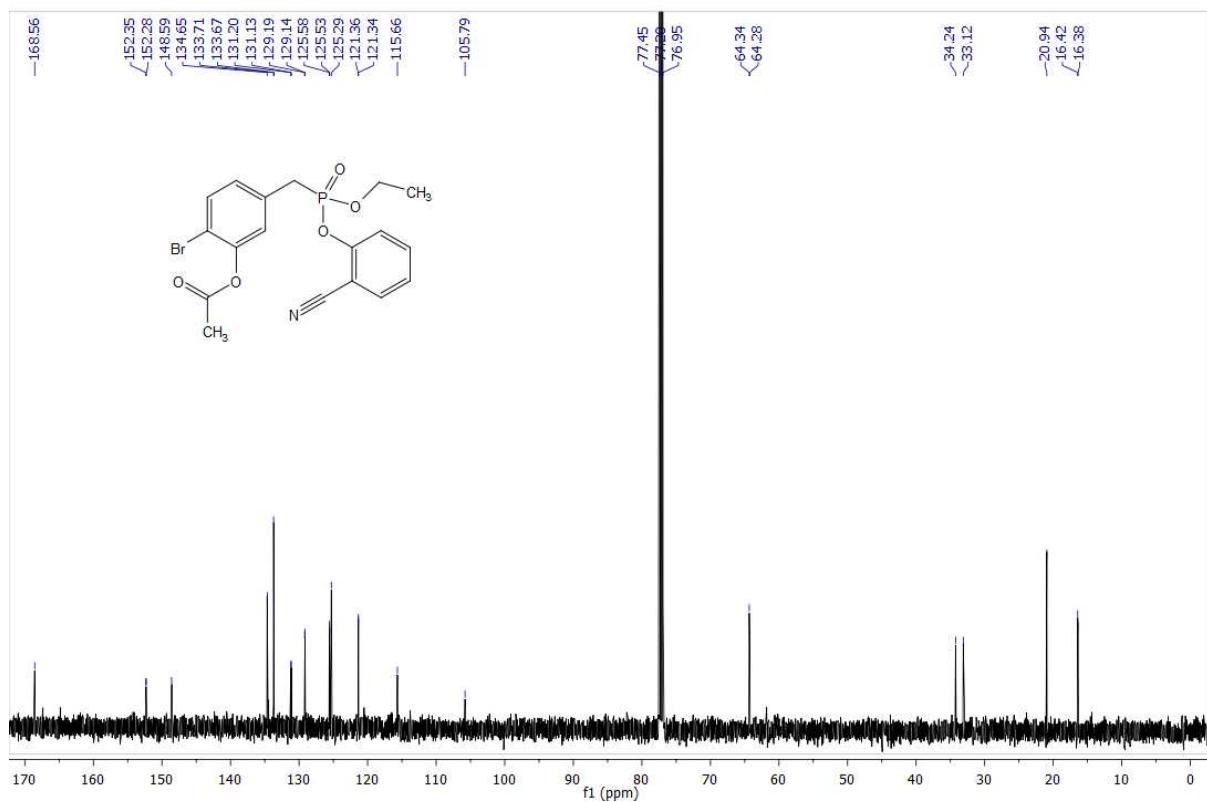


2-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate (5d):

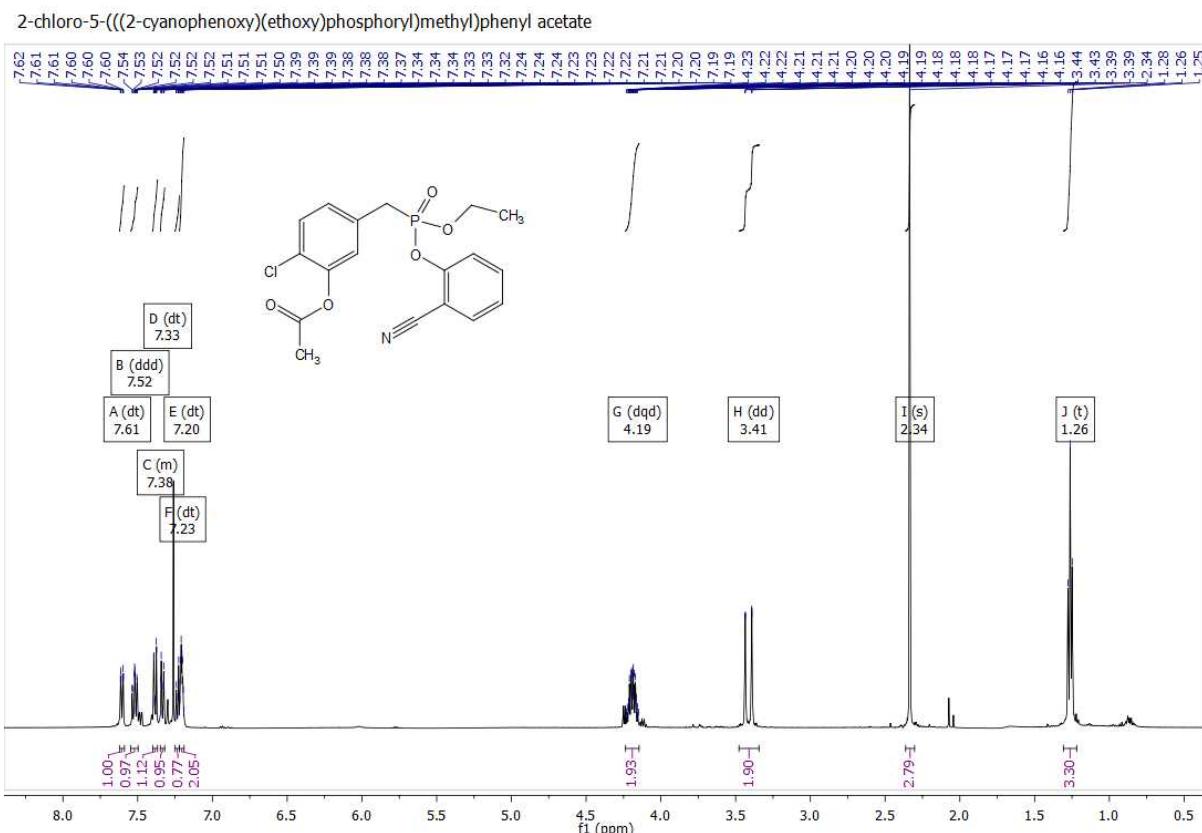
2-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate



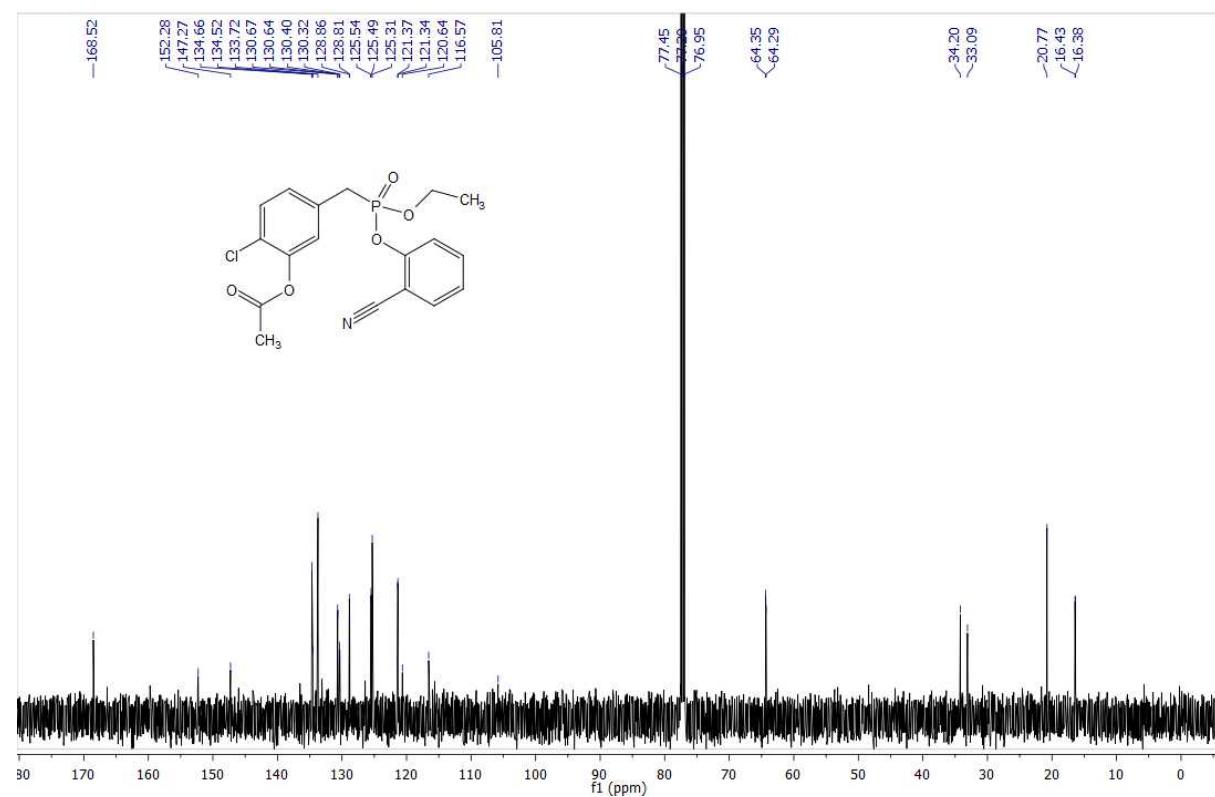
2-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate



2-chloro-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate (5e):

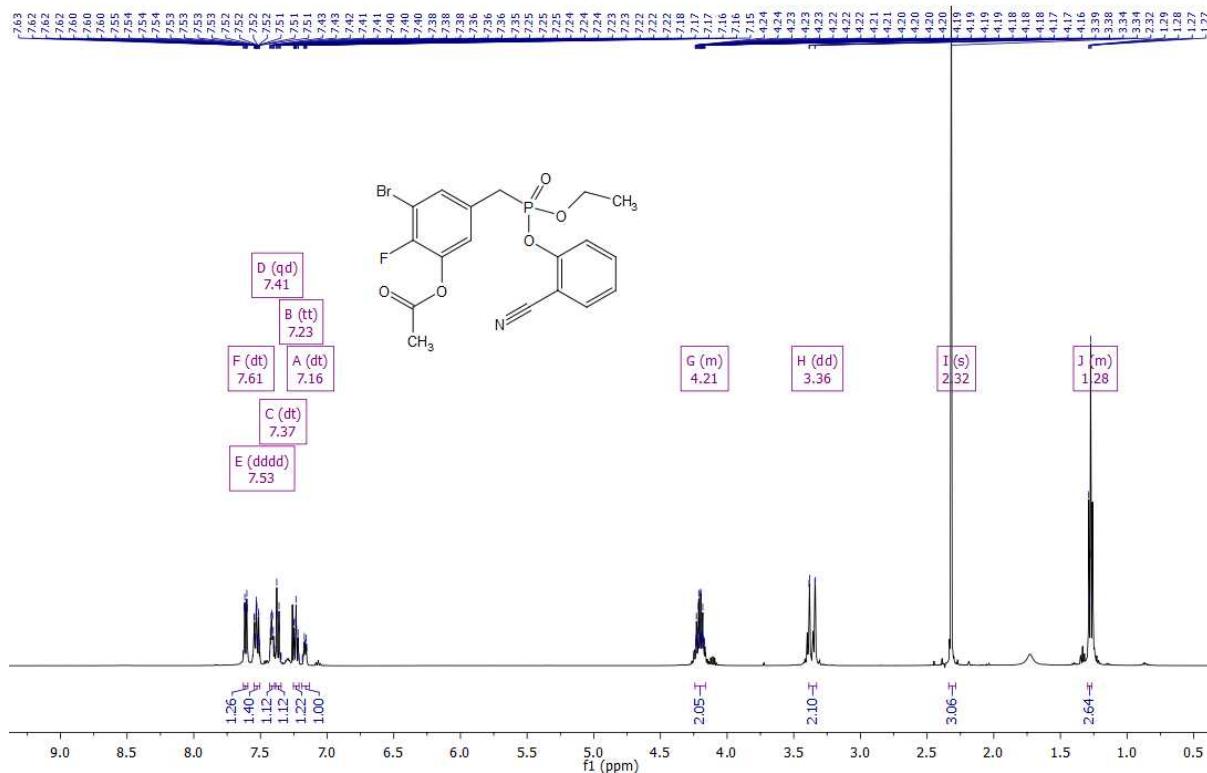


2-chloro-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl acetate

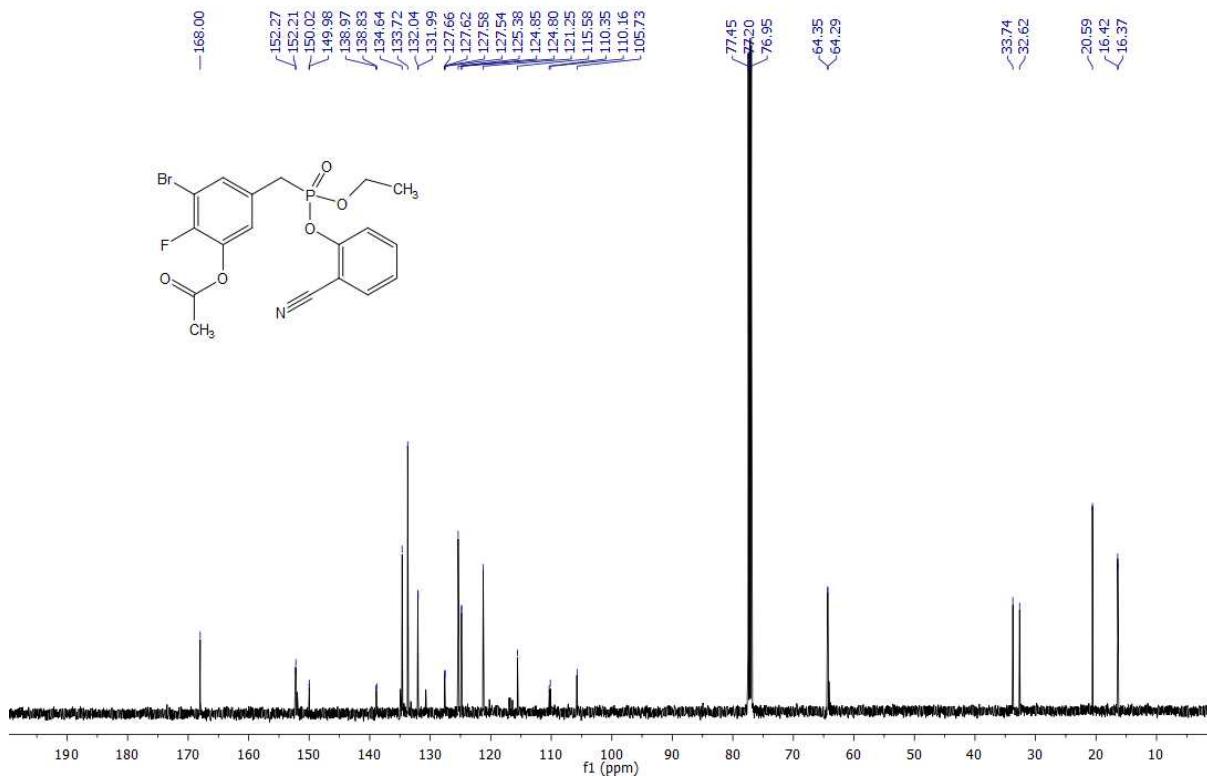


3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-fluorophenyl acetate (5f):

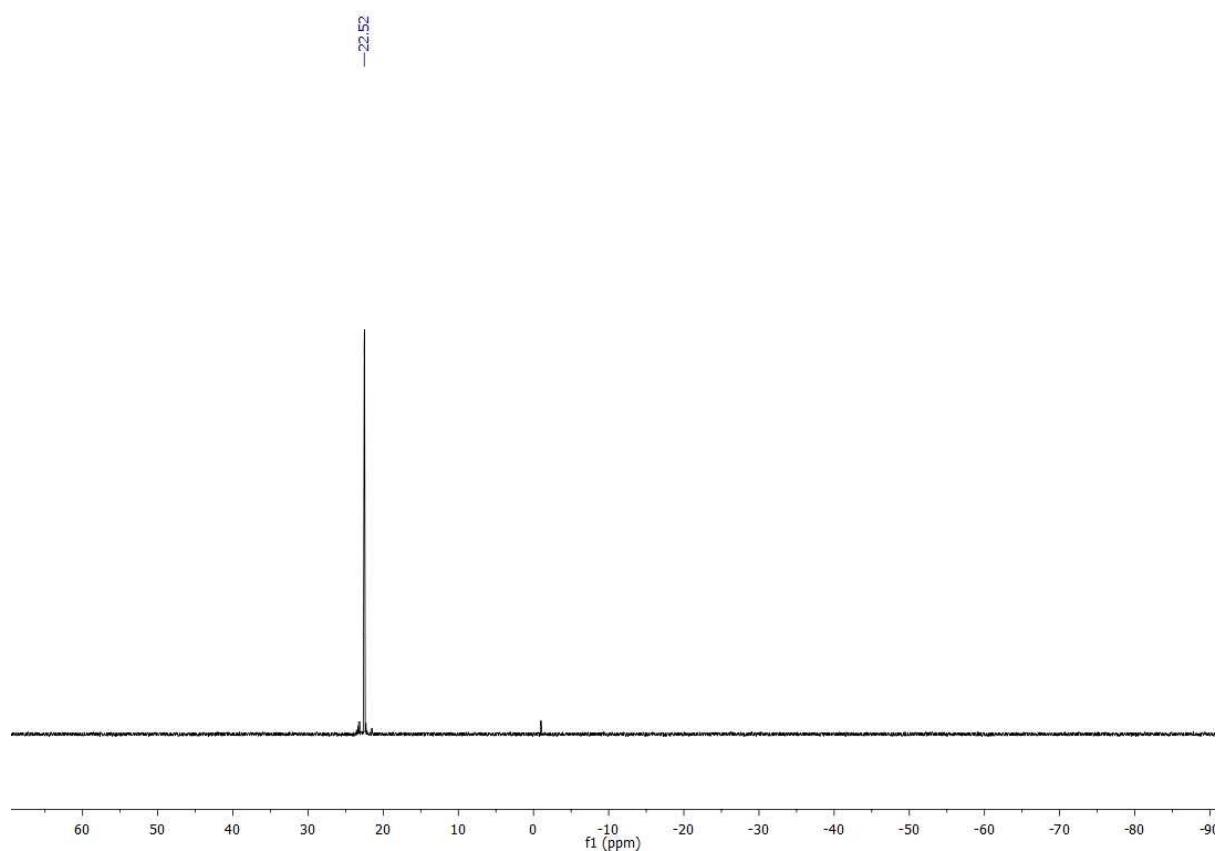
3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-fluorophenyl acetate



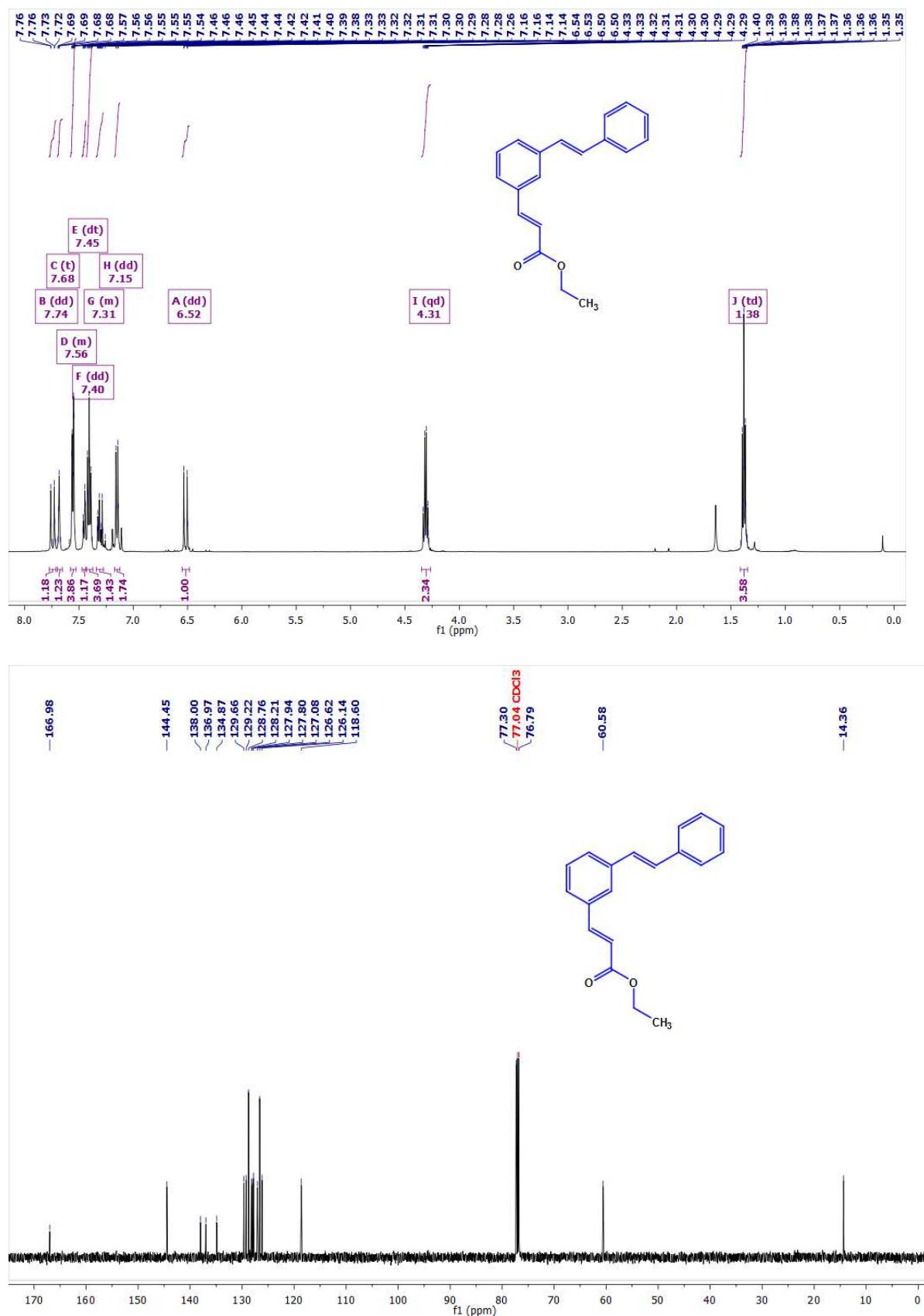
3-bromo-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)-2-fluorophenyl acetate



31P NMR:

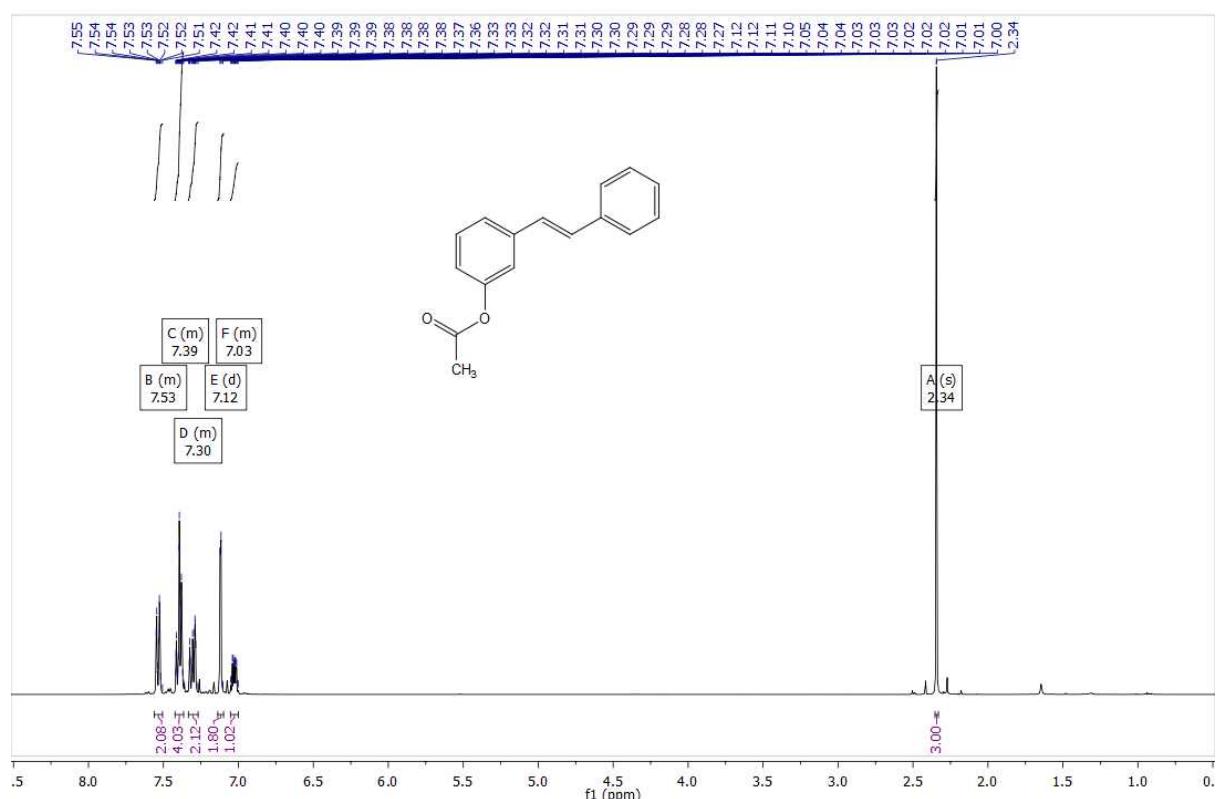


(E)-ethyl 3-(3-styrylphenyl)acrylate (6a):

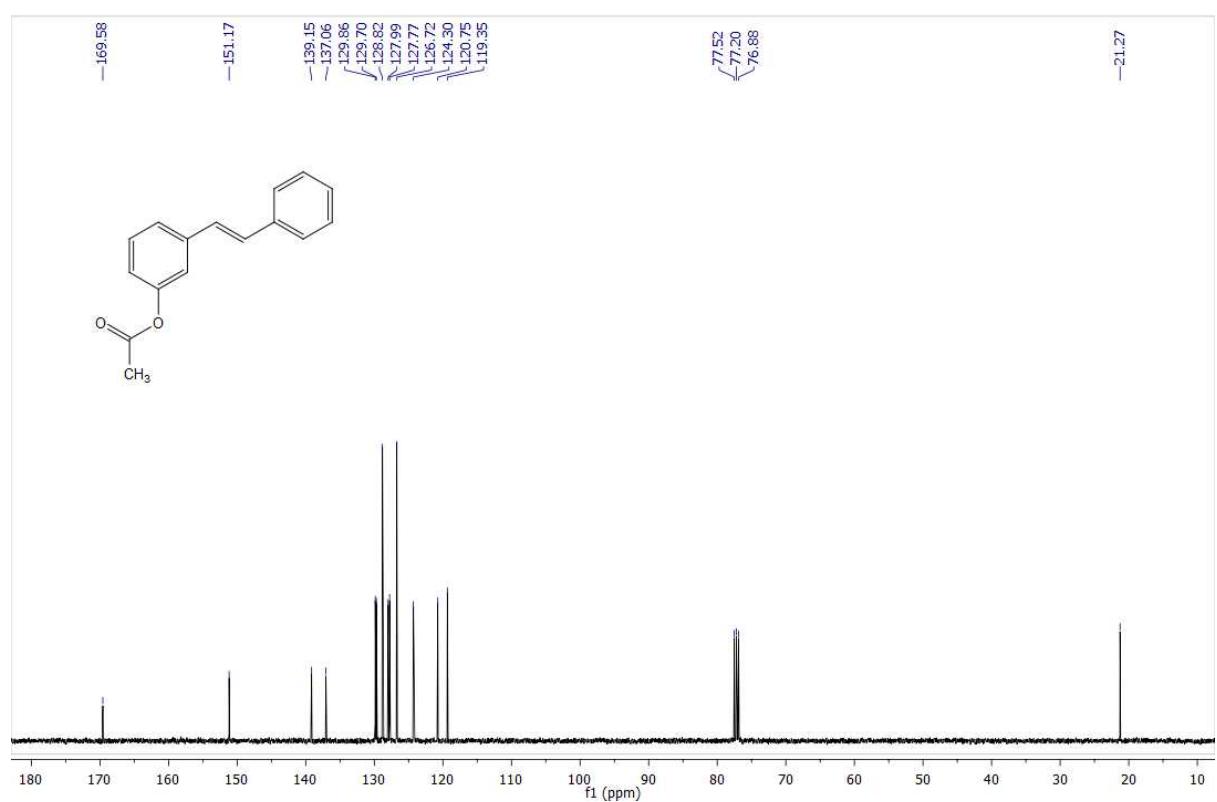


(E)-3-styrylphenyl acetate (6b):

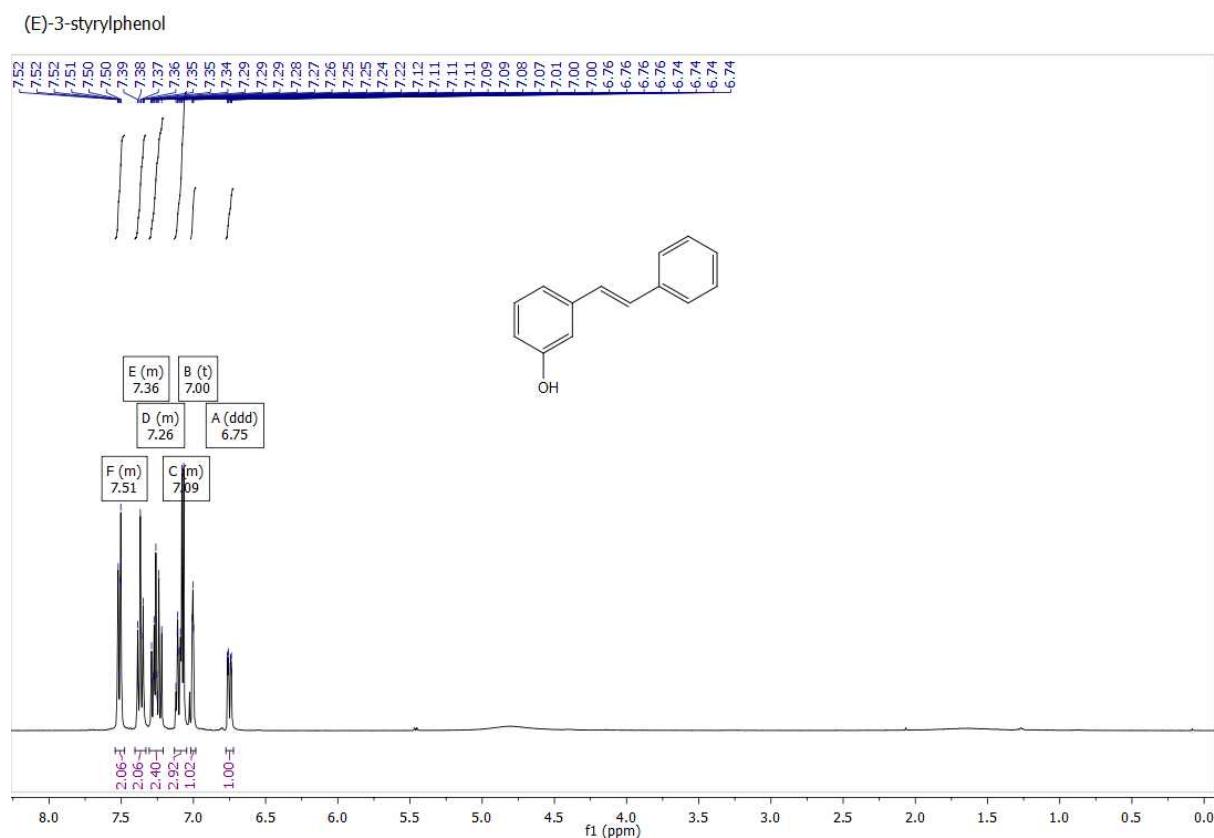
(E)-3-styrylphenyl acetate



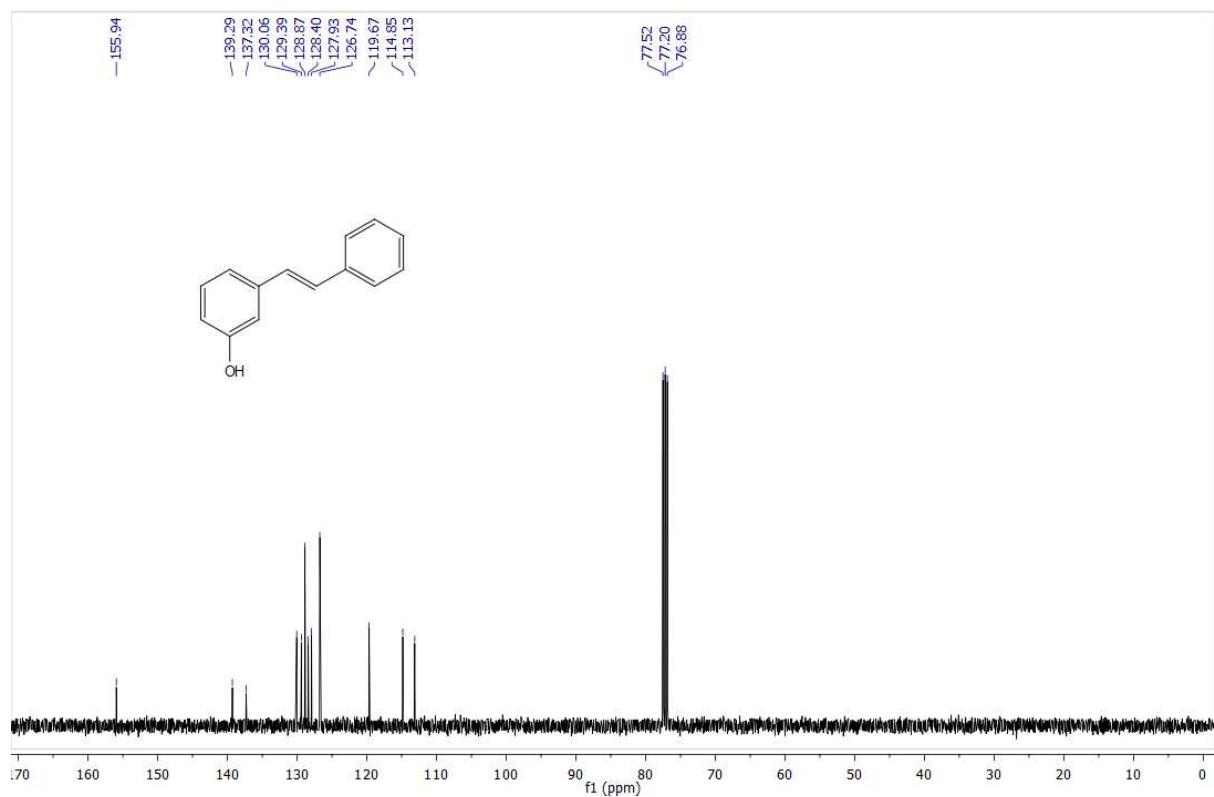
(E)-3-styrylphenyl acetate



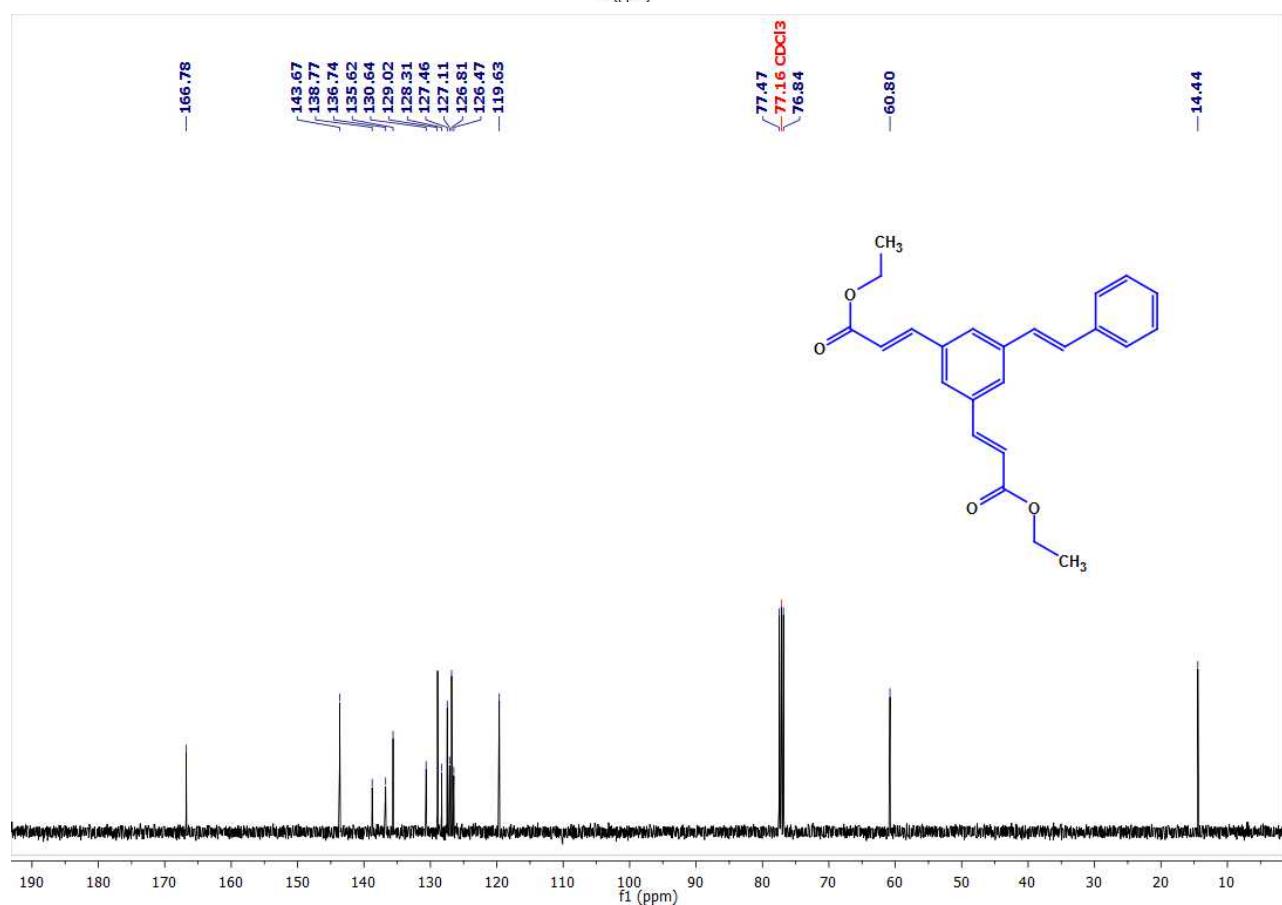
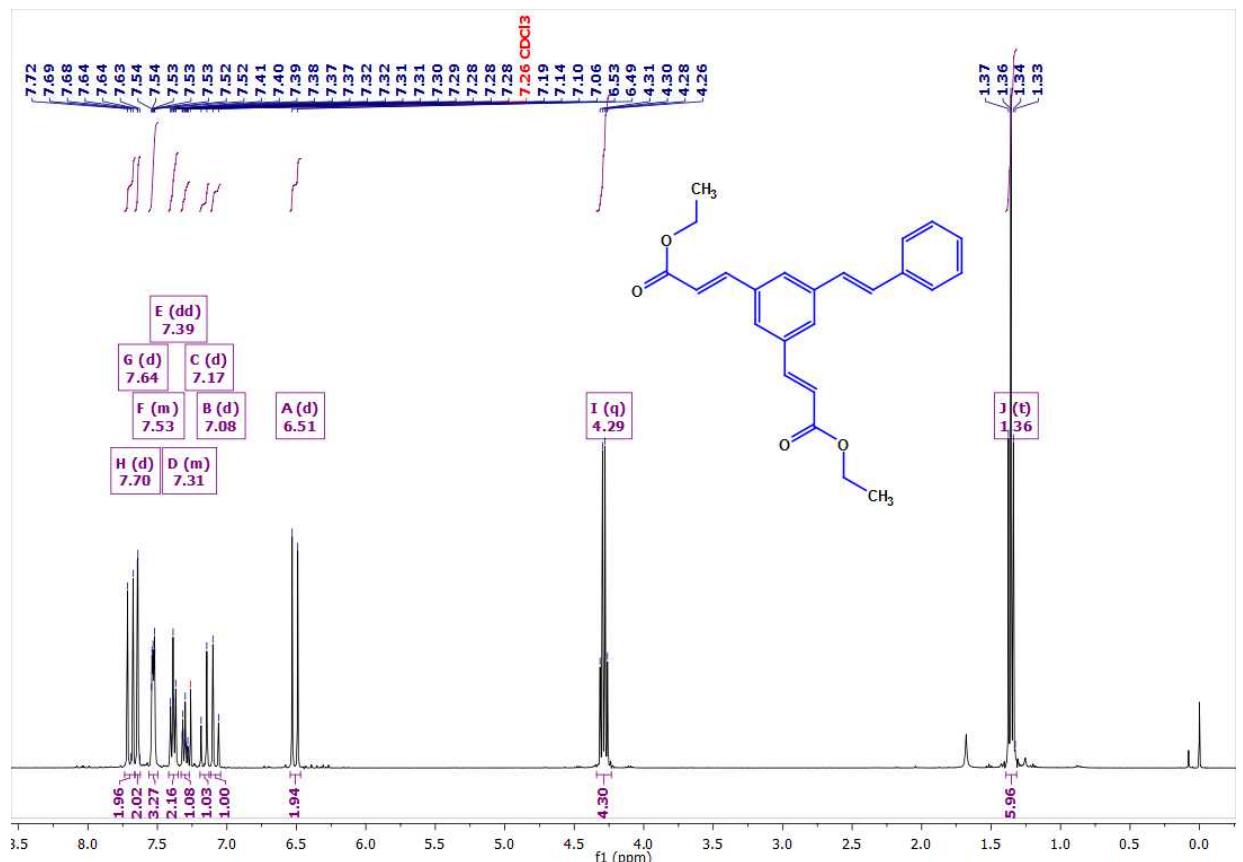
(E)-3-styrylphenol (6c):



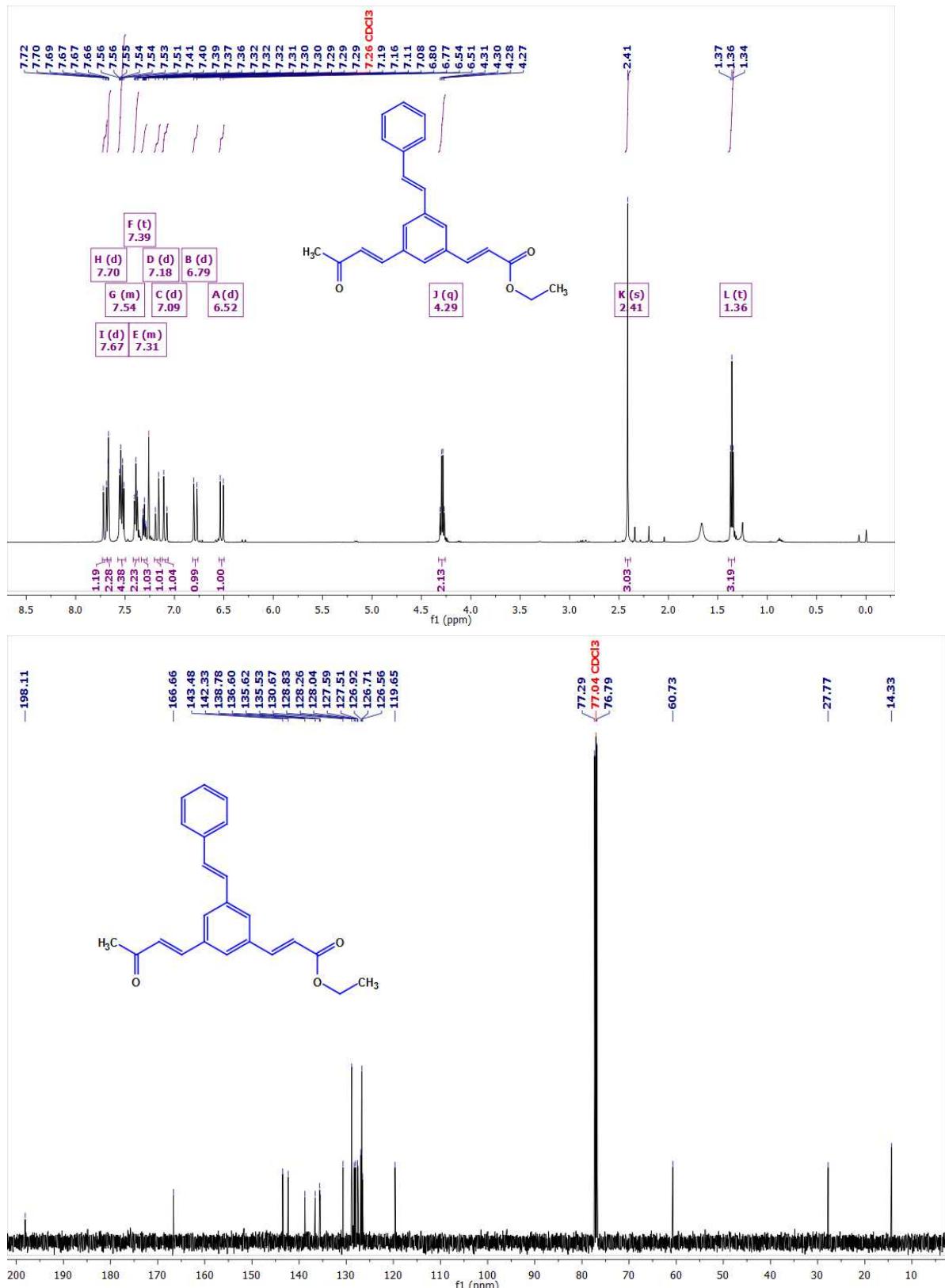
(E)-3-styrylphenol



(2E,2'E)-diethyl 3,3'-(5-styryl-1,3-phenylene)diacrylate (6d):

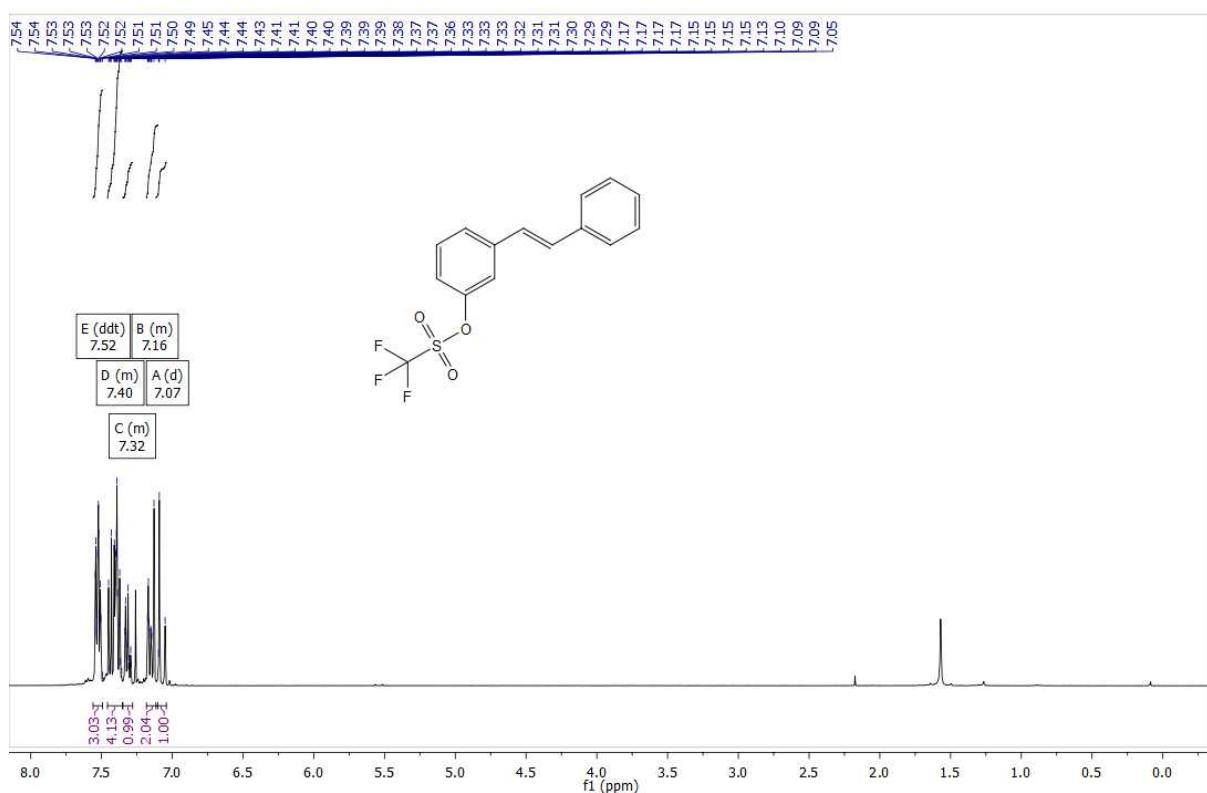


E)-ethyl 3-((E)-3-oxobut-1-enyl)-5-styrylphenylacrylate (6e):

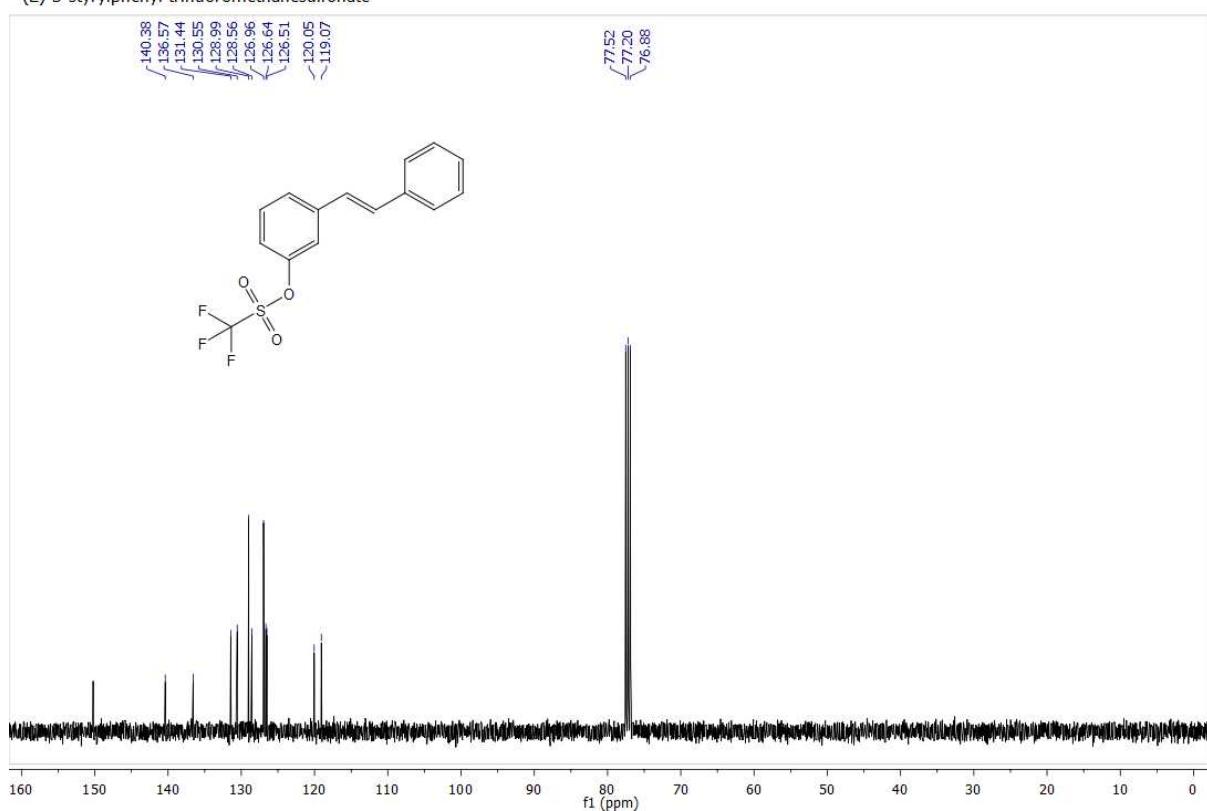


(E)-3-styrylphenyl trifluoromethanesulfonate (7):

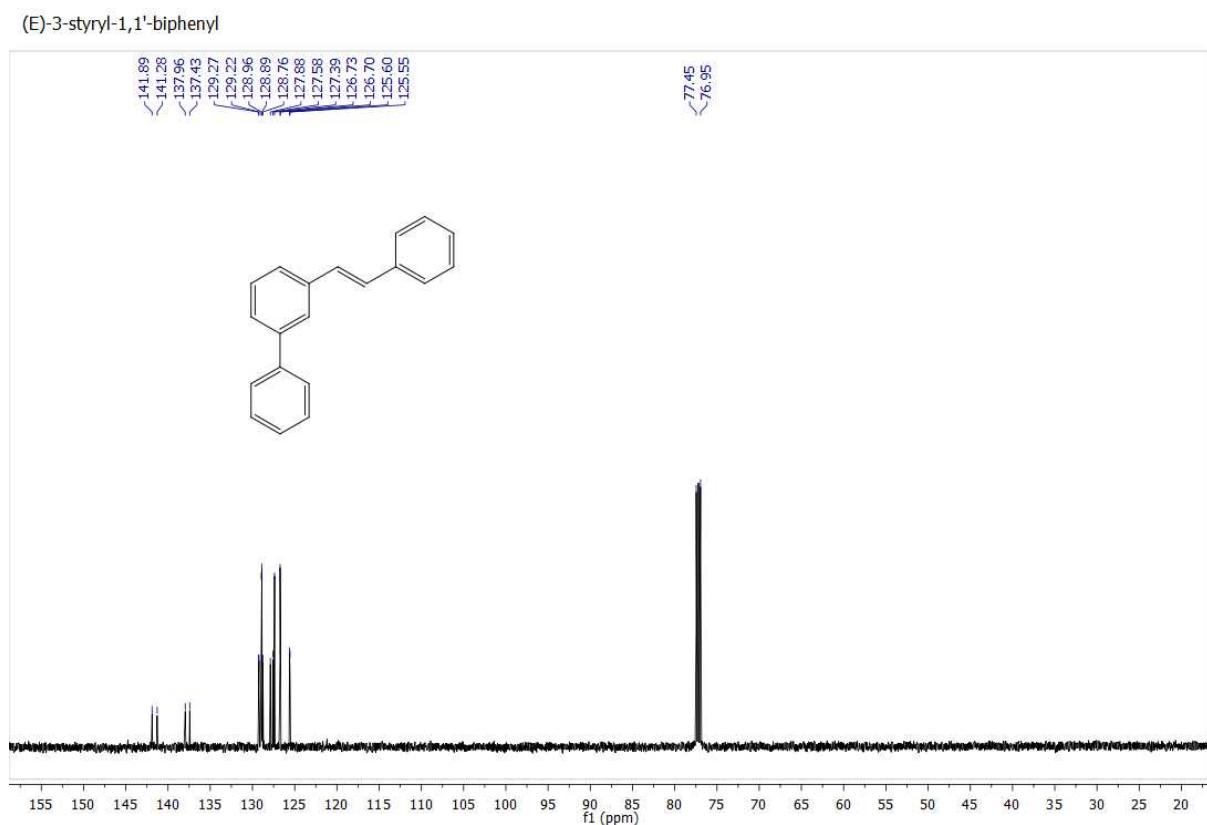
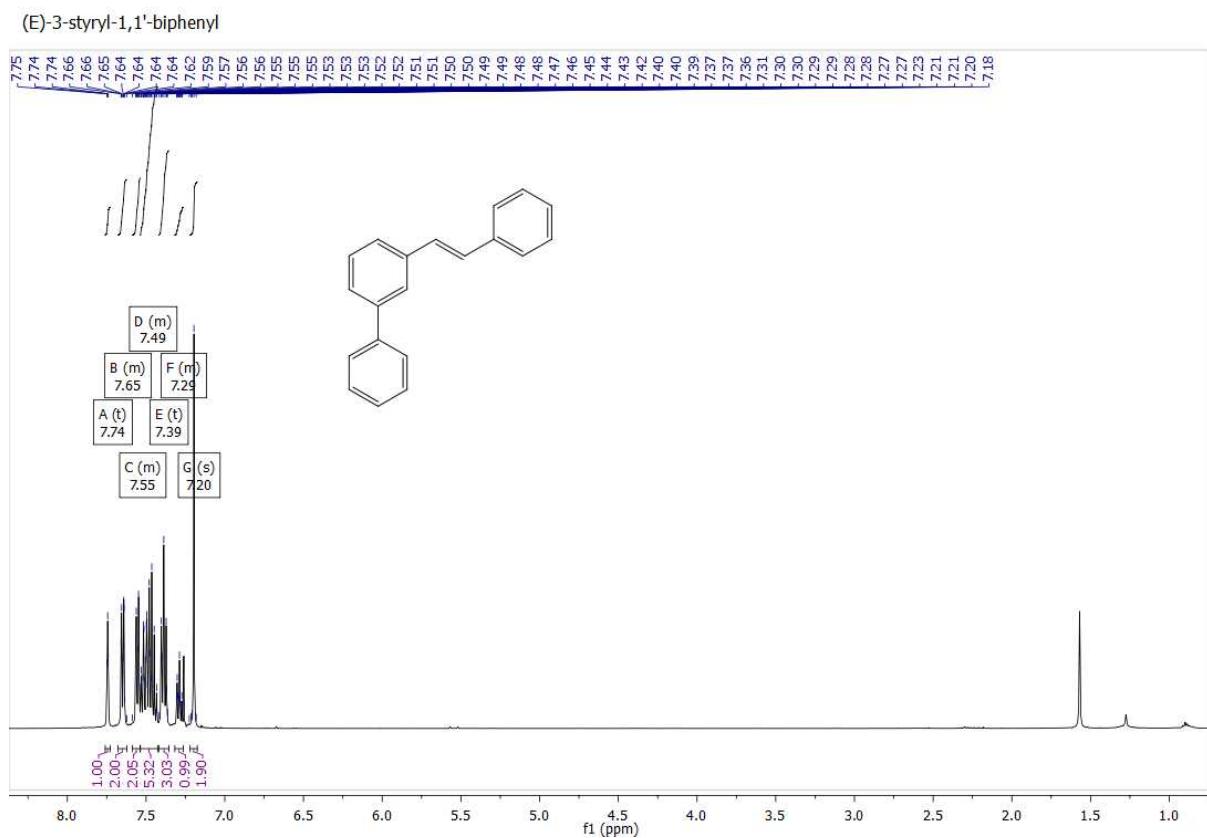
(E)-3-styrylphenyl trifluoromethanesulfonate



(E)-3-styrylphenyl trifluoromethanesulfonate

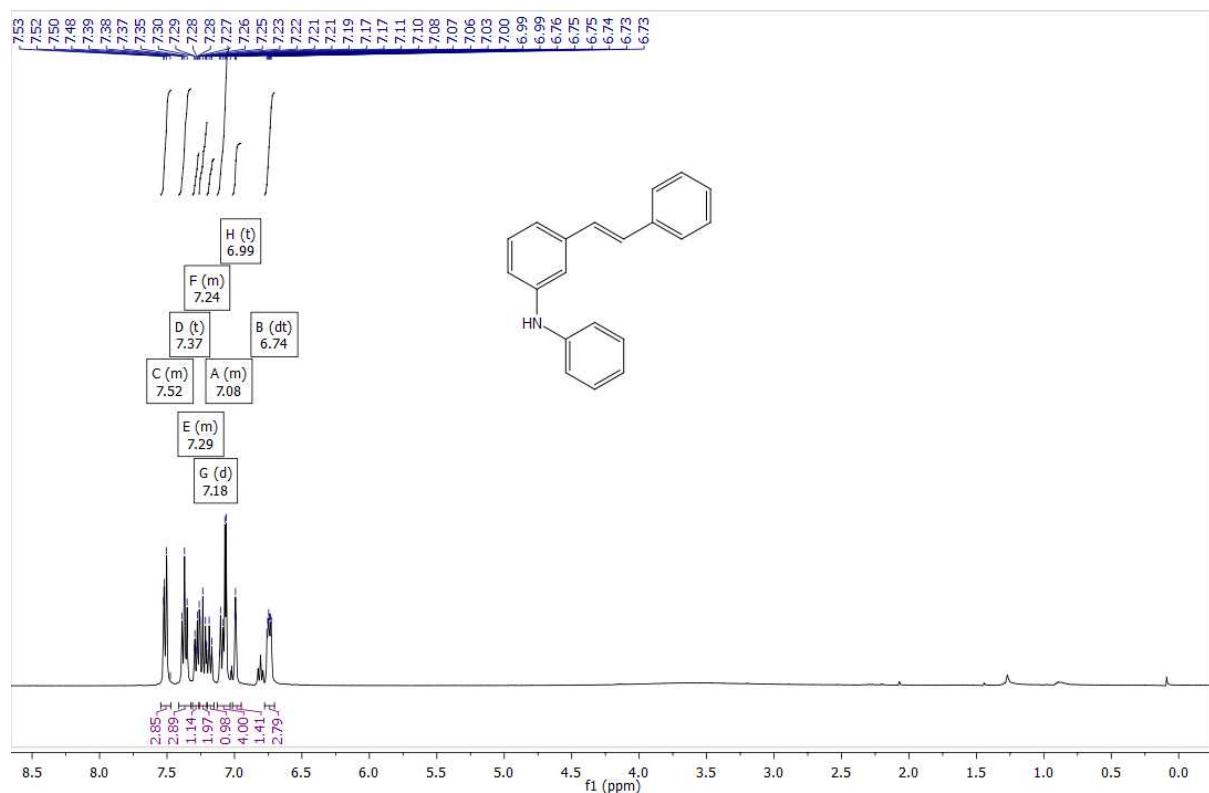


(E)-3-styryl-1,1'-biphenyl (7a):

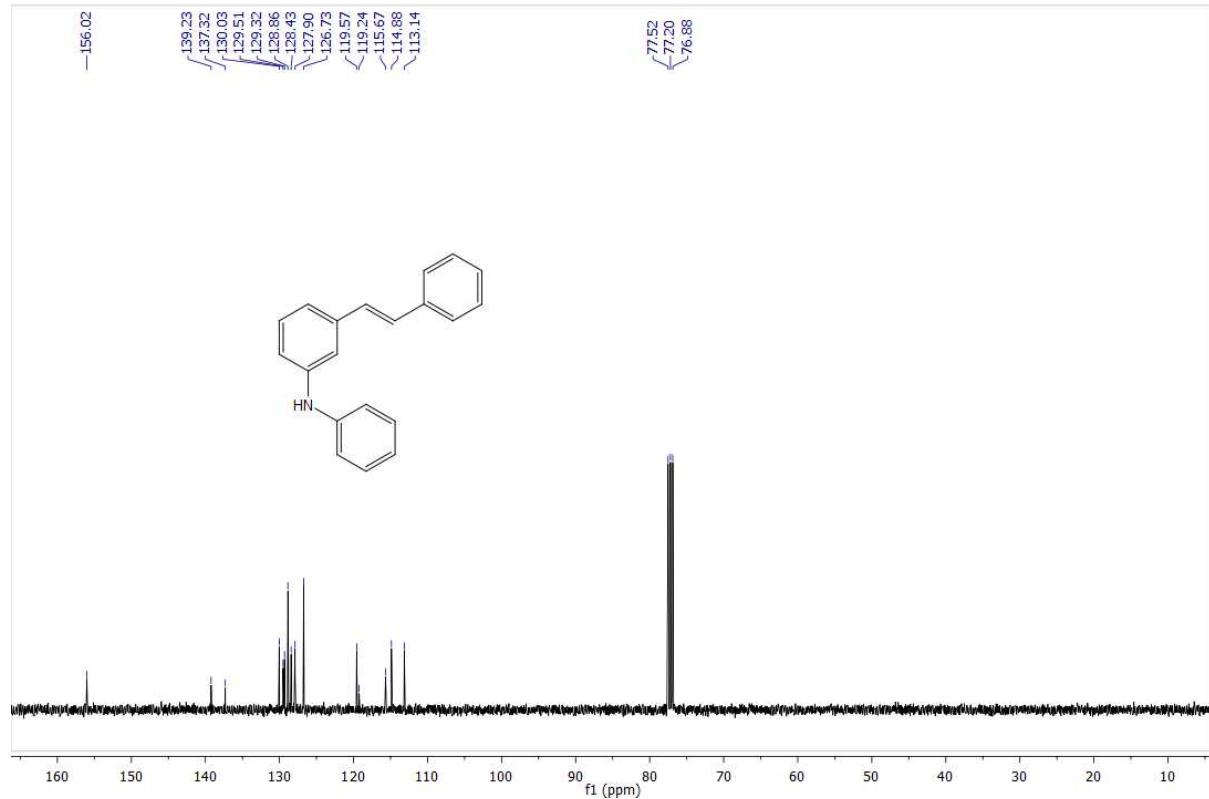


(E)-N-phenyl-3-styrylaniline (7b):

(E)-N-phenyl-3-styrylaniline

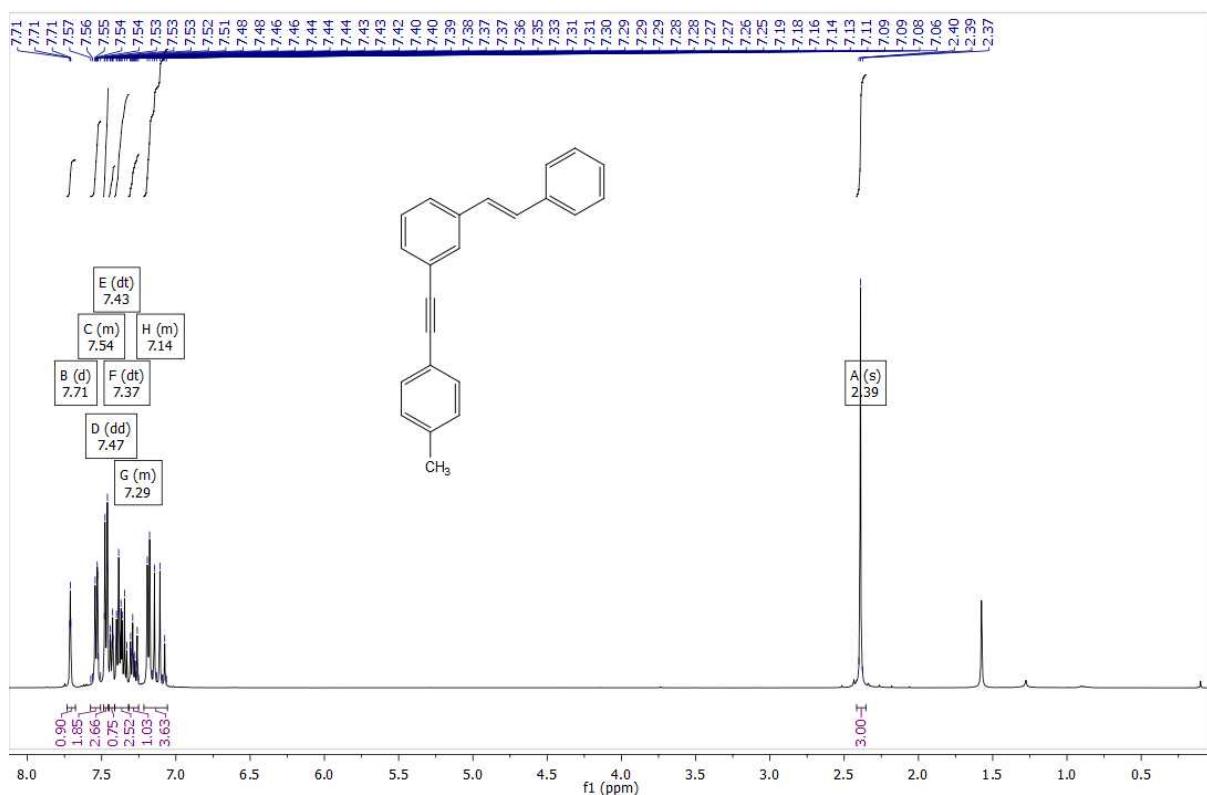


(E)-N-phenyl-3-styrylaniline

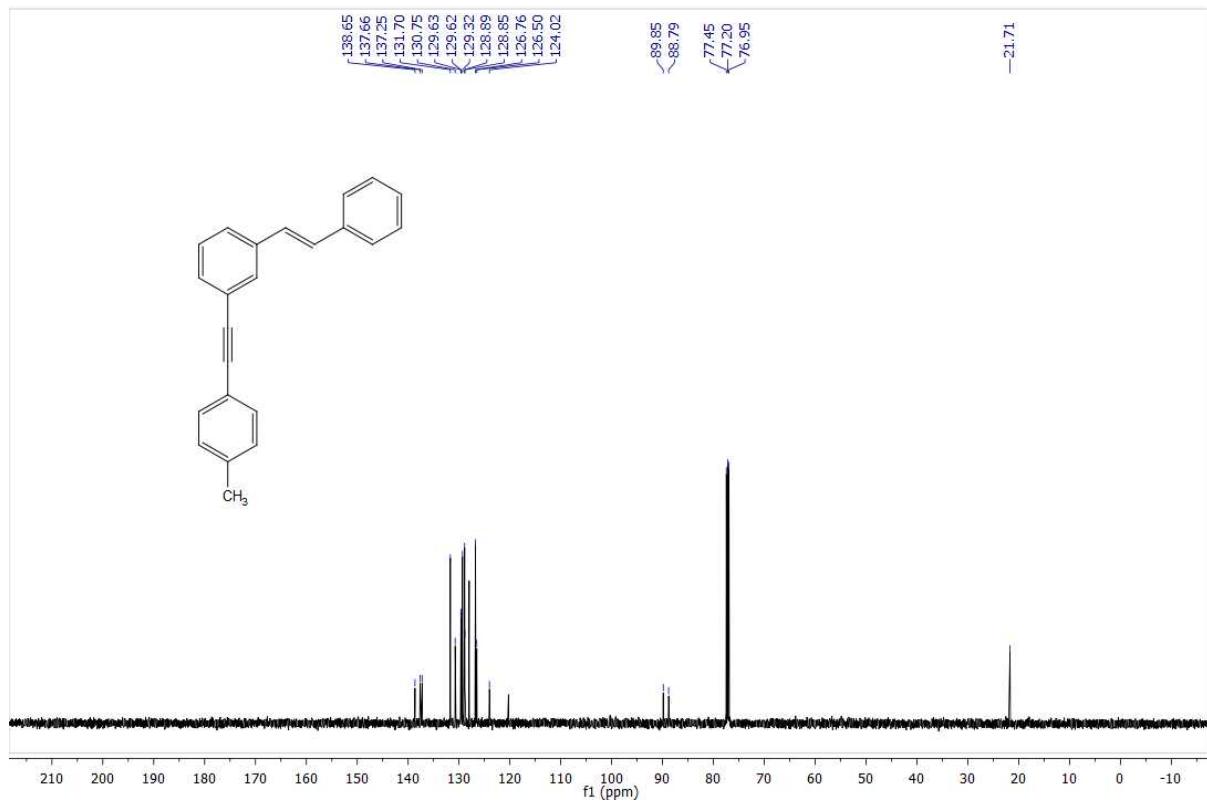


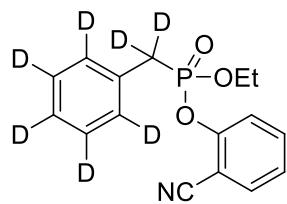
(E)-1-styryl-3-(p-tolylethynyl)benzene (7c):

(E)-1-styryl-3-(p-tolylethynyl)benzene

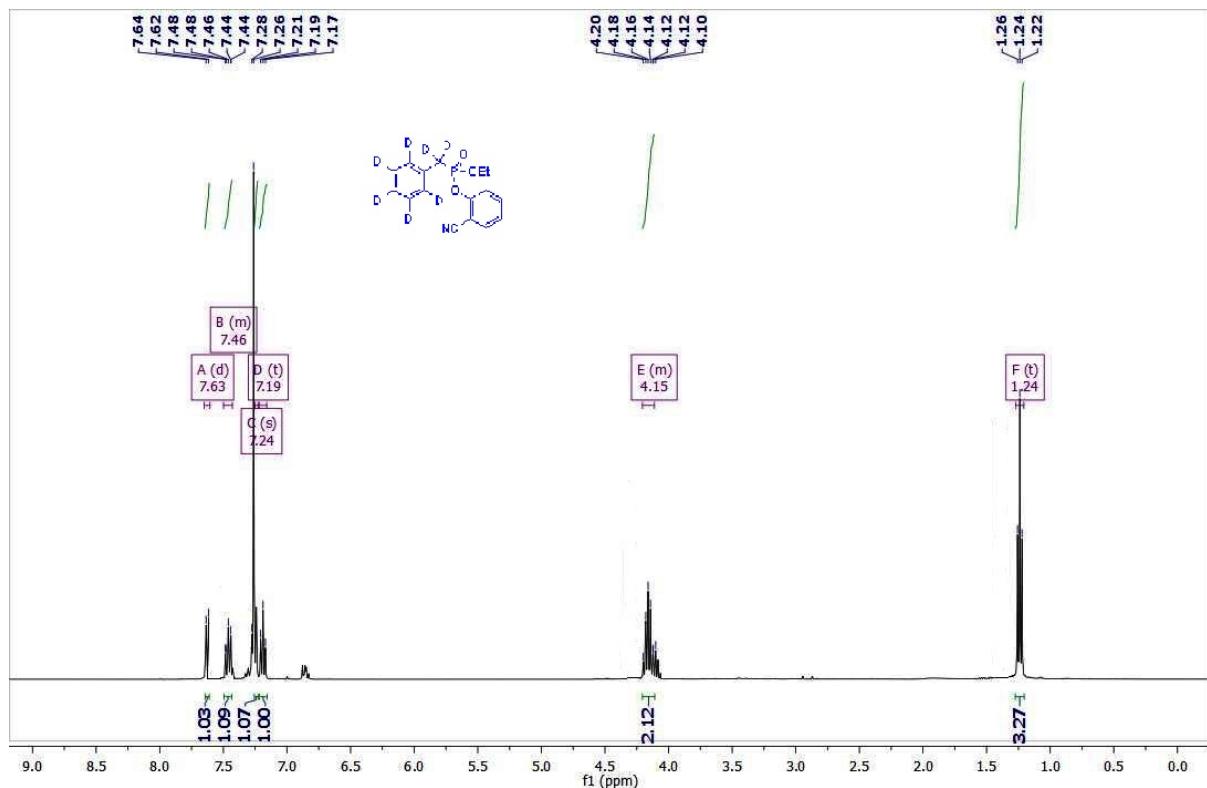


(E)-1-styryl-3-(p-tolylethynyl)benzene

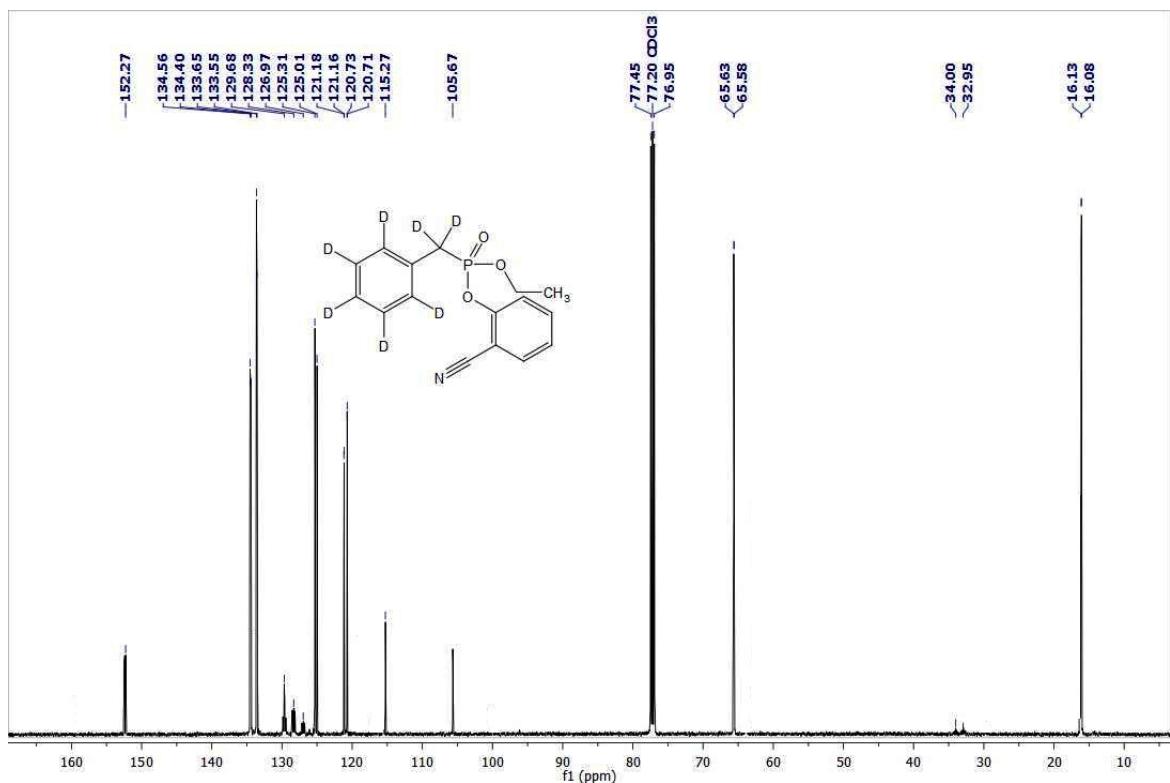




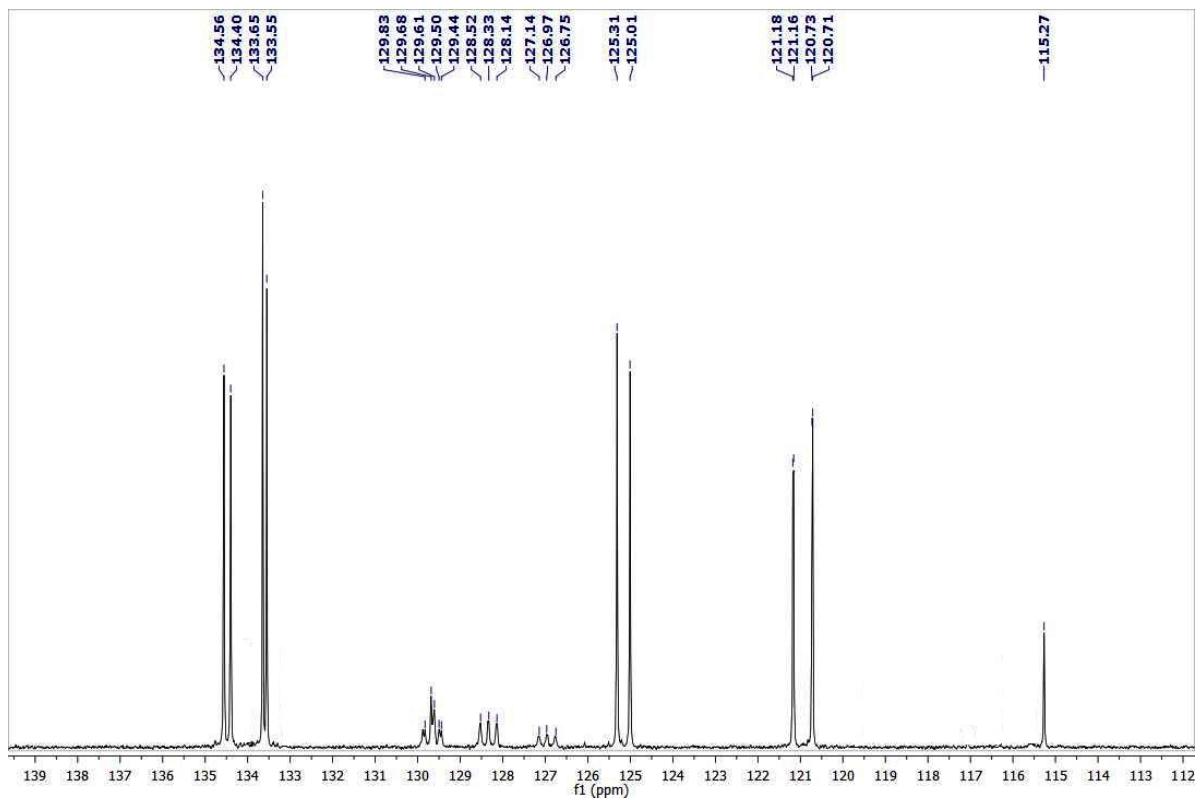
¹H NMR:



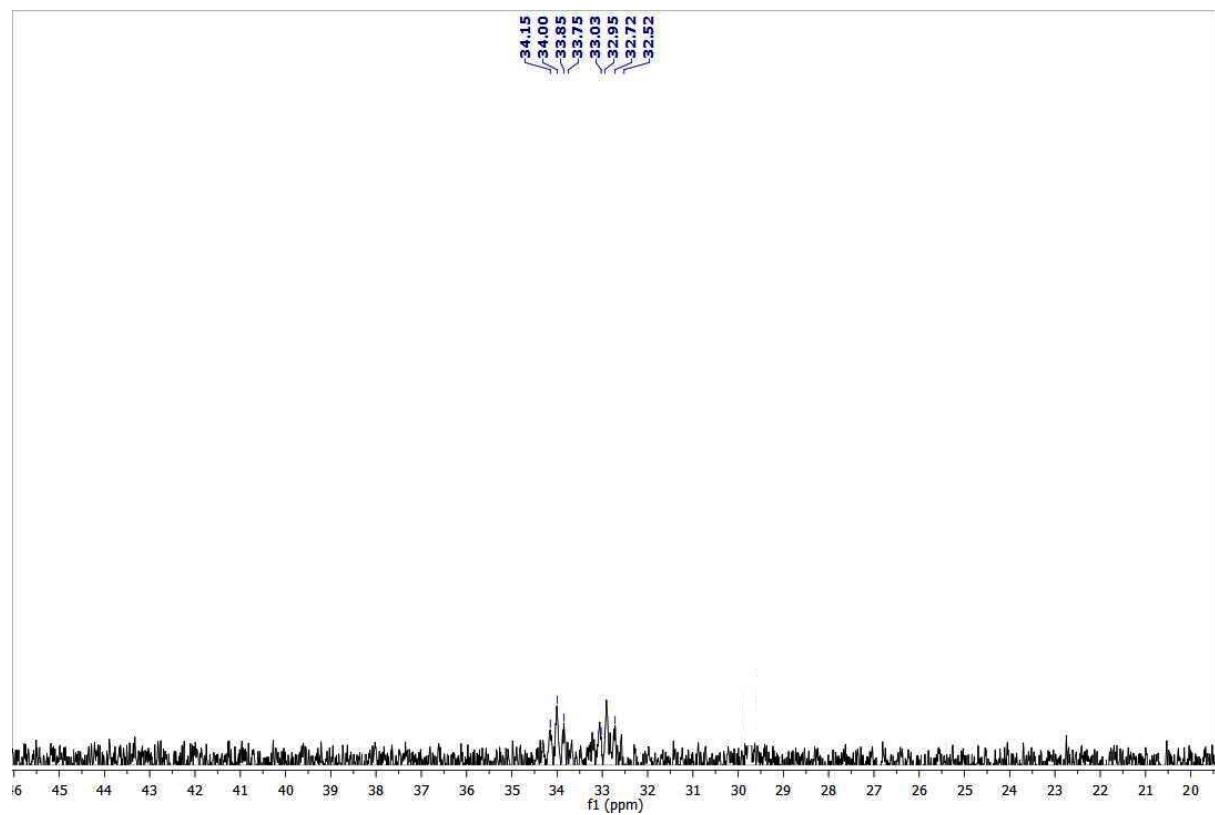
¹³C NMR:



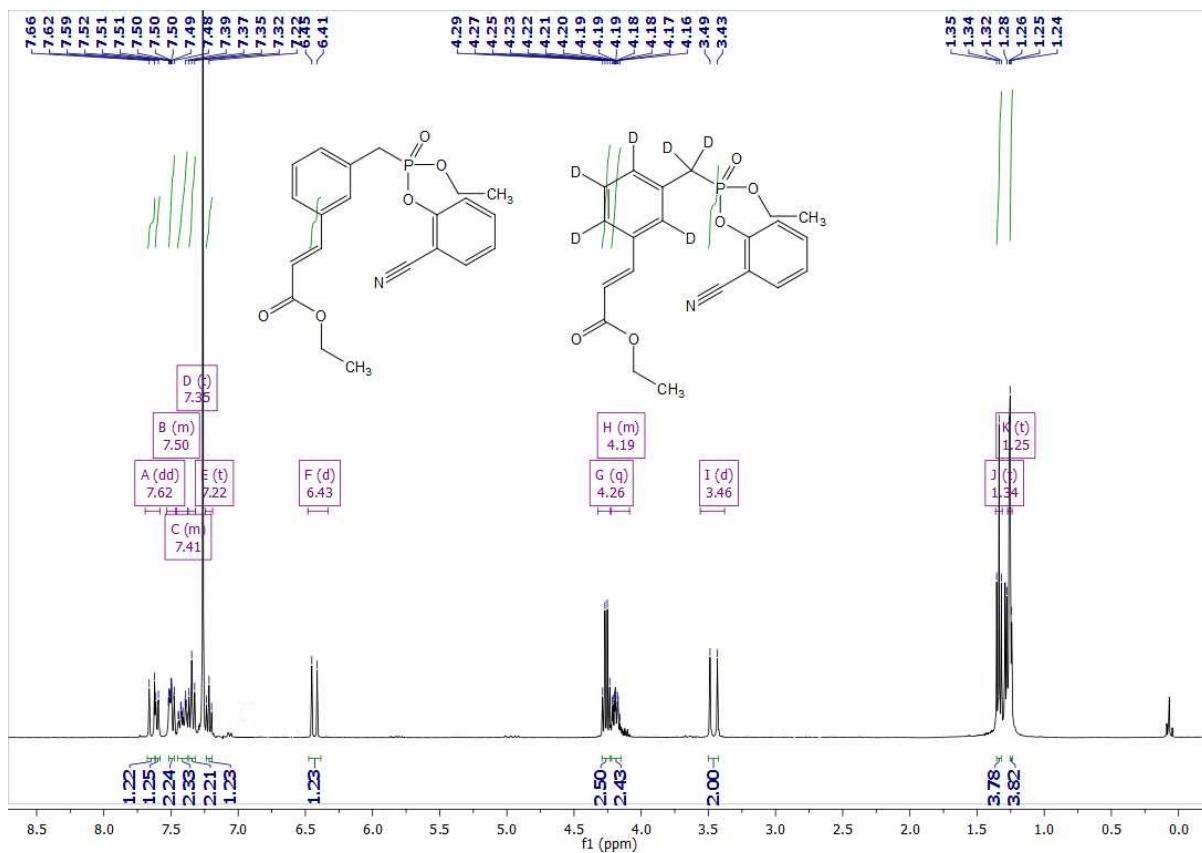
Aromatic region (aromatic C-D triplet and multiplet):



Aliphatic CD₂ multiplet:

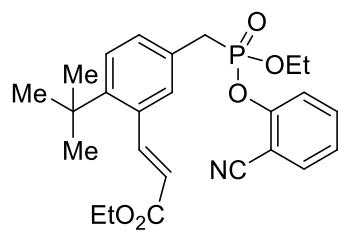


Intermolecular KIE experiment {product distribution [P_H/P_D] spectrum}:



In this spectrum one C-H proton integration coming from compound 2a is “1” and one C-H proton integration coming from compound 2a-D is “0.23”.

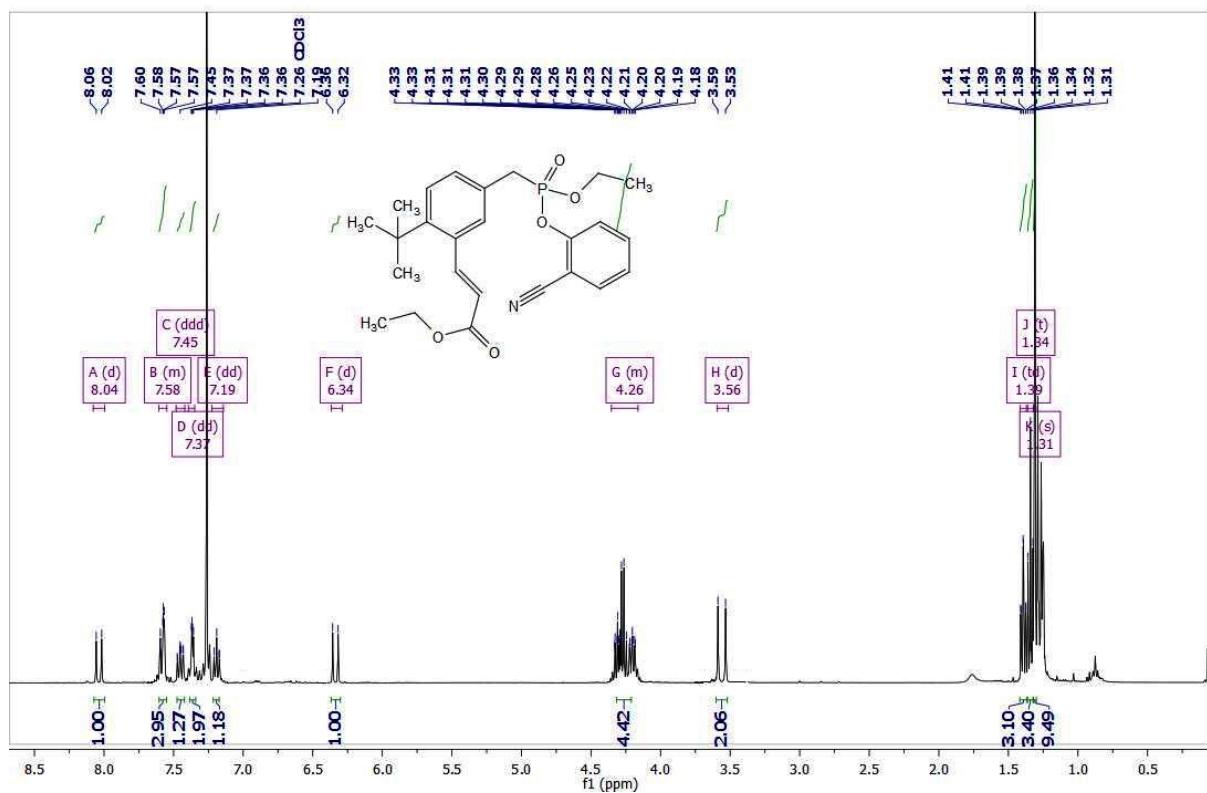
$$[P_H/P_D] = 1/0.23 = 4.5$$



(E)-ethyl 3-(2-tert-butyl-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylates (2o):

¹H NMR:

(E)-ethyl 3-(2-tert-butyl-5-(((2-cyanophenoxy)(ethoxy)phosphoryl)methyl)phenyl)acrylate



¹³C NMR:

(E)-ethyl 3-(2-tert-butyl-5-(((2-cyanophenoxy)ethoxy)phosphoryl)methyl)phenyl)acrylate

